Aerosol Activities at Meteo-France: Modelling, Assimilation and Operational Forecasts

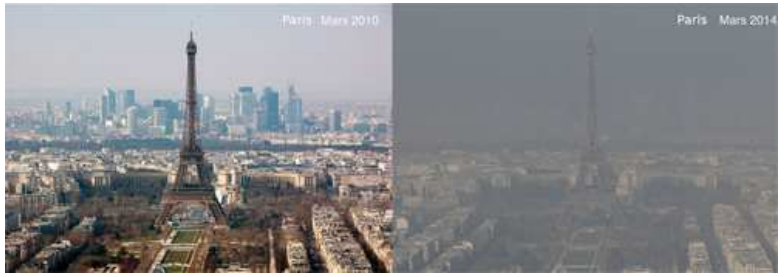
L. El Amraoui (1), B. Sič (1,2), M. Joly (1), N. Asencio (1), et al.(1,2,…)

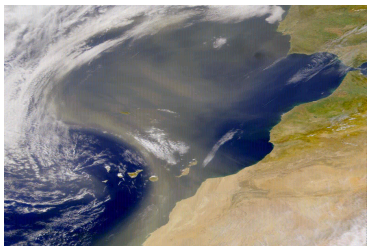
(1) CNRM & Météo-France, Toulouse, France
(2) CERFACS, Toulouse, France
laaziz.elamraoui@meteo.fr

ICAP workshop, 12-14 July 2016, NOAA, USA

Why aerosols are important ?

- Reflect, scatter and absorb radiation
- Influence visibility
- Influence climate
- Affect clouds and precipitation
- Supply minerals to ocean biosphere
- Active in the atmospheric chemistry
- Affect health



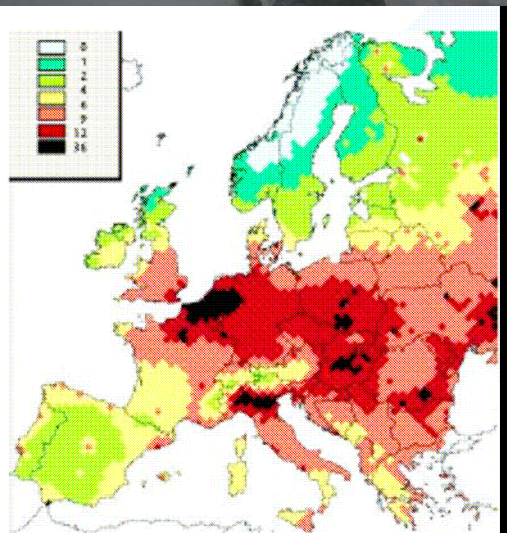


Importance of aerosols for Météo-France

Air Quality

- Météo-France has a mission to produce operational forecasts for air quality for both gases and aerosol (prévair, Copernicus)
- Aerosols have gret impact on air pollution as wellas human health

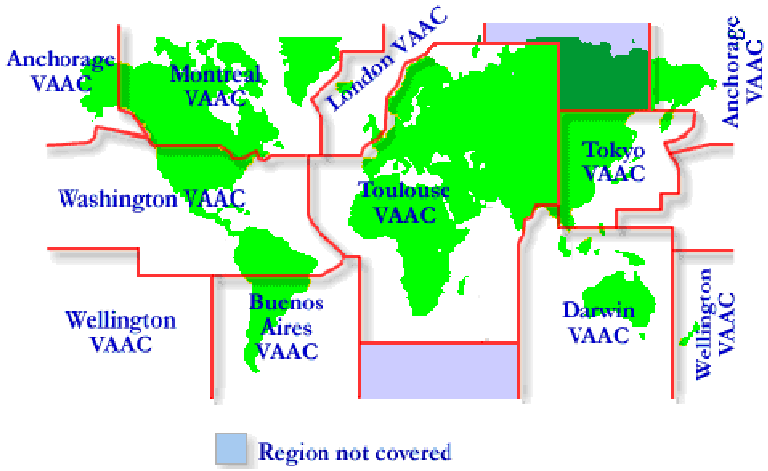
➔ Need for reliable Air Quality forecasts



Aviation safety

- Météo-France is one of the 9 VACC centres (Volcanic Ash Advisory Center) with a responsability over over Africa and the big part of Eurasia

➔ Need for a good representation and forecast of volcanic aerosols in the case of volcanic erruptions

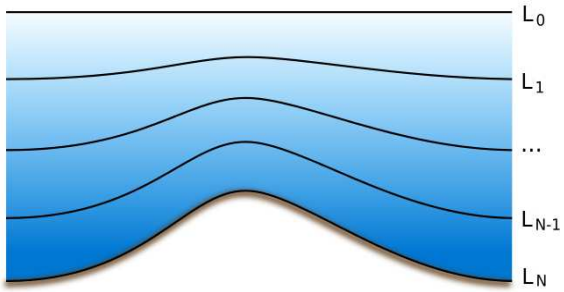


The MOCAGE model

MOCAGE (Modèle de Chimie Atmosphérique à Grand échelle

- CTM MOCAGE is a chemical transport model of Météo-France covers both troposphere and stratosphere with gases and aerosols:

  – 47 vertical levels in sigma-pressure hybrid coordinates from the ground up to 5 mbar (resolution from ~40m next to the surface till ~800m in the stratosphere)



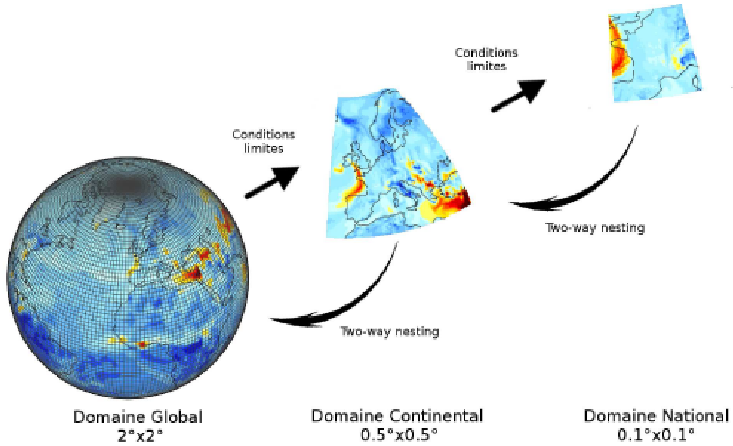
  – Transport: semi-Lagrangian advection , Louis (1979) diffusion, Bechtold et al. (2001) convection

  – Meteorological forcing from ARPEGE or IFS analyses

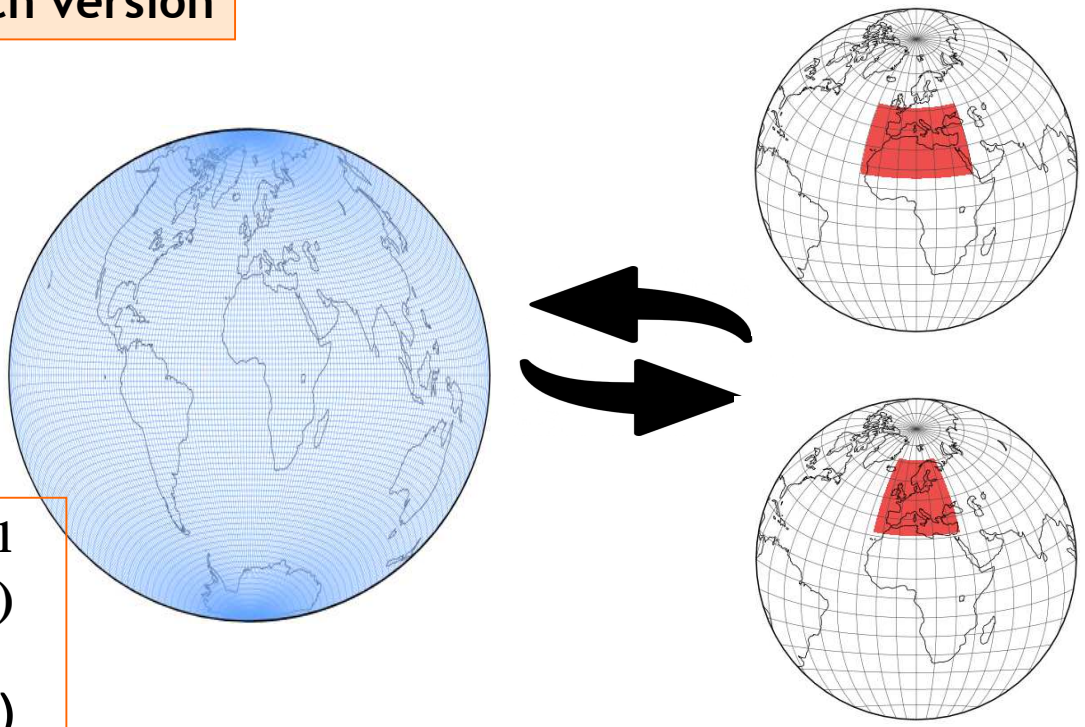
  – **Horizontal resolution**:
    - Global: from 2°x2° to 0.5°x 0.5°
    - Regional: from 0.5°x 0.5° to 0.2°x 0.2°
    - Over France: 0.1°x 0.1° to 0.025°x 0.025°

The MOCAGE model

Operational version



Research version

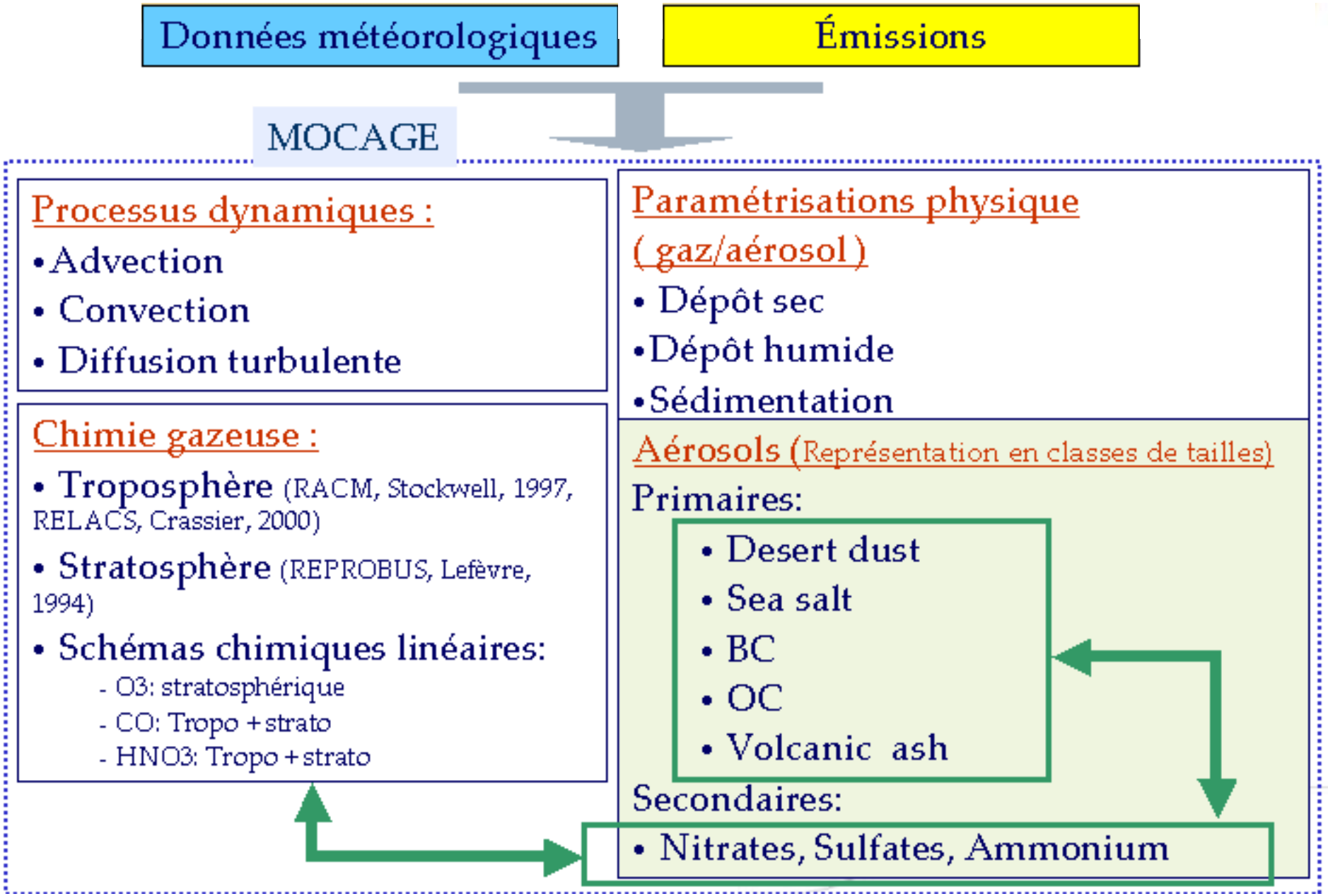


Global
(2°x2°)
or
(1°x1°)

Mediterranean
(0.2°x0.2°)

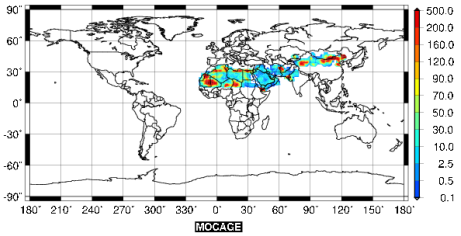
Europe
(0.5°x0.5°)
or
(0.2°x0.2°)

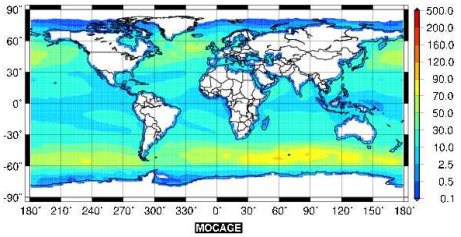
The MOCAGE model

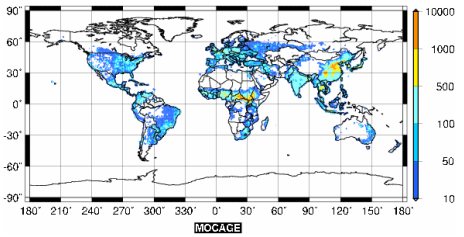


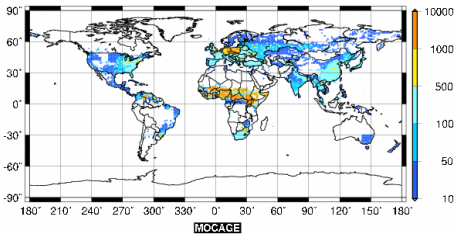
Aerosols within MOCAGE CTM

- **5 types of primary aerosols**
  - **Desert Dust**
    - AEROCOM emission inventory
    - Dynamical emission (wind speed & surface type)
  - **Sea salt**
    - AEROCOM emission inventory
    - Dynamical emission
  - **Black Carbon**
    - AEROCOM emission inventory
    - GEIA emission inventory
    - ACCMIP emission inventory
  - **Organic carbon**
    - ACCMIP emission inventory
  - **Volcanic Aerosols**
    - Point sources depending on each volcano
- **6 bins for all types of aerosols**









Species	desert dust	sea salt	black carbon	organic carbon
size range [µm]	0.1 - 100	$3 \cdot 10^{-2}$ - 20	10^{-3} - 10	$5 \cdot 10^{-3}$ - 10

Contribution to ICAP

Météo-France contribution to ICAP

- Daily production since February 2016
- MOCAGE model available on the ICAP website since may 2016
- 4 days-forecast (17 time-slots from 00 to 96 with 6hr interval)
- Resolution: 2 degrees (regridded at 1 degree)

- Shortcomings of the current version:
  - Desert dust AOD are too low on average
  - Desert dust emissions are too strong for some events (e.g. over the Gobi desert)
  - Lack of AOD over the oceans (issue in the sea salt representation)

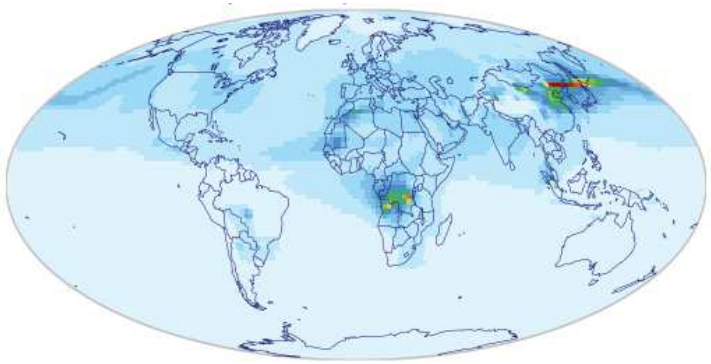
Future version

- A new version of the model MOCAGE will be put operational in September 2016 :
  - Resolution increase to 1°
  - Desert dusts emissions completely revised
  - New distribution of desert dusts into the model bins (Kok 2011)
  - Correction in the sea salt representation
  - Black & organic carbon inventories updated

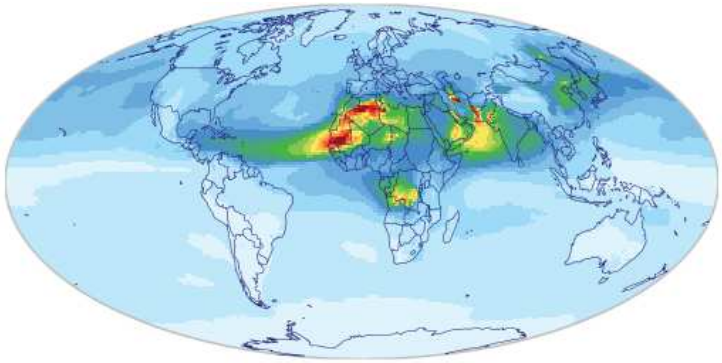
Comparison to MODIS

- Illustration : June 2015, total AOD average

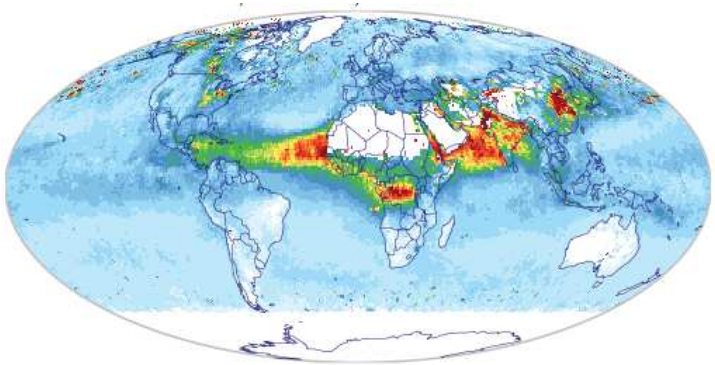
Current version



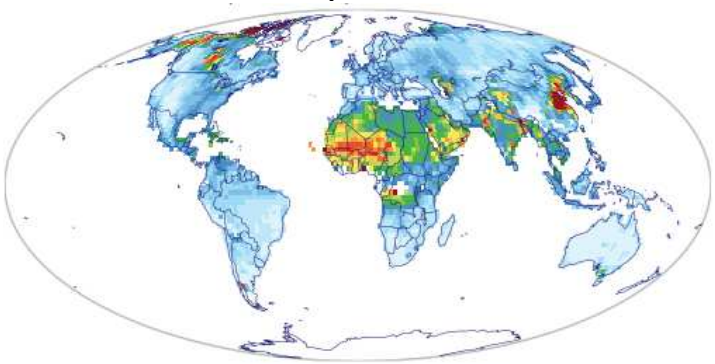
New version (sept. 2016)

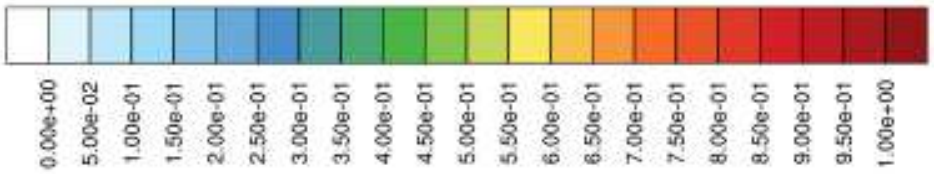


MODIS standard AOD



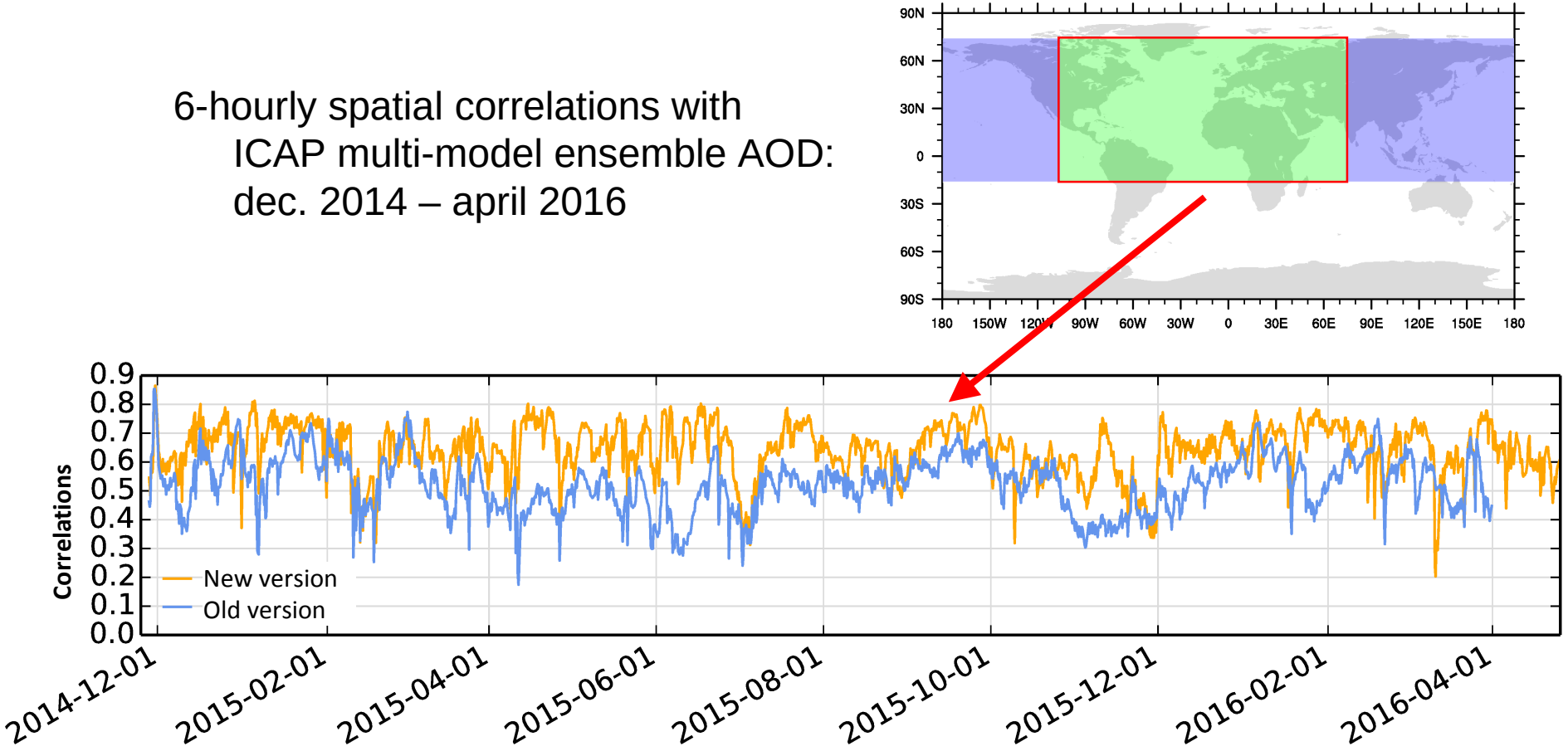
MODIS Deep Blue AOD 550





Comparison to ICAP ensemble

6-hourly spatial correlations with ICAP multi-model ensemble AOD: dec. 2014 – april 2016



- The new version (sept. 2016) is more consistent with ICAP ensemble.

DATA ASSIMILATION

Assimilation of aerosols in the MOCAGE CTM

Sič's Ph.D thesis (2014)

➔ The MOCAGE System is able to assimilate:

- **Aerosol Optical Depth (AOD) measurements**

- **Lidar Signals**
  - → Backscatter Coefficient,
  - → Extinction Coefficient,
  - → Normalized Backscatter signal)

- **With different configurations:**
  - → Ground
  - → Satellite
  - →Aircraft (up / down)

➔ Methodology:

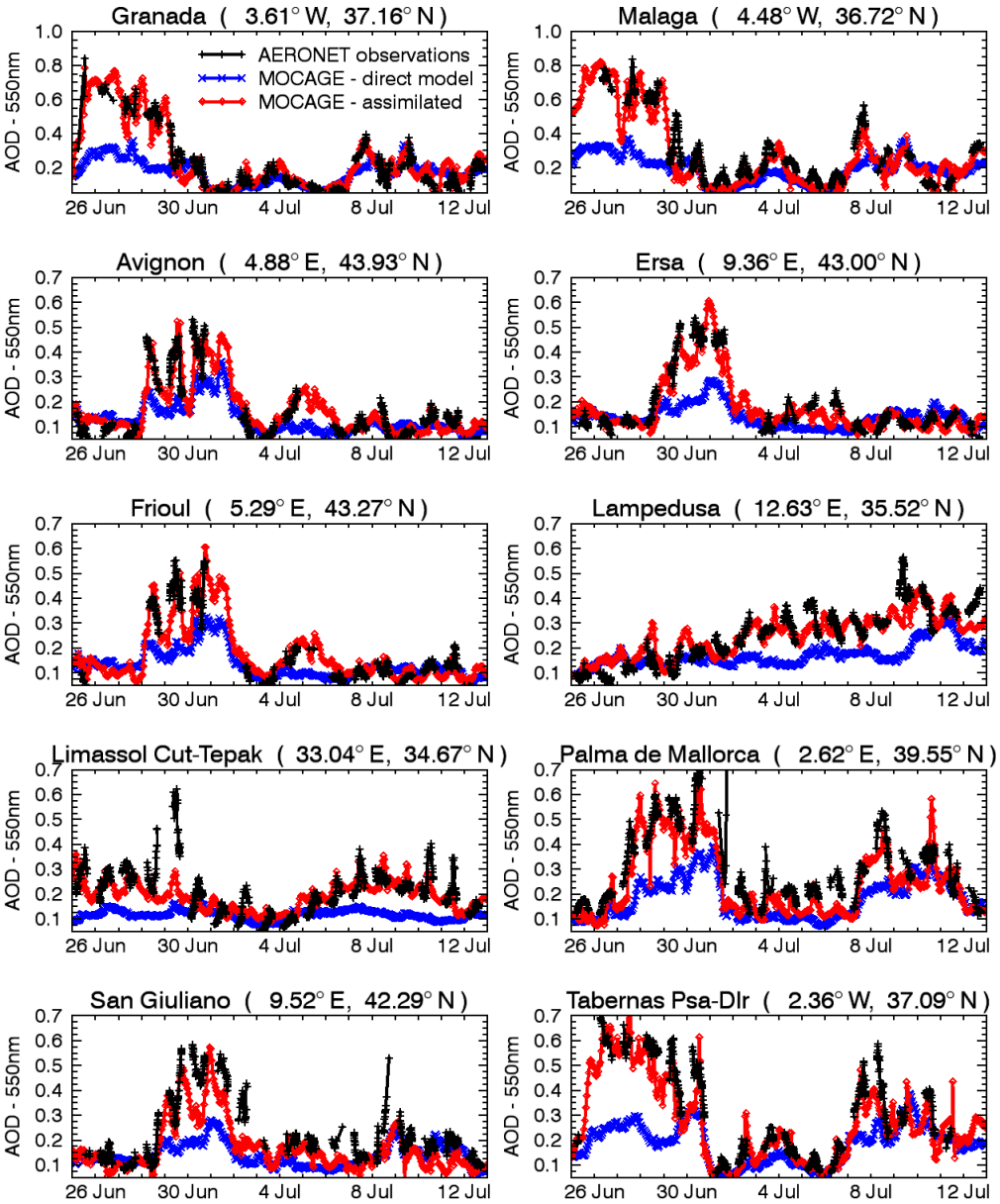
- Neither AOD nor lidar signals are the prognostic variables
- Total concentration (in 3D) as a control variable

➔ Minimization and propagation of the increment are done in terms of the total aerosol concentration

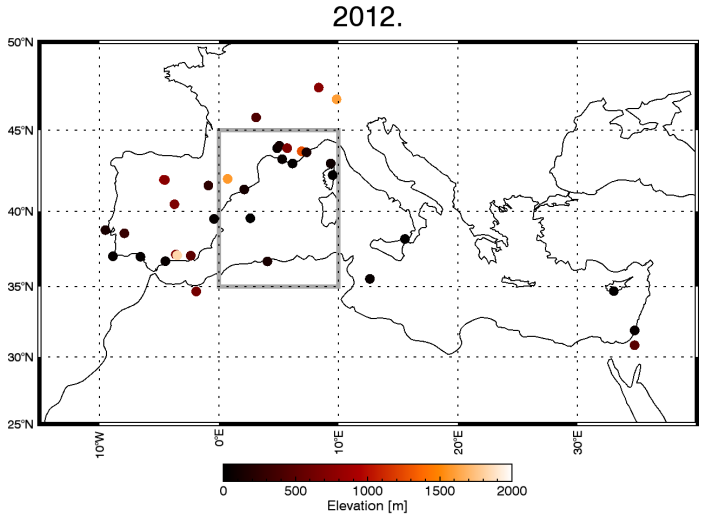
➔ Development of the needed operators: observation, tangent linear and adjoint to switch between the model space and the observation space during the assimilation

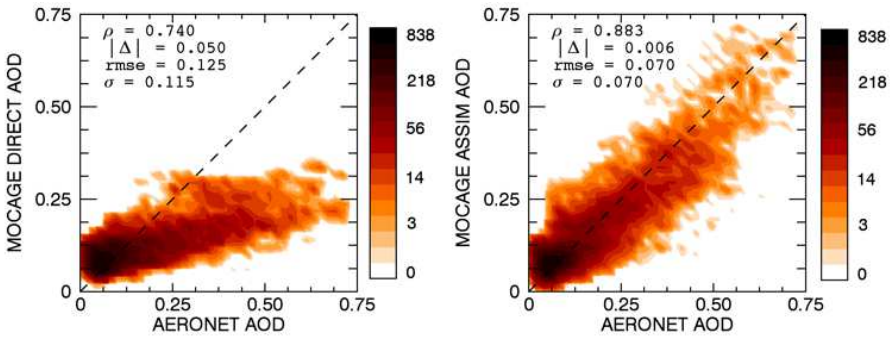
- Update of concentrations to all species/bins in the model After each assimilation window

Assimilation of aerosols (AOD)

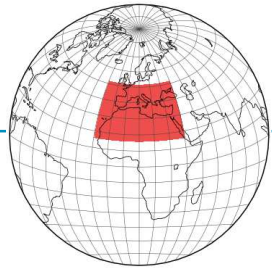


Positions of the stations

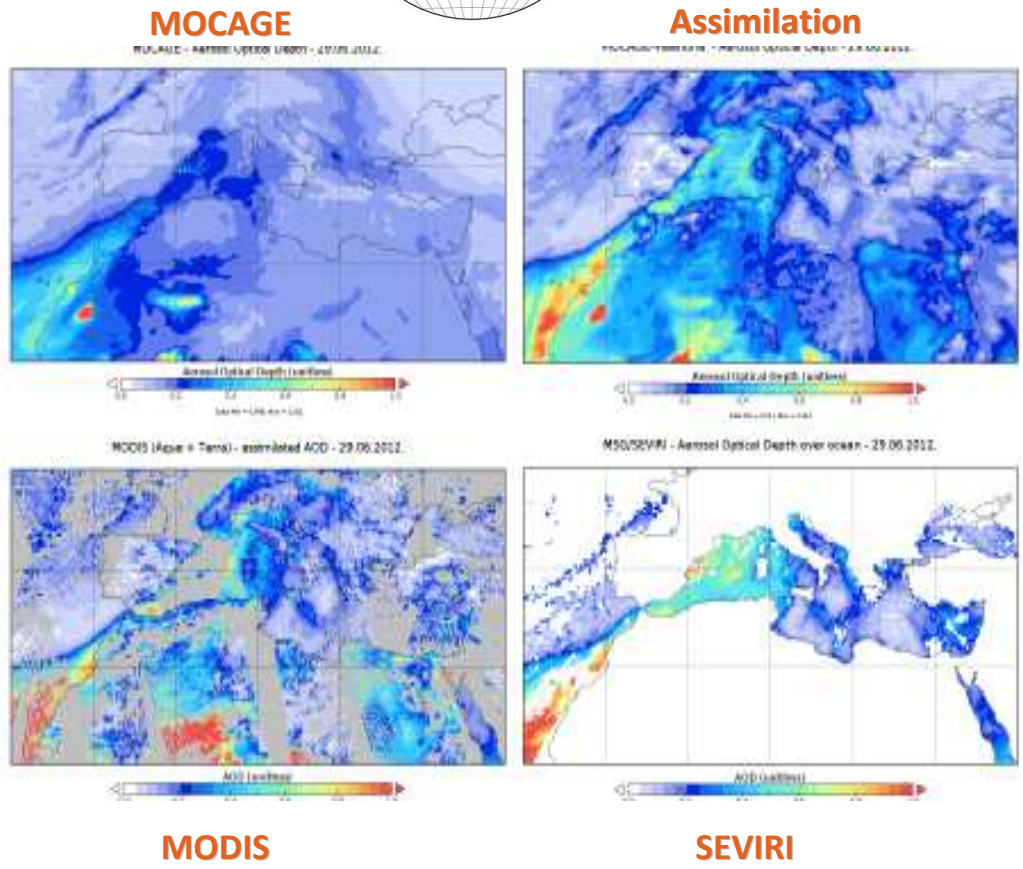




Assimilation of aerosols (AOD)

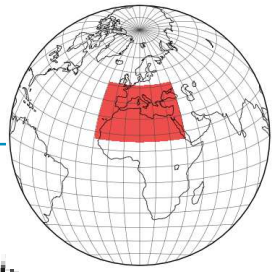


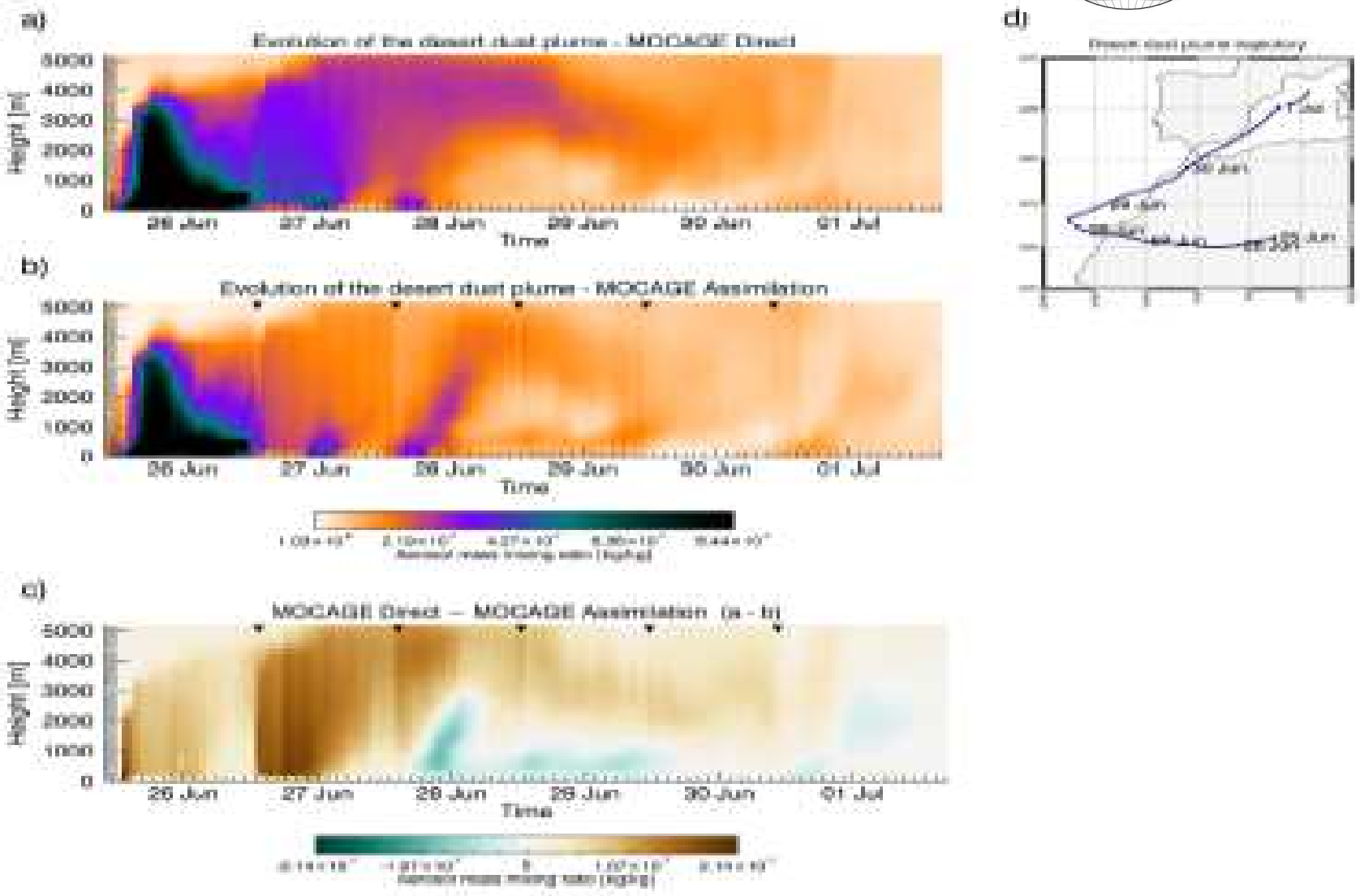
- Module of AOD assimilation is validated for:
  - Period of TRAQA (summer 2012)
  - And CHARMEX (summer 2013)
  - Volcanic plume from Eyjafjöll in 2010
- TRAQA
  - Balloon and aircraft instruments
  - Summer 2012.
- Assimilated observations
  - MODIS (Land, Ocean and Deep-Blue) superobservations
  - over Mediterranean basin
  - June 2012 – July 2012
  - 0.2°x0.2°



Sič et al., AMTD, 2016

Assimilation of aerosols (AOD)



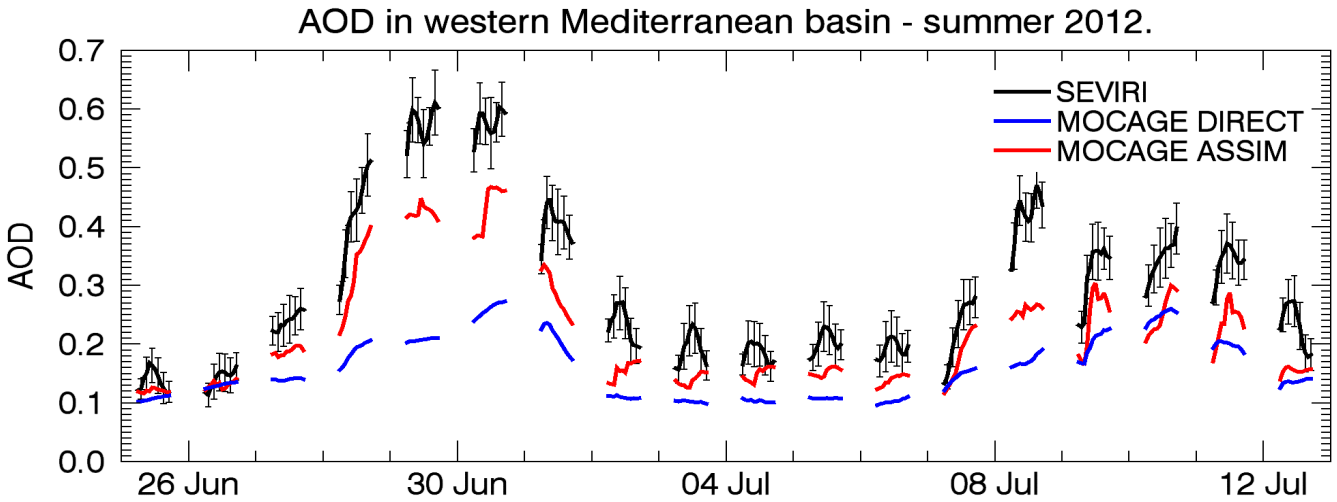


Sič et al., AMTD, 2016

Assimilation of aerosols (AOD)

Comparison with independent AOD observations :

- Independent AOD observations:
  - SEVIRI (over sea)

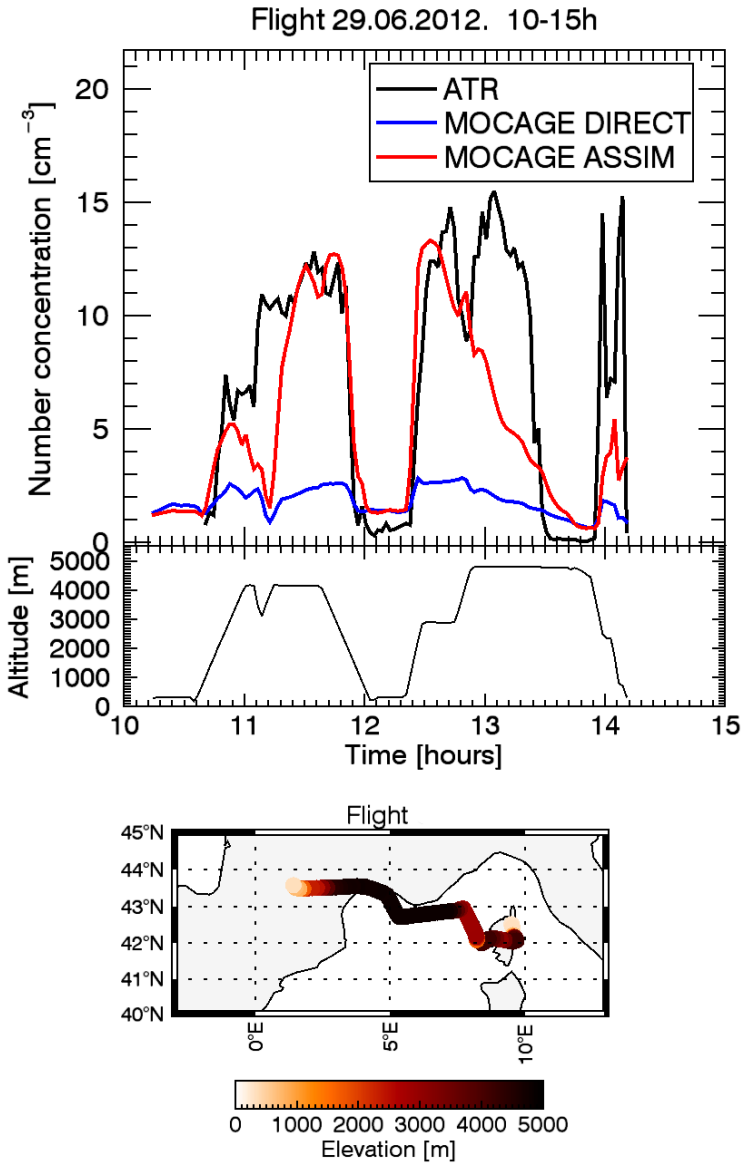


- Statistics

	Direct model				Assimilated model			
	ρ	bias	rmse	st. dev.	ρ	bias	rmse	st. dev.
SEVIRI	0.69	0.14	0.25	0.20	0.87	0.08	0.16	0.14
AERONET	0.74	0.05	0.13	0.12	0.88	0.01	0.07	0.07

Assimilation of aerosols (AOD)

Comparison with independent aircraft measurements :

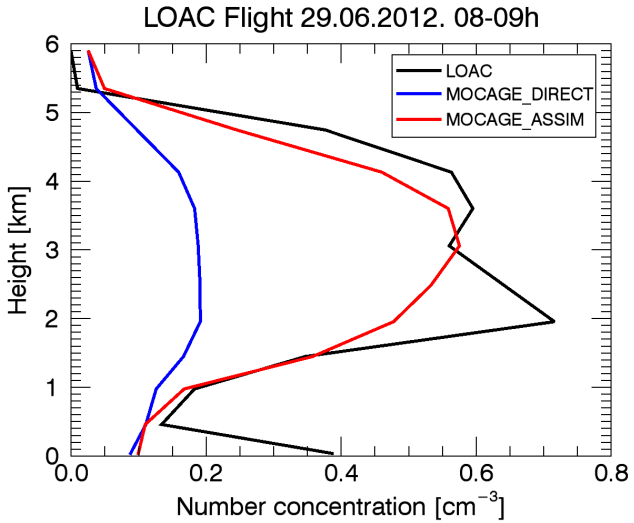


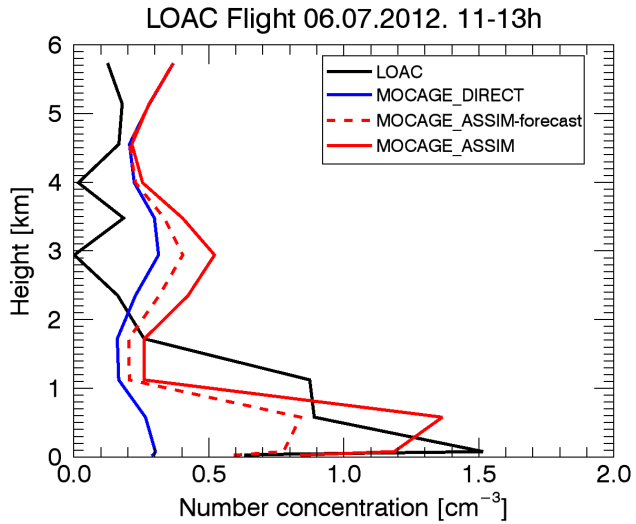
- PCASP/ATR in-situ measurements of aerosol concentration
- Elevated amount of aerosol due to an desert dust event over the Mediterranean basin
- The assimilated run simulated better the amplitude of the event

Sič et al., AMTD, 2016

Assimilation of aerosols (AOD)

Comparison with independent balloon measurements (LOAC) :





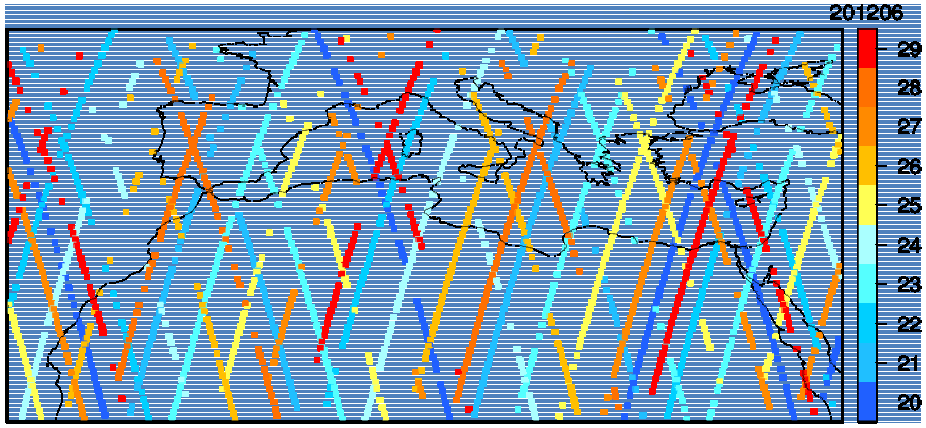
- The LOAC measurements
  - Colocated with airplane measurements
  - Profile shape conserved

- Aerosols coming from different locations, where they were already assimilated in previous cycles, can improve the vertical profile

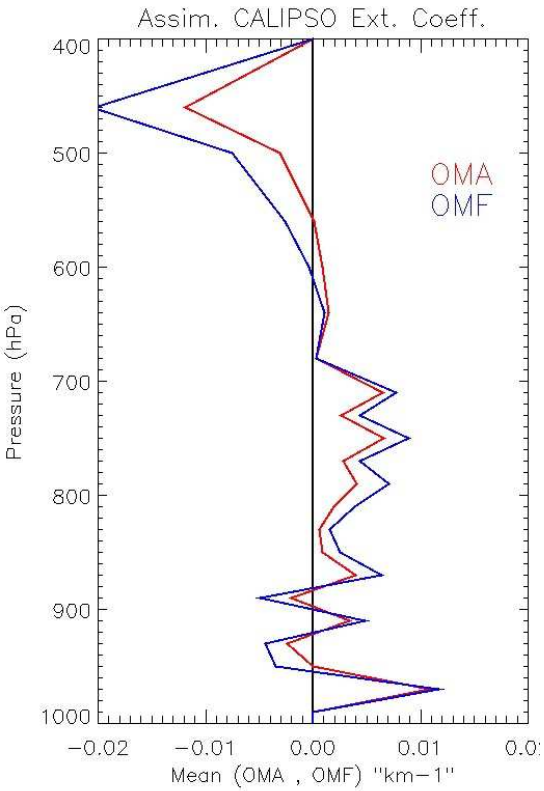
Sič et al., AMTD, 2016

Assimilation of aerosols (CALIPSO Lidar Profiles)

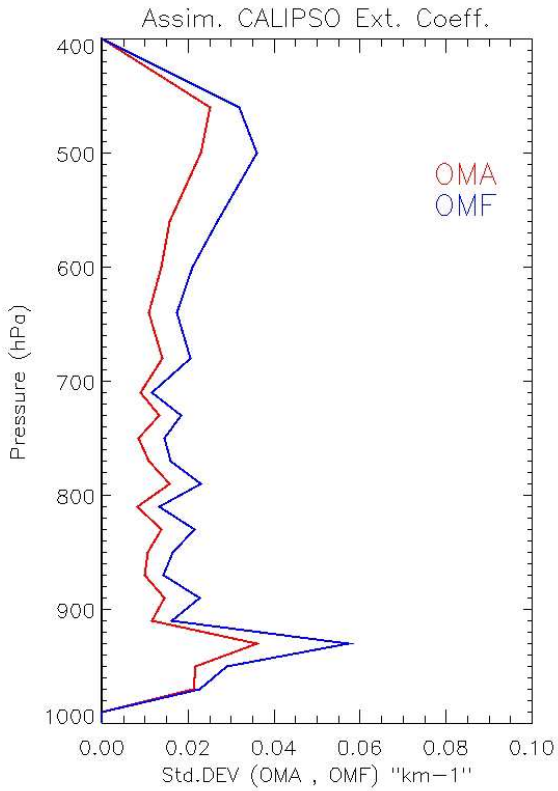
- Extinction Coefficient.
- TRAQA-2012 (20-29 June)
- Saharan Dust Outbreak over The MB

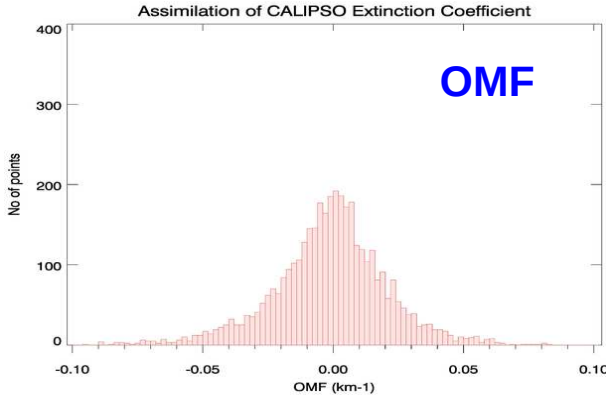


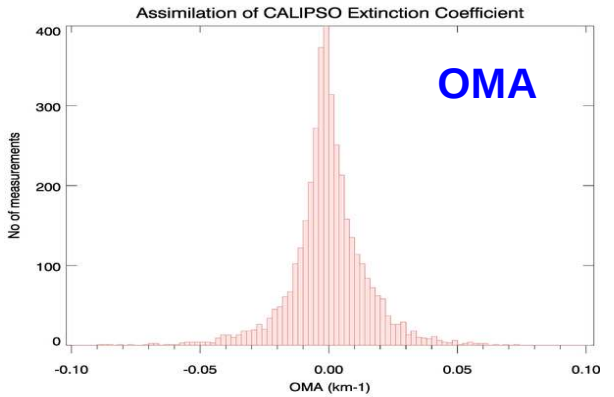
Mean



Std.Dev

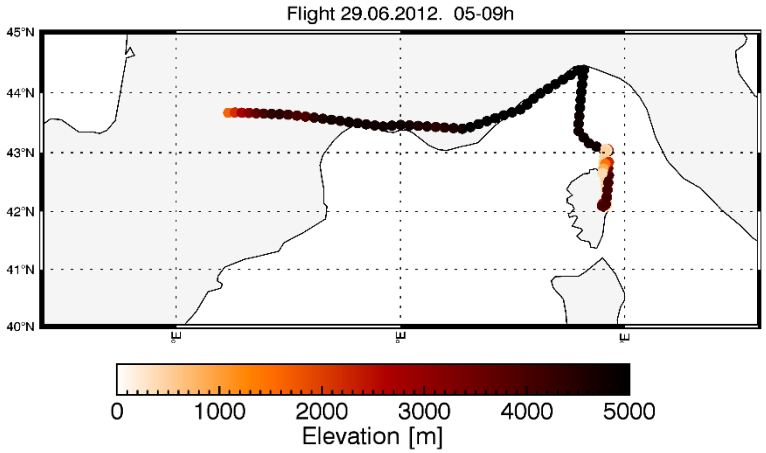


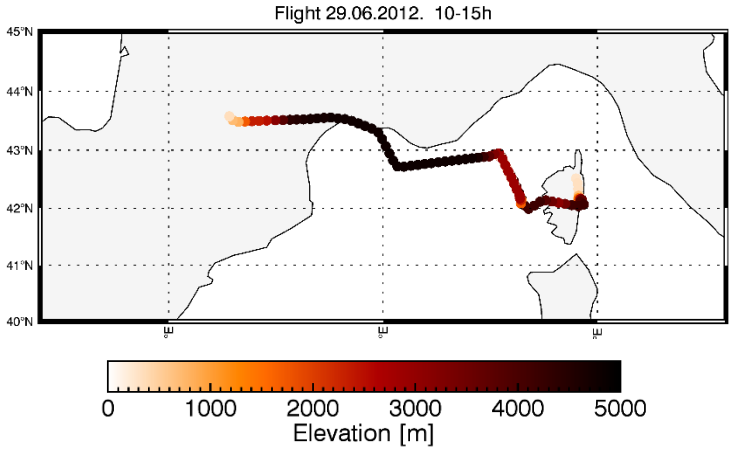


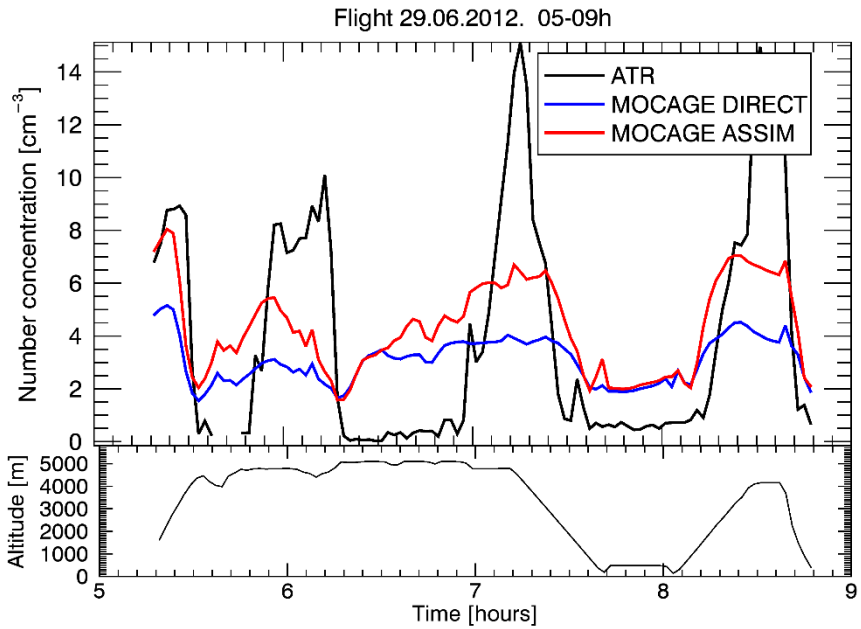


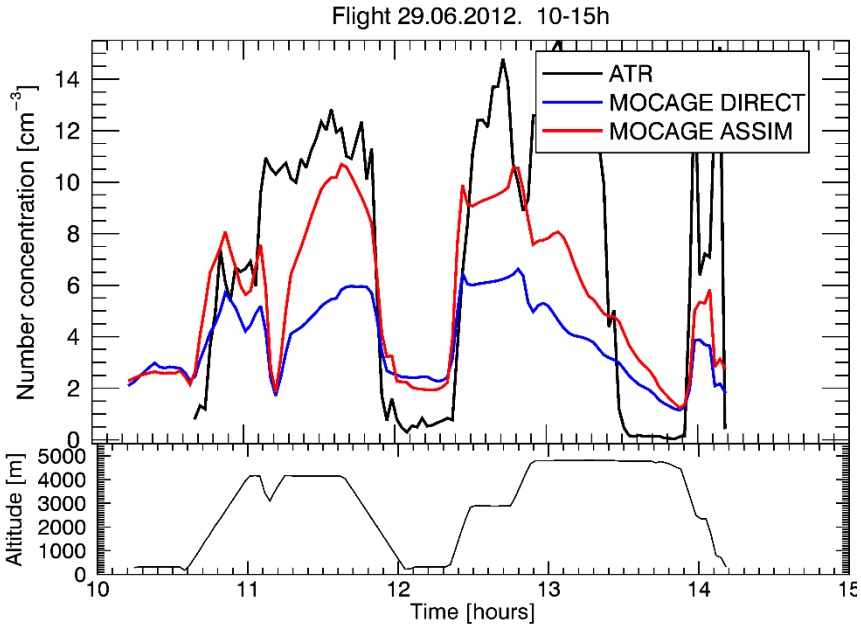
Assimilation of aerosols (CALIPSO Lidar Profiles)

- Validation of Assimilated field (29 June 2012)



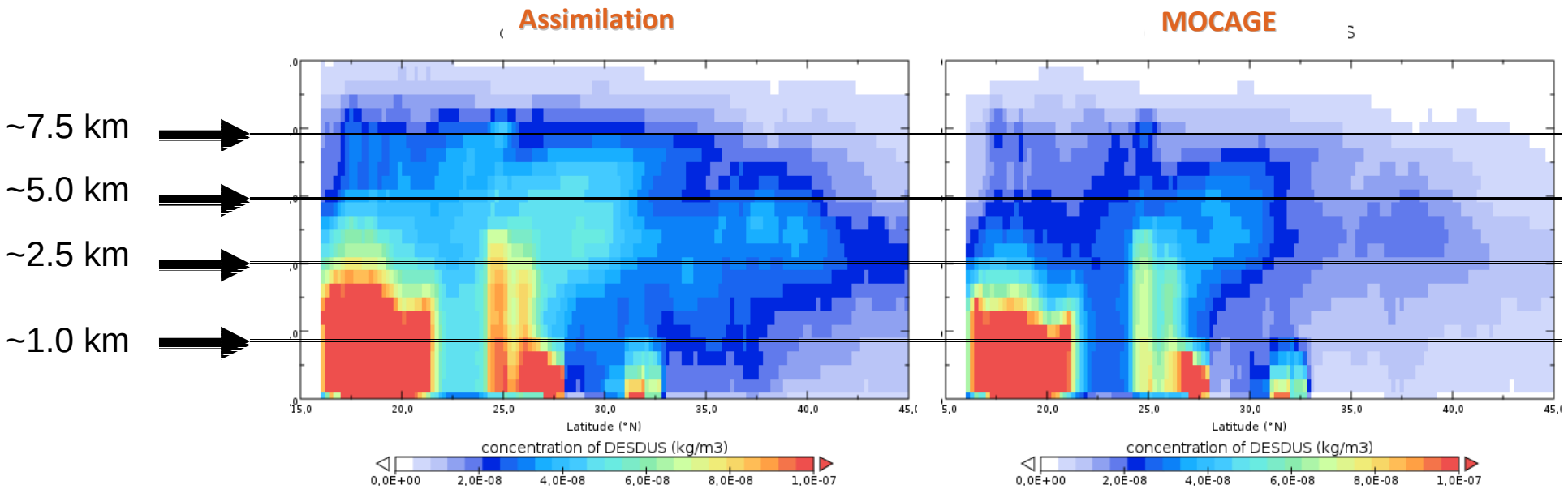






Assimilation of aerosols (CALIPSO Lidar Profiles)

- The vertical distribution of desert dust concentration (zonal mean)

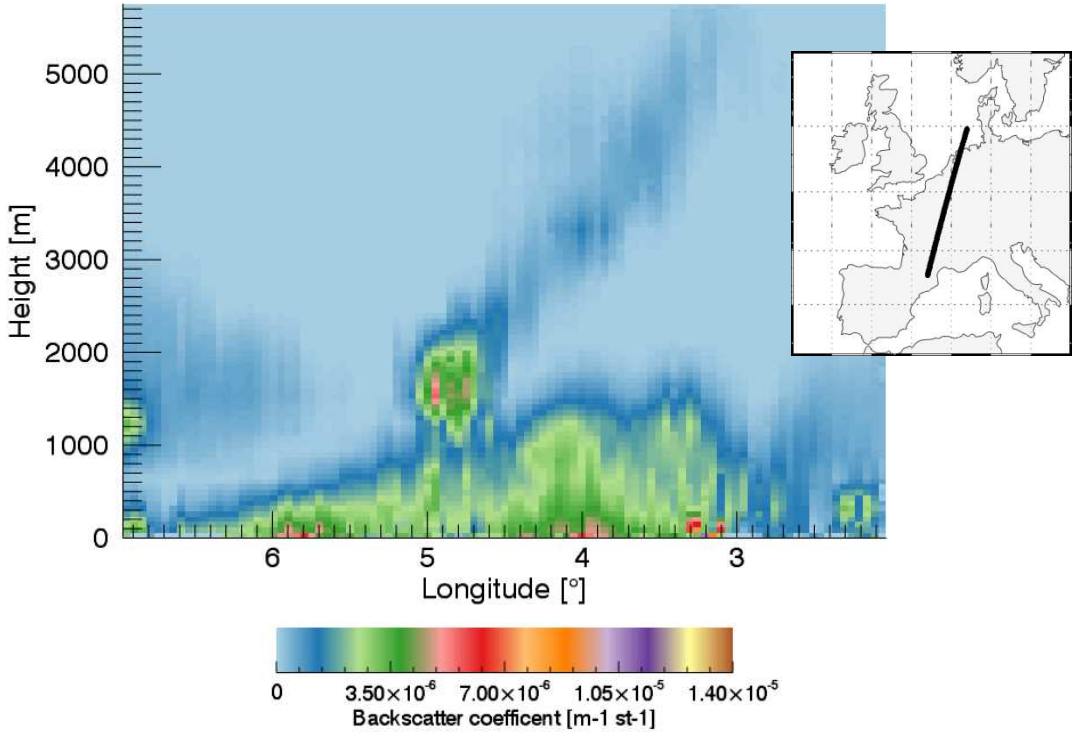


➔ CALIOP Assimilation Improves the Aerosol concentration

- In terms of quantities
- In terms of vertical distribution

Assimilation of aerosols (CALIPSO Lidar Profiles)

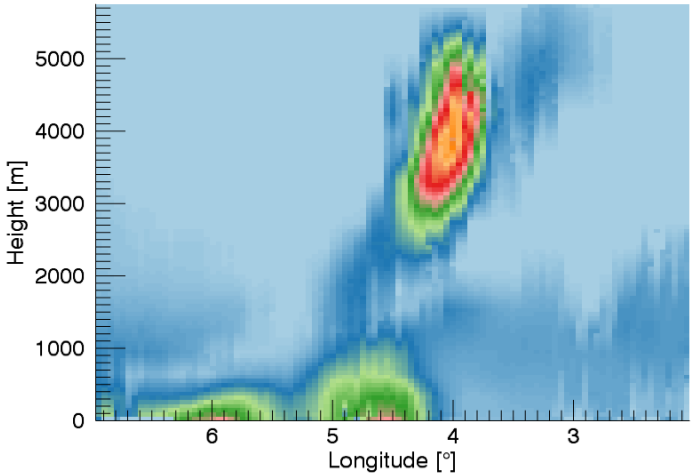
CALIOP inverted backscattering coefficient



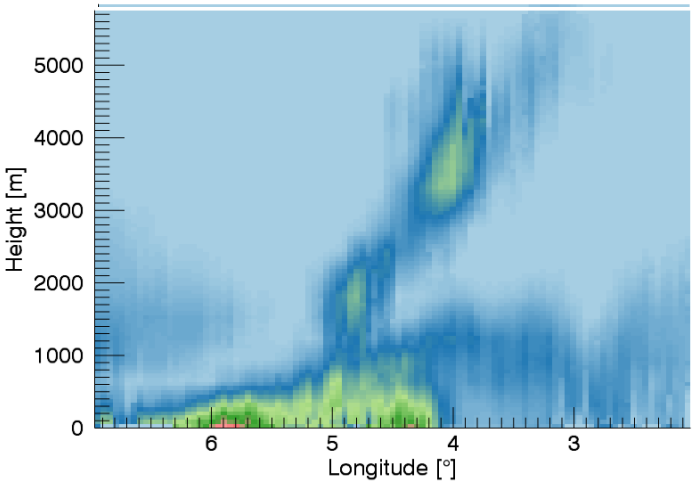
CALIOP observations

and assimilation of volcanic ash plume

Background



Analysis



Summary

❑ Applications regarding Aerosol assimilation :

– **Assimilation of AOD:**

✓ Many wavelengths (~20) are implemented in MOCAGE for AOD assimilation

✓ Many validation exercices are in going during TRAQA and ChARMEx field campaigns (article under review)

– **Assimilation of lidar profiles**

✓ The assimilation system is able to assimilate any lidar profile with all the possible configurations

✓ Great impact on the vertical aerosol structure (Extinction or aerosol concentration).

❑ In the future…

o Inclusion of data assimilation for ICAP contribution

o Taken into account the secondary aerosols

➔ Evaluation of the role of secondary aerosols to better improve the forecast of aerosols

o Assimilation of AOD and lidar products jointly

o Assimilation of many wavelengths at the same time (AOD, lidar profiles)

Thank you