

Regional Wave Modeling & Evaluation for the North Atlantic Coast Comprehensive Study (NACCS)

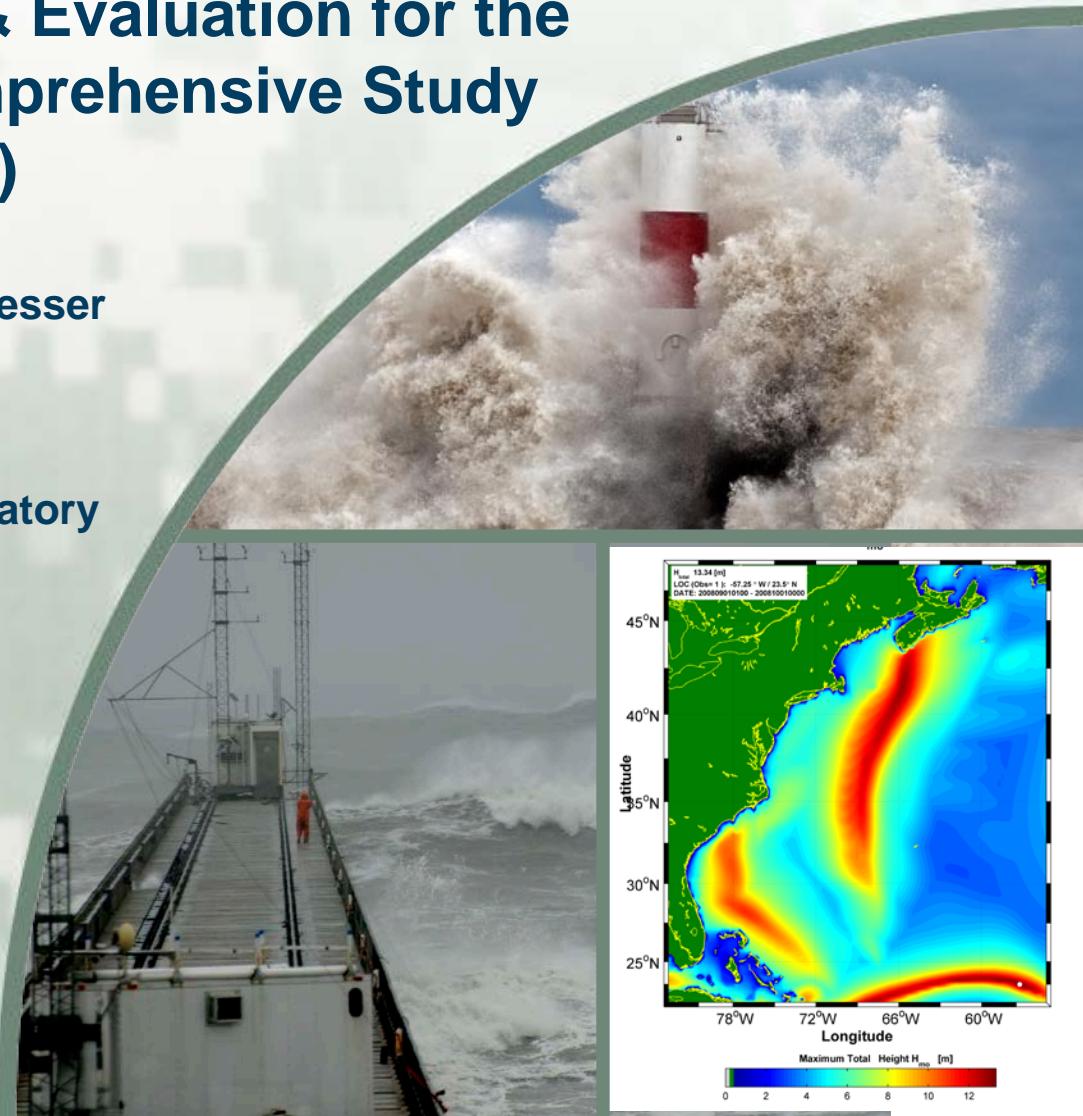
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USACE ERDC
Coastal and Hydraulics Laboratory

14th Waves Workshop
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Key West, Florida



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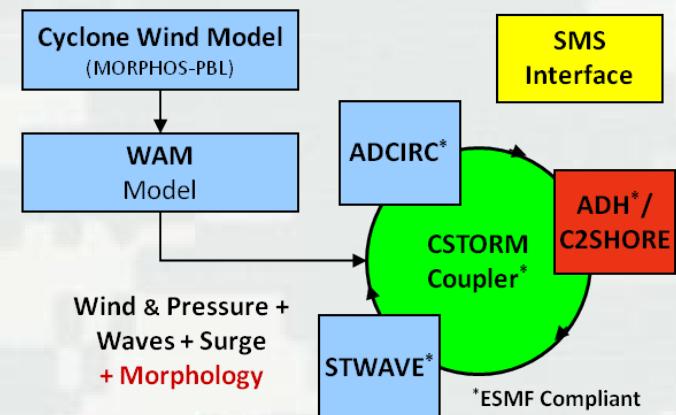
Offshore Wave Climate: Outline

- Motivation
 - ▶ One piece in the NACCS
 - ▶ Generation of offshore BC's
 - ▶ Quality in wave estimates
- Model Selection
 - ▶ Input requirements
- Evaluation
 - ▶ 22 Storms Selected: Tropical / Extra-Tropical
 - ▶ Methods and Results
- Conclusions



Offshore Wave Climate: Motivation

- Quantify Offshore Wave Climate for NACCS
 - ▶ Congressionally mandated timeline !
 - NOT: Hurricane Sandy Specific Study
 - ▶ Production
 - 100 Extra-Tropical Events / 1050 Synthetic Tropical Cyclones
 - ▶ Model Selection
 - WAM Cy4.5.1C
 - Used IPET / Gulf of Mexico JPM Studies
 - Integrated into CSTORM
 - ▶ Wind Field Specification
 - ▶ Evaluation
 - Storm Selection
 - Methods Used / Criteria



Offshore Wave Climate: WAM Cy4.5.1C

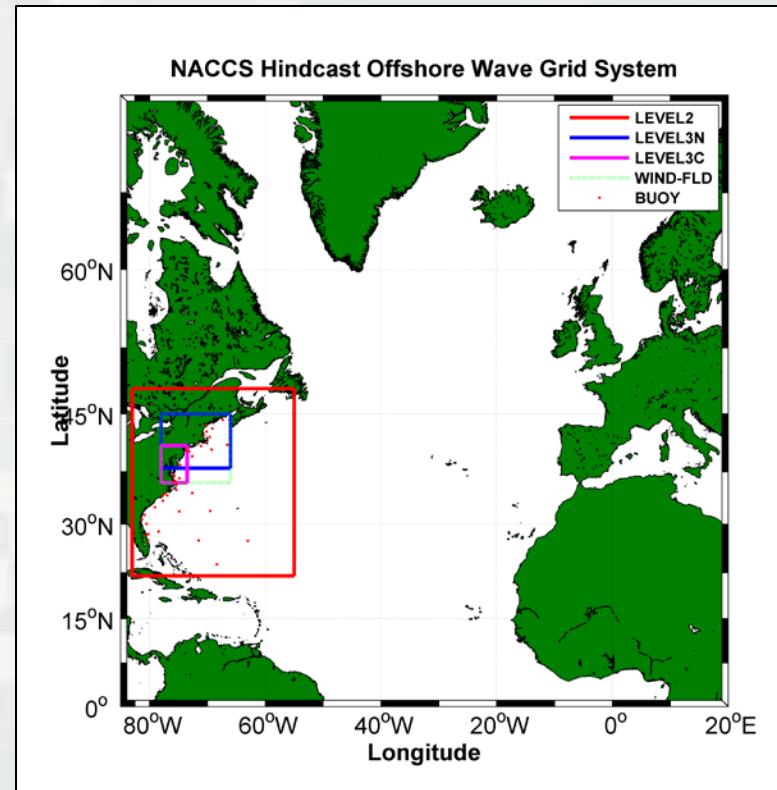
- Acknowledge other Wave Technologies Exist
 - ▶ WAVEWATCH III
 - Successfully used at NCEP for Hurricane Sandy
 - ST4 / ST6 Packages
 - Unstructured Version
 - ▶ SWAN
 - Used in FEMA Regions
 - Hurricane Simulations (Katrina / Ike / Gustav, and others)
- WAM Cy4.5.1C
 - ▶ Used in IPET (Katrina Study)
 - ▶ FEMA
 - LA-East, LA-West, TX-North, TX-South, Great Lakes
 - Exercised using synthetic tropical storm simulations
 - ▶ Time Critical: Set-up in CSTORMS



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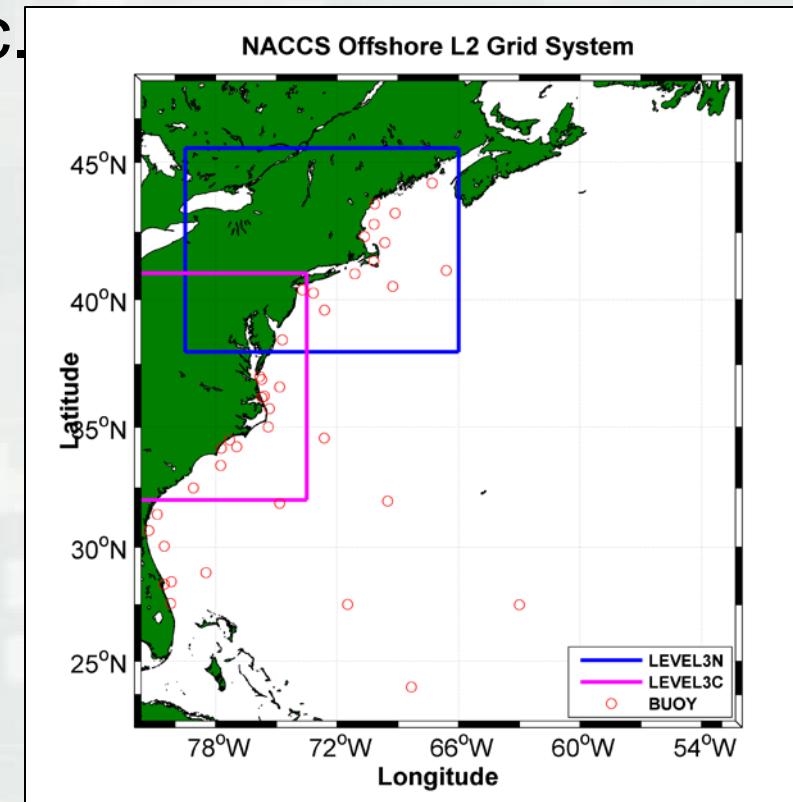
Offshore Wave Climate: Grid System

- Grid System
 - ▶ Derived from WIS Hindcast
 - ▶ Three Levels
 - L1: Atlantic Basin (Res: 1.0°)
 - L2: US Mainland (Res=0.25°)
 - L3: US Nearshore (Res=0.0833°)
 - ▷ L3N: North NACCS Domain
 - ▷ L3C: Central NACCS Domain
 - ▶ Bathymetry: GEBCO
 - ▶ Model
 - $\Delta\theta$: 5° (72 bands)
 - $f(n+1) = 1.1*f(n)$, $f_0=0.031$ (28 bands)



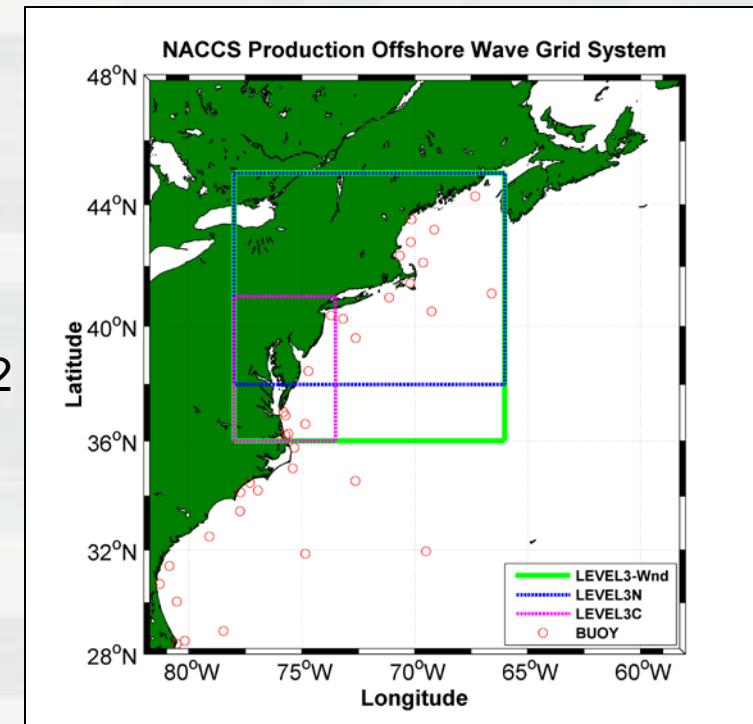
Offshore Wave Climate: Wind Fields

- WINDS: Oceanweather, Inc.
 - ▶ Forensics: WIS Data Base
 - NCEP/NCAR-R1
 - ▷ AES40 / MSC50
 - ▷ IOKA 6-hr snapshots
 - ▷ Embed all tropical cyclones
 - ▷ Blend to background winds
 - ▶ Characteristics
 - L1: Res: 1.0° / 6-hr
 - L2: Res: 0.25° / 1-hr
 - L3: Interpolated from L2
 - ▷ Bi-linearly interpolated (u, v, w)
 - ▷ Linear in time



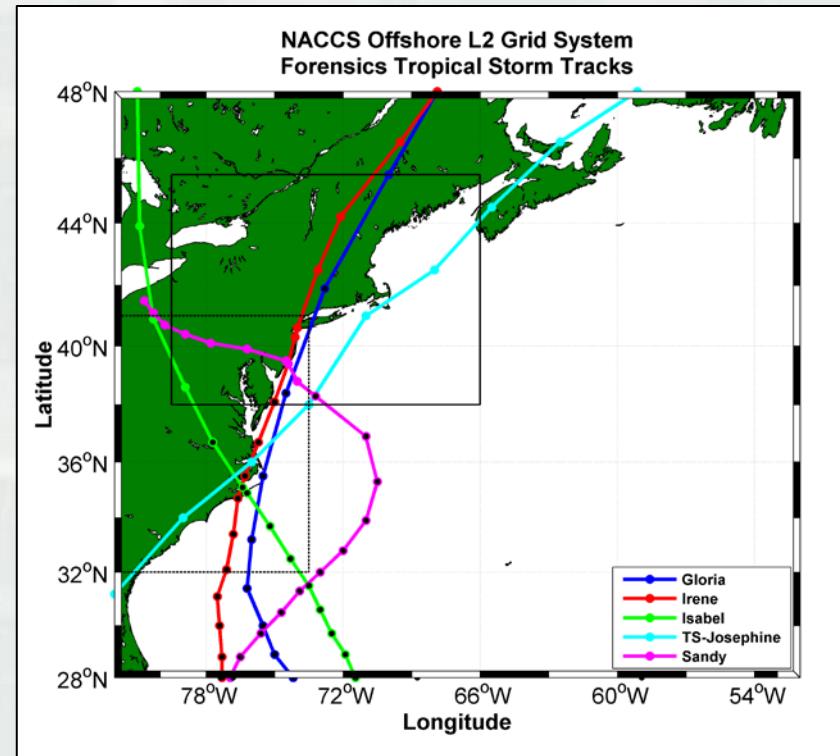
Offshore Wave Climate: Wind Fields

- WINDS: ET / S-TC
 - ▶ Production: OWI Generated
 - L2: Res: 0.25° / 0.25-hr (15-min)
 - L3:
 - ▷ Extra-tropical: Interpolated from L2
 - ▷ Tropical: Res: 0.125° / 0.083-hr (5-min)



Offshore Wave Climate: Storm Selection for Evaluation

- Extreme Storm Events
 - ▶ Tropical: 5 Events
 - Sandy / Irene / Isabel / Gloria / TS-Josephine
 - ▶ Extra Tropical
 - 7 Storms in ET List (based on WL)
 - 10 Supplemental Storms (Waves)
 - ▷ 11 point source measurements
 - ▷ Evaluated on extremes
 - ▷ Maximized number available sites
- TOTAL: 22 Events



Evaluate the wind field specification and wave model under
Extreme Storm Event Conditions.



Offshore Wave Climate: Evaluation Methods

- Individual Event
 - Level / Measurement Site
 - Integral wave properties (H_{mo} , T_p , T_{mean} , θ_{mean})
 - Graphics: Time / Scatter / Q-Q
 - Statistical Tests:
 - ▷ Bias / RMSE / SI / Corr / SymCorr /....



Offshore Wave Climate: Evaluation Methods

Number of Point Source Measurement Sites Forensic Testing								
Storm No.	Date	Description	WAM Grid Levels				Total	Total2
			Level1	Level2	Level3N	Level3C		
ET-0050-08	1984-03	-	3	1	0	1	5	
ET-0054-08	1987-01	-	3	0	0	1	4	
ET-0058-08	1991-02	-	10	5	1	3	19	
ET-0059-08	1991-01	-	9	5	1	2	17	
ET-0060-08	1992-12	-	7	5	1	2	15	
ET-0062-08	1993-03	Storm of Century	7	5	1	2	15	
ET-0065-08	1993-01	-	7	5	1	2	15	
ET-0066-08	1994-03	-	5	4	1	1	11	
ET-0069-08	1995-11	-	7	5	1	2	15	
ET-0070-08	1995-01	-	7	4	1	1	13	
ET-0073-08	1996-12	-	6	4	1	1	12	
ET-0080-08	2003-12	-	10	7	2	2	21	
ET-0086-08	2007-04	-	16	10	2	3	31	
ET-9301-12	2004-12	Added	10	7	1	2	20	
ET-9302-12	2005-03	Added	9	8	2	2	21	
ET-9303-12	2007-11	Added (Noel)	19	11	1	3	34	
ET-9304-12	2012-01	Added	37	29	10	9	85	353
TP-9001-16	2012-10	Sandy	24	17	6	5	52	
TP-9002-16	2011-08	Irene	26	16	4	7	53	
TP-9003-16	2003-09	Isabel	9	7	2	0	18	
TP-9004-16	1996-10	TS-Josephine	6	4	1	2	13	
TP-9005-16	1985-09	Gloria	3	1	0	1	5	141
TOTAL			240	160	40	54	494	

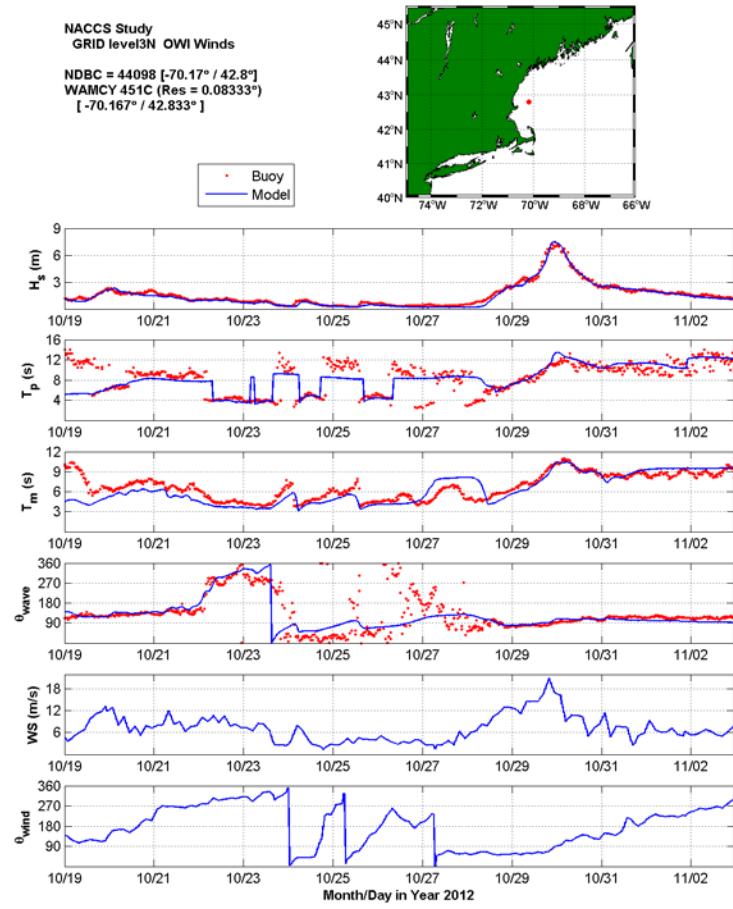
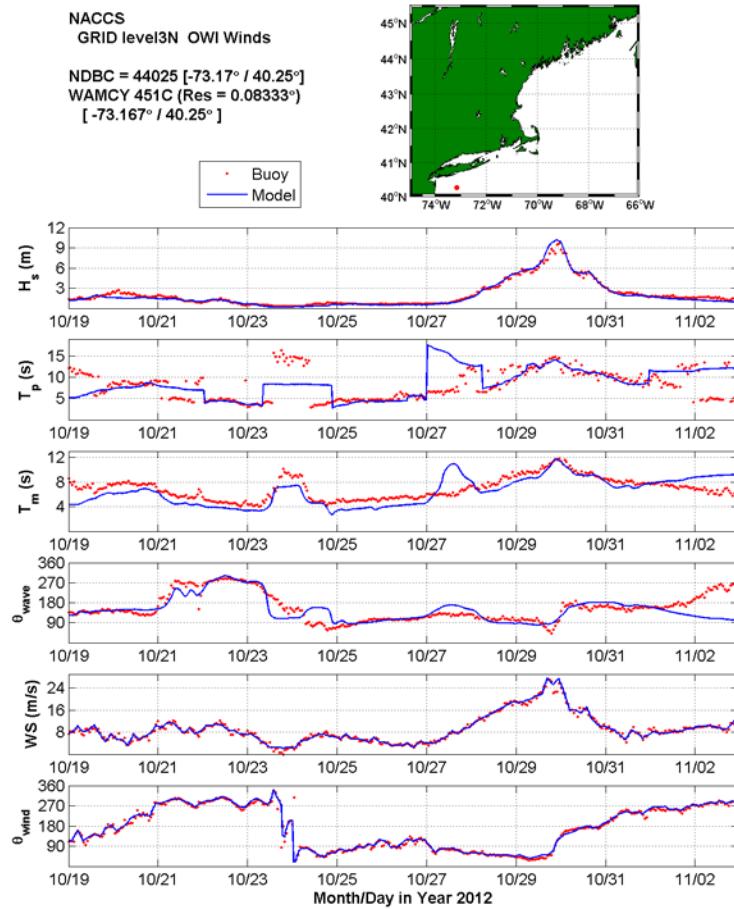


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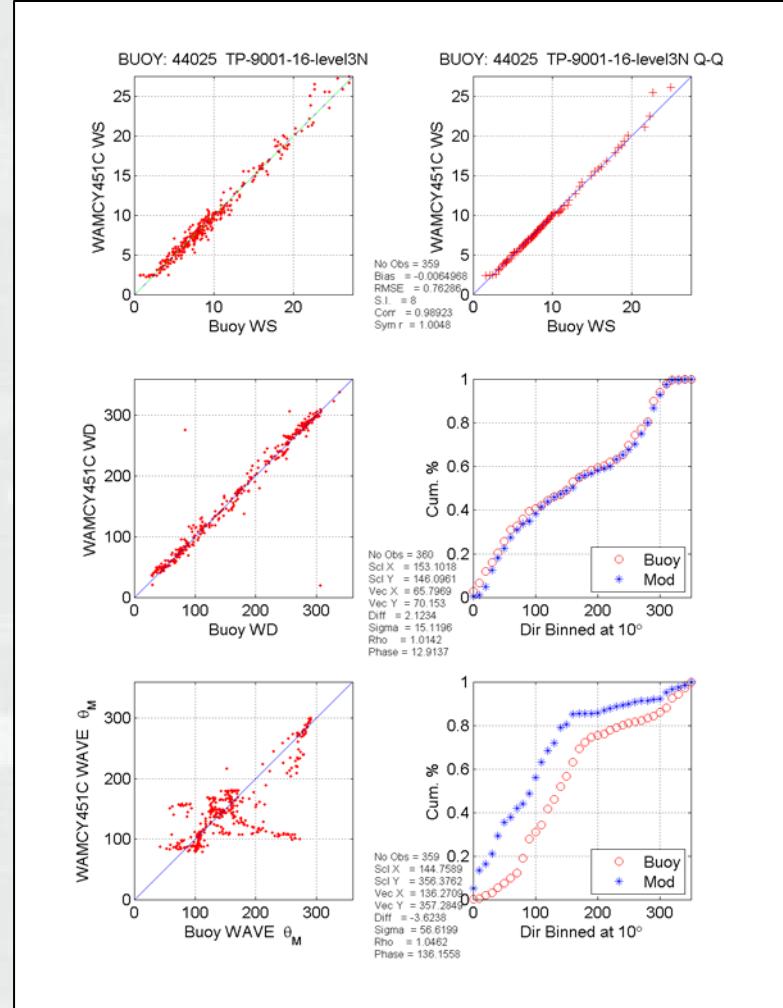
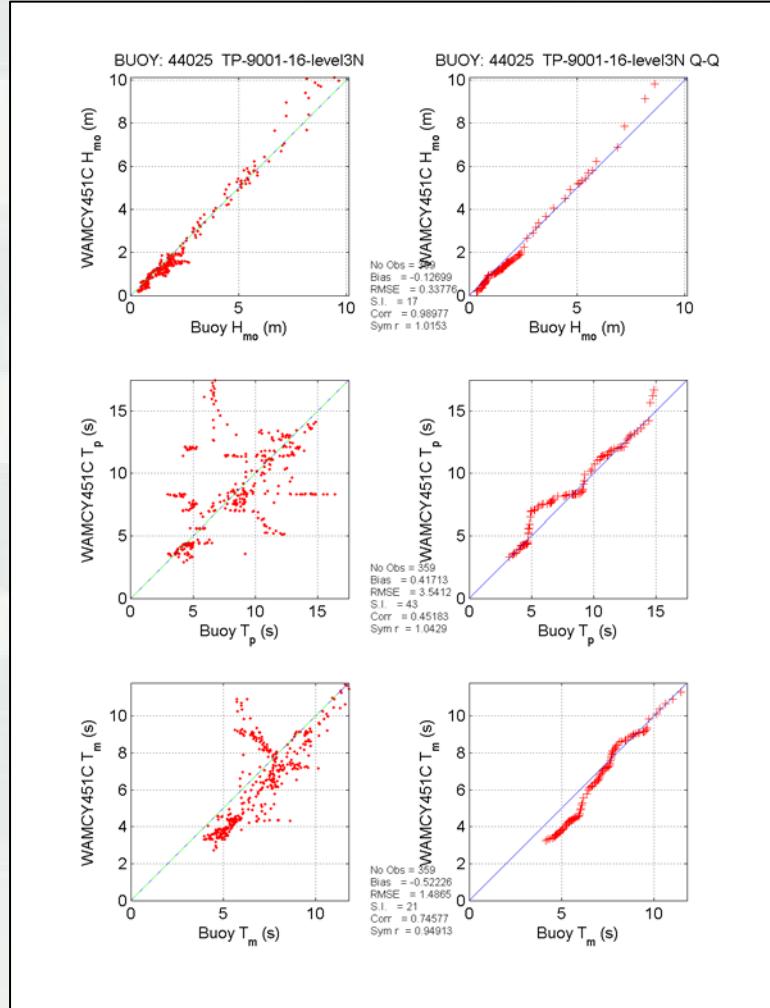
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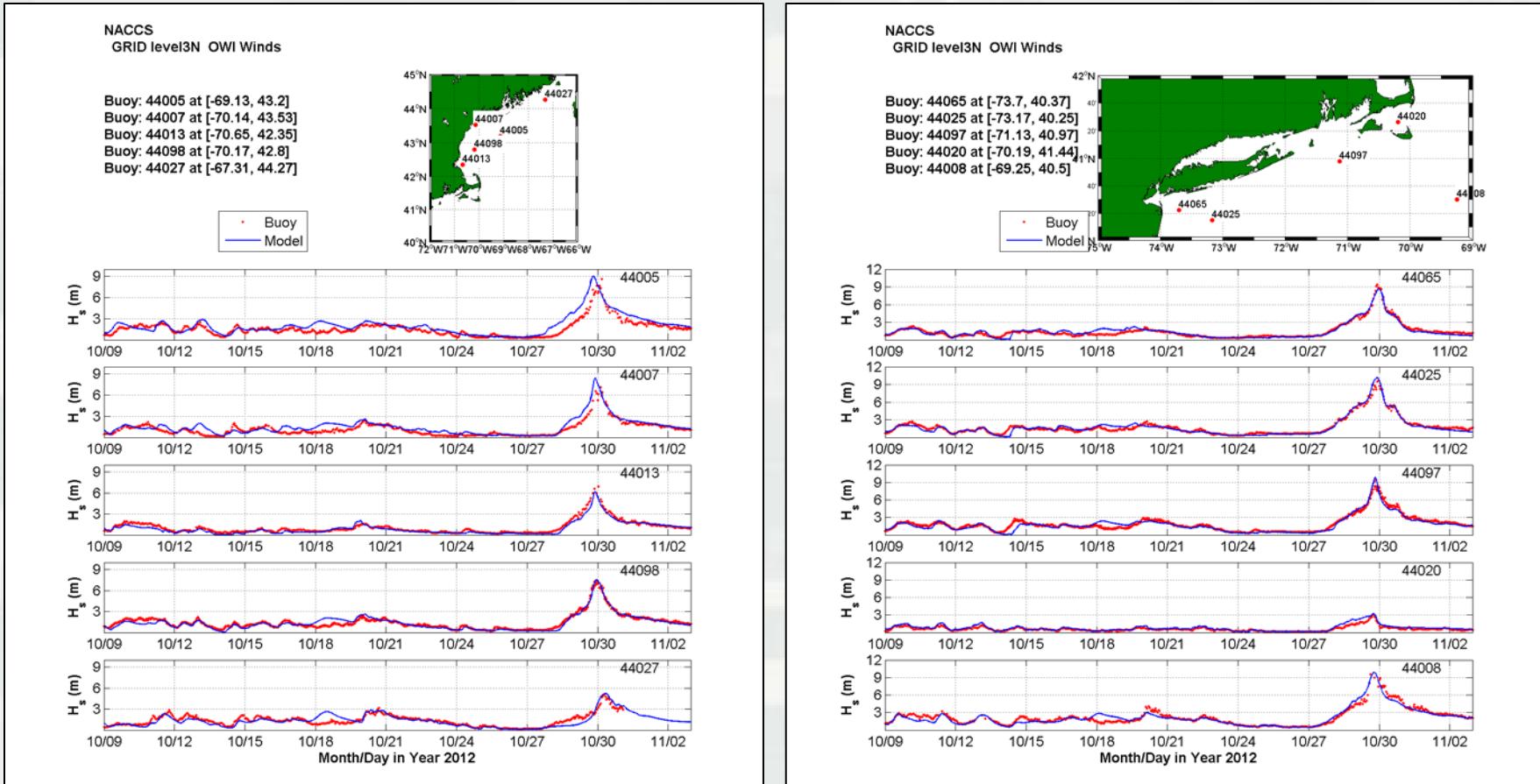
Offshore Wave Climate: Evaluation Methods / Sandy



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Offshore Wave Climate: Evaluation Methods / Sandy



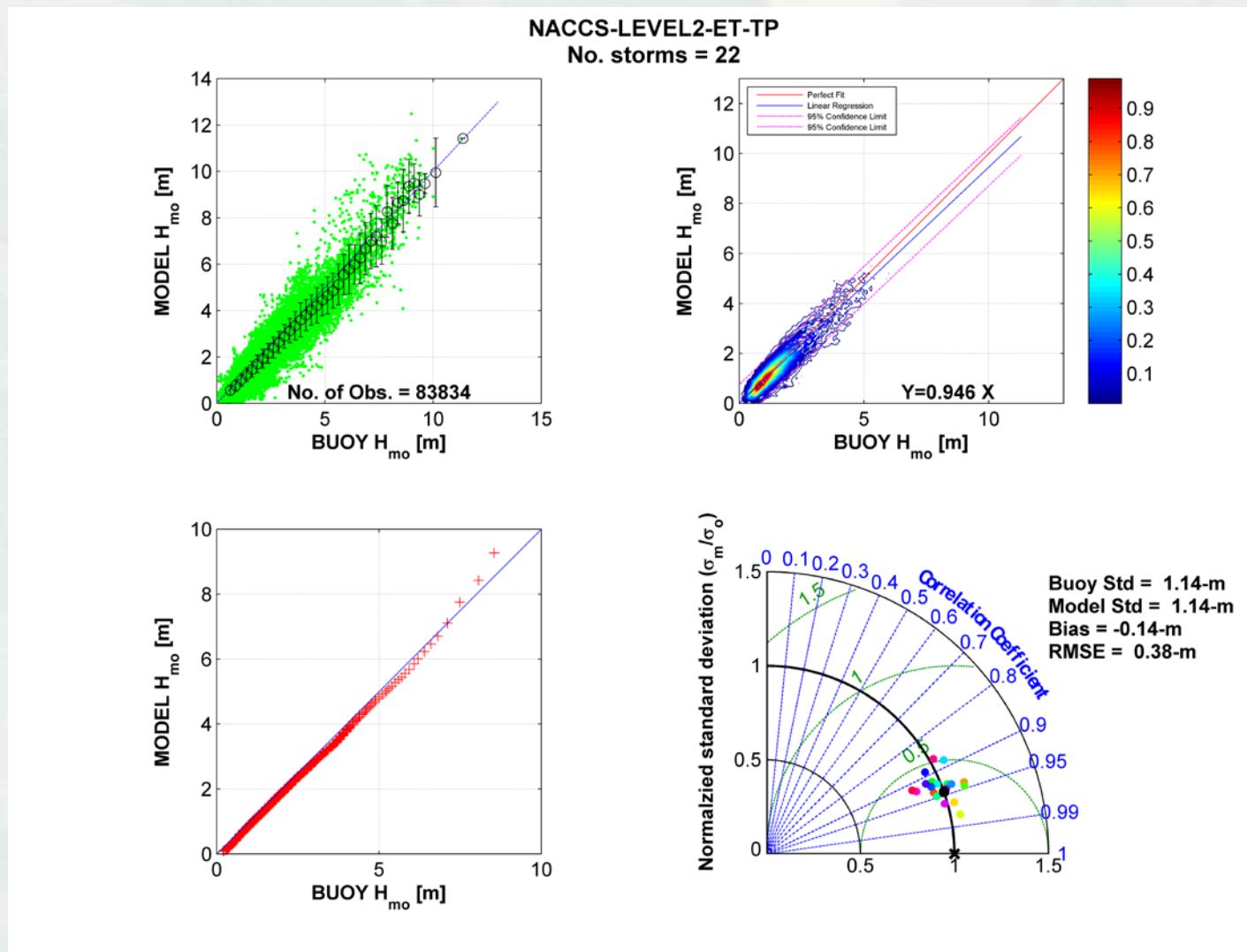
Compendium Plots of H_{mo} during Hurricane Sandy Simulation

Offshore Wave Climate: Evaluation Summary

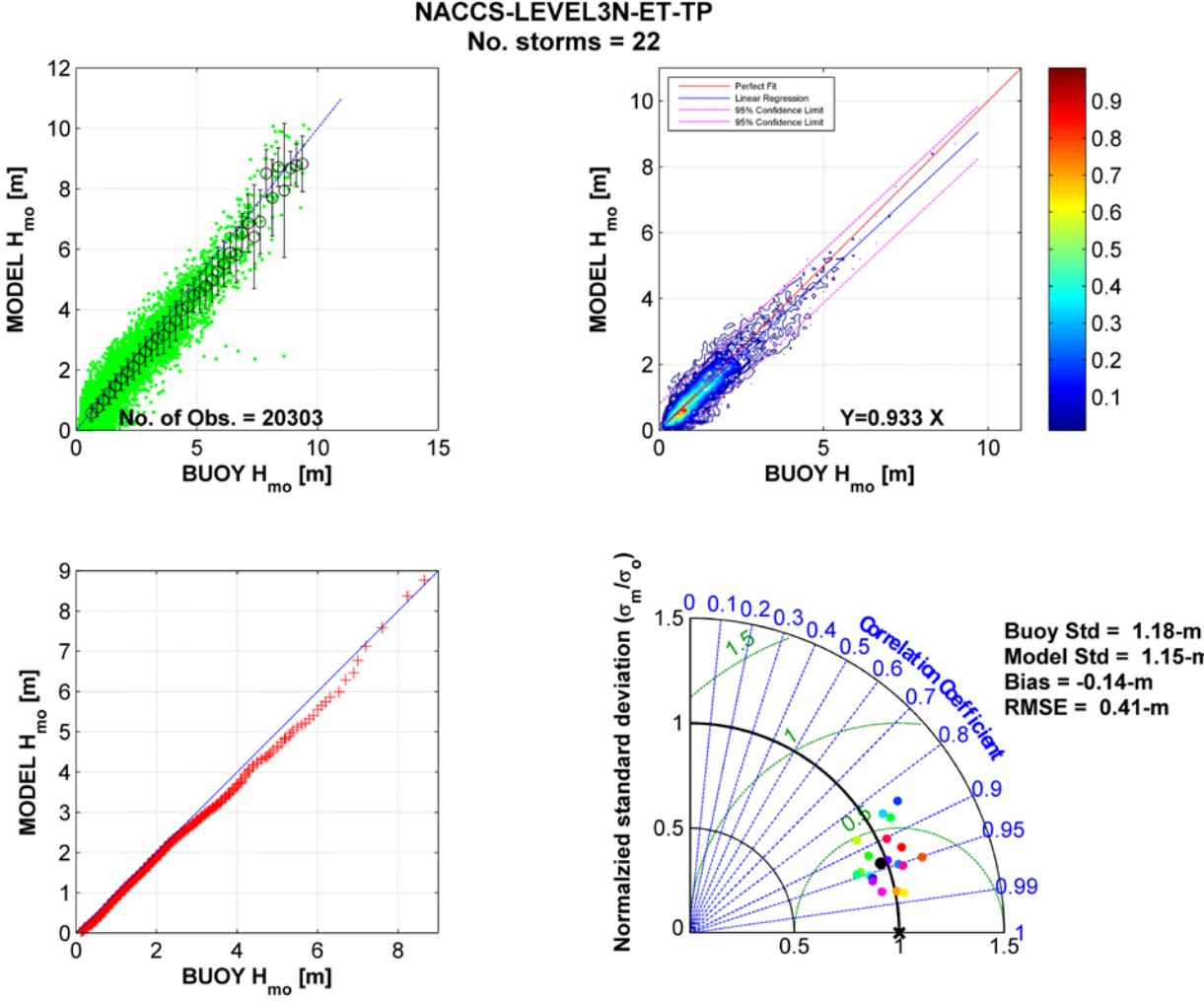
- Summary Graphics / Statistics
 - ▶ 22 Storm Events: 4 TC / 18 ET
 - ▶ Bin Average / Color Contour / Q-Q / Taylor Diagram
 - ▶ Statistical Test Summary: (H_{mo} , T_p , T_{mean} , θ_{mean} WS, WD)
 - Bias, RMSE, SI, Corr Coef, Sym Regression
 - Directional Difference, Root Mean Square Difference
- To provide sufficient information to assess
 - ▶ Quality in the wind and wave estimates
 - ▶ Quantify errors, isolated or persistent and correct



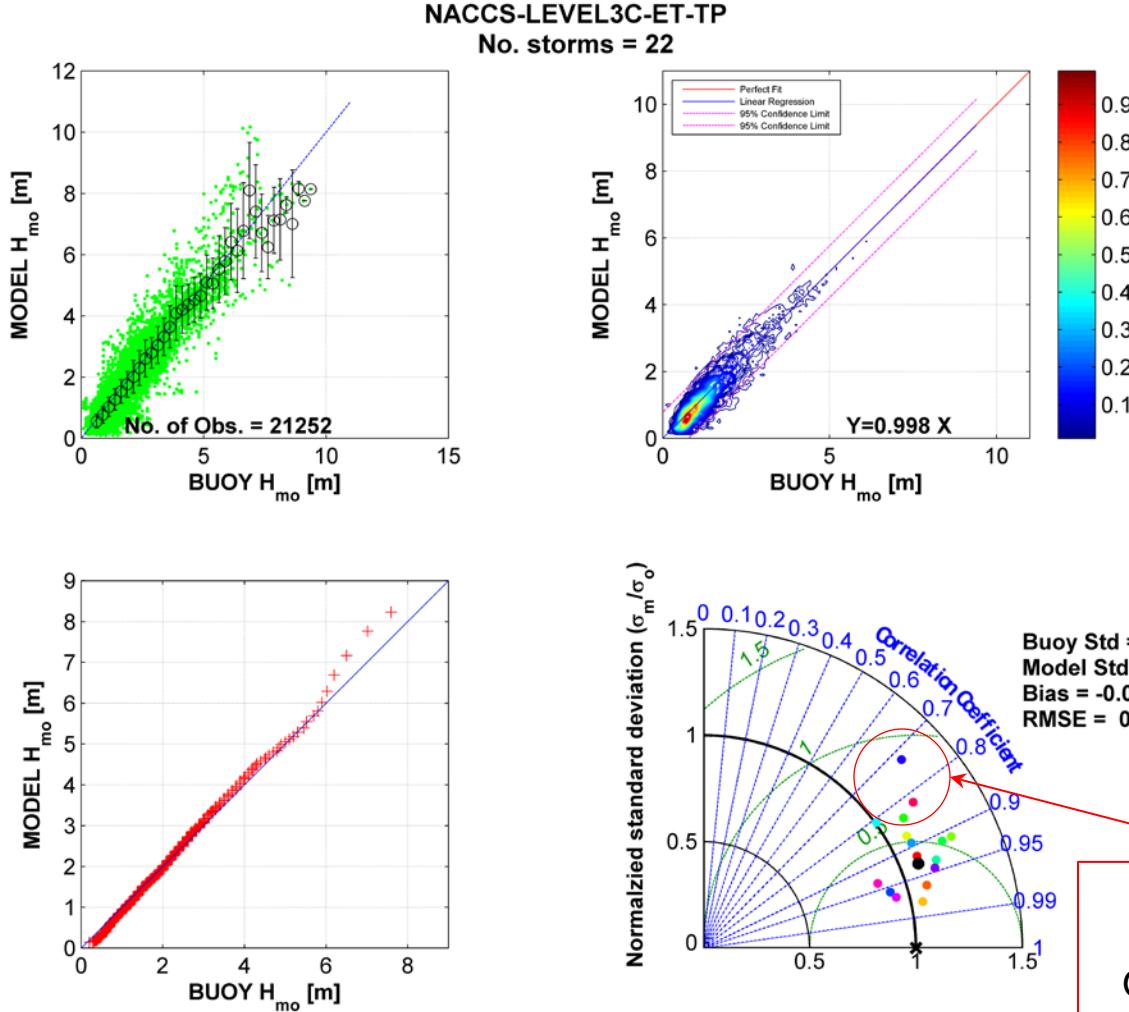
Offshore Wave Climate: Evaluation Summary



Offshore Wave Climate: Evaluation Summary



Offshore Wave Climate: Evaluation Summary



Offshore Wave Climate: Evaluation Summary

Summary Statistics Forensic Storm Simulations (Wind Speed)								
Level	No. Obs	Mean WSpd		Bias (m/s)	RMSE (m/s)	SI (%)	Sym R	Corr Coef
		Meas	Model					
L2	67579	8.06	8.33	0.27	1.28	16	1.016	0.948
L3N	13829	8.65	8.84	0.22	1.40	16	1.011	0.943
L3C	13672	8.24	8.61	0.37	1.74	21	1.028	0.913

Summary Statistics Forensic Storm Simulations (Hmo)								
Level	No. Obs	Mean Hmo		Bias (m)	RMSE (m)	SI (%)	Sym R	Corr Coef
		Meas	Model					
L2	83834	1.69	1.56	-0.13	0.36	23	0.955	0.952
L3N	20303	1.56	1.42	-0.15	0.36	23	0.936	0.954
L3C	21252	1.42	1.35	-0.07	0.39	27	0.998	0.934

Summary Statistics Forensic Storm Simulations (Tmean)								
Level	No. Obs	Mean Tmean		Bias (s)	RMSE (s)	SI (%)	Sym R	Corr Coef
		Meas	Model					
L2	84381	6.68	5.89	-0.79	1.38	21	0.900	0.703
L3N	20313	6.27	5.65	-0.62	1.59	25	0.922	0.659
L3C	21272	6.30	5.62	-0.68	1.52	24	0.915	0.594



Offshore Wave Climate: Evaluation Summary

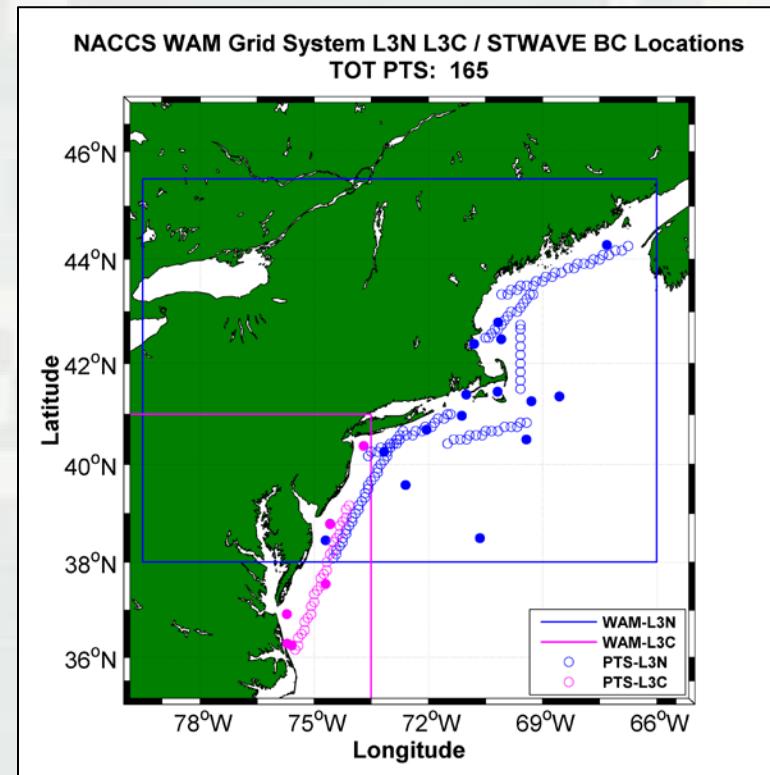
Summary Statistics Forensic Storm Simulations (Wind Dir)			
Level	No. Obs	Bias (°)	RMSD (°)
L2	66616	0.78	27.08
L3N	13551	0.98	28.71
L3C	13013	4.11	34.79

Summary Statistics Forensic Storm Simulations (Wave Dir)			
Level	No. Obs	Bias (°)	RMSD (°)
L2	67579	0.04	55.64
L3N	13829	-0.34	55.56
L3C	13672	4.58	64.27



Offshore Wave Climate: Summary & Conclusions

- 22 Storm events evaluated (4 TC/ 18 ET)
 - ▶ Estimates of winds (OWI) & waves (WAM) demonstrate consistency
 - ▶ Statistics
 - Low Bias, SI
 - Good Correlation
 - Symmetric Regression below 1.0
 - Moderate RMSE
 - ▶ L3C: poorest of all
 - Sites south of NACCS boundary
 - Limited number of sites available
 - ▶ T_p / T_{mean}
 - Pre-swarms on Sandy
 - Poor correlation (wind-sea/swell transition)
- Moved to Production



QUESTIONS



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