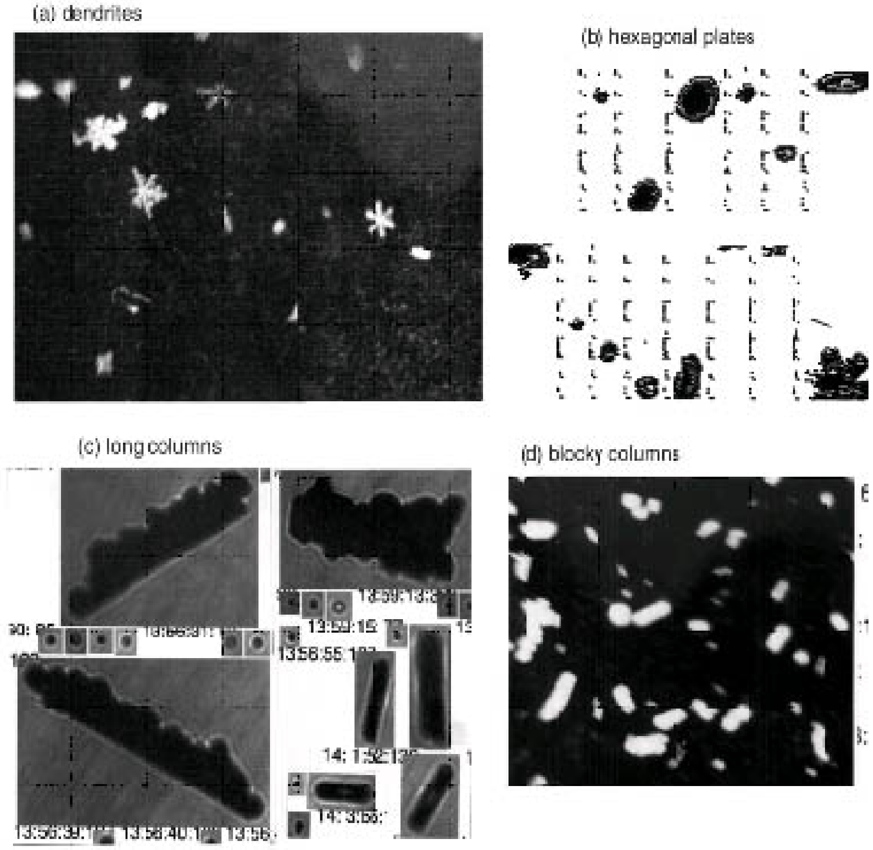
NEW REMOTE SENSING SYSTEM DETECTS HAZARDOUS IN-FLIGHT ICING CONDITIONS IN CLOUDS

April 12, 2002 — According to recent FAA surveys, aircraft crashes due to icing claim about 30 lives, injure 14 others, and result in $96 million in property damage annually in the United States. Icing conditions also disrupt air traffic operations over wide areas. The most serious icing conditions result from supercooled large droplets (SLD), which are chilled to temperatures below 0 degrees Celsius without freezing. Although freezing rain can certainly be a hazard, evidence from cloud physics research using aircraft and wind tunnels shows that the danger posed by SLD can be more serious. These drizzle-sized cloud droplets are called "large droplets," but they have diameters of only 0.05 to 0.50 millimeters and are still much smaller than raindrops.

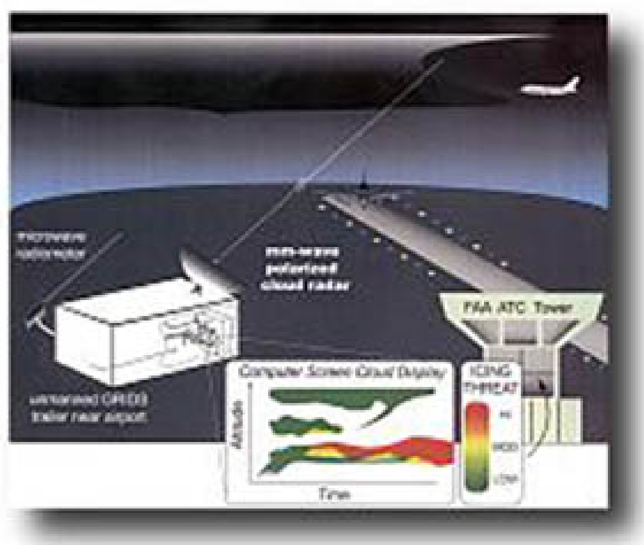
SLD are dangerous because they can collect and freeze almost anywhere on an aircraft's wing—creating a rough ice surface, which quickly increases drag and can cause a relatively serious degradation in aircraft performance. Furthermore, unlike freezing rain, SLD can form anywhere in a cloud making them harder to detect. Freezing rain, on the other hand, tends to form a smoother coating, causing less drag. Tiny cloud droplets (< 0.05 mm) accrete on the leading edge of an aircraft's wing, where the ice can be shed by properly equipped aircraft (unless the amount of liquid water in the cloud is excessive). Because SLD creates a primary icing hazard for in-flight aircraft, a SLD remote sensing detection technology was needed—and NOAA's Environmental Technology Laboratory has the solution.

Aircraft icing hazards due to SLD (and smaller cloud droplets) are particularly challenging because they are notoriously difficult to forecast and there is no operational weather surveillance technology currently available to detect this hazard. The importance of SLD was first recognized in the 1980's from measurements made by research aircraft. By the mid-1990's, SLD became a focus of a FAA-sponsored international conference of aircraft in-flight icing. Based on this conference, there was consensus that the development of remote-sensing methods to detect SLD was a high-priority. Fortunately, NOAA's ETL was already on track to address this challenge.



Specifically, NOAA's ETL was able to combine several technologies to address this problem. First, it had already developed the "microwave radiometer" technology needed to continuously measure the amount of liquid water in clouds overhead. Secondly, it developed radar techniques to distinguish between harmless ice crystals and hazardous SLD for the FAA in a series of Winter Icing and Storms Projects (WISP) that culminated in 1999 with the Mount Washington Icing Sensors Project (MWISP). Because ice crystals form with diverse shapes (see figure above right), they settle through the air with preferred orientations. SLD and the smaller cloud droplets, on the other hand, are spherical and have no preferred orientation. Knowing this, NOAA's ETL was able to use dual-polarization radar to measure the differences between cloud populations of the highly "oriented," harmless ice crystals and the hazardous SLD—a distinction that cannot be made by measuring ordinary radar reflectivity. Specifically, NOAA's ETL could use the depolarization (or "decomposition") of a radar signal—which occurs uniquely according to the shape, density and orientation of ice crystals in the cloud to differentiate between these two types of cloud particle populations.

NOAA's ETL demonstrated the success of these techniques during MWISP and validated their results directly with in-cloud measurements. These experiments laid the foundation for the development of an extremely sensitive, and autonomous radar to continuously monitor clouds for icing hazards within the airspace of airports and provide real-time warnings to air traffic controllers and pilots. Today, the FAA is supporting the design, construction and testing of an operational-grade prototype known as the "Ground-Based Remote Icing Detection System." GRIDS will combine a radar using specialized, high-sensitivity polarization technology with a microwave radiometer to provide a two-fisted approach to the detection of icing hazards. Furthermore, because the temperature profile through clouds is another critical variable used to detect icing conditions, the



system will also take into account hourly temperature soundings—now provided operationally by the NOAA's National Weather Service's rapid-update cycle (RUC) numerical data-assimilation model.

System Advantages
By using this combined sensor approach, GRIDS can determine the presence of SLD and smaller droplets, and estimate how "dense" (and therefore how dangerous) they may be. First, GRIDS will readily identify clouds composed entirely of liquid water or of a mix of ice and liquid water—where SLD occur—versus clouds comprised entirely of ice crystals, which pose no icing threat to in flight aircraft. In the case of mixed-phase clouds (those comprised of both ice crystals and SLD), conventional systems provide no distinction among liquid, mixed-phase, or glaciated cloud systems. With the radar-radiometer combination, on the other hand, GRIDS will make these distinctions to assess the presence and amount of potentially hazardous SLD. Therefore, the system provides a much-improved set of "eyes" to facilitate warnings for potentially hazardous icing condition—even in the more complicated "mixed-phase" cases. Other advantages of the GRID system include the following:

- The radar has the additional capability to measure Doppler velocities, so the turbulence of cloud-embedded shear layers and convective turbulence that threaten aircraft can be observed.
- GRIDS will monitor fog and distinguish snowfall from rainfall.
- Identification of the evolution of the types of ice particles in the continuously updated profile may help to solve a persistent problem in radar meteorology—estimating snowfall rate.
- GRIDS will determine the multiple ceilings of even the wispiest of cloud layers and determine the phases of their water content.

Such observations, taken continuously, should serve well to anchor numerical weather forecast models attempting to estimate and predict cloud layering and the effects on aviation and to characterize the seasonal and climatological properties of clouds for climate and radiation studies.

System Applications
The new software for the operational-grade GRIDS prototype will automatically combine the readings from the radar, radiometer, and computer models to produce a real-time profile of clouds. It will code the internal parts of the clouds with a color scheme such as green, yellow, and red to indicate, respectively, safe, questionable, and dangerous flight altitudes. The coded cloud image will update once every 60 seconds on a Web site that can be accessed by the air traffic control tower and other aviation users.

NOAA's ETL hopes to construct the GRIDS prototype in time for testing during the Second Alliance Icing Research Study (AIRS-II), an international project planned for the winter of 2003-2004 in Montreal, Canada. NOAA's ETL scientists hope to not only demonstrate the core 24/7 GRIDS capability for detecting icing conditions, but also the other potential advantages and applications of the system. The system, for example, offers a viable upgrade to the ETL-designed millimeter cloud radars (MMCRs) used at the Department of Energy's Clouds and Radiation Testbed (CART) sites (i.e., remote areas from tropical islands to the Arctic requiring long term, unattended, continuously-operating radar for highly sensitive cloud detection). The GRIDS radar will be as robust as, and a hundred times more sensitive than, the MMCR. So it is expected to detect those nearly invisible cirrus clouds that are so important to the radiation budget, and it will determine if they are liquid or ice and the shapes of the ice particles.

GRIDS will initially be put to work as a high-end research tool. The ultimate vision for GRIDS is that it will augment the national weather radar network of conventional weather radars at icing-prone airports. Just as satellites see clouds very differently when looking at them with visible versus infrared radiation, no single-wavelength radar (or single remote sensor of any kind), can tell us all we want to know. Long-wavelength (10-cm) weather radars, such as NEXRAD, are only designed to monitor the precipitation-sized particles. So they have difficulty detecting low-altitude, weakly reflecting, non-precipitating clouds that may contain dangerous SLD, which the shorter (8.7-mm) wavelength of the GRIDS radar most readily detects. There are other important differences that also will make the GRIDS and NEXRAD technologies complementary. NEXRAD provides surveillance over a large area, but is encumbered by ground clutter in the near-field. The GRIDS radar, on the other hand, is virtually insensitive to ground clutter and can continuously profile clouds from the ground to the tropopause.

NOAA's National Weather Service is trying to speed the effort, and has entered GRIDS into the seven-year plan of its aviation weather initiative. GRIDS will verify icing forecast models and satellite interpretations of icing conditions, improve model cloud physics, and help to assess and improve the "eyes" of NEXRAD. Once fully implemented, the system will help to improve the FAA and NWS monitoring and forecasts of icing conditions and reduce needless flight cancellations, delays, and re-routing due to suspected, but unconfirmed icing conditions, which have contributed to passenger inconveniences and large financial consequences in the past. Most importantly, GRIDS will provide air traffic controllers and pilots with the information they need to reliably avoid hazardous icing conditions near airports. As with any new technology, many more hurdles must be cleared to move GRIDS into routine operations, but there is hope that many of the transportation issues caused by in-flight icing will soon be alleviated by application of this new technology.

Relevant Web Sites
NOAA's Environmental Technology Laboratory

Ground-Based Remote Icing Detection System (GRID)

Current Icing Potential (CIP)

Aviation Digital Data Service

National Weather Service (NWS)

NEXRAD Mount Washington Icing Sensors Project

Media Contact:
Barbara McGehan, NOAA Research, Boulder, Colo., (303) 497-6288