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

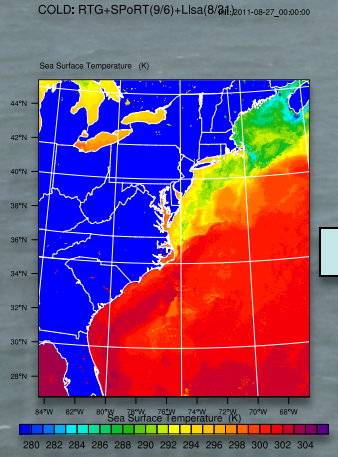
An Advanced Atmosphere/Ocean Assessment Program: Reducing the Risks Associated with NJ Offshore Wind Energy Development

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

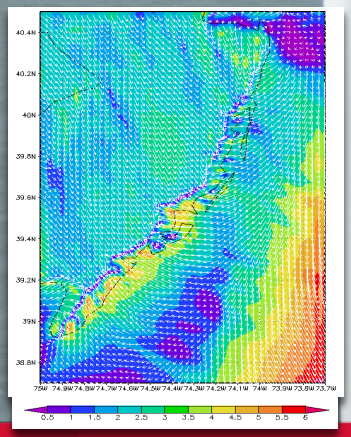
Principal Investigators: *Dr. Scott Glenn and Dr. Rich Dunk, CCM*

Team Members: *Dr. Josh Kohut, Dr. Hugh Roarty, Dr. Travis Miles, Greg Seroka, John Kerfoot, Laura Palamara, Mike Crowley, Ethan Handel, Colin Evans*

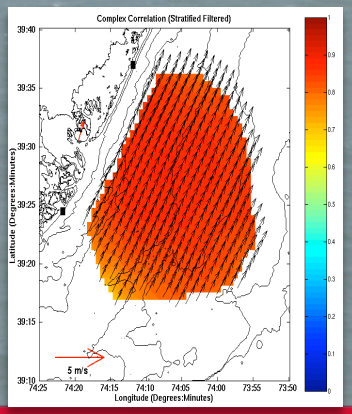
New Ocean Data



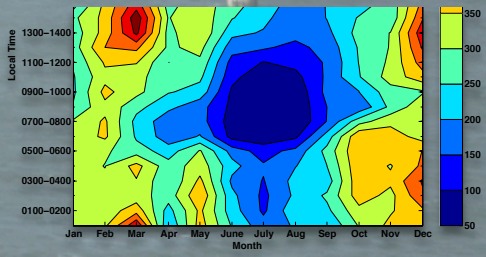
Hi-Res Weather Model



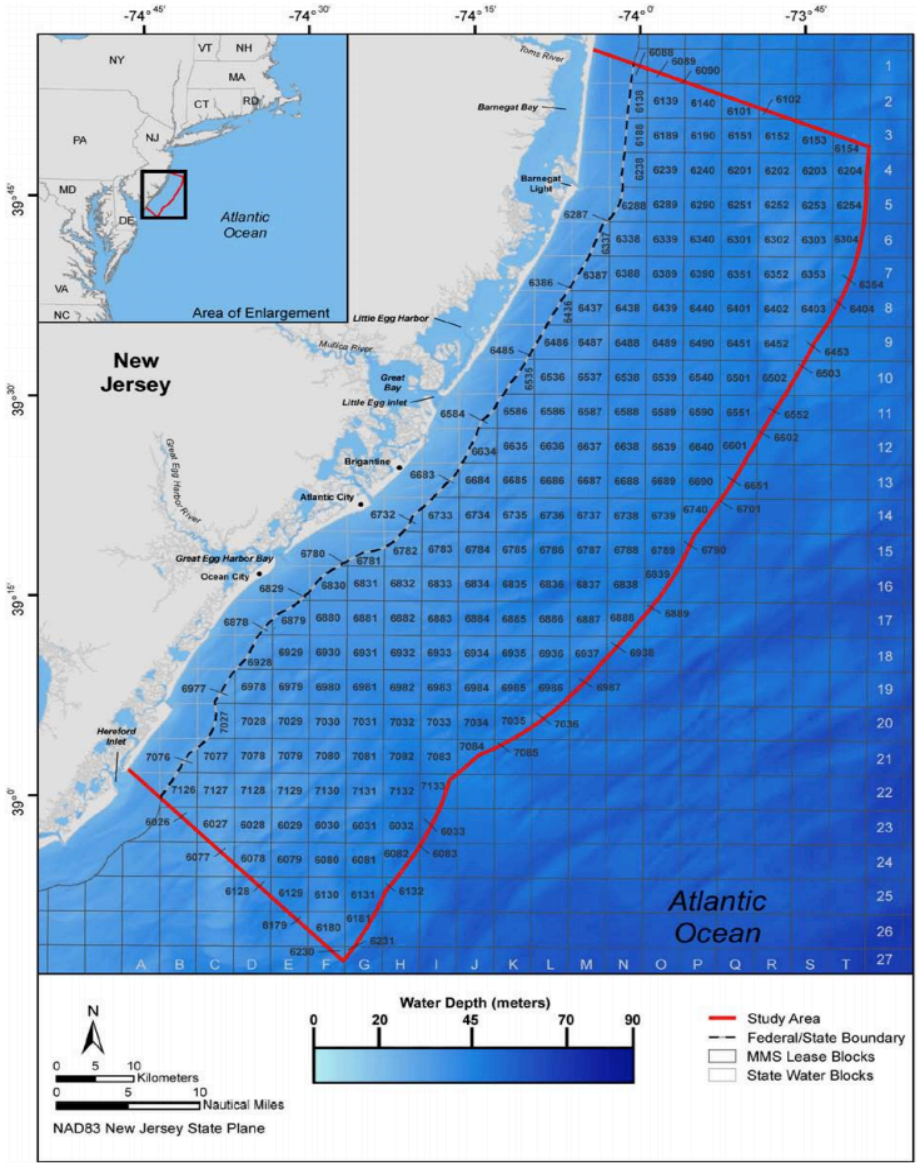
Spatial Validation Data



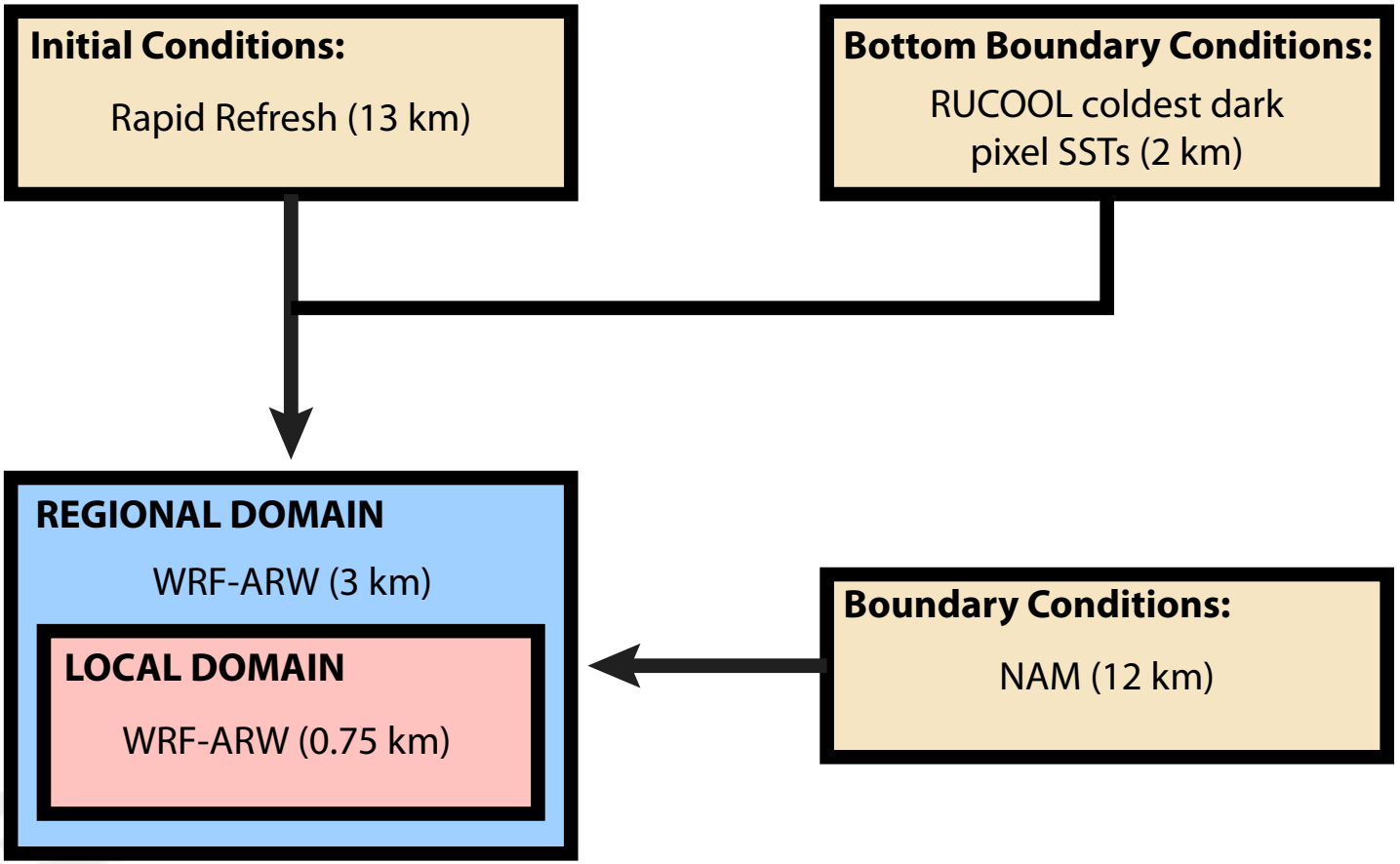
Wind Power Statistics



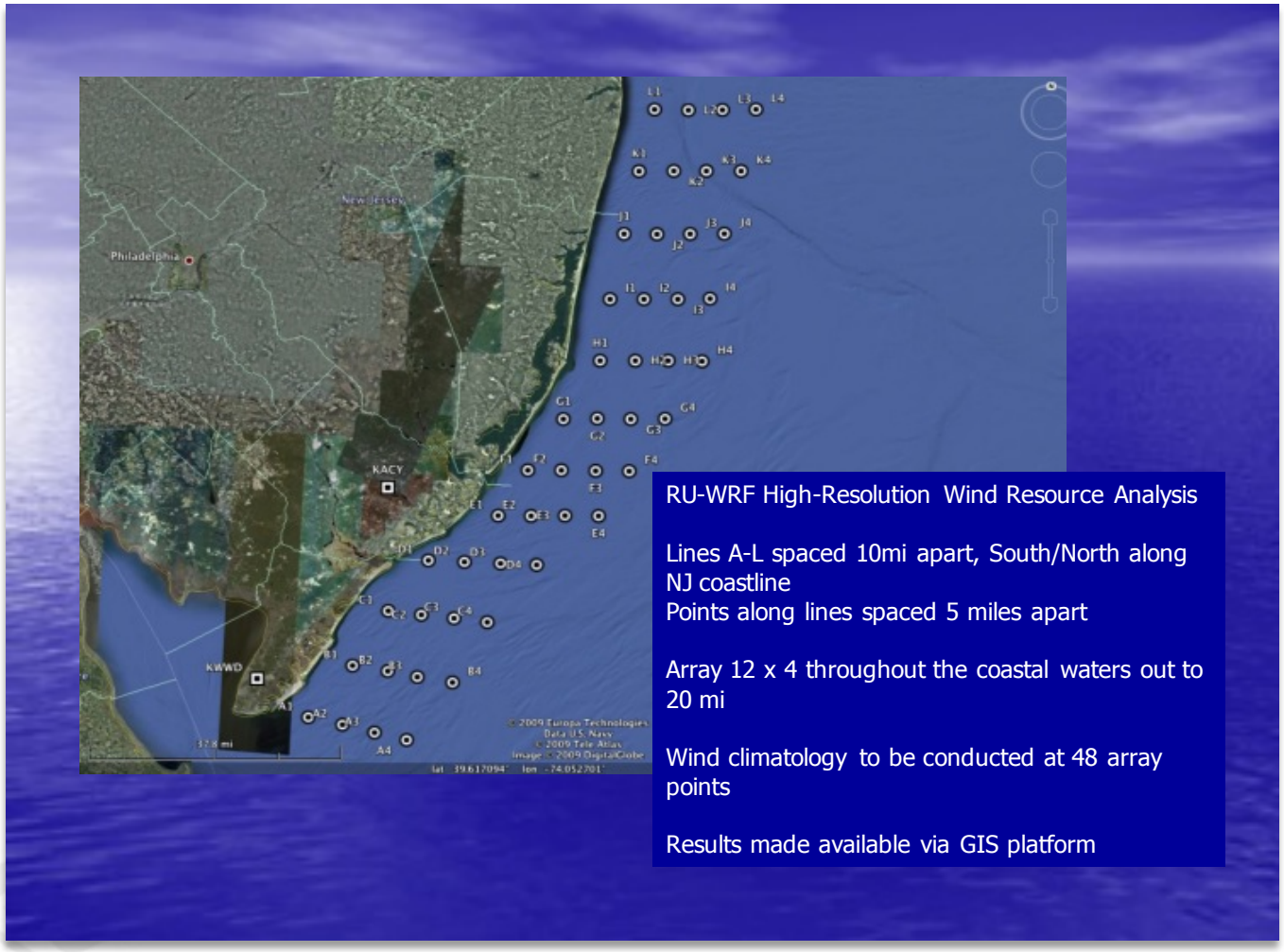
Study Area


-74° 45'
-74° 30'
-74° 15'
-74° 0'
-73° 45'
39° 45'
39° 30'
39° 15'
39° 0'
NY
VT
NH
MA
CT
RI
PA
NJ
MD
DE
VA
NC
Atlantic Ocean
Area of Enlargement
New Jersey
Toms River
Barnegat Bay
Barnegat Light
Little Egg Harbor
Mullica River
Great Bay
Little Egg Inlet
Great Egg Harbor River
Great Egg Harbor Bay
Brigantine
Atlantic City
Ocean City
Hereford Inlet
Atlantic Ocean
A B C D E F G H I J K L M N O P Q R S T
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
N
0 5 10 Kilometers
0 5 10 Nautical Miles
NAD83 New Jersey State Plane
Water Depth (meters)
0 20 45 70 90
Study Area
Federal/State Boundary
MMS Lease Blocks
State Water Blocks

RU-WRF Flow Chart



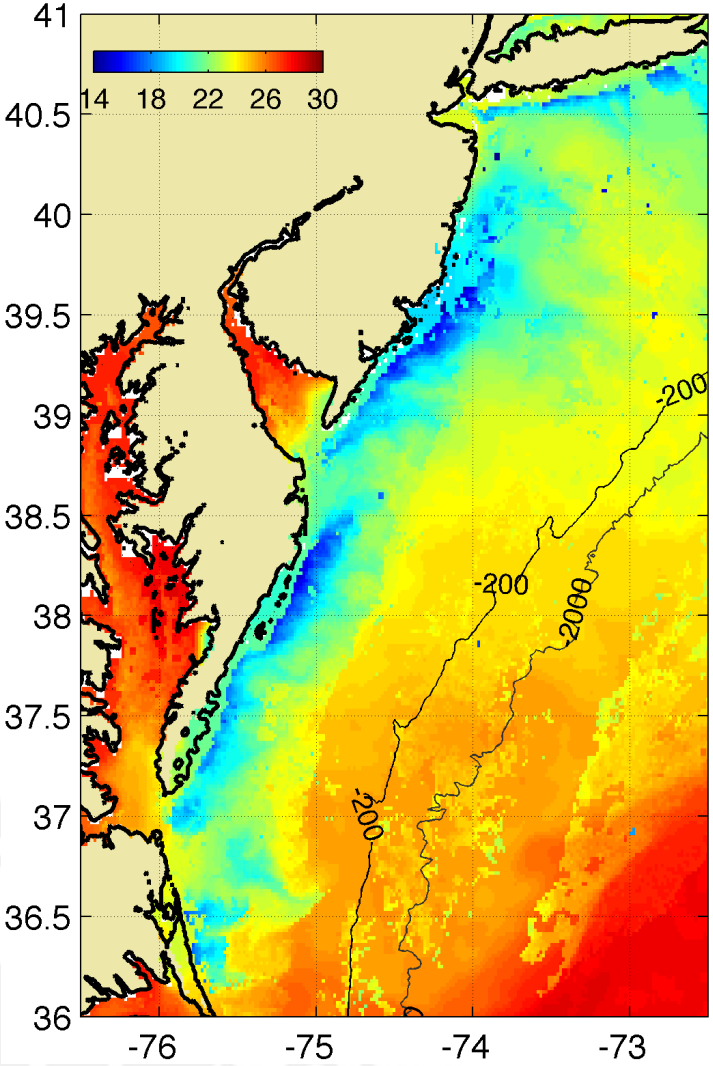
“Virtual Meteorological Tower” Locations



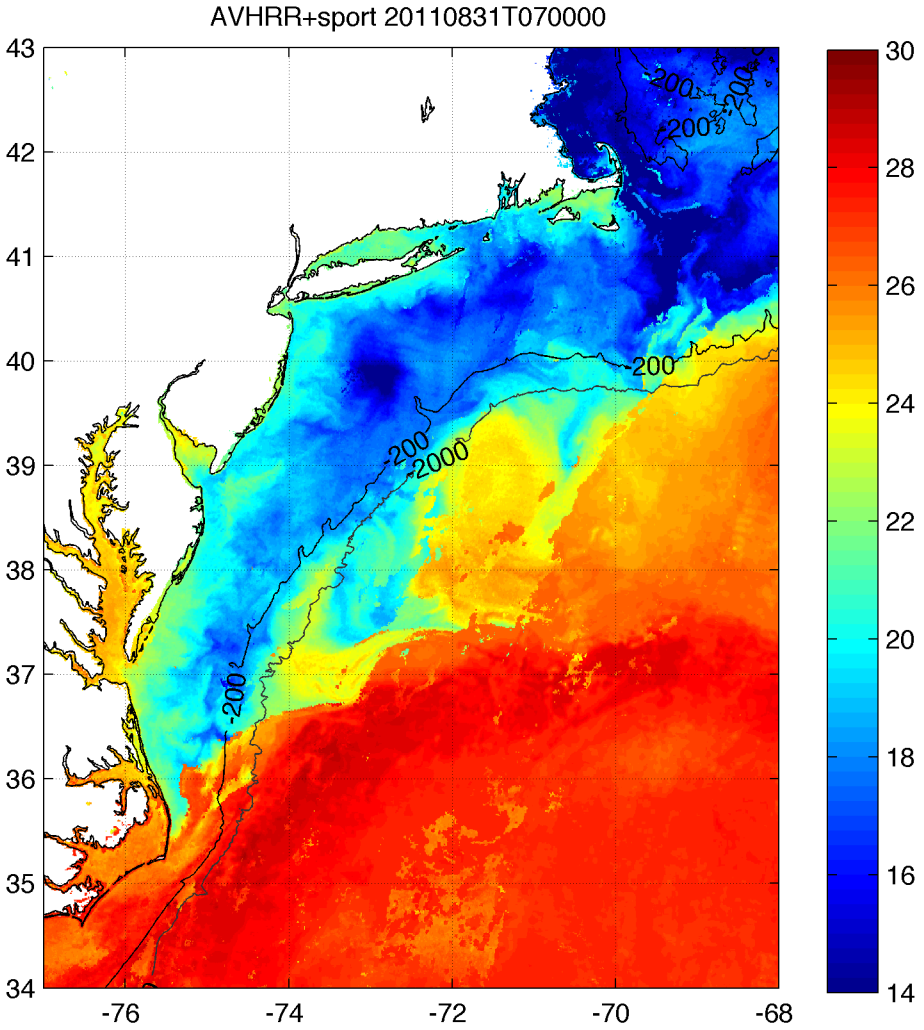
- **At heights of <80, 80, 90, 100, 110, 120, and >120 m depending on atmospheric conditions**

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

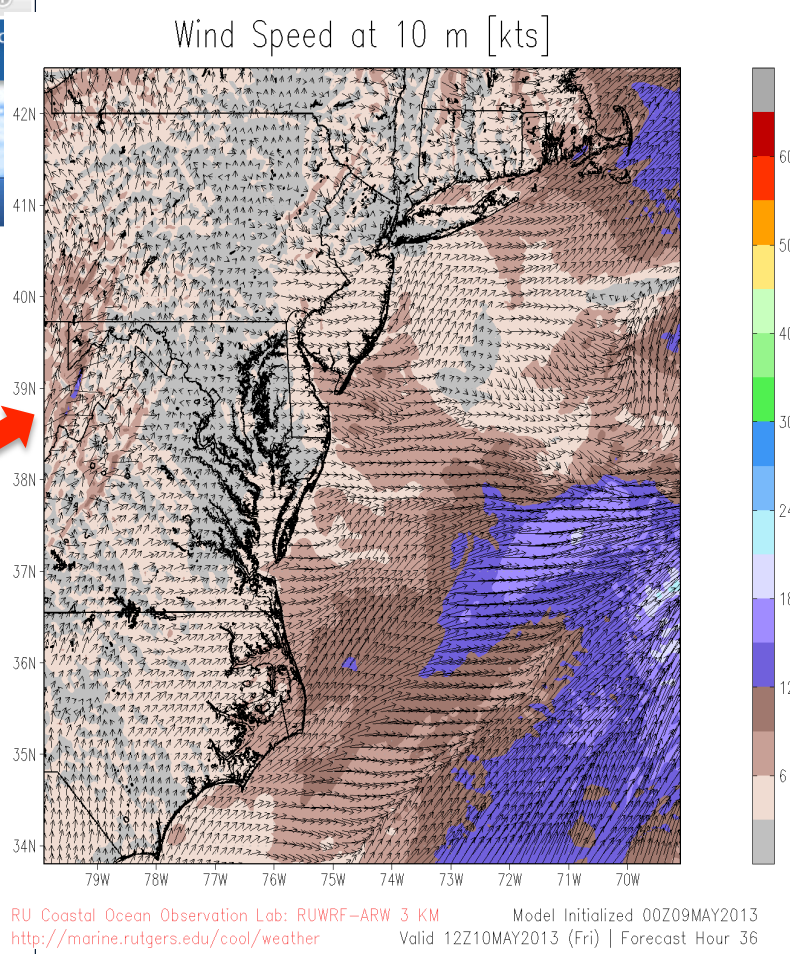
Boundary Conditions: 0000Z 12 km NAM-218 (Forecast Hour 03 to 84)

Boundary Conditions updated every 3 hours

RUWRF 3 km - Initialized at 0000

Model Simulation Complete: 09 May 2013 AT 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



EACH

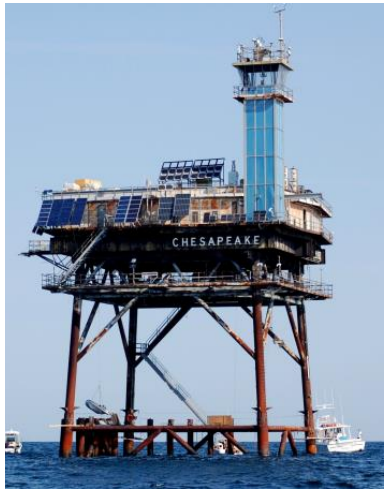
Coastal Ocean Observation Lab

Coastal/Offshore Monitoring

Meteorological Tower

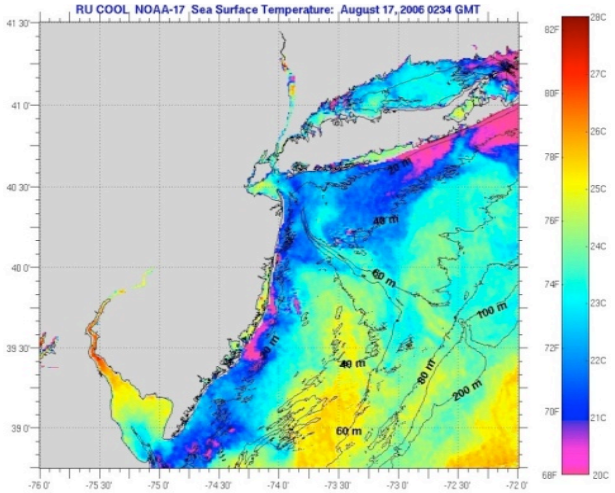
Meteorological Buoy

Chesapeake Bay

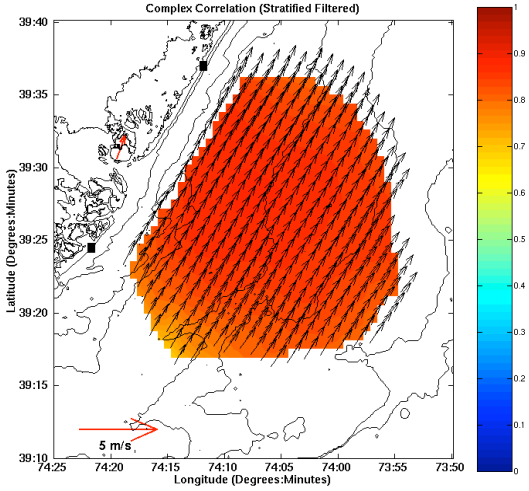


Buzzards Bay

Infrared Satellite



Coastal Radar (CODAR)



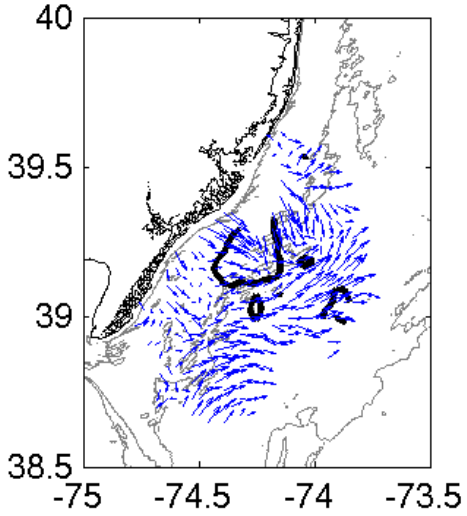
Vertical Validation Results

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/ $\boldsymbol{\sigma_{Obs}}$ * 100)	107.0%	61.9%	73.1%	75.7%	70.9%	73.6%
Validated	No	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Criterion 3 ($RMSE_{ub}$/ $\boldsymbol{\sigma_{Obs}}$ * 100)	107.0%	62.1%	72.9%	78.3%	70.6%	73.6%
Validated	No	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

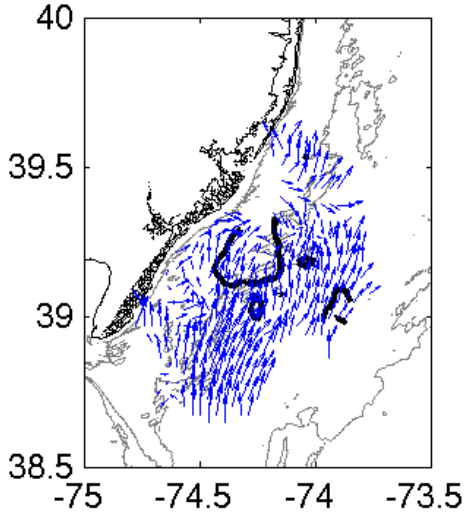
*Based on standard validation criteria for mesoscale atmospheric models (Pielke, 1984; Dvorak et al., 2012)

Horizontal Evaluation Results

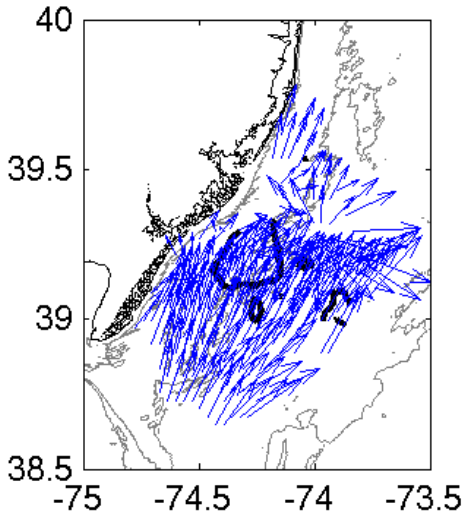
CODAR Detided Currents 2012-09-05 23:00



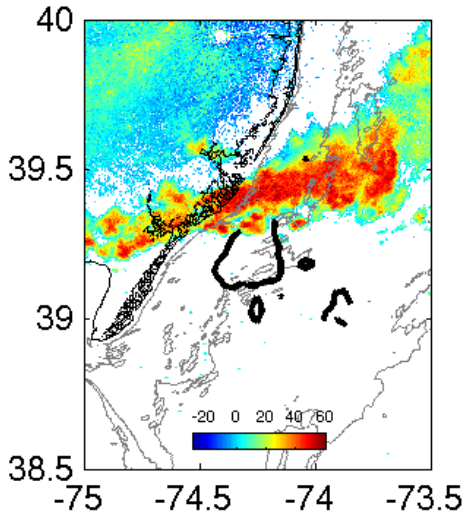
CODAR 3-hr Lag Wind 2012-09-05 23:00



RUWRF Wind 2012-09-05 23:00

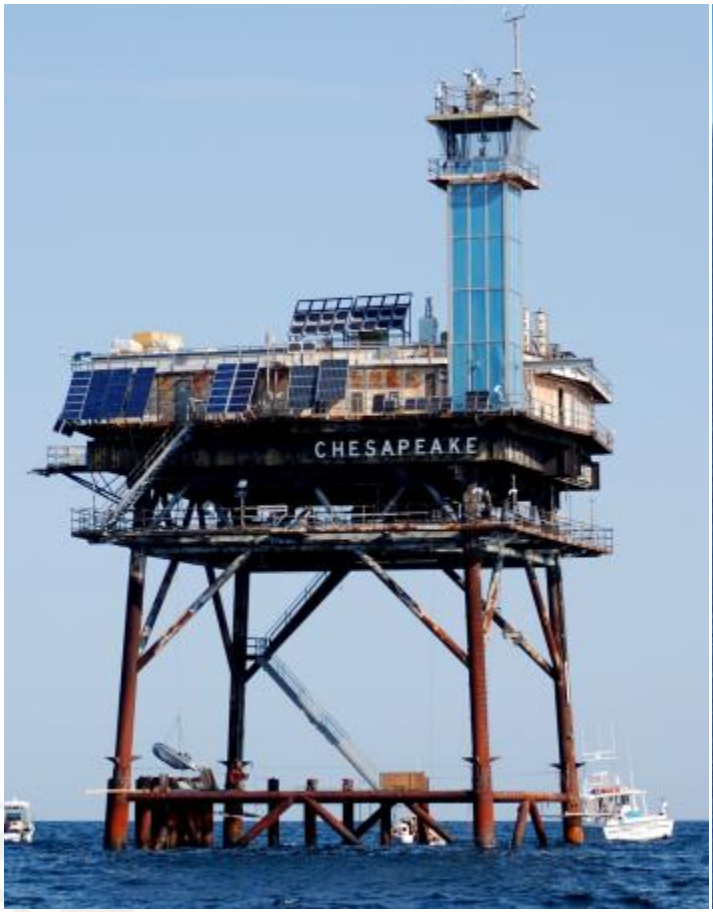


RADAR Reflectivity (dBZ) 2012-09-05 22:58



More Coastal/Offshore Monitoring

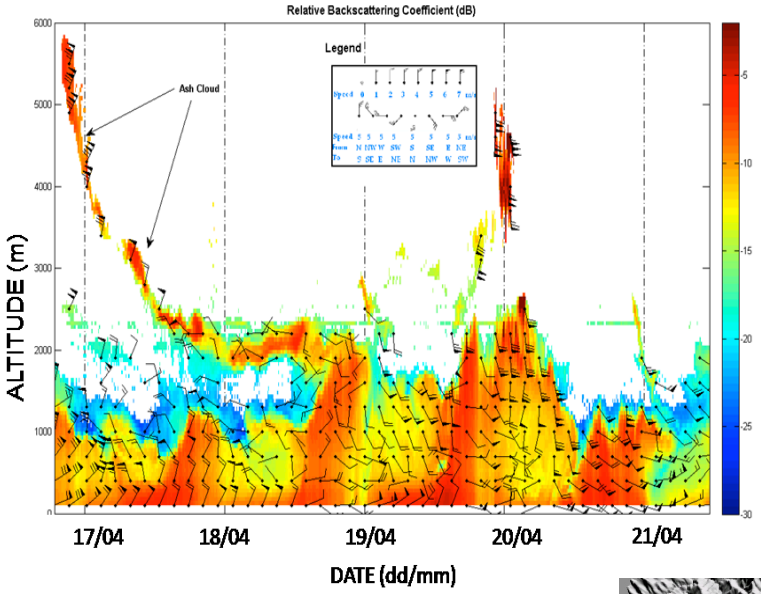
Chesapeake Light Tower



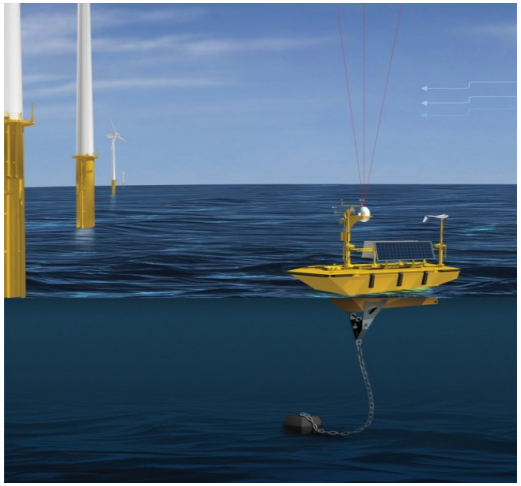
Current

Future

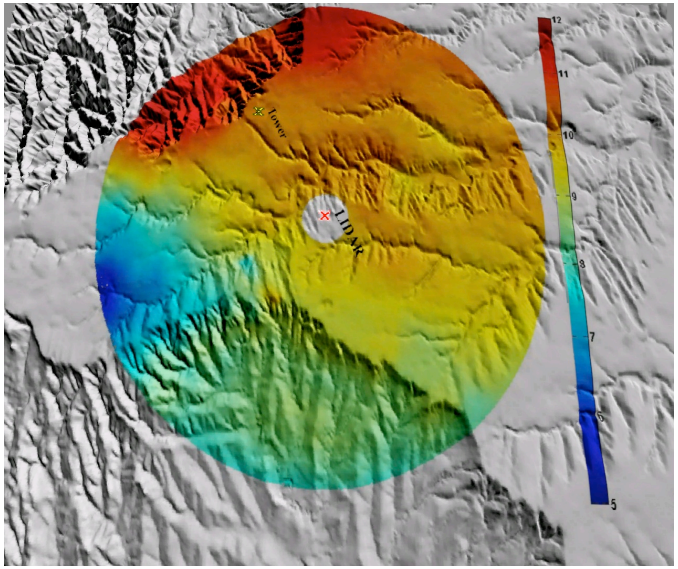
Scanning and Vertical LIDARs



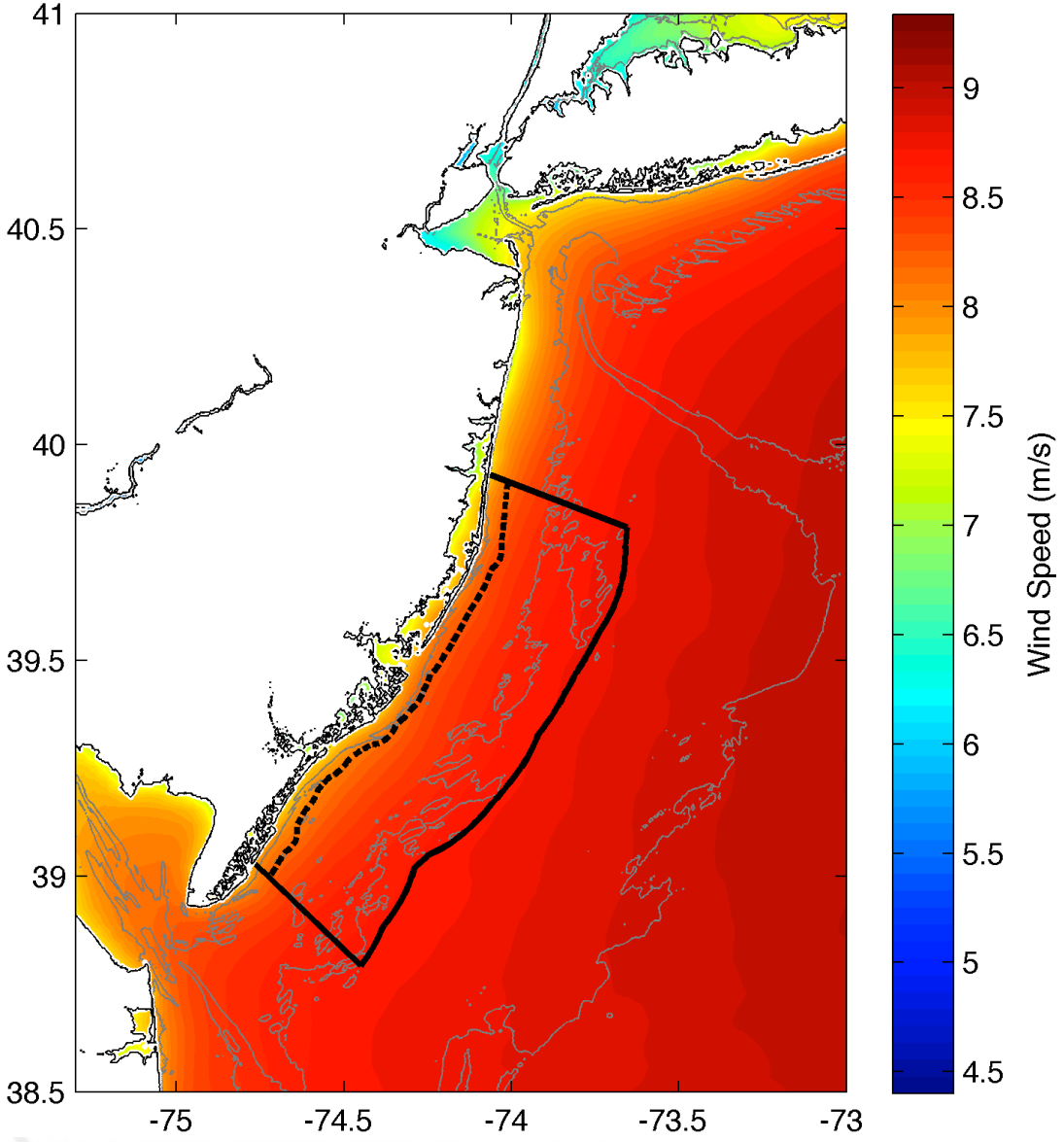
Offshore vertical LIDAR



Coastal/Offshore Scanning LIDAR

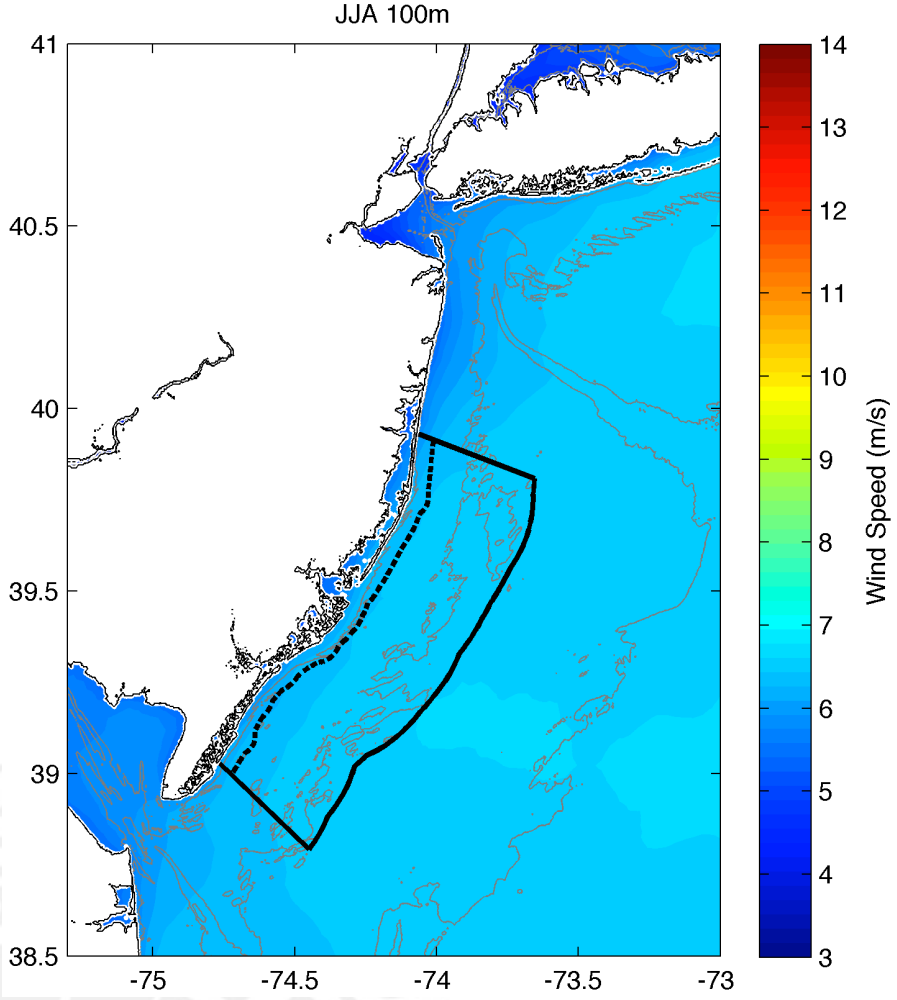


Annual Average 100m Wind Speed

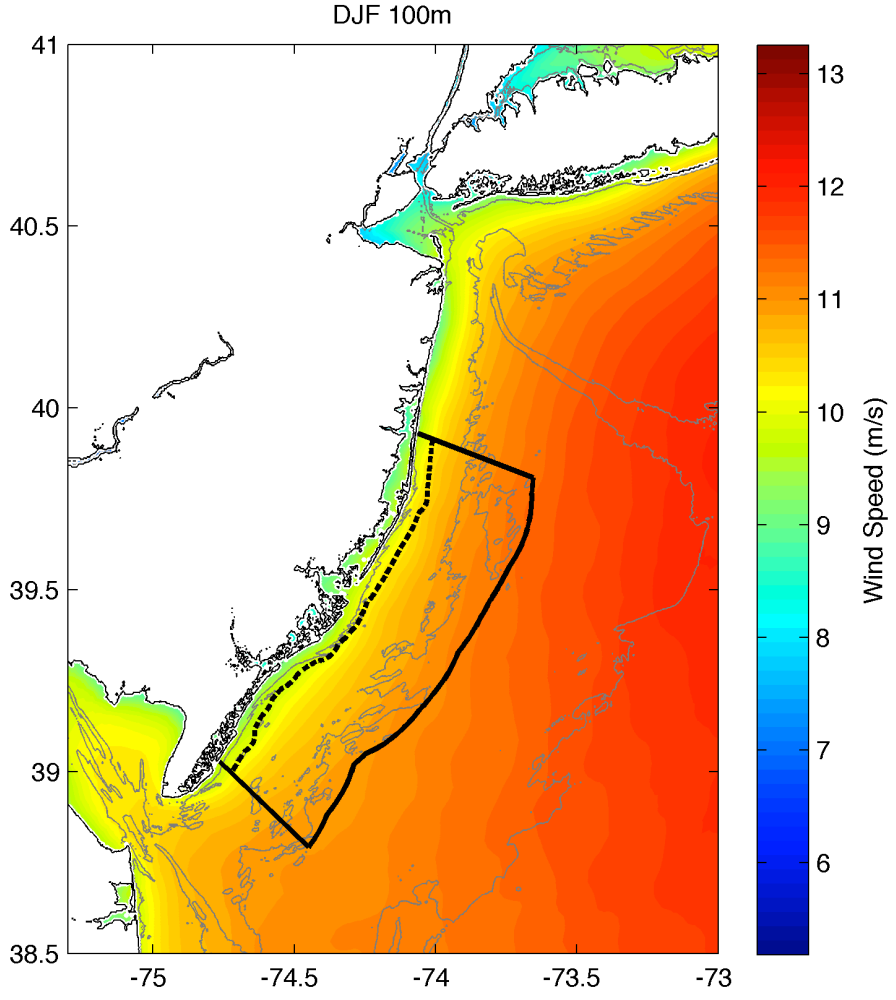


Seasonal 100m Wind Speed

Summer

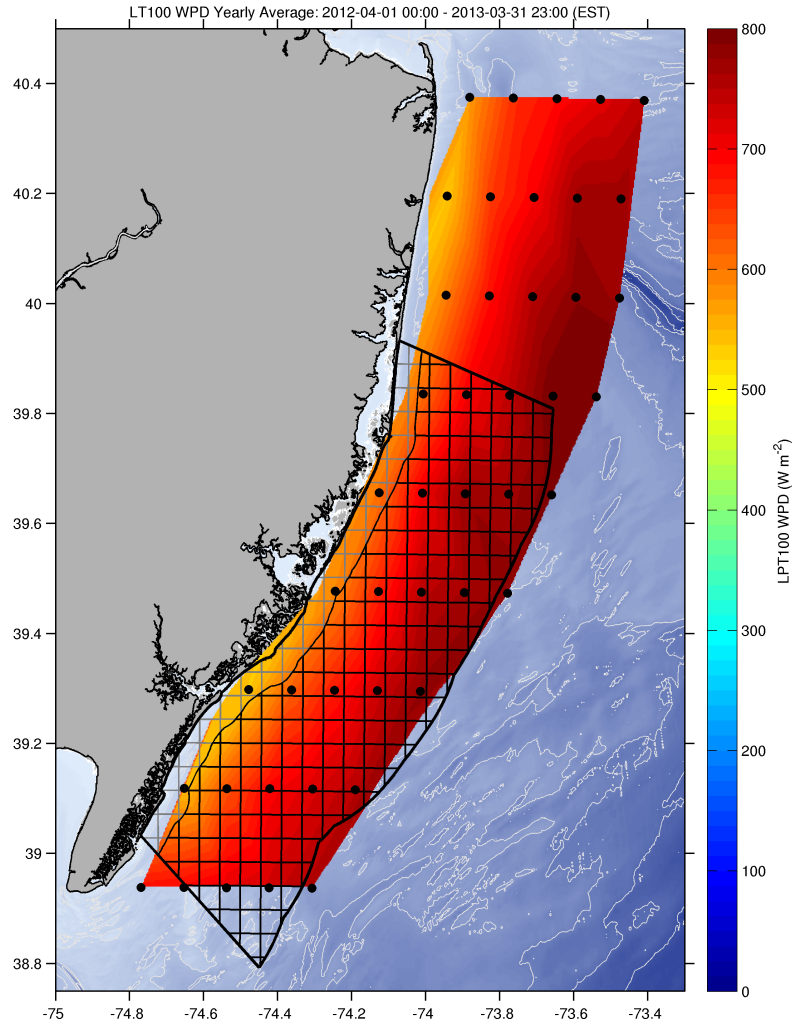


Winter

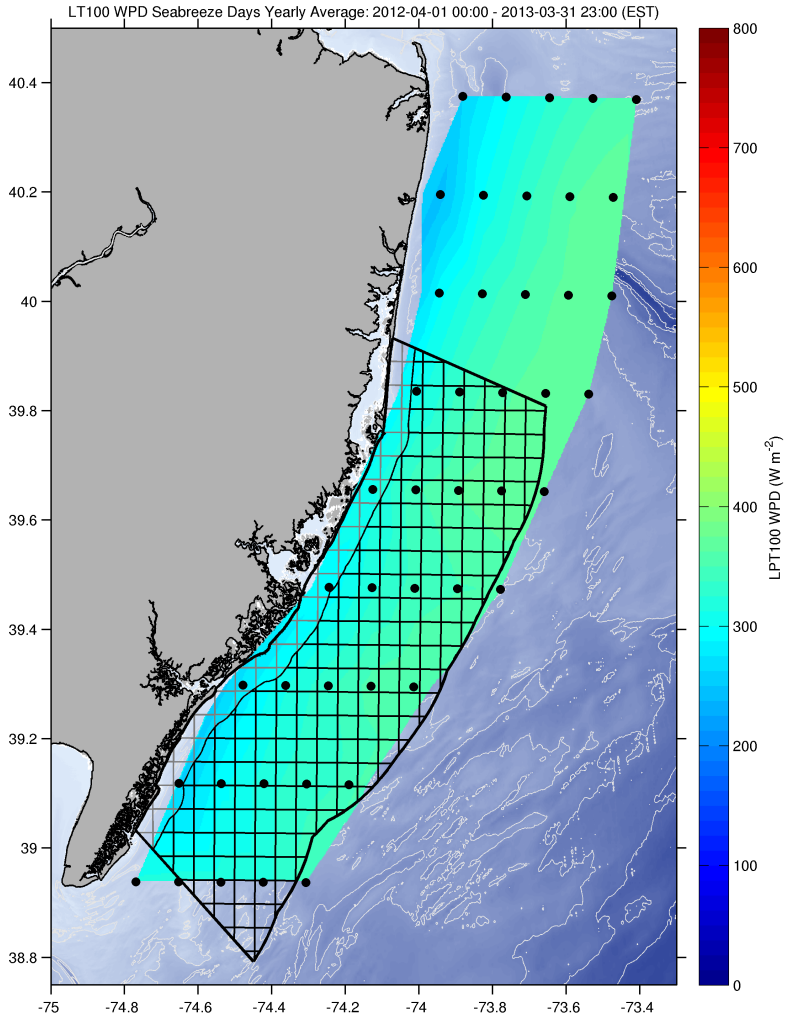


Annual Average vs. Sea Breeze Days

Annual Average

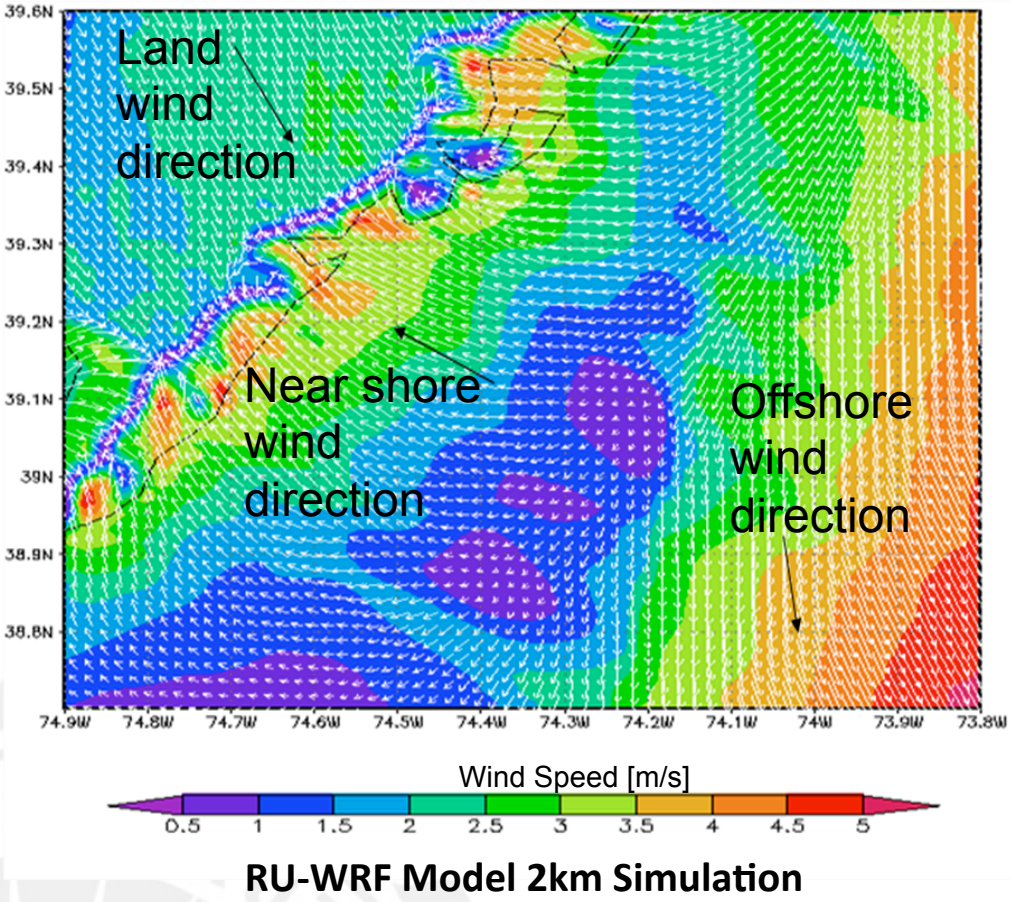


Sea Breeze Average



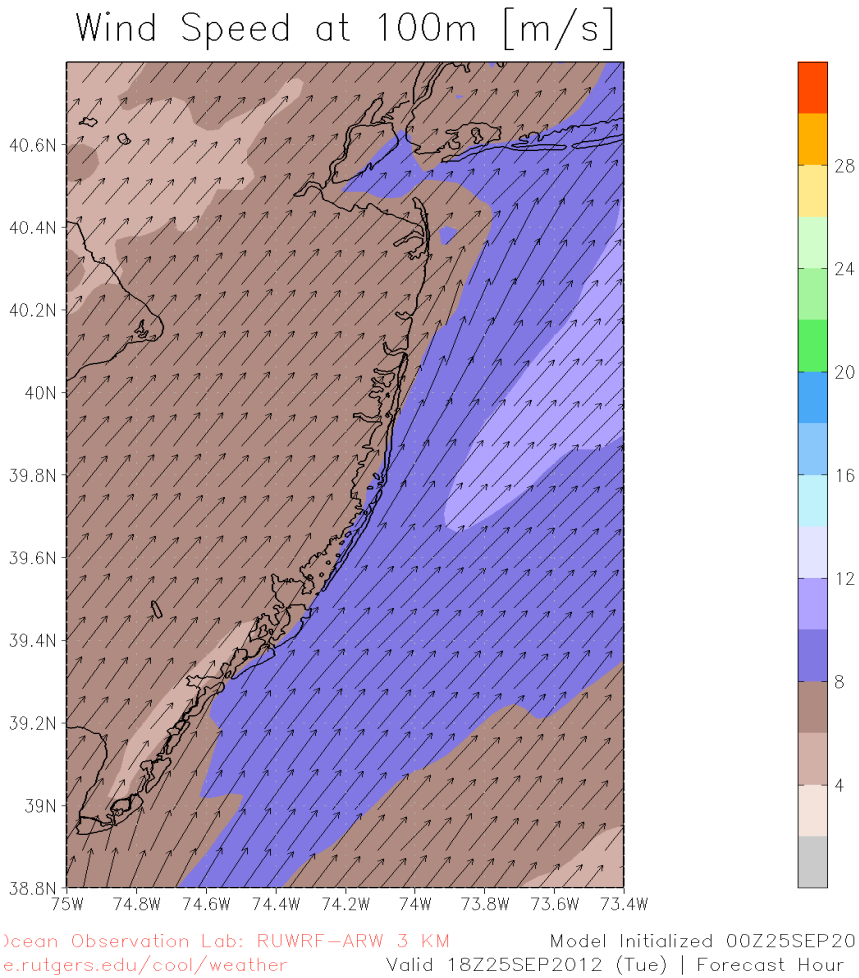
Sea Breeze Variability

Sea Breeze

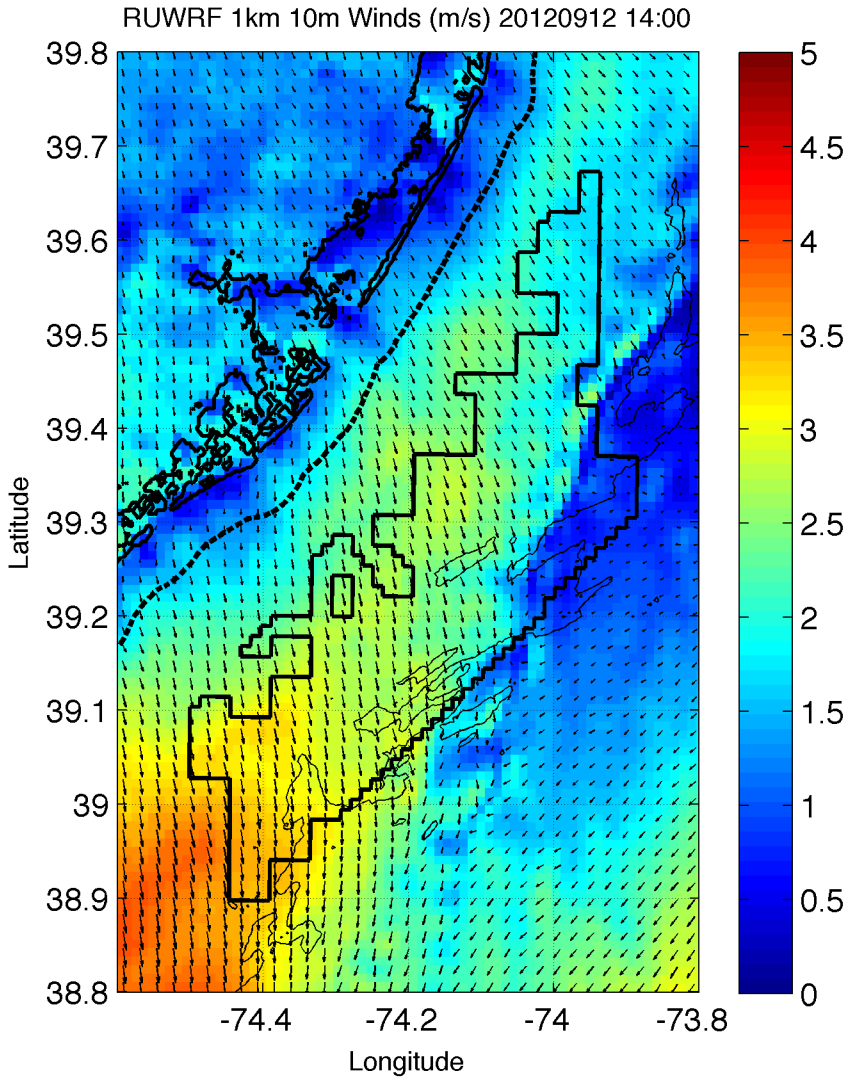


RU-WRF Model 2km Simulation

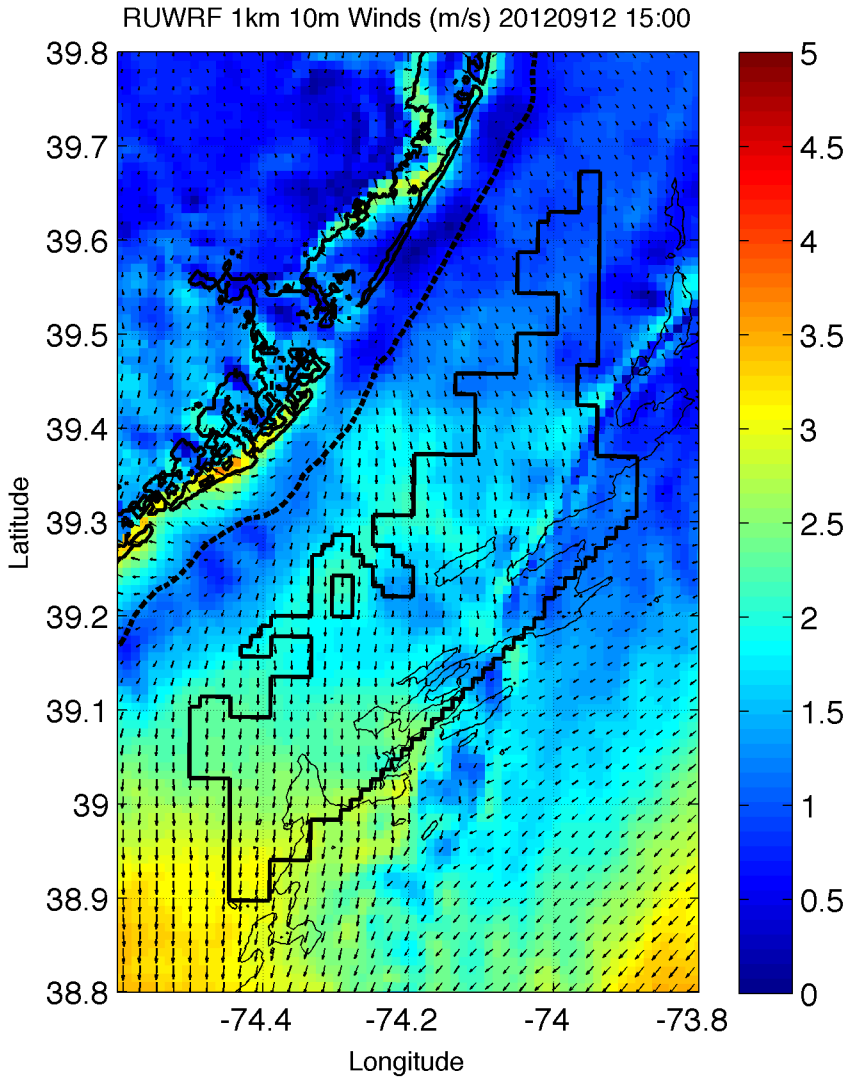
Non-Sea Breeze



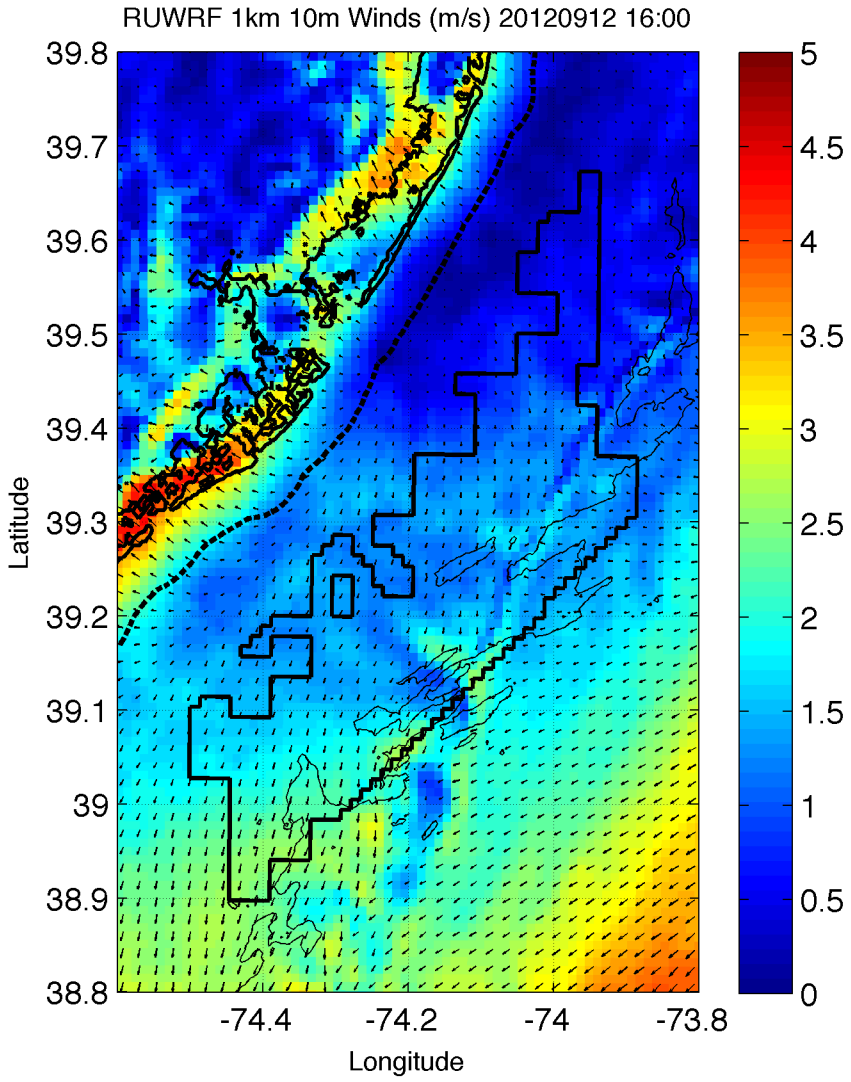
Sea Breeze Variability



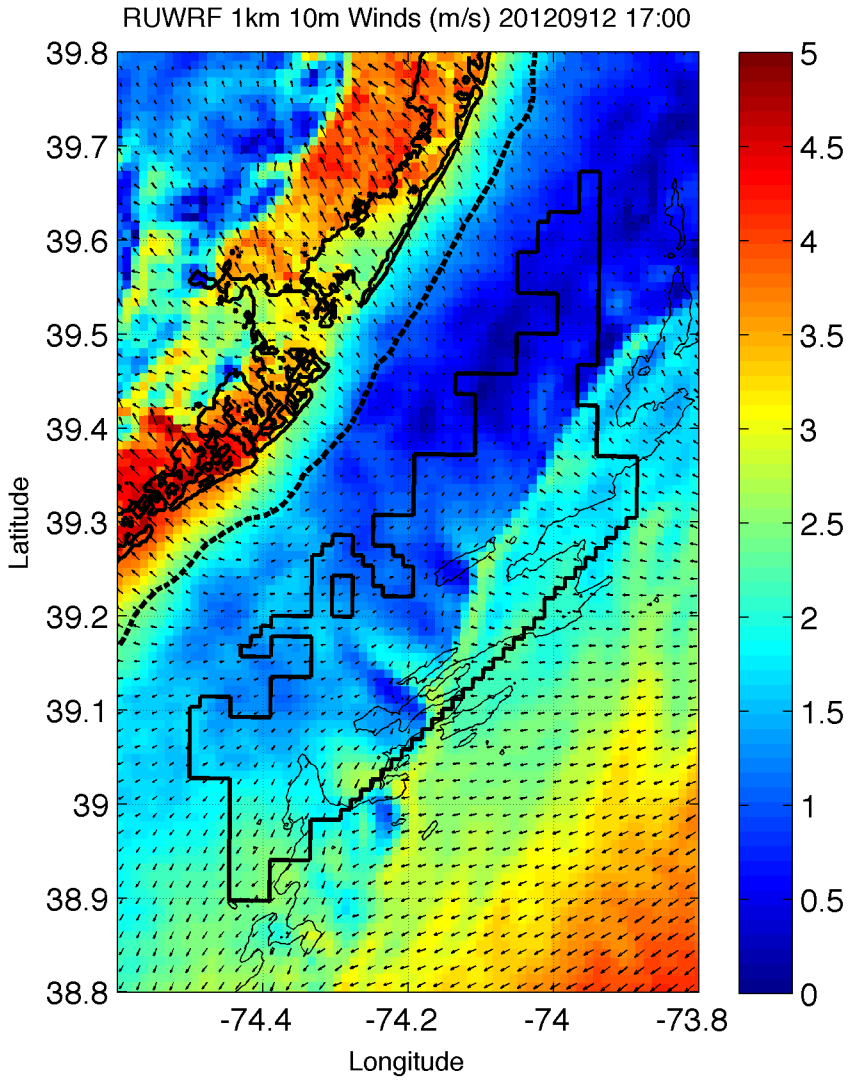
Sea Breeze Variability



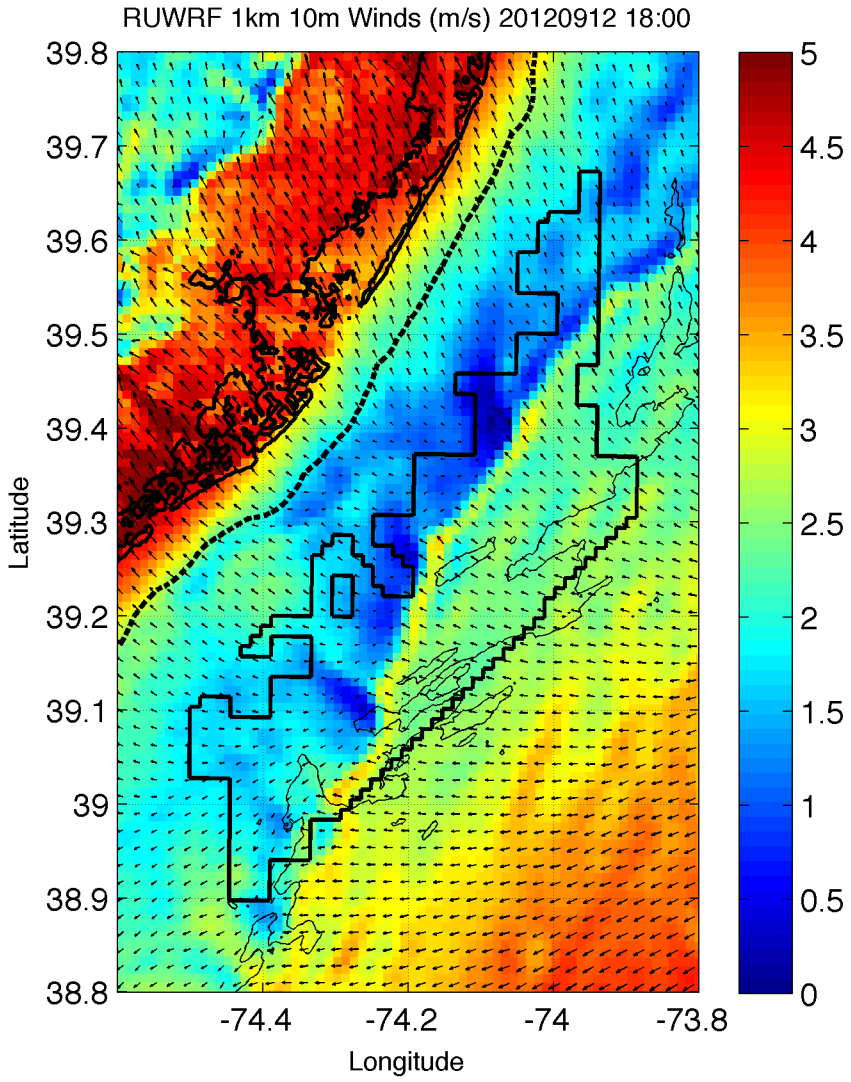
Sea Breeze Variability



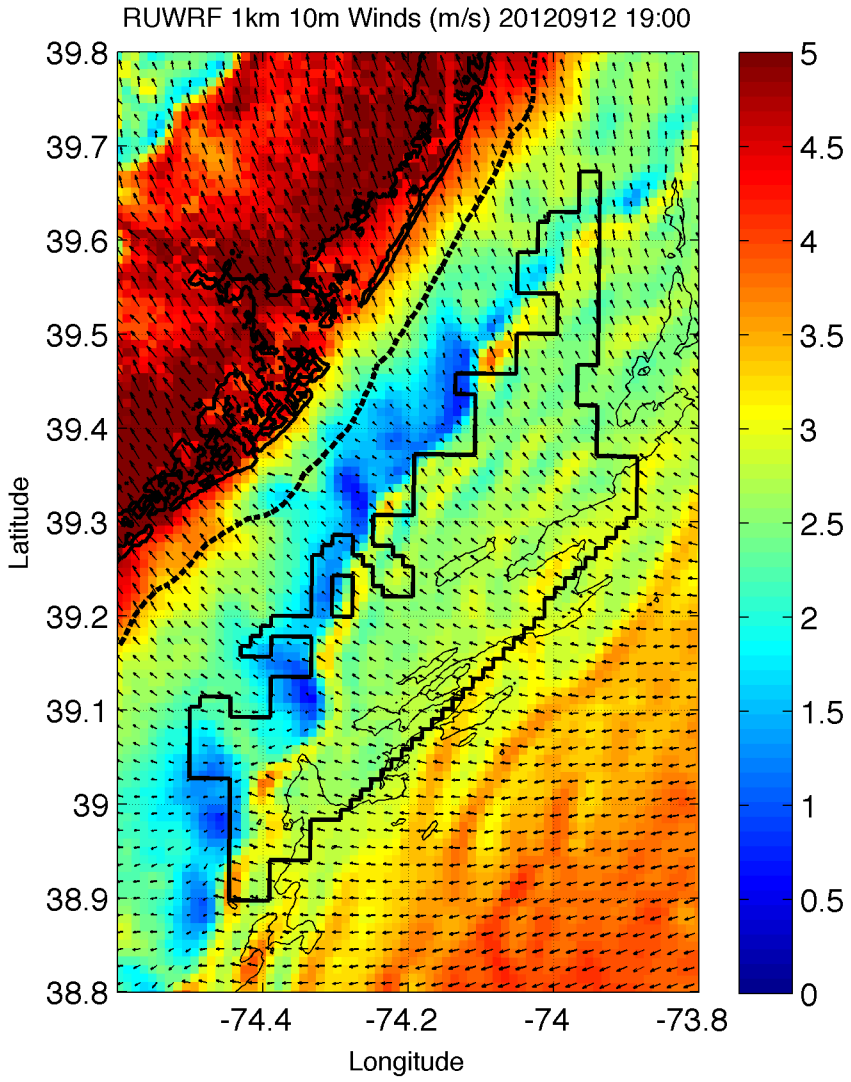
Sea Breeze Variability



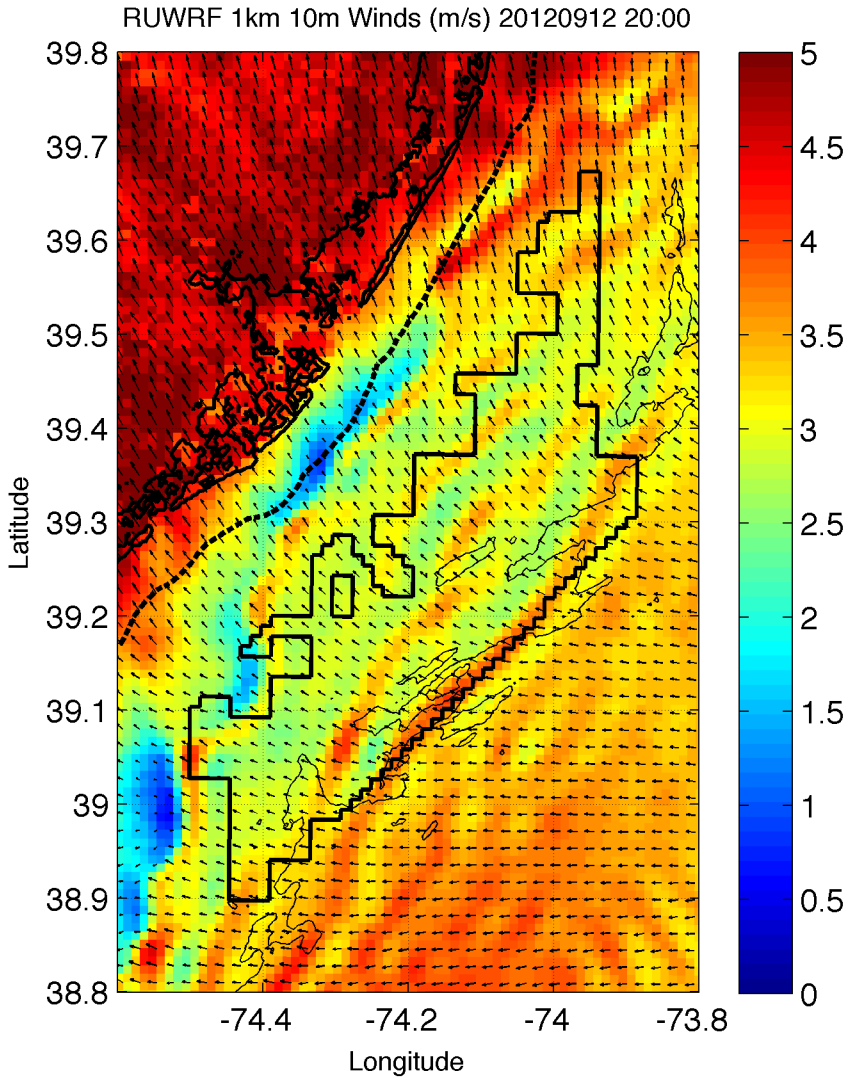
Sea Breeze Variability



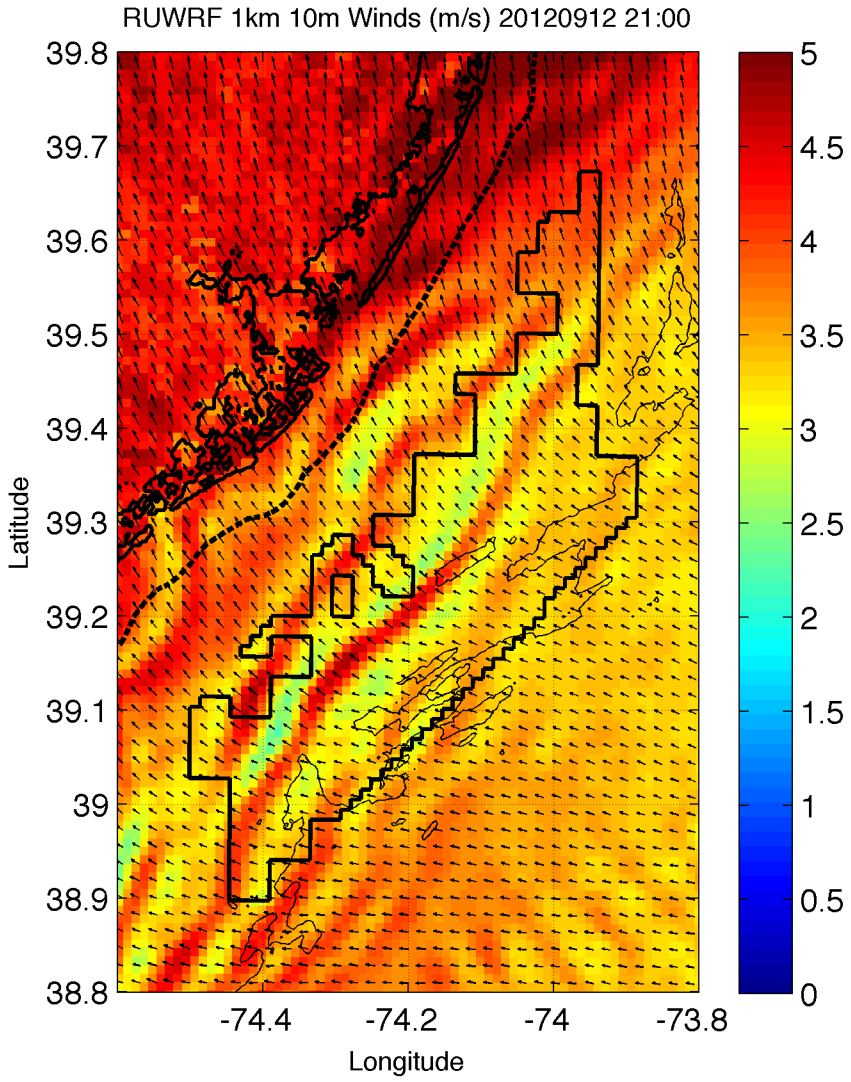
Sea Breeze Variability



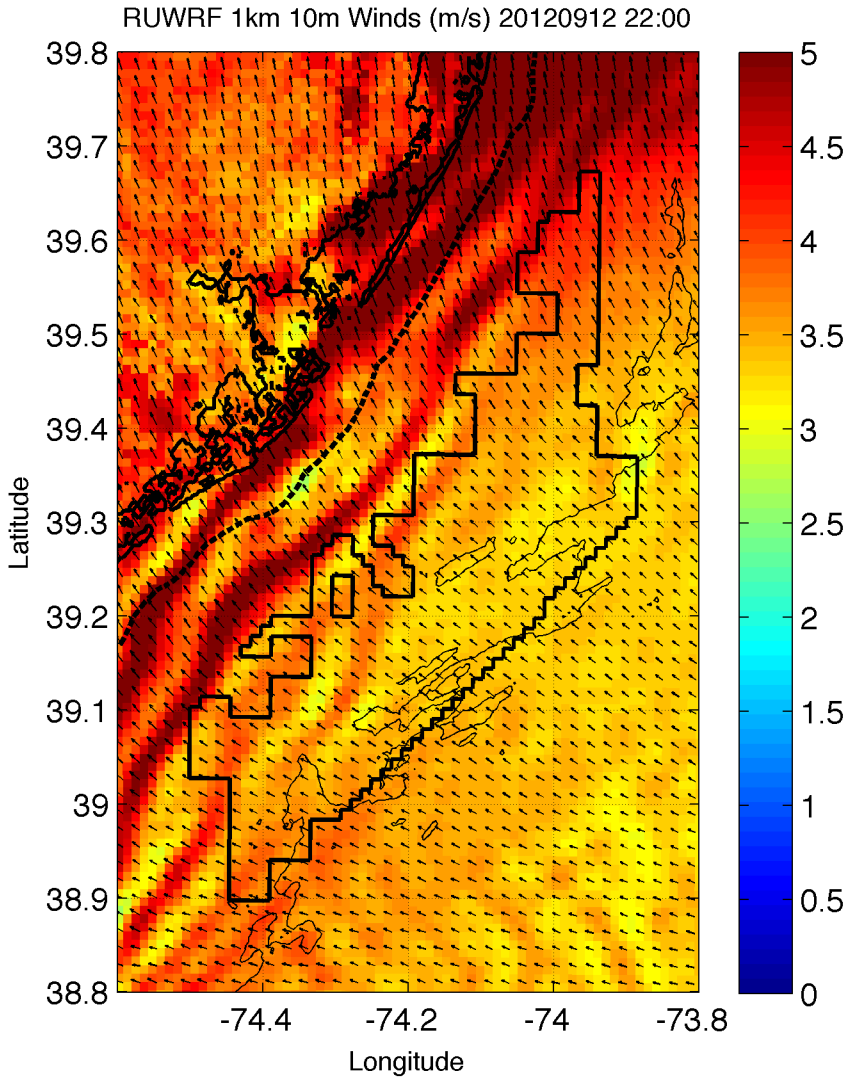
Sea Breeze Variability



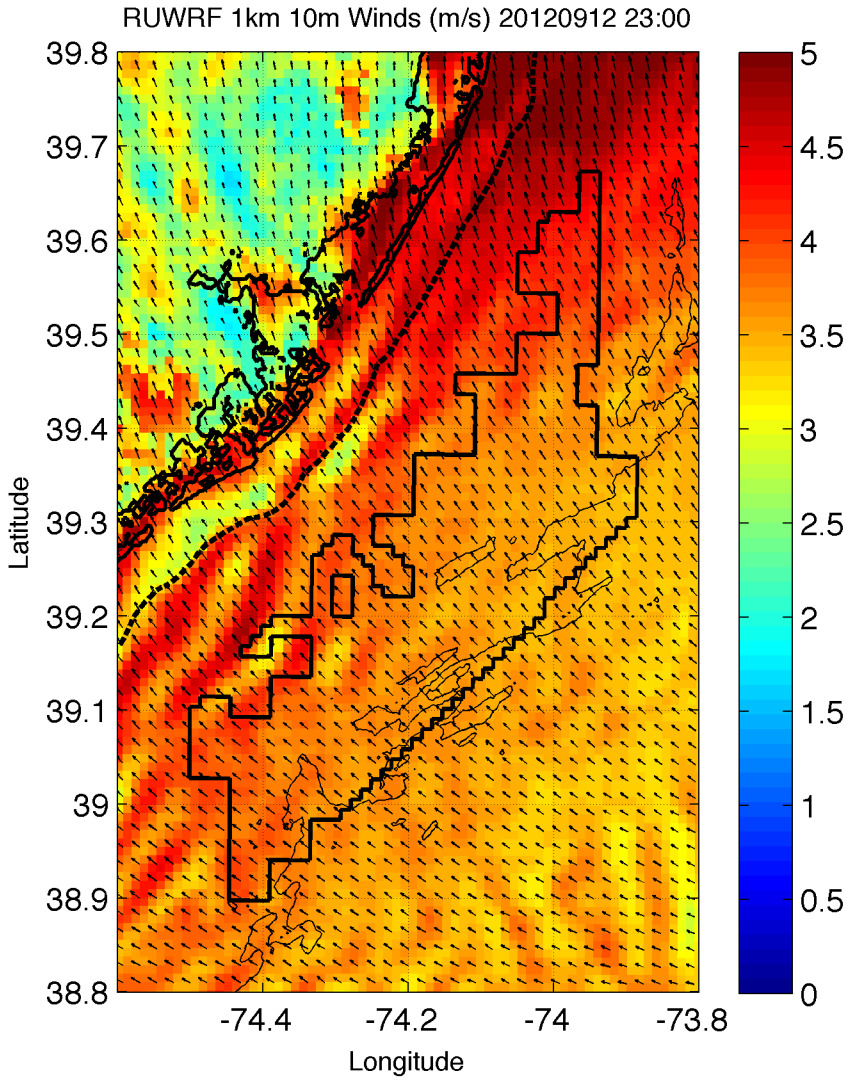
Sea Breeze Variability

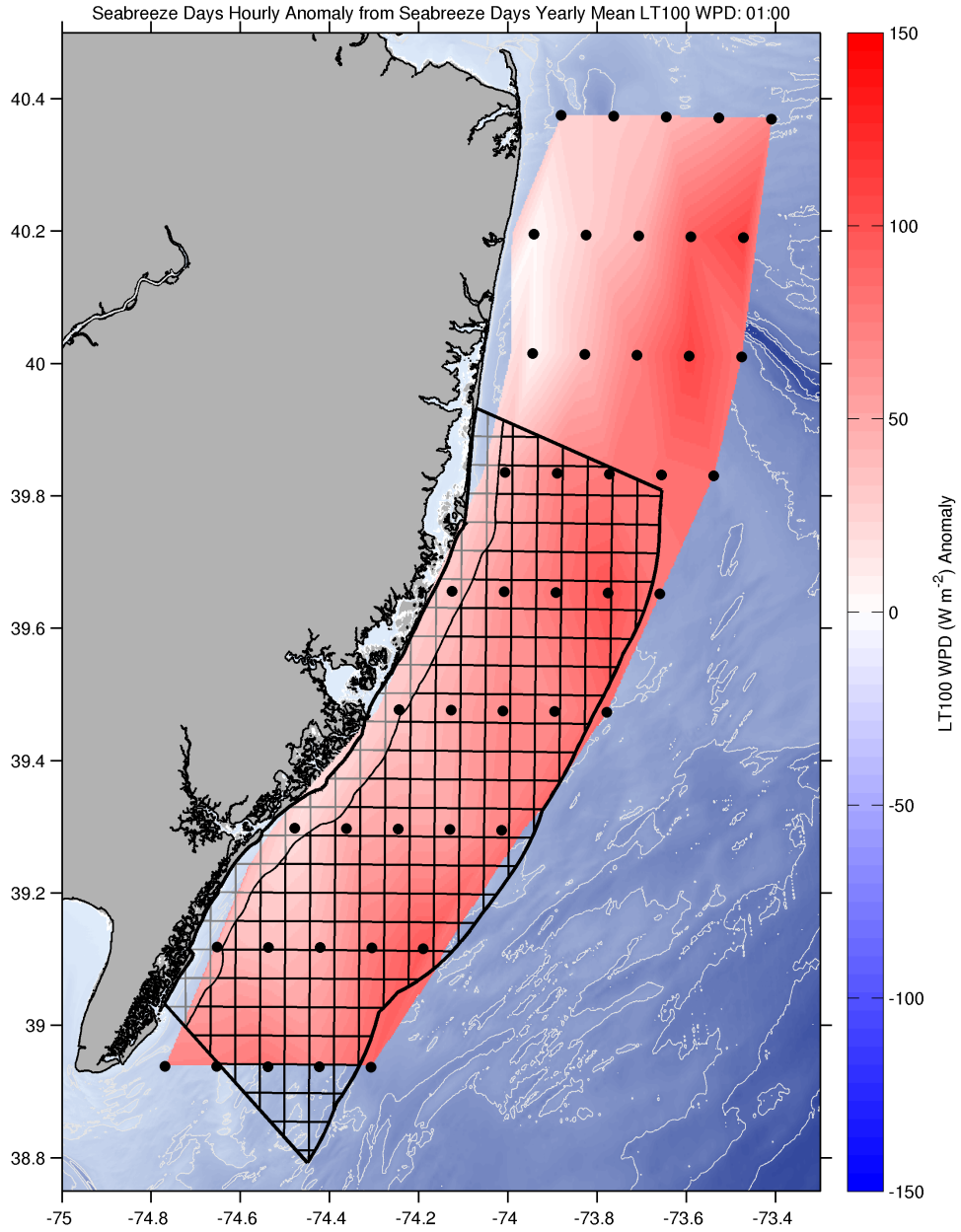


Sea Breeze Variability



Sea Breeze Variability





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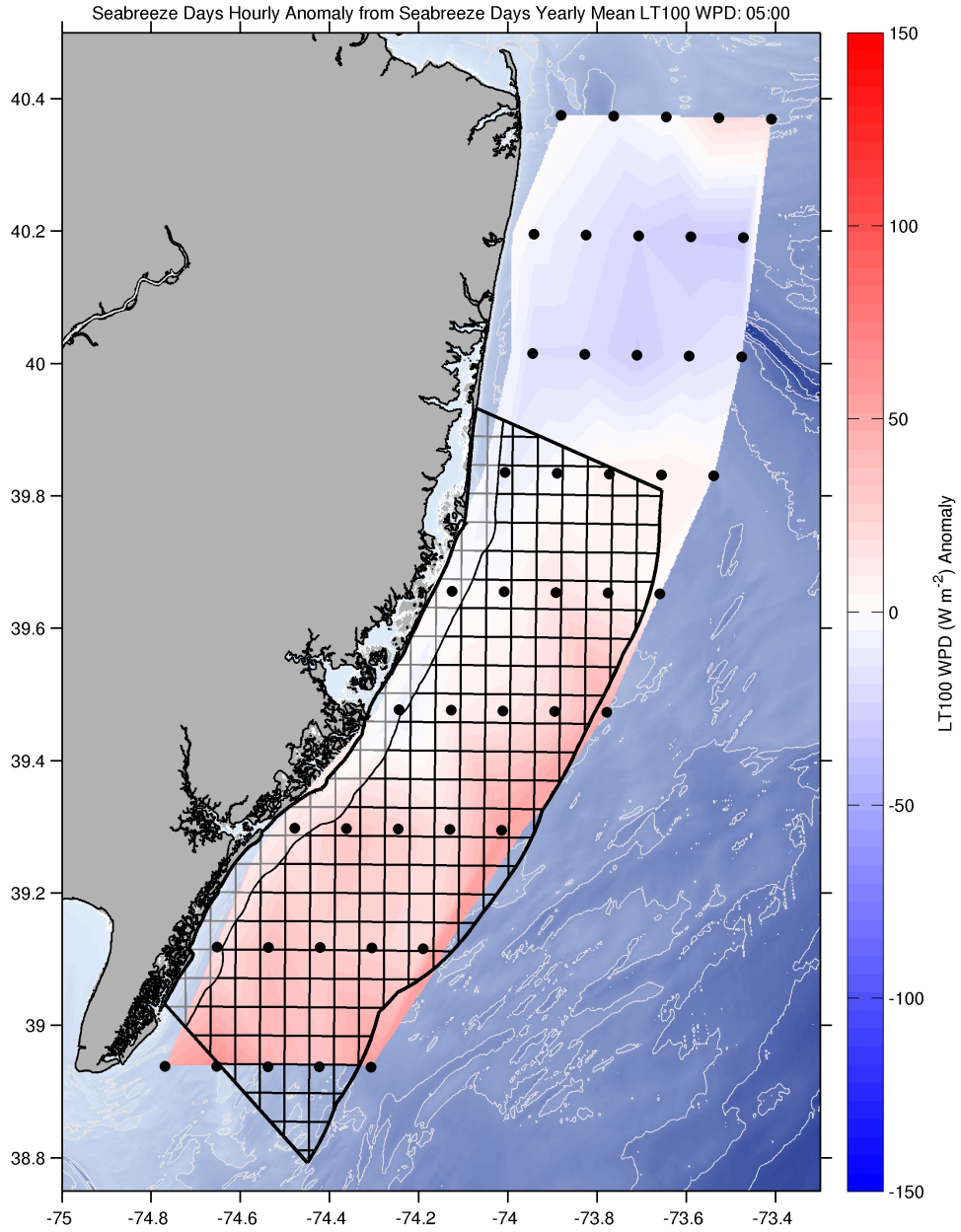
Coastal Ocean Observation Lab



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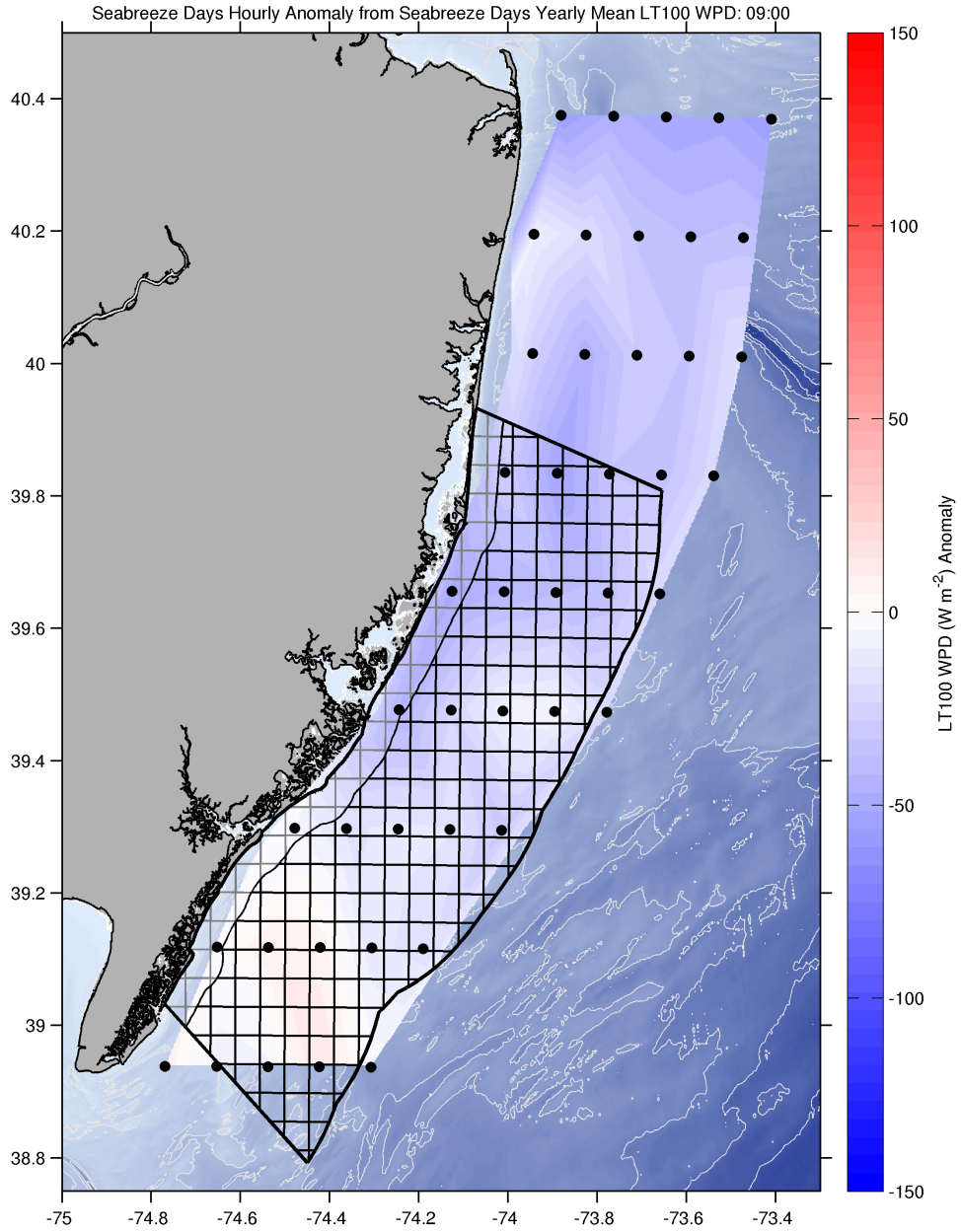
Coastal Ocean Observation Lab



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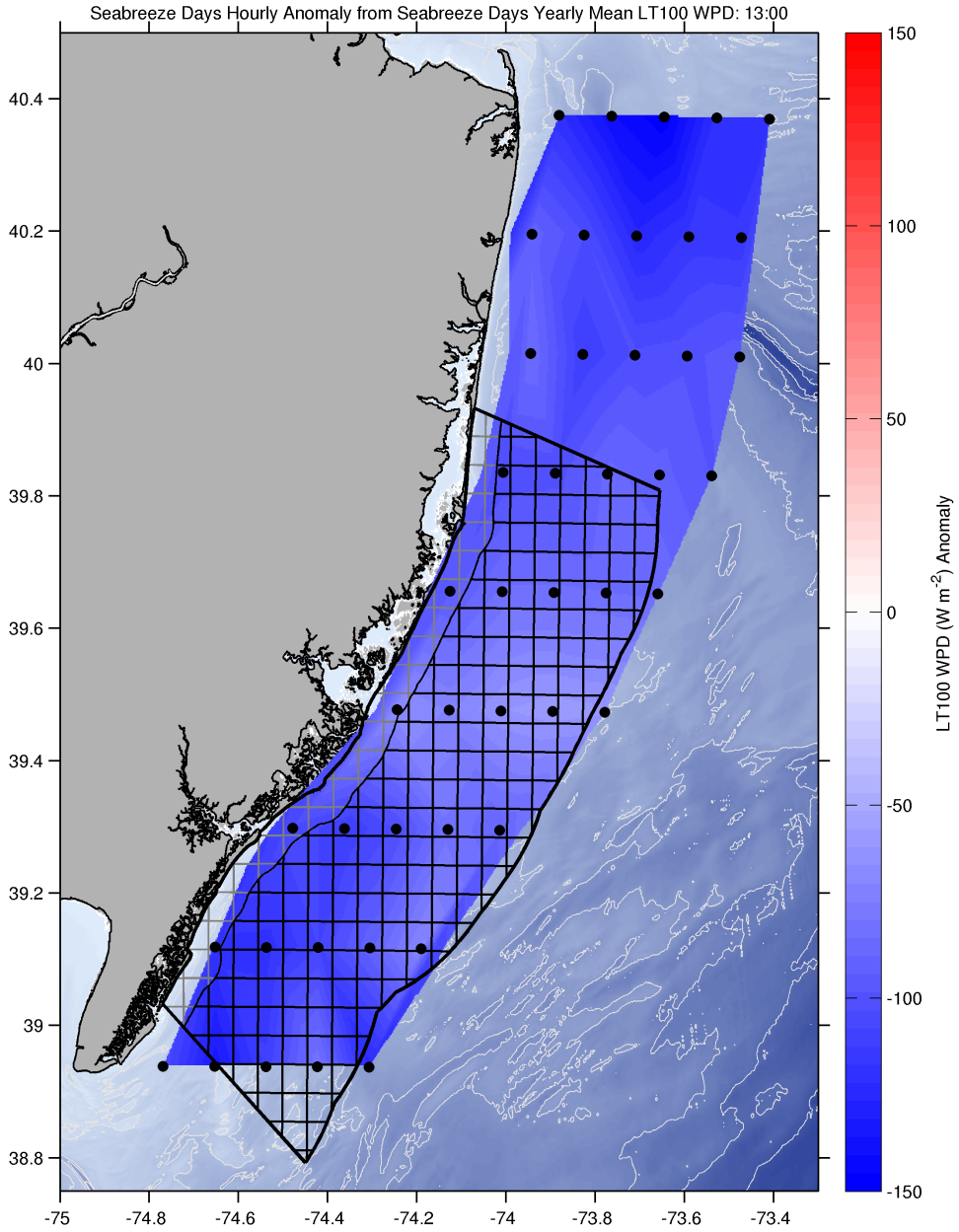
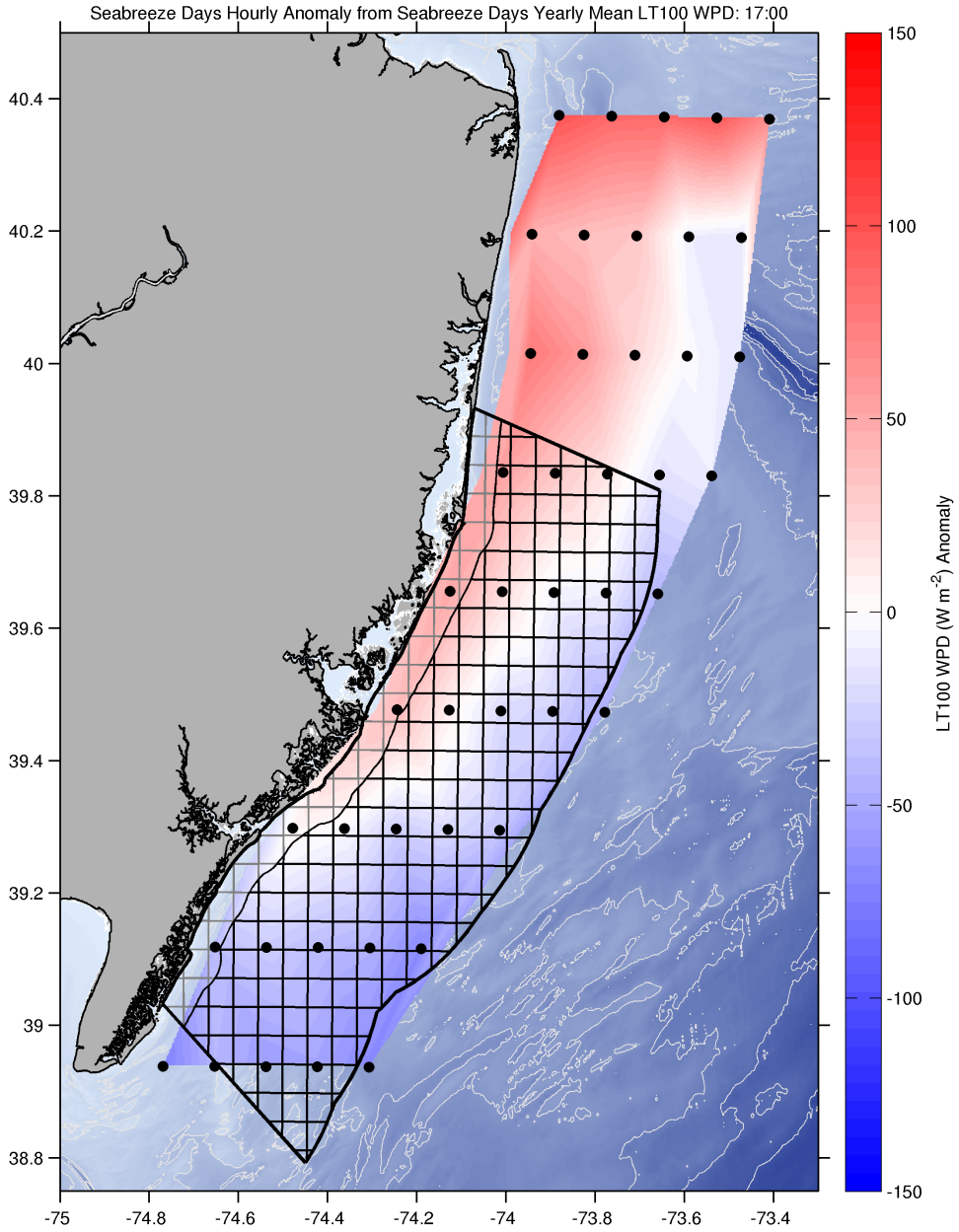
Coastal Ocean Observation Lab



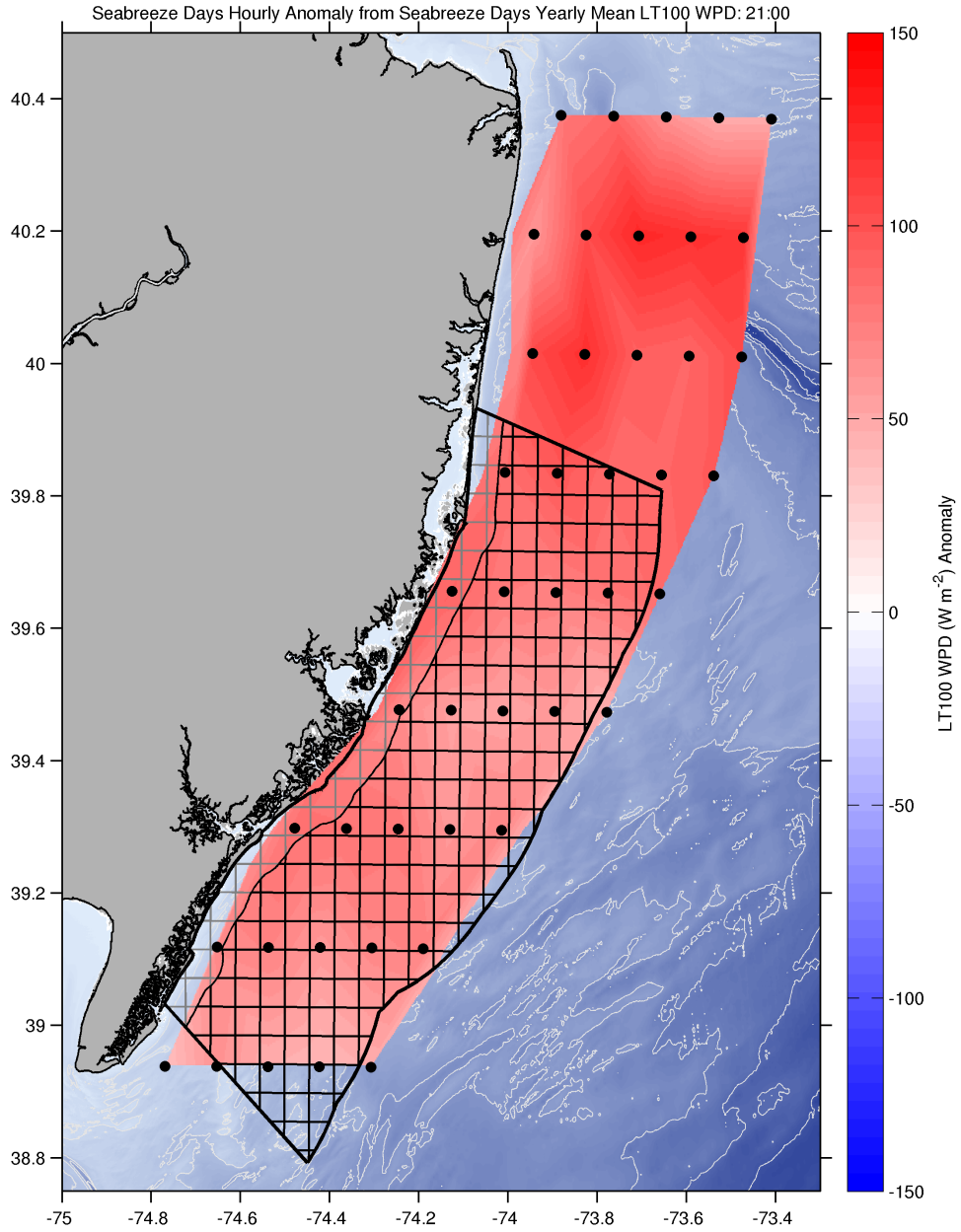
RUTGERS

Coastal Ocean Observation Lab



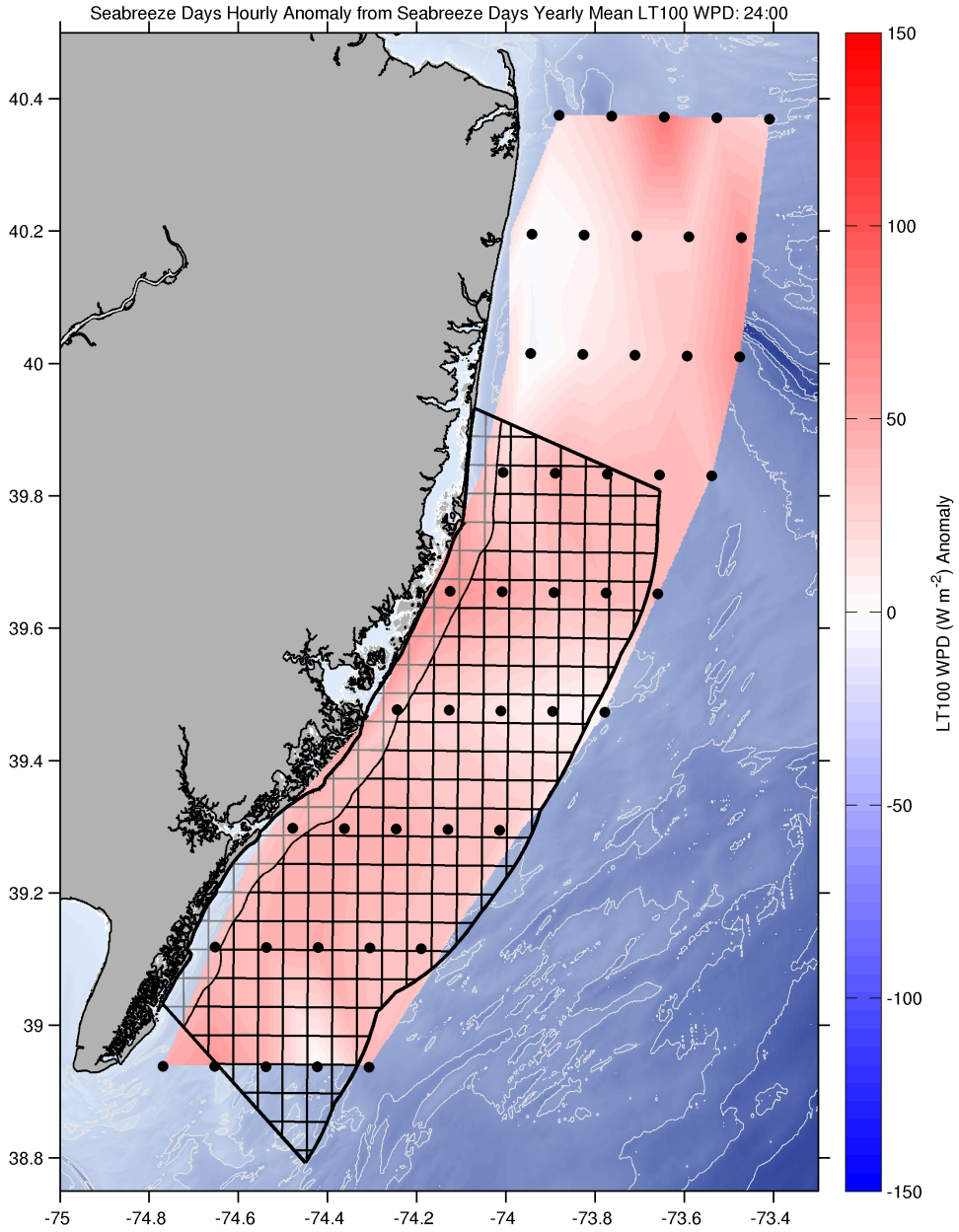
RUTGERS

Coastal Ocean Observation Lab



RUTGERS

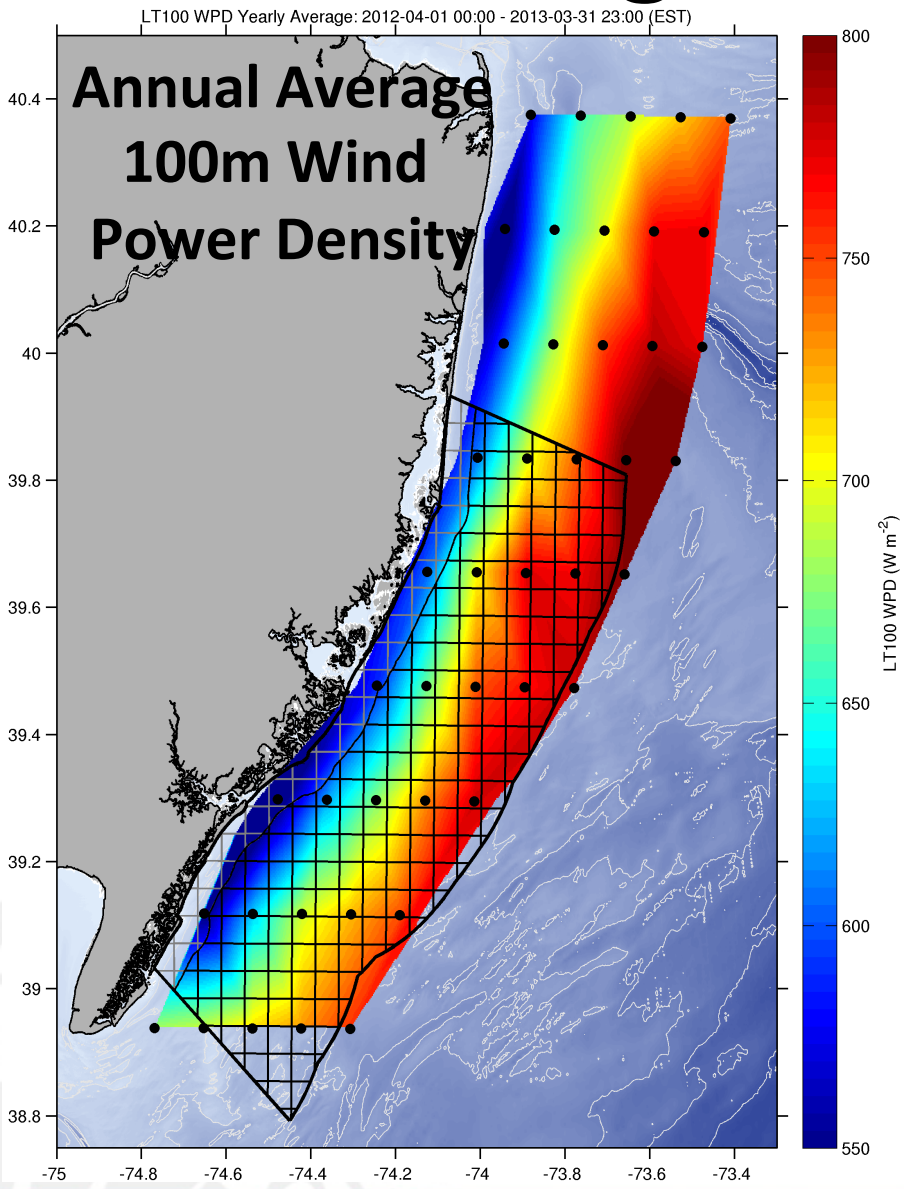
Coastal Ocean Observation Lab

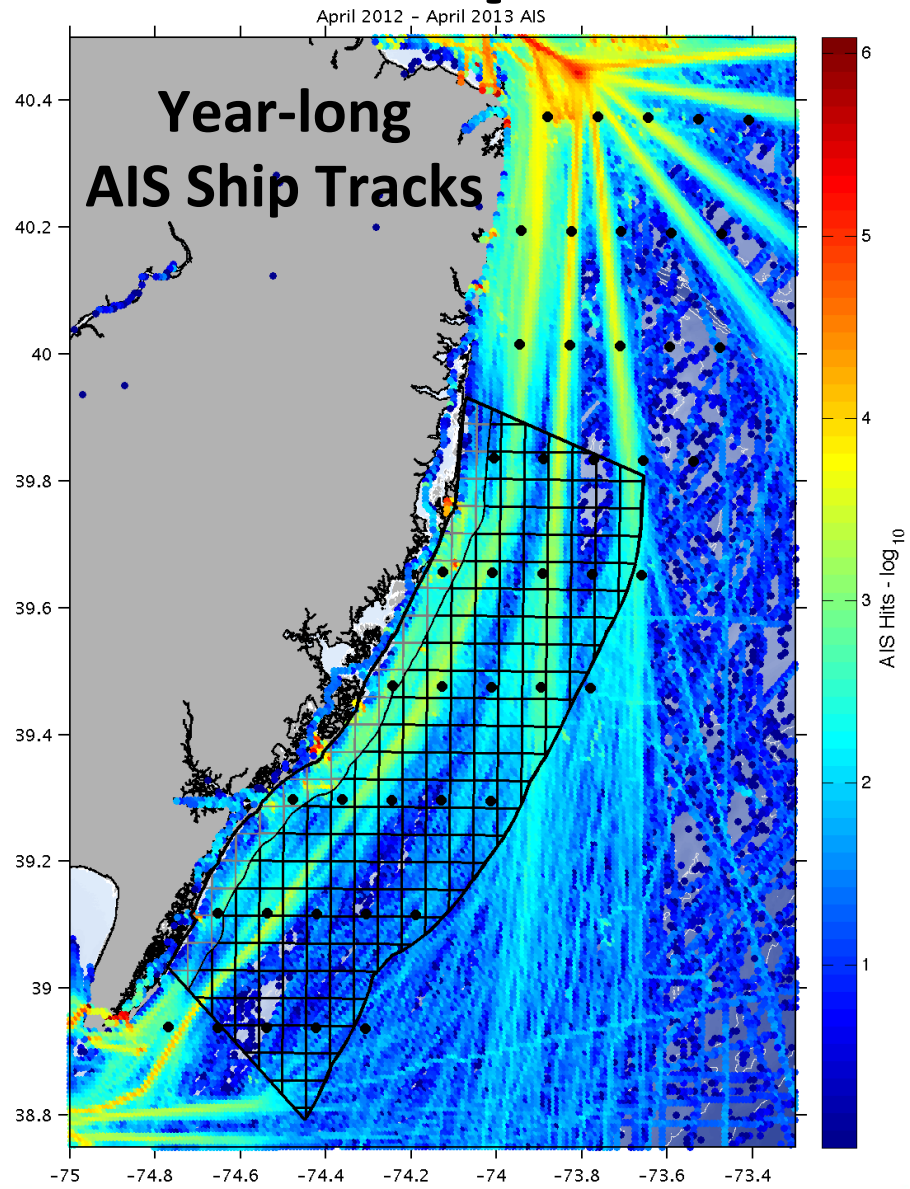


RUTGERS

Coastal Ocean Observation Lab

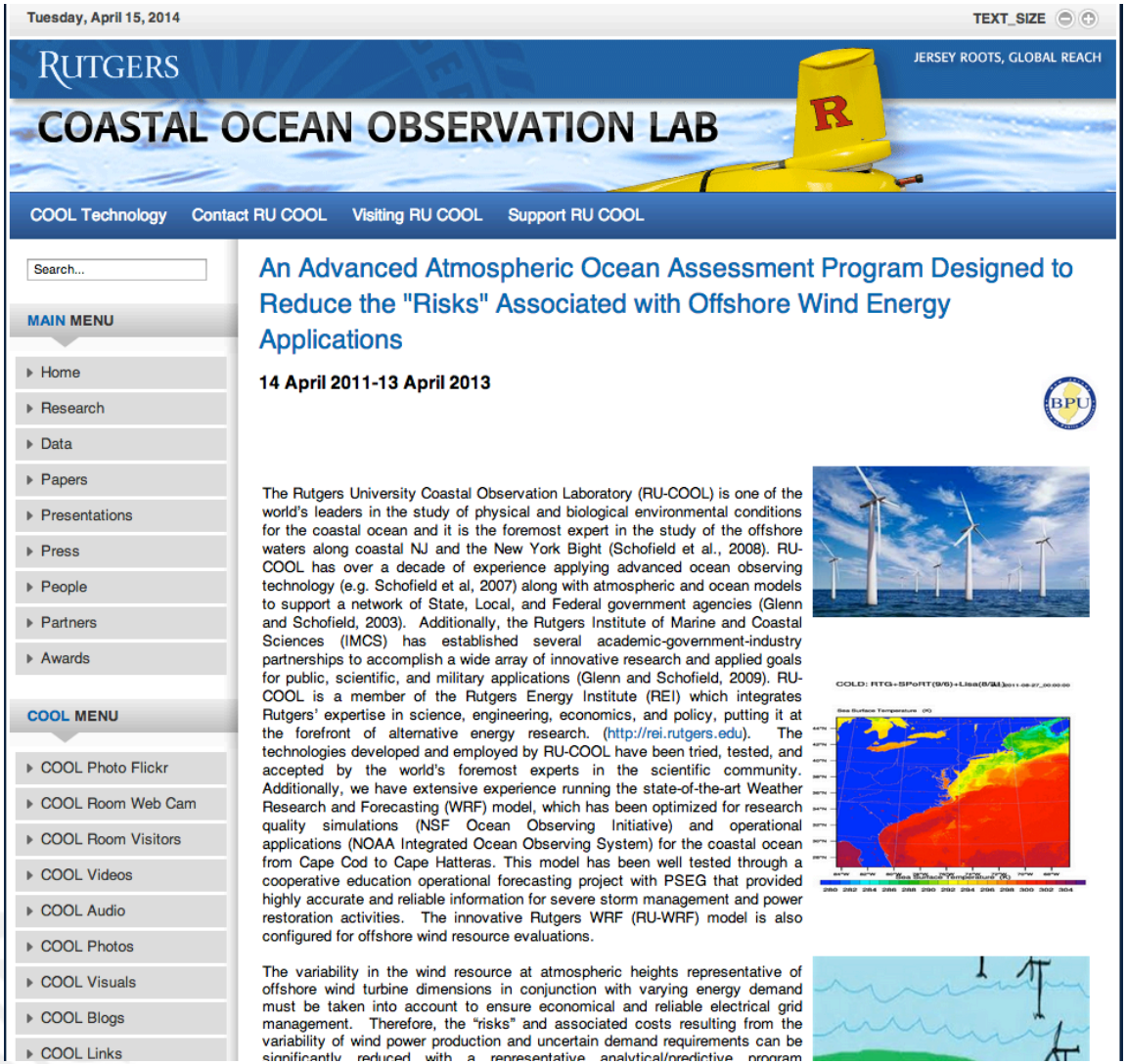
Annual Average Wind and Ship Tracks



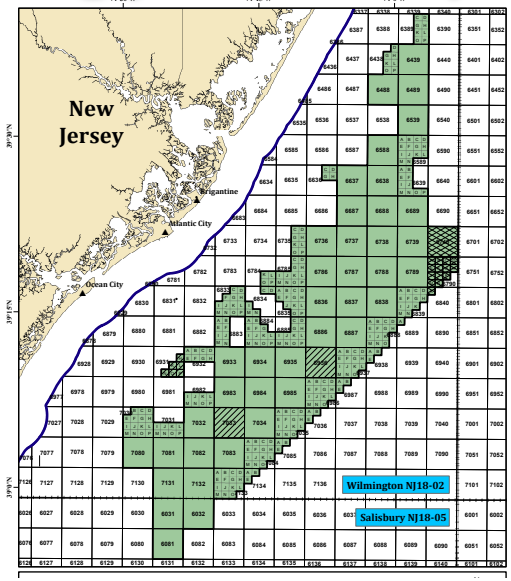


Offshore Wind Analysis Website

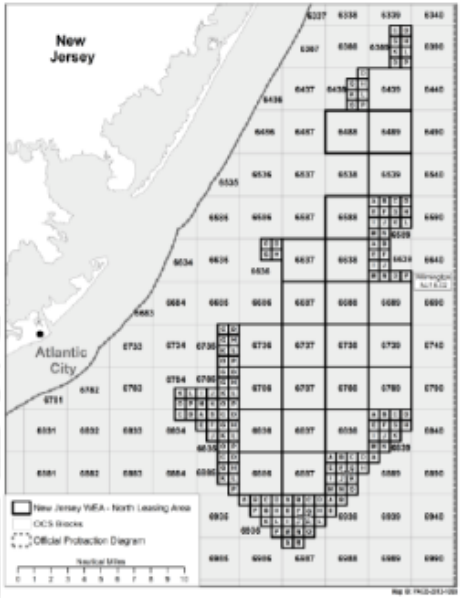
http://rucool.marine.rutgers.edu/bpu



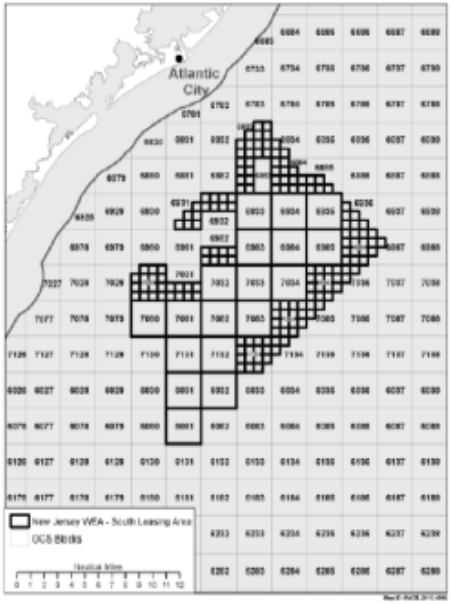
OSW Energy Development Domain and WTG Size



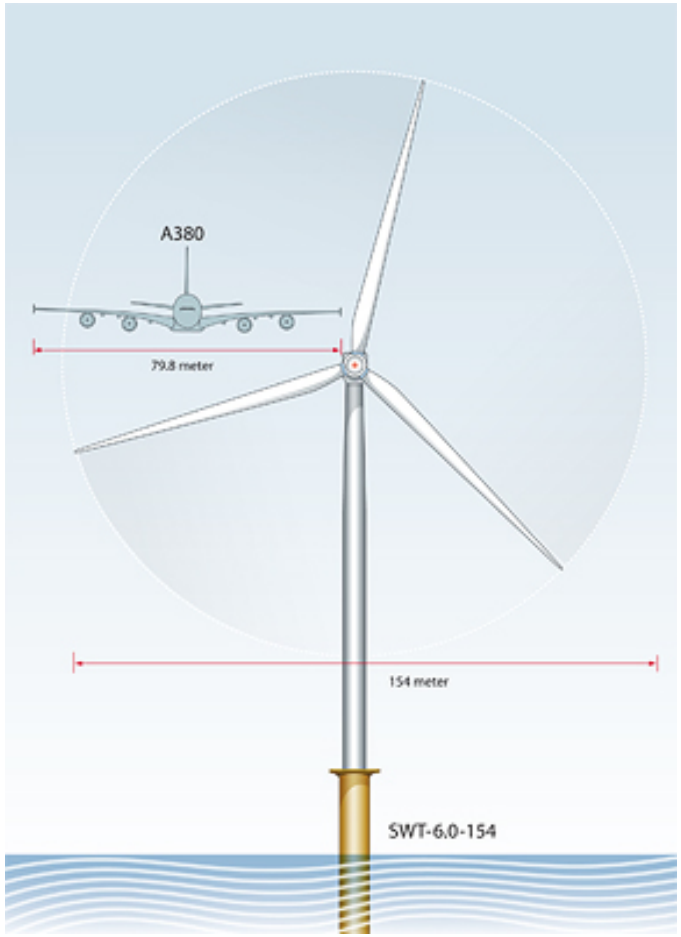
North Zone



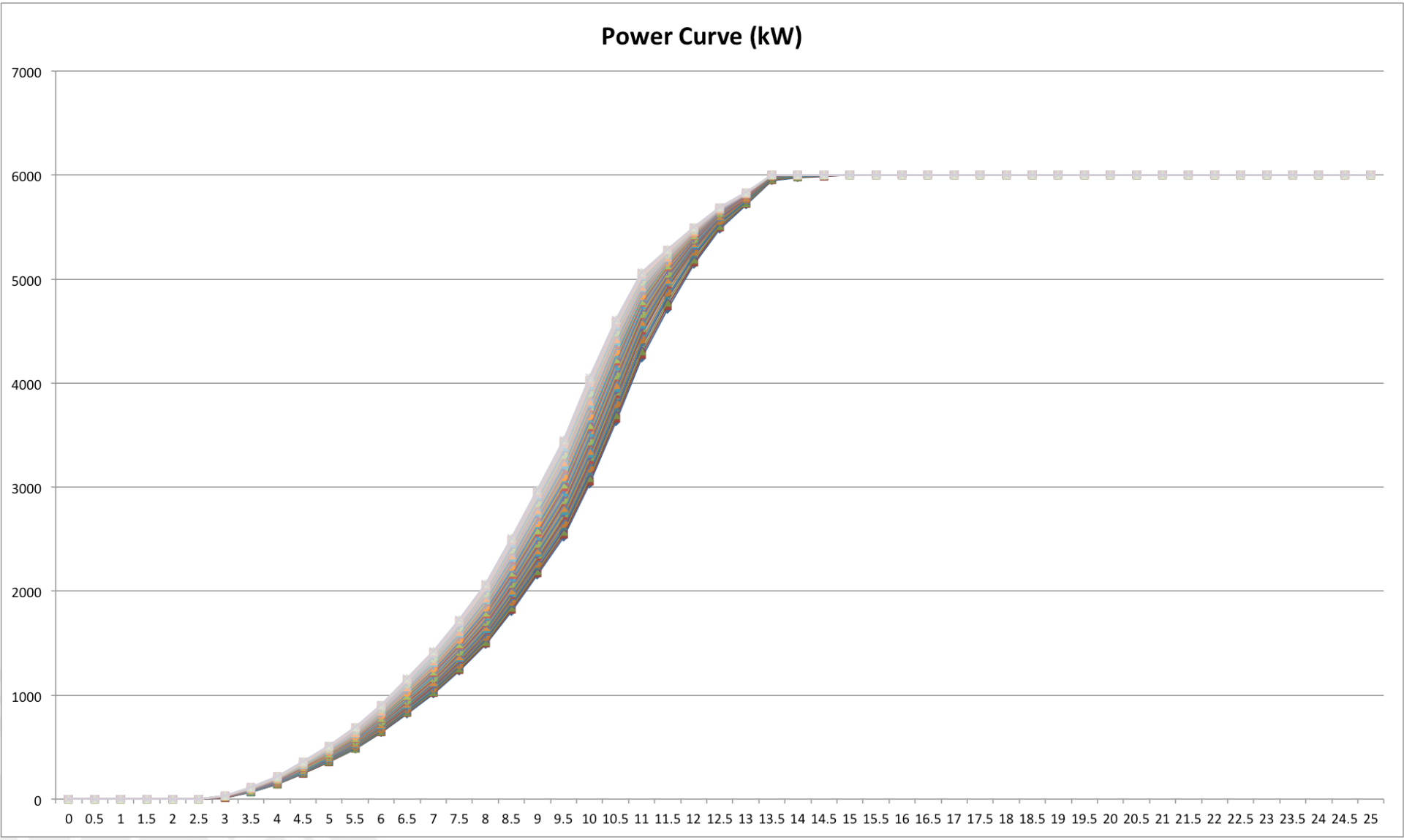
South Zone



6 MW WTG

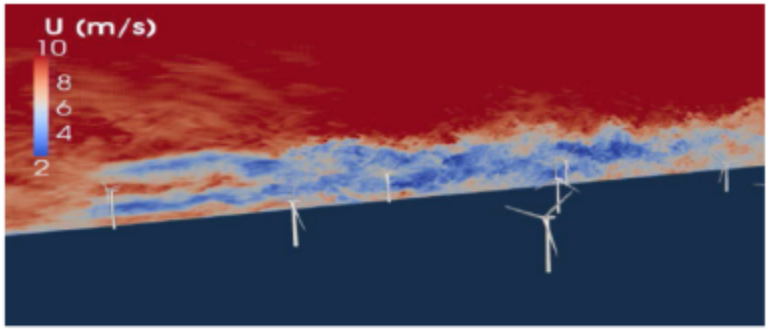


Generic Power Curve – 6 MW WTG

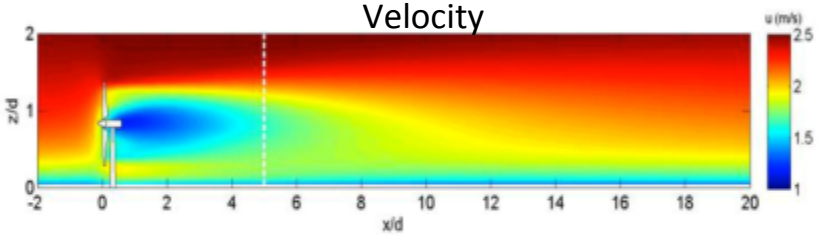


Modeling/Monitoring Upgrades

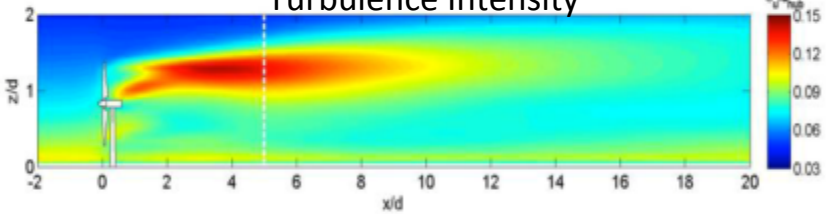
Large-Eddy Simulation (LES)



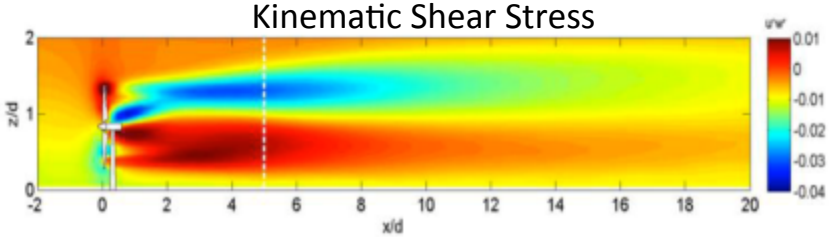
Velocity



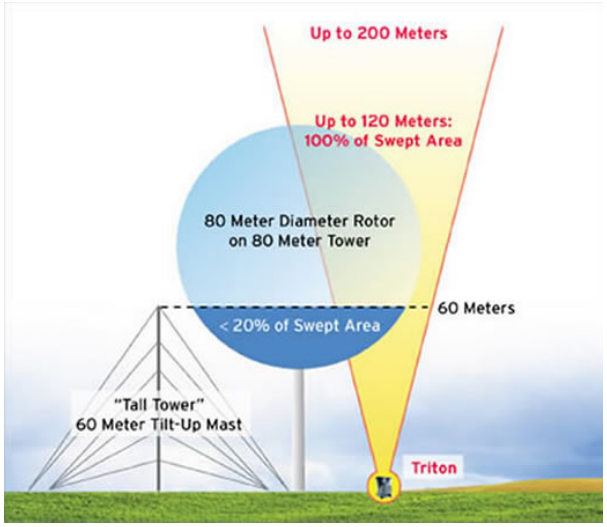
Turbulence Intensity



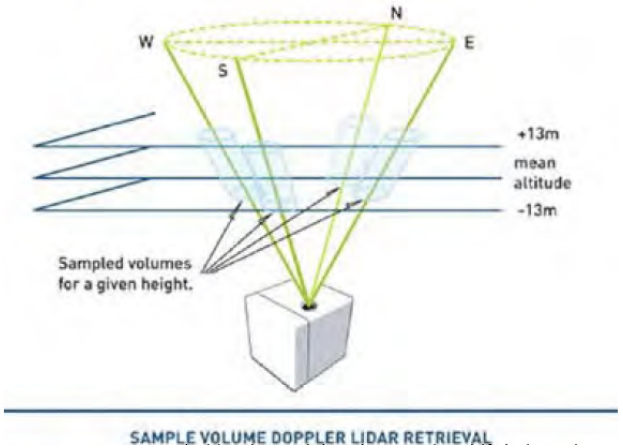
Kinematic Shear Stress



SODAR

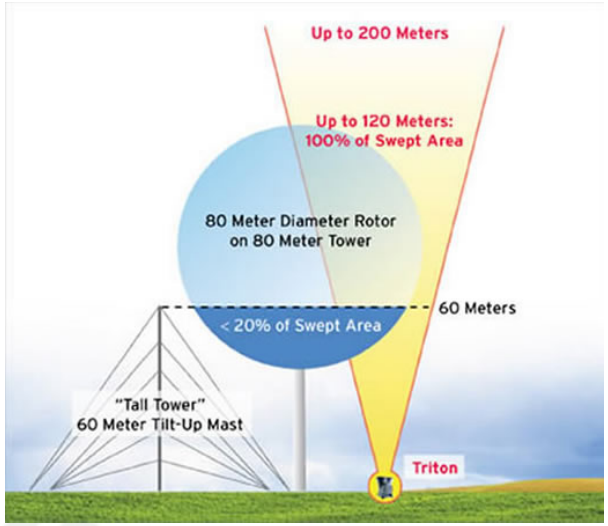


LIDAR

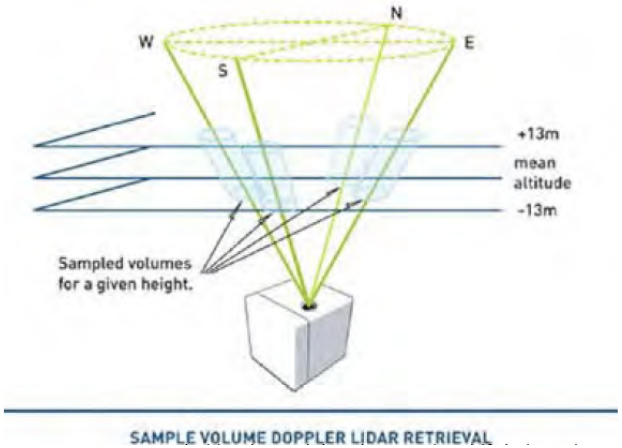


SODAR, MET tower: Tuckerton, NJ
LIDAR: Chesapeake Bay Bridge
WeatherFlow and MARACOOS

SODAR



LIDAR

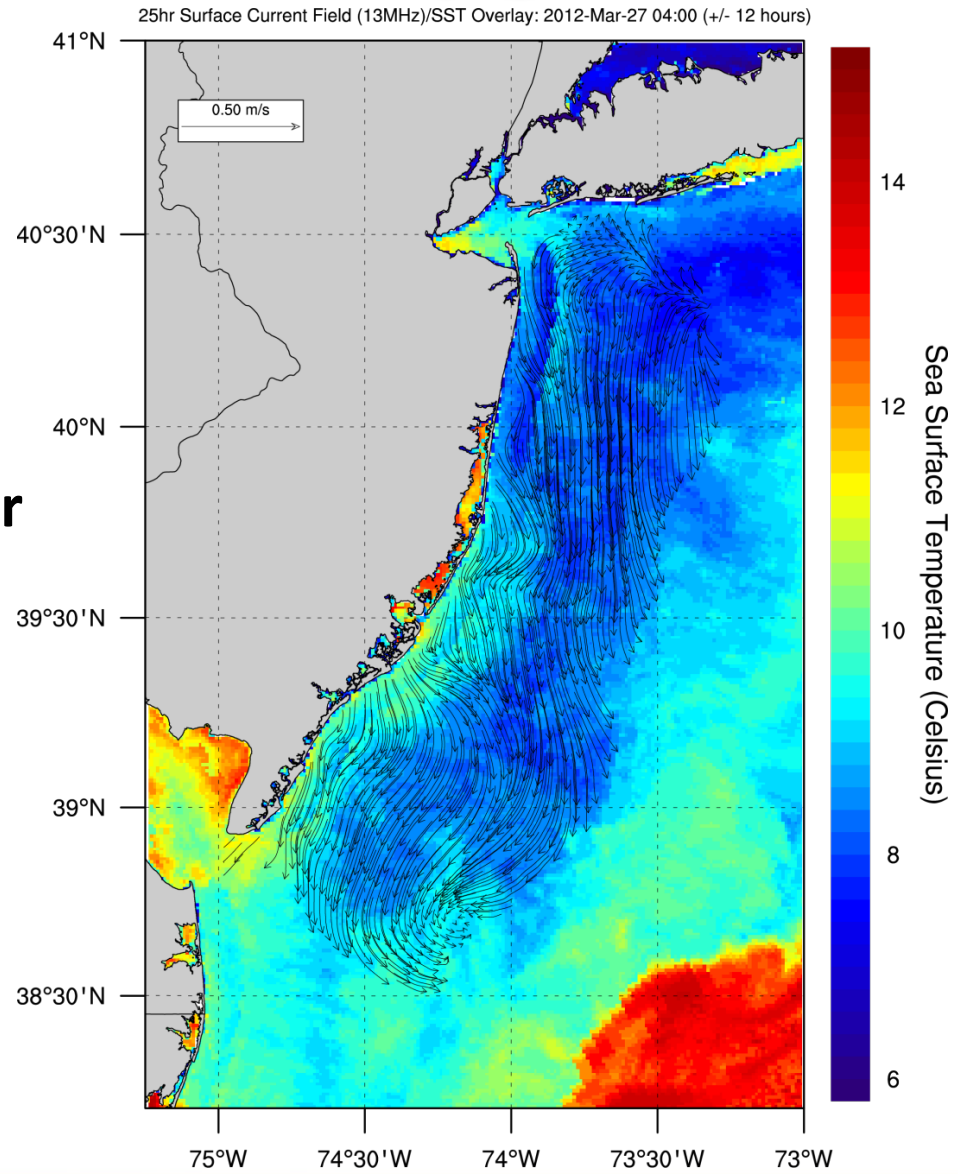


WindSentinel Land Station installed at Stumpy Point

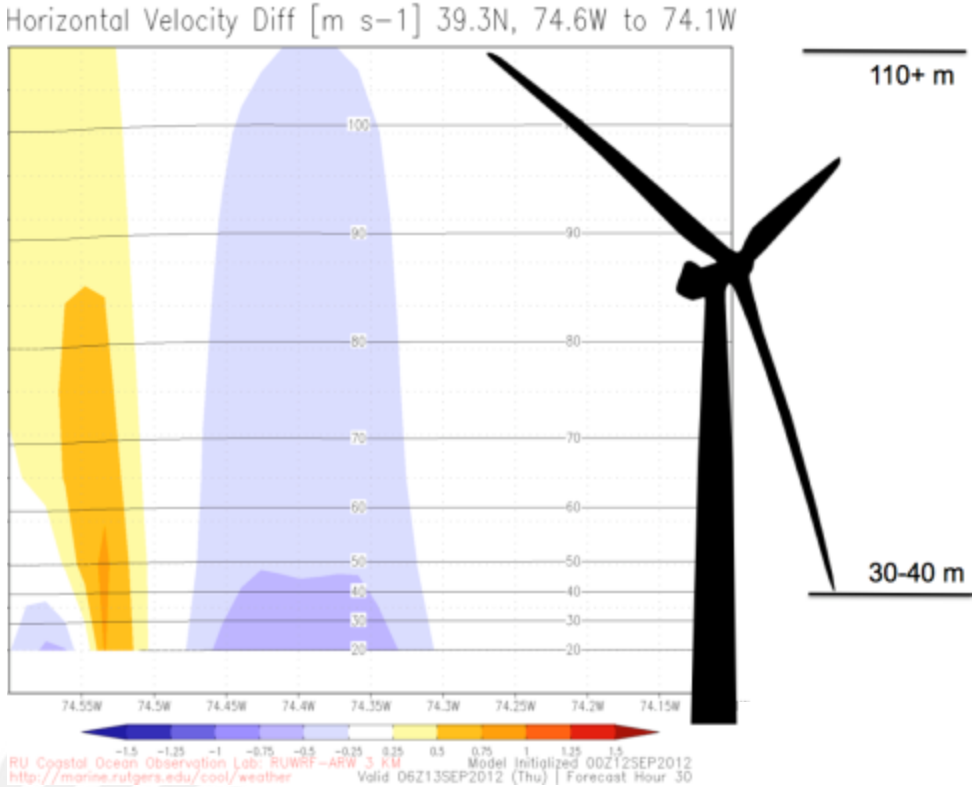
WindSentinel Land Station installed near
Chesapeake Bay Bridge Tunnel

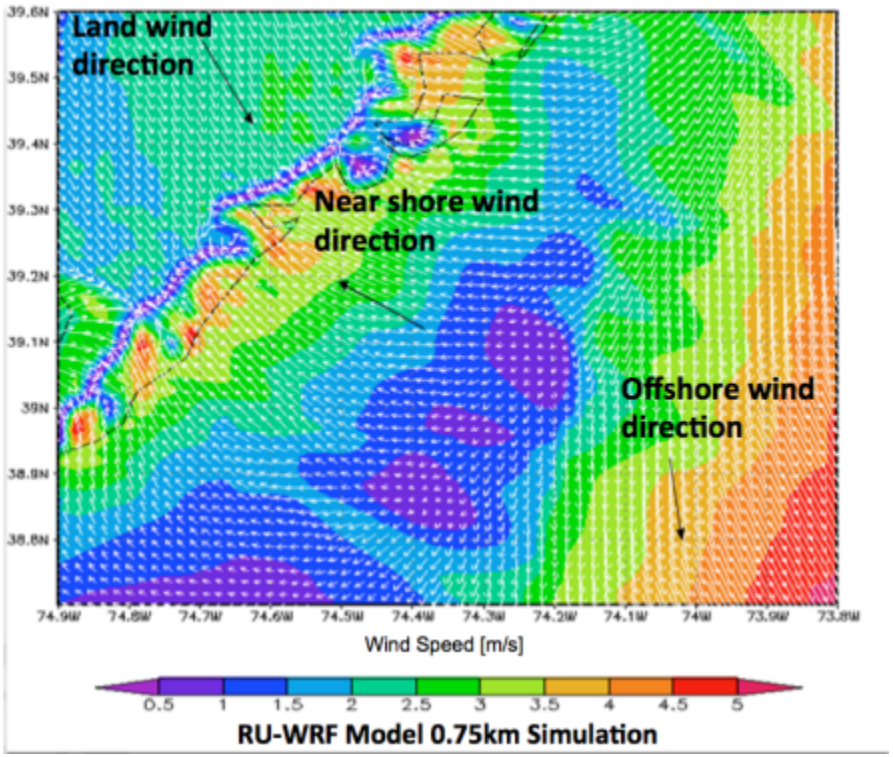
Satellite SST Upgrades

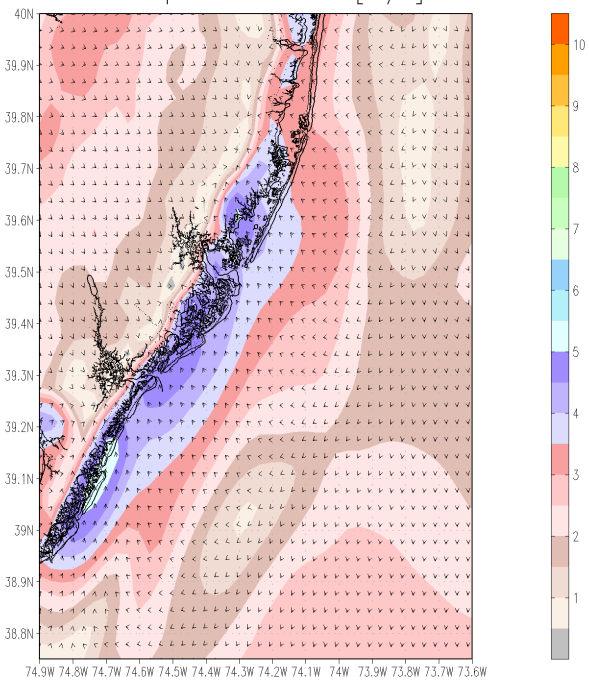
- Improve representation of coastal upwelling
- Develop new statistical methods for gap filling and preservation of features



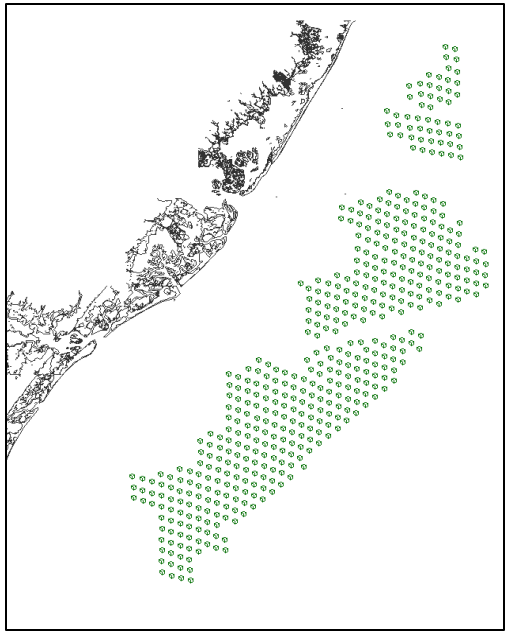
Extend sea breeze and local wind analyses

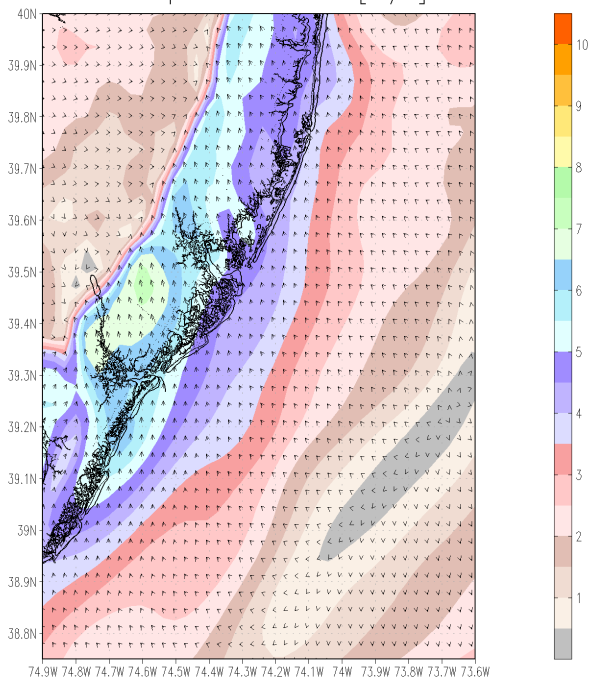




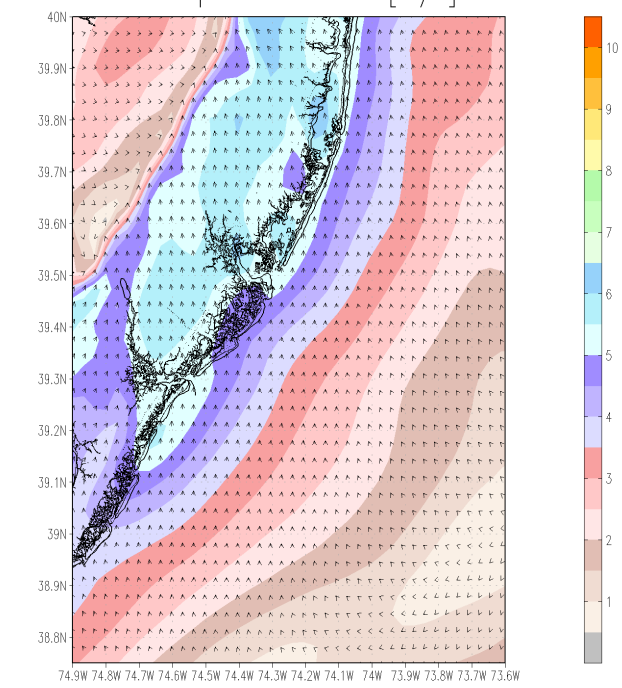


RU Coastal Ocean Observation Lab: RUWRF–ARW 1 KM Model Initialized 00Z06APR2014
http://marine.rutgers.edu/cool/weather Valid 17Z06APR2014 (Sun) | Forecast Hour 17

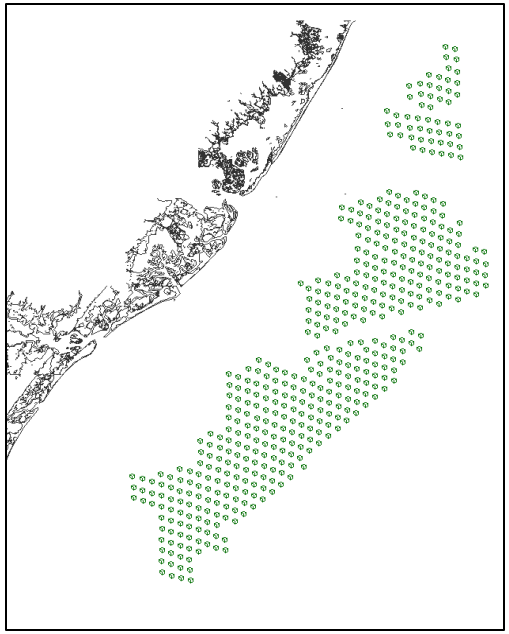


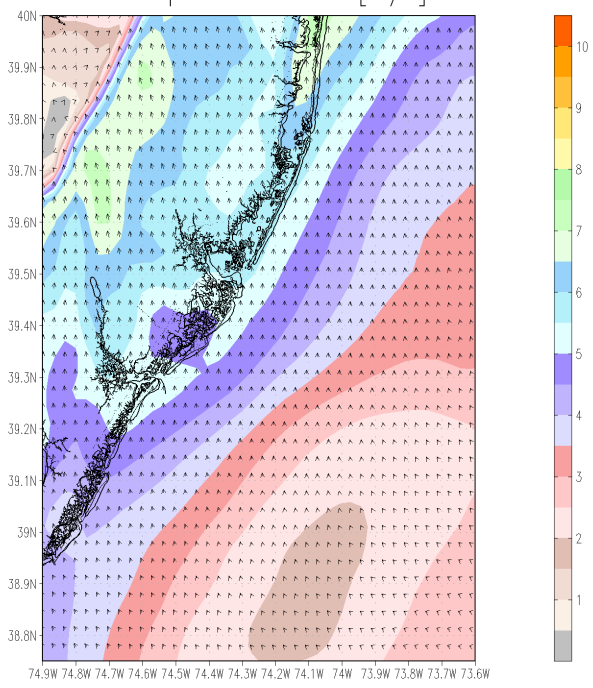


RU Coastal Ocean Observation Lab: RUWRF–ARW 1 KM Model Initialized 00Z06APR2014
http://marine.rutgers.edu/cool/weather Valid 19Z06APR2014 (Sun) | Forecast Hour 19

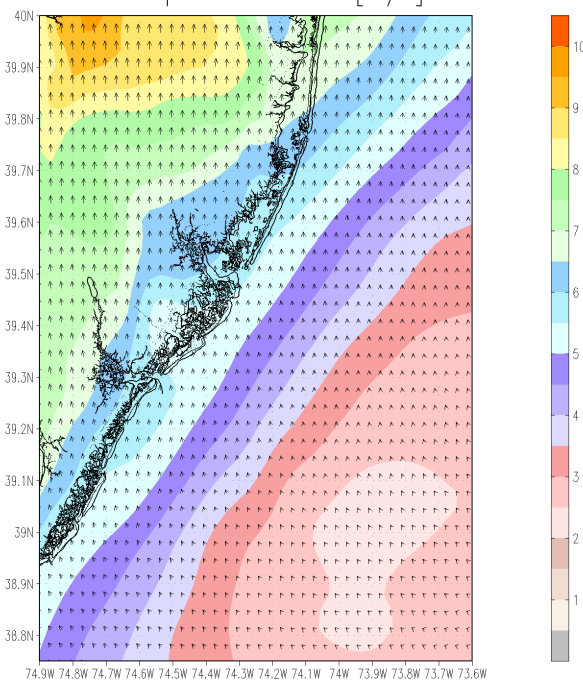


RU Coastal Ocean Observation Lab: RUWRF–ARW 1 KM Model Initialized 00Z06APR2014
http://marine.rutgers.edu/cool/weather Valid 21Z06APR2014 (Sun) | Forecast Hour 21

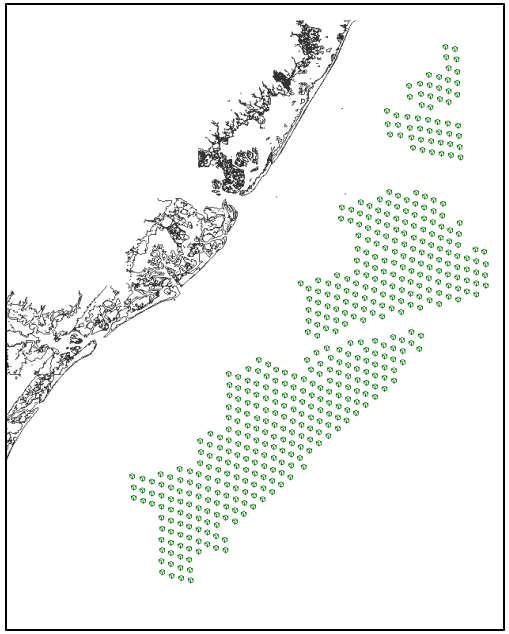


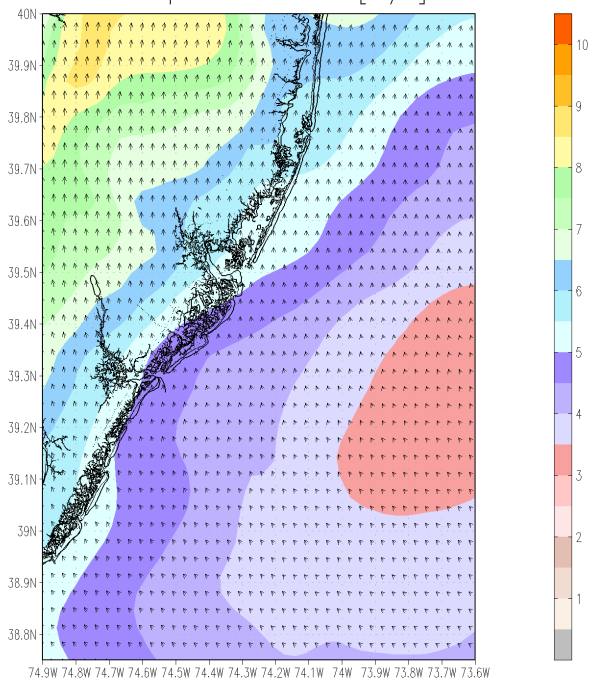


RU Coastal Ocean Observation Lab: RUWRF–ARW 1 KM Model Initialized 00Z06APR2014
http://marine.rutgers.edu/cool/weather Valid 23Z06APR2014 (Sun) | Forecast Hour 23



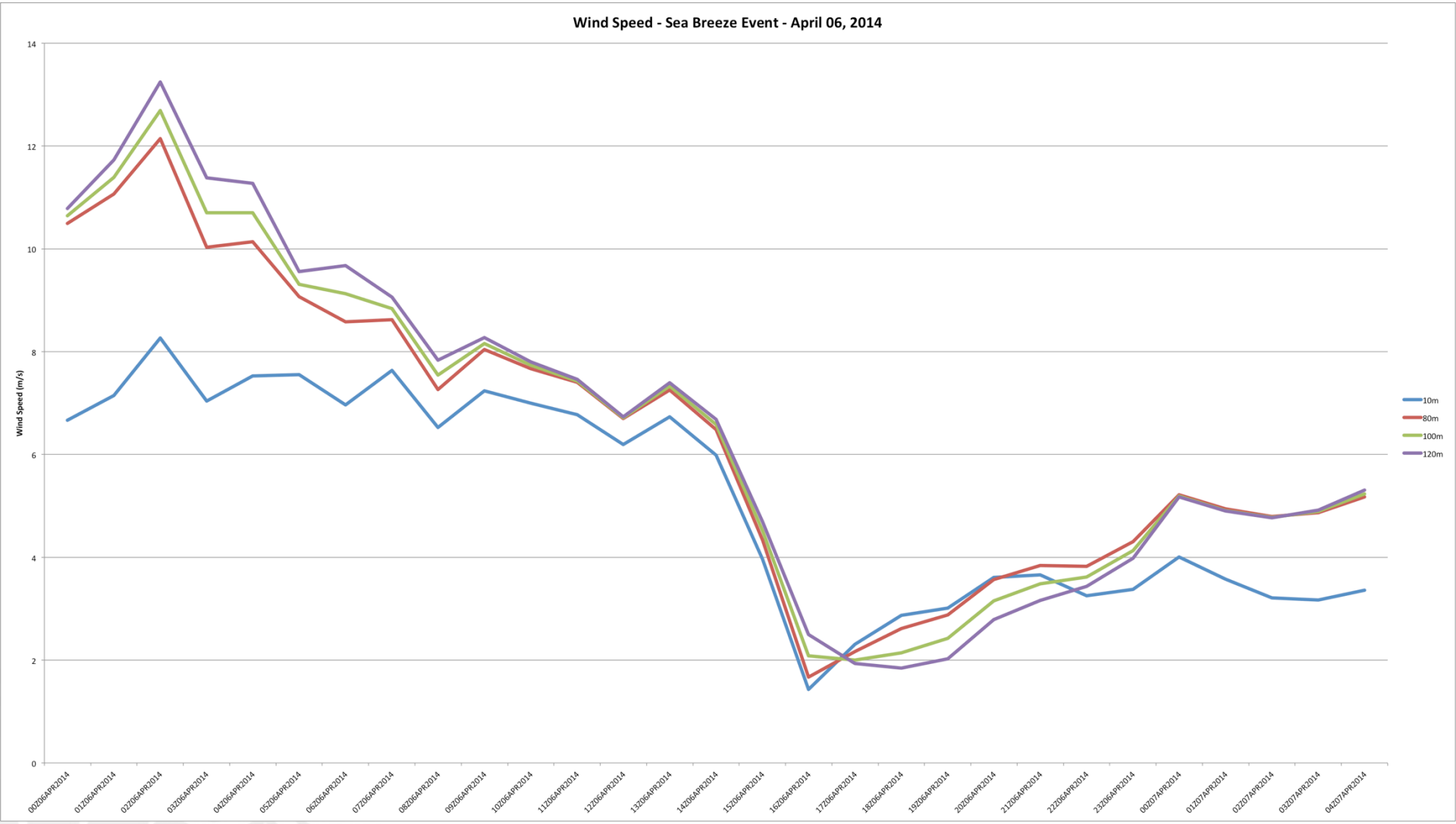
RU Coastal Ocean Observation Lab: RUWRF–ARW 1 KM Model Initialized 00Z06APR2014
http://marine.rutgers.edu/cool/weather Valid 01Z07APR2014 (Mon) | Forecast Hour 25



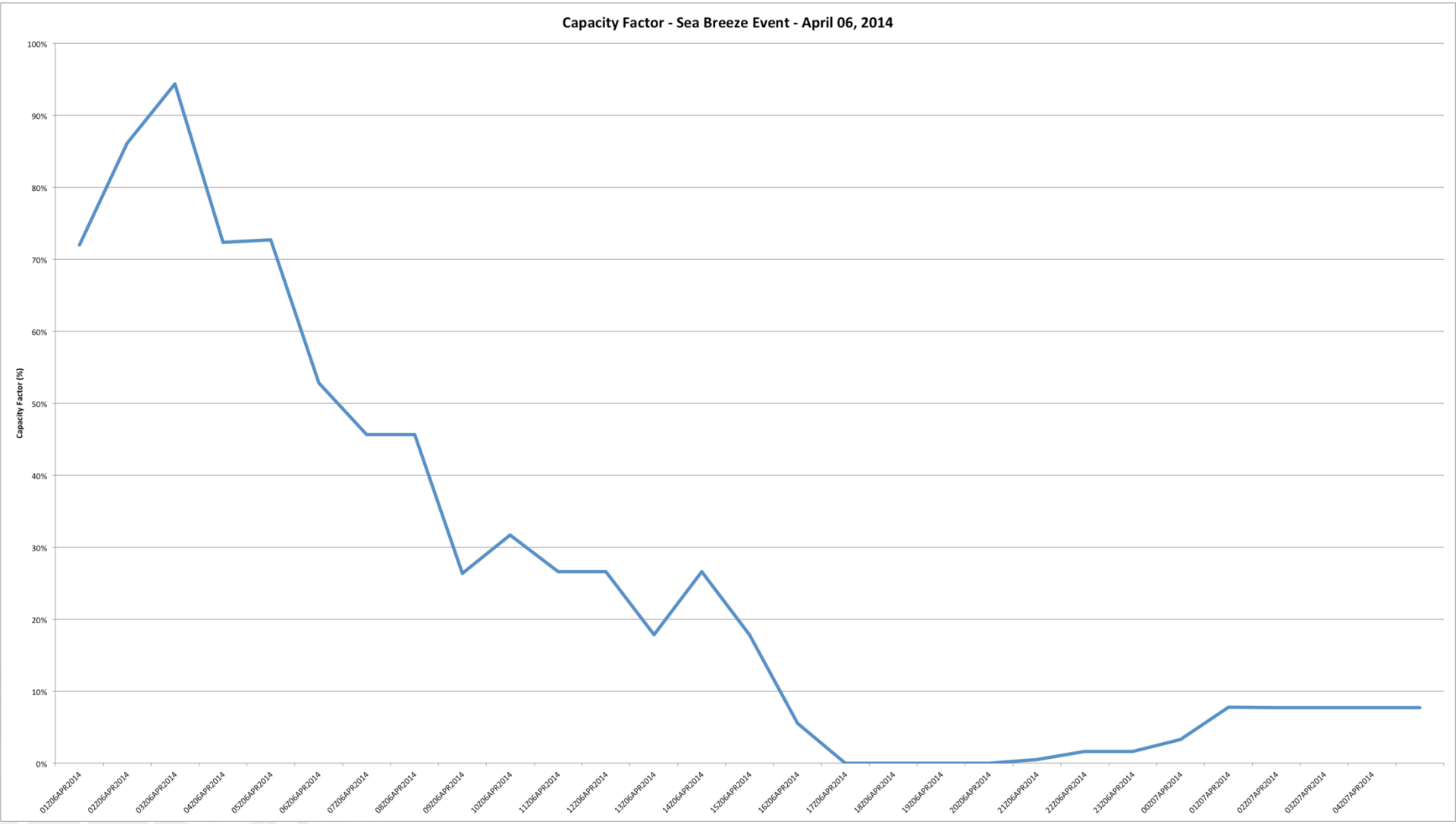


RU Coastal Ocean Observation Lab: RUWRF–ARW 1 KM Model Initialized 00Z06APR2014
http://marine.rutgers.edu/cool/weather Valid 03Z07APR2014 (Mon) | Forecast Hour 27

Wind Speed – Sea Breeze Event – April 6, 2014

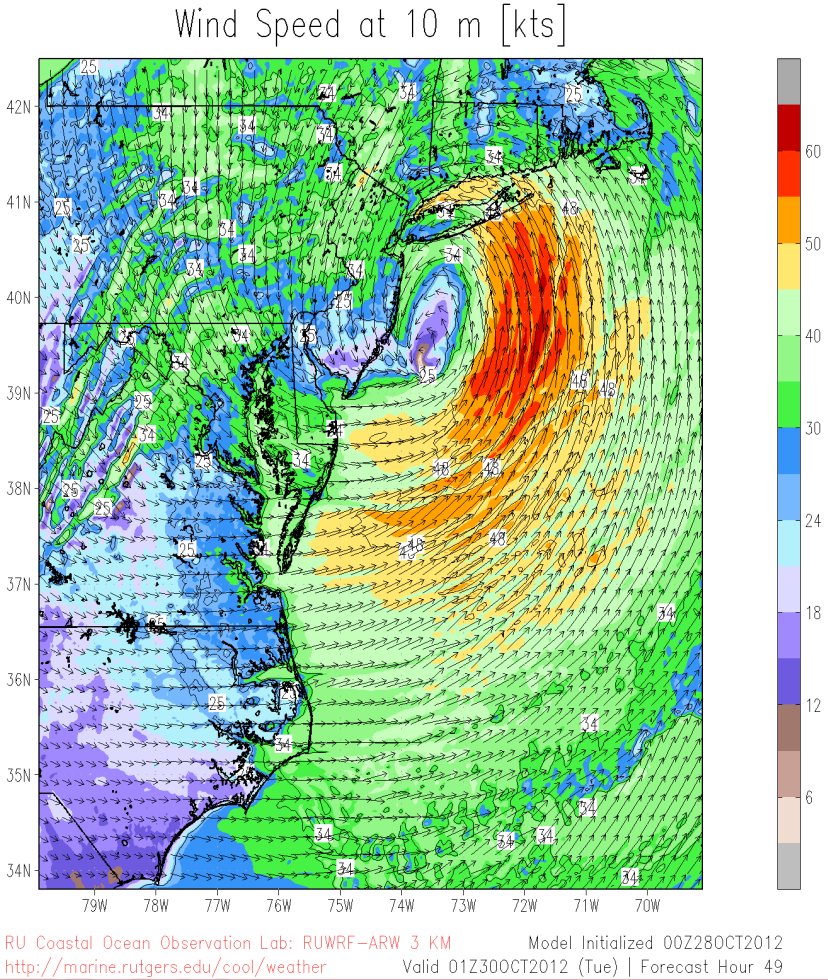


Capacity Factor – Sea Breeze Event – April 6, 2014



Severe Weather Analyses

Sandy, Oct 29-30, 2012



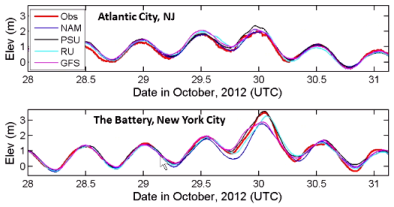
https://ams.confex.com/ams/94Annual/videogateway.cgi/id/25658?recordingid=25658

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

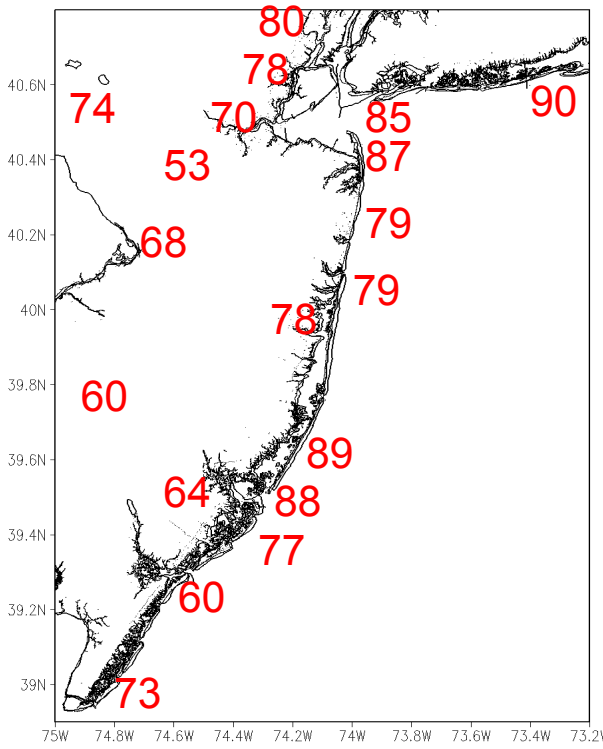
Alan Blumberg, Stevens Institute of Technology, Hoboken, NJ; and P. Orton and N. Georgas

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

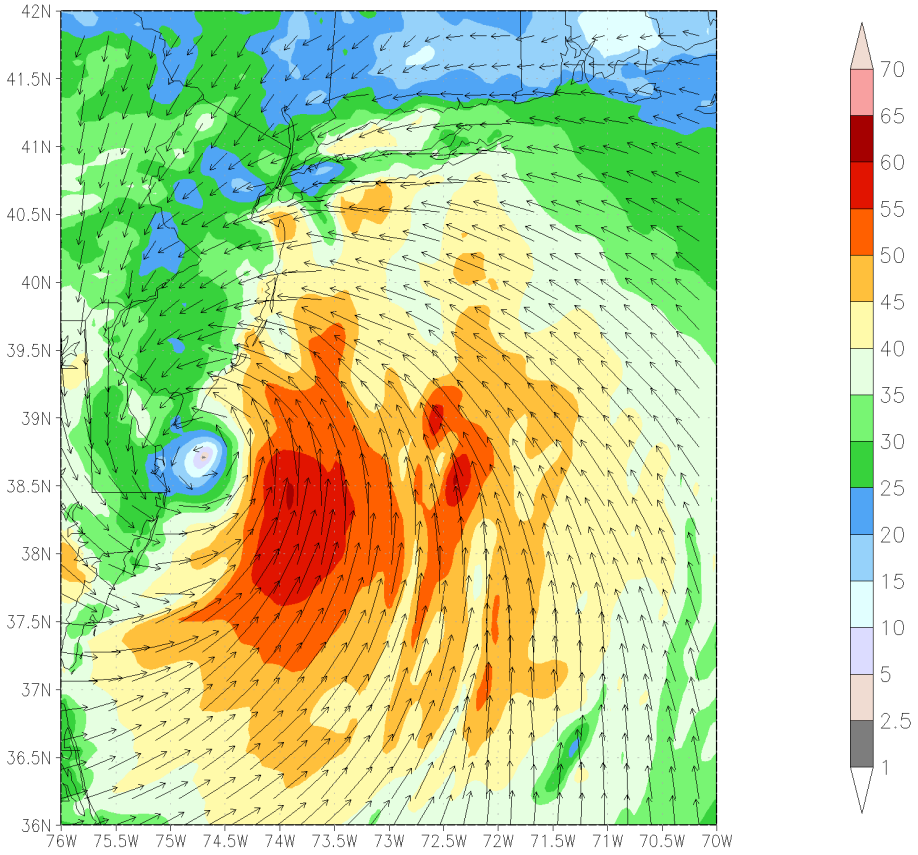


NAM = WRF - North American Mesoscale domain; PSU = WRF with radar data assimilation - Penn State University (Zhang et al. 2011); RU = WRF Rutgers; GFS = NCEP Global Forecasting System

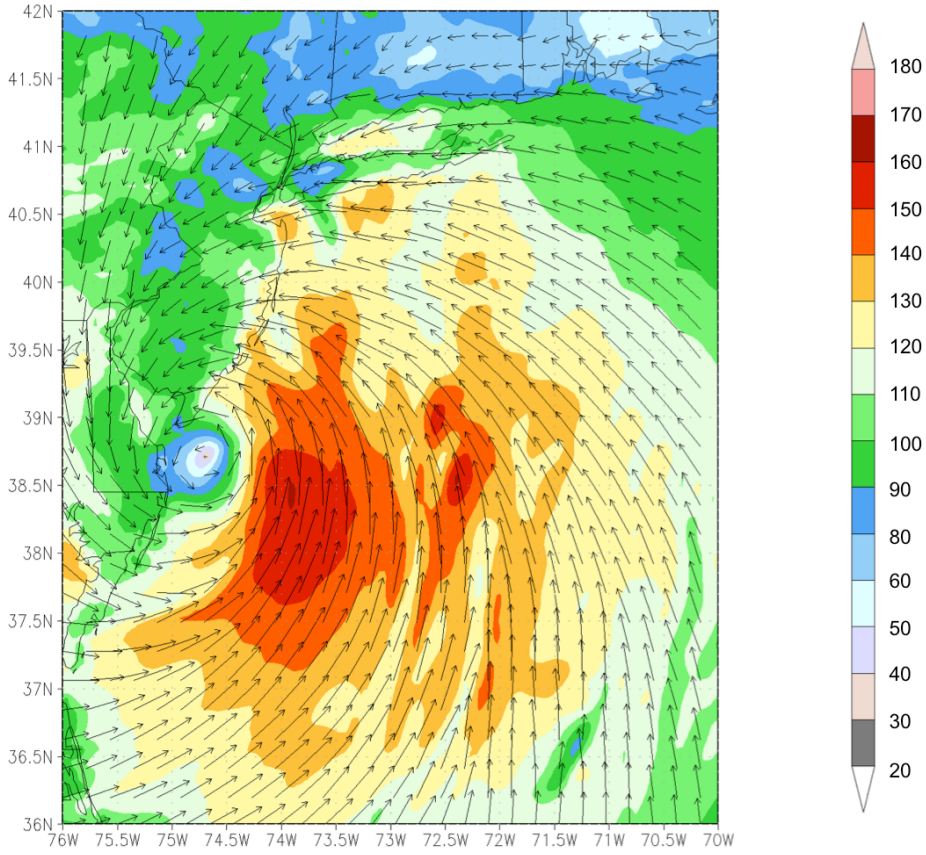


Model Irene with the intensity of the September 1821 Hurricane using RUWRF

Irene Wind Speed at 10m (MPH)

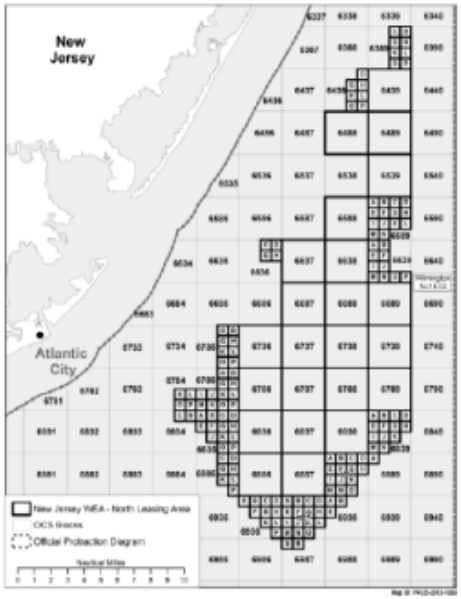


1821 Wind Speed at 10m (MPH)

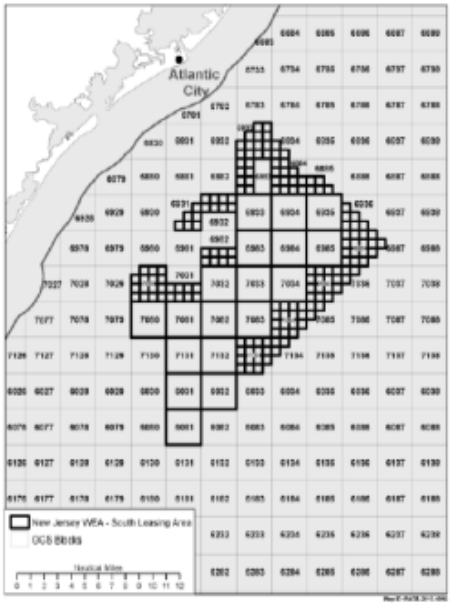


BOEM NJ WEA Analysis

North Zone

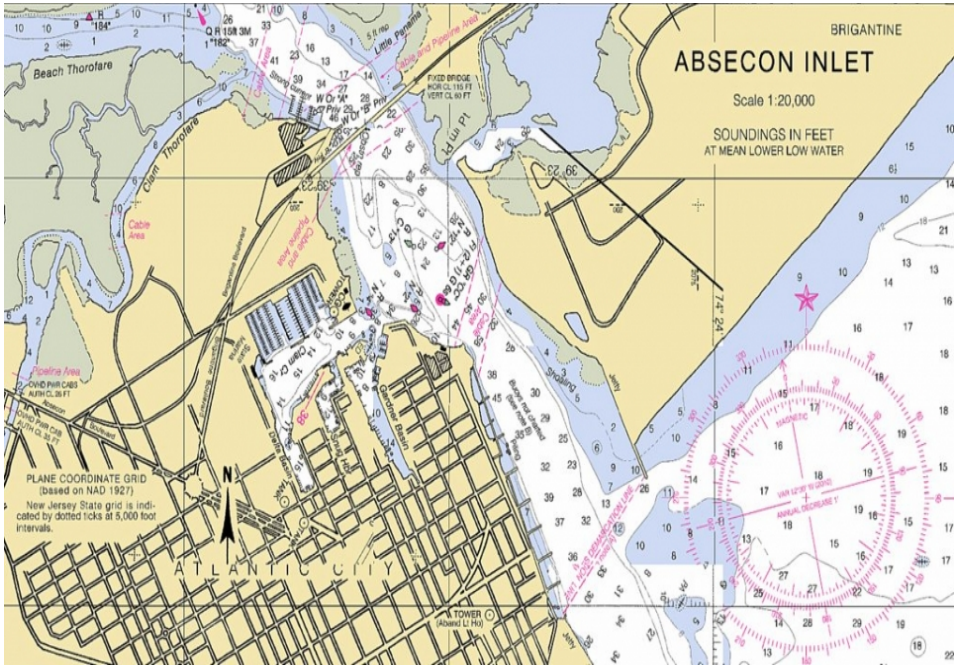


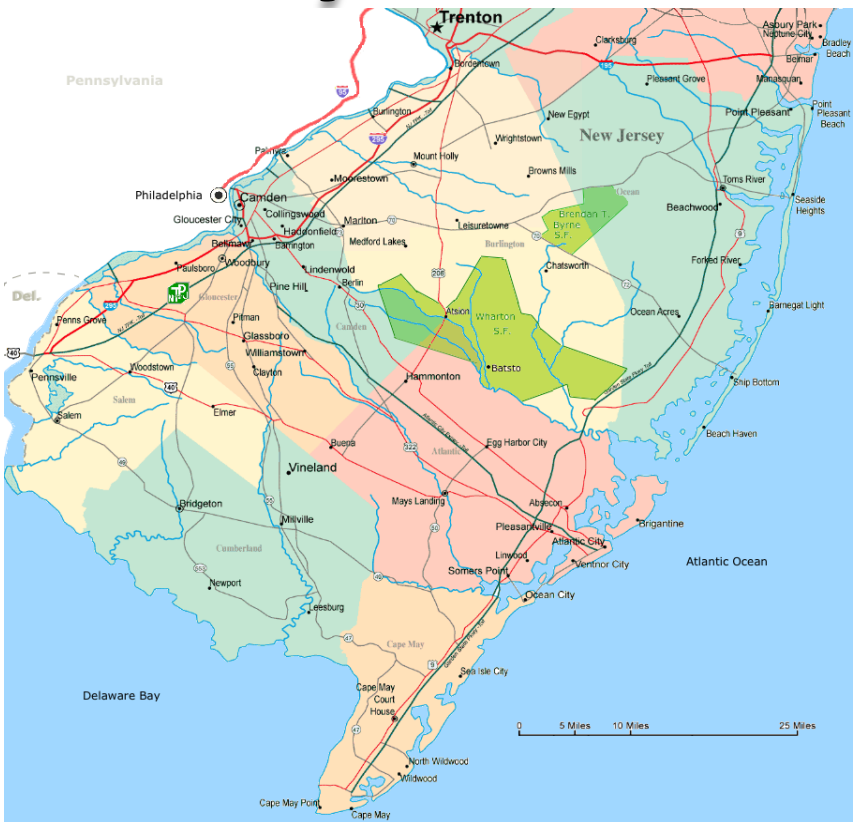
South Zone



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

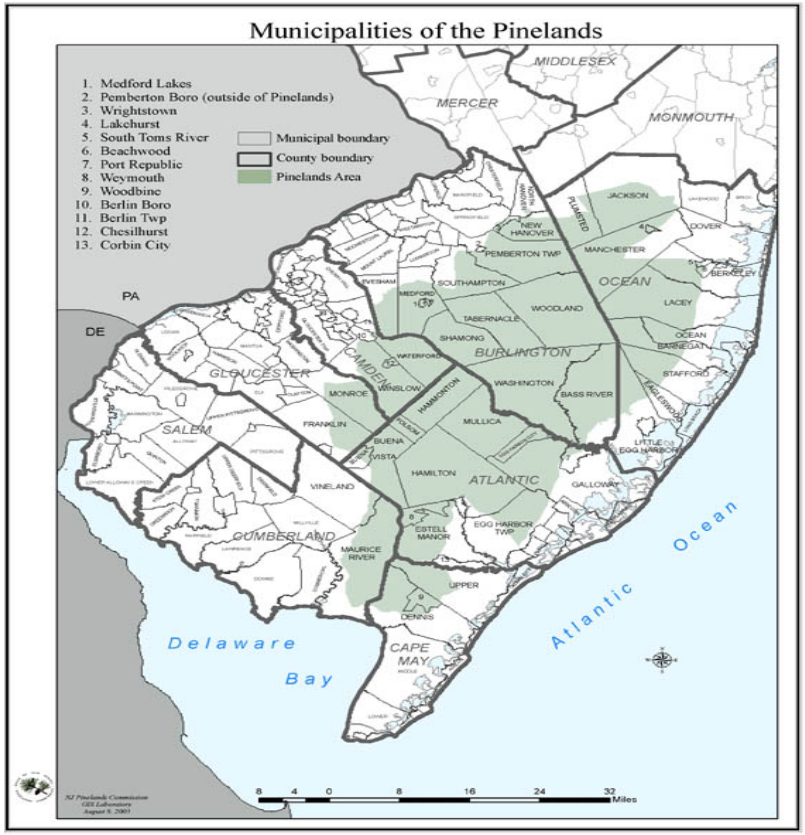
BOEM NJ WEA Analysis





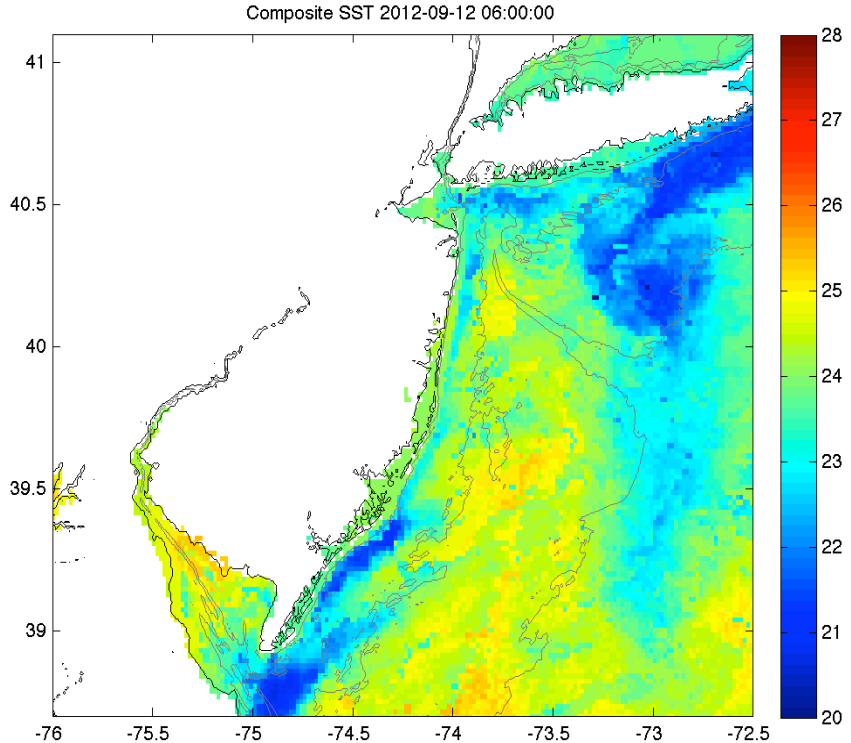
- Delineation line for north/south zones runs NW to SE from Absecon Inlet
- NJ coastline orientation (SW to NE)→turbulent wake increases from south to north in NJ WEA
- Concave coastline in south: offshore flow accelerates, onshore flow decelerates (opposite in northern WEA)

BOEM NJ WEA Analysis

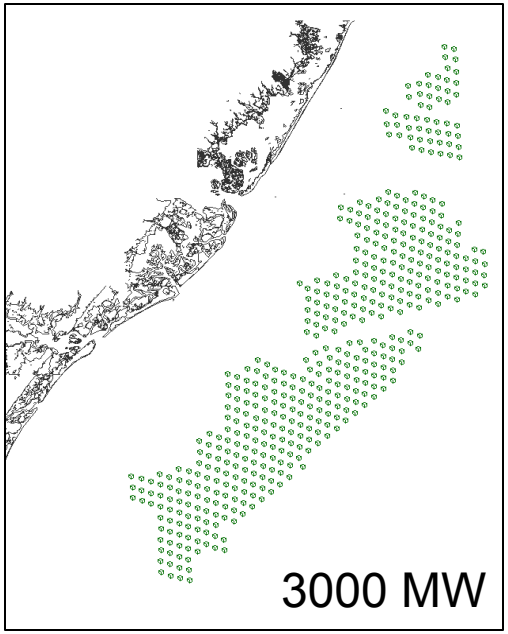


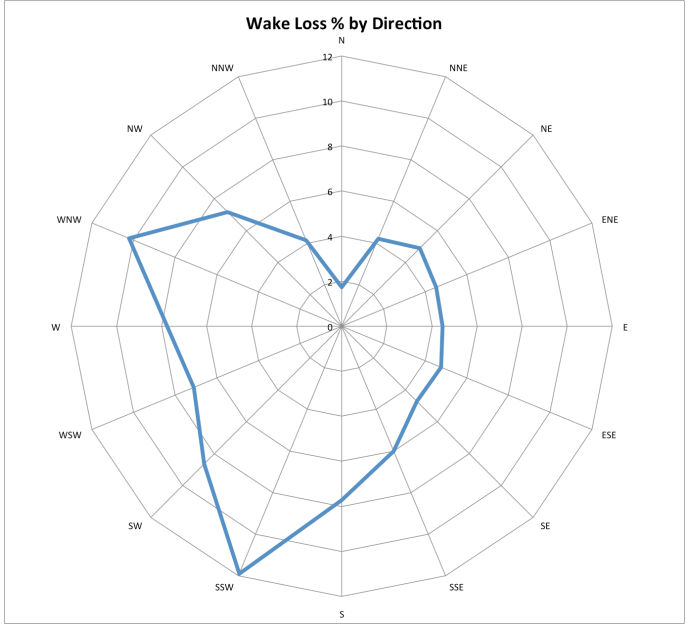
- Pinelands→ large fetch, esp. over northern WEA
- Cold SSTs (esp. during upwelling), warm Pinelands, hot urban centers→ regular sea breeze events during peak energy demand periods

BOEM NJ WEA Analysis

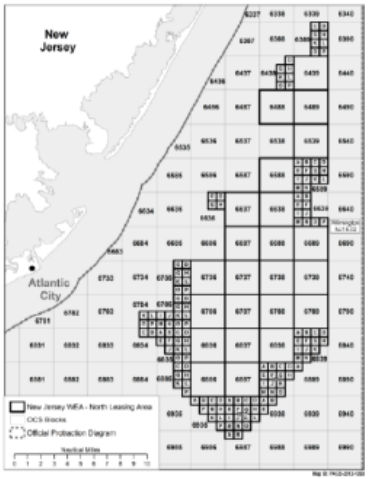


- Coastal upwelling coincides with sea breeze season
  - Impacts sea breeze circulation: more intense but smaller spatial imprint on WEA
- Staggered WTG spacing suggested
- 10D X 12D WTG spacing more viable than 8D X 8D WTG spacing
- NJ WEA is capable of housing 2500 to 3000 MW of installed OSW capacity

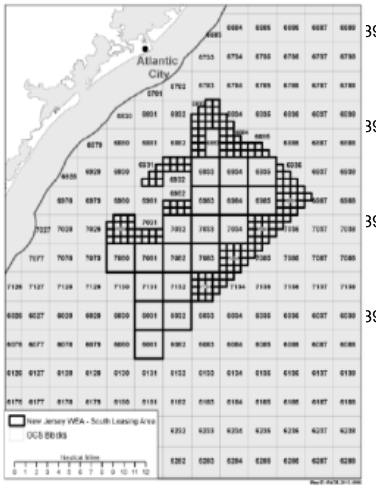


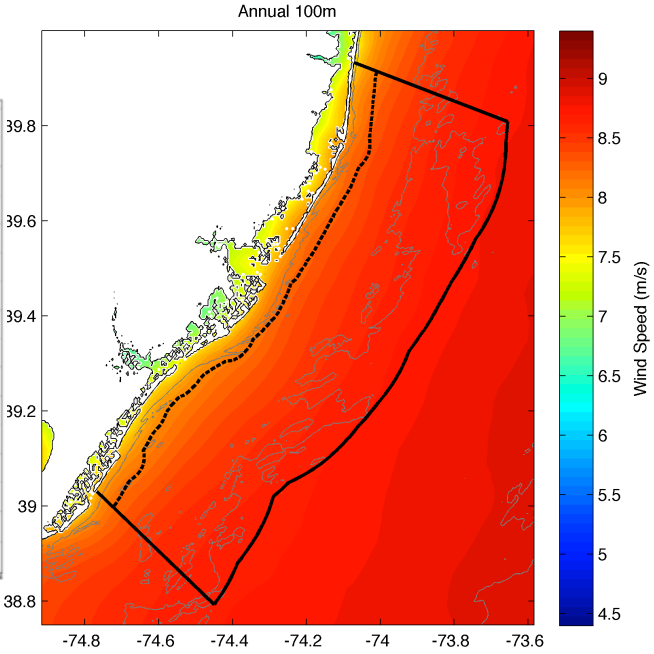


North Zone



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 Δnear IR albedo > 0.15% within 3km x 3km box

ii. AVHRR *Channel 4* (10.3-11.3 µm) tests:

- Remove if T < 5°C (summer), 3.5°C (winter)
- Remove if ΔT > 1°C within ~3km x 3km 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