February 2010

GOES-R Aviation Products
Aircraft Flight Icing Threat

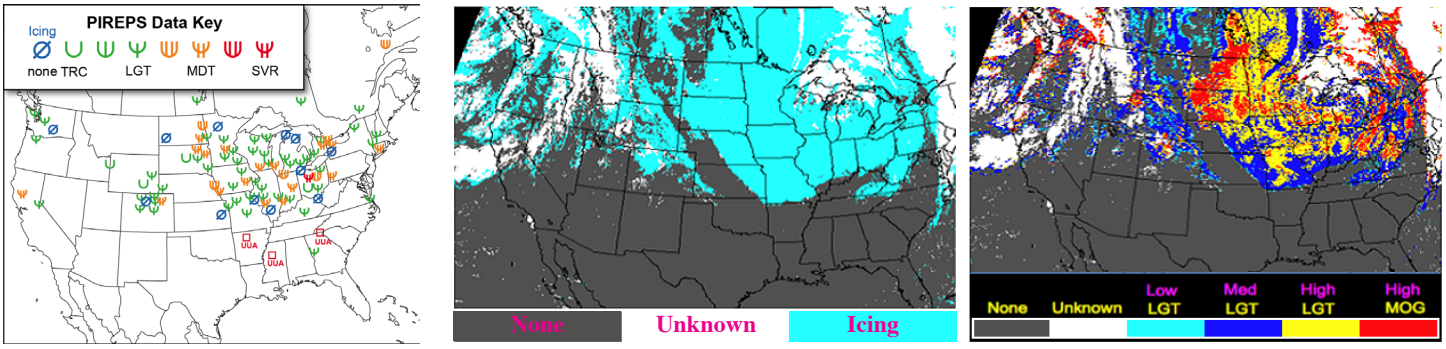
What Is GOES-R?
The Geostationary Operational Environmental Satellite - R Series (GOES-R) is the next generation of National Oceanic and Atmospheric Administration (NOAA) geostationary Earth-observing systems. Superior spacecraft and instrument technology will support expanded detection of environmental phenomena, resulting in more timely and accurate forecasts and warnings. The Advanced Baseline Imager (ABI), a sixteen channel imager with two visible channels, four near-infrared channels, and ten infrared channels, will provide three times more spectral information, four times the spatial resolution, and more than five times faster temporal coverage than the current system. Other advancements over current GOES capabilities include total lightning detection (in-cloud and cloud-to-ground flashes) and mapping from the Geostationary Lightning Mapper (GLM), and increased dynamic range, resolution, and sensitivity in monitoring solar X-ray flux with the Solar UV Imager (SUVI). GOES-R is scheduled for launch in 2015.

Why Is In-flight Icing an Important Safety Issue?
It is natural for clouds to contain liquid water droplets at altitudes where the air temperature is below freezing. When this super-cooled liquid water (SLW) comes in contact with a hard surface such as the frame of an aircraft, it freezes, thereby icing the airframe. As ice accumulates on an aircraft it alters the airflow, which can increase drag and reduce the ability of the airframe to create lift, leading to control problems with potentially disastrous consequences. A significant percentage of weather-related aviation accidents over the last half-century have been attributed to icing. Typically, the flight icing threat to aircraft is reduced by either protecting the aircraft with de-icing and/or anti-icing equipment or by avoidance, particularly for unprotected aircraft. However, severe icing can overwhelm an aircraft's icing protection system. Icing conditions can be highly variable, often occurring in small areas that cannot be resolved with current icing diagnosis and forecasting methods, which tend to overestimate the areal coverage of the flight icing threat. Thus, avoidance can be expensive, resulting in significant increases in flight time or delays on the ground. While there have been improvements in systems to mitigate aircraft icing, no phase of aircraft operations is immune to the threat.

How Will GOES-R Detect Icing Conditions?
Geostationary satellite data are a vital tool that forecasters have traditionally used for qualitatively monitoring clouds and associated weather conditions. The advanced design of GOES-R provides the information needed to quantitatively estimate important properties of clouds, including those that help determine the flight icing threat, such as cloud temperature, thermodynamic composition, vertically integrated liquid water content or liquid water path, and effective droplet size. These cloud products and others derived from GOES-R satellite observations provide unique information about icing conditions and form the basis for the **Flight Icing Threat** detection algorithm.

How Do These Products Work?
The **Flight Icing Threat** is partially determined by the presence and density of SLW and the water droplet size distribution. The GOES-R **Flight Icing Threat** product is available at the pixel level and composed of three components; (1) the icing mask available day and night which discriminates regions of possible aircraft icing, (2) the icing probability, estimated during the daytime only, and (3) a two-category intensity index which is also derived during the daytime only. The icing mask is developed using the cloud thermodynamic phase and cloud top temperature products to identify which cloudy pixels contain SLW. Optically thick clouds composed of ice crystals at cloud

Ice accreted from super-cooled water droplets on the wing leading edge of a research aircraft while in cloud (Left) and after ascending above cloud (Right). Photo credits: NASA Glenn Research Center.



*Left: Icing PIREPS on Nov. 8, 2008. The **Flight Icing Threat** icing mask (Center) and icing intensity (Right) are shown, derived from current GOES at 1745 UTC on Nov. 8, 2008. Icing intensity is expressed as the probability of encountering light (LGT) or moderate or greater (MOG) icing.*

top may obscure possible icing conditions from the satellite view and in such cases the icing threat is deemed to be unknown from the GOES-R data alone. During the daytime, the probability (low, medium, or high) of encountering icing and the intensity category [light (LGT), or moderate or greater (MOG)] are determined using the liquid water path and effective droplet size products. Larger droplets and liquid water paths are associated with a higher probability of more severe icing. In the current algorithm, the MOG category always has a high probability of icing due to its strong dependence on liquid water path. Pilot reports (PIREPS) provide the most widely available in-situ aircraft icing information and have been used extensively in developing and validating the GOES-R **Flight Icing Threat** product.

Research and Development Partners for Flight Icing Threat Products

- NASA Langley Research Center (LaRC)
- National Center for Atmospheric Research, Research Applications Laboratory (NCAR/RAL)
- NASA Glenn Research Center (GRC)
- NOAA National Environmental Satellite, Data, and Information Service, Center for Satellite Applications and Research (NESDIS/STAR)
- FAA Aviation Weather Research Program (AWRP)
- FAA Icing Program
- NOAA National Centers for Environmental Prediction, Aviation Weather Center (NCEP/AWC)
- NOAA National Weather Service Aviation Services Branch
- Science Systems and Applications, Inc. (SSAI)
- National Research Council Canada
- Environment Canada
- Next Generation Air Transportation System (NextGen)

On the Web

http://www-pm.larc.nasa.gov/icing/icing.shtml
http://adds.aviationweather.gov/icing/

For More Information, Contact:

GOES-R Program Office
Code 417
NASA Goddard Space Flight Center
Greenbelt, MD 20771
301-286-1355

Jim Gurka, james.gurka@noaa.gov
Steve Goodman, steve.goodman@noaa.gov

What Are the Benefits?

A recent study by the National Aviation Safety Data Analysis Center reported that icing was a contributing factor in nearly 400 aviation accidents occurring over a 10-year period in the United States. After one of the more serious accidents, which resulted in 68 deaths, the National Transportation Safety board recommended that the Federal Aviation Administration (FAA) continue to sponsor the development of methods to diagnose and forecast the locations of atmospheric icing conditions. Supplementary icing products derived from combined satellite, radar, surface, lightning, and pilot-report observations with numerical model output are now available to the aviation community at NOAA's National Weather Service (NWS) Aviation Weather Center. Current satellite data are only used in a rudimentary way. The advanced spectral, spatial, and temporal resolution of the GOES-R ABI will provide additional information regarding atmospheric icing conditions that is unavailable from any other source. They will be particularly helpful in resolving the small-scale areas of intense icing often missed in current products and will thus benefit the Next Generation Air Transportation System (NextGen). The use of a satellite-based **Flight Icing Threat** product with other aviation weather products will allow the aviation community to conduct safer, more efficient, air transportation.

Contributors: William L. Smith Jr. and Patrick Minnis – NASA Langley Research Center