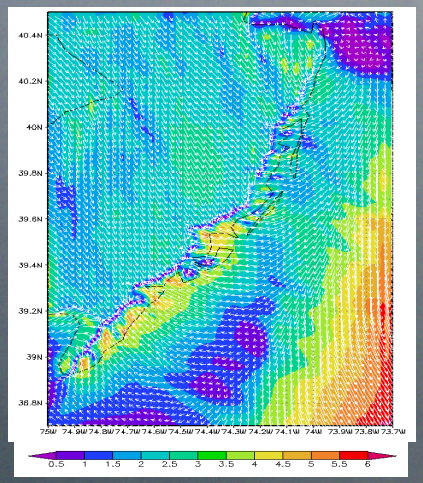
State of New Jersey
New Jersey Board of Public Utilities (NJBPU)

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

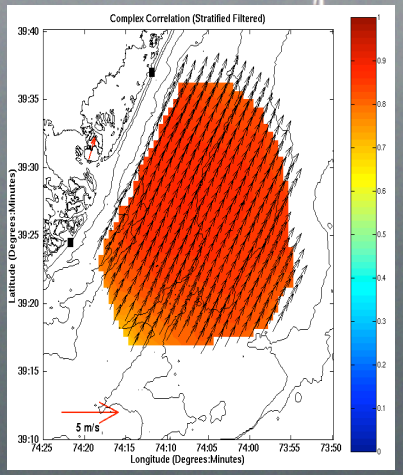
As Defined by The NJ Energy Master Plan and
The NJ Offshore Wind Energy Economic Development Act

Principal Investigators: Scott Glenn, Sc.D. and Rich Dunk, Ph.D., CCM
Team Members: Josh Kohut, Louis Bowers, Greg Seroka, John Kerfoot, Lisa Ojanen, Ethan Handel

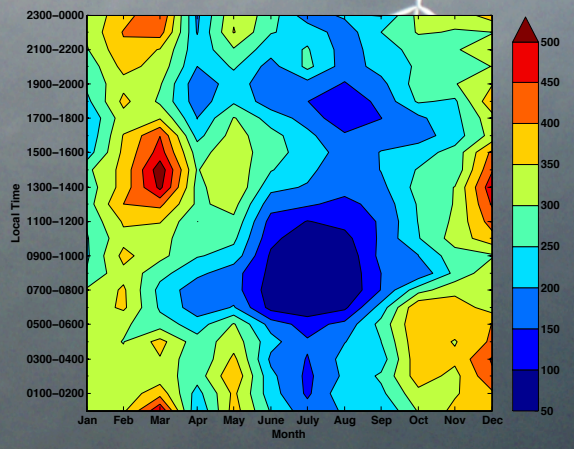
Hi-Res Weather Model



Spatial Validation Data



Wind Power Statistics



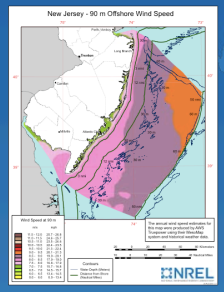
RUTGERS Institute of Marine and Coastal Sciences

RUTGERS Coastal Ocean Observation Lab

New Jersey Offshore Wind Energy

It is crucial to provide offshore wind developers an accurate assessment of the winds off the coast of New Jersey

example map:

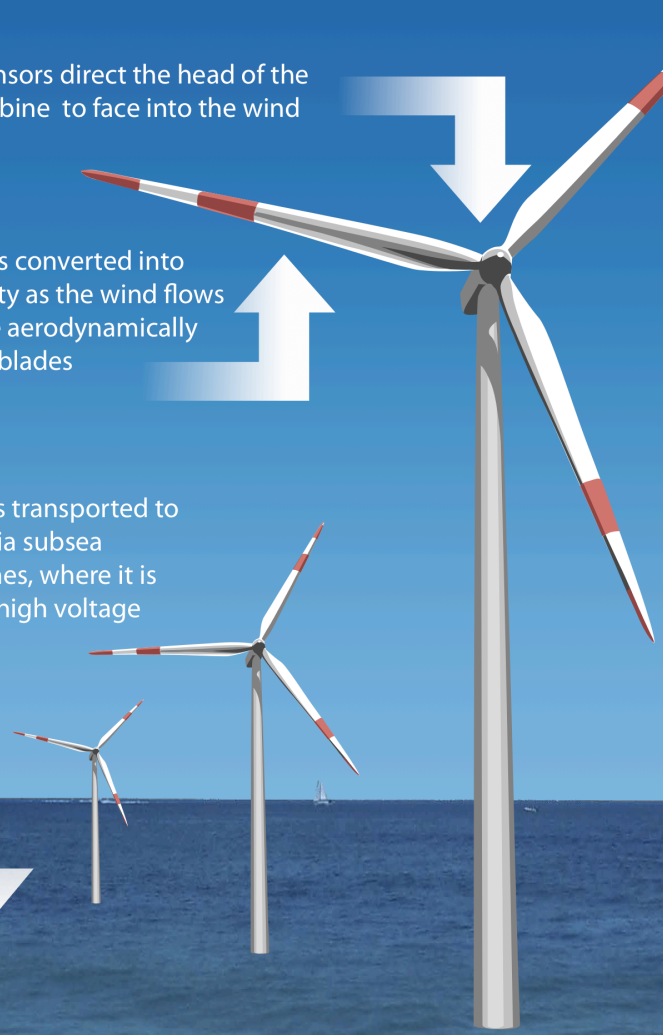


permitted lease areas for NJ offshore wind parks; developers as of Oct. 2011

1. Sensors direct the head of the turbine to face into the wind

2. Energy is converted into electricity as the wind flows over the aerodynamically shaped blades

3. The electricity is transported to a transformer via subsea transmission lines, where it is converted to a high voltage



OffshoreMW

Fishermen's Energy

Bluewater Wind

Garden State Offshore Energy

Bluewater Wind



wikispaces.com



Christian Steiness



nordex-online.com

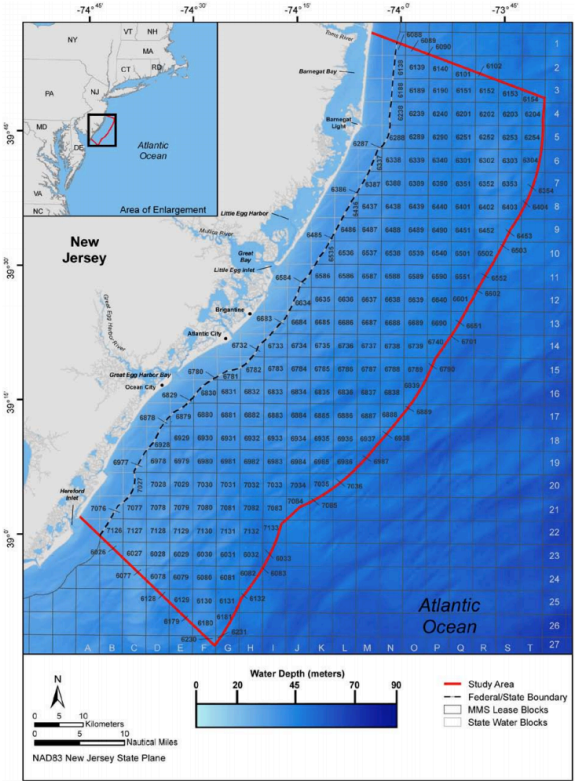
RUTGERS

JERSEY ROOTS, GLOBAL REACH

Coastal Ocean Observation Lab



- Ecological baseline studies of offshore wind power already performed (shown to left)
  - Avian species
  - Fisheries
  - Marine Mammals
  - Sea turtles



- This project will perform physical baseline study

Risks

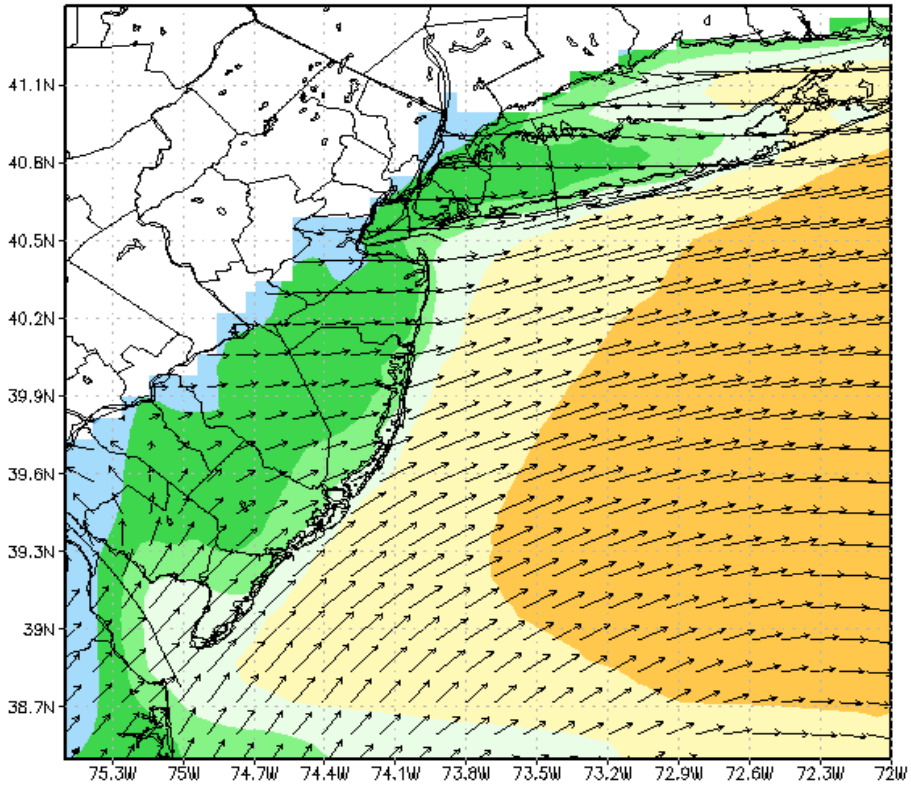
1. Wind park design:
   - What is the optimal spacing of wind turbines?
2. Installation:
   - When is the best time to install planned and future wind turbines?
3. Operation:
   - When do you schedule maintenance? How do you forecast power for the day-ahead market?
4. Planning:
   - Where do we site future wind parks?

Risk reduction

We will develop an improved weather model and spatial datasets for:

1. Design and installation of currently proposed wind parks
2. Comparison with ecological studies for siting of future wind parks
3. Future operations and maintenance of wind parks
4. More accurate day-ahead forecasts for the energy market

90 m Annual Wind Speed (m/s) and Direction from RU-WRF



Why do we need a better atmospheric model?

NJ Sea Breeze

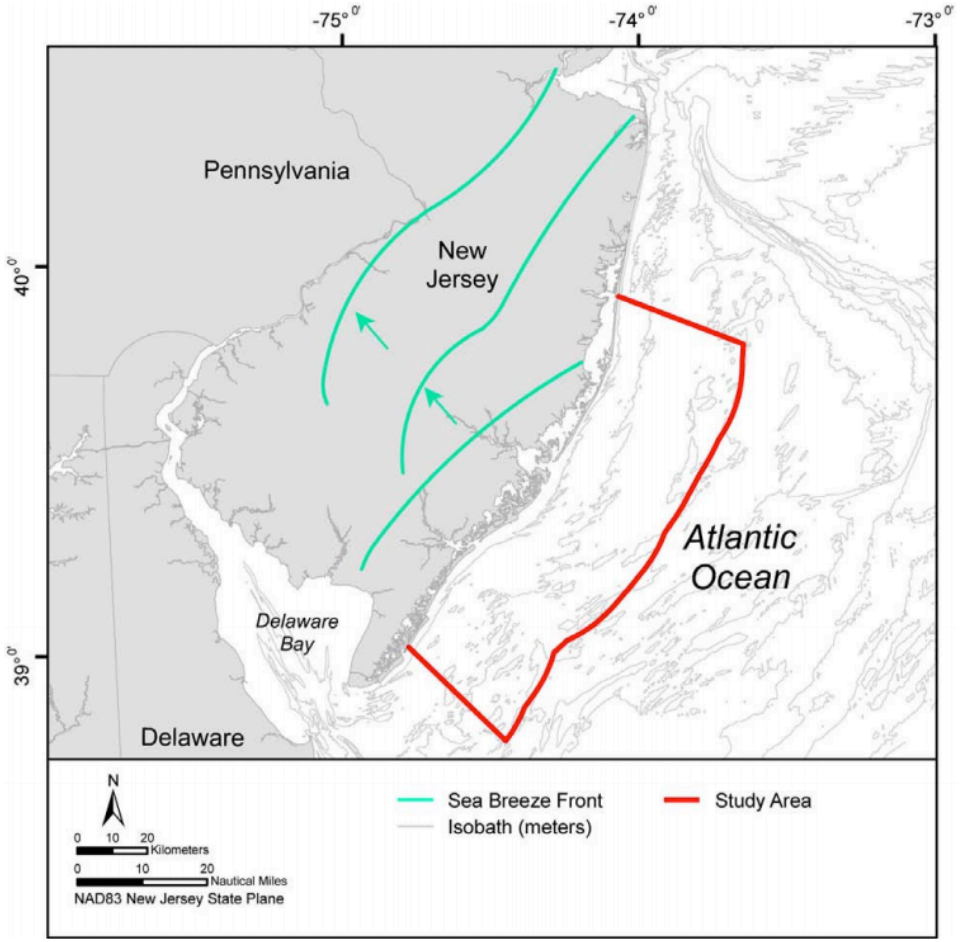
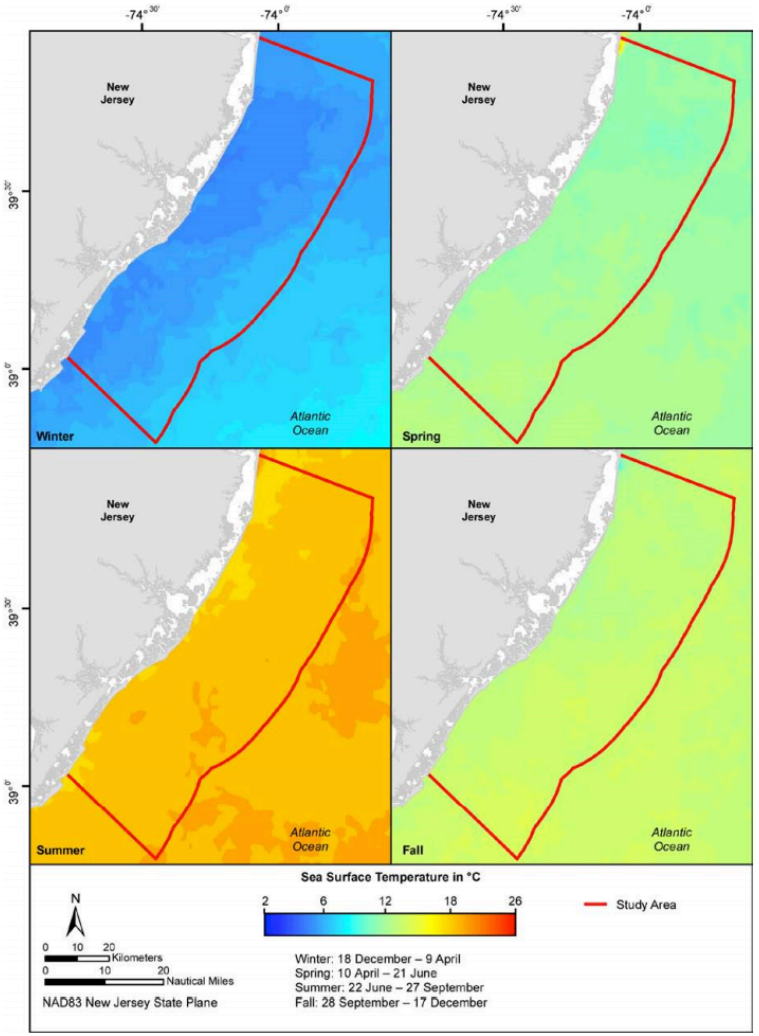


Figure 2-9. The inland progression of a sea breeze front. Map adapted from: Bowers (2004).

Seasonal Sea Surface Temperature



How do we ensure we have a better atmospheric model?

- Vertical validation
  - Coastal/offshore monitoring sites
- Horizontal validation
  - Surface current mapping (CODAR)
  - Satellite, weather radar

Coastal/Offshore Monitoring

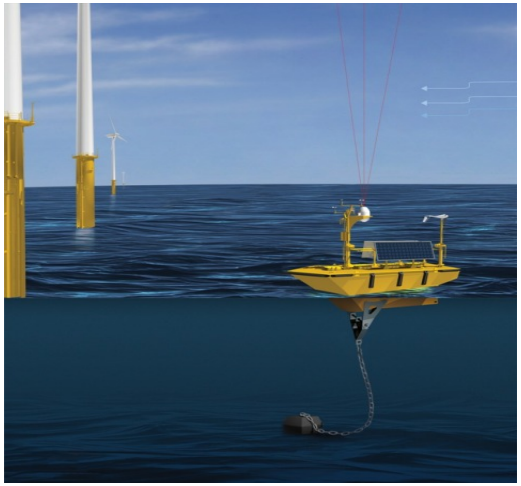
Meteorological Tower



Meteorological Buoy



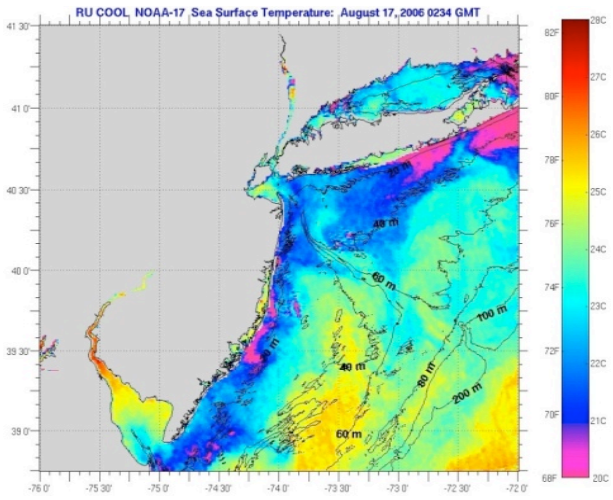
Offshore vertical LIDAR



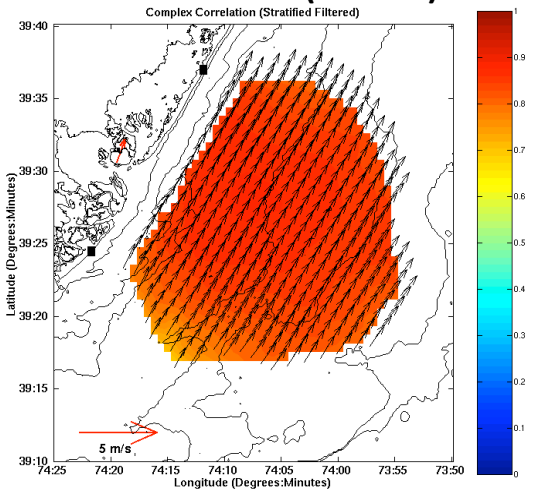
Coastal/Offshore Scanning LIDAR



Infrared Satellite

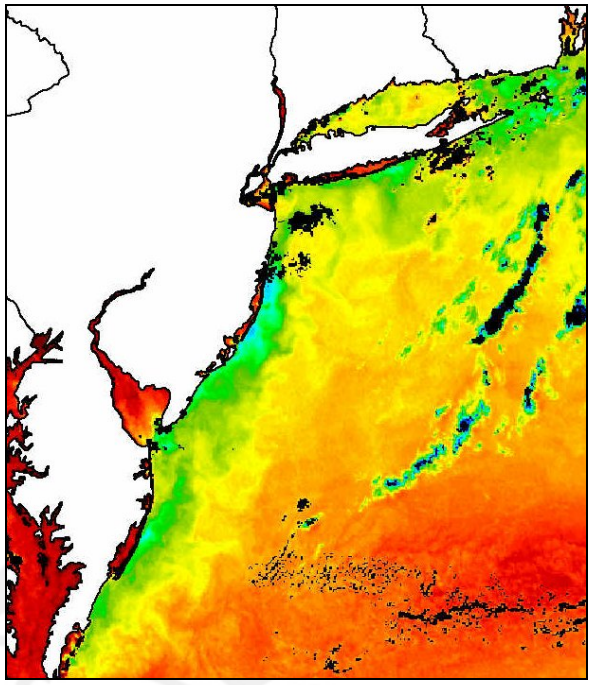


Coastal Radar (CODAR)

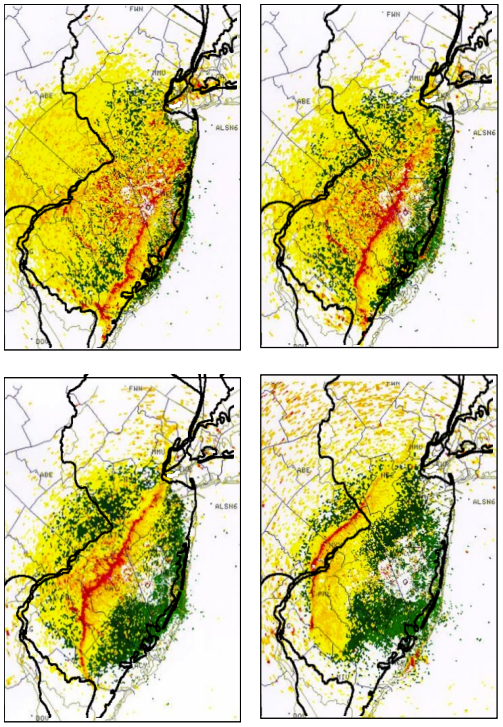


Large-Scale and Small-Scale Offshore Wind

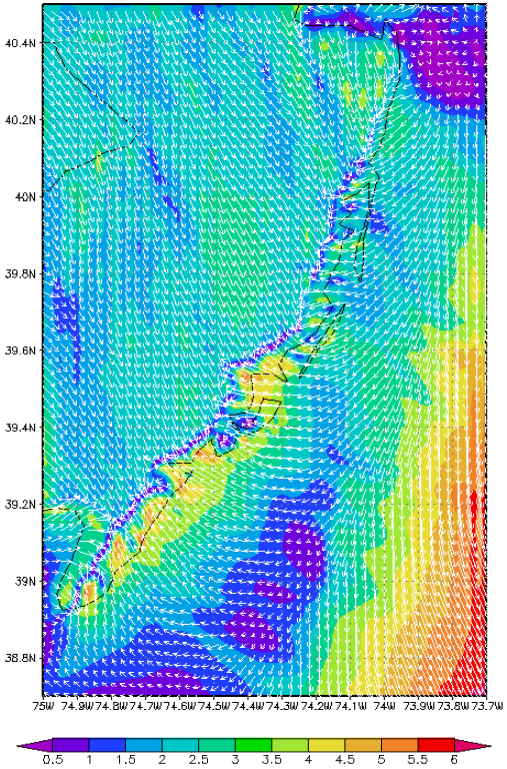
Our experience with both atmospheric and oceanographic monitoring and modeling will provide the best estimates of offshore wind along the coast of New Jersey.



Infrared Satellite



Weather Radar

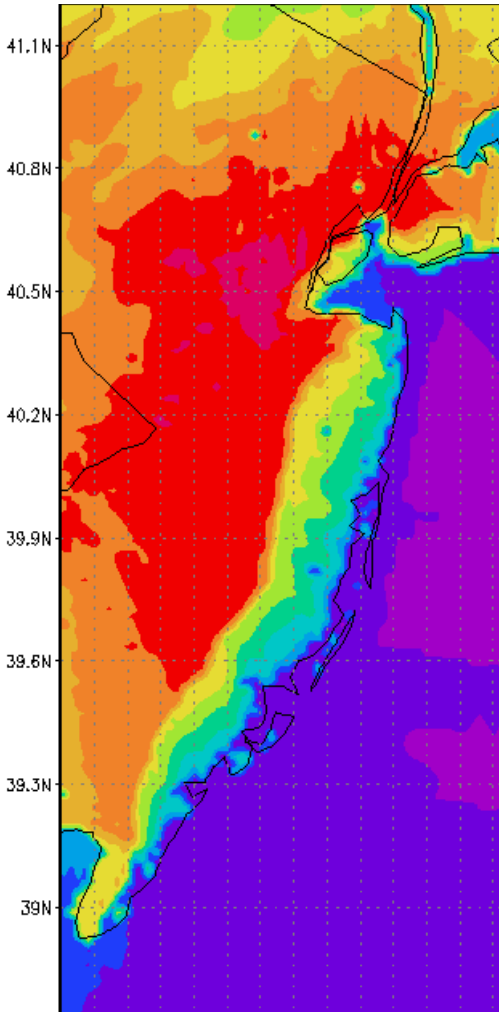


RU-WRF Model 2km Simulation

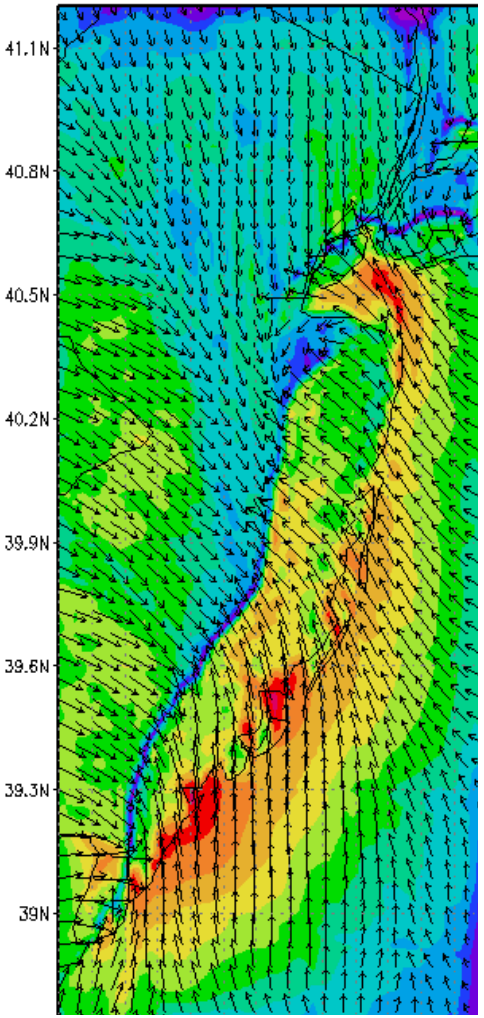
Operational Mesoscale Modeling with RU-WRF

RU-WRF has been proven to be a highly successful and trusted tool in the prediction of day-to-day, severe, and offshore weather.

RU-WRF has been used to forecast day-to-day and severe weather conditions for PSEG for more than seven years. The model has been used for oceanographic projects funded by the Navy, NSF, etc.



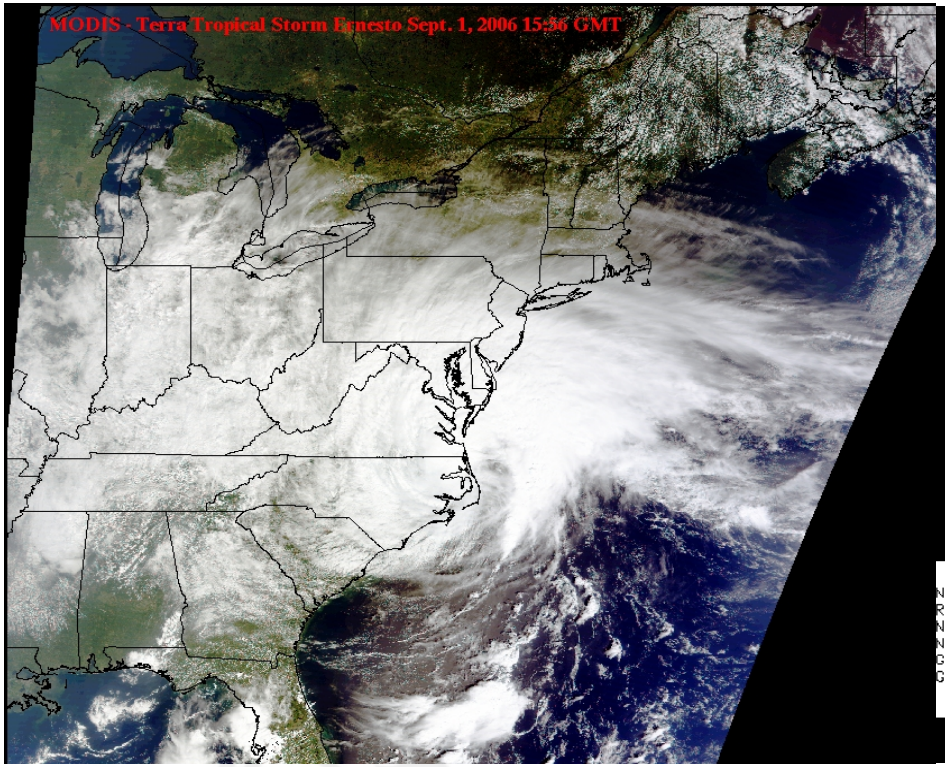
Surface Temperature

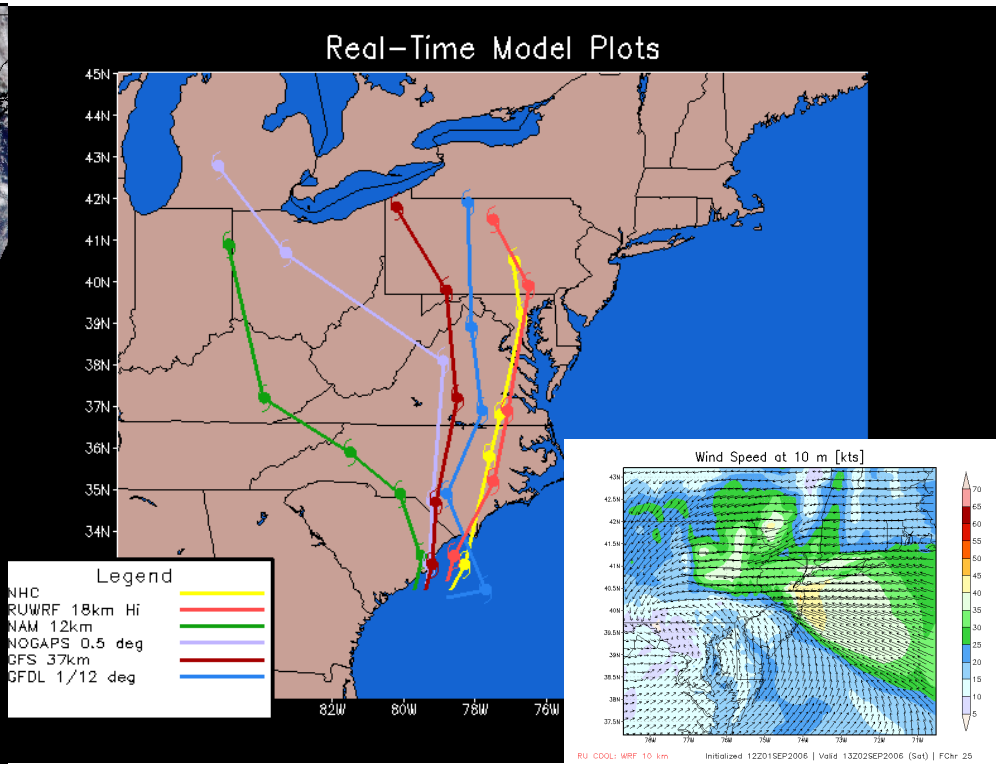


Wind Speed @ 10 m

Operational Mesoscale Modeling with RU-WRF

RU-WRF was the first operational weather model (US Gov. or otherwise) to accurately predict the path of Tropical Storm Ernesto through the Middle-Atlantic States in 2006.



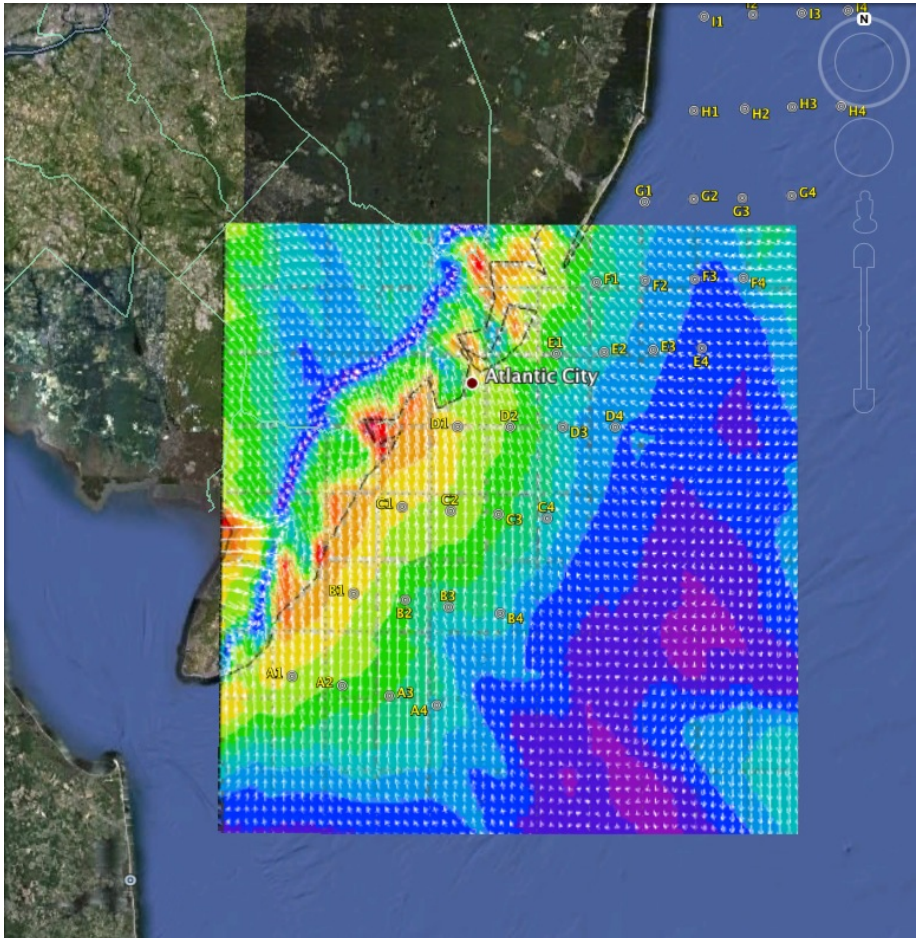


Operational Mesoscale Modeling with RU-WRF

Capability of Real-time Energy Forecasts

•Energy Yield
•Severe Weather Outage
- Tropical Storms
- Nor'easters
- Thunderstorms/lightning
- Ice Accretion

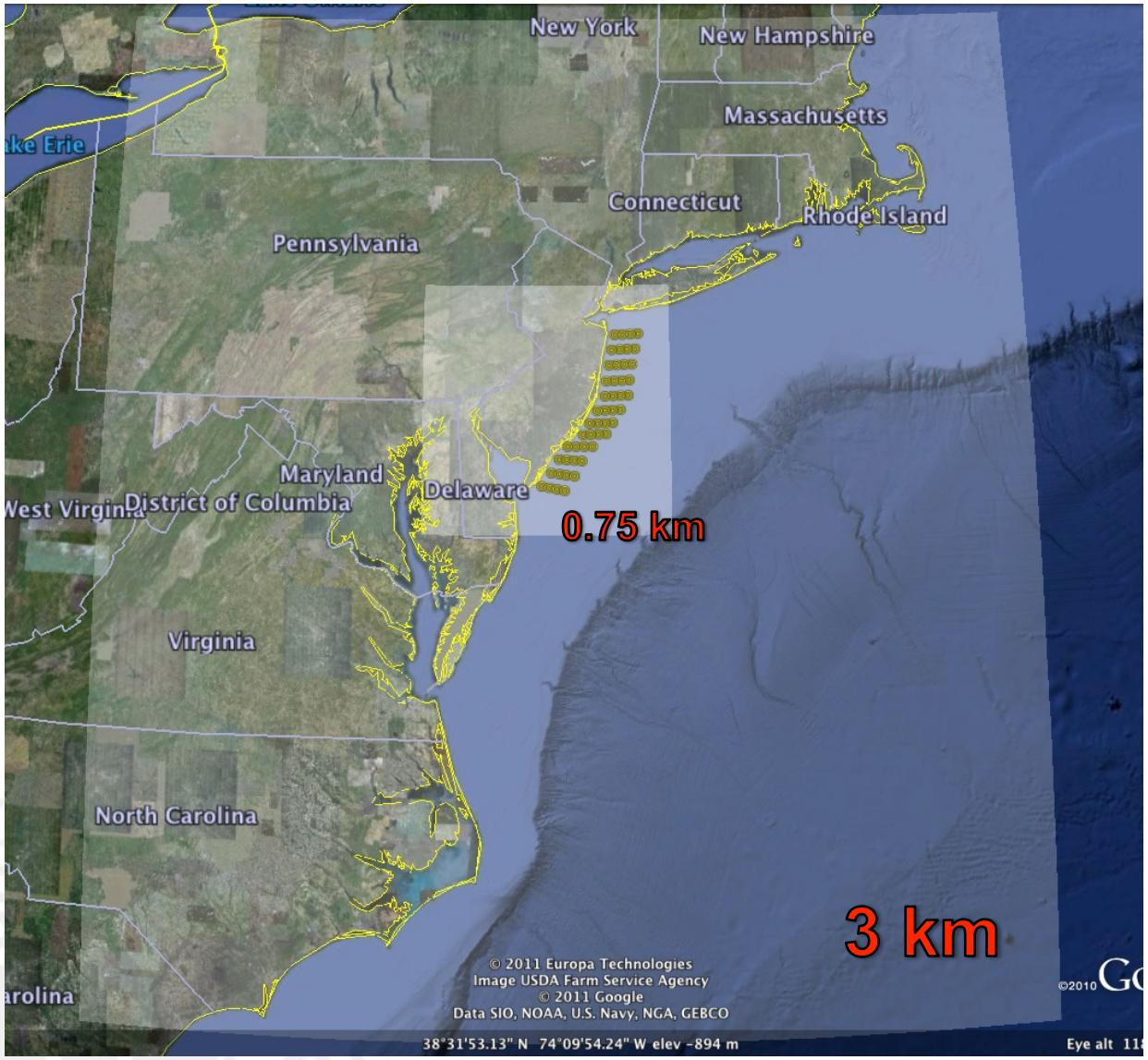
Inaccessibility due to high seas and winds
- Real-time
- Construction
- Climatological



Scope of Work Details

1. Develop *high resolution, 3-D microscale* model that will accurately define the general coastal/offshore wind resource along with resolving local wind resource perturbations, such as the sea breeze circulation, turbulence intensity, and wind shear.

Proposed WRF domains

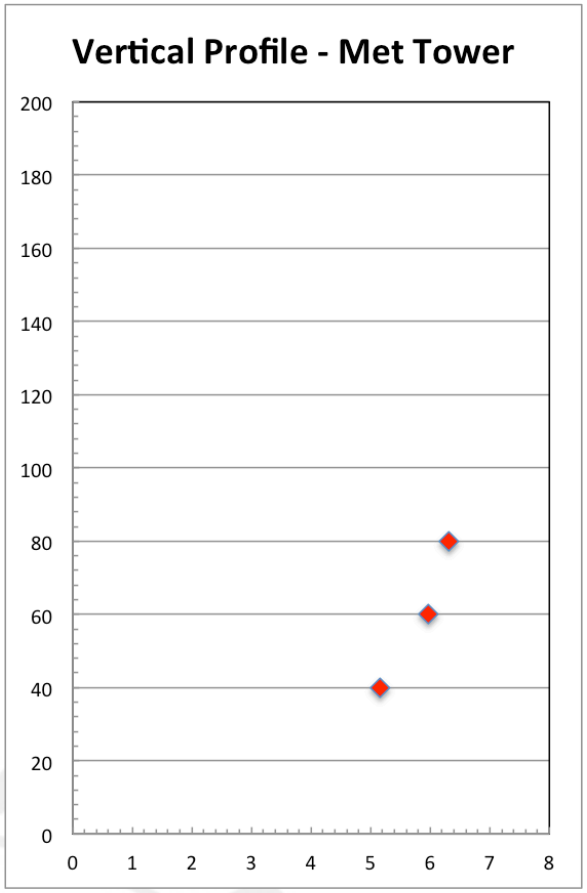


- ***3 km* horizontal resolution over NY Bight**
- ***750 m* horizontal resolution over study area**

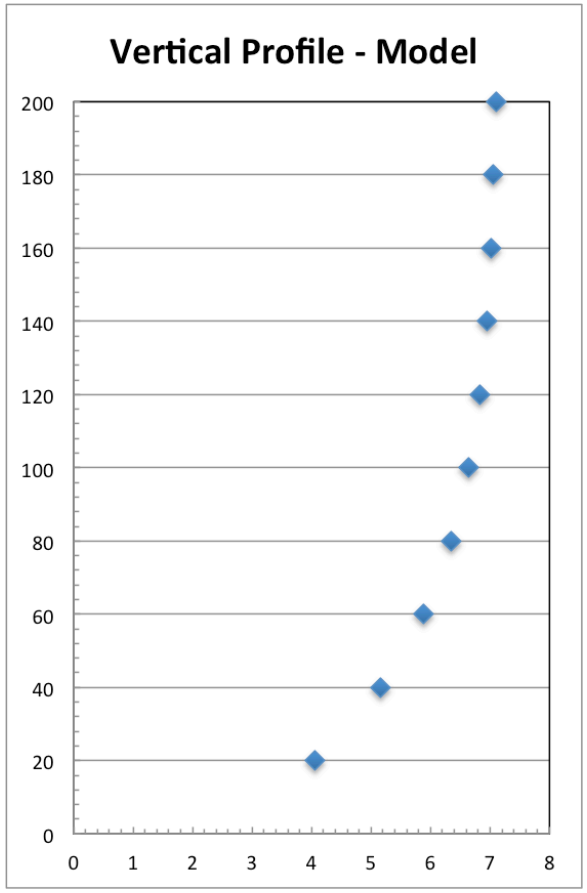
Model will run in real-time, for precise comparison to onsite met towers

Data will be extracted from the model at a selected array of grid points within the study domain producing several **"Virtual" Meteorological Towers**.

Meteorological Tower vs. Model Virtual Meteorological Tower



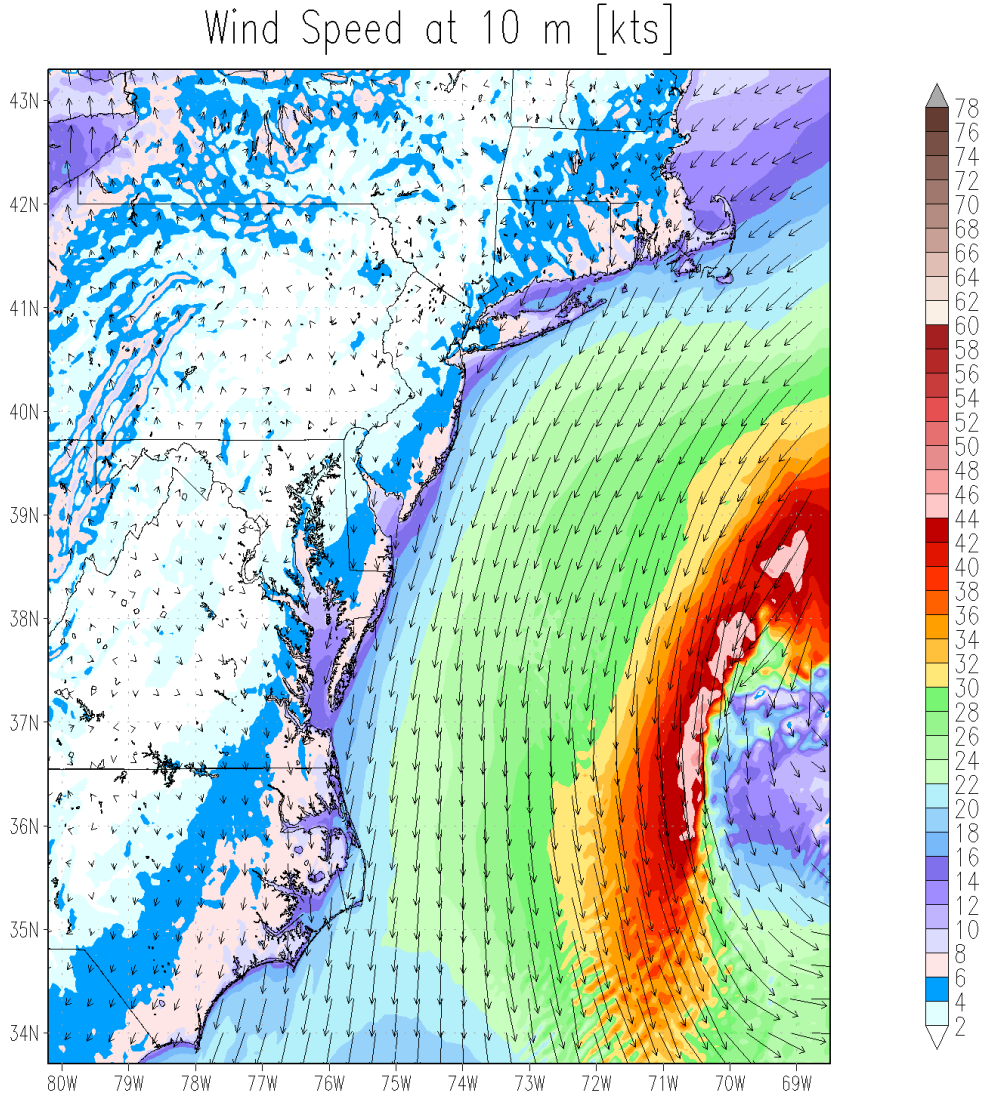
Meteorological Tower provides data at instrumented heights at a single location



Virtual Meteorological Tower provides data at any desired height at any location

The **Virtual Met Tower** can allow for additional variables to be calculated such as temperature, air density, turbulence, potential turbine icing, and blade swept area wind shear.

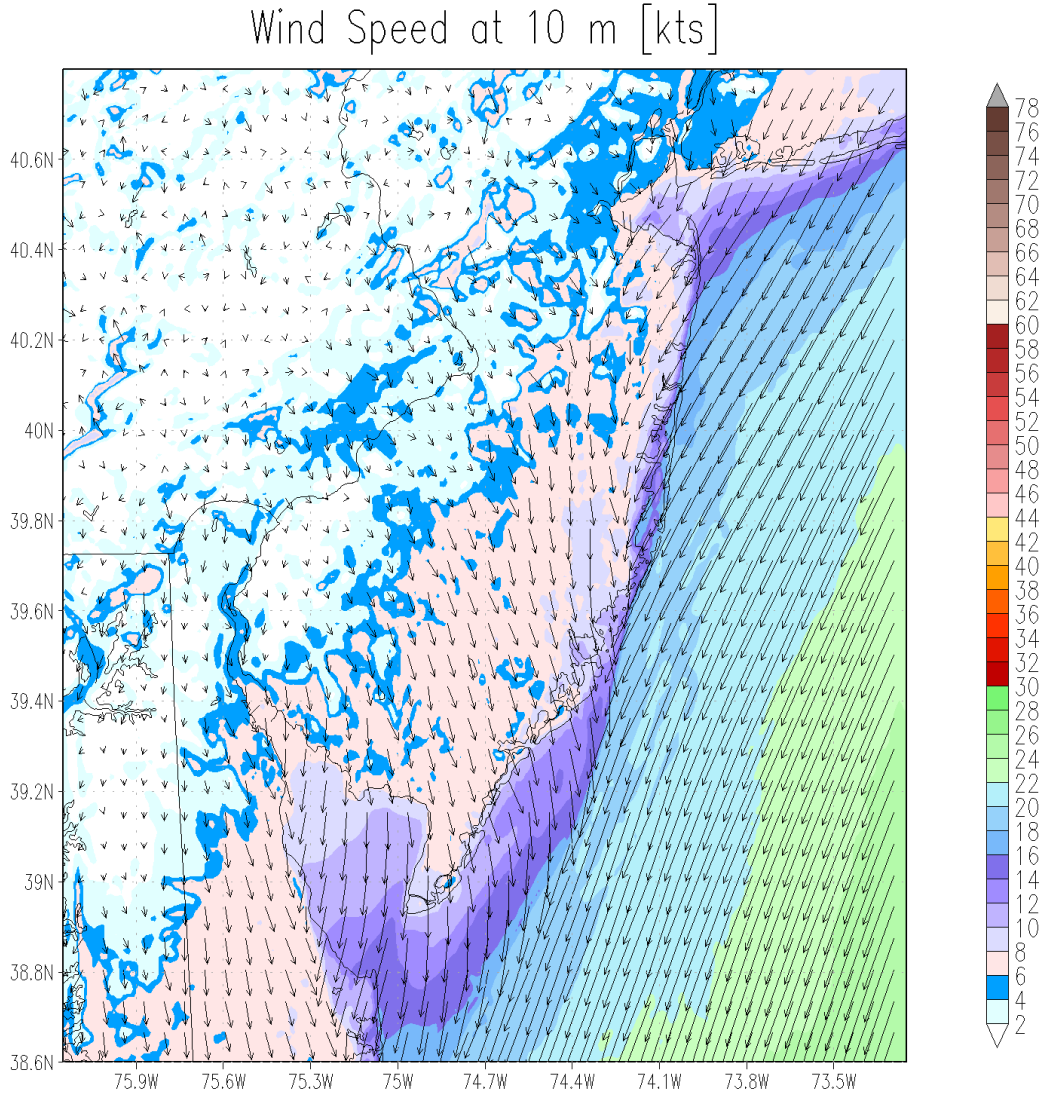
WRF 3km Outer Domain Example



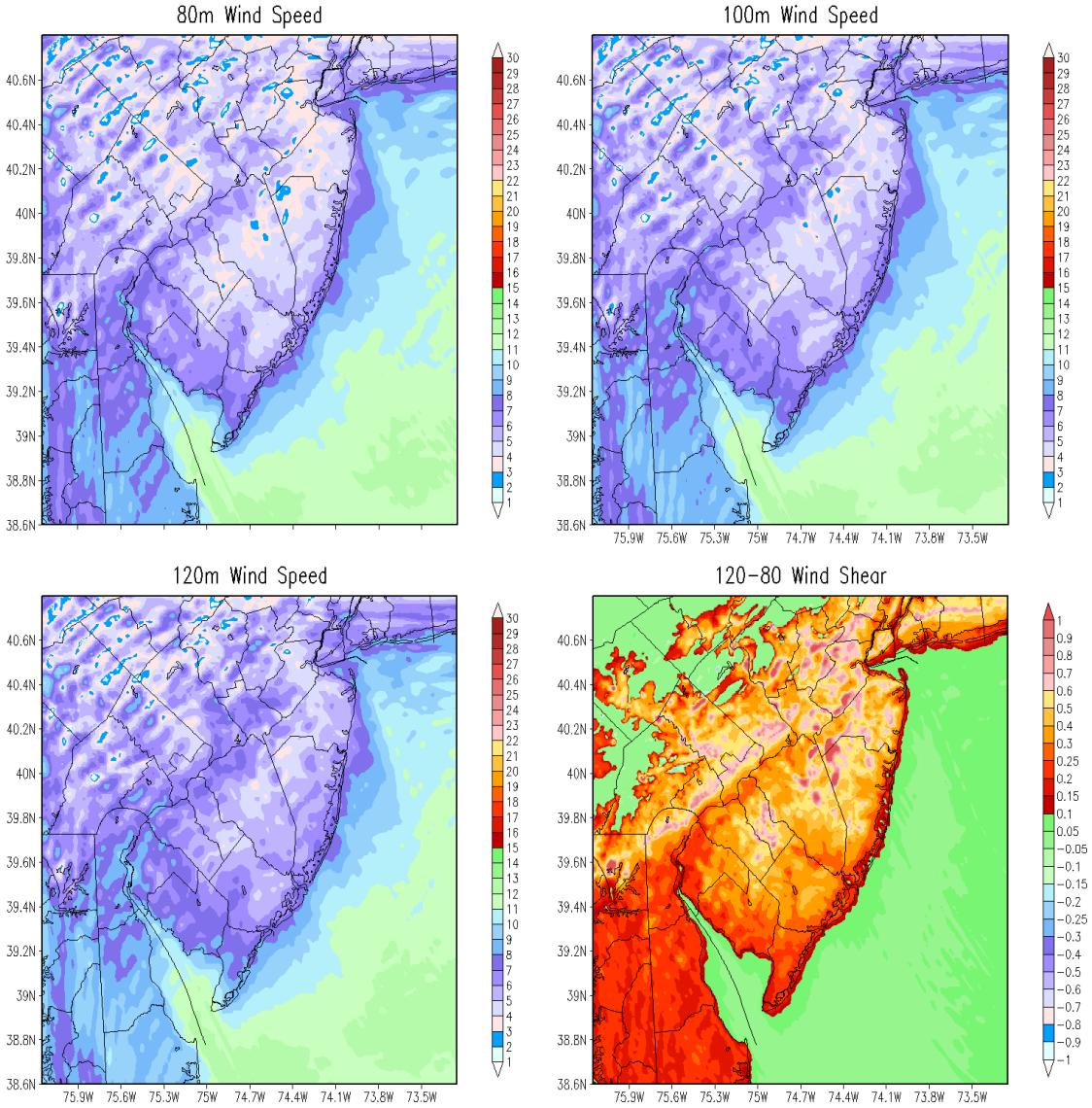
RU Coastal Ocean Observation Lab: RUWRF–ARW 3 KM
http://marine.rutgers.edu/cool/weather

Model Initialized 00Z02NOV2011
Valid 03Z02NOV2011 (Wed) | Forecast Hour 3

WRF 0.75km Inner Domain Example

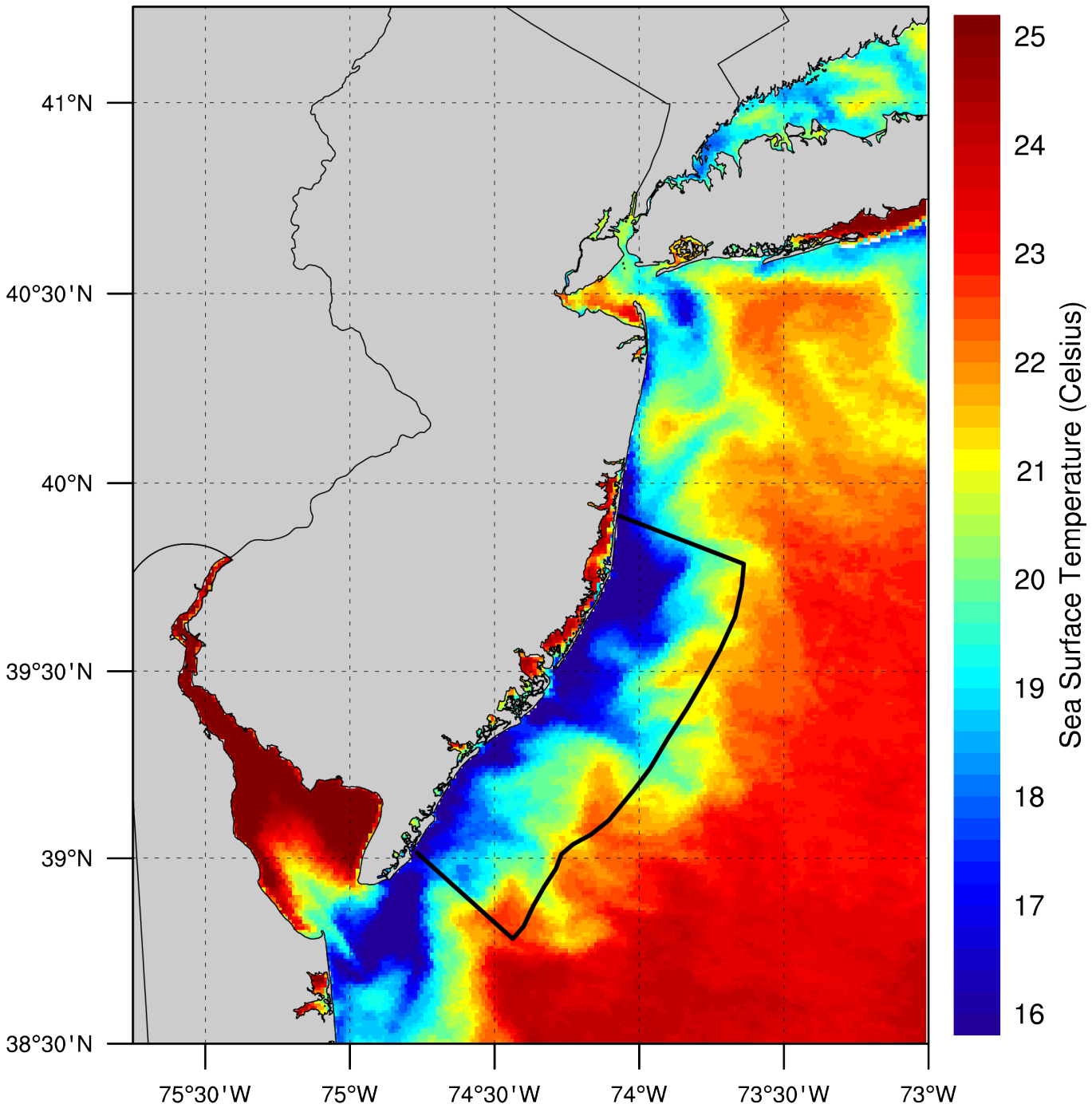


WRF 0.75km Hub Heights, Shear Example



Scope of Work Details

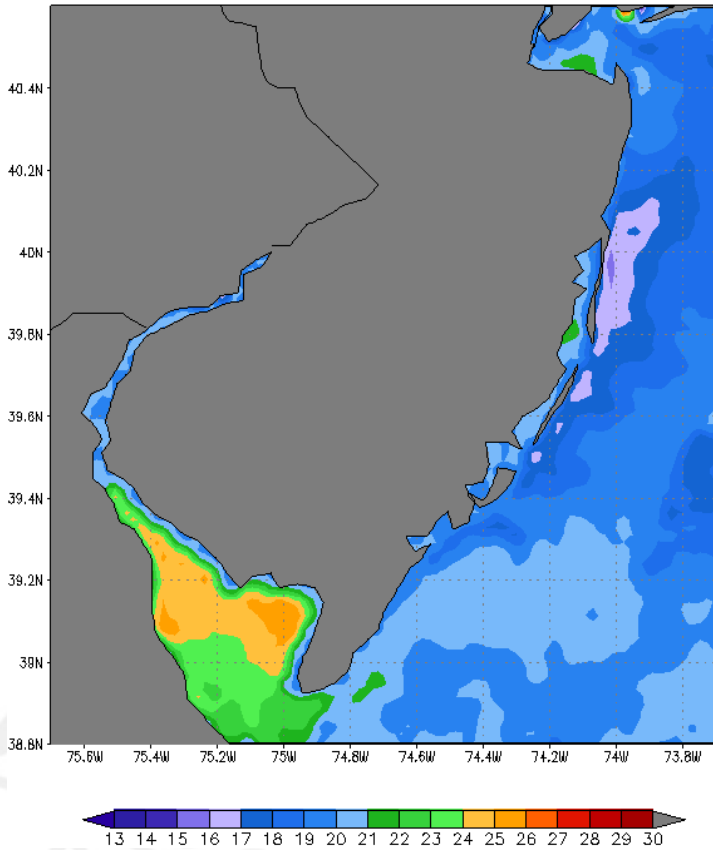
1. Develop *high resolution, 3-D microscale* model that will accurately define the general coastal/offshore wind resource along with resolving local wind resource perturbations, such as the sea breeze circulation, turbulence intensity, and wind shear.
2. **High resolution boundary conditions to resolve upwelling centers.**


AVHRR SST: 2008-07-03 07:36:00 UTC
41°N
40°30'N
40°N
39°30'N
39°N
38°30'N
75°30'W
75°W
74°30'W
74°W
73°30'W
73°W
25
24
23
22
21
20
19
18
17
16
Sea Surface Temperature (Celsius)

Sea Breeze Development

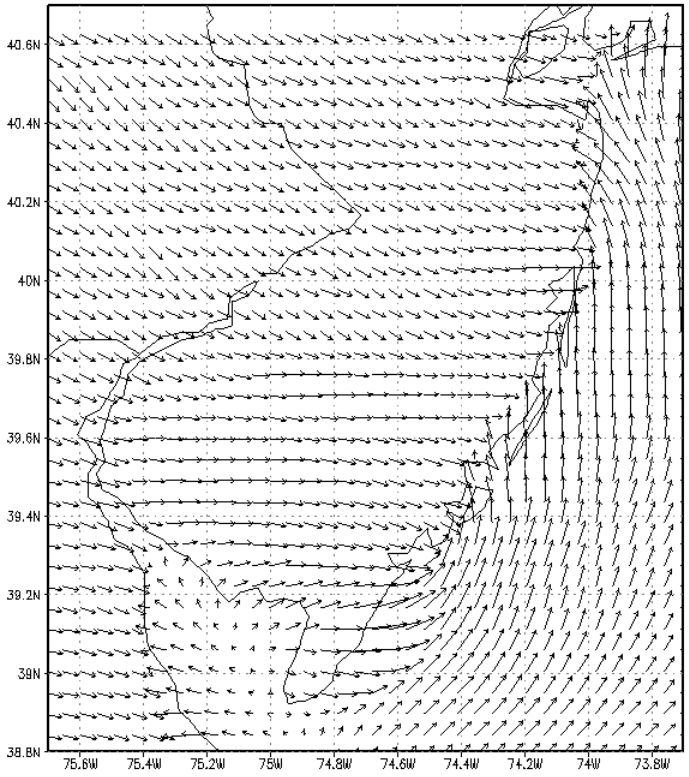
Upwelling Case

Surface Temperature



Infrared Satellite

10m Wind

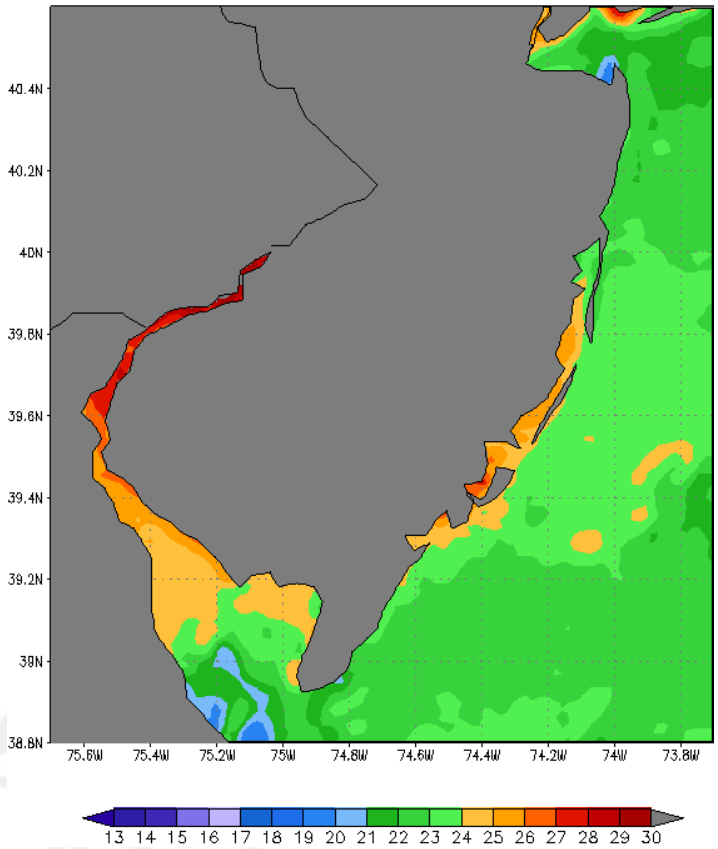


RU-WRF Model Simulation

Sea Breeze Development

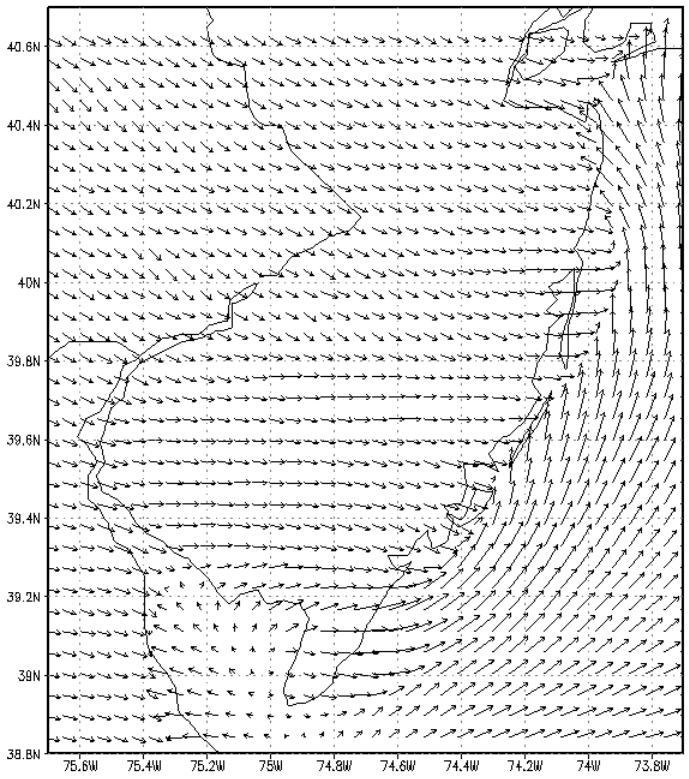
Non-Upwelling
Case

Surface Temperature



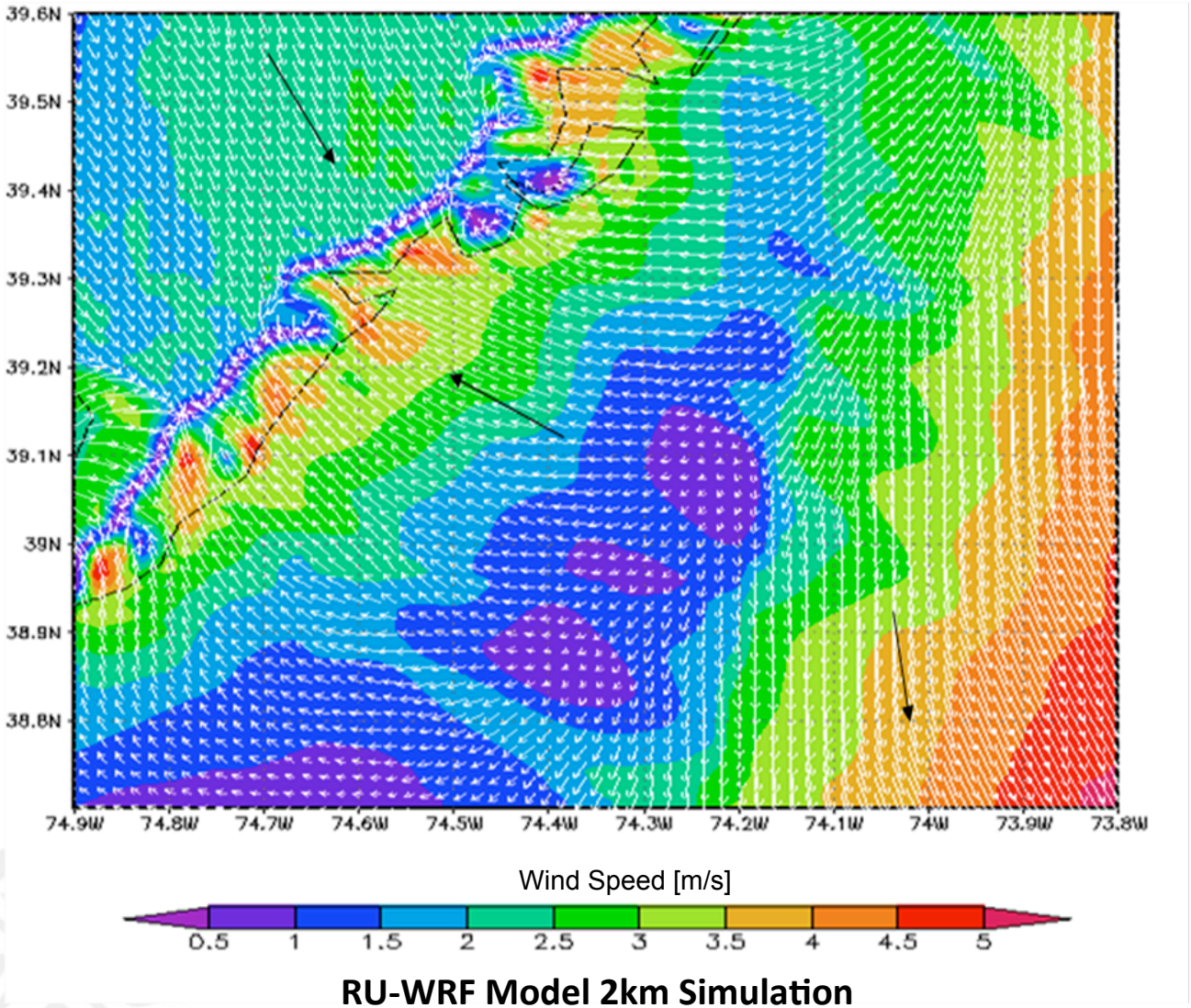
Infrared Satellite

10m Wind



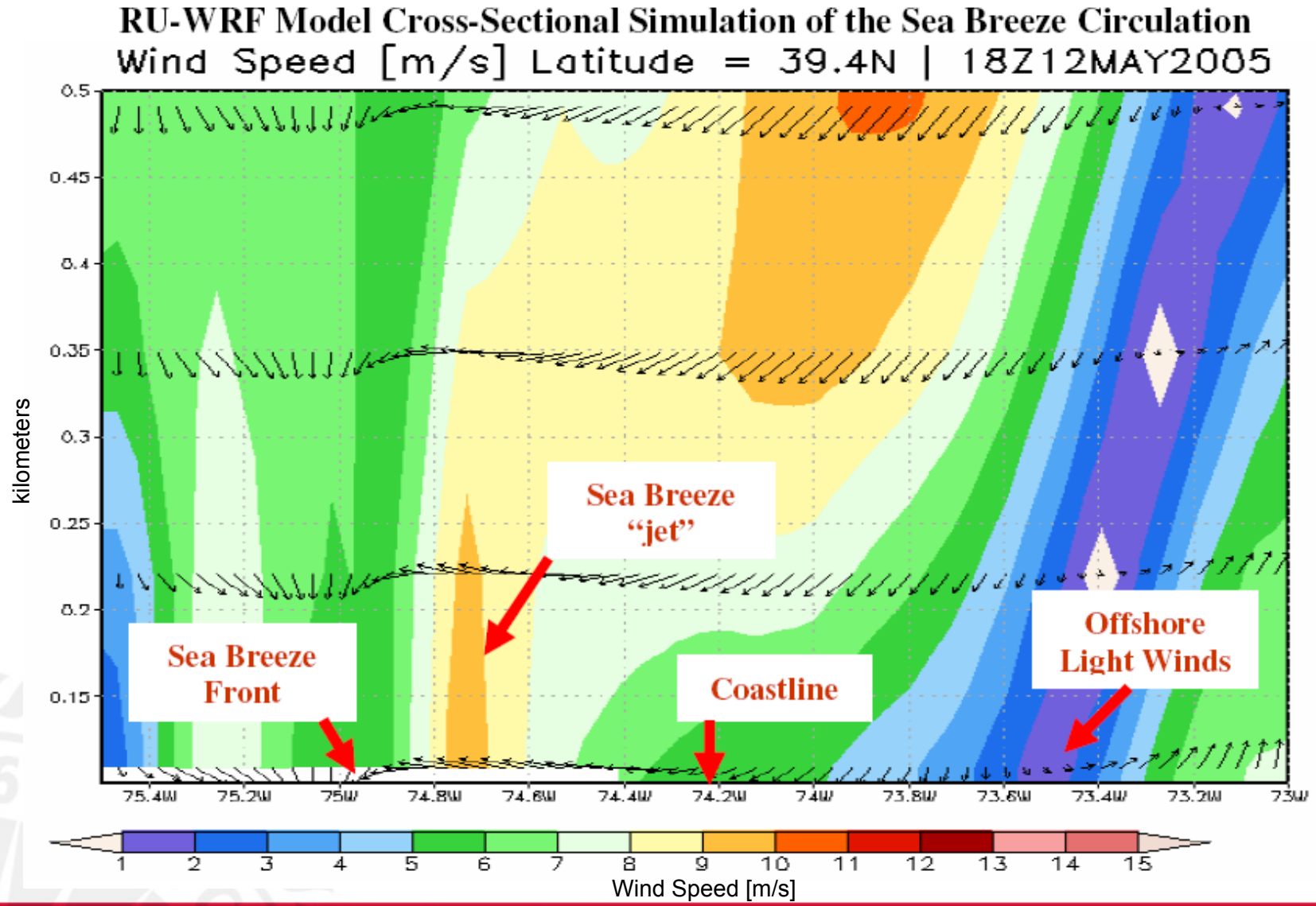
RU-WRF Model Simulation

NJ Sea Breeze Event



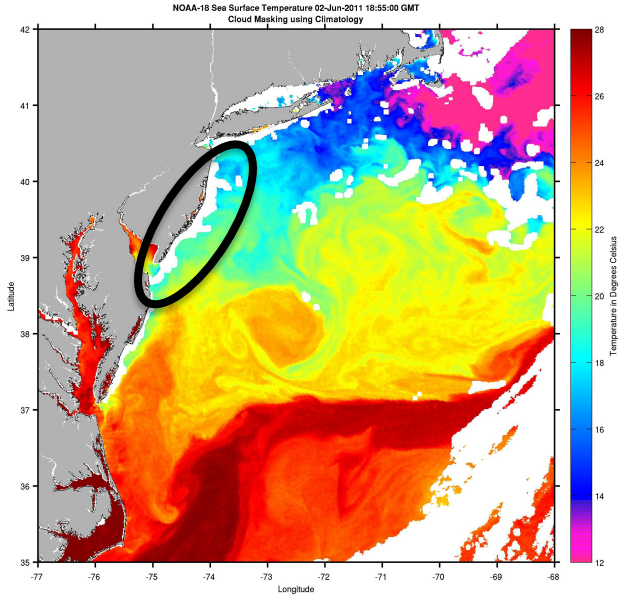
RU-WRF Model 2km Simulation

NJ Sea Breeze Cross Section

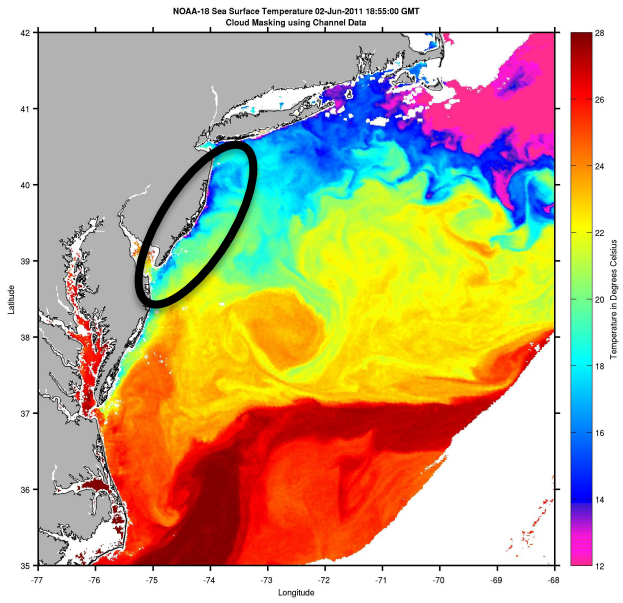


We can now resolve upwelling…

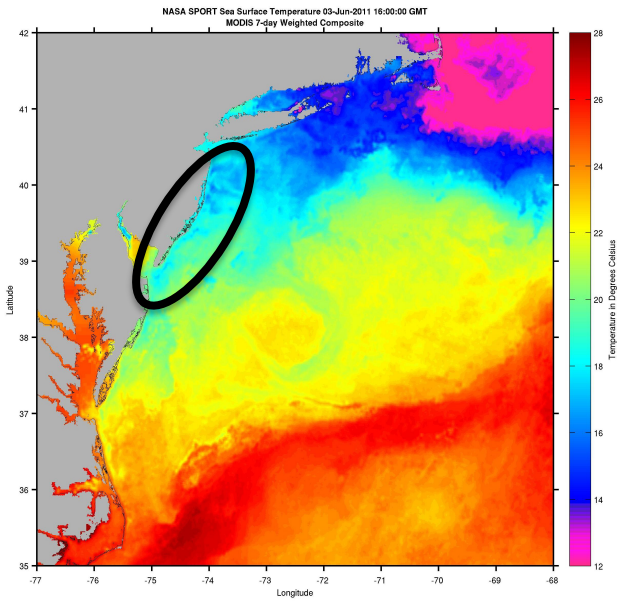
Cloud Masking
(old method)



Cloud Masking
(new method)



MODIS 7-day
(old method)

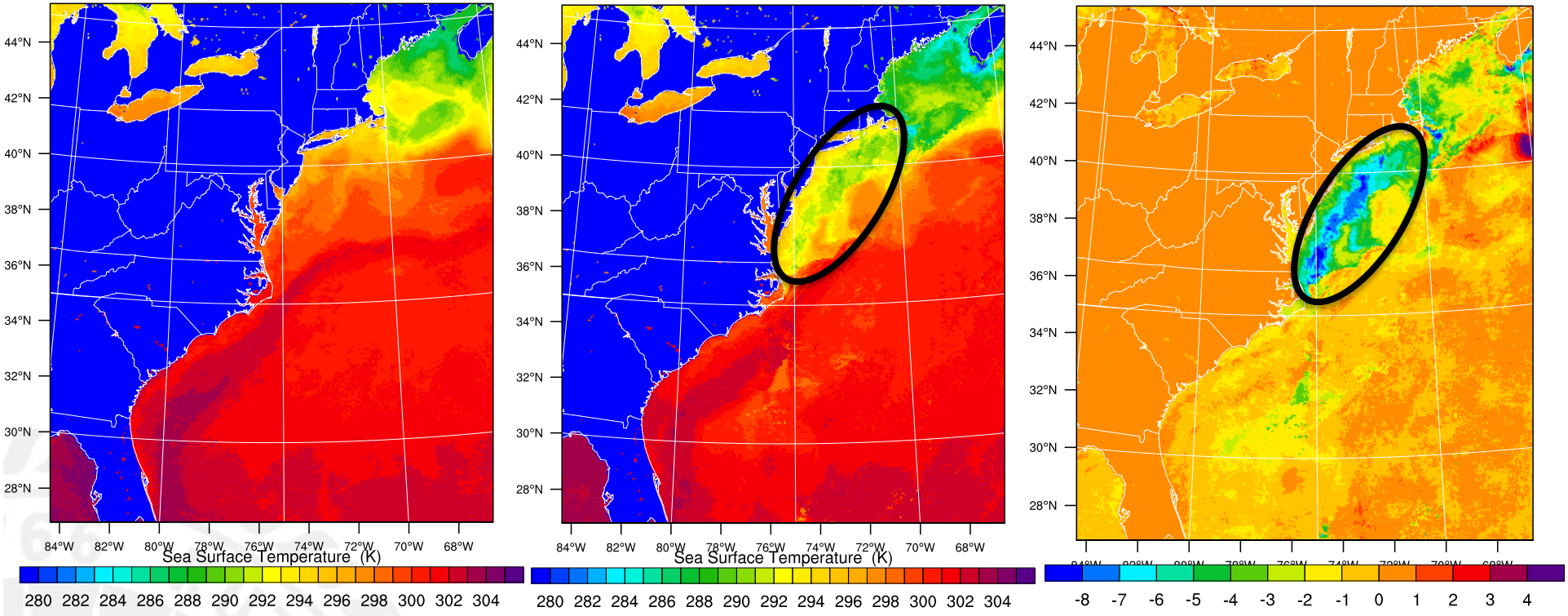


…and SST for hurricane simulations: e.g. *Hurricane Irene*

Warm

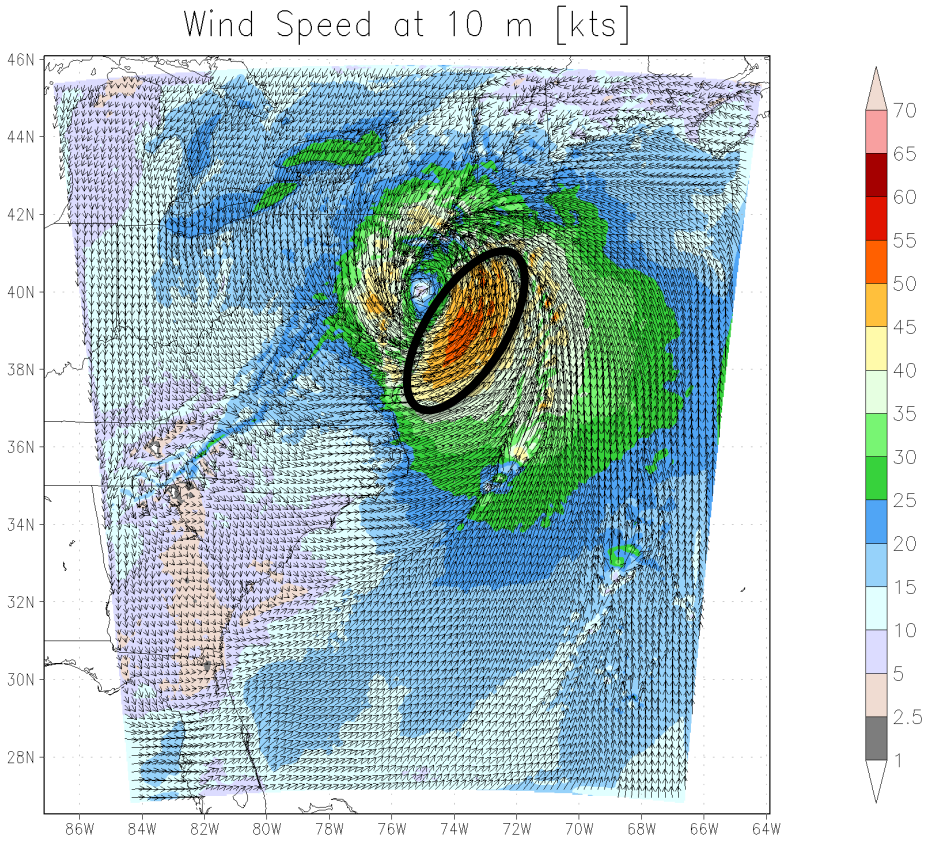
Cold
(our enhanced product)

Difference



Hurricane Irene Wind Speed

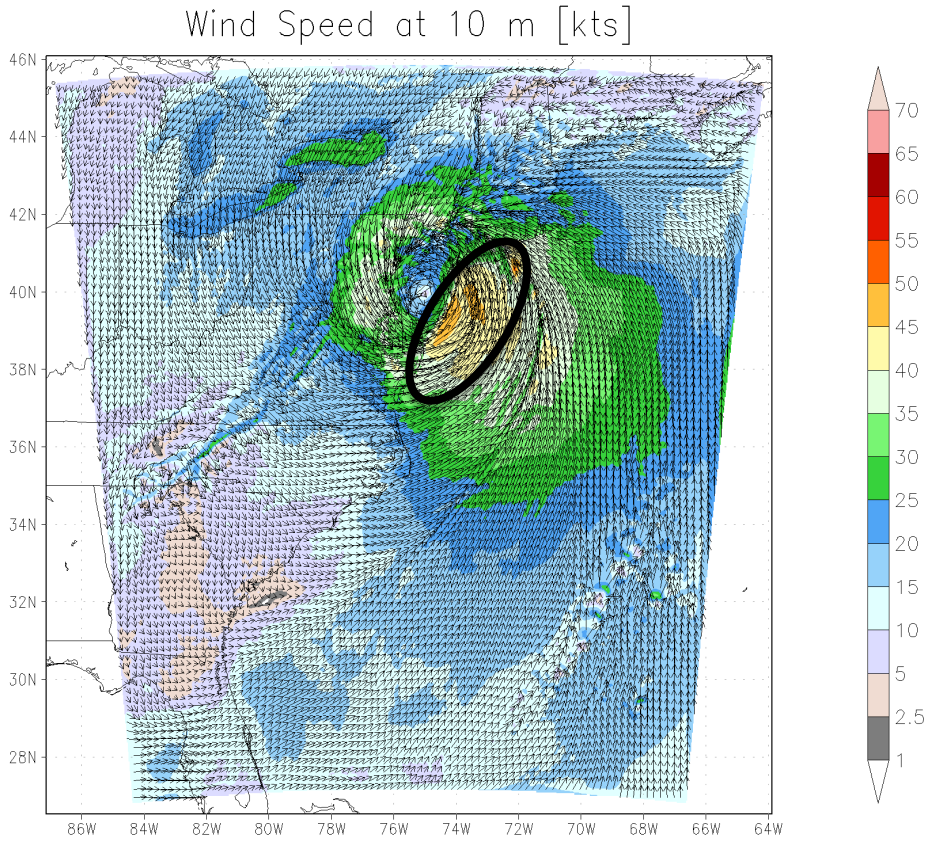
Warm SST



RU Coastal Ocean Observation Lab: WRF-ARW 6 KM
http://marine.rutgers.edu/cool/weather
Model Initialized 00Z27AUG2011
Valid 14Z28AUG2011 (Sun) | Forecast Hour 38

Cold SST

(our enhanced product)

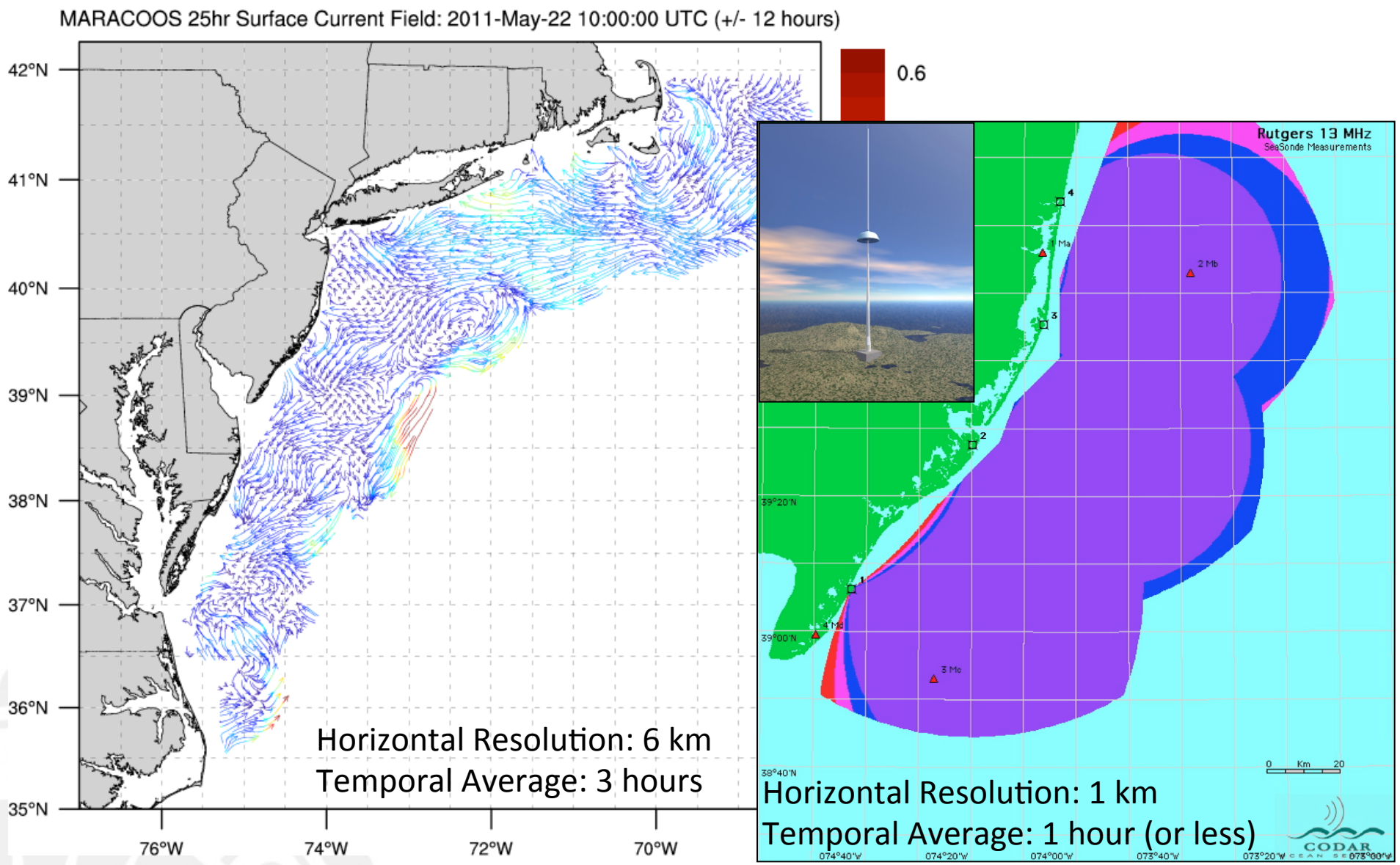


RU Coastal Ocean Observation Lab: WRF-ARW 6 KM
http://marine.rutgers.edu/cool/weather
Model Initialized 00Z27AUG2011
Valid 14Z28AUG2011 (Sun) | Forecast Hour 38

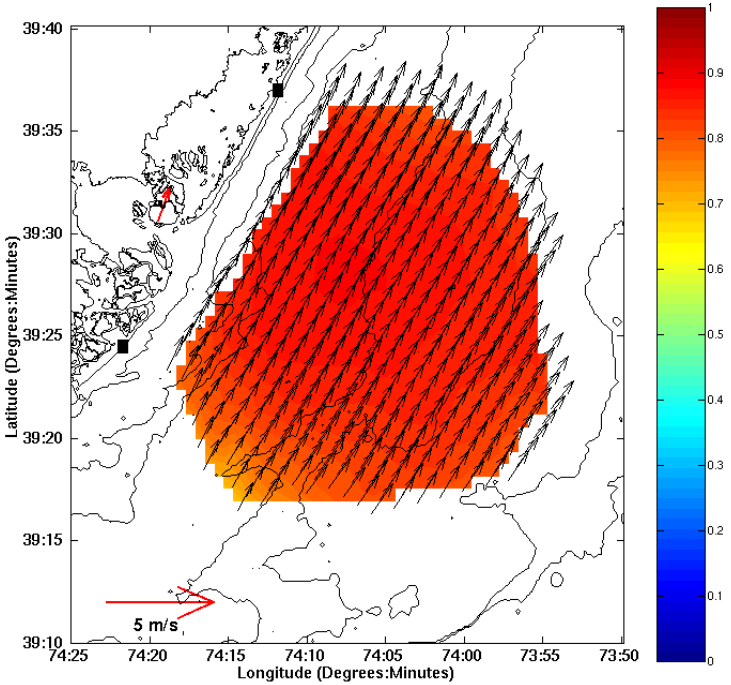
Scope of Work Details

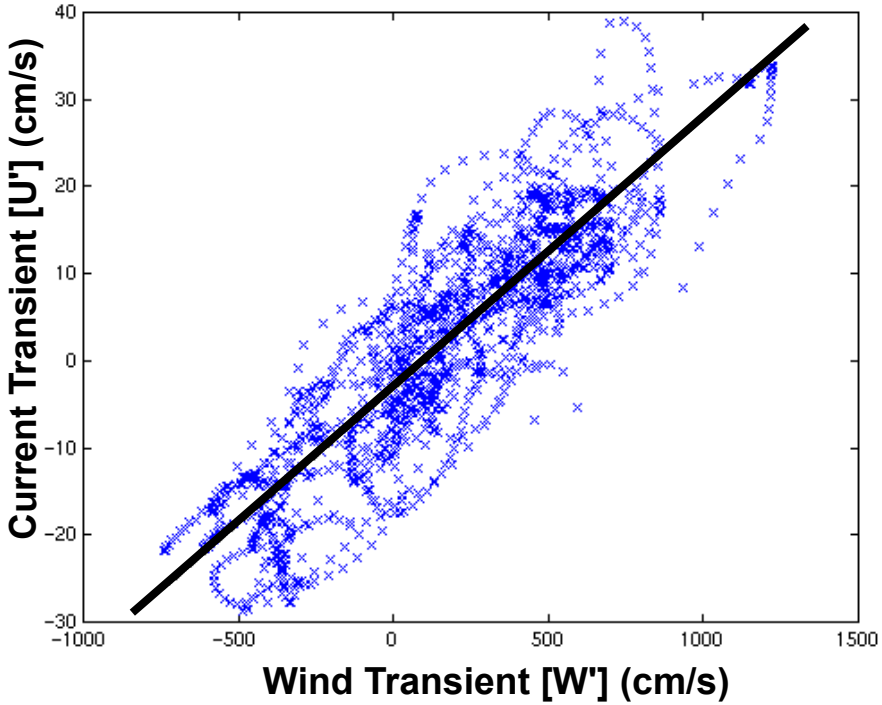
1. Develop *high resolution, 3-D microscale* model that will accurately define the general coastal/offshore wind resource along with resolving local wind resource perturbations, such as the sea breeze circulation, turbulence intensity, and wind shear.
2. High resolution boundary conditions to resolve upwelling centers.
3. **Map surface currents to confirm horizontal wind and sea state distributions at the microscale.**

Enhanced Hi-resolution HF radar Coverage



HF Radar Derived Linear Wind Model

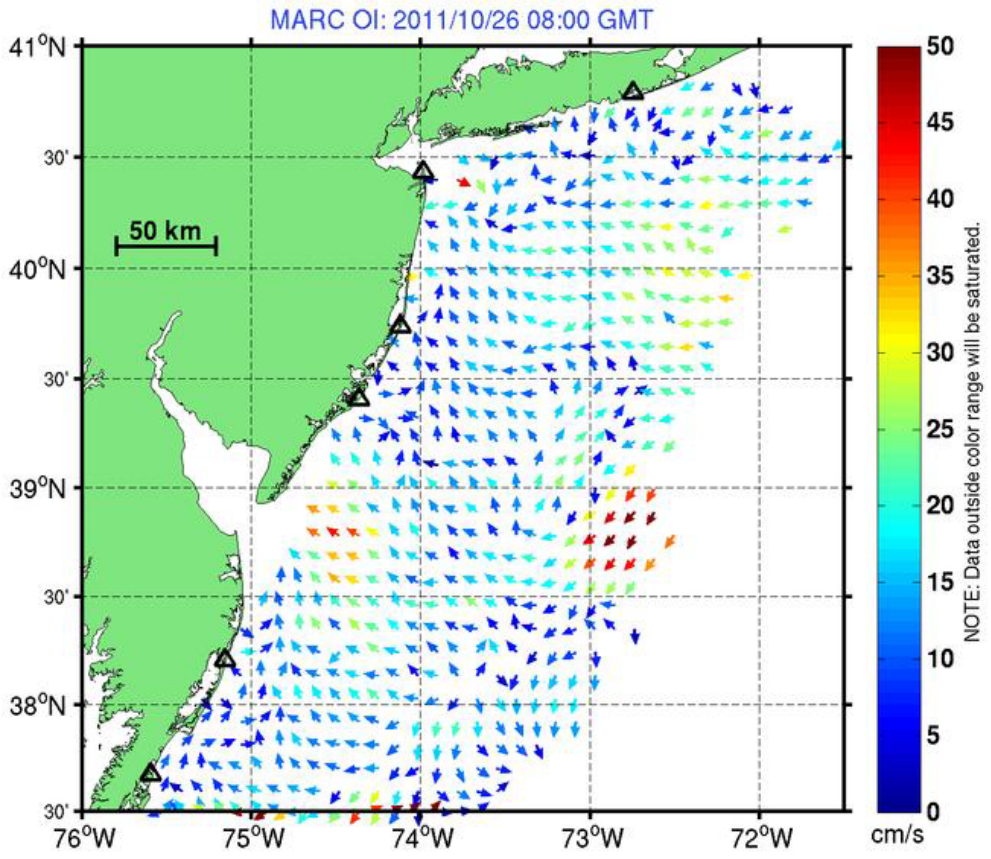


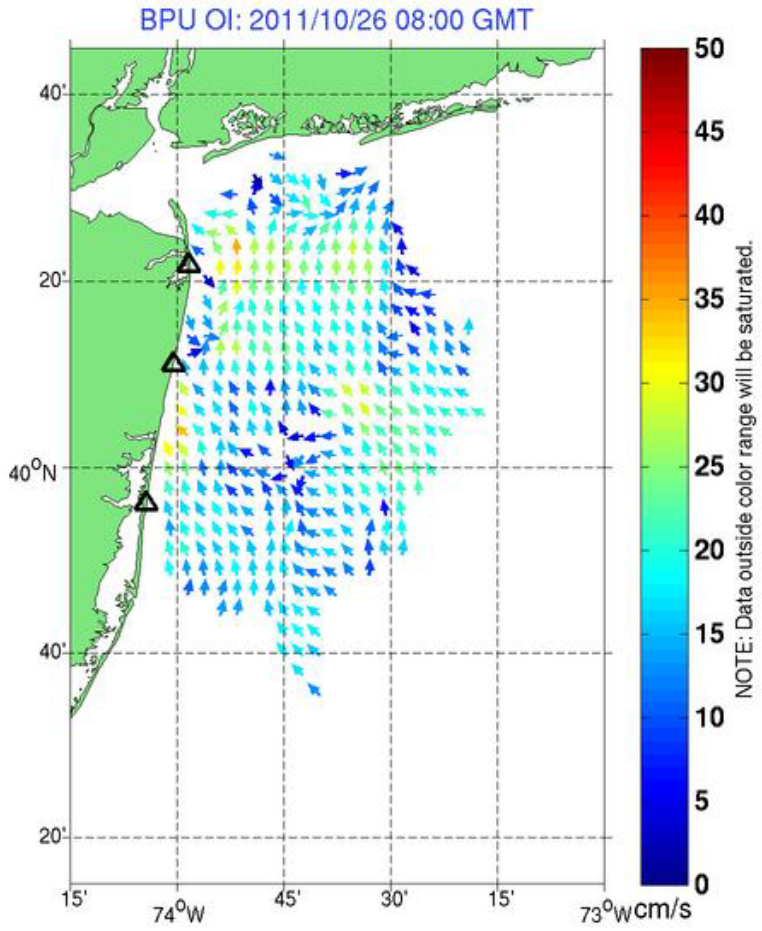


- Rotate wind vectors according to complex correlation
- Calculate the slope and intercept of best fit line

$$U'_c(x,y,t) = slope(x,y)*W'(t)$$

CODAR Sea Surface Current Examples





Scope of Work Details

1. Develop high resolution, 3-D microscale model that will accurately define the general coastal/offshore wind resource along with resolving local wind resource perturbations, such as the sea breeze circulation, turbulence intensity, and wind shear.
2. High resolution boundary conditions to resolve upwelling centers.
3. Map surface currents to confirm horizontal wind and sea state distributions at the microscale.
4. **Vertical validation from monitoring sites.**

Coastal/Offshore Monitoring

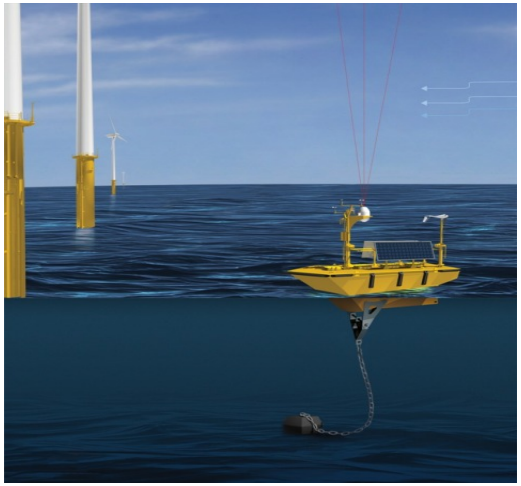
Meteorological Tower



Meteorological Buoy



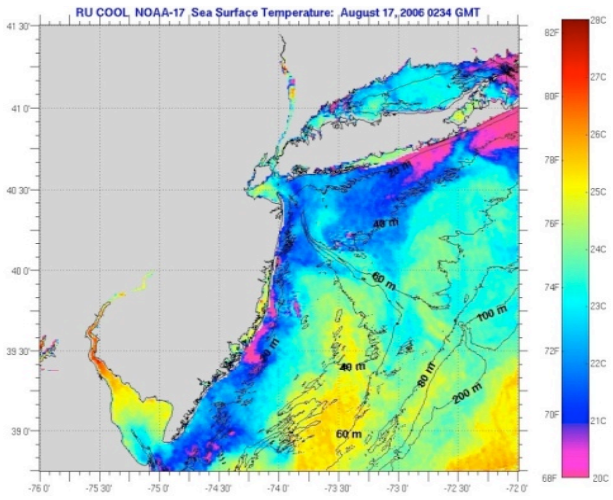
Offshore vertical LIDAR



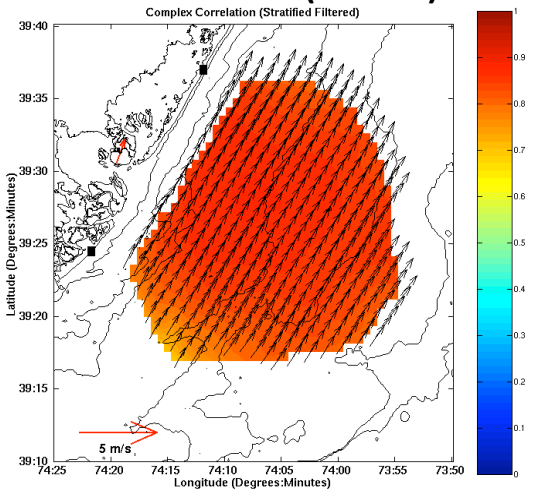
Coastal/Offshore Scanning LIDAR



Infrared Satellite



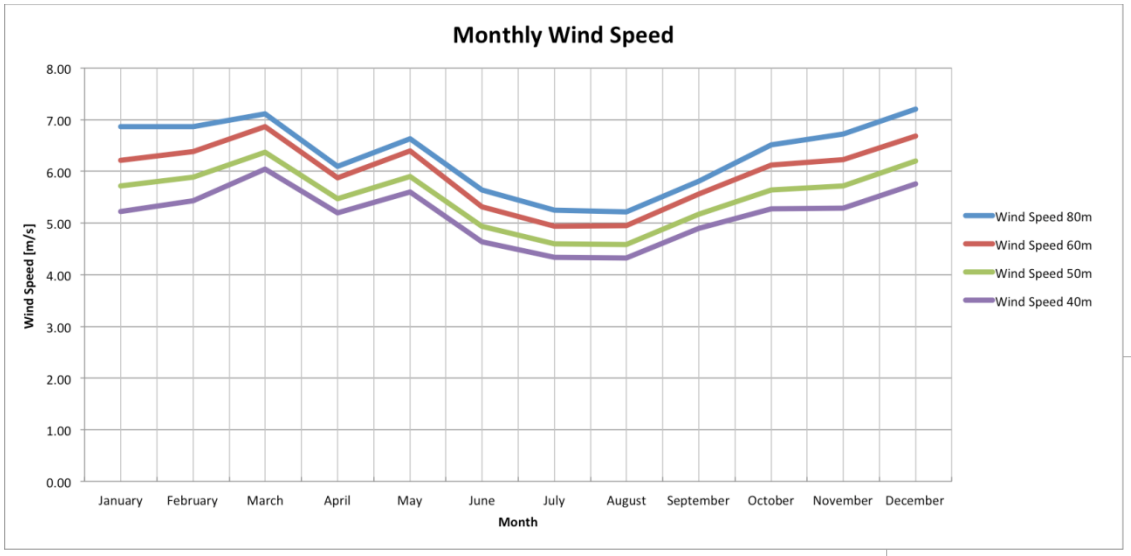
Coastal Radar (CODAR)



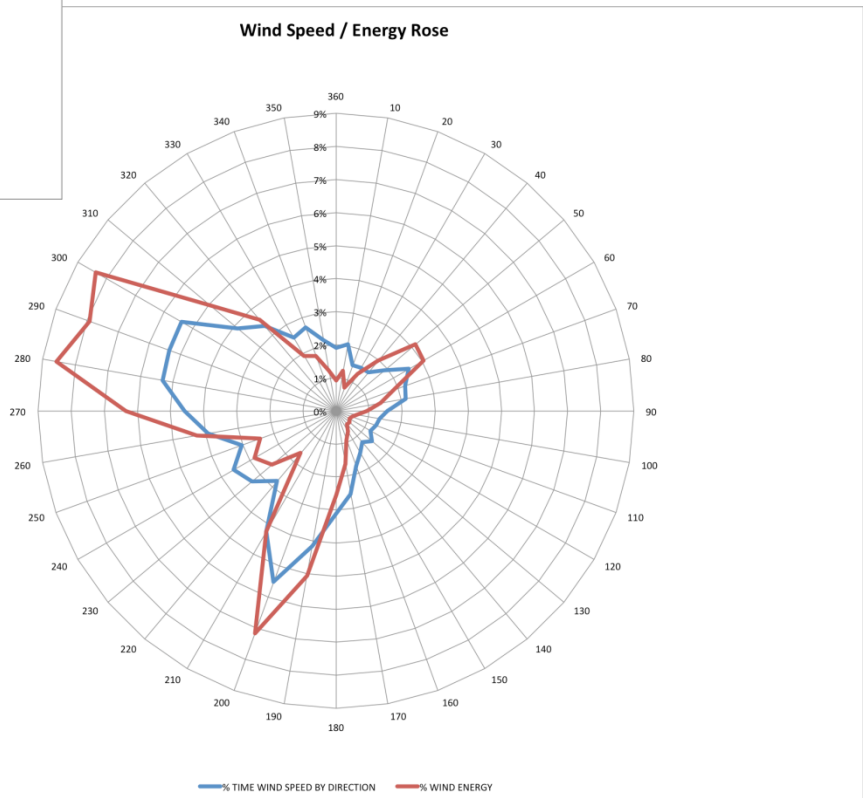
Scope of Work Details

1. Develop high resolution, 3-D microscale model that will accurately define the general coastal/offshore wind resource along with resolving local wind resource perturbations, such as the sea breeze circulation, turbulence intensity, and wind shear.
2. High resolution boundary conditions to resolve upwelling centers.
3. Map surface currents to confirm horizontal wind and sea state distributions at the microscale.
4. Vertical validation from monitoring sites.
5. **Run for at least one year over a sea breeze season to populate database and calculate hourly statistics by month.**

Virtual Meteorological Tower Output at 48 locations

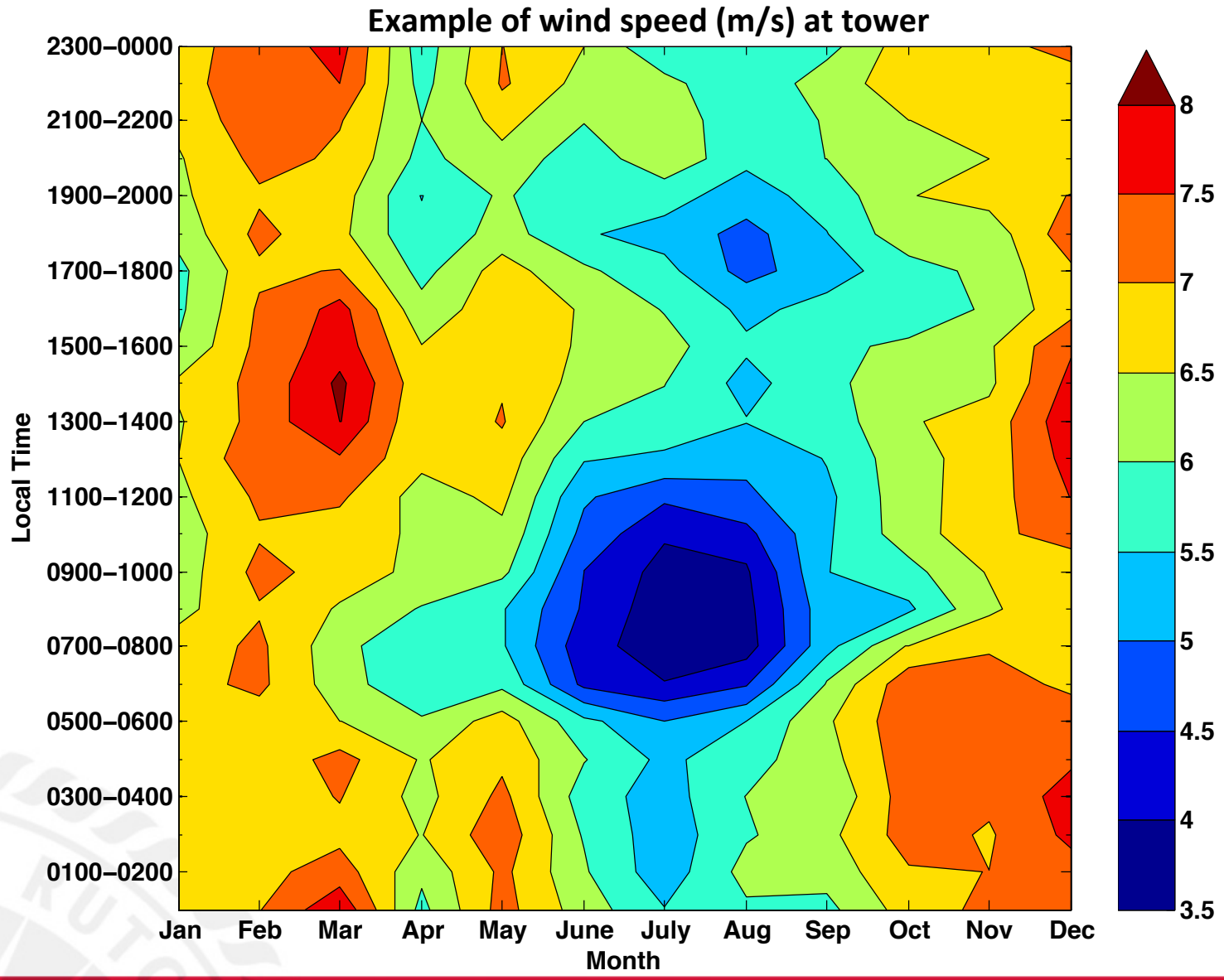


Wind speed data at any desired height above the water surface on hourly, daily, monthly, annual, and long-term temporal scales.

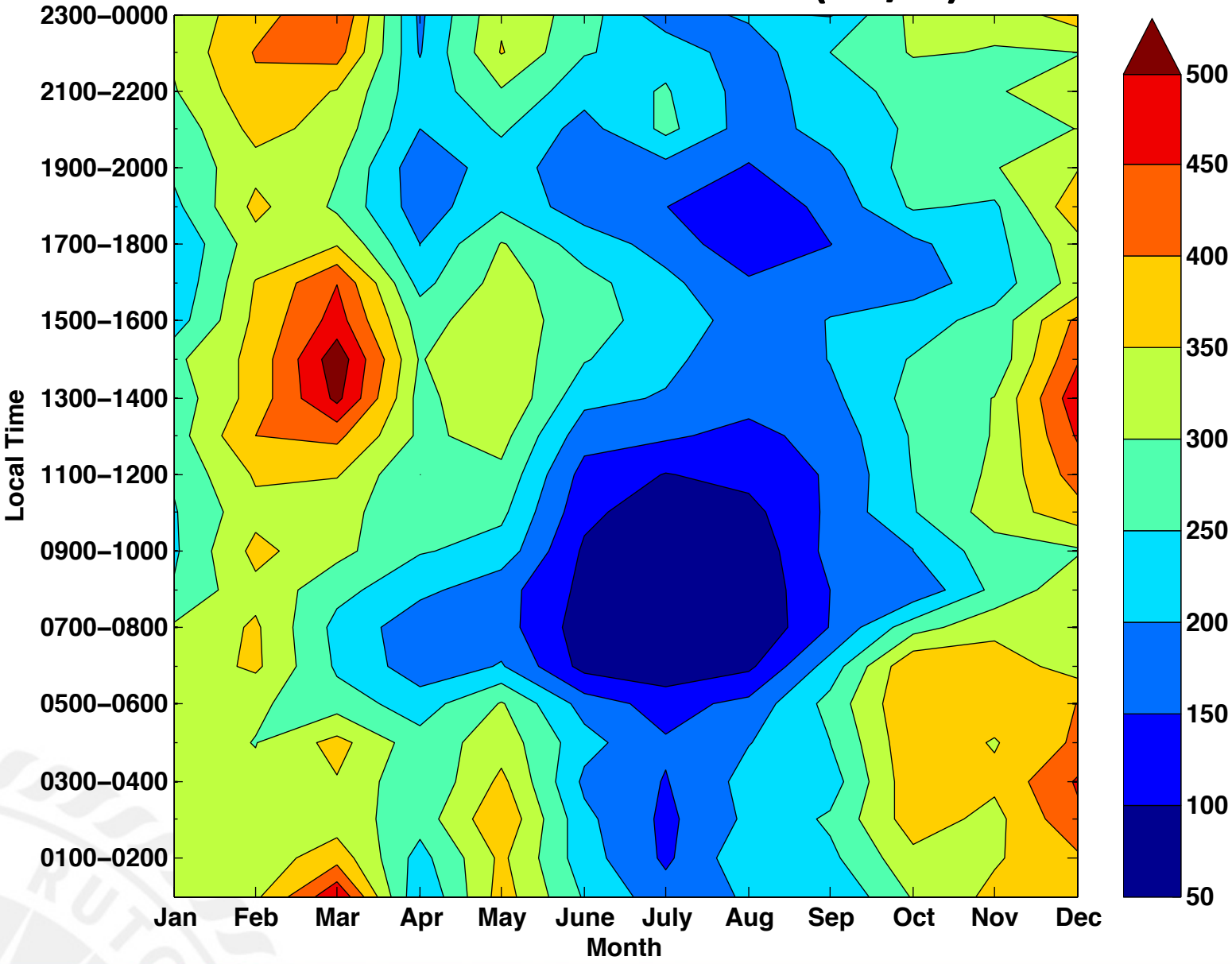


Wind Speed Rose (blue) and Energy Rose (red) – Crucial for determining turbine layout for energy optimization and wake impact.

Virtual Meteorological Tower Output at 48 locations



Wind Power Production (m^3/s^3)



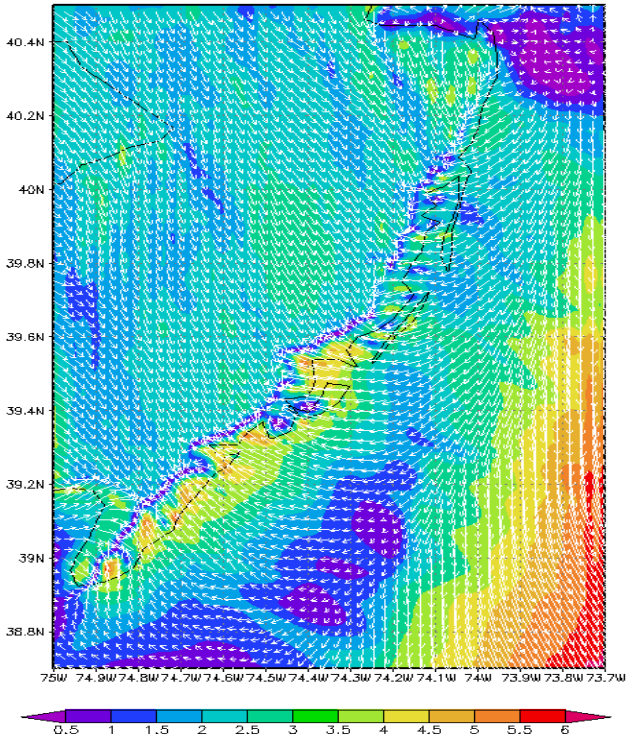
Deliverables

1. Weather analysis database
2. Surface current database
3. Validation study
    a. Use our horizontal data plus OSW developers' vertical data
4. Summary statistics

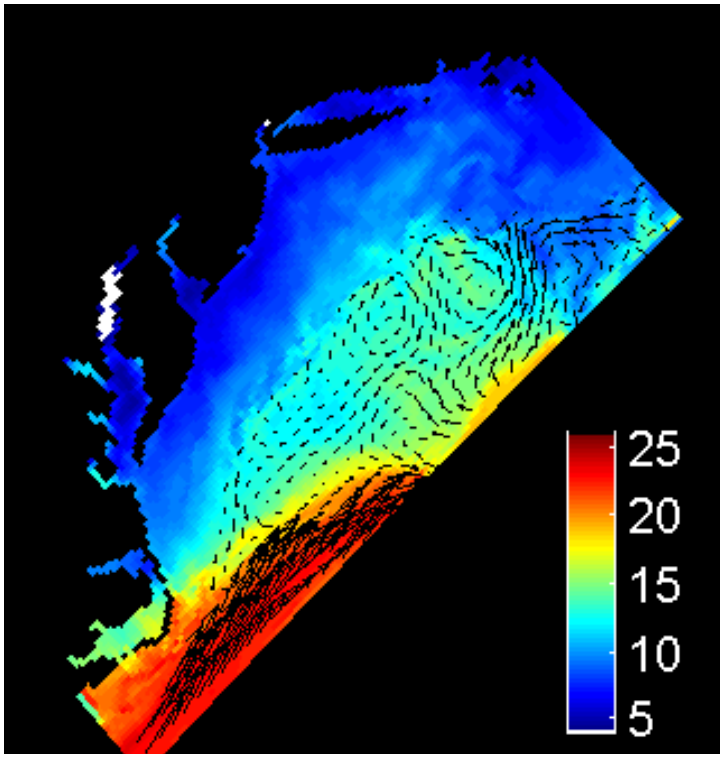
RU-WRF to ROMS Coupling

Our atmospheric model, RU-WRF, will be coupled to our ocean model, ROMS (Regional Ocean Modeling System), to investigate the effects of coastal upwelling on sea breeze activity

WRF THE WEATHER RESEARCH & FORECASTING MODEL ⟷ Regional Ocean Modeling System ROMS Research Community



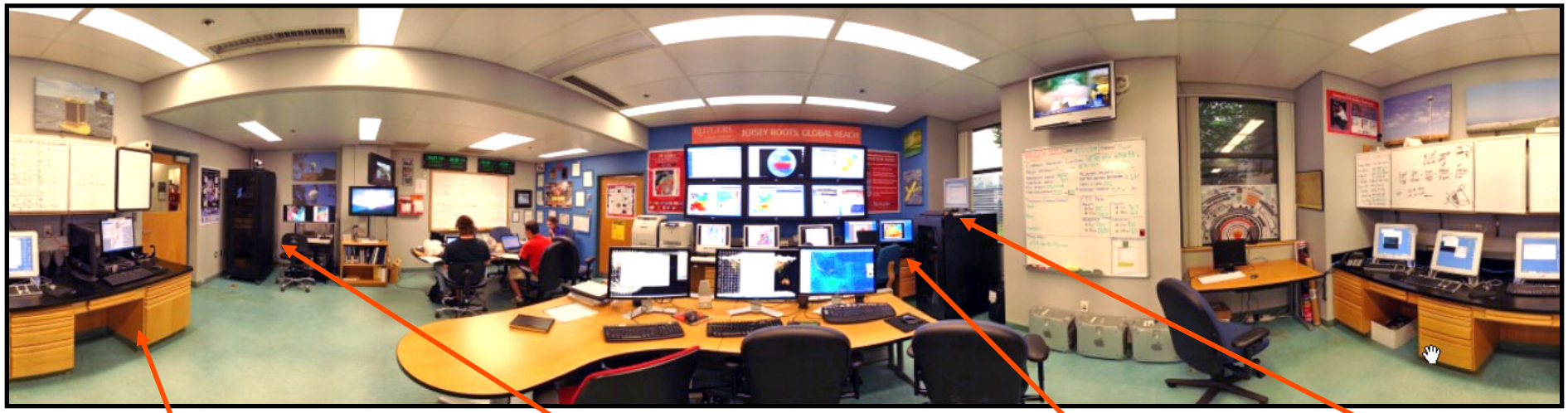
RU-WRF Wind and Surface T



ROMS SST and currents at 200 m

Rutgers University - Coastal Ocean Observation Lab

Observatory Operations & Education Center



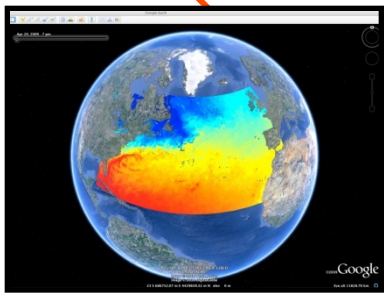


CODAR Network

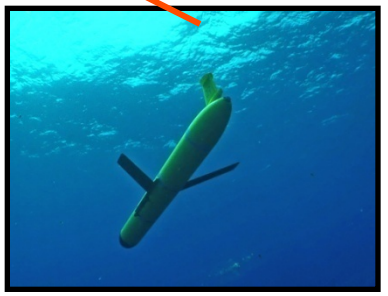




L-Band & X-Band Satellite Receivers



3-D Nowcasts & Forecasts



Glider Fleet

Conclusions

1. A high resolution, sea breeze-resolving atmospheric forecast model will be operated for at least one year to fully encompass a winter storm and summer sea breeze season
2. Improved boundary conditions from de-clouded, upwelling-resolving satellite SST will be used
3. A unique observing network will be deployed to provide spatial validation data
4. An annual database will be developed and summary statistics calculated
5. The results of this study will be used to develop operational prediction models for weather forecasting and energy production projections