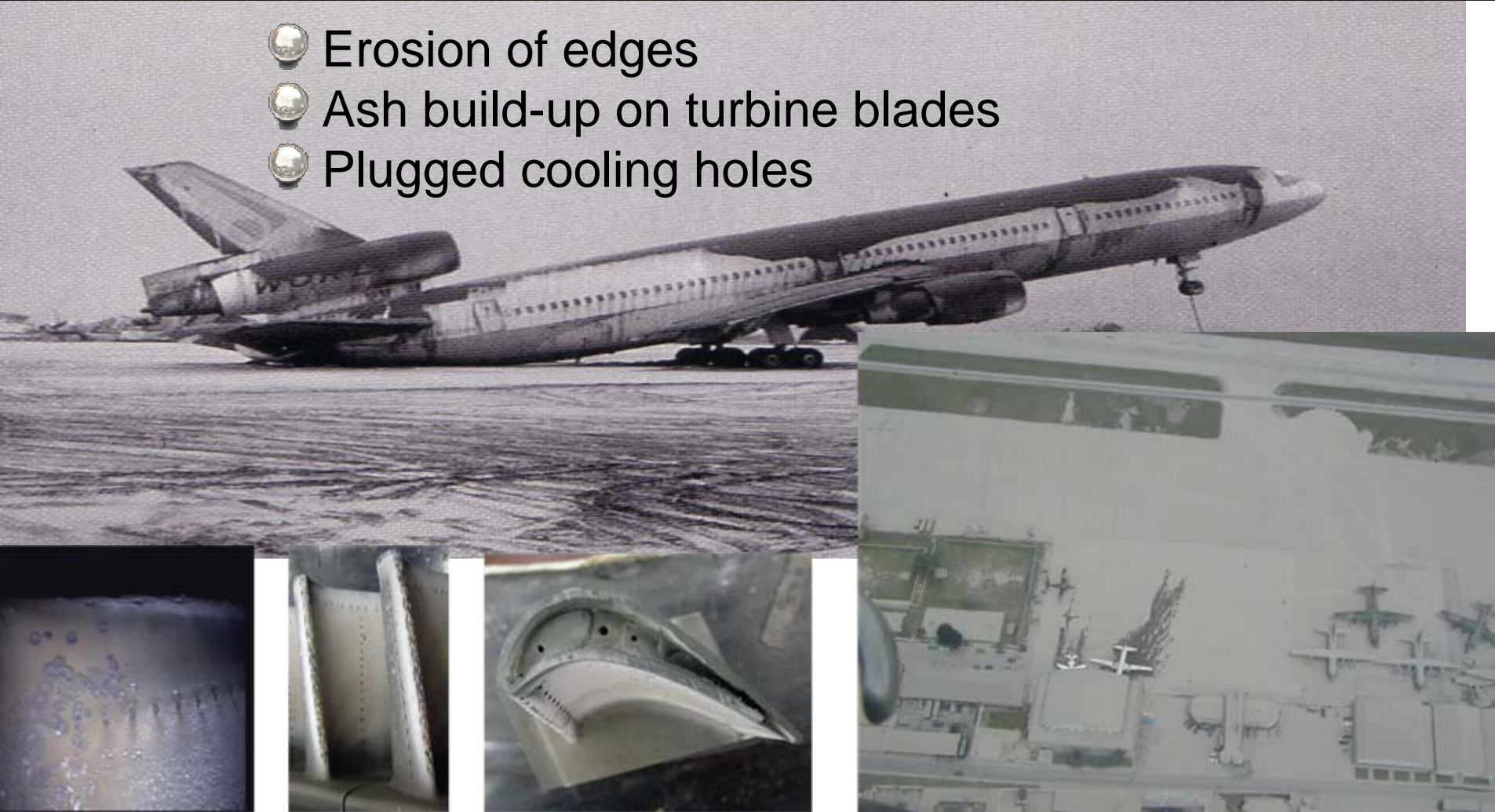


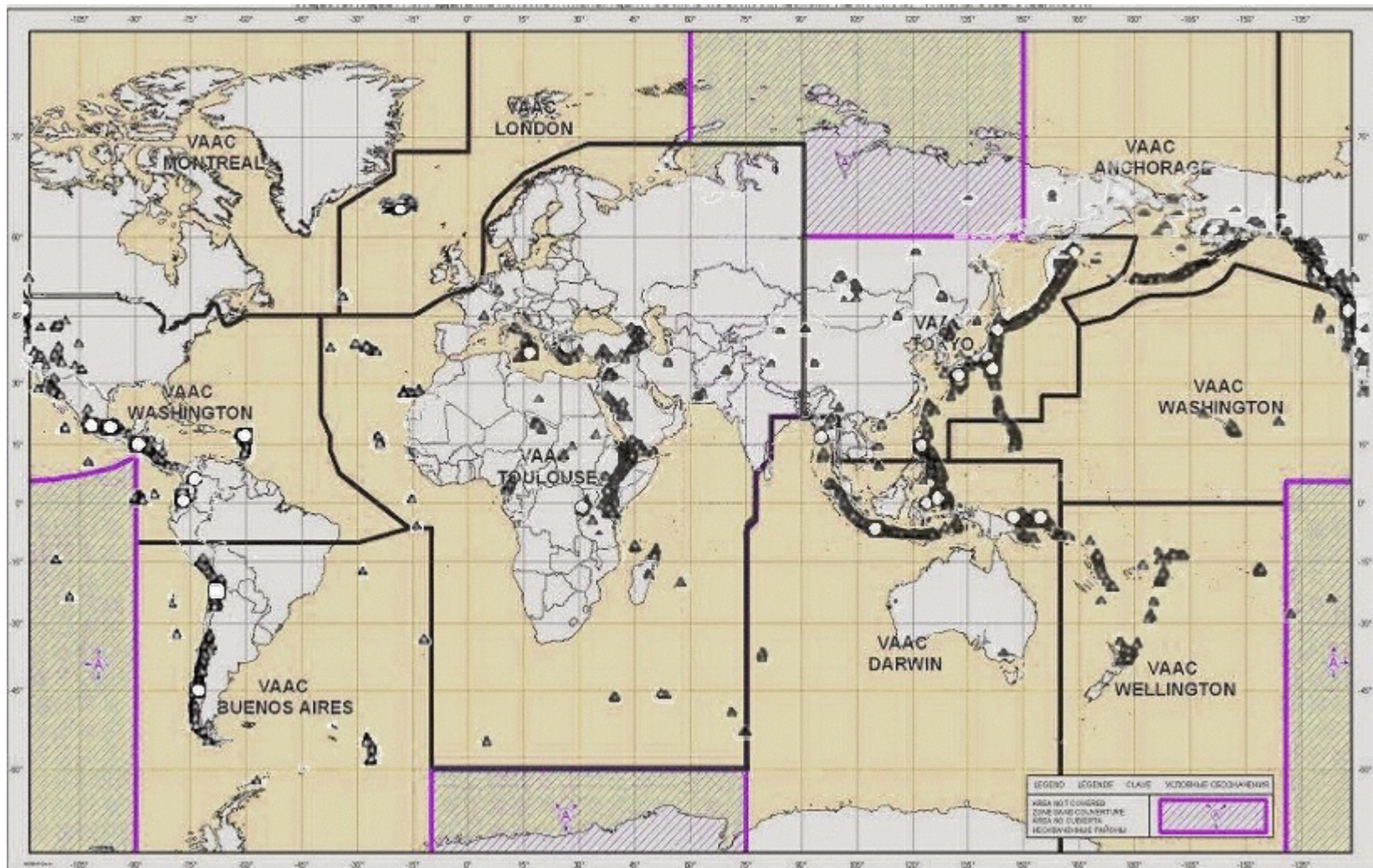
Claus Zehner

What is all the fuss about?

- Erosion of edges
- Ash build-up on turbine blades
- Plugged cooling holes



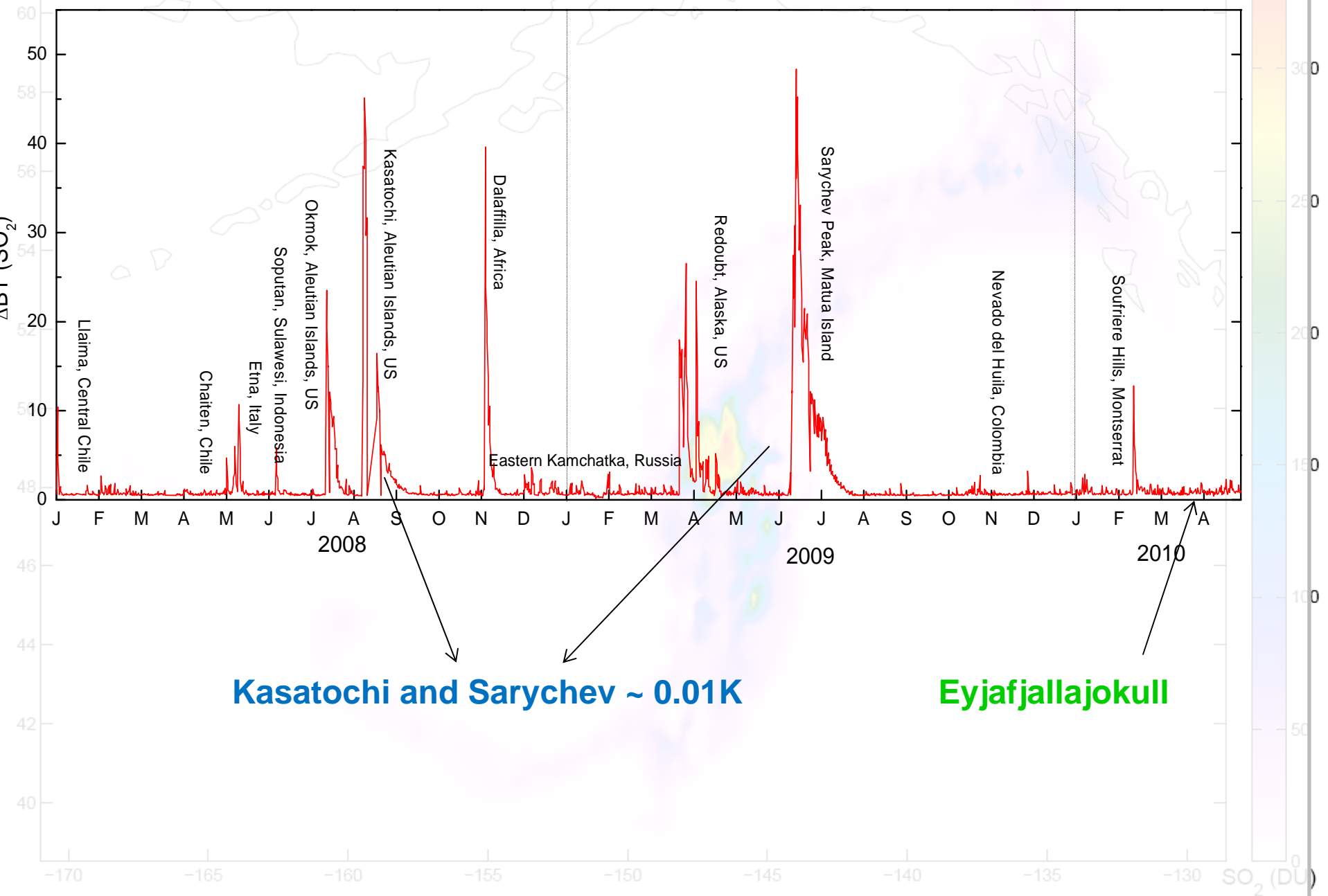
The nine VAACs



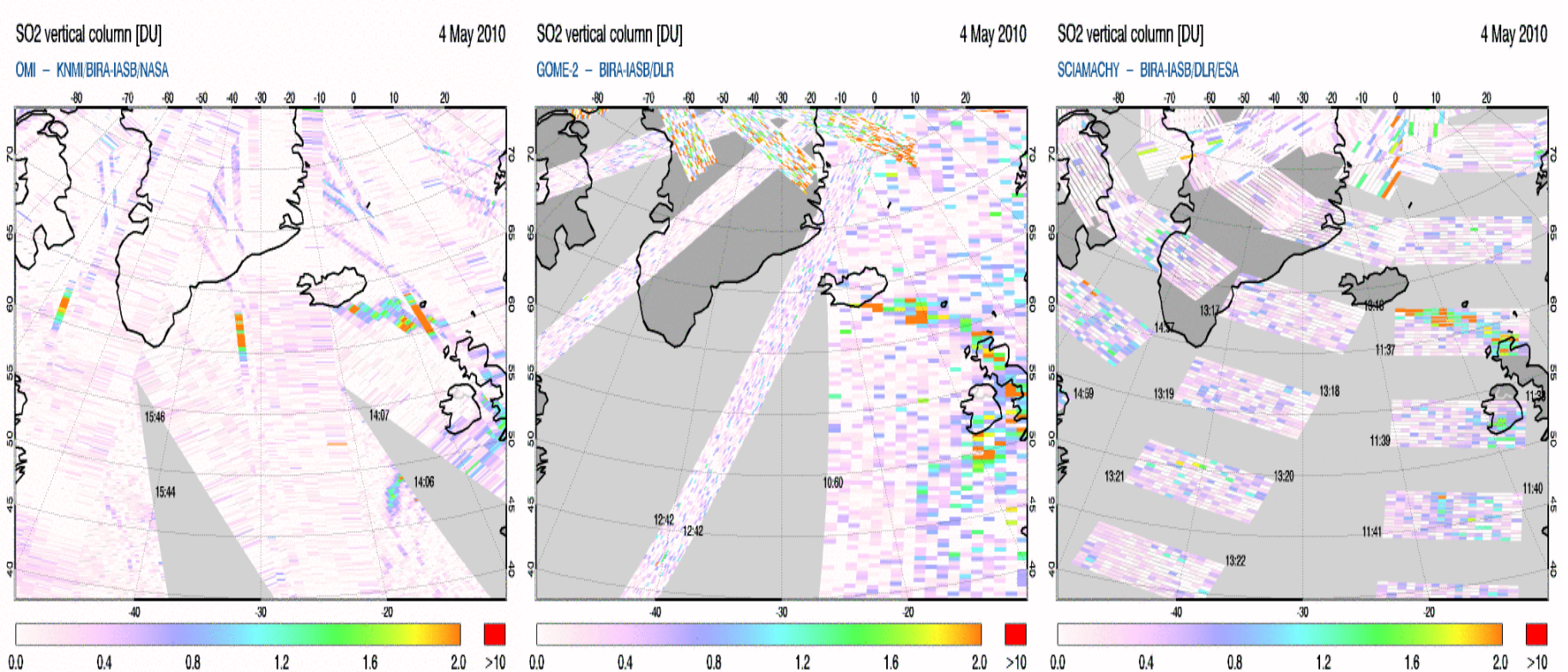
- On average 1 volcanic eruption per week
- Horizontal spread ~1000's km
- Vertical extent up to ~50,000 ft
- Duration ~hours to ~days
- Most danger 0-3 hours after eruption
- Some danger ~days to ~weeks after eruption
- Cost of re-routing is significant
- Still no reliable warning system
- First warning is usually from pilots

Total SO₂ mass (Tg) at 7km: 3.29 (1.06) – 13km: 1.97 (0.12) – 16km: 1.53 (0.18) – 19km: 1.87 (0.29) – 25km: 3.37 (0.73) – 30km: 6.49 (1.58)

• IASI timeseries of UT/LS SO₂



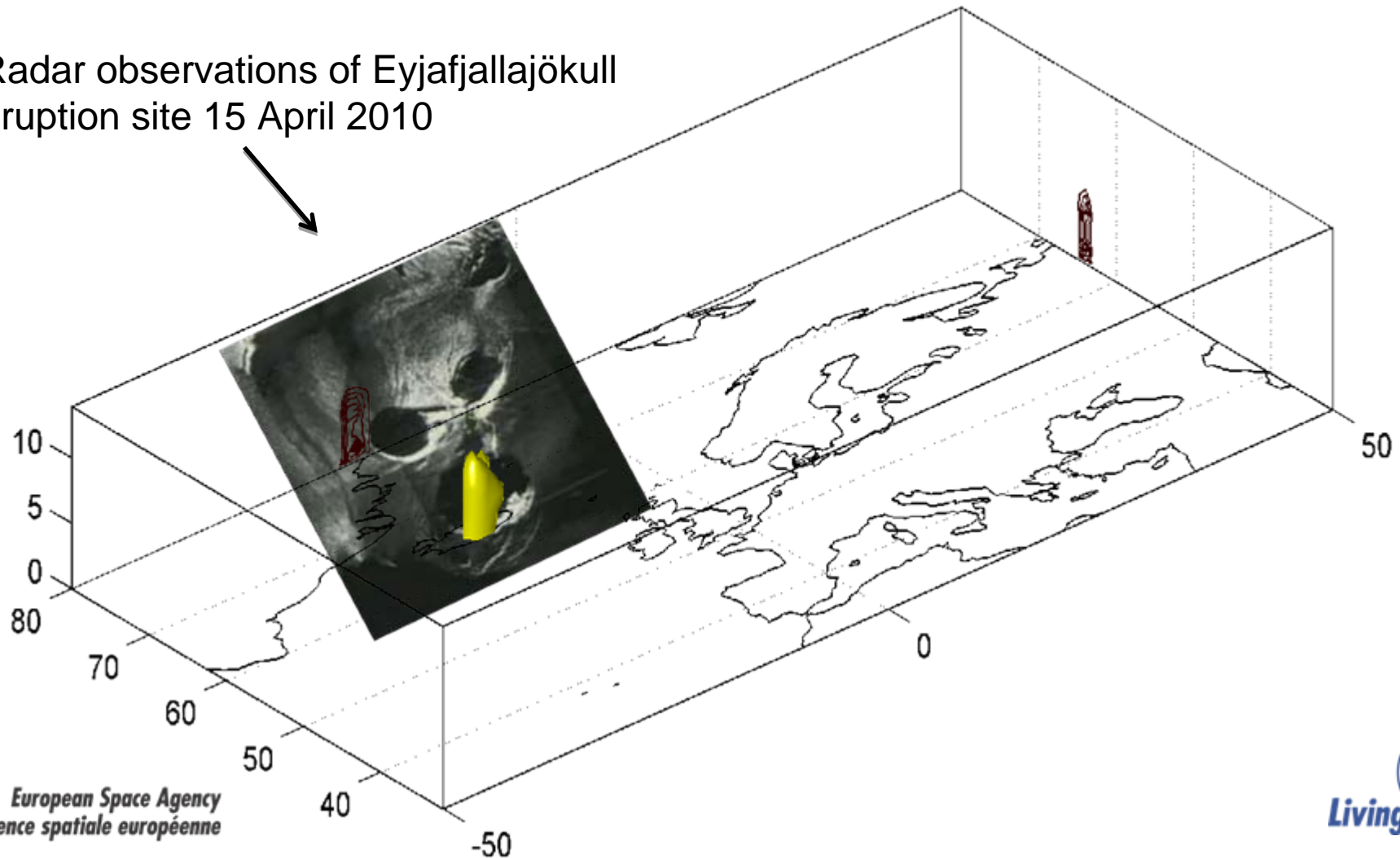
<http://sacs.aeronomie.be/>



<http://savaa.nilu.no> – Model: FLEXPART

FLEXPART simulation of the ash tracer on 2010/04/14 12:00, isosurface at 300 ng/m^3

Radar observations of Eyjafjallajökull eruption site 15 April 2010

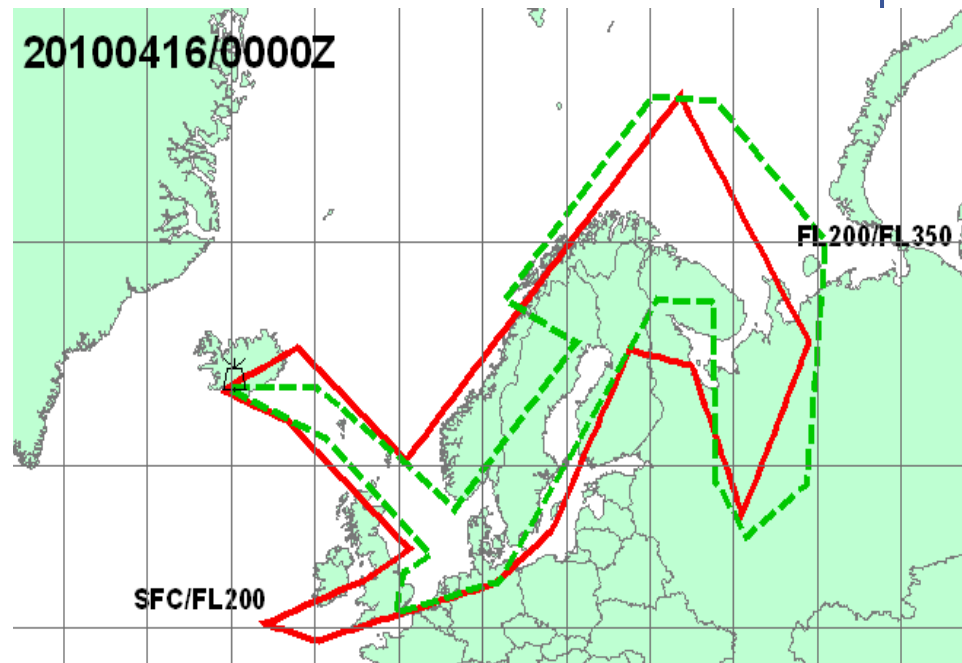
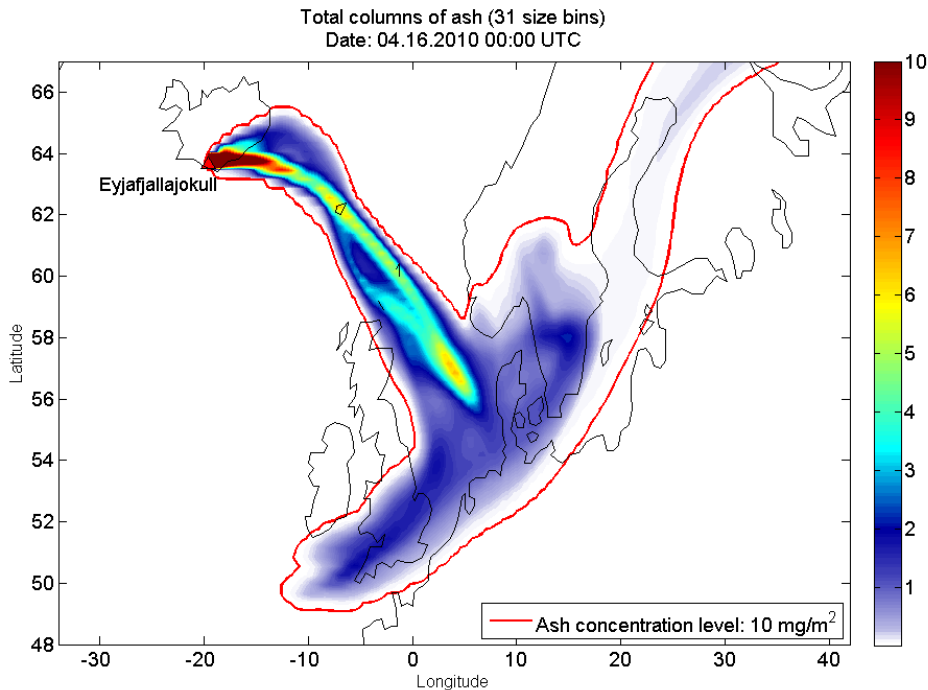


<http://satepsanone.nesdis.noaa.gov/pub/OMI/OMISO2/iceland.html>

http://cimss.ssec.wisc.edu/goes_r/proving-ground/geocat_ash/loops/iceland.html

MODIS, CALIPSO, MISR, and AVHRR data

Event well captured by the London VAAC: 16 April 00:00



VA ADVISORY
DTG: 20100416/0000Z
VAAC: LONDON
VOLCANO:
EYJAFJALLAJOKULL
PSN: N6338 W01937
AREA: ICELAND

SUMMIT ELEV: 1666M
ADVISORY NR: 2010/008
INFO SOURCE: ICELAND MET OFFICE
AVIATION COLOUR CODE: RED
ERUPTION DETAILS: SIGNIFICANT ERUPTION
CONTINUING. PLUME REACHING FL180, BUT
POSSIBLY OCCASIONALLY TO FL240.

Notice: qualitative comparison;
isolines not strictly comparable

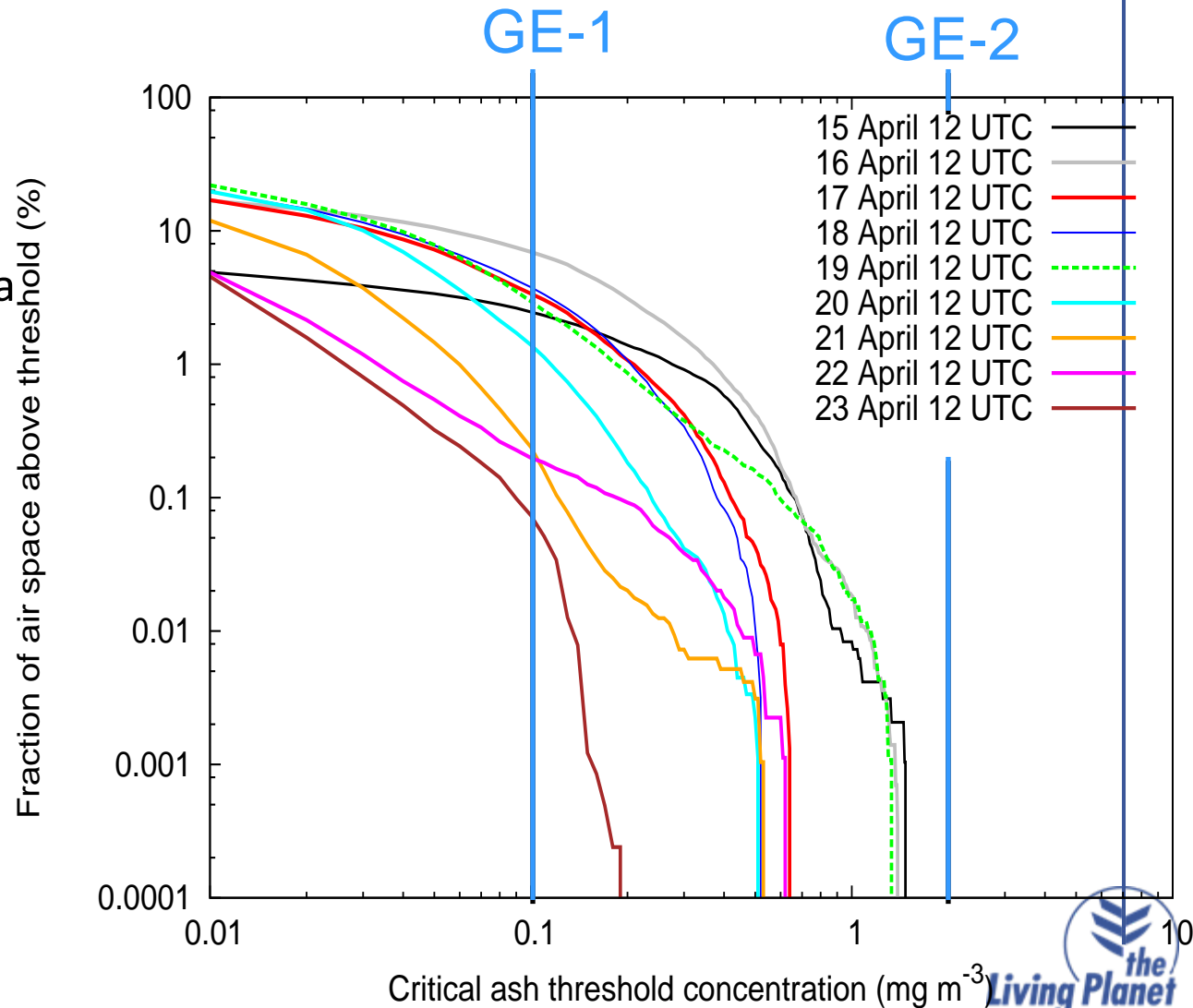
How strongly was the European airspace affected? **PRELIMINARY!!!**

- 10°W - 30°E , 45°N - 60°N ,
0-12 km altitude

- Fraction of air space occupied by the plume as a function of concentrations exceeding a threshold assumed critical to jet engines

GE-1: General Electric "safe continuous operation"

GE-2 guidance on 21 April



- The 2 mgm-3 threshold value is not accepted outside Europe
- During May further changes have been included: flight areas being in excess of 4 mgm-3 are a **No Fly Zone** and areas for which **VAACs** predict volcanic ash density being less than 4 mgm-3 are **Time Limited Zones** (it is possible to fly through for a short time period) – not accepted by France
- **Discussions are ongoing**

Flight information – 18 April



The rules have changed: “No longer do aviation want to know *“is it there?”* they need to know *“how much is there?”*”

Shutdown of most part of Europe airspace from 15 April to 21 April.

The restrictions were lifted 21 April over Europe through the introduction of new guidelines on volcanic ash density.

The ash cloud caused further disruptions to air travel operations in Ireland, Northern Ireland and Scotland on 4 and 5 May and in Spain, Portugal, northern Italy, Austria and southern Germany on 9 May. Irish and UK airspace closed again on 16 May and reopened on 17 May.

Volcanic Ash cost Airlines about \$1.7 to 2.5 Billion

During the three day period of April 17-19, when disruptions were at their peak, airlines lost \$400 million per day.

Emirates, has lost about \$50 million during the airport shutdowns.

Qantas estimates that it lost between \$1.5–2 million a day for 5 days.

ESA/EUMETSAT Workshop on volcanic ash monitoring from Space – 26/27 May at ESRIN

- more than 53 participants (e.g. EC, NASA, USGS, several European Met. Offices, Scientists (remote sensing experts, volcanologists ...))
- Major outcome: position paper on this special event (planned to be ready by end of June)
- http://earth.eo.esa.int/workshops/Volcano/files/STM_280_ash100801_2v.pdf
- Oral Sessions:
 - Eruption, VAACs, New Ash Threshold Value
 - Modelling
 - Remote Sensing of the Ash Plume (airplanes, ground-based, satellites)
- Discussions in splinter meetings
 - Satellite data: usefulness and access?
 - Modelling of the ash plume movement: need to include real data in order to be more credible?
 - Science and ongoing projects (ESA, EUMETSAT, EC , national ...) on using satellite data for the purpose of volcanic ash monitoring?
 - Are there implications for the utility of already planned missions or is there the need for new instrumentation?

Some Lessons Learned

- Operational (NRT) data-streams typically do not contain quantitative information about height or concentration of hazardous species.
- Collaboration between groups who specialise in different sensors was done under best effort, but was limited and uncoordinated.
- The tolerance to ash of commercial aircraft engines was a critical component in information used in the decision making process, and was poorly constrained at the start of the eruption.
- One of the largest uncertainties has been information on the status of the eruption (source information) for model initialisation.
- A second big uncertainty has been obtaining information on ash cloud concentrations and its vertical distribution. Aircraft, primarily research facilities with appropriate instrumentation, have been a key tool but have been unable to fly through thick ash due to engine manufacturer constraints.

- Perform Refractive Index measurements (covering UV to thermal IR wavelength range) of volcanic ash as input for satellite retrieval algorithms.
- Studies on synergistic satellite data usage/intercomparison/validation should be performed.
- Various options to constrain the vertical distribution of the source (e.g., airborne LIDAR, satellite observations) should be explored, because they can provide critical information for the forecast models.
- Geostationary imagery and sounding from UV to thermal IR (like MTG), should be combined with polar orbiting scanning LIDARs, and polar orbiting stereo viewing imagers (like MISR) in order to establish an optimum satellite instruments combination to retrieve ash clouds from space.

ACC Volcanic Ash Monitoring Project

- Provide a global volcanic ash alert system by combining efforts (NOAA, NASA, ESA) to VAACs
- Improve satellite retrievals on ash concentration and height information
- Develop new modelling capabilities (ash plume height information, data assimilation) that could be implemented at VAACs