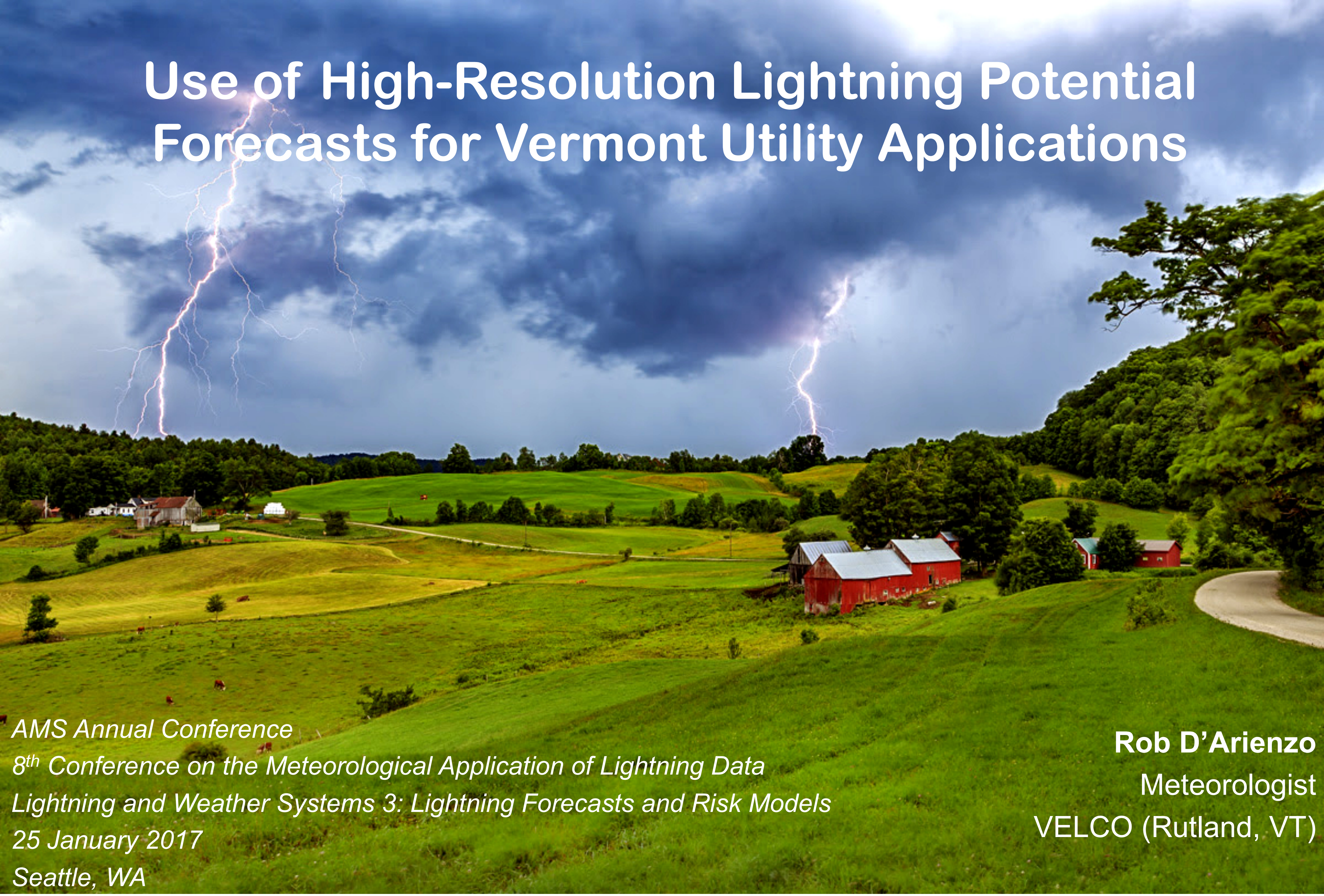


Use of High-Resolution Lightning Potential Forecasts for Vermont Utility Applications

AMS Annual Conference
8th Conference on the Meteorological Application of Lightning Data
Lightning and Weather Systems 3: Lightning Forecasts and Risk Models
25 January 2017
Seattle, WA

Rob D'Arienzo
Meteorologist
VELCO (Rutland, VT)

vermont electric power company
VELCO

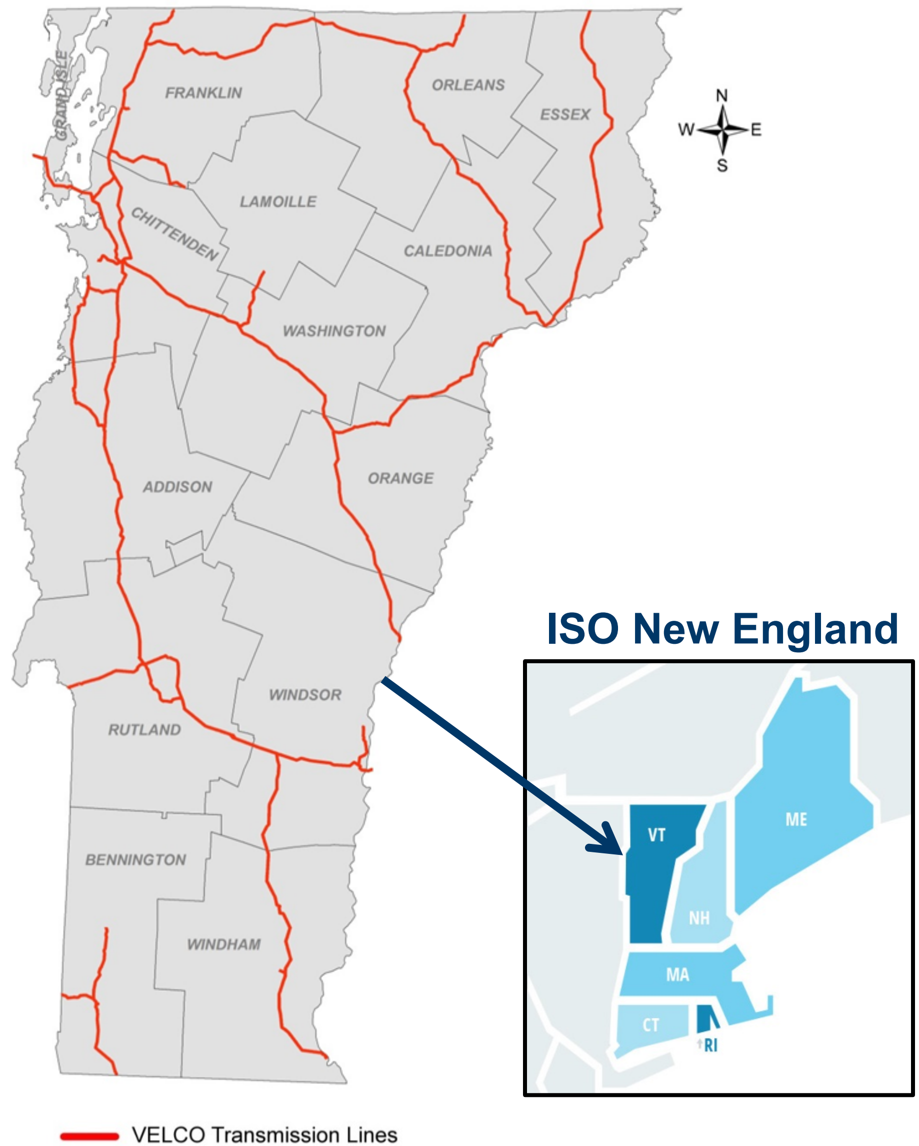
Vermont Weather Analytics Center

Photo: John Vose

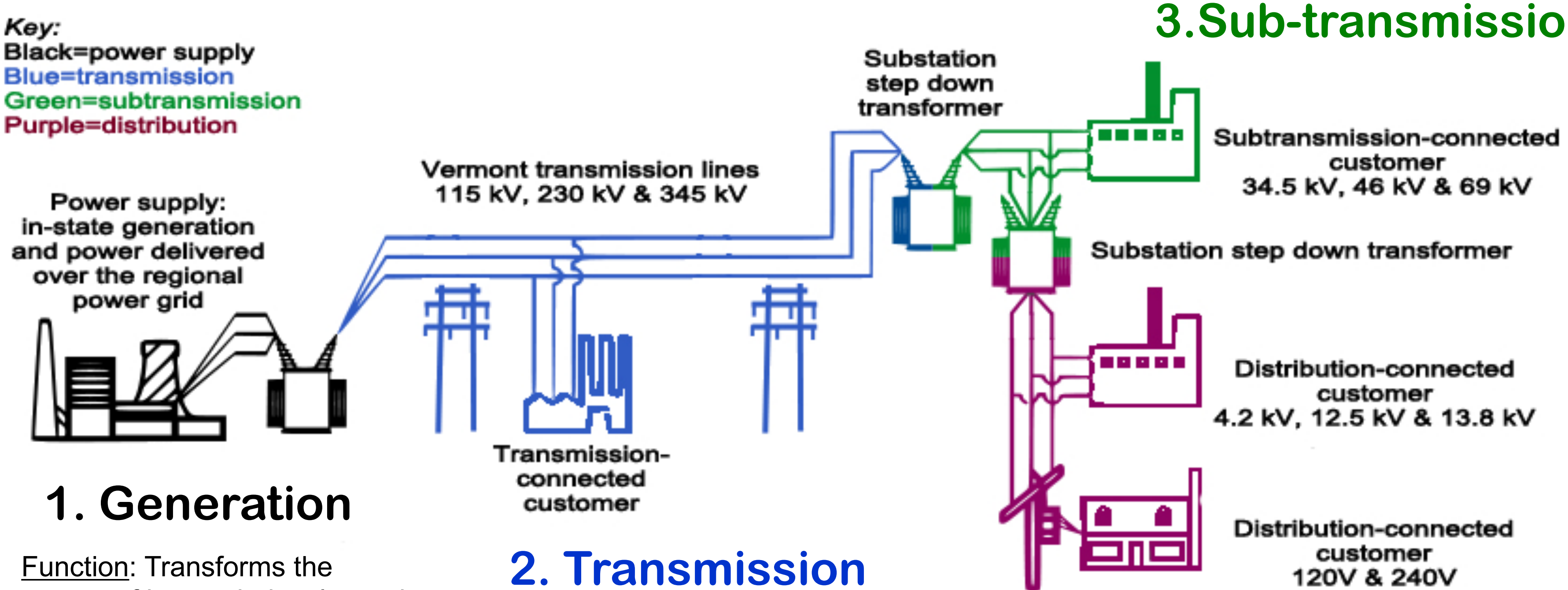
Background
VELCO

- 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 electric substations, switching stations, and terminal facilities
  - 1,500 miles of fiber optic communication network
  - 45-site, statewide radio system
  - Equipment that enables interconnected operations with Hydro-Québec



Background
Electrical Grid 101



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)

2. Transmission

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

Example: VELCO

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.)

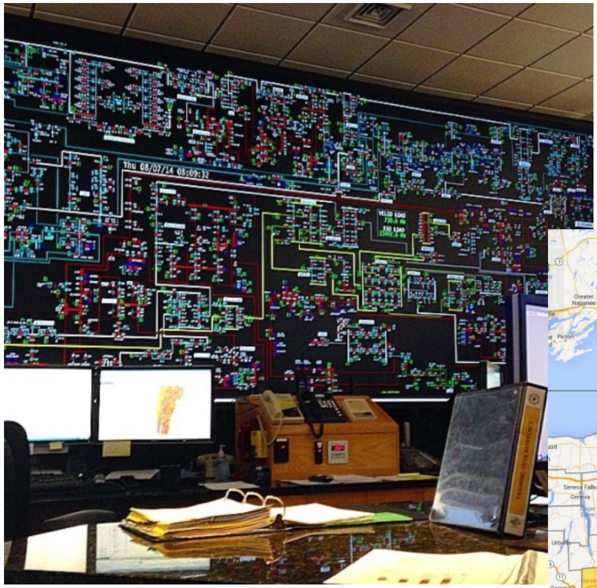
Background

Lightning Impacts

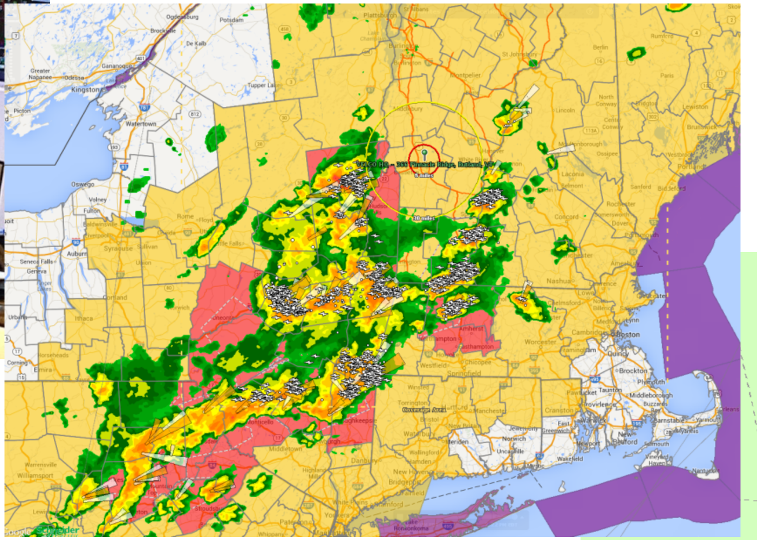
- Lightning is the most frequent cause of transmission outages and costs the nation roughly $1B/year due to damaged or destroyed equipment
- Power system faults caused by lightning can cost large commercial customers millions of dollars due to losses in production
- Lightning detection and prediction for grid operators is critical for:
  - Planning and protecting transmission assets
  - Protecting line crew and field workers to maintain safety
  - Historical analyses of lightning data to support engineering and performance enhancement

Background
Lightning Impacts

Before Event – Outage Planning



During Event – Real-Time Lightning Monitoring



After Event – Analysis

Event Timeline

Vermont Weather Analytics Center
Motivation

2016

Top 10 risks in terms of **Likelihood**	Top 10 risks in terms of **Impact**
1 Large-scale involuntary migration	1 Failure of climate-change mitigation and adaptation
2 Extreme weather events	2 Weapons of mass destruction
3 Failure of climate-change mitigation and adaptation	3 Water crises
4 Interstate conflict	4 Large-scale involuntary migration
5 Natural catastrophes	5 Energy price shock
6 Failure of national governance	6 Biodiversity loss and ecosystem collapse
7 Unemployment or underemployment	7 Fiscal crises
8 Data fraud or theft	8 Spread of infectious diseases
9 Water crises	9 Asset bubble
10 Illicit trade	10 Profound social instability

Sharp increase in environmental risks starting in 2011

Top 5 Global Risks in Terms of Likelihood

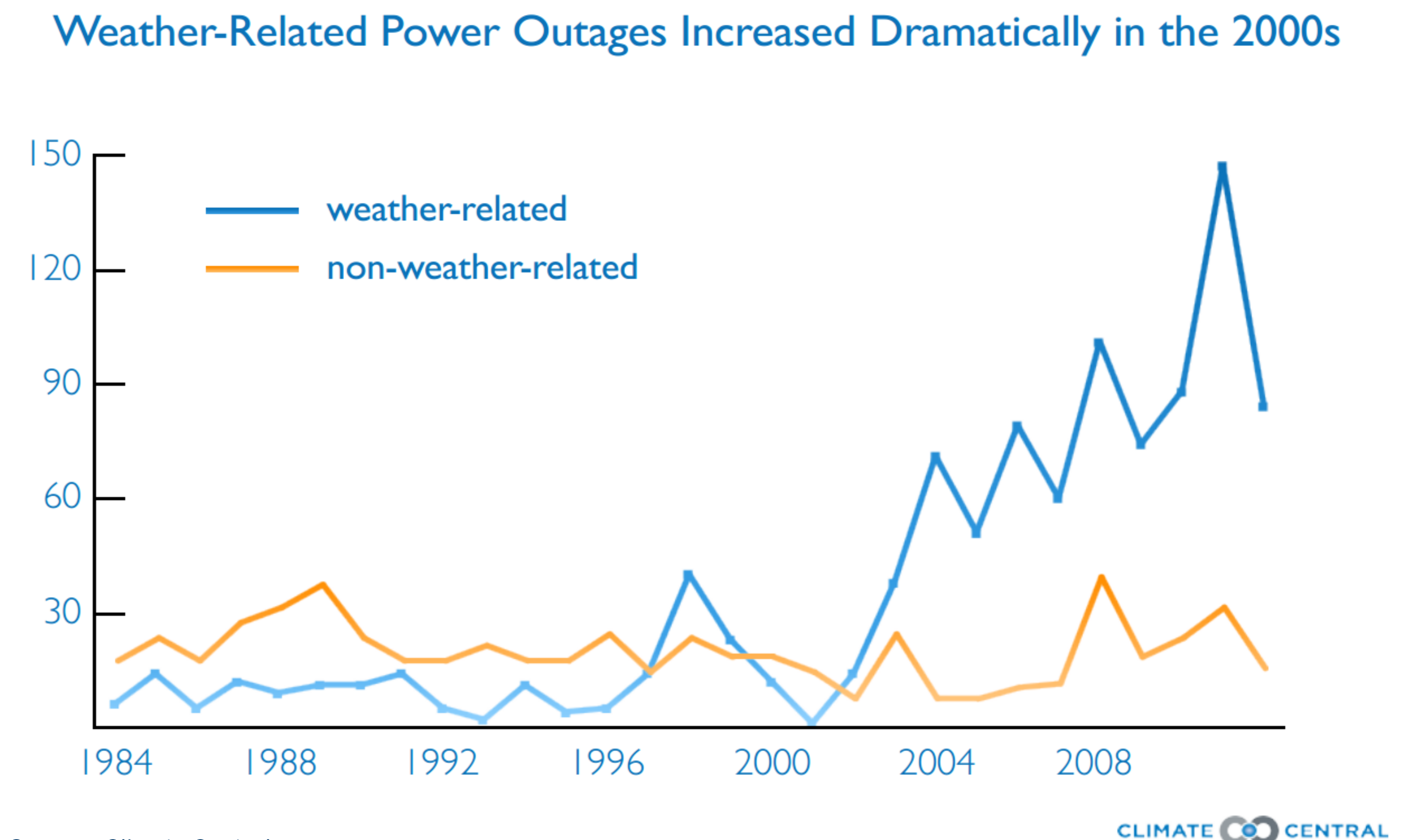
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1st	Breakdown of critical information infrastructure	Asset price collapse	Asset price collapse	Asset price collapse	Storms and cyclones	Severe income disparity	Severe income disparity	Income disparity	Interstate conflict with regional consequences	Large-scale 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

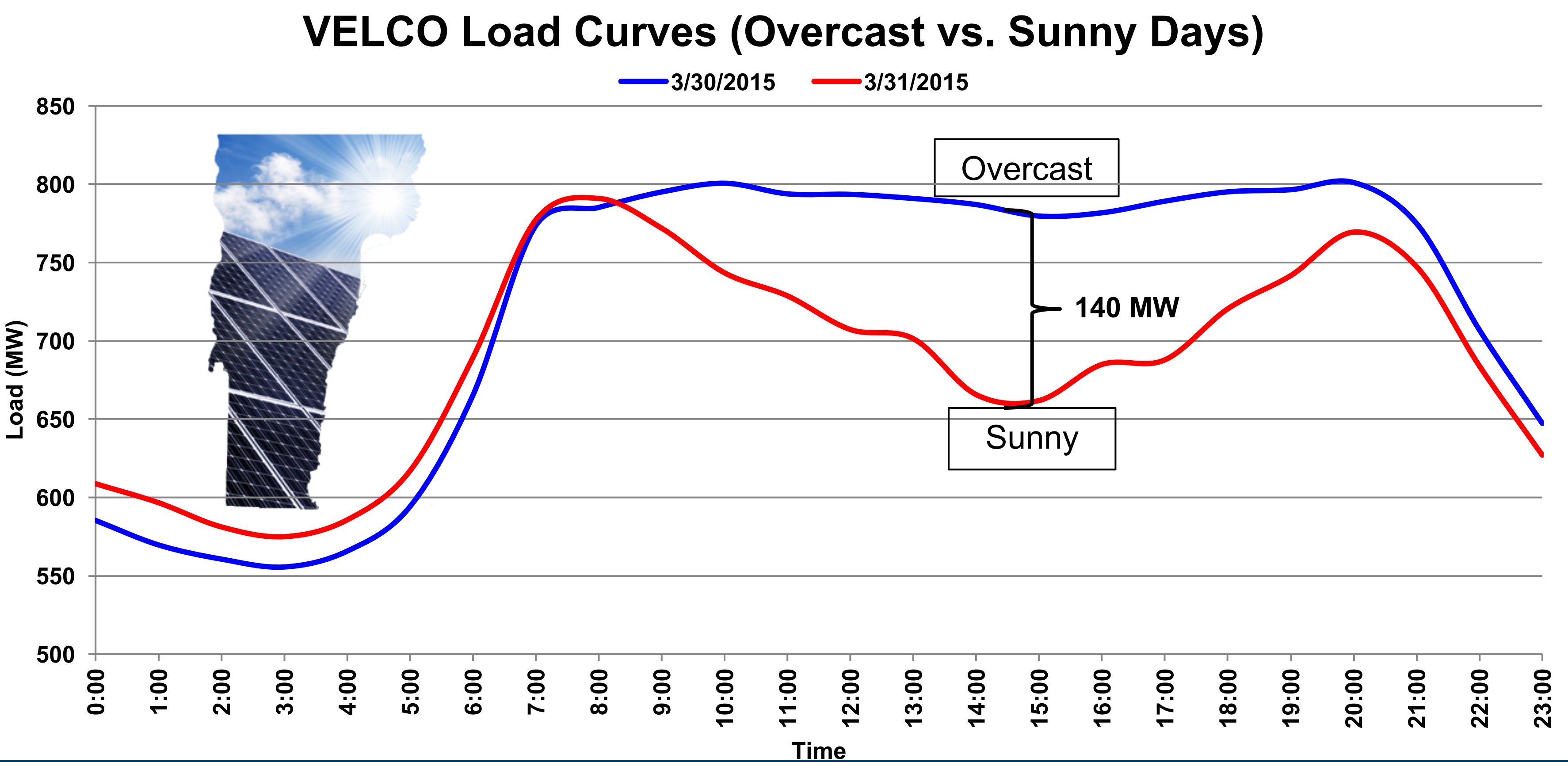
Motivation



Source: Climate Central

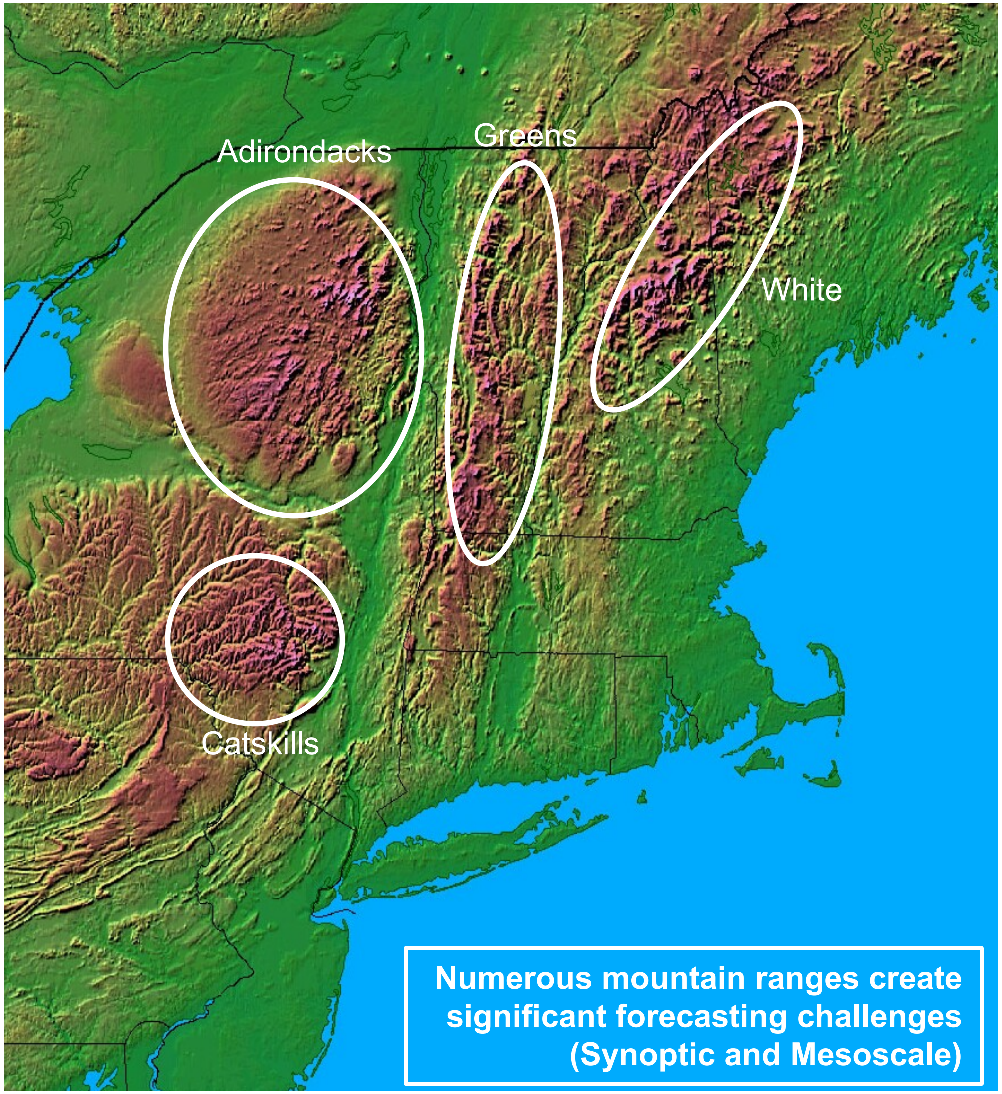
Vermont Weather Analytics Center
Motivation

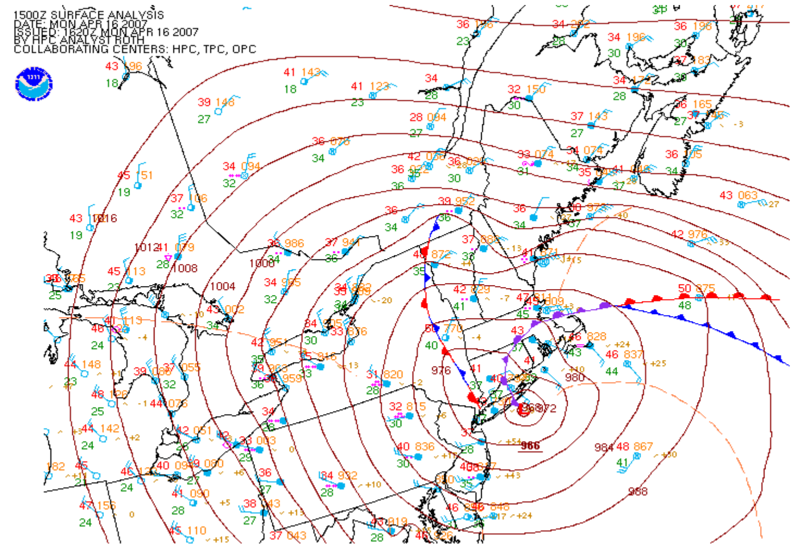
Boom in distributed solar is already changing VT's load shape

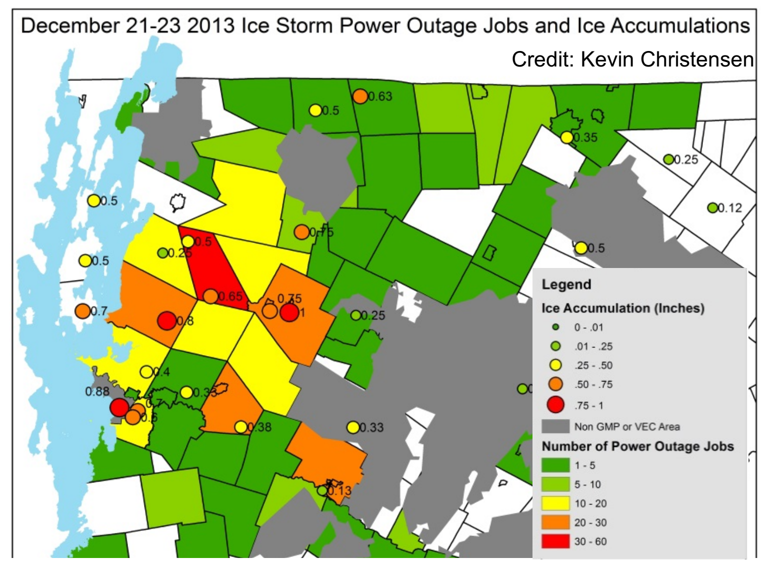


Vermont Weather Analytics Center

Motivation







Vermont Weather Analytics Center
Overview

A powerful weather, energy data and analytics platform built with IBM that utilizes four coupled models and leading-edge analytics to deliver the most precise and accurate wind and solar generation forecasts in the world. VWAC enables us to:


Increase grid reliability, community resiliency

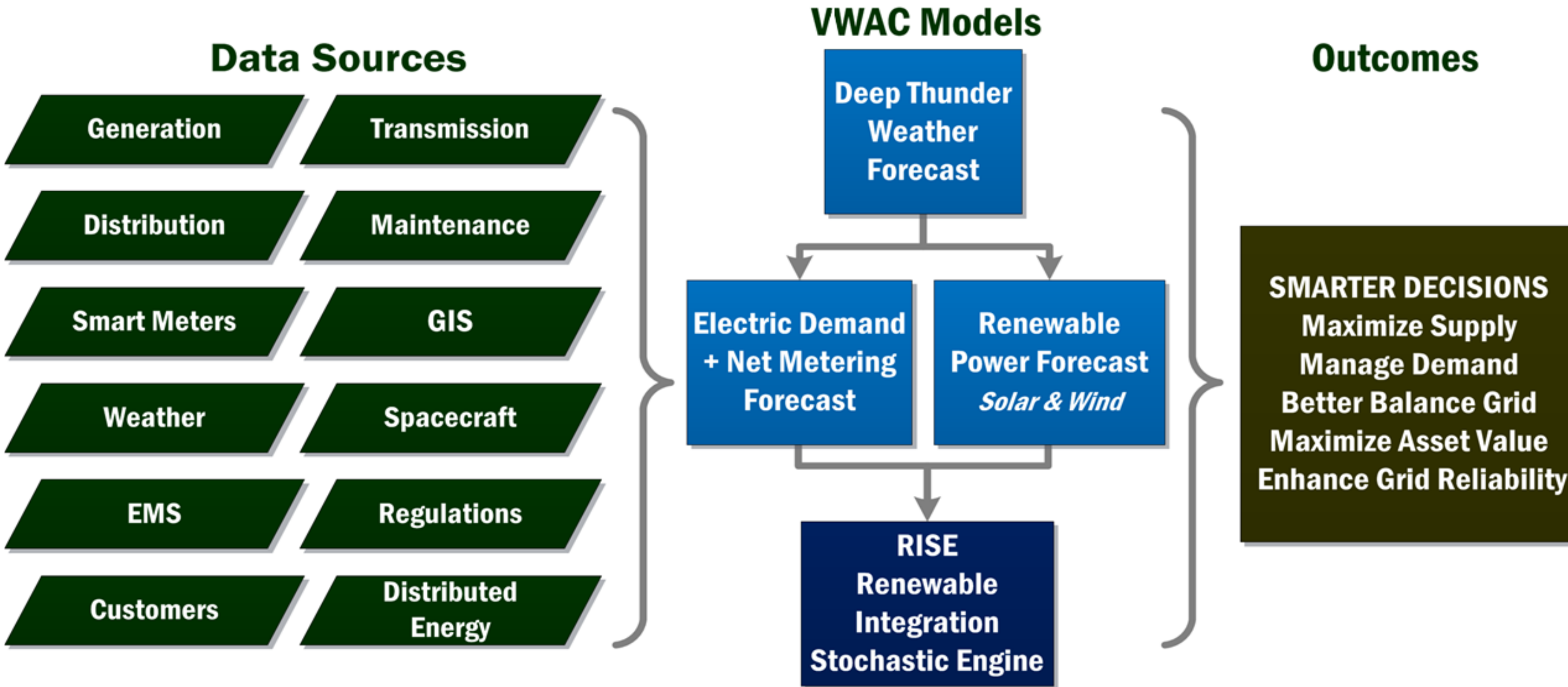

Lower weather event-related operational costs


Garner renewable generation's full value



Vermont Weather Analytics Center

Models



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*

Vermont Weather Analytics Center

Partners

vermont electric power company VELCO

IBM

VT Distribution Utilities (DU's):

GREEN MOUNTAIN POWER

VERMONT ELECTRIC CO OP INC

WEC Washington Electric CO-OP

BURLINGTON Electric DEPARTMENT

Stowe ELECTRIC

VT College/ University:

LYNDON A vermont STATE COLLEGE

The University of Vermont

Other Organizations:

VERMONT AGENCY OF TRANSPORTATION

VPPSA

VLITE Building an energy secure Vermont

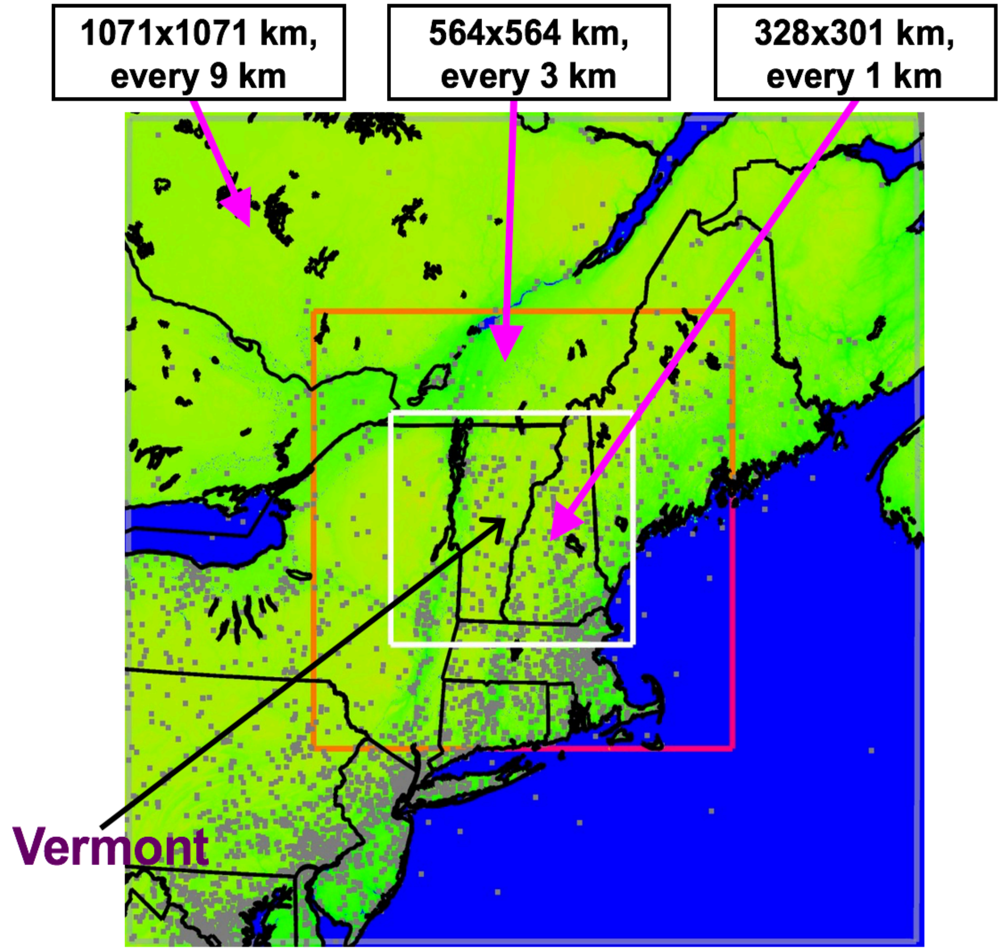
Vermont Energy Investment Corporation

SKI VERMONT Winter in its Original State.

ISO new england

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



(Gray Dots Mark Locations of Sites for Data Assimilation)

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 Processing:

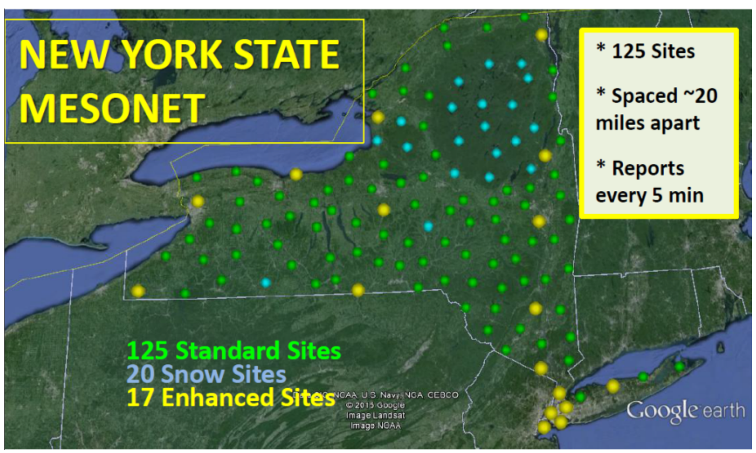
- Data assimilation (3dVAR) of near-real-time surface and upper-air observations from Earth Networks WeatherBug, MADIS and private mesonets
- NASA high-resolution (2km) sea surface temperatures (SST), which include Lake Surface Temperature (LST) analysis over the Great Lakes
- NASA high-resolution (90m) 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

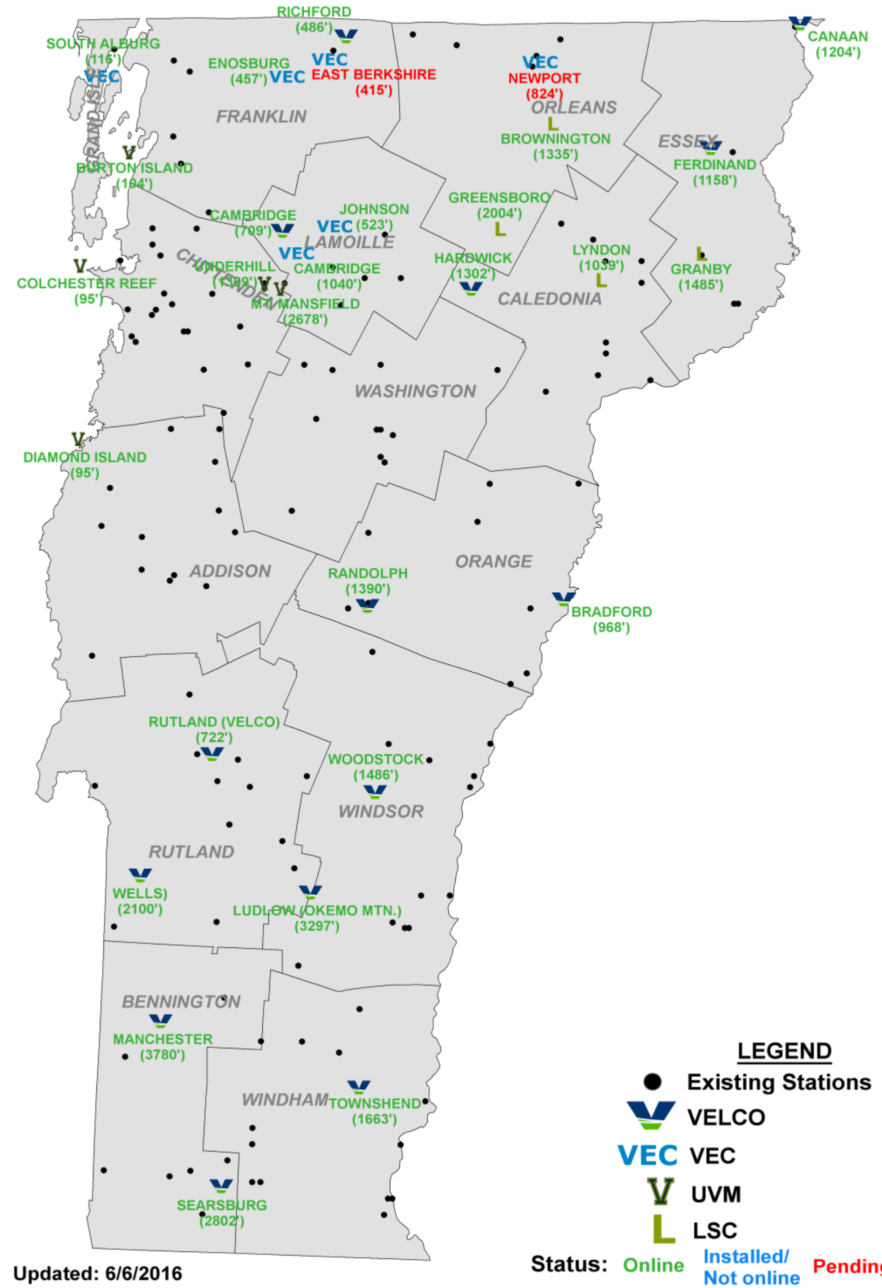
IBM Deep Thunder
VWAC Mesonet

<u>VWAC Mesonet:</u>

VELCO = 14 (additional sites 2017)
VEC = 6 (additional sites 2017)
UVM = 5
LSC = 5
30 Active Stations

→ All data is publically available through MesoWest & MADIS





IBM Deep Thunder

Lightning Potential Index (LPI)

- Current severe weather indices (such as CAPE, LI, KI) do not include the microphysics of charge separation in thunderstorms (Lynn and Yair, 2010)
- Lighting Potential Index (LPI) → the potential for charge generation and separation that produces lightning strikes within convective thunderstorms. LPI is measured in units of J/kg.

V = model unit volume
w = vertical wind component (m/s)

$$LPI = 1/V \int\int\int \varepsilon w^2 \, dx \, dy \, dz$$

$$\varepsilon = 2(Q_i Q_l)^{0.5}/(Q_i + Q_l)$$

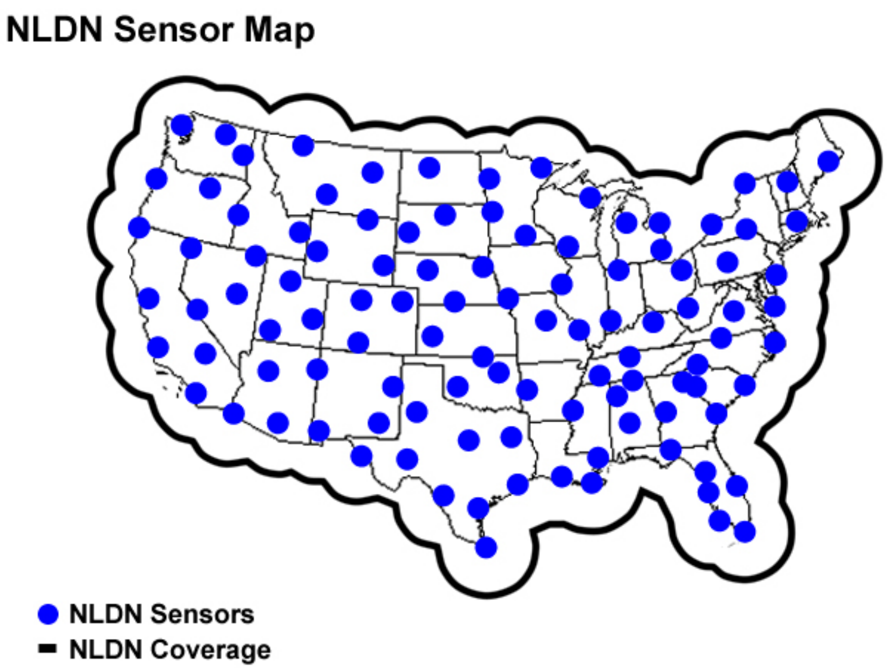
Q_l = total liquid water mass mixing ratio (kg/kg)
Q_i = ice fractional mixing ratio (kg/kg)

$$Q_i = q_g[((q_s q_g)^{0.5}/(q_s + q_g)) + ((q_i q_g)^{0.5}/(q_i + q_g))]$$

q_s = mixing ratio for snow (kg/kg)
q_i = mixing ratio for cloud ice (kg/kg)
q_g = mixing ratio for graupel (kg/kg)

Verifications
NLDN Overview

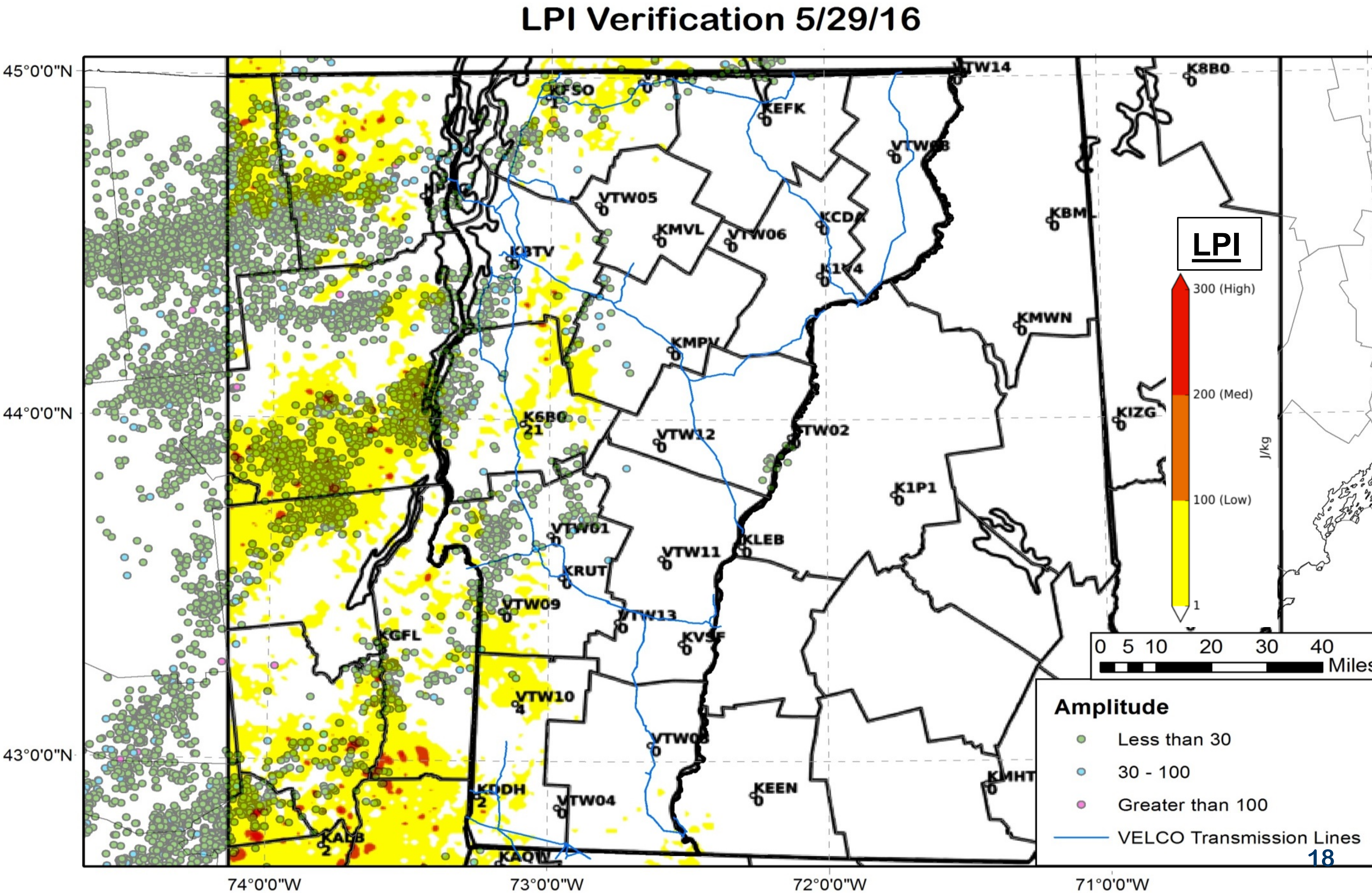
NLDN (National Lightning Detection Network) → monitors real-time cloud-to-ground lightning activity across the continental United States (24/7/365). Current network consists of more than 114 remote, ground-based lightning sensors



Accuracy:

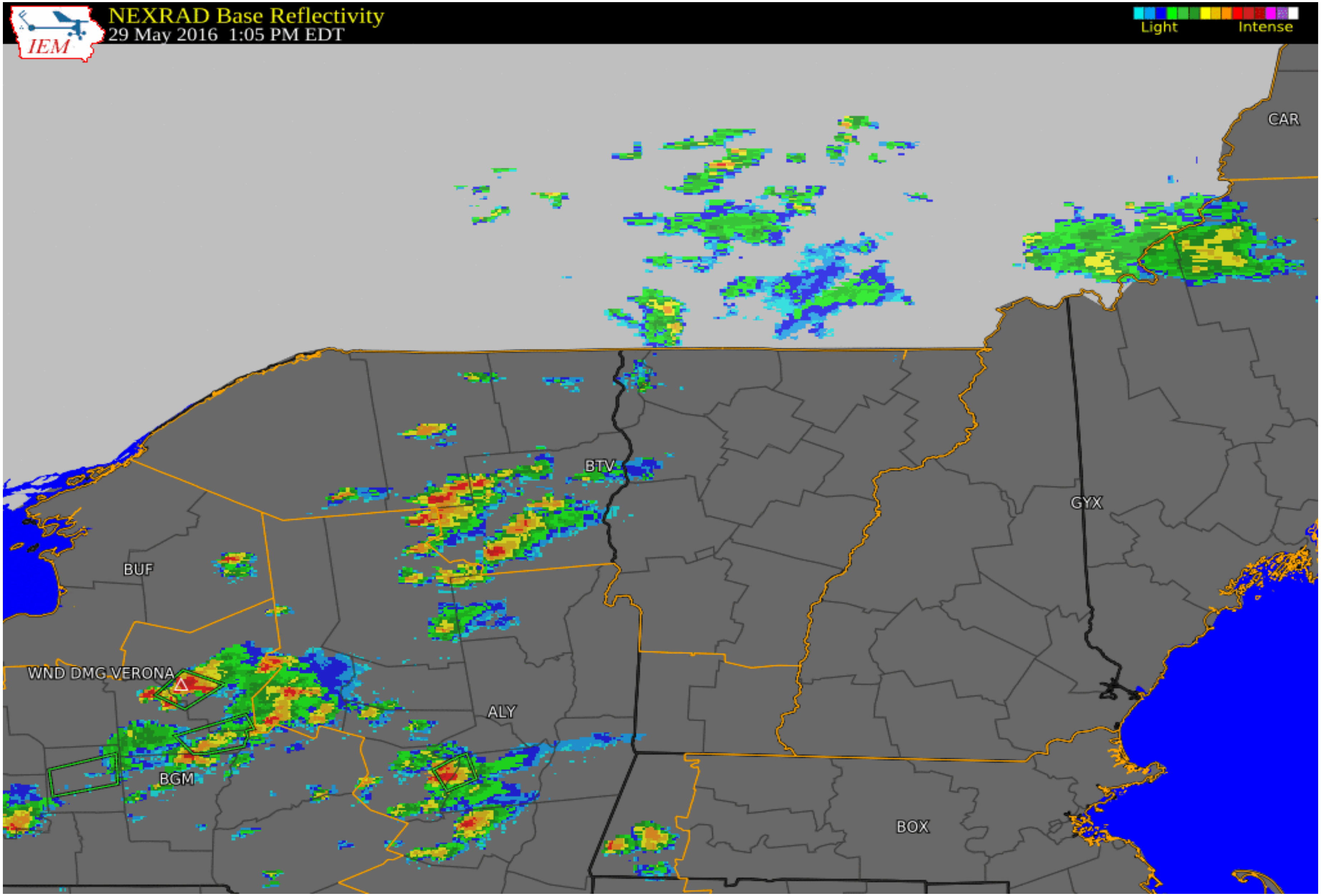
- **Median location accuracy of 150-250 m or better (0.09-0.16 miles)**
- Network uptimes nearing 99.99 %
- Data feed uptimes of better than 99.9 %
- Event timing precision of 1 microsecond RMS or less
- Accurate peak current measurements resulting from magnetic detection methods

Verifications
Case Studies



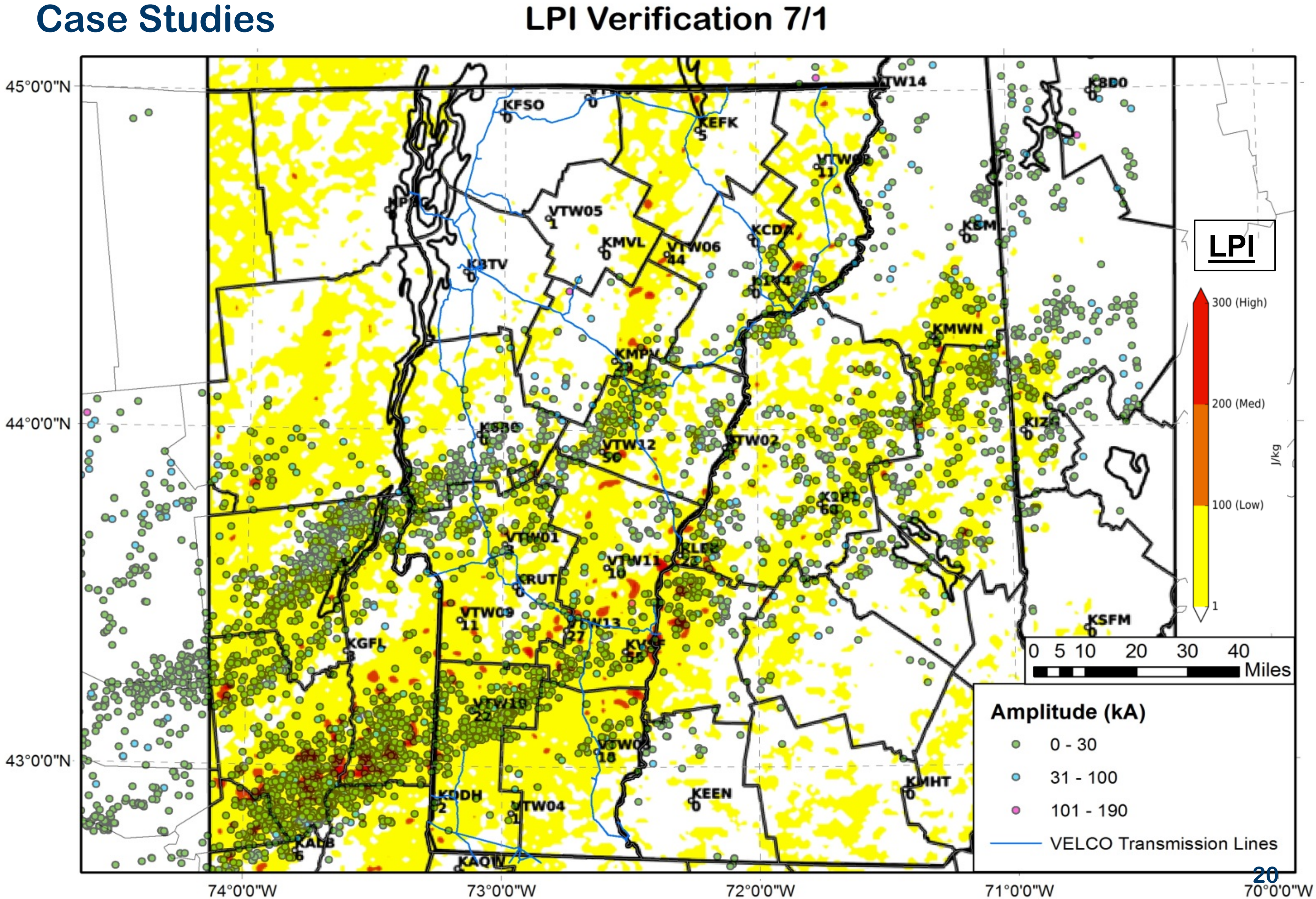
Verifications

Case Studies



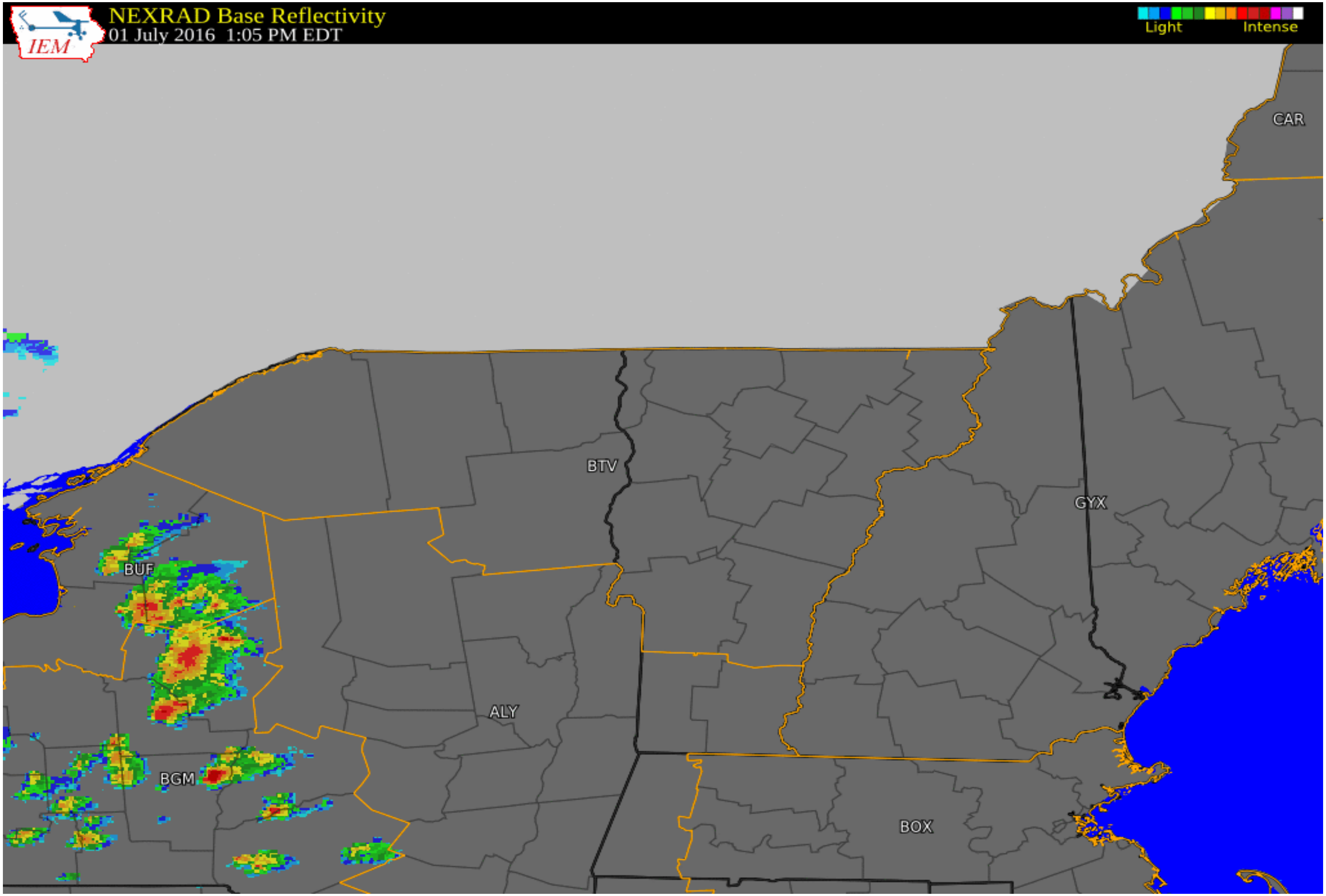
Verifications

Case Studies



Verifications

Case Studies

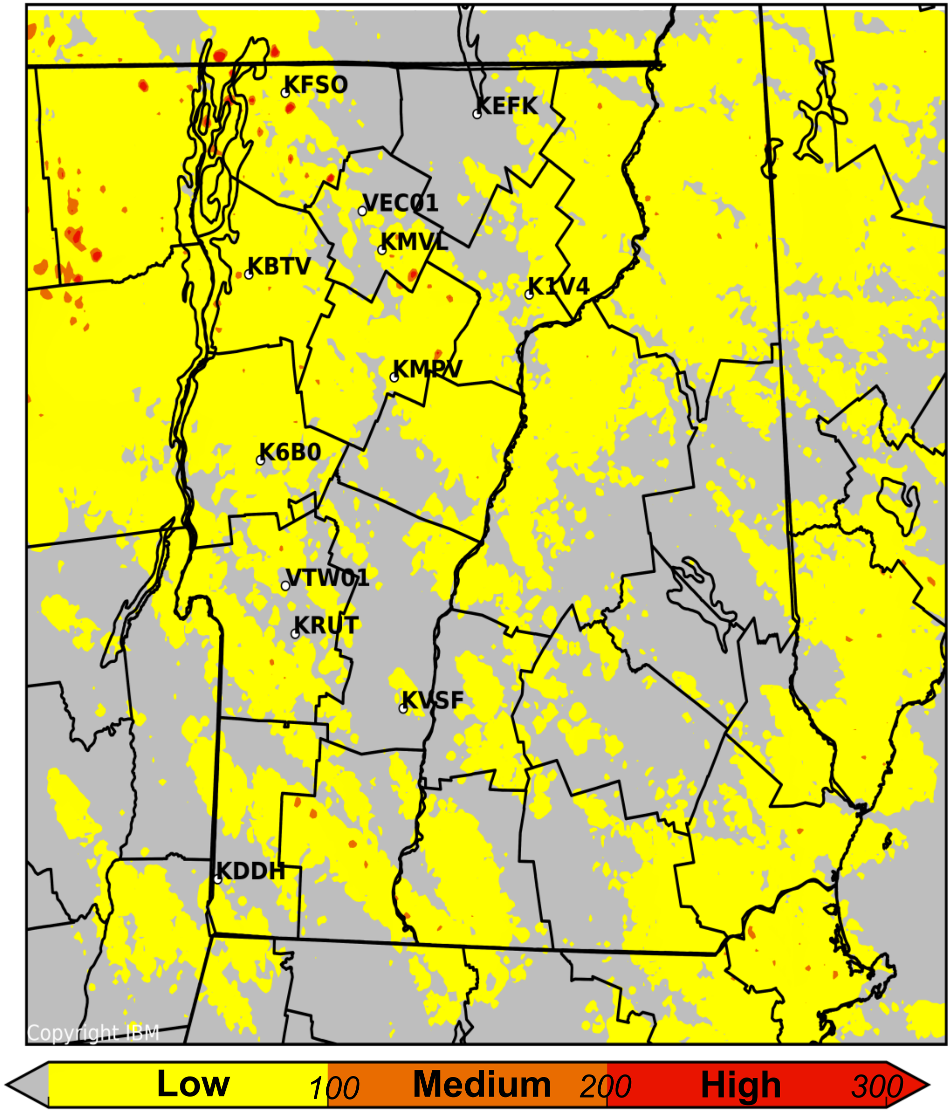


Verifications

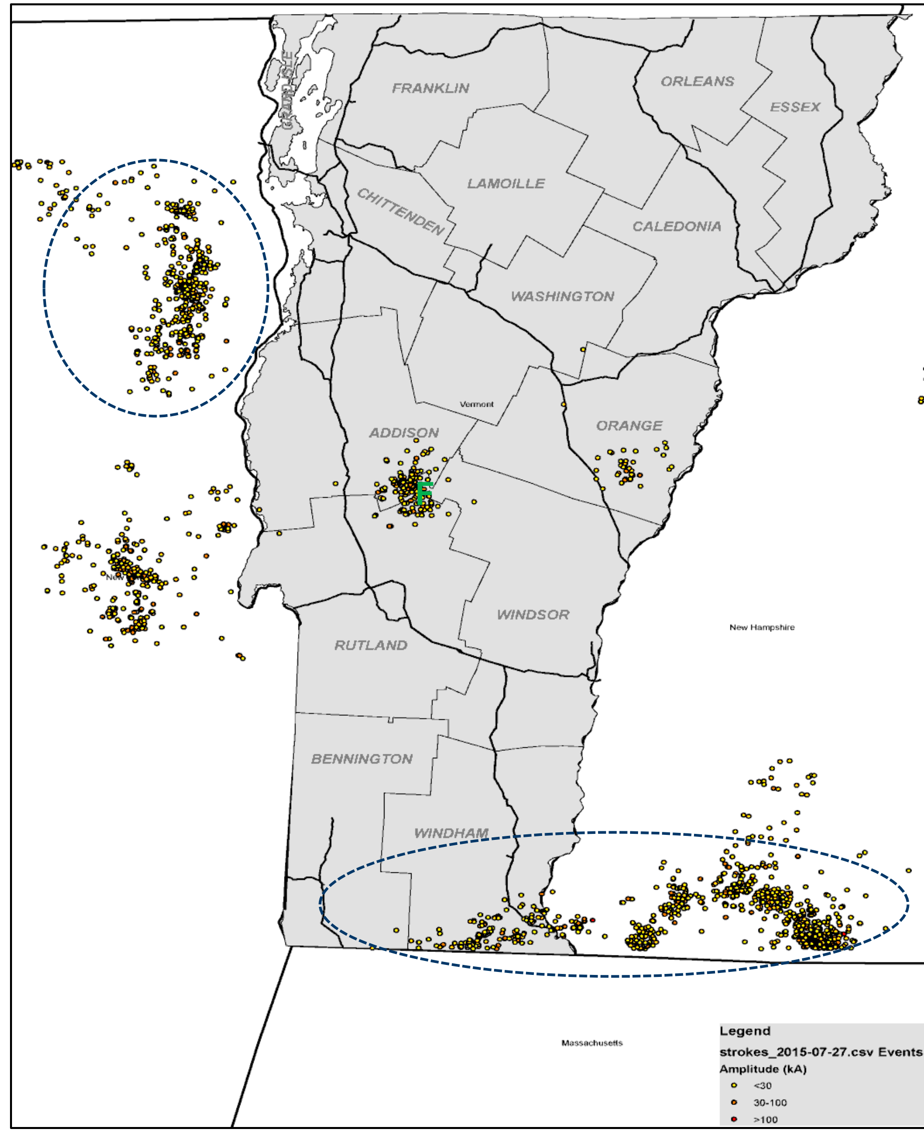
Case Studies

Event: July 27, 2015
(Using 0Z forecast)

Deep Thunder (Lightning Potential Index – J/kg)



Observed

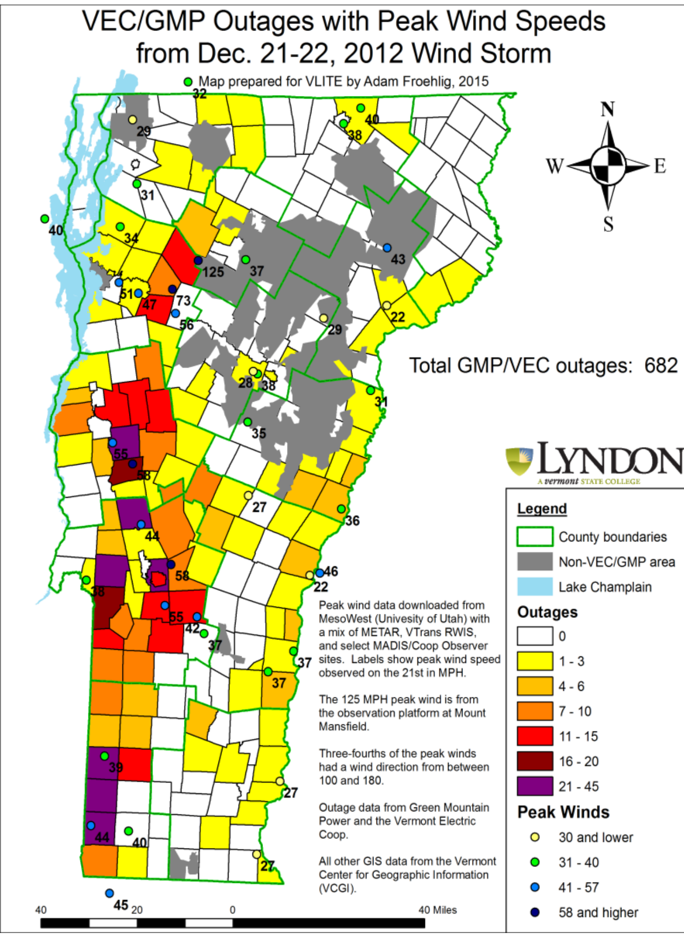


Future Work

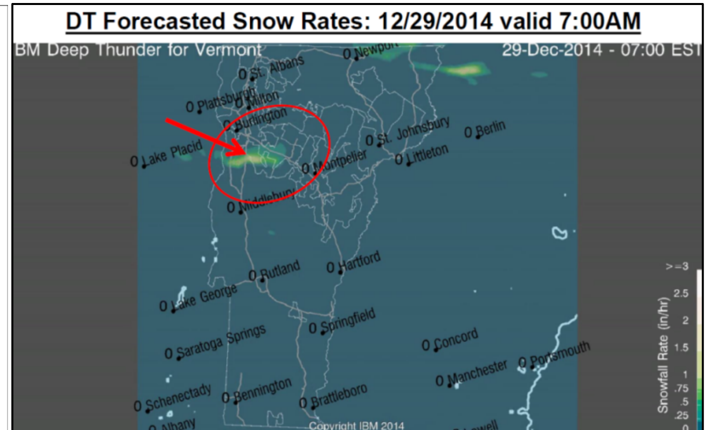
- Develop a quantitative verification metric (i.e. skill scores)
- Expand verifications to include temporal analyses (also add Day 2 and Day 3 forecasts)
- Examine CC (Cloud-to-Cloud) data to differentiate from CG strikes
- Develop an alert system (email or text) to compliment existing real-time lightning tools
- Build in-house HPCC data center to support operational forecast models and develop additional forecasting techniques/models
- Explore other potential sectors that could utilize LPI forecast data
  - NWS Aviation Forecasts (TAF's)
  - U.S. Coast Guard
  - National Parks
  - Local sporting events

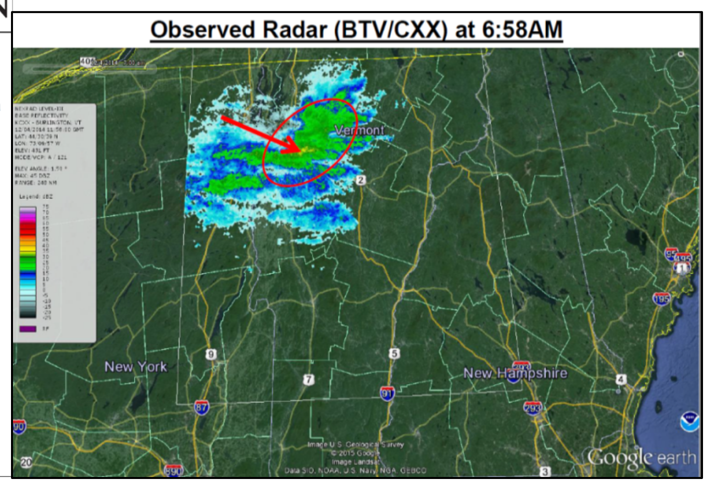
Future Applications

Outage/Impact Prediction

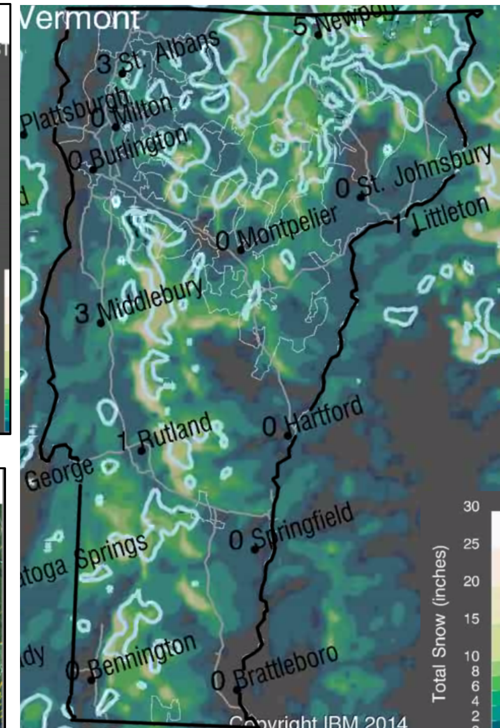


Transportation





Recreation



Other:

Environmental
Agriculture
Emergency Management
Citizen Science

Questions?

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Photo: Andrew Gimino