School of Earth and Environment
INSTITUTE FOR CLIMATE AND ATMOSPHERIC SCIENCE
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Dust Variability

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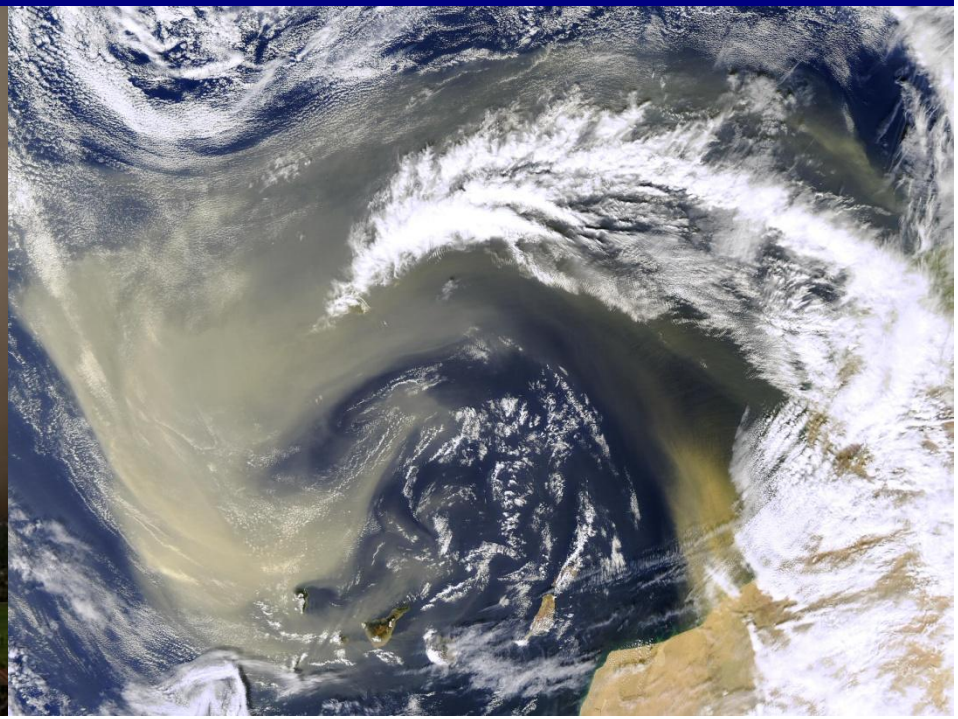
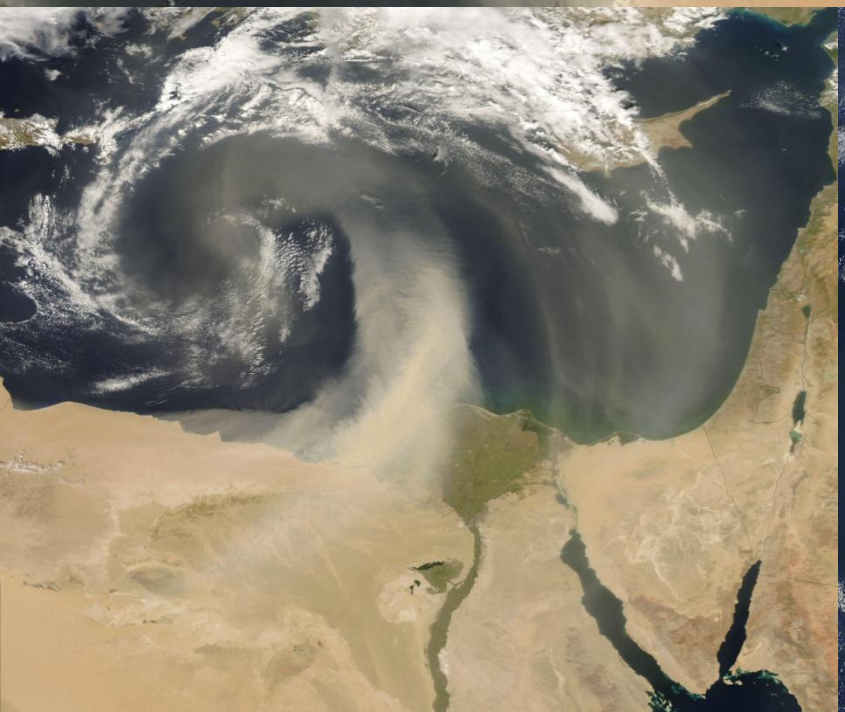


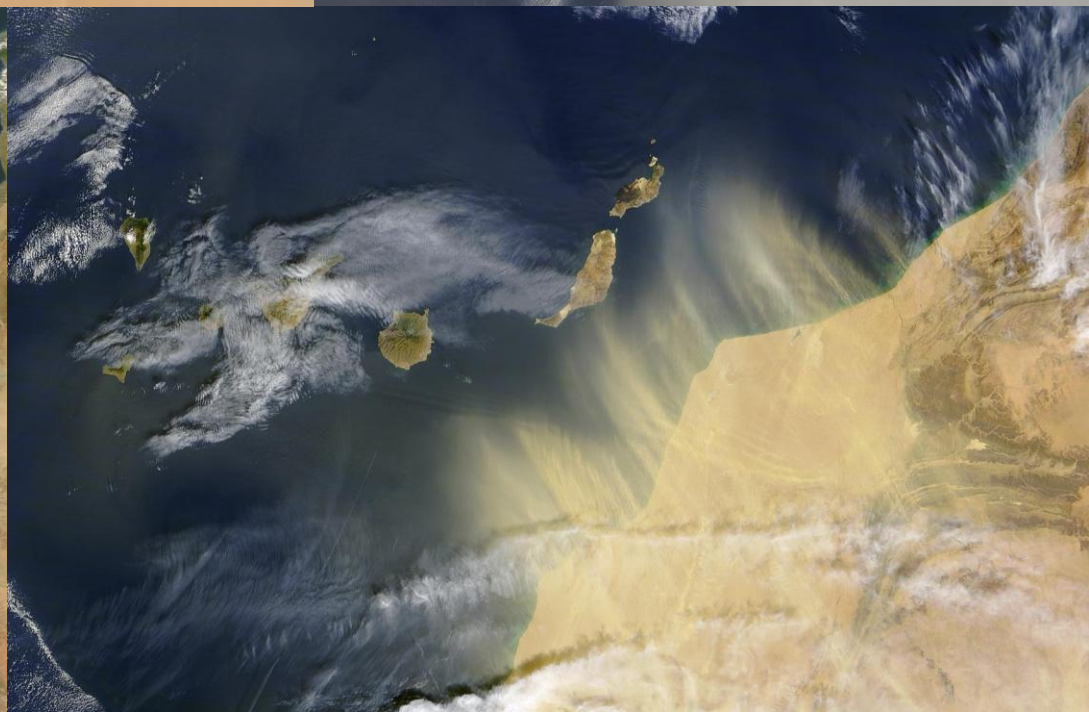

Australia, 23 Sept 2009


Niger, 2006


Texas, 1935


Phoenix, AZ, 2011





Variability of Dust

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- Temporal variability
  - Sub-daily and daily
  - Seasonal
  - Year-to-year
  - (Glacial – interglacial changes)

- Spatial variability
  - Changes in local dust source activity
  - Sediment supply and/or wind regime

Temporal Variability: Scales

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- Daily time scale
  - Controlled by synoptic-scale and meso-scale meteorology
  - Relevant for regional forecast
- Seasonal time scale
  - Controlled by meteorology, i.e. dominant wind regimes (e.g. Harmattan)
  - Controlled by surface characteristics like vegetation, agriculture
- Interannual and decadal time scale
  - Controlled by climate regime and surface modifications
- Glacial-Interglacial time scale
  - Controlled by climate and source areas

Temporal Variability: Short-term

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- Hourly and daily variability in dust atmospheric concentration
  - sub-daily variability in dust emission fluxes
  - transport of dust
- Important for forecasts
- Observations:
  - SYNOP and METAR: report of horizontal visibility, current weather (WX)
  - AERONET sun-photometer network: Aerosol Optical Thickness (AOT)
  - MSG IR dust product (15-minute)

Sun-Photometer AOT

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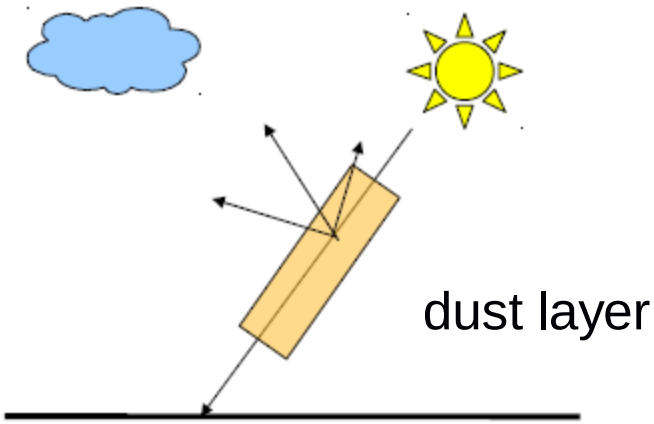
- AOT is a measure for the transmissivity of the atmosphere
- Ratio of radiation measured at surface and radiation at top of atmosphere
- AOT represents the atmospheric aerosol content – large values mean high aerosol loading



Cimel at Zouerat, 2011

Short-term Variability: Sun-Photometer Measurements

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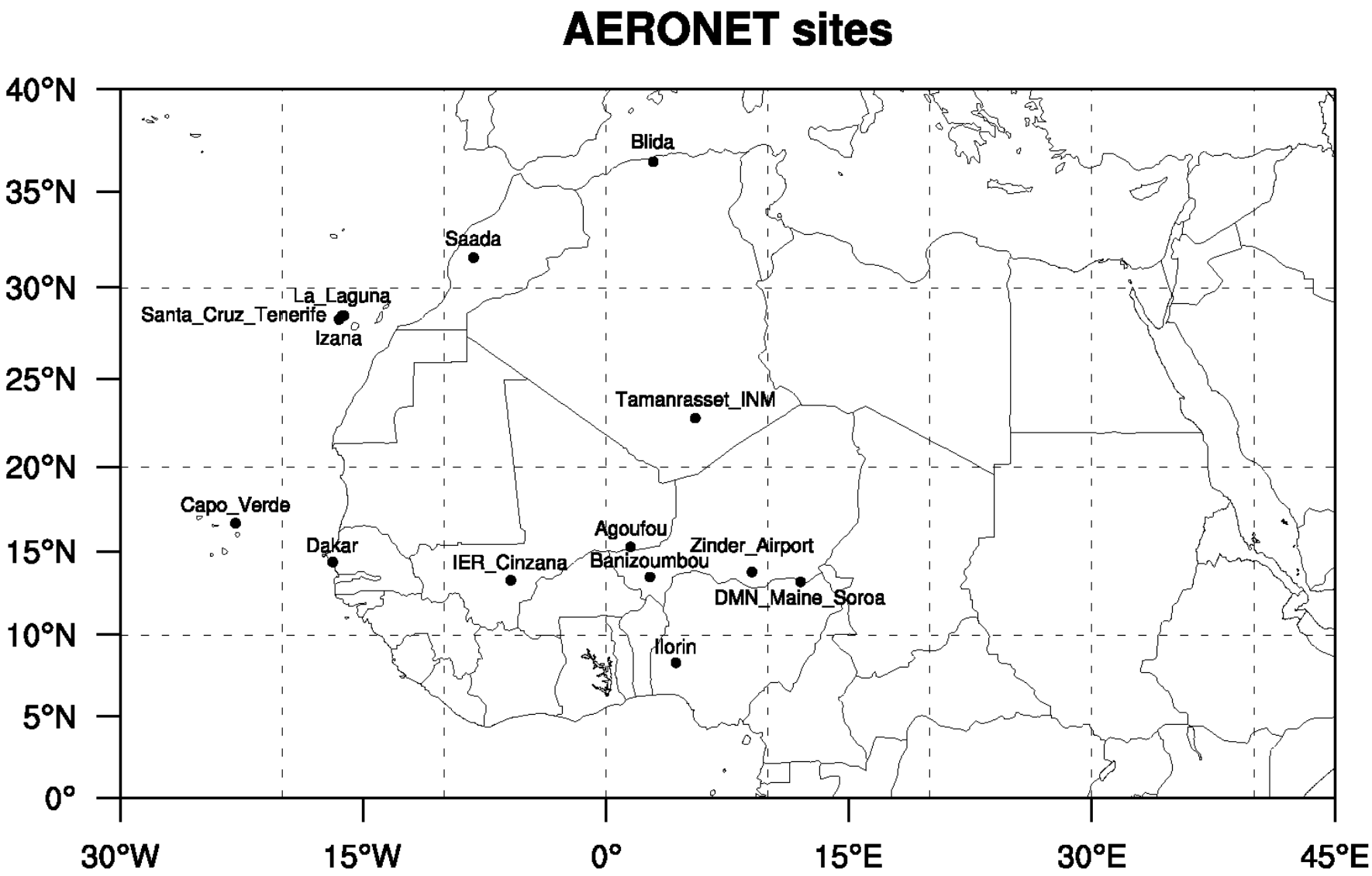

selected AERONET stations, http://aeronet.gsfc.nasa.gov

Short-term Variability: Sun-Photometer Measurements

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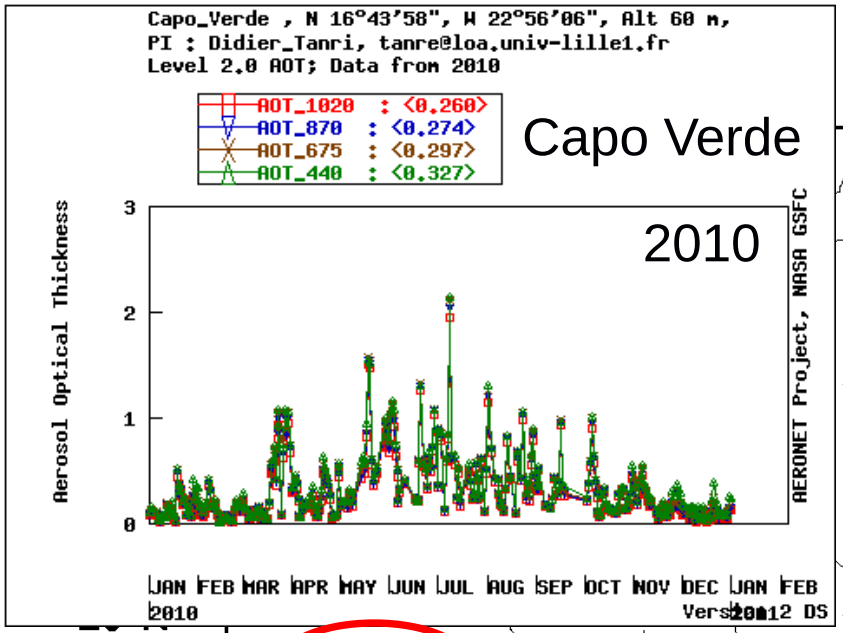

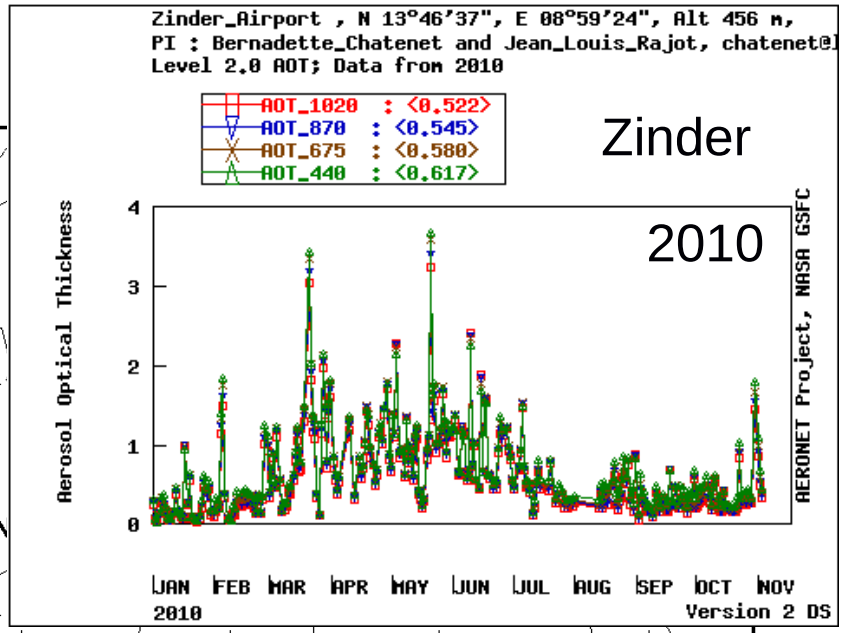

selected AERONET stations, http://aeronet.gsfc.nasa.gov

Short-term Variability: Sun-Photometer Measurements

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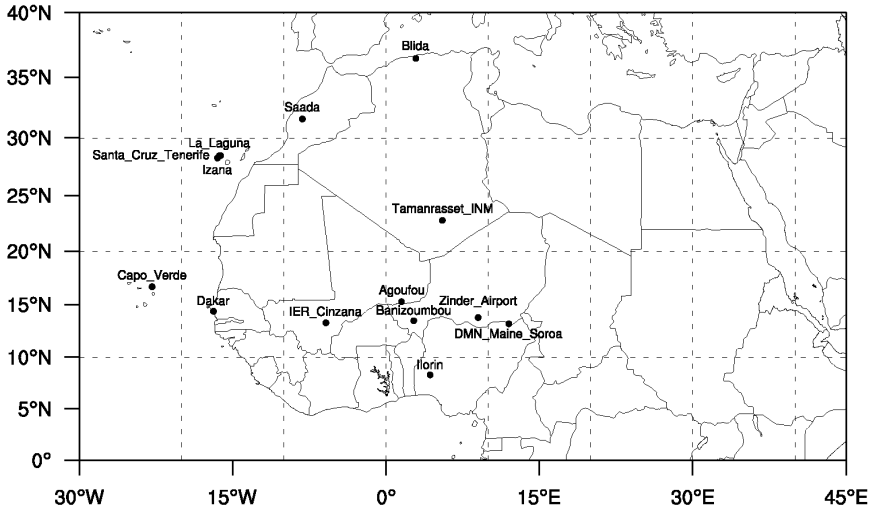
- AERONET provides quantitative information on atmospheric dust load
- Sub-daily temporal resolution revealing temporal changes in atmospheric dust loading, e.g. approaching dust front
- Transported dust
- Due to wind transport, information on dust source variability is limited



Precondition for Dust Emission

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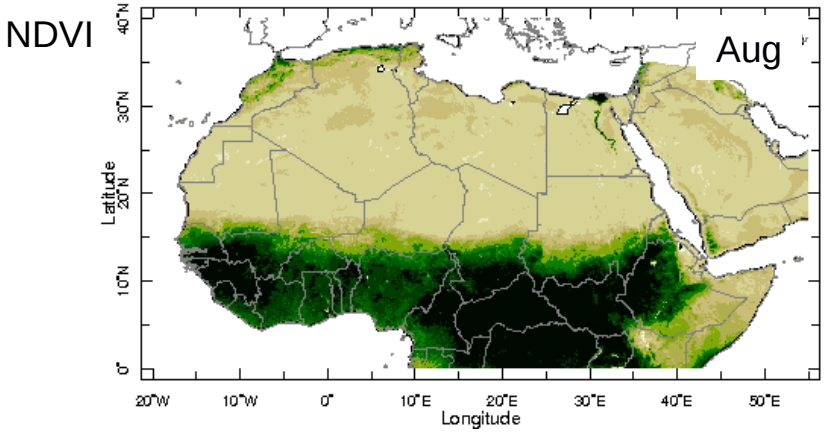
1. Suitable surface conditions
   - Sparse vegetation cover
   - Low soil moisture
   - Smooth surfaces
   - Fine, loose soil particles (e.g. dry river beds, lake sediments, fields)



2. Strong surface winds
   - Frontal systems
   - Down-drafts from meso-scale convective systems (MCS), Haboobs
   - Boundary layer turbulence

Temporal Dust Variability

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- Day-to-day dust emission
  - Dust emission related boundary layer dynamics
  - Break-down of nocturnal LLJ
- Seasonal dust stroms
  - Habbobs
  - Mediterranean Cyclone
- Extra-ordinary dust fronts
  - Sub-continental scale
  - ~ 0.5 in a year

Day-to-Day Dust Emission: Low-Level Jet

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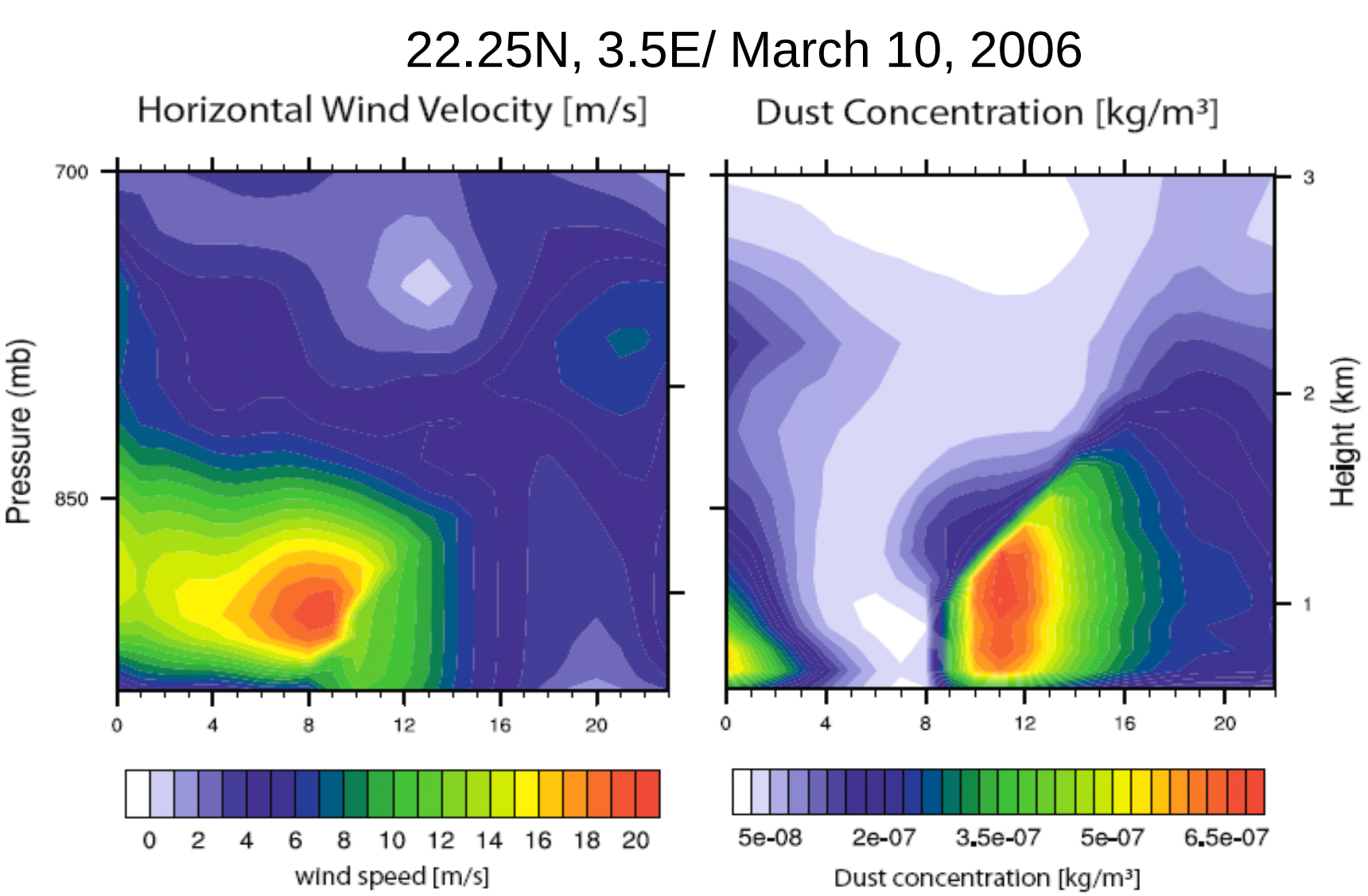

Schepanski et al., 2009

Day-to-Days Dust Emission: LLJ

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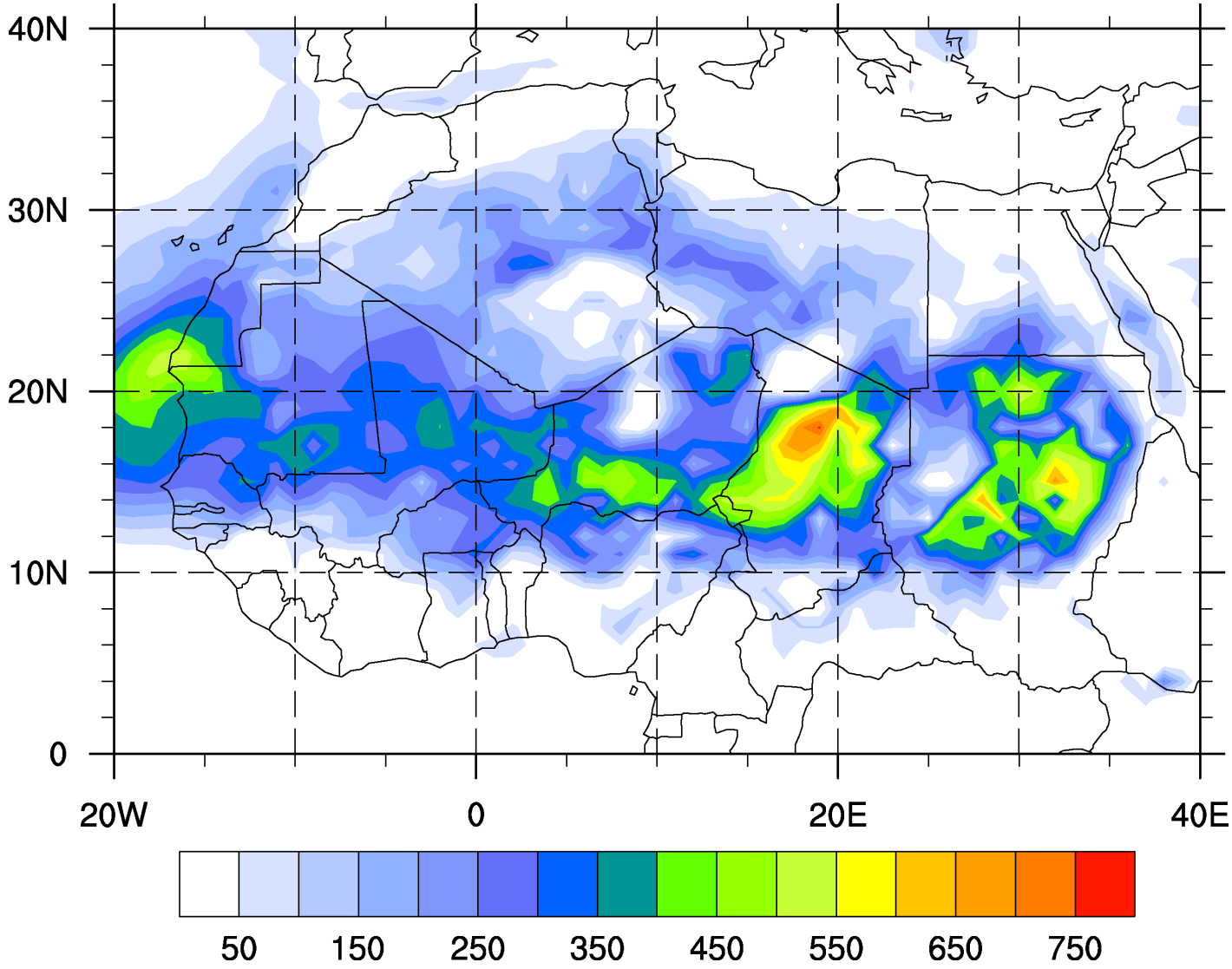
Number of LLJs form ERA-Interim 06UTC wind fields, 03/2006-02/2010



Temporal Variability: Saharan Dust Source

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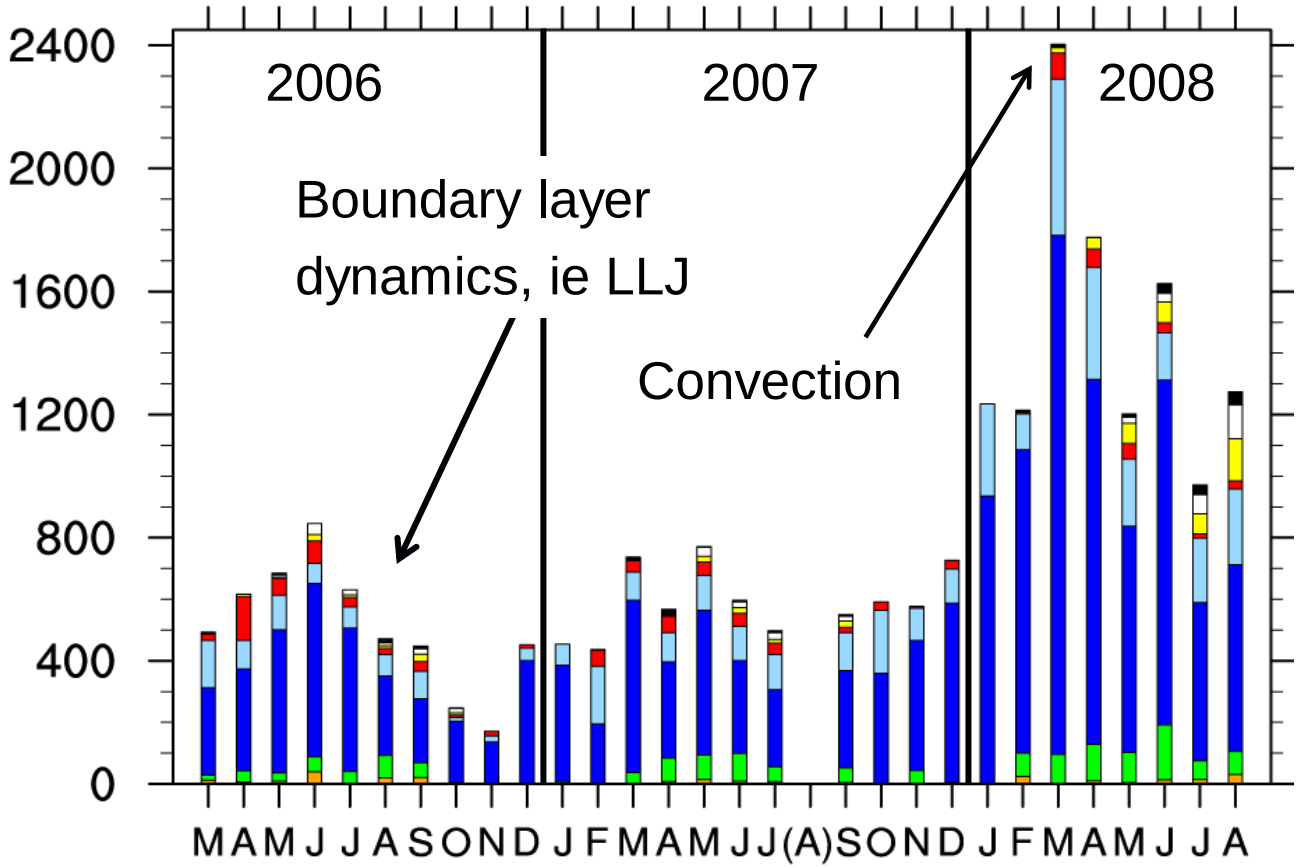

Time of day UTC	Portion [%]
00-03	2
03-06	5
06-09	65
09-12	16
12-15	8
15-18	1
18-21	2
21-00	1

- Number of dust source activations per 1°x1° grid cell per time slot and per month
- Most dust emissions start between 06 and 09 UTC

Schepanski et al., 2009

Seasonal Dust Events: Haboob

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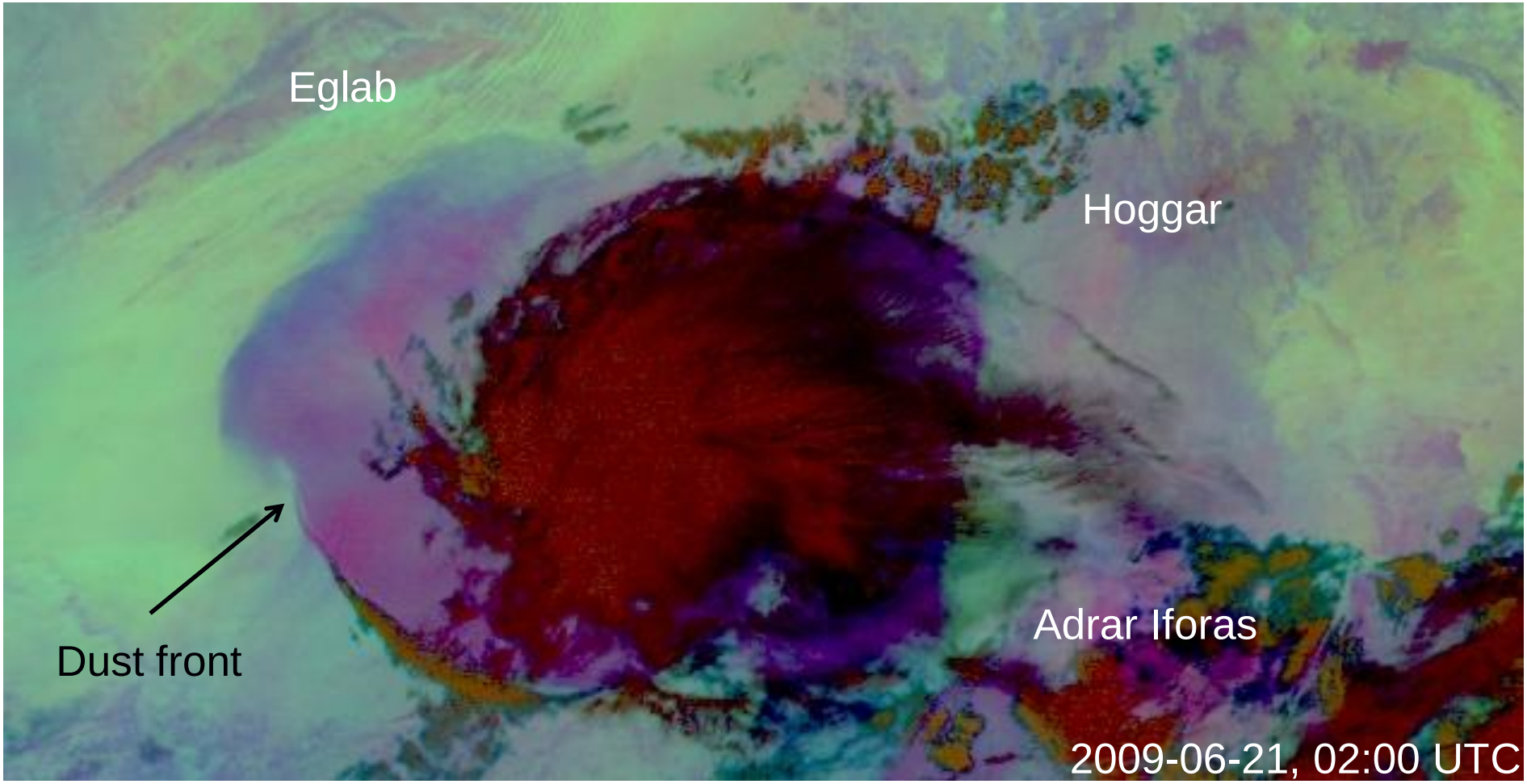

MSG IR dust index, copyright EUMETSAT, 2009

Seasonal Dust Events: Haboobs

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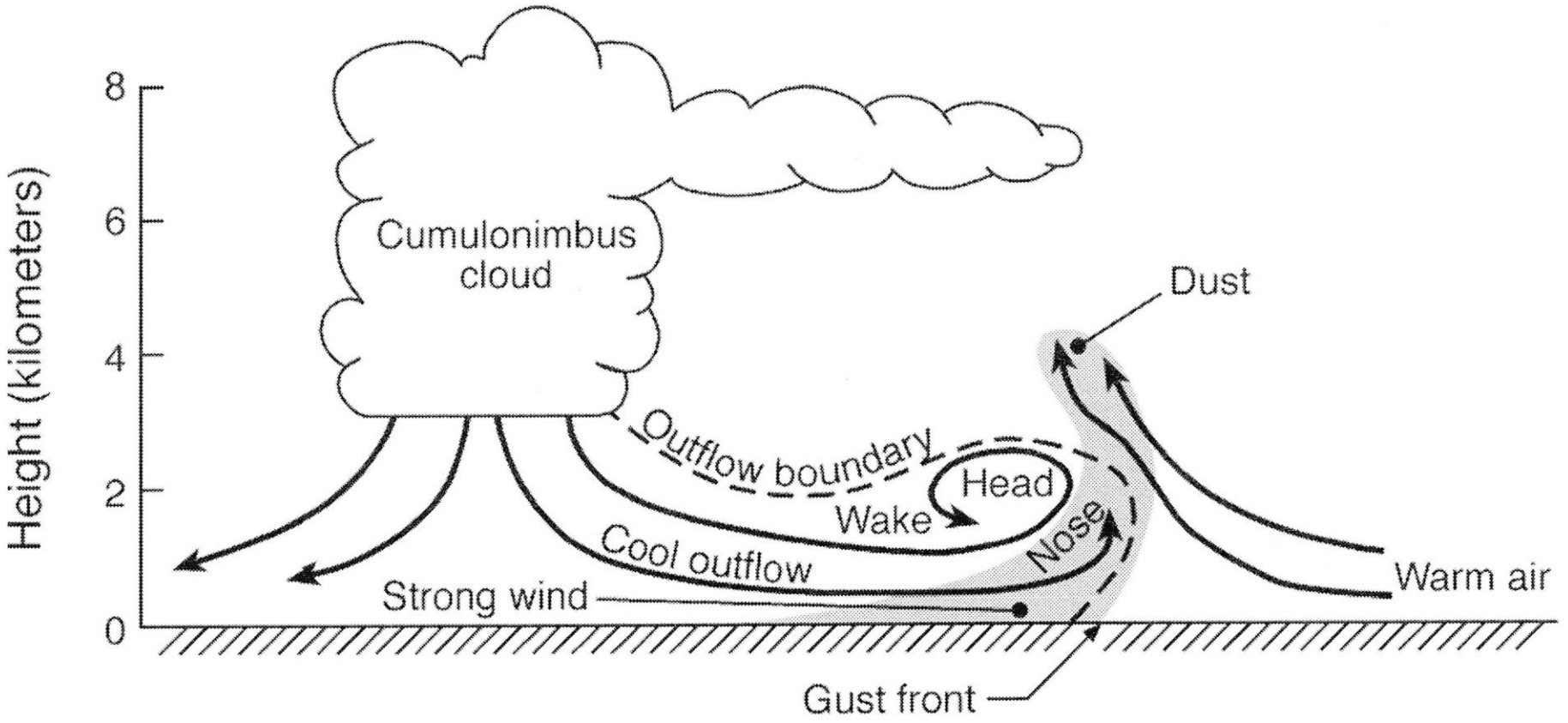
- Dust front initiated by down-drafts from moist convection -



Warner, 2004

Dust related to Cyclones

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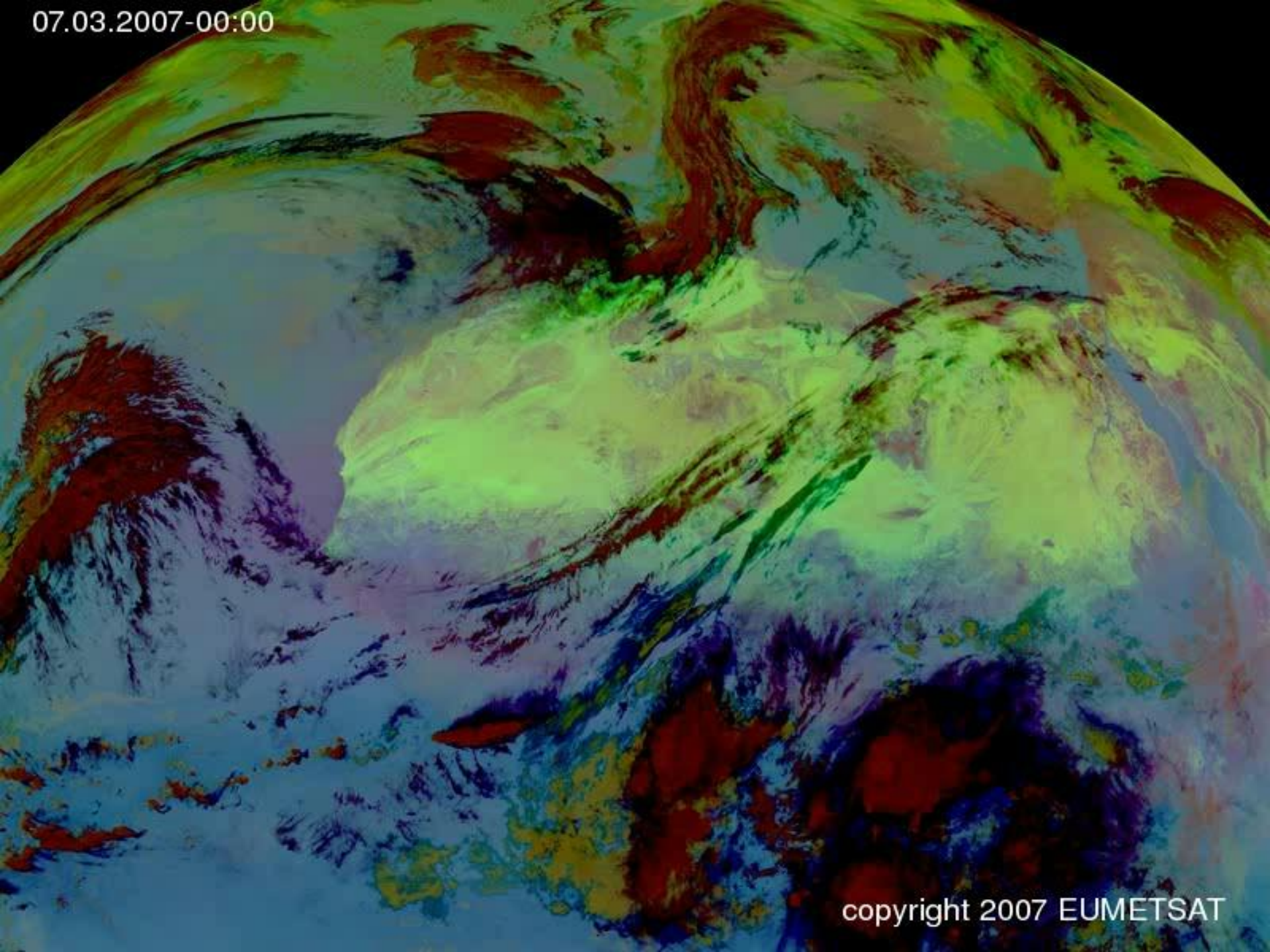
- Wind/gusts associated with front passage

- Sharav cyclones: lee-cyclones enhanced by baroclinity
  - Fast eastward moving (> 10m/s)
  - Active warm front with high temperatures
  - Shallow cold front
  - Heavy dust fronts, low visibilities
  - Frequently observed along Mediterranean coast


07.03.2007-00:00
copyright 2007 EUMETSAT

Extra-Ordinary dust events

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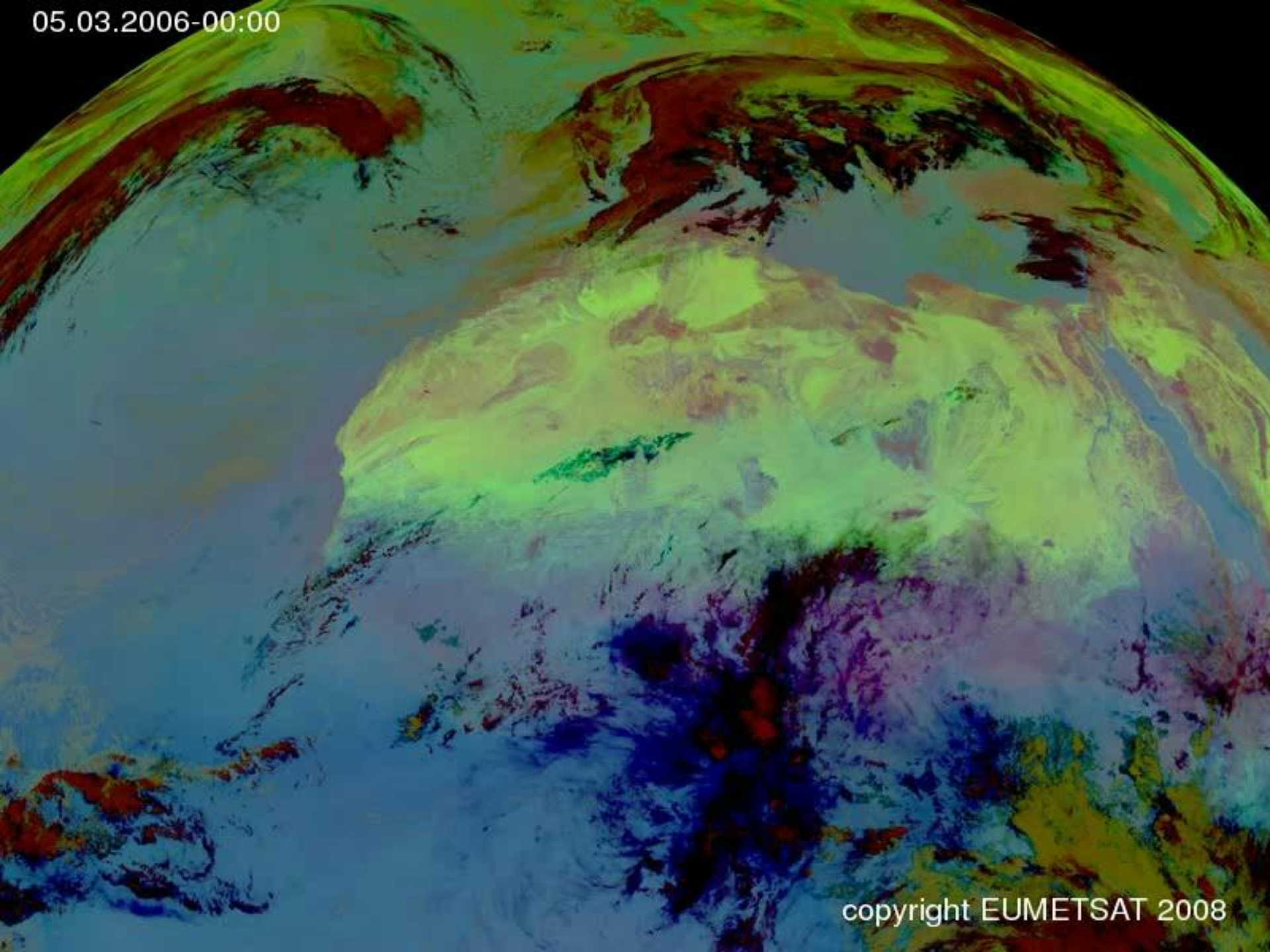
- Mostly initiated by mid-latitude trough over Mahgreb
- About one in two years: 2004, 2006, 2007, 2010
- Dust front travelling fast over North Africa towards
- Associated with high dust concentrations


05.03.2006-00:00
copyright EUMETSAT 2008

Short-term Dust Variability: Transport

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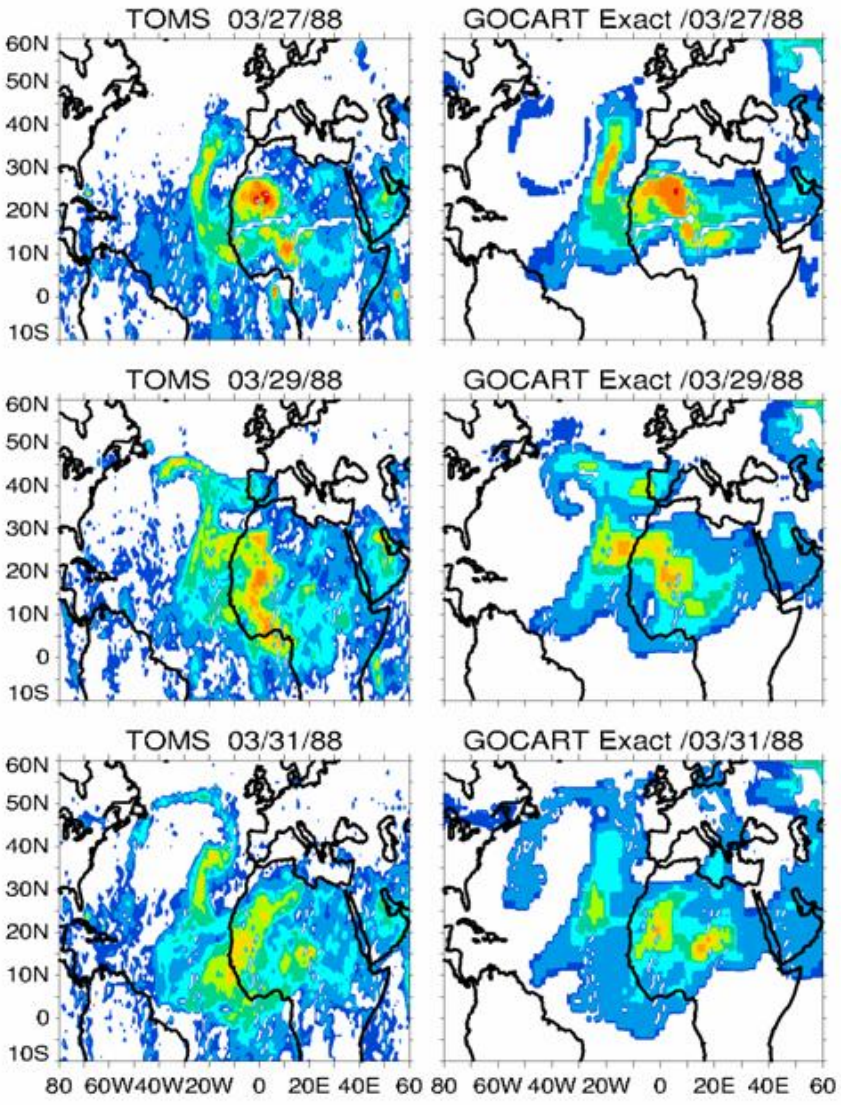
Evolution of a dust event – model vs. Satellite:

- After emission, transport of dust entrained in higher atmospheric layers is controlled by large-scale circulation pattern
- Dust transport captured well by models



Ginoux and Torres, 2003

Short-term Dust Variability: Summary

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- Dust emissions are mostly caused by short-term meteorological processes.
- Variations in dust transport at the daily and sub-daily time scale is relevant for dust forecasting.
- Skills of models to correctly simulate (sub-) daily dust events depends on the model's ability to reproduce the different meteorological events forcing dust emission.
- Dust transport can usually be captured well by forecast models.

Seasonal Variability

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1. Atmospheric seasonality
    - Meso-scale atmospheric circulation, e.g. West African Monsoon circulation, mid-latitude troughs
    - Wind for dust emission (wind velocity)
    - Wind for dust transport (wind direction)

2. Seasonal variability in soil characteristics
    - Vegetation cover (rain season vs dry season)

Seasonal Variability: Dust Sources

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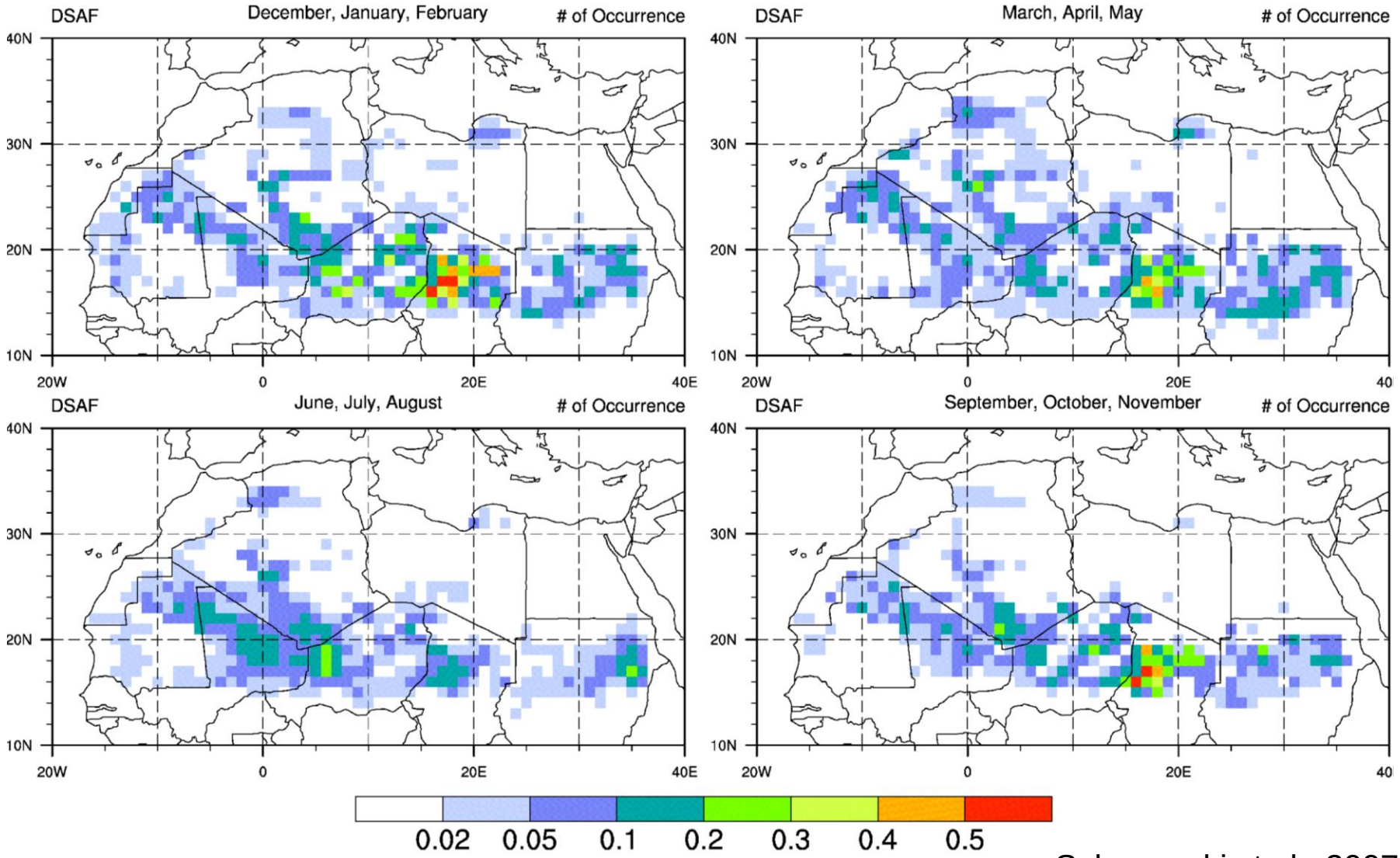

Schepanski et al., 2007

Seasonal Variability: AOT

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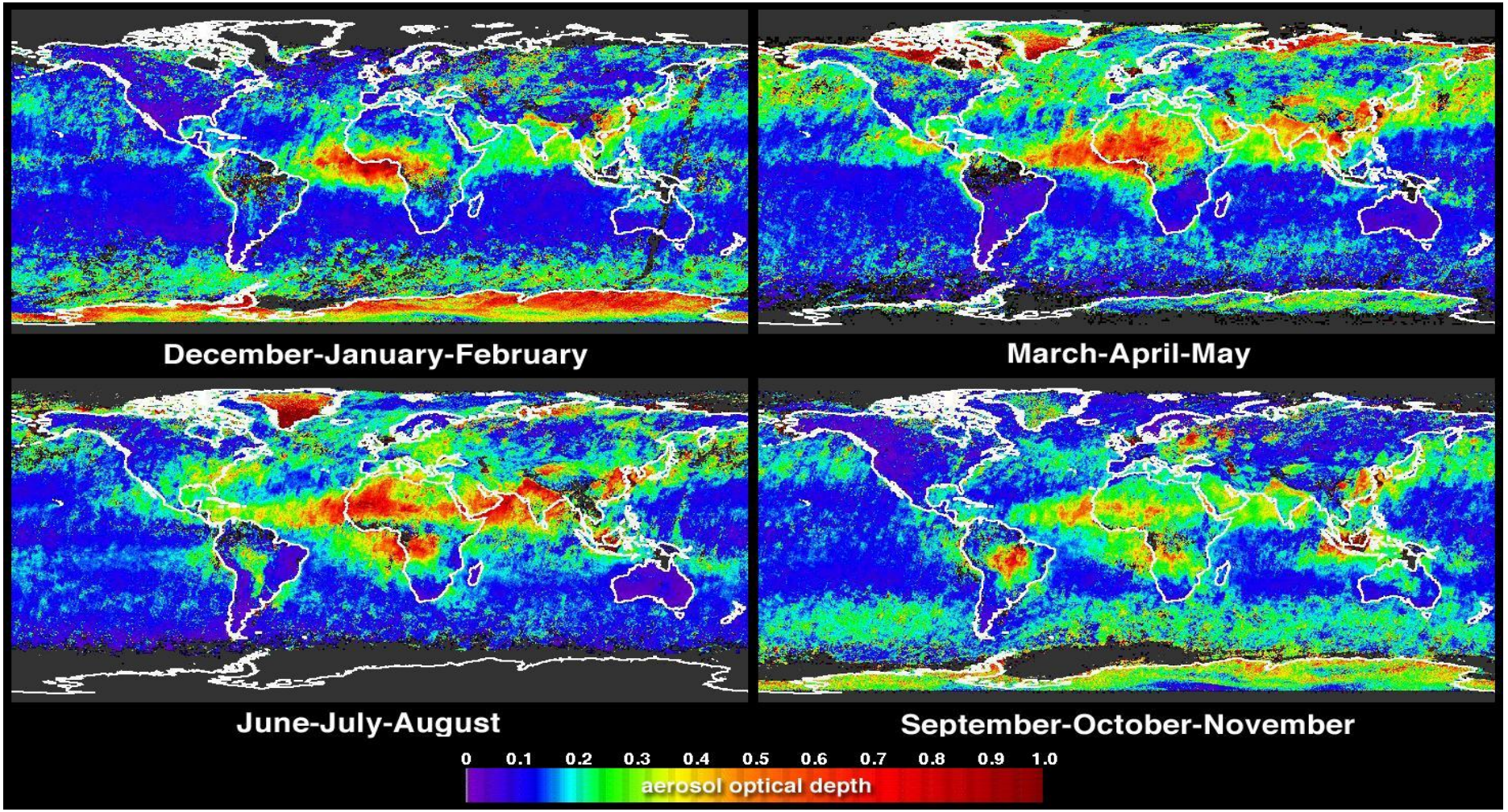
MISR AOT Dec 2001 – Nov 2002



http://eosweb.larc.nasa.gov

Seasonal Variability: Atmospheric Circulation

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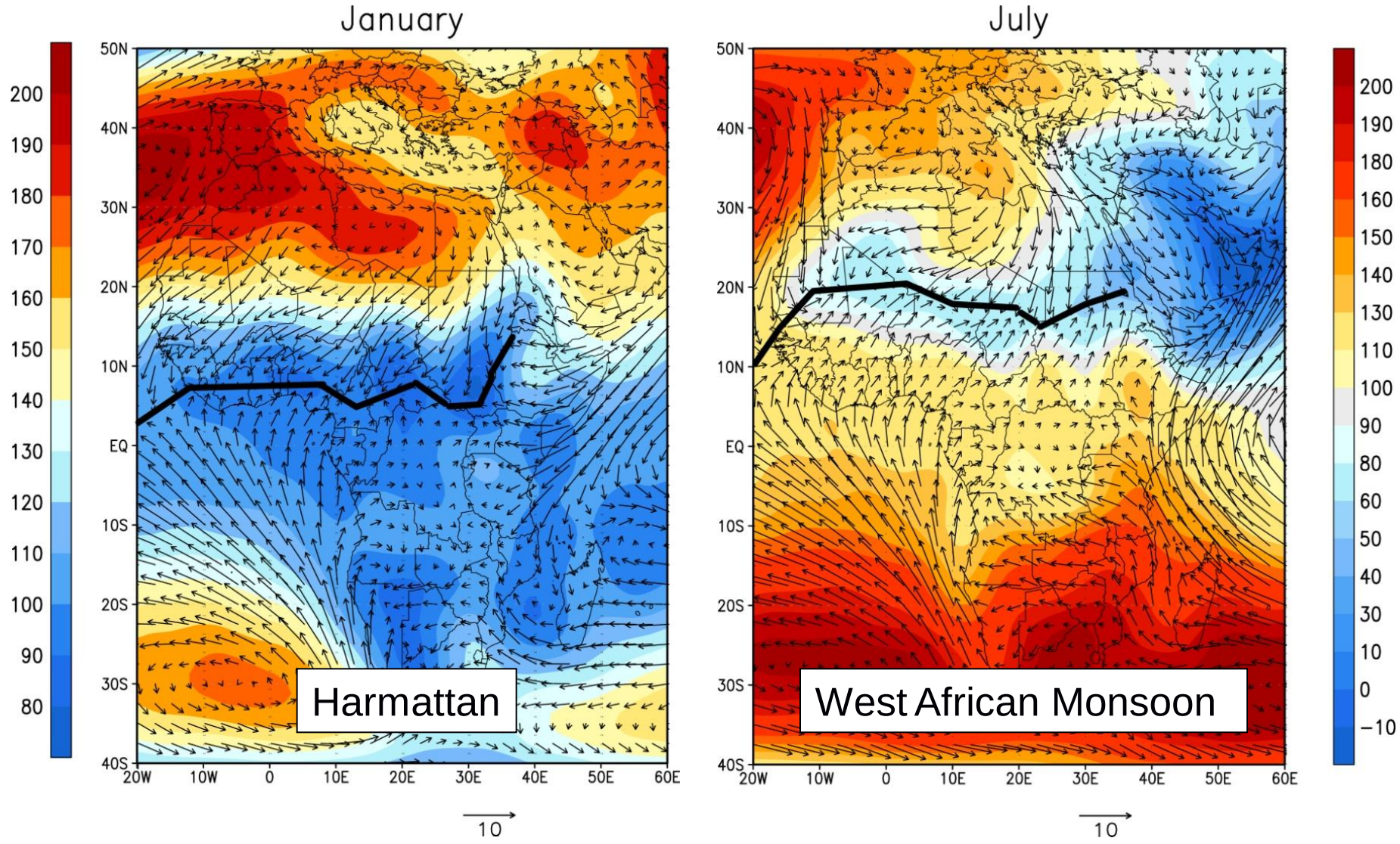

Seasonal Variability: Dust Transport

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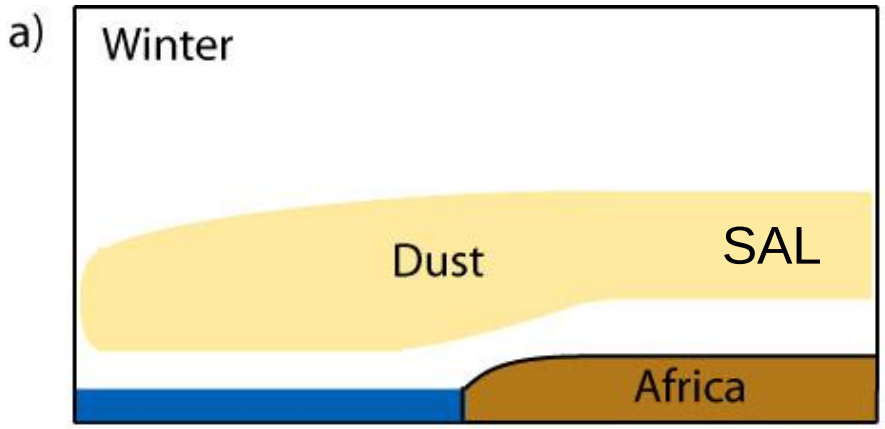

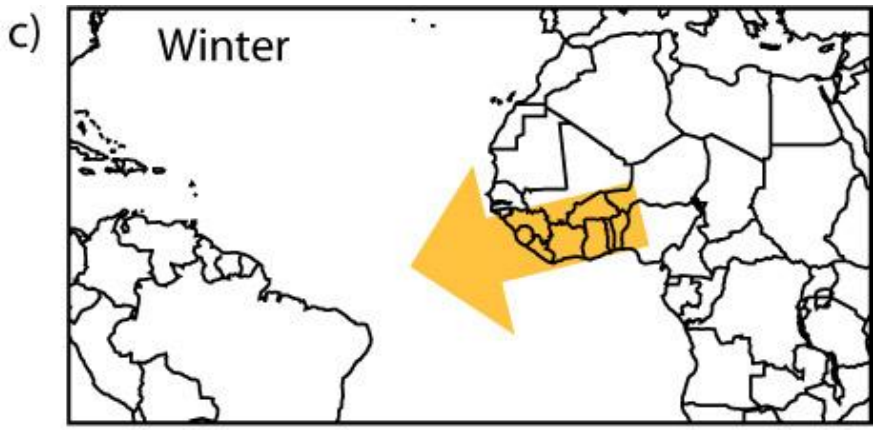

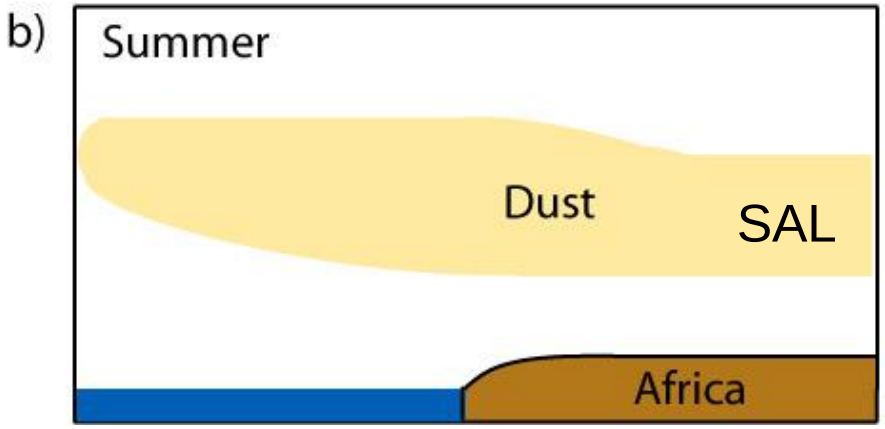

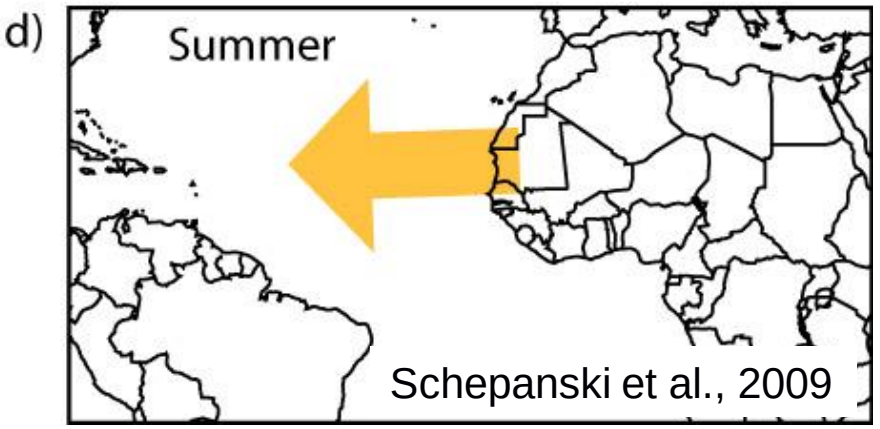

- Winter: dust transport within marine boundary layer
- Summer: dust transport above marine boundary layer

Seasonal Variability: Dust Transport

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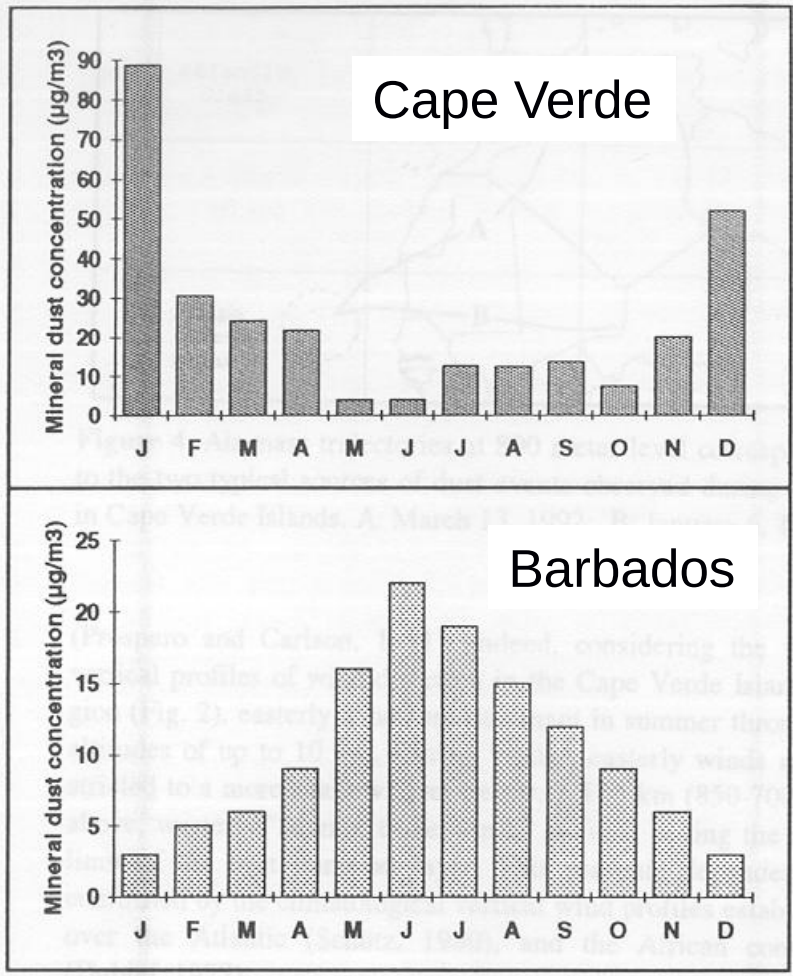
- Clear seasonal signals can be detected in dust concentration measurements

- Seasonal changes
  - Source areas
  - Shift in transporting wind regime
  - Change in height of dust transporting layer



Chiapello et al., 1995

Seasonal Variability: Summary

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- Seasonal changes in dust are controlled by
  - Seasonal meteorology
  - Vegetation phenology
- Seasonal variability in dust is well characterised
  - Long-term measurements: ground-based and space borne
- Most often, dust maxima are observed in spring/early summer

Year-to-Year Variability

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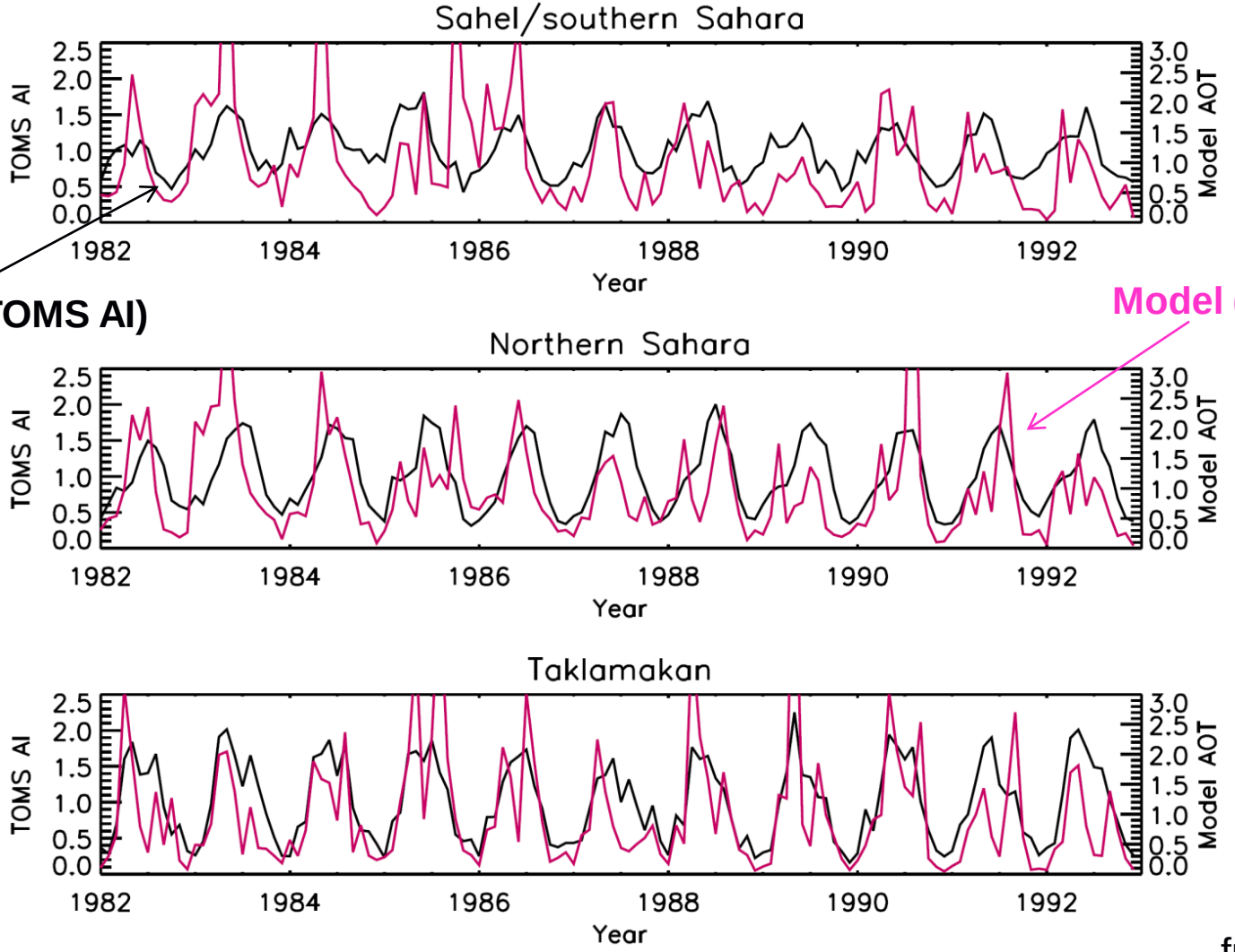
Model results from TM3/ERA-15



Satellite (TOMS AI)

Model (AOD)

from I. Tegen

Decadal Dust Variability

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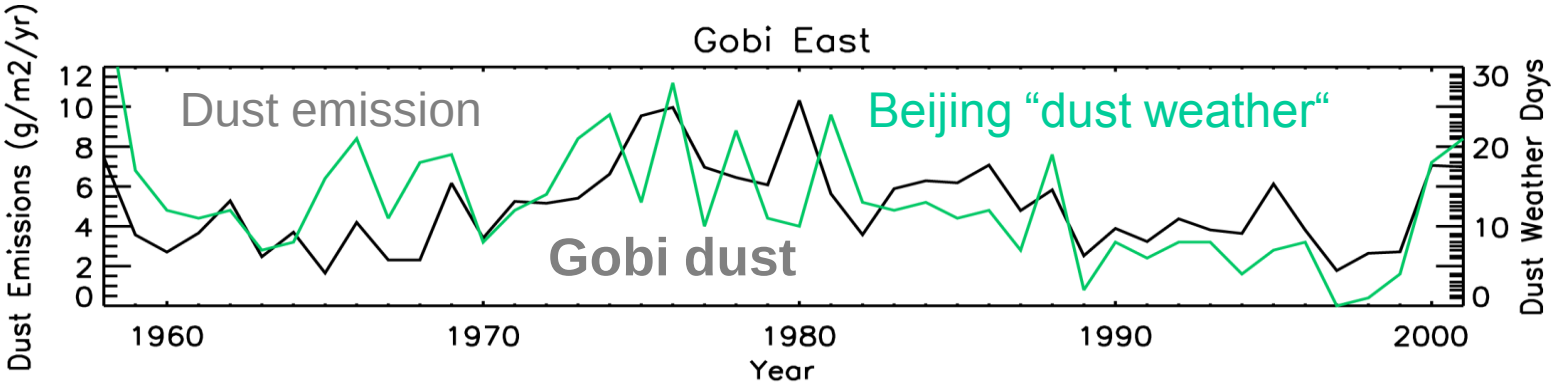

from I. Tegen

- Interannual/decadal change in dust concentration controlled by changes in dust sources
- Changes in meteorology and surface conditions possible causes

Dust Variability: Human Impact

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- Impact on soil surfaces
  - Cultivation in arid and semi-arid regions
  - Overgrazing
  - Deforestation
  - Degradation of vegetation variety
  - Soil erosion
  - Road tracks
- Impact on climate
  - Changes in natural vegetation
  - Changes in local meteorology (precipitation, wind)

Dust Variability: Agriculture

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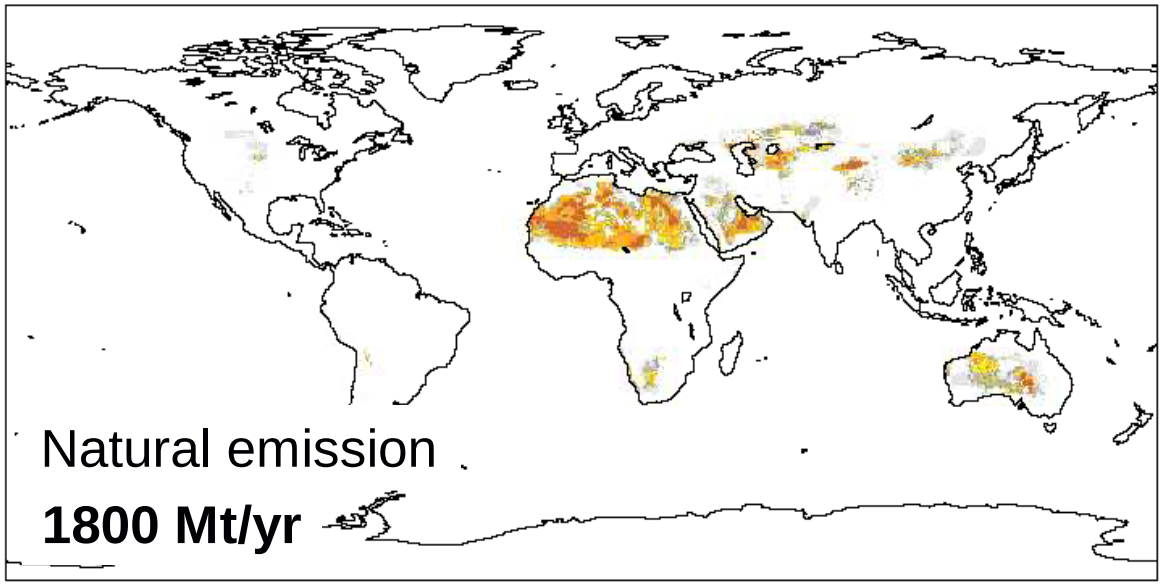
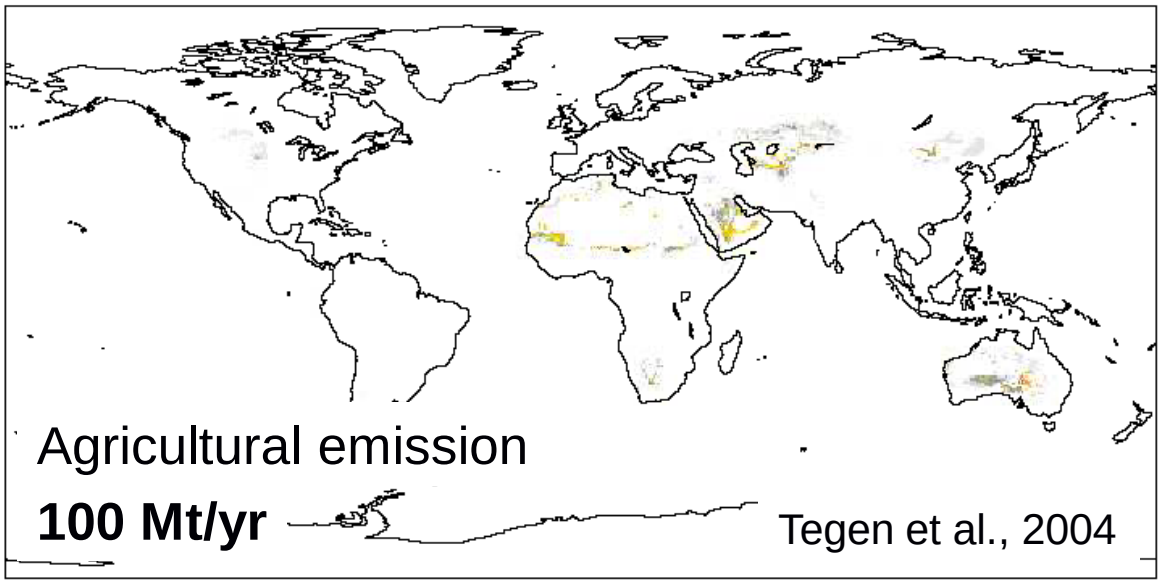
- Satellite z_0
- ECMWF ERA15
- Year 1987
- Contribution of agricultural emission: ~6%



- Global estimates of dust fluxes from anthropogenic disturbed soil varies from 0-50%



Year-to-Year Variability: Summary

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- Interannual changes in dust are less well understood than seasonal changes.

- Changes in Asian dust loads can be related to changes in large-scale circulation patterns.

- Human activities leading to disturbance of soil surfaces may lead to enhanced dust emissions – the magnitude of this effect is not yet known.

Summary

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- Dust varies not only spatially but also temporally at many scales.
- Daily time scale is relevant for regional forecasts, controlled by meteorology.
- Seasonal changes in dust are well characterised, controlled by meteorology and vegetation phenology.
- Interannual and decadal changes are controlled by climate and surface modification.