Caltrans WeatherShare Phase II System:
An Application of Systems and Software Engineering Process to Project Development

Doug Galarus
Principal Investigator
Senior Research Associate, Program Manager – Systems Engineering, Development and Integration
Western Transportation Institute

Shaowei Wang
Research Engineer
Western Transportation Institute

Dan Richter
Research Associate
Western Transportation Institute

Ian Turnbull
Project Champion
Chief, Office of ITS Engineering and Support
Caltrans District 2

Mandy Chu
Project Manager
Senior Transportation Engineer
Caltrans Division of Research and Innovation

NRITS 2009
Session F3: Systems Engineering
Tuesday, August 25, 2009
2:45 PM

Abstract

In cooperation with the California Department of Transportation, Montana State University's Western Transportation Institute has developed the WeatherShare Phase II system by applying Systems Engineering and Software Engineering processes. The system aims at improving weather incident recognition and response by providing streamlined access to surface weather data from multiple sources. The WeatherShare Phase II system covers all of California with emphasis on its' more than 16600 miles of state and federal highways. Information is collected from over 3200 surface weather stations from state and national weather sources such as Caltrans Road Weather Information Systems (RWIS), MesoWest, NOAA's Meteorological Assimilation Data Ingest System (MADIS) and the NOAA National Digital Forecast Database (NDFD). Three-level Quality Control (QC) procedures have been implemented to flag questionable sensor readings. Other value-added steps taken include mapping NDFD data to California highway mileposts, and using combinations of data to detect and display alert conditions.

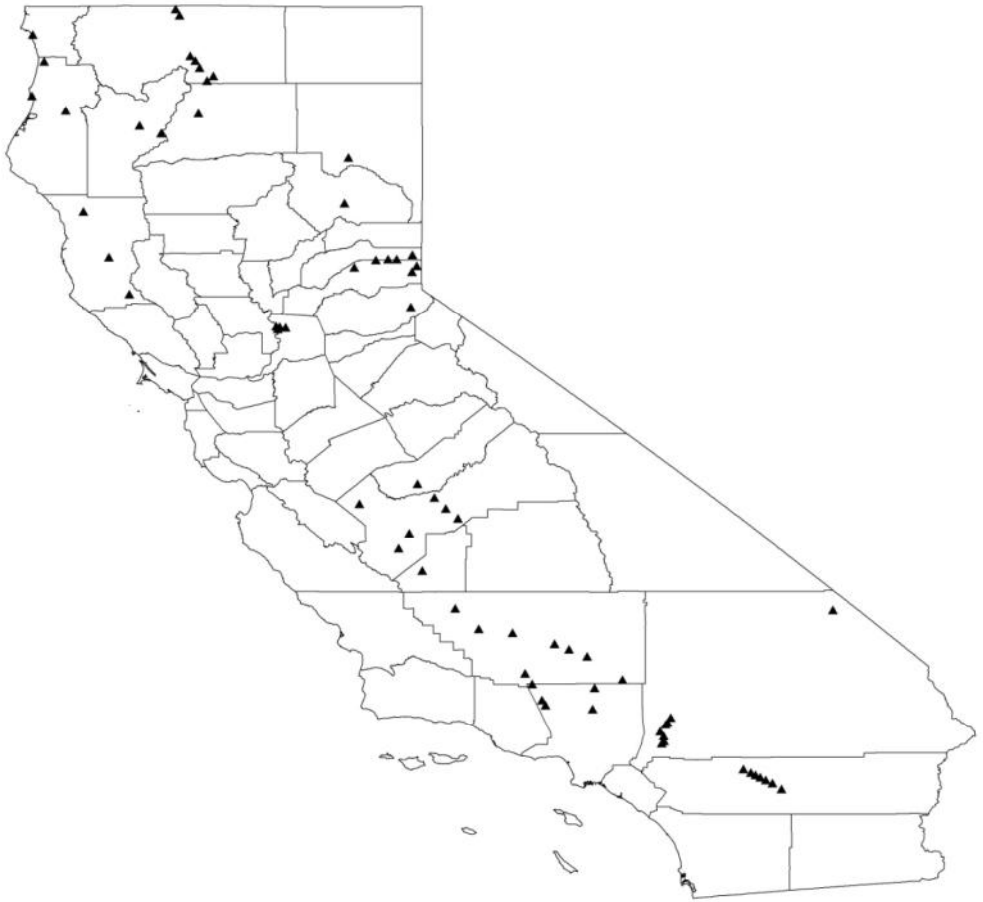
The system was designed using a multi-tiered architecture with open source platform. All mapping information is displayed on a layered Google Maps display. The system is accessible at http://www.weathershare.org/.

This presentation will provide an overview of the Phase II system, the systems and software engineering processes followed in developing the system, as well as lessons learned in implementation.

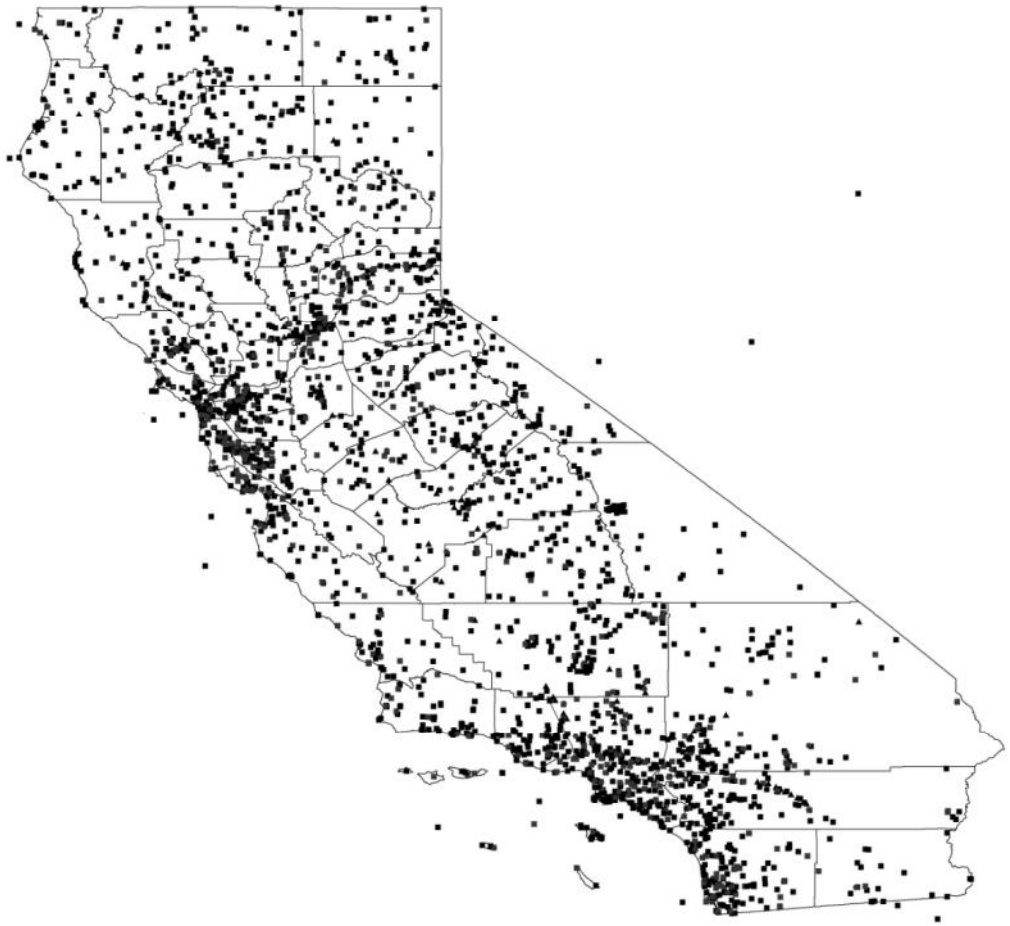
WeatherShare Phase II Background

- The goal is to improve weather incident recognition and response by providing streamlined access to surface weather data from multiple sources.
- Expand on Phase I work, which focused on Redding Incident Management Enhancement (RIME) area – Northern California.
- Provide statewide coverage.
- Include as many surface real time weather stations as possible:
  - Current Total 3271, and growing …
    - 107 Caltrans RWIS stations
    - 690 MADIS stations
    - 2474 MesoWest stations
- Map National Digital Forecast Database (NDFD) data to California mileposts.
- Enhance alert capability.
- Use a layered Google Maps display.

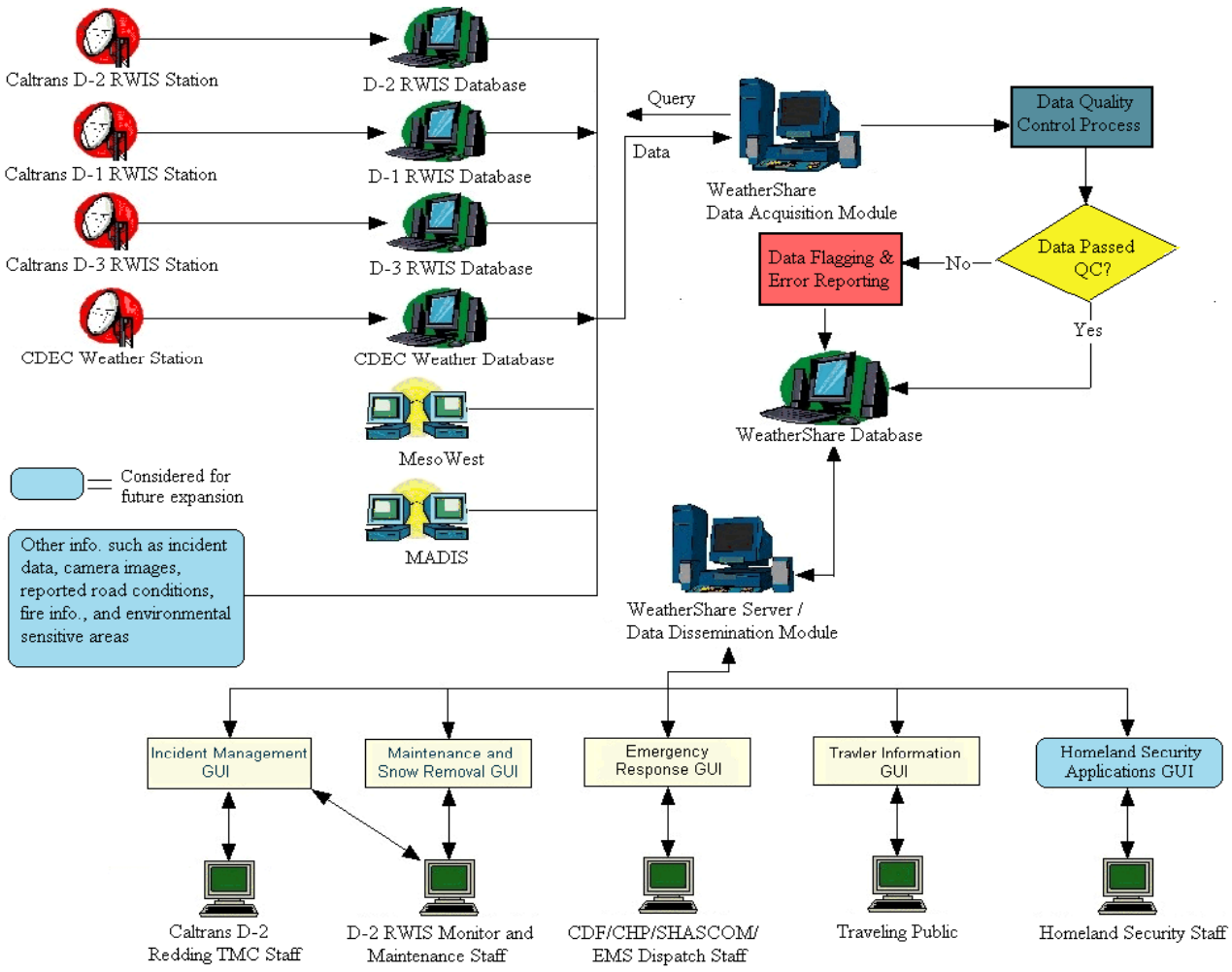
Caltrans RWIS stations (100+)



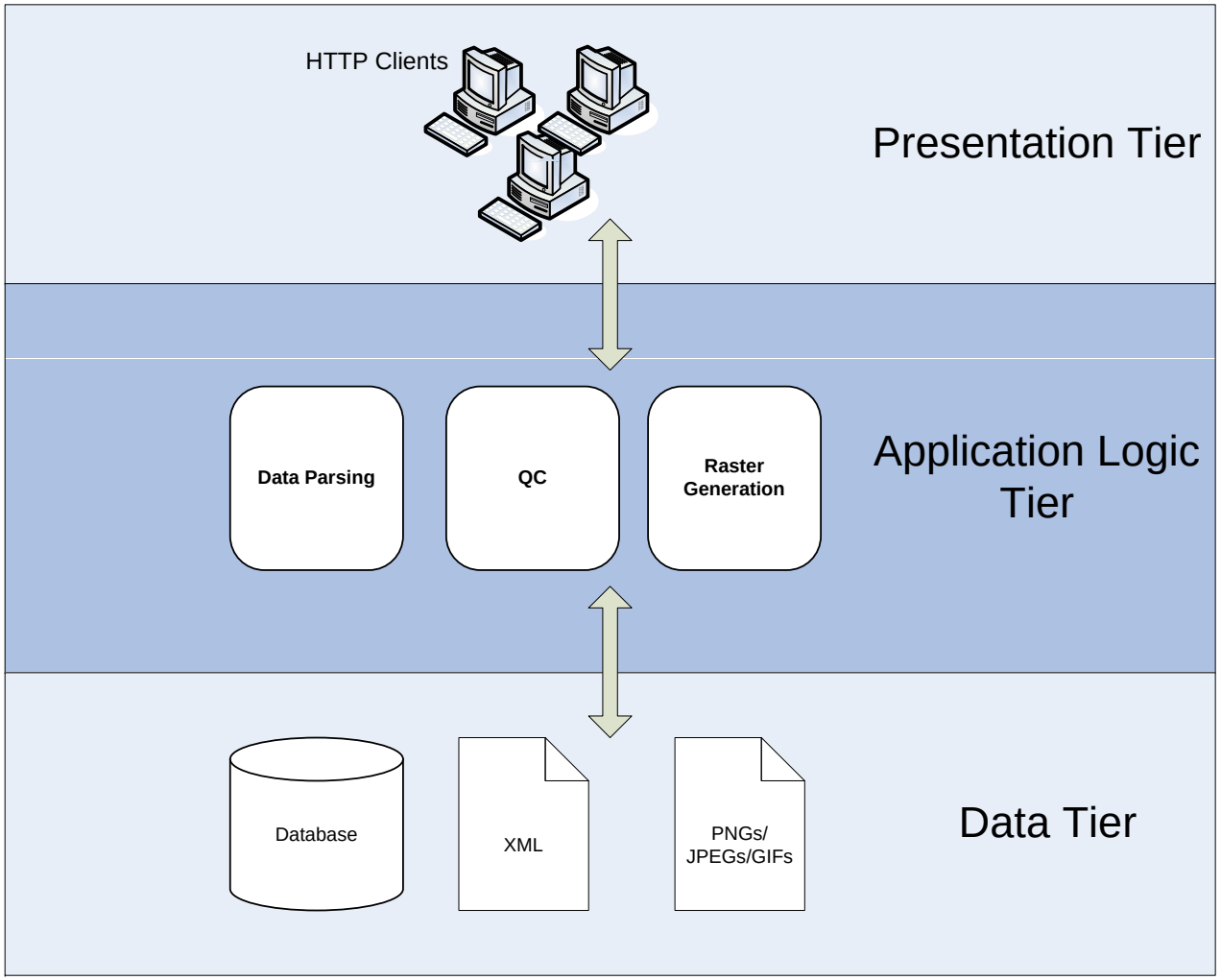
Surface Weather Stations (3000+)



WeatherShare Concept & Information Flow



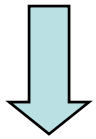
Three-tier System Architecture



System Hardware Configuration

old

- Dual Intel(R) Xeon(TM) CPU 2.40GHz
- Hard drives: 80 GB x 2
- 1 GB memory



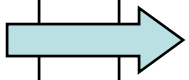
new

- Dual Quad Core Intel® Xeon®X5450 3.0GHz
- Hard drives: 300 GB x 2 RAID 1
- 16 GB memory

Open Source Platform

old

- Debian Linux (kernel 2.4.25)
- Apache v 1.3
- MySQL v 5.0.32
- Perl v 5.8.8
- PHP v 4.4.4-8
- GCC v 4.1.2
- GD 2.0

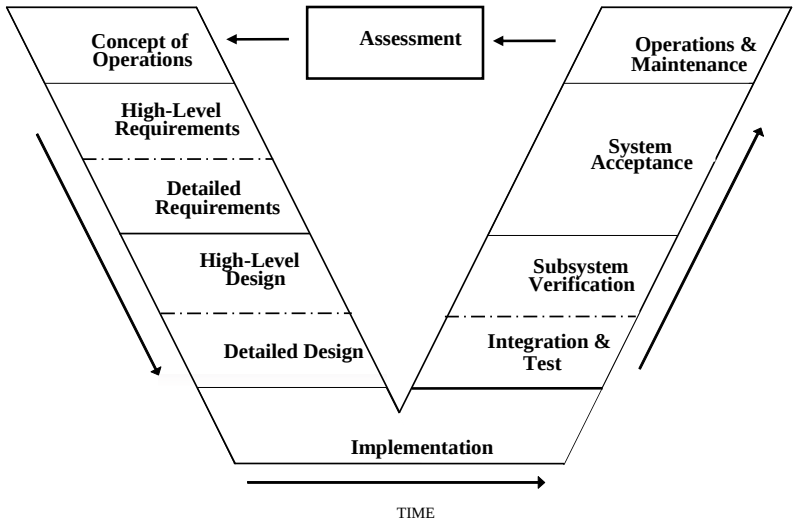


new

- Debian Linux (2.6.26-1-amd64)
- Apache v 2.0
- MySQL v 5.0.51
- Perl v 5.10.0
- PHP v 5.2.6-1
- GCC v 4.3.2
- GD 2.0

Systems Engineering Process

- Phased approach
  - Phase I: Prototype system (2003 – 2006)
  - Phase II: Full system (2006 – 2009)
- Follow the V model on a small scale.



Correspondence to Caltrans Stages of Research Deployment

Project Phase	Caltrans Stages of Research Deployment
Phase 1	Concept Stage
Phase 1	Laboratory Prototype Stage
Phase 1	Controlled Field Demonstration Stage
Phase 2	First Application (Contract) Field Pilot Stage
Phase 2 (partial)	Specification & Standards with Full Corporate Deployment Stage

Current Condition Data Sources, Update Frequency & Sensor Readings

- NOAA MADIS (690 stations): every 30 minutes

  Air Temperature, Relative Humidity, Avg Wind Speed, Avg Wind Direction, Max Wind Gust Speed, Max Wind Gust Dir, Dewpoint Temp, Atmospheric Pressure, Fuel Moisture, Fuel Temperature, Precipitation Rate, Precipitation in 24Hours

- University of Utah MesoWest (2474 stations): every 15 minutes

  Air Temperature, Relative Humidity, Avg Wind Speed,Avg Wind Direction,Max Wind Gust Speed, Atmospheric Pressure, Solar Radiation

- Caltrans RWIS (107 stations): every 30 minutes

  Air Temperature, Dewpoint Temp, Max Temp, Min Temp, Avg Wind Speed, Max Wind Gust Speed, Avg Wind Direction, Max Wind Gust Dir, Relative Humidity, Precipitation Intensity, Precipitation Rate, Accumulate Precipitation, Visibility

- NWS Observed 24 Hours precipitation: twice every 24 hours

Forecast Data Sources, and Update Frequency

- NDFD data: every 60 minutes

  Air Temperature, Humidity, Avg Wind Speed, Avg Wind Direction, Max Wind Gust Speed, Max Wind Gust Dir, Sky cover, 12 hours probability of precipitation, 6 hours amount of precipitation, Snow, weather

- NWS Warnings, Watches and Advisories: every 15 minutes

  Warnings:

  Tornado, Flash flood, Blizzard, Winter Storm, High Wind, Storm, Avalanche, Severe weather statement, Flood, Red flag, Heavy Freezing Spray

  Watches:

  Flash Flood, Winter Storm, Flood, High Wind, Fire Weather, Coastal Flood Statement, Special Weather Statement, Short Term Forecast

  Advisories:

  Winter Weather, Flood, High Surf, Small Craft, Brisk Wind, Lake Wind, Wind

Methods for Accessing, Converting, and Storing Data

- Data is accessed through ftp & http – all pull, no push.
- Raw data formats include csv, xml, netCDF.
- Data is parsed and saved into a MySQL database.
- With a large amount of saved data, database design and access must be optimized.
- CALTRANS data is accessed via http.
- MADIS data is accessed via ftp.
- MesoWest data is accessed via ftp.
- NDFD is accessed via http.

Data Processing Problems and Identified Solutions

- Data provider outages : register email list for early notification.
- Data format changes : error control in code.
- Daylight saving time : all times converted to and stored in UTC time.
- Station META data (Name, locations, etc) changed without notification : manually update based on station error report or batch program update.
- There is overlap in station data from providers : we are using this for “backup” purposes.
- Not all stations report new readings with desired frequencies : only display data updated within 90 minutes.
- Server running slow for bin/raster process : upgrade server, optimize code.

Quality Control

- **Level I:**
  - Range checks
- **Level II:**
  - Temporal consistency checks: rate of change
  - Single sensor time series test: acceptable Delta
- **Level III:**
  - Statistical spatial consistency checks: “buddy” check
    - Multivariate linear regression is being implemented for Level 3 quality control for air temperature only
    - Results are experimental
    - No uniform standard for this
    - It has already proven useful
    - Requires further investigation

Level 1 Quality Control : Range checks

Location	Latitude 0° – 90°N; Longitude 20°W – 120°E
Station Pressure	6.8 inches (568mb) – 32.5 inches (1100mb)
Air temperature	-60°F – 130°F
Soil temperature	-40°F – 150°F
Dewpoint	-80°F – 90°F
Relative Humidity	0 – 100%
Wind Direction	0° – 360°
Wind Speed	0 – 250 knots
Maximum Gust	11 – 250 knots
Visibility	0 – 100 miles
Accumulated Precipitation (24-hour)	0 – 44 inches

Level 2 Quality Control : Temporal Consistency Checks

- Pressure (station) 0.150 inches/hour
- Air Temperature 20°F / hour or no change in 24 hours
- Dewpoint 20°F / hour
- Relative Humidity 50% / hour

Level 3 Quality Control : Spatial Consistency Checks

- Multivariate linear regression establishes an observational parameter (e.g. air temperature) as a function of the station's positional coordinates including elevation and observation data within the past hour from multiple weather stations.

- The predicted values are compared to reported values. If the reported temperature data is different from the predicted regression value over the last 90 minutes by over 10°F, the observation is flagged as "failed".

Reference : Splitt, M.E., and J., Horel (2005). 3, 2005.

Presenting Data: Decisions about Screen Layout

- Statewide Coverage and Deployment
- Enhanced Alert Capability
- Improved Reporting Capability
- Weather Forecasts and Alerts

The WeatherShare Phase II Interface

- Using Google maps API
- HTML
- DHTML
- JavaScript
- AJAX
- Web 2.0
- Broadband connectivity preferred
- Future alert distribution could include: Email, RSS, CAP

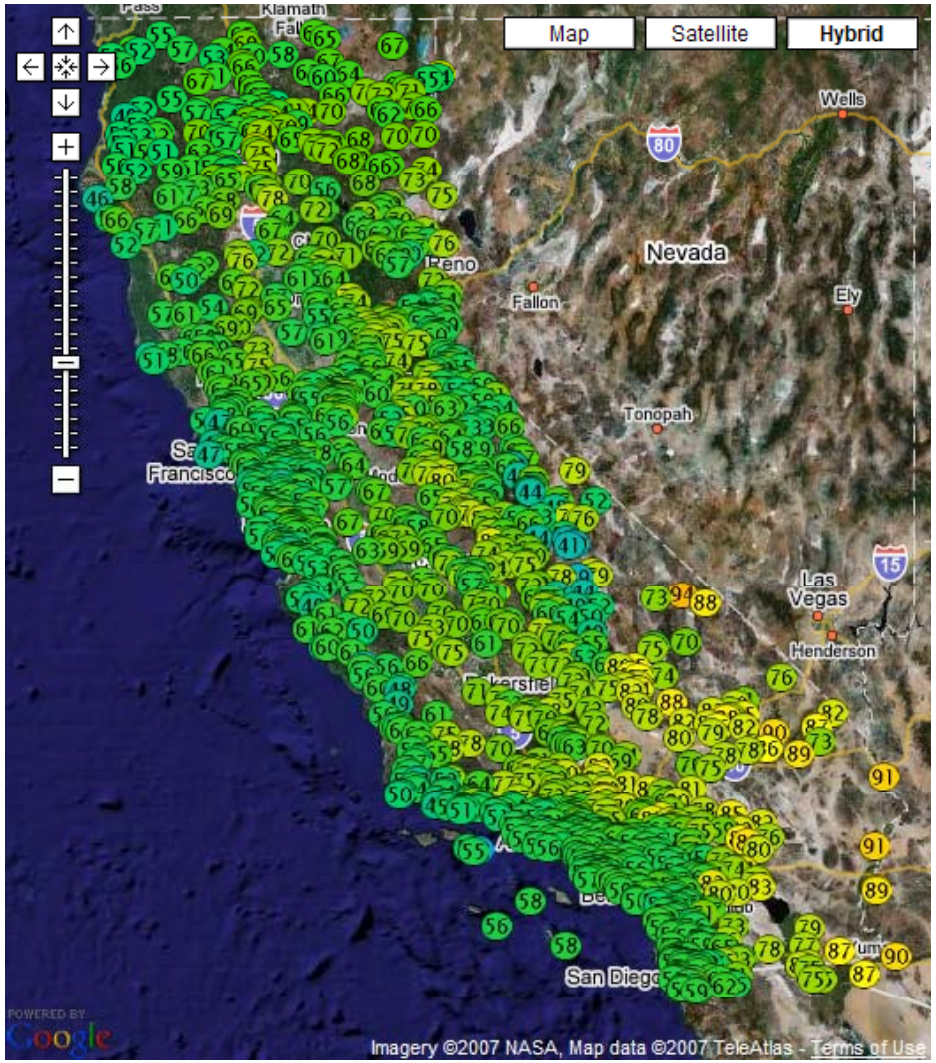
Example GIS-Related Challenges

- Handling Highway MilePosts
- Raster graph generation using Mercator Projection
- NWS public and fire zone for Warning / Alert

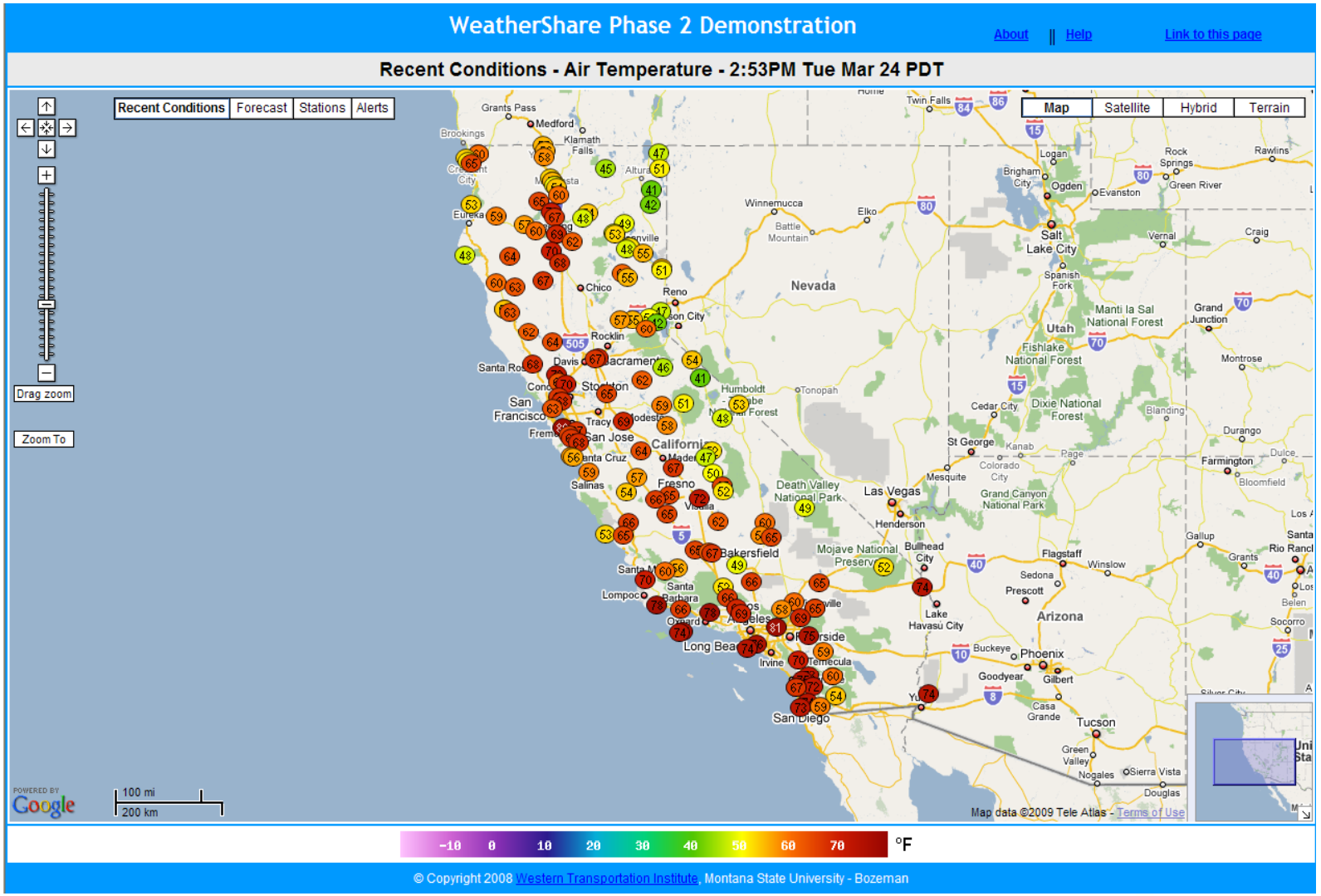
Browser-Related Challenges

- Programming for different Browsers, Firefox vs. Internet Explorer
  - Different style sheets necessary to keep consistent spacing/appearance
  - Different methods to attach/detach and event to an object
- Server side vs. client side code

Data Display Challenges

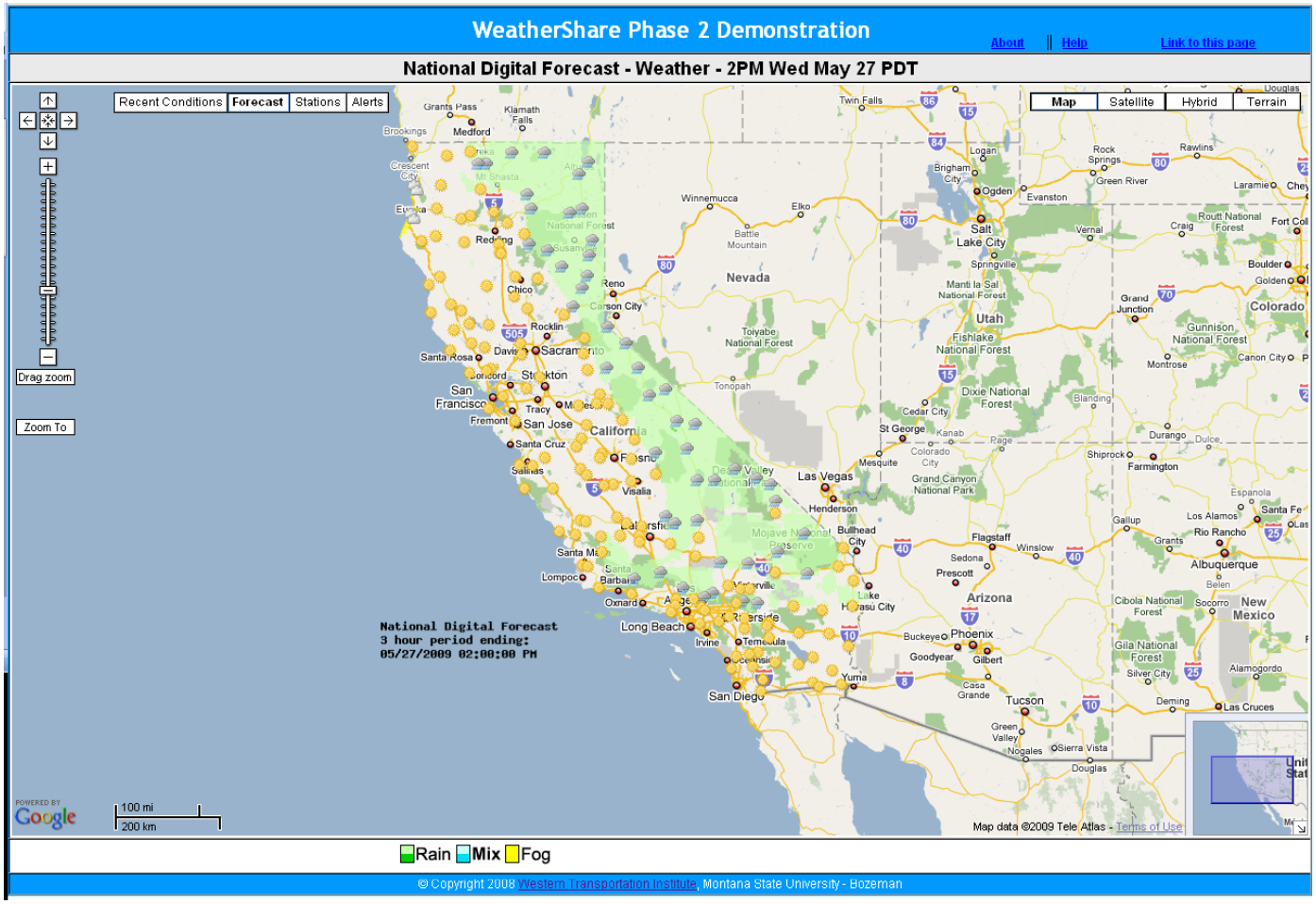


Improved ...



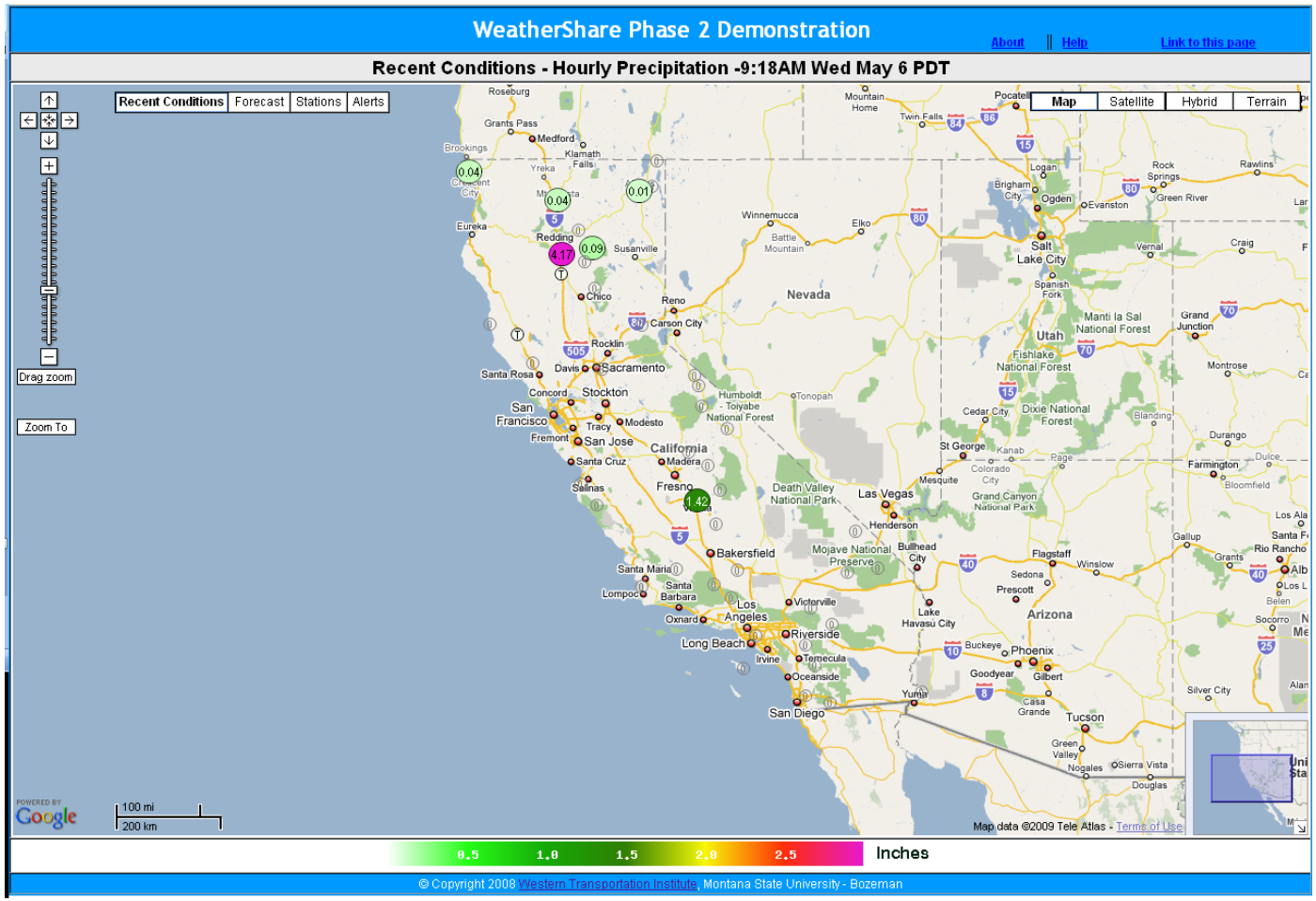
MONTANA STATE UNIVERSITY | College of ENGINEERING | Western Transportation Institute

WeatherShare Graphical Display

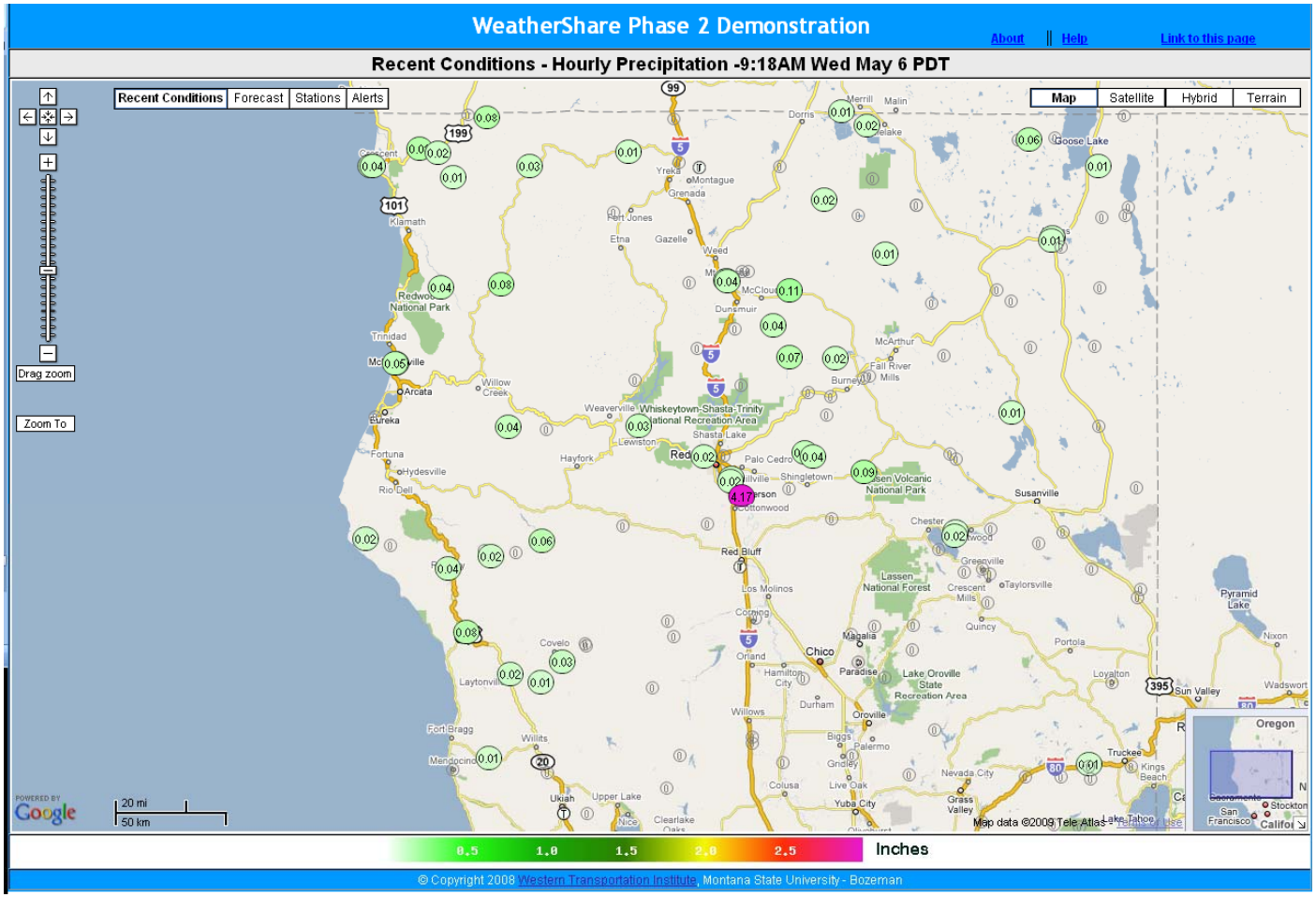


Picking Meaningful Icons

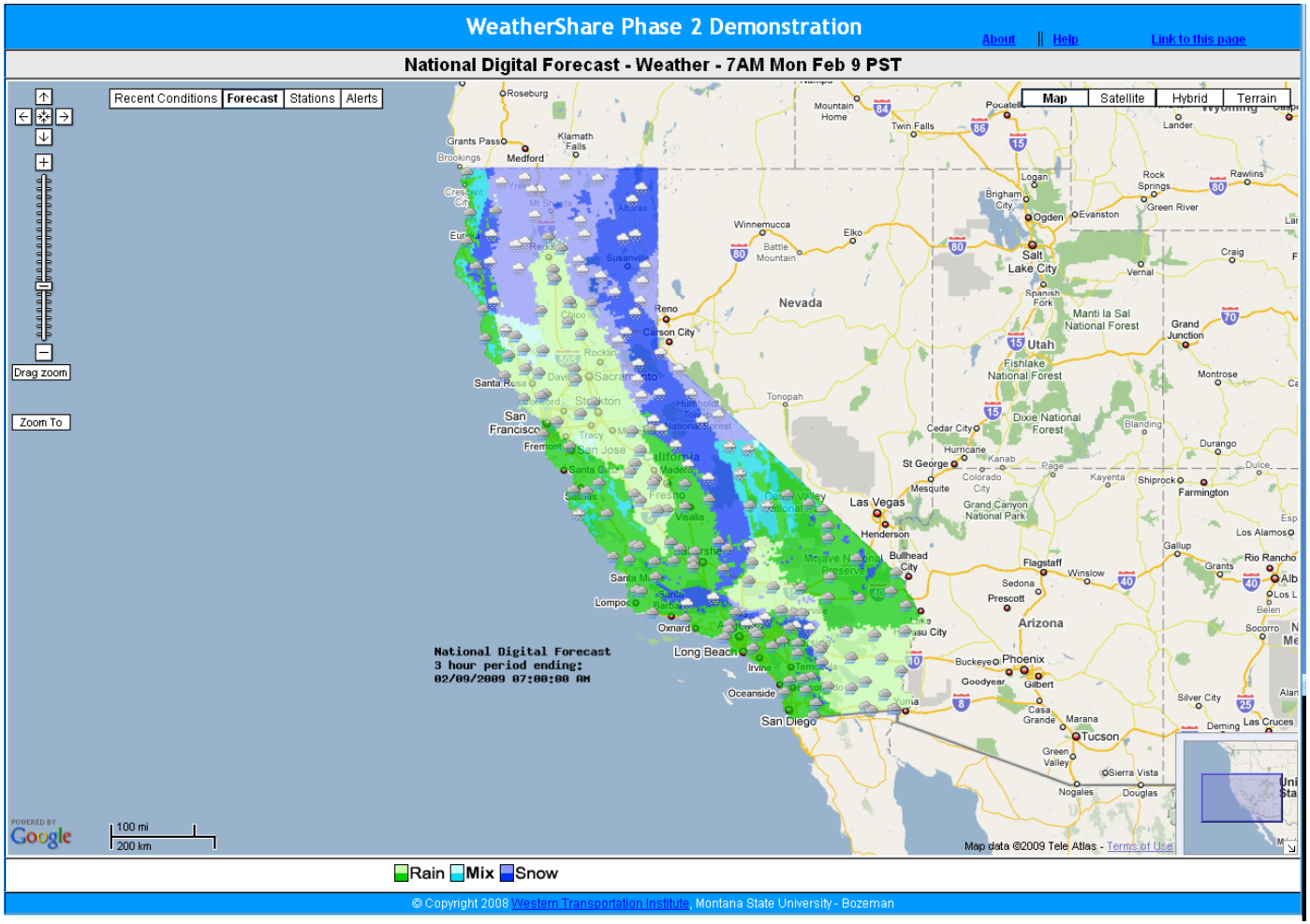
Picking Values to Display



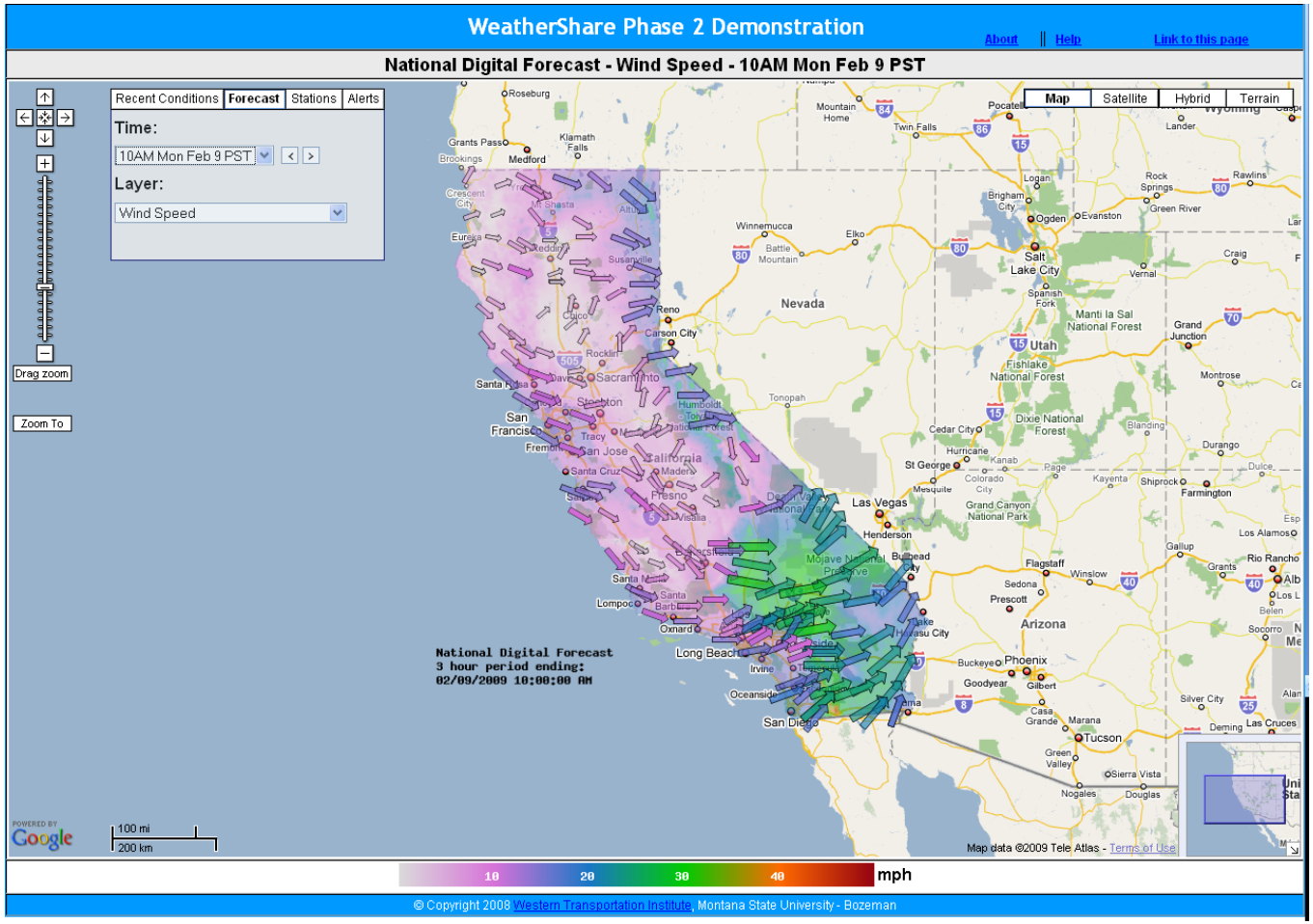
Display more Data at Higher Zoom Levels



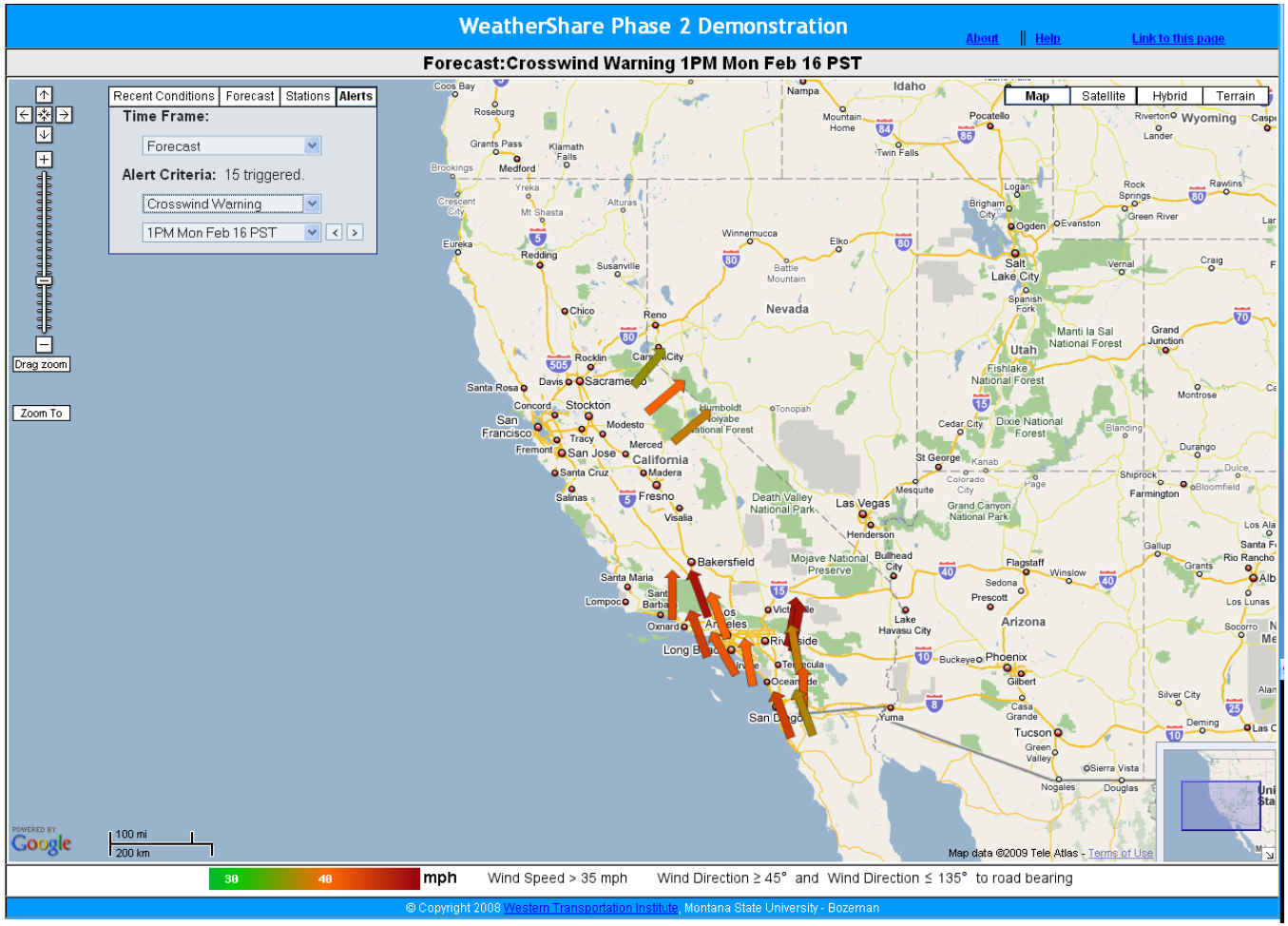
A Good Visual from February



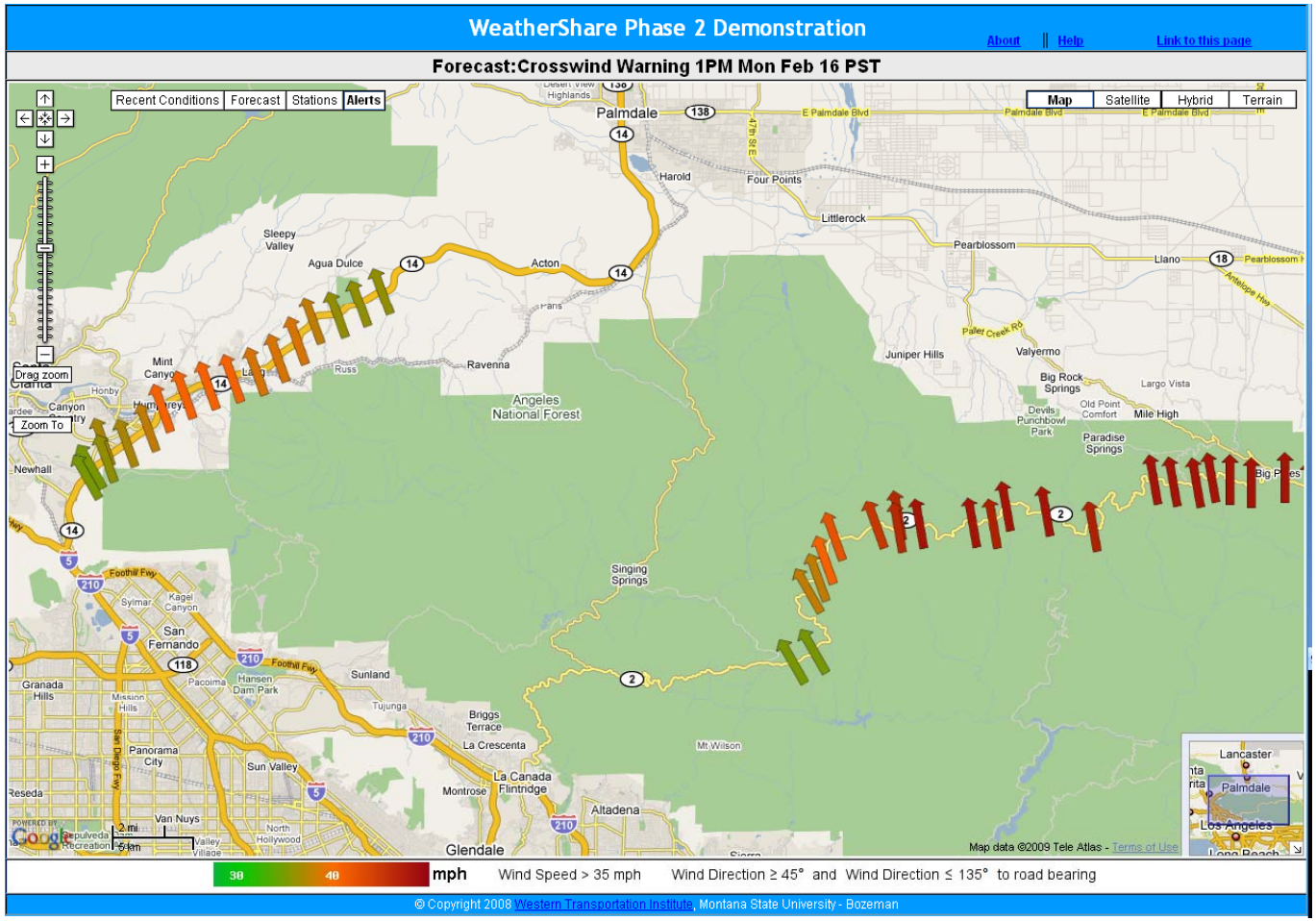
Example of Intensity and Direction of Forecast Winds



Alert Example : Areas with Crosswinds



Crosswind Detail

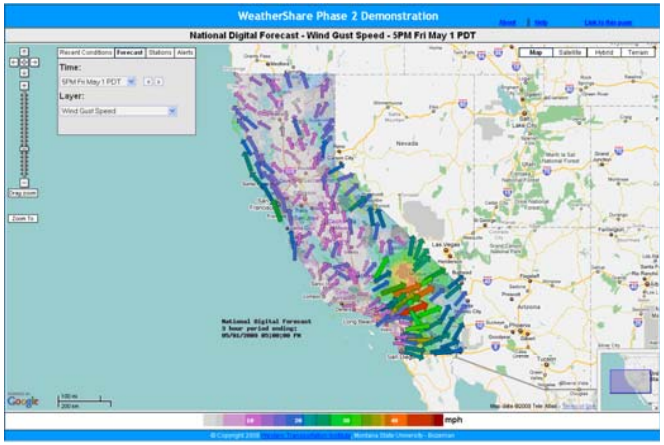


General Lessons Learned

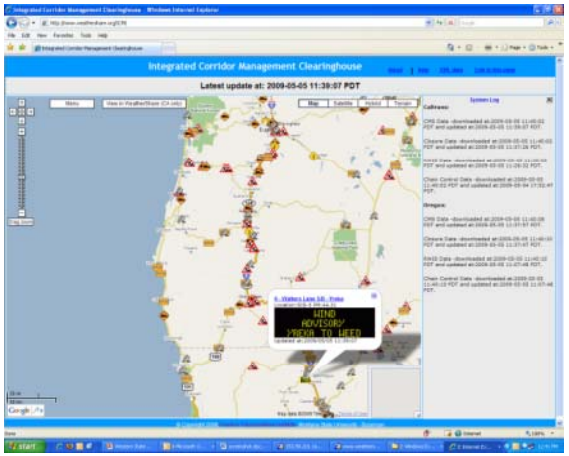
- Understand how users will work with system and give careful consideration to screen layout.
- Check and double check incoming data vs. displayed data.
- Google Maps platform has some limitations when trying to display many markers on map:
  - Watch for memory leaks.
  - Overall a good platform for displaying location based data that can be leveraged to other projects.
  - Generally shows up-to-date mapping data and imagery, although rural areas do lag behind in updates.

Building on WeatherShare

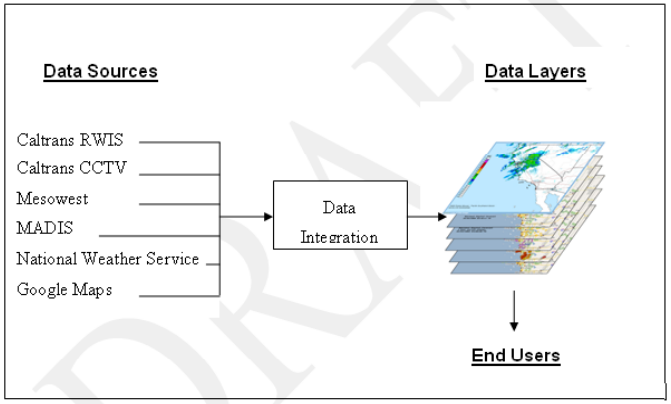
WeatherShare



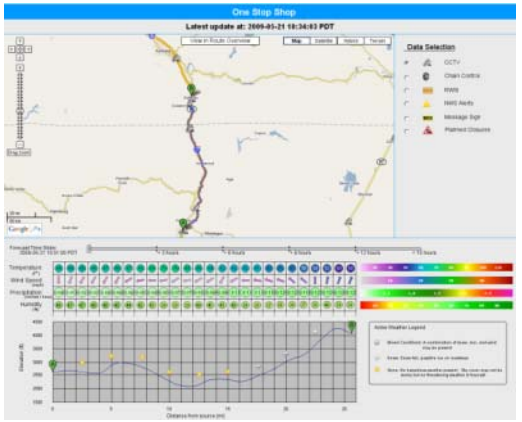
ICM



AWOS / ASOS



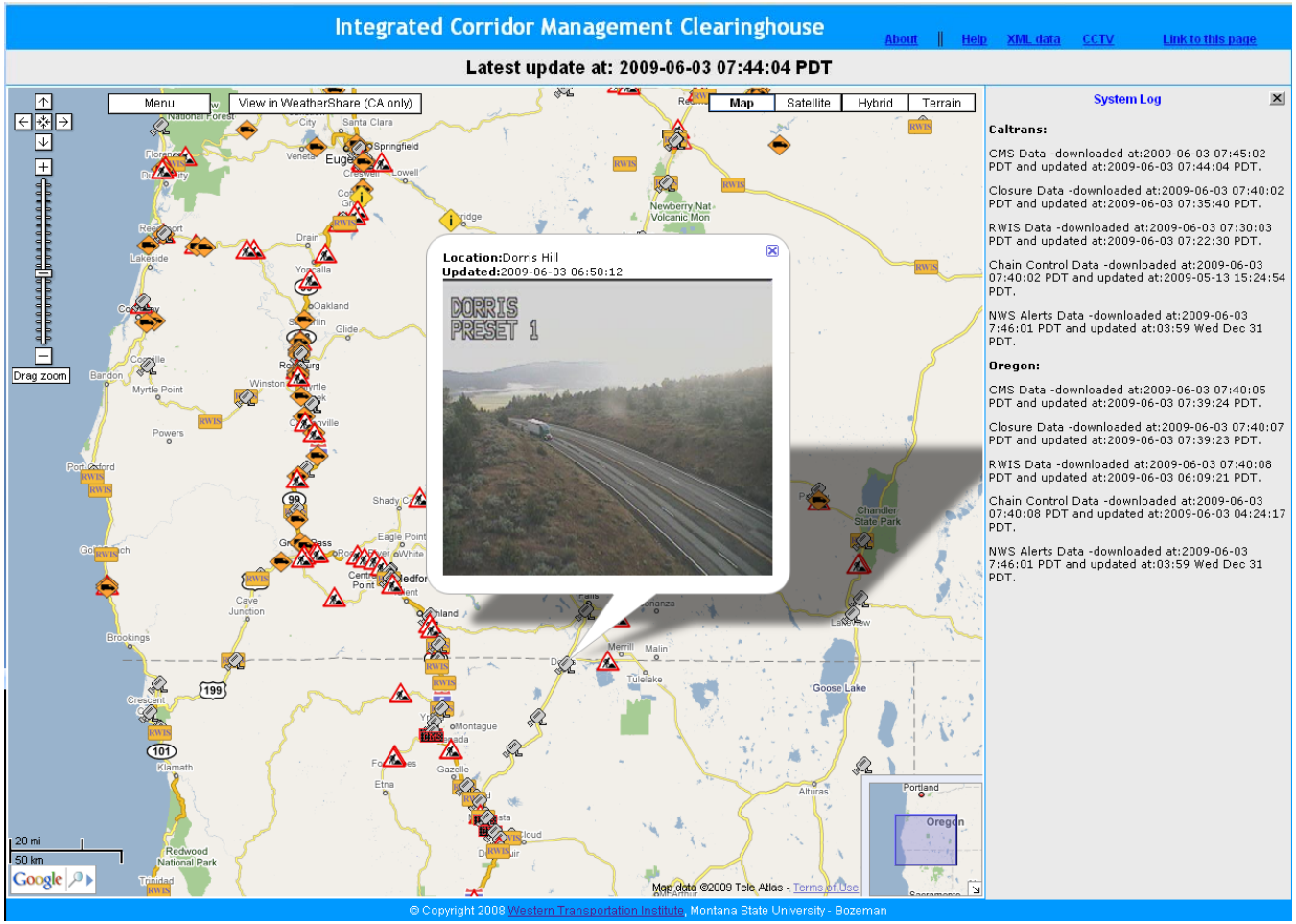
One Stop Shop



Integrated Corridor Management Clearinghouse

A California Oregon Advanced Transportation System (COATS) Project

http://www.weathershare.org/ICM/



MONTANA STATE UNIVERSITY | College of ENGINEERING | Western Transportation Institute

ICM Clearinghouse Objectives

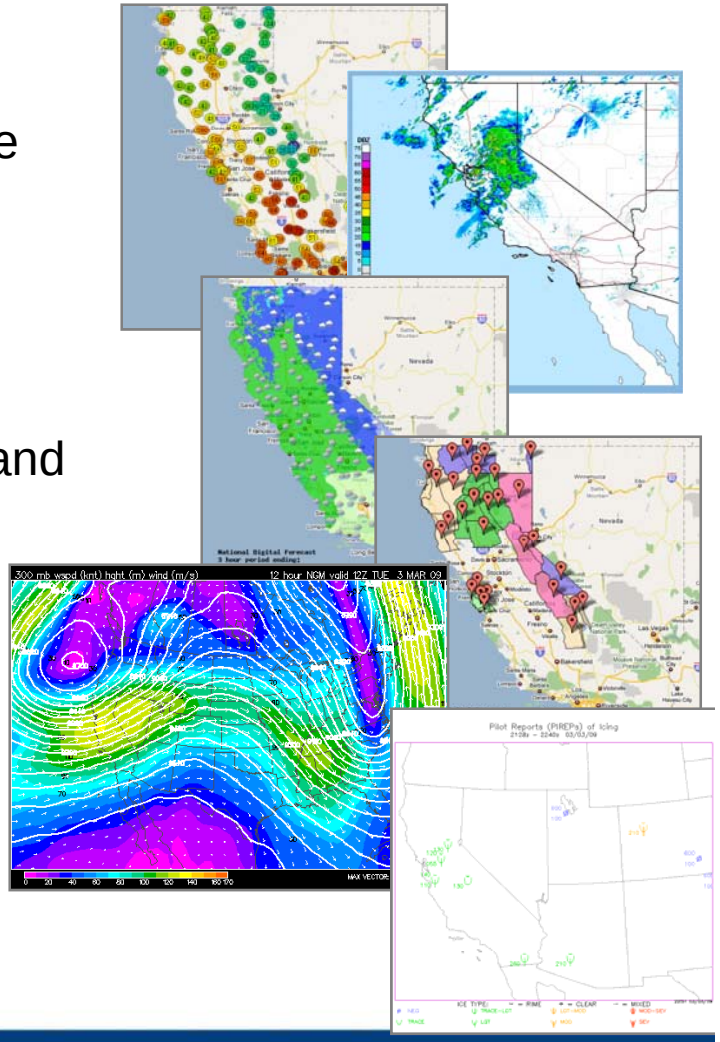
- Investigate the application of ICM to rural areas, as a proof of concept.
- Coordinate individual network operations between parallel facilities/routes to create an interconnected system allowing cross network travel management.
- To provide agencies with timely information related to the roadway network (including images, chain requirements, closures, etc.) for a broad geographic region
  - Implement plans for diverting traffic around impacting events.
  - Better use of existing roadway assets.

Study Area / Routes

- I-5 and US97/OR58
- Roughly parallel routes
- Host to ITS deployments
- Twelve mountain passes
- Potential for numerous scenarios
  - Weather conditions
  - Construction
  - Wildfires
  - Seasonal peaks
  - Accidents

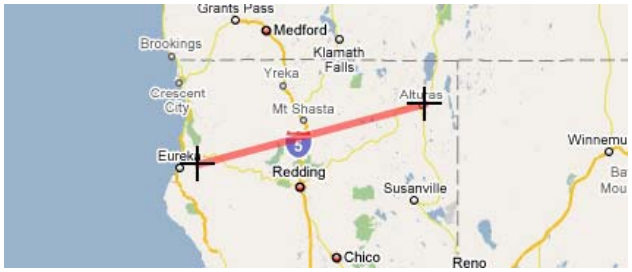
Integration of Aviation Automated Weather Observation Systems (AWOS) with Roadside Weather Information Systems (RWIS)

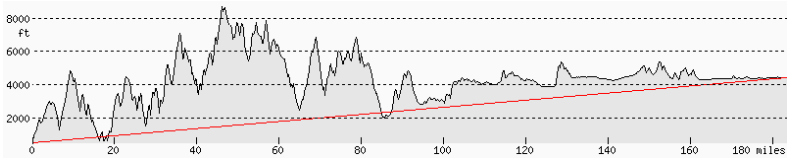
- Surface weather data layers from WeatherShare
- NWS Radar Mosaic
- National Digital Forecast Database layers from WeatherShare
- National Weather Service Watches, Warnings, and Advisories layer from WeatherShare
- NWS wind/temperature aloft
- Pilot reports (PIREP)
- METAR Reports
- Terminal Aerodrome Forecasts



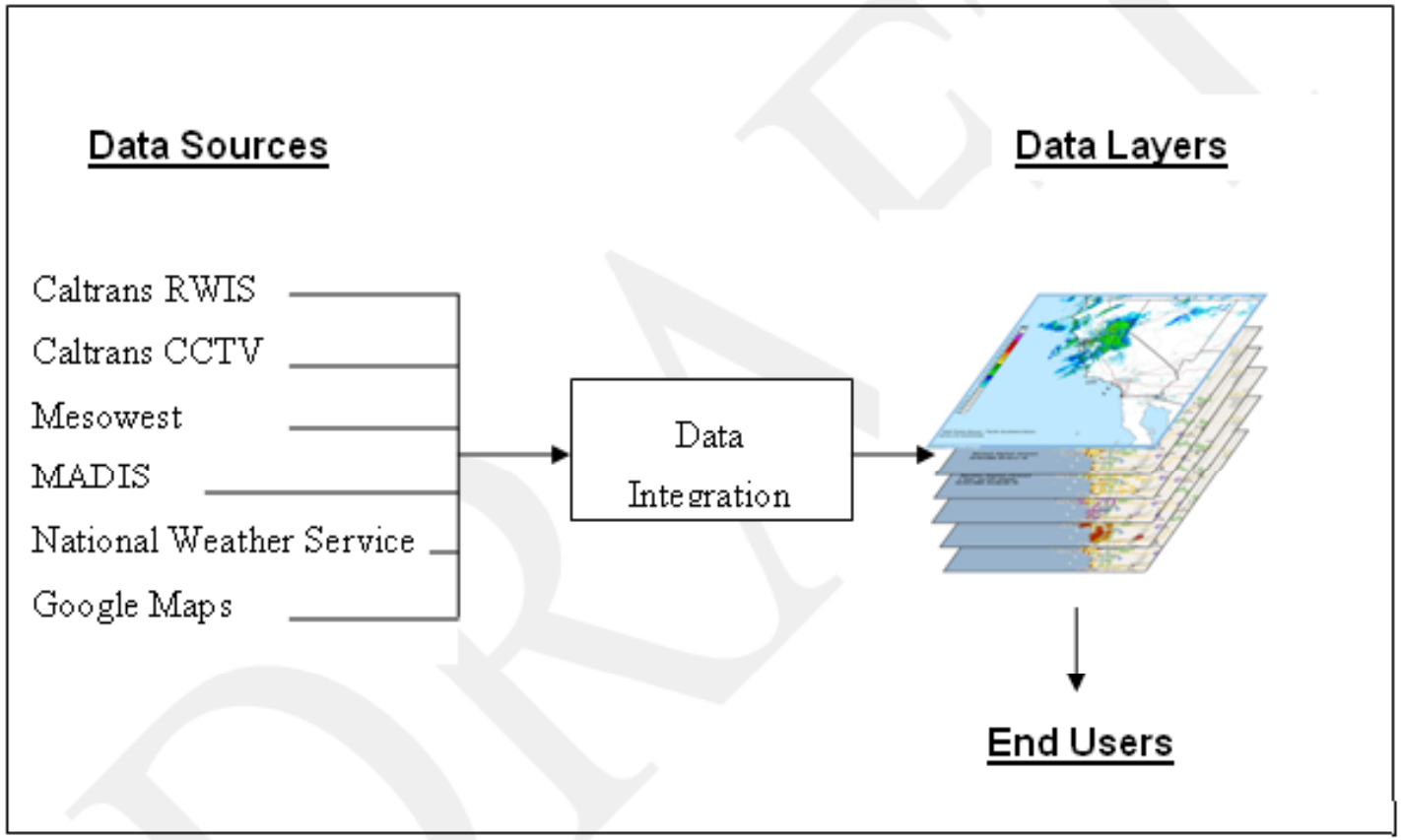
Integration of Aviation Automated Weather Observation Systems (AWOS) with Roadside Weather Information Systems (RWIS) cont.

- Flight Path Profiles
- Caltrans CCTV Images
- NWS Satellite Images
- (Other layers)



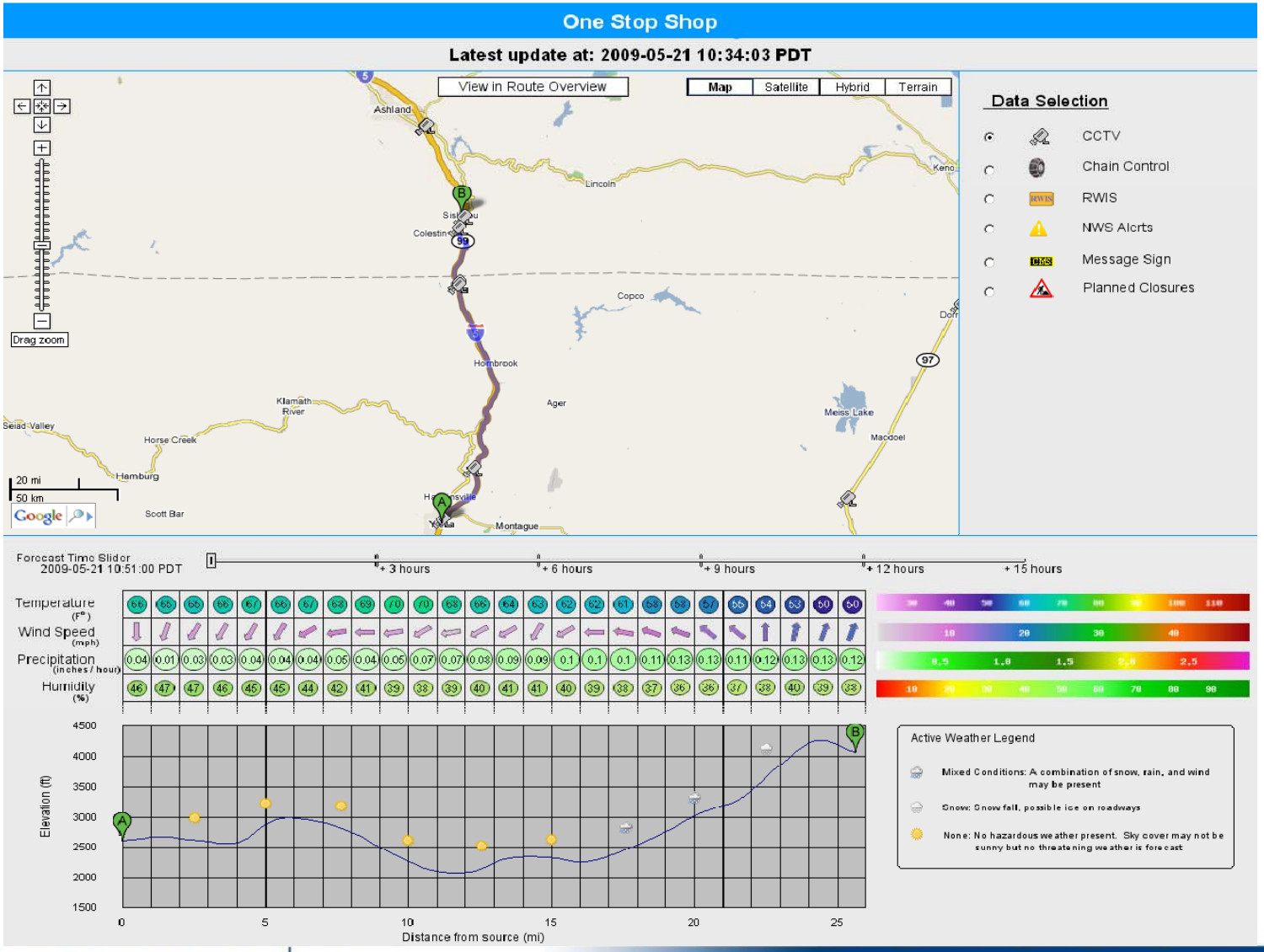


Integration of Aviation Automated Weather Observation Systems (AWOS) with Roadside Weather Information Systems (RWIS) cont.



One Stop Shop

A California Oregon Advanced Transportation System (COATS) Spin-Off Project



Acknowledgements

- California Oregon Advanced Transportation System (COATS)
- Redding Incident Management Enhancement Program (RIME)
- Caltrans District 2
- Caltrans Division of Research and Innovation
- WTI
- Other Stakeholders
  - Other Caltrans Districts
  - Norcal EMS
  - CDF
  - Shascom
  - Others