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Using Infrared Satellite Measurements to Identify and Track Volcanic Ash Clouds that Exceed Aircraft Exposure Thresholds: Capabilities and Limitations

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Satellite-based measurements of infrared radiation have been the primary means for tracking volcanic ash clouds since the 1980's. While measurements at ultra-violet, visible, near-infrared, and microwave wavelengths are also useful for monitoring volcanic ash clouds; infrared measurements are day/night independent and available on a large variety of geostationary and low-earth orbit satellites. More specifically, satellite-based infrared measurements are frequent (every 5 to 60 minutes, depending on instrument capabilities) and can be used to monitor both the proximal and distal portions of volcanic ash clouds. However, if satellite-based infrared measurements are to be used to help identify and track volcanic ash clouds that have mass concentrations that exceed specific aircraft exposure thresholds, the sensitivity of the infrared measurements to the threshold values must be quantified over a large range of conditions. In this paper, lidar measurements from the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite, along with aircraft measurements are used to determine how accurately satellite-based infrared measurements can quantitatively detect a range of mass concentration thresholds, including the proposed 2 mg/m3 threshold used during the 2010 eruption of Eyjafjallajökull. The infrared-based volcanic ash detection and retrieval approach that will be assessed in this paper was developed in preparation for the next generation of Geostationary Operational Environmental Satellites (GOES-R). The GOES-R volcanic ash retrieval algorithm is applied to the Spinning Enhanced Visible and Infrared Imager (SEVIRI) on board the Meteosat Second Generation (MSG) and the MODerate Resolution Imaging Spectroradiometer (MODIS), both of which have taken ample measurements of volcanic ash clouds, including those from the 2010 eruption of Eyjafjallajökull. In addition, SEVIRI and MODIS can both be co-located in space and time with measurements from the CALIPSO satellite.

Comparisons to the lidar on the CALIPSO satellite indicate that the GOES-R infrared approach is able to detect ash clouds with concentrations as low as about 0.06 mg/m3 when the satellite is viewing the cloud at nadir and volcanic ash is the highest cloud layer. Smaller concentrations can be detected when the satellite is viewing the ash cloud at much larger angles. While the infrared detection thresholds will continue to be refined with additional lidar analysis and comparisons to aircraft measurements, it is worth emphasizing that our results indicate that ash clouds that contain mass concentrations of 2 mg/m3 or greater can generally be detected using satellite-based infrared measurements when ash is the highest cloud layer. The overall results are minimally sensitive to background conditions such as atmospheric water vapor loading, atmospheric temperature, surface temperature, and surface emissivity, since these parameters are explicitly accounted for in our infrared-based volcanic ash detection and retrieval approach. In addition, the lidar on CALIPSO is used to show that infrared measurements can be used to accurately determine ash cloud heights using the GOES-R approach. The various limitations of infrared measurements (and our specific retrieval approach) will also be presented.