International Civil Aviation Organization

WORKING PAPER

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INTERNATIONAL VOLCANIC ASH TASK FORCE (IVATF)

FIRST MEETING

Montréal, 27 to 30 July 2010

Agenda Item 6: Improvement of ash detection/avoidance systems (Science sub-group)
6.1: Ways and means to improve ground ash detection systems

OBSERVATIONS OF VOLCANIC ASH BY SATELLITE SENSORS AND LIDAR

(Presented by United States)

SUMMARY

Operational satellite-based sensors are capable of detecting the spatial extent and altitude of the top of volcanic ash clouds. Some limitations with satellite sensors, aside from the inherent spatial coverage and temporal resolution, include differentiating volcanic ash clouds from meteorological clouds, detecting the altitude of the bottom of an ash cloud, and detecting ash clouds with low ash concentration. More recently light detection and ranging (lidar) systems have been able to begin to differentiate ash from other aerosols, but they have not been traditionally located, nor was the original intent, to observe ash.

1. INTRODUCTION

1.1 Why are ash observations important? Clearly aviation interests need to know where the ash is located. One way this information is provided is in the observation section of the Volcanic Ash Advisory/Volcanic Ash Graphic (VAA/VAG). Observations can sometimes be used as a basis for short-term forecasts of ash movement. Observations can be used to evaluate volcanic ash transport and dispersion model, and possibly to initialize dispersion models.

1.2 The U.S. National Oceanic and Atmospheric Administration (NOAA), which operate the U.S. Volcanic Ash Advisory Centers, has access to a suite of satellite observations, including both geostationary (GEO) satellites, useful in the tropics and mid-latitudes and which have a rapid refresh rate, and low earth orbit (LEO) satellites, particularly useful at high latitudes. LEO satellites tend to have additional capabilities to characterize volcanic clouds. NOAA has recently begun the process of transitioning to operations the creation of products that identify ash location and quantify some ash properties that are critical for dispersion forecasting. NOAA is also developing, testing and evaluating new satellite products for the next generation of NOAA satellites.

1.3 Light detection and ranging (lidar) in the U.S. has not been operationally used for observing volcanic ash, though there have been some analysis of lidar data for volcanic ash by U.S. scientists.

1.4 Further, very little *in-situ* measurements of volcanic ash, such as from airborne instrumentation, have been made, but they could be useful as another observational data source.

2. SATELLITE

2.1 Measurements from GEO and LEO satellites are vital for monitoring and characterizing volcanic ash clouds. From an operational perspective, a high measurement refresh rate is desired. As such, GEO instruments are well suited for operationally monitoring volcanic ash, especially in the tropics (in South America, the U.S. VAAC area of responsibility extend to 10 degrees south) and mid-latitudes. At high latitudes, GEO measurements are still valuable though spatial resolution diminishes rapidly toward the poles. While GEO satellites offer measurements with high temporal resolution, LEO satellites are needed to obtain high spatial resolution measurements of ash clouds, especially at high latitudes. LEO satellite instruments, also generally offer a wider range of spectral measurements, which can be used to characterize volcanic clouds with greater detail, compared to GEO instruments.

2.2 The GEO satellite spectral and temporal capabilities vary among the VAAC. For instance, some satellites do not currently have the capability to apply the reverse absorption brightness temperature difference method of ash detection, often referred to as “split-window”. Also, the SEVIRI instrument on the MSG offers superior spectral, spatial, and temporal capabilities compared to the other geostationary instruments currently in orbit. SEVIRI provides full disk imagery every 15 minutes and the spectral measurements can be used to more accurately detect volcanic ash, more accurately retrieve the ash cloud height, mass loading, and ash cloud microphysics, and detect SO_2. Based on current plans, the U.S., Europe, Japan, and China will be upgrading their geostationary capabilities in the 2015–2020 timeframe. The next generation of satellite instruments will offer SEVIRI like or better spatial, spectral, and temporal capabilities, resulting in more homogeneous operational volcanic cloud monitoring capabilities.

2.3 The LEO volcanic cloud remote sensing capabilities are spectrally and/or spatially more advanced compared to GEO, and, as such, should be used to supplement GEO observations. In particular, infrared and UV/Visible hyperspectral instruments provide an enhanced ability to monitor SO_2 clouds and detect smaller concentrations of volcanic ash. Hyperspectral measurements may also provide some information about the vertical distribution of volcanic ash and SO_2.

2.4 Methods for automatically detecting volcanic ash and retrieving ash cloud height, mass loading, and microphysics continue to be refined based on validation and user feedback. NOAA has preliminary plans to ingest this type of information as the initial conditions for dispersion simulations, instead of beginning at the volcano, since much of the initial source information is unknown in real time. In addition, several operational meteorological centers are exploring the assimilation of satellite aerosol optical depth to improve aerosol model initial conditions. As new techniques and/or algorithms are developed they will be added to the “operational tool chest” for real-time support to the U.S. VAAC.

2.5 Satellite products will always be subject to certain fundamental limitations. Traditional operational measurements can only accurately sense the highest cloud layer. Thus, if liquid water or ice clouds obstruct the ash cloud layer, the ash cloud generally cannot be detected. Measurements from LEO research instruments, like the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP), are subject to the highest cloud layer limitation to a lesser extent, but the temporal and spatial coverage of such measurements is very limited. Unambiguous detection of volcanic ash is not always possible when compared to water/ice clouds. For instance volcanic clouds that are liquid water rich and ash poor are very difficult to differentiate from meteorological liquid water clouds. Volcanic ash that is encased by ice can, at times, be detected using new methodologies.

3. LIDAR

3.1 Lidar instruments observe aerosol particles in the atmosphere by transmitting an optical pulse and observing the radiation backscattered from the particles, and are capable of detecting aerosol layers and structure. By measuring the depolarization of the backscattered signals, lidars can provide additional information that may be used to differentiate volcanic ash from other aerosols. Lidars have detected relatively thin layers of volcanic ash, both bottom and top heights. Lidars can be surface-based (e.g. the EARLINET (European Aerosol Research Lidar Network) network), satellite-based, (e.g. CALIPSO), and airborne. Within the U.S. and Canada, only a minimal number of surface based lidars could be applied to detect volcanic ash, especially in Western regions. Most of these lidars are operated intermittently, particularly when interesting aerosol events occur.

3.2 For measurements from above the plume, a lidar system could be augmented by an enhanced dropsonde that would measure ash characteristics as well as meteorological parameters as it descended through the cloud. The combination of the two instruments would be highly synergistic – information on ash particle properties would improve lidar estimates of ash concentrations within the cloud, while the lidar data would observe the plume dimensions and evolution within a continuous curtain below the plane. Because surface-based lidar observations are hampered by the presence of clouds, aircraft observations would likely increase the probability of being able to adequately observe the ash plume.

4. CONCLUSION

4.1 Given the above discussion the group may wish to agree on the following action:

Action Agreed 1/… — Observations of volcanic ash by satellite sensors and lidar

That, the Science sub-group be tasked, in collaboration with WMO, to address limitations on satellite sensors detecting ash *versus* meteorological clouds, detecting multiple layers and ash cloud depths, and the application of lidar to ash detection.

5. ACTION BY THE IVATF

5.1 The IVATF is invited to:

a) note the information in this paper; and

b) decide on the draft action.

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