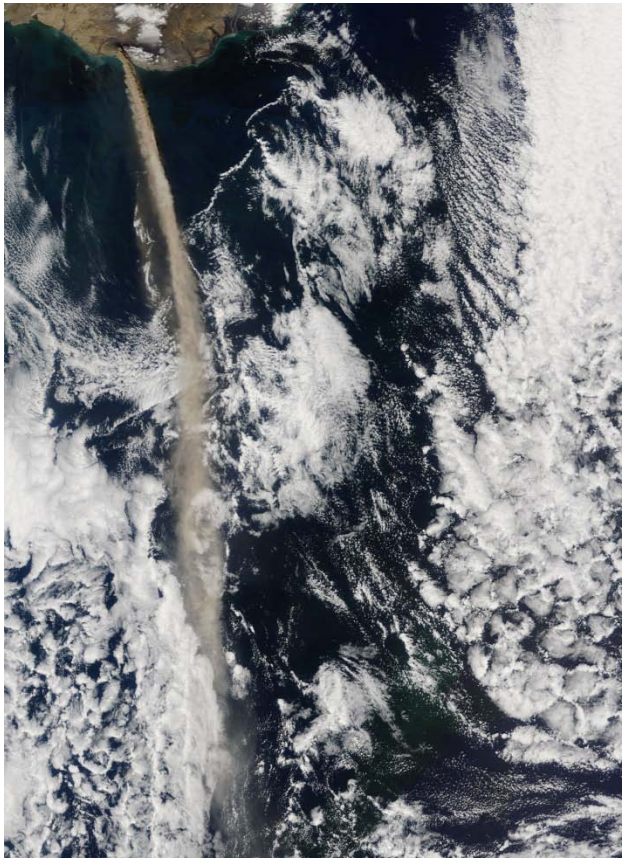
Near real-time monitoring of the April-May 2010 Eyjafjöll's ash cloud



Labazuy P. and the HotVolc Team

Observatoire de Physique du Globe de Clermont-Ferrand, CNRS, Université Blaise Pascal

HVOS

13th International Conference on Harmonization within Atmospheric Dispersion Modelling - 01-04 June 2010 - Paris, France

- **On April 14, 2010**, an eruptive fissure opened in Iceland's Eyjafjallajökull glacier to trigger an explosive phase of the eruption of Eyjafjöll volcano.
- The cloud of ash and gas drifted eastward at an altitude of **5-7 km**, due to the prevailing wind-directions that distributed the fine-ash **over NE Atlantic and Europe**.
- It caused complete closure of European airspace for **several days**.

- However, quite small eruption, with an unspectacular ash plume…
  …though leading to **global chaos**.
- **Lack of practice** related to an unprecedented scenario in the west Europe.
- Generic **atmospheric models** were executed **with some delay**, **quantitative input parameters** were **dramatically missing**.
- **HVOS** (HotVolc Observation System) was able to monitor the plume and provide **near-real-time quantitative parameters**.

- First signs in **April 2009** when 20-25 km deep earthquakes occurred beneath Eyjafjallajökull glacier, in Iceland.
- On **March 20, 2010**, primitive basalt has erupted by the eccentric crater, between the two central volcanoes, **Eyjafjöll** and **Katla**.
- **Lava fountains up to 200m height**, going with degassed activity showing lava effusions.
- Ceased on **April 13, 2010**

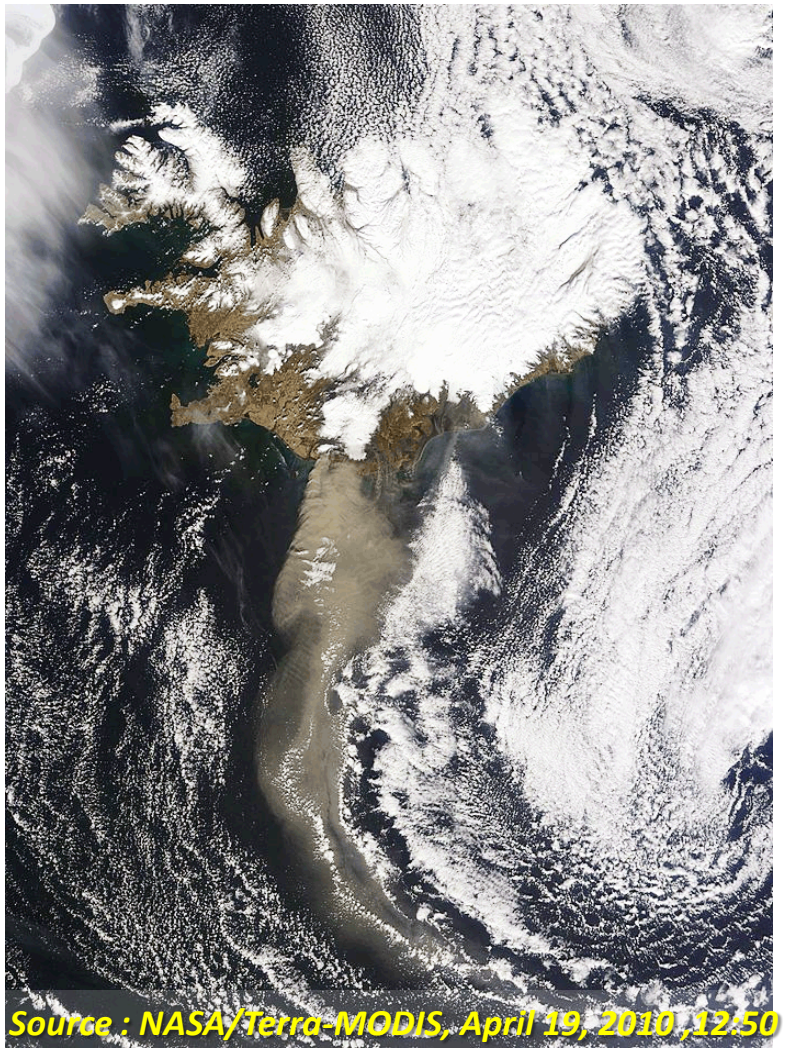
Few hours later (13-14 April) a **seismic crisis** began beneath the summit crater of **Eyjafjöll** capped by the **300m thick Eyjafjallajökull glacier.**

↳ **An eruptive fissure** opened ,

↳ Initiating a **phreatomagmatic stage**

Highly explosive phases due to magma-ice/water interaction increasing fragmentation

- A **large dark-grey volcanic cloud** has been released at the **end of April 14**, drifting eastward at about **5-7 km** of altitude
- Leading the **European air space** to be **shut down** a few hours later, until at least April 20



Source : NASA/Terra-MODIS, April 19, 2010 ,12:50

Directly impacted millions of people!

The volcanic ash-cloud…

The eruption has been characterized by two main phases of intense ash emissions spanning April 14-21 and May 1-10, with a maximum intensity recorded on M

The volcanic ash-cloud…

The eruption has been characterized by two main phases of intense ash emissions

spanning April 14-21 and May 1-10,
with a maximum intensity recorded on May 6

The volcanic ash-cloud…

The eruption stopped some weeks later on May 23, leading to a dormant phase

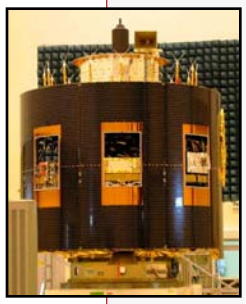
HotVolc Group

- **Near-real-time** monitoring of thermal anomalies
- **Tracking** of volcanic clouds related to the eruptive activity
- **Estimation** of quantitative parameters
- **Constraints** on ash plumes dynamics, from the vent to the atmosphere

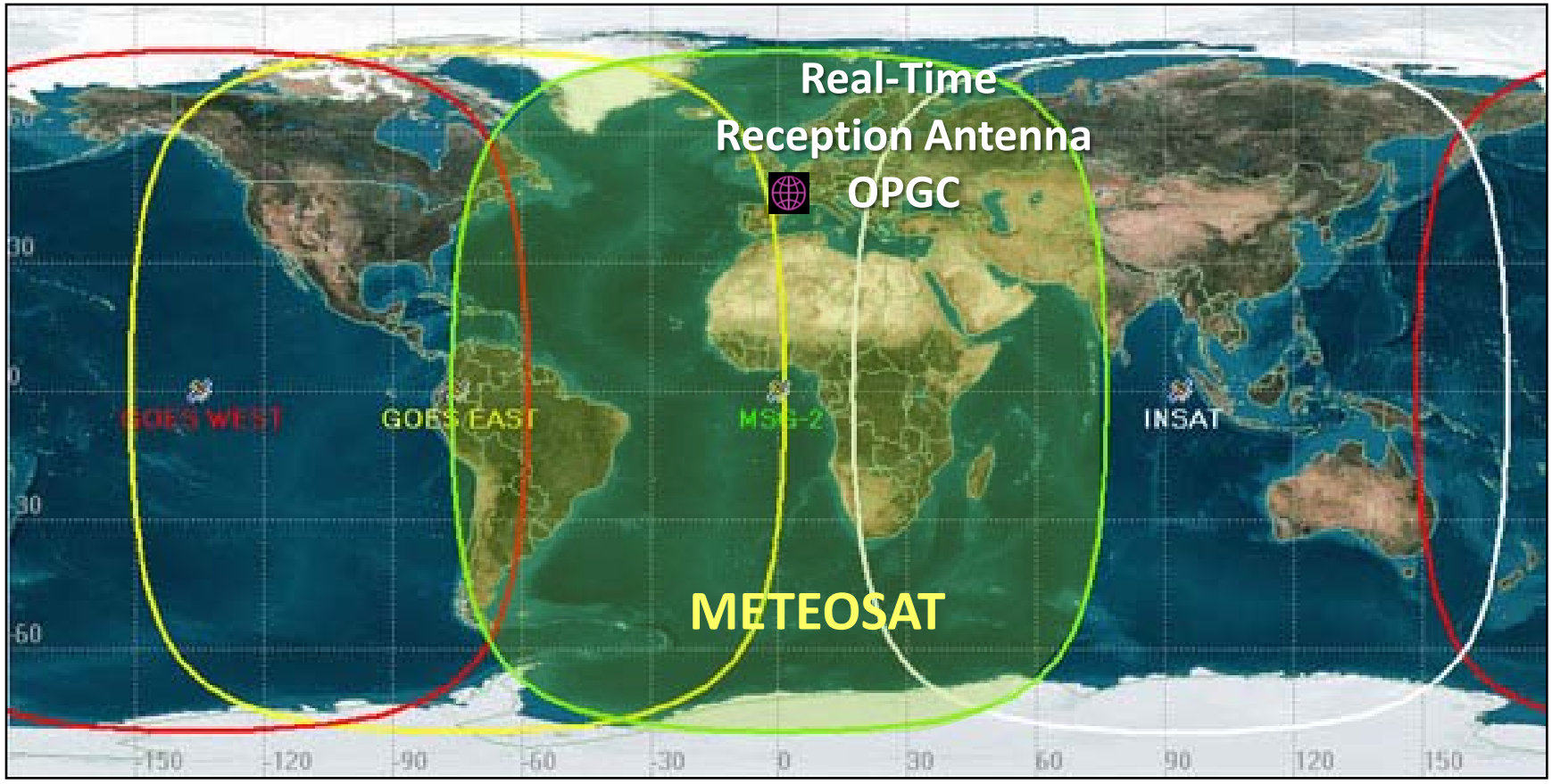
OPGC

= reception platform for geostationary satellites data (**EUMETSAT** convention)

↳ **Real-time products exploitation** of MSG satellite (Meteosat Second Generation)



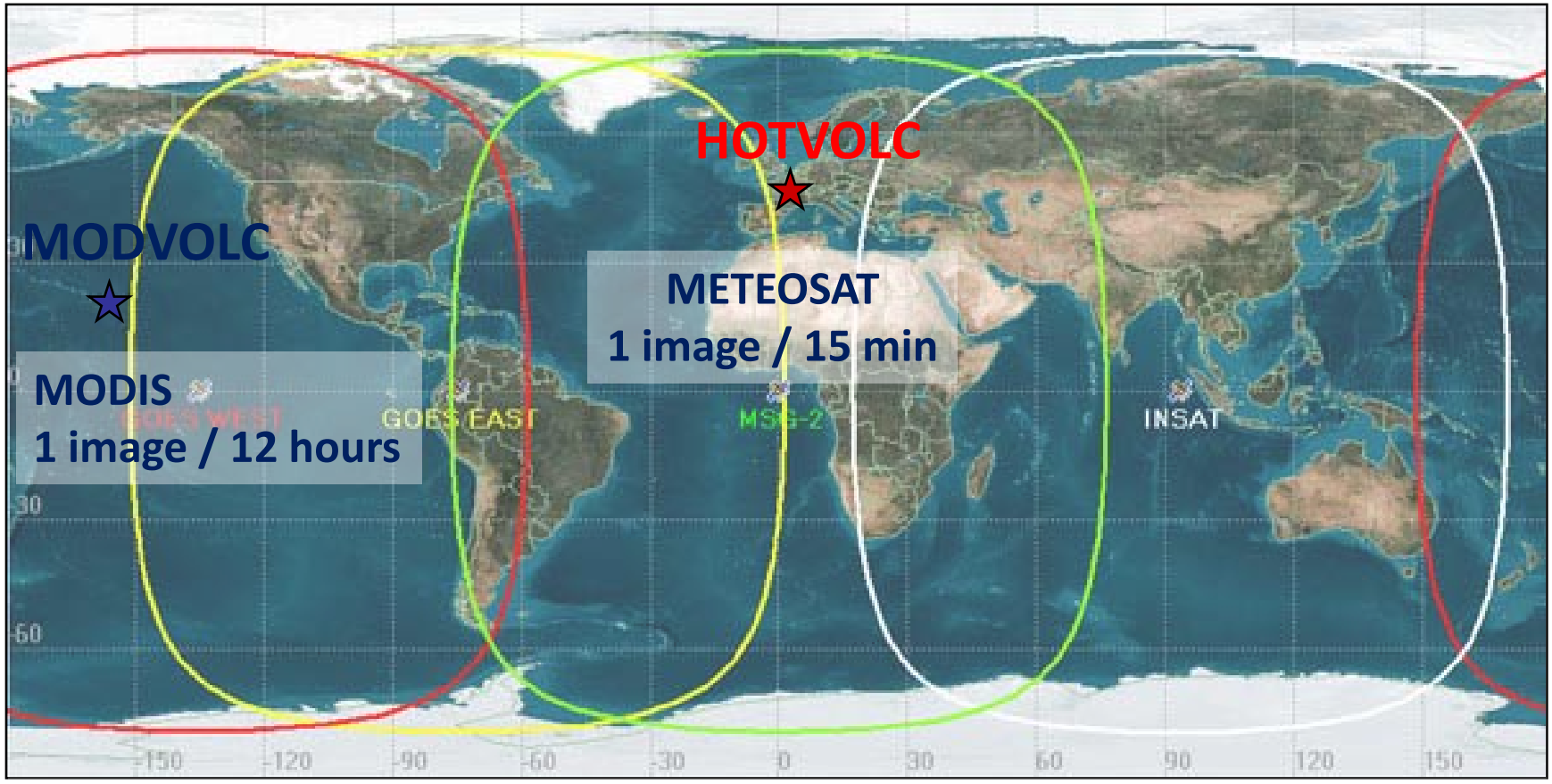
Installation, in **early 2009**, of a real-time reception station of MSG data at **Clermont-Ferrand**.



MSG-Seviri sensor (Spinning Enhanced Visible and InfraRed Imager)

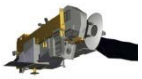
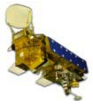
very high temporal resolution (**1 image every 15 minutes** - up to 5 minutes) and large spectral extent (**12 channels** from **visible** to **infra-red** wavelengths)

⇨ **detailed study of volcanic plumes dynamics through time**

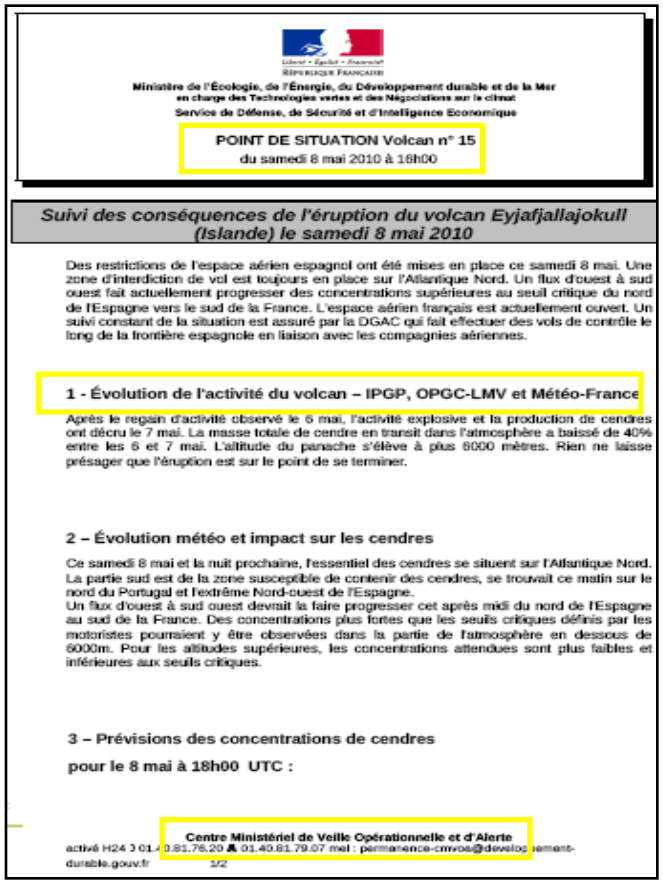


Near-real-time quantitative assessment of **volcanic parameters**

using multiple satellite-based tools,
MSG, **Aura-OMI**, **Terra/Aqua-MODIS**, **Calipso-CALIOP**

Satellites	Sensors	Temporal Resolution	Spatial Resolution	Spectral Domain	Field Studies
Aura 	OMI	1 img / 24h	12km × 24km	UV-VIS (270-532nm)	SO_2 loading Ash index
Aqua/Terra 	MODIS	4 img / 24h	1km × 1km	0.6 - 14.4µm	Ash loading SO_2 loading
Calipso 	CALIOP	2 img / 24h	30m × 333m	532-1064nm	Ash loading Ash properties
Meteosat 	SEVIRI	**1 img / 15min**	3km × 3km	0.6 - 13.4µm	Ash loading SO_2 loading

- HOTVOLC was involved in the **monitoring of the April 2010 eruption** at Eyjafjöll (Iceland) and belonged to a **volcano alert group**, at the **request of the MEEDDM** (French Ministry for ecology, energy, durable development and sea).
- **24/7 monitoring survey** (CMVOA Warning Cell), in order to detect any evolution of the **volcanic activity in Iceland** likely to have **consequences in France**.



Ministère de l'Écologie, de l'Énergie, du Développement durable et de la Mer
en charge des Technologies vertes et des Négociations sur le climat
Service de Défense, de Sécurité et d'Intelligence Economique

POINT DE SITUATION Volcan n° 15
du samedi 8 mai 2010 à 16h00

Suivi des conséquences de l'éruption du volcan Eyjafjallajokull (Islande) le samedi 8 mai 2010

Des restrictions de l'espace aérien espagnol ont été mises en place ce samedi 8 mai. Une zone d'interdiction de vol est toujours en place sur l'Atlantique Nord. Un flux d'ouest à sud ouest fait actuellement progresser des concentrations supérieures au seuil critique du nord de l'Espagne vers le sud de la France. L'espace aérien français est actuellement ouvert. Un suivi constant de la situation est assuré par la DGAC qui fait effectuer des vols de contrôle le long de la frontière espagnole en liaison avec les compagnies aériennes.

1 - Évolution de l'activité du volcan – IPGP, OPGC-LMV et Météo-France

Après le regain d'activité observé le 6 mai, l'activité explosive et la production de cendres ont décru le 7 mai. La masse totale de cendre en transit dans l'atmosphère a baissé de 40% entre les 6 et 7 mai. L'altitude du panache s'élève à plus 6000 mètres. Rien ne laisse présager que l'éruption est sur le point de se terminer.

2 – Évolution météo et impact sur les cendres

Ce samedi 8 mai et la nuit prochaine, l'essentiel des cendres se situent sur l'Atlantique Nord. La partie sud est de la zone susceptible de contenir des cendres, se trouvait ce matin sur le nord du Portugal et l'extrême Nord-ouest de l'Espagne.
Un flux d'ouest à sud ouest devrait la faire progresser cet après midi du nord de l'Espagne au sud de la France. Des concentrations plus fortes que les seuils critiques définis par les motoristes pourraient y être observées dans la partie de l'atmosphère en dessous de 6000m. Pour les altitudes supérieures, les concentrations attendues sont plus faibles et inférieures aux seuils critiques.

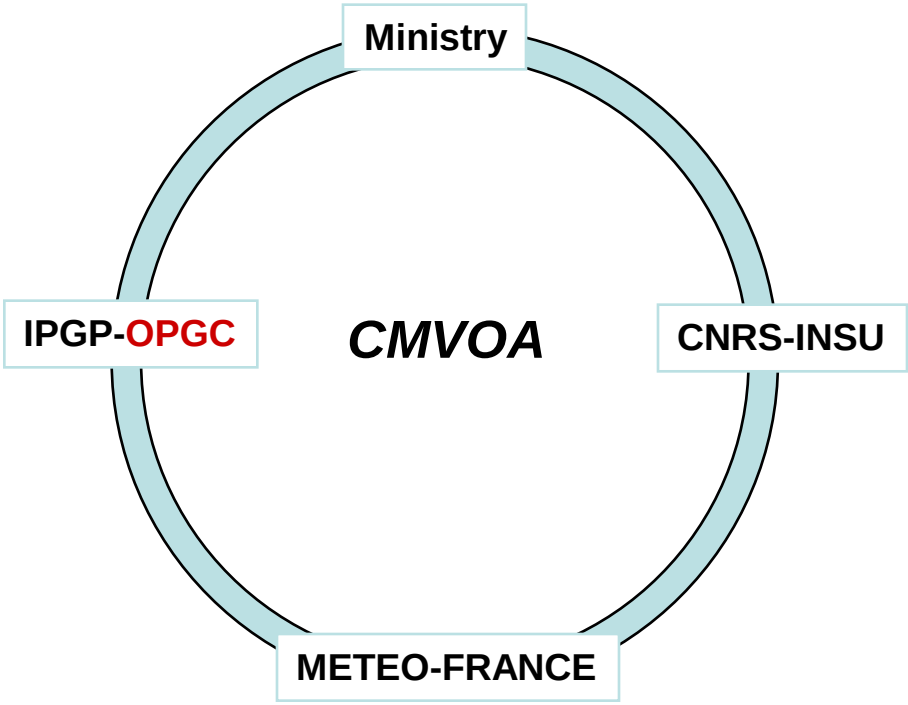
3 – Prévisions des concentrations de cendres

pour le 8 mai à 18h00 UTC :

Centre Ministériel de Veille Opérationnelle et d'Alerte
activé H24) 01.4 0.81.76.20 🖷 01.40.81.79.07 mel : permanence-cmvoa@developpement-durable.gouv.fr
1/2

CMVOA Warning Cell

Operational Warning and Alert Ministry Center

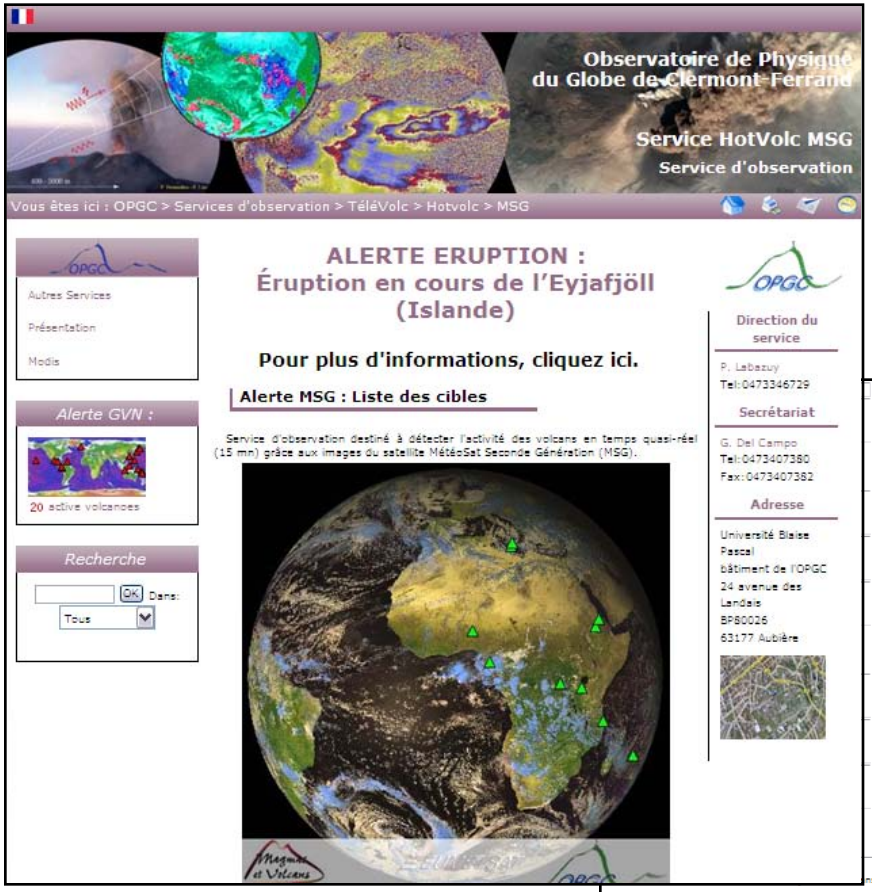


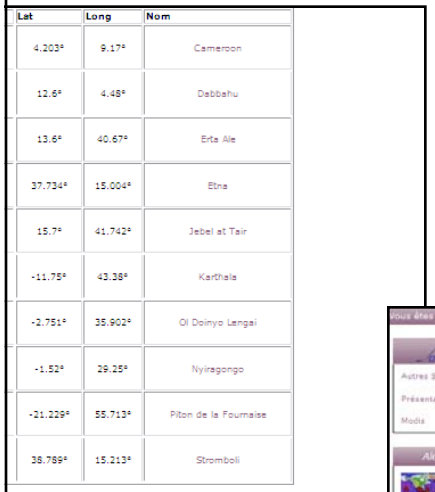
HOTVOLC OBSERVATION SYSTEM (HVOS)

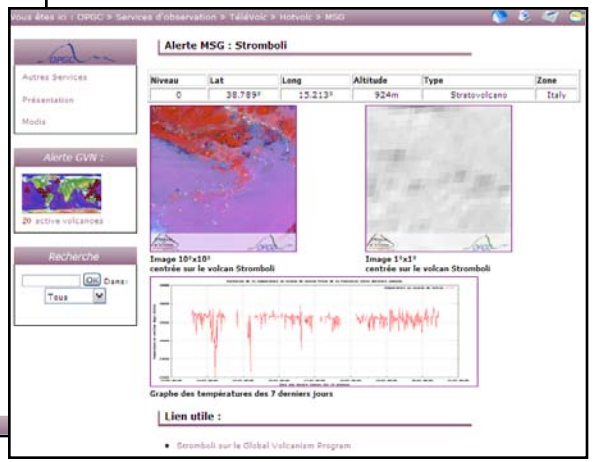
1- Eruption Alert Notice

2- Tracking volcanic products

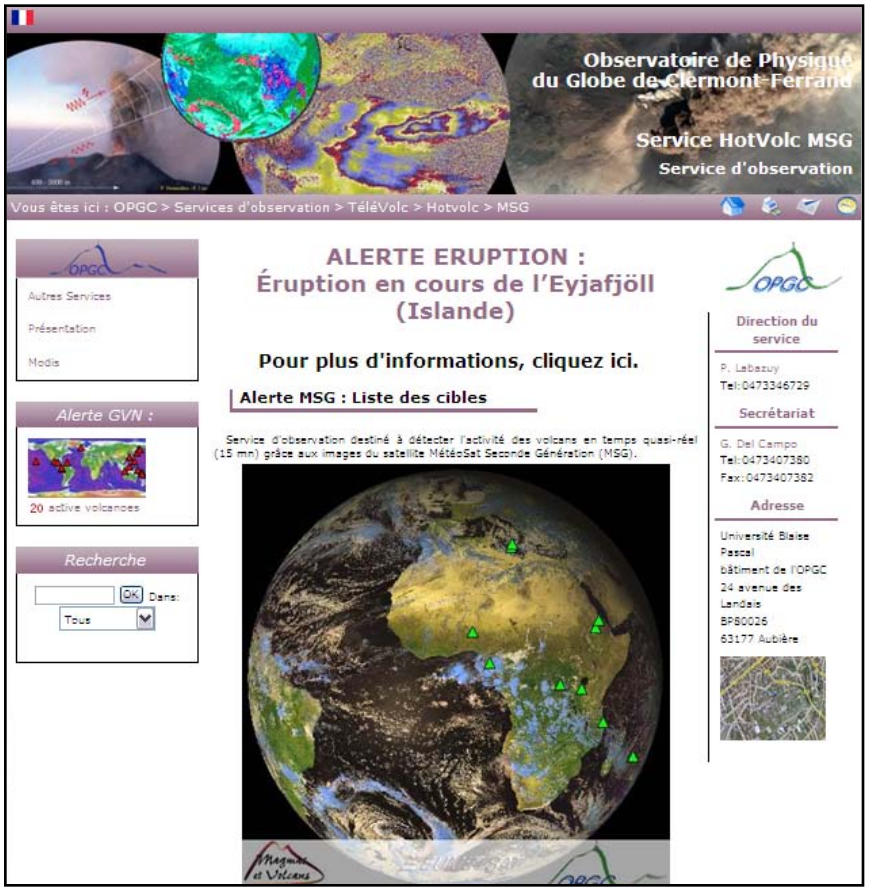
3- Data diffusion ⇨ Community







HOTVOLC OBSERVATION SYSTEM (HVOS)



Eyjafjöll crisis

- **From April 14, 2010**, we provided reliable real-time MSG-9 images to the community **every 15 minutes**

  (up to every 5 minutes with MSG-8 RSS -Rapid Scan Service- images),

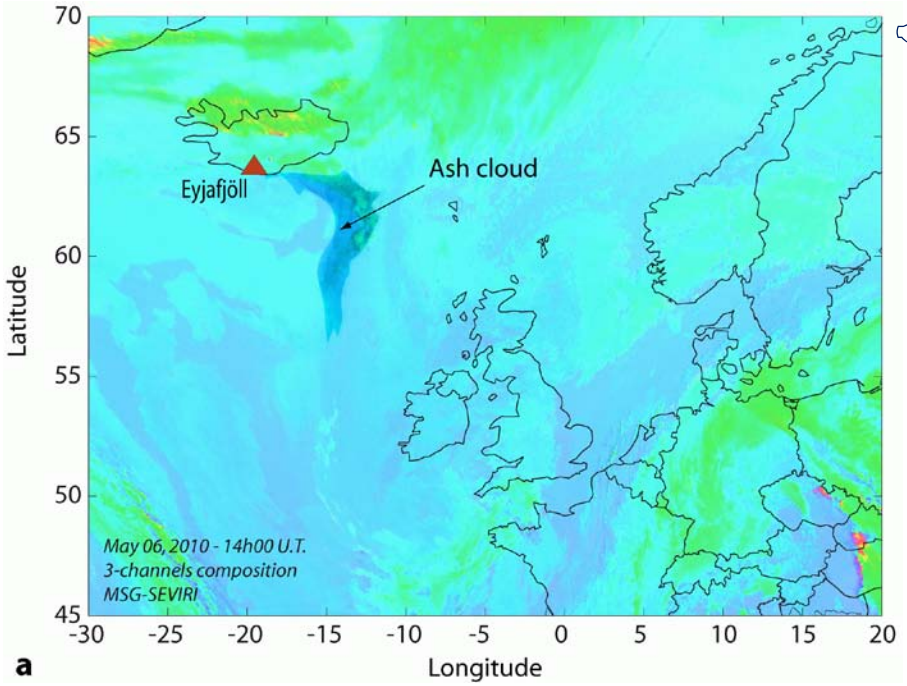
- Data **immediately delivered** to the scientific community on the **HVOS website** :

http://wwwobs.univ-bpclermont.fr/SO/televolc/hotvolc/Islande_Avril2010/

HotVolc – Real-Time Products : Plume Mapping and Tracking

Brightness Temperature Difference (BTD) Method (Prata, 1989)

Detection of Volcanic ash from the **negative BTD** between the spectral bands at 11 and 12µm (thermal infra-red),
Water droplets and ice crystals highlighted from **BTD>0.**



3-channels IR composition using MSG-9-SEVIRI data (3x3 km)

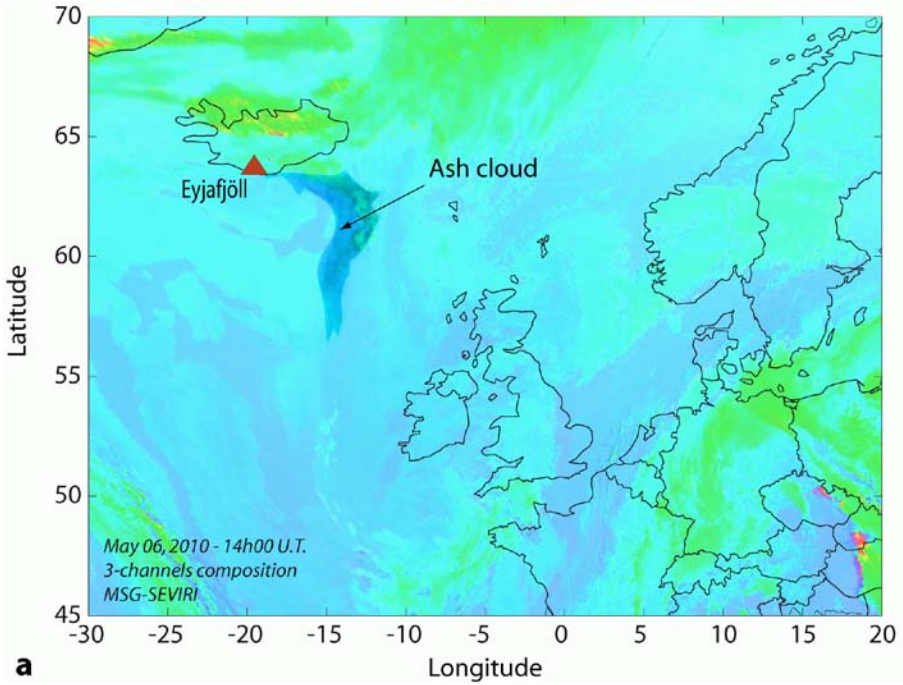
☞ Based on the **differential extinction features** of volcanic aerosols between different wavelengths.

- First channel : 10.8µm-12µm,
- Second channel : 10.8µm-8.7µm
- Third channel : 10.8µm

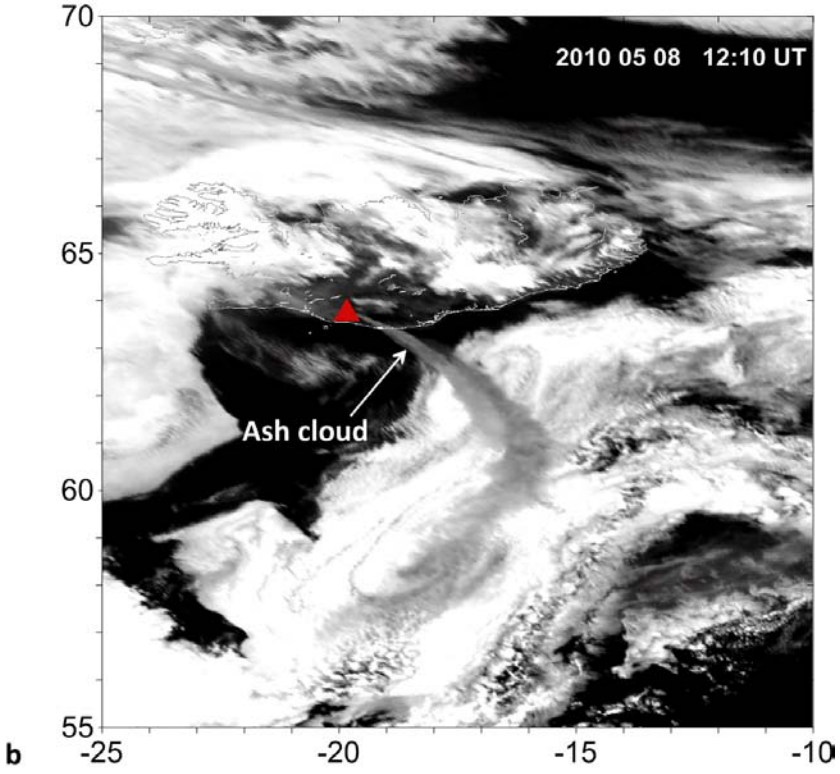
Ash cloud in dark blue,
Water droplets are green,
Ice crystals are bright red

HotVolc – Real-Time Products : Plume Mapping and Tracking

Real-time MSG-9 every 15 min, up to every 5 min with MSG-8 RSS -Rapid Scan Service- images



3-channels IR composition using MSG-9-SEVIRI data (3x3 km, 15 min)

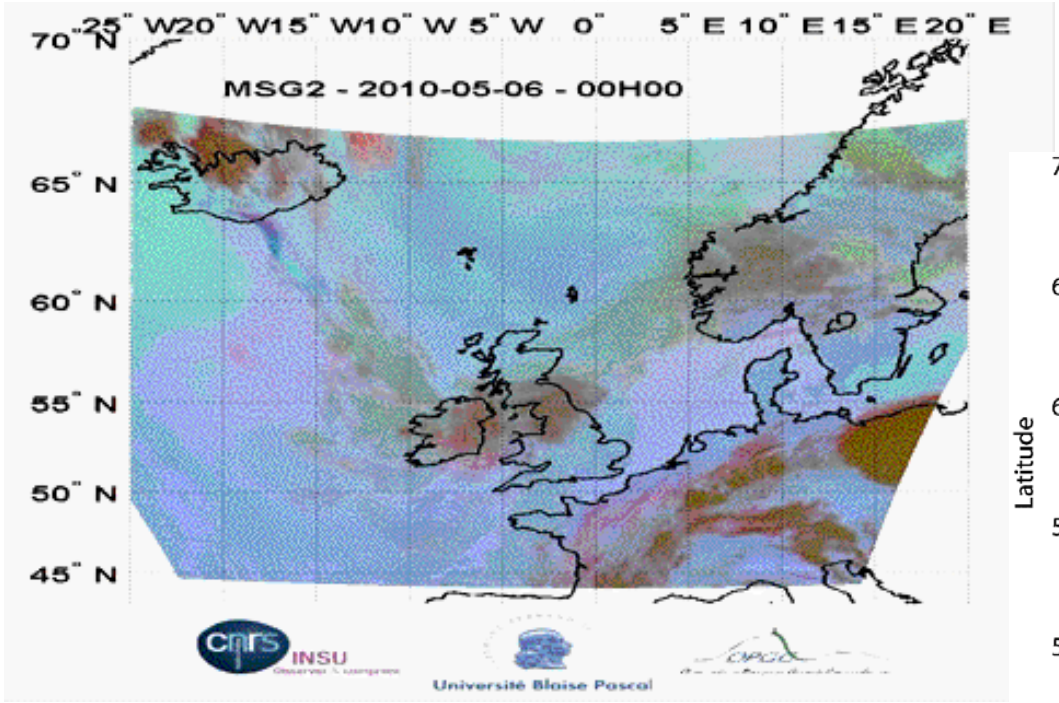


HRV (High Resolution Visible, 1x1 km, 5min) MSG-8 RSS image

HotVolc – Real-Time Products : Plume Mapping and Tracking

3-channels thermal colored composition movie

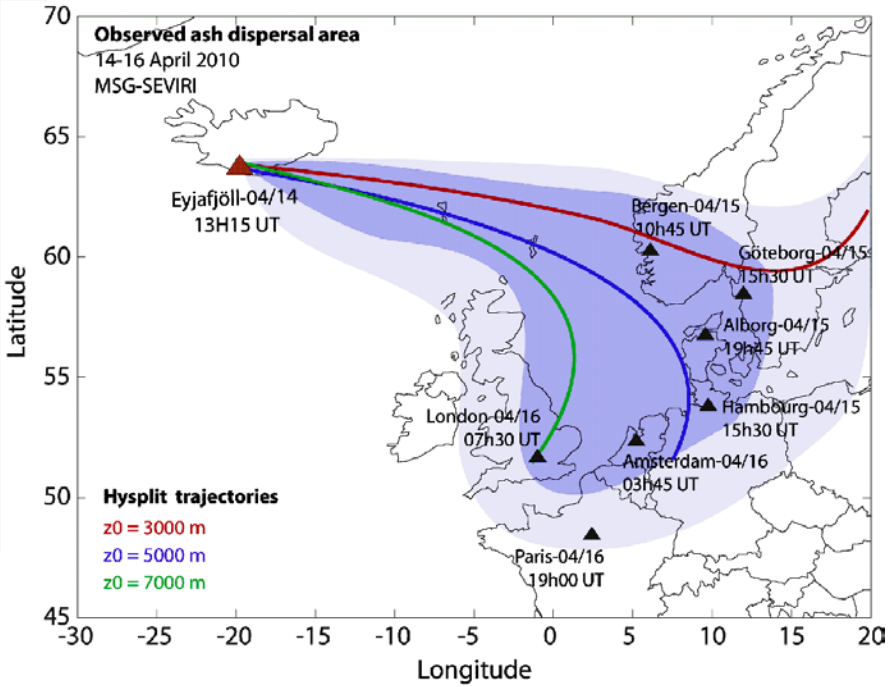
(06-08 May period)



- Ash cloud : dark blue
- Water droplets : deep green
- Ice crystals : bright red

Ash plume-track on West Europe

important information on the cloud dispersal and location.



Chronology of ash dispersal area mapped from MSG-SEVIRI and the Lidar CALIOP-Calipso during the first few days

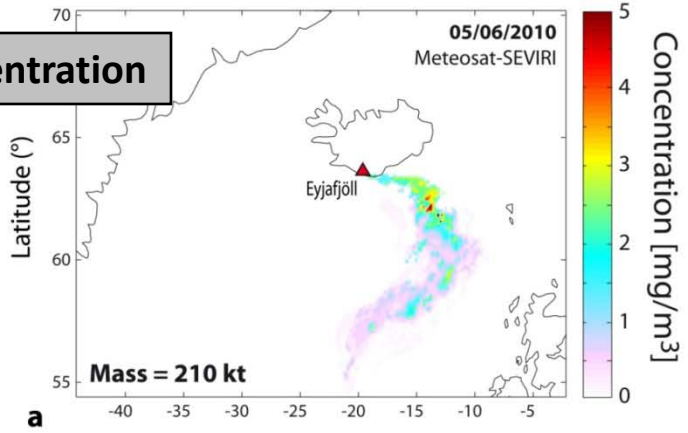
HotVolc – Near-Real-Time Estimation of Quantificative Parameters

Inversion algorithms of MSG-SEVIRI infrared data (Wen and Rose, 1994)

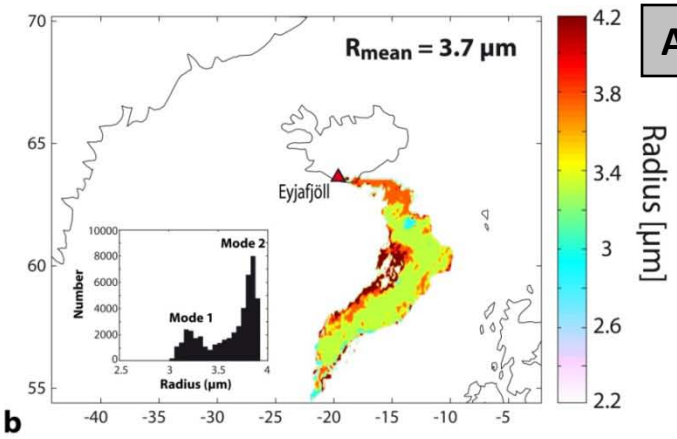
⇨ based on the absorption and diffusion properties of volcanic ash

⇨ allow a first order quantitative estimate of eruptive parameters.

Ash **Concentration**



Ash radius



Give a minimum estimate of fine ash mass loading inside the cloud at a given instant.

⇨ On May 6, 210kt of ash were airborne at that time, with the cloud having a maximum concentration of 5 $mg.m^{-3}$.

⇨ Median ash radius distribution at about 3.7 µm

HotVolc – Near-Real-Time Estimation of Quantificative Parameters

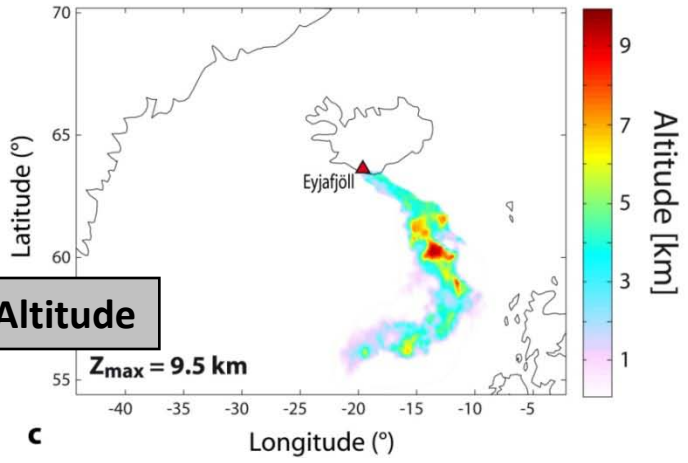
Ash cloud altitude

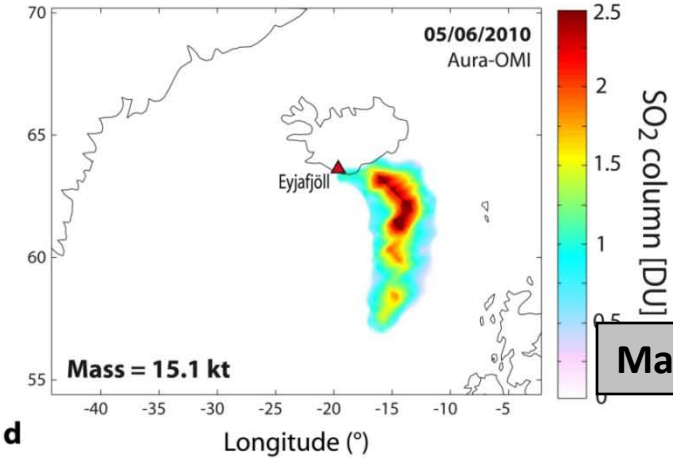
⇨ Cloud temperatures calculated from the 10.8 µm channel, and the altitude to which that temperature related was retrieved from vertical atmospheric soundings. *On May 6, highest point of the volcanic plume was **9.5 km a.s.l***

Mass flux of SO_2

⇨ SO_2 burden obtained using the Aura-OMI instrument which operates at UV wavelengths. *Estimate of **15.1kt** for SO_2 from the May 6 image.*

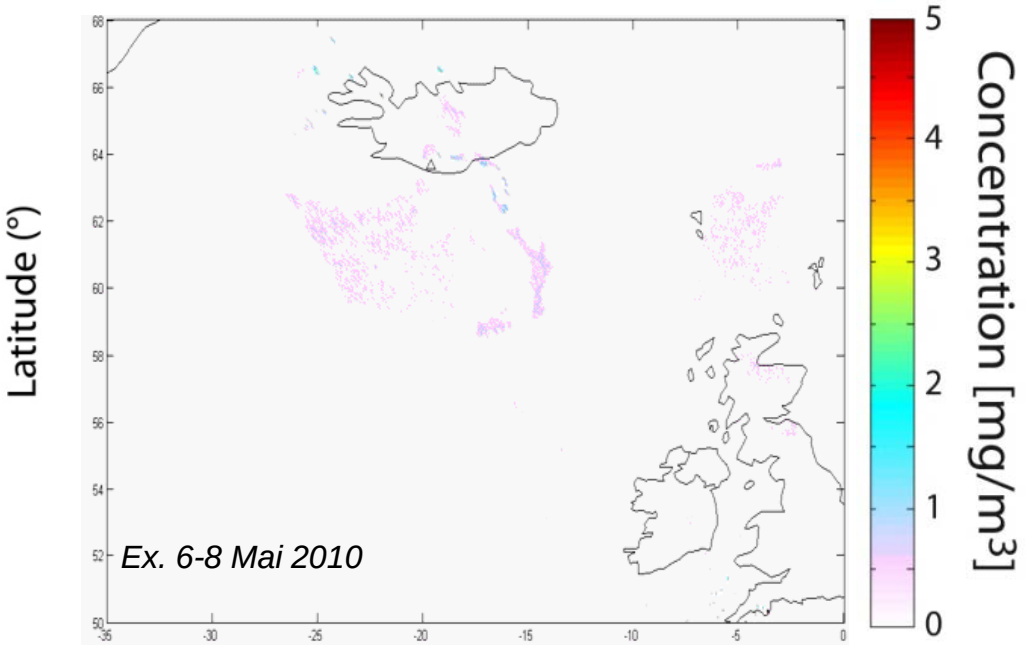
Ash cloud **Altitude**





Mass flux of SO_2

HotVolc – Near-Real-Time Estimation of Quantificative Parameters



Mass Flux and Ash **Concentration**

… with time

⇨ Quantitative information were routinely calculated within a few hours of image reception during the whole eruption.

⇨ We used a total of about **3000** images, with SEVIRI being available at a typical rate of **96 images/day** (one image every 15 minutes).

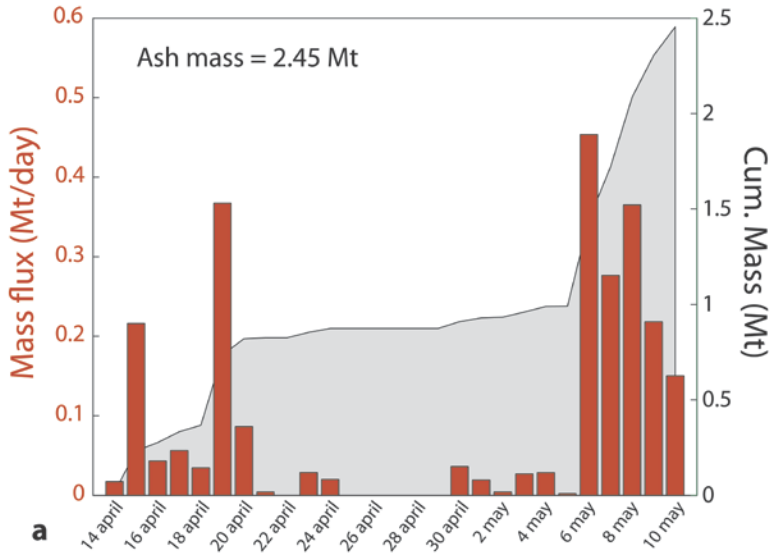
HotVolc – Near-Real-Time Estimation of Quantificative Parameters

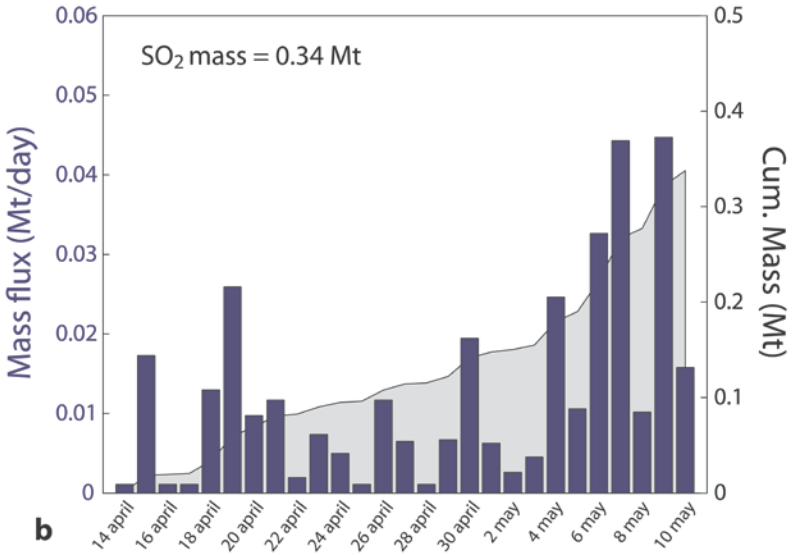
Accurate mass fluxes estimation of **fine ash** emitted in the atmosphere

Mean flux on the whole eruption : ~ **1.33t.s^{-1}**
with **maximum** of **5.3 t.s^{-1}**, **minimum** : **0.02 t.s^{-1}**

Total fine ash emissions ~ **2.3 Mt**
Total SO_2 emissions ~ **0.28 Mt**

From **April 14 to May 9** in the atmosphere





Ash emissions *focused on 2 main phases : 14-21 April and 1-10 May*

SO_2 *emitted much more constantly*

❶ **Remote sensing data** can be used to accurately assess exact **location**, **extent**, **ash concentration**, mass flux and **altitude** of a volcanic plume.

⇨ Improve plume **monitoring** and **tracking**,

⇨ Allow improved **communication** and **understanding** by the media

Answer to the question : ***"Where was the plume and how dense was it? "***

❷ Our maps show that it was likely of **Europe-wide extent**.

↳ **Our inability to detect** any cloud in the south of France from satellite data suggests that the ash cloud was **extremely dilute**.

↳ In addition, ground-based or satellite LIDAR soundings revealed that the cloud was **low and below** the level of most transatlantic routes.

A **remaining question** will need an argued answer in the next future :

"Could planes have flown over it?"

❸ Using a **fully integrated data set of IR and UV images**, we can **track plumes in near-real-time** at a high temporal resolution.

↳ Test ⇨ **web-based, real-time monitoring system** with : automated ingestion of satellite data and **output of maps and values**

⇨ to allow **real-time ash cloud tracking** as well as updating of **cloud trajectory** and **dispersal models**.

❹ **Quantitative near-real-time information** was available to the scientists, monitoring and media communities across the whole of Europe, and was part of the **official crisis response** implemented by the **French government**.

↳ Our **fully transparent information broadcasting system** is aimed to help achieve a **fully informed and unified decision making** and reporting process in the event of a **volcanic ash crisis**.