INTERNATIONAL VOLCANIC ASH TASK FORCE (IVATF)

SECOND MEETING

Montréal, 11 to 15 July 2011

Agenda Item 2: Report of the Science Sub-Group

2.1: Volcanic ash cloud detection/avoidance systems and associated guidance

COMBINING SATELLITE INFRARED DATA AND LIDAR TO CHARACTERIZE ASH CLOUDS

(Presented by the Rapporteur of the Science Sub-Group in collaboration with the WMO-IUGG Volcanic Ash Scientific Advisory Group)

SUMMARY

This information paper describes how the combination of infrared satellite data and lidar measurements can be used to obtain an estimate of the mass concentration of ash in a volcanic cloud.

The accuracy of remotely sensed ash cloud mass-concentration estimates can be improved by fusing different data sets, such as those from infrared sensors and lidar.

1. INTRODUCTION

1.1 Various research groups have successfully used satellite-based infrared measurements from various instruments (e.g., SEVIRI, MODIS, AVHRR, AIRS, IASI) to quantify the height, mass loading (mass per area), and particles sizes of ash clouds. One clear advantage of using the infrared is that the measurements are day/night independent. However, current techniques cannot reliably retrieve ash cloud properties from infrared measurements when the ash cloud is not the highest cloud layer or when the thermal perturbation caused by the ash cloud is too small to be detected. A summary of the various techniques used to estimate volcanic ash cloud properties from satellite-based infrared observations is given in Zehner (2010).

1.2 The geometric thickness of ash clouds, which is needed to convert mass loading into mass concentration, is very difficult to determine from infrared measurements. As discussed in WP/05 of the meeting (IVATF task TF-SC101 Progress Report Part I), lidar measurements provide detailed information on the vertical structure of clouds and aerosols (including cloud top height and geometric
thickness) that cannot be inferred from infrared measurements alone. While lidar observations are rather sparse compared to satellite-based infrared measurements, they are still very useful for characterizing volcanic ash clouds, especially when combined with other measurements, such as infrared measurements.

1.3 In support of Task TF-SCI01, this information paper describes a technique used by the United States National Oceanic and Atmospheric Administration (NOAA) for combining infrared satellite data and lidar measurements to obtain an estimate of volcanic-ash concentration. In addition, the paper discusses the potential of using lidar measurements to develop an empirical approach to estimating the geometric thickness of ash clouds from satellite-based infrared measurements.

2. DISCUSSION

2.1 The United States National Oceanic and Atmospheric Administration (NOAA) has developed a fully automated technique to retrieve ash cloud properties from thermal infrared (TIR) measurements (Heidinger and Pavolonis, 2009; Heidinger et al, 2010; Pavolonis et al., 2006; Pavolonis, 2010). Although still experimental, such volcanic-ash retrievals were produced during the eruption of Eyjafjallajökull in near real-time using SEVIRI (a sensor on the European MSG satellite) and made available to the London Volcanic Ash Advisory Centre (VAAC) and the volcanic-cloud research community. Although these products are currently considered experimental, efforts are underway to transition them to operations at the Anchorage and Washington VAACs.

2.2 In order to estimate volcanic ash mass concentration, the standard NOAA retrieval approach for volcanic ash cloud properties was modified to allow for the incorporation of lidar-derived cloud vertical boundary data. The lidar data were used to constrain the infrared retrieval of mass loading (by constraining the cloud height/temperature) and to determine the cloud geometric thickness. The derived cloud geometrical thickness was used to convert the mass loading (mass per unit area) to mass concentration (mass per unit volume). This is the same basic infrared/lidar fusion technique used by Heidinger and Pavolonis (2009) to derive microphysical properties of cirrus clouds.

2.3 In 2010, the space-borne lidar, Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) (Winker et al., 2010), flew over Eyjafjallajökull volcanic ash clouds on at least 40 occasions. The infrared/lidar fusion technique used by NOAA was applied to the many CALIOP overpasses to estimate the mass concentration of volcanic ash. The results of that particular analysis indicated that mass concentrations frequently exceeded 2 mg/m³ (Pavolonis, 2011) in distal portions of the ash cloud. Detailed comparisons with other data sets (aircraft, satellite, ground-based) still need to be performed.

2.4 Recent research has also indicated that it may be possible to estimate the geometric thickness of ash clouds from satellite-based infrared measurements by using lidar data to obtain an empirical relationship. The empirical relationship would utilize ash-cloud properties (ash-cloud top height, effective particle radius, and mass loading) that can be retrieved using infrared measurements alone to roughly assign an ash cloud thickness range (e.g. < 1 km, 1 – 3 km, > 3 km). The approximate cloud thickness information derived from such an approach can be used to convert mass loading (mass/area) into the more relevant variable, mass concentration. Additional research by the international community is needed in order to improve satellite-based estimates of ash mass concentration and to characterize and quantify their accuracy.
3. **SUMMARY**

3.1 The combination of infrared satellite data and lidar measurements can be used to obtain an estimate of volcanic ash mass concentration.

3.2 The accuracy of remotely sensed estimates of ash-cloud mass concentration can be improved by fusing different data sets, such as those from infrared sensors and lidar.

3.3 The international research community should be encouraged to develop multi-sensor techniques for estimating volcanic-ash cloud-properties such as mass concentration.

3.4 Additional research should also focus on inter-comparing volcanic-ash-cloud properties derived using a variety of techniques and measurements.

4. **ACTION BY THE IVATF**

4.1 The IVATF is invited to note the contents of this information paper.
APPENDIX

LIST OF RELEVANT PUBLISHED SCIENTIFIC PAPERS


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