

# **STORM: Towards Building Spatial Temporal Online Reasoning and Management Systems**

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School of Computing  
University of Utah**

# Spatial Temporal Data?

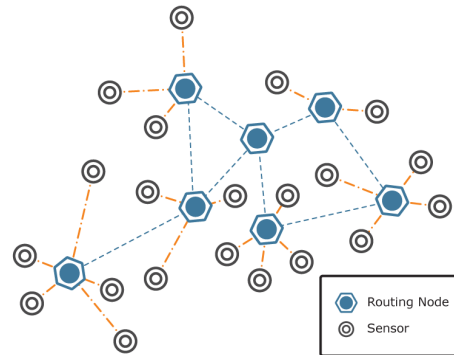
## Location-based Services



Google Maps



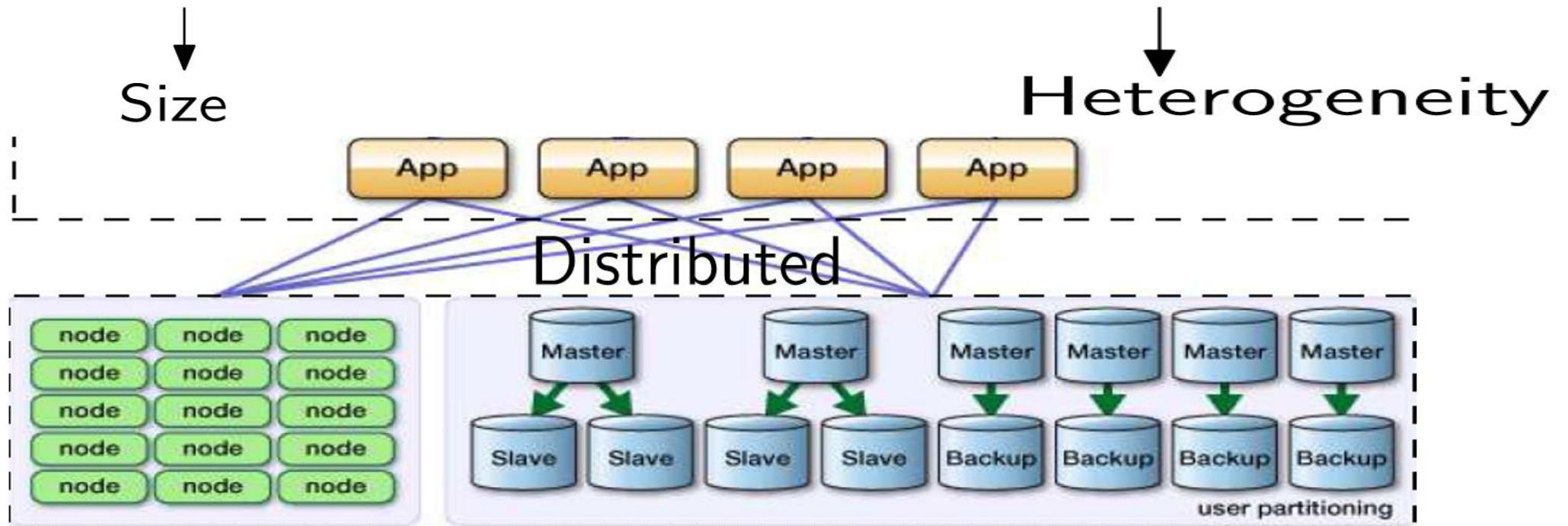
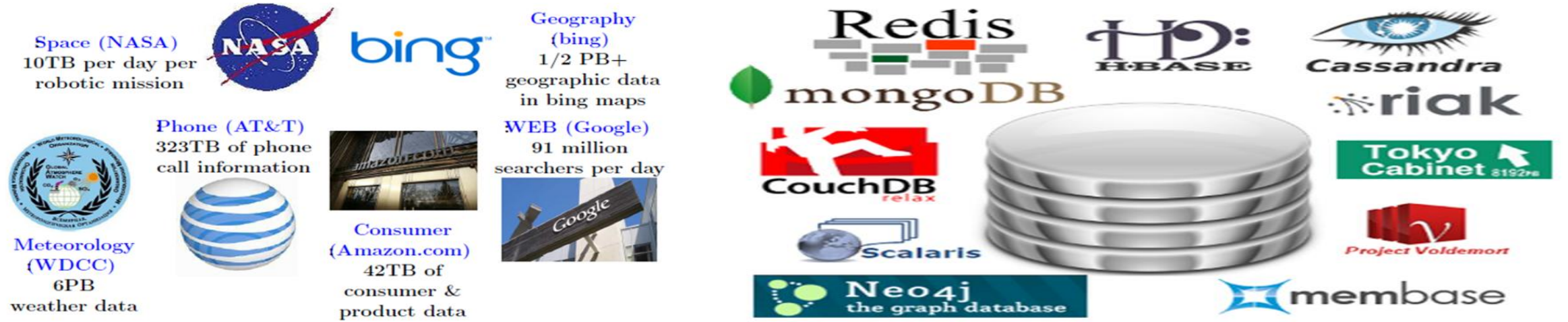
## IoT Projects & Sensor Networks



## Social Media



# The Big Spatial Temporal Data Challenge



# Complex Analytical Queries

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```
SELECT SUM(l_extendedprice * (1 - l_discount))
FROM customer, lineitem, orders, nation, region
WHERE c_custkey = o_custkey
      AND l_orderkey = o_orderkey
      AND l_returnflag = 'R'
      AND c_nationkey = n_nationkey
      AND n_regionkey = r_regionkey
      AND r_name = 'ASIA'
```

This query finds the total revenue loss due to returned orders in a given region.

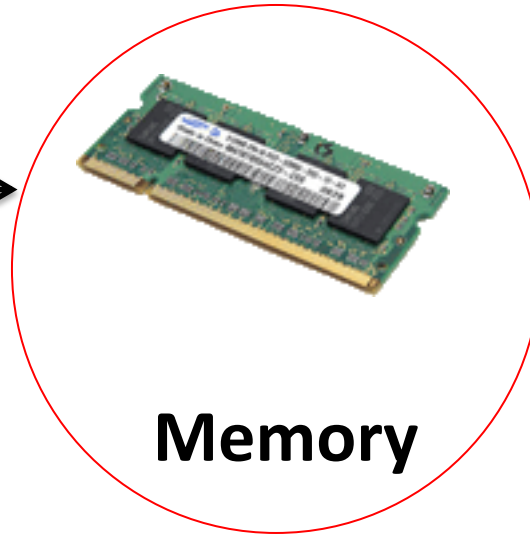
# 100 TB on **1000** machines

½ - 1 Hour

1 - 5 Minutes



Hard Disks

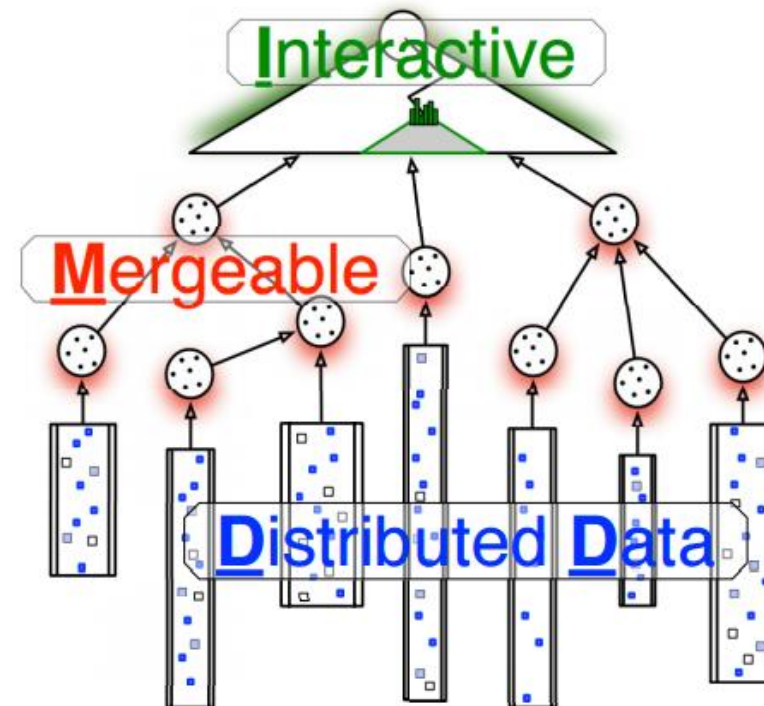


Memory

In memory computation over a cluster

# Challenges and Main Results

- Distributed spatial and temporal data is massive
- **Approximate analysis** is fast and often effective for this type of data
- **Integrating multiple data sources** is a key requirement
- **Results:** Using mergeable and interactive data summaries to enable approximate analysis and data integration effectively



# Data-driven spatio-temporal analytics over heterogeneous data

## The STORM Platform



social media data



sensor data

Device ID: Jason's Phone

Product: Creely

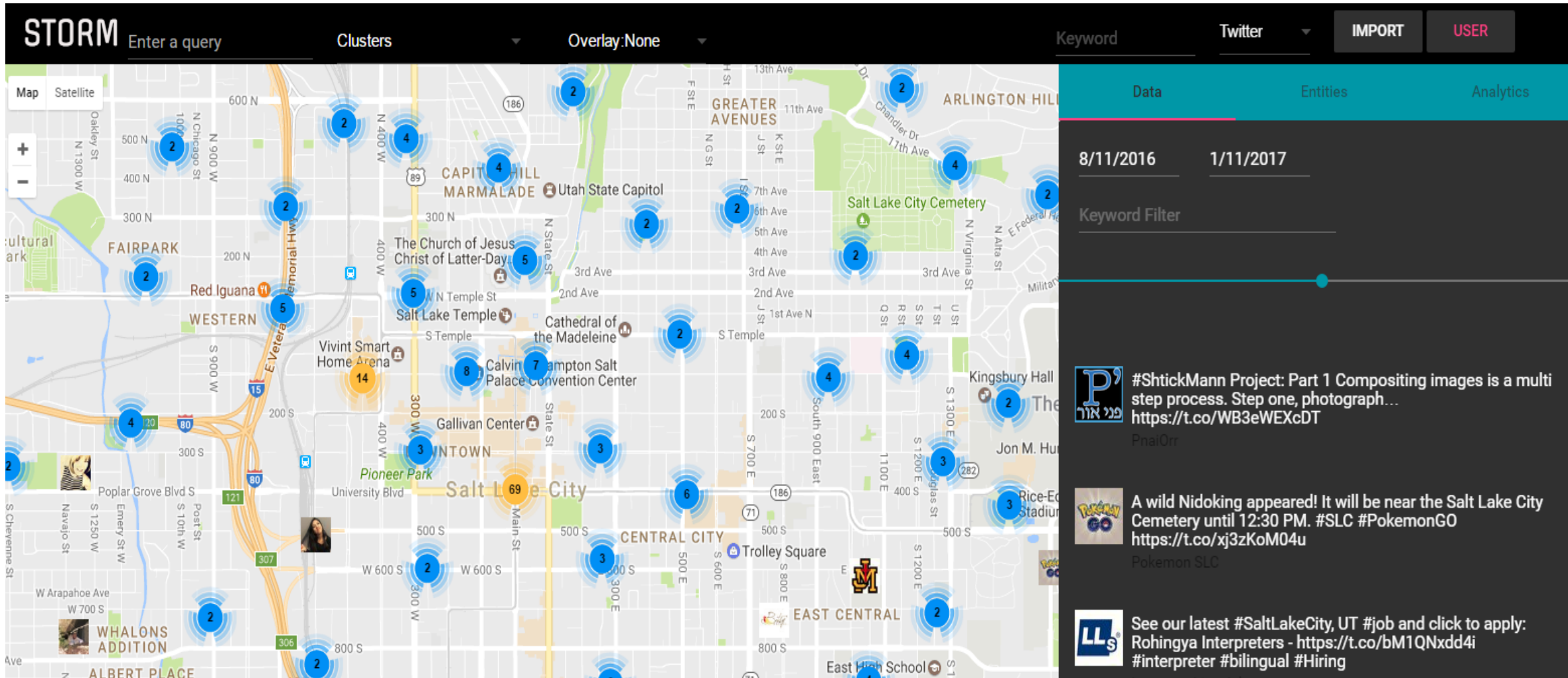
Scanned at: 2015-03-13T08:59:30.253Z

transaction data  
log data

....



# System Infrastructure



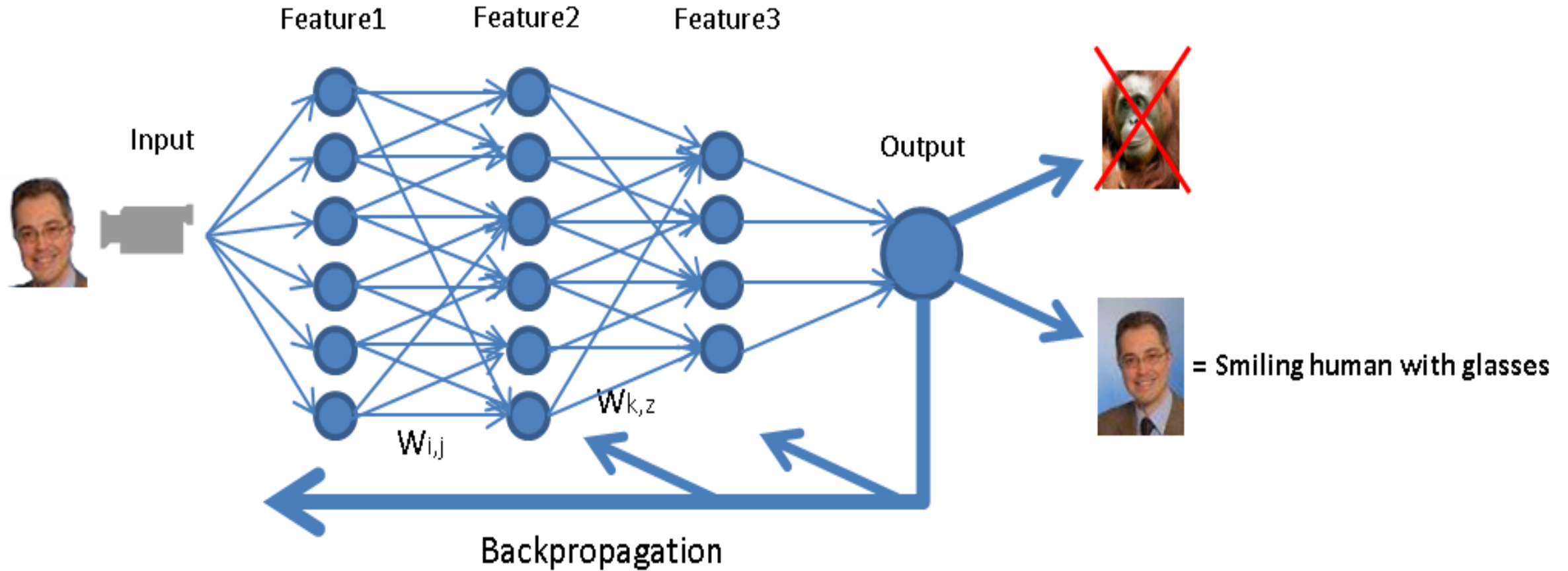


# System infrastructure

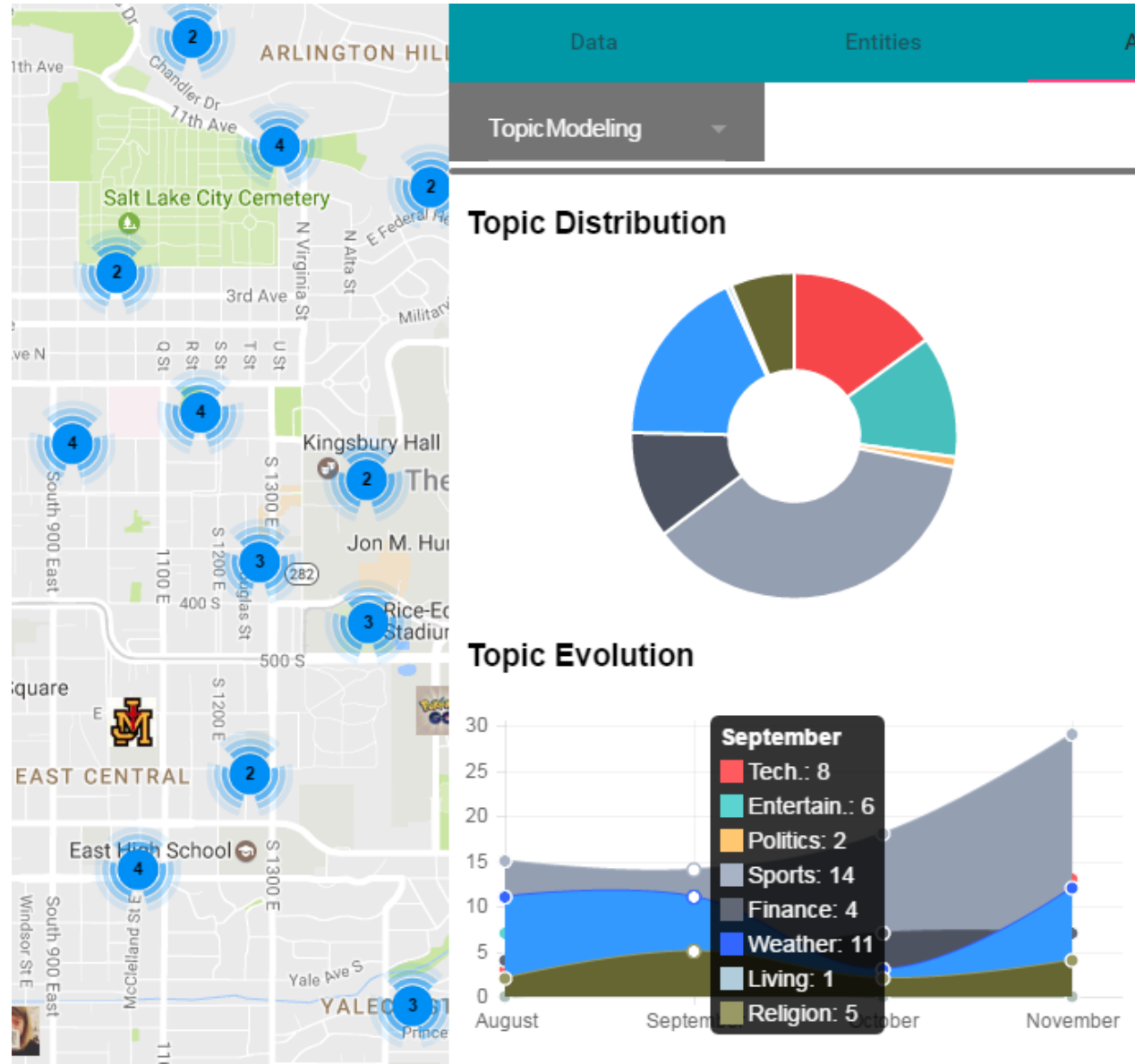
The screenshot displays the VisualLocal application interface. At the top, there is a navigation bar with 'VisualLocal', 'Home', 'Search Locations', 'Go', 'Keywords Filter', and '3 selected'. The main area is a map of Salt Lake City with various location markers and icons. A 'Data Source Selection' dropdown menu is open, listing sources like Instagram, Twitter, Weibo, Foursquare, Yelp, TwitterRT, Weather, and WeatherRT. A 'Temporal Dimension Search' overlay is also visible, showing a date range from 03/09/2014 to 04/07/2014 and a 'Custom Range' button. The map includes labels for 'Mesowest Station' and 'Analytical Query Interface'. The right side of the screen shows a list of search results, including tweets from users like WRHU1 and AllDay\_Tay.



# Combine with machine learning techniques



# Spatial Temporal Topic Modeling





# Application 1: Mesowest (co-PI John Horel from Atmosphere Science)

>40,000  
stations

More than  
10 billion  
readings  
and  
counting

The screenshot displays the Mesowest website interface. At the top, there is a navigation bar with the Mesowest logo (1997-2017), a 'Region' dropdown menu set to 'UTAH', a 'Product' dropdown menu set to 'Surface Weather Maps', and a 'Go' button. Below this is a search bar and a 'Map Product' dropdown menu set to 'Default'. The main content area is divided into three panels on the left and a large map on the right. The 'Data Selection' panel includes a 'Region/Zone' dropdown set to 'UTAH', a 'Radius' dropdown, a 'Network' dropdown set to 'NWS', and a 'Units' dropdown set to 'English'. There is a 'Refresh Map' button. The 'Display' panel includes 'Overlay 1' set to 'Current Temp', 'Overlay 2' set to '- None -', and a checked 'Highlight Data' checkbox. The 'Other Features' panel includes a 'Time Options' link. At the bottom left, there is a 'Select Language' dropdown and a 'Powered by Google Translate' notice. A Facebook logo and the text 'Find us on Facebook' are at the bottom center. The map on the right shows a topographic view of Utah with various cities and towns labeled, including Layton, Bountiful, West Valley City, Sandy, West Jordan, Erda, Grantsville, Tooele, Stockton, Rush Valley, Terra, Cedar Fort, Fairfield, Orem, Provo, Springville, Spanish Fork, and Vernon. A red box with the number '43' is placed over the Grantsville area, with an arrow pointing to it from the text 'A station'. A tooltip above the map reads 'Most recent observation within 1 hr ending at 11:52 UTC 1/11/2017'. The URL <https://mesowest.org/> and <http://mesowest.utah.edu/> are overlaid in blue text at the bottom of the map area.

# Application 1: Mesowest (co-PI John Horel from Atmosphere Science)

**MESOWEST** 1997-2017  
Region: UTAH Product: Surface Weather Maps Go

Hide Menu Search Map Product: Default Change

**Data Selection**  
Region/Zone: UTAH Radius: [ ]  
Network: NWS Units: English Refresh Map

**Display**  
Overlay 1: Current Temp Overlay 2: Current Wind Speed Highlight Data

**Other Features**  
Time Options Select Language Powered by Google Translate Find us on Facebook

**Current Station Observations**  
Salt Lake City Int  
Observation Time: 01/11/17 @ 05:20 MST 12:20 UTC Elevation: 4226 ft OK

Weather Conditions		24 Hour Max/Min Events	
Temperature:	43 °F	Max Temperature:	46 °F
Dew Point:	32 °F	Min Temperature:	39 °F
Humidity:	65 %	Max RH:	70.19 %
Wind:	SSE at 13 MPH	Min RH:	51.01 %
		Max Dew Point:	33 °F
		Min Dew Point:	27 °F
		Max Gust:	48 MPH

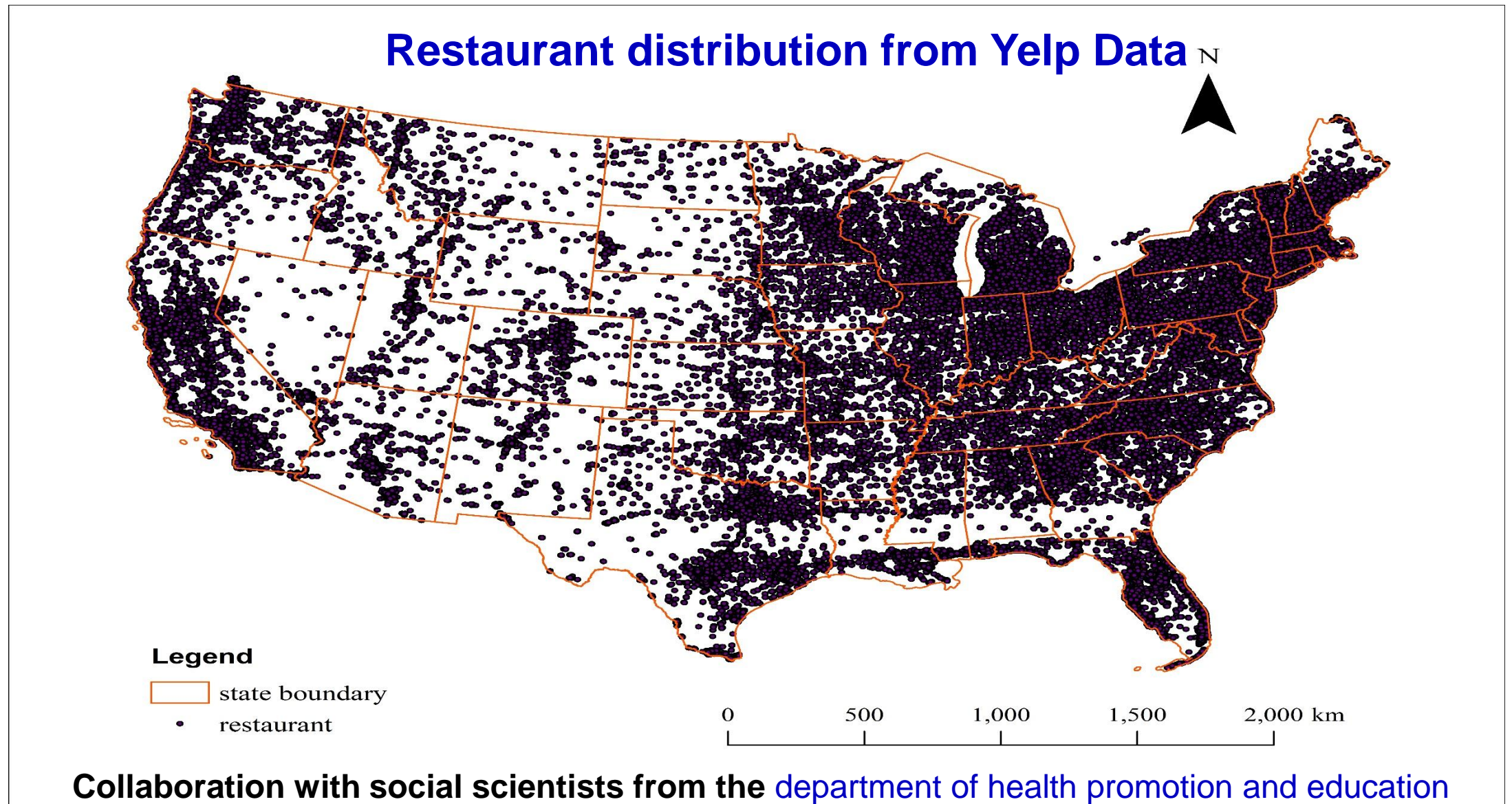
View: Temp Wet Bulb Wind Vector Wind Wind Rose Pressure Precip Snow Solar Help

**Salt Lake City International Airport (MST)**  
Temperature (F) Dewpoint (F) Relative Humidity (%)

Change to UTC Time Additional Tabular and Graphical Displays Download Data



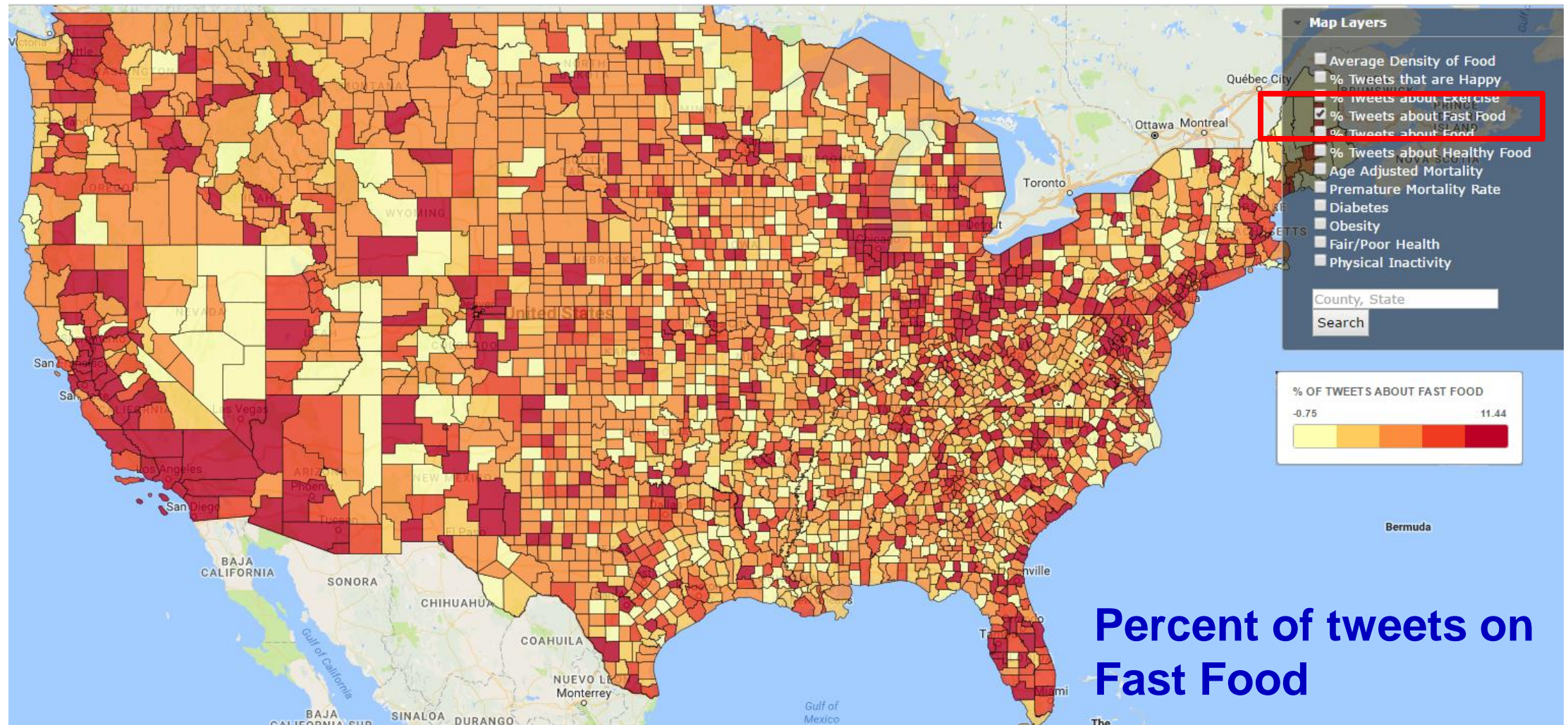
## Application 2: Neighborhood Health Indicator from Social Media Data







## Application 2: Neighborhood Health Indicator from Social Media



April 2015– March 2016. County summaries were derived from 80 million geotagged tweets from the contiguous United States. <https://hashtaghealth.github.io/countymap/map.html>

# Application 3: What Tweets Say about the Election?

General Tweets: 286 million (Worldwide)  
Political Tweets 1.5+ millions (All Geotagged)  
Republican Tweets: 822,062  
Democrat Tweets: 702,042

## ELECTION 2016 SENTIMENT MAP

According to Spatial-Temporal Twitter data

States Counties

Utah

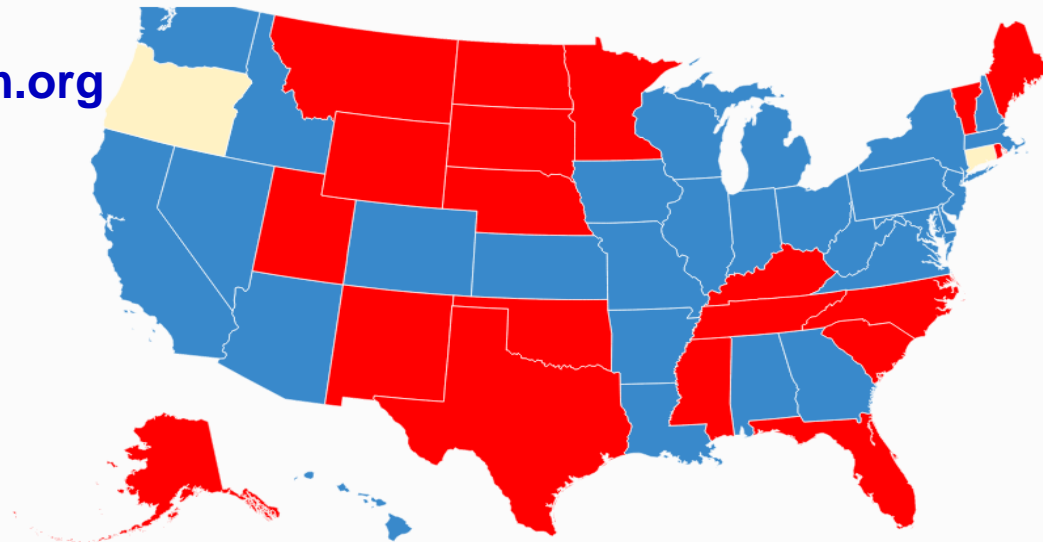
ID: 49

Winning: Republican

Republican : 15 counties

Democrat : 13 counties

<http://www.estorm.org>



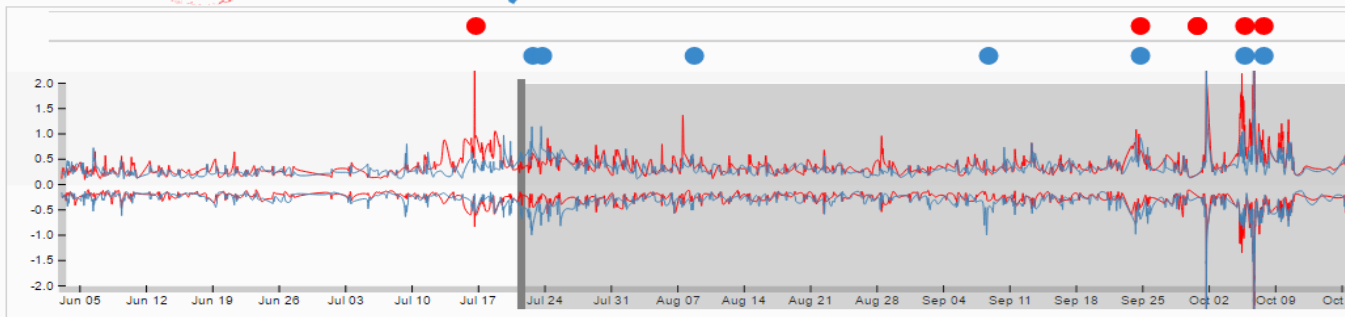
### Dig deeper

Click and drag the timeline below the map or hover over the circles in "Event Timeline" to see how popular opinion changes over time.

[Learn more](#)

### Legend

REPUBLICAN  
DEMOCRAT  
UNDECIDED/TIE  
INSUFFICIENT DATA



### Event Timeline

Positive Sentiment

Negative Sentiment



# Application 3: What Tweets Say about the Election?

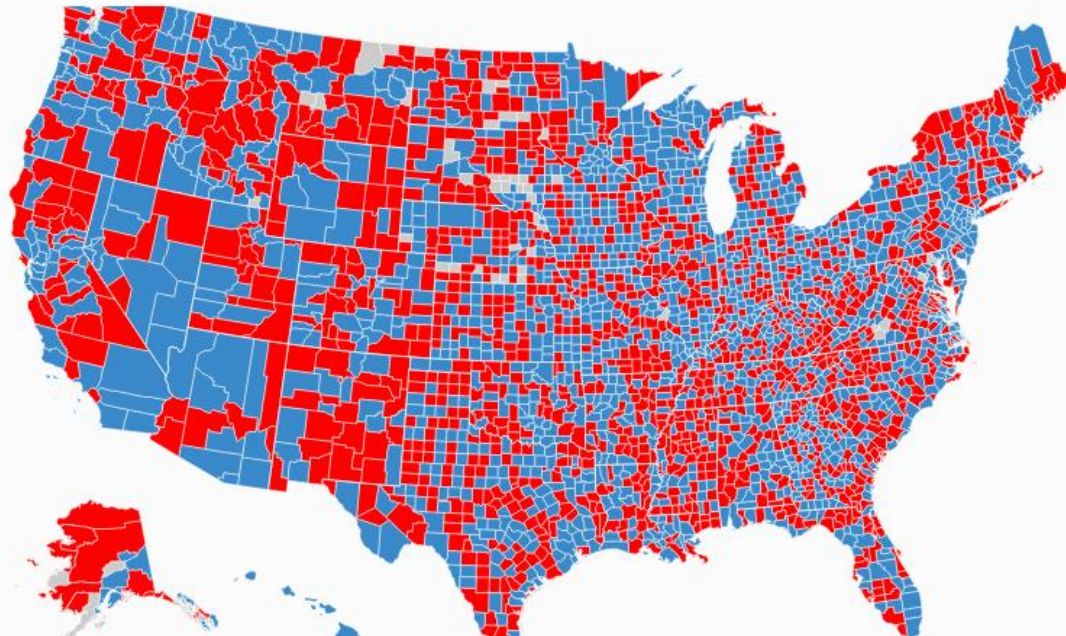
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## ELECTION 2016 SENTIMENT MAP

According to Spatial-Temporal Twitter data

States

Counties



Utah County, Utah

ID: 49049

Winning: Republican

Republican : 0.7030607853 (sentiment score)

Democrat : 0.6838714003 (sentiment score)

### Dig deeper

Click and drag the timeline below the map or hover over the circles in "Event Timeline" to see how popular opinion changes over time.

[Learn more](#)

### Legend

REPUBLICAN



DEMOCRAT



UNDECIDED/TIE



INSUFFICIENT DATA



# Thanks!

**STORM was awarded the SIGMOD'15  
Best Demo Award**

**Pls: Feifei Li, John Horel, Jeff Phillips, Paul Rosen**

