GOMOS

Gulf of Mexico Oceanographic Study

Block Specific Report

Galveston Area 423/427/A56

Submitted to

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INTRODUCTION

Background

The GOMOS (Gulf of Mexico Oceanographic Study) hindcast is Oceanweather's new comprehensive metocean study for the Gulf of Mexico. It is intended as follow-on to the Gulf Joint Industry Projects GUMSHOE (Hurricane Extremes), WINX (Winter Storm Extremes) and GLOW (Operational Statistics), which have set the standard for design criteria in the Gulf.

GOMOS consists of three main components: a tropical hindcast (335 tropical storms/hurricanes from the period 1900-2005), extra-tropical/winter storm hindcast (80 storms from the period 1957-2000) and 16-year continuous hindcast (1990-2005). All three hindcasts used a common 1/8th degree implementation of Oceanweather's UNIWAVE wave model and 2-D current/surge model to produce a full description of the wind, wave, vertically integrated current, and surge height fields for the Gulf.

Time series, statistical analysis, extremal analysis and wave spectra are available from each of these hindcasts separately, or as a complete set. Full documentation on the methodology, model description and validation can be found in the companion report *GOMOS Project Description*. This block specific report details the methodology and deliverables associated with this particular GOMOS request.

Block of Interest

The blocks of interest are the Galveston Area Blocks 423, 427 and A56 located near 28.47-28.57 N and 95.02-95.17 W. The nearest GOMOS grid point that satisfies all three locations is #8832 located at 28.5 N, 95.125 W in 30.5 meters of water (Figure 1). This is a full GOMOS block license that includes the following:

1. Time series of wind, wave, current and surge parameters from the 16-year continuous hindcast (3-hourly time step)
2. Monthly and Annual Frequency of Occurrence tables for wind speed by wind direction in 45 degree sectors
3. Monthly and Annual Frequency of Occurrence tables for wave height by wave period in 45 degree wave direction sectors
4. Persistence-Duration Statistics for wind speed
5. Persistence-Duration Statistics for wave height
6. Time series of wind, wave, current and surge parameters from the 335 tropical system hindcast (30-min time step). List of storm dates given in Appendix A.
7. Omni-directional tropical extremes for 1, 5, 10, 25, 50, 75, 100, 1000 year return periods for wind speed, surge height, vertically integrated current speed, and significant wave height with associated (at time of maximum wave) wind speed, surge height, vertically integrated current speed, maximum wave height, crest height and wave period. Extremes provided for both the full period, 1900-2005 and the last 56 years, 1950-2005.
8. Directional tropical extremes for 100 year return period for wind speed, surge height, vertically integrated current speed, and significant wave height with associated (at time of maximum wave) wind speed, surge height, vertically integrated current speed, maximum wave height, crest height and wave period in 45-degree bins. Extremes provided for both the full period, 1900-2005 and the last 56 years, 1950-2005.
9. Storm peaks (sorted by wave height) from tropical hindcast (see Appendix B).
10. Time series of wind, wave, current and surge parameters from the 80 extra-tropical/winter storm hindcast (30-min time step). List of storm dates given in Appendix C.
11. Omni-directional extra-tropical extremes for 1, 5, 10, 25, 50, 100, 1000 year return periods for wind speed, surge height, vertically integrated current speed and significant wave height with associated (at time of maximum wave) wind speed, surge height, vertically integrated current speed, maximum wave height, crest height and wave period.

12. Directional extra-tropical extremes for 100 year return period for wind speed, surge height, vertically integrated current speed and significant wave height with associated (at time of maximum wave) wind speed, surge height, vertically integrated current speed, maximum wave height, crest height and wave period in 45-degree bins.
13. Storm peaks (wave height) from extra-tropical hindcast
14. Block specific report

Units and Conventions

The following list describes the units and conventions used in this report. Where possible, units have been expressed using the SI convention.

Current speeds are expressed in centimeters per second (cm s^{-1}).

Current directions are expressed in degrees or compass points (N, NNE, NE etc), relative to True North, and describe the direction towards which the current was flowing.

Vertical elevations in the water column are expressed in meters, except surge which is in cm, and referenced to MSL.

Wind speeds are expressed in meters per second (ms^{-1}) at 10 m.

Wind directions are expressed in degrees or compass points (N, NNE, NE etc), relative to True North, and describe the direction from which the wind was blowing.

Wave heights are expressed in meters (m).

Wave directions are expressed in degrees or compass points (N, NNE, NE etc), relative to True North, and describe the direction towards which the waves were traveling.

Sectorized extremal analysis directional bins are all in “from which” convention for all directional variables listed.

CONTINUOUS HINDCAST RESULTS

Validation at Target Location

Figure 2 shows a 4-panel comparison plot of ERS-1/2 and TOPEX altimeter wind and wave measurements vs. the GOMOS continuous hindcast. Individual wind and wave estimates from the altimeter are time-matched with GOMOS hindcast output within 55km of a target location. Scatter plots (right) for wind (top) and significant wave height (bottom) as well as quantile-quantile (Q-Q) plots are presented as well as general statistics. Empirically derived wave period estimates from the altimeter as also included, but are generally suspect.

Based on 2292 comparisons the wave height has a negative 10 cm bias with correlation coefficient of 88% and nearly linear Q-Q comparison up to the 99th percentile. Wind speed comparisons show a positive bias of 1.19 m/s with correlation coefficient of 82%. The Q-Q comparison is linear, but with an offset showing the hindcast running higher than the altimeter in all percentiles. Evidence from altimeter studies in enclosed basins and fetch limited areas generally show that the altimeter winds are biased low which appears to be the case in this comparison as well.

Modification Description

Based on the local validation dataset, modifications were applied to the GOMOS continuous hindcast at this location. The algorithm applies the regression equation $HS_{new} = 0.050 + 1.045*HS_{GOMOS}$, then conserves significant steepness to adjust the peak period and makes compatible corrections to the sea and swell partitions. To prevent very low wave heights (less than 10 cm) from doubling, the adjusted waves were restricted to a 50% change. These adjusted time series were used in any additional tables and figures.

Deliverables

Time series of wind, wave, current and surge values from the 1990-2005 continuous hindcast are provided in electronic form. Descriptions of the fields contained in the time series can be found in the *GOMOS Project Description*. It should be noted that the current/surge model used in GOMOS is a wind-driven vertically integrated model and does not model the general circulation, eddies, etc. that are typically modeled by full 3D models. Great care should be taken in interpreting these results outside their intended use of describing the surge/current conditions in storms contained within the continuous period.

Operational statistics include monthly and annual bivariate frequency of occurrence distributions for wind speed by wind direction and wave period by wave height by wave direction. Wind and wave rose plots, derived from the annual results, are shown in Figures 3 and 4. Persistence-Duration (also known as threshold exceedance and non-exceedance) tables are provided for wind speed and wave height. All results are provided in electronic form with documentation as to the generation and format provided in the *GOMOS Project Description*.

TROPICAL HINDCAST RESULTS

Extremal Analysis

In the tropical extremal analysis an estimate of the maximum individual wave height and crest height and in each event is computed using our standard algorithm. The *GOMOS Project Description* document describes the standard extremal analysis algorithm used to fit the distributions of the peaks-over-threshold to the ranked series of maxima at each point of WS, HS, HMax and HCrest. The wave period associated with return period wave height extremes for storms was assigned from regressions of the form TP = C_0* HS** C_1 (TP in seconds, HS in meters) and were developed from the hindcast storm peaks. Sectorized extremes were derived from selecting WS, HS, HMax and HCrest peaks within 45-degree sectors for each storm and producing extremes for comparison to the omni-directional values. All sectorized extremes use meteorological convention for all wind, current, and wave directions ("from which").

The wind speed extremes for other averaging periods can be derived from the 1-hour average extremes using the following gust factors specifically applicable to tropical cyclones:

1 Hour to 10-Minute Mean:	x 1.09
1 Hour to 1 Minute Wind:	x 1.24
1 Hour to 3-Second Gust:	x 1.53

A number of different thresholds and distributions were tried and ultimately the combination of the Gumbel distribution and ½ maximum event threshold was selected. In return periods where the ½ max rule did not provide sufficient peaks for the calculation of an extreme value, the top 107 storms in the 106-year period were used (typically 1 and 5 year return periods). (The top 57 storms in the 56-year period 1950-2005 were used for those 1 and 5-year return periods.) Due to the variability of storm tracks, the hindcast results at the following suite of points were averaged for the derivation of "site-average" return period extremes:

Grid Point	Latitude	Longitude	Depth (m)
8388	28.000	-96.000	41
8612	28.250	-95.625	30
8832	28.500	-95.125	30
8942	28.625	-94.500	29
8151	28.875	-93.875	24

Within the site-averaging process applied to accurate and unbiased hindcast data, a useful measure of fit is the mean difference over all the individual grid points involved, between the fitted wind speed provided by the distribution at the return period represented by the population fitted, and the highest ranked wind speed. Table 1 compares the fitted 100-year wind speed and the highest ranked wind speed in 106 years at each point for the two most widely applied distributions: Gumbel and Weibull. The mean difference between the fitted peak and the hindcast peak is smaller for Gumbel (-0.53 m/s) than for Weibull (-1.83 m/s). The table gives the site-averaged Gumbel 100-year wind speed peak before (38.28 m/s) and after adding the "unbiasing factor" of 0.53 m/s. This yields an "unbiased" wind speed extreme of 38.81 m/s. To preserve the unbiasing factor for more general use, we expressed it as a percentage difference and applied it to the remaining return periods in Table 2. We repeated this analysis for the 1950-2005 extremal analysis using the 56-year return period (bottom Table 1). The winds are about 6% low, and again we expressed the bias as a factor and applied it to the wind speed extremes in Table 3.

Our final site-averaged wind, wave, current, and surge extremes are given in Table 2 for both the omni-directional (all return periods) and by directional sector (100-year return period only) for 1900-2005. The same extremes are given in Table 3 for 1950-2005. Please note that a 0.21 m bias was added to the HS extremes as described in the companion report. HM and HC ratios as well as TP steepness were all conserved.

Deliverables

Time series of wind, wave, current, and surge values from the 335 tropical storms hindcast are provided in electronic form. Descriptions of the fields contained in the time series can be found in the *GOMOS Project Description*. Storm peaks at the target location sorted by wave height used in the extremal analysis are also provided for the target location in electronic form and in Appendix B. Final extremal analysis values are summarized in Tables 2 and 3.

EXTRA-TROPICAL RESULTS

Extremal Analysis

In the extra-tropical extremal analysis an estimate of the maximum individual wave height and crest height and in each event is computed using our standard algorithm. The *GOMOS Project Description* document describes the standard extremal analysis algorithm used to fit the distributions of the peaks-over-threshold to the ranked series of maxima at each point of WS, HS, HMax and HCrest. The wave period associated with return period wave height extremes for storms was assigned from regressions of the form TP = C_0* HS** C_1 (TP in seconds, HS in meters) and were developed from the hindcast storm peaks. Sectorized extremes were derived from selecting WS, HS, HMax and HCrest peaks within 45-degree sectors for each storm and producing extremes for comparison to the omni-directional values. All sectorized extremes use meteorological convention for all wind, current, and wave directions (“from which”).

The wind speed extremes for other average periods can be derived from the 1-hour average extremes using the following gust factors specifically applicable to extra-tropical storms:

1 Hour to 10-Minute Mean:	x 1.06
1 Hour to 1 Minute Wind:	x 1.22
1 Hour to 3-Second Gust:	x 1.43

A number of different thresholds and distributions were tried and ultimately the combination of the Gumbel distribution and ½ maximum event threshold was selected. In return periods where the ½ max rule did not provide sufficient peaks for the calculation of an extreme value, the top 44 storms in the 43-year period were used (typically 1 and 5 year return periods for the hydrodynamic variables). No site averaging of the extra-tropical/winter storms were required.

Our final wind, wave, current and surge extremes are given in Table 4 for both the omni-directional (all return periods) and by directional sector (100-year return period only). Please note a 0.28 m bias was added to the HS extremes as described in the companion report. HM and HC ratios as well as TP steepness were all conserved.

Deliverables

Time series of wind, wave, current, and surge values from the 80 extra-tropical storms hindcast are provided in electronic form. Descriptions of the fields contained in the time series can be found in the *GOMOS Project Description*. Storm peaks at the target location for wave heights greater than threshold used in the extremal analysis are also provided for the target location in electronic form. Final extremal analysis values are summarized in Table 4.

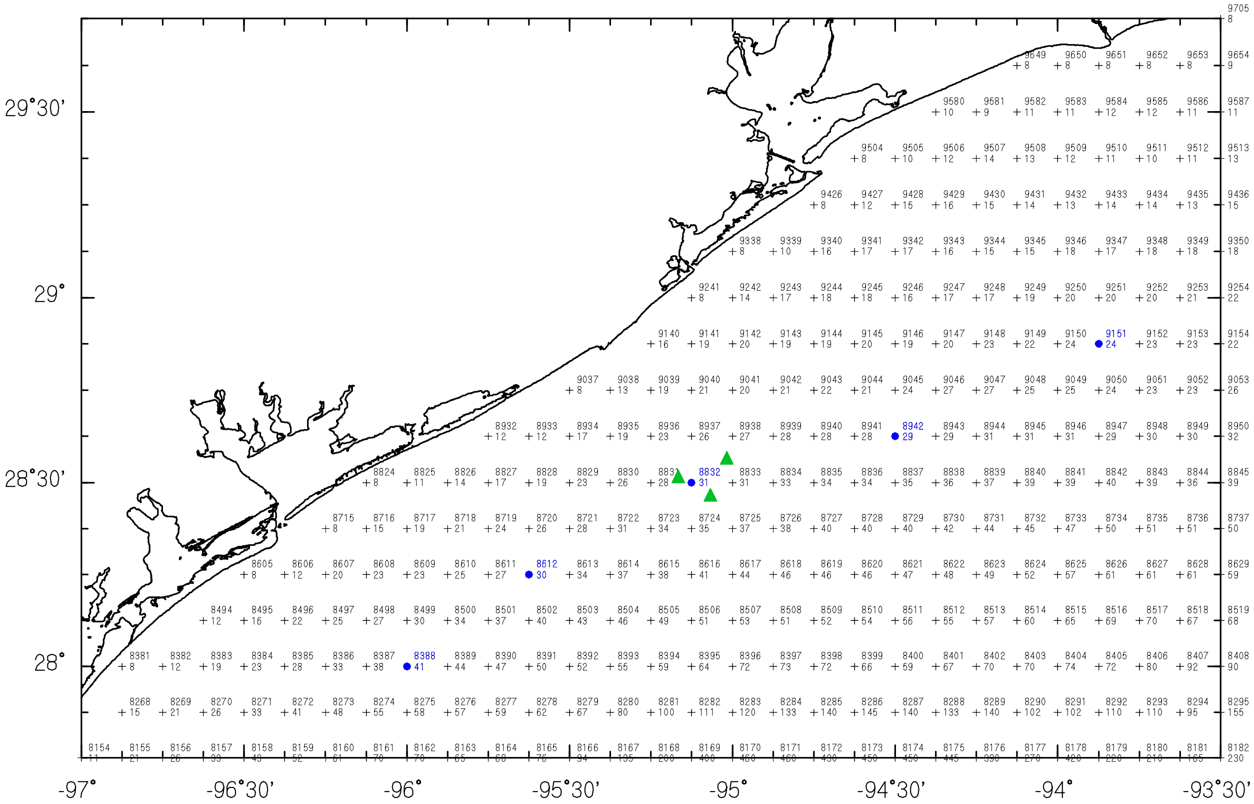
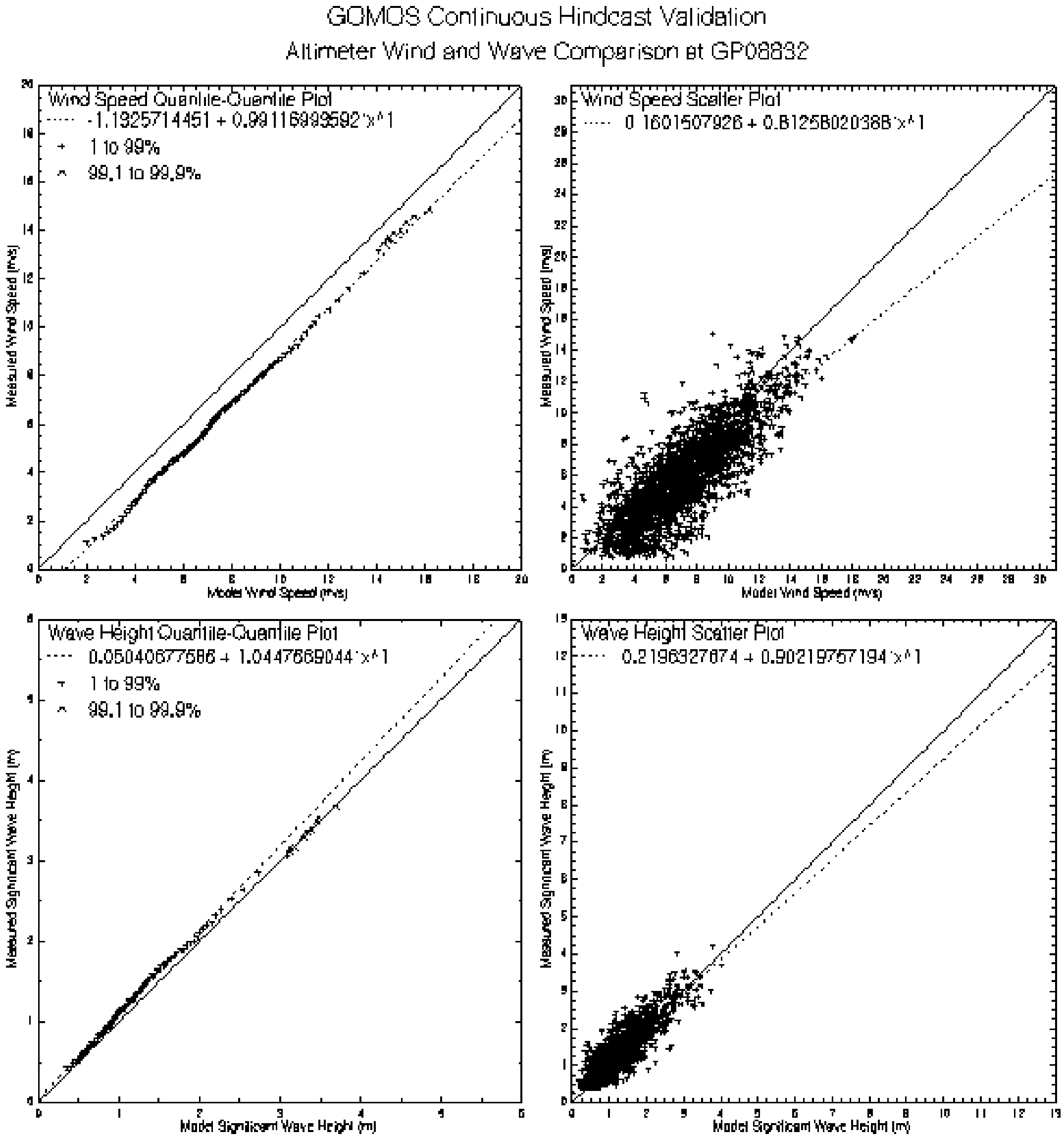


Figure 1. GOMOS grid point locations (grid point numbers, upper right, and depths in meters, right) in area surrounding target locations (green triangles). From left to right the target locations are GA 427, GA A56, and GA 423. Site-average points are highlighted in blue.



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Hindcast Period : 01-JAN-1980 00.00.00 to 01-JAN-2000 00.00:00
Latitude Range  :    15.00 to    32.00
Longitude Range :  -100.00 to   -80.00


                                  Grid    Number    Mean    Mean    Diff    RMS   Stnd   Scat          Corr
                        Station   Point   of Pts    Meas    Hind   (H-M)  Error    Dev  Index  Ratio  Coeif
                        -------  -------- --------  ------  ------  ------  -----  -----  -----  -----  -----
Wind Spd. (m/s) Combined        0     2881    6.01    7.20    1.19   2.02   1.64   0.27   0.79   0.82
Sig Wave Ht  (m) Combined        0     2292    1.30    1.20   -0.10   0.31   0.29   0.23   0.35   0.88
Wave Period (s) Combined        0     2274    5.45    5.57    0.12   0.85   0.84   0.15   0.54   0.68
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Figure 2. Comparison of GOMOS continuous hindcast wind and waves vs. ERS-1/2 and TOPEX altimeter wind and wave measurements.

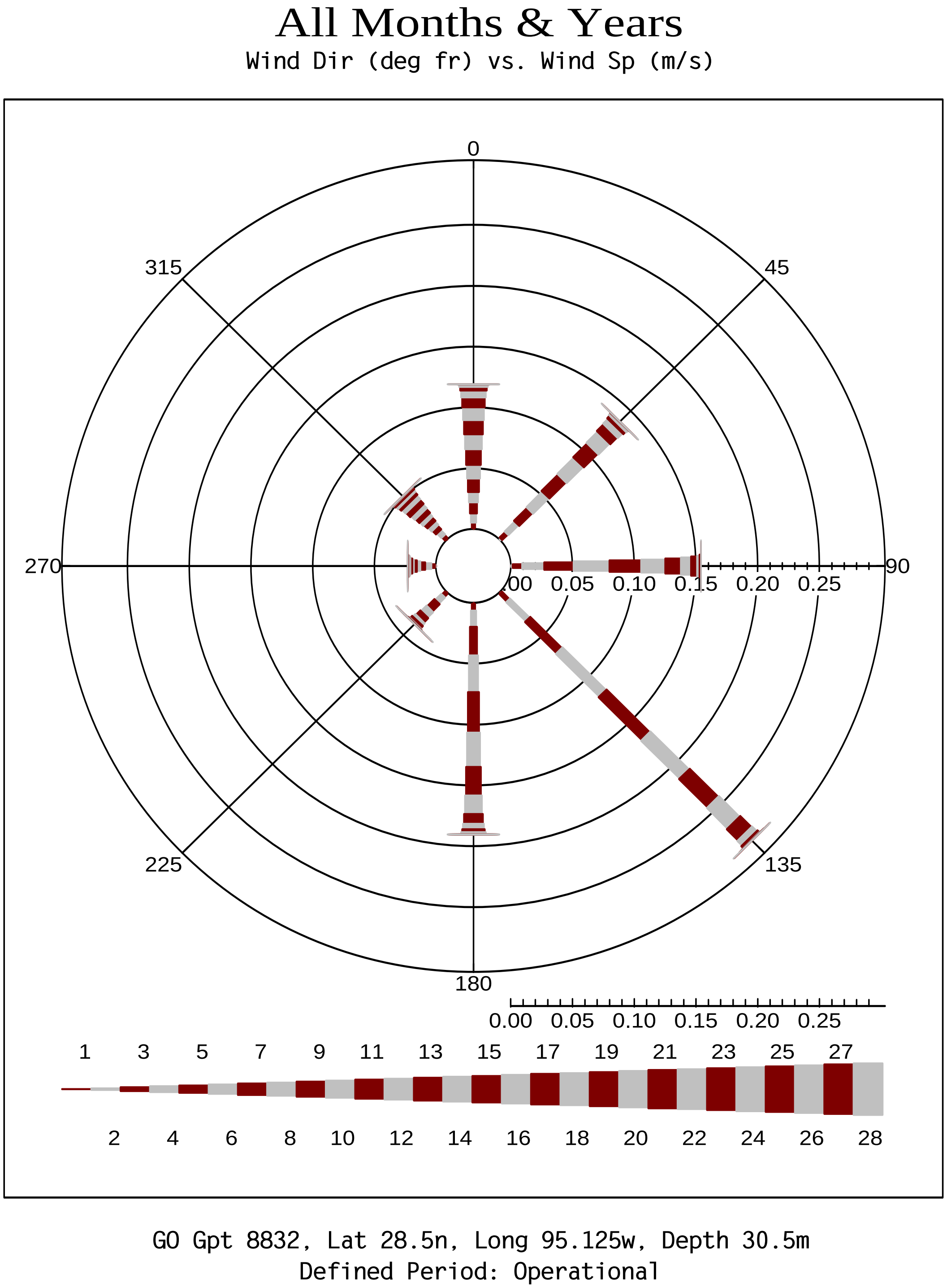

Figure 3. Wind speed (m/s) directional rose for all years combined from GOMOS continuous hindcast. Wind directions are meteorological (from which) convention.

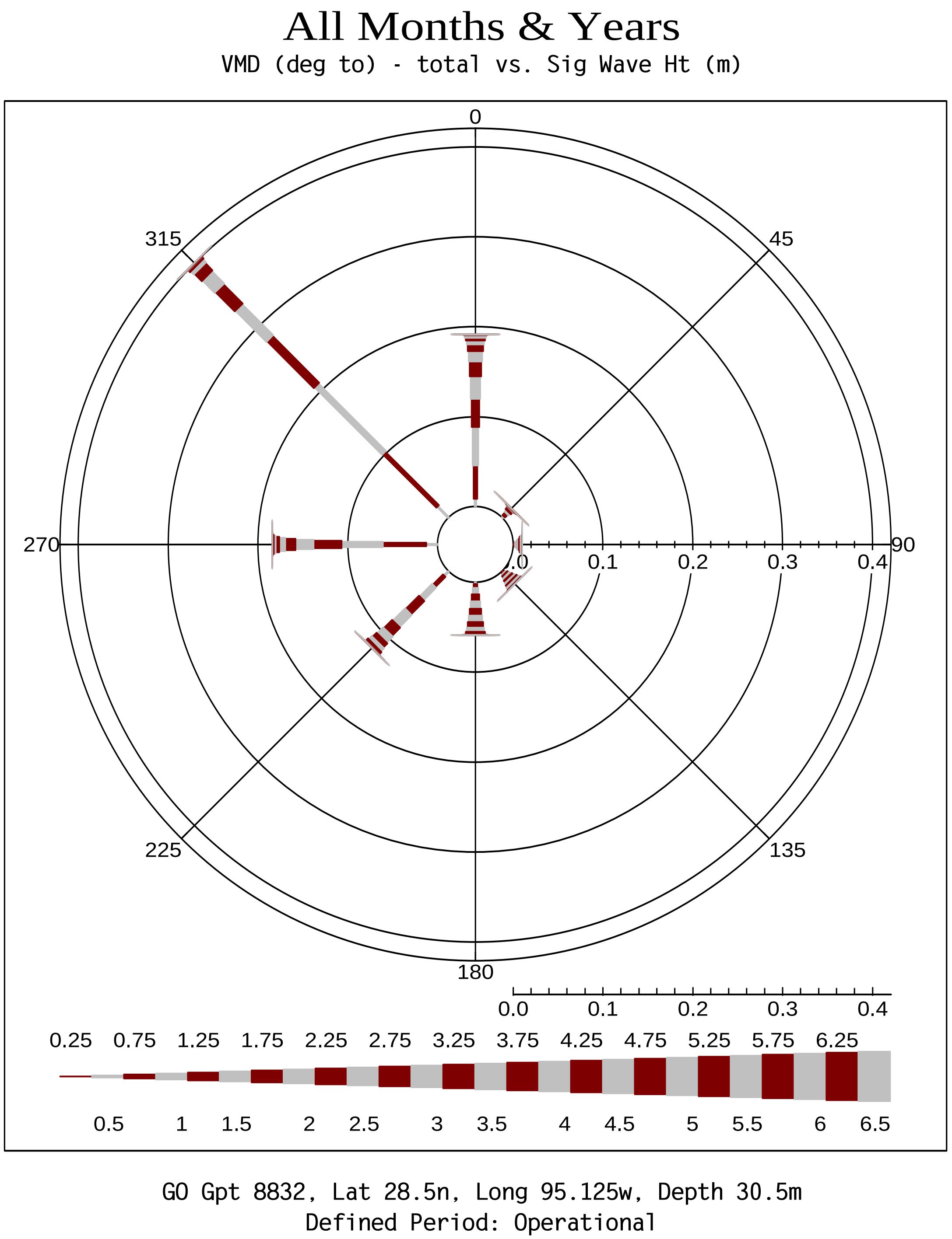

Figure 4. Significant wave height (m) directional rose for all years combined from GOMOS continuous hindcast. Wave directions are vector mean oceanographic (to which) convention.

Table 1: Comparison of Fitted 100-year Extremes (top) and 56-year Extremes (bottom)

Wind Speed and Wind Speed in Top-Ranked Storm, 1900-2005

Grid Point	Gumbel 100-yr	Weibull 100-yr	106-year	Storm Name
8388	38.68	37.30	39.80	Carla
8612	37.60	36.94	38.67	Carla
8832	34.99	33.57	35.88	1941_02
8942	39.13	36.87	37.82	1915_02
9151	42.01	40.21	41.88	1900_01
Bias (Fit-GOMOS)	-0.53	-1.83		
Gumbel site-average				38.28 m/s
Unbias factor				x 1.0138
Gumbel unbiased extreme				38.81 m/s

Carla occurred in 196109, 1941_02 occurred in 194109, 1915_02 occurred in 191508, and 1900_01 occurred in 190009.

Wind Speed and Wind Speed in Top-Ranked Storm, 1950-2005

Grid Point	Gumbel 56-yr	Weibull 56-yr	56-year	Storm Name
8388	35.74	32.22	39.80	Carla
8612	34.50	30.47	38.67	Carla
8832	31.85	31.21	31.71	Carla
8942	33.65	33.82	31.77	Alicia
9151	36.76	33.54	41.25	Audrey
Bias (Fit-GOMOS)	-2.14	-4.39		
Gumbel site-average				34.50 m/s
Unbias factor				x 1.0620
Gumbel unbiased extreme				36.64 m/s

Carla occurred in 196109, Alicia occurred in 198308, and Audrey occurred in 195706.

Table 2. GOMOS tropical extremes for maximum wind speed (m/s), maximum surge height (cm), maximum vertically integrated current speed (cm/s), and significant wave height (m) with associated surge height, vertically integrated current speed, wind speed, maximum wave height (m), wave crest height (m), and peak period (s) at the time of the maximum significant wave height.

1900-2005

OMNI Directional Extremes

RtnPer	maxWS	maxHSUR	maxCS	HSig	assHSUR	assoCS	assoWS	HMax	HCrest	TP(r)
1	12.1	16.4	39.6	2.5	14.0	35.3	11.1	5.0	3.1	8.4
5	22.7	51.6	92.1	5.1	45.2	82.6	21.5	9.4	6.3	10.6
10	27.1	65.1	111.9	6.1	58.0	101.7	25.8	11.2	7.6	11.4
25	32.0	82.2	136.4	7.6	74.0	126.4	31.3	13.3	9.0	12.5
50	35.5	107.4	171.9	8.5	98.2	160.4	34.9	14.8	10.0	13.2
75	37.4	123.6	189.0	9.1	113.7	176.7	37.0	15.6	10.5	13.5
100	38.8	134.1	200.6	9.4	123.8	187.7	38.5	16.2	10.9	13.7
1000	49.7	210.7	287.8	12.4	197.2	270.4	49.7	21.1	14.0	15.3

North Sector (from which 337.5 to 22.5 degrees) 100 Year Extremes

% of Omni	81%	N/A	34%	62%						
Value	31.3	N/A	68.8	5.8	76.5	116.0	23.8	10.0	6.8	10.7

NorthEast Sector (from which 22.5 to 67.5 degrees) 100 Year Extremes

% of Omni	92%	N/A	93%	79%						
Value	35.5	N/A	185.6	7.4	97.8	148.3	30.4	12.8	8.6	12.1

East Sector (from which 67.5 to 112.5 degrees) 100 Year Extremes

% of Omni	94%	N/A	94%	90%						
Value	36.5	N/A	188.0	8.5	111.8	169.5	34.8	14.6	9.9	13.0

SouthEast Sector (from which 112.5 to 157.5 degrees) 100 Year Extremes

% of Omni	94%	N/A	27%	94%						
Value	36.4	N/A	54.4	8.8	115.9	175.7	36.0	15.1	10.2	13.2

South Sector (from which 157.5 to 202.5 degrees) 100 Year Extremes

% of Omni	86%	N/A	10%	87%						
Value	33.2	N/A	20.5	8.2	107.8	163.5	33.5	14.1	9.5	12.7

SouthWest Sector (from which 202.5 to 247.5 degrees) 100 Year Extremes

% of Omni	75%	N/A	28%	52%						
Value	29.1	N/A	55.4	4.9	64.0	97.0	19.9	8.4	5.7	9.8

West Sector (from which 247.5 to 292.5 degrees) 100 Year Extremes

% of Omni	74%	N/A	29%	51%						
Value	28.6	N/A	58.4	4.8	62.8	95.2	19.5	8.2	5.5	9.7

NorthWest Sector (from which 292.5 to 337.5 degrees) 100 Year Extremes

% of Omni	77%	N/A	21%	58%						
Value	29.8	N/A	41.5	5.5	72.1	109.2	22.4	9.4	6.4	10.4

Table 3. GOMOS tropical extremes for maximum wind speed (m/s), maximum surge height (cm), maximum vertically integrated current speed (cm/s), and significant wave height (m) with associated surge height, vertically integrated current speed, wind speed, maximum wave height (m), wave crest height (m), and peak period (s) at the time of the maximum significant wave height.

1950-2005

OMNI Directional Extremes

RtnPer	maxWS	maxHSUR	maxCS	HSig	assHSUR	assoCS	assoWS	HMax	HCrest	TP(r)
1	12.4	16.1	40.4	2.5	14.0	36.0	10.9	5.1	3.2	8.5
5	22.1	48.1	86.0	4.7	42.0	75.4	19.9	8.8	5.9	10.5
10	25.0	61.0	104.0	5.1	54.3	92.1	20.8	10.3	6.9	11.2
25	31.6	75.9	129.7	7.0	67.1	117.3	29.0	12.6	8.5	12.5
50	36.0	114.6	172.2	8.2	104.9	152.9	33.5	14.8	10.1	13.3
75	38.3	134.4	194.3	8.9	124.1	171.5	36.0	16.1	11.0	13.7
100	40.0	147.9	209.4	9.3	137.2	184.3	37.7	16.9	11.6	14.0
1000	53.4	249.9	324.7	12.8	236.1	281.6	51.2	23.4	16.1	15.9

North Sector (from which 337.5 to 22.5 degrees) 100 Year Extremes

% of Omni	79%	N/A	24%	64%						
Value	31.8	N/A	50.0	6.0	88.2	118.5	24.2	10.9	7.4	11.2

NorthEast Sector (from which 22.5 to 67.5 degrees) 100 Year Extremes

% of Omni	96%	N/A	89%	78%						
Value	38.5	N/A	186.8	7.3	107.3	144.1	29.5	13.2	9.0	12.3

East Sector (from which 67.5 to 112.5 degrees) 100 Year Extremes

% of Omni	95%	N/A	98%	97%						
Value	37.9	N/A	205.0	9.0	132.7	178.2	36.5	16.3	11.2	13.7

SouthEast Sector (from which 112.5 to 157.5 degrees) 100 Year Extremes

% of Omni	90%	N/A	32%	93%						
Value	36.0	N/A	67.8	8.7	127.9	171.8	35.1	15.7	10.8	13.5

South Sector (from which 157.5 to 202.5 degrees) 100 Year Extremes

% of Omni	81%	N/A	12%	85%						
Value	32.4	N/A	24.5	8.0	117.2	157.4	32.2	14.4	9.9	12.9

SouthWest Sector (from which 202.5 to 247.5 degrees) 100 Year Extremes

% of Omni	64%	N/A	26%	48%						
Value	25.6	N/A	54.7	4.4	65.4	87.9	18.0	8.1	5.5	9.6

West Sector (from which 247.5 to 292.5 degrees) 100 Year Extremes

% of Omni	75%	N/A	26%	53%						
Value	29.9	N/A	54.9	4.9	72.6	97.5	19.9	8.9	6.1	10.2

NorthWest Sector (from which 292.5 to 337.5 degrees) 100 Year Extremes

% of Omni	79%	N/A	14%	60%						
Value	31.4	N/A	29.1	5.5	81.8	109.8	22.5	10.1	6.9	10.8

Table 4. GOMOS extra-tropical extremes for maximum wind speed (m/s), surge height (cm), vertically integrated current speed (cm/s) and significant wave height (m) with associated surge height, current speed, wind speed, maximum wave height (m), wave crest height (m), and peak period (s) at the time of the max sig. wave height.

OMNI Directional Extremes

RtnPer	maxWS	maxHSUR	maxCS	HSig	assHSUR	assoCS	assoWS	HMax	HCrest	TP(r)
1	15.9	6.4	41.5	3.1	n/a	26.7	14.7	5.9	3.9	7.8
5	19.2	21.0	66.4	3.9	18.8	57.4	18.4	7.4	4.9	9.1
10	20.5	25.3	72.5	4.2	22.8	63.9	19.8	8.0	5.3	9.6
25	22.2	30.9	80.2	4.6	29.9	72.0	21.7	8.7	5.8	10.3
50	23.4	34.9	85.9	4.9	34.6	77.9	23.1	9.3	6.0	10.8
100	24.7	38.7	91.5	5.2	38.7	83.7	24.5	9.8	6.4	11.2
1000	30.1	52.2	111.2	6.2	52.2	101.9	29.1	11.4	7.5	12.7

North Sector (from which 337.5 to 22.5 degrees) 100 Year Extremes

% of Omni	98%	N/A	19%	76%						
Value	24.1	N/A	17.2	3.9	29.4	63.5	18.6	7.5	4.9	9.8

NorthEast Sector (from which 22.5 to 67.5 degrees) 100 Year Extremes

% of Omni	93%	N/A	100%	81%						
Value	22.8	N/A	91.5	4.2	31.5	68.1	19.9	8.0	5.2	10.1

East Sector (from which 67.5 to 112.5 degrees) 100 Year Extremes

% of Omni	80%	N/A	45%	91%						
Value	19.7	N/A	40.7	4.7	35.1	75.9	22.2	8.9	5.8	10.7

SouthEast Sector (from which 112.5 to 157.5 degrees) 100 Year Extremes

% of Omni	73%	N/A	13%	99%						
Value	18.1	N/A	11.6	5.1	38.4	83.0	24.3	9.8	6.4	11.2

South Sector (from which 157.5 to 202.5 degrees) 100 Year Extremes

% of Omni	79%	N/A	12%	100%						
Value	19.5	N/A	11.2	5.2	38.7	83.7	24.5	9.8	6.4	11.2

SouthWest Sector (from which 202.5 to 247.5 degrees) 100 Year Extremes

% of Omni	69%	N/A	88%	62%						
Value	17.1	N/A	80.1	3.2	23.8	51.5	15.1	6.0	4.0	8.8

West Sector (from which 247.5 to 292.5 degrees) 100 Year Extremes

% of Omni	79%	N/A	34%	63%						
Value	19.4	N/A	30.7	3.3	24.4	52.7	15.4	6.2	4.1	8.9

NorthWest Sector (from which 292.5 to 337.5 degrees) 100 Year Extremes

% of Omni	98%	N/A	10%	68%						
Value	24.2	N/A	8.8	3.5	26.4	57.1	16.7	6.7	4.4	9.3

Appendix A

Tropical Storm List

Tropical Storm List

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
1900_01	NOT NAMED	190009041800	190009091200	114	936
1900_03	NOT NAMED	190009100600	190009131800	84	994
1900_06	NOT NAMED	190010081200	190010120600	90	997
1901_01	NOT NAMED	190106101200	190106141200	96	1000
1901_02	NOT NAMED	190107070000	190107101800	90	990
1901_04	NOT NAMED	190108110000	190108151800	114	973
1901_06	NOT NAMED	190109141800	190109180000	78	990
1901_08	NOT NAMED	190109241200	190109271800	78	994
1902_01	NOT NAMED	190206120600	190206141800	60	994
1902_02	NOT NAMED	190206201200	190206271200	168	966
1902_04	NOT NAMED	190210050600	190210101200	126	961
1903_02	NOT NAMED	190308120000	190308161800	114	941
1903_03	NOT NAMED	190309120000	190309140600	54	970
1904_03	NOT NAMED	190410151200	190410201800	126	983
1904_05	NOT NAMED	190410290600	190411030600	120	994
1905_03	NOT NAMED	190509241200	190509291800	126	994
1905_05	NOT NAMED	190510050600	190510100000	114	994
1906_01	NOT NAMED	190606081200	190606130000	108	994
1906_02	NOT NAMED	190606161200	190606171200	24	975
1906_05	NOT NAMED	190609230000	190609271200	108	965
1906_08	NOT NAMED	190610151800	190610221800	168	930
1907_01	NOT NAMED	190706260000	190706290600	78	990
1907_02	NOT NAMED	190709180000	190709220000	96	990
1907_03	NOT NAMED	190709270600	190709290000	42	994
1908_05	NOT NAMED	190809161200	190809181800	54	983
1909_01	NOT NAMED	190906251200	190906301200	120	990
1909_02	NOT NAMED	190906281800	190906301200	42	997
1909_03	NOT NAMED	190907171200	190907221200	120	959
1909_04	NOT NAMED	190908071800	190908110000	78	990
1909_05	NOT NAMED	190908241800	190908281200	90	941
1909_07	NOT NAMED	190909161200	190909210000	108	970
1909_08	NOT NAMED	190909241200	190909270000	60	994
1909_09	NOT NAMED	190910090000	190910111800	66	941
1910_01	NOT NAMED	191008251800	191008311800	144	990

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
1910_02	NOT NAMED	191009100000	191009150000	120	957
1910_04	NOT NAMED	191010130600	191010191200	150	941
1911_01	NOT NAMED	191108090600	191108120600	72	983
1911_04	NOT NAMED	191110260600	191111010000	138	994
1912_01	NOT NAMED	191206071200	191206131200	144	990
1912_03	NOT NAMED	191209111200	191209140600	66	975
1912_05	NOT NAMED	191210111200	191210171800	150	961
1913_01	NOT NAMED	191306241800	191306281200	90	961
1914_01	NOT NAMED	191409170000	191409191200	60	997
1915_02	NOT NAMED	191508140000	191508180000	96	941
1915_04	NOT NAMED	191509011800	191509041200	66	966
1915_05	NOT NAMED	191509261200	191509300000	84	935
1916_01	NOT NAMED	191607021200	191607060000	84	961
1916_04	NOT NAMED	191608161200	191608190000	60	941
1916_13	NOT NAMED	191610150600	191610181200	78	946
1916_14	NOT NAMED	191611131800	191611151800	48	975
1917_03	NOT NAMED	191709241800	191709290000	102	941
1918_01	NOT NAMED	191808041200	191808061800	54	960
1919_01	NOT NAMED	191907020600	191907041200	54	990
1919_02	NOT NAMED	191909091800	191909150000	126	930
1920_02	NOT NAMED	192009191200	192009220000	60	980
1920_04	NOT NAMED	192009250600	192009301200	126	975
1921_01	NOT NAMED	192106180600	192106230600	120	954
1921_02	NOT NAMED	192109060600	192109080600	48	975
1921_06	NOT NAMED	192110221800	192110260600	84	946
1922_01	NOT NAMED	192206131200	192206161800	78	994
1922_03	NOT NAMED	192210121800	192210171200	114	994
1922_04	NOT NAMED	192210151800	192210220600	156	961
1923_03	NOT NAMED	192310131800	192310160600	60	976
1923_06	NOT NAMED	192310161200	192310180000	36	994
1924_01	NOT NAMED	192406181800	192406211800	72	997
1924_04	NOT NAMED	192409130000	192409160600	78	988
1924_05	NOT NAMED	192409280000	192409300000	48	990
1924_06	NOT NAMED	192410120600	192410141200	54	990
1924_07	NOT NAMED	192410170600	192410221200	126	946

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
1925_01	NOT NAMED	192509060000	192509071800	42	997
1925_02	NOT NAMED	192511291800	192512011200	42	979
1926_03	NOT NAMED	192608220000	192608261800	114	959
1926_06	NOT NAMED	192609181200	192609221200	96	935
1926_10	NOT NAMED	192610190600	192610210000	42	941
1928_02	NOT NAMED	192808121800	192808141800	48	987
1928_03	NOT NAMED	192809030600	192809081800	132	990
1929_01	NOT NAMED	192906270000	192906291200	60	969
1929_02	NOT NAMED	192909281200	192910010600	66	951
1930_02	NOT NAMED	193009060000	193009101800	114	997
1931_01	NOT NAMED	193106250000	193106281800	90	997
1931_02	NOT_NAMED	193107121200	193107160000	84	987
1931_03	NOT_NAMED	193108170600	193108181800	36	994
1931_05	NOT_NAMED	193109110000	193109121800	42	983
1931_06	NOT NAMED	193109131200	193109161800	78	983
1932_02	NOT NAMED	193208120000	193208141800	66	942
1932_03	NOT NAMED	193208300600	193209010600	48	975
1932_05	NOT NAMED	193209090600	193209150600	144	994
1932_06	NOT NAMED	193209180600	193209200000	42	1000
1932_07	NOT_NAMED	193209300600	193210031800	84	998
1932_08	NOT_NAMED	193210100600	193210160600	144	991
1933_01	NOT NAMED	193305151800	193305191800	96	997
1933_02	NOT NAMED	193307020600	193307070600	120	972
1933_03	NOT NAMED	193307170600	193307200600	72	994
1933_04	NOT NAMED	193307210600	193307231800	60	997
1933_05	NOT NAMED	193307301800	193308051800	144	975
1933_06	NOT NAMED	193308170000	193308201200	84	997
1933_10	NOT NAMED	193308261800	193308291800	72	1000
1933_11	NOT NAMED	193309011200	193309051800	102	949
1933_12	NOT NAMED	193309040600	193309060000	42	948
1933_14	NOT_NAMED	193309121800	193309151800	72	984
1933_15	NOT NAMED	193309201800	193309250000	102	967
1933_18	NOT NAMED	193310030000	193310050600	54	941
1934_01	NOT NAMED	193405270600	193405281200	30	997
1934_02	NOT_NAMED	193406081800	193406170000	198	966

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
1934_03	NOT NAMED	193407230000	193407260600	78	979
1934_05	NOT NAMED	193408260600	193409011800	156	975
1934_09	NOT NAMED	193410011200	193410060600	114	990
1935_02	NOT NAMED	193509030000	193509050000	48	892
1935_03	NOT NAMED	193508301200	193509011800	54	997
1935_06	NOT NAMED	193511041800	193511081800	96	973
1936_01	NOT_NAMED	193606121200	193606151200	72	994
1936_02	NOT NAMED	193606190600	193606220600	72	1000
1936_03	NOT NAMED	193606261800	193606280600	36	975
1936_04	NOT NAMED	193607260600	193607271200	30	997
1936_05	NOT NAMED	193607290600	193607311800	60	964
1936_07	NOT NAMED	193608070600	193608121800	132	1000
1936_08	NOT NAMED	193608150600	193608191800	108	988
1936_10	NOT NAMED	193608280600	193608301800	60	988
1936_14	NOT NAMED	193609100600	193609141200	102	997
1936_16	NOT NAMED	193610091800	193610110000	30	1000
1937_01	NOT NAMED	193707291200	193707301200	24	997
1937_06	NOT NAMED	193709161200	193709211800	126	997
1937_09	NOT NAMED	193709291200	193710031800	102	1000
1938_02	NOT_NAMED	193808121200	193808150600	66	971
1938_03	NOT NAMED	193808250000	193808281200	84	976
1938_05	NOT_NAMED	193810111200	193810171800	150	987
1938_07	NOT NAMED	193810230600	193810240600	24	997
1939_01	NOT_NAMED	193906121200	193906161200	96	991
1939_02	NOT NAMED	193908111800	193908140000	54	975
1939_03	NOT NAMED	193909230600	193909261800	84	997
1940_02	NOT NAMED	194008021800	194008081800	144	972
1940_06	NOT_NAMED	194009210000	194009250000	96	994
1941_01	NOT NAMED	194109110600	194109161800	132	997
1941_02	NOT NAMED	194109161200	194109240000	180	959
1941_05	NOT NAMED	194110061200	194110071200	24	937
1941_06	NOT NAMED	194110171200	194110220600	114	994
1942_01	NOT NAMED	194208171800	194208221800	120	975
1942_02	NOT_NAMED	194208261800	194208310000	102	948
1942_10	NOT_NAMED	194211071200	194211111800	102	969

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
1943_01	NOT NAMED	194307251800	194307290000	78	975
1943_06	NOT NAMED	194309151800	194309200600	108	961
1944_04	NOT_NAMED	194408211200	194408240600	66	977
1944_05	NOT NAMED	194408191800	194408230600	84	990
1944_06	NOT NAMED	194409090000	194409101800	42	994
1944_08	NOT NAMED	194409190600	194409211800	60	975
1944_11	NOT NAMED	194410140600	194410191800	132	942
1945_01	NOT NAMED	194506201800	194506250000	102	965
1945_02	NOT NAMED	194507190600	194507220600	72	994
1945_05	NOT NAMED	194508240600	194508290000	114	966
1945_07	NOT NAMED	194509031800	194509060600	60	1000
1946_01	NOT NAMED	194606131800	194606161800	72	1000
1946_03	NOT NAMED	194608250000	194608260000	24	1000
1946_05	NOT NAMED	194610050600	194610081200	78	979
1947_01	NOT NAMED	194707310600	194708021200	54	997
1947_02	NOT NAMED	194708120000	194708160600	102	967
1947_03	NOT NAMED	194708181800	194708260600	180	983
1947_04	NOT NAMED	194709180000	194709200000	48	966
1947_05	NOT NAMED	194709071800	194709081800	24	997
1947_06	NOT NAMED	194709210000	194709240000	72	989
1947_08	NOT NAMED	194710101200	194710120600	42	970
1948_02	NOT NAMED	194807071800	194807091200	42	1000
1948_05	NOT NAMED	194809011800	194809041200	66	990
1948_07	NOT NAMED	194809181800	194809221200	90	935
1948_08	NOT NAMED	194810040600	194810060000	42	930
1949_05	NOT NAMED	194909030600	194909041800	36	997
1949_08	NOT NAMED	194909201200	194909261800	150	976
1949_10	NOT_NAMED	194910010000	194910041800	90	963
1950_02	BAKER	195008260000	195008310600	126	979
1950_05	EASY	195009010600	195009070600	144	958
1950_08	HOW	195010010600	195010041800	84	990
1950_09	ITEM	195010080600	195010101800	60	967
1950_13	LOVE	195010180000	195010211800	90	966
1951_03	CHARLIE	195108181200	195108231800	126	946
1951_07	GEORGE	195109200600	195109211800	36	990

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
1951_08	HOW	195109280600	195110021800	108	983
1952_01	NOT NAMED	195202021200	195202030600	18	994
1953_01	ALICE	195305291800	195306061800	192	983
1953_03	NOT NAMED	195308281800	195308291800	24	985
1953_07	NOT NAMED	195309140600	195309201800	156	983
1953_08	FLORENCE	195309240600	195309270000	66	968
1953_12	HAZEL	195310070600	195310091800	60	983
1954_01	ALICE	195406241200	195406260600	42	988
1954_02	BARBARA	195407270600	195407300600	72	997
1954_06	FLORENCE	195409110600	195409121800	36	979
1955_01	BRENDA	195507311800	195508020000	30	983
1955_05	NOT NAMED	195508231200	195508280600	114	997
1955_07	GLADYS	195509041200	195509061800	54	980
1955_08	HILDA	195509150000	195509200600	126	951
1955_10	JANET	195509280000	195509300600	54	950
1956_01	NOT NAMED	195606120000	195606140000	48	990
1956_02	ANNA	195607251800	195607270600	36	979
1956_05	DORA	195609100600	195609121800	60	983
1956_07	FLOSSY	195609211200	195609250600	90	979
1957_01	NOT NAMED	195706080600	195706090000	18	1000
1957_02	AUDREY	195706250000	195706271800	66	946
1957_03	BERTHA	195708081800	195708101200	42	996
1957_05	DEBBIE	195709070600	195709081800	36	1000
1957_06	ESTHER	195709161800	195709181800	48	994
1958_01	ALMA	195806140600	195806151800	36	994
1958_05	ELLA	195809030000	195809061200	84	983
1959_01	ARLENE	195905281200	195905311200	72	1000
1959_02	BEULAH	195906151800	195906181800	72	987
1959_05	DEBRA	195907230000	195907260000	72	984
1959_10	IRENE	195910061800	195910081200	42	994
1959_11	JUDITH	195910171200	195910181800	30	991
1960_01	NOT NAMED	196006220600	196006261200	102	997
1960_05	DONNA	196009100000	196009111200	36	932
1960_06	ETHEL	196009141200	196009160000	36	972
1961_03	CARLA	196109060600	196109121200	150	931

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
1961_11	INGA	196111050000	196111081200	84	983
1963_04	CINDY	196309161200	196309200000	84	996
1964_03	ABBY	196408051800	196408081800	72	1000
1964_10	HILDA	196409281200	196410051800	174	942
1964_11	ISBELL	196410101200	196410150000	108	964
1965_01	NOT NAMED	196506121800	196506151200	66	994
1965_03	BETSY	196509081200	196509101200	48	941
1965_05	DEBBIE	196509241800	196509300000	126	1000
1966_01	ALMA	196606061200	196606100600	90	970
1966_08	HALLIE	196609201200	196609220000	36	994
1966_09	INEZ	196610020000	196610110600	222	948
1967_02	BEULAH	196709151200	196709221200	168	923
1967_06	FERN	196710011800	196710041800	72	987
1968_01	ABBY	196806011800	196806070000	126	992
1968_03	CANDY	196806221800	196806240000	30	997
1968_08	GLADYS	196810150000	196810191200	108	965
1969_03	CAMILLE	196908140600	196908180600	96	908
1969_12	SUBTROP 1	196909291200	196910011800	54	990
1969_13	JENNY	196910011200	196910061800	126	1000
1969_15	LAURIE	196910171800	196910270600	228	957
1970_01	ALMA	197005210000	197005251200	108	998
1970_02	BECKY	197007190000	197007221200	84	987
1970_03	CELIA	197007310000	197008040600	102	944
1970_06	ELLA	197009091800	197009130000	78	967
1970_07	FELICE	197009131200	197009161200	72	998
1971_06	EDITH	197109110600	197109161200	126	977
1971_07	FERN	197109031200	197109121800	222	979
1972_01	ALPHA	197205271800	197205291200	42	996
1972_02	AGNES	197206141200	197206200000	132	978
1973_03	BRENDA	197308180600	197308211200	78	977
1973_05	DELIA	197309011800	197309061800	120	987
1974_06	CARMEN	197409020000	197409091200	180	928
1975_03	CAROLINE	197508261200	197509011200	144	963
1975_05	ELOISE	197509191800	197509231200	90	955
1976_01	SUBTROP 1	197605211200	197605240000	60	998

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
1976_05	DOTTIE	197608180000	197608201200	60	1000
1977_01	ANITA	197708291200	197709021800	102	926
1977_02	BABE	197709030600	197709060600	72	995
1978_05	DEBRA	197808261200	197808290000	60	1000
1979_02	BOB	197907091200	197907111200	48	986
1979_03	CLAUDETTE	197907210000	197907261200	132	997
1979_06	FREDERIC	197909081800	197909130600	108	943
1979_08	HENRI	197909150000	197909241200	228	983
1980_01	ALLEN	198008061800	198008110000	102	899
1980_08	HERMINE	198009221800	198009241800	48	993
1980_10	JEANNE	198011081800	198011160600	180	986
1981_04	DENNIS	198108150600	198108191200	102	998
1982_01	ALBERTO	198206021200	198206061200	96	985
1982_04	CHRIS	198209090000	198209111800	66	994
1983_01	ALICIA	198308151200	198308181800	78	962
1983_02	BARRY	198308251200	198308290600	90	986
1985_04	DANNY	198508120000	198508160000	96	987
1985_05	ELENA	198508281800	198509021800	120	953
1985_10	JUAN	198510260000	198510311800	138	971
1985_11	KATE	198511191200	198511220000	60	954
1986_02	BONNIE	198606231800	198606261800	72	990
1987_07	FLOYD	198710110600	198710121800	36	993
1988_02	BERYL	198808080000	198808100600	54	1000
1988_04	DEBBY	198808311800	198809031800	72	987
1988_07	FLORENCE	198809070600	198809101200	78	982
1988_08	GILBERT	198809131200	198809170600	90	888
1988_12	KEITH	198811201800	198811231200	66	985
1989_01	ALLISON	198906241800	198906301200	138	999
1989_03	CHANTAL	198907301200	198908020000	60	984
1989_10	JERRY	198910121200	198910160600	90	983
1990_04	DIANA	199008051200	199008080600	66	980
1990_13	MARCO	199010091800	199010120600	60	991
1992_02	ANDREW	199208240900	199208261800	57	932
1993_01	ARLENE	199306180000	199306210600	78	1000
1993_07	GERT	199309180600	199309210000	66	970

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
1994_01	ALBERTO	199406300600	199407031800	84	993
1994_02	BERYL	199408141200	199408160600	42	999
1994_07	GORDON	199411150600	199411210600	144	995
1995_01	ALLISON	199506030600	199506051800	60	988
1995_04	DEAN	199507281800	199507311800	72	999
1995_05	ERIN	199508020600	199508031800	36	974
1995_07	GABRIELLE	199508091800	199508120000	54	990
1995_15	OPAL	199509271800	199510050000	174	916
1995_17	ROXANNE	199510091800	199510210000	270	958
1996_04	DOLLY	199608191800	199608231800	96	989
1996_10	JOSEPHINE	199610041800	199610080600	84	981
1997_05	DANNY	199707161200	199707210000	108	984
1998_05	EARL	199808311200	199809030600	66	977
1998_06	FRANCES	199809081800	199809121200	90	990
1998_07	GEORGES	199809250600	199810010600	144	961
1998_08	HERMINE	199809171200	199809201800	78	997
1998_13	MITCH	199811021800	199811051200	66	987
1999_02	BRET	199908181800	199908240000	126	941
1999_08	HARVEY	199909190600	199909211800	60	995
1999_09	IRENE	199910131200	199910161200	72	982
2000_02	BERYL	200008131800	200008151800	48	1006
2000_07	GORDON	200009141200	200009181200	96	982
2000_08	HELENE	200009200000	200009221200	60	996
2000_11	KEITH	200010030600	200010060600	72	980
2001_01	ALLISON	200106051200	200106111800	150	1000
2001_02	BARRY	200108021200	200108060600	90	990
2001_07	GABRIELLE	200109111800	200109151200	90	989
2002_02	BERTHA	200208041800	200208091200	114	1008
2002_05	EDOUARD	200209041800	200209061200	42	1008
2002_06	FAY	200209051800	200209101200	114	997
2002_09	HANNA	200209120000	200209150000	72	1001
2002_10	ISIDORE	200209190600	200209261200	174	934
2002_13	LILI	200209301800	200210031800	72	940
2003_02	BILL	200306280600	200307010000	66	997
2003_03	CLAUDETTE	200307101800	200307160600	132	980

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
2003_05	ERIKA	200308141800	200308161800	48	988
2003_07	GRACE	200308301200	200309010000	36	1006
2003_08	HENRI	200309031800	200309061800	72	997
2003_12	LARRY	200309271800	200310051800	192	993
2004_02	BONNIE	200408071800	200408121800	120	1001
2004_03	CHARLEY	200408121200	200408140600	42	947
2004_06	FRANCES	200409050600	200409070000	42	960
2004_09	IVAN	200409120600	200409240600	288	910
2004_10	JEANNE	200409260600	200409270600	24	953
2004_13	MATTHEW	200410081200	200410101800	54	998
2005_01	ARLENE	200506090600	200506111800	60	990
2005_02	BRET	200506281800	200506300000	30	1005
2005_03	CINDY	200507031800	200507061200	66	992
2005_04	DENNIS	200507081800	200507101800	48	928
2005_05	EMILY	200507171200	200507210000	84	944
2005_07	GERT	200507231800	200507251200	42	1004
2005_11	JOSE	200508221200	200508231200	24	998
2005_12	KATRINA	200508260000	200508291500	87	902
2005_18	RITA	200509201200	200509241200	96	898
2005_20	STAN	200509301800	200510041200	90	979
2005_24	WILMA	200510200600	200510241200	102	901

Appendix B

Storm Peak Table

Storm Peaks Table

This table summarizes the peak wind speed, significant wave height (with associated parameters), surge height, and current speed hindcast. Tides are not included. A minimum threshold for wave height may have been applied, thus grid point locations below a threshold may not report maximum conditions. The header line is as follows:

```
                    max  asso  (               max                                         )   max   max  asso
 ccyymm  ddhhmm      ws    wd     ws    wd      hs      ts  .74*tp   vmd   hsur    cs    cd   hsur    cs    cd    wave   crest   w/hs   c/hs storm ID        storm name
                  -----------  ------------------------------------------------------------  -----   ---------
```

Column	Description
ccyymm	Time of peak wave height given in Century-Year-Month (GMT)
ddhhnn	Time of peak wave height given in Day-Hour-Minute (GMT)
max ws	Maximum 1-hour average (non-tropical) wind speed (m/s) at 10-meter reference height (neutral wind), exact time of peak not given
asso wd	Wind direction associated with maximum wind speed (degrees, from which)
Ws	1-hour average wind speed (m/s) at 10 meter reference height (neutral wind) associated at time of maximum wave height
Wd	Wind direction associated at time of maximum wave height (degrees, from which)
max hs	Maximum significant wave height (meters)
Ts	Significant wave period associated at time of maximum wave height (seconds)
.74*tp	Peak wave period * .74 associated at time of maximum wave height (seconds) Approximation for mean period needed for HCrest computation. (÷ 0.74 to restore TP)
Vmd	Vector mean wave direction associated at time of maximum wave height (deg, to which)
Hsur	Surge height with respect to still water associated at time of maximum wave height (cm)
Cs	Vertically integrated current speed associated at time of maximum wave height (cm/sec)
Cd	Vertically integrated current direction associated at time of maximum wave height (degrees, to which)
max hsur	Maximum surge height with respect to still water (cm), exact time of peak not given
max cs	Maximum vertically integrated current speed (cm/sec), exact time of peak not given
Assoc cd	Vertically integrated current direction associated at time of maximum current speed (degrees, to which)
wave	Maximum Individual Wave Height (m) computed using Forristall (1978)
crest	Maximum Crest Height (m) computed using Haring and Heideman (1978)
w/hs	Ratio of Maximum Individual Wave/Significant Wave Height
c/hs	Ratio of Crest/Significant Wave Height
Storm ID	Storm year, season storm number, and basin identifier
Stm Name	Hurricane center storm name or “Not Named”

```
                    max  asso  (               max                                          )   max   max  asso
ccyymm  ddhhmm       ws    wd     ws    wd      hs      ts  .74*tp   vmd    hsur    cs    cd   hsur    cs    cd    wave   crest   w/hs   c/hs storm ID         storm name
                   -----------  -------------------------------------------------------------  -----   ---------

   Grid Point   8832, Lat  28.5000, Long  -95.1250, Depth    30.50m,  228 events
194109. 231830.   35.88 132.6  35.88 132.6    8.471   9.188    9.315 323.2  131.1 136.6 263.4  132.3 145.9 255.9  15.011  10.234 1.7720 1.2081 1941_02_NOATL   NOT NAMED
194910.  40630.   33.37 137.4  32.81 156.2    8.373   9.574    9.633 340.4   99.0  62.9 263.2  103.6  79.6 257.3  14.016   9.590 1.6740 1.1454 1949_10_NOATL   NOT_NAMED
196109. 111800.   31.71 100.8  31.24 111.3    8.228   9.467    9.918 313.5  130.9 105.3 244.7  139.7 174.2 245.3  15.489  10.546 1.8825 1.2817 1961_03_NOATL   CARLA
192106. 221730.   26.11 134.2  25.96 142.8    6.749   8.739    8.541 336.5   60.3  37.9 232.0   65.0  56.3 251.1  12.109   8.347 1.7942 1.2368 1921_01_NOATL   NOT NAMED
191508. 170530.   31.30 317.9  31.09 308.9    6.557   8.531    7.806 175.4   67.7 113.0 218.5   88.5 113.3 215.8  11.287   7.774 1.7214 1.1856 1915_02_NOATL   NOT NAMED
194208. 300430.   26.14  90.2  25.48 104.0    6.555   8.692    9.251 297.5   72.3 113.6 249.0   73.6 113.6 249.0  11.175   7.614 1.7048 1.1616 1942_02_NOATL   NOT_NAMED
191608. 190000.   23.63  79.9  18.99 100.0    5.835   8.855    8.664 300.7   60.5  93.6 241.7   63.3 103.0 241.9  10.554   7.224 1.8088 1.2381 1916_04_NOATL   NOT NAMED
194508. 271800.   25.36 128.0  25.35 132.1    5.786   7.810    7.685 322.3   52.2  59.0 239.1   53.0  62.0 244.0  10.869   7.471 1.8785 1.2913 1945_05_NOATL   NOT NAMED
199809. 110530.   19.96 135.4  19.90 135.0    5.779   8.406    8.233 315.6   63.3  76.8 239.9   63.9  77.2 240.4  10.606   7.272 1.8352 1.2584 1998_06_NOATL   FRANCES
190107. 100800.   22.42 108.4  22.02 119.7    5.721   8.376    8.597 303.0   45.7  80.4 247.4   46.6  80.5 247.3   9.750   6.576 1.7042 1.1495 1901_02_NOATL   NOT NAMED
198008.  91200.   19.57  95.1  19.07  83.4    5.666   8.578   11.459 292.1   55.3  89.1 242.3   60.2  92.7 242.5  10.485   7.156 1.8505 1.2630 1980_01_NOATL   ALLEN
200307. 151030.   27.51 135.1  27.21 101.6    5.662   7.821    7.635 288.5   65.7 136.3 245.4   70.1 138.0 247.3  10.265   7.008 1.8129 1.2378 2003_03_NOATL   CLAUDETTE
198308. 180100.   28.70   2.5  28.70   2.5    5.498   7.608    7.316 218.0   48.2 144.9 227.4   48.6 146.5 225.7   9.775   6.648 1.7779 1.2092 1983_01_NOATL   ALICIA
197109. 100330.   27.33  58.2  27.04  72.7    5.490   7.545    7.183 266.1   61.4 135.2 244.3   64.5 140.1 247.1   9.881   6.739 1.7999 1.2276 1971_07_NOATL   FERN
190907. 211900.   27.77 321.5  27.17 314.3    5.463   8.114    7.574 187.0   65.0 113.7 223.2   72.6 113.7 223.2   9.356   6.293 1.7126 1.1519 1909_03_NOATL   NOT NAMED
193407. 251200.   25.06  48.4  24.85  64.0    5.446   7.680    7.638 258.7   50.8 132.4 238.4   54.5 137.4 241.4   9.682   6.561 1.7778 1.2048 1934_03_NOATL   NOT NAMED
198809. 161930.   16.32  68.7  13.24 111.5    5.342   9.475   10.088 312.8   43.3  71.4 241.0   46.4  82.5 241.3  10.012   6.794 1.8741 1.2717 1988_08_NOATL   GILBERT
191909. 141300.   23.68  58.0  22.92  69.5    5.223   7.797    7.213 274.1   75.4 130.7 245.0   78.1 132.5 243.8   9.783   6.678 1.8730 1.2785 1919_02_NOATL   NOT NAMED
192906. 282000.   21.17 100.4  20.60 111.7    5.173   7.915    7.806 310.5   49.0  69.3 249.1   50.0  73.1 249.3   9.365   6.330 1.8103 1.2237 1929_01_NOATL   NOT NAMED
193307. 230300.   21.30 134.9  21.26 141.3    5.117   7.693    7.706 324.5   40.1  54.2 254.8   40.1  57.2 252.7   9.156   6.164 1.7894 1.2046 1933_04_NOATL   NOT NAMED
194009. 231600.   20.30 112.5  19.08 128.4    4.930   7.759    7.765 322.3   37.8  52.3 257.3   38.2  52.5 257.4   8.579   5.711 1.7401 1.1584 1940_06_NOATL   NOT_NAMED
190206. 270100.   18.99 150.4  18.25 164.0    4.795   7.684    7.658 356.4   18.8  12.4  62.2   23.3  22.0  72.3   8.826   5.930 1.8406 1.2367 1902_02_NOATL   NOT NAMED
191210. 151430.   23.13  64.9  22.22  66.0    4.784   7.494    6.947 268.3   43.3  98.6 243.4   49.2 100.1 243.1   9.007   6.104 1.8828 1.2759 1912_05_NOATL   NOT NAMED
193208. 132300.   25.55 305.9  25.40 315.2    4.649   7.647    8.344 203.5   48.0 100.6 223.3   48.0 101.6 221.1   8.125   5.365 1.7477 1.1541 1932_02_NOATL   NOT NAMED
195809.  60600.   17.78  80.0  16.84  97.2    4.643   7.923    7.897 293.5   45.5  81.0 243.2   45.7  81.5 243.0   8.182   5.422 1.7622 1.1678 1958_05_NOATL   ELLA
194309. 170530.   22.13  64.3  22.12  65.3    4.590   7.316    6.637 279.1   50.5  96.9 248.4   52.0  97.4 247.7   8.520   5.733 1.8563 1.2490 1943_06_NOATL   NOT NAMED
193408. 281500.   25.05 120.6  24.49 107.1    4.530   6.837    6.331 310.2   25.6  85.4 258.8   31.9  89.2 259.4   8.505   5.719 1.8776 1.2625 1934_05_NOATL   NOT NAMED
195907. 241230.   22.56 255.0  21.77 133.6    4.462   6.966    6.734 311.3   45.2  91.7 254.0   45.4  98.4 249.3   8.288   5.533 1.8575 1.2401 1959_05_NOATL   DEBRA
193309.  41900.   19.88  51.5  19.36  64.3    4.311   7.375    6.451 274.2   54.0  99.9 244.0   55.4 101.5 243.1   8.234   5.523 1.9099 1.2810 1933_11_NOATL   NOT NAMED
190908. 271230.   19.05  77.0  18.83  77.0    4.251   7.505    6.755 282.7   36.8  74.3 242.9   40.1  79.2 242.4   7.947   5.298 1.8695 1.2464 1909_05_NOATL   NOT NAMED
197109. 160200.   19.89  82.0  19.73  89.1    4.181   7.505    6.697 313.3   36.0  43.5 248.4   40.1  78.9 230.9   7.336   4.812 1.7547 1.1508 1971_06_NOATL   EDITH
195706. 270900.   22.82 346.4  22.52 336.5    4.180   7.268    5.971 215.0   40.1  79.0 232.9   42.6  80.6 231.6   7.417   4.920 1.7745 1.1771 1957_02_NOATL   AUDREY
200509. 240030.   21.12 338.8  20.89 337.2    4.177   6.431    5.445 203.7   32.9  72.2 234.9   48.2  73.2 235.3   7.597   5.050 1.8188 1.2090 2005_18_NOATL   RITA
197008.  31830.   18.15  88.2  17.51 100.0    4.156   7.227    6.986 296.3   33.8  64.1 248.1   36.9  64.6 247.7   7.488   4.921 1.8018 1.1841 1970_03_NOATL   CELIA
190009.  82330.   24.28 295.3  24.28 295.3    4.049   7.000    5.515 168.7   40.5  65.7 229.1   76.0  71.6 233.3   7.199   4.762 1.7780 1.1762 1900_01_NOATL   NOT NAMED
193308.  50200.   14.13  92.8  12.64 104.5    4.047   7.837    7.718 307.6   28.9  35.3 242.7   39.8  74.3 241.2   7.686   5.073 1.8991 1.2535 1933_05_NOATL   NOT NAMED
197309.  60100.   20.59 344.3  19.29 109.5    3.972   6.846    6.542 301.8   31.5  57.0 249.7   58.5  94.4 229.7   7.450   4.922 1.8756 1.2393 1973_05_NOATL   DELIA
194507. 210200.   20.28  44.2  20.20  52.0    3.852   6.508    6.233 250.9   33.8  99.2 234.6   34.8 103.1 237.9   7.267   4.775 1.8866 1.2397 1945_02_NOATL   NOT NAMED
196709. 201930.   15.71  91.8  13.85 100.3    3.829   7.504    7.856 307.7   30.5  50.4 238.9   31.9  51.2 240.8   7.475   4.935 1.9523 1.2888 1967_02_NOATL   BEULAH
193606. 271630.   16.05 109.8  15.44 129.4    3.781   7.022    6.397 327.0   18.3  22.6 242.5   21.3  35.8 248.9   7.162   4.704 1.8942 1.2441 1936_03_NOATL   NOT NAMED
198910. 151930.   20.38  39.0  19.77  37.6    3.777   6.902    6.123 258.8   49.4  88.0 237.0   52.3  98.0 228.7   6.481   4.183 1.7158 1.1074 1989_10_NOATL   JERRY
200209.  70830.   15.95  59.2  15.03 152.0    3.566   6.852    6.504 316.6   30.6  73.6 232.7   33.5  84.3 238.2   6.496   4.200 1.8217 1.1779 2002_06_NOATL   FAY
196806. 240130.   14.49 115.3  13.89 127.7    3.555   7.091    6.618 314.7   15.3  34.7 237.3   16.1  35.8 237.4   6.413   4.136 1.8038 1.1635 1968_03_NOATL   CANDY
200106.  51600.   15.54 222.0  14.30 114.5    3.483   6.994    6.943 306.9   18.1  31.2 243.0   19.9  35.7 239.1   6.032   3.830 1.7318 1.0997 2001_01_NOATL   ALLISON
200507. 200600.   12.40  92.2  12.00 100.0    3.358   7.346    6.858 300.3   20.8  44.0 243.5   21.2  44.3 243.3   6.355   4.081 1.8925 1.2152 2005_05_NOATL   EMILY
197709.  20100.   13.69  79.8  13.36  81.0    3.358   7.020    7.708 287.6   29.5  49.2 240.4   31.3  56.3 240.7   6.483   4.173 1.9306 1.2427 1977_01_NOATL   ANITA
198510. 281930.   21.49 318.7  20.69 321.1    3.323   5.923    5.275 148.4   10.1  14.5  45.9   28.2  56.7 239.4   6.356   4.125 1.9126 1.2415 1985_10_NOATL   JUAN
191009. 141030.   15.43  62.8  15.27  68.1    3.322   6.774    5.750 276.4   31.5  69.7 242.9   31.9  70.7 242.3   6.335   4.106 1.9069 1.2360 1910_02_NOATL   NOT NAMED
199610.  60830.   15.73  42.6  15.28  42.9    3.303   6.633    5.797 251.7   35.7  78.1 238.7   35.9  79.3 238.8   6.313   4.092 1.9112 1.2387 1996_10_NOATL   JOSEPHINE
198906. 261000.   14.80 177.8  14.75 147.9    3.295   6.396    5.938 327.5   17.2  25.9 243.7   17.5  26.7 240.5   6.282   4.052 1.9065 1.2298 1989_01_NOATL   ALLISON
191306. 271900.   12.60  78.9  11.52  96.1    3.232   7.379    8.050 296.7   20.9  39.2 243.7   21.1  39.3 243.6   6.081   3.868 1.8815 1.1967 1913_01_NOATL   NOT NAMED
190906. 291600.   13.95  72.5  13.56  81.0    3.210   6.710    6.957 284.8   30.5  52.2 246.4   31.9  61.2 242.4   6.115   3.903 1.9051 1.2158 1909_01_NOATL   NOT NAMED
192310. 150030.   13.79  71.7  13.10  79.2    3.157   6.772    6.988 284.2   24.0  46.3 243.1   27.5  48.2 243.5   6.220   3.999 1.9702 1.2669 1923_03_NOATL   NOT NAMED
190609. 271300.   20.50 330.3  19.92 330.3    3.099   5.756    5.079 161.7  -11.1   4.9 189.4   16.9  36.1 238.3   5.769   3.687 1.8617 1.1898 1906_05_NOATL   NOT NAMED
198011. 140100.   11.53  54.9  10.44  82.5    3.043   7.175    8.322 284.1   28.7  55.2 239.9   28.9  56.0 239.6   5.864   3.719 1.9271 1.2221 1980_10_NOATL   JEANNE
192609. 201430.   19.64 330.9  19.18 330.3    2.997   5.676    4.981 161.9  -31.3  19.9  69.9    1.3  64.7  64.3   5.758   3.686 1.9212 1.2301 1926_06_NOATL   NOT NAMED
196309. 170400.   15.70  26.0  15.51  18.6    2.970   6.352    5.586 239.9   32.9  82.1 235.5   33.7  88.5 233.0   5.534   3.518 1.8633 1.1844 1963_04_NOATL   CINDY
199306. 200600.   11.76  93.4   9.36 119.1    2.932   6.971    6.471 303.5   22.1  45.5 235.1   22.4  47.1 239.2   5.744   3.667 1.9590 1.2508 1993_01_NOATL   ARLENE
190308. 151530.   12.54  91.4  11.61  91.6    2.928   6.763    6.195 290.3   17.7  41.1 241.1   18.4  41.5 241.1   5.611   3.563 1.9162 1.2170 1903_02_NOATL   NOT NAMED
193307.  60330.   11.08  73.4  10.51  75.0    2.925   7.122    8.021 279.1   23.7  50.9 240.7   26.7  52.3 241.3   5.441   3.404 1.8600 1.1637 1933_02_NOATL   NOT NAMED
196006. 240830.   11.44 143.5  11.40 144.0    2.889   6.763    6.818 339.8    7.3   9.1 238.6    7.6  12.0 231.3   5.423   3.408 1.8772 1.1797 1960_01_NOATL   NOT NAMED
197909. 181230.   12.62  21.1  10.58  91.1    2.887   6.906    7.126 292.2   20.8  44.5 240.7   21.0  44.6 240.6   5.579   3.532 1.9326 1.2233 1979_08_NOATL   HENRI
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197907. 260330.  13.33 206.4  12.81 201.8    2.868    6.223    5.353   2.8    14.2  20.1 212.9    31.1  59.1 235.8    5.623    3.593 1.9605 1.2527 1979_03_NOATL   CLAUDETTE
197808. 281130.  10.50  85.9   9.90  76.0    2.815    7.069    6.938 295.1    21.3  41.3 237.3    22.7  48.0 233.9    5.174    3.232 1.8379 1.1483 1978_05_NOATL   DEBRA
195010.  31400.  12.76  50.3  12.50  57.1    2.804    6.374    7.775 265.8    28.4  62.8 241.0    28.9  62.8 241.0    5.279    3.292 1.8828 1.1739 1950_08_NOATL   HOW
200308. 160530.  12.53  65.1  11.43  77.3    2.793    6.651    7.612 272.7    16.7  52.4 241.2    17.3  52.9 241.4    5.235    3.288 1.8745 1.1771 2003_05_NOATL   ERIKA
197509. 230030.  16.78   0.8  16.49   0.2    2.750    5.672    5.050 201.6     3.5  34.3 241.1     8.7  39.9 240.1    5.106    3.216 1.8568 1.1694 1975_05_NOATL   ELOISE
200209. 250030.  15.94   8.6  13.85  40.4    2.741    6.178    5.076 252.4    29.4  59.8 239.7    33.3  61.1 238.6    5.448    3.480 1.9876 1.2696 2002_10_NOATL   ISIDORE
193106. 272200.  10.79 101.7  10.77 106.5    2.727    6.701    6.935 304.9    13.0  27.1 246.0    13.1  28.1 245.0    5.208    3.261 1.9098 1.1958 1931_01_NOATL   NOT NAMED
194708.  20400.  11.46  91.0   9.64 105.6    2.716    6.783    6.443 311.6    13.0  28.4 241.6    14.1  31.5 242.5    5.201    3.270 1.9149 1.2041 1947_01_NOATL   NOT NAMED
194909. 220630.  12.88  26.5  11.07  84.2    2.694    6.513    6.392 289.9    20.6  36.2 246.3    21.8  48.4 240.9    5.074    3.176 1.8833 1.1788 1949_08_NOATL   NOT NAMED
193609. 131600.  10.46 120.2  10.07 126.6    2.669    6.870    7.678 329.4     8.0  12.5 247.4     9.1  15.2 234.2    5.040    3.129 1.8882 1.1723 1936_14_NOATL   NOT NAMED
197009. 121900.  10.41  90.6  10.14 123.3    2.659    6.628    6.536 313.8    12.7  26.4 238.7    14.7  32.7 241.8    5.161    3.239 1.9411 1.2182 1970_06_NOATL   ELLA
200308. 310800.  11.91 235.5   8.93 125.5    2.593    6.908    7.182 305.8    15.0  35.7 238.4    15.7  35.9 238.2    4.560    2.798 1.7584 1.0789 2003_07_NOATL   GRACE
196111.  61500.  15.70  12.4  15.35   7.3    2.580    5.561    5.065 209.0     4.9  38.8 241.2    10.0  38.9 241.5    5.047    3.177 1.9561 1.2313 1961_11_NOATL   INGA
200210.  31000.  10.94  27.5  10.03 355.1    2.509    6.267    9.875 258.4    14.5  41.1 237.8    21.4  41.3 237.8    4.606    2.812 1.8356 1.1207 2002_13_NOATL   LILI
200310.  21300.  13.33  48.0  12.99  47.0    2.487    5.762    4.977 247.3    16.4  41.5 241.0    17.5  43.3 240.7    4.699    2.938 1.8896 1.1814 2003_12_NOATL   LARRY
199908. 222300.   8.84 145.1   8.51 136.8    2.481    6.814    7.084 342.6     6.6  11.5 230.4    10.6  19.9 231.7    4.863    3.044 1.9600 1.2268 1999_02_NOATL   BRET
193808. 281230.  12.03  78.0  11.89  78.2    2.477    6.016    5.937 283.5    11.5  28.2 244.5    12.8  29.8 243.3    4.741    2.960 1.9139 1.1949 1938_03_NOATL   NOT NAMED
199510. 150030.  15.79  15.0  15.49  14.7    2.471    5.455    4.846 214.7     7.6  33.5 241.6    14.5  33.7 242.1    4.623    2.880 1.8711 1.1657 1995_17_NOATL   ROXANNE
199510.  21330.  13.22   1.5  10.31  76.4    2.467    6.333    6.737 280.3    26.1  40.0 241.5    26.7  42.3 240.8    4.798    2.980 1.9450 1.2078 1995_15_NOATL   OPAL
197409.  72130.  14.39   5.9  14.23   8.0    2.466    5.767    4.789 223.3    15.6  46.9 238.9    16.1  47.0 238.9    4.743    2.975 1.9235 1.2062 1974_06_NOATL   CARMEN
198209. 101400.  10.79  70.8  10.79  70.8    2.461    6.185    6.312 275.4    18.2  43.3 238.7    22.9  52.4 234.8    4.597    2.837 1.8679 1.1529 1982_04_NOATL   CHRIS
193808. 141930.   9.51 105.2   7.77 101.4    2.458    6.864    9.869 291.1    11.1  29.5 233.1    19.8  46.7 236.3    4.522    2.711 1.8396 1.1029 1938_02_NOATL   NOT_NAMED
196610.  92300.   9.41  33.7   6.66  95.2    2.418    7.300    6.090 313.1     6.8  19.3 239.7    10.7  31.2 239.5    4.714    2.948 1.9494 1.2193 1966_09_NOATL   INEZ
190411.  11230.  12.08  72.9  11.92  72.6    2.412    5.895    5.235 271.3    12.5  38.5 240.0    13.2  39.5 239.3    4.550    2.829 1.8863 1.1727 1904_05_NOATL   NOT NAMED
196910. 210030.  13.85  29.5  10.46  58.8    2.407    6.443    6.723 277.0    17.3  40.3 240.4    17.7  43.0 238.9    4.700    2.920 1.9527 1.2131 1969_15_NOATL   LAURIE
196410.  22030.  13.62 347.7  11.02  20.8    2.403    6.049   10.237 251.6    25.3  54.6 239.0    29.3  59.9 240.0    4.738    2.877 1.9715 1.1971 1964_10_NOATL   HILDA
192509.  70300.  10.08 110.9   8.82 116.8    2.396    6.919    7.618 323.7     3.3   2.8   2.7     4.3   9.1  83.9    4.492    2.765 1.8747 1.1540 1925_01_NOATL   NOT NAMED
190809. 180430.  12.86  23.5  12.83  16.9    2.379    5.995    4.854 245.8    27.9  62.9 237.7    30.9  69.7 236.7    4.481    2.793 1.8836 1.1742 1908_05_NOATL   NOT NAMED
190510.  71200.  11.61  65.3  11.61  65.3    2.354    5.860    5.096 261.1    14.1  41.1 240.5    16.2  41.1 240.5    4.551    2.836 1.9332 1.2048 1905_05_NOATL   NOT NAMED
199809.  20200.  12.64  11.4  11.85  31.3    2.337    5.854    7.228 258.2    15.3  38.8 237.6    16.1  41.5 237.3    4.478    2.740 1.9163 1.1724 1998_05_NOATL   EARL
195806. 152030.   8.50 152.7   7.26 165.2    2.311    6.641    6.047 332.7     2.8   9.9 226.0     4.2  14.0 236.0    4.365    2.697 1.8886 1.1669 1958_01_NOATL   ALMA
193210. 150430.  12.32 326.4   8.87  75.4    2.299    6.866    8.533 310.5    14.5  24.0 240.7    16.4  39.4  67.9    4.114    2.484 1.7895 1.0807 1932_08_NOATL   NOT_NAMED
195609. 240030.  11.44 357.1  11.37  31.0    2.298    5.890    7.691 255.9    11.3  43.0 237.7    11.9  43.4 237.9    4.314    2.615 1.8772 1.1380 1956_07_NOATL   FLOSSY
193810. 171000.  12.54   6.3  12.15   5.8    2.286    5.921    5.129 228.2    34.7  61.2 232.1    35.2  67.6 231.7    4.112    2.528 1.7988 1.1057 1938_05_NOATL   NOT_NAMED
195406. 260500.   9.40 125.8   7.71 147.1    2.268    6.656    6.997 332.7     1.9   2.4 294.4     4.6   5.3 265.8    4.393    2.697 1.9369 1.1891 1954_01_NOATL   ALICE
198308. 281700.   9.85 110.1   7.98 115.4    2.256    6.224    5.806 315.1     9.7  20.0 242.9    11.2  28.5 243.0    4.350    2.687 1.9282 1.1910 1983_02_NOATL   BARRY
190108. 151300.  15.35 335.5  14.95 335.5    2.236    5.095    4.404 172.4     4.1  27.3 239.7    11.3  34.6 238.0    4.220    2.607 1.8875 1.1659 1901_04_NOATL   NOT NAMED
193608. 102300.  11.77  32.2  11.41  40.7    2.214    5.573    4.868 241.4    19.9  51.3 240.2    20.8  51.9 239.4    4.268    2.640 1.9277 1.1924 1936_07_NOATL   NOT NAMED
200510.  40100.  10.26  68.9  10.11  71.7    2.196    5.837    5.432 267.8    17.5  39.0 239.4    21.9  43.0 238.8    4.338    2.683 1.9756 1.2218 2005_20_NOATL   STAN
200008. 151300.   9.27 130.8   6.75 139.9    2.188    6.347    5.906 327.4    -3.8   5.1 214.6     1.9  10.8 239.8    4.215    2.595 1.9266 1.1862 2000_02_NOATL   BERYL
192608. 250530.  12.15 340.0   9.14  31.7    2.185    6.139    9.417 255.3    22.3  51.7 239.5    29.2  58.6 240.9    4.219    2.572 1.9311 1.1773 1926_03_NOATL   NOT NAMED
195010. 181730.  12.03  11.3  11.92   8.3    2.181    5.638    4.624 224.5    16.0  43.5 237.9    28.1  60.0 238.3    4.316    2.684 1.9790 1.2304 1950_13_NOATL   LOVE
194709. 191300.  14.83 354.9  14.22 353.7    2.170    5.174    4.730 197.1    -8.3  12.9 234.2     2.3  16.1 220.9    4.026    2.466 1.8552 1.1366 1947_04_NOATL   NOT NAMED
196509. 270200.  11.63  32.3  10.93  55.2    2.170    5.581    4.940 251.0    13.2  38.7 238.8    13.5  41.0 238.7    4.321    2.683 1.9914 1.2364 1965_05_NOATL   DEBBIE
198508. 150330.  10.02 356.1   9.47  47.4    2.167    6.157    7.716 268.5    13.4  33.2 235.5    20.0  42.7 237.2    3.947    2.356 1.8215 1.0870 1985_04_NOATL   DANNY
193608. 181400.  10.26  93.6   9.99  94.0    2.167    5.863    5.825 289.3    13.6  24.9 244.1    13.8  25.0 244.1    4.245    2.613 1.9588 1.2060 1936_08_NOATL   NOT NAMED
200410.  81200.  10.59   1.8   6.20 108.9    2.115    6.108    5.432 296.1     9.7  31.7 236.9    12.9  33.6 238.5    4.068    2.505 1.9235 1.1843 2004_13_NOATL   MATTHEW
196408.  72100.  16.69 325.1  14.35 192.0    2.112    4.966    4.311  23.4     0.3  17.8 179.7    10.4  31.1 202.5    3.943    2.418 1.8671 1.1448 1964_03_NOATL   ABBY
198809. 100030.  11.70  25.0  11.04  32.8    2.107    5.598    4.658 236.9    14.9  37.2 240.7    15.5  38.2 240.3    4.008    2.472 1.9021 1.1732 1988_07_NOATL   FLORENCE
199608. 222100.   9.59  84.1   8.87  85.5    2.080    5.911    5.344 283.4    14.9  39.8 237.5    16.2  40.2 237.5    4.181    2.575 2.0103 1.2380 1996_04_NOATL   DOLLY
198908.  10000.  11.50 289.0   9.55  54.4    2.077    6.016    4.944 266.0    14.5  37.2 237.6    28.2  58.9 234.0    3.950    2.424 1.9020 1.1670 1989_03_NOATL   CHANTAL
194211. 111230.  10.72  48.3  10.63  48.2    2.076    5.452    4.818 246.2     8.1  29.7 238.6     9.8  31.2 237.8    4.083    2.514 1.9668 1.2111 1942_10_NOATL   NOT_NAMED
191610. 171600.  14.63 316.5   6.19  32.1    2.059    7.367    8.574 298.2     4.4  18.1 239.2     6.6  20.2  73.7    3.972    2.429 1.9290 1.1799 1916_13_NOATL   NOT NAMED
191509. 291930.  11.23 353.9  11.03 349.7    2.058    5.406   11.206 211.7     6.7  11.6 231.2     7.8  13.2 241.2    3.933    2.298 1.9110 1.1168 1915_05_NOATL   NOT NAMED
190709. 270600.   9.55 316.1   7.00 102.6    2.041    5.962    5.572 295.2     9.3  24.9 240.6     9.3  24.9 240.6    3.732    2.268 1.8283 1.1110 1907_03_NOATL   NOT NAMED
199809. 172330.   9.29  33.4   9.18  34.4    2.039    5.984    6.345 263.3    12.0  33.1 238.0    15.7  35.2 239.3    3.865    2.345 1.8957 1.1499 1998_08_NOATL   HERMINE
195509.  60700.   9.56  90.8   9.35  89.0    2.039    6.050    6.650 310.1     5.4  21.1 240.8     6.3  22.8 241.6    3.860    2.342 1.8930 1.1486 1955_07_NOATL   GLADYS
190909. 201230.  11.90  20.7  11.60  20.0    2.035    5.631    4.394 237.1    10.0  33.5 236.9    12.5  34.8 237.2    3.849    2.356 1.8916 1.1577 1909_07_NOATL   NOT NAMED
191709. 271500.  10.84 341.7   8.99  24.4    2.034    6.235    7.757 260.7    19.1  33.1 240.7    19.3  34.8 239.8    3.999    2.412 1.9660 1.1860 1917_03_NOATL   NOT NAMED
193309. 150100.   9.88  79.1   9.40  77.9    2.031    5.810    6.446 285.8     8.3  23.4 239.4    10.7  26.2 240.8    4.046    2.479 1.9921 1.2208 1933_14_NOATL   NOT_NAMED
191206. 121500.   9.01  68.4   8.31  46.5    1.989    6.208    7.734 273.8    18.6  38.3 237.9    21.6  45.9 236.3    3.817    2.292 1.9191 1.1523 1912_01_NOATL   NOT NAMED
200508. 290700.   8.09 335.9   8.03 331.8    1.988    6.466   11.639 270.5    12.2  15.9 248.5    14.2  18.6 242.0    3.710    2.161 1.8662 1.0870 2005_12_NOATL   KATRINA
192909. 301430.  12.75   0.2  12.42 359.9    1.988    5.225    4.407 208.2     6.4  31.4 240.8     9.8  34.7 239.2    3.914    2.396 1.9690 1.2050 1929_02_NOATL   NOT NAMED
199507. 301900.  11.89   8.2  11.89   8.2    1.985    5.560    4.523 233.9    21.9  50.6 233.3    27.4  55.0 231.4    3.801    2.327 1.9146 1.1720 1995_04_NOATL   DEAN
197909. 121130.  11.51   3.7   9.94  28.7    1.976    5.785    4.461 248.2    12.4  36.0 238.9    16.6  36.4 239.1    3.846    2.359 1.9462 1.1936 1979_06_NOATL   FREDERIC
194708. 240330.  12.17 305.8  11.31   5.0    1.973    5.572    4.937 228.5    26.6  63.0 235.6    26.8  63.4 235.4    3.831    2.345 1.9416 1.1884 1947_03_NOATL   NOT NAMED
200409. 151830.   6.37 101.8   5.02  21.0    1.956    7.821   11.483 299.4    14.3  24.8 237.9    14.9  24.9 237.5    3.658    2.161 1.8701 1.1049 2004_09_NOATL   IVAN
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194307. 271530.  14.97 272.1  14.81 286.4   1.956   4.907   4.168 138.3    1.5    3.7 341.3    5.3   24.1 231.9   3.803   2.333 1.9441 1.1929 1943_01_NOATL   NOT NAMED
195309. 260700.  11.50  31.1  10.30  15.8   1.949   5.475   4.530 233.8   12.7   34.3 239.2   14.2   35.1 239.8   3.864   2.376 1.9827 1.2189 1953_08_NOATL   FLORENCE
191008. 310900.   6.40 104.8   6.38 103.6   1.895   6.734   6.624 316.3    5.9   15.8 236.2    6.2   17.3 238.9   3.655   2.215 1.9289 1.1687 1910_01_NOATL   NOT NAMED
196710.  40030.   9.82  92.2   9.49  92.9   1.890   5.495   5.199 288.9    9.0   26.6 238.2    9.2   27.2 237.5   3.576   2.169 1.8919 1.1477 1967_06_NOATL   FERN
195109. 291330.  10.02  40.6   9.84  41.6   1.878   5.216   4.666 234.6    5.7   29.0 239.3   10.0   33.6 239.5   3.711   2.262 1.9763 1.2046 1951_08_NOATL   HOW
194408. 221630.   7.87  95.4   7.50  88.2   1.868   6.461   6.561 315.8    8.0   18.7 239.7    8.3   20.1 238.7   3.580   2.162 1.9165 1.1576 1944_05_NOATL   NOT NAMED
193406. 160300.   6.93  70.9   6.24  69.0   1.856   6.928   8.993 288.7   25.9   31.1 236.8   32.1   43.7 240.2   3.643   2.184 1.9628 1.1767 1934_02_NOATL   NOT_NAMED
190509. 272130.   9.14  74.4   7.33  70.2   1.827   5.969   7.610 285.1    8.4   29.4 237.1   18.5   46.4 235.9   3.527   2.106 1.9306 1.1529 1905_03_NOATL   NOT NAMED
190210.  91930.   5.32 105.5   3.71  97.5   1.824   7.064   7.654 304.4    5.9   16.9 232.7    8.1   24.3 236.2   3.509   2.113 1.9236 1.1584 1902_04_NOATL   NOT NAMED
199309. 210730.   7.44  96.9   6.52 105.5   1.823   6.438   6.306 311.5    9.6   16.9 240.8   11.1   21.6 240.1   3.487   2.098 1.9126 1.1509 1993_07_NOATL   GERT
198511. 210330.  11.39  17.3  10.77   8.1   1.820   5.061   4.473 212.0    0.4   20.5 243.8    7.1   22.3 241.8   3.642   2.226 2.0009 1.2232 1985_11_NOATL   KATE
195609. 100600.   9.10  73.2   8.92  72.6   1.793   5.329   4.769 251.8   11.4   37.1 237.6   12.7   38.8 238.3   3.487   2.117 1.9450 1.1805 1956_05_NOATL   DORA
195108. 230900.   7.50  82.9   4.99  88.1   1.790   6.943   8.462 330.2    3.8    7.3 239.3    5.9   16.0 244.2   3.571   2.161 1.9949 1.2074 1951_03_NOATL   CHARLIE
195407. 301600.   8.62 165.7   8.23 164.6   1.786   5.343   4.903 344.7    1.7    8.4 203.9    7.8   22.8 236.4   3.351   2.013 1.8762 1.1273 1954_02_NOATL   BARBARA
195905. 300230.   8.29  45.6   8.24  53.7   1.783   5.582   4.681 253.1   14.6   37.7 238.6   19.7   44.1 237.0   3.341   2.018 1.8738 1.1318 1959_01_NOATL   ARLENE
198811. 212100.  10.70  19.9  10.00  25.0   1.782   5.099   4.581 220.2    7.6   22.9 250.2   11.3   27.1 246.4   3.495   2.128 1.9613 1.1940 1988_12_NOATL   KEITH
194409.  92200.   8.01 356.3   7.60  28.5   1.776   6.839   8.753 302.0    6.0   23.3 236.4    6.7   29.8 236.0   3.190   1.871 1.7962 1.0535 1944_06_NOATL   NOT NAMED
191808.  61800.  11.11 345.1  11.11 345.1   1.754   5.717  10.037 248.5    8.0   22.1 232.8   23.8   25.7 255.3   3.094   1.772 1.7640 1.0100 1918_01_NOATL   NOT NAMED
195509. 191300.   8.16  89.1   7.75  82.6   1.750   6.031   5.049 304.3    9.4   23.5 238.9    9.8   23.6 238.9   3.406   2.060 1.9465 1.1769 1955_08_NOATL   HILDA
195906. 180030.   9.16  41.8   8.69  45.4   1.710   5.274   4.803 250.5    6.6   27.1 238.4    6.8   27.2 238.5   3.205   1.921 1.8742 1.1235 1959_02_NOATL   BEULAH
200009. 170030.   9.61  46.5   9.47  46.3   1.709   5.065   4.655 229.8    4.7   19.0 243.2    6.5   24.7 238.8   3.246   1.964 1.8996 1.1491 2000_07_NOATL   GORDON
192009. 291930.   9.70  18.7   9.00  23.5   1.706   5.319   4.345 230.2    7.9   26.4 238.1   14.0   28.2 238.4   3.370   2.056 1.9754 1.2051 1920_04_NOATL   NOT NAMED
200306. 301330.   7.92  54.2   7.47  39.7   1.653   6.140   7.112 280.5    6.3   29.4 238.1    6.6   30.0 238.4   3.040   1.790 1.8390 1.0827 2003_02_NOATL   BILL
192406. 200300.   8.52 152.2   7.90 139.4   1.652   5.241   4.789 319.6    4.5    7.6 245.0    4.8   11.4 235.3   3.289   1.988 1.9910 1.2033 1924_01_NOATL   NOT NAMED
195709. 180030.   8.16  37.0   8.01  36.6   1.646   5.502   7.002 273.0    7.2   25.6 239.4    8.2   27.8 238.7   3.009   1.764 1.8280 1.0717 1957_06_NOATL   ESTHER
194708. 150730.   7.71 100.7   6.10 110.3   1.628   6.064   5.170 318.3    6.4   16.4 240.1    7.6   20.8 240.8   3.275   1.975 2.0116 1.2130 1947_02_NOATL   NOT NAMED
192410. 131830.   8.22  70.1   7.62  69.0   1.626   5.792   7.019 271.8   13.8   36.7 239.9   14.2   37.1 240.3   3.226   1.918 1.9839 1.1796 1924_06_NOATL   NOT NAMED
192110. 250400.   4.46  10.9   4.15  26.3   1.626   7.301   7.652 284.6   10.0   25.6 238.7   11.7   26.0 238.8   3.088   1.832 1.8989 1.1267 1921_06_NOATL   NOT NAMED
197509.  10030.   6.45 105.5   5.19  92.7   1.624   6.776   7.313 344.4    3.6    7.2 245.2    5.9   16.7 239.4   3.180   1.901 1.9581 1.1707 1975_03_NOATL   CAROLINE
194809.  30130.   7.67  43.7   6.63  79.1   1.621   5.855   5.748 306.3    2.5   16.5 239.3    5.9   24.2 237.6   3.206   1.917 1.9778 1.1825 1948_05_NOATL   NOT NAMED
191409. 181300.  12.14 336.5  11.68 336.8   1.610   4.524   3.742 177.6   -9.6    3.4 206.2    3.0   16.2 234.5   3.041   1.828 1.8886 1.1355 1914_01_NOATL   NOT NAMED
193209. 191030.   4.97  94.3   4.82  74.6   1.599   6.933   7.846 317.9    4.8   12.4 236.5    7.0   21.6 235.8   2.880   1.698 1.8008 1.0621 1932_06_NOATL   NOT NAMED
193606. 210800.   5.92  50.6   5.89  42.9   1.572   6.720   7.031 301.7    3.5    5.3 236.4    3.6    5.6 236.9   2.996   1.785 1.9058 1.1355 1936_02_NOATL   NOT NAMED
194008.  61230.  10.46 348.1  10.25 348.7   1.557   4.697   3.981 200.2    4.8   29.2 232.5   11.0   36.0 236.1   3.013   1.818 1.9349 1.1678 1940_02_NOATL   NOT NAMED
198606. 260130.   6.85 191.2   6.44  69.2   1.554   5.785   5.210 271.1   12.7   37.9 235.8   16.5   48.0 235.5   2.872   1.716 1.8481 1.1039 1986_02_NOATL   BONNIE
193710.  30300.   7.15  44.0   6.26  14.9   1.528   6.157   8.440 270.9   10.0   29.0 235.4   12.1   32.8 235.3   2.872   1.671 1.8795 1.0935 1937_09_NOATL   NOT NAMED
196909. 300200.   9.71  44.9   8.89  44.5   1.504   4.712   4.317 233.4    8.5   20.9 240.2   10.8   26.4 240.1   2.923   1.746 1.9438 1.1607 1969_12_NOATL   SUBTROP 1
197206. 181230.   7.28  43.0   7.19  26.8   1.499   5.675   7.663 263.3   12.3   22.9 239.2   13.6   28.7 240.2   3.697   2.243 1.9435 1.1795 1972_02_NOATL   AGNES
200507.  60200.   8.33 160.1   4.78  73.7   1.490   6.422   7.695 283.6    1.8   16.0 231.8    3.1   18.1 232.4   2.744   1.618 1.8413 1.0858 2005_03_NOATL   CINDY
191509.  40400.   7.21  70.5   4.35  46.2   1.483   6.062   7.512 269.3    9.1   31.2 237.7    9.7   32.2 237.0   2.894   1.721 1.9517 1.1606 1915_04_NOATL   NOT NAMED
192009. 220100.   7.17  58.2   4.51  17.3   1.482   6.424   8.568 282.8    8.2   22.5 237.8    8.2   23.4 237.5   2.721   1.573 1.8357 1.0614 1920_02_NOATL   NOT NAMED
193107. 150930.   4.40 171.4   4.24 168.6   1.480   6.105   6.483 290.8    8.8   22.1 235.3   11.0   27.4 238.4   2.745   1.624 1.8550 1.0976 1931_02_NOATL   NOT_NAMED
191607.  51430.   9.54 339.7   8.92 339.2   1.479   4.891  10.171 200.4    4.3    7.0 223.7    6.0    9.8 229.6   2.806   1.587 1.8975 1.0732 1916_01_NOATL   NOT NAMED
192409. 141700.   8.68  31.9   7.79  31.3   1.476   5.179   4.059 243.0    5.1   23.9 239.4    6.7   24.2 239.0   2.832   1.698 1.9190 1.1505 1924_04_NOATL   NOT NAMED
199208. 260300.   8.36  20.1   7.21  16.7   1.469   5.049  10.576 232.6   -0.1   17.6 237.1    2.3   41.6  56.2   2.726   1.546 1.8560 1.0526 1992_02_NOATL   ANDREW
196509. 100400.   9.69 281.6   7.40   1.7   1.464   5.197  11.859 231.0    7.2   12.5 241.7    8.0   46.3  56.2   2.731   1.554 1.8657 1.0616 1965_03_NOATL   BETSY
195010.  91430.   9.59  34.6   8.78  35.5   1.454   4.608   4.088 223.2    0.1   15.9 244.8    4.9   19.1 242.9   2.747   1.643 1.8896 1.1303 1950_09_NOATL   ITEM
190908. 102030.   8.43  72.7   7.37  85.6   1.450   5.209   7.064 286.2    7.2   25.5 238.9    7.3   27.0 236.8   2.918   1.735 2.0125 1.1963 1909_04_NOATL   NOT NAMED
195008. 300030.   7.89 348.5   6.59  42.8   1.433   5.870   6.170 277.2   16.4   22.8 239.4   17.6   24.2 239.5   2.859   1.701 1.9949 1.1872 1950_02_NOATL   BAKER
194208. 211800.   9.29 265.3   8.24   9.2   1.431   5.189   4.521 229.0   22.2   45.5 236.0   22.8   46.9 234.9   2.724   1.623 1.9037 1.1342 1942_01_NOATL   NOT NAMED
200009. 210830.   7.68 127.4   5.59 132.1   1.429   5.155   4.786 315.2    2.2   12.5 235.2    2.8   14.1 237.1   2.867   1.723 2.0061 1.2060 2000_08_NOATL   HELENE
195409. 121630.   8.90  61.7   7.88  66.8   1.428   4.778   3.955 256.9    2.0   12.2 244.4    3.0   14.1 241.3   2.725   1.633 1.9082 1.1432 1954_06_NOATL   FLORENCE
200108.  30230.   7.88  56.4   7.28  63.7   1.412   4.818   4.351 252.0    1.0   26.6 237.2    6.2   28.2 236.9   2.757   1.647 1.9524 1.1664 2001_02_NOATL   BARRY
194909.  42000.   4.84  96.7   2.17 149.1   1.398   6.084   7.204 286.8    4.8   20.0 237.2    6.2   22.3 235.6   2.532   1.473 1.8113 1.0537 1949_05_NOATL   NOT NAMED
200506. 112100.   7.78 126.7   3.09  92.1   1.384   5.845   6.530 283.1    6.9   17.1 235.9    7.9   18.4 233.7   2.593   1.520 1.8733 1.0984 2005_01_NOATL   ARLENE
193909. 252300.   6.62 325.7   4.07  16.9   1.374   6.127   5.638 281.6    9.0   21.3 240.0    9.1   23.8 240.8   2.613   1.552 1.9016 1.1298 1939_03_NOATL   NOT NAMED
192210. 210930.   8.66  45.5   3.95  87.4   1.360   6.687   9.402 296.6   11.7   23.6 239.5   12.9   32.5 237.6   3.221   1.945 1.8838 1.1372 1922_04_NOATL   NOT NAMED
193308. 291500.   7.36  95.3   7.15  95.6   1.348   5.153   6.883 309.9    3.8   11.9 246.0    4.0   12.4 245.5   2.623   1.534 1.9455 1.1379 1933_10_NOATL   NOT NAMED
190010.  91230.   8.33  31.8   8.24  31.4   1.342   4.581   4.168 222.1    1.2   21.8 236.3    1.7   21.8 236.3   2.606   1.551 1.9416 1.1559 1900_06_NOATL   NOT NAMED
192210. 151130.   8.40  42.5   3.38 145.0   1.333   6.065   6.163 284.3    6.5   21.5 240.8    6.7   22.6 238.0   2.613   1.549 1.9605 1.1617 1922_03_NOATL   NOT NAMED
197605. 211200.   7.12  66.9   4.77  86.8   1.329   4.902   4.325 283.3    3.9   21.7 236.0    3.9   22.3 236.3   2.378   1.403 1.7892 1.0554 1976_01_NOATL   SUBTROP 1
194409. 211630.   7.53  71.4   3.88  64.4   1.322   5.854   5.300 284.0    7.5   14.3 241.4    9.1   23.8 241.4   2.625   1.565 1.9853 1.1836 1944_08_NOATL   NOT NAMED
192310. 181200.   9.83 354.6   9.83 354.6   1.315   4.295   3.632 183.6   -1.7   18.0 242.7   15.2   26.1 233.5   2.427   1.439 1.8458 1.0945 1923_06_NOATL   NOT NAMED
193209. 131230.   7.90  72.6   7.83  71.9   1.313   4.813   4.132 266.4    7.4   28.0 238.2    7.9   29.1 238.4   2.573   1.526 1.9594 1.1620 1932_05_NOATL   NOT NAMED
197907. 111200.   7.07  17.9   7.07  17.9   1.309   5.252   7.089 263.0   10.0   22.2 239.0   10.9   23.1 237.8   2.473   1.447 1.8895 1.1053 1979_02_NOATL   BOB
195606. 131300.   5.67 100.6   5.28  33.9   1.308   5.697   5.244 293.9    4.1   20.8 233.6    5.7   23.4 235.3   2.482   1.467 1.8976 1.1219 1956_01_NOATL   NOT NAMED
193709. 181230.   7.49  99.1   7.31  98.4   1.298   5.036   6.348 292.1    4.4   16.8 238.1    5.3   18.3 238.1   2.503   1.468 1.9284 1.1306 1937_06_NOATL   NOT NAMED
```

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193305. 181300.   6.20  72.4   4.35 127.3   1.298   6.053   6.936 296.5   4.8  15.7 236.6   5.2  19.1 240.0   2.551   1.487 1.9656 1.1460 1933_01_NOATL   NOT NAMED
200208.  80900.   8.63  67.1   8.63  67.1   1.296   4.519   4.309 240.3  -0.8  14.1 230.5   0.4  19.1 234.7   2.460   1.454 1.8983 1.1217 2002_02_NOATL   BERTHA
197709.  41700.   8.34 355.9   8.23 344.3   1.286   4.590   4.296 201.4  10.6  28.6 239.3  17.3  32.3 239.2   4.182   2.559 1.7529 1.0724 1977_02_NOATL   BABE
190009. 121500.   7.08 308.4   3.40 102.9   1.281   6.676   8.443 291.8   8.4  20.7 240.5   9.2  22.7 240.9   2.368   1.374 1.8483 1.0722 1900_03_NOATL   NOT NAMED
193410.  42030.   8.09 358.1   4.78  50.2   1.279   6.222   7.567 284.6   9.1  24.2 237.8   9.2  25.6 238.5   2.595   1.536 2.0288 1.2007 1934_09_NOATL   NOT NAMED
191110. 312230.   7.26  24.2   6.48  45.8   1.271   5.077   7.204 251.4   4.5  21.3 237.0   6.9  22.3 236.0   2.492   1.460 1.9605 1.1487 1911_04_NOATL   NOT NAMED
195708.  91300.   8.42  36.8   7.79  35.7   1.262   4.520   4.043 228.9   3.0  22.8 237.1   6.3  24.3 237.0   2.368   1.397 1.8765 1.1071 1957_03_NOATL   BERTHA
194506. 231800.   7.10 228.3   6.61 133.3   1.261   5.141   6.478 298.2   5.2  21.8 235.0   6.3  22.3 234.7   2.489   1.460 1.9738 1.1576 1945_01_NOATL   NOT NAMED
194109. 132130.   9.27 310.0   5.99  21.7   1.257   5.271   4.521 236.9  15.7  37.2 236.9  18.5  42.3 237.0   2.545   1.517 2.0249 1.2072 1941_01_NOATL   NOT NAMED
197308. 210130.   7.76  50.3   7.32  50.3   1.243   4.876   3.602 259.1   4.0  16.0 241.6   5.6  19.4 241.8   2.406   1.417 1.9359 1.1400 1973_03_NOATL   BRENDA
196506. 150000.   5.04 127.7   3.45 121.8   1.227   6.283   6.980 310.7   4.9   6.3 256.7   5.8   7.1 245.1   2.340   1.365 1.9068 1.1121 1965_01_NOATL   NOT NAMED
193607. 311430.   7.71  29.9   7.19  32.4   1.213   4.552   4.063 219.1  -3.7  10.5 222.3  -2.6  14.2 224.8   2.335   1.378 1.9249 1.1360 1936_05_NOATL   NOT NAMED
196606.  91000.   6.96 129.6   4.23 177.2   1.206   6.148   7.036 296.0   2.6   9.5 237.5   7.9  15.6 238.8   2.275   1.323 1.8865 1.0971 1966_01_NOATL   ALMA
195306.  50200.   8.42 137.8   7.29 142.0   1.193   4.403   3.625 311.2   6.6  12.4 237.4   8.9  13.5 236.8   2.358   1.394 1.9765 1.1688 1953_01_NOATL   ALICE
196609. 202100.   8.54   7.7   8.26   6.6   1.175   4.222   3.720 194.3  -4.1   2.9 279.0  -1.8   4.9  14.5   2.311   1.367 1.9670 1.1636 1966_08_NOATL   HALLIE
195709.  81530.   8.43 351.0   8.28 347.2   1.172   4.189   3.510 182.2  -1.3   7.8 247.7  -0.2  10.1 238.3   2.265   1.345 1.9322 1.1474 1957_05_NOATL   DEBBIE
193906. 161230.   8.15 286.9   7.99 284.6   1.169   4.140   3.540  94.4  -2.0   2.7 137.7   0.4   8.1 218.5   2.231   1.310 1.9081 1.1210 1939_01_NOATL   NOT_NAMED
196009. 150130.   8.02  55.7   7.24  52.9   1.165   4.342   3.915 241.9   1.8  18.1 239.8   3.8  21.5 237.0   2.257   1.336 1.9369 1.1472 1960_06_NOATL   ETHEL
190606. 121230.   7.23  13.5   7.11  13.5   1.163   4.604   3.906 224.4   4.9  19.2 236.9   6.4  19.2 236.9   2.228   1.311 1.9155 1.1271 1906_01_NOATL   NOT NAMED
192809.  62100.   7.67  69.9   7.39  73.4   1.158   4.511   3.898 259.8   4.4  22.9 239.1   7.6  23.8 238.8   2.758   1.633 1.9384 1.1476 1928_03_NOATL   NOT NAMED
197009. 152200.   7.72   7.5   7.72   7.5   1.154   4.829   4.546 235.3   6.2  22.8 236.7  12.9  27.4 232.6   3.373   2.036 1.8136 1.0945 1970_07_NOATL   FELICE
194606. 160030.   7.24   3.2   7.23   6.6   1.133   4.742   4.399 221.4   5.8  13.2 229.8   6.6  16.9 228.9   2.128   1.254 1.8786 1.1070 1946_01_NOATL   NOT NAMED
191209. 141200.   7.85 285.9   7.85 285.9   1.124   4.136   3.497 102.2  -7.9   8.7  84.2  -1.4   9.5  83.1   2.199   1.297 1.9561 1.1539 1912_03_NOATL   NOT NAMED
199508.  22230.   7.69 174.6   4.18  99.9   1.122   4.639   3.792 288.1   0.7  18.6 238.8   9.5  21.9 238.5   2.915   1.737 1.7624 1.0502 1995_05_NOATL   ERIN
199809. 281230.   8.46 323.5   8.36 323.2   1.117   4.050   3.362 159.8   0.3   8.6  42.2   4.0  27.0  55.1   2.242   1.325 1.9410 1.1473 1998_07_NOATL   GEORGES
193606. 131300.   7.56  62.4   7.46  62.1   1.116   4.337   3.852 246.0   4.2  21.3 237.9   4.8  23.2 237.8   2.216   1.302 1.9854 1.1664 1936_01_NOATL   NOT_NAMED
193511.  71030.   5.75  70.4   3.07  47.6   1.098   5.544   7.439 275.7  -0.9   8.9 219.1   3.5  13.8 231.1   2.162   1.252 1.9688 1.1403 1935_06_NOATL   NOT NAMED
195309. 190630.   4.12 336.4   2.82 175.9   1.044   8.545   8.101 291.9   5.2   9.6 234.9   5.7  12.4 242.4   1.900   1.110 1.8197 1.0630 1953_07_NOATL   NOT NAMED
194509.  60130.   7.15 103.3   6.75 110.6   1.035   4.127   3.670 297.7   3.2  13.8 234.0   4.0  15.4 233.4   2.076   1.216 2.0056 1.1748 1945_07_NOATL   NOT NAMED
190706. 281100.   5.47  88.0   3.83 285.9   1.026   8.639   8.515 298.5   1.1   9.8 230.3   2.5  10.6 238.1   1.876   1.097 1.8283 1.0691 1907_01_NOATL   NOT NAMED
193209.  11400.   7.87 338.5   7.29 342.6   1.025   4.026   3.344 176.9  -3.8   3.5 188.3   1.4  10.5 233.8   1.950   1.134 1.9021 1.1064 1932_03_NOATL   NOT NAMED
196908. 171830.   6.70 244.4   2.74   9.0   1.022  10.748  10.854 304.6   4.4   9.3 236.3   8.4  10.7 241.8   1.911   1.112 1.8697 1.0881 1969_03_NOATL   CAMILLE
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Appendix C

Extra-tropical/Winter Storm List

Extra-tropical/Winter Storm List

Storm Ref	Start Date	End Date
19570321	Mar-21-1957 00:00	Mar-26-1957 00:00
19571230	Dec-30-1957 00:00	Jan-03-1958 12:00
19580101	Jan-01-1958 00:00	Jan-09-1958 00:00
19580121	Jan-21-1958 00:00	Jan-25-1958 00:00
19580209	Feb-09-1958 00:00	Feb-17-1958 00:00
19581209	Dec-09-1958 00:00	Dec-17-1958 00:00
19590115	Jan-15-1959 00:00	Jan-23-1959 00:00
19590311	Mar-11-1959 00:00	Mar-19-1959 00:00
19591101	Nov-01-1959 00:00	Nov-09-1959 00:00
19591123	Nov-23-1959 00:00	Dec-01-1959 00:00
19600127	Jan-27-1960 00:00	Jan-31-1960 18:00
19600210	Feb-10-1960 00:00	Feb-14-1960 06:00
19600215	Feb-15-1960 00:00	Feb-19-1960 12:00
19601126	Nov-26-1960 00:00	Dec-04-1960 00:00
19601213	Dec-13-1960 00:00	Dec-16-1960 12:00
19620108	Jan-08-1962 00:00	Jan-12-1962 00:00
19620303	Mar-03-1962 00:00	Mar-07-1962 06:00
19630201	Feb-01-1963 00:00	Feb-05-1963 00:00
19630919	Sep-19-1963 00:00	Sep-27-1963 00:00
19631106	Nov-06-1963 00:00	Nov-13-1963 06:00
19631123	Nov-23-1963 00:00	Dec-01-1963 00:00
19631218	Dec-18-1963 00:00	Jan-02-1964 00:00
19631226	Dec-26-1963 00:00	Jan-03-1964 00:00
19641116	Nov-16-1964 00:00	Nov-24-1964 00:00
19650219	Feb-19-1965 00:00	Feb-27-1965 00:00
19650228	Feb-28-1965 00:00	Mar-08-1965 00:00
19660117	Jan-17-1966 00:00	Jan-21-1966 06:00
19660124	Jan-24-1966 00:00	Feb-01-1966 00:00
19660204	Feb-04-1966 00:00	Feb-12-1966 00:00
19670103	Jan-03-1967 00:00	Jan-11-1967 00:00
19671217	Dec-17-1967 00:00	Dec-25-1967 00:00
19681106	Nov-06-1968 00:00	Nov-16-1968 12:00
19681109	Nov-09-1968 00:00	Nov-16-1968 00:00
19690212	Feb-12-1969 00:00	Feb-16-1969 12:00
19690310	Mar-10-1969 00:00	Mar-18-1969 00:00

Storm Ref	Start Date	End Date
19691114	Nov-14-1969 00:00	Nov-22-1969 00:00
19700103	Jan-03-1970 00:00	Jan-07-1970 06:00
19710301	Mar-01-1971 00:00	Mar-05-1971 00:00
19711202	Dec-02-1971 00:00	Dec-07-1971 00:00
19720110	Jan-10-1972 00:00	Jan-18-1972 00:00
19721210	Dec-10-1972 00:00	Dec-18-1972 00:00
19730108	Jan-08-1973 00:00	Jan-13-1973 00:00
19730207	Feb-07-1973 00:00	Feb-11-1973 06:00
19730405	Apr-05-1973 00:00	Apr-08-1973 12:00
19740508	May-08-1974 00:00	May-13-1974 00:00
19761027	Oct-27-1976 00:00	Oct-31-1976 06:00
19770322	Mar-22-1977 00:00	Mar-30-1977 00:00
19780116	Jan-16-1978 00:00	Jan-20-1978 12:00
19780206	Feb-06-1978 00:00	Feb-09-1978 12:00
19781204	Dec-04-1978 00:00	Dec-12-1978 00:00
19781228	Dec-28-1978 00:00	Jan-05-1979 00:00
19790115	Jan-15-1979 00:00	Jan-25-1979 00:00
19800228	Feb-28-1980 00:00	Mar-03-1980 12:00
19801124	Nov-24-1980 00:00	Nov-28-1980 12:00
19820111	Jan-11-1982 00:00	Jan-15-1982 00:00
19830117	Jan-17-1983 00:00	Jan-22-1983 00:00
19830210	Feb-10-1983 00:00	Feb-14-1983 12:00
19830224	Feb-24-1983 00:00	Mar-06-1983 00:00
19830314	Mar-14-1983 00:00	Mar-18-1983 18:00
19831219	Dec-19-1983 00:00	Dec-31-1983 00:00
19840225	Feb-25-1984 00:00	Feb-29-1984 18:00
19840323	Mar-23-1984 00:00	Mar-31-1984 00:00
19850206	Feb-06-1985 00:00	Feb-14-1985 00:00
19860103	Jan-03-1986 00:00	Jan-11-1986 00:00
19861228	Dec-28-1986 00:00	Jan-02-1987 00:00
19870304	Mar-04-1987 00:00	Mar-09-1987 00:00
19880202	Feb-02-1988 00:00	Feb-07-1988 00:00
19880406	Apr-06-1988 00:00	Apr-14-1988 00:00
19891014	Oct-14-1989 00:00	Oct-22-1989 00:00
19891116	Nov-16-1989 00:00	Nov-20-1989 06:00
19891217	Dec-17-1989 00:00	Dec-25-1989 00:00

Storm Ref	Start Date	End Date
19911101	Nov-01-1991 00:00	Nov-05-1991 06:00
19920203	Feb-03-1992 00:00	Feb-06-1992 12:00
19930122	Jan-22-1993 00:00	Jan-26-1993 06:00
19930310	Mar-10-1993 00:00	Mar-14-1993 00:00
19961110	Nov-10-1996 00:00	Nov-18-1996 00:00
19961213	Dec-13-1996 00:00	Dec-21-1996 00:00
19980129	Jan-29-1998 00:00	Feb-06-1998 00:00
19980209	Feb-09-1998 00:00	Feb-17-1998 00:00
19990116	Jan-16-1999 00:00	Jan-24-1999 00:00

GOMOS

Gulf of Mexico Oceanographic Study

Block Specific Report

Brazos Area 309/384S/376S and Galveston Area 380

Submitted to

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INTRODUCTION

Background

The GOMOS (Gulf of Mexico Oceanographic Study) hindcast is Oceanweather's new comprehensive metocean study for the Gulf of Mexico. It is intended as follow-on to the Gulf Joint Industry Projects GUMSHOE (Hurricane Extremes), WINX (Winter Storm Extremes) and GLOW (Operational Statistics), which have set the standard for design criteria in the Gulf.

GOMOS consists of three main components: a tropical hindcast (335 tropical storms/hurricanes from the period 1900-2005), extra-tropical/winter storm hindcast (80 storms from the period 1957-2000) and 16-year continuous hindcast (1990-2005). All three hindcasts used a common 1/8th degree implementation of Oceanweather's UNIWAVE wave model and 2-D current/surge model to produce a full description of the wind, wave, vertically integrated current, and surge height fields for the Gulf.

Time series, statistical analysis, extremal analysis and wave spectra are available from each of these hindcasts separately, or as a complete set. Full documentation on the methodology, model description and validation can be found in the companion report *GOMOS Project Description*. This block specific report details the methodology and deliverables associated with this particular GOMOS request.

Block of Interest

The blocks of interest are the Brazos Areas 309, 376S, 384S, and Galveston Area 380 located near 28.637-28.8817 N and 95.225-95.33 W. The nearest GOMOS grid point that satisfies all three locations is #9093 located at 28.75 N, 95.25 W in 19 meters of water (Figure 1). This is a full GOMOS block license that includes the following:

1. Time series of wind, wave, current and surge parameters from the 16-year continuous hindcast (3-hourly time step)
2. Monthly and Annual Frequency of Occurrence tables for wind speed by wind direction in 45 degree sectors
3. Monthly and Annual Frequency of Occurrence tables for wave height by wave period in 45 degree wave direction sectors
4. Persistence-Duration Statistics for wind speed
5. Persistence-Duration Statistics for wave height
6. Time series of wind, wave, current and surge parameters from the 335 tropical system hindcast (30-min time step). List of storm dates given in Appendix A.
7. Omni-directional tropical extremes for 1, 5, 10, 25, 50, 75, 100, 1000 year return periods for wind speed, surge height, vertically integrated current speed, and significant wave height with associated (at time of maximum wave) wind speed, surge height, vertically integrated current speed, maximum wave height, crest height and wave period. Extremes provided for both the full period, 1900-2005 and the last 56 years, 1950-2005.
8. Directional tropical extremes for 100 year return period for wind speed, surge height, vertically integrated current speed, and significant wave height with associated (at time of maximum wave) wind speed, surge height, vertically integrated current speed, maximum wave height, crest height and wave period in 45-degree bins. Extremes provided for both the full period, 1900-2005 and the last 56 years, 1950-2005.
9. Storm peaks (sorted by wave height) from tropical hindcast (see Appendix B).
10. Time series of wind, wave, current and surge parameters from the 80 extra-tropical/winter storm hindcast (30-min time step). List of storm dates given in Appendix C.
11. Omni-directional extra-tropical extremes for 1, 5, 10, 25, 50, 100, 1000 year return periods for wind speed, surge height, vertically integrated current speed and significant wave height with associated (at time of maximum wave) wind speed, surge height, vertically integrated current speed, maximum wave height, crest height and wave period.

12. Directional extra-tropical extremes for 100 year return period for wind speed, surge height, vertically integrated current speed and significant wave height with associated (at time of maximum wave) wind speed, surge height, vertically integrated current speed, maximum wave height, crest height and wave period in 45-degree bins.
13. Storm peaks (wave height) from extra-tropical hindcast
14. Block specific report

Units and Conventions

The following list describes the units and conventions used in this report. Where possible, units have been expressed using the SI convention.

Current speeds are expressed in centimeters per second (cm s^{-1}).
Current directions are expressed in degrees or compass points (N, NNE, NE etc), relative to True North, and describe the direction towards which the current was flowing.
Vertical elevations in the water column are expressed in meters, except surge which is in cm, and referenced to MSL.
Wind speeds are expressed in meters per second (ms^{-1}) at 10 m.
Wind directions are expressed in degrees or compass points (N, NNE, NE etc), relative to True North, and describe the direction from which the wind was blowing.
Wave heights are expressed in meters (m).
Wave directions are expressed in degrees or compass points (N, NNE, NE etc), relative to True North, and describe the direction towards which the waves were traveling.
Sectorized extremal analysis directional bins are all in “from which” convention for all directional variables listed.

CONTINUOUS HINDCAST RESULTS

Validation at Target Location

Figure 2 shows a 4-panel comparison plot of ERS-1/2 and TOPEX altimeter wind and wave measurements vs. the GOMOS continuous hindcast. Individual wind and wave estimates from the altimeter are time-matched with GOMOS hindcast output within 55km of a target location. Scatter plots (right) for wind (top) and significant wave height (bottom) as well as quantile-quantile (Q-Q) plots are presented as well as general statistics. Empirically derived wave period estimates from the altimeter as also included, but are generally suspect.

Based on 1686 comparisons the wave height has a negative 11 cm bias with correlation coefficient of 86% and nearly linear Q-Q comparison up to the 99th percentile. Wind speed comparisons show a positive bias of 1.30 m/s with correlation coefficient of 81%. The Q-Q comparison is linear, but with an offset showing the hindcast running higher than the altimeter in all percentiles. Evidence from altimeter studies in enclosed basins and fetch-limited areas generally show that the altimeter winds are biased low which appears to be the case in this comparison as well.

Modification Description

Based on the local validation dataset, modifications were applied to the GOMOS continuous hindcast at this location. The algorithm applies the regression equation $HS_{new} = 0.041 + 1.064*HS_{GOMOS}$, then conserves significant steepness to adjust the peak period and makes compatible corrections to the sea and swell partitions. To prevent very low wave heights (less than 10 cm) from doubling, the adjusted waves were restricted to a 50% change. These adjusted time series were used in any additional tables and figures.

Deliverables

Time series of wind, wave, current and surge values from the 1990-2005 continuous hindcast are provided in electronic form. Descriptions of the fields contained in the time series can be found in the *GOMOS Project Description*. It should be noted that the current/surge model used in GOMOS is a wind-driven vertically integrated model and does not model the general circulation, eddies, etc. that are typically modeled by full 3D models. Great care should be taken in interpreting these results outside their intended use of describing the surge/current conditions in storms contained within the continuous period.

Operational statistics include monthly and annual bivariate frequency of occurrence distributions for wind speed by wind direction and wave period by wave height by wave direction. Wind and wave rose plots, derived from the annual results, are shown in Figures 3 and 4. Persistence-Duration (also known as threshold exceedance and non-exceedance) tables are provided for wind speed and wave height. All results are provided in electronic form with documentation as to the generation and format provided in the *GOMOS Project Description*.

TROPICAL HINDCAST RESULTS

Extremal Analysis

In the tropical extremal analysis an estimate of the maximum individual wave height and crest height and in each event is computed using our standard algorithm. The *GOMOS Project Description* document describes the standard extremal analysis algorithm used to fit the distributions of the peaks-over-threshold to the ranked series of maxima at each point of WS, HS, HMax and HCrest. The wave period associated with return period wave height extremes for storms was assigned from regressions of the form TP = C_0* HS** C_1 (TP in seconds, HS in meters) and were developed from the hindcast storm peaks. Sectorized extremes were derived from selecting WS, HS, HMax and HCrest peaks within 45-degree sectors for each storm and producing extremes for comparison to the omni-directional values. All sectorized extremes use meteorological convention for all wind, current, and wave directions (“from which”).

The wind speed extremes for other averaging periods can be derived from the 1-hour average extremes using the following gust factors specifically applicable to tropical cyclones:

1 Hour to 10-Minute Mean:	x 1.09
1 Hour to 1 Minute Wind:	x 1.24
1 Hour to 3-Second Gust:	x 1.53

A number of different thresholds and distributions were tried and ultimately the combination of the Gumbel distribution and ½ maximum event threshold was selected. In return periods where the ½ max rule did not provide sufficient peaks for the calculation of an extreme value, the top 107 storms in the 106-year period were used (typically 1 and 5 year return periods). (The top 57 storms in the 56-year period 1950-2005 were used for those 1 and 5-year return periods.) Due to the variability of storm tracks, the hindcast results at the following suite of points were averaged for the derivation of “site-average” return period extremes:

Grid Point	Latitude	Longitude	Depth (m)
8607	28.250	-96.250	20
8827	28.500	-95.750	17
9093	28.750	-95.250	19
9243	29.000	-94.875	16
9428	29.250	-94.500	15

Within the site-averaging process applied to accurate and unbiased hindcast data, a useful measure of fit is the mean difference over all the individual grid points involved, between the fitted wind speed provided by the distribution at the return period represented by the population fitted, and the highest ranked wind speed. Table 1 compares the fitted 100-year wind speed and the highest ranked wind speed in 106 years at each point for the two most widely applied distributions: Gumbel and Weibull. The mean difference between the fitted peak and the hindcast peak is smaller for Gumbel (-0.14 m/s) than for Weibull (-1.30 m/s). The table gives the site-averaged Gumbel 100-year wind speed peak before (38.71 m/s) and after adding the “unbiasing factor” of 0.14 m/s. This yields an “unbiased” wind speed extreme of 38.85 m/s. To preserve the unbiasing factor for more general use, we expressed it as a percentage difference and applied it to the remaining return periods in Table 2. We repeated this analysis for the 1950-2005 extremal analysis using the 56-year return period (bottom Table 1). The winds are about 4% low, and again we expressed the bias as a factor and applied it to the wind speed extremes in Table 3.

Our final site-averaged wind, wave, current, and surge extremes are given in Table 2 for both the omni-directional (all return periods) and by directional sector (100-year return period only) for 1900-2005. The same extremes are given in Table 3 for 1950-2005. Please note that a 0.21 m bias was added to the HS extremes as described in the companion report. HM and HC ratios as well as TP steepness were all conserved.

Deliverables

Time series of wind, wave, current, and surge values from the 335 tropical storms hindcast are provided in electronic form. Descriptions of the fields contained in the time series can be found in the *GOMOS Project Description*. Storm peaks at the target location sorted by wave height used in the extremal analysis are also provided for the target location in electronic form and in Appendix B. Final extremal analysis values are summarized in Tables 2 and 3.

EXTRA-TROPICAL RESULTS

Extremal Analysis

In the extra-tropical extremal analysis an estimate of the maximum individual wave height and crest height and in each event is computed using our standard algorithm. The *GOMOS Project Description* document describes the standard extremal analysis algorithm used to fit the distributions of the peaks-over-threshold to the ranked series of maxima at each point of WS, HS, HMax and HCrest. The wave period associated with return period wave height extremes for storms was assigned from regressions of the form TP = C_0* HS** C_1 (TP in seconds, HS in meters) and were developed from the hindcast storm peaks. Sectorized extremes were derived from selecting WS, HS, HMax and HCrest peaks within 45-degree sectors for each storm and producing extremes for comparison to the omni-directional values. All sectorized extremes use meteorological convention for all wind, current, and wave directions (“from which”).

The wind speed extremes for other average periods can be derived from the 1-hour average extremes using the following gust factors specifically applicable to extra-tropical storms:

1 Hour to 10-Minute Mean:	x 1.06
1 Hour to 1 Minute Wind:	x 1.22
1 Hour to 3-Second Gust:	x 1.43

A number of different thresholds and distributions were tried and ultimately the combination of the Gumbel distribution and ½ maximum event threshold was selected. In return periods where the ½ max rule did not provide sufficient peaks for the calculation of an extreme value, the top 44 storms in the 43-year period were used (typically 1 and 5 year return periods for the hydrodynamic variables). No site averaging of the extra-tropical/winter storms were required.

Our final wind, wave, current and surge extremes are given in Table 4 for both the omni-directional (all return periods) and by directional sector (100-year return period only). Please note a 0.28 m bias was added to the HS extremes as described in the companion report. HM and HC ratios as well as TP steepness were all conserved.

Deliverables

Time series of wind, wave, current, and surge values from the 80 extra-tropical storms hindcast are provided in electronic form. Descriptions of the fields contained in the time series can be found in the *GOMOS Project Description*. Storm peaks at the target location for wave heights greater than threshold used in the extremal analysis are also provided for the target location in electronic form. Final extremal analysis values are summarized in Table 4.

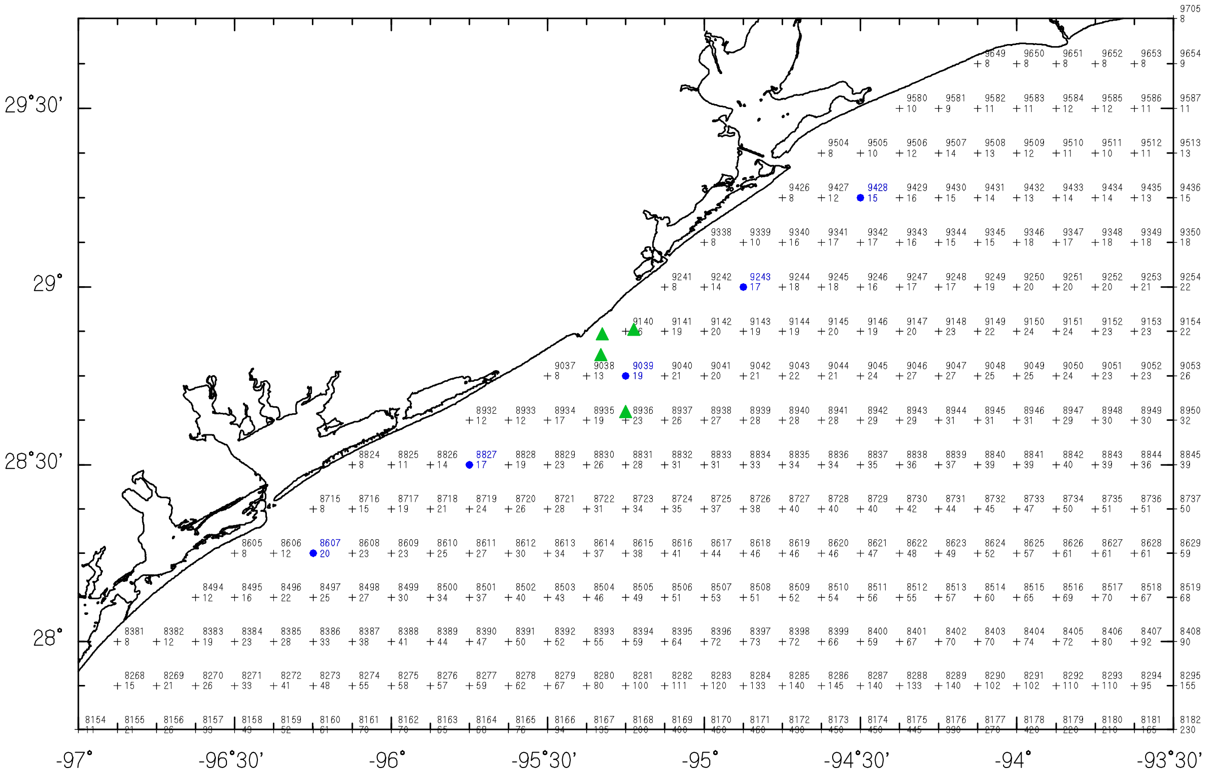
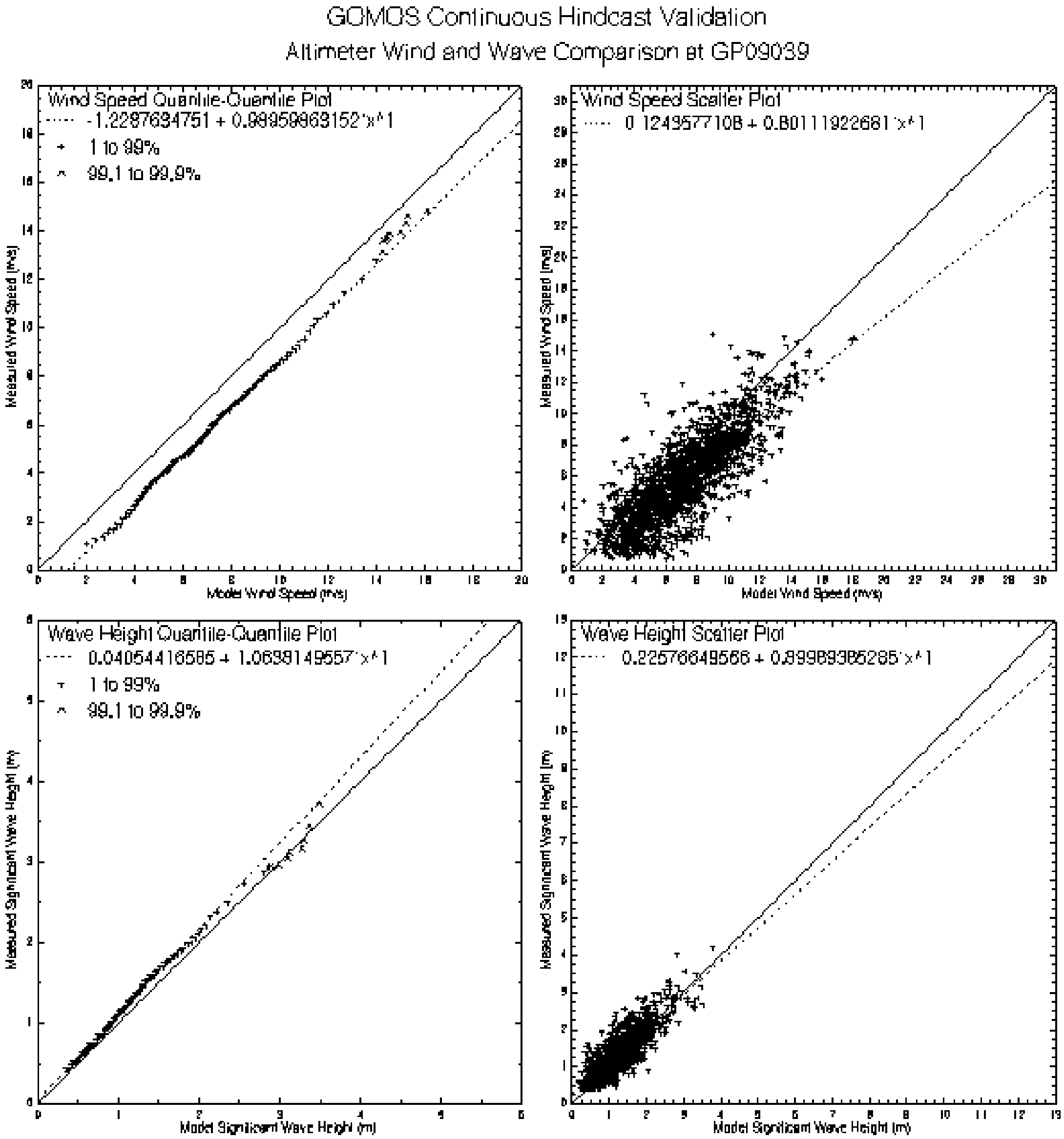


Figure 1. GOMOS grid point locations (grid point numbers, upper right, and depths in meters, right) in area surrounding target locations (green triangles). From the bottom point, moving clockwise the target locations are GA 380, BR 309, BR 384S, and BR 376S. Site-average points are highlighted in blue.



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Hindcast Period : 01-JAN-1980 00,00,00 to 01-JAN-2000 00,00:00
Latitude Range  :     15.00 to    32.00
Longitude Range :   -100.00 to   -80.00


                                  Grid     Number    Mean    Mean     Diff    RMS    Stnd   Scat           Corr
                       Station    Point    of Pts    Meas    Hind    (H-M)   Error    Dev   Index   Ratio  Coeif
                       -------  --------  --------  ------  ------  ------   -----   -----  -----   -----  -----
Wind Spd. (m/s)  Combined         0        1988     5.85    7.15     1.30    2.12    1.87   0.29    0.80   0.81
Sig Wave Ht  (m) Combined         0        1686     1.25    1.14    -0.11    0.31    0.29   0.23    0.33   0.86
Wave Period  (s) Combined         0        1673     5.42    5.46     0.04    0.82    0.82   0.15    0.49   0.67
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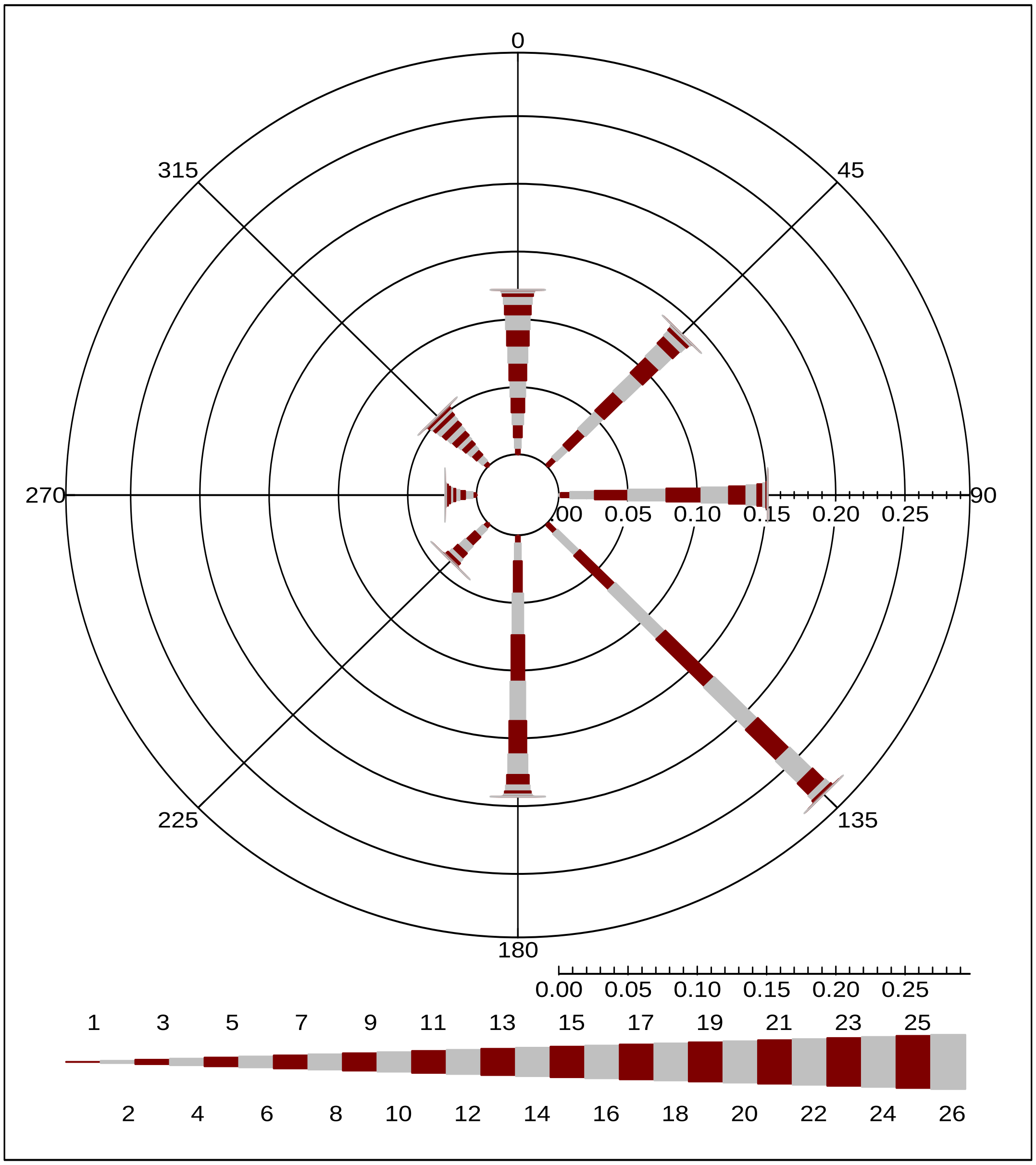
Figure 2. Comparison of GOMOS continuous hindcast wind and waves vs. ERS-1/2 and TOPEX altimeter wind and wave measurements.

All Months & Years

Wind Dir (deg fr) vs. Wind Sp (m/s)



GO Gpt 9039, Lat 28.75n, Long 95.25w, Depth 19m

Defined Period: Operational

Figure 3. Wind speed (m/s) directional rose for all years combined from GOMOS continuous hindcast. Wind directions are meteorological (from which) convention.

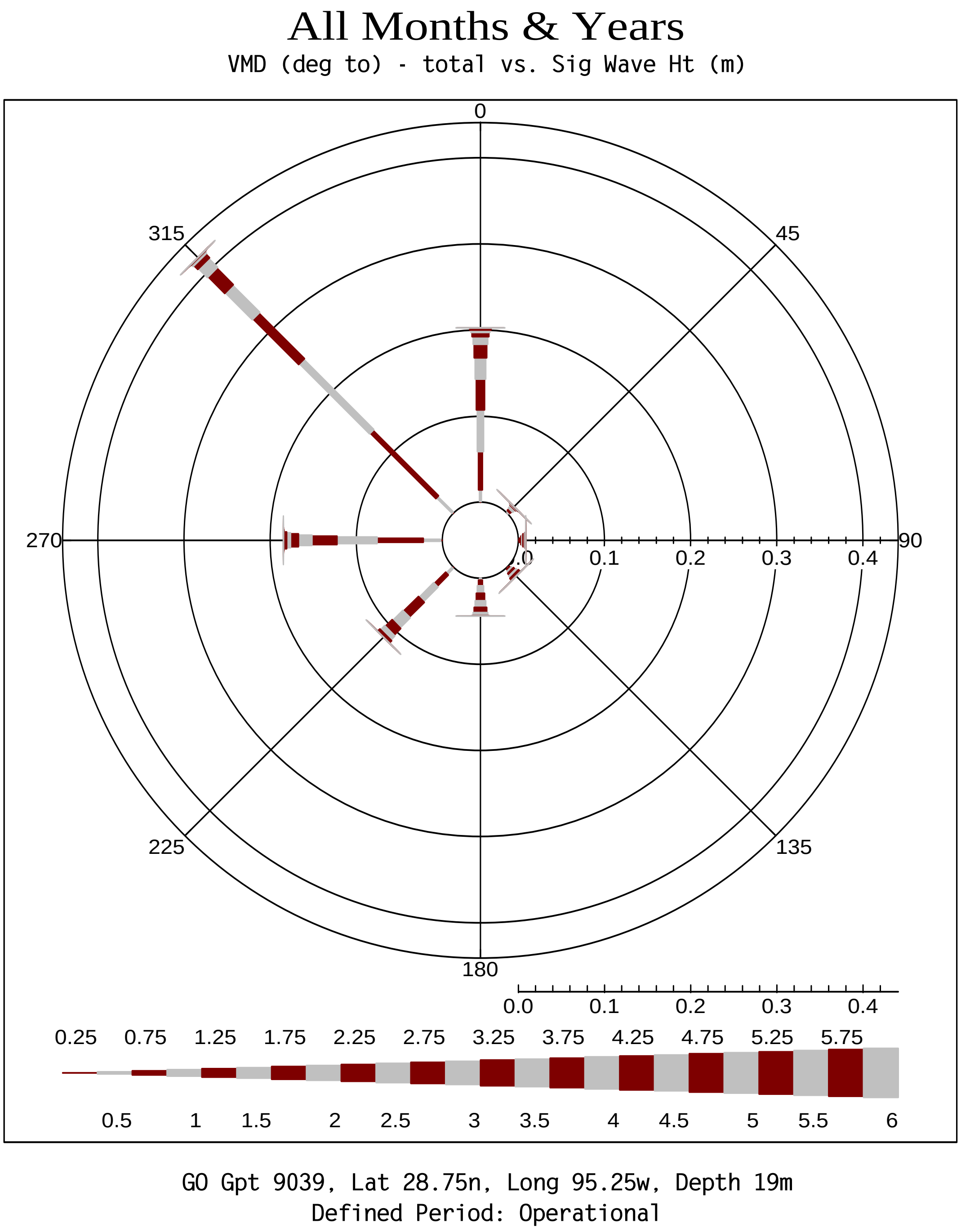


Figure 4. Significant wave height (m) directional rose for all years combined from GOMOS continuous hindcast. Wave directions are vector mean oceanographic (to which) convention.

Table 1: Comparison of Fitted 100-year Extremes (top) and 56-year Extremes (bottom)

Wind Speed and Wind Speed in Top-Ranked Storm, 1900-2005

Grid Point	Gumbel 100-yr	Weibull 100-yr	106-year	Storm Name
8607	38.38	36.43	40.21	Carla
8827	37.59	36.93	38.09	Carla
9093	36.52	35.88	36.15	1949_10
9243	40.08	39.62	38.09	1915_02
9428	40.98	38.89	41.69	1900_01
Bias (Fit-GOMOS)	-0.14	-1.30		
Gumbel site-average				38.71 m/s
Unbias factor				x 1.0035
Gumbel unbiased extreme				38.85 m/s

Carla occurred in 196109, 1949_10 occurred in 194910, 1915_02 occurred in 191508, and 1900_01 occurred in 190009.

Wind Speed and Wind Speed in Top-Ranked Storm, 1950-2005

Grid Point	Gumbel 56-yr	Weibull 56-yr	56-year	Storm Name
8607	35.58	31.93	40.21	Carla
8827	34.43	30.49	38.09	Carla
9093	30.69	30.11	30.85	Carla
9243	31.86	31.33	32.60	Alicia
9428	33.18	33.02	31.30	Audrey
Bias (Fit-GOMOS)	-1.46	-3.23		
Gumbel site-average				33.15 m/s
Unbias factor				x 1.0441
Gumbel unbiased extreme				34.61 m/s

Carla occurred in 196109, Alicia occurred in 198308, and Audrey occurred in 195706.

Table 2. GOMOS tropical extremes for maximum wind speed (m/s), maximum surge height (cm), maximum vertically integrated current speed (cm/s), and significant wave height (m) with associated surge height, vertically integrated current speed, wind speed, maximum wave height (m), wave crest height (m), and peak period (s) at the time of the maximum significant wave height.

1900-2005

OMNI Directional Extremes

RtnPer	maxWS	maxHSUR	maxCS	HSig	assHSUR	assoCS	assoWS	HMax	HCrest	TP(r)
1	11.7	23.9	45.6	2.2	21.8	42.5	11.1	4.4	2.8	7.2
5	22.3	86.2	101.4	4.2	74.9	89.6	21.1	7.8	5.2	10.0
10	26.7	109.5	124.1	5.1	96.4	110.7	25.6	9.4	6.3	11.0
25	31.9	139.0	164.0	6.5	125.4	148.9	31.1	11.3	7.2	12.4
50	35.4	188.8	198.1	7.3	170.7	182.5	34.7	12.6	7.9	13.2
75	37.4	212.5	215.8	7.8	191.6	202.3	36.8	13.3	8.3	13.6
100	38.8	228.0	227.9	8.1	205.6	215.6	38.3	13.8	8.6	13.9
1000	50.0	340.2	320.0	10.7	309.6	313.9	49.8	17.7	10.8	16.0

North Sector (from which 337.5 to 22.5 degrees) 100 Year Extremes

% of Omni	83%	N/A	19%	57%						
Value	32.3	N/A	42.6	4.6	117.8	123.5	21.9	7.9	4.9	10.5

NorthEast Sector (from which 22.5 to 67.5 degrees) 100 Year Extremes

% of Omni	92%	N/A	100%	75%						
Value	35.8	N/A	227.4	6.1	155.0	162.6	28.9	10.4	6.5	12.1

East Sector (from which 67.5 to 112.5 degrees) 100 Year Extremes

% of Omni	95%	N/A	33%	90%						
Value	36.7	N/A	75.4	7.3	184.2	193.2	34.3	12.3	7.7	13.1

SouthEast Sector (from which 112.5 to 157.5 degrees) 100 Year Extremes

% of Omni	91%	N/A	4%	95%						
Value	35.5	N/A	9.3	7.7	195.7	205.3	36.5	13.1	8.2	13.5

South Sector (from which 157.5 to 202.5 degrees) 100 Year Extremes

% of Omni	85%	N/A	7%	88%						
Value	33.0	N/A	15.5	7.2	181.3	190.2	33.8	12.1	7.6	13.0

SouthWest Sector (from which 202.5 to 247.5 degrees) 100 Year Extremes

% of Omni	70%	N/A	28%	51%						
Value	27.0	N/A	62.7	4.1	103.8	108.9	19.3	6.9	4.4	9.9

West Sector (from which 247.5 to 292.5 degrees) 100 Year Extremes

% of Omni	67%	N/A	12%	45%						
Value	26.2	N/A	28.0	3.7	93.1	97.7	17.3	6.2	3.9	9.3

NorthWest Sector (from which 292.5 to 337.5 degrees) 100 Year Extremes

% of Omni	78%	N/A	7%	51%						
Value	30.2	N/A	15.0	4.1	104.0	109.1	19.4	7.0	4.4	9.9

Table 3. GOMOS tropical extremes for maximum wind speed (m/s), maximum surge height (cm), maximum vertically integrated current speed (cm/s), and significant wave height (m) with associated surge height, vertically integrated current speed, wind speed, maximum wave height (m), wave crest height (m), and peak period (s) at the time of the maximum significant wave height.

1950-2005

OMNI Directional Extremes

RtnPer	maxWS	maxHSUR	maxCS	HSig	assHSUR	assoCS	assoWS	HMax	HCrest	TP(r)
1	12.0	23.7	46.1	2.2	21.6	43.1	10.8	4.4	2.8	7.1
5	21.1	74.1	91.5	3.8	67.1	79.9	19.3	7.2	4.8	9.6
10	24.1	93.4	110.8	4.3	86.3	97.0	20.9	7.7	5.8	10.2
25	30.1	118.7	142.2	5.8	112.3	124.8	27.8	10.4	6.8	11.8
50	33.9	168.8	180.7	6.6	160.2	164.5	31.8	12.0	7.6	12.7
75	36.2	194.7	200.9	7.1	184.9	185.4	34.1	12.8	8.1	13.2
100	37.8	212.4	214.8	7.4	201.7	199.7	35.7	13.4	8.4	13.5
1000	50.0	346.3	321.0	10.0	329.4	309.3	48.1	18.1	10.8	15.7

North Sector (from which 337.5 to 22.5 degrees) 100 Year Extremes

RtnPer	maxWS	maxHSUR	maxCS	HSig	assHSUR	assoCS	assoWS	HMax	HCrest	TP(r)
% of Omni	82%	N/A	15%	59%						
Value	31.0	N/A	31.1	4.3	118.0	116.8	20.9	7.8	4.9	10.3

NorthEast Sector (from which 22.5 to 67.5 degrees) 100 Year Extremes

RtnPer	maxWS	maxHSUR	maxCS	HSig	assHSUR	assoCS	assoWS	HMax	HCrest	TP(r)
% of Omni	93%	N/A	100%	71%						
Value	35.1	N/A	214.8	5.3	143.6	142.2	25.4	9.5	6.0	11.4

East Sector (from which 67.5 to 112.5 degrees) 100 Year Extremes

RtnPer	maxWS	maxHSUR	maxCS	HSig	assHSUR	assoCS	assoWS	HMax	HCrest	TP(r)
% of Omni	98%	N/A	22%	93%						
Value	36.9	N/A	47.9	6.9	188.2	186.3	33.3	12.5	7.9	13.0

SouthEast Sector (from which 112.5 to 157.5 degrees) 100 Year Extremes

RtnPer	maxWS	maxHSUR	maxCS	HSig	assHSUR	assoCS	assoWS	HMax	HCrest	TP(r)
% of Omni	91%	N/A	4%	99%						
Value	34.2	N/A	8.6	7.3	198.9	196.9	35.2	13.2	8.3	13.4

South Sector (from which 157.5 to 202.5 degrees) 100 Year Extremes

RtnPer	maxWS	maxHSUR	maxCS	HSig	assHSUR	assoCS	assoWS	HMax	HCrest	TP(r)
% of Omni	83%	N/A	8%	90%						
Value	31.4	N/A	17.0	6.7	182.1	180.3	32.2	12.1	7.6	12.8

SouthWest Sector (from which 202.5 to 247.5 degrees) 100 Year Extremes

RtnPer	maxWS	maxHSUR	maxCS	HSig	assHSUR	assoCS	assoWS	HMax	HCrest	TP(r)
% of Omni	64%	N/A	32%	49%						
Value	24.3	N/A	68.7	3.6	98.8	97.9	17.5	6.6	4.1	9.4

West Sector (from which 247.5 to 292.5 degrees) 100 Year Extremes

RtnPer	maxWS	maxHSUR	maxCS	HSig	assHSUR	assoCS	assoWS	HMax	HCrest	TP(r)
% of Omni	69%	N/A	14%	44%						
Value	26.2	N/A	29.4	3.3	89.4	88.5	15.8	5.9	3.7	9.0

NorthWest Sector (from which 292.5 to 337.5 degrees) 100 Year Extremes

RtnPer	maxWS	maxHSUR	maxCS	HSig	assHSUR	assoCS	assoWS	HMax	HCrest	TP(r)
% of Omni	82%	N/A	7%	52%						
Value	30.9	N/A	14.4	3.8	104.3	103.2	18.5	6.9	4.4	9.7

Table 4. GOMOS extra-tropical extremes for maximum wind speed (m/s), surge height (cm), vertically integrated current speed (cm/s) and significant wave height (m) with associated surge height, current speed, wind speed, maximum wave height (m), wave crest height (m), and peak period (s) at the time of the max sig. wave height.

OMNI Directional Extremes

RtnPer	maxWS	maxHSUR	maxCS	HSig	assHSUR	assoCS	assoWS	HMax	HCrest	TP(r)
1	15.3	10.4	43.2	2.7	n/a	34.8	13.6	5.1	3.4	7.3
5	19.0	34.2	75.2	3.4	31.7	67.9	18.1	6.4	4.4	8.7
10	20.4	40.7	84.5	3.7	38.9	77.9	19.8	6.9	4.8	9.2
25	22.2	52.1	95.7	4.1	50.7	89.5	21.9	7.6	5.2	9.7
50	23.5	59.9	103.9	4.3	59.0	97.8	23.5	8.1	5.6	10.1
100	24.8	67.4	111.9	4.6	67.4	106.0	24.8	8.5	5.9	10.6
1000	29.9	91.7	138.9	5.6	91.7	131.7	29.1	10.3	7.2	12.2

North Sector (from which 337.5 to 22.5 degrees) 100 Year Extremes

% of Omni	100%	N/A	6%	72%						
Value	24.7	N/A	7.2	3.3	48.3	75.9	17.8	6.1	4.2	9.0

NorthEast Sector (from which 22.5 to 67.5 degrees) 100 Year Extremes

% of Omni	87%	N/A	100%	79%						
Value	21.7	N/A	111.9	3.6	53.4	84.1	19.7	6.8	4.6	9.5

East Sector (from which 67.5 to 112.5 degrees) 100 Year Extremes

% of Omni	78%	N/A	11%	87%						
Value	19.2	N/A	12.6	4.0	58.9	92.6	21.7	7.4	5.1	9.9

SouthEast Sector (from which 112.5 to 157.5 degrees) 100 Year Extremes

% of Omni	71%	N/A	5%	100%						
Value	17.7	N/A	5.5	4.6	67.1	105.5	24.7	8.5	5.8	10.6

South Sector (from which 157.5 to 202.5 degrees) 100 Year Extremes

% of Omni	77%	N/A	6%	100%						
Value	19.1	N/A	6.2	4.6	67.4	106.0	24.8	8.5	5.9	10.6

SouthWest Sector (from which 202.5 to 247.5 degrees) 100 Year Extremes

% of Omni	63%	N/A	79%	59%						
Value	15.7	N/A	88.7	2.7	39.8	62.5	14.6	5.0	3.5	8.2

West Sector (from which 247.5 to 292.5 degrees) 100 Year Extremes

% of Omni	79%	N/A	13%	60%						
Value	19.5	N/A	14.4	2.7	40.4	63.5	14.9	5.1	3.5	8.2

NorthWest Sector (from which 292.5 to 337.5 degrees) 100 Year Extremes

% of Omni	99%	N/A	3%	65%						
Value	24.6	N/A	3.2	3.0	43.8	68.9	16.1	5.5	3.8	8.6

Appendix A

Tropical Storm List

Tropical Storm List

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
1900_01	NOT NAMED	190009041800	190009091200	114	936
1900_03	NOT NAMED	190009100600	190009131800	84	994
1900_06	NOT NAMED	190010081200	190010120600	90	997
1901_01	NOT NAMED	190106101200	190106141200	96	1000
1901_02	NOT NAMED	190107070000	190107101800	90	990
1901_04	NOT NAMED	190108110000	190108151800	114	973
1901_06	NOT NAMED	190109141800	190109180000	78	990
1901_08	NOT NAMED	190109241200	190109271800	78	994
1902_01	NOT NAMED	190206120600	190206141800	60	994
1902_02	NOT NAMED	190206201200	190206271200	168	966
1902_04	NOT NAMED	190210050600	190210101200	126	961
1903_02	NOT NAMED	190308120000	190308161800	114	941
1903_03	NOT NAMED	190309120000	190309140600	54	970
1904_03	NOT NAMED	190410151200	190410201800	126	983
1904_05	NOT NAMED	190410290600	190411030600	120	994
1905_03	NOT NAMED	190509241200	190509291800	126	994
1905_05	NOT NAMED	190510050600	190510100000	114	994
1906_01	NOT NAMED	190606081200	190606130000	108	994
1906_02	NOT NAMED	190606161200	190606171200	24	975
1906_05	NOT NAMED	190609230000	190609271200	108	965
1906_08	NOT NAMED	190610151800	190610221800	168	930
1907_01	NOT NAMED	190706260000	190706290600	78	990
1907_02	NOT NAMED	190709180000	190709220000	96	990
1907_03	NOT NAMED	190709270600	190709290000	42	994
1908_05	NOT NAMED	190809161200	190809181800	54	983
1909_01	NOT NAMED	190906251200	190906301200	120	990
1909_02	NOT NAMED	190906281800	190906301200	42	997
1909_03	NOT NAMED	190907171200	190907221200	120	959
1909_04	NOT NAMED	190908071800	190908110000	78	990
1909_05	NOT NAMED	190908241800	190908281200	90	941
1909_07	NOT NAMED	190909161200	190909210000	108	970
1909_08	NOT NAMED	190909241200	190909270000	60	994
1909_09	NOT NAMED	190910090000	190910111800	66	941
1910_01	NOT NAMED	191008251800	191008311800	144	990

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
1910_02	NOT NAMED	191009100000	191009150000	120	957
1910_04	NOT NAMED	191010130600	191010191200	150	941
1911_01	NOT NAMED	191108090600	191108120600	72	983
1911_04	NOT NAMED	191110260600	191111010000	138	994
1912_01	NOT NAMED	191206071200	191206131200	144	990
1912_03	NOT NAMED	191209111200	191209140600	66	975
1912_05	NOT NAMED	191210111200	191210171800	150	961
1913_01	NOT NAMED	191306241800	191306281200	90	961
1914_01	NOT NAMED	191409170000	191409191200	60	997
1915_02	NOT NAMED	191508140000	191508180000	96	941
1915_04	NOT NAMED	191509011800	191509041200	66	966
1915_05	NOT NAMED	191509261200	191509300000	84	935
1916_01	NOT NAMED	191607021200	191607060000	84	961
1916_04	NOT NAMED	191608161200	191608190000	60	941
1916_13	NOT NAMED	191610150600	191610181200	78	946
1916_14	NOT NAMED	191611131800	191611151800	48	975
1917_03	NOT NAMED	191709241800	191709290000	102	941
1918_01	NOT NAMED	191808041200	191808061800	54	960
1919_01	NOT NAMED	191907020600	191907041200	54	990
1919_02	NOT NAMED	191909091800	191909150000	126	930
1920_02	NOT NAMED	192009191200	192009220000	60	980
1920_04	NOT NAMED	192009250600	192009301200	126	975
1921_01	NOT NAMED	192106180600	192106230600	120	954
1921_02	NOT NAMED	192109060600	192109080600	48	975
1921_06	NOT NAMED	192110221800	192110260600	84	946
1922_01	NOT NAMED	192206131200	192206161800	78	994
1922_03	NOT NAMED	192210121800	192210171200	114	994
1922_04	NOT NAMED	192210151800	192210220600	156	961
1923_03	NOT NAMED	192310131800	192310160600	60	976
1923_06	NOT NAMED	192310161200	192310180000	36	994
1924_01	NOT NAMED	192406181800	192406211800	72	997
1924_04	NOT NAMED	192409130000	192409160600	78	988
1924_05	NOT NAMED	192409280000	192409300000	48	990
1924_06	NOT NAMED	192410120600	192410141200	54	990
1924_07	NOT NAMED	192410170600	192410221200	126	946

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
1925_01	NOT NAMED	192509060000	192509071800	42	997
1925_02	NOT NAMED	192511291800	192512011200	42	979
1926_03	NOT NAMED	192608220000	192608261800	114	959
1926_06	NOT NAMED	192609181200	192609221200	96	935
1926_10	NOT NAMED	192610190600	192610210000	42	941
1928_02	NOT NAMED	192808121800	192808141800	48	987
1928_03	NOT NAMED	192809030600	192809081800	132	990
1929_01	NOT NAMED	192906270000	192906291200	60	969
1929_02	NOT NAMED	192909281200	192910010600	66	951
1930_02	NOT NAMED	193009060000	193009101800	114	997
1931_01	NOT NAMED	193106250000	193106281800	90	997
1931_02	NOT_NAMED	193107121200	193107160000	84	987
1931_03	NOT_NAMED	193108170600	193108181800	36	994
1931_05	NOT_NAMED	193109110000	193109121800	42	983
1931_06	NOT NAMED	193109131200	193109161800	78	983
1932_02	NOT NAMED	193208120000	193208141800	66	942
1932_03	NOT NAMED	193208300600	193209010600	48	975
1932_05	NOT NAMED	193209090600	193209150600	144	994
1932_06	NOT NAMED	193209180600	193209200000	42	1000
1932_07	NOT_NAMED	193209300600	193210031800	84	998
1932_08	NOT_NAMED	193210100600	193210160600	144	991
1933_01	NOT NAMED	193305151800	193305191800	96	997
1933_02	NOT NAMED	193307020600	193307070600	120	972
1933_03	NOT NAMED	193307170600	193307200600	72	994
1933_04	NOT NAMED	193307210600	193307231800	60	997
1933_05	NOT NAMED	193307301800	193308051800	144	975
1933_06	NOT NAMED	193308170000	193308201200	84	997
1933_10	NOT NAMED	193308261800	193308291800	72	1000
1933_11	NOT NAMED	193309011200	193309051800	102	949
1933_12	NOT NAMED	193309040600	193309060000	42	948
1933_14	NOT_NAMED	193309121800	193309151800	72	984
1933_15	NOT NAMED	193309201800	193309250000	102	967
1933_18	NOT NAMED	193310030000	193310050600	54	941
1934_01	NOT NAMED	193405270600	193405281200	30	997
1934_02	NOT_NAMED	193406081800	193406170000	198	966

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
1934_03	NOT NAMED	193407230000	193407260600	78	979
1934_05	NOT NAMED	193408260600	193409011800	156	975
1934_09	NOT NAMED	193410011200	193410060600	114	990
1935_02	NOT NAMED	193509030000	193509050000	48	892
1935_03	NOT NAMED	193508301200	193509011800	54	997
1935_06	NOT NAMED	193511041800	193511081800	96	973
1936_01	NOT_NAMED	193606121200	193606151200	72	994
1936_02	NOT NAMED	193606190600	193606220600	72	1000
1936_03	NOT NAMED	193606261800	193606280600	36	975
1936_04	NOT NAMED	193607260600	193607271200	30	997
1936_05	NOT NAMED	193607290600	193607311800	60	964
1936_07	NOT NAMED	193608070600	193608121800	132	1000
1936_08	NOT NAMED	193608150600	193608191800	108	988
1936_10	NOT NAMED	193608280600	193608301800	60	988
1936_14	NOT NAMED	193609100600	193609141200	102	997
1936_16	NOT NAMED	193610091800	193610110000	30	1000
1937_01	NOT NAMED	193707291200	193707301200	24	997
1937_06	NOT NAMED	193709161200	193709211800	126	997
1937_09	NOT NAMED	193709291200	193710031800	102	1000
1938_02	NOT_NAMED	193808121200	193808150600	66	971
1938_03	NOT NAMED	193808250000	193808281200	84	976
1938_05	NOT_NAMED	193810111200	193810171800	150	987
1938_07	NOT NAMED	193810230600	193810240600	24	997
1939_01	NOT_NAMED	193906121200	193906161200	96	991
1939_02	NOT NAMED	193908111800	193908140000	54	975
1939_03	NOT NAMED	193909230600	193909261800	84	997
1940_02	NOT NAMED	194008021800	194008081800	144	972
1940_06	NOT_NAMED	194009210000	194009250000	96	994
1941_01	NOT NAMED	194109110600	194109161800	132	997
1941_02	NOT NAMED	194109161200	194109240000	180	959
1941_05	NOT NAMED	194110061200	194110071200	24	937
1941_06	NOT NAMED	194110171200	194110220600	114	994
1942_01	NOT NAMED	194208171800	194208221800	120	975
1942_02	NOT_NAMED	194208261800	194208310000	102	948
1942_10	NOT_NAMED	194211071200	194211111800	102	969

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
1943_01	NOT NAMED	194307251800	194307290000	78	975
1943_06	NOT NAMED	194309151800	194309200600	108	961
1944_04	NOT_NAMED	194408211200	194408240600	66	977
1944_05	NOT NAMED	194408191800	194408230600	84	990
1944_06	NOT NAMED	194409090000	194409101800	42	994
1944_08	NOT NAMED	194409190600	194409211800	60	975
1944_11	NOT NAMED	194410140600	194410191800	132	942
1945_01	NOT NAMED	194506201800	194506250000	102	965
1945_02	NOT NAMED	194507190600	194507220600	72	994
1945_05	NOT NAMED	194508240600	194508290000	114	966
1945_07	NOT NAMED	194509031800	194509060600	60	1000
1946_01	NOT NAMED	194606131800	194606161800	72	1000
1946_03	NOT NAMED	194608250000	194608260000	24	1000
1946_05	NOT NAMED	194610050600	194610081200	78	979
1947_01	NOT NAMED	194707310600	194708021200	54	997
1947_02	NOT NAMED	194708120000	194708160600	102	967
1947_03	NOT NAMED	194708181800	194708260600	180	983
1947_04	NOT NAMED	194709180000	194709200000	48	966
1947_05	NOT NAMED	194709071800	194709081800	24	997
1947_06	NOT NAMED	194709210000	194709240000	72	989
1947_08	NOT NAMED	194710101200	194710120600	42	970
1948_02	NOT NAMED	194807071800	194807091200	42	1000
1948_05	NOT NAMED	194809011800	194809041200	66	990
1948_07	NOT NAMED	194809181800	194809221200	90	935
1948_08	NOT NAMED	194810040600	194810060000	42	930
1949_05	NOT NAMED	194909030600	194909041800	36	997
1949_08	NOT NAMED	194909201200	194909261800	150	976
1949_10	NOT_NAMED	194910010000	194910041800	90	963
1950_02	BAKER	195008260000	195008310600	126	979
1950_05	EASY	195009010600	195009070600	144	958
1950_08	HOW	195010010600	195010041800	84	990
1950_09	ITEM	195010080600	195010101800	60	967
1950_13	LOVE	195010180000	195010211800	90	966
1951_03	CHARLIE	195108181200	195108231800	126	946
1951_07	GEORGE	195109200600	195109211800	36	990

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
1951_08	HOW	195109280600	195110021800	108	983
1952_01	NOT NAMED	195202021200	195202030600	18	994
1953_01	ALICE	195305291800	195306061800	192	983
1953_03	NOT NAMED	195308281800	195308291800	24	985
1953_07	NOT NAMED	195309140600	195309201800	156	983
1953_08	FLORENCE	195309240600	195309270000	66	968
1953_12	HAZEL	195310070600	195310091800	60	983
1954_01	ALICE	195406241200	195406260600	42	988
1954_02	BARBARA	195407270600	195407300600	72	997
1954_06	FLORENCE	195409110600	195409121800	36	979
1955_01	BRENDA	195507311800	195508020000	30	983
1955_05	NOT NAMED	195508231200	195508280600	114	997
1955_07	GLADYS	195509041200	195509061800	54	980
1955_08	HILDA	195509150000	195509200600	126	951
1955_10	JANET	195509280000	195509300600	54	950
1956_01	NOT NAMED	195606120000	195606140000	48	990
1956_02	ANNA	195607251800	195607270600	36	979
1956_05	DORA	195609100600	195609121800	60	983
1956_07	FLOSSY	195609211200	195609250600	90	979
1957_01	NOT NAMED	195706080600	195706090000	18	1000
1957_02	AUDREY	195706250000	195706271800	66	946
1957_03	BERTHA	195708081800	195708101200	42	996
1957_05	DEBBIE	195709070600	195709081800	36	1000
1957_06	ESTHER	195709161800	195709181800	48	994
1958_01	ALMA	195806140600	195806151800	36	994
1958_05	ELLA	195809030000	195809061200	84	983
1959_01	ARLENE	195905281200	195905311200	72	1000
1959_02	BEULAH	195906151800	195906181800	72	987
1959_05	DEBRA	195907230000	195907260000	72	984
1959_10	IRENE	195910061800	195910081200	42	994
1959_11	JUDITH	195910171200	195910181800	30	991
1960_01	NOT NAMED	196006220600	196006261200	102	997
1960_05	DONNA	196009100000	196009111200	36	932
1960_06	ETHEL	196009141200	196009160000	36	972
1961_03	CARLA	196109060600	196109121200	150	931

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
1961_11	INGA	196111050000	196111081200	84	983
1963_04	CINDY	196309161200	196309200000	84	996
1964_03	ABBY	196408051800	196408081800	72	1000
1964_10	HILDA	196409281200	196410051800	174	942
1964_11	ISBELL	196410101200	196410150000	108	964
1965_01	NOT NAMED	196506121800	196506151200	66	994
1965_03	BETSY	196509081200	196509101200	48	941
1965_05	DEBBIE	196509241800	196509300000	126	1000
1966_01	ALMA	196606061200	196606100600	90	970
1966_08	HALLIE	196609201200	196609220000	36	994
1966_09	INEZ	196610020000	196610110600	222	948
1967_02	BEULAH	196709151200	196709221200	168	923
1967_06	FERN	196710011800	196710041800	72	987
1968_01	ABBY	196806011800	196806070000	126	992
1968_03	CANDY	196806221800	196806240000	30	997
1968_08	GLADYS	196810150000	196810191200	108	965
1969_03	CAMILLE	196908140600	196908180600	96	908
1969_12	SUBTROP 1	196909291200	196910011800	54	990
1969_13	JENNY	196910011200	196910061800	126	1000
1969_15	LAURIE	196910171800	196910270600	228	957
1970_01	ALMA	197005210000	197005251200	108	998
1970_02	BECKY	197007190000	197007221200	84	987
1970_03	CELIA	197007310000	197008040600	102	944
1970_06	ELLA	197009091800	197009130000	78	967
1970_07	FELICE	197009131200	197009161200	72	998
1971_06	EDITH	197109110600	197109161200	126	977
1971_07	FERN	197109031200	197109121800	222	979
1972_01	ALPHA	197205271800	197205291200	42	996
1972_02	AGNES	197206141200	197206200000	132	978
1973_03	BRENDA	197308180600	197308211200	78	977
1973_05	DELIA	197309011800	197309061800	120	987
1974_06	CARMEN	197409020000	197409091200	180	928
1975_03	CAROLINE	197508261200	197509011200	144	963
1975_05	ELOISE	197509191800	197509231200	90	955
1976_01	SUBTROP 1	197605211200	197605240000	60	998

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
1976_05	DOTTIE	197608180000	197608201200	60	1000
1977_01	ANITA	197708291200	197709021800	102	926
1977_02	BABE	197709030600	197709060600	72	995
1978_05	DEBRA	197808261200	197808290000	60	1000
1979_02	BOB	197907091200	197907111200	48	986
1979_03	CLAUDETTE	197907210000	197907261200	132	997
1979_06	FREDERIC	197909081800	197909130600	108	943
1979_08	HENRI	197909150000	197909241200	228	983
1980_01	ALLEN	198008061800	198008110000	102	899
1980_08	HERMINE	198009221800	198009241800	48	993
1980_10	JEANNE	198011081800	198011160600	180	986
1981_04	DENNIS	198108150600	198108191200	102	998
1982_01	ALBERTO	198206021200	198206061200	96	985
1982_04	CHRIS	198209090000	198209111800	66	994
1983_01	ALICIA	198308151200	198308181800	78	962
1983_02	BARRY	198308251200	198308290600	90	986
1985_04	DANNY	198508120000	198508160000	96	987
1985_05	ELENA	198508281800	198509021800	120	953
1985_10	JUAN	198510260000	198510311800	138	971
1985_11	KATE	198511191200	198511220000	60	954
1986_02	BONNIE	198606231800	198606261800	72	990
1987_07	FLOYD	198710110600	198710121800	36	993
1988_02	BERYL	198808080000	198808100600	54	1000
1988_04	DEBBY	198808311800	198809031800	72	987
1988_07	FLORENCE	198809070600	198809101200	78	982
1988_08	GILBERT	198809131200	198809170600	90	888
1988_12	KEITH	198811201800	198811231200	66	985
1989_01	ALLISON	198906241800	198906301200	138	999
1989_03	CHANTAL	198907301200	198908020000	60	984
1989_10	JERRY	198910121200	198910160600	90	983
1990_04	DIANA	199008051200	199008080600	66	980
1990_13	MARCO	199010091800	199010120600	60	991
1992_02	ANDREW	199208240900	199208261800	57	932
1993_01	ARLENE	199306180000	199306210600	78	1000
1993_07	GERT	199309180600	199309210000	66	970

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
1994_01	ALBERTO	199406300600	199407031800	84	993
1994_02	BERYL	199408141200	199408160600	42	999
1994_07	GORDON	199411150600	199411210600	144	995
1995_01	ALLISON	199506030600	199506051800	60	988
1995_04	DEAN	199507281800	199507311800	72	999
1995_05	ERIN	199508020600	199508031800	36	974
1995_07	GABRIELLE	199508091800	199508120000	54	990
1995_15	OPAL	199509271800	199510050000	174	916
1995_17	ROXANNE	199510091800	199510210000	270	958
1996_04	DOLLY	199608191800	199608231800	96	989
1996_10	JOSEPHINE	199610041800	199610080600	84	981
1997_05	DANNY	199707161200	199707210000	108	984
1998_05	EARL	199808311200	199809030600	66	977
1998_06	FRANCES	199809081800	199809121200	90	990
1998_07	GEORGES	199809250600	199810010600	144	961
1998_08	HERMINE	199809171200	199809201800	78	997
1998_13	MITCH	199811021800	199811051200	66	987
1999_02	BRET	199908181800	199908240000	126	941
1999_08	HARVEY	199909190600	199909211800	60	995
1999_09	IRENE	199910131200	199910161200	72	982
2000_02	BERYL	200008131800	200008151800	48	1006
2000_07	GORDON	200009141200	200009181200	96	982
2000_08	HELENE	200009200000	200009221200	60	996
2000_11	KEITH	200010030600	200010060600	72	980
2001_01	ALLISON	200106051200	200106111800	150	1000
2001_02	BARRY	200108021200	200108060600	90	990
2001_07	GABRIELLE	200109111800	200109151200	90	989
2002_02	BERTHA	200208041800	200208091200	114	1008
2002_05	EDOUARD	200209041800	200209061200	42	1008
2002_06	FAY	200209051800	200209101200	114	997
2002_09	HANNA	200209120000	200209150000	72	1001
2002_10	ISIDORE	200209190600	200209261200	174	934
2002_13	LILI	200209301800	200210031800	72	940
2003_02	BILL	200306280600	200307010000	66	997
2003_03	CLAUDETTE	200307101800	200307160600	132	980

Ref#	Storm Name	Start Date (CYMDH)	End Date (CYMDH)	# Hrs in Basin	Minimum Pressure in Basin (mb)
2003_05	ERIKA	200308141800	200308161800	48	988
2003_07	GRACE	200308301200	200309010000	36	1006
2003_08	HENRI	200309031800	200309061800	72	997
2003_12	LARRY	200309271800	200310051800	192	993
2004_02	BONNIE	200408071800	200408121800	120	1001
2004_03	CHARLEY	200408121200	200408140600	42	947
2004_06	FRANCES	200409050600	200409070000	42	960
2004_09	IVAN	200409120600	200409240600	288	910
2004_10	JEANNE	200409260600	200409270600	24	953
2004_13	MATTHEW	200410081200	200410101800	54	998
2005_01	ARLENE	200506090600	200506111800	60	990
2005_02	BRET	200506281800	200506300000	30	1005
2005_03	CINDY	200507031800	200507061200	66	992
2005_04	DENNIS	200507081800	200507101800	48	928
2005_05	EMILY	200507171200	200507210000	84	944
2005_07	GERT	200507231800	200507251200	42	1004
2005_11	JOSE	200508221200	200508231200	24	998
2005_12	KATRINA	200508260000	200508291500	87	902
2005_18	RITA	200509201200	200509241200	96	898
2005_20	STAN	200509301800	200510041200	90	979
2005_24	WILMA	200510200600	200510241200	102	901

Appendix B

Storm Peak Table

Storm Peaks Table

This table summarizes the peak wind speed, significant wave height (with associated parameters), surge height, and current speed hindcast. Tides are not included. A minimum threshold for wave height may have been applied, thus grid point locations below a threshold may not report maximum conditions. The header line is as follows:

```
                    max  asso  (               max                                         )   max   max  asso
 ccyymm  ddhhmm      ws    wd     ws    wd      hs      ts  .74*tp   vmd   hsur    cs    cd   hsur    cs    cd    wave   crest   w/hs   c/hs storm ID        storm name
                  -----------  ------------------------------------------------------------  -----   ---------
```

Column	Description
ccyymm	Time of peak wave height given in Century-Year-Month (GMT)
ddhhnn	Time of peak wave height given in Day-Hour-Minute (GMT)
max ws	Maximum 1-hour average (non-tropical) wind speed (m/s) at 10-meter reference height (neutral wind), exact time of peak not given
asso wd	Wind direction associated with maximum wind speed (degrees, from which)
Ws	1-hour average wind speed (m/s) at 10 meter reference height (neutral wind) associated at time of maximum wave height
Wd	Wind direction associated at time of maximum wave height (degrees, from which)
max hs	Maximum significant wave height (meters)
Ts	Significant wave period associated at time of maximum wave height (seconds)
.74*tp	Peak wave period * .74 associated at time of maximum wave height (seconds) Approximation for mean period needed for HCrest computation. (÷ 0.74 to restore TP)
Vmd	Vector mean wave direction associated at time of maximum wave height (deg, to which)
Hsur	Surge height with respect to still water associated at time of maximum wave height (cm)
Cs	Vertically integrated current speed associated at time of maximum wave height (cm/sec)
Cd	Vertically integrated current direction associated at time of maximum wave height (degrees, to which)
max hsur	Maximum surge height with respect to still water (cm), exact time of peak not given
max cs	Maximum vertically integrated current speed (cm/sec), exact time of peak not given
Assoc cd	Vertically integrated current direction associated at time of maximum current speed (degrees, to which)
wave	Maximum Individual Wave Height (m) computed using Forristall (1978)
crest	Maximum Crest Height (m) computed using Haring and Heideman (1978)
w/hs	Ratio of Maximum Individual Wave/Significant Wave Height
c/hs	Ratio of Crest/Significant Wave Height
Storm ID	Storm year, season storm number, and basin identifier
Stm Name	Hurricane center storm name or “Not Named”

```
                   max  asso  (               max                                         )   max   max  asso
ccyymm  ddhhmm      ws    wd     ws    wd      hs      ts  .74*tp   vmd   hsur    cs    cd   hsur    cs    cd    wave   crest   w/hs   c/hs storm ID        storm name
                  -----------  ------------------------------------------------------------  -----   ---------

   Grid Point   9039, Lat  28.7500, Long  -95.2500, Depth    19.00m,  218 events
194910.  40700.  36.15 128.0  35.32 160.0   7.793   9.320  10.303 336.9  191.9  58.1 238.7  191.9  90.3 240.3  12.683   8.109 1.6275 1.0405 1949_10_NOATL   NOT_NAMED
194109. 232030.  35.97 117.3  35.43 130.8   7.693   8.932   9.453 320.4  201.6 139.3 238.9  202.2 140.3 234.8  13.300   8.421 1.7289 1.0946 1941_02_NOATL   NOT NAMED
196109. 112000.  30.85  97.6  30.04 110.4   7.023   8.793   9.710 308.6  170.8 105.1 229.9  184.2 163.9 229.6  12.957   8.291 1.8450 1.1805 1961_03_NOATL   CARLA
192106. 221830.  27.26 135.2  26.88 140.4   6.091   8.307   8.607 330.8   84.1  50.5 229.0  101.0  68.1 235.3  10.902   7.260 1.7899 1.1919 1921_01_NOATL   NOT NAMED
194208. 300630.  23.55  90.3  21.52 121.7   5.443   8.058   8.674 308.5  107.7 102.6 230.3  112.0 114.0 232.7   9.323   6.328 1.7128 1.1626 1942_02_NOATL   NOT_NAMED
194508. 272100.  27.69 128.5  27.55 134.7   5.441   7.528   7.721 322.2   88.4  72.3 231.3   90.0  77.9 232.3  10.147   6.859 1.8650 1.2606 1945_05_NOATL   NOT NAMED
191508. 170630.  33.24 328.0  32.73 322.5   5.354   7.462   7.021 173.8   74.0 129.7 217.2  128.5 129.7 217.2   9.180   6.281 1.7147 1.1732 1915_02_NOATL   NOT NAMED
200307. 151230.  27.34  97.7  26.83 109.6   5.246   7.627   7.732 298.7  117.8 143.1 233.0  120.0 145.9 232.8   9.373   6.389 1.7867 1.2179 2003_03_NOATL   CLAUDETTE
199809. 110600.  20.04 130.4  20.04 130.4   5.223   7.971   8.443 314.9   91.7  82.0 228.6   92.3  83.5 229.0   9.531   6.487 1.8247 1.2421 1998_06_NOATL   FRANCES
197109. 100630.  27.25  77.5  27.25  77.5   5.050   7.305   7.322 275.5  100.9 152.7 231.9  102.1 152.9 231.9   9.154   6.268 1.8127 1.2411 1971_07_NOATL   FERN
190107. 100900.  21.34  95.3  20.98 114.3   4.995   7.830   8.518 303.7   78.3  88.7 231.7   78.3  89.6 232.4   8.575   5.848 1.7167 1.1709 1901_02_NOATL   NOT NAMED
190907. 211930.  30.07 340.7  30.07 340.7   4.838   7.401   7.887 203.0   81.0 128.9 220.5  110.6 134.8 218.1   8.089   5.537 1.6719 1.1445 1909_03_NOATL   NOT NAMED
198308. 180300.  29.01 354.8  28.67   5.2   4.742   7.218   6.887 227.9   64.4 160.6 222.6   65.7 168.4 218.6   8.339   5.743 1.7586 1.2111 1983_01_NOATL   ALICIA
191608. 190230.  21.90  80.3  15.57 106.5   4.731   7.984   9.489 306.0   71.2  78.4 229.6   91.2 105.9 227.7   8.717   5.985 1.8426 1.2650 1916_04_NOATL   NOT NAMED
193307. 230430.  21.30 131.9  21.29 140.3   4.698   7.329   7.740 324.1   63.4  59.4 234.1   65.0  64.6 234.6   8.369   5.738 1.7813 1.2213 1933_04_NOATL   NOT NAMED
198809. 161830.  16.09  68.6  13.17 111.1   4.490   8.404   9.878 309.4   60.6  70.6 228.7   67.4  84.4 228.8   8.453   5.778 1.8827 1.2869 1988_08_NOATL   GILBERT
192906. 282130.  20.08  99.0  19.49 112.0   4.459   7.389   7.641 310.2   72.8  67.6 231.0   74.5  79.1 232.8   8.127   5.591 1.8226 1.2538 1929_01_NOATL   NOT NAMED
193407. 251300.  22.61  51.4  22.26  68.0   4.426   7.088   7.162 265.2   83.2 135.7 229.6   89.0 135.7 229.6   7.937   5.464 1.7933 1.2345 1934_03_NOATL   NOT NAMED
190206. 270130.  19.52 143.1  19.15 159.9   4.376   7.288   7.667 347.8   25.3  16.0  33.0   33.0  35.5  48.8   8.033   5.527 1.8357 1.2629 1902_02_NOATL   NOT NAMED
198008.  91200.  18.82  98.2  17.62  83.3   4.373   7.988  11.439 293.9   78.2  88.6 229.6   83.2  88.9 229.4   8.487   5.846 1.9409 1.3369 1980_01_NOATL   ALLEN
191909. 141600.  21.62  57.2  20.76  76.8   4.224   7.127   6.652 280.7  104.8 107.7 229.5  105.6 124.1 229.2   7.994   5.536 1.8924 1.3105 1919_02_NOATL   NOT NAMED
195907. 241430.  22.96  97.2  22.95  98.8   4.134   6.710   6.926 296.5   70.4 106.8 233.7   73.4 123.9 225.5   7.641   5.260 1.8484 1.2724 1959_05_NOATL   DEBRA
193408. 281130.  25.63  93.7  25.08  88.8   4.090   6.520   6.343 288.6   53.1 148.3 229.9   54.8 152.2 228.9   7.629   5.274 1.8653 1.2896 1934_05_NOATL   NOT NAMED
193208. 140000.  27.41 326.6  27.41 326.6   3.973   6.845   7.824 200.8   53.0 112.0 220.0   69.9 112.0 220.0   6.989   4.801 1.7591 1.2083 1932_02_NOATL   NOT NAMED
191210. 151430.  21.58  63.5  20.76  64.7   3.905   6.820   6.431 268.3   66.0  98.9 230.3   71.2  99.0 230.2   7.471   5.173 1.9131 1.3247 1912_05_NOATL   NOT NAMED
194009. 231700.  19.25 285.2  18.43 102.6   3.870   7.010   7.634 307.8   55.8  69.6 235.4   56.4  79.5 228.3   6.830   4.676 1.7650 1.2083 1940_06_NOATL   NOT_NAMED
195809.  60700.  16.55  76.0  15.63  97.9   3.711   7.281   8.454 296.0   66.7  78.7 229.5   67.4  82.5 230.0   6.680   4.574 1.8001 1.2327 1958_05_NOATL   ELLA
197309.  60230.  21.87   3.5  19.31 107.1   3.681   6.586   6.700 299.5   57.1  86.0 232.7   81.0 120.0 224.0   6.729   4.632 1.8279 1.2584 1973_05_NOATL   DELIA
194309. 170600.  20.21  60.3  20.21  60.3   3.572   6.546   5.946 273.2   69.1  96.2 230.9   70.1  97.5 230.7   6.672   4.601 1.8679 1.2881 1943_06_NOATL   NOT NAMED
197008.  32000.  17.44  87.8  15.94 103.0   3.486   6.698   6.742 299.7   55.9  65.6 231.4   55.9  71.9 232.5   6.347   4.331 1.8206 1.2425 1970_03_NOATL   CELIA
193308.  50230.  13.25  96.1  12.01  99.6   3.480   7.240   7.586 305.5   37.6  36.9 230.0   56.0  71.4 229.0   6.657   4.550 1.9129 1.3074 1933_05_NOATL   NOT NAMED
200209.  70630.  16.84 108.4  16.28 116.0   3.451   6.547   6.291 297.3   57.4  94.2 226.7   57.7  96.5 227.3   6.438   4.411 1.8655 1.2782 2002_06_NOATL   FAY
193309.  42030.  18.65  53.4  18.26  65.3   3.441   6.595   5.879 273.4   75.3  93.8 229.6   75.5 100.6 229.5   6.604   4.559 1.9192 1.3248 1933_11_NOATL   NOT NAMED
190908. 271330.  17.86  76.8  17.27  77.0   3.423   6.774   5.920 282.6   57.3  79.0 230.5   58.5  79.8 230.2   6.426   4.427 1.8773 1.2933 1909_05_NOATL   NOT NAMED
190009.  90030.  26.79 298.8  26.79 298.8   3.412   6.011   4.922 149.0   33.4  46.3 218.3  101.8  72.9 226.3   6.111   4.193 1.7909 1.2288 1900_01_NOATL   NOT NAMED
198910. 152100.  20.17  37.7  19.82  35.8   3.402   6.480   6.067 255.2   77.3 110.5 227.4   78.2 120.1 223.7   5.775   3.904 1.6974 1.1475 1989_10_NOATL   JERRY
193606. 271800.  15.69 113.6  15.30 127.4   3.398   6.623   6.272 323.4   24.8  32.0 233.6   33.6  47.8 233.7   6.371   4.368 1.8750 1.2855 1936_03_NOATL   NOT NAMED
196709. 202130.  15.09  92.9  13.08 100.6   3.339   6.897   7.733 306.1   42.3  58.8 228.6   46.3  59.1 230.2   6.508   4.465 1.9492 1.3373 1967_02_NOATL   BEULAH
194507. 210300.  19.50  49.5  19.49  46.3   3.252   6.108   5.654 252.9   50.0 107.9 227.8   51.9 109.0 228.2   6.171   4.212 1.8976 1.2953 1945_02_NOATL   NOT NAMED
196806. 240230.  14.69 112.2  13.75 131.9   3.248   6.711   6.156 317.3   25.5  46.1 230.0   29.9  46.1 230.0   5.892   4.007 1.8141 1.2336 1968_03_NOATL   CANDY
200106.  51800.  14.88 100.5  13.01 116.6   3.176   6.732   6.673 308.2   33.9  55.6 232.0   34.5  62.7 226.9   5.471   3.651 1.7226 1.1495 2001_01_NOATL   ALLISON
195706. 270900.  21.71 347.6  21.71 347.6   3.161   6.175   5.497 214.3   44.8  83.8 226.9   56.9  83.8 226.9   5.649   3.836 1.7870 1.2136 1957_02_NOATL   AUDREY
198906. 261130.  14.82 135.6  14.61 144.2   3.119   6.192   5.884 325.4   30.0  39.6 233.7   30.4  42.2 232.6   5.865   3.989 1.8804 1.2788 1989_01_NOATL   ALLISON
197109. 160200.  17.52  74.8  16.59  83.7   3.078   6.537   5.682 304.3   47.2  53.3 234.4   52.1  87.4 226.2   5.616   3.794 1.8246 1.2326 1971_06_NOATL   EDITH
200507. 200630.  11.80  91.6  11.45  99.8   2.852   6.664   6.966 299.8   32.1  47.0 231.2   32.4  48.4 231.4   5.361   3.578 1.8797 1.2547 2005_05_NOATL   EMILY
200509. 240100.  19.86 343.6  19.69 342.2   2.765   5.572   4.652 208.3   32.2  61.2 226.7   55.6  68.8 228.3   5.096   3.386 1.8431 1.2248 2005_18_NOATL   RITA
191306. 272000.  12.14  79.7  10.87  99.1   2.755   6.678   7.722 297.8   31.4  44.0 232.2   31.6  44.4 232.6   5.181   3.425 1.8804 1.2433 1913_01_NOATL   NOT NAMED
197709.  12230.  13.40  79.7  13.09  80.4   2.683   6.255   7.269 286.7   42.9  54.5 229.3   44.7  58.0 228.8   5.254   3.522 1.9583 1.3129 1977_01_NOATL   ANITA
196006. 240930.  11.39 141.6  11.39 141.6   2.652   6.370   5.896 334.9   13.1  15.4 237.8   13.4  18.4 234.0   4.998   3.329 1.8847 1.2552 1960_01_NOATL   NOT NAMED
191009. 141230.  14.58  63.9  14.34  69.6   2.651   6.009   5.113 276.0   46.5  67.6 229.7   47.1  72.0 229.6   5.138   3.464 1.9382 1.3068 1910_02_NOATL   NOT NAMED
198510. 281900.  21.47 324.0  21.00 326.8   2.620   5.154   4.507 154.5   -7.0  24.3  55.3   32.5  61.3 228.4   5.024   3.374 1.9176 1.2878 1985_10_NOATL   JUAN
199610.  60630.  15.49  42.0  15.20  43.9   2.619   5.784   5.194 250.9   50.4  77.5 228.6   51.7  78.7 228.0   5.097   3.420 1.9463 1.3060 1996_10_NOATL   JOSEPHINE
190906. 291900.  13.01  69.8  12.23  86.3   2.583   6.122   7.039 289.1   36.3  43.9 231.0   44.1  60.7 229.8   4.968   3.305 1.9234 1.2795 1909_01_NOATL   NOT NAMED
199306. 200730.  11.50  94.7   9.25 119.7   2.549   6.541   6.089 306.6   33.4  47.8 227.7   34.1  51.0 229.4   5.048   3.380 1.9803 1.3262 1993_01_NOATL   ARLENE
197907. 260430.  13.25 212.9  12.76 206.1   2.530   5.872   5.162   2.7   20.7  14.2 201.7   43.4  63.5 227.4   4.984   3.334 1.9698 1.3178 1979_03_NOATL   CLAUDETTE
196309. 170530.  15.52  24.5  15.42  22.1   2.526   5.776   5.137 238.9   51.5  90.4 226.9   51.5  92.4 226.0   4.758   3.160 1.8834 1.2510 1963_04_NOATL   CINDY
196408.  71700.  18.49  39.2  18.49  39.2   2.521   5.262   4.772 242.0   17.2  56.9 224.2   18.7  67.8 228.1   4.433   2.901 1.7584 1.1508 1964_03_NOATL   ABBY
192310. 142130.  12.87  70.6  11.96  81.3   2.519   6.129   5.255 286.9   32.7  47.4 231.5   38.0  49.9 231.2   4.991   3.351 1.9815 1.3302 1923_03_NOATL   NOT NAMED
197909. 181230.  12.54  20.8  10.43  90.7   2.469   6.300   7.006 290.2   32.2  48.6 229.6   32.2  48.7 229.5   4.688   3.078 1.8988 1.2465 1979_08_NOATL   HENRI
190308. 151330.  11.82  92.0  11.43  92.0   2.459   6.121   5.329 290.7   28.2  45.4 231.1   28.8  45.8 230.8   4.734   3.141 1.9250 1.2773 1903_02_NOATL   NOT NAMED
190609. 271300.  20.16 337.4  19.59 337.2   2.457   5.072   4.439 172.5  -21.7  15.6 219.0   23.2  39.4 228.8   4.607   3.049 1.8752 1.2408 1906_05_NOATL   NOT NAMED
193106. 280000.  10.39 106.2  10.38 108.7   2.432   6.249   6.531 306.3   20.5  30.6 233.8   20.8  33.3 233.6   4.678   3.066 1.9235 1.2606 1931_01_NOATL   NOT NAMED
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198011. 140300.  11.42  54.0   9.82  80.8    2.415    6.370    7.952 283.8   40.6  54.3 228.7   41.4  56.4 228.9    4.644    3.048 1.9231 1.2622 1980_10_NOATL   JEANNE
197009. 121830.  10.18 123.8  10.07 123.7    2.404    6.214    6.464 312.2   20.9  32.3 230.5   24.1  40.2 231.1    4.612    3.035 1.9183 1.2624 1970_06_NOATL   ELLA
197808. 281100.  10.45  81.6  10.45  81.6    2.395    6.301    6.624 294.2   31.1  48.3 229.9   34.1  57.1 227.5    4.422    2.876 1.8465 1.2010 1978_05_NOATL   DEBRA
192609. 201430.  19.36 338.2  18.88 337.7    2.379    5.032    4.365 173.4  -45.1   3.3  98.9   10.3  46.1  53.4    4.614    3.058 1.9395 1.2854 1926_06_NOATL   NOT NAMED
193609. 131630.  10.20 120.9   9.88 125.1    2.340    6.265    6.831 324.2   12.8  14.9 241.9   13.8  19.5 234.3    4.422    2.868 1.8897 1.2258 1936_14_NOATL   NOT NAMED
193810. 171130.  13.96 163.4  12.05  35.8    2.286    5.739    5.136 239.8   51.8  77.1 226.0   55.7  78.9 225.8    4.127    2.680 1.8054 1.1723 1938_05_NOATL   NOT_NAMED
200308. 310830.  11.45 239.9   8.70 113.2    2.268    6.303    6.926 302.6   25.0  43.1 229.8   25.6  43.8 228.5    3.991    2.552 1.7597 1.1251 2003_07_NOATL   GRACE
194708.  20400.  10.57  91.6   9.17 104.9    2.265    6.244    6.110 308.0   20.4  32.7 231.6   22.9  36.6 232.6    4.449    2.914 1.9640 1.2867 1947_01_NOATL   NOT NAMED
200308. 160730.  12.00  65.7  10.43  76.0    2.261    6.002    5.020 276.9   29.6  55.7 229.6   29.6  56.9 229.8    4.298    2.807 1.9008 1.2415 2003_05_NOATL   ERIKA
197509. 230000.  16.66   0.9  16.66   0.9    2.236    5.108    4.733 205.1    5.2  41.8 229.3   15.7  47.9 229.7    4.184    2.720 1.8711 1.2164 1975_05_NOATL   ELOISE
200209. 241200.  15.39  10.0  14.11  38.2    2.233    5.386    4.589 247.1   37.3  62.1 228.9   42.6  63.6 228.4    4.455    2.948 1.9949 1.3202 2002_10_NOATL   ISIDORE
194909. 220600.  11.96  26.4   9.86  89.5    2.228    6.012    5.539 288.5   28.4  39.0 230.8   31.1  51.0 229.6    4.220    2.749 1.8940 1.2337 1949_08_NOATL   NOT NAMED
195010.  31700.  12.10  54.6  11.33  61.5    2.163    5.733    4.606 268.5   41.0  60.0 229.3   41.7  63.3 229.2    4.166    2.730 1.9261 1.2620 1950_08_NOATL   HOW
196111.  61300.  15.67  12.1  15.56  10.4    2.161    5.096    4.720 216.2    9.7  49.2 230.0   15.4  49.4 230.1    4.240    2.774 1.9620 1.2837 1961_11_NOATL   INGA
199908. 231830.   8.74 144.1   7.63 154.6    2.155    6.034    5.570 336.7   12.8  20.1 231.6   17.8  25.8 229.6    4.285    2.801 1.9884 1.2997 1999_02_NOATL   BRET
198209. 101500.  10.95  34.1  10.19  76.3    2.149    5.801    5.485 279.0   28.5  48.5 229.5   34.3  55.8 227.3    4.049    2.612 1.8839 1.2154 1982_04_NOATL   CHRIS
190411.  11230.  11.54  72.6  11.39  72.3    2.126    5.557    4.971 274.0   22.0  46.0 230.5   22.9  46.5 230.2    4.044    2.623 1.9020 1.2335 1904_05_NOATL   NOT NAMED
200310.  21230.  12.90  47.2  12.75  46.9    2.122    5.337    4.631 250.4   24.7  46.6 230.6   26.1  49.0 230.1    3.992    2.596 1.8812 1.2233 2003_12_NOATL   LARRY
199510.  21330.  13.05   1.1  10.15  76.2    2.099    5.818    4.653 279.7   35.3  43.3 230.1   36.0  46.7 230.2    4.083    2.667 1.9450 1.2705 1995_15_NOATL   OPAL
199510. 150000.  15.66  14.5  15.66  14.5    2.097    5.008    4.495 218.9   12.0  45.0 230.7   21.6  45.4 230.8    3.933    2.537 1.8754 1.2096 1995_17_NOATL   ROXANNE
193808. 281300.  11.11  77.3  10.89  77.6    2.093    5.626    4.663 283.2   19.1  35.2 233.7   20.8  36.0 232.8    4.050    2.641 1.9351 1.2620 1938_03_NOATL   NOT NAMED
193307.  60400.   8.79  80.0   8.15  83.1    2.061    6.307    8.169 284.6   34.7  48.9 230.5   37.0  49.0 230.3    3.916    2.500 1.8999 1.2129 1933_02_NOATL   NOT NAMED
197409.  72200.  14.34   7.3  14.23   8.8    2.052    5.213    4.413 223.6   22.5  54.6 228.4   23.5  54.7 228.5    3.985    2.596 1.9420 1.2650 1974_06_NOATL   CARMEN
193808. 141830.   9.11 106.0   8.62 104.1    2.048    6.097    4.737 295.4   17.7  33.6 228.5   30.8  47.5 227.8    3.783    2.441 1.8470 1.1920 1938_02_NOATL   NOT_NAMED
190510.  71200.  11.08  64.6  11.08  64.6    2.027    5.474    4.768 264.6   23.5  45.9 230.2   24.1  46.0 230.2    3.978    2.587 1.9624 1.2763 1905_05_NOATL   NOT NAMED
195806. 151830.   8.31 170.5   8.10 169.7    2.027    6.187    5.965 331.9    7.2  15.4 233.3    8.6  20.4 232.1    3.830    2.450 1.8895 1.2086 1958_01_NOATL   ALMA
200510.  41100.  10.19  69.3   9.71  76.2    1.990    5.563    5.016 274.0   29.7  46.6 229.5   32.2  47.0 229.2    3.967    2.569 1.9935 1.2909 2005_20_NOATL   STAN
199608. 221830.  10.44  83.9   9.98  94.2    1.988    5.583    5.127 282.6   24.8  45.8 229.3   25.4  46.9 229.0    3.861    2.495 1.9421 1.2552 1996_04_NOATL   DOLLY
196910. 200300.  13.70  29.9   9.64  69.9    1.982    5.723    4.927 273.1   26.2  45.9 229.6   27.8  47.3 229.8    3.977    2.586 2.0067 1.3049 1969_15_NOATL   LAURIE
195406. 260600.   9.01 126.9   7.53 149.5    1.976    6.207    6.251 330.8    3.2   3.8 283.5    7.6   8.8 250.9    3.860    2.469 1.9535 1.2493 1954_01_NOATL   ALICE
192509.  70330.   8.38 109.0   8.05 114.9    1.952    6.231    7.299 321.1    3.8   4.8  35.4    6.3  13.5  45.9    3.620    2.282 1.8546 1.1689 1925_01_NOATL   NOT NAMED
199507. 302030.  13.21  17.4  13.18  16.4    1.940    5.163    4.461 234.4   34.5  63.5 226.5   42.7  67.8 225.7    3.682    2.362 1.8981 1.2176 1995_04_NOATL   DEAN
196509. 270100.  11.56  33.0  11.11  55.9    1.936    5.251    4.644 255.6   21.7  44.7 229.7   22.2  47.0 229.3    3.793    2.446 1.9593 1.2636 1965_05_NOATL   DEBBIE
198308. 281730.   8.81 101.1   6.47 111.1    1.933    6.001    5.423 313.6   14.3  20.3 231.7   18.0  29.8 232.5    3.776    2.426 1.9534 1.2549 1983_02_NOATL   BARRY
200008. 151300.   8.56 130.3   6.39 141.1    1.931    6.100    5.796 325.7   -1.2  13.2 232.9    5.6  18.6 230.8    3.765    2.418 1.9495 1.2521 2000_02_NOATL   BERYL
198908.  20000.  12.42 307.4  10.13 178.8    1.917    5.313    4.637 349.6   18.8  10.7 217.2   40.4  61.7 227.2    3.688    2.365 1.9237 1.2335 1989_03_NOATL   CHANTAL
199809.  20030.  12.64  11.9  11.95  35.5    1.907    5.362    7.283 259.1   22.7  47.6 229.6   24.3  51.2 228.9    3.737    2.376 1.9599 1.2459 1998_05_NOATL   EARL
196610. 100100.   9.10  35.4   6.77  98.3    1.898    6.485    5.518 310.2   12.3  23.5 231.2   18.2  38.1 230.0    3.731    2.398 1.9655 1.2633 1966_09_NOATL   INEZ
190809. 180500.  11.74  25.5  11.70  24.2    1.888    5.368    4.384 246.9   40.0  64.6 228.3   44.3  67.8 227.3    3.649    2.352 1.9329 1.2457 1908_05_NOATL   NOT NAMED
194307. 271800.  17.07 285.5  17.07 285.5    1.881    4.523    3.982 117.5   -3.6  26.1  50.3    9.5  37.5  51.8    3.509    2.245 1.8653 1.1935 1943_01_NOATL   NOT NAMED
193608. 181330.   9.34  95.7   9.17  96.0    1.880    5.577    5.397 292.3   19.8  28.5 233.3   20.2  28.9 233.5    3.726    2.378 1.9819 1.2651 1936_08_NOATL   NOT NAMED
195609. 240000.  11.56 358.6  11.45  33.6    1.862    5.368    4.094 255.9   19.9  50.7 228.9   20.6  51.1 228.9    3.581    2.304 1.9232 1.2376 1956_07_NOATL   FLOSSY
200410.  81200.   8.81   6.2   6.27 109.4    1.855    5.773    5.191 300.0   17.4  35.7 229.0   18.5  36.0 229.3    3.497    2.238 1.8850 1.2063 2004_13_NOATL   MATTHEW
196410.  20100.  11.82 356.9   9.96  46.5    1.849    5.579    4.288 258.3   21.2  41.3 230.3   40.2  60.8 228.4    3.665    2.346 1.9823 1.2688 1964_10_NOATL   HILDA
190108. 151230.  15.29 342.9  15.09 342.9    1.846    4.615    3.949 183.8    5.1  34.1 227.4   16.5  40.2 228.3    3.495    2.239 1.8934 1.2128 1901_04_NOATL   NOT NAMED
193608. 102300.  11.01  30.0  10.61  42.2    1.822    5.182    4.505 246.2   29.6  51.8 229.0   30.2  52.6 228.9    3.569    2.279 1.9590 1.2511 1936_07_NOATL   NOT NAMED
193210. 150430.  12.04 332.5   8.23  80.6    1.815    6.077    5.548 306.2   19.9  29.2 232.0   22.2  36.6 229.6    3.315    2.079 1.8265 1.1457 1932_08_NOATL   NOT_NAMED
200210.  30900.  11.12  29.3  10.40   8.8    1.814    5.508    4.327 256.6   22.2  47.9 228.9   28.8  48.4 229.1    3.358    2.108 1.8511 1.1622 2002_13_NOATL   LILI
194211. 111200.  10.36  48.8  10.36  48.7    1.812    5.132    4.510 251.6   15.0  39.4 230.6   16.7  39.5 230.5    3.596    2.305 1.9847 1.2718 1942_10_NOATL   NOT_NAMED
195509.  60800.   9.29  89.8   8.94  85.9    1.808    5.549    5.622 301.7   11.2  29.4 232.0   12.6  31.3 231.7    3.447    2.171 1.9066 1.2007 1955_07_NOATL   GLADYS
194709. 191230.  14.44 357.0  14.14 356.4    1.805    4.747    4.338 203.4   -9.6  23.2 231.4    6.3  28.5 228.1    3.353    2.119 1.8576 1.1741 1947_04_NOATL   NOT NAMED
193309. 150030.   9.16  78.5   8.77  77.4    1.801    5.522    6.417 285.5   14.5  30.4 232.0   17.4  32.3 231.9    3.591    2.290 1.9939 1.2713 1933_14_NOATL   NOT_NAMED
198809. 100000.  11.62  25.6  11.16  34.6    1.798    5.159    4.381 240.8   22.1  44.4 230.4   23.0  45.0 230.0    3.439    2.186 1.9128 1.2160 1988_07_NOATL   FLORENCE
194708. 240730.  13.79 295.5  11.99   4.8    1.787    5.150    4.526 226.4   36.1  61.9 225.9   39.0  63.5 227.1    3.542    2.266 1.9822 1.2679 1947_03_NOATL   NOT NAMED
190709. 270600.   9.15 327.9   6.45 105.1    1.779    5.707    5.515 298.3   15.2  27.5 231.3   15.2  27.5 231.3    3.290    2.072 1.8491 1.1645 1907_03_NOATL   NOT NAMED
198508. 150430.  10.05   4.1   9.64  47.7    1.764    5.569    4.254 266.6   21.8  42.9 229.5   28.4  46.6 228.7    3.248    2.069 1.8411 1.1729 1985_04_NOATL   DANNY
196710.  40030.   9.61  92.8   9.29  93.6    1.753    5.291    4.812 289.3   16.3  33.8 230.6   16.6  34.5 230.3    3.281    2.075 1.8717 1.1839 1967_06_NOATL   FERN
190909. 201230.  12.16  22.1  11.86  21.5    1.753    5.133    4.090 238.1   16.3  43.5 229.6   19.8  44.4 229.3    3.271    2.080 1.8658 1.1864 1909_07_NOATL   NOT NAMED
195010. 181700.  11.89   8.4  11.81   4.6    1.750    5.021    4.164 224.9   23.4  47.3 229.2   38.1  58.2 227.9    3.526    2.264 2.0150 1.2935 1950_13_NOATL   LOVE
199508. 112030.   9.84 109.6   8.97 110.9    1.749    5.264    4.891 305.9   15.6  26.6 232.9   15.7  27.4 232.6    3.437    2.176 1.9654 1.2440 1995_07_NOATL   GABRIELLE
192608. 251030.  12.16 348.6   9.90  32.3    1.740    5.422    4.130 250.6   38.0  57.3 229.0   40.2  57.6 228.9    3.406    2.180 1.9578 1.2528 1926_03_NOATL   NOT NAMED
191206. 121200.   8.72  66.0   8.64  64.0    1.723    5.592    4.279 274.8   25.3  41.3 229.9   30.9  47.3 228.4    3.346    2.114 1.9418 1.2270 1912_01_NOATL   NOT NAMED
192909. 301330.  12.82   3.9  12.63   3.9    1.722    4.803    4.102 216.9   10.4  37.7 229.5   16.2  38.8 229.3    3.352    2.131 1.9465 1.2377 1929_02_NOATL   NOT NAMED
199809. 172300.   9.12  33.1   8.92  35.3    1.708    5.319    6.319 258.6   18.8  38.5 229.6   22.8  39.4 229.6    3.277    2.042 1.9184 1.1958 1998_08_NOATL   HERMINE
197909. 120100.  11.49   3.9   9.80  44.2    1.700    5.193    4.422 250.1   17.1  40.3 230.0   20.9  41.2 229.3    3.257    2.074 1.9157 1.2199 1979_06_NOATL   FREDERIC
195309. 251900.  11.42  31.4  11.21  30.2    1.692    4.933    4.221 242.0   18.1  41.1 229.9   20.1  41.7 230.0    3.290    2.087 1.9443 1.2337 1953_08_NOATL   FLORENCE
195407. 301700.   8.43 164.4   8.03 164.4    1.676    5.236    4.851 343.7    4.9   8.4 218.9   10.3  20.4 229.4    3.115    1.952 1.8586 1.1644 1954_02_NOATL   BARBARA
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191509. 291900.  11.42 359.4  11.19 355.5   1.670   4.969  11.438 217.3    7.4  24.3 230.7    9.7  24.7 230.3   3.225   1.930 1.9310 1.1555 1915_05_NOATL   NOT NAMED
195609. 101800.   8.99  73.3   8.99  73.3   1.655   5.141   4.646 262.0   21.7  43.6 229.1   21.8  44.4 229.1   3.249   2.060 1.9633 1.2445 1956_05_NOATL   DORA
191008. 311200.   6.42 103.3   6.42 103.3   1.623   6.134   6.430 315.4   10.9  23.4 231.6   11.0  24.8 231.2   3.150   1.969 1.9408 1.2130 1910_01_NOATL   NOT NAMED
190509. 272030.   8.95  73.8   7.46  72.0   1.611   5.532   7.728 282.3   15.4  37.0 229.9   27.5  47.2 228.0   3.181   1.980 1.9745 1.2290 1905_03_NOATL   NOT NAMED
196910.  61830.   9.59  58.7   8.94  60.5   1.601   5.103   4.643 256.8   15.3  37.0 231.5   21.1  42.7 230.7   2.971   1.853 1.8558 1.1574 1969_13_NOATL   JENNY
199309. 210700.   7.27  97.2   6.30 108.2   1.591   5.980   6.303 310.5   14.2  22.6 232.6   16.5  27.9 231.3   3.074   1.909 1.9322 1.1996 1993_07_NOATL   GERT
191709. 271230.  10.75 348.3   9.03  30.2   1.584   5.542   7.976 260.1   25.0  35.7 230.2   25.7  35.9 229.9   3.153   1.946 1.9906 1.2288 1917_03_NOATL   NOT NAMED
191610. 181230.  14.06 323.1  13.78 323.0   1.581   4.602   3.467 163.1  -14.3   7.6 219.9   10.1  25.5 231.7   3.102   1.927 1.9620 1.2189 1916_13_NOATL   NOT NAMED
194408. 221700.   6.86  88.3   6.37  80.7   1.564   6.123   6.498 313.2   12.7  22.5 232.1   13.0  25.0 231.7   3.003   1.871 1.9204 1.1960 1944_05_NOATL   NOT NAMED
195509. 191130.   7.96  88.9   7.78  78.9   1.560   5.520   5.077 296.4   15.2  30.5 231.1   16.0  30.6 231.3   3.072   1.920 1.9693 1.2309 1955_08_NOATL   HILDA
195108. 221030.   7.17  82.2   6.99  90.1   1.552   5.930   6.082 307.8    8.5  18.3 234.9   10.4  22.9 233.9   3.084   1.922 1.9874 1.2381 1951_03_NOATL   CHARLIE
192406. 200400.   8.36 155.4   7.58 142.0   1.551   5.094   4.672 321.7    6.6   0.8 101.8    7.7  18.2  52.8   3.090   1.937 1.9921 1.2487 1924_01_NOATL   NOT NAMED
195906. 180030.   9.16  42.1   8.63  45.4   1.548   5.040   4.581 251.2   12.7  35.0 230.1   13.2  35.1 230.1   2.875   1.797 1.8571 1.1606 1959_02_NOATL   BEULAH
195905. 300200.   8.08  31.3   7.51  48.7   1.541   5.284   4.665 256.9   22.8  41.2 229.5   28.9  44.8 228.0   2.903   1.812 1.8838 1.1758 1959_01_NOATL   ARLENE
200009. 170030.   9.51  46.5   9.37  46.2   1.535   4.836   4.375 235.8    9.7  30.0 232.8   12.3  33.5 230.7   2.934   1.828 1.9115 1.1906 2000_07_NOATL   GORDON
198811. 212000.  10.73  20.1   9.99  27.1   1.534   4.786   4.345 227.3   11.7  27.4 232.6   16.5  32.8 231.0   2.999   1.886 1.9548 1.2297 1988_12_NOATL   KEITH
193406. 160630.   7.28  61.8   6.77  64.3   1.528   5.769   9.240 281.3   36.6  41.3 230.0   41.5  45.6 229.5   2.982   1.821 1.9517 1.1916 1934_02_NOATL   NOT_NAMED
191808.  61800.  10.93 352.7  10.93 352.7   1.526   5.183  10.250 248.4    9.9  27.3 230.2   29.1  27.3 230.2   2.740   1.606 1.7956 1.0521 1918_01_NOATL   NOT NAMED
200306. 301300.   8.12  55.3   7.80  47.5   1.506   5.375   7.150 277.0   13.2  37.3 230.0   13.3  37.6 229.9   2.744   1.655 1.8224 1.0990 2003_02_NOATL   BILL
195709. 180100.   8.26  38.6   7.92  38.3   1.481   5.249   7.043 269.7   13.8  34.8 230.9   14.6  35.9 230.2   2.750   1.678 1.8568 1.1329 1957_06_NOATL   ESTHER
192009. 291330.   9.80  21.6   9.63  22.4   1.468   4.875   4.097 234.5   11.5  33.4 230.3   20.6  35.1 229.8   2.926   1.830 1.9932 1.2468 1920_04_NOATL   NOT NAMED
190210.  92330.   5.40 105.0   3.41  87.8   1.462   6.237   7.903 301.9   12.0  26.4 230.4   13.5  29.0 229.9   2.830   1.727 1.9359 1.1810 1902_04_NOATL   NOT NAMED
194708. 150900.   7.15 103.3   5.52 114.1   1.458   5.803   5.046 317.7   10.2  19.2 233.9   13.2  25.6 232.9   2.960   1.838 2.0299 1.2609 1947_02_NOATL   NOT NAMED
198606. 260300.   7.03  69.2   7.03  69.2   1.455   5.386   4.755 272.5   23.9  46.1 228.7   27.2  50.9 227.9   2.680   1.650 1.8417 1.1342 1986_02_NOATL   BONNIE
192410. 140130.   8.02  74.0   7.67  71.2   1.449   5.144   6.333 270.6   21.4  37.0 230.2   22.6  39.9 229.9   2.927   1.809 2.0203 1.2481 1924_06_NOATL   NOT NAMED
194809.  30230.   7.72  41.8   6.38  79.4   1.442   5.633   5.705 305.7    7.4  26.1 232.0   11.5  33.0 230.4   2.899   1.797 2.0107 1.2463 1948_05_NOATL   NOT NAMED
194409.  92200.   7.17   6.7   6.93  35.3   1.439   5.873   8.805 294.7   11.5  31.4 230.7   13.3  35.5 229.3   2.594   1.543 1.8029 1.0725 1944_06_NOATL   NOT NAMED
200409. 151830.   5.95  99.9   4.73  25.1   1.436   7.110  11.617 303.8   19.1  27.9 230.5   20.3  29.7 229.9   2.719   1.624 1.8932 1.1307 2004_09_NOATL   IVAN
194008.  61300.  10.58 359.4  10.18   1.1   1.370   4.483   3.869 214.0   10.7  40.6 228.3   18.4  44.5 228.0   2.709   1.676 1.9774 1.2235 1940_02_NOATL   NOT NAMED
193209. 191130.   4.72  98.8   4.64  83.9   1.362   6.393   7.843 317.0    8.6  18.6 233.2   12.6  26.5 230.7   2.492   1.497 1.8294 1.0989 1932_06_NOATL   NOT NAMED
196909. 300130.   9.62  45.0   8.99  44.6   1.360   4.527   4.072 236.4   13.2  29.4 231.8   16.4  33.2 230.4   2.624   1.631 1.9295 1.1990 1969_12_NOATL   SUBTROP 1
194208. 211700.  10.51 292.4   8.34  27.5   1.358   4.983   4.195 241.4   31.3  44.6 228.4   32.4  48.1 227.4   2.621   1.627 1.9297 1.1983 1942_01_NOATL   NOT NAMED
197508. 312230.   6.57 104.6   5.07  93.9   1.357   6.072   6.981 333.8    6.7  14.2 236.7   10.5  22.9 232.0   2.716   1.659 2.0011 1.2229 1975_03_NOATL   CAROLINE
191409. 181230.  12.04 344.1  11.82 344.2   1.355   4.226   3.446 190.1  -10.6  15.2 229.3    7.2  22.4 231.0   2.567   1.578 1.8945 1.1649 1914_01_NOATL   NOT NAMED
200108.  30230.   7.92  57.1   7.33  63.8   1.344   4.765   4.384 257.6    7.8  36.1 230.3   11.5  36.4 230.1   2.559   1.568 1.9039 1.1669 2001_02_NOATL   BARRY
200009. 210800.   7.65 122.5   5.72 132.4   1.342   4.956   4.768 316.3    6.4  18.6 232.8    7.5  20.0 232.7   2.728   1.695 2.0325 1.2632 2000_08_NOATL   HELENE
200508. 290600.   7.64 338.3   7.64 338.3   1.330   6.118  11.654 278.5   13.8  19.7 234.1   17.4  22.7 233.0   2.489   1.460 1.8713 1.0974 2005_12_NOATL   KATRINA
195409. 121600.   8.94  60.0   7.97  64.8   1.328   4.639   3.938 257.2    5.8  21.5 235.0    7.1  24.2 233.5   2.514   1.555 1.8934 1.1706 1954_06_NOATL   FLORENCE
190908. 101900.   7.97  71.1   7.18  82.1   1.321   4.857   7.222 280.3   13.7  31.3 230.9   13.8  34.4 230.2   2.675   1.642 2.0253 1.2434 1909_04_NOATL   NOT NAMED
193710.  30400.   7.02  44.7   6.36  15.7   1.305   5.504   8.500 266.2   16.9  35.3 229.3   19.2  37.3 228.5   2.466   1.468 1.8899 1.1249 1937_09_NOATL   NOT NAMED
193810. 231600.   9.08  64.9   8.00  62.0   1.300   4.470   3.970 261.4    8.2  20.0 234.8    8.7  22.5 233.2   2.450   1.493 1.8842 1.1482 1938_07_NOATL   NOT NAMED
193107. 151100.   4.43 166.7   4.37 165.7   1.294   5.838   4.604 294.2   15.3  28.3 230.6   17.5  30.2 230.2   2.435   1.474 1.8814 1.1392 1931_02_NOATL   NOT_NAMED
195010.  91430.   9.60  33.9   8.77  34.9   1.291   4.356   3.924 227.6    3.7  24.8 233.8    9.6  27.9 232.4   2.468   1.512 1.9118 1.1712 1950_09_NOATL   ITEM
199208. 260300.   8.48  21.4   7.37  18.7   1.289   4.840  10.757 237.0    3.7  25.6 231.3    7.9  42.2  46.5   2.385   1.387 1.8504 1.0757 1992_02_NOATL   ANDREW
200208.  80930.   8.29  70.8   8.28  74.2   1.270   4.501   4.116 253.5    2.8  19.8 227.6    5.5  28.4 231.8   2.408   1.471 1.8960 1.1581 2002_02_NOATL   BERTHA
192409. 141530.   8.54  31.4   7.92  31.0   1.268   4.654   3.922 238.1   10.1  31.0 231.0   11.9  31.0 231.0   2.457   1.509 1.9378 1.1901 1924_04_NOATL   NOT NAMED
193606. 211030.   5.63  30.0   5.56  32.5   1.255   6.158   7.007 301.0    3.0   1.8 225.7    4.1  11.5 234.2   2.419   1.464 1.9275 1.1663 1936_02_NOATL   NOT NAMED
198511. 211800.  11.39  16.9   8.14 354.1   1.254   4.700  10.323 215.3    9.7  28.4 230.9   11.2  31.2 231.6   3.122   1.973 1.9038 1.2032 1985_11_NOATL   KATE
196509. 100430.   9.80 282.4   7.51   0.6   1.252   4.966  11.946 234.8    7.9  17.9 232.1   11.8  48.9  47.8   2.332   1.350 1.8629 1.0782 1965_03_NOATL   BETSY
197605. 211200.   7.11  67.3   4.79  86.3   1.239   4.825   4.188 286.9    9.4  28.1 230.2    9.4  28.8 230.1   2.237   1.365 1.8052 1.1017 1976_01_NOATL   SUBTROP 1
190010.  91200.   8.20  32.8   8.20  32.8   1.238   4.435   3.988 227.3    6.2  31.4 230.3    6.6  31.4 230.4   2.454   1.499 1.9819 1.2107 1900_06_NOATL   NOT NAMED
195008. 300030.   7.82 348.3   6.39  43.8   1.236   5.329   6.463 276.4   21.7  28.7 231.1   22.9  29.0 231.1   2.450   1.474 1.9822 1.1925 1950_02_NOATL   BAKER
193709. 181200.   7.16  99.7   7.16  99.7   1.236   4.853   6.434 293.9    9.4  25.5 232.3   10.2  25.9 232.4   2.368   1.422 1.9159 1.1504 1937_06_NOATL   NOT NAMED
193209. 131230.   7.63  72.3   7.57  71.5   1.235   4.700   3.952 268.6   14.4  34.8 230.5   14.8  35.3 230.2   2.428   1.481 1.9657 1.1995 1932_05_NOATL   NOT NAMED
191607.  51400.   9.43 347.1   8.94 346.9   1.229   4.725  10.317 219.3    5.5  16.6 230.4    8.2  17.9 230.6   2.342   1.355 1.9060 1.1028 1916_01_NOATL   NOT NAMED
193308. 291600.   6.81  95.7   6.60  95.9   1.226   4.963   6.610 310.6    7.3  17.6 236.5    7.8  18.2 236.2   2.404   1.441 1.9609 1.1753 1933_10_NOATL   NOT NAMED
192110. 250300.   4.22  68.8   3.88  33.2   1.226   6.490   8.395 287.9   15.5  29.0 230.4   16.3  29.0 230.5   2.354   1.407 1.9202 1.1479 1921_06_NOATL   NOT NAMED
192009. 220130.   6.84  58.1   4.70  20.8   1.220   6.024   8.642 284.4   13.2  27.3 230.5   13.6  29.0 230.4   2.279   1.352 1.8684 1.1079 1920_02_NOATL   NOT NAMED
191509.  31430.   7.19  52.0   6.78  51.9   1.218   4.712   4.313 254.4   15.1  36.7 229.3   16.9  36.9 229.3   2.452   1.494 2.0130 1.2267 1915_04_NOATL   NOT NAMED
197907. 110900.   7.23  19.9   6.84  33.1   1.216   5.027   4.917 274.7   14.2  29.0 231.4   16.4  31.0 231.0   2.288   1.375 1.8817 1.1306 1979_02_NOATL   BOB
194506. 231800.   7.09 228.2   6.65 133.6   1.198   4.833   6.555 301.5   11.4  28.1 230.2   11.8  28.1 230.2   2.360   1.412 1.9701 1.1789 1945_01_NOATL   NOT NAMED
195708.  91300.   8.49  37.9   7.91  36.6   1.196   4.403   3.954 233.3    8.2  31.8 230.6   11.6  32.5 230.1   2.216   1.345 1.8531 1.1247 1957_03_NOATL   BERTHA
193607. 311300.   8.19  34.4   7.97  35.2   1.194   4.438   3.983 224.7   -1.3  17.5 226.1    1.2  26.3 228.3   2.258   1.380 1.8908 1.1558 1936_05_NOATL   NOT NAMED
191110. 312200.   7.56  31.0   6.73  48.0   1.185   4.850   7.255 252.7    9.7  29.8 230.4   12.7  30.5 230.0   2.338   1.399 1.9730 1.1802 1911_04_NOATL   NOT NAMED
194909.  42000.   5.76  85.9   2.29 148.3   1.181   5.635   7.370 290.4    9.4  24.7 230.1   11.8  28.9 229.8   2.151   1.275 1.8211 1.0798 1949_05_NOATL   NOT NAMED
195606. 131330.   5.76 101.9   5.37  32.7   1.178   5.466   5.136 293.9    8.7  28.8 230.0   10.9  30.2 229.5   2.239   1.360 1.9004 1.1546 1956_01_NOATL   NOT NAMED
200506. 112030.   7.76 127.6   3.06 101.8   1.176   5.246   6.784 289.4   10.7  23.2 231.2   13.2  26.0 231.2   2.325   1.404 1.9770 1.1936 2005_01_NOATL   ARLENE
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197206. 182230.   7.21  42.3   6.50  16.3   1.175   5.196   7.830 258.4   16.4  27.5 230.7   19.3  29.4 230.6   2.925   1.809 1.8787 1.1616 1972_02_NOATL   AGNES
195306.  50100.   8.38 138.5   7.83 140.3   1.165   4.307   3.611 313.3   11.0  15.5 234.3   12.3  16.8 233.6   2.240   1.376 1.9229 1.1815 1953_01_NOATL   ALICE
197009. 152100.   8.75 345.0   8.14  28.9   1.153   4.575   4.091 244.8   10.8  29.2 230.2   22.4  31.3 227.5   3.252   2.045 1.8085 1.1372 1970_07_NOATL   FELICE
193305. 181400.   5.90  72.5   4.36 128.9   1.151   5.794   6.955 298.9    8.9  20.8 231.1    9.9  25.6 232.0   2.289   1.379 1.9885 1.1978 1933_01_NOATL   NOT NAMED
192210. 210800.   8.71  47.0   4.06  87.7   1.143   6.283   9.319 297.9   17.4  26.4 230.5   19.5  38.7 229.6   2.993   1.883 1.8991 1.1947 1922_04_NOATL   NOT NAMED
197308. 210030.   7.71  50.5   7.55  50.5   1.135   4.627   3.556 257.4    7.8  23.4 232.9   10.3  26.6 232.1   2.198   1.333 1.9369 1.1747 1973_03_NOATL   BRENDA
193410.  61200.   8.25   5.8   8.25   5.8   1.132   4.224   3.951 207.3    3.4  21.6 229.6   14.9  28.8 229.6   2.335   1.413 2.0624 1.2483 1934_09_NOATL   NOT NAMED
193909. 252300.   6.47 333.9   3.89  17.7   1.131   5.845   5.569 285.1   13.4  24.1 231.2   14.3  27.4 231.6   2.182   1.309 1.9295 1.1578 1939_03_NOATL   NOT NAMED
194409. 211930.   6.80  72.9   3.89  62.4   1.120   5.633   5.046 289.0    7.5  16.1 232.8   14.5  27.7 232.3   2.233   1.363 1.9934 1.2171 1944_08_NOATL   NOT NAMED
192310. 181200.   9.83 352.4   9.83 352.4   1.107   4.032   3.104 190.4    0.6  26.1 231.3   20.3  28.8 227.8   2.073   1.260 1.8722 1.1385 1923_06_NOATL   NOT NAMED
196506. 150100.   4.96 129.1   3.69 137.3   1.103   6.045   7.030 313.2    6.9   5.7 244.6    7.8   6.4 238.9   2.106   1.255 1.9092 1.1382 1965_01_NOATL   NOT NAMED
196009. 150100.   7.93  56.9   7.43  55.1   1.095   4.245   3.775 244.5    6.5  27.5 232.3    8.9  29.5 231.3   2.068   1.245 1.8889 1.1368 1960_06_NOATL   ETHEL
192210. 150930.   7.94  43.5   3.45 164.7   1.089   5.535   5.102 291.0   11.5  23.1 231.2   11.7  25.1 230.4   2.143   1.298 1.9678 1.1916 1922_03_NOATL   NOT NAMED
192809.  61630.   7.53  69.5   7.35  71.4   1.078   4.327   3.764 257.9    9.5  30.5 231.3   13.0  31.1 231.1   2.450   1.477 1.9321 1.1649 1928_03_NOATL   NOT NAMED
197709.  41530.   8.54  76.5   8.32 350.6   1.067   4.249   3.737 209.6   15.4  31.8 229.9   26.3  39.0 228.6   3.620   2.305 1.7571 1.1190 1977_02_NOATL   BABE
194109. 140930.   9.43 315.7   8.21 350.0   1.066   4.506   3.953 216.5   23.3  35.8 228.5   26.8  40.8 228.8   2.166   1.311 2.0314 1.2296 1941_01_NOATL   NOT NAMED
194606. 160030.   7.39   9.1   7.30  19.0   1.056   4.581   4.092 229.5    8.3  12.6 229.5   10.0  19.3 228.6   1.983   1.198 1.8777 1.1342 1946_01_NOATL   NOT NAMED
190009. 121530.   6.71 319.4   3.18 102.9   1.052   6.021   8.520 298.2   13.4  23.1 232.1   14.3  24.3 231.8   1.994   1.177 1.8956 1.1185 1900_03_NOATL   NOT NAMED
196606.  91100.   6.99 131.5   3.99 191.6   1.052   5.704   7.065 301.5    4.8  12.1 234.9   12.5  20.7 232.6   2.042   1.218 1.9408 1.1574 1966_01_NOATL   ALMA
190206. 141400.   6.95 171.0   6.10 206.5   1.027   4.659   3.498 347.5    4.4  12.4 228.8    4.8  16.4 228.5   2.046   1.230 1.9921 1.1973 1902_01_NOATL   NOT NAMED
194509.  60000.   7.19 103.3   6.88 108.7   1.023   4.084   3.669 296.9    6.8  14.9 227.9    8.6  20.7 229.5   2.041   1.225 1.9948 1.1972 1945_07_NOATL   NOT NAMED
196609. 202000.   8.48   6.3   8.23   6.3   1.003   3.958   3.633 200.4   -4.0  12.0 240.0   -0.7  13.9 236.7   1.989   1.204 1.9826 1.2007 1966_08_NOATL   HALLIE
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Appendix C

Extra-tropical/Winter Storm List

Extra-tropical/Winter Storm List

Storm Ref	Start Date	End Date
19570321	Mar-21-1957 00:00	Mar-26-1957 00:00
19571230	Dec-30-1957 00:00	Jan-03-1958 12:00
19580101	Jan-01-1958 00:00	Jan-09-1958 00:00
19580121	Jan-21-1958 00:00	Jan-25-1958 00:00
19580209	Feb-09-1958 00:00	Feb-17-1958 00:00
19581209	Dec-09-1958 00:00	Dec-17-1958 00:00
19590115	Jan-15-1959 00:00	Jan-23-1959 00:00
19590311	Mar-11-1959 00:00	Mar-19-1959 00:00
19591101	Nov-01-1959 00:00	Nov-09-1959 00:00
19591123	Nov-23-1959 00:00	Dec-01-1959 00:00
19600127	Jan-27-1960 00:00	Jan-31-1960 18:00
19600210	Feb-10-1960 00:00	Feb-14-1960 06:00
19600215	Feb-15-1960 00:00	Feb-19-1960 12:00
19601126	Nov-26-1960 00:00	Dec-04-1960 00:00
19601213	Dec-13-1960 00:00	Dec-16-1960 12:00
19620108	Jan-08-1962 00:00	Jan-12-1962 00:00
19620303	Mar-03-1962 00:00	Mar-07-1962 06:00
19630201	Feb-01-1963 00:00	Feb-05-1963 00:00
19630919	Sep-19-1963 00:00	Sep-27-1963 00:00
19631106	Nov-06-1963 00:00	Nov-13-1963 06:00
19631123	Nov-23-1963 00:00	Dec-01-1963 00:00
19631218	Dec-18-1963 00:00	Jan-02-1964 00:00
19631226	Dec-26-1963 00:00	Jan-03-1964 00:00
19641116	Nov-16-1964 00:00	Nov-24-1964 00:00
19650219	Feb-19-1965 00:00	Feb-27-1965 00:00
19650228	Feb-28-1965 00:00	Mar-08-1965 00:00
19660117	Jan-17-1966 00:00	Jan-21-1966 06:00
19660124	Jan-24-1966 00:00	Feb-01-1966 00:00
19660204	Feb-04-1966 00:00	Feb-12-1966 00:00
19670103	Jan-03-1967 00:00	Jan-11-1967 00:00
19671217	Dec-17-1967 00:00	Dec-25-1967 00:00
19681106	Nov-06-1968 00:00	Nov-16-1968 12:00
19681109	Nov-09-1968 00:00	Nov-16-1968 00:00
19690212	Feb-12-1969 00:00	Feb-16-1969 12:00
19690310	Mar-10-1969 00:00	Mar-18-1969 00:00

Storm Ref	Start Date	End Date
19691114	Nov-14-1969 00:00	Nov-22-1969 00:00
19700103	Jan-03-1970 00:00	Jan-07-1970 06:00
19710301	Mar-01-1971 00:00	Mar-05-1971 00:00
19711202	Dec-02-1971 00:00	Dec-07-1971 00:00
19720110	Jan-10-1972 00:00	Jan-18-1972 00:00
19721210	Dec-10-1972 00:00	Dec-18-1972 00:00
19730108	Jan-08-1973 00:00	Jan-13-1973 00:00
19730207	Feb-07-1973 00:00	Feb-11-1973 06:00
19730405	Apr-05-1973 00:00	Apr-08-1973 12:00
19740508	May-08-1974 00:00	May-13-1974 00:00
19761027	Oct-27-1976 00:00	Oct-31-1976 06:00
19770322	Mar-22-1977 00:00	Mar-30-1977 00:00
19780116	Jan-16-1978 00:00	Jan-20-1978 12:00
19780206	Feb-06-1978 00:00	Feb-09-1978 12:00
19781204	Dec-04-1978 00:00	Dec-12-1978 00:00
19781228	Dec-28-1978 00:00	Jan-05-1979 00:00
19790115	Jan-15-1979 00:00	Jan-25-1979 00:00
19800228	Feb-28-1980 00:00	Mar-03-1980 12:00
19801124	Nov-24-1980 00:00	Nov-28-1980 12:00
19820111	Jan-11-1982 00:00	Jan-15-1982 00:00
19830117	Jan-17-1983 00:00	Jan-22-1983 00:00
19830210	Feb-10-1983 00:00	Feb-14-1983 12:00
19830224	Feb-24-1983 00:00	Mar-06-1983 00:00
19830314	Mar-14-1983 00:00	Mar-18-1983 18:00
19831219	Dec-19-1983 00:00	Dec-31-1983 00:00
19840225	Feb-25-1984 00:00	Feb-29-1984 18:00
19840323	Mar-23-1984 00:00	Mar-31-1984 00:00
19850206	Feb-06-1985 00:00	Feb-14-1985 00:00
19860103	Jan-03-1986 00:00	Jan-11-1986 00:00
19861228	Dec-28-1986 00:00	Jan-02-1987 00:00
19870304	Mar-04-1987 00:00	Mar-09-1987 00:00
19880202	Feb-02-1988 00:00	Feb-07-1988 00:00
19880406	Apr-06-1988 00:00	Apr-14-1988 00:00
19891014	Oct-14-1989 00:00	Oct-22-1989 00:00
19891116	Nov-16-1989 00:00	Nov-20-1989 06:00
19891217	Dec-17-1989 00:00	Dec-25-1989 00:00

Storm Ref	Start Date	End Date
19911101	Nov-01-1991 00:00	Nov-05-1991 06:00
19920203	Feb-03-1992 00:00	Feb-06-1992 12:00
19930122	Jan-22-1993 00:00	Jan-26-1993 06:00
19930310	Mar-10-1993 00:00	Mar-14-1993 00:00
19961110	Nov-10-1996 00:00	Nov-18-1996 00:00
19961213	Dec-13-1996 00:00	Dec-21-1996 00:00
19980129	Jan-29-1998 00:00	Feb-06-1998 00:00
19980209	Feb-09-1998 00:00	Feb-17-1998 00:00
19990116	Jan-16-1999 00:00	Jan-24-1999 00:00

GOMOS:
Gulf of Mexico Oceanographic Study

Project Description

Revised October 13, 2006

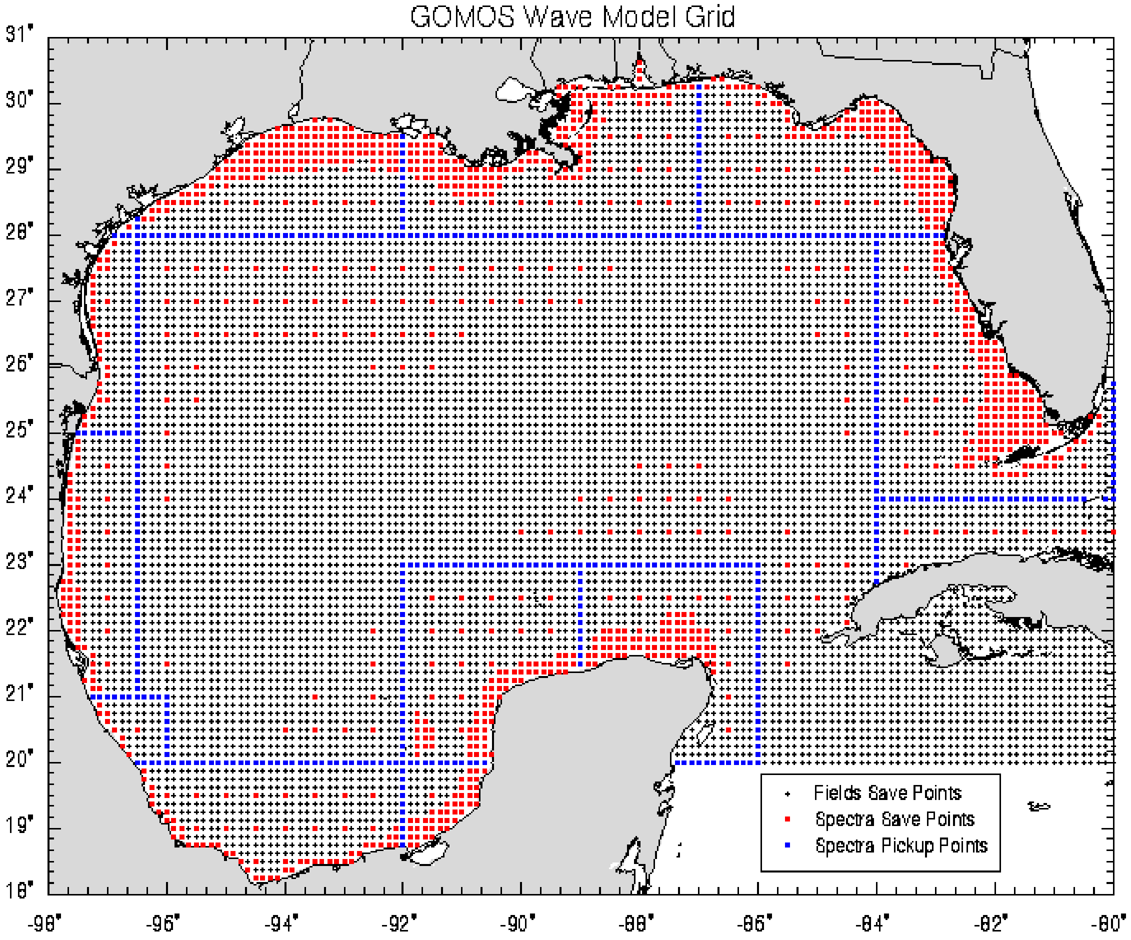
GOMOS Wave Model Grid

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TABLE OF CONTENTS

1. INTRODUCTION

The northern Gulf of Mexico (GM) is a leading region of U.S. hydrocarbon production, accounting for about 30% of its total oil and natural gas output. Production is confined to the central and western Gulf, mainly offshore Louisiana and Texas. While the near-shore shallow waters were the first to be exploited, exploration and production have within the past decade shifted steadily to deepwater (water depth greater than about 1000 feet) areas. However, there is new interest in shallow water areas where it is now suspected that there may be large natural gas fields deep in the sediment below the depths at which oil reservoirs were typically found.

Knowledge of the meteorological and oceanographic climate of the region is needed for specification of design criteria for the exploration and production infrastructure as well as for planning of operations. While in shallow water the production infrastructure is dominated by jacket structures, deep water production has stimulated the introduction of newer concepts such as tension-leg and SPAR platforms and, probably, soon to be used floating production systems. This variety of concepts has resulted in a need for a comprehensive array of meteorological and oceanographic design data. In addition to traditional extreme wind and wave criteria associated with severe tropical cyclones, there is need for surface and deep-layered storm generated currents, frequency and intensity of mesoscale eddy currents and characteristics of wind turbulence. Also, response based analysis has created a need for simulations of the time series of winds, waves and currents in both storms and for continuous periods of sufficient duration (of order years) to model long term fatigue.

While the GM may be considered a region of benign weather compared to higher latitude regions such as the North Sea, the extreme loads are severe because they are associated with occurrence of tropical cyclones that may attain Category Five on the Saffir-Simpson Scale.

Oceanweather Inc. has been central to government and industry sponsored programs over the past 30 years designed to understand, describe and model the surface marine meteorological characteristics of GM hurricanes and winter storms and the corresponding ocean response to the passage of such systems. The impact of that work has been immense on practices of design of offshore structures in the GM. The most notable programs include the so-called Analysis Phases of major measurement programs such as the Ocean Data Gathering Program (ODGP) for winds and waves, the Ocean Current Measurement Program (OCMP) for continental shelf currents, the

Ocean Test Structure (OTS) program for platform response, and a number of Ocean Response to a Hurricane (ORTAH) programs which utilized air-dropped current meters to measure mixed layer storm driven currents. Our trilogy of GM Joint Industry Projects (JIP) conducted in the early 1990s and known as GUMSHOE, WINX and GLOW have become established as the de-facto industry standard base of metocean design data in the northern GMEX and form the basis of the generalized recommendations in the API RP2A Series. Comparable studies have addressed the Bay of Campeche in the southwest GMEX (Cardone and Ramos, 1998). While much of the JIP work has been proprietary, the underlying modeling and analysis methods have been documented and exposed to the scientific and engineering communities in the peer reviewed literature and in proceedings of major conferences (see also reference list attached). For example, the OWI group was the first to demonstrate that a numerical spectral ocean wave prediction model could be used to provide an accurate description of the complex pattern of sea states generated by and traveling with tropical cyclones (Cardone *et al*., 1976). The extremal analysis of the results of hindcasts of the most extreme historical hurricanes which had occurred between 1900 and 1970 carried out with the ODGP hindcast models, provided revised design estimates (Ward *et al*., 1979; Haring and Heideman, 1978), which are credited (e.g. New York Times, 10/21/92, page D7) with greatly increasing the reliability of platforms designed since about 1976. GUMSHOE served to update the ODGP study and provide more reliable extreme design data in shallow water. ODGP and GUMSHOE included substantial hindcast model validation studies because wind, wave, surge and current measurements have been made in some notable historical Gulf of Mexico storms (Audrey, 1957; Bertha, 1957; Carla, 1961; Camille, 1969; Edith, 1971; Delia, 1973; Frederic, 1979; Danny, 1985; Juan 1985). These validation studies (e.g. Reece and Cardone, 1982) demonstrated the accuracy of our hindcast methods when applied to specify peak sea states (significant wave height) at an arbitrary site in a Gulf of Mexico hurricane (bias of less than 0.5 m, mean absolute error of less than 1.0 m and scatter index of 10-15%).

GOMOS is OWI's new comprehensive metocean study of the GM. As such it represents a major upgrade and update of above noted trilogy GM metocean JIPs carried out between 1988 and 1995, known as GUMSHOE (hurricane extremes), WINX (winter storm extremes) and GLOW (long term normal weather statistics).

GOMOS is an update of the previous studies because the continuous hindcast now covers the full decade of the 1990s to ensure that it simulates the recent and current climate, it adds a full decade of hurricane and winter storm experience to the previous studies and it includes much larger storm populations to provide more reliable extremes.

GOMOS is also an upgrade of the previous studies because it utilizes hindcast models of higher resolution and more powerful physics than the previous studies. The hurricane, winter storm and continuous hindcasts all were made on a fine mesh grid of spacing of 1/8th degree covering the entire Gulf of Mexico. The wave model incorporates second- or third-generation physics as appropriate for maximum skill. The hydrodynamic model provides storm surge and 2-D currents in all storms with proven skill in shallow water. One-dimensional current profile modeling has been added for all points in 75 m of water and deeper but only for tropical cyclones.

The products of GOMOS include, for each site of interest, the actual simulated hindcast time series from all models as well as extreme and normal derivative statistics. These products are available in either OWI’s OSMOSIS format (for current licensees of OSMOSIS) or ASCII.

The site-specific results are given in a companion GOMOS Block Report.

2. HINDCAST METHODOLOGY

2.1 Introduction

The GOMOS project applies the hindcast methodology developed at Oceanweather for the specification of wind, wave, current and surge fields in historical time periods. The basic hindcast approach involves the development of accurate wind fields from historical data and application of proven models. This section describes the historical data sources, wind field specification, wave models, and surge/current models applied in GOMOS. We give concise descriptions of each of these processes; more extensive mathematical treatments are reserved to cited references.

2.2 Data Sources

- Aircraft reconnaissance obtained from NOAA and U.S. Air Force hurricane hunter aircraft, including vortex messages as well as continuous flight level wind speed, direction, D-Value, air temperature.
- Gridded and image fields of marine surface wind composites from the Hurricane Research Division HWnd analysis
- Synoptic observations from NOAA buoy and C-MAN stations
- Synoptic observations from coastal and land stations obtained from the GTS (Global Transmission System) in real time
- NOAA NHC/TPC “best track” data
- Loops of NOAA GOES visual, infared and water vapor imagery
- NWS synoptic weather analysis charts
- NCEP/NCAR Reanalysis Products
- Daily sea level pressure data
- QUIKSCAT scatterometer winds
- TOPEX altimeter winds and waves
- ERS-2 altimeter winds and waves
- Analysis from previous Oceanweather storm studies

2.3 Wind Field Specification

2.3.1 Tropical Boundary Layer Model

This model, first developed into a practical tool in the Ocean Data Gathering Program (ODGP) (Cardone *et al.* 1976), can provide a fairly complete description of time-space evolution of the surface winds in the boundary layer of a tropical cyclone from the simple model parameters available in historical storms. The model is an application of a theoretical model of the horizontal airflow in the boundary layer of a moving vortex. That model solves, by numerical integration, the vertically averaged equations of motion that govern a boundary layer subject to horizontal and vertical shear stresses. The equations are resolved in a Cartesian coordinate system whose origin translates at constant velocity, V_f, with the storm center of the pressure field associated with the cyclone. Variations in storm intensity and motion are represented by a series of quasi-steady state solutions. The original theoretical formulation of the model is given by Chow (1971). A similar model was described more recently in the open literature by Shapiro (1983). The version of the model applied in this study is the result of two major upgrades, one described by Cardone *et al.*, (1992) and the second by Cardone *et al.* (1994) and Thompson and Cardone (1996). The first upgrade involved mainly replacement of the empirical scaling law by a similarity boundary layer formulation to link the surface drag, surface wind and the model vertically averaged velocity components. The second upgrade added spatial resolution and generalized the pressure field specification. A more complete description of the theoretical development of the model as upgraded is given by Thompson and Cardone (1996).

The model pressure field is described as the sum of an axially symmetric part and a large-scale pressure field of constant gradient. The symmetric part is described in terms of an exponential pressure profile, which has the following parameters:

Po	minimum central pressure
Pfar	far-field pressure
Rp	scale radius of exponential pressure profile
B	profile peakedness parameter

B is an additional scaling parameter whose significance was discussed by Holland (1980). This analytical form is also used to explicitly model the storm pressure field for use in the hydrodynamic model.

The model is driven from parameters that are derived from data in historical meteorological records and the ambient pressure field. The entire wind field history is computed from knowledge of the variation of those parameters along the storm track by computing solutions, or so-called "snapshots," on the nested grid as often as is necessary to describe different stages of intensity, and then interpolating the entire time history from the snapshots.

The model was validated originally against winds measured in several ODGP storms. It has since been applied to nearly every recent hurricane to affect the United States offshore area, to all major storms to affect the South China Sea since 1945, and to storms affecting many other foreign basins including the Northwest Shelf of Australia, Tasman Sea of New Zealand, Bay of Bengal, Arabian Sea and Caribbean Sea. Comparisons with over-water measurements from buoys and rigs support an accuracy specification of ± 20 degrees in direction and ± 2 meters/second in wind speed (1-hour average at 10-meter elevation). Many comparisons have been published (see e.g., Ross and Cardone, 1978; Cardone and Ross, 1979; Forristall *et al.*, 1977; 1978; 1980; Cardone *et al.*, 1992, Cardone and Grant, 1994).

As presently formulated, the wind model is free of arbitrary calibration constants, which might link the model to a particular storm type or region. For example, differences in latitude are handled properly in the primitive equation formulation through the Coriolis parameter. The variations in structure between tropical storm types manifest themselves basically in the characteristics of the pressure field of the vortex itself and of the surrounding region. The interaction of a tropical cyclone and its environment, therefore, can be accounted for by a proper specification of the input parameters. The assignable parameters of the planetary boundary layer (PBL) formulation, namely planetary boundary layer depth and stability, and of the sea surface roughness formulation, can safely be taken from studies performed in the Gulf of Mexico, since tropical cyclones world-wide share a common set of thermodynamic and kinematic constraints.

2.3.2 Kinematic Analysis

The Wind WorkStation (WWS), first introduced in 1995 (Cox *et al*. 1995), is the primary tool used to perform kinematic analysis of marine surface wind fields. Kinematic analysis is the process applied by a skilled marine meteorologist to re-analyze a storm wind field based on insitu and remotely sensed observations. This approach, first pioneered by Oceanweather for use in developing climatologies for offshore design, as been recognized internationally as producing the best possible wind fields and has been applied in numerous hindcast studies and used in developing reference wind fields in major international field programs and associated ocean response modeling experiments (Cardone *et al*. 1989 and 1996).

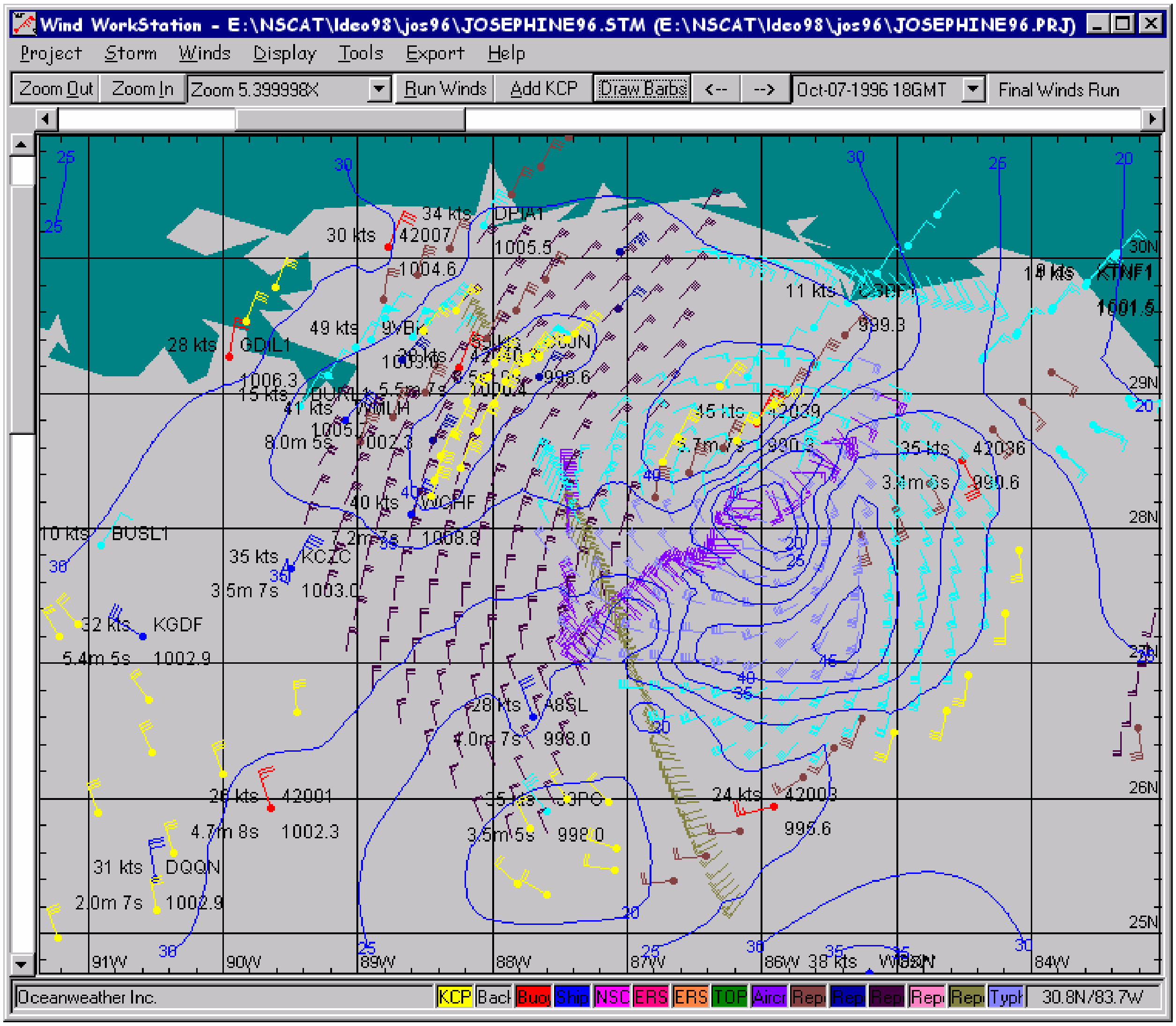

Figure 1 Wind WorkStation analysis of Hurricane Josephine (1996)

2.4 Wave Hindcast Model

OWI’s standard UNIWAVE high-resolution full spectral wave hindcast model was used for all wave hindcasts. UNIWAVE incorporates deep water and shallow processes and the option to use either OWI’s highly calibrated first generation source term physics (ODGP2) or third generation (3G) physics (OWI3G/DIA2). Extensive validations of OWI’s wave models in long-term hindcast studies are given recently by Swail and Cox (2000) and Cox and Swail (2001). Details on the 3rd generation physics applied in UNIWAVE can be found in Khandekar *et al.* (1994).

The GOMOS implementation of the UNIWAVE model was applied using ODGP2 physics in the tropical and storm hindcasts and 3rd generation physics in the continuous hindcast. But, 3-G physics was used for the following tropical hindcasts: Lili (2002), Ivan (2004), Dennis (2005), Katrina (2005), and Rita (2005). The GOMOS grid domain is from 18N to 31N and 98W to 80W with grid spacing of 1/8th of a degree (Figure 2). Bathymetry for the GOMOS model was obtained from the U.S. Army Engineer Research and Development Center (ERDC).

2.5 Storm Surge/Current Model

Oceanweather have applied, in several recent studies, a state-of-the-art current/surge model in problems of this type, including applications in the Gulf of Mexico and South China Sea and Bering Seas. The particular model adapted was developed at Texas A&M under the direction of Professor R. O. Reid, and is described in detail by Bunpapong, Reid, and Whitaker (1985). The model differs from most previous surge models, since it was designed for basin-wide simulations (such as Bunpapong's initial treatment of the problem of hurricane forcing on a grid covering the entire Gulf of Mexico), rather than models restricted to limited stretches of the continental shelf.

The theoretical formulation of the model is based upon the vertically-integrated momentum and conservation equations for quasi-hydrostatic large-scale disturbances in a basin of variable depth. The model is formulated to handle up to two layers, but was used in the single layer mode in this study.

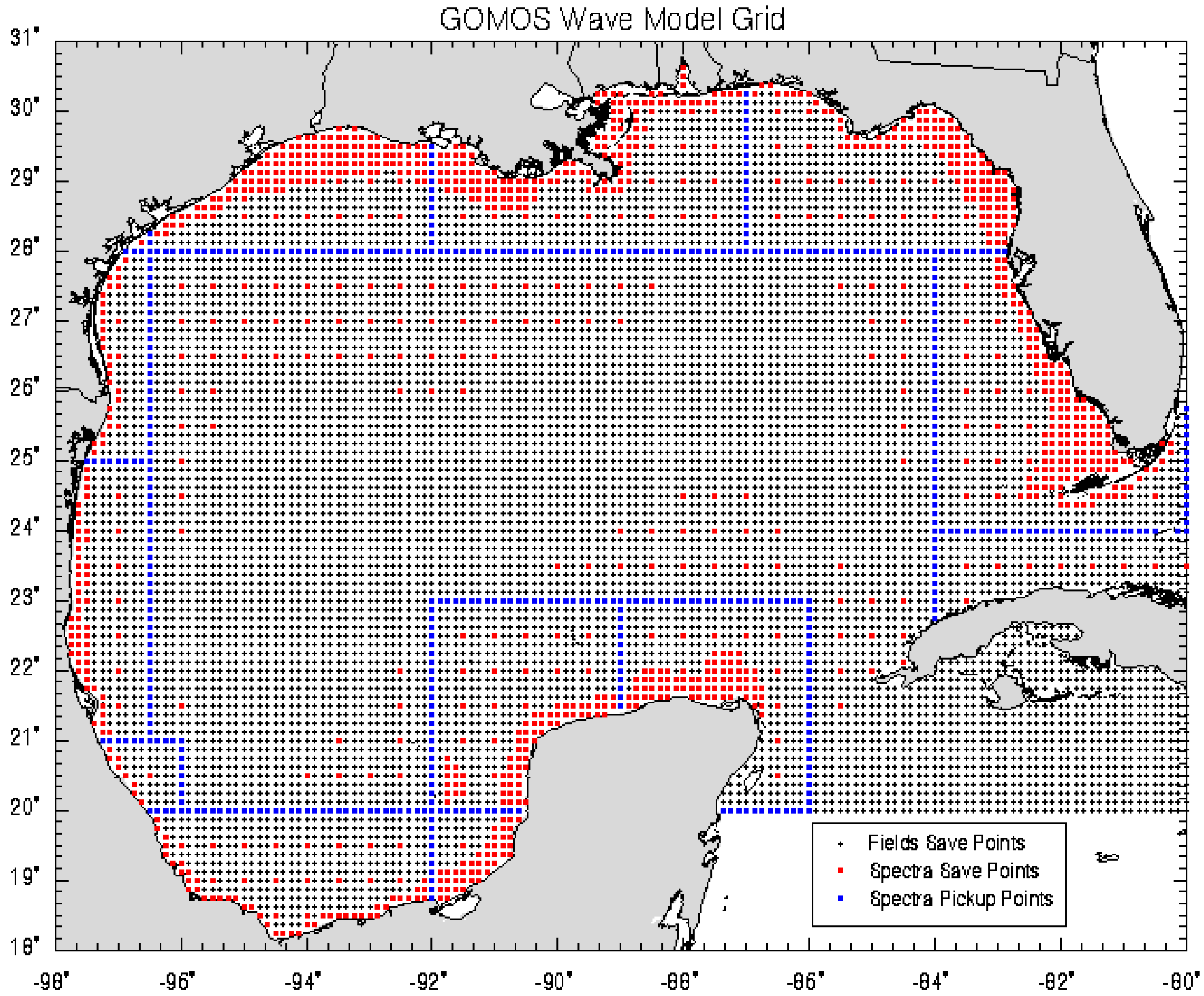

Figure 2 GOMOS 1/8th degree hindcast model grid

The normal mode equations are solved by finite-difference on a time-marching model, employing an alternating direction implicit differencing scheme. The model is quasi-linear, and tides are not included. Variable bathymetry, variable Coriolis parameter, and variable atmospheric pressure are modeled, however. The inverted barometric effect is therefore implicit in the model, and is automatically included in the modeled water-level anomalies. Surface-pressure anomalies are also used to stipulate barotropic height anomalies on the open boundaries of the model. A no-flow condition is taken at all solid boundaries.

The surge model is forced by specification of time histories of surface pressure and wind stress at the top boundary, and bottom friction at the bottom boundary.

The surge model incorporates a quadratic bottom-stress law with a constant friction coefficient. Bunpapong, Reid, and Whitaker (1985) used a coefficient of 2.5×10^{-3} in their Gulf of Mexico hurricane simulations. This was reduced to 1.0×10^{-3} in this study, which is at the lower end of the range of friction factors commonly adopted in models of this type. This value was used because we have found that when driven by wind stresses produced by our wind models, more accurate open coast surges were provided with the reduced friction factor.

The GOMOS implementation of the hydrodynamical model was applied with identical grid spacing and bathymetry inputs as shown in Figure 2.

2.6 1-D Modeling of Hurricane Generated Currents in Deep Water

Steady currents are important part of the load on offshore structures during hurricanes. In deep water, currents near the peak of the storm are in a mixed layer near the surface. Two-dimensional storm surge models cannot describe such currents profiles. A 1-D vertical model can capture most of the processes that create the current profiles at the peak of the storm in deep water. A simple vertical model gives the information necessary to calculate the increased load that hurricane generated surface currents place on an offshore structure.

One-dimensional models can give accurate current profiles for the peak of the storm. They also give reasonably accurate surface current hindcasts for some time after the storm passes. These models are best suited to predicting mixed layer currents in water deeper than 100 m.

One-dimensional models are not the best choice in all cases. They neglect horizontal pressure gradients and nonlinear advection. The pressure gradients drive the deep inertial currents that are observed after the passage of a hurricane. One-dimensional models yield no information on currents below the mixed layer (200 m deep or less). For sites near coastlines, pressure gradients from the storm surge cause barotropic currents that are nearly constant with depth.

The critical factor in a one-dimensional current model is the parameterization of the turbulent stress. This stress is responsible for the downward mixing of momentum from surface wind stress. The Reynolds averaged equations of motion for turbulent flow give us more unknowns than equations. The higher moments in these equations must be parameterized. Mixed layer models of the ocean usually consist of a single conservation equation for the turbulence kinetic energy and a set of algebraic equations for the turbulence second moment quantities. Kantha and Clayson (2000) give a thorough discussion of these models.

The best known second moment closure model is due to Mellor and Yamada (1982). They chose tunable constants that helped the model match laboratory turbulent flows. That model has been successfully applied in many studies of the oceanic mixed layer. One drawback is that it appears to slightly underestimate mixing. That underestimation leads to predictions of sea surface temperatures that are warmer than observed temperatures. Kantha and Clayson (1994) developed a modified second order model with enhanced mixing. Tests of the Mellor and Yamada (1982) and Kantha and Clayson (1994) models are described in Section 3 of Appendix F.

The most important input to turbulence closure models is the wind stress. The standard oceanic wind stress law is from Large and Pond (1981). The stress is given by:

$$\tau = \rho C_d U_{10}^2 \tag{2.1}$$

where ρ is the density of the air, C_d is the drag coefficient and U_{10} is the wind speed at 10 m elevation. Large and Pond (1981) gave the drag coefficient as

$$10^3 C_d = 0.44 + 0.063 U_{10} \tag{2.2}$$

Powell et al. (2003) have recently presented compelling evidence that the drag coefficient does not continue growing at very high wind speeds. They do not propose a specific new drag law, but we can interpret their data as putting a cap of $2.2\text{x}10^{-3}$ on C_d. The cap takes effect for 10 m wind speeds greater than 27.9 m/sec.

The models were run with the GOMOS wind speed and direction hindcast data. The models were started from rest at the first time step in each GOMOS storm. Wind speeds were very low in the early hours of the storms so the modeled currents grew smoothly from rest. No artificial inertial oscillations are created at the start of the storms.

The model also requires initial profiles of temperature and salinity. Those profiles were taken from the NODC World Ocean Atlas of 2001. This atlas gives the profiles on a one degree grid for each month of the year.

The 1-D model was run at all grid points with water depths of 75 m and deeper for a total of 2947 grid points. The complete report and validation can be found in Appendix F.

3. HINDCAST PRODUCTION

3.1 Continuous Period Hindcast

The period Jan-01-1990 to Jan-01-2003 was hindcast as a continuous period in GOMOS. Wind fields were developed in the WWS in monthly segments with storm kinematics from the tropical and extra-tropical hindcasts incorporated into the final wind fields. An analyst reviewed wind fields at 6-hourly intervals and available insitu wind observations were included in the objective analysis.

UNIWAVE model was applied in monthly segments with restart spectra saved for the next hindcast month. Wave spectra along the model boundary of the North Atlantic were obtained from Oceanweather's GROW (Global Analysis of Ocean Waves) hindcast and specified at the model timestep (30 minutes). Output from the continuous hindcast was archived at a 3-hourly timestep for both the wind and wave fields as well as wave spectra at select locations.

The surge/current model was also run in monthly segments, but since this model does not support a restart file between months a full month of spin-up was run for each continuous month. Comparisons of current/surge results along monthly boundaries indicated that this time period was sufficient. Pressures from the NCAR/NCEP reanalysis were used without modification in the surge/current model (unlike the GOMOS tropical hindcast which used the pressure output from the TC96 model at much finer resolution). Output from the surge/current model was also archived at a 3-hourly timestep for later merging with the wave results.

3.2 Tropical Storm Hindcast

All tropical systems in the Gulf of Mexico that attained tropical storm strength (defined as 35-knot one-minute sustained wind) for the time period Jan-01-1900 to Jan-01-2006 were hindcast in GOMOS, a total of 335 storms. Storm periods for each storm were restricted to 48 hours previous to entering the GOMOS region to 24 hours after exit/dissipation. The first 24 hours of storm history are considered spin-up and were removed from the GOMOS archive.

All storms were run through the TC96 model in order to define the wind in the core of the system. This core, typically 350 km, was brought into the WWS for blending into a background wind field. The background wind field was derived from daily sea level pressure data that was run through a wind field boundary layer model for storms previous to 1948. Storms post-1948 used modified NCEP/NCAR reanalysis 10-meter winds. Storms in 1945 did not have available background winds.

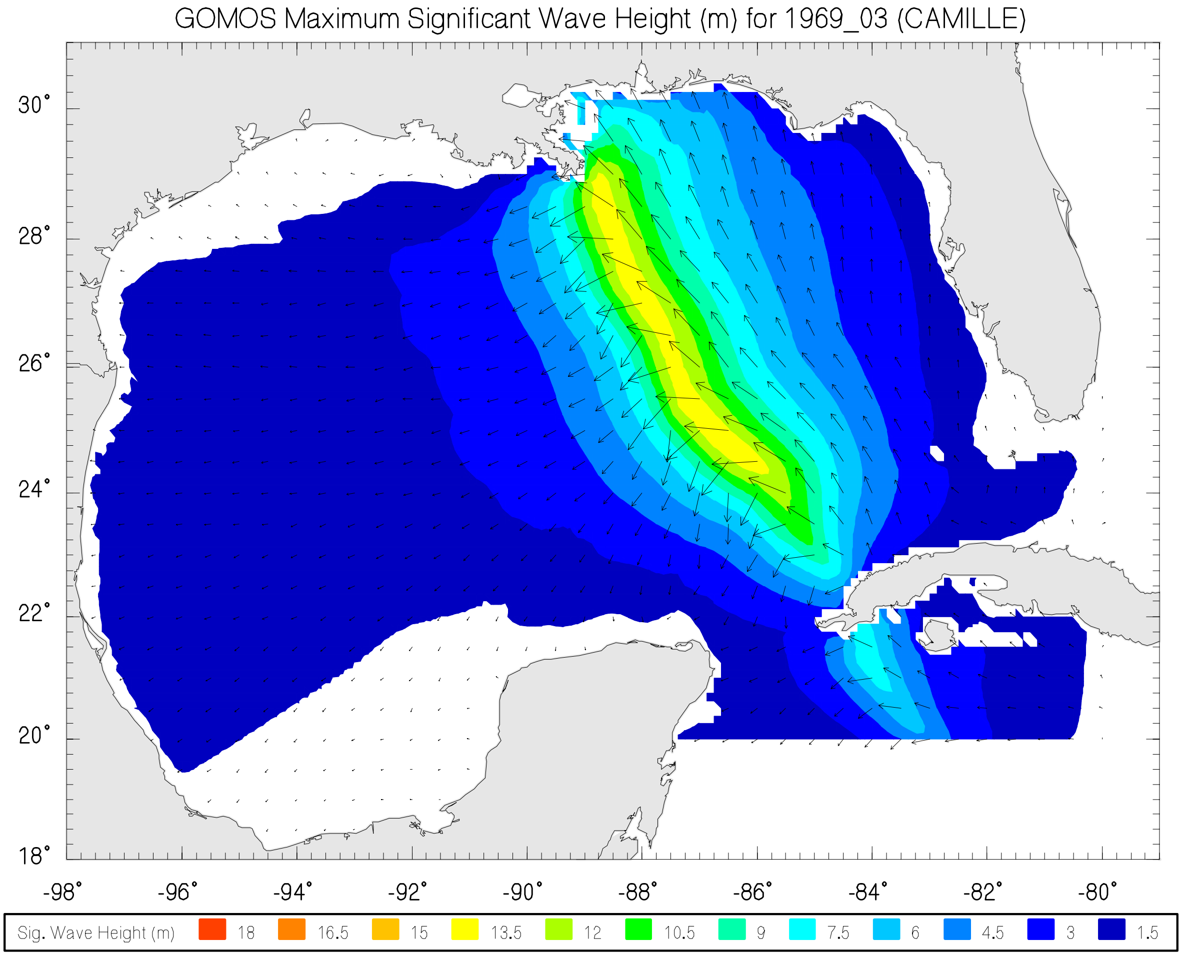

Figure 3 Maximum significant wave height (m) during Hurricane Camille (1969)

3.3 Extra-Tropical Storm Hindcast

Eighty extra-tropical winter storms were hindcast in GOMOS. Winter storm extremes in the study area are associated with two types of storms: migratory extra-tropical cyclones and episodic outbreaks of cold air behind cold fronts (northers). Storms were selected from the period based on the WINX hindcast and from regional storm selection based on the GROW 1958-2000 hindcast. WINX consisted of 34 storms from the period 1957-1990 which was determined by manually scanning NOAA weather maps available on microfilm. The storm selection was biased to Northern Gulf extremes and was later appended with 6 additional storms to better represent extreme conditions in the Southern Gulf. In GOMOS, an additional 40 storms were hindcast based on regional storm selection of wave heights hindcast in GROW for the period 1958 to 2000 for a total of 80 storms hindcast.

All available wind inputs were made available in the WWS for the analysis of each event. Event duration varied from a few days to just under two weeks depending on the event type. The first 24 hours of spin-up were run and deleted from the hindcast archive. Kinematic analysis from WINX and other previous hindcasts were also included.

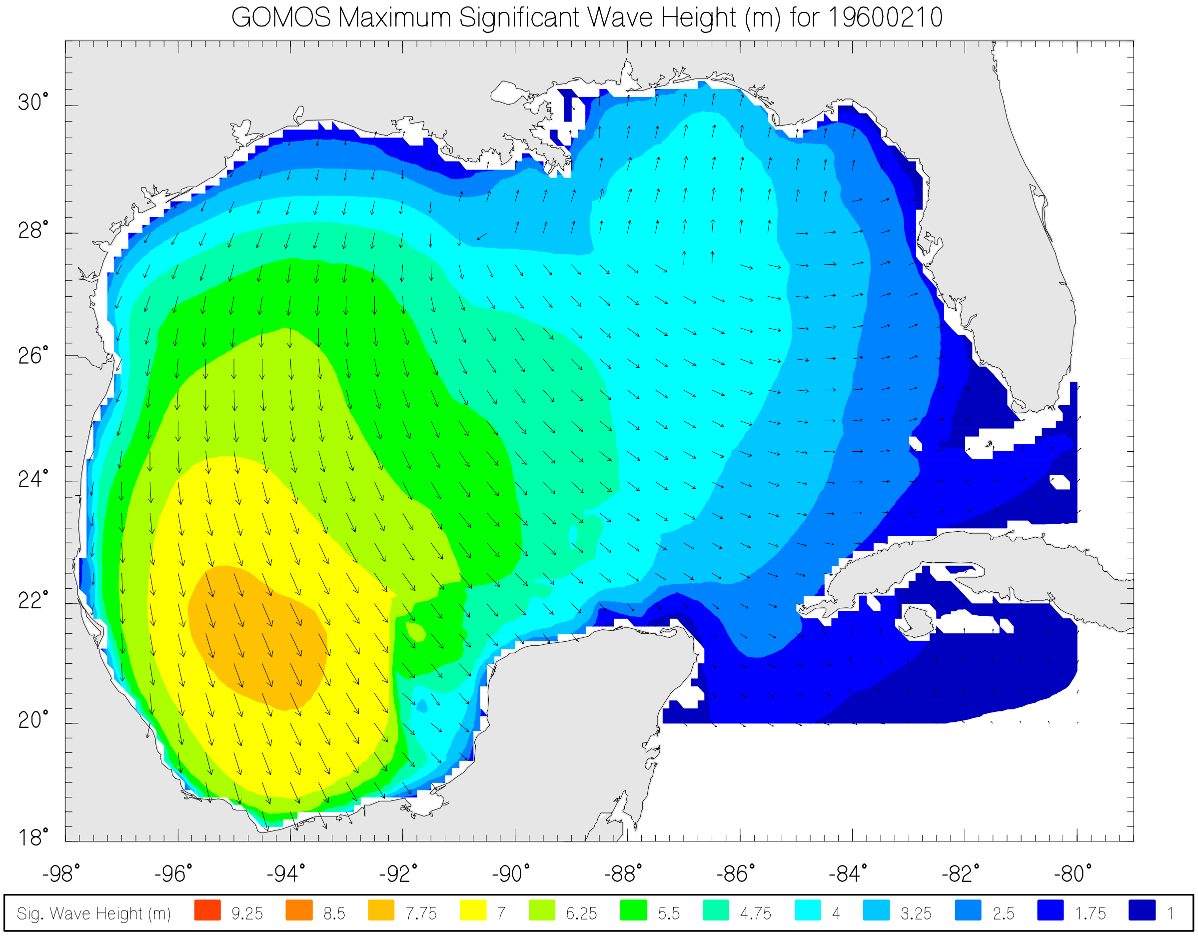

Figure 4 Maximum significant wave height (m) hindcast during February 10th, 1960 GOMOS storm event

4. VALIDATION

4.1 Validation of Continuous Hindcast

GOMOS was intensively validated against buoy observations from the National Data Buoy Center (NDBC) network, altimeter measurements from the ERS-1, ERS-2 and Topex satellites as well as proprietary datasets in the Gulf of Mexico.

NDBC buoy wind observations from 10 buoys in the Gulf (Figure 5) were adjusted for height/stability to a common reference of 10 meters and all hourly observations smoothed +/- 1 hour to reduce sampling variability. Figure 6 shows an example of the GOMOS continuous hindcast vs. conditions measured by NDBC buoy 42036. Based on over 180,000 matched observation/model pairs the GOMOS hindcast has a small negative wave height bias of 8 cm with correlation coefficient of 93%. Wave period bias in under ½ second and the wave direction bias is approximately ½ the model directional bin size (less than 8 degrees bias overall). Complete statistics combined and by buoy are tabulated in Table 1.

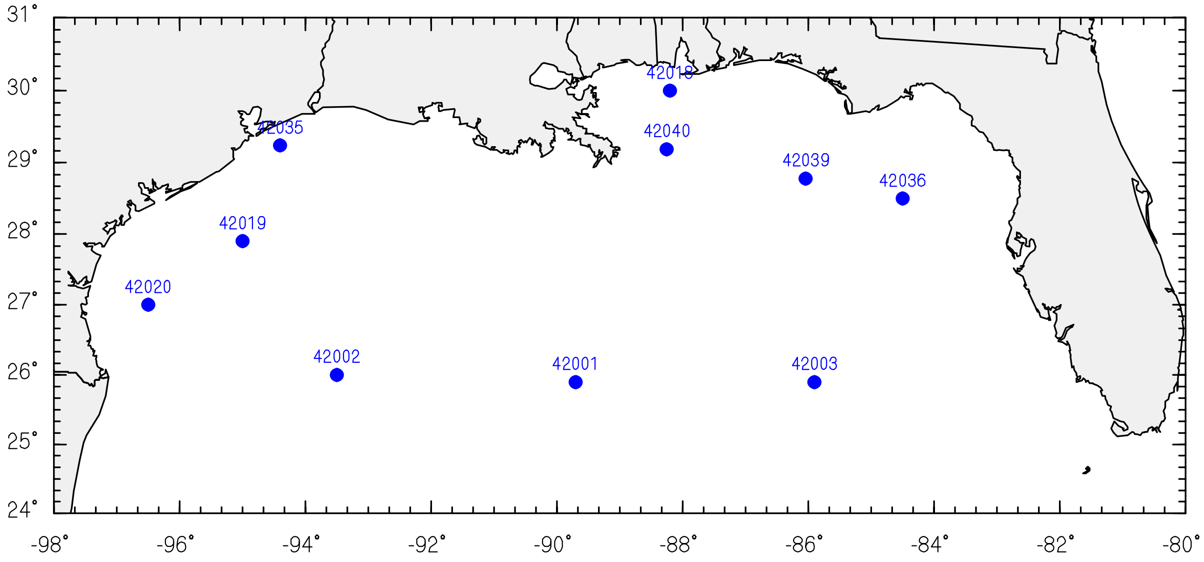

Figure 5 NDBC buoy locations

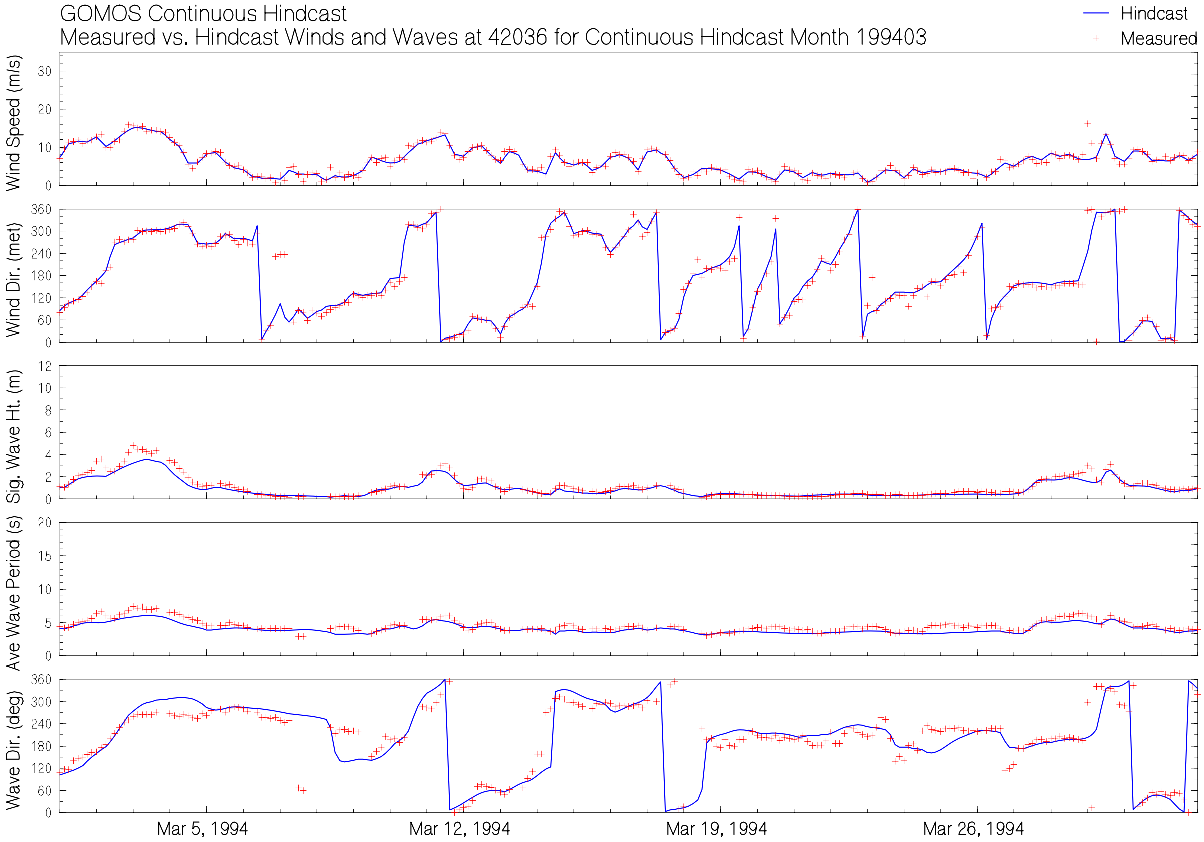

Figure 6 Timeseries comparison of GOMOS vs. NDBC buoy 42036 (WNW of Tampa, FL 28.51N 84.51W, depth 53 meters)

Table 1 Statistical comparison of the GOMOS continuous hindcast vs. NDBC buoys for the period 1990-1999.

	Number of Points	*Mean Measurement*	*Mean Hindcast*	*Bias (H-M)*	*RMS Error*	*Scatter Index*	*Correlation Coefficient*
All Locations Combined							
Wind Speed (m/s)	182593	6.34	6.37	0.02	1.17	0.19	0.92
Wind Direction (deg)	182585	103.85	102.23	-.06	N/A	0.05	N/A
Significant Wave Ht. (m)	180530	1.12	1.02	-0.08	0.27	0.23	0.93
Wave Period (sec)	180532	4.68	4.24	-0.45	0.67	0.11	0.79
Wave Direction (deg)	64034	120.35	102.54	-7.92	N/A	0.1	N/A
Buoy 42001							
Wind Speed (m/s)	27641	6.16	6.07	-0.08	1.03	0.17	0.94
Wind Direction (deg)	27637	92.15	91.77	-0.05	N/A	0.04	N/A
Significant Wave Ht. (m)	26869	1.1	1.06	-0.04	0.24	0.22	0.94
Wave Period (sec)	26869	4.73	4.36	-0.37	0.61	0.1	0.8
Wave Direction (deg)	9105	96.46	90.16	-5.36	N/A	0.09	N/A
Buoy 42002							
Wind Speed (m/s)	27144	6.49	6.67	0.18	1.26	0.19	0.9
Wind Direction (deg)	27144	107.75	103.93	-1.33	N/A	0.07	N/A
Significant Wave Ht. (m)	28059	1.23	1.17	-0.06	0.26	0.2	0.94
Wave Period (sec)	28059	4.91	4.43	-0.48	0.66	0.09	0.83
Wave Direction (deg)	12598	104.98	100.51	-5.3	N/A	0.07	N/A
Buoy 42003							
Wind Speed (m/s)	26652	6.28	6.47	0.19	1.04	0.16	0.94
Wind Direction (deg)	26650	89.13	89.76	-0.29	N/A	0.04	N/A
Significant Wave Ht. (m)	24955	1.09	1.02	-0.07	0.27	0.24	0.93
Wave Period (sec)	24955	4.78	4.16	-0.62	0.91	0.14	0.6
Wave Direction (deg)	14150	119.75	90.83	-9.2	N/A	0.11	N/A
Buoy 42018							
Wind Speed (m/s)	348	5.79	7.13	1.34	2.71	0.41	0.59
Wind Direction (deg)	348	80.72	87.55	7.21	N/A	0.08	N/A
Significant Wave Ht. (m)	330	1.09	1.05	-0.04	0.33	0.3	0.82
Wave Period (sec)	330	4.6	4.22	-0.38	0.66	0.12	0.83
Buoy 42019							
Wind Speed (m/s)	22404	6.64	6.56	-0.08	1.27	0.19	0.91
Wind Direction (deg)	22404	114.05	112.5	-1.06	N/A	0.05	N/A
Significant Wave Ht. (m)	22475	1.26	1.16	-0.1	0.29	0.22	0.92

Wave Period (sec)	22475	4.76	4.4	-0.36	0.54	0.09	0.84
Wave Direction (deg)	5642	125.4	117.62	-10.52	N/A	0.07	N/A
Buoy 42020							
Wind Speed (m/s)	23570	6.84	6.62	-0.21	1.64	0.24	0.83
Wind Direction (deg)	23569	115.38	113.34	-0.53	N/A	0.06	N/A
Significant Wave Ht. (m)	21705	1.32	1.17	-0.15	0.33	0.22	0.91
Wave Period (sec)	21705	4.86	4.45	-0.41	0.59	0.09	0.84
Wave Direction (deg)	4360	112.38	105.58	-11.05	N/A	0.08	N/A
Buoy 42035							
Wind Speed (m/s)	16159	6.26	6.33	0.07	1.11	0.18	0.92
Wind Direction (deg)	16159	123.44	122.35	-0.06	N/A	0.05	N/A
Significant Wave Ht. (m)	18400	0.9	0.81	-0.1	0.24	0.24	0.88
Wave Period (sec)	18400	4.32	3.87	-0.45	0.64	0.11	0.7
Wave Direction (deg)	3225	152.83	129.03	-23.31	N/A	0.08	N/A
Buoy 42036							
Wind Speed (m/s)	16827	5.82	5.83	0.02	0.81	0.14	0.97
Wind Direction (deg)	16827	65.85	65.67	3.19	N/A	0.05	N/A
Significant Wave Ht. (m)	15575	0.92	0.84	-0.08	0.24	0.24	0.95
Wave Period (sec)	15575	4.34	3.93	-0.42	0.65	0.12	0.75
Wave Direction (deg)	14954	191.61	126.98	-5.18	N/A	0.11	N/A
Buoy 42039							
Wind Speed (m/s)	11180	6.07	6.18	0.12	0.87	0.14	0.96
Wind Direction (deg)	11179	89.13	89.81	0.9	N/A	0.05	N/A
Significant Wave Ht. (m)	11111	1.02	0.94	-0.08	0.31	0.3	0.92
Wave Period (sec)	11111	4.52	4.05	-0.47	0.65	0.1	0.8
Buoy 42040							
Wind Speed (m/s)	10668	6.15	6.2	0.06	0.92	0.15	0.96
Wind Direction (deg)	10668	131.5	131.23	0.37	N/A	0.05	N/A
Significant Wave Ht. (m)	11051	1.01	0.96	-0.05	0.24	0.24	0.94
Wave Period (sec)	11053	4.51	4.09	-0.42	0.61	0.1	0.83

Measurements from the ERS-1, ERS-2 and TOPEX altimeters from the period 1991 to 1999 were used in the validation. The median of all altimeter measurements (typically measured at 1 Hz) within a 30 Nmi box were considered a single observation and adjustments to individual satellites based on buoy observations were performed to keep the combined dataset consistent. Overall the GOMOS hindcast shows a small negative bias of 15 cm with correlation coefficient of 87% (Table 2). The largest bias shown in the altimeter measurements is mainly reflected in the southern Bay of Campeche (Figure 3) where less historical measured data is available.

Table 2 Statistical comparisons of GOMOS continuous hindcast and altimeter measurements

	Number of Points	Mean Measurement	Mean Hindcast	Bias (H-M)	RMS Error	Scatter Index	Correlation Coefficient
Wind Speed (m/s)	109594	5.84	6.55	0.71	1.77	0.28	0.81
Significant Wave Ht. (m)	92290	1.31	1.16	-0.15	0.38	0.27	0.87

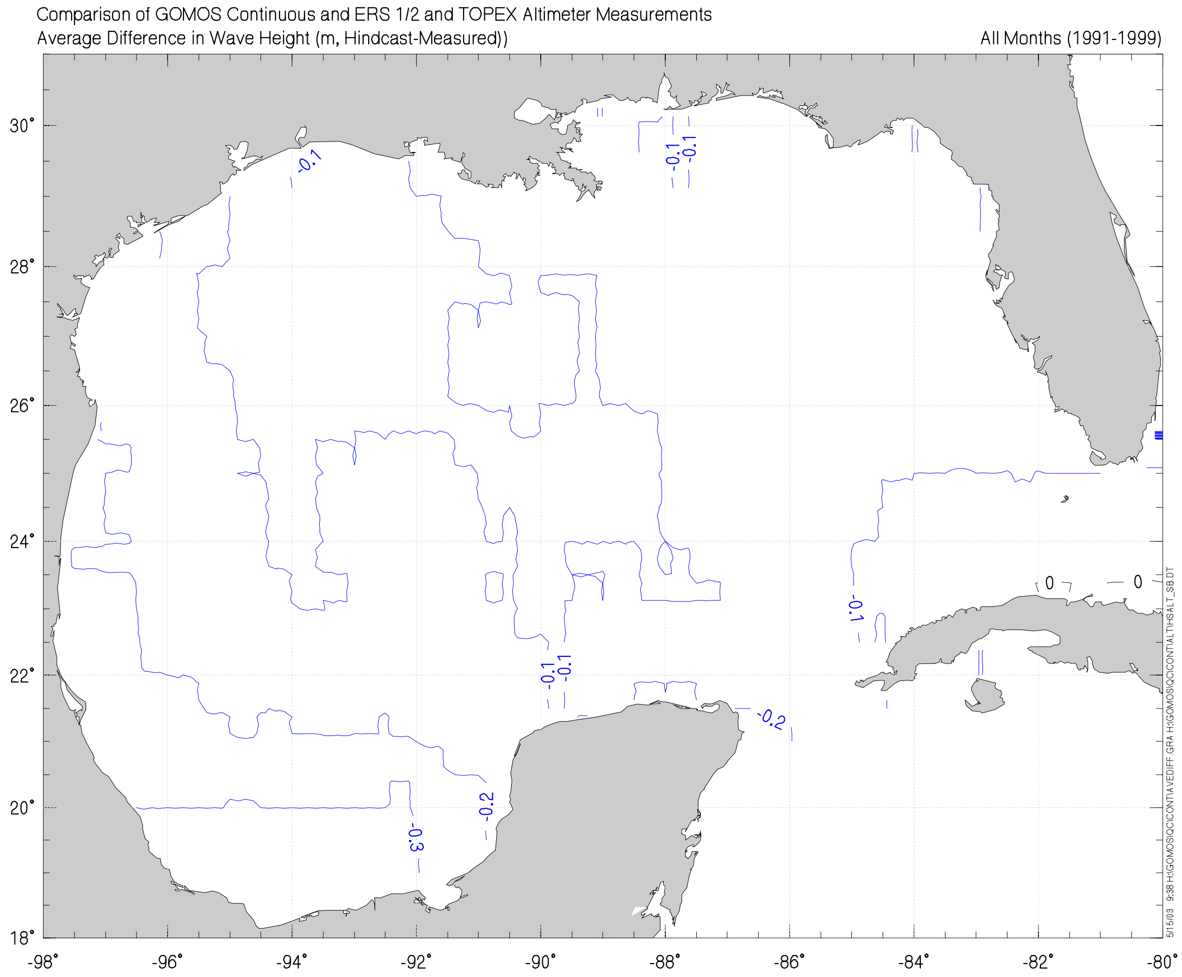

Figure 7 Mean bias (hindcast-altimeter) of significant wave height in GOMOS continuous hindcast.

4.2 Validation of Tropical Storm Hindcasts

The NDBC buoys were also applied in the GOMOS storm hindcast validation set. Figure 8 shows a typical comparison timeseries during Hurricane Roxanne 1995. In order to assess the skill of GOMOS in predicting the storm peaks, a peak-to-peak analysis was performed. All available buoy timeseries in the period 1961-2005 were scanned for tropical storm peaks greater than 6.0 meters. The corresponding GOMOS peak within a time window of +/-1 hour was then found for comparison. Figure 9 shows a scatter plot of all the GOMOS peaks found in the NDBC historical record, overall there is a small 21 cm bias in the peak-to-peak analysis.

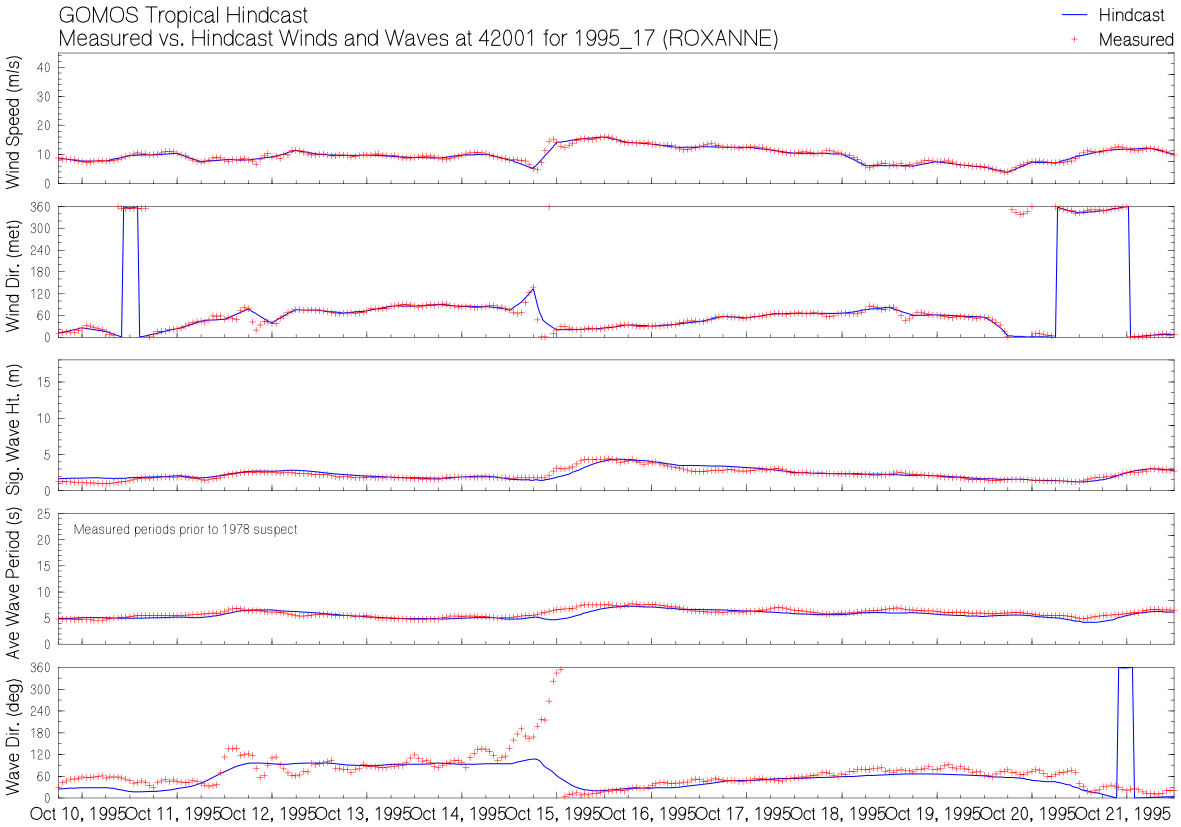

Figure 8 Timeseries comparison of GOMOS tropical hindcast a buoy 42001 during Hurricane Roxanne (1995)

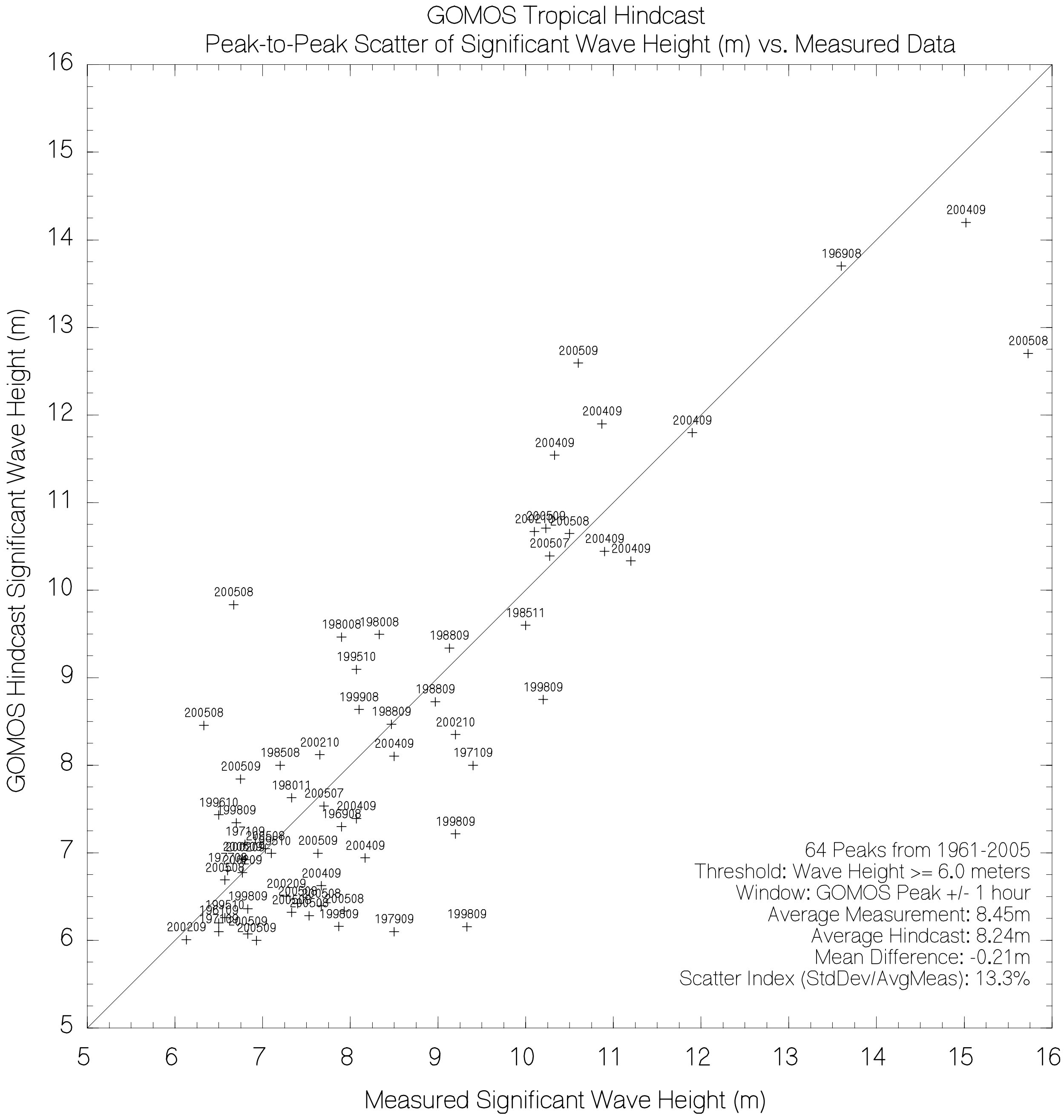

Figure 9 Peak-to-peak significant wave height (m) comparison of GOMOS tropical hindcast and NDBC buoys

4.3 Validation of Extra-Tropical/Winter Storm Hindcasts

As was done for the tropical hindcasts, both inter-comparison of NDBC buoys during individual storms and peak-to-peak analysis were performed for the GOMOS Extra-Tropical hindcast.

Figure 10 shows a typical timeseries comparison at buoy 42001 during the March 1993 “Storm of the Century” event. Figure 11 shows the results of the peak-to-peak analysis which shows a similar bias of the tropical hindcast of 28 cm overall.

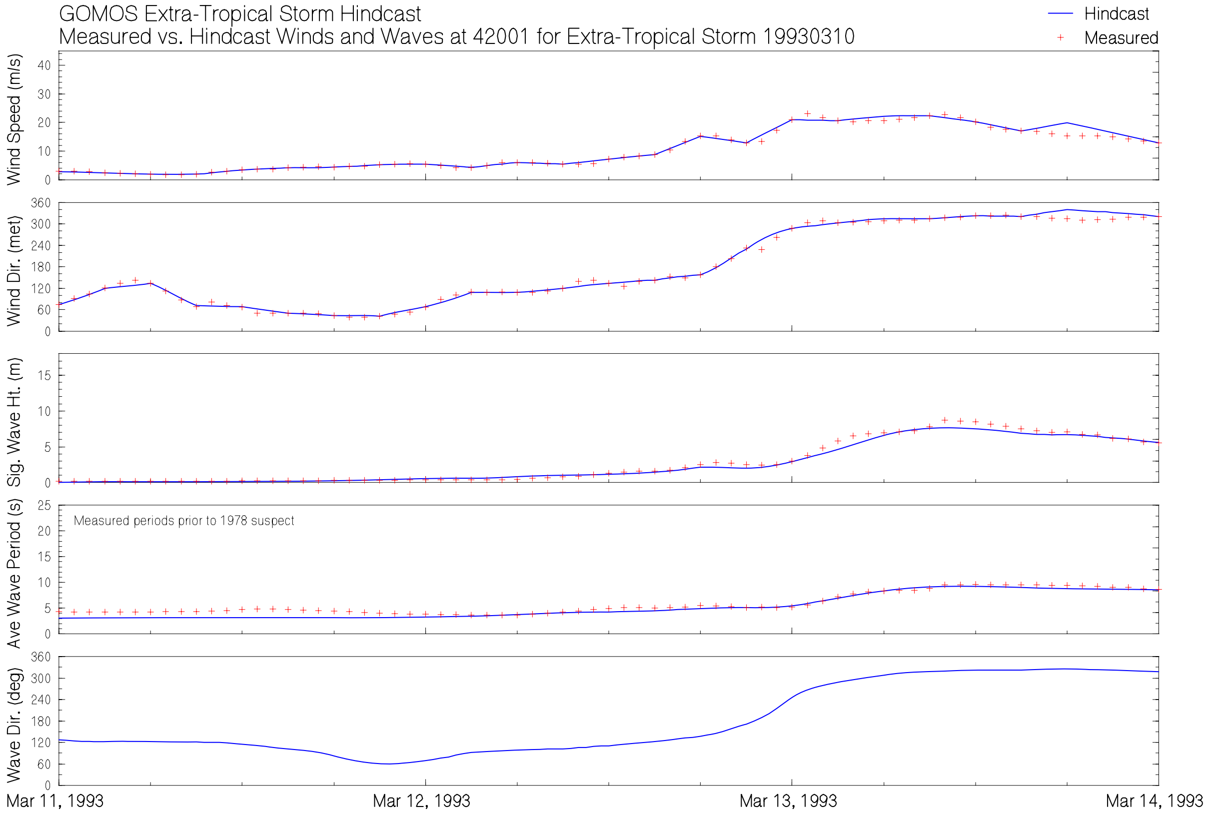

Figure 10 Timeseries of GOMOS extra-tropical storm hindcast during March 10, 1993 event (so-called "Storm of the Century")

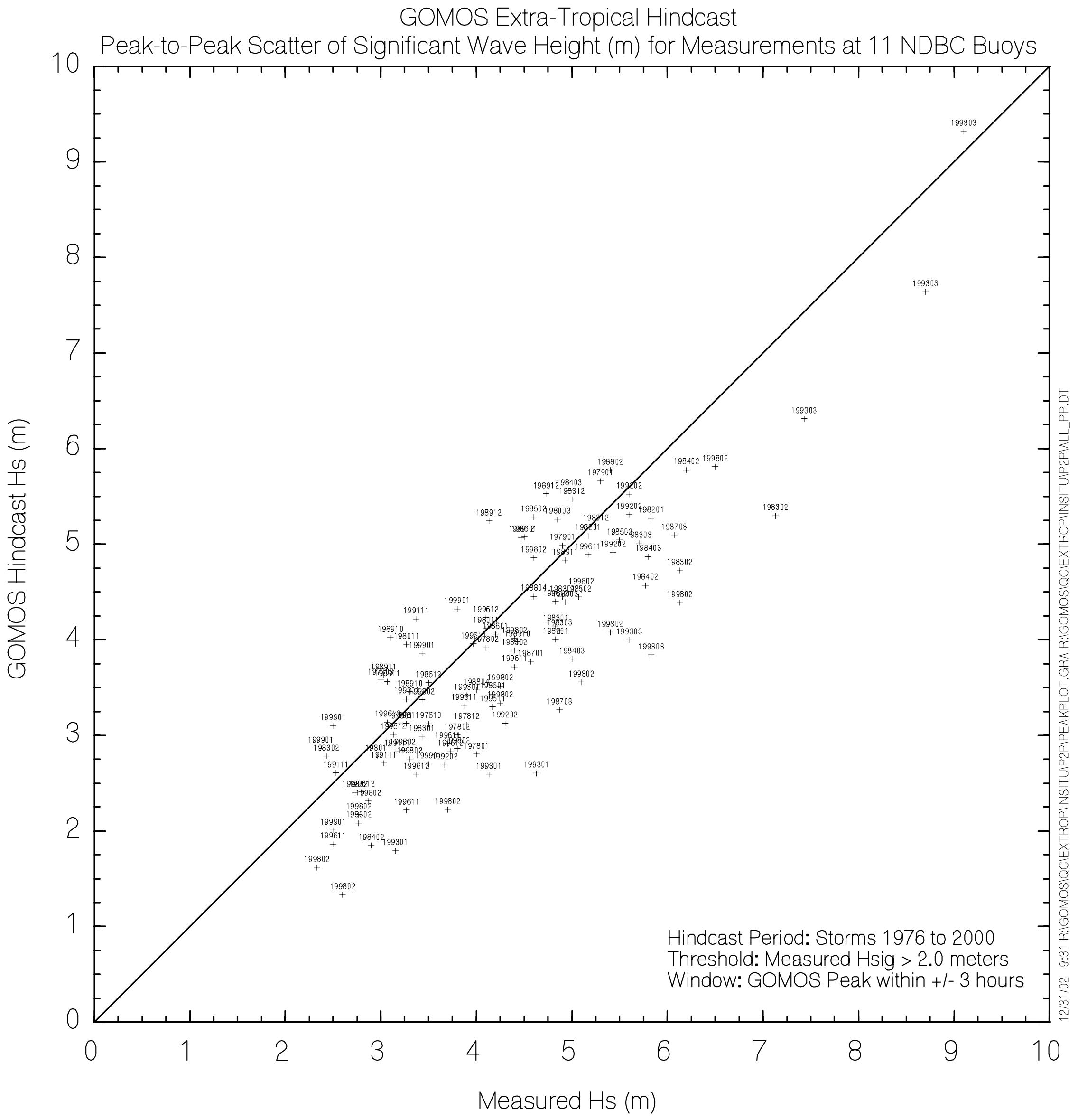

Figure 11 Peak-to-peak significant wave height (m) comparison of GOMOS extra-tropical hindcast and NDBC buoys.

5. DELIVERABLES

This section describes the standard GOMOS deliverable products. Actual products delivered for a GOMOS request may differ depending on which options are taken. See the *GOMOS Block Specific Report* for details on the exact files included in your delivery.

5.1 Wind, Wave, Current and Surge Fields

Oceanweather's standard wind, wave, current and surge fields, as described in Table 3, were archived at all grid points on the GOMOS grid. Operational fields were archived at a 3-hour time step from Jan-01-1990 to Jan-01-2003. Three hundred thirty-five tropical storms from Jan-01-1900 to Jan-01-2006 and 80 winter storms from 1958-2000 were saved at a 30-minute time step (the integration time step of the UNIWAVE model). Five additional fields are available for the tropical database at 2947 points in deep water in the northern Gulf. Fields are available in both ASCII format (see Appendix A for example) and OSMOSIS format. OSMOSIS is Oceanweather's display and analysis software tool that is sold separately.

Table 3 Wind, wave, current and surge 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, $2/\pi$; 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 $\cos\theta^n$ 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.
Surge Height	Storm driven water elevation with respect to mean sea level in cm. Tidal influences not included.
Current Speed	Vertically averaged storm driven current (cm/sec)
Current Direction	To which the currents are traveling, clockwise from north in degrees (oceanographic convention)
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.
Kantha and Clayson (1994) 1-D Currents	For 2947 grid points 75 m and deeper in the northern Gulf.
Surface Current Speed	Current speed in cm/s
Zero Depth	Depth at which current speed equals zero (m)
Mid-Depth	Depth of break in current profile (m)
Mid-Depth Current Speed	Current speed in cm/s at Mid-Depth
Current Direction	Vector average current direction, clockwise from north in degrees (oceanographic convention)

5.2 Standard Statistics Analysis

5.2.1 Extremal Analysis

Return period extremes in both omni-directional and sector stratified form are derived using the Gumbel, Borgman, Galton and Weibull algorithms for the full period and a subset of years, 1950-2005. Standard return period values are 1, 5, 10, 25, 50, 75 and 100 years and are computed for significant wave height, maximum individual wave height, maximum individual crest height, maximum wind speed, associated wave period, storm driven surge and storm driven 2-D currents. Tropical extremes at grid points north of 25° N in deep water will also include extremes of the 1-D current profile variables and alternative results using the subset of years, 1950-2005. Gust factors are provided to convert 1 hour answers to 10-min, 1-min and 3-sec gusts. Sectors are defined as 8 45-degree bins centered on North and extremes are computed for the 100-year return period. See Appendix B for full description of the extremes tables as well as sample output and technical description of the algorithms used. The *GOMOS Block Specific Report* will detail the algorithm applied and any site-averaging applied in deriving the final tabled extremes.

5.2.2 Persistence/Duration Tables

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

5.2.3 Frequency of Occurrence Tables

Frequency of occurrence table is also referred to as joint frequency tables, bivariate distributions and scatter diagram data. These are based on the GOMOS continuous hindcast. See Appendix D for frequency of occurrence tables' sample output.

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

1. Significant Wave Height (HS) by Peak Spectral Period (TP) – (45° sectors & combined)
2. HS by Vector Mean Direction (VMD)
3. Wind Speed by Wind Direction

5.3 Wave Spectra

Wave spectra from the GOMOS hindcast were archived every 3 hours for the continuous hindcast and every 30 minutes for the storm hindcasts on a subset of the GOMOS wave model grid (see Figure 2). Additional points along basin perimeters were also archived for use in driving regional wave models. The UNIWAVE 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 E for a sample and full description).

5.4 Block Specific Report

A concise summary of the hindcast products and tables including storm dates for both the tropical and extra-tropical storms will be delivered. If the extremal analysis option is chosen, a detailed explanation of the procedure will be included for the specific site.

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APPENDIX A

Sample ASCII Time Series

First page for operational, extratropical storms and
tropical shallow water grid points (< 75 m) and all points south of 25° N
Second page for tropical deep water points with an additional 5 variables north of 25° N

```
Time Series

GO Gpt XXXX, Lat XX.XXn, Long XX.XXw, Depth XXm
Defined Period: Everything
Date Ranges: 1/1/1990 00:00 to 12/31/1999 21:00;9/4/1900 18:00 to 10/6/2000 18:00

     Julian CCYYMM DDHHmm    WD    WS   ETOT     TP   VMD ETTSea  TPSea VMDSea  ETTSw   TPSw VMDSw    MO1    MO2     HS DMDIR ANGSPR INLINE    HSUR    CS    CD
                            deg   m/s    m^2    sec   deg    m^2    sec    deg    m^2    sec   deg  m^2/s  m2/s2      m   deg                    cm  cm/s   deg
32874.00000 199001 010000 354.5 10.51  0.115  4.874 152.9  0.109  4.668  154.9  0.006  5.137  99.0  0.166  0.253  1.357 150.5 0.8401 0.7573   -13.4   2.5 190.9
32874.12500 199001 010300 354.5 10.56  0.130  4.997 157.1  0.125  4.902  159.0  0.005  5.146  99.6  0.184  0.275  1.443 154.6 0.8304 0.7397   -13.4   4.3 209.2
32874.25000 199001 010600 354.5 10.62  0.136  5.026 160.0  0.132  4.975  161.7  0.005  5.164  99.2  0.192  0.286  1.478 157.0 0.8211 0.7278   -15.4   5.7 218.8
32874.37500 199001 010900   2.5 10.65  0.133  4.968 166.1  0.127  4.866  168.5  0.007  5.285 113.3  0.189  0.282  1.461 162.6 0.8084 0.7083   -15.3   6.2 232.8
32874.50000 199001 011200  10.5 10.67  0.130  4.927 174.0  0.120  4.834  178.5  0.010  5.231 113.2  0.187  0.282  1.443 171.3 0.7888 0.6794   -15.1   8.9 241.2
32874.62500 199001 011500  12.0  9.00  0.113  4.923 181.5  0.105  4.795  185.1  0.008  5.177 116.0  0.165  0.252  1.344 180.2 0.7786 0.6686   -13.7   9.8 257.4
32874.75000 199001 011800  14.2  7.32  0.085  4.711 187.6  0.079  4.569  190.4  0.006  5.169 124.2  0.128  0.202  1.165 188.1 0.7813 0.6776   -11.3  11.9 255.3
32874.87500 199001 012100  24.5  7.63  0.074  4.868 197.1  0.070  4.815  199.4  0.004  5.059 121.9  0.114  0.181  1.089 198.6 0.7987 0.6942   -13.1  13.6 253.2
32875.00000 199001 020000  34.0  7.94  0.079  4.883 209.5  0.078  4.863  210.0  0.001  5.021 130.0  0.120  0.189  1.126 212.3 0.8195 0.7181   -13.4  14.9 268.7
32875.12500 199001 020300  48.7  7.69  0.079  4.932 223.2  0.078  4.922  223.8  0.001  4.981 143.4  0.118  0.183  1.125 226.3 0.8357 0.7404    -9.8  15.0 272.1
32875.25000 199001 020600  64.3  7.45  0.077  4.945 238.5  0.076  4.945  238.9  0.000  4.947 151.8  0.113  0.175  1.110 241.5 0.8536 0.7664   -10.4  15.5 269.7
32875.37500 199001 020900  71.1  6.65  0.065  4.709 246.9  0.060  4.621  246.2  0.005  6.208 258.2  0.097  0.153  1.021 250.2 0.8614 0.7812   -11.1  15.3 277.9
32875.50000 199001 021200  79.9  5.85  0.051  4.532 254.9  0.039  4.126  250.7  0.011  5.612 268.7  0.077  0.125  0.899 256.9 0.8909 0.8191   -10.2  15.5 280.2
32875.62500 199001 021500  87.5  6.10  0.042  4.416 258.8  0.038  4.226  258.0  0.003  6.303 269.1  0.067  0.111  0.818 260.8 0.8961 0.8277   -10.4  14.9 280.3
32875.75000 199001 021800  94.5  6.36  0.042  4.403 267.1  0.042  4.403  266.9  0.000  7.265 294.5  0.068  0.115  0.822 268.5 0.8942 0.8208   -10.8  14.7 284.6
32875.87500 199001 022100  95.9  6.05  0.039  4.355 270.3  0.038  4.329  269.7  0.001  6.712 286.3  0.063  0.107  0.791 271.4 0.8993 0.8281   -11.0  15.8 288.0
32876.00000 199001 030000  97.5  5.74  0.034  4.153 271.8  0.030  4.052  271.0  0.003  6.602 279.5  0.055  0.095  0.735 272.6 0.9107 0.8457   -10.1  15.6 291.9
32876.12500 199001 030300 101.7  6.30  0.038  4.148 277.3  0.036  4.149  277.0  0.001  7.117 288.5  0.061  0.105  0.775 277.8 0.9066 0.8383    -9.3  15.4 290.9
32876.25000 199001 030600 105.2  6.87  0.048  4.445 280.8  0.048  4.445  280.8  0.000  7.457 301.3  0.076  0.126  0.880 281.3 0.9078 0.8392    -9.4  15.9 295.2
32876.37500 199001 030900 111.5  7.13  0.056  4.613 285.3  0.056  4.613  285.3  0.000  9.961 316.3  0.087  0.140  0.951 285.8 0.9052 0.8348    -8.1  16.9 300.6
32876.50000 199001 031200 117.2  7.39  0.065  4.793 291.2  0.065  4.793  291.2  0.000 10.401 260.3  0.098  0.156  1.018 291.3 0.8964 0.8217    -6.7  15.9 300.1
32876.62500 199001 031500 121.0  7.24  0.065  4.879 295.9  0.065  4.879  295.9  0.000 10.130 315.8  0.098  0.155  1.018 296.1 0.8908 0.8121    -6.8  15.4 301.4
32876.75000 199001 031800 124.8  7.09  0.062  4.889 299.8  0.062  4.889  299.8  0.000 10.035 320.1  0.095  0.152  0.999 299.7 0.8821 0.7991    -6.1  14.9 305.4
32876.87500 199001 032100 135.2  7.54  0.069  4.896 305.4  0.069  4.896  305.4  0.000 10.864 229.4  0.105  0.166  1.052 305.4 0.8790 0.7937    -5.5  13.7 306.9
32877.00000 199001 040000 144.4  7.99  0.081  4.964 312.5  0.080  4.952  313.2  0.001  5.008 255.3  0.121  0.188  1.138 312.4 0.8672 0.7775    -4.8  12.7 308.4
32877.12500 199001 040300 153.6  7.48  0.078  5.030 319.4  0.075  4.918  321.0  0.003  5.160 278.5  0.116  0.180  1.116 319.3 0.8641 0.7733    -4.0  11.5 308.3
32877.25000 199001 040600 164.2  6.97  0.065  4.946 325.0  0.060  4.577  328.9  0.006  5.179 282.2  0.099  0.158  1.022 325.3 0.8590 0.7688    -4.4  10.1 309.4
32877.37500 199001 040900 166.5  5.45  0.051  4.804 328.1  0.031  3.754  340.0  0.020  4.874 310.2  0.080  0.130  0.905 327.5 0.8625 0.7722    -4.9   8.9 311.0
32877.50000 199001 041200 170.5  3.93  0.047  4.623 329.3  0.011  3.588  347.7  0.035  4.633 323.5  0.073  0.119  0.863 328.8 0.8570 0.7628    -5.3   8.3 315.1
32877.62500 199001 041500 169.5  2.18  0.046  4.504 329.2  0.000  0.094  349.5  0.046  4.504 329.2  0.072  0.118  0.855 328.3 0.8425 0.7402    -5.4   7.3 318.9
32877.75000 199001 041800 160.2  0.43  0.045  4.436 328.7  0.000  0.000  400.0  0.045  4.436 328.7  0.072  0.118  0.851 326.4 0.8249 0.7145    -6.9   5.3 323.3
32877.87500 199001 042100  68.0  1.04  0.038  4.403 318.5  0.000  0.000  400.0  0.038  4.403 318.5  0.058  0.093  0.776 314.8 0.8542 0.7646    -8.6   5.4 330.2
32878.00000 199001 050000  52.9  1.65  0.027  4.483 301.6  0.000  0.000  232.9  0.027  4.483 301.6  0.039  0.060  0.653 301.1 0.9488 0.9098    -7.3   5.2 341.6
32878.12500 199001 050300  46.3  1.52  0.027  4.532 300.7  0.000  0.000  226.3  0.027  4.532 300.7  0.039  0.059  0.657 300.7 0.9616 0.9289    -6.9   3.3 339.2
32878.25000 199001 050600  38.3  1.38  0.024  4.633 297.8  0.000  0.000  218.3  0.024  4.633 297.8  0.034  0.049  0.623 297.9 0.9734 0.9501    -8.3   3.2 347.3
32878.37500 199001 050900  55.0  1.37  0.027  4.639 300.5  0.000  0.000  235.0  0.027  4.639 300.5  0.038  0.057  0.663 300.6 0.9718 0.9463    -6.9   3.8 352.7
32878.50000 199001 051200  71.8  1.37  0.031  4.622 303.1  0.000  0.000  251.8  0.031  4.622 303.1  0.044  0.067  0.706 303.2 0.9678 0.9389    -5.8   2.4 350.3
32878.62500 199001 051500  97.8  1.22  0.034  4.607 305.3  0.000  0.000  400.0  0.034  4.607 305.3  0.049  0.075  0.741 305.1 0.9615 0.9276    -6.4   1.6   8.8
32878.75000 199001 051800 131.5  1.08  0.036  4.621 306.6  0.000  0.000  400.0  0.036  4.621 306.6  0.053  0.081  0.763 306.2 0.9559 0.9180    -6.4   2.1 354.1
32878.87500 199001 052100  76.2  1.07  0.037  5.595 306.9  0.000  0.000  400.0  0.037  5.595 306.9  0.054  0.084  0.770 306.4 0.9528 0.9129    -6.1   2.1   6.9
32879.00000 199001 060000  19.8  1.07  0.026  5.524 299.4  0.000  0.000  400.0  0.026  5.524 299.4  0.036  0.052  0.651 299.4 0.9766 0.9551    -6.5   1.0  23.8
32879.12500 199001 060300  10.9  1.53  0.020  5.555 297.7  0.000  0.000  190.9  0.020  5.555 297.7  0.026  0.037  0.566 297.7 0.9756 0.9531    -6.4   1.1  40.0
32879.25000 199001 060600   6.2  1.99  0.016  5.580 297.0  0.000  0.023  186.2  0.016  5.580 297.0  0.021  0.029  0.510 297.0 0.9733 0.9489    -5.5   1.4  32.3
32879.37500 199001 060900   0.4  4.17  0.015  5.525 295.7  0.000  1.201  155.3  0.014  5.525 296.0  0.019  0.027  0.482 296.4 0.9562 0.9446    -6.0   1.1 146.7
32879.50000 199001 061200 358.5  6.34  0.014  5.607 262.7  0.003  2.628  163.3  0.010  5.608 288.6  0.021  0.034  0.467 311.3 0.4226 0.8419    -9.2   1.5 172.5
32879.62500 199001 061500  16.4  6.99  0.031  3.707 192.4  0.026  3.646  181.9  0.005  5.693 296.8  0.053  0.095  0.700 173.7 0.7035 0.7313    -8.8   1.3 300.2
32879.75000 199001 061800  31.2  7.64  0.053  4.249 201.2  0.049  4.239  198.5  0.004  4.252 277.8  0.087  0.149  0.920 193.4 0.7788 0.7030    -7.1   2.0 267.2
32879.87500 199001 062100  39.0  7.51  0.063  4.454 209.7  0.057  4.350  209.6  0.006  4.631 213.9  0.101  0.167  1.003 205.6 0.7779 0.6862    -8.7   3.5 267.7
32880.00000 199001 070000  47.1  7.39  0.065  4.612 219.9  0.060  4.600  219.5  0.005  4.622 238.3  0.102  0.167  1.018 218.1 0.7896 0.6905    -7.7   5.8 292.6
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Time Series

GT Gpt XXXX, Lat XXXXXXn, Long XXXXXXw, Depth XXXXXXm
Defined Period: Tropical Cyclones
Date Ranges: 9/4/1900 18:00 to 10/25/2005 00:00

     Julian CCYYMM DDHHmm    WD    WS   ETOT     TP   VMD ETTSea  TPSea VMDSea  ETTSw   TPSw VMDSw    MO1    MO2     HS DMDIR ANGSPR INLINE    HSUR    CS    CD   VS  DZ  DH   VH VDIR
                            deg   m/s    m^2    sec   deg    m^2    sec    deg    m^2    sec   deg  m^2/s  m2/s2      m   deg                      cm  cm/s   deg cm/s   m   m cm/s  deg
248.75000 190009 041800 116.8  4.78  0.016  3.590 303.3  0.016  3.590  302.7  0.000  4.470 337.6  0.029  0.055  0.502 303.2 0.8750 0.7894    -1.9   2.1 197.0    1   3   3    0  299
248.77083 190009 041830 115.6  4.80  0.016  3.590 302.8  0.016  3.590  302.2  0.000  3.895 341.9  0.029  0.055  0.503 302.8 0.8730 0.7864    -1.9   2.2 197.7    1   3   3    0  301
248.79167 190009 041900 114.5  4.82  0.016  3.590 302.3  0.016  3.590  301.6  0.000  3.857 345.6  0.029  0.055  0.503 302.2 0.8709 0.7832    -1.9   2.3 198.4    1   3   3    0  304
248.81250 190009 041930 113.3  4.84  0.016  3.590 301.7  0.016  3.590  300.9  0.000  3.839 348.3  0.029  0.055  0.503 301.6 0.8688 0.7800    -1.9   2.4 199.2    1   3   3    0  304
248.83333 190009 042000 112.2  4.86  0.016  3.590 301.0  0.016  3.590  300.1  0.000  3.825 350.8  0.029  0.055  0.503 300.8 0.8665 0.7766    -1.9   2.5 199.9    1   3   3    0  305
248.85417 190009 042030 111.1  4.88  0.016  3.590 300.2  0.016  3.590  299.3  0.000  3.822 351.4  0.029  0.055  0.504 300.0 0.8642 0.7731    -1.9   2.6 200.5    2   3   3    0  306
248.87500 190009 042100 109.9  4.89  0.016  3.590 299.4  0.016  3.590  298.4  0.000  3.821 351.4  0.029  0.055  0.504 299.1 0.8619 0.7698    -1.9   2.7 201.1    2   3   3    0  307
248.89583 190009 042130 108.8  4.91  0.016  3.590 298.5  0.016  3.590  297.5  0.000  3.820 350.8  0.030  0.055  0.506 298.1 0.8597 0.7666    -1.9   2.8 201.6    2   3   3    0  309
248.91667 190009 042200 107.7  4.93  0.016  3.590 297.5  0.016  3.590  296.4  0.000  3.819 349.9  0.030  0.056  0.508 296.9 0.8577 0.7639    -1.9   2.9 202.1    2   3   3    0  310
248.93750 190009 042230 106.6  4.95  0.016  3.590 296.4  0.016  3.590  295.3  0.000  3.819 349.0  0.030  0.056  0.510 295.7 0.8561 0.7617    -1.8   3.0 202.7    3   3   3    0  311
248.95833 190009 042300 105.5  4.97  0.016  3.590 295.3  0.016  3.590  294.1  0.000  3.818 347.8  0.030  0.057  0.514 294.3 0.8546 0.7598    -1.8   3.0 203.2    3   3   3    0  313
248.97917 190009 042330 104.4  4.99  0.017  3.590 294.0  0.016  3.590  292.8  0.000  3.817 346.2  0.031  0.058  0.518 292.8 0.8534 0.7584    -1.8   3.1 203.7    3   3   3    0  314
249.00000 190009 050000 103.4  5.01  0.017  3.590 292.7  0.017  3.590  291.5  0.000  3.817 344.4  0.031  0.059  0.523 291.3 0.8520 0.7569    -1.8   3.2 204.2    3   3   3    0  316
249.02083 190009 050030 102.6  5.01  0.017  3.650 291.4  0.017  3.590  290.3  0.000  3.817 342.4  0.032  0.059  0.527 289.9 0.8508 0.7559    -1.7   3.3 204.6    3   3   3    0  317
249.04167 190009 050100 101.7  5.02  0.018  3.663 290.2  0.017  3.590  289.0  0.000  3.817 339.6  0.032  0.060  0.532 288.5 0.8498 0.7551    -1.7   3.4 204.9    3   3   3    0  319
249.06250 190009 050130 100.9  5.03  0.018  3.677 288.9  0.018  3.590  287.8  0.001  3.817 336.1  0.033  0.061  0.538 287.0 0.8491 0.7548    -1.7   3.5 205.3    3   3   3    0  320
249.08333 190009 050200 100.1  5.04  0.018  3.691 287.6  0.018  3.323  286.5  0.001  3.817 331.6  0.034  0.062  0.544 285.5 0.8486 0.7548    -1.7   3.6 205.7    3   3   3    0  321
249.10417 190009 050230  99.3  5.04  0.019  3.706 286.4  0.018  3.420  285.3  0.001  3.818 326.8  0.034  0.063  0.550 284.1 0.8484 0.7552    -1.7   3.7 206.1    3   3   3    0  323
249.12500 190009 050300  98.5  5.05  0.019  3.721 285.2  0.019  3.565  284.2  0.001  3.818 321.5  0.035  0.064  0.556 282.7 0.8484 0.7559    -1.7   3.8 206.4    3   3   3    0  324
249.14583 190009 050330  97.7  5.06  0.020  3.736 283.9  0.019  3.619  283.0  0.001  3.819 316.1  0.035  0.065  0.562 281.3 0.8484 0.7567    -1.7   3.9 206.7    3   3   3    0  325
249.16667 190009 050400  96.9  5.07  0.020  3.751 282.8  0.019  3.712  281.0  0.001  3.792 330.2  0.036  0.066  0.567 280.0 0.8489 0.7582    -1.7   4.1 207.0    3   3   3    0  327
249.18750 190009 050430  96.1  5.07  0.021  3.765 281.7  0.019  3.738  280.0  0.001  6.079 325.3  0.037  0.067  0.573 278.7 0.8494 0.7597    -1.7   4.2 207.3    3   3   3    0  328
249.20833 190009 050500  95.3  5.08  0.021  3.780 280.7  0.020  3.764  279.0  0.001  6.065 320.2  0.037  0.068  0.578 277.5 0.8499 0.7614    -1.6   4.3 207.7    3   3   3    0  329
249.22917 190009 050530  94.5  5.09  0.021  3.793 279.6  0.020  3.788  278.1  0.001  6.056 315.0  0.038  0.069  0.583 276.3 0.8505 0.7631    -1.6   4.4 208.0    3   3   3    0  330
249.25000 190009 050600  93.7  5.10  0.022  3.807 278.6  0.020  3.812  277.2  0.001  6.051 309.3  0.038  0.070  0.589 275.1 0.8511 0.7649    -1.6   4.5 208.2    3   3   3    0  331
249.27083 190009 050630  92.9  5.11  0.022  3.820 277.6  0.021  3.836  276.3  0.001  6.062 304.0  0.039  0.070  0.594 274.0 0.8517 0.7666    -1.6   4.6 208.5    3   3   3    0  332
249.29167 190009 050700  92.2  5.12  0.022  3.833 276.6  0.021  3.859  275.4  0.002  6.076 299.1  0.039  0.071  0.599 273.0 0.8523 0.7684    -1.5   4.7 208.7    3   3   3    0  333
249.31250 190009 050730  91.4  5.14  0.023  3.846 275.7  0.021  3.883  274.5  0.002  6.091 294.7  0.040  0.072  0.605 271.9 0.8530 0.7702    -1.5   4.8 209.0    3   3   3    0  334
249.33333 190009 050800  90.6  5.15  0.023  3.860 274.7  0.021  3.909  273.7  0.002  6.108 290.5  0.041  0.073  0.610 270.9 0.8537 0.7721    -1.5   4.9 209.2    3   3   3    0  335
249.35417 190009 050830  89.9  5.17  0.024  3.879 273.4  0.022  3.938  272.8  0.002  6.127 280.7  0.041  0.073  0.614 269.9 0.8601 0.7787    -1.4   5.0 209.4    3   3   3    0  335
249.37500 190009 050900  89.1  5.18  0.024  3.899 272.1  0.022  3.838  272.5  0.002  6.147 267.4  0.041  0.074  0.618 269.0 0.8654 0.7842    -1.4   5.1 209.6    3   3   3    0  336
249.39583 190009 050930  88.4  5.20  0.024  3.918 271.1  0.022  3.851  271.6  0.002  6.168 265.1  0.042  0.075  0.624 268.1 0.8674 0.7870    -1.4   5.2 209.8    3   3   3    0  336
249.41667 190009 051000  87.6  5.21  0.025  3.938 270.2  0.023  3.865  270.8  0.002  6.189 263.9  0.043  0.076  0.631 267.2 0.8685 0.7891    -1.4   5.3 209.9    3   3   3    0  336
249.43750 190009 051030  86.9  5.22  0.025  3.954 269.3  0.023  3.881  269.9  0.002  6.212 263.1  0.043  0.077  0.637 266.3 0.8694 0.7910    -1.3   5.4 210.1    3   3   3    0  336
249.45833 190009 051100  86.1  5.24  0.026  3.965 268.4  0.023  3.897  269.1  0.003  6.235 262.4  0.044  0.078  0.644 265.4 0.8703 0.7930    -1.3   5.5 210.3    3   3   3    0  335
249.47917 190009 051130  85.4  5.25  0.026  3.977 267.5  0.024  3.914  268.3  0.003  6.260 261.7  0.045  0.079  0.651 264.6 0.8712 0.7950    -1.3   5.7 210.5    2   3   3    0  334
249.50000 190009 051200  84.7  5.27  0.027  3.989 266.7  0.024  3.930  267.5  0.003  6.285 261.1  0.045  0.080  0.658 263.8 0.8724 0.7973    -1.2   5.8 210.6    2   3   3    0  333
249.52083 190009 051230  84.4  5.26  0.028  4.001 265.9  0.024  3.928  266.8  0.003  6.284 260.3  0.046  0.081  0.665 263.0 0.8739 0.7999    -1.2   5.9 210.8    2   3   3    0  332
249.54167 190009 051300  84.2  5.25  0.028  4.013 265.2  0.024  3.920  266.2  0.004  6.285 259.6  0.047  0.082  0.672 262.3 0.8753 0.8024    -1.2   6.0 210.9    2   3   3    0  330
249.56250 190009 051330  84.0  5.25  0.029  4.025 264.5  0.024  3.894  265.6  0.004  6.289 258.8  0.048  0.083  0.679 261.6 0.8770 0.8052    -1.1   6.1 211.0    2   3   3    0  329
249.58333 190009 051400  83.8  5.24  0.029  4.037 263.8  0.025  3.873  265.0  0.005  6.294 258.2  0.048  0.084  0.686 260.9 0.8787 0.8080    -1.1   6.2 211.1    2   3   3    0  327
249.60417 190009 051430  83.6  5.23  0.030  4.048 263.1  0.025  3.857  264.4  0.005  6.300 257.6  0.049  0.085  0.693 260.3 0.8804 0.8108    -1.1   6.3 211.3    2   3   3    0  325
249.62500 190009 051500  83.4  5.23  0.031  4.059 262.4  0.025  3.843  263.9  0.006  6.307 257.1  0.050  0.086  0.700 259.7 0.8821 0.8136    -1.1   6.4 211.4    2   3   3    0  322
249.64583 190009 051530  83.2  5.22  0.031  4.069 261.8  0.025  3.831  263.3  0.007  6.315 256.6  0.051  0.086  0.706 259.1 0.8838 0.8164    -1.0   6.5 211.5    2   3   3    0  320
249.66667 190009 051600  82.9  5.21  0.032  4.078 261.2  0.025  3.821  262.8  0.007  6.323 256.3  0.051  0.087  0.712 258.5 0.8856 0.8192    -1.0   6.6 211.6    2   3   3    0  317
249.68750 190009 051630  82.7  5.21  0.032  4.088 260.6  0.025  3.813  262.2  0.008  6.330 256.0  0.052  0.088  0.718 258.0 0.8874 0.8221    -1.0   6.7 211.7    2   3   3    0  315
249.70833 190009 051700  82.5  5.20  0.033  4.097 260.0  0.024  3.802  261.7  0.008  6.337 255.6  0.052  0.088  0.724 257.5 0.8892 0.8249    -1.0   6.9 211.8    2   3   3    0  312
249.72917 190009 051730  82.3  5.19  0.033  4.106 259.5  0.024  3.806  260.3  0.009  6.344 257.7  0.053  0.089  0.729 257.1 0.8910 0.8277    -0.9   7.0 211.8    2   3   3    0  310
249.75000 190009 051800  82.1  5.19  0.034  4.116 259.0  0.024  3.795  259.8  0.010  6.350 257.2  0.053  0.089  0.735 256.6 0.8926 0.8303    -0.9   7.1 211.9    2   3   3    0  307
249.77083 190009 051830  81.8  5.19  0.034  4.126 258.6  0.024  3.789  259.4  0.010  6.358 256.8  0.054  0.090  0.740 256.2 0.8943 0.8329    -0.9   7.2 212.0    2   3   3    0  305
249.79167 190009 051900  81.5  5.19  0.035  4.138 258.1  0.024  3.784  258.9  0.011  6.366 256.5  0.054  0.090  0.746 255.8 0.8959 0.8355    -0.9   7.3 212.1    2   3   3    0  303
249.81250 190009 051930  81.3  5.18  0.035  4.151 257.7  0.024  3.780  258.5  0.012  6.374 256.1  0.055  0.090  0.751 255.5 0.8977 0.8382    -0.9   7.4 212.2    2   3   3    0  301
249.83333 190009 052000  81.0  5.18  0.036  4.166 257.3  0.024  3.777  258.1  0.012  6.380 255.9  0.055  0.091  0.756 255.2 0.8996 0.8408    -0.8   7.5 212.3    2   3   3    0  300
249.85417 190009 052030  80.7  5.18  0.036  4.183 256.9  0.024  3.774  257.6  0.013  6.384 255.6  0.056  0.091  0.762 254.9 0.9015 0.8435    -0.8   7.6 212.3    2   3   3    0  299
249.87500 190009 052100  80.5  5.18  0.037  6.279 256.5  0.023  3.772  257.2  0.013  6.389 255.4  0.056  0.092  0.767 254.6 0.9033 0.8461    -0.8   7.7 212.3    2   3   3    0  298
249.89583 190009 052130  80.2  5.18  0.037  6.294 256.1  0.023  3.771  256.8  0.014  6.393 255.1  0.056  0.092  0.773 254.3 0.9052 0.8486    -0.9   7.8 212.3    2   3   3    0  297
249.91667 190009 052200  79.9  5.18  0.038  6.309 255.8  0.023  3.771  256.4  0.015  6.398 255.0  0.057  0.092  0.778 254.1 0.9069 0.8510    -0.9   7.9 212.5    3   3   3    0  297
249.93750 190009 052230  79.7  5.18  0.038  6.323 255.5  0.023  3.770  256.0  0.015  6.402 254.8  0.057  0.093  0.784 253.8 0.9087 0.8534    -0.9   8.0 212.6    3   3   3    0  297
249.95833 190009 052300  79.4  5.18  0.039  6.337 255.2  0.023  3.771  255.6  0.016  6.408 254.6  0.058  0.093  0.790 253.6 0.9103 0.8557    -0.8   8.1 212.7    3   3   3    0  297
249.97917 190009 052330  79.1  5.18  0.040  6.353 254.9  0.023  3.771  255.2  0.017  6.415 254.4  0.059  0.094  0.796 253.4 0.9119 0.8579    -0.8   8.2 212.7    3   3   3    0  297
250.00000 190009 060000  78.9  5.18  0.040  6.370 254.6  0.023  3.772  254.8  0.017  6.423 254.3  0.059  0.094  0.803 253.2 0.9134 0.8600    -0.8   8.3 212.7    3   3   3    0  297
250.02083 190009 060030  78.6  5.18  0.041  6.385 254.3  0.023  3.776  254.4  0.018  6.435 254.1  0.060  0.095  0.810 253.0 0.9149 0.8621    -0.8   8.4 212.7    3   3   3    0  297
```

APPENDIX B

Extremal Analysis Description

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.

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:

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

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

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

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:

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

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; $\Pr\{\mathrm{X} < \mu\} = 0$;
σ is a scale parameter such that $\Pr\{\mathrm{X} \geq \mu + \sigma\} = 1/e$

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

$$\frac{d}{d\alpha}\left[\log\frac{dP}{dx}\right] = 0 \text{ and } \frac{d}{d\beta} = \left[\log\frac{dP}{dx}\right] = 0$$ 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).

Sample Extremes (for deep water points maxCS and assoCS are substituted by maximum Csfc, Cmid, Zero Depth, Mid-Depth and associated Csfc, Cmid, Zero Depth, and Mid-Depth):

GOMOS Extremes

OMNI Directional Extremes

RtnPer	maxWS	maxHSUR	maxCS	HSig	assHSUR	assoCS	assoWS	HMax	HCrest	TP(r)
1	18.4	7.8	9.4	4.4	5.9	6.3	17.3	8.3	4.7	9.5
5	23.4	13.9	15.8	6.0	12.1	11.1	22.5	10.8	6.2	10.6
10	26.6	18.0	20.0	7.1	16.2	14.1	25.9	12.5	7.2	11.2
25	32.1	20.6	27.0	9.0	19.2	18.0	31.7	15.6	9.0	12.2
50	35.4	31.0	32.3	10.3	30.1	23.1	35.2	17.5	10.3	12.9
75	36.7	35.4	34.6	10.9	33.3	26.8	36.1	18.4	10.8	13.1
100	38.7	38.3	37.0	11.6	37.9	30.6	38.6	19.3	11.5	13.5

North Sector (from which 337.5 to 22.5 degrees) 100 Year Extremes

% of Omni	92%	N/A	56%	65%						
Value	35.6	N/A	20.7	7.5	24.6	19.9	25.1	12.5	7.5	10.9

NorthEast Sector (from which 22.5 to 67.5 degrees) 100 Year Extremes

% of Omni	98%	N/A	78%	92%						
Value	37.9	N/A	28.9	10.7	34.9	28.2	35.5	17.8	10.6	12.9

East Sector (from which 67.5 to 112.5 degrees) 100 Year Extremes

% of Omni	98%	N/A	91%	96%						
Value	37.9	N/A	33.7	11.1	36.4	29.4	37.1	18.5	11.0	13.2

SouthEast Sector (from which 112.5 to 157.5 degrees) 100 Year Extremes

% of Omni	93%	N/A	83%	85%						
Value	36.0	N/A	30.7	9.9	32.2	26.0	32.8	16.4	9.8	12.4

South Sector (from which 157.5 to 202.5 degrees) 100 Year Extremes

% of Omni	75%	N/A	72%	71%						
Value	29.0	N/A	26.6	8.2	26.9	21.7	27.4	13.7	8.2	11.4

SouthWest Sector (from which 202.5 to 247.5 degrees) 100 Year Extremes

% of Omni	70%	N/A	85%	62%						
Value	27.1	N/A	31.5	7.2	23.5	19.0	23.9	12.0	7.1	10.6

West Sector (from which 247.5 to 292.5 degrees) 100 Year Extremes

% of Omni	64%	N/A	68%	51%						
Value	24.8	N/A	25.2	5.9	19.3	15.6	19.7	9.8	5.9	9.6

NorthWest Sector (from which 292.5 to 337.5 degrees) 100 Year Extremes

% of Omni	69%	N/A	52%	41%						
Value	26.7	N/A	19.2	4.8	15.5	12.5	15.8	7.9	4.7	8.6

APPENDIX C

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 continously exceeded 5 meters;
18.1 is the median duration of events in which SWH continously 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           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%
  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           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%
  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, MAY
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 NON-EXCEEDANCES FOR GRID POINT XXXXX, MAY
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 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, OCTOBER
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 NON-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
 [Data Deleted]
 NON-EXCEEDANCES FOR GRID POINT XXXXX, DECEMBER
 [Data Deleted]
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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           WS          MAXIMUM          MEDIAN   PERCENTAGE POINTS OF JOHNSON DISTRIBUTION
  .GE.  HOURS  MEAN  S.D.  DURATION  COUNT DURATION  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           WS          MAXIMUM          MEDIAN   PERCENTAGE POINTS OF JOHNSON DISTRIBUTION
  .LT.  HOURS  MEAN  S.D.  DURATION  COUNT DURATION  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
 [Data Deleted]
 NON-EXCEEDANCES FOR GRID POINT XXXXX, FEBRUARY
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 EXCEEDANCES FOR GRID POINT XXXXX, MARCH
 [Data Deleted]
 NON-EXCEEDANCES FOR GRID POINT XXXXX, MARCH
 [Data Deleted]
 EXCEEDANCES FOR GRID POINT XXXXX, APRIL
 [Data Deleted]
 NON-EXCEEDANCES FOR GRID POINT XXXXX, APRIL
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 EXCEEDANCES FOR GRID POINT XXXXX, MAY
 [Data Deleted]
 NON-EXCEEDANCES FOR GRID POINT XXXXX, MAY
 [Data Deleted]
 EXCEEDANCES FOR GRID POINT XXXXX, JUNE
[Data Deleted]
 NON-EXCEEDANCES FOR GRID POINT XXXXX, JUNE
[Data Deleted]
 EXCEEDANCES FOR GRID POINT XXXXX, JULY
[Data Deleted]
 NON-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
[Data Deleted]
 NON-EXCEEDANCES FOR GRID POINT XXXXX, SEPTEMBER
[Data Deleted]
 EXCEEDANCES FOR GRID POINT XXXXX, OCTOBER
[Data Deleted]
 NON-EXCEEDANCES FOR GRID POINT XXXXX, OCTOBER
[Data Deleted]
 EXCEEDANCES FOR GRID POINT XXXXX, NOVEMBER
[Data Deleted]
 NON-EXCEEDANCES FOR GRID POINT XXXXX, NOVEMBER
[Data Deleted]
 EXCEEDANCES FOR GRID POINT XXXXX, DECEMBER
[Data Deleted]
 NON-EXCEEDANCES FOR GRID POINT XXXXX, DECEMBER
[Data Deleted]
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APPENDIX D

Frequency of Occurrence Table Sample Output

Different bin definitions available upon request.

```
GO Gpt XXXXX, Lat XX.XXX, Long XXX.XXX, Depth XXXXX
Defined Period: Operational
Date Ranges: 1/1/1990 00:00 to 12/31/1999 21:00

Horizontal variable:  Peak Spectral Period of Total Spectrum (sec)
Vertical variable:    Significant Wave Height (m)
Directional variable: Vector Mean Direction of Total Spectrum (deg to which)
 Number of Observations for January           :      98 from     2480
 Directional Sector (VMD (deg to) - total):  22.50 < dir <=  67.50
 Statistics for var:      Min       Max      Mean    Std Dev.   Median      90%       99%
 --------------------  --------  --------  --------  --------  --------  --------  --------
 TPeak (sec) - total     1.3540    9.2470    5.1548    1.8488    5.2715    7.4664    8.8066
 Sig Wave Ht (m)         0.2130    2.4750    1.1689    0.6523    1.1380    2.0105    2.4478
 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 Total
   0.000 -   0.2499  .0000 .0016 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0016
   0.250 -   0.4999  .0000 .0004 .0040 .0012 .0000 .0000 .0008 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0065
   0.500 -   0.7499  .0000 .0000 .0000 .0016 .0036 .0000 .0000 .0004 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0056
   0.750 -   0.9999  .0000 .0000 .0000 .0004 .0016 .0004 .0000 .0008 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0032
   1.000 -   1.2499  .0000 .0000 .0000 .0004 .0020 .0000 .0012 .0004 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0040
   1.250 -   1.4999  .0000 .0000 .0000 .0000 .0012 .0016 .0004 .0008 .0008 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0048
   1.500 -   1.7499  .0000 .0000 .0000 .0000 .0004 .0032 .0008 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0044
   1.750 -   1.9999  .0000 .0000 .0000 .0000 .0000 .0028 .0004 .0004 .0016 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0052
   2.000 -   2.2499  .0000 .0000 .0000 .0000 .0000 .0016 .0004 .0004 .0000 .0004 .0000 .0000 .0000 .0000 .0000 .0000 .0028
   2.250 -   2.4999  .0000 .0000 .0000 .0000 .0000 .0000 .0008 .0000 .0004 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0012
   2.500 -   2.7499  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
   2.750 -   2.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
   3.000 -   3.2499  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
   3.250 -   3.4999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
   3.500 -   3.7499  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
   3.750 -   3.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
   4.000 -   4.2499  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
   4.250 -   4.4999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
   4.500 -   4.7499  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
             Total   .0000 .0020 .0040 .0036 .0089 .0097 .0048 .0032 .0028 .0004 .0000 .0000 .0000 .0000 .0000 .0000 0.040
 TPeak (sec) - total Bins are    1.00 wide, and are centered on column headers

 Number of Observations for February          :     134 from     2256
 Directional Sector (VMD (deg to) - total):  22.50 < dir <=  67.50
[Data Deleted]
 Number of Observations for March             :     138 from     2480
 Directional Sector (VMD (deg to) - total):  22.50 < dir <=  67.50
[Data Deleted]
 Number of Observations for April             :      99 from     2400
 Directional Sector (VMD (deg to) - total):  22.50 < dir <=  67.50
[Remaining VMD sectors (8 45-deg bins) and months plus all months combined omitted here]

 Number of Observations for January           :    2480 from     2480
 Directional Sector (VMD (deg to) - total): All Directions
[Data Deleted]
 Number of Observations for February          :    2256 from     2256
[Data Deleted]
 Number of Observations for March             :    2480 from     2480
[Data Deleted]
 Number of Observations for April             :    2400 from     2400
[Data Deleted]
 Number of Observations for May               :    2480 from     2480
[Data Deleted]
 Number of Observations for June              :    2400 from     2400
[Data Deleted]
 Number of Observations for July              :    2480 from     2480
[Data Deleted]
 Number of Observations for August            :    2480 from     2480
[Data Deleted]
 Number of Observations for September         :    2400 from     2400
[Data Deleted]
 Number of Observations for October           :    2480 from     2480
[Data Deleted]
 Number of Observations for November          :    2400 from     2400
[Data Deleted]
 Number of Observations for December          :    2480 from     2480
[Data Deleted]
 Number of Observations for All Months & Years:   29216 from    29216
[Data Deleted]
```

```
GO Gpt XXXXX, Lat XX.XXX, Long XXX.XXX, Depth XXXXX
Defined Period: Operational
Date Ranges: 1/1/1990 00:00 to 12/31/1999 21:00

Horizontal variable:  Wind Direction (deg from which)
Vertical variable:    Wind Speed (m/s)
Directional variable: All Directions

 Number of Observations for January          :    2480 from     2480
 Directional Sector (): All Directions
 Statistics for var:      Min       Max      Mean    Std Dev.   Median      90%       99%
 --------------------  --------  --------  --------  --------  --------  --------  --------
 Wind Dir (deg fr)       0.0000  359.6000   58.2114       N/A       N/A       N/A       N/A
 Wind Sp (m/s)           1.2500   16.9700    7.3972    2.7744    7.2050   11.0410   13.8584
 Frequency of Occurrence for January:
 Grid Point XXXXX   , Lat XXX.XXXX, Long  XXX.XXXX, Wind Dir (deg fr)
       Wind Sp (m/s)  45.0  90.0 135.0 180.0 225.0 270.0 315.0 360.0 Total
   0.000 -   0.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
   1.000 -   1.9999  .0004 .0004 .0024 .0008 .0004 .0000 .0004 .0008 .0056
   2.000 -   2.9999  .0040 .0056 .0060 .0048 .0020 .0024 .0036 .0036 .0323
   3.000 -   3.9999  .0101 .0097 .0161 .0077 .0056 .0097 .0069 .0101 .0758
   4.000 -   4.9999  .0198 .0177 .0258 .0085 .0073 .0060 .0073 .0145 .1069
   5.000 -   5.9999  .0125 .0323 .0262 .0105 .0048 .0040 .0121 .0181 .1206
   6.000 -   6.9999  .0266 .0242 .0294 .0125 .0032 .0069 .0105 .0161 .1294
   7.000 -   7.9999  .0234 .0230 .0190 .0105 .0032 .0040 .0145 .0194 .1169
   8.000 -   8.9999  .0254 .0141 .0218 .0137 .0052 .0040 .0117 .0238 .1198
   9.000 -   9.9999  .0157 .0153 .0153 .0105 .0036 .0073 .0169 .0262 .1109
  10.000 -  10.9999  .0190 .0065 .0060 .0097 .0016 .0060 .0133 .0149 .0770
  11.000 -  11.9999  .0093 .0036 .0020 .0024 .0020 .0052 .0125 .0105 .0476
  12.000 -  12.9999  .0060 .0008 .0028 .0024 .0012 .0024 .0060 .0069 .0286
  13.000 -  13.9999  .0012 .0004 .0032 .0004 .0008 .0004 .0065 .0065 .0194
  14.000 -  14.9999  .0000 .0004 .0004 .0008 .0000 .0004 .0024 .0016 .0060
  15.000 -  15.9999  .0008 .0000 .0000 .0000 .0000 .0012 .0004 .0000 .0024
  16.000 -  16.9999  .0004 .0000 .0000 .0000 .0000 .0000 .0004 .0000 .0008
  17.000 -  17.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
  18.000 -  18.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
  19.000 -  19.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
  20.000 -  20.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
  21.000 -  21.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
  22.000 -  22.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
  23.000 -  23.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
  24.000 -  24.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
  25.000 -  25.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
  26.000 -  26.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
  27.000 -  27.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
  28.000 -  28.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
  29.000 -  29.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
  30.000 -  30.9999  .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
             Total   .1746 .1540 .1766 .0952 .0411 .0601 .1254 .1730 1.000
 Wind Dir (deg fr) Bins are   45.00 wide, and are centered on column headers

 Number of Observations for February         :    2256 from     2256
[Data Deleted]
 Number of Observations for March            :    2480 from     2480
[Data Deleted]
 Number of Observations for April            :    2400 from     2400
[Data Deleted]
 Number of Observations for May              :    2480 from     2480
[Data Deleted]
 Number of Observations for June             :    2400 from     2400
[Data Deleted]
 Number of Observations for July             :    2480 from     2480
[Data Deleted]
 Number of Observations for August           :    2480 from     2480
[Data Deleted]
 Number of Observations for September        :    2400 from     2400
[Data Deleted]
 Number of Observations for October          :    2480 from     2480
[Data Deleted]
 Number of Observations for November         :    2400 from     2400
[Data Deleted]
 Number of Observations for December         :    2480 from     2480
[Data Deleted]
 Number of Observations for All Months & Years:   29216 from    29216
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```

APPENDIX E

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 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	

APPENDIX F

One-Dimensional Modeling of Hurricanes Generated Currents

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One-Dimensional Modeling of Hurricane Generated Currents

1. Purpose and Scope

Steady currents are important part of the load on offshore structures during hurricanes. In deep water, currents near the peak of the storm are in a mixed layer near the surface. Two-dimensional storm surge models cannot describe such current profiles. A one-dimensional vertical model can capture most of the processes that create the current profiles at the peak of a storm in deep water. A simple vertical model gives the information necessary to calculate the increased load that hurricane generated surface currents place on an offshore structure.

This report describes the one-dimensional model used to hindcast current profiles for GOMOS. Section 2 is a brief description of one-dimensional turbulence closure modeling. Section 3 evaluates the model output by comparing it to measured hurricane currents. Section 4 describes the production runs and model's output format. Conclusions are given in Section 5.

2. Turbulence Closure Models

Surface layer currents under a hurricane are dominated by local processes. One-dimensional models can give accurate current profiles for the peak of the storm. They also give reasonably accurate surface current hindcasts for some time after the storm passes. These models are best suited to predicting mixed layer currents in water deeper than 100 m.

One-dimensional models are not the best choice in all cases. They neglect horizontal pressure gradients and nonlinear advection. The pressure gradients drive the deep inertial currents that are observed after the passage of a hurricane. One-dimensional models yield no information on currents below the mixed layer (200 m deep or less). For sites near coastlines, pressure gradients from the storm surge cause barotropic currents that are nearly constant with depth.

The critical factor in a one-dimensional current model is the parameterization of the turbulent stress. This stress is responsible for the downward mixing of momentum from surface wind stress. The Reynolds averaged equations of motion for turbulent flow give us more unknowns than equations. The higher moments in these equations must be parameterized. Mixed layer models of the ocean usually consist of a single conservation equation for the turbulence kinetic energy and a set of algebraic equations for the turbulence second moment quantities. Kantha and Clayson (2000) give a thorough discussion of these models.

The best known second moment closure model is due to Mellor and Yamada (1982). They chose tunable constants that helped the model match laboratory turbulent flows. That model has been successfully applied in many studies of the oceanic mixed layer. One drawback is that it appears to slightly underestimate mixing. That underestimation leads to predictions of sea surface temperatures that are warmer than observed temperatures. Kantha and Clayson (1994) developed a modified second order model with enhanced mixing. Our tests of the Mellor and Yamada (1982) and Kantha and Clayson (1994) models are described in Section 3.

The most important input to turbulence closure models is the wind stress. The standard oceanic wind stress law is from Large and Pond (1981). The stress is given by

$$\tau = \rho C_d U_{10}^2 \tag{2.1}$$

where ρ is the density of the air, C_d is the drag coefficient and U_{10} is the wind speed at 10 m elevation. Large and Pond (1981) gave the drag coefficient as

$$10^3 C_d = 0.44 + 0.063 U_{10} \tag{2.2}$$

Powell et al. (2003) have recently presented compelling evidence that the drag coefficient does not continue growing at very high wind speeds. They do not propose a specific new drag law, but we can interpret their data as putting a cap of 2.2×10^{-3} on C_d. The cap takes effect for 10 m wind speeds greater than 27.9 m/sec.

The models were run with the GOMOS wind speed and direction hindcast data. Wind speeds from the nearest GOMOS grid point were used in the comparisons with measurements. The models were started from rest at the first time step in each GOMOS storm. Wind speeds were very low in the early hours of the storms so the modeled currents grew smoothly from rest. No artificial inertial oscillations are created at the start of the storms.

The model also requires initial profiles of temperature and salinity. Those profiles were taken from the NODC World Ocean Atlas of 2001. This atlas gives the profiles on a one degree grid for each month of the year.

3. Verification against Measured Currents

3.1 Ocean Response to a Hurricane JIP

The Ocean Response to a Hurricane Joint Industry Project (ORTAH) measured current profiles in several hurricanes. The first phase of the project, described by Sanford et al. (1987) measured Hurricane Norbert (1984) in the eastern Pacific and Hurricane Josephine (1984) in the Atlantic. The second phase, described by Price et al. (1994) measured Hurricane Gloria (1985) in the Atlantic. The measurements were made using expendable current profilers (AXCP) dropped from airplanes. These instruments record the instantaneous velocity as the instruments fall through the water. Thus the measurements include the large orbital velocities that are due to waves as well as the steady currents. The wave and current velocities were separated by fitting the data to a tri-linear current profile plus the orbital velocity of a regular wave.

Forristall et al. (1991) modeled these measurements using the turbulence closure scheme of Mellor and Durbin (1975). Figure 3.1 is a scatter plot showing the magnitude of the measured and modeled currents at 20 m depth for the three storms. The verifications were made at this depth because the wave orbital velocities make the estimated upper layer shear too uncertain. The largest differences between the Mellor and Durbin (1975) and Kantha and Clayson (1994) models are in the upper layer shear. The Kantha and Clayson model gives results similar to those shown in Figure 3.1 because 20 m depth is approximately the middle of the upper layer. The average error was 0.04 m/sec, so the model is essentially unbiased. The rms error was 0.34 m/sec.

Figure 3.2 is a map of measured and modeled currents in Hurricane Gloria. Gloria was traveling from southeast to northwest and was near the center of the map at the time the measurements were made. There is good visual agreement between measured and hindcast current vectors. It is notable that both the measurements and model show much stronger currents on the right hand side of the storm. This intensification is greater for currents than it is for waves. The reason for the intensifications is that the rotation of the wind vector on the right hand side of the storm is in the same direction as the rotation of the currents due to the Coriolis force.

A third phase of ORTAH measured Hurricanes Florence (1988) and Gilbert (1988) in the Gulf of Mexico. The measurements in Florence were made near the Mississippi Delta as shown in Figure 3.3. Figure 3.4 shows some comparisons of the measured current profiles and predicted current profiles based on the Kantha and Clayson equations. The locations of the AXCP drops are shown by the number on the flight tracks in Figure 3.5. Drop 5 was in only 62 m water depth, but the model gives a reasonable fit to the observations. On the other hand, the agreement is poor at drop 10 on the east side of the Delta. The measured current in drop 10 was guided by bottom topography and sets to the southeast. The one-dimensional current model does not include bathymetry. The model performance is good for drops 13 and 15 which were in deep water.

Hurricane Gilbert made landfall on the south Texas coast in September 1988. It was an intense storm with flight level winds up to 50 m/sec. Figure 3.5 shows comparisons for some of Gilbert's strongest measured and modeled current profiles. Agreement is generally good for both the magnitude of the current and the depth of current penetration. Once again, the measured shear in the upper layer is uncertain.

3.2 Hurricane Andrew

The LATEX project (Nowlin et al., 1988) measured currents at several sites on the Texas and Louisiana continental shelf. In August 1992, Hurricane Andrew came close to LATEX moorings 13 and 14. Mooring 13 was in about 200 m of water, with current meters at 10, 100 and 190 m below the surface. Measured and modeled currents at the shallowest two levels are shown in Figure 3.6. The model does a good job of predicting the timing of the near surface current during the storm. The peak current is under-estimated by about 40 cm/sec. The modeled currents do not reach 100 m depth during the storm passage, but the observations show no sign of storm influence during the storm peak on August 26 either. As discussed in Section 1, the one-dimensional model does not reproduce the inertial oscillations either at the surface or at depth in the days after the storm peak.

Measured and modeled currents at mooring 14 are shown in Figure 3.7. This mooring was in approximately 45 m water depth. There is good agreement at 26 m depth at the peak of the storm, even though the model gives the peak current speed four hours too soon. The model under-estimates the currents at 37 m depth. The error is probably due to the barotropic current caused by the storm surge that is not included in the one-dimensional model. Somewhat surprisingly, there are inertial oscillations after the storm even in this relatively shallow water.

3.3 Hurricane Katrina

Norske Hydro collected an extraordinary set of current measurements at their Telemark site during Hurricane Katrina. These measurements and permission to use them for this study were obtained from Norske Hydro. Their mooring was at 27.881° N, 88.992° W. The mooring included an upward looking 300 kHz ADCP looking upward and a 75 kHz ADCP looking downward. Both instruments were located on a floatation sphere at 72 m depth. Hurricane Katrina passed approximately 30 nautical miles west of Telemark. The combination of an extremely strong storm just to the left of a site is expected to produce very strong currents and Katrina certainly did. The upper panel of Figure 3.8 shows the current speed measured during the passage of the hurricane. The peak measured speed reached 230 cm/sec. During the strongest currents, the mooring was pushed over so that the upper ADCP measured currents below its nominal depth. A set-down of as much as 30 m was measured by a pressure transducer.

Hindcasts of the currents at Telemark were made using the Mellor and Yamada (1982) and Kantha and Clayson (1994) turbulence closure equations. The wind stress was calculated using two different wind stress law. The first was equation 2.2 and the second was that equation capped at a drag coefficient of 2.2×10^{-3} as suggested by the data of Powell et al. (2003). The hindcast based on the Kantha and Clayson equations and the Large and Pond wind stress is shown in the bottom panel of Figure 3.8. It over-estimates the currents at all depths.

The top panel of Figure 3.9 shows a hindcast using the Mellor and Yamada equations with the cap on the stress law. The bottom panel of that figure shows the hindcast using the Kantha and Clayson equations with the stress cap. The stress cap is clearly necessary to prevent over-estimation of the near surface currents. The Mellor and Yamada equations still over-estimate the currents near the surface. The Kantha and Clayson equations mix the momentum too far downward and produce strong currents that are deeper than those observed.

Figures 3.10 and 3.11 compare the measurements at selected depths with the model results at the same depth. Near the surface, the Kantha and Clayson equations with no cap on the wind stress over-estimate the measurements. The Mellor-Yamada equations over-estimate the measurements even when the stress cap is applied. The Kantha equations with a stress cap give results that are slightly lower than the measurements. At 70 m depth, the measurements are intermittent. Measurements were made there only when the mooring is depressed by strong currents. During times of strong currents, the Mellor-Yamada and Kantha and Clayson equations bracket the measurements. At 100 m depth, the measured currents are small. The Kantha and Clayson equations predict that hurricane generated currents penetrate deeper than observed. The Mellor-Yamada equations give better picture of hurricane generated current penetration.

For engineering purposes, it is better to have the best agreement near the surface. The Kantha and Clayson equations with a cap on the stress law perform best near the surface. Comparisons with measurements show that these equations are the best choice for our hindcasts.

4. Production Runs

The production runs were made using the Kantha and Clayson (1994) turbulence closure equations. The wind speed at each grid point was taken from the GOMOS hindcast data base. Equation 2.1 with the coefficient capped at 2.2×10^{-3} was used to calculate the stress. The initial temperature and salinity profiles were taken from the NODC Ocean Atlas 2001. This atlas gives the profiles on a one degree grid for each month of the year.

The model was run with a grid size of one meter in the vertical direction and a time step of 300 seconds. Results were output every 30 minutes to match the GOMOS time step. The profiles of speed and direction were output to files with names of the form `GT00nnnn.spd` and `GT00nnnn.dir` where `nnnn` is the grid point number. These profiles have a grid size of five meters in the vertical direction. They extend to 200 meters depth when the water is deeper than 200 meters. If the water depth is less than 200 meters, the profiles extend to the bottom, with one grid point one meter above the bottom. The speed and direction shown for d = 0 are actually from d = 1 in the model because of the high shear in the model very close to the surface. Profiles were calculated only for grid points with water depth greater than 75 meters.

The profile files at five meter resolution are very large. This level of detail is not necessary for most engineering purposes. To save storage space, the detailed profiles were fit to a bi-linear profile described by five parameters. These parameters are listed in the GOMOS Fields files. They are described in Table 4.1. The full profiles are available on request.

Parameter	Description
VS	Surface current speed (cm/sec)
DZ	Depth at which current speed = 0 (m)
DH	Depth of break in current profile (m)
VH	Current speed at depth of break (cm/sec)
DIR	Vector average current direction (degrees true from North)

Table 4.1. Parameters of bi-linear current profiles listed in the fields files.

Complete current profiles should be calculated using linear interpolation on the parameters listed in Table 4.1. The current is VS at the surface, VH at depth DH, and zero at depth DZ.

5. Conclusions

Current profiles have been hindcast using a one-dimensional turbulence closure model for all storms and grid points with water depths greater than 75 m in the GOMOS data base. These hindcasts do not include the current that is in balance with the storm surge. That storm surge current is most important in water depths less than 75 m. For depths less than 75 m, currents from the storm surge model in GOMOS should be used.

The one-dimensional hindcasts accurately predict currents during the peak of a hurricane. The currents at the time of the peak winds and waves are most important for calculation of loads on offshore structures. The comparisons of calculated and measured hurricane currents indicate that the best accuracy is achieved using the Kantha and Clayson (1994) turbulence closure equations with a wind stress cap. The rms error of these hindcasts is approximately 30 cm/sec.

The hindcasts made by the one dimensional model do not predict the inertial currents observed after the passage of a hurricane. Other models are necessary to predict those currents.

6. References

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Sanford, T.B., P.G. Black, J.R. Haustein, J.W. Feeney, G.Z. Forristall, and J.F. Price (1987), Ocean response to a hurricane. Part I: Observations, *J. Phys. Oceanogr.*, **11**, 2065-2083.

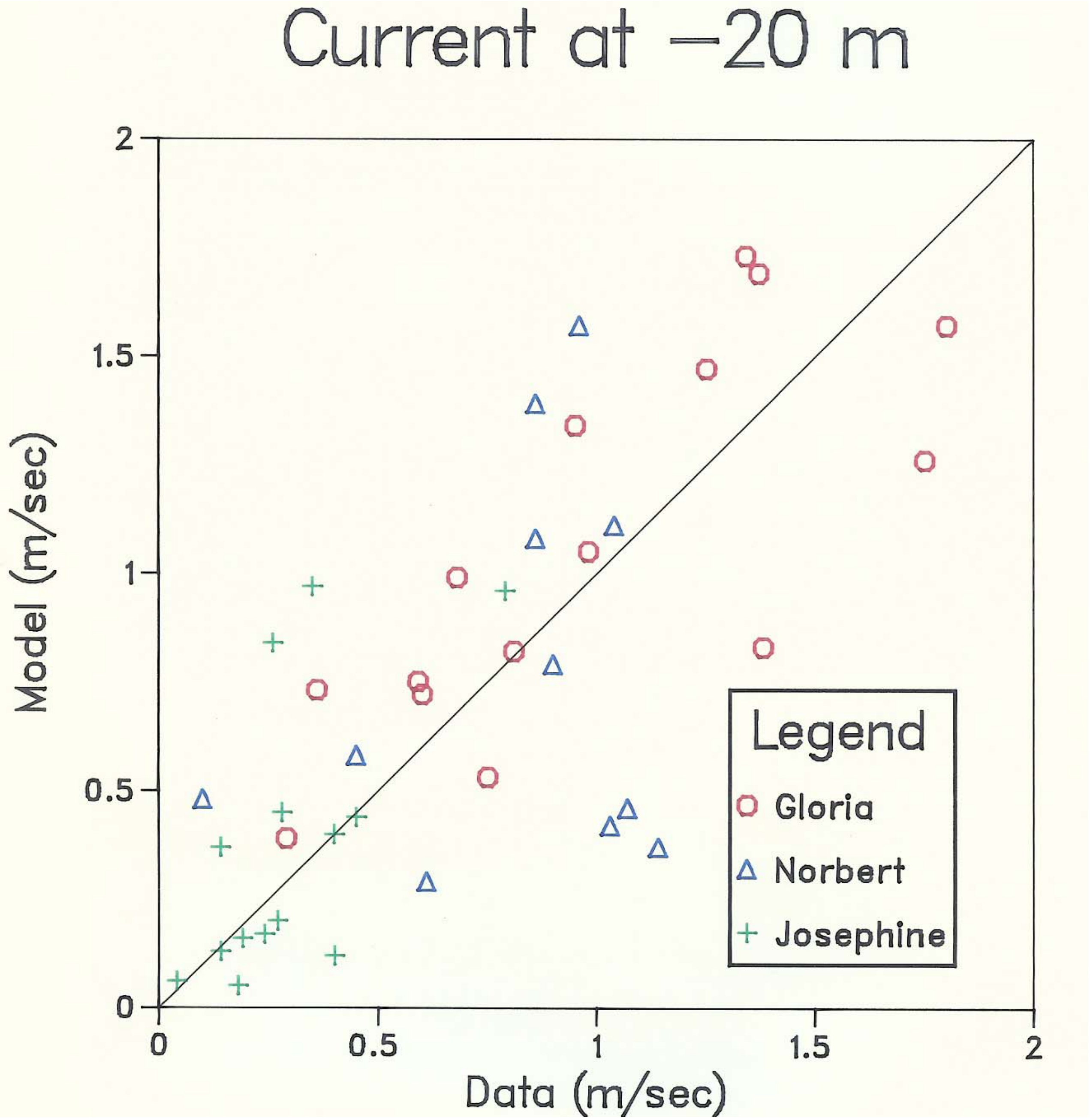


Figure 3.1. Measured and hindcast near surface currents in Hurricanes Norbert, Josephine and Gloria.

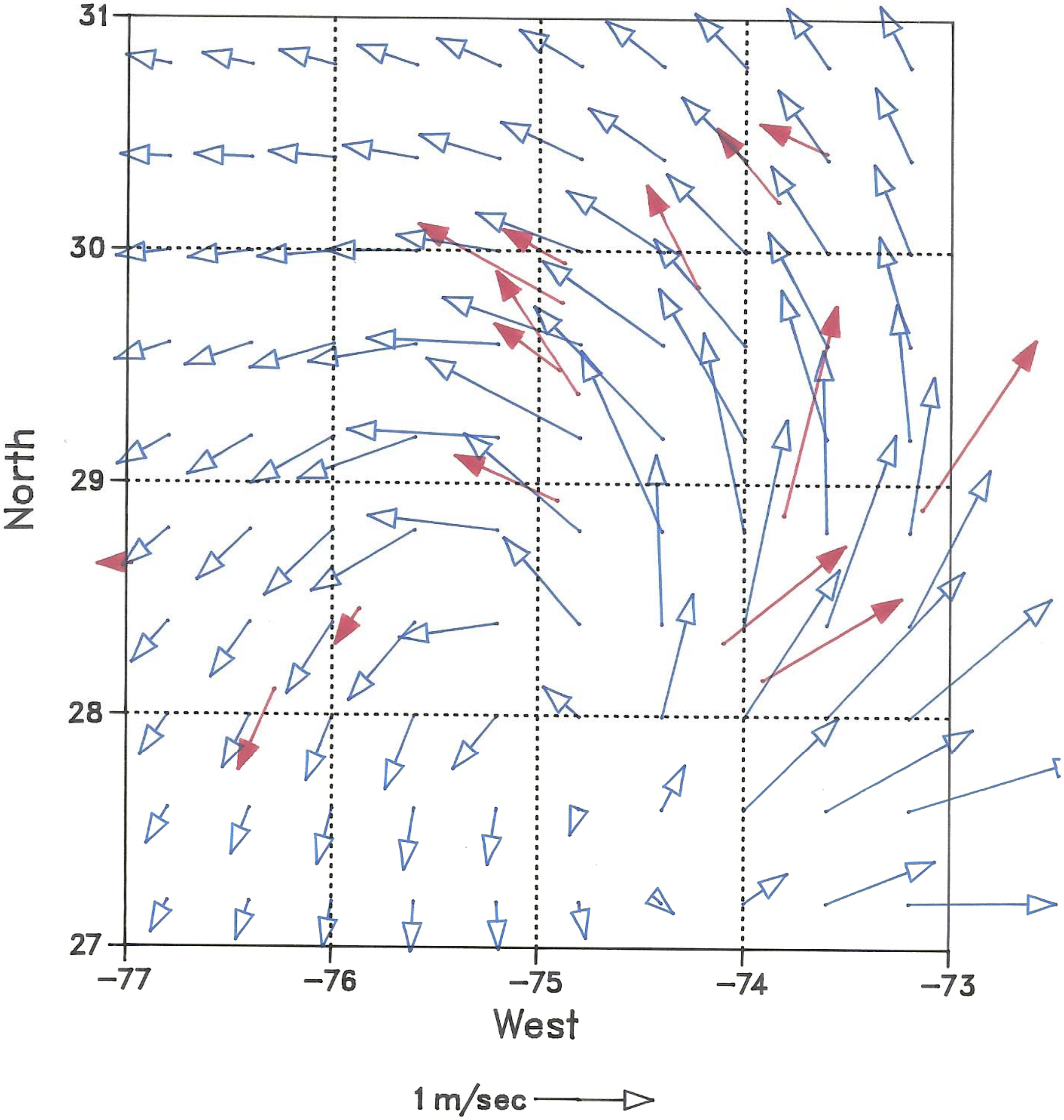


Figure 3.2. Currents at 20 m depth in Hurricane Gloria near 0800 on 26 September 1985. Measured currents are red vectors with solid heads. Modeled currents are blue vectors with open heads.

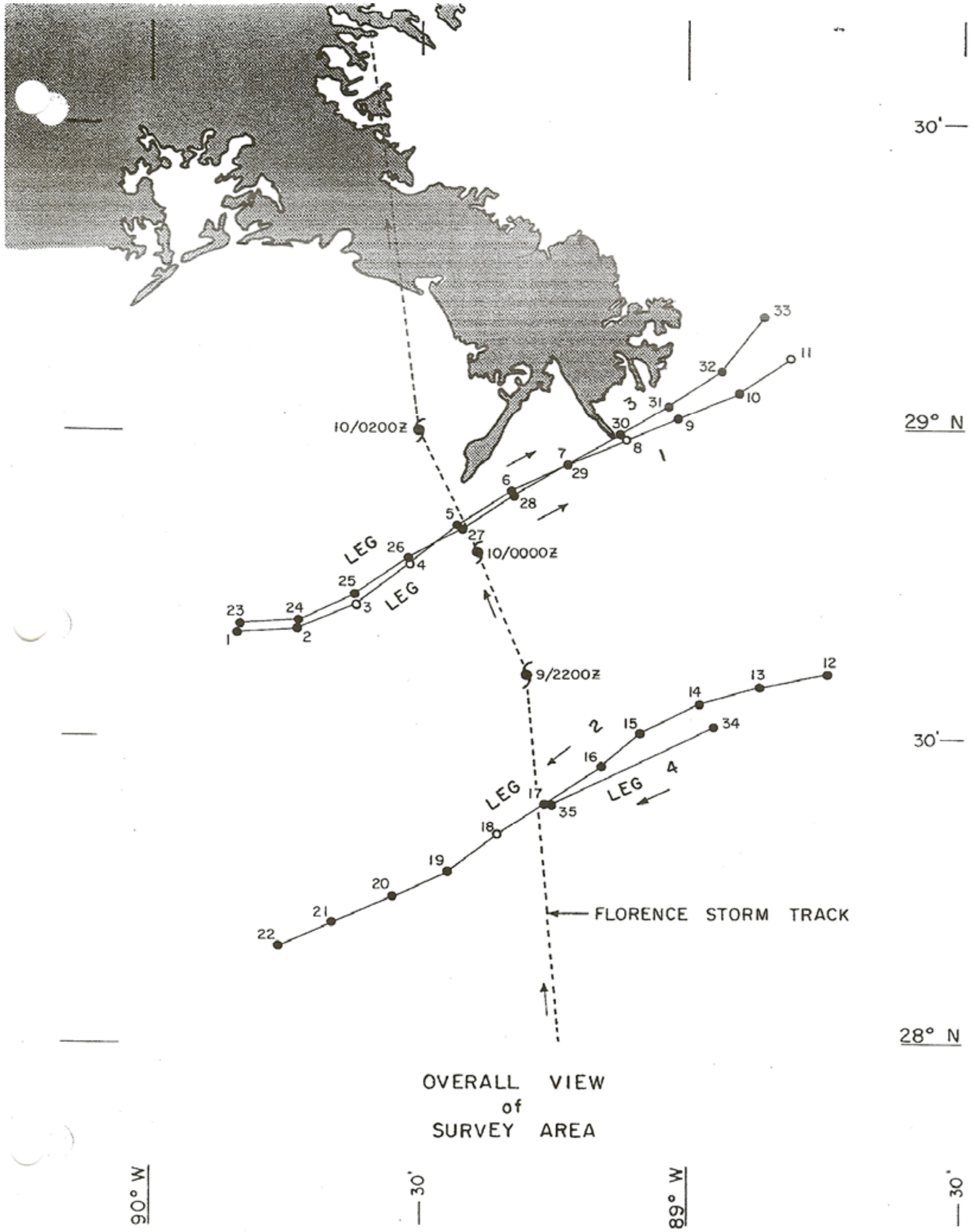
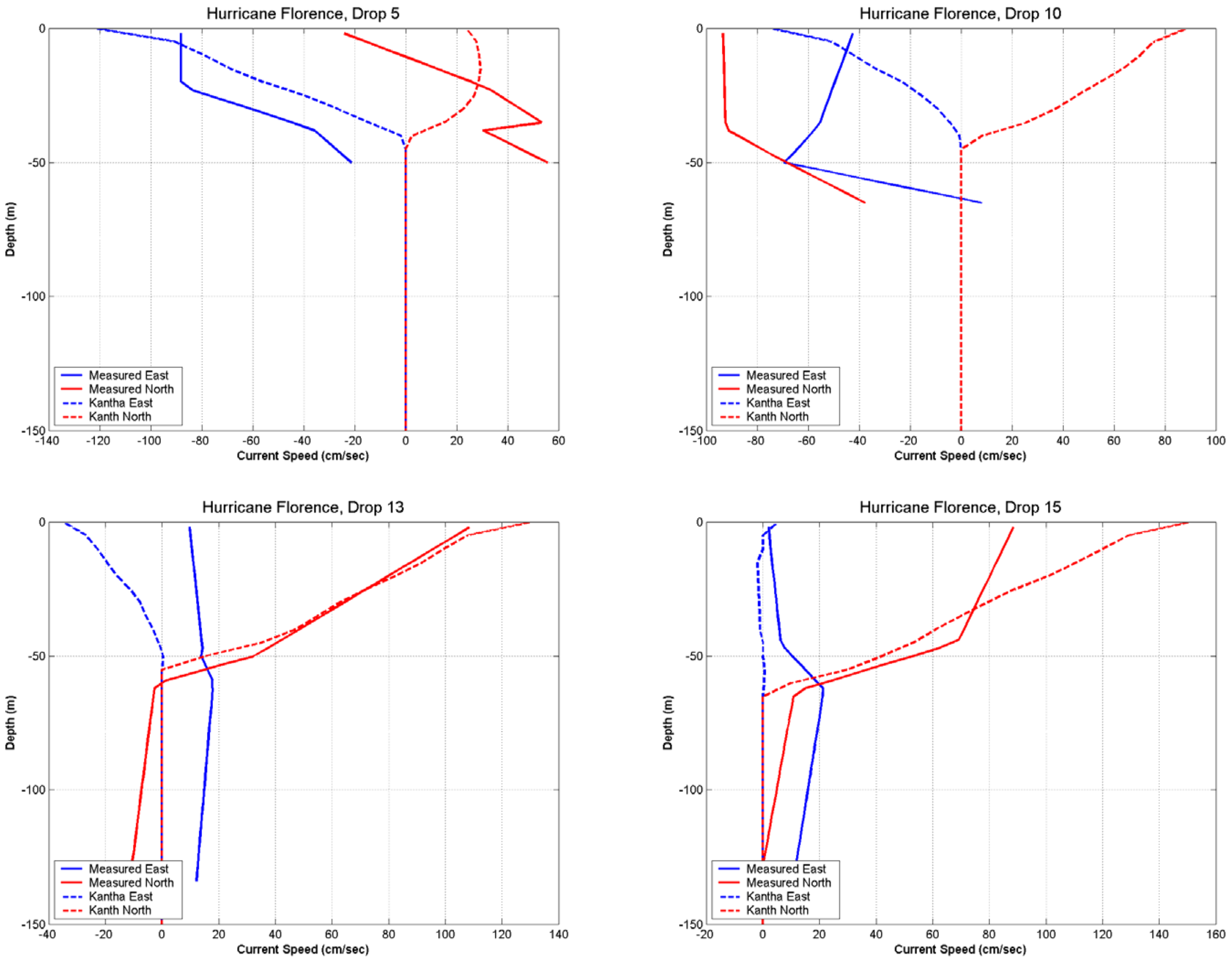


Figure 3.3. Locations of current measurements in Hurricane Florence on 9 September, 1988.


Hurricane Florence, Drop 5

Hurricane Florence, Drop 10

Hurricane Florence, Drop 13

Hurricane Florence, Drop 15

Figure 3.4. Measured and hindcast current profiles in Hurricane Florence.

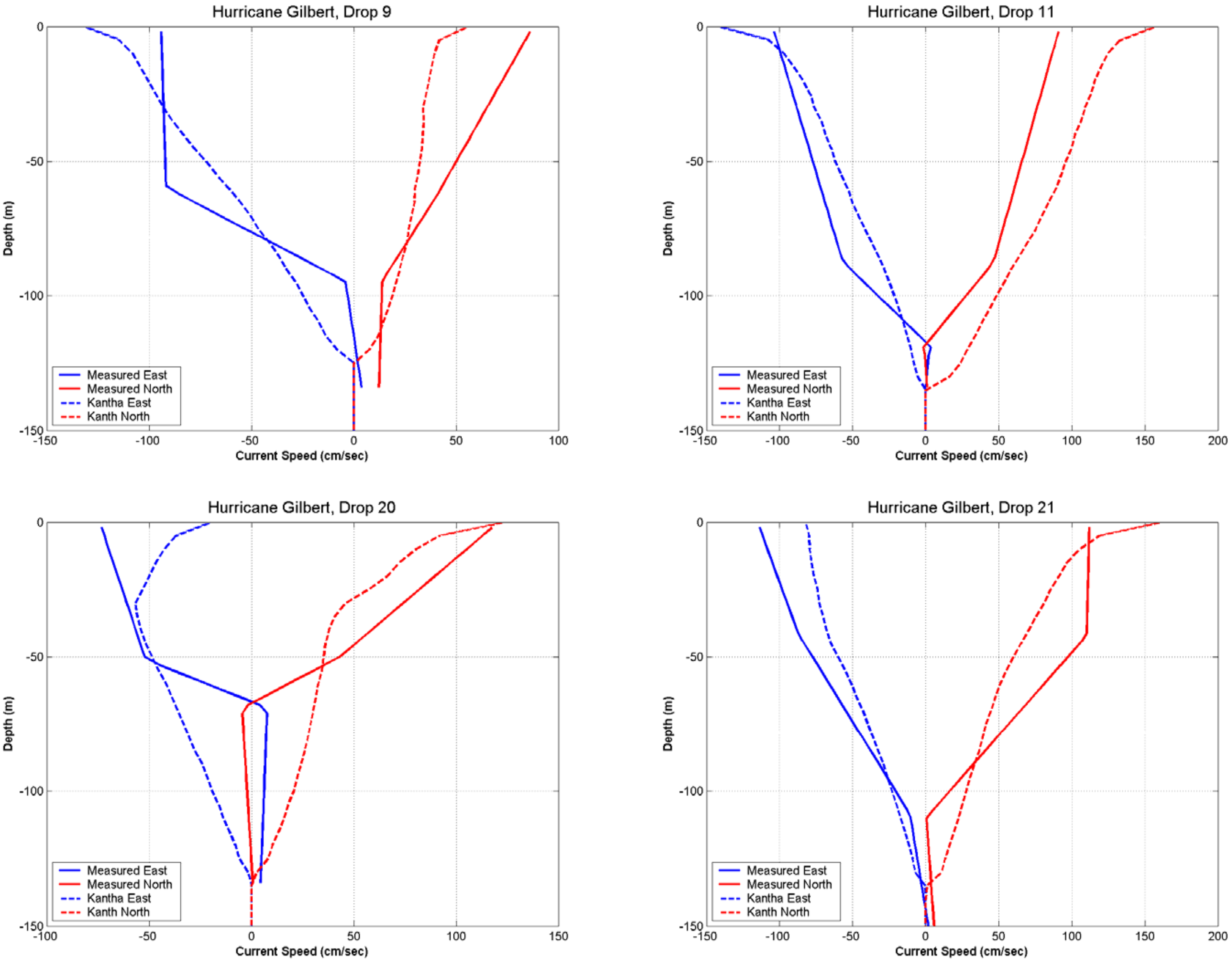
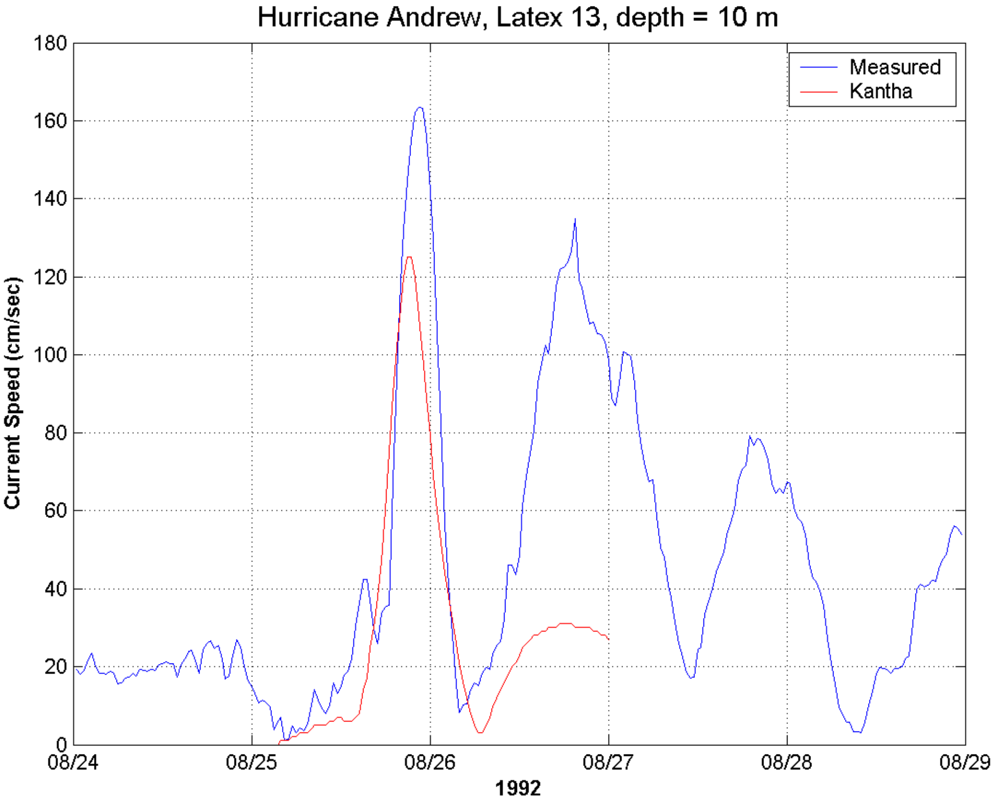


Figure 3.5. Measured and hindcast currents in Hurricane Gilbert.



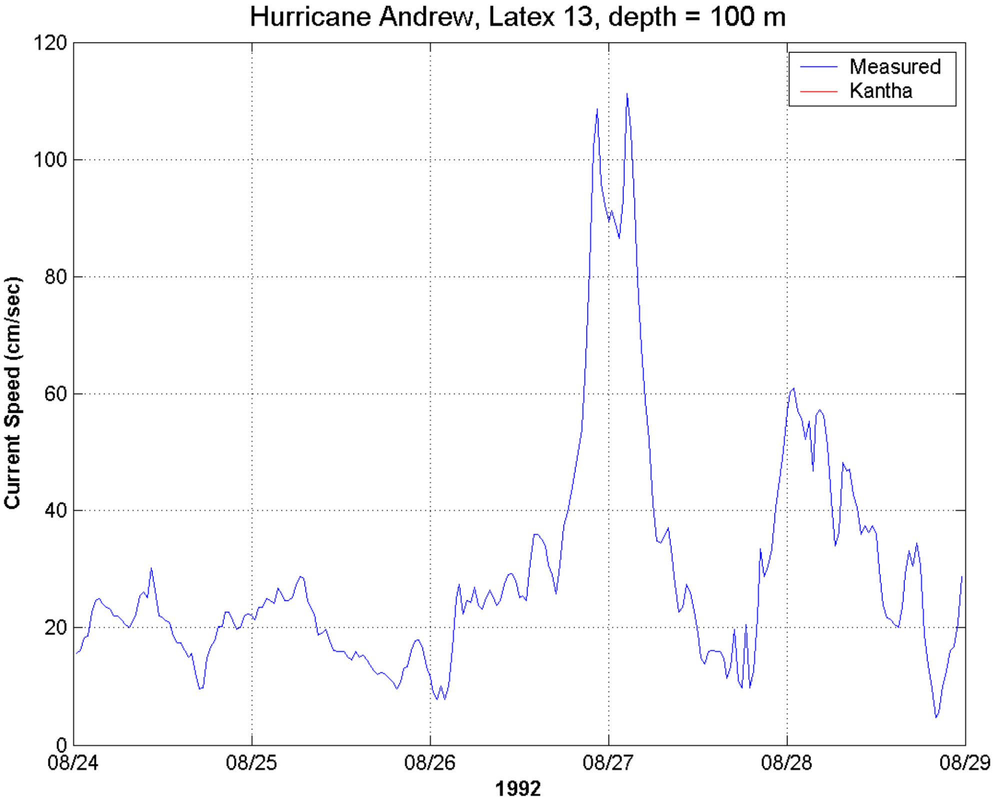


Figure 3.6. Measured and modeled currents at LATEX mooring 13 in 200 m water depth.

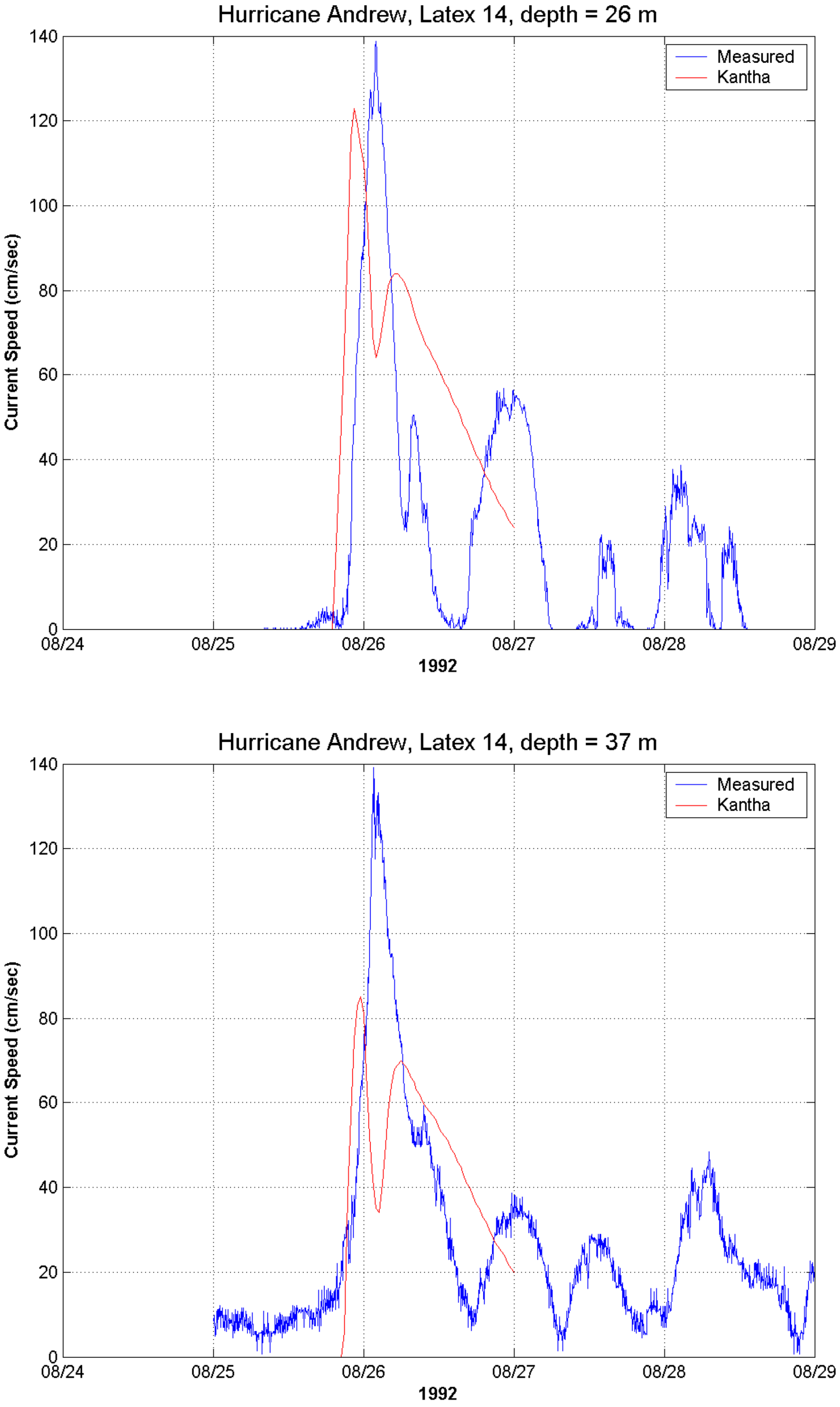


Figure 3.7. Measured and modeled currents at LATEX mooring 14 in 45 m water depth.

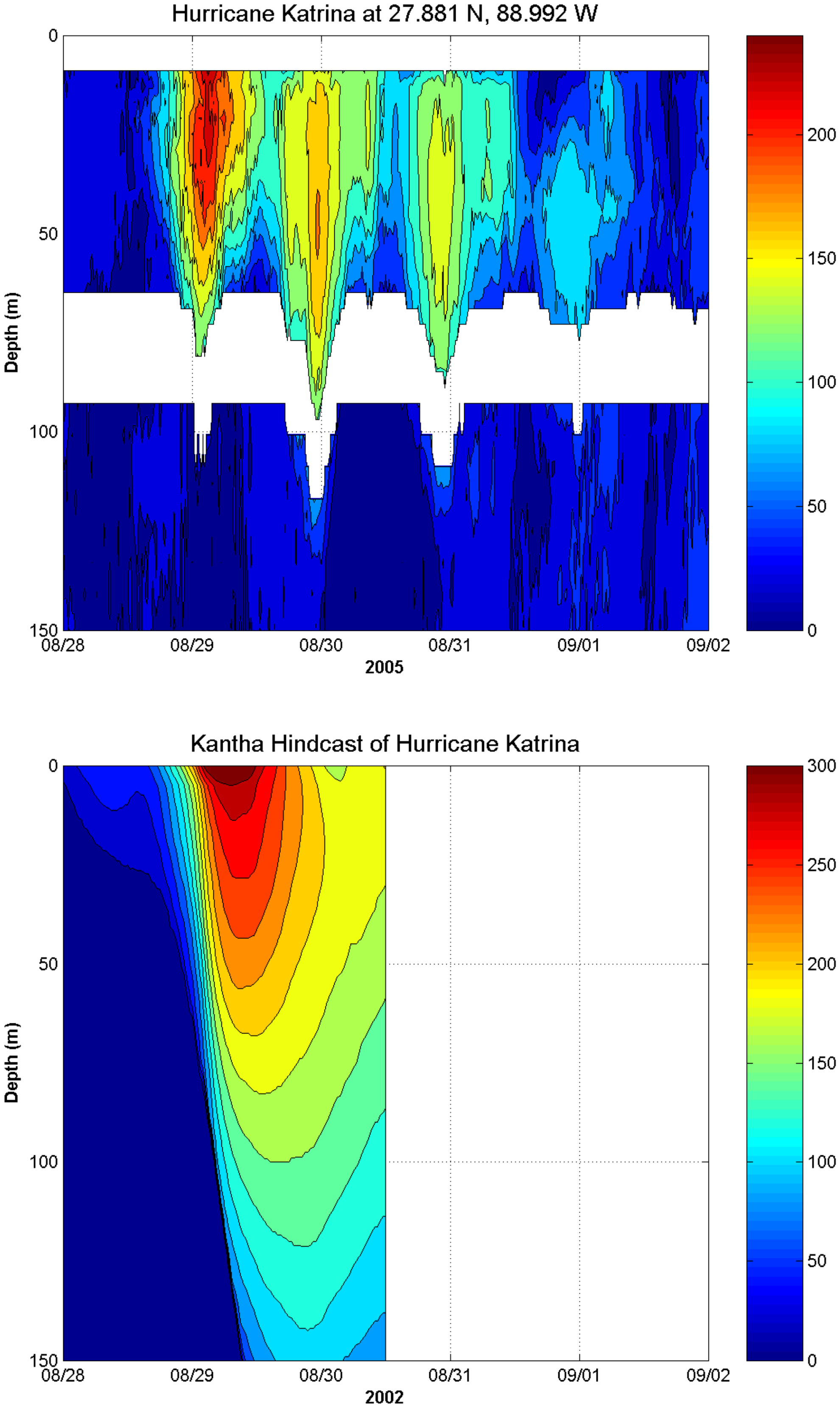


Figure 3.8. The top panel shows current speed measured during Katrina. The bottom panel shows the current hindcast using the Kantha and Clayson equations with the Large and Pond wind stress.

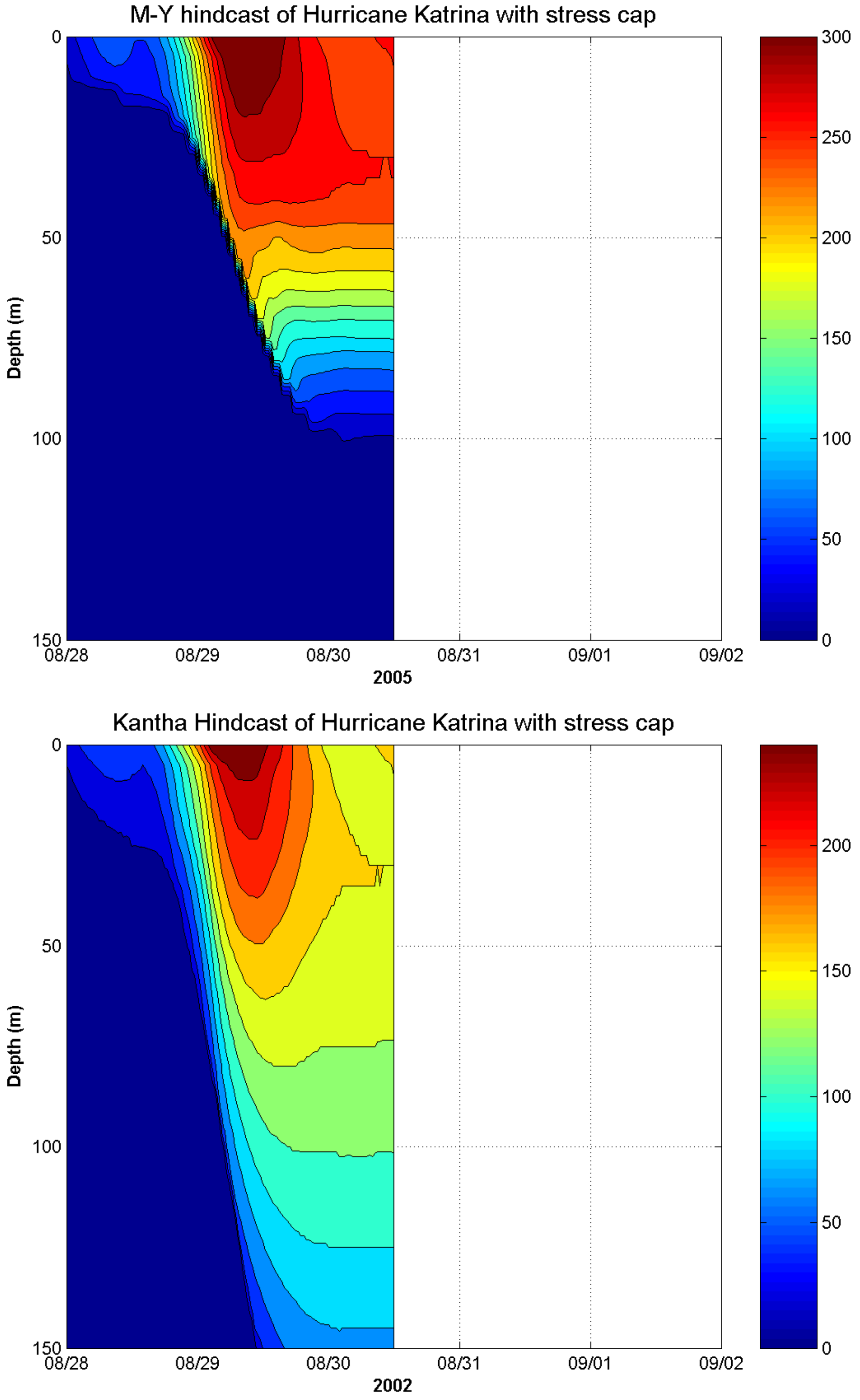


Figure 3.9. The top panel shows the hindcast using the Mellor and Yamada turbulence closure equations with the wind stress coefficient capped at $2.2\text{x}10^{-3}$. The bottom panel shows the hindcast with the Kantha and Clayson equations and the same cap on the wind stress law.

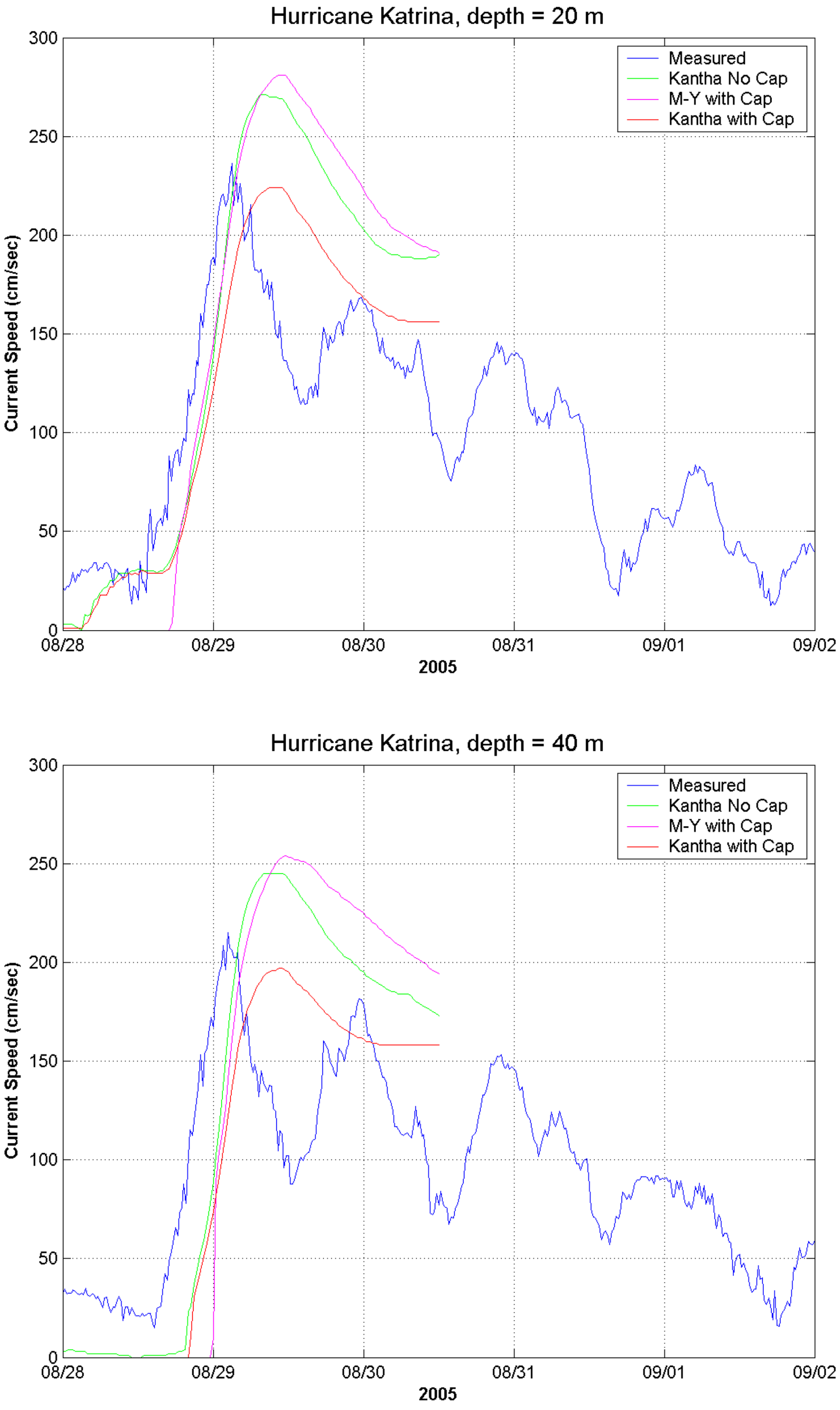


Figure 3.10. Comparison of measured and modeled currents at 20 and 40 m depth during Hurricane Katrina.

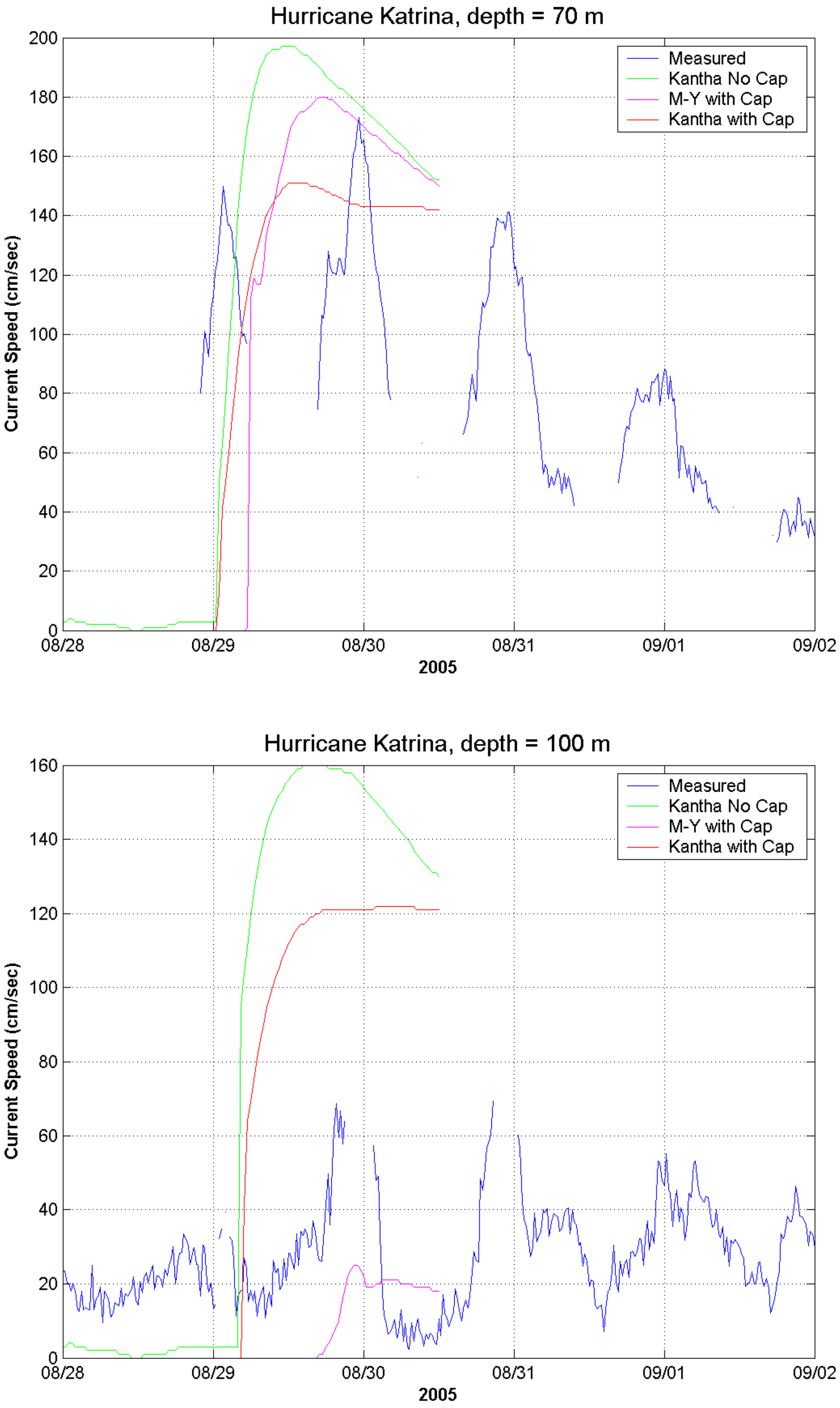


Figure 3.11. Comparison of measured and modeled currents at 70 and 100 m depth during Hurricane Katrina.