# Executive Summary

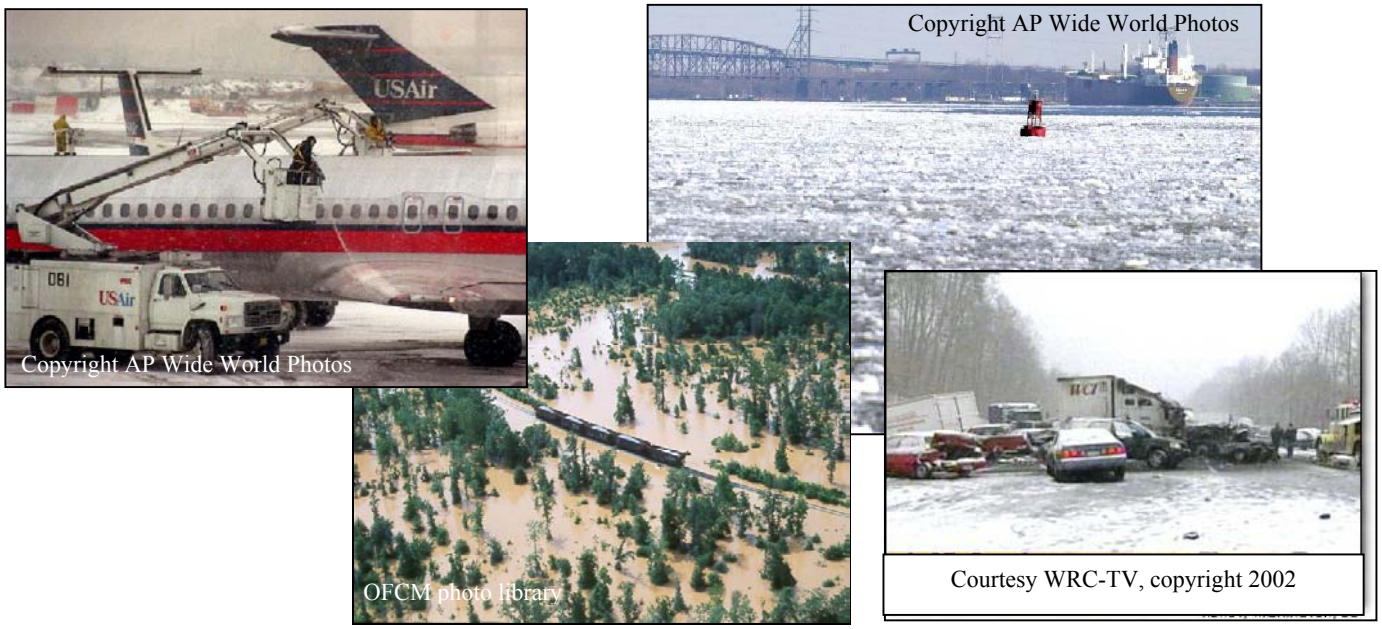
In 1998, a federal interagency committee identified the weather information needs of surface transportation sectors (including ground and marine transportation systems) as a priority for coordinated action. In response, the Office of the Federal Coordinator for Meteorological Services and Supporting Research undertook a study of existing and potential needs for weather information for surface transportation (WIST).

This report presents a compilation of these needs and analyzes them in the context of interests and concerns expressed in two symposia on WIST, plus many smaller meetings and interviews. Its purposes are first, to make the compiled needs accessible to the many audiences with an interest in WIST, and second, to suggest next steps in a coordinated WIST initiative. To achieve the second purpose, the report draws some general conclusions about WIST needs that cut across the six transportation sectors included in the study. It relates these conclusions to overarching themes present in the current transportation environment (Chapter 1) and confirmed by the compiled WIST user needs. These conclusions

**Surface Transportation Sectors**

This report covers six transportation sectors:

**Roadway—**state and federal highways, roads, and streets
**Long-Haul Railway**—rail lines providing intercity freight and passenger service, with their yards, stations, and depots
**Marine Transportation System**—coastal and inland waterways, ports and harbors, and the intermodal terminals serving them
**Rural and Urban Transit**—bus and van service on streets and roadways, rail lines for metropolitan subway and surface "light rail" systems
**Pipeline Systems**—Above and below ground pipelines for commodities such as crude oil, refined petroleum products, and natural gas, plus the storage, transfer, and pumping facilities for pipelines
**Airport Ground Operations**—All ground movement of vehicles, work crews, and passengers.




Weather can increase safety risks and economic costs, while disrupting the efficiency of systems in every surface transportation sector. Among the threats are (left to right) wing icing on planes before takeoff, hurricane flood damage to railbeds, ice on waterways, and winter weather on highways.

provide the basis for suggesting next steps in each of six strategic thrust areas for continuing the WIST initiative.

## Why We Should Be Concerned About Transportation Weather

The effects of weather on the nation's surface transportation systems touch our lives every day. Weather affects the safety, efficiency, and economic productivity of our transportation systems and facilities. According to a National Highway Traffic Safety Administration estimate, 7,000 fatalities and 800,000 injuries each year involve weather-related adverse road conditions as a factor. The Coast Guard attributes 7 percent of recreational boating accidents to weather. Weather has daily impacts on the goods carried by the nation's Marine Transportation System and its intermodal connections to rail, motor carrier, pipeline, and air cargo transportation systems. These impacts affect the transit time, delivery reliability, efficiency, and cost of all goods transported by these systems.

## Meeting WIST Needs—The Time Is Right!

We cannot control the weather or its effects on vital transportation systems. What we can do is ***use information about the weather more effectively in managing the operation of transportation systems***. We can mitigate or avoid the negative consequences of adverse weather for users of those systems, while getting the most value from benign weather conditions. Fortunately, the immense advances made in meteorological and environmental sciences, coupled with the twin technological revolutions in computing and digital-based communications, provide us with powerful new tools for delivering weather information to potential users across the surface transportation sectors.

**Costs of Roadway Weather**

Adverse weather is estimated to play a role, directly or indirectly, in 800,000 injuries and 7,000 fatalities annually resulting from vehicle crashes. This represents about 28 percent of all highway crashes and 19 percent of all fatalities. The estimated annual economic cost, just from weather-related crashes (deaths, injuries and property), amounts to nearly $42 billion. A study of the effects of snow, ice, and fog estimated that these weather conditions caused 544 million vehicle-hours of delay on highways in 1999.

As an example, forecast-activated anti-icing pretreatment has been tested on a 29-mile length of Idaho highway that is frequently icy in winter. The test resulted in a 62 percent reduction in road maintenance labor hours, an 83 percent reduction in abrasives used to improve traction, ***and an 83 percent decrease in crashes***. A road weather service system in Finland for both road maintenance personnel and road users has an estimated cost–benefit ratio of approximately 1 to 5 for snow and ice control.

As these examples show, the answer lies not simply in providing more and more data; the information conveyed by the data must be useful. It must be timely and accurate enough for decision makers to rely on it when each decision can be costly in terms of both safety and economic consequences. These requirements merge in two ***key challenges*** to be met by current and emerging capabilities for delivering WIST to users:

- **WIST is for decision support**. Transportation system managers, infrastructure operators and maintenance personnel, vehicle operators, shippers, and travelers—the

entire gamut of potential WIST users—need WIST as one factor in often complex decisions about their actions.

- **WIST users have diverse needs.** Because the kinds of transportation-related decisions made by WIST users differ, as do the circumstances in which decisions must be made, the information content and its attributes vary from user to user.

## Identifying and Validating WIST Users' Needs

This report presents a compilation of needs for weather information that have been expressed by, and validated by, existing and potential users of that information from the affected surface transportation communities. Representatives from those communities were asked:

- Which specific weather elements (a weather event or a condition affected by the weather or related environmental factors) can affect their activities?
- What information about those weather elements (spatial scale, thresholds of severity or proximity important to decisions, timing of onset and duration) would help the operators and users of those transportation systems to ameliorate negative consequences and exploit positive consequences?
- When is the information needed (the lead time of forecasts or the currency of observations) to be most effective in supporting the decision processes of transportation system managers, travelers, and others who decide on transportation activities?

This report presents weather information needs expressed and validated by existing and potential information users from surface transportation communities. These user-derived information needs are compiled in the WIST Needs Templates in Appendix B.

Appendix A identifies the entities from the public and private sectors that participated by providing answers to the above questions through an initial questionnaire and a more detailed follow-up survey. The data provided by these information users on their existing and potential needs for WIST were compiled as a set of WIST Needs Templates, which constitute Appendix B. The draft template for each transportation sector was validated with many of these same information users. Their comments were used to produce the final set of templates included with this report and incorporated in the report's analyses and conclusions.

## Cross-Sector Conclusions from Analysis of WIST User Needs

The analyses of the compiled WIST needs (discussed in Chapter 4), together with the detailed discussions with WIST users during the WIST symposia and the template validation process, support five conclusions that apply to all six of the transportation sectors for which user needs were identified.

### Conclusion 1. Users recognize the value of weather information.

During the WIST needs study, decision makers, regulators, and operators across the spectrum of transportation activities confirmed the value of ***appropriate*** weather information for

In a 2002 survey of potential users of "511" traveler advisory services, road weather and road surface conditions were most frequently identified as the most critical component for this service.

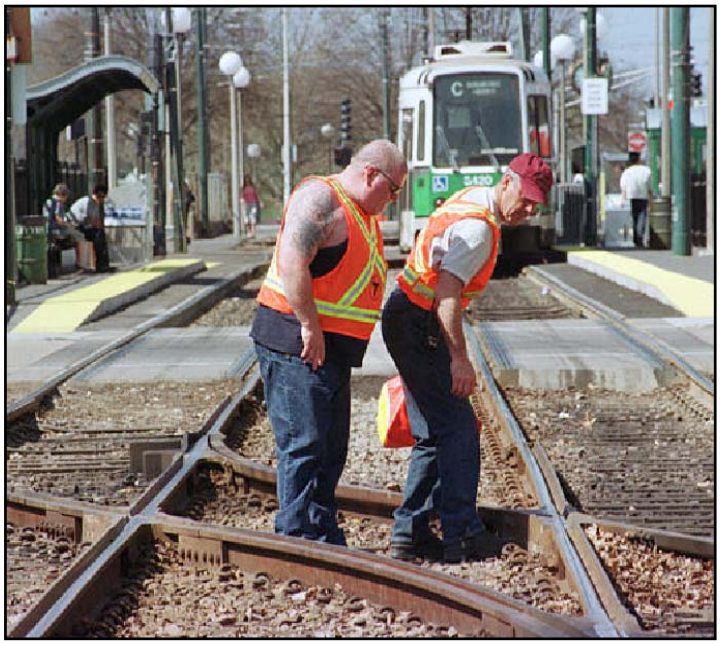
improving safety and enhancing the efficiency and effectiveness of their activities. Highway maintenance managers concerned about freezing precipitation, pipeline operators worried about hurricane-induced tidal surge, and vessel captains concerned about keel clearance in shallow water must take actions whose consequences depend critically on ***accurate and timely*** knowledge of weather and related conditions. The value of accurate and timely weather information is well recognized throughout the surface transportation user community.

### Conclusion 2. Users want information tailored to their activities.

In every transportation sector, users stressed the importance of getting weather information tailored for the activity or decision-making process for which they are responsible. They want detailed, location-specific forecasts and situation reports. They also need multiple ways of getting the information—from radio and television, the Internet and other electronic data links, and other communications media. Repeatedly, users stated needs for information that is much more precise, focused, and relevant to their operations. They want higher resolutions, both spatial and temporal. At the same time, they demand better accuracy in the forecasts.

### Conclusion 3. WIST needs cover a variety of weather elements, user activities, thresholds, and lead times.

The WIST needs validated by the surface transportation user communities encompass many diverse weather elements, including a range of important environmental conditions that depend on "the weather" as commonly understood but that are not viewed as meteorological parameters. Examples include ground surface and rail temperatures, wave height and tidal predictions, and air quality. The WIST needs also cover a broad range of desired lead times and action thresholds for various user activities within each transportation sector.



Trackwalkers inspect a transit line track switch for warped rails on a hot day in Massachusetts. Copyright AP Wide World Photos.

### Conclusion 4. Users differ in their knowledge of weather impacts and awareness of WIST sources.

Within each transportation sector, there were users with a clear understanding of how information on weather and weather-related conditions could make a difference in the efficiency and effectiveness of their operations, as well as users with lesser degrees of awareness. The latter category of users knew how ***the weather*** affected their operations; they just had not considered how ***better information about the weather*** would be useful. In many instances, once users had an opportunity to discuss the subject, they quickly saw how timely and more accurate weather information could be of benefit.

Users also varied widely in their knowledge of what weather information was available and where they could get it (information sources). Education of potential WIST users, including interactions between the users and providers of weather information, must be part of the WIST service delivery process. Providers must also understand users' decision contexts and provide information that supports the real-life decisions to be made.

### Conclusion 5. Significant differences exist between and within transportation sectors.

The user groups that participated in the WIST needs study come from across the nation; they represent the full geographic and climatic spectrum of the United States. Consequently, there is significant variation in specification of WIST needs, both between the transportation sectors and within a sector. These variations affect which weather elements are important and the thresholds at which the user needs information to make key decisions. Chapter 4 includes a sector-by-sector analysis of what users reported about the impacts of weather elements on their activities and the mitigating actions they could take.

## Goals and Next Steps for WIST Strategic Thrust Areas

Chapter 5 defines one or more goals in each of six strategic thrust areas for continuing a coordinated WIST initiative. Next steps are suggested to move toward these goals.

### Strategic Thrust Area 1: Identifying and Specifying the Gaps in Coverage of WIST User Needs

The first strategic thrust area for continuing the WIST effort is to determine where there are gaps in coverage of WIST user needs and how a diverse provider community—comprising both public and private sector providers—can address them. A joint effort is needed to determine which needs are not fully met and how the resulting gaps should be addressed.

**Goal for Identifying Gaps in Coverage of WIST Needs.** Identify validated user needs for surface transportation weather information that cannot be met with existing information resources of the public–private provider community. Determine whether technology development in progress will meet the need or if additional technical development and/or research is needed.

**Next Step 1A.** Establish a task force to:

- Ascertain (1) which WIST user needs in the initial baseline compilation are fully met now, (2) which could be met more fully through improved presentation and interpretation of current observational and forecast data, and (3) which require data that are not yet available or that have attributes (e.g., accuracy, spatial and temporal scale, timeliness) beyond what is now available
- Review and sustain or adjust priorities for research programs and for transitioning promising tools and other technologies into operations

- Support agency processes to validate and update user needs and provider community programs and approaches for addressing them.

**Next Step 1B.** Sustain and expand the dialogue between the meteorological community as information providers and surface transportation communities as information users.

**Next Step 1C.** Use the baseline of WIST needs represented by the templates developed during this study as a work in progress, to be refined, extended, updated, and validated by the participants in a continuing assessment of where capabilities can be delivered that fill an identified gap or enhance value.

### Strategic Thrust Area 2: Expanding Coordination Among WIST R&D Programs and WIST Providers

To accelerate the application and use of new or emerging technologies and capabilities for WIST support, technology transfer processes (concepts, capabilities, practices, and tools) linking the government and private sectors need to be enhanced. Work to be done in this area includes more, and better, coordination and agreement among federal, state, and local governments and the private sector on the provision of data and services. The guiding principle for expanded coordination and partnering must be to transfer the results of research and development (R&D) programs, typically funded with federal support, to whichever entities are most capable of implementing effective and efficient delivery of WIST services and products to the users.

**Goal for Coordinating R&D and Technology Transfer.** Expand and improve the coordination and communication among both WIST-relevant R&D programs and field implementation programs and projects aimed at incorporating WIST elements in the decision processes and decision support systems used by transportation activities in all sectors. New and expanded partnerships among government entities, the private sector, the academic R&D community, and public-private entities for provision of WIST services and products should aim at increasing the efficiency and effectiveness of translating R&D results into operational value for WIST users.


Traffic advisory signs, like this one in Atlanta, represent an initial step toward intelligent transportation systems with route weather information. Copyright AP Wide World Photos.

**Next Step 2A.** Coordinate the WIST-related R&D research efforts and technology transfer programs of federal agencies, including but not limited to the U.S. Weather Research Program, the national Intelligent Transportation Systems research efforts, and a WIST R&D Program as proposed in this report. Transfer of research results and technology demonstrations to operational capabilities, services, and products available to WIST users should be a major component of this expanded coordination effort.

**Next Step 2B.** Prepare for and form strategic partnerships and alliances among government entities (federal, state, and regional/local), the private sector, the academic R&D community, and public-private entities.

**Next Step 2C.** To provide the legislative basis and funding support for expanded coordination, the provider communities, with the support of the WIST user communities, should give immediate attention to:

- Reauthorization of the U.S. Department of Transportation surface transportation program under the Transportation Equity Act for the 21st Century (TEA-21).
- Full support for the Marine Transportation System as proposed by the Marine Transportation System National Advisory Council and the Interagency Committee for the Marine Transportation System.

### Strategic Thrust Area 3: Clarifying and Defining Provider Roles and Responsibilities

The primary roles in providing weather information for surface transportation are shared among a diverse array of partners in the public and private sectors. In the public sector are federal entities and a large number of state and local government activities. In the private sector, commercial entities sell value-added meteorological services and products. An even larger set of commercial entities provides general information and communication products or services, in which WIST is now or could be incorporated. Partnerships and alliances are critical in this environment, where thousands of entities have roles in developing, maintaining, and operating the nation's transportation system.

A significant barrier to improving the products and services available to WIST users is that the roles of federal entities versus those of state and local governments or the private sector are neither clear nor consistent. Continued cooperative efforts by all parties in the WIST provider community will be necessary to resolve these conflicts and fill gaps in the service, guidance, and regulatory structures that influence delivery of weather information to WIST user communities. Explicit policy guidance on the roles and responsibilities of public and private sector participants in providing and tailoring weather information would provide a solid basis for expediting provision of new and improved products and services to WIST user communities.

**Data Standards and a National Data Collection System.** The means of generating, obtaining, transferring, and applying weather information are not standardized at present. This lack of standards significantly hinders dissemination and application. Nonstandard or erratic updates to observations and forecasts undermine the value of weather information for transportation-related decision processes and systems.

A nationwide collection of local weather data does not exist and has not been mandated. These data are usually of greatest value locally, but ideally they should then be passed to a national collection location, where the data can be subjected to quality controls, aggregated, synthesized, and archived. The Cooperative Observer Network, operated by the National Oceanic and Atmospheric Administration's National Weather Service (NWS), is a nationwide weather and climate observing network that, when modernized, will provide a useful framework for more extensive national collection and integration of weather and environmental data from regional mesonets.

**Goal for Data Standards.** Provide guidance on the roles and responsibilities of the public and private sectors for various types of observations and networks, particularly in light of better understanding of the accuracy needed to support the nontraditional weather/environmental elements and the new higher-resolution observation and modeling products required by WIST users.

**Goal for Nationwide Data Collection.** Integrate proliferating surface weather observations and networks and incorporate their data into a nationwide data system. This data system should provide access to related geophysical data of value to surface transportation operations. This effort should address:

- Equipment (measurement/sensor adequacy and accuracy, siting criteria, calibration, metadata, and legacy systems)
- Communications protocols and standards
- Data standards for quality control, accessibility, compatibility, interoperability, and archiving.

**Next Step 3A.** Determine the roles of NWS and/or other public and private sector partners in pursuing the above goal for nationwide data collection.

**Next Step 3B.** Address issues of observation standards and protocols, equipment siting, data collection, processing, archiving, access, and proprietary data through the use of a task force or similar action group.

**Next Step 3C.** Examine, test, and implement operationally current and emerging technologies for system definition and transition, system optimization, modal optimization, and environmental considerations.

The National Weather Service maintains automated surface observation systems, like this one, at airports and other locations across the nation. Local and regional mesonets provide more detailed coverage over limited areas. Courtesy NWS, Medford, Oregon.

**Value of an Open Systems Approach for WIST.** A WIST information network will have many providers of services and products and will serve a diverse community of consumers. For this network, there are technical advantages to open systems architectures for communications and interfaces. Decision support tools can be implemented as an application layer on top of this open-

systems foundation. The national Intelligent Transportation System (ITS) architecture can provide a starting point for discussing technical issues of data management and accessibility (e.g. format standards) for WIST communications. There must also be attention to security issues, including protecting the integrity of shared data resources and managing the risk that open information will be used in hostile actions.

**Goal for Open Systems in WIST Communications.** Resolve the technical aspects of providing open access to weather information in a manner that benefits diverse WIST users fairly, while providing commercial or mixed public-private value-added suppliers with a level playing field and reasonable incentives for participating. Address issues of data system security.

**Next Step 3D.** Work toward full compatibility of transportation-related communications and information systems with the national Intelligent Transportation Systems architecture.

**Next Step 3E.** Establish a task force to develop a security strategy for national weather information networks, addressing issues of data integrity and the balance between open access to data and restrictions to avoid hostile use of data systems and resources.

### Strategic Thrust Area 4: Translating Research Results and New Technologies into WIST Applications

A number of currently unmet WIST user needs can be met in the near term (within 5 years) through applied research or development of technology applications. Some of these technologies incorporate advances in observing or forecasting meteorological parameters, others involve weather-affected conditions, such as black ice on highways or railbed ground heave. Still others involve information technology and software to make WIST data easier to incorporate and apply in users' decision processes. For these areas, translating research results and science into practical information for users is the primary objective.

Icy conditions after a March 9, 2002 storm in Nebraska caused this trailer truck to jackknife on Interstate 80. Technology is now available to detect black ice that drivers cannot see. Copyright AP Wide World Photos.

Decision support systems will need to incorporate techniques for working with the predictive uncertainty inherent in high-resolution forecasting at longer lead times. For a number of

activities in the surface transportation sectors, an accurate forecast of favorable weather is often just as important as a forecast of adverse or mission-limiting weather.

There are significant near-term opportunities to translate technology advances into operations supporting the Marine Transportation System. One key to reducing risks while increasing efficiency in this vital transportation system is to invest in the information infrastructure that supports it. This infrastructure includes weather predictions and forecast models that use both meteorological and oceanographic data to forecast conditions for navigation.

The U.S. Weather Research Program, a partnership of federal entities with the academic and commercial communities, plays a key role in providing the fundamental knowledge and application development that feed the ongoing stream of new meteorological technology from the modernization of the National Weather Service. This research program has substantial value as an umbrella program through which all federal entities with weather-relevant program objectives contribute resources to a coordinated R&D effort. However, the limited portfolio of the U.S. Weather Research Program, together with its emphasis on research rather than operational implementation, constrains its capability to serve all the WIST R&D needs of federal agencies. The range of R&D required, and particularly the specificity of applications tailored to the needs of the surface transportation communities, argues for a separate ***WIST R&D program***. This program would address issues relevant to weather impacts on surface transportation (all sectors) and to improving the capability to move meteorological and other weather-related information into users' decision processes.

R&D programs under a number of federal departments and agencies also provide technology for various surface transportation communities. Greater coordination of the R&D effort across these intramural programs, in conjunction with an interagency WIST R&D Program, would leverage the federal investment in improving and expanding WIST. Cooperative planning and participation by all levels of government, the university research community, and the private sector can leverage the investments made in research to obtain the greatest benefit for and from the transportation systems of the future. The WIST R&D Program should include mechanisms for transitioning research results and new technology into WIST applications. Special attention should be given to leveraging research that has linkages, synergy, or applications in other high priority programs such as homeland security.

**Goal for Translating R&D into WIST Applications.** Establish a WIST R&D Program. This program should be coordinated with and complement the U.S. Weather Research Program, as well as other R&D programs in transportation weather, including work in progress, planned, or funded by federal entities, state and local public sector entities, universities, or private sector organizations.

**Next Step 4A.** Users and providers need access to information about the technology developments and research initiatives relevant to their WIST needs.

- This information must be structured and presented in ways that allow users to understand how they can best exploit available and emerging technology and information resources.

- Access to the information can be facilitated through interdepartmental cooperation at the federal level, coupled with strategic partnerships and alliances within and among the weather information provider communities of the public and private sectors.

**Next Step 4B.** The federal partners in the Federal Committee for Meteorological Services and Supporting Research (FCMSSR) should propose a significant, cohesive research and development program that will provide the basis for improved, integrated weather information, tailored to supporting users' decision processes across all surface transportation sectors and activities.

### Strategic Thrust Area 5: Providing the Fundamental Knowledge to Support Future Technology Development and Application

There are areas in which our fundamental knowledge of weather phenomena is too limited to provide all the information WIST users need, when they need it. If these needs are to be met, fundamental research is needed that is oriented toward filling in the gaps in what we know. Over the next decade, additional and substantial benefits to the nation, in terms of safety, reduced economic losses, and increased productivity, are possible with (1) better spatial and temporal resolution in both forecasts and observations and (2) better forecast accuracy.

The spatial and temporal resolution of weather information needed for surface transportation applications in general and for decision support systems in particular is typically in the misoscale horizontally (grid spacing of 40 meters to 4 km) and in a very shallow layer vertically (from ground level to about 2 meters above it). To meet operational time lines, updates must be rapid—on a scale of minutes to hours—and coupled with lead times of 48 hours. These spatial and temporal requirements present formidable scientific challenges. Meeting them will require improved understanding in areas such as boundary layer meteorology, misoscale thermodynamics, the effects of small local variations, probability and statistics, high-resolution numerical modeling that includes land-air-water interactions, the verification and quality control of nonstandard data, and the preparation and communication of probabilistic forecasts. Processing data at these finer scales will require expanded computational capabilities.

**Goal for Providing the Fundamental Knowledge Base.** Identify and support fundamental research representing a longer-term investment in acquiring the knowledge base needed to meet important WIST user needs that cannot be fully satisfied on the basis of current knowledge.

**Next Step 5a.** Include in the coordinated R&D programs for WIST a substantial level of fundamental research with ***strategic potential for expanding the fundamental knowledge*** needed to meet WIST users' needs.

**Next Step 5b.** The federal agency partners in the FCMSSR should present a unified rationale to Congress and the Administration for the strategic potential of the fundamental research topics included in the WIST R&D Program and other coordinated R&D programs, similar to what has been done in the past for the U.S. Global Change Program.

## Strategic Thrust Area 6. Expanding Outreach and Education

There are major cultural differences between the meteorology and transportation disciplines. Users need assistance and training to achieve maximum benefit from applications of weather information. To help with educating WIST users, universities can offer surface transportation weather courses in programs for transportation management degrees. Training programs for users and managers of transportation systems that provide emphasis on weather factors and the use of weather information will benefit the transportation industry and its consumers.

At the same time, those with training in the meteorological and environmental sciences, as well as expertise in the technologies and techniques of observing and forecasting weather and related phenomena of concern to WIST users, must do better at communicating the significance of their knowledge and technology to the users. Courses in both degree programs and continuing education programs will help meteorologists and other scientific specialists understand surface transportation systems and management processes. This formal training in the conceptual frameworks, operational environments, and technical systems within which transportation decision makers work can be coupled with direct experience working with the user communities.

As traveler-oriented weather information services evolve, the general public needs to be informed about them. Broad support for WIST initiatives can be fostered by communicating the values of WIST, in improving both transportation safety and economic efficiency, beyond just transportation system managers and operators.

**Goals for WIST Outreach and Education.** (1) Incorporate mechanisms for education of potential WIST users, including interactions between the users and providers of weather information, in WIST service delivery processes. Include current information on WIST applications and the value of WIST in transportation systems operations in the training for surface transportation professionals. (2) Provide and promote educational opportunities for meteorologists and related professionals to learn about surface transportation systems where weather and related environmental information can improve system performance. (3) Include information about WIST applications and ways that the public can access and use WIST in their

Hands-on training with state-of-the-art meteorological information systems is part of this course conducted by the Cooperative Program for Operational Meteorology, Education, and Training (COMET), funded by the NOAA National Weather Service. Photo courtesy COMET and NOAA.

own transportation activities in "weather education" outreach to the general public and in school weather education programs.

**Next Step 6.** Conduct a WIST Education Forum on the status of, and directions for expanded efforts in, education, training, and outreach for delivery of services and products to meet WIST user needs. There should be broad participation from the provider and user communities, as well as from the FCMSSR partners. Include topics on:

- Mechanisms for education of WIST users
- Opportunities for meteorologists and related professionals to learn about surface transportation systems
- Outreach to the general public through the media and school programs.