Volcanic Ash Monitoring

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Support to Aviation Control Service

A global Alert (and Analysis – demonstration only) system for volcanic Ash and SO2 emissions using satellite measurements

CEOS Atmospheric Composition Constellation (ACC) Project to combine and extend existing activities on Volcanic Emission monitoring from Space

Contents

- **Volcanic ash and aviation**
- **User information (slides from Toulouse VAAC)**
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Eruption of the Grímsvötn volcano on Iceland in November 2004.
(Photo: Matthew J. Roberts)

Volcanic ash and aviation

- Volcanic eruptions may bring ash high up into the atmosphere, where it poses a **hazard** to aviation:

  Ash clogs censors, melts in engines, sandblasts forward facing surfaces – windows, landing light covers, leading edges of wings – etc.
- More than 90 aircraft suffered damage from ash cloud encounters:
  - At least 7 cases of in-flight loss of power
  - Pinatubo (1991): aircraft damaged >1000 km.
- Per year about 10 eruptions reach flight levels.
- Economic cost estimation of US$ 250 Million during 1982-2000.

Part of an engine and a landing light cover of the BA Boeing 747 that passed through an ash cloud of Galunggung (Indonesia) on 24 June 1982, temporarily loosing power on all four engines.

Volcanic Ash Advisory Centres

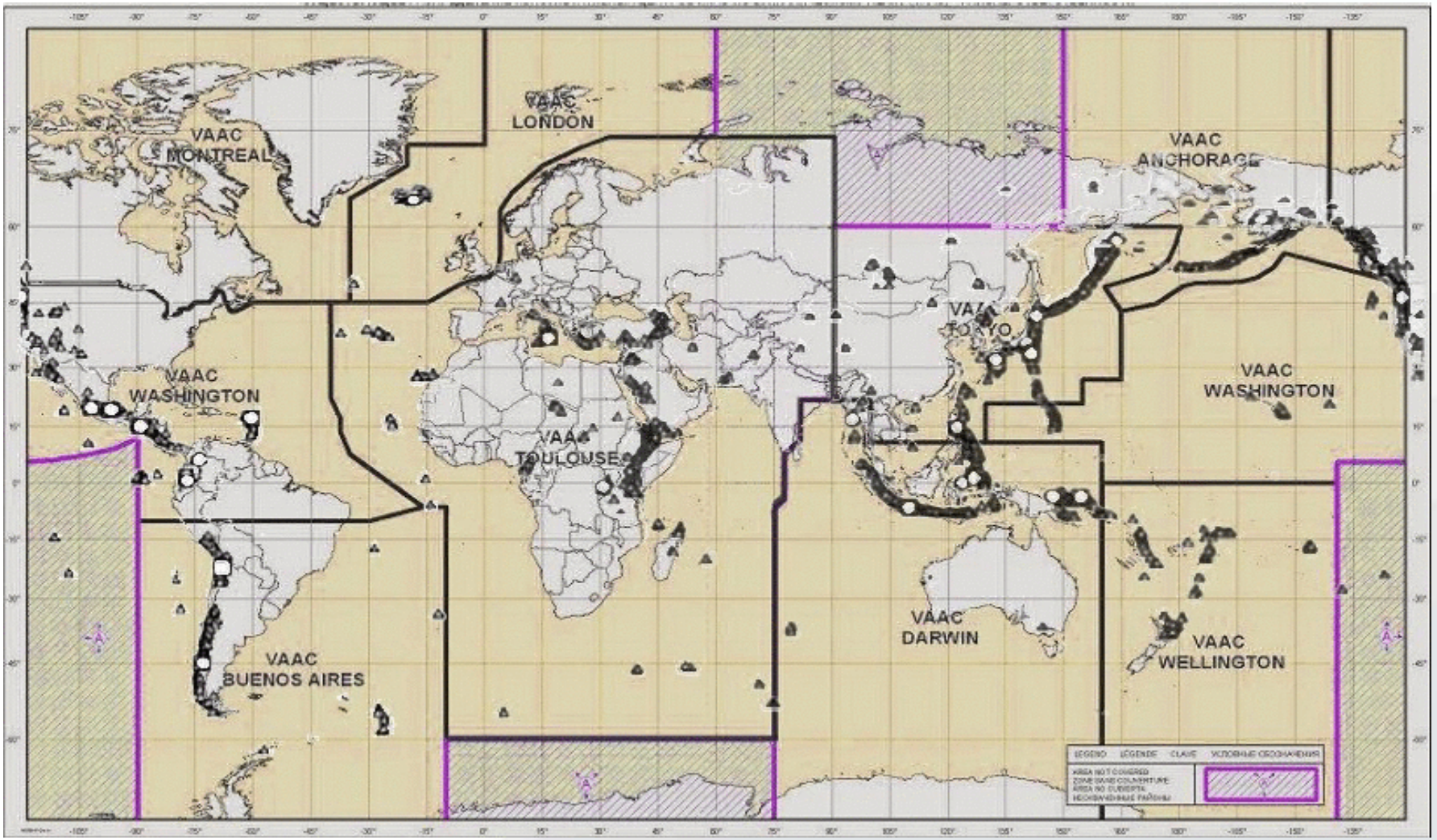
Volcanic Ash Advisory Centres (VAACs) are the official organisations charged with gathering information on volcanic ash clouds and, on the basis of that, issue advices and alerts to air line and air traffic control organisations on the possible danger of volcanic clouds.

The VAACs are part of an international 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:

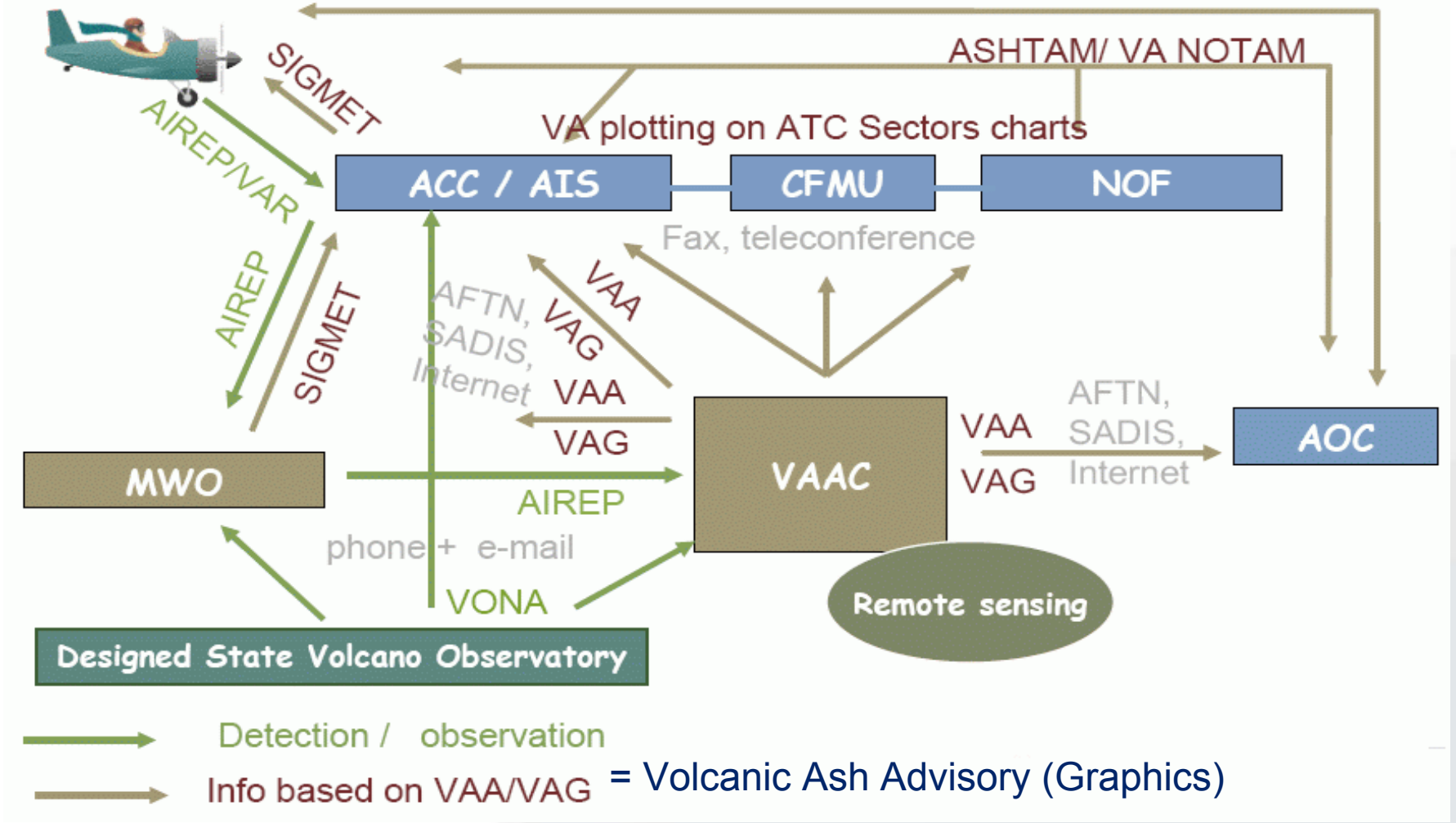
- **Utilise satellite data, pilot reports, etc. to detect and track ash clouds.**
- **Use trajectory/dispersion models to forecast the motion of ash plumes.**

The nine VAACs



VAAC advisory position

VAACs gather information and issue advisories (VAAs)



Some abbreviations

MWO = Meteorological Watch Office
ACC = Area Control Centre
ATS / AIS = Air Traffic Service / Aeronautical Information Services
NOF = Notam Office
AOC = Airline Operations Centre
CFMU = Central Flow Management Unit

VAA / VAG = Volcanic Ash Advisory / Volcanic Ash Graphics
SIGMET = Significant Meteorological Information
AIREP / PIREP = Aircraft Report / Pilot Report
VAR = Volcanic Activity Report
ASHTAM = NOTAM reporting (volcanic) ash hazards
NOTAM = Notice to Airmen
AFTN = Aeronautical Fixed Telecommunication Network
SADIS = Satellite Distribution
VONA = Volcano Observatory Notice for Aviation

VAAC start of activity

The input for VAAC activities comes from pilot reports, volcanological observatories, notifications from others (e.g. remote sensing using satellite data),

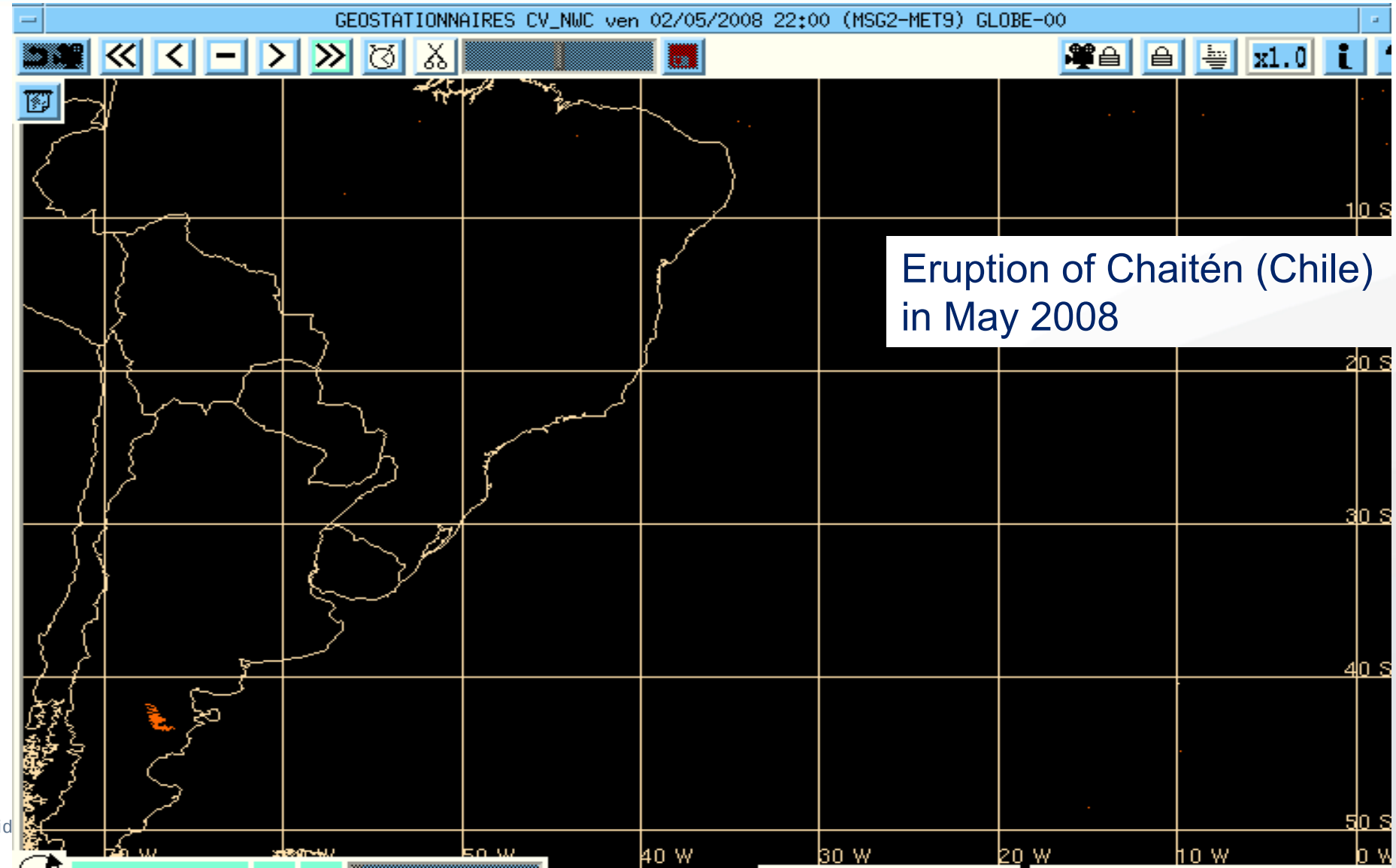
Once notified of a possible volcanic event, the VAACs try to gather as much information as possible, and assess this information

In case of a volcanic ash cloud, they issue a Volcanic Ash Advisory (VAA) and they produce forecasts of the motion of the ash cloud.

VAAC forecaster tools

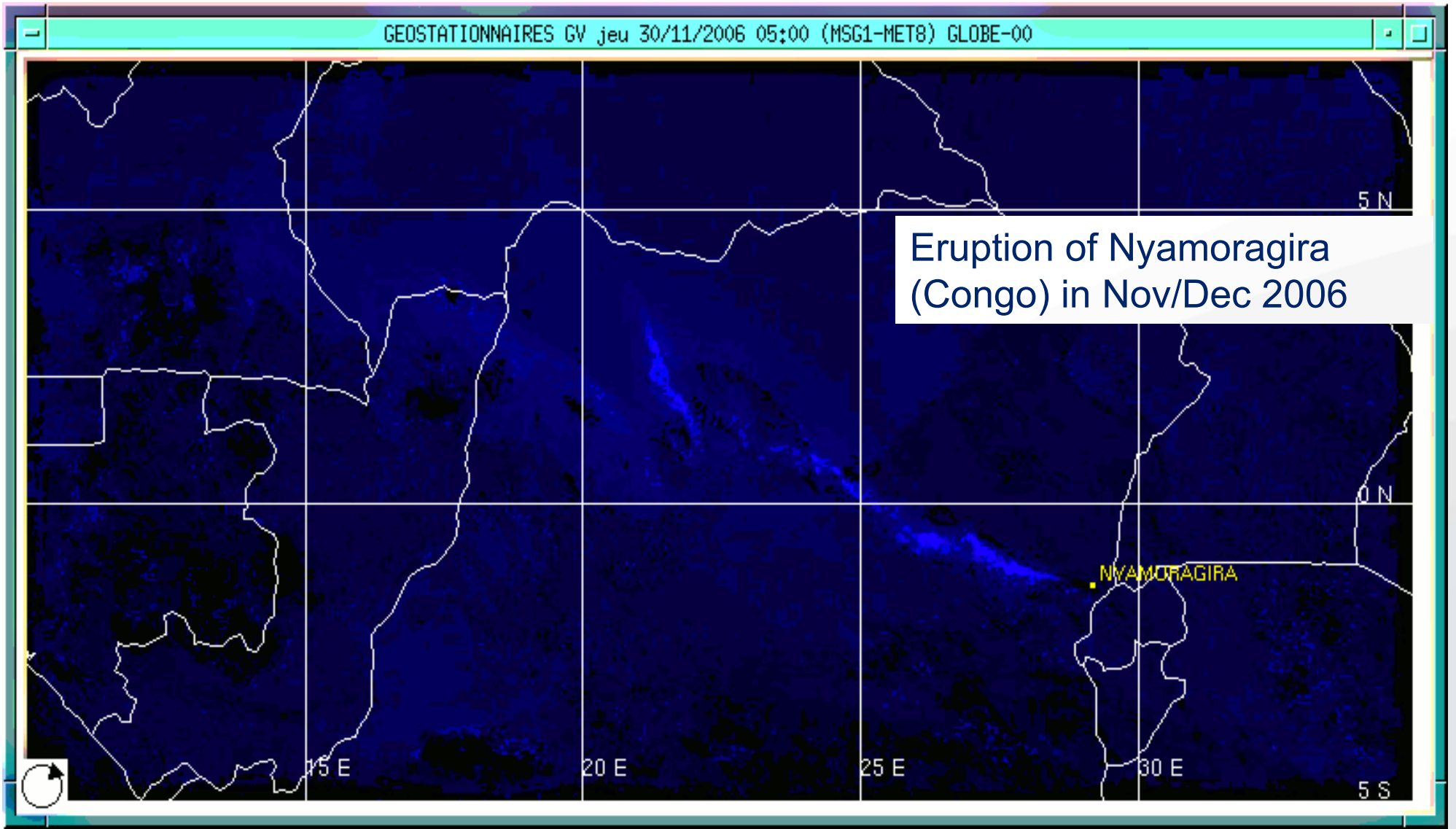
- **Visualize all available meteorological data -- Numerical model output, ground, sea and radar observations, sat. images (geostationnary, polar, forecasted), radar imagery (local or mosaics), vertical profiles (observed and forecasted), Metgrams (temporal serie), raw bulletins, faxes ...**
- **Support Weather Watch**
- **Understand (Enhancing informations, animating ...)**
- **Merge (combining different types of data ...)**
- **Produce documents and images for end users or systems taking advantage of all the data -- raw or value added data**
- **Allow a replay for training and case studies**

Remote Sensing: Volcanic Ash Flag



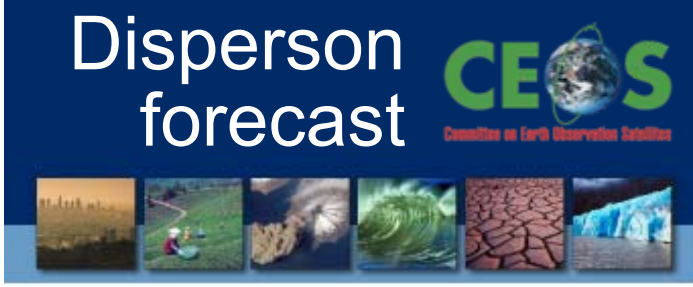
Eruption of Chaitén (Chile) in May 2008

Remote Sensing: SO2 from METEOSAT



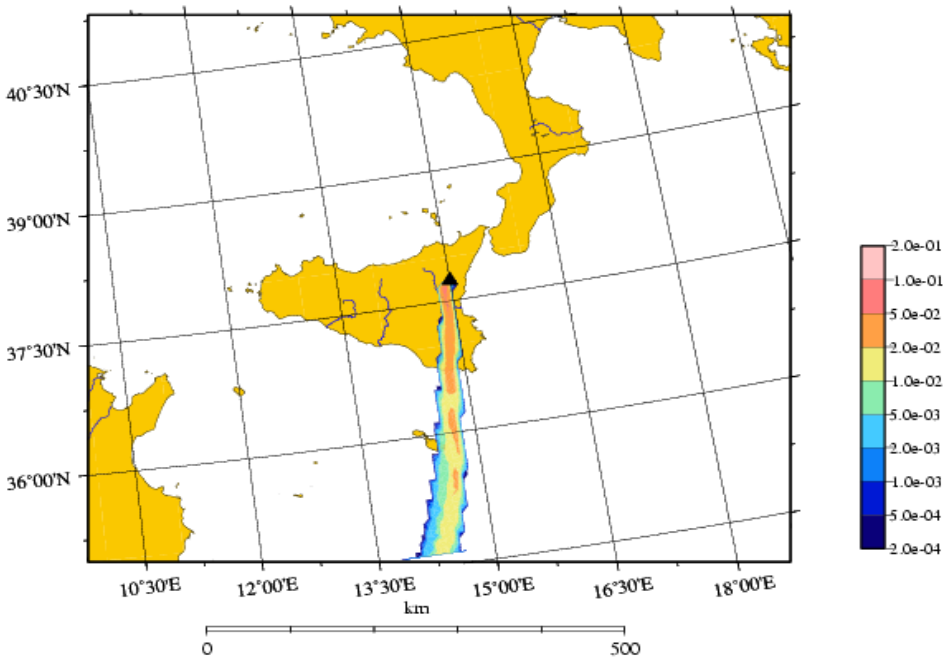
Eruption of Nyamoragira (Congo) in Nov/Dec 2006

Disperson forecast



PERLE
modèle météo : MESO-NH
modèle de dispersion : SPRAY (ARIA Technologies SA)

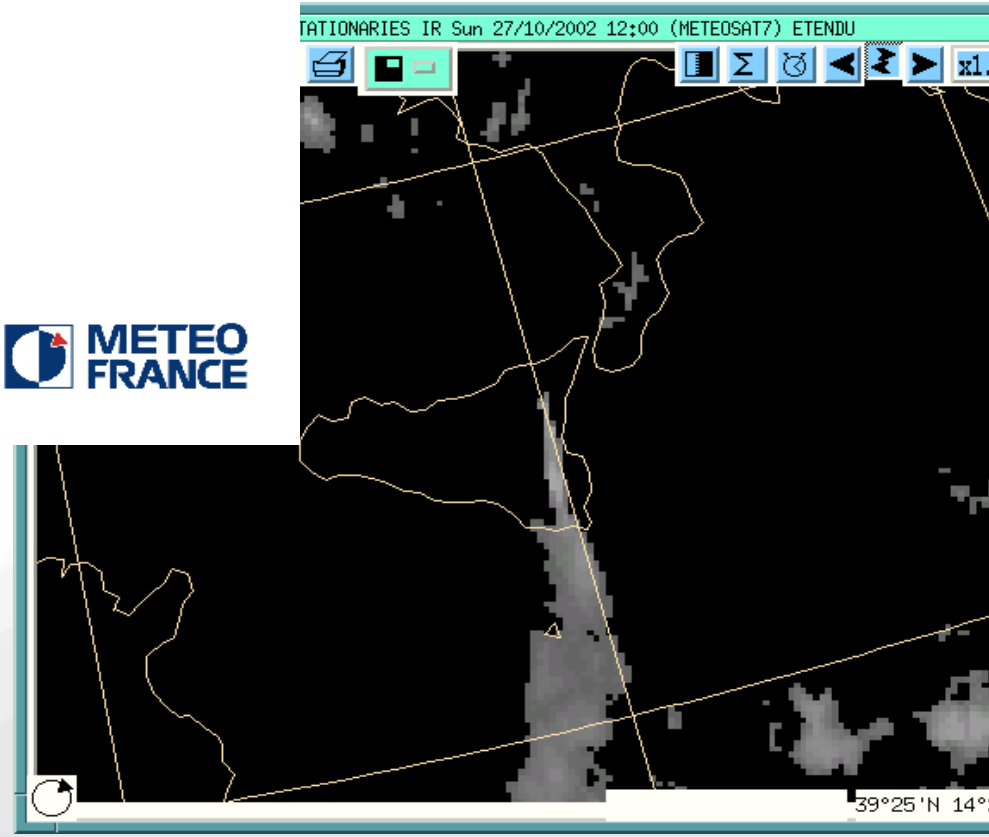
27/10/2002 12h00



INFOS REJET
Effluent : traceur passif
Date rejet 27/10/2002
Heure rejet 02h30
Durée rejet 12h00
Lat. rejet 37.73 37°43'47"
Lon. rejet 15.0 15°0'0"
Base 0m
Sommet 2000m
Quantité totale rejetée 1.2e+11g

INFOS MODELE
Grille résolution 8km
Domaine 720km*720km
Base modèle ARPEGE pour MESONH
Réseau 26/10/2002 18UTC

METEO FRANCE



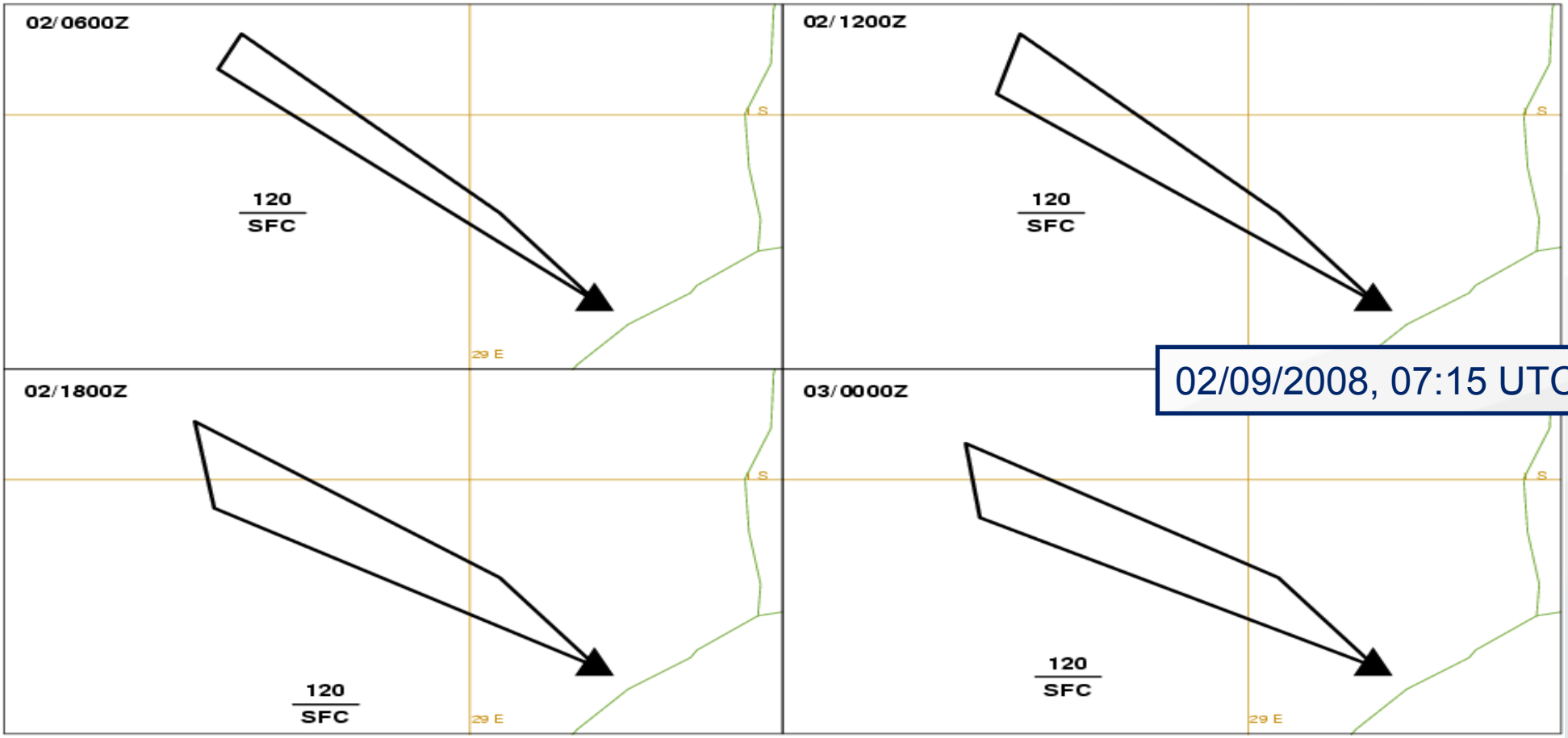
Eruption of Etna (Italy) on 27 Oct. 2002

Example VAA: Nyiragongo (Congo)

FVXX01 LFPW 020718
VA ADVISORY
DTG: 20080902/0715Z
VAAC: TOULOUSE
VOLCANO: NYIRAGONGO 0203-03
PSN: S0131 E02915
AREA: AFRICA-C
SUMMIT ELEV: 3470M
ADVISORY NR: 2008/08
INFO SOURCE: METEOSAT IMAGERY
AVIATION COLOUR CODE: UNKNOWN
ERUPTION DETAILS: ERUPTED EARLIER THAN 0500 UTC
OBS VA DTG: 02/0630Z
OBS VA CLD: SFC/FL120 S0131 E02915 - S0045 E02830 - S0050 E02825 - S0131 E02915
FCST VA CLD + 6H: 02/1230Z SFC/FL120 S0131 E02915 - S0045 E02830 - S0050 E02825 - S0131 E02915
FCST VA CLD + 12H: 02/1830Z SFC/FL120 S0131 E02915 - S0115 E02900 - S0050 E02825 - S0105 E02825 - S0131 E02915
FCST VA CLD + 18H: 03/0030Z SFC/FL120 S0131 E02915 - S0115 E02900 - S0050 E02825 - S0105 E02825 - S0131 E02915
RMK: NIL
NXT ADVISORY: 20080902/1315Z
=

02/09/2008, 07:15 UTC

Example VAA: Nyiragongo (Congo)



02/09/2008, 07:15 UTC

VOLCANIC ASH ADVISORY
DTG: 20080902/0715Z
VAAC: TOULOUSE
VOLCANO: NYIRAGONGO 0203-03
AREA: AFRICA-C
SUMMIT ELEV: 3470M

METEO FRANCE

ADVISORY NR: 2008/08
INFO SOURCE: METEOSAT IMAGERY
AVIATION COLOUR CODE: UNKNOWN
ERUPTION DETAILS: ERUPTED EARLIER THAN 0500 UTC
RMK: NIL
NXT ADVISORY: 20080902/1315Z

VAAC Conclusions

- **VAACs are a key point within the International Airways Volcano Watch and must be able to provide a quick and efficient response under all conditions (24h maintained robust systems / back up).**

- **The consistency of information given to final users (ACC, MWO, AOC, etc) is of paramount importance and cannot come from other sources then the VAACs.**

- **Any additional information (quantitative & qualitative) about explosive eruption and/or volcanic ash cloud detection is profitable to a VAAC (and to IAVW) depending on:**
  - **swiftness of notification**
  - **interoperability with VAAC tools**
  - **quality & integrity of data (e.g.: rate of false detection)**

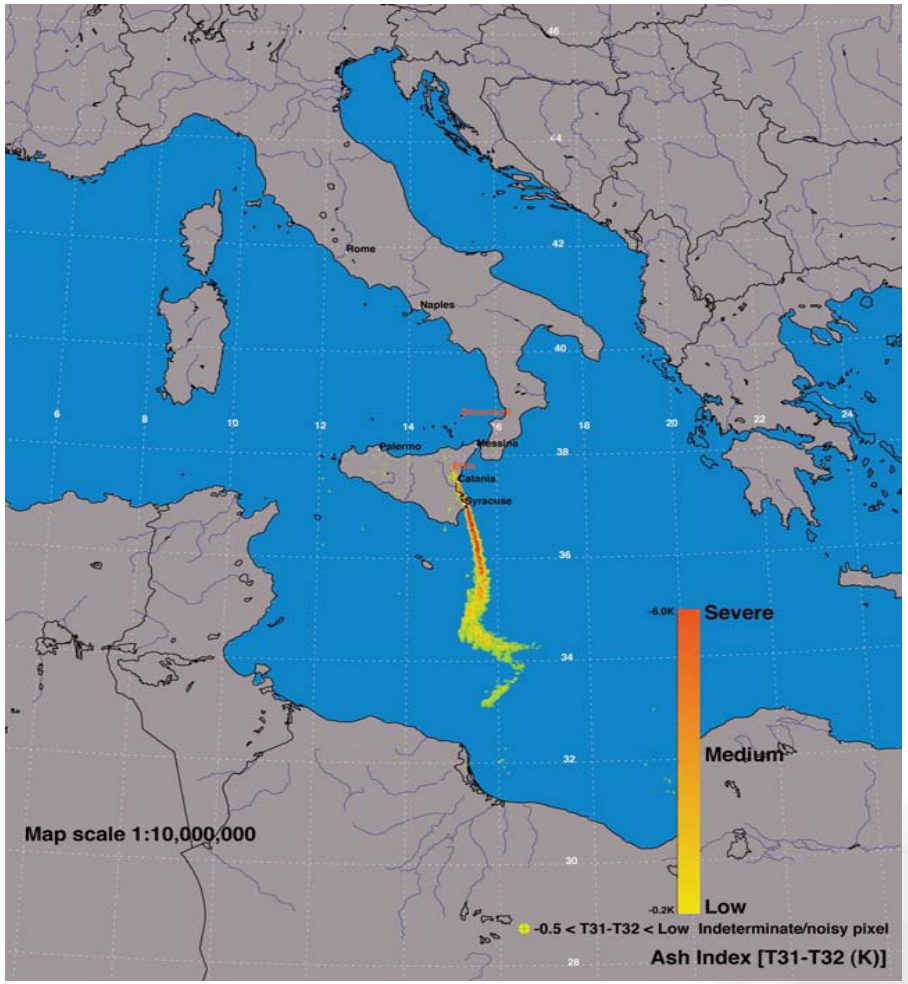
Background and aim of the ACC service

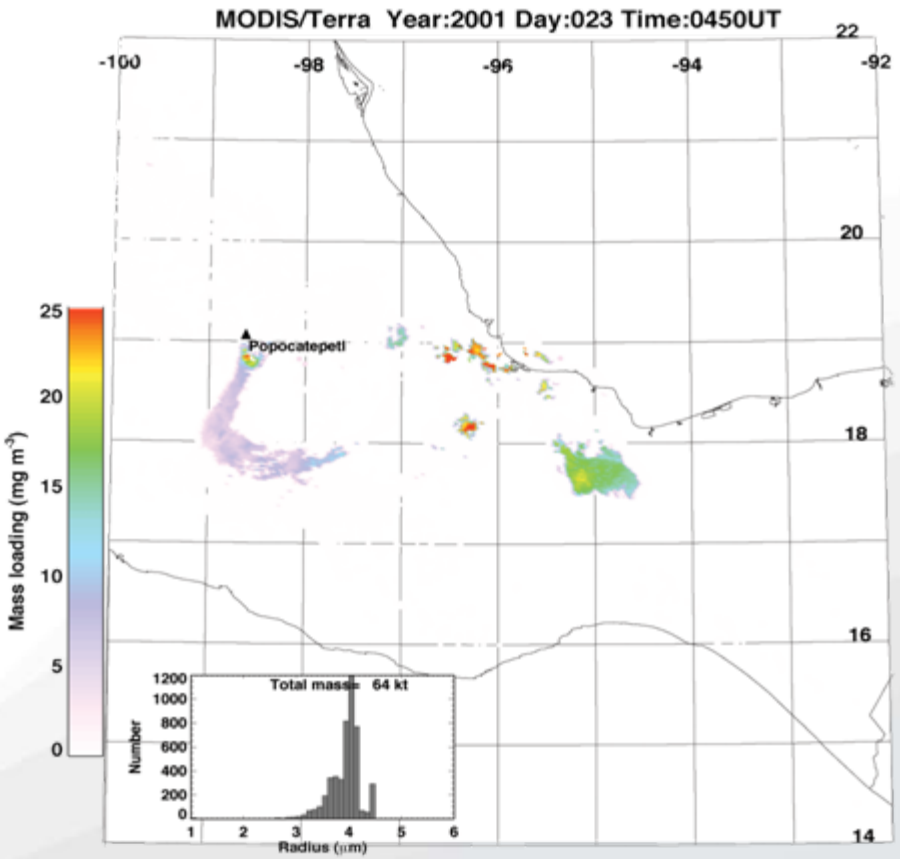
- **Most volcanoes are not monitored on a regular basis from ground-based stations.**
- **In the first day or two after an eruption SO2 and ash will travel together and therefore SO2 may serve as a marker for the ash.**

Monitoring of Ash and SO2 concentrations on a global scale from satellite, with an automated notification of exceptional concentrations, is very useful to VAACs.

Etna, Nov. 2002 (Photo: Tom Pfeiffer)

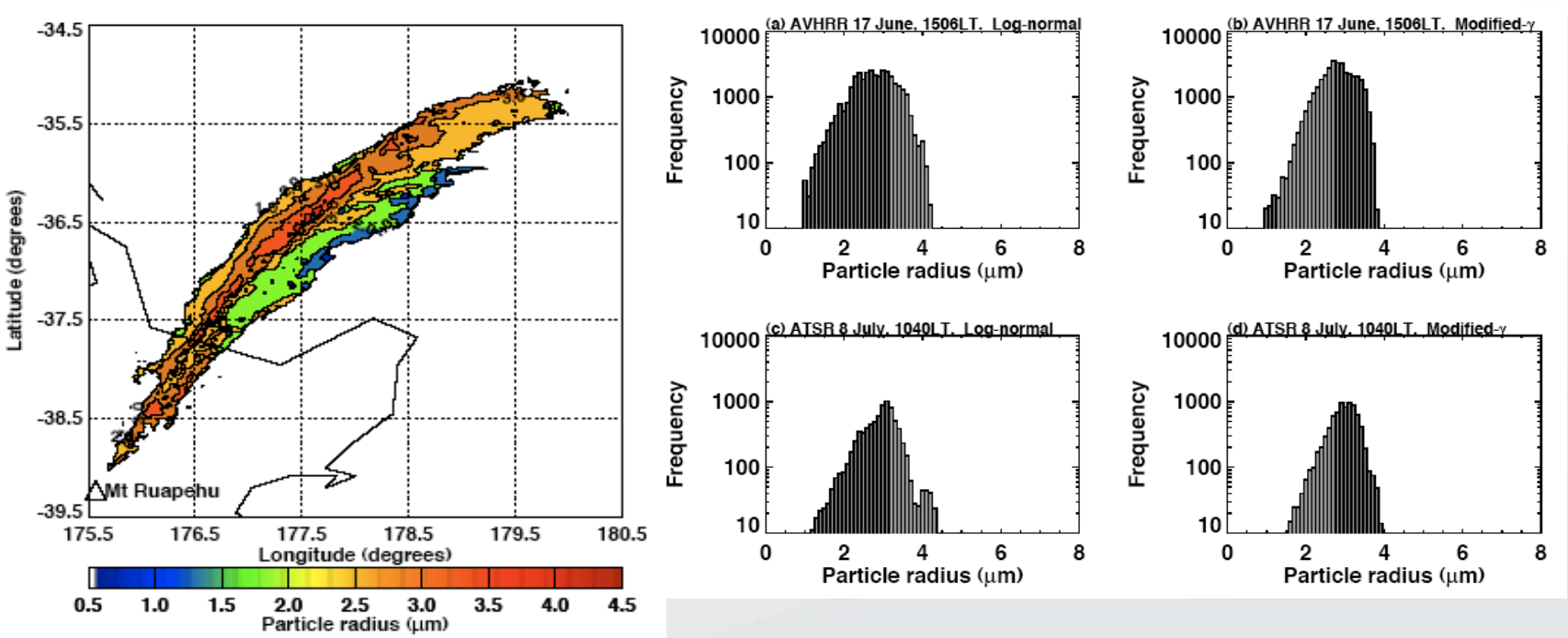
Satellites can detect and quantify ash





Estimating ash from satellites

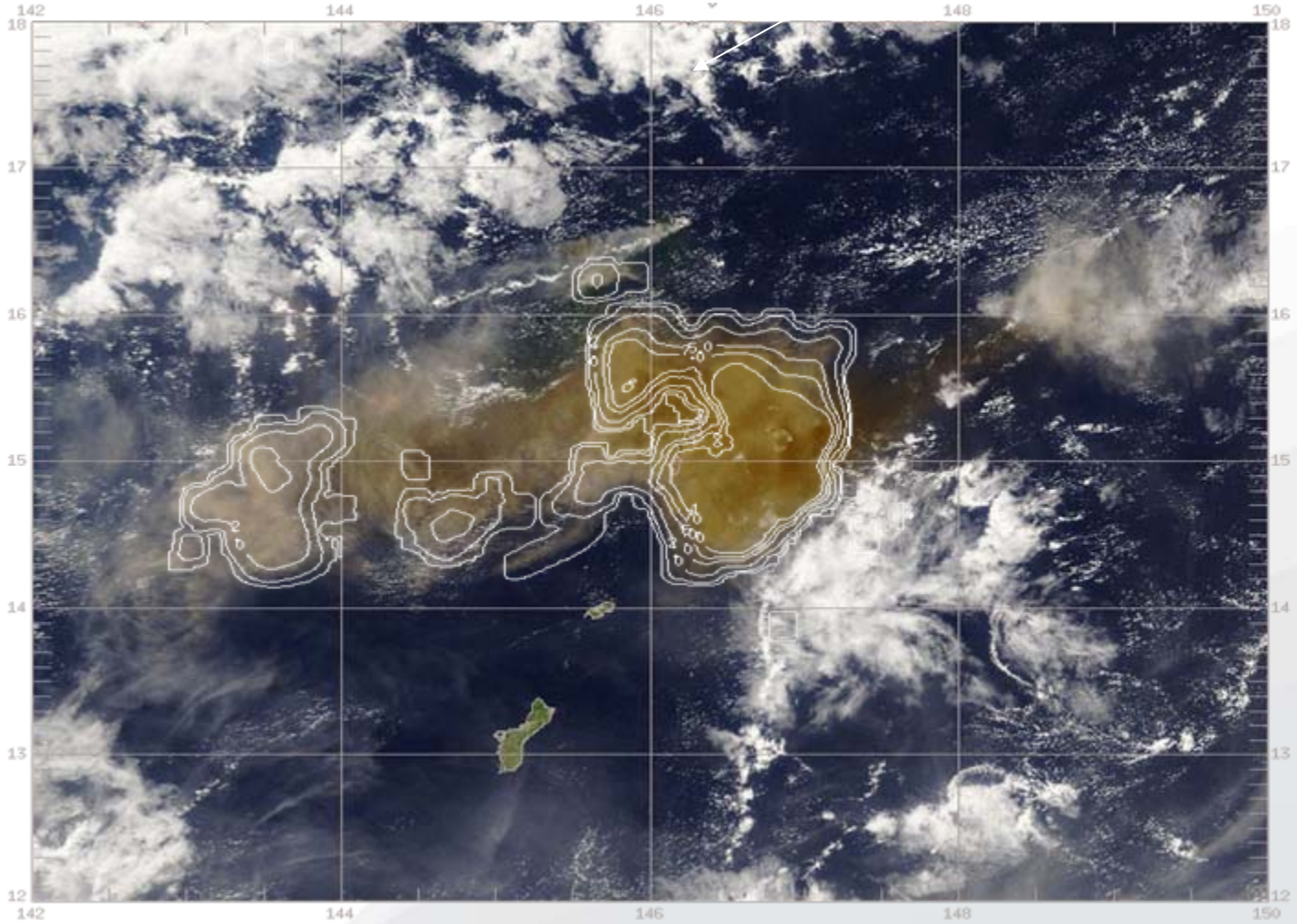
Date:Time	Sensor	Size distribution			
		Log-normal		Modified–γ	
		Mass loading ($mg\ m^{-3}$)	Mode radius (μm)	Mass loading ($mg\ m^{-3}$)	Mode radius (μm)
17-06-96:1506	AVHRR-2	3.5–6.9	2.7	3.2–6.3	2.7
08-07-96:1040	ATSR-2	1.4–2.7	3.1	1.4–2.6	3.1
08-07-96:1440	AVHRR-2	1.5–2.9	3.0	1.4–2.6	2.9
08-07-96:1909	AVHRR-2	1.7–3.2	3.2	1.5–2.9	3.5



Prata, A. J., and I. F. Grant, 2001, Quart.J.Roy.Meteorol. Soc, **127**, 2153–2179.

Ash Retrievals

Anatahan



Global Alert system (under development)

SACS (Support to Aviation Control Service) intends to deliver in near-real time SO2 and aerosol data possibly related to volcanic activity. http://sacs.aeronomie.be/

Operational on SO2 alerts using SCIAMACHY, OMI and IASI data. Extension planned on Aerosols Index alerts.

Currently: 62 subscribers

SAVAA (Support to Aviation for Volcanic Ash Avoidance) SAVAA will provide a means for delivering quantitative satellite-based products aimed at the aviation industry to assist in the avoidance of hazardous volcanic ash clouds. http://savaa.nilu.no/

Prototype on SO2 alerts using GOME-2 data http://www.doas-bremen.de/gome2_so2_alert.htm. Extension planned on ash alert using SEVIRI, AVHHR, MODIS and AIRS data.

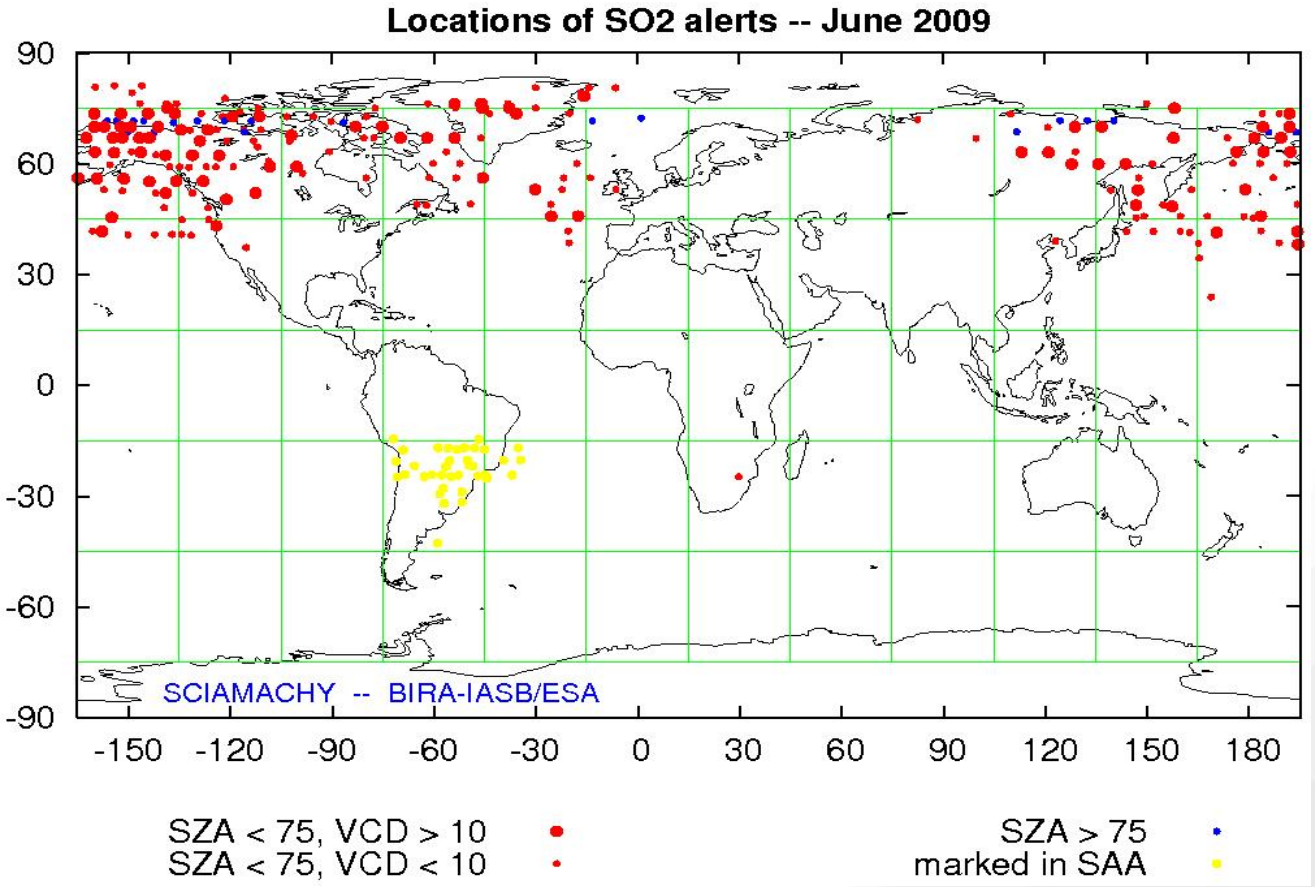
NOAA Alert Services using OMI and AIRS data:

http://www.star.nesdis.noaa.gov/smcd/spb/iosspdt/iosspdt.php?so2=1#1

http://satepsanone.nesdis.noaa.gov/pub/OMI/OMISO2/index.html

Alaid, Russia, April 1981 (Photo: Smithsonian GVP)

Example of Alerts: **Sarychev**
Peak volcano eruption – started 12 June 2009



SZA ≤ 75° VCD < 10 DU
SZA > 75° all VCD

Category	No. of alerts
SZA ≤ 75° VCD > 10 DU	**81**
	119
	19
In SAA area; all VCD, SZA	**37**
Total	**256**

Note: data is limited to SZA ≤ 80°

A large number of the alerts in June is related to activity of the Sarychev Peak volcano on one of the Kuril islands, which started on 12 June. SO2 alerts triggered by this eruption event continued well into July.

Example of alerts: Sarychev Peak

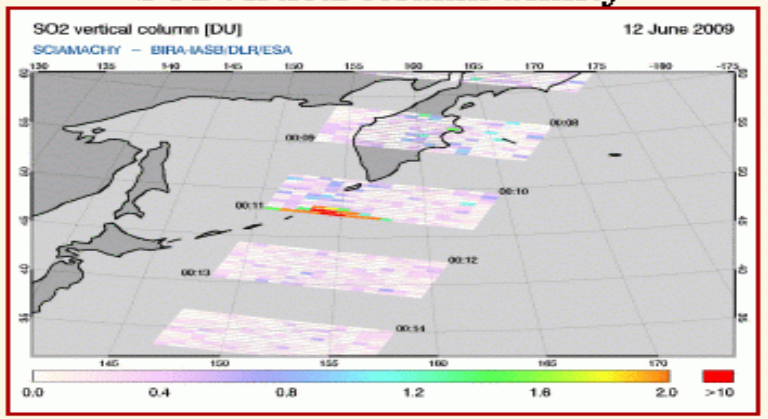
First alert message related to the Sarychev eruption:

```
SACS notification of exceptional SO2 concentration
==================================================
Process date : 2009 06 13
Process time : 05:00:01 CEST
Instrument   : SCIAMACHY
No. notices  : 1


Alert notice : 1
-----------------
http://sacs.aeronomie.be/alert/?alert=20090613_050001_001

Start date   : 2009 06 13
Start time   : 00:10:15.491  UTC
Aver. long.  :  157.5  deg.
Aver. latit. :   48.5  deg.
Aver. sza    :   30.1  deg.
Max. SO2 vcd :   18.5  DU
```

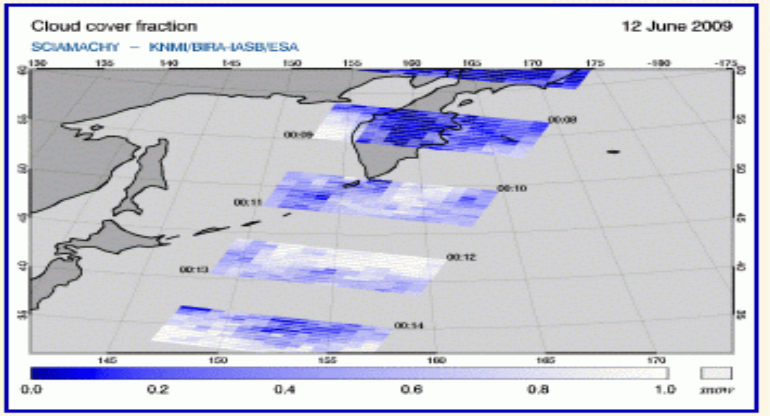
Example of alerts: Sarychev Peak

SCIAMACHY

SO2 vertical column density



Cloud cover fraction

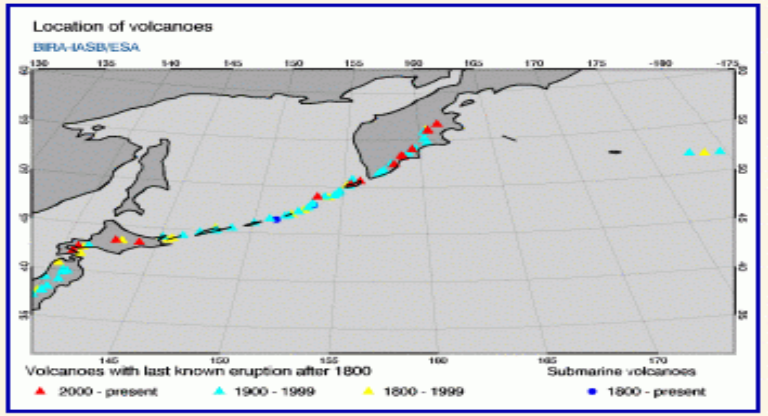


Other plots
SO2 slant column density

Download the data files of 12 June 2009
(*The data files cover the whole world*)

REGION

Location of volcanoes

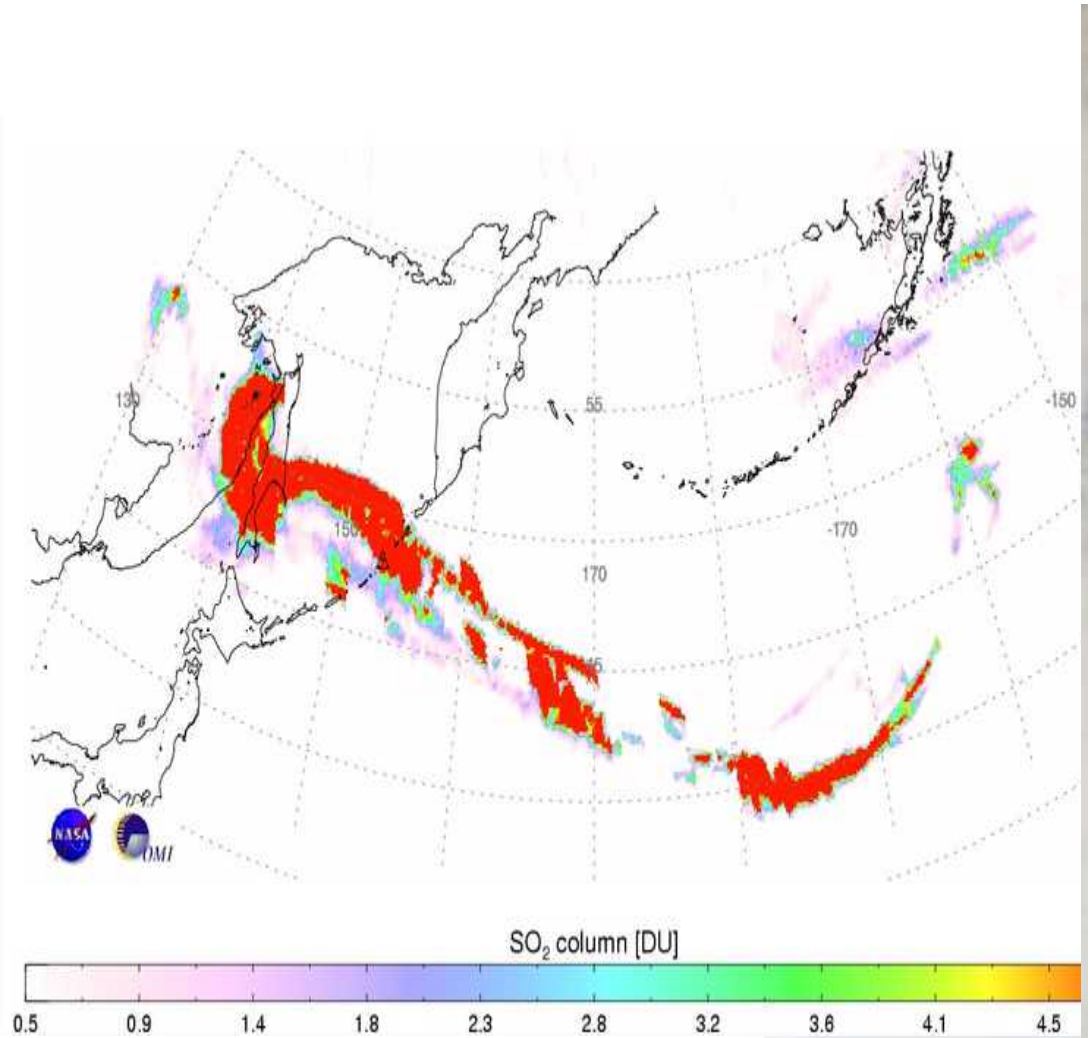


Links to the near-real-time data pages with maps from different instruments

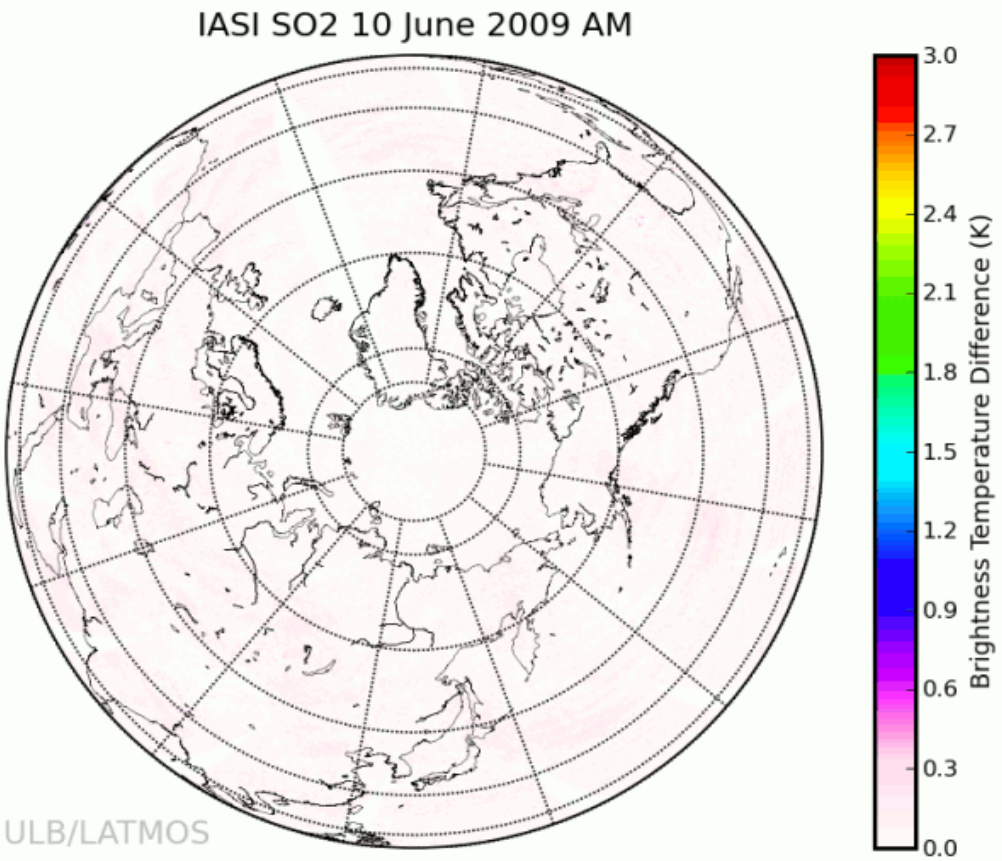
> 111 == 150.0 60.0
> 112 == 180.0 60.0
> 211 == 150.0 30.0
> 212 == 180.0 30.0

(*The numbers given behind the 3-digit region number are the centre longitude and latitude of the region.*)

Sarychev Peak (OMI, ISS)



Sarychev Peak SO2 – IASI

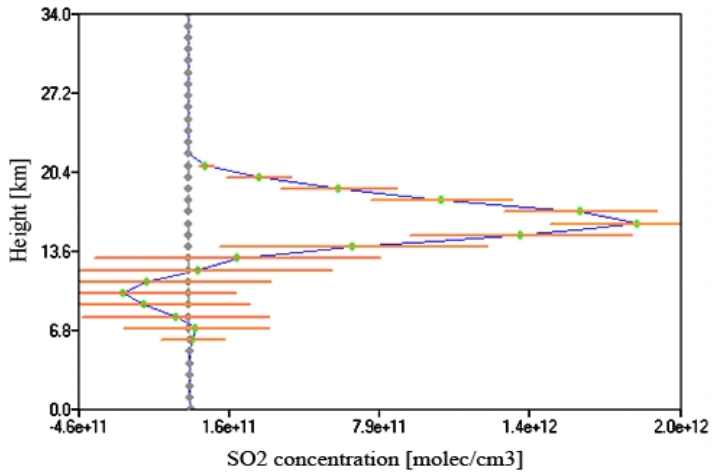


Movie courtesy Pierre Coheur (ULB / SACS).

Analyses - Elevation and Motion of volcanic cloud

VAACs need more information on the elevation of the volcanic cloud: to know whether aircraft may pass under or over the cloud and to better forecast the future motion of the cloud.

- **Within SACS: use advanced retrieval schemes to derive altitude information from the measurement data, both in UV/Visible and IR.**
- **Within SAVAA: which aims to set up a system that computes the injection height profile the motion of volcanic emissions, using trajectory and inverse modelling.**



Vertical profile of SO2 released by the Jebel at Tair eruption on 30 Sept. 2007, derived from IASI measurements.

Concluding Remarks

- **Satellite observations of Ash and SO2 are a useful addition when monitoring volcanic activity, in support to aviation and to assist volcanological institutes in their monitoring activities.**
- **Currently SCIAMACHY, OMI, GOME-2, AIRS, and IASI data are being used to provide alerts and maps to VAACs in near real time.**
- **Work is going on to extend the list of satellite data to be used and to provide also height information/trajectory analyses about the Ash and SO2 cloud in the near future.**