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# Decrease of anthropogenic emission from aviation and detection of natural hazards with potential application in geosciences using satellite sensors, ground-based networks and model forecasts in the context of the SACS/ALARM early warning system

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Aviation safety can be jeopardised by multiple hazards arising from natural phenomena, e.g., severe weather, aerosols/gases from natural hazard, space weather. Furthermore, there is the anthropogenic emissions and climate impact of aviation, that could be reduced. The use of satellite sensors, ground-based networks, and model forecasts is essential to detect and mitigate the risk of airborne hazards for aviation, as flying through them can have a strong impact on engines (abrasion and damages caused by aerosols) and on the health of passengers (e.g. due to associated hazardous trace gases).

The goal of this work is to give an overview of the alert data products in development in the ALARM SESAR H2020 Exploratory Research project. The overall objective of ALARM (multi-hAzard monitoring and earLy wARning system; https://alarm-project.eu) is to develop a prototype global multi-hazard monitoring and Early Warning System (EWS), building upon SACS (Support to Aviation Control Service; https://sacs.aeronomie.be). This work presents the creation of alert data products, which have a potential use in geosciences (e.g. meteorology, climatology, volcanology). These products include observational data, alert flagging and tailored information (e.g., height of hazard and contamination of flight level – FL). We provide information about the threat to aviation, but also notifications for geoscience applications. Three different manners are produced, i.e., early warning (with geolocation, level of severity, quantification, ...), nowcasting (up to 2 hours), and

forecasting (from 2 to 48 hours) of hazard evolution at different FLs. Note that nowcasting and forecasting concerns $SO_2$ contamination at FL around selected airports and the risk of environmental hotspots. This study shows the detection of 4 types of risks and weather-related phenomena, for which our EWS generates homogenised NetCDF Alert Products (NCAP) data. The first type is the near real-time detection of recent volcanic plumes, smoke from wildfires, and desert dust clouds, and the interest of combining geostationary and polar orbiting satellite observations. For the second type, ALARM EWS uses satellite and ground-based (GB) observations, and model forecasts to create NCAP related to real-time space weather activity. Exploratory research is developed by ALARM partners to improve detection of a third type of risk, i.e., the initiation of small-scale deep convection (under 2 km) around airports. GNSS data (ground-based networks and radio-occultations), lightning and radar data, are used to implement NCAP data (designed with the objective of bringing relevant information for improving nowcasts around airports). The fourth type is related to the detection of environmental hotspots, which describe regions that are strongly sensitive to aviation emissions. ALARM partners investigate the climate impact of aviation emissions with respect to the actual atmospheric synoptical condition, by relying on algorithmic Climate Change Functions (a-CCFs). These a-CCFs describe the climate impact of individual non-$CO_2$ forcing compounds (contrails, nitrogen oxide and water vapour) as function of time, geographical location and cruise altitude.

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