Design and Deployment of Specialized Visualizations for Weather-Sensitive Electric Distribution Operations

Lloyd A. Treinish

IBM, Yorktown Heights, NY

lloydt@us.ibm.com

http://www.research.ibm.com/weather/DT.html

Design and Deployment of Specialized Visualizations for Weather-Sensitive Electric Distribution Operations

- Background and motivation
- Visualization issues
- Approach
- Example results
- Discussion and future work

Other Presentations of Related Work

- **1.6 *Development and Deployment of a Mesoscale Weather and Outage Prediction Service for Electric Utility Operations* (Symposium on Urban High Impact Weather)**
- **P1.7 *A Spatial Model for the Prediction of Electrical Power Outages Caused by Severe Storms* (Symposium on Urban High Impact Weather)**
- **12B.2 *Estimating high-resolution near-surface forecast uncertainty to support optimization of resources* (13th Conference on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface)**
- **JP5.4 *Application of an operational meso-scale modelling system for commercial/industrial plant operations* (Eighth Symposium on the Urban Environment Symposium)**
- **P1.3 *Urban Flood Forecasting using an Integrated Hydrometeorological System* (Symposium on Urban High Impact Weather)**

Background and Motivation

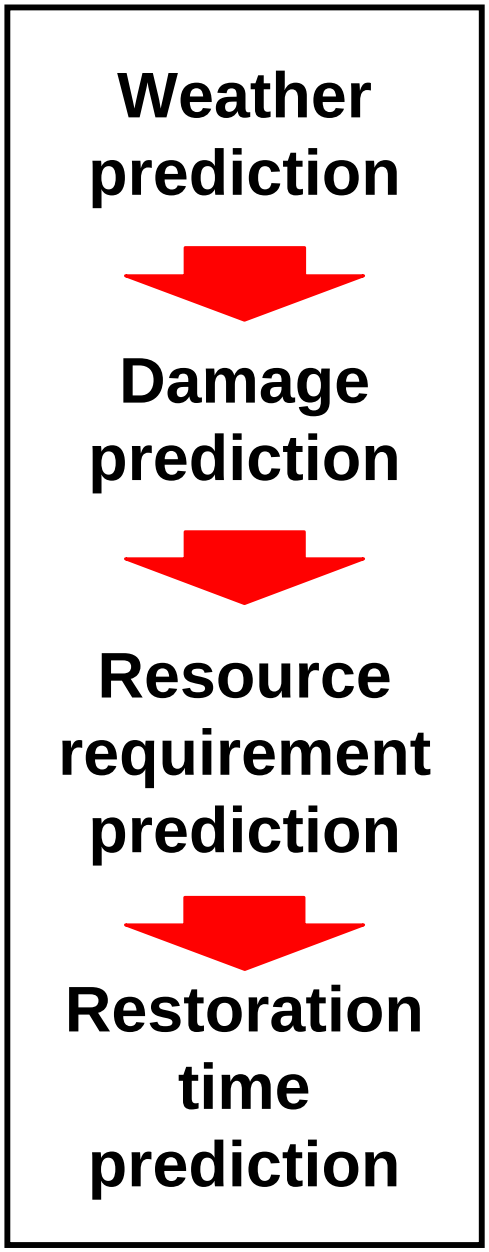
- The operation of the distribution system of an electric utility, particularly with an overhead infrastructure, can be highly sensitive to local weather conditions

- For predictions of such conditions to be useful for decision makers, the information must be disseminated in a timely fashion that enables effective decisions to be made with confidence

  - Visualization is a critical but it requires appropriate designs to permit interpretation as part of operational planning prior to a severe storm event

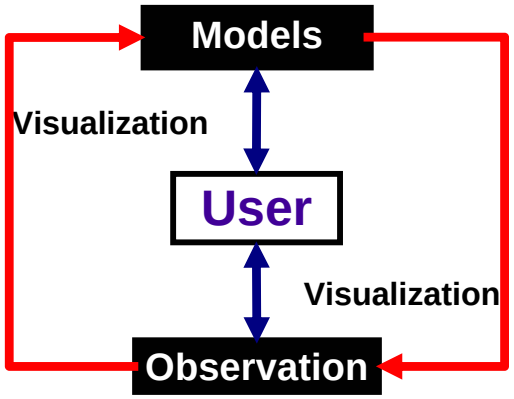
Storm Impact and Response Prediction

- Weather causes damage and outages
- Outages require restoration (resources)
- Restoration takes time, people, etc.
- Build stochastic model from weather observations, storm damage and related data, and couple it to either NWP or observations
  - Outage location, timing and response
  - Wind, rain, lightning and duration
  - Demographics of effected area
  - Ancillary environmental conditions
- How can the results of such a model be disseminated as forecast of impact to plan effective responses?



One Person's Emergency May Be Another's Routine

"Emergency Response Schema" *



* (based upon experience, e.g., scenario training)

"Weather" Visualization

Assess

Attention: (Filter on Relevance) Use or Ignore

Action

Request

Monitor and Evaluate

Decision Making Process / Workflow

Many tasks are involved in how one examines and assesses a situation, obtains and interprets information, and communicates with others.

Visualization Issues

- Traditional meteorological visualization is driven by data for analysis -- inappropriate for decision support applications
- Traditional business visualization is driven by methods for tabular data – inappropriate for meteorological data
- Timely and effective usability requires the visualization designer to
  - Understand how experienced people use their expertise in decision making, and how they work and interact
  - Avoid an impedance mismatch between the data vs. how the data should be utilized
  - Identification of user goals, which are mapped to visualization tasks and to data
  - Design in terms relevant for user, employing familiar terminology and metaphors -- readily understood in real-time without expert interpretation and used with confidence
  - Understanding how users perceive and interpret visualizations

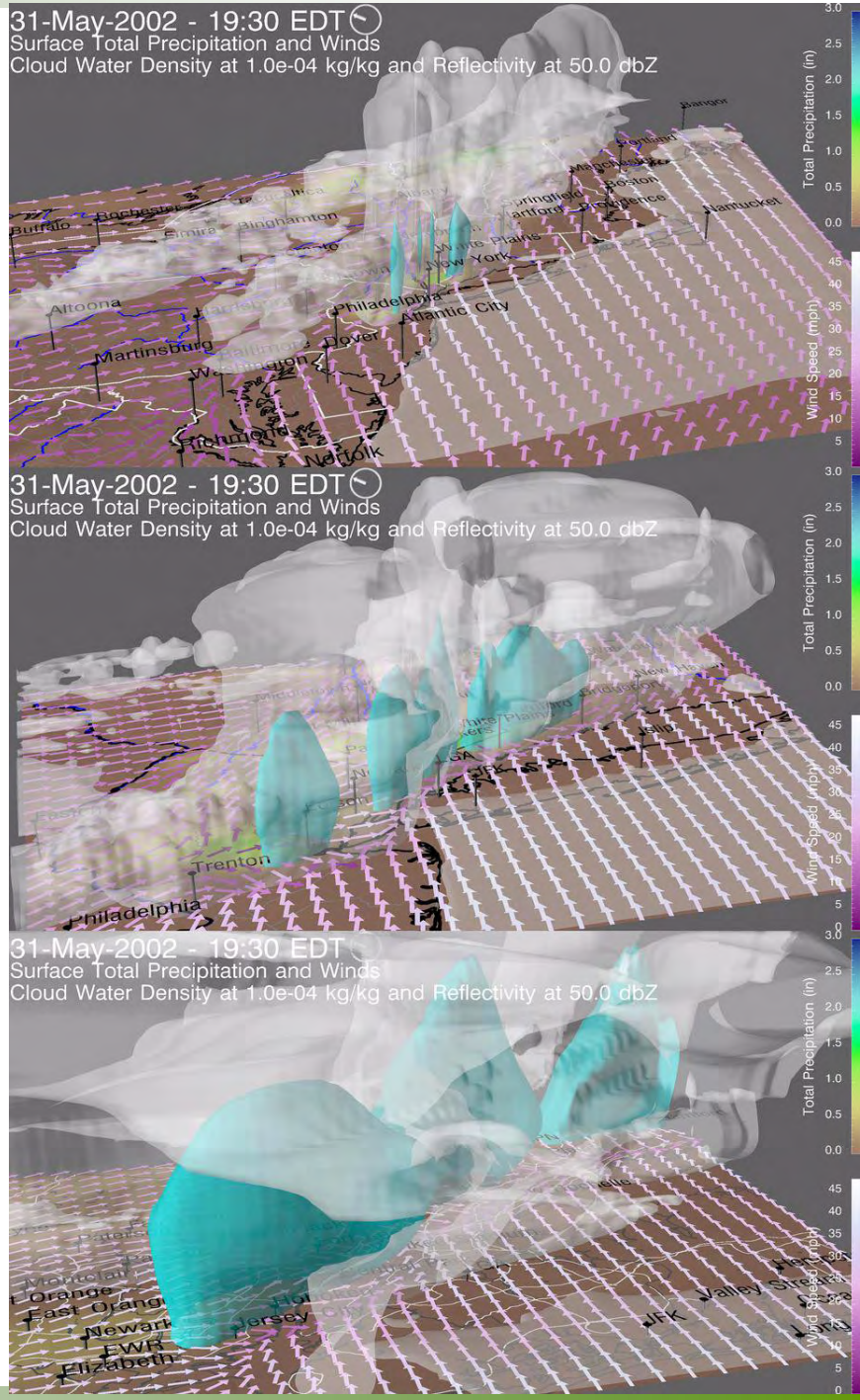
Disciplines Needed for Effective Visual Design

(Understand Limitations in Content and Interpretation)

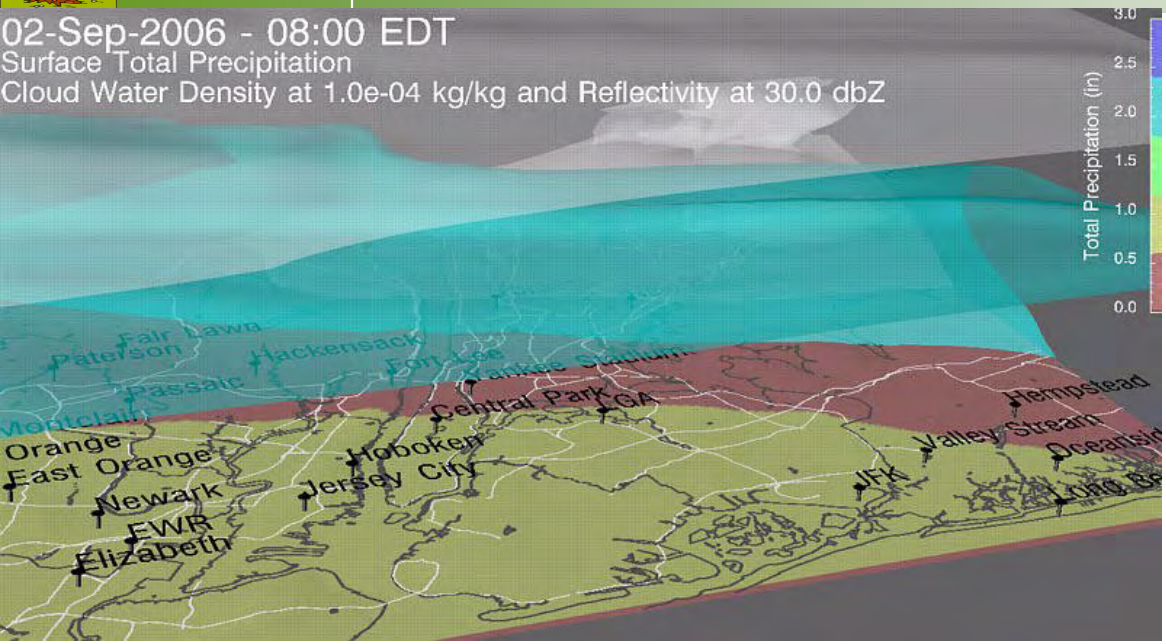
- **Meteorology**
  - Preserve data fidelity (and science)
- **Psychophysics and human vision**
  - Perceptual rules for use of color, geometry, texture, etc.
- **Cartography**
  - Rules for use of projections (i.e., making appropriate maps)
- **Computer graphics**
  - Algorithms for transformation, realization, rendering, etc.
- **Workflow and decision-making process**
  - Human factors, systems engineering, etc.

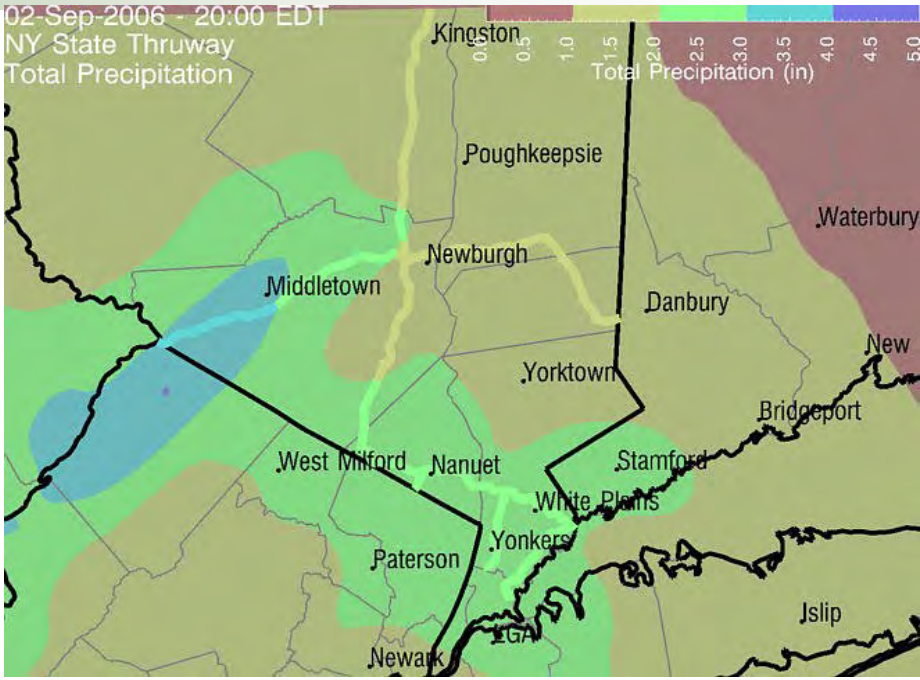
Dissemination Requirements

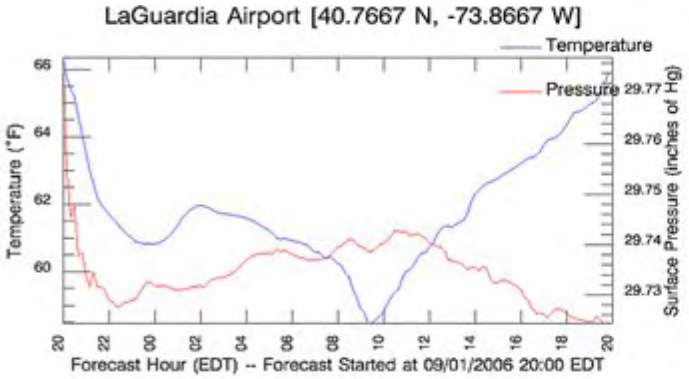
- **Tailored weather visualizations available via a web browser, which are automatically updated for each forecast cycle**
- **Storm classification and outage estimation**
- **Uncertainty visualization for operational decision making**

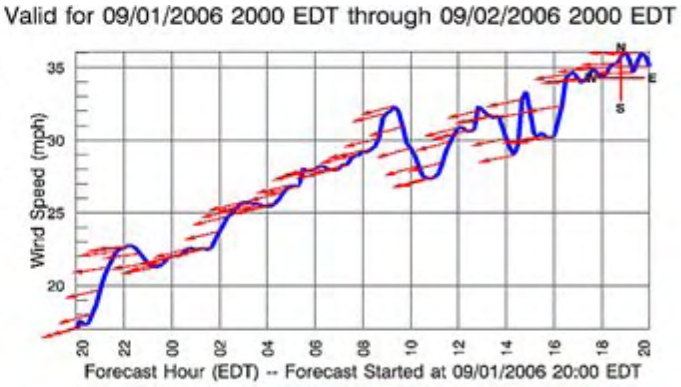


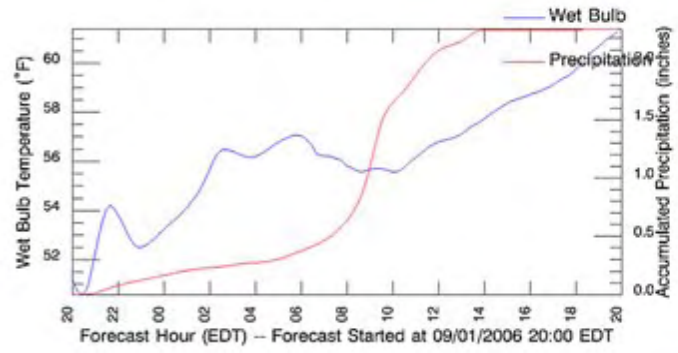
Project began with capabilities already in place for various 3d and 2d visualizations

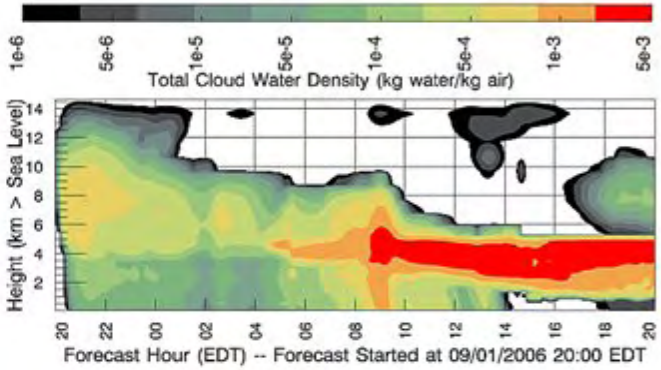












Project began with capabilities already in place for various 3d and 2d visualizations

Common Themes

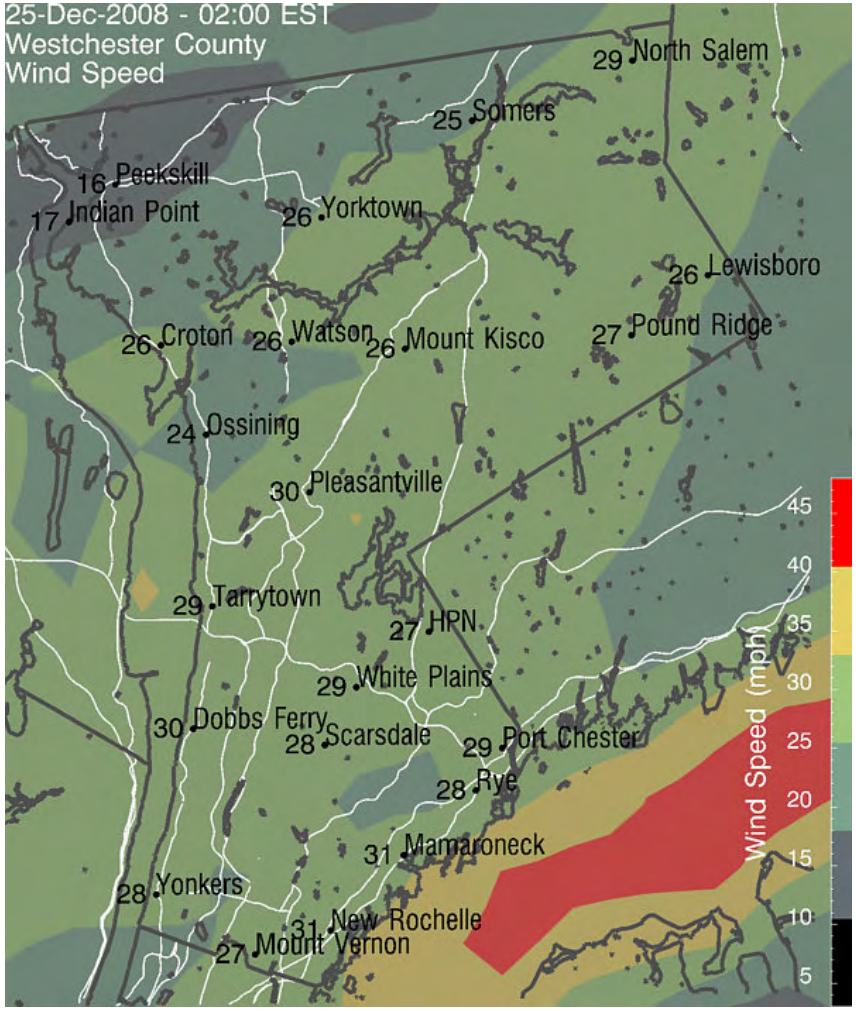
- **Ease of use by diverse users who**
  - **are experts in utility operations, emergency management and weather impact**
  - **are not meteorologists, mathematicians or computer scientists**
- **Enable proactive decision making affected by weather**
  - **Rapid assessment important (visualizations may need to be almost pre-attentive)**
  - **Thresholds often more important than overall content**
  - **Addressing uncertainty in results when available**
- **Customized appearance and fused with ancillary data**
  - **Appropriate utilization of visualization elements (e.g., geometry, color)**
  - **Consistency with data**
  - **Incorporation of information concerning the distribution network**
  - **Cartographic reprojection to minimize spatial distortion**
- **Presentation of derived properties critical to decisions**
  - **Weather or secondary physical phenomena may not be shown**

Visualization Tasks for Tailored Content

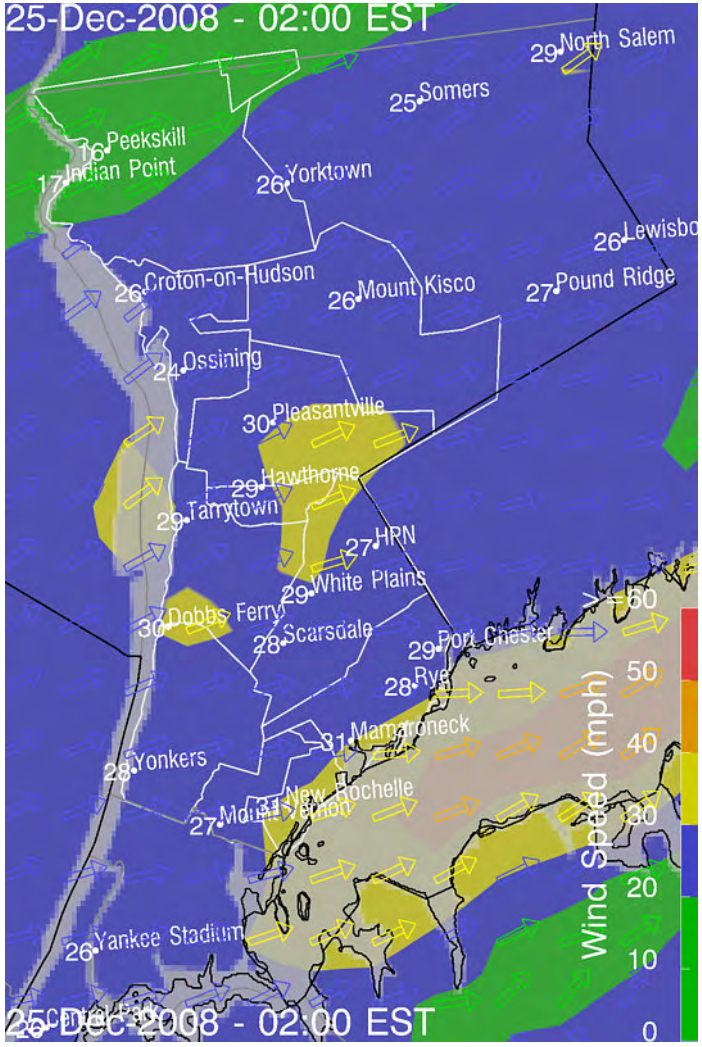
- **Direct results from the weather model**
- **Derived results from the weather model (indirect)**
- **Direct results from the damage model (derived)**

Examples of each and how the designs evolved

Forecasted Surface Winds



Equal Area Projection



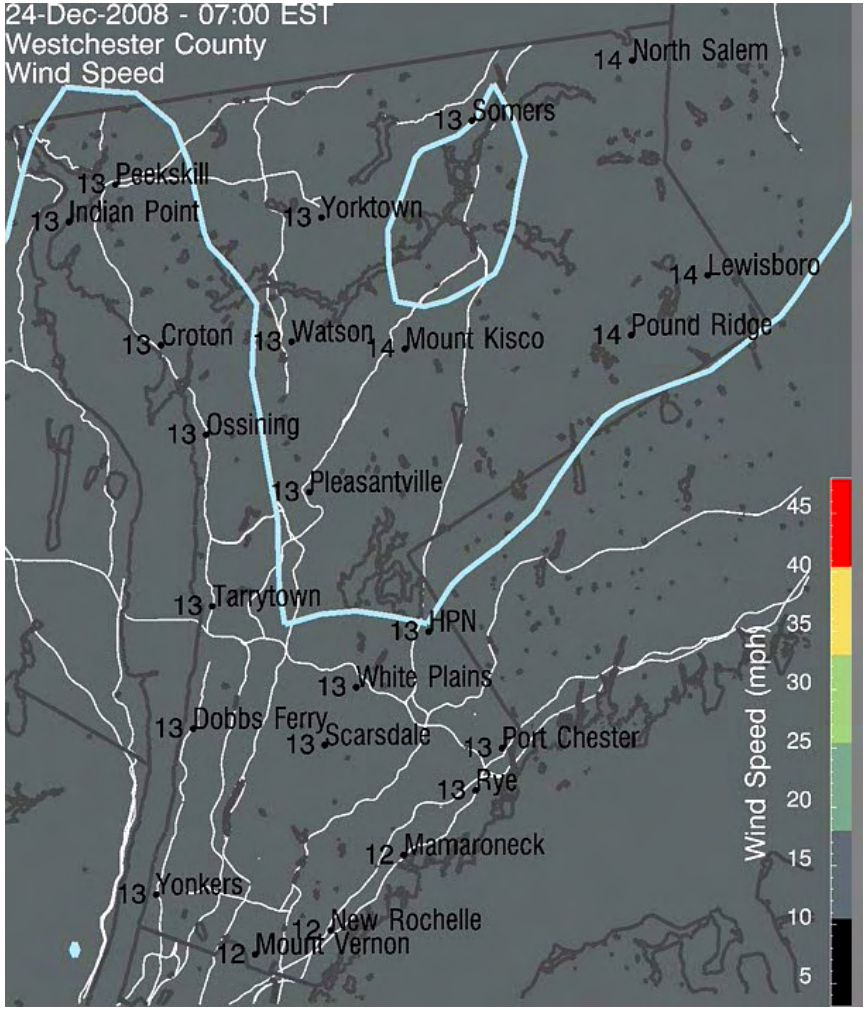
Original:

- **Magnitude only**
- **Colormap with perceptual ordering**
- **Full precision visible, but varies with each forecast**

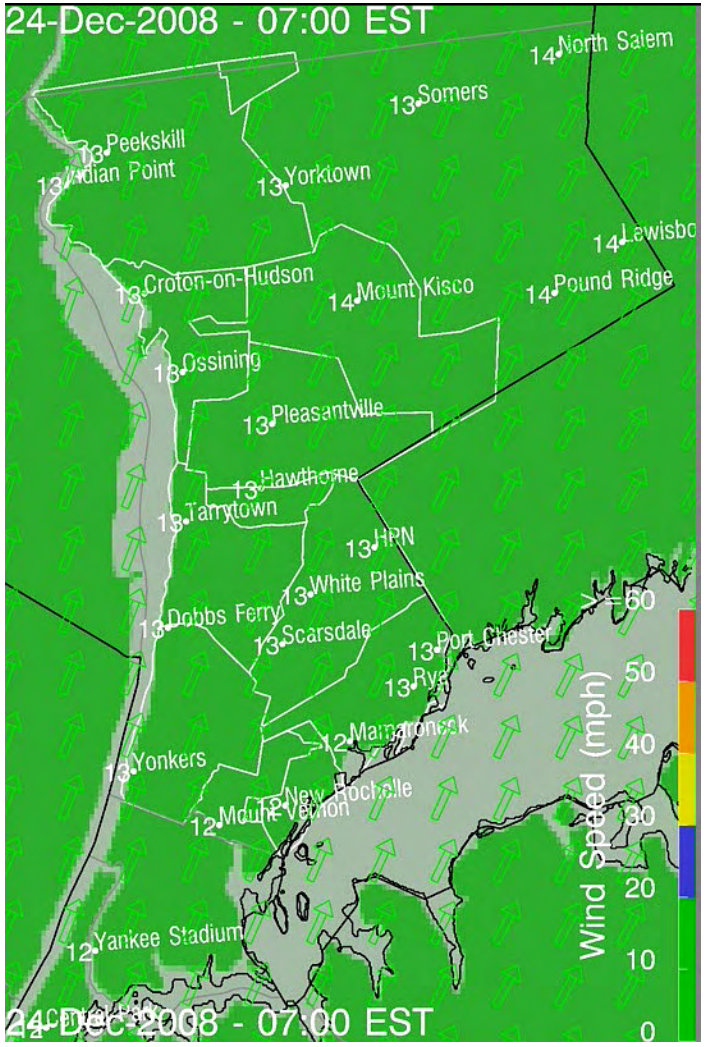
Final:

- **Emphasis on magnitude with directional overlay**
- **Fixed (familiar colormap), following DHS scale but less saturated**
- **Less precision visible but semantic association with color with user-defined thresholds**

Forecasted Surface Winds



Equal Area Projection



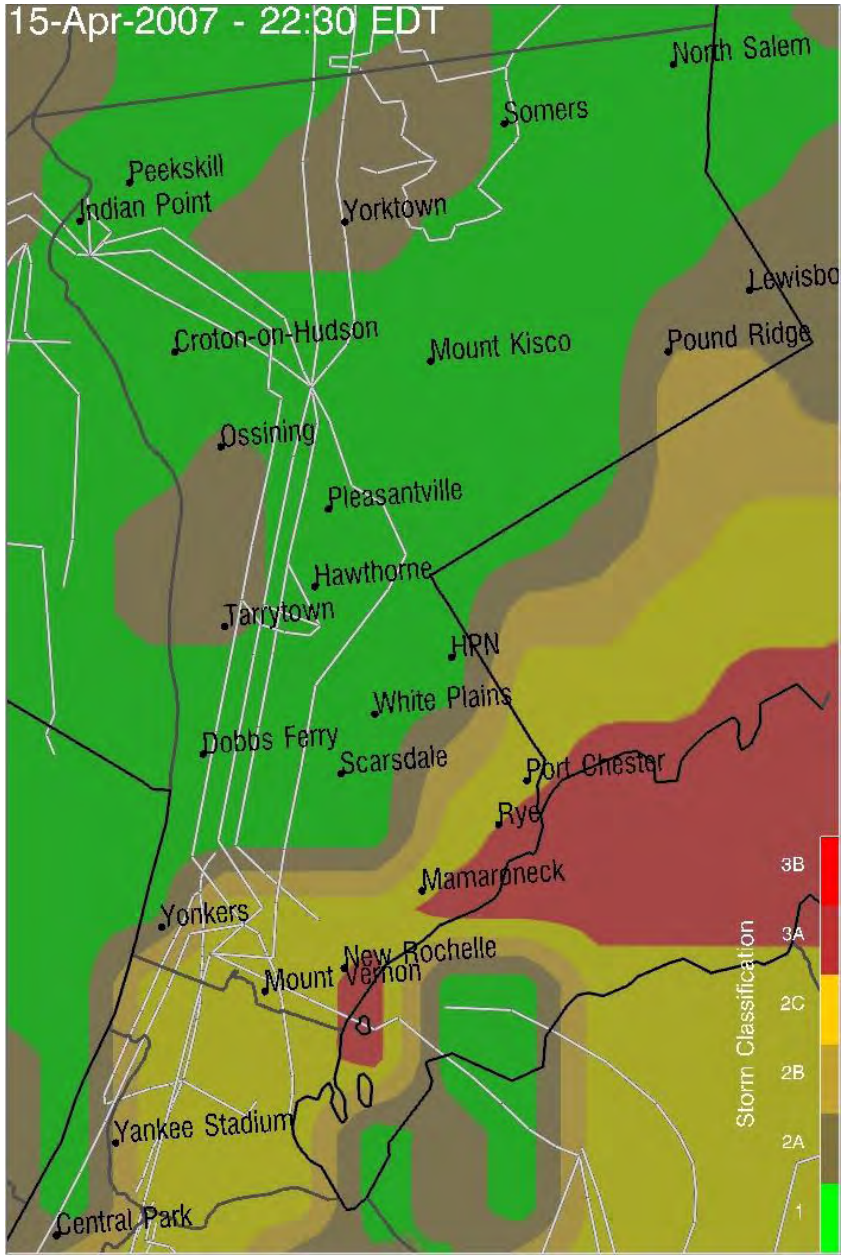
Original:

- **Magnitude only**
- **Colormap with perceptual ordering**
- **Full precision visible, but varies with each forecast**

Final:

- **Emphasis on magnitude with directional overlay**
- **Fixed (familiar colormap), following DHS scale but less saturated**
- **Less precision visible but semantic association with color with user-defined thresholds**

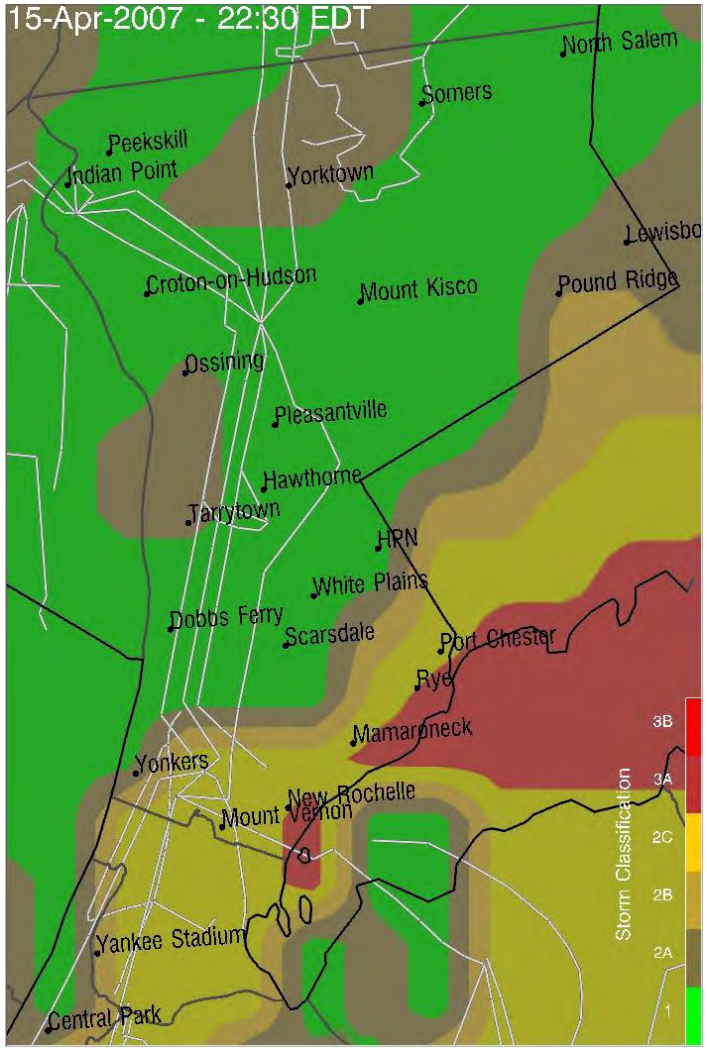
Deep Thunder Storm Classification -- 15 April 2007



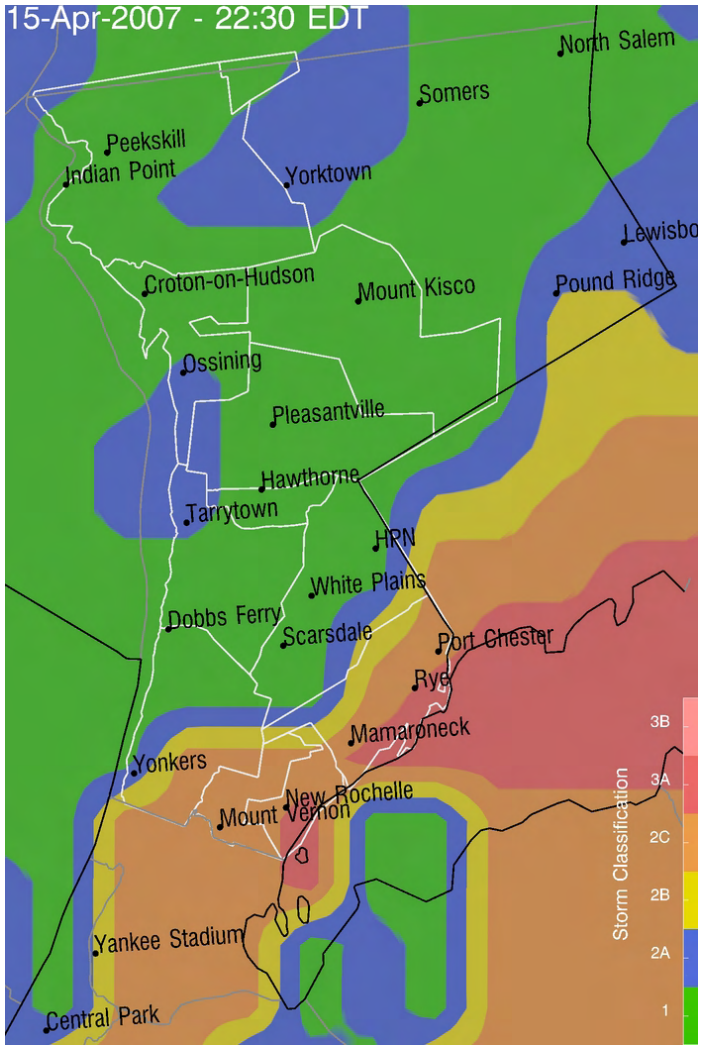
Storm Category/Plan and Number of Customers Out of Service

1. **Upgraded (e.g., thunderstorms), < 7000**
2. **2A. Serious (e.g., heavy thunderstorms), 7000-9000**
3. **2B. Serious, 9000-12000**
4. **2C. Serious, 12000-15000**
5. **3A. Full Scale (e.g., severe storm), 15000-40000**
6. **3B. Full Scale (e.g., hurricane), > 40000**

Deep Thunder Storm Classification -- 15 April 2007



Equal Area Projection



<u>Original</u>:

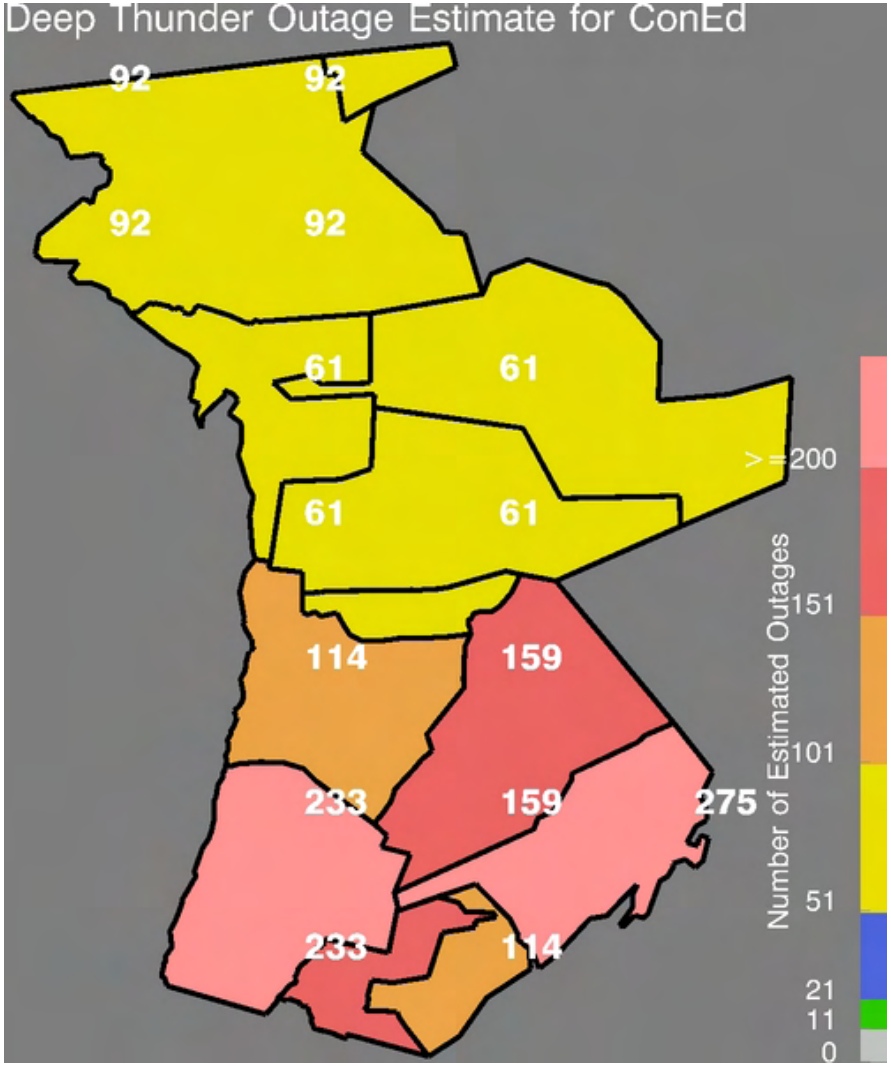
- **Colormap with Perceptual Ordering**
- **Overhead transmission lines Overlay**

<u>Final</u>:

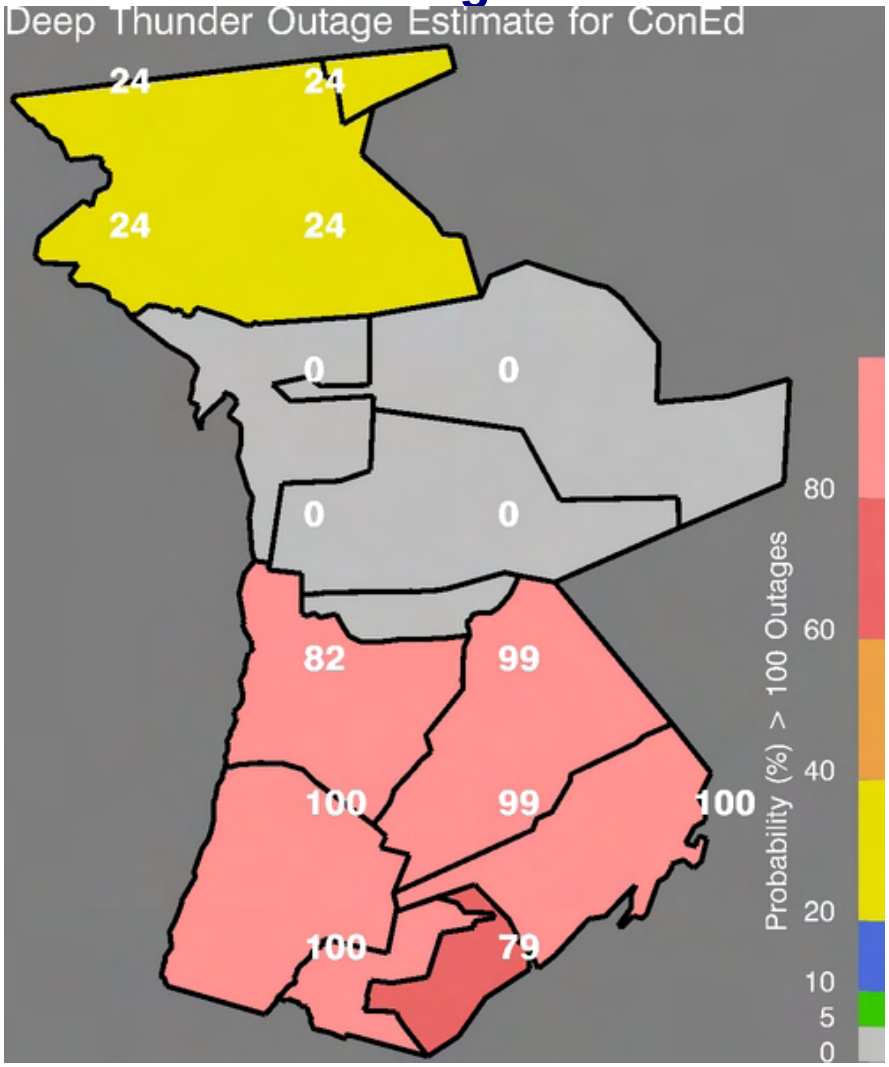
- **Fixed (familiar colormap), following DHS scale but less saturated and an additional level**
- **Area substation Overlay**

Deep Thunder Damage Prediction – 02 September 2006

Forecasted Outages

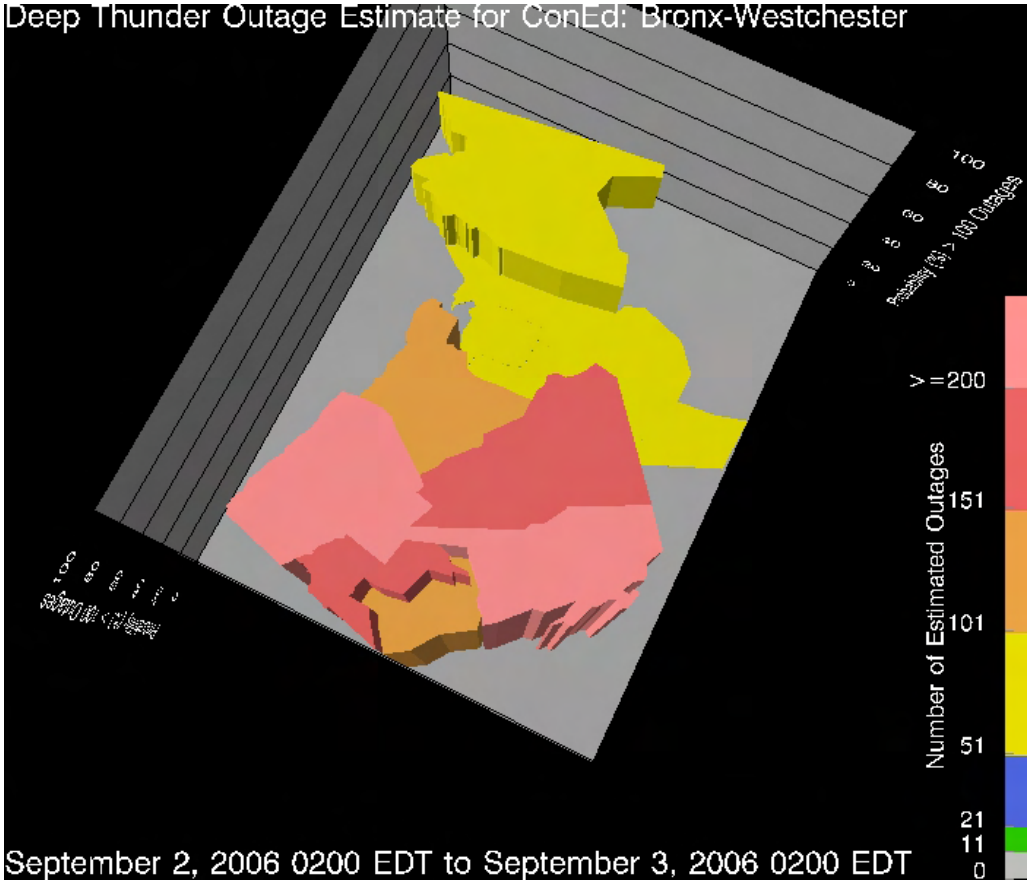


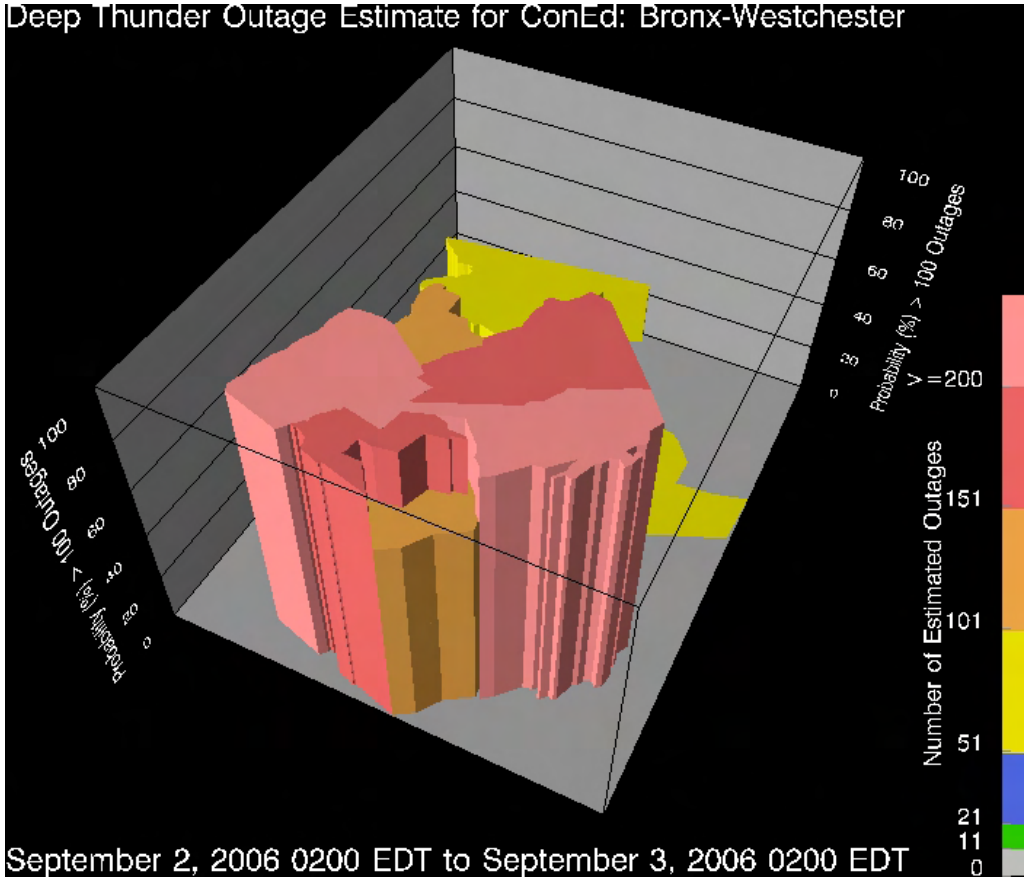
Probability of More than 100 Outages



Deep Thunder Damage Prediction – 02 September 2006

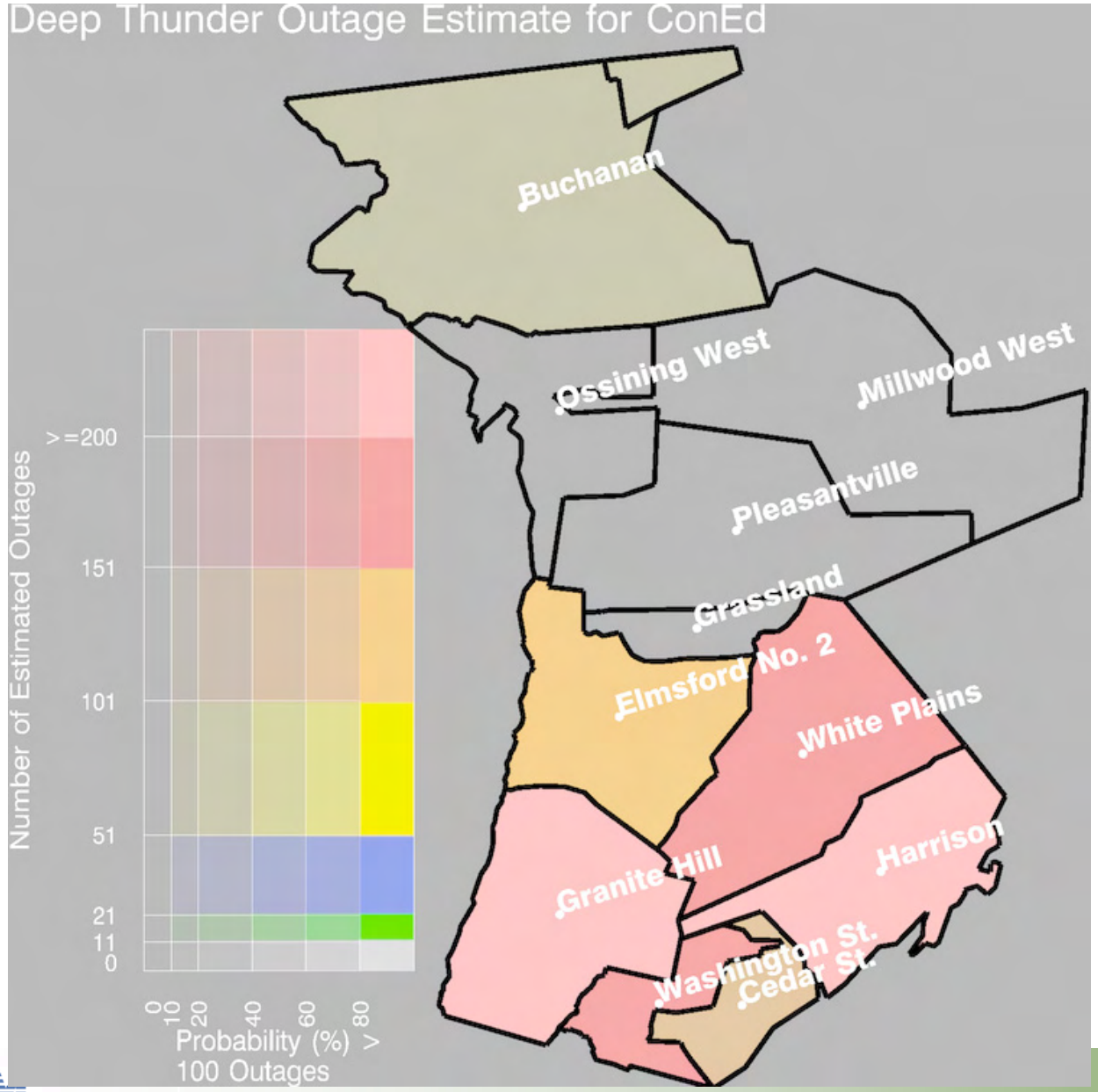
Forecasted Outages Combined with Probability of More than 100 Outages





Deep Thunder Damage Prediction – 02 September 2006

Forecasted Outages Combined with Probability of More than 100 Outages



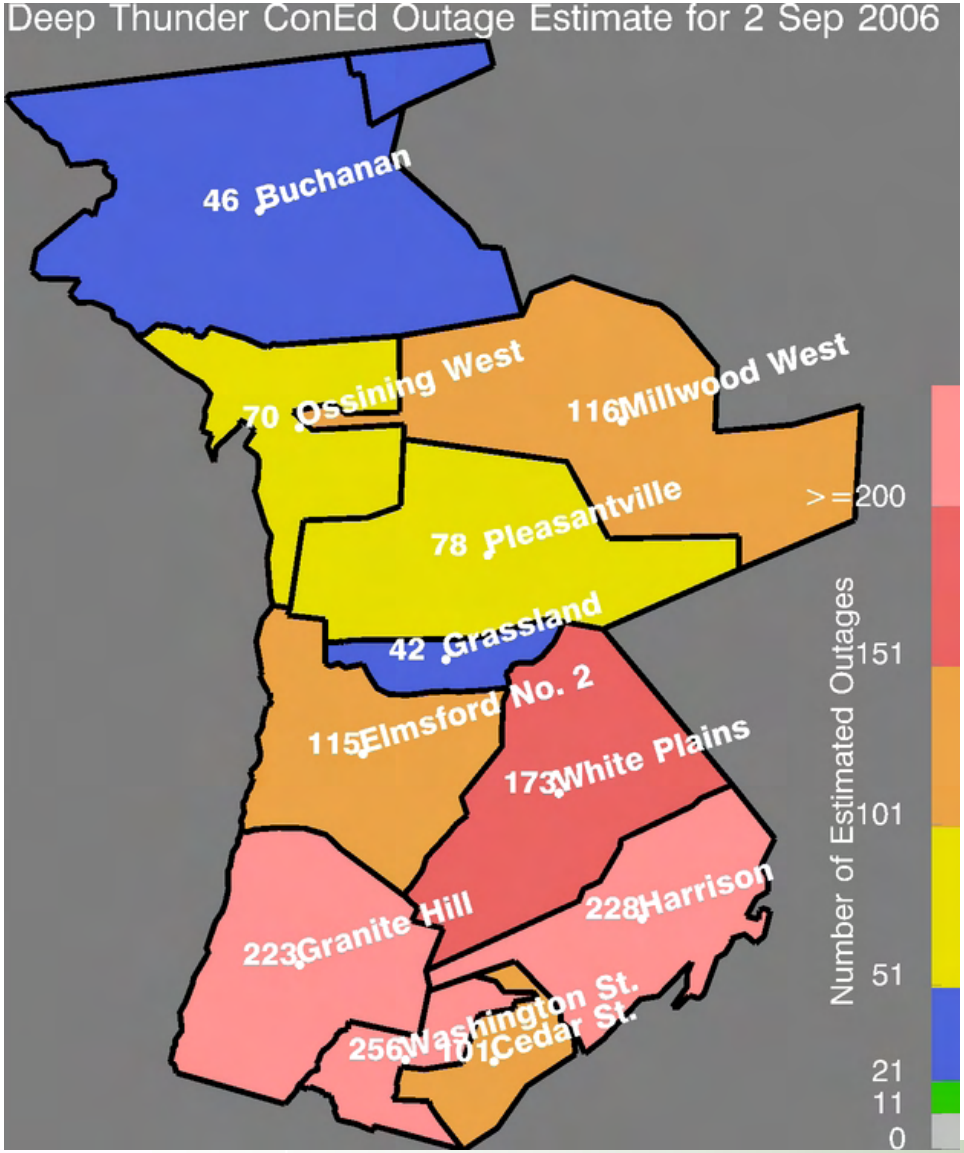
Opacity of Colored

Area Illustrates

Probability

Deep Thunder Damage Prediction – 02 September 2006

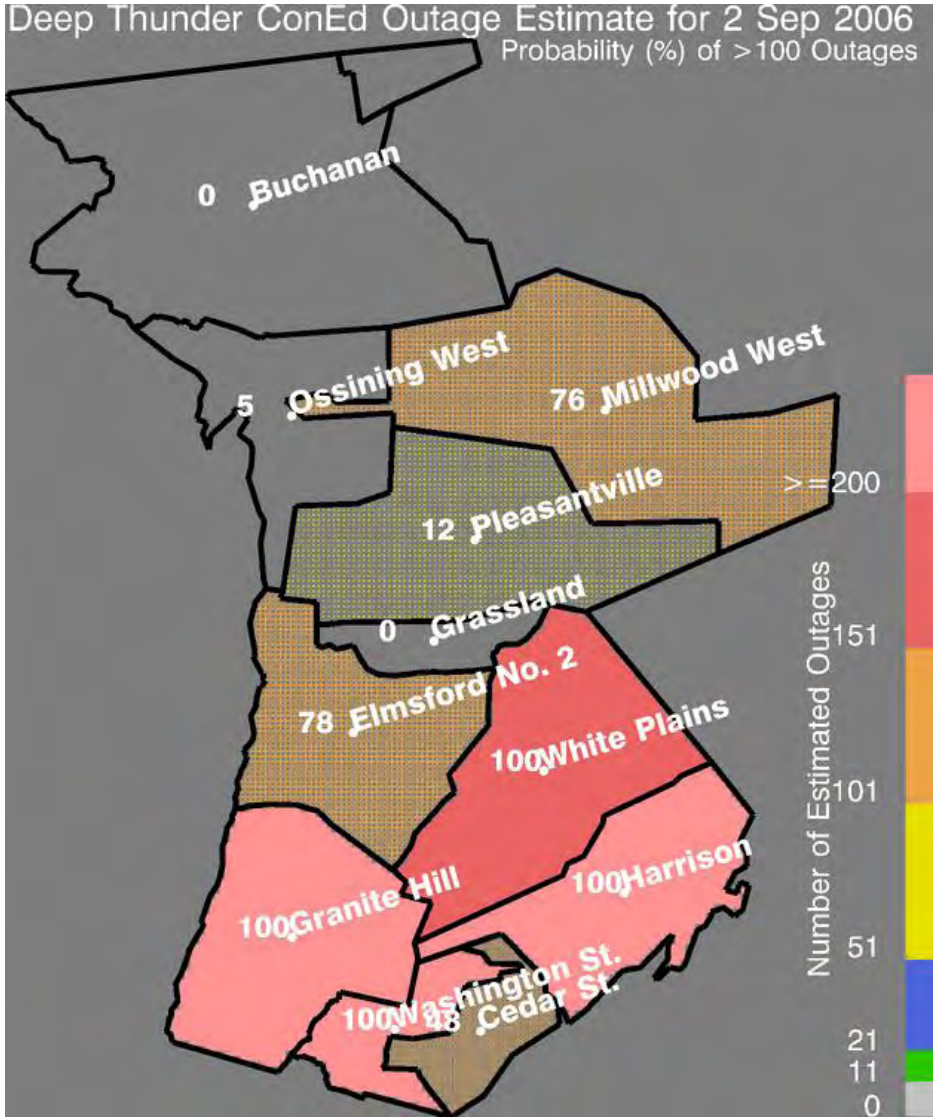
Forecasted Outages

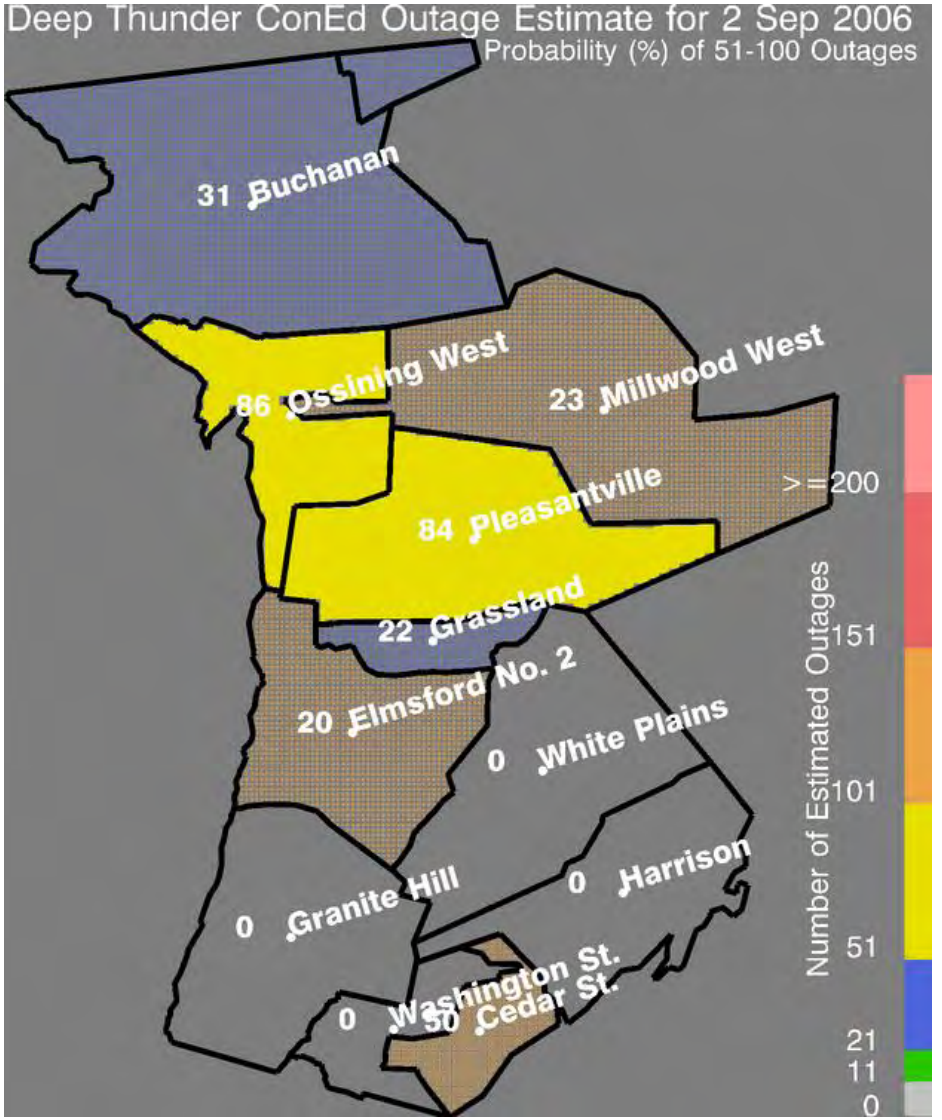


Somewhat modified

Uncertainty in Damage Prediction -- 02 September 2006

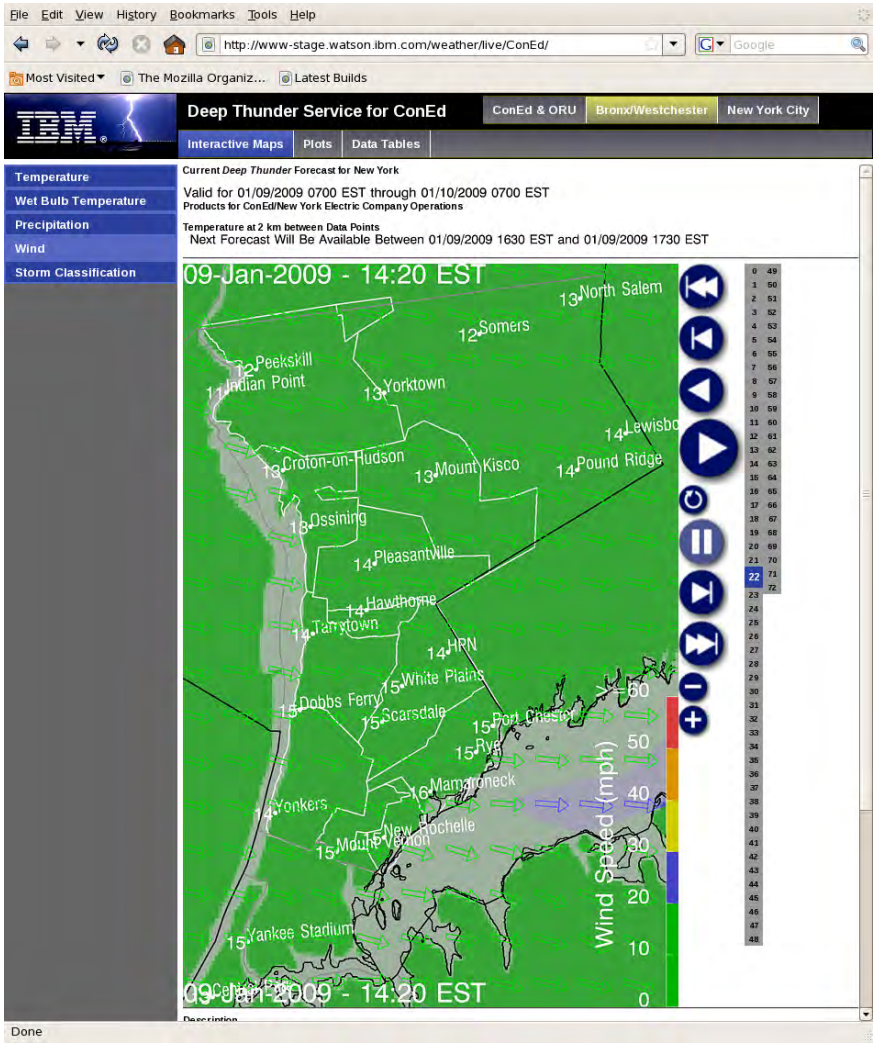
Forecasted Outages Combined with Probability of More than 100 Outages



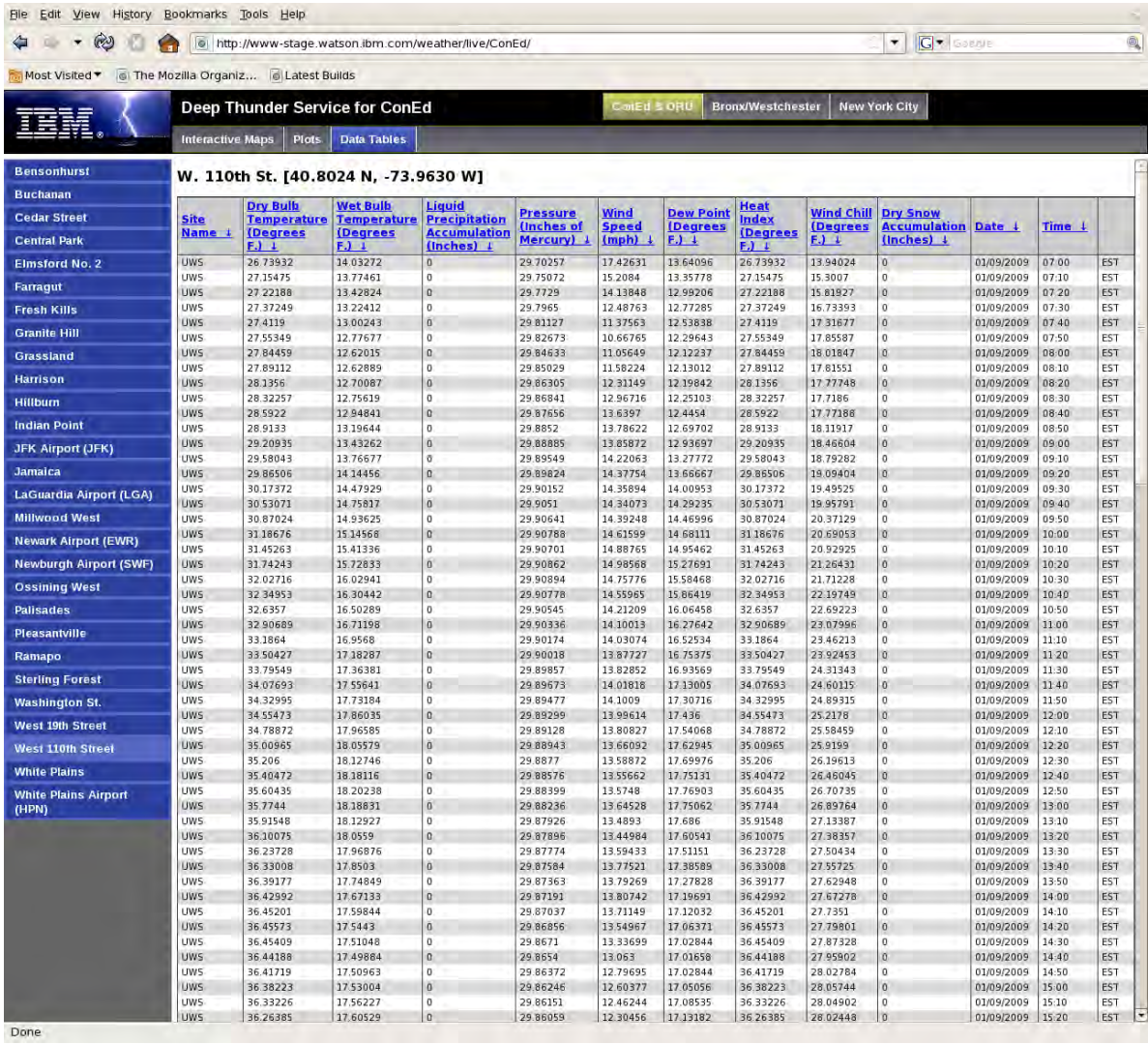


Texturing of Outage Color Illustrates Probability with Value

Web Interface for Consolidated Edison



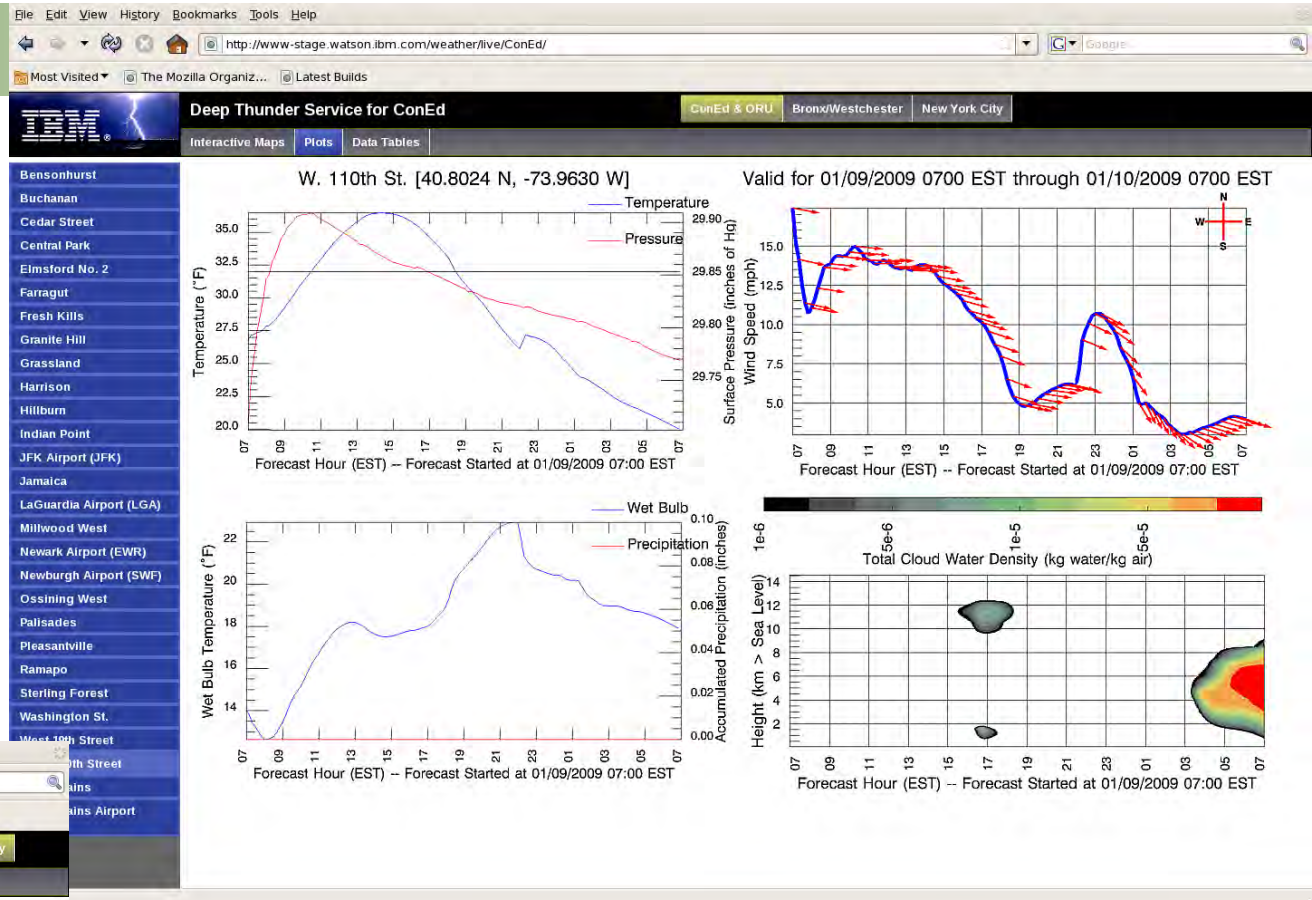
Surface Wind Animation

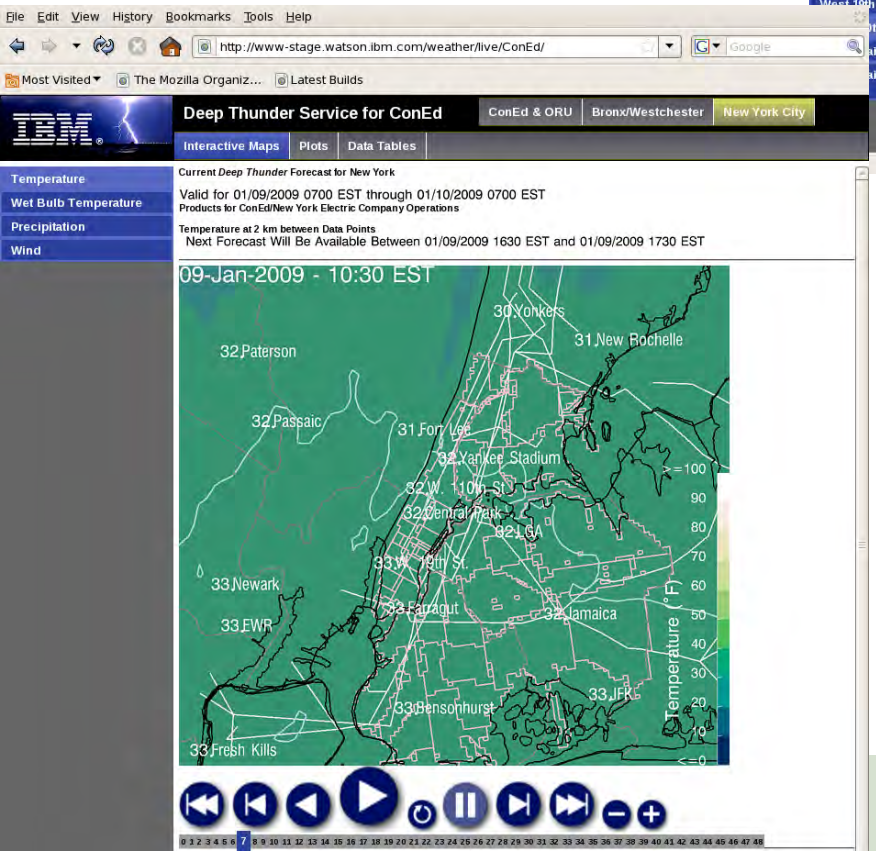


Site Name	Dry Bulb Temperature (Degrees F.)	Wet Bulb Temperature (Degrees F.)	Liquid Precipitation Accumulation (Inches)	Pressure (Inches of Mercury)	Wind Speed (mph)	Dew Point (Degrees F.)	Heat Index (Degrees F.)	Wind Chill (Degrees F.)	Dry Snow Accumulation (Inches)	Date	Time	
UWS	26.73932	14.03272	0	29.70257	17.42631	13.64096	26.73932	13.94024	0	01/09/2009	07:00	EST
UWS	27.15475	13.77461	0	29.75072	15.2084	13.35778	27.15475	15.3007	0	01/09/2009	07:10	EST
UWS	27.22188	13.42824	0	29.7729	14.13848	12.99206	27.22188	15.81927	0	01/09/2009	07:20	EST
UWS	27.37249	13.22412	0	29.7965	12.48763	12.77285	27.37249	16.73393	0	01/09/2009	07:30	EST
UWS	27.4119	13.00243	0	29.81127	11.37563	12.53838	27.4119	17.31677	0	01/09/2009	07:40	EST
UWS	27.55349	12.77677	0	29.82673	10.66765	12.29643	27.55349	17.85587	0	01/09/2009	07:50	EST
UWS	27.84459	12.62015	0	29.84633	11.05649	12.12237	27.84459	18.01847	0	01/09/2009	08:00	EST
UWS	27.89112	12.62889	0	29.85029	11.58224	12.13012	27.89112	17.81551	0	01/09/2009	08:10	EST
UWS	28.1356	12.70087	0	29.86305	12.31149	12.19842	28.1356	17.77748	0	01/09/2009	08:20	EST
UWS	28.32257	12.75619	0	29.86841	12.96716	12.25103	28.32257	17.7186	0	01/09/2009	08:30	EST
UWS	28.5922	12.94841	0	29.87656	13.6397	12.4454	28.5922	17.77188	0	01/09/2009	08:40	EST
UWS	28.9133	13.19644	0	29.8852	13.78622	12.69702	28.9133	18.11917	0	01/09/2009	08:50	EST
UWS	29.20935	13.43262	0	29.88885	13.85872	12.93697	29.20935	18.46604	0	01/09/2009	09:00	EST
UWS	29.58043	13.76677	0	29.89549	14.22063	13.27772	29.58043	18.79282	0	01/09/2009	09:10	EST
UWS	29.86506	14.14456	0	29.89824	14.37754	13.66667	29.86506	19.09404	0	01/09/2009	09:20	EST
UWS	30.17372	14.47929	0	29.90152	14.35894	14.00953	30.17372	19.49525	0	01/09/2009	09:30	EST
UWS	30.53071	14.75817	0	29.9051	14.34073	14.29235	30.53071	19.95791	0	01/09/2009	09:40	EST
UWS	30.87024	14.93625	0	29.90641	14.39248	14.46996	30.87024	20.37129	0	01/09/2009	09:50	EST
UWS	31.18676	15.14568	0	29.90788	14.61599	14.68111	31.18676	20.69053	0	01/09/2009	10:00	EST
UWS	31.45263	15.41336	0	29.90701	14.88765	14.95462	31.45263	20.92925	0	01/09/2009	10:10	EST
UWS	31.74243	15.72833	0	29.90862	14.98568	15.27691	31.74243	21.26431	0	01/09/2009	10:20	EST
UWS	32.02716	16.02941	0	29.90894	14.75776	15.58468	32.02716	21.71228	0	01/09/2009	10:30	EST
UWS	32.34953	16.30442	0	29.90778	14.55965	15.86419	32.34953	22.19749	0	01/09/2009	10:40	EST
UWS	32.6357	16.50289	0	29.90545	14.21209	16.06458	32.6357	22.69223	0	01/09/2009	10:50	EST
UWS	32.90689	16.71198	0	29.90336	14.10013	16.27642	32.90689	23.07996	0	01/09/2009	11:00	EST
UWS	33.1864	16.9568	0	29.90174	14.03074	16.52534	33.1864	23.46213	0	01/09/2009	11:10	EST
UWS	33.50427	17.18287	0	29.90018	13.87727	16.75375	33.50427	23.92453	0	01/09/2009	11:20	EST
UWS	33.79549	17.36381	0	29.89857	13.82852	16.93569	33.79549	24.31343	0	01/09/2009	11:30	EST
UWS	34.07693	17.55641	0	29.89673	14.01818	17.13005	34.07693	24.60115	0	01/09/2009	11:40	EST
UWS	34.32995	17.73184	0	29.89477	14.1009	17.30716	34.32995	24.89315	0	01/09/2009	11:50	EST
UWS	34.55473	17.86035	0	29.89299	13.99614	17.436	34.55473	25.2178	0	01/09/2009	12:00	EST
UWS	34.78872	17.96585	0	29.89128	13.80827	17.54068	34.78872	25.58459	0	01/09/2009	12:10	EST
UWS	35.00965	18.05579	0	29.88943	13.66092	17.62945	35.00965	25.9199	0	01/09/2009	12:20	EST
UWS	35.206	18.12746	0	29.8877	13.58872	17.69976	35.206	26.19613	0	01/09/2009	12:30	EST
UWS	35.40472	18.18116	0	29.88576	13.55662	17.75131	35.40472	26.46045	0	01/09/2009	12:40	EST
UWS	35.60435	18.20238	0	29.88399	13.5748	17.76903	35.60435	26.70735	0	01/09/2009	12:50	EST
UWS	35.7744	18.18831	0	29.88236	13.64528	17.75062	35.7744	26.89764	0	01/09/2009	13:00	EST
UWS	35.91548	18.12927	0	29.87926	13.4893	17.686	35.91548	27.13387	0	01/09/2009	13:10	EST
UWS	36.10075	18.0559	0	29.87896	13.44984	17.60541	36.10075	27.38357	0	01/09/2009	13:20	EST
UWS	36.23728	17.96876	0	29.87774	13.59433	17.51151	36.23728	27.50434	0	01/09/2009	13:30	EST
UWS	36.33008	17.8503	0	29.87584	13.77521	17.38589	36.33008	27.55725	0	01/09/2009	13:40	EST
UWS	36.39177	17.74849	0	29.87363	13.79269	17.27828	36.39177	27.62948	0	01/09/2009	13:50	EST
UWS	36.42992	17.67133	0	29.87191	13.80742	17.19691	36.42992	27.67278	0	01/09/2009	14:00	EST
UWS	36.45201	17.59844	0	29.87037	13.71149	17.12032	36.45201	27.7351	0	01/09/2009	14:10	EST
UWS	36.45573	17.5443	0	29.86856	13.54967	17.06371	36.45573	27.79801	0	01/09/2009	14:20	EST
UWS	36.45409	17.51048	0	29.8671	13.33699	17.02844	36.45409	27.87328	0	01/09/2009	14:30	EST
UWS	36.44188	17.49884	0	29.8654	13.063	17.01658	36.44188	27.95902	0	01/09/2009	14:40	EST
UWS	36.41719	17.50963	0	29.86372	12.79695	17.02844	36.41719	28.02784	0	01/09/2009	14:50	EST
UWS	36.38223	17.53004	0	29.86246	12.60377	17.05056	36.38223	28.05744	0	01/09/2009	15:00	EST
UWS	36.33226	17.56227	0	29.86151	12.46244	17.08535	36.33226	28.04902	0	01/09/2009	15:10	EST
UWS	36.26385	17.60529	0	29.86059	12.30456	17.13182	36.26385	28.02448	0	01/09/2009	15:20	EST

Interactive Site-Specific Forecast Table

Web Interface for Consolidated Edison





Site-Specific Forecast Plots

Surface Temperature Animation

Discussion and Future Work

- Less is more…
- Familiar metaphors (colors, overlays) required for ease of use and in minimizing training
- Iteration with users critical to incorporate feedback into designs
- Continued work on representation of uncertainty
- Develop additional tailored weather visualizations (e.g., frozen precipitation, wind gusts)
- Apply to similar operational needs for water utilities, municipal emergency management and transportation agencies