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EVOLVING REQUIREMENTS FOR SPACE-BASED REMOTE SENSING OF VOLCANIC ASH AND OTHER AEROSOLS FOR AERONAUTICAL METEOROLOGY

In response to CGMS action/recommendation A 38.31

Aeronautical Meteorology has traditionally concerned itself with both meteorological hazards and phenomena impacting the regularity and economy of civil air navigation. Of these hazards, several are linked to aerosols such as volcanic ash, supercooled water droplets and ice, which affect the safe operation of engines, dynamic sensors such as Pitot-tubes and electric/electronic components of aircraft systems.

New airspace concepts, increased air traffic and higher safety standards needed to maintain or improve safety under increased traffic loads require higher temporal and spatial resolution, accuracy and additional elements to be quantitatively observed on a global basis.

Whilst in-situ and ground-based remote sensing systems are capable of providing highly accurate and reliable data of such aerosols locally, space-based systems are paramount to ensuring a near-global availability of these data considered crucial for the safety of air transport. In view of evolving needs, gaps are identified on current observation systems in particular for the vertical distribution of hazardous aerosols.

It is suggested to aim at harmonizing imager characteristics, to implement as soon as possible the next generation geostationary platforms with enhanced multispectral capabilities, and to consider the deployment of operational LIDAR sensors in LEO. Cooperation between the satellite community and ground-based and airborne system operators is encouraged with a view of establishing a composite observing system for ash density and ice loading.

Version 2 of this paper includes, as an appendix, a letter of support received from ICAO.

Recommendation proposed:

To strive to harmonize the spectral characteristics of future Visible and Infrared imager channels in order to enable seamless application of differential absorption methods to data acquired from different platforms

To ensure the earliest possible deployment of next generation geostationary platforms with enhanced multi-spectral VIS-IR capabilities

Consider the deployment of operational LIDAR sensors in Low Earth Orbit to provide multi-daily coverage over global air routes

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1 INTRODUCTION

Recent events in aviation (Volcanic eruptions, accidents) have re-focused attention on the impact of both volcanic ash and dense ice-clouds near Cumulonimbus tops. Whilst current observing systems are capable of detecting the horizontal extent of such danger areas in many cases, emerging requirements for more quantitative and vertically differentiated observations are posing a challenge to current composite observing systems. While in some regions such as Europe, parts of North America and Japan ground-based LIDAR and research aircraft equipped with sophisticated in-situ sensors can help to enhance available remote sensing data, most of the global air routes are only covered by space-based observing systems, and even these are challenged by deployment delays and changes of platforms.

2 OBSERVATION NEEDS AND CAPABILITIES

2.1 The eruptions of volcanoes in Iceland, Indonesia and Chile in 2010 and 2011 have seen unprecedented disruption to global air traffic over both extended periods and vast areas of airspace. While in the past any volcanic ash was to be avoided by aircraft according to manufacturers and aviation authorities, intense efforts are now underway to define an acceptable threshold of ash concentration through which aircraft can continue to operate safely. Once such a threshold is globally agreed and implemented, the requirement for reliable, quantified detection methods of volcanic ash concentrations will become a core requirement for an integrated volcanic ash observing system.

2.2 Current detection methods using IR sensors on space-based remote sensing systems rely mostly on the differential absorption in the near infrared at wavelengths near 10 micron. Many techniques have been developed for geostationary satellite systems (GOES, METEOSAT, GMS and others), which are in operational use by the Volcanic Ash Advisory Centers. These methods can provide reasonable estimates of total ash atmospheric column loading under the following conditions:

1) the underlying air mass is not loaded with other aerosols such as dust and sand from storms in arid areas, biomass burning or urban pollution
2) the volcanic ash is not too low (the infrared techniques begin to “lose” the signal typically below 3-5 km)
3) the ash is not masked by water or ice clouds from convection, which in tropical regions is often triggered by steam-rich eruptions.

2.3 Total atmospheric column ash loading, even if reasonably accurate measurements can be provided, require additional vertical profiles of density to permit the calculation of layer-mean ash concentration values. Such vertical profiles are difficult to obtain from IR methods alone, only the tops of ash clouds may be identified with a reasonably degree of accuracy. This limitation explains the need for additional information to identify the thickness of volcanic ash layers and in this respect LIDAR measurements from space, e.g. the CALIPSO polar-orbiting satellite, ground-based LIDAR and aerosol networks offer some potential future options. Ideally these should be fully integrated to take account of the respective strength and weaknesses of each capability e.g. occultation by cloud layers. The current space-based CALIPSO system cannot yet provide an operationally adequate capability, relying on just one polar orbiting spacecraft with a relatively narrow scanning path width. Attempts are underway in Europe to study the potential capability of traditional low power LIDAR ceilometer networks, which are used at many airports, to provide some information on the lower boundary of volcanic ash layers to supplement the more sophisticated, high- power research-based LIDAR networks such as those coordinated by EARLINET. Research-based networks, however, are very limited in coverage, and typically operated by scientific institutions unable to maintain a 24/7 operation for a prolonged volcanic ash event.

2.3 Recent accidents and incidents of aircraft encountering dense ice clouds near the tops of tropical and extra-tropical Cumulonimbus clouds with engine flame-outs and sensor failures (e.g. Pitot-tubes) have prompted research in these phenomena. Engineers have estimated a critical value of ice loading exceeding 5 g/m3 to be a realistic estimate of a risk threshold of such events, depending of course on individual engine or sensor design characteristics.

2.4 As in the case of Volcanic Ash, quantitative information in three dimensions is required to allow a tactical risk assessment and response by flight crews. Again, current sensors in combination with differential Infrared absorption techniques are capable of detecting ice in the top cloud layers, but again, absolute values of ice loading are very difficult to derive from space-based instruments alone for reasons similar to those for volcanic ash. Airborne sensors of humidity have the potential to provide the necessary quantitative information needed to calibrate and enhance space-based detection techniques.

3 CONCLUSIONS

Operators of space based observing platform are strongly encouraged to coordinate their efforts with a view to:

- Provide comparable spectral characteristics of Visible and Infrared imager channels permitting the application of differential absorption methods with comparable results and accuracies for different platforms and operators
- Ensure the earliest possible deployment of new geostationary platforms with enhanced multi-spectral capabilities
- Consider the deployment of operational LIDAR sensors on LEO platforms to provide multi-daily coverage over global air routes

Furthermore, cooperation is encouraged with the operators and coordinators of ground-based systems (LIDARS e.g. EARLINET[1], National Meteorological Services and International Air Navigation Meteorological Service Providers) and airborne systems (AMDAR, EUFAR[2]) in order to establish a composite observing system with calibrated, absolute measurements of ash density and ice loading. Collaboration is also

1 A European Aerosol Research Lidar Network to Establish an Aerosol Climatology: EARLINET
2 European Facility for Airborne Research

encouraged with international organisations and initiatives (ICAO, WMO, IATA, SESAR[3], NextGen[4], WEZARD[5], HAIC[6]) to ensure a common understanding of user requirements and coordinated implementation strategies.

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3 Single European Sky Air Traffic Management Research
4 Next Generation Air Transportation System (United States)
5 Weather Hazards for Aeronautics (European Union, 7th Framework Programme)
6 High-Altitude Ice Concentration (European Union, 7th Framework Programme)

International Civil Aviation Organization

30/9/11

ICAO COMMENTS IN SUPPORT OF WMO WP/6 PRESENTED TO THE THIRTY-NINTH MEETING OF THE COORDINATION GROUP FOR METEOROLOGICAL SATELLITES (CGMS/39)

(Prepared by the International Civil Aviation Organization in coordination with the World Meteorological Organization)

1. As air transport continues to grow, the demands placed on airspace capacity and the overall aviation system will become severe. Aviation supports the world economy and the continuing socio-economic development of many States and the International Civil Aviation Organization (ICAO) is committed to achieving its vision of the safe, secure and sustainable development of civil aviation through the cooperation of our Member States and partnering international organizations.

2. Volcanic eruptions are, for many parts of the world, a day-to-day occurrence. There is a recognized need to enhance ICAO's ability to observe and forecast the presence of volcanic ash in the atmosphere. By keeping the satellite community fully informed, in particular in those parts of world with such capability (China, Japan, Europe and the United States), ICAO believes that resulting enhancements to volcanic ash detection by satellite-based remote-sensing systems will significantly enhance the capability of volcano observatories and volcanic ash advisory centres within the Organization's International Airways Volcano Watch (IAVW).

3. Based on advice from scientific advisors, ICAO has identified a need for widespread availability of quantitative satellite-derived volcanic ash and gas products. Improved availability of such data can constrain modelled ash concentrations and support a safety risk approach to hazard mitigation. Sophisticated approaches for using satellite data with dispersion models (using data assimilation and inversion techniques) are now being developed by the scientific community but, due to the aforementioned need, they are not yet ready for operational use.

4. Air transport globally has had a vested interest in mitigating the hazards posed by volcanic ash since the 1980s. Following several aircraft encounters with ash clouds early in that decade, ICAO developed and continues to operate (with the support of WMO) the IAVW system. Within the IAVW, information on the extent and forecast evolution of volcanic ash in the atmosphere is relayed to aircraft in flight and other concerned users in a timely and efficient manner. Today, ICAO's International Airways Volcano Watch Operations Group (IAVWOPSG) administers the operation and the development of the IAVW. In the past two decades, since the introduction of the IAVW system, there have been no significant aircraft encounters with volcanic ash, and no loss of life.

5. Following the significant disruption to air transport caused by the volcanic eruption of Eyjafjallajökull in 2010, ICAO established an International Volcanic Ash Task Force (IVATF) to accelerate development of a global safety risk management framework. This framework will make it possible to determine the safe levels of aircraft operation when airspace is contaminated by volcanic ash. The work of the IVATF in this regard is complementary to that of the IAVWOPSG.

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6. Through the work of the IAVWOPSG, and more recently the IVATF, ICAO has documented its recognition that qualitative and quantitative satellite-based remote-sensing of volcanic ash clouds (and the associated chemical constituents) plays a pivotal role in supporting the information needs of aviation stakeholders. In fact, a recent Volcanic Ash Challenge Team that ICAO organized, involving senior-level officials from States, international organizations and industry, noted the importance of such information and agreed to develop a proposal for lobbying the satellite community to enhance satellite coverage, resolution and availability of data. The primary objective of these efforts is to improve the capabilities of the volcanic ash advisory centres.

7. Complementary to data available from ground-based, in-situ and airborne detection systems, satellite-based remote sensing is used by volcano observatories and volcanic ash advisory centres to enhance their ability to monitor, qualify and, more recently, quantify the presence and areal extent of volcanic ash in the atmosphere. Such qualitative and, more particularly, quantitative information is assimilated into numerical dispersion/trajectory models used by the volcanic ash advisory centres to improve their forecasts. Increased forecast accuracy and confidence, and a reduction in the level of uncertainty, are valuable constituents of a safety risk management approach to hazard mitigation.

8. Notwithstanding the fact that satellite-based remote sensing of volcanic ash has matured significantly over the past two decades (particularly in the context of quantitative volcanic ash and sulphur dioxide gas retrievals), scientific advisors supporting ICAO's work believe that the re-purposing of on-board sensors towards environmental monitoring activities may have had an unintended impact on the advances that could have otherwise been achieved for volcanic ash detection. Similarly, it has been indicated to ICAO that satellites with onboard volcanic ash detection capability/sensors are presently in need of enhancement.

9. ICAO works very closely with the WMO on matters relating to aeronautical meteorology, including volcanic ash. Volcanic ash in the atmosphere poses significant hazards to aviation – both from a safety perspective (including total or partial loss of thrust and blockage of flight-critical on-board sensors) and an efficiency perspective (including re-routing and closure of airspace and/or airports). Consequently, the timely availability of consistent and reliable information (including satellite data) is of paramount importance to our stakeholders so that informed decisions can be made to mitigate the hazards posed.

10. ICAO fully supports WMO WP/6 as presented to CGMS/39, and respectfully appreciates CGMS consideration of the comments presented here.

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