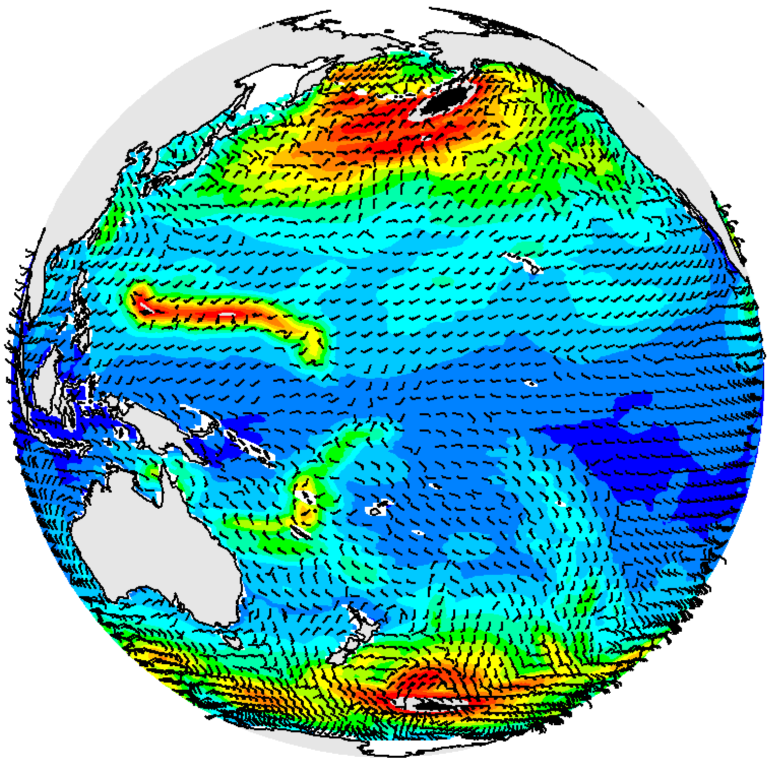
Global Reanalysis of Ocean Waves (GROW)

Project Description

Revised October 2, 2007



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1.0 DESCRIPTION

GROW couples Oceanweather's proven global wave model, tropical boundary layer model, and its vast experience in developing marine surface wind fields to produce a revolutionary global wave hindcast. The result is a first-of-its-kind long term analysis of the global wave climate which can be applied to offshore structure design, tow-analysis, operability, and other applications where wind and wave data are required. Standard products from GROW include time series of wind and wave parameters (including sea/swell partitions), extreme criteria, operability statistics, and wave spectra.

GROW is intended as a fast turnaround product for initial estimates of site-specific extremes and operability data for the global oceans. Final design criteria, especially those in tropical basins, are best served by a more intense hindcast approach such as one of the many Oceanweather's Joint Industry Projects (JIPs) or site-specific hindcast studies.

2.0 HINDCAST METHODOLOGY

2.1 Data Sources

Historical data for the generation of GROW consist of background wind fields, tropical system data archives, ice edge data, and wave measurements for validation purposes. A substantial data assembly, processing and interpolation effort was performed from the following sources:

1. National Centers for Environmental Prediction/National Center for Atmospheric Research Reanalysis (NRA) six-hourly 10-meter surface wind fields
2. Joint Typhoon Warning Center Tropical Database
3. National Hurricane Center/Tropical Prediction Center Hurricane Archive
4. NCAR/UCAR Tropical Database
5. National Data Buoy Center Archive
6. MEDS (Environment Canada) Buoy Archive
7. National Climatic Data Center Ship Report/Buoy Archive
8. National Snow and Ice Center
9. Jet Propulsion Laboratory Physical Oceanography Distributed Active Archive Center (JPL PODAAC) TOPEX Geophysical Data Record
10. Ifremer ERS-1/ERS-2 Altimeter Data Set
11. GEOSAT Altimeter Data Set
12. NSCAT Scatterometer Data Set from JPL PODAAC

2.2 Tropical Wind Field Generation

Prior to the generation of GROW there was no global archive of tropical surface wind fields ever developed for use in global wave hindcasting. Tropical archives from national warning centers contained such information as track and intensity, but little data as to the radius of maximum winds (RMW) or radii of 35 or 50 knot winds. In site-specific hindcast studies performed at Oceanweather involving tropical analysis, time-consuming analysis is done on each tropical system to best resolve the track, intensity, RMW and other inputs used to drive Oceanweather's Tropical Boundary Layer Model (TC96) (Cardone *et al*. 1992 and Cardone *et al*. 1994). Such analysis often involved satellite analysis, aircraft reconnaissance, radar data, marine/coastal observations and other information. In GROW, such a time-intensive process was not attempted due to a) the sheer number of tropical systems involved (over 2,900 in the period 1970-2000 alone) and b) the coarseness of the GROW wave model (.625° in latitude by 1.25° in longitude) for tropical wave field simulation. Therefore, while the inclusion of tropical systems in GROW is a vast improvement over the base NRA wind fields and is very useful for describing the swell climate generated by tropical systems we do not recommend direct use of GROW for peak sea-states in tropical systems.

When available, the radii of 35 and 50 knot winds as analyzed by the national warning centers were used in a inverse modeling sense to determine the RMW and other TC96 inputs. Given the wind radii and maximum intensity from the historical archive, a database lookup was performed to determine the TC96 inputs that would give the closest match. More information on this process can be found in *Cox and Cardone* [2000]. Where wind radii were not available, a basin-specific climatological RWM-intensity relationship developed from Oceanweather's previous hindcast experience was used. The TC96 model was run on a .3125° latitude/longitude grid and tropical winds within 180 nautical miles of the center of the system were used for inclusion in the continuous wind fields.

2.3 Continuous Wind Field Generation

The base wind fields used in the generation of GROW were the NRA six-hourly 10-meter surface wind fields. These source wind fields are on the NRA guassian grid which is approximately 2° in latitude and longitude. A adjustment to neutral stability was performed using NRA sea-surface temperature and surface temperature fields via a technique described by *Cardone et al.* [1990]. Comparisons of NRA wind fields in the tropics and in the southern oceans against NSCAT Scatterometer and in-situ wind measurements led to additional basin wide wind field corrections applied to the base NRA winds. Tropical wind fields as described in section 2.2 were included into the final GROW winds using the Interactive Objective Kinematic Analysis (IOKA) system (Cox *et al*. 1995) and output onto the GROW wave model grid.

2.4 Wave Hindcast Model

The latest variant of Oceanweather's well established and validated ODGP model (ODGP2) wave model was used in the generation of GROW. This latest version of ODGP2 includes a new formulation of the Pierson-Moskowitz fully developed sea theory (Resio *et al.*, 1999). The new wind scaling used therein appears to correct a known tendency of all previous wave models, including third generation (3G) variants, to specify very extreme sea states in a special class of storms characterized by resonant dynamic fetches or very long physical fetches and durations. Details of the ODGP model can be found in *Khandekar et al.* [1994]. The skill of the model has been documented in numerous studies worldwide, most recently by *Cardone et al.* [1996] and *Cardone and Resio* [1998].

The GROW implementation of the ODGP2 model consisted of 46,529 grid points on a global .625° by 1.25° degree latitude/longitude grid (Figure 1). All model grid points were treated as deep (no shallow water effects included). Mean-monthly ice tables for the period 1973 to present were derived from the National Snow and Ice Center data sets and interpolated onto the GROW modeling grid. Grid points with mean-monthly ice concentrations greater than 50% were treated as landed points in the model. Prior to 1973, actual Northern Hemisphere mean monthly ice tables were continued, but long-term average ice tables were used in the Southern Oceans due to lack of measured data. The wave model was run on a 1-hourly internal time step and archived wind, wave, and spectra fields every 3 hours.

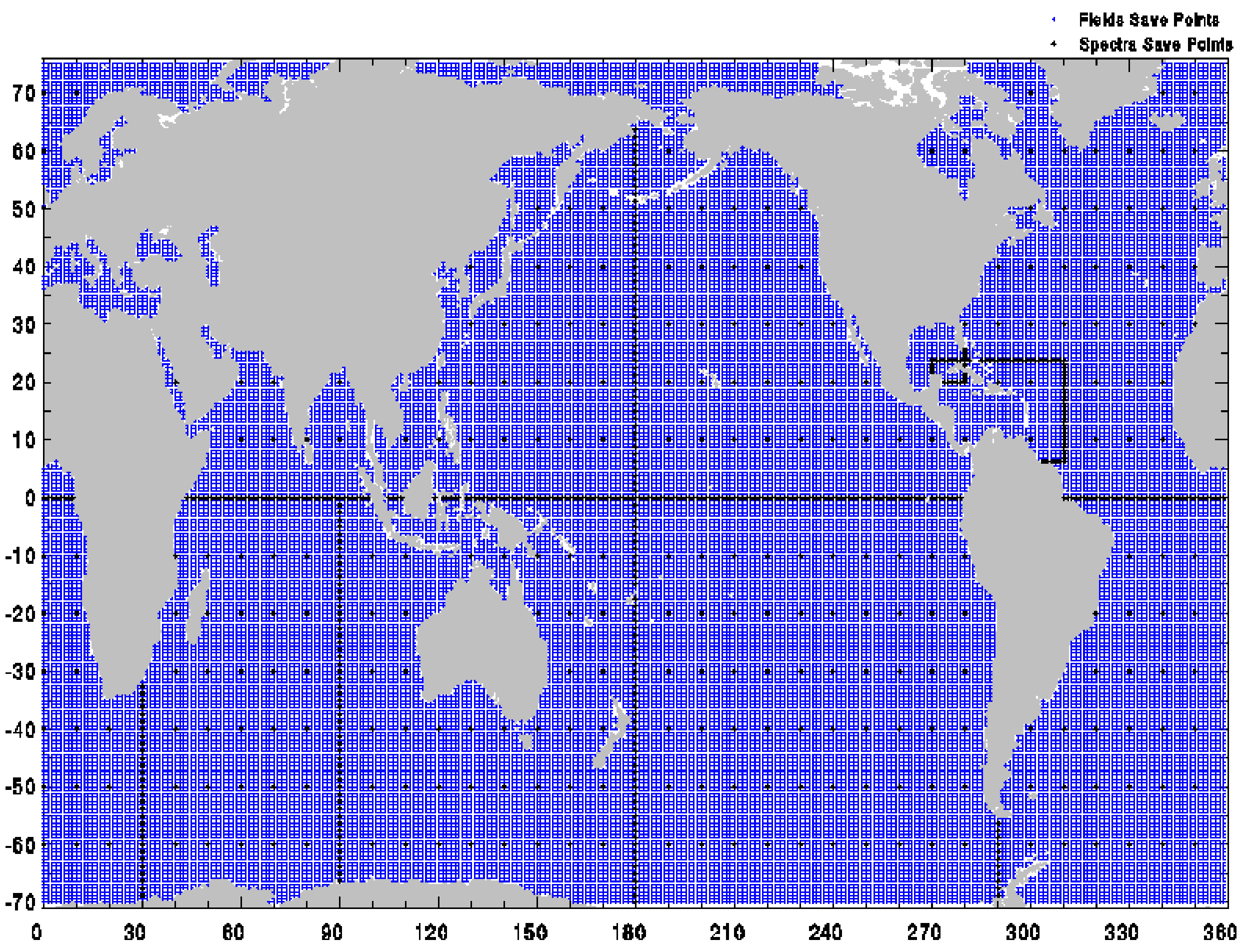

Figure 1 - GROW Wind and Wave Model Grid

3.0 VALIDATION

The GROW hindcast was intensively validated against world-wide wave measurements from deep-water buoys and from global altimeter measurements. An extensive validation of the original GROW (run in 1997 on a lower-resolution grid) appeared in the Journal of Geophysical Research (Cox and Swail, 2000). Comparisons of the current GROW show even better results due to the inclusion of tropical systems, wind modifications, and increased resolution of the GROW wave model.

3.1 In-situ Validation

Buoy wind and wave observations from the National Data Buoy Center, MEDS (Environment Canada) and National Climatic Data Center (includes data from the Eastern North Atlantic and offshore Japan) were used in the in-situ validation of GROW. Over 40 buoy locations, mainly in the Northern Hemisphere, were time-matched with the GROW hindcast and compared. Locations were restricted to high quality, deep water sites at least 2 grid spacings from the coast. The in-situ validation consisted of nearly 3 million individual observations. Table 1 shows the overall statistics grouped by region. Overall, the average wave bias is under 10 cm with a root mean square difference of 80 cm and correlation coefficient of 86%.

Table 1 Buoy Comparison Statistics Grouped By Region

	Number of Points	*Mean Measurement*	*Mean Hindcast*	*Bias (H-M)*	*RMS Error*	*Scatter Index*	*Correlation Coefficient*
Bering Sea							
Wind Speed (m/s)	187,595	8.02	8.56	0.54	2.28	0.28	0.85
Wind Direction (deg)	187,593	44	37	-4.8	N/A	0.08	N/A
Significant Wave Ht. (m)	105,772	2.67	2.58	-0.09	.56	0.21	0.94
Wave Period (sec)	105,772	6.77	6.22	-0.56	1.20	0.16	0.76
Gulf of Mexico							
Wind Speed (m/s)	477,756	6.23	6.59	0.36	1.93	0.30	0.81
Wind Direction (deg)	477,744	98	93	-1.8	N/A	0.09	N/A
Significant Wave Ht. (m)	456,163	1.14	1.33	0.19	0.44	0.35	0.90
Wave Period (sec)	456,017	4.83	4.68	-0.14	0.73	0.15	0.69
Wave Direction (deg)	80,511	107.51	95.56	-6.20	N/A	0.10	N/A
Northeast Atlantic							
Wind Speed (m/s)	96,685	9.00	8.72	-0.28	2.64	0.29	0.78
Wind Direction (deg)	96,738	244	245	-0.9	N/A	0.10	N/A
Significant Wave Ht. (m)	52,662	3.47	3.17	-0.30	1.41	0.40	0.73
Northeast Pacific							
Wind Speed (m/s)	1,222,763	7.67	8.17	0.50	2.70	0.35	0.74
Wind Direction (deg)	1,222,741	266	259	-0.6	N/A	0.11	N/A
Significant Wave Ht. (m)	1,206,818	2.79	2.96	0.17	0.81	0.29	0.88

Wave Period (sec)	1,207,266	7.90	7.23	-0.67	2.56	0.31	0.41
Northwest Atlantic							
Wind Speed (m/s)	865,354	7.57	7.80	0.24	2.78	0.37	0.76
Wind Direction (deg)	865,340	247	263	1.8	N/A	0.10	N/A
Significant Wave Ht. (m)	820,811	2.11	2.03	-0.08	0.65	0.31	0.88
Wave Period (sec)	817,490	7.74	6.79	-0.95	3.55	0.44	0.48
North Sea							
Wind Speed (m/s)	435,479	8.28	8.73	0.45	2.58	0.31	0.82
Wind Direction (deg)	435,472	245	235	-4.2	N/A	0.09	N/A
Significant Wave Ht. (m)	339,823	2.45	2.42	-0.02	0.94	0.38	0.83
Wave Period (sec)	343,982	12.19	8.63	-3.57	5.19	0.31	0.42

3.2 Altimeter Validation

Altimeter wind and wave measurements provide the best global coverage to evaluate the skill of GROW. Measurements from the ERS-1/2 and TOPEX instruments from the period 1991 to present and GEOSAT measurements from 1987 to 1989 were used in the validation. The median of all altimeter observations (typically measured at 1 Hz) within a 2.5° box +/- 30 minutes were considered a single validation point. Overall, there were just less than 39 million validation points with an average wave bias of less than 10 cm, root mean square error of 0.68 and correlation coefficient of 83% (Table 2). A plot of wave bias on a global projection (Figure 2) shows some coherent areas of over and underestimation of significant wave height in GROW. However, the vast majority of the global oceans have a mean bias less than 25 cm.

Table 2 Altimeter Comparison Statistics

	Number of Points	*Mean Measurement*	*Mean Hindcast*	*Bias (H-M)*	*RMS Error*	*Scatter Index*	*Correlation Coefficient*
Wind Speed (m/s)	39,250,971	7.42	7.59	0.18	2.07	0.28	0.78
Significant Wave Ht. (m)	38,985,860	2.69	2.61	-0.08	0.68	0.25	0.83

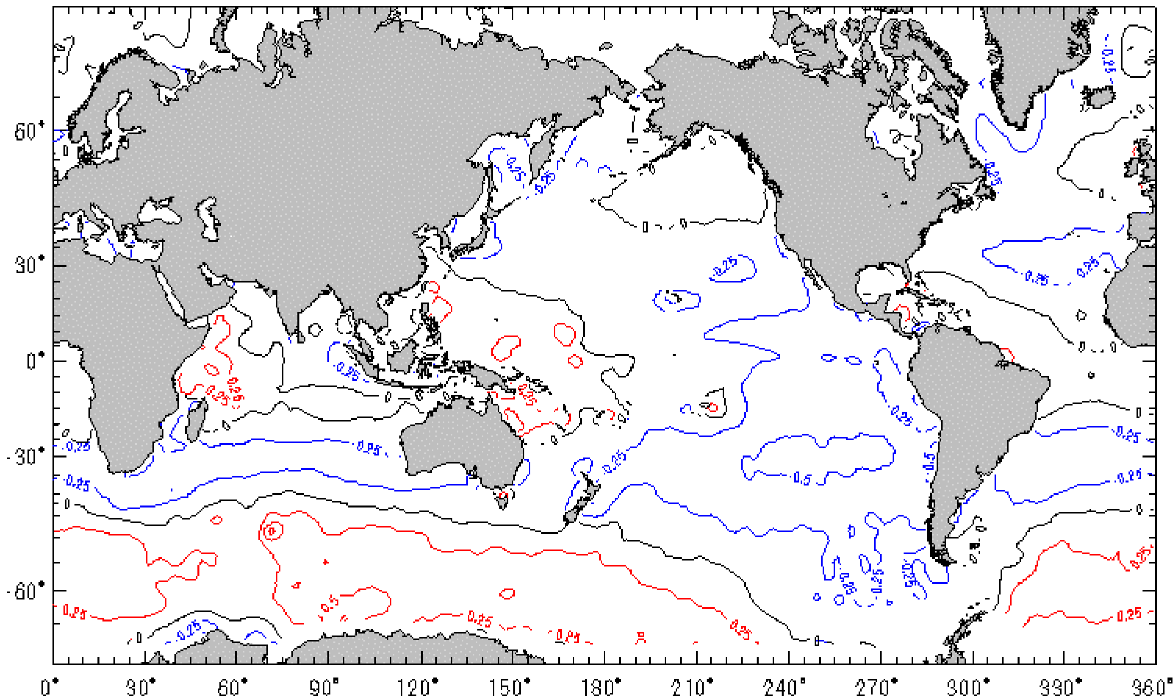

Figure 2 - Mean Difference (GROW-Altimeter) of All Altimeter Wave Comparisons (m)

4.0 DELIVERABLES

4.1 Wind/Wave Fields

Oceanweather's standard wind and wave fields (see Table 3) were saved at all GROW wave model grid points every 3 hours. However, only select grid points have been "point sorted" and processed for distribution (for an interactive map of archived GROW grid points please see http://www.oceanweather.com/metocean/grow/). Wind and wave fields are available in an ASCII format (a sample can be found in Appendix A) or in OSMOSIS format. OSMOSIS is Oceanweather's display and analysis tool which is sold separately.

Table 3 GROW Wind and Wave Fields Definitions

Field	*Description*
Date	Julian format (where Jan 1 1900 = 1, Jan 2 1900 = 2, etc.)
Wind Direction	From which the wind is blowing, clockwise from true north in degrees (meteorological convention).
Wind Speed	1-hour average of the effective neutral wind at a height of 10 meters, units in meters/second.
Total Spectrum Wave Fields:	
Total Variance	The sum of the variance components of the hindcast spectrum, over the 552 bins of the wave model, in meters squared.
Significant Wave Height	4.000 times the square root of the total variance, in meters.
Peak Spectral Period	Peak period is the reciprocal of peak frequency, in seconds. Peak frequency is computed by taking the spectral density in each frequency bin, and fitting a parabola to the highest density and one neighbor on each side. If highest density is in the .32157 Hz bin, the peak period reported is the peak period of a Pierson-Moskowitz spectrum having the same total variance as the hindcast spectrum.
Vector Mean Direction	To which waves are traveling, clockwise from north in degrees (oceanographic convention).
First Spectral Moment	Following Haring and Heideman (OTC 3230, 1978) the first and second moments contain powers of $\omega = 2\pi f$; thus: $M_1 = \sum\sum 2\pi f dS$ where dS is a variance component and the double sum extend over 552 bins.
Second Spectral Moment	Following Haring and Heideman (OTC 3230, 1978) the first and second moments contain powers of $\omega = 2\pi f$; thus: $M_2 = \sum\sum (2\pi f)^2 dS$ where dS is a variance component and the double sum extend over 552 bins.
Dominant Direction	Following Haring and Heideman, the dominant direction ψ is the solution of the equations $A\cos 2\psi = \sum\sum \cos 2\theta\pi dS$

	$A \sin 2\psi = \sum\sum \sin 2\theta\pi dS$ The angle ψ is determined only to within 180 degrees. Haring and Heideman choose from the pair (ψ, ψ+180) the value closer to the peak direction.
Angular Spreading	The angular spreading function (Gumbel, Greenwood & Durand) is the mean value, over the 552 bins, of cos(θ - VMD), weighted by the variance component in each bin. If the angular spectrum is uniformly distributed over 360 degrees, this statistic is zero; if uniformly distributed over 180 degrees, 2/π; if all variance is concentrated at the VMD, 1. For the use of this statistic in fitting an exponential distribution to the angular spectrum, see Pearson & Hartley, Biometrika Tables for statisticians, 2:123 ff. Angular spreading (ANGSPR) is related to $\cos^n(\theta)$ spreading as follows: n = (2*ANGSPR)/(1-ANGSPR)
In-Line Variance Ratio	Directional spreading by Haring and Heideman, p 1542. Computed as: $Rat = \frac{\sum\sum \cos^2(\theta-\psi)ds}{\sum\sum dS}$ If spectral variance is uniformly distributed over the entire compass, or over a semicircle, Rat = 0.5; if variance is confined to one angular band, or to two band 180 degrees apart, Rat = 1.00 . According to Haring and Heideman, cos^2 spreading corresponds to Rat = 0.75.
Wave Partition Fields (Sea/Swell): Total Variance of "Sea" Partition Peak Spectral Period of "Sea" Partition Vector Mean Direction of "Sea" Partition Total Variance of "Swell" Partition Peak Spectral Period of "Swell" Partition Vector Mean Direction of "Swell" Partition	Explanation of sea/swell computation: The sum of the variance components of the hindcast spectrum, over the 552 bins of the wave model, in meters squared. To partition sea (primary) and swell (secondary) we compute a P-M (Pierson-Moskowitz) spectrum, with a $\cos^3$ spreading, from the adopted wind speed and direction. For each of the 552 bins, the lesser of the hindcast variance component and P-M variance component is thrown into the sea partition; the excess, if any, of hindcast over P-M is thrown into the swell partition.

4.2 Standard Statistical Analysis

This section describes the techniques and output of Oceanweather's standard statistical analysis. A full sample of each type is available in Appendix A.

4.2.1 Extremal Analysis

Return period extremes are derived using the Gumbel, Borgman, Galton and Weibull algorithms. Standard return period values are 1, 5, 10, 25, 50 and 100 years and are computed for significant wave height, maximum wind speed, and associated wave period. See Appendix A for full description of the extremes tables as well as sample output and technical description of the algorithms used.

4.2.2 Persistence/Duration Tables

Persistence/Duration are monthly duration statistics based upon the defined time period and are provided for significant wave height and mean wind speed. See Appendix A for a full description of the persistence/duration tables as well as sample output.

4.2.3 Frequency of Occurrence Tables

Frequency of occurrence table is also referred to as joint frequency tables, bivariate distributions and scatter diagram data. See Appendix A for full description of the frequency of occurrence tables as well as sample output.

Tables are provided for the following pairs of variables (monthly and annual):

1. Significant Wave Height (HS) by Peak Spectral Period (TP)
2. HS by Vector Mean Direction (VMD)
3. Wind Speed by Wind Direction

4.3 Wave Spectra

Wave spectra from the GROW hindcast were archived every 3 hours on a 10° subset of the GROW wave model grid (Figure 1). Additional points along basin perimeters were also archived for use in driving regional wave models (see http://www.oceanweather.com/metocean/grow/ for an interactive map of archived GROW grid points). The ODGP2 model has a spectral resolution of 23 frequency bins by 24 direction bins. Wave spectra are delivered as an ASCII file in Oceanweather's standard format (see Appendix A for a sample and full description).

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APPENDIX A

Sample GROW Deliverables

Sample ASCII Timeseries of Wind and Wave Parameters

G2 Gpt XXXXX, Lat XX.XX, Long XXX.XXX, Depth XXXXX
Defined Period: Operational
Date Ranges: 1/1/79 00:00 to 12/31/98 21:00

Julian	CCYYMM	DDHHmm	WD	WS	ETOT	TP	VMD	ETTSea	TPSea	VMDSea	ETTSw	TPSw	VMDSw	MO1	MO2	HS	DMDIR	ANGSPR	INLINE
			deg	m/s	m^2	sec	deg	m^2	sec	deg	m^2	sec	deg	m^2/s	m2/s2	m	deg		
28856.00000	197901	010000	120.9	8.40	0.715	13.014	43.2	0.073	5.265	310.7	0.642	13.014	49.1	0.456	0.359	3.382	49.7	0.8549	0.8575
28856.12500	197901	010300	126.2	8.16	0.702	12.824	41.4	0.070	5.271	310.9	0.632	12.824	47.0	0.453	0.361	3.351	47.3	0.8611	0.8593
28856.25000	197901	010600	131.9	7.92	0.650	12.654	40.3	0.055	5.026	316.2	0.595	12.654	44.8	0.418	0.328	3.226	44.5	0.8844	0.8716
28856.37500	197901	010900	134.1	8.23	0.604	12.417	38.0	0.056	4.948	319.7	0.548	12.417	42.9	0.399	0.323	3.109	42.2	0.8845	0.8681
28856.50000	197901	011200	136.2	8.54	0.568	11.997	35.5	0.069	5.315	321.7	0.499	11.997	42.0	0.391	0.329	3.015	41.0	0.8681	0.8516
28856.62500	197901	011500	124.9	8.08	0.507	11.732	34.5	0.062	5.090	311.6	0.445	11.732	41.5	0.359	0.312	2.848	41.2	0.8501	0.8438
28856.75000	197901	011800	112.1	7.63	0.429	11.516	34.5	0.056	4.785	299.5	0.373	11.516	42.3	0.311	0.279	2.621	43.4	0.8155	0.8331
28856.87500	197901	012100	115.2	7.66	0.362	11.238	35.4	0.053	4.792	300.3	0.308	11.238	44.3	0.269	0.249	2.405	45.9	0.7936	0.8223
28857.00000	197901	020000	118.2	7.70	0.313	10.920	35.2	0.057	4.856	301.3	0.255	10.920	46.8	0.244	0.238	2.238	49.3	0.7531	0.7990
28857.12500	197901	020300	122.1	6.07	0.258	10.717	39.1	0.041	4.720	302.4	0.216	10.717	49.1	0.199	0.192	2.030	52.1	0.7667	0.8090
28857.25000	197901	020600	128.9	4.45	0.212	10.569	43.2	0.012	3.262	306.9	0.200	10.569	46.9	0.161	0.152	1.842	54.5	0.7852	0.8247
28857.37500	197901	020900	176.1	4.39	0.181	10.439	47.5	0.010	3.310	321.0	0.171	10.439	50.8	0.134	0.123	1.700	57.1	0.8104	0.8429
28857.50000	197901	021200	224.7	4.34	0.157	10.311	54.6	0.004	3.354	348.8	0.153	10.311	55.9	0.107	0.087	1.583	58.7	0.9005	0.8781
28857.62500	197901	021500	267.7	6.27	0.149	10.190	61.6	0.010	3.860	69.8	0.139	10.190	61.1	0.103	0.088	1.543	62.0	0.9558	0.9205
28857.75000	197901	021800	288.9	8.20	0.180	10.109	70.8	0.050	4.476	93.2	0.130	10.122	63.1	0.151	0.165	1.696	69.2	0.9230	0.8701
28857.87500	197901	022100	286.8	9.37	0.251	10.058	81.1	0.135	5.891	97.8	0.115	10.197	63.3	0.235	0.269	2.002	78.1	0.8815	0.8050
28858.00000	197901	030000	285.2	10.55	0.341	10.028	86.9	0.254	6.808	96.6	0.088	10.698	61.0	0.325	0.366	2.338	84.3	0.8695	0.7822
28858.12500	197901	030300	266.6	9.90	0.349	10.002	82.1	0.250	7.225	90.7	0.099	14.202	62.3	0.327	0.361	2.365	79.7	0.8824	0.8044
28858.25000	197901	030600	245.3	9.26	0.332	13.996	76.0	0.195	6.665	81.8	0.137	13.997	68.2	0.301	0.326	2.304	74.4	0.9044	0.8383
28858.37500	197901	030900	240.4	8.34	0.330	13.798	72.2	0.139	6.043	75.7	0.191	13.798	69.7	0.292	0.310	2.299	71.1	0.9172	0.8586
28858.50000	197901	031200	234.2	7.42	0.335	13.109	69.0	0.084	5.064	66.9	0.251	13.109	69.7	0.286	0.293	2.317	68.5	0.9309	0.8781
28858.62500	197901	031500	238.6	7.65	0.354	12.712	67.1	0.099	5.517	68.0	0.255	12.712	66.8	0.296	0.297	2.381	66.8	0.9370	0.8877
28858.75000	197901	031800	242.7	7.88	0.378	12.352	65.6	0.110	5.692	67.7	0.268	12.353	64.8	0.312	0.307	2.460	65.3	0.9409	0.8939
28858.87500	197901	032100	239.5	6.96	0.403	11.677	64.2	0.074	5.052	62.9	0.330	11.677	64.5	0.328	0.316	2.541	64.0	0.9444	0.8993
28859.00000	197901	040000	235.3	6.04	0.429	11.288	62.8	0.042	4.268	58.3	0.387	11.288	63.2	0.345	0.325	2.619	62.6	0.9469	0.9031
28859.12500	197901	040300	233.7	5.98	0.453	10.918	61.5	0.040	4.250	57.0	0.412	10.918	62.0	0.362	0.337	2.691	61.4	0.9480	0.9046
28859.25000	197901	040600	232.2	5.92	0.470	10.675	60.5	0.038	4.234	55.6	0.432	10.675	60.9	0.376	0.347	2.744	60.4	0.9487	0.9055
28859.37500	197901	040900	234.6	6.83	0.481	10.512	59.7	0.064	5.227	57.2	0.417	10.512	60.0	0.386	0.356	2.774	59.6	0.9489	0.9058
28859.50000	197901	041200	236.4	7.73	0.485	10.416	59.0	0.106	5.634	58.4	0.379	10.423	59.2	0.393	0.365	2.787	59.0	0.9482	0.9047
28859.62500	197901	041500	229.8	6.28	0.480	10.369	58.4	0.048	4.605	54.8	0.433	10.369	58.8	0.389	0.360	2.773	58.5	0.9490	0.9061
28859.75000	197901	041800	219.1	4.83	0.470	10.341	57.9	0.016	3.420	46.5	0.455	10.341	58.3	0.381	0.350	2.743	58.0	0.9501	0.9076
28859.87500	197901	042100	238.8	5.37	0.458	10.304	57.5	0.024	3.915	55.6	0.434	10.304	57.6	0.372	0.341	2.707	57.6	0.9509	0.9089
28860.00000	197901	050000	254.8	5.91	0.444	10.125	57.3	0.032	4.210	63.3	0.411	10.125	56.9	0.361	0.333	2.665	57.4	0.9510	0.9091
28860.12500	197901	050300	258.2	6.05	0.429	9.944	57.0	0.038	4.528	63.2	0.391	9.944	56.4	0.351	0.324	2.620	57.0	0.9511	0.9093
28860.25000	197901	050600	261.5	6.19	0.413	9.818	56.6	0.038	4.544	65.0	0.376	9.818	55.8	0.338	0.313	2.572	56.6	0.9512	0.9096
28860.37500	197901	050900	254.9	7.27	0.403	9.764	56.3	0.078	5.516	63.1	0.326	9.772	54.8	0.332	0.313	2.540	56.2	0.9496	0.9073
28860.50000	197901	051200	250.1	8.36	0.401	9.794	56.1	0.128	6.184	61.6	0.273	9.948	53.6	0.335	0.324	2.533	55.8	0.9454	0.9011
28860.62500	197901	051500	255.0	7.99	0.397	9.926	55.5	0.103	6.117	64.1	0.294	9.981	52.6	0.329	0.319	2.521	55.1	0.9440	0.8993
28860.75000	197901	051800	260.4	7.62	0.396	10.155	54.7	0.086	5.590	65.6	0.310	10.164	51.9	0.323	0.309	2.517	54.3	0.9445	0.9003

Extremal Analysis Description and Sample Output

The distributional assumptions used computing return periods are:

1. Gumbel distribution of extremes:

$$Pr\ \{\ H\ \leq\ h\ \} = \exp\left[\ -\exp\left(\frac{a_1\ -\ h}{b_1}\right)\right]$$

2. Borgman distributions of extremes, i.e., Gumbel distribution of squared extremes:

$$Pr\{\ H\ \leq\ h\ \} = \exp\left[\ -\exp\left(\frac{a_2\ -\ h^2}{b_2}\right)\ \right]$$

3. Galton distribution of height, i.e. normal distribution of log heights:

$$Pr\ \{\ H\ \leq\ h\ \} = \frac{1}{\sqrt{2\pi}}\int_{\infty}^{x}\exp\left(-\frac{t^2}{2}\right)dt$$, where $$x = \frac{\log h - a_3}{b_3}$$

4. Weibull distribution (described in next section)

The fitting procedure of Gumbel (1958, pp. 34 - 36) was followed for Gumbel, Borgman and Galton, with plotting positions based in i/(n+1), often called Weibull plotting position. Specifically, let

$$y_i = -\log_e\left[-\log_e\ \left(\frac{i}{n\ +\ 1}\right)\right],$$

and define z_i as the root of the equation

$$\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{z}\exp\ \left(\frac{-1}{2t^2}\right)\ dt = \frac{1}{n+1}.$$

Then the constants *a* and *b* are determined from

$$b_1 = \sqrt{\frac{Var(h)}{Var(\ y_i\ )}}, a_1 = Av(h)\ -\ b_1\,Av(\ y_i\ )$$

$$b_2 = \sqrt{\frac{Var(\ h^2\ )}{Var(\ y_i\ )}}, a_2 = Av(\ h^2\ )\ -\ b_2\,Av(\ y_i\ )$$

$$b_3 = \sqrt{\frac{Var\ \ (\log_e h)}{Var\ \ (\ z_i\ )}}, a_3 = Av(\ \log_e h)$$

where *Av* and *Var* denote the average and the variance of the operand. The extrapolations corresponding to a return period of *T* years are based upon n storms as a complete enumeration of the relevant storm events in *Y* years.

The cumulative distribution function corresponding to return period *T* is

$$P_T = 1\ -\ \frac{Y}{nT}.$$

Define z_T as the root of

$$\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{z}\ \exp(\frac{-1}{2t^2})dt = P_T.$$

Then the height with return period *T* is computed as

$$h_{T1} = a_1 - b_1 \log_e(-\log_e P_T);$$

$$h_{T2} = \sqrt{a_2 - b_2 \log_e(-\log_e P_T)};$$

$$h_{T3} = \exp(a_3 + b_3 z_T).$$

The 90% confidence limits shown on the individual predicted extreme values were computed according to the method of Dick and Darwin (1954) (see also Gumbel, 1958, p. 218). In 90% of extrapolations, the true values of the return period extremes will be between the limits indicated.

The Weibull distribution is a generalization of the exponential distribution, most expediently defined in terms of the exceedance probability:

$$Q = \Pr\{X \geq x\} = \exp[-y^{\alpha}]$$, where $y = (x - \mu)/\sigma$;

X is the variable to be distributed (for example, wave height);
α is the shape parameter:
for $\alpha = 1$, the distribution is exponential
for $\alpha < 1$, the distribution is long-tailed
for $\alpha > 1$, the distribution is short-tailed
μ is the lower limit of the distribution; $\Pr\{X < \mu\} = 0$;
σ is a scale parameter such that $\Pr\{X \geq \mu + \sigma\} = 1/e$
The parameter α is a pure number; μ and σ have the same units as X; whence it follows that *y* is dimensionless. For some purposes, the probability density, -dQ/dx, is more convenient than Q:

$$-\frac{dQ}{dx} = \frac{Q\alpha}{\sigma} y^{\alpha-1}$$

The fitting method adopted is to take an arbitrary value for μ, and then fit σ and α by the method of maximum likelihood. The value assumed for μ is
$\mathrm{M} = 0.5(H_1 + 0.98H_2)$, where
M is the assumed μ, used in the subsequent computation;
H_1 is a value, often taken as a percentage of the largest X reported, such that X-values less than H_1 are excluded from extremal analysis.
H_2 is the smallest X used in the extremal analysis. Thus $H_2 \geq H_1$.
The method of maximum likelihood finds $\hat{\alpha}, \hat{\beta}$, such that
$\frac{d}{d\alpha}\left[\log \frac{dP}{dx}\right] = 0$ and $\frac{d}{d\beta} = \left[\log \frac{dP}{dx}\right] = 0$ when evaluated at the point ($\hat{\alpha}, \hat{\beta}$);
then the adopted is given by $\sigma = \hat{\beta}^{-1/\hat{\alpha}}$.
Printed and plotted extremes are based on the observation that if X is Weibull distributed, then $Z = -\log_e[X - \mathrm{M}]$ is Gumbel distributed; specifically,

$$Q = \Pr\{Z \leq z\} = \exp\left[-\exp\left(\frac{z - A}{B}\right)\right], A = \sigma, B = \frac{1}{\alpha}.$$

The ordinate and abscissa of a Weibull exceedance plot are respectively log X and log(log Q).

Maximum Individual Wave Height and Crest Height

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.

Maximum Individual Wave Height (Forristall, 1978):

$$Pr\ \{H\ > h\} = \exp \left[-1.08311 \left(\frac{h^2}{8 M_0} \right)^{1.063} \right]$$

$T = M_0/M_1$

Maximum Crest Height (Haring and Heideman, 1978):

$$\Pr\{H\ >\ h\}\ =\ \exp\left[\left(-\frac{h^2}{2M_0} \right) \left(1 - 2.4909\, \frac{h}{d} + 4.37\, \frac{h^2}{d^2} \right) \right]$$

where *h* is elevation and *d* is water depth

$T = .74\ TP$

TP is the reciprocal of fpeak, found by solving $\frac{\partial^2 S}{\partial f^2} = 0$ by inverse interpolation

The median of the resulting distribution was taken as the maximum expected single peak in the storm.

References:

Borgman, L. E. 1973. Probabilities for the highest wave in a hurricane. J. Waterways, Harbors and Coastal Engineering Div., ASCE, 185 - 207.

Forristall, G. Z. 1978. On the statistical distribution of wave heights in a storm. J. Of Geophys. Res., 83, 2353 - 2358.

Haring R.E. and J.C. Heideman, 1978. Gulf of Mexico Rare Wave Return Periods. OTC 3230, 10th Annual Offshore Technology Conference, Houston, TX May 8-11 1978.

Sample Extremes Distributions:

```
G2 Gpt XXXXX, Lat XX.XX, Long XXX.XXX, Depth XXXXX
Defined Period: Operational
Date Ranges: 1/1/79 00:00 to 12/31/98 21:00

"lcl" = lower confidence limit
"ucl" = upper confidence limit

G2 GPT XXXXX: Wind Speed (m/s)
Top 50 storms
21.64,21.09,20.96,20.40,20.05,19.93,19.93,19.82,19.80,19.68,19.68,19.59,19.22,19.18,
19.02,18.99,18.89,18.68,18.62,18.59,18.42,18.39,18.34,18.25,18.24,18.11,18.05,18.02,
18.02,17.87,17.81,17.77,17.71,17.71,17.59,17.56,17.56,17.47,17.47,17.45,17.42,17.40,
17.39,17.32,17.28,17.25,17.24, 17.22, 17.22, 17.21,

Gumbel Parameters: Location 17.94798, Scale 0.9888408
Borgman Parameters: Location 17.94798, Scale 0.9888408
Weibull Parameters: Location 16.8658, Scale 1.806105, Shape 1.478992

Period   Prob.  Gumbel   lcl    ucl Borgman   lcl    ucl Weibull   lcl    ucl Galton
     1. 0.4000  18.61  18.27  18.96  18.65  18.29  19.00  18.57  18.23  18.99  18.76
     5. 0.0800  20.40  19.65  21.15  20.39  19.68  21.08  20.24  19.12  21.92  20.22
    10. 0.0400  21.11  20.19  22.03  21.04  20.20  21.86  20.85  19.39  23.15  20.68
    25. 0.0160  22.03  20.89  23.17  21.86  20.84  22.82  21.58  19.69  24.73  21.22
    50. 0.0080  22.72  21.41  24.02  22.45  21.32  23.52  22.10  19.90  25.91  21.58
   100. 0.0040  23.41  21.94  24.88  23.02  21.78  24.20  22.60  20.08  27.08  21.93

G2 GPT XXXXX: Significant Wave Height (m)
Top 50 storms
10.04, 9.03, 9.00, 8.97, 8.76, 8.60, 8.49, 8.47, 8.47, 8.37, 8.25, 8.22, 8.00, 7.96,
 7.92, 7.87, 7.80, 7.73, 7.71, 7.68, 7.67, 7.64, 7.63, 7.59, 7.56, 7.51, 7.50, 7.44,
 7.40, 7.36, 7.33, 7.33, 7.30, 7.28, 7.27, 7.23, 7.21, 7.16, 7.14, 7.11, 7.10, 7.09,
 7.08, 7.08, 7.05, 7.02, 6.93, 6.91, 6.89, 6.88,

Gumbel Parameters: Location 7.378988, Scale 0.5861943
Borgman Parameters: Location 7.378988, Scale 0.5861943
Weibull Parameters: Location 6.7375, Scale 1.072152, Shape 1.496398

Period   Prob.  Gumbel   lcl    ucl Borgman   lcl    ucl Weibull   lcl    ucl Galton
     1. 0.4000   7.77   7.57   7.98   7.81   7.59   8.02   7.75   7.55   8.00   7.85
     5. 0.0800   8.84   8.39   9.28   8.84   8.42   9.24   8.73   8.07   9.72   8.72
    10. 0.0400   9.25   8.71   9.80   9.22   8.73   9.69   9.08   8.22  10.43   8.99
    25. 0.0160   9.80   9.12  10.47   9.69   9.10  10.24   9.51   8.40  11.36   9.32
    50. 0.0080  10.21   9.43  10.98  10.02   9.38  10.63   9.81   8.51  12.04   9.55
   100. 0.0040  10.61   9.74  11.49  10.35   9.64  11.01  10.10   8.62  12.72   9.76

Associated Peak Period - Based on Regression Analysis with HSig (TP=Co*HS**C1)
Period          Gumbel                Borgman               Weibull                Galton
     1.          15.64                 15.65                 15.64                 15.66
     5.          15.89                 15.89                 15.86                 15.86
    10.          15.97                 15.97                 15.94                 15.92
    25.          16.09                 16.06                 16.03                 15.99
    50.          16.17                 16.13                 16.09                 16.04
   100.          16.24                 16.19                 16.14                 16.08
```

From the extremes, the best performing distribution is selected and provided as a table including wind speed and significant wave height, as well as the maximum individual and crest heights and peak period associated with significant wave height.

Persistence/Duration Tables Description and Sample Output

Table entries are:

HOURS is the total number of hours above or below the indicated level;

MEAN is the mean of the wave height (or whatever field) in the category;

S.D is the standard deviation of the wave height (or whatever field) in the category;

MAXIMUM DURATION in hours of the longest run above or below the indicated level; since the statistics are stratified by month, this can never exceed the number of hours in the month;

COUNT is the number of events in the category;

The MEDIAN DURATION is the median of the fitted Johnson curve; not the median of the observed durations. It is computed as the value y for which

$$N \times \log\left(\frac{y-a}{b-y}\right) = \sum \log\left(\frac{x-a}{b-x}\right)$$

PERCENTAGE POINTS

DURATIONS in hours corresponding to the indicated cumulative percentage levels (10% to 90%) are calculated from the Johnson fit to the durations of exceedances and non-exceedances. The log normal distribution, used in exceedance tables in previous studies is unsuitable for series where many runs have duration half a month or more. We have now adopted a modified logarithmic transformation introduced by N. L. Johnson (Biometrika, 1949). Johnson posits that the quantity

$$\log\left(\frac{x-a}{b-x}\right)$$

is normally distributed, where a & b are the lower & upper limits of the measurements. Here we take a = 0 and take b as (one month plus 1/2 hour).

For example, the table below for January is based upon continuous hindcasts of a nine year period. We have the following table entries for durations of events which continuously exceeded 5 meters in significant wave height (SWH):

1173. is the number of hours in nine years for which SWH exceeded 5.00 meters;
6.35 is the mean SWH and 1.28 is the standard deviation about the mean of the SWH over those 1173 hours;
69. is the maximum observed duration in hours of SWH continuously exceeding 5 meters;
54. is the number of events in which SWH continosly exceeded 5 meters;
18.1 is the median duration of events in which SWH continosly exceeded 5 meters based on the fitted Johnson curve, not the median of the observed durations;

10% of the events had durations less than **7.8** hours;
50% of the events had durations less than **18.1** hours;
90% of the events had durations less than **41.4** hours.

Persistence-Duration for Significant Wave Height (m)

Gpt XXXXX, Lat XX.XXXXn, Long XX.XXXXe, Depth XXX.XXXXm
Defined Period: Continuous Years
Date Ranges: 1/1/90 00:00 to 12/31/98 21:00

EXCEEDANCES FOR GRID POINT XXXXX, JANUARY

HS .GE.	HOURS	HS MEAN	S.D.	MAXIMUM DURATION	COUNT	MEDIAN DURATION	PERCENTAGE POINTS OF JOHNSON DISTRIBUTION 10%	20%	30%	40%	50%	60%	70%	80%	90%
1.00	6651.	3.58	1.67	744.	13.	709.6	47.1	241.2	493.7	646.3	709.6	732.8	741.0	743.6	744.4
2.00	5580.	3.95	1.55	642.	42.	76.2	9.9	20.3	33.8	51.8	76.2	110.3	159.8	235.9	365.8
3.00	3777.	4.64	1.43	231.	82.	29.9	7.9	12.5	17.4	23.1	29.9	38.6	50.6	69.0	104.3
4.00	2244.	5.45	1.34	93.	71.	23.2	7.4	11.0	14.6	18.5	23.2	29.0	36.6	48.1	69.5
5.00	**1173.**	**6.35**	**1.28**	**69.**	**54.**	**18.1**	**7.8**	**10.4**	**12.9**	**15.4**	**18.1**	**21.4**	**25.5**	**31.3**	**41.4**
6.00	576.	7.32	1.19	54.	34.	13.7	5.4	7.4	9.4	11.4	13.7	16.4	19.9	25.0	34.0
7.00	276.	8.31	1.00	30.	21.	11.1	4.9	6.5	8.0	9.5	11.1	13.1	15.5	18.9	24.9
8.00	126.	9.19	0.79	18.	12.	8.8	3.6	4.9	6.1	7.4	8.8	10.5	12.6	15.7	21.2
9.00	60.	9.86	0.60	15.	7.	7.8	4.1	5.1	6.0	6.9	7.8	8.9	10.1	11.9	14.8
10.00	21.	10.56	0.41	9.	4.	4.7									
11.00	3.	11.25	0.00	3.	1.	3.0									

NON-EXCEEDANCES FOR GRID POINT XXXXX, JANUARY

HS .LT.	HOURS	HS MEAN	S.D.	MAXIMUM DURATION	COUNT	MEDIAN DURATION	PERCENTAGE POINTS OF JOHNSON DISTRIBUTION 10%	20%	30%	40%	50%	60%	70%	80%	90%
1.00	45.	0.96	0.02	15.	4.	11.0									
2.00	1116.	1.58	0.28	153.	39.	19.8	6.5	9.5	12.6	15.9	19.8	24.5	30.9	40.3	57.8
3.00	2919.	2.16	0.54	255.	84.	21.3	5.5	8.8	12.3	16.3	21.3	27.7	36.5	50.3	77.4
4.00	4452.	2.61	0.78	288.	75.	33.9	7.1	12.2	18.0	25.0	33.9	45.7	62.6	89.5	142.6
5.00	5523.	2.97	1.02	726.	60.	52.1	7.6	14.9	24.1	36.0	52.1	74.6	107.8	161.4	263.1
6.00	6120.	3.20	1.21	744.	41.	104.3	7.4	19.0	36.9	63.9	104.3	164.1	251.5	375.4	540.4
7.00	6420.	3.35	1.37	744.	28.	209.0	11.5	33.6	70.6	127.5	209.0	315.7	441.0	568.0	674.9
8.00	6570.	3.45	1.49	744.	20.	412.4	6.9	35.4	106.9	238.7	412.4	570.0	671.5	721.1	740.0
9.00	6636.	3.50	1.57	744.	16.	610.1	8.4	60.9	209.6	432.9	610.1	697.4	730.6	741.3	744.1
10.00	6675.	3.54	1.63	744.	13.	697.1	24.4	159.6	410.1	607.4	697.1	729.6	740.3	743.6	744.4
11.00	6693.	3.56	1.67	744.	10.	742.2	478.0	680.4	725.6	738.1	742.2	743.7	744.2	744.4	744.5
12.00	6696.	3.56	1.67	744.	9.	744.0									

Persistence-Duration Sample Output:

Persistence-Duration for Significant Wave Height (m) [HS]

G2 Gpt XXXXX, Lat XX.XXXX, Long XXX.XXXX, Depth XXXXX
Defined Period: Operational
Date Ranges: 1/1/79 00:00 to 12/31/98 21:00

EXCEEDANCES FOR GRID POINT XXXXX, JANUARY

HS		HS		MAXIMUM		MEDIAN	PERCENTAGE POINTS OF JOHNSON DISTRIBUTION								
.GE.	HOURS	MEAN	S.D.	DURATION	COUNT	DURATION	10%	20%	30%	40%	50%	60%	70%	80%	90%
0.50	13197.	1.44	0.77	684.	103.	86.1	16.5	29.5	44.6	63.0	86.1	116.2	157.3	217.8	320.3
1.00	8466.	1.82	0.71	243.	175.	37.0	12.6	18.3	23.9	30.0	37.0	45.6	56.8	73.1	102.5
1.50	4845.	2.25	0.64	156.	146.	24.5	8.2	12.0	15.7	19.8	24.5	30.4	38.1	49.4	70.4
2.00	2583.	2.72	0.55	78.	101.	19.2	6.3	9.3	12.2	15.5	19.2	23.9	30.1	39.4	56.7
2.50	1512.	3.06	0.45	48.	75.	16.0	5.9	8.4	10.7	13.2	16.0	19.5	23.9	30.4	42.3
3.00	690.	3.45	0.39	39.	46.	12.2	4.9	6.7	8.4	10.2	12.2	14.5	17.5	21.9	29.6
3.50	234.	3.89	0.35	27.	18.	10.8	4.5	6.1	7.6	9.1	10.8	12.8	15.4	19.1	25.5
4.00	63.	4.36	0.32	21.	7.	7.1	2.7	3.8	4.8	5.9	7.1	8.6	10.5	13.3	18.4
4.50	18.	4.78	0.20	15.	2.	6.7									
5.00	3.	5.11	0.00	3.	1.	3.0									

NON-EXCEEDANCES FOR GRID POINT XXXXX, JANUARY

HS		HS		MAXIMUM		MEDIAN	PERCENTAGE POINTS OF JOHNSON DISTRIBUTION								
.LT.	HOURS	MEAN	S.D.	DURATION	COUNT	DURATION	10%	20%	30%	40%	50%	60%	70%	80%	90%
0.50	1683.	0.36	0.10	87.	87.	13.6	4.4	6.5	8.6	10.9	13.6	17.0	21.6	28.5	41.5
1.00	6414.	0.65	0.22	222.	171.	25.9	7.4	11.4	15.6	20.3	25.9	33.0	42.6	57.2	85.1
1.50	10035.	0.86	0.34	342.	150.	48.8	14.3	21.9	29.7	38.5	48.8	61.6	78.7	103.8	149.4
2.00	12297.	1.02	0.46	579.	114.	72.1	14.6	25.6	38.1	53.2	72.1	96.8	130.8	181.8	271.8
2.50	13368.	1.12	0.55	738.	92.	105.3	18.6	34.5	53.2	76.2	105.3	143.1	194.1	266.8	382.7
3.00	14190.	1.21	0.66	744.	66.	206.1	17.6	43.7	81.9	135.1	206.1	296.3	403.9	522.2	639.1
3.50	14646.	1.27	0.73	744.	38.	570.1	23.2	101.0	245.8	422.3	570.1	663.2	711.7	733.7	742.3
4.00	14817.	1.30	0.78	744.	27.	728.6	147.6	444.9	628.3	701.5	728.6	738.8	742.6	744.0	744.4
4.50	14862.	1.31	0.79	744.	22.	743.0	682.6	726.5	737.3	741.3	743.0	743.8	744.2	744.4	744.5
5.00	14877.	1.31	0.80	744.	21.	743.5									
5.50	14880.	1.32	0.80	744.	20.	744.0									

EXCEEDANCES FOR GRID POINT XXXXX, FEBRUARY
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NON-EXCEEDANCES FOR GRID POINT XXXXX, FEBRUARY
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EXCEEDANCES FOR GRID POINT XXXXX, MARCH
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NON-EXCEEDANCES FOR GRID POINT XXXXX, MARCH
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EXCEEDANCES FOR GRID POINT XXXXX, OCTOBER
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EXCEEDANCES FOR GRID POINT XXXXX, NOVEMBER
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NON-EXCEEDANCES FOR GRID POINT XXXXX, NOVEMBER
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EXCEEDANCES FOR GRID POINT XXXXX, DECEMBER
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NON-EXCEEDANCES FOR GRID POINT XXXXX, DECEMBER
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Persistence-Duration for Wind Speed (m/s) [WS]

G2 Gpt XXXXX, Lat XX.XXXX, Long XXX.XXXX, Depth XXXXX
Defined Period: Operational
Date Ranges: 1/1/79 00:00 to 12/31/98 21:00

EXCEEDANCES FOR GRID POINT XXXXX, JANUARY

WS .GE.	HOURS	WS MEAN	S.D.	MAXIMUM DURATION	COUNT	MEDIAN DURATION	PERCENTAGE POINTS OF JOHNSON DISTRIBUTION 10%	20%	30%	40%	50%	60%	70%	80%	90%
1.00	14880.	7.31	2.88	744.	20.	744.0									
2.00	14781.	7.35	2.85	744.	43.	408.1	15.6	58.8	140.6	263.1	408.1	542.9	642.8	703.5	733.8
3.00	14166.	7.55	2.73	567.	119.	78.9	16.0	28.1	41.9	58.3	78.9	105.7	142.2	196.4	290.1
4.00	13023.	7.91	2.55	369.	166.	51.6	11.7	19.7	28.4	38.8	51.6	68.3	91.3	126.4	191.7
5.00	11535.	8.34	2.39	252.	218.	34.5	8.3	13.6	19.4	26.2	34.5	45.4	60.5	83.9	129.1
6.00	9591.	8.92	2.20	195.	243.	25.1	6.0	9.9	14.1	19.0	25.1	33.1	44.3	61.9	96.7
7.00	7482.	9.61	2.01	192.	227.	22.6	6.4	9.9	13.5	17.6	22.6	28.8	37.4	50.5	75.6
8.00	5709.	10.27	1.85	114.	210.	18.9	5.6	8.5	11.5	14.9	18.9	24.0	30.9	41.4	61.6
9.00	3948.	11.07	1.69	93.	176.	15.8	4.8	7.3	9.7	12.5	15.8	19.9	25.4	33.7	49.7
10.00	2589.	11.91	1.51	75.	143.	12.6	3.8	5.8	7.7	10.0	12.6	15.9	20.4	27.3	40.6
11.00	1683.	12.68	1.31	45.	96.	13.7	4.9	7.0	9.0	11.2	13.7	16.7	20.6	26.4	37.0
12.00	1056.	13.40	1.14	42.	79.	10.4	4.0	5.5	7.0	8.6	10.4	12.6	15.4	19.6	27.1
13.00	576.	14.17	1.01	36.	54.	8.5	3.4	4.7	5.8	7.1	8.5	10.1	12.2	15.3	20.7
14.00	258.	15.06	0.86	24.	33.	5.9	2.3	3.2	4.0	4.9	5.9	7.1	8.7	11.1	15.3
15.00	99.	15.98	0.65	18.	12.	6.5	2.5	3.5	4.4	5.4	6.5	7.9	9.6	12.1	16.8
16.00	45.	16.56	0.45	15.	6.	6.4									
17.00	6.	17.49	0.47	3.	2.	3.0									

NON-EXCEEDANCES FOR GRID POINT XXXXX, JANUARY

WS .LT.	HOURS	WS MEAN	S.D.	MAXIMUM DURATION	COUNT	MEDIAN DURATION	PERCENTAGE POINTS OF JOHNSON DISTRIBUTION 10%	20%	30%	40%	50%	60%	70%	80%	90%
2.00	99.	1.72	0.21	9.	23.	3.9	2.3	2.7	3.1	3.5	3.9	4.4	4.9	5.6	6.7
3.00	714.	2.46	0.40	33.	100.	5.6	2.3	3.2	3.9	4.7	5.6	6.7	8.0	9.9	13.3
4.00	1857.	3.11	0.61	51.	150.	9.4	3.5	4.9	6.3	7.8	9.4	11.5	14.1	18.0	25.1
5.00	3345.	3.74	0.87	72.	204.	11.6	3.7	5.5	7.3	9.3	11.6	14.5	18.3	24.1	35.1
6.00	5289.	4.39	1.10	90.	230.	16.4	5.2	7.8	10.3	13.1	16.4	20.6	26.1	34.4	50.1
7.00	7398.	4.98	1.34	150.	224.	22.9	6.5	10.0	13.7	17.9	22.9	29.3	38.0	51.3	76.9
8.00	9171.	5.46	1.56	213.	210.	28.4	7.0	11.4	16.1	21.6	28.4	37.2	49.3	68.2	105.1
9.00	10932.	5.95	1.81	285.	184.	37.3	8.2	13.9	20.2	27.8	37.3	49.9	67.5	95.2	149.0
10.00	12291.	6.34	2.03	576.	156.	49.4	10.1	17.6	26.1	36.4	49.4	66.6	90.8	128.4	199.4
11.00	13197.	6.62	2.23	576.	111.	78.5	15.4	27.3	41.0	57.6	78.5	105.8	143.2	198.9	295.4
12.00	13824.	6.84	2.40	735.	96.	101.1	17.4	32.5	50.4	72.7	101.1	138.2	188.7	261.4	378.3
13.00	14304.	7.03	2.57	738.	72.	154.1	24.4	47.6	75.7	110.5	154.1	209.1	279.5	371.5	496.8
14.00	14622.	7.17	2.71	744.	52.	316.1	21.5	61.3	123.3	209.4	316.1	433.2	545.6	639.2	705.9
15.00	14781.	7.25	2.80	744.	32.	686.3	36.5	186.0	417.5	596.4	686.3	723.5	737.7	742.7	744.2
16.00	14835.	7.28	2.83	744.	26.	735.0	179.4	503.9	663.2	717.0	735.0	741.3	743.5	744.2	744.5
17.00	14874.	7.30	2.87	744.	22.	743.0	685.1	727.0	737.5	741.3	743.0	743.8	744.2	744.4	744.5
18.00	14880.	7.31	2.88	744.	20.	744.0									

EXCEEDANCES FOR GRID POINT XXXXX, FEBRUARY
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NON-EXCEEDANCES FOR GRID POINT XXXXX, FEBRUARY
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EXCEEDANCES FOR GRID POINT XXXXX, MARCH
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NON-EXCEEDANCES FOR GRID POINT XXXXX, JUNE
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EXCEEDANCES FOR GRID POINT XXXXX, JULY
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EXCEEDANCES FOR GRID POINT XXXXX, AUGUST
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EXCEEDANCES FOR GRID POINT XXXXX, SEPTEMBER
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NON-EXCEEDANCES FOR GRID POINT XXXXX, SEPTEMBER
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EXCEEDANCES FOR GRID POINT XXXXX, NOVEMBER
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NON-EXCEEDANCES FOR GRID POINT XXXXX, NOVEMBER
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EXCEEDANCES FOR GRID POINT XXXXX, DECEMBER
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NON-EXCEEDANCES FOR GRID POINT XXXXX, DECEMBER
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Frequency of Occurrence Tables Description and Sample Output

There are 39 tables provided in total grouped into three files of 13 tables each. Thirteen refers to the time categories considered: 12 months and all years combined. Within each time category there is 1 Significant Wave Height (HS) by Peak Period (TP) table, 1 HS by Vector Mean Direction (VMD) table and 1 WS by WD table. VMD is defined as the angle towards which waves propagate. The angle is measured positive clockwise from north.

The first 13 tables give the array of frequencies of occurrence with TP horizontally and HS vertically aligned. There may be 15 or more HS rows and 20 or more TP columns. The TP column headers may range from 0 sec to 24.9999 sec in steps of 1 sec. The HS row labels may range from 0 m to 15.000 m in steps of 0.50 m. Smaller or wider bins may be requested if needed.

The next 13 tables have Vector Mean Direction (VMD) horizontally and HS vertically. There are 16 VMD columns each representing 22.5 degrees of a compass. There are 20 or more HS rows. The HS rows are binned typically the same way as for the HS by TP tables.

The last 13 tables have Wind Direction (WD) horizontally and Wind Speed (WS) vertically. There are 16 WD columns each representing 22.5 degrees of a compass. There are 8 or more WS rows. The WS row is typically binned in steps of 2.0 m/s.

For every table there are 10 header lines (the first one is blank) and 1 footer line per table. Within the header lines there are 4 lines of statistics. These include the minimum and maximum value for each variable, mean, standard deviation, median, and 90th and 99th percentile exceedances. The tenth line contains the column headers. Here is a sample header:

```
Number of Observations for January          :    7688 from     7688
Directional Sector: ALL DIRECTIONS
Statistics for var:      Min       Max      Mean    Std Dev.   Median      90%       99%
--------------------  --------  --------  --------  --------  --------  --------  --------
TPeak (sec) - total     3.6150   24.0000   12.2046    2.7412   11.9060   15.7696   19.6533
Sig Wave Ht (m)         0.4480   11.6270    4.2012    1.6013    4.1585    6.2736    8.4967
Frequency of Occurrence for January  :
Grid Point          , Lat         , Long         , Sig. Wave Ht. (m)
```

The footer is:

```
Data range =  0.50 and is centered on column headers
```

The divisor for each table is the second number in the first header line (in this particular case it is 7688). In each table the bin probabilities sum to 1. The 7688 is the total number of values in 31 Januarys from 1970-2000. (Values get dropped if both the period and wave height are zero, which is the case if the location is iced out.)

Frequency of Occurrence Sample Output:

G2 Gpt XXXXX, Lat XX.XXX, Long XXX.XXX, Depth XXXXX
Defined Period: Operational
Date Ranges: 1/1/1970 00:00 to 12/31/2000 21:00

Horizontal variable: Peak Spectral Period of Total Spectrum (sec)
Vertical variable: Significant Wave Height (m)
Directional variable: All Directions
Number of Observations for January : 7688 from 7688
Directional Sector (): All Directions

Statistics for var:	Min	Max	Mean	Std Dev.	Median	90%	99%
TPeak (sec) - total	3.6150	24.0000	12.2046	2.7412	11.9060	15.7696	19.6533
Sig Wave Ht (m)	0.4480	11.6270	4.2012	1.6013	4.1585	6.2736	8.4967

Frequency of Occurrence for January:
Grid Point XXXXX , Lat XXX.XXXX, Long XXX.XXXX, TPeak (sec) - total

Sig Wave Ht (m)	0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50	24.50	Total
0.000 - 0.4999	.0000	.0000	.0000	.0000	.0000	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0003
0.500 - 0.9999	.0000	.0000	.0000	.0001	.0003	.0008	.0010	.0000	.0000	.0004	.0000	.0003	.0007	.0016	.0008	.0009	.0008	.0005	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0081
1.000 - 1.4999	.0000	.0000	.0000	.0000	.0004	.0029	.0010	.0018	.0013	.0018	.0007	.0003	.0023	.0029	.0017	.0029	.0008	.0014	.0004	.0004	.0000	.0001	.0000	.0000	.0000	.0230
1.500 - 1.9999	.0000	.0000	.0000	.0000	.0000	.0009	.0044	.0066	.0023	.0033	.0023	.0034	.0044	.0061	.0072	.0036	.0017	.0007	.0007	.0007	.0001	.0000	.0000	.0000	.0000	.0484
2.000 - 2.4999	.0000	.0000	.0000	.0000	.0000	.0001	.0039	.0108	.0087	.0055	.0077	.0065	.0039	.0066	.0073	.0061	.0025	.0026	.0012	.0003	.0003	.0001	.0000	.0000	.0000	.0740
2.500 - 2.9999	.0000	.0000	.0000	.0000	.0000	.0000	.0008	.0114	.0150	.0095	.0100	.0095	.0079	.0069	.0052	.0049	.0030	.0033	.0005	.0004	.0005	.0004	.0000	.0000	.0000	.0892
3.000 - 3.4999	.0000	.0000	.0000	.0000	.0000	.0000	.0003	.0018	.0174	.0178	.0164	.0118	.0079	.0075	.0059	.0046	.0030	.0031	.0010	.0012	.0013	.0003	.0001	.0000	.0000	.1015
3.500 - 3.9999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0004	.0061	.0230	.0250	.0170	.0143	.0101	.0065	.0039	.0025	.0018	.0004	.0004	.0007	.0003	.0001	.0000	.0000	.1125
4.000 - 4.4999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0021	.0215	.0395	.0243	.0191	.0096	.0070	.0069	.0018	.0008	.0010	.0009	.0003	.0003	.0000	.0001	.0000	.1353
4.500 - 4.9999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0005	.0068	.0325	.0268	.0176	.0111	.0079	.0047	.0020	.0025	.0016	.0004	.0004	.0000	.0001	.0003	.0001	.1151
5.000 - 5.4999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0018	.0182	.0274	.0173	.0108	.0062	.0031	.0017	.0012	.0010	.0001	.0003	.0004	.0005	.0000	.0000	.0901
5.500 - 5.9999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0003	.0059	.0156	.0186	.0107	.0065	.0053	.0033	.0023	.0012	.0007	.0007	.0000	.0000	.0000	.0000	.0709
6.000 - 6.4999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0036	.0083	.0143	.0099	.0066	.0044	.0027	.0039	.0021	.0010	.0001	.0001	.0001	.0000	.0000	.0574
6.500 - 6.9999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0014	.0042	.0078	.0051	.0051	.0030	.0012	.0009	.0004	.0004	.0001	.0000	.0000	.0000	.0000	.0295
7.000 - 7.4999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0009	.0034	.0056	.0027	.0016	.0007	.0007	.0005	.0004	.0000	.0000	.0000	.0000	.0000	.0165
7.500 - 7.9999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0008	.0017	.0034	.0033	.0014	.0009	.0003	.0003	.0003	.0000	.0000	.0000	.0000	.0000	.0122
8.000 - 8.4999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0004	.0005	.0022	.0016	.0004	.0004	.0001	.0001	.0000	.0001	.0000	.0000	.0000	.0060
8.500 - 8.9999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0018	.0004	.0007	.0004	.0004	.0003	.0000	.0000	.0000	.0000	.0000	.0039
9.000 - 9.4999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0005	.0012	.0005	.0004	.0004	.0004	.0000	.0000	.0000	.0000	.0000	.0034
9.500 - 9.9999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0007	.0001	.0003	.0003	.0001	.0000	.0000	.0000	.0000	.0000	.0014
10.000 - 10.4999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0005	.0001	.0000	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0008
10.500 - 10.9999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001
11.000 - 11.4999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0003	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0003
11.500 - 11.9999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001
12.000 - 12.4999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
12.500 - 12.9999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
13.000 - 13.4999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
13.500 - 13.9999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
Total	.0000	.0000	.0000	.0001	.0007	.0048	.0114	.0329	.0535	.0916	.1634	.1573	.1416	.1084	.0845	.0617	.0303	.0277	.0135	.0083	.0047	.0021	.0010	.0004	.0001	1.000

TPeak (sec) - total Bins are 1.00 wide, and are centered on column headers

Number of Observations for February : 7008 from 7008
[Data Deleted]
Number of Observations for March : 7688 from 7688
[Data Deleted]
Number of Observations for April : 7440 from 7440
[Data Deleted]
Number of Observations for May : 7688 from 7688
[Data Deleted]
Number of Observations for June : 7440 from 7440
[Data Deleted]
Number of Observations for July : 7688 from 7688
[Data Deleted]
Number of Observations for August : 7688 from 7688
[Data Deleted]
Number of Observations for September : 7440 from 7440
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Number of Observations for October : 7688 from 7688
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Number of Observations for November : 7440 from 7440
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Number of Observations for December : 7688 from 7688
[Data Deleted]
Number of Observations for All Months & Years: 90584 from 90584
[Data Deleted]

G2 Gpt 15305, Lat 35.0s, Long 115.0e, Depth 1000m
Defined Period: Operational
Date Ranges: 1/1/1970 00:00 to 12/31/2000 21:00

Horizontal variable: Vector Mean Direction of Total Spectrum (deg to which)
Vertical variable: Significant Wave Height (m)
Directional variable: All Directions
Number of Observations for January : 7688 from 7688
Directional Sector (): All Directions

Statistics for var:	Min	Max	Mean	Std Dev.	Median	90%	99%
VMD (deg to) - total	0.0000	359.9000	64.4777	N/A	N/A	N/A	N/A
Sig Wave Ht (m)	0.4480	11.6270	4.2012	1.6013	4.1585	6.2736	8.4967

Frequency of Occurrence for January:
Grid Point XXXXX , Lat XXX.XXXX, Long XXX.XXXX, VMD (deg to) - total

Sig Wave Ht (m)	22.5	45.0	67.5	90.0	112.5	135.0	157.5	180.0	202.5	225.0	247.5	270.0	292.5	315.0	337.5	360.0	Total
0.000 - 0.4999	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0003
0.500 - 0.9999	.0005	.0004	.0004	.0014	.0016	.0009	.0013	.0003	.0004	.0001	.0001	.0001	.0000	.0000	.0001	.0004	.0081
1.000 - 1.4999	.0001	.0018	.0031	.0013	.0022	.0039	.0030	.0021	.0009	.0008	.0007	.0003	.0007	.0008	.0008	.0007	.0230
1.500 - 1.9999	.0033	.0057	.0082	.0031	.0030	.0056	.0055	.0023	.0018	.0014	.0013	.0007	.0013	.0014	.0018	.0020	.0484
2.000 - 2.4999	.0053	.0109	.0139	.0100	.0053	.0100	.0029	.0038	.0016	.0013	.0008	.0009	.0034	.0005	.0017	.0017	.0740
2.500 - 2.9999	.0066	.0116	.0144	.0151	.0064	.0057	.0061	.0046	.0016	.0022	.0012	.0014	.0044	.0029	.0021	.0030	.0892
3.000 - 3.4999	.0099	.0169	.0194	.0153	.0085	.0035	.0047	.0030	.0029	.0021	.0008	.0020	.0020	.0021	.0035	.0051	.1015
3.500 - 3.9999	.0126	.0217	.0245	.0211	.0101	.0033	.0020	.0014	.0012	.0005	.0007	.0021	.0023	.0018	.0034	.0039	.1125
4.000 - 4.4999	.0174	.0307	.0302	.0230	.0117	.0027	.0009	.0012	.0009	.0007	.0000	.0021	.0023	.0020	.0031	.0064	.1353
4.500 - 4.9999	.0134	.0245	.0269	.0182	.0126	.0026	.0016	.0016	.0001	.0003	.0000	.0007	.0016	.0033	.0030	.0049	.1151
5.000 - 5.4999	.0117	.0195	.0178	.0166	.0065	.0030	.0021	.0010	.0004	.0000	.0000	.0000	.0007	.0012	.0029	.0068	.0901
5.500 - 5.9999	.0082	.0177	.0155	.0127	.0044	.0017	.0008	.0007	.0001	.0001	.0000	.0000	.0005	.0009	.0023	.0052	.0709
6.000 - 6.4999	.0072	.0172	.0116	.0090	.0040	.0004	.0005	.0000	.0000	.0000	.0000	.0000	.0008	.0000	.0012	.0056	.0574
6.500 - 6.9999	.0047	.0061	.0077	.0033	.0026	.0004	.0000	.0000	.0000	.0000	.0000	.0000	.0005	.0001	.0009	.0033	.0295
7.000 - 7.4999	.0007	.0035	.0070	.0009	.0014	.0003	.0003	.0000	.0000	.0000	.0000	.0000	.0000	.0003	.0005	.0017	.0165
7.500 - 7.9999	.0013	.0025	.0042	.0021	.0005	.0000	.0005	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0007	.0005	.0122
8.000 - 8.4999	.0004	.0014	.0020	.0016	.0003	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0004	.0000	.0060
8.500 - 8.9999	.0005	.0008	.0012	.0010	.0004	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0039
9.000 - 9.4999	.0001	.0009	.0013	.0008	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0034
9.500 - 9.9999	.0001	.0004	.0005	.0003	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0014
10.000 - 10.4999	.0000	.0000	.0001	.0003	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0004	.0008
10.500 - 10.9999	.0000	.0000	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001
11.000 - 11.4999	.0000	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0003
11.500 - 11.9999	.0000	.0000	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001
12.000 - 12.4999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
12.500 - 12.9999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
13.000 - 13.4999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
13.500 - 13.9999	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
Total	.1042	.1943	.2102	.1571	.0818	.0440	.0320	.0219	.0120	.0095	.0055	.0101	.0204	.0172	.0284	.0515	1.000

VMD (deg to) - total Bins are 22.50 wide, and are centered on column headers

Number of Observations for February : 7008 from 7008
[Data Deleted]
Number of Observations for March : 7688 from 7688
[Data Deleted]
Number of Observations for April : 7440 from 7440
[Data Deleted]
Number of Observations for May : 7688 from 7688
[Data Deleted]
Number of Observations for June : 7440 from 7440
[Data Deleted]
Number of Observations for July : 7688 from 7688
[Data Deleted]
Number of Observations for August : 7688 from 7688
[Data Deleted]
Number of Observations for September : 7440 from 7440
[Data Deleted]
Number of Observations for October : 7688 from 7688
[Data Deleted]
Number of Observations for November : 7440 from 7440
[Data Deleted]
Number of Observations for December : 7688 from 7688
[Data Deleted]
Number of Observations for All Months & Years: 90584 from 90584
[Data Deleted]

```
G2 Gpt XXXXX, Lat XX.XXX, Long XXX.XXX, Depth XXXXX
Defined Period: Operational
Date Ranges: 1/1/1970 00:00 to 12/31/2000 21:00

Horizontal variable:  Wind Direction (deg from which)
Vertical variable:    Wind Speed (m/s)
Directional variable: All Directions
 Number of Observations for January          :    7688 from     7688
 Directional Sector (): All Directions
 Statistics for var:      Min       Max      Mean    Std Dev.   Median      90%       99%
 --------------------  --------  --------  --------  --------  --------  --------  --------
 Wind Dir (deg fr)       0.0000  359.8000  215.6527       N/A       N/A       N/A       N/A
 Wind Sp (m/s)           0.8400   22.2100    9.9186    3.5301    9.8900   14.5630   18.0413
 Frequency of Occurrence for January:
 Grid Point XXXXX    , Lat XXX.XXXX, Long  XXX.XXXX, Wind Dir (deg fr)
       Wind Sp (m/s)  22.5  45.0  67.5  90.0 112.5 135.0 157.5 180.0 202.5 225.0 247.5 270.0 292.5 315.0 337.5 360.0 Total
   0.000 -   0.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0001 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0001
   1.000 -   1.9999  .0001 .0001 .0000 .0003 .0003 .0005 .0001 .0003 .0001 .0001 .0001 .0000 .0000 .0003 .0000 .0001 .0025
   2.000 -   2.9999  .0003 .0005 .0001 .0004 .0004 .0010 .0004 .0004 .0004 .0009 .0001 .0003 .0004 .0007 .0004 .0005 .0072
   3.000 -   3.9999  .0009 .0010 .0013 .0012 .0012 .0018 .0021 .0020 .0017 .0013 .0020 .0010 .0008 .0010 .0012 .0022 .0226
   4.000 -   4.9999  .0022 .0020 .0020 .0018 .0040 .0036 .0044 .0036 .0051 .0042 .0035 .0034 .0034 .0026 .0016 .0031 .0505
   5.000 -   5.9999  .0027 .0021 .0018 .0038 .0036 .0036 .0047 .0062 .0074 .0069 .0066 .0066 .0039 .0044 .0026 .0030 .0701
   6.000 -   6.9999  .0018 .0023 .0025 .0040 .0043 .0072 .0055 .0065 .0079 .0083 .0074 .0057 .0043 .0044 .0040 .0022 .0784
   7.000 -   7.9999  .0022 .0034 .0036 .0030 .0042 .0048 .0061 .0060 .0111 .0086 .0088 .0081 .0048 .0035 .0049 .0035 .0866
   8.000 -   8.9999  .0023 .0030 .0022 .0023 .0049 .0059 .0077 .0092 .0114 .0114 .0087 .0078 .0049 .0036 .0051 .0035 .0942
   9.000 -   9.9999  .0022 .0027 .0017 .0031 .0048 .0052 .0083 .0092 .0134 .0114 .0111 .0088 .0052 .0043 .0046 .0035 .0996
  10.000 -  10.9999  .0029 .0022 .0025 .0018 .0048 .0056 .0101 .0126 .0118 .0127 .0098 .0092 .0051 .0039 .0034 .0038 .1022
  11.000 -  11.9999  .0043 .0025 .0025 .0023 .0027 .0052 .0083 .0099 .0108 .0133 .0096 .0092 .0068 .0040 .0020 .0023 .0957
  12.000 -  12.9999  .0026 .0020 .0017 .0017 .0035 .0039 .0083 .0092 .0101 .0103 .0092 .0085 .0068 .0040 .0016 .0018 .0852
  13.000 -  13.9999  .0008 .0008 .0014 .0020 .0033 .0034 .0062 .0070 .0105 .0081 .0069 .0081 .0059 .0036 .0025 .0014 .0718
  14.000 -  14.9999  .0005 .0004 .0012 .0007 .0018 .0022 .0055 .0064 .0082 .0062 .0044 .0060 .0039 .0026 .0033 .0022 .0554
  15.000 -  15.9999  .0004 .0001 .0004 .0007 .0010 .0025 .0056 .0043 .0039 .0035 .0031 .0026 .0018 .0018 .0022 .0004 .0343
  16.000 -  16.9999  .0000 .0000 .0001 .0003 .0013 .0004 .0027 .0030 .0033 .0027 .0021 .0016 .0017 .0005 .0009 .0000 .0206
  17.000 -  17.9999  .0000 .0000 .0000 .0003 .0001 .0009 .0025 .0017 .0017 .0014 .0009 .0014 .0005 .0001 .0007 .0000 .0122
  18.000 -  18.9999  .0000 .0000 .0004 .0000 .0005 .0009 .0009 .0001 .0007 .0007 .0003 .0008 .0004 .0001 .0001 .0000 .0059
  19.000 -  19.9999  .0000 .0000 .0000 .0000 .0000 .0005 .0004 .0003 .0004 .0003 .0009 .0003 .0000 .0001 .0000 .0000 .0031
  20.000 -  20.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0001 .0000 .0000 .0004 .0003 .0000 .0001 .0001 .0000 .0000 .0010
  21.000 -  21.9999  .0000 .0000 .0000 .0000 .0000 .0001 .0000 .0000 .0000 .0000 .0001 .0000 .0000 .0000 .0000 .0000 .0003
  22.000 -  22.9999  .0000 .0000 .0000 .0000 .0000 .0004 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0004
  23.000 -  23.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
  24.000 -  24.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
  25.000 -  25.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
             Total   .0263 .0251 .0254 .0295 .0468 .0597 .0900 .0981 .1199 .1128 .0960 .0894 .0606 .0459 .0408 .0337 1.000
 Wind Dir (deg fr) Bins are   22.50 wide, and are centered on column headers

 Number of Observations for February         :    7008 from     7008
[Data Deleted]
 Number of Observations for March            :    7688 from     7688
[Data Deleted]
 Number of Observations for April            :    7440 from     7440
[Data Deleted]
 Number of Observations for May              :    7688 from     7688
[Data Deleted]
 Number of Observations for June             :    7440 from     7440
[Data Deleted]
 Number of Observations for July             :    7688 from     7688
[Data Deleted]
 Number of Observations for August           :    7688 from     7688
[Data Deleted]
 Number of Observations for September        :    7440 from     7440
[Data Deleted]
 Number of Observations for October          :    7688 from     7688
[Data Deleted]
 Number of Observations for November         :    7440 from     7440
[Data Deleted]
 Number of Observations for December         :    7688 from     7688
[Data Deleted]
 Number of Observations for All Months & Years:   90584 from    90584
[Data Deleted]
```

Wave Spectra Description and Sample Output

Please refer to sample table below. The top of the file indicates the number of frequencies and directions per table as well as the number of time steps and the number of grid points per time step within the file (not shown). It is followed by one blank line. Every table is 32 lines long, with 5 header lines (the fourth one is blank), 24 data lines, and 3 footer lines (the last one is blank). The first line of each table includes the latitude, longitude, angle, and water depth.

The second line is a character string indicating which variables are located in the third line and include wind speed, wind direction (measured from which), peak period, sea and swell partitions as well as significant wave height and is followed by a blank line. The next line gives the nominal frequencies of each frequency bin. Within the 24 data lines, directional bands are identified at the left. The 552 element array contains the variance components (NOT spectral densities) for 23 frequencies and 24 directions. The 24 directional bins, each 15 degrees wide, are numbered clockwise from north; the first bin, with a nominal direction of 7.5 degrees, extends from 0 to 15 degrees. The sum over all the frequencies per one direction band is given in the right most column.

Frequency bins are spaced in geometric progression (to facilitate the computation of interactions); the nominal frequency is the geometric mean of the two ends (see table below format explanation). The frequency ratio is .75**(-1./3.), i.e. 1.100642416; this ratio was chosen in preference to the 1.1000 of official WAM to simplify interaction formulas. The first 22 bins are straightforward; the last requires explanation. The 23rd frequency band is an integrated band comprising what would be bins 23 through 44 (continuing the geometric progression) of a fully discrete bin system. To model the cascade of wave energy from high to low frequencies endorsed by non-linear interactions, we compute interactions involving bins out to 44. This requires a parametric assumption about the spectral density between 0.30652 and 2.52741 Hz; and the customary assumption is that density is proportional to omega**(-x), where x is a disposable parameter. We are using x = 4.5 for the following reasons:

(1) There are quasi-physical arguments supporting the exponents 4 & 5. The exponent 5 is germane to a Pierson-Moskowitz spectrum.
(2) A crude energy balance computation in the tail, with wind input scaled as omega**2 and interactions scaled as omega**11, shows that 4.5 is the only exponent capable of yielding an equilibrium spectrum in the tail.

To compute a "density" at 0.32157 Hz, we compute what fraction of the integrated band belongs to the bin from 0.30652 to 0.33737 Hz. Sparing a few details, the result is:

dens = (variance component)*rbw

where rbw (dimensions seconds) is a function of the exponent as follows:

x	rbw
4.0	8.11849
4.5	9.24794
5.0	10.32933

The sum of the energy per frequency (over all directions) is given in the first footer line. The second footer line contains the "density" as explained above.

Sample Wave Spectra:

Latitude 46.8750, Longitude -49.1667, Angle 0.0000, Depth 1000.0000m

CCYYMM	DDHHmm	LPoint	WD	WS	ETot	TP	VMD	ETotSe	TPSe	VMDSe	ETotSw	TPSw	VMDSw	Mo1	Mo2	HSig	DomDr	AngSpr	Inline	Tau
199812	010000	5621	343.2	10.035	0.760	10.049	158.6	0.435	7.406	159.1	0.326	10.946	157.4	0.681	0.726	3.488	159.6	0.6730	0.7500	0.00

freq	0.0390	0.0429	0.0472	0.0520	0.0572	0.0630	0.0693	0.0763	0.0840	0.0924	0.1017	0.1120	0.1233	0.1357	0.1493	0.1643	0.1809	0.1991	0.2191	0.2412	0.2655	0.2922	0.3216	anSpec
7.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0004	0.0006	0.0005	0.0003	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0023
22.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0004	0.0006	0.0005	0.0003	0.0002	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0026
37.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0004	0.0005	0.0008	0.0008	0.0006	0.0004	0.0003	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0045
52.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0007	0.0017	0.0024	0.0023	0.0016	0.0010	0.0006	0.0003	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0004	0.0117
67.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0006	0.0025	0.0048	0.0047	0.0028	0.0015	0.0008	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0009	0.0211
82.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0007	0.0017	0.0023	0.0018	0.0012	0.0008	0.0007	0.0007	0.0008	0.0009	0.0008	0.0007	0.0006	0.0005	0.0015	0.0160
97.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0004	0.0005	0.0008	0.0014	0.0019	0.0020	0.0019	0.0017	0.0014	0.0012	0.0010	0.0007	0.0021	0.0172
112.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0004	0.0008	0.0018	0.0031	0.0040	0.0039	0.0034	0.0029	0.0025	0.0021	0.0017	0.0013	0.0010	0.0027	0.0319
127.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0004	0.0008	0.0017	0.0036	0.0062	0.0073	0.0069	0.0059	0.0050	0.0042	0.0034	0.0027	0.0021	0.0016	0.0012	0.0031	0.0563
142.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0008	0.0022	0.0045	0.0074	0.0103	0.0118	0.0113	0.0099	0.0084	0.0068	0.0053	0.0040	0.0030	0.0023	0.0017	0.0012	0.0033	0.0944
157.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0022	0.0088	0.0168	0.0176	0.0173	0.0169	0.0151	0.0128	0.0101	0.0077	0.0058	0.0043	0.0032	0.0024	0.0017	0.0013	0.0034	0.1477
172.50	0.0000	0.0000	0.0000	0.0000	0.0001	0.0010	0.0049	0.0125	0.0203	0.0193	0.0162	0.0149	0.0129	0.0110	0.0092	0.0074	0.0057	0.0043	0.0032	0.0024	0.0018	0.0013	0.0034	0.1517
187.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0012	0.0021	0.0030	0.0048	0.0068	0.0077	0.0076	0.0070	0.0063	0.0056	0.0048	0.0039	0.0030	0.0023	0.0017	0.0013	0.0033	0.0726
202.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0009	0.0026	0.0022	0.0013	0.0014	0.0019	0.0027	0.0034	0.0037	0.0035	0.0032	0.0029	0.0024	0.0020	0.0015	0.0011	0.0030	0.0398
217.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0007	0.0007	0.0003	0.0002	0.0003	0.0006	0.0009	0.0014	0.0018	0.0019	0.0018	0.0015	0.0014	0.0012	0.0009	0.0025	0.0183
232.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0002	0.0003	0.0005	0.0008	0.0009	0.0009	0.0008	0.0007	0.0006	0.0018	0.0078
247.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0003	0.0003	0.0003	0.0004	0.0003	0.0012	0.0036
262.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0003	0.0003	0.0003	0.0003	0.0002	0.0001	0.0001	0.0001	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0006	0.0028
277.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0007	0.0011	0.0011	0.0007	0.0004	0.0003	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0052
292.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0013	0.0024	0.0027	0.0016	0.0007	0.0004	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0100
307.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0015	0.0035	0.0047	0.0027	0.0011	0.0005	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0147
322.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0009	0.0031	0.0050	0.0033	0.0012	0.0005	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0147
337.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0004	0.0014	0.0029	0.0025	0.0011	0.0005	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0093
352.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0003	0.0004	0.0008	0.0011	0.0007	0.0004	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0042
fSpec	0.0000	0.0000	0.0000	0.0000	0.0003	0.0023	0.0109	0.0325	0.0593	0.0749	0.0856	0.0826	0.0723	0.0636	0.0548	0.0460	0.0383	0.0312	0.0250	0.0200	0.0157	0.0118	0.0333	0.760
dens	0.00	0.00	0.00	0.00	0.05	0.38	1.64	4.44	7.36	8.45	8.77	7.69	6.11	4.89	3.83	2.92	2.20	1.64	1.19	0.87	0.62	0.42	0.31	

Each table can be read with the following FORTRAN format statements:

```
   REAL THETA(24), SPEC(23,24), FREQ(23), ANGSPEC(24)
      REAL FSPEC(23), ETOT, DENS(23)
      INTEGER CYM, DHM, GP
      REAL LAT, LONG, ANGLE, DEPTH
      REAL WD, WS, TP, VMD, ETOTSE, TPSE,
     & VMDSE, ETOTSW, TPSW, VMDSW, MO1, MO2, HSIG, DOMDR,
     & ANGSPR, INLINE, TAU

10    format (9x, f9.4, 11x, f10.4, 7x, f10.4, 7x, f10.4)
11    format (f7.2, 24f7.4)
12    format (7x, 23f7.4, f7.3)
13    format (7x, 23f7.2)
14    format (3i7, f6.1, f7.3, 3(2f7.3,f7.1), 3f7.3,
     & f6.1, 2f7.4, f7.2)
15    format (7x, 23f7.4)

      READ (10,*) !summary line at top of file
      READ (10,*)!blank line at top of file
20    READ (10,10,END=30) LAT, LONG, ANGLE, DEPTH !Looped for each tau
      READ (10,*)
      READ (10,14)CYM,DHM,GP,WD,WS,ETOT,TP,VMD,ETOTSE,TPSE,
     & VMDSE,ETOTSW,TPSW,VMDSW,MO1,MO2,HSIG,DOMDR,ANGSPR,
     & INLINE,TAU
      READ (10,*) !blank header line
      READ (10,15) (FREQ(I), I=1,23)
      READ (10,11) (THETA(J), (SPEC(I,J), I=1,23), ANGSPEC(J), J=1,24)
      READ (10,12) (FSPEC(I), I=1,23), ETOT
      READ (10,13) (DENS(I), I=1,23)
      READ (10,*)!blank footer line
      ! ****** [insert processing code here]
      GO TO 20  !read next table
30    CONTINUE  !end of file during read
```

Variable definitions:

CYM	Year and month in the format CCYYMM
DHM	Day, hour and minute (gmt) in the format DDHHmm
GP	Grid point
LAT	Latitude of grid point
LONG	Longitude of grid point
DEPTH	Depth of grid point
WS	Wind speed (m/s) at grid point
WD	Wind direction (from which, clockwise from true north)
TP	Peak period (sec)
VMD	Vector mean direction (to which)
"SE"	Sea partitions of TP, ETOT, and VMD
"SW"	Swell partitions of TP, ETOT, and VMD
HS	Significant wave height (m)
MO1, MO2	First and second spectral moments
DOMDR	Dominant direction (to which)
ANGSPR	Angular Spreading function

INLINE	In-line variance ratio
TAU	Always=0 for hindcast purposes
FREQ(I)	Geometric mean of the lower and upper ends of the bandwidth. The frequency bands are given below.
THETA(J)	Mean direction of angular bin, to which waves are traveling, clockwise from true north. The bin extends +/- 7.5 degrees from the center (the value displayed in the table).
SPEC(I,J)	Variance component (not spectral density), in m**2, in frequency band I and angular band J.
ANSPEC(J)	Variance summed over all frequencies per direction (the right most column).
FSPEC(I)	Variance summed over all directions per frequency (the first footer line).
ETOT	Total variance located at the end of the first footer line.
DENS(I)	Frequency spectrum represented as density in units of m**2 Hz (second footer line).

Frequency bands:

	nom. freq	left end	right end	bandwidth
1	0.0390000	0.0371742	0.0409155	0.0037413
2	0.0429251	0.0409155	0.0450333	0.0041178
3	0.0472451	0.0450333	0.0495656	0.0045323
4	0.0520000	0.0495656	0.0545540	0.0049884
5	0.0572334	0.0545540	0.0600444	0.0054904
6	0.0629935	0.0600444	0.0660874	0.0060430
7	0.0693333	0.0660874	0.0727386	0.0066512
8	0.0763112	0.0727386	0.0800592	0.0073206
9	0.0839914	0.0800592	0.0881166	0.0080574
10	0.0924444	0.0881166	0.0969849	0.0088683
11	0.1017483	0.0969849	0.1067457	0.0097608
12	0.1119885	0.1067457	0.1174888	0.0107431
13	0.1232593	0.1174888	0.1293131	0.0118244
14	0.1356644	0.1293132	0.1423275	0.0130144
15	0.1493180	0.1423275	0.1566517	0.0143242
16	0.1643457	0.1566517	0.1724175	0.0157658
17	0.1808858	0.1724175	0.1897700	0.0173525
18	0.1990906	0.1897700	0.2088690	0.0190989
19	0.2191276	0.2088690	0.2298900	0.0210211
20	0.2411811	0.2298900	0.2530267	0.0231367
21	0.2654541	0.2530267	0.2784919	0.0254652
22	0.2921701	0.2784919	0.3065200	0.0280281
23	0.3215748	0.3065200	2.5274134	