10.13 SUPPORTING SURFACE TRANSPORTATION WEATHER FORECASTING AT MERIDIAN ENVIRONMENTAL TECHNOLOGY, INC.

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1. INTRODUCTION

Weather forecasting in support of surface transportation-related activities is a rapidly growing discipline within the field of meteorology. This is demonstrated by the recent development and growth of 511 traveler information systems and by continuing research and development of winter Maintenance Decision Support Systems (MDSS). Both the traveling public and state departments of transportation (DOTs) are beginning to realize the benefits of receiving detailed, high-resolution, rapidly updating weather and pavement forecasts. For years, Meridian Environmental Technology, Inc. has been developing and implementing new technologies to support the surface transportation community, providing sophisticated tools to meteorologists in order to efficiently create, disseminate, and monitor a rapidly increasing volume of forecasts.

2. DESIGN PHILOSOPHY

Meridian's forecasting system was developed in response to a growing demand for detailed, high-resolution weather forecasts from DOTs and traveler information systems. As DOTs adopt more sophisticated, pro-active approaches to winter snow and ice control, they require a higher degree of forecast specificity and accuracy to be successful. Also, 511 market research surveys indicate that route-specific weather and road condition information are likely to be the most vital components of successful 511 systems in many areas of the country.

Considering that these emerging activities must be accomplished using only modest state budgets, Meridian's goal was to develop a suite of tools that allows for the creation of a greater number of forecasts in less time, in formats that can be easily adapted to take advantage of developing technologies. The current toolset revolves around a grid-based forecasting system, composed of a suite of forecast initialization, alteration, dissemination, and verification tools. Also playing integral roles in the system are mesoscale modeling, historical weather analyses, and rule-based reasoning. Meridian's existing system allows a small team of meteorologists to construct and disseminate over 25,000 temporally and spatially detailed forecasts per day in numerous formats (including computer telephony, web, e-mail, pager, etc.). Increased forecast generation and dissemination efficiency provides the meteorologists with more time to analyze weather, which in turn results in more accurate forecasts.

3. FORECAST SYSTEM COMPONENTS

Meridian's forecasting system represents an integrated collection of components. The forecast system's primary function is to streamline the process of converting the meteorologist's expertise into a comprehensive digital forecast product and to limit the cumbersome processes associated with product generation. This is accomplished through a series of graphical user interfaces and tools for maintaining gridded, multi-parameter digital forecasts and a highly automated system for acquiring, reconfiguring, and disseminating data.

3.1 *Data Acquisition*

The data acquisition infrastructure is a key component of any forecast system; however, with the explosive increase in data availability, the ease with which that data can be successfully processed, fused, and integrated is now of primary importance.

To provide its meteorologists access to the vast array of observed and modeled data available from various National Oceanic and Atmospheric

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Administration (NOAA) branches, Meridian assembled its own NOAAPORT system and a database infrastructure capable of ingesting and archiving the tremendous volume of data on a national and global scale. In addition, Meridian acquires data from state-sponsored mesonets and works with state DOTs to obtain information gathered from Road/Weather Information Systems (RWIS) and road condition reporting systems, such as the Condition Acquisition and Reporting System (CARS) and the Highway Condition Reporting System (HCRS).

In order to efficiently utilize this information, Meridian has developed a suite of tools that decode, re-map, and fuse datasets into the gridded forecast system. The Local Analysis and Prediction System (LAPS; developed by NOAA's Forecast Systems Laboratory (FSL)) serves as the primary data fusion system for observational data and provides Meridian forecasters the ability to view hourly atmospheric analyses in a three dimensional manner. Possessing the capability to analyze not only the atmosphere's current surface state, but also its vertical structure, is very useful when forecasting the short-term evolution of critical weather events that may impact surface transportation, such as severe storms or freezing rain. Another integral tool, developed by Meridian staff, is a dynamic surface map (figure 1) that integrates METAR, RWIS, and agricultural weather observations into one display. The map interface updates automatically as new observations arrive, and furthermore, observations indicative of hazards to surface transportation, such as low visibilities, heavy snow, or freezing rain, are highlighted and brought to the front of the display for immediate attention.

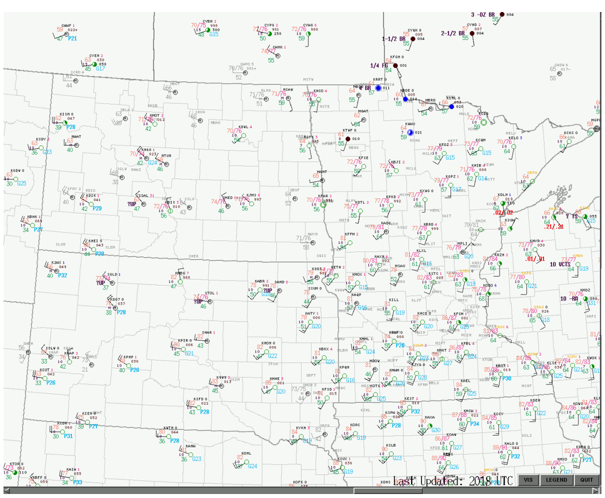

Figure 1: Surface map interface developed at Meridian to display current and historical weather observations.

3.2 *Numerical Weather Prediction*

Numerical Weather Prediction plays a key role in Meridian's transportation weather forecasting. As mentioned, Meridian meteorologists are provided with data from several numerical weather models available from NOAA's National Center for Environmental Prediction (NCEP). However, to support the detailed nature of the forecasting involved, Meridian has actively pursued the operation and maintenance of mesoscale models. These include the Mesoscale Modeling System Version 5.0 (MM5), developed by the National Center for Atmospheric Research (NCAR) and the Pennsylvania State University (PSU), as well as the Advanced Regional Prediction System (ARPS), developed at the University of Oklahoma's Center for Analysis and Prediction of Storms (CAPS). Running mesoscale models in-house allows the Meridian staff to create forecasts on a scale beneficial to its forecasters and clients. Meridian forecasters are also provided the necessary tools to quickly configure and carry out customized high-resolution mesoscale model runs over areas where extra forecast guidance is desired. The arrival and creation of new model data is continually monitored and is available for the forecasters' viewing (Figure 2) so they're constantly aware of the most current information available for use.

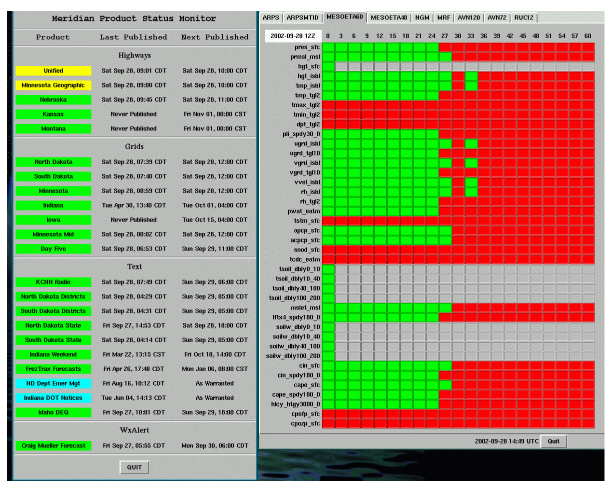

Figure 2: Interfaces used for monitoring the arrival of numerical weather data (right) and product issuance and schedule (left).

The display of numerical weather data is accomplished primarily through the use of the Grid Analysis and Display System (GrADS), developed at the Center for Ocean-Land-Atmosphere Studies (COLA). GrADS scripts written by Roberto Deidda of the Center for Advanced Studies, Research, and Development in Sardinia have also been incorporated and modified to provide forecasters with a convenient, mouse-driven graphical user interface to view numerical data. GrADS is an efficient tool for viewing model output in great detail and has the additional advantage of being easily tailored to individual models and also depicting hybrid fields. In addition, recent updates at Meridian allow GrADS to display GRIB data directly, and thus, model information is immediately available to the meteorologists as it arrives, allowing for last minute adjustments to forecasts prior to dissemination.

3.3 *Grid-Based Forecast Creation and Alteration*

At the heart of the Meridian forecasting system is a collection of tools (Figure 3), which are tied together through one user interface and allows meteorologists to initialize, adjust, disseminate, and maintain thousands of grid-based forecasts each day.

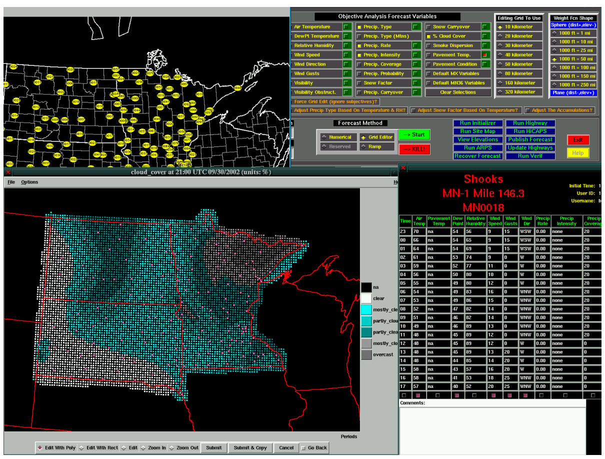

Figure 3: A screenshot including some of the tools which Meridian staff employ to create and disseminate forecasts.

The Meridian meteorologists have a number of options available when initializing a new forecast. They can select one of several models, a statistical blend of models, or a combination of overlapping portions of previous gridded forecasts and model data. A few minutes after an initialization is requested over a particular domain high-density grids containing client-specific parameters are created for each period of the forecast (e.g. hourly) and made available to the forecasters.

Once a forecast has been initialized, the forecaster(s) can utilize a suite of graphical tools to make modifications. These tools include grid and site-specific editors, as well as various objective analysis (OA) and observational blending routines. Several options are available when running OA routines over the forecast domains. Forecasters choose whether or not to incorporate model background fields in analyses, as well as each point's influence within the grid. Terrain datasets also accompany the forecast fields, allowing elevation to be efficiently and accurately used in making forecast modifications over complex terrain.

Artificial intelligence appears in the forecast system in the form of rule-based reasoning and can be turned on and off at the will of the forecaster. A form of fuzzy logic has been explored in pursuit of improved guidance in assessing fog potential on a point-specific basis. (Knutsvig, 2002). Also, previous investigation into improving precipitation type forecasting as related to surface transportation (Block and McQuade, 1998) has resulted in improvements to forecast initialization and maintenance routines. All of these options result in a versatile system in which forecasters can tailor adjustments to suit particular regions or weather events, depending on how well a particular model solution is expected to verify.

A critical element in the support of surface transportation is the ability to utilize detailed weather and road condition information to make explicit forecasts of road temperatures and conditions. Pavement forecasting at Meridian is performed primarily by the HiCAPS™ model, developed internally by Meridian's scientists. HiCAPS™ is rather unique in the world of pavement models in that it does not utilize balanced fluxes and the iterative approach to pavement temperature forecasting used by most other models (Shao and Lister, 1996). Instead, HiCAPS™ utilizes hourly location-specific weather conditions extracted from gridded forecasts to make explicit forecasts of the change in road surface temperature at each model time step as well as the depths and phases of any water on the pavement. Latent heat and mass exchanges associated with precipitation, runoff, condensation, deposition, evaporation, sublimation, phase changes, and even road maintenance practices (e.g., snow plowing) are all accounted for within the model. HiCAPS™ is easily operated by the meteorologists and pavement forecasts can be quickly updated as weather forecasts are modified or new R/WIS information becomes available, providing rapidly updating guidance for snow and ice control to the winter maintenance community.

3.4 *Dissemination & Alerts*

Completed forecasts are disseminated through the same interface that is employed to create them. The digital, grid-based nature of the forecasts provides for tremendous flexibility for distribution, whether via the internet, computer telephony, PDA, pager, fax,, or any combination thereof. Also, an additional tool and display (Figure 2) is employed to insure that products are issued and updated in a timely manner, with both visual and audible alerts used to notify forecasters that publishing deadlines are nearing, have been reached, or have been exceeded.

Software extracts the necessary information from the gridded forecasts with very little interaction on behalf of the meteorologists. For the maintenance community this means that weather forecast information is available virtually everywhere within the forecast domain with unparalleled resolution. Spatial forecast maps and site-specific forecasts with hourly resolution for any arbitrary location can be constructed within seconds, at any time, from the same source dataset.

To support 511 traveler information systems, software queries each grid point along individual highway segments over time and constructs forecast phrases for distribution over computer telephonies (CT) equipped with various Interactive Voice Response (IVR), Automated Speech Recognition (ASR), concatenated speech, and text-to-speech technologies. The automation of dissemination processes contributes significantly to increasing forecasting efficiency and permits more analysis of the weather and forecasts themselves.

The forecast dissemination system also supports automated detection and alert of user-configurable conditions within the forecast. Alerts can be sent in any of the aforementioned distribution formats. For example, a snowplow driver may wish to be automatically alerted via pager whenever snow greater than 2” is detected in the forecast.

3.5 *Monitoring and Maintaining Forecasts*

To provide the greatest benefit to the transportation community, as well as other customers, forecasts should be continually monitored after their initial generation and dissemination. The site-specific nature of Meridian’s surface transportation forecasting means that even a minute change in a storm’s location or anticipated track can dramatically influence the forecast that is delivered, and thus, tools were developed to constantly assess forecast accuracy and to indicate when and where maintenance may be necessary.

An interactive, color-coded verification tool (Figure 4) that has been developed at Meridian provides a quick, easy way for forecasters to track recent forecasts and visualize their accuracy without having to manually wade through an overwhelming number of forecasts and observations. The tool monitors root mean square (RMS) error and bias for selected forecast parameters on an hourly basis and for blocks of time and also assesses the improvement made to a previous forecast or model initialization. Using it in real-time allows forecaster to quickly isolate any errors in a recently issued, currently valid forecast.

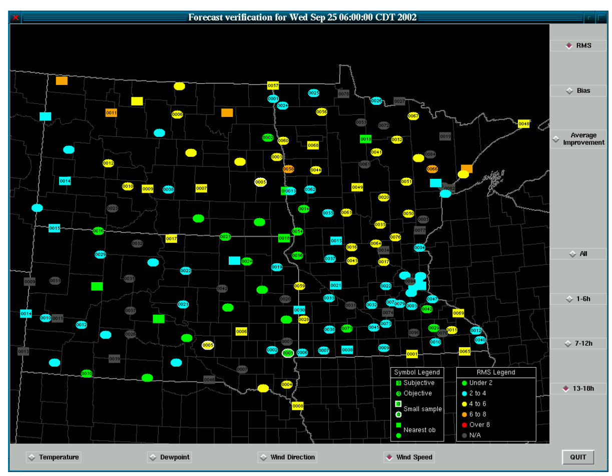

Figure 4: Forecast verification tool created at Meridian Environmental Technology, Inc.

Also, the same automated detection and alert software used to send user-defined alerts to customers can be configured to alert forecasters if a forecast falls out of tolerance. If a wayward forecast is identified, meteorologists can use their grid and site editors, as well as OA routines to make adjustments. In addition, a more automated process of adjustment to certain forecast parameters is also implemented at Meridian. That process uses current and recent LAPS grids, in combination with forecast grids, to assess the degree of forecast inaccuracies and adjust the forecasts from the current time forward.

Also included in the forecast maintenance process is the use of HiCAPS to very quickly create new pavement temperature and condition forecasts as weather forecasts are modified. Since pavement models have been shown to be most sensitive to atmospheric conditions and forecasts (Sass, 1992), having this ability is considered to be of great importance in surface transportation applications.

4. FUTURE DEVELOPMENT

Research and development is performed on a continuing basis at Meridian to develop modifications to the forecasting system and improve its use in surface transportation weather forecasting. A new grid editor is reaching the final stages of development and provides even more flexibility to the meteorologists in terms of parameter manipulating, copying, and animating that will further increase the pace of forecast creation. Additional enhancements being applied to the grid-based forecasting system revolve around improvements to the OA and statistical model blending software. Refinements to precipitation type and fog forecasting rule-based systems also continue, as does development of a new blowing snow algorithm.

Meridian also recognizes a need to develop an MDSS (Osborne et al, 2002) that will make use of the point specific data generated by the grid-based forecasting system. A Federally-funded MDSS prototype (project description and plans located at: http://www.rap.ucar.edu/projects/rdwx_mdss/) has been in development for a couple of years. Meridian will pursue the incorporation of prototype modules from that MDSS into its own proprietary system that is in early stages of development, via a separate Federal Highway Administration (FHWA) multi-state, pooled-fund study led by the South Dakota DOT.

5. SUMMARY

Numerical weather prediction models are becoming more advanced but are not considered an adequate replacement for the human weather forecasters. Meridian Environmental Technology, Inc. takes the position that meteorologists must remain at the core of the forecasting process. Modern numerical models can provide very high-resolution guidance; however, well-trained meteorologists can still use their knowledge and a wealth of other available datasets to create even more accurate and useful forecasts than models alone, especially in the shorter-term timeframe so critical to surface transportation.

To make the greatest use of today's more detailed model guidance and to meet the growing demands of weather forecasting support to surface transportation activities, Meridian Environmental Technology, Inc. has developed a more sophisticated forecasting system. Through the incorporation of increasing computing technologies, Meridian's current toolset allows a small team of meteorologists to create, disseminate, and monitor a tremendous volume of weather forecasts with increased efficiency.

6. REFERENCES

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