On-going Utilization and Evaluation of a Coupled Weather and Outage Prediction Service for Electric Distribution Operations

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On-going Utilization and Evaluation of a Coupled Weather and Outage Prediction Service for Electric Distribution Operations

- Background and motivation
- Approach
  - Meteorology (modelling and analysis)
  - Outages (modelling and analysis)
  - Coupling and calibration
  - Verification
- Example results and visualizations
- Conclusions and future work

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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

Symposium on the Coastal Environment:

- 8.3 Forecast Performance of an Operational Mesoscale Modeling System for Tropical Storm Irene and Post-Tropical Cycle Sandy in the New York City Metropolitan Region
- 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 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

Conference on Hydrology:

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

Conference on Climate Variability and Change:

- 551 Seasonal Climatology Studies for Tropical Region - Borneo Island Case Study

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
- 800 Utilization of a High Resolution Weather and Impact Model to Predict Tropical Storm Irene
- 409 Advanced Data Assimilation for Short-term Renewable Power Prediction: a Complex Terrain Case

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Background and Motivation

- The operation of the distribution system of an electric utility, particularly with an overhead infrastructure, can be highly sensitive to local weather conditions

- What is the potential to enable proactive allocation and deployment of resources (people and equipment) to minimize time for restoration?
  - –Ability to predict specific events or combination of weather conditions that can disrupt that distribution network with sufficient spatial (i.e., area substation level) and temporal precision, and lead time
  - –Can highly localized, NWP-based forecasts be adapted to address these problems and reduce the uncertainty in decision making?
  - –Can the link between weather and impact be quantified to improve preparation and response?

Weather prediction

↓

Damage prediction

↓

Resource requirement prediction

↓

Restoration time prediction

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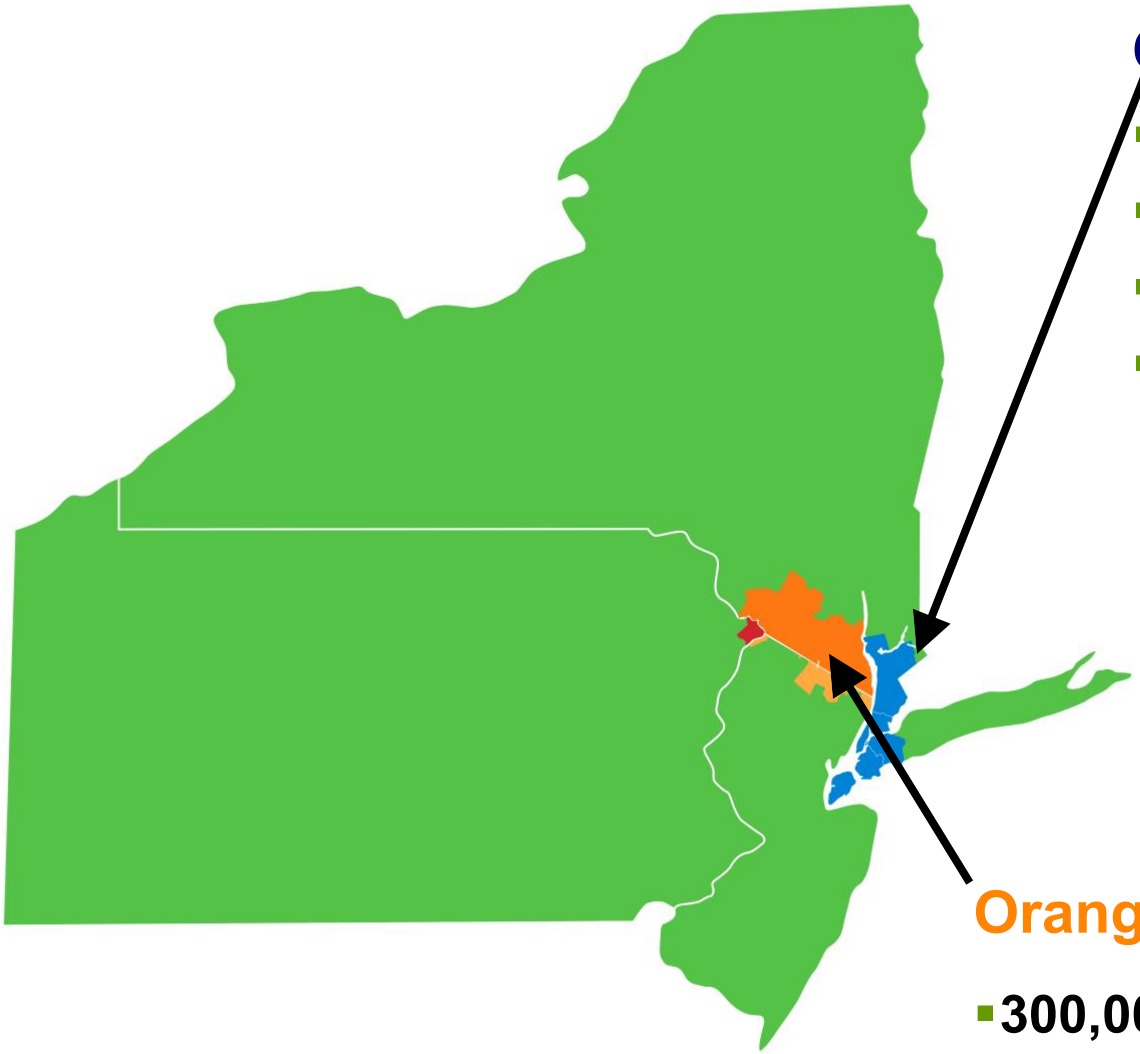
Consolidated Edison Service Territory



Con Edison Co. of New York

- 3.2 million electric customers
- 1.0 million gas customers
- 1,800 steam customers
- 709 MW of regulated generation

Orange and Rockland

- 300,000 electric customers
- 127,000 gas customers

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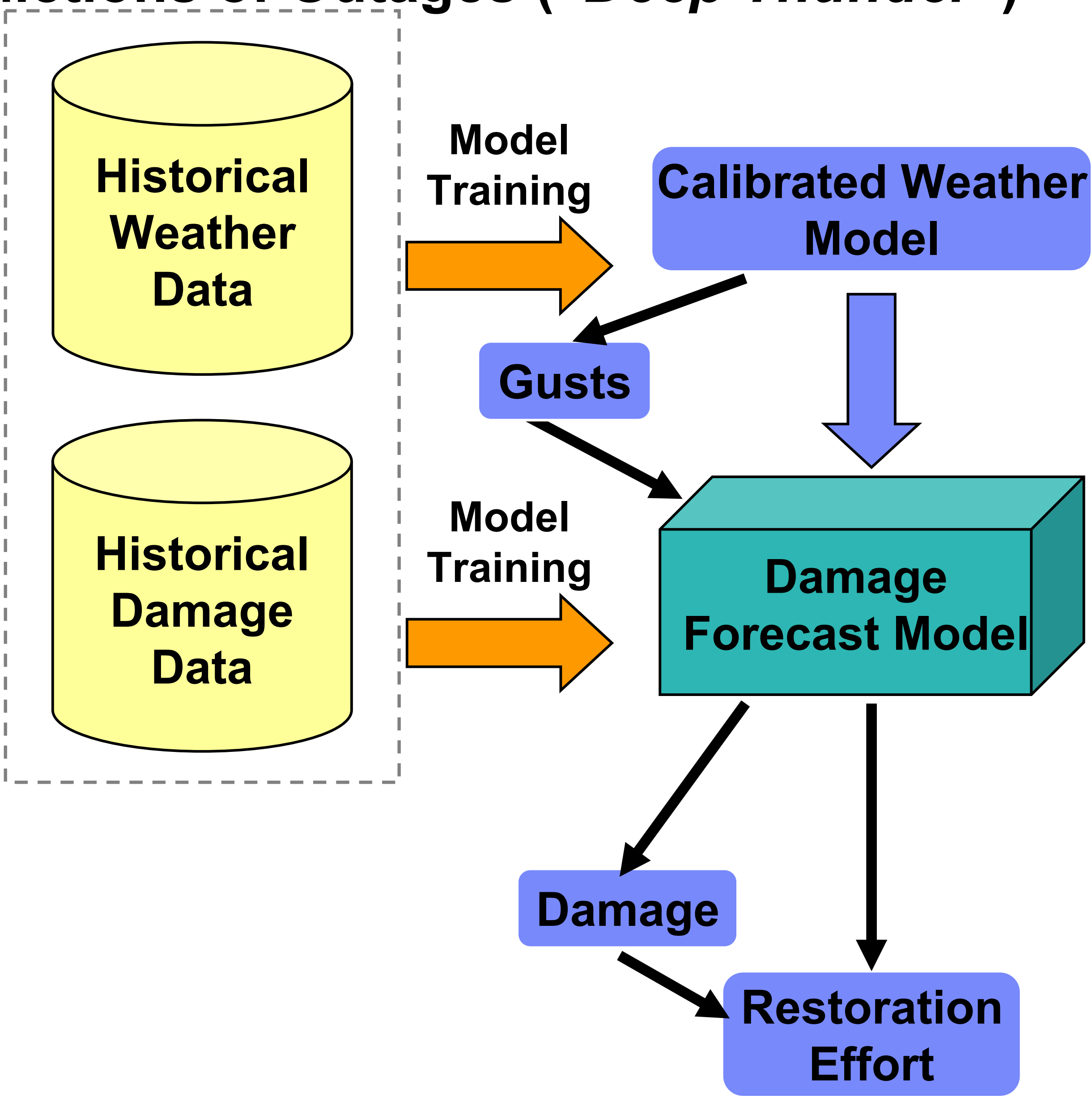
Approach: Coupled Weather and Impact Modelling

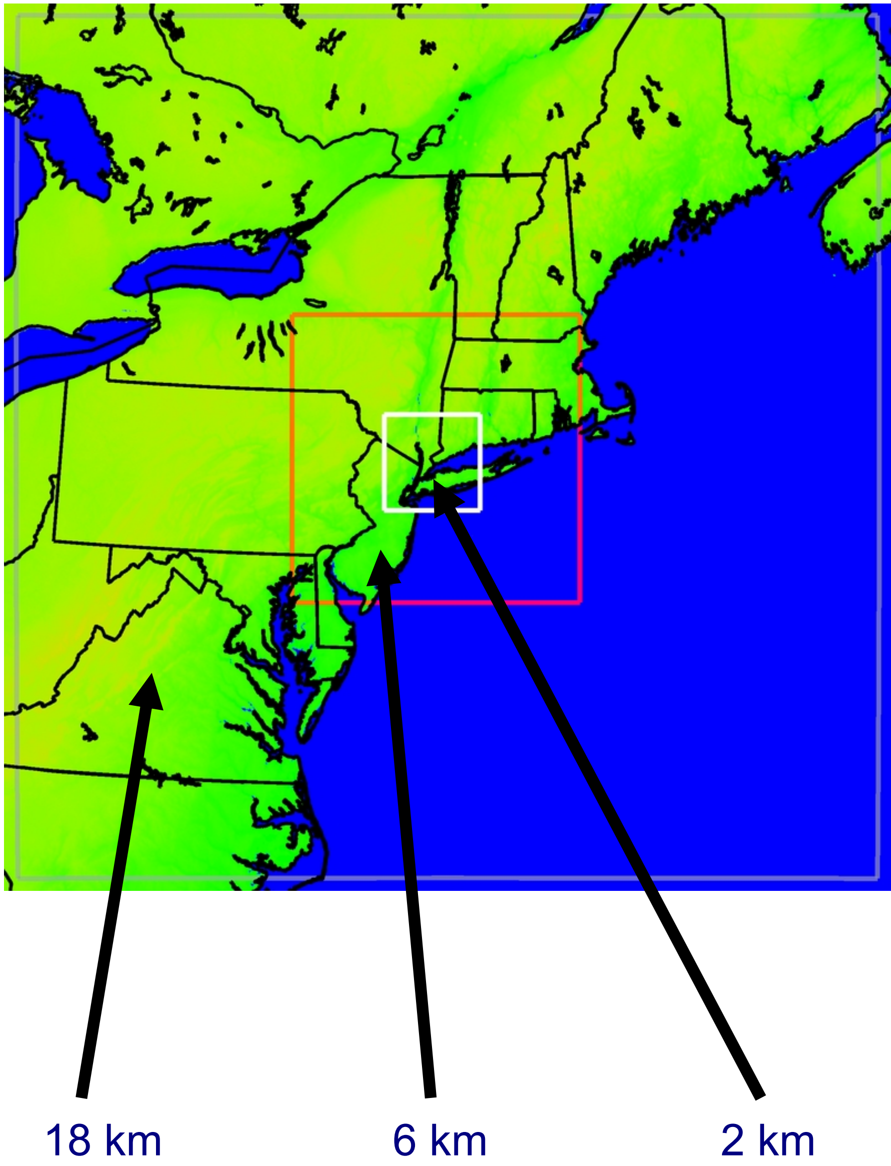
Custom Modelling for Predictions of Outages ("*Deep Thunder*")

- Weather causes damage
- Damage requires restoration (resources)
- Restoration takes time, people, etc.
- Build predictive model from environmental observations, storm impact and related data
  - Damage location, timing and response
  - Wind, rain, lightning and duration
  - Demographics of effected area
  - Infrastructure impacted in effected area
  - Ancillary environmental conditions



Coupled Weather and Outage Model Configuration (Operational Since April 2009)

- **Modelling**
  - Weather: utilize WRF-ARW to enable effective forecasts with up to 72 hours lead time
  - Outages: spatial-temporal statistical modelling to enable predictions of damage, outages and restoration effort
- **Dissemination**
  - Tailored weather visualizations available via a web browser, which are automatically updated for each forecast cycle
  - Gust and outage estimation
  - Uncertainty visualization for operational decision making
  - E-mail alerting system
  - Customized verification



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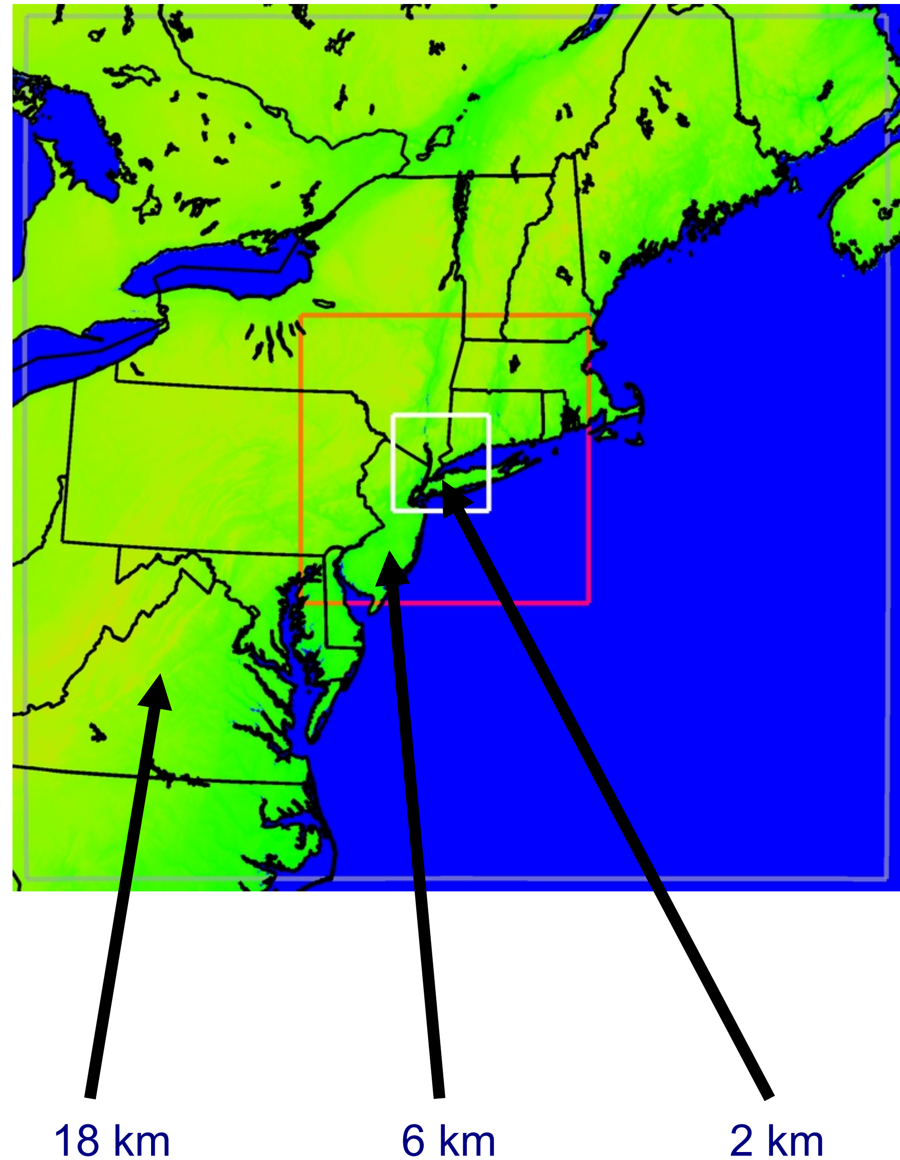
Initial Weather Model Configuration – WRF-ARW 3.1.1 (Operational from April 2009 – October 2012)

- 18/6/2 km nested (76x76x42) with 2 km resolution across entire extended service area for 84 hours
- Run twice daily (initialized at 0 and 12 UTC)
- NAM for background fields and lateral boundary conditions
- Physics configuration for highly urbanized to rural domain determined via numerical hindcast experiments
  - 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



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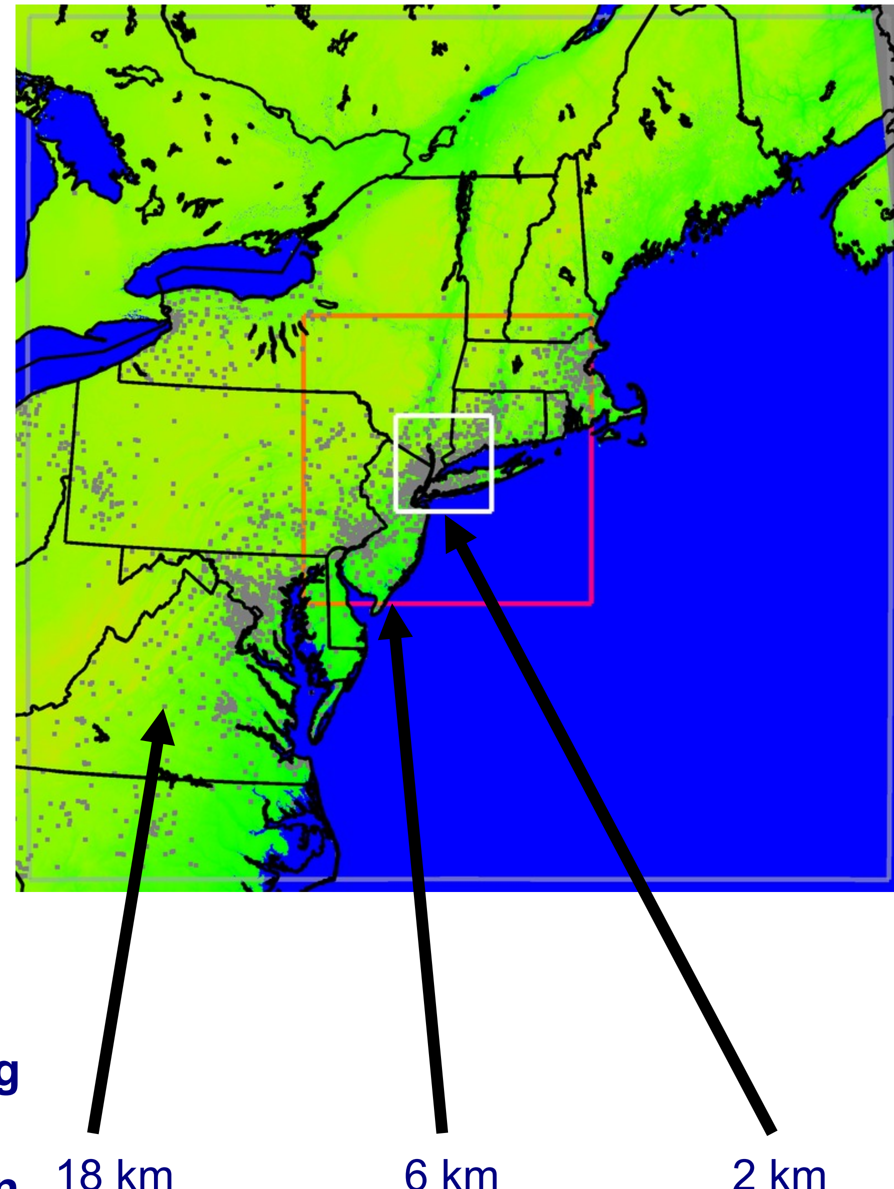
Current Operational Weather Model Configuration

- 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 data
  - 1km SSTs
- Data assimilation (3dVAR) of near-real-time Earth Networks WeatherBug data (updated)
  - 3520 stations (gray markers on map): 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 end-to-end processing
  - ~1/3 the wall-clock time for end-to-end processing compared to previous implementation



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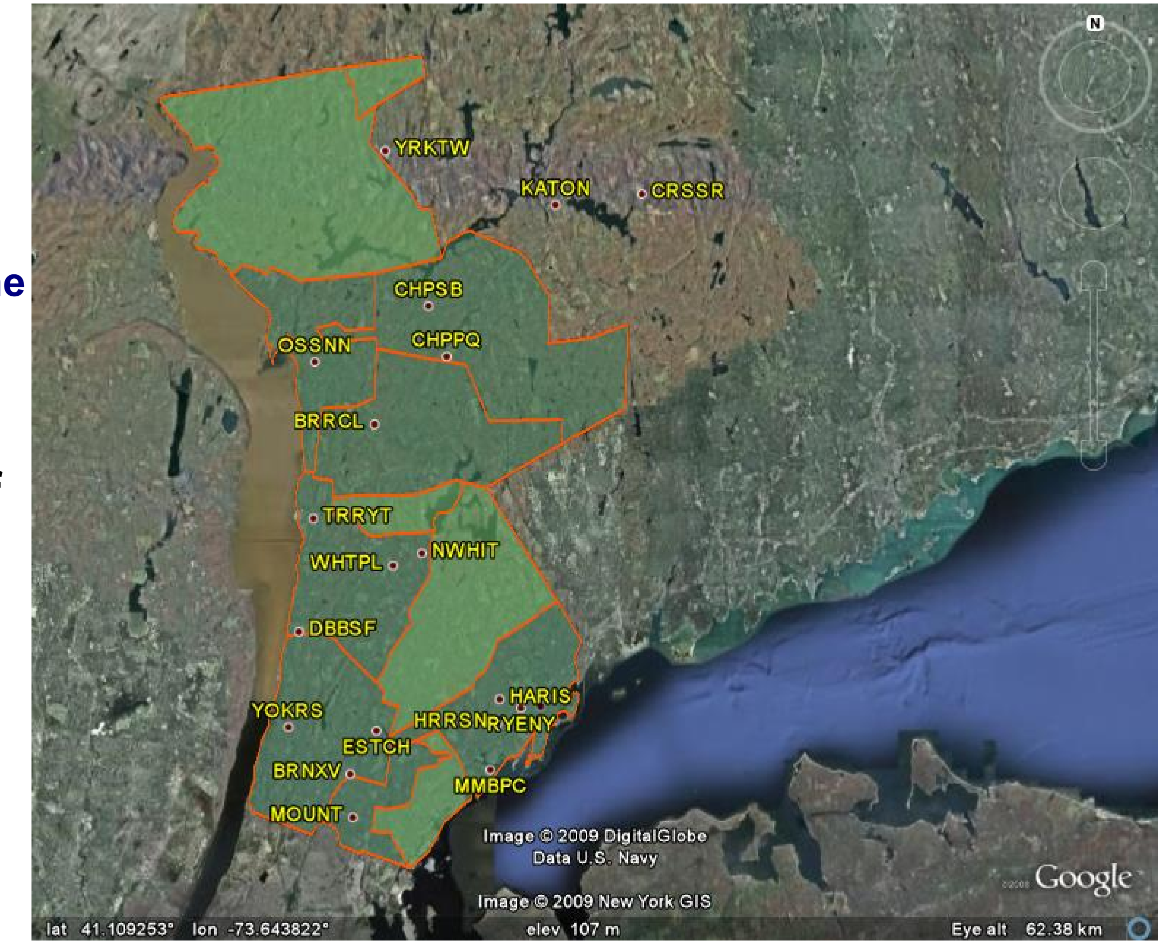
Outage Model Configuration

- Statistical post-processor for weather data
  - Temporal-spatial Bayesian hierarchical modelling
  - "Predictive mode" operates on WRF output and generates daily gust maximums, assuming generalized extreme value distribution
  - "Probable mode" operates on near-real-time WeatherBug data (i.e., nowcasting)
- Produces *probabilistic* estimate of number of restoration jobs per substation, once per each of three forecast days
- E-mail alerting system, triggered by total number of jobs with 75% confidence
- Trained and calibrated with historical predicted and observed weather and outage data
- Uncertainty quantification
  - Multiple sources (not just meteorological)



Location of Consolidated Edison Westchester County Substation Areas and Earth Networks WeatherBug Stations

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Modelling Process

Model set-up:

Let $\mathcal{S} = \{s_1, \ldots, s_n\}$ be the set of locations of AWS weather stations where gust observations are recorded

Let $\mathcal{U} = \{u_1, \ldots, u_m\}$ be the set of DT forecast grids

- AWS daily maximum gust speed: $Y_d(s_i), i = 1, \ldots, n$
- DT daily maximum wind forecast: $X_d(u_j), j = 1, \ldots, m$

The goal is to obtain $\mathbf{Y_d}(\mathcal{U})|\mathbf{X_d}(\mathcal{S})$

Bayesian Hierarchical Modeling Data Process:

$$f(Y_d(u)) = \frac{1}{\sigma(u)}\left[1+\xi\left(\frac{Y_d(u)-\mu(u)}{\sigma(u)}\right)\right]^{-1/\xi-1}\exp\left\{-\left[1+\xi\left(\frac{Y_d(u)-\mu(u)}{\sigma(u)}\right)\right]^{-1/\xi}\right\}$$

where $1+\xi\left(\frac{Y_d(u)-\mu(u)}{\sigma(u)}\right) > 0$

Location parameter and scale parameter are location dependent

Bayesian Hierarchical Modeling Latent Process:

$$\mu(\mathcal{U}) = g_\mu\left(X(\mathcal{S}), \boldsymbol{\alpha}, \omega_\mu\right)$$
$$\sigma(\mathcal{U}) = g_\sigma\left(X(\mathcal{S}), \boldsymbol{\beta}, \omega_\sigma\right)$$

$$\boldsymbol{\alpha} \sim Gau(\mathbf{a}, \boldsymbol{\Sigma}_\alpha(\rho, \tau_\alpha))$$
$$\boldsymbol{\beta} \sim Gau(\mathbf{b}, \boldsymbol{\Sigma}_\beta(\rho, \tau_\beta))$$

- **Prior set-up and derive posterior distributions of the parameters**
- **Use Markov Chain Monte Carlo (MCMC) to draw posterior samples and stop after convergence is achieved**

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Meteorological Forecast Verification

- Meteorological metrics
  - How should the model results be evaluated?
- Business metrics (especially for the probabilistic outage forecasts)
  - What is the value of the forecast information, even with meteorological errors?
  - Identification of what is “good enough” for decision making
- Data
  - 84-hour 00 UTC and 12 UTC forecasts (hourly from every 10 minutes, 2km), 00 UTC and 12 UTC NAM (3-hourly, 12km), Weatherbug observations (5-minute intervals)
- Tools
  - Perl and shell scripting languages for reformatting observations, WRF Post-Processor (WPPV3) for conversion of raw model output, Model Evaluation Tools (METv3.0) for statistical computation
- Methodology
  - Final statistics are computed as monthly averages for each forecast day for each cycle
    - T, Td, WSP: Root Mean Square Error, Mean Absolute Error, Mean Error (for additive bias)
    - Accumulated Precipitation: contingency table values (hits, misses, false alarms, correct negatives); with and without temporal/amount constraints
    - Utilize specific thresholds and ranges of relevance to decision makers in the verification
  - Verification completed using the METv3.0 statistical package
- Evaluate use of spatial methods

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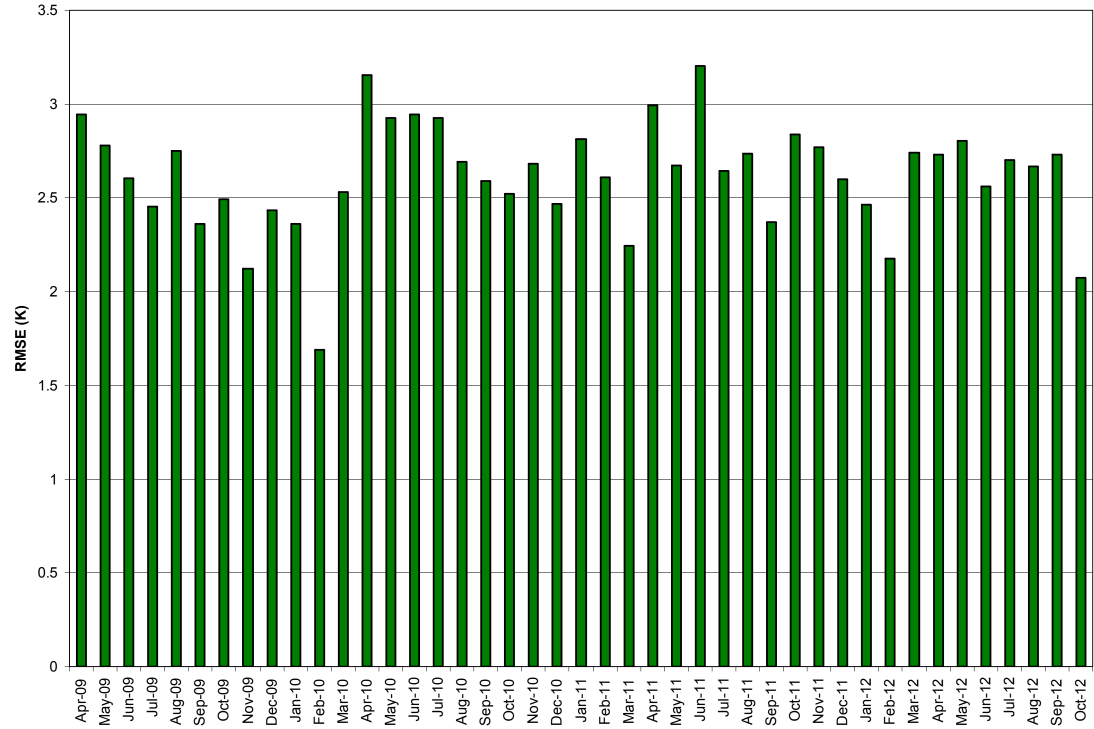
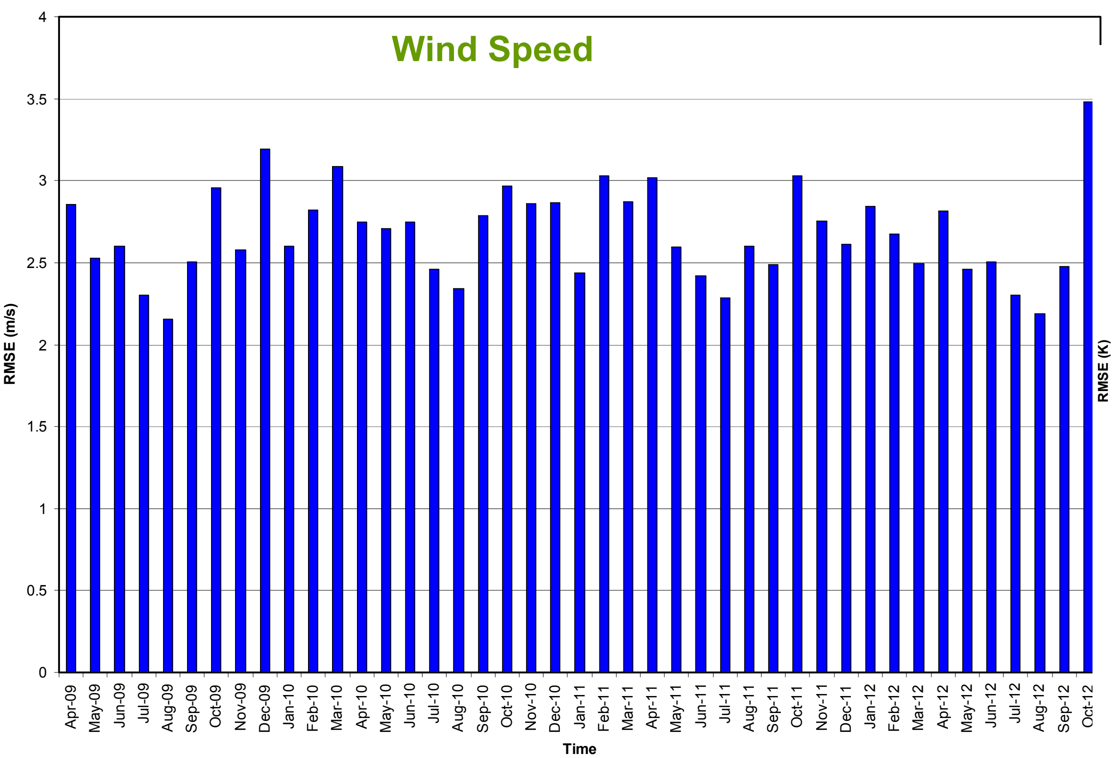
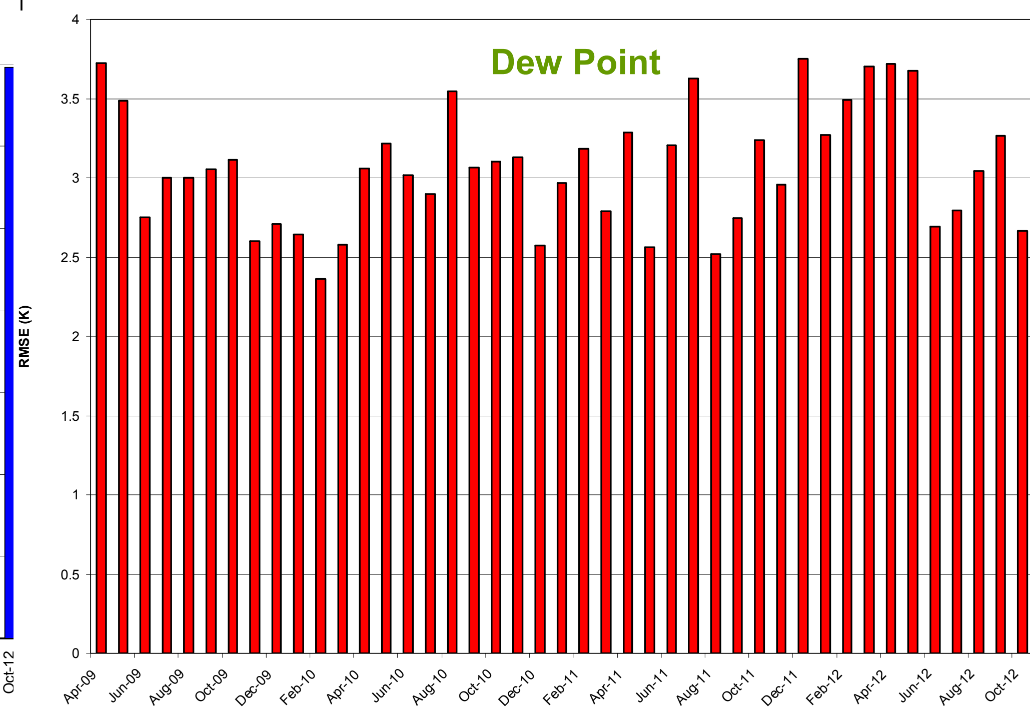
Monthly Average Forecast Statistics

Temperature







Example Statistics with Current Weather Model Configuration: 11/30/2012 – 12/04/2012

- Day1, TMP, 00Z: *2.32 (F)* Day1, DPT, 00Z: 2.39 (F) Day1, WIND, 00Z: 4.59 (mph)
- Day2, TMP, 00Z: 3.05 (F) Day2, DPT, 00Z: 3.47 (F) Day2, WIND, 00Z: *5.86 (mph)*
- Day3, TMP, 00Z: 3.65 (F) Day3, DPT, 00Z: 3.37 (F) Day3, WIND, 00Z: 6.31 (mph)

- Day1, TMP, 12Z: 2.51 (F) Day1, DPT, 12Z: 2.45 (F) Day1, WIND, 12Z: 4.80 (mph)
- Day2, TMP, 12Z: 3.37 (F) Day2, DPT, 12Z: 2.72 (F) Day2, WIND, 12Z: 6.12 (mph)
- Day3, TMP, 12Z: 3.92 (F) Day3, DPT, 12Z: 3.06 (F) Day3, WIND, 12Z: 5.45 (mph)

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Outage Forecast Verification – In Progress

- Comparing aggregated ticket data vs. probability of dispatched repair jobs for all substations
- Two approaches to weighted scores
  - 3x3 multi-category contingency table (hits vs. misses)
  - 2x2 contingency table (hits, misses, false alarms, correct negatives)
- Three job bins: <= 50, 51-100, >= 101
  - Six probabilities, corresponding to six bins (11-20, 21-50, 51-100, 101-150, 151-200, >200), are summed, resulting in probabilities for <= 50, 51-100, >= 101
- 3x3 contingency table → Accuracy, HSS, Gerrity
  - hit*probability + miss*probability = 1.0
- 2x2 contingency table → Accuracy, CSI/Threat, POD, Frequency Bias, HK, HSS, Success Ratio
  - hit*probability + miss*probability + CN*probability + FA*probability = 1.0
  - Over-prediction → false alarm
  - Under-prediction → miss
  - 0-10 bin becomes important for (1) correct negatives and (2) misses
  - The 2x2 approach allows for the utilization of many additional scores

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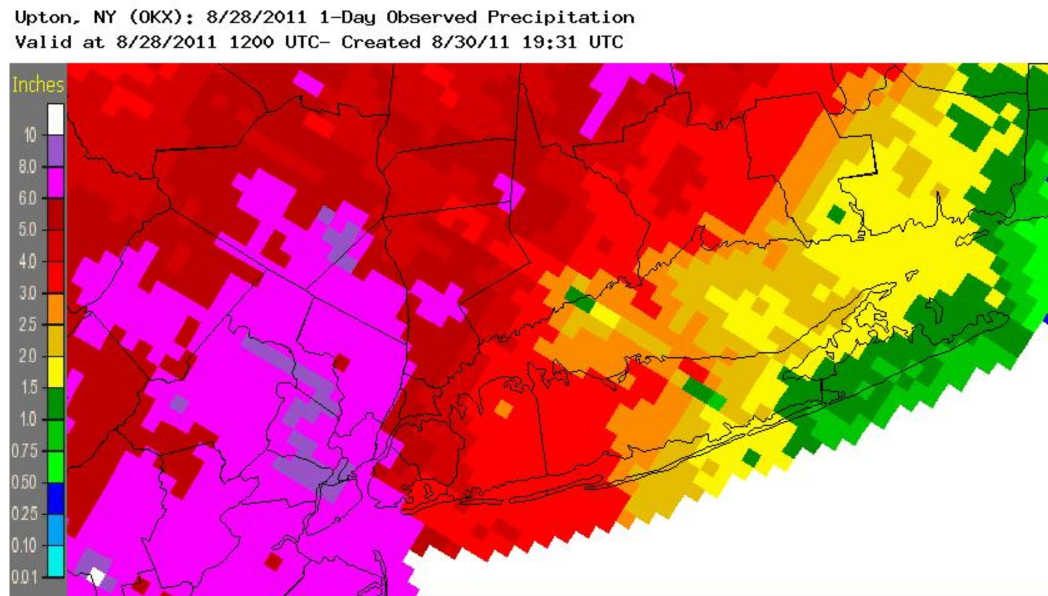
28 August 2011: Tropical Storm Irene Impacts the New York City Metropolitan Area

- 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 of 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



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

- Sustained winds 40 to 52 mph with

See Energy Poster 800 on Wednesday afternoon

and

Coastal Environment Talk 8.3 on Thursday morning

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

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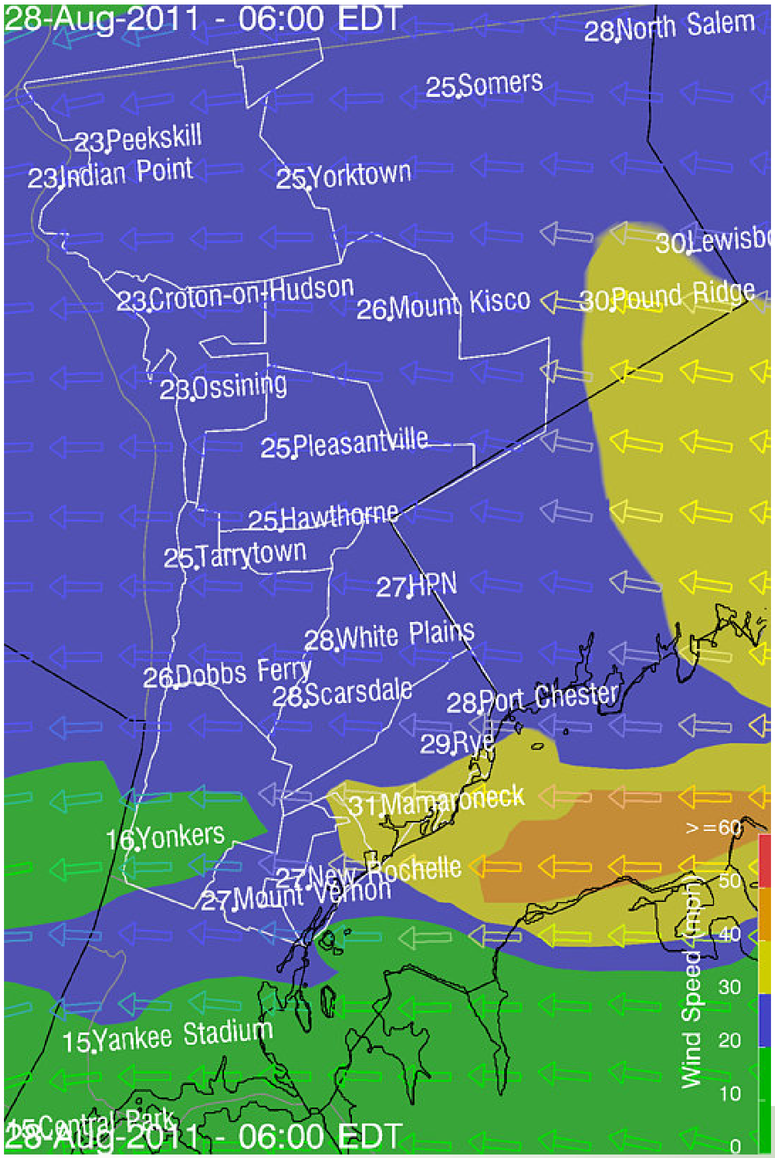
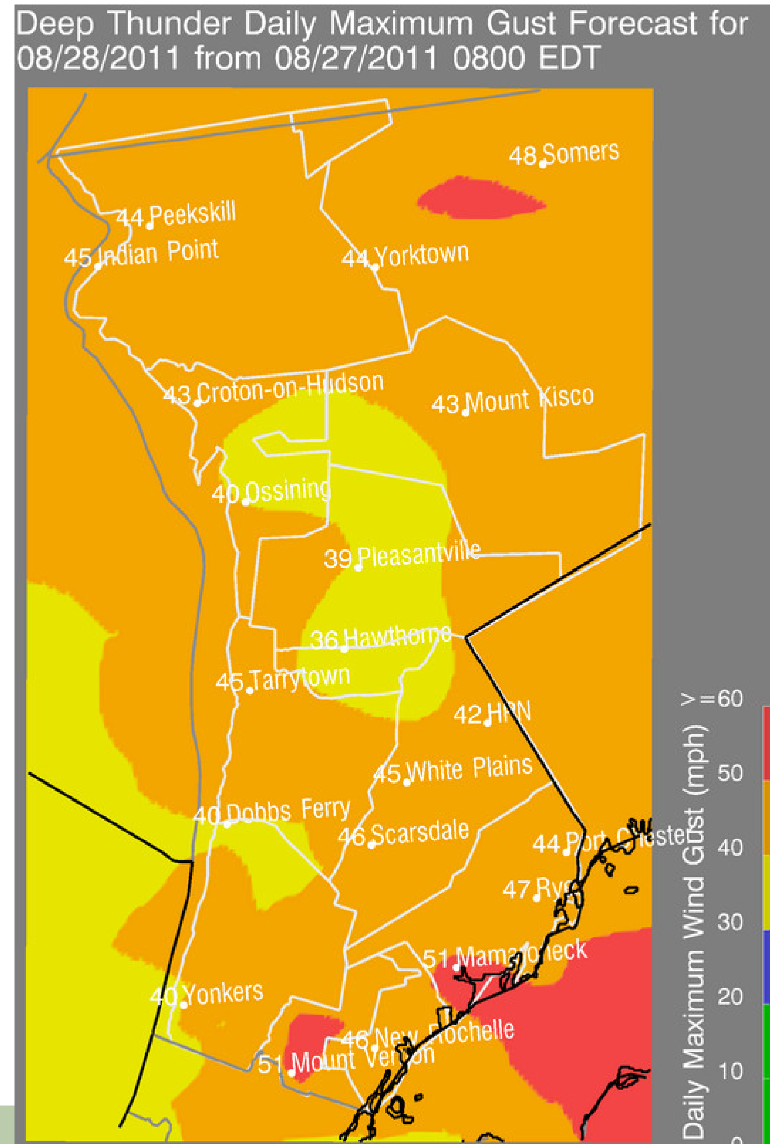
Wind Forecast for Tropical Storm Irene: Afternoon of 27 August 2011

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

Maximum Sustained Wind



Maximum Daily Gust



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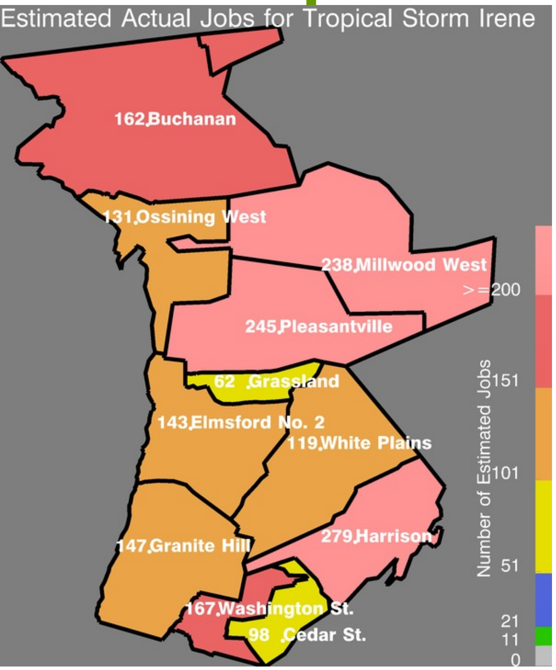
Tropical Storm Irene Deep Thunder Impact Forecast



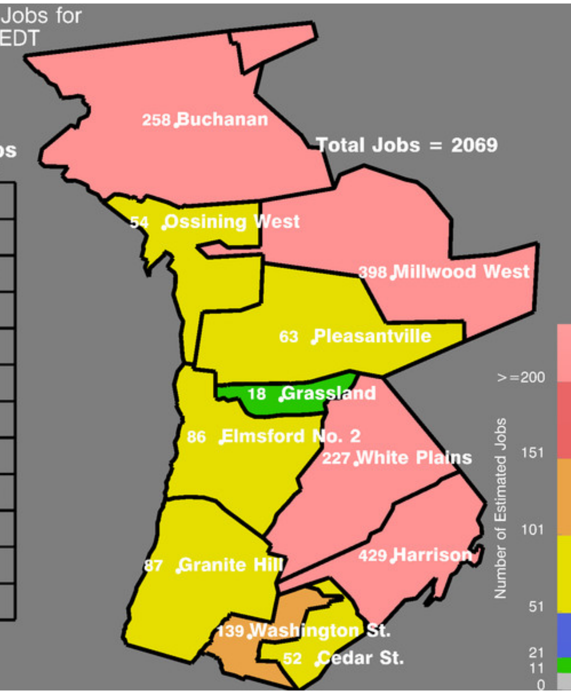
Forecasted Outages per Substation (Repair Jobs)

- **Deterministic Aggregate Accuracy ~94.1% (Total = 2069)**
- **Probabilistic Substation Accuracy ~ 83.1%**

Estimated Actual Number of Repair Jobs per Substation Area (Total = 1953)

Deep Thunder Forecast of ConEd Jobs for 08/28/2011 from 08/27/2011 0800 EDT

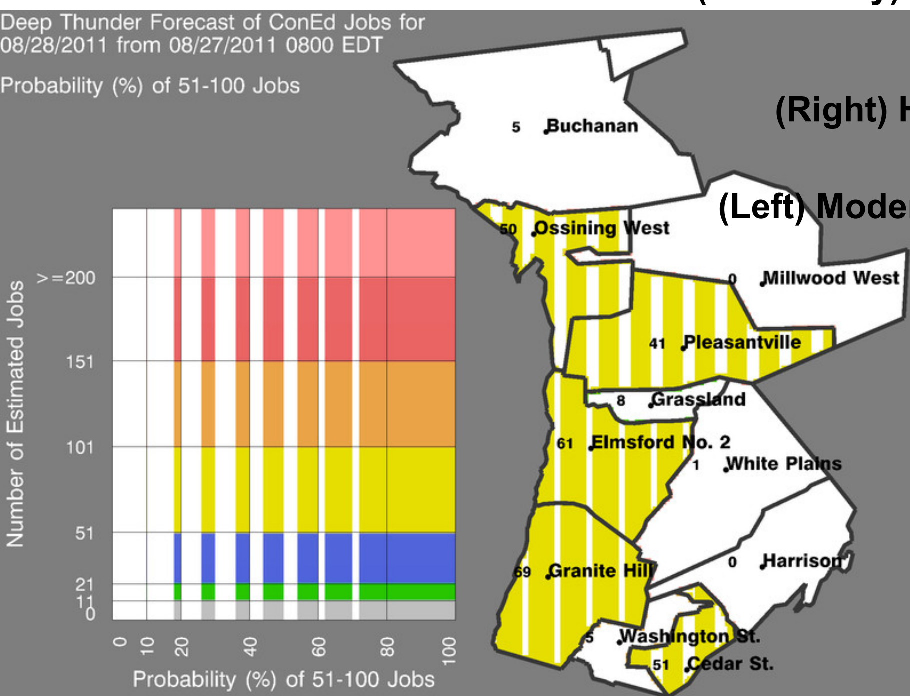
Area	Range of Jobs Low	High
Mohansic	132	391
Buchanan	132	391
Millwood West	236	550
Ossining West	33	81
Pleasantville	38	96
Grassland	10	27
White Plains	154	289
Elmsford No. 2	58	109
Harrison	321	514
Cedar St.	36	66
Washington St.	110	161
Granite Hill	66	104

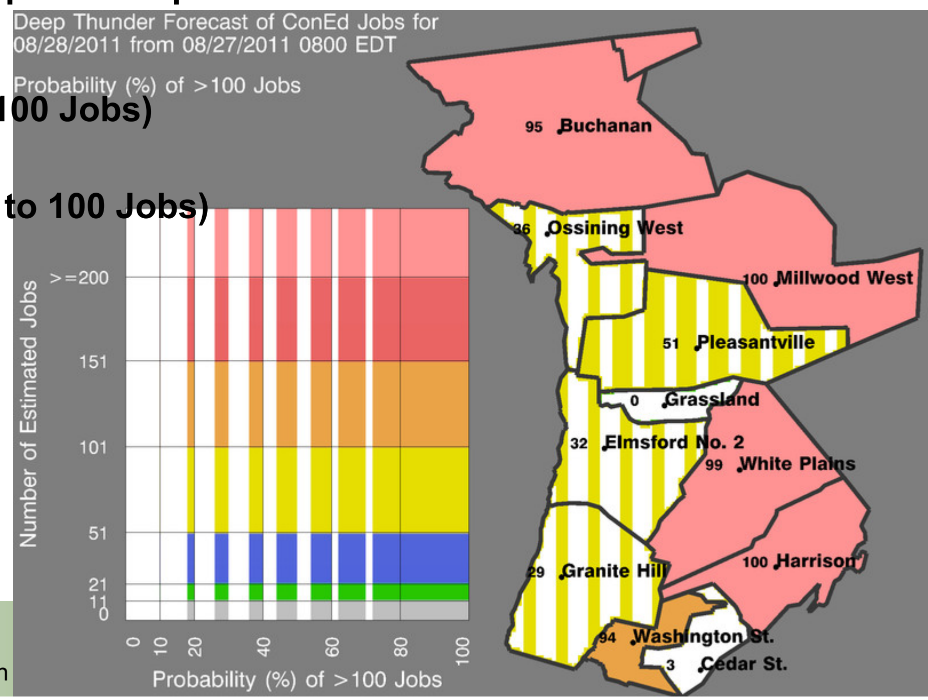


Likelihood (Probability) of a Range of Repair Jobs per Substation

(Right) High Severity (> 100 Jobs)

(Left) Moderate Severity (51 to 100 Jobs)





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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

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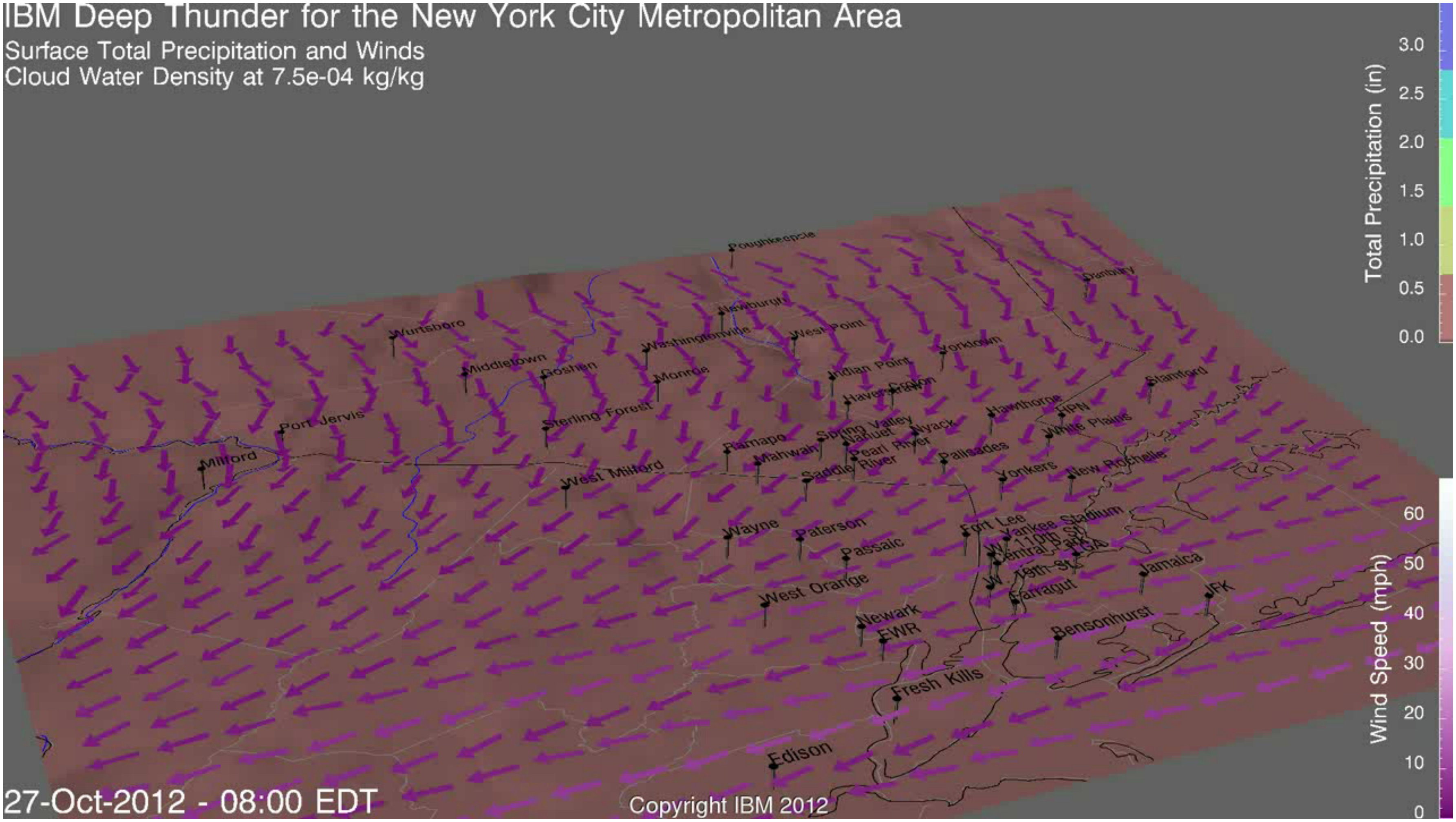
29 October 2012:
Post-Tropical Cyclone Sandy Impacts New York & New Jersey

- 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, available in the mid-afternoon
- Very strong winds and rainfall predicted with similar distribution to reports



Visualization of Clouds, Wind and Precipitation, including Rain Bands

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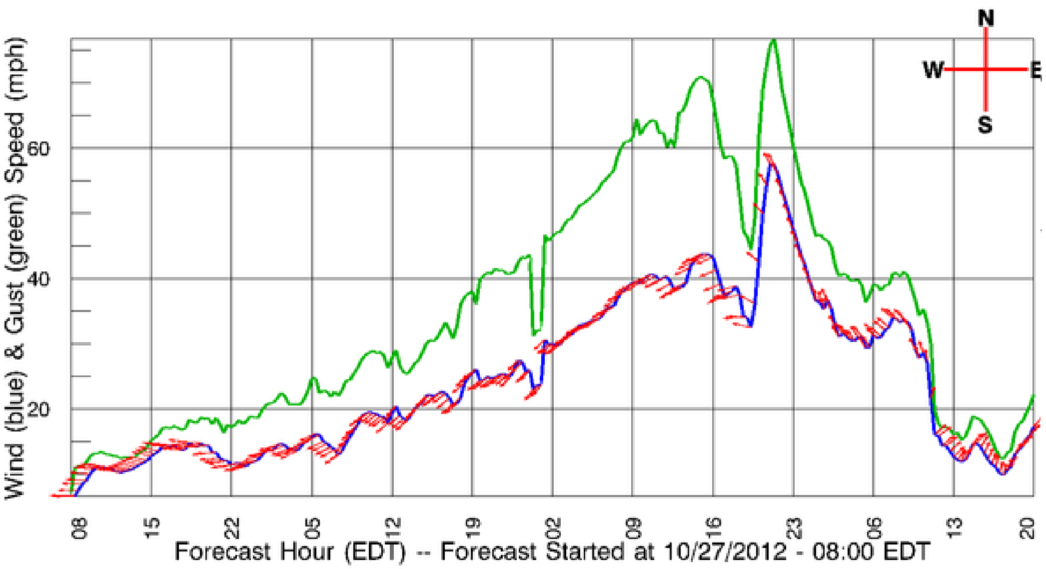
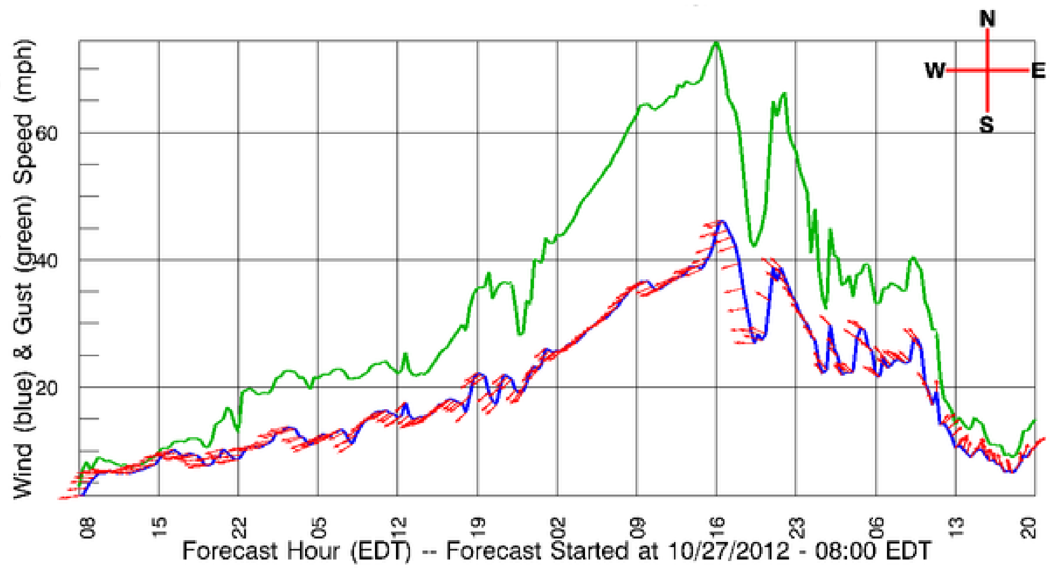
Deep Thunder Forecast for Post-Tropical Cyclone Sandy

- 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

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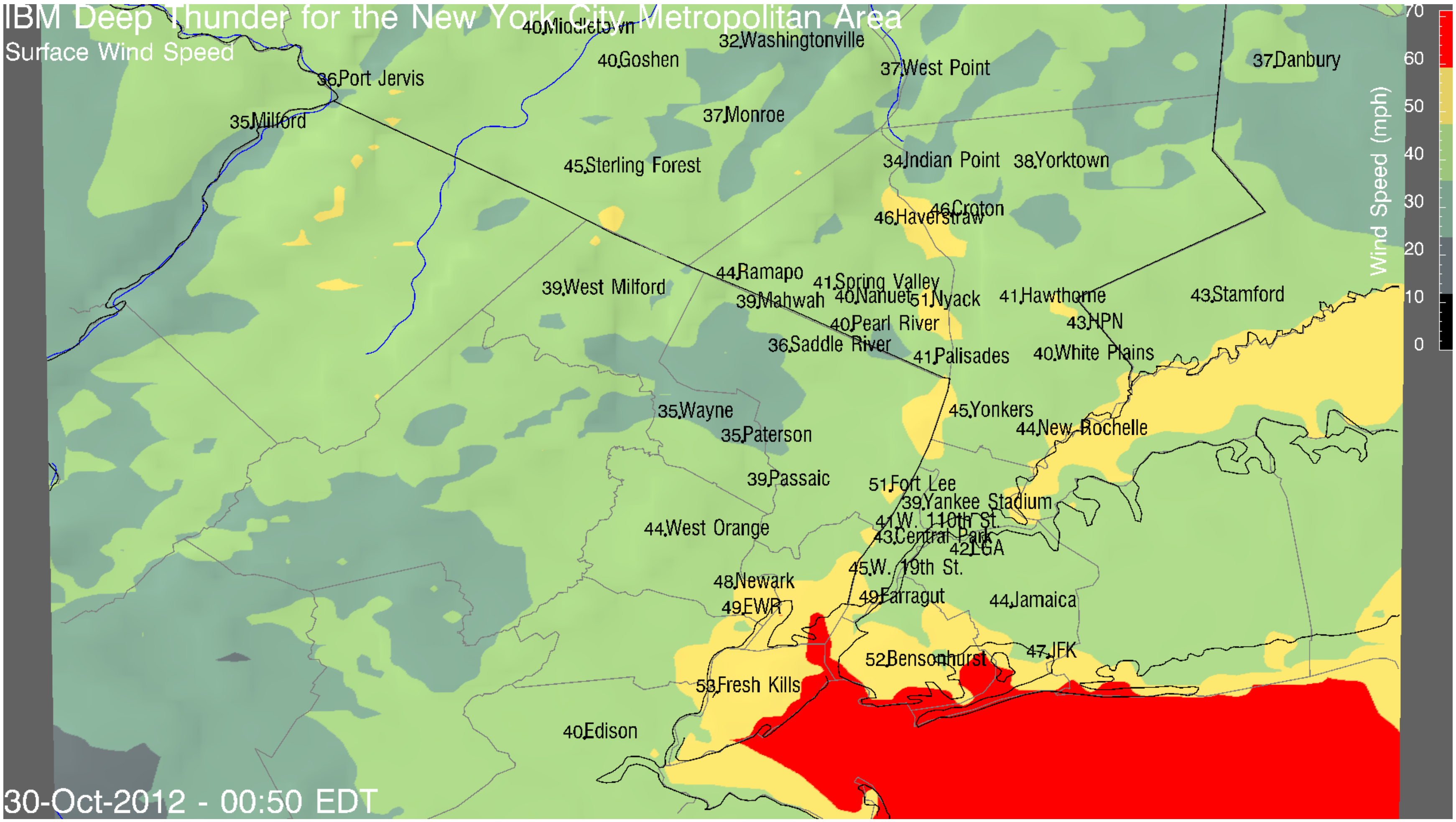
Deep Thunder New York Forecast for Post-Tropical Cyclone Sandy

- One of ten operational forecasts covering the event
- Using data from 2000 EDT on 27 October, available in the early morning of the 28th
- Very strong winds and rainfall predicted with similar distribution to reports



Visualization of Sustained Wind Speed

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Discussion

- We enabled and continue to use and improve an operational capability useful for overhead distribution network emergency management

- Yet, there are many on-going challenges…

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On-Going Challenges

- **Quality of weather observations**
  - Relatively dense network of surface stations from WeatherBug
  - Reporting inconsistent from WeatherBug network
  - Lack of availability of upper air data at the appropriate scale
- **Quality of outage (job ticket) data**
  - Must rely on field crews and service representatives
  - Need to filter storm-related damage
- **Impact model**
  - Determining appropriate inputs (e.g., gusts, soil moisture, foliage, etc.) and their relative correlation
  - Incorporation of “Black Swan” events
  - Insufficient data to adequately evaluate some weather events
- **Utilization**
  - Need to build trust with diverse users
  - Deliver complex information succinctly (e.g., visualization of probabilistic data)
  - Must be integrated with utility company procedures

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Next Steps

- Continued operational evaluation and utilization, including further development of verification methods
- Evaluate and incorporate additional data sets to improve initial conditions
- Evaluate and incorporate enhancements in weather model
- Evaluate and incorporate enhancements in outage model

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Summary

- Enabled an operational capability
- Collaborative and diverse team critical to success
- 84-hour weather model disseminated operationally
  - Updates every twelve hours
  - Full service territory and control center views of weather forecasts
  - Better results compared to other sources
- Sophisticated outage model shown to be feasible
  - Assuming calibration, can be coupled to different sources of weather data
  - Ability to incorporate all sources of uncertainty in damage estimates
  - Daily outage estimate per day (three) of model output for Westchester County
- Continue to improve calibration of weather and outage models, and characterization of uncertainties
  - Operational statistics for evaluation
  - Retrospective analysis and tuning using new events that have impact
- Deploying real-time outage estimate using WeatherBug data
- Developing additional specialized visualizations and methods of dissemination
- Coupling the weather prediction to business impact forecasts is operationally viable, yet challenges remain

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Backup

Slides

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Many Utilities Face Substantial Challenges in Outage Management

- The location and cause of outages is difficult to determine without physical inspection, resulting in delayed restoration and excessive costs
- Regulators are pressing for improvements in outage duration and frequency as measured by CAIDI, SAIFI, and SAIDI
- Some well-publicized outage events are resulting in substantial pressure to improve outage management information and processes
- Many customers are dissatisfied with the lack of dependable information on outage cause and expected restoration time
- Planning and staging for storm events is based on broad storm expectations rather than focused forecasts, resulting in inefficient staging and slow response times

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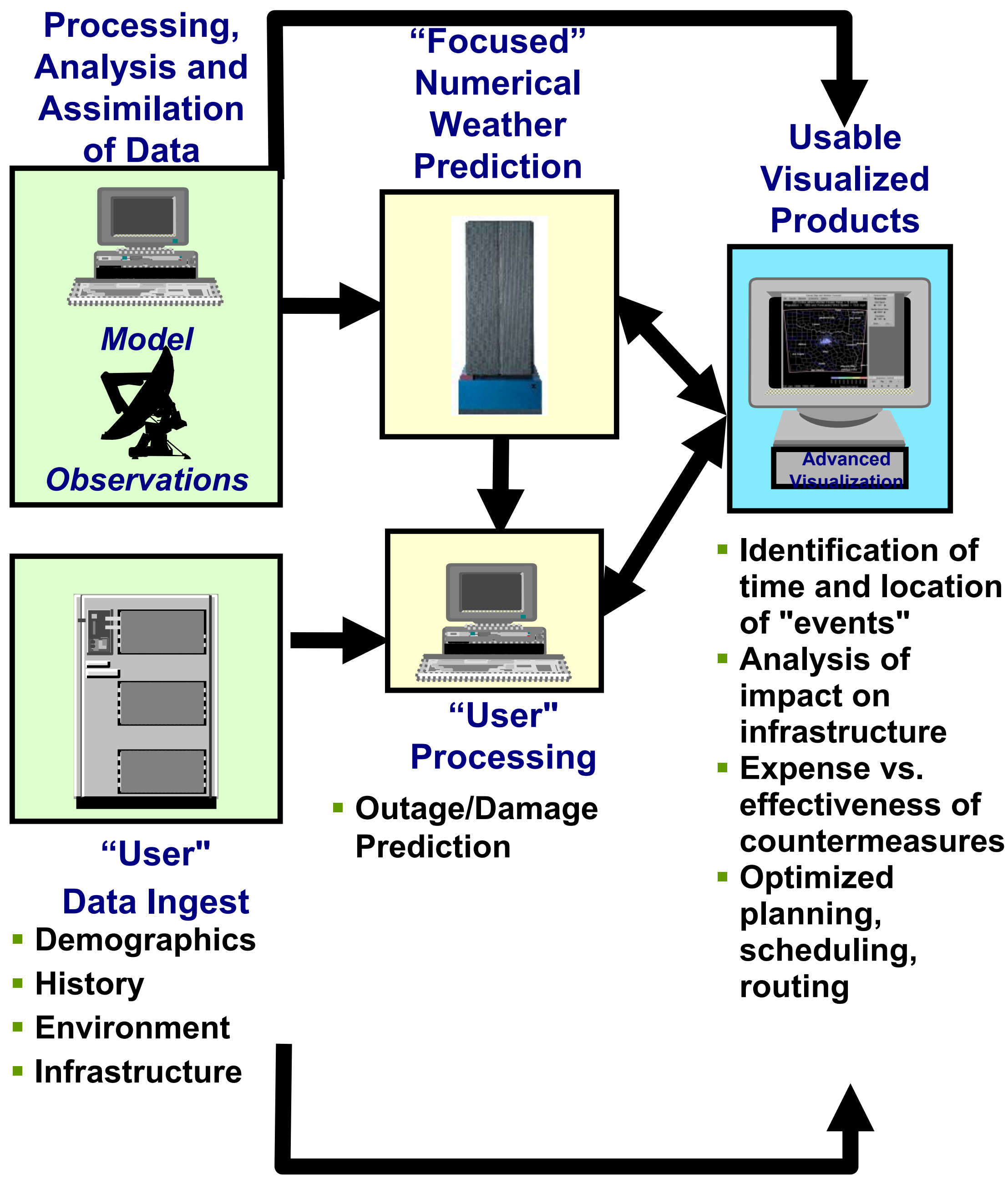
Challenges of Coupling NWP to the Decision Making Process

- **Damage forecast model inputs**
  - Which weather data really matter (avoid multicollinearity)?
  - For example, gust speed has a stronger relationship to damages vs. wind speed
- **Weather forecast calibration**
  - Forecasted variables (e.g., wind speed) may differ in meaning vs. observations used in the damage-forecast-model training
  - How should physical model outputs be calibrated so that they can be used as the inputs of damage forecast model?
- **How should damage forecasts, multiple spatial resolution interpolations and calibration be integrated in one framework?**



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Initial Steps

- Determine causes of damage due to storms that lead to outages
- Analyze static and time-varying geo-spatial data, each of which have different uncertainties
  - Damage location, timing, type and response
  - Historical weather observations and NWP data
  - Demographics of affected area
  - Infrastructure impacted in affected area (e.g., poles, wires)
  - Ancillary environmental conditions (e.g., soil, trees)
- Build predictive model from environmental observations, storm impact, weather and related data

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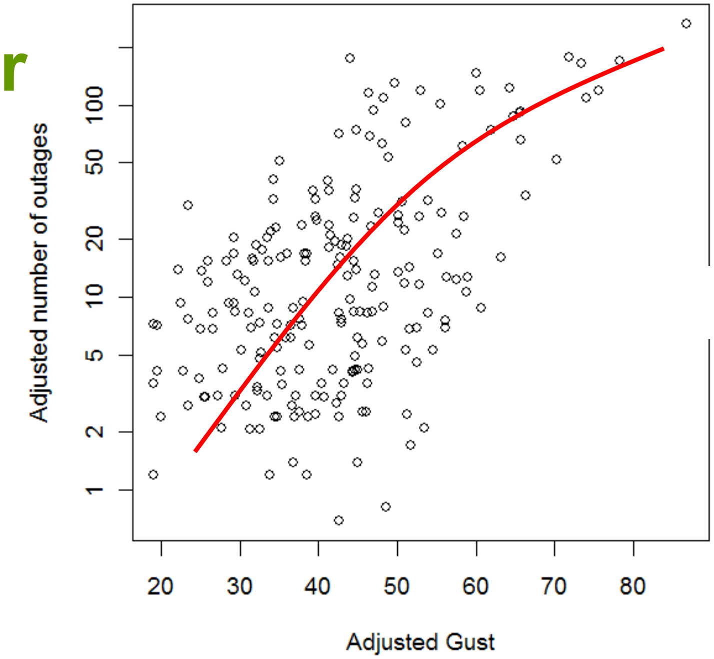
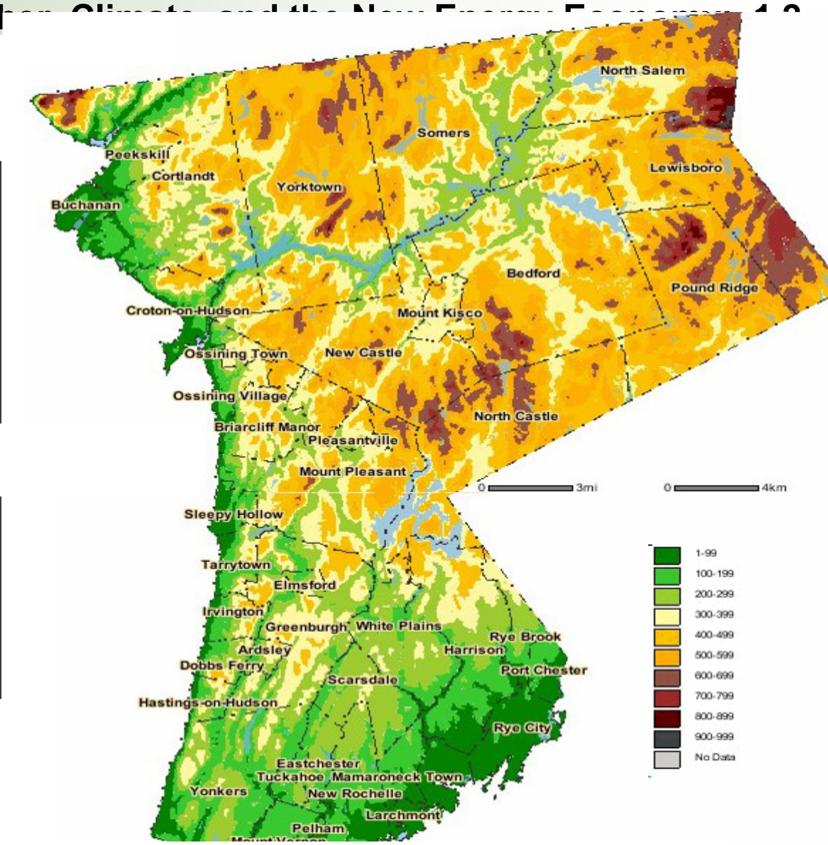
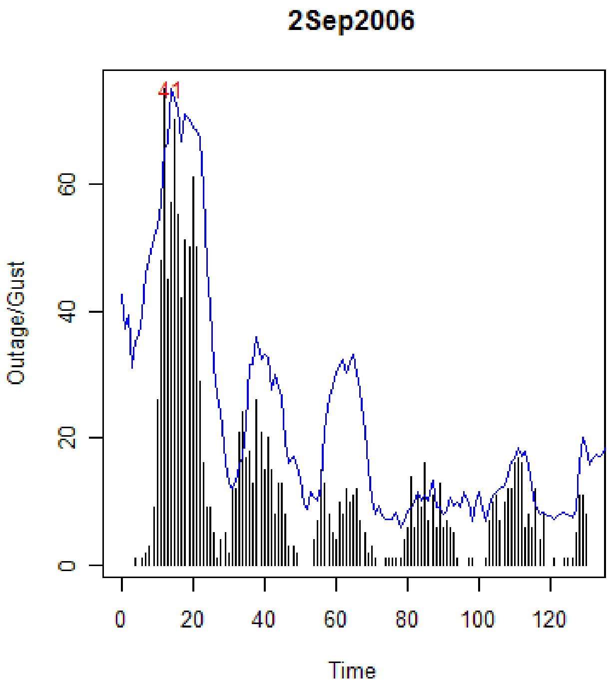
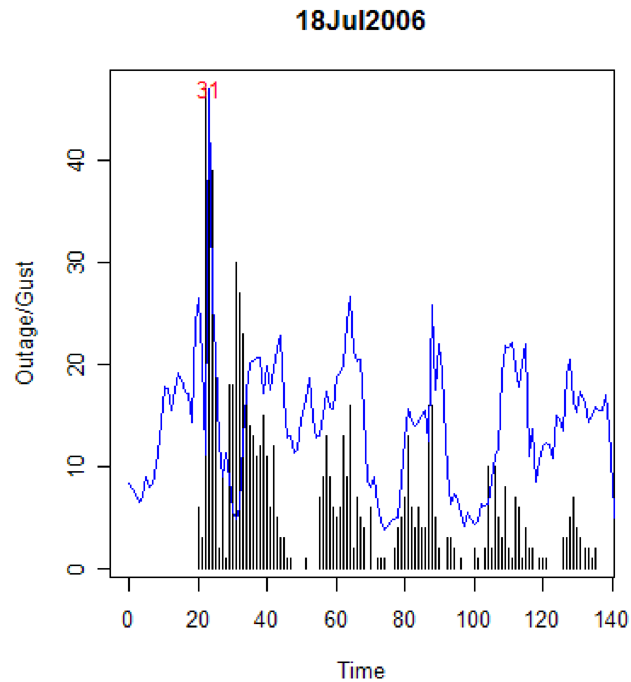
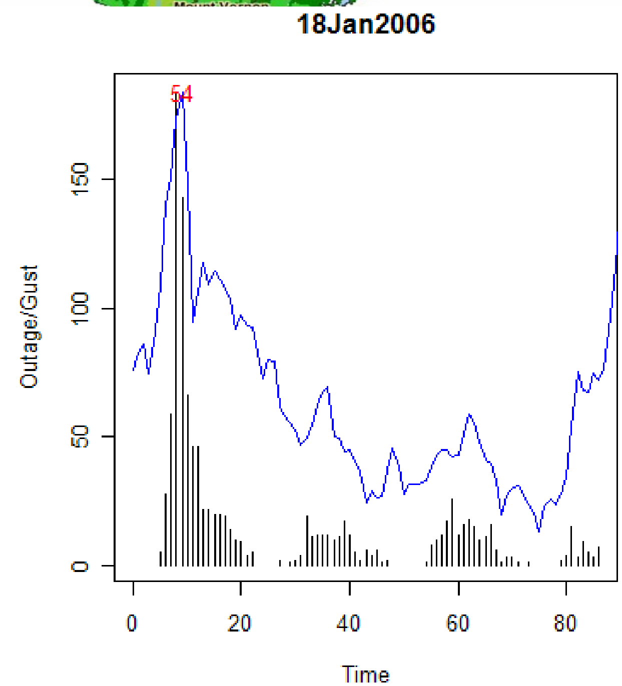
Wind Gusts Are a Primary Driver for Outages in this Service Territory











Implication of Gusts as a Driver for Outages

- **Storm-driven disruptions of the overhead electric distribution network (e.g., poles and wires) are caused by physical interaction of the atmosphere directly with that infrastructure or indirectly via nearby trees**
- **Reliable NWP at this turbulence scale with sufficient throughput for operational utilization is neither tractable from a computational perspective nor verifiable from observations**
- **Ensemble NWP cannot capture uncertainty related to impacts**
- **Therefore, outage prediction must be approached stochastically by post-processing NWP**
- **Since the relevant data and applications are inherently temporal and spatial, we use a Bayesian hierarchical model**

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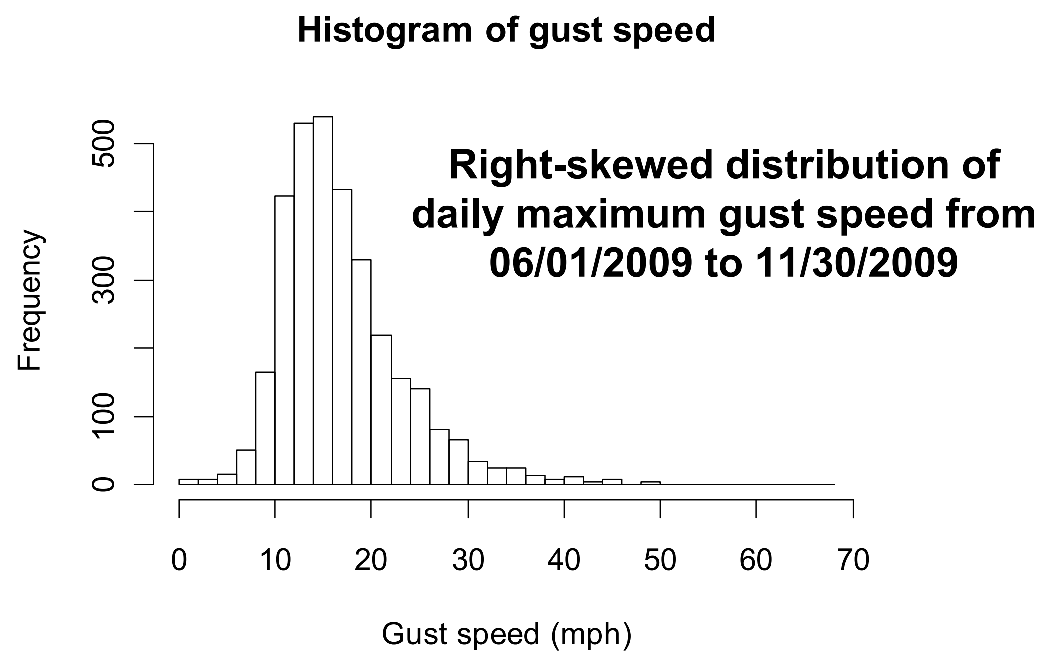
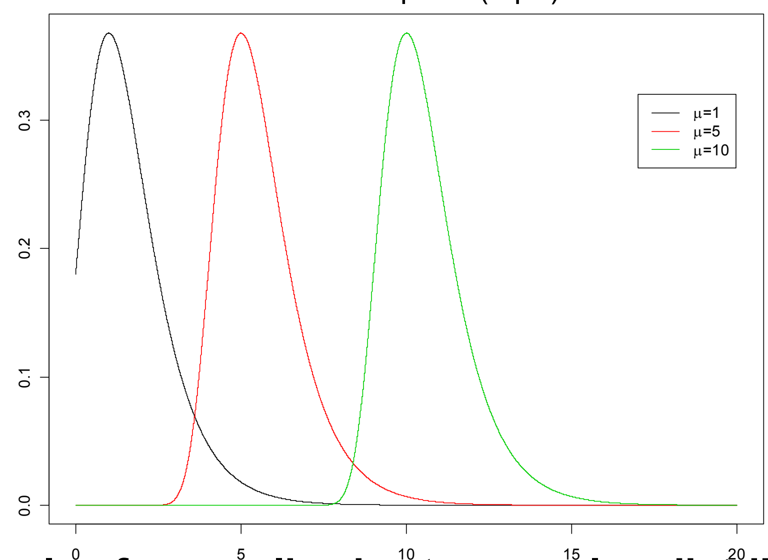
Modelling Extreme Values

- Distribution of daily maximum gust speed shows a highly right skewed tail which indicates a Gaussian distribution assumption does not hold
- Generalized extreme value (GEV) distribution have three parameters, μ, σ, ξ, which controls the location, scale and shape of a distribution, respectively
- Use a GEV distribution to model daily maximum gust speed given a daily maximum wind forecast, while location parameter and scale parameter are spatially correlated





Example of generalized extreme value distribution with location parameter varied

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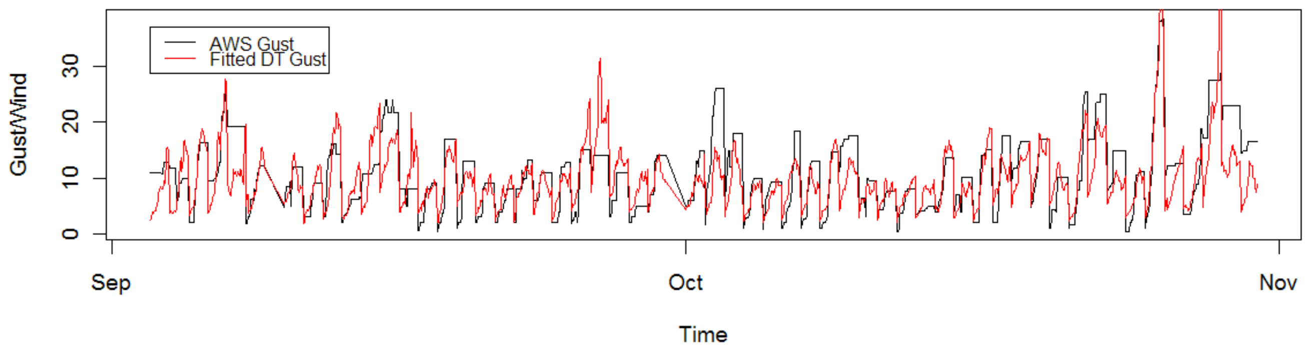
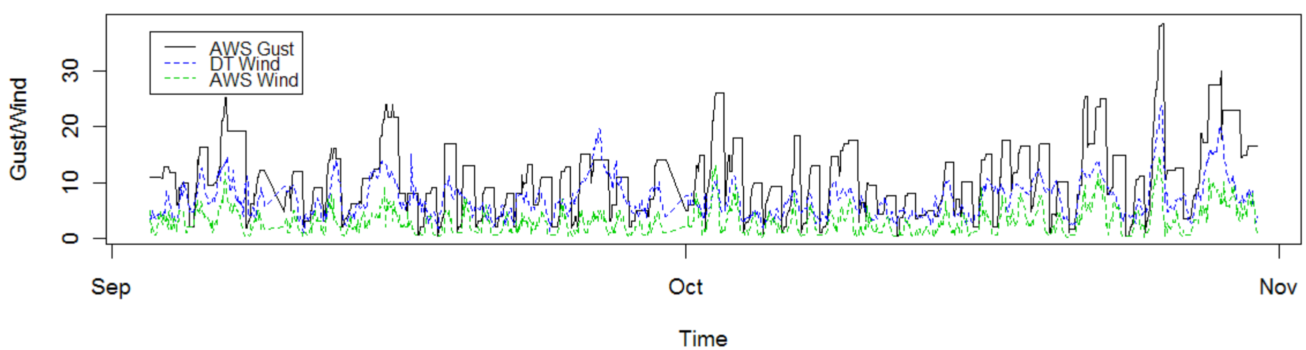
Issues with Wind Data and Example Results

- Gusts are measured as maximum wind speed in 2 seconds
- Sustained wind is averaged wind speed in 2 minutes, recorded as instantaneous
- Gust speed is updated only if the current 5-minute gust speed value exceeds the previous value and will be set as 0 at midnight of each day
- Therefore, gust speed is aggregated to daily maximum for modelling





Example Observed and Modelled Wind and Gust Speed (mph) for One Weather Station

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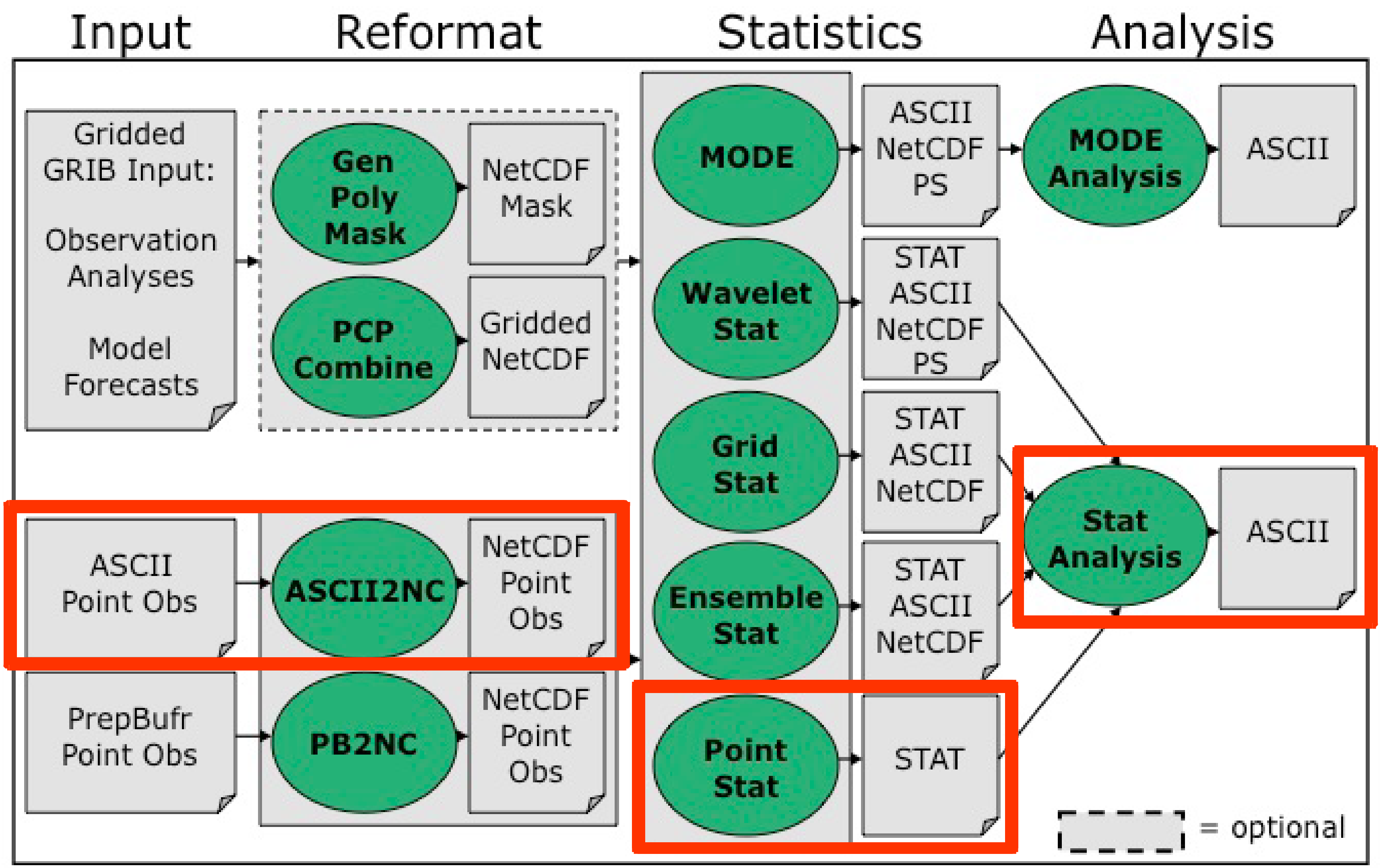
How MET 3.0 Is Used for Forecast Verification



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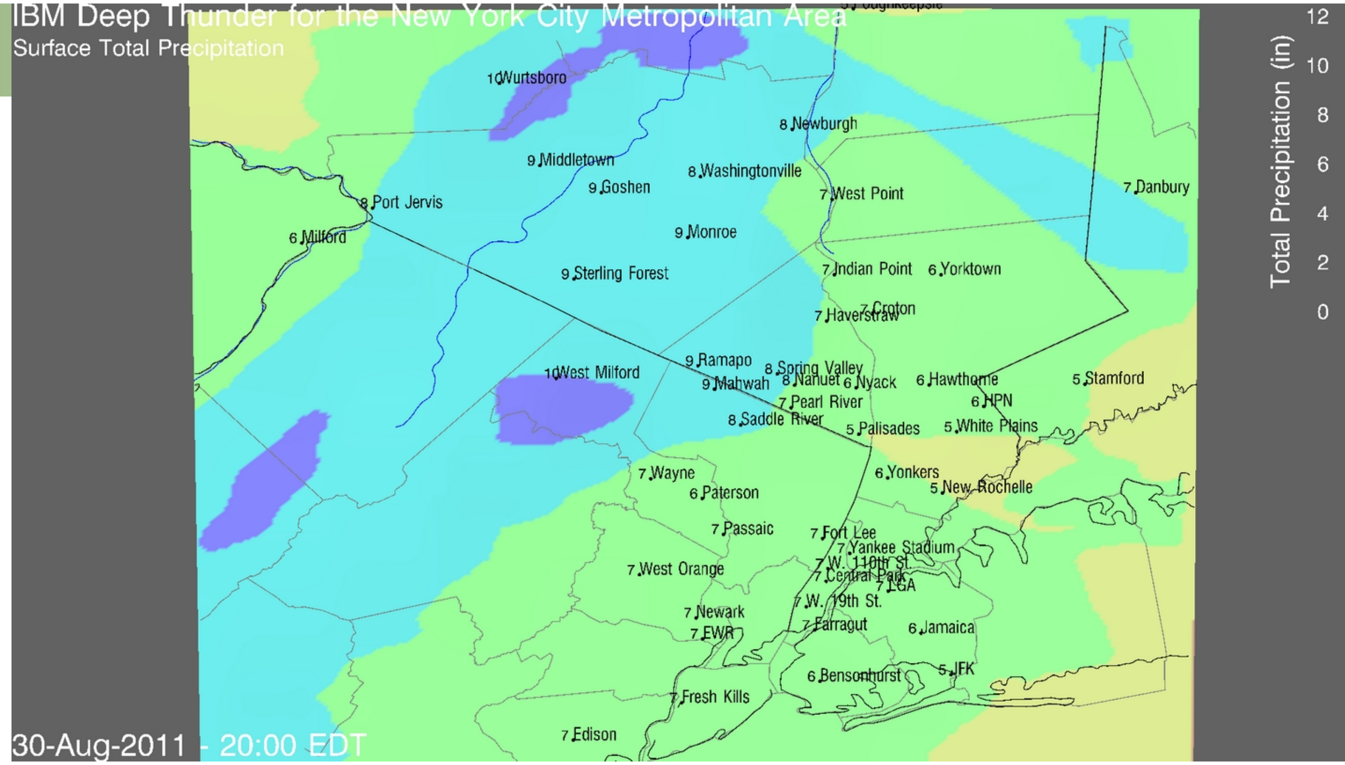
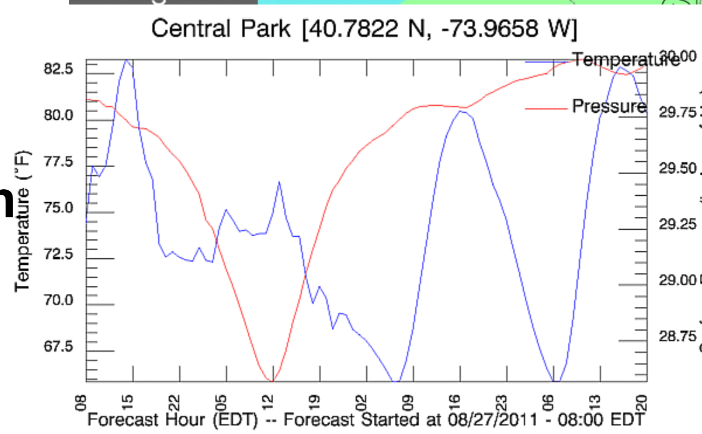
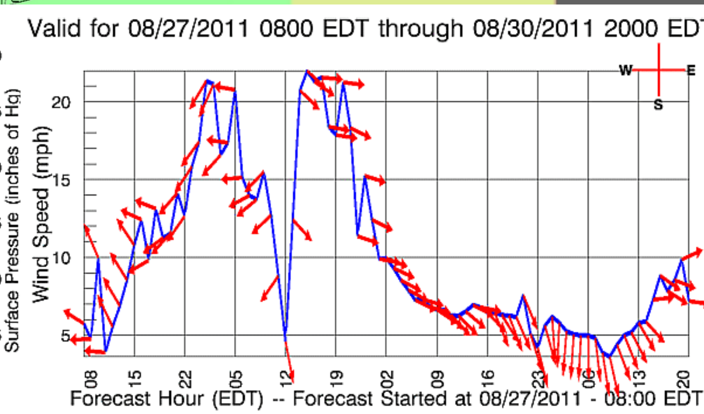
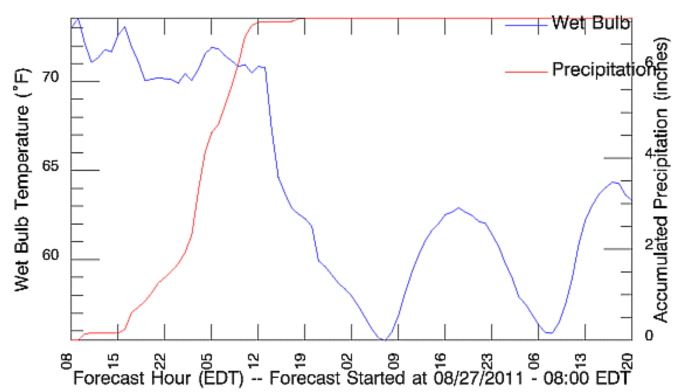
Deep Thunder New York Forecast for Tropical Storm Irene: Afternoon of 27 August 2011

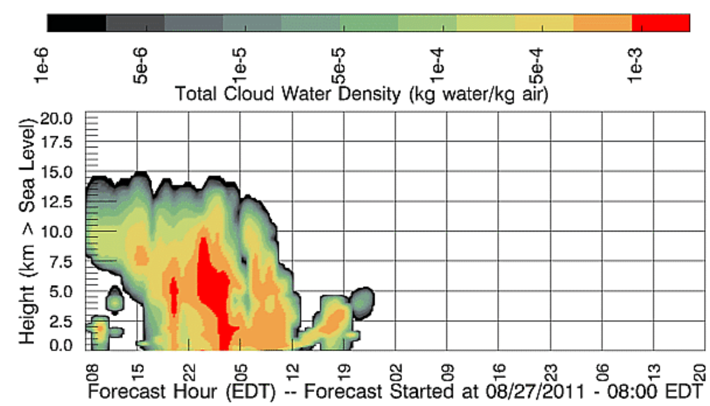
- Initiated with data from 0800 EDT on 8/27 with results available in the late afternoon
- Shows rainfall beginning in parts of New York City in the evening on 8/27 and ending the afternoon of 8/28
- Sustained winds in parts of New York City well below hurricane strength











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%

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Outage Model Verification

- "Weighted Accuracy": weighted by Forecast/Observed ("multiplicative bias")
- *Method A*
  - hit*probability + miss*probability + CN*probability + FA*probability = 1.0
  - Accuracy = SUM(hit+CN)/total + F(total)/O(total)
    - If (F > O) → Accuracy = SUM(hit+CN)/total + 1.0/(F(total)/O(total))
    - If (F <= O) → Accuracy = SUM(hit+CN)/total + F(total)/O(total)
  - New Accuracy = Accuracy/2.0
    - Perfect Score = 2.0
- *Method B*
  - hit*probability + miss*probability + CN*probability + FA*probability = 1.0
  - Accuracy = SUM(hit+CN)/total * F(total)/O(total)
    - If (F > O) → Accuracy = SUM(hit+CN)/total * 1.0/(F(total)/O(total))
    - If (F <= O) → Accuracy = SUM(hit+CN)/total * F(total)/O(total)
    - Perfect Score = 1.0

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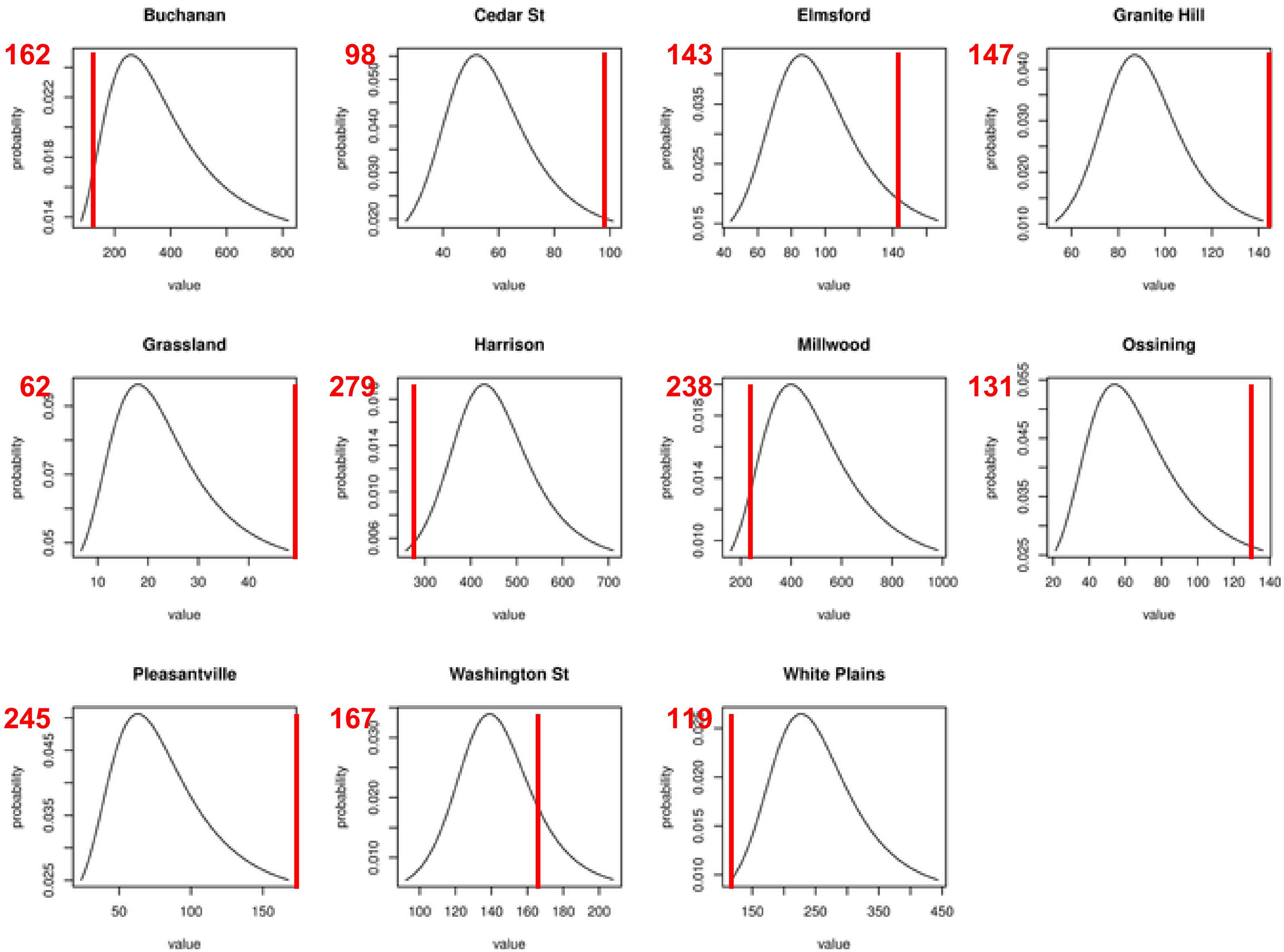
Tropical Storm Irene Deep Thunder Impact Forecast

Deep Thunder Substation Job Probability Curves for 2011-08-27, Day 2



Initiated with data from 0800 EDT on 8/27 with results available in the late afternoon

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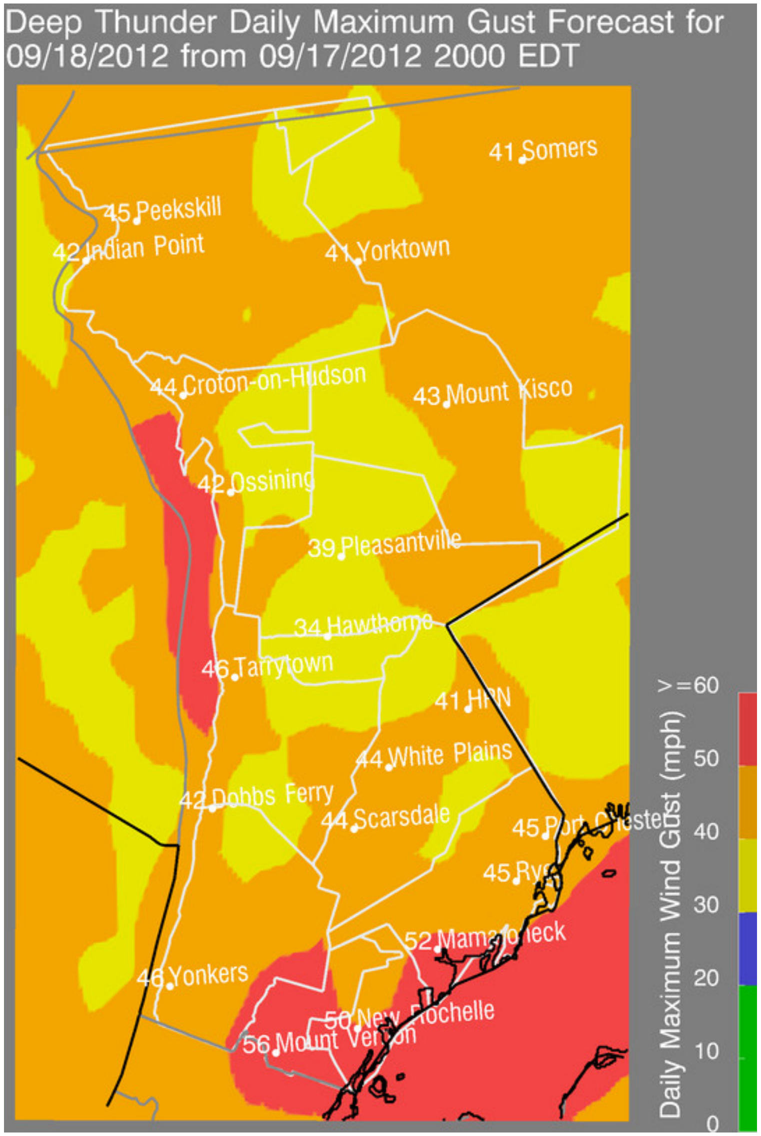
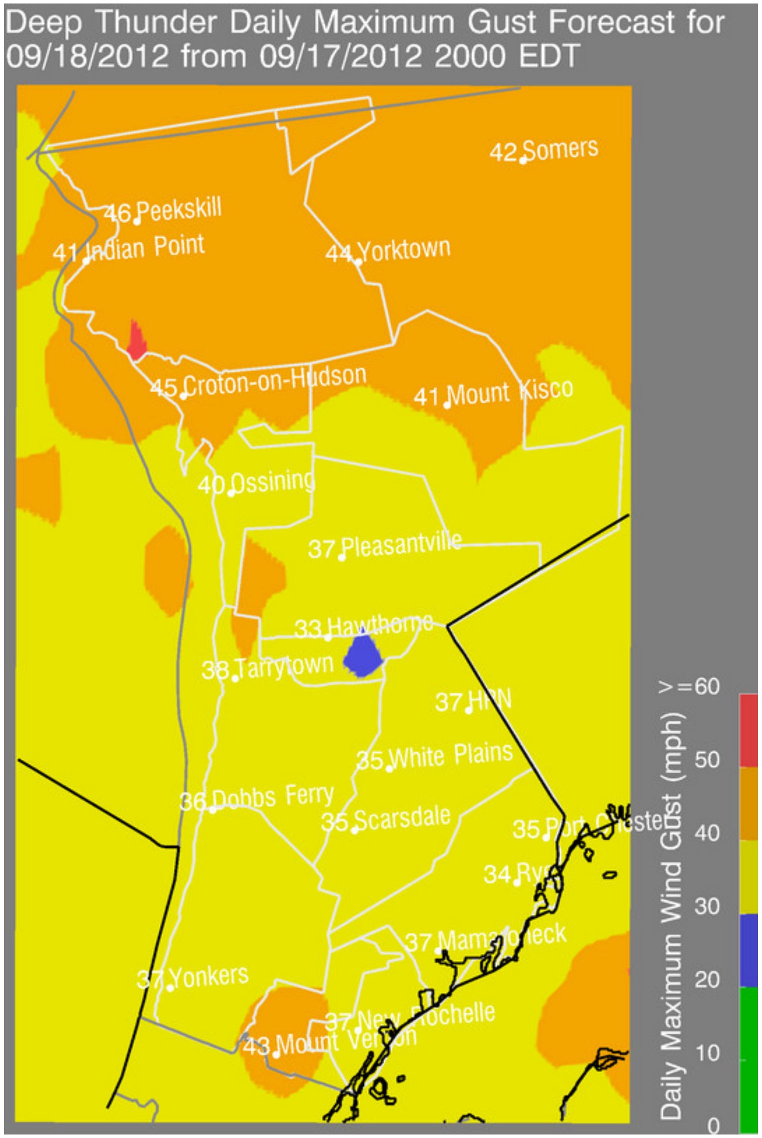
Gust Estimates Driven by the Two Weather Models: Example – 18 September 2012 00 UTC



Current Version



April 2009 – October 2012 Version

White Plains:
47mph at 1554

Croton-on-Hudson
45 mph at 1552

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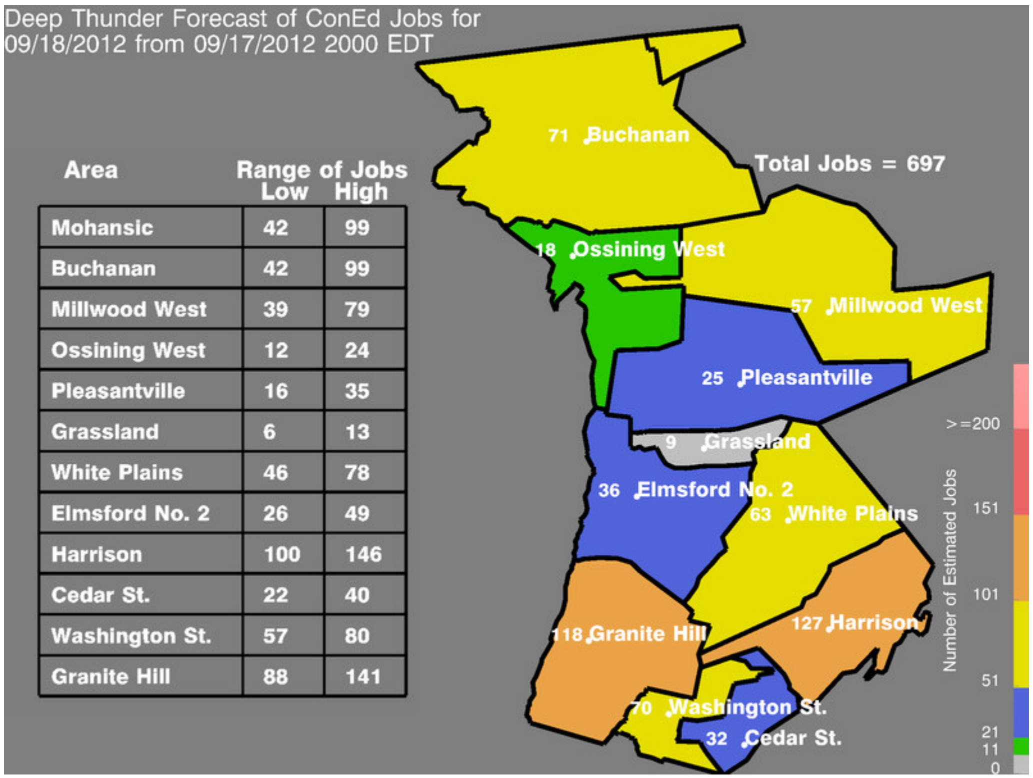
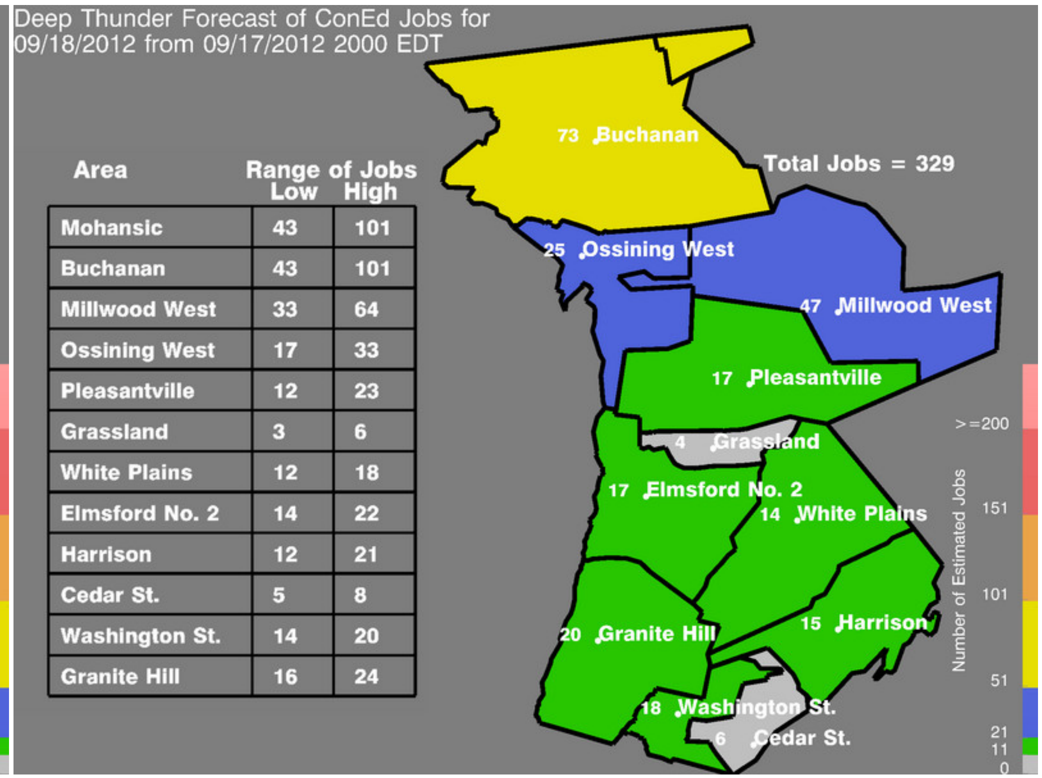
Job Estimates Driven by the Two Weather Models: Example – 18 September 2012 00 UTC



Area	Range of Jobs Low	Range of Jobs High
Mohansic	42	99
Buchanan	42	99
Millwood West	39	79
Ossining West	12	24
Pleasantville	16	35
Grassland	6	13
White Plains	46	78
Elmsford No. 2	26	49
Harrison	100	146
Cedar St.	22	40
Washington St.	57	80
Granite Hill	88	141

Current Version



Area	Range of Jobs Low	Range of Jobs High
Mohansic	43	101
Buchanan	43	101
Millwood West	33	64
Ossining West	17	33
Pleasantville	12	23
Grassland	3	6
White Plains	12	18
Elmsford No. 2	14	22
Harrison	12	21
Cedar St.	5	8
Washington St.	14	20
Granite Hill	16	24

April 2009 – October 2012 Version

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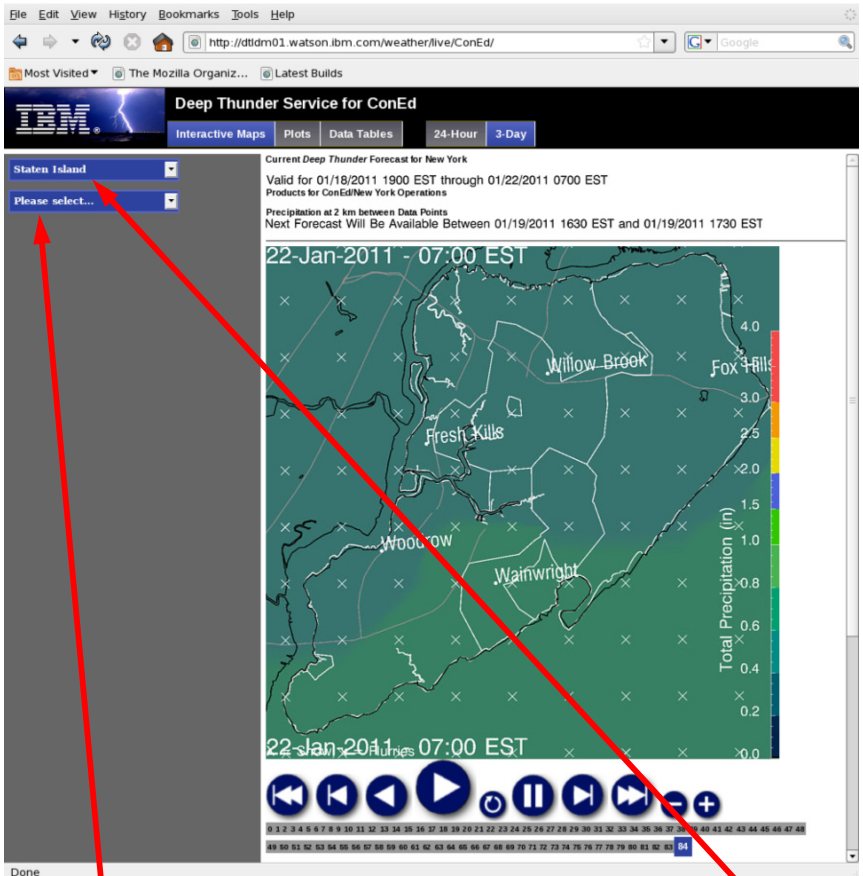
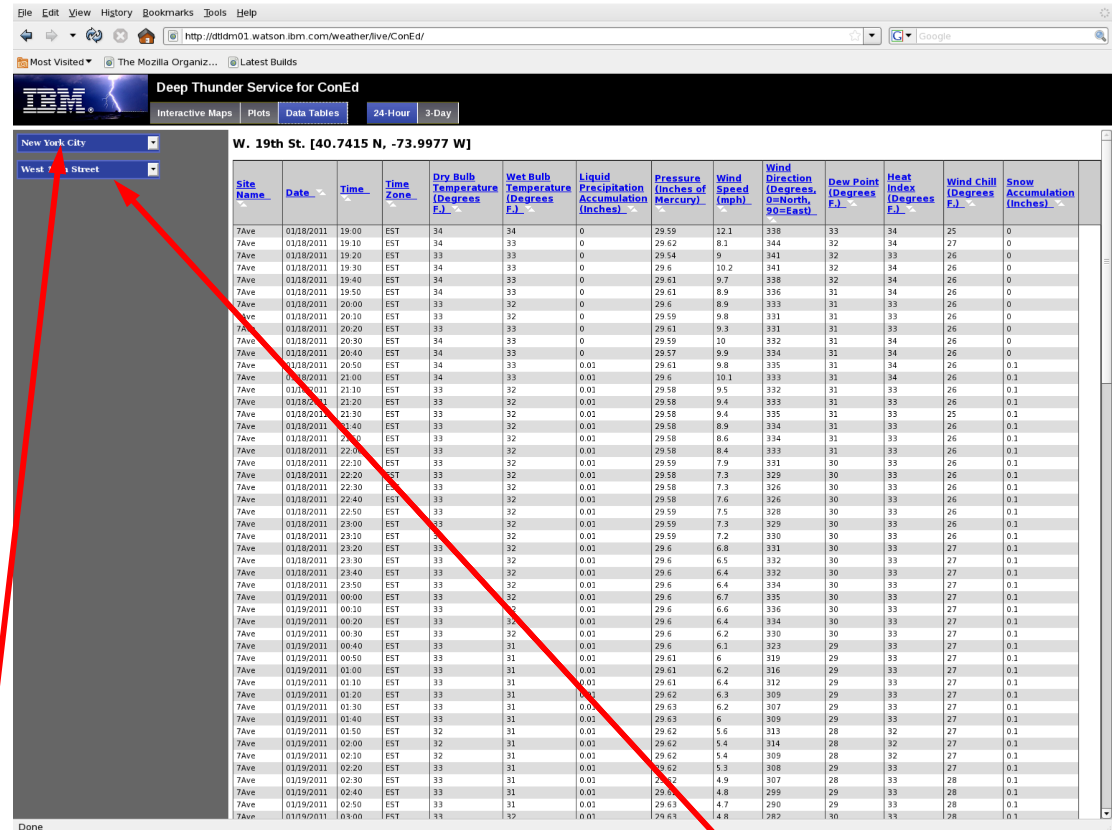
Web Interface for Consolidated Edison





Temperature Animation

Interactive Site-Specific Forecast Table

Selection of Geographic Area (7 Choices)

Site Selection

Selection of Animation Variable (Dry Bulb, Wet Bulb, Precipitation, Wind)

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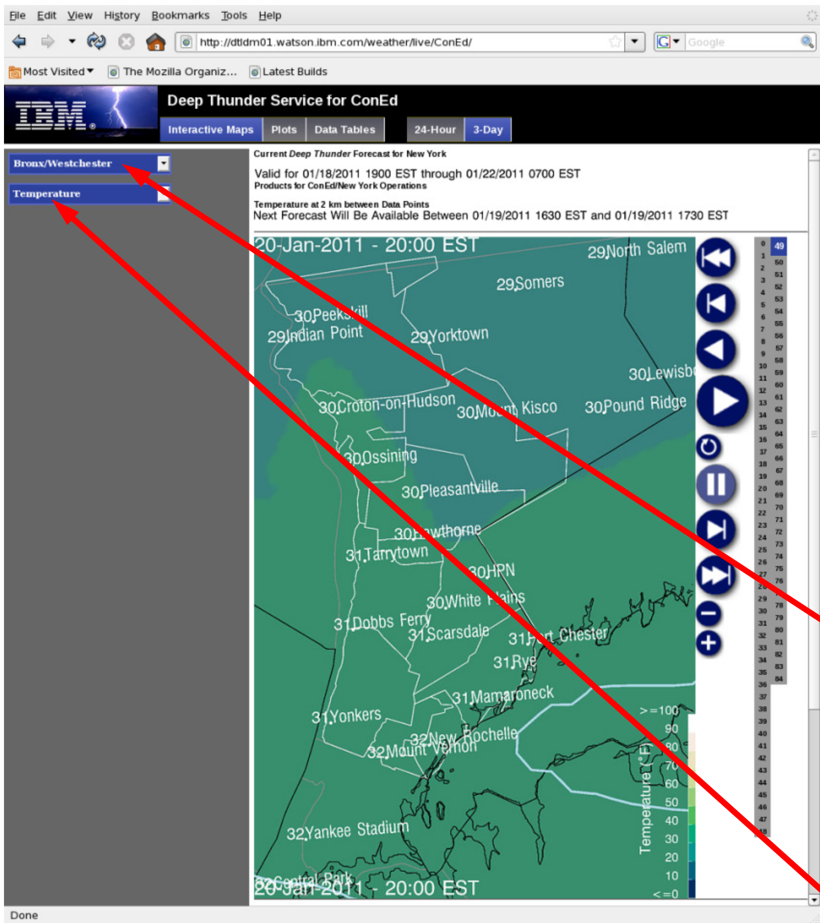
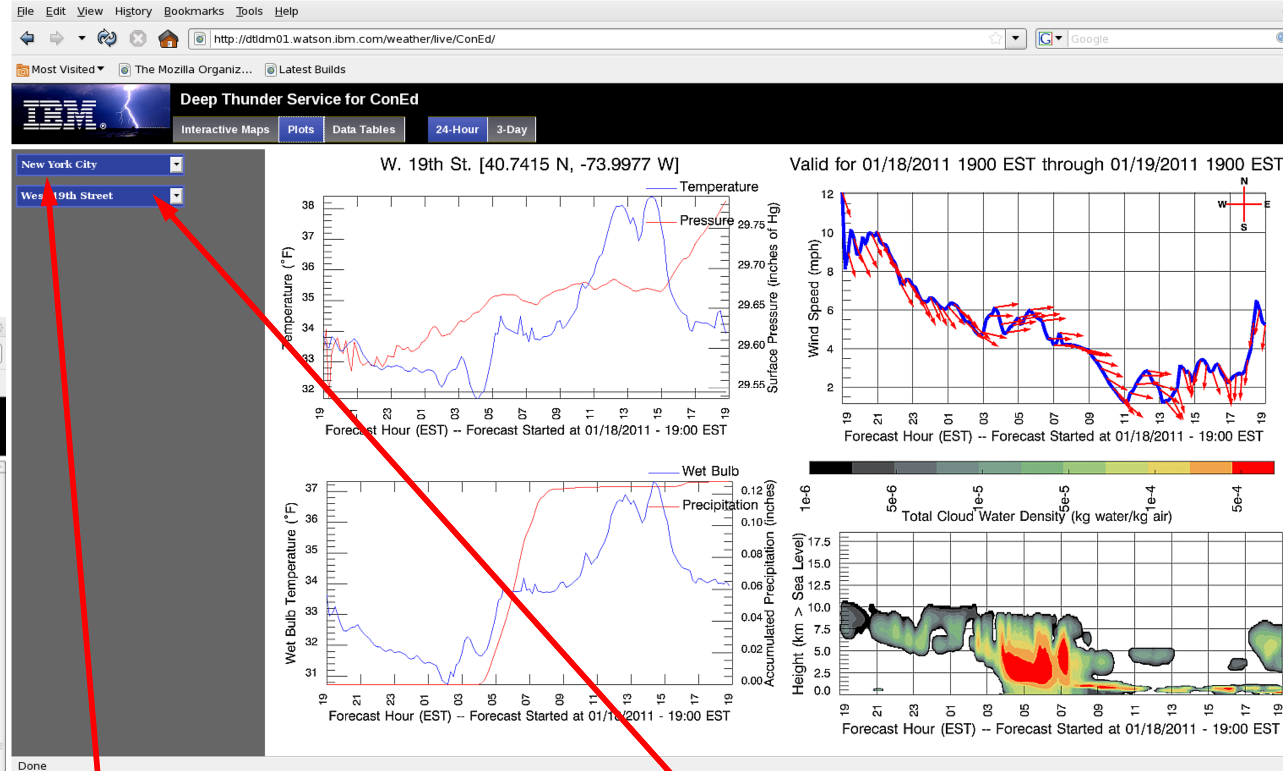
Web Interface for Consolidated Edison



Surface Temperature Animation



Site-Specific Forecast Plots

Selection of Geographic Area (7 Choices)

Site Selection

Selection of Animation Variable (Dry Bulb, Wet Bulb, Precipitation, Wind, Gust and Outage Jobs)

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