

# VERIFICATION OF NATIONAL WEATHER SERVICE SPOT FORECASTS USING SURFACE OBSERVATIONS

Matthew Robert Lammers

John Horel

14 July 2014

Funded by the Joint Fire Science Program



# RESEARCH OUTLINE

- ❖ Introduction
  - ❖ Objectives
  - ❖ Where are Spot Forecasts Issued?
- ❖ How Do We Verify Spot Forecasts?
  - ❖ Surface Observations
  - ❖ Text Parsing
  - ❖ Visualizing Forecasts and Verifying Data
- ❖ Tucson (TWC) Weather Forecast Office Case Study
- ❖ All Forecast Offices
- ❖ Conclusion
  - ❖ Summary
  - ❖ Recommendations
  - ❖ The Transition to Operations

# OUTLINE

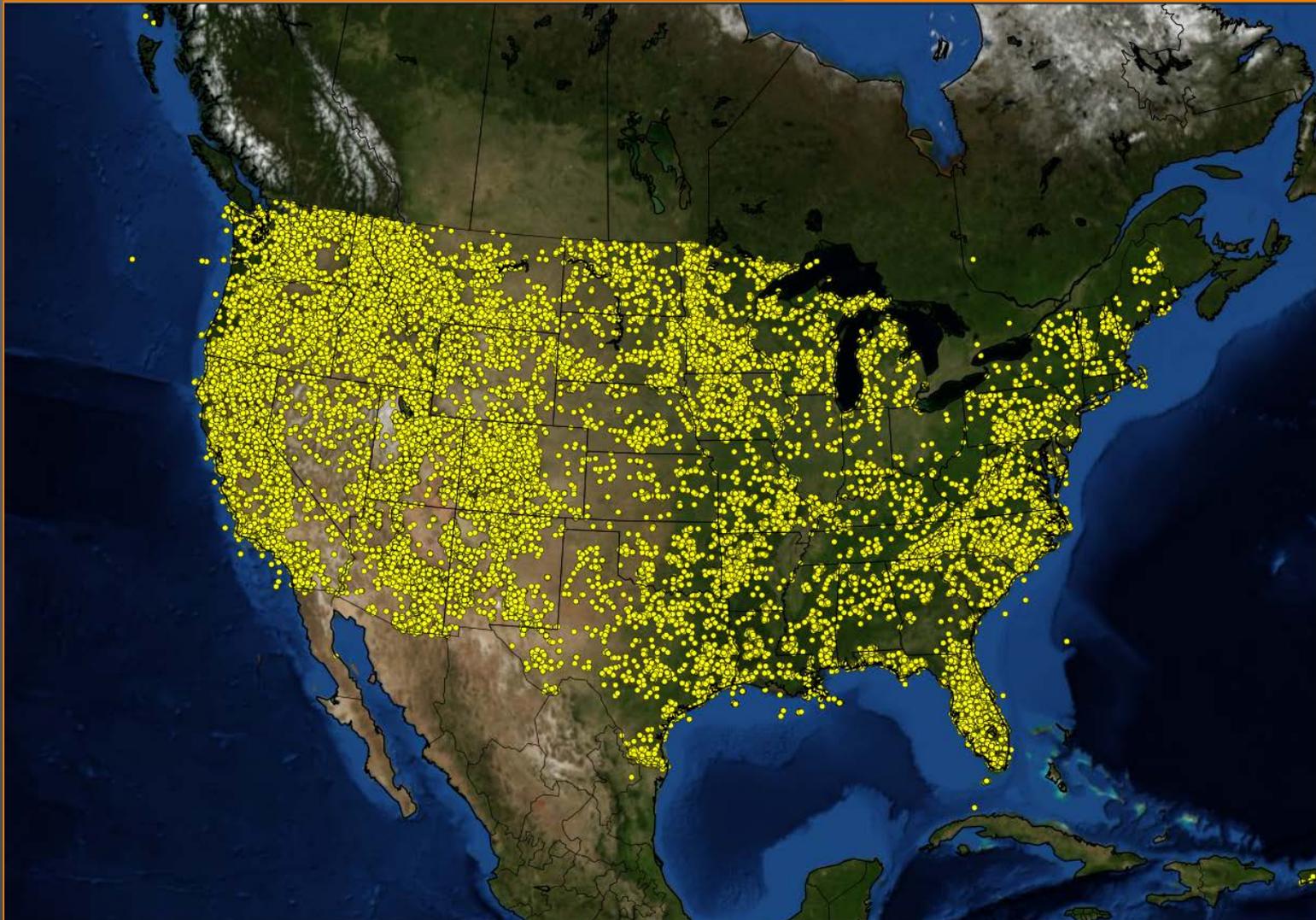
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# OBJECTIVES

- ❖ To facilitate the transfer from research to operations of methodologies to verify spot forecasts
- ❖ To devise approaches to assess the degree of improvement provided by such forecasts relative to those available from the National Digital Forecast Database (NDFD)
- ❖ To develop examples of web tools that could transition into a product usable by the National Weather Service Performance Management System

# SPOT FORECASTS

Total Forecasts: 103370



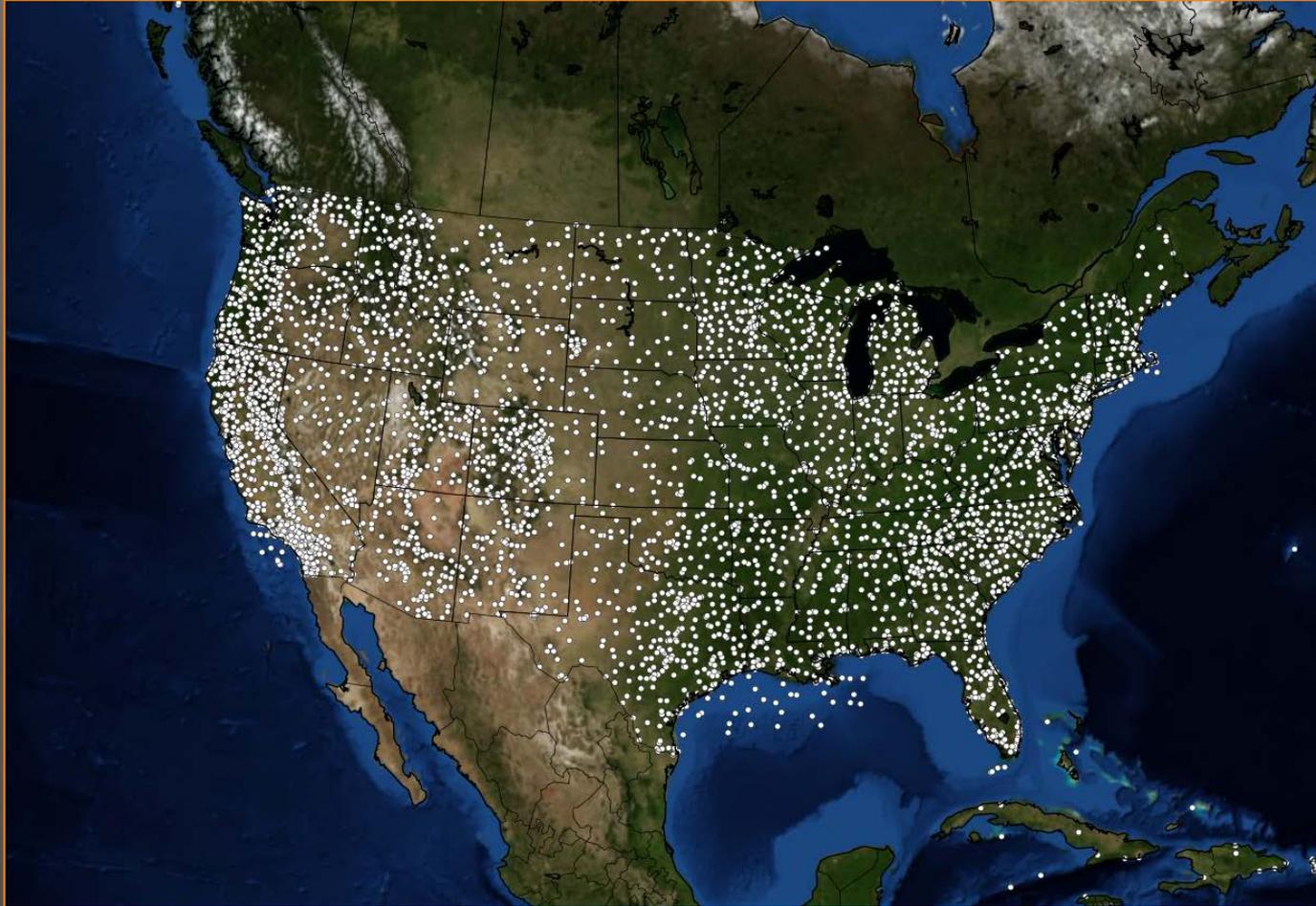
All Spot Forecasts April 1, 2009 to November 30, 2013

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# VERIFYING DATASETS

## - SURFACE OBSERVATIONS



All Currently  
Active Stations in  
NWS/FAA and  
RAWS Networks

# PARSING A SPOT FORECAST

A Natural Language Problem - Interpreting the Intentions of the Forecaster

FNUS75 KSLC 202145  
FWSSLC

SPOT FORECAST FOR PATCH SPRINGS  
NATIONAL WEATHER SERVICE SALT LAKE CITY UT  
323 PM MDT TUE AUG 20 2013

.DISCUSSION...SHOWERS AND THUNDERSTORMS WILL CONTINUE ACROSS NORTHERN UTAH INTO THE OVERNIGHT HOURS. THERE IS THE POTENTIAL FOR THESE STORMS TO IMPACT THE PATCH SPRINGS FIRE. THESE STORMS ARE WET...AND WILL BE ACCOMPANIED BY MODERATE TO HEAVY RAIN. EVEN IF A STORM DOES NOT DIRECTLY IMPACT THE FIRE...GUSTY AND ERRATIC WINDS FROM STORMS IN THE VICINITY MAY AFFECT THE FIRE. THE POTENTIAL FOR THUNDERSTORMS TO DEVELOP DECREASES TOMORROW THROUGH FRIDAY AS MOISTURE DECREASES ACROSS THE AREA. WINDS WILL INCREASE FROM THE SOUTH ON FRIDAY.

.REST OF TODAY...

LAL.....3.  
HAINES INDEX.....3 ..VERY LOW.  
CLEARING INDEX.....1000+.  
SKY/WEATHER.....PARTLY CLOUDY (65-75 PERCENT CLOUD COVER).  
SCATTERED SHOWERS AND THUNDERSTORMS.  
MAX TEMPERATURE....87-91.  
MIN HUMIDITY.....22-24 PERCENT.  
WINDS - 20-FOOT.....UPSLOPE/UPVALLEY 6 TO 11 MPH. GUSTY AND  
ERRATIC IN THE VICINITY OF THUNDERSTORMS.

.TONIGHT...

LAL.....3.  
HAINES INDEX.....3 ..VERY LOW.  
SKY/WEATHER.....MOSTLY CLOUDY (75-85 PERCENT CLOUD COVER).  
SCATTERED SHOWERS AND THUNDERSTORMS.  
MIN TEMPERATURE....65-67.  
MAX HUMIDITY.....52-54 PERCENT.  
WINDS - 20-FOOT.....DOWNSLOPE/DOWNVALLEY 5 TO 9 MPH.

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89°F = 31.7°C

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$$11 \text{ mi hr}^{-1} = 4.9 \text{ m s}^{-1} (?)$$

# KEY DEVELOPMENT:

# [HTTP://MESO1.CHPC.UTAH.EDU/JFSP](http://meso1.chpc.utah.edu/jfsp)

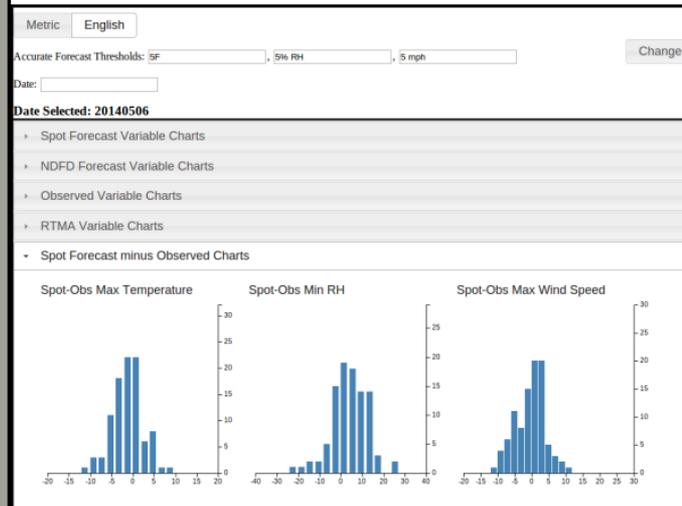
## Joint Fire Science Program Spot Forecast Verification Project

[Home](#)[Prescribed By Date](#)[Wildfires By Date](#)[Prescribed By WFO](#)[Wildfires By WFO](#)[All Prescribed](#)[All Wildfires](#)[Box Creek](#)

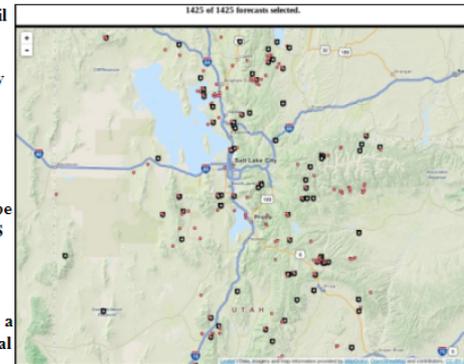
This website uses innovative techniques for interactive data exploration to analyze a large set of spot weather forecasts issued by the National Weather Service. Spot forecasts are requested by local, state, and federal officials when a situation arises that requires a detailed short-term weather forecast to ensure the safety of those involved in search and rescue, hazardous materials, and wildland fire operations. A large number of these forecasts have been compared as part of my graduate research to both surface weather observations, the National Digital Forecast Database (NDFD), and the Real-Time Mesoscale Analysis (RTMA).

Above are tabbed links to pages exploring different subsets of the 100,000+ spot forecast database spanning from April 2009 to Present.

"Prescribed By Date" and "Wildfires By Date" allow the user to view the forecasts issued as recently as yesterday by date. Once a date has been selected (defaults to yesterday), the user can use the histograms to further explore and reduce the forecasts featured.



"Prescribed By WFO" and "Wildfires By WFO" allow subsets of the forecasts to be divided by WFO or by NWS Region. This enables the same exploration that was discussed concerning the previous two pages, only on a more geographically regional level. While forecast characteristics and practices may vary from office to office, by selecting a WFO, the hope is that you are getting a relatively homogeneous set of forecasts, even while the actual forecaster may change.



"Box Creek" is an illustration of the usage of all of the tools used in the Master's Thesis research on a single case study, including adjustable joint distribution tables.

Most of the credit for these multivariate data exploration tools has to go to Jason Davies and Square, developers of [Crossfilter](#). The plots were built with [D3](#).

Many thanks to the Joint Fire Science Program for their support, as well as my advisor, Dr. John Horel.

Below are examples of a spot forecast request (on the left) and the top section of the corresponding spot forecast (right) from the recent Patch Springs fire in Northern Utah.

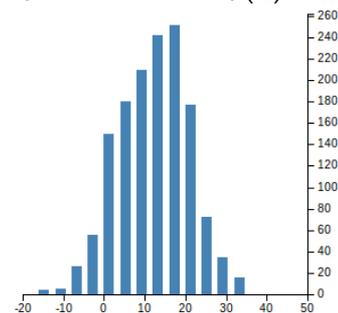
<http://meso1.chpc.utah.edu/jfsp>

# REAL-TIME ANALYTICS

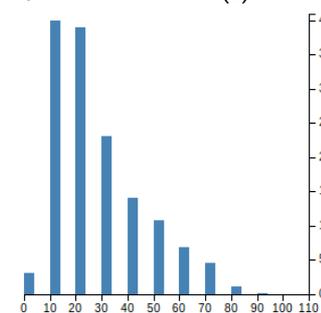
With all of the variables included in the analysis, we needed a way to sift through the impacts of selecting on certain thresholds efficiently and interactively.

## Spot Forecast Variable Charts

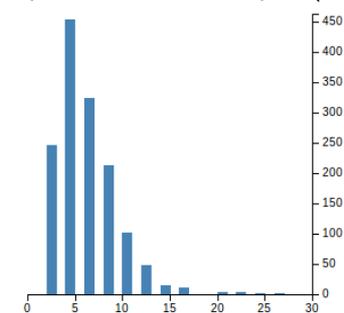
Spot Forecast Max Temp (°C)



Spot Forecast Min RH (%)



Spot Forecast Max Wind Speed (ms<sup>-1</sup>)



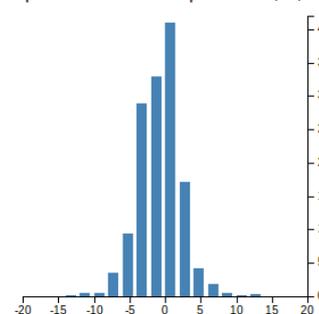
## NDFD Forecast Variable Charts

### Observed Variable Charts

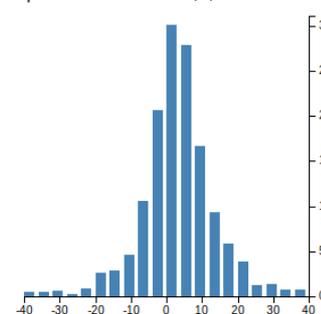
### RTMA Variable Charts

## Spot Forecast minus Observed Charts

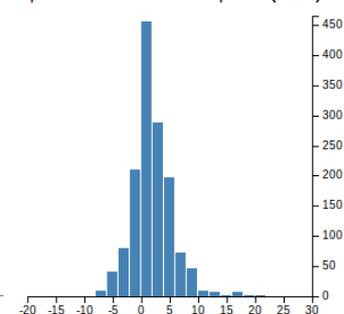
Spot-Obs Max Temperature (°C)



Spot-Obs Min RH (%)



Spot-Obs Max Wind Speed (ms<sup>-1</sup>)

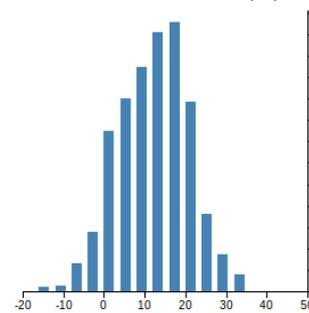


# VISUALIZING FORECASTS AND VERIFYING DATA

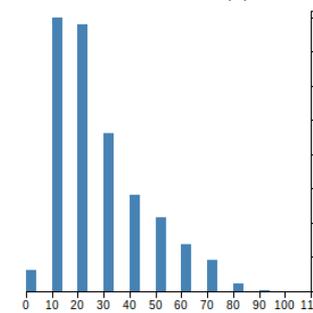
By selecting a range of values in any of the histograms, the other distributions will respond accordingly.

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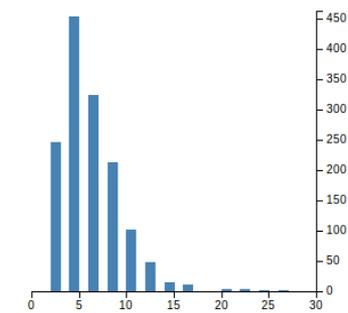
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Spot Forecast Min RH (%)



Spot Forecast Max Wind Speed (ms<sup>-1</sup>)



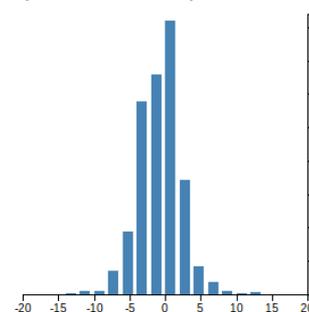
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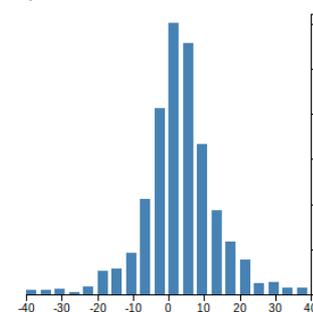
### RTMA Variable Charts

## Spot Forecast minus Observed Charts

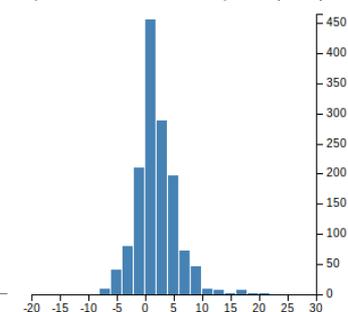
Spot-Obs Max Temperature (°C)



Spot-Obs Min RH (%)



Spot-Obs Max Wind Speed (ms<sup>-1</sup>)

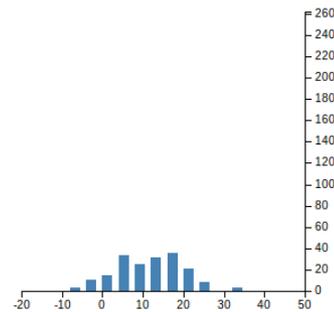


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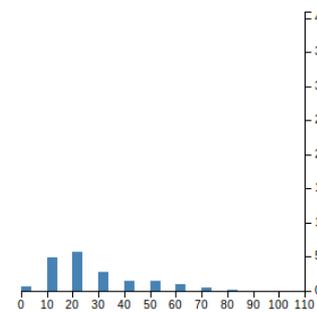
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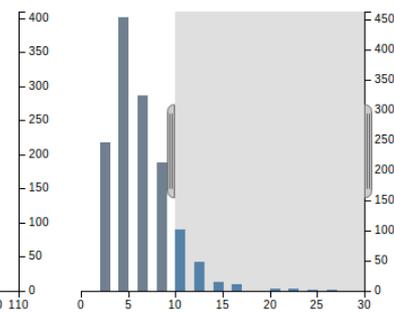
Spot Forecast Max Temp (°C)



Spot Forecast Min RH (%)



Spot Forecast Max Wind Speed [reset](#)



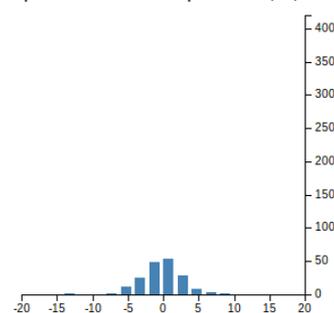
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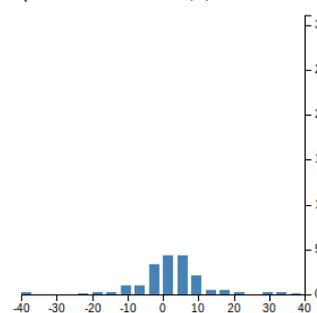
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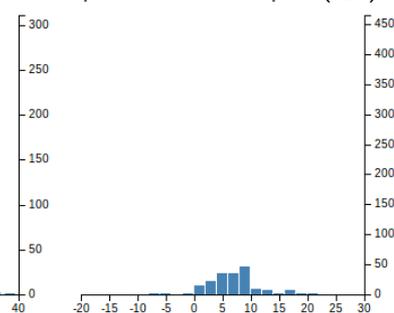
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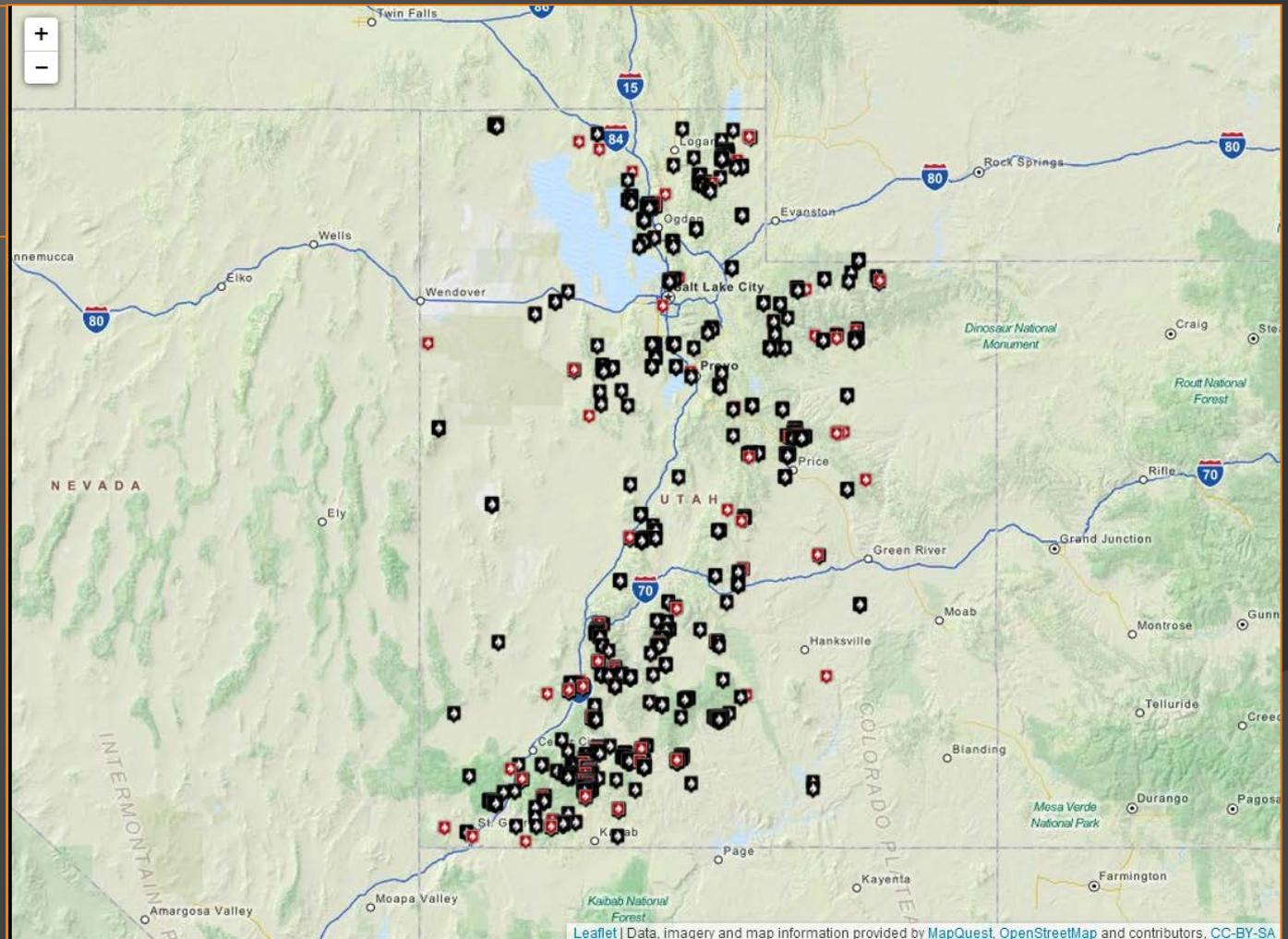


Spot-Obs Max Wind Speed (ms<sup>-1</sup>)



# VISUALIZING FORECASTS AND VERIFYING DATA

These adjustments also apply to the map markers

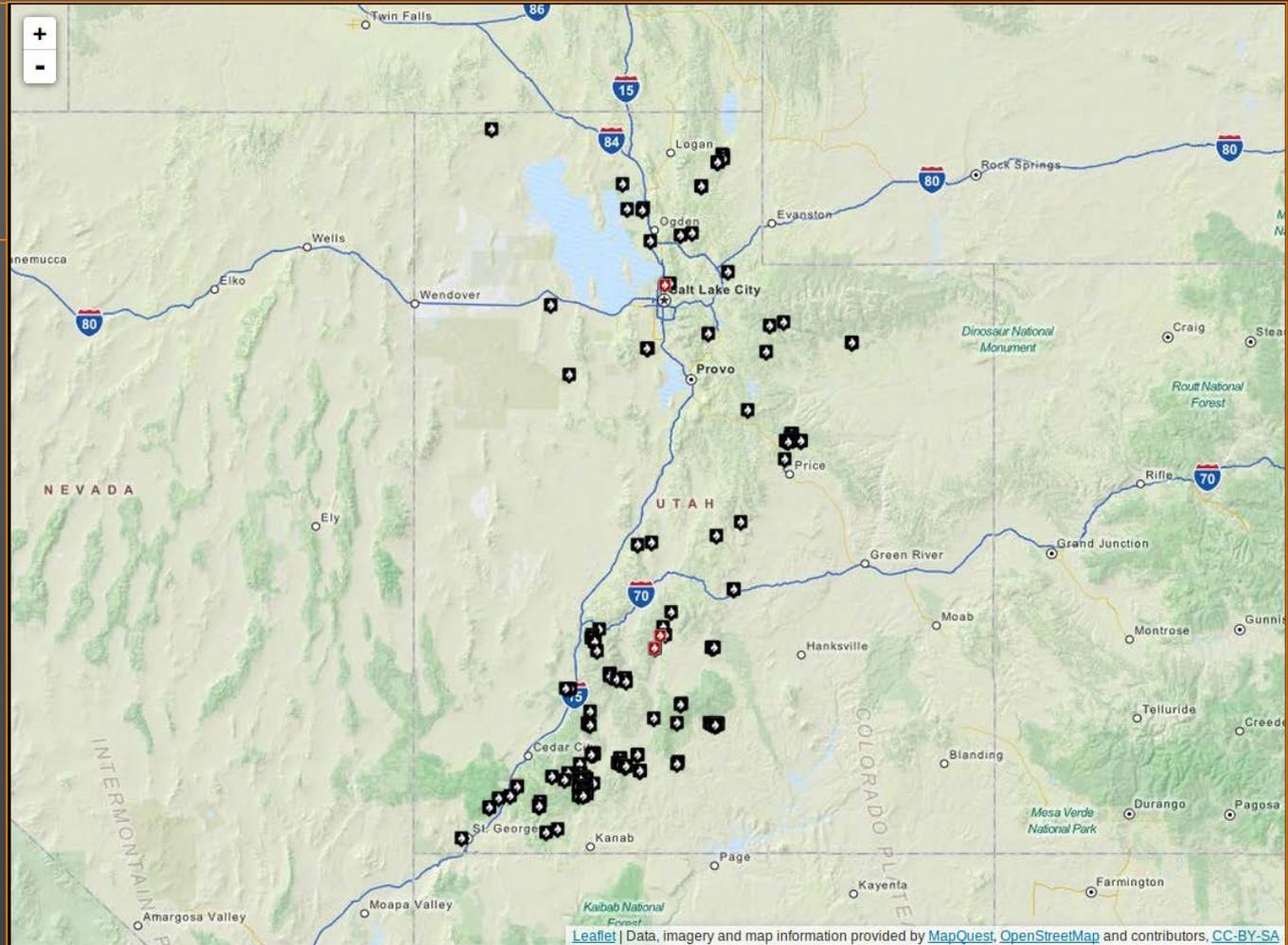


Leaflet | Data, imagery and map information provided by MapQuest, OpenStreetMap and contributors, CC-BY-SA

<http://meso1.chpc.utah.edu/jfsp>

# VISUALIZING FORECASTS AND VERIFYING DATA

These adjustments also apply to the map markers



<http://meso1.chpc.utah.edu/jfsp>

# GIVING THE USER CONTROL

Why are some markers black and others red?

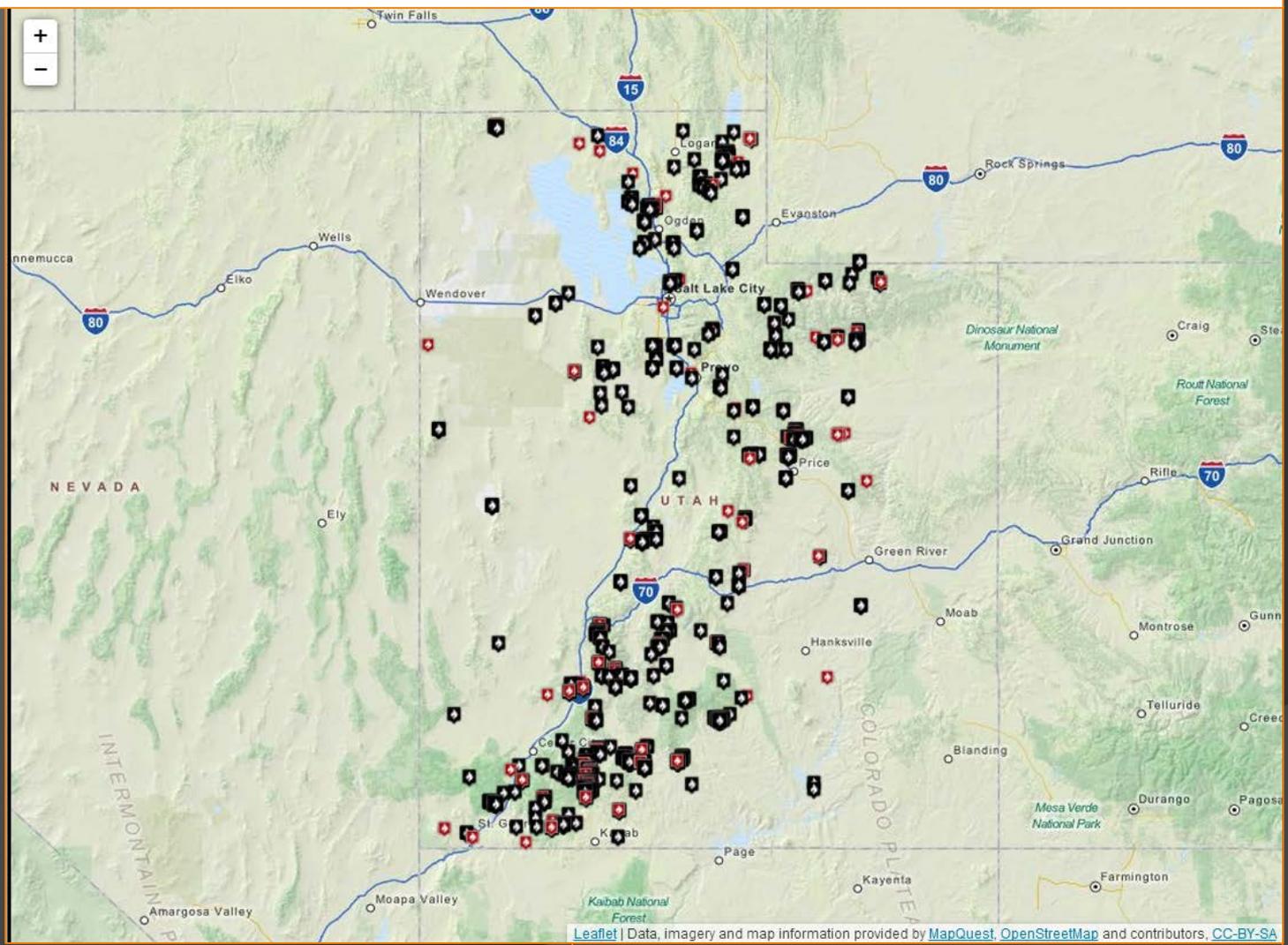
Accurate Forecast Thresholds:  ,  ,

Change

- ❖ These are the thresholds used in the evaluation presented here and are the defaults for the web tools
  - ❖ Not universally useful or even reasonable in some cases
- ❖ Red markers are forecasts where the difference between the forecast and observed values are less than all of the thresholds
- ❖ Black markers are cases where either temperature, relative humidity, or wind speed forecasts are off from the observation by more than the thresholds.

# GIVING THE USER CONTROL

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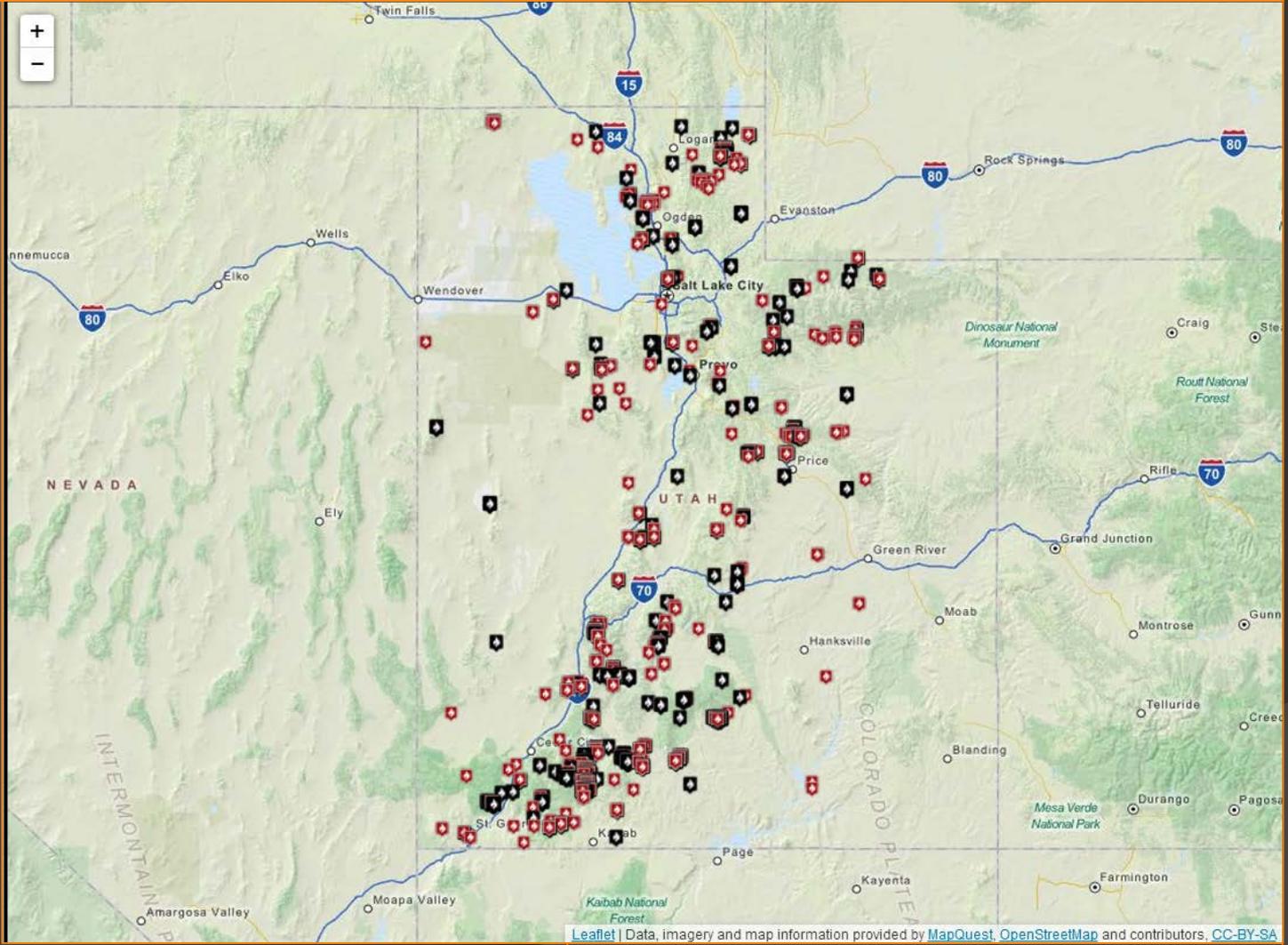
Leaflet | Data, imagery and map information provided by MapQuest, OpenStreetMap and contributors, CC-BY-SA

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# GIVING THE USER CONTROL

Accurate Forecast Thresholds:  ,  ,

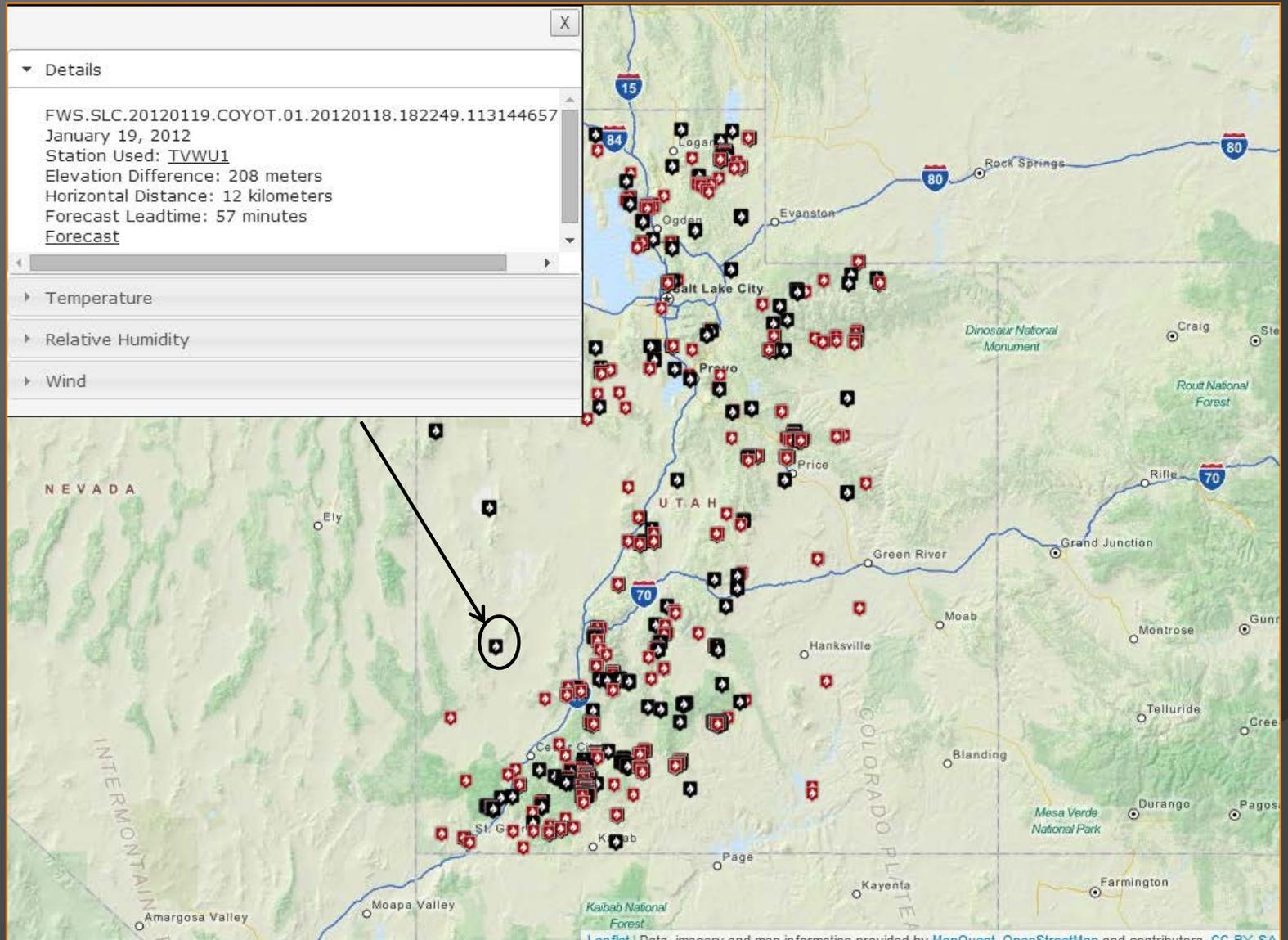
[Change](#)



Leaflet | Data, imagery and map information provided by MapQuest, OpenStreetMap and contributors, CC-BY-SA

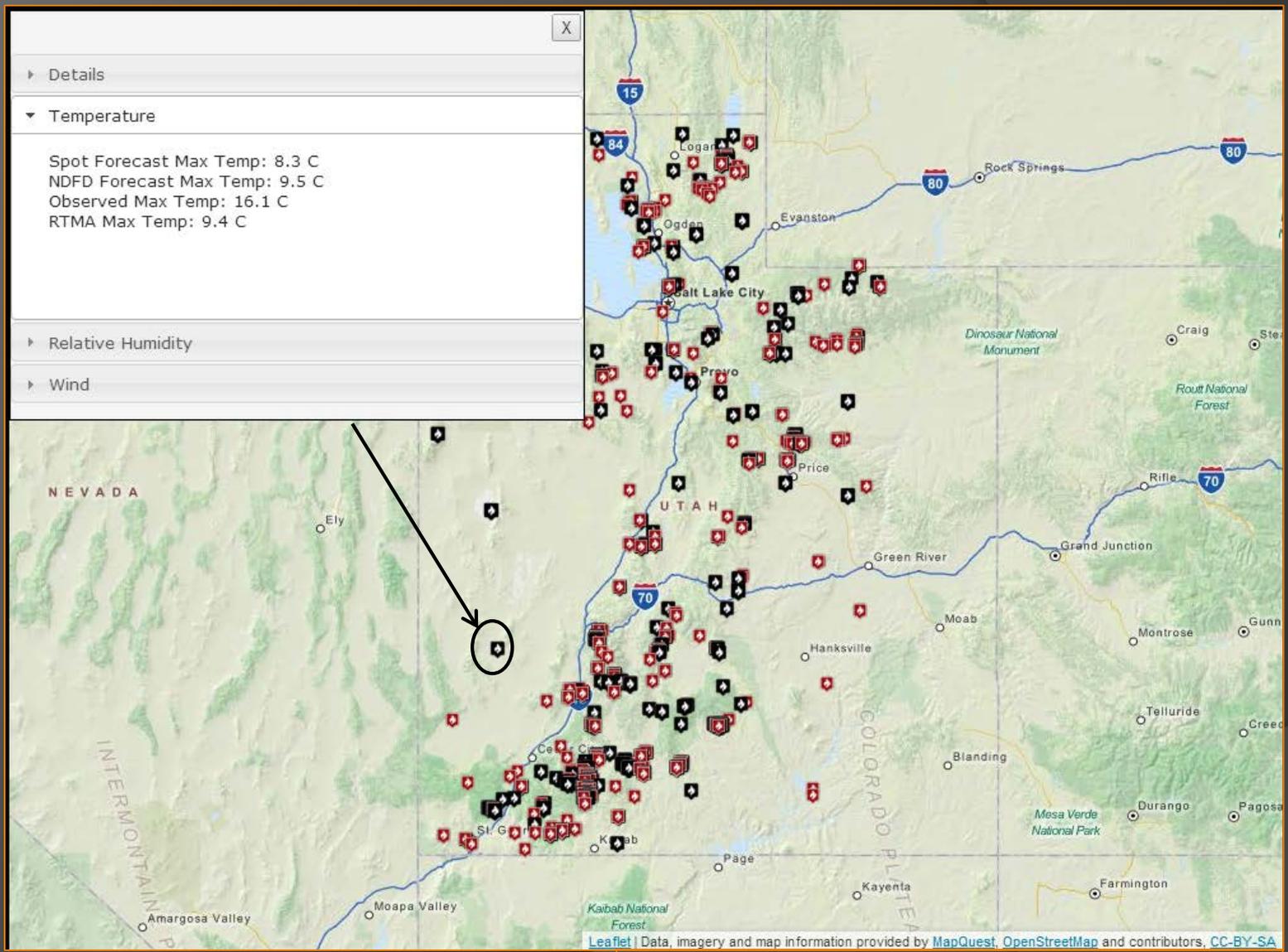
<http://meso1.chpc.utah.edu/jfsp>

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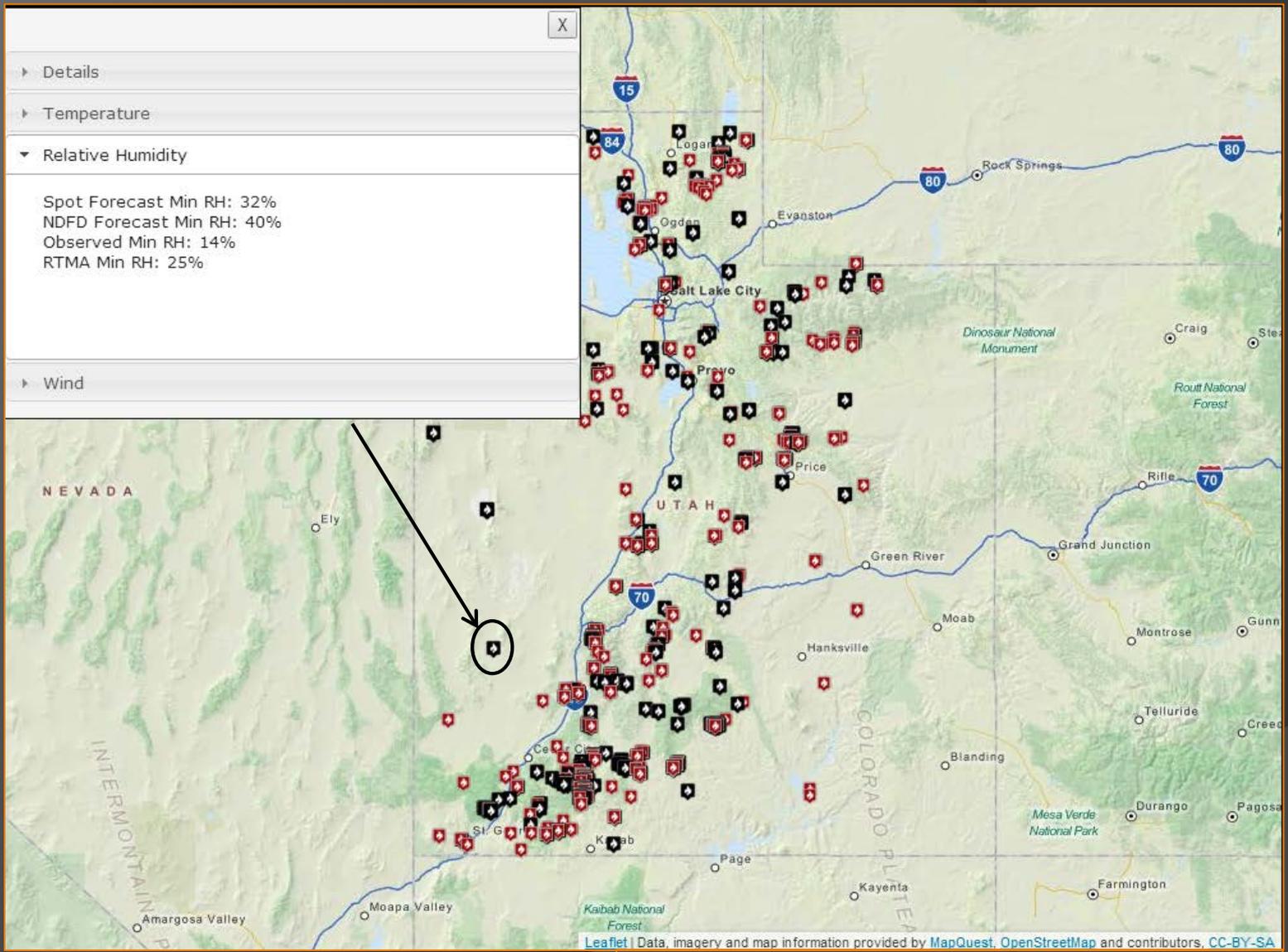
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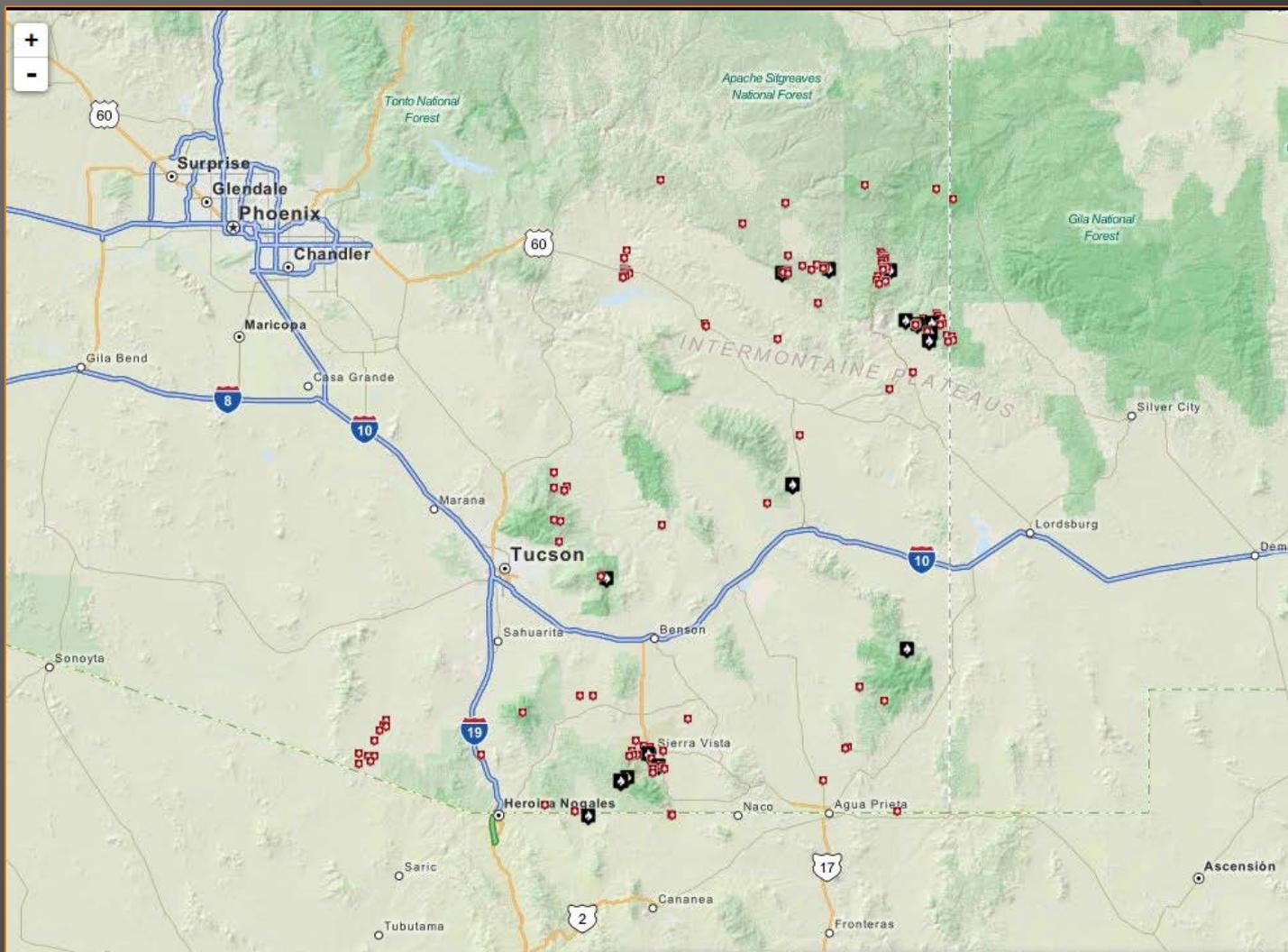
# NEEDS FOR RESEARCH EVALUATION DIFFER FROM REAL-TIME VALIDATION

- ❖ For the sample evaluated in the research, the following restrictions were made:
  - ❖ NDFD and Real-Time Mesoscale Analysis (RTMA, not shown) used were at 5 km grid spacing
  - ❖ NDFD forecasts used were issued at 9 UTC for 6-, 9-, 12-, and 15-hour lead times (for 15, 18, 21, and 24 UTC)
  - ❖ RTMAs used were for 15, 18, 21, and 24 UTC as well
  - ❖ The verifying observation had to be within 50 km and 333 vertical meters of the spot forecast location and elevation

# OUTLINE

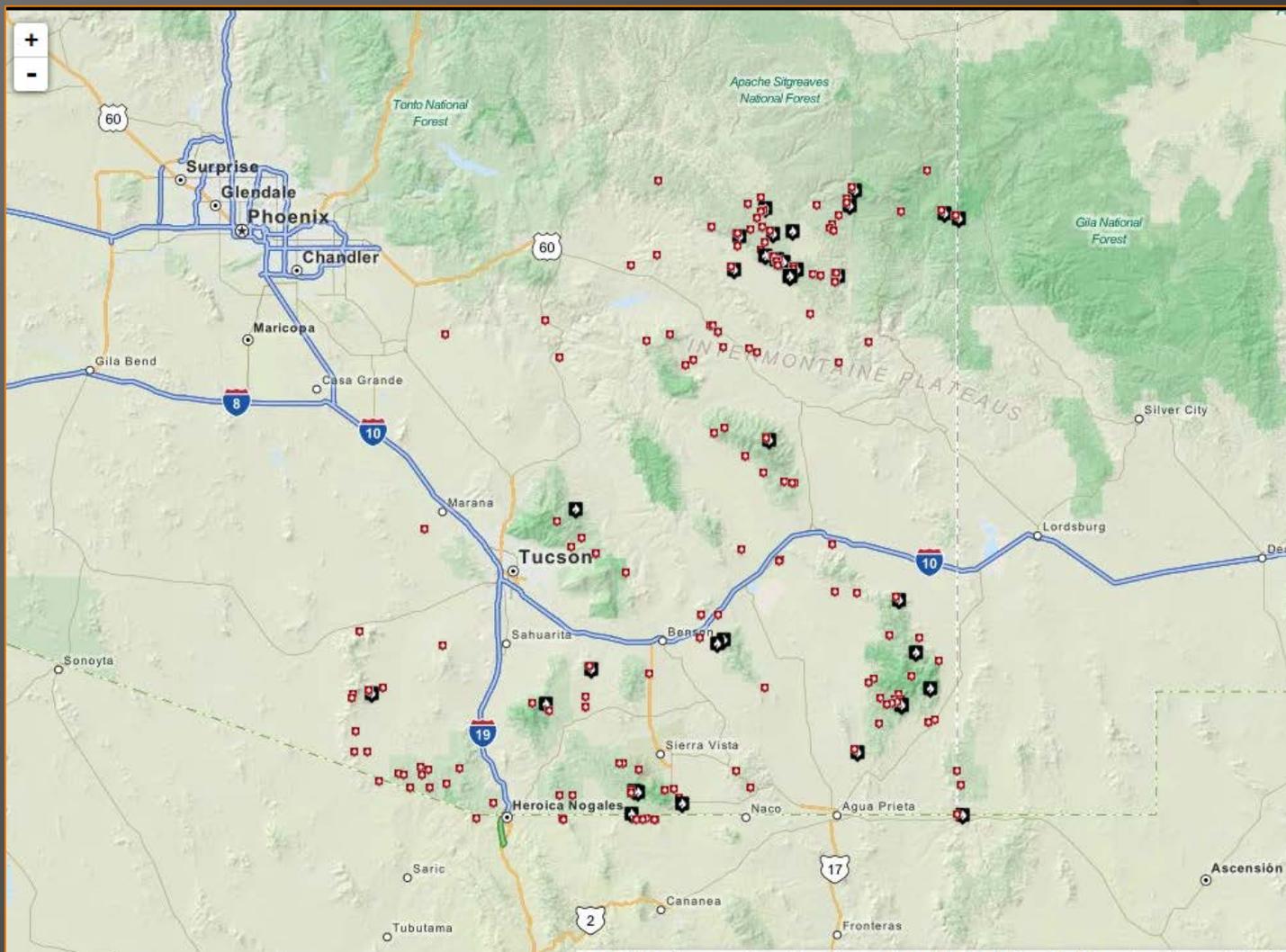
- ❖ Introduction
  - ❖ Objectives
  - ❖ Where are Spot Forecasts Issued?
- ❖ How Do We Verify Spot Forecasts?
  - ❖ Surface Observations
  - ❖ Text Parsing
  - ❖ Visualizing Forecasts and Verifying Data
- ❖ Tucson (TWC) Weather Forecast Office Case Study
- ❖ All Forecast Offices
- ❖ Conclusion
  - ❖ Summary
  - ❖ Recommendations
  - ❖ The Transition to Operations

# TUCSON, AZ (TWC)



Prescribed Burn Spot Forecasts from TWC

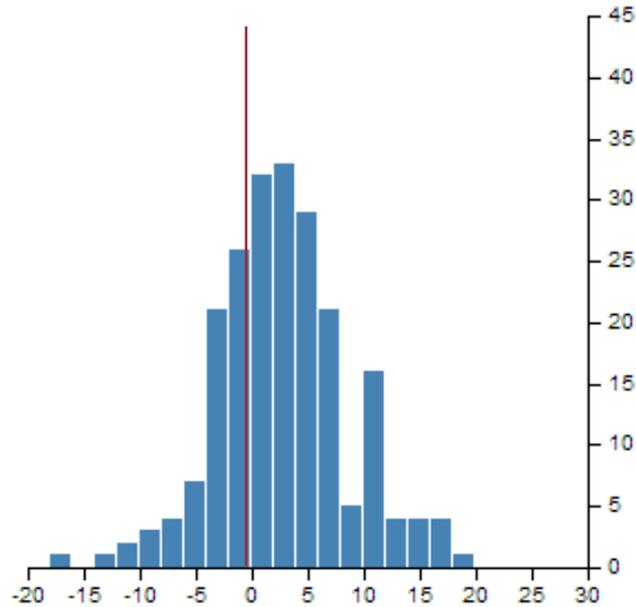
# TUCSON, AZ (TWC)



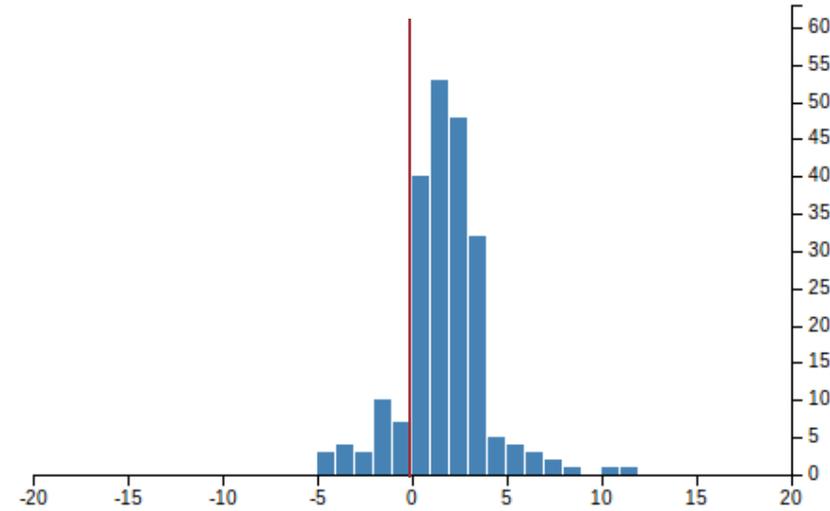
Wildfire Spot Forecasts from TWC

# TUCSON, AZ (TWC)

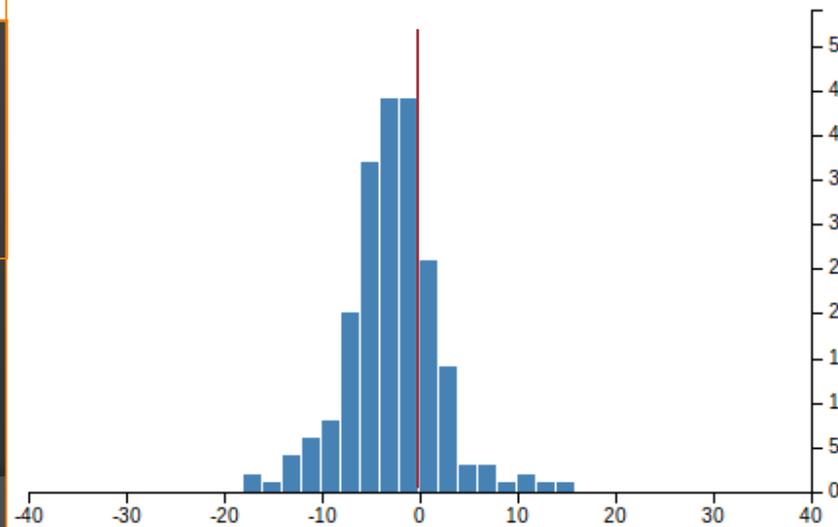
Spot-Obs Max Wind Speed ( $\text{ms}^{-1}$ )



Spot-Obs Max Temperature (C)



Spot-Obs Min Relative Humidity (%)



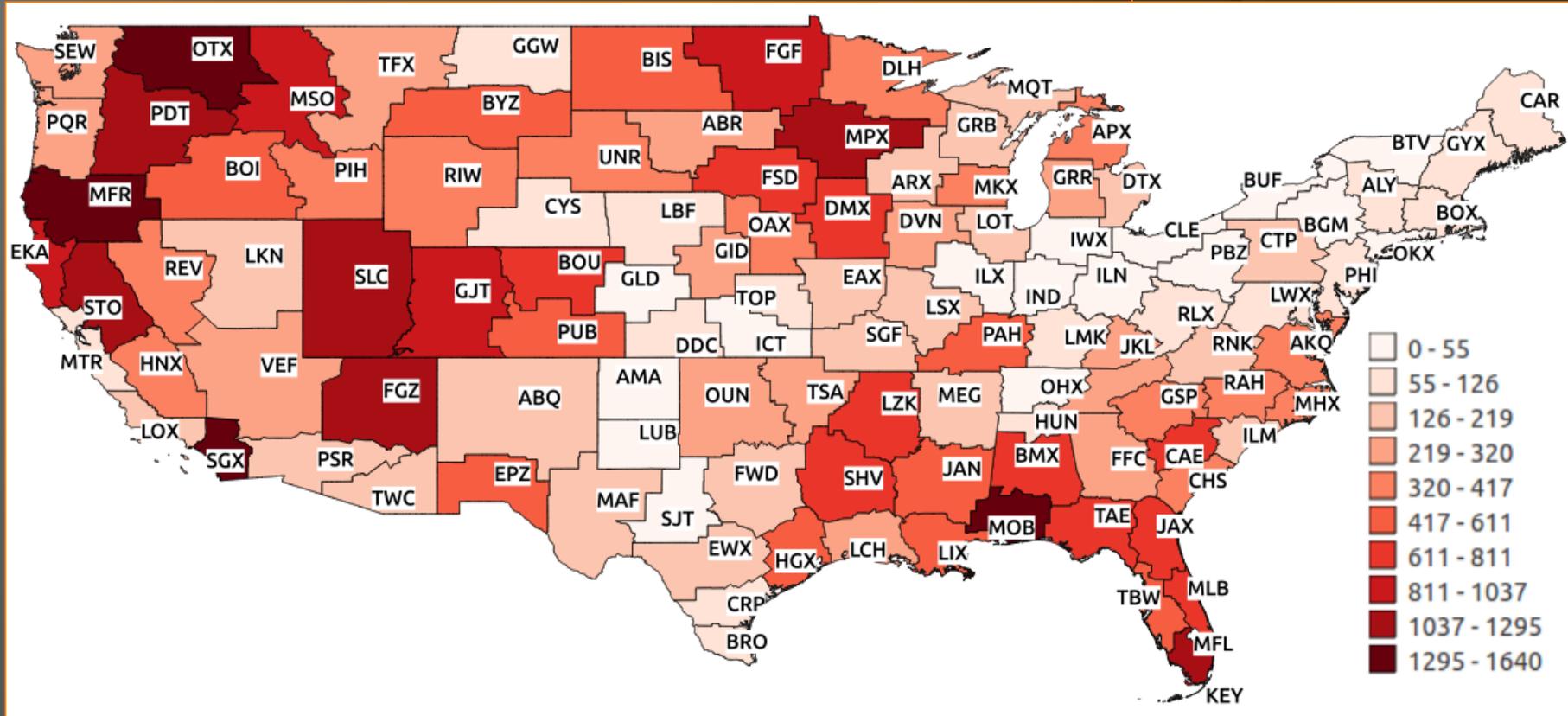
Distributions of (Forecast - Observation) Errors for Prescribed Burn Spot Forecasts

# OUTLINE

- ❖ Introduction
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- ❖ How Do We Verify Spot Forecasts?
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- ❖ **All Forecast Offices**
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# ALL FORECAST OFFICES

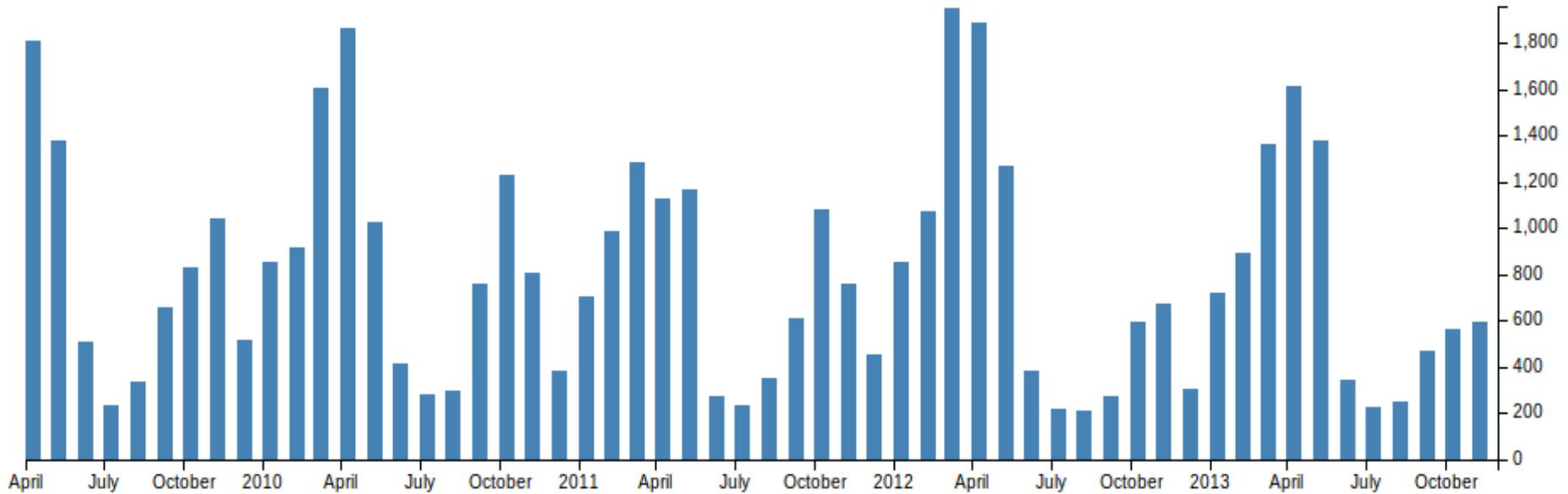
Total Forecasts: 41180



Prescribed Burn Spot Forecasts April 1, 2009 to November 30, 2013

# ALL FORECAST OFFICES

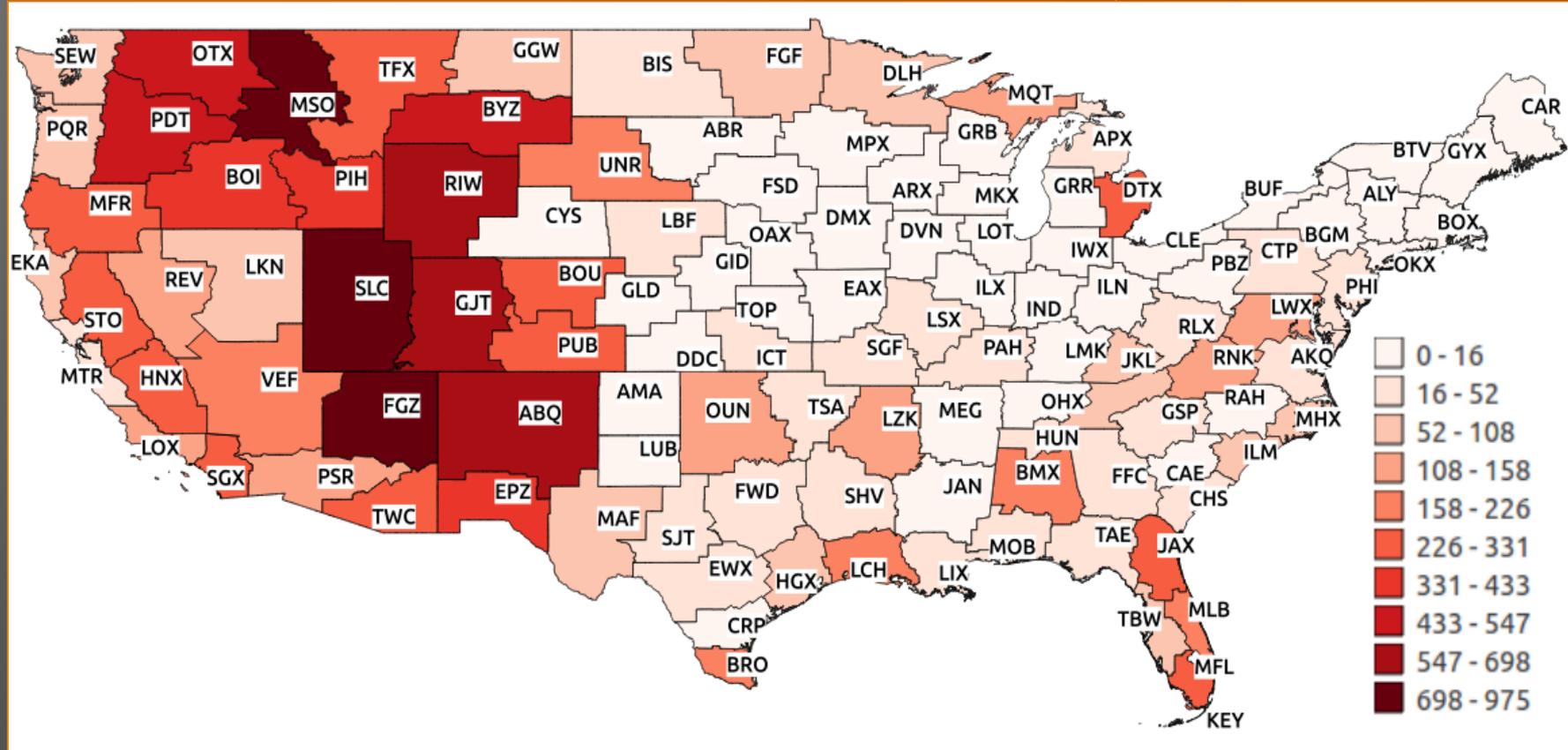
Spot Forecast Date



Prescribed Burn Spot Forecasts in the analysis broken down by month

# ALL FORECAST OFFICES

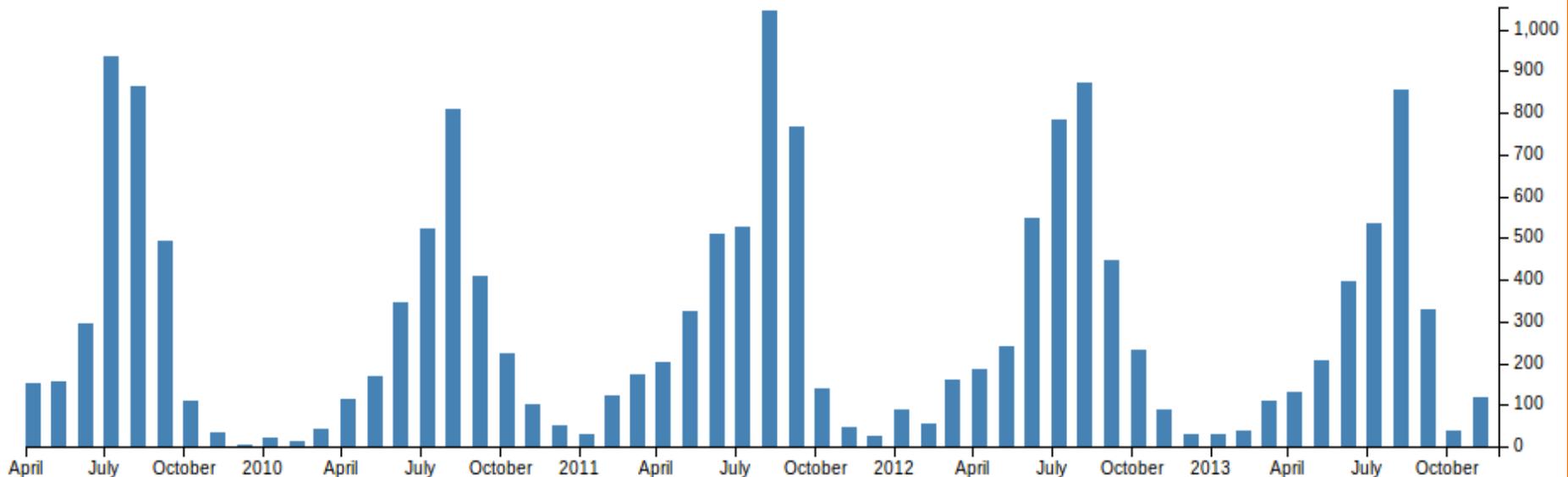
Total Forecasts: 10414



Wildfire Spot Forecasts April 1, 2009 to November 30, 2013

# ALL FORECAST OFFICES

Spot Forecast Date



Wildfire Spot Forecasts in the analysis broken down by month

# ALL FORECAST OFFICES

	Number of Forecasts (Spot - Observation)	(Spot - Observation) Mean Error	(Spot - Observation) Median Absolute Error	Number of Forecasts (NDFD - Observation)	(NDFD - Observation) Mean Error	(NDFD - Observation) Median Absolute Error
Prescribed Burn Temperature	44,901	-0.53 °C	1.33 °C	42,924	-1.72 °C	1.69 °C
Prescribed Burn Relative Humidity	44,901	1.46%	5.29%	42,924	6.04%	6.64%
Prescribed Burn Wind Speed	38,017	0.22 m s <sup>-1</sup>	1.34 m s <sup>-1</sup>	35,979	0.42 m s <sup>-1</sup>	1.42 m s <sup>-1</sup>
Wildfire Temperature	16,280	-0.37 °C	1.67 °C	14,680	-1.46 °C	1.99 °C
Wildfire Relative Humidity	16,280	0.69%	4.00%	14,680	4.10%	5.05%
Wildfire Wind Speed	8,860	0.72 m s <sup>-1</sup>	1.50 m s <sup>-1</sup>	8,075	0.79 m s <sup>-1</sup>	1.59 m s <sup>-1</sup>

Aggregate Statistics for Spot and NDFD Forecast Errors relative to Observations

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Aggregate Statistics for Spot and NDFD Forecast Errors relative to Observations

# ALL FORECAST OFFICES

	Accurate Spot Forecasts	Accurate NDFD Forecasts	Difference (Spot - NDFD)
Prescribed Burn Temperature	75.4%	65.8%	9.6%
Prescribed Burn Relative Humidity	43.9%	39.2%	4.7%
Prescribed Burn Wind Speed	76%	74.4%	1.6%
Wildfire Temperature	66.6%	59.1%	7.5%
Wildfire Relative Humidity	53.3%	49.5%	3.8%
Wildfire Wind Speed	70.4%	68.8%	1.6%

Marginal distributions of accurate Spot and NDFD forecasts  
"Accurate" is  $|\text{forecast} - \text{observation}| < 2.5^{\circ}\text{C}$ , 5% RH, or  $2.5 \text{ m s}^{-1}$

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# SUMMARY

- ❖ It is possible to develop a framework to help users identify the causes and ramifications of spot forecast errors.
- ❖ Verification of spot forecasts requires detailed exploration that can be facilitated using the web tools developed in the process of this research. These tools can be transitioned to operational use.
- ❖ Research continues at Desert Research Institute into verification of upper-air variables in spot forecasts.
- ❖ Aggregate statistics indicate that spot forecasters are adding value above the NDFD gridded values, more so for temperature than for relative humidity and wind speed.

# RECOMMENDATIONS

- ❖ Make clear distinctions between numerical values and words/alphabetical phrases in the forecasts to ease verification
- ❖ This includes separating “gust” values from sustained wind forecasts
- ❖ Allow the Graphical Forecast Editor (GFE) to populate numerical values and focus forecaster attention on developing the Discussion section
- ❖ 90% of forecasts are evaluated with current parsing system, capturing final 10% requires these revisions

TIME (CDT)	9AM	10A	11A	12P	1PM	2PM	3PM	4PM	5PM	6PM
SKY (%).....	39	44	51	65	72	72	70	70	67	62
WEATHER COV.....										
WEATHER TYPE.....										
TEMP.....	35	42	49	54	59	63	65	66	65	62
RH.....	59	50	44	41	37	35	34	33	34	36
20 FT WIND DIR..S	S	S	SW	W	W	W	NW	NW	NW	N
20 FT WIND SPD..10	12	15	15	18	20	21	22	24	25	25
20 FT WIND GUST.15	15	15	20	25	25	25	30	30	30	30
CWR.....	0	0	0	0	0	0	0	0	0	0

# RECOMMENDATIONS

- ❖ Consistent and clear wind levels should be standard for all spot forecasts - “20 Foot” winds are generally used, but there are offices that exclusively forecast “Eye Level” or even “General” winds
- ❖ Local forecasts can have varying parameters available for request, but wind level should be clear upon request

20 FOOT WIND.....WEST WINDS 8-12 MPH WITH LOCALIZED WIND GUSTS TO  
25 MPH AT TIMES.

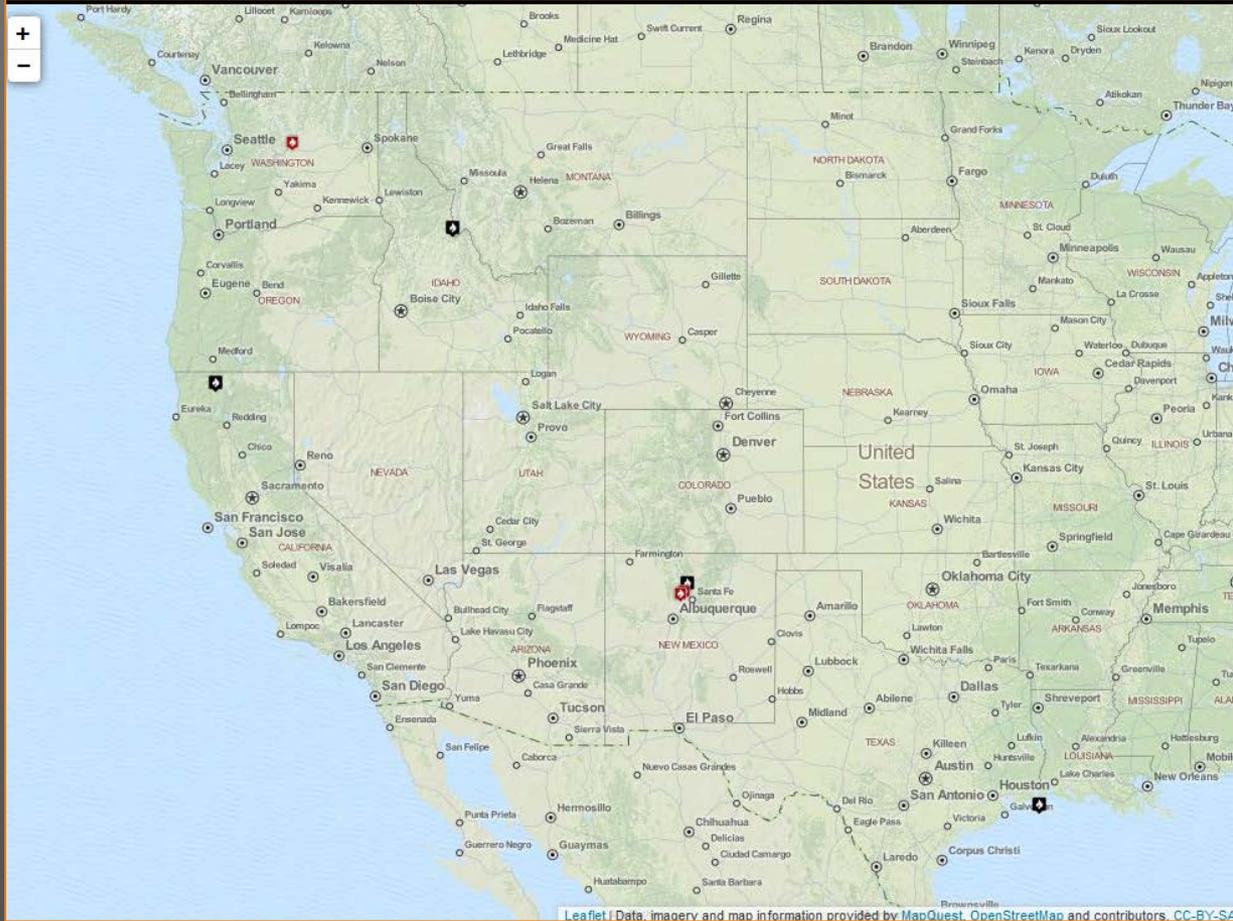
WIND - EYE LEVEL....WEST 3 TO 9 MPH. GUSTS UP TO 14 MPH IN THE  
AFTERNOON.

GENERAL WINDS.....WINDS NORTHEAST WINDS 5 TO 10 MPH.

# THE TRANSITION TO OPERATIONS

- ❖ Evaluation of further aspects of the spot forecasts can be implemented upon transitioning into operational service – these include verifying other forecast periods and leveraging other verification tools
- ❖ We have illustrated the feasibility of daily-updating verification of spot forecasts with a user-friendly web interface available for integration within the Performance Management System
- ❖ The data available provides the opportunity for real-time analytics to be performed for spot forecasts

# THE TRANSITION TO OPERATIONS



Wildfire Spot Forecasts Analyzed Yesterday

# ACKNOWLEDGEMENTS

- ❖ Joint Fire Science Program
- ❖ Virgil Middendorf
- ❖ MesoWest Group