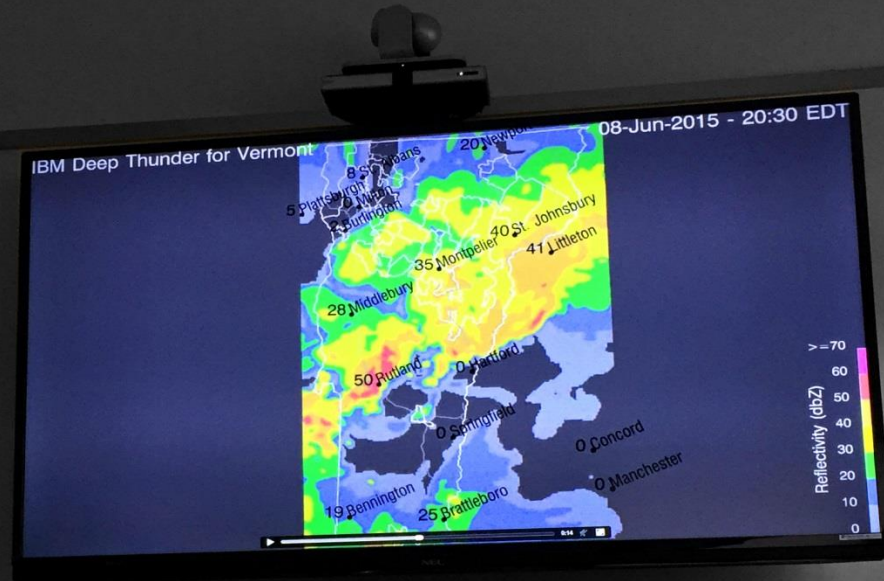


# Utilization of High-Resolution Weather Modeling to Improve Downsloping Wind Event Prediction for Vermont Utility Applications



**17<sup>th</sup> AMS Conference on Mountain Meteorology**  
*Numerical Weather Prediction, Data Assimilation, and  
Forecasting in Complex Terrain: Part I*  
Session 1.3 – 9:45 AM  
27 June 2016 – Burlington, VT

**Rob D'Arienzo**  
Meteorologist  
VELCO (Rutland, VT)

# Outline

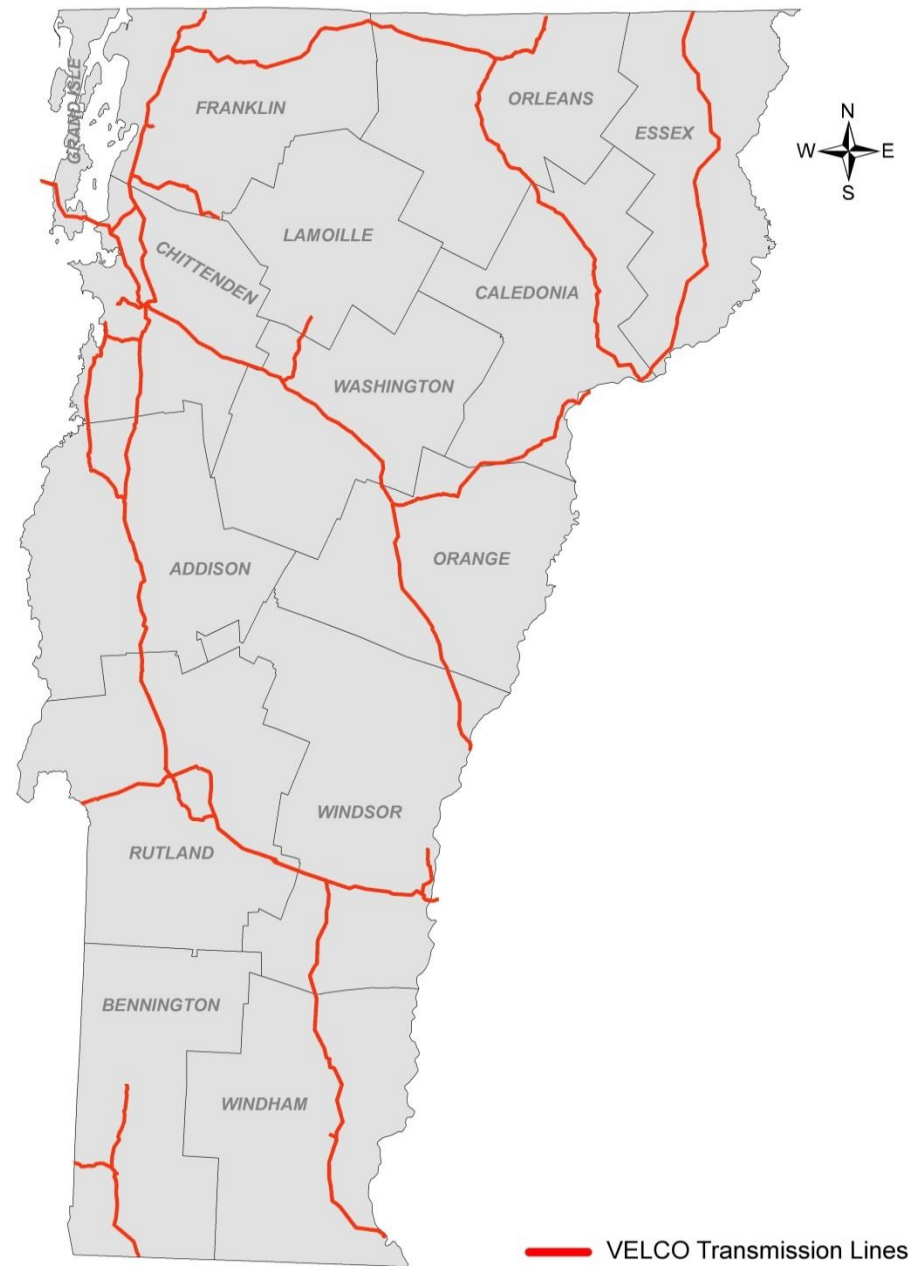
- **Background**
  - VELCO
  - Electrical Grid 101
- **Vermont Weather Analytics Center (VWAC)**
  - Motivation
  - Overview
  - Partners
  - Models
- **IBM Deep Thunder**
  - Overview
  - Physics & Data Assimilation
  - VWAC Mesonet
  - Web Portal Interface
- **VTWAC Mesonet**
- **Verifications**
  - 1/10/16 High Wind Event
  - 2/29/16 High Wind Event
- **Forecast Analysis & Communication**
- **Future Work & Applications**
- **Q&A**



# Background

## VELCO

- Vermont Electric Power Company (VELCO) was founded in 1956 when local utilities joined together to create the nation's first "transmission only" electric company
- VELCO operates an interconnected electric transmission grid consisting of:
  - 738 miles of transmission lines
  - 13,000 acres of rights-of-way
  - 55 substations, switching stations, and terminal facilities
  - 1,400 miles of fiber optic communication network
  - Equipment that enables interconnected operations with Hydro-Québec
- **VELCO: Vermont's transmission reliability resource**





# Background

## Electrical Grid 101

**Key:**  
Black=power supply  
Blue=transmission  
Green=subtransmission  
Purple=distribution

**Power supply:**  
in-state generation  
and power delivered  
over the regional  
power grid

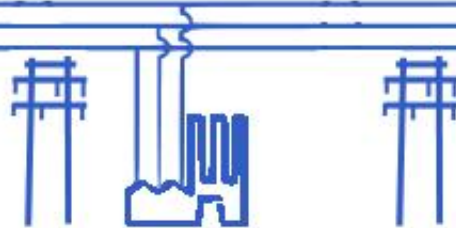


### 1. Generation

Function: Transforms the energy of heat, wind, solar and water to electrical energy to power homes and businesses

Examples: Hydro-Quebec, In-state renewables (wind, solar, and hydro)

Vermont transmission lines  
115 kV, 230 kV & 345 kV



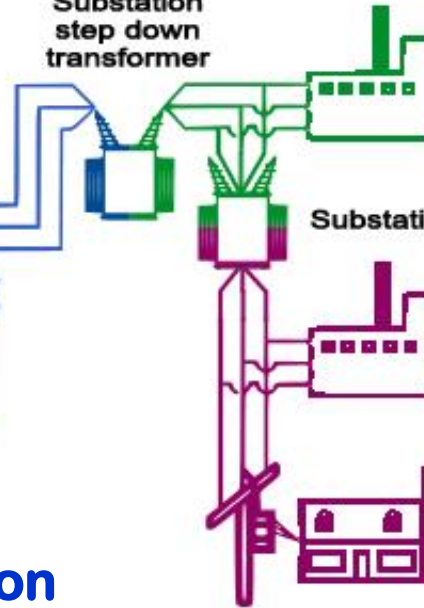
Transmission-  
connected  
customer

### 2. Transmission

Function: Bulk transfer of electrical energy. Moves electricity at high voltage from generators to local sub-transmission and distribution systems.

Example: VELCO

Substation  
step down  
transformer



Subtransmission-connected  
customer  
34.5 kV, 46 kV & 69 kV

Substation step down transformer

Distribution-connected  
customer  
4.2 kV, 12.5 kV & 13.8 kV

Distribution-connected  
customer  
120V & 240V

### 3. Sub-transmission

Function: Moves medium amounts of electrical energy at medium voltages from transmission to distribution systems

### 4. Distribution

Function: Moves electrical energy from transmission and sub-transmission to local customers

Examples: One of VT's 17 local distribution utilities (Green Mountain Power, Vermont Electric Cooperative, Burlington Electric Dept., etc.)

# Vermont Weather Analytics Center Motivation

2016

Top 10 risks in terms of

Likelihood

- 1 Large-scale involuntary migration
- 2 Extreme weather events
- 3 Failure of climate-change mitigation and adaptation
- 4 Interstate conflict
- 5 Natural catastrophes
- 6 Failure of national governance
- 7 Unemployment or underemployment
- 8 Data fraud or theft
- 9 Water crises
- 10 Illicit trade

Top 10 risks in terms of

Impact

- 1 Failure of climate-change mitigation and adaptation
- 2 Weapons of mass destruction
- 3 Water crises
- 4 Large-scale involuntary migration
- 5 Energy price shock
- 6 Biodiversity loss and ecosystem collapse
- 7 Fiscal crises
- 8 Spread of infectious diseases
- 9 Asset bubble
- 10 Profound social instability

Sharp increase in environmental risks starting in 2011

Top 5 Global Risks in Terms of Likelihood

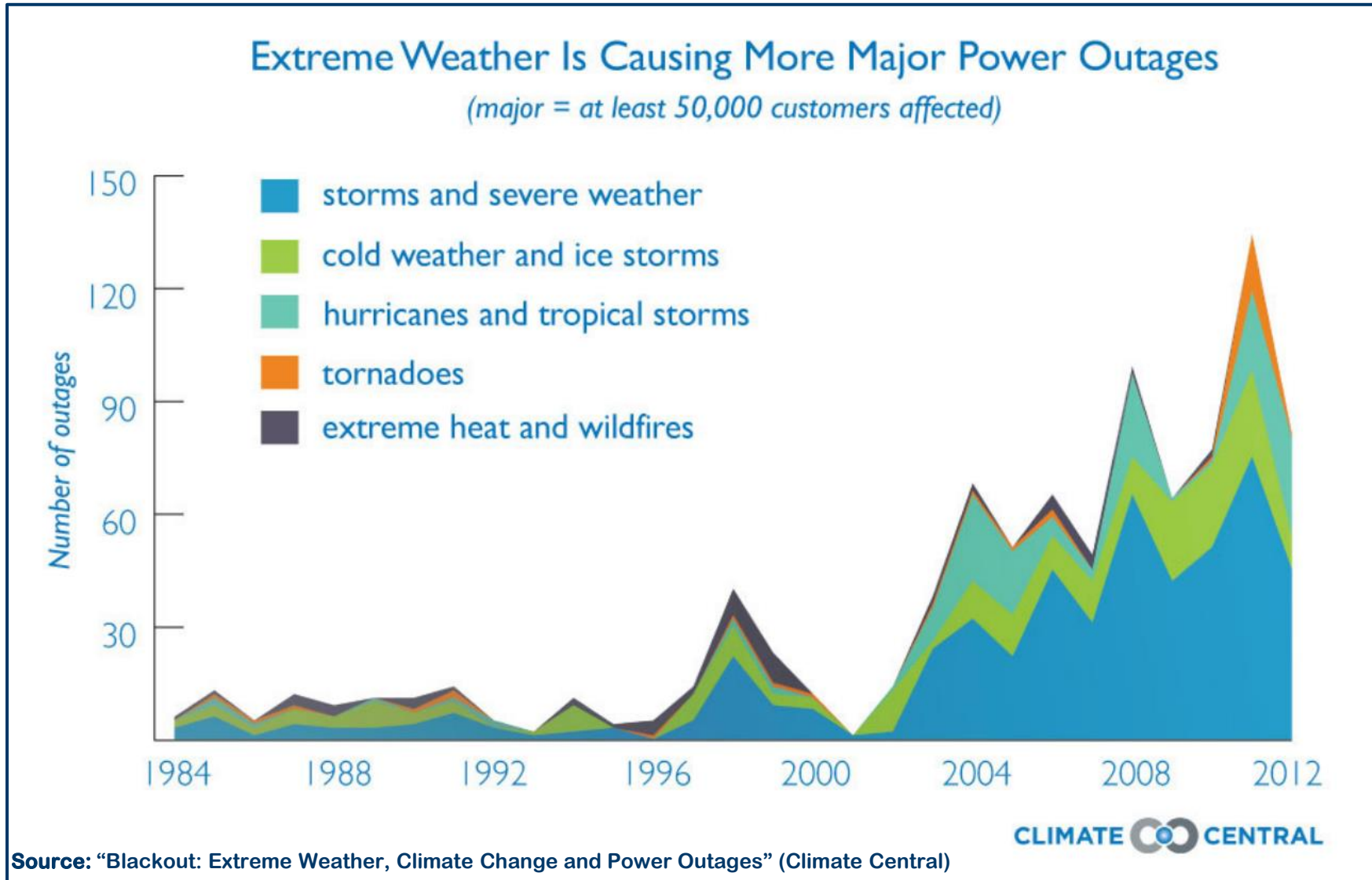
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1st	Breakdown of critical information infrastructure	Asset price collapse	Asset price collapse	Asset price collapse	Storms and cyclones	Severe income disparity	Severe income disparity	Income disparity	Interstate conflict with regional consequences	Large-scale involuntary migration
2nd	Chronic disease in developed countries	Middle East instability	Slowing Chinese economy (<6%)	Slowing Chinese economy (<6%)	Flooding	Chronic fiscal imbalances	Chronic fiscal imbalances	Extreme weather events	Extreme weather events	Extreme weather events
3rd	Oil price shock	Failed and failing states	Chronic disease	Chronic disease	Corruption	Rising greenhouse gas emissions	Rising greenhouse gas emissions	Unemployment and underemployment	Failure of national governance	Failure of climate-change mitigation and adaptation
4th	China economic hard landing	Oil and gas price spike	Global governance gaps	Fiscal crises	Biodiversity loss	Cyber attacks	Water supply crises	Climate change	State collapse or crisis	Interstate conflict with regional consequences
5th	Asset price collapse	Chronic disease, developed world	Retrenchment from globalization (emerging)	Global governance gaps	Climate change	Water supply crises	Mismanagement of population ageing	Cyber attacks	High structural unemployment or underemployment	Major natural catastrophes

■ Economic ■ Environmental ■ Geopolitical ■ Societal ■ Technological

Source: World Economic Forum

# Vermont Weather Analytics Center

## Motivation

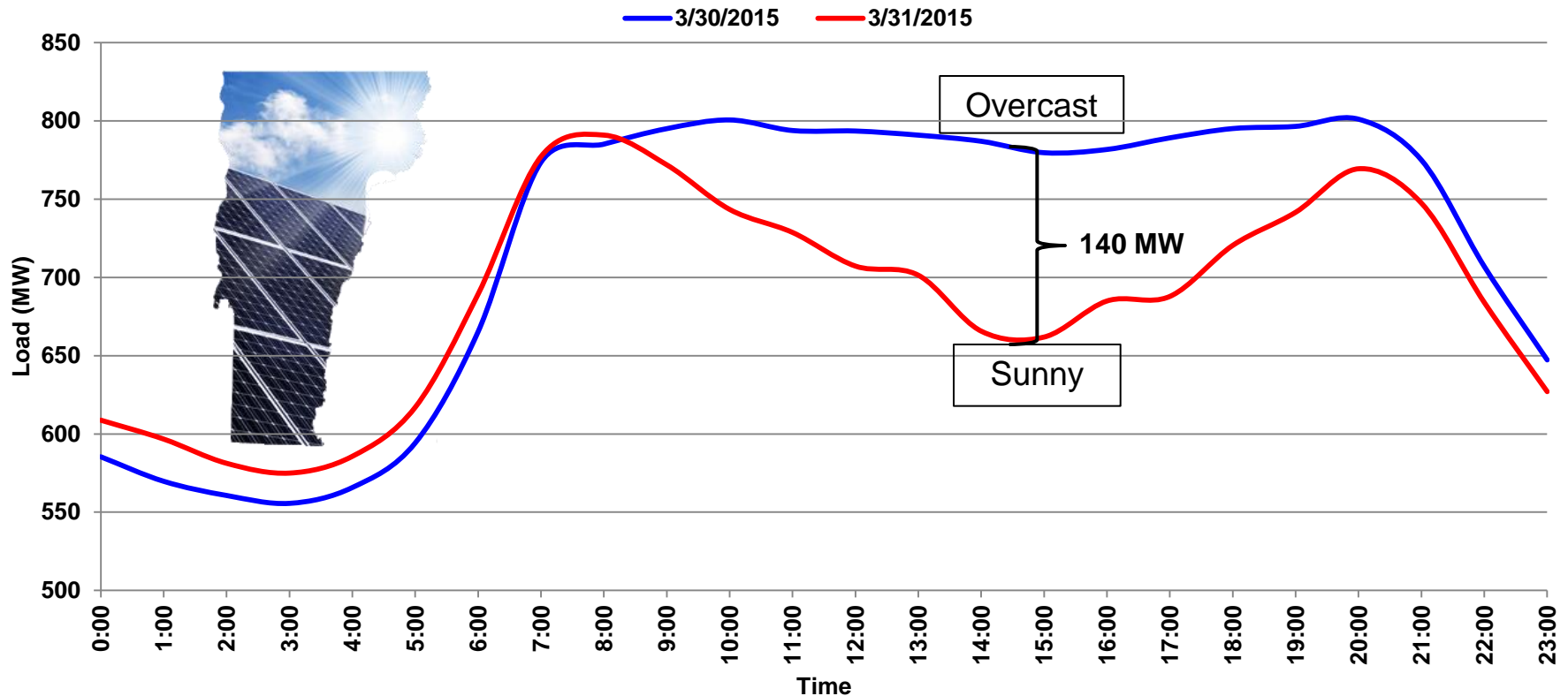


# Vermont Weather Analytics Center

## Motivation

Boom in distributed solar is already changing VT's load shape

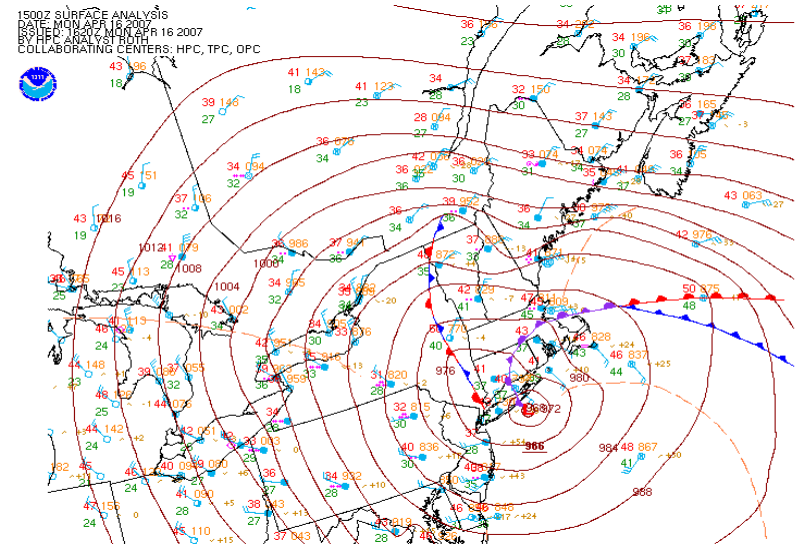
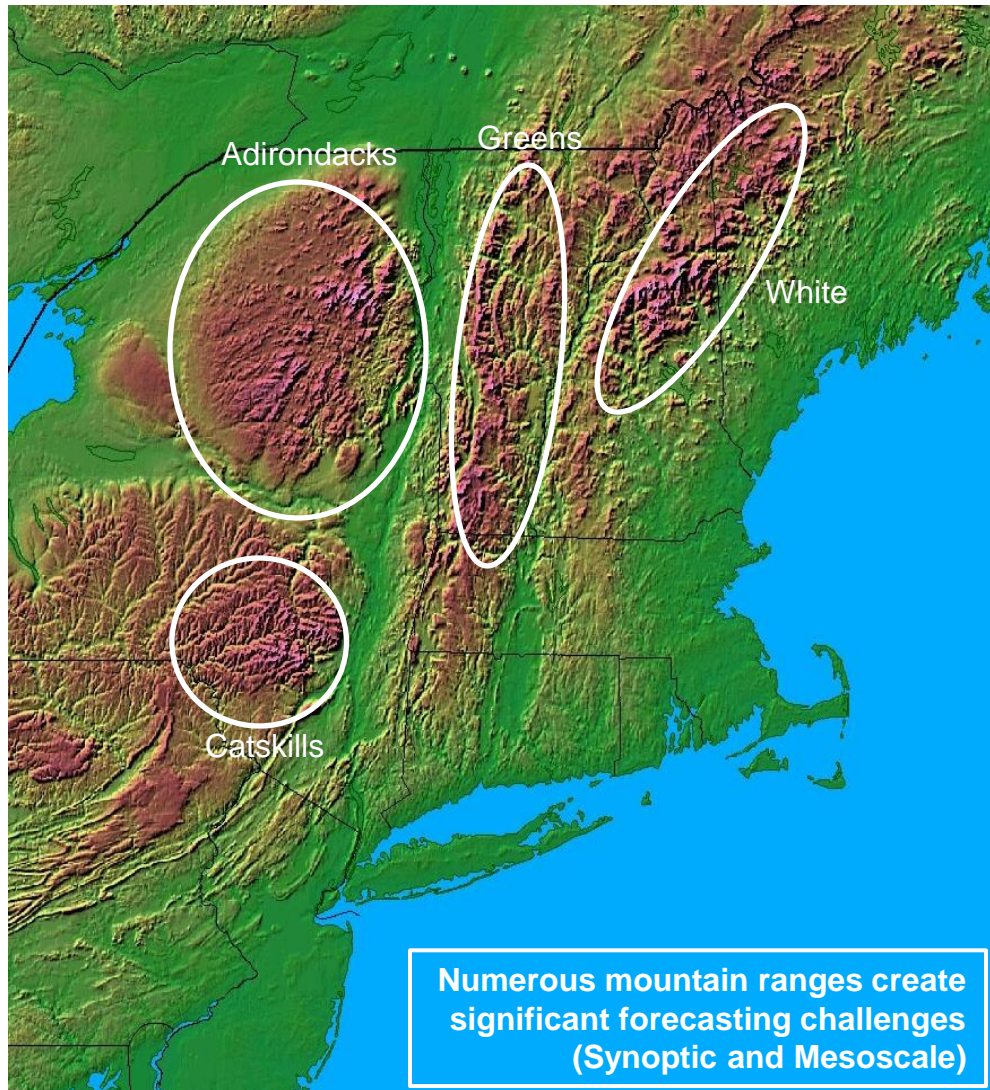
### VELCO Load Curves (Overcast vs. Sunny Days)



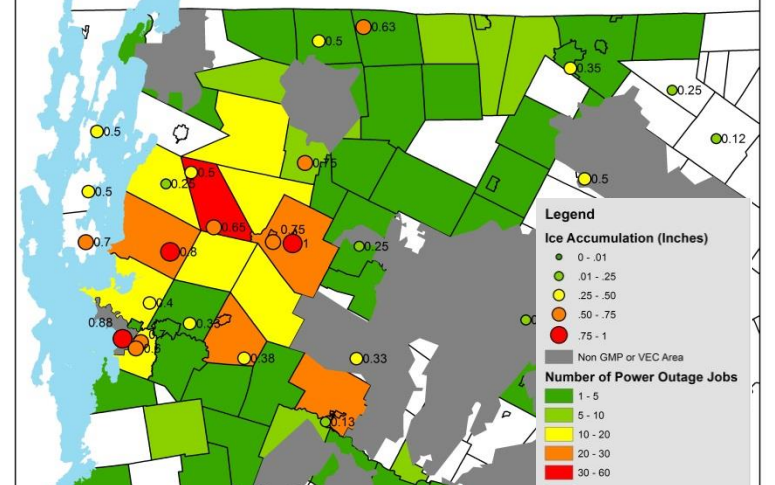


# Vermont Weather Analytics Center

## Motivation



December 21-23 2013 Ice Storm Power Outage Jobs and Ice Accumulations  
Credit: Kevin Christensen





# Vermont Weather Analytics Center

## Overview

Initiative with IBM Research to build an energy data and analytics platform that utilizes linked data, coupled models and leading-edge analytics to:



Increase grid reliability, community resiliency



Lower weather event-related operational costs

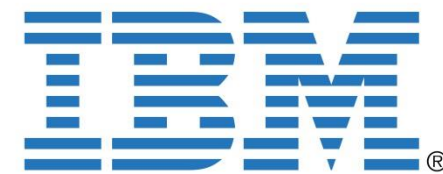


Garner renewable generation's full value



# Vermont Weather Analytics Center

## Partners



VT  
Distribution  
Utilities  
(DU's):



VT College/  
University:



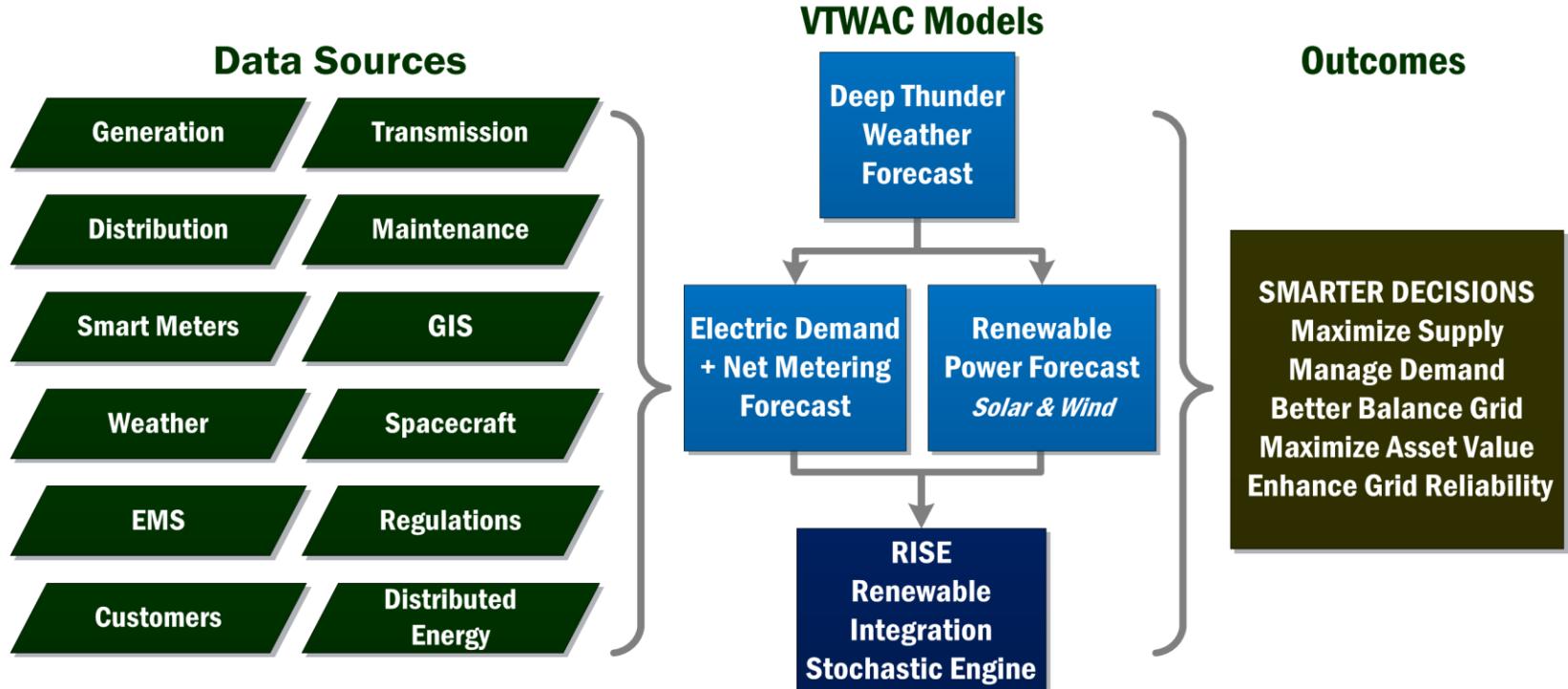
The University of Vermont

Other  
Organizations:



# Vermont Weather Analytics Center

## Models

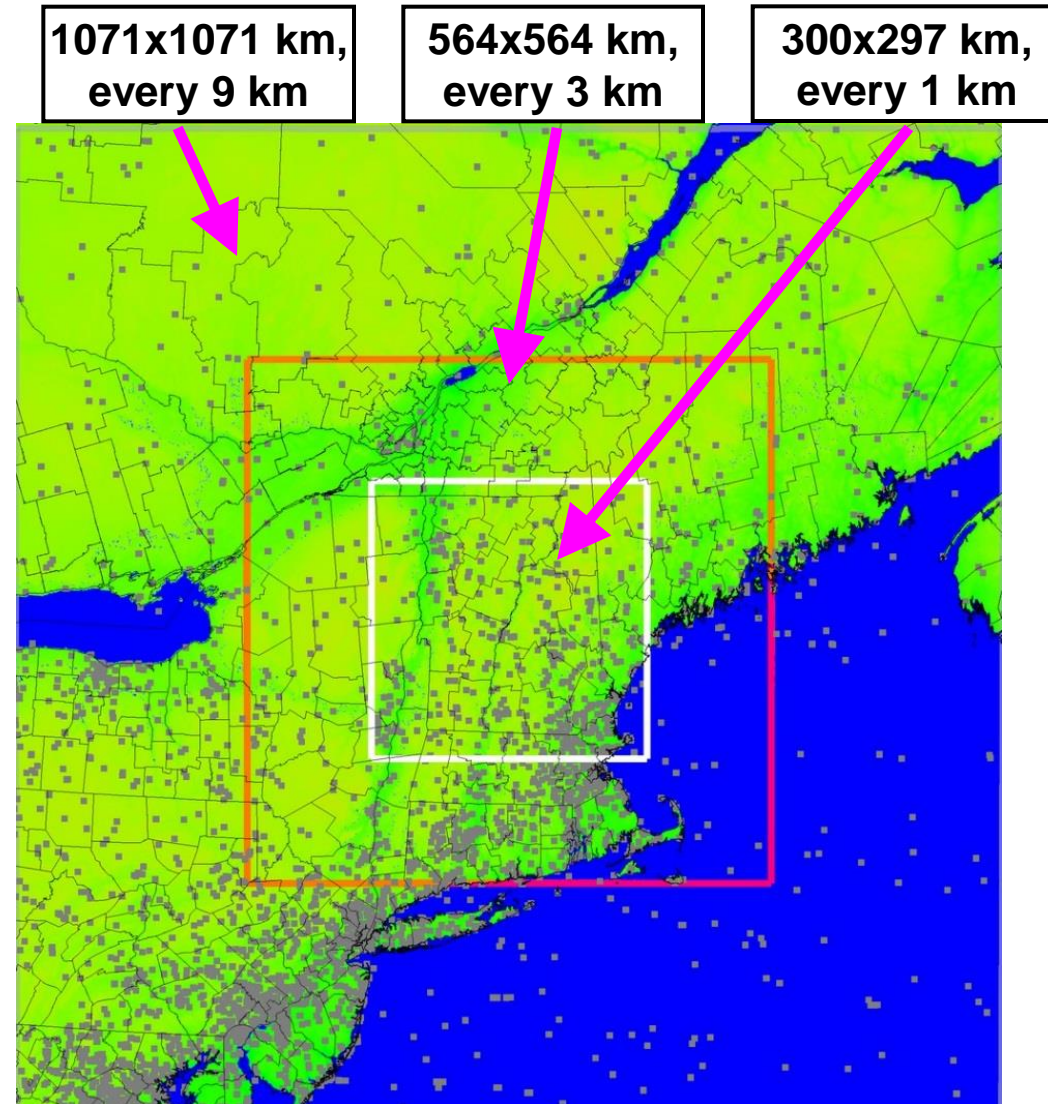


Daily Data Volumes		
Model	Input	Output
Weather	5 GB	670 GB*
Solar	2 MB	15 MB
Wind	5 MB	3 MB
Demand	5 MB**	30 MB
RISE	20 MB	1.1 GB
*50 GB drive downstream models		
**plus 5 GB smart meter data		



# IBM Deep Thunder Overview

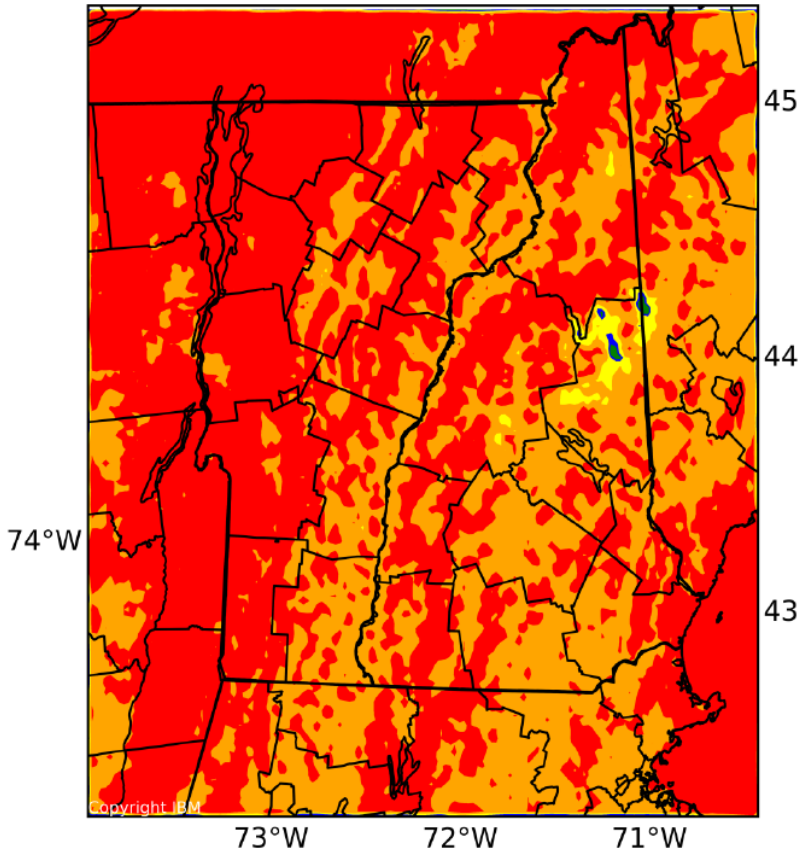
- Utilizes WRF-ARW (v. 3.5.1 since July 2014)
- 9/3/1 km horizontal nest (previously: 18/6/2 km)
- 51 vertical levels to target turbine hub heights
- Run 2x daily (00/12Z) out to **72 hours** in 10 minute intervals (previously: 48 hours)
- RAP used for background fields
- NAM used for lateral boundary conditions
- Complex physics configurations for highly rural and urban environments



# IBM Deep Thunder Overview

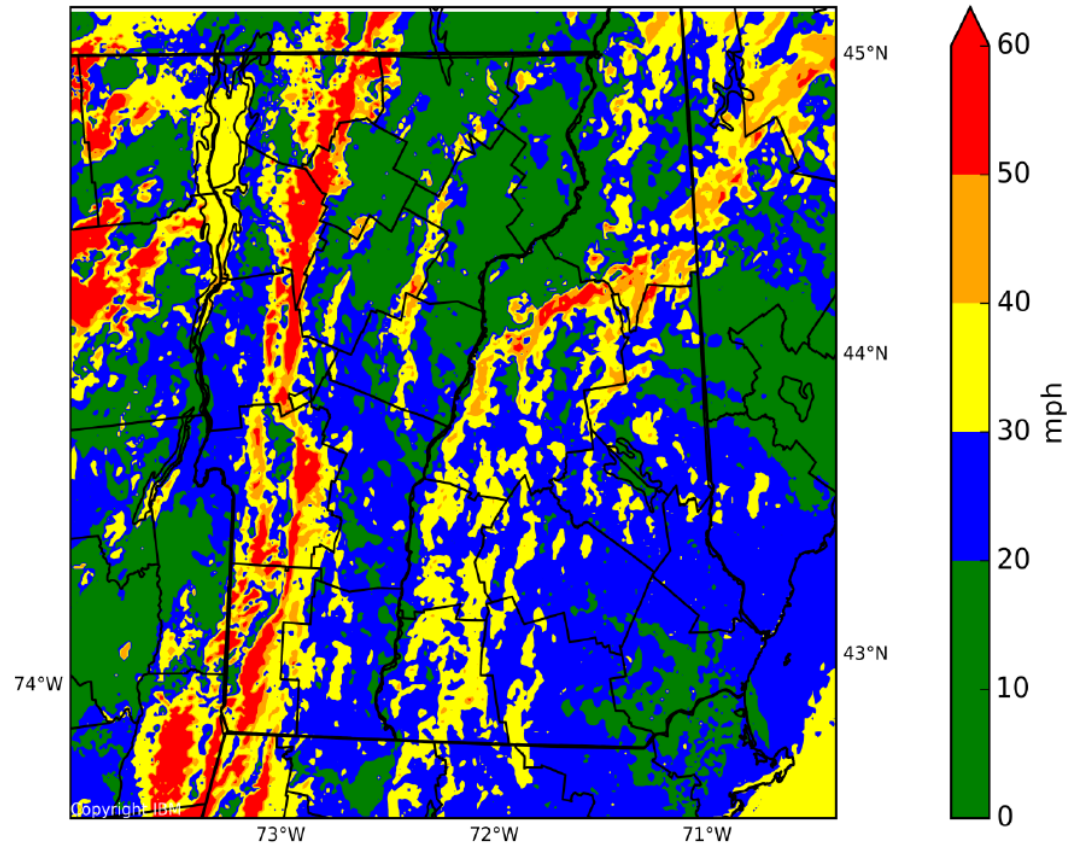
## 2 km (Previous)

Maximum Wind Gust  
Valid: 2014-11-23 13:00:00 - 2014-11-24 13:00:00 LT  
DT Forecast: 2014-11-23 13:00:00 LT



## 1 km (Operational)

Maximum Wind Gust  
Valid: 2014-11-23 07:00:00 - 2014-11-24 07:00:00 LT  
DT Forecast: 2014-11-23 07:00:00 LT



# IBM Deep Thunder

## Physics & Data Assimilation

### Physics:

- Thompson double-moment microphysics (includes explicit ice, snow and graupel)
- Mellor-Yamada-Nakanishi-Niino (MYNN) PBL scheme with turbulent kinetic energy (TKE)-based local mixing and 2.5-order closure
- NOAH land-surface modeling with soil temperature and moisture in four layers, fractional snow cover and frozen soil physics
- Explicit cumulus physics for innermost nests, Grell Freitas for outer nest
- 3-category urban canopy model with surface effects for roofs, walls, and streets
- RRTMG long- and short-wave radiation

### Data Assimilation:

- Data assimilation (3dVAR) of near-real-time surface and upper-air observations from Earth Networks WeatherBug, MADIS and private mesonets
- NASA high-resolution (2km) sea surface temperatures (SST), which include Lake Surface Temperature (LST) analysis over the Great Lakes
- NASA high-resolution (90m) Shuttle Radar Topography Mission (SRTM) terrain elevation
- MODIS 1km 20-category land use data
- NASA 4km dynamic (daily) VIIRS Green Vegetation Fraction (GVF) data
- NASA 3km land surface fields for initialization



# IBM Deep Thunder VWAC Mesonet

## VWAC Mesonet:

VELCO = 14 (additional sites 2016-2017)

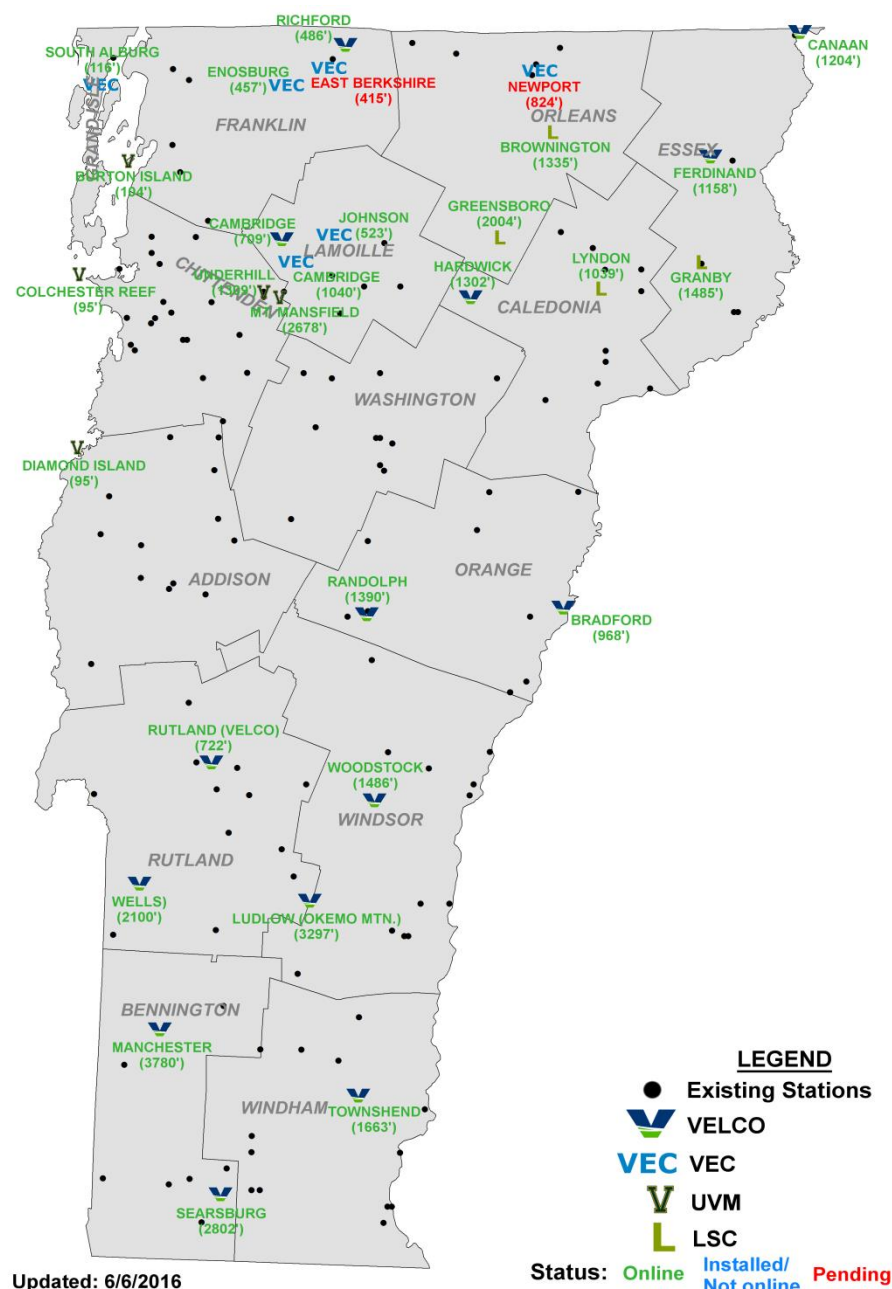
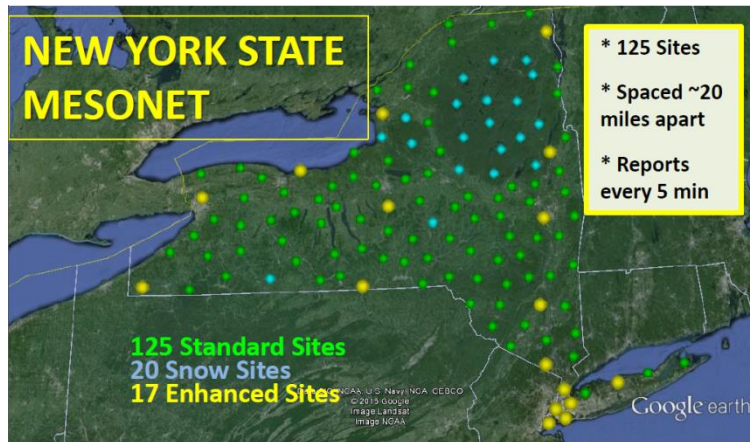
VEC = 4 (additional sites 2016)

UVM = 5

LSC = 4

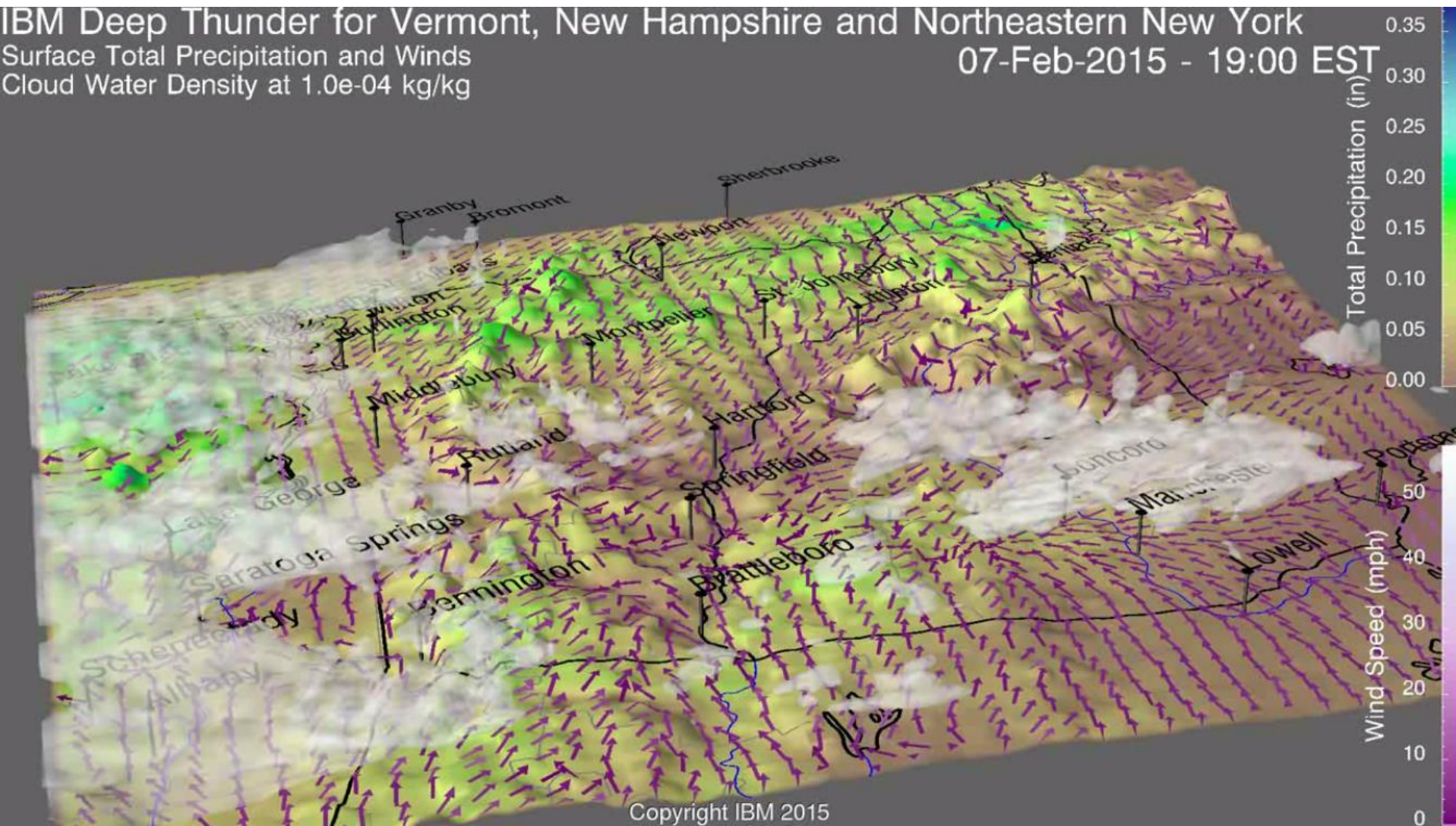
**27 Active Stations**

→ All data is publically available through  
MesoWest & MADIS



# IBM Deep Thunder

## Web Portal Interface – Interactive Maps



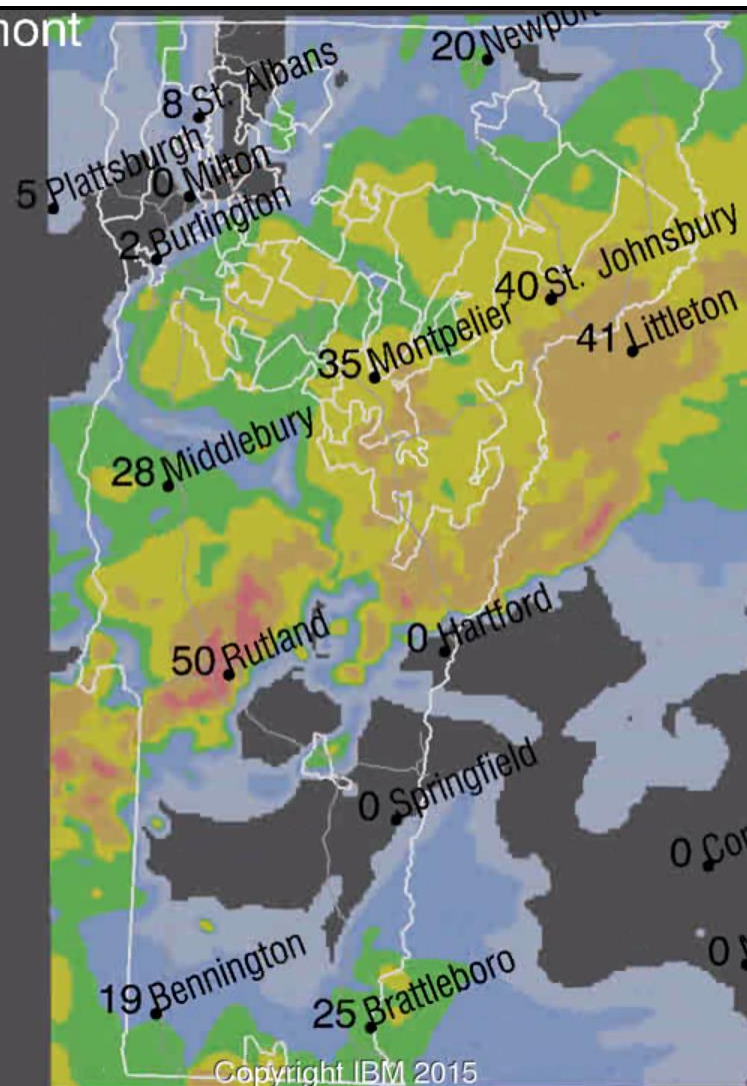


# IBM Deep Thunder

## Web Portal Interface – Interactive Maps

IBM Deep Thunder for Vermont

08-Jun-2015 - 20:30 EDT

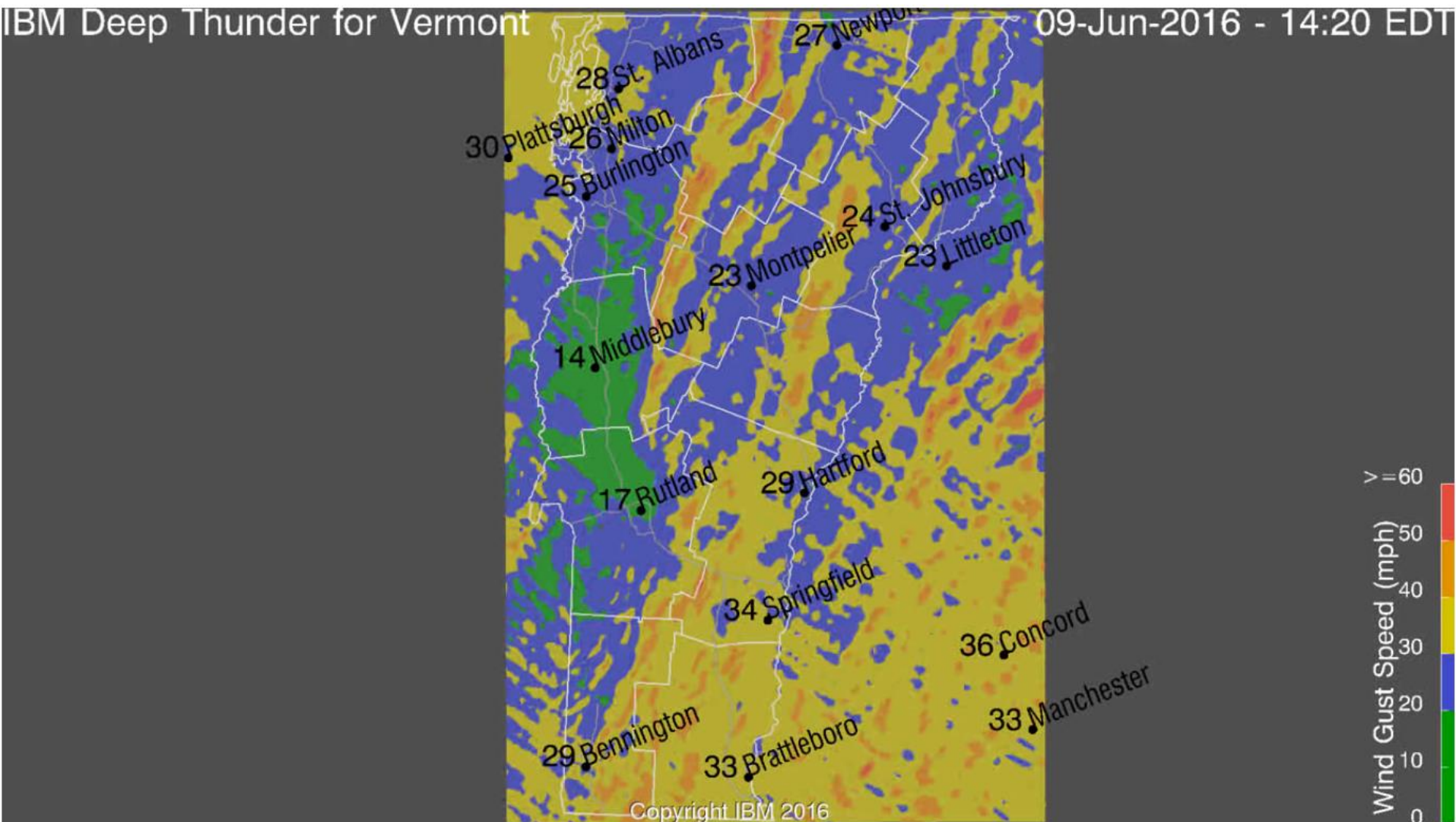


Copyright IBM 2015



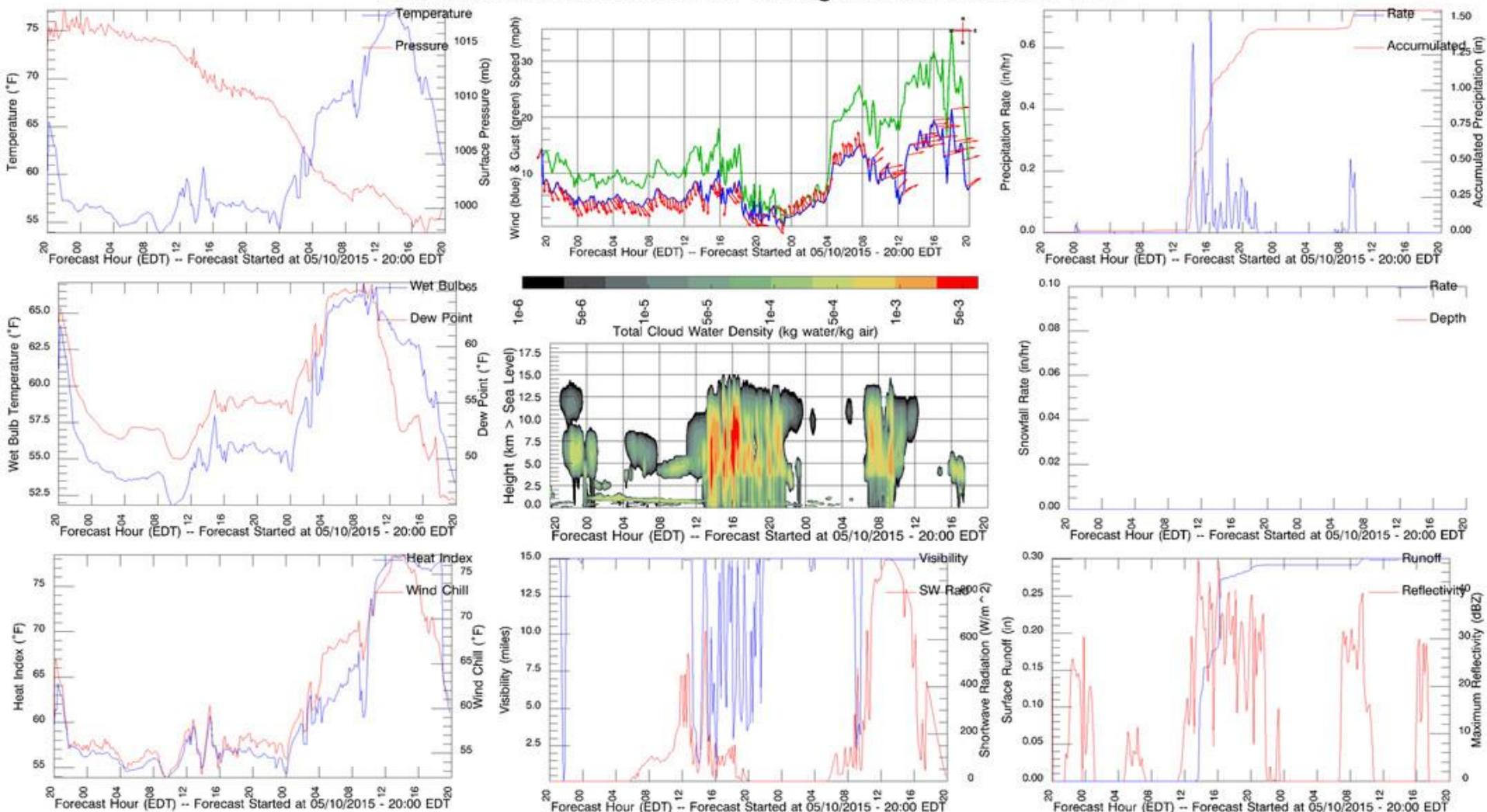
# IBM Deep Thunder

## Web Portal Interface – Interactive Maps



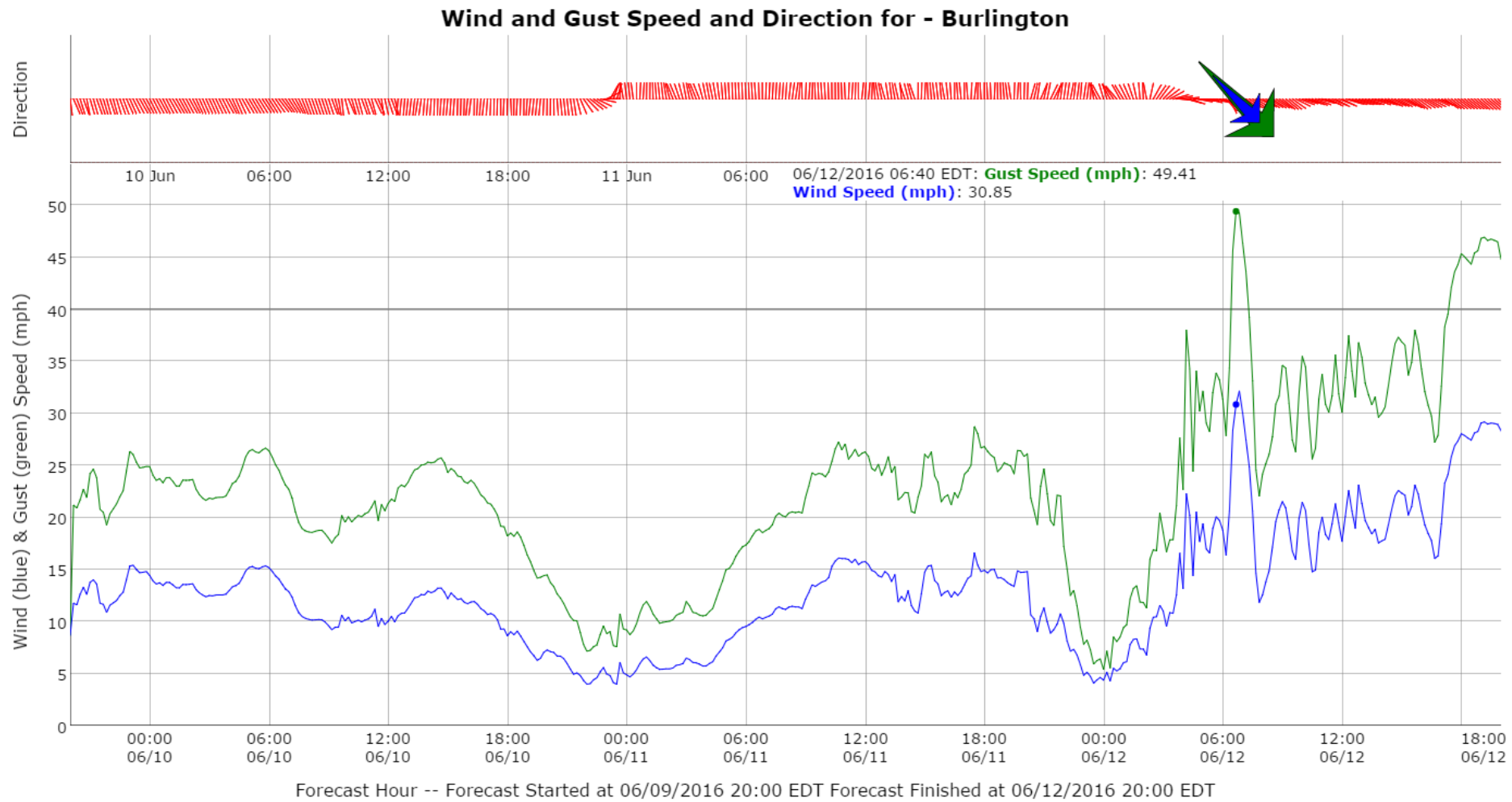
# IBM Deep Thunder Web Portal Interface – Plots

Burlington [44.5033 N, -73.2097 W]  
Valid for 05/10/2015 2000 EDT through 05/12/2015 2000 EDT



# IBM Deep Thunder

## Web Portal Interface – Weather Charts





# IBM Deep Thunder

## Web Portal Interface – Data Tables



Site	Date	Time	Time Zone	Dry Bulb Temperature (F)	Wet Bulb Temperature (F)	Precipitation (in)	Precipitation Rate (in/hr)	Pressure (mb)	Wind Speed (mph)	Wind Direction (Degrees)
Burlington	05/10/2015	20:20	EDT	65	63.9	0.01	0	1015.89	8.5	359
Burlington	05/10/2015	20:30	EDT	64	63.1	0.01	0	1016.47	9	355
Burlington	05/10/2015	20:40	EDT	64	62.6	0.01	0	1015.69	8.4	349
Burlington	05/10/2015	20:50	EDT	63	62	0.01	0	1015.71	7.5	354
Burlington	05/10/2015	21:00	EDT	63	61.6	0.01	0	1017.1	6.9	357
Burlington	05/10/2015	21:10	EDT	62	60.8	0.01	0	1016.3	6.3	346
Burlington	05/10/2015	21:20	EDT	60	59.8	0.01	0	1015.56	7	343
Burlington	05/10/2015	21:30	EDT	59	59.2	0.01	0	1015.77	7.4	340
Burlington	05/10/2015	21:40	EDT	58	57.8	0.01	0	1016.13	8.4	338
Burlington	05/10/2015	21:50	EDT	57	57	0.01	0	1016.47	8.4	341
Burlington	05/10/2015	22:00	EDT	57	56.9	0.01	0	1018.12	7.1	341
Burlington	05/10/2015	22:10	EDT	57	56.6	0.01	0	1018.03	7.5	341
Burlington	05/10/2015	22:20	EDT	57	56.4	0.01	0	1016.53	6.9	357
Burlington	05/10/2015	22:30	EDT	57	56.3	0.01	0	1016.72	6.3	359
Burlington	05/10/2015	22:40	EDT	57	56.1	0.01	0	1016.22	7.1	349
Burlington	05/10/2015	22:50	EDT	57	56	0.01	0	1017.02	6.3	350
Burlington	05/10/2015	23:00	EDT	57	55.8	0.01	0	1017.32	6.2	357
Burlington	05/10/2015	23:10	EDT	57	55.5	0.01	0	1016.64	6	355
Burlington	05/10/2015	23:20	EDT	56	55.2	0.01	0	1016.61	5.4	357
Burlington	05/10/2015	23:30	EDT	56	55	0.01	0	1017.58	5.6	348
Burlington	05/10/2015	23:40	EDT	56	54.9	0.01	0	1016.94	4.1	344
Burlington	05/10/2015	23:50	EDT	56	54.8	0.01	0.03	1016.48	5.2	348
Burlington	05/10/2015	20:10	EDT	66	64.2	0.01	0.01	1016.64	8	10
Burlington	05/11/2015	22:10	EDT	56	55.4	1.43	0	1010.06	3.5	307
Burlington	05/11/2015	00:10	EDT	56	54.7	0.01	0.01	1016.25	5.8	337
Burlington	05/11/2015	00:30	EDT	57	54.8	0.01	0	1016.86	4.9	344
Burlington	05/11/2015	00:40	EDT	57	54.8	0.02	0	1017.39	4.8	349
Burlington	05/11/2015	00:50	EDT	57	54.7	0.02	0	1017.44	4.8	353
Burlington	05/11/2015	01:00	EDT	57	54.5	0.02	0	1016.82	5.2	358
Burlington	05/11/2015	01:10	EDT	57	54.3	0.02	0	1016.22	5.1	353
Burlington	05/11/2015	01:20	EDT	57	54.3	0.02	0	1016.35	5.2	354
Burlington	05/11/2015	01:30	EDT	57	54.2	0.02	0	1016.37	6	351
Burlington	05/11/2015	01:40	EDT	57	54.2	0.02	0	1016.04	5.6	355
Burlington	05/11/2015	01:50	EDT	57	54.1	0.02	0	1016.12	6	352
Burlington	05/11/2015	02:00	EDT	57	54.1	0.02	0	1016.47	4.8	344
Burlington	05/11/2015	02:10	EDT	57	54.1	0.02	0	1016.39	3.7	344
Burlington	05/11/2015	02:20	EDT	57	54.1	0.02	0	1016.61	5.1	343
Burlington	05/11/2015	02:30	EDT	57	54.1	0.02	0	1016.87	4.6	328
Burlington	05/11/2015	02:40	EDT	57	54	0.02	0	1016.47	4.7	333
Burlington	05/11/2015	02:50	EDT	56	53.8	0.02	0	1016.15	5.1	349
Burlington	05/11/2015	03:00	EDT	56	53.7	0.02	0	1015.78	4.6	352



# IBM Deep Thunder

## Web Portal Interface – Forecast Summary/Alerts

Vermont Weather Analytics Center  
 Forecast summary for Burlington (Vermont):  
 Valid for 06/09/2016 2000 EDT through 06/12/2016 2000 EDT  
 06/10/2016, 00Z Forecast

Summary table:

Saturday - Sunday		6/11/2016 - 6/12/2016			
	full day	20:00 - 04:00	04:00 - 12:00	12:00 - 20:00	
Precipitation accum (alert when > 1 in)	0.58	0.1	0.12	0.36	
Peak Precipitation Rate (in/hr)	0.37 at 6:20	0.25	0.37	0.17	
Accumulated Snowfall Average liq.ratio, (alert when > 4/10)	-	-	-	-	
Start Time	20:00	20:00	6:00	12:10	
End Time	20:00	21:20	6:50	20:00	
Max Sustained Wind (alert when > 40 mph)	32.2 NW at 6:50	16.6 W at 3:50	32.2 NW at 6:50	29.2 NW at 19:10	
Max Wind Gust (alert when > 40 mph)	<b>49.4 at 6:40</b>	27.6 at 3:50	<b>49.4 at 6:40</b>	<b>46.9 at 19:10</b>	
Low Temp (alert when < 0 F)	51°	64°	51°	51°	
Wind Chill (alert when <-20 F)	44°	63°	45°	44°	
High Temp (alert when > 90 F)	69°	69°	68°	57°	
Heat Index (alert when > 100 F)	75°	73°	75°	57°	

Forecasted weather variables  
 that meet impact thresholds  
 will display in **red**

### Current Thresholds:

Precip Accum: >1.00"+  
 Peak Precip rate: >1.00"/hr  
 Max Sustained: >30 mph  
 Max Gust: >40 mph  
 Low Temp: >90°F  
 High Temp: <0°F  
 Wind Chill: <-20°F  
 Heat Index: >100°F  
 Snowfall: >4"  
 Snow ratio: 10:1 or less

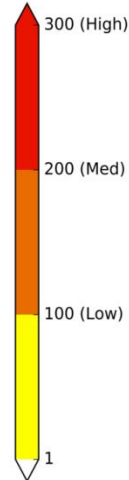
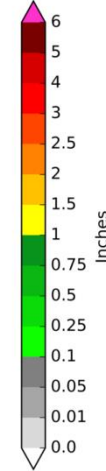
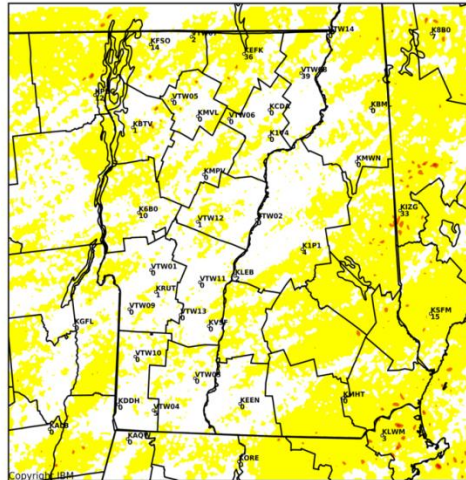
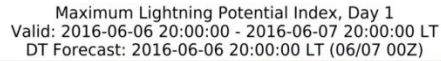
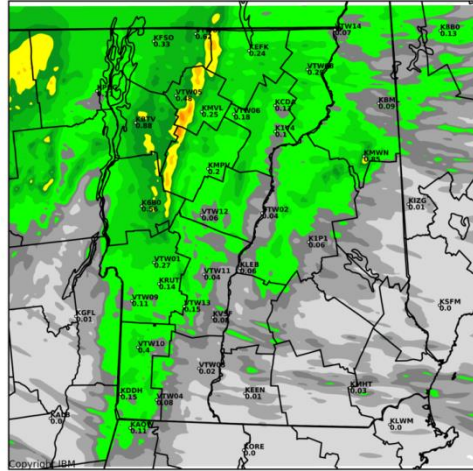
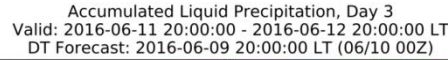
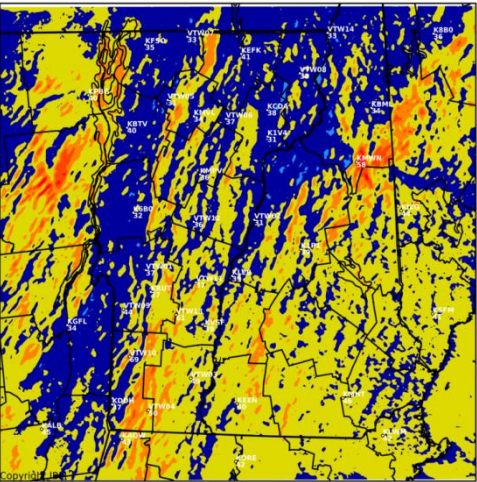
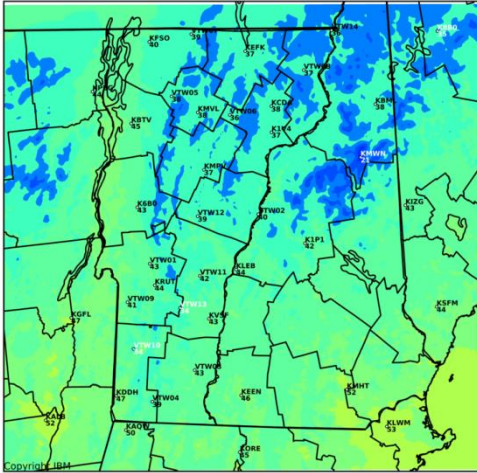
You are subscribed to alerts from this location.  
[Unsubscribe from alert](#)

→ **Forecast Email Alerts** →

From: Deep Thunder <noreply@vtvac.velco.com>  
 To: Robert D'Arienzo  
 Cc:  
 Subject: There are 16 active Deepthunder Weather Alerts

Deepthunder weather forecast raised the following 16 alert(s) for your area of interest:  
[72 hours forecast for Vermont, Burlington](#) -> Max Wind Gust (alert when > 40 mph) (49.4mph)

## Web Portal Interface – Static Maps



## Static Maps:

1. Accumulated Snow
2. Accumulated Snow (water equivalent)
3. Accumulated Precipitation
4. Max Gust
5. Max Reflectivity
6. Max Lightning Potential Index (LPI)
7. Max Temp
8. Min Temp
9. Max Heat Index
10. Max Wind Chill





# Verifications

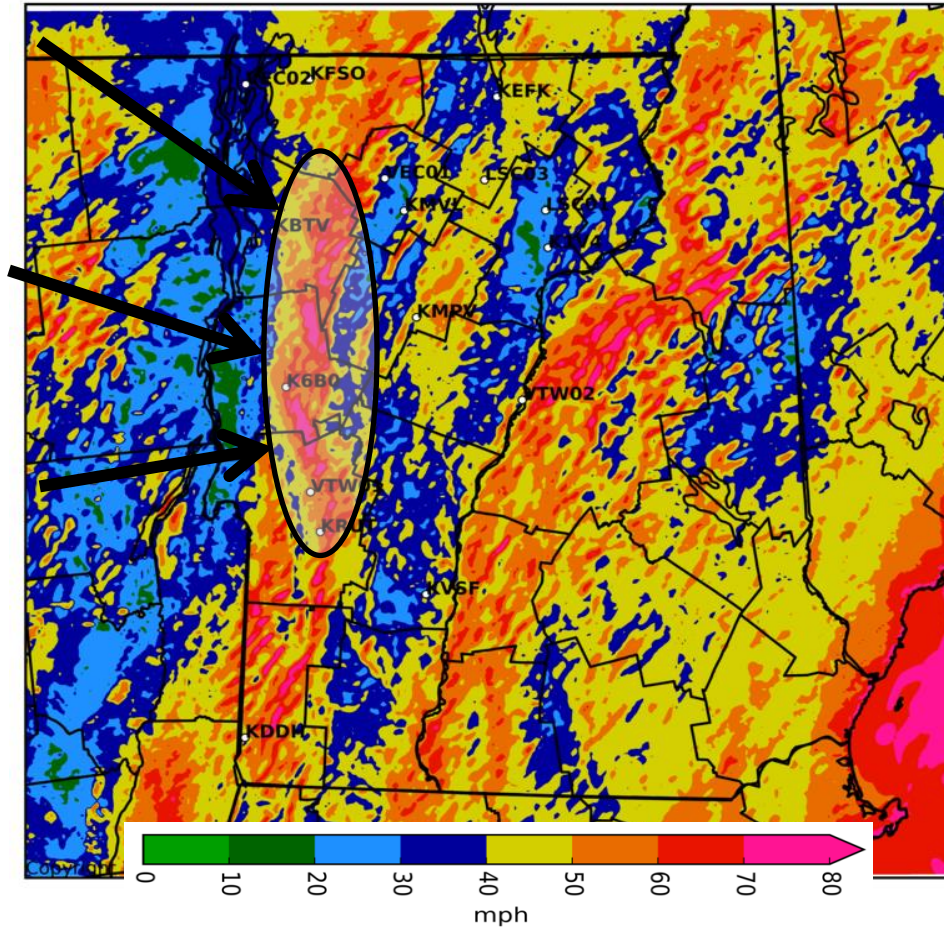
## 1/10/2016 High Wind Event

### DT – Max Wind Gust Forecast

Maximum Wind Gust

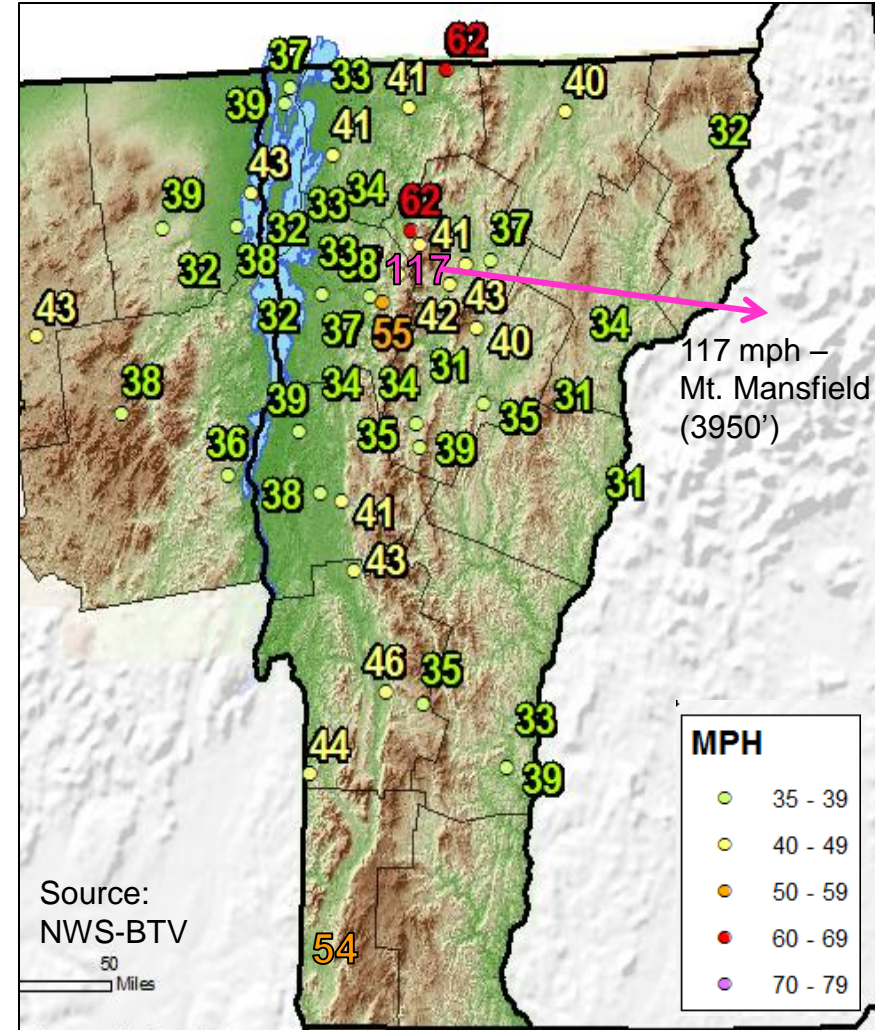
Valid: 2016-01-09 19:00:00 - 2016-01-10 19:00:00 LT

DT Forecast: 2016-01-09 19:00:00 LT



Strong correlation between the highest forecasted and highest observed wind gust values

### Observed Wind Gusts





# Verifications

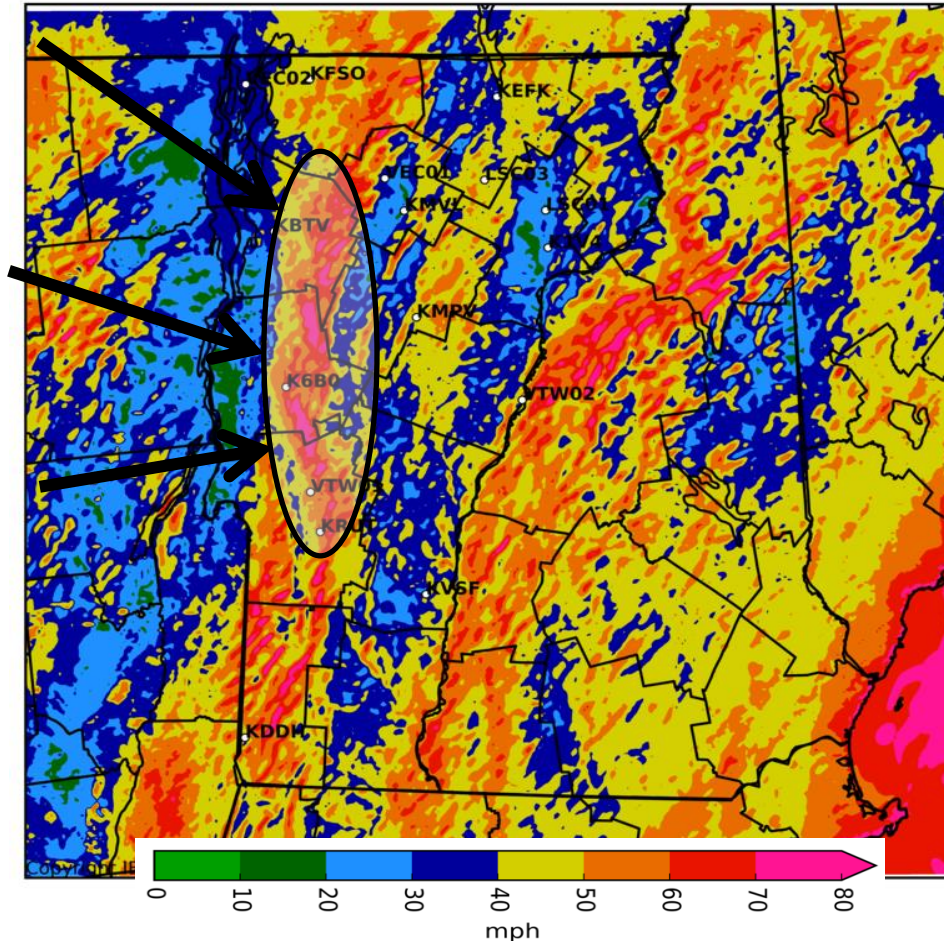
## 1/10/2016 High Wind Event

### DT – Max Wind Gust Forecast

Maximum Wind Gust

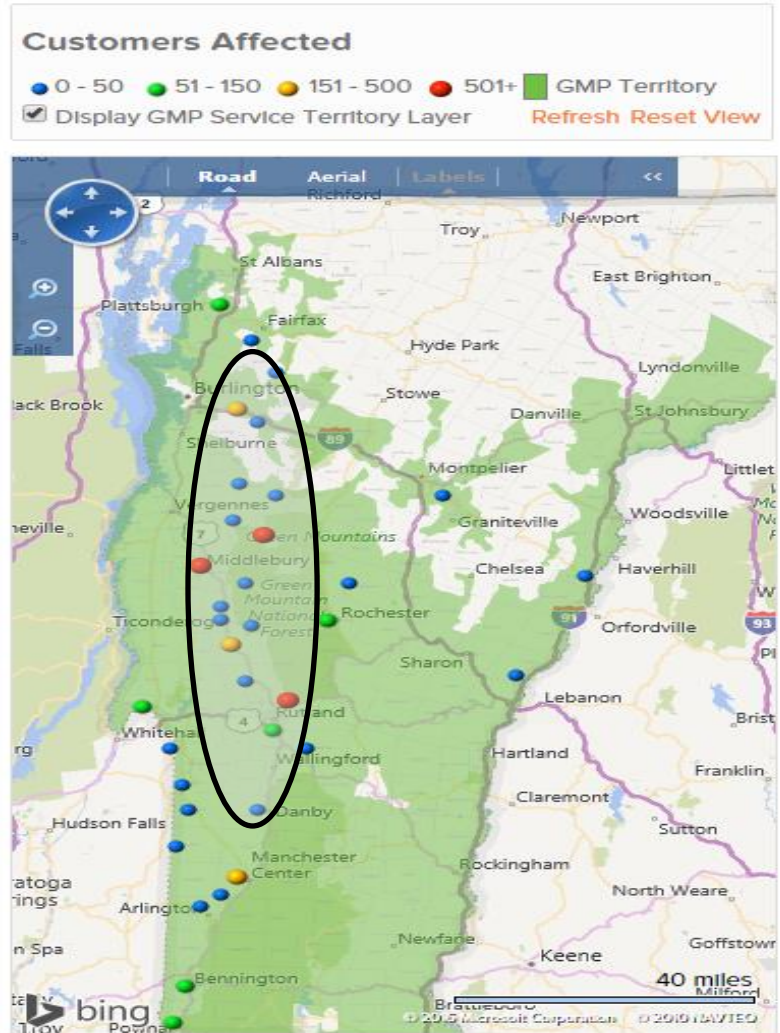
Valid: 2016-01-09 19:00:00 - 2016-01-10 19:00:00 LT

DT Forecast: 2016-01-09 19:00:00 LT



Areas of the strongest forecasted wind gusts matched well with the highest density of outages

### GMP Outages @ 1300 hrs





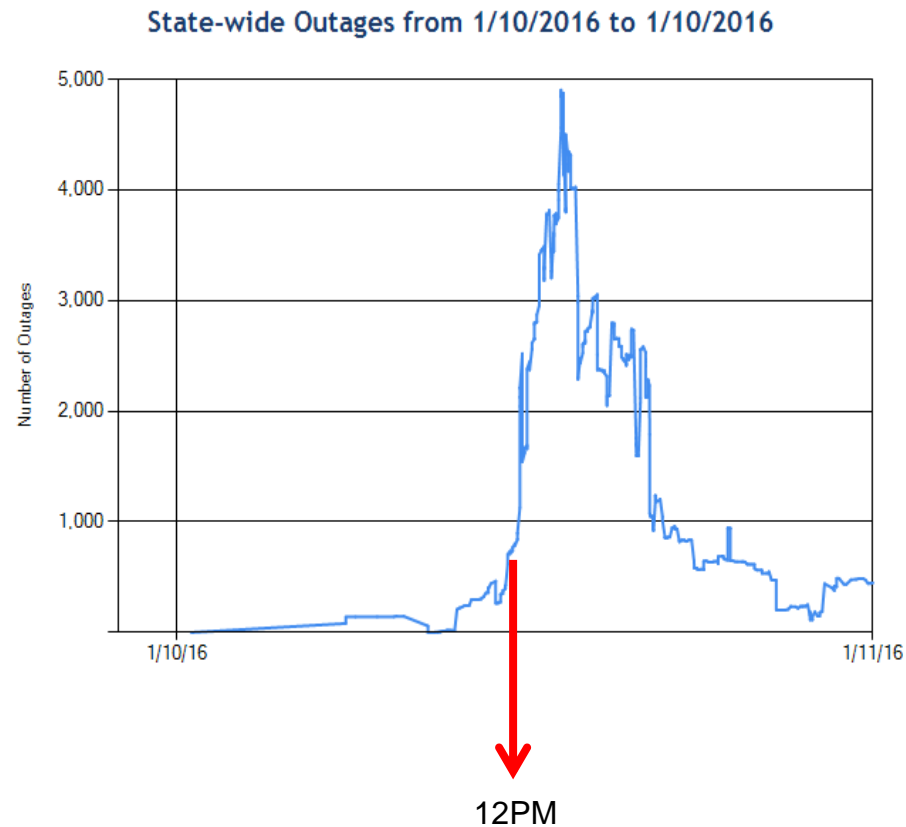
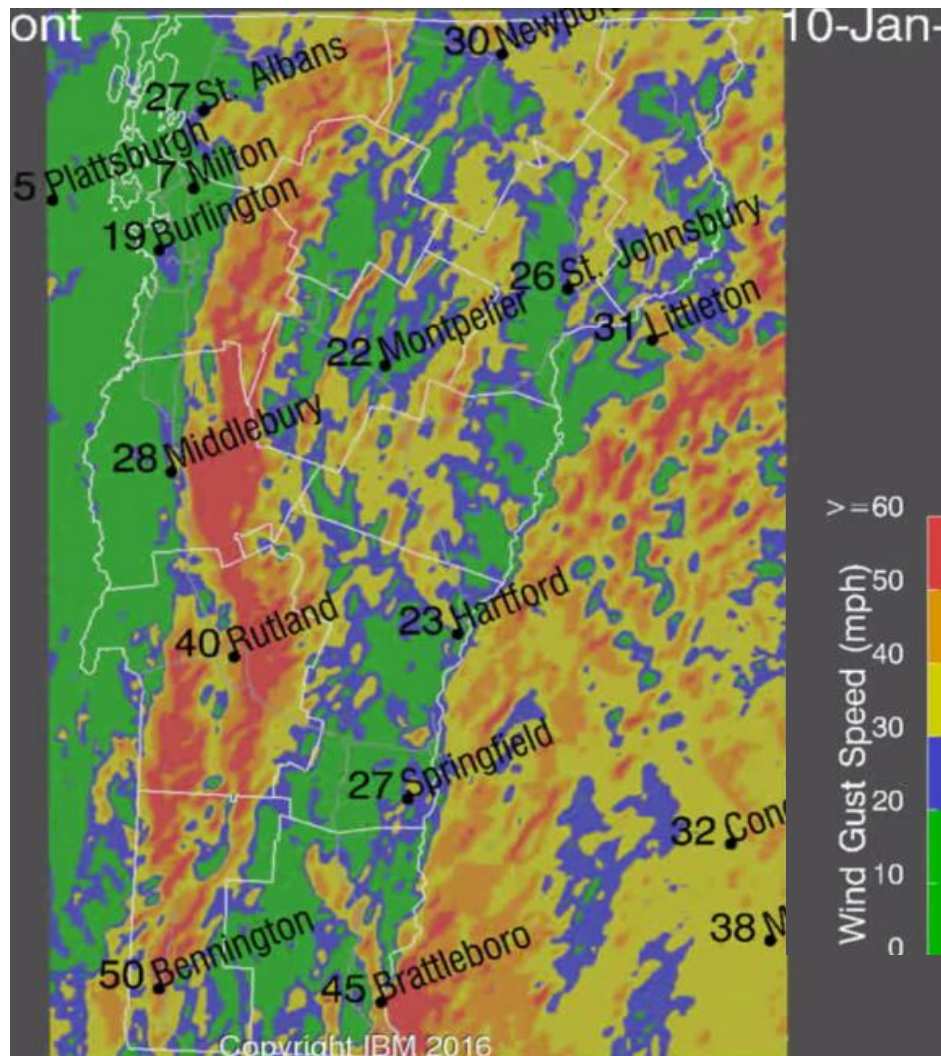
# Verifications

## 1/10/2016 High Wind Event

### DT – Wind Gust Forecast @ 1200 hrs

Time of strongest forecasted wind gusts correlated very well to time of peak outages (~1200-1300 hrs)

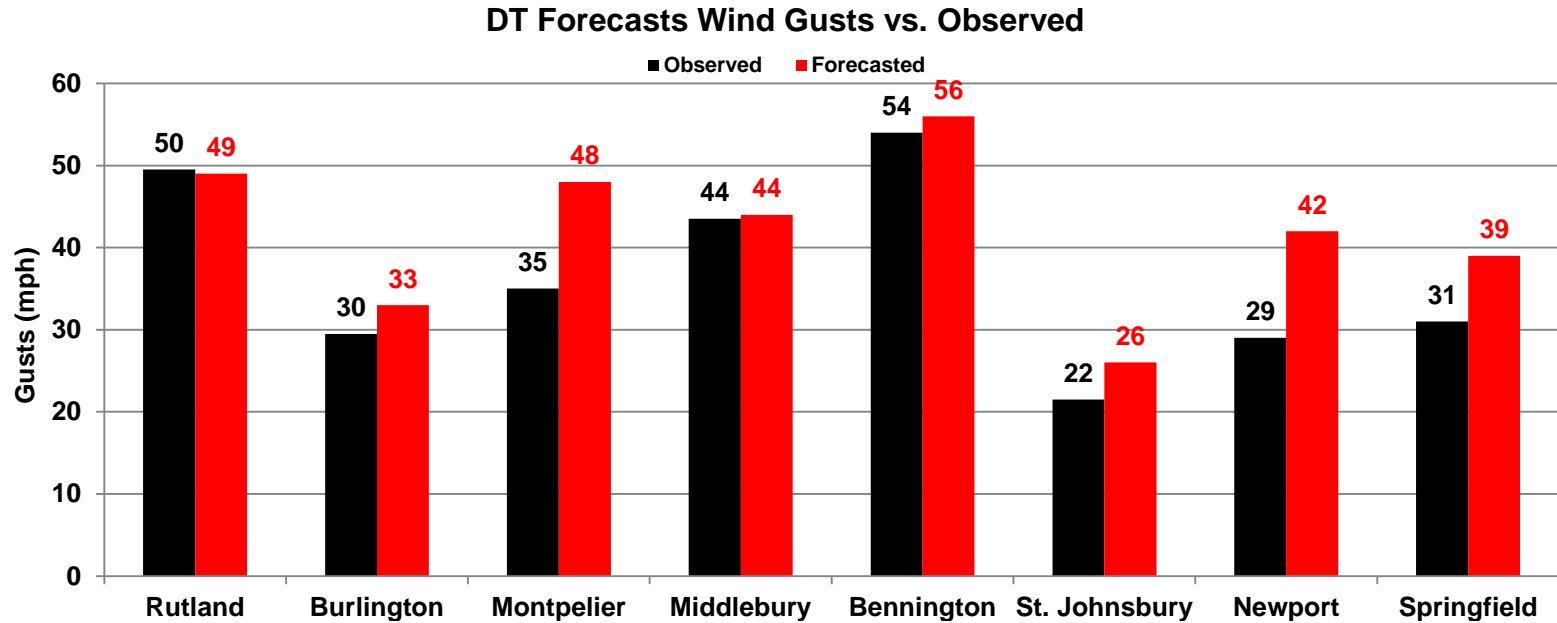
### Statewide Outage Graph – 1/10





# Verifications

## 1/10/2016 High Wind Event

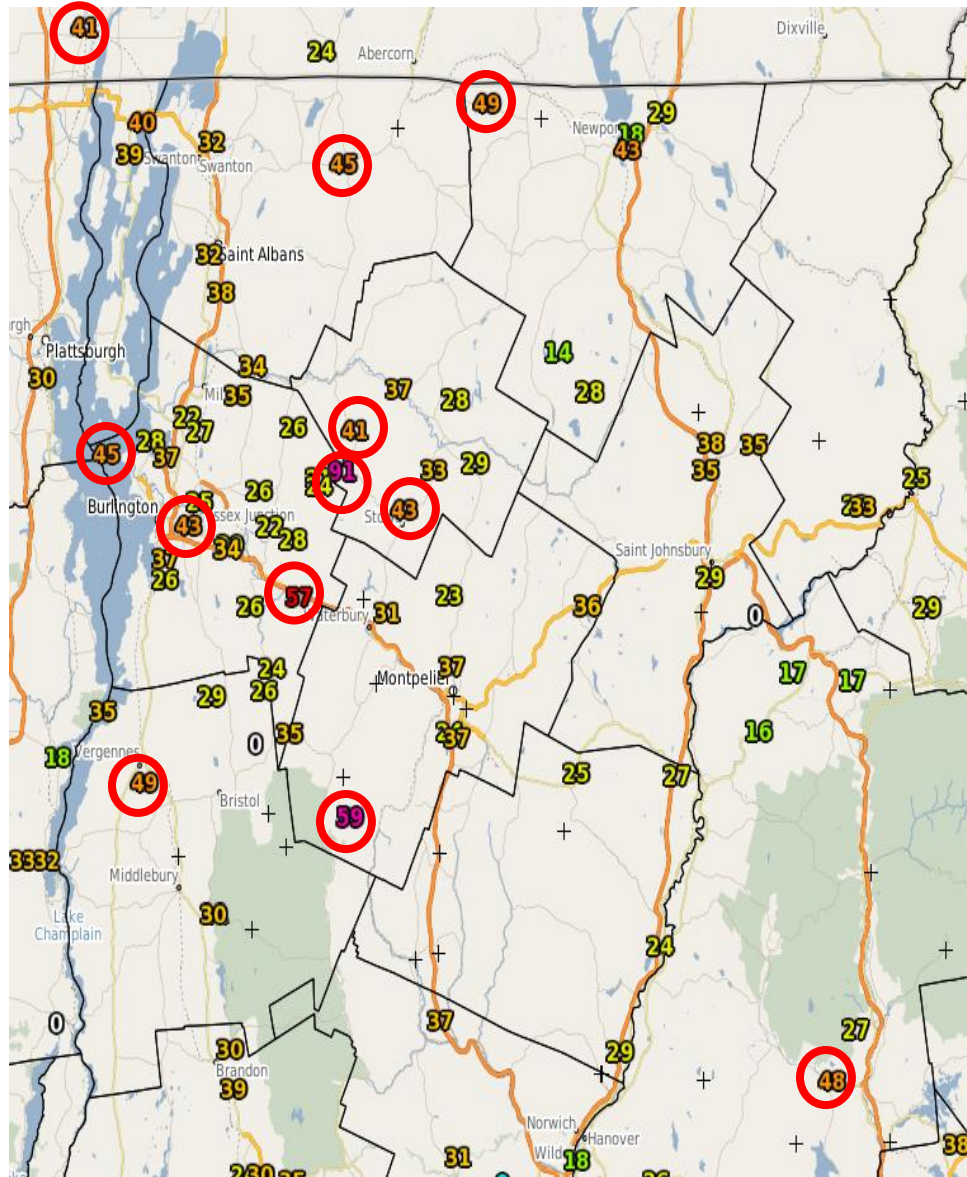


	Day 3	Day 2	Day 1
Bias	8.3	11.4	5.5
MAE	8.9	11.4	5.6

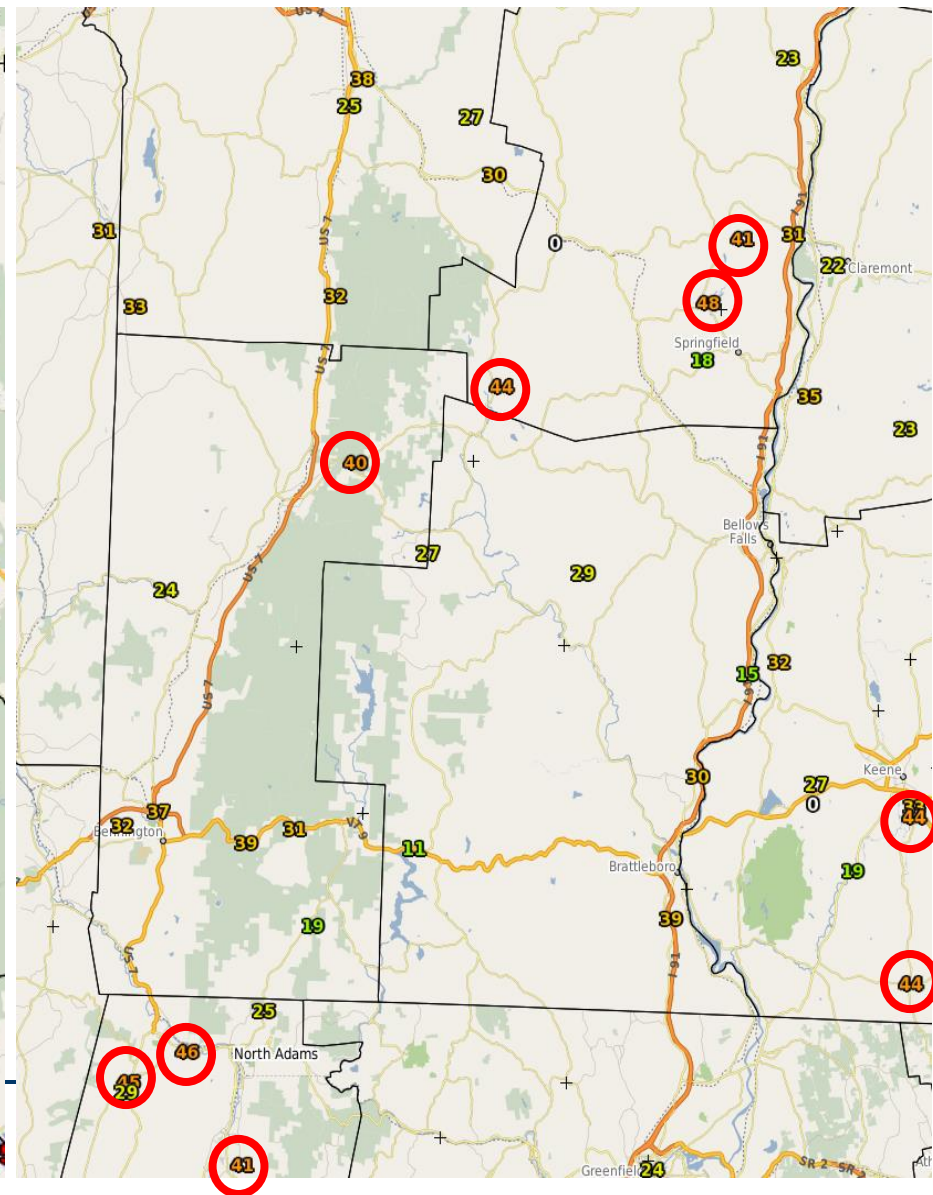
# Verifications

## 2/29/2016 High Wind Event

### Northern Vermont



### Southern Vermont



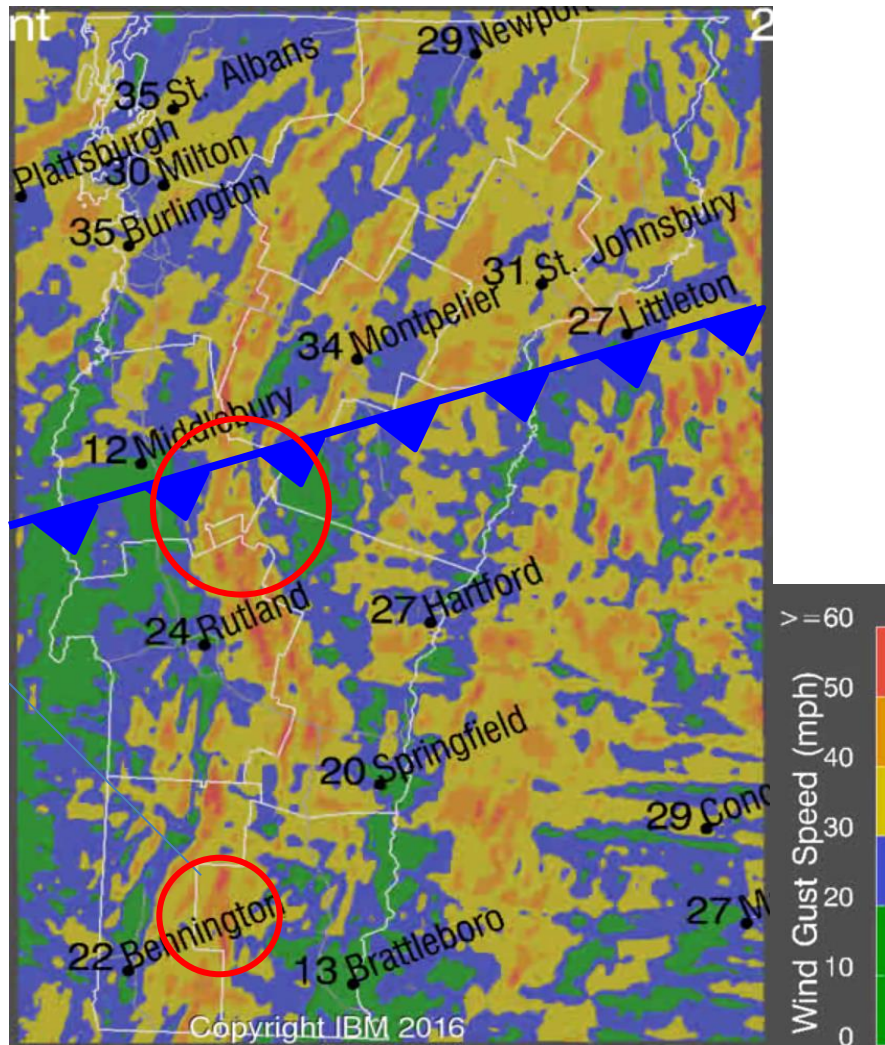
○ = 40+ mph observed gusts



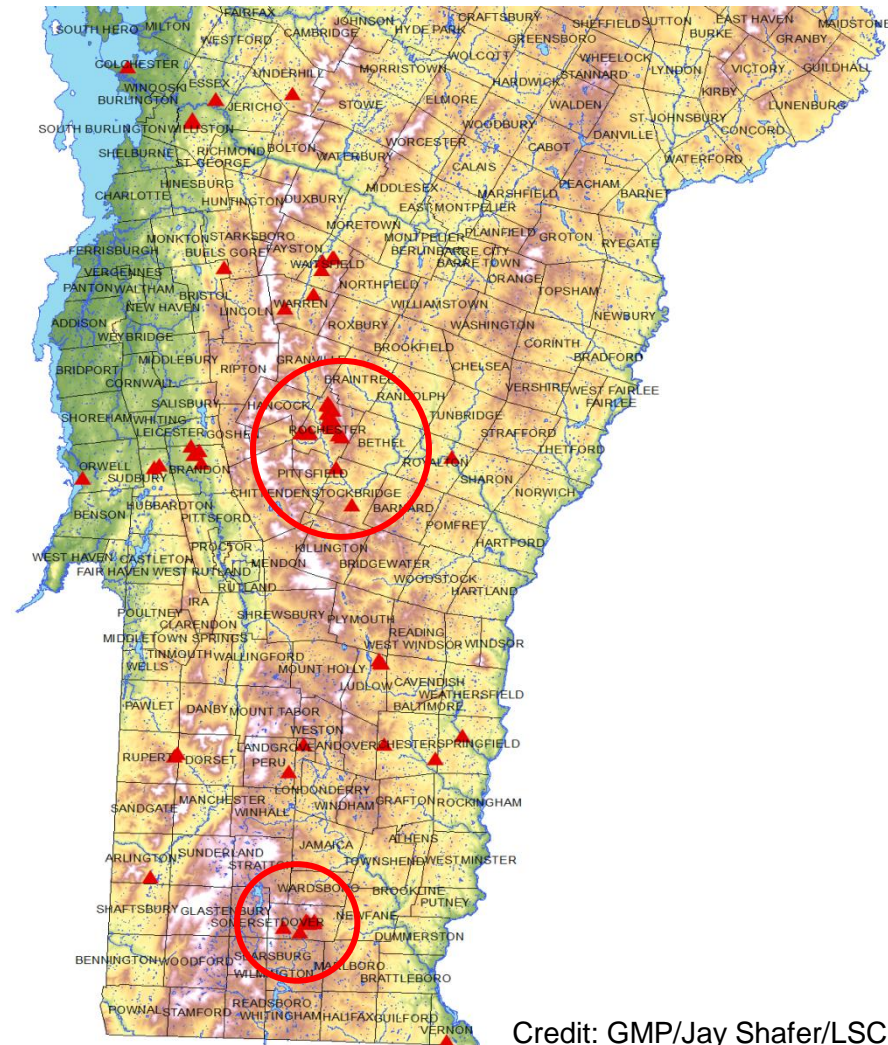
# Verifications

## 2/29/2016 High Wind Event

### DT Max Wind Gust Forecast @ 11:30PM



### Observed Outages (GMP Only)



Credit: GMP/Jay Shafer/LSC



# Verifications

## 2/29/2016 High Wind Event

Location	Station	Observed	DT						MAE					
			Day 3		Day 2		Day 1		Day 3		Day 2		Day 1	
			2/27 0Z	2/27 12Z	2/28 0Z	2/28 12Z	2/29 0Z	2/29 12Z	2/27 0Z	2/27 12Z	2/28 0Z	2/28 12Z	2/29 0Z	2/29 12Z
Burlington	KBTM	43	37	43	36	44	52	49	6	0	7	1	9	6
Montpelier	KMPV	37	38	34	31	41	44	39	1	3	6	4	7	2
Morrisville	KMVL	33	39	44	38	40	32	42	6	11	5	7	1	9
St. Johnsbury	VTSTJ	29	35	30	23	36	35	34	6	1	6	7	6	5
Rutland	KRUT	38	46	28	29	27	34	34	8	10	9	11	4	4
Springfield	KVSF	48	43	33	30	25	36	36	5	15	18	23	12	12
Bennington	KDDH	32	33	32	31	30	32	32	1	0	1	2	0	0
Brattleboro	VTGUI	39	39	29	27	29	28	37	0	10	12	10	11	2
AVG									4	6	8	8	6	5

### Key:

<5 mph (Exceptional)  
 5-15 mph (Acceptable)  
 >15 mph (Poor)

# Forecast Analysis & Communication

## DT Forecast Summary for 2/16 (valid 00:00 to 23:59) [STORM TOTAL/MAX]

Location	Elevation (ft)	WINDS		PRECIPITATION			TEMPERATURES	
		Max Sustained Wind (mph)	Max Gust (mph)	Total Liquid Precipitation (in)	Total Snow (in)	Average Snow-to-Liquid Ratio	Max Temperature (F)	Min Temperature (F)
Barre	612	24	36	1.47	4.1	6.4	52	17
Barton	880	28	43	0.86	1.1	3.1	51	19
BED HQ	107	27	44	1.19	1.6	3.6	55	20
Bennington	708	26	45	0.75	0.3	0.0	57	25
Brattleboro	237	27	44	1.96	3.9	5.7	55	19
Cambridge	743	28	42	0.97	0.8	1.1	54	22
Canaan	1305	21	35	1.50	1.8	3.3	49	17
Coldchester	273	25	37	1.24	1.5	3.4	54	20
Essex Junction	346	26	39	1.14	1.1	2.7	56	20
Enosburg Falls	408	22	37	1.64	6.1	4.1	52	25
Ferdinand	1161	23	35	2.51	2.3	3.0	50	19
GMP South HQ	620	20	35	0.81	0.9	0.0	57	27
Hardwick	855	23	38	1.28	2.7	5.2	52	16
Hartford	401	17	31	1.64	4.2	5.9	53	17
Hyde Park	635	23	34	0.97	0.7	0.0	52	19
Jacksonville	1315	24	40	4.47	3.4	5.4	52	16
Jay Peak	3814	39	65	1.46	2.5	3.6	44	14
Johnson	497	18	29	1.06	1.0	0.6	52	21
Killington	4236	37	59	1.01	2.2	5.7	45	16
Ludlow	1039	23	40	1.93	5.3	6.6	52	18
Lyndonville	713	19	33	1.22	2.3	4.8	53	16
Manchester	237	24	42	1.57	3.0	5.4	55	20
Mt. Mansfield	3719	43	65	1.11	1.8	5.0	43	12
Middlebury	386	26	40	1.38	2.9	4.7	54	22
Montpelier	676	21	36	1.67	3.3	5.6	53	17
Morrisville	774	22	36	1.55	1.1	2.0	52	18
Newport	683	26	39	0.82	1.0	1.2	52	19
Northfield	749	25	42	1.60	5.9	7.0	52	17
Orleans	781	25	38	1.06	1.0	1.8	52	19
Randolph	1396	22	31	1.30	3.9	6.8	50	15
Richford	489	22	33	0.89	0.7	0.0	52	24
Rutland	561	23	33	0.79	0.9	0.0	56	25
S. Alburgh	128	25	31	1.16	1.2	1.6	45	20
S. Burlington	314	25	42	1.25	1.6	3.6	55	19
Searsburg	2298	34	50	1.25	1.5	5.3	47	13
Sheffield	2360	31	46	1.27	1.5	5.4	47	13
Smuggler's	3637	33	52	1.27	2.2	5.8	44	11
Springfield	374	24	41	2.09	3.8	5.3	54	17
St. Albans	400	24	34	1.65	3.4	3.2	51	21
St. Johnsbury	604	20	36	1.14	2.3	5.4	55	17
Stowe HQ	697	19	35	0.59	0.9	0.0	52	18
Swanton	156	23	34	1.42	1.9	2.7	52	20
Townshend	1668	32	50	2.79	3.8	5.9	52	16
VEC HQ	523	18	33	1.03	1.1	2.0	53	21
VELCO HQ	722	24	34	0.92	0.8	0.0	55	25
Virgennes	178	27	36	1.38	2.6	4.9	53	18
WEC HQ	722	21	35	1.30	2.6	5.6	53	17
Wells	2099	32	55	0.96	2.2	4.9	53	23
Woodstock	1488	16	32	1.36	3.7	6.5	53	17

Values in red indicate forecast threshold exceedance (Sustained: >30 mph, Gust: >40 mph, Rainfall: >1", Snow: >4", Snow-to-Liquid Ratio: <8:1)

# Future Work

- Develop a quantitative verification strategy for maximum wind gusts (automated)
- Research additional forecasting and modeling techniques (probabilistic, ensembles, etc.)
- Research and build historical weather/outage database in an effort to increase storm preparedness/response (LSC → wet snow/ice loading and gradient wind events)
- Build in-house HPCC data center to support operational forecast models and various research

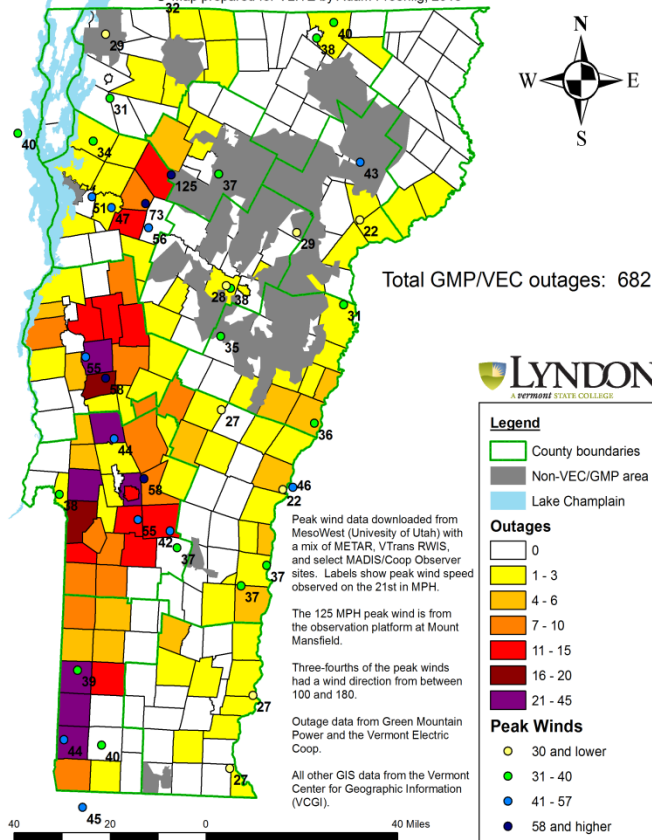


# Future Applications

## Outage/Impact Prediction

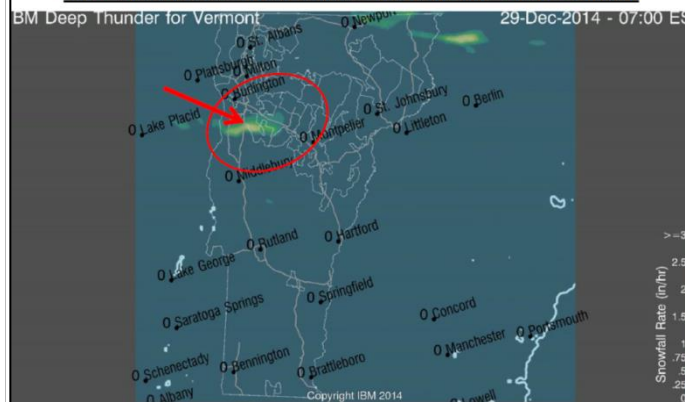
VEC/GMP Outages with Peak Wind Speeds  
from Dec. 21-22, 2012 Wind Storm

Map prepared for VLITE by Adam Froehlig, 2015



## Transportation

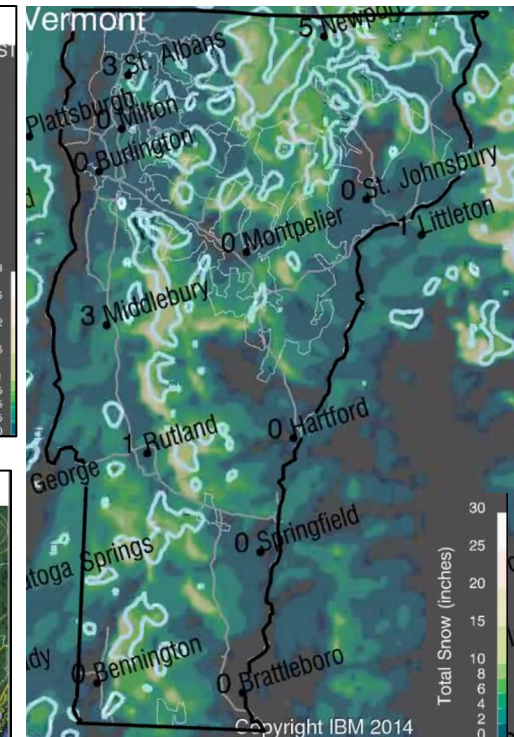
DT Forecasted Snow Rates: 12/29/2014 valid 7:00AM



Observed Radar (BTV/CXX) at 6:58AM



## Recreation



**Other:**

Environmental  
Agriculture  
Emergency Management  
Citizen Science

# Questions?

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