Forecast Performance of an Operational Mesoscale Modelling, System for Tropical Storm Irene and Post Tropical Storm Sandy in the New York City Metropolitan Region

SCE 3.1

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Other Presentations of Related Work

Conference on US 2012 Weather Impacts

- **2.4 Hindcast Analysis of the June 2012 Derecho and Its Impact on the Baltimore-Washington Metropolitan Area using High-resolution WRF-ARW**

Conference on Transition of Research to Operations

- **3.1 Enabling a High-Resolution, Coupled Hydro-Meteorological System for Operational Forecasting of Severe Weather and Flooding Events in Rio de Janeiro**

Symposium on the Coastal Environment:

- **2.2 High-resolution Simulations of a High-impact Rainfall Event for the Montpellier Region using WRF-ARW**
- **2.3 December 2010 Northeast Blizzard: Event Analysis using High-resolution WRF for the New York City Metropolitan Area**

Symposium on the Next Level of Predictions in Tropical Meteorology:

- **1.5 A Numerical Weather Prediction-Based Infrastructure for Tropical Meteorology Research and Operations in Brunei**
- **TJ36.3 The DOTSTAR Observations in Improving Tropical Cyclones Forecast using Ensemble-based Data Assimilation**

Conference on Hydrology:

- **533 A Dynamic River Network Model for Regional-Scale Simulation**

Conference on Weather, Climate, and the New Energy Economy:

- **10.1 Precision Wind Power Forecasting via Coupling of Turbulent-Scale Atmospheric Modeling with Machine Learning Methods**
- **1.2 On-going utilization and evaluation of a coupled weather and outage prediction for electric distribution operations**
- **800 Utilization of a High Resolution Weather and Impact Model to Predict Hurricane Irene**
- **409 Advanced Data Assimilation for Short-term Renewable Power Prediction: a Complex Terrain Case**

Overview

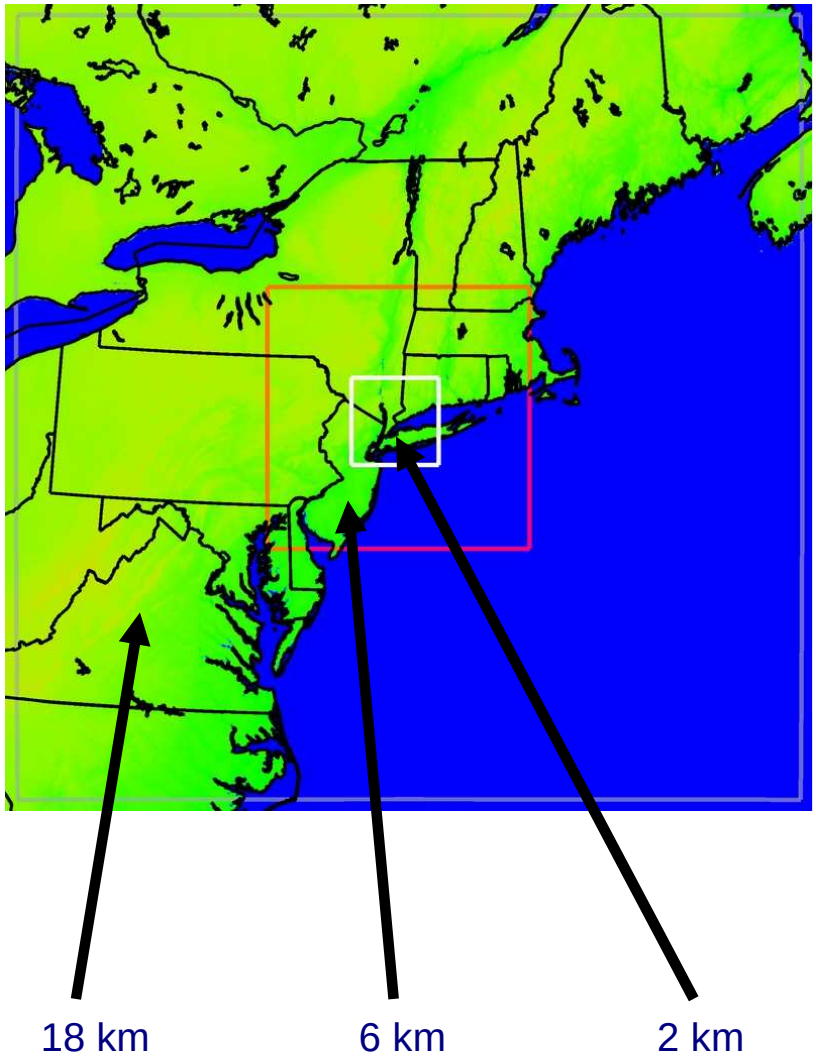
- Motivation
- NWP Model Configuration
- Tropical Storm Irene
  - Winds, Rainfall
- Post Tropical Storm Sandy
  - Winds, Rainfall
- Summary

Motivation

- **High-resolution physical weather modelling can provide significant value in predicting environmental impacts at a local as well as regional scales**
- **A key aspect is the customization of the models for specific applications coupled with the decision making**
- **Visualization is critical for decision making by people and workflow management**
- **Integration with other models as well as existing infrastructure enables actionable, proactive behavior**

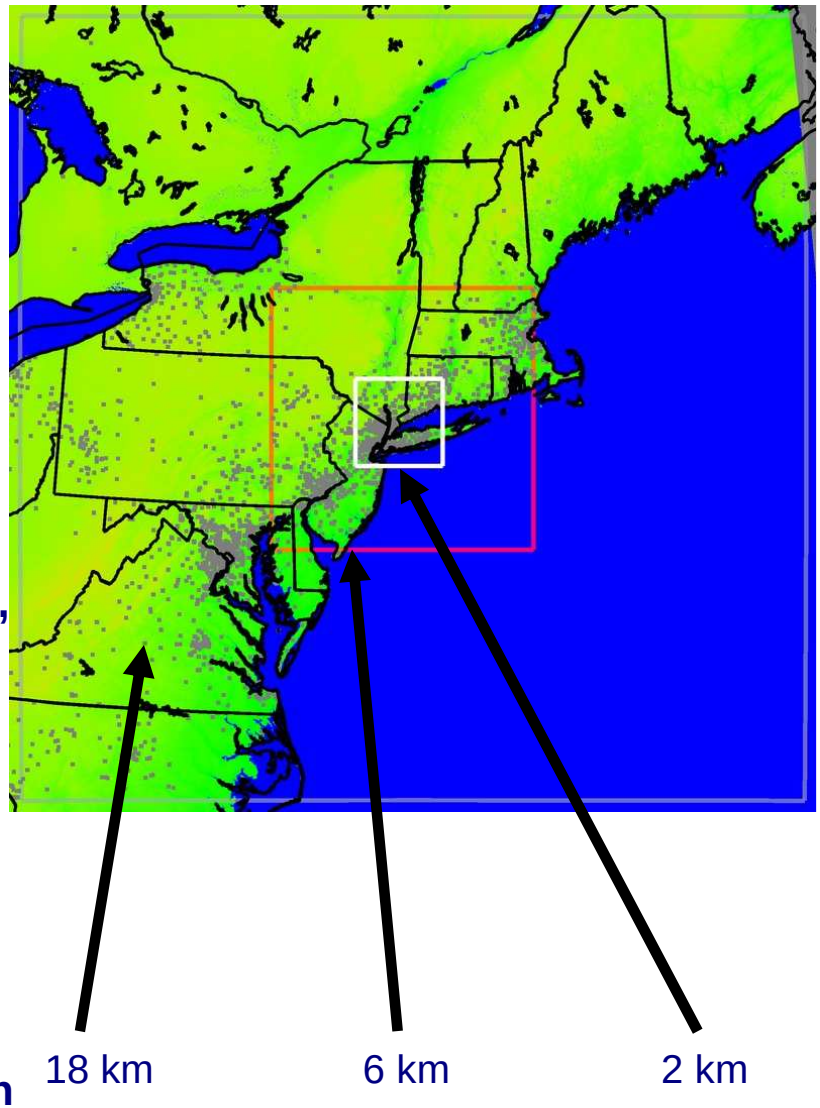
Initial Weather Model Configuration – WRF-ARW 3.1.1 (Operational from April 2009 – October 2012)

- 18/6/2 km nested (76x76x42) with 2 km resolution across entire extended service area for 84 hours since April 2009
- Run twice daily (0 and 12 UTC)
- NAM for background and boundary conditions
- Physics configuration for highly urbanized to rural domain
  - WSM 6-class microphysics (includes explicit ice, snow and graupel)
  - Yonsei University non-local-K scheme with explicit entrainment layer and parabolic K profile in the unstable mixed layer for the PBL
  - NOAH land-surface modeling with soil temperature and moisture in four layers, fractional snow cover and frozen soil physics
  - Grell-Devenyi ensemble cumulus parameterization
  - 3-category urban canopy model with surface effects for roofs, walls, and streets



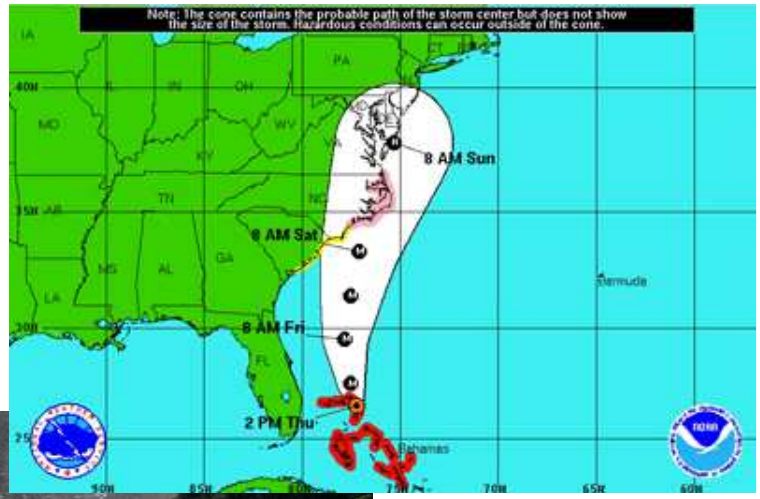
Current Operational Weather Model Configuration

- **WRF-ARW (updated to v3.3.1)**
  - Physics, model configuration, etc. remain the same
- **Direct input data sets from NASA (new)**
  - SRTM 30m terrain
  - MODIS-based land use, soil and vegetation data
  - 1km SSTs
- **Data assimilation of near-real-time Earth Networks WeatherBug data (updated)**
  - 3520 stations: 18km nest (3520), 6km nest (1592), 2km nest (584)
  - Domain-specific 30-day covariance statistics
  - Additional quality control
- **Operations (updated)**
  - Migration to newer HPC platform
  - Optimization of underlying processing
  - ~1/3 the wall-clock time for end-to-end processing compared to previous implementation



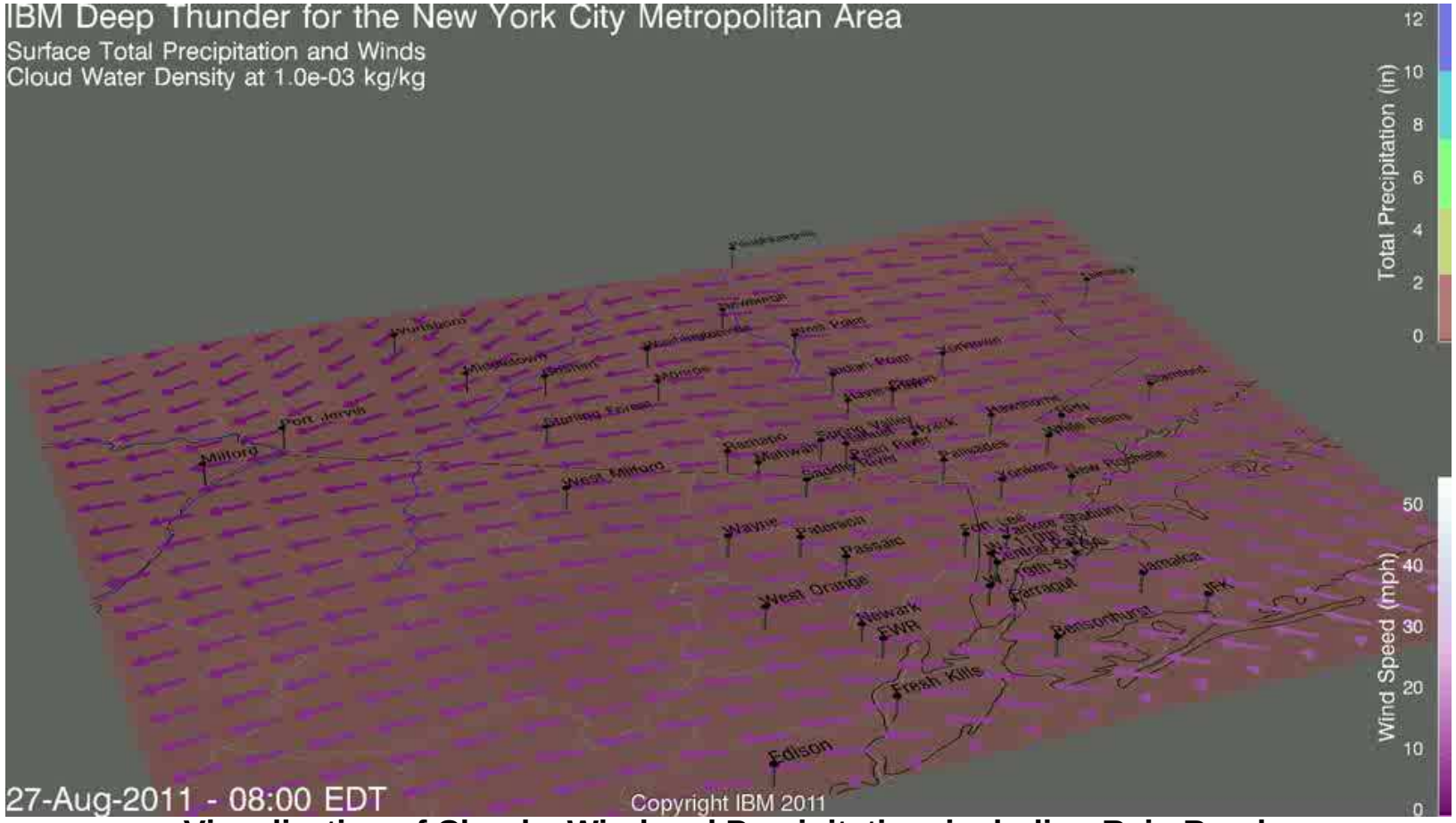
28 August 2011: Tropical Storm Irene Impacts the New York City Metropolitan Area

- Sustained winds 40 to 52 mph with gusting 60 to 90 mph and heavy rains (over 10” in some areas)
- Innumerable downed trees and power lines, and local flooding and evacuations
- Electricity service lost to about 1M residences and businesses (half o CT)
- Widespread disruption of transportation systems (e.g., road and bridge closures, airport and rail delays)
- Others forecasted storm as Category 1 or 2 but actually tropical storm at landfall
- Hence, expectation of much greater impacts of wind, and far less impact from heavy rainfall



Deep Thunder New York Forecast for Tropical Storm Irene

- **Fourth of six operational forecasts covering the event confirming the earlier forecast of tropical storm not hurricane strength at landfall and showing the track to the north**
- **Heavy rainfall predicted with similar distribution to reported rainfall**

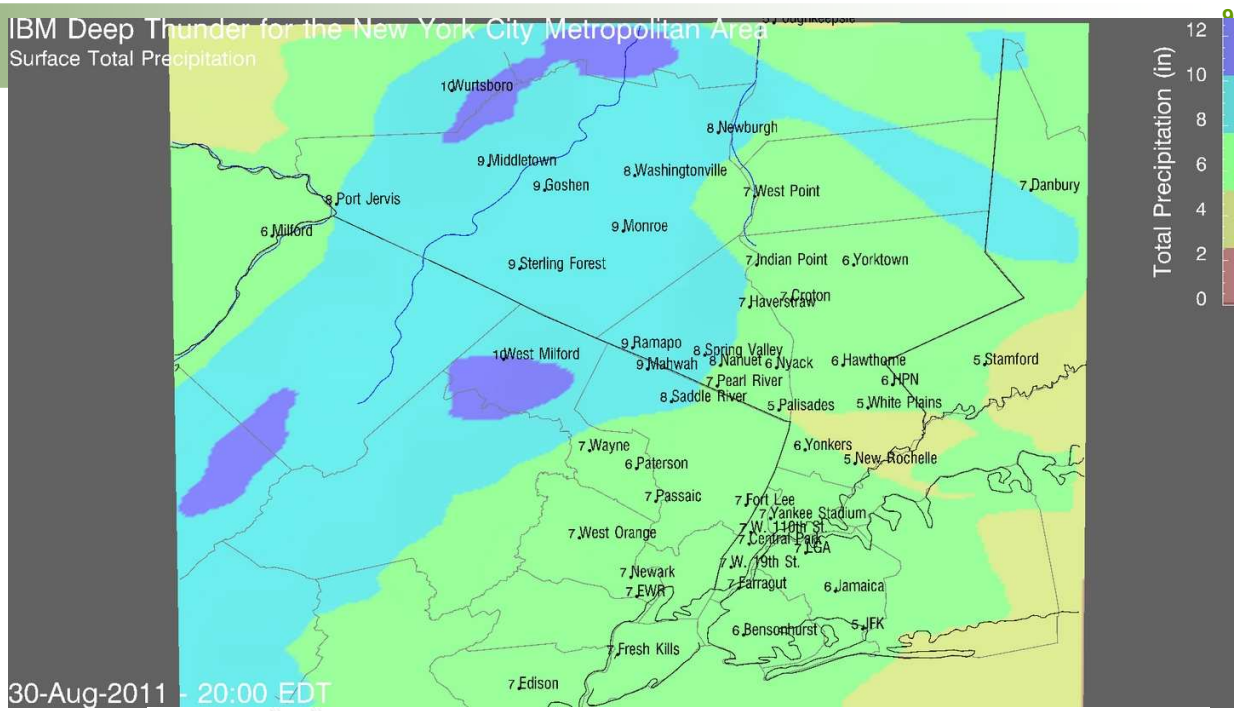


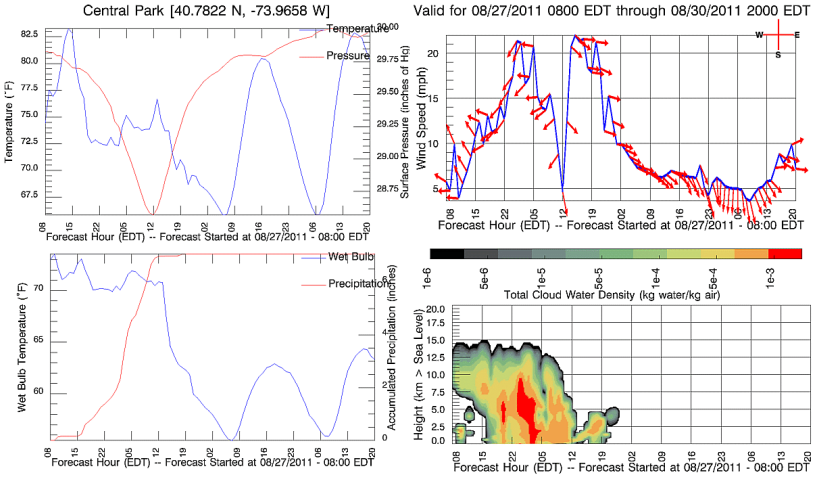
Visualization of Clouds, Wind and Precipitation, including Rain Bands

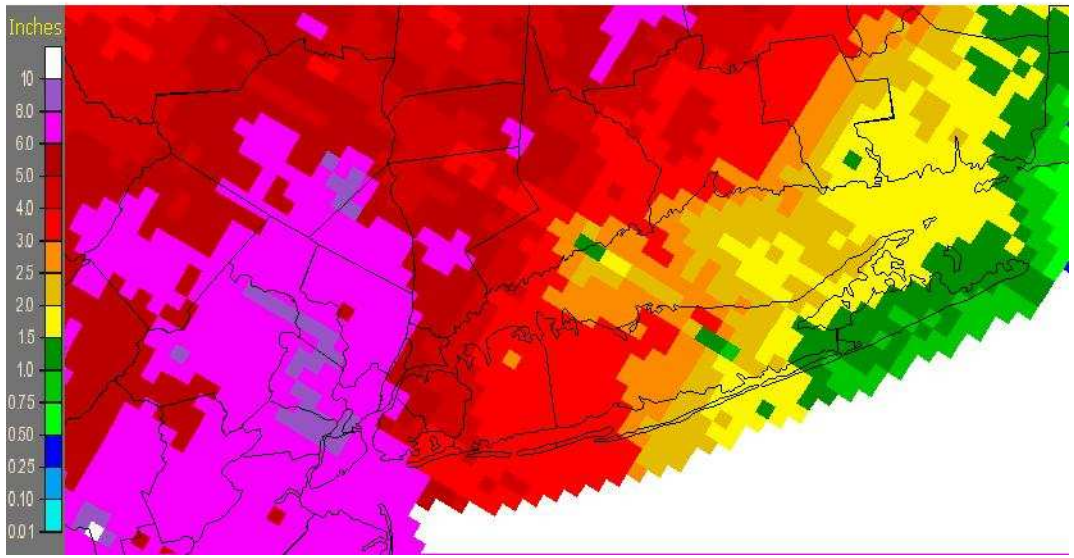
Deep Thunder New York Forecast for Tropical Storm Irene

Afternoon of 27 August 2011

- **Initiated with data from 0800 EDT on 8/27 with results available in the late afternoon**
- **Shows rainfall beginning in parts of New York City in the evening on 8/27 and ending the afternoon of 8/28**
- **Sustained winds in parts of New York City well below hurricane strength**

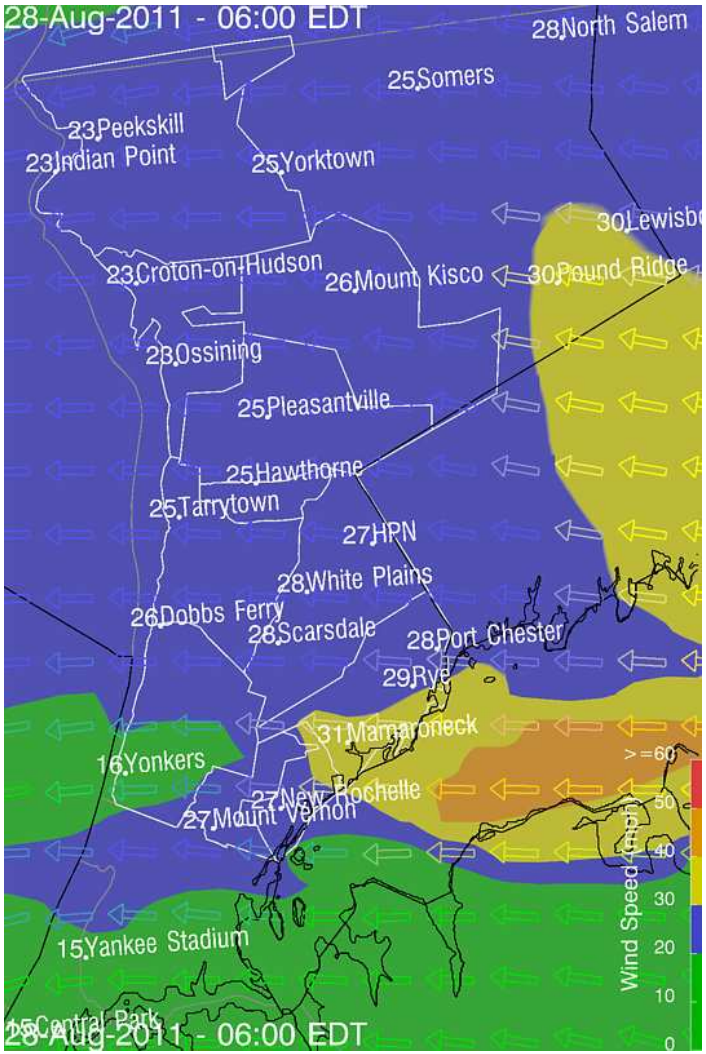




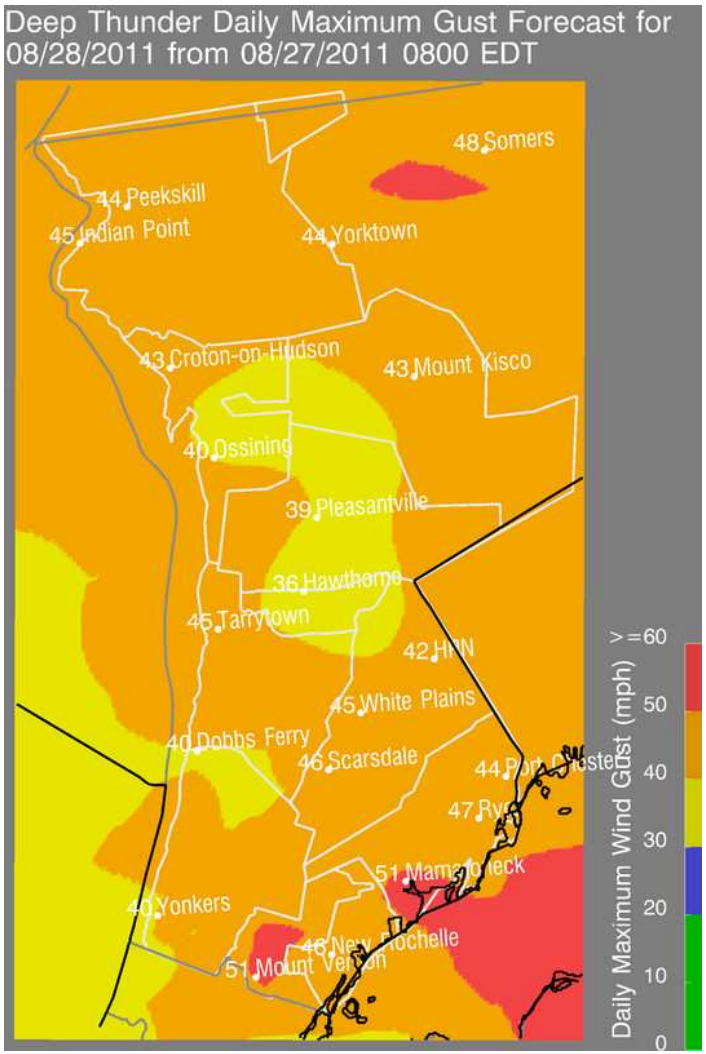


Deep Thunder Wind Forecast for Tropical Storm Irene: Afternoon of 27 August 2011

Maximum Sustained Wind



Maximum Daily Gust



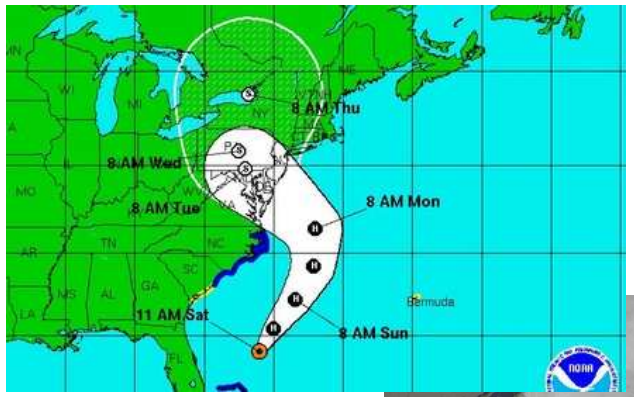
Spatial Verification Hurricane Irene)
08/27/2011, 12z forecast

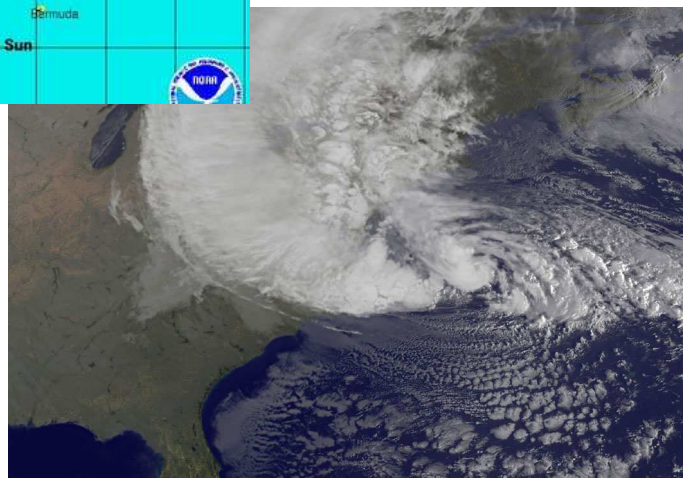
- ***Traditional Scores (KATON)***
- **DAY1:**
  - **CSI = 0.08, ACC = 0.20, OR = NA**
- **DAY2:**
  - **CSI = NA, ACC = NA, OR = NA**
- **DAY3:**
  - **CSI = 0.0, ACC = 1.00, OR = NA**

- ***Spatial Verification***
- **Grid-Stat**
  - **DAY1: CSI = 0.76, ACC = 0.77, OR = 2.53**
  - **DAY2: CSI = 0.33, ACC = 0.67, OR = 100.6**
  - **DAY3: CSI = 0.0, ACC = 1.00, OR = NA**
- **Wavelet-Stat**
  - **DAY1: Dominant spatial scale is 4-km with 7.5 mm/hr intensity**
  - **DAY2: Dominant spatial scale is 16-km with 0 mm/hr intensity**
  - **DAY3: NA**

29 October 2012:
Post-Tropical Cyclone Sandy Impacts New York & New Jersey

- Post-Tropical Cyclone Sandy was the 18th named tropical storm of the 2012 Atlantic season
- Sandy formed in the central Caribbean on 22 October and intensified into a hurricane as is it tracked north across Jamaica, eastern Cuba and the Bahamas
- Sandy paralleled the east coast of the United States until turning west toward the middle Atlantic coast on 28 October
- Sandy transitioned into a post-tropical cyclone just prior to moving on-shore near Atlantic City
- The track resulted in a worse case scenario for storm surge for coastal regions from New Jersey to Connecticut
- Unfortunately, the storm surge occurred near the time of high tide, contributing to record tide levels



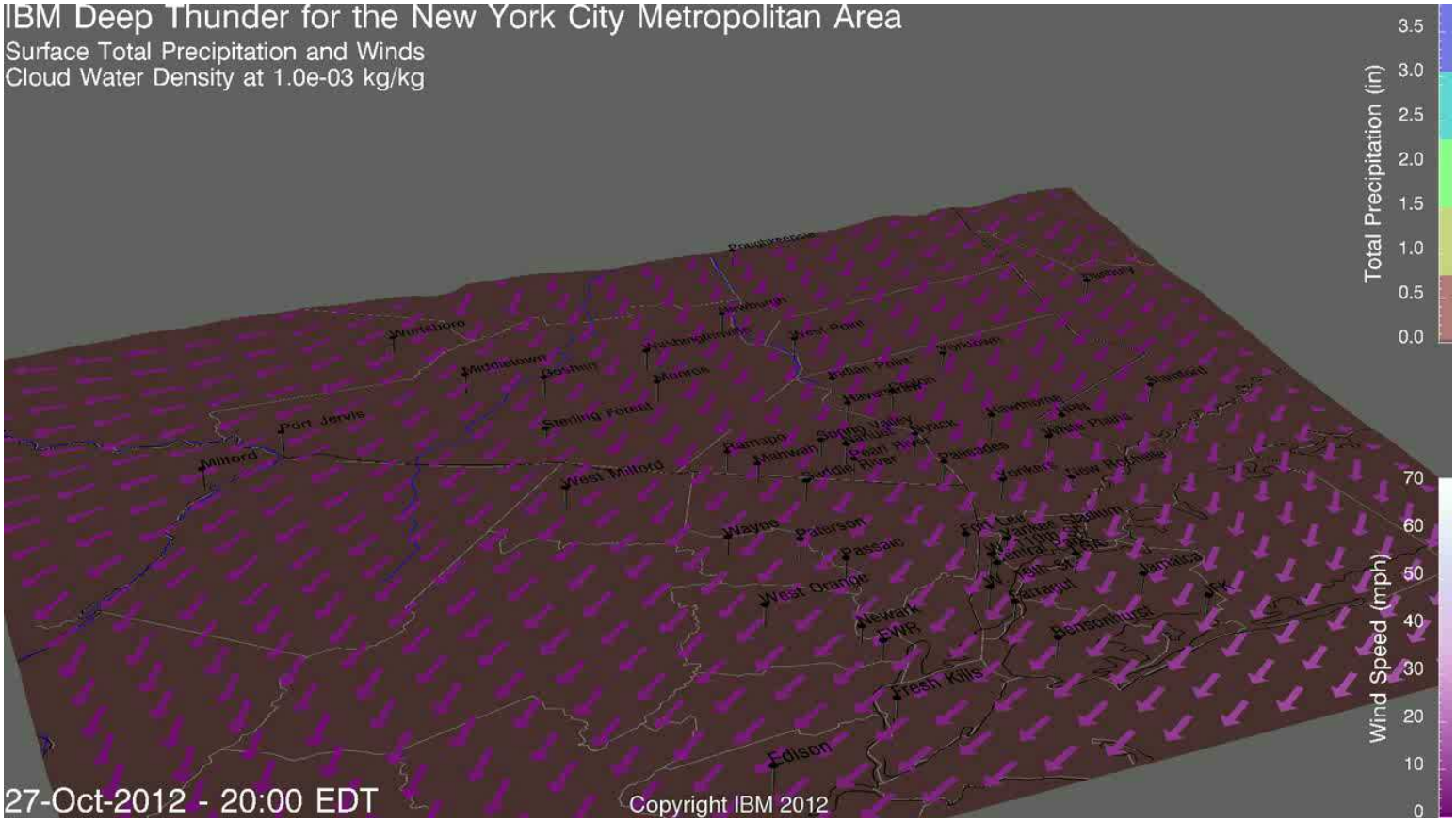


29 October 2012:
Post-Tropical Cyclone Sandy Impacts New York & New Jersey

- Wind gusts of 60 to 90 mph with extensive coastal flooding
- Over 100 deaths and $80B in property damage
- Electricity service lost to about 8M residences and businesses
- Thousands left homeless
- Widespread disruption of all transportation systems
- Significant disruption of communications systems

Deep Thunder New York Forecast for Post Tropical Cyclone Sandy

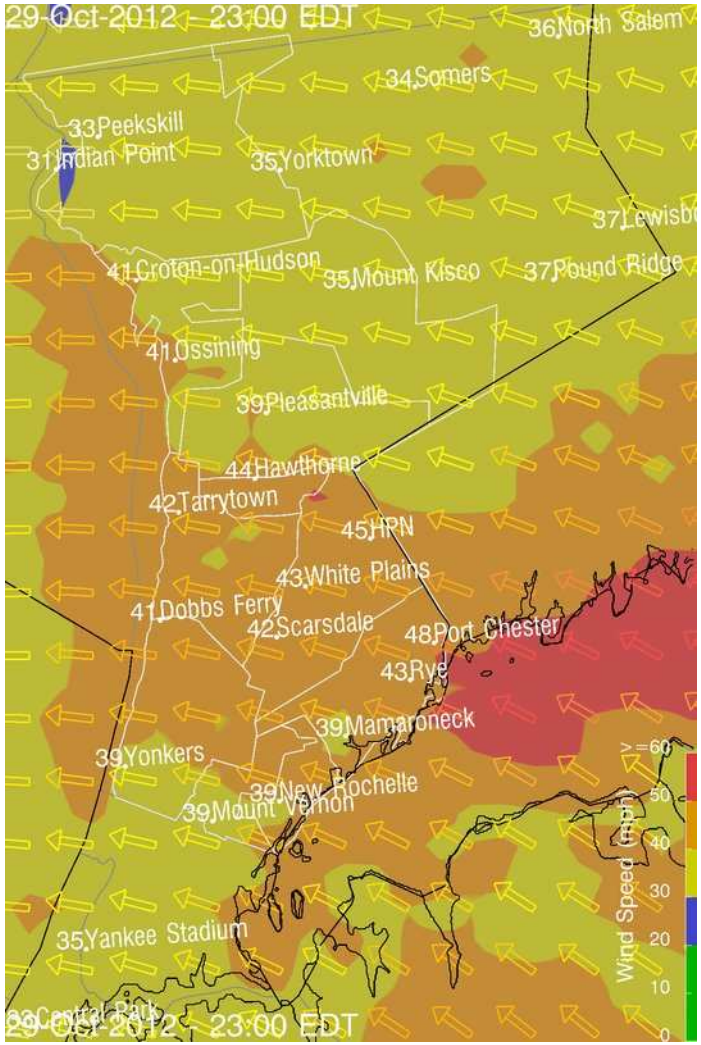
- One of ten operational forecasts covering the event
- Using data from 0800 EDT on 27 October in the mid-afternoon
- Very strong winds and rainfall predicted with similar distribution to reports



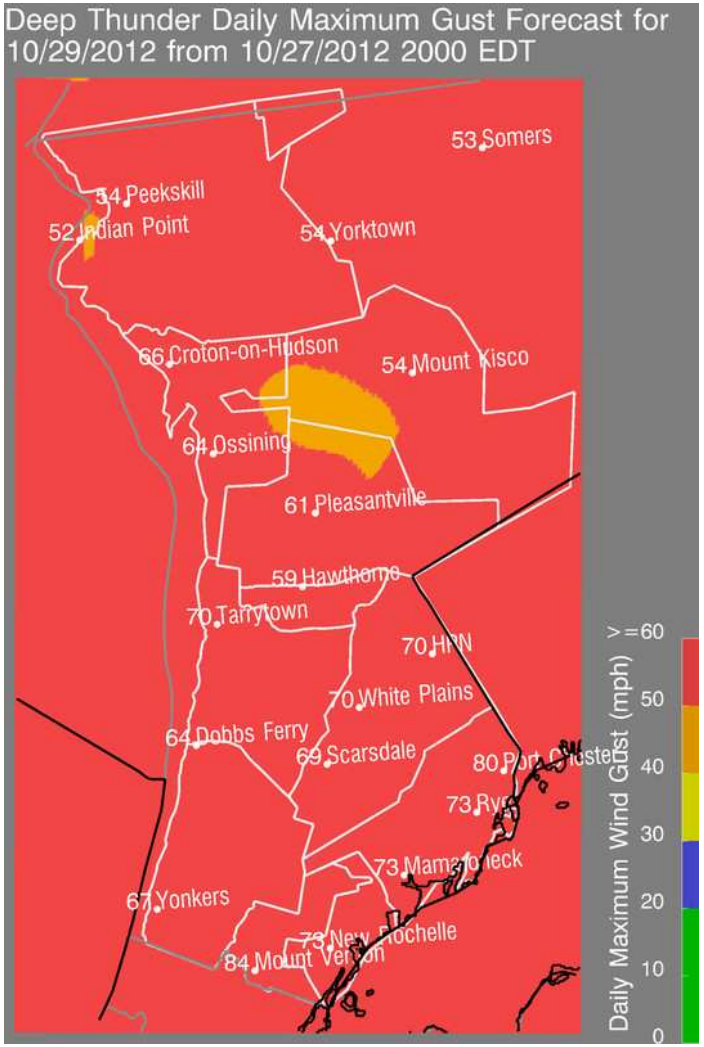
Visualization of Clouds, Wind and Precipitation, including Rain Bands

Deep Thunder Wind Forecast for Post Tropical Cyclone Sandy

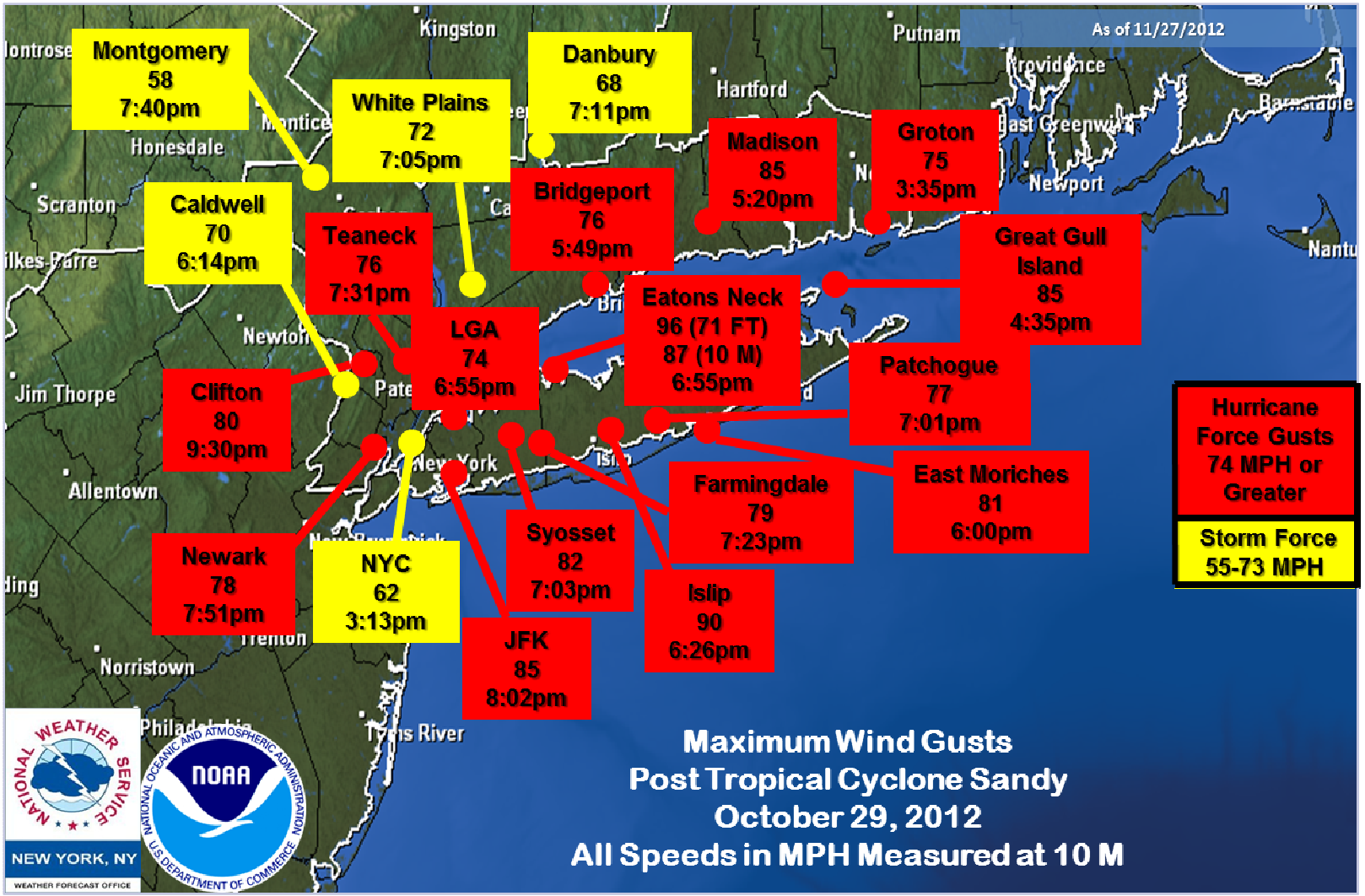
Maximum Sustained Wind



Maximum Daily Gust

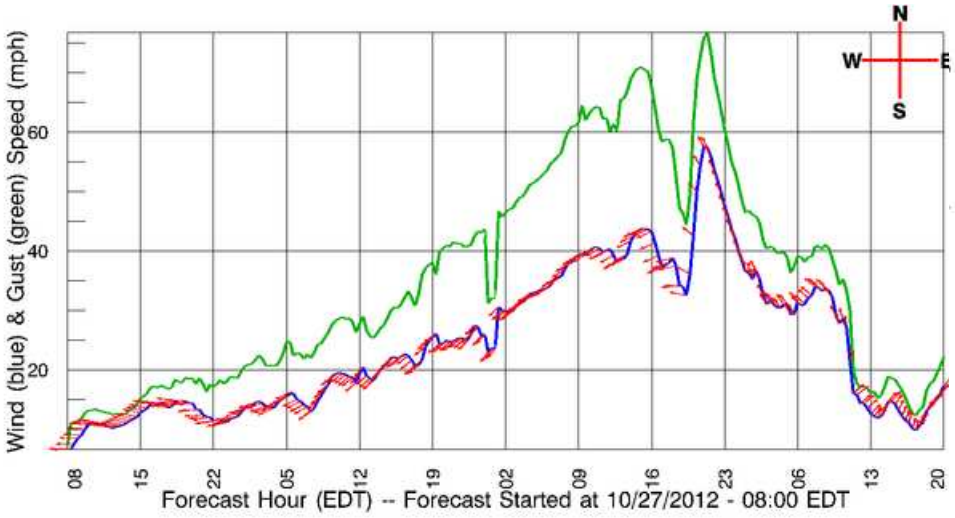


Post Tropical Storm Sandy – Observed Gusts

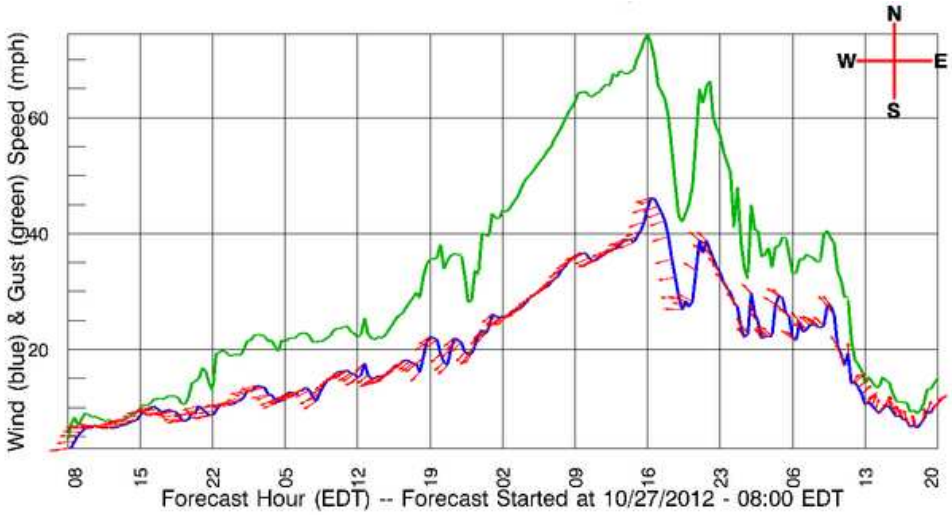


Deep Thunder New York Forecast for Post-Tropical Cyclone Sandy

- One of ten operational forecasts covering the event
- Using data from 0800 EDT on 27 October, available in the mid-afternoon
- Very strong winds predicted with similar magnitude and timing as reports



Coney Island (observed maximum gust 69 mph at 1842 EDT, 29 October)



Central Park (observed maximum gust 62 mph at 1513 EDT, 29 October)

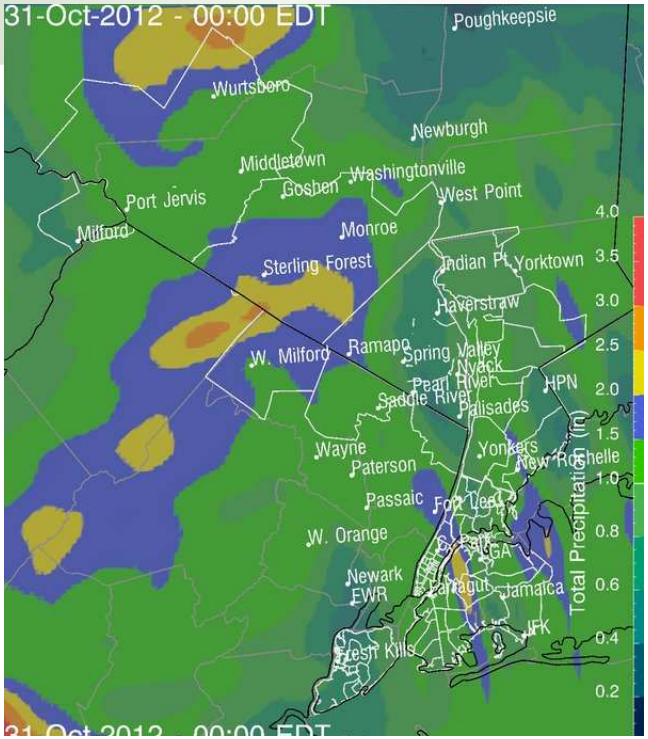
Forecasts of Sustained Wind Speed and Direction and Wind Gusts

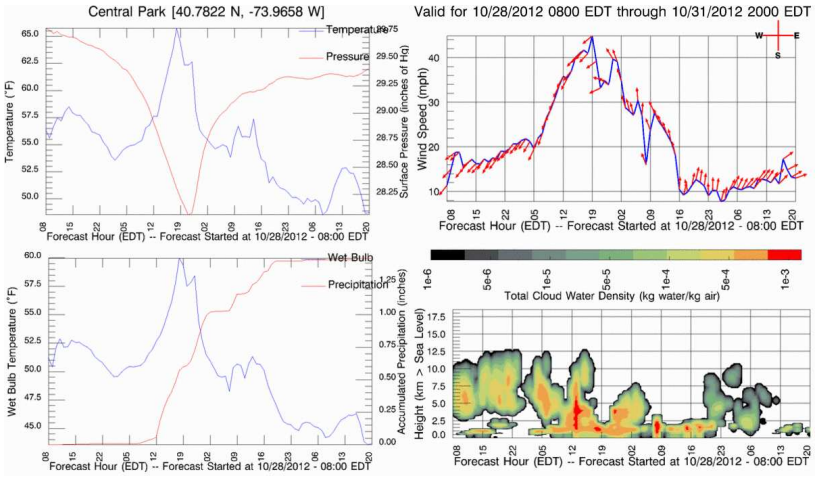
Deep Thunder New York Forecast for Post Tropical Storm Sandy

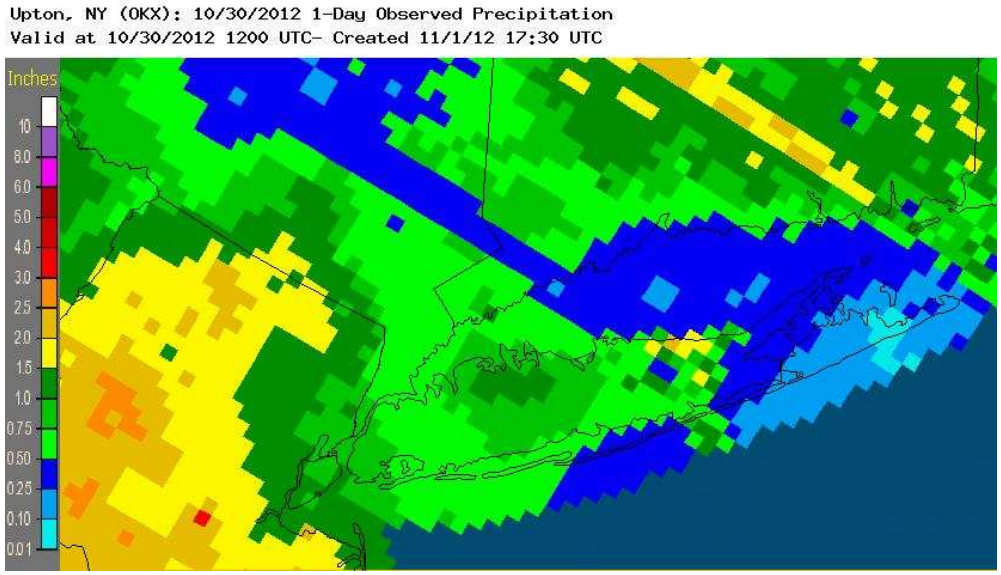
- **Initiated with data from 0800 EDT on 10/27 with results available in the late afternoon**

- **Shows rainfall beginning in parts of New York City in the morning on 10/29 and ending the evening of 10/30**

- **Sustained winds in New York City at tropical storm force strength**







Spatial Verification for Hourly Accumulated Rainfall for Post-Tropical Cyclone Sandy

Using data from 0800 EDT on 28 October:

- Grid-Stat Neighborhood Approach, **Day1**
  - 0-mm/hr threshold: **70.1%** (Accuracy), **.343** (HK), 4.2 (Odds Ratio)
  - (N/A) 2.5mm-10mm were not the dominant intensity scales, so Accuracy values were > 90%
- Grid-Stat Neighborhood Approach, **Day2**
  - 0-mm/hr threshold: **79.8%** (Accuracy), **0.793** (CSI), 9.17 (Odds Ratio)
  - 2.5mm/hr threshold: **78.4%** (Accuracy), **0.3** (HK), 4.4 (Odds Ratio)
  - 5-mm/hr threshold: 93.3% (Accuracy), 0.242 (HK), 6.97 (Odds Ratio)
  - (N/A) 7.5mm-10mm were not the dominant intensity scales, so Accuracy values were > 90%

Using data from 2000 EDT on 28 October:

- Grid-stat Neighborhood Approach, **Day1**
  - 0-mm/hr threshold: **76.3%** (Accuracy), **0.655** (CSI), **0.551** (HK), **37.0** (Odds Ratio)
  - 2.5mm/hr threshold: **79.8%** (Accuracy), 0.153 (HK), 2.34 (Odds Ratio)
  - 5-mm/hr threshold: 92.4% (Accuracy), 0.114 (HK), 3.0 (Odds Ratio)
  - 7.5mm-10mm were not the dominant intensity scales, so Accuracy values were > 90%

Summary

- The model demonstrated good skill in predictions of rainfall and winds for the two storm events there were studied.
- Local and regional scale features are resolved and illustrate the value of high-resolution physical weather modelling in predicting environmental impacts
- Visualization is a key element in supporting the decision making process
- Positive stakeholder as well as economic and societal benefits can be realized in the application of the end-user-focused methodology
- Future work will focus on coupling and integrating models for specific applications and enabling broader solutions