ARROWS EVALUATION

WA-RD 608.1

Research Report
February 2005

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Planning and Capital Program Management
in cooperation with:
U.S. DOT - Federal Highway Administration

Final Report

ARROWS EVALUATION

by

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16. ABSTRACT

In a June 2002 meeting, winter maintenance managers at the Washington State Department of Transportation (WSDOT) said that more accurate forecasts, that told not only where but when inclement weather was due, would be a valuable tool to aid them in keeping Washington State highways safe and passable during winter months. In response, the WSDOT ITS Office teamed with the University of Washington Department of Atmospheric Sciences to build weather information and forecasting Web pages specifically tailored to the managers' desires and needs.

The result was the development of the ARROWS (Automated Real-time Road Weather System) Web pages, made available to all WSDOT winter maintenance managers for the 2003-2004 winter season. WSDOT subsequently conducted an in-house survey to determine what ARROWS users thought about the usefulness and presentation of information. This report presents the results of that survey, which have been used as input to the continuing development of ARROWS.

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ARROWS EVALUATION

In a June 2002 meeting, winter maintenance managers at the Washington State Department of Transportation (WSDOT) said that more accurate forecasts, that told not only where but when inclement weather was due, would be a valuable tool to aid them in keeping Washington State highways safe and passable during winter months. In response, the WSDOT ITS Office teamed with the University of Washington Department of Atmospheric Sciences to build weather information and forecasting Web pages specifically tailored to the managers' desires and needs.

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THE ARROWS WEB PAGES

ARROWS is a Web-based graphical presentation of weather conditions (see Figure 1). It also provides links to other useful sites to aid winter maintenance managers in anticipating weather conditions.

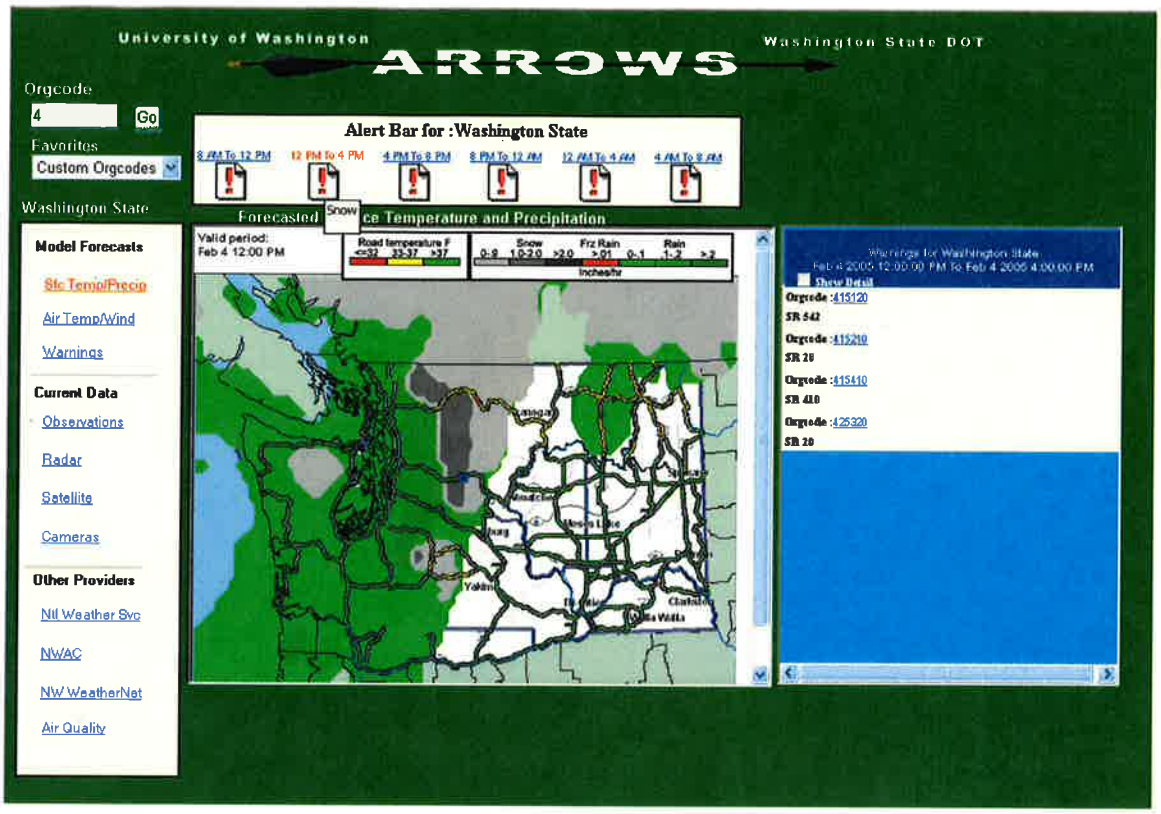

Figure 1: Sample ARROWS page showing the statewide precipitation and pavement temperature forecast

Forecasts are provided in 4-hour increments, and three views of each forecast are available for each period. The preferred view is selected from the left hand menu, while the time period is selected from the top menu.

The "surface temperature and precipitation" view indicates the forecast pavement temperature with color coding, in which green indicates forecast temperatures over 37°F, yellow between 37°F and 33°F, and red under 33° F. Forecast precipitation is also indicated by color: various shades of green indicate rain and shades of gray indicate snow. Deeper shades indicate more intense precipitation. Red is also used to show areas of possible freezing rain.

Similar to the first page, the air temperature and wind page (see Figure 2) reports forecast air temperatures by color: yellow indicates temperatures between 37°F and 33°F and red indicates temperatures below 33° F. The standard meteorological symbols are used to indicate forecast wind direction and speed.

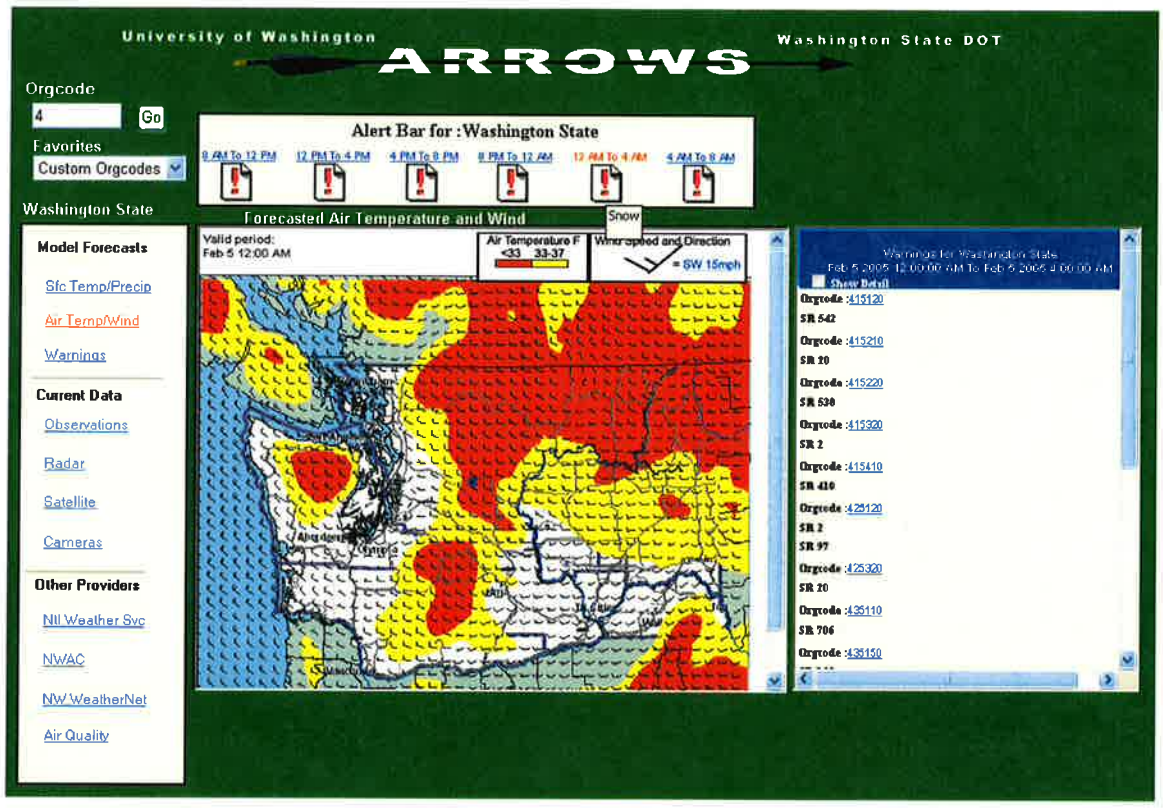

Figure 2: State view of "Air Temperature/Wind" page

The "Warnings" screen (see Figure 3) relays statewide weather information, along with specific warning notices addressed to the local maintenance unit regarding conditions that may affect its work.

In winter these warnings are for snow, frost, freezing fog, or other weather that will adversely affect the highways. In the example in Figure 3, the summer warnings are

for high temperatures, which is important for some paving and pesticide application tasks.

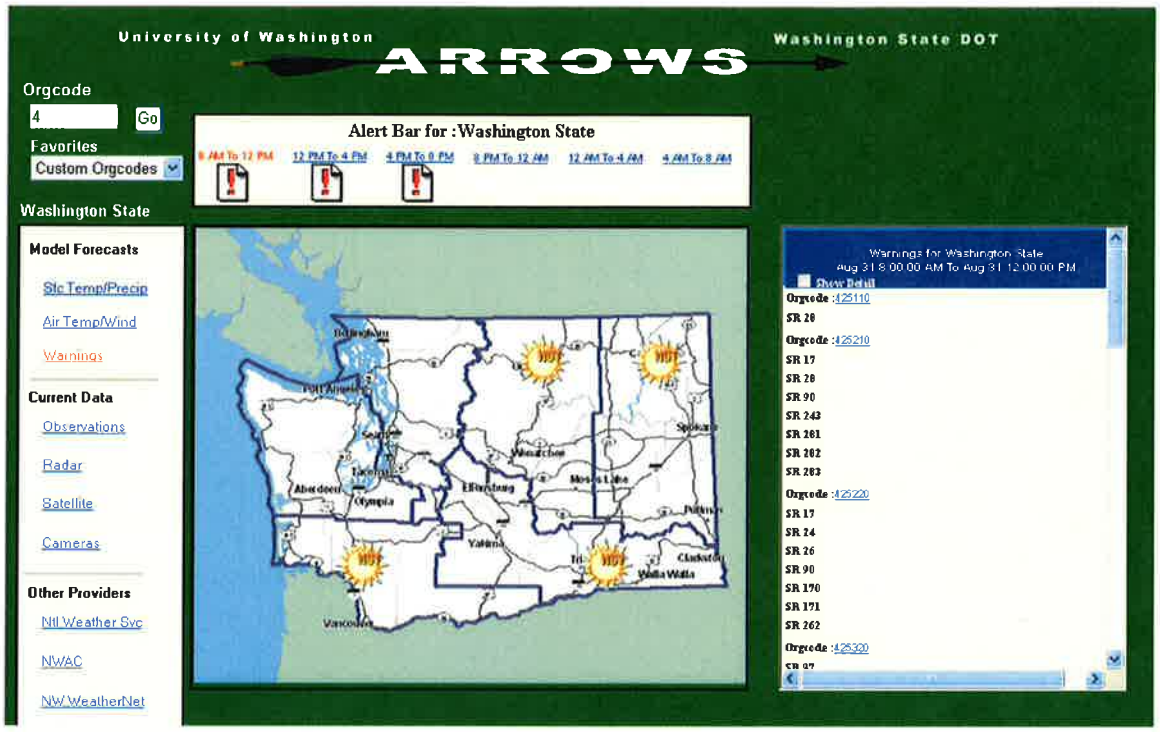

Figure 3: State view of Warnings page

Users can narrow the display to their immediate area by entering their WSDOT organization code ("org.code"), which identifies a maintenance group responsible for a particular area (see Figure 4). The use of the WSDOT organization code for navigation was desired by the attendees of the 2002 meeting. However, this method of navigation would make the use of ARROWS difficult for non-WSDOT personnel.

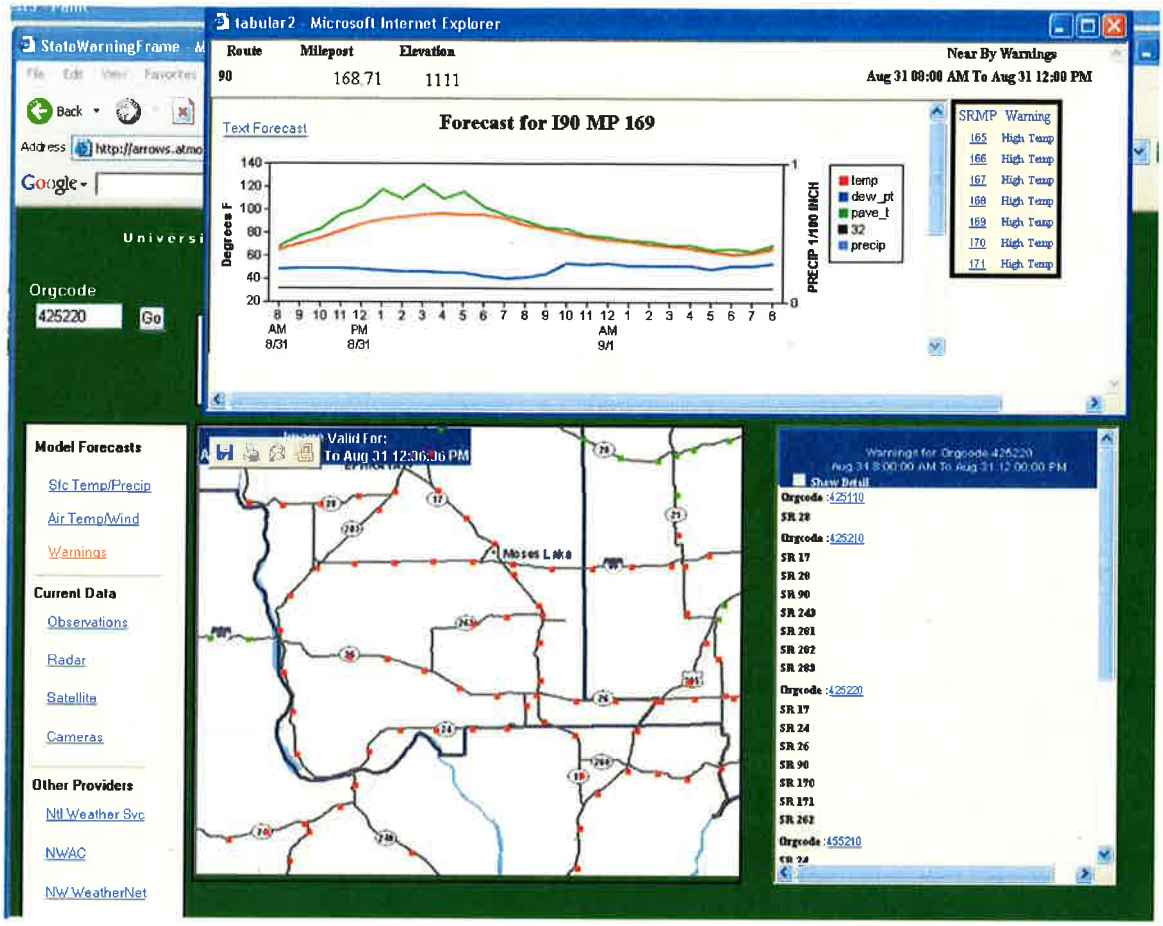

Figure 4: Close up of Org.code 425220 showing areas that have warnings (red dots)

Clicking on a location brings up a graphical forecast for air temperature, road temperature, and dewpoint. The forecast is also available in tabular form.

These tools are intended to give maintenance managers a way to anticipate the occurrence of freezing pavement or air temperatures, snow or rain, frost, and transitions between rain and snow. These are all considerations for managers deciding on a course of treatment. Accurate forecasts have the potential to improve the effectiveness of snow and ice treatments, which will result in a safer roadway while reducing labor and materials costs. Reducing material usage also reduces the amount of pollutants released into the environment.

Current observations from WSDOT weather sites are available, as well as a composite weather doppler radar showing the entire state (see Figure 5). The composite image is generated at the UW Department of Atmospheric Sciences. A loop of radar images covering the last 3 hours is also available, allowing users to see the track of a storm front or precipitation as it moves across the state.

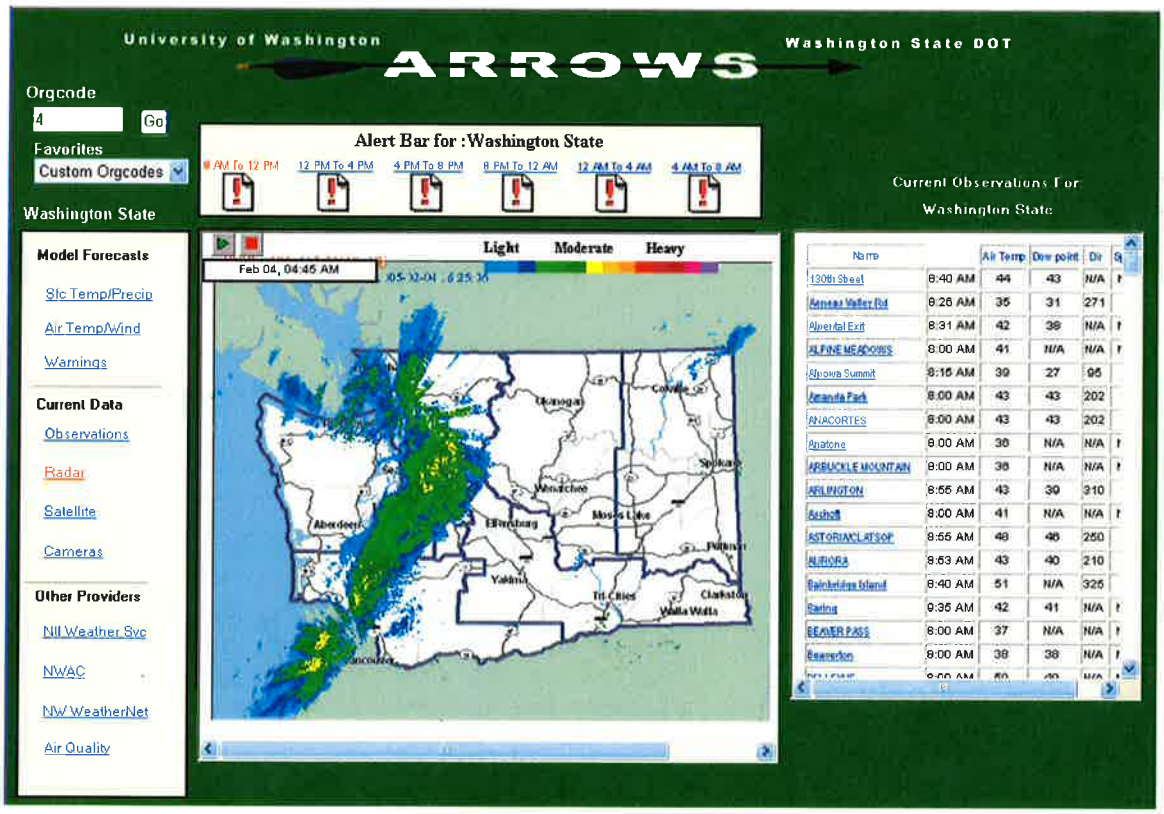

Figure 5: Doppler radar image

In addition to the forecasts, ARROWS provides useful links to outside sources for additional information. A link to the local National Weather Service (NWS) gives direct access to several satellite images from visible light, infrared, and water vapor images. Several of these products also can be viewed as a loop showing movement over the last

few hours. Other links connect to the Northwest Avalanche Center and to weather consultants under contract with WSDOT.

SOURCES OF ARROWS FORECASTS

ARROWS is driven by a group, or ensemble, of MM5 (Mesoscale Model 5) forecasts, which are run twice a day. Seventeen different forecast runs make up the ensemble. Each forecast uses initial and boundary conditions from a large-scale global model. Eight of the forecasts use different large-scale models for initial conditions; one forecast uses the average of the eight initial conditions (called the "centroid"); and eight other forecasts use the same eight initial conditions but each with a different set of physical parameters within in the MM5 model.

There is a trade-off between running a high resolution MM5 forecast and running many different forecasts in an ensemble at lower resolution. Insufficient computer power was available to do both, so the team chose to use the ensemble for ARROWS. This ensemble of forecasts has several advantages over using one high resolution model. First of all, it can continue running even if one or more of the global models fails to provide initial conditions on a given day. Second, the ensemble gives the ability to identify how likely a forecast is to be accurate. If all the ensemble members predict the same thing, that forecast is more likely to be true than if the ensemble forecasts vary widely. The measure of how close the ensemble members are to one another is called “spread.” A high spread indicates low confidence in the forecast, and a low spread equates to greater confidence. While this assumption does not always prove correct, there is a definite correlation between spread and forecast skill.

USER ACCEPTANCE

In general, field personnel reported that they like ARROWS, want continued access to ARROWS, and would like the development process to continue.

As people began to use ARROWS they identified a few deficiencies in the data displays. The researchers at the University of Washington quickly installed fixes. These included adding road detail and geographic references to the map displays for ease in location registration, adding a radar data intensity scale, and adding date time groups to surface observation tables.

A training course was developed to help potential users understand ARROWS, how it was created, and how to use it. The training was conducted in group sessions or as a hands-on session in a maintenance facility. Although the course was originally an informal training session, it is now a formal course in WSDOT's training system

ARROWS performed well during the first portion of the 2003-2004 winter. It correctly forecast an early snowfall in the Cascades Mountains in September. In late October, ARROWS also correctly forecast a no-snow situation in the Puget Sound area, which became the basis for a television interview with a WSDOT highway maintenance crew. The crew touted the benefits of having an accurate forecast to avoid unnecessary personnel callouts and associated costs. Shortly thereafter the Road Weather Program Manager issued a mild alert to ARROWS users to not expect the same sort of success all of the time and reminded them that ARROWS continues to be only one of the "tools in the toolbox."

Unfortunately, in early January 2004 ARROWS suffered the same problems that all other meteorological models faced at that time. They are all unable to predict the

location and influence of a layer of cold air near the surface. Consequently, the models did not forecast the extended freezing rain and subsequent ice storms that occurred in southwest Washington the week of January 5th. Similar problems arose on the east side of the mountains during mid-January. As a result of these problems, some users reverted to their previous methods of gathering or obtaining weather information. Of these, a limited number never returned to using ARROWS.

At the end of the winter season, the Road Weather Program Manager sent a questionnaire to ARROWS users in all of WSDOT's regions to determine whether ARROWS was meeting their needs. The rate of return was somewhat underwhelming; with approximately 150 surveys distributed, 38 responses were returned. Figure 6 shows the number of responses by region (Northwest, Olympic, Southwest, North Central, Eastern, and South Central). Figure 7 shows that the largest number of responses came from supervisors and technicians. Other respondents included superintendents and lead technicians.

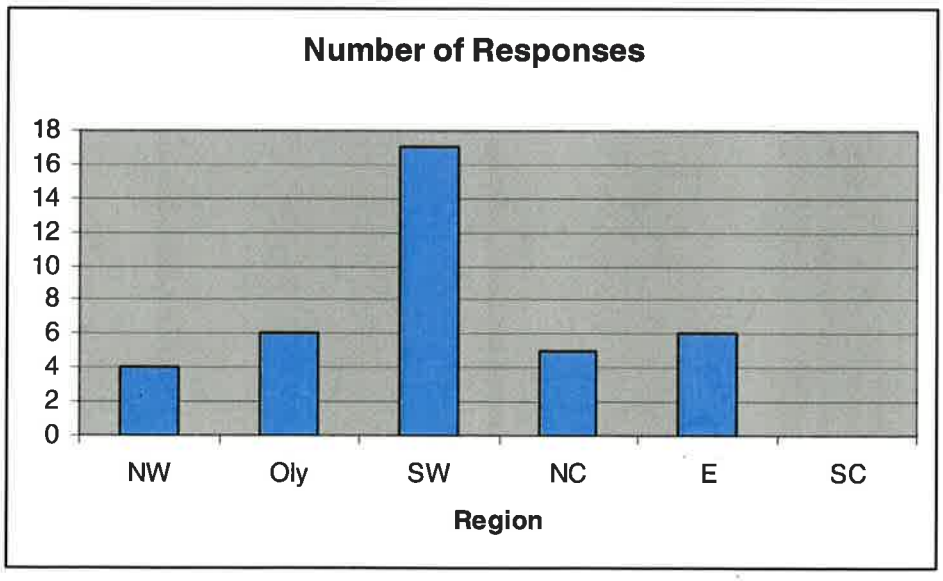

Figure 6: Number of survey responses by WSDOT region

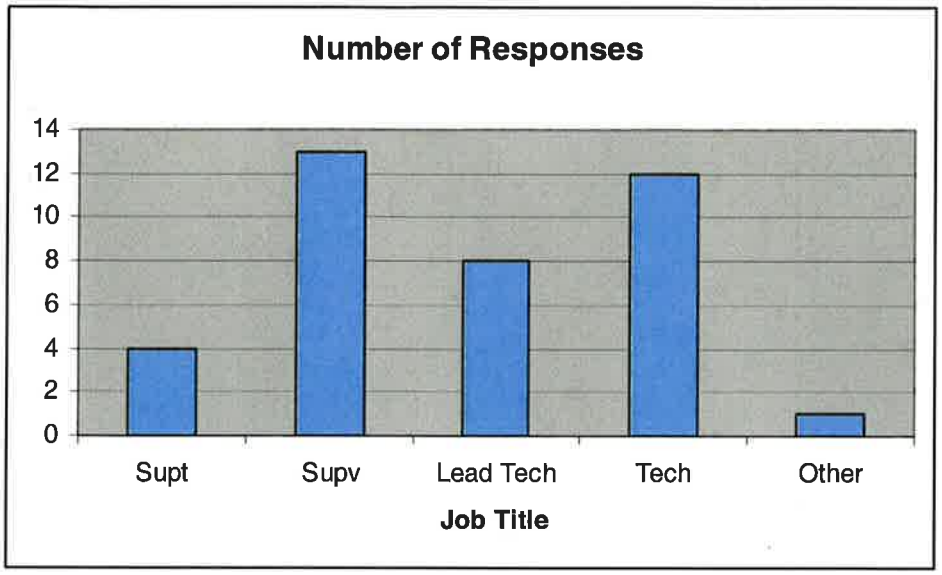

Figure 7: Number of survey responses by job title

Below are some of the results from the respondents. Note that all of the extremely negative comments came from two individuals located at the same maintenance facility.

Sources of Weather Information

Figure 8 shows the various sources of weather information used by the respondents, including the Weather Channel, the University of Washington Department of Atmospheric Sciences web site (http://www.atmos.washington.edu/data/), National Weather Service (NWS), Northwest Weathernet, newspapers, television newscasts, DTN, radio, NOAA Weather Radio and others. The graph highlights the apparent importance of television weathercasters, which ranked higher than the NWS in terms of use.

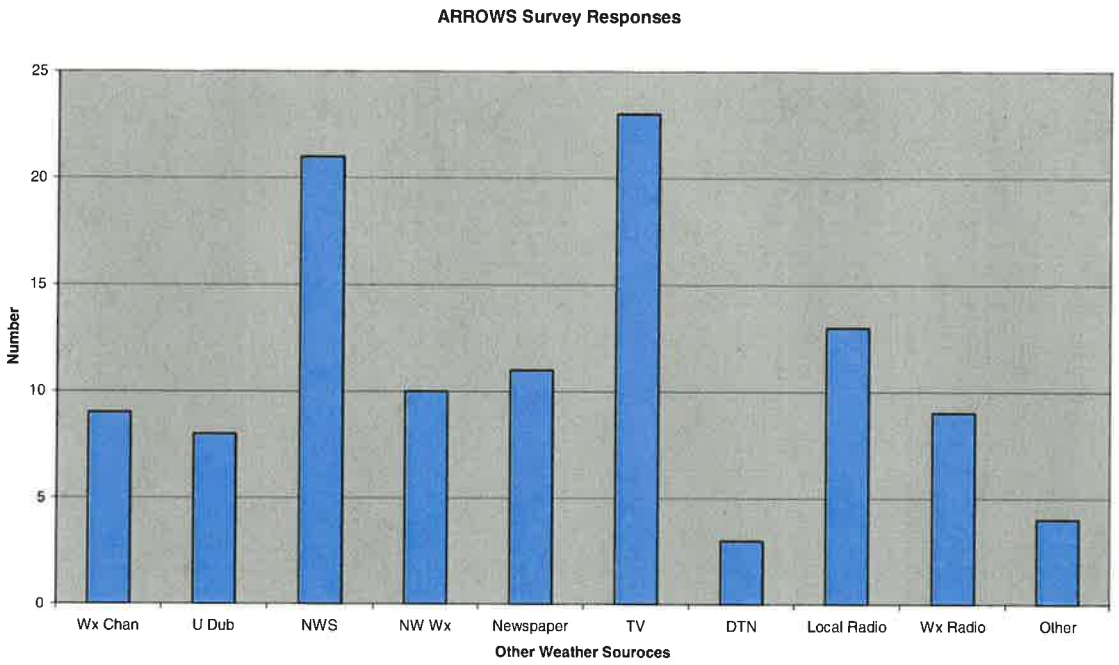

Figure 8: Sources of weather information other than ARROWS.

ARROWS Features Most Liked

Figure 9 shows the ARROWS features that users said they liked. The most popular features were the main distinctive features of ARROWS: the road maps, weather warnings, and pavement temperature information. Most maintenance people understand the importance of pavement temperature for their winter maintenance activities. In conversations, this was the key forecast parameter. Other features identified by users were the forecast graphs, icons, ease of use, links, ease of access, and "other," the composite weather radar images.

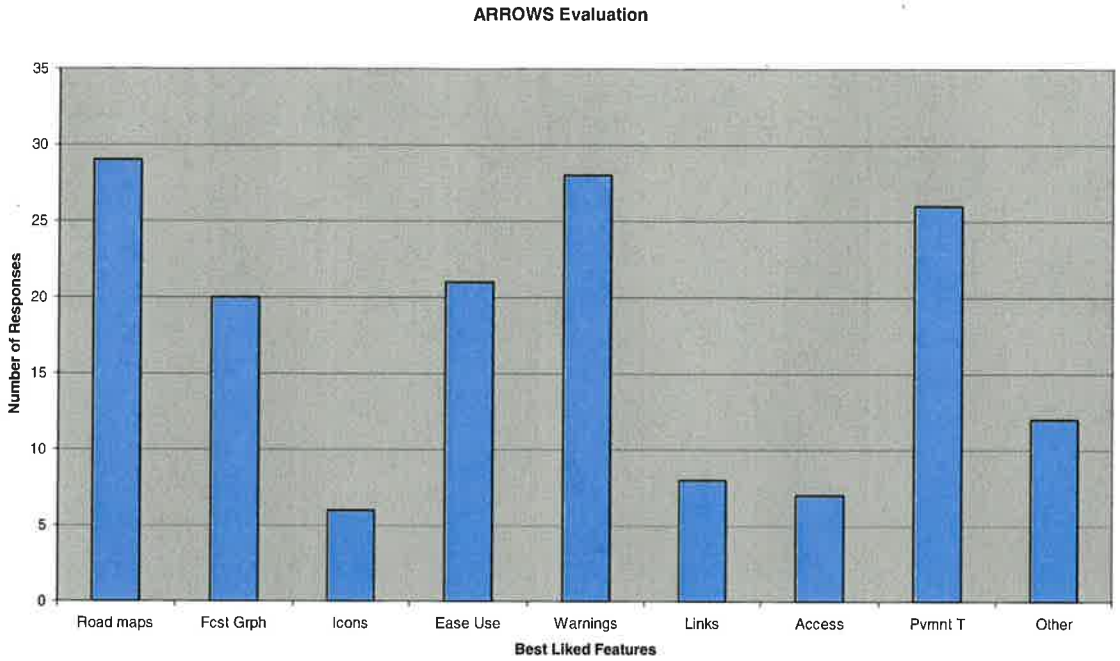

Figure 9: Features most liked by ARROWS users

ARROWS Features Most Disliked

Figure 10, on the other hand, shows items or features disliked by users. The one item identified most, albeit by only five respondents, was "ease of use." In talking with users, most of the people who found ARROWS difficult to use did not have ARROWS training. The forecast graphs presented some problems because users didn't always understand the graph process. Training has helped users understand that text forecasts are available. The two individuals who selected "Links" wanted to see additional links. The "Other" category was a catch-all for comments such as "not always up," "inaccurate" (2), "don't like the % confidence going to zero with the precipitation forecast," "reliability," "too hard to decipher," and "not as good as TV/internet."

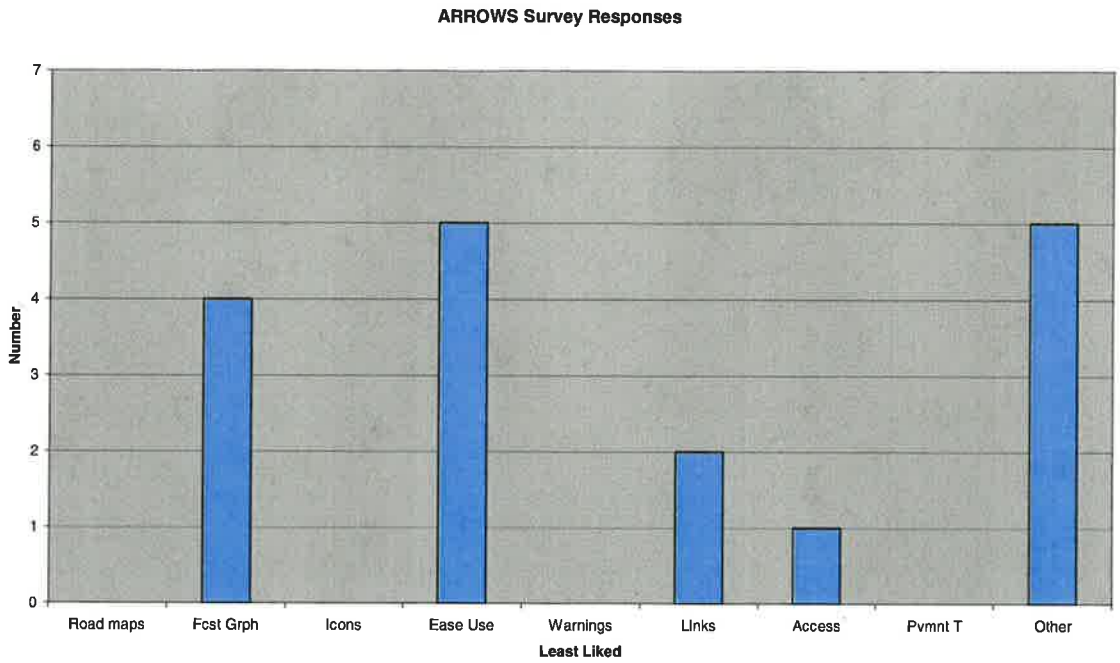

Figure 10: Features of ARROWS disliked by users

ARROWS Features Needing Change

Figure 11 shows what people said they would like to see changed in ARROWS. The most requested change was to increase the forecast length. Currently ARROWS forecasts are in six 4-hour time blocks. Most users wanted a minimum of 36 hours; some at least 48 hours. The issue of map sizes also generated discussion. Some users said they would like to see the map views larger on the screen. The screens appear to provide some unused space that could be used for larger maps. Also, users said they wanted the ability to click on a map to zoom in or out rather than entering organization codes to navigate.

A few others commented on adding or deleting links, changing the warnings, and pavement temperature. The "Other" category comments included "increase the

reliability" [accuracy] (2), "need forecasts out to seven days," "make more user friendly," and "make at least as good as TV Web sites"

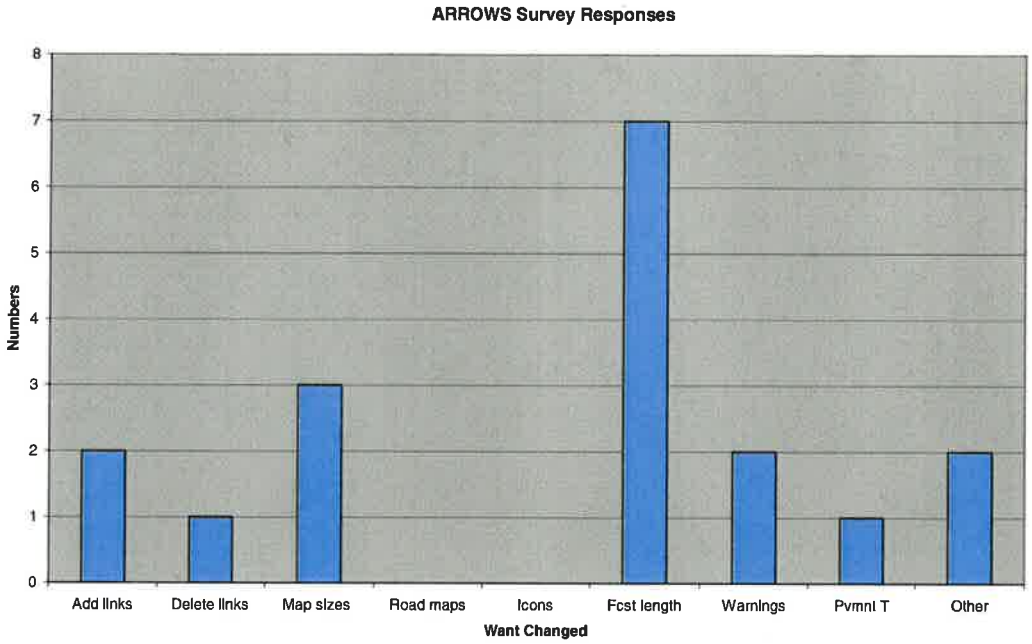

Figure 11: Items users want changed in ARROWS

Rankings of ARROWS Output Parameters

Figure 12 presents the rankings for various ARROWS output parameters, including pavement and air temperatures; precipitation amount and time; wind speed and direction; and snow, frost, and freezing fog warnings. Not all respondents ranked each parameter. Most features were subjectively rated "OK" or better. Few users rated parameters "Very Bad." The most dissatisfaction was indicated for snow warnings. Much of that dissatisfaction derived from users' experiences in the first week of January, when the computer models had difficulty dealing with cold air trapped near the Earth's surface west of the Cascade Mountains. Given some computer model adjustments that

have been made since last winter, this forecast feature should improve, and satisfaction should increase.

Few comments were provided regarding the output parameters. In the "Other" category, the two Very Bad and the ten Very Good responses were accompanied by no comments. One verbal comment was, "Freezing rain good."

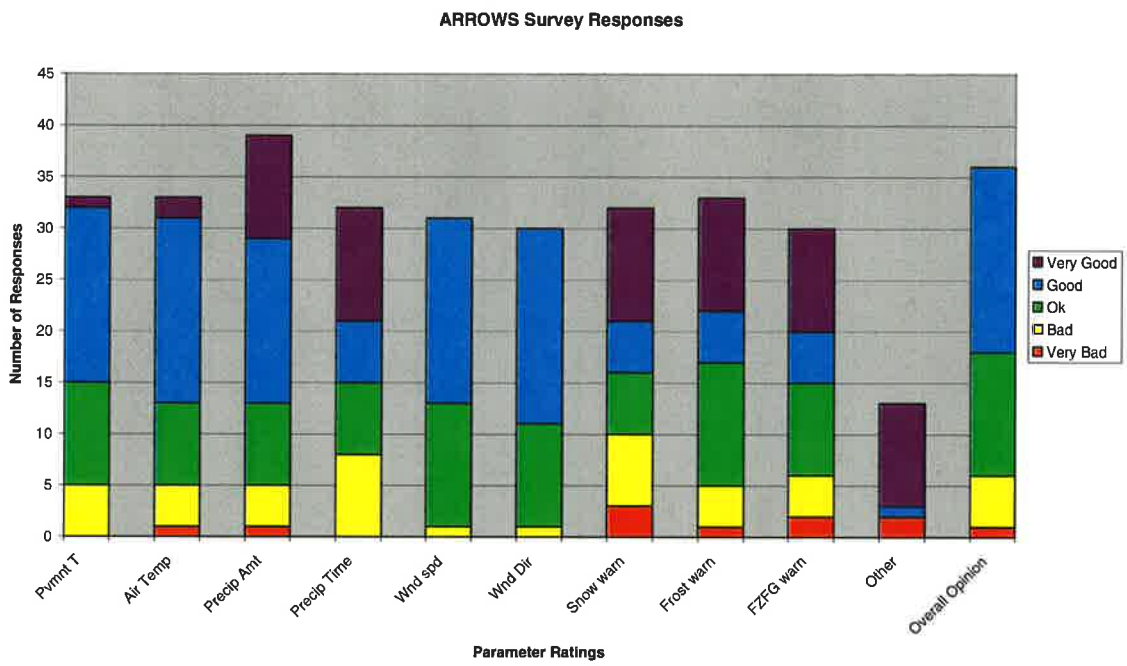

Figure 12: Rankings of ARROWS output parameters

ARROWS' Usefulness and Continuation

One of the most important components of the evaluation was a question about whether people were better able to do their jobs because of ARROWS. Figure 13 shows the results: 27 said "yes" and 9 said "no." A similar question asked whether WSDOT

should continue with development of ARROWS. In a resoundingly positive reply, 30 said "yes" and 3 said "no" (see Figure 13).

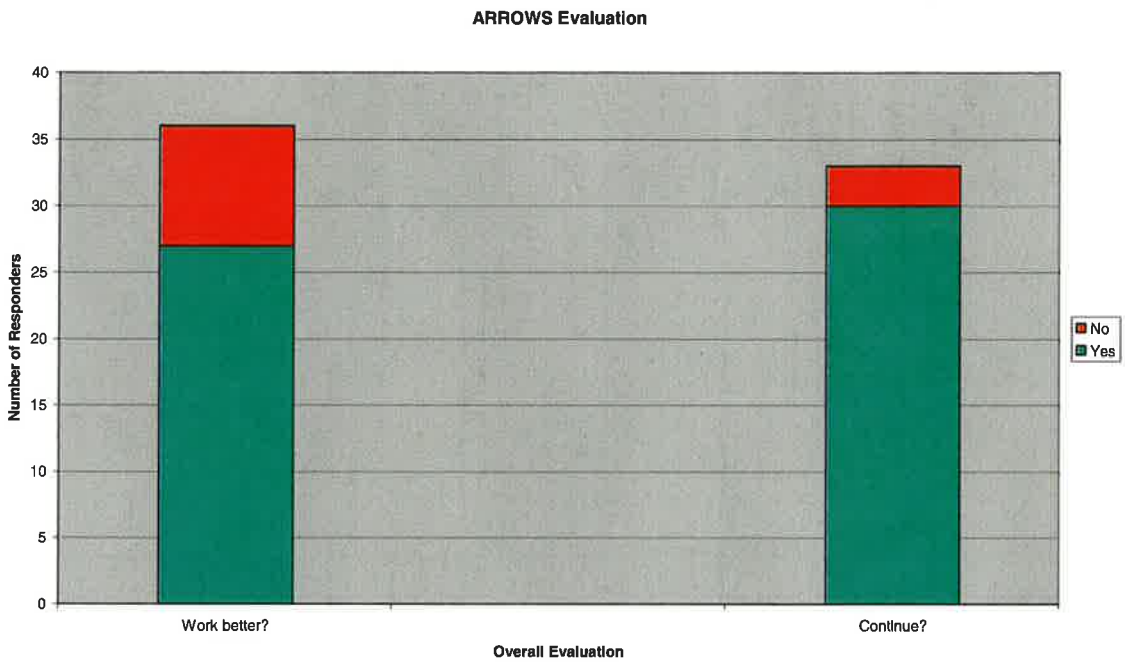

Figure 13: Overall ARROWS evaluation from user perspective

New Features for Development

Users were also asked for input on what they would like to see developed in ARROWS. Verbatim responses follow:

- ARROWS + 5 days, in 6-12 hr incr. OK
- Warning notification capability, esp when below freezing
- Better warnings of freeze/snow events
- Snow Techs need info in a hurry, not searching thru graphics … they can call NW WeatherNet (a local meteorological forecasting company)

- More forecast links, more site estimates
- Add more specific sites
- More sites and make it more current
- Links to cameras.

Additional Comments

Respondents were also was asked to provide additional comments. Below is a list of the comments as written:

- Need RWIS sensors to work
- Not easy to use, not fast enuf
- Little opportunity to use 'cuz of connectivity probs
- Comments based on limited time
- Temps OK early, but from mid Dec on was off, showing snowing when not
- Little or no use, inaccurate, questionnaire just as bad
- As long as ARROWS is another tool and not a tool for scheduling/committing resources, we'll be fine
- I get better forecasts from TV Wx sites
- very useful … please continue to provide and improve
- only access 3 times. Don't think it was any more useful than the local forecast
- Pavement temp are not very accurate
- Other sources proved much more accurate
- Good tool to use. Only as good as raw data
- Need better data to improve the end product.

Some of the comments showed an understanding of the process; some did not. Some of the issues mentioned are being resolved. For example, maintenance shed connectivity is being improved. Also, more computers are being acquired to give more people access.

SUMMARY

One issue buried within the evaluation and the success of ARROWS is training. Many of the comments about user friendliness related to a lack of proper training. A formal course now exists. The hope is that more maintenance locations will request the training and that the training will be conducted at a level below Maintenance Area so that hands-on training will become the norm.

It is apparent from the questionnaire responses, and from conversations with users, that the initial ARROWS test proved positive and that development and improvement should continue.