Monitoring the Eyjafjöll volcanic plume using OPGC platforms : remote sensing and in-situ measurements

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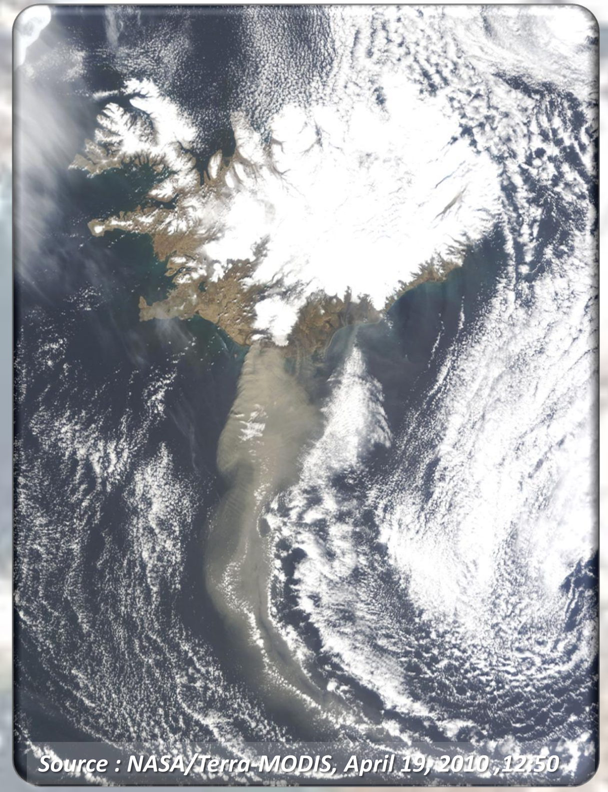
OBSERVATOIRE DE PHYSIQUE DU GLOBE DE CLERMONT-FERRAND (OPGC)

The OPGC, one of the most important "Observatoires des Sciences de l'Univers" (OSU, INSU/french CNRS), belongs to Blaise Pascal University (UBP, Clermont-Ferrand, France). **The OPGC presents a unique combination of knowledge in volcanology and atmosphere physics, for the tracking and the monitoring of volcanic plumes.** These competences interact through the combination of the mastering of lidar and radar techniques by the Laboratoire de Météorologie Physique (LaMP, OPGC) and the expertise of the Laboratoire Magmas et Volcans (LMV, OPGC) in eruption dynamics and spatial remote sensing. Platforms for observations benefit fromthe technical support and expertise of the OPGC staff.



Source : NASA/Terra-MODIS, April 15, 2010 , 12:50

HOTVOLC : REMOTE SENSING OF VOLCANOES BY SATELLITE

The HOTVOLC group is dedicated to the near-real-time monitoring of thermal anomalies related to the eruptive activity of volcanoes. The main goal of HOTVOLC deals with estimation of quantitative parameters that give stringent constraints on ash plumes dynamics, from the vent to the atmosphere.

HOTVOLC was involved in the monitoring of the April 2010 eruption at Eyjafjöll (Iceland) and belongs to a volcano alert group, at the request of the MEEDDM (French Ministry for ecology, energy, sustainable development and sea).

The objective was to ensure a 24/7 monitoring survey, in order to detect any evolution of the volcanic activity in Iceland likely to have consequences in France.

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

1. HOTVOLC - REMOTE SENSING BY SATELLITE : NEAR REAL TIME MONITORING OF THE EYJAFJÖLL VOLCANIC PLUME

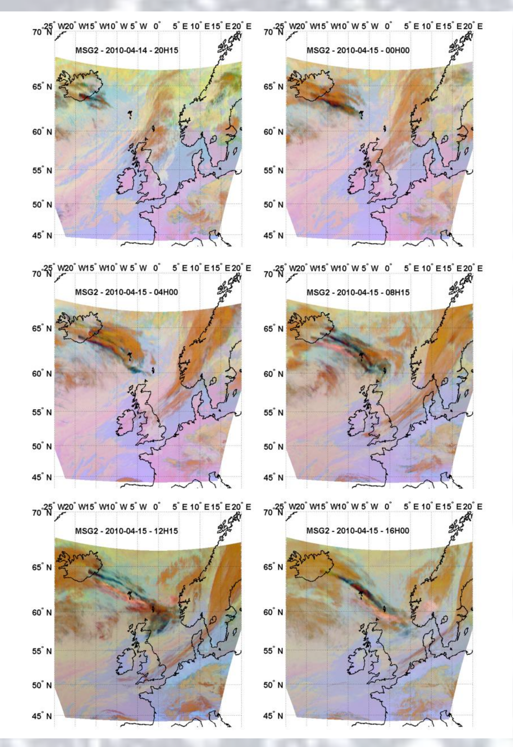


Figure 1.1 : MSG RGB images –colour composites : R : IR12µm – IR10.8µm; G : IR10.8µm – IR8.7µm; B : IR10.8µm

We use the meteorological satellites like **Météosat Seconde Generation (MSG)**, with SEVIRI sensor (Spinning Enhanced Visible and InfraRed Imager), showing a very **high temporal recurrence** (one image every 15mn), and a large spectral range (12 channels from visible to infra-red wavelengths) .

Figure 1.1. shows the evolution of the Eyjafjöll's ash plume during the first 20 hours of the eruption. The ice-rich plume appears in dark blue, and volcanic ash in bright red. As the eruption first occurred underneath an ice cap, the first emissions are very rich in water and ice.

The BTD (Brightness Temperature Difference) method (Figure 1.2) allows to discriminate ash clouds, that will have negative BTD[10.8-12], from ice-rich clouds that have a positive BTD[10.8-12]. Thus in this figure, ice clouds are in warm colors (yellow to red) and ash clouds in cool colors (blue).

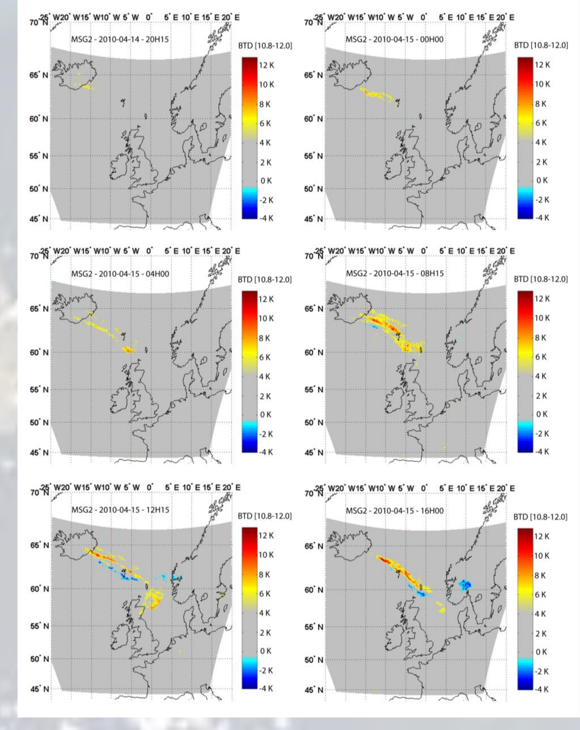


Figure 1.2 : Brightness Temperature Difference between channels at 10.8 and 12 µm (BTD[10.8-12])

Plume heights

Once the ash plume has been detected, the following step is to determine its height, this parameter being crucial for predictive models and risk assessment.

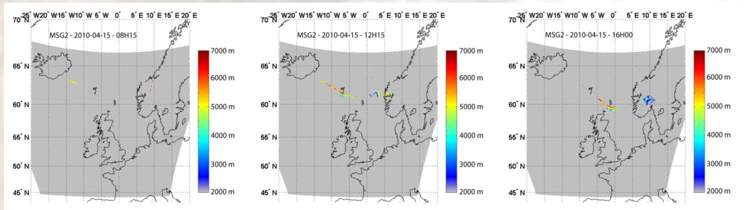


Figure 1.3 : Hotvolc Product : Plume heights

In this aim, the opaque part of the volcanic cloud is considered to be in thermal equilibrium with the surrounding atmosphere, and a vertical profile of atmospheric temperatures obtained near the volcanic cloud allows the determination of the altitude associated with the measured temperature of the volcanic cloud.

The height of the plume of Eyjafjöll on April 15 2010 at 12:00 UTC was estimated at 5000-6500m, in accordance with ground observations and Lidar data.

2. HOTVOLC - REMOTE SENSING BY SATELLITE : QUANTITATIVE DESCRIPTION OF THE EYJAFJÖLL VOLCANIC PLUME

Terra-MODIS

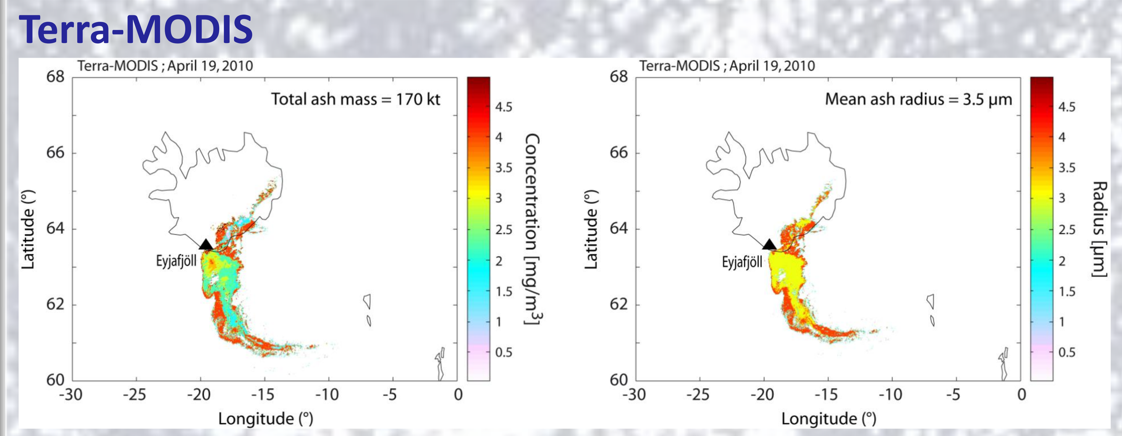


Figure 2.1 : The Terra-MODIS sensor has permitted the detection of ash in the volcanic plume with quite a good spatial resolution (pixel = 1×1km) and gave the opportunity to provide near-real-time quantitative parameters

The negative Brightness Temperature Difference (BTD<0) between the 11µm and 12µm channels permits the qualitative discrimination of ash among various species (water droplets, ice crystals, etc.) in the volcanic cloud. Then, forward modelling of ash scattering in the atmosphere (Wen and Rose, 1994) permits the inversion of Terra-MODIS infrared data, and gives minimum first order estimates of ash concentration and radius particularly (Figure 2.1). Results obtained **on April 19 show an ash concentration in the range 2-5mg/m³ that gives a total ash mass integrated on the considered area of 170 kt. Mean ash radius was estimated at about 3µm.**

Aura-OMI

On April 19, 2010, the amount of SO_2 released by the Eyjafjöll volcano was estimated at 12kt (Figure 2.2).

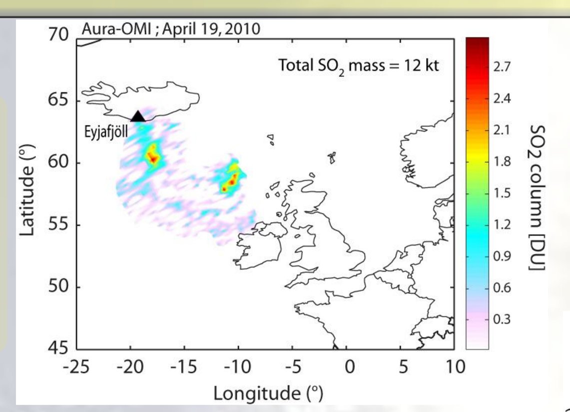


Figure 2.2 : The Aura-OMI sensor operating at UV wavelengths permits the accurate detection and concentration estimate of SO_2 in the volcanic cloud.

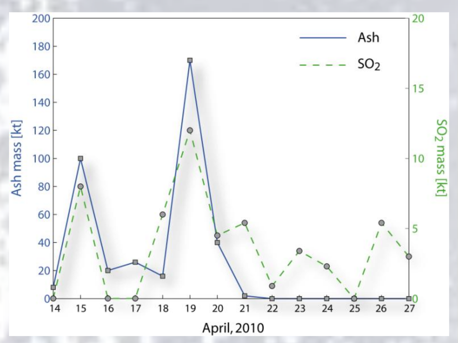


Figure 2.3 : Terra-MODIS and Aura-OMI instruments were used for the daily quantitative estimation of ash and SO_2 burden respectively

The times series of Figure 2.3 shows **two peaks of ash and SO_2 emissions** occurring on April 15 (100kt and 8kt) and 19 (170kt and 12kt). After April, 21, ash emissions are weaker, and almost undetectable from IR imagery. By contrast, SO_2 emissions are still important, with values ranging from 1 to 5kt between April 21 and 27.

CALIOP-Calipso

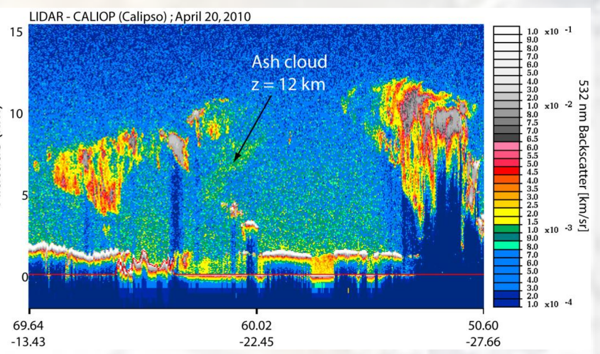


Figure 2.4 : The Lidar (Caliop-Calipso) instrument has the capability to give vertical information on the volcanic cloud

On April 20, 2010, the Calipso satellite went over the Eyjafjöll volcano (Figure 2.4), clearly showing a distorted ash plume rising up to about 12km in altitude .

3. LIDAR REMOTE SENSING AND IN SITU MEASUREMENT OF THE EYJAFJÖLL VOLCANIC PLUME ABOVE CLERMONT-FD

The Lidar of the OPGC, at Clermont-Ferrand, is a Rayleigh-Mie Lidar emitting at 355 nm, with parallel and crossed polarization channels. On May 19, around 04:00 UTC, **we observed** a layer of depolarizing particles i.e. non-spherical particles **at 3000 m a.s.l, with maximum thickness of 500m**. The intensity of which peaked at about 10:00 UTC (Figure 3.1). Later in the day, the plume intensity decreased slowly until cumulus clouds developed at the same altitude. Such a layer was not observed during the next days. Nevertheless, **a signal of supermicron particles was detected (May 19-27) in the planetary boundary layer (PBL) from in situ measurements at the Puy de Dôme station**, 1465 m a.s.l. (see below). The LIDAR signal showed that, at that time, ash particles were probably mixed in the boundary layer where their depolarization signature could not be distinguished.

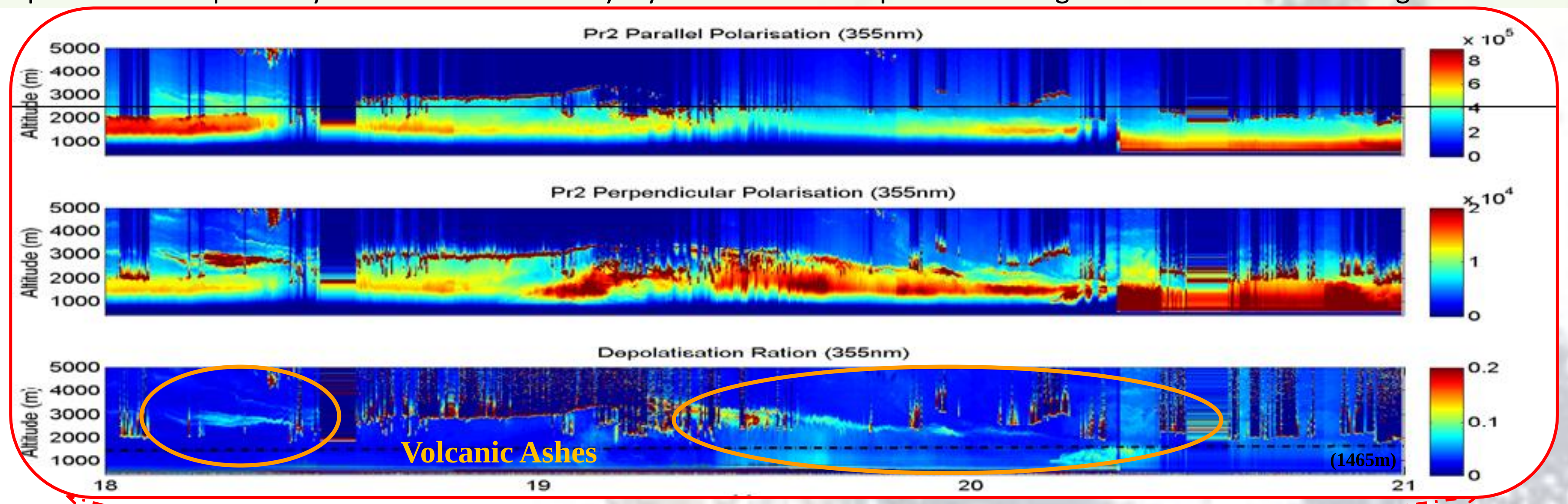


Figure 3.1 : LIDAR backscattered signal from the 18th to the 21st of May 2010

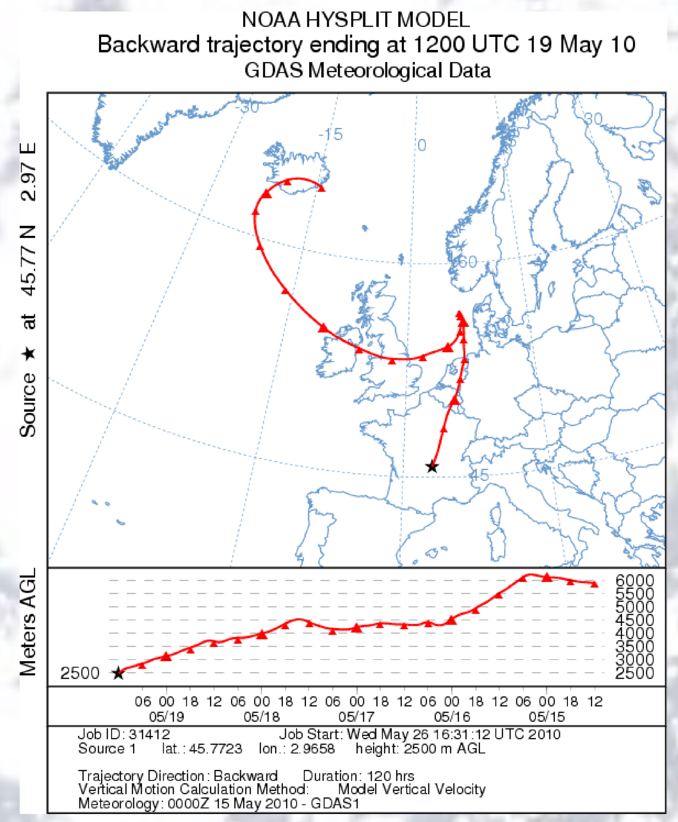


Figure 3.2 : Hysplit back trajectory the 26/05/2010 above Clermont Ferrand

Back-trajectory simulations using the Hysplit model (NOAA) indicate that the volcanic clouds observed at Clermont-Fd on May 25 in the early morning were likely emitted by Eyjafjoll at an altitude of 6500-7000m a.s.l.

In Situ Measurements at the Puy de Dôme (1465m)

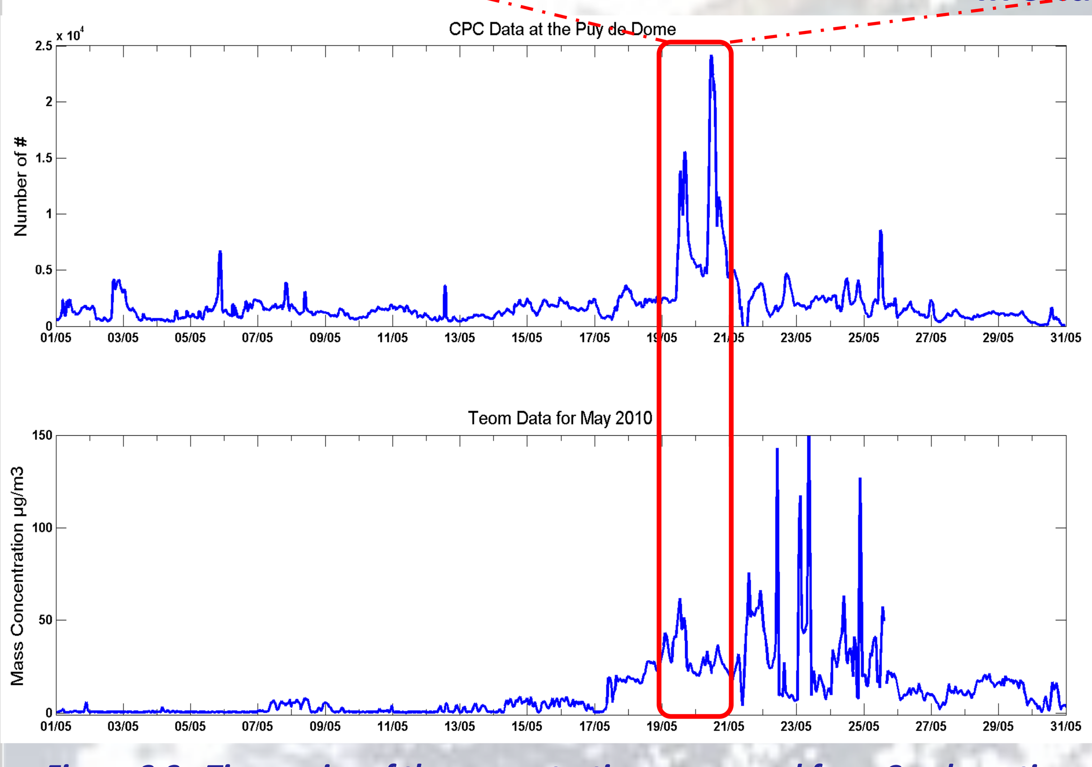


Figure 3.3 : Time series of the concentrations measured from Condensation Particle Counter (CPC), and mass concentration from Tapered Element Oscillating Microbalance (TEOM) for May 2010 at the Put de Dôme (1465m)

The instrumented station at the top of the Puy de Dôme allows measurements of optical, chemical and microphysical properties of aerosols.

A few days after the volcanic plume was observed from the Lidar, concentrations of particles significantly increased (Figure 3.3). The modal diameter of the volcanic ash was measured to be around 2 µm (Figure 3.4). The large size of the particles was confirmed by the increase of the mass concentration measured during that period from an independent device (TEOM, Figure 3.3b). **Supermicron particle concentrations were correlated with SO2 concentrations** which may come from long distance transport. Both the supermicron particle concentrations and the SO2 concentrations were relatively low, indicating that the plume was very dilute when reaching the PDD site.

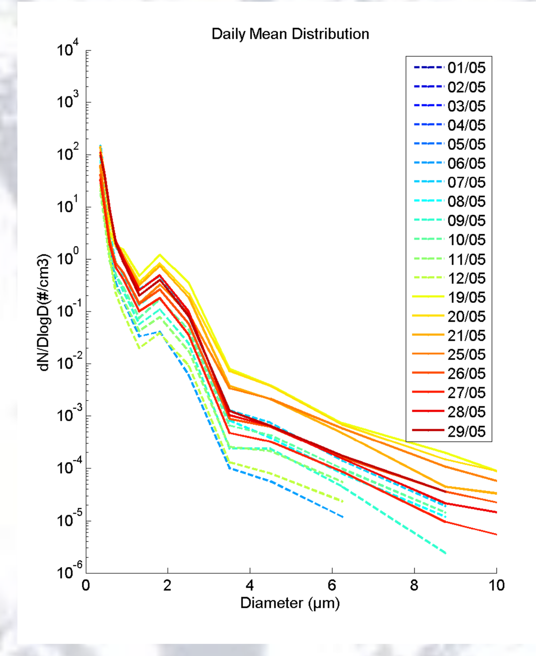


Figure 3.4 : Daily mean distribution

4. ATR-42 FRENCH AIRCRAFT IN SITU MEASUREMENTS ABOVE FRANCE - CASE STUDY OVER CLERMONT-FERRAND

From April 19 to April 22, the French research aircraft ATR 42, equipped with microphysical probes FSSP 100, FSSP 300, 2D and PCASP 100X performed 4 scientific flights above France, in order to quantify the volcanic ash plumes. We present here in situ measurements for a flight between Rouen and Toulouse on April 22nd passing over Clermont-Ferrand around 11:40 UTC (red rectangle).

Figure 4.1 presents the temporal evolution of particle concentration per diameter measured by the FSSP 300 probe. High particle concentrations are well correlated to the aircraft passing though the planetary boundary layer (PBL). The **coarse mode around 3-4 µm** highlighted by white circles isn't usually found in the PBL to that extent and **is potentially related to Eyjafjöll's ashes**.

Figure 4.2a presents the mean aerosol size distributions measured over Clermont-Ferrand in the PBL by PCASP (blue curve) and FSSP 300 (green curve) probes. FSSP data highlight the coarse mode mentioned above. This coarse mode has been simultaneously detected by OPGC measurements at the Puy de Dôme station.

Figure 4.2b presents the mean aerosol size distributions for the whole flight in the PBL, thus including volcanic ash particles (solid line), and in the free troposphere (dotted line).