October 2009

GOES-R Aviation Products
Volcanic Ash and SO_2 Detection

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.

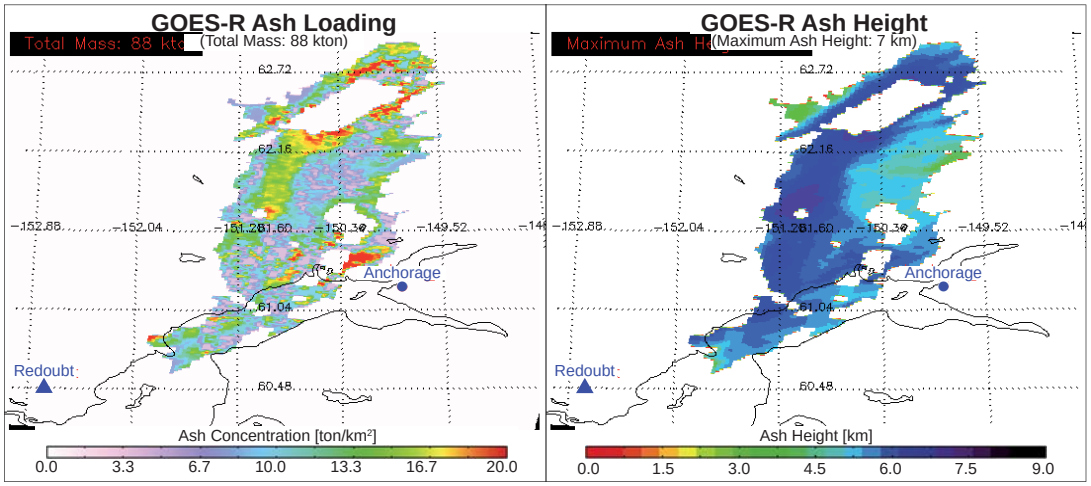
Why Is Volcanic Ash an Important Safety Issue?
Airborne volcanic ash is a major aviation, health, and infrastructure hazard. When ingested into aircraft engines, volcanic ash can lead to engine damage or failure. For example, in December 1989, a 747 jetliner carrying 231 passengers encountered an ash cloud during an eruption of the Mount Redoubt volcano, located southwest of Anchorage, AK. Within 60 seconds of encountering the heavy ash cloud, all four engines of the aircraft had stalled. Fortunately, the pilot was able to restart the engines, narrowly avoiding a crash. Volcanic ash is extremely abrasive, and even small concentrations can cause severe damage to the exterior of aircraft. In addition, ash falls pose significant health and infrastructure threats to those on the ground. Breathing volcanic ash can result in serious illness or death, and ash falls can also pollute water supplies and damage or destroy buildings.

How Will GOES-R Address This Hazard?
A suite of GOES-R products will detect and monitor volcanic ash as well as sulfur dioxide (SO_2), which is often co-located with ash in volcanic clouds. Current GOES operational volcanic cloud products are qualitative, primarily due to sensor limitations. Improved spatial resolution and a large selection of spectral channels will enable the GOES-R ABI to generate more advanced quantitative volcanic cloud products. The **SO_2 Detection** product will automatically detect volcanic clouds during very early stages when an ash signal is generally obscured by liquid water/ice. The **Volcanic Ash** product will provide objective estimates of ash cloud coverage, height, mass, and particle size, which are necessary to issue Significant Meteorological Information (SIGMET) advisories for aircraft and accurately forecast the dispersion of ash clouds.

How Do These Products Work?
The GOES-R **Volcanic Ash** and **SO_2 Detection** products are generated from infrared radiances, which are day/night independent. ABI channels centered at 7.3, 8.5, 11, 12, and 13.3 μm are used in the algorithms. The 8.5, 11, and 12 μm channels provide information on cloud particle size and composition, the 13.3 μm channel detects ash cloud height, and the 7.3 μm channel detects SO_2 clouds. These algorithms are unique because they account for background

Image of the December 1989 Mt. Redoubt eruption (Upper) demonstrates that a large quantity of volcanic ash can be rapidly injected to aircraft cruising level. Heavy ash fall from this eruption also caused significant engine damage to a KLM passenger jet (Lower).

conditions such as surface temperature, surface emissivity, atmospheric temperature, and water vapor on a pixel-by-pixel basis. Consideration of background conditions results in greater sensitivity to thin ash and consistent algorithm performance from the tropics to the high latitudes.



*GOES-R-like **Volcanic Ash Loading** and **Height** products are shown for ash clouds produced by eruptions of Mount Redoubt on March 23, 2009.*

The **Volcanic Ash** and **SO_2 Detection** algorithms were developed and tested by using the Spinning Enhanced Visible and Infrared Imager (SEVIRI) on-board the European Meteosat Second Generation (MSG) satellites and the NASA Moderate Resolution Imaging Spectroradiometer (MODIS), providing proxy data for the ABI. The **Volcanic Ash** and **SO_2 Detection** products are validated by using spaceborne lidar and high spectral resolution ultraviolet measurements provided by instruments on NASA research satellites.

What Are the Benefits?

On average, more than 50 volcanic eruptions occur each year, many of which are within or downwind of the region viewed by the GOES satellites. More than 80,000 large aircraft per year and 30,000 people per day are in the airspace near and potentially downwind of the 90 active volcanoes in Alaska. The International Civil Aviation Organization (ICAO) has designated 24/7 volcanic cloud monitoring duties to 9 Volcanic Ash Advisory Centers (VAAC's) around the world. The VAAC's are responsible for issuing Volcanic Ash Advisories, which alert aviation interests to the presence of volcanic ash clouds. The National Weather Service (NWS) is responsible for operating the Anchorage, AK and the Washington, D.C. VAAC.

Volcanic ash clouds can have serious economic impact. For instance, Alaska Airlines was forced to cancel 295 flights (stranding over 20,000 passengers) in March and April of 2009 due to ash clouds produced by Mount Redoubt. While the economic impact of the 2009 Redoubt eruptions is still being tabulated, the total estimated cost of eruptions of Redoubt in 1989-1990 was $160 million. The cost to the aviation industry alone was $101 million.

As airborne volcanic ash has significant aviation, health, infrastructure, and economic impacts, frequent observation of volcanic regions and prompt identification of ash clouds are necessary to minimize risk. The advanced spectral, spatial, and temporal resolution of the GOES-R ABI will be utilized to generate a complete set of volcanic cloud detection and monitoring products, resulting in improved air and ground safety as well as economic savings. The GOES-R products will also be used to improve the modeling of volcanic ash clouds, which will allow for more accurate ash cloud dispersion and ash fall forecasts.

Research and Development Partners for Volcanic Ash and SO_2 Products

- Cooperative Institute for Meteorological Satellite Studies (CIMSS)
- NOAA National Environmental Satellite, Data and Information Service, Center for Satellite Applications and Research (NESDIS/STAR)
- NOAA/NESDIS Office of Satellite Data, Processing and Distribution (OSDPD)/Satellite Recovery Branch/Volcanic Ash Advisory Center

On the Web www.ssd.noaa.gov/VAAC/vaac.html

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Additional Source: Tuck, H.B., and Huckey, L., 1994, Economic disruption bt Redoubt volcano: Assessment methodology and anecdotal empirical evidence: U.S. Geological Survey Bulletin 2047, p. 137-140.