Application of Local Data Assimilation in Complex Terrain
FHWA/COMET Award No: S01-24244
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Ralph Patterson: Utah Department of Transportation

1. Summary of Original Scope of Work

This study expanded upon work originally funded by the Utah Department of Transportation ("Implementing Roadway Weather Information Support Management of Winter Maintenance", Utah DOT Contract No. 98-8298). That project helped to coordinate and identify weather resources in Utah pertinent to winter road maintenance. Results from that study were presented at a special session on RWIS at the AMS IIPS Conference (Horel et al. 2001). As a result of our prior work, we were able to begin this project having worked towards several of the objectives of the FHWA/NWS COMET program, including, for example, establishing cooperative working relations between state DOTs, the university community, and WFOs. We had also fostered an open repository of RWIS observations that integrates them with other weather observations around the West as part of the MesoWest project (Horel et al. 2002A,b).

The specific goals of this project were to:

- facilitate and improve access to RWIS observations in Arizona, Idaho, Nevada, Montana, Utah, and Wyoming,
- evaluate special weather statements for the 2002 Winter Olympics and Paralympics to be issued by the Salt Lake City WFO on hazardous winter weather along major transportation corridors in northern Utah,
- develop and evaluate RWIS applications of weather data in areas of complex terrain on the basis of local data assimilation,
- establish guidance on factors that affect the utility of ESS and weather observations for RWIS decision making in complex terrain.

2. Summary of Work Completed

a. Work Accomplished and Changes to Scope

Access to RWIS Observations

A major accomplishment of this project was to continue to facilitate and improve access to RWIS observations in the western United States. Figure 1 shows the locations of RWIS stations from which we obtain weather information routinely(additional road state information is available from many of these stations as well). We currently collect, archive, and disseminate RWIS information from stations in California, Colorado,

Idaho, Montana, Nevada, Oregon, Utah, Washington, and Wyoming. The scope of our data collection efforts expanded as opportunities to collaborate with state transportation department developed. This component of the study represented the largest fraction of effort. The following summarizes this ongoing data collection effort.

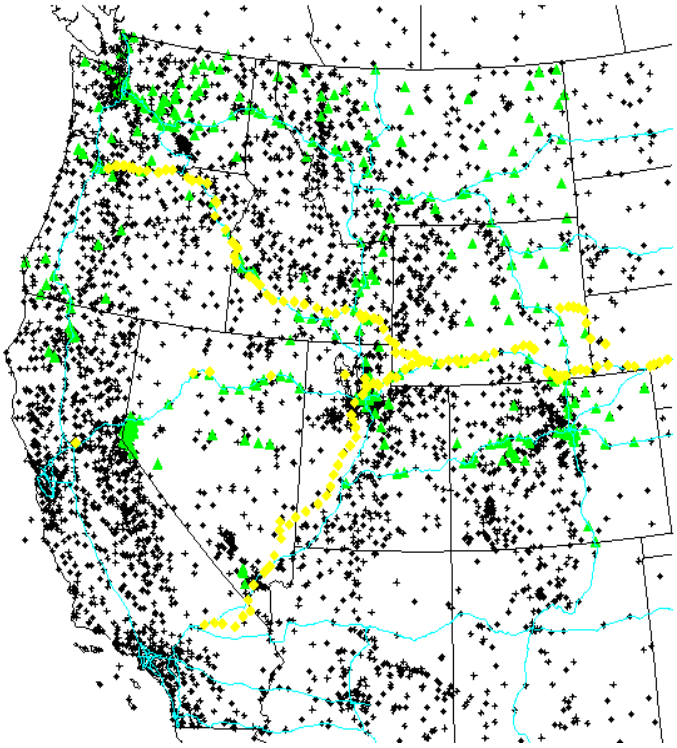


Figure 1. Locations of MesoWest stations (plus symbols), RWIS stations (green triangles), and Union Pacific Railroad stations (yellow diamonds).

California

Nancy Dean, MIC Eureka WFO, provided the initial contact with CalTrans representatives in northern California to facilitate access to 11 stations along Interstate 5 north of Redding. Updates every 30 minutes are available via ftp. Our contact is Steve Roger, CalTrans.

Colorado

FSL, as part of the MADIS project, in cooperation with the Boulder WFO provide access to Colorado DOT observations from 55 stations. The data are distributed to us via LDM. In addition, winter road maintenance observations in support of avalanche control work are collected in cooperation with the Grand Junction WFO. As part of this project, we supported the installation of software at the Grand Junction WFO to dial weather stations at several mountain passes and continue to assist them troubleshooting problems in data collection as they occur. Our contact is Patty Miller, FSL.

Idaho

As part of this project, considerable effort was undertaken to develop software to collect RWIS data (weather and road state) from the Idaho Transportation Department (ITD). This initially involved writing software and installing that software on a ITD computer. ITD has now installed a system to collect the data and we access the data via ftp. ITD depends upon MesoWest for access to real-time weather information for its Road Weather Integrated Data System. See http://164.165.237.41/RWIDS_Public/default.asp Our activities as part of this project in support of ITD were second only to that provided to the Utah Department of Transportation. Our contact is Bryon Breen, Idaho Transportation Department.

Montana

The Montana Department of Transportation and Great Falls WFO office have collaborated for a number of years to share weather and road state information. We obtain the weather and road state data from 59 stations via LDM. We have worked with Montana DOT personnel to identify data quality problems as they become evident. Our contact is Theresa Bousliman, Montana Department of Transportation.

Nevada

Data from 47 stations in Nevada are obtained via ftp from the Nevada Department of Transportation. This work has been facilitated by staff at the Desert Research Institute and the Reno WFO. Our contact is James Ellis, Nevada Transportation Department.

Oregon

Staff at the Pendleton, Oregon WFO helped to facilitate access to weather information at 28 stations supported by the Oregon Department of Transportation. We collect the weather information via access to the DOT web server. Our contact is Patrick Hoke, Oregon Department of Transportation.

Utah

We have worked closely with the Utah Department of Transportation to facilitate access to weather and road state information at 53 locations around the state. Information is collected directly via ftp from a RWIS server supported by UDOT as well as through a computer at the Salt Lake City WFO. Our contact is Ralph Patterson, Utah Department of Transportation.

Washington

Weather and road state information is collected from 72 stations maintained by the Washington Department of Transportation. These data are accessible as a result of the efforts of staff at the Seattle WFO and the university of Washington. We collect the data via ftp from the University of Washington. Our contact is Mark Albright, University of Washington.

Access to Union Pacific Railroad Observations

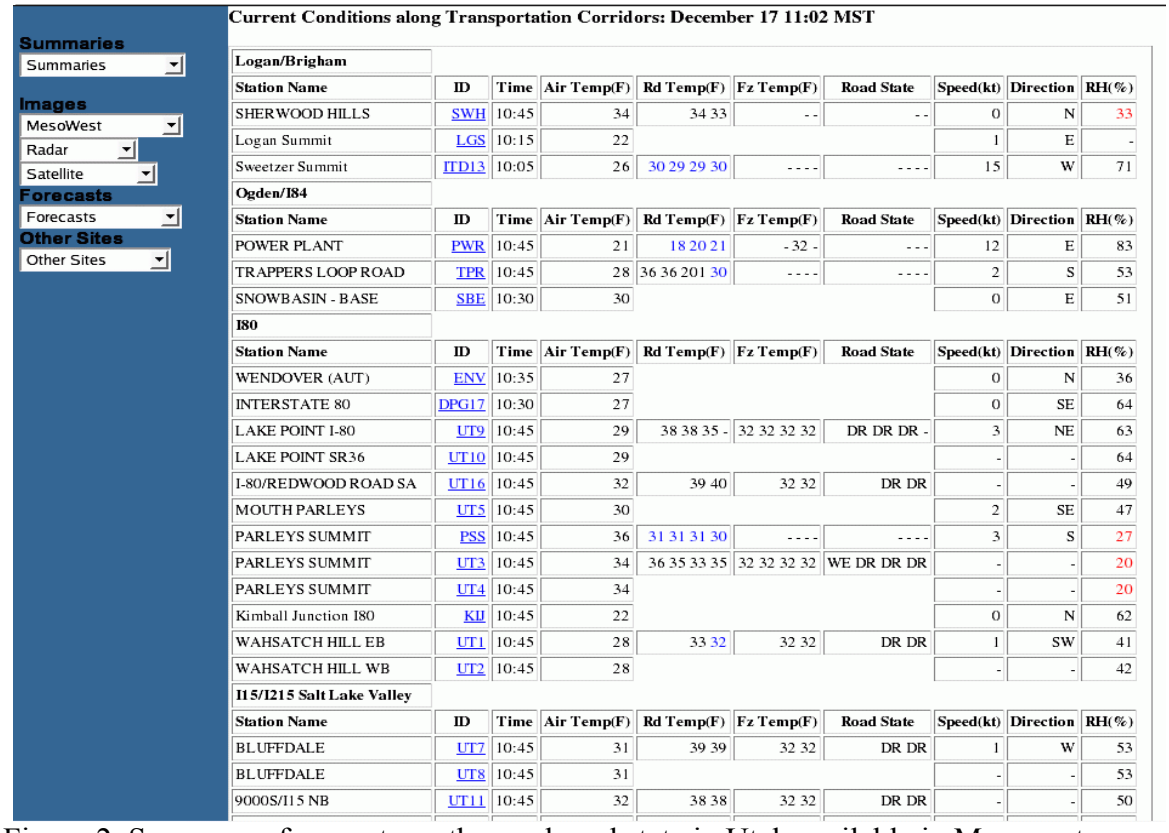
We were approached by personnel of Meteorologix, Inc. to facilitate access to weather observations collected by Union Pacific Railroad. As shown in Fig. 1, we have obtained access to weather information at 264 locations along the major Union Pacific rail corridors in the West. Most of the stations report temperature only (in order to detect track contraction/expansion), however, wind conditions are reported at many critical locations. Our contact is Mark Corbin, Meteorologix.

Olympic Weather Support

The NWS, UDOT, and University of Utah worked closely to provide weather and road state information as well as forecasts to Olympic organizers, public safety personnel, and the public for the 2002 Winter Olympics and Paralympics (Horel et al. 2002b). These efforts were judged to be highly successful by representatives of many different organizations related to the Olympics. Formal evaluation of the NWS weather forecasts issued along the transportation corridors was not pursued.

MesoWest RWIS Data Interface

A specialized web interface to the MesoWest database (www.met.utah.edu/mesowest) was developed and maintained for use by UDOT personnel. This interface has been used extensively for winter road maintenance as well as road construction and summer paving projects. An example of the summary of current conditions is provided in Fig. 2.



Summaries
Summaries

Images
MesoWest
Radar
Satellite

Forecasts
Forecasts

Other Sites
Other Sites

Current Conditions along Transportation Corridors: December 17 11:02 MST

Logan/Brigham									
Station Name	**ID**	**Time**	**Air Temp(F)**	**Rd Temp(F)**	**Fz Temp(F)**	**Road State**	**Speed(kt)**	**Direction**	**RH(%)**
SHERWOOD HILLS	SWH	10:45	34	34 33	- -	- -	0	N	33
Logan Summit	LGS	10:15	22				1	E	-
Sweetzer Summit	ITD13	10:05	26	30 29 29 30	- - - -	- - - -	15	W	71
Ogden/I84									
Station Name	**ID**	**Time**	**Air Temp(F)**	**Rd Temp(F)**	**Fz Temp(F)**	**Road State**	**Speed(kt)**	**Direction**	**RH(%)**
POWER PLANT	PWR	10:45	21	18 20 21	- 32 -	- - -	12	E	83
TRAPPERS LOOP ROAD	TPR	10:45	28	36 36 201 30	- - - -	- - - -	2	S	53
SNOWBASIN - BASE	SBE	10:30	30				0	E	51
I80									
Station Name	**ID**	**Time**	**Air Temp(F)**	**Rd Temp(F)**	**Fz Temp(F)**	**Road State**	**Speed(kt)**	**Direction**	**RH(%)**
WENDOVER (AUT)	ENV	10:35	27				0	N	36
INTERSTATE 80	DPG17	10:30	27				0	SE	64
LAKE POINT I-80	UT9	10:45	29	38 38 35 -	32 32 32 32	DR DR DR -	3	NE	63
LAKE POINT SR36	UT10	10:45	29				-	-	64
I-80/REDWOOD ROAD SA	UT16	10:45	32	39 40	32 32	DR DR	-	-	49
MOUTH PARLEYS	UT5	10:45	30				2	SE	47
PARLEYS SUMMIT	PSS	10:45	36	31 31 31 30	- - - -	- - - -	3	S	27
PARLEYS SUMMIT	UT3	10:45	34	36 35 33 35	32 32 32 32	WE DR DR DR	-	-	20
PARLEYS SUMMIT	UT4	10:45	34				-	-	20
Kimball Junction I80	KIJ	10:45	22				0	N	62
WAHSATCH HILL EB	UT1	10:45	28	33 32	32 32	DR DR	1	SW	41
WAHSATCH HILL WB	UT2	10:45	28				-	-	42
I15/I215 Salt Lake Valley									
Station Name	**ID**	**Time**	**Air Temp(F)**	**Rd Temp(F)**	**Fz Temp(F)**	**Road State**	**Speed(kt)**	**Direction**	**RH(%)**
BLUFFDALE	UT7	10:45	31	39 39	32 32	DR DR	1	W	53
BLUFFDALE	UT8	10:45	31				-	-	53
9000S/I15 NB	UT11	10:45	32	38 38	32 32	DR DR	-	-	50

Figure 2. Summary of current weather and road state in Utah available in Mesowest.

Local Data Assimilation

Graduate student, David Myrick, in collaboration with Dr. Steven Lazarus, Florida Institute of Technology, developed anisotropic weighting functions for the ADAS data assimilation system (Lazarus et al. 2003). These anisotropic weights are critical to resolving a systematic source of error in the analyses where weather observations in one valley affect the analysis in an adjacent valleys (Myrick 2003). This error has affected the suitability of the analyses along some transportation corridors. The results from Dave's thesis will be submitted for publication to *Weather Analysis and Forecasting* next month.

Our data assimilation efforts over complex terrain are receiving increased attention by the NWS to initialize and validate IFPS gridded forecasts at WFOs around the West. The support from COMET contributed to the further development of ADAS for these applications.

RWIS Decision Making

In part as a result of the increased data collection efforts, less effort was placed upon evaluating the utility of RWIS observations in the decision making process. Questionnaires were distributed to winter maintenance personnel during the 2001 winter season to collect information on the utility of local RWIS data. Preliminary analysis during the following spring of the data collected from shed foremen in Idaho, Montana, and Utah was inconclusive ; hence, this effort was suspended for the 2002 winter season.

b. Problems Encountered

Access to RWIS data in some states has been difficult to obtain. We were not able to develop contacts at the CalTrans district level in many parts of California. We also have been waiting for several years to access RWIS data from Arizona. We have not been able to identify an appropriate contact in New Mexico either.

3. University, Forecast Office, and DOT Participation

A number of personnel changes took place during the lifetime of this project. Co-PI Steven Lazarus accepted a faculty position at Florida Institute of Technology. Steven continued to participate in this effort through his collaborative research with Dave Myrick on data assimilation in complex terrain. Co-PI Rand Decker accepted a faculty position at Northern Arizona State University; his departure affected the proposed work on RWIS decision making. Steve Conger, our lead contact at the Utah Department of Transportation at the beginning of the project, left the agency and was later replaced by Ralph Patterson.

The greatest level of interaction between the Salt Lake City WFO, UDOT, and University of Utah took place during the first year of the project as a result of the need for preparation and coordination of research, development, and operations for the 2002 Winter Olympics and Paralympics. This interaction was very positive and beneficial to all three organizations. A major goal of the Olympic weather support effort was to

provide a legacy of improved understanding of winter storms and enhanced capabilities to predict weather in the region. This legacy is in place in part because of projects such as this one. For example, the Traffic Operations Center, UDOT, now employs several former undergraduates of the Department of Meteorology to provide weather information and forecast guidance to DOT staff.

3. Recommendations

The FHWA/NWS COMET program provided a framework for us to approach state DOTs to share weather and road state information. However, support to sustain this effort is not clear. We are exploring initially with our closest DOT partners (UDOT and ITD) ways to sustain this effort through their participation in our Cooperative Institute for Regional Prediction (CIRP) Consortium. CIRP has developed innovative tools to conduct research and assist government and commercial operations that are sensitive to weather around the nation in part with funding from research and development efforts supported by the NWS, FHWA, and other agencies. These tools include MesoWest, which provides real-time monitoring and analysis of environmental conditions, and our data assimilation and modeling efforts. The CIRP Consortium has been established to further develop and apply these tools for the unique environmental problems of the Intermountain West and other regions of the nation. The Consortium is intended to provide the support for the continued real-time operations of MesoWest and provide the foundation for further applied research and development related to real-time weather and emergency management operations, air quality, fire weather, winter road maintenance, wind power, and water resource management. The CIRP consortium is modeled after the Northwest Regional Modeling Consortium developed at the University of Washington.

The initial feedback from UDOT and ITD to the Consortium funding approach is favorable, since they are relying on our products heavily. However, is it reasonable to expect those states to fund our efforts to access weather and road state information in other regions of the West? There is a clear need for the FHWA and NWS to support data collection efforts on a national scale, that relies in part on the existing local partnerships that already exist in some regions of the country.

Further research is also required to improve the utility of local analysis and forecast grids for road weather applications. The National Digital Forecast Database (NDFD) under development by the NWS potentially provides a tool to improve road weather decision making. However, there are a number of technical issues that remain to be resolved as to how best to use that information.

4. Publications and Conference Presentations

Horel, J. D., M. Splitt, S. Conger, 2001: RWIS Applications of MesoWest in the Western United States. *17th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology.*

Horel, J., and M. Splitt, RWIS Applications of MesoWest. ITS America Annual Meeting. Miami, FL.

Horel, J., T. Potter, L. Dunn, W. J. Steenburgh, M. Eubank, M. Splitt, and D. J. Onton, 2002: Weather support for the 2002 Winter Olympic and Paralympic Games. *Bull. Amer. Meteor. Soc.,* **83**, 227-240.

Horel, J., M. Splitt, L. Dunn, J. Pechmann, B. White, C. Ciliberti, S. Lazarus, J. Slemmer, D. Zaff, J. Burks, 2002: MesoWest: Cooperative Mesonets in the Western United States. *Bull. Amer. Meteor. Soc*., **83**, 211-226.

Lazarus, S., C. Ciliberti, J. Horel, K. Brewster, 2002: Near-real-time Applications of a Mesoscale Analysis System to Complex Terrain. *Wea. Forecasting*. 17, 971-1000.

Myrick, D., *An Improvement to Data Assimilation over Complex Terrain*. M.S. Thesis. University of Utah. 56 pp.

Splitt, M., and J. Horel, 2002: Application of Environmental Sensor Stations in the western United States. *18th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology.*