Hurricane Spectral Measurements and Modeling

R.E. Jensen & D.T. Resio

8th International Workshop on Wave Hindcasting and Forecasting

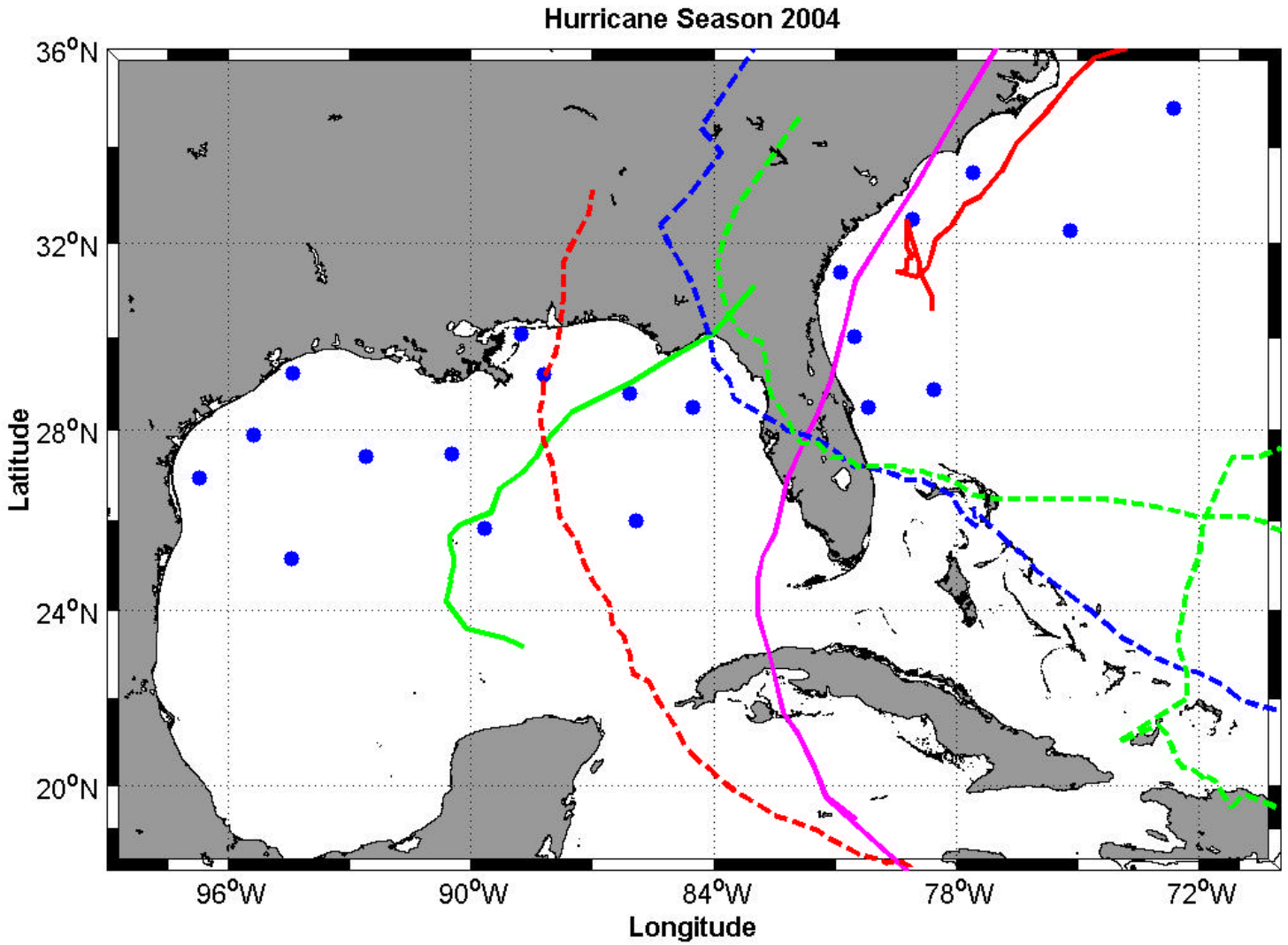
(ONR: N0001402MP20038 N0001401MP0034)

US Army Corps of Engineers

Coastal and Hydraulics Laboratory
Engineer Research and Development Center

Outline

- Overview of Data Sources
  - Hurricane Season 2004
- General Characteristics of the Wave Climate
- Analysis of Spectra
  - Are They Consistent?
- Wave Model Results
  - Comparisons: Model to Measurements
- Summary, Conclusions and Recommendations

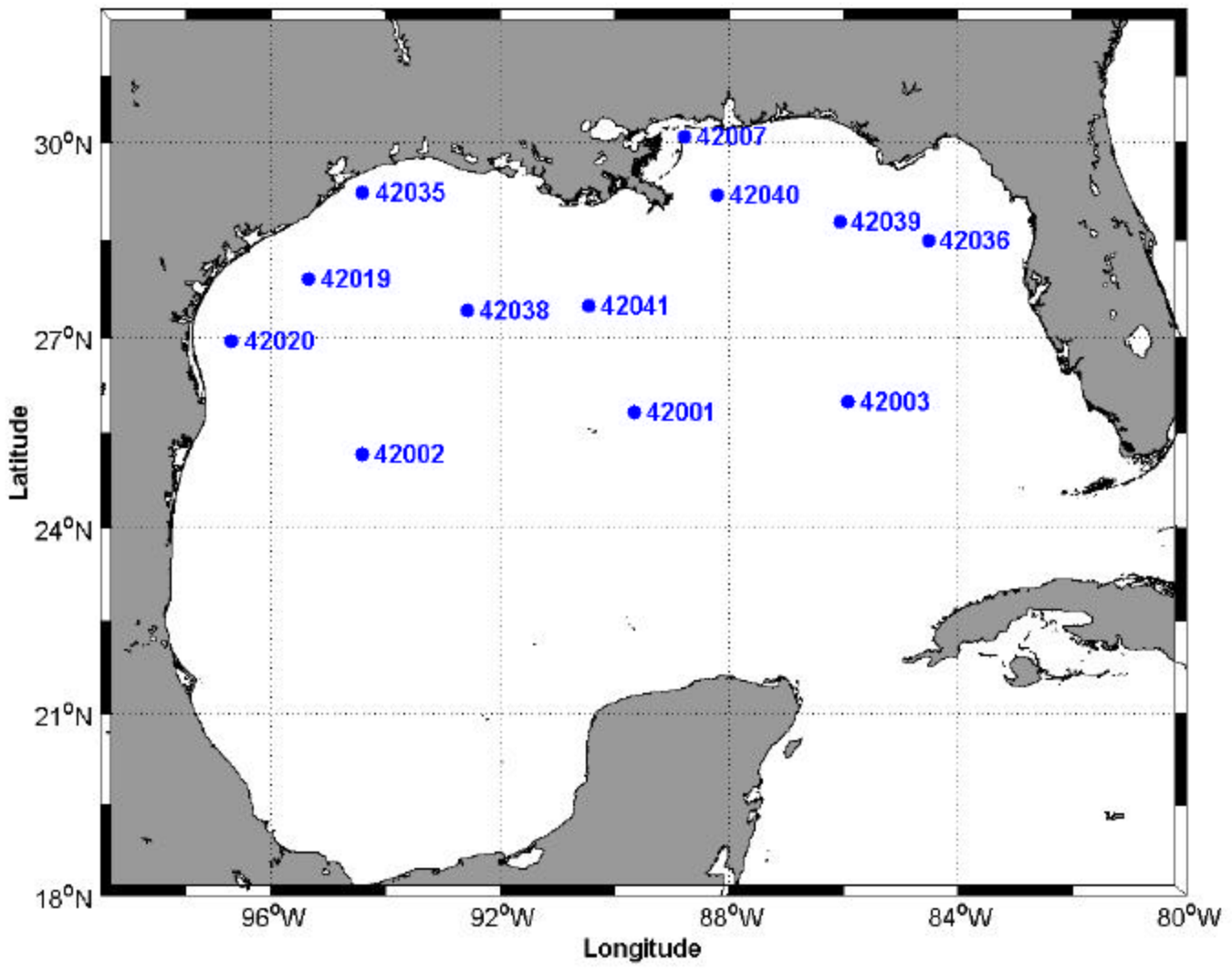


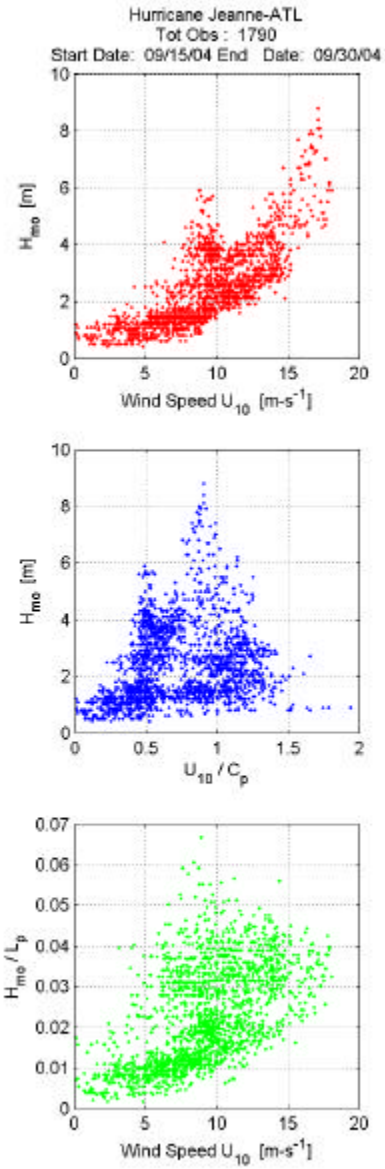
#	Name	Dates	Wind	Pres	Cat
1	Hurricane ALEX	07/31 - 08/06	105	957	3
3	Trop Strm BONNIE	08/09 - 08/12	55	1000	-
4	Hurricane CHARLEY	08/09 - 08/15	125	941	4
7	Hurricane FRANCES	08/25 - 09/09	125	935	4
10	Hurricane IVAN	09/02 - 09/24	145	910	5
12	Hurricane JEANNE	09/13 - 09/28	110	950	3

Partitioned by Hurricane

- Alex (ATL) 07/31 – 08/06
- Charlie (GoM / ATL) 08/09 – 08/15
- Frances (ATL / GoM) 08/25 – 09/09
- Ivan (GoM) 09/02 – 09/24*
- Jeanne (ATL) 0913 – 09/28

EFFECTS OF OVERLAPPING SYSTEMS


42007
42035
42040
42039
42036
42019
42038
42041
42020
42001
42003
42002
30°N
27°N
24°N
21°N
18°N
96°W
92°W
88°W
84°W
80°W
Latitude
Longitude


Hurricane Jeanne-ATL
Tot Obs : 1790
Start Date: 09/15/04 End Date: 09/30/04
H_{mo} [m]
Wind Speed U_{10} [m-s^{-1}]
H_{mo} [m]
U_{10} / C_p
H_{mo} / L_p
Wind Speed U_{10} [m-s^{-1}]

Spectral Analysis

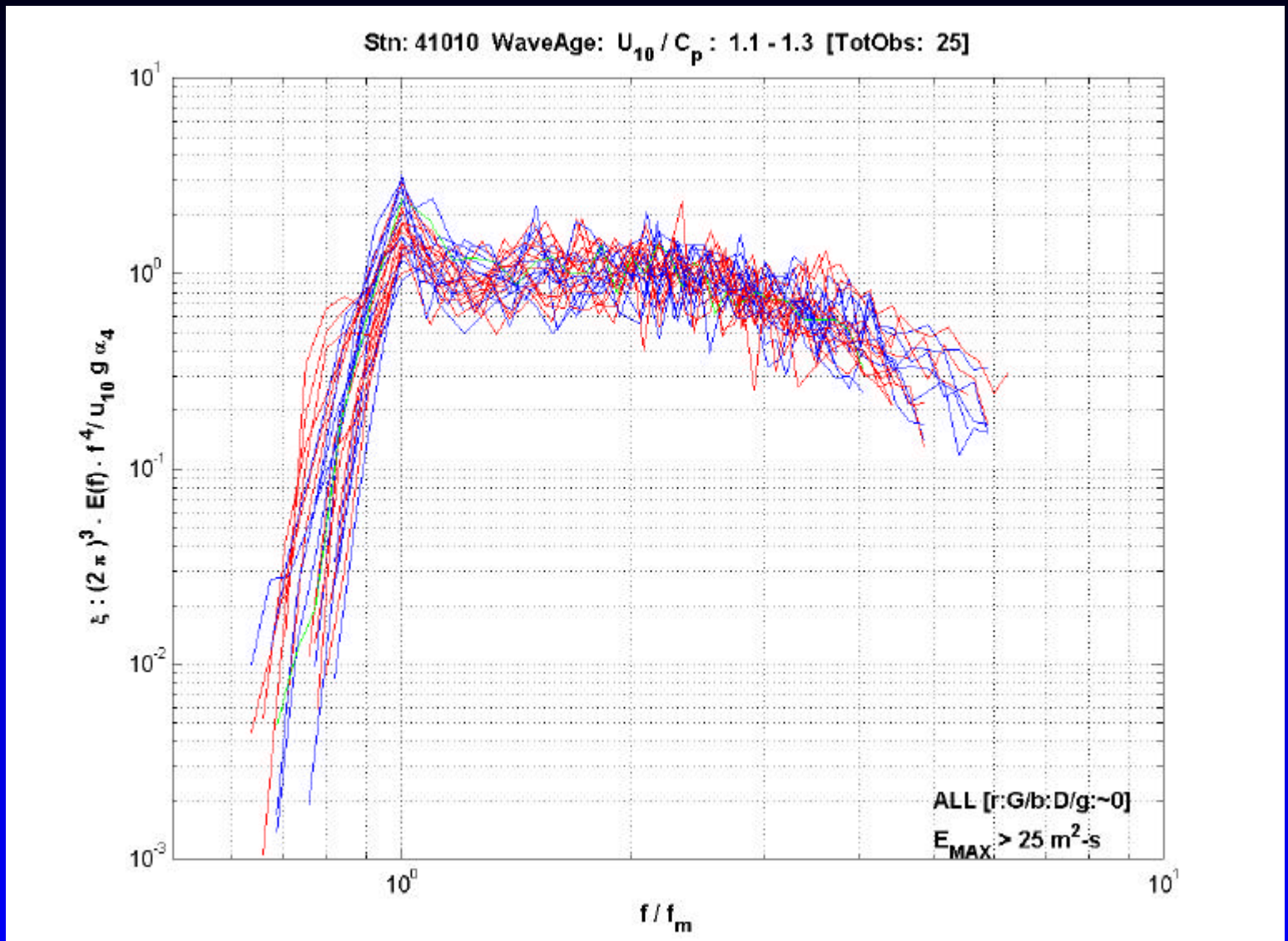
- By Storm Event
- By Station

  Wave Age Bins (U_{10} / C_p)
- Analysis

  Two Buoy Locations

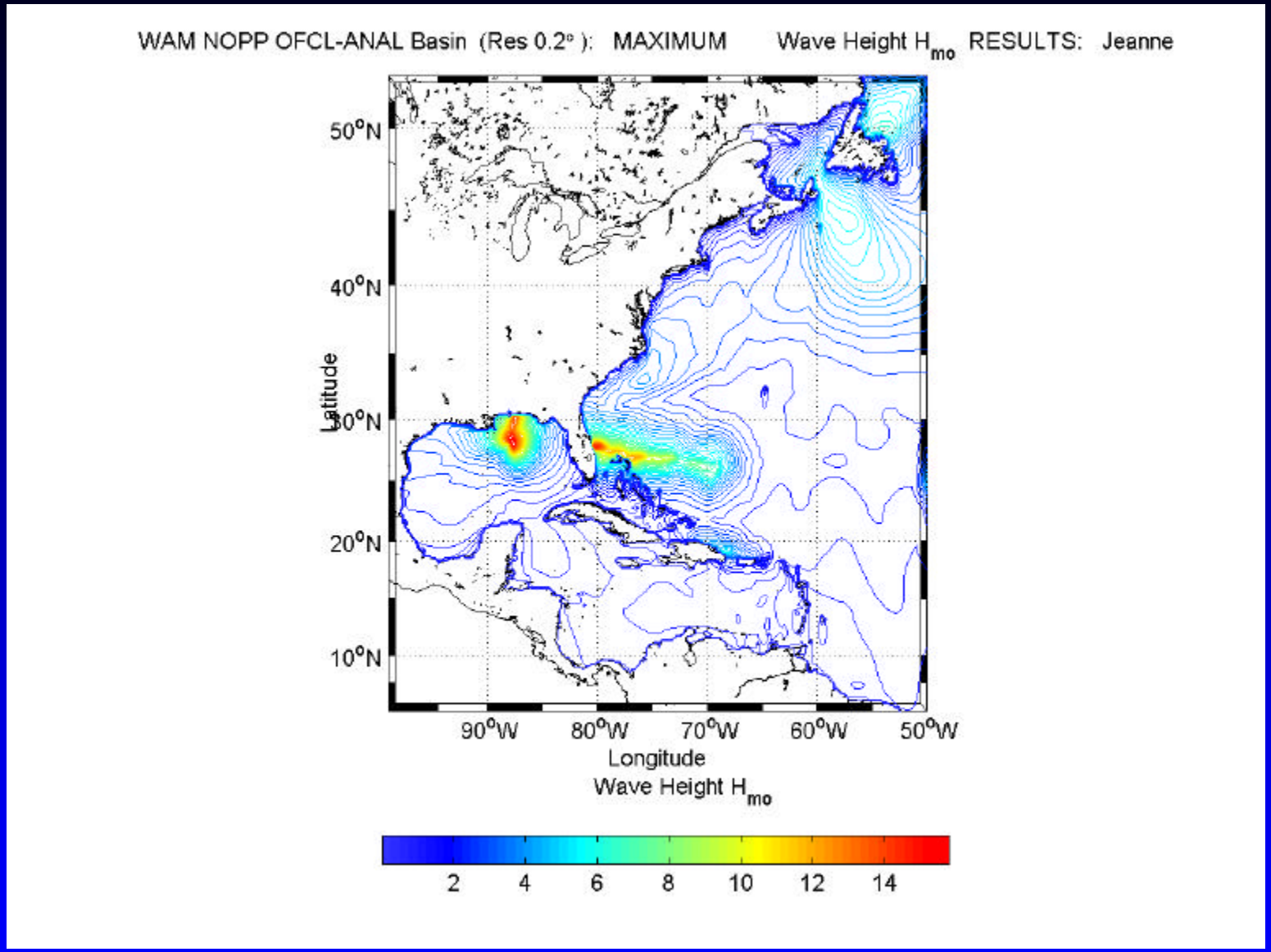
  Frances / Jeanne

  Ivan


Stn: 41010 WaveAge: U_{10} / C_p : 1.1 - 1.3 [TotObs: 25]
$\xi : (2\pi)^3 \cdot E(f) \cdot f^4 / U_{10}\, g\, \alpha_4$
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^0
10^1
f / f_m
ALL [r:G/b:D/g:~0]
E_{MAX} > 25 m^2-s

Wave Modeling – WAM CY4.5

- Overview of the Simulations
  - Outside of the present NOPP work (Graber et al.)
  - Investigating the details of the results
  - Spectral level (Hanson and Jensen)
- Wave Field Examples
- Problems?


WAM NOPP OFCL-ANAL Basin (Res 0.2°): MAXIMUM Wave Height H_{mo} RESULTS: Jeanne
50°N
40°N
30°N
20°N
10°N
Latitude
90°W
80°W
70°W
60°W
50°W
Longitude
Wave Height H_{mo}
2
4
6
8
10
12
14

Verification

- Model to Buoy Comparisons were consistent
  - H_{mo} Elevated before tuning
  - T_p Elevated with phasing problems
  - θ_{MEAN} Directions appear to be biased

APPEARS TO BE POINTING TO HIGH WINDS

Verification

- What produced ovepredictions?
  - The wind fields NO
  - Resolution [grid and $E(f,\theta)$] NO
  - Depth effects NO

- SOURCE TERMS: S_{in}
  - *Pseudo Linear Coupling*
  - Does it HOLD for High Winds?
  - Does JONSWAP Growth HOLD for $U_{10} > 20$ m-s^{-1} ?
  - Is it Wave Stress / Total Stress f { U_{10}, C_D, and u_* } ?

Drag Laws

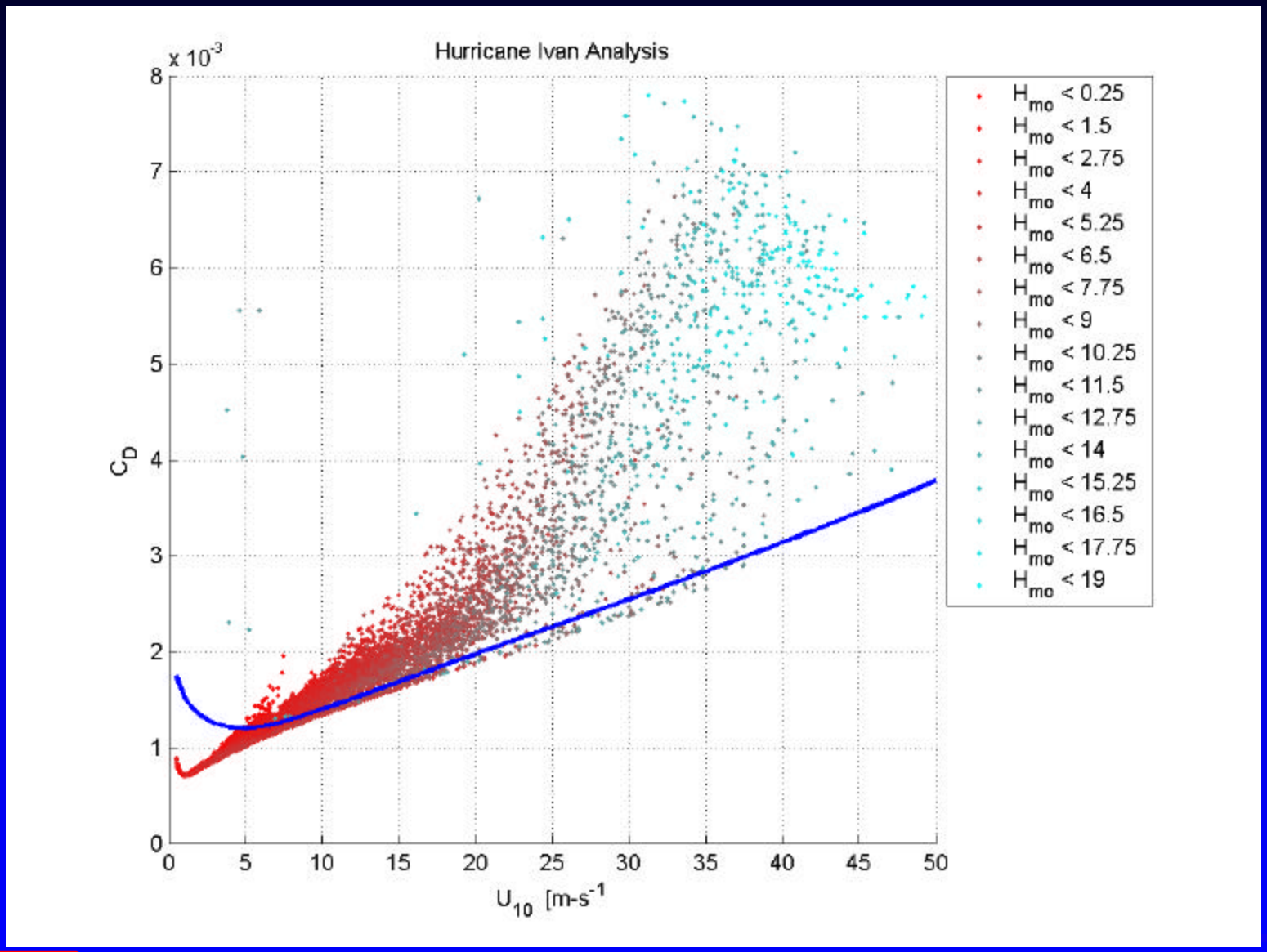
- Drag Laws and Limits

  Powell et al. (2003): ~ $2.5 \cdot 10^{-3}$

  Donelan et al. (2004): ~ $2.3 \cdot 10^{-3}$

- Janssen (1991): No Limit ?

  Numerical Studies ~ $5.5 \cdot 10^{-3}$ at 25 $m\text{-}s^{-1}$


Hurricane Ivan Analysis
x 10^-3
C_D
U_10 [m-s^-1]
0
1
2
3
4
5
6
7
8
0
5
10
15
20
25
30
35
40
45
50
H_mo < 0.25
H_mo < 1.5
H_mo < 2.75
H_mo < 4
H_mo < 5.25
H_mo < 6.5
H_mo < 7.75
H_mo < 9
H_mo < 10.25
H_mo < 11.5
H_mo < 12.75
H_mo < 14
H_mo < 15.25
H_mo < 16.5
H_mo < 17.75
H_mo < 19

Summary Conclusions Recommendations

- WAM performs OK in Hurricanes with significant tuning
- Uncertainties in source terms or C_d could be responsible
- More tests are needed to validate physics
  - Academic Testing (SWAMP Cases)
  - Non-tuned Range of Storms
  - Proper Metrics including spectral shapes
    - Observed spectra are self-similar WAM spectra are not
  - Wave System Approach


QUESTIONS ?