The WeaTher Wizards

By Mike Haenggi

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Airmanship

Pilots are generally pretty savvy about the weather. We can decode METARs and TAFs, get satellite weather pictures, and understand NEXRAD radar images. Most of us even remember how to read winds aloft, constant pressure analysis, and composite moisture stability charts. You remember what a K-index is, right? We all know that forecasting the weather is not an easy thing to do. You have to predict the movement of trillions of air molecules influenced by more than enough variables to make your head spin. Short-lived atmospheric events are difficult to study because no one can predict precisely where they'll occur next. If you try to study them when they pop up, they're often gone before you get there. And large climate models are so complex they challenge the fastest supercomputers.

The National Center for Atmospheric Research Mesa Laboratory is located on Table Mesa along the Front Range of the Rocky Mountains in Boulder, Colo.

But scientists aren't giving up. In fact, they're making great progress. The National Center for Atmospheric Research (NCAR) in Boulder, Colo., is a federally funded research and development center tasked with studying the weather. It is the place where government agencies and universities turn when they need facilities, equipment, aircraft, supercomputers, and scientists to conduct weather and climate research. Timely weather information and specialized forecasting tools are in great demand. Government clients for NCAR include the National Oceanic and Atmospheric Administration, NASA and the Departments of Defense, Energy, Commerce and Agriculture to name just a few. Whether you're launching a satellite, forecasting next year's soybean crop or planning an amphibious assault, you want to predict the weather as accurately as possible. The FAA, through its Aviation Weather Research Program, uses NCAR services, too. The NCAR laboratory that does most of the work for the FAA is the Research Applications Laboratory (RAL), which aims to improve the timeliness, accuracy and presentation of aviation weather information to better warn of atmospheric hazards. If science is to be truly useful to society, there must be a strong connection between scientific work and the needs of the end users. RAL's work doesn't just get published in some obscure weather journal that only scientists read. End-user requirements are considered at each step as projects evolve. RAL works closely with pilots and aircraft operators to learn what weather issues create the biggest problems, then it develops tools to help actually deal with them. Since RAL's foundation, most of its work has been heavily oriented towards real-time, operational systems.

Microbursts

Microburst blowing dust

The first problem they tackled was to create an operational system to warn pilots about microbursts. Bruce Carmichael, Director, Aviation Application Programs at RAL, explains, "RAL got started in the early 1980s with a microburst and windshear program. Back then there were quite a few accidents involving Part 121 operators getting caught in a microburst and losing an aircraft. However, people didn't really understand what a microburst was. It was still a mysterious phenomenon. So the FAA came to NCAR and asked us to do a research program to try and figure out what was going on. "It was from this effort that the notion of the microburst emerged. With FAA funding, NCAR scientists conducted the research to define what microbursts are and determined what causes them. From there we figured out how to detect them, then devised a way to get out alerts and warnings to the aviation community if they were around. The research resulted in three different airport-based systems we now use to detect and alert for microburst and windshear. These are the terminal Doppler weather radar, the low-level windshear alert system, and the windshear processor, which is an add-on function to the ASR-9 air traffic control radar." From a scientific perspective, the microburst problem was pretty well solved by 1991. The program was a great success, and its legacy and equipment continue to contribute to safer flying today. Meanwhile, RAL researchers and scientists moved on to study other aviation weather problems. Today the laboratory is one of the largest within NCAR, with 180 meteorologists and software engineers conducting weather research. Current projects include in-flight icing, snowfall and freezing precipitation, convective storms and rainfall, atmospheric turbulence, precipitation physics, ceiling and visibility and oceanic weather. Work is also being done on numerical weather prediction, remote sensing, verification methods, data assimilation, surface hydrology and land-surface modeling. All of these areas have been given priority and funding by NCAR and the FAA for further research with the aim of improving aviation safety. In each program, RAL's goal is to provide solutions that pilots can actually use. As weather issues are solved, or improved methods are devised to warn the aviation community of hazardous weather, the results are typically communicated directly to aviation users via National Weather Service and the **ADDS Web site**.

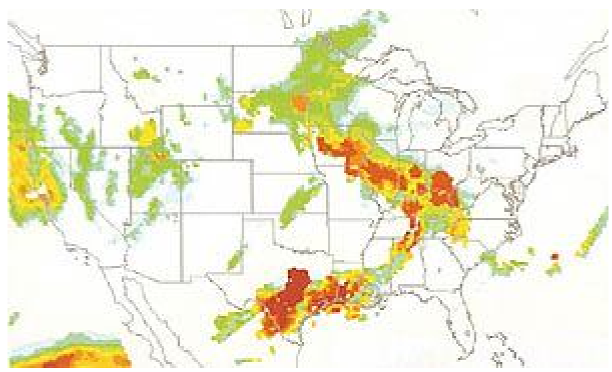
ADDS

ADDS Home Page

The Aviation Digital Data Service (ADDS) is the main public face of the aviation research funded by the FAA. ADDS is a Web-based, real-time, aviation-weather dissemination system that provides aviation decision-makers (pilots and dispatchers) with easy, inexpensive, real-time access to the latest operational aviation weather observations and forecasts. Users can view and retrieve aviation weather in a variety of formats and tailor it to fit their individual needs. The users can view and print text and graphics products, or interactively query the ADDS site by running Java applets in their Web browsers. Prior to ADDS, the only sources of official aviation weather information were older, text-based systems that required multiple pages of computer printout or speaking by phone with a specialist in an FAA Flight Service Station. With the text-based system, pilots had to read or listen to a series of cryptic airport or navaid identifiers and mentally connect the dots to construct a polygon to determine the boundaries of weather advisories. With ADDS, pilots see maps with the outline of predicted hazardous areas clearly marked; other maps show temperatures and winds in different colors for easy interpretation. A flight-path tool displays a vertical cross-section of weather conditions along the pilot's proposed route. While the ADDS Web site is extremely popular with general aviation pilots, NCAR was surprised to learn it also had other fans. Carmichael explains, "When we built ADDS, we always believed that general aviation would be the primary user. But when we started looking at where the hits were coming from, we were surprised to find the number one user of ADDS happens to be the military. We get more hits from the military than anybody else, particularly the Air Force. We were also surprised to find that several major airlines are also big users. If you go into Delta Airlines Dispatch in Atlanta, for example, you will see ADDS up on virtually every workstation." Most everyone appreciates the simple interface and graphical weather products that ADDS provides. A few clicks of the mouse and you can have a comprehensive picture of the weather along your route and altitude you intend to fly. As you dig deeper into ADDS, you begin to see how scientists are trying to help the aviation community tackle its biggest weather challenges. Icing and turbulence are hazards to pilots. The FAA funded several NCAR programs to create sophisticated algorithms to predict icing and turbulence and output them into simple graphical forecasts on ADDS. A closer look at these products provides some insight into how NCAR works to benefit the aviation community.

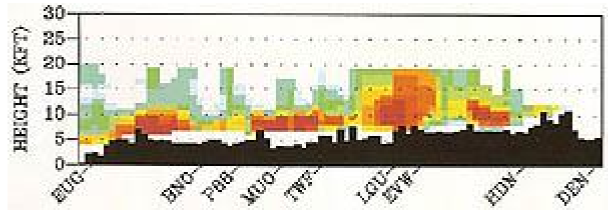
Current Icing Potential

The current icing potential (CIP) is an online display of high-precision maps and plots, updated hourly, that identifies areas of potential aircraft icing produced by cloud droplets, freezing rain and drizzle. To create CIP information, NCAR scientists had to develop new methods and software for detecting and forecasting icing potential in the atmosphere. The information is derived from surface observations, numerical models, satellite and radar data and pilot reports, which is then output to a set of grids describing current icing conditions. "CIP helps identify areas of potential icing so pilots can feel more confident about choosing a flight path," says NCAR's Marcia Politovich, head of the FAA's In-Flight Icing Product Development Team. "It will most benefit commuter planes and other propeller-driven aircraft. Smaller aircraft are more vulnerable to icing hazards because they cruise at lower, ice-prone altitudes. They also often lack the mechanisms common on larger jets that prevent ice buildup by heating the front edges of wings." The FAA approved CIP as a tool for dispatchers to make fly/no-fly decisions and for flight planning, route changes, and altitude selection. CIP supplements but does not replace the forecast or intensity information in AIRMETs, the traditional icing alert issued at six-hour intervals. Once NCAR scientists had the CIP tool in place for depicting current icing conditions, the next step was to create an icing forecast.



The Current Icing Potential (CIP) combines sensor and numerical model data to provide a three-dimensional diagnosis of the icing environment. CIP output consists of a likelihood field ranging from 0 (no icing) to 100 (certain icing). This chart is for 18,000 feet, and depicts severe icing potential over central Texas and in a line extending through Iowa, Illinois, and Indiana.

Forecast Icing Potential



Using the flight path tool, users can also view Current Icing Product information in a profile view. This cross-section of flight from Eugene, Oreg., (EUG), to Denver, Colo., (DEN) enables you to quickly see that by flying at 25,000 feet or higher, you will have the best chance of avoiding the ice.

With the Forecast Icing Potential (FIP) tool, pilots can make themselves aware of expected icing hazards along their route up to 12 hours in advance. FIP provides a high-tech, color, weather map and a flight-route display of icing potential at flight levels from 3,000 to 18,000 feet. The algorithm analyzes weather data from a vertical column perspective. It determines the cloud top and base heights, checks for embedded cloud layers, and identifies precipitation types. Once the likely locations of clouds and precipitation are found, the physical icing situation is determined, and a fuzzy logic method is used to determine the icing potential. Every three hours the model generates forecasts out to 12 hours. The user can select forecast times from three-, six-, nine-, and 12-hour intervals to plan safe routes of travel. "One of the best ways to manage the effects of bad weather is to avoid it altogether," said FAA Administrator Marion Blakey. "With information provided by this automated tool, pilots flying aircraft under 18,000 feet can make critical flight decisions."

Graphical Turbulence Guidance

Kelvin-Helmholtz waves can be a sign of severe turbulence. They are formed between two layers of air with different densities, traveling at different speeds. When the wind shears across the two layers, strong eddies develop along the boundary. (Credit: Benjamin Foster via University Center for Atmospheric Research)

Turbulence, like icing, also poses a significant threat to aircraft. Pilots learn to expect turbulence around convective weather, but are continually blindsided by clear-air turbulence. NCAR's graphical turbulence guidance (GTG) product is an automatically generated turbulence chart that predicts the location and intensity of clear air turbulence over the continental United States between 10,000 and 45,000 feet. The GTG was developed by the NCAR Turbulence Product Development Team and implemented by the National Weather Service as a supplement to turbulence AIRMETs and SIGMETs. The target audience for the GTG product includes pilots, airline dispatchers, aviation meteorologists, the FAA and other government agencies and other interested aviation users in the general public. Algorithms combine domestic pilot reports (PIREPs) and lightning data to produce an upper-level clear-air-turbulence predictor. GTG uses a computational scheme that assigns a weighting function to twelve operationally used and tested turbulence forecasting tools. The GTG product then maps each of these tools to a common scale, and the chart is computed from numerical weather predictions at the time of publication. Out of this complex process comes an easy-to-read, color-coded chart depicting areas where clear-air turbulence is most likely to occur.

Future ADDS Tools

If you want to see what new tools NCAR has in store for the future, you can go to the **ADDS Web site** and click on "Experimental ADDS" to see what's coming down the pike. The goal of the Experimental ADDS site is to rapidly release new and improved aviation weather products to the aviation community, and allow scientists to involve end-users at an early stage in the development cycle. For example, a recent Experimental ADDS test was the evaluation of a new flight path tool. The old flight path tool uses a Java Applet to show you weather and icing conditions along your flight path and also gives you a profile view of the conditions along your route. The problem is it requires a pretty high-speed Internet connection to get all the data in a timely fashion. The new flight path tool is much faster and more flexible because it is an application that you download once and let reside on your computer. Each time you go back to get weather information, all it has to do is get the data. It also remembers your preferences and preferred viewing style. If the new flight path tool passes its trial, it will be moved to the operational ADDS site. Then both versions will be available to users. "Experimental ADDS is the Skunk Works where we put up new weather tools, let people kick the tires and then give us feedback," says Bruce Carmichael. "When the tools are ready we transfer them to the National Weather Service in Kansas City, where they are put onto the operational ADDS site."

Tomorrow's 4D Weather

Looking further into the future, NCAR is moving to a whole new way of thinking about weather. Four-dimensional grids (latitude, longitude, altitude, and time) will be used to track the location and time of all existing weather conditions and forecasts. It's a different way of thinking for weather researchers. Most are accustomed to polygons on a map and some text that describes what is happening within that box. With 4D grids, all weather information is standardized into a logical coordinate system. "Let's say you're planning a flight at 10,000 feet, flying from Kansas City to Denver," says Carmichael. "With 4-dimensional data we can actually generate something graphic. You can say, 'Give me a plan view for 10,000 feet so I can see what sort of weather my intended route passes through.' Or, 'Show me the vertical profile, and let me see what level the icing is at in relation to the terrain I'll be flying over.'" The aim is to have 4D grids become the official product of the National Weather Service. Then researchers can create tools for slicing things up however they want to visualize it. Future cockpits and air traffic management systems will use the 4D weather data to automatically calculate the best headings and altitudes based on the weather data being fed to them. They may even incorporate weather hazards into cockpit synthetic vision systems. Changing to a 4D weather system comes with a significant hurdle. Carmichael explains, "One of the challenges of implementing this system is that weather scientists are never going to get the forecasts 100-percent right. Forecasts continue to improve and they will get better, but they are always going to contain errors. As more and more researchers admit this, we are coming to the realization that aviation is going to have to deal with probabilistic weather. "Probabilistic weather is hard for pilots to get their minds around. Everyone prefers a binary forecast. Either yes there is icing, or no there is not. Unfortunately, with weather, it's not a matter of yes or no. Pilots already recognize this when they look at an icing AIRMET. It's translated into a polygon on a map, but you know there's a chance you can fly through the polygon and not see ice anywhere. You could also pick up ice right outside the polygon. Even though drawing the polygon makes it a binary situation from a regulatory standpoint, from a real-life standpoint it's just not. "So what we're doing now is recognizing that and saying in the future we are going to describe things in terms of probabilities, and it will be up to decision support systems to evaluate and combine the probability information and make the best recommendation. It's becomes a risk-minimization problem. "We are now learning how to produce reliable probability forecasts. By that I mean, if we say probability of 50 percent at this grid point of something happening, then if we have 100 cases, 50 times it will happen and 50 times it won't. The people who are building weather-decision support systems are going to have to learn how to take a reliable probability forecast and merge it with an algorithm to produce the kind of aid that a pilot or dispatcher or controller needs to do their job. "This is a whole new experimental area." If all this talk of probabilistic weather and 4D grids sounds complicated, you may be wondering how you'll keep up during routine pilot briefings. Don't worry. Computerized decision support systems will crunch all the probabilities, present you with an executive summary of the weather, and even recommend the safest route. And if you want to read the full weather report, or zero in on individual details, it will only be a click away. But just so you know, if you really start trying to make sense of it all, you might just dig your way down to those same fundamentals found in today's composite moisture stability chart. You do remember what a K-index is, don't you?