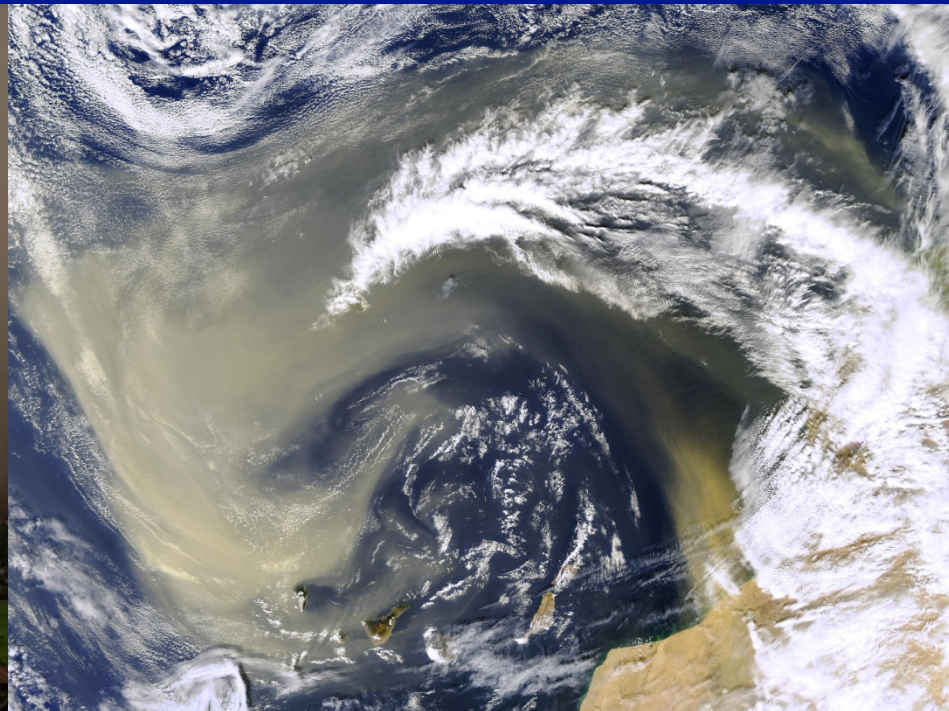


Dust Variability

Kerstin Schepanski

k.schepanski@leeds.ac.uk





Australia, 23 Sept 2009



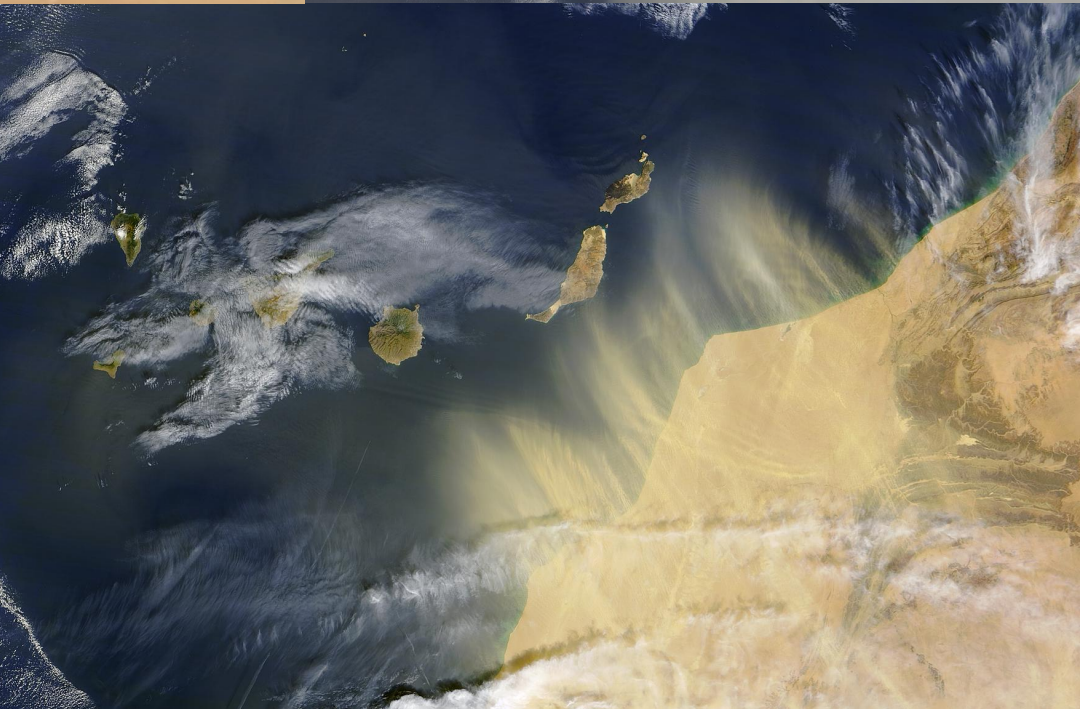
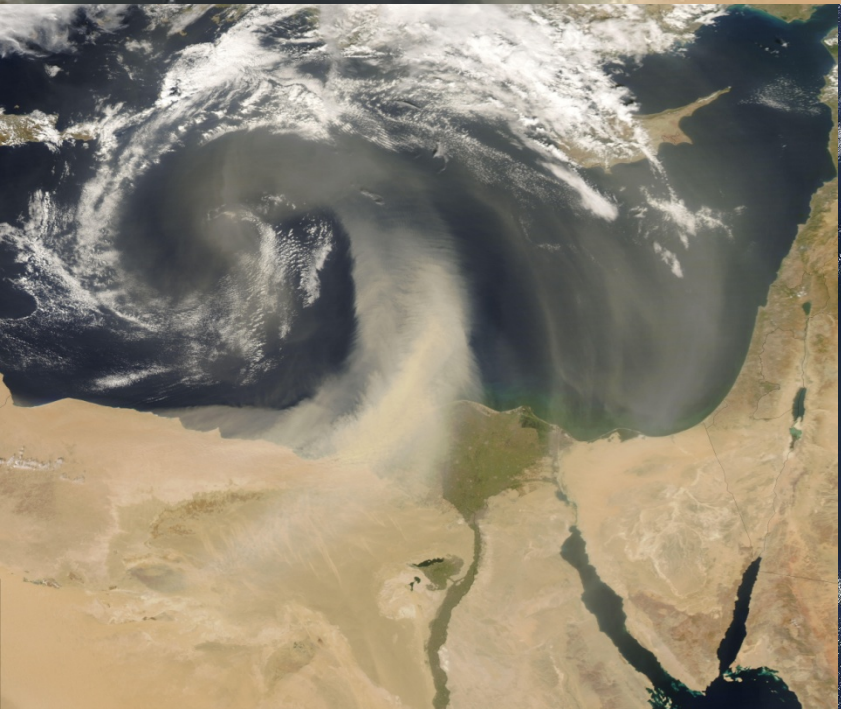
Niger, 2006



Texas, 1935



Phoenix, AZ, 2011



- 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

- 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

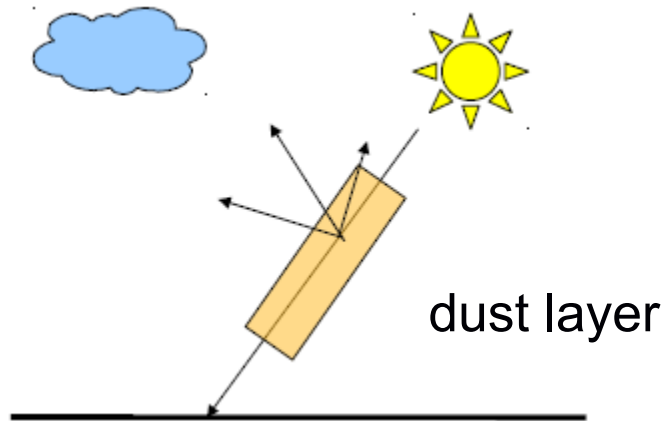
- Hourly and daily variability in dust atmospheric concentration
 - sub-daily variability in dust emission fluxes
 - transport of dust
- Important for forecasts
- Observations:
 - SYNOP and METAR: report of horizontal visibility, current weather (WX)
 - AERONET sun-photometer network: Aerosol Optical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



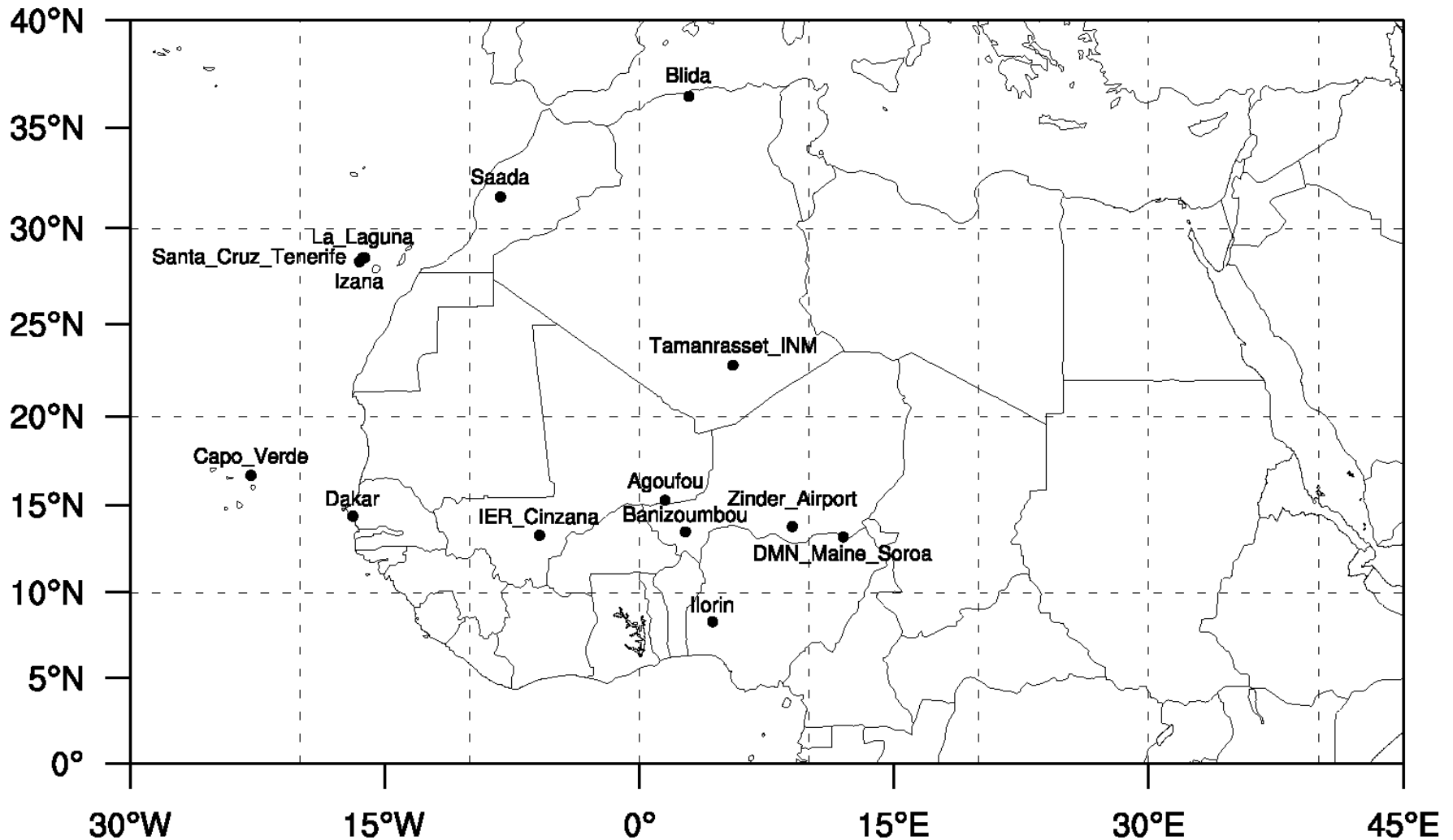
Cimel at Zouerat, 2011

Short-term Variability: Sun-Photometer Measurements



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AERONET sites



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

Short-term Variability: Sun-Photometer Measurements

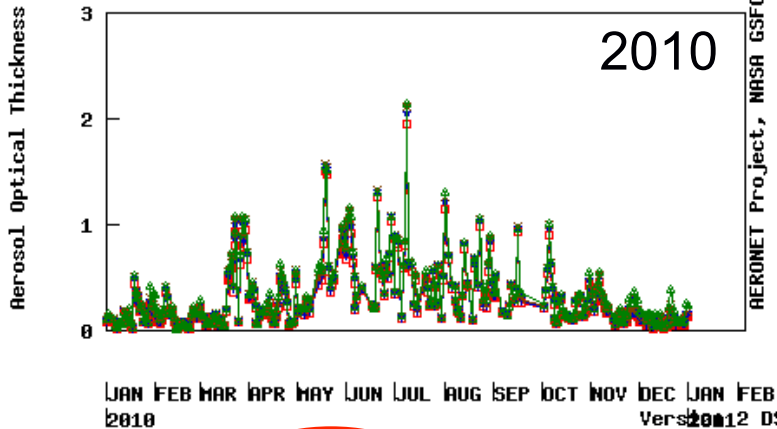


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Capo_Verde , N 16°43'58", W 22°56'06", Alt 68 m,
PI : Didier_Tanri, tanre@loa.univ-lille1.fr
Level 2.0 AOT; Data from 2010

AOT_1020 : <0.260>
 AOT_870 : <0.274>
 AOT_675 : <0.297>
 AOT_440 : <0.327>

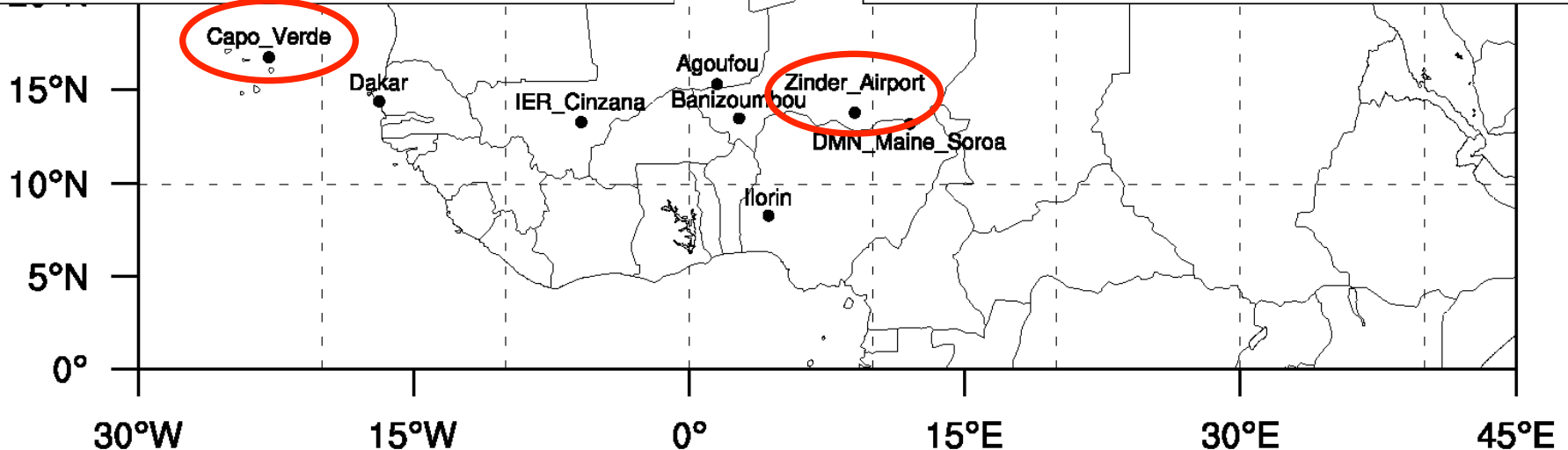
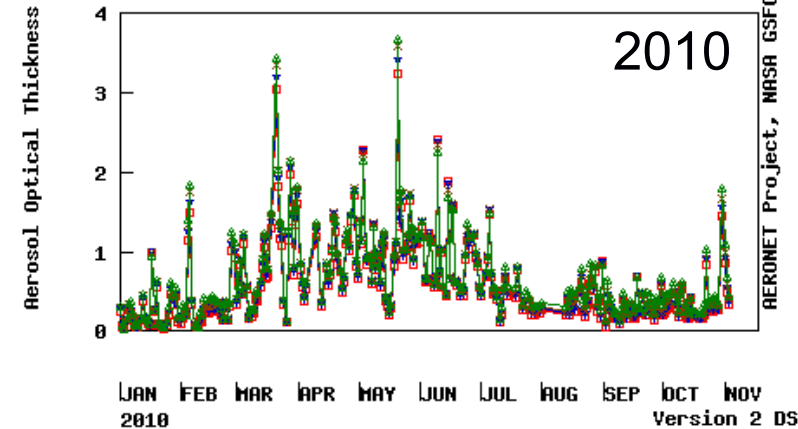
Capo Verde



Zinder_Airport , N 13°46'37", E 08°59'24", Alt 456 m,
PI : Bernadette_Chatenet and Jean_Louis_Rajot, chatenet@
Level 2.0 AOT; Data from 2010

AOT_1020 : <0.522>
 AOT_870 : <0.545>
 AOT_675 : <0.580>
 AOT_440 : <0.617>

Zinder



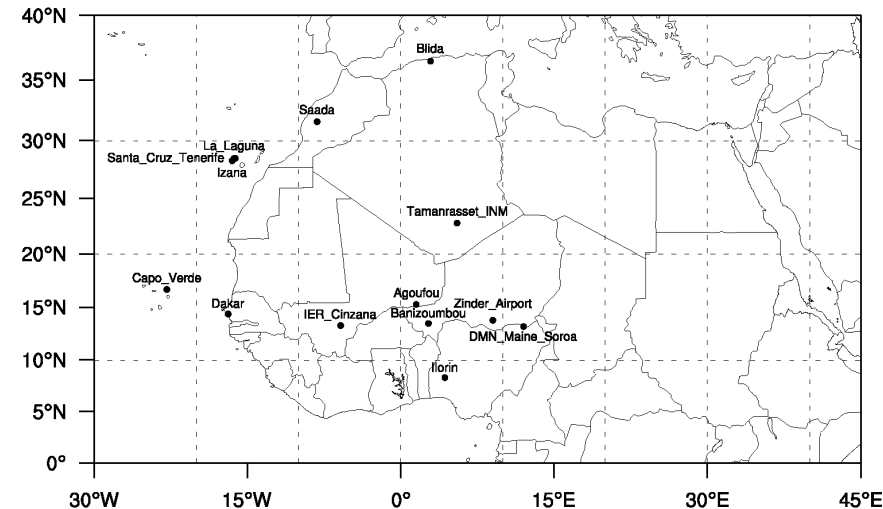
selected AERONET stations, <http://aeronet.gsfc.nasa.gov>

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



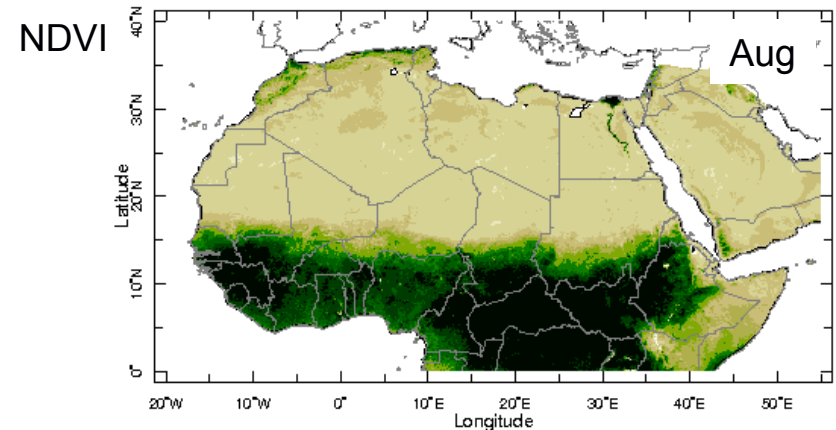
Precondition for Dust Emission



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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)



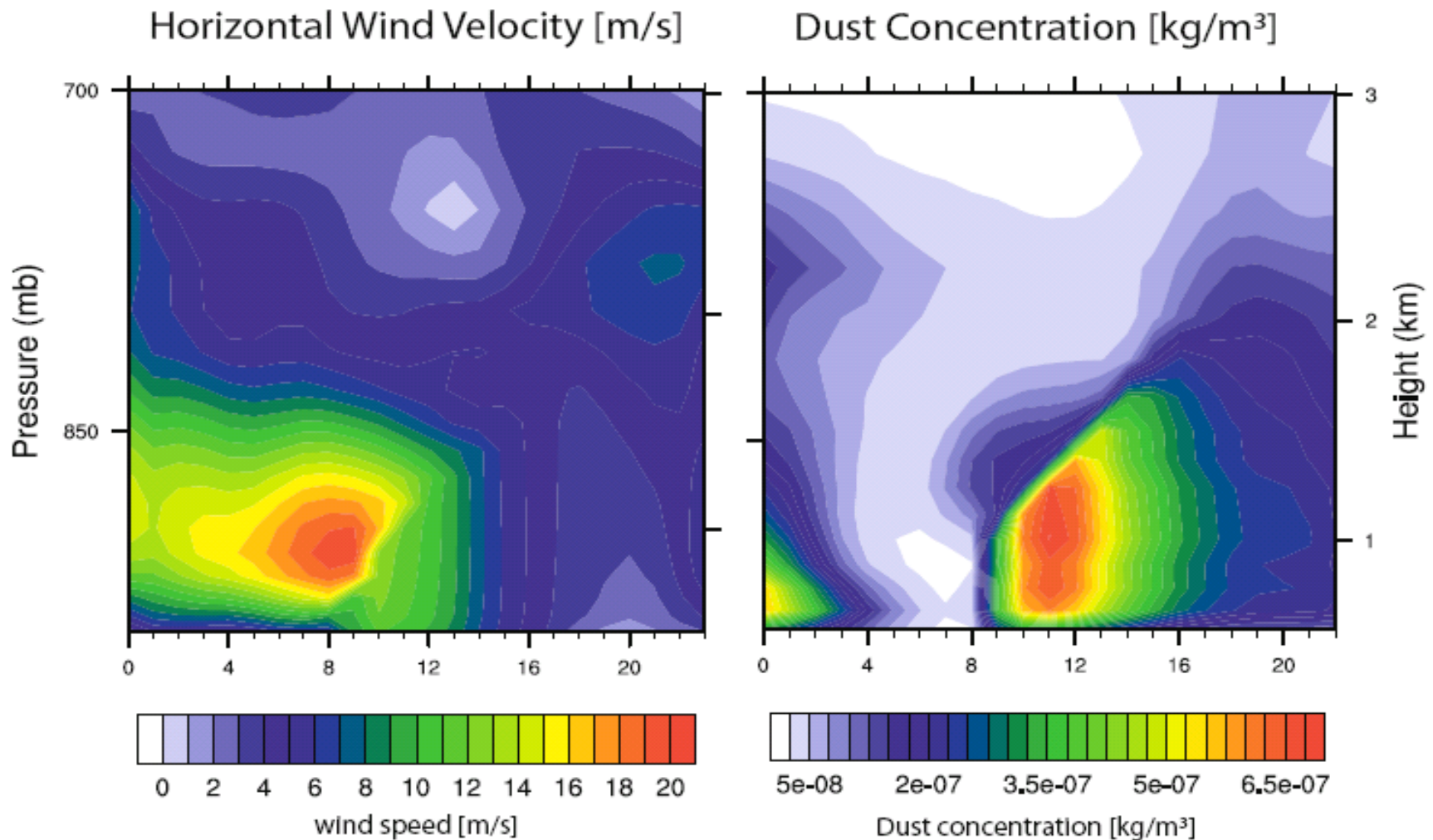
2. Strong surface winds

- Frontal systems
- Down-drafts from meso-scale convective systems (MCS), Haboobs
- Boundary layer turbulence

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

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

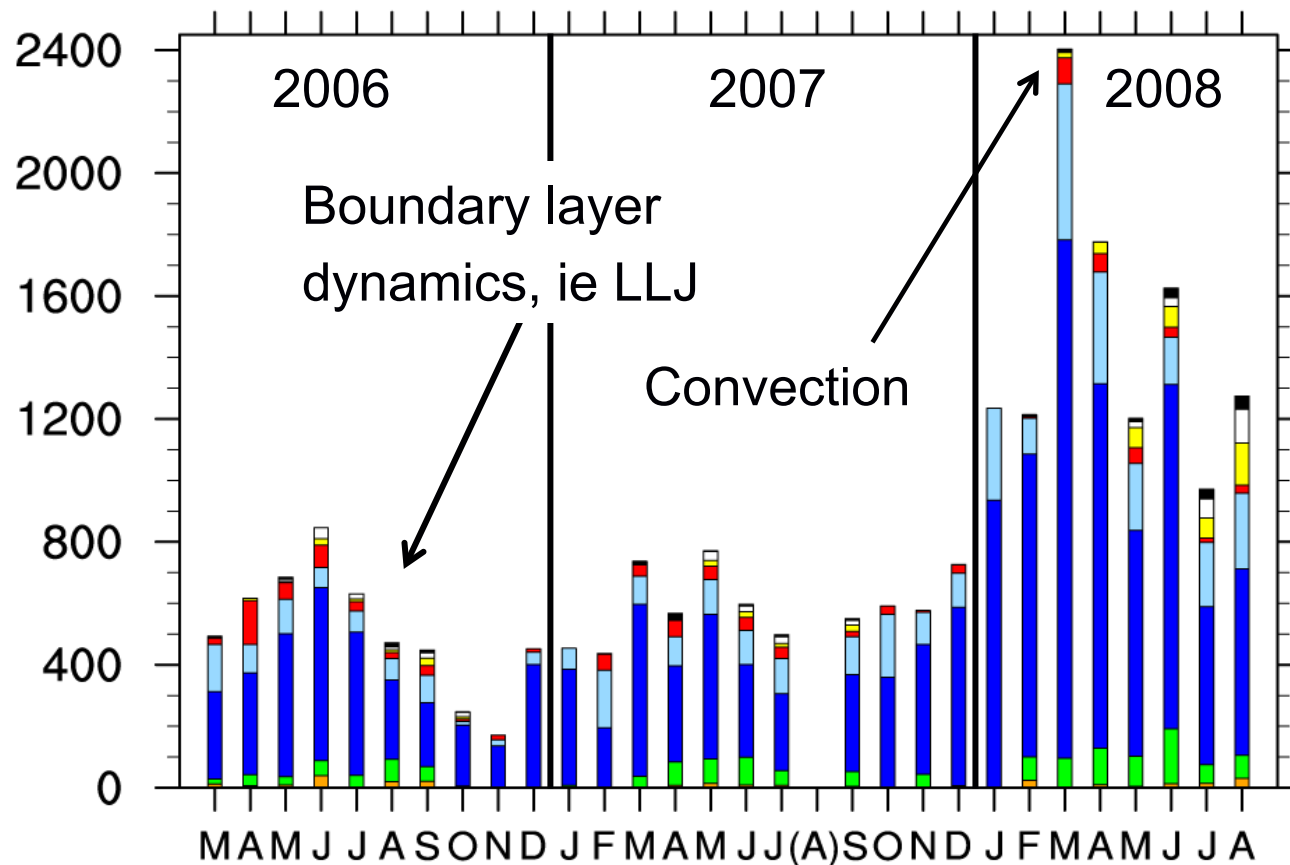
22.25N, 3.5E/ March 10, 2006



Temporal Variability: Saharan Dust Source



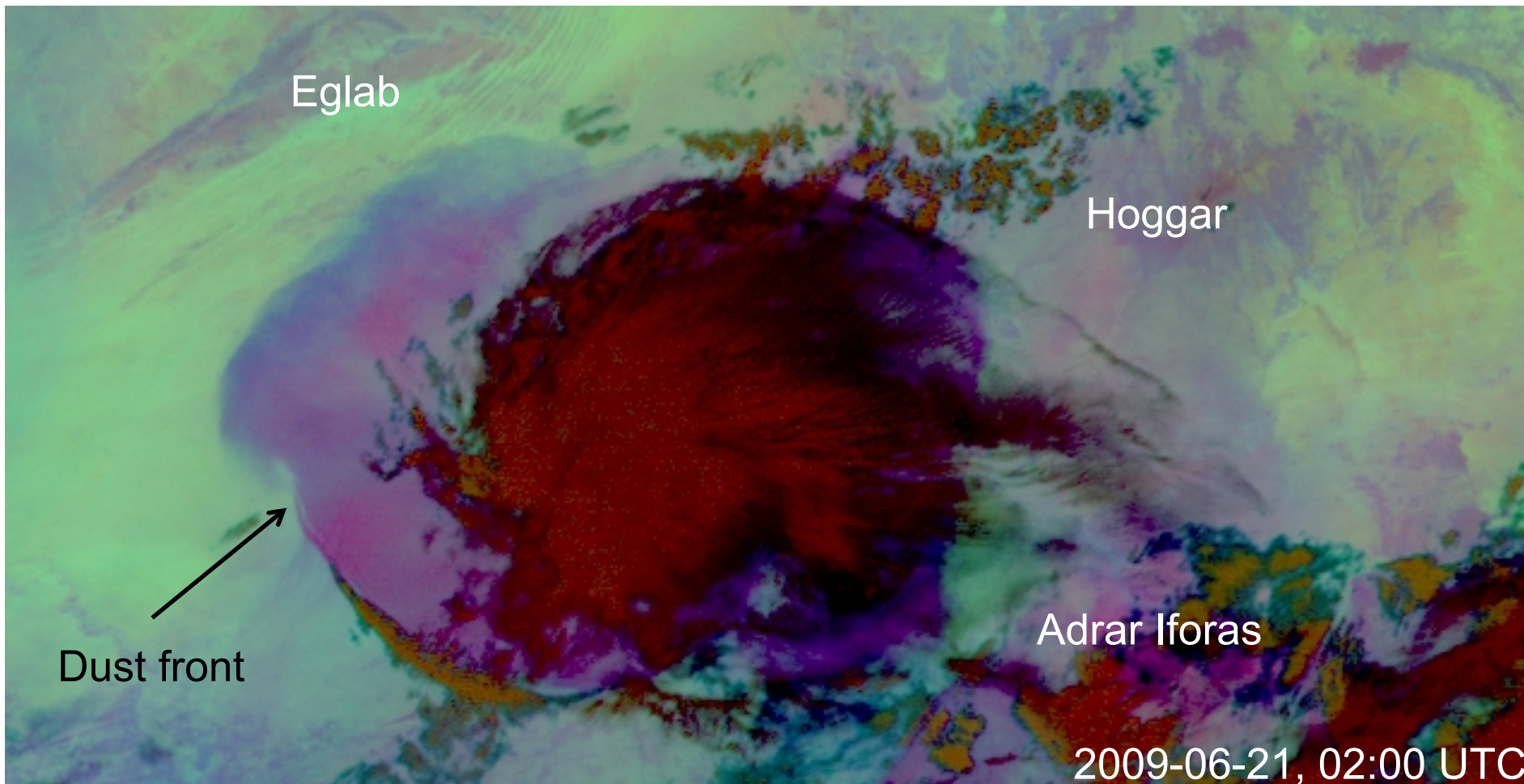
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Time of day UTC	Portion [%]
00-03	2
03-06	5
06-09	65
09-12	16
12-15	8
15-18	1
18-21	2
21-00	1

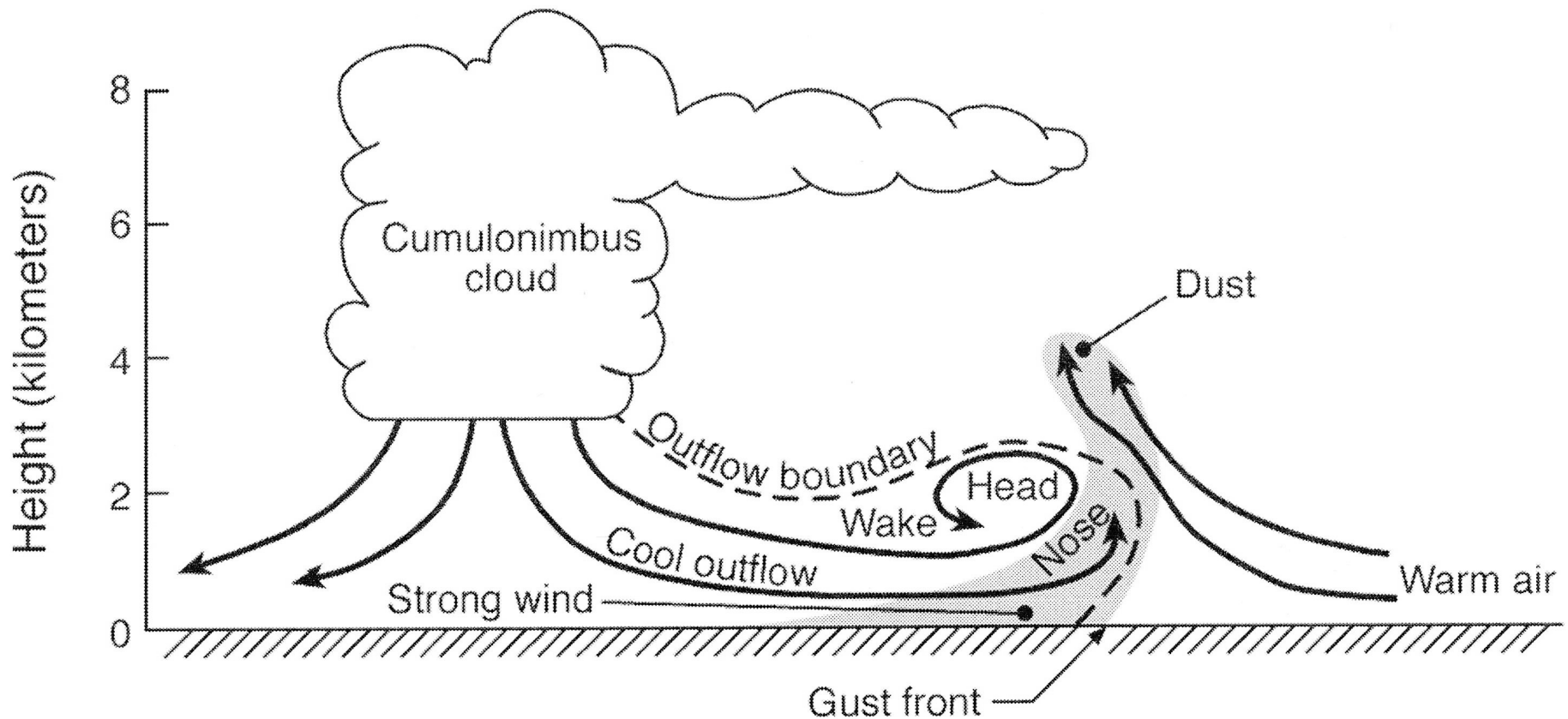
- Number of dust source activations per 1°x1° grid cell per time slot and per month
- Most dust emissions start between 06 and 09 UTC

Seasonal Dust Events: Haboob



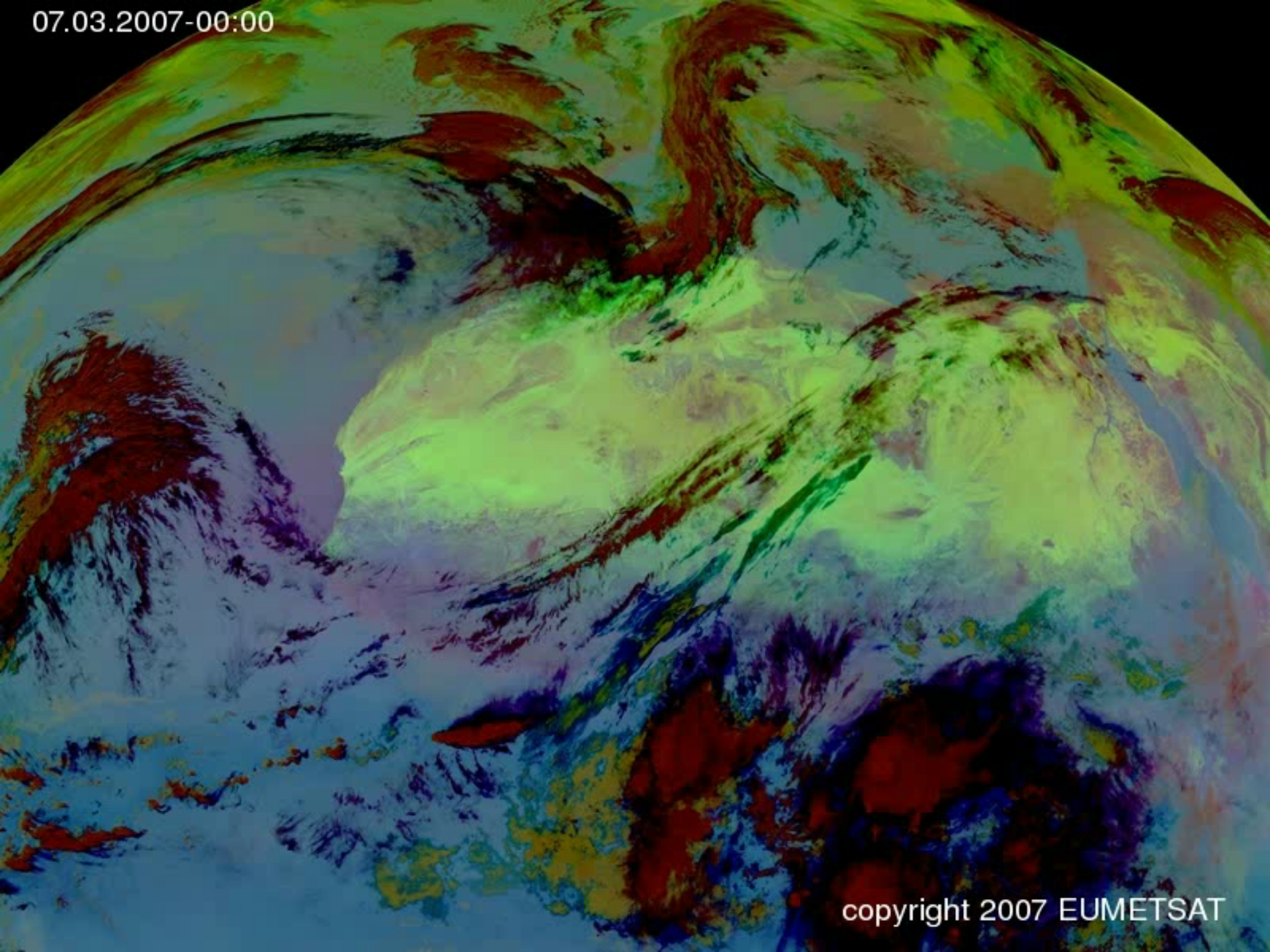
Seasonal Dust Events: Haboobs

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



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

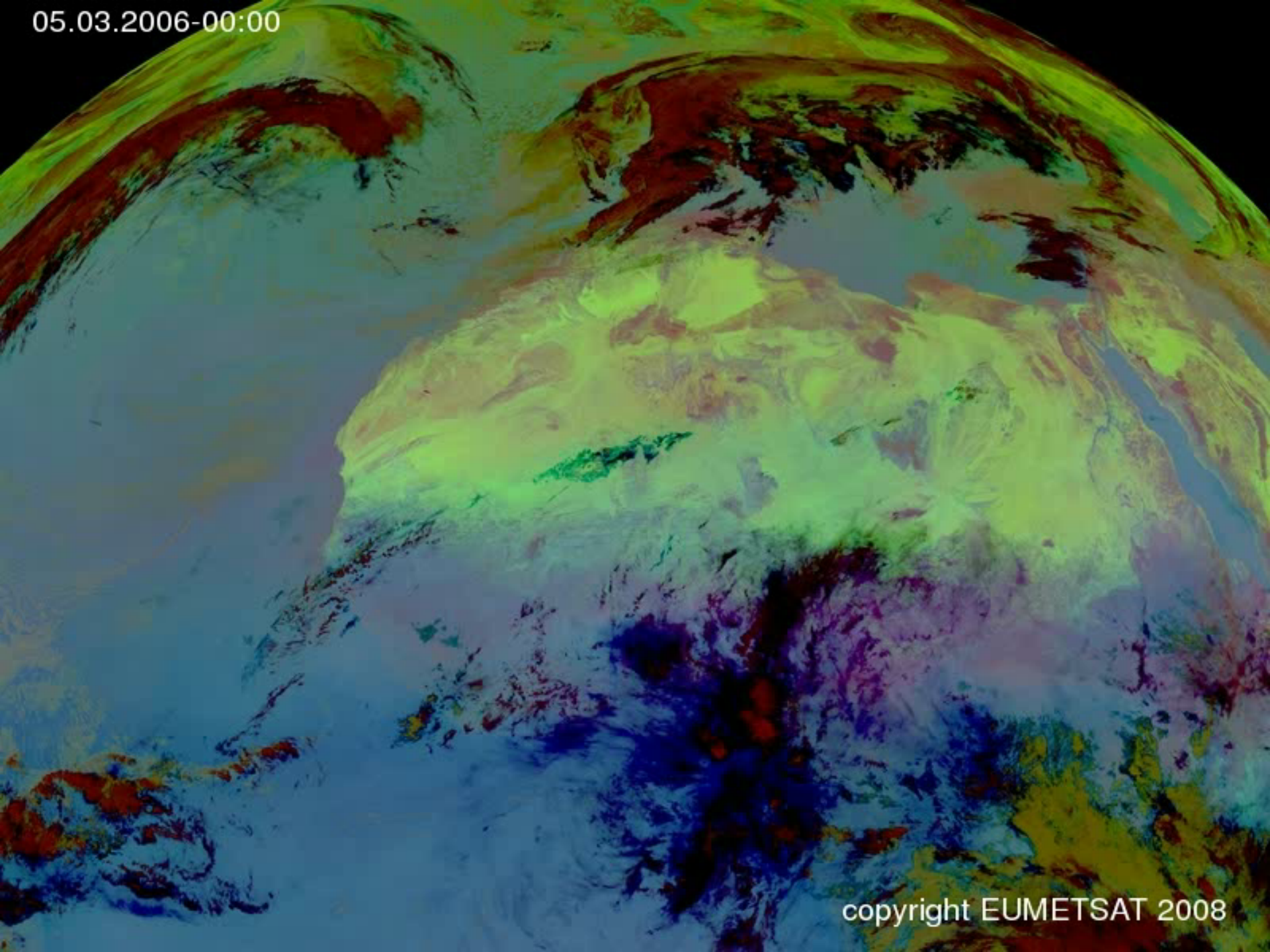
07.03.2007-00:00



copyright 2007 EUMETSAT

- 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

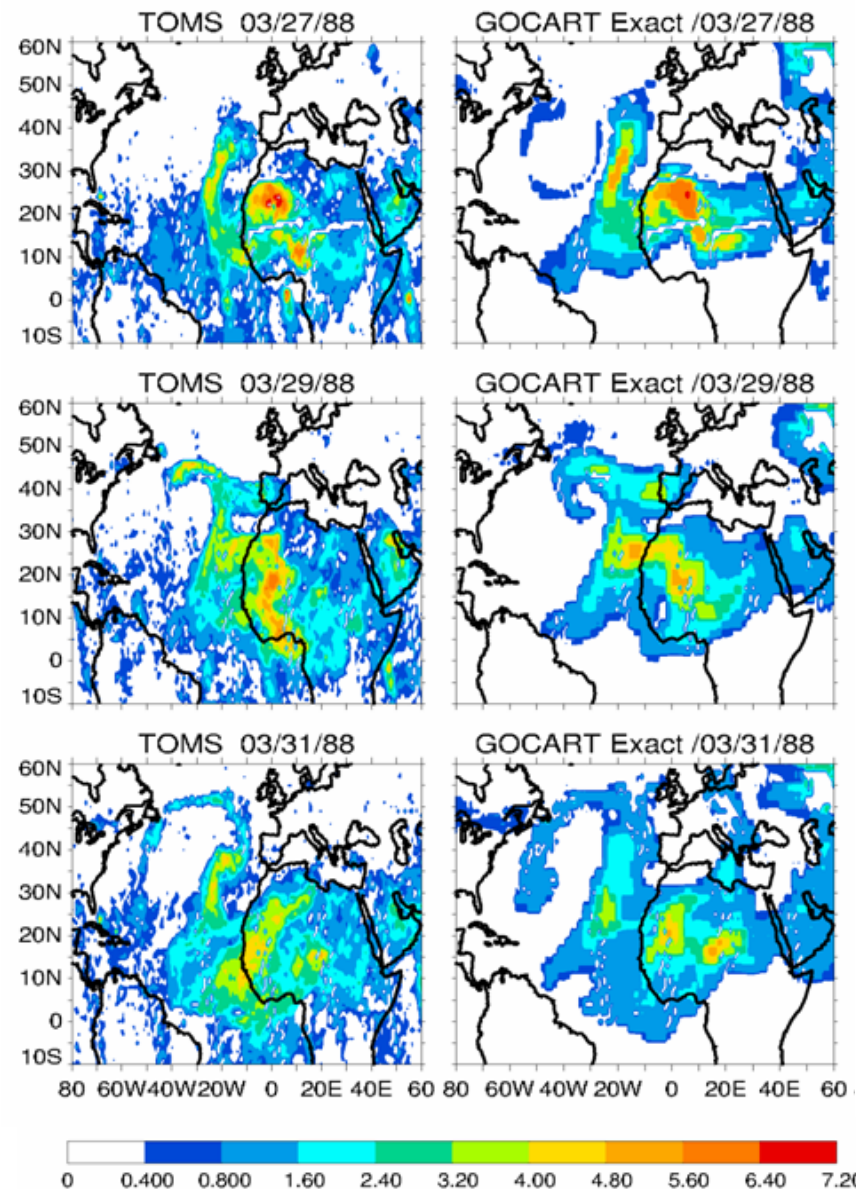
Short-term Dust Variability: Transport



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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

- 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.

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)

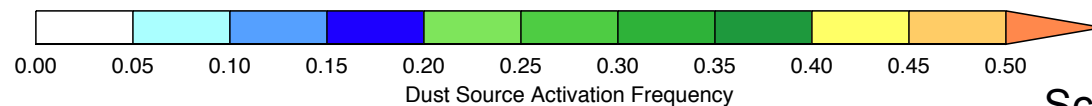
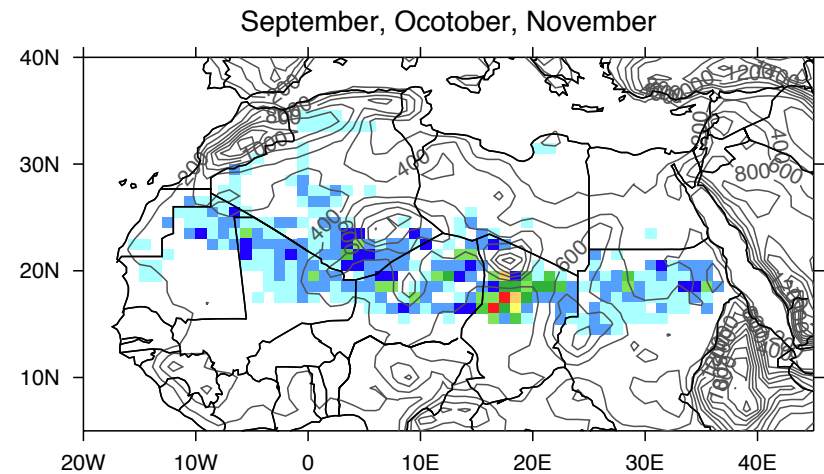
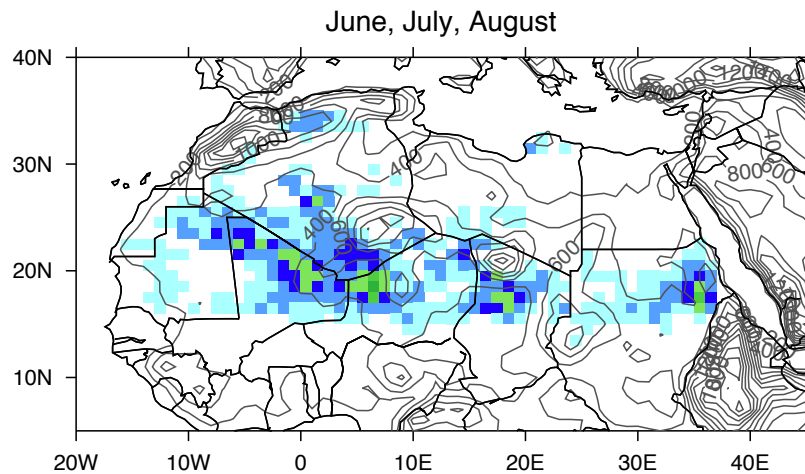
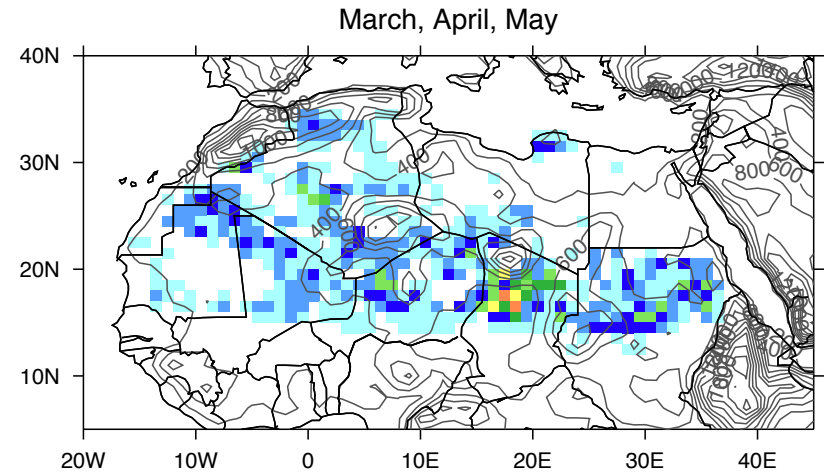
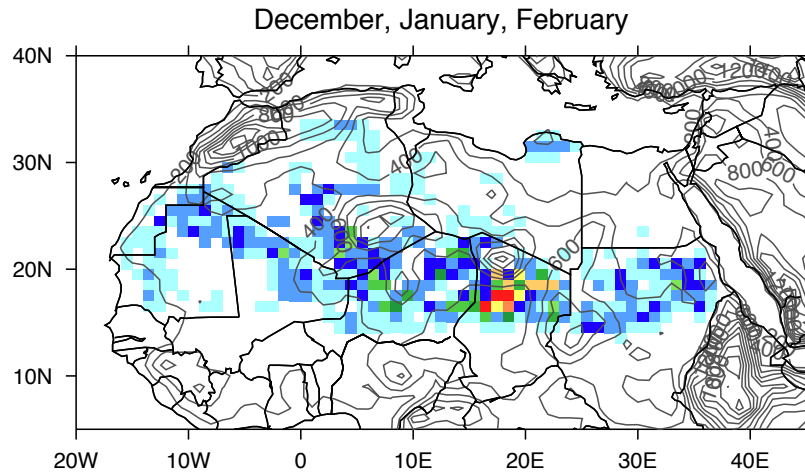
2. Seasonal variability in soil characteristics

- Vegetation cover (rain season vs dry season)

Seasonal Variability: Dust Sources



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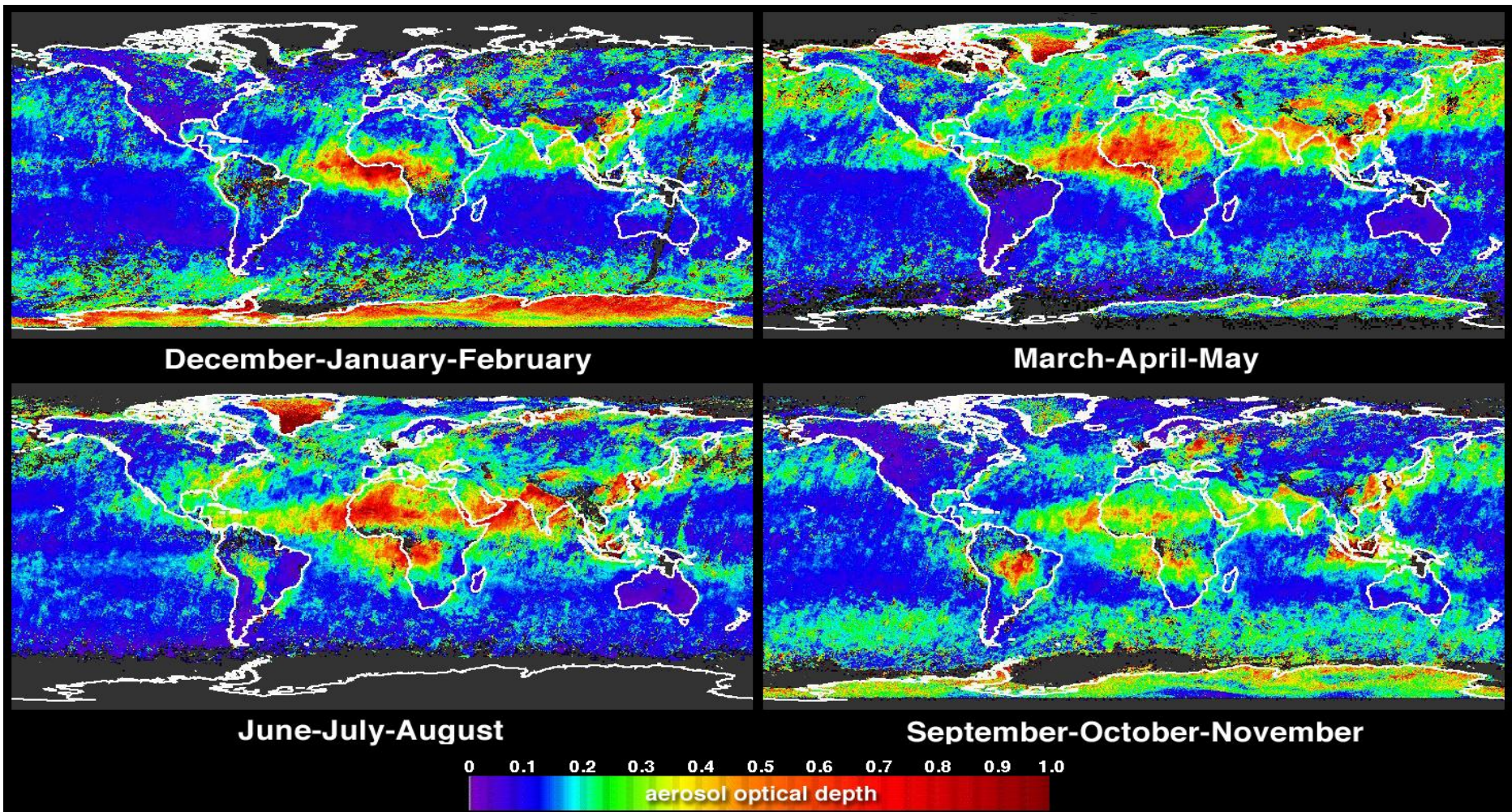
Schepanski et al., 2009

Seasonal Variability: AOT



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MISR AOT Dec 2001 – Nov 2002

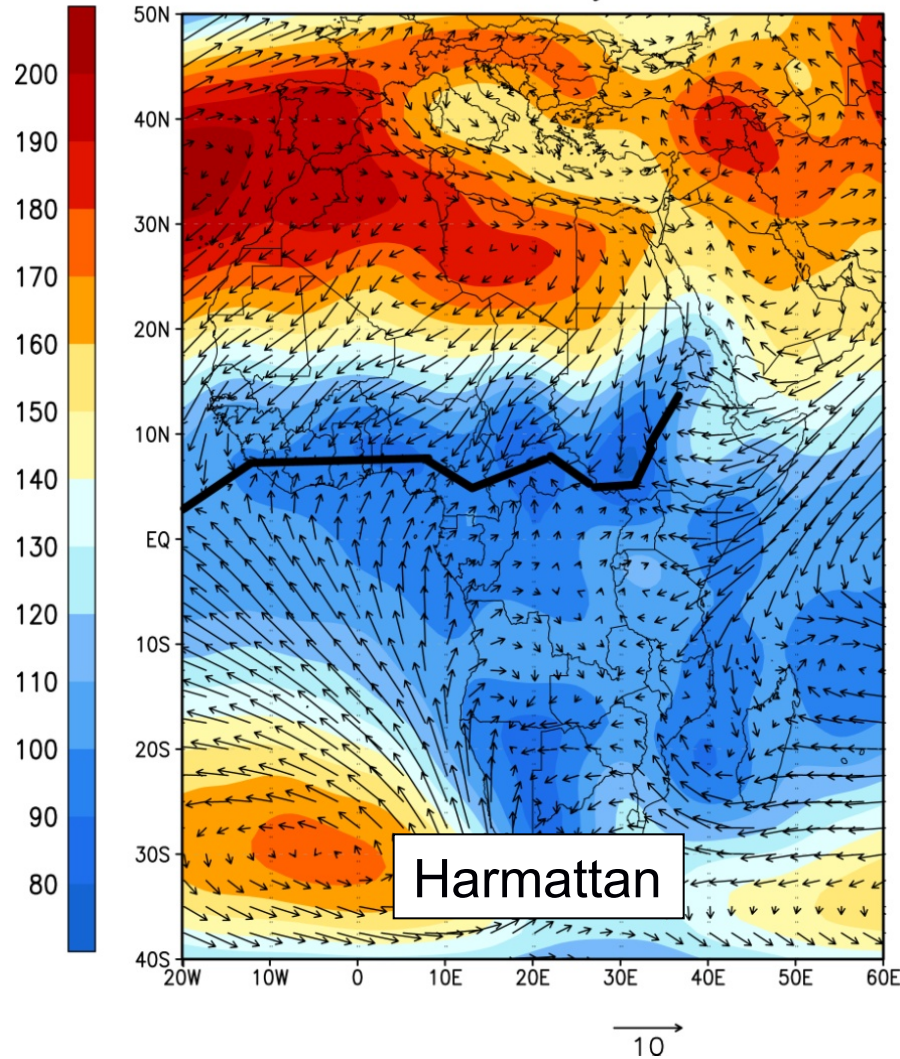


Seasonal Variability: Atmospheric Circulation

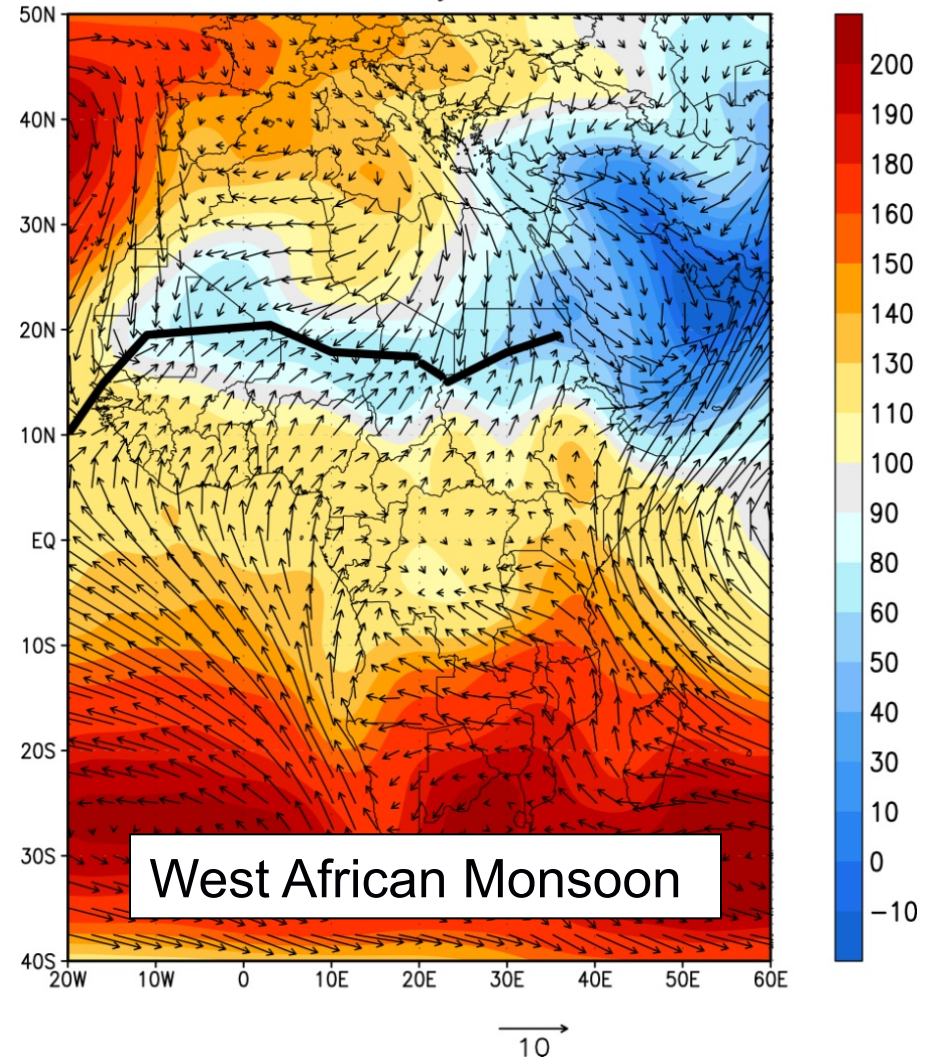


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January



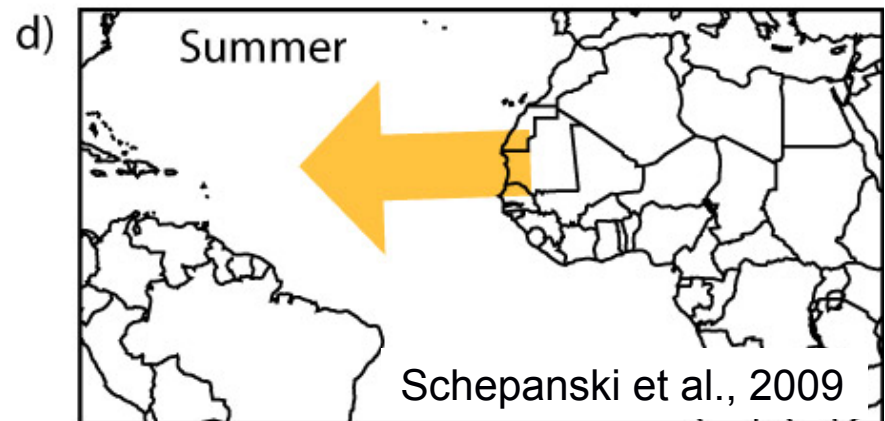
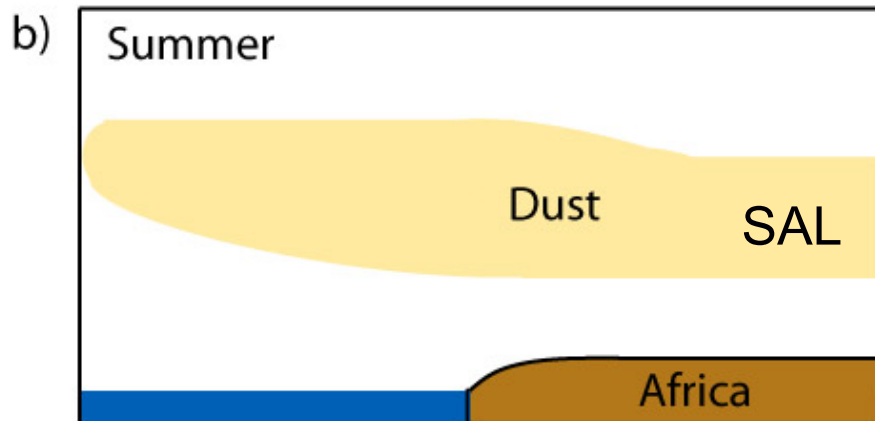
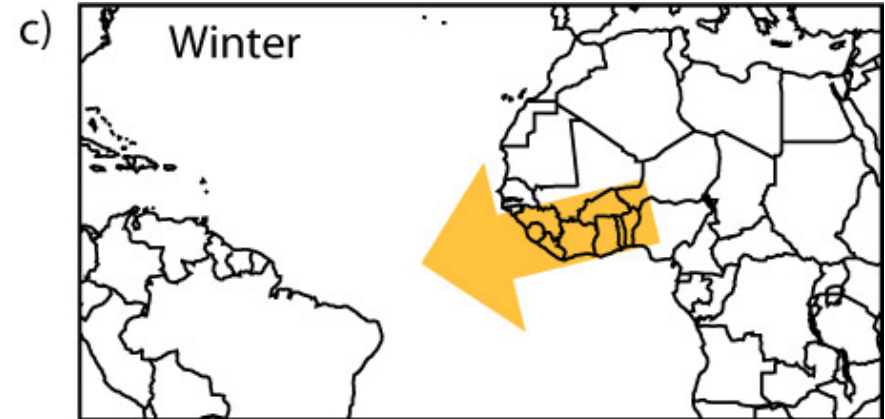
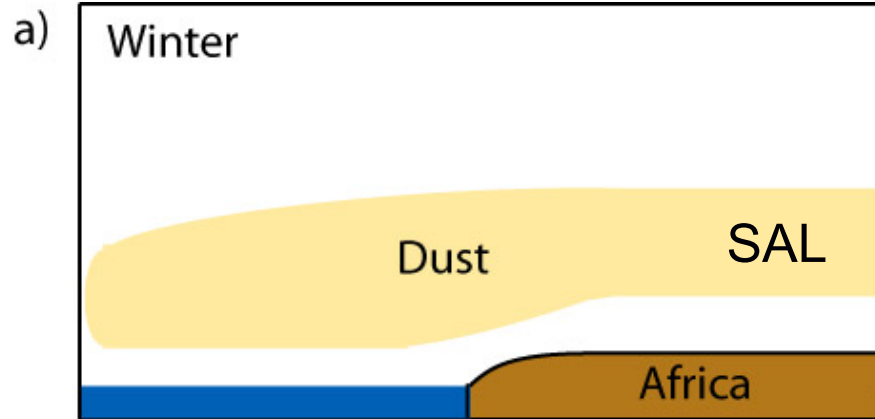
July



Seasonal Variability: Dust Transport



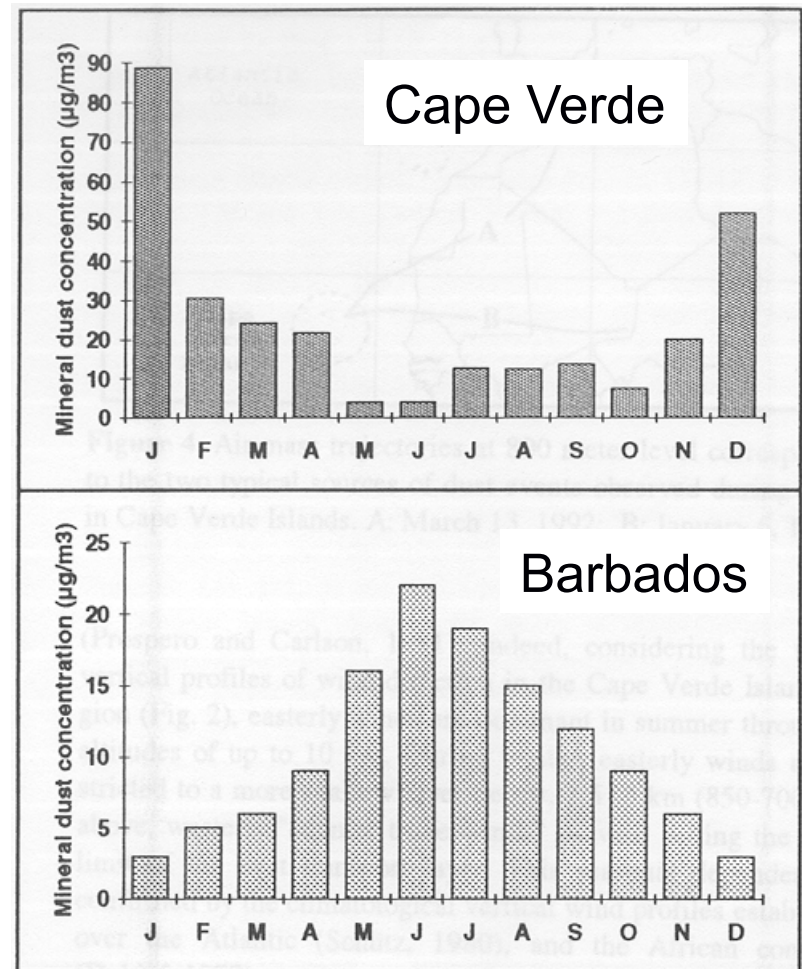
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- Winter: dust transport within marine boundary layer
- Summer: dust transport above marine boundary layer

Seasonal Variability: Dust Transport

- 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



- 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

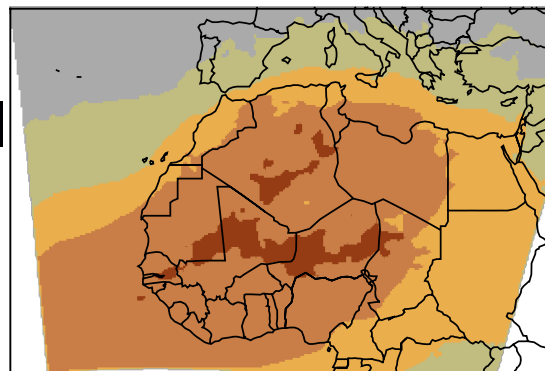
Year-to-Year Variability



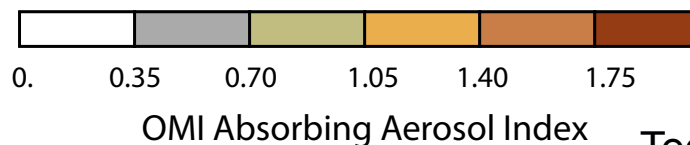
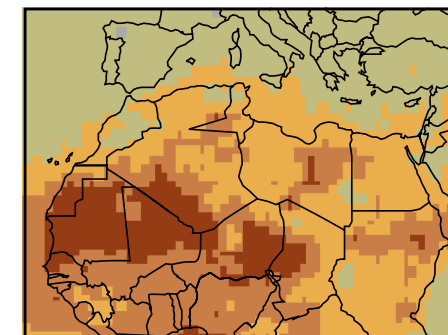
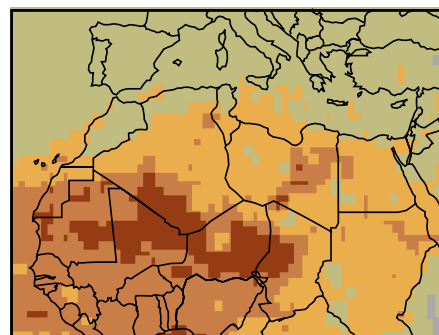
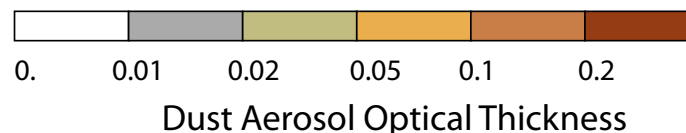
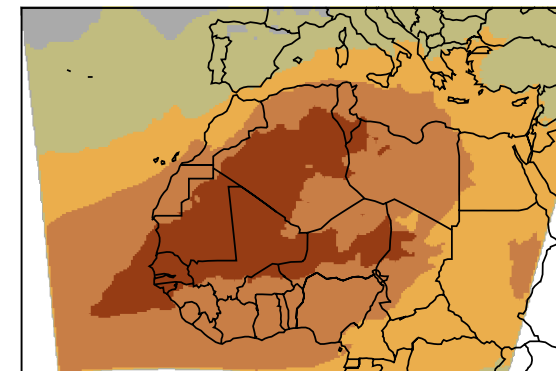
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- COSMO-MUSCAT regional model simulation
- Interannual variability in atmospheric dust loading
- Possible causes:
 - Atmospheric controls
 - Emissivity of dust sources

2007



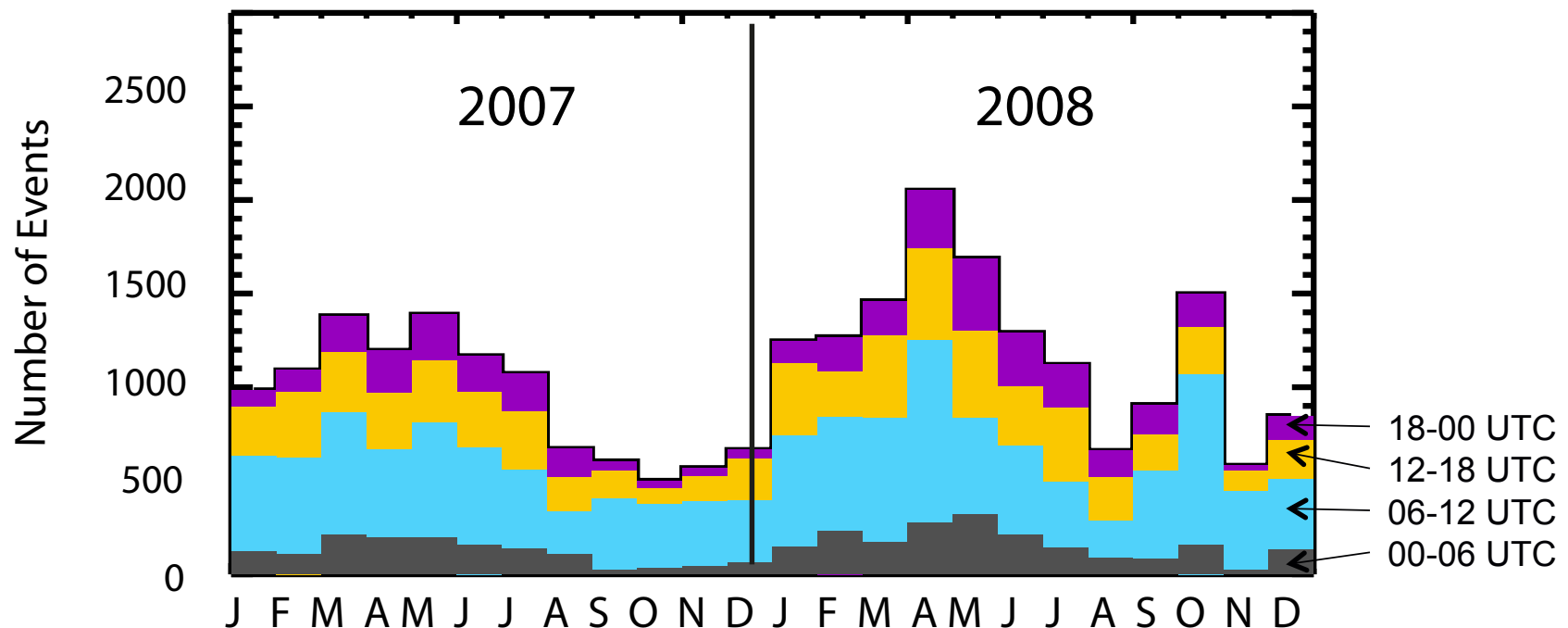
2008



Tegen et al., 2012

- Time-of-day distribution of dust emission events can provide evidence for possible meteorological mechanism involved, e.g. LLJ during morning hours

Number of dust emission events derived from COSMO-MUSCAT model



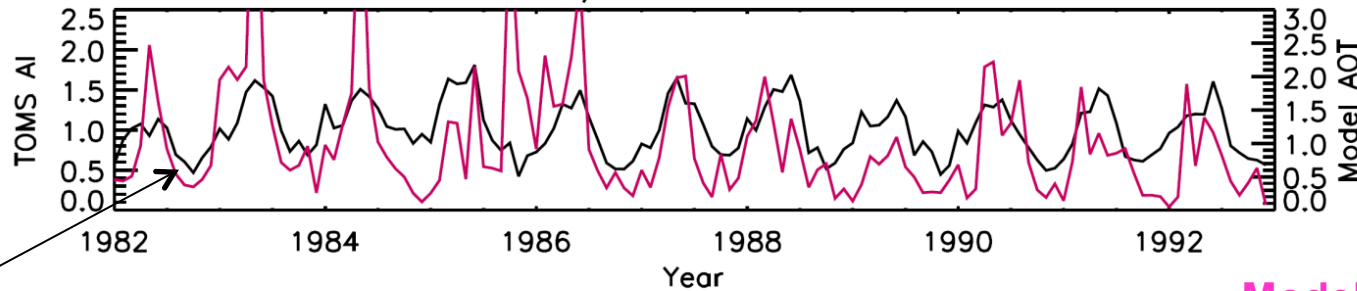
Year-to-Year Variability



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Model results from TM3/ERA-15

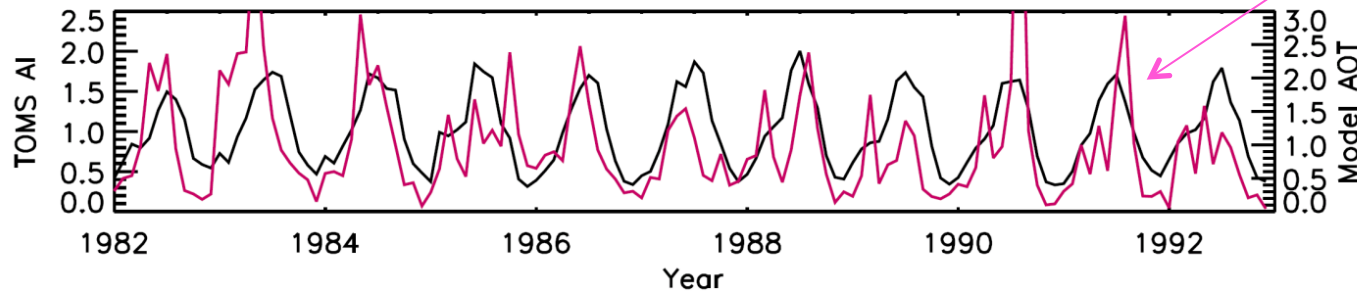
Sahel/southern Sahara



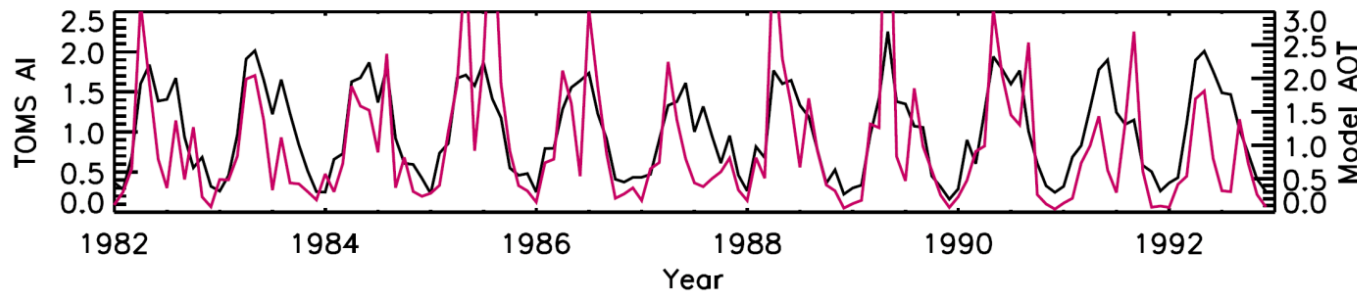
Satellite (TOMS AI)

Model (AOD)

Northern Sahara



Taklamakan

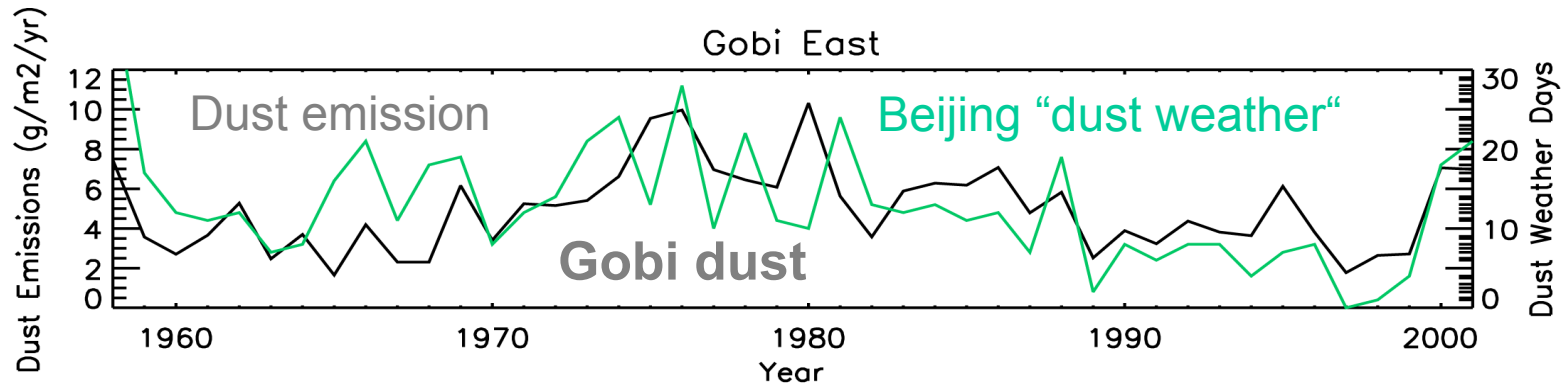


from I. Tegen

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)

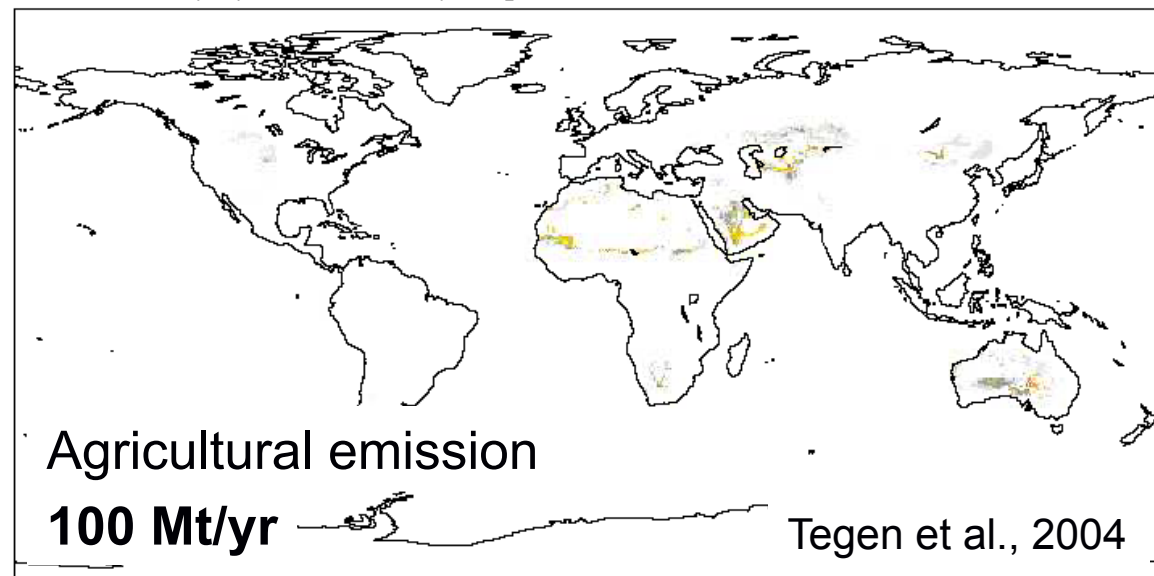
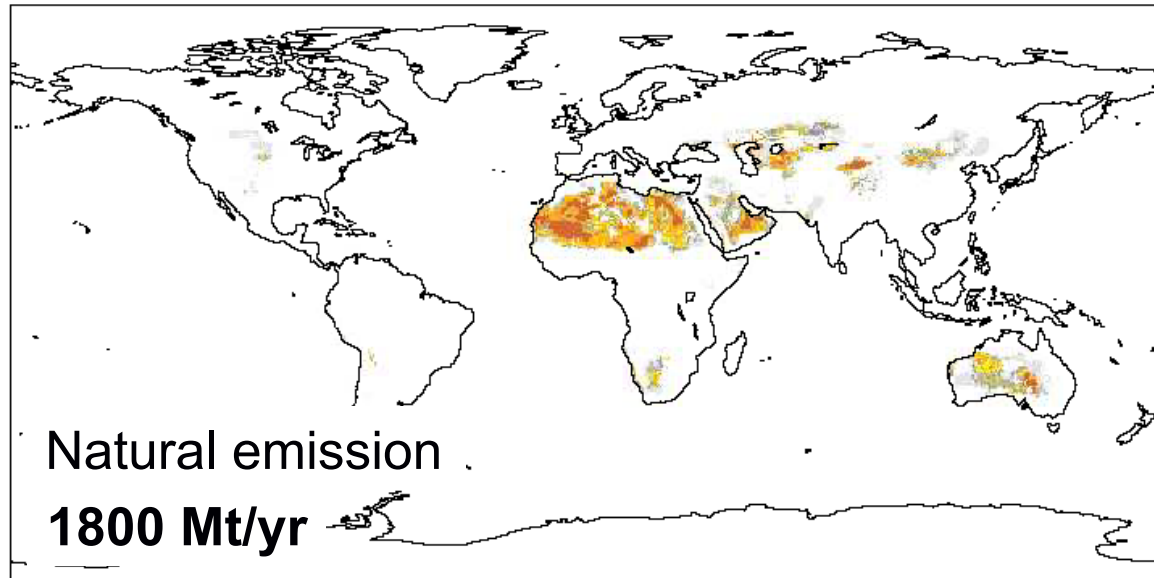


Dust Variability: Agriculture

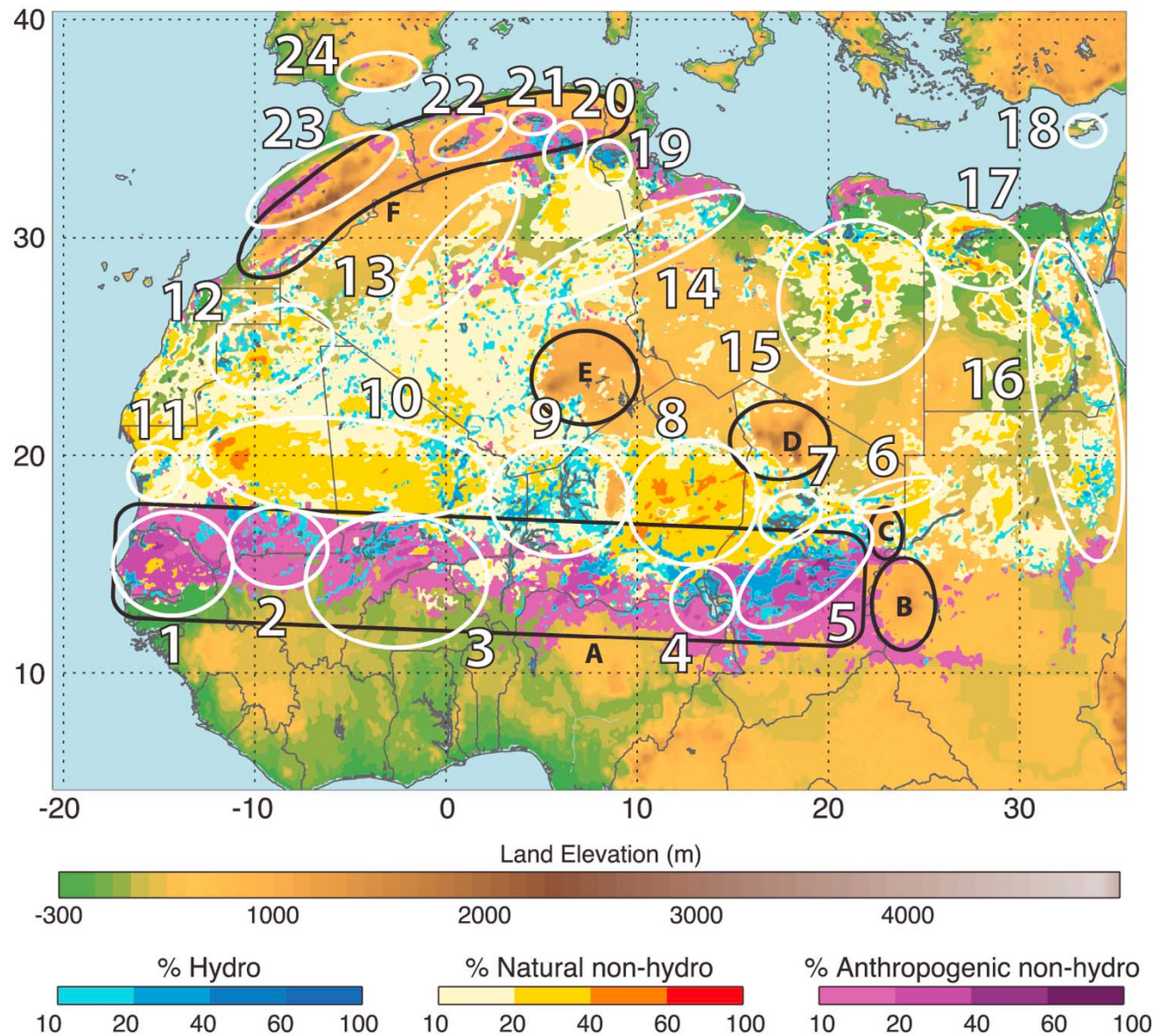


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- Satellite z_0
- ECMWF ERA15
- Year 1987
- Contribution of agricultural emission: ~6%
- Global estimates of dust fluxes from anthropogenic disturbed soil varies from 0-50%



Dust Variability: Dust Source Types



- Interannual changes in dust are less well understood than seasonal changes.
 - Variability in atmospheric circulation, sediment supply within dust sources, vegetation, ...
- 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.

- 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.