The *Clarus* Regional Demonstration

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ABSTRACT

Imagine having a single Web portal where all public surface transportation weather observations are collected, quality checked and made available to the transportation community, the weather enterprise and even individual users. After several years of investing in system design, implementation and testing, the U.S. Department of Transportation's (USDOT) *Clarus* System is operating in an experimental mode and is being populated with Environmental Sensor Station (ESS) observations from State, municipal and provincial transportation agencies from across North America.

Clarus, which means "Clear" in Latin, is the USDOT's prototype surface transportation weather data management system. The *Clarus* System uses state of the art algorithms to quality check atmospheric and pavement observations from both fixed and mobile platforms. Data contributors can receive information on the health of their environmental sensor station (ESS) networks as well as the calibration of individual sensors. Data users can receive a full suite of observations, quality checking flags and metadata information either via use of a web-based portal or through a data subscription service.

As part of the developmental process of the *Clarus* System, the USDOT began a multi-phased regional demonstration in 2007. The first phase included having teams of State and Provincial Departments of Transportation provide conceptual use cases for new products and services which would use *Clarus* data to support and enhance transportation agency operations. The second phase involved recruiting public transportation agencies to join the *Clarus* community by providing their observations and metadata.

The third phase began during the summer of 2008. Using concepts which originated within the first regional demonstration phase, five different use cases were presented and demonstrations were awarded to weather enterprise contractors. The use cases were divided into two main categories: one to improve the state of the practice of weather forecasting for surface transportation; the other to foster the development of new or improved products, algorithms, decision support tools or other innovations that are enabled through the use of *Clarus* data and support transportation operations.

This paper provides an update on the progress of the demonstration use cases as well as those innovations that are being implemented as a result of demonstrations.

BACKGROUND

Each year on average, 7,400 people are killed in fatal crashes during adverse weather conditions in the United States. In 2003, the USDOT/Federal Highway Administration (FHWA) approached the National Academies of Science (NAS) and described the problems and challenges associated with forecasting road weather conditions. In 2004, they responded with their landmark report, Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services (1). In this report, the NAS acknowledged the troubling statistics associated with adverse weather-related vehicle fatalities and delays, and recommended that the nation invest in a robust, integrated road weather observational network and database management system. This visionary idea was the impetus for the Clarus Initiative. Clarus is intended to facilitate and improve the value of road weather information that is provided by both the public and private weather enterprise to the breadth of transportation users and operators. Figure 1 shows the current status of *Clarus* development and participation by US State and Canadian Province transportation departments.

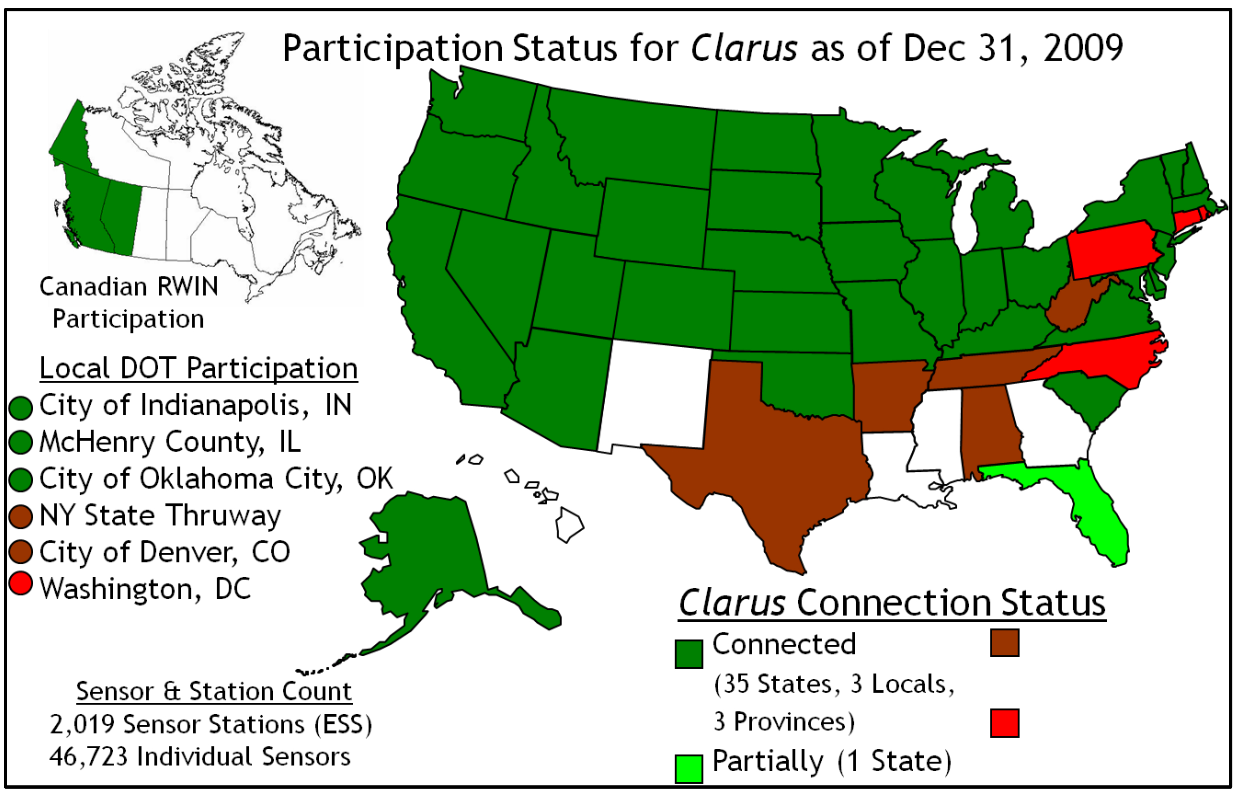

Figure 1. *Clarus* System Status

The goal of the initiative is to create a robust data assimilation, quality checking, and data dissemination system that can provide near real-time atmospheric and pavement observations from the collective public Departments of Transportation's investments in Road Weather Information Systems (RWIS), Environmental Sensor Stations (ESS).

This paper is a continuation of a series of publications which are intended to document the progress of USDOT initiatives as well as update both the weather and transportation communities on a project of mutual interest. A discussion of plans and a layout for the Clarus Initiative was first published in Pisano, 2005 (2). This paper provides the vision and estimated timeline for the development, testing and deployment of the Clarus System. Pisano, et al (3), discussed the Concept of Operations document for the Initiative and the proof of concept demonstration that followed the implementation of the prototype. Stern, et al (4), provided a technical discussion about creating a new generation of quality checking algorithms for both atmospheric and pavement data for the expanded forecasting capability envisioned in *Clarus* and the demonstrations in Use Case 1. Pisano, et al (5) and (6), provided a roadmap toward having the weather enterprise innovate using Clarus System data to benefit public transportation agency operations through regional demonstrations. Finally, Osborne and Boyce, (7) and (8) provided the development of the use case tools and progress so far on the internet interface with users of the tools. As the tools and uses progress more, information will be gathered on lessons learned and evaluations.

Clarus **Demonstrations**

The third phase is specifically focused on the development and deployment of Clarus-enabled services. Within the regional concepts of operations, a set of use case scenarios were defined, identifying the prospective services and applications that could use Clarus to improve agency operational efficiency, streamline decisions and procedures, and target hazardous conditions during adverse weather to improve safety. Use cases have been developed for a range of public sector needs such as maintenance and construction operations, traffic operations, and traveler information.

To advance the development of new Clarus applications and services, the U.S. Department of Transportation (USDOT) released a Request for Proposals (RFP) for regional demonstrations of the use cases in spring 2008 to engage the private sector and academia. The regional demonstration awards are for a period of two years, which includes one year of research and development, and one year of implementation and evaluation with partnering public transportation agencies and teams of independent evaluators. In total, two awards were presented in October 2008. The contracts were awarded to:

- Meridian Environmental Technology, Inc. of Grand Forks, North Dakota with University of North Dakota (UND) Surface Transportation Weather Research Center (STWRC); Iteris, Inc.; and the State departments of transportation of Idaho, Minnesota, Montana, North Dakota and South Dakota
- Mixon/Hill, Inc., of Overland Park, Kansas with the National Center for Atmospheric Research (NCAR), Nortel Government Solutions, KMJ Consulting, Athey Creek Consultants, and the State departments of transportation of Illinois, Indiana and Iowa

Both prime contractors have been involved in the design and development of the Clarus System. Meridian created the initiative concept of operations document. Mixon/Hill engineered, implemented and maintains the prototype system. Figure 2, below, depicts the developers and their State department of transportation partners. The public agencies will work with and provide feedback on the new innovations. In addition to development and implementation activities, The Mixon/Hill team and the Meridian Team will document their experiences in accessing and using the Clarus system and Clarus data, providing further insight into potentially new system uses or whether further modifications are necessary. The conduct of the scenarios and their evaluation will continue throughout 2010 and into 2011.

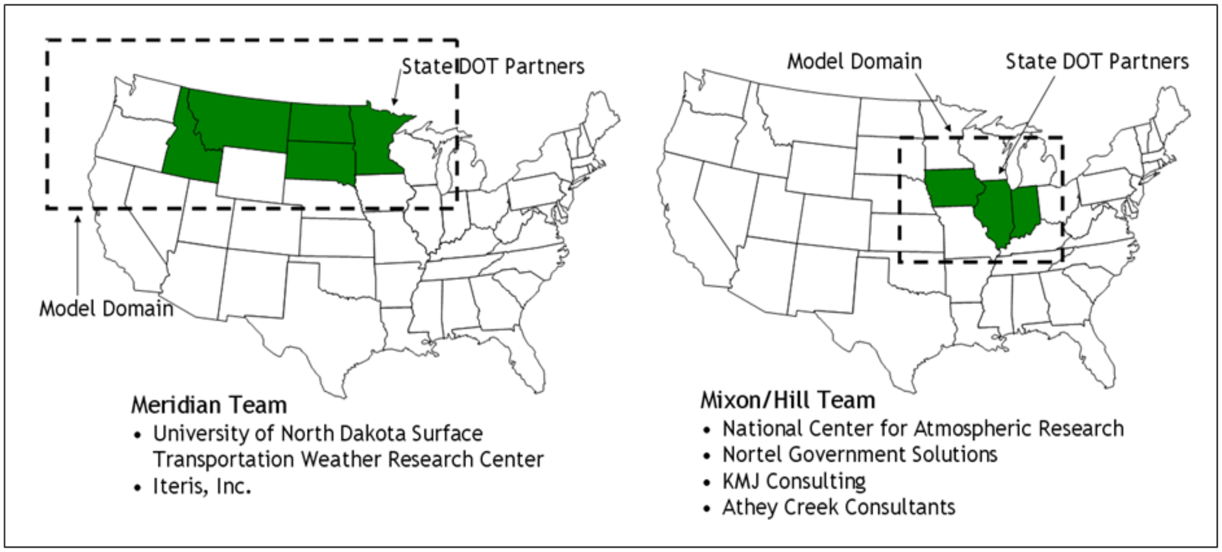

Figure 2. Clarus System Developers and their State Department of Transportation Partners

Use Case Scenarios

USDOT selected five concepts from Phase 1 as use case scenarios for possible implementation. Use Case Scenario #1 is mandatory for both teams as it substantiates the value of Clarus data to improve the state of the practice for surface transportation meteorology. Independent evaluations of the use case scenarios will identify measurable evidence that can show whether or not weather forecasting improved as a result of this service.

Use Case Scenario #1 – Enhanced Road Weather Forecasting Enabled by Clarus: Throughout the duration of the Clarus Initiative, the FHWA Road Weather Management Program has been demonstrating that the investments made in deploying ESS go beyond just site-specific winter maintenance operations. Clarus seeks to remove restrictive network borders, making quality checked, near real-time ESS observation data available to all transportation agencies and promote the use of data as input to enhanced road weather forecasting service providers and the greater weather enterprise.

In this scenario, the Meridian Team and Mixon Hill Team will utilize Clarus-based ESS data to enhance (atmospheric and pavement) forecasting for surface transportation and clearly trace the usage and benefits of Clarus data within this service. Enhanced surface transportation forecasting can come from many different types of services. Some examples include (but are not limited to):

- Adding Clarus data into numerical weather prediction model assimilation fields that produce more realistic initialization conditions at the atmosphere/land interface and result in some measurable improvement to short-term "nowcast" or forecast output.
- Modifying numerical weather prediction models to use Clarus data to create measurable improvement to surface transportation-related weather or pavement predictions.
- Modifying planetary boundary layer models to use Clarus data to better predict atmospheric elements that directly affect the transportation system (e.g., precipitation type predictions, rain/snow change line location predictions, wind character/gustiness predictions).
- Creating new algorithms, techniques and/or products that use Clarus data and whose output demonstrates a measurable improvement to surface transportation (atmospheric or pavement) forecasting.

This first scenario will provide a foundation for working on any of the remaining scenarios, as well as improving road weather forecasting capabilities within the weather enterprise.

Use Case Scenario #2 – Seasonal Weight Restriction Decision Support Tool: Based upon the Alaska/Canada Team concept of operation, this scenario was assigned to the Meridian Team.

The seasonal weight restriction use case describes a decision support tool that analyzes the sub-pavement conditions given near real-time Clarus ESS observations, historical weather and historical pavement conditions (and other elements as necessary) to provide estimates of road segment locations and time periods where vehicle weight restrictions are necessary. Observations from the Clarus System (e.g., air temperature, pavement temperature, subsurface temperature, etc.) will be used as input, along with other available observations, into a data analysis, meteorological and pavement modeling decision support tool to support transportation agency control strategies during critical freeze/thaw periods.

Clarus ESS observations, historical seasonal information on freeze/thaw cycles, soil and roadbed profiles, and forecasted weather conditions will be integrated into this tool. The resulting output will be recommendations to transportation agency personnel (and by extension commercial vehicle operators) on where and when seasonal weight restrictions may be imposed. As a road weather control strategy, this Seasonal Weight Restriction Tool will be based on agency rules of practice and user needs. The figure below shows an example of a internet based tool screen image depicting counties where various degrees of weight restrictions are depicted and available for trucking companies.

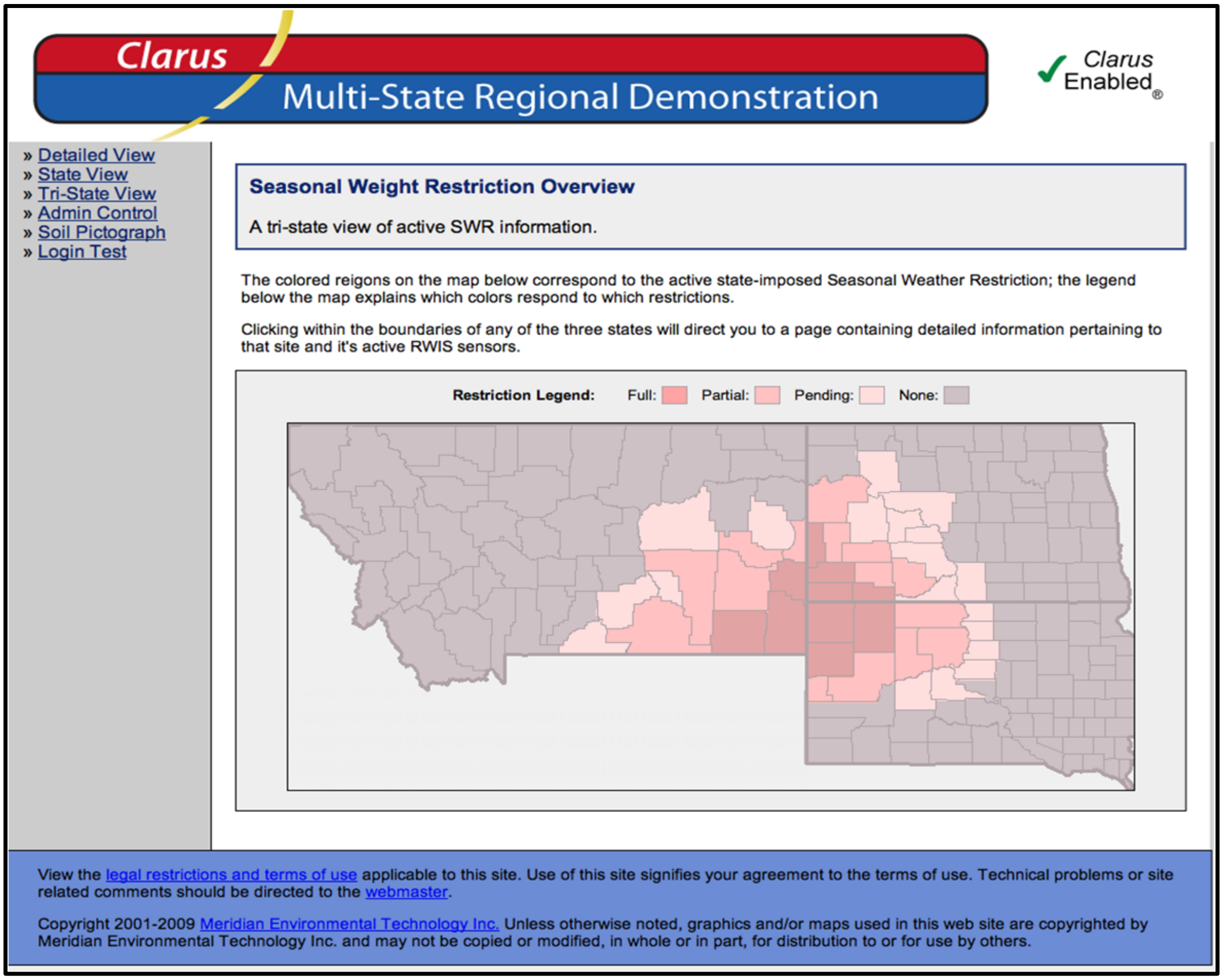

Figure 3. Seasonal Weight Restriction Overview Screen Image

Use Case Scenario #3 – Non-Winter Maintenance and Operations Decision Support Tool: Based primarily on the concepts of operation from the Alaska/Canada Team and the Aurora Team, this scenario was assigned to the Mixon Hill Team.

Many of the efforts that have been put forth on the development of decision support tools have focused on supporting winter maintenance and operations best practices. However, this scenario is intended to take a broader look at expanding decision support activities, beyond snow and ice control. Specifically, this scenario focuses on how Clarus data can be used to assist in decision making for road maintenance scheduling decisions, especially those activities that affect traffic flow and mobility (e.g., lane closures for striping or pothole filling), and construction-related scheduling decisions such as for pavement applications, curing, and inspections.

It is envisioned that this tool would leverage the work that has already been performed in the creation of the winter Maintenance Decision Support System (MDSS). Documentation and source code for the MDSS federal prototype can be found at the National Center for Atmospheric Research (NCAR) website at http://www.rap.ucar.edu/projects/rdwx_mdss The federal prototype is a system consisting of communication modules for the ingest of observations and model data, data fusion components to create optimized weather and pavement temperature forecasts, and a rules of practice module that contains customization algorithms that work on specific tasks (such as snowfall accumulation or road temperature forecasts).

The key to this scenario is being able to participate with transportation agency members to assess their needs, and document their rules of practice so that operationally based recommendations can be generated by the tool and presented to the agency. These recommendations will provide assistance in task planning and scheduling for year-round maintenance and construction operations. This decision support system will use Clarus data along with other weather, route and local information as input into weather and pavement condition forecasts. These forecasts will then be fed into customized algorithms that provide scheduling recommendations for operational transportation agency personnel. The analyzed weather data is based on the weather-related practices established for the activity. (i.e., airTemp > 70) The planner will display available times to perform the activity. notify users when observations are outside the weather-related practice range, and give decision makers three options: reschedule activity, cancel activity, or keep original schedule.

The figure below depicts the example of a screen from the activity planning capability of this tool. The activity planner will show observed and forecasted environmental parameters important for a particular operation and when the parameter values are within operational limits.

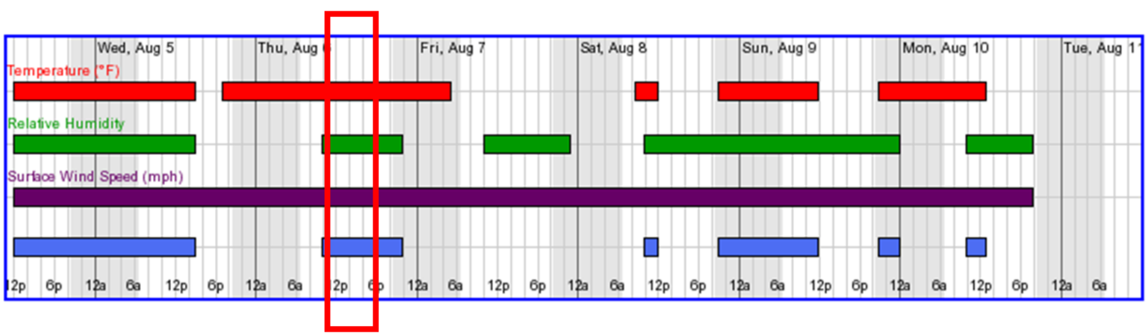

Figure 4. Activity Planner

Use Case Scenario #4 – Multi-State Control Strategy Tool: Based on the concepts of operation of the Northwest Passage Team and the Aurora Team, this scenario was assigned to the Mixon Hill Team.

Closing a road along a transportation corridor at or just beyond the border in the next state or province can result in significant impacts on transportation agencies along with potential hardships on travelers. One effect might be congestion, as long lines of vehicles wait for roads to re-open at a state border. In extreme cases, travelers may need lodging or in extreme cases even require the National Guard to be mobilized to deliver blankets or food to stranded travelers. Having information in advance or at the time controls are imposed provides an effective means of informing the public of travel delays, detours or closures, as well as improve agency coordination across jurisdictional borders.

The use of control strategies (e.g., lane/road/bridge closures, contraflow operations, detours, etc.) is a well-documented process for transportation agencies when road conditions deteriorate during adverse weather. However, there is the need for improved coordination within states as well as with adjacent states with respect to the imposition of controls and dissemination of associated advisories. These actions can result in significant travel impacts as traffic stalls in areas that are not well prepared to handle the influx of stranded motorists. The development of a timely process to communicate changes in road status would permit officials in adjacent areas the opportunity to take proactive steps to mitigate the impact on travelers. Such actions include rerouting travelers prior to a blockage in areas that have better infrastructure to handle lodging, fueling and dining.

Once a control action has been performed, it is necessary to transmit this information to a common repository or data warehouse where the information from all jurisdictions can be stored and made available for posting to appropriate channels of information dissemination. Interested parties could include transportation agencies, law enforcement agencies, fleet managers, information service providers, travelers, and traveler-related interests. This use case scenario will create of a data management system that combines (but is not limited to) Clarus ESS observations and road condition data for input into a decision support tool to support agency control strategies within and across multiple states or provinces. The figure below shows a screen image of an internet based tool used to conference State DOTs of hazards across state boundaries.

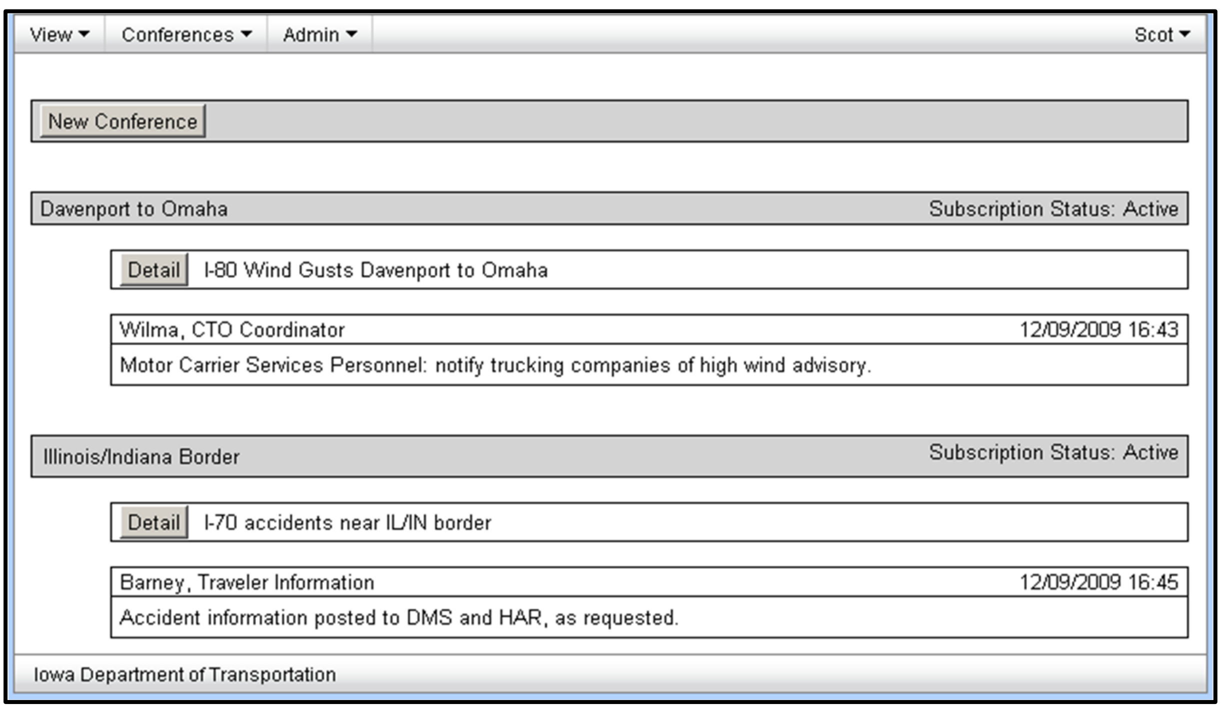

Figure 5. Iowa DOT coordination screen image

Some scenarios where such a tool would benefit transportation agencies include:
- During winter storms, Clarus ESS data would provide information about freezing pavement temperatures while road condition data would provide information about pavement conditions and mobility. Resulting recommendations might be to recommend tire controls (e.g., snow tires, chains).
- During rain events, Clarus ESS data would provide information about rainfall intensity or flooding while road condition data would provide information about resulting closures of roads or bridges.
- During high winds, Clarus ESS data would provide information about strong crosswinds along interstates or bridges. Road condition data would provide information about wind buffeting on high profile vehicles that could lead to travel restrictions on bridges.

Use Case Scenario #5 – Enhanced Road Weather Content for Traveller Advisories: In this scenario, assigned to the Meridian Team, the goal is to improve content related to enhanced road weather advisories for traveller information systems such as dynamic message signs (DMS), highway advisory radio (HAR) broadcasts, 511 telephone services, related websites or "push" technologies (e.g., text messages, personal digital assistants [PDAs], really simply syndication [RSS] alerts, e-mail messages, etc.). This scenario does not propose to change the framework of existing traveller information systems. Instead, it is intended to enhance the pooling of informational resources already in use and improve its accessibility and content by each State's service provider for improved data, advisory and forecast delivery over the width of a corridor. This includes interstate, route-specific weather forecast information, road condition data, and the ability to provide actual atmospheric and pavement conditions and advisories enabled through use of the Clarus System.

Some traveller information systems have limited capabilities to access information across borders and are limited to the exchange of information with adjacent states. Enhancing available weather and pavement condition information and providing mechanisms to permit the data warehousing of traveller information – including current/forecast road conditions, weather conditions, and advisories – would provide a framework enhancing traveller decision support along highway corridors spanning multiple states.

The service implemented within this scenario would be a tool that provides transportation agencies and/or private sector partners with accurate and concise information about pavement and weather conditions for use in disseminating traveller information as shown in the sample screen shot below of an internet based tool. Examples include providing or creating:
- Enhanced road weather content using ESS and road condition information along specific routes to 511 service providers
- Enhanced road weather content for a regional traveler alert system (possibly using mobile technologies)
- Enhanced road weather messages for use by HAR or DMS

- ESS data and enhanced road condition information along specific routes to traffic management personnel to support their decision making and operations
- Road weather coordination messages or advisories from the public transportation agency to emergency managers, state police and first responders
- A new visualization display to show the value of Clarus data in real time, integrated with other relevant data as a tool for both transportation agencies and travelers

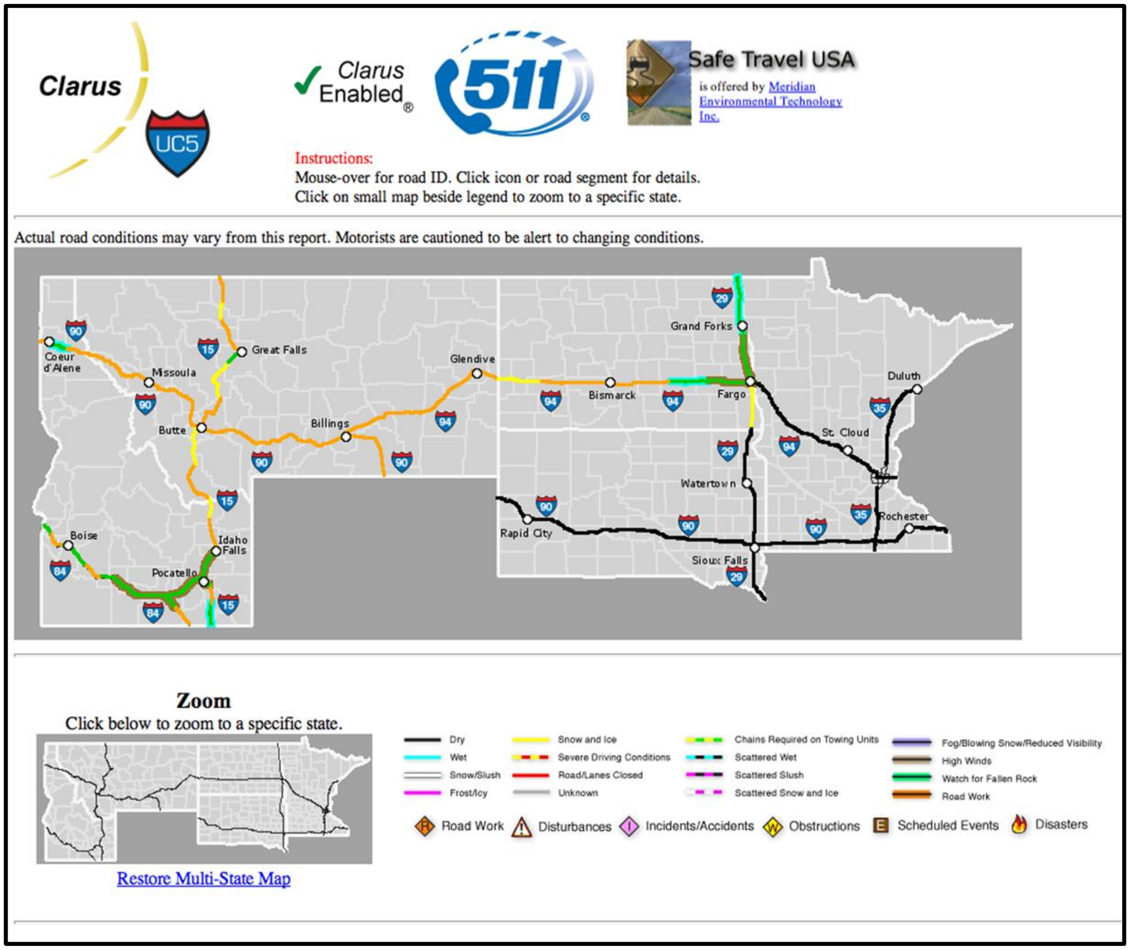

Figure 6 Travellers' advisory for cross-state road hazards

Additional possibilities in this scenario include value-added Business-to-Traveler (B2T) services such as partnering with a regional or national media outlet or dissemination vendor to provide traveler alerts (e.g., satellite communications, cable TV, in-vehicle devices, etc.).

Use Case Evaluations

There will be independent evaluations of each use case and the Clarus System & developed innovations. Two contracts were awarded to perform independent evaluations of the Phase 3 innovations. Two independent teams will evaluate the new products. One team will focus on Use Case 1 and the scientific/statistical analysis value or benefits that may result from the improvements made for surface transportation meteorology and operational forecasting. The second team will focus on use cases 2-5 and how the innovations may improve operations within the public agencies including tangible versus intangible benefits (mobility, productivity, safety).

Conclusions

It is hoped that at the conclusion of the Clarus Regional Demonstrations, the nation will have a valuable resource to aid the public sector in operational decision-making, and provide the academic sector with a consolidated and quality checked data source. New tools borne from C*larus* data may also provide the private sector with near real-time information and data that translates into higher impact products and services.

References

(1) National Academies of Science: 2004: *Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services.* The National Academies Press, Washington, D.C., www.nap.edu/catalog/10893.html

(2) Pisano, P.A., R.M. Alfelor, J.S. Pol, L.C. Goodwin, and A.D. Stern, (2005). *Clarus* – The Nationwide Surface Transportation Weather Observing and Forecasting System, 21st Conf. on Interactive Information and Processing Systems, San Diego, CA, Amer. Meteor. Soc., Paper 6.3

(3) Pisano, P.A., J.S. Pol, L.C. Goodwin, and A.D. Stern, (2006). FHWA's *Clarus* Initiative: Concept of Operations and Associated Research, 22nd Conf. on Interactive Information and Processing Systems, Atlanta, GA, Amer. Meteor. Soc., Paper 13.4

(4) Stern, A.D., P.A. Pisano, P. J. Kennedy and B.B. McKeever, (2008). Latest Developments in Fixed and Mobile Road Weather Observing as they relate to the *Clarus* and Vehicle Infrastructure Integration (VII) Initiatives, Intelligent Transportation Society of America World Congress, New York City, NY, Session TS59

(5) Pisano, P.A., P.J. Kennedy, B.C Boyce and A.D. Stern, (2008). Regional Demonstrations of the FHWA *Clarus* System, 24th Conference on Interactive Information and Processing, Amer. Meteor. Soc., New Orleans, LA, Paper 8.4

(6) Pisano, P.A., J.S. Pol, A.D. Stern, B.C. Boyce and J.K Garrett, (2007). Evolution of the U.S. Department of Transportation *Clarus* Initiative: Project Status and Future Plans, 23rd Conf. on Interactive Information and Processing Systems, San Antonio, TX, Amer. Meteor. Soc., Paper 4A.5

(7) Osborne, L., Meridian Environmental Technology, Inc., 2010: Advancing Road Weather Management Using *Clarus* Data, Presentation at the January 11, 2010, National Academies, Transportation Research Board Workshop, Washington, D.C.

(8) Boyce, B., Mixon Hill, Inc., 2010: Advancing Road Weather Management Using *Clarus* Data, Presentation at the January 10, 2010, National Academies, Transportation Research Board Workshop, Washington, D.C.