THREE SPACEWALKS

Fuglesang's mission covered operations conducted both inside and outside the ISS. As a qualified Mission Specialist with a specialization in Extravehicular Activities (EVA), he took part in the second and the third of the mission's spacewalks, on 3 and 5 September, together with NASA astronaut John Olivas. The main objective of these two EVAs was to install more than 20 metres of vital cabling outside the ISS to prepare for the arrival of the ESA-provided tranquility Node 3 module in 2010. In parallel, the astronauts also removed and replaced a depleted Ammonia Tank Assembly (ATA) used as part of the ISS active thermal control system. At 800 kg, this was the heaviest object ever manipulated in space by a single astronaut.

The EVA of 1st September was dedicated to the retrieval of the European Technology Exposure Facility (EuTEF) currently mounted on an external payload facility outside ESA's Columbus laboratory module, and its storage in Discovery's cargo bay for its return to Earth. Designed to expose various sample materials and experiments to the vacuum of space, this facility has been returned to Earth inside Discovery's payload bay. This science package, which incorporates nine experiments designed to expose samples to the harsh conditions of space, test materials, analyse the near Earth orbit environment and take pictures of the Earth, has been operating for 18 months.

RETURN TO EARTH

Discovery undocked from the ISS on 8 September, bringing back NASA astronaut Timothy Kopra from the permanent crew, who has been replaced onboard by NASA astronaut Nicole Stott, launched with STS-128. Landing in Florida took place on 12 September at 02:53 CEST (00:53 TU).

Frank De Winne will remain on the ISS until late November 2009, assuming the 'commander seat' in October.

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MONITORING OF VOLCANIC ACTIVITY FROM SATELLITE : A SUPPORT TO AVIATION CONTROL SERVICE

by Dr Jos van Geffen, Institut d'Aéronomie Spatiale de Belgique

Volcanic eruptions can emit large quantities of rock fragments and fine particles (ash) into the atmosphere as well as several trace gases, such as carbon dioxide (CO), sulphur dioxide (SO_2), bromine monoxide (BrO), and water vapour. These volcanic ejecta can have a considerable impact on air traffic safety and on the human health. Ground based monitoring is only carried out at a limited number of volcanoes and, in fact, most volcanoes are not monitored on a regular basis. Satellite observations of sulphur dioxide (SO_2) and aerosols may therefore provide useful complementary information to assess, on a global level, the possible impact of volcanic eruptions on air traffic control and on public safety. Such is precisely the aim of the SACS programme (Support to Aviation Control Service).

HAZARDS TO AVIATION

Of the volcanic ejecta, the larger rock fragments usually fall back to Earth close to the volcano. The lighter ash and the gases, however, can rise high into the troposphere and even reach the lower stratosphere, up to 15 or 20 km, depending on the type of volcano erupting. Since airlines fly usually at 10-12 km altitude, aircraft may encounter volcanic ash clouds along their route.

The ash emitted by volcanic eruptions is a major hazard to aviation. The ash can, for example, severely damage the material of the aircraft, it can clog its sensors, it can limit the view of its pilots, and it can severely scratch ("sandblast") the windows of the aircraft. And when it enters the aircraft's engines, the ash can melt (it has a melting point of about 1100°C), as a result of which the engine may fail (*figure 1*).

More than 90 aircraft have sustained damage after flying through volcanic ash clouds. In at least 7 cases this resulted in temporary loss of power of one or more of the engines. In three cases, a Boeing 747 lost all four engines (1982 and 1989); fortunately the engines could be restarted once outside the ash cloud, but meanwhile the aircraft had dropped several kilometres. The ash emitted during the eruption of the Pinatubo volcano in 1991 is known to have damaged aircraft as far away from the volcano as 1000 km (*figure 2*).

Every year there are about 60 volcano eruptions. On average the ash cloud of 10 of these eruptions reach flight level along major aircraft routes. The total cost of the damage sustained by aircraft due to volcanic ash clouds in the period 1982-2000 is estimated at 250 million US dollar. So far none of the incidents have resulted in fatal accidents or of people being injured.

Of the gases emitted during a volcano eruption, sulphur dioxide (SO_2) is in itself also a hazard to aircraft, as SO_2 reacts with water vapour to form sulphuric acid (SO_4H_2), which is corrosive and can therefore scratch the paint and the

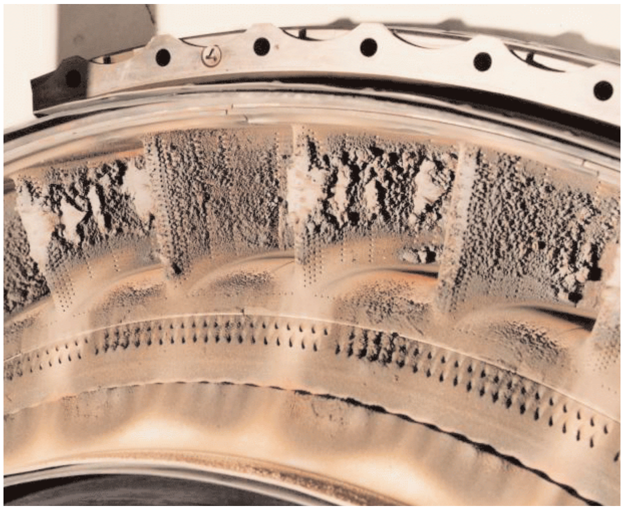


Figure 1. Damaged part of a Boeing-747 engine after flying through an ash plume, June 1982. [Photo: Eric Moody, British Airways]

windows of the aircraft, and it can create sulphate deposites in the engines. Depending on the kind of eruption, the SO_2 may be inside the ash cloud.

From all these considerations it is clear that the safest procedure for aircraft is to stay clear of volcanic clouds. But pilots cannot always see an ash cloud, e.g. at night, and the ash does not show up on radar. And SO_2 and SO_4H_2 are colourless gases, therefore invisible. If it penetrates into the aircraft, sulphuric acid is noticed easily because of its strong smell, but then the aircraft is already inside the cloud. Hence, it is of major importance to know in advance where volcanic clouds are and whet elevation they reach.

Figure 2. Heavy ashfall from the 1991 eruption of the Pinatubo volcano in the Philippines caused this World Airways DC-10 to set on its tail. About 4 cu km of ash was erupted on 15 June. It accumulated to depths of 10-15 cm at this airfield at the Cubi Point Naval Air Station, 40 km SSW of Pinatubo. [Photo: R.L. Rieger, U.S. Navy]

THE VOLCANIC ASH ADVISORY CENTRES

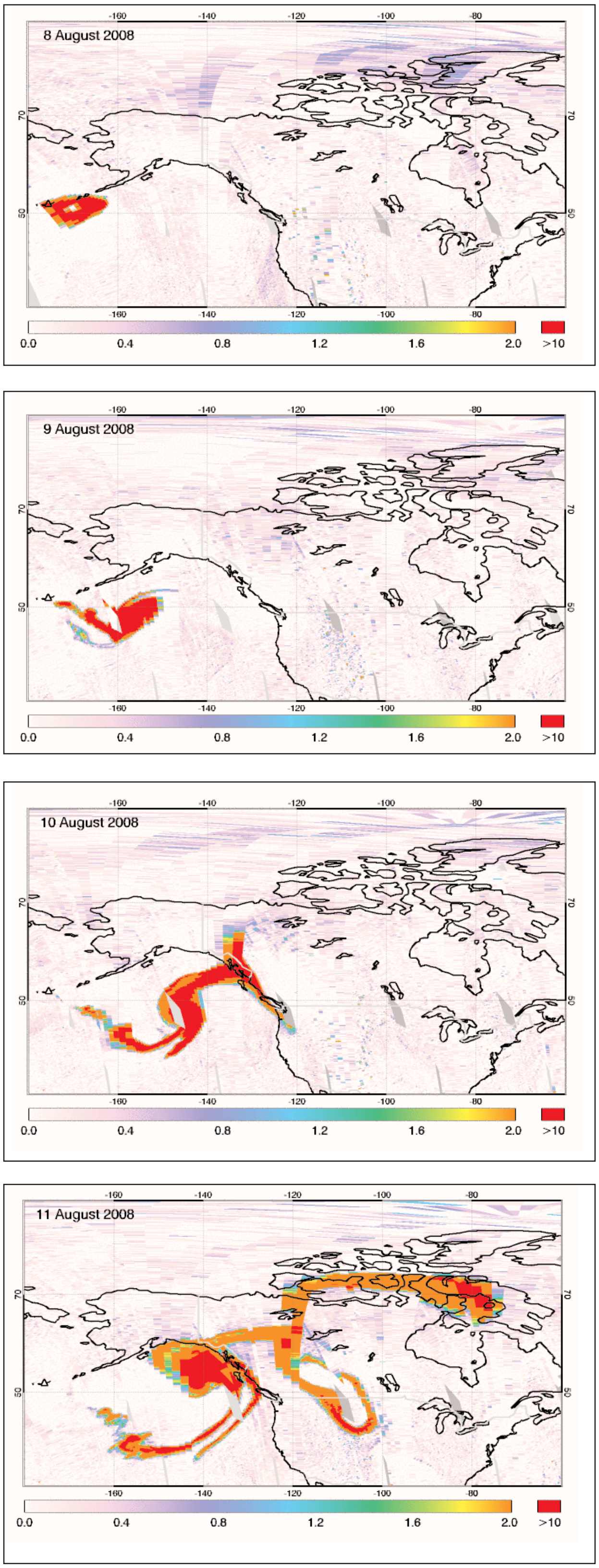
The Volcanic Ash Advisory Centres (VAACs) are the official organisations charged with gathering information on the presence and motion of volcanic clouds. On the basis of this they issue advices and alerts to airline and air traffic control organisations on the possible danger of volcanic clouds. The VAACs are part of a system set up by the International Civil Aviation Organization (ICAO) called the International Airways Volcano Watch (IAVW), which was founded at an ICAO meeting in 1995.

VAAC responsibilities to aviation users include to utilise satellite data, pilot reports, and other sources of information to detect and track ash clouds, and to use trajectory and dispersion models to forecast the motion of ash plumes. Satellite observations of SO_2 can assist the VAACs in their tasks, though SO_2 is not officially part of the VAAC responsibilities: SO_2 measurements can help pinpoint the presence of volcanic ash clouds, in particular during the first few days after an eruption. In general the ash will drop due to gravity effects faster than the SO_2, so that some distance away from the volcano the ash and SO_2 clouds may be separated.

THE SUPPORT TO AVIATION CONTROL SERVICE

With the above considerations in mind, a Support to Aviation Control Service – SACS for short – is being set up. The aim of SACS is to deliver in near-real time (i.e. around 3 hours after observation) measurements of SO_2 concentrations derived from satellite observations. In case of exceptional SO_2 concentrations ("SO_2 events") SACS issues a notification by e-mail to the VAACs and other interested parties, such as volcanological observatories. The core users of SACS are the London and Toulouse VAACs, which cover Europe and Africa, but the data is not restricted to these areas: the service covers SO_2 concentrations world-wide.

SACS currently uses observations from the satellite instruments SCIAMACHY (aboard the EnviSat satellite), OMI (aboard EOS-Aura) (*figure 3*) and GOME-2 (aboard MetOp-A). These instruments are on polar-orbiting satellites at about 800 km and they measure the SO_2 in the Ultraviolet, which means they provide one measurement per day during daylight. To provide additional data, SACS will be extended in the near future to include SO_2 measurements obtained in the Infrared, notably from the IASI instrument (aboard MetOp-A), as these are also available during night-time. In addition, all instruments will be used to give some basic information on the distribution of certain types of aerosols.



Sulphur dioxide is not only emitted by volcanic eruptions, but also by some anthropogenic activities, such as fossil fuel combustion, oxidation of organic materials in soils, and biomass burning. From the satellite measurements it is at the moment not possible to distinguish the different sources of SO_2. Studies are ungoing to improve this situation, by trying to determine the altitude of the SO_2 cloud from the measurements and from trajectory/disperison modelling.

SACS is primarily set up under the umbrella of the ESA financed project GSE-PROMOTE, combining activities at the Belgian Institute for Space Aeronomy (BIRA-IASB, which acts as service leader), Carlo Gavazzi Space (CSG, Italy), the German Aerospace Center (DLR), and the Royal Netherland Meteorological Institute (KNMI). SACS is financed by ESA to continue beyond PROMOTE and will then include activities at the Free University of Brussels (ULB), and work in close collaboration with the Norwegian Institute for Air Research (NILU).

For more information on SACS, maps of the SO_2 data and alerts of SO_2 events, see http://sacs.aeronomie.be/

Figure 3. The eruption of the Kasatochi volcano, on 7 August 2008, sent a massive amount of SO2 and ash into the atmosphere; more than 40 flights were cancelled by Alaska Airlines because of the ash clouds. Driven by the winds at different altitude, the SO2 travelled to the East along different routes. The maps show the total column amount of SO2 in Dobson Units (DU), based on observations from the OMI instrument from 8 to 11 August; the location of Kasatochi is indicated by a triangle. [Maps: BIRA-IASB / KNMI / NASA]