Mesoscale Weather Forecasting: Technological and Institutional Challenges

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Summary of Proceedings

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These proceedings offer a summary of the seminar on Mesoscale Weather Forecasting: Technological and Institutional Challenges, held at the Volpe Center on July 16, 1996. They do not propose or advocate any specific views or actions, nor do they necessarily reflect the policies or views of the Department of Transportation or any of its elements.

Mesoscale Weather Forecasting:
Technological and Institutional Challenges

I. Foreword

On October 26-27, 1995, more than 200 transportation leaders and decision makers from around the nation convened in Cambridge, Massachusetts, to participate in a two-day symposium on "Challenges and Opportunities for Global Transportation in the 21st Century." The symposium was held at the John A. Volpe National Transportation Systems Center, or Volpe Center, which is part of the Research and Special Programs Administration of the U.S. Department of Transportation (DOT). The purpose of this event was to support effective public and private sector policy decisions by focusing on the core issues that underlie several of the most challenging transportation topics now on the national agenda.

As a follow-up to this event, the Volpe Center is conducting a series of six seminars in 1996 to explore in greater detail critical issues in transportation for the next century that were identified at the symposium. These six issues, and the planned dates for the seminars, are:

- "Emerging Issues in Transportation Information Infrastructure Security" (May 21).
- "Current and Future Federal Applications of Tagging and Tracking Technology" (June 18).
- "Mesoscale Weather Forecasting: Technological and Institutional Challenges" (July 16).
- "Spectrum Availability and Digital Communications Links" (August 20).
- "Travel and Tourism as the World's Largest Industry: Transportation Challenges and Opportunities" (September 18).
- "Transportation Health Effects: A Current Assessment" (October 16).

Each seminar assembles approximately 40 to 50 public and private sector experts and transportation officials to provide in-depth focus on these important issues and identify potential areas where policy changes or further research and analysis may be required. This report summarizes the presentations and discussions that occurred during the third of these seminars, "Mesoscale Weather Forecasting: Technological and Institutional Challenges," which was held at the Volpe Center on July 16, 1996.

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III. Overview of the Issue

Adverse weather is all too common in the U.S., due to the country's vast size and diverse geography. Severe winter storms occur throughout the northern and central states and in mountainous regions. Arid areas experience dust storms. And much of the country must live with frequent rain, severe thunderstorms, fog, and strong winds.

For the transportation system, the safety, mobility, and economic impacts of these weather conditions is considerable. According to the White House Office of Science and Technology Policy (OSTP, 1992), each year weather causes or contributes to 6,000 fatalities on U.S. highways and 800 aviation-accident-related deaths. The OSTP estimates that about half of all flight delays are attributable to weather, and that uncertainties in predicting flight-level winds add a quarter billion dollars annually to the nation's aviation fuel bill. Citing a Dutch study on weather and road conditions, a Federal Highway Administration report (1995) states that between 25 and 35 percent of all intercity road accidents occur during adverse weather, with the risk of accidents increasing during bad weather by a factor of from 2 to 5. And highway agencies spend an estimated half a billion dollars a year preparing for snowstorms that are predicted but never occur (OSTP, 1992).

Advances in weather technologies and meteorology during the past decade promise to mitigate many of the impacts of severe weather on transportation. Among these are new observation systems, such as Doppler radars and Automated Surface Observing Systems; advances in computing speed and capacity; and greater fundamental knowledge of weather systems. Together, these improvements are making possible dramatically improved weather forecasts, ultimately leading to reliable short-term forecasts (from a few minutes to 48 hours) on a local and regional basis (or mesoscale). Such site- and time-specific forecasts would be particularly beneficial to transportation. Already, state and local highway departments, air carriers, and emergency responders are making use of and benefiting from the new capabilities. However, according to the OSTP, the National Weather Service (NWS), and other agencies, these improvements' full potential will not be realized without advances in other related areas, most importantly in weather data analysis, forecast applications, and information dissemination.

IV. Topic 1: Aviation Requirements and Challenges

(a) Background

Weather has a major impact on aviation safety and efficiency. As reported by the National Research Council (1995), during 1988 to 1992 one-fourth of all aircraft accidents, and one-third of fatal accidents, were related to weather. Moreover, in 1990 flight delays attributable to weather accounted for approximately $4.1 billion of direct costs to the airline industry, not counting the additional financial loss and inconvenience to the traveling public.

As the demand for air travel grows, improved weather forecasts will be essential for ensuring the safe, efficient, convenient, and affordable service that the public expects. By improving capabilities for flight planning and severe weather avoidance, short-term forecasts on hazardous conditions—such as icing, turbulence, thunderstorms, microbursts, and windshears—will significantly enhance flight safety. In terms of capacity, such forecasts offer the potential for increasing system throughput more cost-effectively than new airports, new runways, or other alternatives. Still other benefits include reduced aviation fuel consumption and lower deicing costs for airports.

In the United States, aviation weather services and related research are the role of the FAA, the NWS, the Department of Defense, NASA, and the private sector. Almost all day-to-day aviation operations depend on the NWS for forecasts, severe weather watches and warnings, flight planning information, and other weather services. (Very few airlines operate their own meteorology departments.) In R&D, the FAA is responsible for establishing and validating aviation requirements and for meeting these needs either internally or by coordinating with other agencies. It also has a lead role in developing and operating aviation weather systems. In particular, the FAA has provided key support for research, development, and procurement of the Next Generation Weather Radar and Automated Surface Observing System, which are operated by the NWS, and has a major interest in other major components of the NWS modernization program.

(b) Discussion

As explained by one seminar participant, aviation weather is essentially mesoscale weather; that is, the weather events of most concern for flight safety are associated with mesoscale, or local, phenomena. For this reason, the FAA, NWS, and other agencies are modernizing services to detect and predict mesoscale weather. Working together, these agencies are installing new networks of weather sensors, developing models for assimilating mesoscale data, and creating improved forecasts of potentially hazardous local events such as microbursts, turbulence, and icing. At selected airports, for example, new Integrated Terminal Weather Systems, or ITWS, are providing terminal-area "nowcasts" that predict microbursts within 2 to 5 minutes in advance. (This system, which processes weather observations from Automated Surface Observing Systems, Next Generation Weather Radars, Terminal Doppler

Weather Radars, and other weather observers, will ultimately cover all major airports in the U.S.) Taken together, these advances in aviation weather technology could increase significantly the accuracy and timeliness of information available to users of weather services. Yet, according to the seminar participants, a number of impediments—not all of them technological—may prevent aviation users from realizing the full benefits of these and future improvements.

The biggest technological obstacle, by far, is limitations in existing communications and dissemination technologies. Participants were nearly unanimous in agreeing that the lack of graphical weather products, adequate ground-to-air communications, and cockpit displays has resulted in weather products that deliver too much data and not enough real information. According to one panelist from the FAA, these limitations not only will prevent the dissemination of future improved weather forecasts, but they also already limit the distribution of valuable weather information that now exists. The main problem, said this panelist, is the FAA's communications system: although the agency is able to create graphical representations of weather information, it lacks the communications capability to disseminate them.

For many participants, the primary issue was the need for graphical weather reports in the cockpit. Pilots currently receive weather information in the form of lengthy text messages, which are often confusing and difficult to interpret. As one participant put it, "A good picture is worth five pages of teletype." This participant said that the current system has failed because it was developed from the start to meet the needs of ground-based users, such as air traffic controllers, rather than those of flight crews. He added that the flexibility upon which the FAA's vision of "free flight" depends will not be possible without providing pilots directly with accurate, short-term weather forecasts.

One effort to overcome the limitations of existing weather services is the FAA's Terminal Weather Information for Pilots, or TWIP, program, a joint undertaking with the airline industry. This program is demonstrating the transmission to pilots of ground-based terminal weather information generated from the ITWS or by a Terminal Doppler Weather Radar. The TWIP weather products include simple text and character graphics information, which is updated and stored in a database each minute. Pilots can request and receive reports from six participating airports via the ACARS data link. For the near future, the FAA plans to extend the program to all Terminal Doppler Weather Radar sites and to demonstrate full graphical weather products via Mode S and ACARS.

Despite the promise of programs such as the TWIP and ITWS, a major question remains unanswered: Will the FAA, NWS, and other agencies be able to secure continued funding for these and other weather system improvements? Several participants pointed out the difficulty of arguing for weather programs solely on the basis of improved safety, since the aviation system is already very safe, and serious incidents resulting from weather (or any other cause) are rare. And while the biggest benefit of improved forecasts is increased capacity, it is not enough in today's budget climate to show cost savings for airlines and consumers or overall economic benefits.

Rather, said participants, the determining factor will be whether agencies can demonstrate reduced costs and greater efficiency in their own operations.

A number of participants discussed the need for airlines' support in the development and implementation of weather systems. One panelist, for example, stated that while the FAA today has the resources to research new weather technologies, it no longer can afford to build operational systems. Another explained how the move to graphical forecasts will require airlines to invest in new communications systems before pilots can use the improved weather products—a problem, he added, that is compounded by the fact that airlines often expect to see a return on their technology investments within 18 months.

V. Topic 2: Marine Requirements and Challenges

(a) Background

Uncertainties in weather forecasting are a major impediment to ensuring the safety of marine travel, upon which hurricanes, squalls, typhoons, tsunamis, and other severe weather frequently have a devastating impact. In addition to safety concerns, incorrect forecasts result in significant financial losses for ocean shippers, which rely on the forecasts to plan the most efficient routes.

Providing marine meteorological services is the role of the NWS and the U.S. Coast Guard. The NWS has responsibility for issuing marine weather forecasts and warnings. The Coast Guard reports marine weather observations to the NWS, broadcasts the NWS forecasts, and provides operational support to the National Oceanic and Atmospheric Administration (NOAA) for deployment and servicing of buoys that monitor marine meteorological conditions. This latter effort is led by NOAA's National Data Buoy Center, or NDBC, which provides meteorological and oceanographic data to forecasters, researchers, and other users in the U.S. and worldwide. The NDBC's buoys measure and transmit data on barometric pressure; wind direction, speed, and gust; air and sea temperature; and wave energy spectra.

Another source of marine weather data is the NWS Voluntary Observing Ship Program. In fact, observations from ships form the basis of marine weather forecasts in both coastal and high-seas areas. In this program, observations are taken by deck officers, coded in a special format, and transmitted in near-real-time to the NWS. The NWS meteorologists then use these observations in preparing forecasts and warnings. The ship observations also are inputs to computer forecast models used by the entire weather community.

(b) Discussion

The Coast Guard has been actively exploring new applications of current technology to improve operational efficiency through the use of marine weather information. The agency has recently begun using satellite imaging to support its domestic ice-breaking operations, and is investigating the capability of satellite sensors to locate icebergs for the International Ice Patrol and to determine surface currents and winds as an aid in search and rescue.

Another advance that may soon improve marine weather services is the development of electronic navigational charts that could be combined with weather radar graphics. These graphical reports would provide mariners with localized nowcasts of winds, waves, visibility, surface currents, and other conditions, and, together with the electronic charts, would offer a "tactical view" of all weather affecting a ship's operations.

In addition to the Coast Guard's programs, the NWS modernization is significantly upgrading the meteorological services available to mariners. According to one participant, NWS forecasts and warnings are becoming more and more localized, and will ultimately make possible the very small scale weather information that marine nowcasts require. In San Diego, for example, the NWS is using an advanced Local Analysis and Prediction System, or LAPS, that assimilates weather data from Next Generation Weather Radar, satellites, profilers, surface observing systems, and buoys to make short-term marine forecasts within a 10-kilometer grid. However, the weak link in the NWS program is dissemination—delivering the mesoscale weather data and forecasts to users and the general public. One way the NWS plans to improve dissemination is through installation of the Advanced Weather Interactive Processing System, or AWIPS, a network of high-speed computer workstations that will be installed at all NWS offices over the next two years. The AWIPS will integrate high-resolution satellite data, radar data, surface observations, and computer-generated forecasts to display the rapidly changing state of the weather from many different aspects. According to a panelist from the NWS, it will produce forecasts and warnings more quickly and at a level of spatial and temporal resolution never before available. Ultimately, the AWIPS will also disseminate localized weather forecasts—including information for waterways, highways, airports, and airways—to mariners, emergency responders, state and local governments, and the public. The Internet is one option that the NWS is exploring for providing this broad public access.

Although many of the Coast Guard and NWS programs discussed at the seminar are already well under way, panelists emphasized that a number of unresolved issues may prohibit further progress. One participant, for instance, discussed the need for local and private sector involvement in NWS modernization if the public is to realize its full benefits; in particular, state and local agencies and vendors will have greater opportunities to integrate the nationwide gridded data made available by the NWS with local geographical information. Moreover, as with aviation weather services, a major obstacle to improving marine forecasts is the need to demonstrate potential operating-cost savings to secure program funding. A third issue that agencies must address is the need for training to support the use of new marine weather products.

VI. Topic 3: Surface Transportation Requirements and Challenges

(a) Background

As every driver knows, weather has a serious impact on the safety of highway travel: about a third of all intercity road accidents occur during bad weather. The meteorological conditions having the greatest impact on traffic safety are rainfall, snow, ice, fog, and wind. These conditions adversely affect traffic by reducing 1) surface friction, 2) visibility, and 3) vehicle stability. As such, there is a critical need for real-time, accurate local data on hazardous driving conditions.

Yet another requirement is for accurate short-term predictions of snowfall and icing on a very small scale—a stretch of highway, a city block, or a particular street. For state and local highway maintenance departments, such information can greatly reduce the costs of snow and ice control, perhaps by 10 percent or more (Boselly, 1992). Given statistics showing such costs exceeding $2 billion a year in the U.S. and Canada, total savings could be as high as $200 million annually.

Currently, most motorists and highway agencies rely on the general regional forecasts issued by the NWS for their travel and operational planning. But these forecasts are simply not specific enough. For drivers, avoiding hazardous weather requires real-time detection and warning of dangerous local conditions such as flooding, high winds, blowing snow, icing, dense fog, or dust. And highway maintenance engineers responsible for snow and ice control need to know not only if it *will* snow but exactly *where, when,* and *how much* snow will accumulate and on *what* roads or stretches of road icing will occur.

Over the past few years, many state and local highway agencies have taken steps to improve road weather forecasting through the use of information systems that provide detailed, site-specific observations, particularly of snow and ice. These systems, called road weather information systems, or RWIS, comprise a number of technologies for sensing and collecting site-specific weather and road condition information; processing and disseminating this information; and using the information to create specific, very small scale forecasts. The technologies that these systems employ can include any or all of the following: pavement sensors to measure road temperature and conditions, particularly for ice detection; atmospheric sensors to provide information on wind speed and direction, air temperature and dewpoint, precipitation, and visibility; thermal mapping, which involves driving an instrumented vehicle over roads to measure pavement temperature; data from weather observing systems, such as Next Generation Weather Radar and weather satellites; and communications/processing links that centrally gather sensor data and weather forecasts, produce information about existing and projected road conditions, and disseminate information and guidance to responsible persons and agencies. In addition to their use by highway agencies, these systems are also becoming part of intelligent transportation systems, or ITS, designed to aid vehicle operators.

(b) Discussion

For many state highway agencies, snow and ice control is the single most expensive item in the maintenance budget. The need to reduce costs is a major reason more than half of all states now use some form of RWIS. Participants cited significant savings for states employing this technology to monitor snowfall, icing, and other road conditions. Still other benefits include reduced environmental impacts of deicing chemicals and abrasives (because less is needed) and, of course, increased safety (though participants pointed out that this is extremely difficult to quantify).

Most recently, states have started to look at ways to communicate and display RWIS information to vehicle drivers as part of their ITS programs. The Idaho Storm Warning System, for example, will provide drivers with road visibility and weather information—such as warnings, speed advisories, and road closures—via changeable message signs. States also are demonstrating other dissemination techniques, including North Dakota's cellular-phone-based system, which will give drivers road condition information for up to 50 miles ahead, and Washington's Travel-Aid project at Snoqualmie Pass, which will employ in-vehicle communications and signing equipment in addition to variable message and speed limit signs.

However, despite growing acceptance of RWIS, a number of technological and other issues may constrain these applications—whether for ITS or for snow and ice control. A major technological limitation is the nature of most NWS local forecasts, which, according to participants, are often far too general to meet the unique needs of road users and maintainers. One state, Nevada, has even found it advantageous to hire its own meteorologist to enhance the NWS reports. Although NWS forecasts are indeed becoming more localized, the agency is neither charged with nor able to meet the specific needs of all weather service users. Nevertheless, road applications will benefit from a number of emerging service improvements, among them the NWS's LAPS and AWIPS and the FAA's ITWS. Moreover, participants pointed out that the NWS data itself may be enhanced in the future by local RWIS observations, which in turn would yield more accurate small-scale forecasts. Private vendors also will have a key role in creating tailored weather products for highway applications.

Another technological barrier to more widespread use of RWIS is the lack of compatibility among various manufacturers' communications systems. This lack of standardization prevents information sharing among different RWIS networks and severely limits potential ITS applications. The Department of Transportation is addressing this issue as part of an analysis of the overall communication protocols for ITS.

Beyond the technological constraints, a number of political and institutional factors may now limit RWIS applications. A primary issue is state agencies' budget limitations and the resulting need to justify the initial costs of an RWIS by demonstrating operational savings. Other problems at the state level are highway agencies' resistance to change and states' potential liability for accidents that do occur (particularly when ITS applications of RWIS are involved, such as changeable weather message signs or in-vehicle advisories). A number of participants also discussed the need for DOT and the states to understand fully drivers' functional requirements before committing to any specific RWIS/ITS application. Still another issue raised by participants was the need for greater coordination and information exchange among states and between states and DOT. One panelist, in particular, felt that it was DOT's role to inform states and other potential users of the applications, successes, and cost savings associated with RWIS.

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