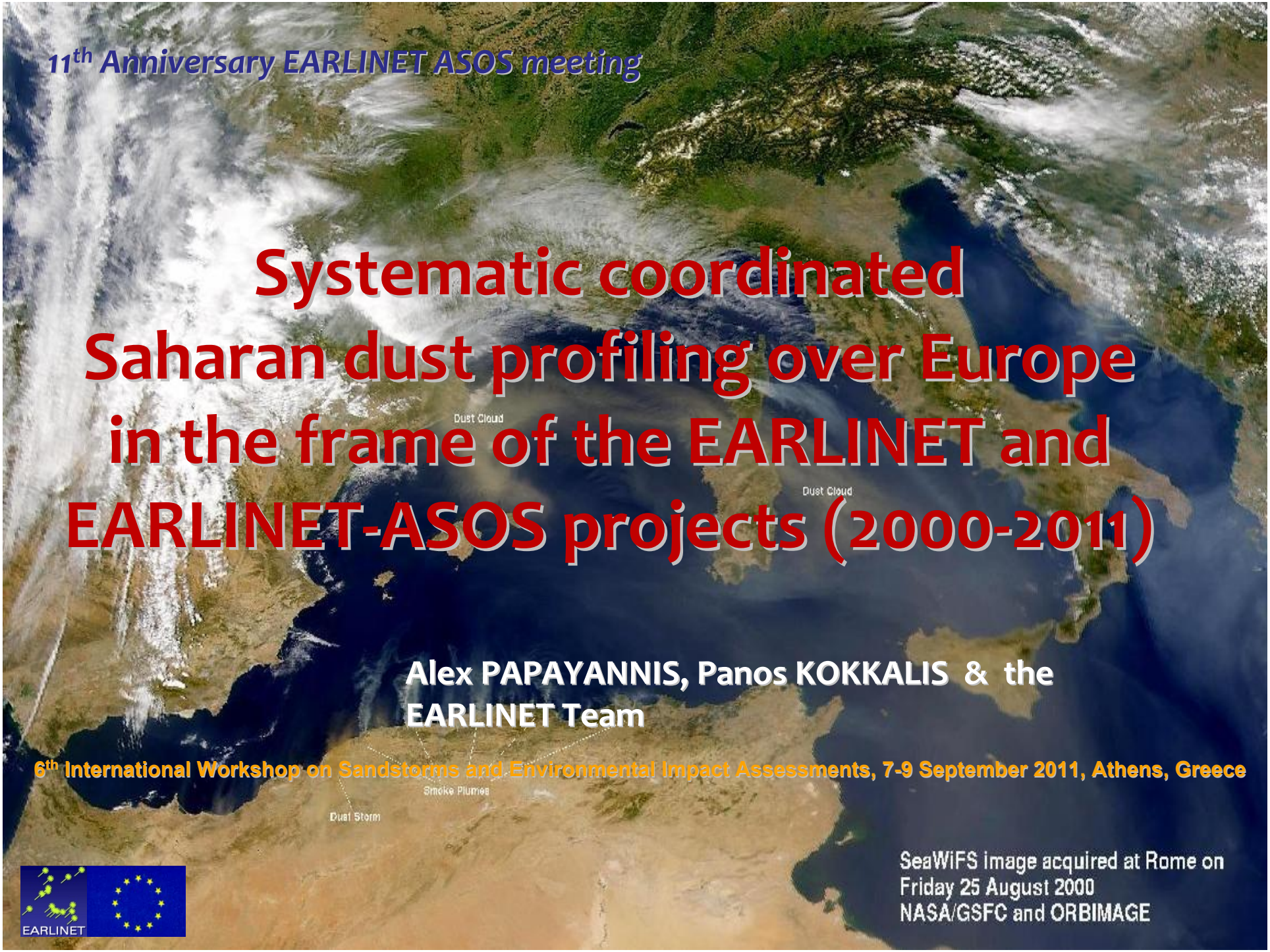
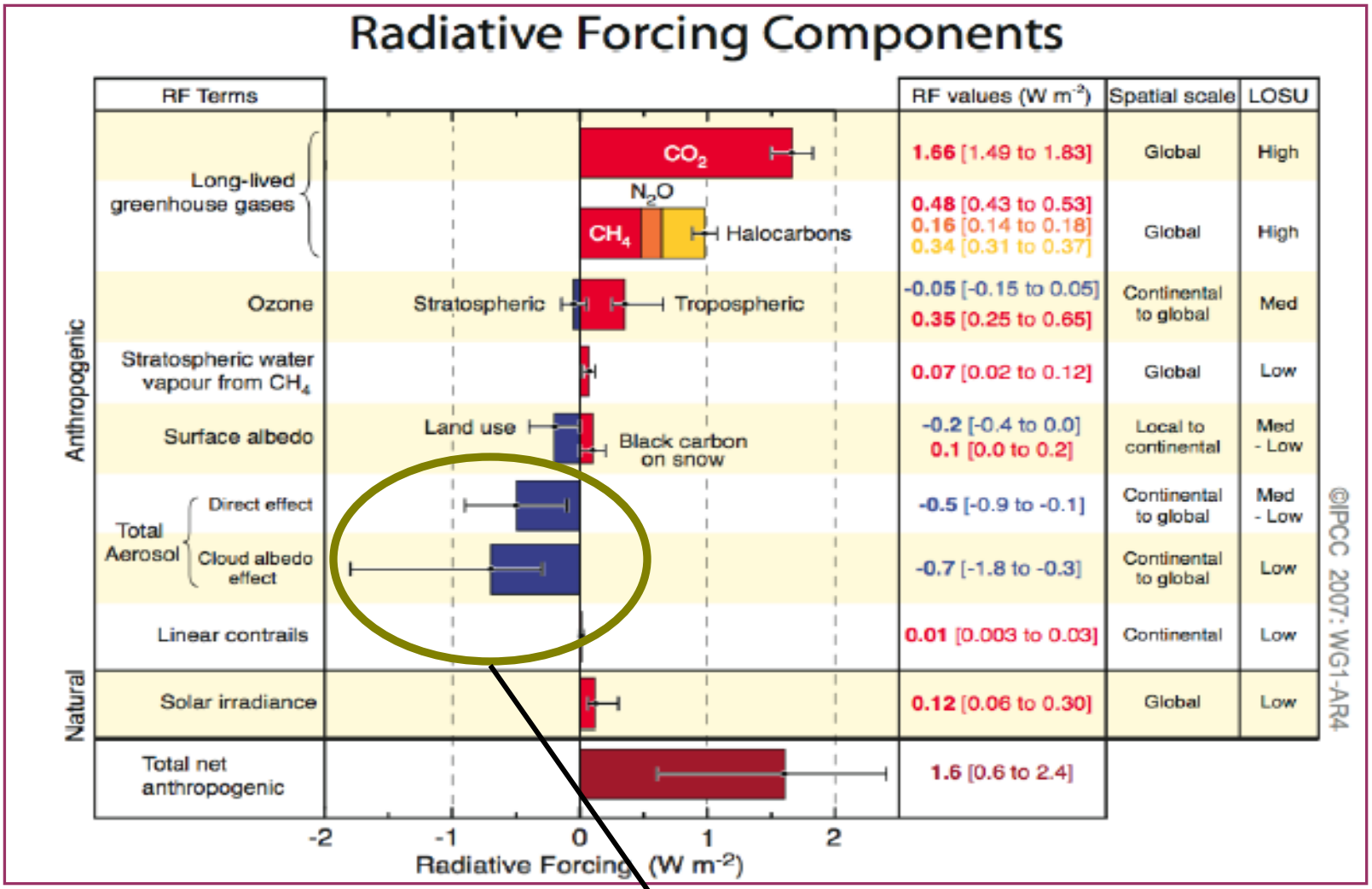

11th Anniversary EARLINET ASOS meeting
Systematic coordinated Saharan dust profiling over Europe in the frame of the EARLINET and EARLINET-ASOS projects (2000-2011)
Dust Cloud
Dust Cloud
Smoke Plumes
Dust Storm
Alex PAPAYANNIS, Panos KOKKALIS & the EARLINET Team
6th International Workshop on Sandstorms and Environmental Impact Assessments, 7-9 September 2011, Athens, Greece
EARLINET
SeaWiFS image acquired at Rome on Friday 25 August 2000
NASA/GSFC and ORBIMAGE

OUTLINE

- Role of aerosols in climate forcing
- EARLINET Network for Correlative/Systematic measurements
- - Validation tools
- 2-Cases study analysis (Pure dust event – Dust/Volcanic ash mixing)
- General results
- Conclusions

Role of aerosols in climatic forcing



Positive or Negative (Chemical composition)

IPCC, 2007

Why dust aerosols are important?

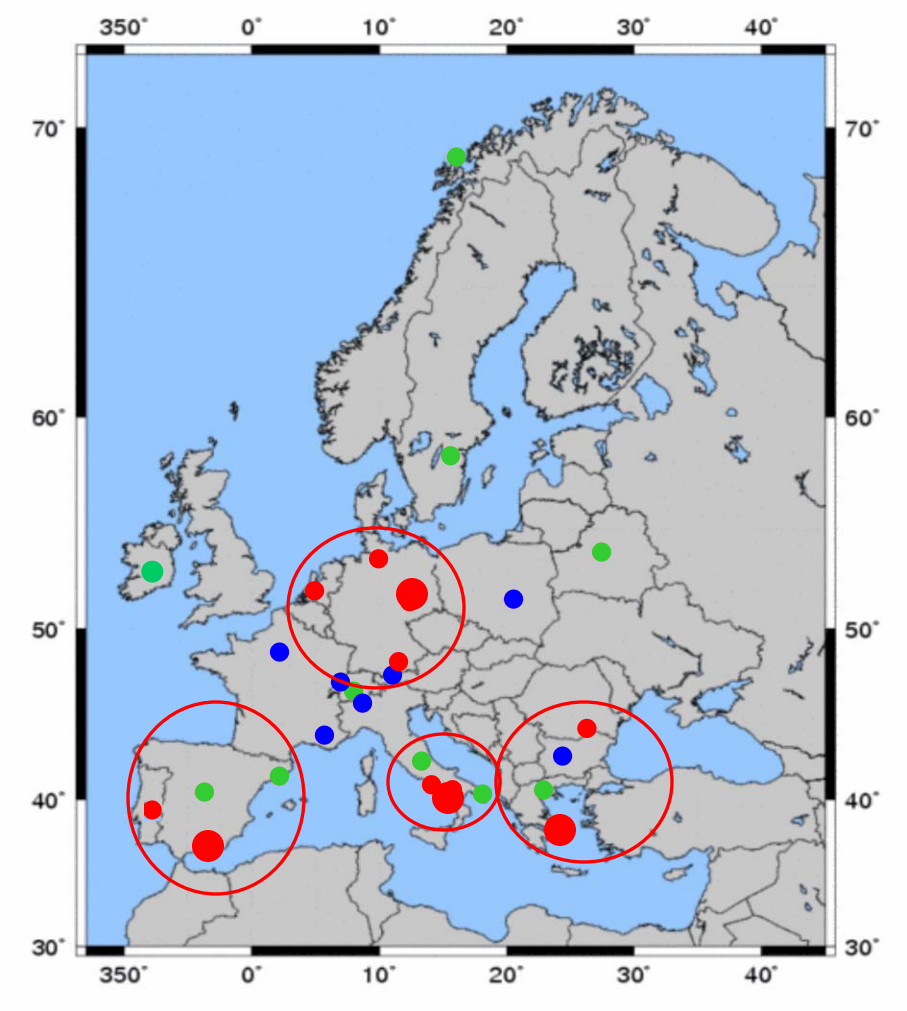
- Dust aerosols are produced in desert areas (e.g. Sahara, Gobbi deserts etc.)
- Dust aerosols interact dynamically in a nonlinear way (nucleation, condensation, coagulation, dry/wet deposition)
- Dust aerosols can be transported over large distances (inter-continental transport)

Systematic measurements are needed to assess and improve the understanding of aerosol processes-transport-deposition and their treatment in models!

Synergistic measurements are needed:

- In situ measurements
- Ground-based remote sensing measurements
- Satellite measurements.

The EARLINET Network (2000-…)



27 lidar stations

-**10 multi-wavelength Raman** lidar stations backscatter (355, 532 and 1064 nm) + extinction (355 and 532 nm) + depol-ratio (532 nm) (●)

-**10 UV Raman** lidar stations (●)

-**7 single backscatter** lidar stations (●)

EARLINET: Perform systematic aerosol measurements by lidar to obtain a quantitative database of the horizontal, vertical, and temporal distribution of aerosols over Europe.

EARLINET (2000-2003), EARLINET-ASOS (2006-2011), ACTRIS (2011-2015)

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 (DREAM8b/BSCC, 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/MODIS & SeaWiFS data - CALIPSO data

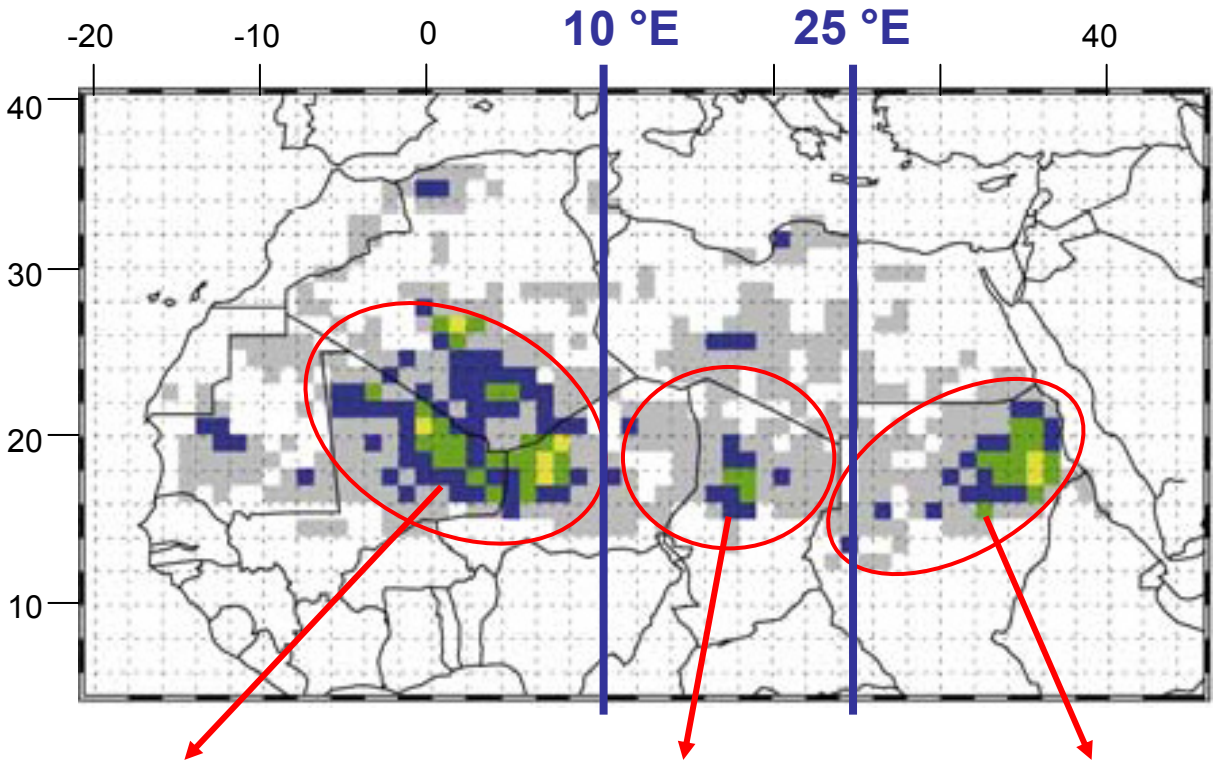
- **Sun photometer data analysis**

  Aerosol Optical Depth data + aerosol microphysical properties

Saharan dust events (2000-2011)

➢**3856 vertical profiles (extinction and backscatter profiles) stored in the EARLINET data base (http://www.earlinet.org)**

Definition of Saharan dust source regions



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

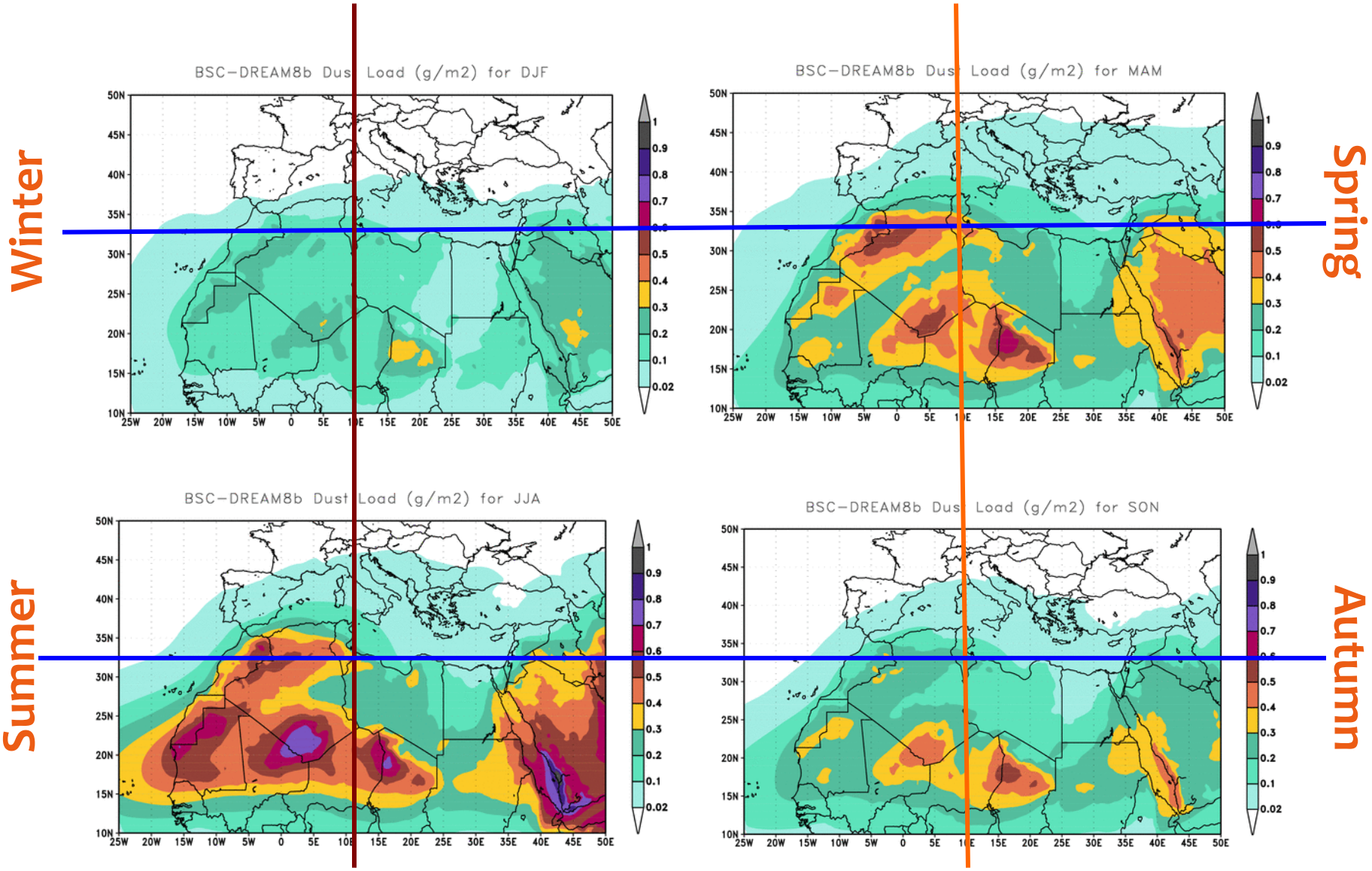
Central Sahara
Bodele Depression
(Lake Chad Basin)

Eastern Sahara
Foothills of the
Red Sea Mountains
(Sudan)

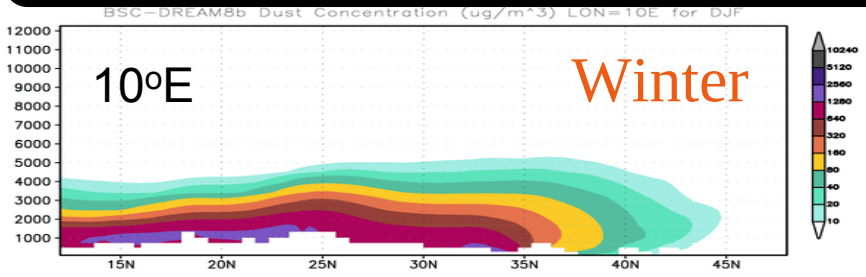
Geographical lows and foothills, dry lakes and rivers
→ mobilization of sediments of fine soil

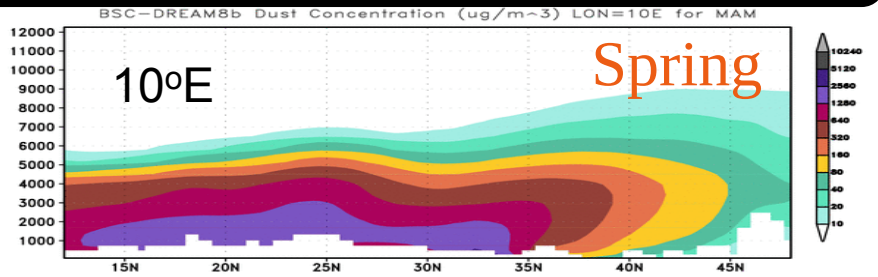
Prospero et al., 2002
Schepanski et al., 2007

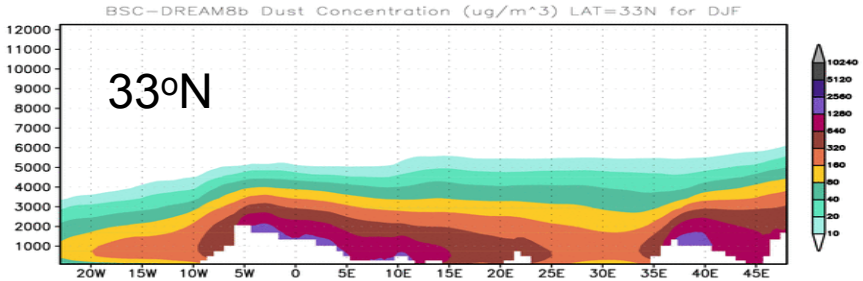
DREAM model [2000-2011]

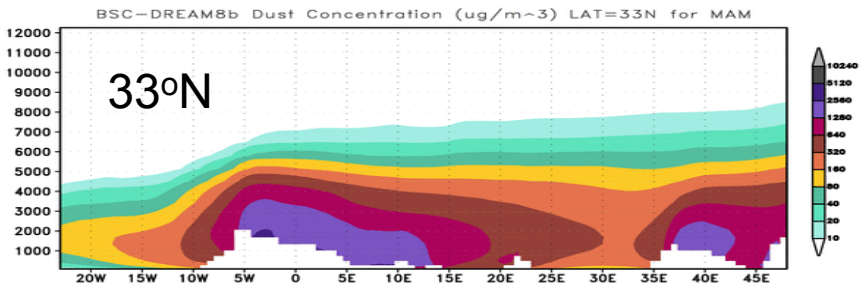


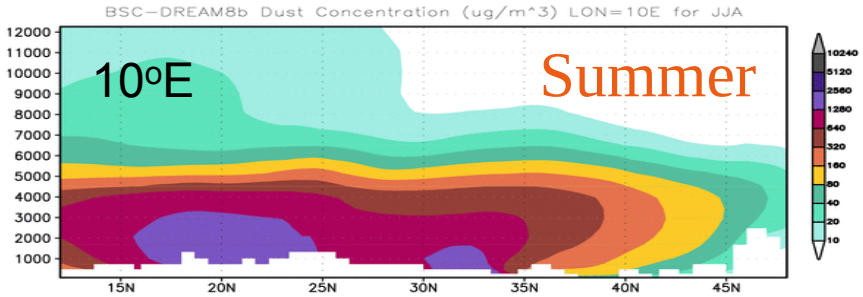
DREAM model [2000-2011] Cross section over 33°N, 10°E

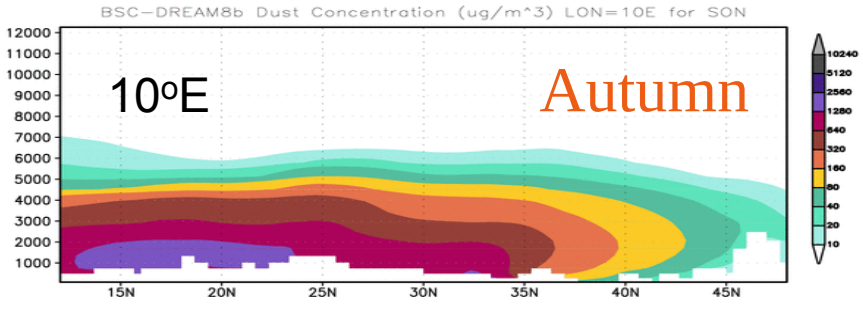


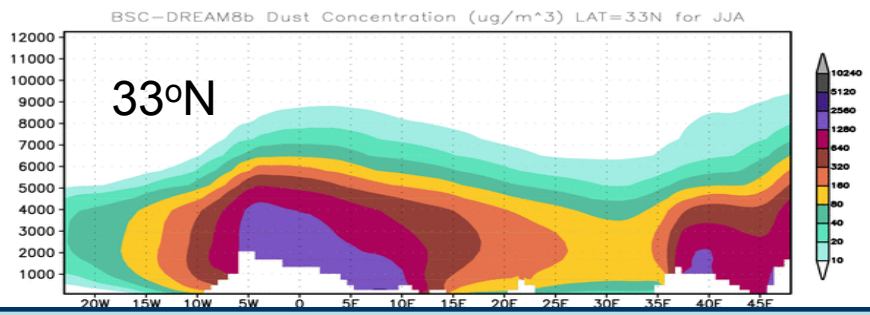


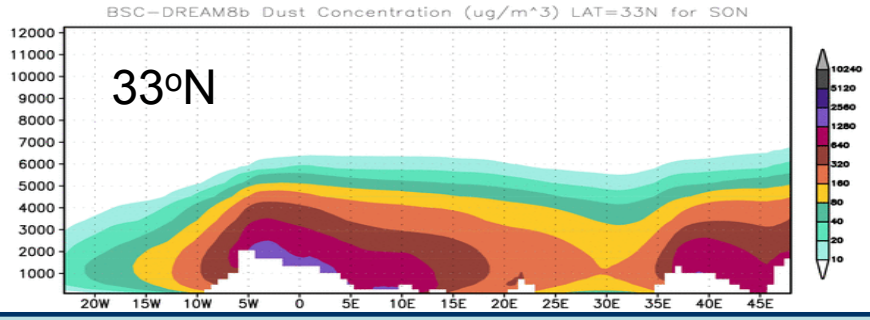






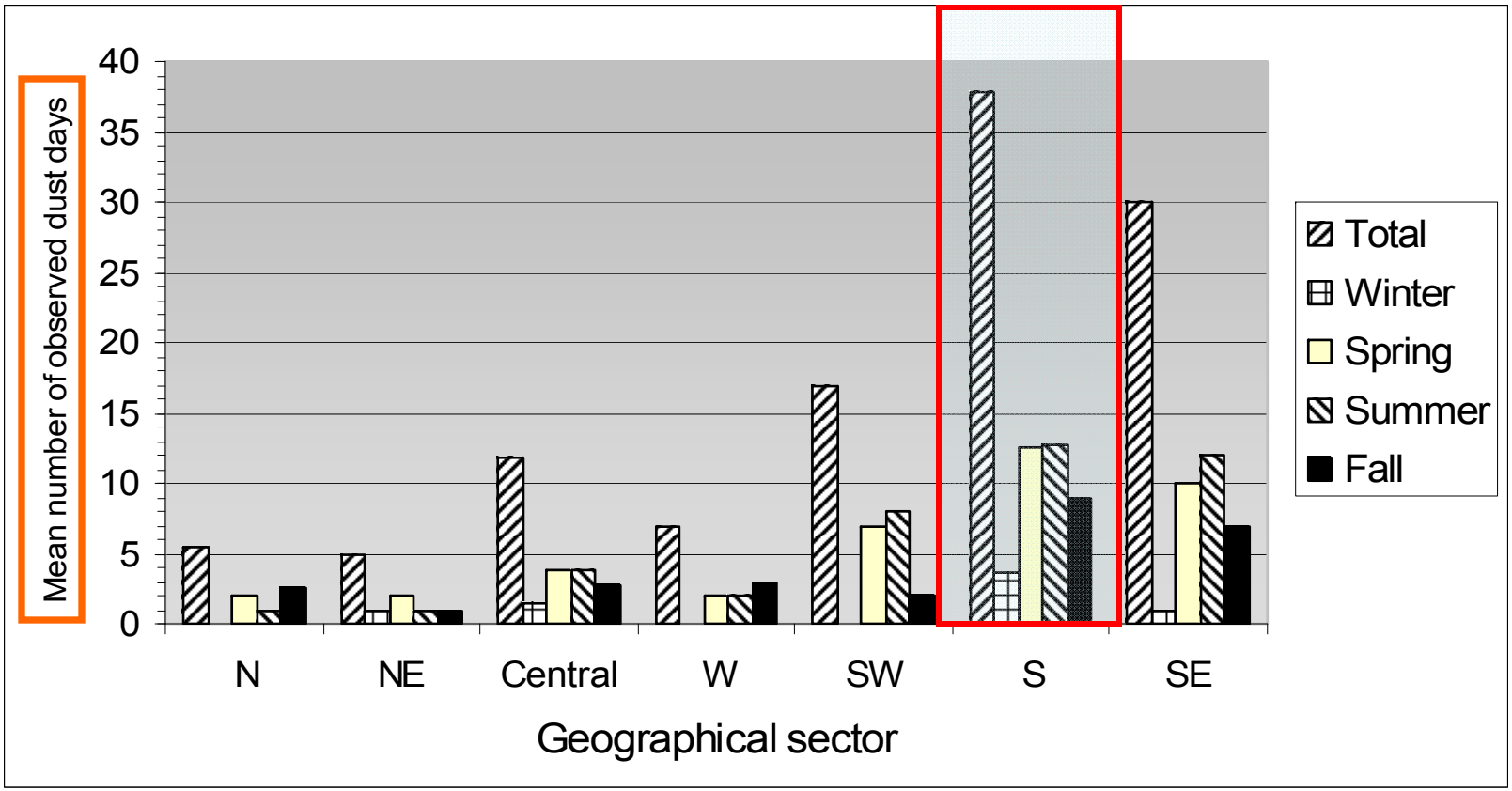






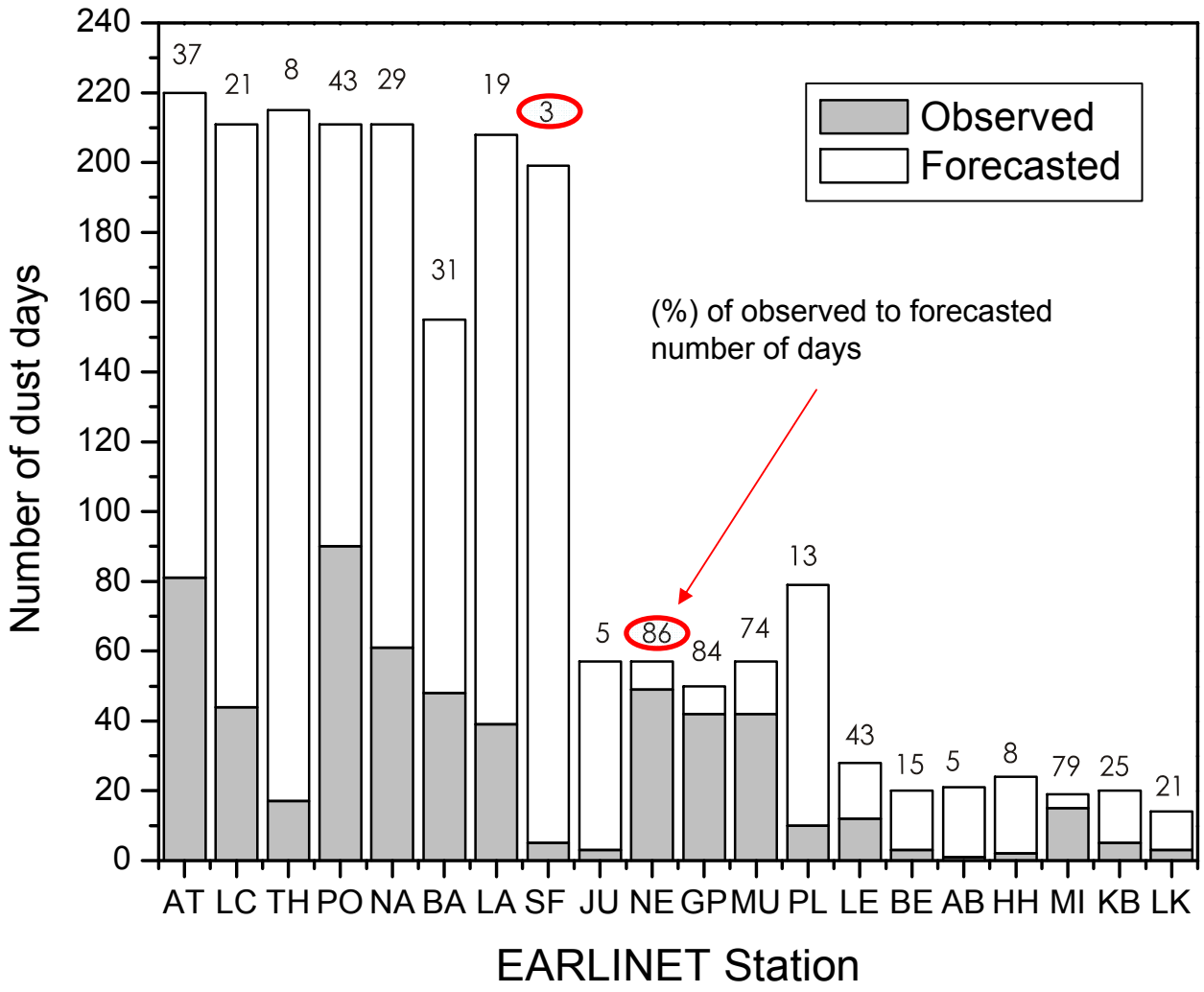
Saharan dust days [2000-2002]

Seasonal variability of observed mean number of Saharan dust days



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

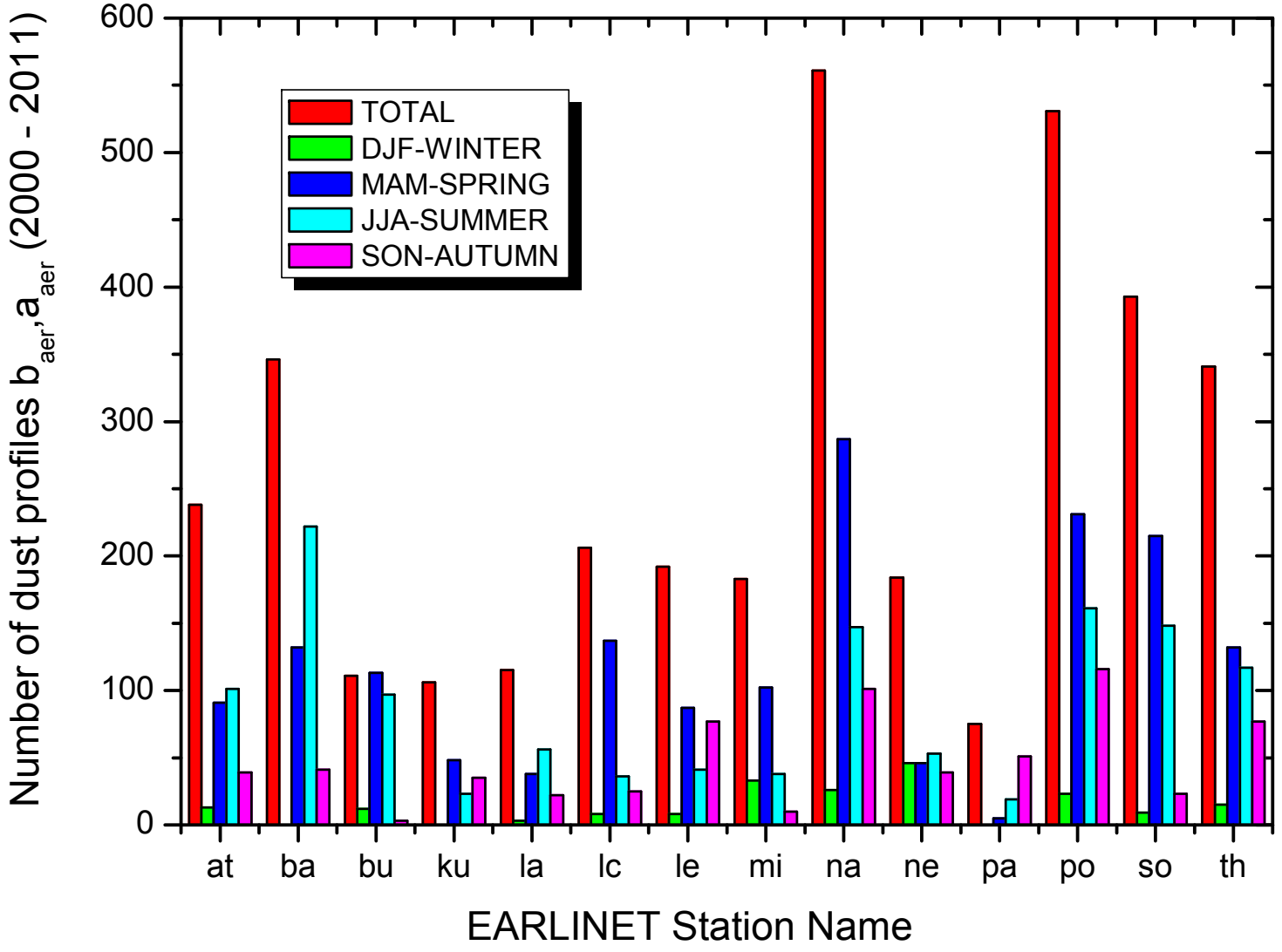
Saharan dust days [2000-2002] – EARLINET stations



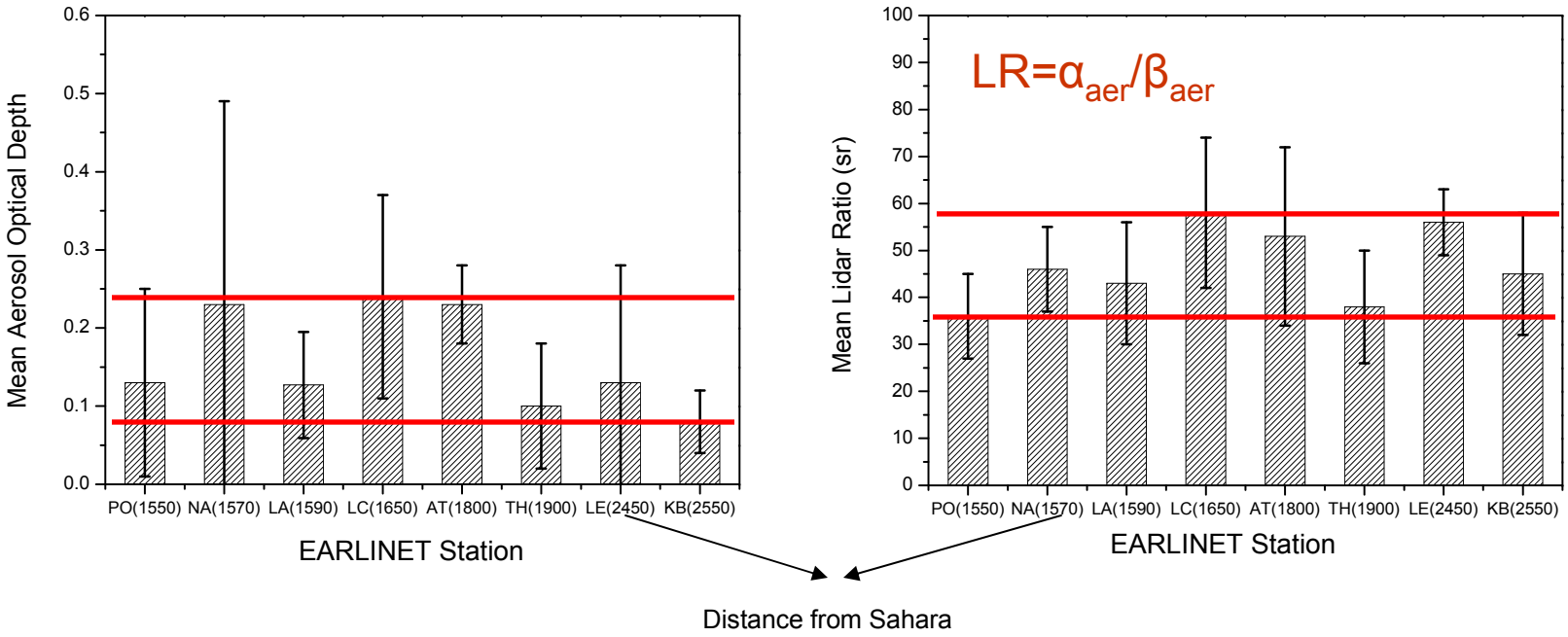
Papayannis et al., *J. Geophys. Res.*, 113, D10204, doi:10.1029/2007JD009028, 2008

Saharan dust days – EARLINET stations (2000-2011)

3856 vertical profiles



Saharan dust days [2000-2002] – EARLINET stations

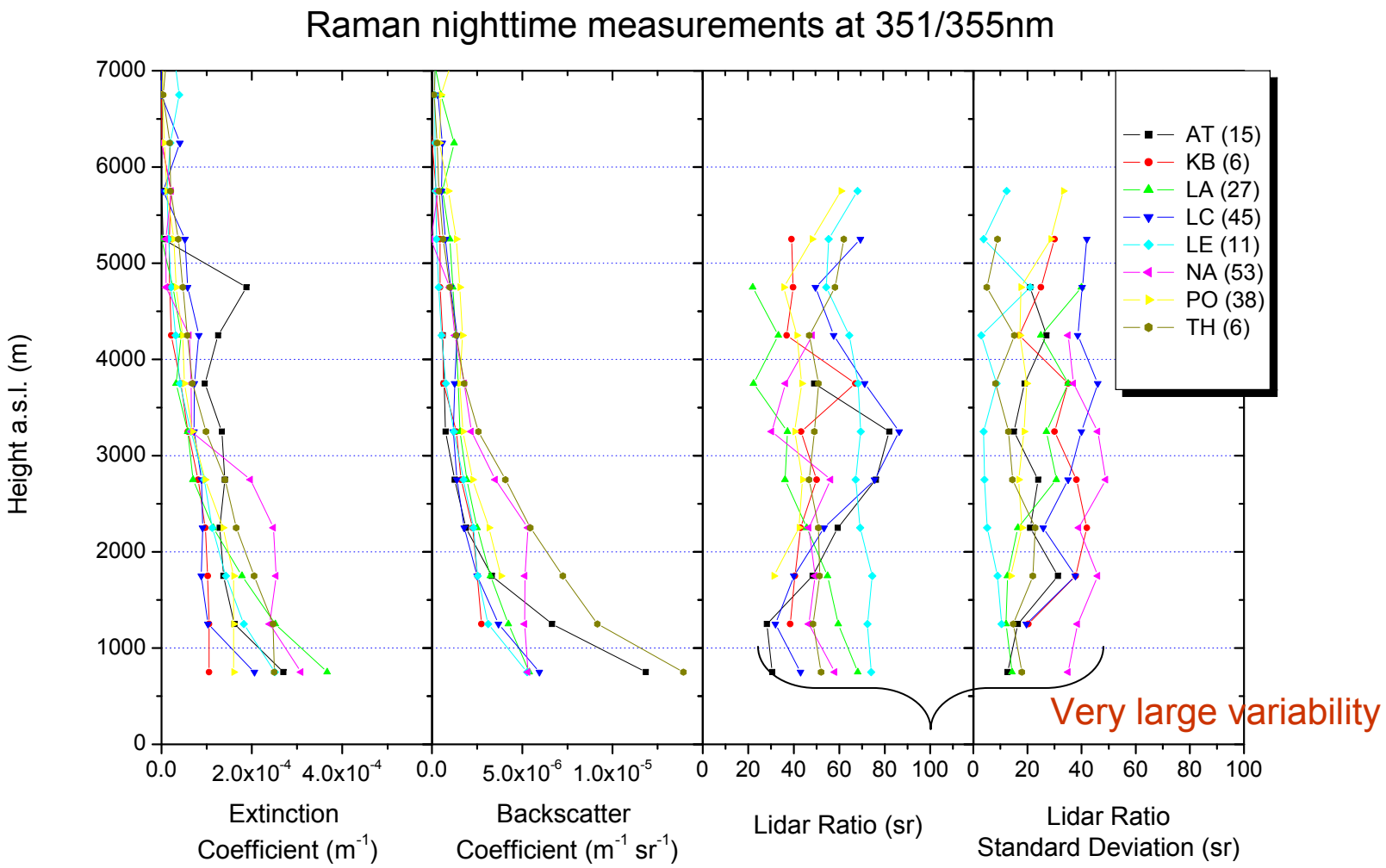


Mean **AOD** and **LR** (both at 355 nm) **inside the dust layer**

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

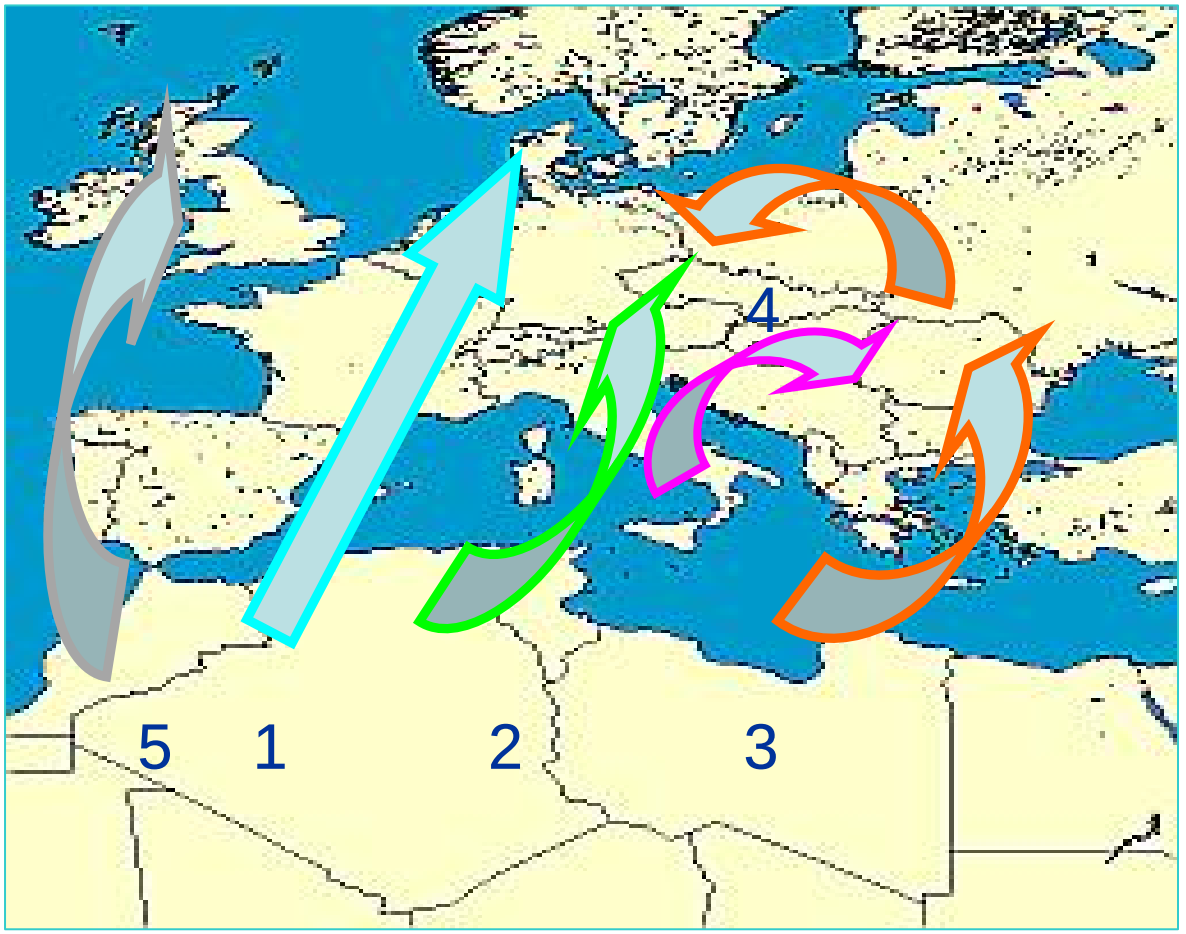
Papayannis et al., *J. Geophys. Res.*, 113, D10204, doi:10.1029/2007JD009028, 2008

Saharan dust days [2000-2002] – EARLINET stations



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: ~ 25 %

4: ~ 10 %

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:
DREAM/BSC
Air Mass Trajectory Computation:
HYSPLIT 4.6 code – FLEXTRA/FLEXPART

Papayannis et al., SPIE, 74790C, 2009

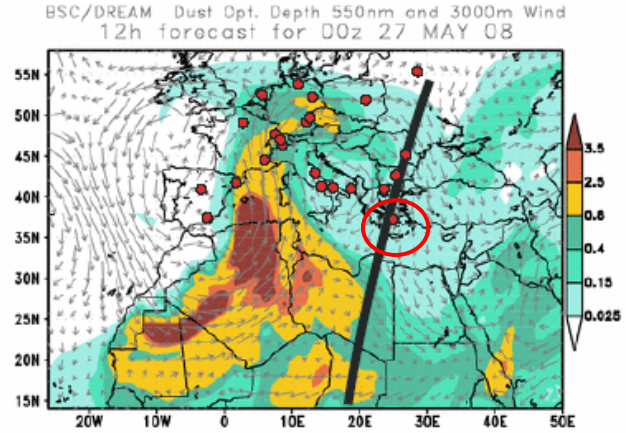
DREAM model: Aerosol Optical Depth [550 nm] & Winds [3 km]

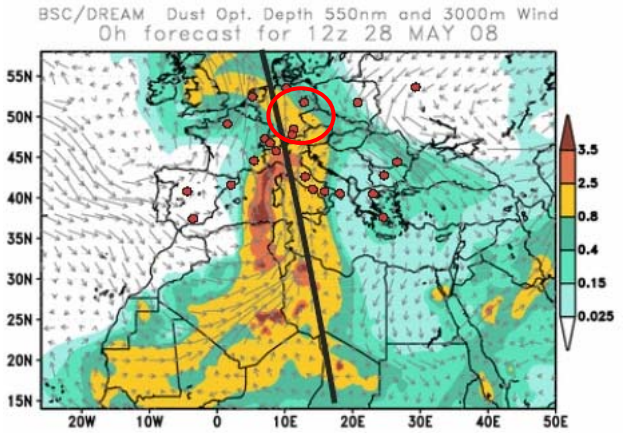
Dream model

May 27, 2008

May 28, 2008

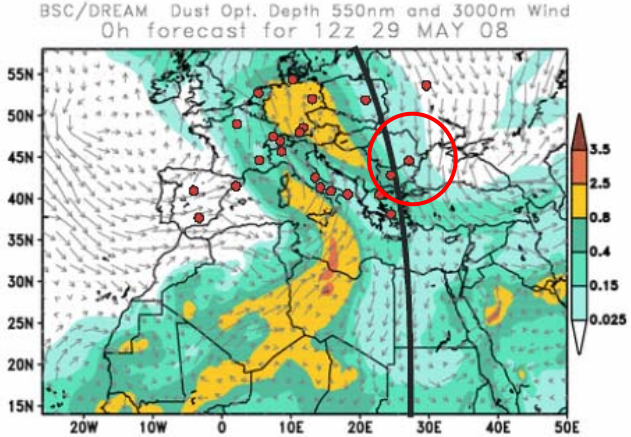
Athens

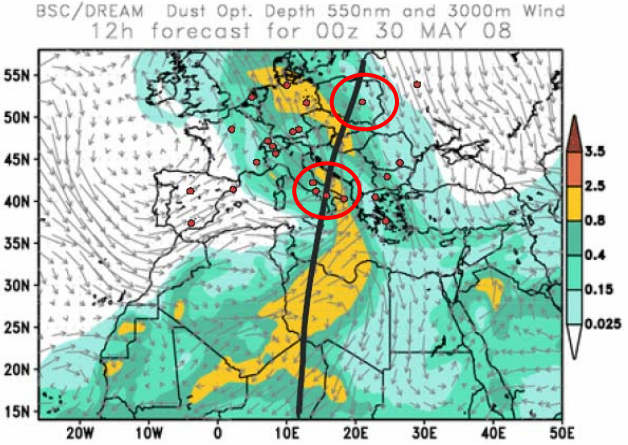




Munich, Leipzig

Sofia





Potenza, Belsk

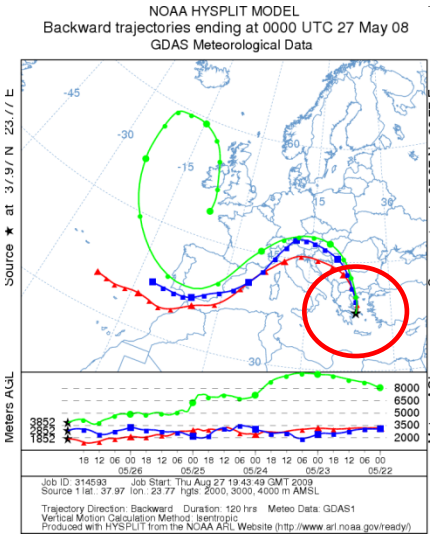
May 29, 2008

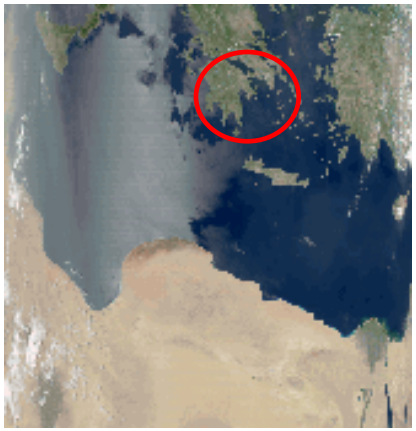
May 30, 2008

HYSPLIT 4.6 Air Mass Trajectory Model SeaWiFS data

Athens

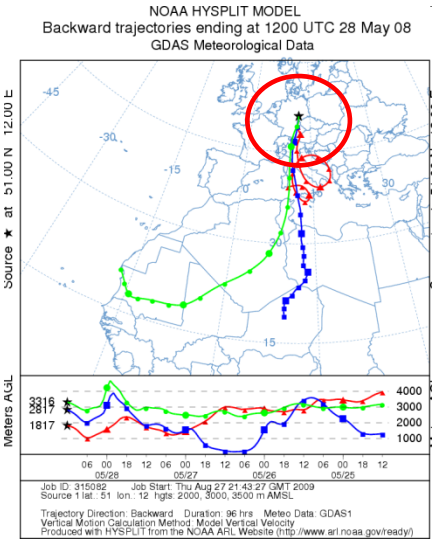
May 27, 2008

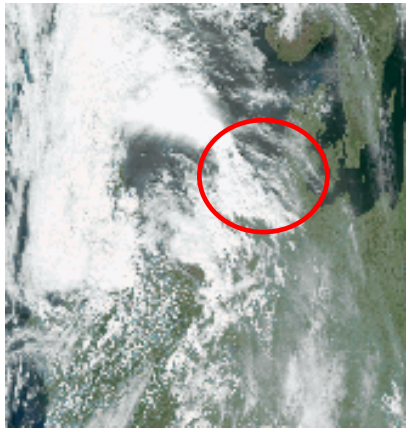




Leipzig

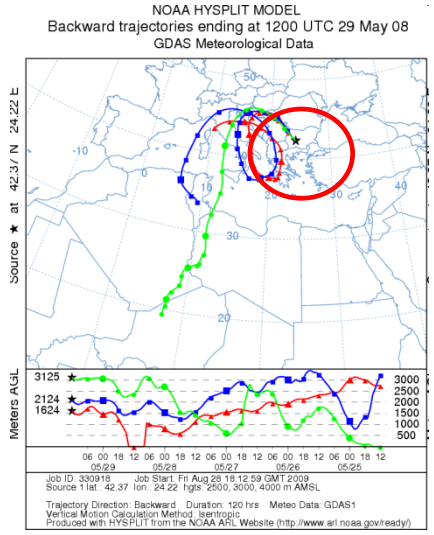
May 28, 2008





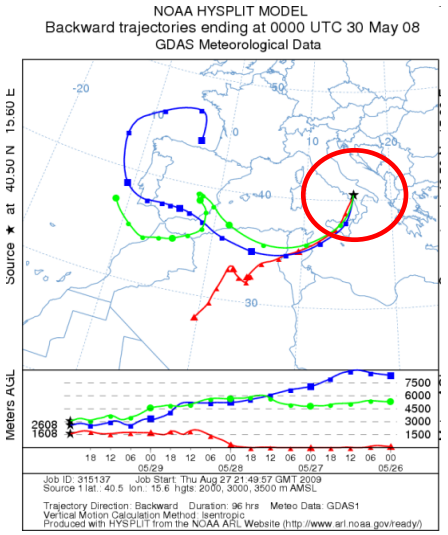
Sofia

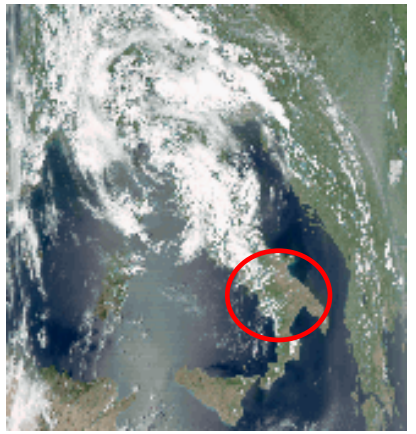
May 29, 2008



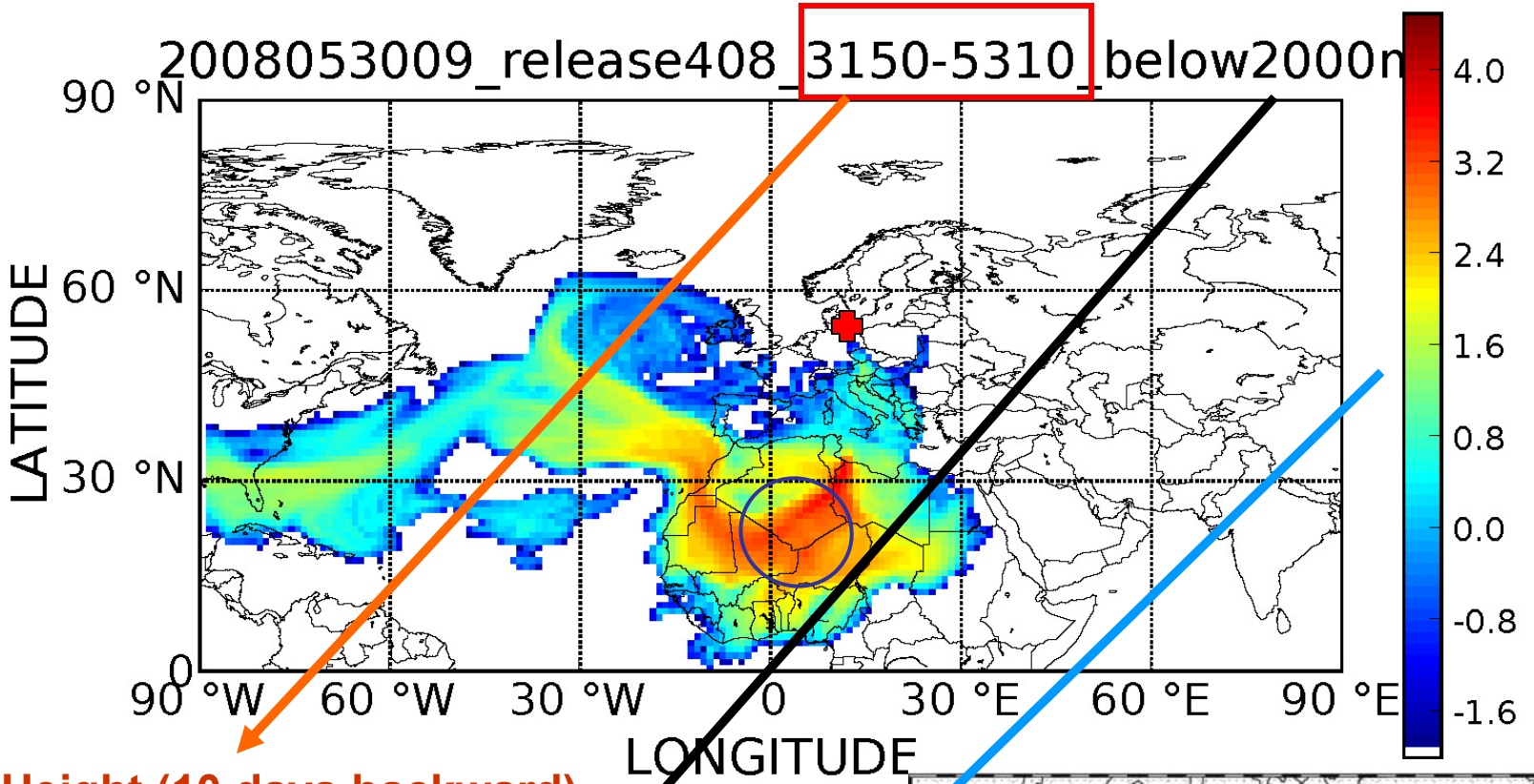
Potenza

May 30, 2008



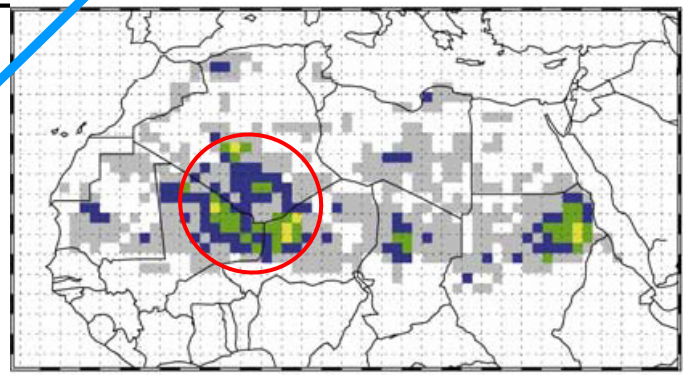


FLEXPART footprint [<2000m] Leipzig, 30 May 2008



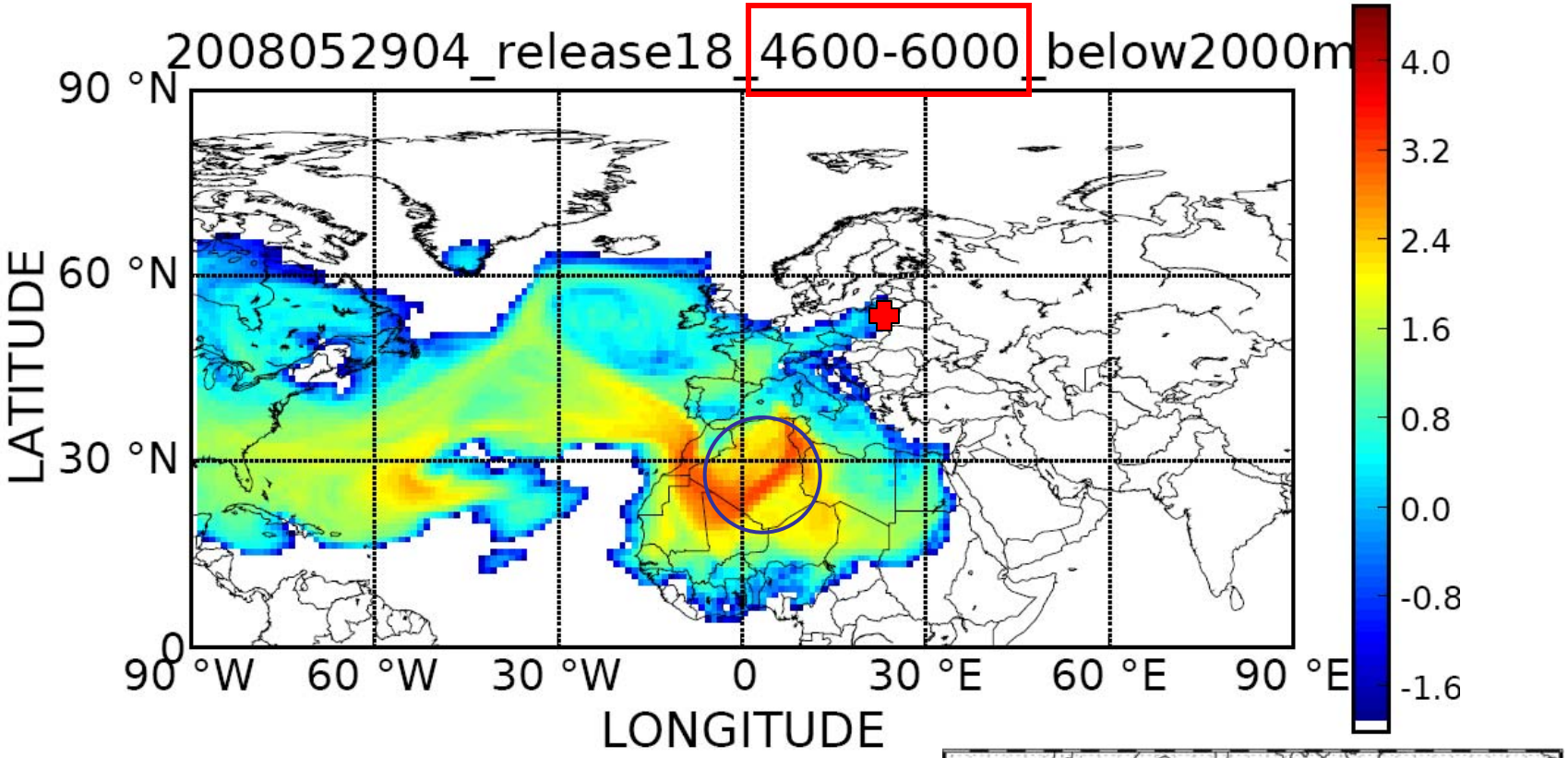
Arrival Height (10 days backward)

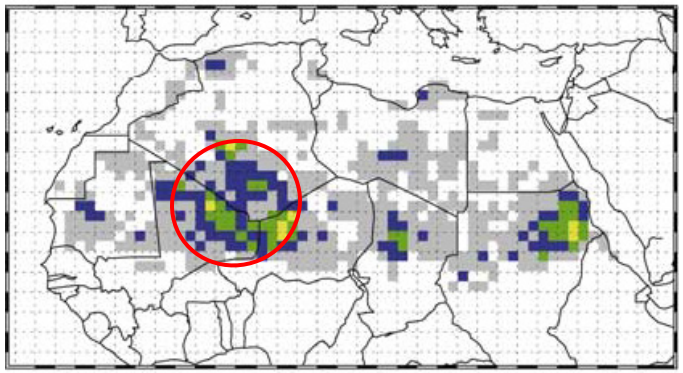
Air masses travel height: < 2 km



Log of integrated residence time (in sec)

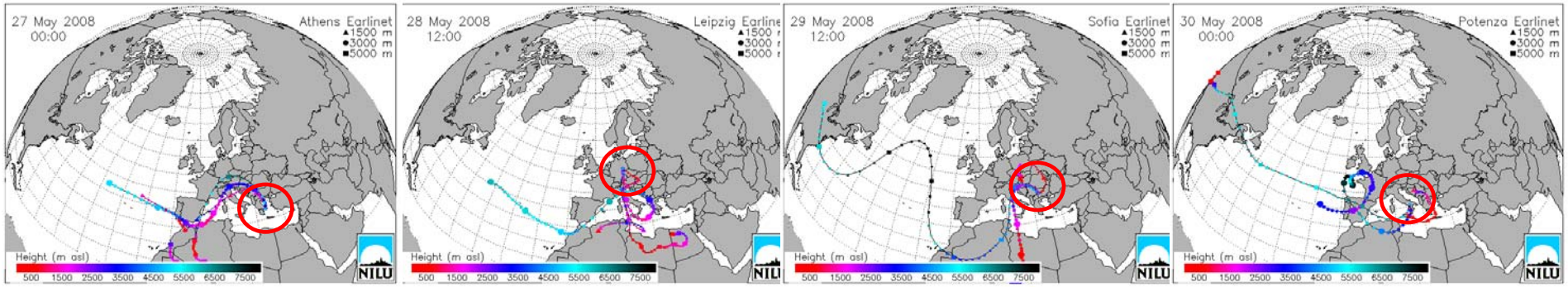
FLEXPART footprint [<2000m] Belsk, 30 May 2008



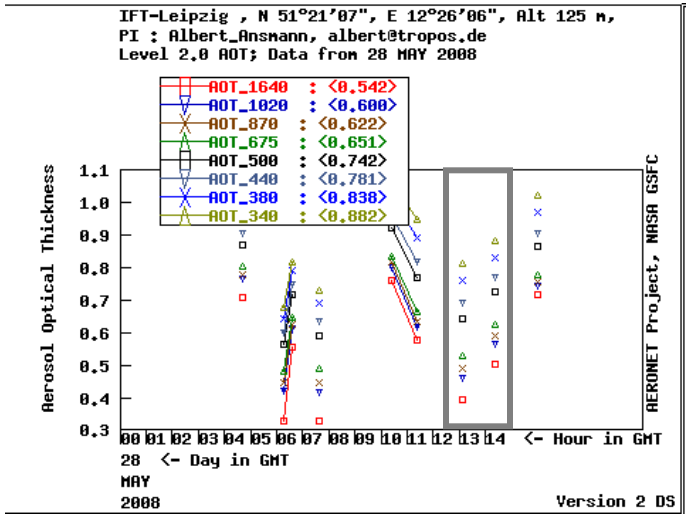


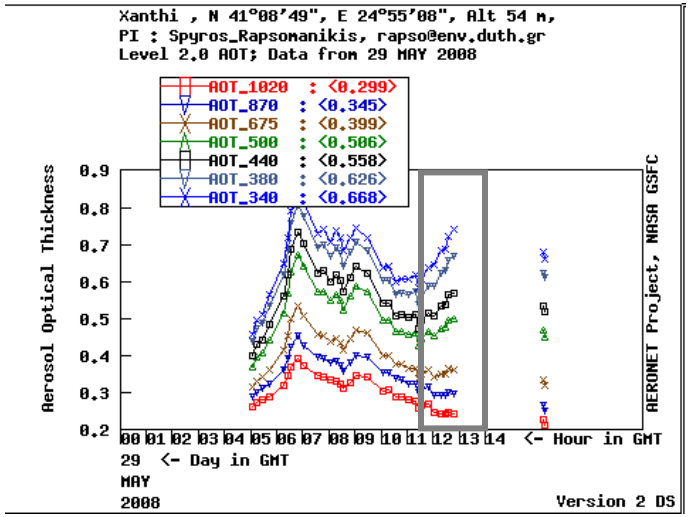
FLEXTRA Air mass Trajectory Model

May 27, 2008 | May 28, 2008 | May 29, 2008 | May 30, 2008



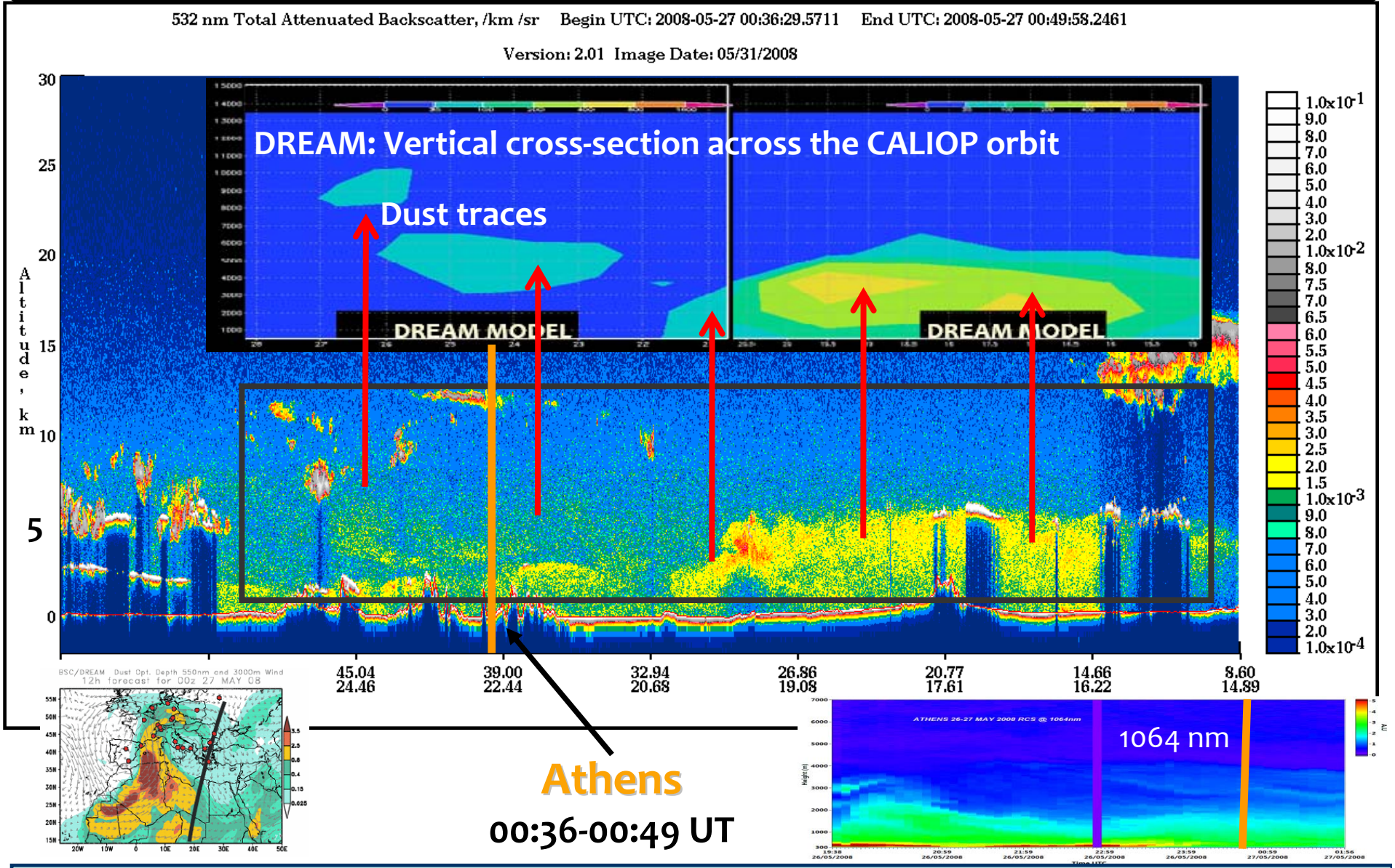
Athens (1.5,5 km) | **Leipzig (1.5,5 km)** | **Sofia (3 km)** | **Potenza (3 km)**



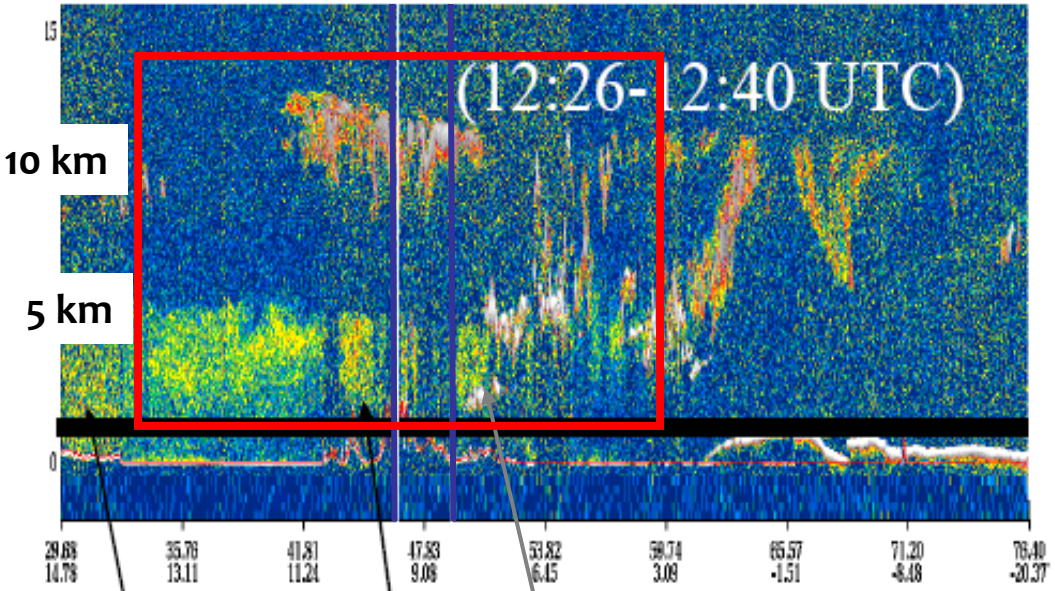


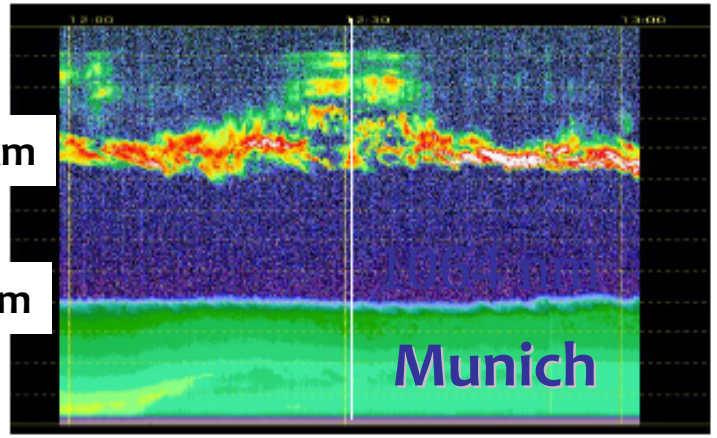
CIMEL AOD data

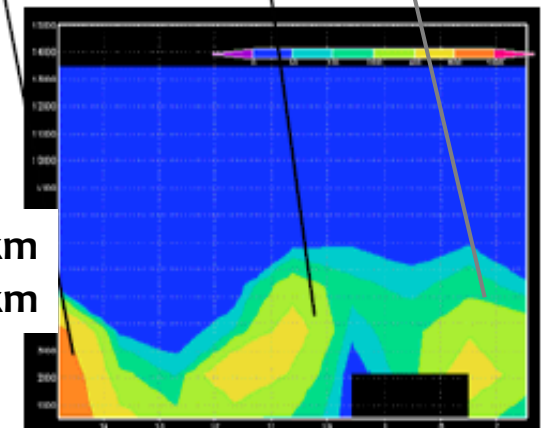
CALIPSO-DREAM Athens EARLINET station, 27 May 2008

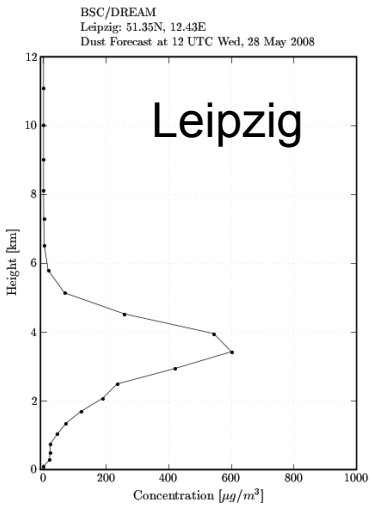


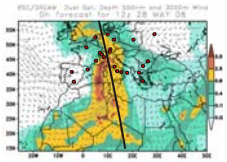
Munich & Leipzig EARLINET stations, 28 May 2008

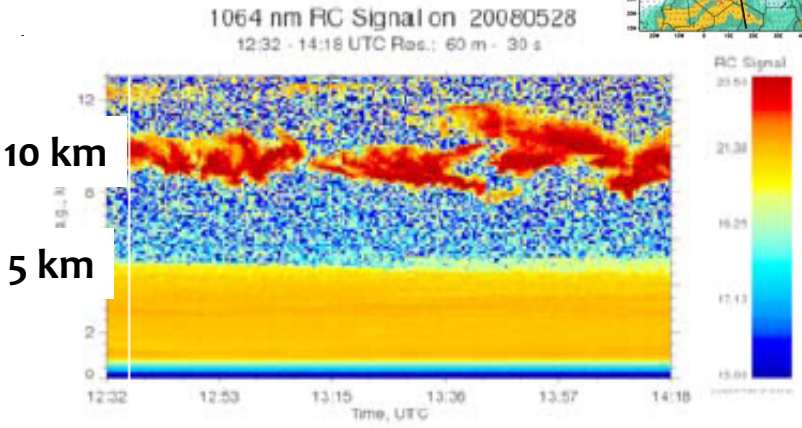








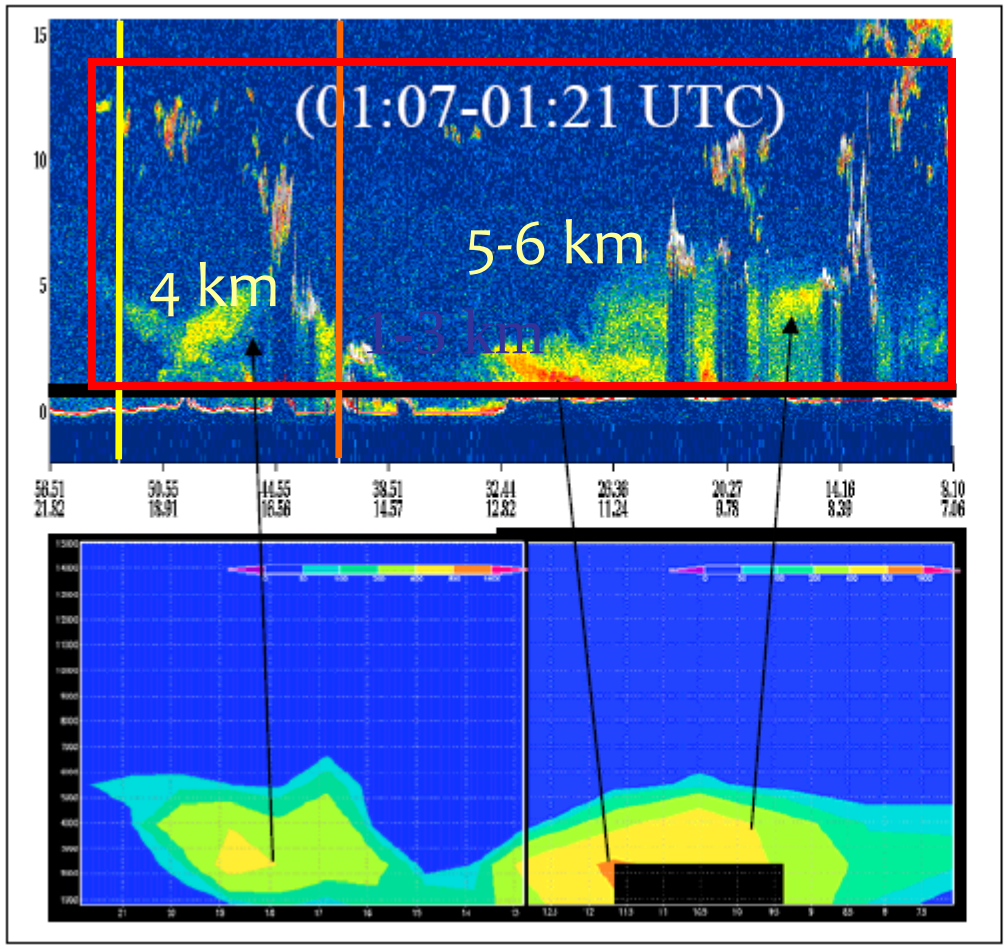


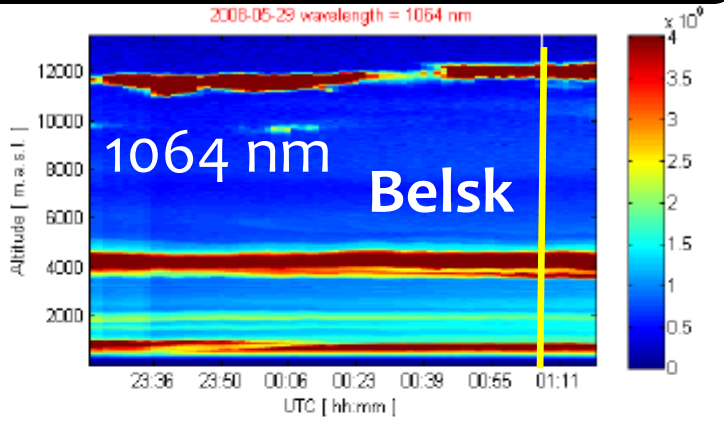


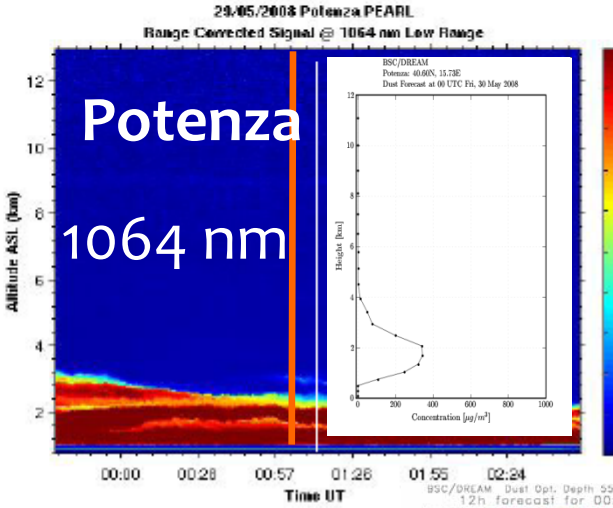
Leipzig

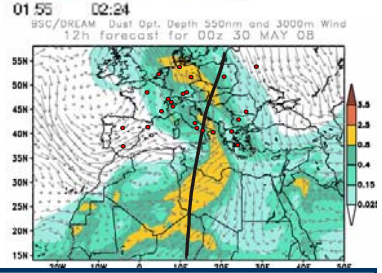
May 28, 12:26-12:40 UT

Belsk & Potenza EARLINET station, 30 May 2008









May 30, 01:07-01:21 UT

Saharan Dust Outbreak 26-30 May 2008

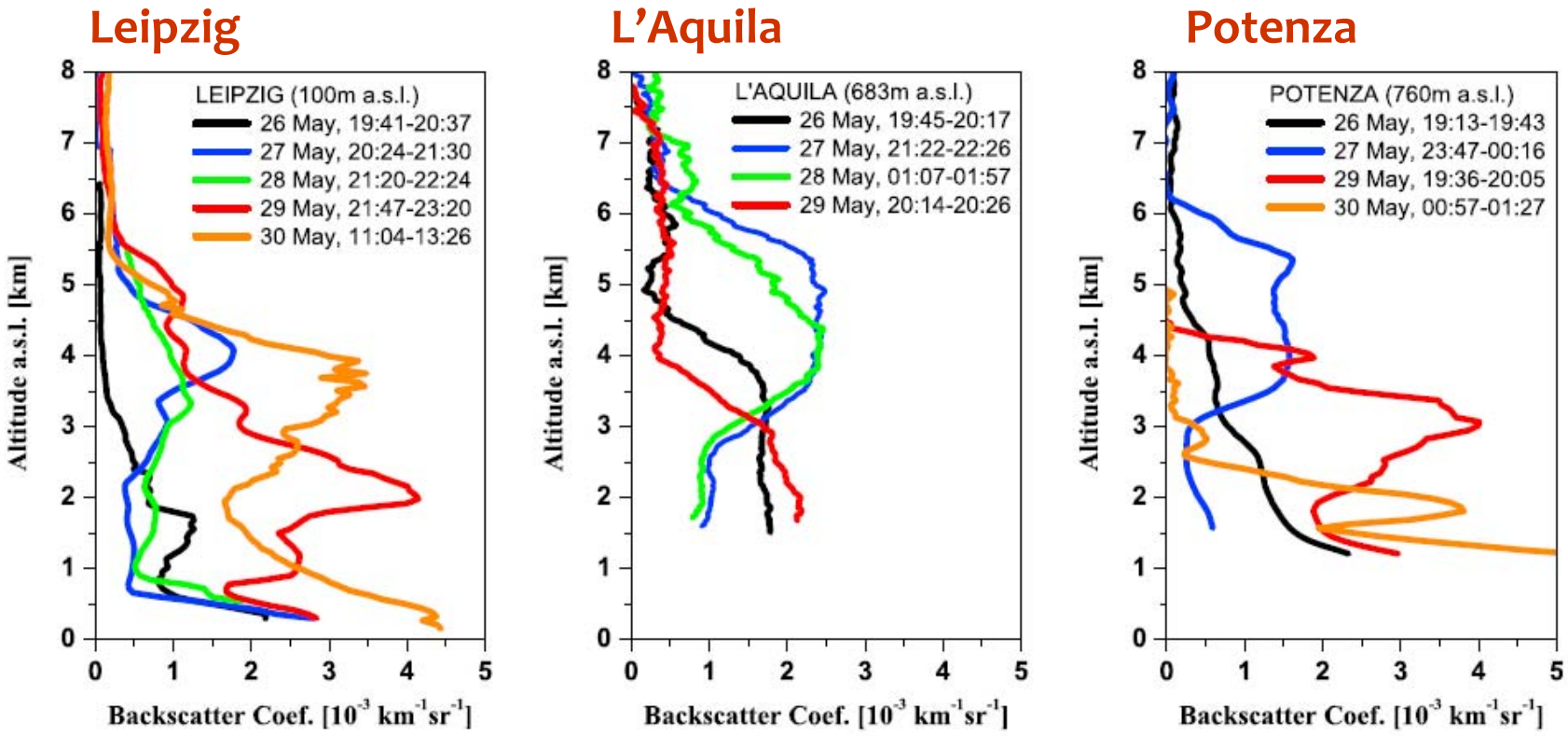
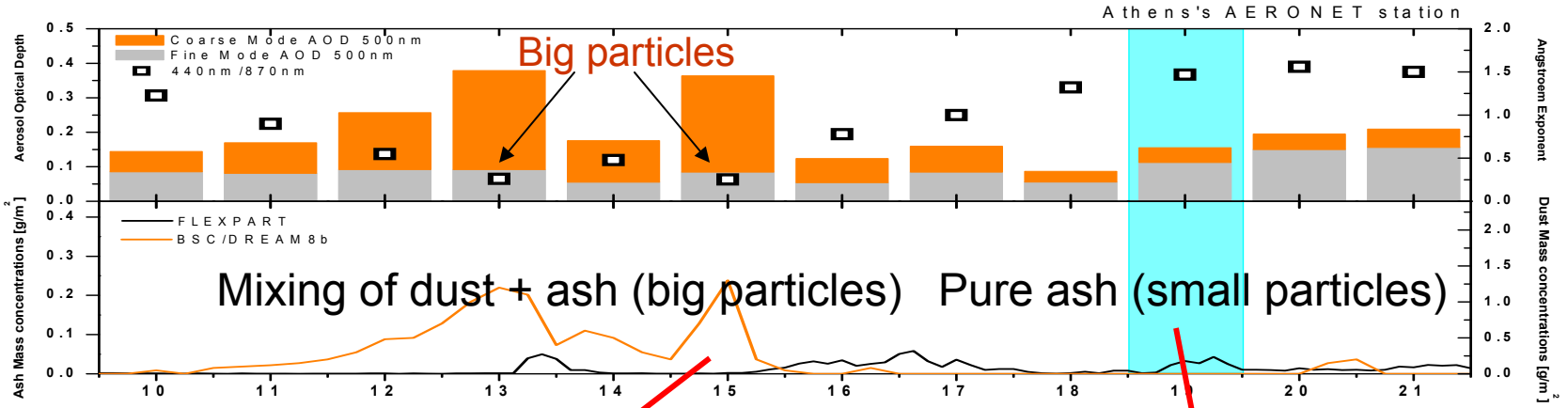


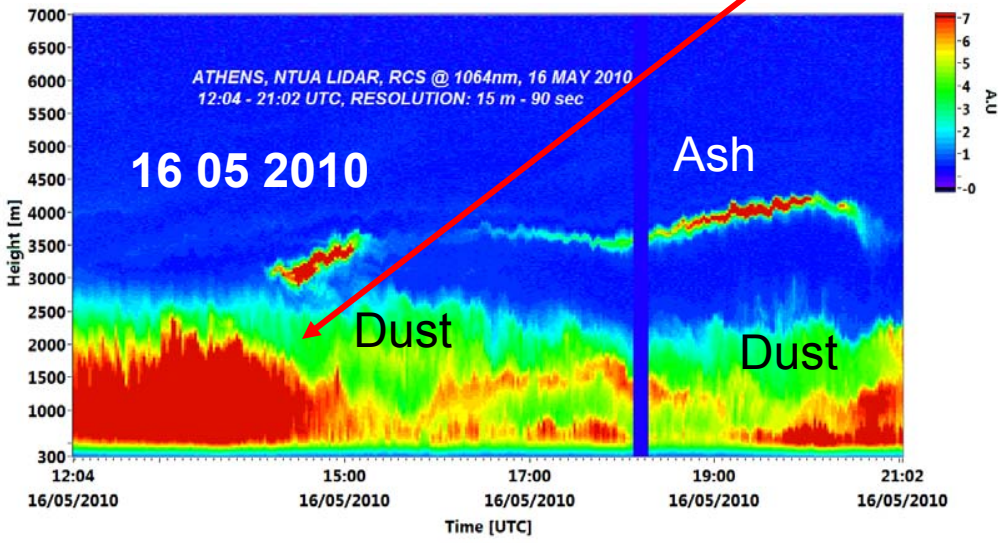
Figure 6. Backscatter coefficient profiles measured at the EARLINET stations (left) Leipzig (532 nm), (middle) L'Aquila (355 nm), and (right) Potenza (532 nm) during the major Saharan dust outbreak in the period 26–30 May 2008.

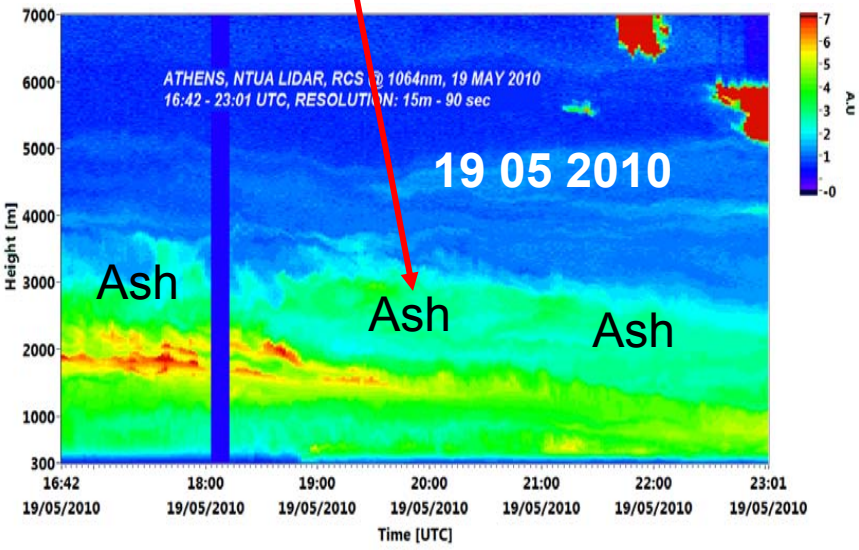
Pappalardo et al., *J. Geophys. Res.*, 115, D00H19, doi:10.1029/2009JD012147, 2010

Ash/Saharan Dust Outbreak May 2010 – Eyjaf volcano

ATHENS

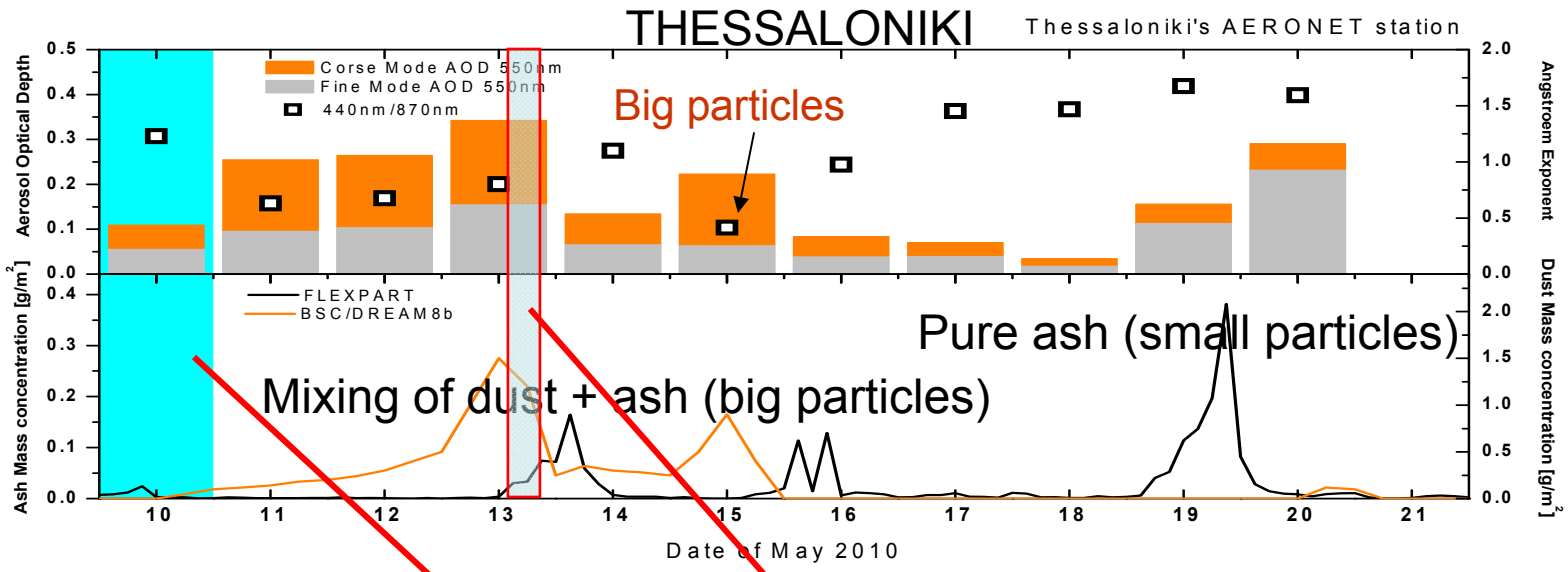


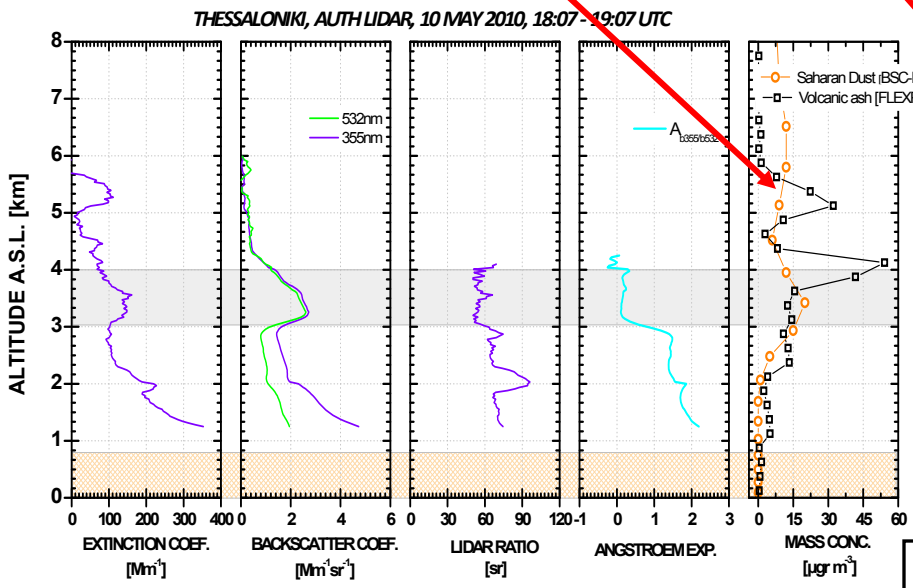


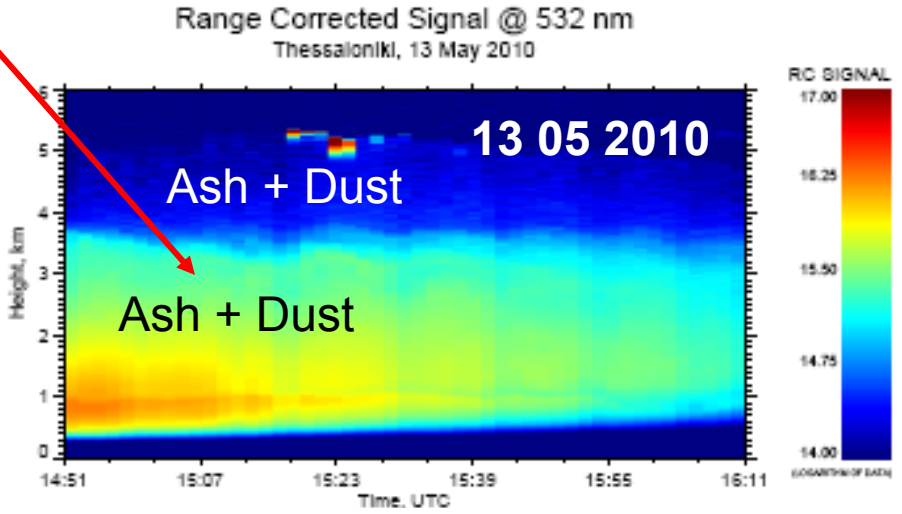


Papayannis et al., Atmos. Environ., (in press, 2011)

Ash/Saharan Dust Outbreak May 2010 – Eyjaf volcano

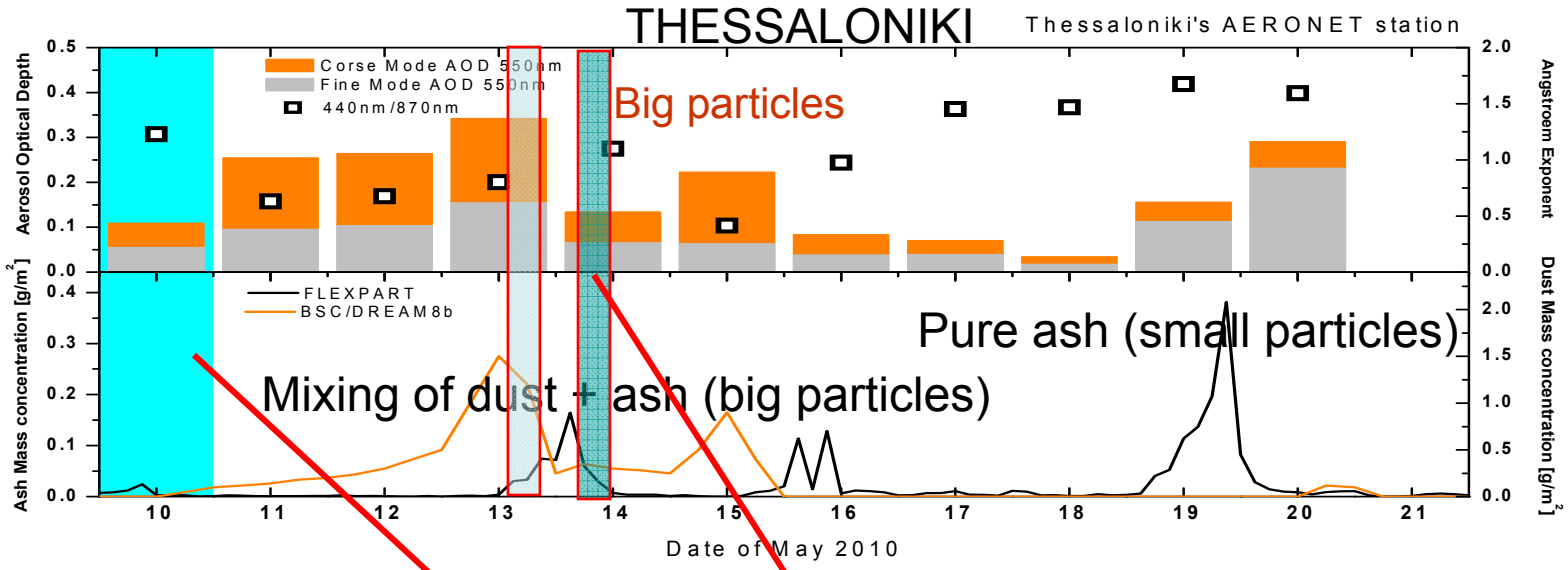


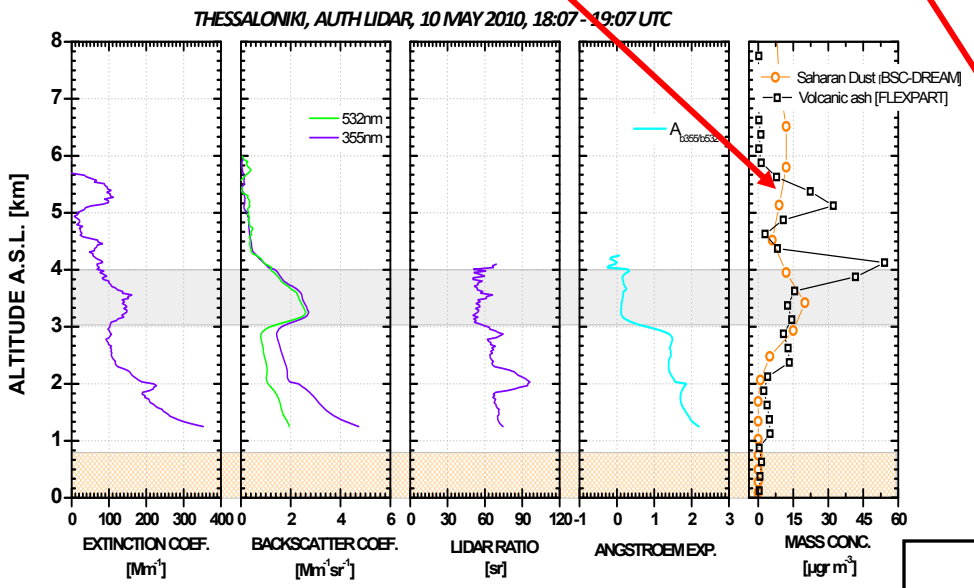


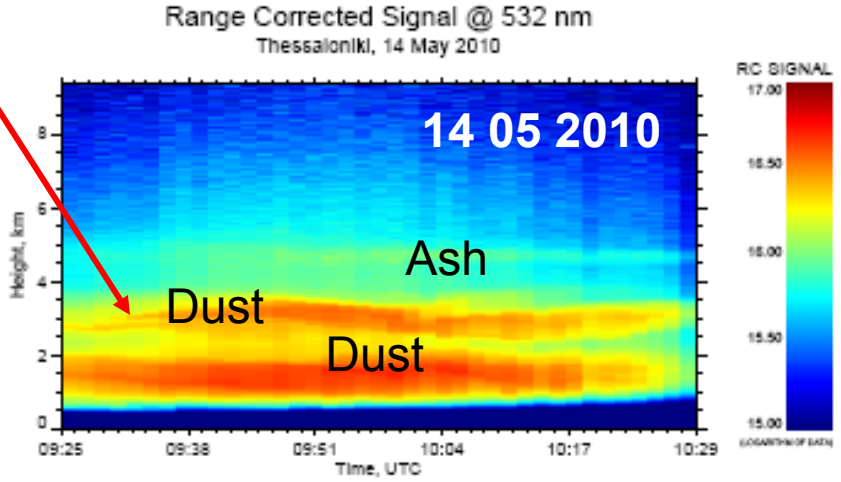


Papayannis et al., Atmos. Environ., (in press, 2011)

Ash/Saharan Dust Outbreak May 2010 – Eyjaf volcano







Papayannis et al., Atmos. Environ., (in press, 2011)

CONCLUSIONS [May 2008, May 2010]

- We presented 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 DREAM/BSC 3-D profiles and the CALIPSO & EARLINET aerosol vertical profiles showed a good (at least qualitative) agreement concerning the location – in time and space - of the various dust layers detected.

- Dust and ash was mixed over Greece during the Eyjaf volcano eruption on May 2010 (between 2-10 km). Good agreement between models and lidar observations was found.

GENERAL Conclusions (Dust outbreaks)

Geometric Characteristics of the dust layers (3856 dust profiles)

- Thickness (ranges) : **0.2-7.5 km** asl ; Mean value [1.5-3.4 km]/ depending on station
- Center of mass (ranges) : **0.85-8 km** asl. ; Mean value [2.5-6 km]/depending on station
- Dust aerosols can penetrate deeply up to central, Eastern and Northern Europe
  [up to 8-10 km height asl., where may co-exist with ice clouds]
- Transport time [**2-5 days**]

Optical Characteristics of the dust layers

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

- Mean lidar ratios: 49±10 sr in UV and 56±7 sr in VIS

-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)

Acknowledgments

All colleagues from the EARLINET TEAM
(with Special Thanks to **Anja Hiebsch**, **Lucia Mona, Elina Giannakaki** and **Rodelize Mamouri**).

Dr. Sara Basart (BSC/DREAM 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], the European Space Agency (ESA) under contract AO/1-5502/07/NL/HE and the EU-FP7 (ACTRIS project: Infra-2010.1.1.16., Grant No 262254).