WIND/WAVE HINDCAST EXTREMES FOR THE WEST COAST OF CANADA

Prepared by:

MacLaren Plansearch (1991) Limited
A division of SNC*Lavalin Inc.
Suite 200, Park Lane Terraces
5667 Spring Garden Road
Halifax, Nova Scotia
B3J 3R4

MPL File No. 58440

Oceanweather Inc.
Suite 1, 5 River Road
Cos Cob, Connecticut
06807, U.S.A.

For:

Atmospheric Environment Service
Environment Canada
4905 Dufferin Street
Downsview, Ontario
M3H 5T4

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STUDY PRINCIPAL INVESTIGATORS

MacLaren Plansearch (1991) Limited - Prime Contractor & Project Manager

- Dr. Bassem Eid, Project Manager
- Mrs. Cindy Morton, Research Engineer
- Mr. David Kuntz, Meteorologist

Oceanweather Inc. - Subcontractor

- Dr. Vince Cardone, Study Principal
- Dr. Arthur Greenwood, Numerical Modeller
- Mr. Scott Keeney, Meteorologist

STUDY SCIENTIFIC AUTHORITY

- Mr. Val Swail, AES, Downsview, Ontario

STUDY REVIEW COMMITTEE

- Mr. Bob Beal, AES, Vancouver
- Dr. John Garrett, IOS, Sidney
- Dr. Ken Sato, NEB, Calgary
- Mr. Val Swail, AES, Chairman
- Mr. David Szabo, Mobil MRDC, Dallas
- Dr. Ron Wilson, MEDS, Ottawa

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EXECUTIVE SUMMARY

Accurate specification of historical wind and wave fields is a critical requirement for many offshore engineering design and operation applications. The objective of this study was to specify, following a hindcast approach, the extreme wave climate offshore the west coast of Canada, by providing accurate surface wind and wave fields in the top-ranked waveproducing storms. The study area included the AES marine forecasting areas: West Coast Vancouver Island, Queen Charlotte Sound, West Coast Charlottes, and exposed parts of the Hecate Strait and Dixon Entrance.

The hindcast approach applied is based on the following main steps: (1) assembly of a comprehensive data base of archived historical meteorological data, measured wave data, and results of previous studies; (2) identification and ranking of historical storm occurrences over as long a period as possible, and selection of hindcast storms; (3) adoption and validation of the most accurate numerical procedures to specify time histories of surface wind fields, surface wave fields, and directional wave spectra in each selected historical storm; (4) hindcast of the top severe storms; (5) analysis of extremes at each hindcast model grid point in the study area to estimate the significant and maximum individual wave height, crest height, and associated wind speed and wave period, associated with given return period or probability of exceedance (i.e. 100 year return period or probability of exceedance of 10^{-2}).

The data base assembly was intended to be exhaustive and utilized all the available resources. The historical period considered in this study extended from 1957 to 1990. The data base for earlier periods is much less extensive and wind fields may not be specified as accurately. The storm selection work was designed to identify storms based on their potential to generate high sea states somewhere within the study area. This task proceeded in several stages. First, all data sources were utilized to develop an initial candidate list of extratropical storms. A total of 500 events comprised this initial list. This list was distilled in several stages, with the aid of both objective storm intensity ranking procedures, and subjective ranking and intensity assessments made by experienced meteorologists and wave modellers, to produce the final hindcast population of 51 severe events. Since the typical scale of an intense extratropical storm is large with respect to the study area, many selected storms affect more than one of the study sub-areas, and individual storms often overlap two or more areas. At any given site therefore, the study is expected to include the 20-30 topranked extreme wave events associated with the extratropical storms during the historical period considered.

The wind and wave hindcast methodology adapted in this study has already undergone considerable refinement and validation in several

previous studies. The method used for hindcasting wind fields for the selected storms is based on man-machine mix techniques using a blend of surface pressure analysis and kinematic analysis wind fields. In this method the specification of 6-hourly wind fields in each storm includes a complete reanalysis of the evolution of the surface pressure fields, calculation of objective wind fields using a proven calibrated marine planetary boundary layer model, and finally kinematic analysis to provide winds of the highest accuracy achievable for the available data. The wave hindcasts were carried out using the ODGP spectral wave model adapted to the North Pacific basin on a high-resolution nested grid, with temporal resolution of 2 hours and spatial resolution of an average of about 85 km. It should be noted here that the ODGP model used in this study is a DEEP WATER wave model, and therefore the results should be treated accordingly.

A substantial validation of model predictions was included in this study, involving comparison of hindcasts of a number of storms against measured data at several sites in the study area. The comparison of the model predictions with the time series of buoy measurements showed the similarity between the model hindcast of storm parameters to the buoy-measured values. The peak-to-peak comparison, which is of considerable importance for extremal analysis, has shown a high degree of agreement between the measured and hindcast peak seastates. The overall mean difference or bias in model hindcast was 0.27 m for significant wave height (H_s) and 0.22 s for peak period (T_p) with scatter indices of 16.9% and 14.4% for H_s and T_p, respectively. Wind errors were greater near shore due to the effect of the coastal mountain range in this area. Also, the sheltering effect of the islands and the mesoscale effect was pronounced in the wave hindcast results in the near shore areas (e.g. Hecate Strait and Dixon Entrance). These require special treatment, which was beyond the scope of this study.

Finally, an extremal analysis was carried out using site-specific hindcasts of peaks-overthreshold (POT), at each grid point of the fine mesh model grid area. At each point, the threshold was determined and the top-ranked storms above the selected threshold were input to the extreme analysis program. Extremes of significant wave height (H_s), maximum individual wave height (H_m), and crest height (H_c) were specified at all grid points within the study area, using Gumbel extreme value distribution fitted by the method-of-moments (MOM) for given return periods (up to 100 years or probability of exceedance of 0.01).

The analysis included sensitivity studies on threshold limits, distribution function, and fitting scheme. The maximum wind speed associated with extreme seastate was also calculated. The peak period (T_p) associated with extreme sea state was estimated from the correlation analysis of the T_p and H_s pairs. The main extremal analysis considered hindcast peaks regardless of wave direction. The hindcast population was too small to warrant a full extremal analysis stratified by directional sectors of wave approach.

Finally, recommendations were made for future investigations including treatment of near shore areas using finer grid/shallow water model, treatment of near shore wind fields and a study the effect of global climate changes (e.g. global warming due to the greenhouse effect) on storm population, storm characteristics and severity.

RÉSUMÉ

Pour nombre d'applications d'exploitation et de conception technique au large des côtes, il faut une spécification précise des champs historiques des vents et de vagues. Cette étude visait à spécifier, par des provisions a posteriori, le climat des vagues extrêmes au large de la côte ouest du Canada, en fournissant des champs précis de vagues et de vents de surface dans les tempêtes productrices de vagues classées en tête. La zone étudiée comprenait les zones de provision maritime du SEA : île Vancouver de la côte ouest, détroit de la reine Charlotte, îles Charlotte de la côte ouest et parties exposées du détroit Hecate et de Dixon Entrance.

La méthode de provision a posteriori repose sur ces principales étapes : 1) constitution d'une base complète de données météorologiques historiques archivées, de mesure des vagues et de résultats d'études antérieures; 2) determination et classement des phénomènes historiques de tempêtes sur la période la plus longue possible et sélection des tempêtes prévues a posteriori; 3) adoption et validation des méthodes numériques les plus précises pour spécifier le comportement, dans le temps, des champs de vent de surface, des champs de vagues de surface et des spectres directionnels de vagues dans chacune des tempêtes historiques choisies; 4) provision a posteriori des plus violentes tempêtes; 6) analyse des extremes à chaque point de quadrillage du modéle de provision a posteriori pour la zone étudiée, afin d'estimer la hauteur significative et maximale des vagues et des crêtes individuelles, la vitesse du vent et la période des vagues correspondantes, liées à la période de recurrence donnée ou à la probability de dépassement (exemple : période de recurrence de 100 ans ou probability de dépassement de 10^{-2}).

La constitution de la base de données, censée exhaustive, a fait appel à toutes les ressources disponibles. La période historique étudiée allait de 1957 à 1990. La base des données, pour les périodes antérieures, est nettement moins vaste et l'on ne peut pas spécifier les champs de vents avec autant de precision. La sélection des tempêtes visait à déterminer les tempêtes suivant leur capacité d'engendrer des états de grosse mer dans la zone étudiée. Cette tache s'est accomplie en plusieurs étapes. Tout d'abord, on a utilisé toutes les sources de données pour dresser la liste initiale de présélection des tempêtes extratropicales. Cette liste en comprenait 500. On a écourté cette liste en plusieurs étapes, grace à des méthodes objectives de classement de l'intensité des tempêtes et aux Evaluations subjectives de l'intensité et du classement effectuées par des météorologues et des spécialistes expérimentés de la modélisation des vagues. On a ainsi obtenu une liste de provisions a posteriori comptant 51 phénomènes violents. Vu que l'étendue type d'une intense tempête extratropicale est grande par rapport à la zone étudiée,

nombre de tempêtes frappent plus dune des sous-régions étudiées et, souvent, les tempêtes individuelles se chevauchent dans deux ou plusieurs zones. En consequence, à tout emplacement donné, l'étude comprend en principe les 20 à 30 phénomones extrêmes de vagues classés en tête et liés aux tempêtes extratropicales pendant la période historique étudiée.

Les méthodes de provision a posteriori des vents et des vagues, adaptées A cette étude, ont déjà fait l'objet d'améliorations et de validations considérables dans plusieurs études antérieures. La méthode utilisée pour prévoir a posteriori les champs de vents des tempêtes sélectionnées repose sur des techniques mixtes homme-machine et fait appel A une conjonction d'analyse de la pression de la surface et d'analyse cinématique des champs de vents. Dans cette méthode, la spécification des champs de vents de chaque tempête, sur six heures, renferme une nouvelle analyse complète de l'évolution des champs de pression de surface, le calcut des champs objectifs de vents à l'aide dun modéle étalonné et éprouvé pour finalement, l'analyse cinématique, afin de determiner les vents avec le plus de précision possible, compte tenu des données disponibles. Pour la provision a posteriori des vagues, on a utilisé le modéle spectral ODGP de vagues adapté au bassin du Pacifique Nord sur un quadrillage emboité à haute resolution, la resolution temporelle étant de 2 heures et la resolution spatiale moyenne d'environ 85 km. Notons qu'on a ici utilisé un modéle ODGP d'étude des vagues POUR EAUX PROFONDES et qu'il convient de traiter les résultats en consequence.

Cette étude incorporait une importante validation des provisions des modéles, où entrait en jeu des provisions a posteriori de plusieurs tempêtes avec les données mesurées à plusieurs emplacements de la zone étudiée. En comparant les provisions du modéle avec la série temporelle des mesures par bouées, on a établi la similitude des provisions a posteriori du modéle pour les paramétres de tempête et des valeurs mesurées par bouées. La comparaison de crate à crête, dune considerable importance pour l'analyse des extremes, a révélé une grande concordance des mesures et des provisions des états de la mer à la crête. L'écart moyen global ou erreur systématique de la provision a posteriori du modèle était de 0,27 m pour une hauteur significative de vague (H_s) et de 0,22 s pour la période de créte (T_p), les indices de dispersion étant respectivement de 16,9 et de 14,4 p. 100 pour H_s et T_p. Étant donné l'effet de la chaine de montagnes côtières de la région, les erreurs de vent étaient plus élevées près de la côte. En outre, l'effet d'abri des îles et l'effet sous-synoptique étaient prononcés dans les résultats des provisions des vagues dans les zones proches du rivage (comme le détroit Hecate et Dixon Entrance). Ces éléments nécessitent une analyse spéciale qui dépasse le cadre de la présente étude.

Enfin, on a analysé les extrémes en recourant aux provisions a posteriori de crêtes sur seuils (CSS) propres à tel ou tel emplacement à chaque point du fin quadrillage d'un modéle. A chaque point, on a déterminé le seuil et introduit au programme d'analyse des extrémes les tempêtes classées en tote qui dépassaient le seuil choisi. En observant la distribution Gumble des extrêmes ajustée par la méthode des moments (MDM) pour des périodes de recurrence données (jusqu'à 100 années ou probability de dépassement de 0,01), on a spécifé à tous les points de quadrillage de la zone étudiée, les extremes des hauteurs significatives de vagues (H_S), des hauteurs maximales des vagues individuelles (H_M) et des hauteurs de crates (H_C).

L'analyse renfermait des études de sensibility sur les limites de seuils, la fonction de distribution et la formule d'ajustement. En outre, on a calculé la vitesse maximale du vent liée à l'état extreme de la mer. Pour estimer la période de crête (T_p) liée à l'état extrême de la mer, on a fait appel A l'analyse de la correlation des éléments T_p et H_s qui vont ensemble. La principals analyse des extrémes a étudié les cr8tes des provisions a posteriori indépendamment de la direction des vagues. Le nombre de provisions a posteriori était trop faible pour justifier une analyse intégrale des extrêmes divisée en secteurs de direction de l'approche des vagues.

Enfin, on a formulé des conseils pour de futures études, dont l'analyse des zones proches des rives à l'aide d'un modéle à quadrillage plus fin pour eaux peu profondes, l'analyse des champs de vents proches des rives et l'étude de l'effet des changements climatiques mondiaux (comme le réchauffement du globe attribuable à l'effet de serre) sur la population, les caractéristiques et la violence des tempêtes.

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ACRONYMS AND ABBREVIATIONS

AES	Atmospheric Environment Service
CCC	Canadian Climate Centre
CCAH	Hydrometeorology and Marine Division
CCT	Computer Compatible Tape
CMC	Canadian Meteorological Centre, Montreal, Quebec
COADS	Comprehensive Ocean-Atmosphere Data Set
COGLA	Canada Oil and Gas Lands Administration (now National Energy Board)
DSS	(Department of) Supply and Services Canada
ESRF	Environmental Studies Research Funds
GTS	Global Telecommunication System
IOS	Institute of Ocean Sciences, Sidney, B.C.
LFM	Limited Area Fine Mesh Model of NOAA
MANMAR	Manual Marine Observations
MEDS	Marine Environmental Data Service
METOC	Meteorological and Oceanographic Center, Halifax
MPBL	Marine Planetary Boundary Layer
MPL	MacLaren Plansearch Limited
MRDC	Mobil Research and Development Center, Dallas
NCDC	National Climatic Data Center
NDBO	National Data Buoy Office
NEB	National Energy Board, Calgary
NH	Northern Hemisphere
NMC	U.S. National Meteorological Center
NOAA	National Oceanographic and Atmospheric Administration
NWP	Numerical Weather Prediction Model
ODGP	Ocean Data Gathering Program Spectral Ocean Wave Model
OWI	Oceanweather Inc.
OWS	Ocean Weather Stations/Ocean Weather Ships
PBL	Planetary Boundary Layer
PWC	Pacific Weather Centre, Vancouver, B.C.
SOWM	Spectral Ocean Wave Model of the U.S. Navy
WES	Waterways Experiment Station, U.S. Army Engineers
WMO	World Meteorological Organization

1.0 INTRODUCTION

1.1 STUDY OBJECTIVES AND SCOPE

The main objective of this study was to describe the extreme wave climate of the offshore areas of the Canadian west coast using a hindcast approach (Figure 1.1). The intention of the study was to provide accurate surface wind fields and wave fields in the top-ranked storms and use these data to provide design wave parameters for a given risk level (or return period).

The storm selection task identified potentially severe wave-producing storms in the study area. The top 50 severe storms selected from this population (from 1957 to 1989) were hindcast using calibrated hindcast methods adapted for the North Pacific Basin on a suitable grid system.

In this study, the winds were hindcast using the method developed at Oceanweather Inc. (e.g. Cardone et al., 1980); the ODGP (Ocean Data Gathering Program) Spectral Ocean Wave Model was used to hindcast the top storm events. Wave spectra were archived at selected grid points. An extremal analysis was then carried out to determine the probable extreme parameters for given recurrence intervals (e.g. 2, 5, 10, 25, 50 and 100 year return periods).

The application of the hindcast method included the following main steps:

(1) survey of historical meteorological and oceanographic data, to identify the most severe storms of the relevant types which have occurred within as long a period of history as possible;

(2) the specification of surface wind fields on a discrete grid for each storm;

(3) the numerical hindcast of the time history of the sea state on a grid of points for each storm;

(4) calculation of the expected maximum wave heights and associated properties for each storm at each point; and

(5) extrapolation of the hindcast maxima through the process of extremal analysis, which provides estimates of extremes associated with specified return periods (the average interval in years between events equal to or greater than the associated extremes).

The results of the hindcast were saved on computer tapes for inclusion in the AES climatological database for future applications.

1.2 STUDY AREA

The study area was the West Coast of Canada extending from the shoreline to approximately 144°W longitude and from 45° to 60°N latitude. The model domain, however, extends from 120°W to 220°W and 30°N to 60°N to provide sufficient coverage of distant storms and long swells.

A map showing the general study area, bathymetry, locations, names of places, etc. is given in Figure 1.1 . The study area covers most of the AES marine forecasting areas (i.e. West Coast Vancouver Island, Queen Charlotte Sound, West Coast Charlottes, the exposed part of Hecate Strait and Dixon Entrance, and offshore areas Bowie and Explorer), as shown in Figure 1.2 .

1.3 **HISTORICAL PERIOD COVERED**

Previous experience with the historical meteorological database of the N.E. Pacific Ocean basin supported selection of storms from the past 30 years or so. The database for earlier periods is much less extensive and wind fields may not be specified as accurately. In addition, the CMC charts on microfilm go back only to 1957. Therefore, the historical period which is covered in this study extends from 1967 to 1989 (i.e. 33 years).

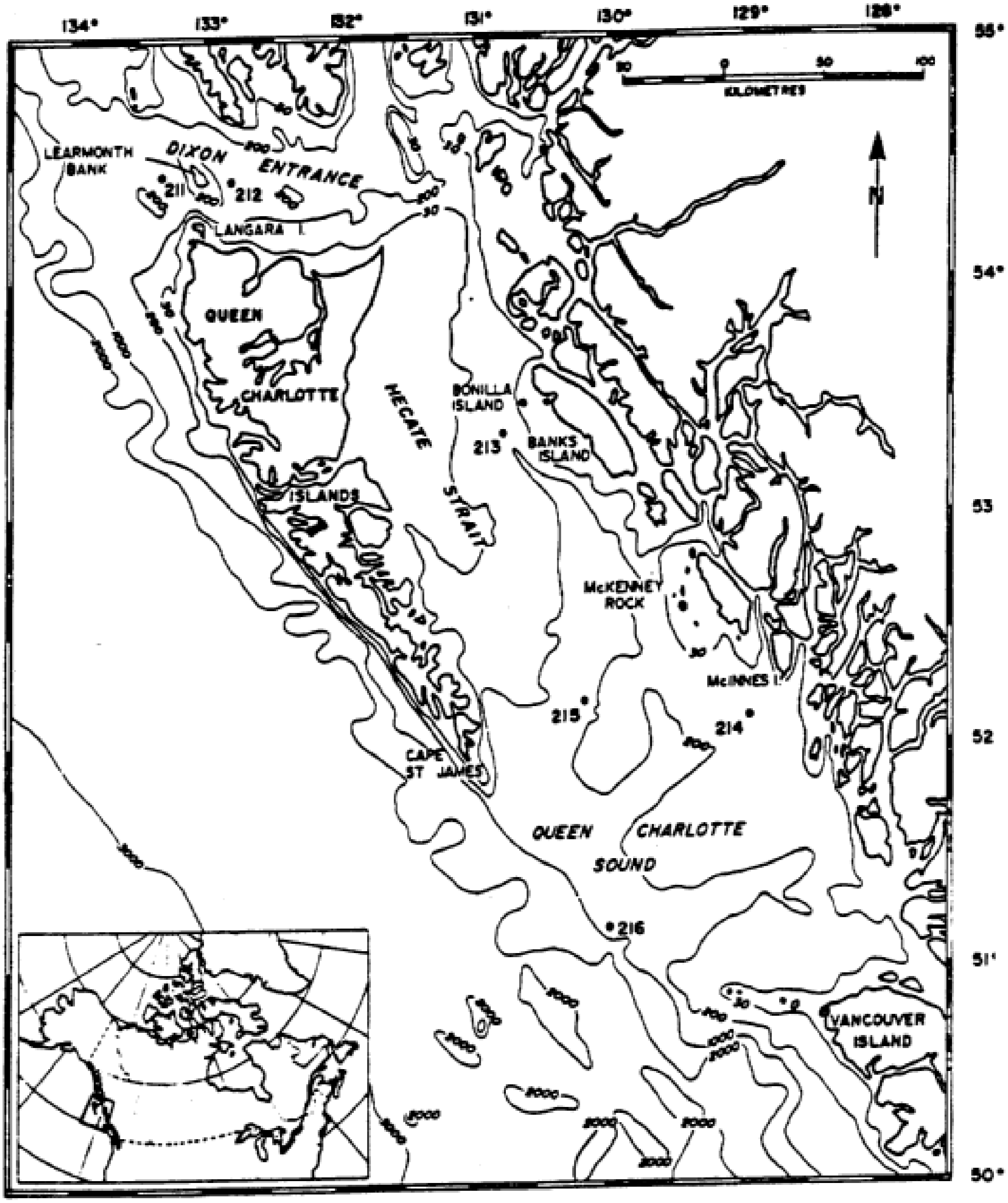


Figure 1.1 Study Location Map

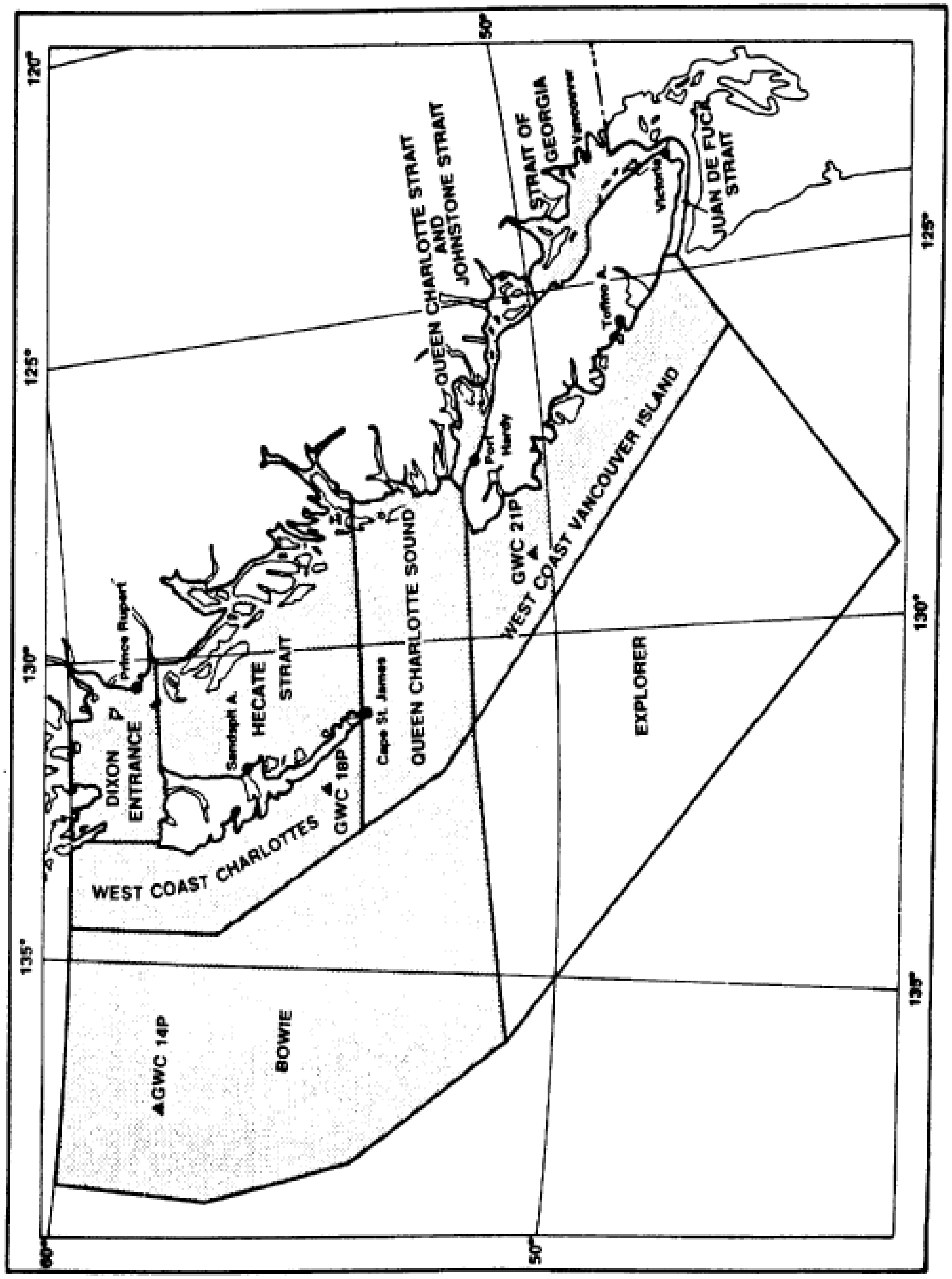


Figure 1.2 Study Area

2.0 DATABASE ASSEMBLY

In order to specify surface wind fields for the production of historical storms, historical meteorological data were assembled into a comprehensive file. The data can be categorized generally in the following 4 types: (1) archived historical surface weather maps; (2) weather observations from ships in transit; (3) weather observations from stationary platforms and land stations; and (4) wave data from instruments, visual observations and numerical models.

The data sources used in this study to aid the selection of the top 50 extreme storm set are listed below.

2.1 ATMOSPHERIC ENVIRONMENT SERVICE (AES)

The Hydrometeorology and Marine Division (CCAH) of the Canadian Climate Centre, AES has collected and compiled a large number of marine data sets. In addition, several software packages were also available to access these databases and analyze the data (e.g. MAST, LAST, DUST). A description of these databases and a list of available information and software to access these files was given in CCAH internal report No. 90-1 (CCC, 1990) entitled ”Marine Climate Directory Datasets and Services”.

The following AES products (or databases) were used:

- CMC microfilm 6-hourly weather maps from 1957;
- PWC microfilm 6-hourly weather maps from 1970;
- COADS ship observations up to the end of 1979 (1854-1979);
- Canadian co-operating ships 1980-89;
- NOAA buoy data (1972-87);
- AES land observations (1953-89);
- Ocean Weather Station (OWS) PAPA (1951-81);
- Selected lighthouse data (1953-present, variable);
- AES Geostrophic Wind Climatology (GWC), (1946-1988); and
- SOWM Pacific Hindcast (1964-76).

2.2 NATIONAL CLIMATIC DATA CENTER, NOAA

Two data types were assembled from NCDC/NOAA: surface weather map series and digital files of historical ship reports.

a) Surface Weather Maps

The following weather map series were utilized:

(1) 3-hourly North American surface analyses produced at the U.S. National Meteorological Center (NMC) in real-time and archived on microfilm 1954 present; and

(2) 6-hourly Northern Hemisphere surface analyses produced at NMC in real-time and archived on microfilm 1954 - present.

b) Synoptic Ship Reports

The most extensive collections of historical surface weather observations from ships reside in three separate magnetic tape archive files available from the U.S. National Climatic Data Center (NCDC). The NCDC files consist of the following:

(1) "Marine Deck" files which cover the period 1954-1969;

(2) "Decade of the 1970's", which covers the period 1970-1979; and

(3) "Tape Deck 1129" which covers the period 1980-present and which consists mainly of recorded ship reports transmitted over the Global Telecommunications System (GTS) in real-time, and ship reports punched from ships' logs received at the NCDC within about 3 months of real-time.

These tape files were updated for this study over the domain of the study area to ensure that the latest collections assembled by NCDC were available for use in the kinematic analysis. The first two ship files above are also part of the COADS file which, as noted above, is available from AES.

Measurements from stationary platforms in the study area are mainly from the buoy network of the National Data Buoy Office (NDBO) operated by NOAA off the West Coasts of Canada and the U.S.A. These measurements are already contained in the ship observation collections described above since observations from most buoys are transmitted at hourly intervals over the GTS. In order to avoid redundancy, an inventory of all available data from each source was carried out to select the most appropriate sources without having the same data sets in 2 sources.

2.3 MARINE ENVIRONMENTAL DATA SERVICE

The Marine Environmental Data Services Branch (MEDS) of the Department of Fisheries and Oceans has been largely responsible for collection, archiving, and analysis of the data from the majority of wave measurement programs in Canadian waters since 1970. The bulk of MEDS wave data are from non-directional waverider buoys. In recent years, a very limited amount of wave data has been collected at a few locations in Canadian waters.

MEDS has initiated a wave climate program of the Northern British Columbia coast of Canada from October 1982 to present (with the exception of MEDS Station #103 at Tofino which has been operational since 1970). This program included wave measurements at six locations (five non-directional waverider buoys and one WAVEC directional wave buoy at Langara). This provided an excellent data set for model validation.

In addition, MEDS has acquired and archived the NOAA buoy data from the National Data Buoy Office (NDBO). These data were also used in the present study.

3.0 STORM CLASSIFICATION AND STORM SELECTION

The single most important property of candidate storms in this study was the potential for generation of severe sea states somewhere within the study area, as defined in Section 1.0 . The process of identifying candidate storms was greatly complicated by the large size of the study areas, unlike many extreme climate studies, which generally consider a specific site. Therefore, it was necessary to explore in this study many different possible indicators of storm severity.

Previous experience has shown that the most effective screening parameter is simply the maximum integrated wind speed (integration time 12 to 24 hours) in the fetch zone of wave generation directed toward the target site or area. Unfortunately, this parameter is not usually directly available in archived meteorological data, except where continuous measured series are available (meteorological buoys, Ocean Weather Ships, island/coastal weather stations). In the absence of long continuous wind series, we have substituted, where available, results of long-term wind field hindcast studies (e.g., the U.S. Navy 20-year Northern Hemisphere hindcast wind fields).

Indirect estimates of storm generation were used in the study to identify potentially severe storms. These included maximum sea-level pressure gradients, storm intensity, and pressure difference between high and low. Ultimately, some subjective assessments by meteorologists with experience in correlation of meteorological storm properties with wave generation must also be used in the ranking process, especially in the final selection of the most severe storms.

This task proceeded in several steps. First, all data sources were screened to develop a comprehensive list of candidate storms in the study area. This list was then reduced in several stages to refined storm lists, with the aid of both objective storm intensity ranking parameters and subjective ranking and intensity assessments.

In summary, the storm selection is accomplished in three main steps:

1) potentially severe storms were selected from the past 33 years;

2) storm verification and cross-checking between different data sources; and

3) storm ranking and final selection.

In addition, previous studies were reviewed and their results assessed and used in cross-checking the selection of top-ranked storms.

3.1 PREVIOUS STUDIES

A number of studies have been carried out to study severe storms off Canada’s West Coast, some having objectives similar to this study. A list of these relevant studies, which were assessed for verification purposes, is given below:

- Canadian Climate Center (CCC) Report #85-7: "Severe storms off Canada's west coast - a catalogue summary for the period 1957 to 1983";
- Canadian Contractor Report of Hydrography and Ocean Sciences No. 22, MEDS, DFO, March 1988: "A wave climate study, of the Northern British Columbia Coast - Volume I: wave observations, Volume II: wave properties and wave prediction;
- Seaconsult Marine Research Limited (1986) report for IOS entitled "On the impact of new observing sites on severe sea state warning for the B.C. Coast"; and
- Juszko (1990): "Analysis of the West Coast wave climate", report prepared for Defence Research Establishment Atlantic (DREA).

3.2 IDENTIFICATION OF POTENTIAL SEVERE STORMS

The development of the initial coarse list of potentially severe wave-producing storms consisted of examining the databases listed in Section 2.0 . For each storm identified, the starting and ending dates, and selected wind and wave values, including maximum wind speed, duration of wind speed above the threshold, and maximum significant wave height measured, observed or predicted from previous hindcast studies, were abstracted from the data records.

3.2.1 AES Digital Databases

Potentially severe storms in the period 1957-1989 were identified by using the MAST system to scan the AES digital databases listed in Section 2.1 . All wind and wave data greater than or equal to specified thresholds were extracted. The thresholds were established upon examination of wind and wave records, and selected to be in the range of 45-50 knots for wind speed and 7-8 metres for significant wave height. Table 3.1 provides a summary of the data sources, threshold values, and number of events yielded from this first screening.

3.2.2 MEDS Waverider Buoy Measurements

All waverider buoy data compiled by MEDS for the study area from 1970 through 1989 were screened to identify all events with significant wave height (H_S) greater than or equal to 7 metres. A separate list of potential candidates was identified. The list identifies the area, starting and end dates of storm, MEDS station number, and the corresponding maximum H_S measured in the area. This list was then blended with the above list.

Table 3.1

Storm Selection Criteria

Data Source	Threshold	Period	# Storms
NOAA Buoy Wave Data	Wave ≥ 8 m	76-87	51
NOAA Buoy Wind Data	Wind ≥ 45 kts	76-87	52
Estevan Point (land observations) Wind Data	Wind ≥ 45 kts	83-87	4
GWC Winds	Wind ≥ 50 kts Duration ≥ 12 hrs	57-88	545
Lighthouse (LIGHT) Wind Data	Winds ≥ 45 kts Duration ≥ 12 hrs	66-77	217
Lighthouse (LIGHT) Wave Data	Wave ≥ 8 m Winds ≥ 45 kts Duration ≥ 12 hrs	57-84	4
Land Observations: North Wind	Wind ≥ 45 kts Duration ≥ 6 hrs	57-88	317
Land Observations: South Wind	Wind ≥ 45 kts Duration ≥ 6 hrs	64-77	224
MEDS Buoy Data	Wave ≥ 7 m	73-89	113
Ship Observations: Wave Data	Wave ≥ 8 m	57-87	310
Ship Observations: Wind Data	Wave ≥ 45 kts	57-88	1693
Ocean Weather Station PAPA Wave Data	Wave ≥ 8 m	63-81	135
Ocean Weather Station PAPA Wind Data	Wind ≥ 45 kts	57-81	278

3.2.3 <u>NOAA Buoy Measurements</u>

Data from NOAA buoys in the North East Pacific were also scanned and storms with values of wind speed, wave height and duration which met or exceeded the thresholds stated in Table 3.1 were extracted and blended in the coarse list.

From this first scan of all data sources, 1167 storms were identified.

3.3 DEVELOPMENT OF MASTER CANDIDATE LIST (MCL)

The preliminary list (coarse list of 1167 storms) derived from the above screening was further analyzed. In order to retain only the most significant events from the coarse list, the following thresholds were applied:

Significant Wave Height (H_s) ≥ 8 m
H_s ≥ 7 m for MEDS data (i.e. buoy measurements)
Duration ≥ 12 hrs except for MEDS data
Wind Speed ≥ 50 knots

This process yielded a list of the 500 most severe storms, which constitutes the Master Candidate List (MCL). The complete MCL is listed in Appendix A .

For each event, pertinent parameters which were taken into account in the selection process were extracted from the various sources and tabulated as shown in Appendix A , Table A-1 . They include storm duration above given thresholds, peak wind speed and direction, peak significant wave height H_s, peak period (T_p), and the severity index. The latter was calculated by multiplying storm duration above a given threshold by peak wind speed and is often a good indicator for storm severity. As for the coarse list, values extracted are the maximum measured, hindcast or observed for each parameter.

3.4 REDUCTION OF TIE[E MASTER CANDIDATE LIST

A further reduction to 297 severe events was performed. All remaining storms met the following thresholds:

Wind Speed ≥ 60 knots unless winds ≥ 55 knots and H_s ≥ 10m
Wave Height ≥ 9.5m
Duration ≥ 12 hours except for MEDS data

A microfilm scan was performed for these 297 storms. Each map file on microfilm (i.e. CMC, PWC and NOAA/NMC weather maps) was examined.

The microfilm scan is the process in which a meteorologist inspects each 6-hourly historical weather map and identifies storms against threshold criteria specifically designed to capture occurrences of high sea-states in the study area. The threshold criteria in this case are based upon study of the meteorological patterns associated with measured high wave events in the last several years, as well as the extensive experience gained over the past few years through similar hindcasting studies.

The list of selected 297 storms is shown in Appendix A , Table A-2 .

3.4.1 Threshold Analysis Ranking (TAR)

In recent hindcast studies carried out by Oceanweather, increased emphasis has been given to a method of objective ranking of historical storms based upon readily available properties of the surface pressure pattern of extratropical storms. In a study of the Hibernia storm population, Szabo et.al. (1989), it was shown that there is a high correlation between certain storm properties and maximum H_s in a storm at a site. The same criteria were successfully applied to the East Coast hindcast study (Canadian Climate Centre, 1991).

The following storm properties which are most highly correlated with peak H_s in the West Coast area were extracted from the microfilm maps: (1) maximum pressure gradient; (2) duration of maximum pressure gradient; (3) pressure difference between the low over the Gulf of Alaska and high offshore California; (4) width of the fetch and (5) storm intensity.

For the present study, the above parameters were defined as follows:

1) maximum pressure gradient (mb/60 n.mi. (1-degree lat.)) - this gradient is simply scaled off the isobaric analysis in the tightest zone of maximum pressure gradient at the low situated over the region of interest;

2) duration of maximum pressure gradient: the length of time (in hours) for which the wind direction remained constant during the maximum pressure gradient;

3) pressure difference (in mb) between low over The Gulf of Alaska and the high over California;

4) width of the fetch in degrees of latitude; and

5) storm intensity: duration for which 75% Of the maximum pressure gradient remained in the same direction (±15°) during the storm.

Given sufficient measured wave height data in storms, the correlations between measured wave height and the above parameters may be used to calibrate the ranking system in terms of parameters thresholds. The calibration consists simply of defining for each single parameter that threshold is satisfied by all observed (or hindcast) storms in which H_s exceeds a specified threshold. The established thresholds then provide a basis for the TAR values.

While the Szabo et.al. (1989) included a calibration against Hibernia measured and hindcast data, (this was also validated in the previous east coast extreme hindcast study (CCC, 1991) a similar calibration for all regions of interest in this study would require a much larger database of measured peak H_s than is currently available. Nevertheless, the guidance of previous studies, and analysis of recent storms where buoy measurements were available, were used to establish the threshold values for the study area. It was found that the following three parameters have strong correlation with the severity of the wave-generating storms in the study area. The TAR thresholds for these parameters are:

Maximum Pressure Gradient:	6 mb/degrees latitude
Storm Duration:	10 hours
Pressure Difference Between: High and Low	50 mb

Note: These thresholds were increased during the process of refinement of the storm list described hereafter.

In addition, for West Coast storms there is a strong evidence that swell, combined with wind wave, is an important factor and should be looked at during the selection processes. In order to quantify this effect and help in the selection process, an arbitrary wave and swell summation (WASS) Factor was determined from the surface analysis charts and a weighted combination of above TAR parameters. It is calculated as follows:

WASS Factor $10\ (G_w) + T_w + \Delta + 10\ (G_S) + T_S + D_S$

Where:
G_w = Maximum (wind wave) producing pressure gradient (mb) in the study area;
T_w = Duration of at least 75% of $+G_w$ (hrs);
Δ = Maximum pressure difference between high pressure centre and low pressure centre (mb);
G_S = Maximum (swell producing) pressure gradient directed toward the study area (mb);
T_S = Duration of at least 75% of G_S (hrs); and
D_S = Fetch of 75% of G_S (nautical miles).

3.4.2 <u>Semi-Final last</u>

The semi-final list (165 storms) was selected by correlating all of the aforementioned criteria from the microfilm scan as well as directly observed or measured parameters.

This list was established after vigorous assessment and further examination of the microfilm charts and other data sources, and by successive increase of the previously listed thresholds (e.g. Hs ≥ 9.5m, maximum pressure gradient ≥ 7 mb/deg. lat., storm intensity ≥ 24 hrs.).

This analysis yielded the semi-final list of 165 storms shown in Table A-3 , Appendix A . All the storms included in this list have a WASS Factor greater than 160 except for storms #204,263, 285 and 289. These latter storms were selected for their high wind speed and wave height and high severity index.

3.4.3 Final List

The semi-final list of 165 storms was further distilled to produce the targeted final storm list of approximately 80 events, of which the top 50 storms were selected for hindcast production. The storms in the semi-final list were further re-examined. All storms with WASS Factor greater than 200 were selected, with the exception of 3 storms (MCL #447, 289 and 285). These were selected because of their very high wind speeds (≥ 75 kts) and/or measured wave heights (≥ 13 m) as well as high severity index. A total of 78 storms were selected to represent the final top severe storm population. These are listed in Table 3.2 .

The top 50 storms were then selected out of the above 78 events. In this list all storms having a WASS Factor greater than 300 (i.e. a total of 37 storms) were included. The remainder were selected because of their higher observed or measured wave height and wind speed.

The final list of 78 storms with the top 50 storms identified by (*) is shown in Table 3.2 . The distribution of these storms by month is shown in Figure 3.1 . As shown, November has the largest percentage of storms, followed by October and January.

Note: The storm of October 26, 1990 was later added to the above 50 severe storms to bring the total hindcast events to 51 storms (see Section 6.0).

TABLE 3.2 FINAL 78 TOP SEVERE STORM LIST

MCL #	START YYMMDDHH END YYMMDDHH	DUR (hr)	OBS #	WIND		COMBINED SEA			SEVERITY INDEX	WASS INDEX	SOURCE	TOP 50 STORMS
				SPD (kts)	DIR	HS (m)	TP (s)	DIR				
45.	62112215-62112512	343	33	65.	220	10.5	14.5	188	22295	303	D,G,I,J,K,L	*
56.	63101906-63102518	143	42	74.	290	12.7	16.5	260	10582	309	D,G,H,I,J,K	*
66.	64101718-64101912	132	23	70.	140	12.0	16.5	180	9240	258	D,F,G,I,K,M,N	
77.	65100200-65100700	114	24	65.	300	11.5	16.5	180	7410	240	D,H,I,J,K,L,M,N	
81.	65112706-65120100	186	43	57.	200	10.0	16.5	170	10602	309	D,F,G,K,L,M,N	*
99.	67010612-67011118	159	26	82.	250	12.0	16.5	160	13038	301	D,F,G,K,M,N	*
111.	67112806-67120900	247	206	84.	130	13.5	18.5	280	20748	274	D,F,G,H,I,J,K,L,M,N	
134.	68110100-68111006	227	29	70.	150	14.5	10.0	100	15890	253	F,D,F,G,H,I,J,K,M,N	
137.	68112500-68120112	134	28	95.	140	15.0	12.0	270	13680	341	F,G,H,I,J,K,L,M,N	*
145.	69020606-69021118	75	14	80.	160	11.5	8.5	180	5760	248	D,G,J,K,L,M,N	
150.	69041800-69042200	99	23	63.	260	15.4	14.0	250	6237	257	D,F,G,H,I,K,L	
154.	69103106-69110700	219	28	80.	320	19.1	13.0	235	17520	318	D,F,G,H,I,J,K,L,M,N	*
155.	69111506-69112206	441	70	62.	260	14.4	12.0	238	27342	310	D,F,G,H,I,K,M,N	*
158.	69121600-69122006	235	53	61.	140	16.0	12.0	263	14335	244	D,F,H,I,K,M,N	
164.	70020118-70020709	114	31	64.	200	14.9	12.0	260	7296	286	D,F,G,H,I,K,M,N	
165.	70021718-70022312	121	22	63.	210	16.0	8.5	190	6655	333	D,F,M,N	*
172.	70102600-70110206	165	25	98.	040	9.5	8.5	140	16170	333	D,F,K,L,M,N	*
176.	70112906-70120112	48	15	70.	070	10.6	6.5	020	3360	202	F,H,I,K,M,N	
186.	71011412-71011512	99	22	65.	050	9.6	10.0	122	6435	225	D,F,K,L,M,N	
194.	71030606-71031418	232	52	65.	110	12.6	11.0	265	15080	219	D,F,G,I,J,K,L,M,N	
210.	71112006-71112400	96	19	64.	010	15.0	7.0	350	6144	207	H,I,J,K,M,N	
218.	72010806-72011100	105	46	81.	280	15.5	8.5	280	8505	278	D,F,G,H,I,J,K,M,N	
219.	72011306-72011612	87	18	65.	140	16.5	10.5	250	5655	219	D,F,G,H,I,J,K,M,N	*
235.	72111912-72112606	162	23	75.	260	18.0	14.0	216	11475	259	D,F,G,H,I,J,K,M,N	
243.	73012600-73020112	160	28	86.	160	14.1	6.5	160	13760	327	D,F,H,I,J,K,M,N	*
255.	73111818-73112206	78	46	87.	140	15.5	11.0	311	6786	248	D,H,I,J,K,L,M,N,P	
267.	74021918-74022406	126	21	63.	200	13.0	12.0	142	7938	249	D,F,H,I,K,L,M,N	
285.	75010406-75010612	239	40	107.	140	13.9	14.0	274	25573	124	D,F,G,H,I,K,L,M,N	*
289.	75031900-75032206	168	39	78.	250	19.5	14.0	285	13104	147	H,I,J,K	
292.	75100212-75100606	82	29	68.	220	10.5	8.5	240	5576	239	F,H,I,J,K,M,N	
299.	75111006-75111400	249	95	79.	230	23.0	9.0	144	19671	363	D,F,G,I,J,K,L,M,N,P	*
303.	75121600-75122106	153	46	74.	210	21.4	8.0	130	11322	372	D,H,I,J,K,L,M,N	*
309.	76012500-76013118	156	47	68.	200	14.0	8.5	190	10608	315	D,F,I,J,K,L,M,N	*
312.	76022106-76022818	181	31	60.	120	12.7	12.0	290	10860	352	D,F,J,K,M	*
314.	76031918-76032218	75	19	69.	180	16.3	14.0	226	5175	271	D,F,H,I,K,L,M,N	
315.	76032312-76032706	90	13	67.	230	16.3	14.0	226	6030	257	D,F,H,I,K,L,M,N	
321.	76102306-76102806	115	34	65.	240	10.0	8.5	190	7475	301	D,F,G,K,L,M,N	*
322.	76102918-76110400	123	31	80.	140	12.1	8.5	220	9840	306	A,B,D,F,J,K,M,N	*

TABLE 3.2 FINAL 78 TOP SEVERE STORM LIST (Cont'd)

MCL #	START YYMMDDHH	END YYMMDDHH	DUR (hr)	OBS #	WIND SPD (kts)	WIND DIR	COMBINED SEA HS (m)	COMBINED SEA TP (s)	COMBINED SEA DIR	SEVERITY INDEX	WASS INDEX	SOURCE	TOP 50 STORMS
334.	77011400	77011812	111	46	80.	190	11.0	8.5	220	8160	339	A,D,F,H,I,J,K,L,M,N	*
337.	77020818	77021500	165	34	66.	180	11.4	10.0	215	9834	337	A,D,F,H,I,J,K,L,M,N	*
338.	77021700	77022300	138	99	68.	250	18.0	14.0	239	9384	386	A.B,D,H,I,J,K,L,M,N	*
340.	77030412	77031006	213	63	92.	140	16.6	12.0	266	19596	291	A,B,D,F,H,I,J,K,L	
345.	77101100	77101400	114	26	93.	160	21.4	12.0	170	10602	270	D,F,H,J,K	
346.	77101606	77101906	42	5	93.	160	21.4	12.0	170	3906	288	D,H,I,J,K	
347.	77102312	77102618	162	67	103.	260	21.4	12.0	170	16686	308	A,B,D,F,G,H,I,J,K,L,P	*
352.	77111000	77111612	158	93	71.	220	15.6	14.0	212	11218	270	D,F,G,H,I,J,K,L	
356.	78010618	78011006	150	45	83.	140	20.2	6.5	160	12450	321	D,F,G,J,K	*
372.	78102900	78110212	108	60	72.	210	12.5	12.5	220	7776	334	A,B,D,F,G,J,K	*
378.	78121200	78121606	166	87	70.	250	19.8	8.5	260	11620	357	A,B,D,F,G,H,I,J,K,L	*
384.	79021212	79021812	232	98	101.	330	18.0	10.0	324	23432	336	A,B,D,F,J,K,L,P	*
385.	79030212	79030800	147	39	61.	180	10.0	10.5	160	8967	317	D,F,J,K,L	*
395.	79111806	79112300	126	79	97.	130	17.7	10.5	000	12222	329	B,D,F,G,I,J,K,L	*
396.	79112700	79120318	204	159	91.	150	16.8	13.0	131	18564	277	B,D,F,H,I,J,K	
398.	79121506	79121918	291	68	81.	100	18.4	12.0	180	23571	217	D,F,G,H,I,J,K,L	*
409.	81091700	81091900	36	19	66.	220	11.5	10.5	-099	2376	221	A,B,D,K	
413.	81113000	81120300	126	157	67.	190	10.0	12.5	-099	8442	314	A,B,D,F,G	*
423.	83110800	83111200	92	44	74.	180	10.8	8.0	170	6808	273	D,F,G,K,P	
427.	84040812	84041100	98	47	70.	280	17.0	11.0	245	6860	335	C,D,G,J,K,P	*
431.	84101200	84101400	51	76	90.	270	13.0	14.0	238	4590	260	A,B,D,G,K,L,P	*
432.	84103112	84110406	101	117	76.	170	10.5	10.5	270	7676	318	A,B,D,K,P	*
436.	85021018	85021518	120	54	89.	100	12.5	12.5	250	10680	359	A,D,G,P	*
437.	85030312	85030512	48	21	72.	330	14.1	12.0	310	3456	283	A,B,D,J,K	
442.	86010612	86011016	201	108	97.	160	9.5	16.5	210	19497	326	A,D,G,K,L,P	*
445.	86022606	86030206	120	32	67.	190	10.7	18.2	-99	8040	266	D,P	*
447.	86042400	86042518	42	16	64.	330	14.0	12.5	290	2688	192	D,J,K,P	*
449.	86111712	86111912	75	51	83.	320	12.5	16.5	260	6059	206	A,B,D,G,K,P	*
450.	86112106	86112418	193	74	73.	270	13.5	14.5	230	14089	273	A,B,D,G,L,P	*
451.	86122300	86122700	96	35	67.	180	9.8	12.4	-99	3360	248	A,D,G,L,P	*
453.	87010618	87011018	96	33	70.	180	10.0	0.0	340	6720	312	D,G,J,L,P	*
461.	87041212	87041706	103	40	71.	250	10.6	14.3	-99	3871	303	A,D,G,P	*
469.	87120418	87121106	153	128	76.	190	11.5	10.5	160	11628	501	C,D,G,J,K,L,P	*
472.	88011200	88011600	98	50	77.	150	10.2	14.3	-99	7546	362	D,G,P	*
476.	88030318	88030612	60	71	67.	200	12.0	14.2	-99	4020	266	D,G,P	*
485.	88111818	88112406	135	106	78.	150	11.2	14.2	-99	8424	421	D,G,L,P	*
486.	88112606	88112812	41	39	86.	260	14.8	17.1	-99	2580	318	D,G,P	*

TABLE 3.2 FINAL 78 TOP SEVERE STORM LIST (Cont'd)

MCL #	START YYMMDDHH	END YYMMDDHH	DUR (hr)	OBS #	WIND SPD (kts)	WIND DIR	COMBINED SEA HS (m)	COMBINED SEA TP (s)	COMBINED SEA DIR	SEVERITY INDEX	WASS INDEX	SOURCE	TOP 50 STORMS
487.	88112812	88120112	46	74	78.	210	12.2	14.2	-99	3588	321	D,G,P	*
488.	88120200	88120412	44	31	72.	170	9.6	15.1	-99	3168	266	D,P	*
497.	89011818	89012212	7	17			11.2	16.0	-99	0		P	*

Selection Criteria

All these storms have: winds >= 60 kts unless wind >= 55 kts had waves >= 10 m
waves >= 9.5 m
dur >= 12 hrs except MEDS

Sources :

	Source	Wave		Wind		Duration
A)	BUOY wave	>= 8 m	or	>= 45 kts		
B)	BUOY wind	>= 8 m	or	>= 45 kts		
C)	ESTEVAN wind			>= 45 kts		
D)	GWC wind			>= 50 kts	and	>= 12 hrs
E)	LIGHT wave	>= 8 m	or	>= 45 kts		
F)	LIGHT wind	>= 8 m	or	>= 45 kts	and	>= 6 hrs
G)	NORTH wind			>= 45 kts	and	>= 6 hrs
H)	PAPA wave	>= 8 m	or	>= 45 kts		
I)	PAPA wind	>= 8 m	or	>= 45 kts		
J)	SHIP wave	>= 8 m	or	>= 45 kts		
K)	SHIP wind	>= 7 m	or	>= 45 kts		
L)	SOUTH wind			>= 45 kts	and	>= 6 hrs
M)	SOWM wave	>= 8 m	or	>= 45 kts		
N)	SOWM wind	>= 8 m	or	>= 45 kts		
P)	MEDS	>= 7 m				

Definitions:

MCL #:	storm Master Candidate List number
START/END:	storm start and end dates
DUR:	storm duration above a predefined threshold (i.e. wind speed >= 34 kts was used here)
OBS:	number of reported observations above a given threshold

Wind Speed (SPD) and Combined Sea Height (H_s) and Peak Period (T_p) represent the heighest reported (measured, observed or hindcast) values of these parameters from all data sources.

Severity Index:	DUR * Wind Spd
*:	storms selected in the top 50 list

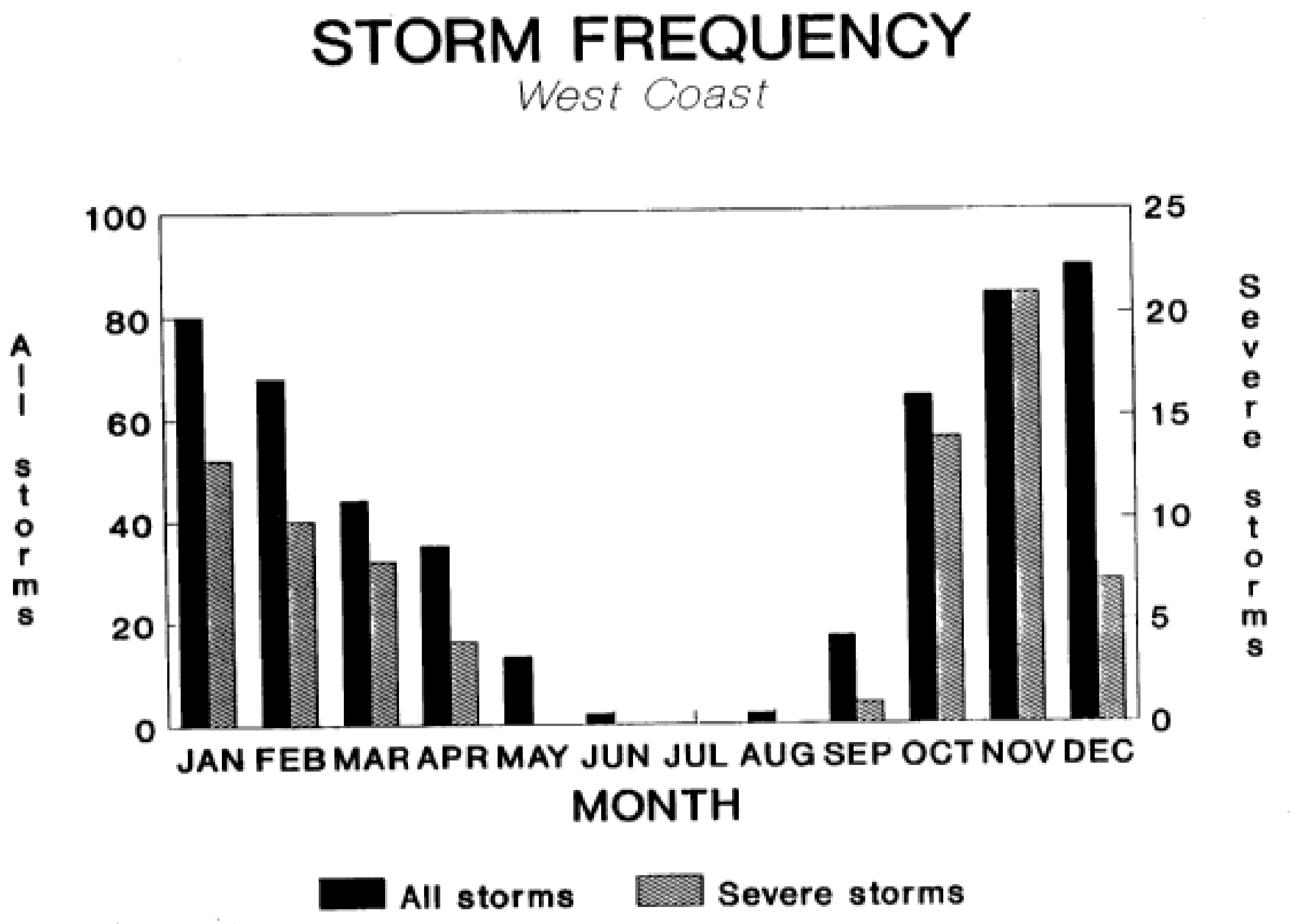


Figure 3.1 Storm Frequency of Occurrence by Month

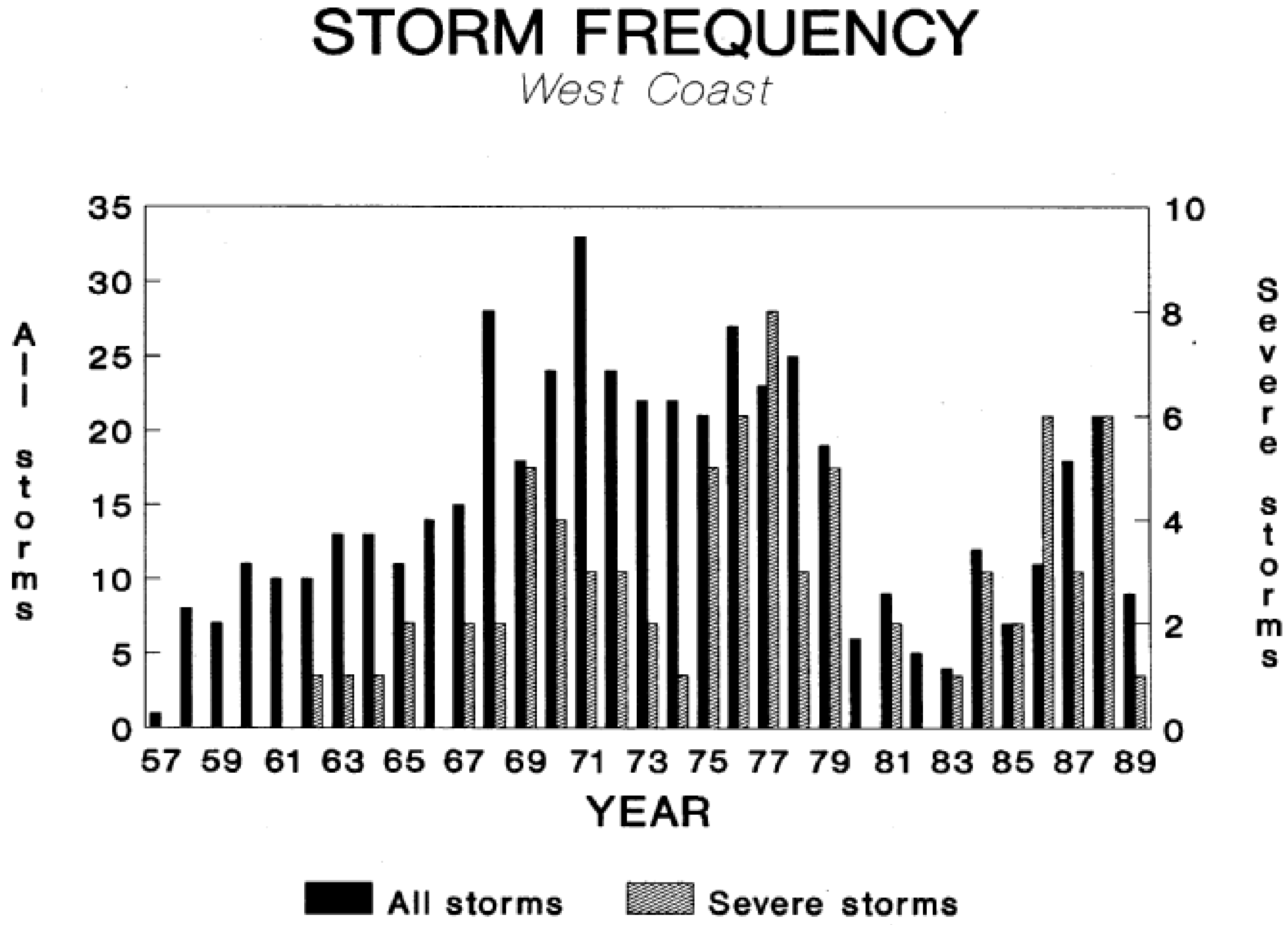


Figure 3.2 Storm Frequency by Year

4.0 WIND FIELD ANALYSIS AND WAVE HINDCASTING

4.1 WIND FIELD ANALYSIS

The method used for hindcasting wind fields for the selected storms was based on Cardone et al. (1980). It is based on man-machine mix intensive wind field analysis using a blend of surface pressure analysis using Cardone's Marine Planetary Boundary Layer (MPBL) Model, and kinematic analysis wind fields.

The hindcasting period of each storm consists of:

(a) period of spinup of background seas in the model domain in which principal wave generation occurs prior to the peak of the selected storm (about 48 hrs.);

(b) period during which selected storm generates seas in the study areas and including always the period within ±12 hours of expected occurrence of peak sea states in each area; and

(c) 24-hour period following (b) in which peak seas continue to decay.

For the spinup and decay periods, the approach is to specify winds from the sea level pressure analyses. Gridded pressures are then converted to "effective neutral" 20-m winds through the marine planetary boundary layer (MPBL) model developed by Cardone (1969,1978). The "effective neutral" speed, introduced by Cardone (1969) to describe the effects of thermal stratification in the marine boundary layer on wave generation, is simply the wind which would produce the same surface stress at the sea surface in a neutrally stratified boundary layer as the wind speed in a boundary layer of a given stratification. This is consistent with the similarity approach and produces analogous functions. The baroclinic forcing term is supplied at each grid point from climatological horizontal air temperature gradients appropriate to the North Pacific Ocean in the cold season. The atmospheric stability term is specified as a function of local geostrophic wind direction.

Kinematic winds are extracted from the streamline/isotach analyses at the fine mesh grid point locations in the model domain for the period (b), i.e. the peak of the storm, and represent the effective 1-hour average 20-m level neutral wind. Reports of wind speed from buoys, ships and rigs equipped with anemometers are transformed into the effective neutral 20 m values. For ships which use estimated wind speeds, values are adjusted according to the Scientific Beaufort scale. The kinematic winds replace the winds derived from the pressure field in the interior of the kinematic domain, and are blended with the pressure-derived winds along the boundaries of the domain.

Kinematic winds are by far the most accurate and least biased winds, primarily because the method allows a thorough re-analysis of the evolution of the wind fields. Kinematic analysis also allows the wind fields to represent effects not well modelled by pressure-wind transformation techniques, such as inertial accelerations associated with large spatial and temporal variations in surface pressure gradients and deformation in surface winds near and downstream of coasts.

The final step in the wind field analysis is interpolation from 6 hours to 2 hours (as required to drive the wave model). Linear interpolation in time of zonal and meridional wind components is used for wind direction, while the fourth power of wind speed is used for interpolation of wind speed. Further interpolation is done near centres of rapidly propagating cyclones to avoid errors due to excessive smoothing of winds. The gridded wind fields were produced on the ODGP wave model grid shown in Figure 4.1 . The grid specification is given in Section 4.2.1 .

4.2 WAVE HINDCASTING

The ODGP Spectral Ocean Wave model was used in this study to hindcast the wave fields for the selected top 51 storms.

The ODGP wave model is a first generation deep-water, fully directional spectral model (24 directions by 15 frequencies) which evolved from the U.S. Navy’s Spectral Ocean Wave Model (SOWM). The same model was used to provide a similar extreme hindcast climatology for the East Coast of Canada (CCC, 1991) as well as a wave climate database for the East Coasts of Canada and U.S.A (Eid et al, 1989). A detailed description of the model physics and hindcast techniques is given to Cardone et al. (1976), MacLaren Plansearch (1985), and Eid and Cardone (1987). A special version of the model which includes capes and islands (CAIPS) was used in the present application.

4.2.1 Model Domain and Grid Specification

The ODGP model domain has been extended to a sufficient distance offshore to cover the source of the long period swells that arrive at the study sites.

The model domain and grid specification are shown in Figures 4.1 and 4.2 . The model comprises two nested grids; a coarse grid and fine grid as described below.

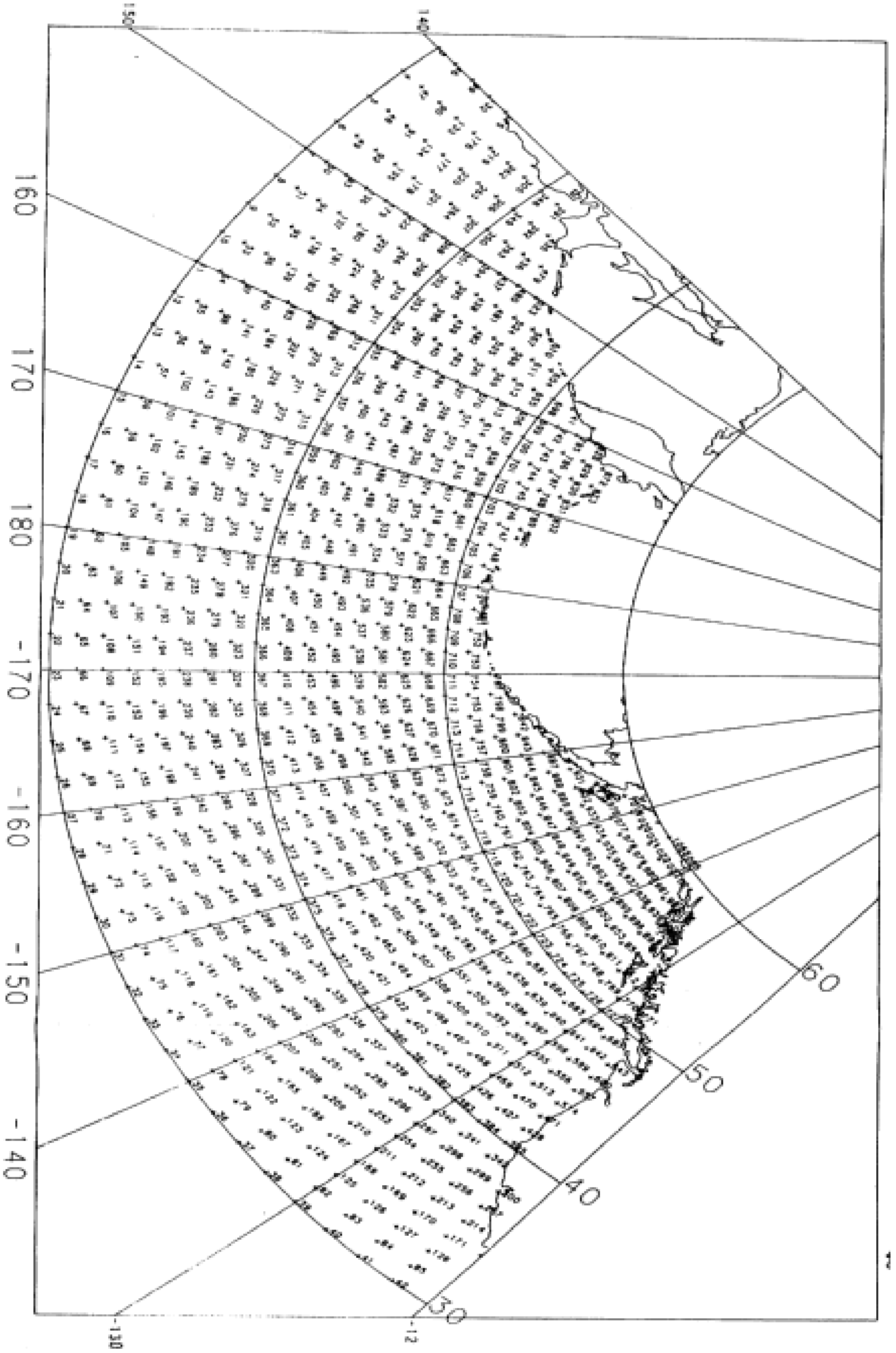


Figure 4.1 The ODGP Model Domain (Coarse Grid)

	Coarse Grid	Fine Grid
Domain:	30°N - 60°N	45°N - 60°N
	120°W - 220°W	142°W to the coast irregular shape
Spacing:	1.25° lat. x 2.5° long.	0.625° lat x 1.25° long.
Active Grid Points:	755	173
Time Step:	2 hours	
Time Step Sequencing:	1h grow, 2h propagation, 1h grow	
Angular Spectral resolution:	24 directions, 15° band width	
Frequency Spectral Resolution:	15 frequencies (Table 4.1)	

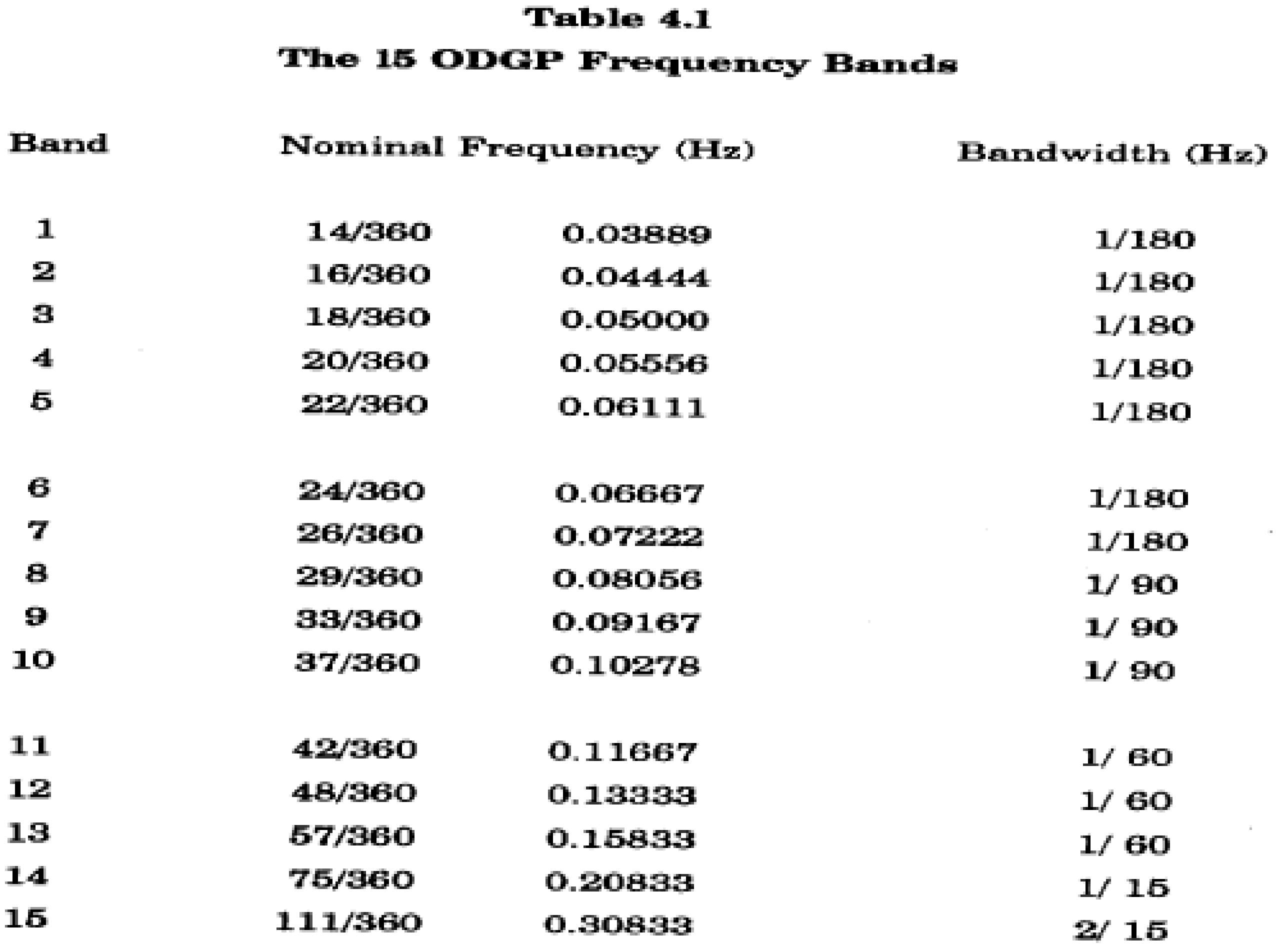


Table 4.1

The 15 ODGP Frequency Bands

Band	Nominal Frequency (Hz)		Bandwidth (Hz)
1	14/360	0.03889	1/180
2	16/360	0.04444	1/180
3	18/360	0.05000	1/180
4	20/360	0.05556	1/180
5	22/360	0.06111	1/180
6	24/360	0.06667	1/180
7	26/360	0.07222	1/180
8	29/360	0.08056	1/ 90
9	33/360	0.09167	1/ 90
10	37/360	0.10278	1/ 90
11	42/360	0.11667	1/ 60
12	48/360	0.13333	1/ 60
13	57/360	0.15833	1/ 60
14	75/360	0.20833	1/ 15
15	111/360	0.30833	2/ 15

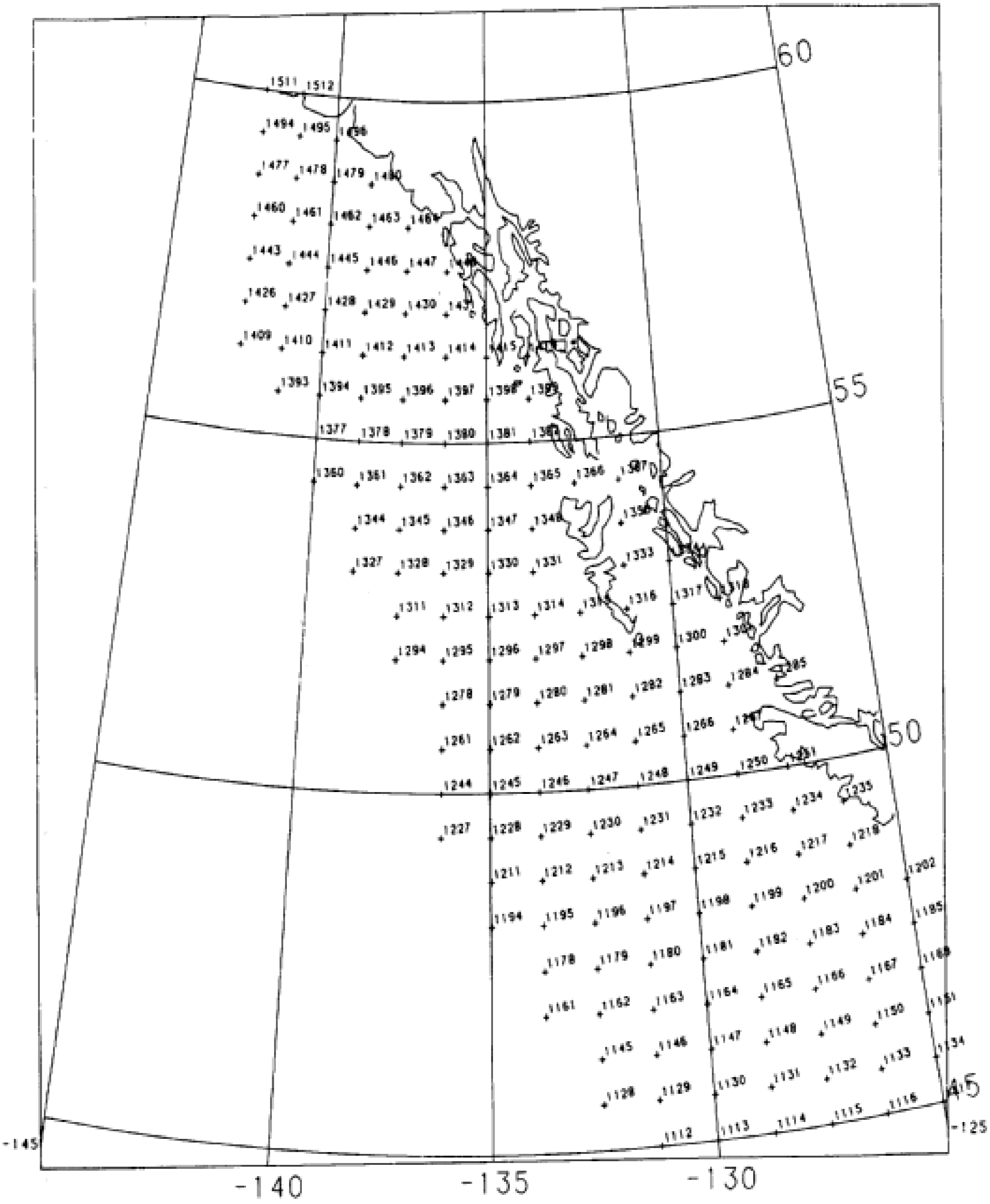


Figure 4.2 ODGP Fine Grid

4.2.2 Physics Algorithms

Only a very brief summary is presented here. For a detailed description of the model physical and numerical algorithms, the reader is referred to Cardone et al. (1976) and MacLaren Plansearch (1985). The general energy balance equation for wave evolution is given by the equation:

$$\frac{\partial}{\partial t} S(f,\Theta;x,t) + Cg.\,\nabla S = F(f,\Theta;x,t) \quad (1)$$

where:

$S=S(f,\Theta;x,t)$ is the two-dimensional wave spectrum as a function of frequency (f) and direction (Θ) at a given location (x) and time (t);

$C_g=C_g(f,\Theta)$ is the deep-water group velocity;

$F(F,\Theta;x,t)$ is the source function which represents all physical processes that transfer energy from or to the spectrum.

The source function may be expressed as a sum of three terms:

$F = F_{in} + F_{nl} + F_{ds}$

where: F_{in} = energy input function by wind,
F_{nl} = non-linear transfer by wave-wave interaction,
F_{ds} = energy dissipation term.

The input source function (F_{in}) is represented in ODGP as a function of wind speed and frequency according to the linear equation:

$F_{in} = A + B \times S$

The "A" term in the above equation $=A(f_i,u)$ is a function of frequency (f) and wind speed (u). This term represents Phillips' external turbulent pressure forcing. The "B.S" term corresponds to Miles' linear feedback mechanism. The term $B(f_i,u_*)$ is expressed in ODGP as a function of frequency and the friction velocity (u_*).

The energy transfer associated with the non-linear wave-wave interaction is not explicitly included in ODGP.

In general, hindcast models work by applying alternate steps to model the effects of propagation and growth. In the propagation step, the frequency bands of the model are totally uncoupled, and the directional bands are weakly coupled by convergence of meridians on a spherical earth. In the growth step, the grid points are totally uncoupled; the frequency and direction bins at one grid point are coupled because of the treatment of the source and sink terms in the spectral energy balance equation.

The propagation scheme used in the ODGP operational model was constructed for use with a spherical earth, and combines elements of jump and interpolatory propagation. When an ocean basin is mapped on a plane by an arbitrary projection, and a rectangular or triangular grid overlaid, the distance from each point to its neighbours, and thus the coefficients in the propagation formula, are functions of both latitude and longitude. Coefficients dependent on latitude alone arise when one set of grid lines is meridians equally spaced, and the other set parallels at any convenient spacing.

The ODGP growth algorithm developed by Cardone, Pierson, and Ward (1976), is a part of the family of PTB discrete-type spectral models described by Pierson, Tick, and Baer (1966). While the ODGP spectral growth/dissipation algorithm is of the PTB type, significant differences between it and the U.S. Navy SOWM model (also a PTB type) evolved in the application and verification of the ODGP model against measured wave spectra in hurricanes. An important difference is in the calculation of the wave growth as a function of the angle between the wave direction and wind direction. In the SOWM, the energy in a given frequency component summed within ±90 degrees of the local wind is the quantity subjected to growth. The incremental growth is then spread out over the same components.

In the ODGP model, each downwind spectral component is grown separately, and after computation of growth for all components within ±90 degrees of the local wind direction, energy is redistributed over angles. This algorithm leads to slower growth of wave height with time in a turning wind than in a wind of constant direction. A more detailed description of the growth algorithm is given in MacLaren Plansearch (1985).

4.2.3 Capes and Island Propagation System (CAIPS)

CAIPS is an algorithm which provides an array of transmissivities for each frequency direction band at fine-mesh grid points adjacent (within two grid spaces) to land, and which accounts for propagation on an implied hyper-fine grid, taken as one-third the grid spacing of the fine grid. The implementation of this algorithm proceeds as follows:

a) Set-up a grid mesh, land-sea table, and calculate a nominal propagation table. The domain of this grid in this case extends over the eastern part of the fine grid over its full north-south extent. The grid spacing is one-third that of the fine grid.

b) For each grid point on the hyper-fine grid from which energy can be propagated, run the propagation model for 3 time steps, for each frequency direction band;

c) Average the results of step (b) over the blocks of nine transmitting points and nine receiving points which comprise each fine-mesh grid block, thereby yielding the average effect of propagation in the implied hyper-fine grid over three time steps on the fine grid for one time step.

The CAIPS modified propagation table of the fine grid requires more storage than that of a standard fine grid, but for this application, the grid table size is not troublesome and the increment of run time is small.

Two versions of the model were used in the study. The first model neglected capes and islands, and the second model included the effects of capes and islands using the CAIPS software. This was used to evaluate model results with and without CAIPS. However final hindcast was carried out with CAIPS included.

5.0 VERIFICATION OF WIND AND WAVE HINDCASTS

In order to assess the quality of the wave model predictions, it is necessary to isolate the errors (i.e. bias or any systematic errors) in the input winds which are used to drive the wave model. After the maximum effort has been expended on wind analysis, the wave hindcasts and comparisons should reveal the skill achievable in the hindcasts carried out with the present wave model. In this section, the wind and wave specifications are presented simultaneously in the form of graphical and statistical comparisons.

5.1 VERIFICATION CASES

Eleven verification cases were selected from the Top 51 storms as follows:

Storm #	MCL #	Storm Peak Duration From (YRMODYHR)	To	Verification Periods From (YRMODYHR)	To
1	431	84101000	84101418	84101100	84101418
2	432	84103000	84110400	84103100	84110400
3	436	85021000	85021600	85021112	85021600
4	445	86022518	86022818	86022612	86022818
5	450	86112100	86112500	86112200	86112500
6	461	87041312	87041806	87041418	87041806
7	469	87120400	87121018	87120500	87121018
8	485	88111812	88112418	88112000	88112400
9	486	88112500	88112800	88112600	88112800
10	487	88112900	88120100	88112900	88120300
11	488	88120200	88120500	88120300	88120500

These cases were chosen from more recent events where more measured data coverage was available. The above events were hindcast using the model described in Section 4.0 .

5.2 VERIFICATION OF WIND ANALYSIS

The buoys' wind measurements archived in the AES and MEDS databases were used in the verification analysis. The buoy wind measurements are given at an anemometer height of approximately 5 metres. Since the model produces winds at 20 metres above sea level, the winds had to be adjusted to the same level before they could be compared. Using the air-sea temperature difference, the measured winds were converted to "effective neutral" winds at 20 m using the MPBL model. When the time series plots were made, no air and surface water temperatures were readily available in the database. Thus, an air-sea temperature difference of 0°C was assumed. The observed wind at a given site was compared directly with the hindcast wind at the nearest grid point.

Two other factors must be considered before the buoy measured winds may be declared to represent effective 20 m level average winds: the averaging interval and method, and the effect of buoy motion. It is well established (Gilhousen, 1987) that vector averaging provides winds speeds which are about 7% lower than scalar (true) averaged wind speeds. Gilhousen’s comparison of standard 8.5 minute averages and hourly averages suggests that the 8.5 minute winds are unbiased but that their rms variability is .72 m/s for speed and 10% for direction. The effect of buoy motion is not well documented. Gilhousen has recently argued that buoy motion or sheltering in high waves has no significant effect, but one of his comparison data sets shows that a 3 metre discus buoy provided lower wind speeds, by about 10% at speeds greater than 10 m/s, in high sea states in Lake Superior, than measured by a collocated (larger) NOMAD buoy. Sea states in storms off the West Coast are considerably higher, and periods are longer, than those in Lake Superior, so any buoy motion effect might be amplified in open ocean storms.

Table 5.1

Buoy Location, Water Depth and Buoy Type

Station ID	Name	Location Lat(N)	Location Long(W)	Depth (m)	Nearest ODGP Grid Point	Buoy Type
MEDS 103	Tofino	49.0	125.7	40	1235	WR
MEDS 211	Langara West	54.4	133.3	293	1365,1366	WC
MEDS 213	Bonilla Island	53.3	130.6	146	1333	WR
MEDS 226	Cape Scott	50.8	128.9	91	1267	WR
MEDS 257	Quatsino	50.5	128.2	84	1267	WR
MEDS 502	Hecate Strait	52.2	130.3	330	1317	WP
MEDS 503	Queen Charlotte	51.3	130.0	293	1283	WP
46004	B.C. NOAA	50.9	135.9	3658	768	ND
46005	Washington NOAA	46.1	131.0		598	ND
46036	Vancouver	48.3	133.8	3646	682	CA
46041	C. Elizabeth	47.4	124.5		643	ND
46184	AES NOMAD	53.9	138.9	3600	852	CA
46205	Dixon Entrance	54.3	133.4	445	1365	CA
46206	La Perouse Bank	48.8	126.0	80	1218	CA
CYAZWV	Tofino	49.0	125.8	37	1218	WR

Buoy Types:
WR: Waverider Buoy (MEDS)
WC: Directional Waverider Buoy (MEDS)
WP: WRIPS Waverider Buoy (MEDS)
ND: NOAA Buoy (NDBO)
CA: Real-Time Waverider Buoy Data

All buoys which measured winds at the comparison sites in this study employed the vector-averaging method. In addition, except for 46004 and 46005, which are NOMAD hull types, all other 46-prefix buoys listed in Table 5.1 are 3-m discus types, which suggests greater vulnerability to bias (probably negative bias) in wind speed measurements.

Effects of anemometer height, averaging method and possibly buoy motion all conspire to negatively bias buoy wind speed, especially in high winds and sea states. Therefore, in the kinematic analyses process, buoy winds were not given significantly greater weight than ship reports, particularly if redundant ship observations or continuity supported adjustment of buoy winds for suspected biases. These considerations are reflected in the many comparison time histories of measured (adjusted to 20 m for neutral wind profile only) and analyzed wind speed in Appendix B . It showed a definite tendency for the analyzed speeds to be higher than the buoy wind speeds (See Table 5.2). The finding that the resulting wave hindcasts are generally unbiased provides further support for our contention that in the range of extreme winds and sea states represented by the validation storms, that (at least for vector averaged winds from the smaller NDBO hull-types such as 3 m and NOMAD) buoy winds speeds are negatively biased. None of the effects just discussed are likely to bias buoy wind direction. Therefore buoy wind direction was weighted heavily in the analysis and the time histories in Appendix B show that the analyzed wind directions during the kinematic analysis part of the hindcast period especially, closely track the measurements.

5.3 VERIFICATION OF WAVE HINDCASTS

During the last 5-6 years, a large amount of wave data has been collected by MEDS wave stations and NOAA buoys. All available wave measurements were obtained from the MEDS database which has archived most of the MEDS and NOAA wave buoy measurements. 1-D and 2-D spectral data were also obtained from the database and used in the evaluation of the model, as described in the next section.

In Table 5.1 , the name, location, and water depths are listed for each measurement site along with the ODGP grid point nearest the wave buoy. The buoy locations and the nearest grid points are shown in Figure 5.1 .

Most waverider measurements were taken at 3 hour intervals. Some sites had 1 hour, 35 minute or 20 minute measuring intervals during some storms. Whenever the time interval was less than 3 hours (or continuous recording mode), an attempt was made to smooth the wave height and peak period time series by using a 3-7 point moving average (i.e. for hourly data a 3 point moving point average was used, where as for 20 minute records, a 7 point moving average was used). Whenever possible, comparison of measured values of wind speed, wind direction, significant wave height (Hs), peak period (Tp), and vector mean wave direction were made to model values at the nearest grid point to the measuring site. These comparisons were made on a site by site basis, as detailed below.

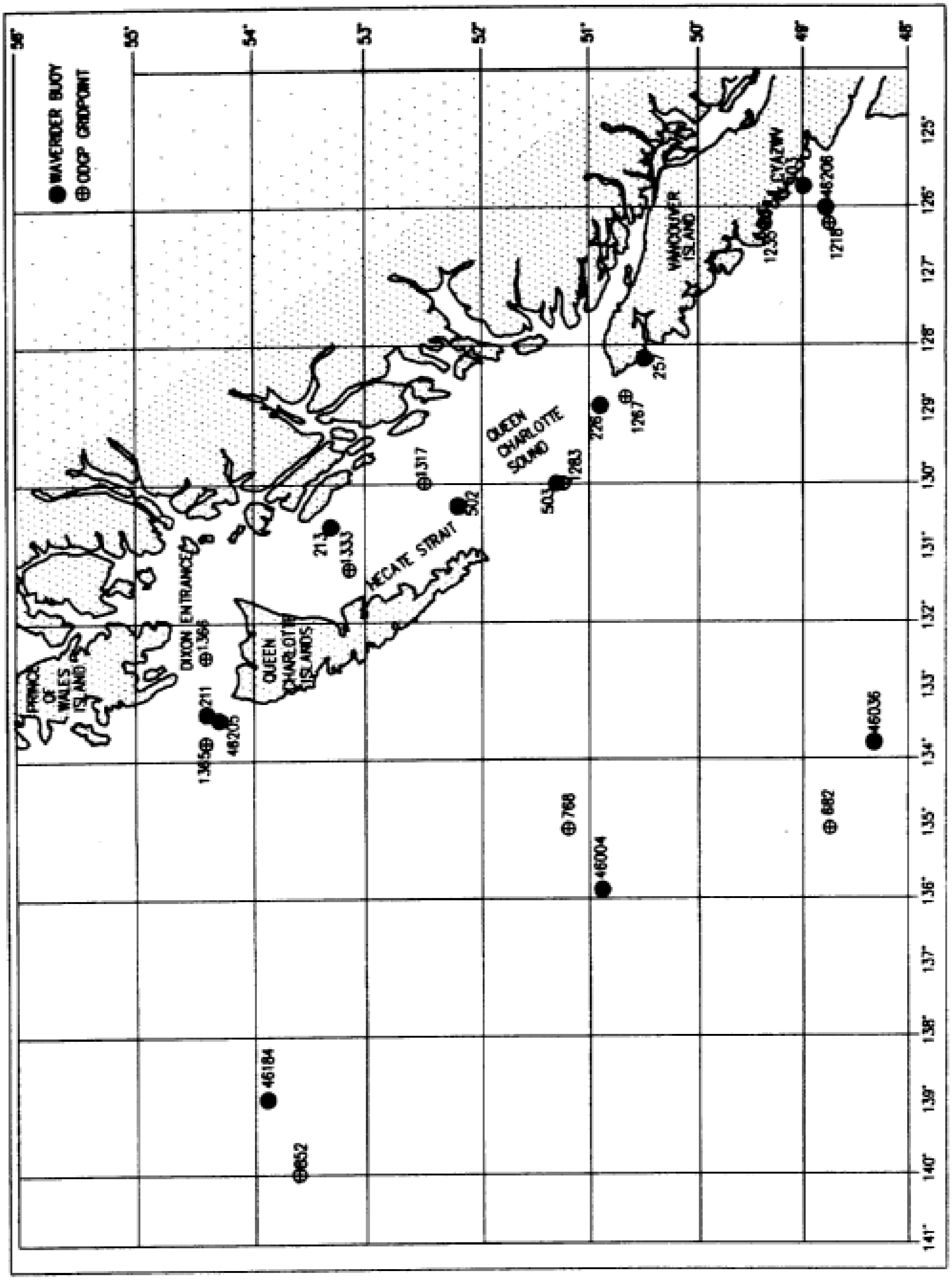


Figure 5.1 Verification Sites

5.3.1 Validation Sites for Each Storm

A list of verification buoys used for each storm is given below.

Storm#	Date	Verification Buoys			
		Offshore Deep	Inshore Deep	Inshore Deep Sheltered	Shallow
431	841010	46004 46005[1]	-	-	MEDS103
432	841030	46005[1]	-	-	MEDS103
436	850210	46004[1]		MEDS213[1,2]	MEDS103
445	860225	46004[1] 46005[1]		MEDS211[1] MEDS226[1]	MEDS103[1]
450	861121	46004[1]	MEDS503	MEDS213[1,2] MEDS211	MEDS103[1]
461	870413	46004 46005[1] 46036[1]	MEDS503	MEDS257 MEDS502[1] MEDS213[2] MEDS211[1]	CYAZWV[1]
469	871204	46004 46005[1] 46036	46041[1] MEDS503		CYAZWV[1]
485	881118	46004[1] 46036[1] 46184[1]	46205[1] 46206[1] 46041	MEDS502[1]	CYAZWV[1]
486	881125	46004[1] 46036[1] 46184[1]	46205[1] 46206[1] 46041	MEDS502[1]	CYAZWV[1]
487	881129	46004[1] 46036[1] 46184[1]	46205[1] 46206[1] 46041	MEDS502[1]	CYAZWV[1]
488	881202	46004[1] 46036[1] 46184[1]	46205[1] 46206[1]	MEDS211[1]	CYAZWV[1]

[1] Smoothing was performed on data from these buoys.

[2] Station MEDS213 is partly sheltered by the Queen Charlotte Islands for some wave directions; however, when waves come from the southwest, the fetch could be sufficent to consider the station unsheltered. For this reason the MEDS213 was treated separately, and not included in any grouping.

5.3.2 Grouping of Sites

Analysis was carried out on the peak storm wave values for specific groups of buoys. These groups were classified into 4 categories according to the geographic and topographic conditions. The buoy classification listed below provides a more realistic basis for evaluation of model predictions. More specifically, this grouping provides more meaningful statistical calculations on homogeneous data. The categories are as follows:

Category	Buoy I.D.
Offshore Deep	NOAA 46004 NOAA 46005 NOAA 46036 NOMAD 46184
Inshore Deep	AES 46205 AES 46206 AES 46041 MEDS 503
Deep, Inshore, Sheltered	MEDS 211 MEDS 213 MEDS 226 MEDS 257 MEDS 502
Shallow	CYAZWV, MEDS 103*
Excluded from Grouping	MEDS 213

* Buoys CYAZWV and MEDS 103 at Tofino represent the same station which is located in fairly shallow water.

5.4 VERIFICATION METHODS

The following evaluation methods were applied:

1. Time Series Plots of Hindcasts vs. Observations

For each storm, time series of the hindcast wind speed and direction, significant wave height, peak period, and vector mean wave direction were plotted with the corresponding measured values at the selected evaluation sites. In the time series, the model results with and without CAIPS (Model C and Model N, respectively) were plotted. The time series can be found in Appendix B .

2. Statistical Comparison of Hindcasts vs. Observations

A quantitative statistical analysis was carried out to provide an overall evaluation of the model predictions. The statistical parameters considered in this study are:

Mean Error (Bias) = $[\Sigma(X_1 - X_2)]/NPTS$
Mean Absolute Error = $\Sigma|X_1 - X_2|/NPTS$
Root Mean Square Error (RMSE) = $[\Sigma(X_1 - X_2)^2/NPTS]$
Scatter Index (%) = (RMSE/AVE) x 100

where X_1 is the hindcast value
X_2 is the observed value
AVE is the mean of observed values
NPTS is the number of data pairs

These statistics were provided for all observations within a storm and, more importantly, for the peak values in each storm.

3. Comparison of All Observations in a Storm

These statistics were provided for each site for significant wave height and peak period (and wind speed and direction at NOAA and AES buoys). Tables 5.2 and 5.3 present the above evaluation results for unsmoothed and smoothed waverider data, respectively. The data in the smoothed table contains unsmoothed data when smoothing was not possible.

For MEDS buoy 211, the model results at two grid points were compared to the measured values. The results are given in Table 5.4 . The results indicate the effect of sheltering in the CAIPS model. The results show the measured values compare best with model values at grid point 1365 since the site is not very sheltered by the islands. The model and measured wave direction were also compared.

4. Peak-to-Peak Comparisons

In Table 5.5 , peak storm values of H_s and T_p are listed for smoothed and unsmoothed measured values and CAIPS and NO CAIPS model values. These values were then used to evaluate the peak storm parameters of the models. In Table 5.6 , the unsmoothed measured peak values were compared to the peak values predicted by the CAIPS and NO CAIPS models. The results show little difference in the two models at the offshore sites, and an improvement in the CAIPS statistics at the shallower sites. In Table 5.7 , the statistics for smoothed peak values were compared to the statistics of the peak values unsmoothed. The measured values were compared to the CAIPS model values, and show a slight improvement in the smoothed statistics. However, the number of data points is too few to provide definitive results.

5. Scatter Plots and Linear Regression Analysis

The correlation between measured and hindcast parameters was carried out using linear regression analysis. The scatter plots in Figure 5.2 show the correlation between measured (smoothed and unsmoothed) values and the CAIPS model values for both H_s and T_p. The correlation coefficients are also given in Tables 5.2 - 5.7 .

Table 5.2 Unsmoothed Buoy Data Compared to West Coast Model

Var	Model Name	Num of Points	Average Obs	Standard Dev.	Average Model	Standard Dev	Mean Err	Absolute Mean Err	RMSE	Scatter Index	Corr Coef
WS	46004	303	25.37	9.43	29.17	11.05	3.80	5.62	7.45	29.35	0.816
	46005	184	25.10	11.68	24.67	10.89	-0.43	4.09	5.33	21.25	0.891
	46036	210	24.09	8.44	28.38	8.87	4.30	6.17	8.62	35.81	0.628
	46041	69	17.82	8.28	21.51	8.14	3.69	5.72	7.10	39.86	0.727
	46184	138	25.86	8.61	30.04	9.08	4.18	5.91	7.36	28.48	0.766
	46205	107	22.83	10.71	25.67	12.59	2.84	5.86	7.00	30.67	0.861
	46206	108	16.96	6.89	18.74	7.20	1.78	6.02	7.34	43.25	0.491
	ALL WIND	1119	23.63	9.85	26.58	10.67	2.95	5.58	7.30	30.91	0.791
WD	46004	303	0.00	0.00	0.00	0.00	-9.43	19.95	28.95	0.00	0.000
	46005	183	0.00	0.00	0.00	0.00	-3.69	16.25	22.46	0.00	0.000
	46036	211	0.00	0.00	0.00	0.00	-8.35	24.27	37.78	0.00	0.000
	46041	69	0.00	0.00	0.00	0.00	32.19	38.34	50.16	0.00	0.000
	46184	138	0.00	0.00	0.00	0.00	-4.21	20.49	30.61	0.00	0.000
	46205	107	0.00	0.00	0.00	0.00	-3.54	34.54	48.14	0.00	0.000
	46206	108	0.00	0.00	0.00	0.00	18.56	47.16	59.15	0.00	0.000
	ALL WIND	1119	0.00	0.00	0.00	0.00	-1.81	25.38	37.53	0.00	0.000
HS	46004	346	5.96	1.94	6.39	2.16	0.43	0.79	1.03	17.21	0.903
	46005	184	5.14	1.90	6.07	2.58	0.93	1.24	1.62	31.58	0.867
	46036	226	5.83	1.66	6.74	1.72	0.91	1.00	1.20	20.56	0.896
	46041	69	4.40	1.37	5.80	1.81	1.41	1.51	1.78	40.56	0.795
	46184	138	5.66	1.44	6.29	1.72	0.64	0.90	1.16	20.51	0.826
	46205	107	6.21	2.47	5.58	2.22	-0.63	0.90	1.08	17.42	0.936
	46206	108	4.22	1.46	5.16	1.71	0.93	0.95	1.19	28.12	0.905
	CYAZWV	260	4.15	1.46	5.42	1.63	1.28	1.35	1.54	37.18	0.848
	MEDS 103	93	4.20	1.42	5.19	1.88	0.99	1.19	1.45	34.67	0.829
	MEDS 211	102	5.36	1.77	5.35	1.93	-0.02	0.65	0.81	15.09	0.908
	MEDS 213	55	3.35	1.82	3.91	1.55	0.56	1.36	1.65	49.30	0.585
	MEDS 226	15	4.38	1.22	4.89	1.66	0.51	0.87	1.11	25.44	0.804
	MEDS 257	14	4.05	0.85	4.99	1.14	0.95	1.00	1.18	29.25	0.778
	MEDS 502	51	3.12	1.29	4.02	1.67	0.89	1.07	1.46	46.73	0.725
	MEDS 503	41	5.61	1.90	6.37	1.69	0.76	1.22	1.41	25.17	0.785
TP	46004	346	12.30	2.27	12.43	1.94	0.13	1.27	1.61	13.08	0.720
	46005	184	12.89	2.43	12.35	2.62	-0.54	2.15	2.81	21.80	0.408
	46036	226	12.94	1.97	13.30	1.53	0.36	1.49	1.88	14.53	0.465
	46041	69	13.35	1.92	13.05	1.72	-0.30	1.49	1.94	14.56	0.450
	46184	138	12.15	1.69	12.55	1.48	0.40	1.24	1.55	12.78	0.558
	46205	107	13.09	1.70	12.70	1.38	-0.39	1.20	1.54	11.74	0.550
	46206	108	13.40	2.32	13.35	1.52	-0.05	1.54	2.19	16.36	0.411
	CYAZWV	260	13.26	2.04	13.24	1.47	-0.02	1.61	2.15	16.21	0.285
	MEDS 103	93	12.37	2.40	12.28	2.93	-0.09	1.76	2.31	18.69	0.641
	MEDS 211	102	12.64	2.06	12.18	1.63	-0.45	1.26	1.57	12.41	0.692
	MEDS 213	55	9.42	2.81	10.68	1.84	1.26	2.24	2.98	31.64	0.386
	MEDS 226	15	12.85	2.21	12.29	3.18	-0.56	2.28	2.91	22.62	0.488
	MEDS 257	14	12.41	1.44	12.77	2.10	0.36	1.76	2.25	18.15	0.254
	MEDS 502	51	11.21	2.29	11.81	1.71	0.60	2.08	2.52	22.51	0.278
	MEDS 503	41	12.75	1.80	12.73	1.98	-0.02	1.55	2.15	16.83	0.361

WS	Wind Speed (m/s)
WD	Wind Direction (degrees)
HS	Significant Wave Height (m)
TP	Wave Period (s)

Table 5.3 Smoothed Buoy Data Compared to West Coast Model

Var	Model Name	Num of Points	Average Obs	Standard Dev.	Average Model	Standard Dev	Mean Err	Absolute Mean Err	RMSE	Scatter Index	Corr Coeff
HS	46004	240	6.14	2.07	6.54	2.19	0.41	0.70	0.92	15.05	0.926
	46005	180	5.14	1.92	6.06	2.60	0.92	1.26	1.62	31.48	0.870
	46036	141	5.41	1.71	6.41	1.76	1.00	1.04	1.25	23.04	0.907
	46041	22	4.93	1.15	7.06	1.84	2.13	2.27	2.46	49.96	0.752
	46184	125	5.74	1.41	6.36	1.70	0.62	0.88	1.14	19.86	0.827
	46205	102	6.33	2.50	5.58	2.24	-0.74	0.96	1.15	18.12	0.938
	46206	100	4.22	1.48	5.17	1.74	0.95	0.95	1.18	28.05	0.916
	CYAZWV	259	4.07	1.47	5.33	1.69	1.26	1.34	1.54	37.72	0.852
	MEDS 103	43	4.38	1.16	5.43	1.28	1.05	1.16	1.34	30.59	0.768
	MEDS 211	82	5.35	1.56	5.32	1.85	-0.04	0.60	0.73	13.64	0.923
	MEDS 213	37	3.61	1.71	4.24	1.47	0.63	1.40	1.69	46.78	0.525
	MEDS 226	15	4.45	1.24	4.89	1.66	0.45	0.81	1.01	22.72	0.842
	MEDS 502	51	3.12	1.30	4.02	1.67	0.89	1.07	1.46	46.69	0.725
TP	46004	240	12.37	2.24	12.63	1.95	0.25	1.12	1.43	11.56	0.782
	46005	180	12.88	2.32	12.35	2.64	-0.53	2.15	2.82	21.87	0.384
	46036	141	12.87	1.79	13.16	1.51	0.29	1.29	1.73	13.48	0.472
	46041	22	13.10	1.67	13.41	2.05	0.31	1.61	2.14	16.32	0.368
	46184	125	12.32	1.54	12.57	1.46	0.25	1.09	1.42	11.55	0.567
	46205	102	13.11	1.63	12.72	1.39	-0.39	1.16	1.46	11.12	0.577
	46206	100	13.50	2.09	13.39	1.54	-0.11	1.29	1.83	13.55	0.528
	CYAZWV	259	13.11	2.10	13.07	1.72	-0.04	1.60	2.15	16.38	0.384
	MEDS 103	43	12.76	2.00	12.83	2.26	0.07	1.16	1.57	12.30	0.736
	MEDS 211	82	12.65	1.77	12.23	1.55	-0.43	0.99	1.28	10.12	0.743
	MEDS 213	37	9.78	2.71	11.06	1.82	1.28	2.15	2.91	29.70	0.392
	MEDS 226	15	12.86	2.05	12.29	3.18	-0.57	1.88	2.78	21.61	0.531
	MEDS 502	51	11.21	2.29	11.81	1.71	0.60	2.08	2.52	22.51	0.278

Table 5.4 Comparison of MEDS Buoy #211 Measurements Vs. Two Adjacent ODGP Grid Points (1365 and 1366)

MEDS 211 BUOY COMPARED TO 2 GRID POINTS

Var	Model Name	Num of Points	Average Obs	Standard Dev.	Average Model	Standard Dev	Mean Err	Absolute Mean Err	RMSE	Scatter Index	Corr Coeff
HS	UNSMOOTHED VS 1365	102	5.36	1.77	5.35	1.93	-0.02	0.65	0.81	15.09	0.908
	UNSMOOTHED VS 1366	102	5.36	1.77	3.92	1.51	-1.45	1.45	1.67	31.05	0.884
	SMOOTHED VS 1365	82	5.35	1.56	5.32	1.85	-0.04	0.60	0.73	13.64	0.923
	SMOOTHED VS 1366	83	5.33	1.56	4.48	1.65	-0.85	1.80	2.08	39.04	0.300
TP	UNSMOOTHED VS 1365	102	12.64	2.06	12.18	1.63	-0.45	1.26	1.57	12.41	0.692
	UNSMOOTHED VS 1366	102	12.64	2.06	11.93	2.65	-0.71	1.74	2.43	19.25	0.535
	SMOOTHED VS 1365	82	12.65	1.77	12.23	1.55	-0.43	0.99	1.28	10.12	0.743
	SMOOTHED VS 1366	83	12.66	1.76	12.26	2.55	-0.39	1.92	2.34	18.49	0.476
WD	UNSMOOTHED VS 1365	102	0.00	0.00	0.00	0.00	-7.37	43.97	51.13	0.00	0.000
	UNSMOOTHED VS 1366	102	0.00	0.00	0.00	0.00	0.26	46.12	54.31	0.00	0.000

HS	Significant Wave Height (m)
TP	Peak Period (s)
WD	Wave Direction (degrees)

Table 5.5 Peak to Peak Comparisons

		MEASURED				MODEL				
		Unsmoothed		Smoothed		Grid point	CAIPS		NO CAIPS	
STORM	BUOY	Hs	Tp	Hs	Tp		Hs	Tp	Hs	Tp
1	46004	7.5	11.1			768	8.9	12.1	8.9	12.1
1	46005	10.7	16.7	9.9	15.1	598	10.4	15.5	10.4	15.5
1	M103	8.4	17.1			1235	9.9	16.4	10.7	16.6
2	46005	10.4	14.3	10.0	14.3	598	12.4	16.4	12.4	16.4
2	M103	7.6	12.4			1235	8.5	15.5	9.5	15.5
3	46004	11.4	14.3	10.5	14.3	768	10.9	14.9	10.9	14.9
3	M103	7.0	13.7	6.5	12.4	1235	6.9	14.0	7.9	14.2
3	M213	8.9	12.4	8.4	12.4	1334	8.2	14.0	10.1	15.0
4	46004	9.8	14.3			768	10.5	14.2	10.5	14.2
4	46005	7.8	16.7			598	6.5	14.4	6.5	14.4
4	M103	4.6	15.2			1235	5.1	14.5	5.8	14.5
4	M211	10.7	18.2	9.4	16.6	1365	9.0	14.8	9.0	14.8
4	M226	7.1	12.4	6.8	15.0	1267	6.5	14.9	6.5	14.6
5	46004	14.1	16.7	13.5	16.7	768	11.3	17.2	11.3	17.2
5	M103	7.1	15.2	6.4	15.9	1235	7.5	17.4	8.5	17.5
5	M211	9.2	18.2			1365	9.3	14.8	9.3	14.8
5	M213	7.4	10.5	7.0	11.1	1334	5.9	12.7	8.5	16.6
5	M503	10.8	16.0			1283	9.9	17.2	9.9	17.2
6	46004	10.6	14.3			768	9.7	14.5	9.7	14.5
6	46005	6.6	16.7	6.4	15.9	598	5.8	14.0	5.8	14.0
6	46036	7.5	14.3			682	7.6	14.7	7.6	14.7
6	CYAZWV	6.5	15.4	6.2	15.0	1235	5.1	14.7	5.7	14.8
6	M211	10.5	12.5	8.9	14.3	1365	9.4	14.0	9.4	14.0
6	M213	5.6	9.8			1334	5.7	12.0	7.3	13.6
6	M257	5.5	15.2			1267	6.7	14.8	6.7	14.8
6	M502	5.0	10.2			1317	6.5	12.5	7.6	13.9
6	M503	7.8	14.2			1283	7.3	15.1	7.4	15.0
7	46004	9.2	14.3			768	9.1	15.9	9.1	15.9
7	46005	10.4	14.3			598	9.3	15.4	9.3	15.4
7	46036	11.1	14.2			682	10.9	16.2	10.9	16.2
7	46041	7.1	16.7			643	8.9	15.4	9.0	15.4
7	CYAZWV	7.6	13.3	7.3	12.5	1235	8.3	14.8	8.9	15.4
7	M503	11.3	13.5			1283	9.3	13.9	9.3	14.0
8	46004	9.9	12.2	9.7	12.6	768	11.7	16.1	11.7	16.1
8	46036	11.2	14.2	11.1	15.1	682	11.7	16.0	11.7	16.0
8	46041	9.2	16.7			643	9.1	16.1	9.2	16.0
8	46184	7.8	14.2	7.4	14.2	852	9.4	14.8	9.4	14.8
8	46205	8.9	12.2	8.6	13.3	1365	6.7	13.9	6.7	13.9
8	46206	9.2	15.1	8.8	15.1	1218	9.6	16.1	9.7	16.1
8	CYAZWV	8.1	16.7	7.7	15.5	1218	9.6	16.1	9.7	16.1
8	M502	5.9	10.7			1317	9.1	15.5	10.7	16.0
9	46004	14.8	17.1			768	12.9	16.6	12.9	16.6
9	46036	10.1	18.3			682	10.2	16.2	10.2	16.2
9	46041	3.9	12.5			643	6.1	12.8	6.2	12.9
9	46184	10.5	12.2	9.9	13.1	852	9.9	12.9	9.9	12.9
9	46205	12.8	17.1	12.6	16.4	1365	11.4	15.7	11.4	15.7
9	46206	7.0	17.1	7.1	17.9	1218	6.9	15.9	6.9	15.8
9	CYAZWV	6.8	18.2	6.8	18.2	1218	6.9	15.9	6.9	15.8
9	M502	*6.9	11.6			1317	8.1	17.3	9.8	17.2
10	46004	10.1	12.8			768	9.1	14.4	9.1	14.4
10	46036	7.0	12.8	6.7	12.4	682	7.2	14.6	7.2	14.6
10	46041	4.1	12.5			643	5.8	13.2	6.1	13.3
10	46184	7.9	12.8	7.7	12.2	852	9.0	13.8	9.0	13.8
10	46205	12.2	14.2	11.4	13.5	1365	9.4	14.7	9.4	14.7
10	46206	*4.4	12.2	4.3	13.1	1218	5.5	12.5	5.7	12.5
10	CYAZWV	4.1	13.3	4.0	13.3	1218	5.5	12.5	5.7	12.5
10	M502	6.9	11.1			1317	6.7	14.6	7.1	14.8
11	46004	*7.4	15.1			768	8.5	13.6	8.5	13.6
11	46036	*6.4	16.0			682	8.0	13.4	8.0	13.4
11	46184	*7.1	12.8			852	9.0	13.3	9.0	13.3
11	46205	9.6	15.1	9.6	15.1	1365	7.1	13.7	7.2	13.7
11	46206	3.9	15.1	3.7	14.3	1218	4.7	12.3	4.7	12.3
11	CYAZWV	3.9	15.4			1218	4.7	12.3	4.7	12.3
11	M211	7.9	15.4	7.2	14.8	1365	7.1	13.7	7.2	13.7

* - value did not occur at the peak of the storm

Table 5.6 Peak to Peak Summary Comparison Statistics (Unsmoothed)

			CAIPS					NO CAIPS				
Var	Model Name	Num of Points	Mean Err	Absolute Mean Err	RMSE	Scatter Index	Corr Coef	Mean Err	Absolute Mean Err	RMSE	Scatter Index	Corr Coef
HS	OFFSHORE DEEP	22	-0.09	0.95	1.19	12.13	0.818	-0.09	0.95	1.19	12.13	0.818
	INSHORE DEEP	14	-0.40	1.39	1.64	19.51	0.857	-0.34	1.41	1.67	19.88	0.846
	INSHORE SHELTER	9	0.18	1.16	1.46	19.07	0.688	0.53	1.44	2.01	26.29	0.385
	SHALLOW	11	0.57	0.85	0.99	15.19	0.889	1.12	1.26	1.39	21.30	0.907
TP	OFFSHORE DEEP	22	0.55	1.35	1.63	11.28	0.540	0.55	1.35	1.63	11.28	0.540
	INSHORE DEEP	14	-0.14	1.10	1.26	8.51	0.678	-0.14	1.13	1.28	8.61	0.666
	INSHORE SHELTER	9	0.63	2.61	2.89	21.00	0.259	0.83	2.81	3.14	22.81	-0.058
	SHALLOW	11	-0.16	1.45	1.76	11.68	0.408	-0.06	1.52	1.83	12.17	0.361

Table 5.7 Peak to Peak Summary Comparison Statistics (Smoothed)

			SMOOTHED					UNSMOOTHED				
Var	Model Name	Num of Points	Mean Err	Absolute Mean Err	RMSE	Scatter Index	Corr Coef	Mean Err	Absolute Mean Err	RMSE	Scatter Index	Corr Coef
HS	OFFSHORE DEEP	11	0.63	1.14	1.40	15.02	0.799	0.20	1.11	1.36	13.96	0.785
	INSHORE DEEP	7	-0.86	1.37	1.56	17.64	0.882	-1.11	1.46	1.76	19.38	0.885
	INSHORE SHELTER	4	-0.07	0.32	0.36	4.42	0.961	-1.05	1.05	1.13	12.48	0.987
	SHALLOW	7	0.70	1.01	1.16	18.11	0.765	0.37	0.80	0.99	14.66	0.773
TP	OFFSHORE DEEP	11	0.94	1.32	1.64	11.58	0.478	0.83	1.54	1.84	12.89	0.383
	INSHORE DEEP	7	-0.47	1.27	1.38	9.12	0.585	-0.51	1.43	1.57	10.40	0.474
	INSHORE SHELTER	4	-0.83	0.83	1.07	7.03	0.620	-0.28	2.28	2.40	16.38	0.128
	SHALLOW	7	0.37	1.34	1.53	10.45	0.652	-0.06	1.20	1.41	9.34	0.619

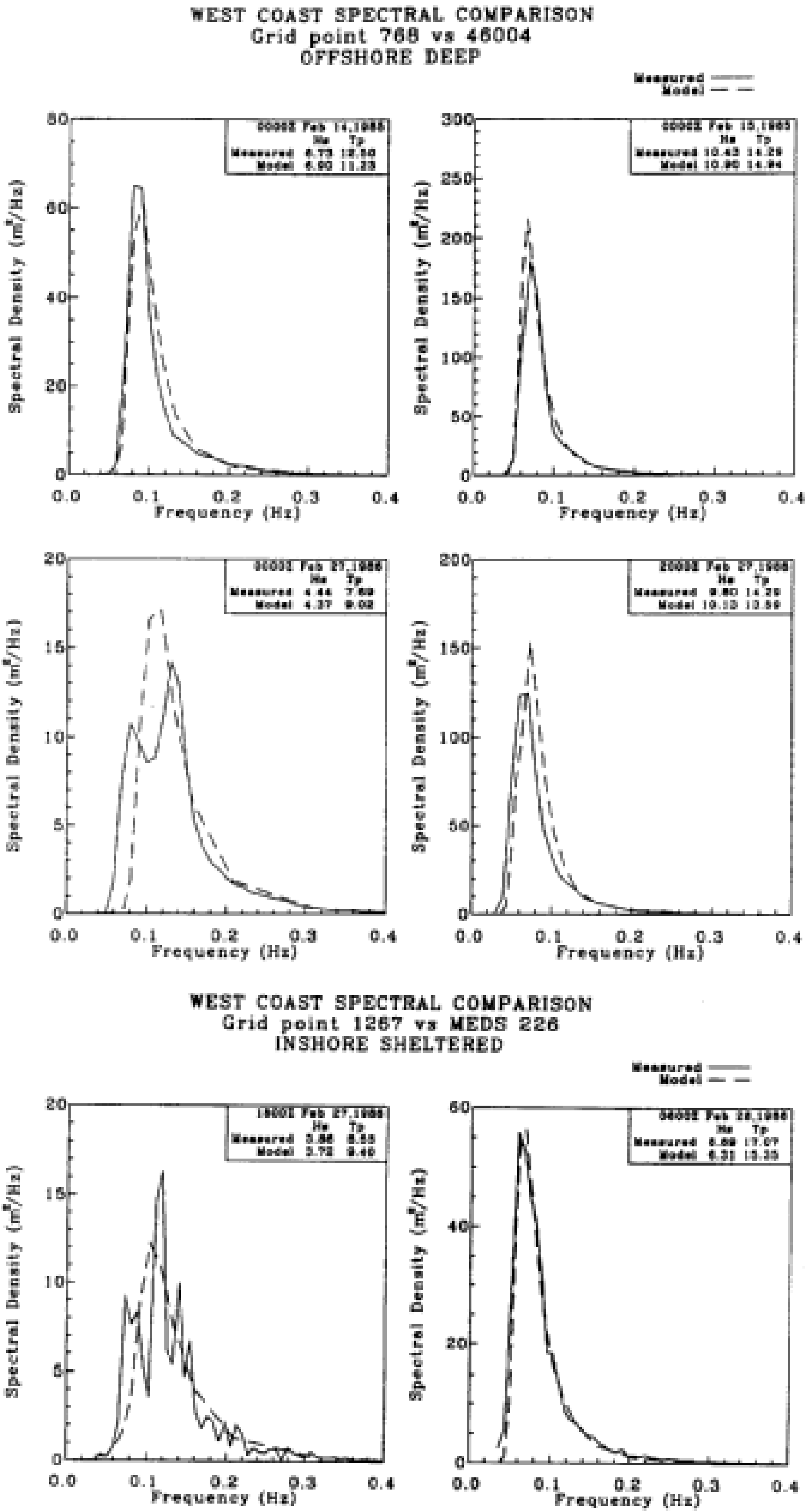
6. One Dimensional (1-D) Spectral Comparison

Near the storm peak, plots containing 1-D spectra of measured and modelled data were provided for evaluation of model spectra during well developed sea states (Figure 5.2). Since the modelled spectra were hindcast every 2 hours, the measured spectra were averaged using an appropriate moving average if the measurement interval was less than 1 hour. For example, for a measurement interval of 20 minutes, a 6 or 7 point moving average was used. For a 3 hour measurement interval, no moving average was done.

Direct comparison of measured spectra with model spectra at a specific time and location indicates that the two spectra are very similar (see Figure 5.2). However, this comparison does not indicate whether the spectra are similar during other times. For a more general comparison, the most probable spectra determined using the six-parameter fit of Ochi and Hubble (1976) were compared. In this approach, a large number of wave spectra are used to provide representative (or most probable) spectra for a number of wave height (sea state) classes. For this study, the measured and hindcast spectra are separated into 4 classes; 4-6m, 6-8m, 8-10m and ≥10m. Each spectrum was then fitted to the Ochi-Hubble six parameter wave model using a nonlinear least squares fit. For each class, a most probable spectrum was generated by calculating the most probable values of the fitted coefficients.

Prior to fitting the Waverider spectra to the six parameter spectral model, the spectra were smoothed by using a 5 point moving frequency average to eliminate any spikes which would adversely affect the model fit. Since the ODGP model has a much coarser frequency resolution, the frequency smoothing of the waverider spectra will not adversely affect the spectral comparison.

The most probable model and measured spectra from each class were then normalized to common energy and plotted in Figure 5.3 .



WEST COAST SPECTRAL COMPARISON
Grid point 768 vs 46004
OFFSHORE DEEP

WEST COAST SPECTRAL COMPARISON
Grid point 1267 vs MEDS 226
INSHORE SHELTERED

Figure 5.2 Comparison of Measured Versus Model Spectra

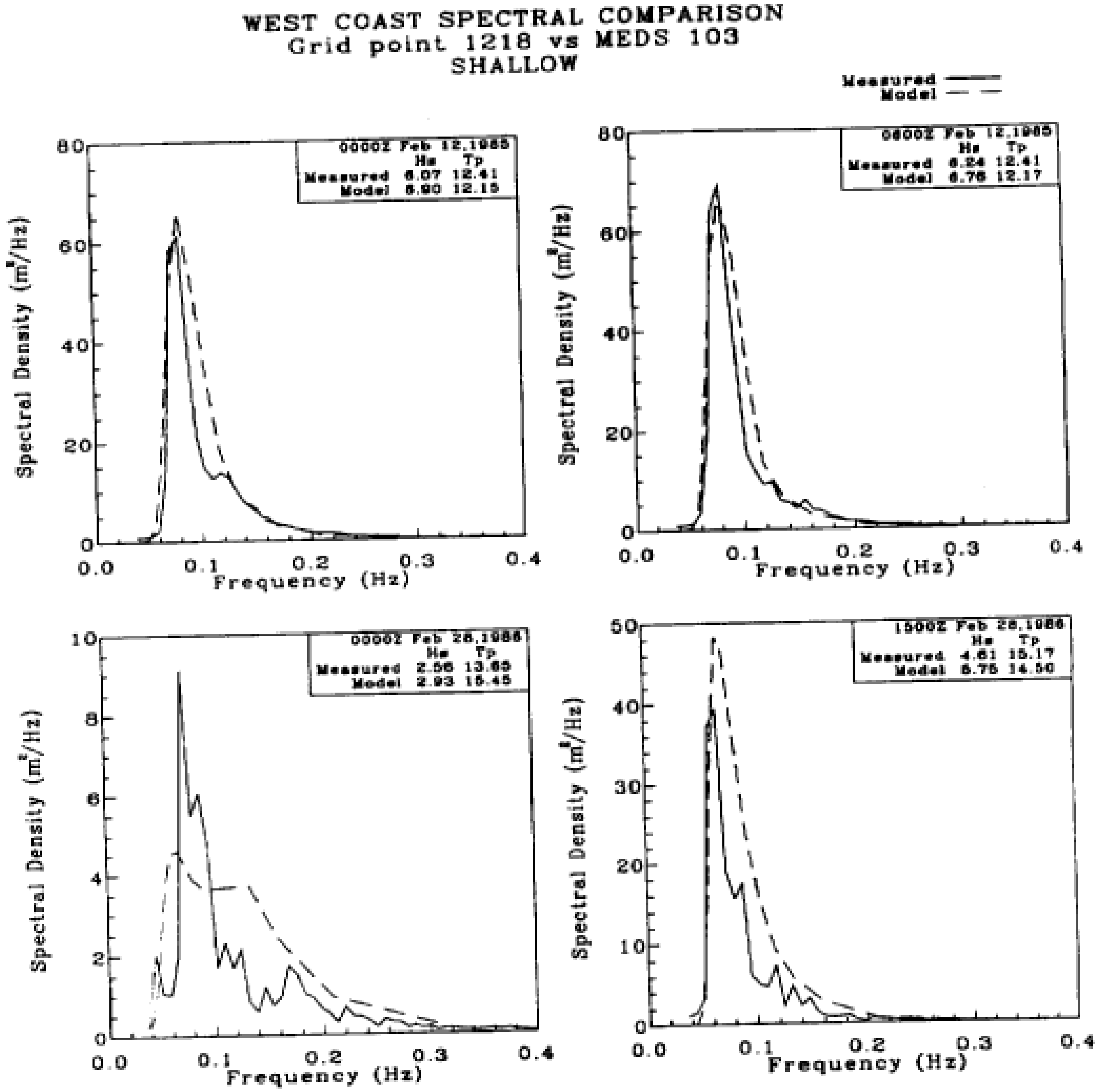


Figure 5.2 (cont'd)

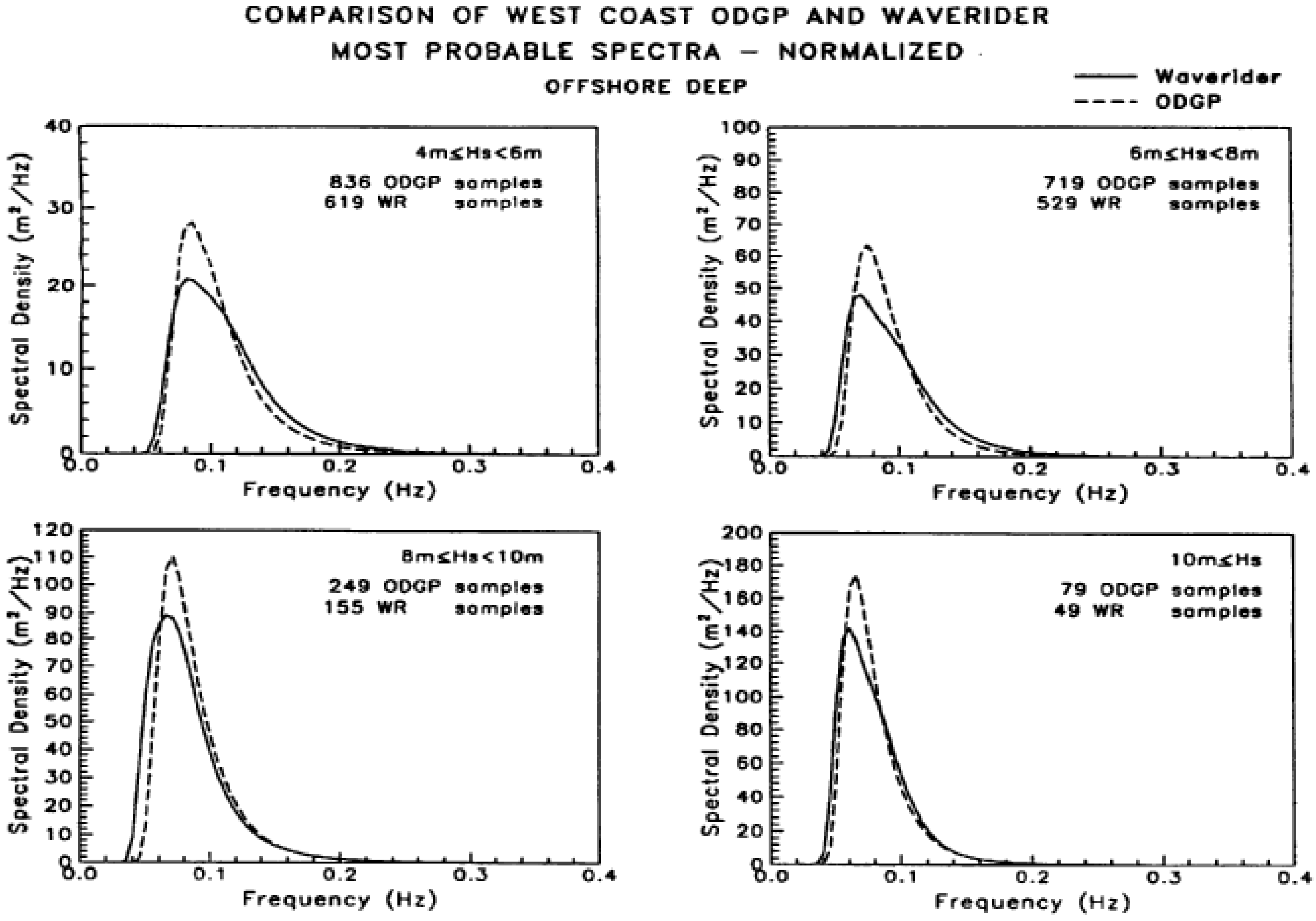


Figure 5.3 Comparison of Most Probable Spectra (Measured Vs. Hindcast)

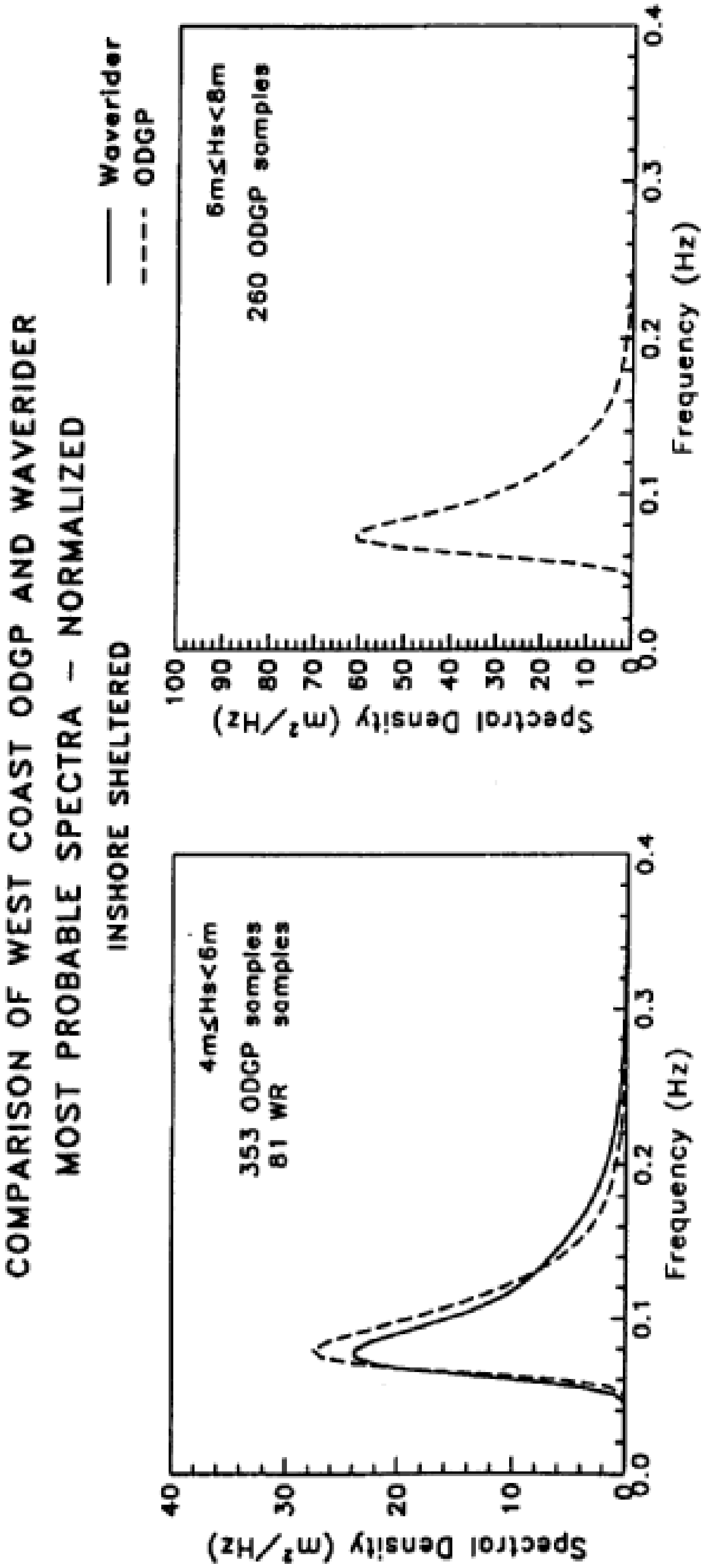


Figure 5.3 (cont'd)

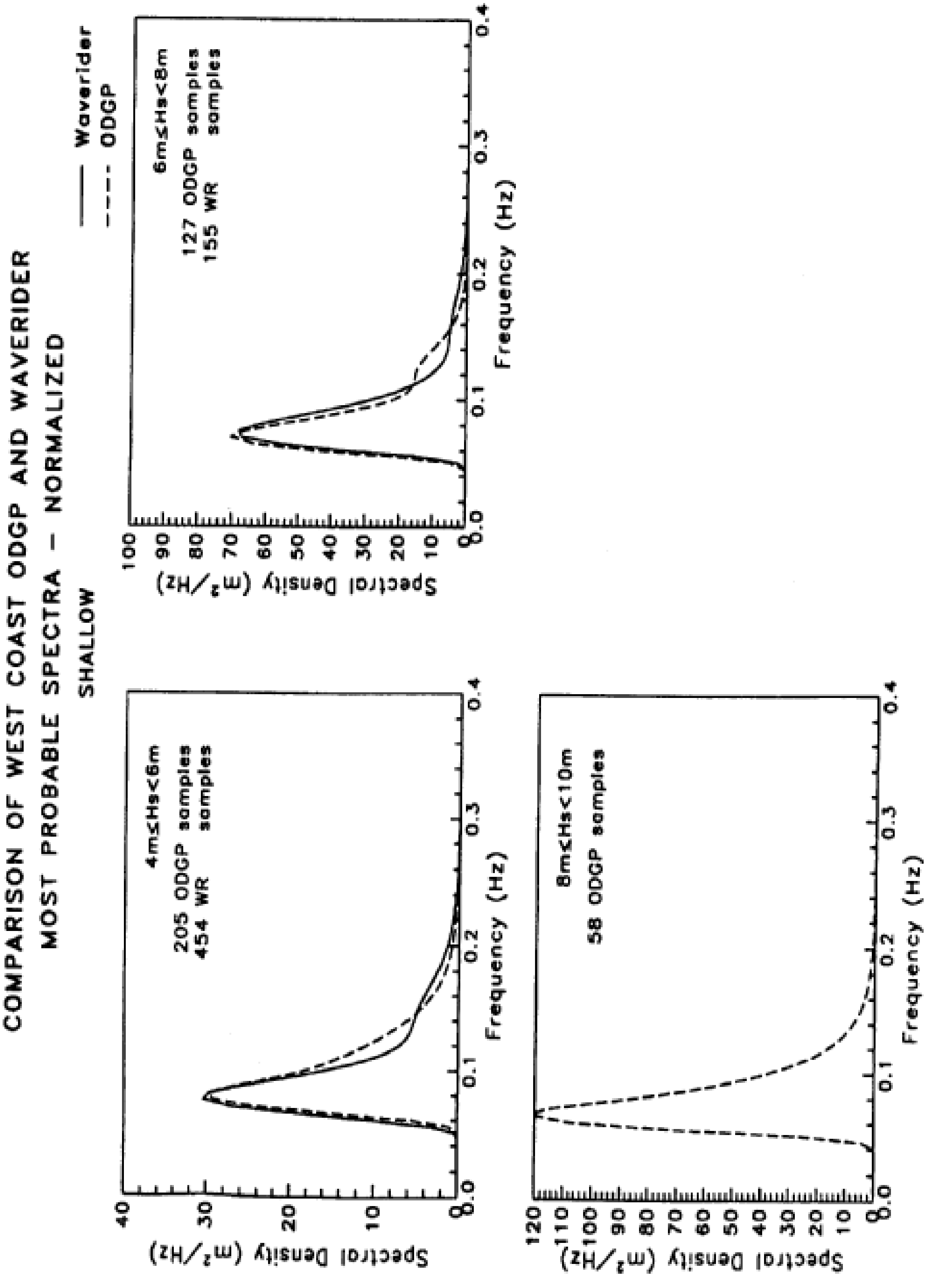

COMPARISON OF WEST COAST ODGP AND WAVERIDER
MOST PROBABLE SPECTRA — NORMALIZED
SHALLOW

Figure 5.3 (cont'd)

7. Directional (2-D) Spectral Comparison

A comparison of hindcast and measured directional spectra was also done near the storm peak for a selected number of storms. The WAVEC heave-pitch-roll buoy directional spectra from MEDS 211 were compared to the hindcast spectra at ODGP grid point 1365. Directional spectra were only available at MEDS 211 during three verification storms; February 1986, April 1987 and December 1988. For the comparison, spectra with similar time of occurrence, significant wave height, and peak period were chosen.

The ODGP spectra had a variable frequency resolution, so they were interpolated into a grid with a fixed frequency resolution in order to produce contour plots of the directional spectral energy. After the interpolation, the frequency resolution was equal to half of the minimum ODGP frequency bandwidth. The spectra were then rotated by 180 degrees to represent waves ”coming from”.

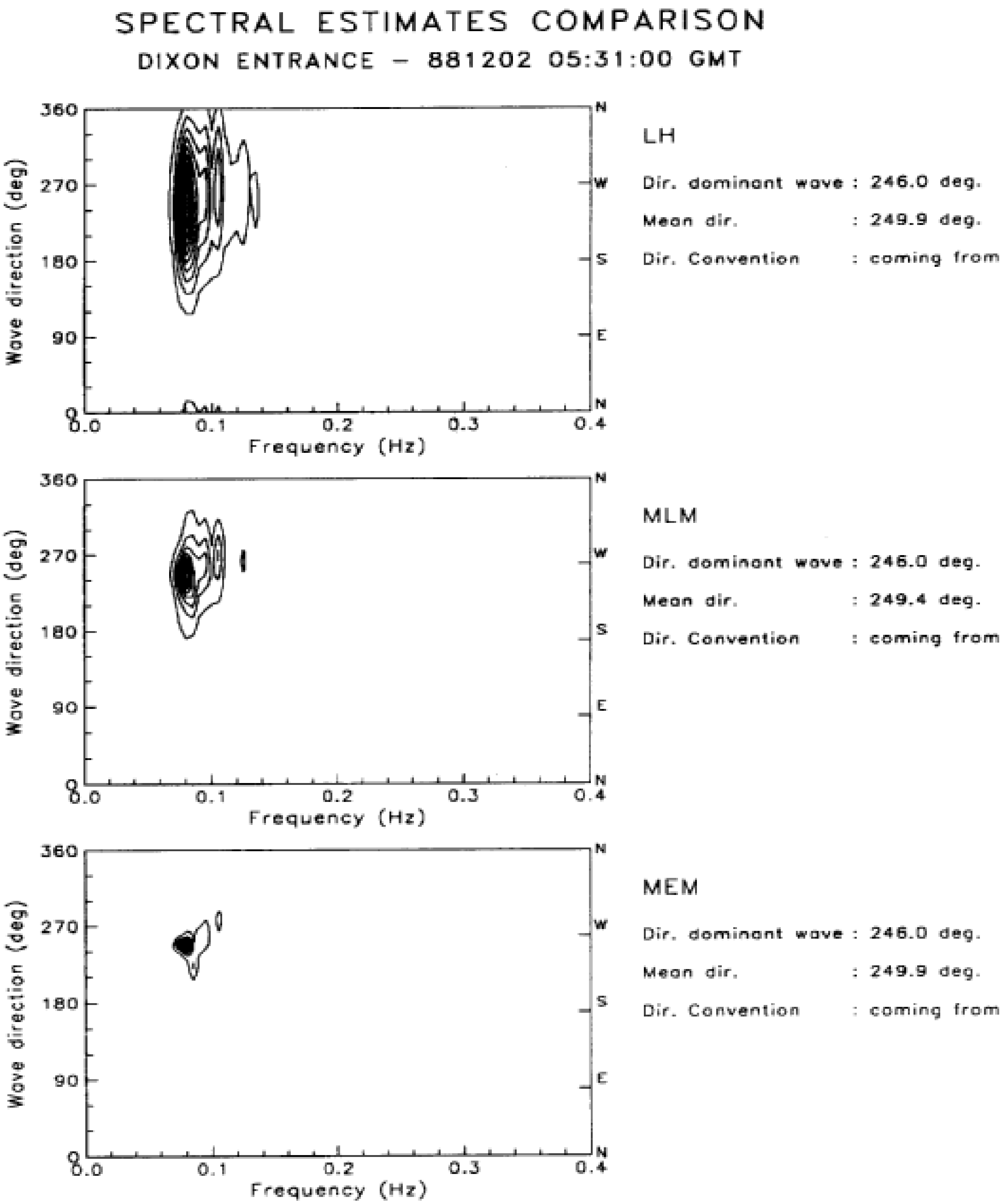
The WAVEC spectra were obtained from the covariance and quadrature (C-Q) spectral coefficients, C_{11}, C_{22}, C_{33}, C_{23}, Q_{12}, and Q_{13}, calculated at a frequency interval of 0.005 Hz. The indices 1, 2, 3 refer to vertical, north and west positive orientations, respectively. During processing, coordinate 3 was changed to east positive by changing the signs of C_{13} and Q_{13}. The spectral directions represented waves ”coming from”.

The WAVEC buoy had a sampling frequency of 0.78125s for 34 minutes and stored the spectra every 3 hours during calm conditions, and every 35 minutes during storm periods. Since the ODGP spectra were hindcast every 2 hours, five WAVEC spectra with a measurement interval of 35 minutes were averaged to provide comparable spectra.

The WAVEC directional spectra were estimated using three methods: the conventional method of Longuet-Higgins et.al. (1963), Maximum Likelihood Method (MLM), and the Maximum Entropy Method (MEM). All three methods estimated spectra which had practically the same directional characteristics but differed in the angular resolution, as shown in Figure 5.4 . The Longuet-Higgins (LH) method estimates a very broad-banded spectrum, while the data adaptive methods, MLM and MEM, estimate spectra with better resolution.

The MEM estimate has a better spectral resolution when two wave fields coexist in the same frequency band than the MLM method, and preserves the values of the measured Fourier coefficient, as discussed by Lygre and Krogstad (1986). As discussed by Lacoss (1971), the spectral peaks from the MEM are proportional to the square of the power in the peaks with the area equal to the power, while the peak values of the MLM reflect the power directly. As a result, the MEM produces spectra which are more narrow and sharply defined than the MLM. For this reason, the MEM contour plots show little topology around the narrow peaks.

In all cases studied, MLM and MEM produced spectral estimates with practically the same spectral characteristics. Because the MLM spectra have a more realistic topology, only the MLM spectral estimates are shown in comparison with the hindcast spectra. In Figures 5.5 and 5.6 , directional spectra corresponding to fully developed sea conditions are shown for the storm peaks in 1986 and 1987. During the 1988 storm, spectra obtained at different stages of the storm development are shown in Figure 5.7 .



SPECTRAL ESTIMATES COMPARISON

DIXON ENTRANCE – 881202 05:31:00 GMT

LH

Dir. dominant wave : 246.0 deg.

Mean dir. : 249.9 deg.

Dir. Convention : coming from

MLM

Dir. dominant wave : 246.0 deg.

Mean dir. : 249.4 deg.

Dir. Convention : coming from

MEM

Dir. dominant wave : 246.0 deg.

Mean dir. : 249.9 deg.

Dir. Convention : coming from

Figure 5.4 Wave Buoy 2-D Spectra Using 3 Methods

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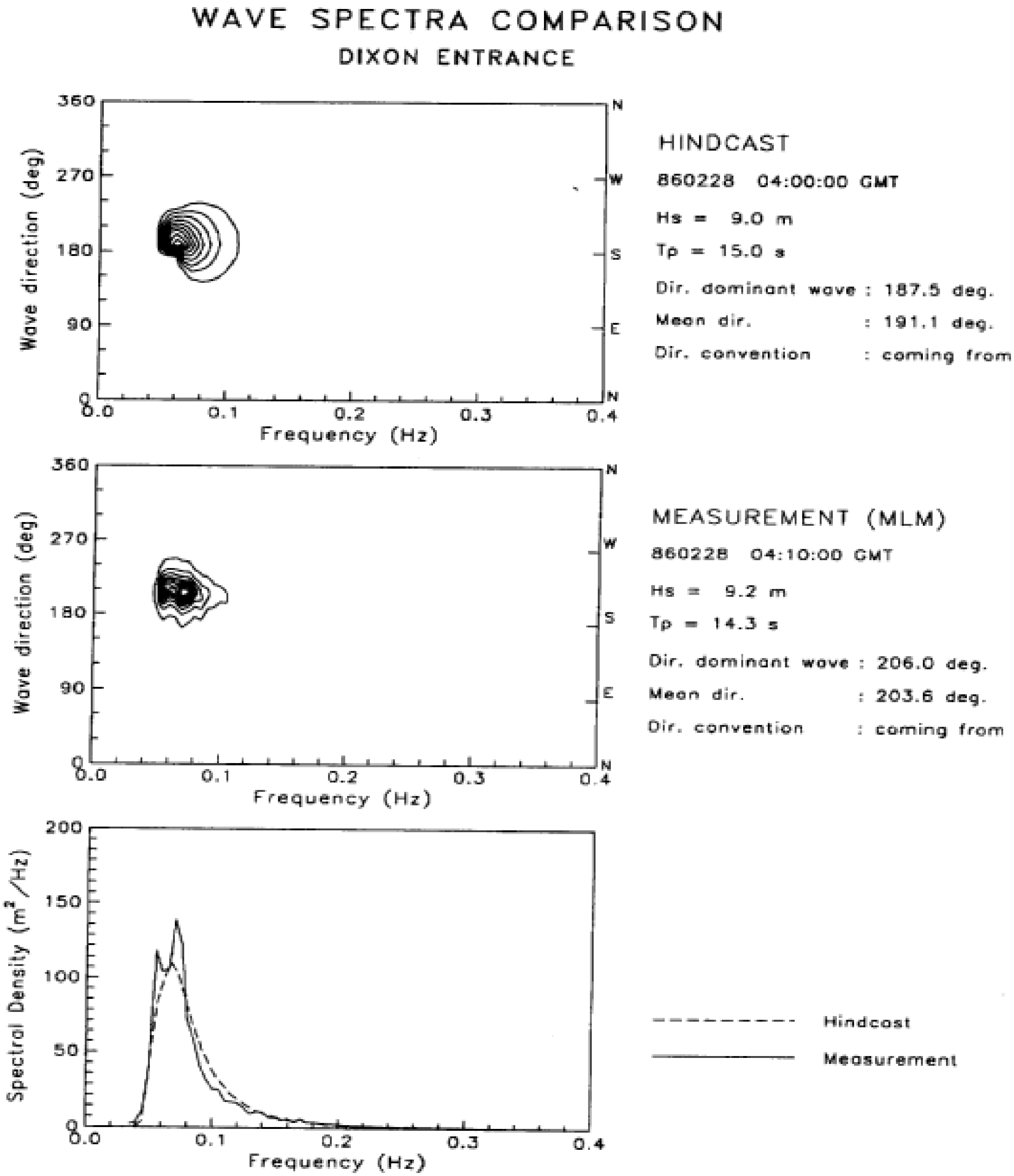


Figure 5.5. **Wave Spectral Comparison, Hindcast versus Measured (February 28, 1986)**

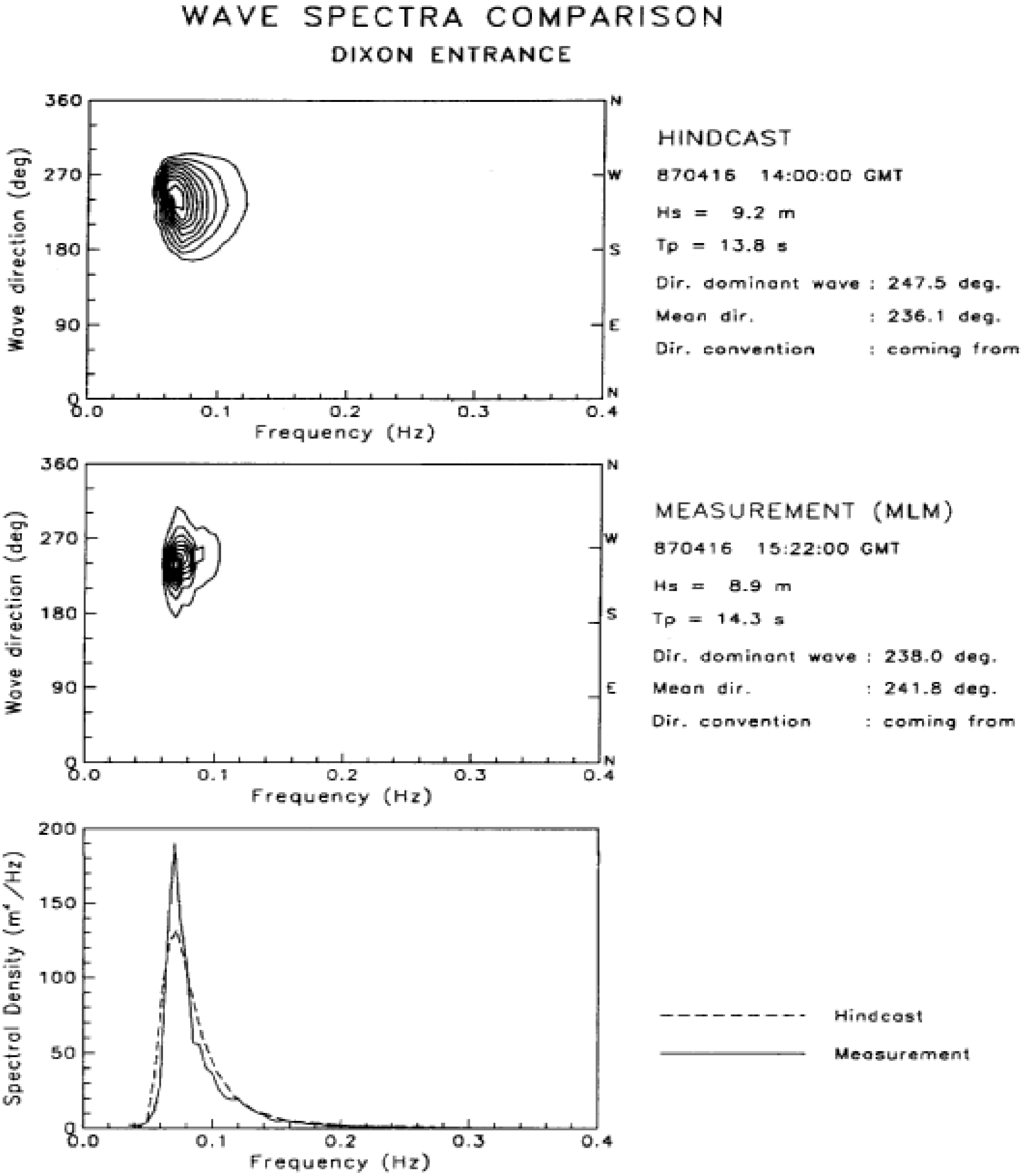


Figure 5.6 Wave Spectral Comparison, Hindcast Vs. Measured (April 16, 1984)

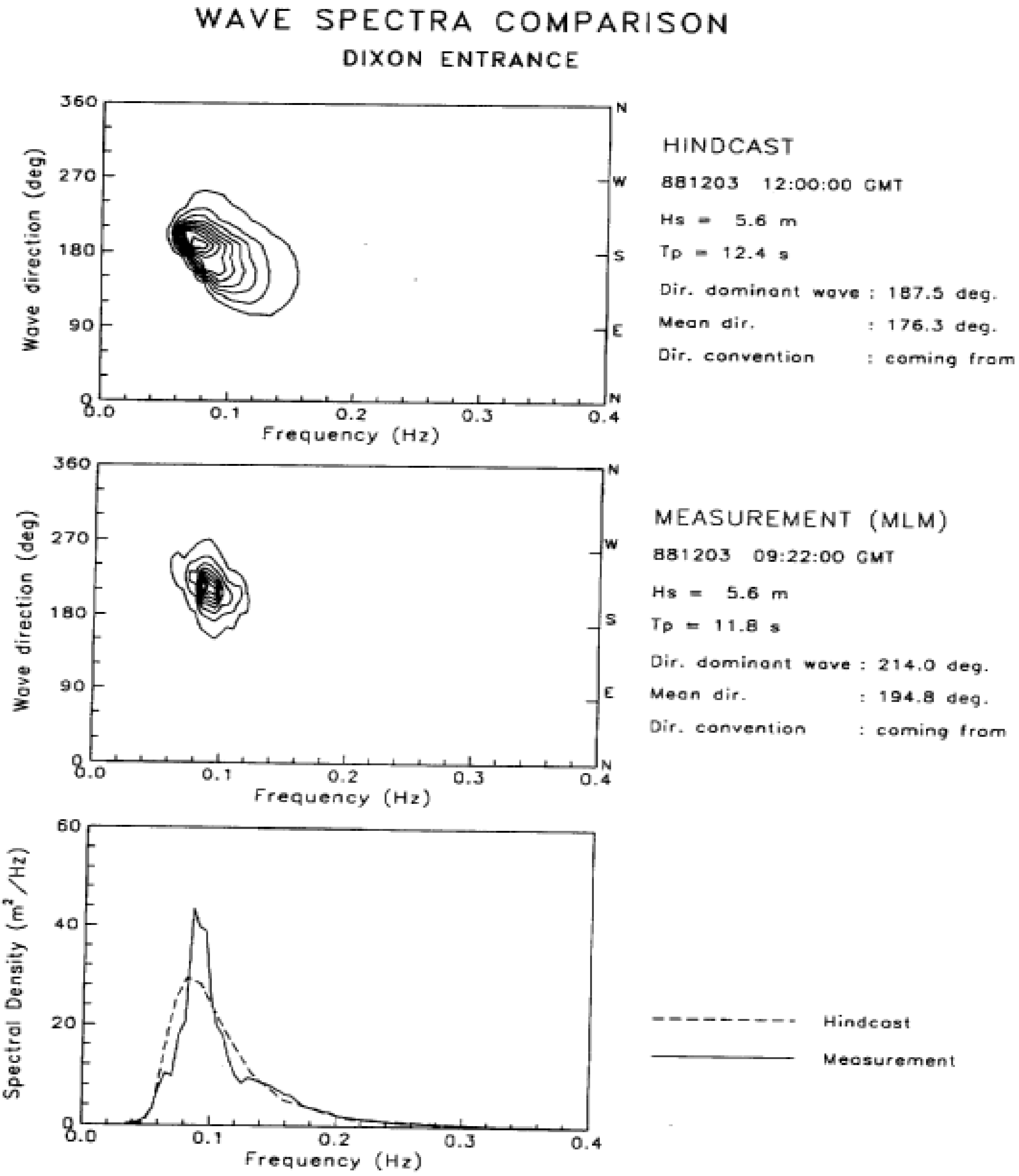


Figure 5.7 **Wave Spectral Comparison, Hindcast versus Measured (December 2, 1988)**

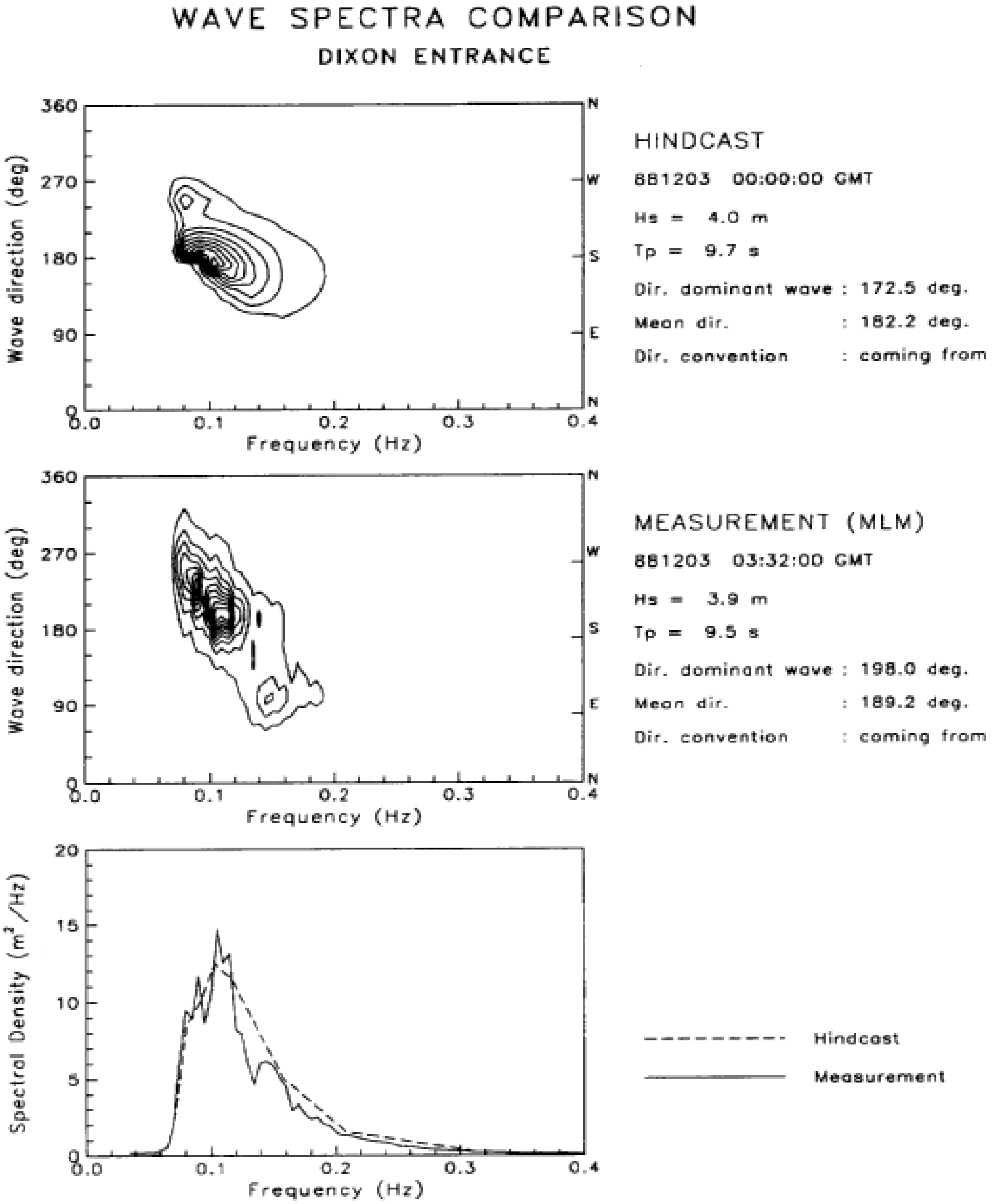


Figure 5.7 (cont'd)

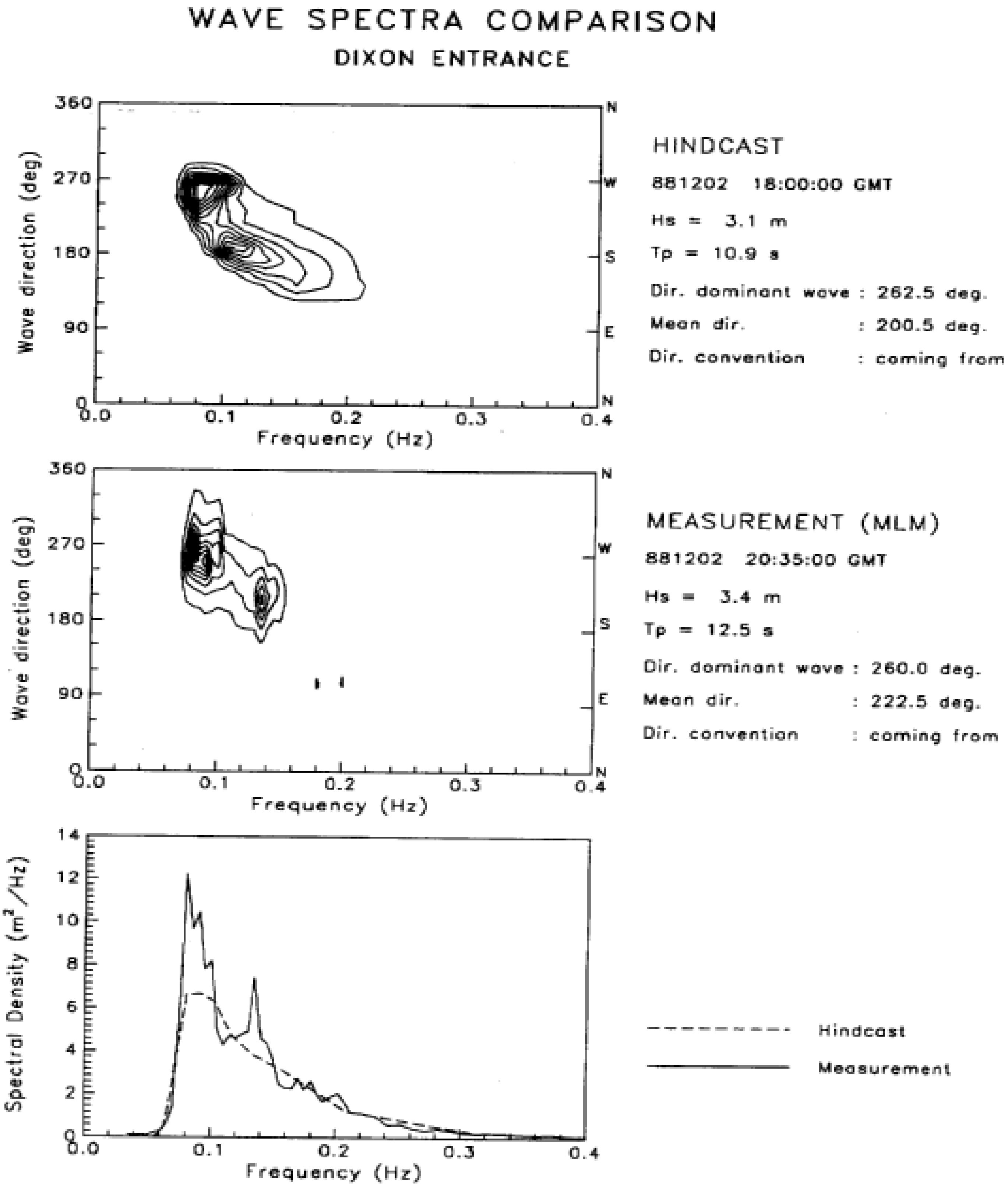


Figure 5.7 (cont'd)

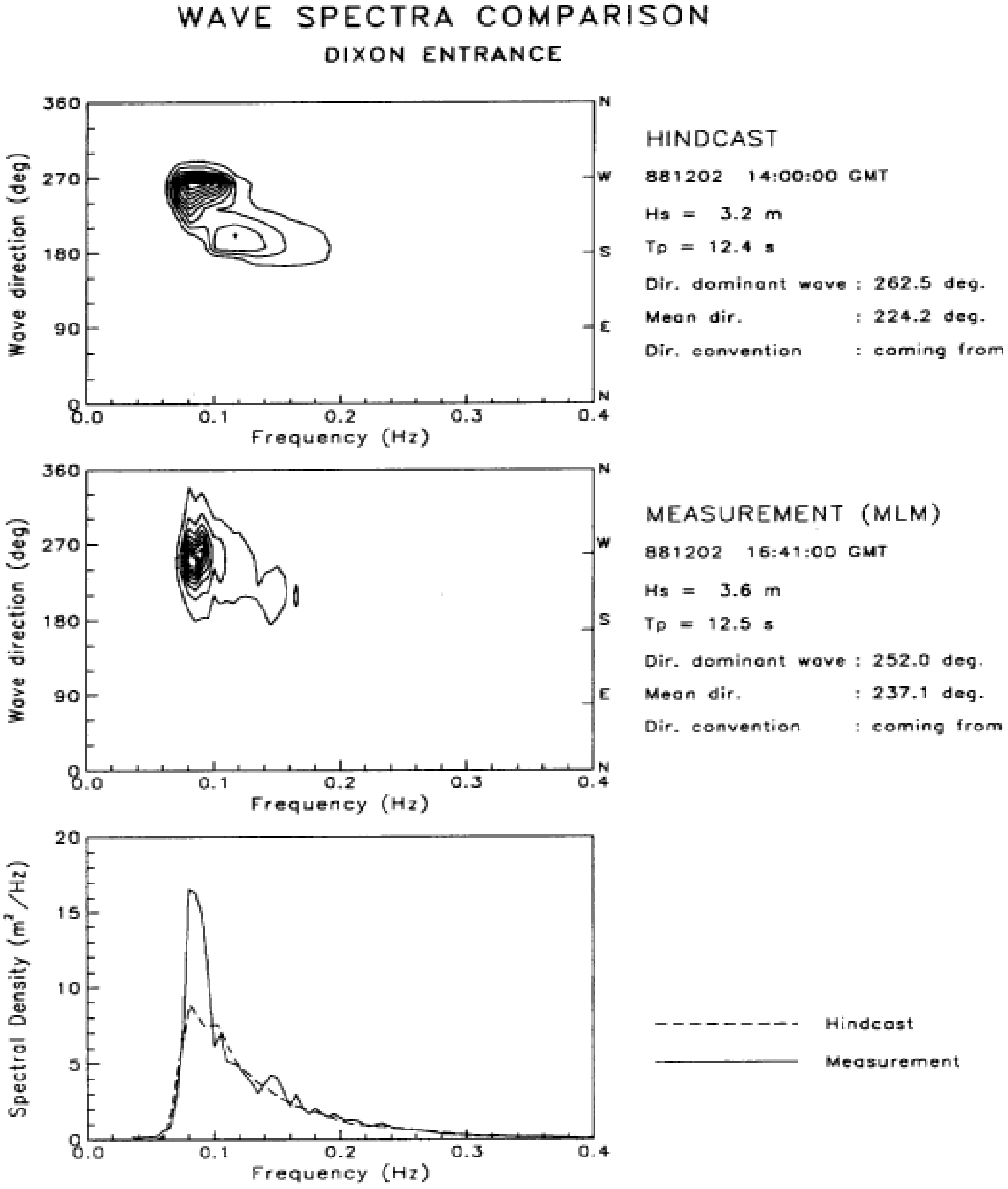


Figure 5.7 (cont'd)

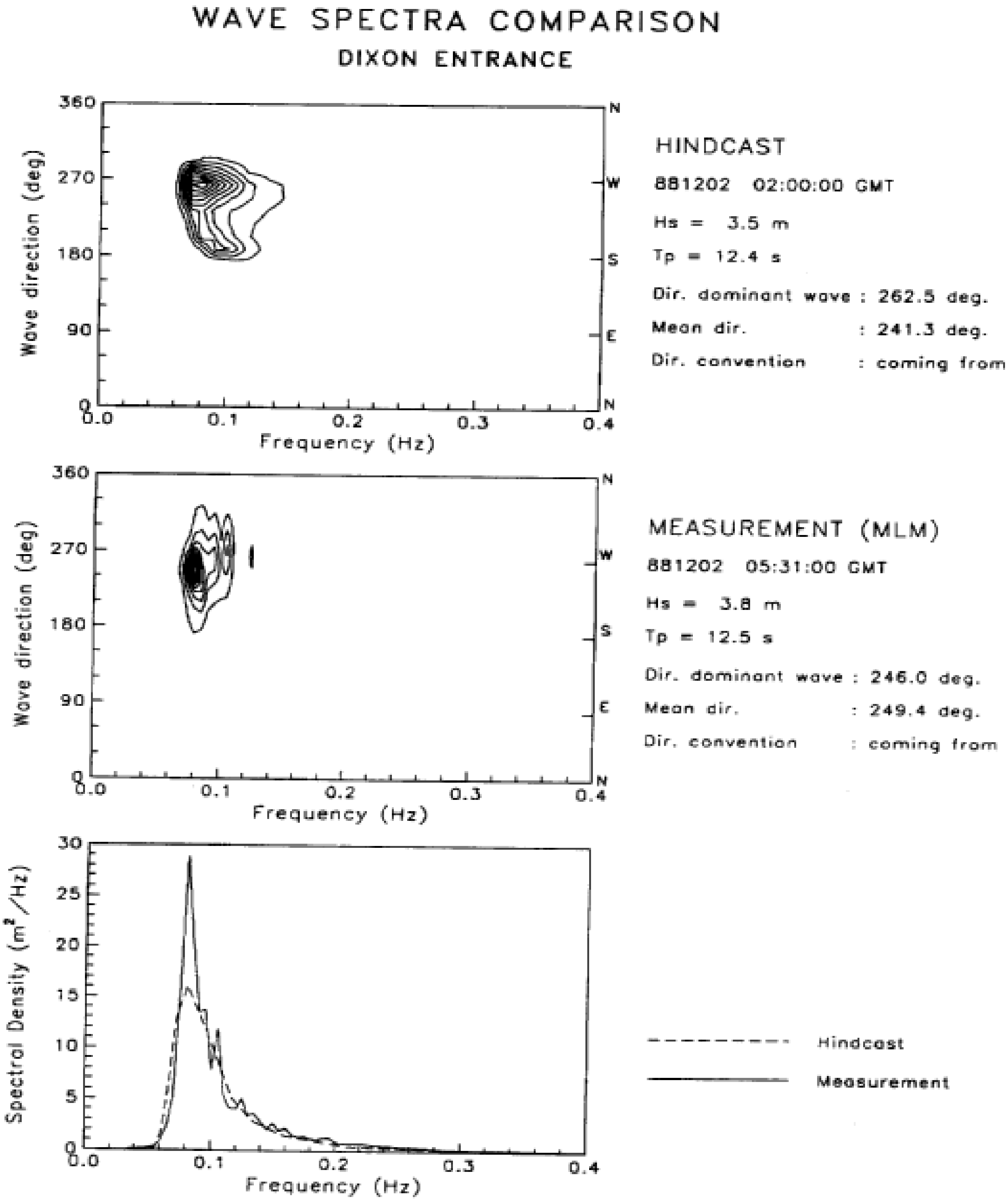


Figure 5.7 (cont'd)

5.5 DISCUSSION

The ability of the model to predict waves on the west coast was first tested by comparing the time series of buoy measurements with the model hindcast values. In general, this method indicated that the development of storm wave conditions by the model at the buoy locations was similar to the conditions observed at the site. However, in this study, the wave conditions at the storm peak are required for the extremal analysis, which requires careful analysis of model prediction of the storm peak values in relation with the measured values.

5.5.1 Storm Peak Verification Results

For the extremal analysis, the most important aspect of the model is its ability to predict the storm peak accurately. Therefore, for the present study, the most important evaluation criterion is the peak-to-peak comparison for storm design parameters such as peak significant wave height and peak period.

In Table 5.5 , a summary list of measured and hindcast storm peaks is given for the verification storms. The measurement data were divided into the four different groups listed in Section 5.3.2 to determine how geographical and topological conditions may affect the model results. The comparison statistics were determined for the CAIPS and NO CAIPS model storm peaks versus the unsmoothed measured storm peaks in Table 5.6 , and for the CAIPS model storm peaks versus the smoothed and unsmoothed measured storm peaks in Table 5.7 .

The results in Table 5.6 were obtained from the eleven verification storms. Since the ODGP model has not been extensively tested for the west coast, the model’s ability to predict storm peaks was further tested by comparing all model hindcast peaks to all available measured storm peaks. In Table 5.8 , a summary list of measured and CAIPS hindcast storm peaks is given for all the hindcast storms with measured data. The results of the statistical comparisons between the measurements and model values are summarized in Table 5.9 . Again, the measurements were divided into the four different groups. In addition, the four groups were combined to provide the overall error statistics. Evaluation results are discussed below for each group.

DEEP WATER AREAS

The largest measurement group contains the offshore deep measurements. In Table 5.6 , this group shows no difference between the CAIPS and NO CAIPS hindcasts since the coastal effects in the CAIPS model will have little or no effect in the offshore regions. The effects of smoothing on the statistics for this region show a slight increase in the mean error in Table 5.7 . Smoothing of the measured data tended to reduce the storm peak wave height, and increased the difference between the model and measured peak wave heights since the model tended to over predict the peak wave height. The scatterplot of the measured and model values in Figure 5.8 shows that the model tends to over estimate in the low storm peaks, and to under estimate in the high storm peaks. In Table 5.9 , the mean difference (model-measured) is 0.51m for H_S. and -0.06s for Tp with a scatter index of 16.2% and 12.4%, respectively. The root mean square error in H_S is 1.35m.

In the inshore deep area, the coastal effects of the CAIPS model produces a small reduction of the wave height in the higher energies. In Table 5.6 , the difference between the two models is very small. Smoothing of the waverider peak energy slightly improved the comparison statistics since the model tended to under estimate the measured peak. The statistics in Table 5.9 show a mean difference of -0.42m for H_S and 0.12s for Tp with scatter indices of 17.1% and 9.9%, respectively. The root mean square error in H_S is 1.51m.

The statistics from the deep water area compare favourably with other comprehensive hindcast studies carried out with calibrated spectral wave models. For the verification of storm hindcasts off the east coast of Canada (Canadian Climate Centre, 1991), a scatter index of 13.2% was achieved for unsmoothed deep water hindcasts at offshore sites. That particular study used the same wind field and wave hindcast methodology as applied here. In Reece and Cardone (1982), verification of the ODGP hindcast model for a wide range of storm types including hurricanes in various basins, exhibited a scatter index of 12% in H_S. Scatter indices in the range of 10-15% for H_S and Tp appear to represent the maximum skill achievable given the limitations in the meteorological data base, which limits the wind field accuracy. In addition, the sampling variability of conventional wave measurements implies an uncertainty of about 12% in actual measurements of H_S and about 7% in Tp. Considering these limitations, the model performs within expectations for this area.

SHELTERED AND SHALLOW AREAS

In the sheltered and shallow areas, the CAIPS model provided a better estimate of the peak wave height than the NO CAIPS model. The CAIPS model effectively reduced the hindcast wave height by considering coastal effects. Smoothing the waverider measurements reduced the measured storm peaks, and increased the statistical error since the model tended to overestimate the measured peak. In Figure 5.9 , the scatterplots show tendency for the model to overestimate in the low wave heights and underestimate in the higher wave heights. For the sheltered area, the mean difference is -0.08 for H_S and 0.82s for Tp with scatter indices of 19.1% and 23.42% respectively. For the shallow area, the mean difference is 0.44m for H_S and 0.43s for Tp with scatter indices of 16.1% and 14.3%, respectively.

Table 5.8 Peak to Peak Comparisons Using All Available Measured Data

No Smoothing applied

Date	Stn	BUOY				ODGP					
YYMMDD		Hs	Tp	Ws	Wdir	GP	Hs	Tp	VMD from	Ws	Wdir
750107	M103	6.93	15.20			1235	6.3	12.7	257	17.1	273
751113	M103	7.75	12.40			1235	8.6	16.0	206	20.9	187
751221	M103	4.41	10.50			1235	6.5	12.5	178	18.2	155
760127	M103	4.82	12.40			1235	6.8	14.2	229	9.5	192
760222	M103	4.19	9.80			1235	4.7	11.9	220	10.1	156
761026	46004	4.80	10.00	17.4	203	768	5.9	11.9	216	15.0	214
761025	46005	5.50	14.29	15.4	287	1147	6.0	11.8	280	16.3	279
761025	M103	5.49	13.70			1235	5.2	12.2	226	15.9	210
761030	46004	8.00	16.67	17.3	223	768	9.8	15.1	225	22.6	220
761031	46005	5.80	16.67	6.7	201	1147	6.5	14.2	256	13.1	222
761031	M103	6.39	17.10			1235	5.7	15.0	245	14.4	200
770115	46004	6.40	16.67	10.1	187	768	7.8	16.8	221	9.7	179
770117	M103	4.70	17.10			1235	5.7	16.7	240	11.8	181
770213	46004	8.10	14.29	10.9	208	768	8.9	15.1	228	20.6	220
770221	46004	8.50	16.67	20.5	187	768	11.1	15.9	192	22.0	183
771024	46005	7.80	14.29	15.9	238	1147	9.8	15.5	233	18.0	210
771025	M103	8.98	17.10			1235	8.2	17.2	234	15.4	200
780108	M103	4.22	10.50			1235	4.4	12.9	181	14.4	140
780109	46005	5.00	14.29	15.5	134	1147	5.6	11.7	196	11.4	156
781031	46004	7.70	14.29	17.2	220	768	8.3	13.8	225	21.5	206
781031	46005	4.50	14.29	9.9	213	1147	5.8	13.0	255	4.1	284
781102	M103	3.59	13.70			1235	4.9	12.9	252	4.6	295
781214	46004	8.10	16.67	22.6	282	768	9.5	15.4	280	21.6	290
781215	46005	6.10	16.67	12.8	327	1147	7.5	14.9	297	12.5	286
781215	M103	5.33	15.20			1235	6.4	13.2	279	18.2	290
790216	46004	4.40	12.50	5.3	155	768	5.4	10.8	234	16.3	225
790218	46005	4.70	14.29	12.2	220	1147	5.3	11.2	245	12.8	247
790218	M103	5.44	12.40			1235	4.6	11.5	231	8.4	217
790305	46004	6.10	12.50	15.0	223	768	8.2	14.0	233	19.6	233
790307	46005	4.20	12.50	9.1	219	1147	6.9	13.5	227	11.8	201
791121	46004	8.60	14.29	21.0	191	768	11.4	16.5	194	23.1	200
791121	46005	7.30	12.50	12.4	201	1147	10.5	15.6	218	14.5	210
791122	M103	* 6.81	17.10			1235	8.1	16.1	219	13.4	180
791217	M103	* 5.19	9.80			1235	6.2	14.1	212	8.4	171
791218	46005	4.40	16.67	8.2	164	1147	7.5	13.2	206	12.4	191
791222	46004	6.30	14.29	14.6	262	768	6.8	13.1	205	11.1	194
811201	46004	8.80	16.67	15.5	206	768	8.2	14.9	251	17.8	240
811201	46005	7.00	12.50	16.7	267	1147	7.1	14.4	260	12.6	227
811201	M103	5.37	13.70			1235	6.2	14.6	250	13.1	216
840409	M103	7.41	10.50			1235	7.7	14.2	240	10.5	218
840410	46004	8.70	16.67	7.4	196	768	8.8	15.5	236	13.1	216
840411	46005	9.70	16.67			1147	9.1	16.5	266	13.3	245
841012	46005	10.70	16.67	20.4	266	1147	10.3	15.3	244	21.0	236
841013	46004	7.50	11.11	12.7	261	768	8.9	12.1	268	23.4	287
841013	M103	8.38	17.10			1235	9.9	16.4	230	22.1	230
841102	46005	10.40	14.29	23.7	270	1147	12.5	16.3	253	24.9	260
841103	M103	7.55	12.40			1235	8.5	15.5	217	14.4	230
850211	M213	8.91	12.40			1333	7.0	13.4	191	23.9	217

Table 5.8 Peak to Peak Comparisons Using All Available Measured Data (Cont'd)

Date YYMMDD	Stn	BUOY				ODGP					
		Hs	Tp	Ws	Wdir	GP	Hs	Tp	VMD from	Ws	Wdir
850212	M103	6.99	13.70			1235	6.9	14.0	249	11.3	265
850215	46004	11.40	14.29	15.5	251	768	10.9	14.9	237	24.2	240
860107	46004	10.00	14.29	13.8	214	768	9.2	14.1	200	21.1	200
860107	M226	8.27	9.80			1267	6.8	13.9	178	18.0	143
860108	M103	6.68	10.50			1235	5.8	14.5	187	17.0	150
860112	M211	8.19	18.20	225		1365	8.7	14.5	182	20.5	173
860227	46004	9.80	14.29			768	10.5	14.2	184	24.8	179
860227	46005	7.80	16.67	9.9	191	1147	6.4	14.0	228	9.7	205
860228	M103	4.56	15.20			1235	5.2	14.1	233	2.9	207
860228	M211	10.66	18.20	211		1365	9.0	14.8	191	21.3	190
860228	M226	7.14	12.40			1267	6.5	14.6	225	5.8	215
860424	M211	5.45	9.10	119		1365	4.3	8.5	145	17.0	111
860424	M213	7.99	12.40			1333	4.2	10.2	144	15.4	120
860424	M226	7.21	9.10			1267	8.3	14.1	243	14.8	226
860425	46004	8.70	14.29			768	8.4	13.2	299	23.1	320
860425	46005	8.20	14.29	12.7	289	1147	7.6	13.4	271	17.7	266
860425	M103	5.48	13.70			1235	7.5	14.8	254	14.9	240
861118	46004	7.80	11.11	16.3	321	768	7.8	11.3	322	24.1	334
861118	M211	4.73	9.10	83		1365	5.0	9.3	113	21.1	90
861118	M213	5.53	13.70			1333	4.8	9.3	137	20.3	120
861118	M502W	8.83	11.60			1317	5.8	12.2	178	12.7	164
861118	M503W	9.56	16.00			1283	8.1	13.4	217	14.9	190
861119	M103	8.13	17.10			1235	9.2	16.4	248	18.3	236
861123	46004	14.10	16.67	16.2	245	768	11.3	17.2	234	22.1	235
861123	M213	7.37	10.50			1333	4.9	11.9	197	18.4	213
861123	M503W	10.76	16.00			1283	9.9	17.2	243	17.5	250
861124	M103	7.12	15.20			1235	7.5	17.4	256	10.2	292
861124	M211	9.24	18.20	227		1365	9.3	14.8	241	21.1	250
861224	M503W	8.87	14.20			1283	9.0	14.2	244	19.3	241
861225	M213	9.81	12.40			1333	5.6	12.3	187	19.7	193
861226	46004	10.20	16.67	13.3	222	768	10.9	15.6	224	23.1	220
861226	46005	8.10	20.00	8.1	204	1147	7.2	15.1	245	10.1	205
861226	M103	6.69	17.10			1235	6.2	15.3	239	8.8	209
861226	M211	8.22	18.20	248		1365	9.0	15.0	208	19.5	200
870109	46004	7.00	11.11	15.5	187	768	6.8	11.8	197	18.2	181
870109	M211	9.05	11.80	213		1365	6.9	12.6	192	19.1	186
870109	M213	9.16	12.40			1333	5.3	11.2	180	19.9	187
870110	M257	5.73	12.40			1267	5.7	11.8	201	14.0	197
870110	M503W	6.76	10.70			1283	6.3	12.1	203	17.5	185
870111	M103	5.12	9.10			1235	5.5	12.5	207	14.9	204
870112	46005	* 7.10	14.29	13.0	200	1147	6.5	13.0	223	16.5	199
870416	46004	10.60	14.29	16.0	247	768	9.7	14.5	241	22.3	233
870416	46005	6.60	16.67	3.5	253	1147	5.8	14.0	273	4.8	279
870416	46036	7.54	14.30			682	7.6	14.7	254	16.2	234
870416	M103	6.49	15.40			1235	5.1	14.7	265	10.7	277
870416	M211	10.52	12.50	245		1365	9.4	14.0	233	23.1	240
870416	M213	5.61	9.80			1333	4.8	9.6	204	20.1	216
870416	M257	5.47	15.20			1267	6.7	14.8	258	11.8	257
870416	M502W	5.01	10.20			1317	6.5	12.5	223	17.9	223
870416	M503W	7.80	14.20			1283	7.3	15.1	251	14.1	241
871208	M103	7.62	13.30			1235	8.3	14.8	185	21.5	161
871208	M503W	11.27	13.50			1283	9.3	13.9	165	22.6	154
871210	46004	9.10	12.50	13.4	272	768	9.1	15.9	253	17.8	263
871210	46005	10.40	14.29	16.5	258	1147	9.3	15.4	256	13.7	251
871210	46036	11.10	14.20	10.1	57	682	10.9	16.2	259	22.5	255
871210	46041	* 7.13	16.70	10.0	260	1185	8.9	15.4	251	16.6	265
880112	M503W	8.82	11.60			1283	9.4	14.8	227	16.6	230
880113	46004	8.90	16.67	11.7	133	768	9.4	14.5	243	21.3	240
880115	46005	11.00	14.29	16.4	251	1147	10.3	15.8	241	20.5	240
880115	46036	7.20	13.50	12.1	281	682	9.0	14.9	240	19.3	247
880115	M103	7.32	13.30			1235	8.4	15.7	228	19.0	240
880116	46041	7.30	14.30	13.0	260	1185	9.6	15.9	234	15.4	234

Table 5.8 Peak to Peak Comparisons Using All Available Measured Data (Cont'd)

Date	Stn	BUOY				ODGP					
YYMMDD		Hs	Tp	Ws	Wdir	GP	Hs	Tp	VMD from	Ws	Wdir
880304	46184	7.70	12.80	10.4	155	853	8.5	13.8	222	20.4	222
880304	M502W	7.71	12.20			1317	8.5	14.9	217	20.6	217
880305	46004	8.90	12.50	14.2	242	768	10.1	14.5	230	24.2	230
880305	46005	11.00	16.67			1147	10.9	15.8	246	22.1	240
880305	46036	12.00	14.20	4.7	100	682	10.4	14.2	257	25.3	276
880306	46041	7.22	16.70	12.0	240	1185	9.8	15.9	252	15.9	266
880306	M103	8.49	18.20			1235	9.8	16.2	239	20.6	240
881121	M502W	* 5.91	10.70			1317	9.1	15.5	235	23.1	240
881122	46004	9.90	12.20	20.0	305	768	11.7	16.1	281	25.0	284
881122	46036	11.20	14.20	15.9	294	682	11.7	16.0	279	23.9	284
881123	46041	9.20	16.70	10.0	270	1185	9.1	16.1	262	15.7	269
881123	46184	7.80	14.20	8.5	244	853	9.8	15.1	284	23.4	297
881123	46205	8.90	12.20	14.9	302	1365	6.7	13.9	264	16.6	283
881123	46206	9.20	15.10	12.6	288	1218	9.6	16.1	256	18.0	250
881123	M103	8.06	16.70			1235	8.7	15.9	253	18.5	250
881127	46004	14.80	17.10	19.1	250	768	12.9	16.6	238	27.2	228
881127	46036	10.10	18.30	14.6	248	682	10.2	16.2	251	21.6	236
881127	46184	10.50	12.20	17.6	296	853	10.8	14.1	261	26.2	290
881127	46205	12.80	17.10	13.3	187	1365	11.4	15.7	229	25.7	240
881127	M502W	6.89	11.60			1317	8.1	17.3	226	17.0	220
881128	46041	6.32	16.70	5.0	260	1185	6.9	15.8	270	13.2	295
881128	46206	7.70	18.30	9.7	276	1218	7.5	16.2	261	12.6	283
881128	M103	7.64	18.20			1235	6.8	16.1	258	11.8	274
881129	46184	7.90	12.80	15.8	179	853	9.6	14.0	195	22.1	180
881130	46004	10.10	12.80	18.2	205	768	9.1	14.4	205	23.7	190
881130	46036	7.00	12.80	10.4	227	682	7.2	14.6	216	20.0	186
881130	46205	12.20	14.20	17.1	219	1365	9.4	14.7	211	23.7	230
881130	46206	4.10	13.50	8.2	138	1218					
881130	M502W	6.94	11.10			1317	6.7	14.6	203	21.1	180
881201	M103	4.12	13.30			1235					
881202	46206	4.40	12.20	8.8	310	1218	4.7	12.3	224	12.4	182
881203	46004	* 7.40	15.10	9.4	224	768	8.5	13.6	187	20.5	176
881203	46036	* 6.40	16.00	11.0	173	682	8.0	13.4	195	20.4	183
881203	46184	* 7.10	12.80	13.5	188	853	8.2	14.1	179	18.6	168
881203	46205	9.60	15.10	15.9	153	1365	7.1	13.7	181	18.0	169
881203	M211	7.91	15.40	222		1365	7.1	13.7	181	18.0	169
881204	M103	3.40	13.30			1235	4.3	12.5	222	12.7	180
890120	46004	*11.20	16.00	16.8	232	768	11.1	17.4	230	24.2	220
890120	46005	6.30	16.67	8.5	231	1147	6.9	16.1	268	10.1	262
890120	46036	* 6.40	16.00	13.8	199	682	9.9	16.2	253	21.6	240
890120	46184	* 7.60	15.10	7.8	243	853	10.3	17.0	211	19.8	213
890120	46205	* 7.90	13.50	14.8	175	1365	9.8	15.2	211	20.9	200
890120	M503W	* 5.00	12.80			1283	9.0	17.3	242	18.7	237

Notes : For M211, values are Hs, Tp and peak direction
* indicates value may not be at a peak

Table 5.9 Storm Peak to Peak Comparison Statistics

(Using All Available Measured Data)
Measured versus Model (unsmoothed)

Var	Model Name	Num of Points	Average Obs	Standard Dev.	Average Model	Standard Dev	Mean Err	Absolute Mean Err	RMSE	Scatter Index	Corr Coef
Hs	Offshore Deep	62	8.32	2.28	8.83	1.89	0.51	1.07	1.35	16.22	0.837
	Inshore Deep	18	8.82	2.05	8.39	1.61	-0.42	1.18	1.51	17.13	0.711
	Sheltered	20	7.45	1.69	7.37	1.48	-0.08	1.15	1.42	19.10	0.604
	Shallow	32	6.30	1.50	6.73	1.60	0.44	0.87	1.01	16.08	0.828
	All Buoys	132	7.77	2.20	8.04	1.94	0.27	1.05	1.31	16.90	0.815
Tp	Offshore Deep	62	14.58	1.98	14.52	1.50	-0.06	1.51	1.81	12.40	0.489
	Inshore Deep	18	14.71	2.04	14.83	1.38	0.12	1.21	1.46	9.91	0.703
	Sheltered	20	12.85	3.15	13.67	2.01	0.82	2.52	3.01	23.42	0.438
	Shallow	32	14.09	2.56	14.52	1.63	0.43	1.73	2.02	14.33	0.639
	All Buoys	132	14.21	2.43	14.43	1.64	0.22	1.67	2.05	14.39	0.557

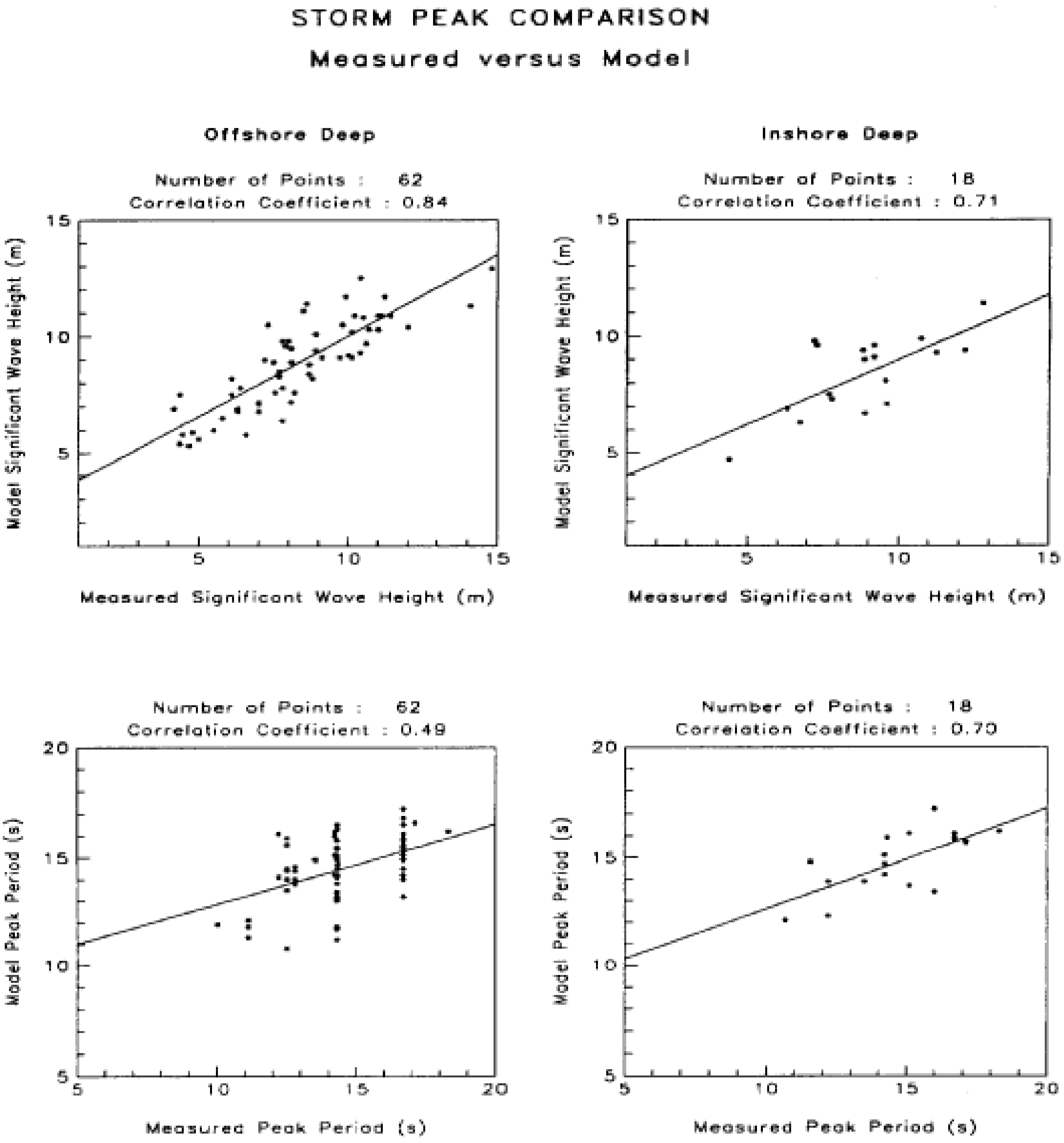


Figure 5.8 Scatter Plots of Measured Vs. Model Peak Values

Although the sheltered area has a lower mean difference in H_S, the scatter is somewhat larger. The most likely explanation for the increased scatter is that wind errors are greater near shore due to the well known effect of the coastal mountain ranges. The kinematic analysis can only partially account for this effect since there is sparse wind data for the inshore regions. Despite the large scatter indices, the mean difference between the model and the measured peak wave heights are, on average, less than half a meter for the sheltered and shallow verification locations.

Although the model tended to overpredict, on average, there were sites where the average measured H_S was greater than the average predicted values. This tendency is mainly due to the sheltering effect of the islands, particularly the Queen Charlotte Islands. Also, local effects on the winds near shore can have significant effects on the verifications at the sites where the phenomena prevail. For example, coastal tunnelling in Hecate Strait could cause a significant effect on the verification results. Shallow water effects were not considered in the model. At shallow water sites, such as MEDS 103, the model overprediction of sea state is evident. Finally, the effect of currents (which can be very strong in some areas, such as Dixon Entrance and Hecate Strait) on wave prediction was not considered in this study.

5.5.2 Spectral Comparison

The model parameters H_S and Tp are determined from the frequency spectra. It was found that when the model and measured wave spectra have comparable energies (H_S) near the storm peak, the overall shape of the frequency spectra are similar, as shown in Figure 5.2 . There tends to be a slight shift in the model’s peak energy, which may be due to the coarser frequency resolution of the model. The finer resolution of the waverider spectra allows a more precise measurement of the peak energy, but provides a noisier spectral shape.

The peak frequency shift is also evident in Figure 5.3 where the most probable spectra for wave heights ranges are compared. In the offshore deep area, the measured spectra tend to be broader than the model spectra with slightly more energy in the higher frequencies. The model spectra in the lower frequencies are limited by the model’s higher cutoff frequency. In the inshore sheltered area, the most probable spectra show the same trend as in the offshore deep area. In this area, the peak energies are more comparable, and there is a slight difference in the higher frequencies. In the shallow area, the peak energies of the most probable spectra are almost identical. However, the spectral shapes in the higher frequencies differ. Despite these differences, the spectra are very similar.

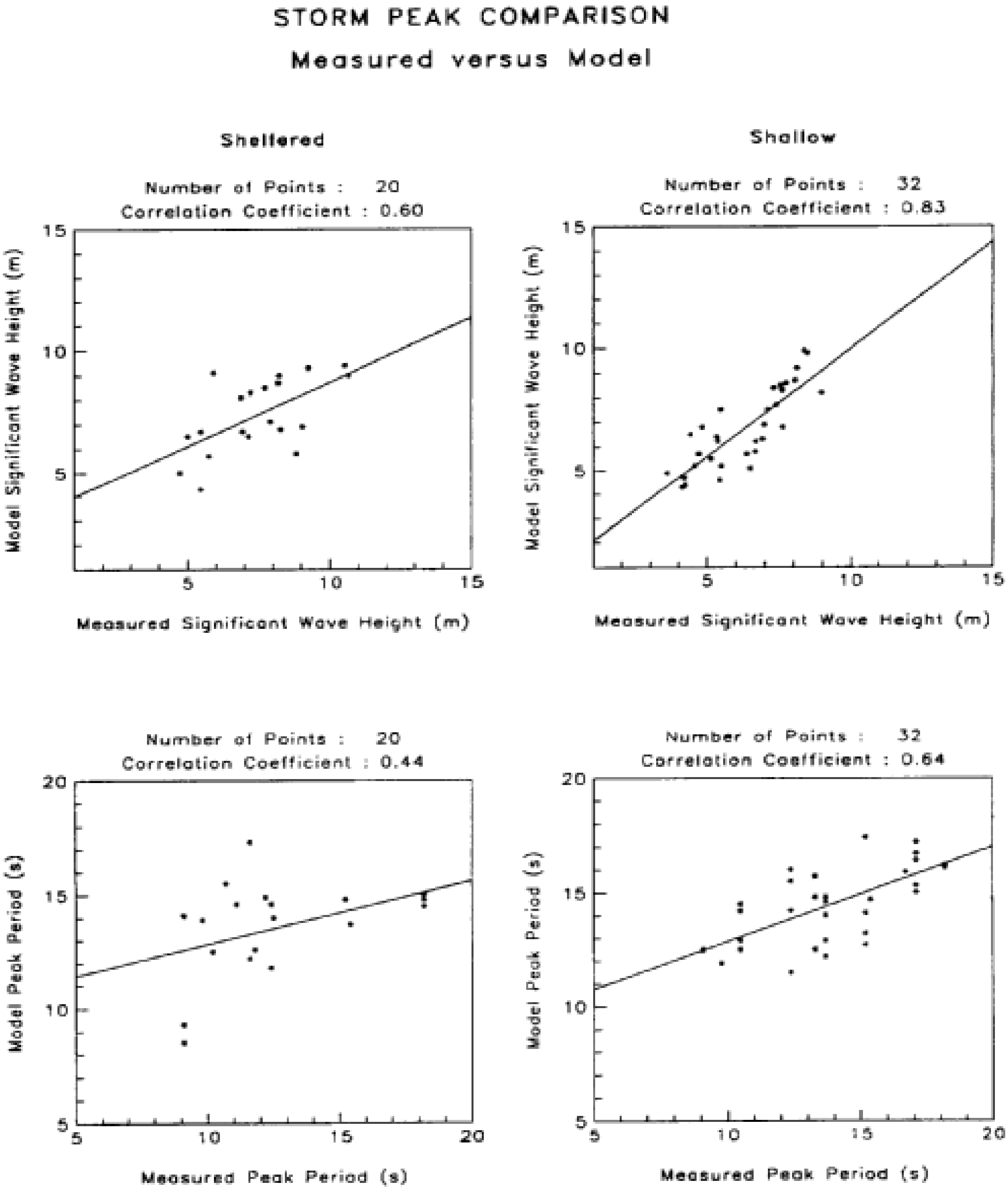


Figure 5.9 Scatter Plots of Measured versus Model Peak Values (Sheltered/Shallow)

A comparison of directional spectra could only be done at the MEDS 211 site in Dixon Entrance. The one-to-one comparison of the ODGP spectra with the spectra estimated from WAVEC data shows a shift in both the dominant wave and the mean wave directions. The order of magnitude of this shift ranges from few degrees to approximately twice the ODGP directional resolution (i.e. 30°). However, one has to remember that the ODGP grid point location is some distance (50 km) from the site where the WAVEC buoy was deployed. Because the area in question is not in the open ocean or in deep water there can be significant differences in the sea conditions in both locations.

The sequence of spectra presented in Figure 5.7 shows more complex sea conditions than those in Figures 5.4 and 5.6 . During the storm of 1988, the wind shifted direction, which resulted in the occurrence of the second peak in the wave spectrum. The second peak is seen in both the hindcast and WAVEC spectra.

Based on the above results one can conclude that, in all cases studied, the ODGP model gave a very good agreement with the WAVEC spectral estimates.

5.5.3 Overall Performance

The statistical and spectral comparisons show a high degree of agreement between measured and hindcast seastates. In Figure 5.10 , all model and buoy storm peaks are plotted in a scatterplot. Although, on average, the model tends to overpredict the storm peaks (as shown in Table 5.9), the very highest storm peaks tend to be underpredicted. The effect of this underprediction of the very high storm peaks on the results of the extreme analysis is further examined in Section 7.4.4 . Overall, the mean difference (bias) was 0.27 m for H_s and 0.22 s for Tp with scatter indices of 16.9% and 14.4%, respectively.

These results, taken together with the generally skillful time history comparisons (Appendix B), support our contention that the hindcast methodology adopted and applied yields the maximum skill achievable at the current state-of-the-art of hindcasts of mid-latitude extratropical storm wave regimes.

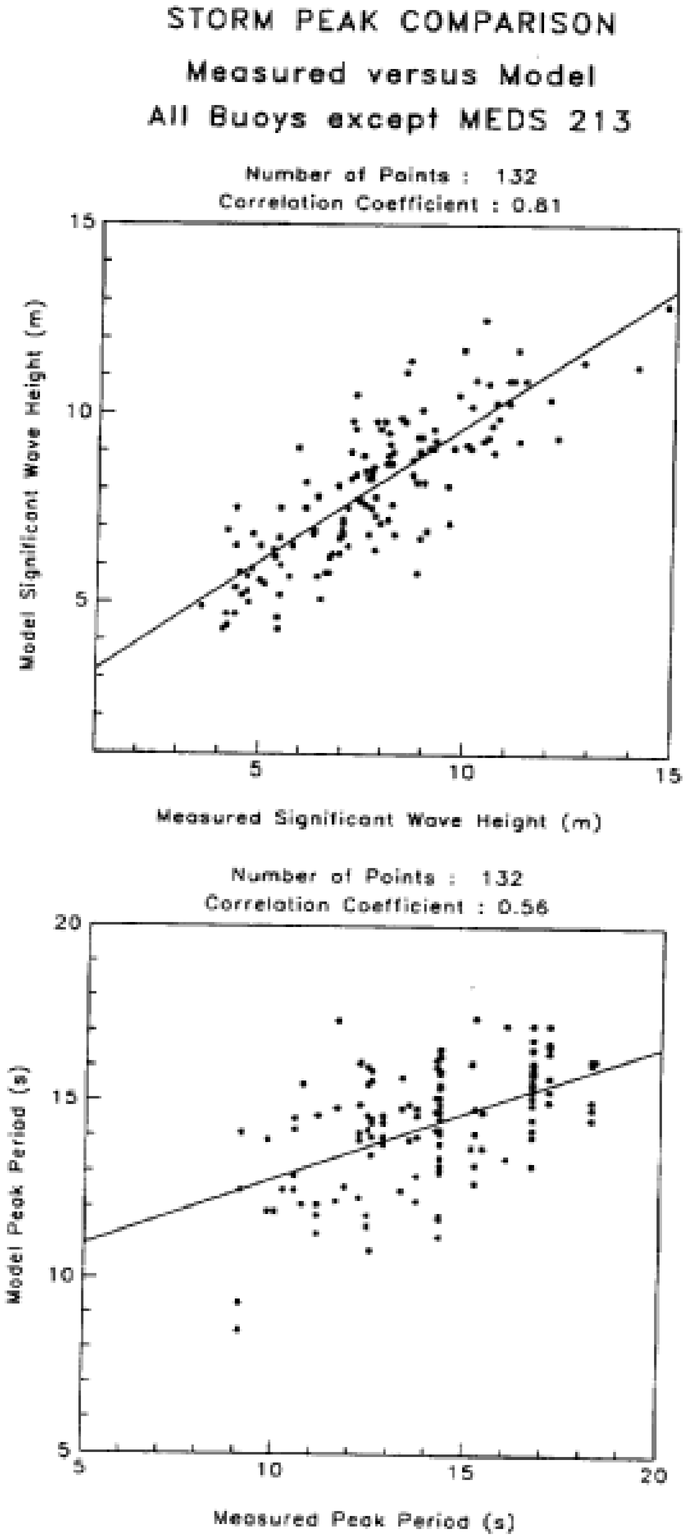


Figure 5.10 Scatter Plots of Measured versus Hindcast Peak-to-Peak Values

6.0 PRODUCTION HINDCAST

The selected top 50 storms and the recent October 26, 1990 storm were hindcast using the techniques and procedures described in earlier sections of this report. Again, only the deep water version of the ODGP model was used for the production hindcast. A list of the final top storms is given in Table 6.1 . The table provides the MCL reference number (except the 1990 storm which was not given an MCL number), storm hindcast period, and summary of hindcast peak significant wave height (H_s), corresponding peak period (T_p), and vector mean wave direction (VMD in degrees from true North, going towards) at three grid points representing the three regions (i.e. grid point #1218 for West of Vancouver Island, #1283 for Queen Charlotte Sound, and #1366 for Dixon Entrance).

The results of the wind and deep water wave hindcast were archived and delivered to the ABS and MEDS on magnetic tapes. The archived data are:

1. Winds

   All gridded wind fields (every 2 hours) at all grid points (coarse and fine). The parameters archived are: wind speed in knots (20-m effective neutral winds) and wind direction (in degrees from true using meteorological convention, i.e. coming from).

2. Waves

   Summary of wave fields (H_s, T_p and vector mean direction) at all coarse and fine grid points every 2 hours.

   Spectral data file which contains a header line and the 2-D spectral variance (15x24 fields) at all grid points in the study areas (118 points) every 0 hours. The spectral file contains date (YRMODYHR), grid point number, wind speed (kts) and direction, U_*, H_s(m), T_p(s), vector mean direction, and directional spectral variance (m^2).

For each storm, the peak significant wave height and corresponding peak period, wave mean direction, wind speed and direction were compiled, and other parameters were computed (i.e. ratios of H_{max}/H_s and H_c/H_s) at each grid point in the study area. This information was used in the extremal analysis as described in Chapter 7.0 . The computation of H_{max} and H_c is described in Section 7.2 .

Tables 6.2 to 6.6 provide a summary of hindcast results for the 51 storms at a selected number of grid points representing different wave climates. It also shows spatial variation of hindcast results and extremal values, as shown in the next section. The selected points are given below together with the areas they represent (refer to Figures 2.1 and 5.1 for map locations).

- G.P. #1218 represents West Coast Vancouver Island (near Tofino);
- G.P. #1283 represents Queen Charlotte Sound (near MEDS Station 503);
- G.P. #1365 represents West Coast Charlottes/Dixon Entrance (see also Table 6.1 for G.P. #1366 in Dixon Entrance);
- G.P. #682 near NOAA Buoy 46036 - offshore West Vancouver Island; and 0 G.P. #768 near NOAA Buoy 46004 - Explorer Marine Forecast area.

Table 6.1 List of Production Hindcast Storms and Results at Three Grid Points

	STORM PERIOD		GRID PT 1218			GRID PT 1283			GRID PT 1366		
Stm #	Start YYMMDDHH	Finish YYMMDDHH	Hs (m)	Tp (s)	VMD (to)	Hs (m)	Tp (s)	VMD (to)	Hs (m)	Tp (s)	VMD (to)
45	62112200	62112600	9.9	15.0	42	9.9	15.0	45	6.9	14.8	52
56	63101900	63102612	9.5	17.0	78	10.6	16.4	53	6.0	13.9	70
81	65112612	65120112	5.9	12.6	37	8.3	13.1	33	4.3	11.2	20
99	67010612	67011200	5.5	12.1	54	8.1	13.3	354	4.9	11.2	76
137	68112412	68120112	6.7	13.2	49	7.8	13.5	30	5.9	13.6	24
154	69110100	69110712	7.7	15.4	40	6.3	14.3	2	4.6	10.9	50
155	69111700	69112212	7.6	13.7	46	8.2	14.1	23	3.6	15.3	67
165	70021700	70022100	3.8	13.8	56	5.1	14.1	42	4.1	13.8	9
172	70102600	70110212	5.4	12.3	7	6.8	13.1	348	3.8	8.5	309
219	72011212	72011718	5.5	12.4	73	6.3	13.3	77	5.4	12.9	56
243	73012512	73020200	6.0	13.0	79	7.0	12.9	333	4.3	10.7	60
285	75010318	75010712	7.0	13.2	79	6.9	13.2	89	4.5	10.4	117
299	75111000	75111400	9.4	15.8	29	8.2	13.1	39	4.6	13.2	47
303	75121600	75122200	7.2	12.9	1	8.0	12.8	344	4.6	9.1	325
309	76012412	76013100	7.7	14.2	49	8.4	14.1	58	4.8	11.6	62
312	76021906	76022412	5.3	12.0	39	6.3	11.5	50	5.5	13.0	57
321	76102312	76102812	5.7	12.2	86	7.8	13.3	32	4.4	11.3	39
322	76102900	76110400	6.3	14.9	69	8.1	13.9	69	7.8	15.9	50
334	77011200	77011812	6.3	16.6	62	7.2	14.6	36	4.8	8.8	15
337	77020900	77021512	5.9	11.7	35	6.6	15.7	58	5.9	14.7	48
338	77021612	77022212	8.8	15.6	47	9.1	17.3	40	4.7	10.3	344
347	77102300	77102812	9.1	17.1	56	10.6	17.2	46	6.4	16.3	13
356	78010600	78011018	4.8	13.0	1	5.4	12.6	351	3.8	8.4	307
372	78102812	78110312	5.5	13.2	72	7.1	14.0	56	6.9	13.2	68
378	78121200	78121700	7.3	15.8	106	8.6	15.4	98	8.9	15.8	76
384	79021400	79021900	5.2	11.5	53	5.4	10.7	7	4.5	8.7	324
385	79030212	79030900	6.5	13.4	48	6.5	13.5	64	5.9	13.7	52
395	79111712	79112300	9.1	15.9	40	10.2	15.6	358	5.2	16.7	0
398	79121500	79122300	7.1	13.9	28	7.0	13.4	25	4.1	9.8	329
413	81112812	81120212	7.0	14.7	74	7.3	14.6	69	6.5	13.6	66
427	84040612	84041112	8.7	14.3	62	8.9	14.4	32	4.8	9.3	313
431	84101000	84101418	10.4	16.2	65	12.9	16.2	42	4.7	10.1	83
432	84103000	84110400	10.3	15.7	46	7.6	15.1	355	4.5	8.9	294
436	85021000	85021600	7.8	13.9	73	9.9	14.8	56	8.2	13.9	57
442	86010612	86011412	6.4	13.1	40	7.4	14.1	353	5.1	9.7	340
445	86022518	86022818	5.8	14.1	53	7.2	15.0	36	5.9	15.9	24
447	86042212	86042600	8.4	15.1	83	7.7	13.5	54	3.4	7.4	308
449	86111600	86112012	10.2	16.5	68	8.1	13.4	37	4.1	8.5	286
450	86112100	86112518	8.4	18.0	76	9.9	17.2	63	7.9	14.9	74
451	86122100	86122800	7.0	15.4	61	9.0	14.2	64	6.4	15.0	47
453	87010612	87011200	6.1	12.4	23	6.3	12.1	23	5.3	9.2	18
461	87041312	87041806	5.7	14.7	87	7.3	15.1	71	7.9	14.4	64
469	87120400	87121018	9.0	15.4	68	9.3	13.9	345	5.2	9.5	320
472	88011112	88011618	9.4	15.8	53	9.4	14.8	47	5.3	13.3	38
476	88030200	88030712	10.6	16.2	63	9.9	15.1	49	6.0	13.9	40
485	88111812	88112418	9.6	16.1	76	11.0	15.8	74	5.9	14.4	89
486	88112500	88112818	7.5	16.2	81	9.4	17.1	67	9.4	15.9	71
487	88112700	88120112	6.4	13.5	95	6.6	13.6	58	7.1	14.8	35
488	88120100	88120500	4.7	12.3	44	5.2	14.6	32	4.4	8.8	4
497	89011818	89012212	7.0	17.1	81	9.0	17.3	62	6.6	16.0	39
	90102600	90102812	6.2	15.4	60	8.2	16.3	41	6.3	15.8	19

Hs = Significant Wave Height (m)
Tp = Peak Period (s)
VMD = Vector Mean Wave Direction (degrees towards)

Table 6.2 Hindcast Results at Grid Point #1218 West Vancouver Island

GRID POINT 1218 AT 48.750 N, 126.25 W

YYMMDD-HH	WIND SPEED (m/s)	WIND DIR (from)	Hs (m)	Tp (s)	WAVE DIR (to)	Ts (s)	Hm (m)	Hc (m)	Hm/Hs	Hc/Hs
621124-16	21.8	209.	9.9	15.0	42.	11.8	18.3	10.2	1.84	1.02
631025-12	14.0	241.	9.5	17.0	78.	13.0	17.8	9.9	1.88	1.04
651130-06	10.3	212.	5.9	12.6	37.	10.3	11.6	6.4	1.97	1.10
670111-08	8.5	249.	5.5	12.1	54.	10.1	10.6	5.9	1.92	1.07
681130-18	15.9	225.	6.7	13.2	49.	10.3	11.9	6.6	1.78	0.99
691105-18	18.0	140.	7.7	15.4	40.	11.7	14.4	8.0	1.86	1.03
691120-22	13.9	218.	7.6	13.7	46.	10.9	14.3	8.0	1.88	1.05
700220-14	6.1	139.	3.8	13.8	56.	11.2	7.1	4.0	1.89	1.05
701101-00	6.3	153.	5.4	12.3	7.	9.9	10.1	5.6	1.86	1.04
720117-00	13.4	250.	5.5	12.4	73.	9.7	10.6	5.9	1.93	1.08
730131-00	5.7	259.	6.0	13.0	79.	10.4	11.6	6.5	1.93	1.08
750105-22	17.7	273.	7.0	13.2	79.	10.4	13.2	7.3	1.88	1.05
751113-08	21.0	194.	9.4	15.8	29.	11.8	17.1	9.5	1.82	1.01
751221-20	18.7	155.	7.2	12.9	1.	10.1	13.0	7.2	1.81	1.01
760127-20	9.6	218.	7.7	14.2	49.	11.8	14.4	8.0	1.88	1.05
760222-12	9.8	190.	5.3	12.0	39.	9.8	10.2	5.7	1.94	1.08
761025-12	9.8	274.	5.7	12.2	86.	9.9	10.7	6.0	1.90	1.06
761031-14	13.3	209.	6.3	14.9	69.	10.9	11.9	6.6	1.89	1.05
770116-08	11.1	185.	6.3	16.6	62.	12.3	11.9	6.6	1.90	1.05
770210-14	17.2	231.	5.9	11.7	35.	9.4	11.1	6.2	1.86	1.04
770222-00	13.0	192.	8.8	15.6	47.	12.7	16.0	8.9	1.82	1.01
771025-18	14.9	200.	9.1	17.1	56.	12.6	17.2	9.6	1.90	1.06
780109-12	15.4	140.	4.8	13.0	1.	8.9	9.5	5.3	1.96	1.09
781102-20	4.6	295.	5.5	13.2	72.	10.4	10.6	5.9	1.92	1.07
781215-08	14.2	286.	7.3	15.8	106.	11.4	13.7	7.6	1.89	1.05
790218-14	8.5	214.	5.2	11.5	53.	9.6	9.9	5.6	1.91	1.07
790306-02	9.4	208.	6.5	13.4	48.	11.0	12.6	7.0	1.93	1.08
791122-12	13.4	180.	9.1	15.9	40.	12.8	17.1	9.6	1.88	1.05
791218-10	7.9	183.	7.1	13.9	28.	11.4	13.6	7.6	1.94	1.08
811202-02	13.1	223.	7.0	14.7	74.	11.4	13.2	7.3	1.89	1.05
840410-18	11.0	226.	8.7	14.3	62.	12.4	16.5	9.3	1.89	1.06
841013-04	19.3	236.	10.4	16.2	65.	12.5	19.1	10.6	1.84	1.02
841103-00	19.5	240.	10.3	15.7	46.	13.0	18.9	10.5	1.83	1.02
850215-14	10.7	264.	7.8	13.9	73.	11.8	14.5	8.1	1.86	1.04
860114-10	8.4	174.	6.4	13.1	40.	11.0	12.7	7.1	1.98	1.10
860228-18	2.6	196.	5.8	14.1	53.	10.9	10.5	5.8	1.80	1.00
860425-14	14.0	254.	8.4	15.1	83.	11.7	15.3	8.5	1.82	1.01
861119-00	19.5	230.	10.2	16.5	68.	12.5	18.5	10.3	1.81	1.00
861124-04	9.8	281.	8.4	18.0	76.	12.9	15.0	8.3	1.79	0.99
861227-00	7.7	208.	7.0	15.4	61.	11.6	13.4	7.5	1.93	1.08
870111-02	15.0	182.	6.1	12.4	23.	9.9	11.7	6.5	1.92	1.07
870417-02	8.6	284.	5.7	14.7	87.	11.1	10.8	6.0	1.88	1.05
871210-14	15.6	255.	9.0	15.4	68.	12.5	17.4	9.7	1.92	1.07
880115-08	18.7	240.	9.4	15.8	53.	12.3	17.4	9.7	1.86	1.04
880306-06	18.5	240.	10.6	16.2	63.	12.9	19.3	10.7	1.83	1.02
881123-06	18.0	250.	9.6	16.1	76.	12.4	17.9	9.9	1.85	1.03
881128-04	12.6	283.	7.5	16.2	81.	12.2	14.0	7.8	1.86	1.03
881201-10	3.3	169.	5.5	14.0	64.	0.0	0.0	0.0	0.00	0.00
881204-20	12.4	182.	4.7	12.3	44.	9.4	8.9	4.9	1.91	1.06
890121-04	10.4	245.	7.0	17.1	81.	12.6	13.0	7.2	1.86	1.03
901027-16	10.2	202.	6.2	15.4	60.	11.1	11.7	6.5	1.89	1.05

Table 6.3 Hindcast Results at Grid Point #1283 Queen Charlotte Sound

GRID POINT 1283 AT 51.250 N, 130.00 W

YYMMDD-HH	WIND SPEED (m/s)	WIND DIR (from)	Hs (m)	Tp (s)	WAVE DIR (to)	Ts (s)	Hm (m)	Hc (m)	Hm/Hs	Hc/Hs
621124-14	19.7	210.	9.9	15.0	45.	11.9	18.3	10.2	1.86	1.03
631024-20	21.7	218.	10.6	16.4	53.	12.6	19.1	10.6	1.81	1.01
651201-00	19.0	200.	8.3	13.1	33.	10.8	15.2	8.4	1.83	1.02
670110-08	20.2	162.	8.1	13.3	354.	10.5	14.8	8.2	1.82	1.01
681128-22	17.7	208.	7.8	13.5	30.	10.7	14.4	8.0	1.85	1.03
691105-08	14.5	99.	6.3	14.3	2.	10.6	11.9	6.6	1.88	1.04
691120-18	20.6	200.	8.2	14.1	23.	10.7	14.9	8.3	1.82	1.01
700220-08	6.2	184.	5.1	14.1	42.	10.4	9.8	5.4	1.92	1.06
701031-20	16.3	160.	6.8	13.1	348.	10.0	12.3	6.8	1.82	1.01
720117-08	14.2	242.	6.3	13.3	77.	10.1	12.2	6.8	1.94	1.08
730127-16	17.9	126.	7.0	12.9	333.	10.0	13.0	7.2	1.87	1.04
750106-00	18.0	290.	6.9	13.2	89.	10.1	12.9	7.1	1.86	1.03
751111-22	21.0	197.	8.2	13.1	39.	10.6	15.7	8.8	1.92	1.07
751221-18	21.1	140.	8.0	12.8	344.	10.3	14.6	8.1	1.84	1.02
760128-20	18.9	238.	8.4	14.1	58.	11.0	15.2	8.5	1.81	1.01
760222-12	9.3	230.	6.3	11.5	50.	10.1	12.1	6.8	1.92	1.07
761027-08	20.5	206.	7.8	13.3	32.	10.2	14.2	7.9	1.83	1.01
761031-18	20.6	250.	8.1	13.9	69.	10.7	14.8	8.2	1.84	1.02
770117-08	17.9	196.	7.2	14.6	36.	10.5	13.6	7.5	1.88	1.04
770213-10	12.9	187.	6.6	15.7	58.	11.3	12.0	6.6	1.82	1.01
770221-14	13.0	193.	9.1	17.3	40.	12.9	16.7	9.3	1.83	1.01
771025-16	21.5	201.	10.6	17.2	46.	12.7	19.9	11.0	1.88	1.04
780109-14	15.6	149.	5.4	12.6	351.	9.0	10.4	5.8	1.93	1.08
781031-16	16.6	239.	7.1	14.0	56.	10.7	13.4	7.4	1.88	1.05
781214-22	19.4	287.	8.6	15.4	98.	11.6	16.3	9.1	1.89	1.05
790215-16	16.4	186.	5.4	10.7	7.	8.5	9.9	5.5	1.84	1.03
790307-12	9.5	262.	6.5	13.5	64.	10.7	12.8	7.2	1.98	1.10
791121-22	20.7	179.	10.2	15.6	358.	12.4	19.3	10.8	1.89	1.05
791218-12	9.3	194.	7.0	13.4	25.	11.1	13.6	7.6	1.95	1.09
811201-22	15.0	224.	7.3	14.6	69.	11.3	14.1	7.9	1.93	1.08
840407-18	21.1	190.	8.9	14.4	32.	11.3	16.6	9.3	1.87	1.04
841013-00	28.8	230.	12.9	16.2	42.	12.8	23.0	12.8	1.79	0.99
841101-14	20.5	145.	7.6	15.1	355.	10.2	13.8	7.7	1.82	1.01
850215-02	21.3	240.	9.9	14.8	56.	11.8	18.3	10.1	1.85	1.03
860112-10	18.3	140.	7.4	14.1	353.	10.4	14.5	8.1	1.96	1.09
860228-06	10.3	190.	7.2	15.0	36.	11.5	13.3	7.3	1.85	1.03
860425-04	13.6	217.	7.7	13.5	54.	10.9	14.0	7.8	1.83	1.02
861118-18	14.9	190.	8.1	13.4	37.	11.2	14.9	8.3	1.84	1.02
861123-22	17.5	250.	9.9	17.2	63.	13.1	18.0	10.0	1.81	1.01
861224-10	19.3	241.	9.0	14.2	64.	11.2	16.5	9.2	1.83	1.02
870109-18	17.5	185.	6.3	12.1	23.	9.5	11.8	6.6	1.88	1.05
870416-16	14.1	241.	7.3	15.1	71.	11.3	13.6	7.6	1.86	1.03
871208-08	22.6	154.	9.3	13.9	345.	11.4	17.3	9.7	1.86	1.04
880115-08	16.6	230.	9.4	14.8	47.	12.2	17.2	9.6	1.82	1.02
880305-02	21.5	221.	9.9	15.1	49.	11.9	17.8	9.9	1.79	1.00
881123-04	22.0	244.	11.0	15.8	74.	12.6	20.0	11.1	1.81	1.01
881127-20	17.5	241.	9.4	17.1	67.	12.6	17.4	9.6	1.84	1.02
881201-04	7.5	233.	6.6	13.6	58.	10.8	12.5	6.9	1.91	1.06
881204-00	11.9	190.	5.2	14.6	32.	9.9	10.0	5.6	1.94	1.08
890120-22	18.7	237.	9.0	17.3	62.	12.2	16.5	9.1	1.84	1.02
901027-12	16.0	194.	8.2	16.3	41.	11.5	15.4	8.5	1.87	1.04

Table 6.4 Hindcast Results at Grid Point #1365 West Coast Charlottes/ Dixon Entrance (Learmouth Bank)

GRID POINT 1365 AT 54.375 N, 133.75 W

YYMMDD-HH	WIND SPEED (m/s)	WIND DIR (from)	Hs (m)	Tp (s)	WAVE DIR (to)	Ts (s)	Hm (m)	Hc (m)	Hm/Hs	Hc/Hs
621124-14	20.6	197.	8.8	14.5	25.	11.1	16.4	9.1	1.88	1.04
631024-08	21.0	147.	7.2	12.5	352.	9.8	13.6	7.6	1.90	1.06
651201-02	15.4	191.	6.2	12.7	16.	9.7	11.3	6.3	1.82	1.01
670110-12	18.0	200.	6.6	12.6	6.	9.9	12.4	6.9	1.88	1.04
681128-22	21.4	203.	8.9	13.8	15.	11.1	15.8	8.8	1.78	0.99
691102-16	17.1	222.	5.7	11.0	31.	8.8	10.5	5.9	1.85	1.03
691122-12	10.6	196.	4.6	14.9	58.	10.0	8.8	4.9	1.93	1.07
700220-02	15.1	175.	6.2	13.0	15.	9.8	11.5	6.4	1.85	1.03
701102-02	17.3	120.	5.5	11.2	321.	8.7	10.0	5.6	1.84	1.02
720117-02	16.4	225.	6.6	13.0	52.	9.9	12.6	7.0	1.90	1.06
730127-12	17.0	120.	5.8	13.8	330.	9.3	10.9	6.0	1.86	1.03
750105-10	10.9	202.	5.4	11.7	27.	9.4	10.2	5.7	1.87	1.05
751111-22	11.7	198.	5.6	12.4	47.	9.7	10.8	6.0	1.93	1.08
751221-14	19.0	137.	6.8	12.5	338.	9.7	12.6	7.0	1.85	1.03
760127-16	15.2	242.	6.2	13.2	40.	10.2	12.1	6.7	1.95	1.09
760222-08	17.1	235.	6.9	12.4	50.	9.9	12.9	7.2	1.86	1.03
761026-18	16.2	207.	5.4	11.5	29.	8.9	10.3	5.8	1.90	1.06
761030-22	23.0	213.	10.3	15.5	34.	12.1	18.6	10.3	1.81	1.00
770117-08	17.1	192.	6.2	13.2	23.	9.6	11.4	6.3	1.84	1.02
770213-04	18.5	207.	8.1	14.5	38.	11.1	14.7	8.1	1.81	1.00
770221-10	16.7	156.	8.1	15.7	360.	11.6	15.0	8.3	1.86	1.03
771025-08	19.0	140.	9.1	16.4	360.	12.3	17.1	9.5	1.88	1.04
780108-20	17.1	147.	5.7	12.0	348.	9.0	10.8	6.0	1.89	1.05
781102-04	20.2	240.	8.4	13.1	53.	10.6	15.2	8.5	1.82	1.01
781214-08	21.8	256.	10.4	15.9	69.	12.4	19.3	10.7	1.86	1.03
790215-20	20.1	148.	6.3	11.3	336.	8.9	11.6	6.4	1.83	1.01
790307-04	19.8	223.	7.8	13.3	33.	10.5	14.3	8.0	1.84	1.02
791122-02	19.8	163.	9.1	15.9	357.	11.8	16.6	9.2	1.82	1.01
791217-10	16.6	143.	5.5	11.1	336.	8.8	10.7	5.9	1.94	1.08
811201-14	18.6	237.	7.8	13.8	60.	10.8	14.4	8.0	1.86	1.03
840409-18	17.5	150.	6.4	12.4	353.	9.6	12.0	6.7	1.86	1.04
841010-16	16.3	171.	5.4	11.4	352.	8.7	10.1	5.7	1.89	1.06
841101-14	20.6	100.	6.1	11.0	324.	9.2	11.3	6.3	1.85	1.03
850215-04	23.8	230.	10.0	14.5	45.	11.4	18.5	10.3	1.84	1.02
860107-14	20.5	173.	8.7	14.5	2.	11.1	15.9	8.8	1.82	1.01
860228-04	21.3	190.	9.0	14.8	11.	11.6	16.2	9.0	1.79	1.00
860424-16	17.0	111.	4.3	8.5	325.	7.4	8.0	4.4	1.87	1.04
861118-06	21.1	90.	5.0	9.3	293.	7.5	9.3	5.2	1.87	1.04
861124-00	21.1	250.	9.3	14.8	61.	11.6	16.7	9.3	1.80	1.00
861226-12	19.5	200.	9.0	15.0	28.	11.6	17.0	9.5	1.88	1.05
870109-18	19.1	186.	6.9	12.6	12.	9.8	12.7	7.0	1.82	1.01
870416-12	23.1	240.	9.4	14.0	53.	11.2	17.1	9.5	1.82	1.01
871205-22	21.8	126.	7.7	13.3	335.	10.3	14.1	7.8	1.82	1.01
880113-02	20.5	138.	7.1	13.6	336.	9.9	13.4	7.4	1.89	1.05
880305-04	19.6	210.	7.9	13.9	30.	10.7	14.3	7.9	1.81	1.01
881123-08	16.6	283.	6.7	13.9	84.	10.3	12.3	6.8	1.84	1.02
881127-18	25.7	240.	11.4	15.7	49.	12.4	20.5	11.4	1.79	0.99
881130-18	23.7	230.	9.4	14.7	31.	11.5	17.0	9.5	1.81	1.01
881203-20	18.0	169.	7.1	13.7	1.	10.3	13.0	7.2	1.82	1.01
890120-14	20.9	200.	9.8	15.2	31.	12.0	17.6	9.8	1.79	0.99
901027-10	22.3	173.	9.6	15.4	13.	11.7	17.6	9.8	1.82	1.01

Table 6.5 Hindcast Results at Grid Point #682 Offshore Near NOAA Buoy #46036

GRID POINT 682 AT 48.750 N, 135.00 W

YYMMDD-HH	WIND SPEED (m/s)	WIND DIR (from)	Hs (m)	Tp (s)	WAVE DIR (to)	Ts (s)	Hm (m)	Hc (m)	Hm/Hs	Hc/Hs
621124-08	21.9	230.	10.1	15.1	62.	11.9	18.4	10.2	1.83	1.01
631025-02	25.0	263.	12.6	16.8	87.	13.3	23.3	13.0	1.86	1.03
651130-20	20.7	224.	8.3	12.7	56.	10.6	14.9	8.3	1.79	1.00
670110-06	17.0	210.	6.9	12.3	26.	10.0	13.0	7.3	1.90	1.06
681130-14	18.9	282.	8.3	13.9	95.	11.0	15.7	8.7	1.90	1.06
691105-08	25.0	320.	10.4	15.0	126.	11.5	19.5	10.8	1.86	1.04
691120-14	18.6	243.	7.2	13.3	51.	10.1	13.0	7.2	1.82	1.01
700219-20	16.8	194.	6.6	13.7	33.	10.0	12.2	6.7	1.84	1.02
701031-06	17.7	145.	6.2	11.7	331.	9.2	11.5	6.4	1.86	1.04
720117-06	17.0	270.	6.7	13.7	102.	10.2	13.1	7.3	1.96	1.09
730127-06	19.0	140.	7.7	12.5	335.	10.2	14.5	8.1	1.88	1.05
750105-16	17.8	287.	7.2	13.8	89.	10.4	13.7	7.6	1.91	1.06
751111-18	20.0	223.	7.8	12.8	59.	10.4	14.2	7.9	1.84	1.02
751219-22	4.8	160.	7.5	15.9	61.	12.5	14.0	7.8	1.87	1.04
760127-08	15.9	239.	8.1	14.6	49.	11.6	15.2	8.5	1.89	1.05
760223-16	13.3	245.	6.2	15.0	97.	10.5	11.9	6.6	1.92	1.07
761026-18	17.5	204.	6.1	11.9	37.	9.2	11.6	6.4	1.91	1.06
761030-20	17.0	223.	7.9	14.8	63.	11.2	14.8	8.2	1.88	1.04
770115-18	13.8	202.	8.3	17.0	50.	12.7	15.1	8.4	1.82	1.01
770213-00	14.9	210.	7.0	14.7	57.	10.7	13.1	7.3	1.88	1.05
770221-02	23.0	196.	11.3	16.4	31.	12.7	21.0	11.6	1.85	1.03
771025-02	26.1	217.	12.9	17.3	49.	13.3	23.8	13.2	1.85	1.02
780108-18	19.6	161.	7.3	12.5	354.	10.1	13.4	7.5	1.83	1.02
781031-18	19.5	240.	7.8	13.6	61.	10.6	15.2	8.5	1.95	1.09
781215-00	21.1	290.	8.8	14.9	107.	11.4	16.0	8.9	1.81	1.00
790215-18	15.4	250.	5.0	10.9	82.	8.5	9.6	5.3	1.91	1.06
790307-00	18.0	230.	6.8	12.8	54.	9.9	13.3	7.4	1.95	1.09
791121-22	22.5	213.	11.3	16.2	33.	12.9	20.7	11.5	1.83	1.02
791220-18	16.9	258.	7.3	13.8	69.	10.7	13.8	7.7	1.89	1.05
811201-12	17.0	240.	8.2	14.9	76.	11.5	15.4	8.6	1.88	1.05
840410-04	18.3	234.	10.0	16.0	66.	12.4	18.9	10.5	1.89	1.05
841012-22	25.5	261.	10.6	14.0	81.	11.6	19.2	10.7	1.82	1.02
841103-02	21.7	305.	8.8	14.1	107.	11.0	16.0	8.9	1.81	1.01
850214-20	23.2	236.	10.3	14.5	60.	11.5	18.7	10.4	1.82	1.01
860112-02	19.2	172.	7.9	12.6	13.	10.6	14.8	8.3	1.87	1.05
860227-18	23.1	200.	9.7	13.9	17.	11.4	17.4	9.7	1.80	1.00
860425-04	23.3	287.	9.5	14.5	107.	11.1	17.6	9.8	1.86	1.03
861118-14	24.2	290.	10.0	14.1	97.	11.4	18.6	10.4	1.86	1.03
861123-18	24.7	240.	11.8	17.4	69.	13.0	21.1	11.7	1.80	1.00
861226-04	20.4	217.	9.2	14.9	52.	11.6	16.9	9.4	1.83	1.02
870109-14	17.7	193.	6.4	11.2	31.	9.5	11.9	6.6	1.86	1.04
870416-08	16.2	234.	7.6	14.7	74.	10.9	14.4	8.0	1.89	1.05
871210-02	22.5	255.	10.9	16.2	79.	12.6	19.5	10.9	1.79	0.99
880115-02	19.3	247.	9.0	14.9	60.	11.6	16.5	9.2	1.83	1.02
880305-20	25.3	276.	10.4	14.2	77.	11.6	19.3	10.8	1.85	1.03
881122-20	23.9	284.	11.7	16.0	99.	12.6	21.0	11.7	1.80	1.00
881127-14	21.6	236.	10.2	16.2	71.	12.1	18.8	10.4	1.85	1.02
881129-20	20.0	186.	7.2	14.6	36.	10.1	14.0	7.8	1.95	1.09
881203-14	20.4	183.	8.0	13.4	15.	10.6	14.6	8.1	1.81	1.01
890120-18	21.6	240.	9.9	16.2	73.	12.3	18.2	10.1	1.85	1.02
901027-02	21.9	196.	9.6	16.2	43.	11.7	17.5	9.7	1.82	1.01

Table 6.6 Hindcast Results at Grid Point #768 Offshore Near NOAA Buoy #46004

GRID POINT 768 AT 51.250 N, 135.00 W

YYMMDD-HH	WIND SPEED (m/s)	WIND DIR (from)	Hs (m)	Tp (s)	WAVE DIR (to)	Ts (s)	Hm (m)	Hc (m)	Hm/Hs	Hc/Hs
621124-10	23.3	223.	10.4	14.9	51.	11.9	19.1	10.6	1.84	1.02
631024-12	23.1	210.	10.8	15.8	45.	12.4	20.2	11.3	1.87	1.04
651130-20	20.5	217.	8.6	13.5	44.	10.8	15.4	8.6	1.80	1.00
670110-10	17.3	207.	7.3	13.3	21.	10.4	13.6	7.6	1.86	1.03
681128-20	21.6	215.	9.2	13.4	30.	11.0	16.7	9.3	1.82	1.01
691106-00	19.0	320.	7.0	12.4	136.	9.7	13.2	7.3	1.88	1.05
691121-00	16.5	256.	5.9	12.0	58.	9.2	11.1	6.2	1.89	1.05
700219-20	18.4	194.	7.2	13.7	26.	10.2	13.2	7.3	1.84	1.02
701031-00	19.5	130.	6.3	11.7	334.	9.1	12.1	6.8	1.93	1.07
720117-02	19.4	253.	7.8	13.7	81.	10.6	14.7	8.2	1.88	1.05
730127-10	20.8	123.	8.2	12.8	323.	10.5	15.3	8.6	1.88	1.05
750105-08	17.7	231.	6.8	12.5	51.	10.1	13.0	7.2	1.91	1.06
751111-14	14.6	215.	7.1	14.0	68.	11.0	13.6	7.6	1.91	1.06
751220-00	3.3	173.	7.9	15.8	54.	12.4	14.8	8.3	1.88	1.05
760126-20	19.1	180.	7.8	13.5	5.	10.5	14.9	8.3	1.91	1.06
760222-02	18.8	247.	7.4	12.4	70.	10.0	13.6	7.6	1.86	1.03
761026-20	15.0	214.	5.9	11.9	36.	9.4	11.4	6.4	1.93	1.08
761030-18	22.6	220.	9.8	15.1	45.	11.8	17.9	9.9	1.81	1.01
770115-22	9.7	179.	7.8	16.8	41.	12.7	14.3	7.9	1.84	1.02
770213-00	20.6	220.	8.9	15.1	48.	11.3	16.1	8.9	1.82	1.00
770221-04	22.0	183.	11.1	15.9	12.	12.7	20.3	11.3	1.83	1.02
771025-04	25.4	203.	12.8	17.2	28.	13.3	23.4	13.0	1.82	1.01
780108-18	17.8	165.	6.5	13.2	356.	9.8	12.4	6.9	1.91	1.06
781031-08	21.5	206.	8.3	13.8	45.	10.8	15.6	8.7	1.88	1.05
781214-18	21.6	290.	9.5	15.4	100.	11.9	18.1	10.1	1.90	1.06
790215-20	16.3	225.	5.4	10.8	54.	8.6	9.7	5.4	1.79	0.99
790307-02	19.6	233.	8.2	14.0	53.	10.7	15.0	8.3	1.83	1.01
791122-00	23.1	200.	11.4	16.5	14.	12.9	20.6	11.5	1.82	1.01
791218-06	11.1	194.	6.8	13.1	25.	10.7	13.0	7.3	1.93	1.08
811201-14	17.8	240.	8.2	14.9	71.	11.4	15.7	8.7	1.91	1.06
840410-08	13.1	216.	8.8	15.5	56.	12.1	16.4	9.1	1.87	1.04
841013-02	23.4	287.	8.9	12.1	88.	10.6	16.1	9.0	1.81	1.01
841101-08	20.0	137.	7.6	15.1	345.	10.2	13.7	7.6	1.81	1.01
850215-00	24.2	240.	10.9	14.9	57.	11.9	20.0	11.1	1.83	1.02
860107-12	21.1	200.	9.2	14.1	20.	11.1	17.0	9.4	1.85	1.03
860227-20	24.8	179.	10.5	14.2	4.	11.8	19.0	10.6	1.80	1.00
860425-06	23.1	320.	8.4	13.2	119.	10.3	15.5	8.6	1.86	1.03
861118-20	24.1	334.	7.8	11.3	142.	9.5	14.3	8.0	1.85	1.03
861123-14	22.1	235.	11.3	17.2	54.	13.0	20.3	11.3	1.80	1.00
861226-06	23.1	220.	10.9	15.6	44.	12.5	20.0	11.1	1.83	1.02
870109-14	18.2	181.	6.8	11.8	17.	9.6	12.6	7.1	1.87	1.04
870416-08	22.3	233.	9.7	14.5	61.	11.5	17.6	9.8	1.81	1.00
871210-04	17.8	263.	9.1	15.9	73.	12.1	17.2	9.6	1.89	1.06
880115-04	21.3	240.	9.4	14.5	63.	11.5	17.0	9.4	1.81	1.00
880305-00	24.2	230.	10.1	14.5	50.	11.5	18.0	10.0	1.78	0.99
881123-02	25.0	284.	11.7	16.1	101.	12.6	21.1	11.7	1.81	1.00
881127-14	27.2	228.	12.9	16.6	58.	13.0	23.0	12.8	1.79	0.99
881130-12	23.7	190.	9.1	14.4	25.	10.9	16.9	9.4	1.85	1.03
881203-16	20.5	176.	8.5	13.6	7.	10.9	15.5	8.6	1.82	1.01
890120-12	24.2	220.	11.1	17.4	50.	12.8	20.0	11.1	1.80	0.99
901027-06	23.7	210.	11.1	15.8	36.	12.3	20.2	11.2	1.83	1.01

7.0 EXTREMAL ANALYSIS OF HINDCAST DATABASE

7.1 BASIC APPROACH

The wave model provided time histories of the following quantities at each grid point of the fine grid, which are used in the statistical analysis of extremes:

H_s = significant wave height
T_p = spectral peak period
Θ_d = vector mean wave direction
W_s = wind speed (1-hour average at 20 m elevation)
Θ_w = wind direction

The basic approach was to carry out site specific extremal analysis of hindcast peaks over-threshold (POT), at each fine grid location. Site averaging was not considered necessary or desirable for the following reasons:

1) a large number of storms were hindcast, thereby providing a reasonably large population of peaks at each grid location;

2) the meteorological properties of storms responsible for wave generation vary gently across regions. This tends to minimize the kind of sampling variations which site averaging is intended to suppress; and

3) the site specific approach may preserve real variations in extremes of wave height and period, associated with fine-scale variations in the complicated shoreline geometry which bounds the three areas of interest.

The objective of the analysis was to determine long term statistical distributions of significant and maximum individual wave height, crest height, and associated wind speed, for subpopulations of storms stratified into sectors of wave approach direction for selected grid points, and omni-directional extremes at all points. It was found, however, that no more than one or two broad directional sectors could be justified at any point based upon the given hindcast population of storms.

Finally, estimates were provided of extremes for quantities such as T_p, H_{max}, and H_c based on correlations between these quantities and H_s. Correlations were developed from the hindcast data at each grid point between such quantities.

In the remainder of this section, a more detailed description of each of the key steps of the statistical analysis is given. The statistical models and fitting techniques are well established and have been described in several previous studies (e.g. Muir and El-Shaarawi, 1986).

7.2 CALCULATION OF MAXIMUM WAVE HEIGHT AND CREST HEIGHT

It is by now well known that the statistics of individual wave heights and crest heights in naturally occurring sea states deviate from predictions of the theoretical Rayleigh distribution. A large number of alternative distributions have been proposed. We have adopted the empirical distribution of Forristall (1978) for maximum individual wave height, and the Jahns-Wheeler distribution with Haring, Osborne, and Spencer's (HOS) empirical constants (Haring and Heideman, 1978) for crest height in a wide range of water depths. HOS have also proposed a distribution of maximum individual wave heights which nominally provides maximum heights about two percent lower than Forristall's, but whose constants may be adjusted slightly to provide essentially the same results as Forristall (1978).

The various distributions cited above provide estimates of maximum wave height (H_{max}) and crest height (H_c) in runs of n individual waves, expressed usually as zerocrossing waves. In our standard approach, we use Borgman's (1973) integral expression to account for the effect of the actual buildup and decay for each individual storm on the effective number of waves in a storm at a site. This expression used significant wave period, T_s, to relate the period properties of the seaway to the effective number of individual waves. Other approaches have included the use of an average normalized buildup and decay for all storms, or the simple adoption of a constant storm duration. The computation may also be carried out with different relationships between T_s and zero-crossing period, T_z, and properties of the hindcast spectrum, such as T_p or the spectral moments.

In the calculation of H_{max} in this study, the distribution of Forristall (1978) and the method of Borgman (1973) were applied throughout. The adopted H_{max} at each site and in each storm was taken as the median of the fitted distribution. This method uses the significant wave period, T_s, directly from the hindcast spectrum as computed from the zeroth and first moments (M_0 and M_1).

In the calculation of H_c, the method of HOS was adopted, except that as for H_{max} the actual buildup and decay in each storm was used following the method of Borgman (1973). In this calculation, T_z was calculated from T_p using the constant ratio T_z/T_p of 0.74 found empirically to characterize storm sea states in extratropical storms. In particular the program evaluates Borgman's (1973) integral:

$$Pr\{H \leq h\} = \exp \int_{t_a}^{t_b} \log \left[1 - e^{h^2/a^2(t)}\right] \frac{dt}{T(t)}$$

where H is the largest wave height; a^2 is the mean square height taken as a function of time, t; t_a and t_b are the beginning and end of the storm; and T(t) is the wave period, taken here as the significant wave period. The equation shown incorporates the Rayleigh probability distribution function.

The integral was actually evaluated for the following distributions of individual wave height, crest height, and wave period T:

individual wave height:

$$\Pr\{H > h\} = \exp\,[-1.08311(h^2/8M_0)^{1.063}]\ \text{(Forristall)};\ T = M_0/M_1$$

crest height:

$$PR\{H > h\} = \exp[(-h^2/2M_0)(1 - 2.4909z + 0.57z^2)],$$

where h is crest height, d is water depth, and z = h/d (Haring et al.);

$T = .74\ T_p$

Since the model hindcasts assumed deep water physics, water depth limitations were ignored in the calculation of crest height. The median of the resulting distribution was taken as the maximum expected single peak height in the storm.

7.3 EXTREMAL ANALYSIS METHODS

The objective of the extremal analysis was to describe extremes at all contiguous grid locations (Figure 7.1) of the following variables:

- H_s versus risk (i.e. annual exceedance probability or return period)
- W_s versus risk (wind speed which corresponds to the peak Hs in each storm).

At a selected subset of grid locations (25 points) a more detailed analysis of the extremes was carried out in order to determine:

1. effective ratios of H_{max}/H_s and H_c/H_s based on the analysis described in Section 7.2 ;
2) H_{max} and H_c versus risk (or return period); and
3) peak spectral periods T_p associated with peak H_s from the relation $T_p = A(H_s)^B$.

At a number of "representative" grid locations (representing different areas), a further analysis of the extremes was considered. This included sensitivity of extremes to assumed distribution (i.e. Gumbel vs. Borgman), fitting method and thresholds.

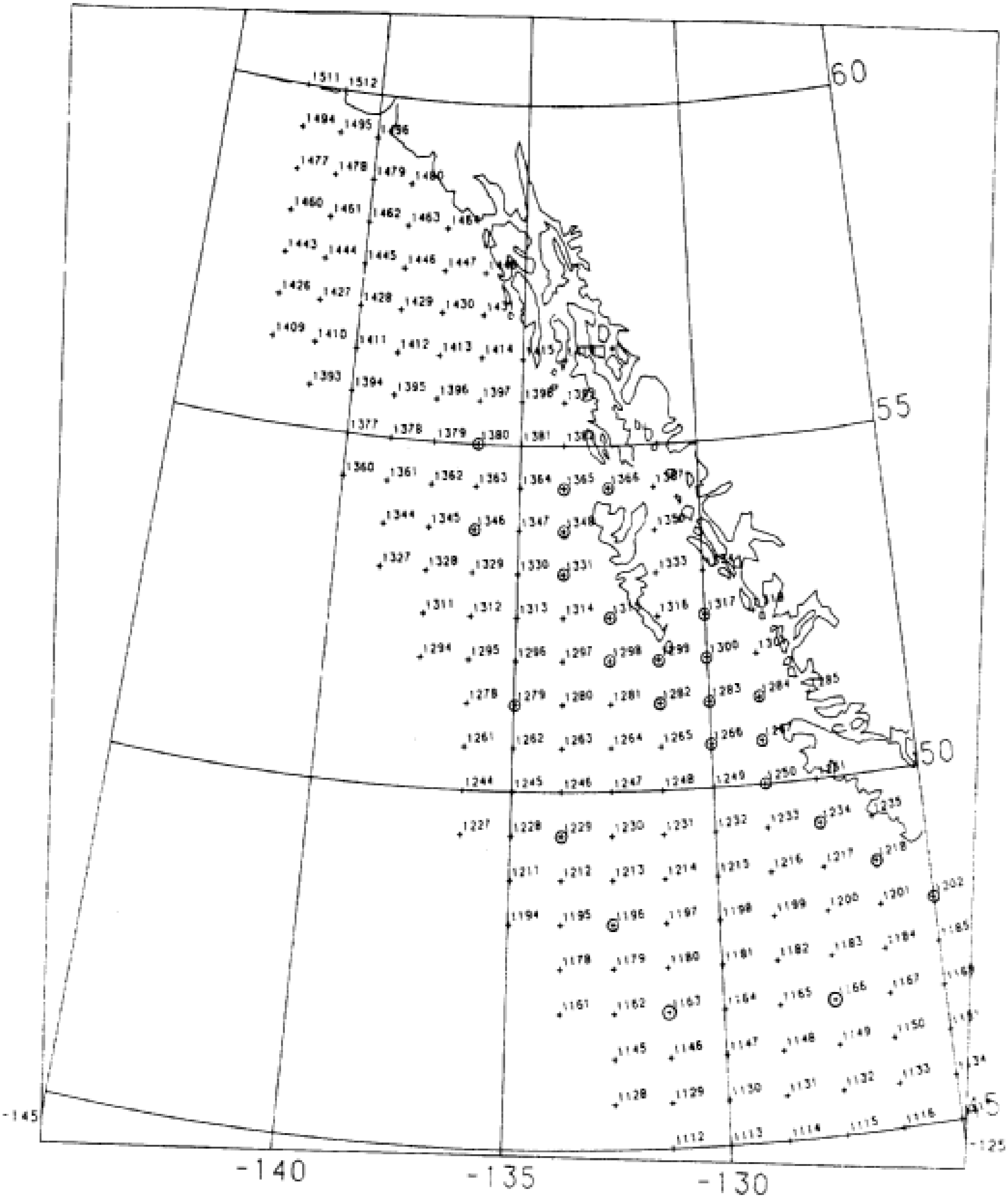


Figure 7.1 Wave Model Grid Numbering Scheme in the Study Area (⊕) Indicates Selected Points for Detailed Analysis

The results of the above analyses were presented in both tabular and graphical form. The following methods were applied in the analysis.

Extreme Value Distributions

Two extreme value distributions were tested:

GUMBEL: $Pr\{x \le X\} = \exp[-\exp(-(x-a)/b)]$
BORGMAN: $Pr\{x \le X\} = \exp[-\exp(-(x^2-a)/b)]$

where x is the parameter to be fitted (e.g. H_S); a and b are constants determined from the fitting of the hindcast data.

The recommended distribution is the Gumbel. The chosen fitting scheme is the method of moments (MOM). This is in line with what AES use in their Marine Statistics (MAST) System, also is similar to the approach used for the east coast of Canada (Canadian Climate Centre, 1991).

For most environmental data, the Gumbel distribution, fitted by the method of moments has been accepted as appropriate for representing the probability distribution for extremes. As described by Muir and El-Shaarawi (1986), the method of moments is simple, robust, and is unbiased for the Gumbel type distribution. The method involves equating the sample moments (i.e. mean and variance) to the moments derived from the distribution and solving for the estimated parameters. In the present study, the so-called plotting position was determined using the "exact" expression given by Carter and Challenor (1983).

The Borgman distribution with method of moments was also applied to the subset of three grid locations to assess the sensitivity of results to the type of distribution used.

Return Period

The return period, T, is calculated from the cumulative distribution function:

$P_T = 1-N/nT$

where n is the number of samples from N years. Correlating the candidate distribution, $Pr\{x \le X\}$, to the above distribution of return period T yields:

$X_T = [a - b \ln (-\ln (P_T))]^c$

where c = 1 for Gumbel and 0.5 for the Borgman.

Numerical Solution

The Gumbel distribution fitted to the extreme value series (whether annual maximum or peak-over-threshold) by the method of moments is simply represented by:

$X_T = x_{mean} + K_T.s$

where X_T is the value of the variable equalled or exceeded once in the return period T; x_{mean} and s are the mean and the standard deviation respectively, of the hindcast series of extremes; K_T is a frequency factor dependent on the return period obtained from:

$K_T = -(\sqrt{6}/\Pi)\ \{0.5772 + \ln[\ln(T/(T - 1))]\}$

Confidence Limits

The extreme values calculated from the above approach represent the "best fit" estimates. However it is necessary to provide the confidence intervals for this estimate (e.g. 90% or 95%). The confidence interval is given by the range:

$X_T - t(\alpha)\ S_e$ to $X_T + t(\alpha)S_e$

where: $Se = \beta\ .\ s/n$
where: $\beta = (1 + 1.14\ K_T + 1.1\ K_T^2)$

and $t(\alpha)$ is the student t-distribution value corresponds to confidence level α for samples.

The span of the upper limit (UL) to lower limit (LL) values normalized by the best fit (i.e., [UL - LL]/mean) is a relative measure of the goodness-of-fit. It should be noted that these confidence limits address only statistical characteristics of input data, and not the possible errors in storm selection and hindcast accuracy.

All other parameters (i.e. T_p, H_{max} and H_c) are derived from the estimated extreme H_s for given return periods (or probability of occurrence). The derived values are based on the mean or best-fit values of H_s and the methods described in the previous section. The above equations were -used to provide the desired extremes both in tabular and graphical form as shown in the following section.

7.4 RESULTS - SENSITIVITY ANALYSIS

The results from the 51 storms hindcast were input to the extremal analysis program. At each grid point the predicted peak H_s (and other corresponding parameters) was arranged in a descending magnitude for all 51 storms. The top number of storms above a given threshold were identified and used in the extremal analysis at each grid point in the study area (i.e. a total of 126 points, as shown in Figure 7.1).

For detailed analyses, four grid points were selected to represent the regions of interest:

- West coast of Vancouver Island: G.P. #1218 at 48.75°N, 126.25°W;
- Queen Charlotte Sound: G.P. #1283 at 51.25°N, 130.0°W;

- Dixon Entrance: G.P. #1366 at 54.375°N, 132.50°W; and
- Offshore West Coast Charlottes near NOAA Buoy 46004, Grid Point 768 at 51.25°N) 135.0°W.

The results of the extremal analyses are presented below.

7.4.1 Effect of Probability Distribution and Fitting Method

Peak significant wave heights in the top 30 storms were input to the extremal analysis using Gumbel and Borgman probability distributions. The results are presented in Figures 7.2 , 7.3 and 7.4 for grid points 1218, 1283 and 1366, respectively. As shown, the two distributions provide similar results at low return periods (i.e. < 25 years) and slightly higher values from Gumbel at large return periods (50-100 years), e.g. about 2% at 100 year return period. Interestingly, the 90% UL values were systematically higher from the Borgman distribution.

Extreme analysis results from Gumbel distribution with Method of Moment (MOM) were compared with those estimated using Gumbel distribution with Maximum Likelihood Method (MLM) fitting. The results are presented in Figure 7.5 . As shown, the two methods of fitting provided very close results with MLM slightly higher only at 1218; at 1283, 1366 MLM is slightly lower.

7.4.2 Effect of Wave Height Threshold

Extremal analysis was carried out with different wave height thresholds for each population at the above selected grid points. In the selection of the thresholds, a minimum number of 20 storms was maintained. The results are presented in Table 7.1 .

It was found, in general, the lower thresholds provided higher extreme wave heights, in the order of 5-10%, than those calculated with higher thresholds, at large return periods (50-100 years).

Table 7.1 Effect of Population Thresholds on Extreme Analysis

GRID POINT 1218 at 48.75 °N, 126.25°W

Threshold	*= 3.8 m*		*= 5.4 m*		*= 6.0 m*	
No. of Storms	*= 51*		*= 46*		*= 36*	
Correlation	*= 0.978*		*= 0.975*		*= 0.973*	
Return Period (year)	**H_s (m)**	**90% U.L.**	**H_s (m)**	**90% U.L.**	**H_s (m)**	**90% U.L.**
5	9.27	9.90	9.24	9.85	9.27	9.88
10	10.25	11.10	10.15	10.97	10.08	10.91
25	11.52	12.66	11.32	12.43	11.12	12.24
50	12.46	13.84	12.19	13.52	11.89	13.23
100	13.41	15.01	13.06	14.60	12.66	14.22

GRID POINT 1283 at 51.25 °N, 130.00°W

Threshold	*= 5.1 m*		*= 6.5 m*		*= 7.1 m*	
No. of Storms	*= 51*		*= 43*		*= 36*	
Correlation	*= 0.991*		*= 0.993*		*= 0.989*	
5	9.93	10.52	9.88	10.43	9.9	10.46
10	10.85	11.65	10.68	11.43	10.65	11.41
25	12.04	13.11	11.71	12.72	11.60	12.62
50	12.93	14.21	12.48	13.69	12.31	13.54
100	13.81	15.31	13.24	14.65	13.02	14.44

GRID POINT 1366 at 54.375°N, 132.50°W

Threshold	*= 3.4 m*		= 4.7 m		= 5.1 m	
No. of Storms	*= 51*		= 34		= 28	
Correlation	*= 0.996*		= 0.992		= 0.988	
5	7.16	7.66	7.21	7.76	7.25	7.82
10	7.94	8.62	7.92	8.67	7.92	8.70
25	8.95	9.87	8.83	9.84	8.78	9.83
50	9.71	10.81	9.50	10.71	9.41	10.67
100	10.47	11.74	10.17	11.58	10.04	11.50

GRID POINT 1366 AT 54.375 N, 132.50 W

BORGMAN – Method of Moments

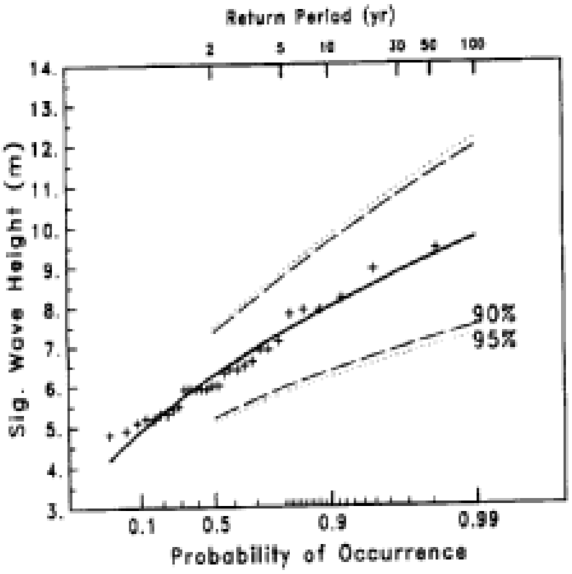
30 storms
Wave height threshold = 4.80 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	6.3	7.4	13.8	11.5	6.4
5	7.3	8.7	14.9	13.5	7.5
10	8.0	9.6	15.6	14.6	8.1
30	8.8	10.8	16.4	16.2	9.0
50	9.2	11.3	16.8	16.9	9.3
100	9.7	11.9	17.2	17.8	9.8

Tp, Hmax, and Hc were calculated using

$$Tp = 5.332\ Hs^{0.516}$$
$$Hmax = 1.835\ Hs$$
$$Hc = 1.015\ Hs$$

Correlation = 0.98



GRID POINT 1366 AT 54.375 N, 132.50 W

GUMBEL – Method of Moments

30 storms
Wave height threshold = 4.80 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	6.2	6.5	13.7	11.4	6.3
5	7.2	7.8	14.8	13.3	7.3
10	7.9	8.7	15.5	14.6	8.1
30	9.0	10.1	16.6	16.5	9.1
50	9.5	10.7	17.0	17.4	9.6
100	10.1	11.6	17.6	18.6	10.3

Tp, Hmax, and Hc were calculated using

$$Tp = 5.332\ Hs^{0.516}$$
$$Hmax = 1.835\ Hs$$
$$Hc = 1.015\ Hs$$

Correlation = 0.99

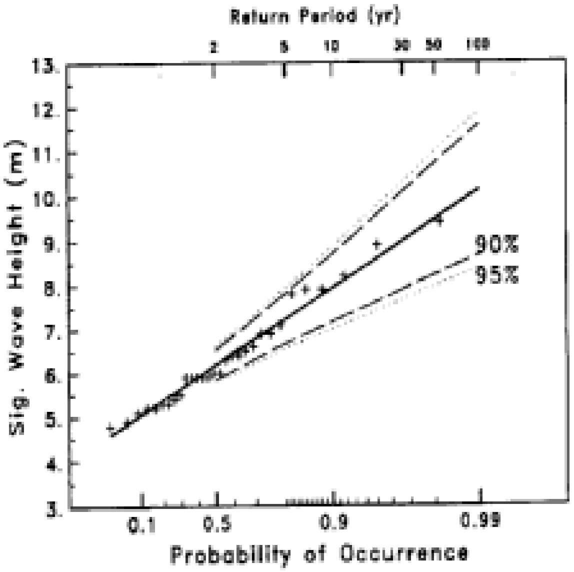


Figure 7.2 Gumbel vs. Borgman - West Vancouver Island (G.P. #1218)

GRID POINT 1283 AT 51.250 N, 130.00 W

BORGMAN – Method of Moments

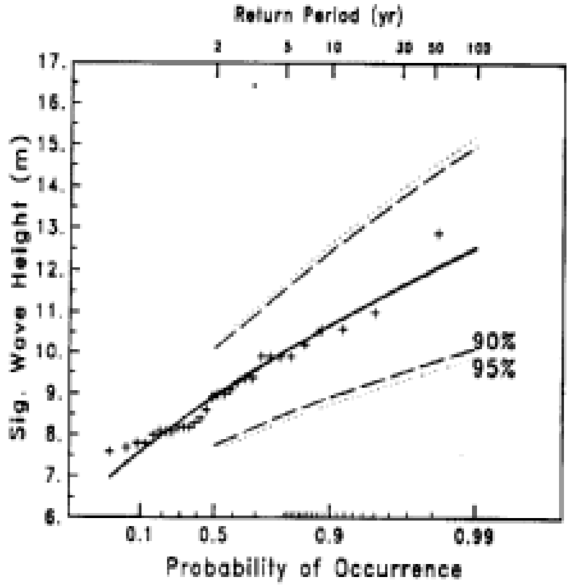
30 storms
Wave height threshold = 7.60 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.9	10.1	14.8	16.4	9.1
5	10.0	11.6	15.6	18.5	10.3
10	10.7	12.5	16.1	19.7	10.9
30	11.6	13.7	16.8	21.4	11.9
50	12.0	14.3	17.1	22.1	12.3
100	12.6	15.0	17.4	23.1	12.8

Tp, Hmax, and Hc were calculated using

$Tp = 5.187\ Hs^{0.478}$
$Hmax = 1.840\ Hs$
$Hc = 1.023\ Hs$

Correlation = 0.98



GRID POINT 1283 AT 51.250 N, 130.00 W

GUMBEL – Method of Moments

30 storms
Wave height threshold = 7.60 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.9	9.2	14.7	16.3	9.1
5	9.9	10.5	15.6	18.3	10.2
10	10.6	11.4	16.1	19.6	10.9
30	11.7	12.8	16.8	21.5	12.0
50	12.2	13.5	17.2	22.4	12.5
100	12.9	14.3	17.6	23.6	13.1

Tp, Hmax, and Hc were calculated using

$Tp = 5.187\ Hs^{0.478}$
$Hmax = 1.840\ Hs$
$Hc = 1.023\ Hs$

Correlation = 0.99

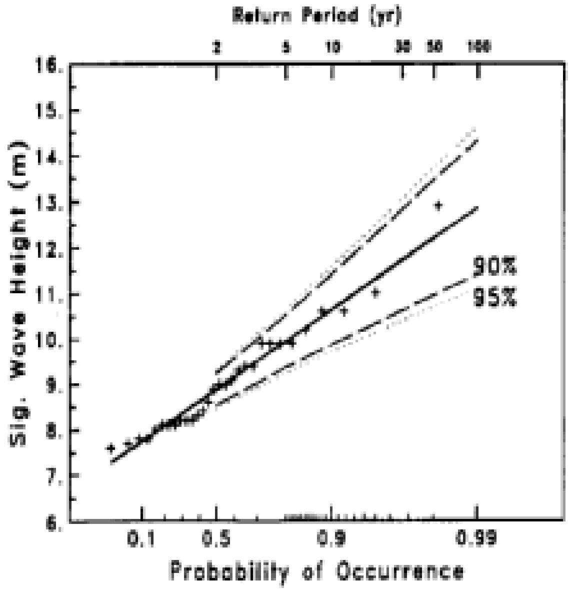


Figure 7.3 Gumbel vs. Borgman - Queen Charlotte Sound (G.P. #1283)

GRID POINT 1218 AT 48.750 N, 126.25 W

BORGMAN – Method of Moments

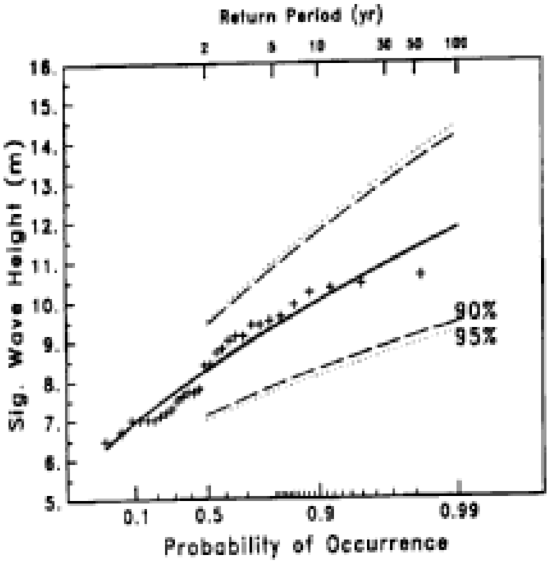
30 storms
Wave height threshold = 6.50 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.3	9.4	15.2	15.4	8.6
5	9.4	10.8	15.8	17.4	9.7
10	10.0	11.7	16.2	18.6	10.4
30	10.9	13.0	16.7	20.3	11.3
50	11.3	13.5	16.9	21.0	11.7
100	11.8	14.2	17.1	22.0	12.2

Tp, Hmax, and Hc were calculated using

$Tp = 7.551\ Hs^{0.332}$
$Hmax = 1.861\ Hs$
$Hc = 1.036\ Hs$

Correlation = 0.97



GRID POINT 1218 AT 48.750 N, 126.25 W

GUMBEL – Method of Moments

30 storms
Wave height threshold = 6.50 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.2	8.5	15.2	15.2	8.5
5	9.3	9.9	15.8	17.3	9.6
10	10.0	10.8	16.2	18.7	10.4
30	11.1	12.3	16.8	20.7	11.5
50	11.6	13.0	17.0	21.7	12.1
100	12.3	13.9	17.4	23.0	12.8

Tp, Hmax, and Hc were calculated using

$Tp = 7.551\ Hs^{0.332}$
$Hmax = 1.861\ Hs$
$Hc = 1.036\ Hs$

Correlation = 0.96

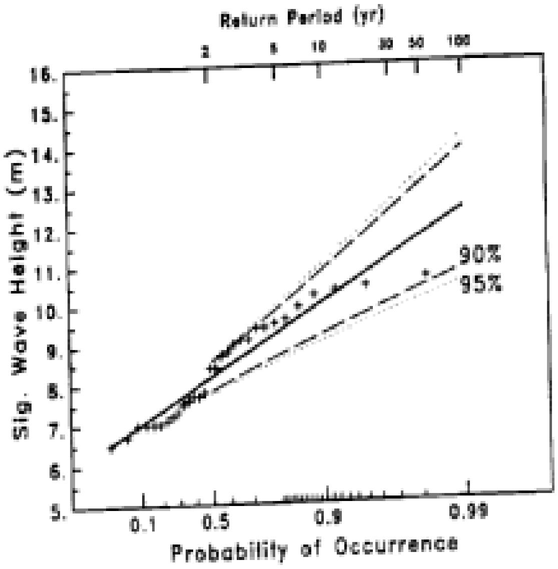


Figure 7.4 Gumbel Vs. Borgman - Dixon Entrance (G.P. #1366)

GRID POINT 1218 AT 48.750 N, 126.25 W

GUMBEL – Maximum Likelihood Method

30 storms
Wave height threshold = 6.50 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.2	8.6	15.2	15.2	8.5
5	9.4	10.1	15.9	17.4	9.7
10	10.2	11.1	16.3	18.9	10.5
30	11.3	12.7	16.9	21.1	11.7
50	11.9	13.4	17.2	22.1	12.3
100	12.6	14.4	17.5	23.5	13.1

Tp, Hmax, and Hc were calculated using

$Tp = 7.551\ Hs^{0.332}$
$Hmax = 1.861\ Hs$
$Hc = 1.036\ Hs$

Correlation = 0.96

GRID POINT 1283 AT 51.250 N, 130.00 W

GUMBEL – Maximum Likelihood Method

30 storms
Wave height threshold = 7.60 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.9	9.2	14.7	16.3	9.1
5	9.8	10.4	15.5	18.1	10.1
10	10.5	11.3	16.0	19.3	10.7
30	11.4	12.6	16.7	21.1	11.7
50	11.9	13.2	17.0	21.9	12.2
100	12.5	14.0	17.4	23.0	12.8

Tp, Hmax, and Hc were calculated using

$Tp = 5.187\ Hs^{0.478}$
$Hmax = 1.840\ Hs$
$Hc = 1.023\ Hs$

Correlation = 0.99

GRID POINT 1366 AT 54.375 N, 132.50 W

GUMBEL – Maximum Likelihood Method

30 storms
Wave height threshold = 4.80 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	6.2	6.5	13.6	11.3	6.3
5	7.2	7.8	14.7	13.1	7.3
10	7.8	8.6	15.4	14.3	7.9
30	8.8	10.0	16.4	16.2	8.9
50	9.3	10.6	16.8	17.0	9.4
100	9.9	11.4	17.4	18.1	10.0

Tp, Hmax, and Hc were calculated using

$Tp = 5.332\ Hs^{0.516}$
$Hmax = 1.835\ Hs$
$Hc = 1.015\ Hs$

Correlation = 0.99

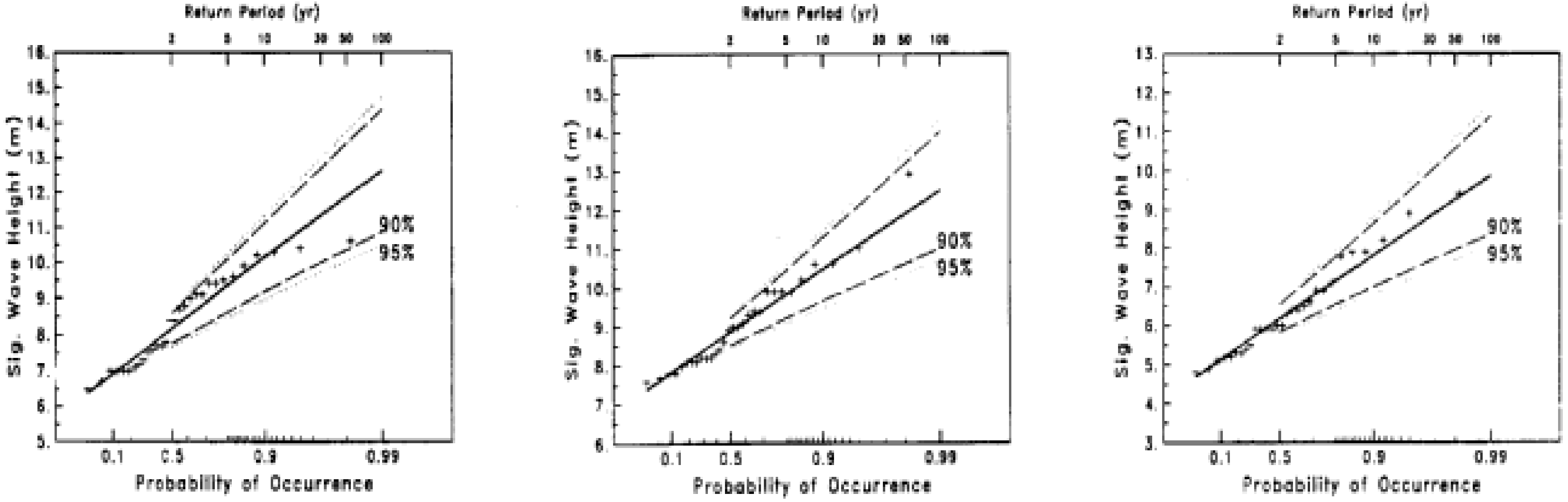
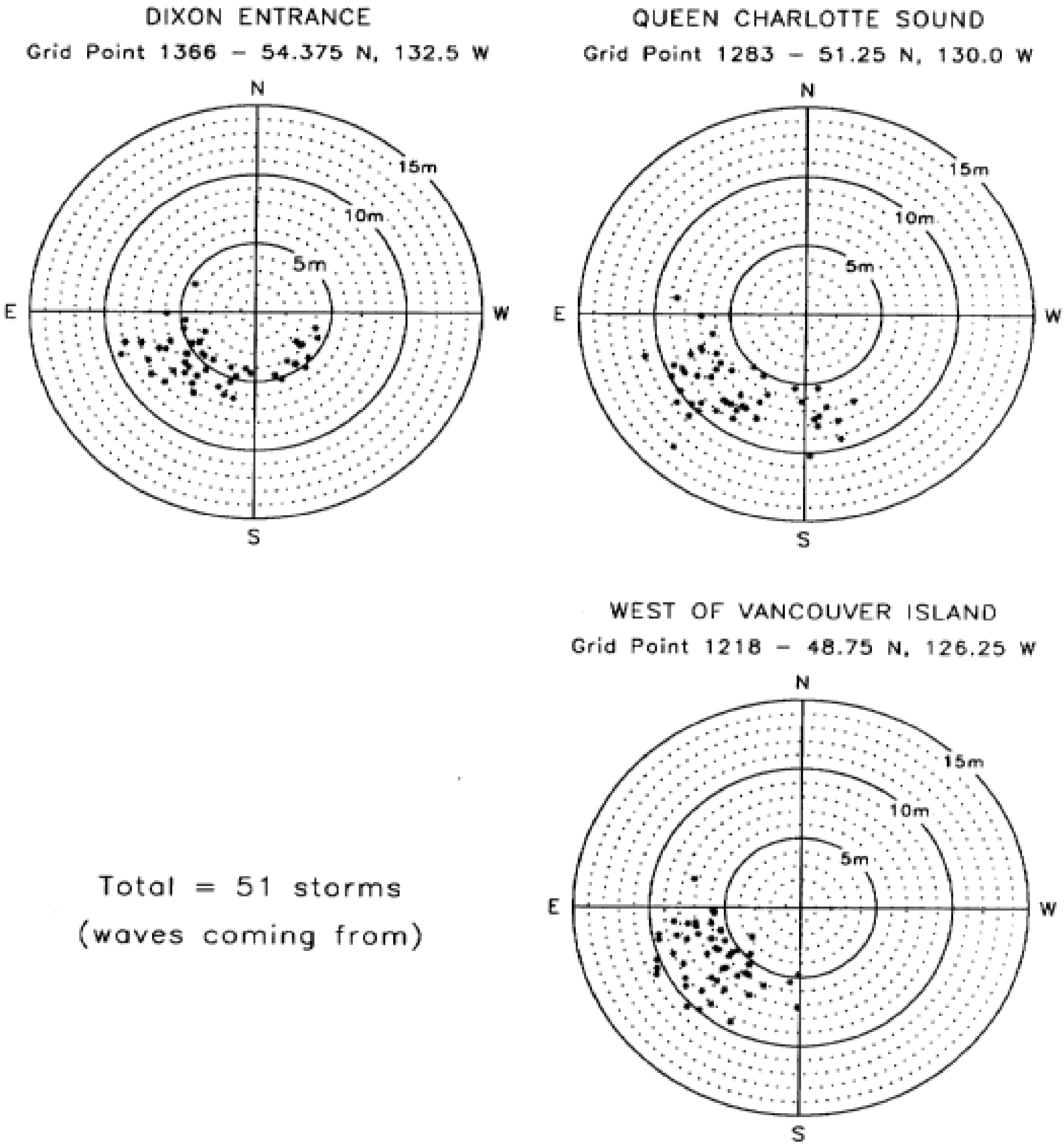


Figure 7.5 Extreme Analysis Results for Gumbel Distribution with Maximum Likelihood Method fit

DISTRIBUTION OF STORM WAVE HEIGHTS BY DIRECTION



DIXON ENTRANCE
Grid Point 1366 – 54.375 N, 132.5 W

QUEEN CHARLOTTE SOUND
Grid Point 1283 – 51.25 N, 130.0 W

WEST OF VANCOUVER ISLAND
Grid Point 1218 – 48.75 N, 126.25 W

Total = 51 storms
(waves coming from)

Figure 7.6 Distribution of Storm Wave Heights by Direction

Due to the very large size of the study area and the large range of the peak wave heights, it is not a simple task to select a single representative threshold as it would vary from one location to another. A large number of tests were conducted to establish a criterion for defining the appropriate threshold at each grid point. After several trials and comparisons with buoy data and previous studies, it was decided to use a threshold value which is one-half of the highest peak significant wave height in the storm population at each grid point. The final extreme analysis results presented in the next sections are based on this criterion. As one would expect, the number of storms which were used in the final extreme analysis varied from one point to another.

It can be concluded from the above that the extremal analysis results are slightly affected by the type of distribution tested and to a larger extent by the threshold value used. In the final analysis the peak-over-threshold method applied to the Gumbel distribution with Method of Moment fitting was used. The thresholds were defined at each grid point in the study area as described above.

7.4.3 Storm Population Stratified by Direction

The 51 storm population at each of the three grid points was stratified by wave direction as shown in Figure 7.6 . As shown, the given size of storm population is not sufficient to provide a full directional extreme analysis. Therefore no directional stratification was done.

7.4.4 Extreme Analysis Results - Buoy Versus Hindcast

In Section 5.0 , the ability of the ODGP model for predicting storm peaks was evaluated. While the skill over the whole population of storms in which there were measurements at offshore buoys was found to be comparable to the best skill exhibited in hindcast studies of this type, the wave height peaks observed in the top two or three storms (depending on buoy) tended to be higher than the hindcast peak. For example, at buoy 46004, the top ranked peak H_s of 14.8 in was recorded (unsmoothed) in the storm of 881127; the hindcast peak at this site in this storm was found to be 12.9 in. In the storm of 881123, a peak H_s of 14.10 in was observed at 46004 against a hindcast peak of 11.3 in. Underspecification of storm peak H_s was not found to be a general characteristic of the hindcasts. For example, in the storm of 841105, the hindcast peak H_s was 12.5 in against a measured peak at the buoy of 10.40 in, while for the aggregate of offshore deep peak-peak comparisons, the hindcast peak H_s averaged 0.51 in higher than the measured.

The tendency for hindcast models to underpredict only the most extreme events in an historical storm population appears to be a common characteristic of recently completed comprehensive extreme event hindcast studies, including some carried out with different wind field analysis methods and well calibrated second generation wave models. In earlier (pre-1970's) hindcast studies and in studies carried out in data-sparse regions, hindcast peaks tend to be underspecified in the mean as well as in topranked storms and the culprit is usually the tendency for hindcast wind fields to underspecify the intensity of storms and the strength of the maximum surface wind speeds. However, in relatively data-rich regions (e.g., East Coast of Canada, this study and North Sea) and where intensive wind field analysis methods including kinematic analysis are used, this is not necessarily the most likely explanation for this effect. Perhaps some remaining deficiency of even second and third generation models is the cause (such as the modelling of H_S associated with fully developed seas at wind speeds in excess of 25 m/sec). It appears that some light may be shed on this issue through analysis of the high quality wind and wave data sets acquired in recently completed field programs (ERICA, SWADE) and in the Halloween storm of October, 1991.

Of immediate concern to this study is the potential impact of the tendency of the model to underpredict the top few events, on the extremal analysis. We considered but ultimately abandoned one approach which involves "adjusting" the hindcast peaks before carrying out the extremal analysis. This approach has been used with some success in past studies of this type when a simple regression of the hindcast peaks on measured peaks at a specific location yields an effective mechanism to minimize systematic errors for the derivation of site-specific extremes. Such an approach was not warranted here for two reasons. First, as noted above, at the offshore buoys the underspecification was not found to be systematic overall but only to affect the top few events. At the inshore and shallow buoy sites there was no clear underspecification of the top ranked storms. Second, since the aim of this study is an area-wide description of extremes, we require a spatial map of model peak adjustment factors; it is not at all clear how such a spatial distribution of systematic model errors could be derived from the available set of measured data.

The approach we pursued therefore was to carry out an extremal analysis at measurement locations which have sampled a large population of storms and to compare the derived extremes with those derived exclusively from hindcast (unadjusted) peaks at nearby hindcast model grid points. The degree of agreement between these alternative extremes can then be taken as a measure of the effect of hindcast errors on the extremes derived from the hindcast data.

The storm peaks measured by the wave buoys and the corresponding hindcast peaks at the nearest grid point to the measuring location, were listed in Table 5.8 . As shown, the NOAA Buoy 46004 has recorded data since 1976 and provided a large enough number of storm peaks (i.e. 30 storms) to adequately perform an extreme analysis on buoy data for comparison with model hindcast. The results were sensitive to the threshold values (or number of storms used), as shown in Figures 7.7 and 7.8 . For example, the buoy's 100-year H_s was 15.27 m for a threshold equal to 6.1 m (27 storms) and 14.94 m when the threshold increased to 7.5 m (23 storms), whereas the 100-year values at the nearest ODGP grid point #768 varied from 15.0 m to 14.1 m for threshold from 6.3 m (48 storms) to 8.2 m (30 storms). The final estimated 100 year wave height value (at Grid Point 768) is 14.9 m (Table 7.2) which is close to the estimated value from the nearest NOAA buoy data. It should be noted that the maximum significant wave height recorded at this buoy location was 14.8 m (November 27, 1988). In Hodgins et al. (1988), a Weibull distribution fitted to 7 - 8 years of measured data at NOAA Buoy 46004 predicted 13.9 m 100-year H_s.

In Queen Charlotte Sound, the 100-year H_s was estimated to be 12.9 m from the top 30 storms (threshold = 7.6 m) or 13.2 m for the top 43 storms (with a threshold = 1/2 maximum peak H_s). Hodgins et al. (1988) estimated the 100-year value to be 16.9 m by fitting a Weibull distribution to 2 - 3 years of measured data at MEDS 503 waverider station. The maximum measured H_s at this location was 11.3 m.

A similar analysis was performed at ODGP grid points 1366 and 1365 in the Dixon Entrance. In Hodgins et al. (1988), the 100 year extreme wave height was estimated to be 14.4 m by fitting a Weibull distribution to 2 - 3 years of measured data at MEDS 211. The largest measured wave at this location was 10.7 m. Using hindcast data, the 100 year significant wave height was estimated to be 13.0 m at grid point 1365 (west of MEDS 211) and 10.2 at grid point 1366 (east of MEDS 211), refer to Figure 5.1 for map locations and Appendix C for detailed analysis results. The MEDS 211 station is between the grid points 1365 and 1366. However, grid point 1365 (which is closer and less sheltered than grid point 1366) may be better representing the MEDS 211 location.

As shown above, Hodgins et al. (1988) provided much higher 100-year significant wave height estimates for Queen Charlotte Sound (16.9 m), Hecate Strait (16.1 m) and Langara West (Dixon Entrance (14.4 m)) than the present study, while at NOAA Buoy 46004 the 100-year estimate from Hodgins et al. (1988) was lower (13.9 m). For the NOAA Buoy 46004, 7-8 years of data were available for the Hodgins et al. study, while for the other three MEDS wave buoy sites, only 2-3 years of data were available. The large discrepancies between the studies are likely due to the limited data coverage used in Hodgins et al. (1988). Local bathymetry, wave-current interaction or coastal effects causing intensification of storms in these areas may also have an effect on these results. These are areas which require further investigation.

NOAA 46004 WAVERIDER

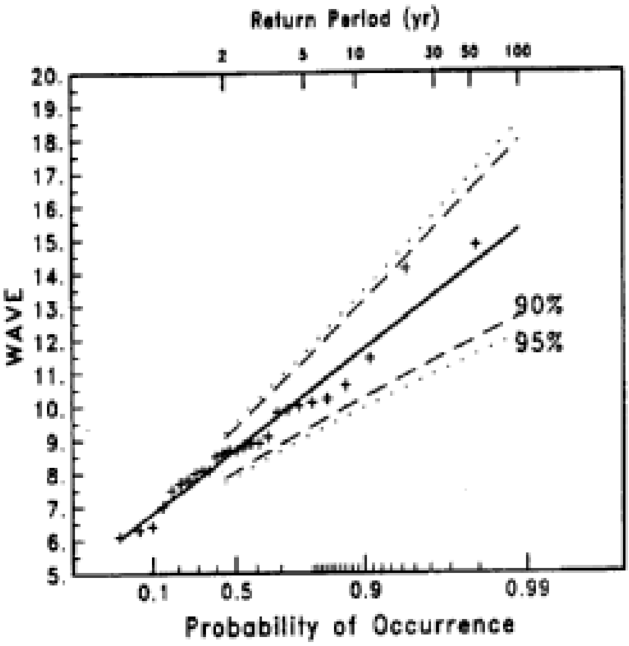
GUMBEL – Method of Moments

27 storms

Threshold = 6.10 m

Return Period (yr)	Best Fit m	90% U.L. m	95% U.L. m
2	8.46	9.07	9.20
5	10.32	11.36	11.57
10	11.52	12.93	13.21
30	13.33	15.32	15.73
50	14.16	16.42	16.88
100	15.27	17.90	18.44

Correlation = 0.98



GUMBEL – Method of Moments

23 storms

Threshold = 7.50 m

Return Period (yr)	Best Fit m	90% U.L. m	95% U.L. m
2	8.57	9.19	9.32
5	10.39	11.42	11.64
10	11.51	12.90	13.19
30	13.17	15.15	15.56
50	13.93	16.17	16.64
100	14.94	17.56	18.11

Correlation = 0.96

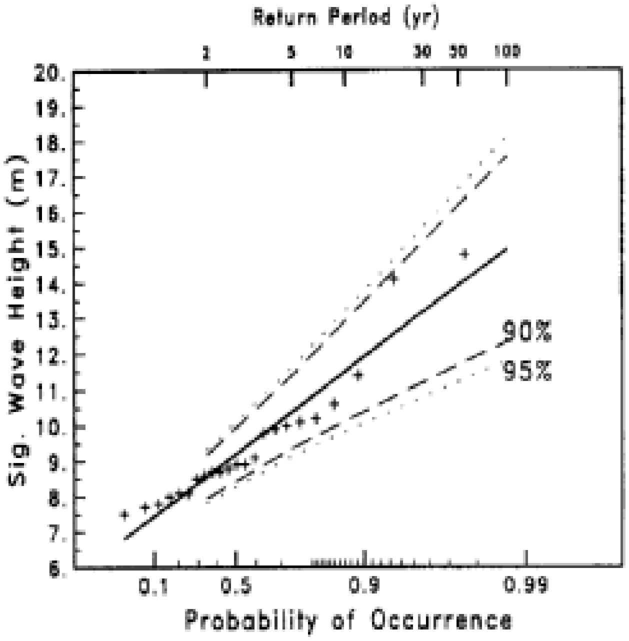


Figure 7.7 Extreme Analysis Results from NOAA Buoy 46004

GRID POINT 768 AT 51.250 N, 135.00 W

GUMBEL – Method of Moments

48 storms

Wave height threshold = 6.30 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	9.6	9.9	14.8	17.7	9.8
5	10.9	11.6	15.7	20.2	11.2
10	11.9	12.7	16.3	22.0	12.2
30	13.4	14.6	17.1	24.7	13.7
50	14.0	15.4	17.5	26.0	14.4
100	15.0	16.6	18.0	27.7	15.4

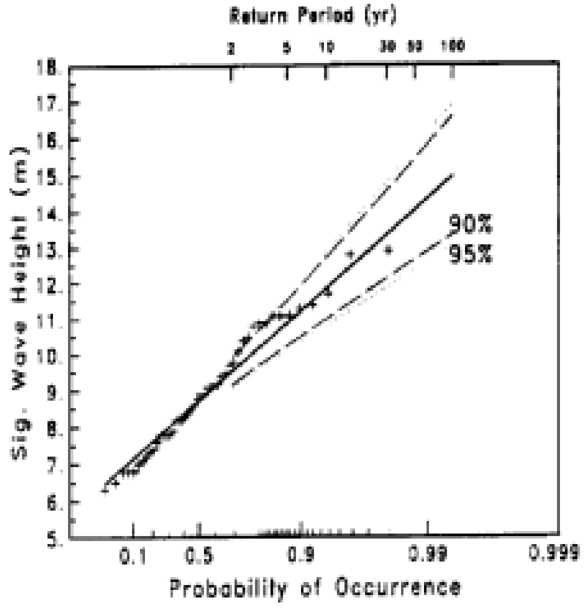
Tp, Hmax, and Hc were calculated using

$Tp = 5.583\ Hs^{0.433}$

$Hmax = 1.849\ Hs$

$Hc = 1.027\ Hs$

Correlation = 0.99



GRID POINT – 768 AT 51.250 N 135.00 W

GUMBEL – Method of Moments

30 storms

Wave height threshold = 8.20 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	9.8	10.2	14.8	18.0	10.0
5	11.0	11.6	15.8	20.1	11.1
10	11.7	12.6	16.4	21.5	11.9
30	12.9	14.1	17.2	23.6	13.1
50	13.4	14.8	17.6	24.5	13.6
100	14.1	15.7	18.2	25.8	14.4

Tp, Hmax, and Hc were calculated using

$Tp = 4.145\ Hs^{0.558}$

$Hmax = 1.831\ Hs$

$Hc = 1.017\ Hs$

Correlation = 0.98

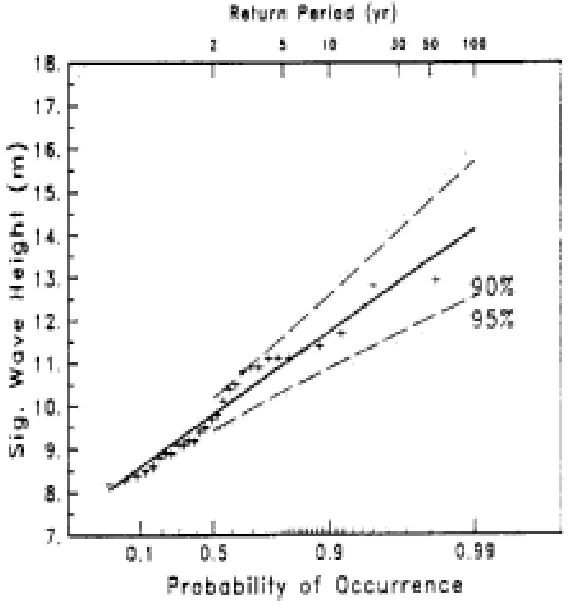


Figure 7.8 Extreme Analysis Results from Model Hindcast at G.P. #768 NOAA Buoy 46004

7.5 FINAL RESULT

The extremal analysis was carried out at each grid point in the study domain (i.e. 126 sites) using the top number of storms (which was defined for the given threshold as discussed in Section 7.4.2), i.e. a different storm population was selected for each grid point.

Extremes of significant wave height (H_s) and corresponding wind speed (W_s) for risk factors from 0.5 to 0.01 (i.e. return period from 2 to 100 years) for all grid points in the study area are provided in Tables 7.2 and 7.3 . The tables provide the best fit and 90% upper limit values. Refer to Figure 7.1 for map location.

The results of the detailed analysis carried out at the selected 25 grid points (Figure 7.1) are presented in Appendix C . It includes the H_s, H_{max}, H_c and T_p versus risk, the relation between T_p, and H_s, H_{max}/H_s and H_c/H_s ratios, and plot of H_s versus risk with 90% and 95% confidence levels.

Contour presentations of the 50 and 100 year return period significant wave height, maximum wave height, and the corresponding wind speed are given in Figures 7.9 and 7.14 .

It should be noted that the estimated values at the top edge of the fine grid (i.e. north of 55°) may not be accurate as they are outside the study area. This also applies to the coastal areas, where sheltering, shallow water and wind tunnelling effects may have a large effect on the hindcast results. These results should be used with caution.

Table 7.2 Summary of Extreme Analysis Significant Wave Height at All Grid Points in the Study Area

SIGNIFICANT WAVE HEIGHT

risk factor return period			.50 2 yr		0.20 5 yr		0.10 10 yr		0.04 25 yr		0.02 50 yr		0.01 100 yr			
grid point	Lat (N)	Long (W)	Best Fit (m)	90% U.L. (m)	Best Fit (m)	90% U.L. (m)	Best Fit (m)	90% U.L. (m)	Best Fit (m)	90% U.L. (m)	Best Fit (m)	90% U.L. (m)	Best Fit (m)	90% U.L. (m)	Thres. Hs (m)	Num Pts
1512	60.00	141.25	2.9	3.1	3.4	3.6	3.7	4.0	4.1	4.5	4.4	4.9	4.7	5.3	2.08	43
1511	60.00	142.50	3.4	3.6	3.9	4.2	4.3	4.6	4.7	5.2	5.0	5.6	5.3	6.0	2.68	35
1496	59.38	140.00	5.5	5.7	6.3	6.7	6.8	7.4	7.5	8.3	8.1	9.0	8.6	9.7	4.09	36
1480	58.75	138.75	5.9	6.2	6.9	7.4	7.5	8.2	8.4	9.3	9.0	10.1	9.6	10.9	4.37	38
1479	58.75	140.00	6.1	6.4	7.1	7.6	7.7	8.4	8.5	9.4	9.1	10.2	9.8	11.0	4.67	35
1023	58.75	142.50	6.9	7.2	8.0	8.6	8.8	9.6	9.8	10.8	10.5	11.8	11.2	12.7	4.97	36
1464	58.13	137.50	6.2	6.5	7.2	7.7	7.9	8.6	8.8	9.7	9.4	10.6	10.1	11.4	4.59	38
1463	58.13	138.75	6.5	6.9	7.5	8.1	8.2	8.9	9.1	10.0	9.7	10.8	10.3	11.6	5.06	34
1462	58.13	140.00	6.4	6.7	7.4	7.9	8.1	8.8	9.0	9.9	9.7	10.8	10.3	11.6	4.64	39
1448	57.50	136.25	5.9	6.1	6.8	7.0	7.5	7.7	8.3	8.6	8.9	9.3	9.5	10.0	4.28	42
1447	57.50	137.50	6.7	7.0	7.7	8.2	8.4	9.1	9.3	10.3	10.0	11.1	10.7	12.0	4.93	38
1446	57.50	138.75	6.8	7.1	7.8	8.4	8.5	9.2	9.4	10.4	10.1	11.2	10.8	12.1	4.96	37
1445	57.50	140.00	6.6	6.9	7.6	8.1	8.3	9.0	9.2	10.1	9.9	11.0	10.6	11.8	4.64	40
980	57.50	142.50	7.4	7.7	8.5	9.1	9.3	10.1	10.3	11.4	11.1	12.3	11.8	13.3	5.46	37
1431	56.88	136.25	6.8	7.1	7.8	8.3	8.5	9.1	9.4	10.2	10.0	11.1	10.7	11.9	4.92	40
1430	56.88	137.50	7.0	7.3	8.1	8.6	8.8	9.5	9.7	10.6	10.4	11.5	11.1	12.4	4.98	40
1429	56.88	138.75	7.0	7.3	8.0	8.6	8.7	9.4	9.7	10.6	10.3	11.4	11.0	12.3	5.12	38
1428	56.88	140.00	6.7	6.8	7.7	8.0	8.4	8.7	9.4	9.7	10.0	10.5	10.7	11.3	4.51	42
1416	56.25	133.75	3.2	3.3	3.6	3.8	3.9	4.2	4.3	4.6	4.6	5.0	4.8	5.3	2.15	47
1415	56.25	135.00	6.7	7.0	7.6	8.1	8.3	8.9	9.2	10.0	9.8	10.8	10.4	11.6	4.56	41
1414	56.25	136.25	7.3	7.6	8.4	8.9	9.1	9.8	10.0	11.0	10.7	11.9	11.5	12.8	5.19	41
1413	56.25	137.50	7.3	7.6	8.3	8.8	9.0	9.7	9.9	10.9	10.6	11.8	11.3	12.6	5.55	36
1412	56.25	138.75	7.1	7.4	8.1	8.6	8.8	9.5	9.7	10.6	10.4	11.5	11.0	12.3	5.34	37
1411	56.25	140.00	6.6	6.9	7.7	8.1	8.4	9.0	9.3	10.1	9.9	11.0	10.6	11.8	4.47	44
937	56.25	142.50	7.7	8.0	8.8	9.3	9.5	10.2	10.5	11.4	11.2	12.3	11.9	13.2	5.34	43
1399	55.63	133.75	7.1	7.2	8.1	8.3	8.8	9.1	9.7	10.1	10.4	10.9	11.1	11.7	5.01	42
1398	55.63	135.00	7.6	7.9	8.8	9.3	9.5	10.3	10.6	11.6	11.3	12.5	12.1	13.5	5.09	44
1397	55.63	136.25	7.6	7.9	8.7	9.3	9.5	10.2	10.4	11.4	11.2	12.3	11.9	13.2	5.46	41
1396	55.63	137.50	7.4	7.7	8.4	8.9	9.1	9.8	10.0	10.9	10.7	11.8	11.3	12.6	5.63	38
1395	55.63	138.75	7.1	7.4	8.0	8.5	8.7	9.3	9.5	10.4	10.2	11.2	10.8	12.0	5.45	37
1382	55.00	133.75	7.8	8.1	9.0	9.6	9.9	10.6	11.0	12.0	11.8	13.1	12.6	14.1	5.09	46
1381	55.00	135.00	7.9	8.3	9.1	9.7	9.9	10.7	11.0	12.0	11.8	13.0	12.5	14.0	5.27	45
1380	55.00	136.25	7.9	8.2	9.0	9.5	9.8	10.5	10.7	11.7	11.5	12.6	12.2	13.5	5.93	41
1379	55.00	137.50	7.5	7.8	8.5	9.0	9.2	9.9	10.1	11.0	10.8	11.9	11.4	12.7	5.57	41
895	55.00	140.00	6.6	6.9	7.7	8.1	8.4	9.0	9.3	10.1	9.9	11.0	10.6	11.8	4.47	44
1367	54.38	131.25	5.9	6.1	6.6	7.0	7.2	7.7	7.9	8.6	8.4	9.2	8.9	9.9	4.27	44
1366	54.38	132.50	6.2	6.5	7.2	7.8	7.9	8.7	8.8	9.8	9.5	10.7	10.2	11.6	4.71	34
1365	54.38	133.75	8.2	8.5	9.4	10.0	10.2	11.0	11.3	12.4	12.1	13.4	12.9	14.4	5.85	40
1364	54.38	135.00	8.3	8.6	9.5	10.1	10.4	11.2	11.5	12.5	12.3	13.6	13.1	14.6	5.48	46
1363	54.38	136.25	7.9	8.2	9.1	9.6	9.9	10.6	10.9	11.8	11.6	12.8	12.4	13.7	5.35	47
1362	54.38	137.50	7.5	7.7	8.5	8.9	9.2	9.8	10.1	10.9	10.7	11.8	11.4	12.6	5.35	45
1350	53.75	131.25	5.4	5.6	6.1	6.4	6.6	7.0	7.2	7.8	7.7	8.4	8.1	8.9	3.64	50
1348	53.75	133.75	8.3	8.7	9.5	10.1	10.4	11.2	11.5	12.6	12.3	13.6	13.2	14.7	5.90	43
1347	53.75	135.00	8.4	8.7	9.6	10.2	10.5	11.3	11.6	12.7	12.5	13.7	13.3	14.7	5.49	48
1346	53.75	136.25	7.6	7.8	8.6	9.0	9.3	9.9	10.2	11.1	10.9	11.9	11.5	12.8	5.29	46
853	53.75	137.50	9.2	9.4	10.5	10.7	11.3	11.7	12.4	12.9	13.2	13.8	14.0	14.7	6.41	42
1334	53.13	130.00	6.2	6.5	7.1	7.4	7.6	8.2	8.4	9.1	8.9	9.8	9.5	10.5	4.53	44
1333	53.13	131.25	5.5	5.7	6.2	6.6	6.7	7.2	7.4	8.0	7.9	8.7	8.4	9.3	3.60	51
1331	53.13	133.75	8.5	8.9	9.7	10.3	10.6	11.4	11.7	12.7	12.5	13.7	13.3	14.7	5.75	46
1330	53.13	135.00	8.4	8.8	9.7	10.3	10.6	11.3	11.7	12.7	12.5	13.8	13.4	14.8	5.48	49
1329	53.13	136.25	7.8	8.1	8.9	9.4	9.7	10.4	10.7	11.6	11.4	12.5	12.1	13.4	5.22	48
1318	52.50	128.75	7.5	7.8	8.6	9.2	9.4	10.2	10.3	11.4	11.1	12.3	11.8	13.2	5.99	34
1317	52.50	130.00	7.7	8.0	8.7	9.2	9.5	10.1	10.4	11.3	11.1	12.2	11.8	13.1	5.75	41
1316	52.50	131.25	6.1	6.3	6.9	7.3	7.5	8.0	8.2	8.9	8.8	9.6	9.3	10.3	3.94	51
1315	52.50	132.50	8.7	9.0	9.9	10.5	10.8	11.6	11.9	13.0	12.8	14.1	13.6	15.1	5.91	47
1314	52.50	133.75	9.0	9.3	10.2	10.8	11.1	11.9	12.2	13.3	13.1	14.4	13.9	15.4	6.20	45
1313	52.50	135.00	8.5	8.8	9.7	10.2	10.5	11.2	11.5	12.6	12.3	13.5	13.1	14.5	5.70	46
810	52.50	137.50	9.4	9.8	10.8	11.4	11.7	12.6	13.0	14.1	13.9	15.2	14.8	16.4	6.18	49
1301	51.88	128.75	8.2	8.5	9.3	9.9	10.1	10.9	11.1	12.2	11.9	13.1	12.6	14.1	6.43	38
1300	51.88	130.00	8.6	8.9	9.7	10.3	10.6	11.4	11.6	12.7	12.4	13.7	13.2	14.7	6.42	43
1299	51.88	131.25	8.8	9.1	10.0	10.6	10.9	11.6	12.0	13.0	12.8	14.1	13.7	15.1	5.84	48
1298	51.88	132.50	8.9	9.3	10.2	10.8	11.1	11.8	12.2	13.2	13.0	14.3	13.9	15.3	6.21	48
1297	51.88	133.75	9.1	9.4	10.3	10.9	11.2	12.1	12.4	13.5	13.3	14.6	14.1	15.7	6.44	46
1296	51.88	135.00	8.9	9.3	10.2	10.8	11.1	12.0	12.3	13.5	13.2	14.6	14.1	15.7	6.24	45
1285	51.25	127.50	5.6	5.9	6.5	7.0	7.1	7.7	7.8	8.6	8.3	9.4	8.9	10.1	4.65	30
1284	51.25	128.75	8.4	8.7	9.5	10.1	10.3	11.0	11.2	12.2	12.0	13.2	12.7	14.1	6.45	39
1283	51.25	130.00	8.7	9.1	9.9	10.4	10.7	11.4	11.7	12.7	12.5	13.7	13.2	14.6	6.49	43
1282	51.25	131.25	9.0	9.3	10.2	10.7	11.0	11.7	12.1	13.1	12.9	14.1	13.7	15.1	6.24	47
1281	51.25	132.50	9.1	9.5	10.4	11.0	11.3	12.1	12.4	13.5	13.3	14.5	14.1	15.6	6.48	48
1280	51.25	133.75	9.3	9.7	10.7	11.3	11.6	12.4	12.8	13.9	13.6	15.0	14.5	16.1	6.50	47

Table 7.2 Summary of Extreme Analysis Significant Wave Height at All Grid Points in the Study Area
(Cont'd)

SIGNIFICANT WAVE HEIGHT

risk factor return period			.50 2 yr		0.20 5 yr		0.10 10 yr		0.04 25 yr		0.02 50 yr		0.01 100 yr			
grid point	Lat (N)	Long (W)	Best Fit (m)	90% U.L. (m)	Best Fit (m)	90% U.L. (m)	Best Fit (m)	90% U.L. (m)	Best Fit (m)	90% U.L. (m)	Best Fit (m)	90% U.L. (m)	Best Fit (m)	90% U.L. (m)	Thres. Hs (m)	Num Pts
768	51.25	135.00	9.6	9.9	10.9	11.5	11.9	12.7	13.1	14.2	14.0	15.4	14.9	16.5	6.51	47
1267	50.63	128.75	8.5	8.8	9.7	10.2	10.5	11.3	11.5	12.6	12.3	13.6	13.1	14.6	6.43	43
1266	50.63	130.00	8.8	9.1	9.9	10.5	10.7	11.5	11.8	12.8	12.5	13.7	13.3	14.7	6.55	43
1265	50.63	131.25	9.0	9.3	10.2	10.8	11.1	11.8	12.1	13.2	13.0	14.2	13.8	15.2	6.61	47
1264	50.63	132.50	9.1	9.5	10.4	11.0	11.3	12.1	12.4	13.5	13.3	14.6	14.1	15.6	6.52	48
1263	50.63	133.75	9.4	9.7	10.7	11.3	11.6	12.4	12.8	13.9	13.7	15.0	14.6	16.1	6.59	47
1251	50.00	127.50	7.2	7.5	8.3	8.9	9.1	9.8	10.1	11.1	10.8	12.1	11.6	13.0	5.41	39
1250	50.00	128.75	8.6	9.0	9.8	10.4	10.7	11.5	11.8	12.9	12.6	13.9	13.4	14.9	6.28	44
1249	50.00	130.00	8.8	9.2	10.0	10.6	10.9	11.6	11.9	13.0	12.7	14.0	13.5	15.0	6.55	44
1248	50.00	131.25	9.0	9.3	10.2	10.7	11.0	11.7	12.1	13.1	12.9	14.1	13.7	15.1	6.44	47
1247	50.00	132.50	9.1	9.5	10.4	11.0	11.3	12.1	12.5	13.6	13.4	14.7	14.3	15.8	6.27	49
1246	50.00	133.75	9.3	9.6	10.6	11.2	11.5	12.3	12.7	13.8	13.5	14.9	14.4	16.0	6.42	47
725	50.00	135.00	9.5	9.9	10.9	11.5	11.8	12.7	13.1	14.2	14.0	15.4	14.9	16.5	6.65	47
1235	49.38	126.25	7.1	7.3	8.3	8.5	9.1	9.4	10.1	10.6	10.9	11.4	11.7	12.3	4.96	42
1234	49.38	127.50	8.3	8.7	9.6	10.2	10.5	11.3	11.7	12.8	12.6	13.9	13.4	15.0	5.77	46
1233	49.38	128.75	8.7	9.0	10.0	10.6	10.9	11.7	12.0	13.2	12.9	14.2	13.8	15.3	6.22	46
1232	49.38	130.00	8.9	9.3	10.2	10.8	11.0	11.9	12.2	13.3	13.0	14.3	13.9	15.4	6.56	45
1231	49.38	131.25	9.1	9.4	10.3	10.9	11.2	12.0	12.3	13.4	13.2	14.5	14.0	15.5	6.63	44
1230	49.38	132.50	9.1	9.5	10.5	11.1	11.4	12.2	12.6	13.7	13.4	14.8	14.3	15.9	6.28	48
1229	49.38	133.75	9.3	9.7	10.7	11.3	11.6	12.5	12.8	14.0	13.7	15.1	14.6	16.2	6.45	46
1218	48.75	126.25	7.9	8.3	9.2	9.8	10.2	11.0	11.3	12.4	12.2	13.5	13.1	14.6	5.28	47
1217	48.75	127.50	8.3	8.7	9.7	10.3	10.6	11.4	11.8	12.9	12.7	14.0	13.5	15.1	5.63	47
1216	48.75	128.75	8.7	9.0	10.0	10.6	10.9	11.7	12.1	13.2	13.0	14.3	13.8	15.4	6.10	46
1215	48.75	130.00	8.9	9.3	10.2	10.8	11.1	11.9	12.3	13.4	13.1	14.5	14.0	15.5	6.44	45
1214	48.75	131.25	9.0	9.4	10.4	11.0	11.3	12.1	12.5	13.6	13.4	14.7	14.2	15.8	6.23	46
1213	48.75	132.50	9.1	9.5	10.4	11.1	11.4	12.2	12.6	13.7	13.5	14.8	14.4	16.0	6.18	47
682	48.75	135.00	9.4	9.8	10.8	11.4	11.7	12.6	13.0	14.1	13.9	15.3	14.8	16.4	6.60	46
1202	48.13	125.00	7.0	7.3	8.1	8.6	8.8	9.6	9.7	10.8	10.4	11.7	11.1	12.6	5.45	32
1201	48.13	126.25	8.1	8.2	9.4	9.6	10.3	10.6	11.4	11.9	12.3	12.9	13.1	13.8	5.70	42
1200	48.13	127.50	8.4	8.7	9.7	10.3	10.6	11.4	11.8	12.9	12.6	14.0	13.5	15.1	5.63	46
1199	48.13	128.75	8.6	9.0	9.9	10.5	10.8	11.7	12.0	13.1	12.9	14.2	13.8	15.3	6.00	46
1198	48.13	130.00	8.8	9.2	10.2	10.8	11.1	11.9	12.3	13.4	13.1	14.5	14.0	15.6	6.25	45
1197	48.13	131.25	9.0	9.3	10.3	10.9	11.2	12.1	12.4	13.6	13.3	14.7	14.2	15.9	6.45	45
1196	48.13	132.50	9.0	9.4	10.3	11.0	11.3	12.1	12.5	13.6	13.4	14.8	14.3	15.9	6.04	47
1185	47.50	125.00	8.0	8.3	9.2	9.9	10.1	11.0	11.2	12.4	12.0	13.4	12.8	14.5	6.00	34
1184	47.50	126.25	8.2	8.6	9.5	10.1	10.4	11.2	11.5	12.6	12.3	13.7	13.1	14.7	6.12	35
1183	47.50	127.50	8.5	8.9	9.7	10.4	10.6	11.4	11.7	12.8	12.5	13.9	13.3	14.9	6.35	38
1182	47.50	128.75	8.6	8.8	9.9	10.2	10.8	11.2	12.0	12.5	12.9	13.5	13.8	14.5	6.15	42
1181	47.50	130.00	8.7	9.1	10.1	10.7	11.0	11.9	12.2	13.4	13.2	14.6	14.1	15.7	5.98	46
1180	47.50	131.25	8.7	9.1	10.0	10.7	11.0	11.8	12.2	13.3	13.1	14.5	14.0	15.6	5.72	47
640	47.50	132.50	8.9	9.2	10.2	10.9	11.2	12.0	12.4	13.6	13.3	14.7	14.2	15.9	5.83	47
1168	46.88	125.00	8.1	8.5	9.4	10.0	10.2	11.1	11.3	12.6	12.2	13.6	13.0	14.7	6.08	33
1167	46.88	126.25	8.3	8.7	9.6	10.3	10.5	11.5	11.7	12.9	12.5	14.0	13.4	15.1	6.25	34
1166	46.88	127.50	8.5	8.9	9.9	10.5	10.8	11.7	11.9	13.1	12.8	14.2	13.6	15.3	6.60	36
1165	46.88	128.75	8.6	9.0	10.0	10.6	10.9	11.8	12.1	13.3	12.9	14.4	13.8	15.5	6.46	38
1164	46.88	130.00	8.7	9.1	10.0	10.7	11.0	11.9	12.2	13.4	13.1	14.6	14.0	15.7	6.33	41
1163	46.88	131.25	8.6	9.0	10.0	10.7	11.0	11.9	12.2	13.4	13.2	14.6	14.1	15.7	6.06	46
1151	46.25	125.00	8.1	8.5	9.4	10.1	10.3	11.3	11.5	12.7	12.3	13.8	13.2	14.9	6.10	34
1150	46.25	126.25	8.3	8.8	9.7	10.4	10.6	11.6	11.8	13.1	12.7	14.2	13.5	15.4	6.46	33
1149	46.25	127.50	8.5	9.0	9.9	10.6	10.8	11.8	12.0	13.3	12.9	14.4	13.8	15.6	6.66	36
1148	46.25	128.75	8.6	9.0	9.9	10.6	10.9	11.8	12.1	13.3	13.0	14.5	13.9	15.6	6.43	38
1147	46.25	130.00	8.6	9.0	10.0	10.6	10.9	11.8	12.1	13.4	13.1	14.5	14.0	15.7	6.27	41
597	46.25	132.50	8.5	8.9	9.8	10.4	10.7	11.6	11.9	13.0	12.8	14.1	13.6	15.2	5.98	44
557	45.00	125.00	8.1	8.5	9.4	10.1	10.3	11.3	11.5	12.7	12.3	13.8	13.2	14.9	6.10	34
556	45.00	127.50	8.5	9.0	9.9	10.6	10.8	11.8	12.0	13.3	12.9	14.4	13.8	15.6	6.66	36
555	45.00	130.00	8.6	9.0	10.0	10.6	10.9	11.8	12.1	13.4	13.1	14.5	14.0	15.7	6.27	41

Table 7.3 Wind Speed Corresponding to Extreme Wave Height for Given Return Period

WIND SPEED

risk factor return period			.50 2 yr		0.20 5 yr		0.10 10 yr		0.04 25 yr		0.02 50 yr		0.01 100 yr		
grid point	Lat (N)	Long (W)	Best Fit m/s	90% U.L. m/s	Best Fit m/s	90% U.L. m/s	Best Fit m/s	90% U.L. m/s	Best Fit m/s	90% U.L. m/s	Best Fit m/s	90% U.L. m/s	Best Fit m/s	90% U.L. m/s	NUM PTS
1512	60.00	141.25	17.9	18.6	20.5	21.6	22.2	23.8	24.5	26.7	26.2	28.8	28.0	30.9	49
1511	60.00	142.50	17.3	17.9	19.5	20.5	21.0	22.3	22.9	24.8	24.4	26.6	25.9	28.4	48
1496	59.38	140.00	17.0	17.8	19.4	20.6	20.9	22.6	22.9	25.1	24.4	27.0	25.8	28.9	33
1480	58.75	138.75	17.1	17.7	19.3	20.5	20.9	22.4	22.9	25.0	24.4	26.9	25.9	28.8	40
1479	58.75	140.00	17.1	17.8	19.5	20.7	21.2	22.8	23.3	25.5	24.9	27.6	26.5	29.6	39
1023	58.75	142.50	17.4	18.3	20.3	21.8	22.2	24.2	24.7	27.4	26.5	29.7	28.3	32.1	34
1464	58.13	137.50	17.7	18.4	20.0	21.1	21.5	23.0	23.5	25.5	24.9	27.4	26.4	29.3	36
1463	58.13	138.75	17.4	18.0	19.7	20.7	21.3	22.7	23.3	25.3	24.9	27.2	26.4	29.1	49
1462	58.13	140.00	17.7	18.4	20.0	21.2	21.7	23.2	23.7	25.8	25.3	27.8	26.8	29.7	41
1448	57.50	136.25	17.7	18.3	19.9	20.9	21.4	22.8	23.4	25.2	24.9	27.0	26.3	28.9	49
1447	57.50	137.50	17.9	18.5	20.1	21.2	21.7	23.1	23.8	25.7	25.3	27.6	26.9	29.5	50
1446	57.50	138.75	17.9	18.5	20.0	21.0	21.5	22.8	23.4	25.2	24.9	27.0	26.3	28.8	48
1445	57.50	140.00	18.3	19.0	20.8	22.0	22.6	24.2	24.8	27.0	26.5	29.1	28.2	31.2	47
980	57.50	142.50	17.6	18.5	20.6	22.1	22.7	24.7	25.3	28.0	27.3	30.5	29.2	33.0	38
1431	56.88	136.25	18.1	18.7	20.4	21.4	22.0	23.4	24.0	25.9	25.6	27.8	27.1	29.7	50
1430	56.88	137.50	18.6	19.3	21.1	22.2	22.8	24.3	25.0	27.0	26.6	29.1	28.3	31.1	47
1429	56.88	138.75	19.0	19.6	21.4	22.6	23.2	24.7	25.4	27.5	27.1	29.6	28.8	31.7	48
1428	56.88	140.00	18.7	19.4	21.3	22.5	23.1	24.7	25.5	27.6	27.2	29.8	29.0	32.0	49
1416	56.25	133.75	19.1	19.6	21.1	22.0	22.5	23.7	24.3	26.0	25.7	27.7	27.1	29.4	51
1415	56.25	135.00	18.4	18.9	20.4	21.4	21.9	23.2	23.8	25.5	25.2	27.3	26.6	29.0	49
1414	56.25	136.25	18.7	19.3	21.0	22.0	22.6	24.0	24.7	26.6	26.3	28.6	27.8	30.5	49
1413	56.25	137.50	19.2	19.8	21.5	22.6	23.1	24.6	25.2	27.1	26.7	29.1	28.2	31.0	45
1412	56.25	138.75	19.1	19.8	21.6	22.8	23.4	25.0	25.7	27.8	27.4	30.0	29.1	32.1	48
1411	56.25	140.00	18.9	19.6	21.2	22.3	22.9	24.3	25.0	27.0	26.6	28.9	28.1	30.9	47
937	56.25	142.50	18.4	19.1	20.7	21.9	22.3	23.9	24.4	26.6	26.0	28.5	27.5	30.5	38
1399	55.63	133.75	18.6	19.2	20.5	21.4	21.9	23.1	23.6	25.2	24.9	26.9	26.2	28.5	47
1398	55.63	135.00	18.6	19.2	20.8	21.7	22.2	23.6	24.2	26.0	25.6	27.8	27.0	29.5	48
1397	55.63	136.25	19.1	19.8	21.4	22.5	23.0	24.5	25.1	27.1	26.6	29.0	28.2	30.9	46
1396	55.63	137.50	19.6	20.2	21.9	22.9	23.5	24.9	25.5	27.5	27.0	29.4	28.6	31.4	44
1395	55.63	138.75	19.5	20.2	21.9	23.0	23.6	25.1	25.7	27.8	27.3	29.8	28.9	31.7	46
1382	55.00	133.75	19.4	20.0	21.5	22.4	22.9	24.2	24.8	26.5	26.2	28.3	27.6	30.0	49
1381	55.00	135.00	19.6	20.1	21.6	22.5	23.0	24.2	24.7	26.4	26.1	28.1	27.4	29.7	49
1380	55.00	136.25	19.9	20.5	22.1	23.1	23.6	25.0	25.6	27.5	27.1	29.3	28.6	31.2	49
1379	55.00	137.50	20.3	21.0	22.6	23.7	24.2	25.7	26.3	28.3	27.9	30.2	29.4	32.2	45
895	55.00	140.00	18.8	19.5	21.2	22.3	22.9	24.3	25.0	27.0	26.6	29.0	28.2	31.0	48
1367	54.38	131.25	18.9	19.3	20.5	21.2	21.7	22.7	23.1	24.5	24.3	25.9	25.4	27.3	51
1366	54.38	132.50	19.2	19.7	21.0	21.8	22.2	23.3	23.8	25.3	25.0	26.8	26.3	28.3	50
1365	54.38	133.75	20.1	20.6	22.1	23.0	23.5	24.8	25.4	27.1	26.7	28.8	28.1	30.5	48
1364	54.38	135.00	20.5	21.1	22.6	23.6	24.2	25.5	26.1	27.9	27.6	29.8	29.1	31.6	49
1363	54.38	136.25	20.7	21.3	22.9	23.8	24.3	25.7	26.3	28.0	27.7	29.8	29.1	31.6	49
1362	54.38	137.50	20.6	21.3	22.8	23.9	24.4	25.8	26.4	28.3	27.9	30.1	29.4	32.0	48
1350	53.75	131.25	19.4	19.9	21.3	22.2	22.7	23.8	24.4	25.9	25.7	27.5	27.0	29.1	51
1348	53.75	133.75	20.5	21.1	22.8	23.8	24.4	25.8	26.4	28.3	28.0	30.2	29.5	32.1	50
1347	53.75	135.00	21.3	21.9	23.4	24.4	25.0	26.3	26.9	28.7	28.4	30.5	29.8	32.4	49
1346	53.75	136.25	20.8	21.4	23.1	24.1	24.7	26.1	26.8	28.7	28.4	30.7	29.9	32.6	48
853	53.75	137.50	21.2	21.9	23.8	25.0	25.6	27.2	28.0	30.2	29.7	32.4	31.5	34.6	48
1334	53.13	130.00	19.0	19.5	20.9	21.8	22.3	23.4	24.0	25.6	25.3	27.2	26.6	28.8	50
1333	53.13	131.25	19.8	20.3	21.8	22.6	23.1	24.3	24.9	26.5	26.2	28.1	27.5	29.8	51
1331	53.13	133.75	21.2	21.8	23.4	24.4	24.9	26.2	26.8	28.7	28.3	30.5	29.7	32.3	47
1330	53.13	135.00	21.7	22.4	24.2	25.3	25.9	27.4	28.2	30.2	29.9	32.3	31.5	34.4	50
1329	53.13	136.25	21.8	22.4	24.1	25.1	25.7	27.1	27.8	29.6	29.3	31.6	30.9	33.5	50
1318	52.50	128.75	18.4	19.0	20.5	21.5	21.9	23.3	23.8	25.7	25.2	27.4	26.5	29.1	40
1317	52.50	130.00	19.3	19.9	21.5	22.5	23.0	24.4	25.0	26.9	26.5	28.7	28.0	30.6	47
1316	52.50	131.25	20.1	20.7	22.1	23.1	23.6	24.8	25.4	27.0	26.8	28.7	28.1	30.4	51
1315	52.50	132.50	20.4	21.0	22.5	23.5	24.0	25.3	25.9	27.7	27.4	29.5	28.8	31.3	48
1314	52.50	133.75	21.3	21.9	23.6	24.6	25.1	26.5	27.1	29.0	28.7	30.9	30.2	32.8	48
1313	52.50	135.00	22.4	23.1	24.9	26.1	26.7	28.3	29.0	31.1	30.7	33.3	32.4	35.4	49
810	52.50	137.50	21.5	22.2	23.9	25.0	25.5	27.1	27.7	29.7	29.3	31.7	30.9	33.7	46
1301	51.88	128.75	17.8	18.5	20.2	21.4	21.7	23.4	23.8	25.9	25.3	27.9	26.7	29.8	35
1300	51.88	130.00	19.3	19.6	21.6	22.1	23.2	23.8	25.2	26.1	26.7	27.8	28.2	29.4	42
1299	51.88	131.25	20.1	20.8	22.4	23.4	23.9	25.3	25.9	27.8	27.4	29.7	28.9	31.6	45
1298	51.88	132.50	20.8	21.4	22.9	23.9	24.4	25.8	26.4	28.2	27.8	30.0	29.3	31.8	49
1297	51.88	133.75	21.4	21.9	23.5	24.5	25.1	26.4	27.1	28.9	28.5	30.7	30.0	32.5	49
1296	51.88	135.00	22.3	22.9	24.7	25.7	26.3	27.8	28.5	30.4	30.1	32.4	31.7	34.4	49
1285	51.25	127.50	17.1	17.7	19.4	20.6	21.0	22.6	23.1	25.2	24.7	27.2	26.2	29.1	40
1284	51.25	128.75	18.2	18.9	20.6	21.8	22.2	23.9	24.3	26.6	25.9	28.6	27.5	30.6	36
1283	51.25	130.00	19.4	20.1	21.7	22.8	23.2	24.8	25.2	27.3	26.7	29.2	28.2	31.1	39
1282	51.25	131.25	20.5	21.1	22.9	24.1	24.7	26.2	26.9	29.0	28.6	31.1	30.3	33.2	48
1281	51.25	132.50	20.9	21.5	23.1	24.1	24.6	26.0	26.6	28.4	28.1	30.3	29.5	32.1	49
1280	51.25	133.75	21.3	21.9	23.4	24.4	24.9	26.3	26.9	28.7	28.3	30.5	29.8	32.3	49
768	51.25	135.00	21.9	22.5	24.2	25.3	25.9	27.3	28.0	30.0	29.6	32.0	31.1	33.9	47
1267	50.63	128.75	18.6	19.4	21.3	22.6	23.1	25.0	25.5	28.0	27.3	30.3	29.1	32.5	38
1266	50.63	130.00	19.7	20.4	22.1	23.2	23.7	25.3	25.8	27.9	27.4	29.9	29.0	31.9	41

Table 7.3 Wind Speed Corresponding to Extreme Wave Height for Given Return Period

(Cont'd)

WIND SPEED

risk factor return period			.50 2 yr		0.20 5 yr		0.10 10 yr		0.04 25 yr		0.02 50 yr		0.01 100 yr		
grid point	Lat (N)	Long (W)	Best Fit m/s	90% U.L. m/s	Best Fit m/s	90% U.L. m/s	Best Fit m/s	90% U.L. m/s	Best Fit m/s	90% U.L. m/s	Best Fit m/s	90% U.L. m/s	Best Fit m/s	90% U.L. m/s	NUM PTS
1265	50.63	131.25	20.2	20.8	22.6	23.7	24.2	25.8	26.4	28.4	28.0	30.5	29.6	32.5	46
1264	50.63	132.50	20.9	21.5	23.2	24.2	24.8	26.1	26.8	28.7	28.3	30.5	29.8	32.4	49
1263	50.63	133.75	21.2	21.8	23.4	24.5	25.0	26.4	27.0	28.9	28.5	30.7	30.0	32.6	49
1251	50.00	127.50	17.8	18.6	20.5	21.8	22.4	24.2	24.8	27.2	26.6	29.5	28.3	31.7	40
1250	50.00	128.75	18.2	19.0	21.0	22.4	22.9	24.8	25.4	27.9	27.2	30.2	29.0	32.5	39
1249	50.00	130.00	19.4	20.1	21.9	23.1	23.6	25.3	25.8	28.0	27.5	30.1	29.1	32.2	41
1248	50.00	131.25	20.1	20.7	22.4	23.5	24.0	25.5	26.1	28.1	27.7	30.1	29.3	32.1	46
1247	50.00	132.50	20.8	21.4	22.9	23.9	24.4	25.7	26.3	28.1	27.7	29.8	29.1	31.6	46
1246	50.00	133.75	21.1	21.8	23.6	24.7	25.3	26.8	27.5	29.6	29.2	31.6	30.8	33.7	49
725	50.00	135.00	21.3	21.9	23.7	24.8	25.4	26.9	27.5	29.6	29.2	31.6	30.8	33.6	48
1235	49.38	126.25	15.8	16.6	18.5	19.9	20.3	22.2	22.6	25.2	24.3	27.4	26.0	29.6	33
1234	49.38	127.50	17.1	17.9	19.8	21.2	21.7	23.6	24.1	26.6	25.8	28.9	27.6	31.1	36
1233	49.38	128.75	18.7	19.5	21.4	22.8	23.3	25.1	25.7	28.1	27.4	30.4	29.2	32.6	38
1232	49.38	130.00	19.4	20.2	21.9	23.1	23.6	25.2	25.7	27.9	27.3	30.0	28.9	32.0	39
1231	49.38	131.25	20.1	20.8	22.6	23.8	24.4	26.0	26.6	28.8	28.3	31.0	30.0	33.1	44
1230	49.38	132.50	20.6	21.2	22.8	23.9	24.4	25.8	26.4	28.3	27.9	30.2	29.4	32.1	44
1229	49.38	133.75	21.2	21.9	23.8	25.0	25.7	27.3	28.0	30.3	29.8	32.5	31.6	34.7	48
1218	48.75	126.25	15.3	16.2	17.9	19.4	19.7	21.6	21.9	24.5	23.5	26.6	25.1	28.8	30
1217	48.75	127.50	17.0	17.9	19.8	21.3	21.7	23.6	24.1	26.7	25.9	29.0	27.7	31.3	35
1216	48.75	128.75	18.6	19.4	21.3	22.7	23.2	25.0	25.6	28.0	27.3	30.3	29.1	32.6	38
1215	48.75	130.00	19.6	20.3	22.2	23.5	24.1	25.8	26.4	28.8	28.2	31.0	29.9	33.3	40
1214	48.75	131.25	20.1	20.9	22.9	24.2	24.8	26.6	27.3	29.7	29.1	32.0	30.9	34.3	43
1213	48.75	132.50	20.6	21.3	23.1	24.3	24.8	26.4	27.0	29.2	28.6	31.2	30.3	33.3	43
682	48.75	135.00	21.2	21.9	23.8	25.0	25.6	27.2	28.0	30.2	29.8	32.4	31.6	34.6	50
1202	48.13	125.00	15.9	16.8	18.6	20.1	20.4	22.4	22.7	25.3	24.3	27.5	26.0	29.7	30
1201	48.13	126.25	15.6	16.5	18.4	20.0	20.3	22.4	22.8	25.6	24.6	27.9	26.4	30.3	31
1200	48.13	127.50	17.1	17.9	19.8	21.3	21.7	23.6	24.0	26.6	25.8	28.9	27.5	31.1	33
1199	48.13	128.75	18.3	19.2	21.2	22.6	23.1	25.1	25.6	28.3	27.5	30.6	29.3	33.0	37
1198	48.13	130.00	18.9	19.7	21.9	23.3	23.9	25.9	26.6	29.3	28.6	31.8	30.6	34.3	41
1197	48.13	131.25	19.6	20.5	22.7	24.2	24.9	26.9	27.7	30.4	29.8	33.0	31.8	35.6	44
1196	48.13	132.50	20.2	21.0	23.0	24.3	24.9	26.7	27.4	29.8	29.2	32.1	31.1	34.4	45
1185	47.50	125.00	15.1	15.8	17.5	18.8	19.2	20.9	21.3	23.7	22.9	25.7	24.4	27.7	32
1184	47.50	126.25	15.5	16.4	18.3	19.7	20.1	22.0	22.4	25.0	24.1	27.3	25.9	29.5	32
1183	47.50	127.50	17.2	18.1	20.0	21.4	21.9	23.8	24.2	26.8	26.0	29.1	27.7	31.4	33
1182	47.50	128.75	18.1	19.0	21.0	22.5	23.0	25.0	25.5	28.2	27.4	30.7	29.3	33.1	36
1181	47.50	130.00	18.4	19.3	21.2	22.7	23.1	25.1	25.6	28.2	27.4	30.6	29.2	32.9	34
1180	47.50	131.25	18.9	19.8	22.0	23.5	24.2	26.2	26.9	29.7	29.0	32.3	31.0	34.9	41
640	47.50	132.50	19.7	20.4	22.3	23.6	24.2	25.9	26.6	28.9	28.4	31.1	30.2	33.3	46
1168	46.88	125.00	14.9	15.7	17.6	19.0	19.4	21.4	21.7	24.3	23.4	26.6	25.2	28.8	32
1167	46.88	126.25	16.2	17.2	19.2	20.8	21.1	23.3	23.5	26.5	25.3	28.8	27.1	31.2	28
1166	46.88	127.50	17.4	18.4	20.3	21.9	22.2	24.3	24.6	27.4	26.4	29.8	28.2	32.1	30
1165	46.88	128.75	18.0	18.9	20.9	22.5	22.9	25.1	25.4	28.3	27.3	30.7	29.1	33.2	31
1164	46.88	130.00	18.3	19.2	21.1	22.7	23.1	25.1	25.6	28.3	27.4	30.7	29.2	33.0	33
1163	46.88	131.25	18.6	19.5	21.6	23.1	23.7	25.8	26.4	29.2	28.4	31.7	30.4	34.3	39
1151	46.25	125.00	14.6	15.5	17.4	18.9	19.2	21.3	21.5	24.3	23.3	26.5	25.0	28.8	30
1150	46.25	126.25	16.1	17.1	19.1	20.8	21.0	23.3	23.4	26.5	25.2	28.8	26.9	31.2	25
1149	46.25	127.50	17.7	18.7	20.6	22.1	22.4	24.5	24.7	27.6	26.4	29.9	28.2	32.1	28
1148	46.25	128.75	18.2	19.1	20.9	22.4	22.7	24.7	24.9	27.7	26.6	29.9	28.3	32.1	29
1147	46.25	130.00	17.8	18.7	20.7	22.2	22.7	24.8	25.2	28.0	27.1	30.4	28.9	32.8	34
597	46.25	132.50	19.1	19.8	21.7	22.9	23.4	25.1	25.7	27.9	27.4	30.0	29.1	32.2	43
557	45.00	125.00	14.0	14.9	16.7	18.1	18.4	20.3	20.5	23.2	22.2	25.3	23.8	27.4	29
556	45.00	127.50	16.7	17.6	19.4	21.0	21.2	23.3	23.4	26.2	25.1	28.4	26.7	30.6	27
555	45.00	130.00	17.1	17.9	19.8	21.2	21.6	23.5	23.8	26.5	25.5	28.7	27.2	30.9	30

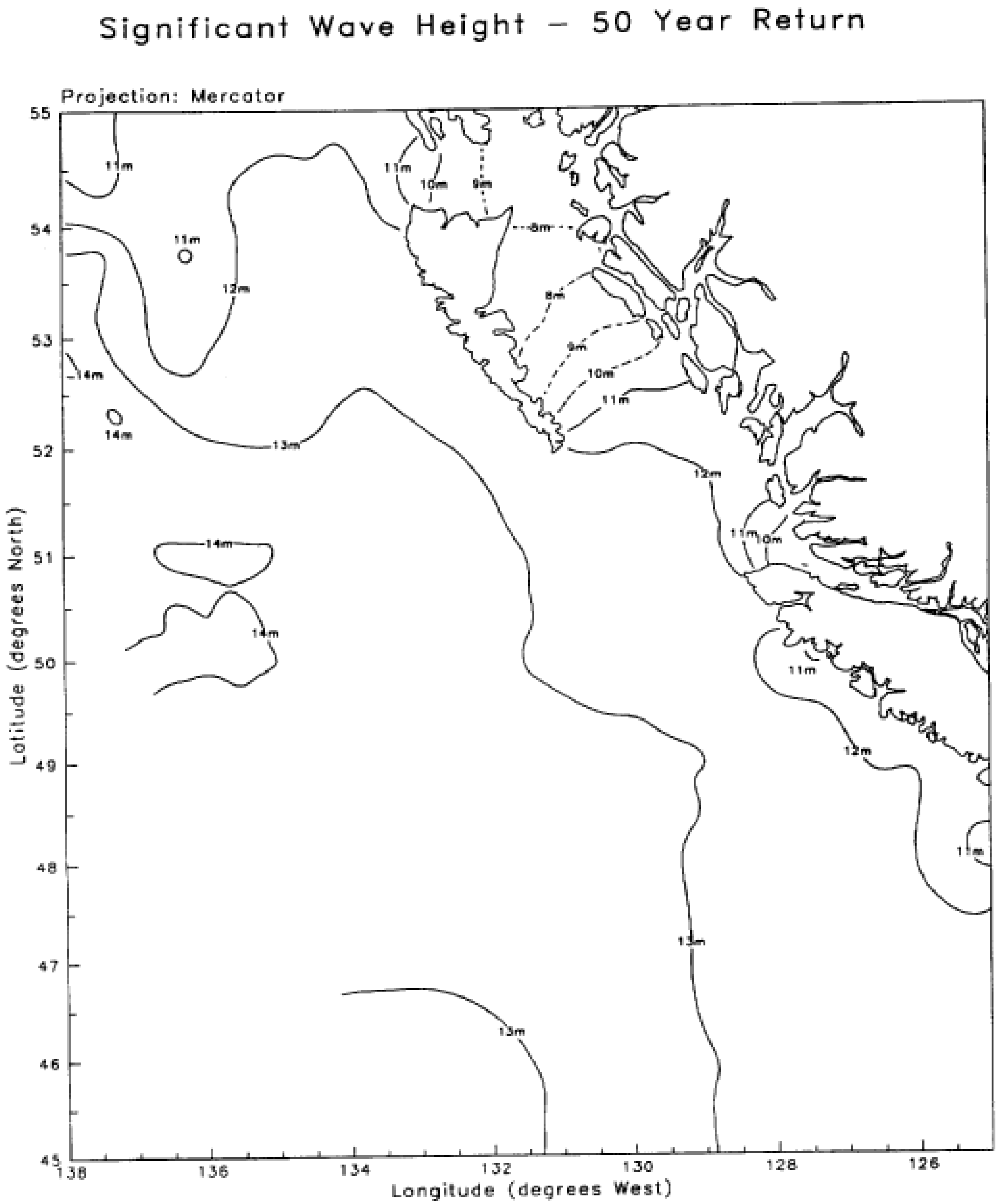


Figure 7.9 50-Year Significant Wave Height

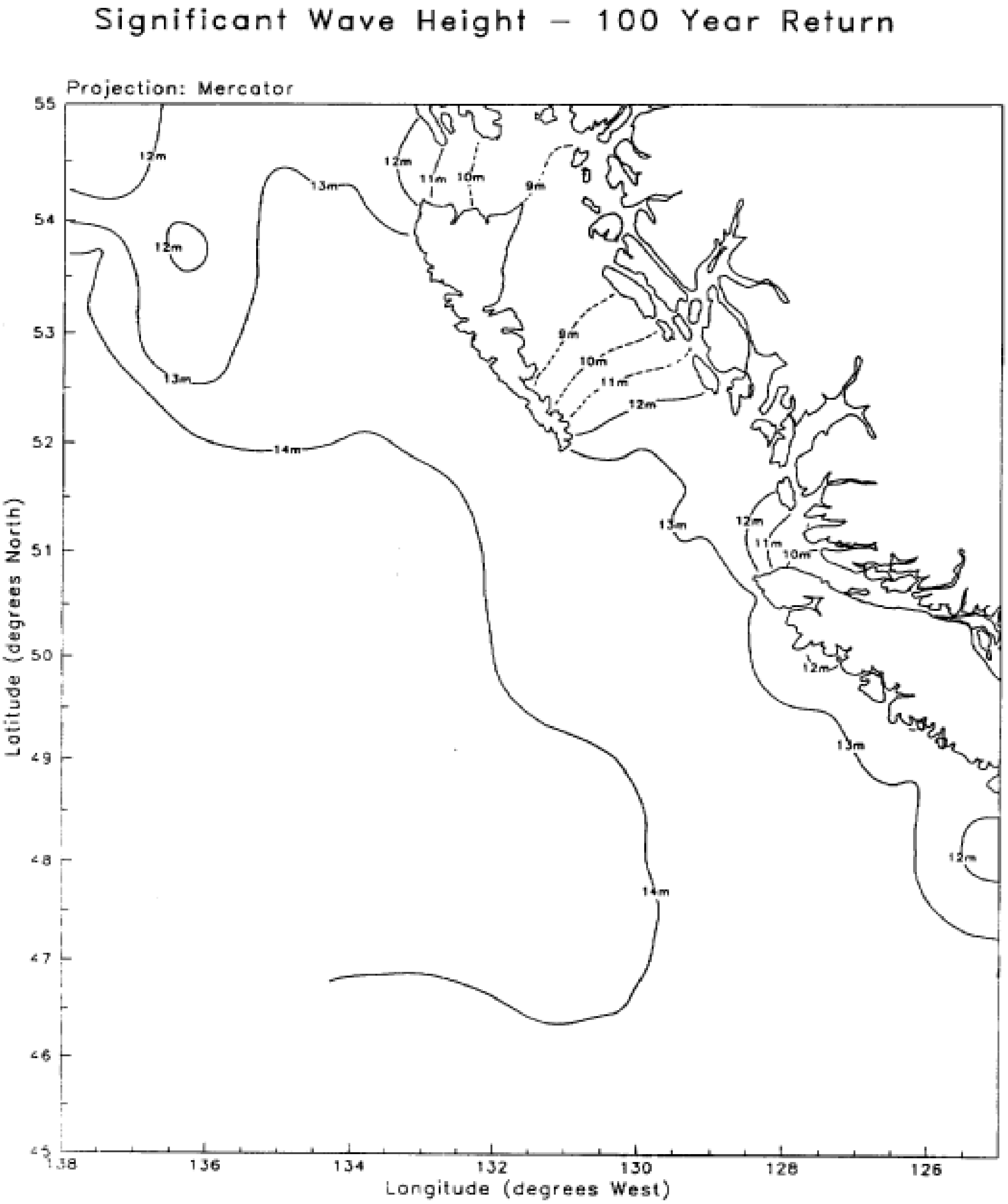


Figure 7.10 100-Year Significant Wave Height

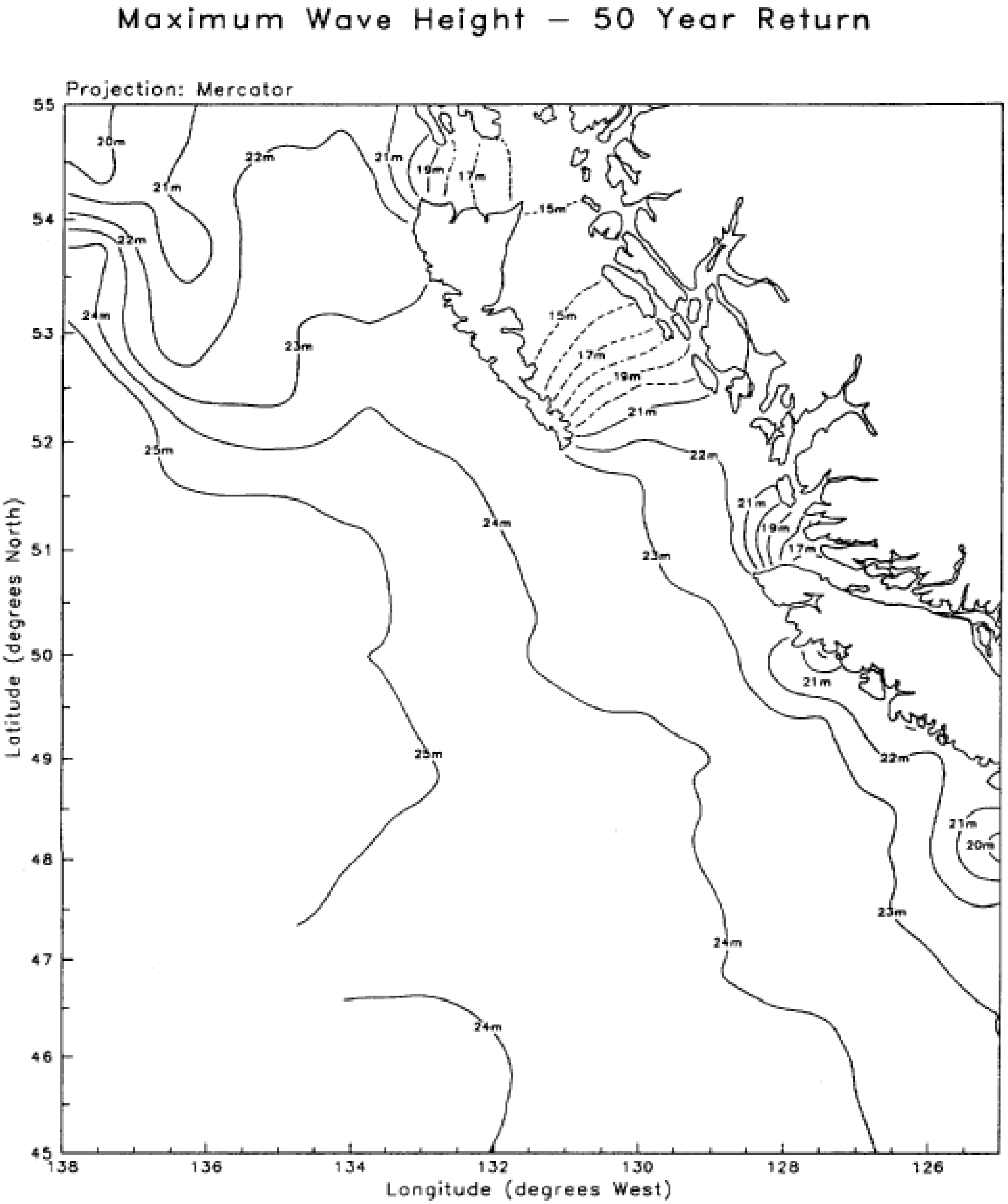


Figure 7.11 50-Year Maximum Wave Height

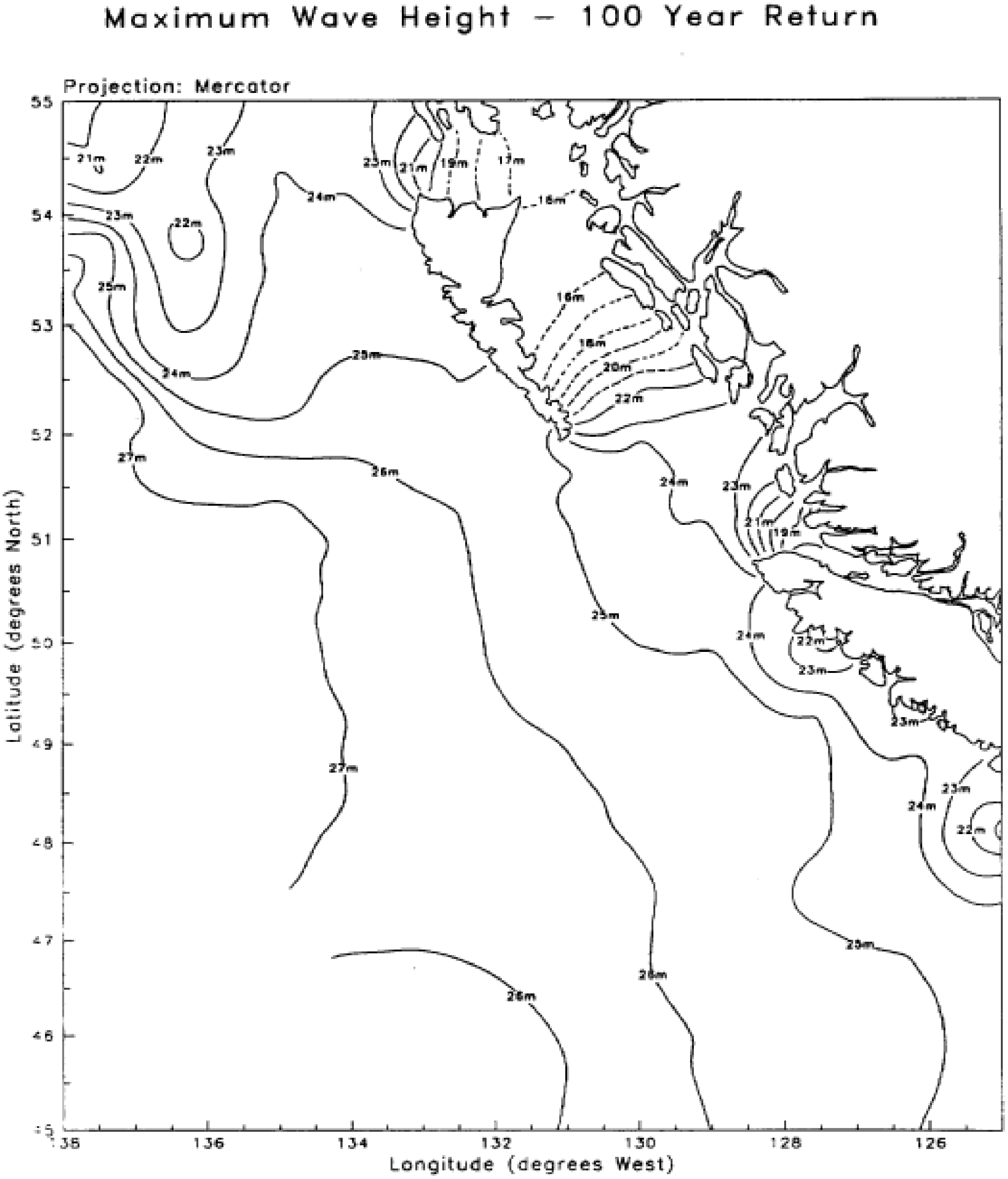


Figure 7.12 100-Year Maximum Wave Height

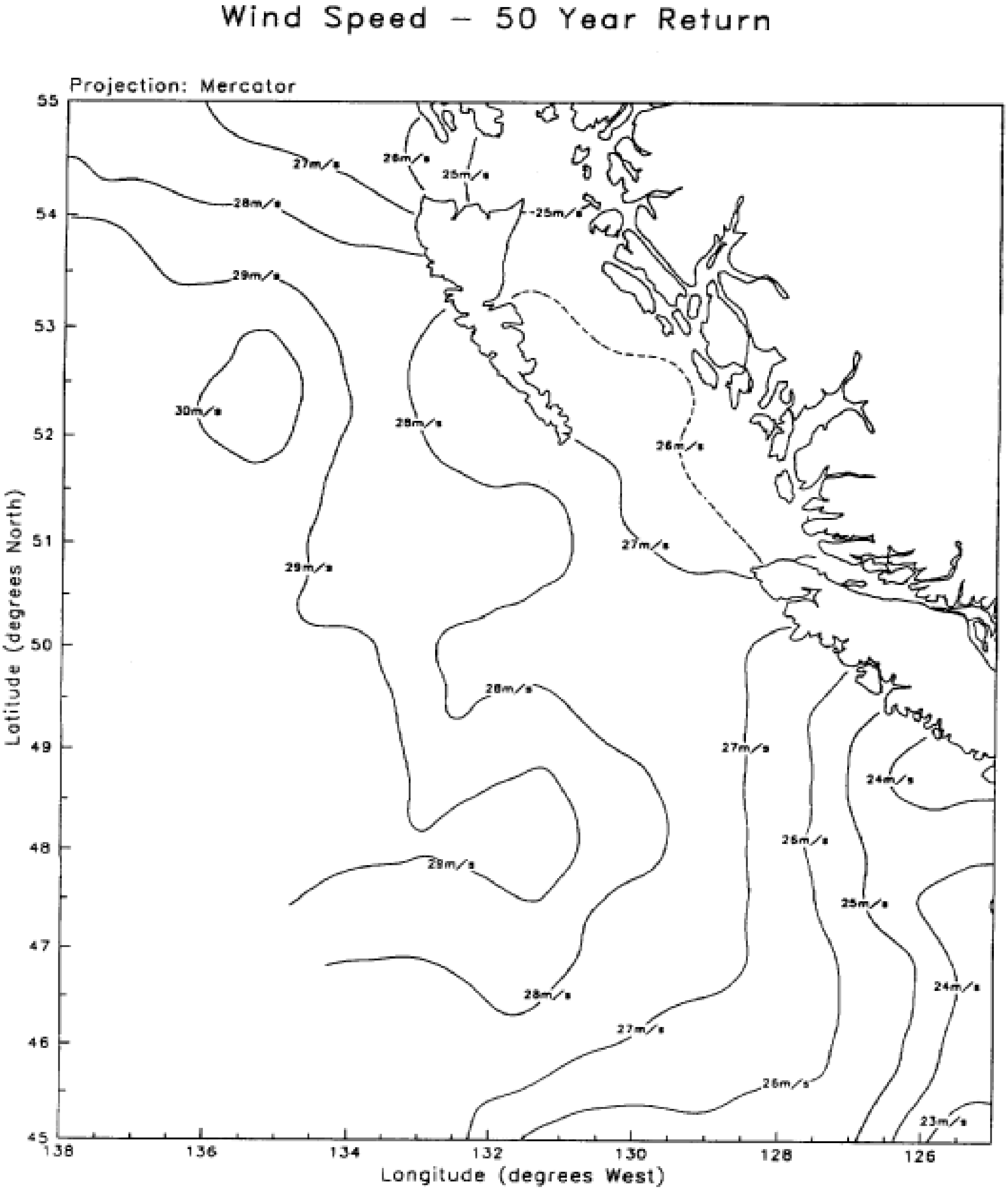


Figure 7.13 50-Year Wind Speed Corresponding to Extreme Waves

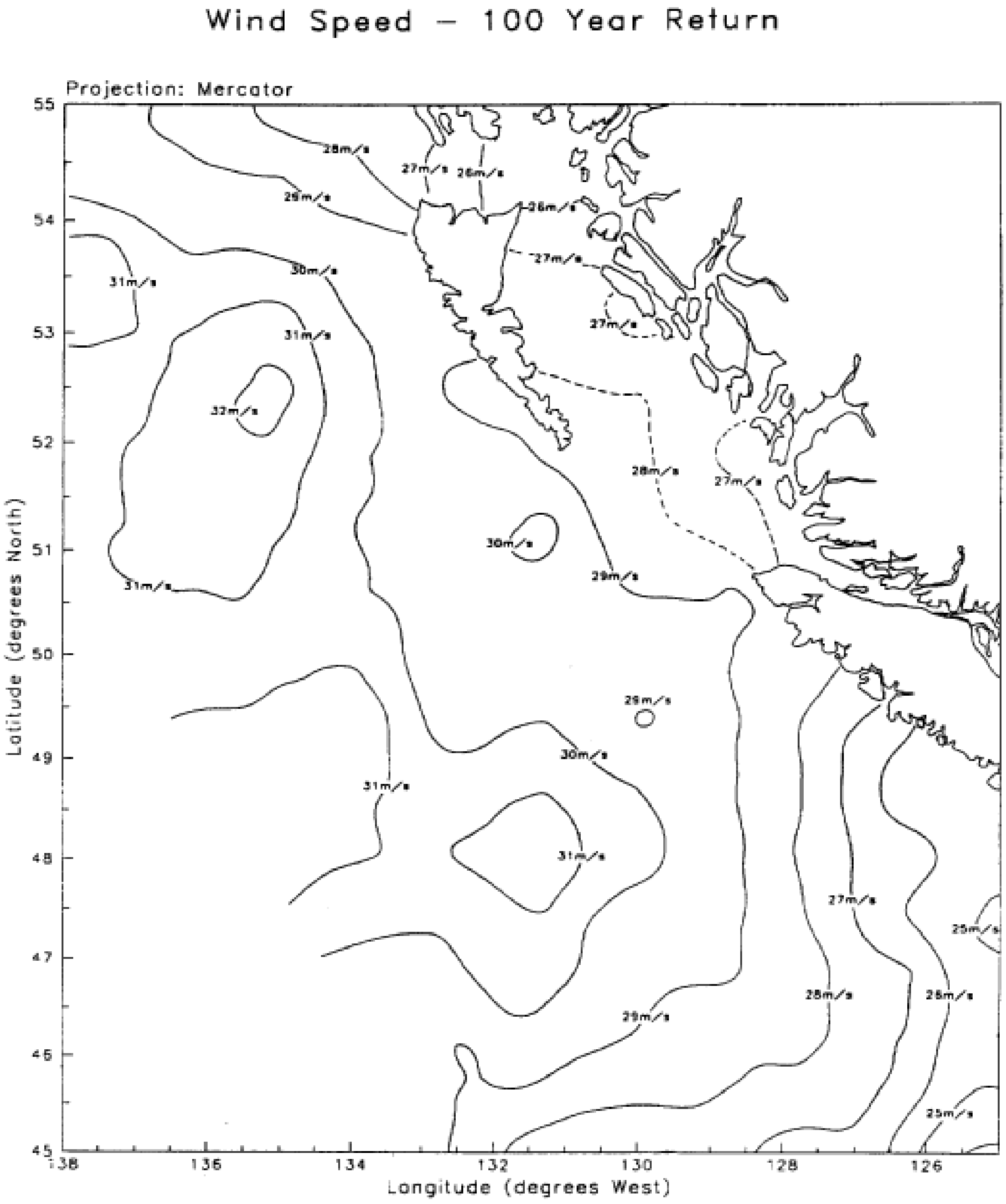


Figure 7.14 100-Year Wind Speed Corresponding to Extreme Waves

8.0 SUMMARY, RESULTS AND RECOMMENDATIONS

8.1 SUMMARY

A hindcast approach was applied to specify the extreme wave climate in the Canadian West Coast offshore including the AES marine forecasting areas (West Coast Vancouver Island, Queen Charlotte Sound, West Coast Charlottes, exposed parts of Hecate Strait and Dixon Entrance and Bowie and Explorer). The basic hindcast approach which was used for the East Coast extreme hindcast study (CCC, 1991) was applied here. It includes the following steps: (1) assembly of a comprehensive data base of archived historical meteorological data, measured wave data and results of previous studies; (2) identification and ranking of historical storm occurrences over as long a period of history as possible, and selection of hindcast storms; (3) adoption and validation of the most accurate numerical procedures to specify time histories of surface wind fields, surface wave fields and directional wave spectra in each selected historical storm; (4) hindcast of a number of selected historical storms; and (5) analysis of extremes at each hindcast model grid point to estimate the significant and maximum individual wave height, crest height, and associated wind speed and wave period, associated with rare return intervals.

The data base assembly was intended to be exhaustive, and tapped the resources of the Atmospheric Environment Service, the NOAA, National Climatic Data Center, the MEDS, and products of numerous previous programs and studies conducted by government centres, and private industry. The historical meteorological and wave data assembled and referred to includes complete microfilm records of surface weather map series of AES-PWC, CMC and NOAA-NMC, 20 year U.S. Navy SOWM wind and wave hindcasts, AES Geostrophic Wind Climatology, digital files of synoptic observations from coastal stations, NOAA buoys and, Ocean Weather ships (PAPA), and wave measurements from MEDS buoys. The processing facilities of the AES were extensively utilized.

The storm selection work was designed to identify storms based on their potential to generate high sea states somewhere within the study area. This task proceeded in several stages. First, all the data sources noted above were reviewed and utilized to develop an initial candidate list of extratropical storms. A total of about 500 events which occurred within the period 1957-1990 comprised this initial list. This list was eventually refined and distilled to the final hindcast population of 51 events. The initial list was distilled in several stages, with the aid of both objective storm intensity ranking procedures, and subjective ranking and intensity assessments made by experienced meteorologists and wave modellers. Since the typical scale of an intense extratropical storm is large with respect to the study area, many selected storms affect more than one of the study sub-areas, and individual storms often overlap two or more areas. At any given site therefore, the study is expected to include over 20 - 30 top-ranked extreme wave events associated with extratropical storms during the historical period considered. It should be noted here, although considerable effort was made to select the top 51 severe storms, the selection process is far from perfect and would contribute to some uncertainties in the results.

The wind and wave hindcast methodology adapted to the basin of interest in this study has already undergone considerable refinement and validation in previous studies of this type. The specification of 6-hourly wind fields in each storm included a complete reanalysis of the evolution of the surface pressure field, starting with the best archived analysis available, and adding additional ship reports, buoy and other data not available in real time. Wind fields were then calculated from the pressure fields using a proven calibrated marine planetary boundary layer model. The assembled wind data were used to develop kinematic analyses as needed to provide winds of the highest accuracy achievable for the available data. The wave hindcasts were carried out with the ODGP spectral wave model adapted to the North Pacific basin on a high-resolution nested grid, which provides temporal and spatial resolution of the wind and wave field in the study area of 2 hours, and average of about 85 km, respectively.

While the hindcast methodology adapted had already undergone extensive validation against measured data in other areas (e.g. the East Coast of Canada, CCC, 1991), a substantial validation was included in this study, involving comparison of hindcasts of eleven extreme storms against measured data at several sites.

The basic approach of the extremal analysis was to carry out site-specific hindcasts of peaks-over-threshold, at each grid point of the fine mesh model grid system. At each of the points, the threshold was determined and the top-ranked storms above a selected threshold were input to the extreme analysis program. The first step of the analysis was to calculate the extreme maximum individual wave height (H_m) and crest height (H_c) in each storm at each point using the entire hindcast storm history. The peak H_s, H_m and H_c were then extrapolated to rare return period (up to 100 years) using the Gumbel distribution fitted to Method of Moments (MOM). The analysis included sensitivity studies on threshold, distribution function, and fitting scheme. The maximum wind speed associated with the extreme sea state was also extrapolated. The peak period associated with the maximum sea state was estimated from the hindcast data base using correlation analysis of the pairs T_p, H_s. The main extremal analysis considered hindcast peaks regardless of direction of approach. An attempt to develop extremes stratified by directional sector of wave approach met with limited success as it was found that the hindcast population was too small to resolve more than one or two very broad directional sectors.

8.2 RESULTS

The ability of the model to predict waves on the west coast was first tested by comparing time series of buoy measurements with model hindcast values. In general, the model hindcast of the storm wave parameters was similar to the buoy-measured values, with slightly different skill scores based on the areas where evaluation was made, i.e. deepwater, offshore, inshore, sheltered, or shallow water areas.

However, for extremal analysis, the most important aspect of the model is its ability to predict the storm peak accurately. Therefore, in this study the peak-to-peak comparisons were considered to be of significant importance for evaluating model predictions. This was initially carried out for the eleven verification storms and further tested for model hindcast peaks that correspond to all available measured storm peaks. The results were divided into four different areas as follows:

		Bias	RMSE	SI(%)
OFFHORE	H_s(M)	+0.51	1.35	16.2
DEEPWATER	T_p(s)	-0.06		12.4
INSHORE DEEP	H_s(m)	-0.42	1.51	17.1
	T_p(s)	+0.12		9.9
SHELTERED	H_s(m)	-0.08	1.42	19.1
	T_p(s)	+0.82	3.0	23.4
SHALLOW	H_s(m)	0.44	1.0	16.1
	T_p(s)	0.82	2.0	14.3
OVERALL	H_s(m)	0.27	1.3	16.9
	T_p(s)	0.22	2.0	14.4

Spectral comparisons based on the results of this study showed that in all cases considered the ODGP model spectra were in very good agreement with the buoy spectral estimates.

Overall Results

The statistical and spectral comparisons show a high degree of agreement between measured and hindcast seastates. Overall, the model overpredicted storm peaks by less than 0.5 m, however, the higher storm peaks tend to be underpredicted. The overall mean difference (bias) was 0.27 m for H_s and 0.22 s for T_p with scatter indices of 16.9% for H_s and 14.4% for T_p. These results, taken together with the generally skillful time history comparisons, support the conclusion that the hindcast methodology adopted and applied here yields the maximum skill achievable at the current state-of-the-art hindcasts of mid-latitude extratropical storm wave regimes.

Wave (and wind) errors were greater near shore due to the well known effect of coastal mountain ranges in this area. The kinematic analysis can only partially account for this effect since there is sparse wind data for the inshore regime; and also the model's large scale grid may not provide a good description of the island configuration and sheltering effect.

8.3 RECOMMENDATION FOR FUTURE STUDIES

The resolution of even the nested grid of the wave model is too coarse to resolve the wave climate very nearshore, and in Hecate Strait. Therefore, it is recommended that an even finer mesh be laid out near shore, with grid spacing at least three times finer than that of the nested grid (that is 10 n. mi. or smaller). This wave model could cover a very limited domain, as it could be driven by boundary spectra taken from the file of archived directional spectra saved in this study on the fine mesh grid.

There is some evidence that in very severe storms, waves in Hecate Strait are affected by the bottom topography. Therefore it is recommended that any nearshore ultra-fine mesh wave model also include shallow water processes.

For the nearshore areas, particularly the inshore points in Hecate Strait and Dixon Entrance, the local effects, such as mesoscale wind, wave-current interaction, and the bathymetry would affect the wave climate and therefore present results should be treated with caution in these inshore areas. Further work is required to resolve these issues. Enough data are now available from several buoys to adequately specify input fields and to verify the wave field products. The assimilation of these buoy data in model predictions should be considered in future investigations.

Following successful validation of the nearshore wave model, those storms which are important to the nearshore climate could be rerun, and the extreme wave climate re-estimated following the same method applied to the deep water results of this study.

Because of the strong influence of the coastal mountains on the nearshore wind field, any new hindcast study should be accompanied by a parallel program to investigate the best way to specify mesoscale wind fields nearshore and in Hecate Strait. Candidates include application of the same type of subjective kinematic analysis techniques as applied in the present study. However, the effectiveness of terrain - following numerical boundary layer models should also be investigated. The benefits of such a program, if successful, could be applied beyond wave modelling to areas such as current modelling and oil-spill trajectory prediction.

As shown, the model tends to underpredict the very highest storms in this area. This was found to be the case in other hindcasts (with other models and other areas). Although as shown the effect of underpredicting the worst severe storm events did not have significant effect on the final extreme analysis results of this study, some future research is needed on the accuracy of the hindcast methods for simulating peaks of the individual most severe storms.

Finally, several winter seasons have already transpired since the winter season from which the last storm hindcast in this study was selected. The unusually warm decade of the 1980’s has been surpassed by even warmer years in the early 1990’s, and this climate anomaly seems to be affecting storm severity in the Northern Hemisphere basins. For example several events (at least 4) have occurred during the last two years with significant wave height in excess of 12 metres. It is therefore prudent to update the study at reasonable intervals of time, in order that the extremes represent a wide and presumably more realistic range of climate patterns. Also, it is recommended that the effect of potential global climate changes (e.g. global warming due to the greenhouse effect) on storm population, storm characteristics and severity be studied.

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APPENDIX A
STORM LIST

TABLE A.1 MASTER LIST FOR THE WEST COAST

All these remaining storms have: winds >= 50 kts
waves >= 8 m
dur >= 12 hrs
except for MEDS which has waves >= 7 m

Sources :					
A)	BUOY wave	>= 8 m	or	>= 45 kts	
B)	BUOY wind	>= 8 m	or	>= 45 kts	
C)	ESTEVAN wind			>= 45 kts	
D)	GWC wind			>= 50 kts	and >= 12 hrs
E)	LIGHT wave	>= 8 m	or	>= 45 kts	
F)	LIGHT wind	>= 8 m	or	>= 45 kts	and >= 6 hrs
G)	NORTH wind			>= 45 kts	and >= 6 hrs
H)	PAPA wave	>= 8 m	or	>= 45 kts	
I)	PAPA wind	>= 8 m	or	>= 45 kts	
J)	SHIP wave	>= 8 m	or	>= 45 kts	
K)	SHIP wind	>= 7 m	or	>= 45 kts	
L)	SOUTH wind			>= 45 kts	and >= 6 hrs
M)	SOWM wave	>= 8 m	or	>= 45 kts	
N)	SOWM wind	>= 8 m	or	>= 45 kts	
P)	MEDS	>= 7 m			

	START YYMMDDHH	END YYMMDDHH	DUR (hr)	OBS	WIND SPD (kts)	WIND DIR	COMBINED SEA HS (m)	COMBINED SEA TP (s)	COMBINED SEA DIR	SEVERITY INDEX	SOURCE
1.	57122210	57123003	185	19	52.	160	9.5	14.5	270	3744	G,I,J,L
2.	58020200	58020312	36	5	60.	090	9.0	10.5	020	1320	D,K
3.	58021704	58021906	58	19	72.	130	9.5	12.5	180	4176	D,J,L
4.	58030500	58030912	108	29	64.	300	9.5	12.5	320	6912	I,J,K
5.	58041706	58041821	39	14	74.	250	9.5	8.5	250	2886	J,K
6.	58102810	58110218	128	21	78.	150	9.5	8.5	180	9984	D,G,I,J,K,L
7.	58110415	58111415	240	44	75.	260	9.5	12.5	240	18000	D,G,I,J,K
8.	58112900	58120300	96	18	61.	090	9.5	16.5	220	5856	J,K,L
9.	58122500	58122703	51	5	50.	130	8.0	8.5	130	2550	I,J
10.	59011115	59011221	30	11	78.	010	8.0	8.5	240	2340	J,K
11.	59021600	59021812	60	13	65.	020	9.5	12.5	020	3900	D,J,K
12.	59022412	59030400	180	33	70.	240	9.5	16.5	250	12600	D,G,I,J
13.	59091400	59091412	12	5	50.	160	8.0	6.5	120	600	J,K
14.	59111903	59112303	96	29	70.	110	8.0	14.5	220	6720	D,I,J,K,L
15.	59120906	59121200	66	16	76.	280	9.5	8.5	230	4352	D,G,I,J,K,L
16.	59121705	59121906	49	11	60.	300	9.5	14.5	270	2880	J,K,L

TABLE A.1 MASTER LIST FOR THE WEST COAST (Cont'd)

	START YYMMDDHH	END YYMMDDHH	DUR (hr)	OBS	WIND SPD (kts)	WIND DIR	COMBINED SEA HS (m)	COMBINED SEA TP (s)	COMBINED SEA DIR	SEVERITY INDEX	SOURCE
17.	60011216	60011518	74	9	55.	200	8.0	14.5	200	4070	D,G,I,J,K,L
18.	60012006	60012221	63	7	54.	160	8.0	14.5	130	3402	D,J,K
19.	60012806	60020110	100	28	84.	200	9.5	14.5	130	8400	D,G,I,J,K,L
20.	60020422	60020715	65	32	73.	160	9.5	14.5	200	4745	D,I,J,K,L
21.	60021312	60021606	66	14	75.	300	8.0	10.5	270	3762	D,I,J,K
22.	60040815	60041018	51	11	50.	320	9.5	14.5	230	2550	G,J,K
23.	60041300	60041500	48	7	65.	280	9.0	8.5	290	3120	J,K,L
24.	60102218	60102618	96	27	71.	220	9.5	10.5	230	6816	D,G,I,J,K,L
25.	60102818	60103000	30	5	68.	140	8.5	12.5	210	2040	J,K
26.	60110106	60110312	54	5	60.	230	9.5	10.5	230	3240	J,K
27.	60111609	60112512	219	55	78.	270	9.5	20.5	250	17082	D,G,I,J,K,L
28.	61022018	61022412	90	19	56.	250	9.0	10.5	270	5040	D,G,I,J,K
29.	61031406	61031615	57	12	62.	270	8.5	6.5	220	3534	D,I,J,K
30.	61101210	61101512	76	8	61.	160	9.5	12.5	250	4636	G,J,K
31.	61102406	61102900	114	16	58.	270	9.5	10.5	260	6612	I,J,K
32.	61111915	61112312	93	18	52.	250	9.5	18.5	260	4371	G,I,J,K
33.	61112500	61112612	36	10	55.	290	9.5	8.5	190	1980	I,J
34.	61120212	61120515	75	19	68.	250	9.5	12.5	300	5100	D,G,I,J
35.	61121612	61121818	54	13	57.	300	9.5	10.5	100	3078	D,J,K
36.	61122119	61122306	36	7	57.	180	9.5	10.5	190	2052	D,G,J,K
37.	61122618	61122712	18	3	60.	140	9.5	8.5	140	1080	J,K
38.	62010318	62010515	45	13	66.	230	8.0	14.5	160	2970	D,G,I,J,K
39.	62012610	62012922	84	18	52.	180	8.0	8.5	190	4368	G,J
40.	62030509	62030618	33	15	57.	360	9.5	14.5	340	1881	J,K
41.	62032112	62032221	33	17	56.	290	9.5	12.5	280	1848	J,K
42.	62032406	62032418	12	4	50.	230	8.5	12.5	260	450	J,K
43.	62092715	62093007	64	18	62.	310	9.5	18.5	260	3968	D,G,I,J,K,L
44.	62102518	62102812	66	41	81.	180	9.0	12.5	160	5346	D,G,I,J,K
45.	62111800	62120207	343	33	65.	220	10.5	14.5	188	22295	D,G,I,J,K,L
46.	62120406	62120506	24	10	59.	220	9.5	8.5	240	1416	D,G,I,J,K
47.	62120812	62121612	192	30	69.	200	8.5	12.5	070	13248	D,G,I,J,K
48.	63010318	63010500	30	12	62.	230	8.1	10.5	220	1860	D,G,I,J,K
49.	63013000	63013118	42	17	57.	090	8.5	14.5	100	2394	D,J,K
50.	63020218	63020418	48	14	58.	240	8.5	12.5	160	2784	D,J,K
51.	63020612	63020803	39	23	67.	180	9.5	14.5	170	2613	D,I,J,K
52.	63022703	63030118	63	14	52.	260	11.0	14.5	268	3276	H,I,J
53.	63031600	63031712	36	4	50.	130	8.0	12.5	300	1800	J,K

TABLE A.1 MASTER LIST FOR THE WEST COAST (Cont'd)

	START YYMMDDHH - END YYMMDDHH	DUR (hr)	OBS	WIND SPD (kts)	WIND DIR	COMBINED SEA HS (m)	COMBINED SEA TP (s)	COMBINED SEA DIR	SEVERITY INDEX	SOURCE
54.	63032700-63033012	84	16	60.	310	9.5	12.5	270	5040	D,H,I,J,K
55.	63101000-63101300	72	29	68.	270	12.4	18.5	190	4896	D,I,J,K
56.	63101918-63102517	143	42	74.	290	12.7	16.5	260	10582	D,G,H,I,J,K
57.	63112912-63113000	12	5	52.	180	10.5	14.5	180	624	K
58.	63120121-63120422	73	10	60.	200	9.2	14.5	150	4380	G,I,K
59.	63122021-63122300	51	26	74.	180	8.2	12.5	180	3213	D,G,I,K,L
60.	63122618-63123122	124	34	75.	220	8.7	6.5	194	9300	D,G,I,K
61.	64010813-64011012	47	14	52.	140	9.6	6.5	237	2444	I,J,K,L
62.	64011318-64011806	108	23	70.	310	9.5	12.5	280	7560	D,G,H,I,J,K,L
63.	64020816-64021818	242	28	60.	140	10.3	6.5	-099	14520	F,G,I,J,K
64.	64031409-64031800	87	8	52.	180	9.6	10.5	278	4524	G,H,I,K
65.	64100312-64100418	30	7	55.	070	9.0	8.5	170	1650	H,I,J,K
66.	64101403-64101915	132	23	70.	140	12.0	16.5	180	9240	D,F,G,I,K,M,N
67.	64110419-64110618	47	14	52.	140	8.0	8.5	270	2444	F,G,H,I
68.	64110812-64111009	45	16	55.	140	9.5	14.5	290	2250	F,H,I,J,K
69.	64111112-64111300	36	10	51.	310	9.5	5.0	310	1530	H,I,J,K
70.	64112822-64120103	77	16	66.	130	8.5	14.5	200	4884	D,G,L,M,N
71.	64120406-64120900	114	44	60.	180	12.6	10.5	244	6840	D,F,G,J,K,M,N
72.	64122600-64123003	99	30	63.	320	9.5	14.5	300	6237	D,G,I,J,K,M,N
73.	64123106-65010312	78	12	63.	160	9.0	10.5	310	4914	D,G,H,I,J,K,N
74.	65012415-65012503	12	5	50.	270	8.0	14.5	280	600	H,I
75.	65021218-65021309	15	3	53.	270	8.0	14.5	280	795	D,M,N
76.	65050209-65050418	57	11	55.	100	12.0	14.5	295	2970	G,H,I,K,M,N
77.	65100203-65100621	114	24	65.	300	11.5	16.5	180	7410	D,H,I,J,K,L,M,N
78.	65101515-65101722	55	15	65.	270	9.0	14.5	260	3575	D,G,H,I,J,K,M
79.	65111303-65111500	57	10	60.	060	9.0	14.5	020	3420	D,G,J,K,M,N
80.	65112100-65112200	24	5	55.	290	8.5	12.5	290	1320	J,K
81.	65112709-65120503	186	43	57.	200	10.0	16.5	170	10602	D,F,G,K,L,M,N
82.	65121903-65122009	30	6	56.	140	9.5	16.5	220	1680	G,M,N
83.	65122003-65122415	108	26	57.	140	8.5	6.5	311	6156	G,H,I
84.	65122715-66010215	144	37	65.	140	9.7	18.5	327	9360	D,J,K,M,N
85.	66011118-66011316	46	8	63.	120	8.0	14.5	230	2898	D,G,M,N
86.	66011503-66011707	52	13	52.	140	9.0	14.5	220	2496	F,G,M,N
87.	66012303-66012803	120	42	51.	160	11.5	18.5	110	6120	M,N
88.	66022418-66030106	108	11	75.	140	9.2	14.5	321	8100	D,H,I,M
89.	66030809-66031100	63	14	55.	180	9.6	14.5	320	3465	D,G,H,I,K,M,N
90.	66031500-66032018	138	30	55.	130	8.0	14.5	000	7590	G,J,K

TABLE A.1 MASTER LIST FOR THE WEST COAST (Cont'd)

	START YYMMDDHH	END YYMMDDHH	DUR (hr)	OBS	WIND SPD (kts)	WIND DIR	COMBINED SEA HS (m)	COMBINED SEA TP (s)	COMBINED SEA DIR	SEVERITY INDEX	SOURCE
91.	66091406	66091721	87	11	65.	250	9.5	10.5	250	5655	H,I,K,M,N
92.	66101506	66102006	120	22	80.	180	8.5	5.0	360	9600	D,F,G,H,I,M,N
93.	66102216	66102404	36	7	52.	180	8.0	14.5	220	1872	F,G,M,N
94.	66102807	66102922	39	11	60.	160	9.0	14.5	200	2028	D,G,K,M,N
95.	66103112	66110206	42	11	60.	270	10.5	14.5	150	2520	D,K,M,N
96.	66111812	66112100	60	18	56.	340	12.7	14.5	000	3360	J,K
97	66112900	66120100	48	12	61.	090	9.5	14.5	060	2623	D,G,H,I,J,K
98.	66120903	66121809	222	49	56.	130	11.0	16.5	190	12432	F,G,K,M,N
99.	67010615	67011306	159	26	82.	250	12.0	16.5	160	13038	D,F,G,K,M,N
100.	67011418	67011509	15	5	63.	120	8.0	14.5	220	756	D,F,M,N
101.	67011718	67012112	90	28	63.	210	11.5	18.5	220	5670	D,H,I,M,N
102.	67013013	67020522	153	25	62.	220	10.0	16.5	220	9486	D,F,G,H,I,L,M,N
103.	67020706	67021306	144	27	70.	230	12.0	10.5	226	10080	G,H,I,J,K,M,N
104.	67021700	67021807	30	10	60.	300	9.5	20.5	300	1800	J,K,L,M,N
105.	67022522	67022722	48	16	61.	180	9.5	14.5	180	2928	F,G,M,N
106.	67052612	67052715	27	6	53.	180	8.5	14.5	180	1431	D,M,N
107.	67091713	67091900	35	8	52.	140	8.3	6.5	200	1820	G,J,K
108.	67100100	67100118	18	7	50.	270	10.6	16.5	275	900	K
109.	67102406	67102712	78	18	61.	140	10.0	14.5	180	4056	F,G,J,K,L,M,N
110.	67111300	67111312	12	5	54.	040	9.9	14.5	049	648	K
111.	67112815	67120822	247	206	84.	130	13.5	18.5	280	20748	D,F,G,H,I,J,K,L,M,N
112.	67120912	67121603	159	32	66.	020	13.5	20.5	190	9108	D,F,H,I,J,K,M,N
113.	67122115	67122403	60	17	64.	130	9.0	18.5	260	3840	D,H,I,M,N
114.	68010400	68010512	36	5	90.	290	12.4	14.0	290	3240	K
115.	68010712	68011603	207	46	89.	210	11.5	8.5	110	18423	D,F,G,J,K,L,M,N
116.	68011707	68012021	86	18	89.	210	11.3	14.0	325	7654	D,G,K,L,M,N
117.	68012121	68012618	117	18	89.	210	11.5	8.5	190	10413	F,G,J,K,M,N
118.	68013106	68020106	24	9	89.	210	11.3	14.0	325	1392	D,K
119.	68020212	68020606	90	9	89.	210	11.3	14.0	325	5040	D,F,G,I,J,K
120.	68020518	68021012	114	27	62.	170	11.4	14.0	180	7068	K,M,N
121.	68021809	68022206	93	16	70.	240	9.0	8.5	190	6510	D,K,M,N
122.	68022509	68022803	66	28	60.	170	14.0	8.5	160	3960	D,I,M,N
123.	68022912	68030106	18	5	60.	120	8.0	8.5	140	1080	K,M,N
124.	68031015	68031400	81	20	80.	140	10.0	8.5	160	6480	D,I,K,M,N
125.	68031918	68032203	57	18	60.	140	12.0	8.5	160	3420	D,F,M,N
126.	68033009	68033109	24	9	53.	070	9.6	10.5	079	1272	H,I,K
127.	68041700	68041800	24	5	53.	290	12.5	13.0	250	1272	K

TABLE A.1 MASTER LIST FOR THE WEST COAST (Cont'd)

	START YYMMDDHH	END YYMMDDHH	DUR (hr)	OBS	WIND SPD (kts)	WIND DIR	COMBINED SEA HS (m)	COMBINED SEA TP (s)	COMBINED SEA DIR	SEVERITY INDEX	SOURCE
128.	68053118	68060206	36	8	50.	070	8.1	12.0	062	1800	K
129.	68082800	68082918	42	8	52.	180	9.6	12.5	234	2184	F,G,H,I
130.	68091221	68091600	75	16	56.	270	9.0	12.5	270	2856	F,H,I,K
131.	68092315	68092418	27	10	55.	180	9.7	8.0	314	1485	F,K
132.	68100203	68100516	85	12	64.	300	8.5	8.5	170	5440	F,K,M,N
133.	68101412	68102718	318	53	75.	180	13.5	16.5	200	23850	D,F,G,H,I,J,K,L,M,N
134.	68103116	68110903	227	29	70.	150	14.5	10.0	100	15890	F,D,F,G,H,I,J,K,M,N
135.	68111012	68111203	39	9	65.	140	9.3	12.0	289	2535	F,K
136.	68111613	68112218	149	45	75.	180	11.7	8.5	130	11175	D,F,I,K,L,M,N
137.	68112513	68120103	134	28	95.	140	15.0	12.0	270	13680	F,G,H,I,J,K,L,M,N
138.	68120118	68120512	90	16	70.	130	15.0	12.0	270	4950	F,H,I,K
139.	68120607	68121103	116	26	82.	130	15.0	12.0	270	9512	D,F,G,K,L
140.	68121213	68121600	86	19	75.	160	11.0	14.0	220	6450	D,F,G,K,L,M,N
141.	68122116	69010318	314	68	95.	050	15.2	14.5	200	29830	D,F,G,H,K,L
142.	69010718	69011100	102	15	99.	050	9.6	11.0	300	10098	D,F,I,K
143.	69012510	69012803	65	14	99.	050	9.0	8.5	340	6435	D,F,G,M,N
144.	69013018	69013121	27	7	99.	050	8.2	13.0	273	2673	D,F,I,L,M,N
145.	69020600	69020903	75	14	80.	160	11.5	8.5	180	5760	D,G,J,K,L,M,N
146.	69021003	69021206	63	16	56.	120	12.2	13.0	302	3192	D,F,H,I,K,L,M,N
147.	69021400	69021616	64	12	55.	170	8.0	8.5	150	3520	D,F,M,N
148.	69021915	69022315	96	22	52.	260	16.7	14.0	272	4992	H,I
149.	69040100	69040415	87	17	60.	130	10.0	8.5	200	5220	D,F,K,L,M,N
150.	69041800	69042203	99	23	63.	260	15.4	14.0	250	6237	D,F,G,H,I,K,L
151.	69050318	69050506	36	7	50.	250	9.6	13.0	266	1800	F,H,I,K
152.	69101100	69101321	69	10	53.	150	10.5	8.5	170	3657	D,M,N
153.	69102503	69102715	60	13	50.	050	11.7	11.0	210	3000	F,J,K
154.	69103109	69110812	219	28	80.	320	19.1	13.0	235	17520	D,F,G,H,I,J,K,L,M,N
155.	69111506	69120315	441	70	62.	260	14.4	12.0	238	27342	D,F,G,H,I,K,M,N
156.	69120418	69120809	86	28	57.	150	13.5	8.5	130	4902	D,J,K,M,N
157.	69121013	69121415	98	34	70.	140	15.7	8.0	260	6860	D,F,G,K,L,M,N
158.	69121521	69122516	235	53	61.	140	16.0	12.0	263	14335	D,F,H,I,K,M,N
159.	69122715	69123121	102	13	51.	170	12.5	8.5	190	5202	M,N
160.	70010318	70010700	78	18	60.	160	8.5	9.0	133	4680	D,F,K
161.	70011103	70011405	80	10	70.	050	9.0	7.0	190	5600	D,F,K
162.	70011812	70012403	135	39	70.	050	11.5	8.5	180	9450	D,F,K,M,N
163.	70012813	70013103	62	18	50.	140	8.5	8.5	190	3100	F,G,M,N
164.	70013118	70020512	114	31	64.	200	14.9	12.0	260	7296	D,F,G,H,I,K,M,N

TABLE A.1 MASTER LIST FOR THE WEST COAST (Cont'd)

	START YYMMDDHH - END YYMMDDHH	DUR (hr)	OBS	WIND SPD (kts)	WIND DIR	COMBINED SEA HS (m)	COMBINED SEA TP (s)	COMBINED SEA DIR	SEVERITY INDEX	SOURCE
165.	70021615-70022116	121	22	63.	210	16.0	8.5	190	6655	D,F,M,N
166.	70032012-70032403	87	11	50.	240	9.5	8.5	250	4350	F,G,K,M,N
167.	70040506-70040909	99	20	58.	130	11.0	8.5	180	5742	D,F,G,K,L,M,N
168.	70040911-70041006	19	17	62.	100	10.0	8.0	270	1178	J,K
169.	70042309-70042512	51	16	52.	290	28.9	-99.0	280	2244	H,I,K
170.	70101712-70101918	54	30	60.	120	12.5	14.0	311	3240	F,G,J,K,L
171.	70102109-70102412	75	26	61.	140	12.5	14.0	303	4575	D,F,G,H,I,J,K,L,M,N
172.	70102600-70110121	165	25	98.	040	9.5	8.5	140	16170	D,F,K,L,M,N
173.	70110918-70111409	111	52	63.	190	15.5	8.5	210	6993	D,K,L,M,N
174.	70112000-70112412	108	17	60.	150	11.3	12.0	100	6480	D,F,J,K,M,N
175.	70112604-70112803	47	13	70.	070	10.6	6.5	020	3150	F,K,L
176.	70112909-70120109	48	15	70.	070	10.6	6.5	020	3360	F,H,I,K,M,N
177.	70120415-70120715	72	43	76.	100	13.5	8.5	240	5472	D,F,G,K,L,M,N
178.	70120900-70121101	49	57	61.	310	14.8	14.5	290	2989	F,K,L,M,N
179.	70121115-70121803	156	34	68.	290	14.8	14.5	290	10608	D,F,J,K,L,M,N
180.	70121912-70122103	39	7	59.	340	11.1	6.0	319	2301	D,F,K,M,N
181.	70122218-70122500	54	8	54.	280	10.0	8.5	280	2916	J,K
182.	70122600-70122709	33	10	68.	150	14.1	14.0	275	2244	H,I,K,L
183.	70122815-71010118	99	15	68.	150	14.1	14.0	275	6324	D,F,G,K,L,M,N
184.	71010218-71010509	63	13	68.	150	15.0	8.5	150	4284	D,K,M,N
185.	71010918-71011318	96	49	56.	340	12.5	14.0	357	4800	F,J,K
186.	71011418-71011821	99	22	65.	050	9.6	10.0	122	6435	D,F,K,L,M,N
187.	71012000-71012312	84	23	50.	290	10.1	10.0	261	4200	K
188.	71012518-71012800	54	8	50.	260	9.6	6.0	286	2700	K
189.	71020200-71020405	53	15	57.	280	12.0	12.5	270	3021	J,K
190.	71021011-71021509	118	11	51.	330	10.8	12.0	265	6018	I,K,M,N
191.	71021621-71022200	123	19	54.	190	11.7	10.0	110	4374	D,H,I,K,M,N
192.	71022312-71022521	57	5	60.	320	18.0	13.0	284	3420	J,K,M,N
193.	71030109-71030403	66	20	60.	320	15.0	10.0	320	3960	D,F,G,H,I,K,L,M,N
194.	71030521-71031513	232	52	65.	110	12.6	11.0	265	15080	D,F,G,I,J,K,L,M,N
195.	71031603-71031809	54	8	51.	180	12.5	10.5	360	2754	I,M,N
196.	71032203-71032518	87	18	50.	050	8.5	14.0	255	4350	F,K
197.	71032721-71032903	30	10	60.	180	8.5	8.5	200	1800	E,F,M,N
198.	71033100-71040415	135	12	60.	140	9.5	8.5	200	8100	F,G,K,M,N
199.	71040800-71041006	54	13	53.	150	8.7	14.0	108	2597	H,I,K
200.	71041209-71041600	87	11	56.	240	11.5	8.5	220	4872	D,H,K,M,N
201.	71051418-71051617	47	17	58.	310	10.1	8.0	219	2726	K

TABLE A.1 MASTER LIST FOR THE WEST COAST (Cont'd)

	START YYMMDDHH – END YYMMDDHH	DUR (hr)	OBS	WIND SPD (kts)	WIND DIR	COMBINED SEA HS (m)	COMBINED SEA TP (s)	COMBINED SEA DIR	SEVERITY INDEX	SOURCE
202.	71082706-71082812	30	4	65.	320	12.0	5.0	300	1950	K
203.	71091000-71091218	66	9	50.	220	10.0	12.5	250	3300	H,I,K,M,N
204.	71100709-71101009	72	11	96.	120	12.0	8.5	170	2592	K,M,N
205.	71101903-71102215	84	22	57.	090	10.5	8.5	210	4788	F,G,H,I,K,L,M,N
206.	71103118-71110400	78	10	87.	130	8.0	7.0	190	6786	G,J,K,M,N
207.	71110503-71111000	117	29	97.	230	12.0	8.5	210	11349	F,H,I,J,K,L,M,N
208.	71111200-71111400	48	18	56.	240	11.2	10.0	317	2688	F,K,M,N
209.	71111503-71111606	27	10	60.	240	12.5	12.5	240	1620	J,K,M,N
210.	71112100-71112500	96	19	64.	010	15.0	7.0	350	6144	H,I,J,K,M,N
211.	71112721-71120306	129	14	52.	140	16.5	9.0	320	6708	F,J,K,L,M,N
212.	71120720-71121009	61	14	65.	320	20.2	10.0	130	3965	H,I,J,K,L,M,N
213.	71121318-71121418	24	6	65.	320	20.2	10.0	130	1560	H,I,K
214.	71121606-71121618	12	5	60.	230	8.5	8.0	260	720	K
215.	71122006-71122618	156	41	60.	360	11.4	12.0	334	9360	F,H,I,J,K,M,N
216.	71123003-72010103	48	9	60.	180	10.5	8.5	200	2880	F,M,N
217.	72010319-72010621	75	15	78.	220	16.9	10.5	245	5850	D,F,H,J,K,M,N
218.	72010718-72011203	105	46	81.	280	15.5	8.5	280	8505	D,F,G,H,I,J,K,M,N
219.	72011312-72011703	87	18	65.	140	16.5	10.5	250	5655	D,F,G,H,I,J,K,M,N
220.	72011706-72012203	117	28	77.	100	9.5	8.5	210	9009	D,F,K,M,N
221.	72012500-72012612	36	8	87.	230	8.9	12.0	140	3132	D,K,N
222.	72012700-72012900	48	1	87.	230	14.8	12.5	110	4176	J,K
223.	72020406-72021706	312	37	82.	110	13.0	8.5	190	26520	D,F,J,K,L,M,N
224.	72021806-72022303	117	59	93.	110	11.0	8.5	100	10881	D,F,J,K,L,M,N
225.	72022506-72030306	168	21	83.	110	18.0	8.0	048	13944	D,J,K,L,M,N
226.	72030712-72031015	75	16	68.	100	8.0	8.5	100	4080	D,K,M,N
227.	72031812-72032003	39	5	56.	200	10.5	8.5	180	2184	D,M,N
228.	72042200-72042403	51	25	91.	210	12.5	7.0	127	4641	D,J,K,M,N
229.	72042603-72042712	33	13	55.	140	8.0	8.5	220	1815	F,M,N
230.	72092008-72092200	40	5	55.	200	19.2	7.0	200	2200	F,K,L
231.	72100115-72100312	45	18	68.	200	10.5	8.5	210	3060	D,G,I,J,K,M,N
232.	72102006-72102600	138	9	98.	200	19.2	14.0	200	13524	F,J,K,M,N
233.	72110600-72110711	35	10	76.	250	8.3	8.0	150	2660	K,L
234.	72111212-72111312	24	3	58.	130	12.6	8.0	303	1392	K
235.	72111921-72112615	162	23	75.	260	18.0	14.0	216	11475	D,F,G,H,I,J,K,M,N
236.	72120500-72120715	63	9	65.	050	10.0	6.5	010	4095	F,J,K
237.	72121318-72121703	81	22	90.	120	13.0	8.5	170	7290	D,F,K,L,M,N
238.	72121815-72121915	24	9	58.	180	11.0	8.5	230	1392	D,K,M,N

TABLE A.1 MASTER LIST FOR THE WEST COAST (Cont'd)

	START YYMMDDHH - END YYMMDDHH	DUR (hr)	OBS	WIND SPD (kts)	WIND DIR	COMBINED SEA HS (m)	COMBINED SEA TP (s)	COMBINED SEA DIR	SEVERITY INDEX	SOURCE
239.	72122115-72122621	126	34	73.	210	18.0	8.5	210	9198	D,F,G,I,K,M,N
240.	72123113-73010115	26	12	59.	230	9.5	8.5	220	1534	D,F,G,M
241.	73010900-73011209	87	9	71.	200	23.5	10.0	120	5394	D,J,K,L,M,N
242.	73011500-73012423	239	46	85.	140	20.5	8.5	210	20315	D,F,G,J,K,L,M,N
243.	73012600-73020115	160	28	86.	160	14.1	6.5	160	13760	D,F,H,I,J,K,M,N
244.	73021100-73021200	24	3	54.	230	15.7	13.0	289	1296	K
245.	73021218-73021715	117	27	67.	190	15.5	8.5	160	7839	D,F,I,K,M,N
246.	73021912-73022109	45	11	56.	190	12.5	8.5	200	2520	D,I,M,N
247.	73022603-73022706	27	8	59.	130	8.5	8.5	200	1593	D,M,N
248.	73030918-73031915	237	26	61.	330	15.7	13.0	285	14457	D,H,I,K,L,M,N
249.	73052309-73052506	45	21	55.	100	13.5	14.0	302	2475	J,K,M,N
250.	73061100-73061400	72	17	61.	150	14.1	14.0	311	4392	D,J,K,M,N
251.	73101703-73101718	15	5	52.	200	10.3	6.5	185	780	K
252.	73102709-73103100	87	18	58.	180	11.5	8.5	250	5046	D,F,H,I,K,M,N
253.	73111018-73111119	25	4	50.	050	8.9	13.0	026	1250	F,K
254.	73111218-73111400	30	9	60.	080	10.5	8.5	320	1800	D,J,K
255.	73111818-73112200	78	46	87.	140	15.5	11.0	311	6786	D,H,I,J,K,L,M,N,P
256.	73112306-73112809	123	38	64.	280	13.5	8.5	280	7872	D,F,J,K,M,N
257.	73120212-73120700	108	27	75.	180	16.1	14.0	255	8100	D,F,K,L,M,N
258.	73121107-73121409	74	34	59.	110	11.5	8.5	200	4366	D,I,K,L,M,N
259.	73121504-73121609	29	16	64.	190	11.0	8.5	170	1856	L,M,N,P
260.	73121800-73122100	72	27	98.	180	15.5	8.5	180	7056	D,K,L,M,N
261.	73122303-73122518	63	17	87.	270	10.5	8.5	250	5481	I,K,M,N
262.	73122612-73122821	57	9	68.	160	10.5	8.5	120	2652	D,H,I,J,M,N
263.	74011200-74012000	192	62	83.	140	12.5	8.5	210	15936	D,F,G,J,K,L,M,N
264.	74012109-74012518	105	16	57.	290	12.5	8.5	250	5985	D,F,H,I,J,K,M,N
265.	74012700-74020315	183	23	64.	120	9.0	10.0	077	11712	D,F,G,K,M,N
266.	74021300-74021709	105	32	56.	190	11.0	8.5	180	5880	D,F,K,M,N
267.	74021918-74022500	126	21	63.	200	13.0	12.0	142	7938	D,F,H,I,K,L,M,N
268.	74022800-74022822	21	14	54.	110	13.5	11.0	110	1134	J,K,L
269.	74022823-74030102	3	2			7.4	12.4	-99	0	P
270.	74030312-74031221	225	66	76.	130	14.0	12.0	300	17100	D,F,J,K,L,M,N
271.	74040501-74040615	38	6	53.	240	9.5	8.5	240	2014	D,F,L,M,N
272.	74041015-74041409	90	17	64.	140	11.0	8.5	160	5760	D,K,M,N
273.	74093019-74100301	54	14	58.	220	10.3	12.0	230	2808	D,F,G,J,K
274.	74101112-74101203	15	5	60.	180	10.8	12.5	156	900	F,K
275.	74101318-74101603	57	16	61.	200	14.8	12.0	220	3477	D,F,G,H,I,J,K

TABLE A.1 MASTER LIST FOR THE WEST COAST (Cont'd)

	START-END	DUR	OBS	WIND		COMBINED SEA			SEVERITY	SOURCE
	YYMMDDHH YYMMDDHH	(hr)		SPD (kts)	DIR	HS (m)	TP (s)	DIR	INDEX	
276.	74102106-74102421	87	8	52.	170	15.0	13.0	220	4524	D,F.K
277.	74102603-74103118	135	28	80.	170	12.5	8.0	138	10800	D,H,I,J,K,M,N
278.	74110206-74110315	33	23	60.	200	8.0	8.5	190	1980	D,M,N
279.	74111418-74111818	96	18	65.	210	11.5	8.5	230	6240	D,H,I,L,K,M,N
280.	74112606-74112903	69	8	60.	170	12.0	10.5	170	2520	D,F,J,K,M,N
281.	74120700-74121100	96	19	62.	190	8.5	8.0	140	5568	D,F,K,M
282.	74121208-74121415	55	31	68.	120	9.9	10.0	250	3740	D,F,K,L,M,N
283.	74121612-74122603	231	27	74.	240	14.6	11.0	266	17094	D,F,G,K,L,M,N
284.	74122815-75010318	147	26	76.	200	16.3	12.0	243	11172	D,F,G,I,K,L,M,N
285.	75010404-75011403	239	40	107.	140	13.9	14.0	274	25573	D,F,G,H,I,K,L,M,N
286.	75013006-75020418	132	43	66.	100	14.1	10.5	320	8712	D,F,J,K
287.	75020606-75020806	48	23	68.	170	14.5	10.5	104	2928	D,F,J,K
288.	75021003-75022609	318	53	85.	330	18.4	10.5	250	27030	D,F,G,I,J,K,L,M,N
289.	75031900-75032600	168	39	78.	250	19.5	14.0	285	13104	H,I,J,K
290.	75033018-75040221	75	7	57.	290	15.3	9.0	295	4275	D,K,N
291.	75050800-75050903	27	10	70.	130	11.3	9.0	090	1890	D,J,K,M,N
292.	75100212-75100522	82	29	68.	220	10.5	8.5	240	5576	F,H,I,J,K,M,N
293.	75100806-75101012	54	15	50.	140	8.3	7.0	096	2700	K
294.	75101501-75101709	56	10	62.	210	10.0	8.5	210	3472	D,K,L,M,N
295.	75101815-75102009	42	23	68.	250	11.0	8.5	250	2856	D,J,K,M,N
296.	75102506-75102703	45	8	55.	190	9.0	8.5	310	2475	K,M,N
297.	75103100-75110403	126	30	73.	220	12.0	8.5	230	9198	D,F,G,K,L,M,N
298.	75110518-75110803	57	28	85.	250	21.5	14.0	235	4845	D,F,G,I,J,K,L,M,N,P
299.	75110918-75112003	249	95	79.	230	23.0	9.0	144	19671	D,F,G,I,J,K,L,M,N,P
300.	75112518-75112812	66	9	85.	300	9.5	8.5	290	5610	K,M,N
301.	75120508-75120804	68	24	60.	100	9.6	7.0	286	4080	D,F,K,M,N
302.	75121218-75121415	45	13	70.	230	11.3	9.0	295	2940	D,G,K,M,N
303.	75121603-75122212	153	46	74.	210	21.4	8.0	130	11322	D,H,I,J,K,L,M,N
304.	75122400-75122412	12	3	54.	140	14.5	8.5	200	648	D,F,M,N
305.	75122600-76010100	144	18	64.	260	14.5	8.5	200	9216	D,F,G,K,M,N,P
306.	76010413-76010822	105	31	75.	130	8.0	8.5	100	6300	D,F,M,N
307.	76011315-76011615	72	16	57.	130	9.0	8.5	270	4104	D,F,M,N
308.	76012006-76012221	63	10	50.	210	16.8	10.5	210	3150	I,J,K,M,N
309.	76012503-76013121	156	47	68.	200	14.0	8.5	190	10608	D,F,I,J,K,L,M,N
310.	76020712-76021121	114	21	64.	210	12.5	12.0	270	7296	D,F,G,I,K,M,N
311.	76021600-76021821	69	42	78.	270	14.5	8.5	290	3480	D,H,I,J,K,M,N,P
312.	76022108-76022821	181	31	60.	120	12.7	12.0	290	10860	D,F,J,K,M

TABLE A.1 MASTER LIST FOR THE WEST COAST (Cont'd)

	START	END	DUR	OBS	WIND		COMBINED SEA			SEVERITY	SOURCE
	YYMMDDHH	YYMMDDHH	(hr)		SPD (kts)	DIR	HS (m)	TP (s)	DIR	INDEX	
313.	76031515-	76031815	72	16	67.	230	16.3	14.0	226	4824	D,F,K,L,M,N
314.	76031918-	76032221	75	19	69.	180	16.3	14.0	226	5175	D,F,H,I,K,L,M,N
315.	76032315-	76032709	90	13	67.	230	16.3	14.0	226	6030	D,H,I,K,L,M,N
316.	76041318-	76041603	57	14	55.	150	13.5	8.0	299	3135	K,L,M,N
317.	76041706-	76041718	12	3	62.	260	10.6	8.5	228	744	J,K
318.	76042606-	76042718	36	9	60.	180	11.0	8.5	170	2160	D,K,M,N
319.	76050900-	76051021	45	10	58.	190	9.5	8.5	180	2610	D,M,N
320.	76100600-	76100615	15	4	56.	190	8.5	8.5	160	840	D,M,N
321.	76102311-	76102806	115	34	65.	240	10.0	8.5	190	7475	D,F,G,K,L,M,N
322.	76102918-	76110321	123	31	80.	140	12.1	8.5	220	9840	A,B,D,F,J,K,M,N
323.	76110721-	76110903	30	5	51.	180	12.5	8.5	200	1530	M,N
324.	76111206-	76111309	27	3	60.	160	10.8	9.0	160	1620	K,M,N
325.	76111406-	76111523	41	19	69.	160	12.7	16.5	240	2829	D,H,I,J,K,M,N
326.	76111918-	76112302	80	27	69.	150	10.6	8.0	130	5520	D,F,H,I,K,M,N
327.	76112615-	76112821	54	11	59.	160	10.0	8.5	190	3186	D,M,N
328.	76120800-	76121209	105	12	87.	340	10.0	8.5	220	9135	F,K,L,M,N
329.	76121121-	76121518	93	27	59.	180	9.0	8.5	200	5487	D,F,I,K,M,N
330.	76121812-	76122003	39	11	62.	130	9.0	8.5	130	2418	D,M,N
331.	76122400-	76122509	33	13	68.	190	10.5	8.5	130	1632	D,M,N
332.	76122709-	76123000	63	12	50.	290	9.5	8.5	170	3150	B,K,M,N
333.	77010103-	77010306	51	19	50.	270	16.8	14.0	324	2550	K,M,N
334.	77011400-	77011815	111	46	80.	190	11.0	8.5	220	8160	A,D,F,H,I,J,K,L,M,N
335.	77020112-	77020221	33	6	53.	170	11.0	8.5	160	1749	D,M,N
336.	77020321-	77020708	83	17	93.	180	11.2	9.0	200	7719	D,E,F,K,M,N
337.	77020818-	77021515	165	34	66.	180	11.4	10.0	215	9834	A,D,F,H,I,J,K,L,M,N
338.	77021718-	77022312	138	99	68.	250	18.0	14.0	239	9384	A.B,D,H,I,J,K,L,M,N
339.	77022506-	77030312	150	45	78.	270	11.3	8.5	255	11700	J,K
340.	77030409-	77031306	213	63	92.	140	16.6	12.0	266	19596	A,B,D,F,H,I,J,K,L
341.	77041018-	77041719	166	20	57.	230	14.1	11.0	250	9462	A,D,E,F,G,H,I,J,K,L
342.	77050218-	77050400	30	4	70.	210	8.1	14.0	275	2100	K
343.	77052517-	77052712	43	24	66.	110	13.6	10.0	246	2838	J,K,L
344.	77092206-	77092221	15	4	50.	260	9.9	10.0	270	750	K
345.	77101100-	77101518	114	26	93.	160	21.4	12.0	170	10602	D,F,J,H,K
346.	77101606-	77101800	42	5	93.	160	21.4	12.0	170	3906	D,H,IJ,,K
347.	77102106-	77102800	162	67	103.	260	21.4	12.0	170	16686	A,B,D,F,G,H,I,J,K,L,P
348.	77102806-	77102806	0	1			7.1	17.1	-99	0	P
349.	77110100-	77110215	39	17	65.	250	9.0	14.5	290	2535	D,F,G,K

TABLE A.1 MASTER LIST FOR THE WEST COAST (Cont'd)

	START END	DUR	OBS	WIND		COMBINED SEA			SEVERITY	SOURCE
	YYMMDDHH YYMMDDHH	(hr)		SPD (kts)	DIR	HS (m)	TP (s)	DIR	INDEX	
350.	77110606-77110717	35	13	65.	250	9.0	14.5	290	2275	F,K
351.	77110813-77110918	29	2	65.	250	9.0	14.5	290	1560	D,K,L
352.	77111002-77111616	158	93	71.	220	15.6	14.0	212	11218	D,F,G,H,I,J,K,L
353.	77112206-77112718	132	14	64.	140	11.4	10.0	104	8448	D,F,K
354.	77120218-77121518	312	34	75.	110	11.7	5.0	013	23400	B,D,F,J,K,L
355.	77121906-77122200	66	34	57.	100	13.4	10.5	130	3762	D,J,K
356.	78010318-78011000	150	45	83.	140	20.2	6.5	160	12450	D,F,G,J,K
357.	78010700-78011000	72	45	83.	140	9.0	6.5	120	5976	D,F,G,J
358.	78013006-78020117	59	16	52.	100	8.5	10.5	100	3068	F,K
359.	78020406-78021000	138	42	65.	140	11.7	8.0	232	8970	D,F,K,L
360.	78021121-78021218	21	12	65.	120	12.1	10.0	300	1365	D,K
361.	78021400-78021918	138	36	67.	160	15.6	8.5	230	9246	D,H,I,J,K
362.	78030606-78030813	55	16	68.	300	14.1	6.5	220	3740	D,F,J,K,L
363.	78040321-78040606	57	11	54.	230	11.0	11.0	236	3078	K
364.	78040918-78041116	46	9	55.	160	20.6	12.5	160	2530	K,L
365.	78042921-78050212	63	16	61.	220	13.9	12.5	247	3843	D,F,I,J,K
366.	78051406-78051506	24	3	98.	170	10.8	7.0	297	2352	K
367.	78091200-78091518	90	35	69.	050	17.0	8.0	155	6210	J,K
368.	78092612-78092800	36	12	55.	190	16.7	14.0	090	1980	J,K
369.	78093000-78100112	36	4	51.	180	14.1	8.0	069	1836	J,K
370.	78100706-78101100	90	30	70.	190	10.6	7.0	146	6300	D,I,K
371.	78101312-78101418	30	4	65.	230	8.0	5.0	180	1950	K
372.	78102818-78110206	108	60	72.	210	12.5	12.5	220	7776	A,B,D,F,G,J,K
373.	78110412-78110618	54	22	57.	240	10.8	8.5	230	2970	D,J,K
374.	78111100-78111200	24	17	60.	310	10.6	12.0	333	1440	K
375.	78112606-78112800	42	9	50.	240	9.7	6.0	236	2100	K
376.	78120218-78120512	66	17	63.	250	11.9	12.0	247	4158	D,K
377.	78121010-78121111	25	18	54.	100	9.9	7.0	100	1350	K,L
378.	78121108-78121806	166	87	70.	250	19.8	8.5	260	11620	A,B,D,F,G,H,I,J,K,L
379.	78122004-78122412	104	41	65.	260	11.7	7.0	274	6760	D,F,G,J,K
380.	78123112-79010405	89	14	60.	120	10.3	12.5	140	5340	K
381.	79010912-79011018	30	12	63.	140	10.5	8.5	126	1890	D,F,K
382.	79011706-79012012	78	30	59.	210	13.7	7.0	209	2124	D,H,I,K,L
383.	79020406-79020513	18	98	101.	250	9.6	12.0	262	1818	A,B,D,G,K
384.	79021102-79022018	232	98	101.	330	18.0	10.0	324	23432	A,B,D,F,J,K,L,P
385.	79030215-79030818	147	39	61.	180	10.0	10.5	160	8967	D,F,J,K,L
386.	79031206-79031412	54	30	58.	200	12.4	13.0	270	3132	A,D,J,K

TABLE A.1 MASTER LIST FOR THE WEST COAST (Cont'd)

	START YYMMDDHH – END YYMMDDHH	DUR (hr)	OBS	WIND SPD (kts)	WIND DIR	COMBINED SEA HS (m)	COMBINED SEA TP (s)	COMBINED SEA DIR	SEVERITY INDEX	SOURCE
387.	79041211-79041312	25	40	77.	290	14.1	5.0	250	1925	B,D,J,K
388.	79050812-79051106	66	20	64.	270	10.6	7.0	140	4224	D,H,I,K
389.	79091206-79091312	30	8	57.	210	9.3	11.0	196	1710	D,K
390.	79092812-79100600	180	19	58.	180	21.3	13.0	193	10440	D,F,H,I,K
391.	79101720-79102009	61	51	58.	340	9.9	11.0	205	2989	A,B,D,K
392.	79102112-79102712	144	84	82.	280	9.0	10.5	230	11808	A,B,D,J
393.	79102112-79103005	209	112	82.	280	12.2	14.0	206	17138	A,B,D,G,J,K,L
394.	79111400-79111500	24	12	51.	150	8.8	8.5	169	1224	K
395.	79111806-79112312	126	79	97.	130	17.7	10.5	000	12222	B,D,F,G,I,J,K,L
396.	79112600-79120412	204	159	91.	150	16.8	13.0	131	18564	B,D,F,H,I,J,K
397.	79120518-79120618	24	7	92.	270	18.0	10.0	350	2208	J,K
398.	79120918-79122121	291	68	81.	100	18.4	12.0	180	23571	D,F,G,H,I,J,K,L
399.	79122223-79010500	313	39	79.	190	18.4	12.0	180	24101	B,D,F,G,I,J,K
400.	80031215-80031321	30	20	65.	280	9.5	10.5	240	1380	A,B,D
401.	80031608-80031702	18	17	53.	140	8.1	7.0	167	954	F,K
402.	80110212-80110406	42	11	55.	220	9.0	10.5	180	2310	D,H,I
403.	80112605-80112808	51	42	90.	160	9.7	12.0	245	4590	B,D,F,G,H
404.	80112621-80112709	12	5	51.	260	9.7	12.0	243	612	I
405.	80112911-80112911	0	1			7.6	12.4	-99	0	P
406.	81011705-81012405	168	60	70.	180	9.0	8.5	170	11760	A,B,F,G,H,I
407.	81031600-81031817	52	20	68.	150	9.0	14.5	110	3536	A,D,H,I
408.	81042918-81050106	36	8	53.	260	10.0	12.5	360	1908	D,H,I,K
409.	81091706-81091818	36	19	66.	220	11.5	10.5	-099	2376	A,B,D,K
410.	81100512-81100801	61	26	73.	170	8.5	10.5	-099	4453	A,D
411.	81110917-81111218	73	9	52.	140	8.5	8.5	-099	3796	A,B,F
412.	81112512-81112705	41	34	50.	290	11.0	10.5	-099	2050	A,B,K
413.	81113020-81120602	126	157	67.	190	10.0	12.5	-099	8442	A,B,D,F,G
414.	81121306-81122003	165	81	74.	180	8.5	10.5	-099	12210	A,B,D,F,G
415.	82012518-82012612	18	15	65.	180	10.5	10.5	-099	1170	B,D,P
416.	82042612-82042721	33	10	61.	180	9.0	10.5	120	945	D,J,K
417.	82100500-82100606	30	19	62.	210	9.5	10.0	180	1860	B,D,G,J,K
418.	82121400-82121621	69	47	72.	240	8.0	8.5	-099	4968	B,D,F,G,P
419.	82121713-82121906	41	9	73.	170	10.1	12.0	230	2993	B,D,K,P
420.	83012709-83012709	0	1			7.2	17.1	-99	0	P
421.	83021121-83021121	0	1			7.3	12.4	-99	0	P
422.	83040212-83040212	0	1			7.1	17.1	-99	0	P
423.	83110806-83111202	92	44	74.	180	10.8	8.0	170	6808	D,F,G,K,P

TABLE A.1 MASTER LIST FOR THE WEST COAST (Cont'd)

	START YYMMDDHH	END YYMMDDHH	DUR (hr)	OBS	WIND SPD (kts)	WIND DIR	COMBINED SEA HS (m)	COMBINED SEA TP (s)	COMBINED SEA DIR	SEVERITY INDEX	SOURCE
424.	84020112	84020218	30	2	56.	190	18.0	14.0	196	1680	D,J,K
425.	84030318	84030500	30	3	53.	170	14.5	10.0	160	1590	D,J
426.	84032718	84032806	12	2	58.	280	9.5	10.5	-099	696	B,D
427.	84040616	84041018	98	47	70.	280	17.0	11.0	245	6860	C,D,G,J,K,P
428.	84050706	84050906	48	10	55.	150	17.5	14.5	142	2640	D,J,K
429.	84100602	84100806	52	26	63.	180	8.0	8.5	190	3276	A,D
430.	84100906	84101107	49	46	60.	180	8.5	10.5	160	2940	A,D
431.	84101203	84101400	51	76	90.	270	13.0	14.0	238	4590	A,B,D,G,K,L,P
432.	84103106	84110411	101	117	76.	170	10.5	10.5	270	7676	A,B,D,K,P
433.	84111712	84111904	40	24	57.	180	8.5	10.5	290	2280	A,D,G
434.	84112617	84112923	78	35	73.	170	8.0	8.5	160	5694	A,B,D
435.	84121212	84121506	66	9	80.	300	14.1	10.0	270	5280	G,K
436.	85021018	85021518	120	54	89.	100	12.5	12.5	250	10680	A,D,G,P
437.	85030312	85030512	48	21	72.	330	14.1	12.0	310	3456	A,B,D,J,K
438.	85032318	85032321	3	10			8.7	13.7	-99	0	P
439.	85040405	85040405	0	1			7.0	14.3	-99	0	P
440.	85042516	85042616	24	16	56.	160	9.0	13.3	-99	1344	D,G,
441.	85120400	85120515	39	36	78.	160	8.5	14.5	230	3042	A,D,P
442.	86010521	86011406	201	108	97.	160	9.5	16.5	210	19497	A,D,G,K,L,P
443.	86012418	86012606	36	30	68.	190	8.0	11.8	-99	2448	D,P
444.	86021406	86021607	49	10	58.	120	10.0	11.0	065	2842	D,G,K
445.	86022606	86030306	120	32	67.	190	10.7	18.2	-99	8040	D,P
446.	86032103	86032107	4	16			8.7	12.4	-99	0	P
447.	86042400	86042518	42	16	64.	330	14.0	12.5	290	2688	D,J,K,P
448.	86092312	86092512	48	41	57.	320	11.0	16.5	330	2736	A,D
449.	86111718	86112021	75	51	83.	320	12.5	16.5	260	6059	A,B,D,G,K,P
450.	86112118	86112919	193	74	73.	270	13.5	14.5	230	14089	A,B,D,G,L,P
451.	86122300	86122700	96	35	67.	180	9.8	12.4	-99	3360	A,D,G,L,P
452.	86122718	87010415	189	47	72.	180	9.0	20.5	170	13608	A,D,L,P
453.	87010618	87011018	96	33	70.	180	10.0	0.0	340	6720	D,G,J,L,P
454.	87012412	87012812	96	40	66.	250	8.0	14.5	200	6336	A,D,P
455.	87012823	87013112	61	16	66.	160	8.6	10.5	-99	4026	D,G,P
456.	87020116	87020120	3	2			7.5	13.5	-99	0	P
457.	87020307	87020608	73	21	65.	210	9.3	16.7	-99	4745	A,D,L,P
458.	87021821	87021821	0	1			8.8	16.7	-99	0	P
459.	87021906	87022115	57	19	60.	140	9.0	15.4	-99	3420	A,D,P
460.	87040600	87041121	141	29	63.	230	8.0	12.5	250	8883	A,D,G,P

TABLE A.1 MASTER LIST FOR THE WEST COAST (Cont'd)

	START	END	DUR	OBS	WIND		COMBINED SEA			SEVERITY	SOURCE
	YYMMDDHH	YYMMDDHH	(hr)		SPD (kts)	DIR	HS (m)	TP (s)	DIR	INDEX	
461.	87041217	87041700	103	40	71.	250	10.6	14.3	-99	3871	A,D,G,P
462.	87100406	87100513	31	26	89.	270	11.0	15.1	-99	2759	A,D,J,K,P
463.	87102702	87102707	5	6			7.9	16.0	-99	0	P
464.	87110602	87110605	3	4			8.4	11.1	-99	0	P
465.	87111115	87111118	3	4			7.7	14.3	-99	0	P
466.	87111403	87111406	3	2			7.6	14.3	-99	0	P
467.	87111618	87111807	37	17	63.	140	8.6	12.8	-99	2331	D,P
468.	87113000	87120216	64	75	95.	190	13.6	20.0	-99	6080	D,G,L,P
469.	87120418	87121103	153	128	76.	190	11.5	10.5	160	11628	C,D,G,J,K,L,P
470.	87122103	87122212	33	20			8.4	16.7	-99	0	P
471.	88010917	88011007	14	13	72.	270	9.2	11.1	-99	1008	D,G,P
472.	88011200	88011603	98	50	77.	150	10.2	14.3	-99	7546	D,G,P
473.	88012400	88012508	32	22	65.	220	9.0	17.1	-99	1560	D,G,P
474.	88020312	88020606	66	25	89.	130	8.3	12.8	-99	5874	D,P
475.	88021512	88021514	2	2			7.0	12.8	-99	0	P
476.	88030406	88030618	60	71	67.	200	12.0	14.2	-99	4020	D,G,P
477.	88032218	88032320	26	7	55.	230	9.1	14.3	-99	660	D,P
478.	88032902	88032902	0	1			7.0	12.2	-99	0	P
479.	88040300	88040302	2	2			7.7	12.5	-99	0	P
480.	88040806	88041206	96	27	79.	170	10.6	14.0	200	7584	D,K,P
481.	88041418	88041609	39	13	68.	180	9.7	18.3	-99	2040	D,P
482.	88060210	88060312	26	18	82.	230	8.8	14.3	-99	2132	D,L,P
483.	88110922	88110922	0	1			7.8	11.1	-99	0	P
484.	88111200	88111212	12	4			7.1	13.5	-99	0	P
485.	88111818	88112409	135	106	78.	150	11.2	14.2	-99	8424	D,G,L,P
486.	88112618	88112812	41	39	86.	260	14.8	17.1	-99	2580	D,G,P
487.	88112906	88120104	46	74	78.	210	12.2	14.2	-99	3588	D,G,P
488.	88120206	88120402	44	31	72.	170	9.6	15.1	-99	3168	D,P
489.	88122006	88122212	54	27	69.	320	11.6	16.7	-99	3726	D,P
490.	88122216	88122306	13	10			7.5	15.1	-99	0	P
491.	88122822	88123106	55	30	52.	330	8.6	11.8	-99	2860	D,P
492.	89010320	89010320	0	1			7.0	13.5	-99	0	P
493.	89010904	89011011	31	15			7.8	13.5	-99	0	P
494.	89011121	89011121	0	1			7.2	9.0	-99	0	P
495.	89011320	89011401	5	4			8.1	16.0	-99	0	P
496.	89011618	89011803	33	34			8.6	12.2	-99	0	P
497.	89012002	89012010	7	17			11.2	16.0	-99	0	P
498.	89012608	89012612	4	4			7.3	11.1	-99	0	P
499.	89012723	89012809	10	14			8.2	12.2	-99	0	P
500.	89020200	89020205	5	3			7.3	11.6	-99	0	P

TABLE A.2 TOP 297 STORMS FOR THE WEST COAST

All these remaining storms have:
winds >= 60 kts unless wind >= 55 kts had waves >= 10 m
waves >= 9.5 m
dur >= 12 hrs except MEDS

Sources :

A)	BUOY wave	>= 8 m	or	>= 45 kts	
B)	BUOY wind	>= 8 m	or	>= 45 kts	
C)	ESTEVAN wind			>= 45 kts	
D)	GWC wind			>= 50 kts	and >= 12 hrs
E)	LIGHT wave	>= 8 m	or	>= 45 kts	
F)	LIGHT wind	>= 8 m	or	>= 45 kts	and >= 6 hrs
G)	NORTH wind			>= 45 kts	and >= 6 hrs
H)	PAPA wave	>= 8 m	or	>= 45 kts	
I)	PAPA wind	>= 8 m	or	>= 45 kts	
J)	SHIP wave	>= 8 m	or	>= 45 kts	
K)	SHIP wind	>= 7 m	or	>= 45 kts	
L)	SOUTH wind			>= 45 kts	and >= 6 hrs
M)	SOWM wave	>= 8 m	or	>= 45 kts	
N)	SOWM wind	>= 8 m	or	>= 45 kts	
P)	MEDS	>= 7 m			

	START YYMMDDHH	END YYMMDDHH	DUR (hr)	OBS	WIND SPD (kts)	WIND DIR	COMBINED SEA HS (m)	COMBINED SEA TP (s)	COMBINED SEA DIR	SEVERITY INDEX	SOURCE
1.	57122210	57123003	185	19	52.	160	9.5	14.5	270	3744	G,I,J,L
3.	58021704	58021906	58	19	72.	130	9.5	12.5	180	4176	D,J,L
4.	58030500	58030912	108	29	64.	300	9.5	12.5	320	6912	I,J,K
5.	58041706	58041821	39	14	74.	250	9.5	8.5	250	2886	J,K
6.	58102810	58110218	128	21	78.	150	9.5	8.5	180	9984	D,G,I,J,K,L
7.	58110415	58111415	240	44	75.	260	9.5	12.5	240	18000	D,G,I,J,K
8.	58112900	58120300	96	18	61.	090	9.5	16.5	220	5856	J,K,L
11.	59021600	59021812	60	13	65.	020	9.5	12.5	020	3900	D,J,K
12.	59022412	59030400	180	33	70.	240	9.5	16.5	250	12600	D,G,I,J
15.	59120906	59121200	66	16	76.	280	9.5	8.5	230	4352	D,G,I,J,K,L
16.	59121705	59121906	49	11	60.	300	9.5	14.5	270	2880	J,K,L
19.	60012806	60020110	100	28	84.	200	9.5	14.5	130	8400	D,G,I,J,K,L
20.	60020422	60020715	65	32	73.	160	9.5	14.5	200	4745	D,I,J,K,L
22.	60040815	60041018	51	11	50.	320	9.5	14.5	230	2550	G,J,K
24.	60102218	60102618	96	27	71.	220	9.5	10.5	230	6816	D,G,I,J,K,L
26.	60110106	60110312	54	5	60.	230	9.5	10.5	230	3240	J,K
27.	60111609	60112512	219	55	78.	270	9.5	20.5	250	17082	D,G,I,J,K,L
30.	61101210	61101512	76	8	61.	160	9.5	12.5	250	4636	G,J,K

TABLE A.2 TOP 297 STORMS (Cont'd)

	START YYMMDDHH	END YYMMDDHH	DUR (hr)	OBS	WIND SPD (kts)	WIND DIR	COMBINED SEA HS (m)	COMBINED SEA TP (s)	COMBINED SEA DIR	SEVERITY INDEX	SOURCE
31.	61102406	61102900	114	16	58.	270	9.5	10.5	260	6612	I,J,K
32.	61111915	61112312	93	18	52.	250	9.5	18.5	260	4371	G,I,J,K
33.	61112500	61112612	36	10	55.	290	9.5	8.5	190	1980	I,J
34.	61120212	61120515	75	19	68.	250	9.5	12.5	300	5100	D,G,I,J
35.	61121612	61121818	54	13	57.	300	9.5	10.5	100	3078	D,J,K
36.	61122119	61122306	36	7	57.	180	9.5	10.5	190	2052	D,G,J,K
37.	61122618	61122712	18	3	60.	140	9.5	8.5	140	1080	J,K
40.	62030509	62030618	33	15	57.	360	9.5	14.5	340	1881	J,K
41.	62032112	62032221	33	17	56.	290	9.5	12.5	280	1848	J,K
43.	62092715	62093007	64	18	62.	310	9.5	18.5	260	3968	D,G,I,J,K,L
45.	62111800	62120207	343	33	65.	220	10.5	14.5	188	22295	D,G,I,J,K,L
46.	62120406	62120506	24	10	59.	220	9.5	8.5	240	1416	D,G,I,J,K
51.	63020612	63020803	39	23	67.	180	9.5	14.5	170	2613	D,I,J,K
54.	63032700	63033012	84	16	60.	310	9.5	12.5	270	5040	D,H,I,J,K
55.	63101000	63101300	72	29	68.	270	12.4	18.5	190	4896	D,I,J,K
56.	63101918	63102517	143	42	74.	290	12.7	16.5	260	10582	D,G,H,I,J,K
62.	64011318	64011806	108	23	70.	310	9.5	12.5	280	7560	D,G,H,I,J,K,L
63.	64020816	64021818	242	28	60.	140	10.3	6.5	-099	14520	F,G,I,J,K
66.	64101403	64101915	132	23	70.	140	12.0	16.5	180	9240	D,F,G,I,K,M,N
71.	64120406	64120900	114	44	60.	180	12.6	10.5	244	6840	D,F,G,J,K,M,N
72.	64122600	64123003	99	30	63.	320	9.5	14.5	300	6237	D,G,I,J,K,M,N
76.	65050209	65050418	57	11	55.	100	12.0	14.5	295	2970	G,H,I,K,M,N
77.	65100203	65100621	114	24	65.	300	11.5	16.5	180	7410	D,H,I,J,K,L,M,N
81.	65112709	65120503	186	43	57.	200	10.0	16.5	170	10602	D,F,G,K,L,M,N
84.	65122715	66010215	144	37	65.	140	9.7	18.5	327	9360	D,J,K,M,N
91.	66091406	66091721	87	11	65.	250	9.5	10.5	250	5655	H,I,K,M,N
95.	66103112	66110206	42	11	60.	270	10.5	14.5	150	2520	D,K,M,N
96.	66111812	66112100	60	18	56.	340	12.7	14.5	000	3360	J,K
97.	66112900	66120100	48	12	61.	090	9.5	14.5	060	2623	D,G,H,I,J,K
98.	66120903	66121809	222	49	56.	130	11.0	16.5	190	12432	F,G,K,M,N
99.	67010615	67011306	159	26	82.	250	12.0	16.5	160	13038	D,F,G,K,M,N
101.	67011718	67012112	90	28	63.	210	11.5	18.5	220	5670	D,H,I,M,N
102.	67013013	67020522	153	25	62.	220	10.0	16.5	220	9486	D,F,G,H,I,L,M,N
103.	67020706	67021306	144	27	70.	230	12.0	10.5	226	10080	G,H,I,J,K,M,N
104.	67021700	67021807	30	10	60.	300	9.5	20.5	300	1800	J,K,L,M,N
105.	67022522	67022722	48	16	61.	180	9.5	14.5	180	2928	F,G,M,N
109.	67102406	67102712	78	18	61.	140	10.0	14.5	180	4056	F,G,J,K,L,M,N
111.	67112815	67120822	247	206	84.	130	13.5	18.5	280	20748	D,F,G,H,I,J,K,L,M,N
112.	67120912	67121603	159	32	66.	020	13.5	20.5	190	9108	D,F,H,I,J,K,M,N

TABLE A.2 TOP 297 STORMS (Cont'd)

	START YYMMDDHH	END YYMMDDHH	DUR (hr)	OBS	WIND SPD (kts)	WIND DIR	COMBINED SEA HS (m)	COMBINED SEA TP (s)	COMBINED SEA DIR	SEVERITY INDEX	SOURCE
114.	68010400	68010512	36	5	90.	290	12.4	14.0	290	3240	K
115.	68010712	68011603	207	46	89.	210	11.5	8.5	110	18423	D,F,G,J,K,L,M,N
117.	68012121	68012618	117	18	89.	210	11.5	8.5	190	10413	F,G,J,K,M,N
118.	68013106	68020106	24	9	89.	210	11.3	14.0	325	1392	D,K
120.	68020518	68021012	114	27	62.	170	11.4	14.0	180	7068	K,M,N
122.	68022509	68022803	66	28	60.	170	14.0	8.5	160	3960	D,I,M,N
124.	68031015	68031400	81	20	80.	140	10.0	8.5	160	6480	D,I,K,M,N
125.	68031918	68032203	57	18	60.	140	12.0	8.5	160	3420	D,F,M,N
133.	68101412	68102718	318	53	75.	180	13.5	16.5	200	23850	D,F,G,H,I,J,K,L,M,N
134.	68103116	68110903	227	29	70.	150	14.5	10.0	100	15890	F,D,F,G,H,I,J,K,M,N
136.	68111613	68112218	149	45	75.	180	11.7	8.5	130	11175	D,F,I,K,L,M,N
137.	68112513	68120103	134	28	95.	140	15.0	12.0	270	13680	F,G,H,I,J,K,L,M,N
138.	68120118	68120512	90	16	70.	130	15.0	12.0	270	4950	F,H,I,K
139.	68120607	68121103	116	26	82.	130	15.0	12.0	270	9512	D,F,G,K,L
140.	68121213	68121600	86	19	75.	160	11.0	14.0	220	6450	D,F,G,K,L,M,N
141.	68122116	69010318	314	68	95.	050	15.2	14.5	200	29830	D,F,G,H,K,L
142.	69010718	69011100	102	15	99.	050	9.6	11.0	300	10098	D,F,I,K
145.	69020600	69020903	75	14	80.	160	11.5	8.5	180	5760	D,G,J,K,L,M,N
146.	69021003	69021206	63	16	56.	120	12.2	13.0	302	3192	D,F,H,I,K,L,M,N
149.	69040100	69040415	87	17	60.	130	10.0	8.5	200	5220	D,F,K,L,M,N
150.	69041800	69042203	99	23	63.	260	15.4	14.0	250	6237	D,F,G,H,I,K,L
154.	69103109	69110812	219	28	80.	320	19.1	13.0	235	17520	D,F,G,H,I,J,K,L,M,N
155.	69111506	69120315	441	70	62.	260	14.4	12.0	238	27342	D,F,G,H,I,K,M,N
156.	69120418	69120809	86	28	57.	150	13.5	8.5	130	4902	D,J,K,M,N
157.	69121013	69121415	98	34	70.	140	15.7	8.0	260	6860	D,F,G,K,L,M,N
158.	69121521	69122516	235	53	61.	140	16.0	12.0	263	14335	D,F,H,I,K,M,N
162.	70011812	70012403	135	39	70.	050	11.5	8.5	180	9450	D,F,K,M,N
164.	70013118	70020512	114	31	64.	200	14.9	12.0	260	7296	D,F,G,H,I,K,M,N
165.	70021615	70022116	121	22	63.	210	16.0	8.5	190	6655	D,F,M,N
167.	70040506	70040909	99	20	58.	130	11.0	8.5	180	5742	D,F,G,K,L,M,N
168.	70040911	70041006	19	17	62.	100	10.0	8.0	270	1178	J,K
170.	70101712	70101918	54	30	60.	120	12.5	14.0	311	3240	F,G,J,K,L
171.	70102109	70102412	75	26	61.	140	12.5	14.0	303	4575	D,F,G,H,I,J,K,L,M,N
172.	70102600	70110121	165	25	98.	040	9.5	8.5	140	16170	D,F,K,L,M,N
173.	70110918	70111409	111	52	63.	190	15.5	8.5	210	6993	D,K,L,M,N
174.	70112000	70112412	108	17	60.	150	11.3	12.0	100	6480	D,F,J,K,M,N
175.	70112604	70112803	47	13	70.	070	10.6	6.5	020	3150	F,K,L
176.	70112909	70120109	48	15	70.	070	10.6	6.5	020	3360	F,H,I,K,M,N
177.	70120415	70120715	72	43	76.	100	13.5	8.5	240	5472	D,F,G,K,L,M,N

TABLE A.2 TOP 297 STORMS (Cont'd)

	START YYMMDDHH	END YYMMDDHH	DUR (hr)	OBS	WIND SPD (kts)	WIND DIR	COMBINED SEA HS (m)	COMBINED SEA TP (s)	COMBINED SEA DIR	SEVERITY INDEX	SOURCE
178.	70120900	70121101	49	57	61.	310	14.8	14.5	290	2989	F,K,L,M,N
179.	70121115	70121803	156	34	68.	290	14.8	14.5	290	10608	D,F,J,K,L,M,N
180.	70121912	70122103	39	7	59.	340	11.1	6.0	319	2301	D,F,K,M,N
182.	70122600	70122709	33	10	68.	150	14.1	14.0	275	2244	H,I,K,L
183.	70122815	71010118	99	15	68.	150	14.1	14.0	275	6324	D,F,G,K,L,M,N
184.	71010218	71010509	63	13	68.	150	15.0	8.5	150	4284	D,K,M,N
185.	71010918	71011318	96	49	56.	340	12.5	14.0	357	4800	F,J,K
186.	71011418	71011821	99	22	65.	050	9.6	10.0	122	6435	D,F,K,L,M,N
189.	71020200	71020405	53	15	57.	280	12.0	12.5	270	3021	J,K
192.	71022312	71022521	57	5	60.	320	18.0	13.0	284	3420	J,K,M,N
193.	71030109	71030403	66	20	60.	320	15.0	10.0	320	3960	D,F,G,H,I,K,L,M,N
194.	71030521	71031513	232	52	65.	110	12.6	11.0	265	15080	D,F,G,I,J,K,L,M,N
198.	71033100	71040415	135	12	60.	140	9.5	8.5	200	8100	F,G,K,M,N
200.	71041209	71041600	87	11	56.	240	11.5	8.5	220	4872	D,H,K,M,N
201.	71051418	71051617	47	17	58.	310	10.1	8.0	219	2726	K
202.	71082706	71082812	30	4	65.	320	12.0	5.0	300	1950	K
204.	71100709	71101009	72	11	96.	120	12.0	8.5	170	2592	K,M,N
205.	71101903	71102215	84	22	57.	090	10.5	8.5	210	4788	F,G,H,I,K,L,M,N
207.	71110503	71111000	117	29	97.	230	12.0	8.5	210	11349	F,H,I,J,K,L,M,N
208.	71111200	71111400	48	18	56.	240	11.2	10.0	317	2688	F,K,M,N
209.	71111503	71111606	27	10	60.	240	12.5	12.5	240	1620	J,K,M,N
210.	71112100	71112500	96	19	64.	010	15.0	7.0	350	6144	H,I,J,K,M,N
212.	71120720	71121009	61	14	65.	320	20.2	10.0	130	3965	H,I,J,K,L,M,N
213.	71121318	71121418	24	6	65.	320	20.2	10.0	130	1560	H,I,K
215.	71122006	71122618	156	41	60.	360	11.4	12.0	334	9360	F,H,I,J,K,M,N
216.	71123003	72010103	48	9	60.	180	10.5	8.5	200	2880	F,M,N
217.	72010319	72010621	75	15	78.	220	16.9	10.5	245	5850	D,F,H,J,K,M,N
218.	72010718	72011203	105	46	81.	280	15.5	8.5	280	8505	D,F,G,H,I,J,K,M,N
219.	72011312	72011703	87	18	65.	140	16.5	10.5	250	5655	D,F,G,H,I,J,K,M,N
220.	72011706	72012203	117	28	77.	100	9.5	8.5	210	9009	D,F,K,M,N
222.	72012700	72012900	48	1	87.	230	14.8	12.5	110	4176	J,K
223.	72020406	72021706	312	37	82.	110	13.0	8.5	190	26520	D,F,J,K,L,M,N
224.	72021806	72022303	117	59	93.	110	11.0	8.5	100	10881	D,F,J,K,L,M,N
225.	72022506	72030306	168	21	83.	110	18.0	8.0	048	13944	D,J,K,L,M,N
227.	72031812	72032003	39	5	56.	200	10.5	8.5	180	2184	D,F,M,N
228.	72042200	72042403	51	25	91.	210	12.5	7.0	127	4641	D,J,K,M,N
230.	72092008	72092200	40	5	55.	200	19.2	7.0	200	2200	F,K,L
231.	72100115	72100312	45	18	68.	200	10.5	8.5	210	3060	D,G,I,J,K,M,N
232.	72102006	72102600	138	9	98.	200	19.2	14.0	200	13524	F,J,K,M,N

TABLE A.2 TOP 297 STORMS (Cont'd)

	START YYMMDDHH	END YYMMDDHH	DUR (hr)	OBS	WIND SPD (kts)	WIND DIR	COMBINED SEA HS (m)	COMBINED SEA TP (s)	COMBINED SEA DIR	SEVERITY INDEX	SOURCE
234.	72111212	72111312	24	3	58.	130	12.6	8.0	303	1392	K
235.	72111921	72112615	162	23	75.	260	18.0	14.0	216	11475	D,F,G,H,I,J,K,M,N
236.	72120500	72120715	63	9	65.	050	10.0	6.5	010	4095	F,J,K
237.	72121318	72121703	81	22	90.	120	13.0	8.5	170	7290	D,F,K,L,M,N
238.	72121815	72121915	24	9	58.	180	11.0	8.5	230	1392	D,K,M,N
239.	72122115	72122621	126	34	73.	210	18.0	8.5	210	9198	D,F,G,I,K,M,N
241.	73010900	73011209	87	9	71.	200	23.5	10.0	120	5394	D,J,K,L,M,N
242.	73011500	73012423	239	46	85.	140	20.5	8.5	210	20315	D,F,G,J,K,L,M,N
243.	73012600	73020115	160	28	86.	160	14.1	6.5	160	13760	D,F,H,I,J,K,M,N
245.	73021218	73021715	117	27	67.	190	15.5	8.5	160	7839	D,F,I,K,M,N
246.	73021912	73022109	45	11	56.	190	12.5	8.5	200	2520	D,I,M,N
248.	73030918	73031915	237	26	61.	330	15.7	13.0	285	14457	D,H,I,K,L,M,N
249.	73052309	73052506	45	21	55.	100	13.5	14.0	302	2475	J,K,M,N
250.	73061100	73061400	72	17	61.	150	14.1	14.0	311	4392	D,J,K,M,N
252.	73102709	73103100	87	18	58.	180	11.5	8.5	250	5046	D,F,H,I,K,M,N
254.	73111218	73111400	30	9	60.	080	10.5	8.5	320	1800	D,J,K
255.	73111818	73112200	78	46	87.	140	15.5	11.0	311	6786	D,H,I,J,K,L,M,N,P
256.	73112306	73112809	123	38	64.	280	13.5	8.5	280	7872	D,F,J,K,M,N
257.	73120212	73120700	108	27	75.	180	16.1	14.0	255	8100	D,F,K,L,M,N
258.	73121107	73121409	74	34	59.	110	11.5	8.5	200	4366	D,I,K,L,M,N
259.	73121504	73121609	29	16	64.	190	11.0	8.5	170	1856	L,M,N,P
260.	73121800	73122100	72	27	98.	180	15.5	8.5	180	7056	D,K,L,M,N
261.	73122303	73122518	63	17	87.	270	10.5	8.5	250	5481	I,K,M,N
262.	73122612	73122821	57	9	68.	160	10.5	8.5	120	2652	D,H,I,J,M,N
263.	74011200	74012000	192	62	83.	140	12.5	8.5	210	15936	D,F,G,J,K,L,M,N
264.	74012109	74012518	105	16	57.	290	12.5	8.5	250	5985	D,F,H,I,J,K,M,N
266.	74021300	74021709	105	32	56.	190	11.0	8.5	180	5880	D,F,K,M,N
267.	74021918	74022500	126	21	63.	200	13.0	12.0	142	7938	D,F,H,I,K,L,M,N
270.	74030312	74031221	225	66	76.	130	14.0	12.0	300	17100	D,F,J,K,L,M,N
272.	74041015	74041409	90	17	64.	140	11.0	8.5	160	5760	D,K,M,N
273.	74093019	74100301	54	14	58.	220	10.3	12.0	230	2808	D,F,G,J,K
274.	74101112	74101203	15	5	60.	180	10.8	12.5	156	900	F,K
275.	74101318	74101603	57	16	61.	200	14.8	12.0	220	3477	D,F,G,H,I,J,K
277.	74102603	74103118	135	28	80.	170	12.5	8.0	138	10800	D,H,I,J,K,M,N
279.	74111418	74111818	96	18	65.	210	11.5	8.5	230	6240	D,H,I,K,L,M,N
280.	74112606	74112903	69	8	60.	170	12.0	10.5	170	2520	D,F,J,K,M,N
282.	74121208	74121415	55	31	68.	120	9.9	10.0	250	3740	D,F,K,L,M,N
283.	74121612	74122603	231	27	74.	240	14.6	11.0	266	17094	D,F,G,K,L,M,N

TABLE A.2 TOP 297 STORMS (Cont'd)

	START YYMMDDHH – END YYMMDDHH	DUR (hr)	OBS	WIND SPD (kts)	WIND DIR	COMBINED SEA HS (m)	COMBINED SEA TP (s)	COMBINED SEA DIR	SEVERITY INDEX	SOURCE
284.	74122815-75010318	147	26	76.	200	16.3	12.0	243	11172	D,F,G,I,K,L,M,N
285.	75010404-75011403	239	40	107.	140	13.9	14.0	274	25573	D,F,G,H,I,K,L,M,N
286.	75013006-75020418	132	43	66.	100	14.1	10.5	320	8712	D,F,J,K
287.	75020606-75020806	48	23	68.	170	14.5	10.5	104	2928	D,F,J,K
288.	75021003-75022609	318	53	85.	330	18.4	10.5	250	27030	D,F,G,I,J,K,L,M,N
289.	75031900-75032600	168	39	78.	250	19.5	14.0	285	13104	H,I,J,K
290.	75033018-75040221	75	7	57.	290	15.3	9.0	295	4275	D,K,L,N
291.	75050800-75050903	27	10	70.	130	11.3	9.0	090	1890	D,J,K,M,N
292.	75100212-75100522	82	29	68.	220	10.5	8.5	240	5576	F,H,I,J,K,M,N
294.	75101501-75101709	56	10	62.	210	10.0	8.5	210	3472	D,K,L,M,N
295.	75101815-75102009	42	23	68.	250	11.0	8.5	250	2856	D,J,K,M,N
297.	75103103-75110403	123	30	73.	220	12.0	8.5	230	8979	D,F,G,K,L,M,N
298.	75110518-75110803	57	28	85.	250	21.5	14.0	235	4845	D,F,G,I,J,K,L,M,N,P
299.	75110918-75112003	249	95	79.	230	23.0	9.0	144	19671	D,F,G,I,J,K,L,M,N,P
300.	75112518-75112812	66	9	85.	300	9.5	8.5	290	5610	K,M,N
301.	75120508-75120804	68	24	60.	100	9.6	7.0	286	4080	D,F,K,M,N
302.	75121218-75121415	45	13	70.	230	11.3	9.0	295	2940	D,G,K,M,N
303.	75121603-75122212	153	46	74.	210	21.4	8.0	130	11322	D,H,I,J,K,L,M,N
305.	75122600-76010100	144	18	64.	260	14.5	8.5	200	9216	D,F,G,K,M,N,P
309.	76012503-76013121	156	47	68.	200	14.0	8.5	190	10608	D,F,I,J,K,L,M,N
310.	76020712-76021121	114	21	64.	210	12.5	12.0	270	7296	D,F,G,I,K,M,N
311.	76021600-76021821	69	42	78.	270	14.5	8.5	290	3480	D,H,I,J,K,M,N,P
312.	76022108-76022821	181	31	60.	120	12.7	12.0	290	10860	D,F,J,K,M
313.	76031515-76031815	72	16	67.	230	16.3	14.0	226	4824	D,F,K,L,M,N
314.	76031918-76032221	75	19	69.	180	16.3	14.0	226	5175	D,F,H,I,K,L,M,N
315.	76032315-76032709	90	13	67.	230	16.3	14.0	226	6030	D,F,H,I,K,L,M,N
316.	76041318-76041603	57	14	55.	150	13.5	8.0	299	3135	K,L,M,N
317.	76041706-76041718	12	3	62.	260	10.6	8.5	228	744	J,K
318.	76042606-76042718	36	9	60.	180	11.0	8.5	170	2160	D,K,M,N
321.	76102311-76102806	115	34	65.	240	10.0	8.5	190	7475	D,F,G,K,L,M,N
322.	76102918-76110321	123	31	80.	140	12.1	8.5	220	9840	A,B,D,F,J,K,M,N
324.	76111206-76111309	27	3	60.	160	10.8	9.0	160	1620	K,M,N
325.	76111406-76111523	41	19	69.	160	12.7	16.5	240	2829	D,H,I,J,K,M,N
326.	76111918-76112302	80	27	69.	150	10.6	8.0	130	5520	D,F,H,I,K,M,N
327.	76112615-76112821	54	11	59.	160	10.0	8.5	190	3186	D,M,N
328.	76120800-76121209	105	12	87.	340	10.0	8.5	220	9135	F,K,L,M,N
331.	76122400-76122509	33	13	68.	190	10.5	8.5	130	1632	D,M,N
334.	77011400-77011815	111	46	80.	190	11.0	8.5	220	8160	A,D,F,H,I,J,K,L,M,N
336.	77020321-77020708	83	17	93.	180	11.2	9.0	200	7719	D,E,F,K,M,N

TABLE A.2 TOP 297 STORMS (Cont'd)

	START YYMMDDHH – END YYMMDDHH	DUR (hr)	OBS	WIND SPD (kts)	WIND DIR	COMBINED SEA HS (m)	COMBINED SEA TP (s)	COMBINED SEA DIR	SEVERITY INDEX	SOURCE
337.	77020818-77021515	165	34	66.	180	11.4	10.0	215	9834	A,D,F,H,I,J,K,L,M,N
338.	77021718-77022312	138	99	68.	250	18.0	14.0	239	9384	A.B,D,H,I,J,K,L,M,N
339.	77022506-77030312	150	45	78.	270	11.3	8.5	255	11700	J,K
340.	77030409-77031306	213	63	92.	140	16.6	12.0	266	19596	A,B,D,F,H,I,J,K,L
341.	77041018-77041719	166	20	57.	230	14.1	11.0	250	9462	A,D,E,F,G,H,I,J,K,L
343.	77052517-77052712	43	24	66.	110	13.6	10.0	246	2838	J,K,L
345.	77101100-77101518	114	26	93.	160	21.4	12.0	170	10602	D,F,H,J,K
346.	77101606-77101800	42	5	93.	160	21.4	12.0	170	3906	D,H,I,J,K
347.	77102106-77102800	162	67	103.	260	21.4	12.0	170	16686	A,B,D,F,G,H,I,J,K,L,P
352.	77111002-77111616	158	93	71.	220	15.6	14.0	212	11218	D,F,G,H,I,J,K,L
353.	77112206-77112718	132	14	64.	140	11.4	10.0	104	8448	D,F,K
354.	77120218-77121518	312	34	75.	110	11.7	5.0	013	23400	B,D,F,J,K,L
355.	77121906-77122200	66	34	57.	100	13.4	10.5	130	3762	D,J,K
356.	78010318-78011000	150	45	83.	140	20.2	6.5	160	12450	D,F,G,J,K
359.	78020406-78021000	138	42	65.	140	11.7	8.0	232	8970	D,F,K,L
360.	78021121-78021218	21	12	65.	120	12.1	10.0	300	1365	D,K
361.	78021400-78021918	138	36	67.	160	15.6	8.5	230	9246	D,H,I,J,K
362.	78030606-78030813	55	16	68.	300	14.1	6.5	220	3740	D,F,J,K,L
364.	78040918-78041116	46	9	55.	160	20.6	12.5	160	2530	K,L
365.	78042921-78050212	63	16	61.	220	13.9	12.5	247	3843	D,F,I,J,K
366.	78051406-78051506	24	3	98.	170	10.8	7.0	297	2352	K
367.	78091200-78091518	90	35	69.	050	17.0	8.0	155	6210	J,K
368.	78092612-78092800	36	12	55.	190	16.7	14.0	090	1980	J,K
370.	78100706-78101100	90	30	70.	190	10.6	7.0	146	6300	D,I,K
372.	78102818-78110206	108	60	72.	210	12.5	12.5	220	7776	A,B,D,F,G,J,K
373.	78110412-78110618	54	22	57.	240	10.8	8.5	230	2970	D,J,K
374.	78111100-78111200	24	17	60.	310	10.6	12.0	333	1440	K
376.	78120218-78120512	66	17	63.	250	11.9	12.0	247	4158	D,K
378.	78121108-78121806	166	87	70.	250	19.8	8.5	260	11620	A,B,D,F,G,H,I,J,K,L
379.	78122004-78122412	104	41	65.	260	11.7	7.0	274	6760	D,F,G,J,K
380.	78123112-79010405	89	14	60.	120	10.3	12.5	140	5340	K
381.	79010912-79011018	30	12	63.	140	10.5	8.5	126	1890	D,F,K
382.	79011706-79012012	78	30	59.	210	13.7	7.0	209	2124	D,H,I,K,L
383.	79020406-79020513	18	98	101.	250	9.6	12.0	262	1818	A,B,D,G,K
384.	79021102-79022018	232	98	101.	330	18.0	10.0	324	23432	A,B,D,F,J,K,L,P
385.	79030215-79030818	147	39	61.	180	10.0	10.5	160	8967	D,F,J,K,L
386.	79031206-79031412	54	30	58.	200	12.4	13.0	270	3132	A,B,D,J,K
387.	79041211-79041312	25	40	77.	290	14.1	5.0	250	1925	B,D,J,K
388.	79050812-79051106	66	20	64.	270	10.6	7.0	140	4224	D,H,I,K

TABLE A.2 TOP 297 STORMS (Cont'd)

	START END	DUR	OBS	WIND		COMBINED SEA			SEVERITY	SOURCE
	YYMMDDHH YYMMDDHH	(hr)		SPD (kts)	DIR	HS (m)	TP (s)	DIR	INDEX	
390.	79092812-79100600	180	14	58.	180	21.3	13.0	193	10440	D,F,H,I,K
392.	79102112-79103005	209	112	82.	280	12.2	14.0	206	17138	A,B,D,G,J,K,L
395.	79111806-79112312	126	79	97.	130	17.7	10.5	000	12222	B,D,F,G,I,J,K,L
396.	79112600-79120412	204	159	91.	150	16.8	13.0	131	18564	B,D,F,H,I,J,K
397.	79120518-79120618	24	7	92.	270	18.0	10.0	350	2208	J,K
398.	79120918-79122121	291	68	81.	100	18.4	12.0	180	23571	D,F,G,H,I,J,K,L
399.	79122223-79010500	313	39	79.	190	18.4	12.0	180	24101	B,D,F,G,I,J,K
400.	80031215-80031321	30	20	65.	280	9.5	10.5	240	1380	A,B,D
404.	80112605-80112808	51	42	90.	160	9.7	12.0	245	4590	B,D,F,G,H
409.	81091706-81091818	36	19	66.	220	11.5	10.5	-099	2376	A,B,D,K
413.	81113020-81120602	126	157	67.	190	10.0	12.5	-099	8442	A,B,D,F,G
415.	82012518-82012612	18	15	65.	180	10.5	10.5	-099	1170	B,D,P
417.	82100500-82100606	30	19	62.	210	9.5	10.0	180	1860	B,D,G,J,K
419.	82121713-82121906	41	9	73.	170	10.1	12.0	230	2993	B,D,K,P
423.	83110806-83111202	92	44	74.	180	10.8	8.0	170	6808	D,F,G,K,P
424.	84020112-84020218	30	2	56.	190	18.0	14.0	196	1680	D,J,K
427.	84040616-84041018	98	47	70.	280	17.0	11.0	245	6860	C,D,G,J,K,P
428.	84050706-84050906	48	10	55.	150	17.5	14.5	142	2640	D,J,K
431.	84101203-84101400	51	76	90.	270	13.0	14.0	238	4590	A,B,D,G,K,L,P
432.	84103106-84110411	101	117	76.	170	10.5	10.5	270	7676	A,B,D,K,P
435.	84121212-84121506	66	9	80.	300	14.1	10.0	270	5280	G,K
436.	85021018-85021518	120	54	89.	100	9.5	12.5	250	10680	A,D,G,P
437.	85030312-85030512	48	21	72.	330	14.1	12.0	310	3456	A,B,D,J,K
442.	86010521-86011406	201	108	97.	160	9.5	16.5	210	19497	A,D,G,K,L,P
444.	86021406-86021607	49	10	58.	120	10.0	11.0	065	2842	D,G,K
445.	86022606-86030306	120	32	67.	190	10.7	18.2	-99	8040	D,P
447.	86042400-86042518	42	16	64.	330	14.0	12.5	290	2688	D,J,K,P
448.	86092312-86092512	48	41	57.	320	11.0	16.5	330	2736	A,D
449.	86111718-86112021	75	51	83.	320	12.5	16.5	260	6059	A,B,D,G,K,P
450.	86112118-86112919	193	74	73.	270	12.0	14.5	230	14089	A,B,D,G,L,P
451.	86122300-86122700	96	35	67.	180	9.8	12.4	-99	3360	A,D,G,L,P
453.	87010618-87011018	96	33	70.	180	10.0	0.0	340	6720	D,G,J,L,P
461.	87041217-87041700	103	40	71.	250	10.6	14.3	-99	3871	A,D,G,P
462.	87100406-87100513	31	26	89.	270	11.0	15.1	-99	2759	A,D,J,K,P
468.	87113000-87120216	64	75	95.	190	13.6	20.0	-99	6080	D,G,L,P
469.	87120418-87121103	153	128	76.	190	11.5	10.5	160	11628	C,D,G,J,K,L,P
472.	88011200-88011603	98	50	77.	150	10.2	14.3	-99	7546	D,G,P
476.	88030406-88030618	60	71	67.	200	12.0	14.2	-99	4020	D,G,P
480.	88040806-88041206	96	27	79.	170	10.6	14.0	200	7584	D,K,P

TABLE A.2 TOP 297 STORMS (Cont'd)

	START END	DUR	OBS	WIND		COMBINED SEA			SEVERITY	SOURCE
	YYMMDDHH YYMMDDHH	(hr)		SPD (kts)	DIR	HS (m)	TP (s)	DIR	INDEX	
481.	88041418-88041609	39	13	68.	180	9.7	18.3	-99	2040	D,P
485.	88111818-88112409	135	106	78.	150	11.2	14.2	-99	8424	D,G,L,P
486.	88112618-88112812	41	39	86.	260	14.8	17.1	-99	2580	D,G,P
487.	88112906-88120104	46	74	78.	210	12.2	14.2	-99	3588	D,G,P
488.	88120206-88120402	44	31	72.	170	9.6	15.1	-99	3168	D,P
489.	88122006-88122212	54	27	69.	320	11.6	16.7	-99	3726	D,P
497.	89012002-89012010	7	17			11.2	16.0	-99	0	P

TABLE A.3 SEMI-FINAL "165" STORM LIST FOR THE WEST COAST

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All these remaining storms have:   winds >= 60 kts    unless wind >= 55 kts
                                                      had waves >= 10 m
                                   waves >= 9.5 m
                                   dur   >= 12 hrs   except MEDS

Sources : A) BUOY wave      >= 8 m  or  >= 45 kts
          B) BUOY wind      >= 8 m  or  >= 45 kts
          C) ESTEVAN wind               >= 45 kts
          D) GWC wind                   >= 50 kts  and  >= 12 hrs
          E) LIGHT wave     >= 8 m  or  >= 45 kts
          F) LIGHT wind     >= 8 m  or  >= 45 kts  and  >= 6 hrs
          G) NORTH wind                 >= 45 kts  and  >= 6 hrs
          H) PAPA wave      >= 8 m  or  >= 45 kts
          I) PAPA wind      >= 8 m  or  >= 45 kts
          J) SHIP wave      >= 8 m  or  >= 45 kts
          K) SHIP wind      >= 7 m  or  >= 45 kts
          L) SOUTH wind                 >= 45 kts  and  >= 6 hrs
          M) SOWM wave      >= 8 m  or  >= 45 kts
          N) SOWM wind      >= 8 m  or  >= 45 kts
          P) MEDS           >= 7 m
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	START END	DUR	OBS	WIND		COMBINED SEA			SEVERITY	WASS	SOURCE
	YYMMDDHH YYMMDDHH	(hr)		SPD (kts)	DIR	HS (m)	TP (s)	DIR	INDEX	FACTOR	
3.	58021704-58021906	58	19	72.	130	9.5	12.5	180	4176	248	D,J,L
6.	58102810-58110218	128	21	78.	150	9.5	8.5	180	9984	292	D,G,I,J,K,L
7.	58110415-58111415	240	44	75.	260	9.5	12.5	240	18000	237	D,G,I,J,K
8.	58112900-58120300	96	18	61.	090	9.5	16.5	220	5856	163	J,K,L
11.	59021600-59021812	60	13	65.	020	9.5	12.5	020	3900	257	D,J,K
12.	59022412-59030400	180	33	70.	240	9.5	16.5	250	12600	212	D,G,I,J
15.	59120906-59121200	66	16	76.	280	9.5	8.5	230	4352	280	D,G,I,J,K,L
16.	59121705-59121906	49	11	60.	300	9.5	14.5	270	2880	224	J,K,L
19.	60012806-60020110	100	28	84.	200	9.5	14.5	130	8400	297	D,G,I,J,K,L
20.	60020422-60020715	65	32	73.	160	9.5	14.5	200	4745	255	D,I,J,K,L
27.	60111609-60112512	219	55	78.	270	9.5	20.5	250	17082	275	D,G,I,J,K,L
30.	61101210-61101512	76	8	61.	160	9.5	12.5	250	4636	179	G,J,K
35.	61121612-61121818	54	13	57.	300	9.5	10.5	100	3078	226	D,J,K
41.	62032112-62032221	33	17	56.	290	9.5	12.5	280	1848	201	J,K
43.	62092715-62093007	64	18	62.	310	9.5	18.5	260	3968	211	D,G,I,J,K,L
45.	62111800-62120207	343	33	65.	220	10.5	14.5	188	22295	303	D,G,I,J,K,L
55.	63101000-63101300	72	29	68.	270	12.4	18.5	190	4896	248	D,I,J,K

TABLE A.3 SEMI-FINAL "165" STORM LIST FOR THE WEST COAST (cont'd)

	START	END	DUR	OBS	WIND		COMBINED SEA			SEVERITY INDEX		SOURCE
	YYMMDDHH	YYMMDDHH	(hr)		SPD (kts)	DIR	HS (m)	TP (s)	DIR			
56.	63101918	63102517	143	42	74.	290	12.7	16.5	260	10582	309	D,G,H,I,J,K
66.	64101403	64101915	132	23	70.	140	12.0	16.5	180	9240	258	D,F,G,I,K,M,N
71.	64120406	64120900	114	44	60.	180	12.6	10.5	244	6840	193	D,F,G,J,K,M,N
77.	65100203	65100621	114	24	65.	300	11.5	16.5	180	7410	240	D,H,I,J,K,L,M,N
81.	65112709	65120503	186	43	57.	200	10.0	16.5	170	10602	309	D,F,G,K,L,M,N
84.	65122715	66010215	144	37	65.	140	9.7	18.5	327	9360	164	D,J,K,M,N
98.	66120903	66121809	222	49	56.	130	11.0	16.5	190	12432	270	F,G,K,M,N
99.	67010615	67011306	159	26	82.	250	12.0	16.5	160	13038	301	D,F,G,K,M,N
103.	67020706	67021306	144	27	70.	230	12.0	10.5	226	10080	238	G,H,I,J,K,M,N
105.	67022522	67022722	48	16	61.	180	9.5	14.5	180	2928	225	F,G,M,N
109.	67102406	67102712	78	18	61.	140	10.0	14.5	180	4056	227	F,G,J,K,L,M,N
111.	67112815	67120822	247	206	84.	130	13.5	18.5	280	20748	274	D,F,G,H,I,J,K,L,M,N
112.	67120912	67121603	159	32	66.	020	13.5	20.5	190	9108	268	D,F,H,I,J,K,M,N
115.	68010712	68011603	207	46	89.	210	11.5	8.5	110	18423	174	D,F,G,J,K,L,M,N
120.	68020518	68021012	114	27	62.	170	11.4	14.0	180	7068	283	K,M,N
122.	68022509	68022803	66	28	60.	170	14.0	8.5	160	3960	259	D,I,M,N
125.	68031918	68032203	57	18	60.	140	12.0	8.5	160	3420	297	D,F,M,N
133.	68101412	68102718	318	53	75.	180	13.5	16.5	200	23850	248	D,F,G,H,I,J,K,L,M,N
134.	68103116	68110903	227	29	70.	150	14.5	10.0	100	15890	253	F,D,F,G,H,I,J,K,M,N
136.	68111613	68112218	149	45	75.	180	11.7	8.5	130	11175	239	D,F,I,K,L,M,N
137.	68112513	68120103	134	28	95.	140	15.0	12.0	270	13680	341	F,G,H,I,J,K,L,M,N
138.	68120118	68120512	90	16	70.	130	15.0	12.0	270	4950	213	F,H,I,K
140.	68121213	68121600	86	19	75.	160	11.0	14.0	220	6450	259	D,F,G,K,L,M,N
145.	69020600	69020903	75	14	80.	160	11.5	8.5	180	5760	248	D,G,J,K,L,M,N
150.	69041800	69042203	99	23	63.	260	15.4	14.0	250	6237	257	D,F,G,H,I,K,L
154.	69103109	69110812	219	28	80.	320	19.1	13.0	235	17520	318	D,F,G,H,I,J,K,L,M,N
155.	69111506	69120315	441	70	62.	260	14.4	12.0	238	27342	310	D,F,G,H,I,K,M,N
156.	69120418	69120809	86	28	57.	150	13.5	8.5	130	4902	259	D,J,K,M,N
157.	69121013	69121415	98	34	70.	140	15.7	8.0	260	6860	270	D,F,G,K,L,M,N
158.	69121521	69122516	235	53	61.	140	16.0	12.0	263	14335	244	D,F,H,I,K,M,N
162.	70011812	70012403	135	39	70.	050	11.5	8.5	180	9450	260	D,F,K,M,N
164.	70013118	70020512	114	31	64.	200	14.9	12.0	260	7296	286	D,F,G,H,I,K,M,N
165.	70021615	70022116	121	22	63.	210	16.0	8.5	190	6655	333	D,F,M,N
167.	70040506	70040909	99	20	58.	130	11.0	8.5	180	5742	290	D,F,G,K,L,M,N
171.	70102109	70102412	75	26	61.	140	12.5	14.0	303	4575	200	D,F,G,H,I,J,K,L,M,N
172.	70102600	70110121	165	25	98.	040	9.5	8.5	140	16170	333	D,F,K,L,M,N
173.	70110918	70111409	111	52	63.	190	15.5	8.5	210	6993	214	D,K,L,M,N

TABLE A.3 SEMI-FINAL "165" STORM LIST FOR THE WEST COAST (cont'd)

	START END	DUR	OBS	WIND		COMBINED SEA			SEVERITY		SOURCE
	YYMMDDHH YYMMDDHH			SPD	DIR	HS	TP	DIR	INDEX		
		(hr)		(kts)		(m)	(s)				
176.	70112909-70120109	48	15	70.	070	10.6	6.5	020	3360	202	F,H,I,K,M,N
177.	70120415-70120715	72	43	76.	100	13.5	8.5	240	5472	220	D,F,G,K,L,M,N
179.	70121115-70121803	156	34	68.	290	14.8	14.5	290	10608	279	D,F,J,K,L,M,N
184.	71010218-71010509	63	13	68.	150	15.0	8.5	150	4284	220	D,K,M,N
186.	71011418-71011821	99	22	65.	050	9.6	10.0	122	6435	225	D,F,K,L,M,N
194.	71030521-71031513	232	52	65.	110	12.6	11.0	265	15080	219	D,F,G,I,J,K,L,M,N
198.	71033100-71040415	135	12	60.	140	9.5	8.5	200	8100	231	F,G,K,M,N
204.	71100709-71101009	72	11	96.	120	12.0	8.5	170	2592	144	K,M,N
210.	71112100-71112500	96	19	64.	010	15.0	7.0	350	6144	207	H,I,J,K,M,N
217.	72010319-72010621	75	15	78.	220	16.9	10.5	245	5850	201	D,F,H,J,K,M,N
218.	72010718-72011203	105	46	81.	280	15.5	8.5	280	8505	278	D,F,G,H,I,J,K,M,N
219.	72011312-72011703	87	18	65.	140	16.5	10.5	250	5655	302	D,F,G,H,I,J,K,M,N
225.	72022506-72030306	168	21	83.	110	18.0	8.0	048	13944	183	D,J,K,L,M,N
228.	72042200-72042403	51	25	91.	210	12.5	7.0	127	4641	220	D,J,K,M,N
232.	72102006-72102600	138	9	98.	200	19.2	14.0	200	13524	219	F,J,K,M,N
235.	72111921-72112615	162	23	75.	260	18.0	14.0	216	11475	259	D,F,G,H,I,J,K,M,N
237.	72121318-72121703	81	22	90.	120	13.0	8.5	170	7290	230	D,F,K,L,M,N
239.	72122115-72122621	126	34	73.	210	18.0	8.5	210	9198	235	D,F,G,I,K,M,N
241.	73010900-73011209	87	9	71.	200	23.5	10.0	120	5394	171	D,J,K,L,M,N
242.	73011500-73012423	239	46	85.	140	20.5	8.5	210	20315	188	D,F,G,J,K,L,M,N
243.	73012600-73020115	160	28	86.	160	14.1	6.5	160	13760	327	D,F,H,I,J,K,M,N
245.	73021218-73021715	117	27	67.	190	15.5	8.5	160	7839	221	D,F,I,K,M,N
250.	73061100-73061400	72	17	61.	150	14.1	14.0	311	4392	176	D,J,K,M,N
255.	73111818-73112200	78	46	87.	140	15.5	11.0	311	6786	248	D,H,I,J,K,L,M,N,P
256.	73112306-73112809	123	38	64.	280	13.5	8.5	280	7872	224	D,F,J,K,M,N
257.	73120212-73120700	108	27	75.	180	16.1	14.0	255	8100	206	D,F,K,L,M,N
260.	73121800-73122100	72	27	98.	180	15.5	8.5	180	7056	238	D,K,L,M,N
261.	73122303-73122518	63	17	87.	270	10.5	8.5	250	5481	207	I,K,M,N
263.	74011200-74012000	192	62	83.	140	12.5	8.5	210	15936	127	D,F,G,J,K,L,M,N
267.	74021918-74022500	126	21	63.	200	13.0	12.0	142	7938	249	D,F,H,I,K,L,M,N
270.	74030312-74031221	225	66	76.	130	14.0	12.0	300	17100	263	D,F,J,K,L,M,N
272.	74041015-74041409	90	17	64.	140	11.0	8.5	160	5760	263	D,K,M,N
275.	74101318-74101603	57	16	61.	200	14.8	12.0	220	3477	268	D,F,G,H,I,J,K
277.	74102603-74103118	135	28	80.	170	12.5	8.0	138	10800	241	D,H,I,J,K,M,N
279.	74111418-74111818	96	18	65.	210	11.5	8.5	230	6240	231	D,H,I,K,L,M,N
284.	74122815-75010318	147	26	76.	200	16.3	12.0	243	11172	281	D,F,G,I,K,L,M,N
285.	75010404-75011403	239	40	107.	140	13.9	14.0	274	25573	124	D,F,G,H,I,K,L,M,N

TABLE A.3 SEMI-FINAL "165" STORM LIST FOR THE WEST COAST (cont'd)

	START END	DUR	OBS	WIND		COMBINED SEA			SEVERITY		SOURCE
	YYMMDDHH YYMMDDHH	(hr)		SPD (kts)	DIR	HS (m)	TP (s)	DIR	INDEX		
286.	75013006-75020418	132	43	66.	100	14.1	10.5	320	8712	191	D,F,J,K
287.	75020606-75020806	48	23	68.	170	14.5	10.5	104	2928	231	D,F,J,K
288.	75021003-75022609	318	53	85.	330	18.4	10.5	250	27030	263	D,F,G,I,J,K,L,M,N
289.	75031900-75032600	168	39	78.	250	19.5	14.0	285	13104	147	H,I,J,K
291.	75050800-75050903	27	10	70.	130	11.3	9.0	090	1890	210	D,J,K,M,N
292.	75100212-75100522	82	29	68.	220	10.5	8.5	240	5576	239	F,H,I,J,K,M,N
297.	75103103-75110403	123	30	73.	220	12.0	8.5	230	8979	290	D,F,G,K,L,M,N
298.	75110518-75110803	57	28	85.	250	21.5	14.0	235	4845	262	D,F,G,I,J,K,L,M,N,P
299.	75110918-75112003	249	95	79.	230	23.0	9.0	144	19671	363	D,F,G,I,J,K,L,M,N,P
302.	75121218-75121415	45	13	70.	230	11.3	9.0	295	2940	235	D,G,K,M,N
303.	75121603-75122212	153	46	74.	210	21.4	8.0	130	11322	372	D,H,I,J,K,L,M,N
305.	75122600-76010100	144	18	64.	260	14.5	8.5	200	9216	166	D,F,G,K,M,N,P
309.	76012503-76013121	156	47	68.	200	14.0	8.5	190	10608	315	D,F,I,J,K,L,M,N
310.	76020712-76021121	114	21	64.	210	12.5	12.0	270	7296	278	D,F,G,I,K,M,N
311.	76021600-76021821	69	42	78.	270	14.5	8.5	290	3480	288	D,H,I,J,K,M,N,P
312.	76022108-76022821	181	31	60.	120	12.7	12.0	290	10860	352	D,F,J,K,M
313.	76031515-76031815	72	16	67.	230	16.3	14.0	226	4824	292	D,F,K,L,M,N
314.	76031918-76032221	75	19	69.	180	16.3	14.0	226	5175	271	D,F,H,I,K,L,M,N
315.	76032315-76032709	90	13	67.	230	16.3	14.0	226	6030	257	D,F,H,I,K,L,M,N
316.	76041318-76041603	57	14	55.	150	13.5	8.0	299	3135	273	K,L,M,N
321.	76102306-76102806	115	34	65.	240	10.0	8.5	190	7475	301	D,F,G,K,L,M,N
322.	76102918-76110321	123	31	80.	140	12.1	8.5	220	9840	306	A,B,D,F,J,K,M,N
328.	76120800-76121209	105	12	87.	340	10.0	8.5	220	9135	271	F,K,L,M,N
334.	77011400-77011815	111	46	80.	190	11.0	8.5	220	8160	339	A,D,F,H,I,J,K,L,M,N
336.	77020321-77020708	83	17	93.	180	11.2	9.0	200	7719	281	D,E,F,K,M,N
337.	77020818-77021500	165	34	66.	180	11.4	10.0	215	9834	337	A,D,F,H,I,J,K,L,M,N
338.	77021718-77022312	138	99	68.	250	18.0	14.0	239	9384	386	A.B,D,H,I,J,K,L,M,N
340.	77030409-77031306	213	63	92.	140	16.6	12.0	266	19596	291	A,B,D,F,H,I,J,K,L
343.	77052517-77052712	43	24	66.	110	13.6	10.0	246	2838	237	J,K,L
345.	77101100-77101400	114	26	93.	160	21.4	12.0	170	10602	270	D,F,H,J,K
346.	77101606-77101800	42	5	93.	160	21.4	12.0	170	3906	288	D,H,I,J,K
347.	77102106-77102800	162	67	103.	260	21.4	12.0	170	16686	308	A,B,D,F,G,H,I,J,K,L,P
352.	77111002-77111616	158	93	71.	220	15.6	14.0	212	11218	270	D,F,G,H,I,J,K,L
356.	78010318-78011000	150	45	83.	140	20.2	6.5	160	12450	321	D,F,G,J,K
360.	78021121-78021218	21	12	65.	120	12.1	10.0	300	1365	254	D,K
361.	78021400-78021918	138	36	67.	160	15.6	8.5	230	9246	297	D,H,I,J,K
364.	78040918-78041116	46	9	55.	160	20.6	12.5	160	2530	227	K,L

TABLE A.3 SEMI-FINAL "165" STORM LIST FOR THE WEST COAST (cont'd)

	START YYMMDDHH END YYMMDDHH	DUR (hr)	OBS	WIND		COMBINED SEA			SEVERITY INDEX		SOURCE
				SPD (kts)	DIR	HS (m)	TP (s)	DIR			
372.	78102818-78110206	108	60	72.	210	12.5	12.5	220	7776	334	A,B,D,F,G,J,K
378.	78121108-78121806	166	87	70.	250	19.8	8.5	260	11620	357	A,B,D,F,G,H,I,J,K,L
379.	78122004-78122412	104	41	65.	260	11.7	7.0	274	6760	228	D,F,G,J,K
381.	79010912-79011018	30	12	63.	140	10.5	8.5	126	1890	252	D,F,K
384.	79021102-79022018	232	98	101.	330	18.0	10.0	324	23432	336	A,B,D,F,J,K,L,P
385.	79030212-79030800	147	39	61.	180	10.0	10.5	160	8967	317	D,F,J,K,L
387.	79041211-79041312	25	40	77.	290	14.1	5.0	250	1925	213	B,D,J,K
392.	79102112-79103005	209	112	82.	280	12.2	14.0	206	17138	252	A,B,D,G,J,K,L
395.	79111806-79112312	126	79	97.	130	17.7	10.5	000	12222	329	B,D,F,G,I,J,K,L
396.	79112600-79120412	204	159	91.	150	16.8	13.0	131	18564	277	B,D,F,H,I,J,K
398.	79120918-79122121	291	68	81.	100	18.4	12.0	180	23571	217	D,F,G,H,I,J,K,L
399.	79122223-79010500	313	39	79.	190	18.4	12.0	180	24101	226	B,D,F,G,I,J,
409.	81091700-81091900	36	19	66.	220	11.5	10.5	-099	2376	221	A,B,D,K
413.	81113000-81120300	126	157	67.	190	10.0	12.5	-099	8442	314	A,B,D,F,G
423.	83110800-83111200	92	44	74.	180	10.8	8.0	170	6808	273	D,F,G,K,P
427.	84040616-84041018	98	47	70.	280	17.0	11.0	245	6860	335	C,D,G,J,K,P
431.	84101203-84101400	51	76	90.	270	13.0	14.0	238	4590	260	A,B,D,G,K,L,P
432.	84103106-84110411	101	117	76.	170	10.5	10.5	270	7676	318	A,B,D,K,P
435.	84121212-84121506	66	9	80.	300	14.1	10.0	270	5280	289	G,K
436.	85021018-85021518	120	54	89.	100	12.5	12.5	250	10680	359	A,D,G,P
437.	85030312-85030512	48	21	72.	330	14.1	12.0	310	3456	283	A,B,D,J,K
442.	86010521-86011406	201	108	97.	160	9.5	16.5	210	19497	326	A,D,G,K,L,P
445.	86022606-86030306	120	32	67.	190	10.7	18.2	-99	8040	266	D,P
447.	86042400-86042518	42	16	64.	330	14.0	12.5	290	2688	192	D,J,K,P
449.	86111718-86112021	75	51	83.	320	12.5	16.5	260	6059	206	A,B,D,G,K,P
450.	86112118-86112919	193	74	73.	270	13.5	14.5	230	14089	273	A,B,D,G,L,P
451.	86122300-86122700	96	35	67.	180	9.8	12.4	-99	3360	248	A,D,G,L,P
453.	87010618-87011018	96	33	70.	180	10.0	0.0	340	6720	312	D,G,J,L,P
461.	87041217-87041700	103	40	71.	250	10.6	14.3	-99	3871	303	A,D,G,P
469.	87120418-87121103	153	128	76.	190	11.5	10.5	160	11628	501	C,D,G,J,K,L,P
472.	88011200-88011603	98	50	77.	150	10.2	14.3	-99	7546	362	D,G,P
476.	88030406-88030618	60	71	67.	200	12.0	14.2	-99	4020	266	D,G,P
485.	88111818-88112409	135	106	78.	150	11.2	14.2	-99	8424	421	D,G,L,P
486.	88112618-88112812	41	39	86.	260	14.8	17.1	-99	2580	318	D,G,P
487.	88112906-88120104	46	74	78.	210	12.2	14.2	-99	3588	321	D,G,P
488.	88120206-88120402	44	31	72.	170	9.6	15.1	-99	3168	226	D,P
497.	89012002-89012010	7	17			11.2	16.0	-99	0		P

APPENDIX B
VERIFICATION RESULTS
TIME SERIES PLOTS

STORM MCL # 431

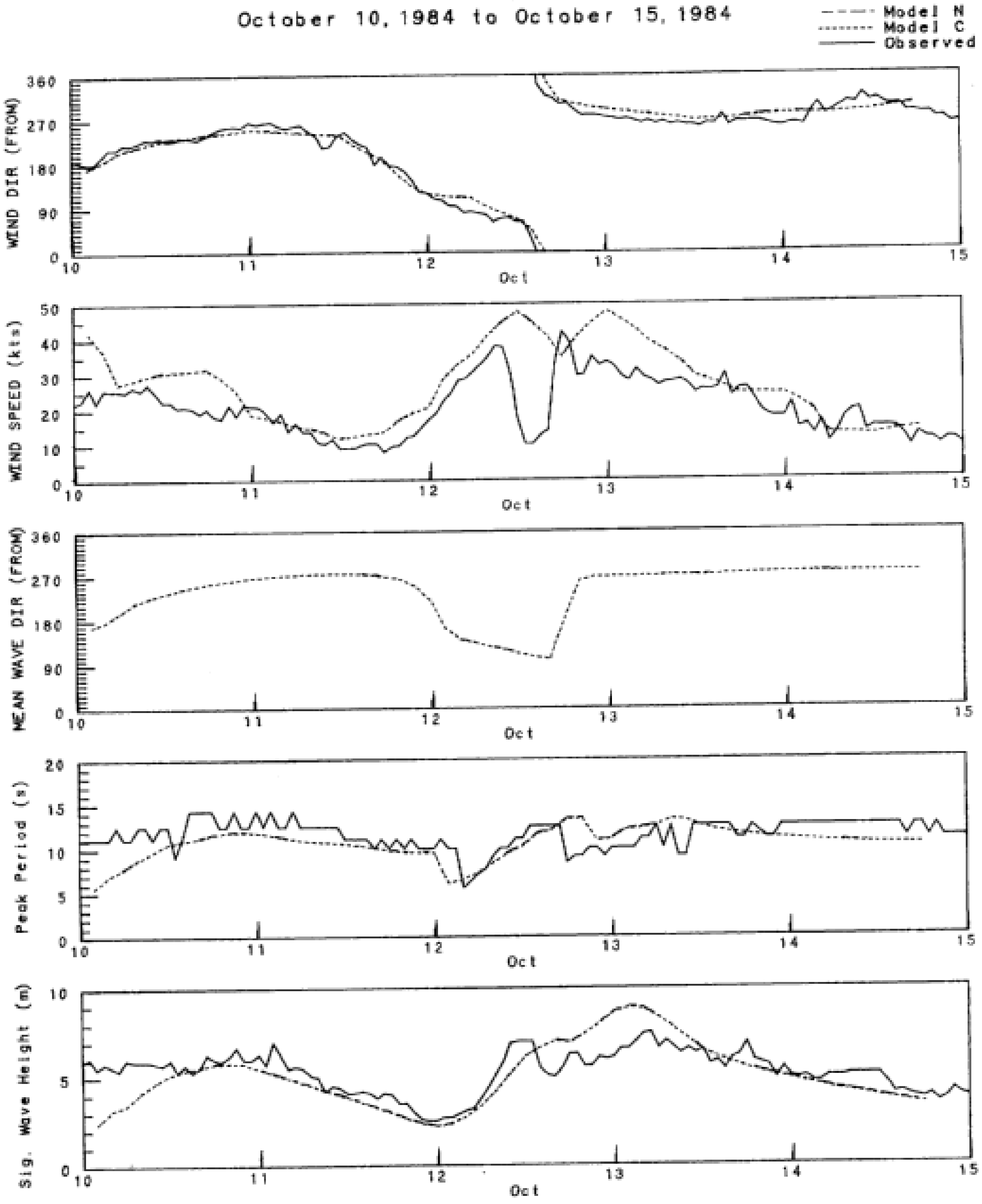
FROM OCTOBER 10 TO OCTOBER 15, 1984

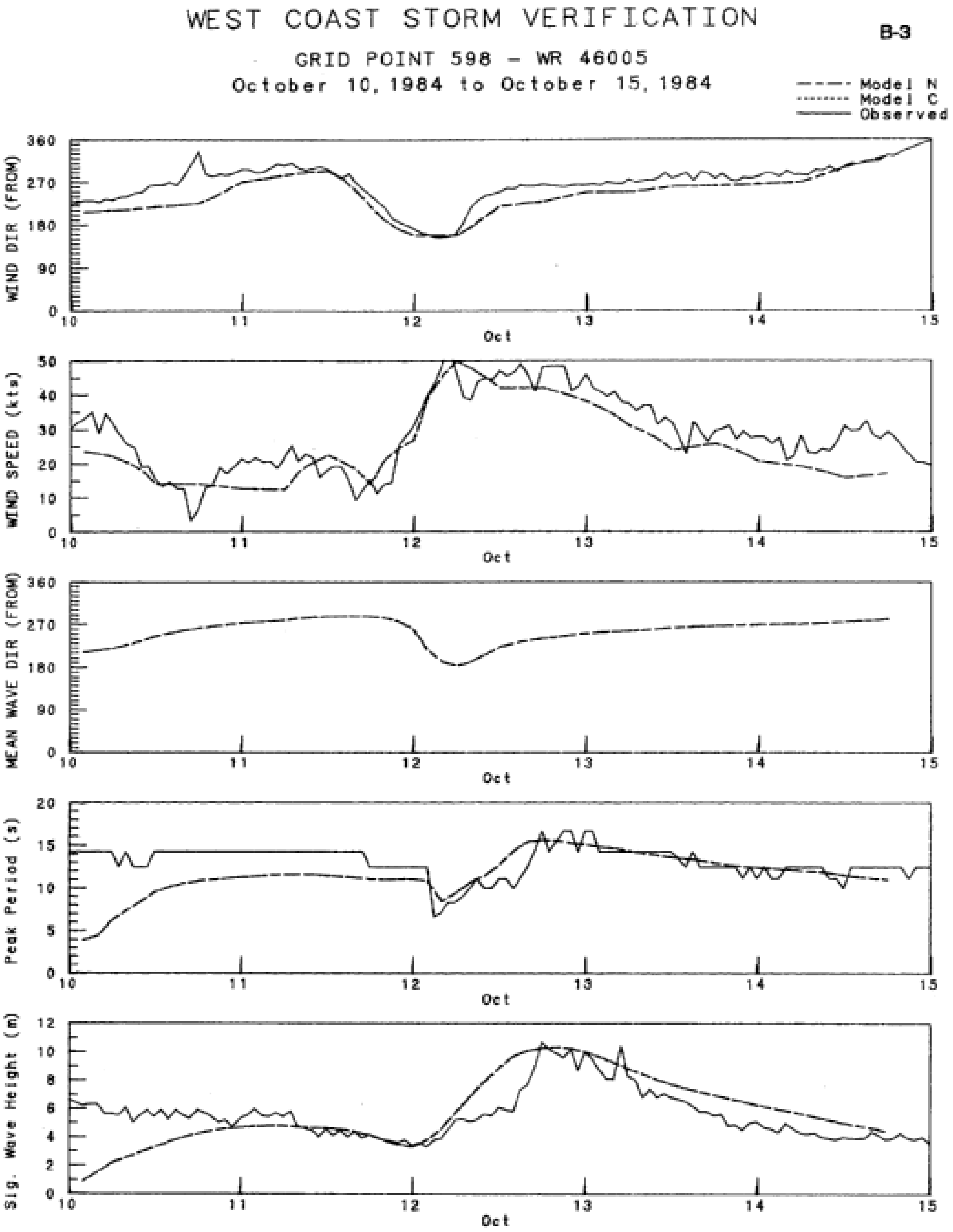
WEST COAST STORM VERIFICATION

B-2

GRID POINT 768 – WR 46004

October 10, 1984 to October 15, 1984

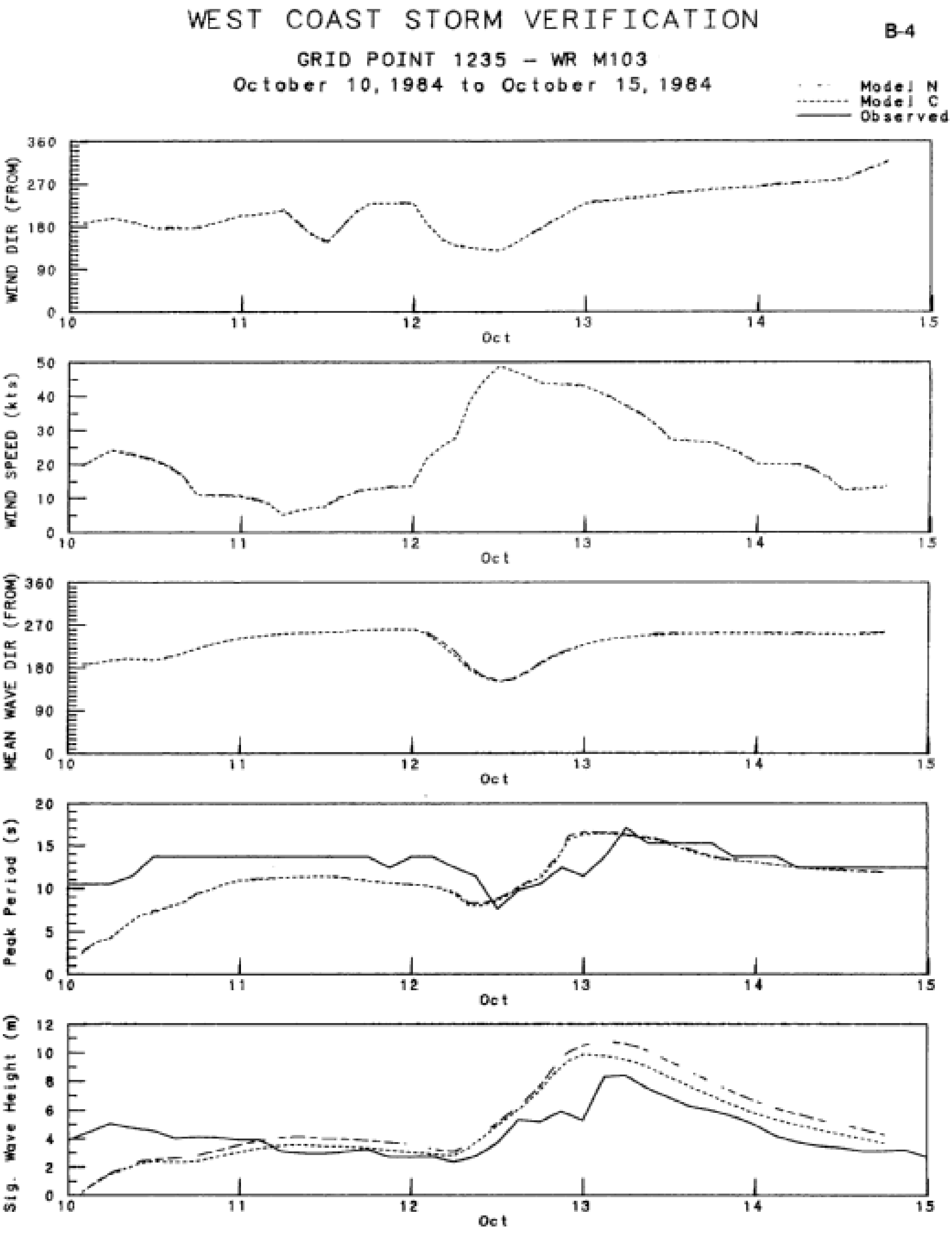




WEST COAST STORM VERIFICATION

B-3

GRID POINT 598 – WR 46005
October 10, 1984 to October 15, 1984



WEST COAST STORM VERIFICATION

B-4

GRID POINT 1235 – WR M103

October 10, 1984 to October 15, 1984

STORM MCL # 432

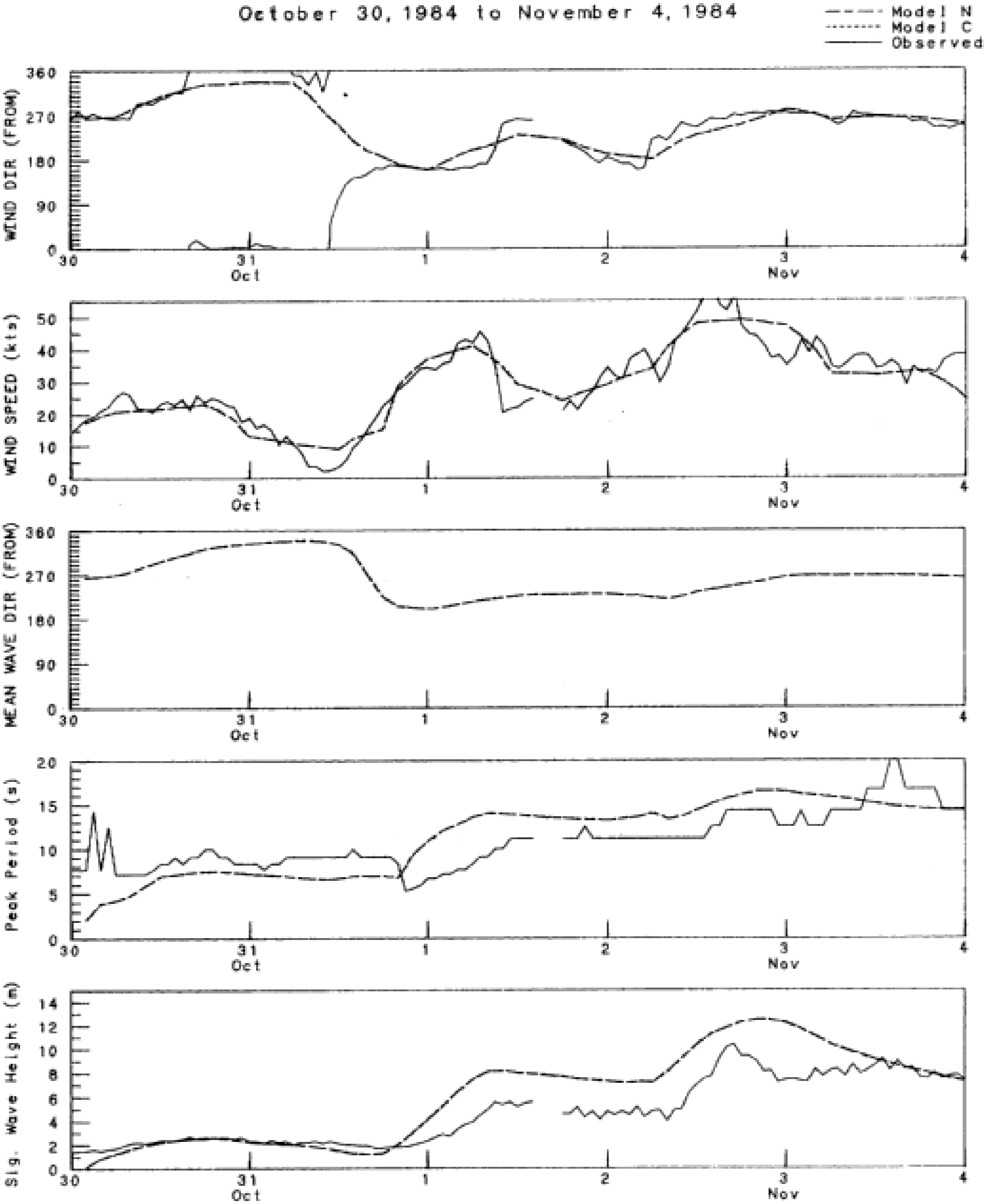
OCTOBER 30 TO NOVEMBER 4, 1984

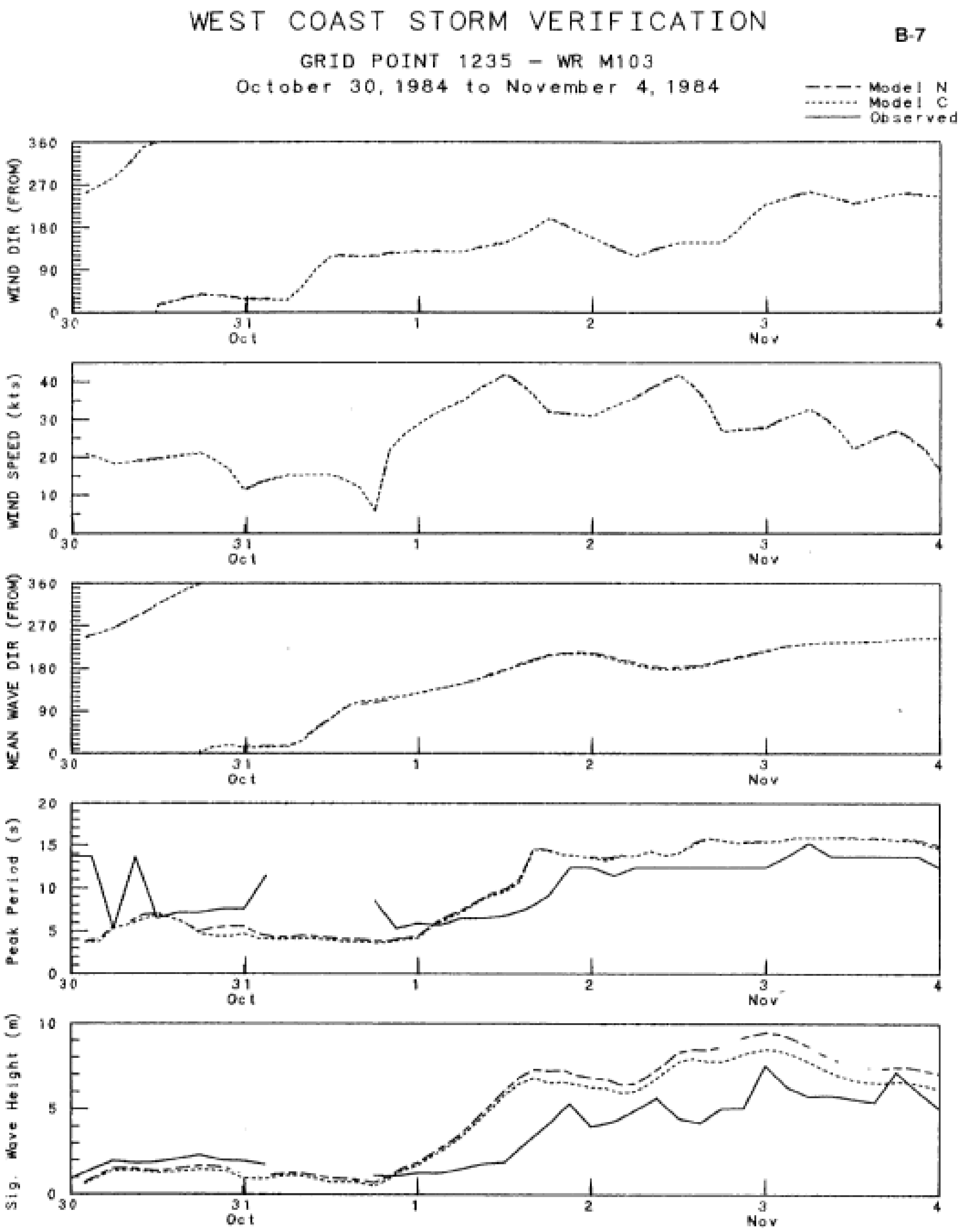
WEST COAST STORM VERIFICATION

B-6

GRID POINT 598 — WR 46005

October 30, 1984 to November 4, 1984





WEST COAST STORM VERIFICATION

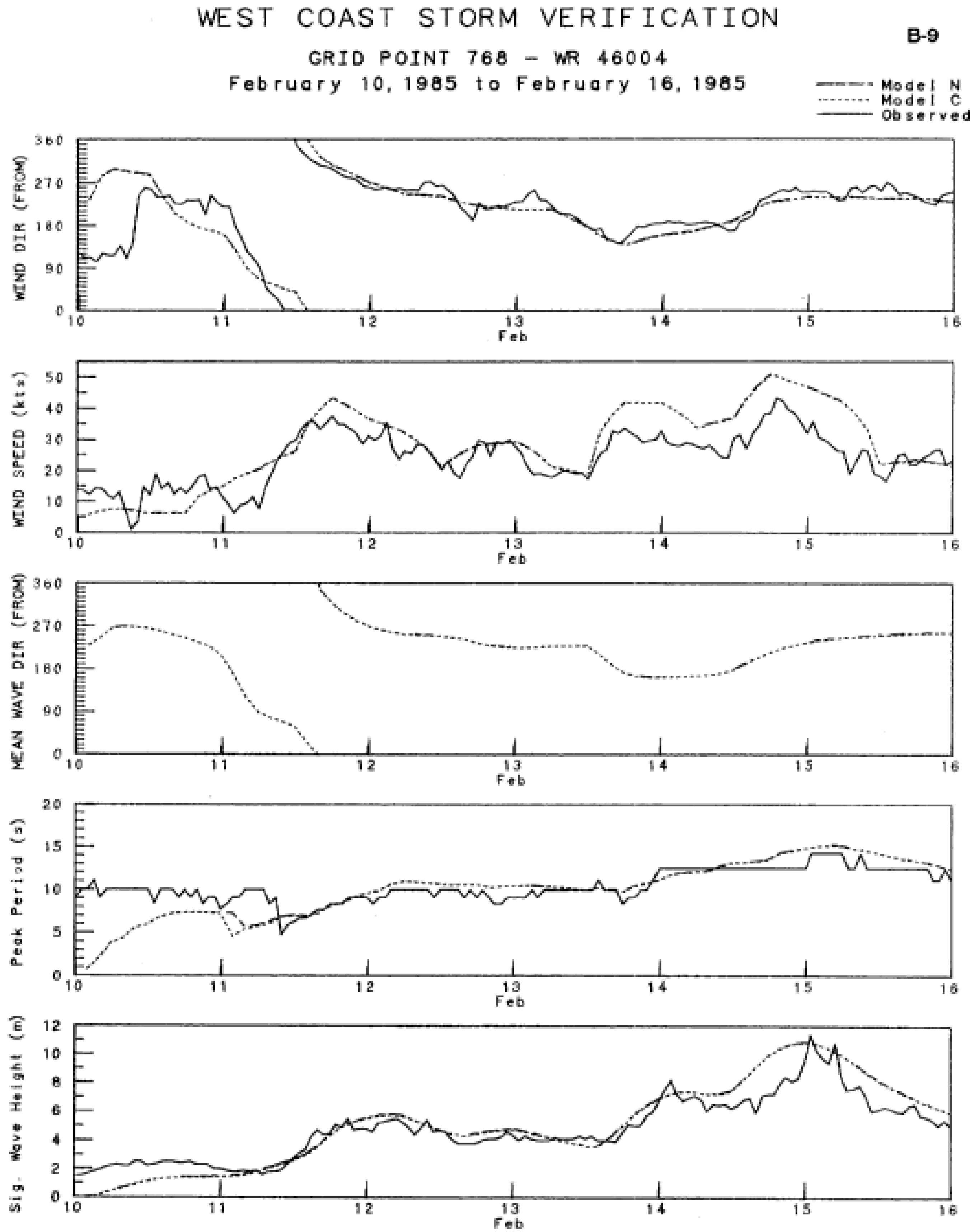
B-7

GRID POINT 1235 – WR M103

October 30, 1984 to November 4, 1984

STORM MCL # 436

FEBRUARY TO FEBRUARY 16, 1985

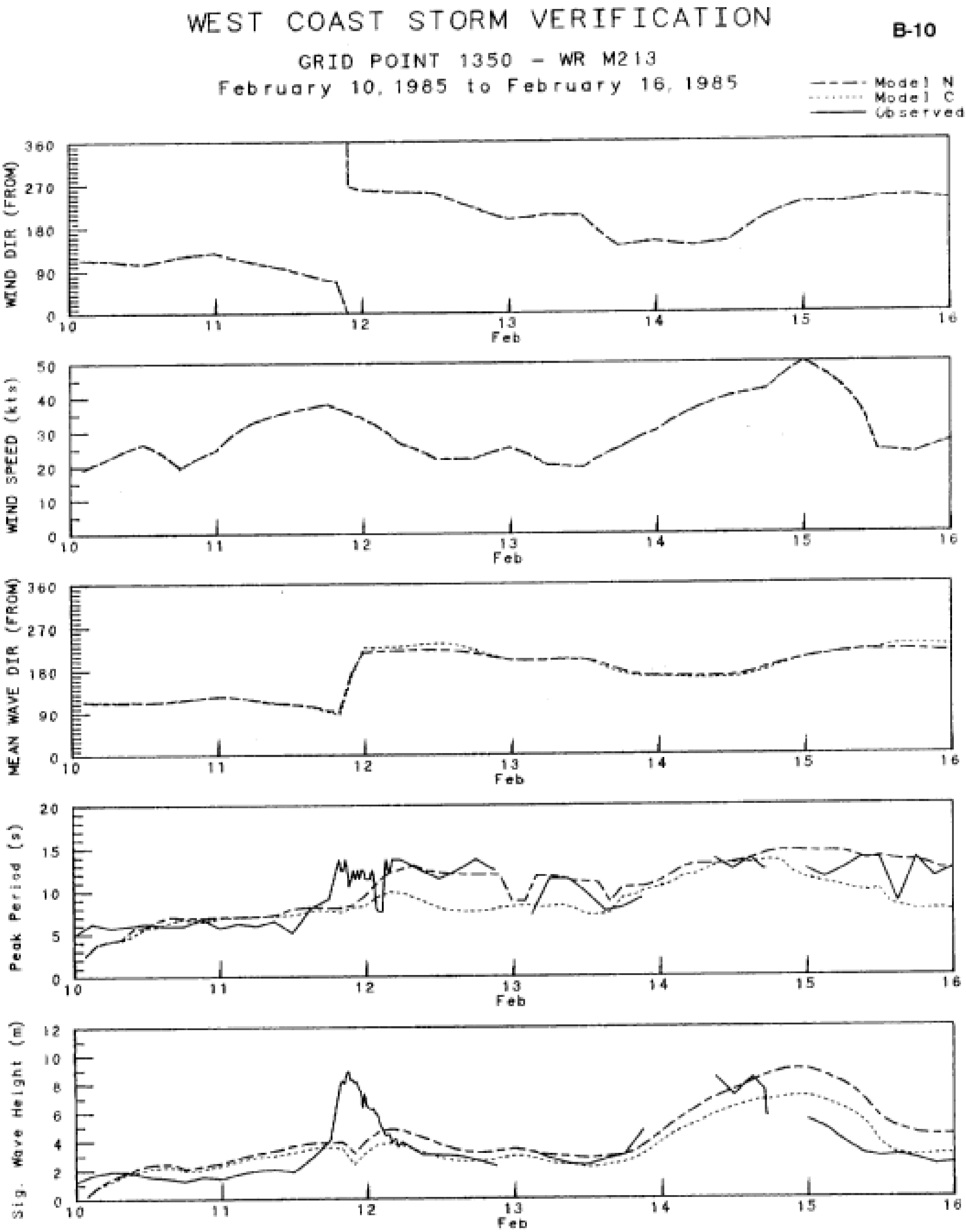


WEST COAST STORM VERIFICATION

B-9

GRID POINT 768 – WR 46004

February 10, 1985 to February 16, 1985



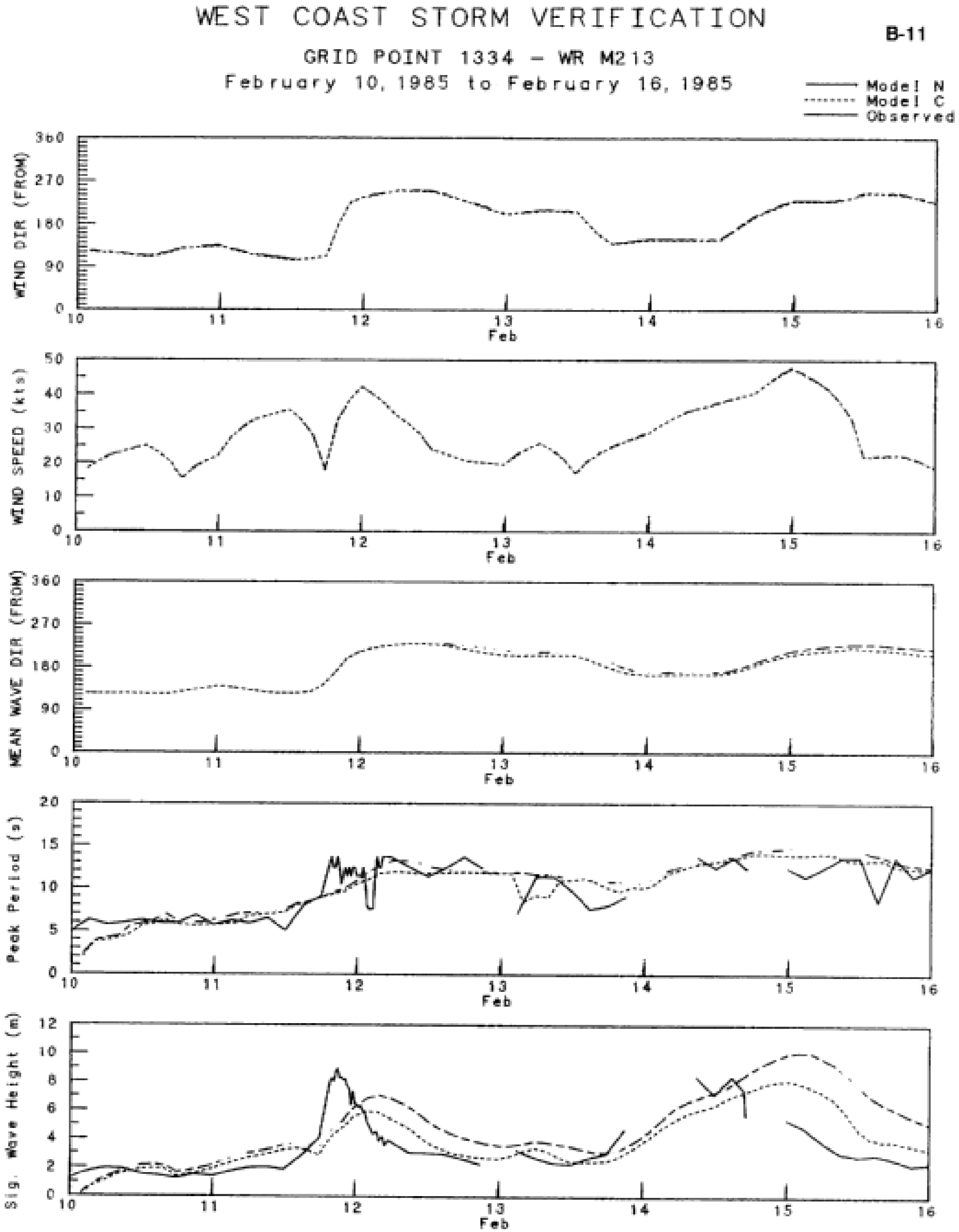
WEST COAST STORM VERIFICATION

B-10

GRID POINT 1350 – WR M213

February 10, 1985 to February 16, 1985

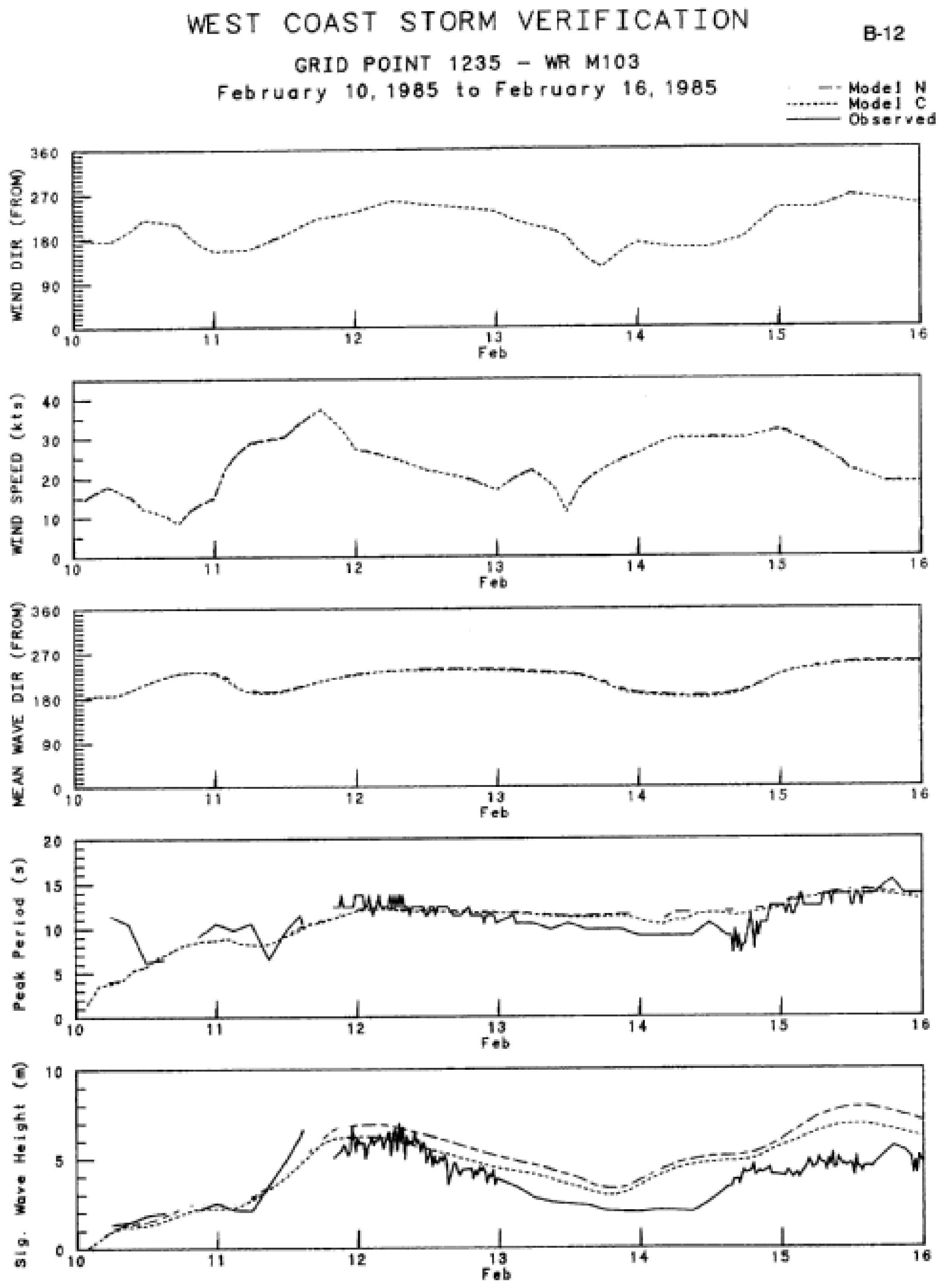
B-11



WEST COAST STORM VERIFICATION

GRID POINT 1334 – WR M213

February 10, 1985 to February 16, 1985


WEST COAST STORM VERIFICATION
B-12
GRID POINT 1235 – WR M103
February 10, 1985 to February 16, 1985
Model N
Model C
Observed
WIND DIR (FROM)
360
270
180
90
0
WIND SPEED (kts)
40
30
20
10
0
MEAN WAVE DIR (FROM)
360
270
180
90
0
Peak Period (s)
20
15
10
5
0
Sig. Wave Height (m)
10
5
0
10
11
12
13
14
15
16
Feb

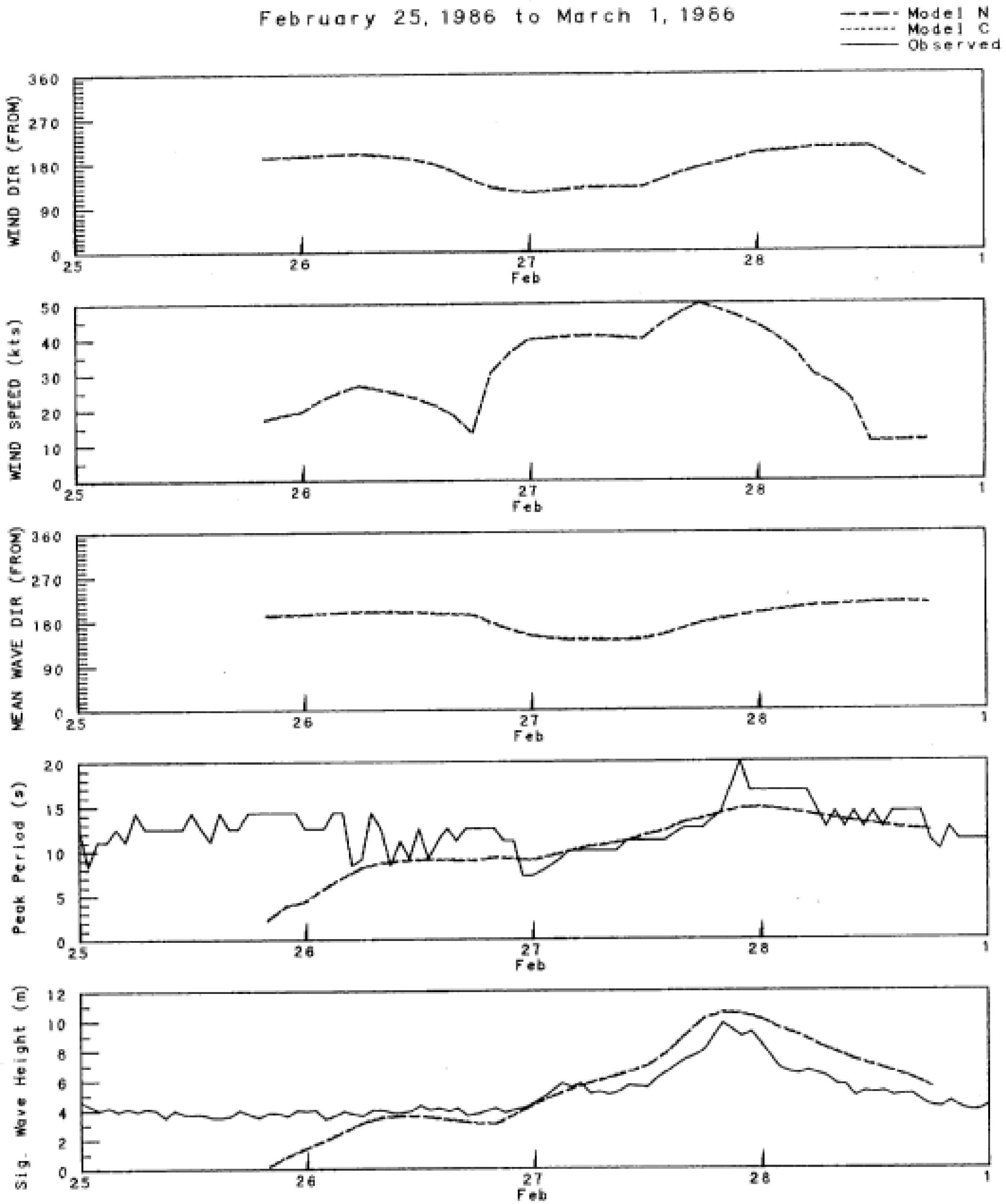
STORM MCL # 444

FEBRUARY 25 TO MARCH 1, 1986

WEST COAST STORM VERIFICATION

GRID POINT 768 – WR 46004

February 25, 1986 to March 1, 1986

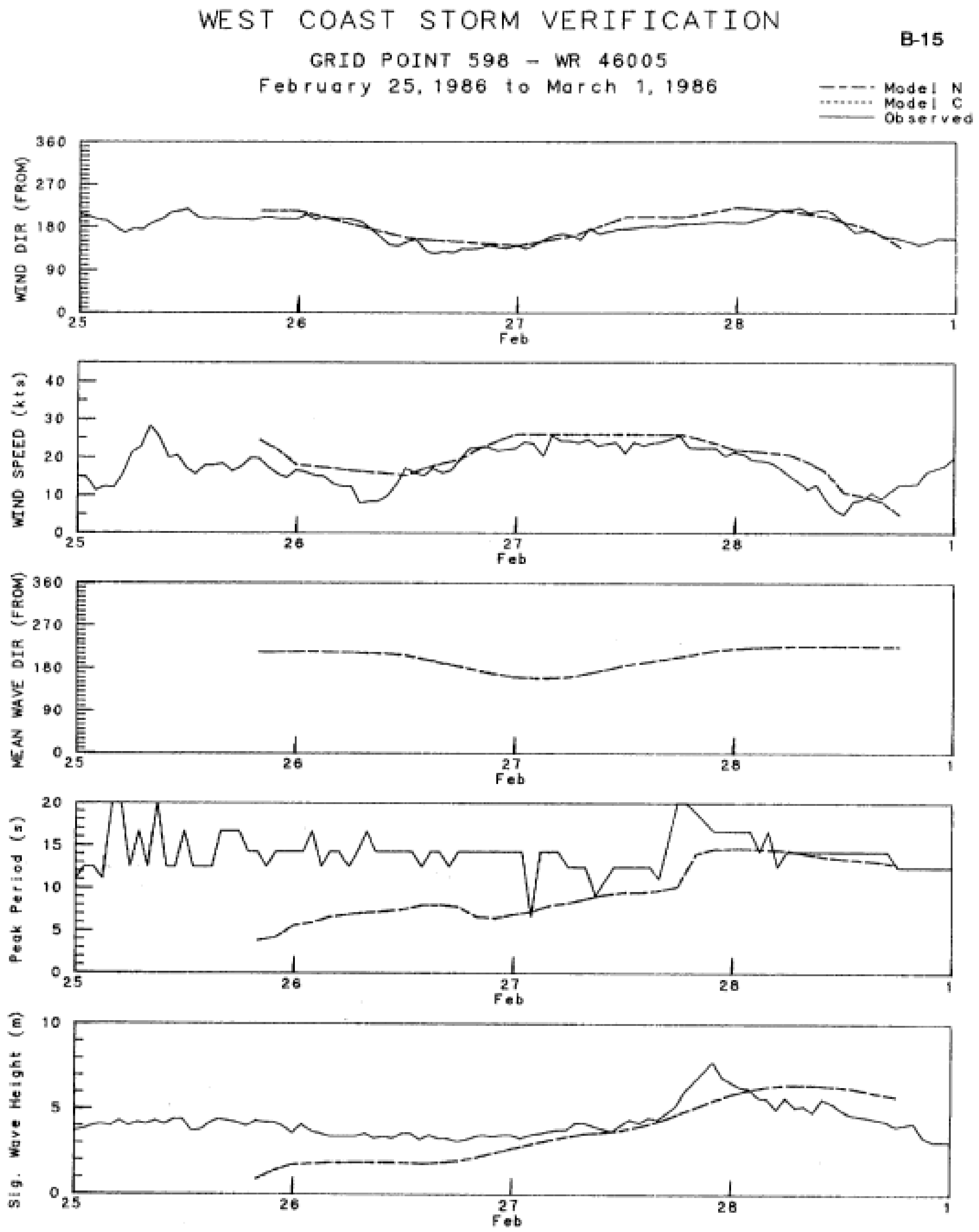


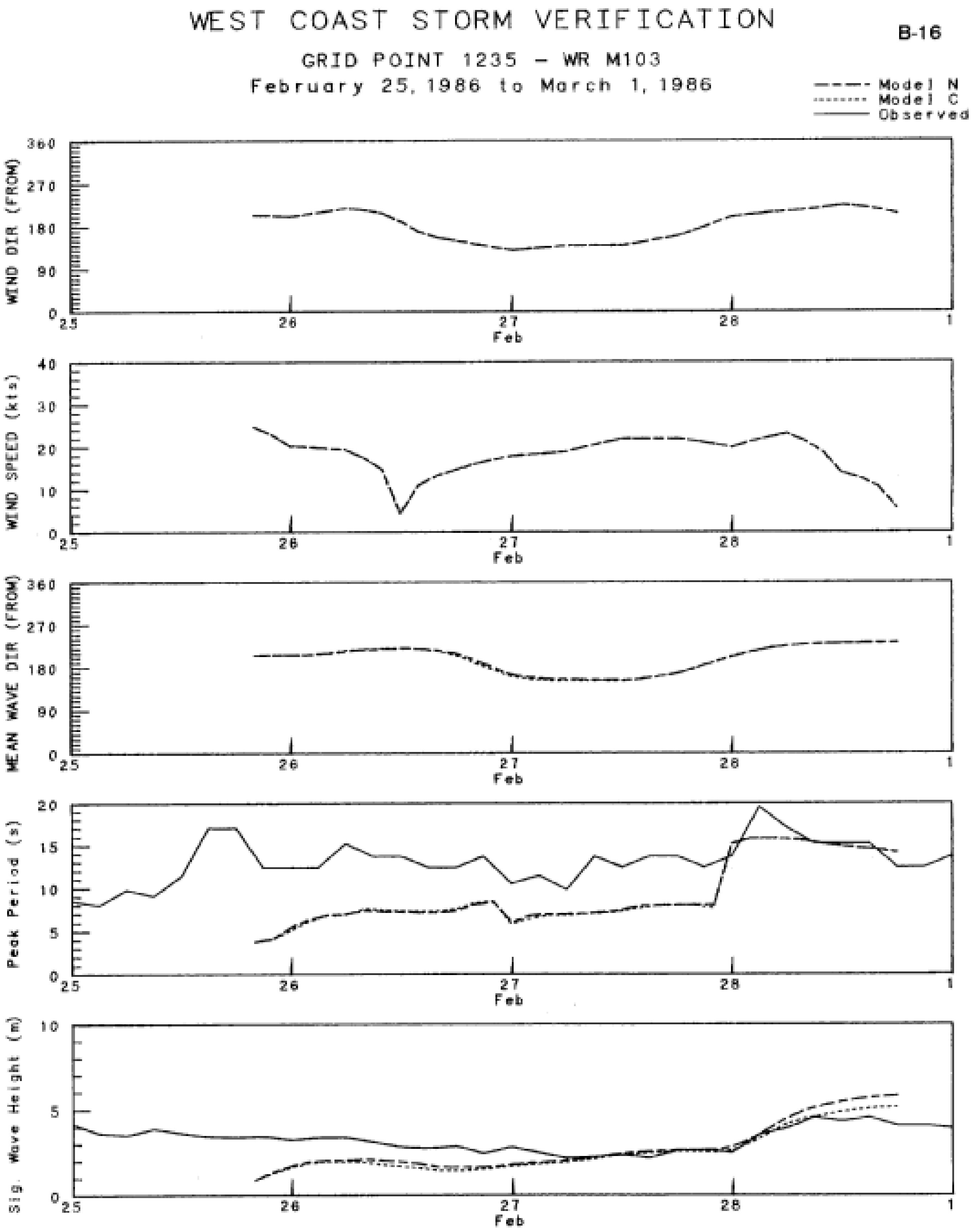
WEST COAST STORM VERIFICATION

B-15

GRID POINT 598 – WR 46005

February 25, 1986 to March 1, 1986





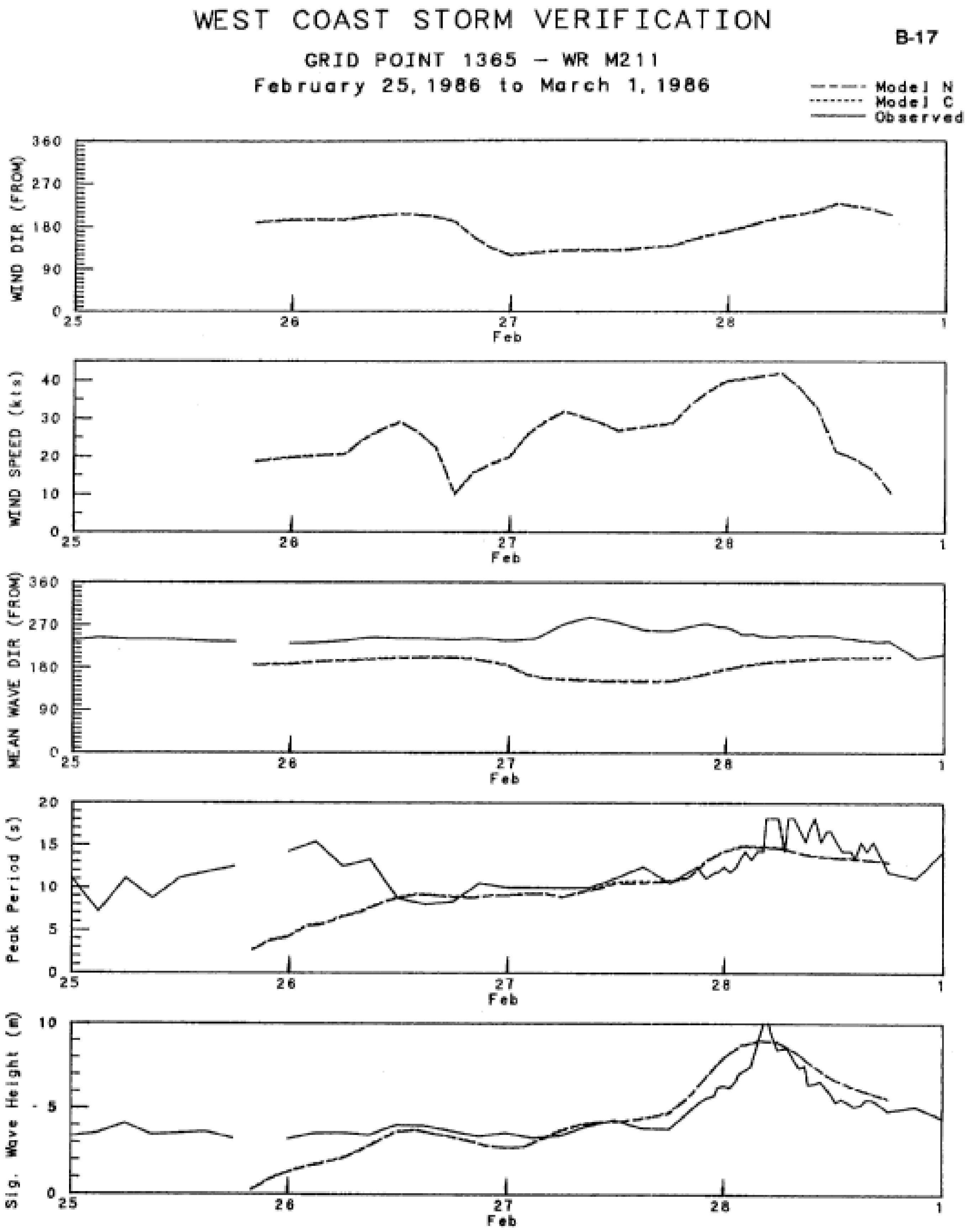
WEST COAST STORM VERIFICATION

B-16

GRID POINT 1235 – WR M103

February 25, 1986 to March 1, 1986

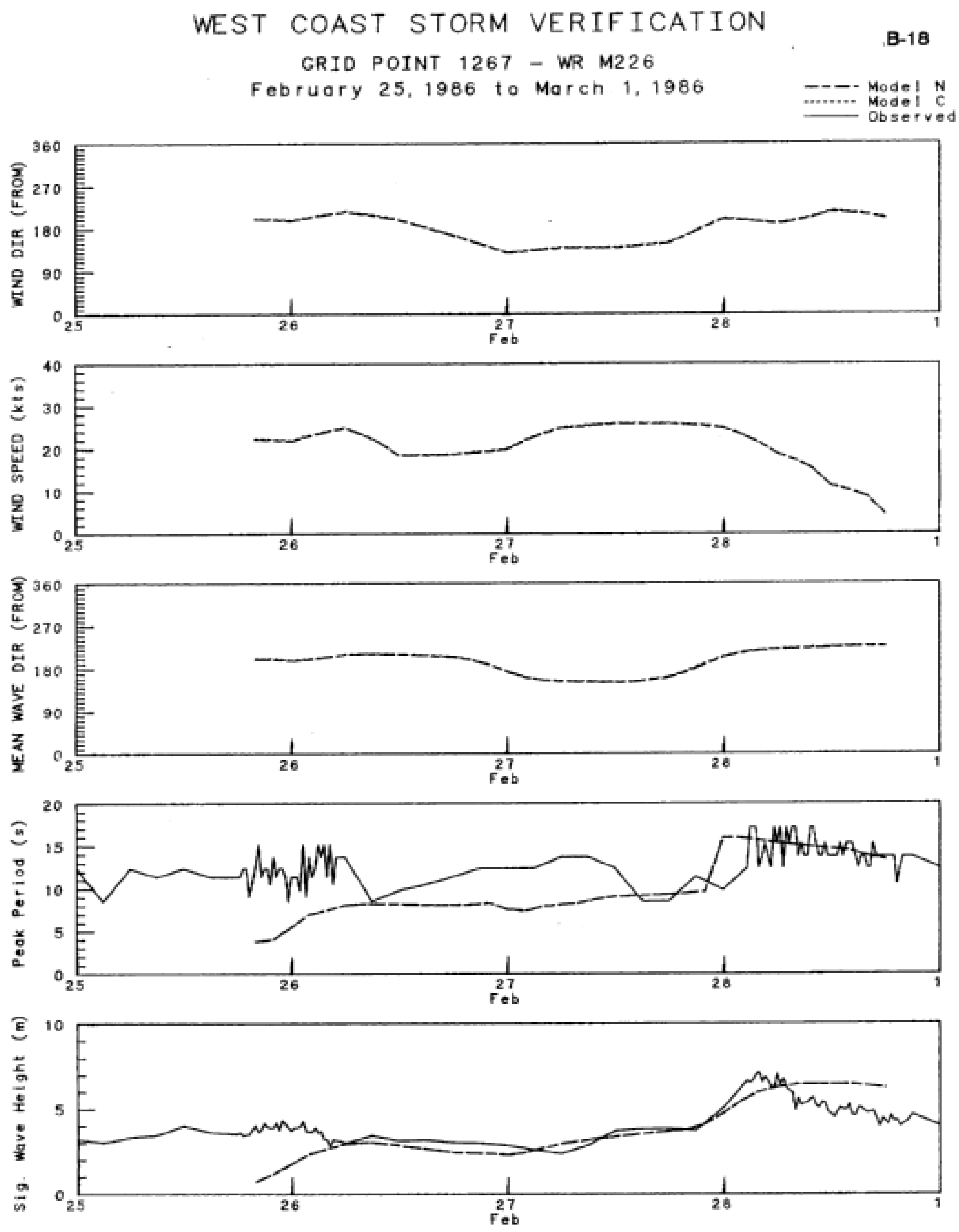
B-17



WEST COAST STORM VERIFICATION

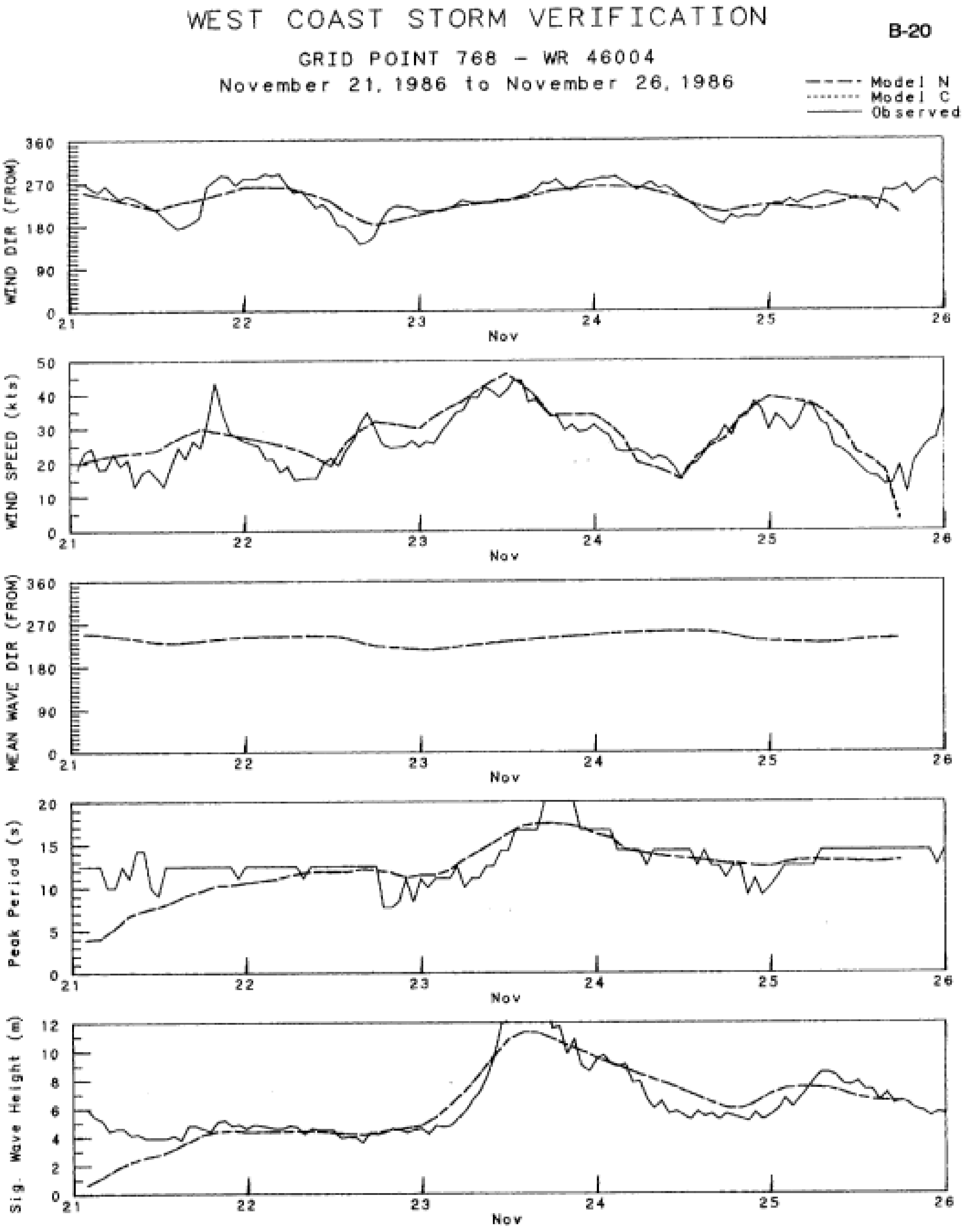
GRID POINT 1365 – WR M211

February 25, 1986 to March 1, 1986


WEST COAST STORM VERIFICATION
GRID POINT 1267 – WR M226
February 25, 1986 to March 1, 1986
B-18
Model N
Model C
Observed
WIND DIR (FROM)
360
270
180
90
0
25
26
27
28
1
Feb
WIND SPEED (kts)
40
30
20
10
0
MEAN WAVE DIR (FROM)
Peak Period (s)
20
15
10
5
Sig. Wave Height (m)
10
5
0

STORM MCL # 450

NOVEMBER 21 TO NOVEMBER 26, 1986

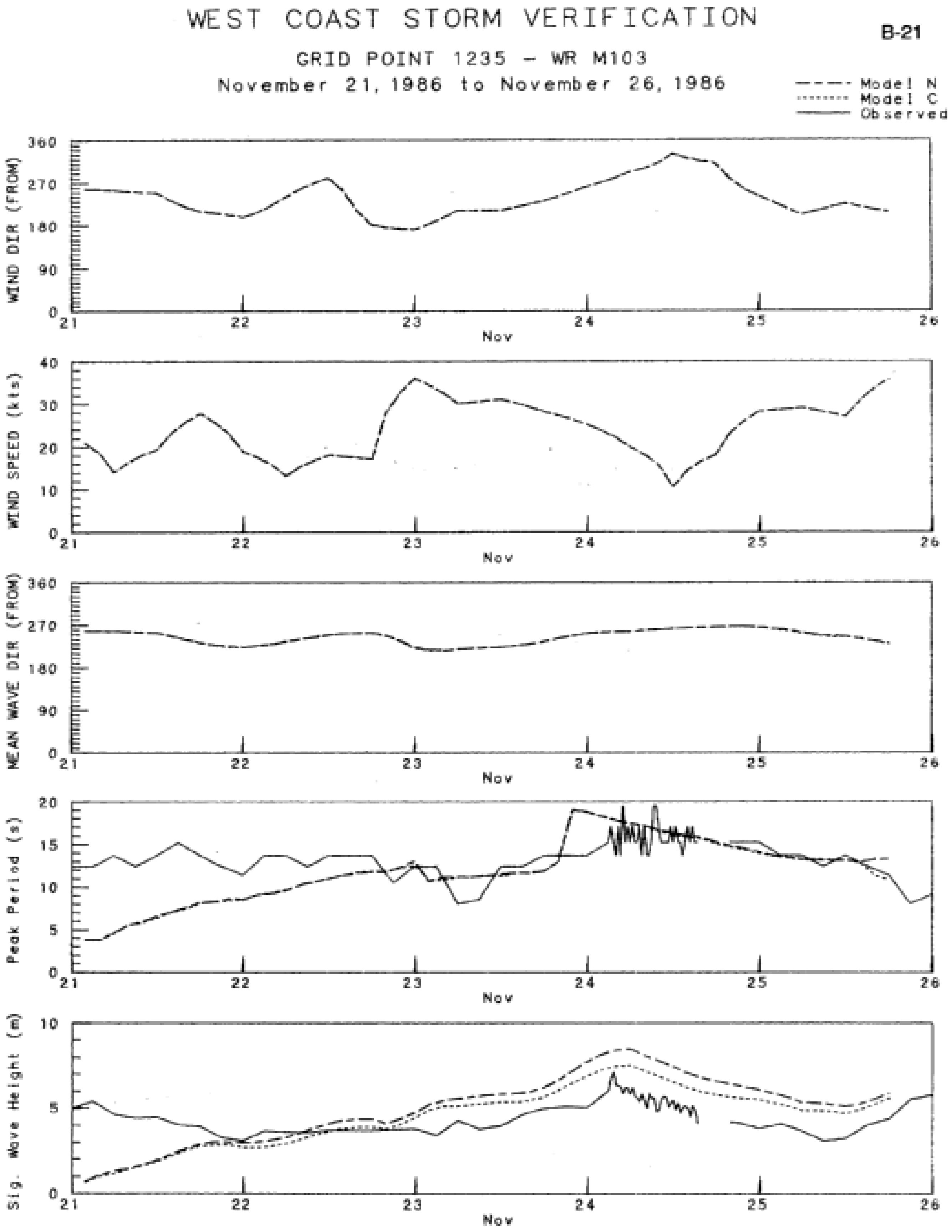


WEST COAST STORM VERIFICATION

GRID POINT 768 – WR 46004

November 21, 1986 to November 26, 1986

B-20



WEST COAST STORM VERIFICATION

B-21

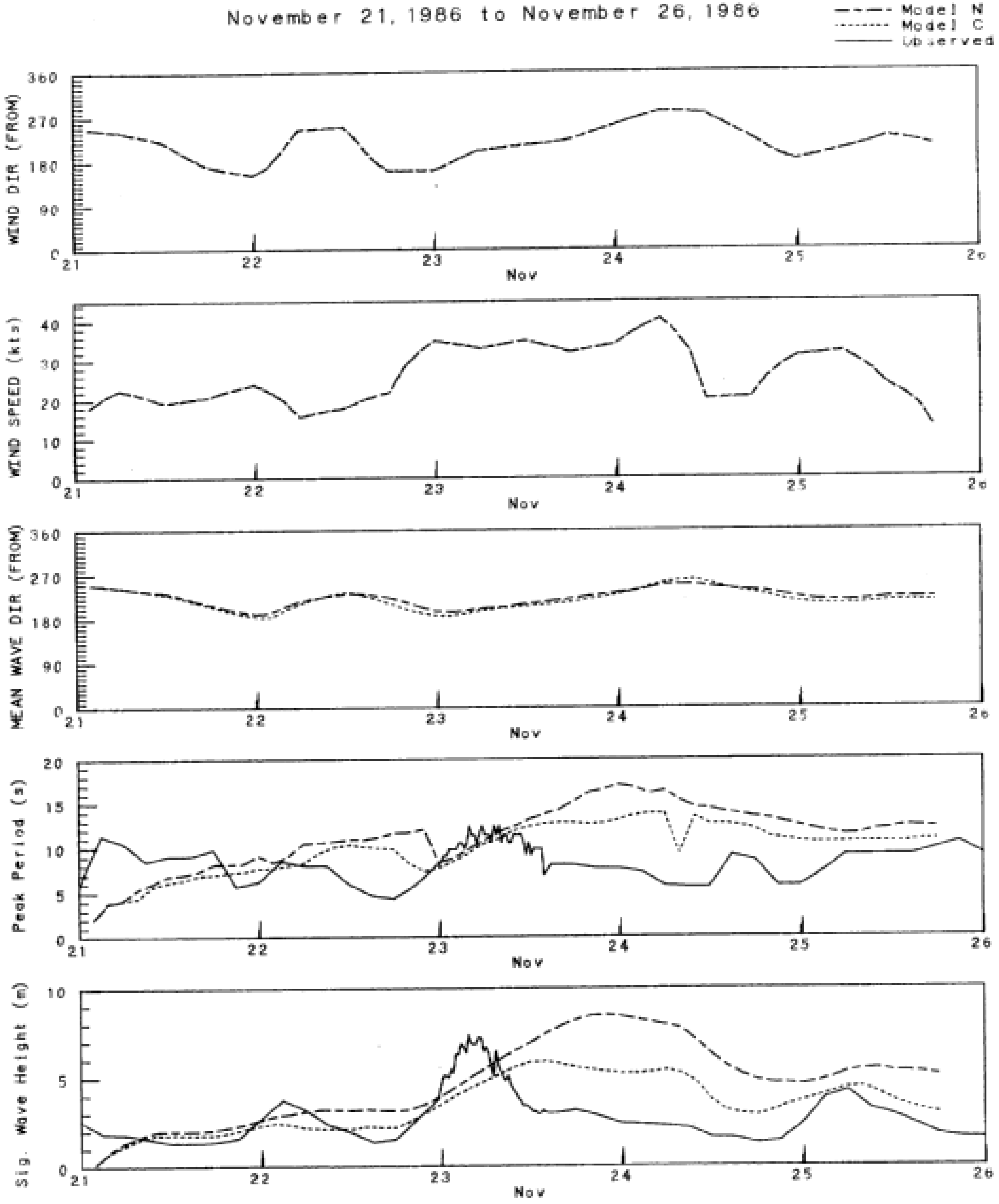
GRID POINT 1235 – WR M103

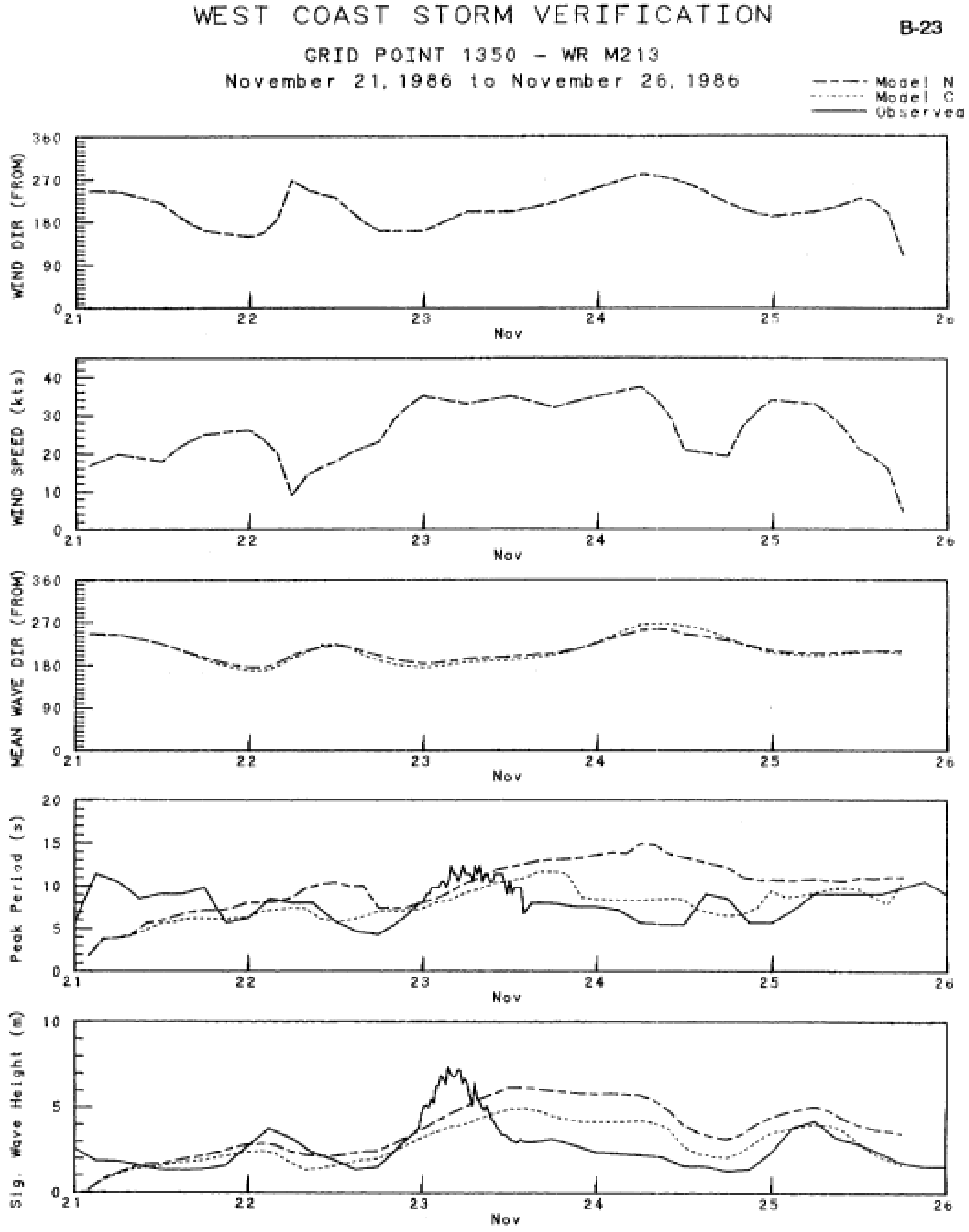
November 21, 1986 to November 26, 1986

WEST COAST STORM VERIFICATION

B-22

GRID POINT 1334 – WR M213
November 21, 1986 to November 26, 1986



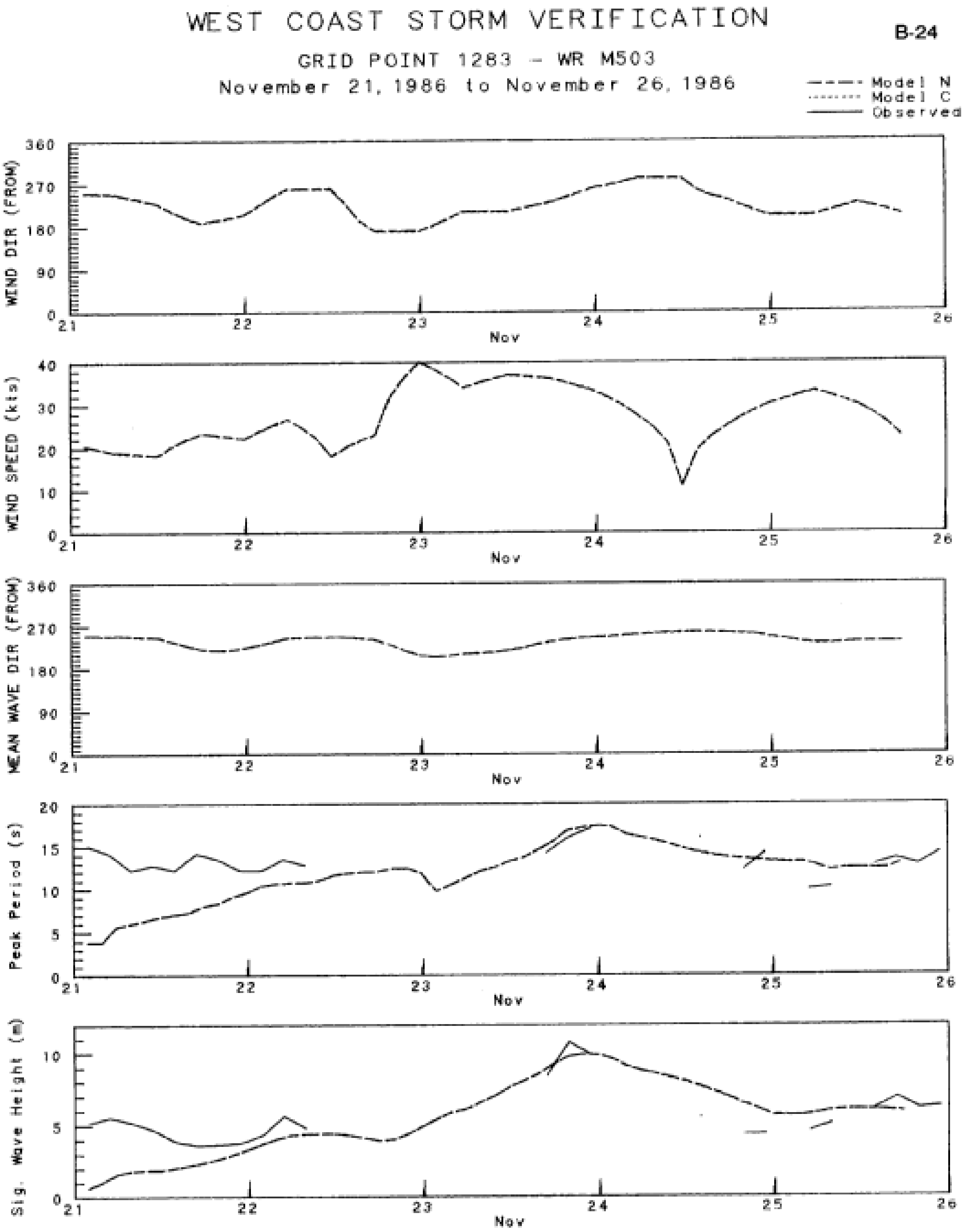


WEST COAST STORM VERIFICATION

B-23

GRID POINT 1350 – WR M213

November 21, 1986 to November 26, 1986



WEST COAST STORM VERIFICATION

GRID POINT 1283 – WR M503

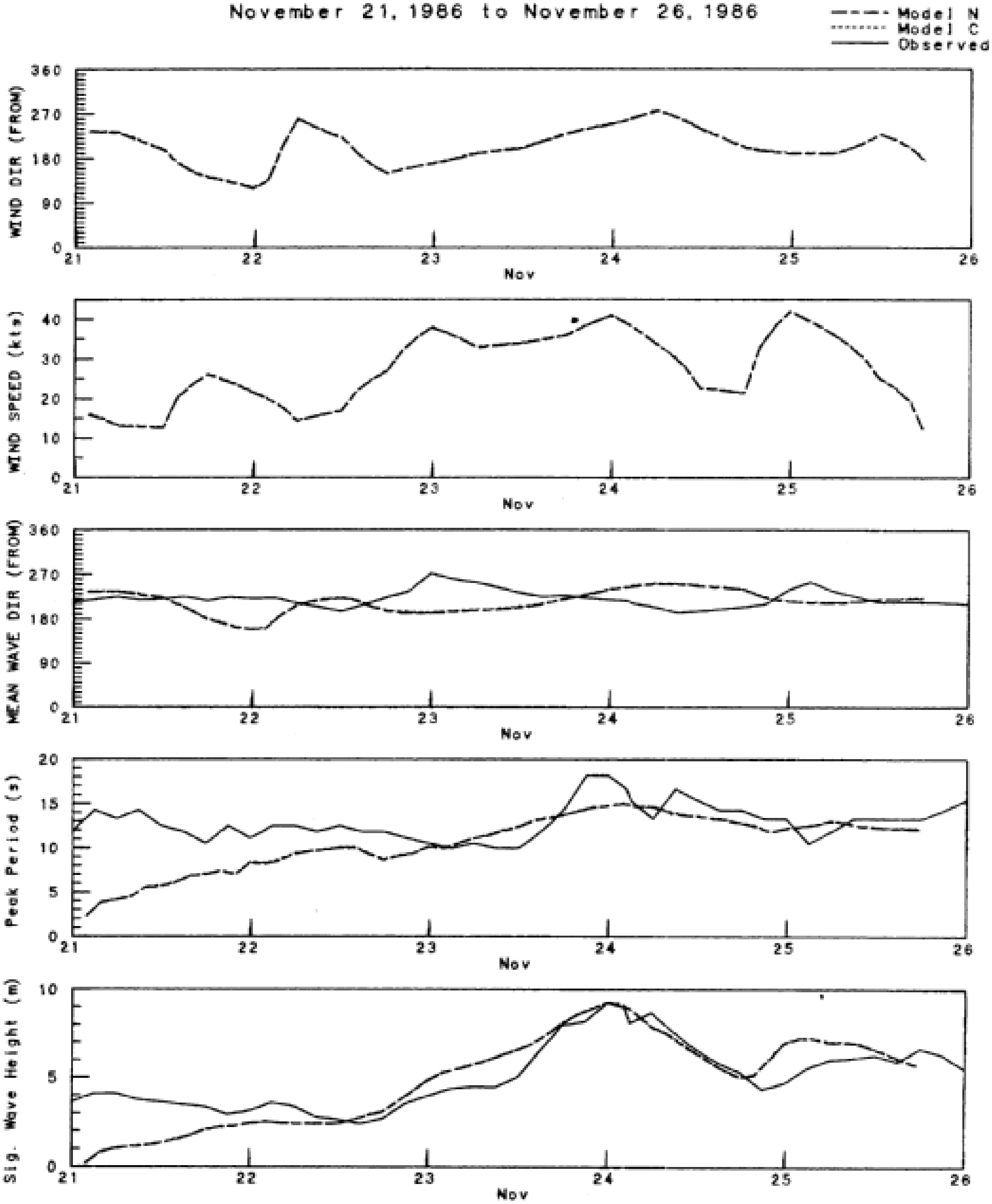
November 21, 1986 to November 26, 1986

WEST COAST STORM VERIFICATION

B-25

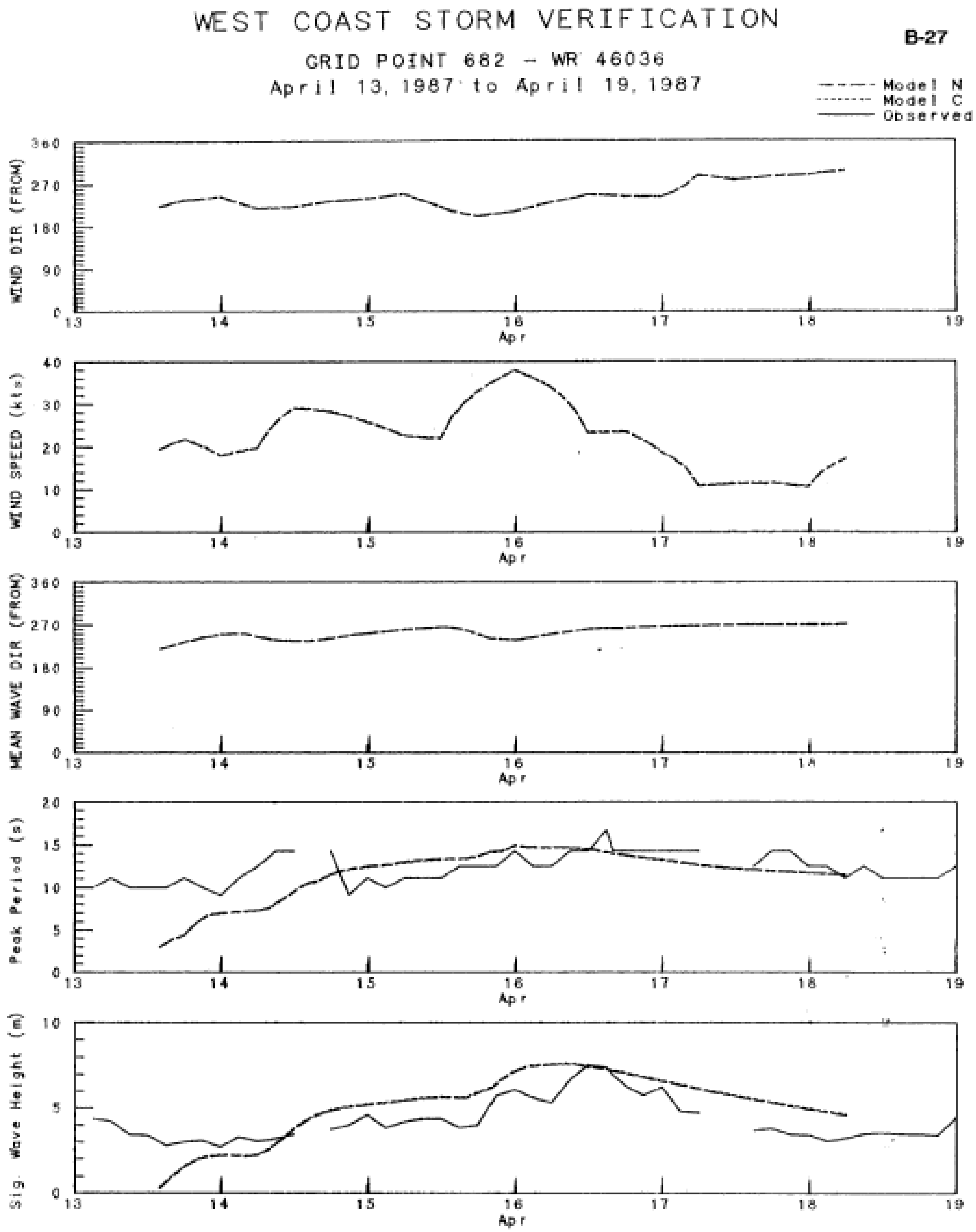
GRID POINT 1365 – WR M211

November 21, 1986 to November 26, 1986



STORM MCL # 461

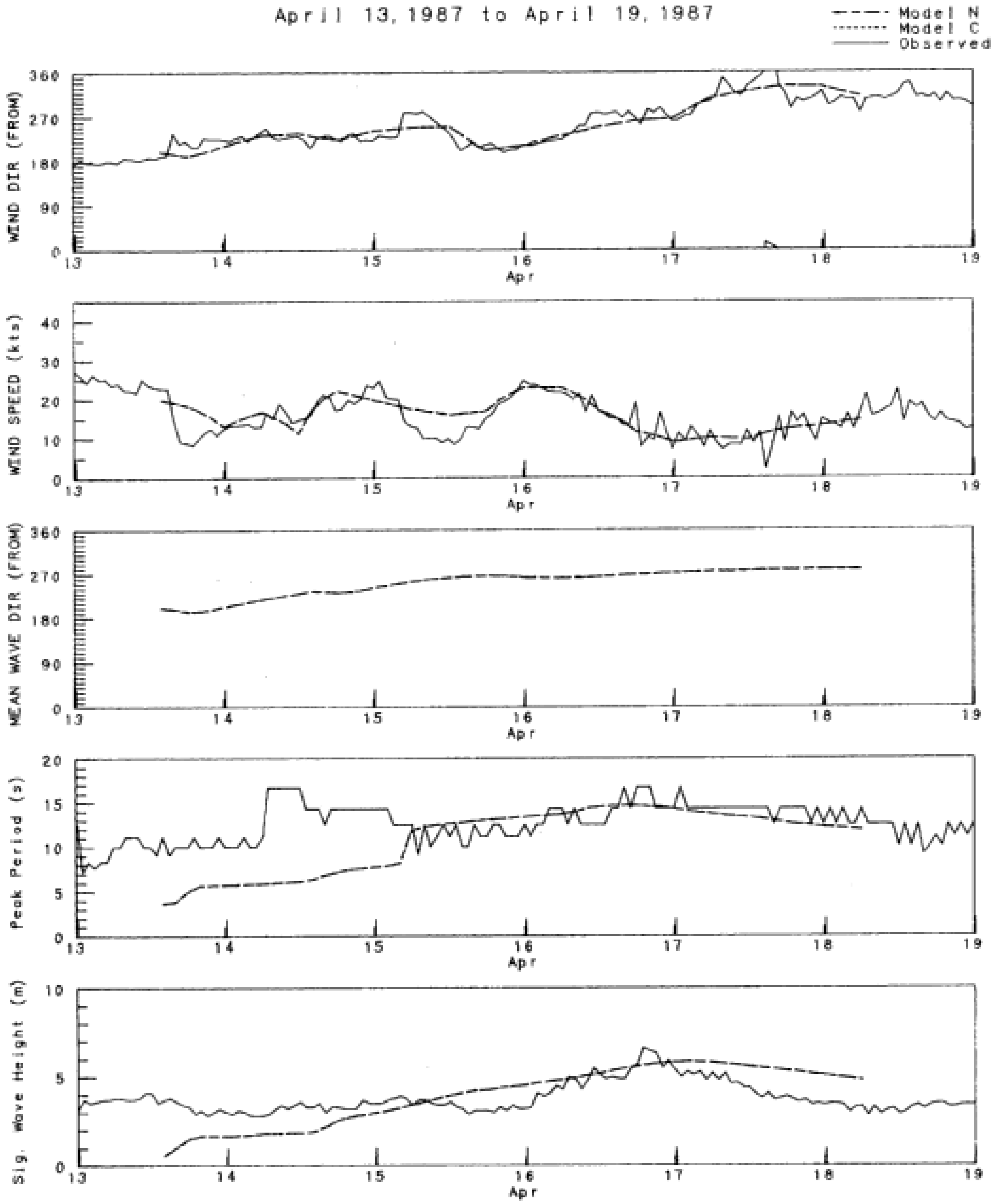
APRIL 13 TO APRIL 19, 1987


WEST COAST STORM VERIFICATION
B-27
GRID POINT 682 – WR 46036
April 13, 1987 to April 19, 1987
Model N
Model C
Observed
WIND DIR (FROM)
360
270
180
90
0
WIND SPEED (kts)
40
30
20
10
0
MEAN WAVE DIR (FROM)
360
270
180
90
0
Peak Period (s)
20
15
10
5
0
Sig. Wave Height (m)
10
5
0
13
14
15
16
17
18
19
Apr

WEST COAST STORM VERIFICATION

B-28

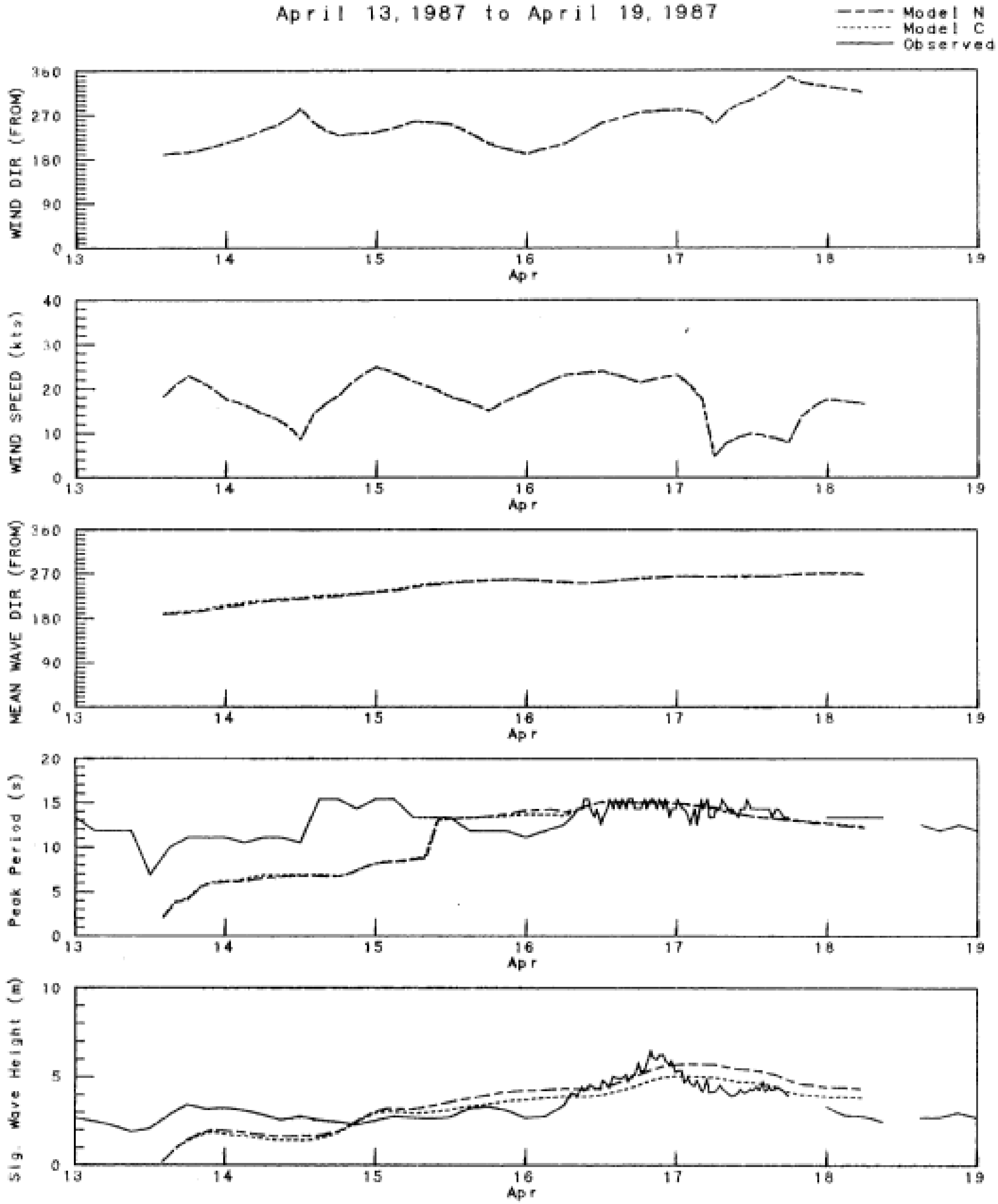
GRID POINT 598 – WR 46005
April 13, 1987 to April 19, 1987

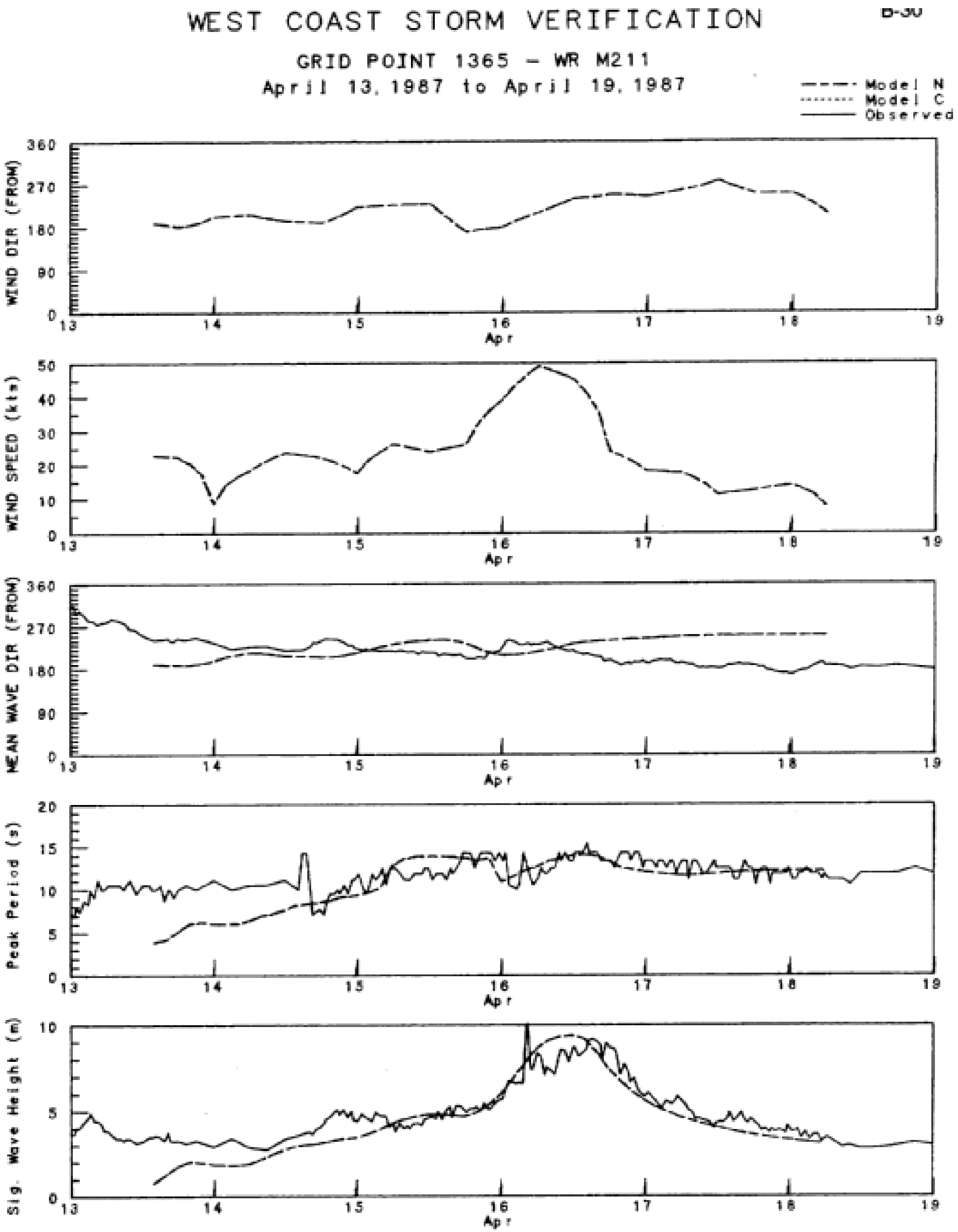


WEST COAST STORM VERIFICATION

GRID POINT 1235 - WR CYAZWV

April 13, 1987 to April 19, 1987



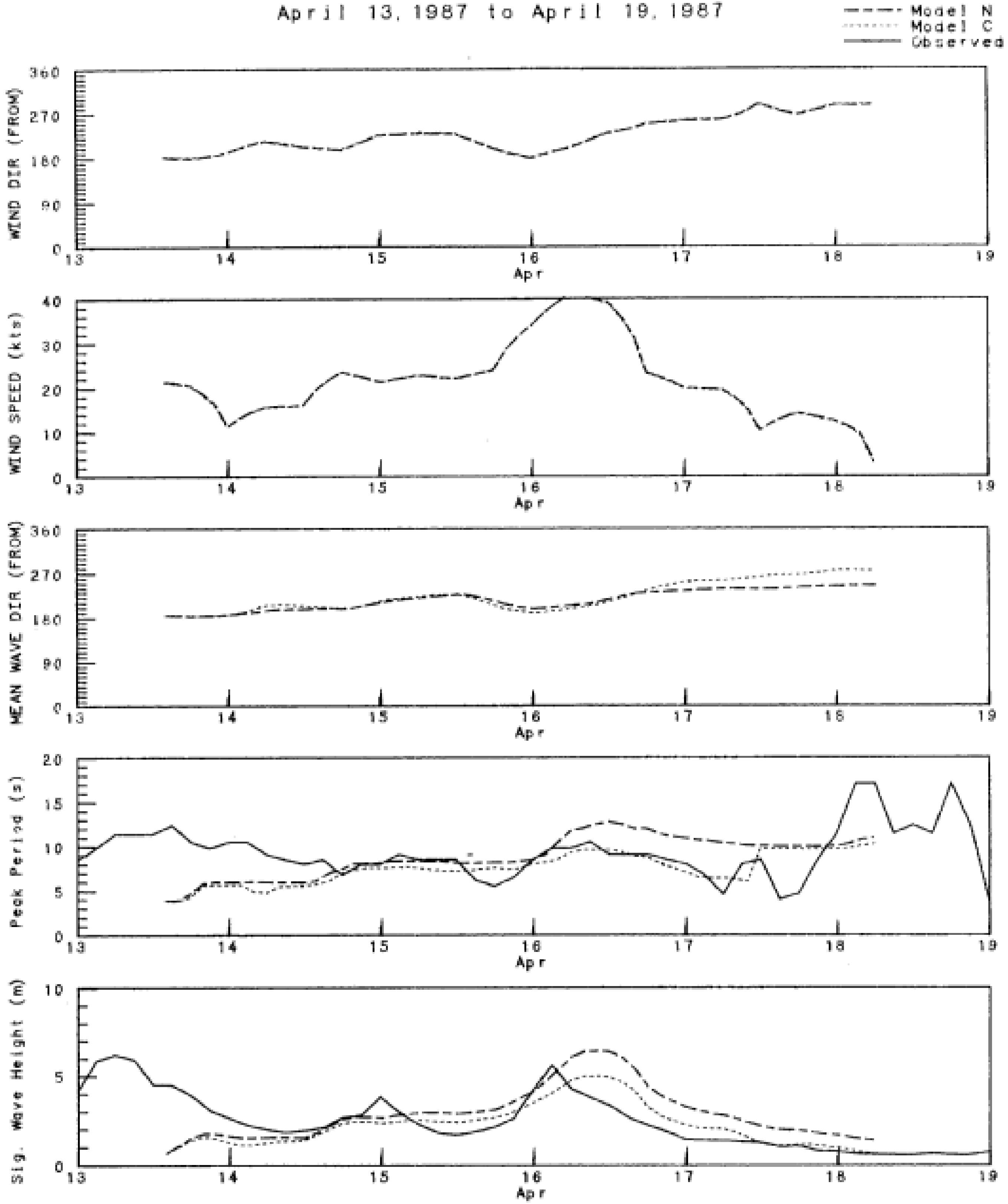


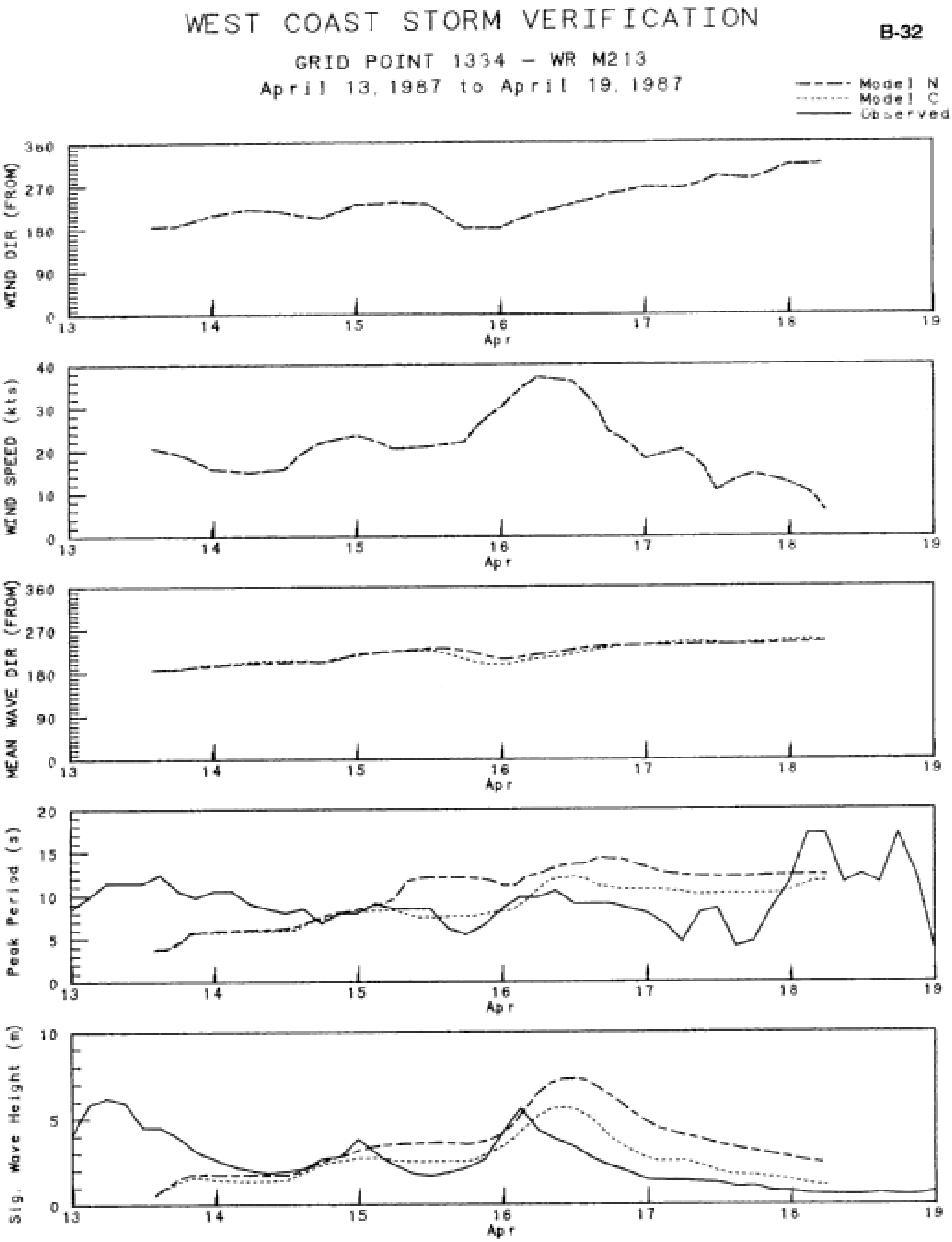
WEST COAST STORM VERIFICATION

GRID POINT 1365 – WR M211
April 13, 1987 to April 19, 1987

WEST COAST STORM VERIFICATION

GRID POINT 1350 – WR M213
April 13, 1987 to April 19, 1987

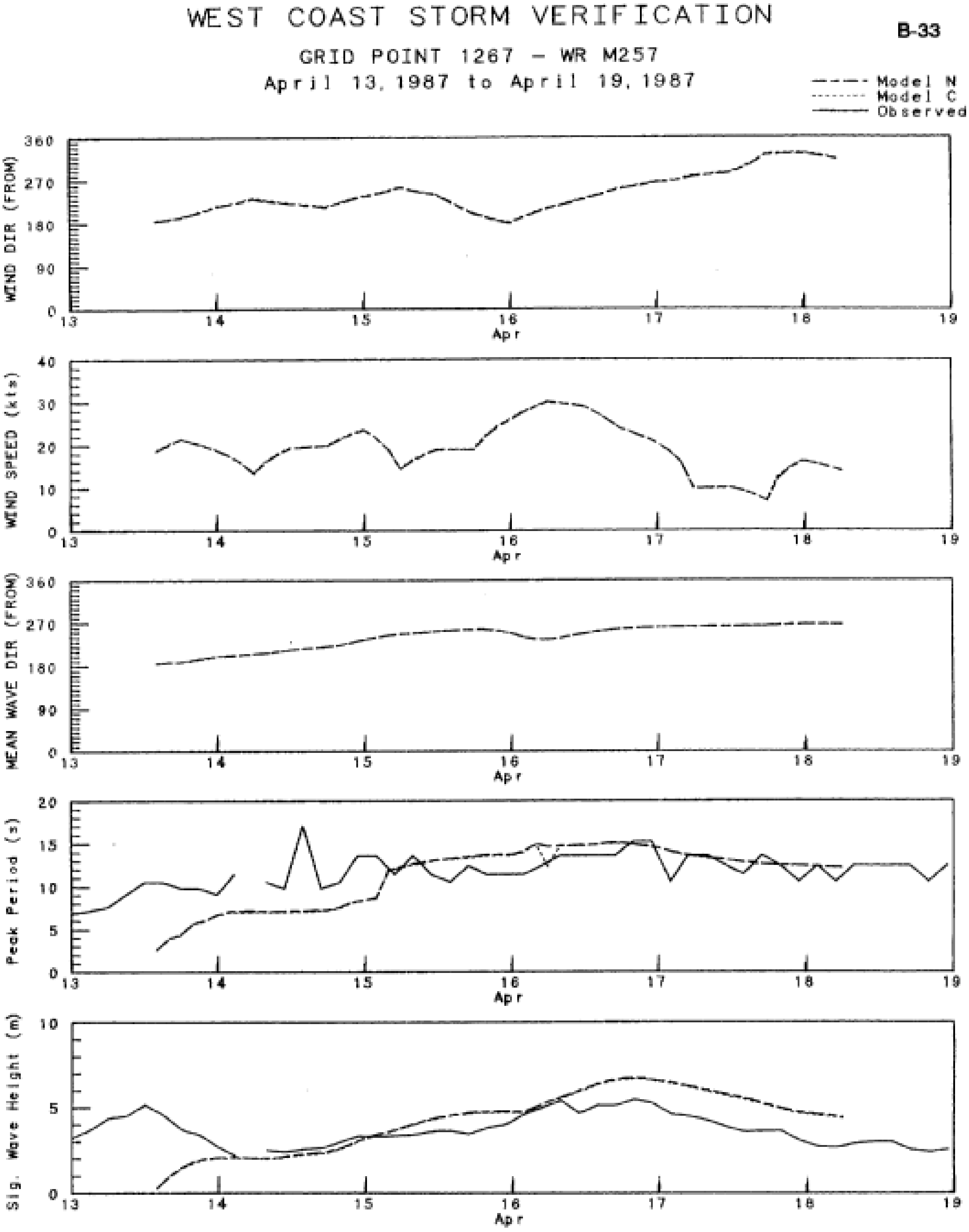


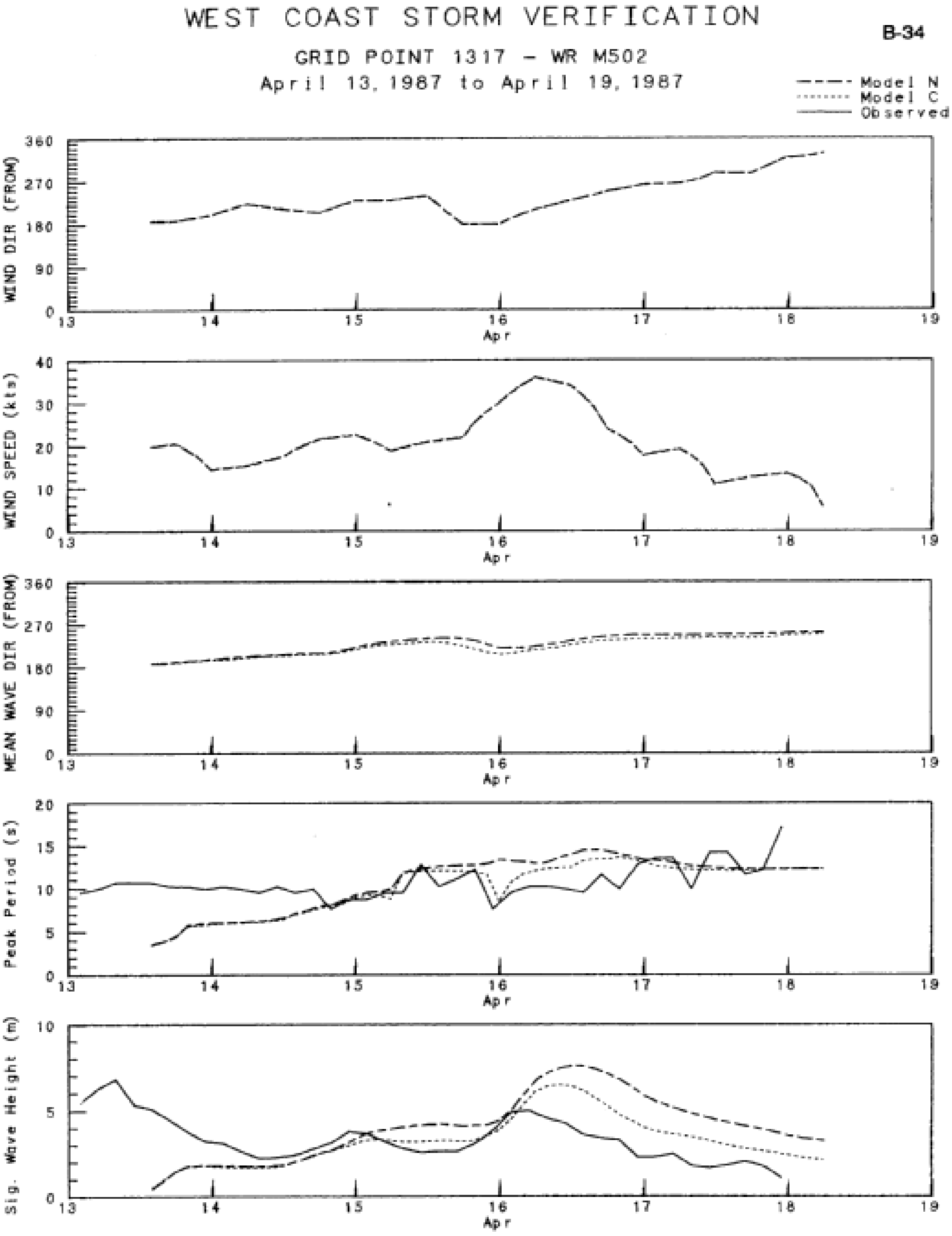


WEST COAST STORM VERIFICATION

GRID POINT 1334 – WR M213

April 13, 1987 to April 19, 1987


WEST COAST STORM VERIFICATION
B-33
GRID POINT 1267 – WR M257
April 13, 1987 to April 19, 1987
Model N
Model C
Observed
WIND DIR (FROM)
360
270
180
90
0
WIND SPEED (kts)
40
30
20
10
0
MEAN WAVE DIR (FROM)
360
270
180
90
0
Peak Period (s)
20
15
10
5
0
Sig. Wave Height (m)
10
5
0
13
14
15
16
17
18
19
Apr

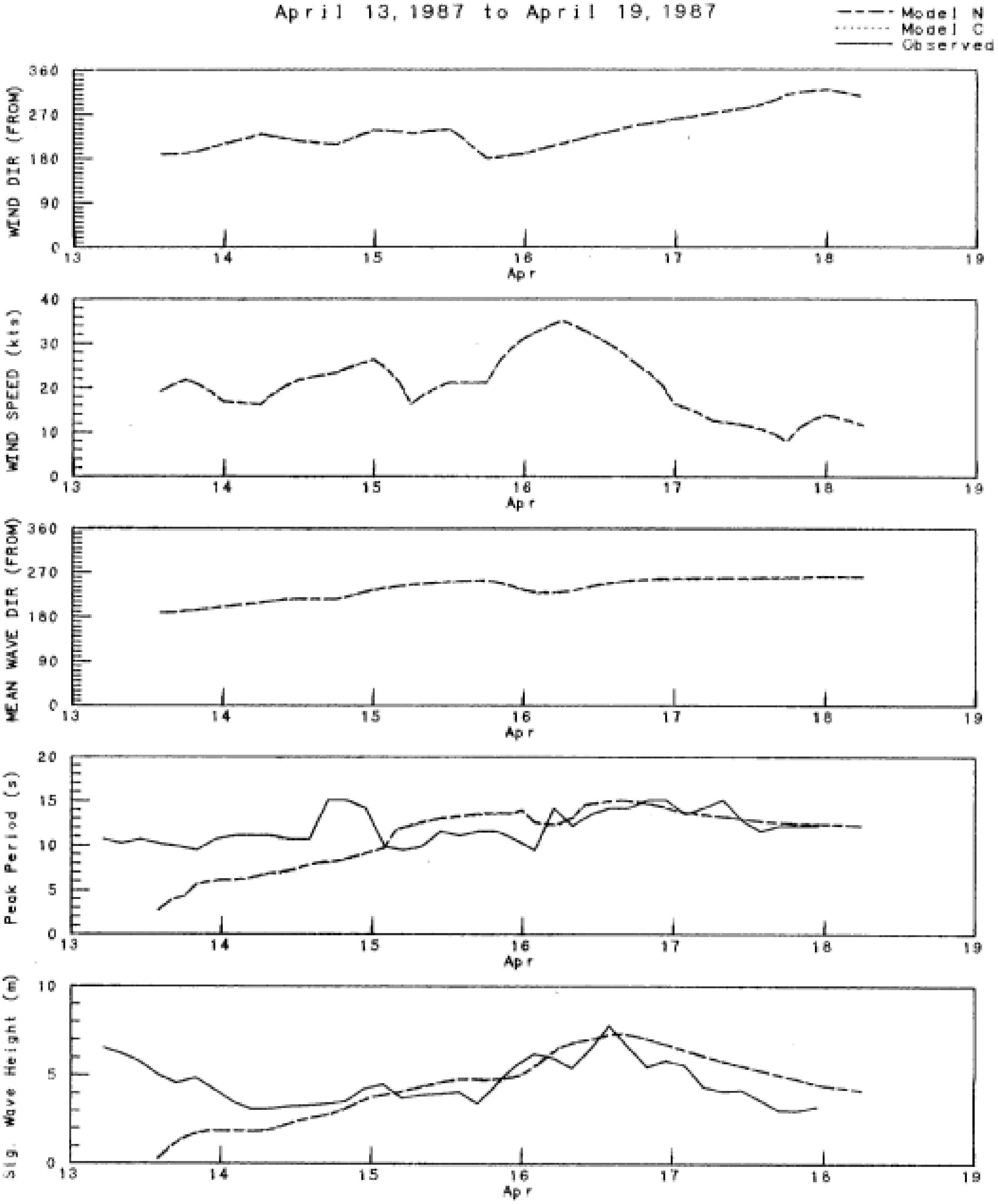

WEST COAST STORM VERIFICATION
B-34
GRID POINT 1317 - WR M502
April 13, 1987 to April 19, 1987
Model N
Model C
Observed
WIND DIR (FROM)
360
270
180
90
0
WIND SPEED (kts)
40
30
20
10
0
MEAN WAVE DIR (FROM)
360
270
180
90
0
Peak Period (s)
20
15
10
5
0
Sig. Wave Height (m)
10
5
0
13
14
15
16
17
18
19
Apr

WEST COAST STORM VERIFICATION

B-35

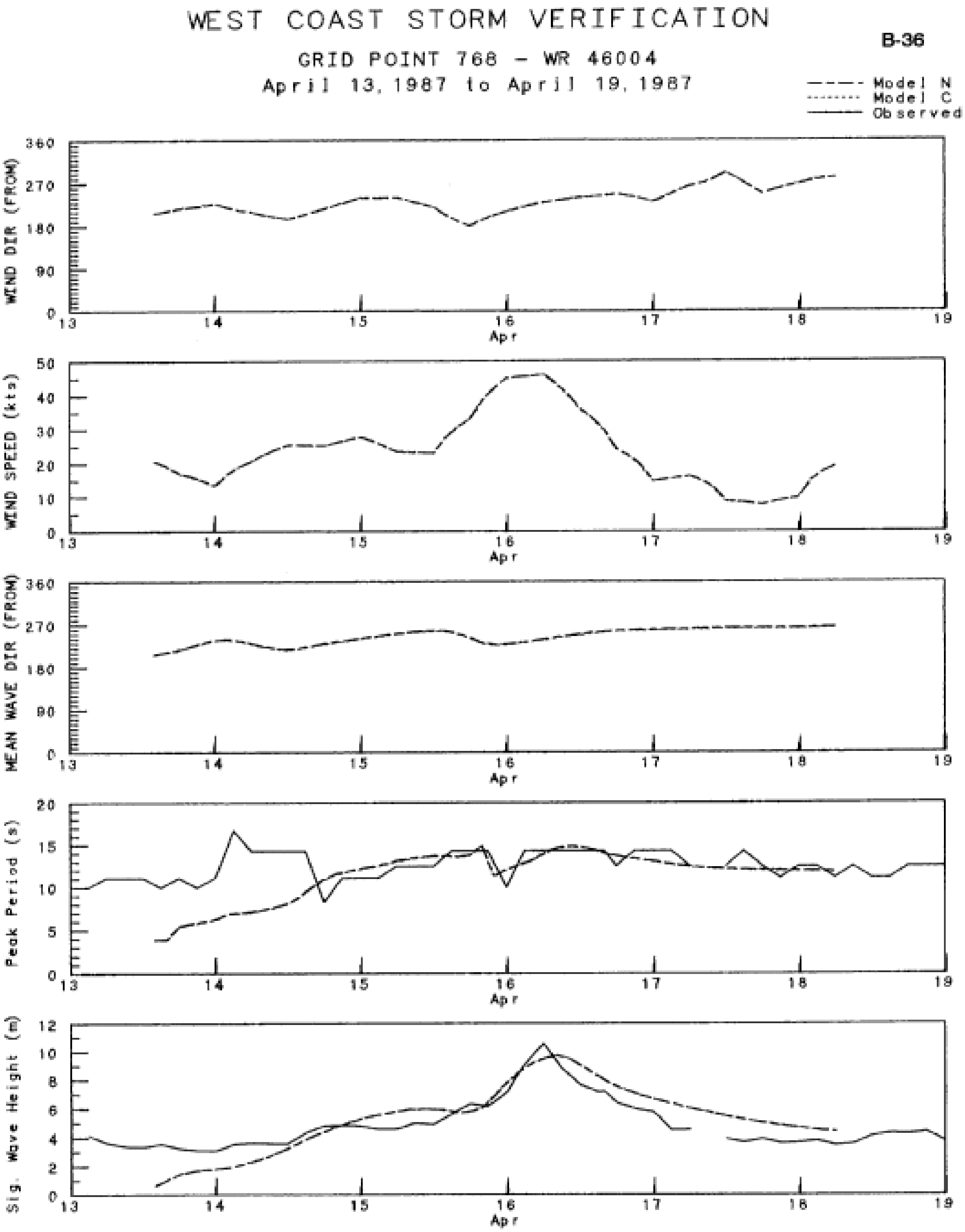
GRID POINT 1283 – WR M503

April 13, 1987 to April 19, 1987



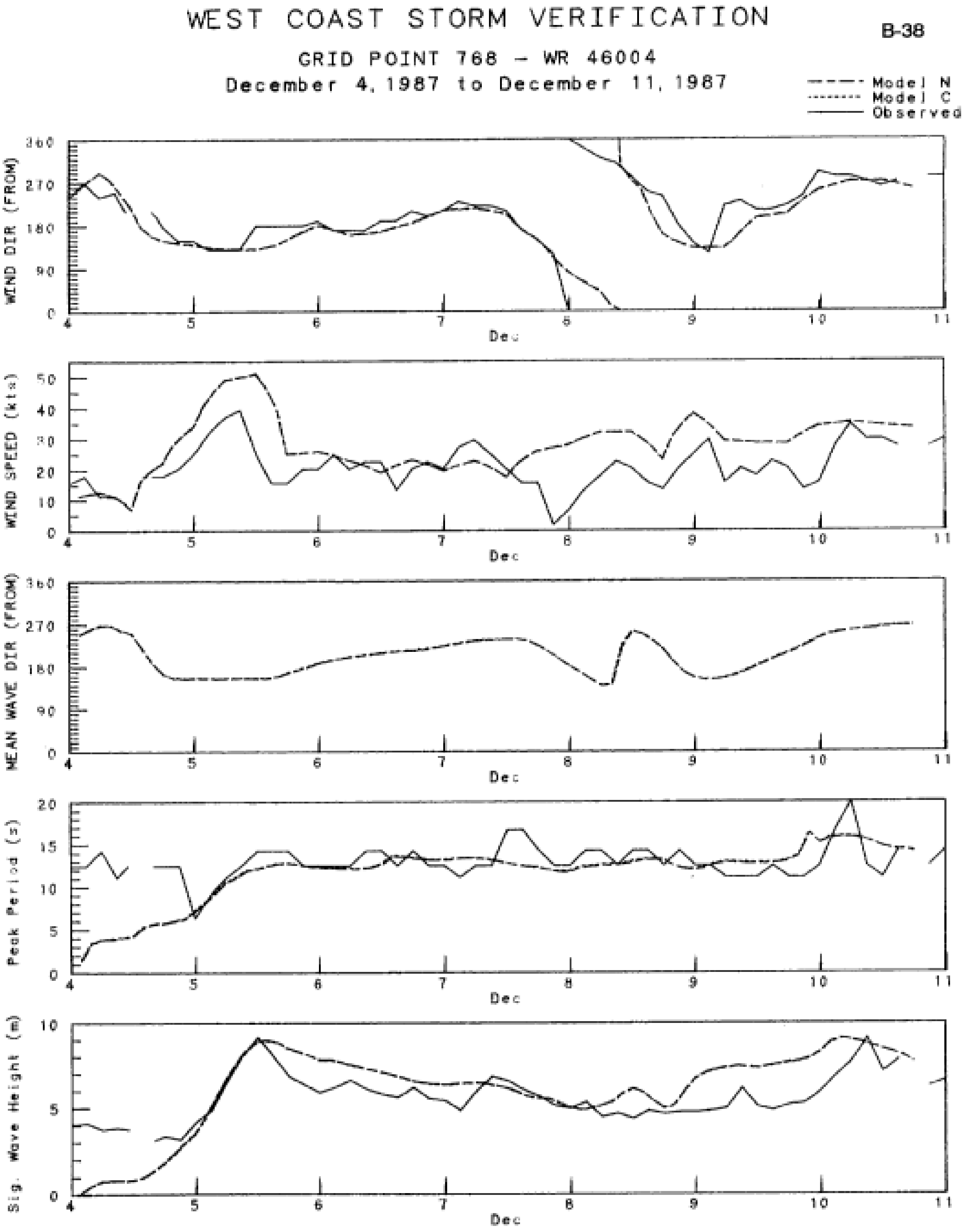
WEST COAST STORM VERIFICATION

B-36



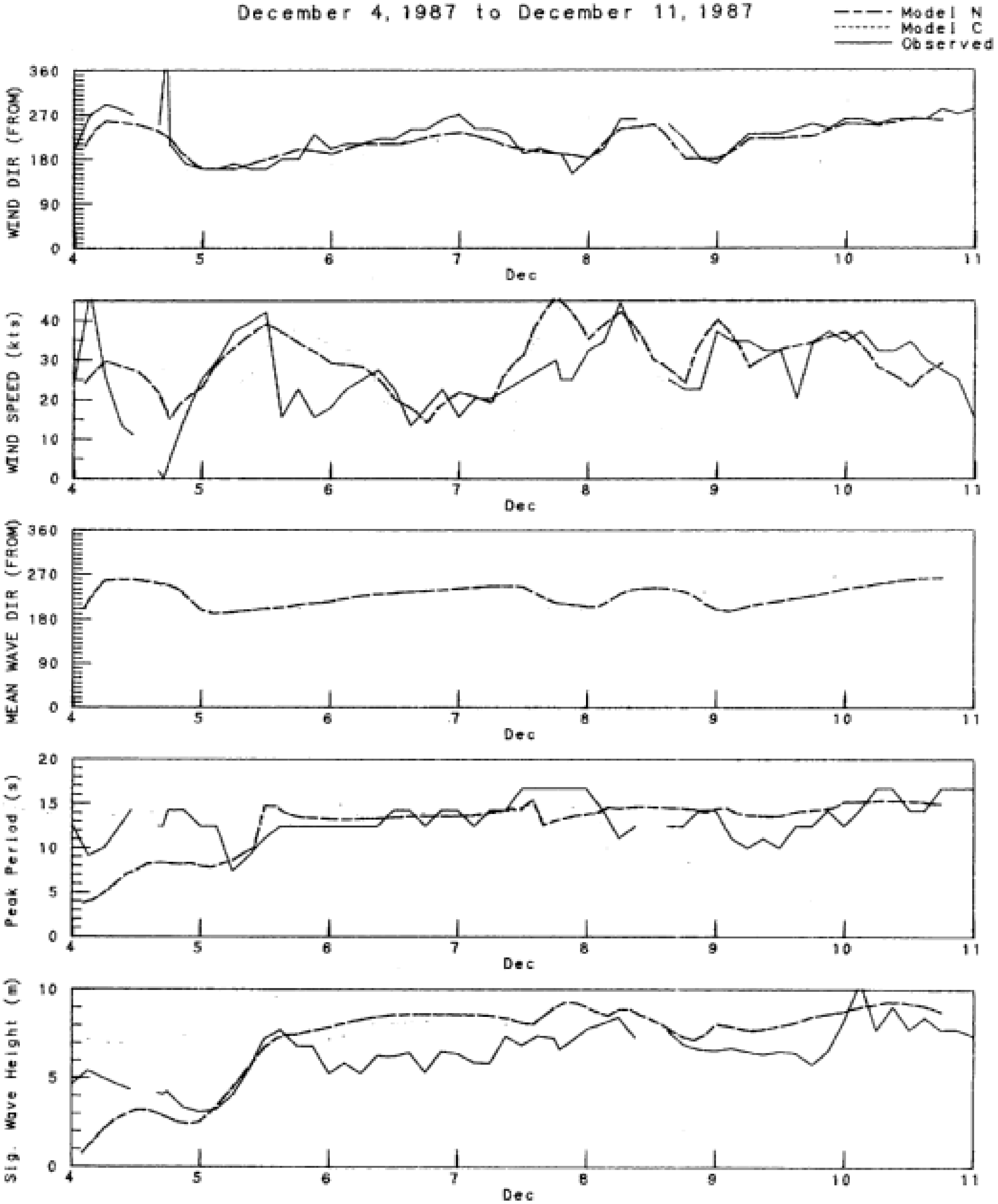
STORM MCL # 469

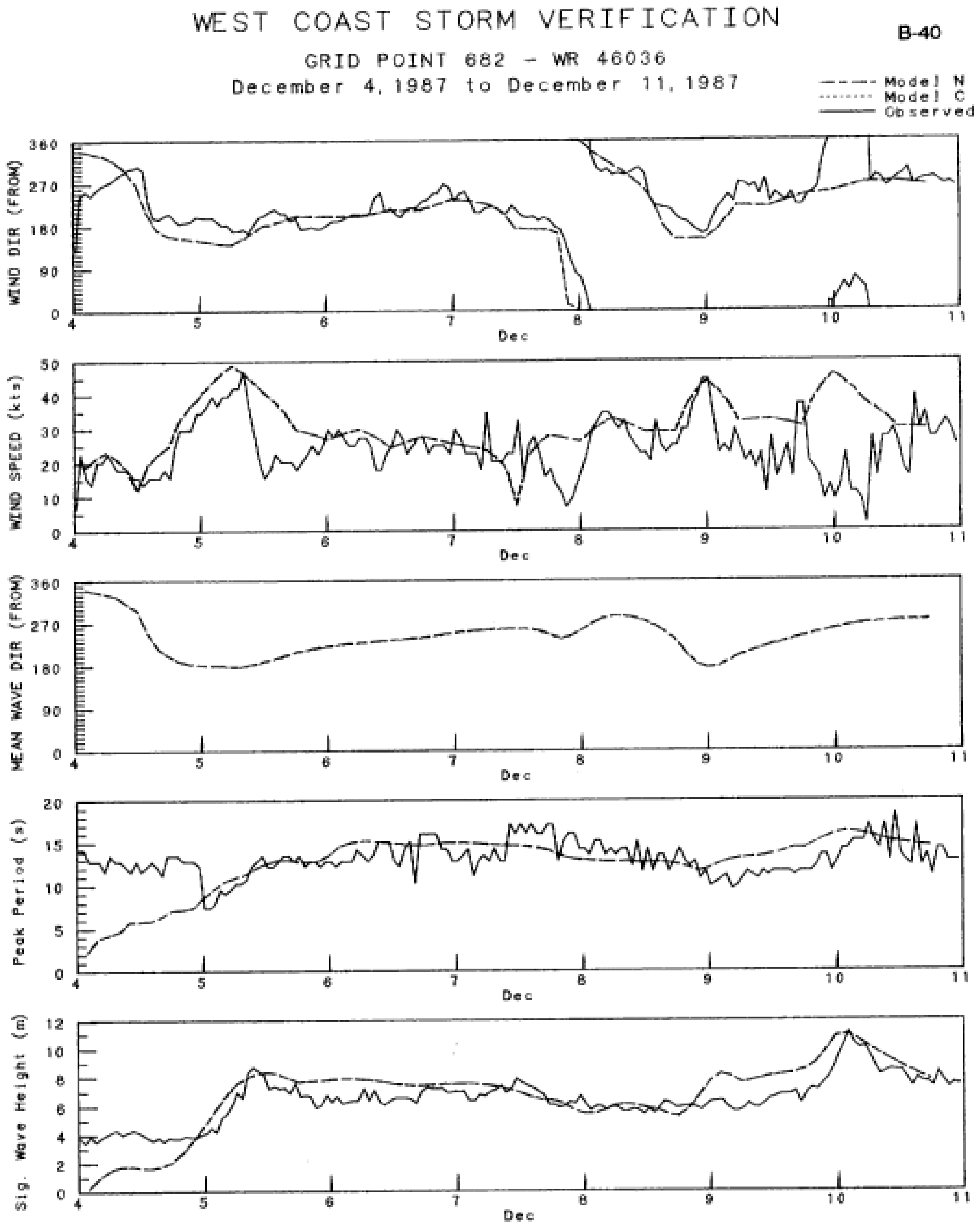
DECEMBER 4 TO DECEMBER 11, 1987


WEST COAST STORM VERIFICATION
B-38
GRID POINT 768 – WR 46004
December 4, 1987 to December 11, 1987
Model N
Model C
Observed
WIND DIR (FROM)
360
270
180
90
0
4
5
6
7
8
9
10
11
Dec
WIND SPEED (kts)
50
40
30
20
10
0
MEAN WAVE DIR (FROM)
Peak Period (s)
20
15
10
5
Sig. Wave Height (m)
10
5
0

WEST COAST STORM VERIFICATION

GRID POINT 598 - WR 46005
December 4, 1987 to December 11, 1987





WEST COAST STORM VERIFICATION

B-40

GRID POINT 682 – WR 46036

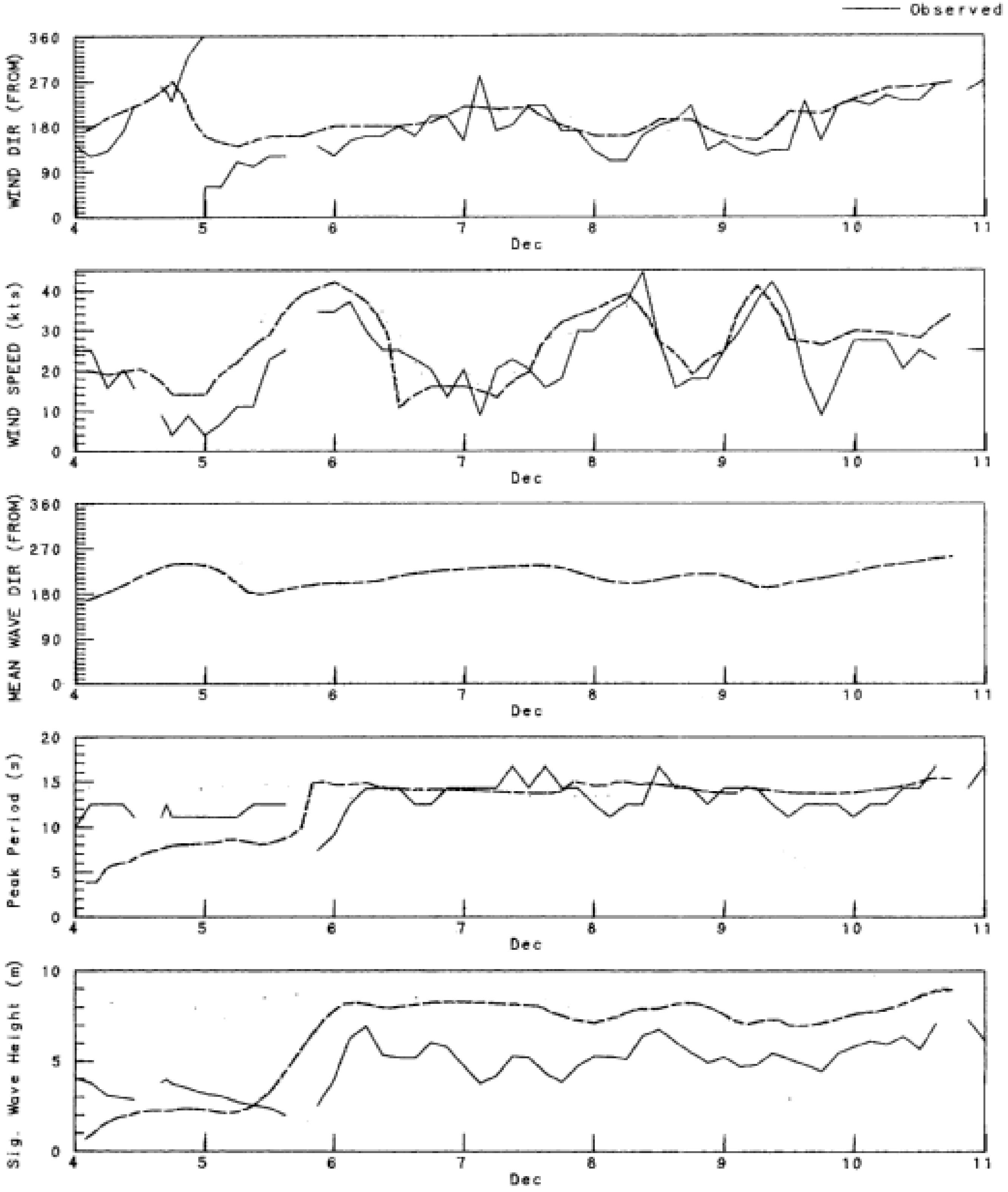
December 4, 1987 to December 11, 1987

B-41

WEST COAST STORM VERIFICATION

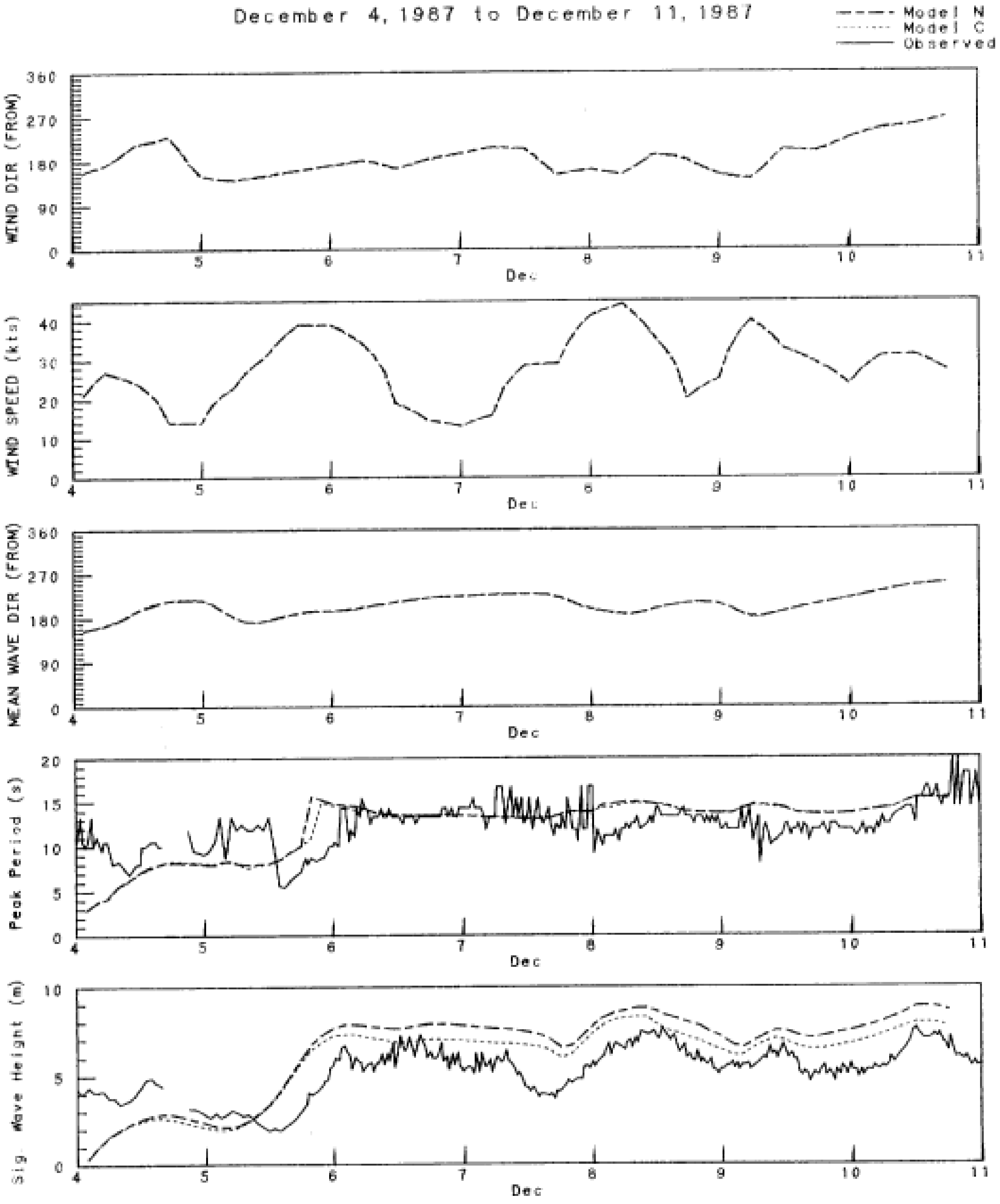
GRID POINT 643 - WR 46041

December 4, 1987 to December 11, 1987



WEST COAST STORM VERIFICATION

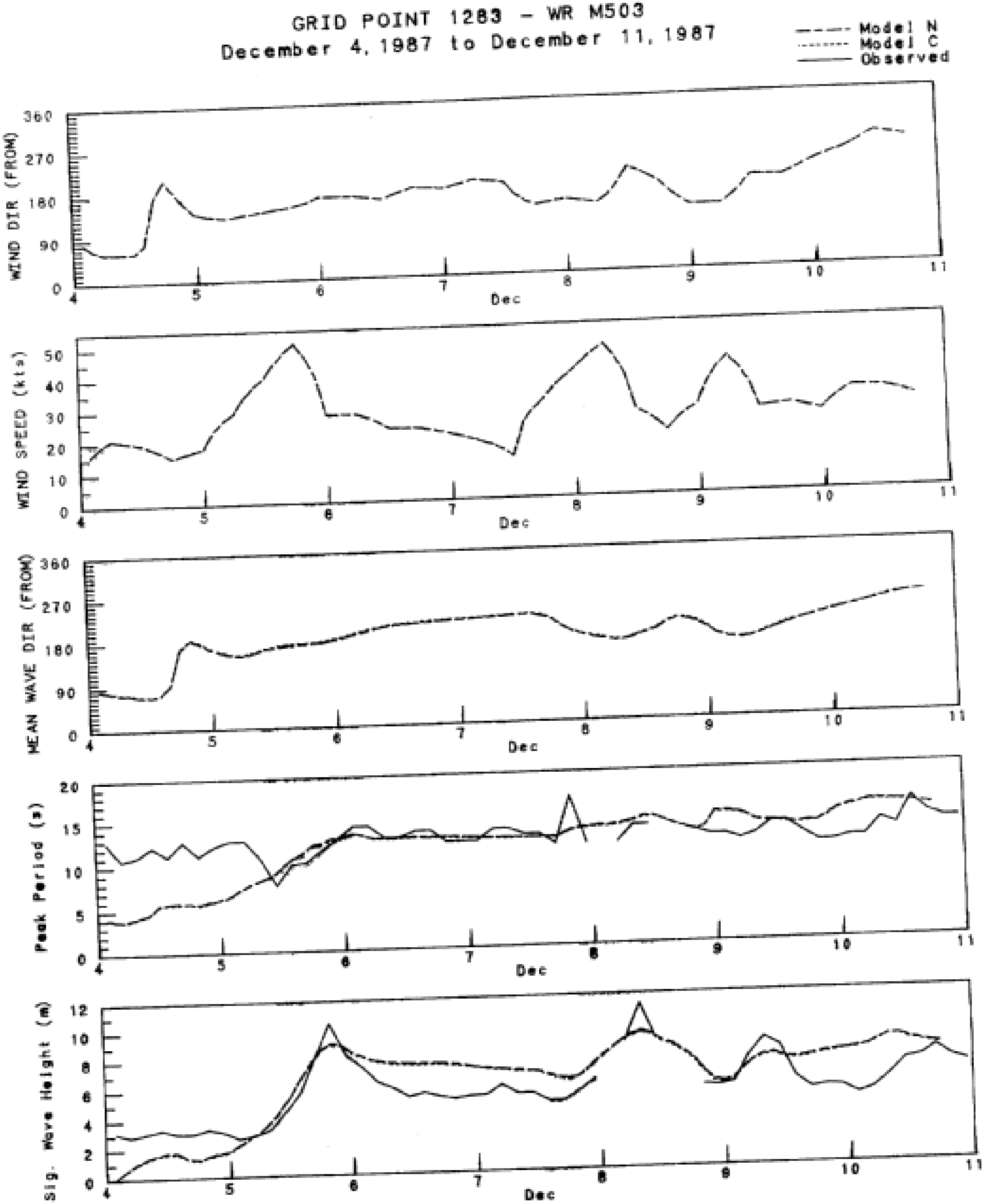
GRID POINT 1235 — WR CYAZWV
December 4, 1987 to December 11, 1987



WEST COAST STORM VERIFICATION

B-43

GRID POINT 1283 – WR M503
December 4, 1987 to December 11, 1987



STORM MCL # 485, 486, 487 AND 488

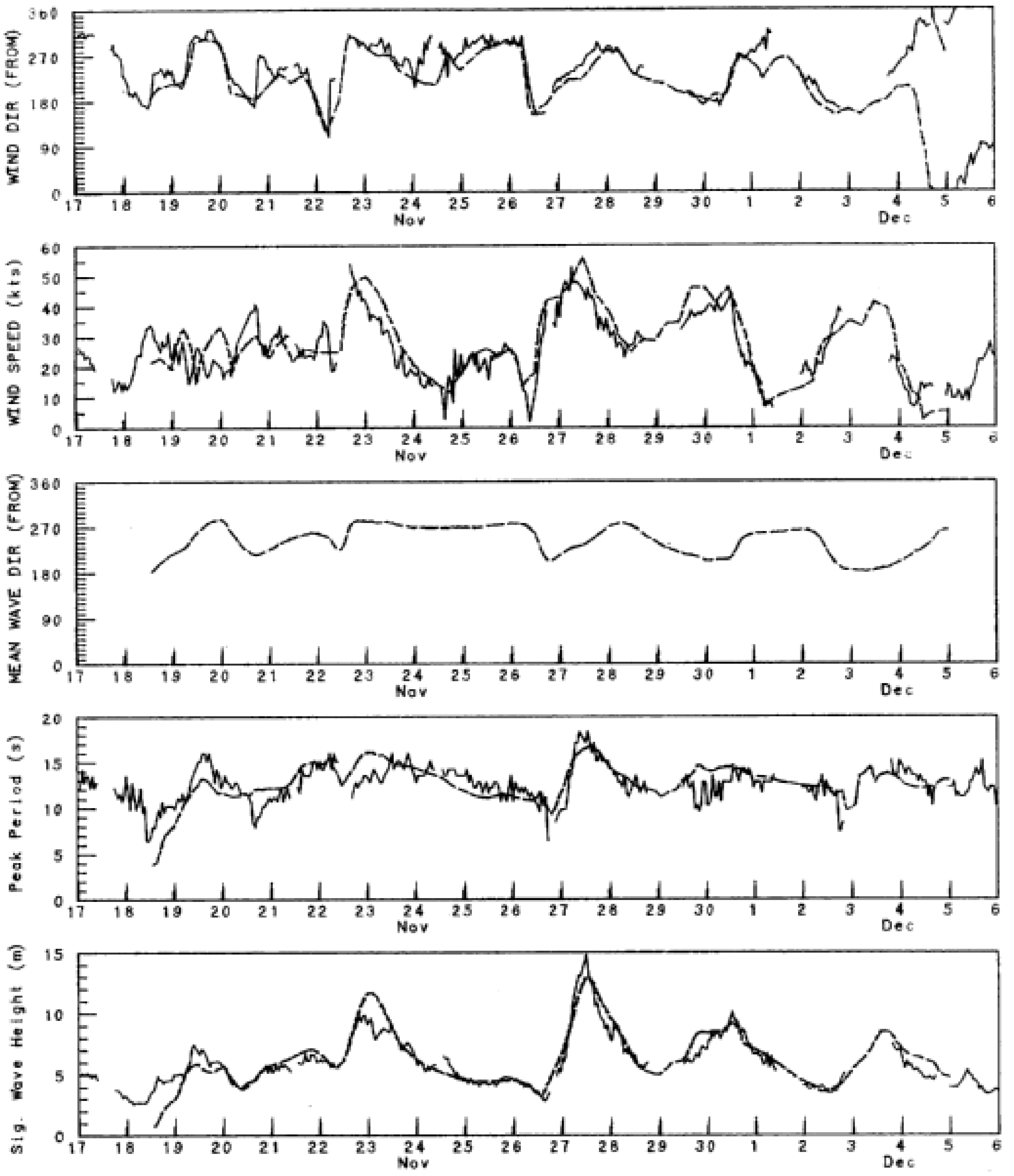
#485: NOVEMBER 17 TO DECEMBER 6, 1988
#486: NOVEMBER 25 TO NOVEMBER 29, 1988
#487: NOVEMBER 29 TO DECEMBER 4, 1988
#488: DECEMBER 2 TO DECEMBER 5, 1988

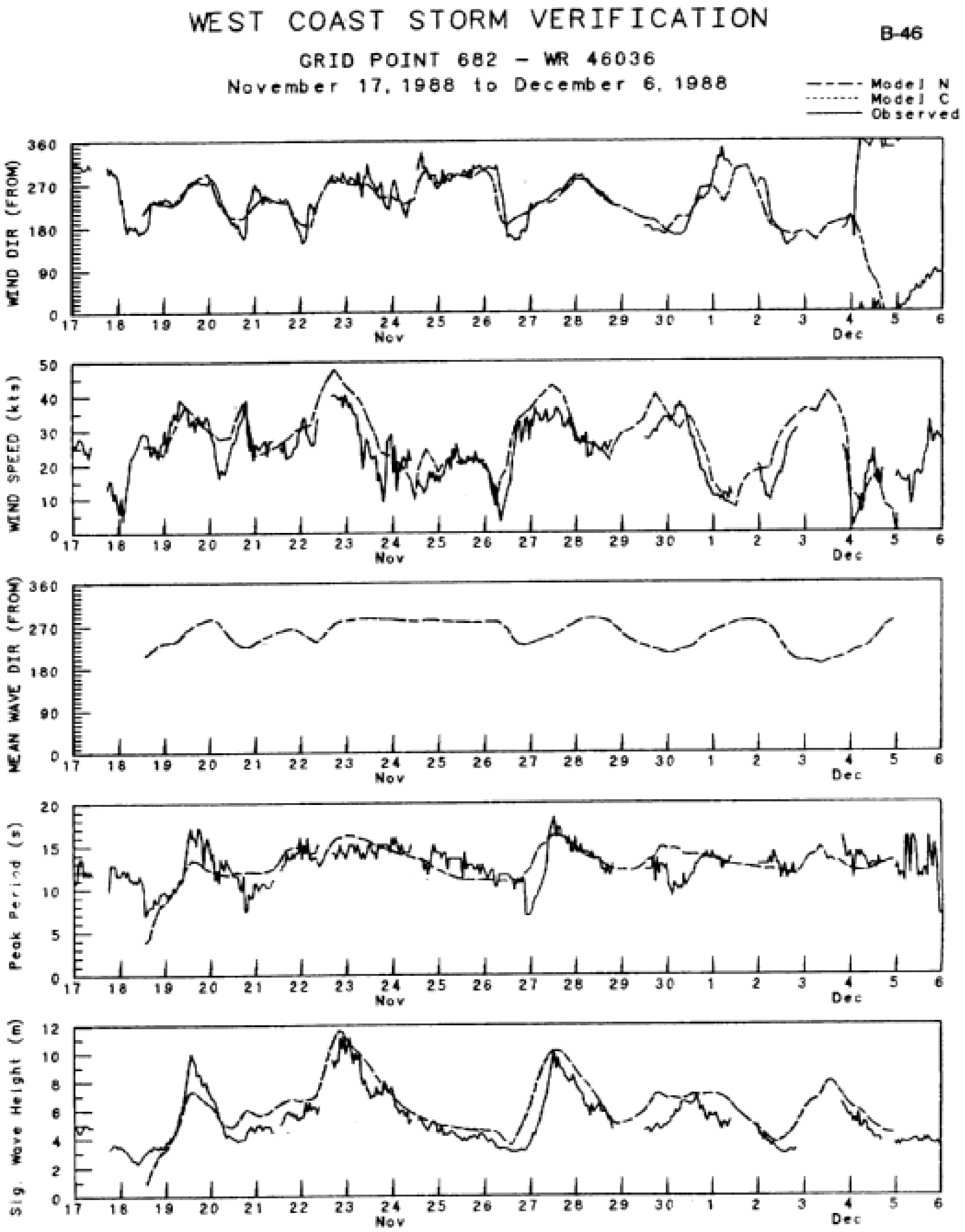
WEST COAST STORM VERIFICATION

B-45

GRID POINT 768 – WR 46004

November 17, 1988 to December 6, 1988



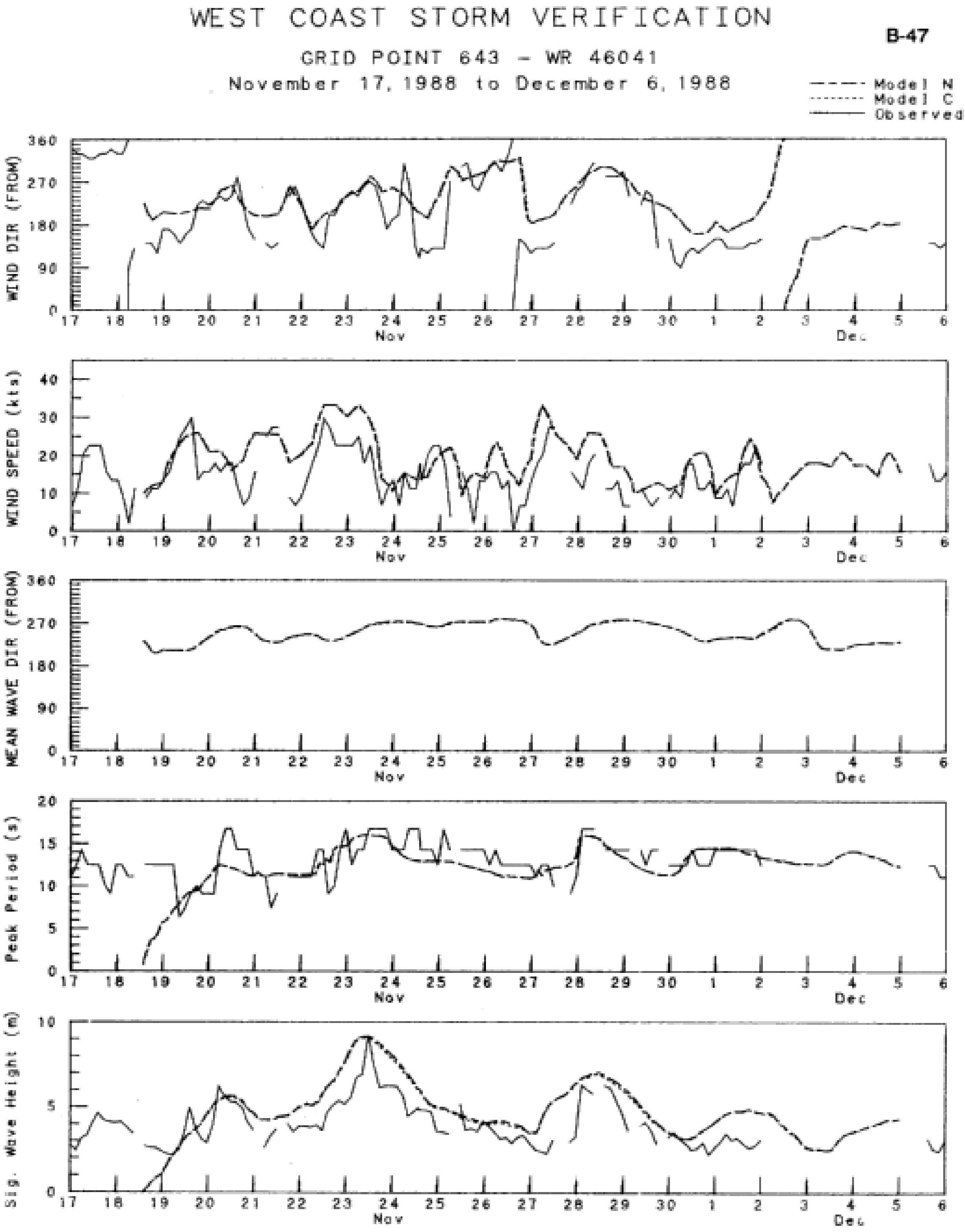


WEST COAST STORM VERIFICATION

B-46

GRID POINT 682 – WR 46036

November 17, 1988 to December 6, 1988



WEST COAST STORM VERIFICATION

GRID POINT 643 – WR 46041

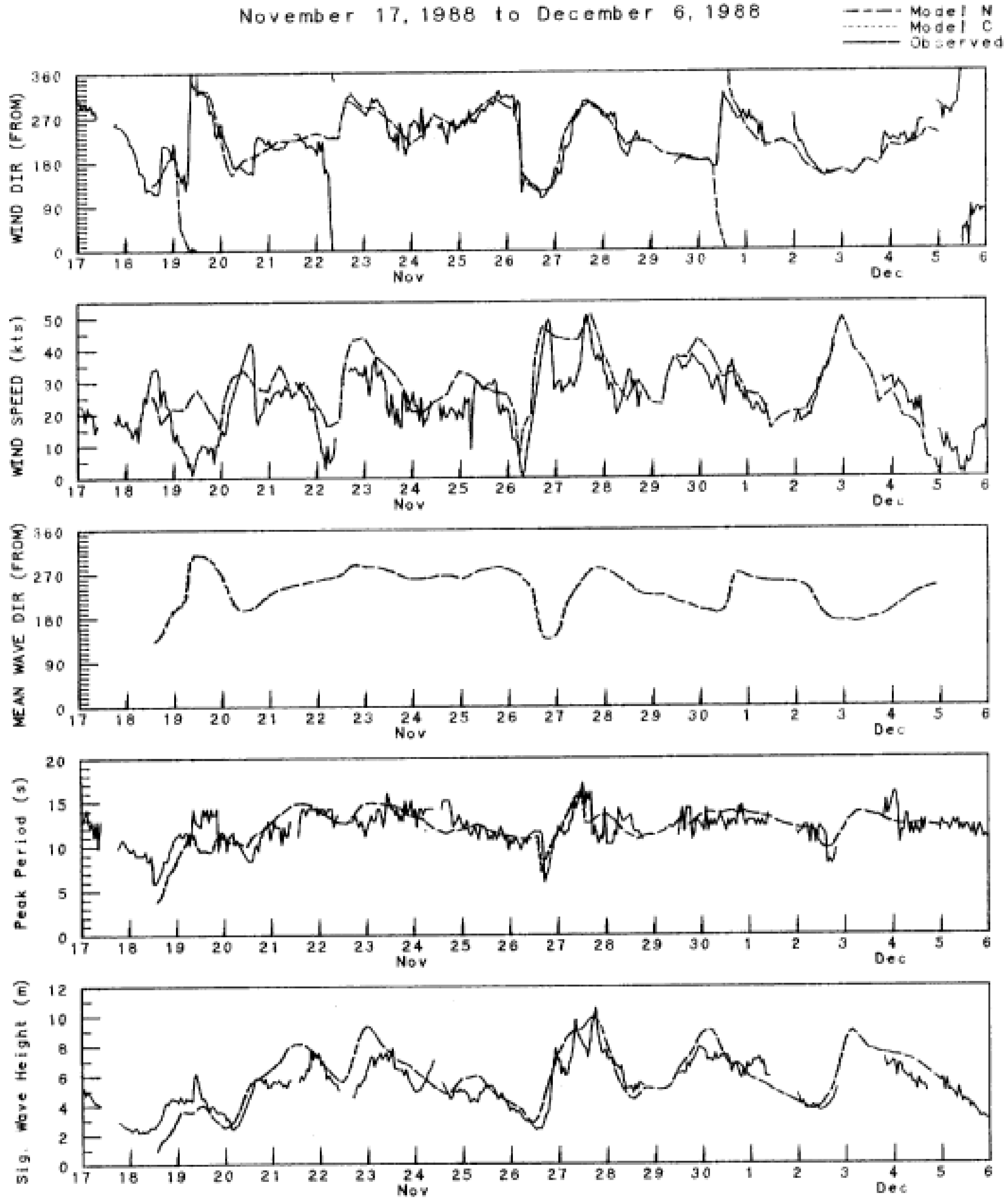
November 17, 1988 to December 6, 1988

WEST COAST STORM VERIFICATION

B-48

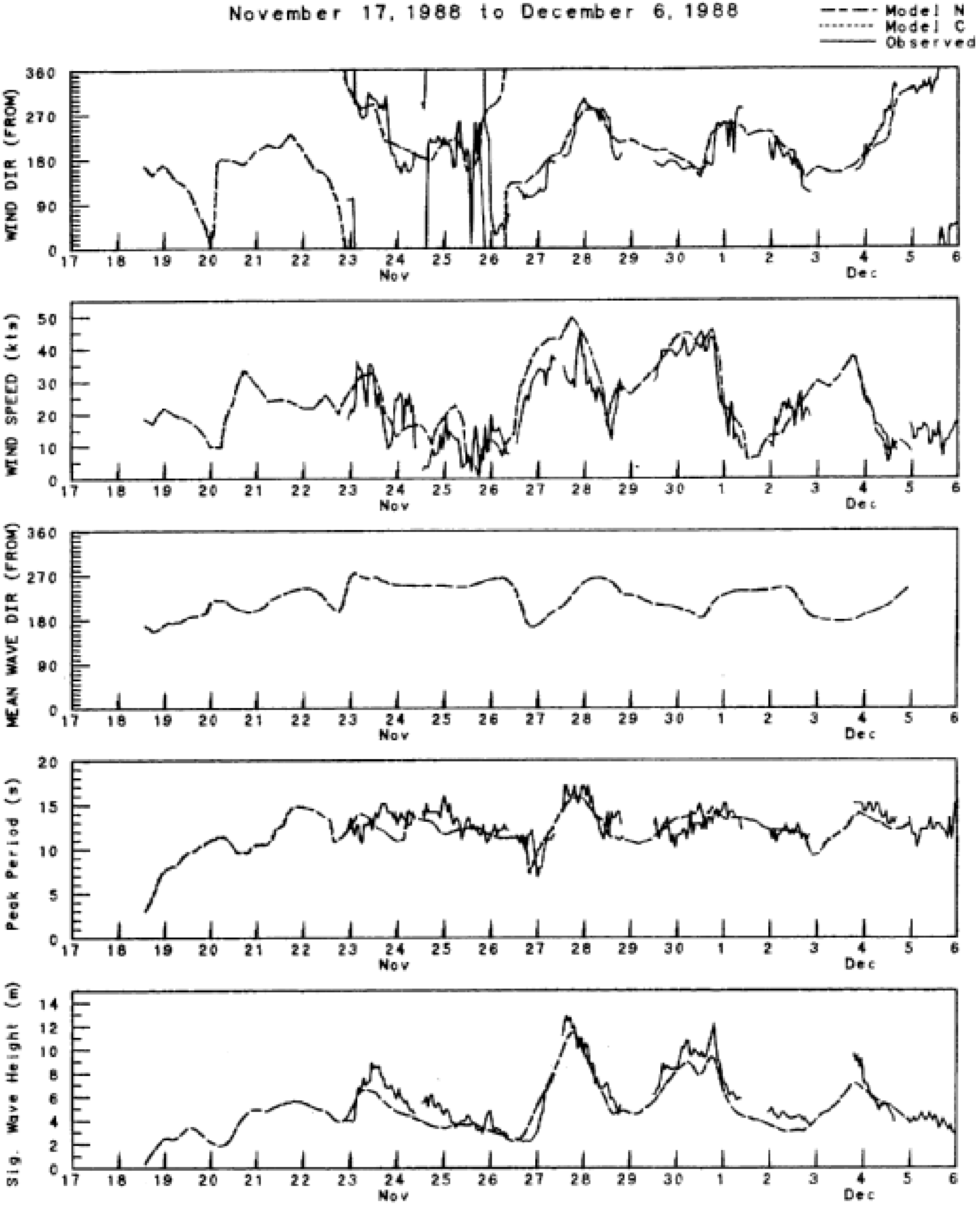
GRID POINT 852 – WR 46184

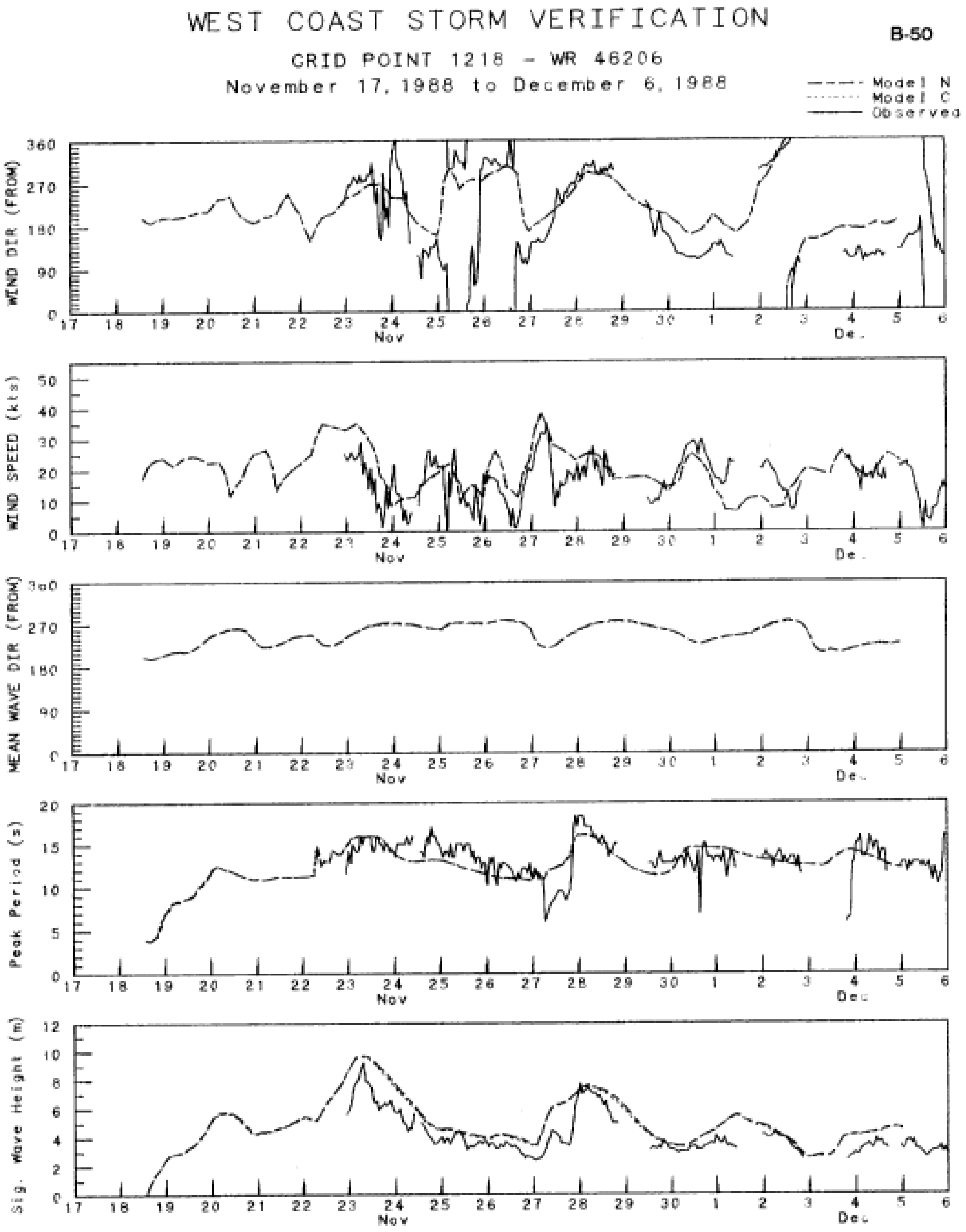
November 17, 1988 to December 6, 1988



WEST COAST STORM VERIFICATION

GRID POINT 1365 – WR 46205
November 17, 1988 to December 6, 1988





WEST COAST STORM VERIFICATION

B-50

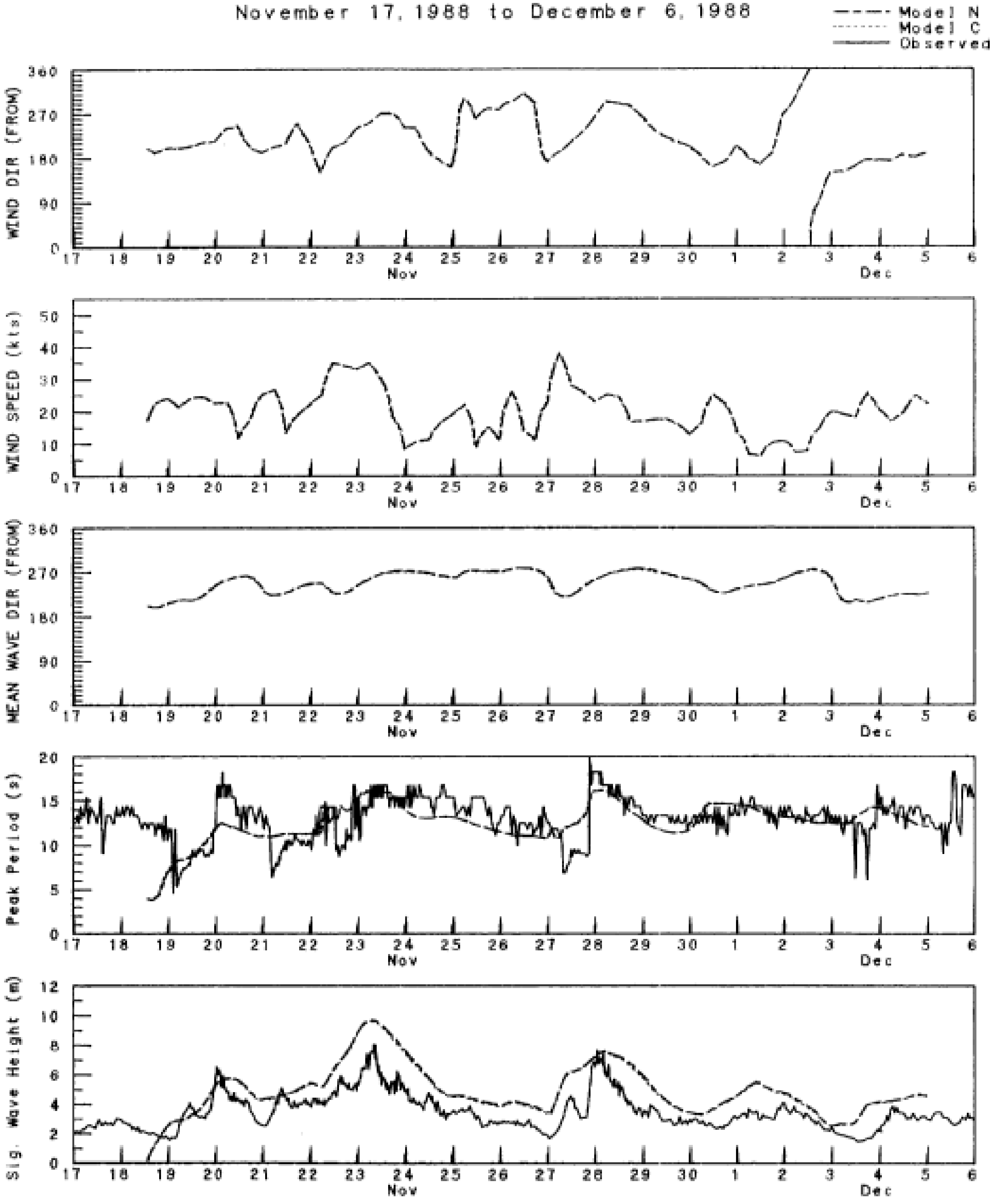
GRID POINT 1218 - WR 46206

November 17, 1988 to December 6, 1988

WEST COAST STORM VERIFICATION

B-51

GRID POINT 1218 – WR CYAZWV
November 17, 1988 to December 6, 1988

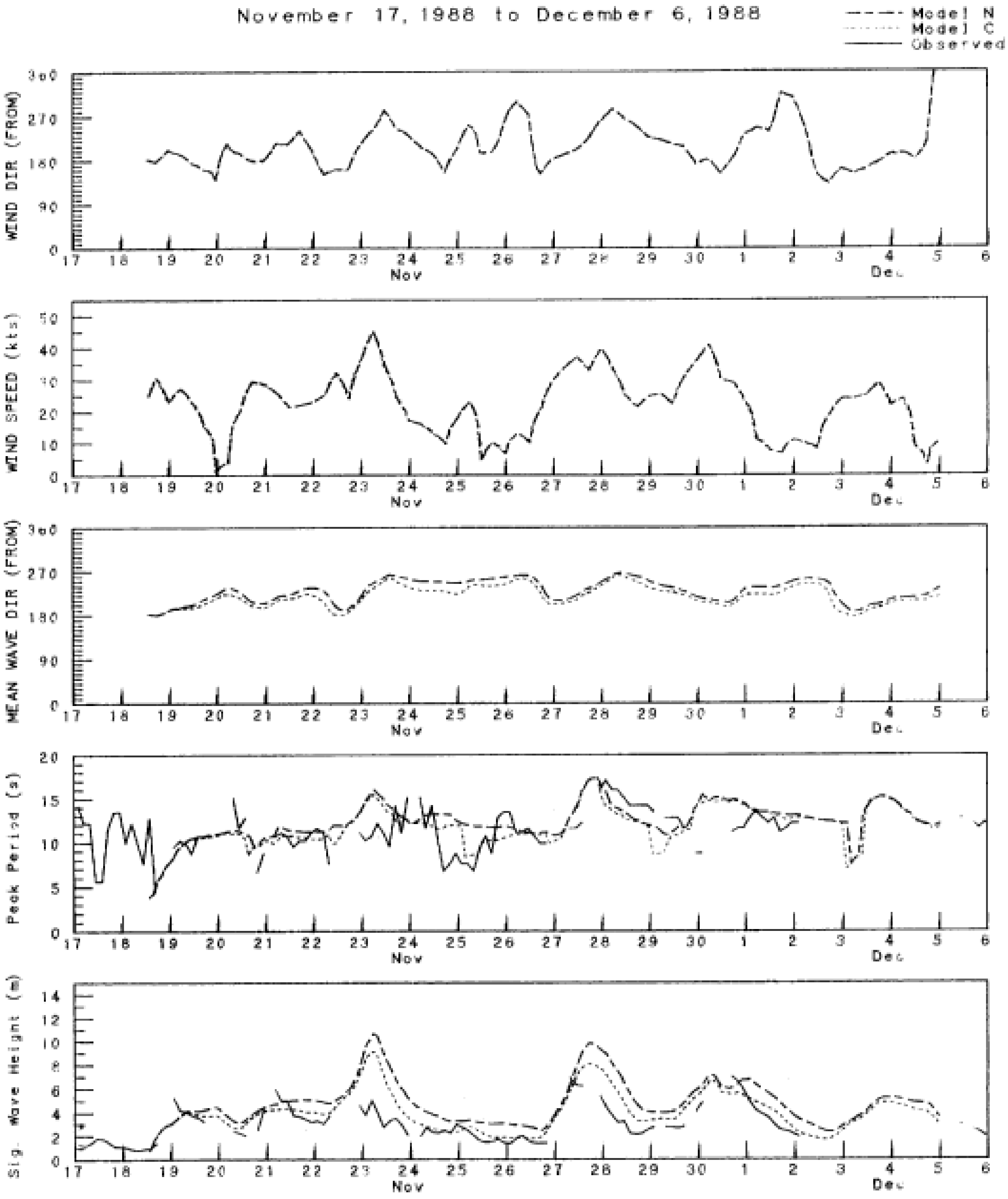


WEST COAST STORM VERIFICATION

B-52

GRID POINT 1317 – WR M502

November 17, 1988 to December 6, 1988

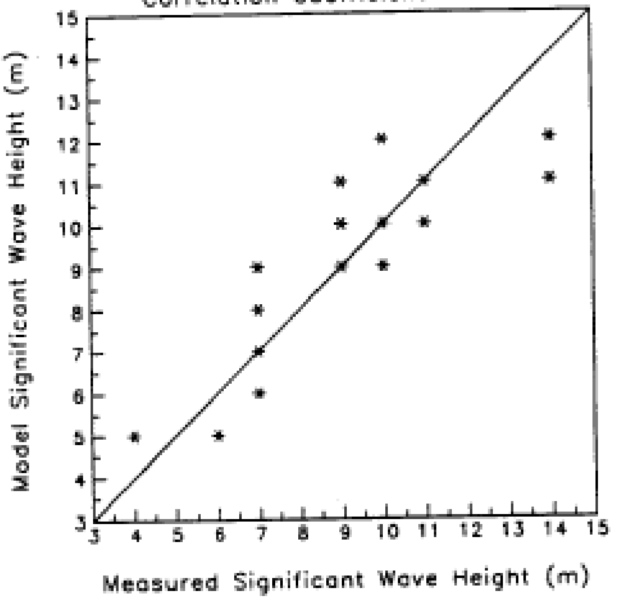


VERIFICATION RESULTS
SCATTER DIAGRAMS

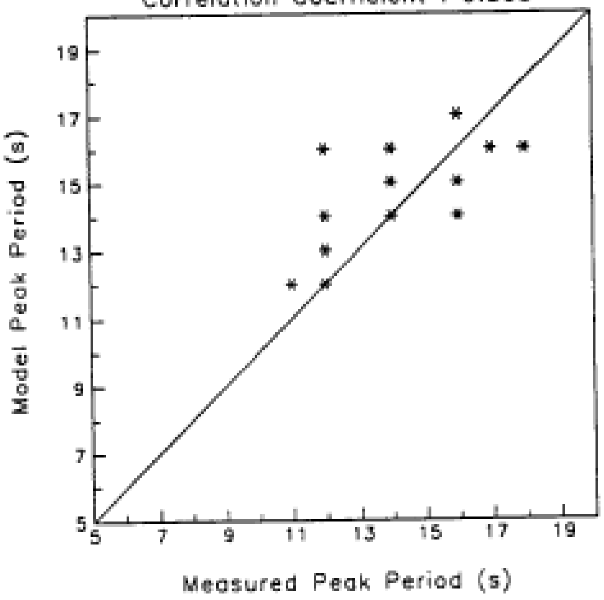
MEASURED versus MODEL FOR WEST COAST
Peak To Peak Comparison

OFFSHORE DEEP – NO SMOOTHING

Number of Points : 22
Correlation Coefficient : 0.843



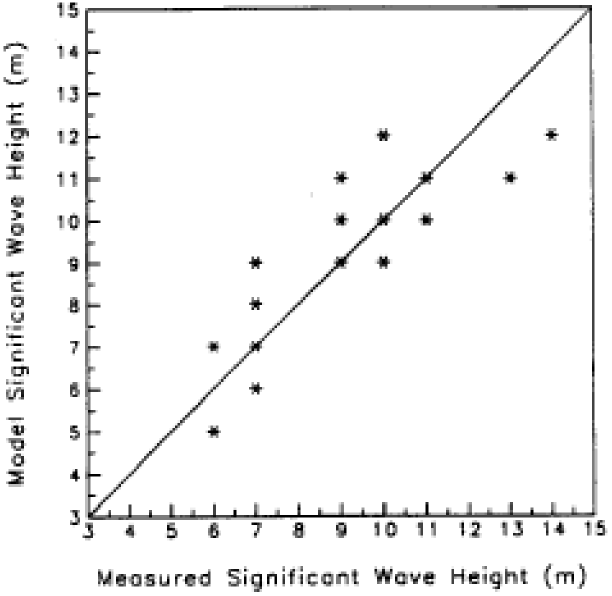
Number of Points : 22
Correlation Coefficient : 0.565



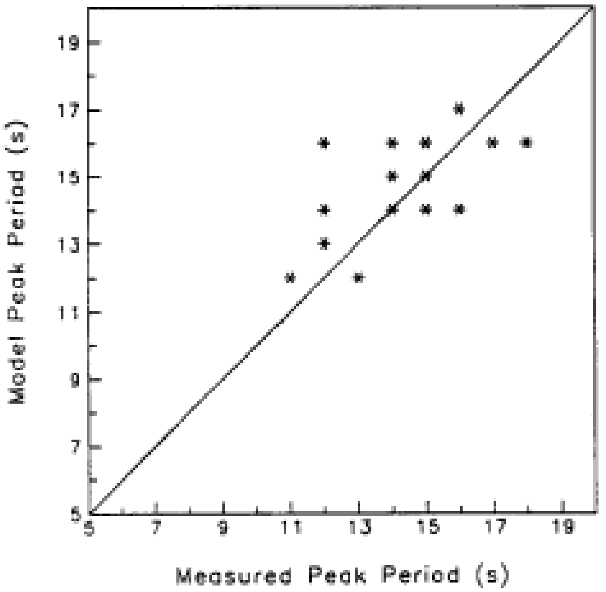
MEASURED versus MODEL FOR WEST COAST
Peak To Peak Comparison

OFFSHORE DEEP – SMOOTHED

Number of Points : 22
Correlation Coefficient : 0.799

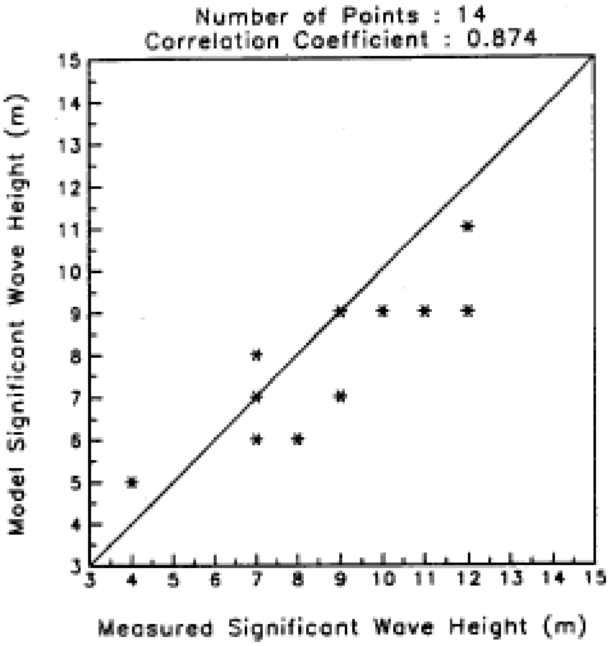


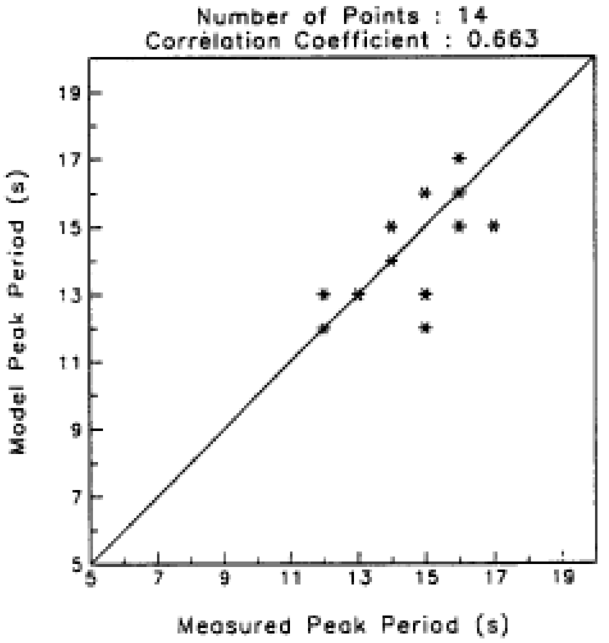
Number of Points : 22
Correlation Coefficient : 0.579



MEASURED versus MODEL FOR WEST COAST
Peak To Peak Comparison

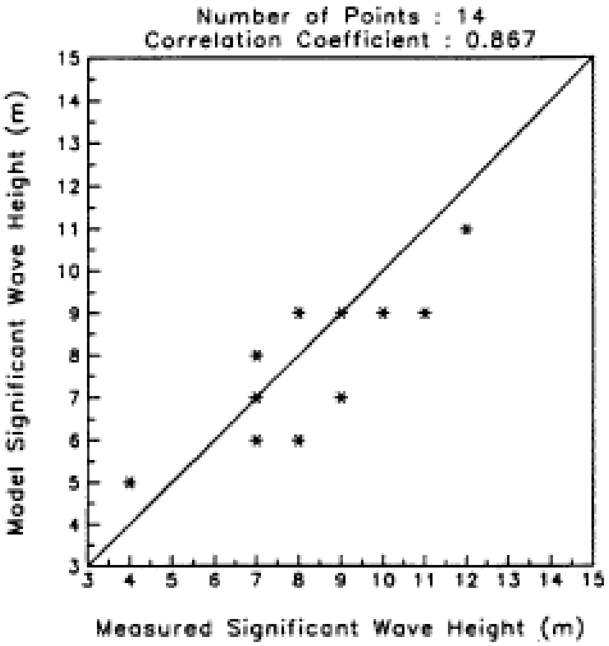
INSHORE DEEP – NO SMOOTHING

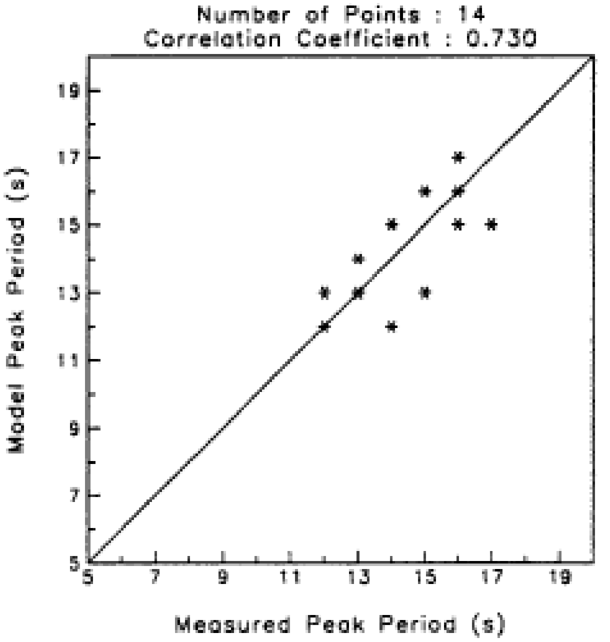




MEASURED versus MODEL FOR WEST COAST
Peak To Peak Comparison

INSHORE DEEP – SMOOTHED

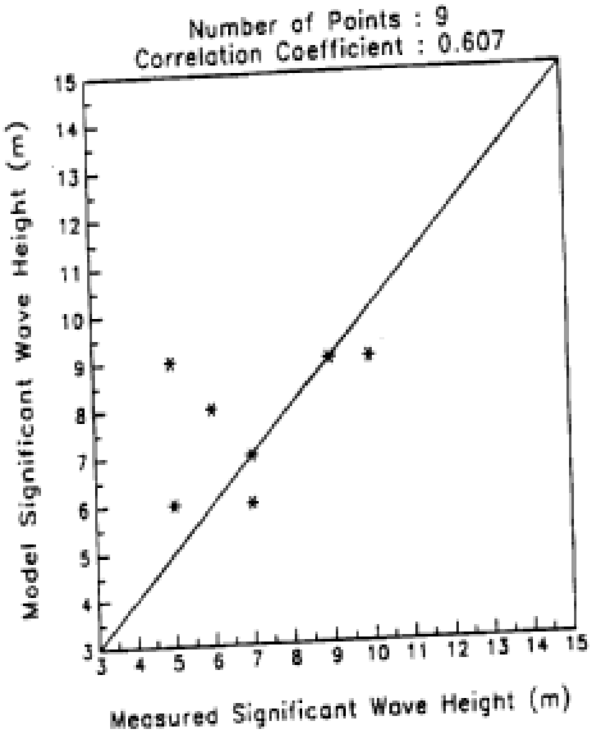


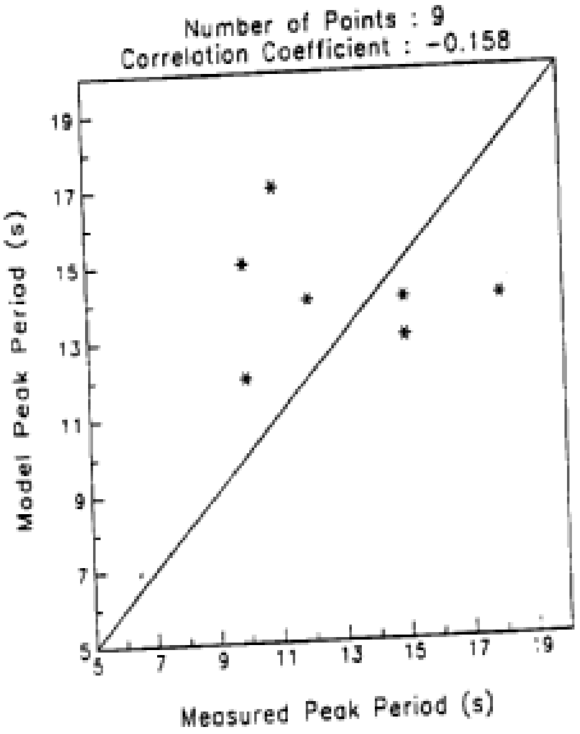


EC 12

MEASURED versus MODEL FOR WEST COAST
Peak To Peak Comparison

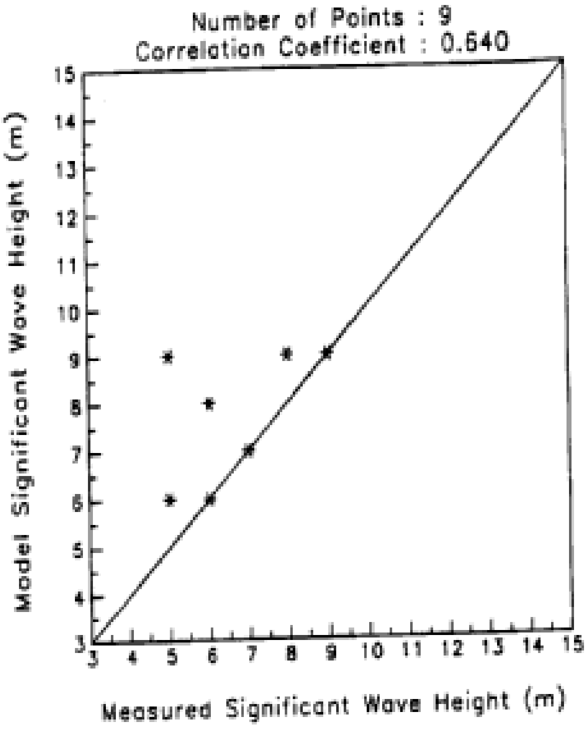
INSHORE SHELTERED – NO SMOOTHING

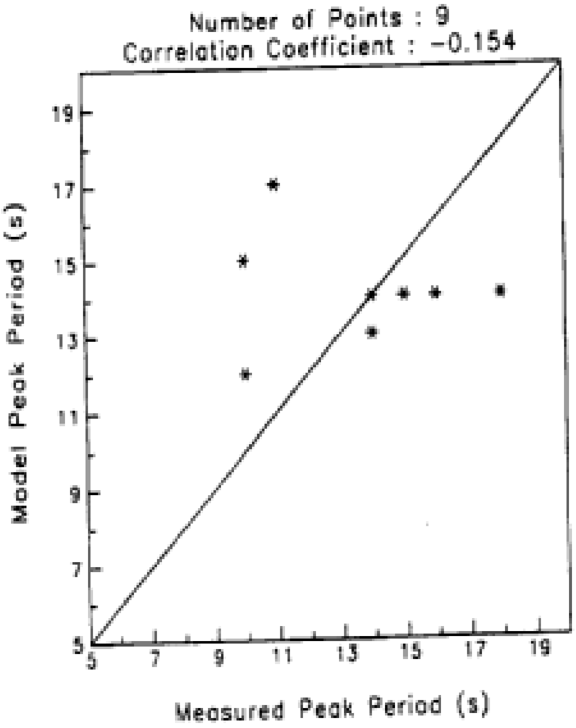




MEASURED versus MODEL FOR WEST COAST
Peak To Peak Comparison

INSHORE SHELTERED – SMOOTHED

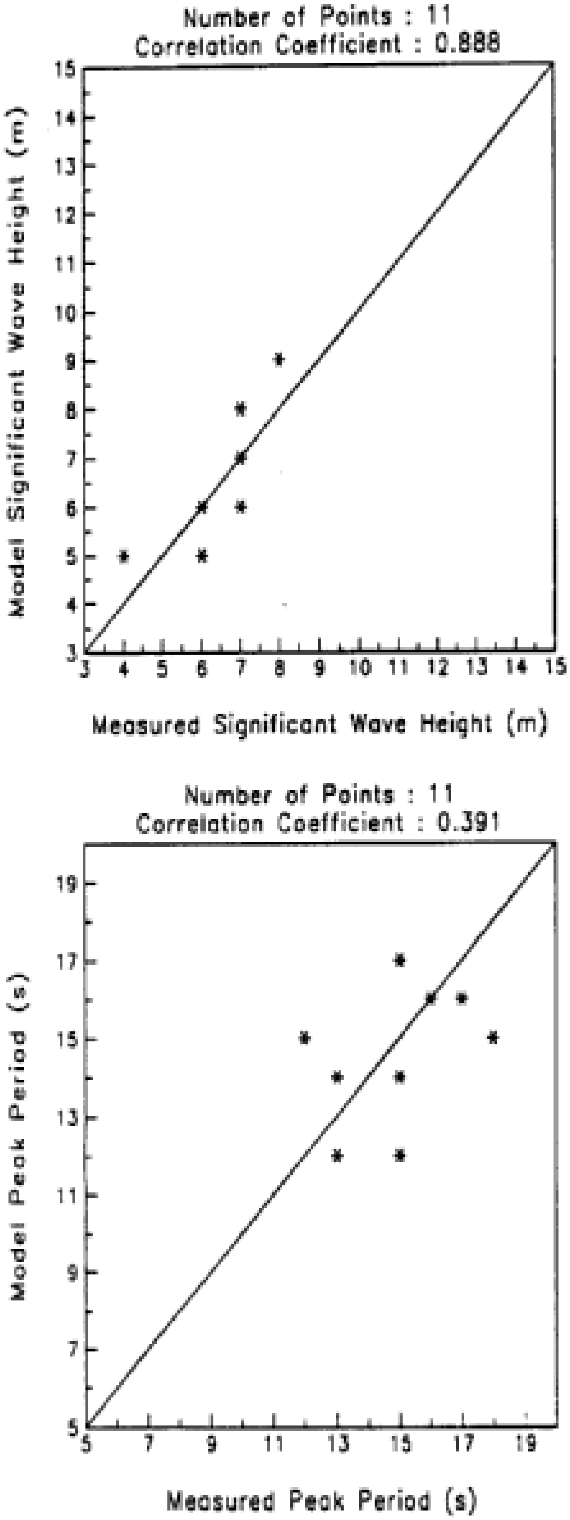




EC 12

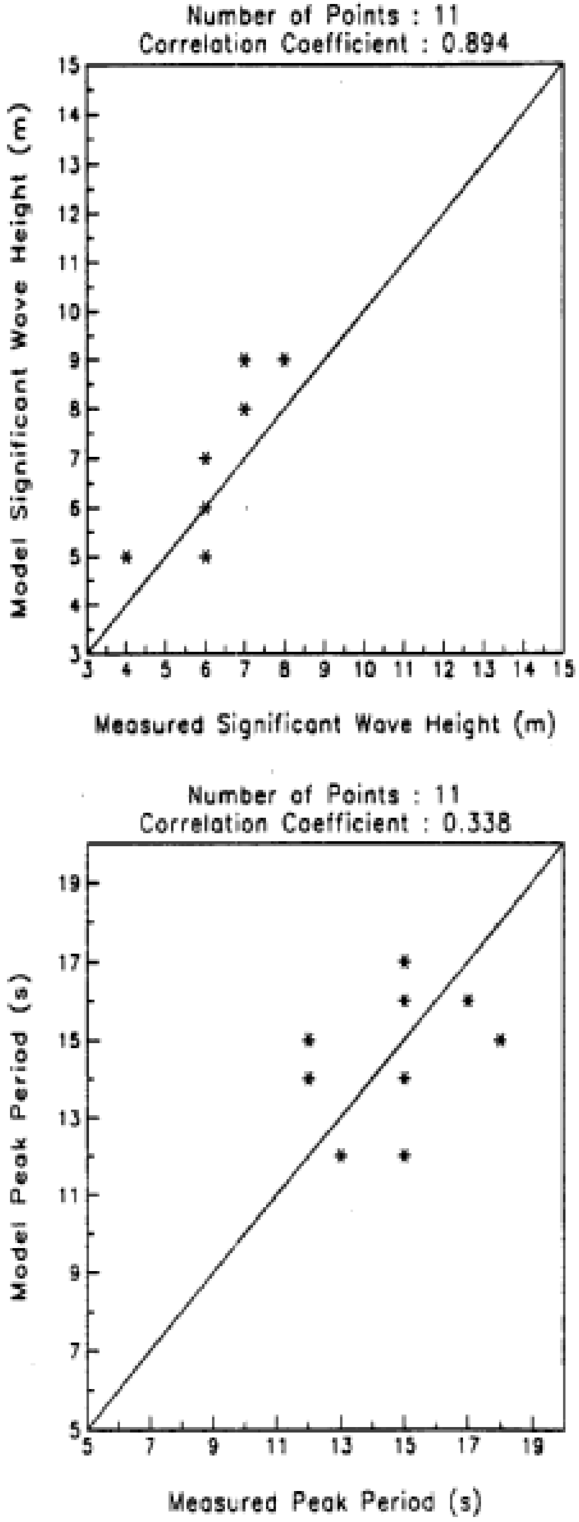
MEASURED versus MODEL FOR WEST COAST
Peak To Peak Comparison

SHALLOW – NO SMOOTHING



MEASURED versus MODEL FOR WEST COAST
Peak To Peak Comparison

SHALLOW – SMOOTHED



APPENDIX C
FINAL DETAILED EXTREME ANALYSIS RESULTS AT 25 SELECTED GRID POINTS

GRID POINT 768 AT 51.250 N, 135.00 W

GUMBEL – Method of Moments

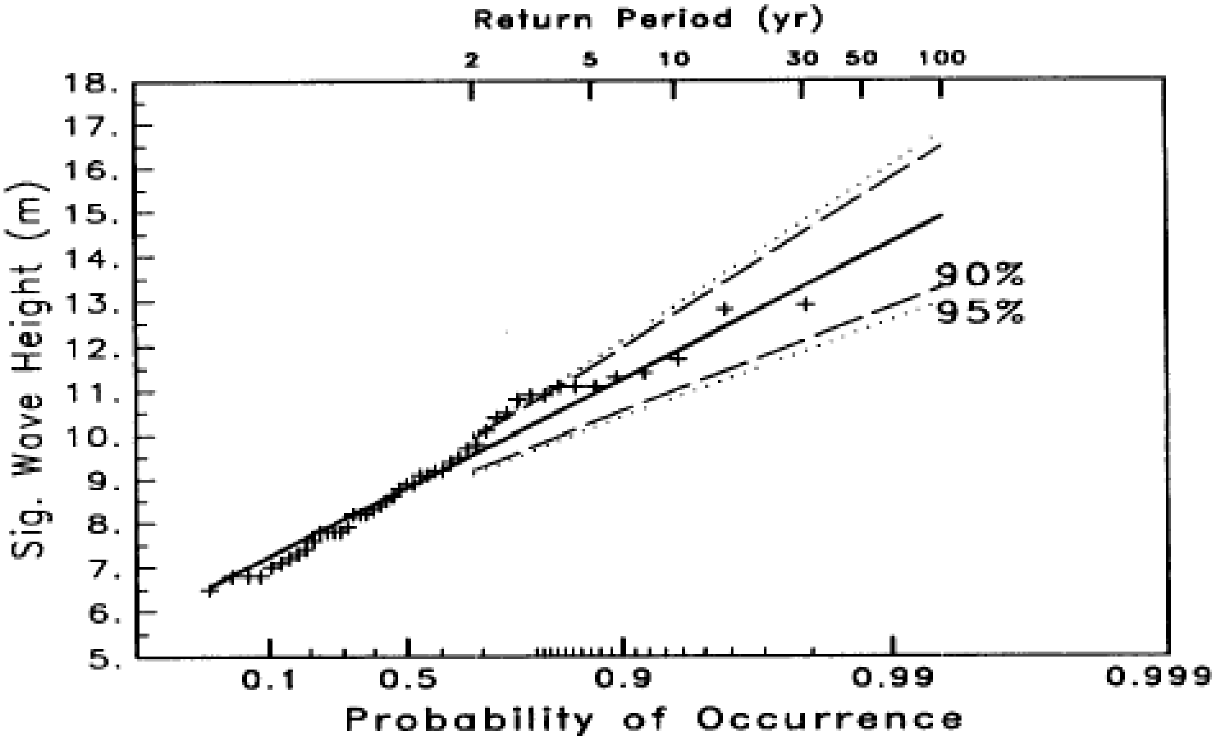
47 storms
Wave height threshold = 6.50 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	9.6	9.9	14.8	17.7	9.8
5	10.9	11.5	15.7	20.2	11.2
10	11.9	12.7	16.2	21.9	12.2
30	13.3	14.5	17.0	24.6	13.7
50	14.0	15.4	17.4	25.8	14.3
100	14.9	16.5	17.9	27.5	15.3

Tp, Hmax, and Hc were calculated using

$$Tp = 5.751\ Hs^{0.420}$$
$$Hmax = 1.847\ Hs$$
$$Hc = 1.026\ Hs$$

Correlation = 0.99



GRID POINT 1163 AT 46.875 N, 131.25 W

GUMBEL – Method of Moments

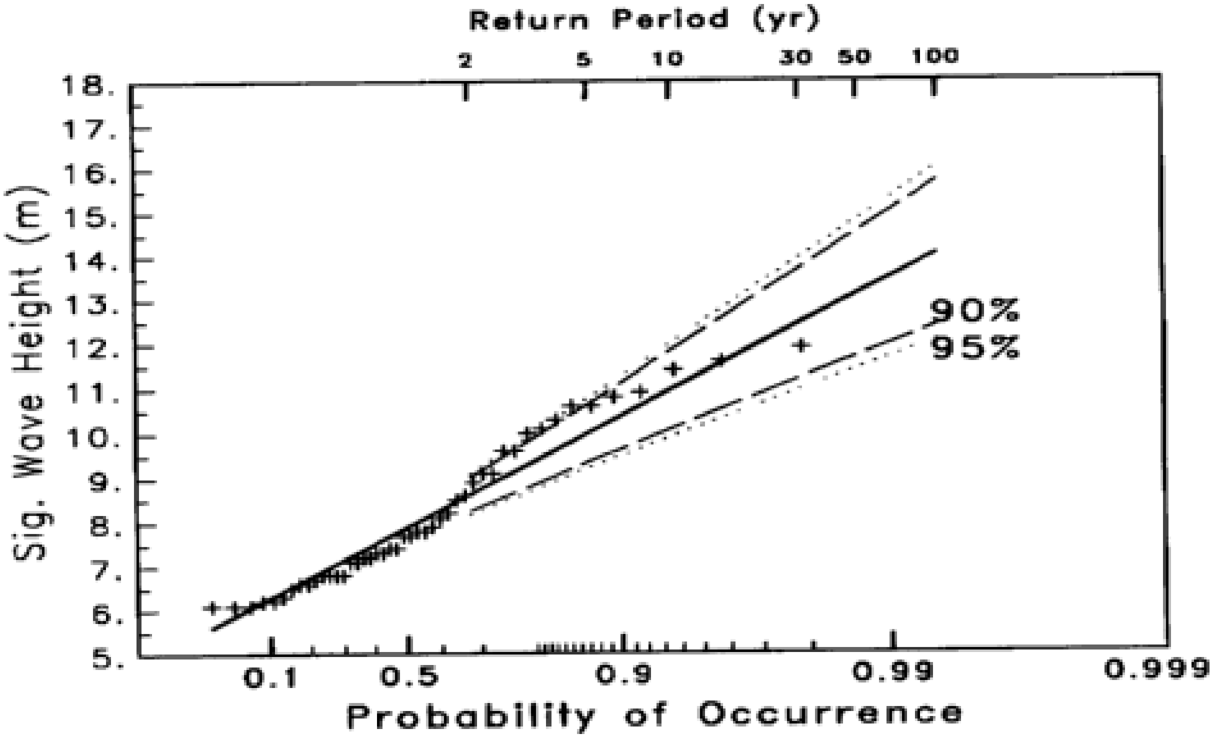
46 storms
Wave height threshold = 6.10 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.6	9.0	14.8	16.2	9.0
5	10.0	10.7	15.7	18.8	10.4
10	11.0	11.8	16.2	20.6	11.4
30	12.5	13.7	17.0	23.4	13.0
50	13.1	14.5	17.3	24.6	13.7
100	14.1	15.7	17.7	26.4	14.7

Tp, Hmax, and Hc were calculated using

$Tp = 6.745\ Hs^{0.366}$
$Hmax = 1.877\ Hs$
$Hc = 1.043\ Hs$

Correlation = 0.98



GRID POINT 1166 AT 46.875 N, 127.50 W

GUMBEL – Method of Moments

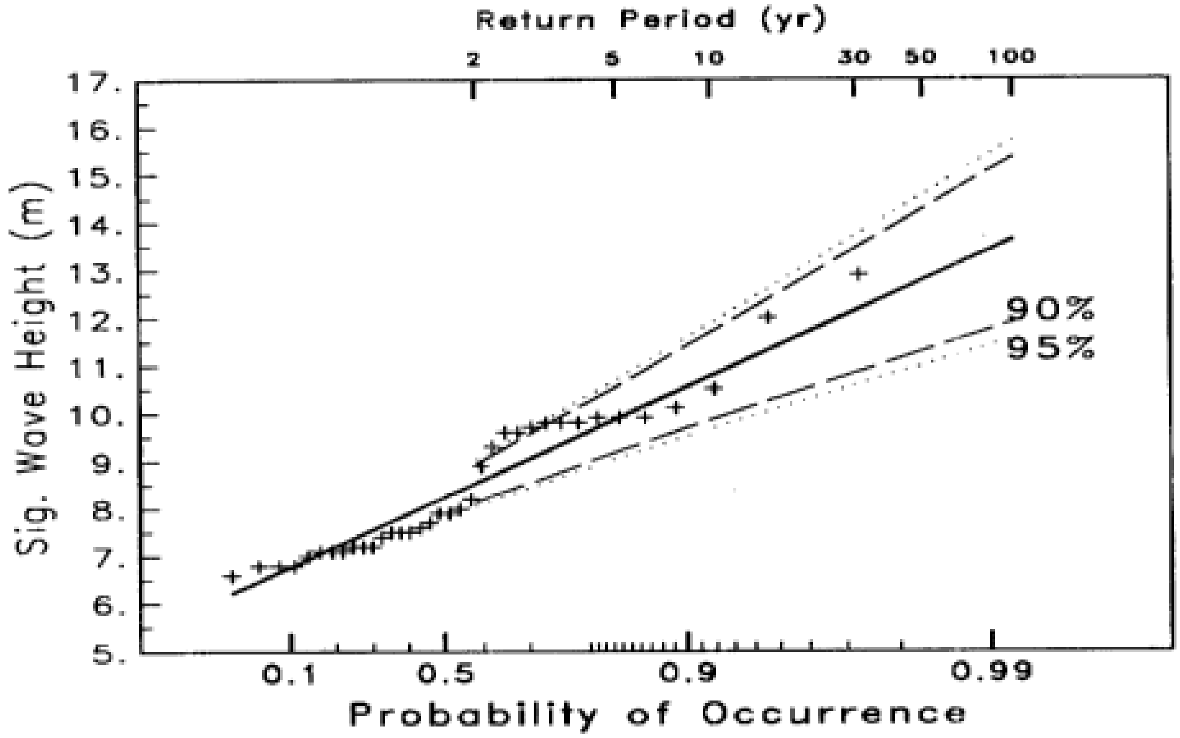
36 storms
Wave height threshold = 6.60 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.5	9.0	15.0	16.0	8.9
5	9.9	10.6	15.7	18.4	10.3
10	10.8	11.7	16.2	20.1	11.2
30	12.2	13.5	16.8	22.7	12.6
50	12.8	14.3	17.1	23.9	13.3
100	13.6	15.4	17.5	25.5	14.2

Tp, Hmax, and Hc were calculated using

$$Tp = 7.394\ Hs^{0.329}$$
$$Hmax = 1.869\ Hs$$
$$Hc = 1.039\ Hs$$

Correlation = 0.97



GRID POINT 1196 AT 48.125 N, 132.50 W

GUMBEL – Method of Moments

47 storms

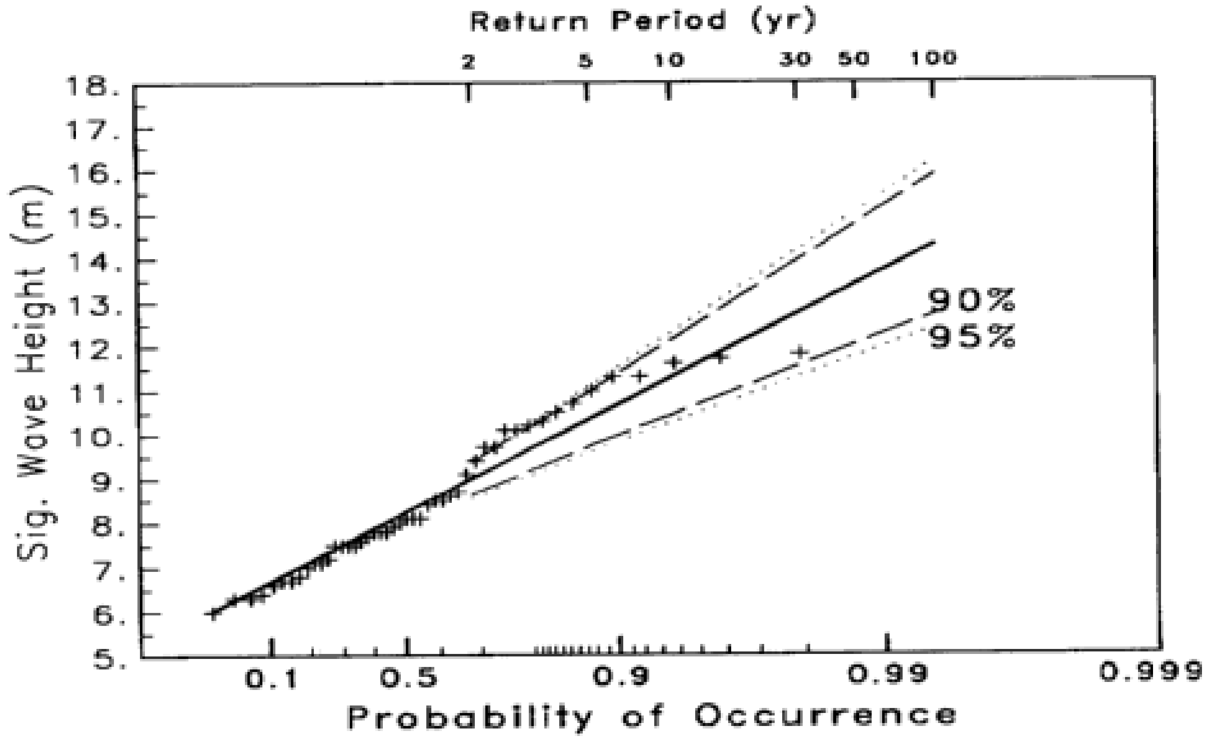
Wave height threshold = 6.00 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	9.0	9.4	14.8	16.8	9.3
5	10.3	11.0	15.8	19.2	10.7
10	11.3	12.1	16.4	21.0	11.7
30	12.7	13.9	17.3	23.7	13.2
50	13.4	14.8	17.7	24.9	13.9
100	14.3	15.9	18.2	26.6	14.8

Tp, Hmax, and Hc were calculated using

$$Tp = 5.659\ Hs^{0.439}$$
$$Hmax = 1.861\ Hs$$
$$Hc = 1.034\ Hs$$

Correlation = 0.98



GRID POINT 1202 AT 48.125 N, 125.00 W

GUMBEL — Method of Moments

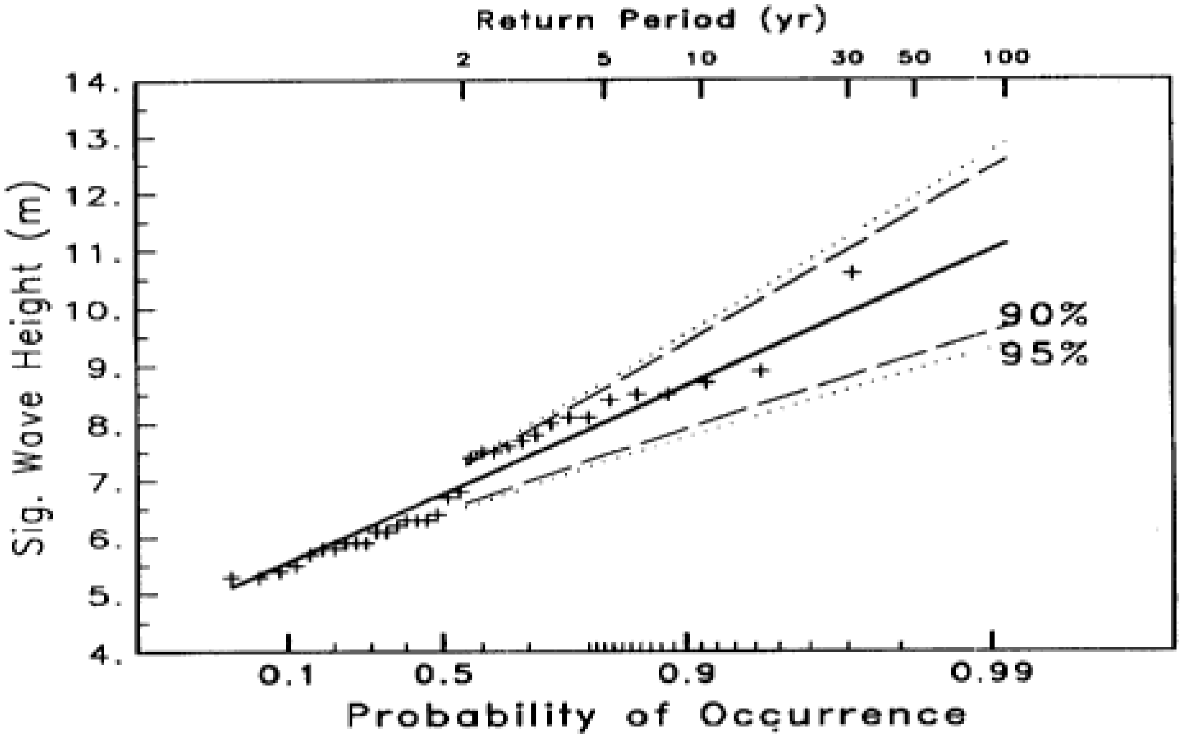
34 storms
Wave height threshold = 5.30 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	6.9	7.3	14.9	12.9	7.2
5	8.0	8.6	15.7	14.9	8.3
10	8.8	9.6	16.2	16.3	9.1
30	9.9	11.0	17.0	18.4	10.2
50	10.4	11.7	17.3	19.4	10.8
100	11.1	12.6	17.7	20.7	11.5

Tp, Hmax, and Hc were calculated using

$$Tp = 7.391\ Hs^{0.362}$$
$$Hmax = 1.859\ Hs$$
$$Hc = 1.032\ Hs$$

Correlation = 0.98



GRID POINT 1218 AT 48.750 N, 126.25 W

GUMBEL – Method of Moments

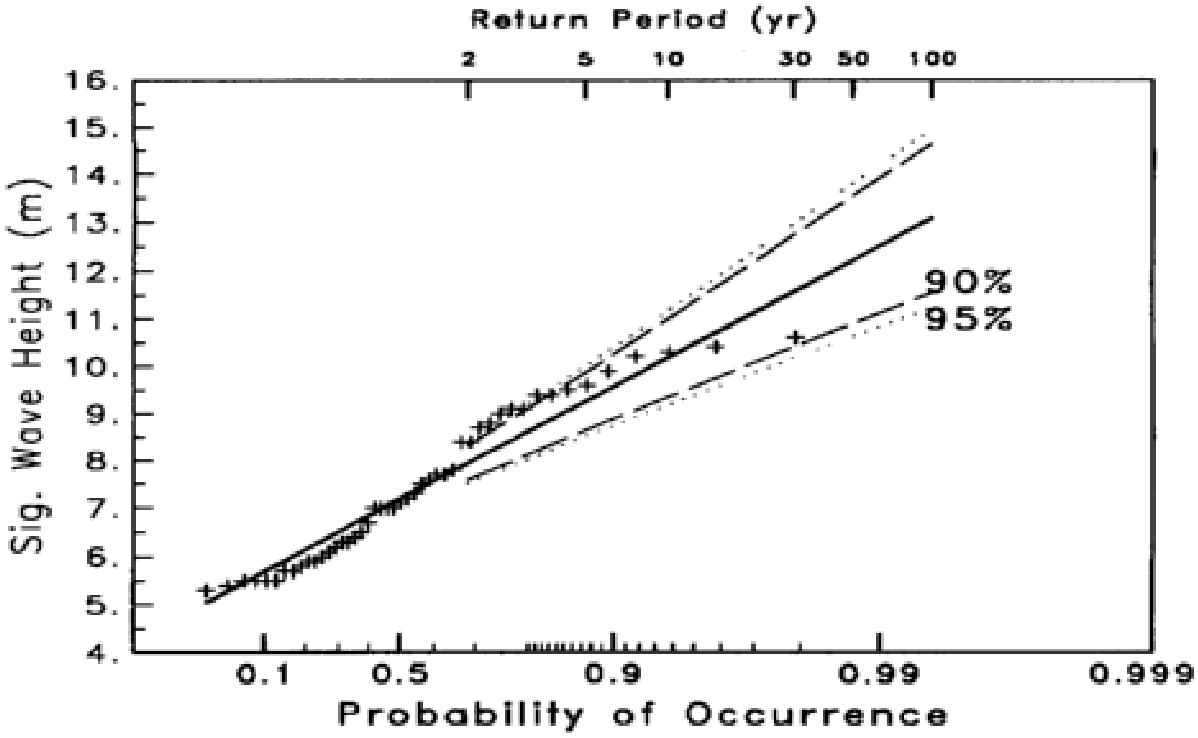
47 storms
Wave height threshold = 5.30 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	7.9	8.3	15.0	14.9	8.3
5	9.2	9.9	15.9	17.3	9.7
10	10.2	11.0	16.4	19.1	10.6
30	11.6	12.7	17.3	21.7	12.1
50	12.2	13.5	17.6	22.9	12.8
100	13.1	14.6	18.1	24.6	13.7

Tp, Hmax, and Hc were calculated using

$$Tp = 6.768\ Hs^{0.383}$$
$$Hmax = 1.877\ Hs$$
$$Hc = 1.045\ Hs$$

Correlation = 0.98



GRID POINT 1229 AT 49.375 N, 133.75 W

GUMBEL – Method of Moments

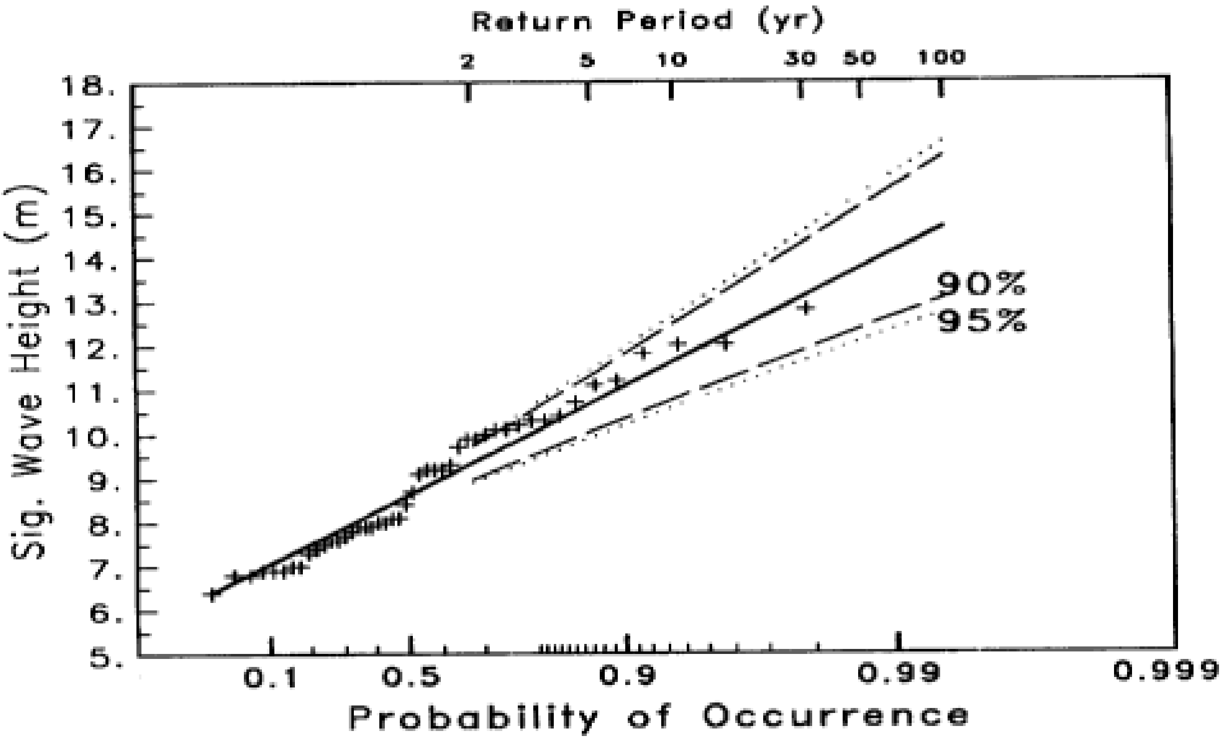
46 storms
Wave height threshold = 6.40 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	9.4	9.7	14.8	17.4	9.6
5	10.7	11.3	15.5	19.9	11.0
10	11.6	12.5	16.1	21.6	12.0
30	13.1	14.3	16.8	24.3	13.5
50	13.8	15.2	17.1	25.5	14.2
100	14.7	16.3	17.6	27.2	15.1

Tp, Hmax, and Hc were calculated using

$$Tp = 6.210\ Hs^{0.387}$$
$$Hmax = 1.856\ Hs$$
$$Hc = 1.032\ Hs$$

Correlation = 0.99



GRID POINT 1234 AT 49.375 N, 127.50 W

GUMBEL — Method of Moments

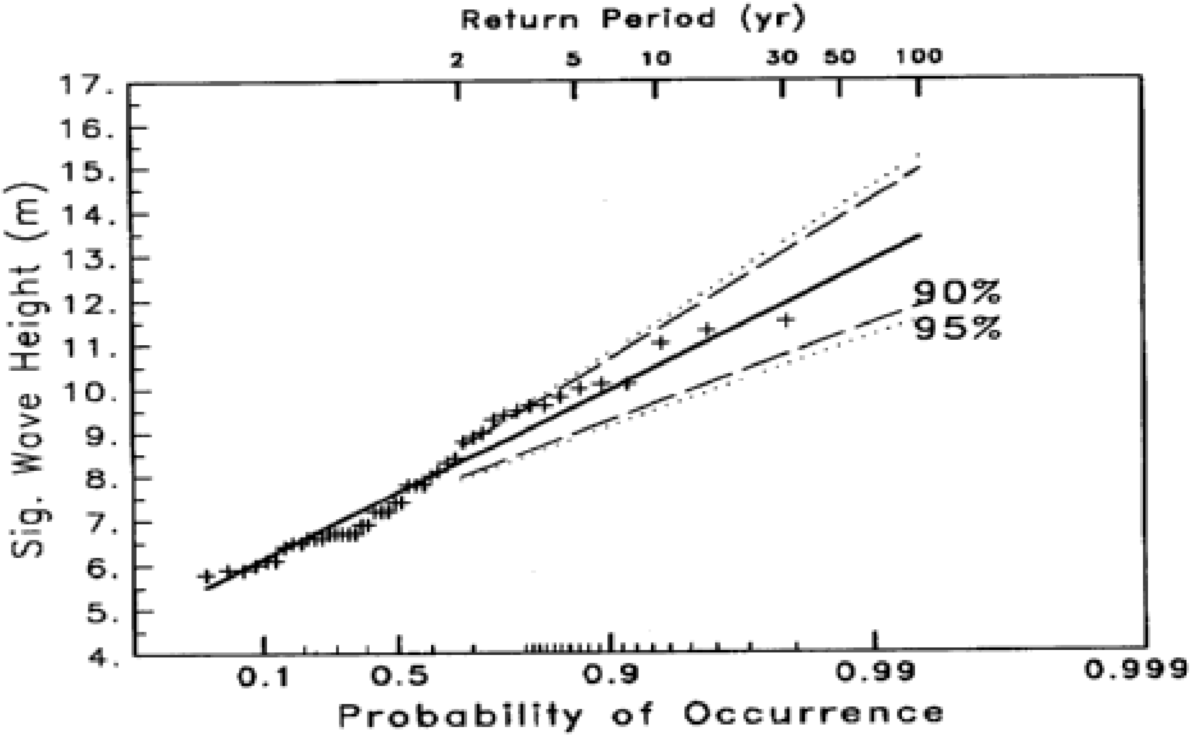
46 storms
Wave height threshold = 5.80 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.3	8.7	15.0	15.5	8.6
5	9.6	10.2	15.8	17.9	10.0
10	10.5	11.3	16.4	19.6	10.9
30	11.9	13.0	17.1	22.2	12.3
50	12.5	13.8	17.5	23.4	13.0
100	13.4	14.9	17.9	25.0	13.9

Tp, Hmax, and Hc were calculated using

$$Tp = 6.721\ Hs^{0.378}$$
$$Hmax = 1.867\ Hs$$
$$Hc = 1.038\ Hs$$

Correlation = 0.98



GRID POINT 1250 AT 50.000 N, 128.75 W

GUMBEL – Method of Moments

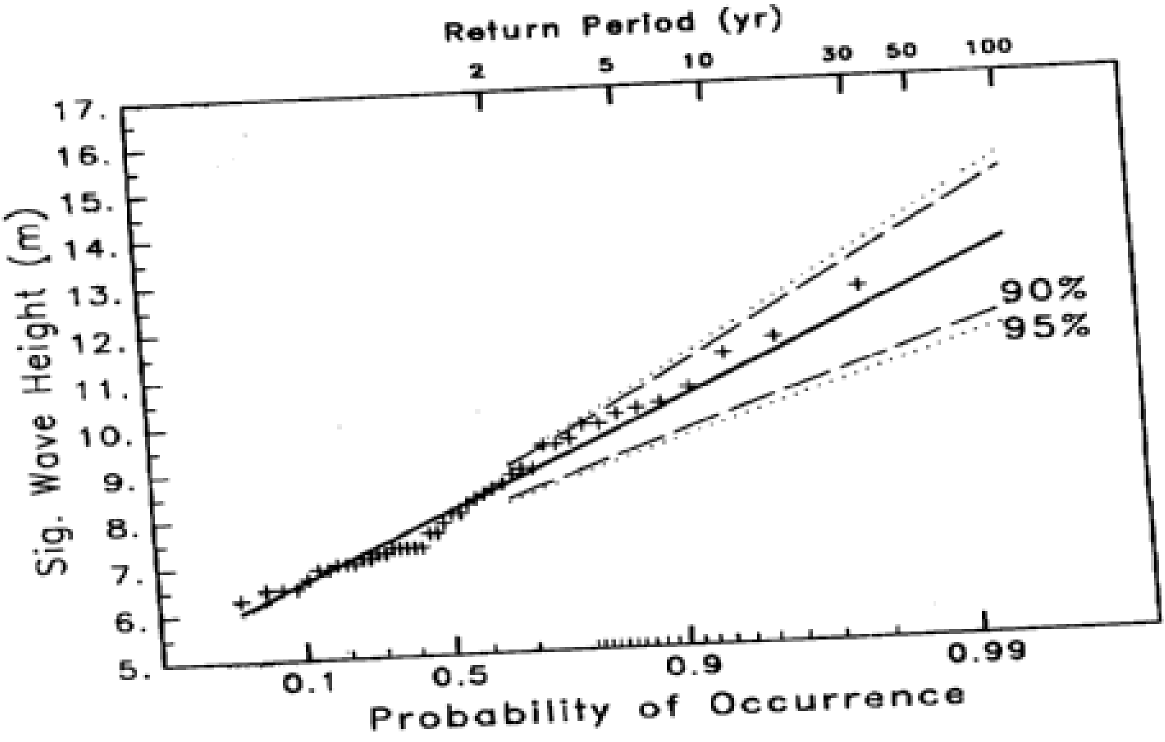
44 storms
Wave height threshold = 6.30 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.6	9.0	14.9	16.1	8.9
5	9.8	10.4	15.6	18.3	10.2
10	10.7	11.5	16.1	19.9	11.1
30	12.0	13.1	16.7	22.4	12.4
50	12.6	13.9	17.0	23.5	13.1
100	13.4	14.9	17.4	25.0	13.9

Tp, Hmax, and Hc were calculated using

$$Tp = 7.065\ Hs^{0.347}$$
$$Hmax = 1.862\ Hs$$
$$Hc = 1.036\ Hs$$

Correlation = 0.99



GRID POINT 1266 AT 50.625 N, 130.00 W

GUMBEL – Method of Moments

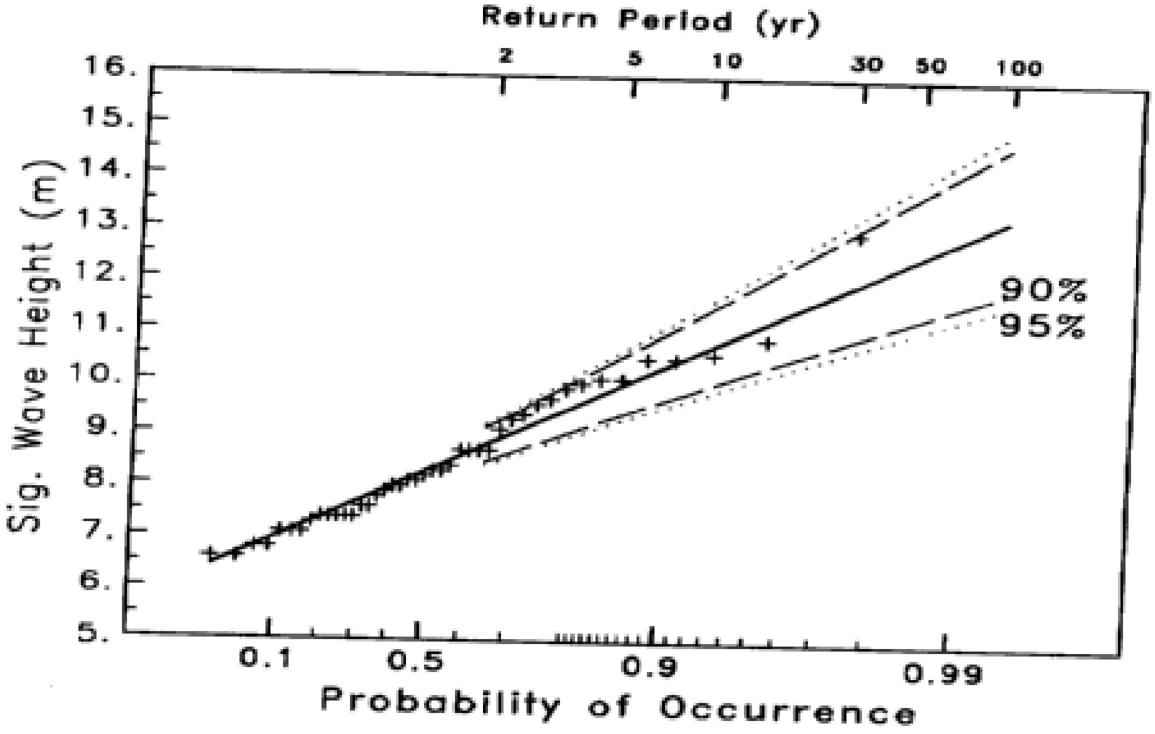
43 storms
Wave height threshold = 6.60 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.8	9.1	14.8	16.4	9.1
5	10.0	10.5	15.4	18.5	10.3
10	10.8	11.5	15.9	20.0	11.1
30	12.0	13.0	16.5	22.2	12.4
50	12.5	13.7	16.8	23.3	13.0
100	13.3	14.7	17.1	24.7	13.8

Tp, Hmax, and Hc were calculated using

$$Tp = 6.727\ Hs^{0.361}$$
$$Hmax = 1.857\ Hs$$
$$Hc = 1.034\ Hs$$

Correlation = 0.99



GRID POINT 1267 AT 50.625 N, 128.75 W

GUMBEL – Method of Moments

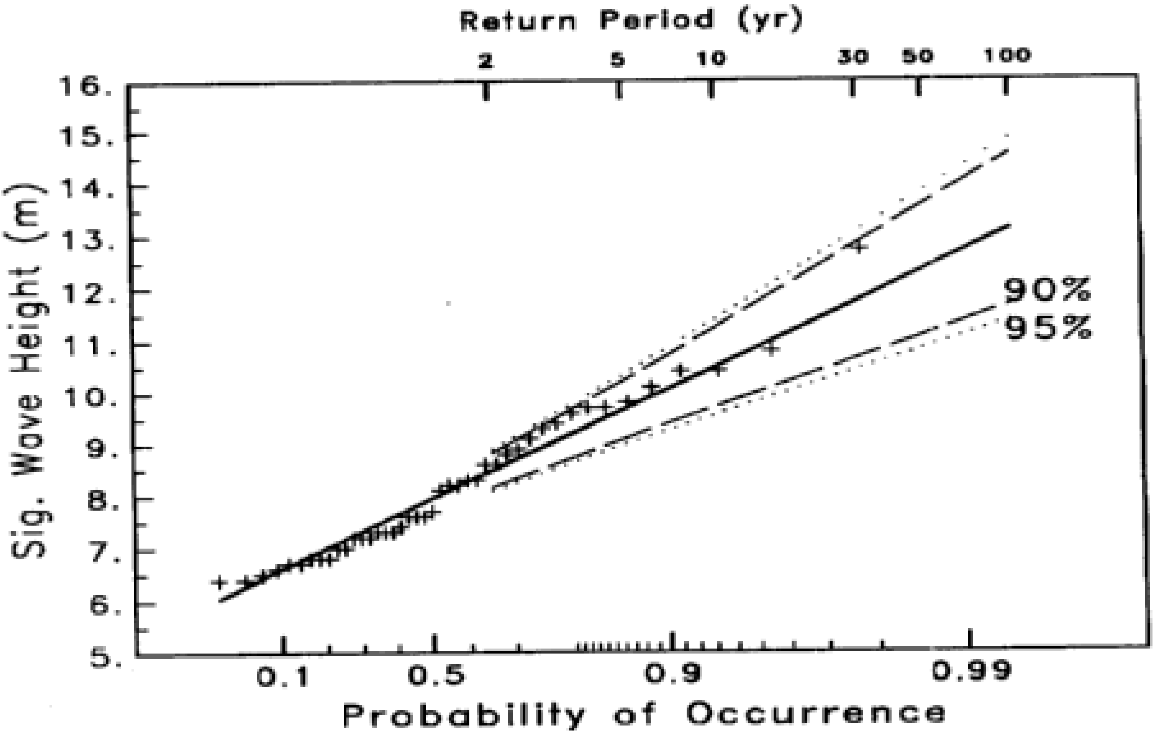
43 storms
Wave height threshold = 6.40 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.5	8.8	14.8	15.8	8.8
5	9.7	10.2	15.6	18.0	10.0
10	10.5	11.3	16.2	19.5	10.9
30	11.7	12.8	16.9	21.9	12.2
50	12.3	13.6	17.2	22.9	12.8
100	13.1	14.5	17.7	24.4	13.6

Tp, Hmax, and Hc were calculated using

$$Tp = 6.202\ Hs^{0.407}$$
$$Hmax = 1.863\ Hs$$
$$Hc = 1.035\ Hs$$

Correlation = 0.99



GRID POINT 1282 AT 51.250 N, 131.25 W

GUMBEL – Method of Moments

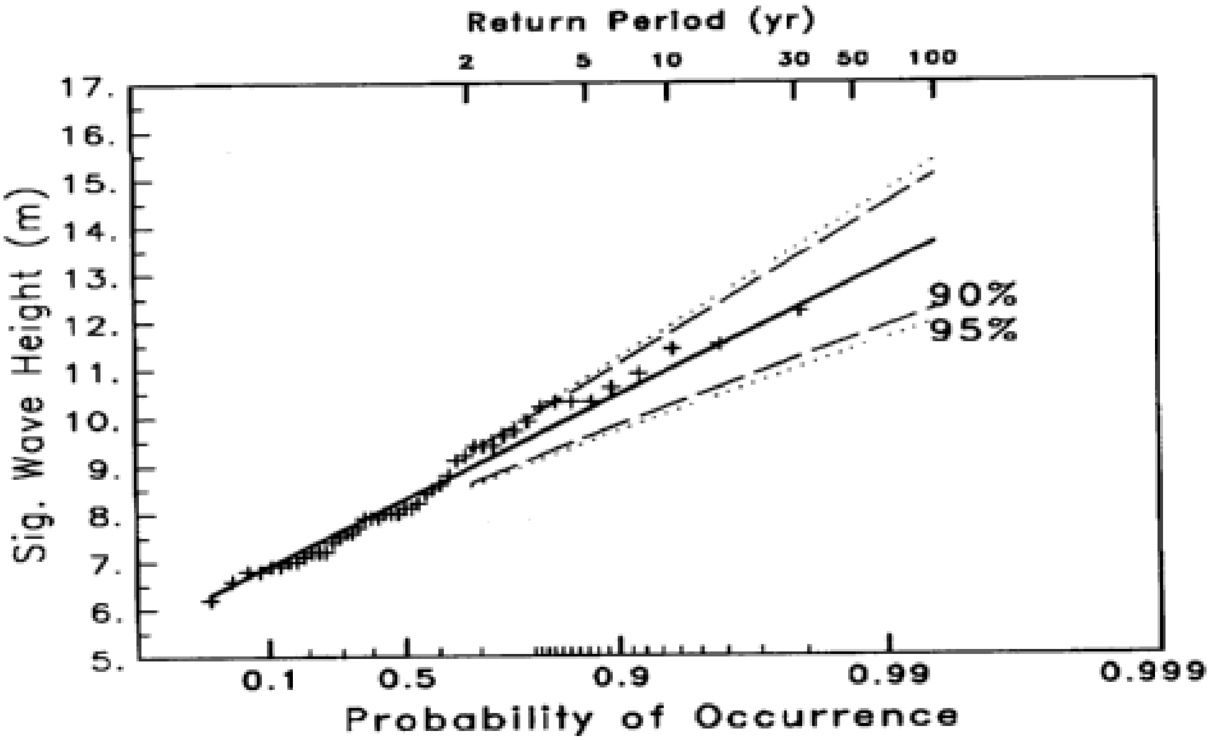
47 storms
Wave height threshold = 6.20 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	9.0	9.3	14.8	16.6	9.2
5	10.1	10.7	15.5	18.8	10.4
10	11.0	11.7	16.0	20.3	11.3
30	12.3	13.3	16.7	22.7	12.6
50	12.9	14.1	17.0	23.8	13.2
100	13.7	15.1	17.4	25.3	14.1

Tp, Hmax, and Hc were calculated using

$$Tp = 6.311\ Hs^{0.388}$$
$$Hmax = 1.851\ Hs$$
$$Hc = 1.029\ Hs$$

Correlation = 0.99



GRID POINT 1283 AT 51.250 N, 130.00 W

GUMBEL – Method of Moments

43 storms

Wave height threshold = 6.50 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.7	9.1	14.8	16.2	9.0
5	9.9	10.4	15.5	18.3	10.2
10	10.7	11.4	15.9	19.8	11.0
30	11.9	13.0	16.4	22.1	12.3
50	12.5	13.7	16.7	23.1	12.9
100	13.2	14.6	17.0	24.5	13.6

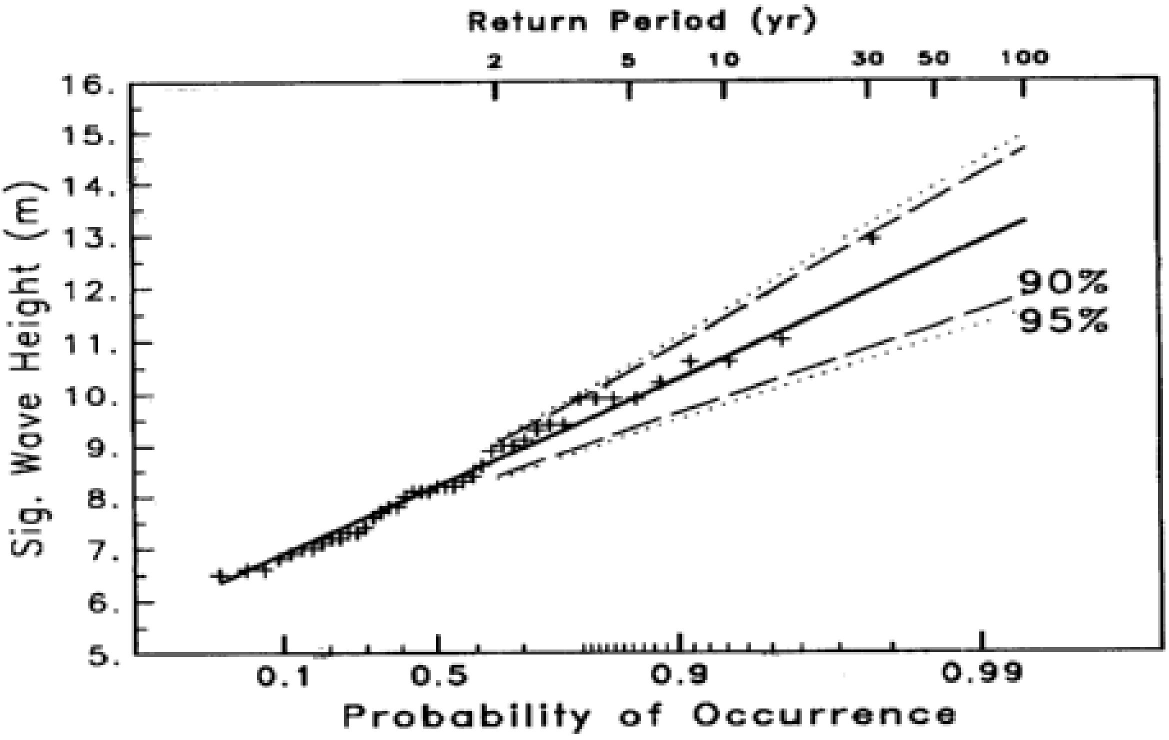
Tp, Hmax, and Hc were calculated using

$$Tp = 7.158\ Hs^{0.336}$$

$$Hmax = 1.855\ Hs$$

$$Hc = 1.031\ Hs$$

Correlation = 0.99



GRID POINT 1284 AT 51.250 N, 128.75 W

GUMBEL – Method of Moments

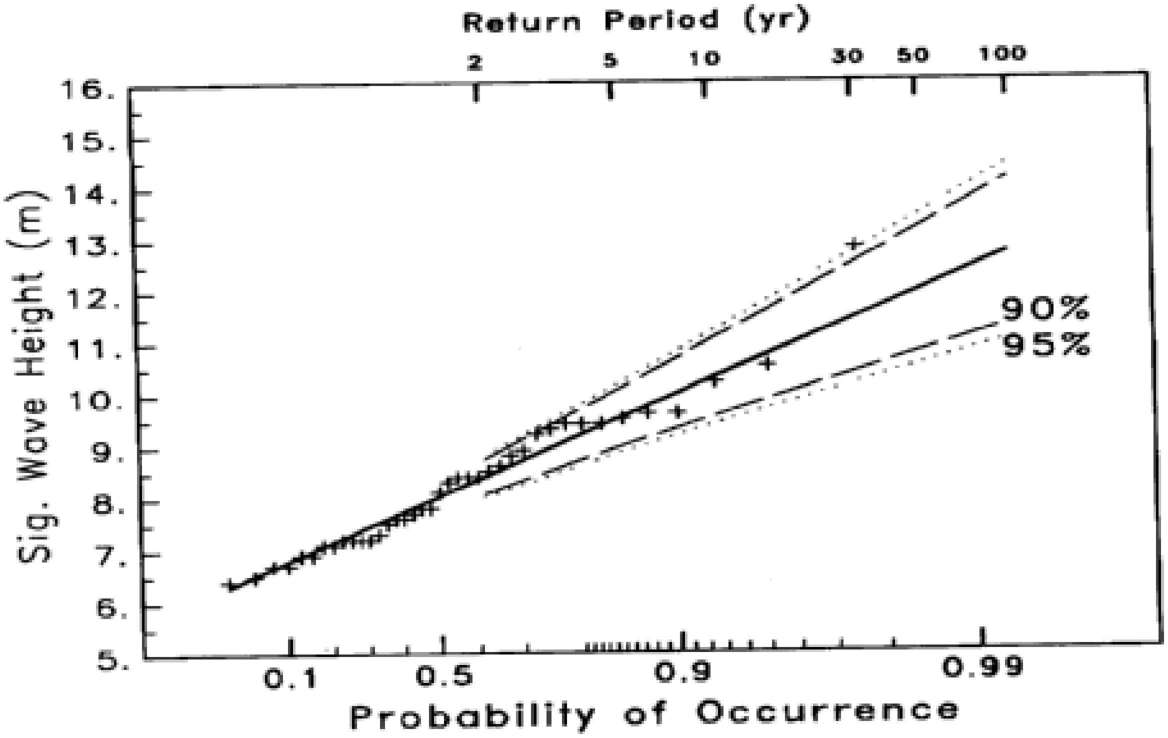
39 storms
Wave height threshold = 6.40 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.4	8.7	14.9	15.6	8.6
5	9.5	10.1	15.7	17.6	9.8
10	10.3	11.0	16.2	19.0	10.6
30	11.4	12.5	16.9	21.2	11.7
50	12.0	13.2	17.3	22.2	12.3
100	12.7	14.1	17.7	23.5	13.0

Tp, Hmax, and Hc were calculated using

$$Tp = 6.097\ Hs^{0.420}$$
$$Hmax = 1.853\ Hs$$
$$Hc = 1.028\ Hs$$

Correlation = 0.98



GRID POINT 1298 AT 51.875 N, 132.50 W

GUMBEL – Method of Moments

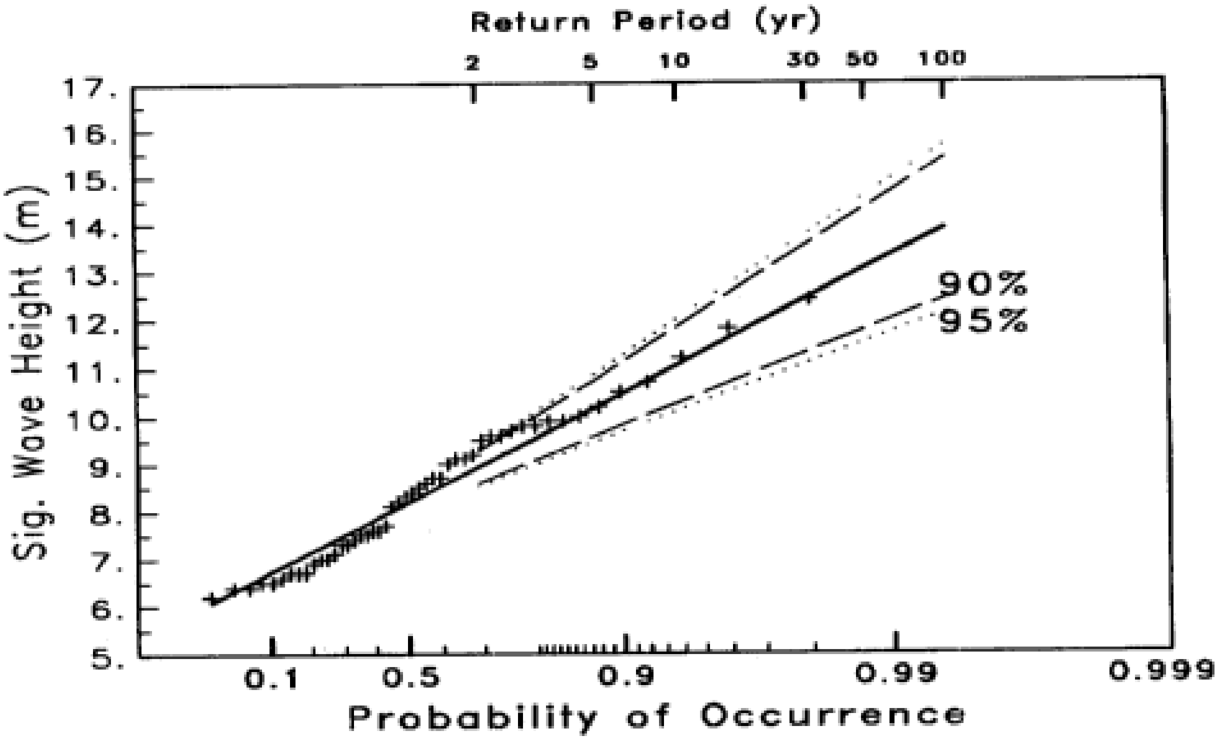
48 storms
Wave height threshold = 6.20 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.9	9.3	14.5	16.5	9.2
5	10.2	10.8	15.4	18.8	10.5
10	11.1	11.9	16.1	20.5	11.4
30	12.4	13.5	17.0	23.0	12.8
50	13.1	14.3	17.4	24.1	13.4
100	13.9	15.4	17.9	25.7	14.3

Tp, Hmax, and Hc were calculated using

$$Tp = 5.065\ Hs^{0.480}$$
$$Hmax = 1.848\ Hs$$
$$Hc = 1.026\ Hs$$

Correlation = 0.99



GRID POINT 1299 AT 51.875 N, 131.25 W

GUMBEL – Method of Moments

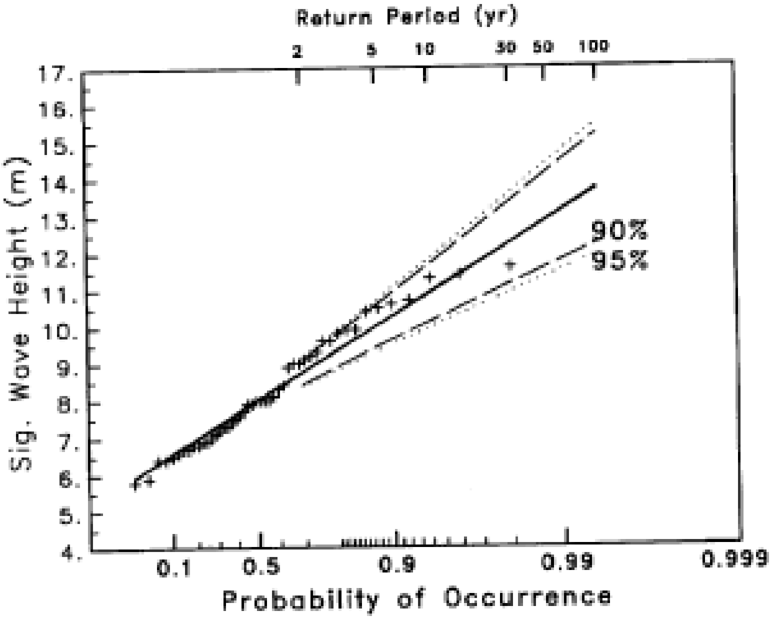
48 storms
Wave height threshold = 5.80 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.8	9.1	14.6	16.2	9.0
5	10.0	10.6	15.4	18.5	10.3
10	10.9	11.7	15.9	20.1	11.2
30	12.2	13.3	16.6	22.6	12.6
50	12.9	14.1	17.0	23.8	13.2
100	13.7	15.2	17.4	25.3	14.1

Tp, Hmax, and Hc were calculated using

$$Tp = 6.170\ Hs^{0.396}$$
$$Hmax = 1.849\ Hs$$
$$Hc = 1.028\ Hs$$

Correlation = 0.99



GRID POINT 1300 AT 51.875 N, 130.00 W

GUMBEL – Method of Moments

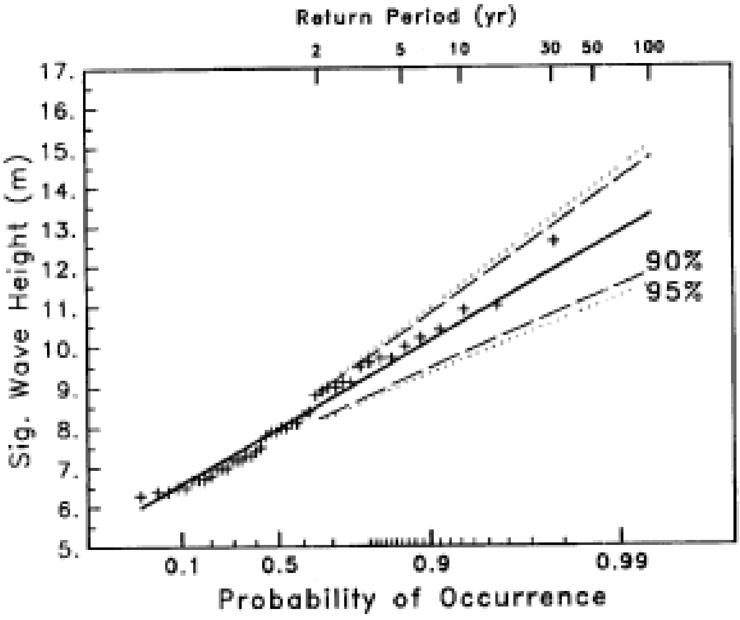
44 storms
Wave height threshold = 6.30 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.5	8.9	14.7	15.8	8.8
5	9.8	10.3	15.4	18.1	10.0
10	10.6	11.4	15.8	19.6	10.9
30	11.9	13.0	16.4	22.0	12.2
50	12.5	13.7	16.7	23.1	12.8
100	13.3	14.7	17.0	24.6	13.7

Tp, Hmax, and Hc were calculated using

$Tp = 7.189\ Hs^{0.333}$
$Hmax = 1.851\ Hs$
$Hc = 1.029\ Hs$

Correlation = 0.99



GRID POINT 1315 AT 52.500 N, 132.50 W

GUMBEL – Method of Moments

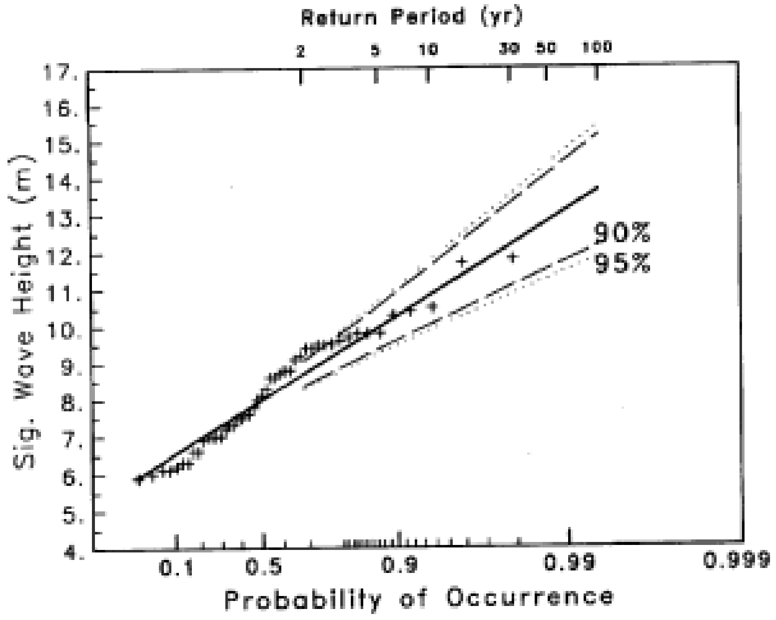
47 storms
Wave height threshold = 5.90 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.7	9.1	14.6	16.1	8.9
5	10.0	10.5	15.5	18.4	10.2
10	10.8	11.6	16.1	20.0	11.1
30	12.2	13.3	16.9	22.5	12.5
50	12.8	14.1	17.3	23.6	13.1
100	13.6	15.1	17.8	25.2	14.0

Tp, Hmax, and Hc were calculated using

$$T_p = 5.731\ H_s^{0.433}$$
$$H_{max} = 1.844\ H_s$$
$$H_c = 1.024\ H_s$$

Correlation = 0.98



GRID POINT 1317 AT 52.500 N, 130.00 W

GUMBEL – Method of Moments

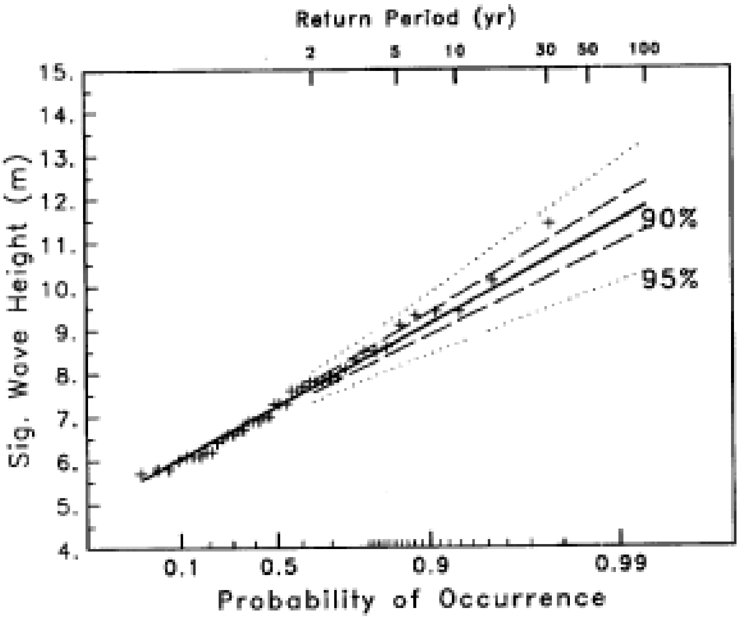
42 storms
Wave height threshold = 5.70 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	7.7	7.8	14.0	14.2	7.9
5	8.7	9.0	14.9	16.1	9.0
10	9.5	9.8	15.5	17.5	9.7
30	10.6	11.0	16.4	19.6	10.9
50	11.1	11.6	16.8	20.5	11.4
100	11.8	12.4	17.3	21.8	12.1

Tp, Hmax, and Hc were calculated using

$$Tp = 5.062\ Hs^{0.498}$$
$$Hmax = 1.847\ Hs$$
$$Hc = 1.026\ Hs$$

Correlation = 0.99



GRID POINT 1331 AT 53.125 N, 133.75 W

GUMBEL – Method of Moments

46 storms

Wave height threshold = 5.80 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.5	8.9	13.9	15.7	8.7
5	9.7	10.3	14.9	17.9	10.0
10	10.6	11.4	15.6	19.5	10.8
30	11.9	13.0	16.6	21.9	12.2
50	12.5	13.7	17.0	23.0	12.8
100	13.3	14.8	17.6	24.5	13.6

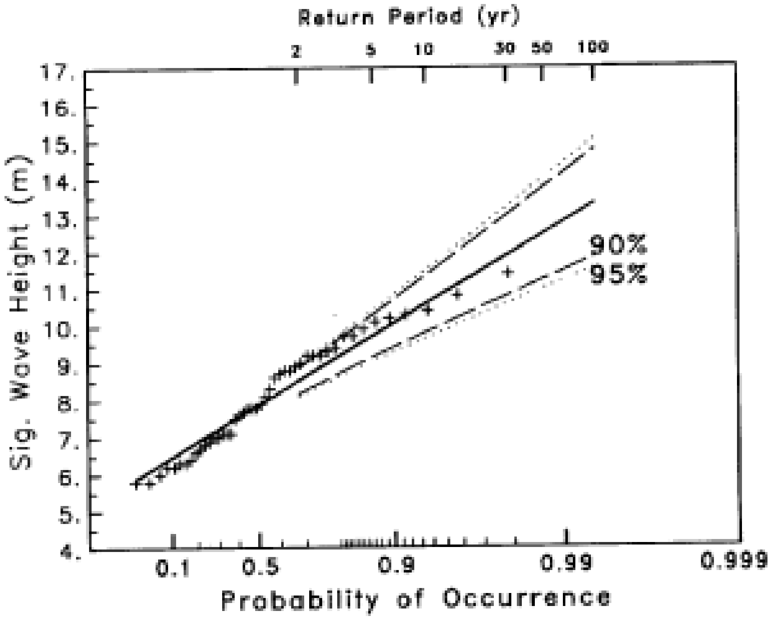
Tp, Hmax, and Hc were calculated using

$$Tp = 4.385\ Hs^{0.537}$$

$$Hmax = 1.842\ Hs$$

$$Hc = 1.024\ Hs$$

Correlation = 0.98



GRID POINT 1346 AT 53.750 N, 136.25 W

GUMBEL – Method of Moments

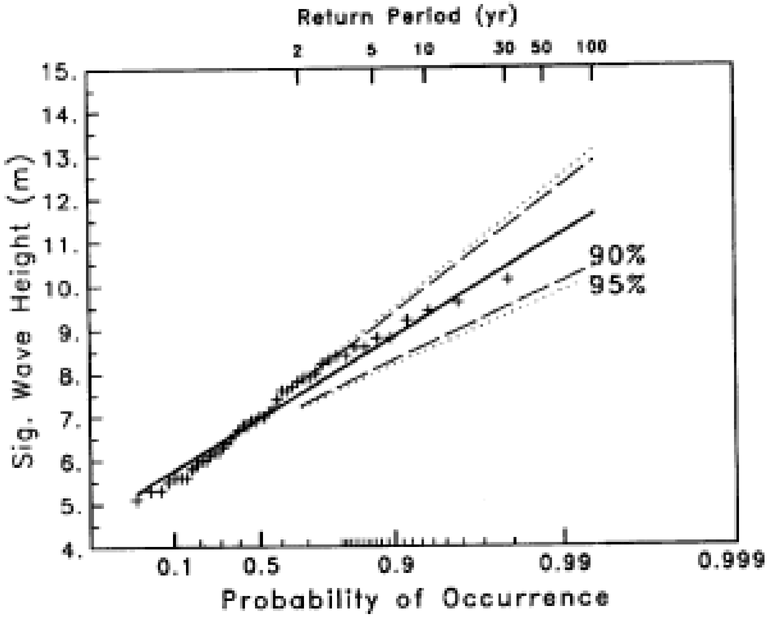
47 storms
Wave height threshold = 5.10 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	7.5	7.8	13.8	14.0	7.8
5	8.6	9.1	14.6	15.9	8.8
10	9.3	9.9	15.2	17.2	9.6
30	10.4	11.3	16.0	19.3	10.7
50	10.9	12.0	16.4	20.2	11.2
100	11.6	12.8	16.8	21.5	11.9

Tp, Hmax, and Hc were calculated using

$$Tp = 5.378\ Hs^{0.466}$$
$$Hmax = 1.852\ Hs$$
$$Hc = 1.029\ Hs$$

Correlation = 0.99



GRID POINT 1348 AT 53.750 N, 133.75 W

GUMBEL – Method of Moments

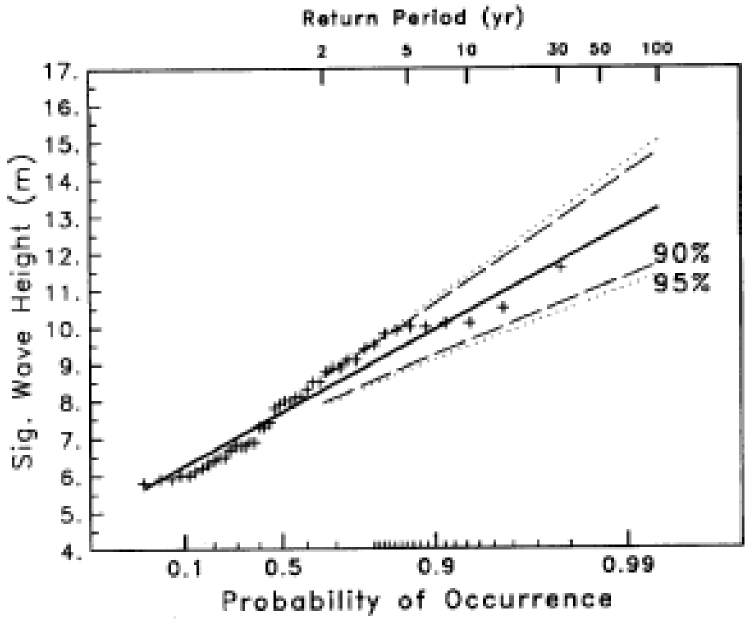
44 storms
Wave height threshold = 5.80 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.3	8.7	13.9	15.3	8.5
5	9.5	10.1	14.9	17.6	9.8
10	10.4	11.2	15.5	19.2	10.7
30	11.8	12.9	16.4	21.7	12.0
50	12.4	13.7	16.8	22.8	12.7
100	13.2	14.7	17.3	24.3	13.5

Tp, Hmax, and Hc were calculated using

$$Tp = 5.163\ Hs^{0.469}$$
$$Hmax = 1.844\ Hs$$
$$Hc = 1.025\ Hs$$

Correlation = 0.98



GRID POINT 1365 AT 54.375 N, 133.75 W

GUMBEL – Method of Moments

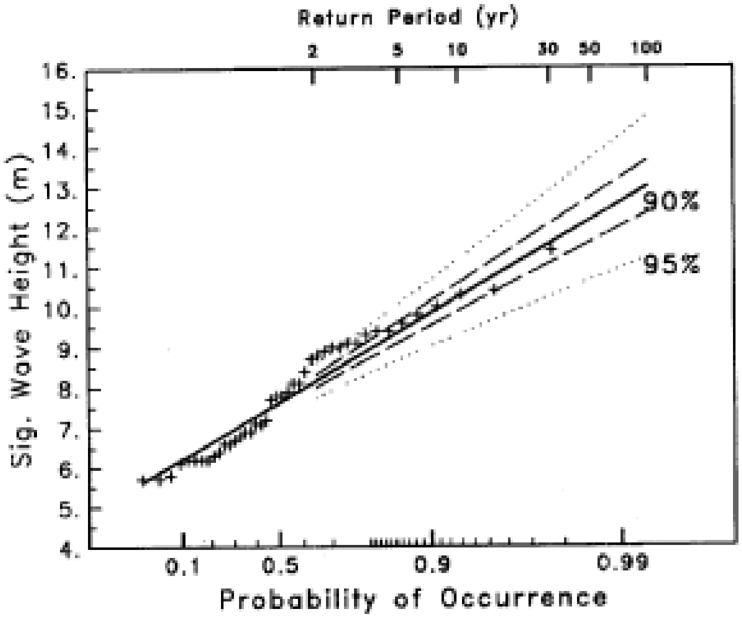
42 storms
Wave height threshold = 5.70 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	8.2	8.3	14.0	15.0	8.3
5	9.4	9.7	14.9	17.3	9.6
10	10.3	10.6	15.5	18.9	10.5
30	11.6	12.1	16.3	21.3	11.8
50	12.2	12.7	16.7	22.4	12.5
100	13.0	13.7	17.2	24.0	13.3

Tp, Hmax, and Hc were calculated using

$Tp = 5.635\ Hs^{0.435}$
$Hmax = 1.842\ Hs$
$Hc = 1.023\ Hs$

Correlation = 0.98



GRID POINT 1366 AT 54.375 N, 132.50 W

GUMBEL – Method of Moments

34 storms

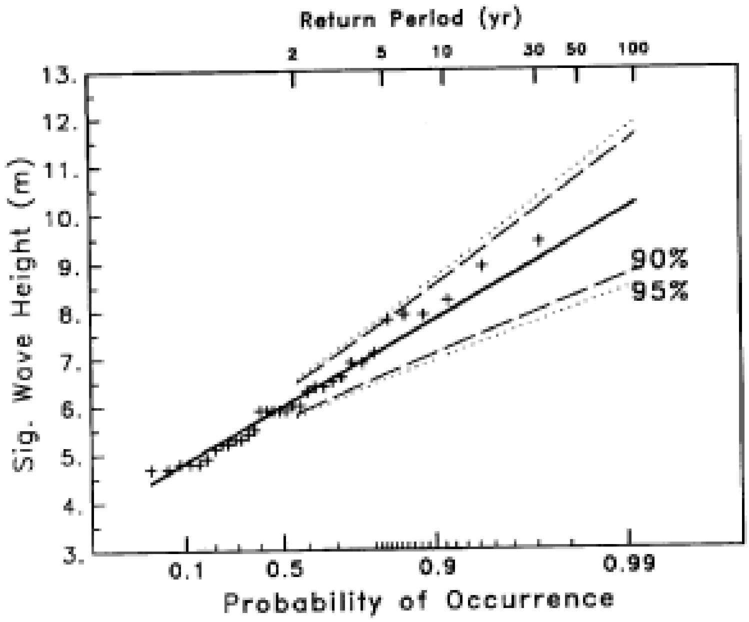
Wave height threshold = 4.70 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	6.2	6.5	13.3	11.3	6.3
5	7.2	7.8	14.8	13.2	7.3
10	7.9	8.7	15.9	14.6	8.1
30	9.0	10.1	17.3	16.6	9.2
50	9.5	10.7	18.0	17.5	9.7
100	10.2	11.6	18.9	18.7	10.4

Tp, Hmax, and Hc were calculated using

$$Tp = 3.784\ Hs^{0.692}$$
$$Hmax = 1.836\ Hs$$
$$Hc = 1.016\ Hs$$

Correlation = 0.99



GRID POINT 1380 AT 55.000 N, 136.25 W

GUMBEL – Method of Moments

41 storms

Wave height threshold = 5.90 m

Return Period (yr)	Best Fit (m)	90% U.L. (m)	Tp (s)	Hmax (m)	Hc (m)
2	7.9	8.2	13.7	14.6	8.1
5	9.0	9.5	14.5	16.6	9.2
10	9.8	10.5	14.9	18.0	10.0
30	10.9	12.0	15.7	20.1	11.1
50	11.5	12.6	16.0	21.1	11.7
100	12.2	13.5	16.4	22.4	12.4

Tp, Hmax, and Hc were calculated using

$Tp = 5.727\ Hs^{0.421}$

$Hmax = 1.839\ Hs$

$Hc = 1.020\ Hs$

Correlation = 0.99