Characterization of volcanic aerosol properties by CALIPSO

J. Pelon[1], J.P. Vernier[4], A. Garnier[1], J. Jumelet[1], J.-P. Pommereau[1], D. Josset[2], P. Dubuisson[3], Y. Hu[4], S. Bekki[1], L. Thomason[4], N. Pascal[5], J. Descloitres[5]

(1) LATMOS, IPSL, CNRS-UPMC-UVSQ, France
(2) SSAI, Hampton, VA, USA
(3) LOA, Université Lille 1, France
(4) LaRC, NASA, Hampton VA, USA
(5) ICARE, Lille, France

CALIPSO

NASA-CNES

Volcanic plumes have recently come back on the front of the scene due to their potential threat for air traffic activity over the Atlantic and Europe
→ A need for a better assessment of risk was identified !

Volcanic plumes are a source of modifications of cloud properties in the troposphere, and can be useful tracers of UTLS dynamics

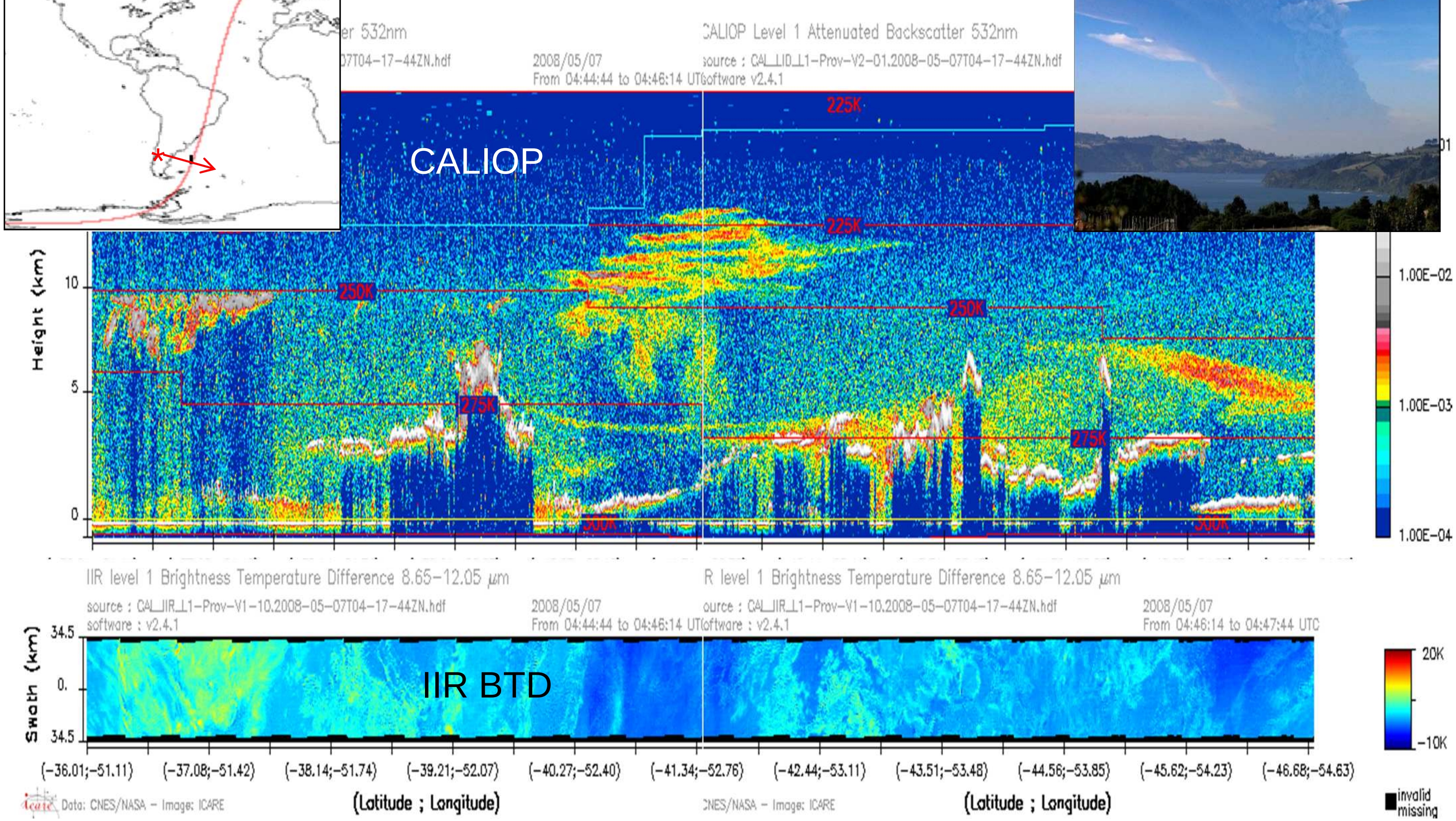
Stratospheric content has shown radiative impact and their occurrence/impact need to be accounted for in climate studies …
their presence in the stratosphere also leads to some issues in CALIOP signal calibration requiring specific processing

Plumes can be characterized by their concentration in sulfur gases (SO_2, H_2S, H_2SO_4, …) and solid material (silicates, sulphates, …).

Such plumes thus present specific spectral signatures in the IR and also induce large depolarization of light in the visible due to scattering by non-spherical solid mineral particles that helps detection using CALIPSO

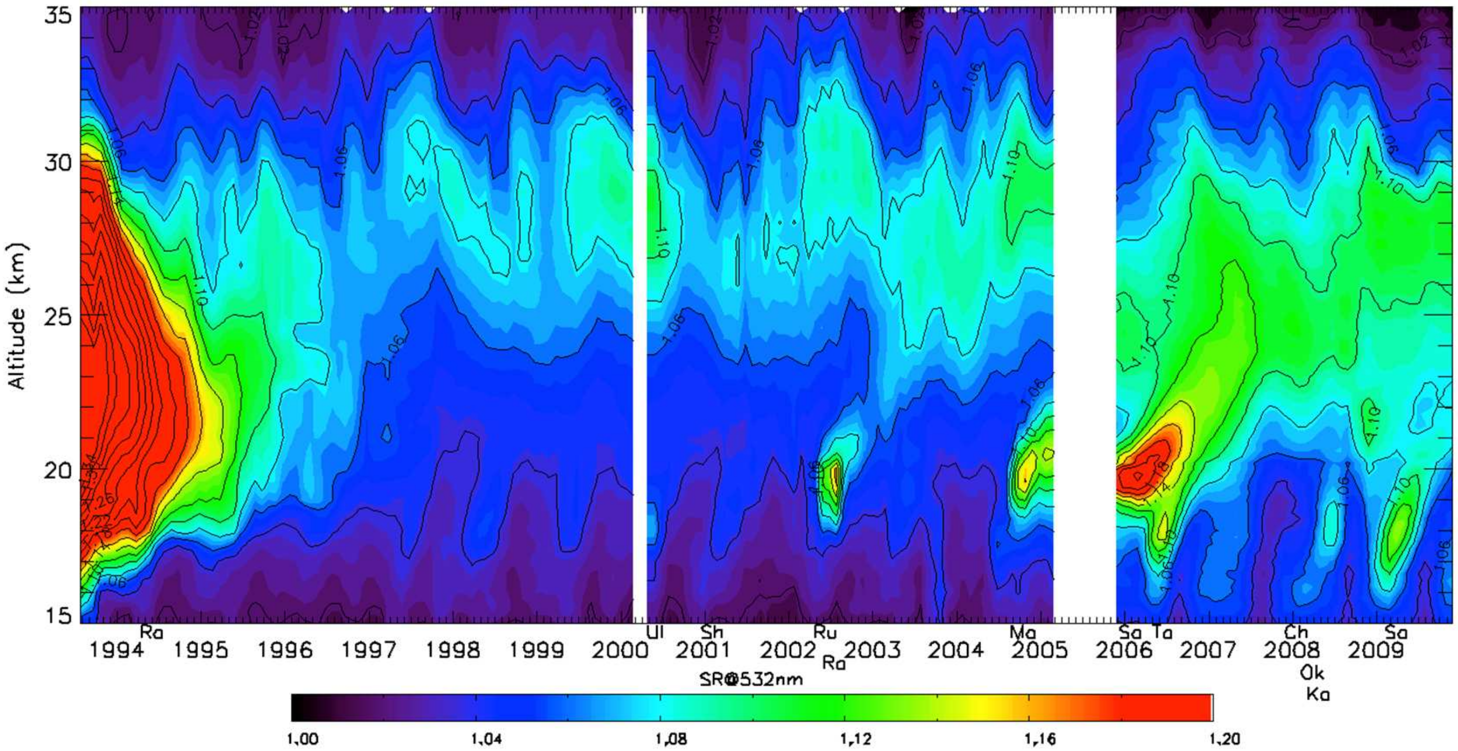
Stratosphere

Chaiten Volcanic Plume characterization



Stratospheric plume injection and transport

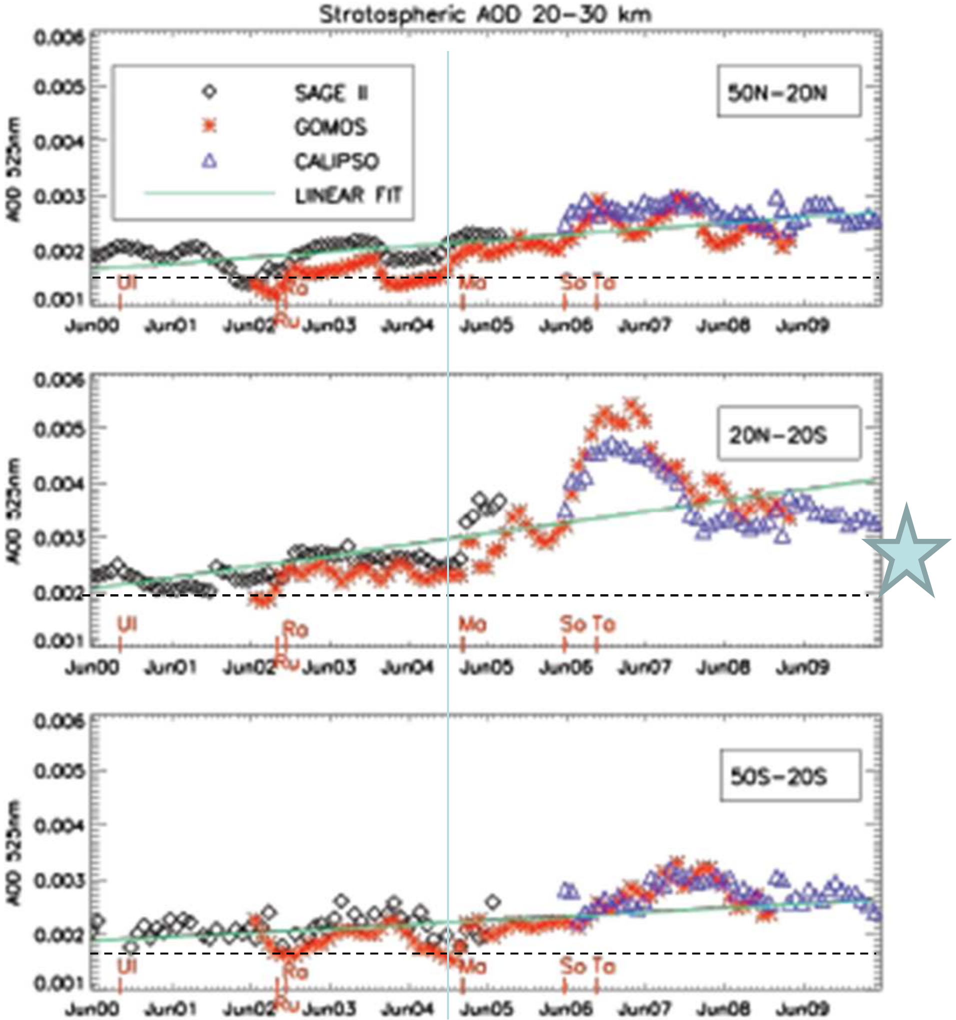
Scattering ratio from SAGE and CALIPSO



→ Stratospheric load change and UTLS Transport Vernier et al., GRL & ACP, 2011

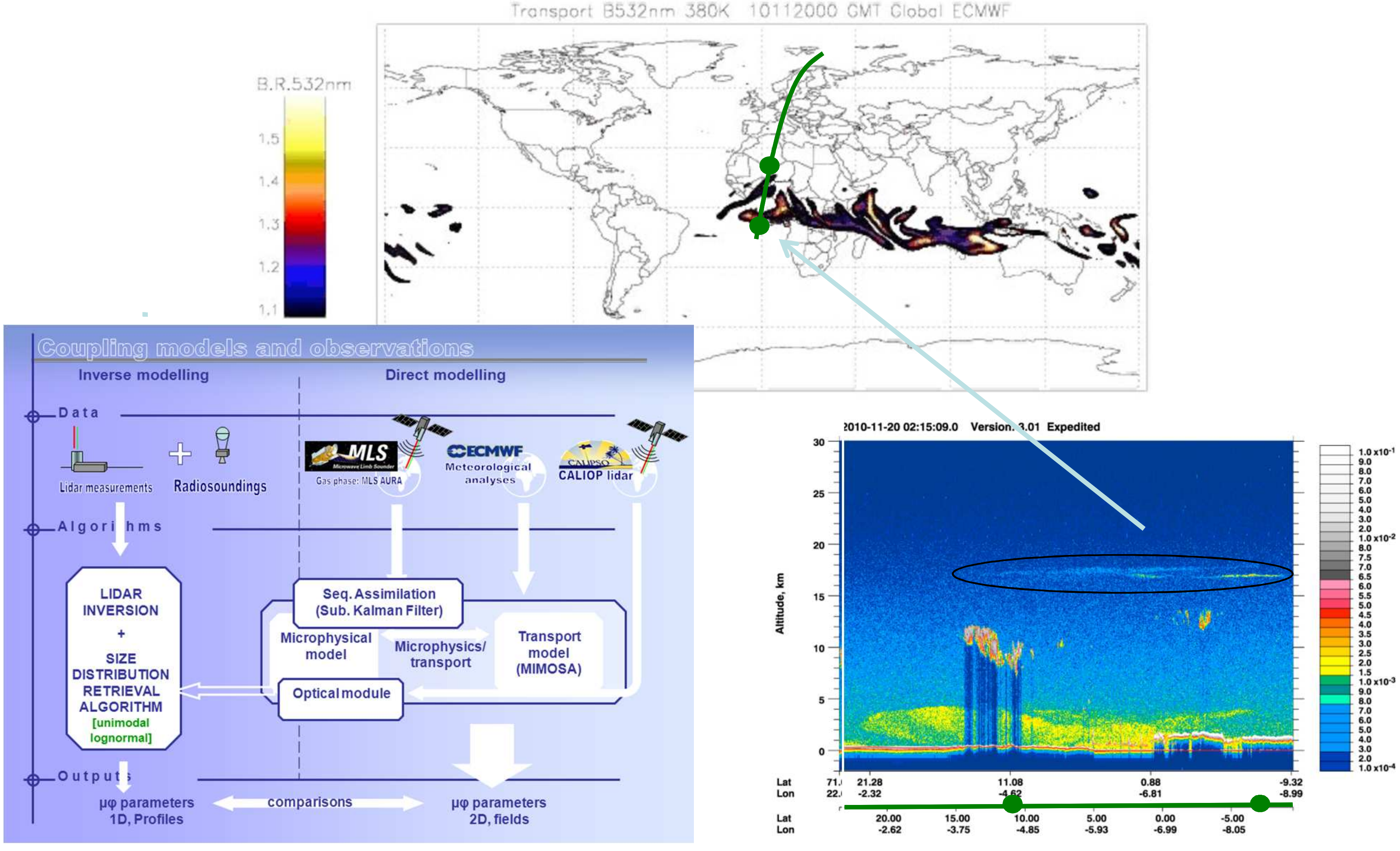
→ Stratospheric aerosol impact on climate, (Salomon et al., 2011)

Stratospheric plume injection and transport

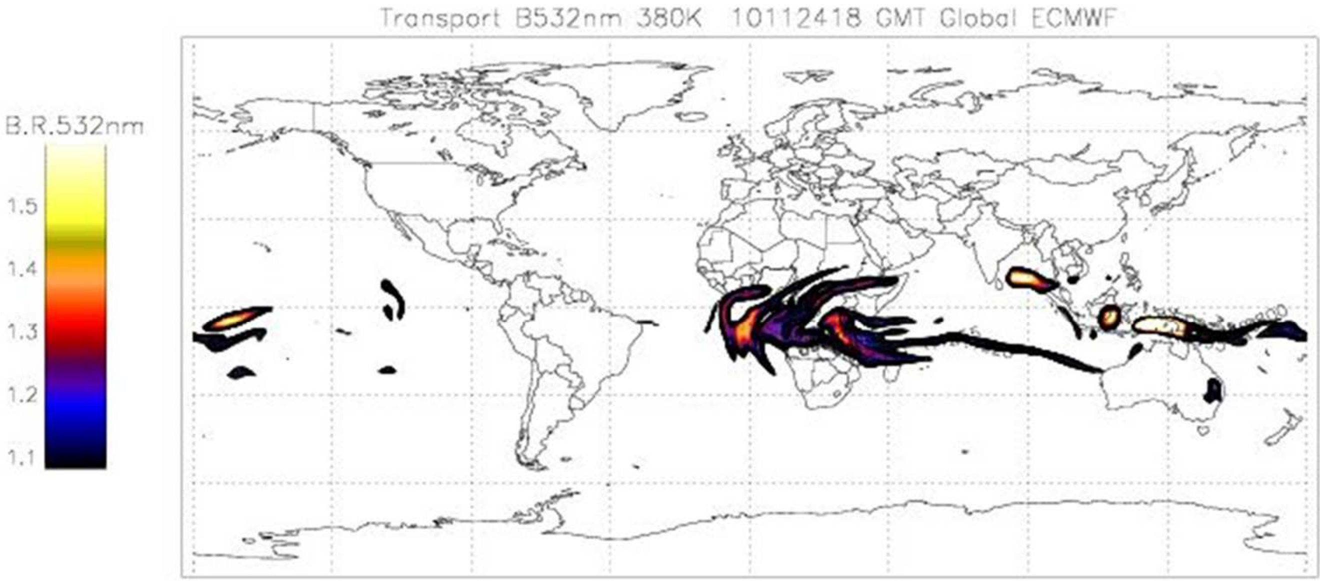


Recent increase starting in 2005 : need to continue the survey, MERAPI end of 2010,
→ new product in V4

Assimilation of aerosol CALIPSO data in high resolution model (J. Jumelet, LATMOS)

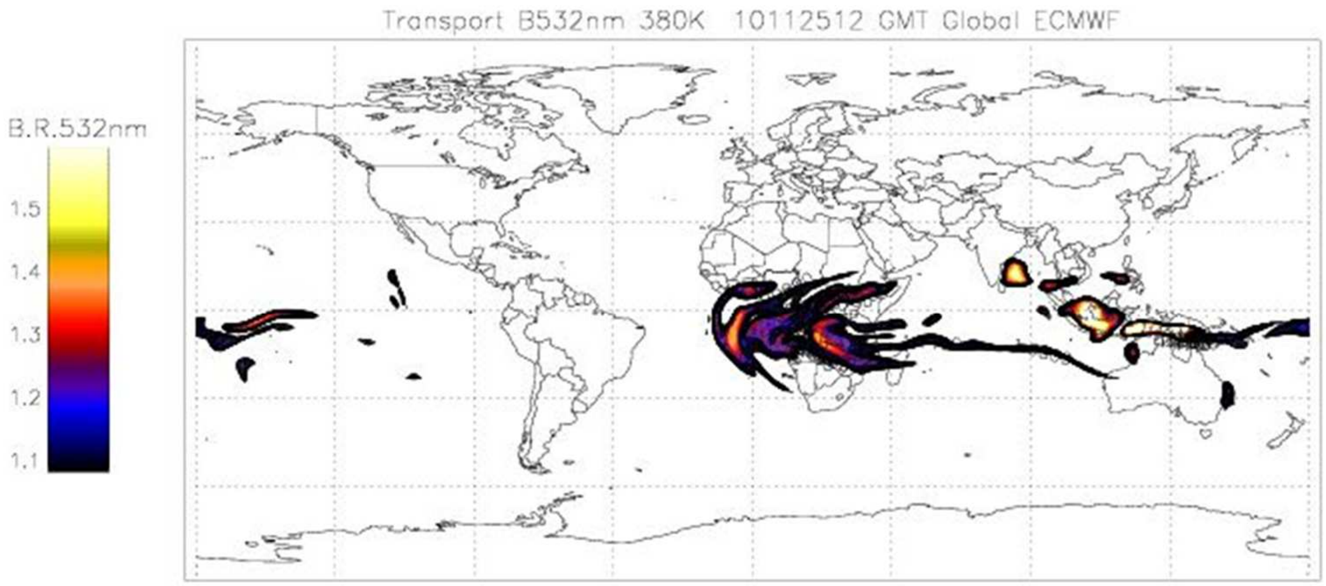


Stratospheric plume injection and transport
MERAPI case



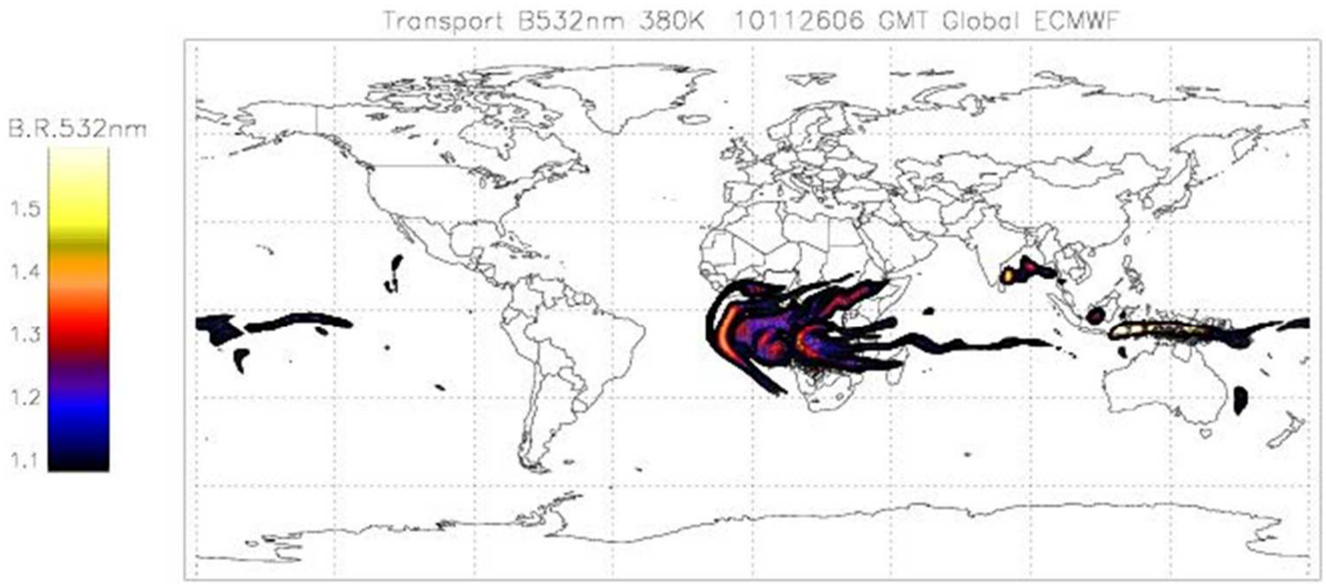
Courtesy J. Jumelet

Stratospheric plume injection and transport
MERAPI case



Courtesy J. Jumelet

Stratospheric plume injection and transport
MERAPI case



Courtesy J. Jumelet

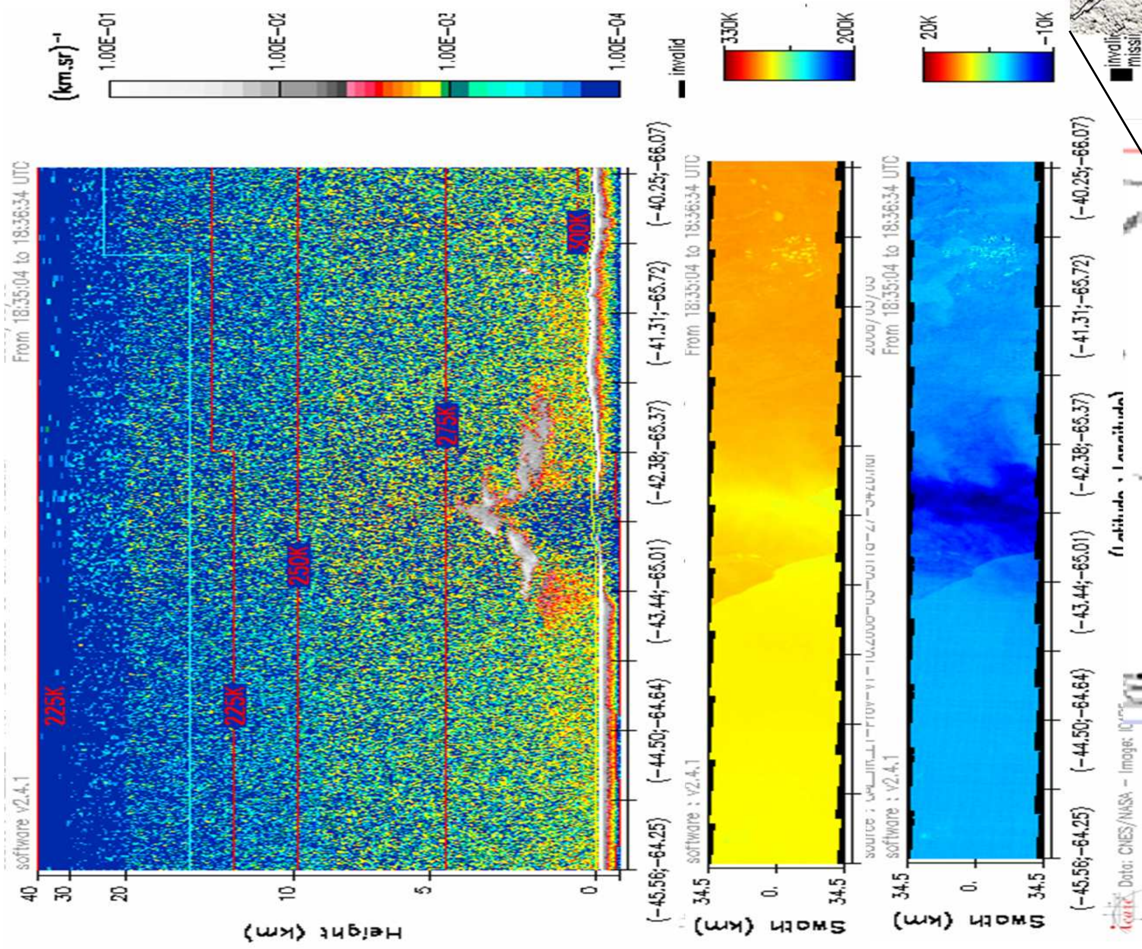
TROPOSPHERE

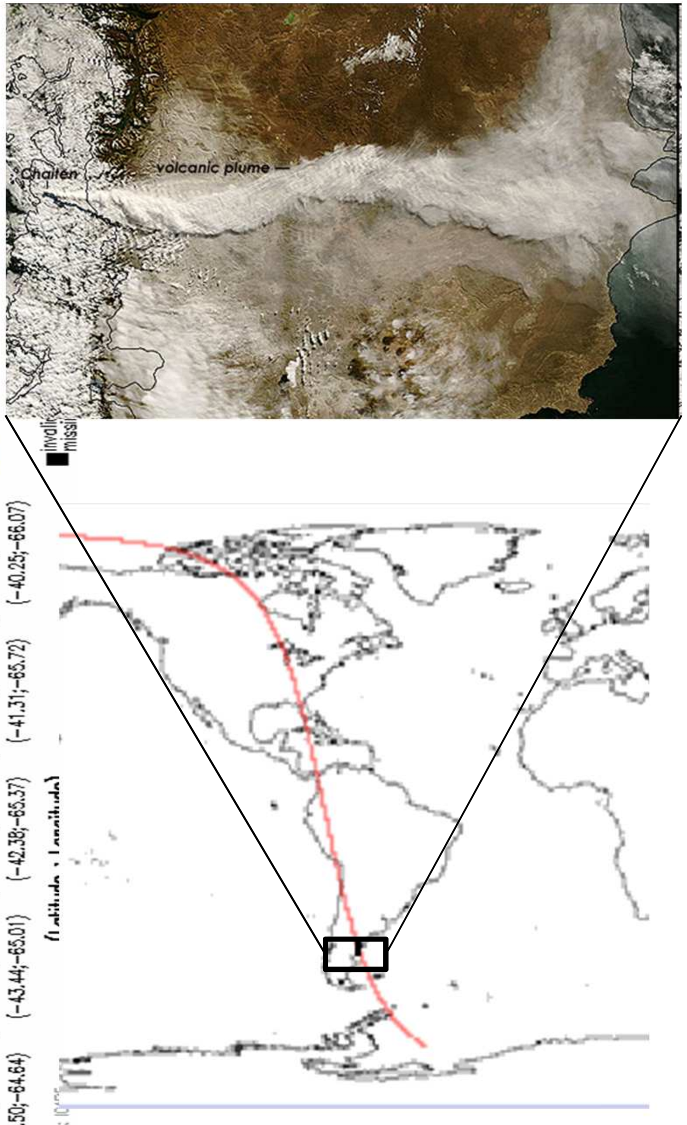
Volcanic emissions impact the tropical regions

but

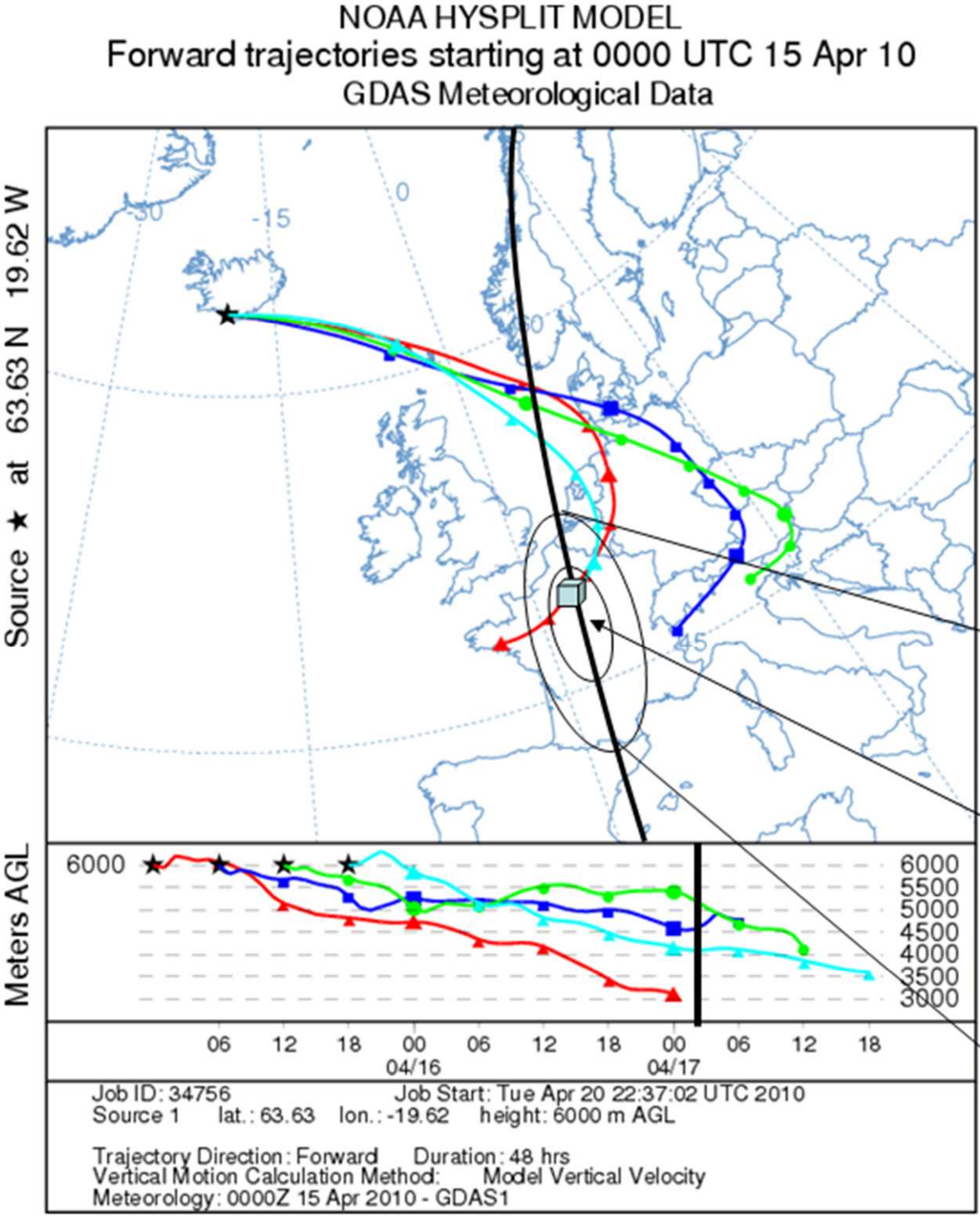
Midlatitudes/polar as well

Volcanic emission can lead to transport of dense plumes in the troposphere (Chaiten)





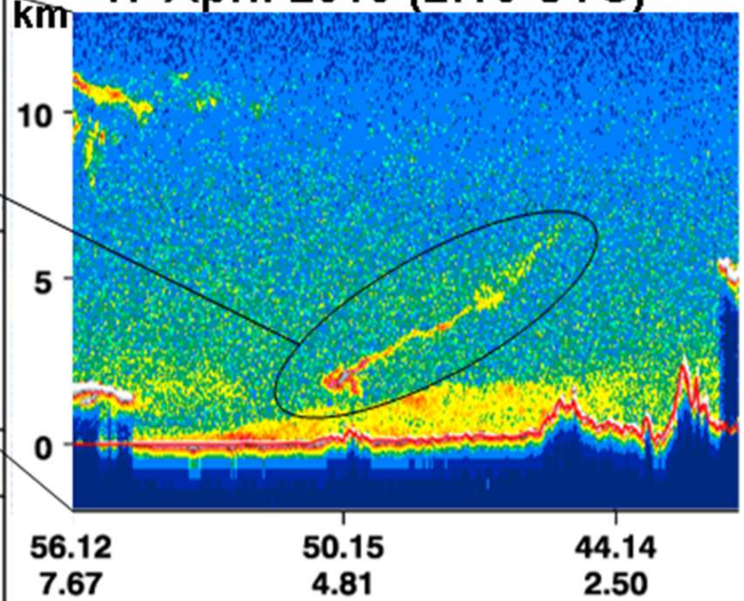
2 May 2008



HYSPLIT Trajectories for particles injected at 6000m height

Particles emitted on
15 April 2010
00-24 UTC

CALIOP Lidar Observations
17 April 2010 (2:10 UTC)

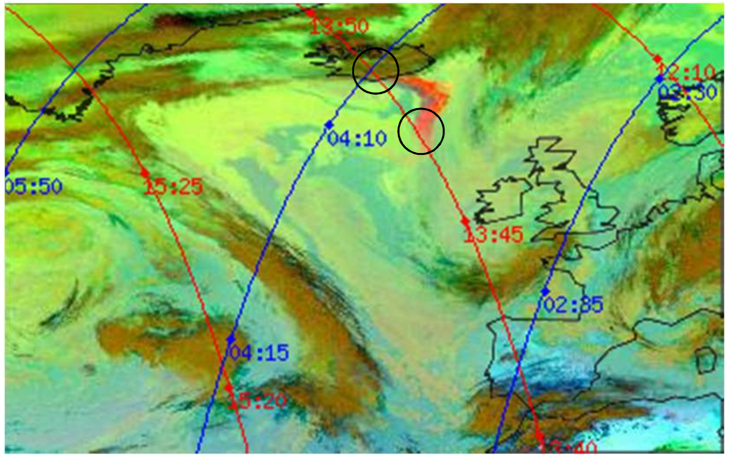


Institut Pierre Simon Laplace

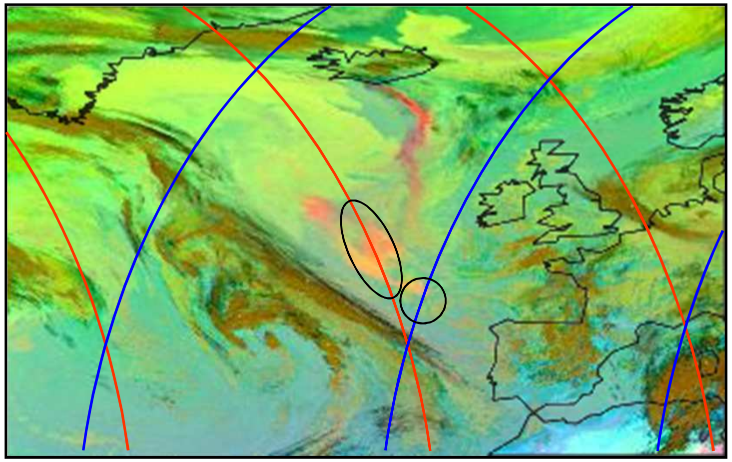
It is the advantage of the **CALIPSO** mission to combine **Lidar (CALIOP) and a 3-band Infrared Imaging Radiometer (IIR)** instruments to provide co-located observations directly exploitable for the detection and characterization of volcanic emissions using altitude information and extending detection capabilities offered by **SEVIRI/MSG**

CALIPSO is furthermore a mission of the **A-Train**, allowing further combinations with other instruments (MODIS, Parasol, AIRS, OMI, …)

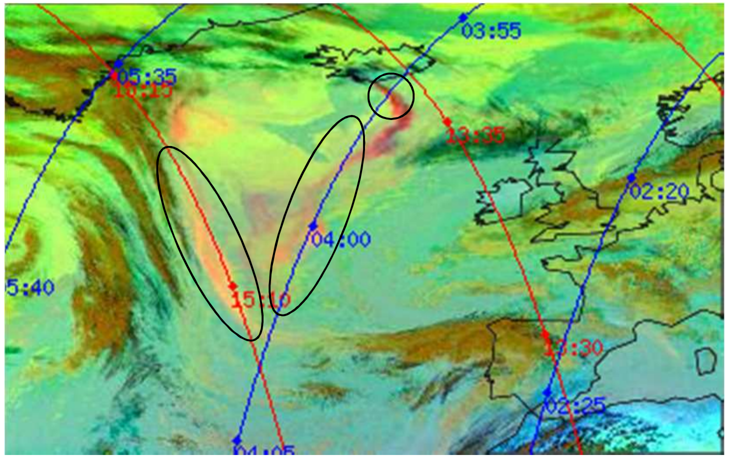
As identified for long, volcanic plumes can be directly evidenced in the IR



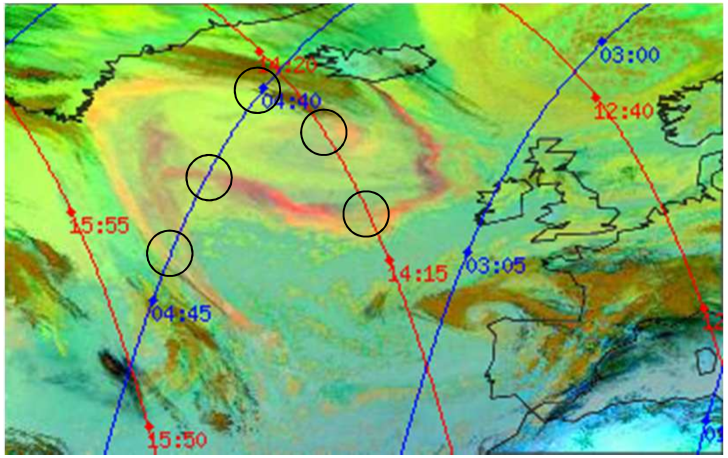
May, 6



May, 7



May, 8



May, 9

SEVIRI/MSG (13:00 UTC) ***EUMETSAT***

Several parameters can be derived

- **Identification of the layer type**
- **Altitude of the plume**
- **Optical parameters**
- **Microphysical (size and composition)**

for transport analysis, radiative impact and risk for air traffic.

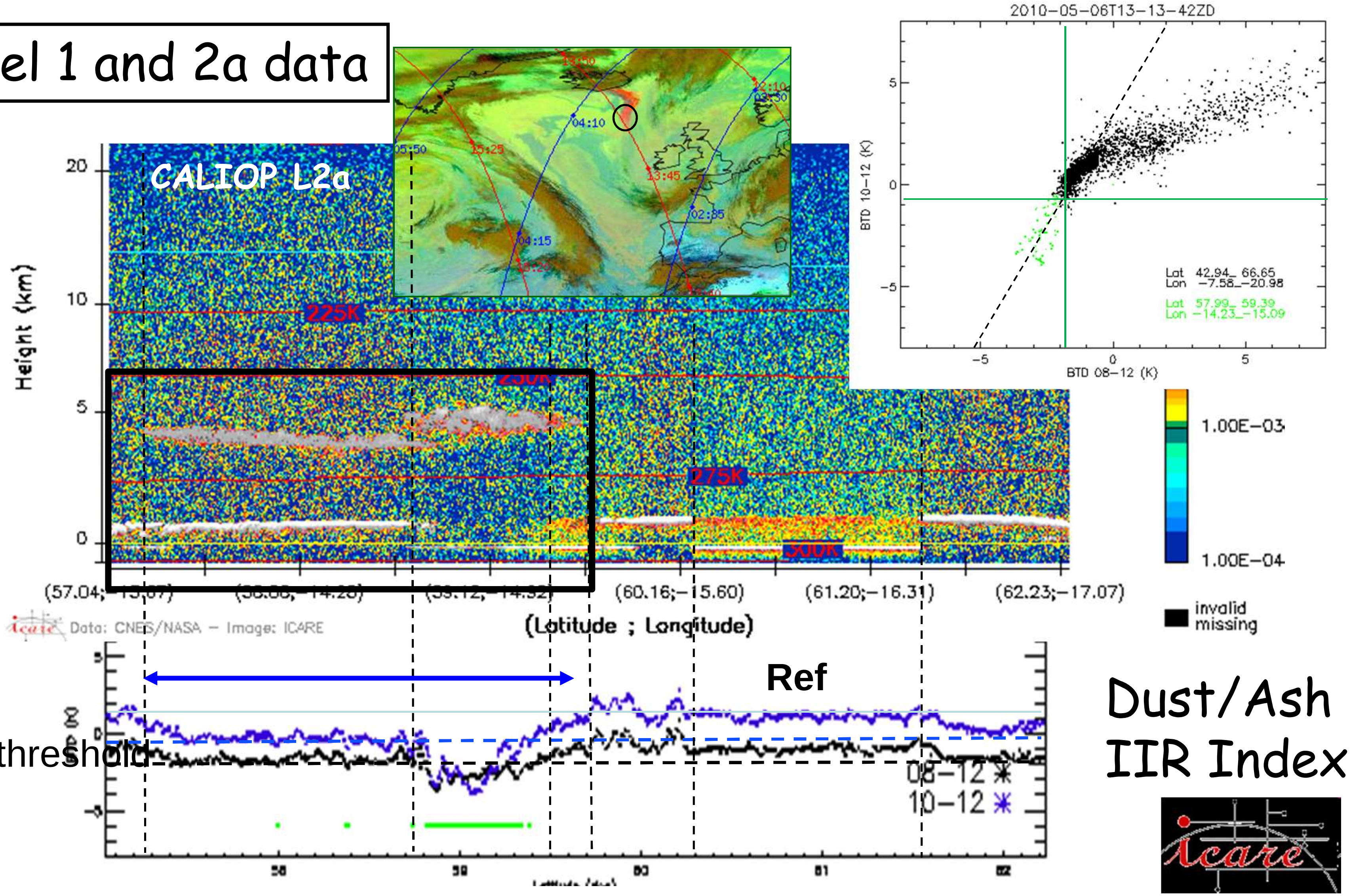
WHAT WE CAN USE TO DO SO

- **CALIPSO/IIR pre-operational V3 L2 data (emissivities and optical depths)**

- **CALIPSO/CloudSat AODs using lidar signal return on clouds (Hu et al, 2007) and radar/lidar ocean surface (Josset et al., 2008, 2009) - joint CNES-NASA SODA product at ICARE-**
  → no need of an *a priori* knowledge of aerosol lidar ratio

EYJAFJALLAJOKULL ERUPTION 6 MAY 2010 13:50 UTC

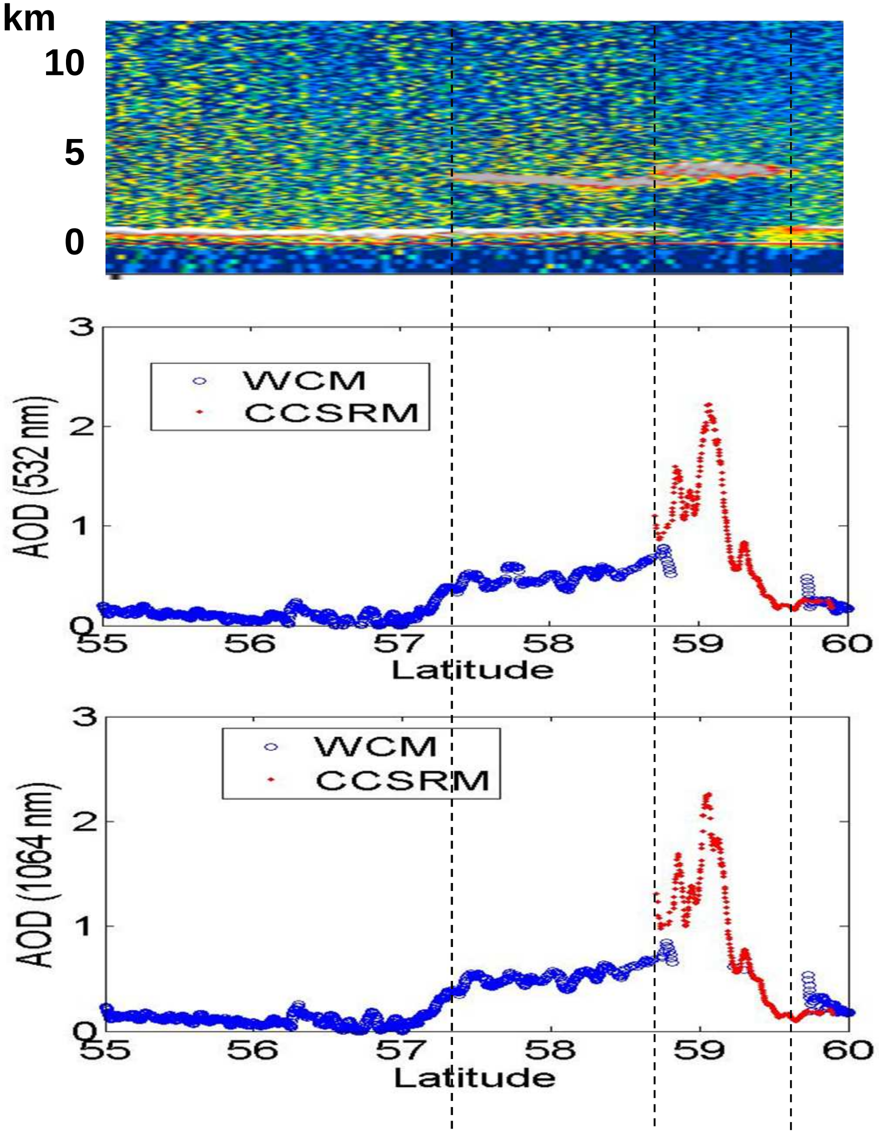
Level 1 and 2a data

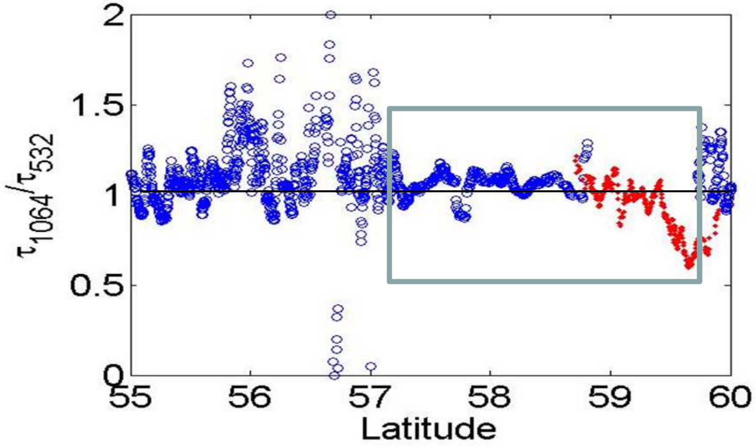


The volcano plume extent is detected by the IIR using 10-12 BTDs according to a standard threshold used in the algorithm.

EYJAFJALLAJOKULL ERUPTION 6 MAY 2010 13:50 UTC

New retrievals using CALIPSO-CloudSat data



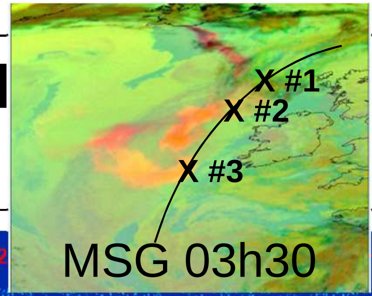


Optical depths larger than 2
Close to the source

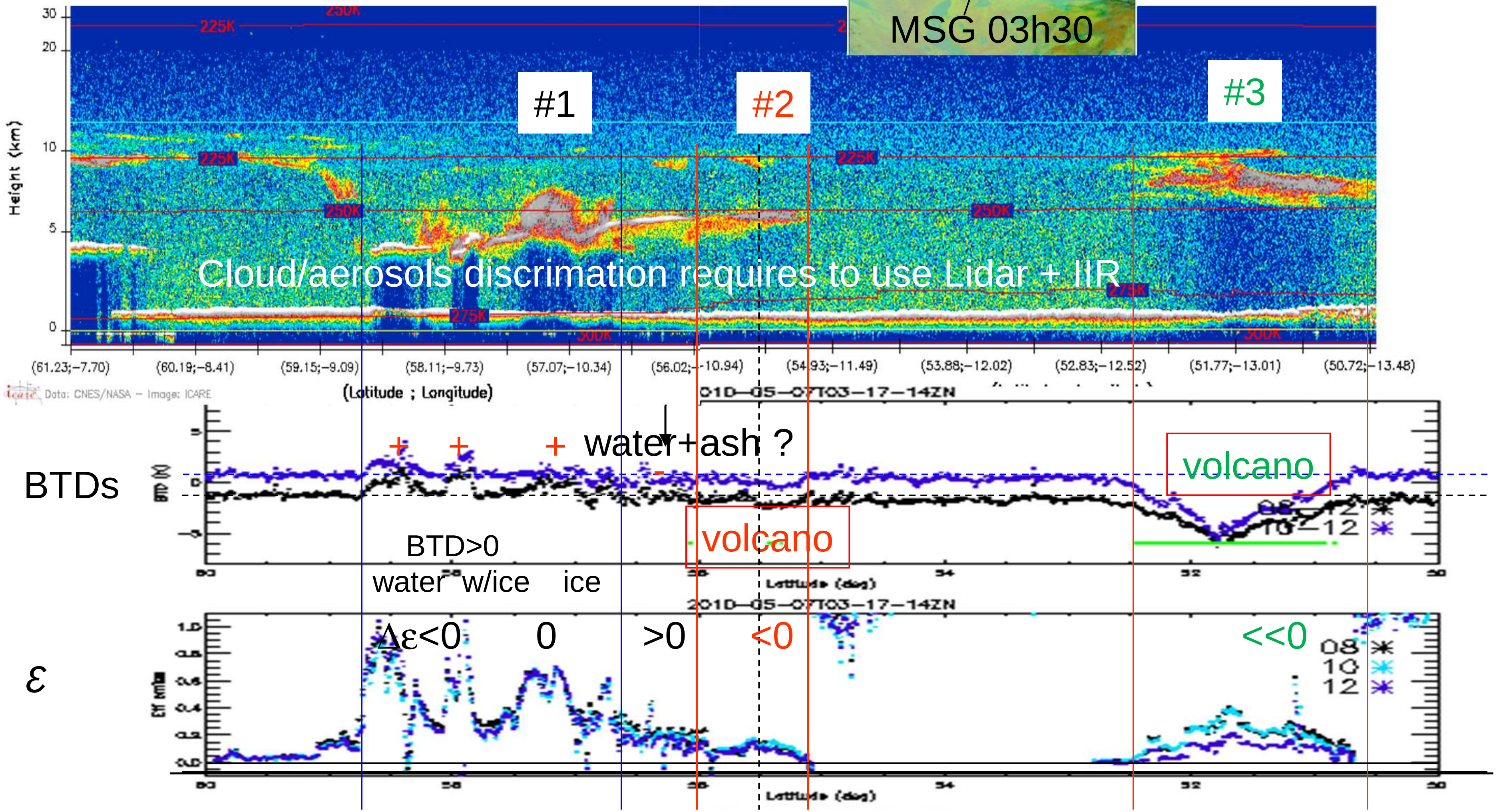
No spectral dependence
(532/1064 nm)
→ Larger amount of big particles

Better assessment of mass from
Vis AOD

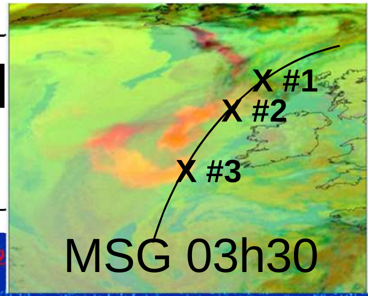
EYJAFJALLAJOKULL ERUPTION

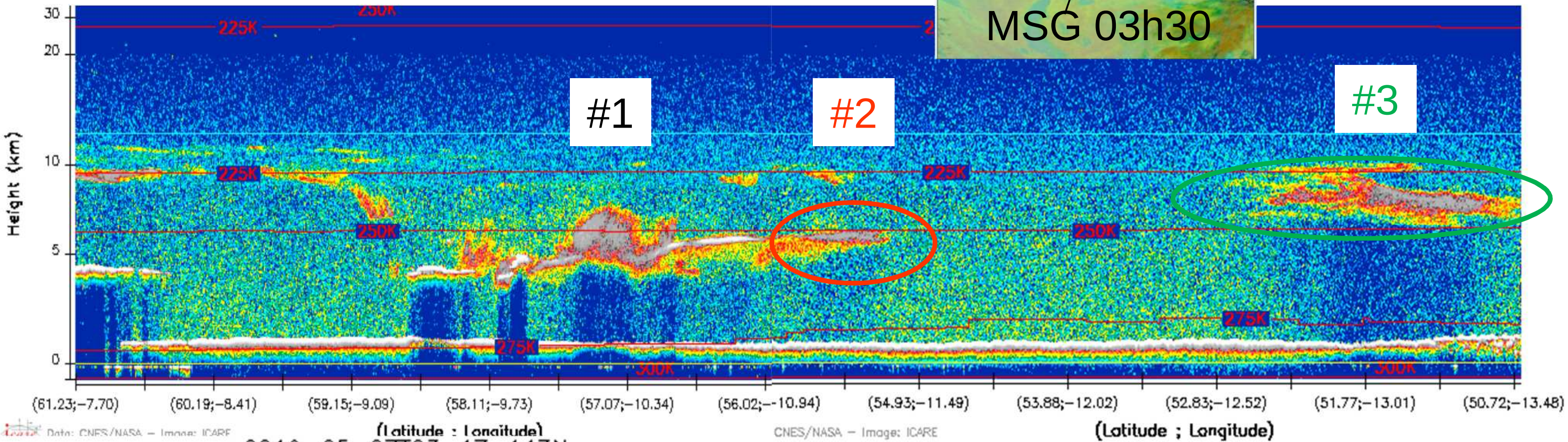


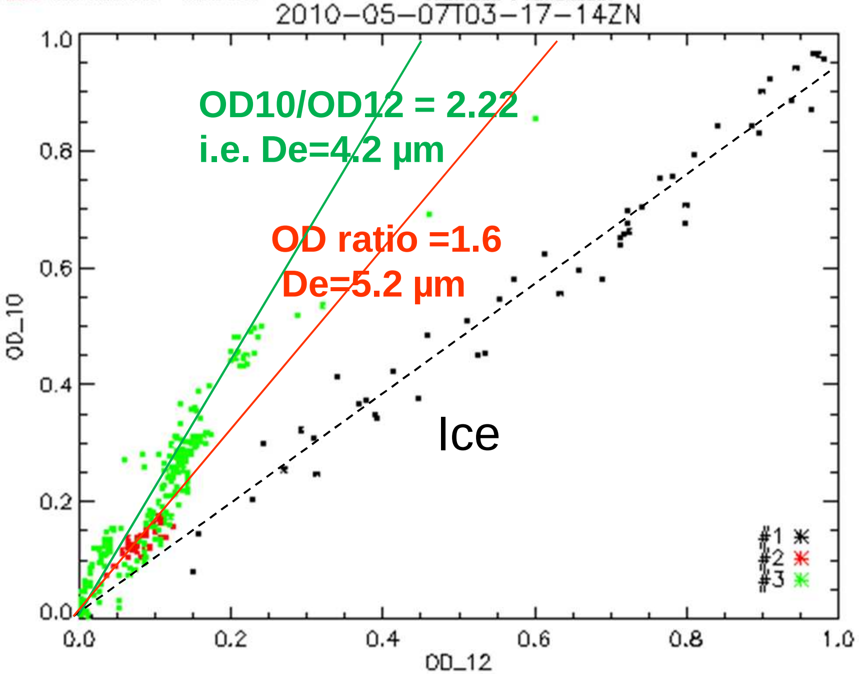
07 MAY 2010 03:20 UTC



EYJAFJALLAJOKULL ERUPTION 07 MAY 2010 03:20 UTC







The mass concentration estimate in the plume is

$$M = \frac{2}{3}\rho\frac{\alpha}{Q_{ext}}D_e$$

→ **From CALIOP (OD, Angström, δ) and IIR (OD, De),**
peak value M are > 2 000 µg/m3

Summary

CALIPSO data are of precious help for analyzing volcanic emissions

The combination of Lidar and IR measurements onboard CALIPSO has allowed to characterize the **EYJAFJALLAJOKULL plume** over several days from combined active/passive observations to better identify particle properties (altitude of injection, type of material, microphysical and radiative properties)

The optical properties of the plume in the IR and visible allowed to identify mass concentrations larger than 2 000 µg/m3 linked to mineral particles with De~5 µm), probable occurrence of H_2SO_4.

Further application of such observations are to merge them with coincident observations from geostationary platforms and use in assimilation schemes (as for ex. Mimosa/ST & MACC/troposphere).

More to be included on volcanic aerosols in CALIPSO V4.