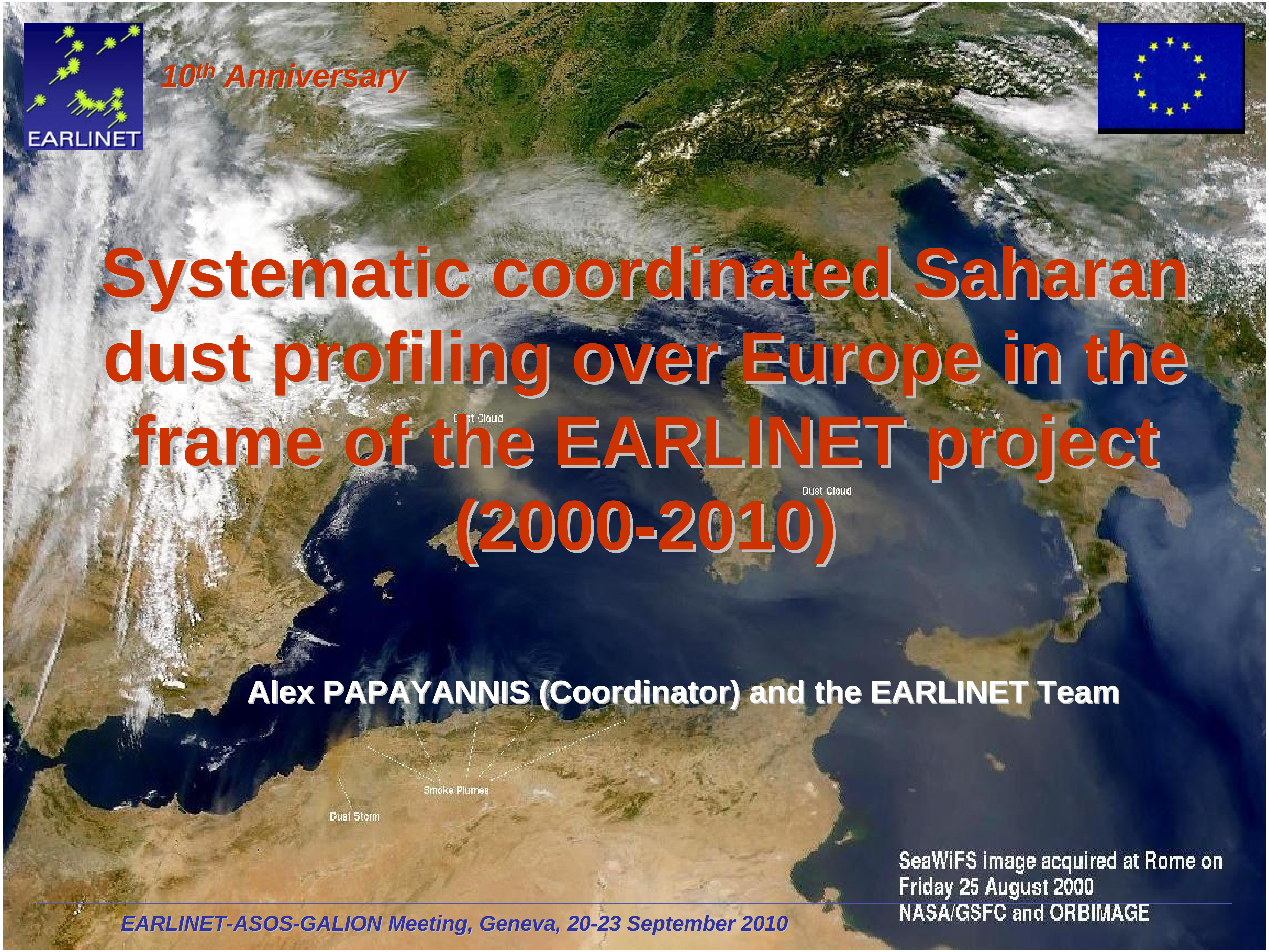
10th Anniversary

Systematic coordinated Saharan dust profiling over Europe in the frame of the EARLINET project (2000-2010)

Alex PAPAYANNIS (Coordinator) and the EARLINET Team



Outline

Role of aerosols in climate forcing

EARLINET Network Correlative measurements-
Validation tools

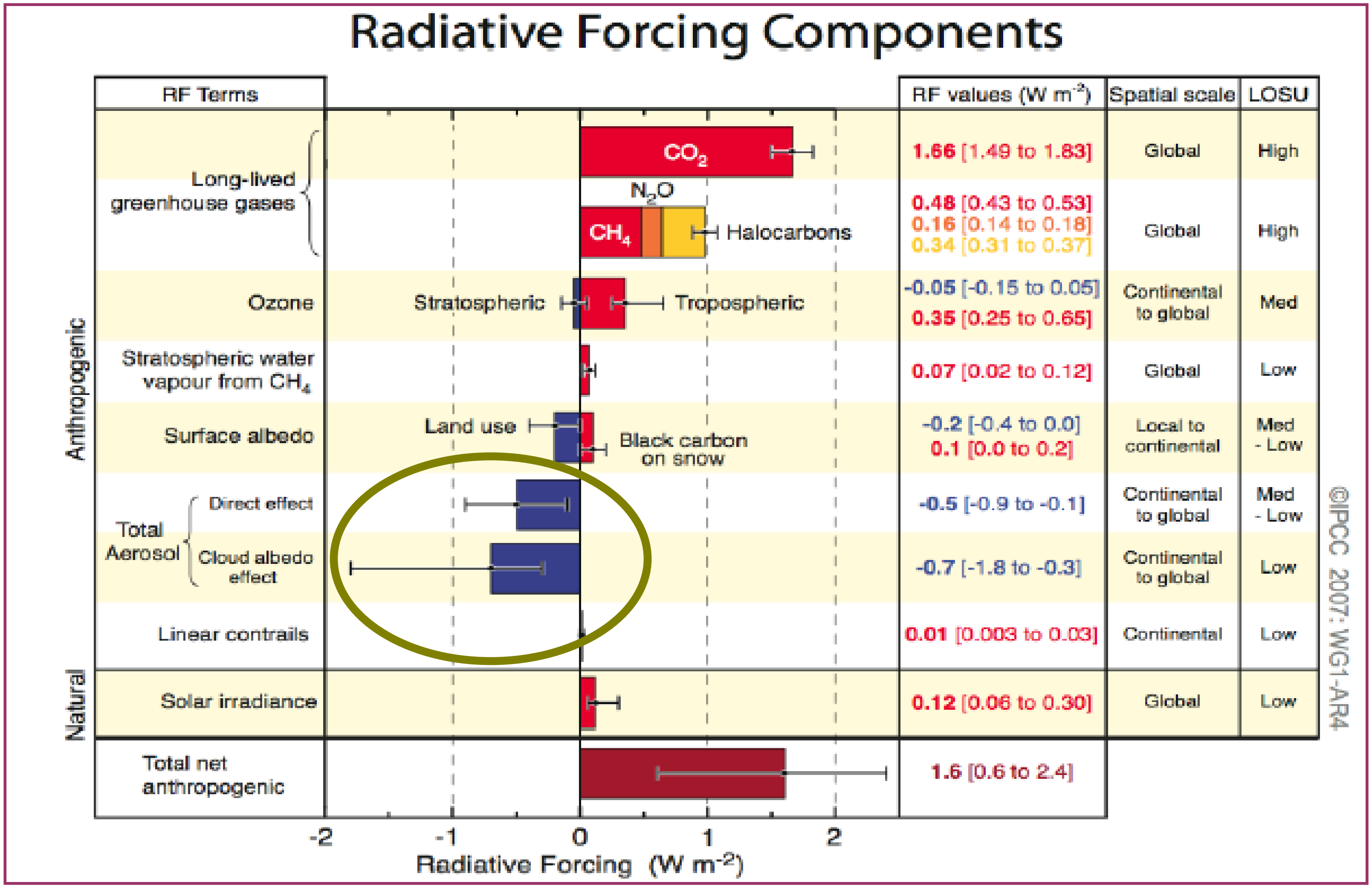
Case study analysis (May 27-30, 2008)

General results

Conclusions

❖Role of aerosols in climatic forcing

IPCC, 2007

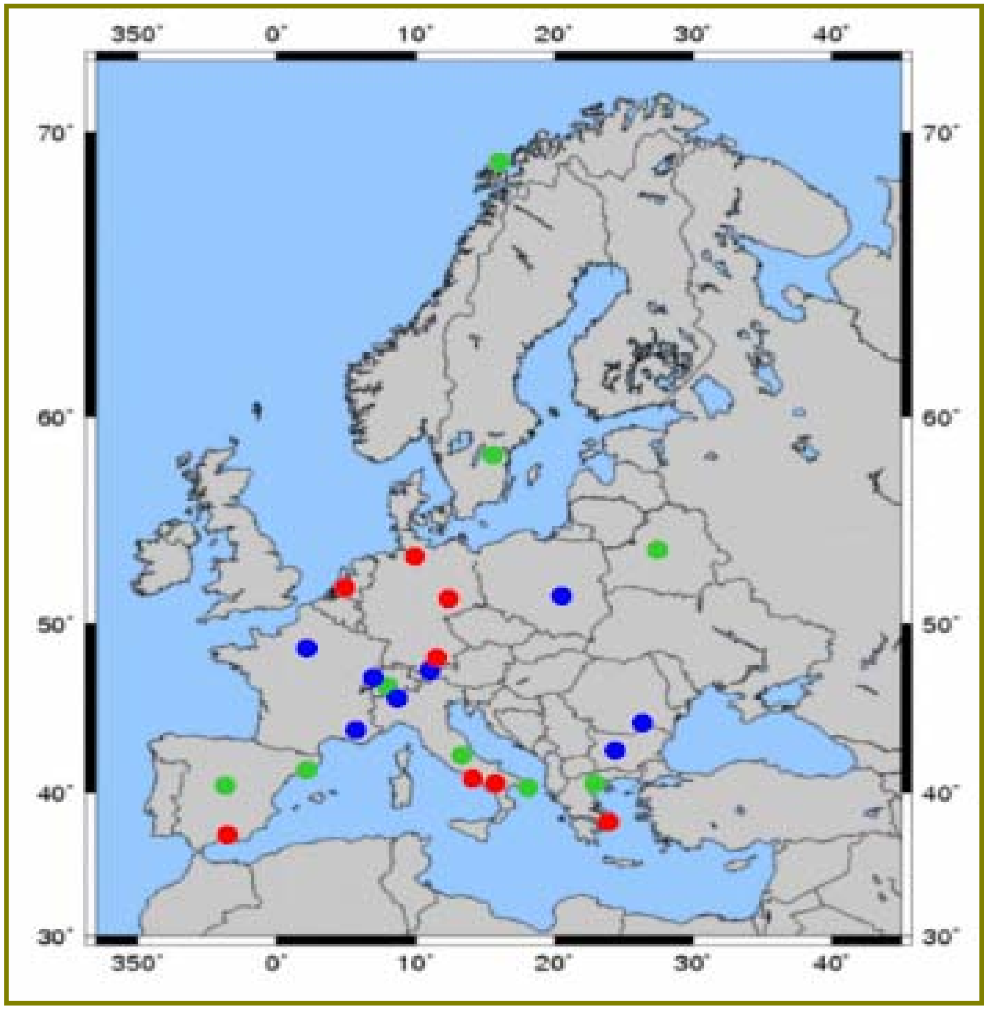


❖Why dust aerosols are important

• Dust aerosols are produced in desert areas (e.g. Sahara desert)
• Dust aerosols interact dynamically in a nonlinear way (nucleation, condensation, coagulation, deposition)
• Dust aerosols can be transported over large distances (inter-continental transport)
→ **Systematic measurements are needed to assess and improve the understanding of aerosol processes-transport-deposition and their treatment in models!**

Synergetic measurements are needed:
- In situ measurements
- Ground-based remote sensing (active/passive) measurements
- Satellite (active/passive) measurements.

The EARLINET Network

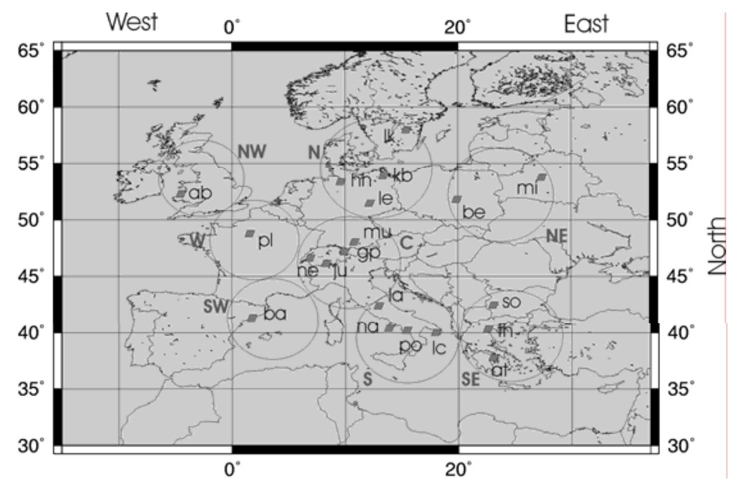


25 lidar stations

- 8 multiwavelength Raman lidar stations $3\beta + 2\alpha + \delta$ (red)

- 9 Raman lidar stations (green)

- 8 single backscatter lidar stations (blue)



Saharan dust outbreaks to Europe monitored by EARLINET

Objectives

Implementation of a routine monitoring scheme, for the observation of specifically high aerosol loads in the lower troposphere, resulting from Saharan dust outbreaks.

Methodology

Perform correlative lidar-sun photometric supported by space-borne measurements (e.g. MODIS, CALIPSO, etc).

Forecasting scheme

Use dust forecasting models (BSC-DREAM8b, SKIRON)

Coordination: National Technical Univ. of Athens **(Warnings: 24-48 h)**

Validation tools

- **Air-mass back-trajectory analysis**

  German Meteorological Service (DWD/GME Model)

  HYSPLIT Model, FLEXTRA/FLEXPART Models

- **Satellite data analysis**

  EP/TOMS & SeaWiFS data

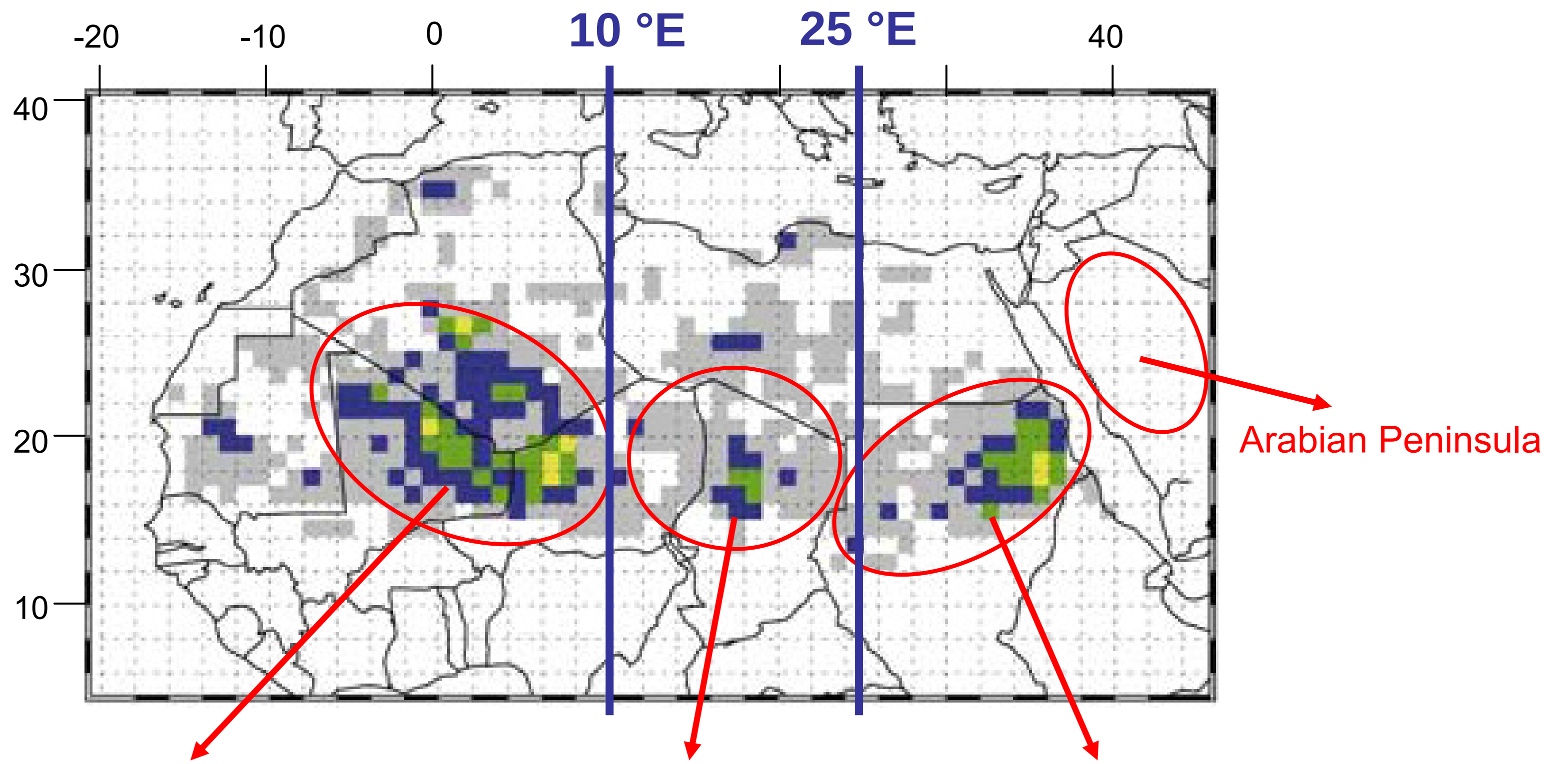
- **Sun photometer data analysis**

  Aerosol Optical Depth (AOD) data

Saharan dust events (2000-2010)

> 3666 vertical profiles (extinction and backscatter profiles)

Definition of Saharan dust source regions



Western Sahara
Foothills of Ahaggar
and other mountains
(Algeria, Mali, Niger)

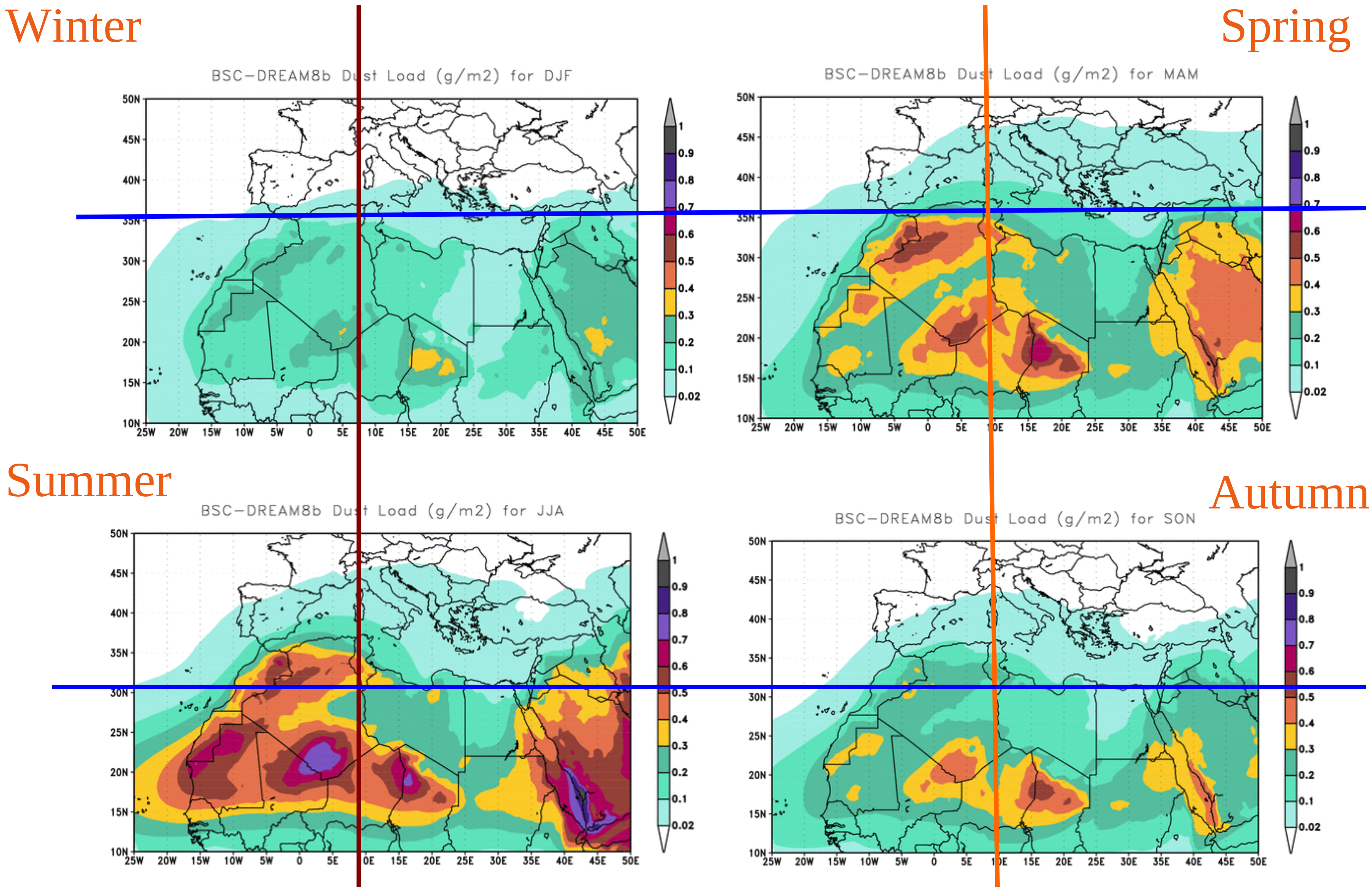
Central Sahara
Bodele Depression
(Lake Chad Basin)

Eastern Sahara
Foothills of the
Red Sea Mountains
(Sudan)

Geographical lows and foothills, dry lakes and rivers
→ mobilization of sediments of fine soil

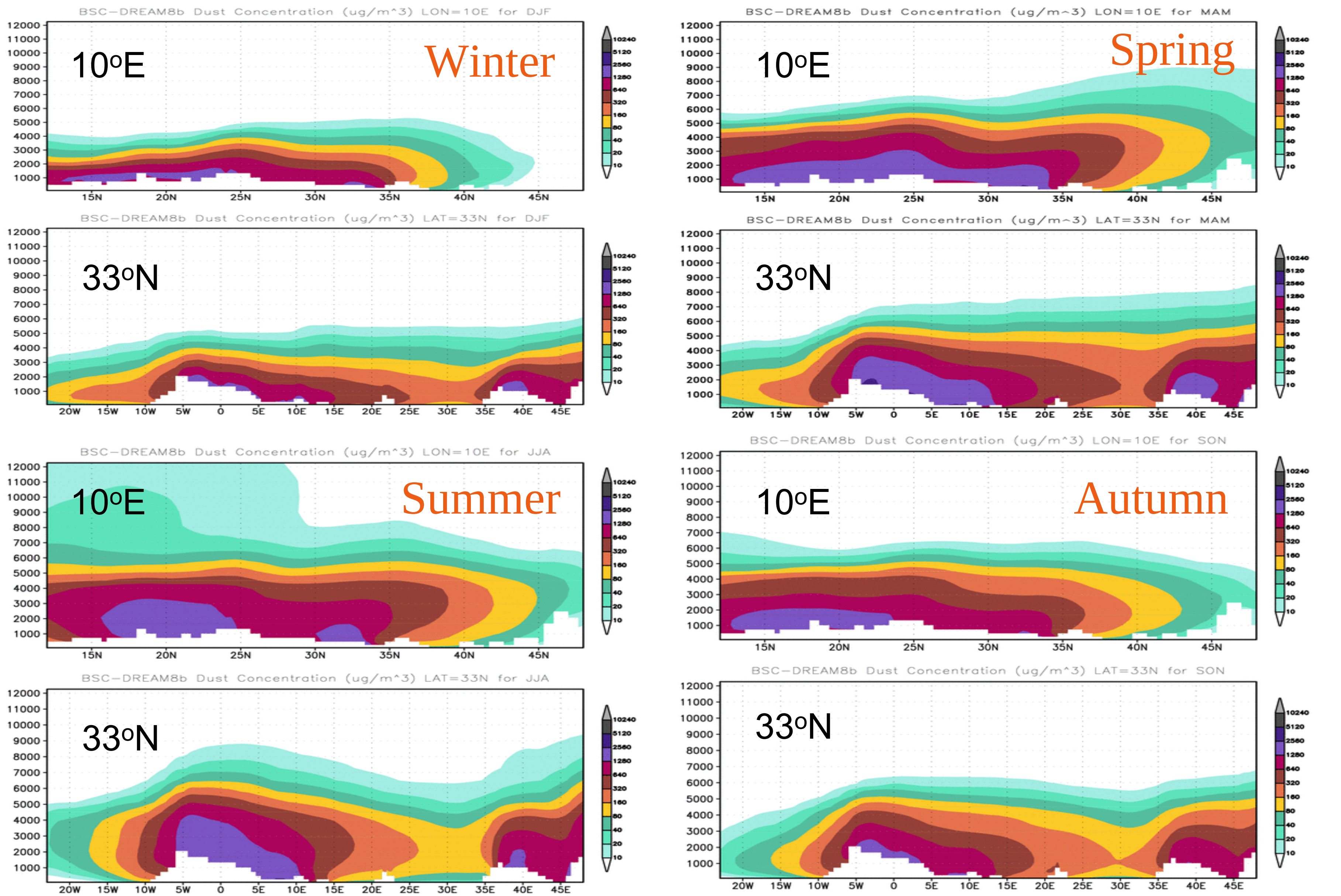
Prospero et al., 2002
Schepanski et al., 2007

BSC-DREAM8b Model (2000-2009)

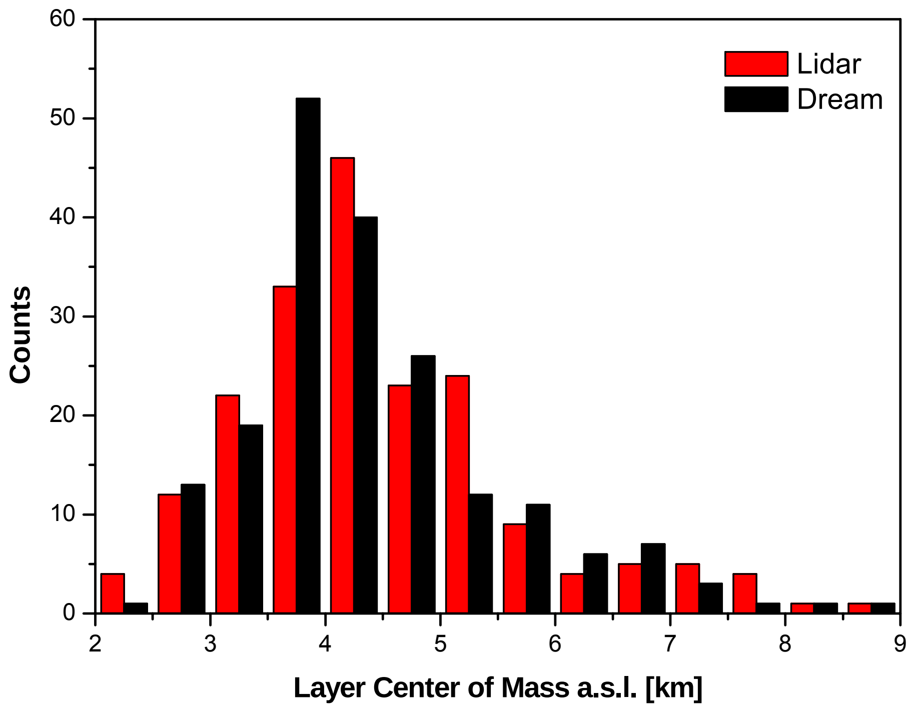


BSC-DREAM8b Model (2000-2009)

Cross section over 33°N, 10°E



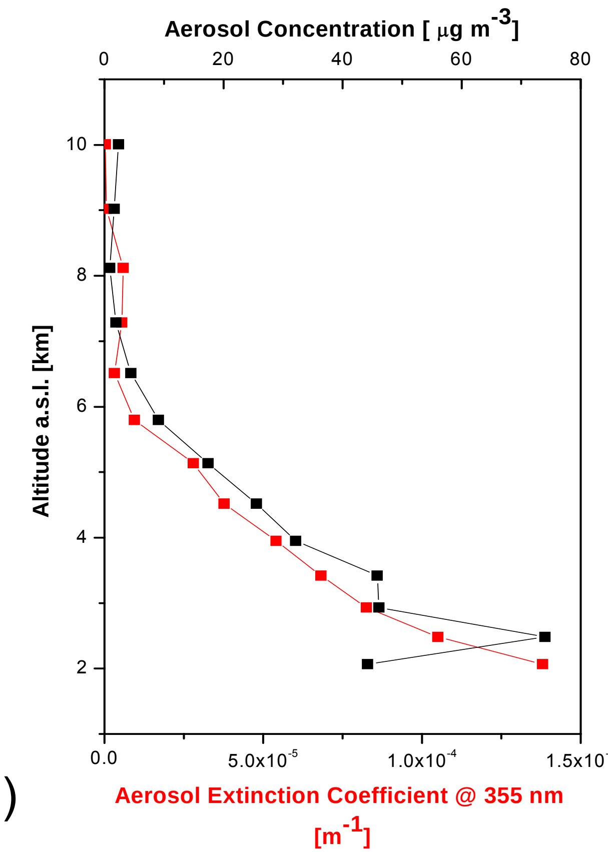
BSC-DREAM8b Model (May 2000-April 2005) – Potenza station



Center of Mass (CoM)

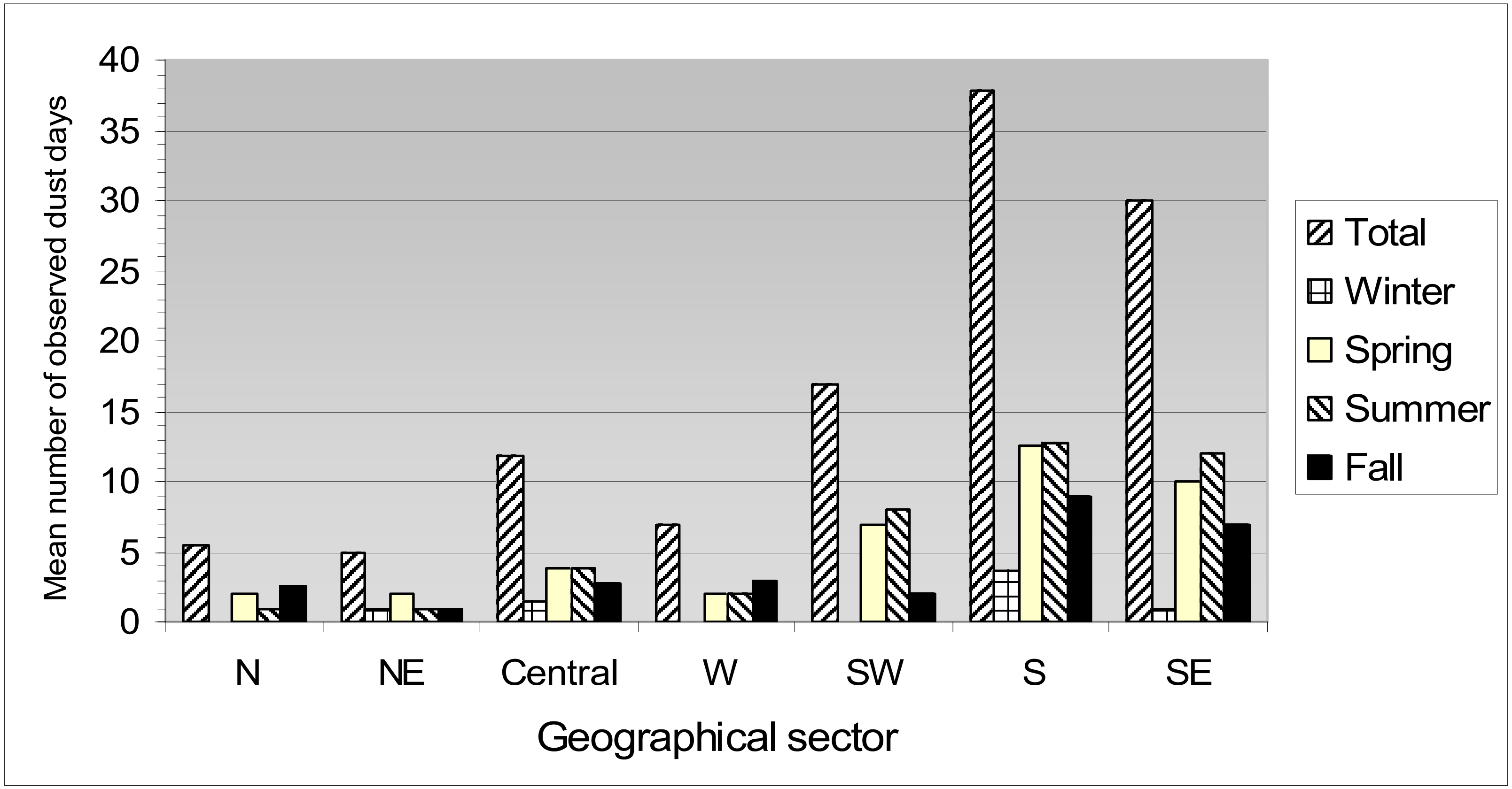
$CoM_{Lidar} = (4.5 \pm 1.2)$ km

$CoM_{Dream} = (4.4 \pm 1.1)$ km

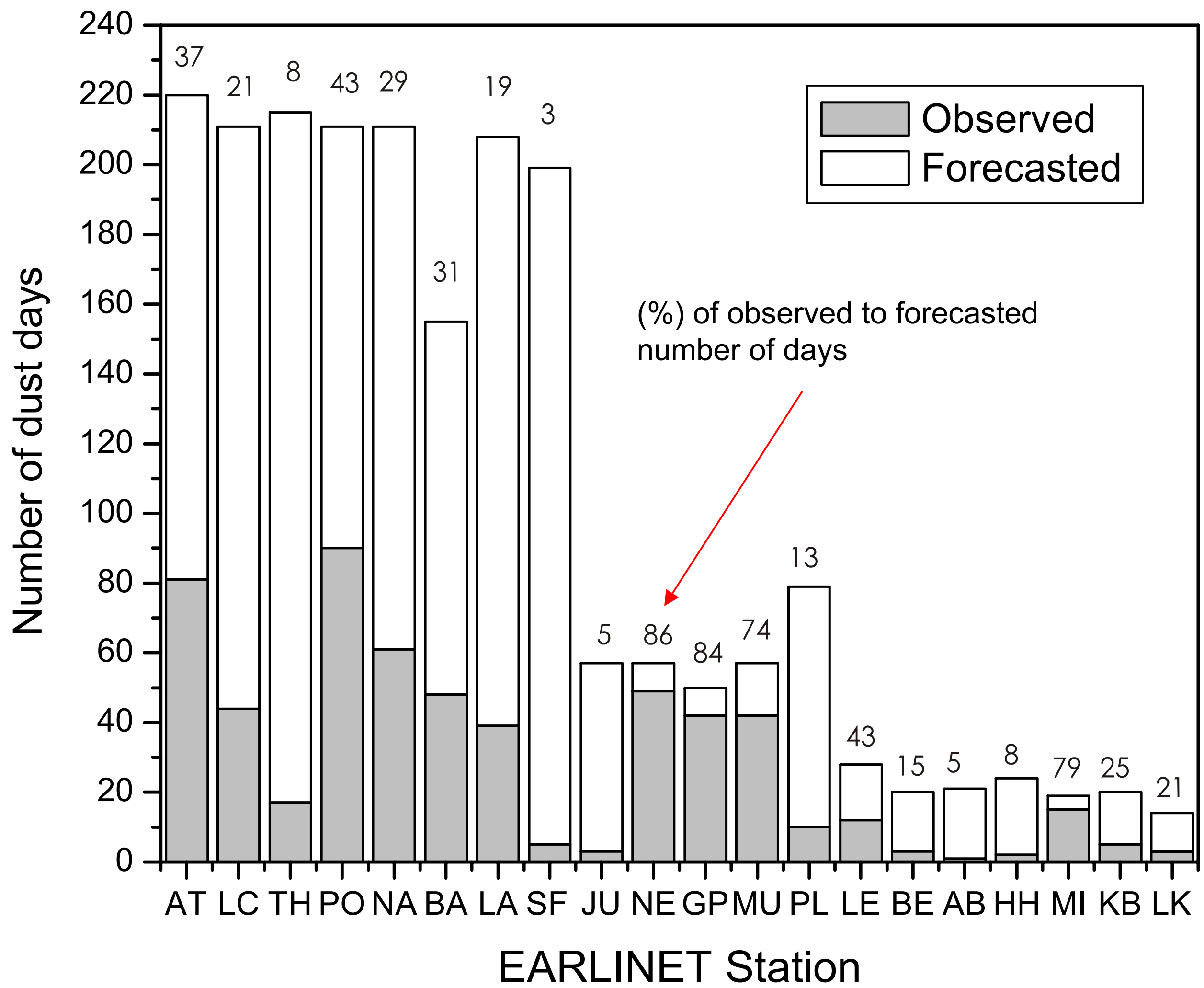


Aerosol concentration-Aerosol extinction (355 nm)

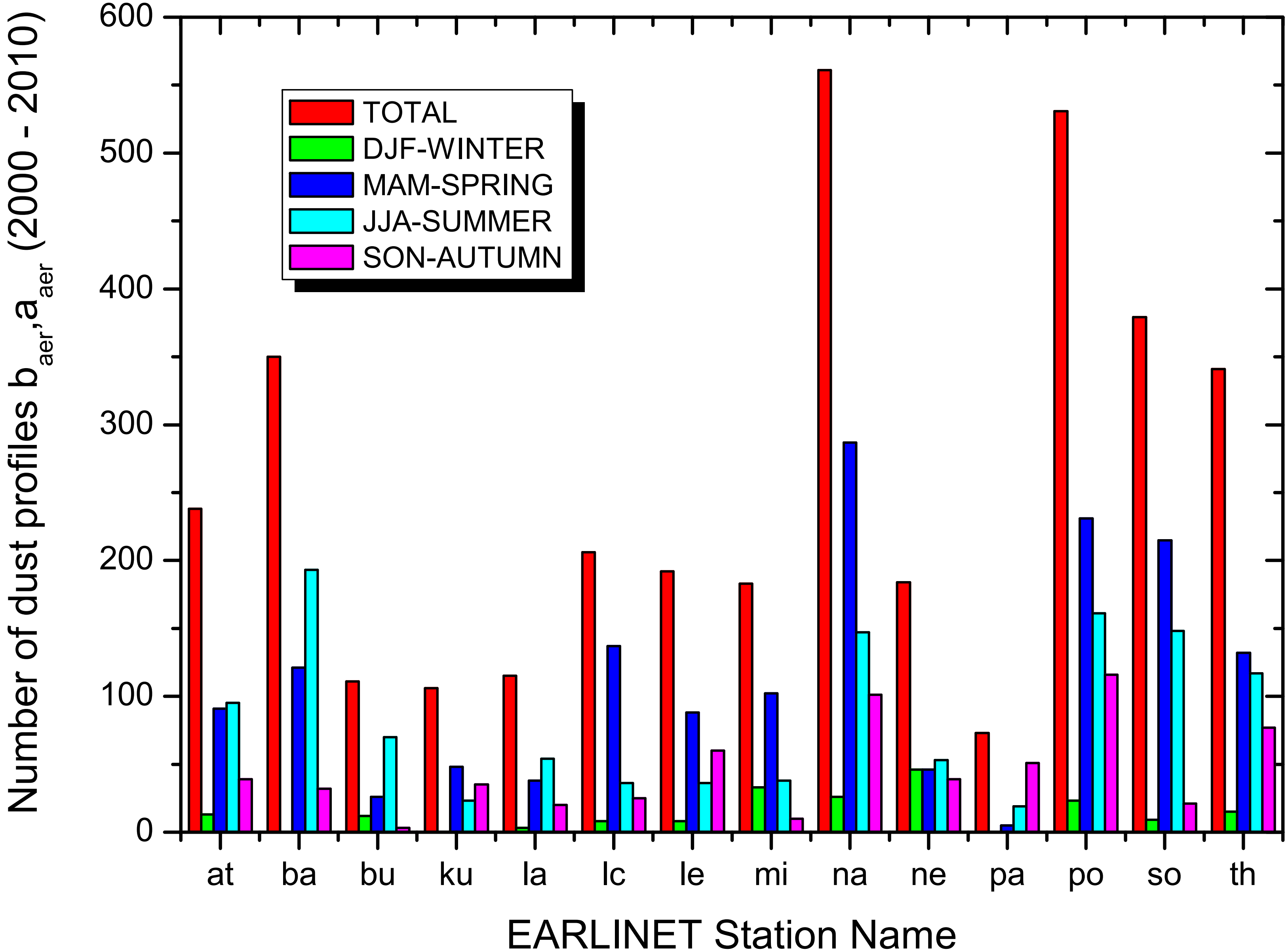
Seasonal variability of observed mean number of Saharan dust days (2000-2002)



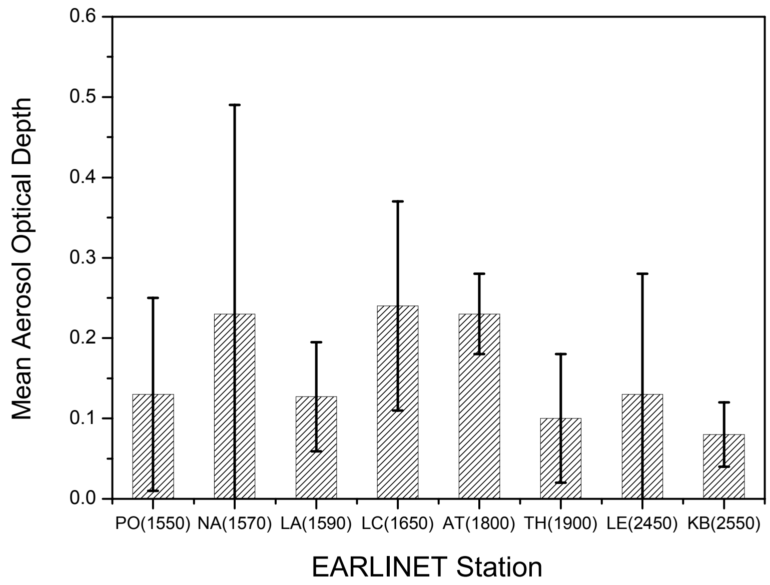
Papayannis et al., *J. Geophys. Res.*, 113, D10204, doi:10.1029/2007JD009028, 2008

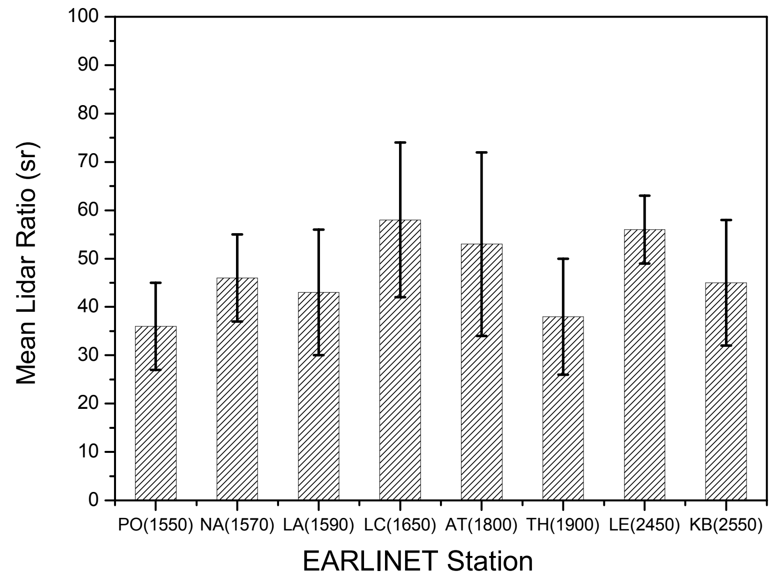


Papayannis et al., *J. Geophys. Res.*, 113, D10204, doi:10.1029/2007JD009028, 2008



TOTAL
DJF-WINTER
MAM-SPRING
JJA-SUMMER
SON-AUTUMN
Number of dust profiles b_{aer},a_{aer} (2000 - 2010)
0
100
200
300
400
500
600
at
ba
bu
ku
la
lc
le
mi
na
ne
pa
po
so
th
EARLINET Station Name

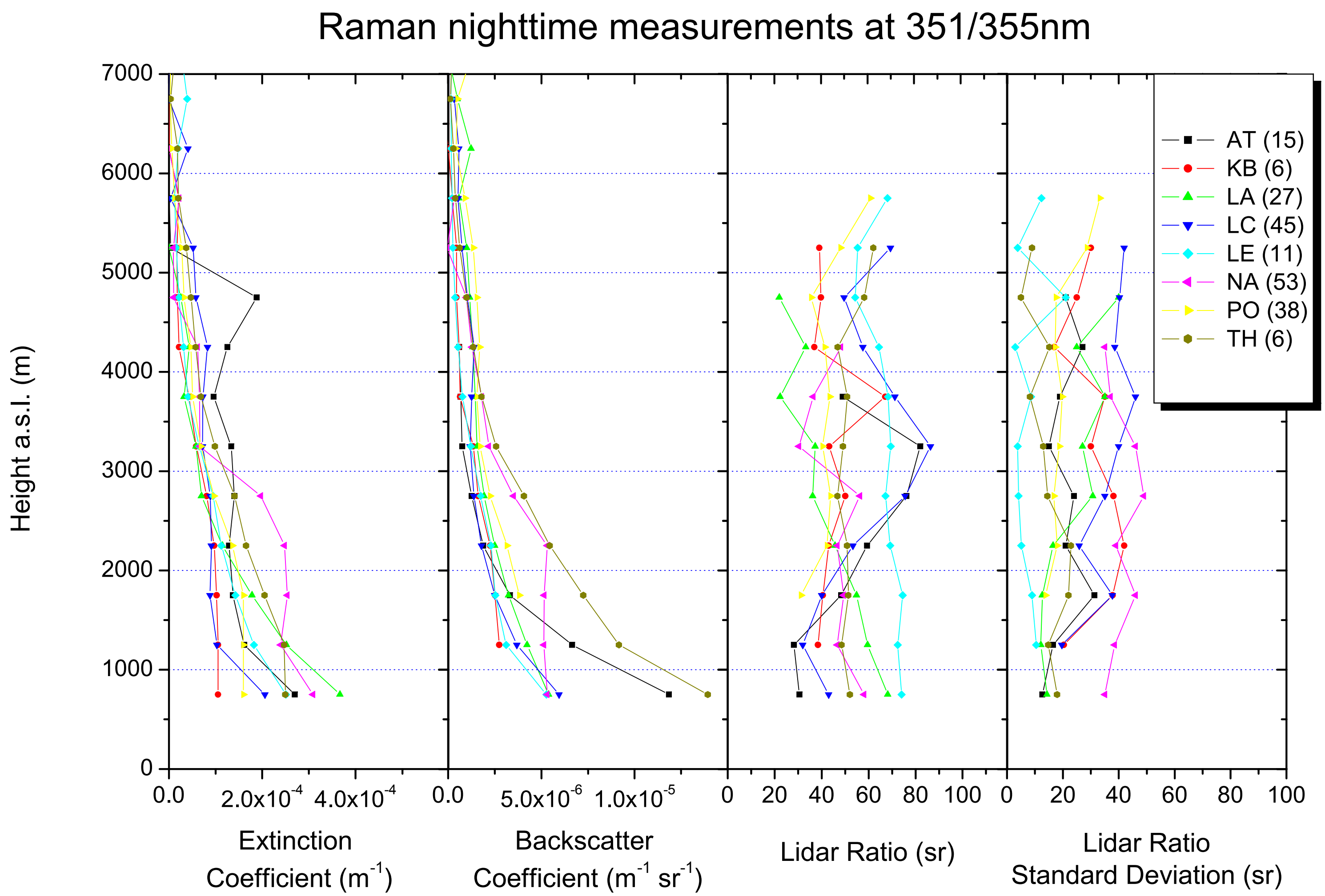




Mean AOD and LR inside the dust layer (351/355 nm)

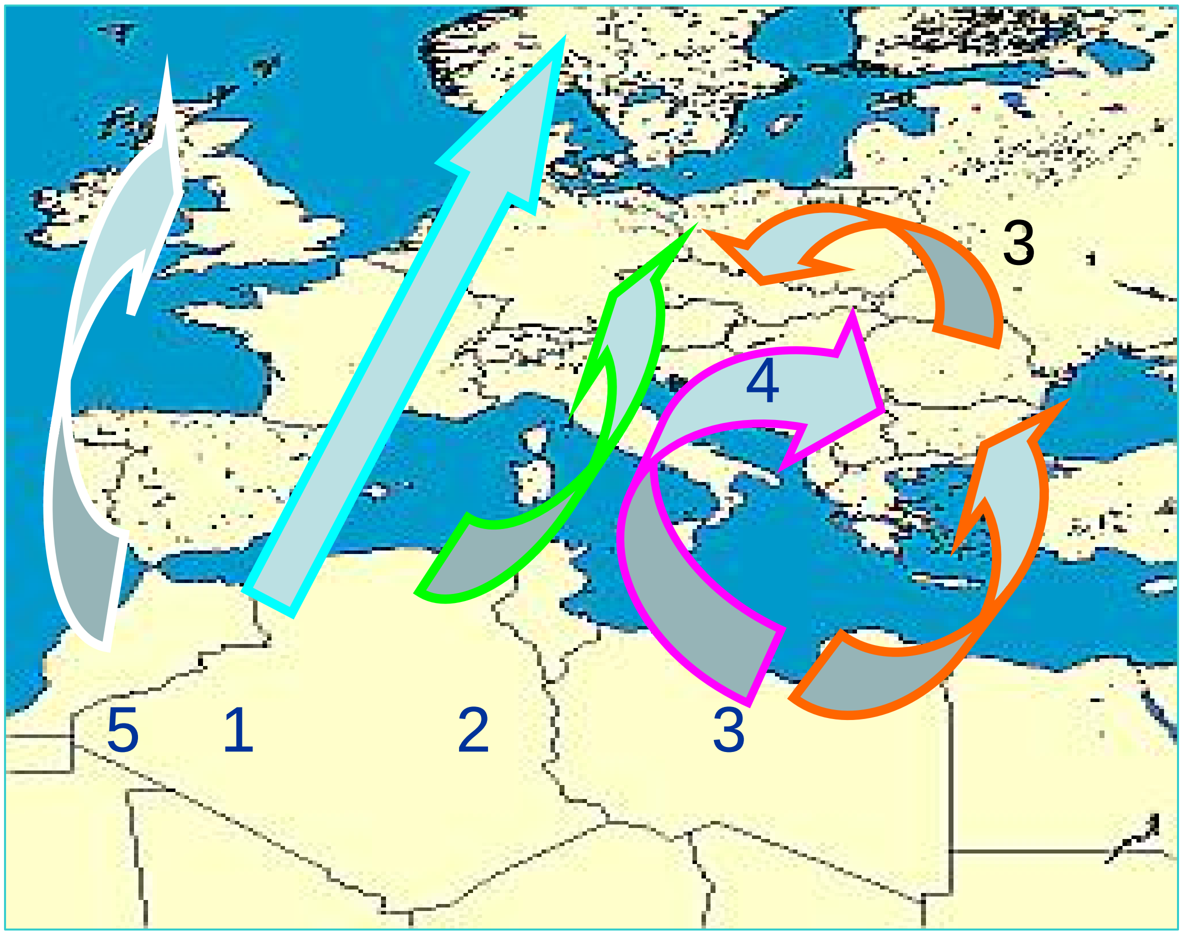
as a function of distance from the Saharan region (2000-2002)

Papayannis et al., *J. Geophys. Res*., 113, D10204, doi:10.1029/2007JD009028, 2008



Papayannis et al., *J. Geophys. Res.*, 113, D10204, doi:10.1029/2007JD009028, 2008

Possible Pathways of Saharan Dust Transport over Europe



1: ~20 %

2: ~ 35 %

3: ~ 30 %

4: ~ 5 %

5: ~ 10 %

EARLINET Correlative Measurements

CASE STUDY ANALYSIS: May 27 - 30, 2008

Saharan dust transport over Europe

Synergy of various sensors + Validation tools:

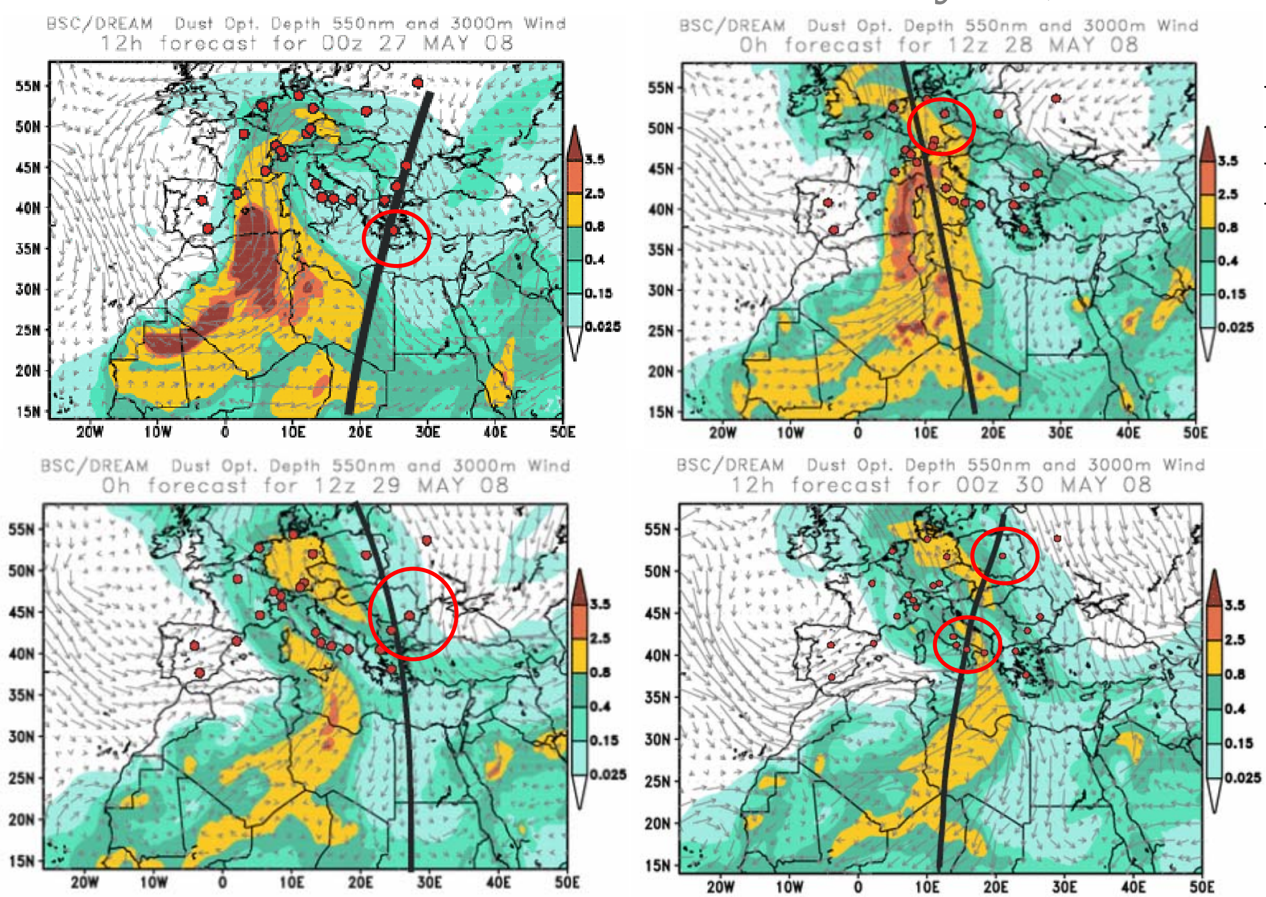
Active/Passive sensors: Lidar - CALIOP - SeaWiFS, CIMEL
Dust Forecast Modeling: BSC-DREAM8b
Air Mass Trajectory Computation: HYSPLIT 4.6 code – FLEXTRA/FLEXPART

BSC-DREAM8b Model: Aerosol Optical Depth (AOD) @ 550 nm (Winds @ 3000 m)

May 27, 2008 | May 28, 2008

Athens

Munich, Leipzig



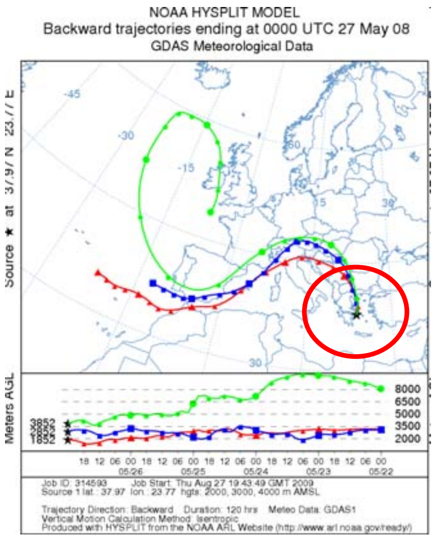
Sofia

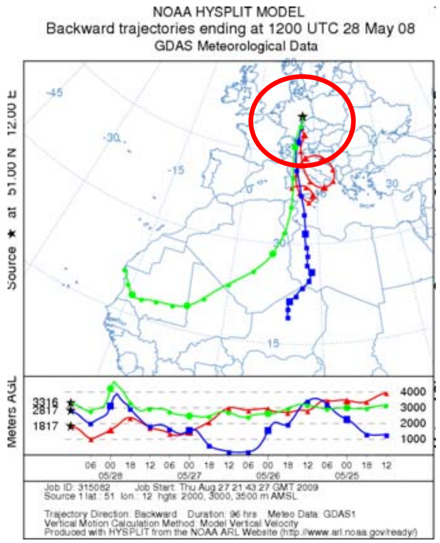
Potenza, Belsk

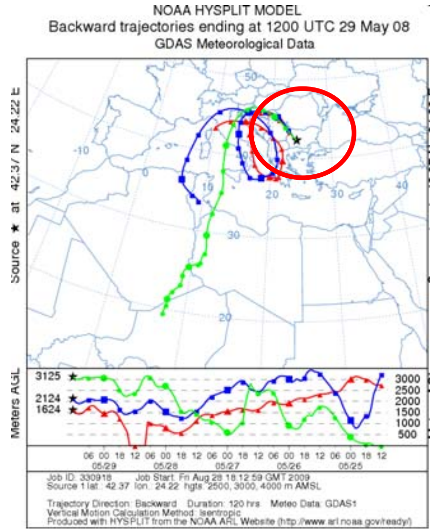
May 29, 2008 | May 30, 2008

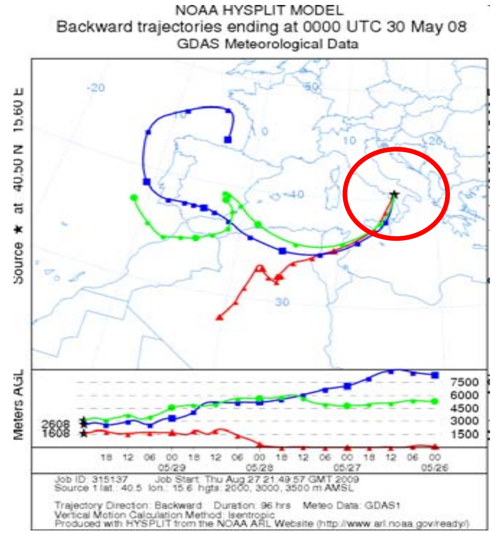
Hysplit 4.6 Air Mass Trajectory Model

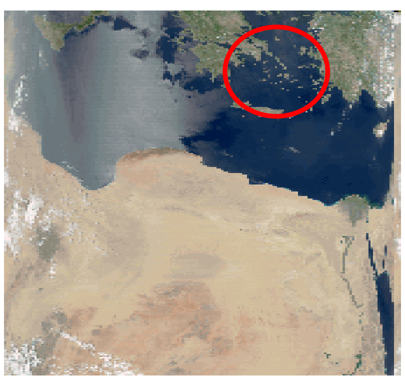
Athens	Leipzig	Sofia	Potenza
May 27, 2008	May 28, 2008	May 29, 2008	May 30, 2008

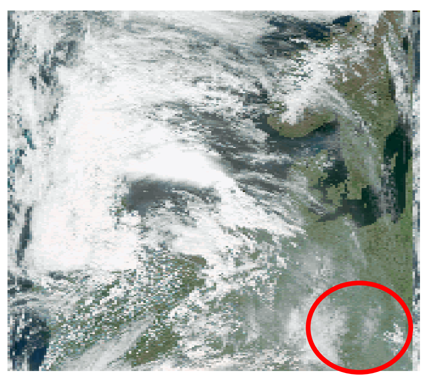


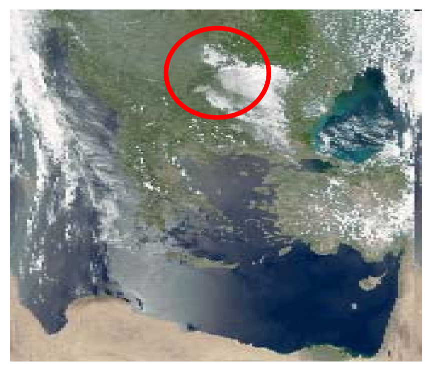


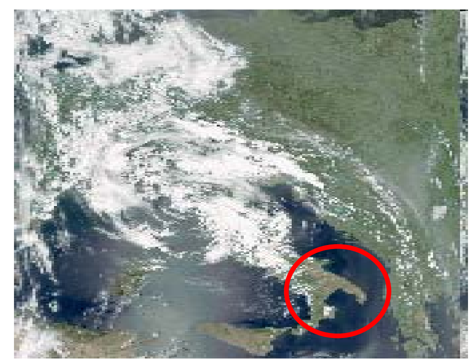






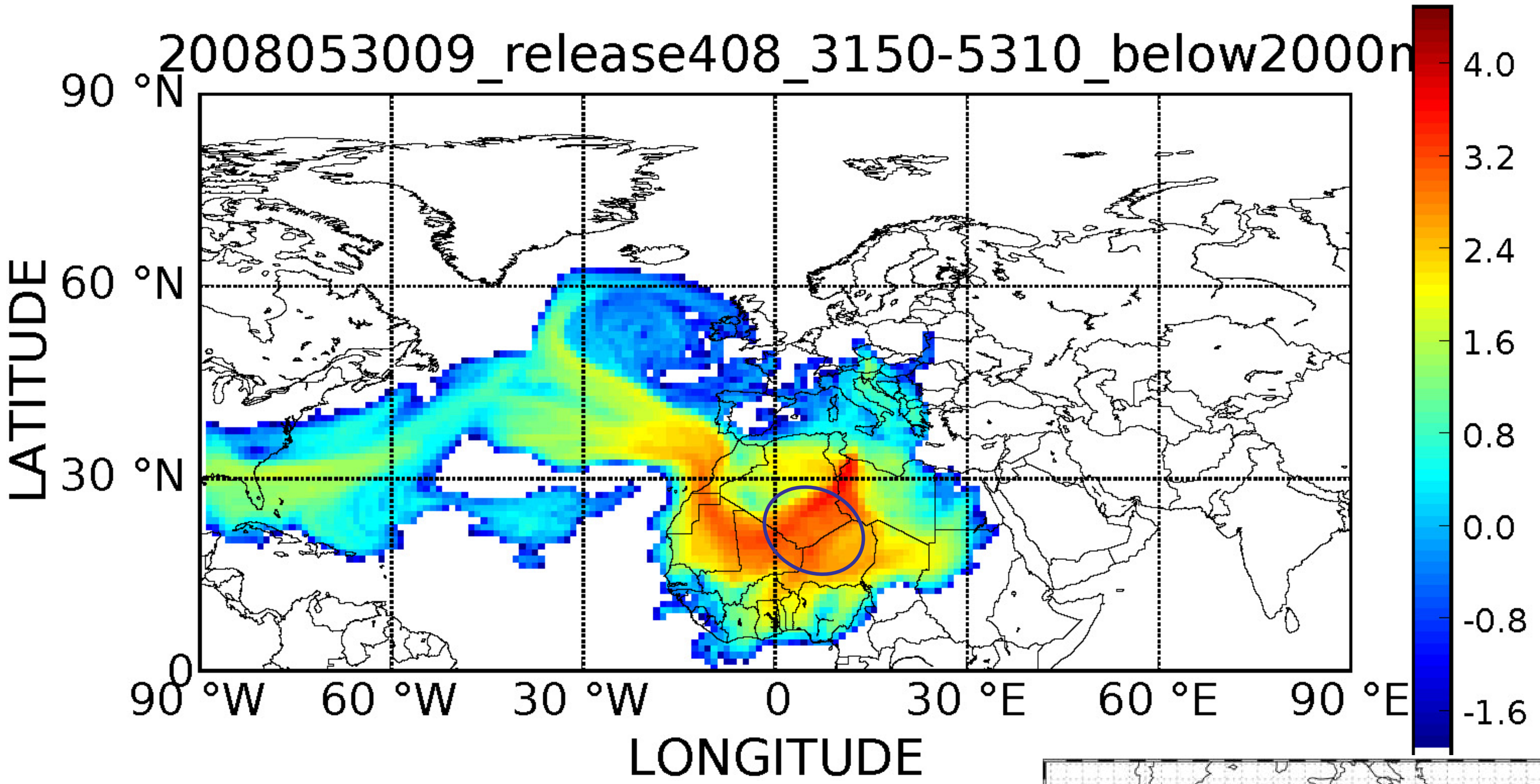


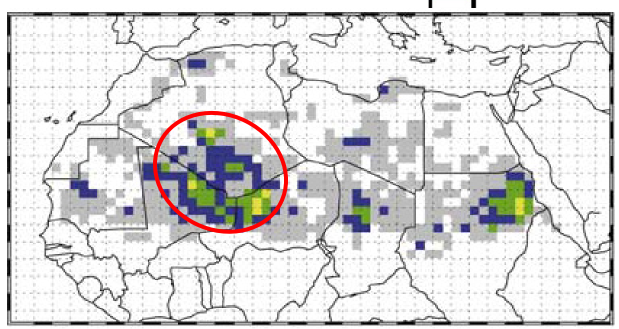


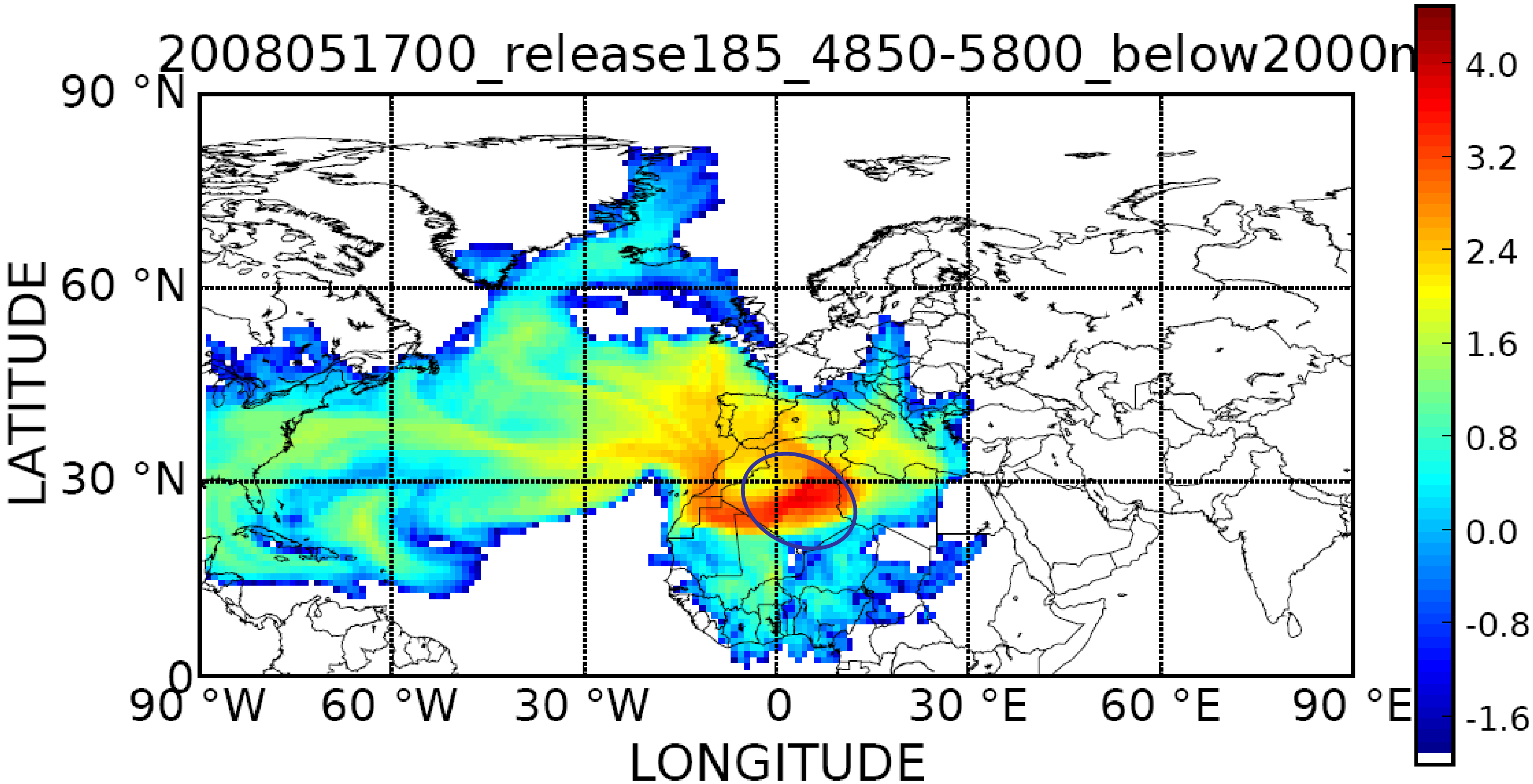


SeaWiFS data

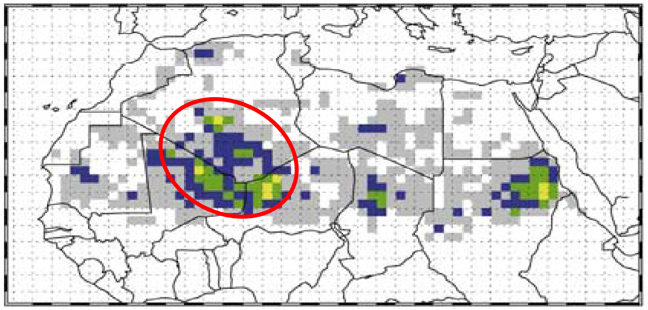
FLEXPART footprint (2000 m) Leipzig, 30 May 2008

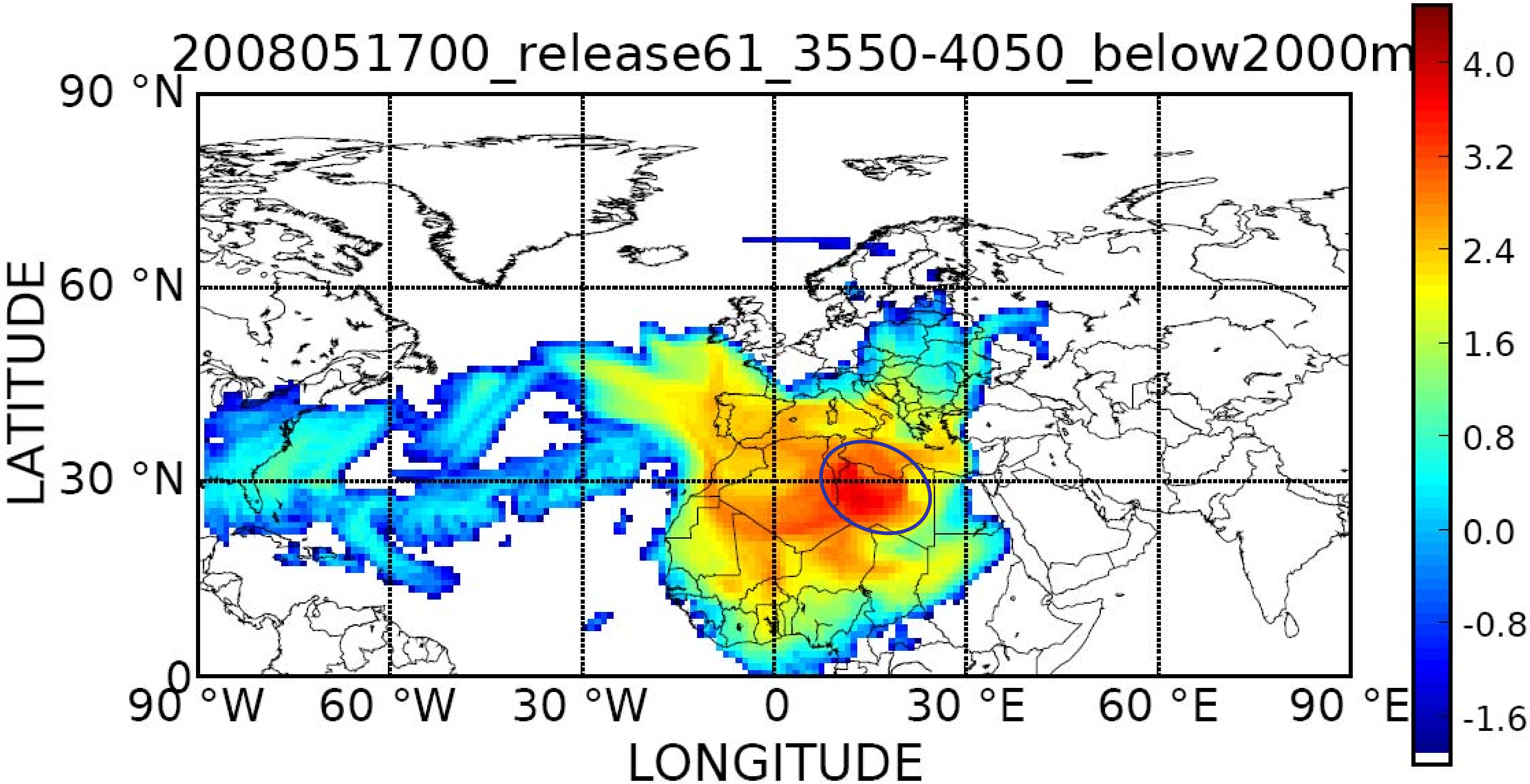


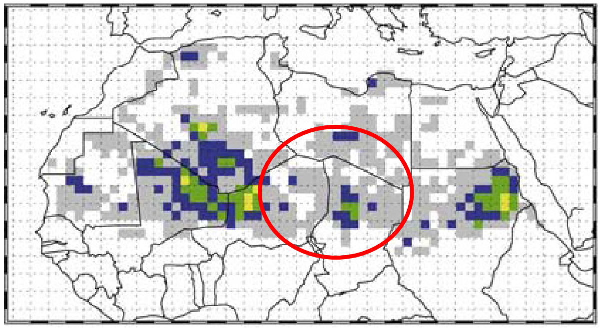




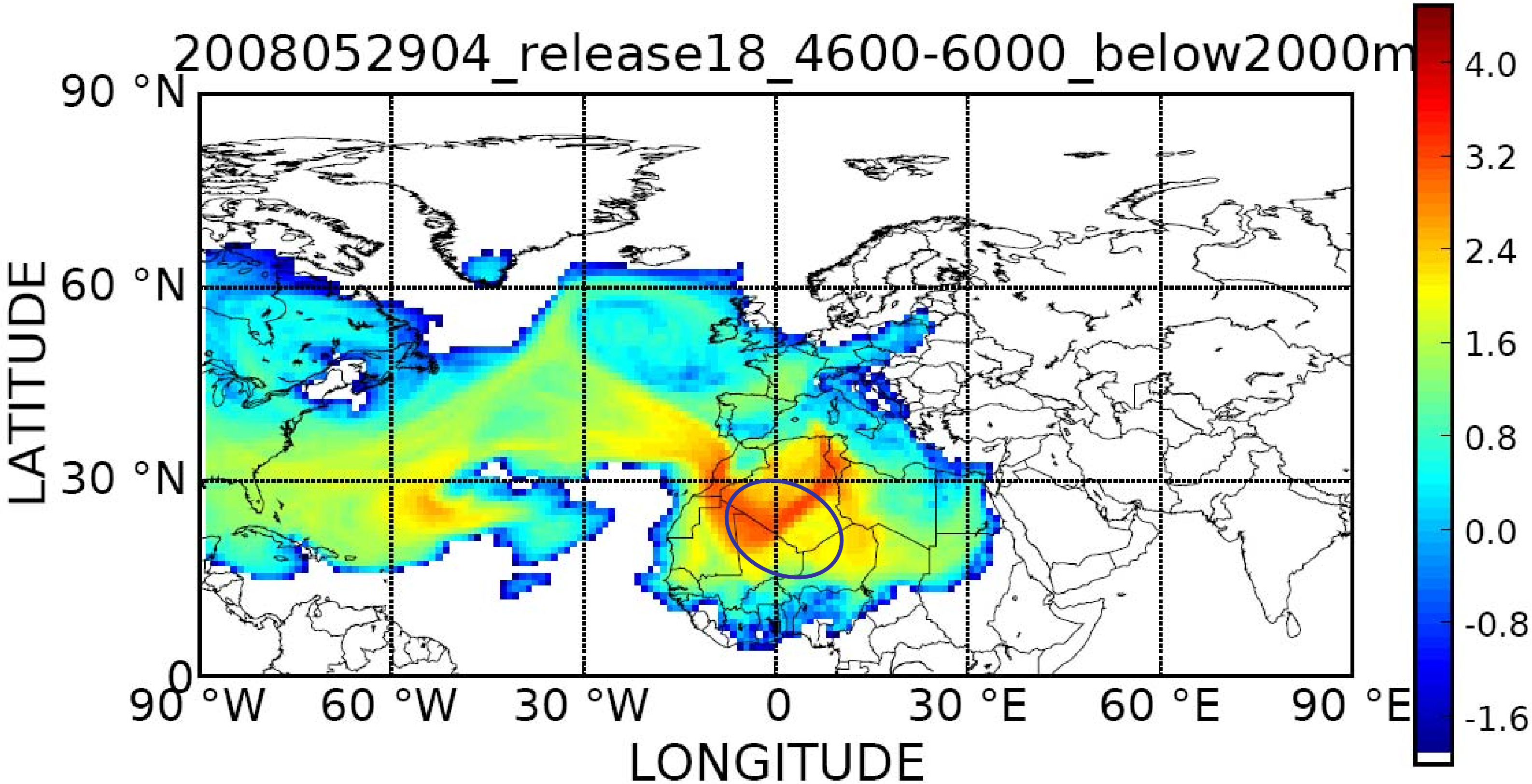
FLEXPART footprint (2000 m) Potenza, 17 May 2008

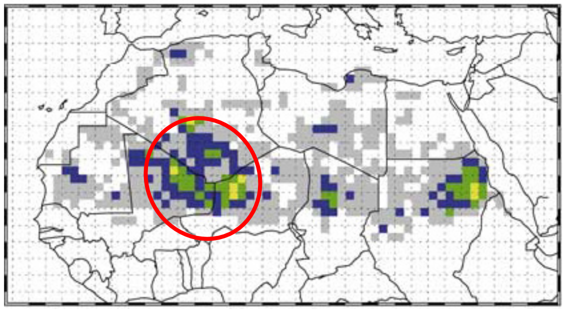






FLEXPART footprint (2000 m) Potenza, 17 May 2008

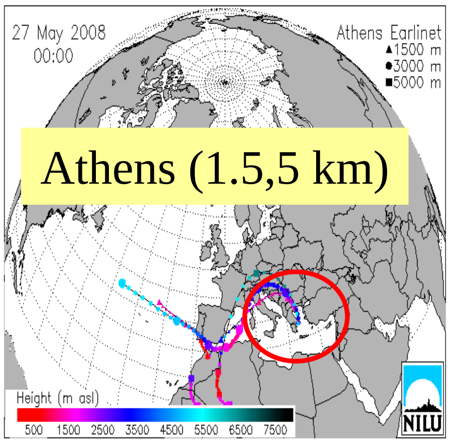




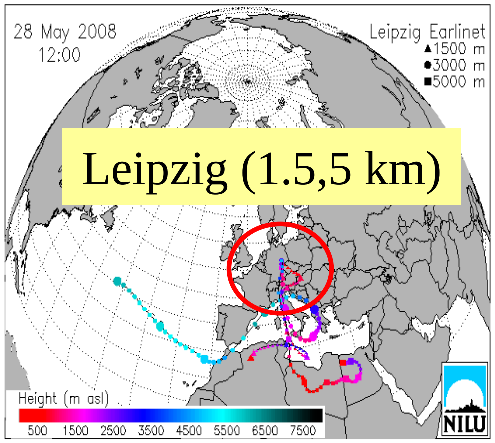
FLEXPART footprint (2000 m) Belsk, 30 May 2008

FLEXTRA Air Mass Trajectory Model

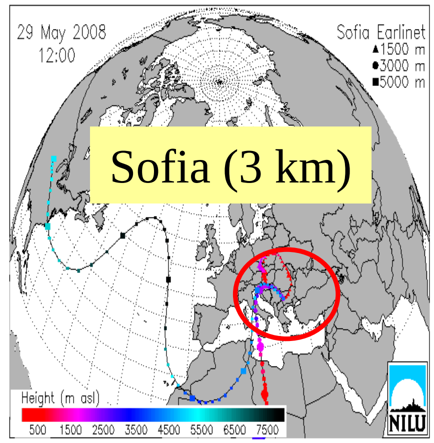
May 27, 2008



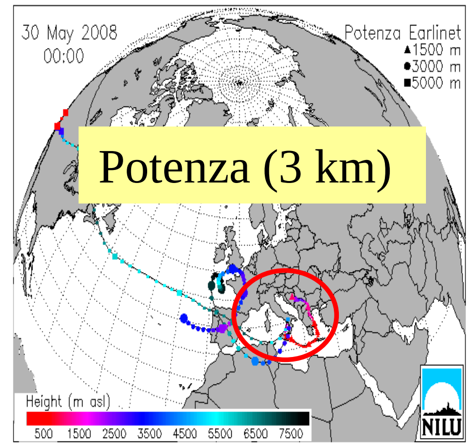
May 28, 2008

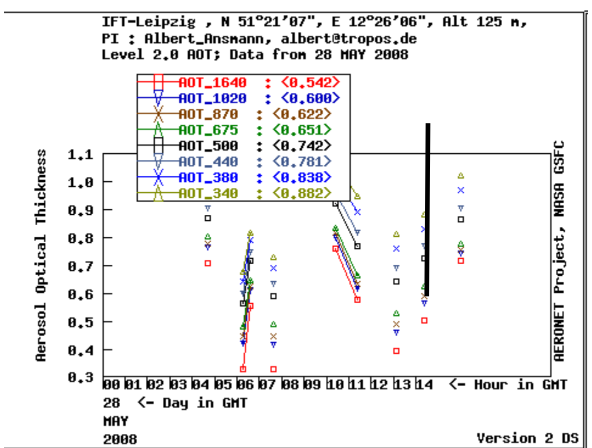


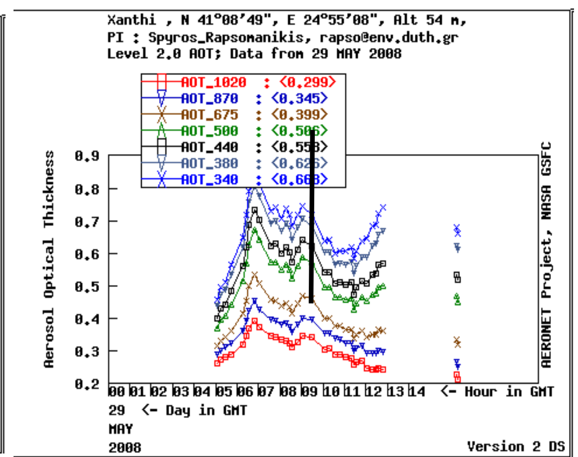
May 29, 2008



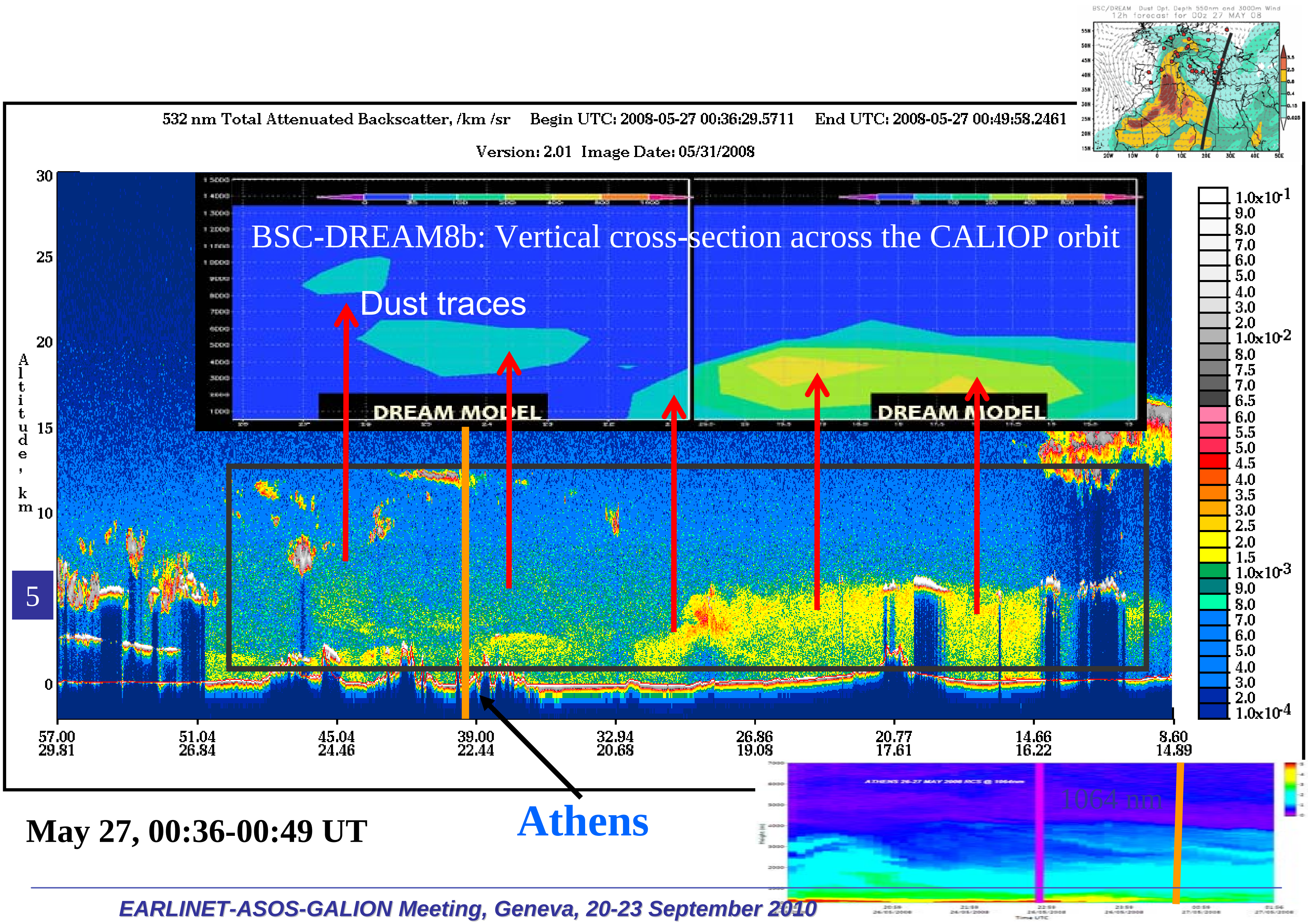
May 30, 2008



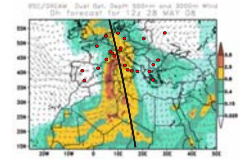




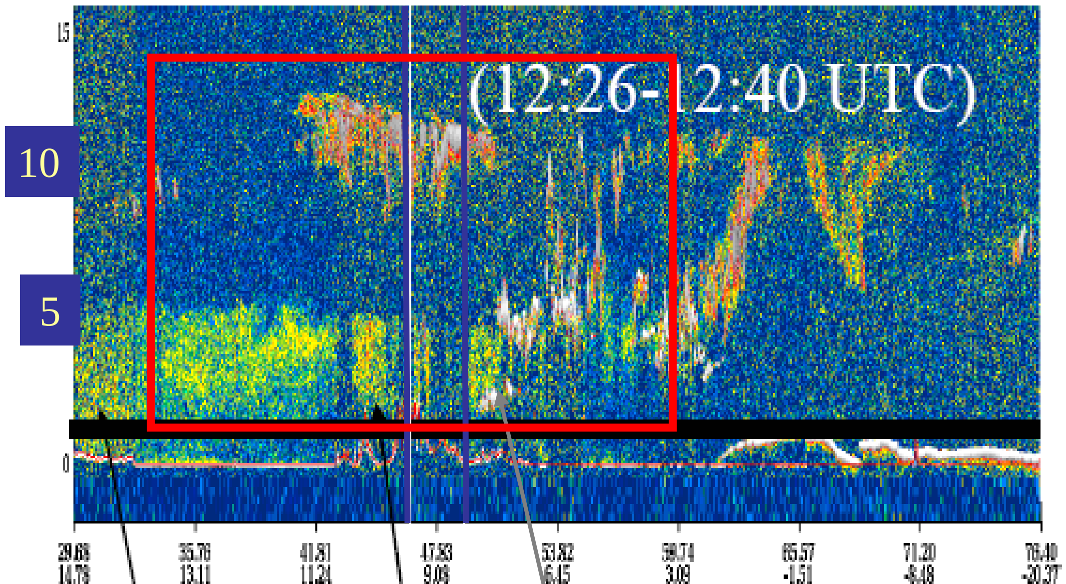
CIMEL AOD data

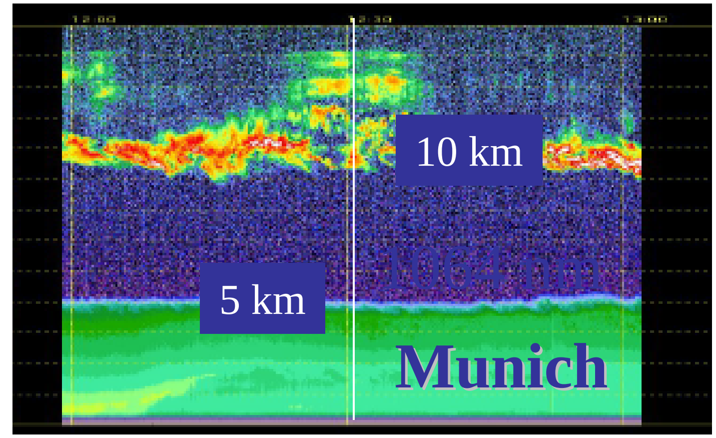


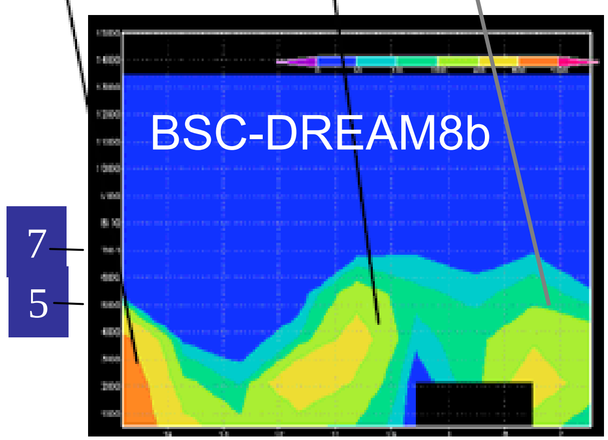
May 27, 00:36-00:49 UT

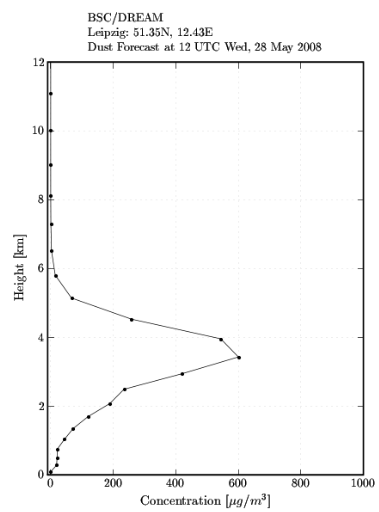


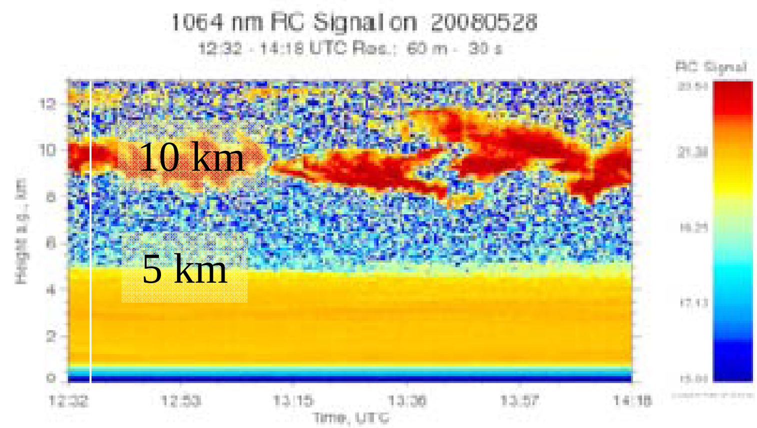
CALIOP





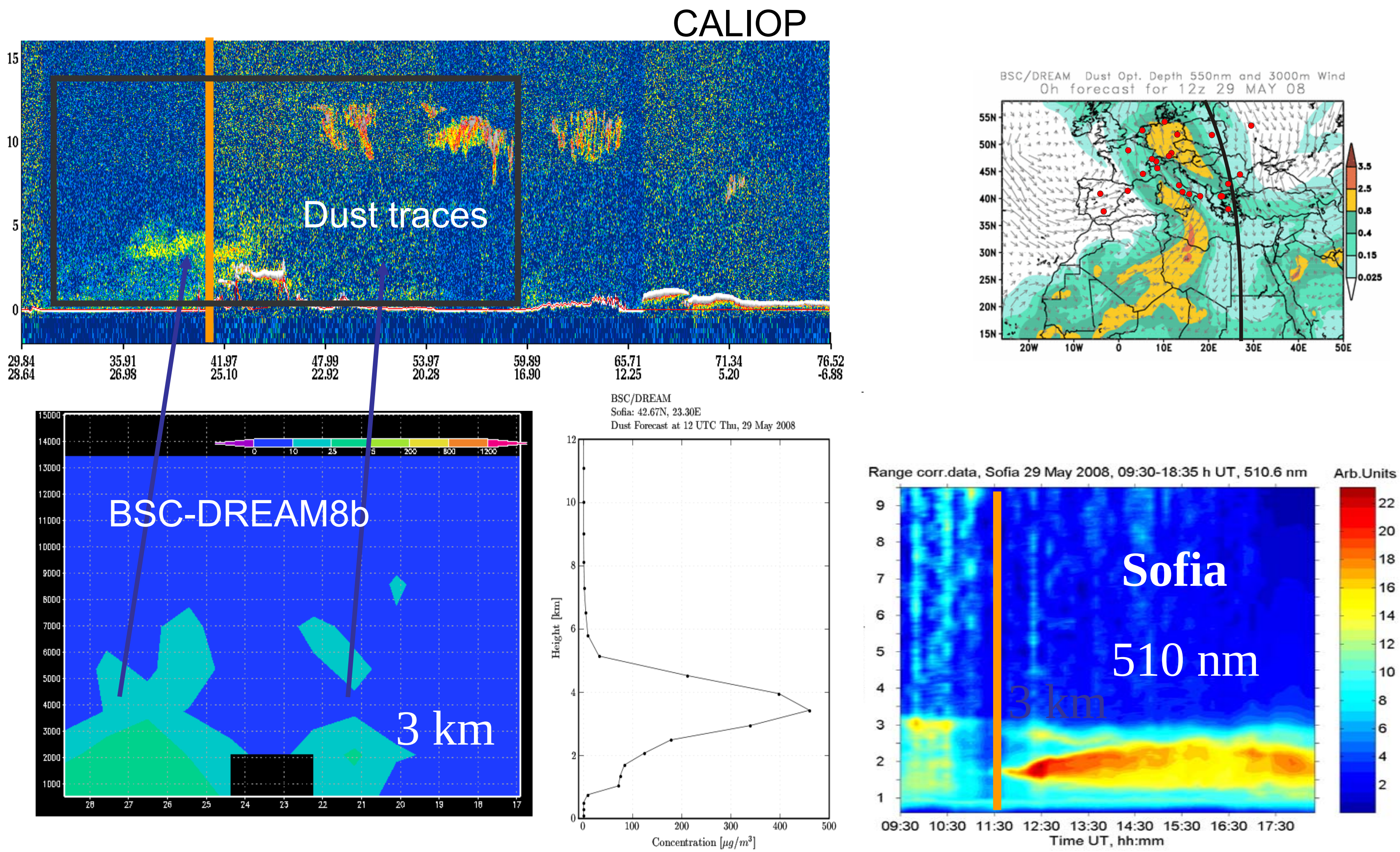






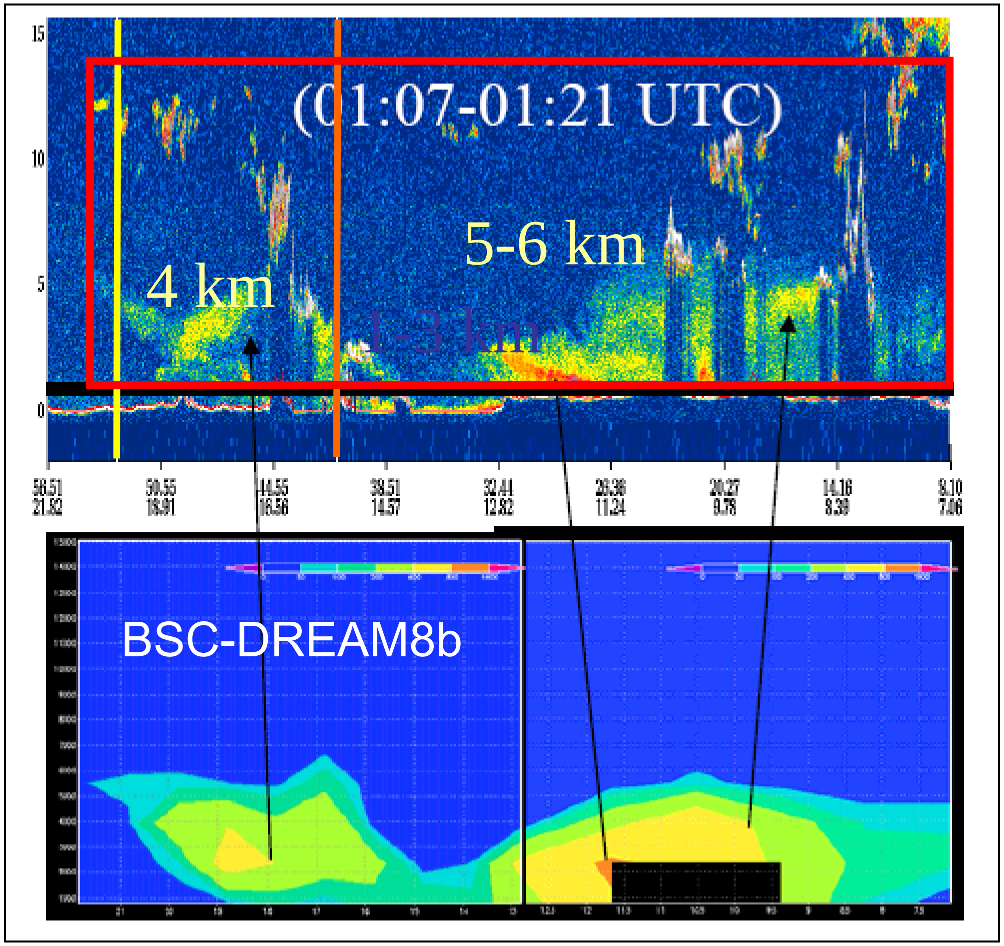
Leipzig

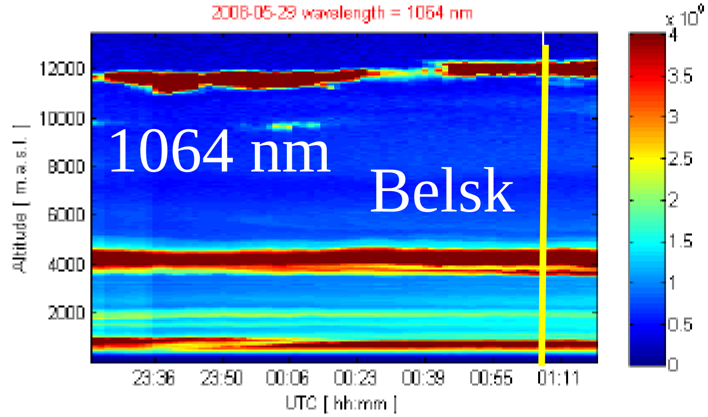
May 28, 12:26-12:40 UT

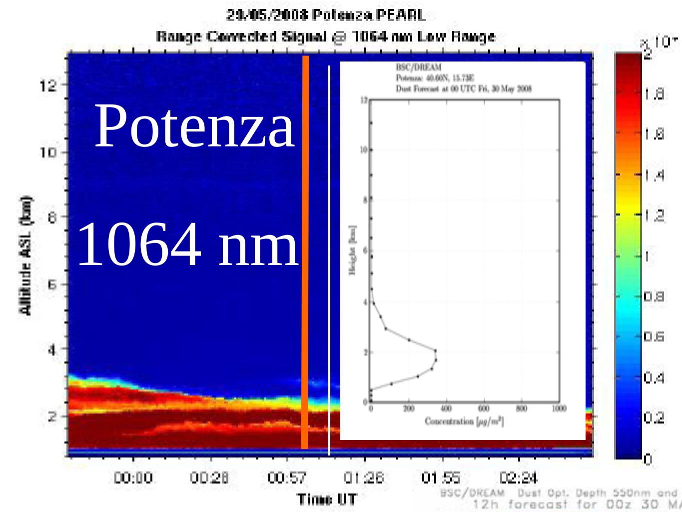


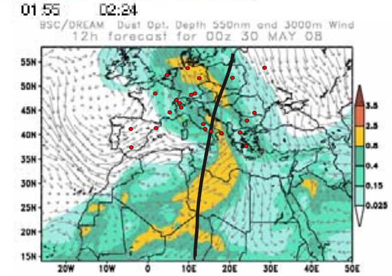
May 29, 11:31-11:44 UT

CALIOP









May 30, 01:07-01:21 UT

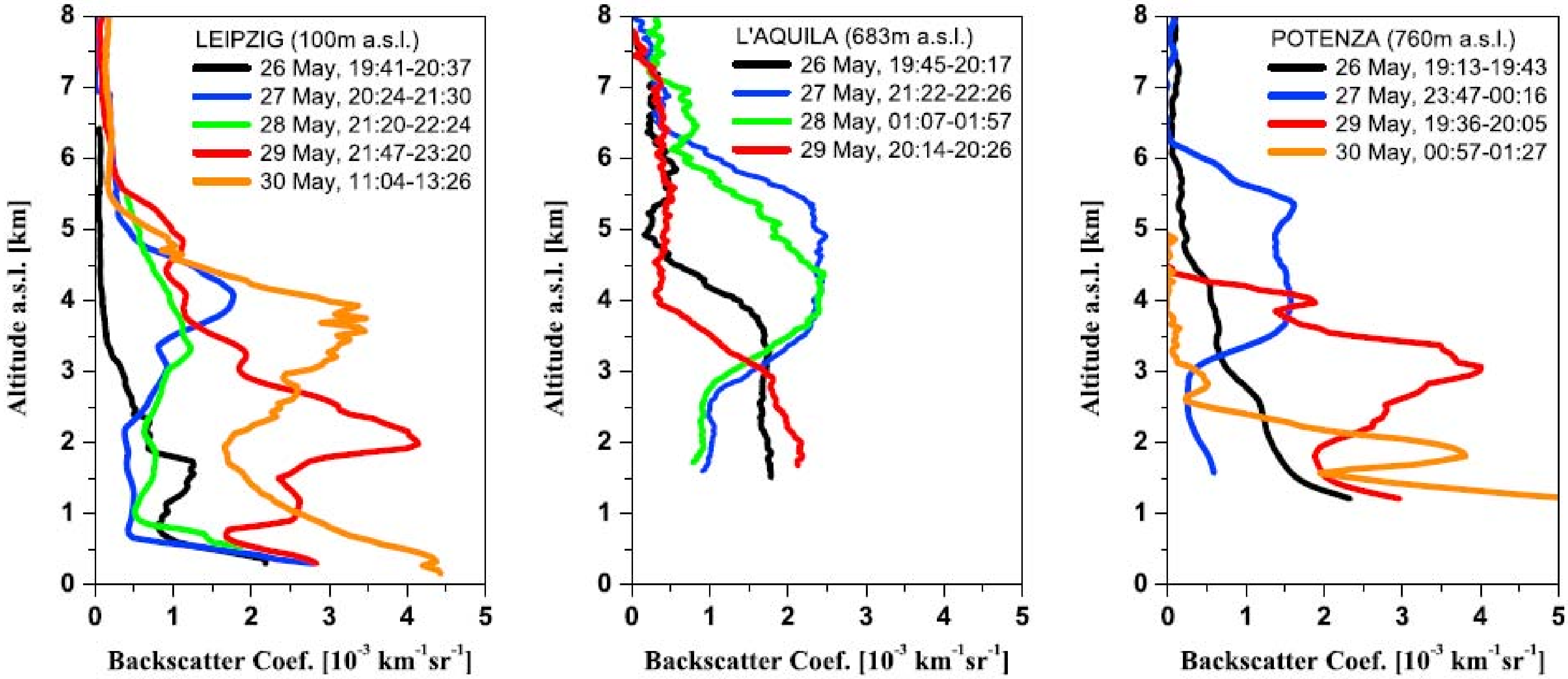


Figure 6. Backscatter coefficient profiles measured at the EARLINET stations (left) Leipzig (532 nm), (middle) L'Aquila (355 nm), and (right) Potenza (532 nm) during the major Saharan dust outbreak in the period 26–30 May 2008.

Leipzig L'Aquila Potenza

Pappalardo et al., *J. Geophys. Res*., 115, D00H19, doi:10.1029/2009JD012147, 2010

Level 2 CALIOP data

❖ Conclusions (dust event May 2008)

✓ We analyzed a strong dust event over the European continent (May 27-30, 2008) using a synergy of ground-based EARLINET lidars and CALIOP, as well as space-borne sensors and dust models (3-dimensional cross-section).

✓ The comparison between the BSC-DREAM8b 3-D profiles and the CALIOP & EARLINET aerosol vertical profiles shows a good (at least qualitative) agreement concerning the location – in time and space - of the various dust layers detected.

Conclusions

- Dust layer thickness (0.2-7.5 km); Mean value (1.5-3.4 km)

- Dust layer center of mass (0.85-8 km asl.); Mean value (2.5-6 km)

- Dust aerosols can penetrate deeply up to central, Eastern and Northern Europe (up to 8-10 km height asl., where may co-exist with clouds)

- Transport time (typically 2-5 days)

- Lidar ratios (ranges): 30-100 sr (including mixtures of dust with other particles)

- Mean lidar ratios: 49±10 sr (355 nm), 56±7 sr (532 nm)

-Mean AOD (0.1-0.25) inside the dust layer

-TOMS Aerosol Index (AI) values:

3-3.5 (Mediterranean Region), 1-2.5 (Central Europe)

- Maximum of dust outbreaks: South-South-Eastern Europe:

* Summer, autumn and spring period (S-SE Europe)

* Spring and summer (SW, central Europe)

***Acknowledgements*:**

All colleagues from the EARLINET TEAM (with Special thanks to Anja Hiebsch and Lucia Mona and Rodelize Mamouri).

Prof. J.M. Baldasano and Dr. Sara Basart (BSC-DREAM8b model); NOAA-ARL (Hysplit code); Dr. Andreas Stohl (FLEXTRA data); AERONET (CIMEL data); SeaWIFS (NASA).

This work was funded by the EU-FP5 (EARLINET project: EVR1-CT1999-40003), EU-FP6 (EARLINET-ASOS project: RICA-025991] and the European Space Agency (ESA) under contract AO/1-5502/07/NL/HE.