

State of New Jersey
New Jersey Board of Public Utilities (NJBPUB)



An Advanced Atmosphere/Ocean Assessment Program: Reducing the Risks Associated with NJ Offshore Wind Energy Development

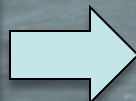
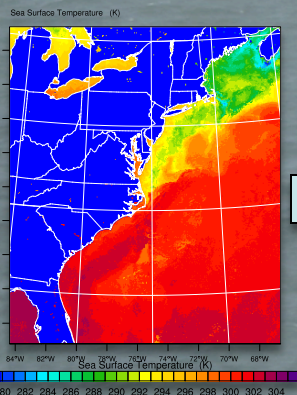
As Defined by The NJ Energy Master Plan, The NJ Offshore Wind Energy Economic Development Act,
And NJBPUB's Offshore Wind Renewable Energy Rules



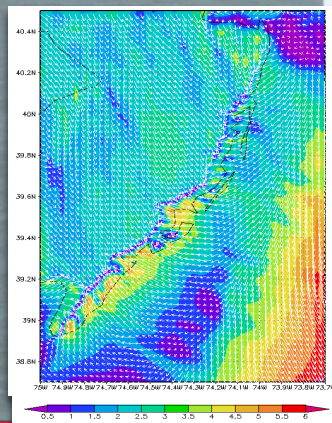
Principal Investigators: *Dr. Scott Glenn and Dr. Rich Dunk, CCM*
Team Members: *Dr. Josh Kohut, Dr. Hugh Roarty, Dr. Travis Miles,
Greg Seroka, John Kerfoot, Laura Palamara,
Mike Crowley, Ethan Handel, Colin Evans*

New Ocean Data

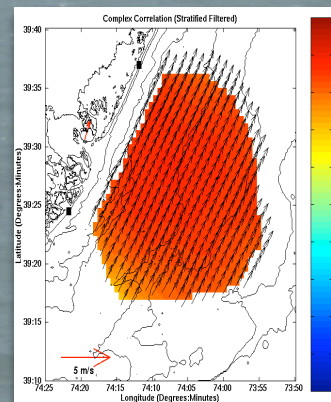
COLD: RTG+SPoRT(9/6)+Lisa(8/04)2011-08-27_00:00:00



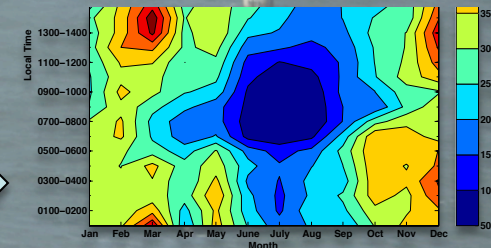
Hi-Res Weather Model



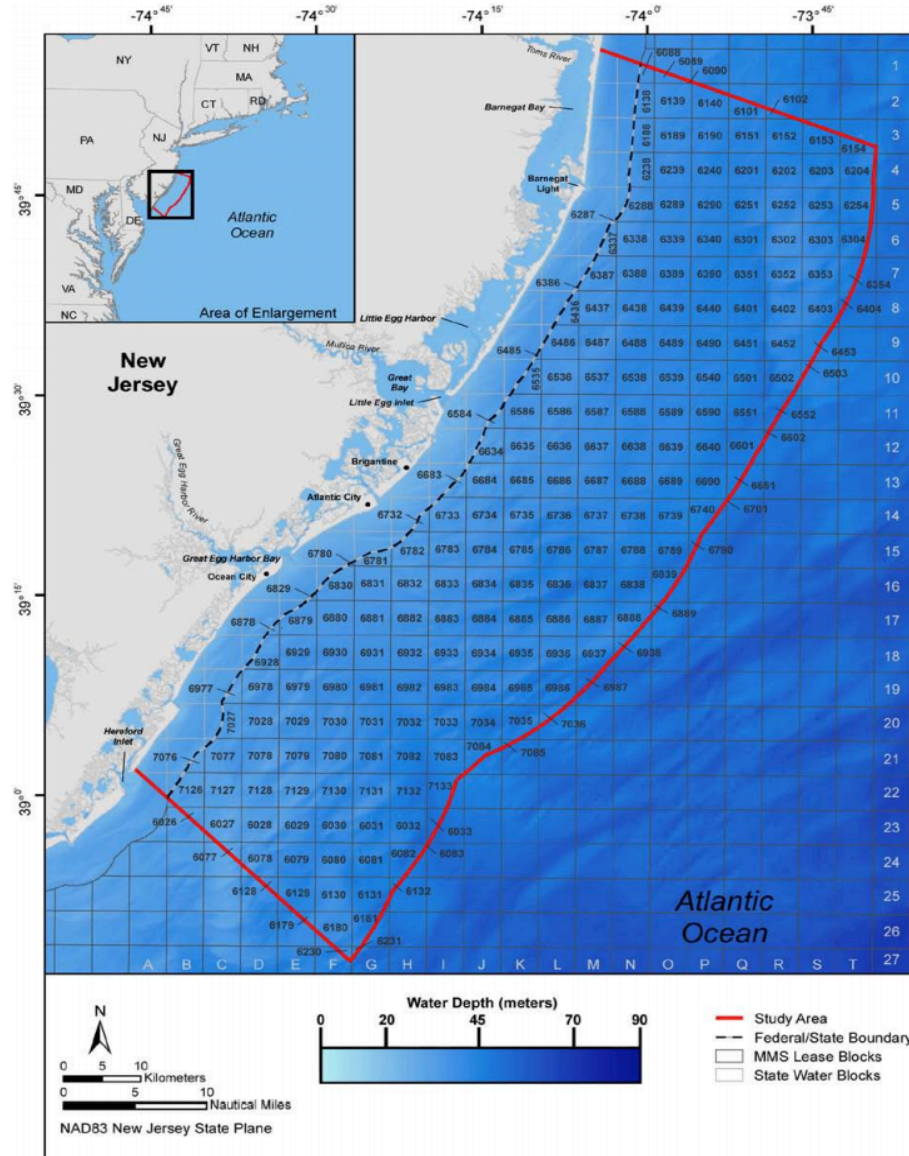
Spatial Validation Data



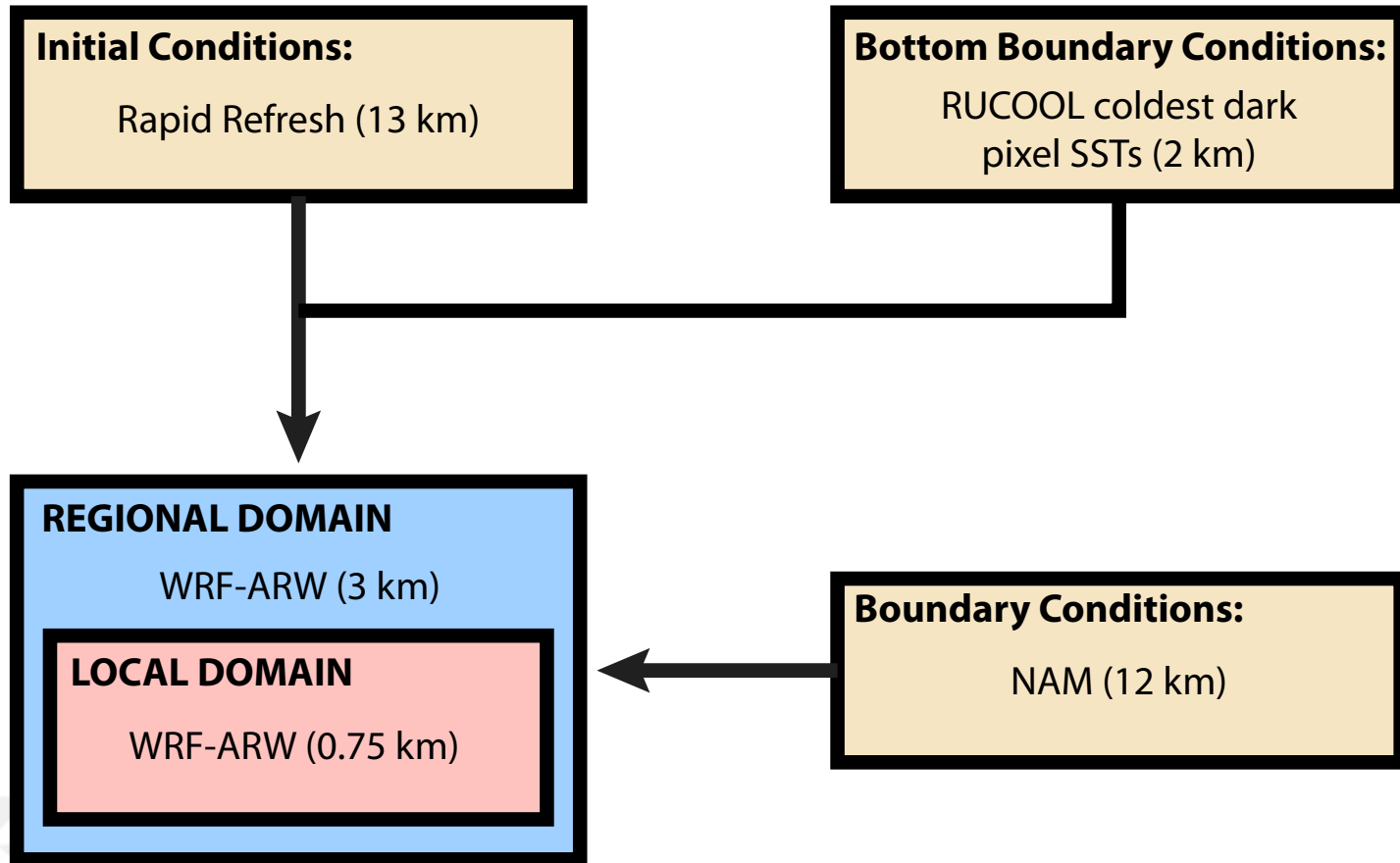
Wind Power Statistics



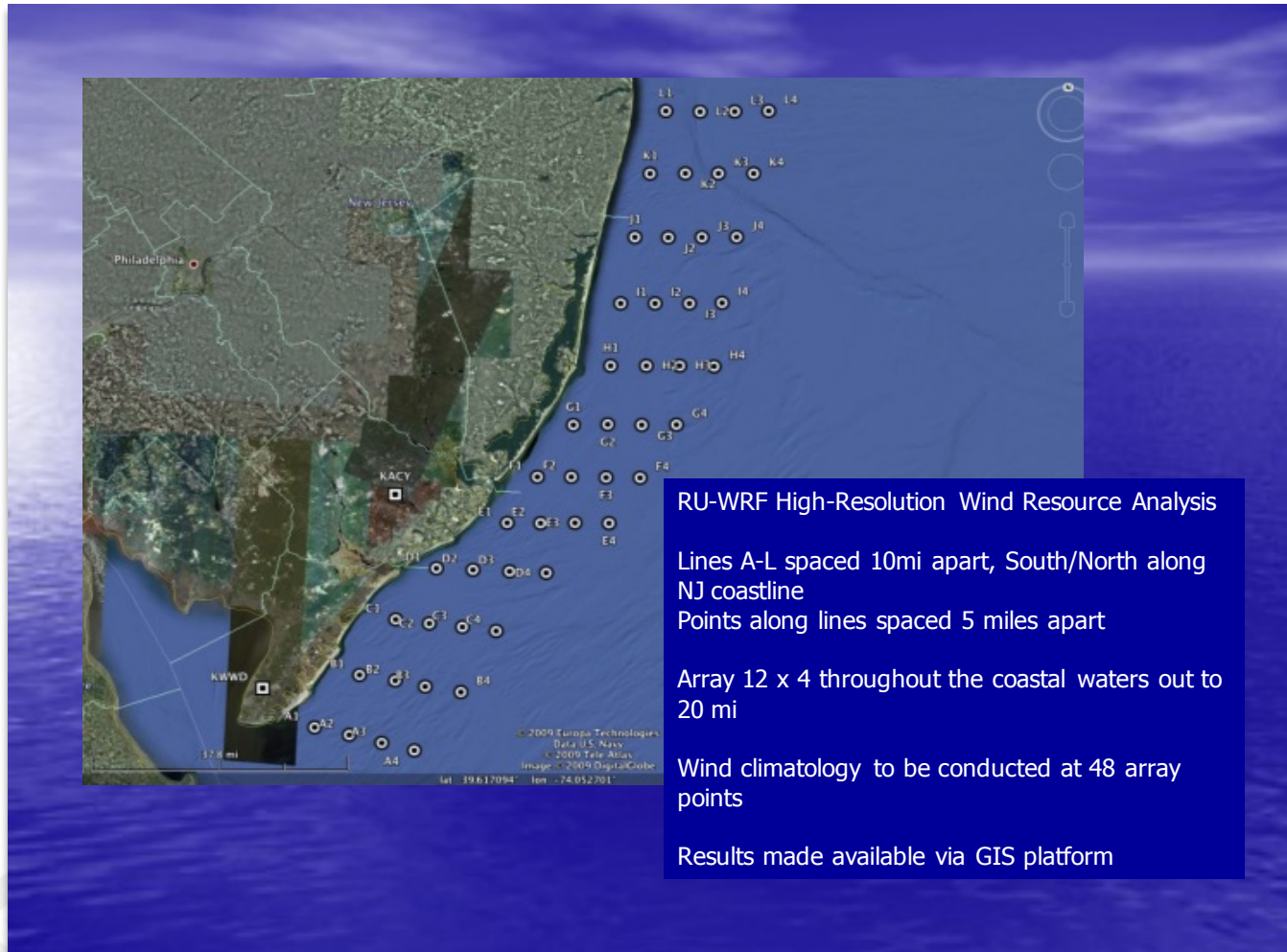
Study Area



RU-WRF Flow Chart



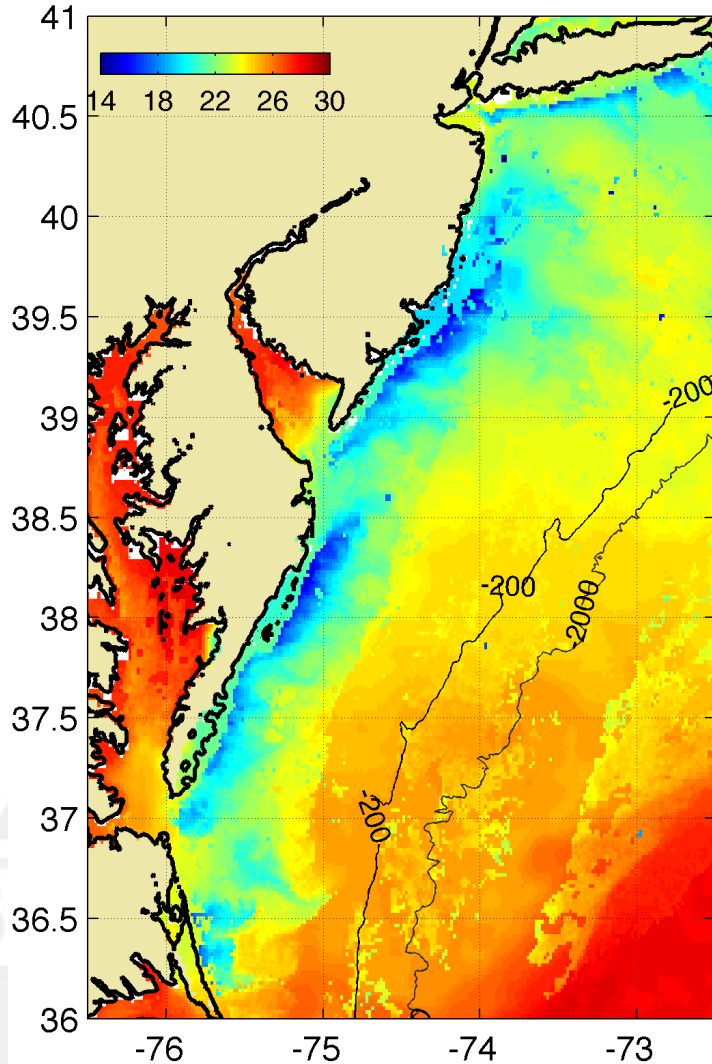
“Virtual Meteorological Tower” Locations



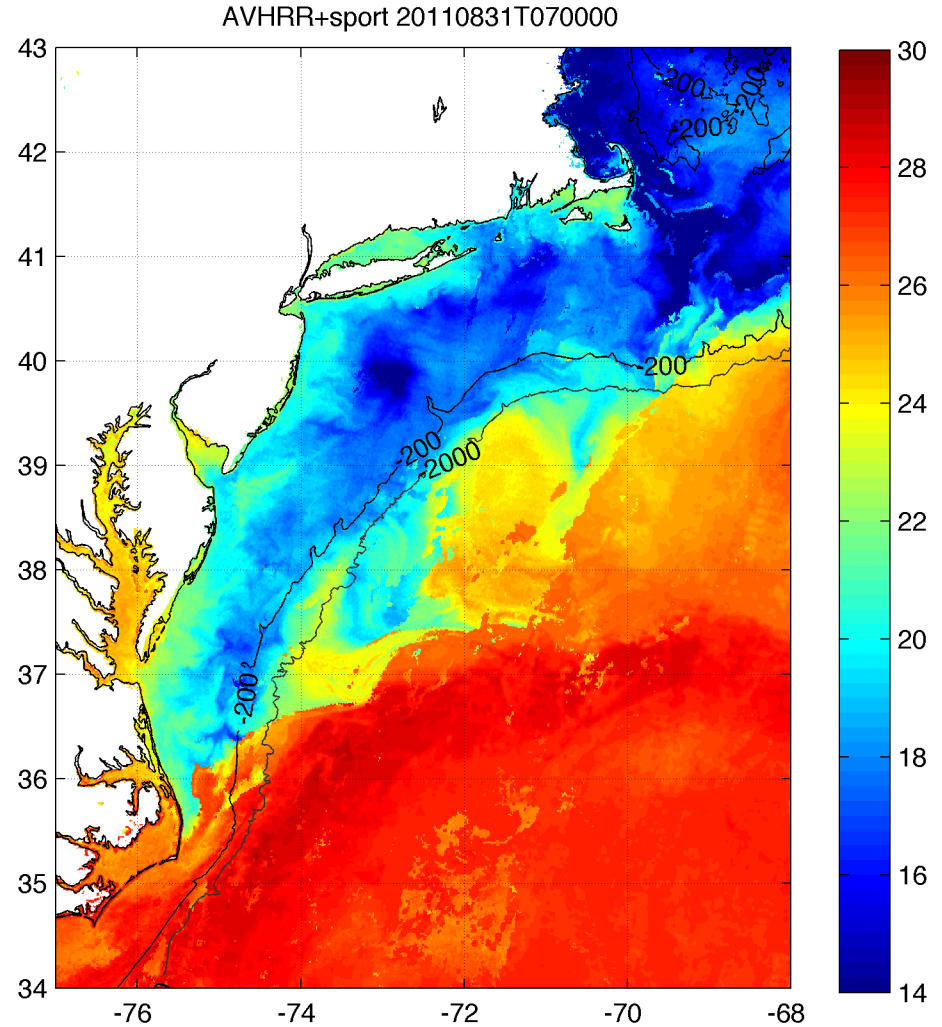
- At heights of <80, 80, 90, 100, 110, 120, and >120 m depending on atmospheric conditions

RUCOOL SST Satellite Composite

Coastal upwelling



Hurricane cooling



RU-WRF in Real-Time

<http://rucool.marine.rutgers.edu/COOL-Data/ruwrf-model-output>

Thursday, May 09, 2013

TEXT SIZE - +

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RUWRF Model Output

RUWRF 3 km

Initial Condition: 0000Z 13km Rapid Refresh (Forecast Hour 00)

Bottom Boundary Condition: Rutgers SST Composite

NJ Zoom Bottom Boundary Condition: NJ Zoom Rutgers SST Composite

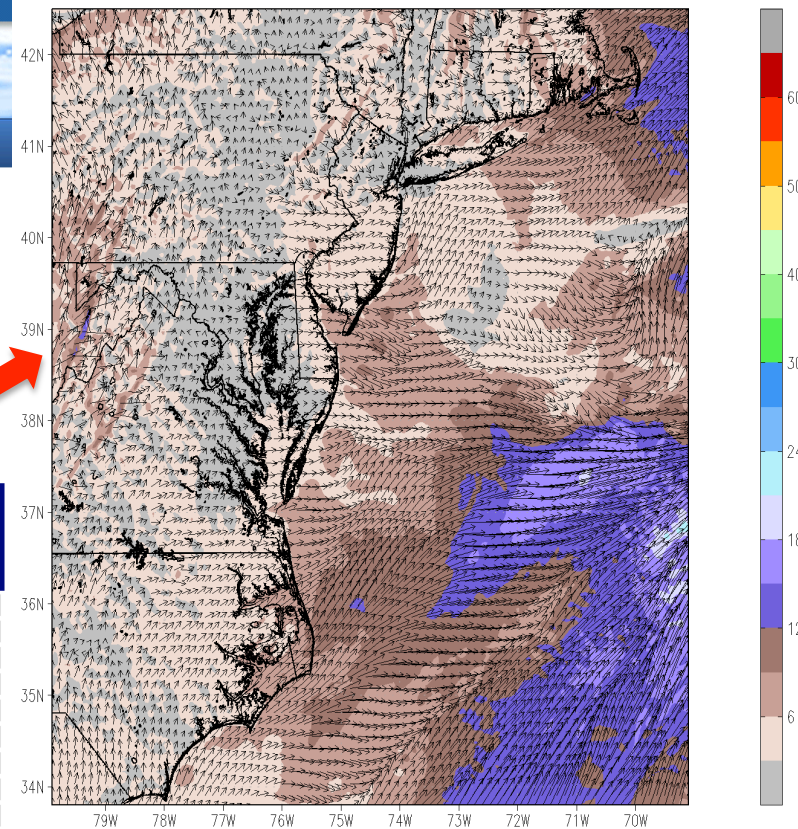
Boundary Conditions: 0000Z 12 km NAM-218 (Forecast Hour 03 to 84)

Boundary Conditions updated every 3 hours

RUWRF 3 km - Initialized at 0000Z
Model Simulation Complete: 09 May 2013 AT 0000Z EASTERN TIME

GMT Time	00	03	06	09	12	15	18	21	00	03	06	09	12	15	18	21	00	
Wind Speed @ 10m	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42	45	48	Animation
Wind Gust @ 10m	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42	45	48	Animation
Temperature @ 2m	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42	45	48	Animation
Relative Humidity @ 2m	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42	45	48	Animation
Sea Surface and Skin Temperature	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42	45	48	Animation
Sea Level Pressure	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42	45	48	Animation
Radar Reflectivity	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42	45	48	Animation
Hourly Rainfall	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42	45	48	Animation
Accumulated Rainfall	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42	45	48	Animation
Hourly Snowfall	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42	45	48	Animation
Accumulated Snowfall	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42	45	48	Animation
Precipitation Type	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42	45	48	Animation
NY Bight Winds @ 10m	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42	45	48	Animation
NY Bight Wind Gusts @ 10m	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42	45	48	Animation
NY Bight Temperature @ 2m	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42	45	48	Animation
850 mb Wind/Temp/Hgt	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42	45	48	Animation
700 mb Hgt and RH	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42	45	48	Animation
1000-500 mb Thickness	00	03	06	09	12	15	18	21	24	27	30	33	36	39	42	45	48	Animation

Wind Speed at 10 m [kts]



RU Coastal Ocean Observation Lab: RUWRF-ARW 3 KM Model Initialized 00Z09MAY2013
<http://marine.rutgers.edu/cool/weather> Valid 12Z10MAY2013 (Fri) | Forecast Hour 36

Coastal/Offshore Monitoring

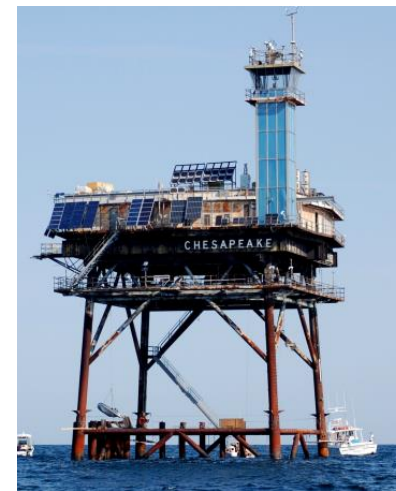
Meteorological Tower



Meteorological Buoy



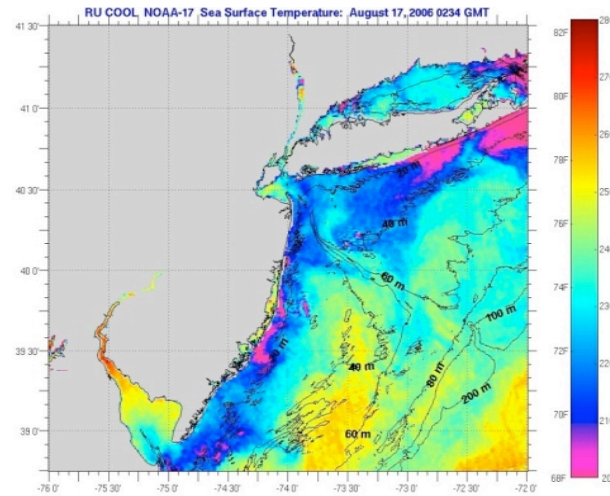
Chesapeake Bay



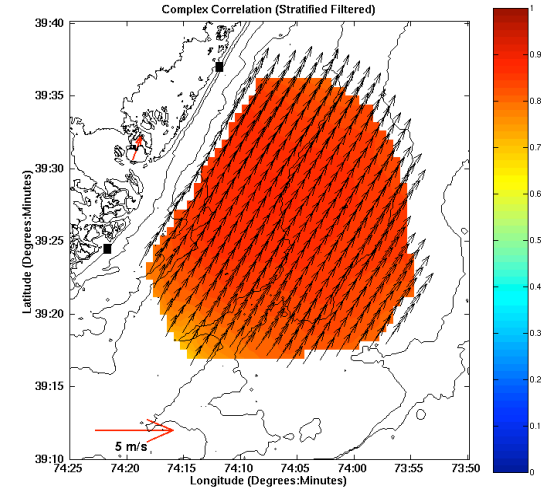
Buzzards Bay



Infrared Satellite



Coastal Radar (CODAR)



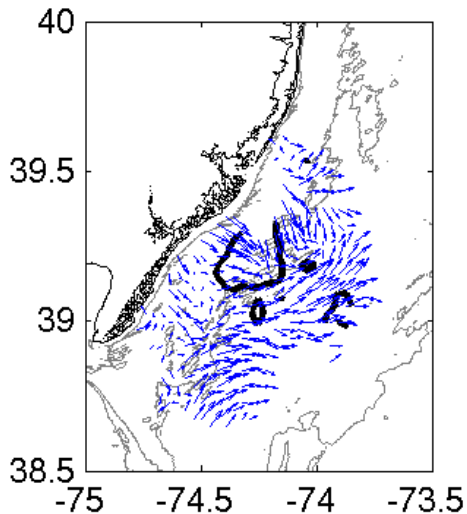
Vertical Validation Results

Site	Delaware Bay Buoy	Buzzards Bay	Chesapeake Light	Brandywine Light	Ship John Shoal	Oyster Creek
	44009	BUZM3	CHLV2	BRND1	SJSN4	OYC
Observation Height (m)	5	24.8	43.3	19.3	20.4	115
Observed Average Wind Speed (m/s)	5.70	7.59	7.54	6.07	5.60	6.41
Observed Standard Deviation (m/s)	3.24	3.91	3.79	3.00	3.02	2.80
RUWRF Average Wind Speed (m/s)	5.75	7.30	7.72	6.59	5.51	6.49
RUWRF Standard Deviation (m/s)	2.89	3.53	3.42	3.26	2.85	2.98
Model Bias (m/s)	0.04	-0.29	0.18	0.52	-0.09	0.09
RMSE (m/s)	3.46	2.42	2.77	2.27	2.14	2.06
RMSE unbiased (m/s)	3.46	2.43	2.76	2.35	2.13	2.06
Criterion 1 (% diff between σ_{RUWRF} and σ_{Obs})	10.66%	9.78%	9.82%	-8.62%	5.53%	-6.40%
Validated	No	Yes	Yes	Yes	Yes	Yes
Criterion 2 ($RMSE / \sigma_{Obs} * 100$)	107.0%	61.9%	73.1%	75.7%	70.9%	73.6%
Validated	No	Yes	Yes	Yes	Yes	Yes
Criterion 3 ($RMSE_{ub} / \sigma_{Obs} * 100$)	107.0%	62.1%	72.9%	78.3%	70.6%	73.6%
Validated	No	Yes	Yes	Yes	Yes	Yes

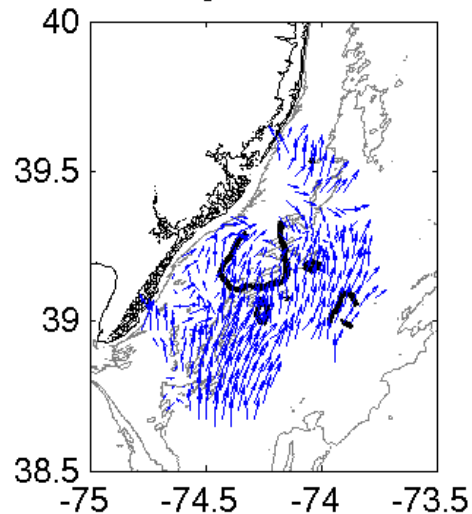
*Based on standard validation criteria for mesoscale atmospheric models (Pielke, 1984; Dvorak et al., 2012)

Horizontal Evaluation Results

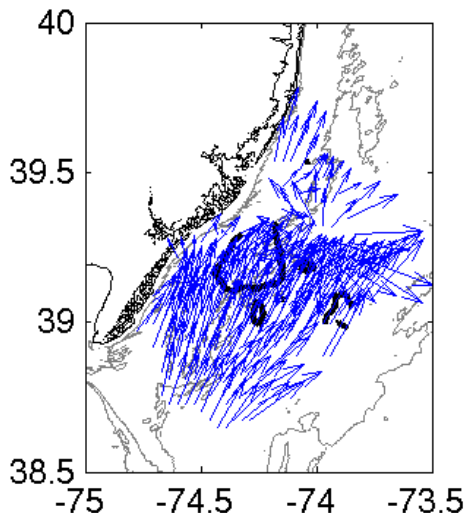
CODAR Detided Currents 2012-09-05 23:00



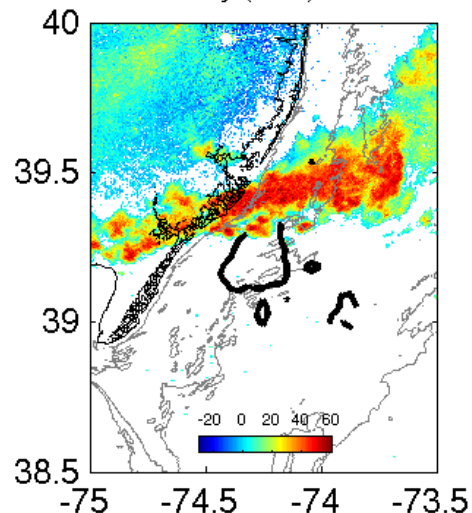
CODAR 3-hr Lag Wind 2012-09-05 23:00



RUWRF Wind 2012-09-05 23:00



RADAR Reflectivity (dBZ) 2012-09-05 22:58



More Coastal/Offshore Monitoring

Chesapeake Light Tower

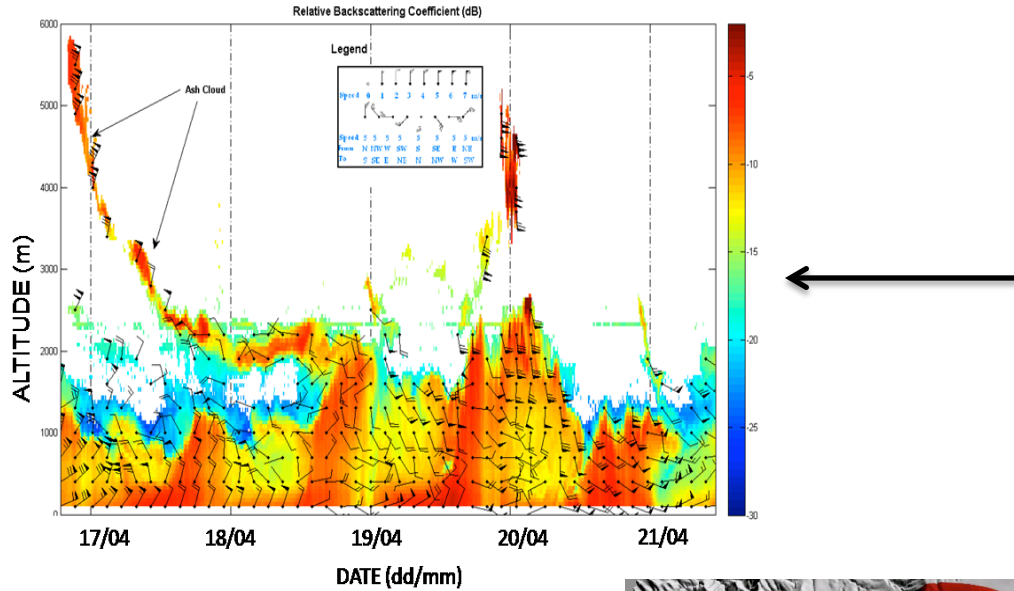


Current

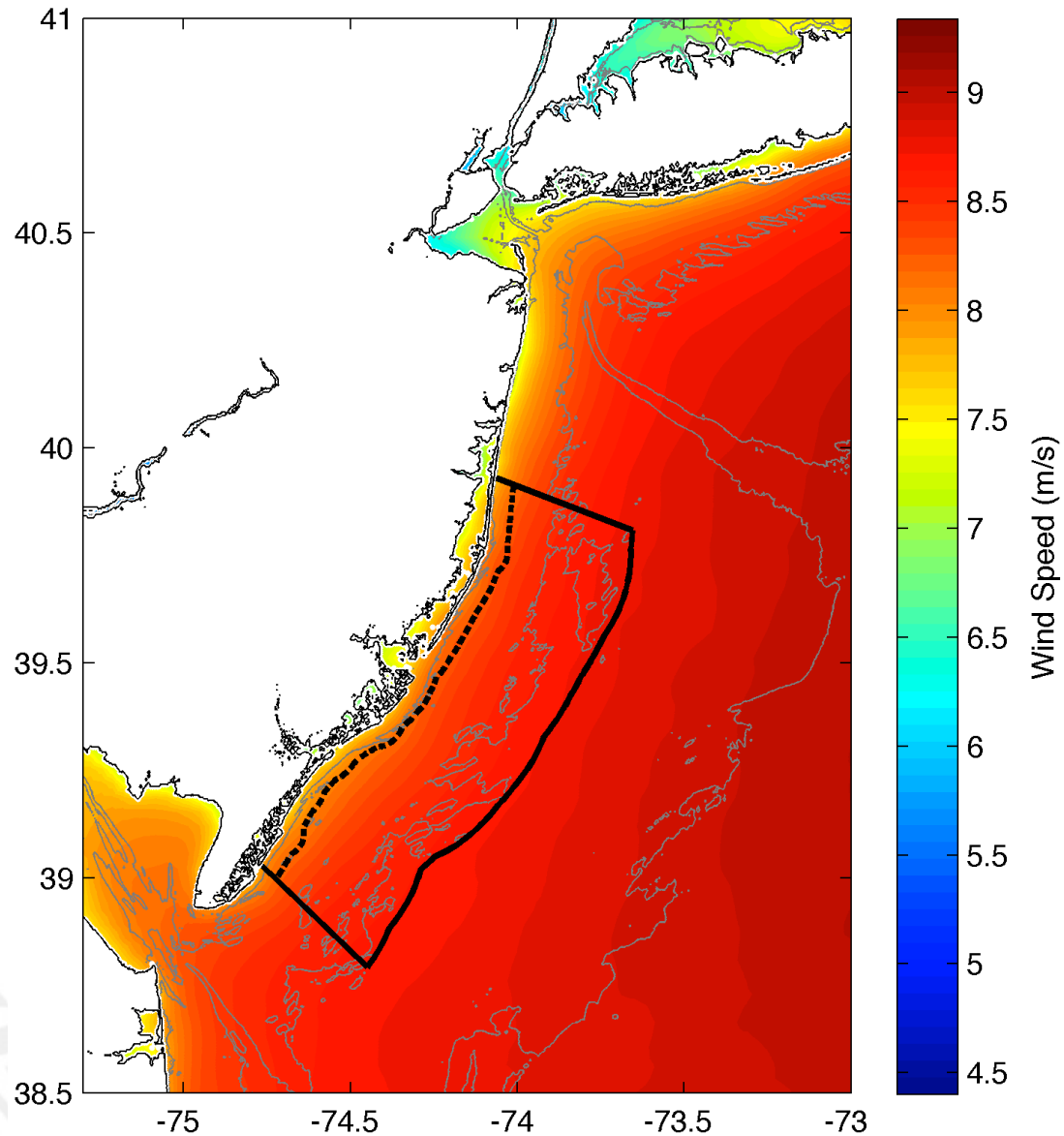


Future

Scanning and Vertical LIDARs



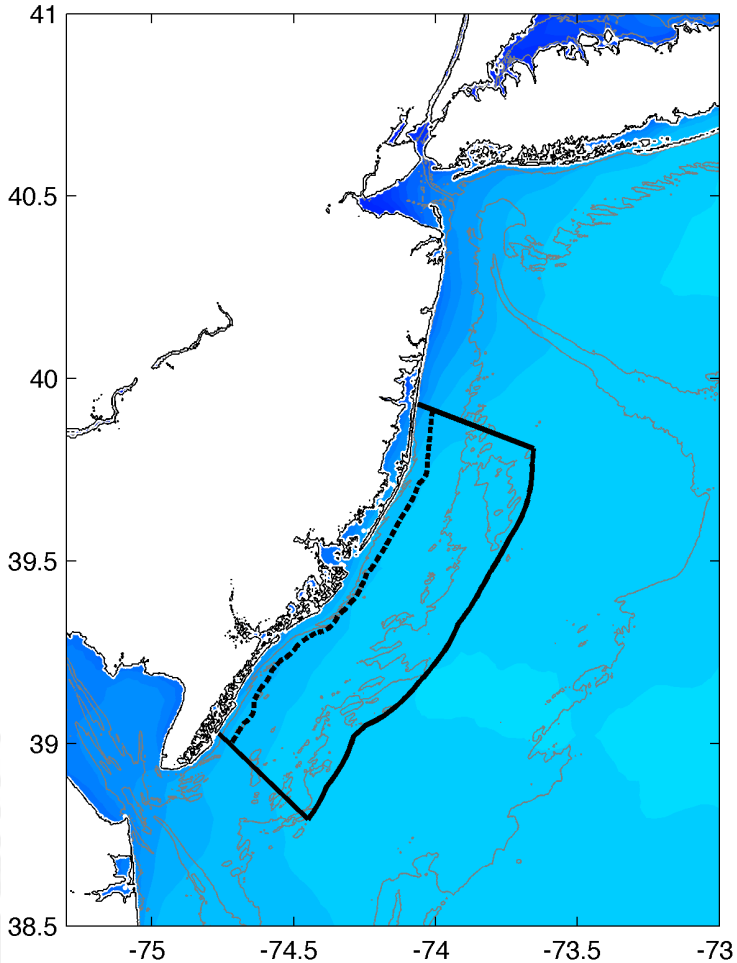
Annual Average 100m Wind Speed



Seasonal 100m Wind Speed

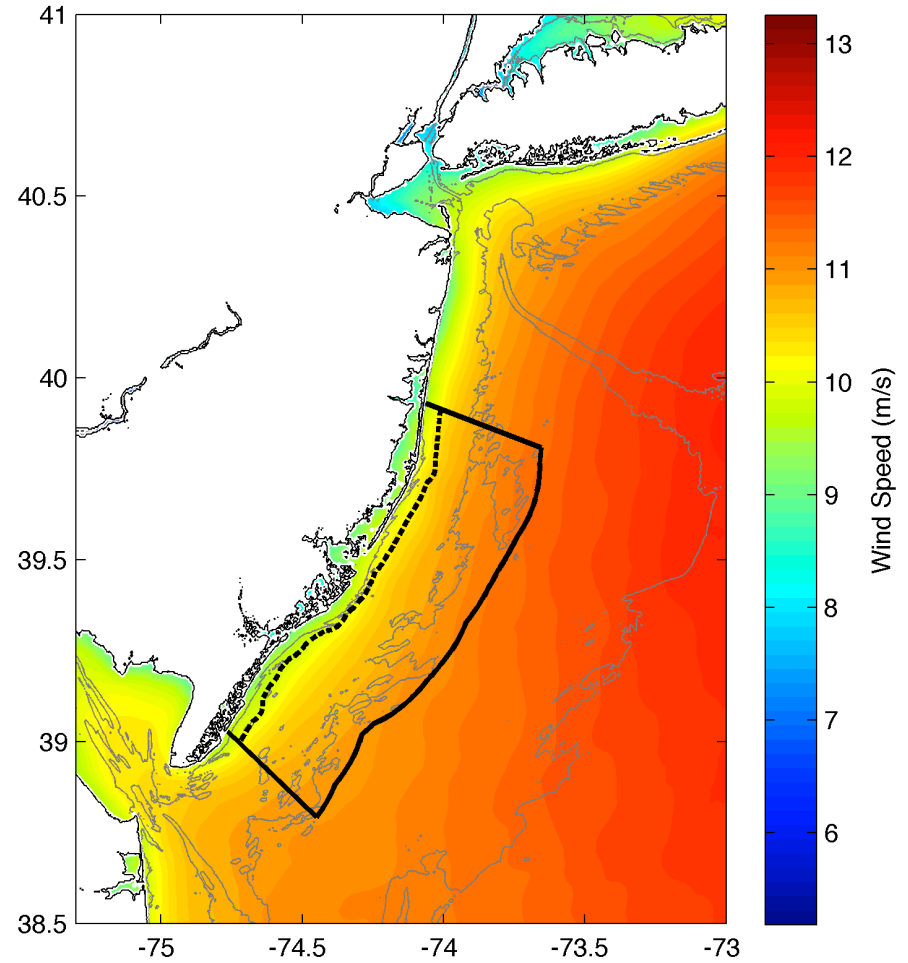
Summer

JJA 100m



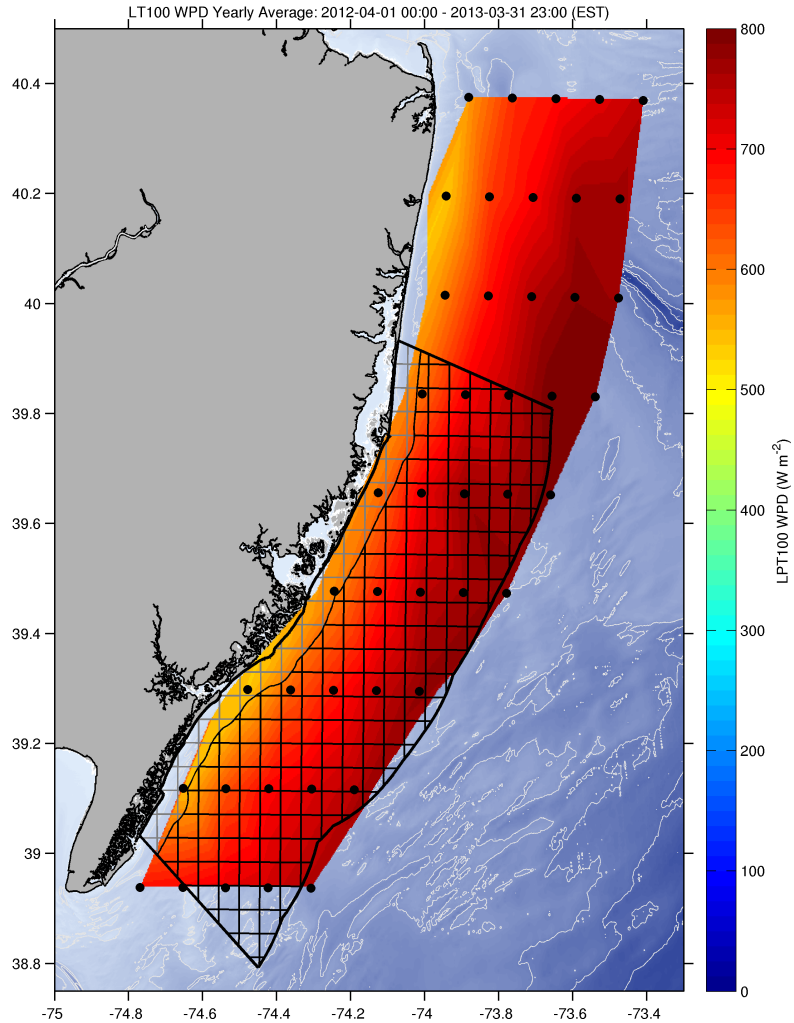
Winter

DJF 100m

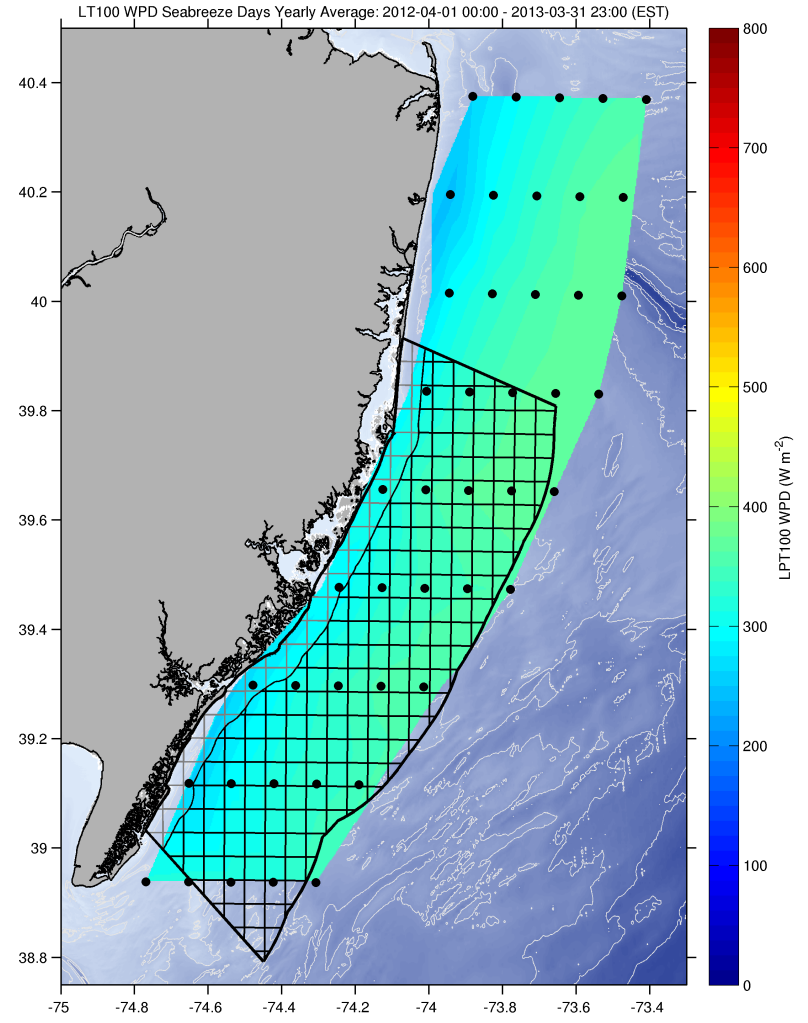


Annual Average vs. Sea Breeze Days

Annual Average



Sea Breeze Average

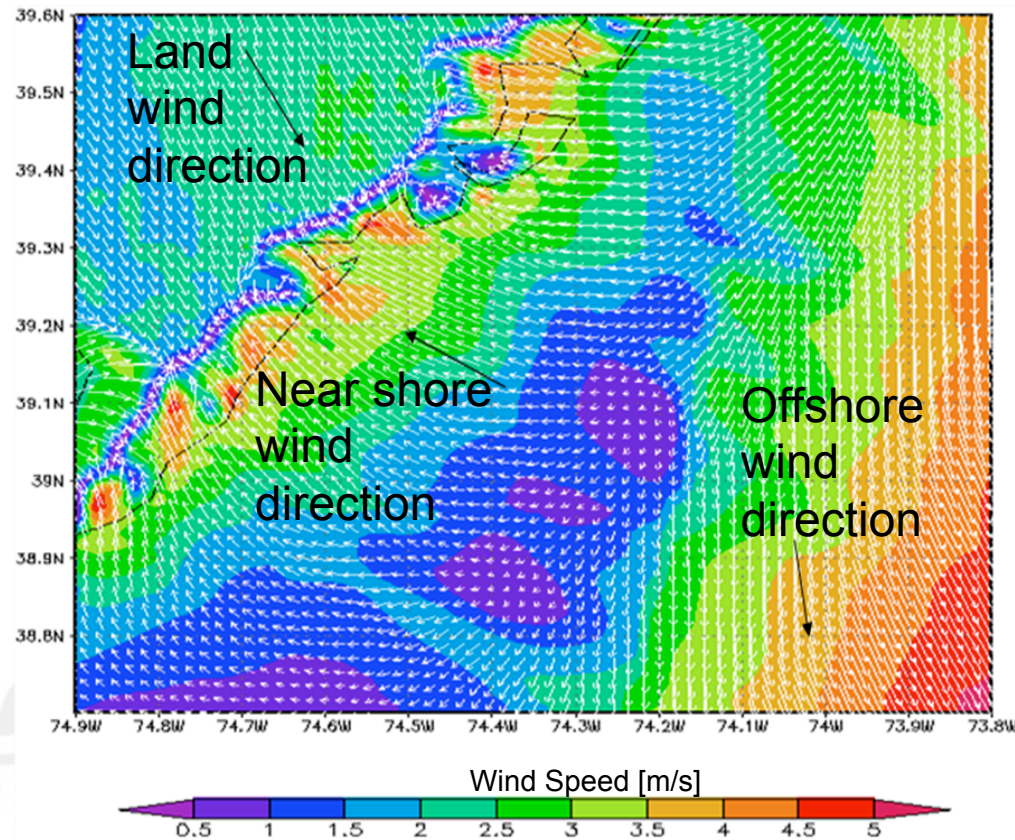


Sea Breeze Variability

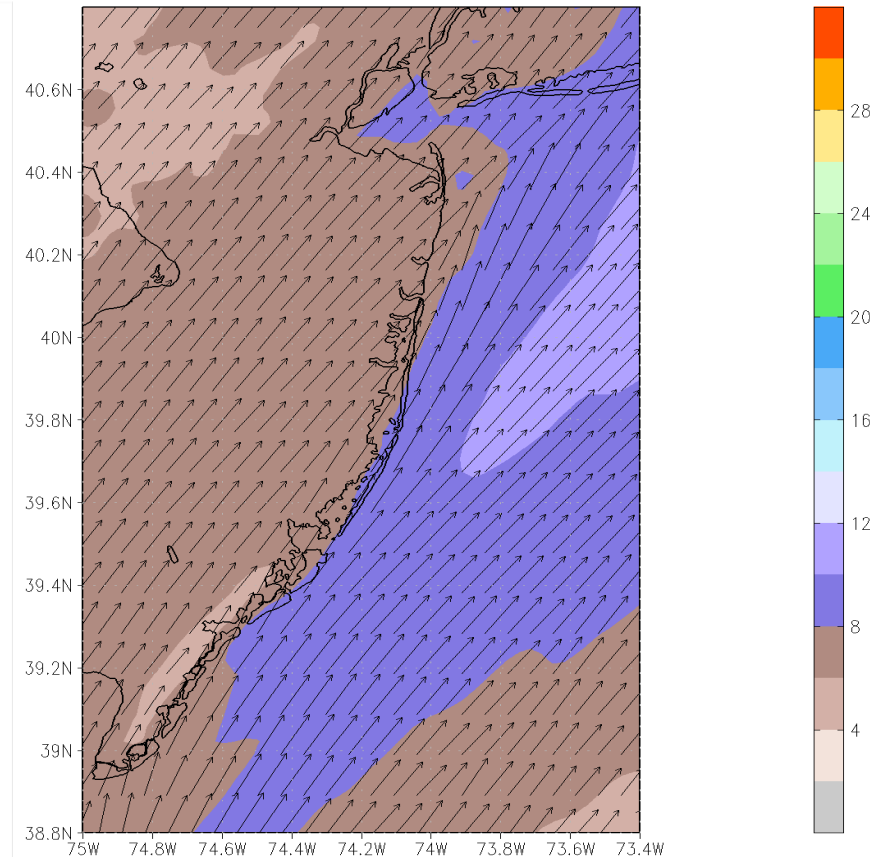
Sea Breeze

Non-Sea Breeze

Wind Speed at 100m [m/s]

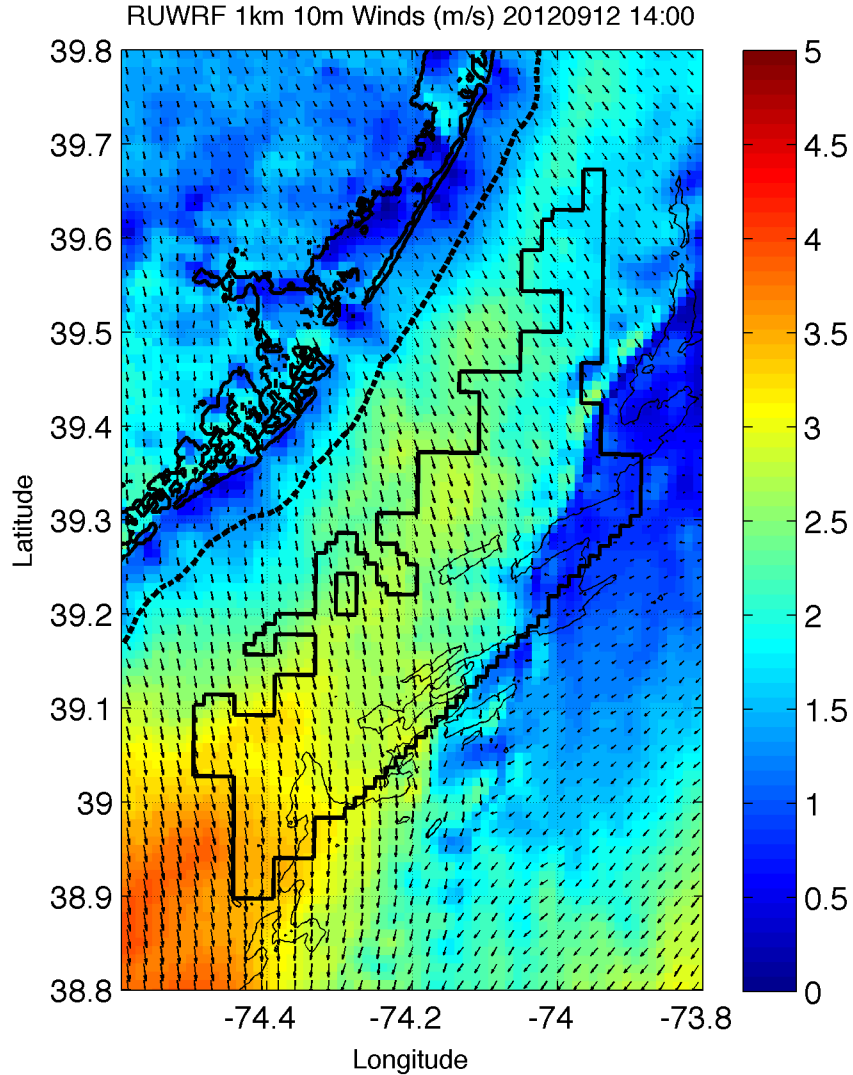


RU-WRF Model 2km Simulation

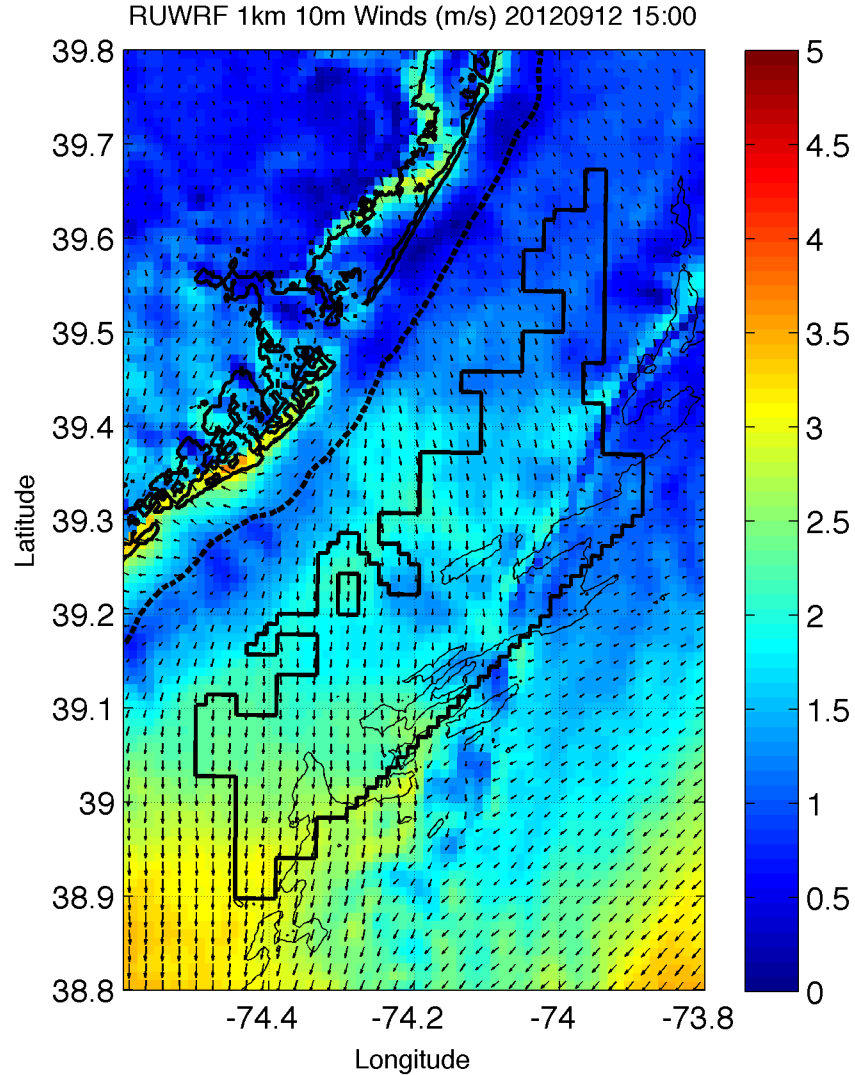


Ocean Observation Lab: RUWRF-ARW 3 KM e.rutgers.edu/cool/weather Model Initialized 00Z25SEP2012 Valid 18Z25SEP2012 (Tue) | Forecast Hour

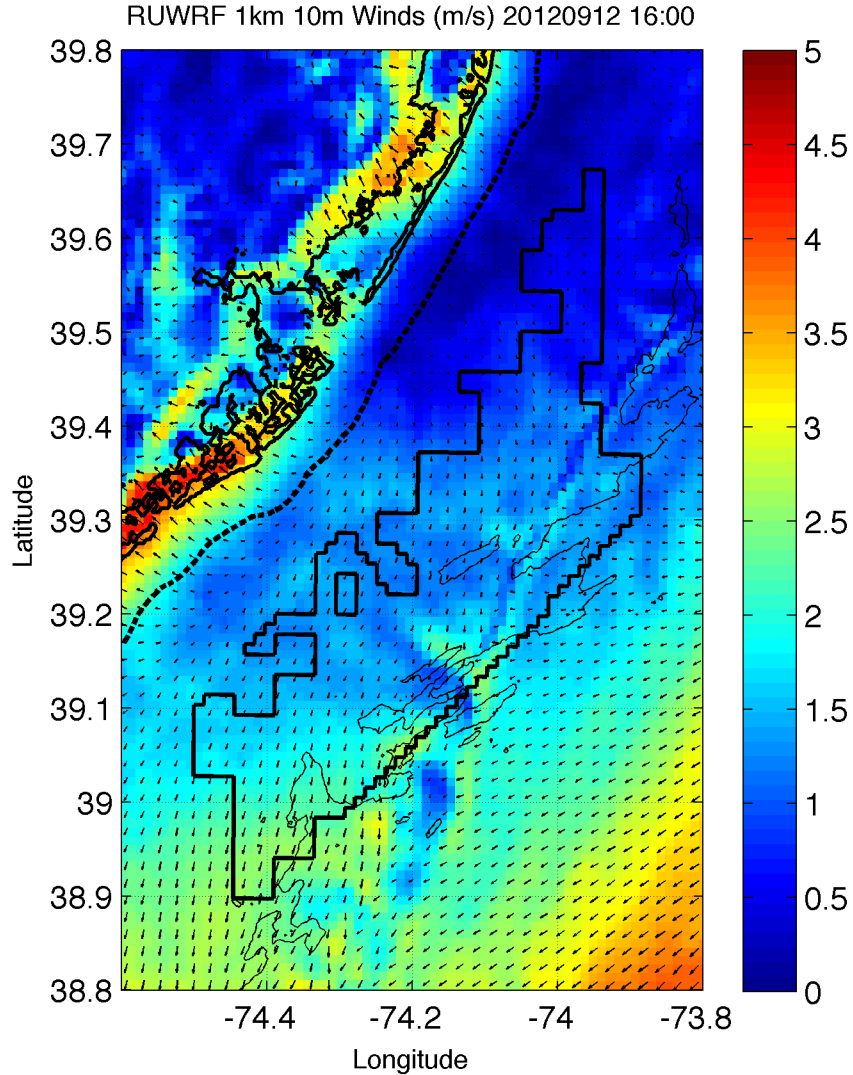
Sea Breeze Variability



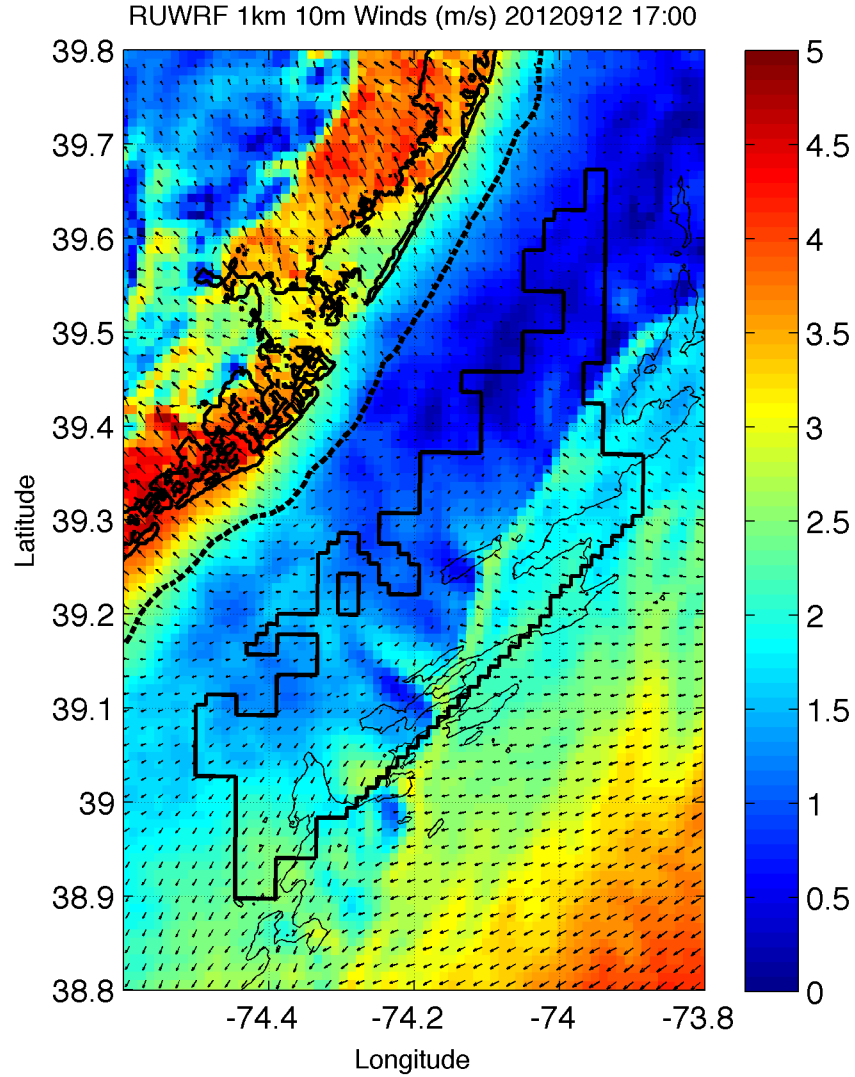
Sea Breeze Variability



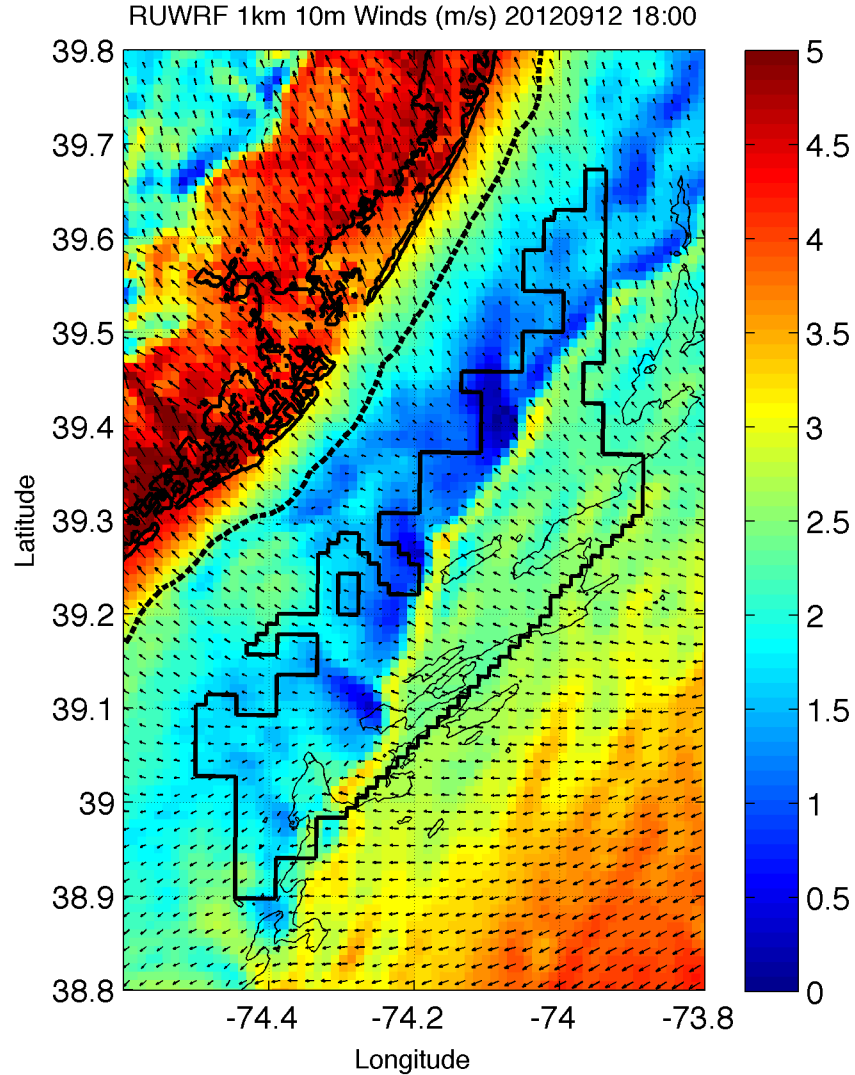
Sea Breeze Variability



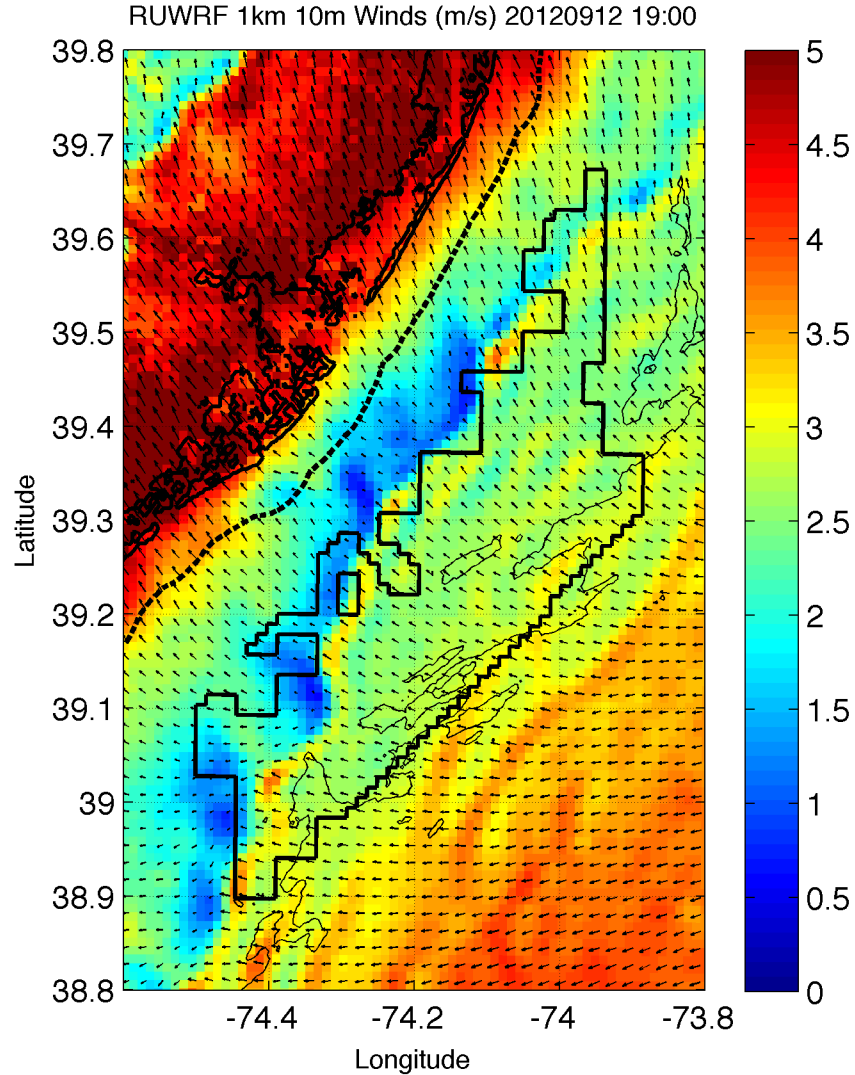
Sea Breeze Variability



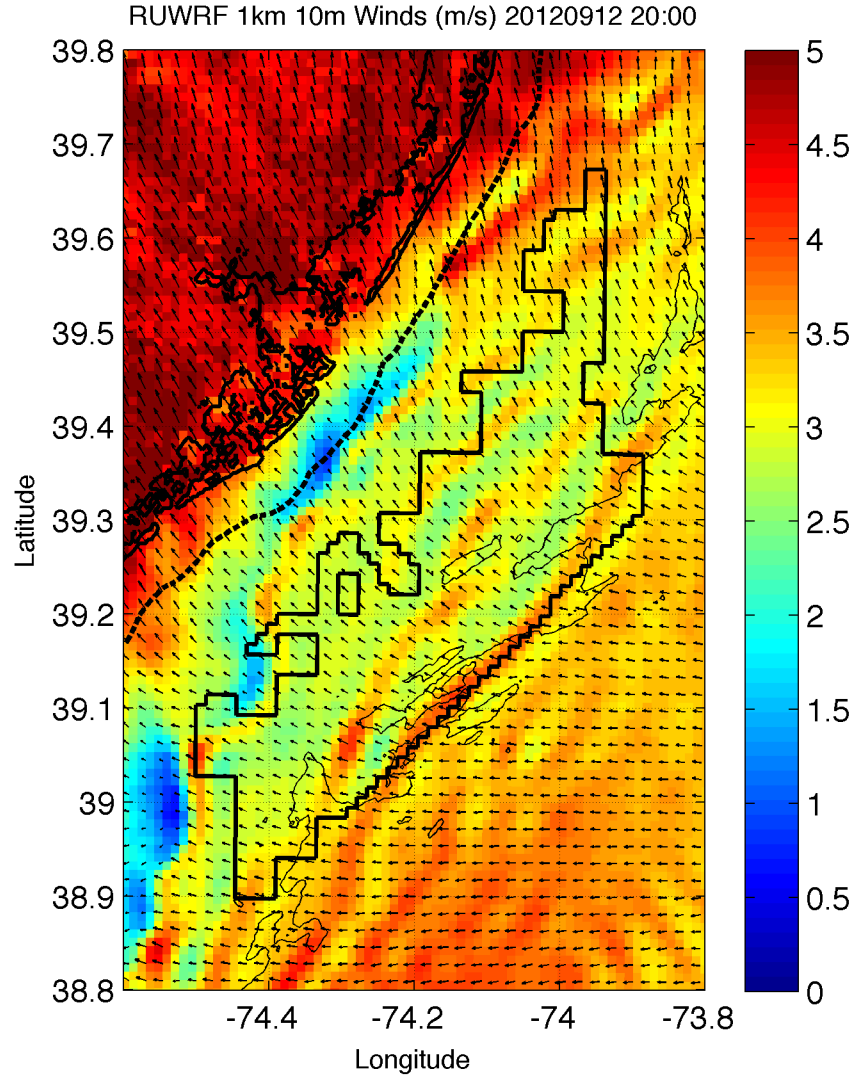
Sea Breeze Variability



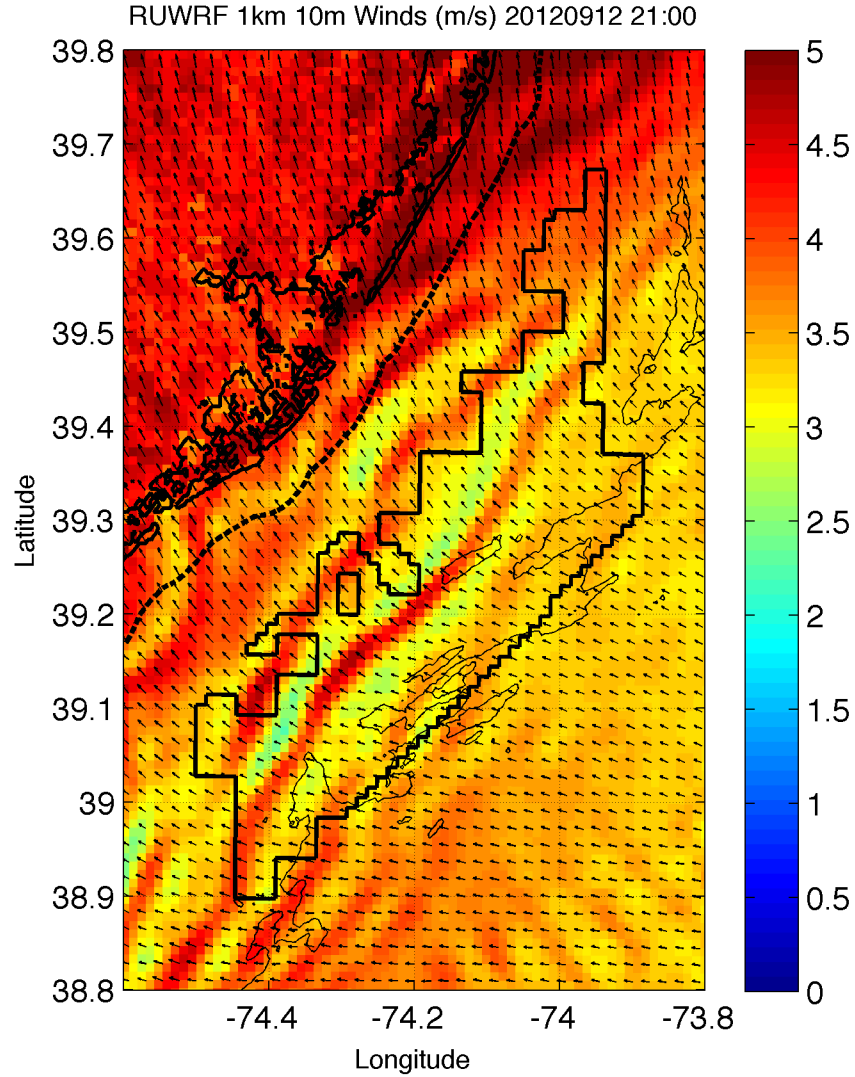
Sea Breeze Variability



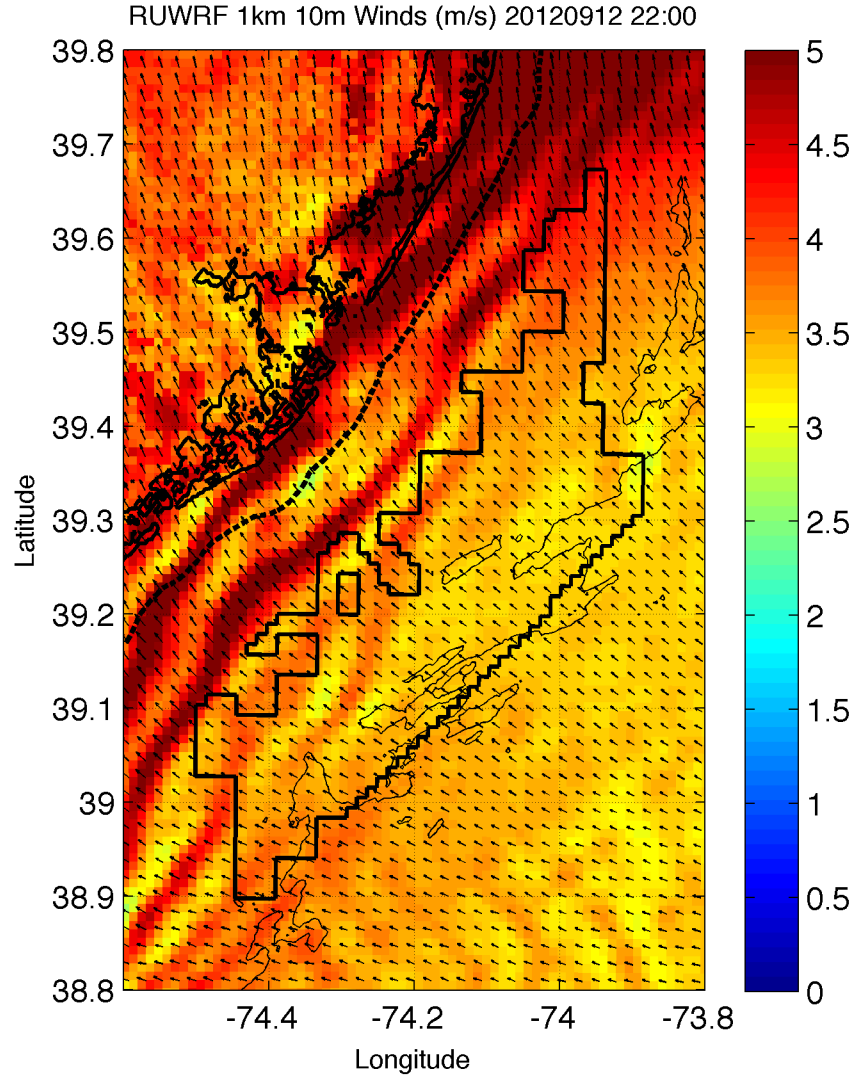
Sea Breeze Variability



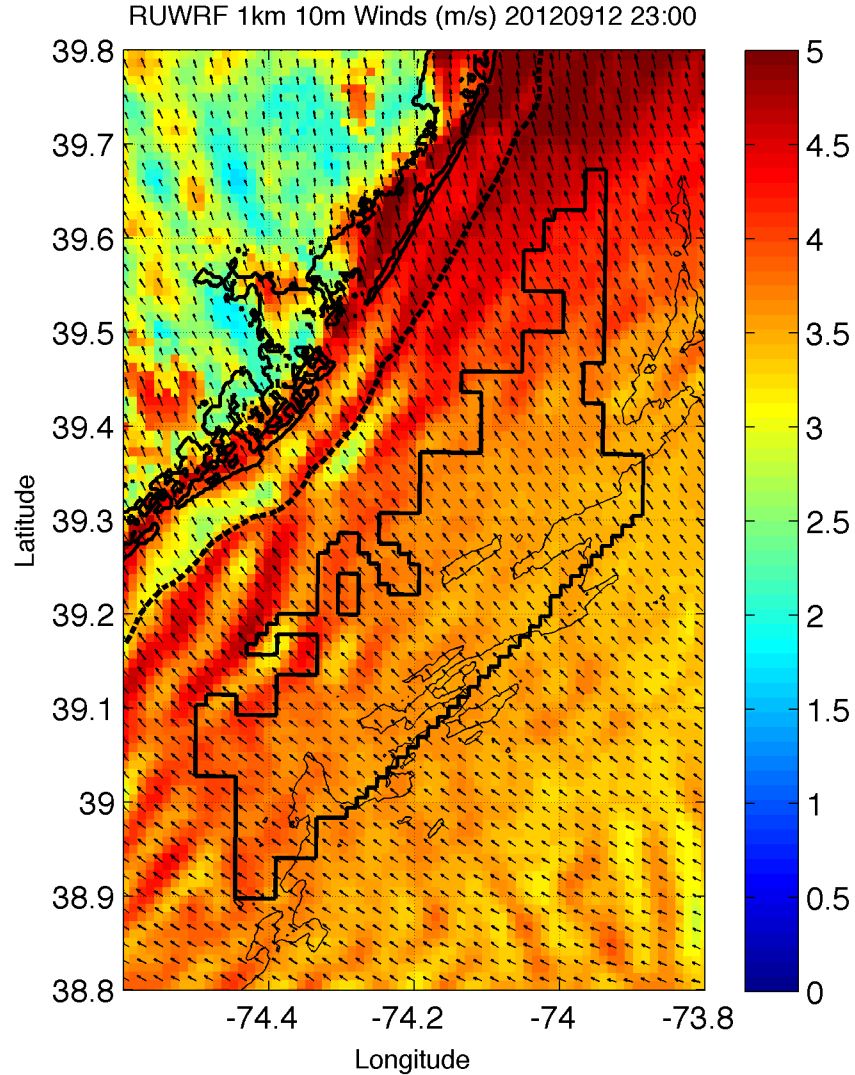
Sea Breeze Variability



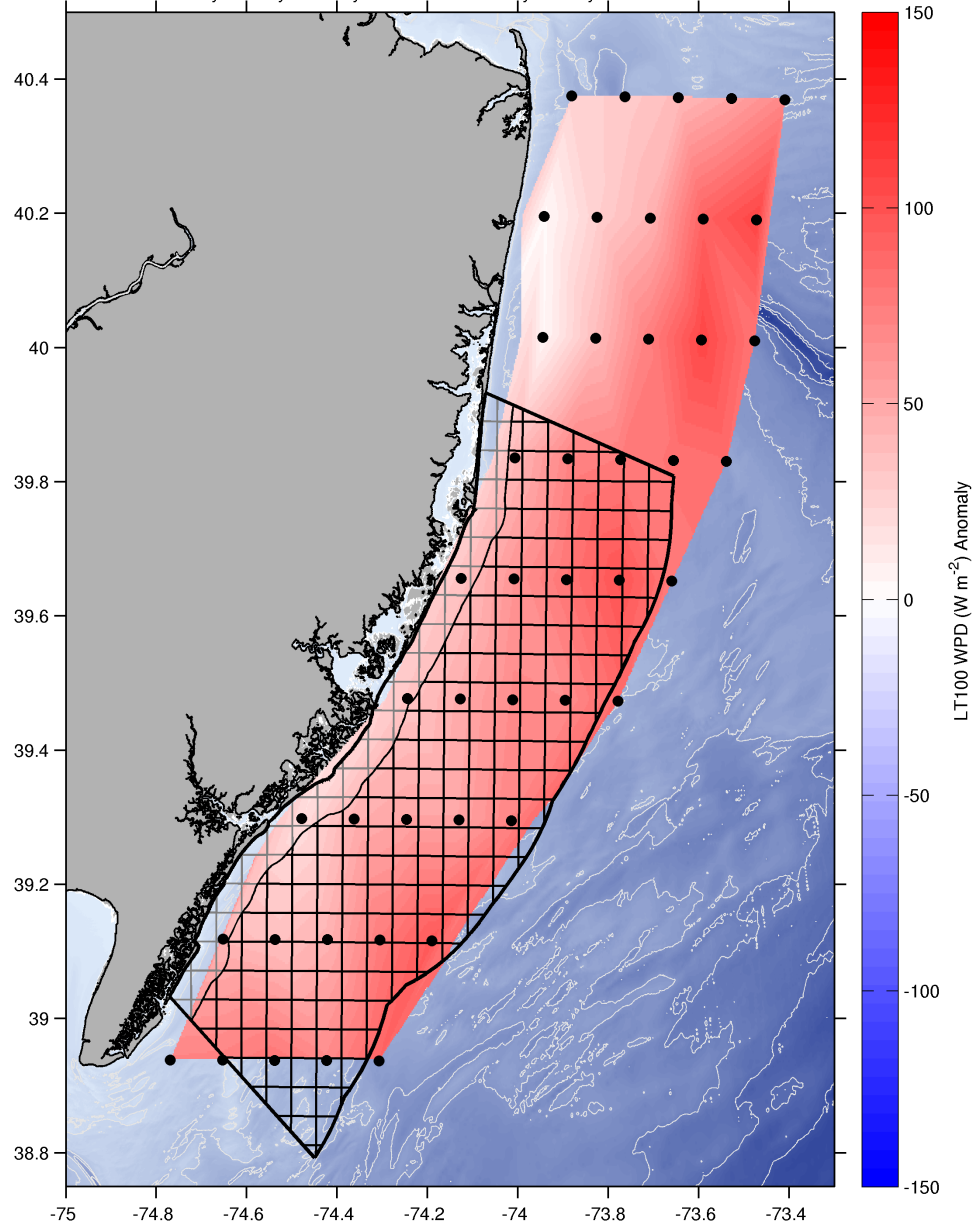
Sea Breeze Variability



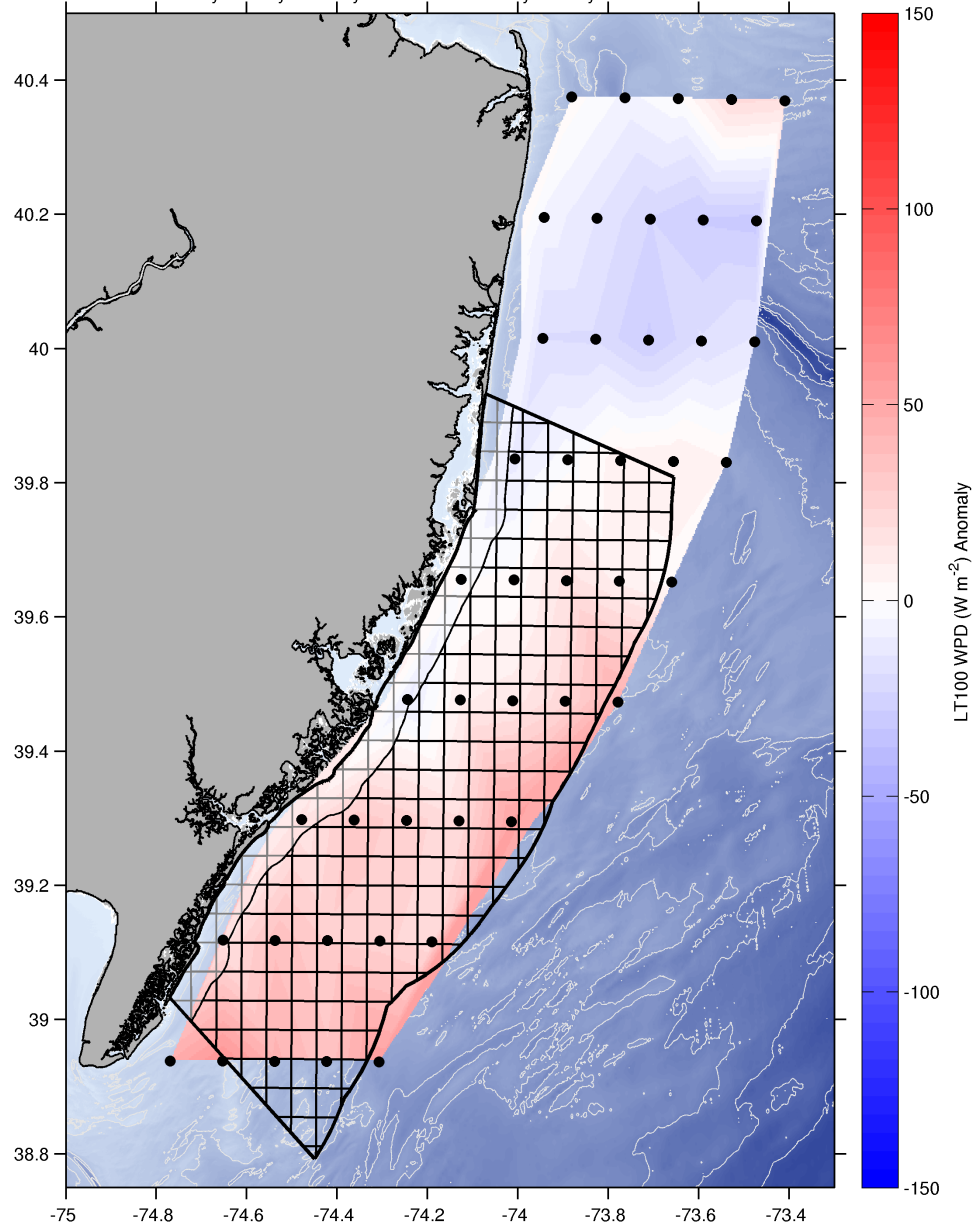
Sea Breeze Variability



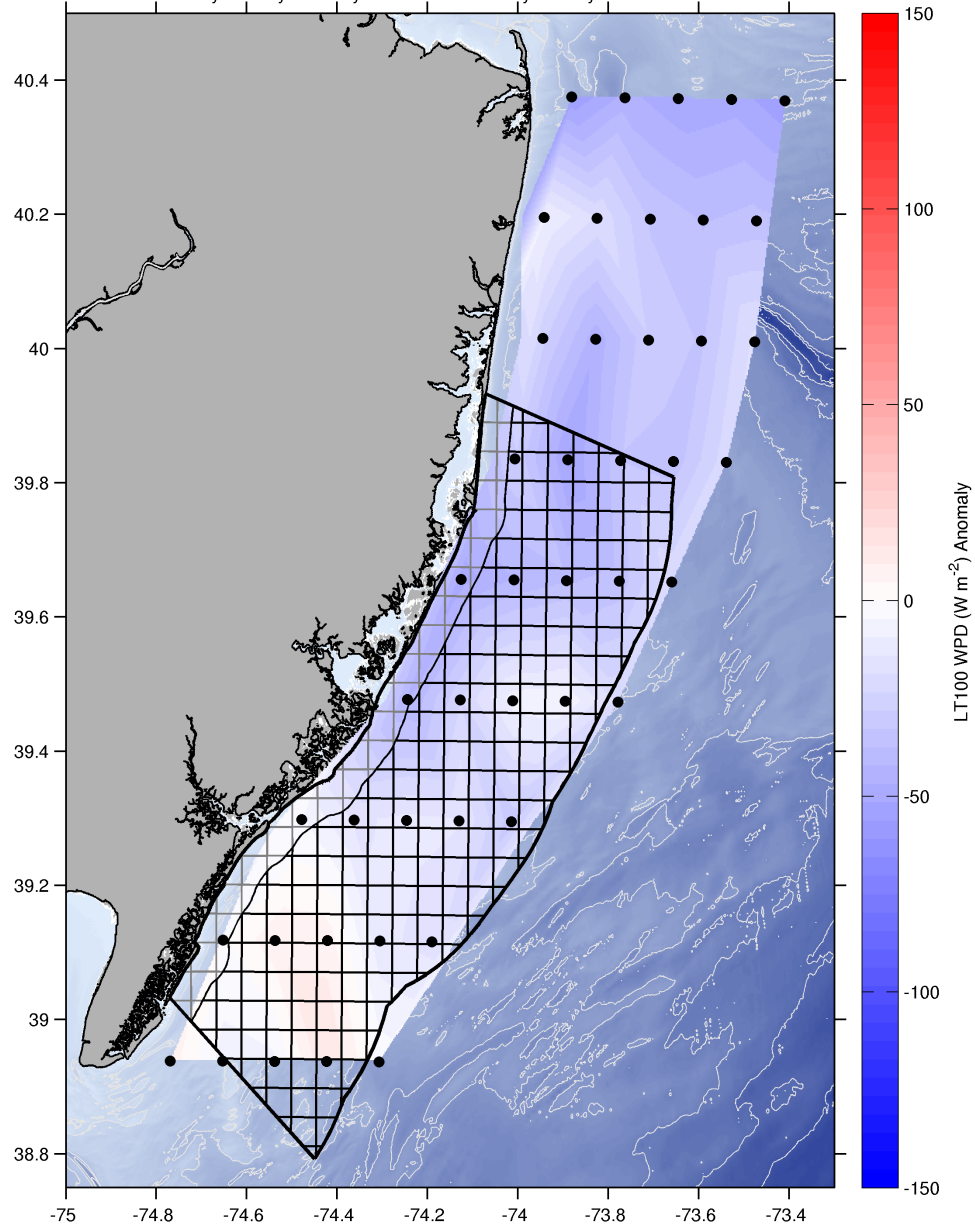
Seabreeze Days Hourly Anomaly from Seabreeze Days Yearly Mean LT100 WPD: 01:00



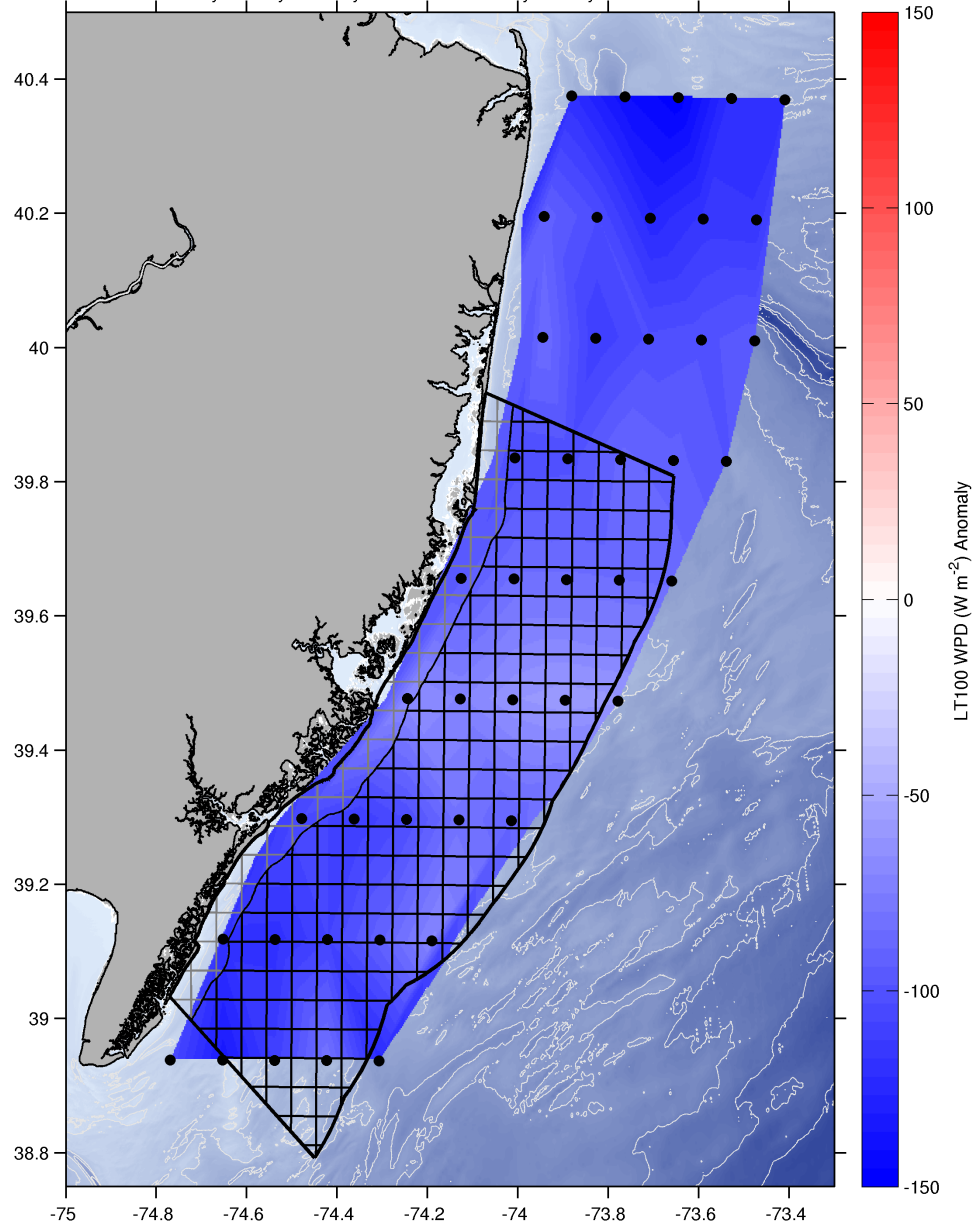
Seabreeze Days Hourly Anomaly from Seabreeze Days Yearly Mean LT100 WPD: 05:00



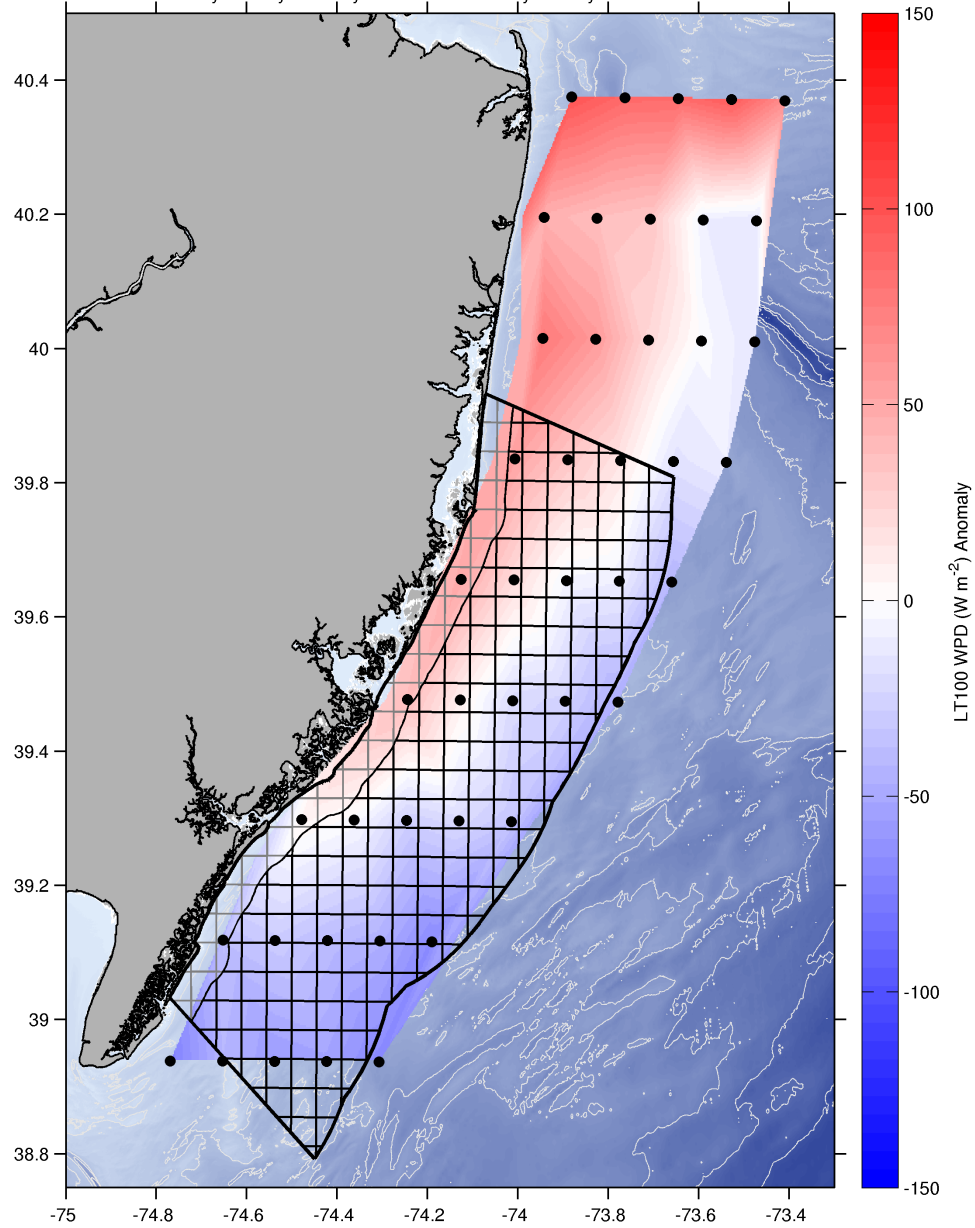
Seabreeze Days Hourly Anomaly from Seabreeze Days Yearly Mean LT100 WPD: 09:00



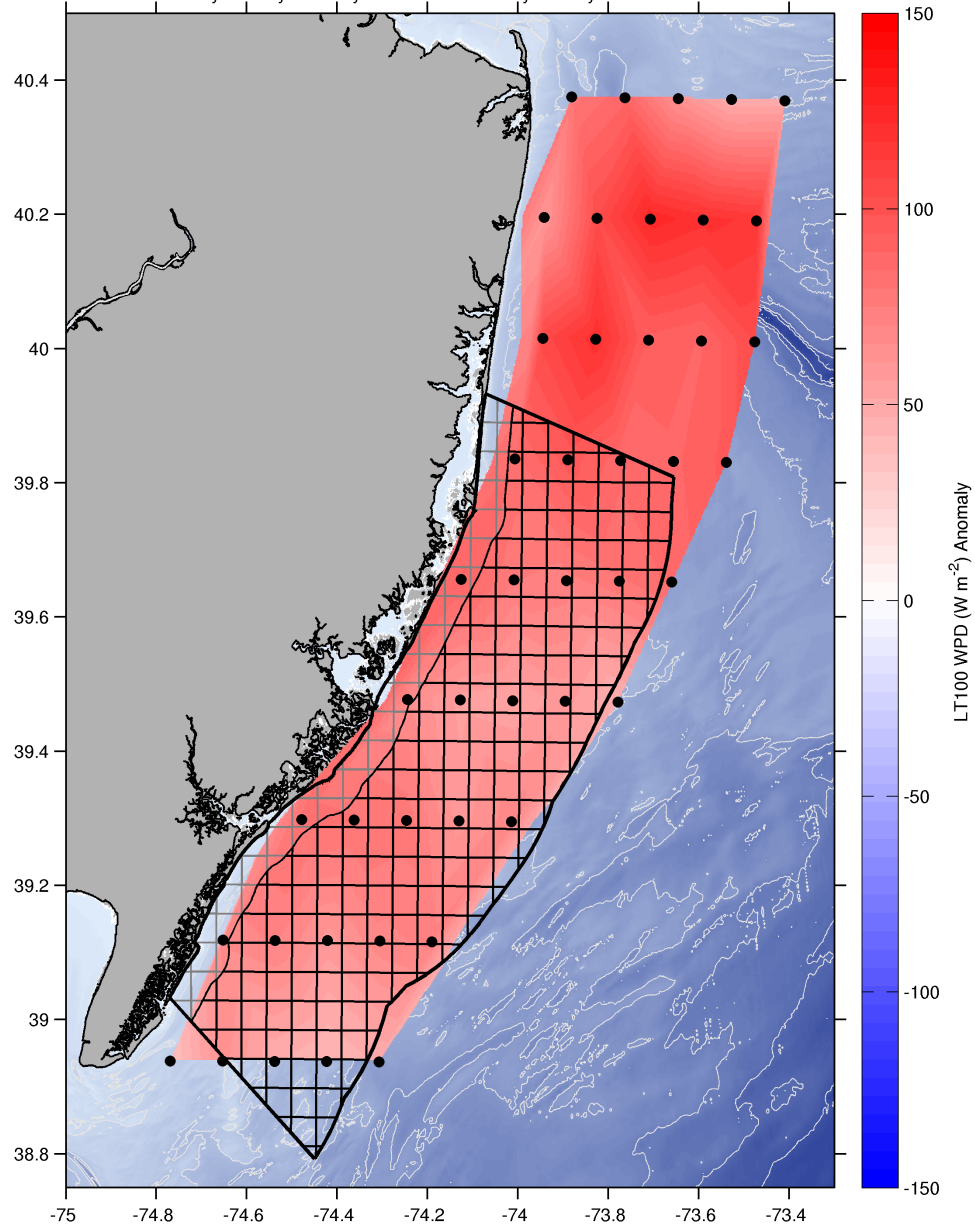
Seabreeze Days Hourly Anomaly from Seabreeze Days Yearly Mean LT100 WPD: 13:00



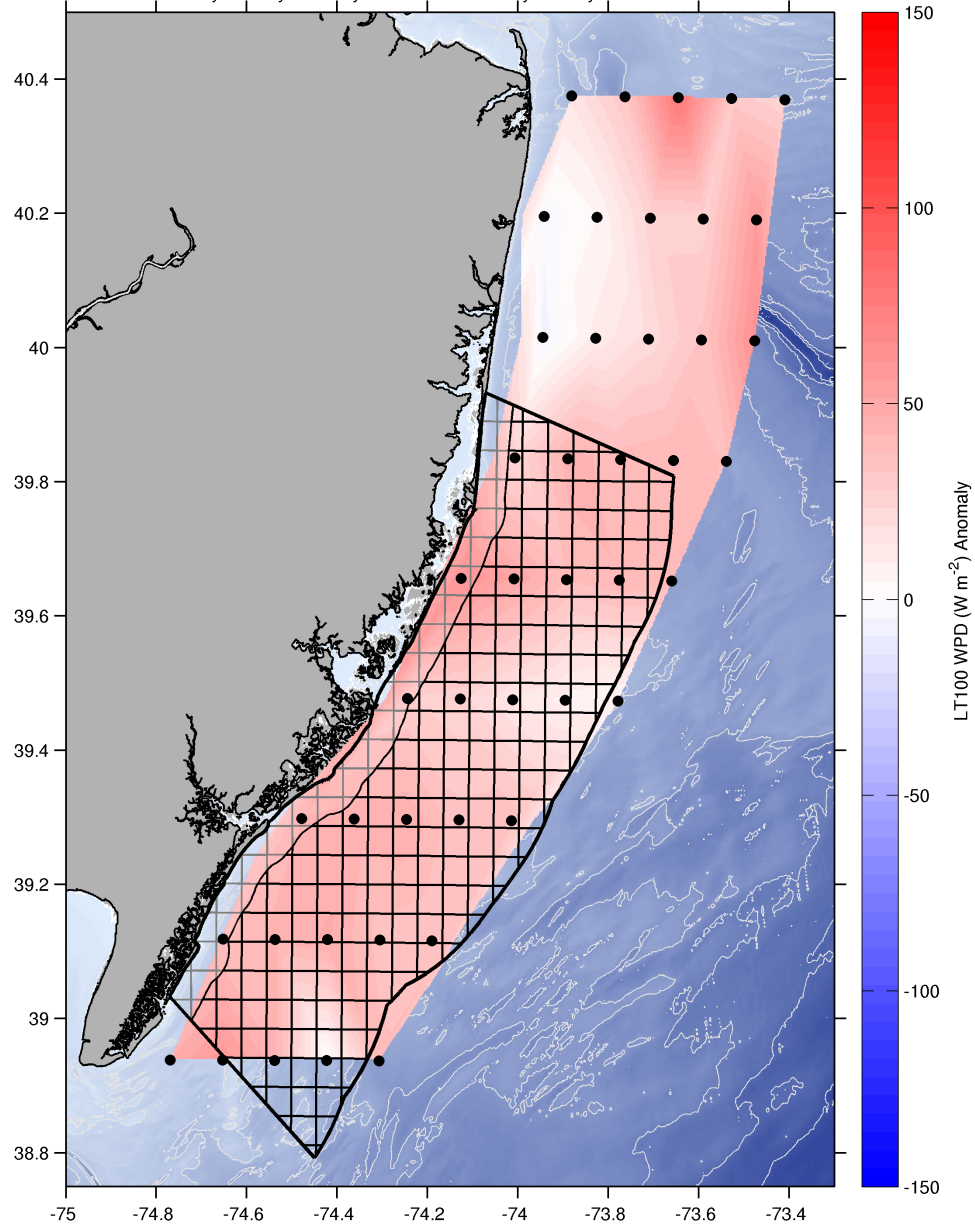
Seabreeze Days Hourly Anomaly from Seabreeze Days Yearly Mean LT100 WPD: 17:00



Seabreeze Days Hourly Anomaly from Seabreeze Days Yearly Mean LT100 WPD: 21:00

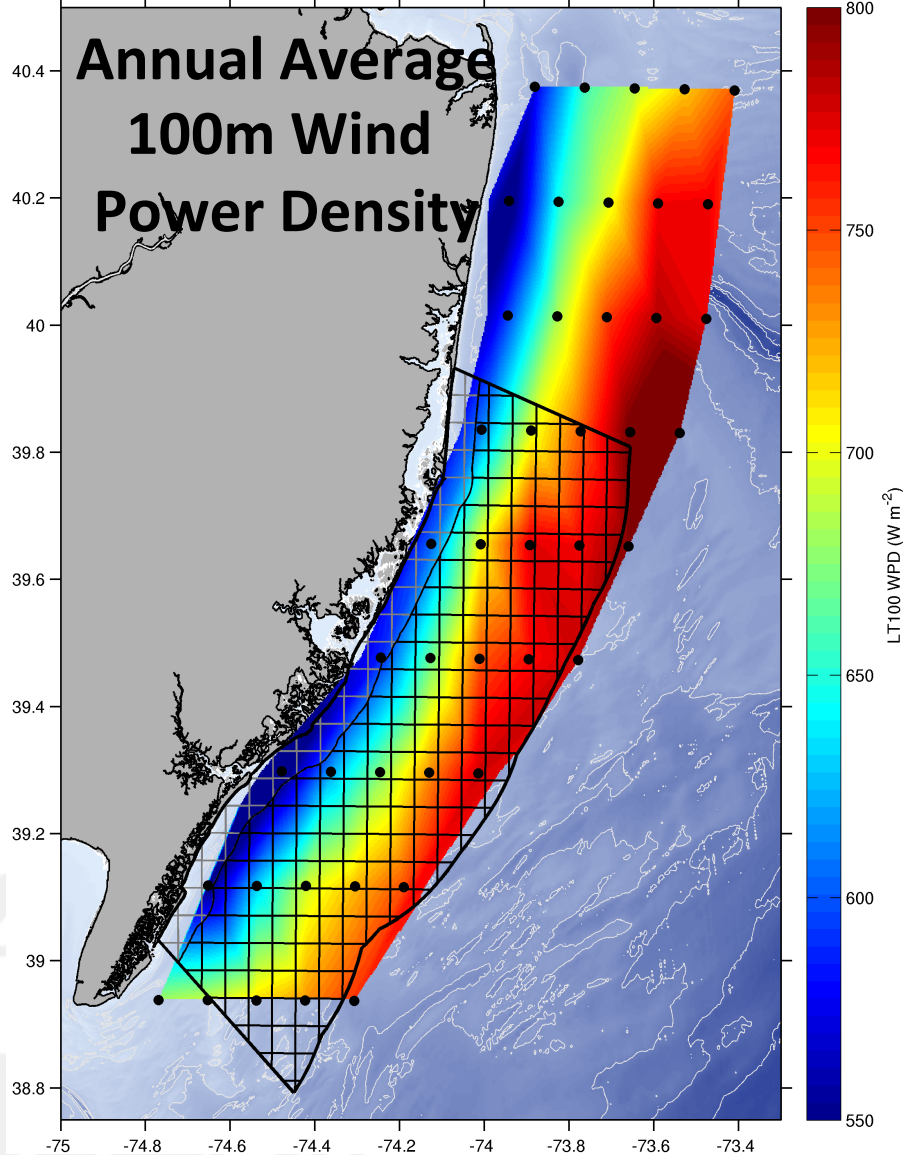


Seabreeze Days Hourly Anomaly from Seabreeze Days Yearly Mean LT100 WPD: 24:00

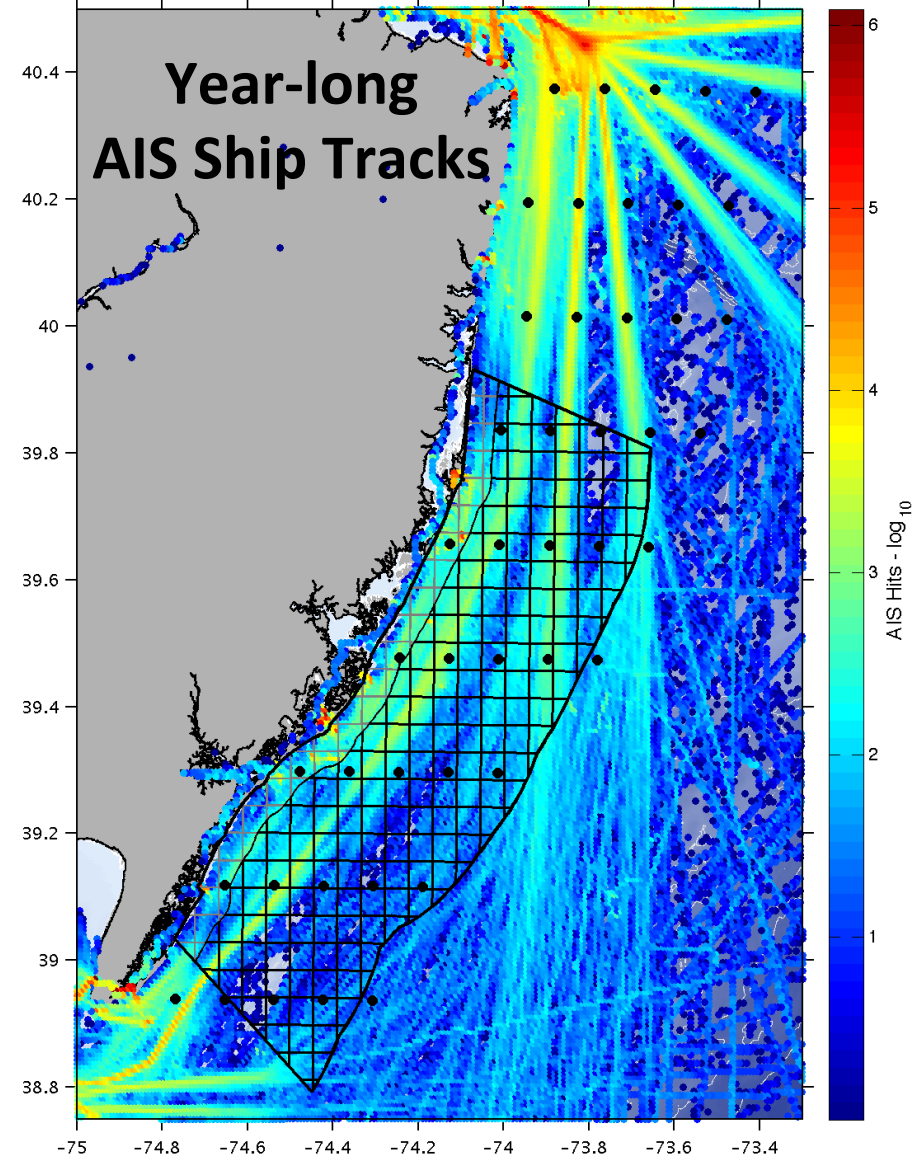


Annual Average Wind and Ship Tracks

LT100 WPD Yearly Average: 2012-04-01 00:00 - 2013-03-31 23:00 (EST)



April 2012 - April 2013 AIS



Offshore Wind Analysis Website

<http://rucool.marine.rutgers.edu/bpu>

Tuesday, April 15, 2014 TEXT_SIZE

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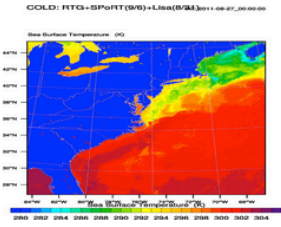
An Advanced Atmospheric Ocean Assessment Program Designed to Reduce the "Risks" Associated with Offshore Wind Energy Applications


14 April 2011-13 April 2013

The Rutgers University Coastal Observation Laboratory (RU-COOL) is one of the world's leaders in the study of physical and biological environmental conditions for the coastal ocean and it is the foremost expert in the study of the offshore waters along coastal NJ and the New York Bight (Schofield et al., 2008). RU-COOL has over a decade of experience applying advanced ocean observing technology (e.g. Schofield et al, 2007) along with atmospheric and ocean models to support a network of State, Local, and Federal government agencies (Glenn and Schofield, 2003). Additionally, the Rutgers Institute of Marine and Coastal Sciences (IMCS) has established several academic-government-industry partnerships to accomplish a wide array of innovative research and applied goals for public, scientific, and military applications (Glenn and Schofield, 2009). RU-COOL is a member of the Rutgers Energy Institute (REI) which integrates Rutgers' expertise in science, engineering, economics, and policy, putting it at the forefront of alternative energy research. (<http://rei.rutgers.edu>). The technologies developed and employed by RU-COOL have been tried, tested, and accepted by the world's foremost experts in the scientific community. Additionally, we have extensive experience running the state-of-the-art Weather Research and Forecasting (WRF) model, which has been optimized for research quality simulations (NSF Ocean Observing Initiative) and operational applications (NOAA Integrated Ocean Observing System) for the coastal ocean from Cape Cod to Cape Hatteras. This model has been well tested through a cooperative education operational forecasting project with PSEG that provided highly accurate and reliable information for severe storm management and power restoration activities. The innovative Rutgers WRF (RU-WRF) model is also configured for offshore wind resource evaluations.



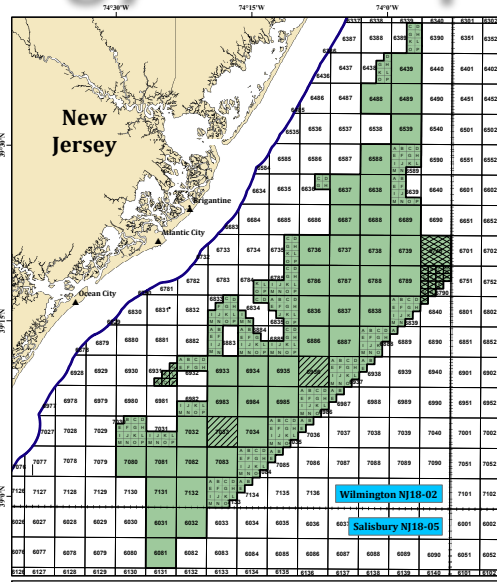
COLD: HTG + BPOUTT (WB) + LIND (B)M Jan 14 06:27_20130308





The variability in the wind resource at atmospheric heights representative of offshore wind turbine dimensions in conjunction with varying energy demand must be taken into account to ensure economical and reliable electrical grid management. Therefore, the "risks" and associated costs resulting from the variability of wind power production and uncertain demand requirements can be significantly reduced with a representative analytical/radiative program

OSW Energy Development Domain and WTG Size

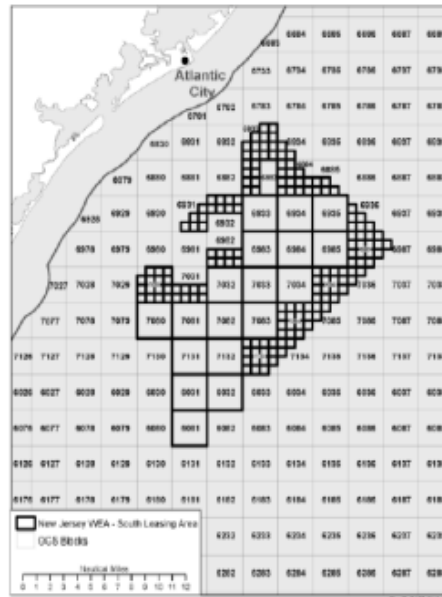
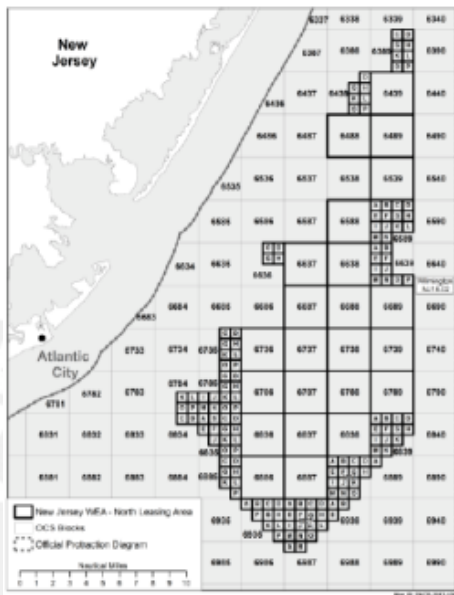


6 MW WTG

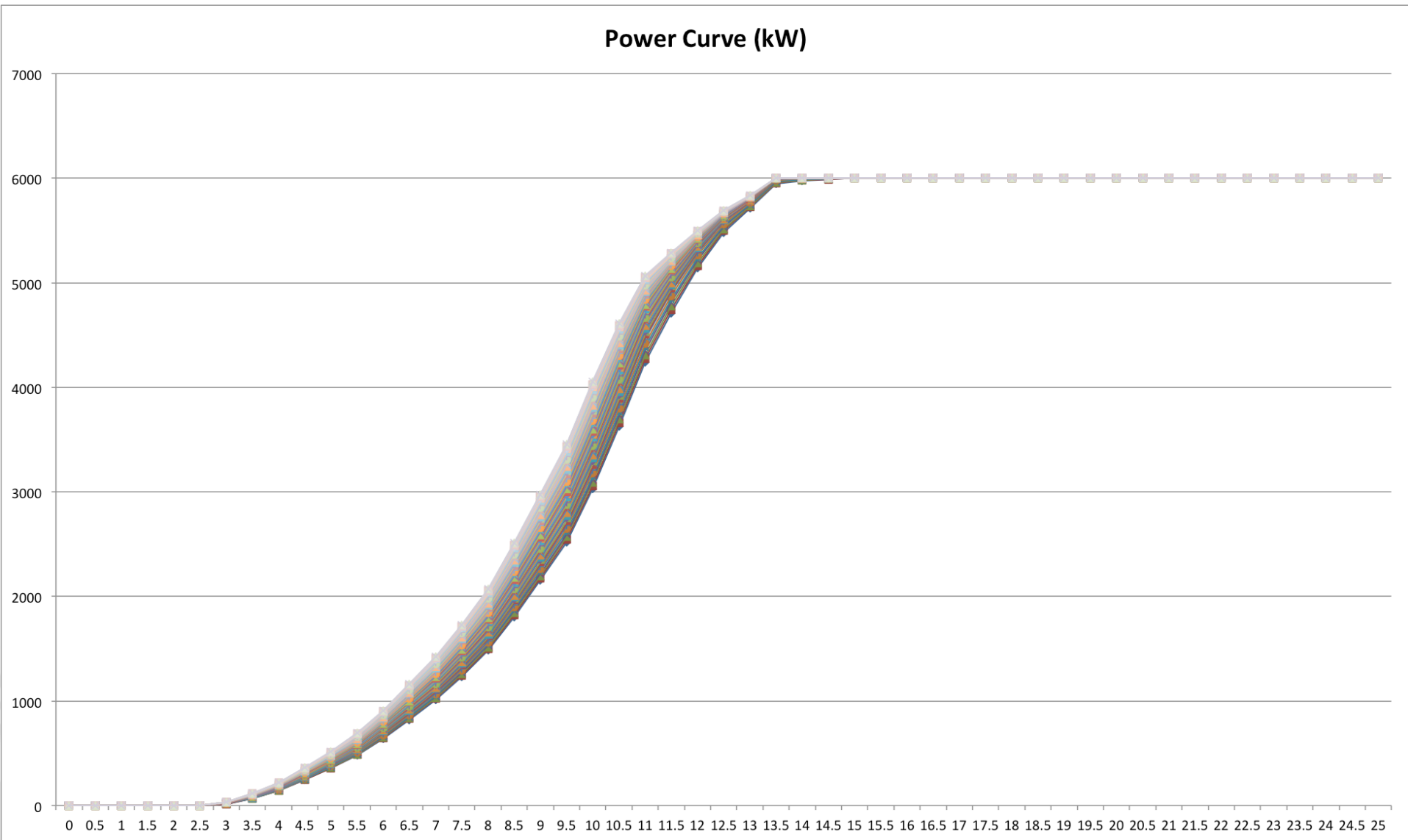


North Zone

South Zone

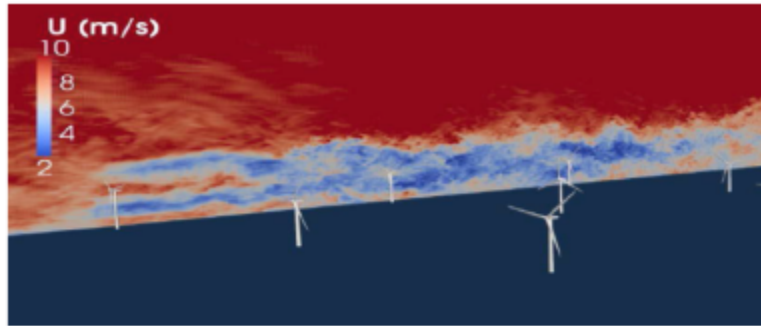


Generic Power Curve – 6 MW WTG

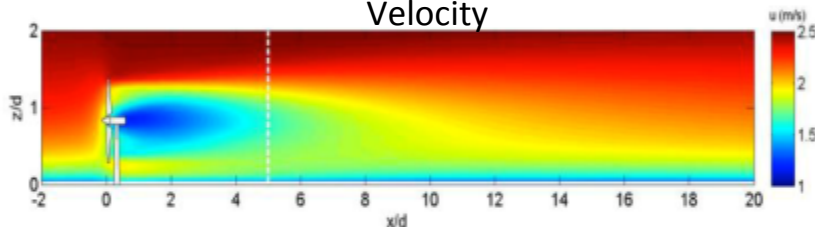


Modeling/Monitoring Upgrades

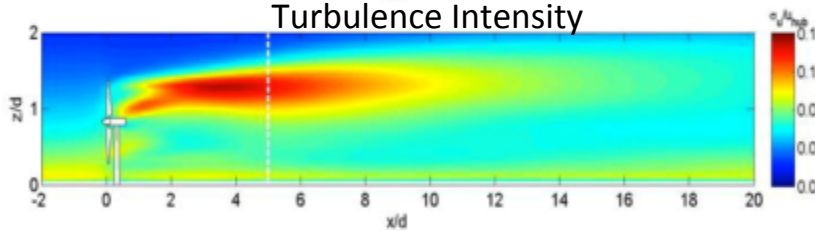
Large-Eddy Simulation (LES)



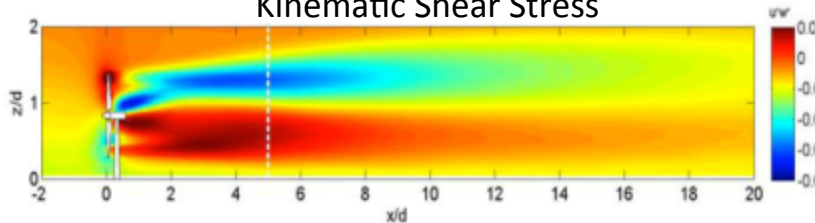
Velocity



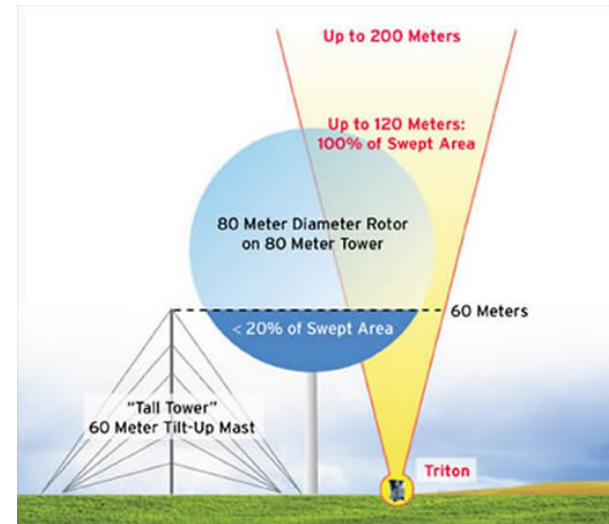
Turbulence Intensity



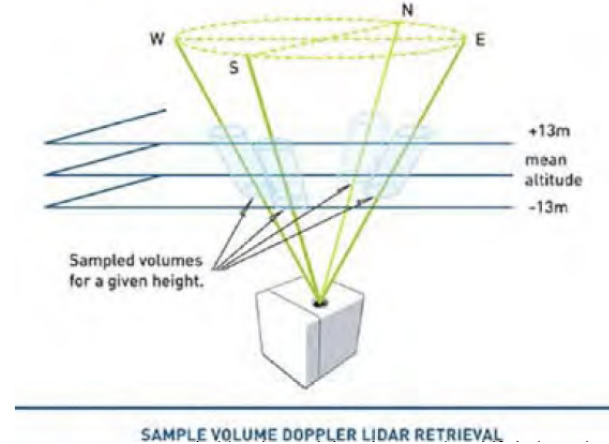
Kinematic Shear Stress



SODAR



LIDAR

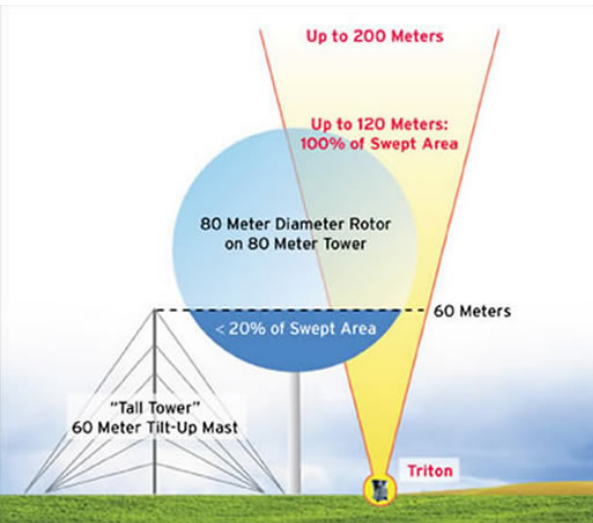


SODAR, MET tower: Tuckerton, NJ

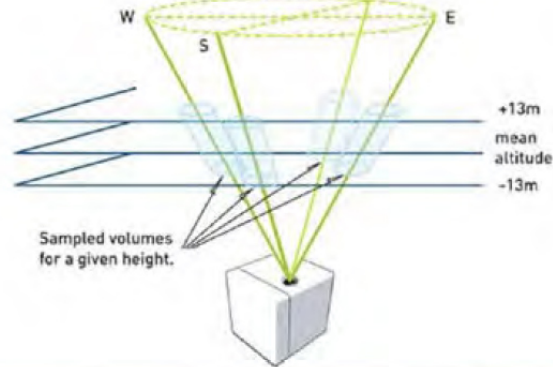
LIDAR: Chesapeake Bay Bridge

WeatherFlow and MARACOOS

SODAR



LIDAR

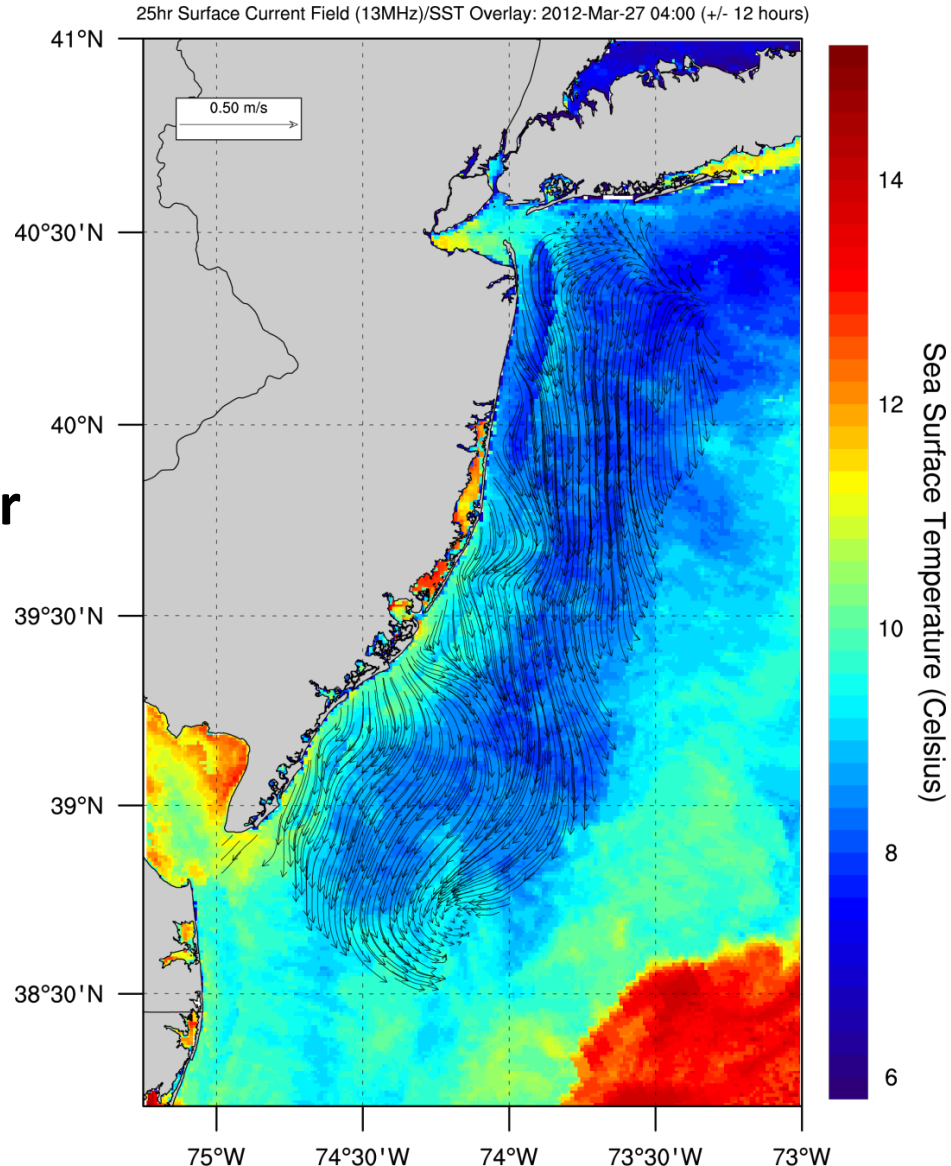


SAMPLE VOLUME DOPPLER LIDAR RETRIEVAL

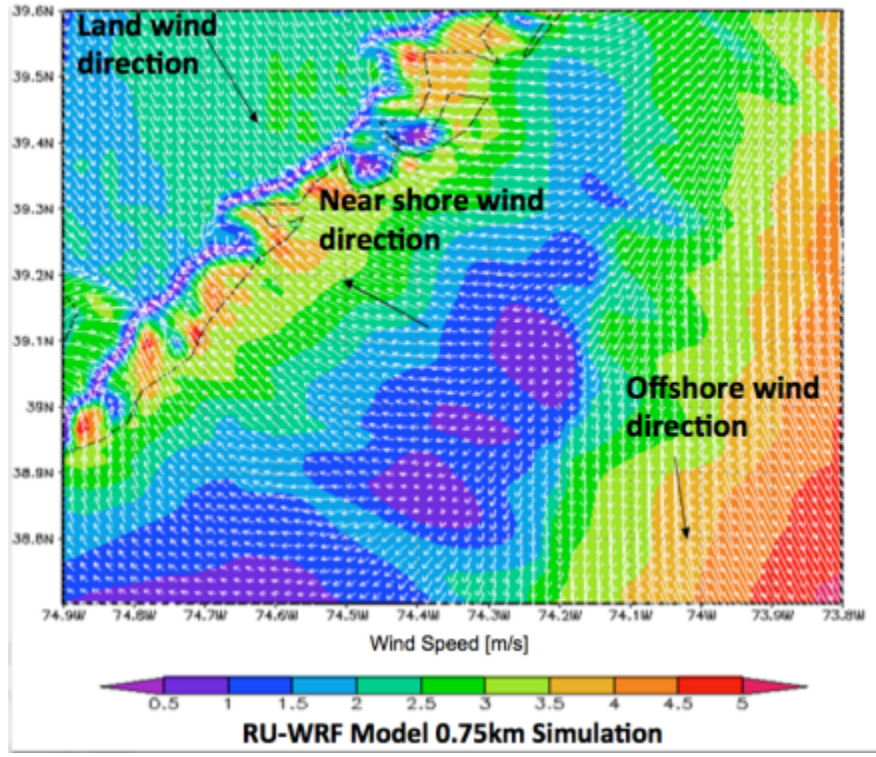
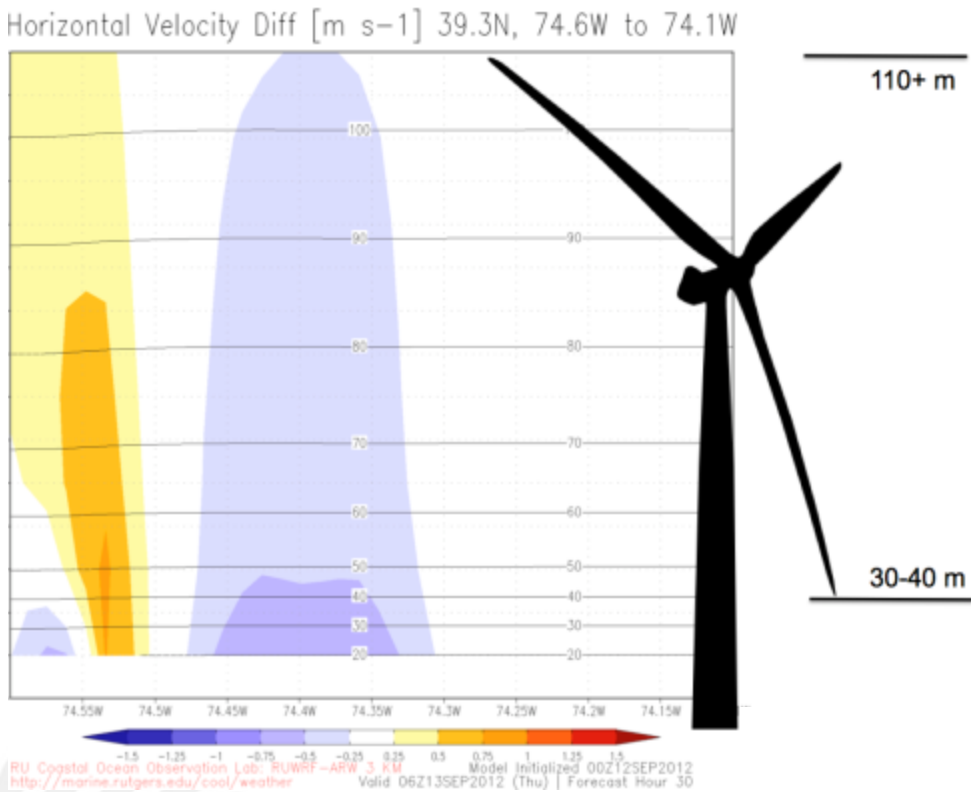


Satellite SST Upgrades

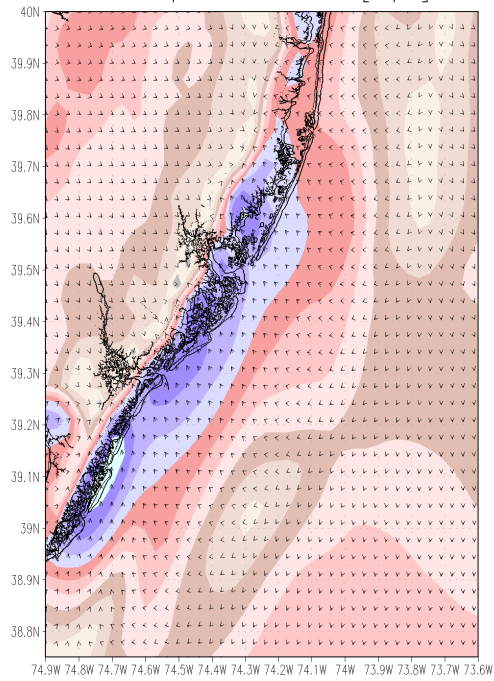
- Improve representation of coastal upwelling
- Develop new statistical methods for gap filling and preservation of features



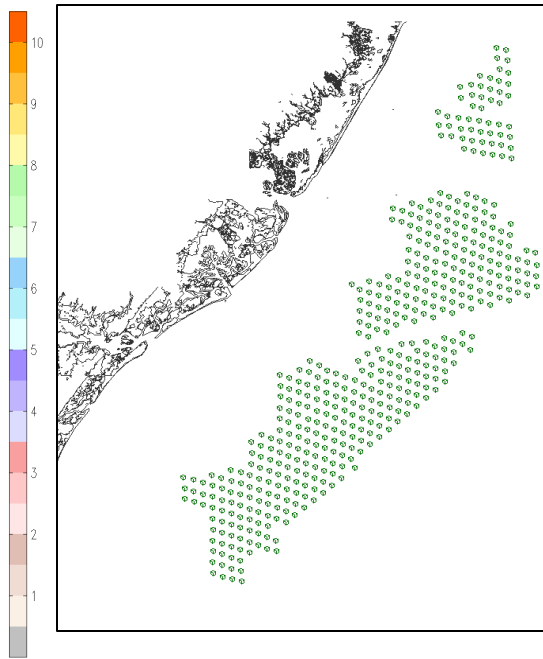
Extend sea breeze and local wind analyses



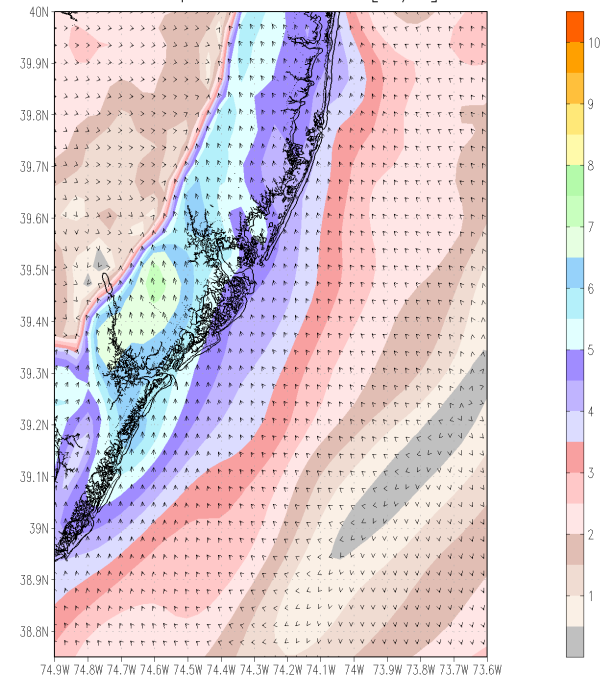
Wind Speed at 100 m [m/s]



RU Coastal Ocean Observation Lab: RUWRF-ARW 1 KM Model Initialized 00Z06APR2014
<http://marine.rutgers.edu/cool/weather> Valid 17Z06APR2014 (Sun) | Forecast Hour 17



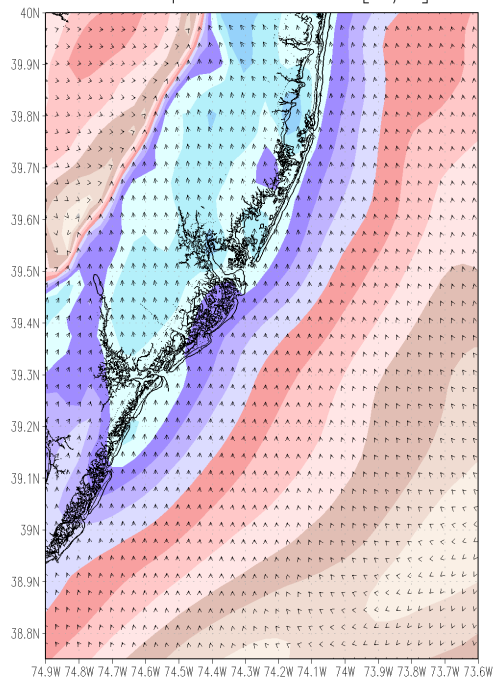
Wind Speed at 100 m [m/s]



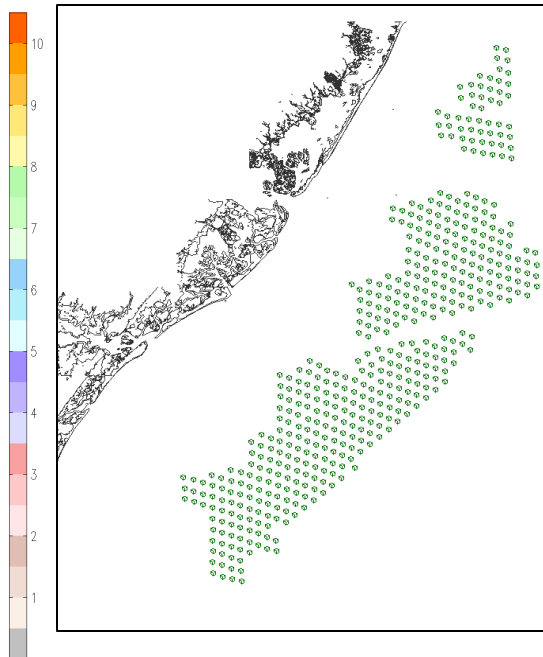
RU Coastal Ocean Observation Lab: RUWRF-ARW 1 KM Model Initialized 00Z06APR2014
<http://marine.rutgers.edu/cool/weather> Valid 19Z06APR2014 (Sun) | Forecast Hour 19



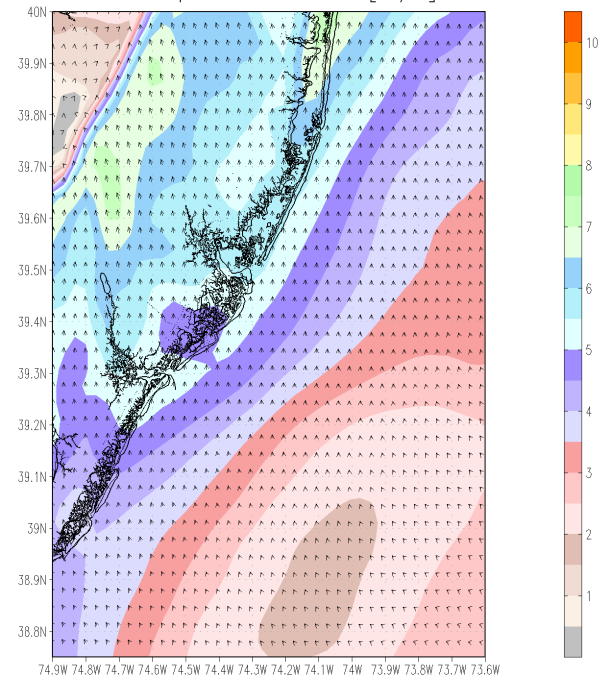
Wind Speed at 100 m [m/s]



RU Coastal Ocean Observation Lab: RUWRF-ARW 1 KM Model Initialized 00Z06APR2014
<http://marine.rutgers.edu/cool/weather> Valid 21Z06APR2014 (Sun) | Forecast Hour 21



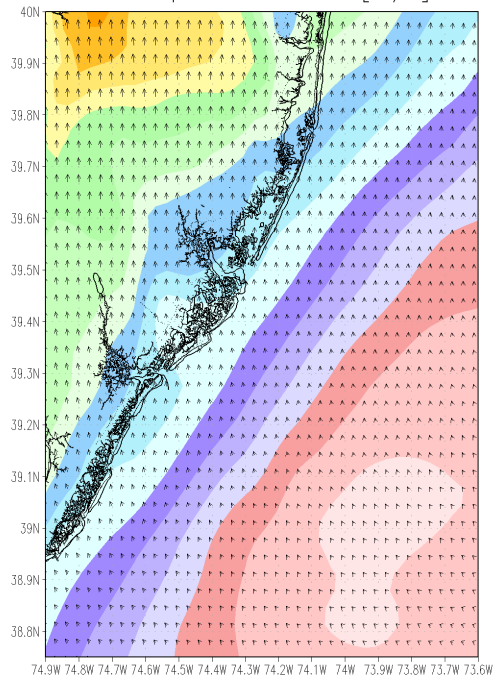
Wind Speed at 100 m [m/s]



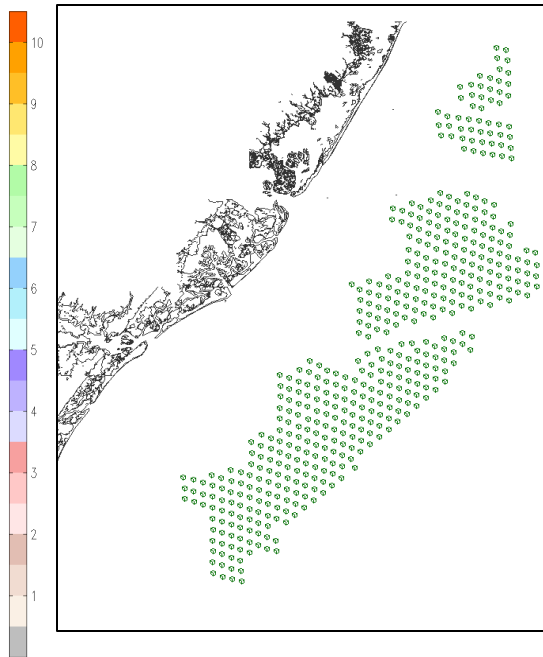
RU Coastal Ocean Observation Lab: RUWRF-ARW 1 KM Model Initialized 00Z06APR2014
<http://marine.rutgers.edu/cool/weather> Valid 23Z06APR2014 (Sun) | Forecast Hour 23



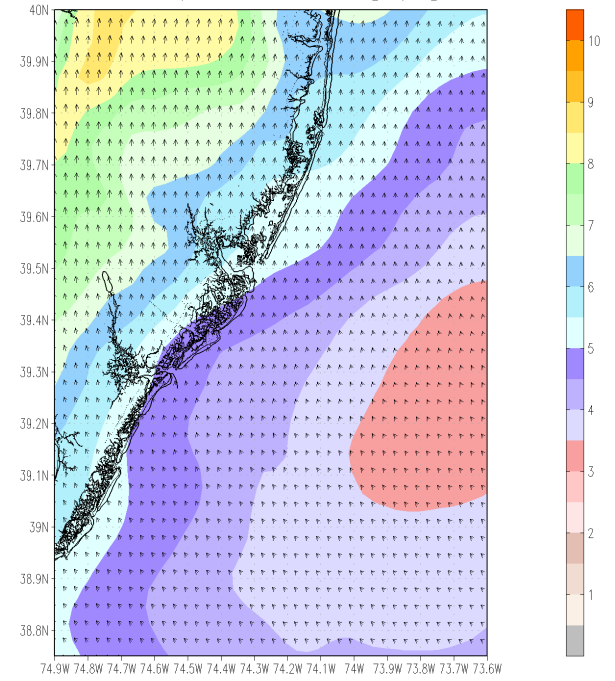
Wind Speed at 100 m [m/s]



RU Coastal Ocean Observation Lab: RUWRF-ARW 1 KM Model Initialized 00Z06APR2014
<http://marine.rutgers.edu/cool/weather> Valid 01Z07APR2014 (Mon) | Forecast Hour 25



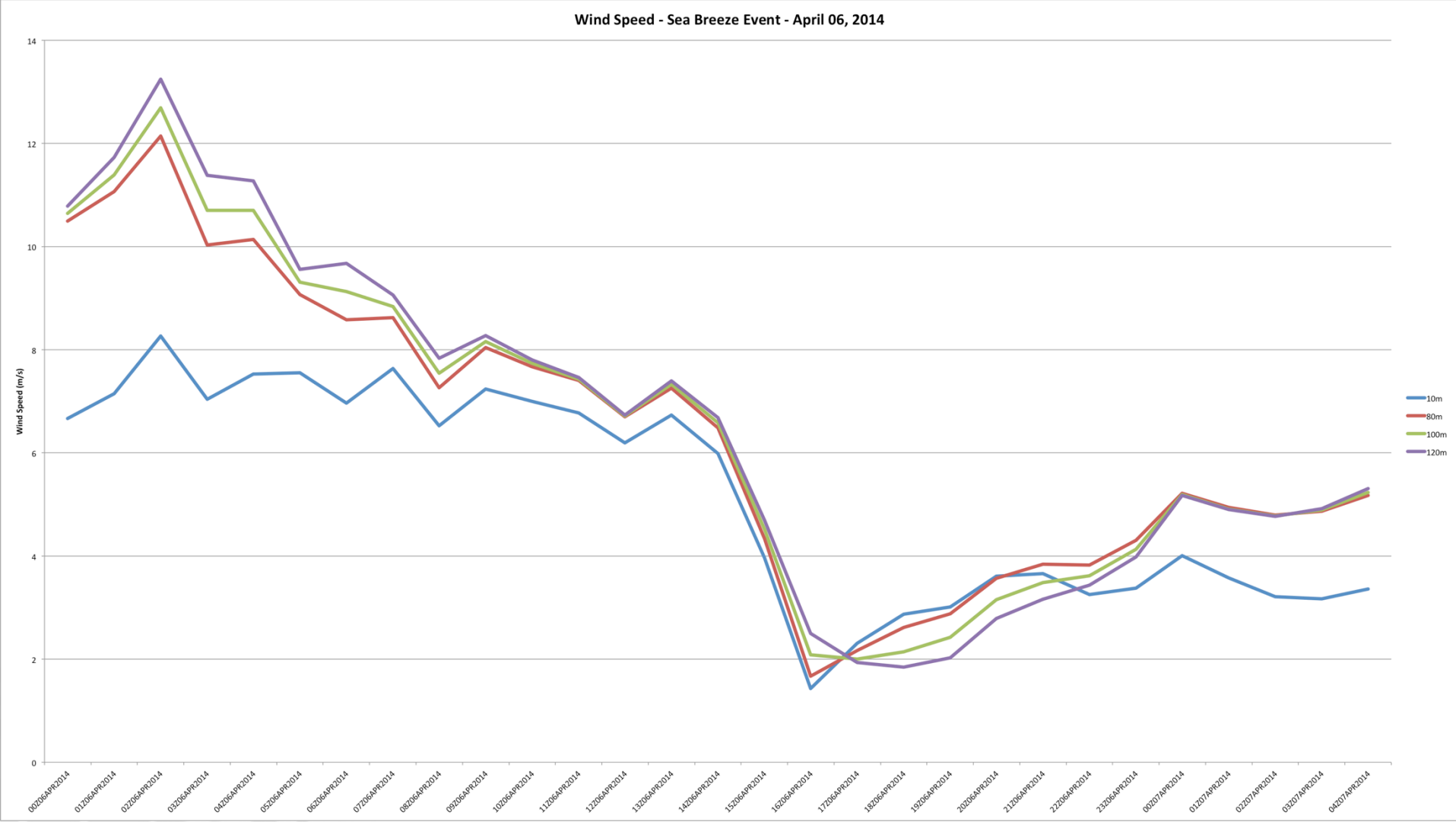
Wind Speed at 100 m [m/s]



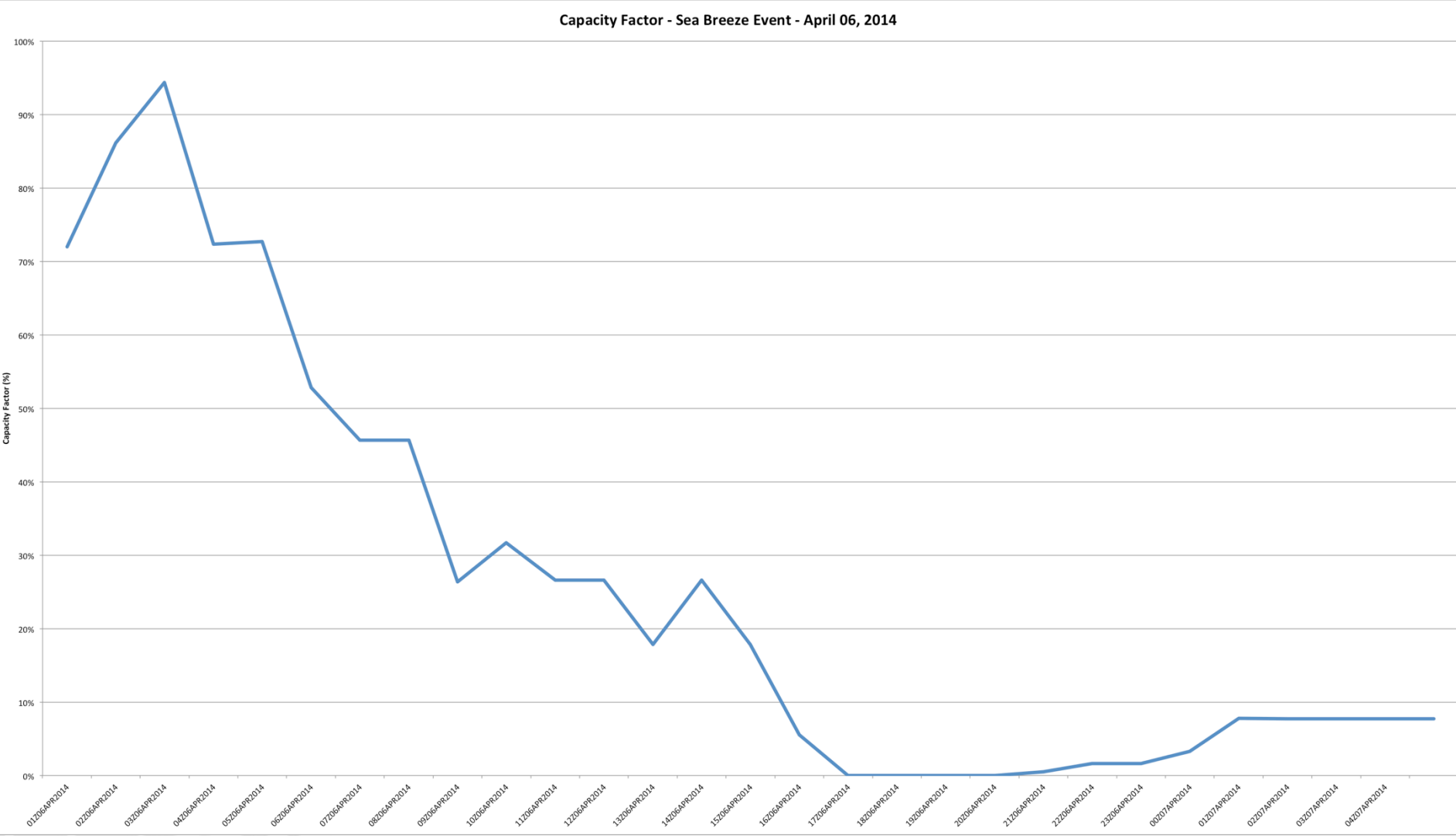
RU Coastal Ocean Observation Lab: RUWRF-ARW 1 KM Model Initialized 00Z06APR2014
<http://marine.rutgers.edu/cool/weather> Valid 03Z07APR2014 (Mon) | Forecast Hour 27



Wind Speed – Sea Breeze Event – April 6, 2014



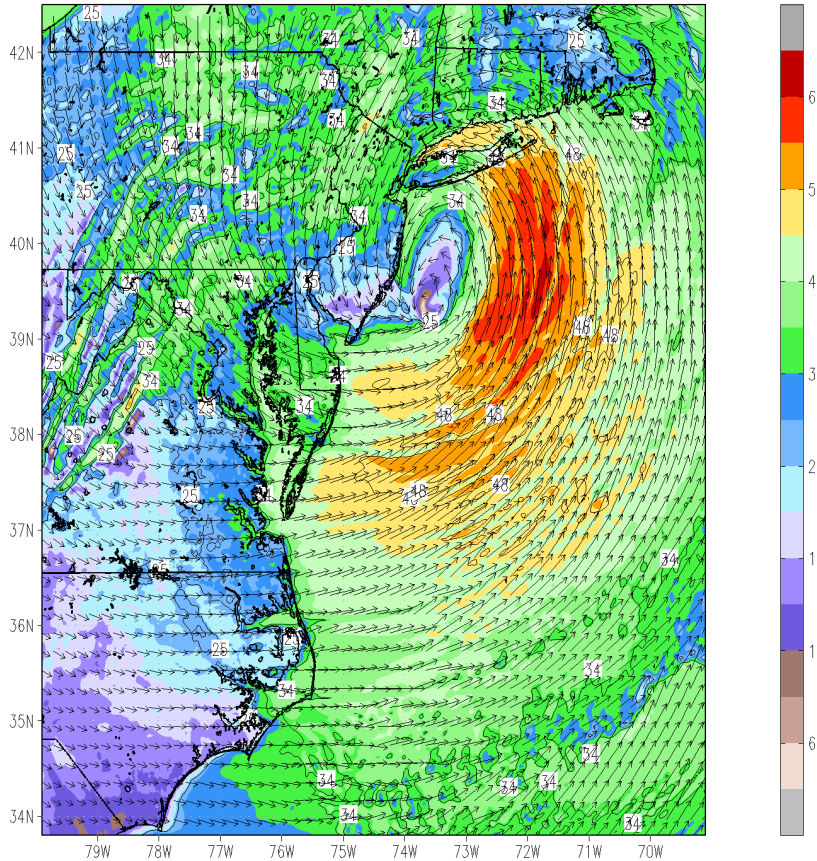
Capacity Factor – Sea Breeze Event – April 6, 2014



Severe Weather Analyses

Sandy, Oct 29-30, 2012

Wind Speed at 10 m [kts]



RU Coastal Ocean Observation Lab: RUWRF-ARW 3 KM Model Initialized 00Z28OCT2012
<http://marine.rutgers.edu/cool/weather> Valid 01Z30OCT2012 (Tue) | Forecast Hour 49

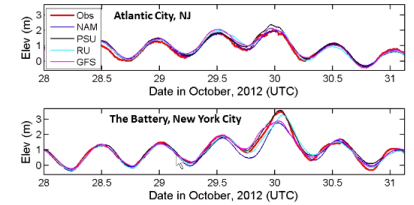
https://ams.confex.com/ams/94Annual/video gateway.cgi/id/25658?recordingid=25658

Modeling and Dissecting Hurricane Sandy's Storm Surge and Overland Inundation

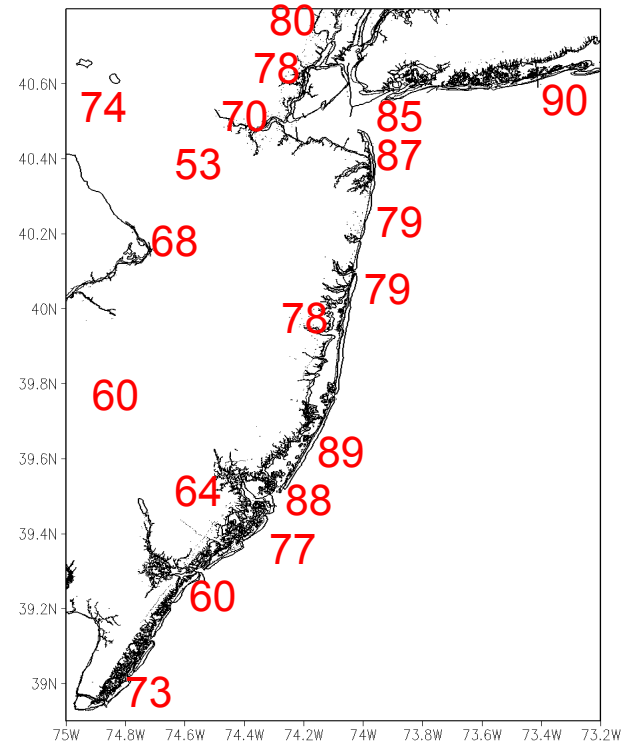
Alan Blumberg, Stevens Institute of Technology, Hoboken, NJ; and P. Orton and N. Georgas

Met Forecast Products Give Wide Range of Results

Shown are observed total water levels, with sECOM-modeled surge results from met forecasts 30-40 hours prior to landfall

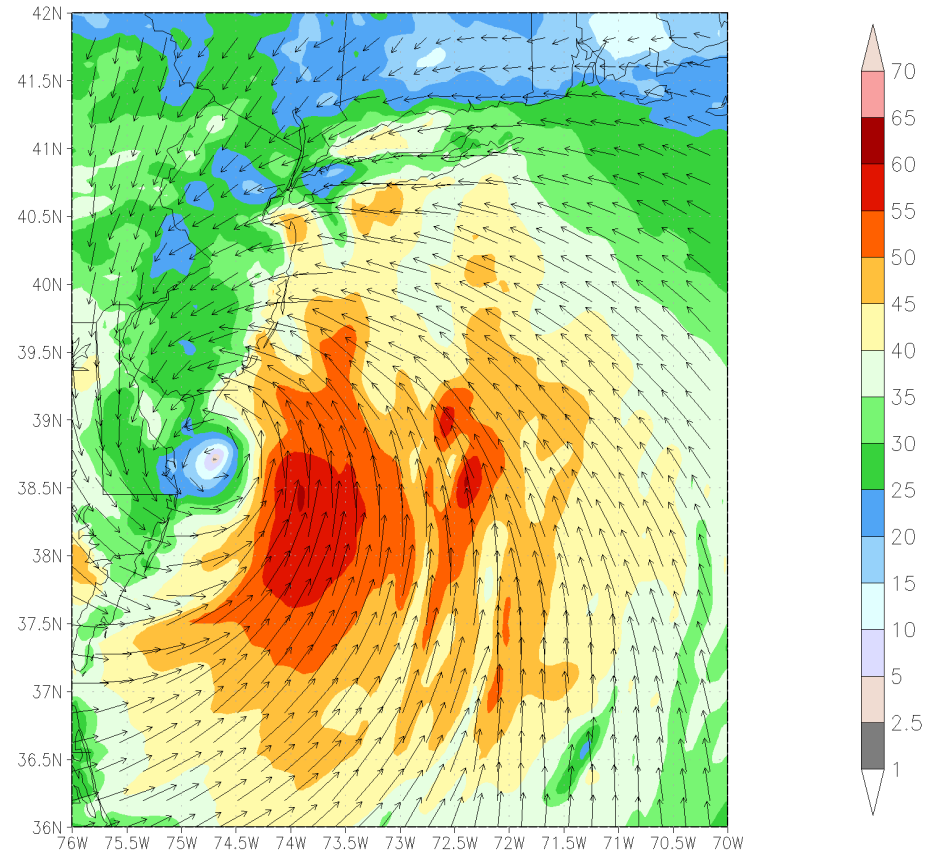


NAM = WRF - North American Mesoscale domain; PSU = WRF with radar data assimilation - Penn State University (Zhang et al. 2011); RU = WRF Rutgers; GFS = NCEP Global Forecasting System

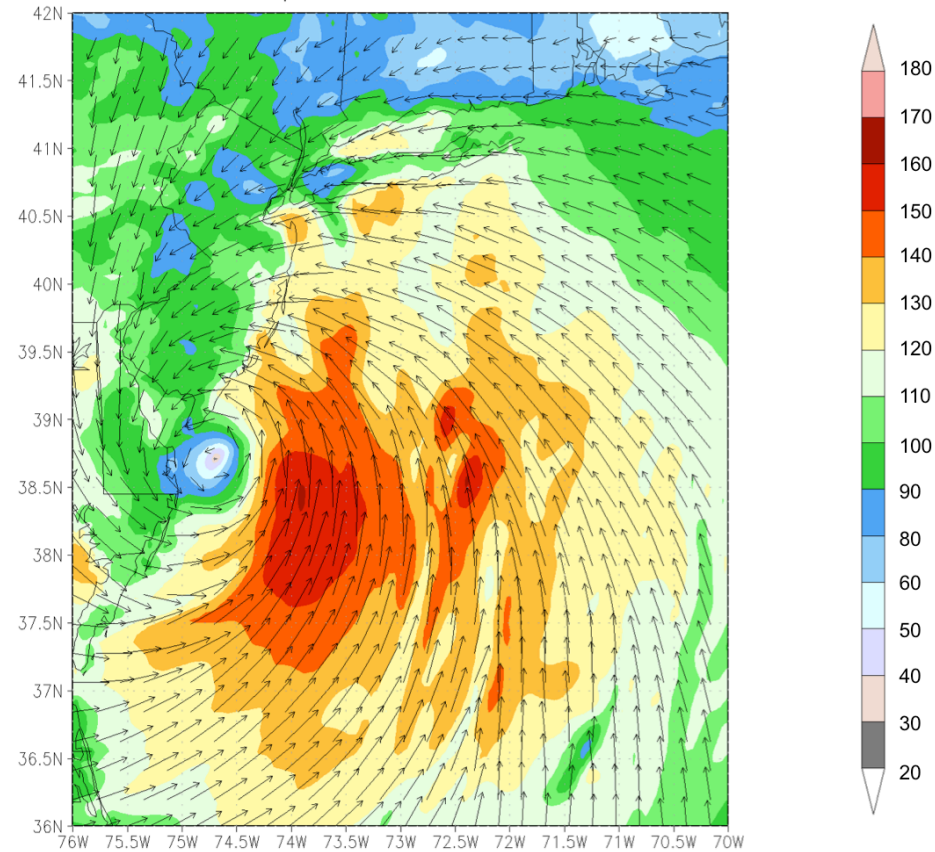


Model Irene with the intensity of the September 1821 Hurricane using RUWRF

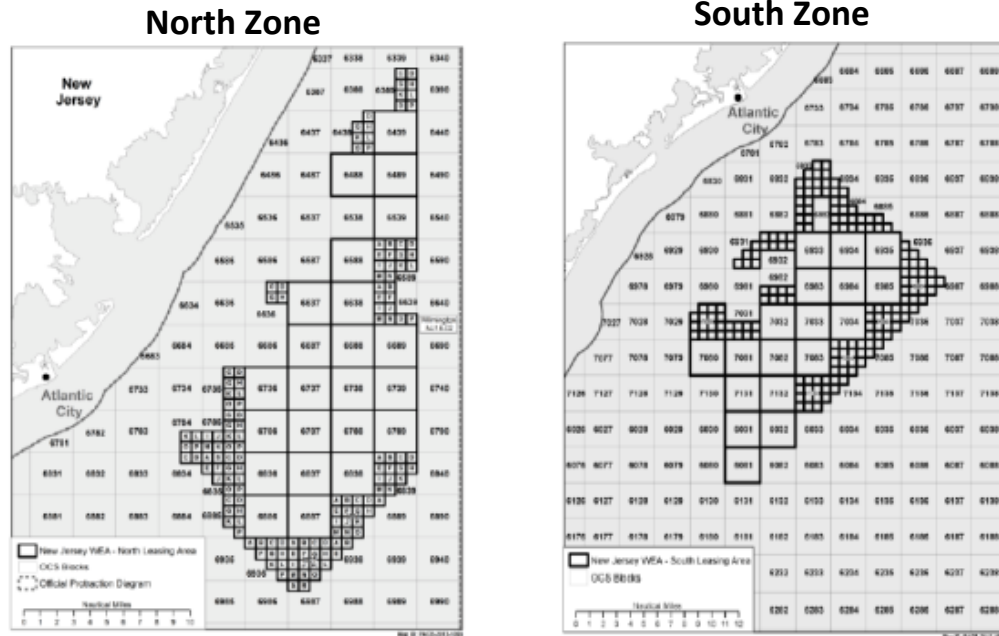
Irene Wind Speed at 10m (MPH)



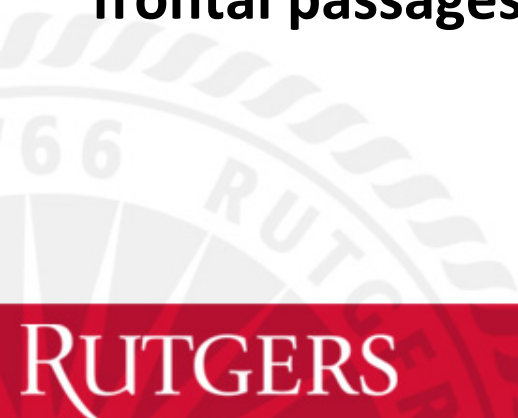
1821 Wind Speed at 10m (MPH)



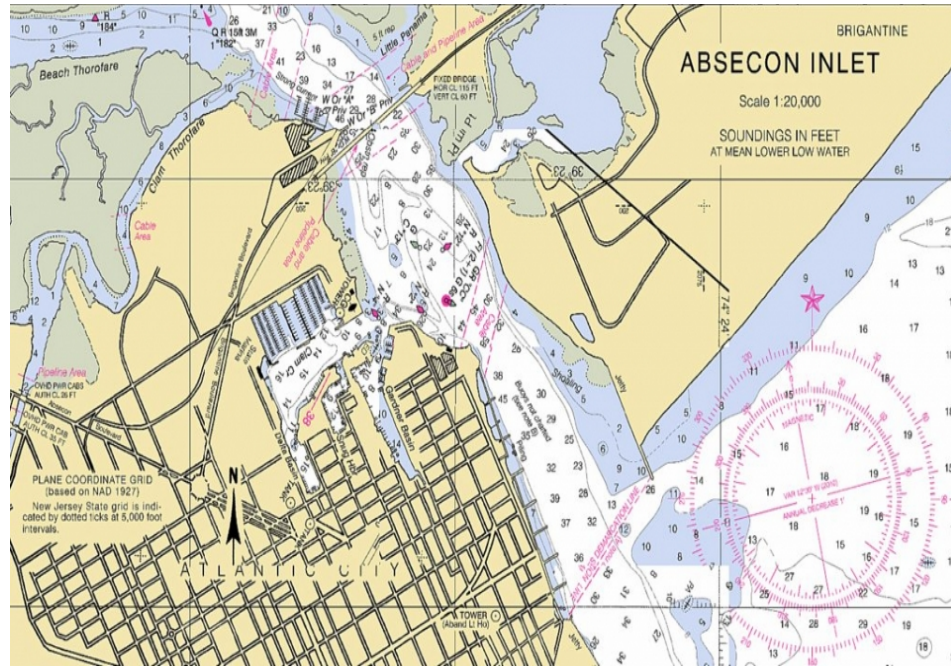
BOEM NJ WEA Analysis



- Relatively consistent wind resource and bathymetry across NJ WEA
- Convergence zone of storms (Northeasters, tropical cyclones), frontal passages, **sea breeze**, and **coastal upwelling** events

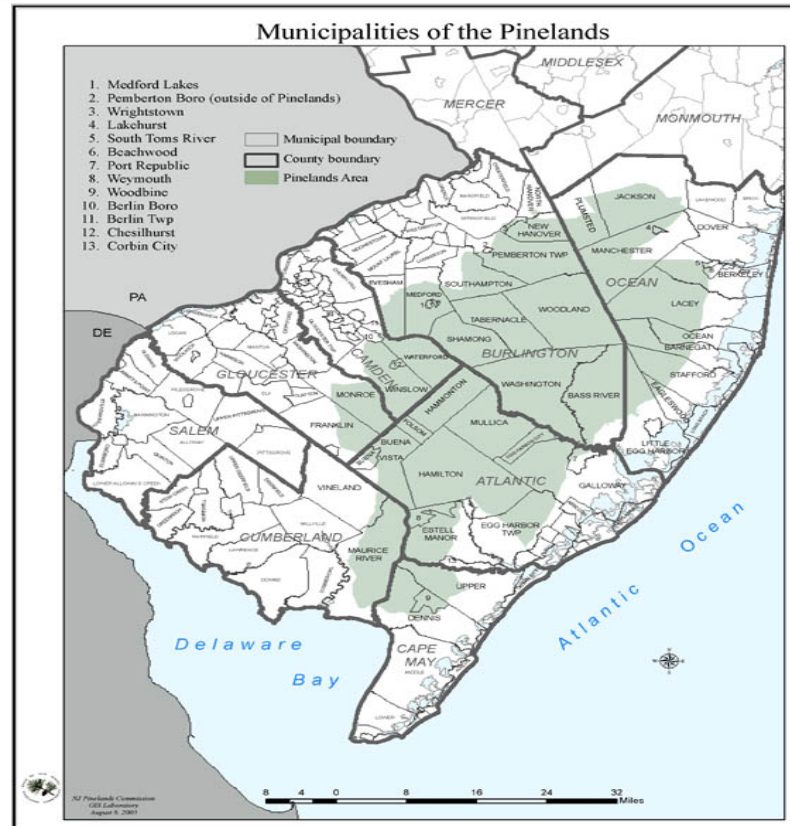


BOEM NJ WEA Analysis



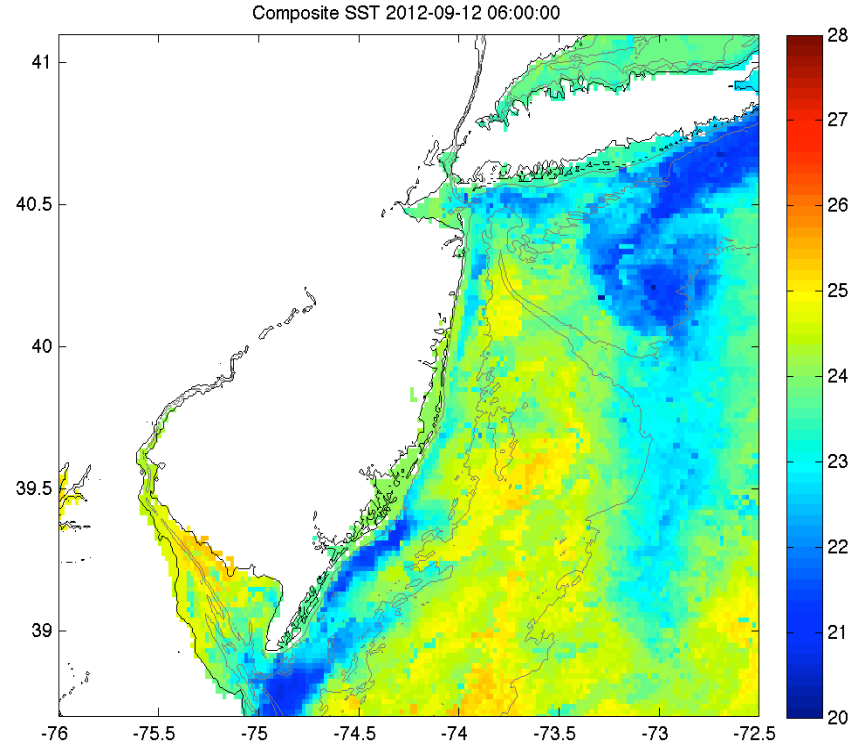
- Delineation line for north/south zones runs NW to SE from Absecon Inlet
- NJ coastline orientation (SW to NE) → turbulent wake increases from south to north in NJ WEA
- Concave coastline in south: offshore flow accelerates, onshore flow decelerates (opposite in northern WEA)

BOEM NJ WEA Analysis



- Pinelands → large fetch, esp. over northern WEA
- Cold SSTs (esp. during upwelling), warm Pinelands, hot urban centers → regular sea breeze events during peak energy demand periods

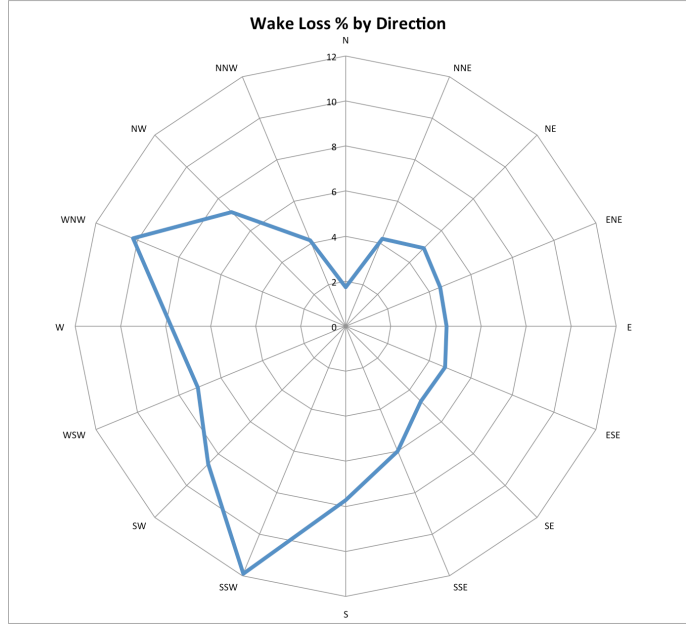
BOEM NJ WEA Analysis



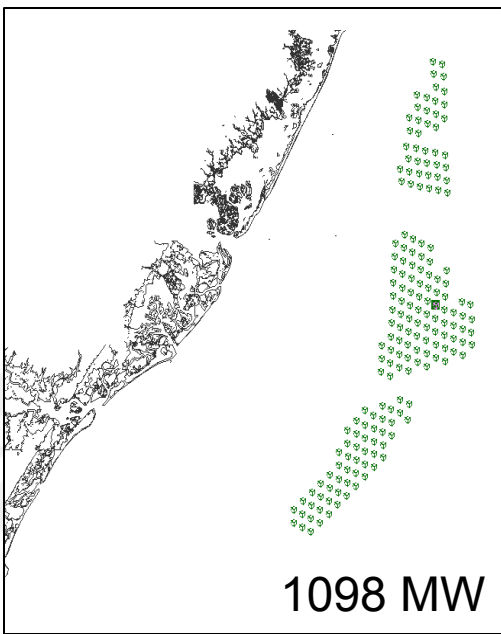
- Coastal upwelling coincides with sea breeze season
 - Impacts sea breeze circulation: more intense but smaller spatial imprint on WEA
- Staggered WTG spacing suggested
- 10D X 12D WTG spacing more viable than 8D X 8D WTG spacing
- NJ WEA is capable of housing 2500 to 3000 MW of installed OSW capacity



3000 MW



1998 MW

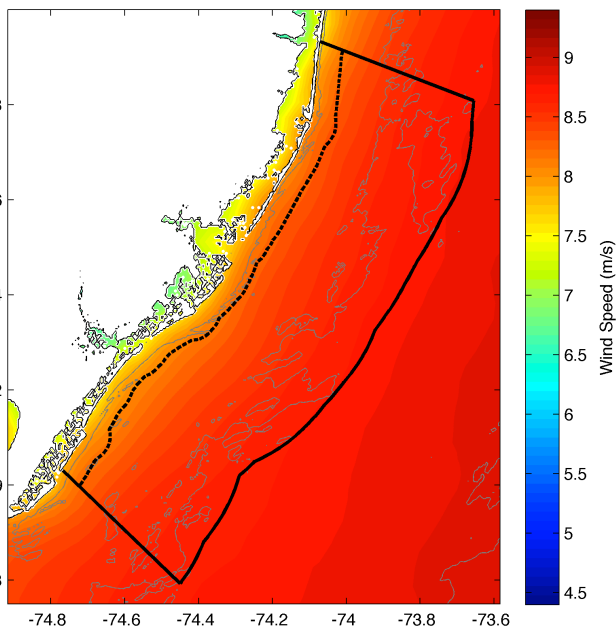
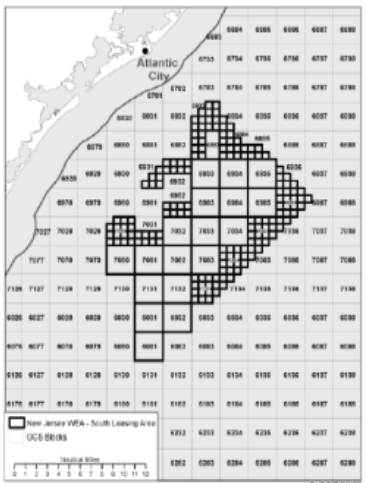
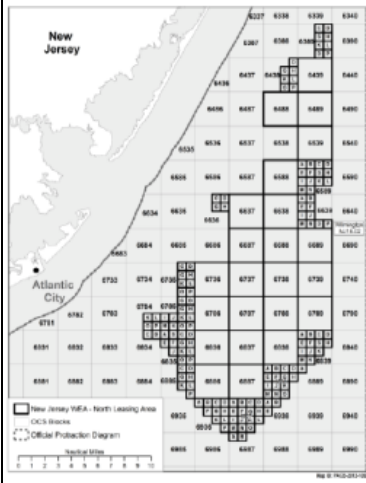


1098 MW

Annual 100m

North Zone

South Zone



Thank you!

Questions?



Extra Slides



RUCOOL SST Satellite Composite

1. Clean up AVHRR scans

- i. Remove sun glint, data close to edge

2. Decloud (specific to MAB)

- i. AVHRR Channel 2 (0.725-1 μm) tests:
 - Remove if near IR albedo > 2.3%
 - Remove if Δ near IR albedo > 0.15% within 3km x 3km box
- ii. AVHRR Channel 4 (10.3-11.3 μm) tests:
 - Remove if $T < 5^\circ\text{C}$ (summer), 3.5°C (winter)
 - Remove if $\Delta T > 1^\circ\text{C}$ within $\sim 3\text{km} \times 3\text{km}$ box

• 3-day coldest pixel composite with NASA SPoRT 2km SST

- i. Keep only coldest pixel between SPoRT SST and 12-17 UTC AVHRR scans
 - AVHRR Channel 2 needs daytime

