Identification and characterisation of dust sources using satellite observations and model simulations

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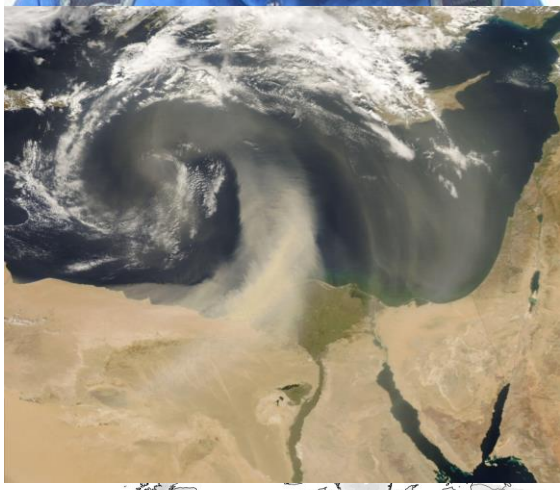

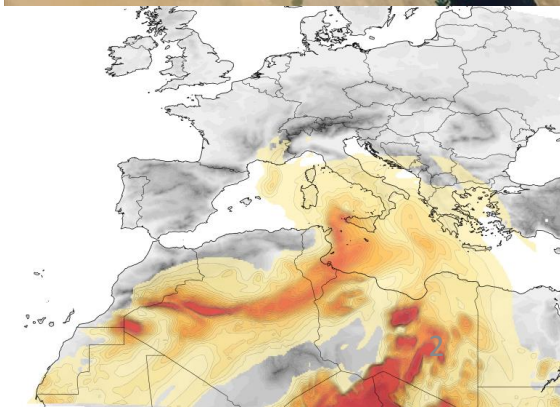

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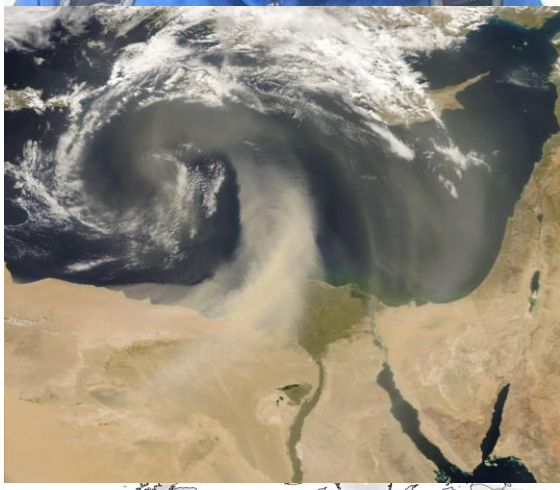
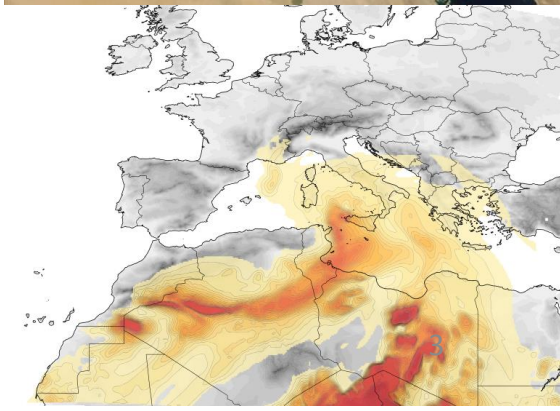
  - Dust in the atmosphere - when, where and which processes are involved?
  - Dust removal from the atmosphere





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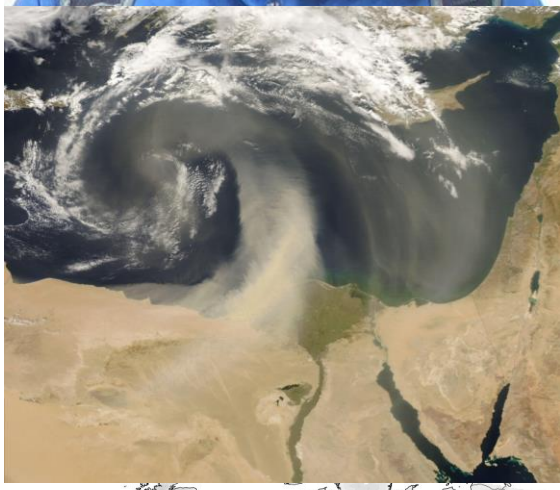
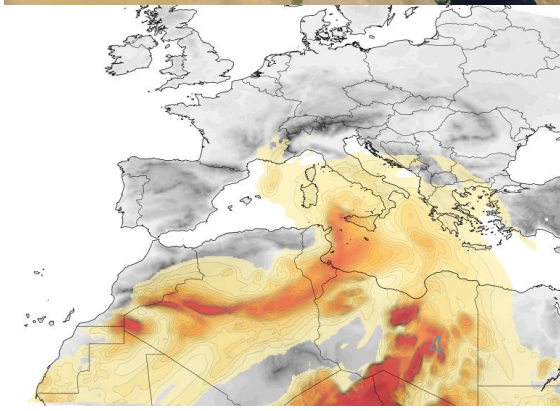
  - What makes a dust source to an active dust source emitting dust?
  - Dust in the atmosphere - when, where and which processes are involved?
  - Dust removal from the atmosphere
- Tools: Satellite observations & model simulations (and of course some other)





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Desert dust ...

- ... is with an emission flux of ~2,000 Mt per year (70% Sahara) a dominant contributor to the atmospheric burden of natural aerosols.
- ... is a “global player“: 20-70 Mt per year are exported toward Europe.
- ... resides in the atmosphere for a time of some hours up to 2-3 Weeks.
- ... shows a complex and manifold mineralogical composition.
- ... has a typical size of 0.1-10 µm.

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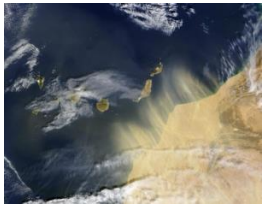
Mineral dust as a global player

dust uplift

Airborne Dust



Dust Emission

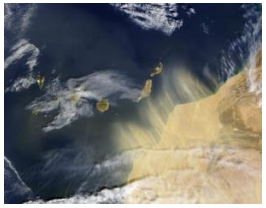
settlement

Dust Deposition

Mineral dust as a global player

dust uplift

Airborne Dust



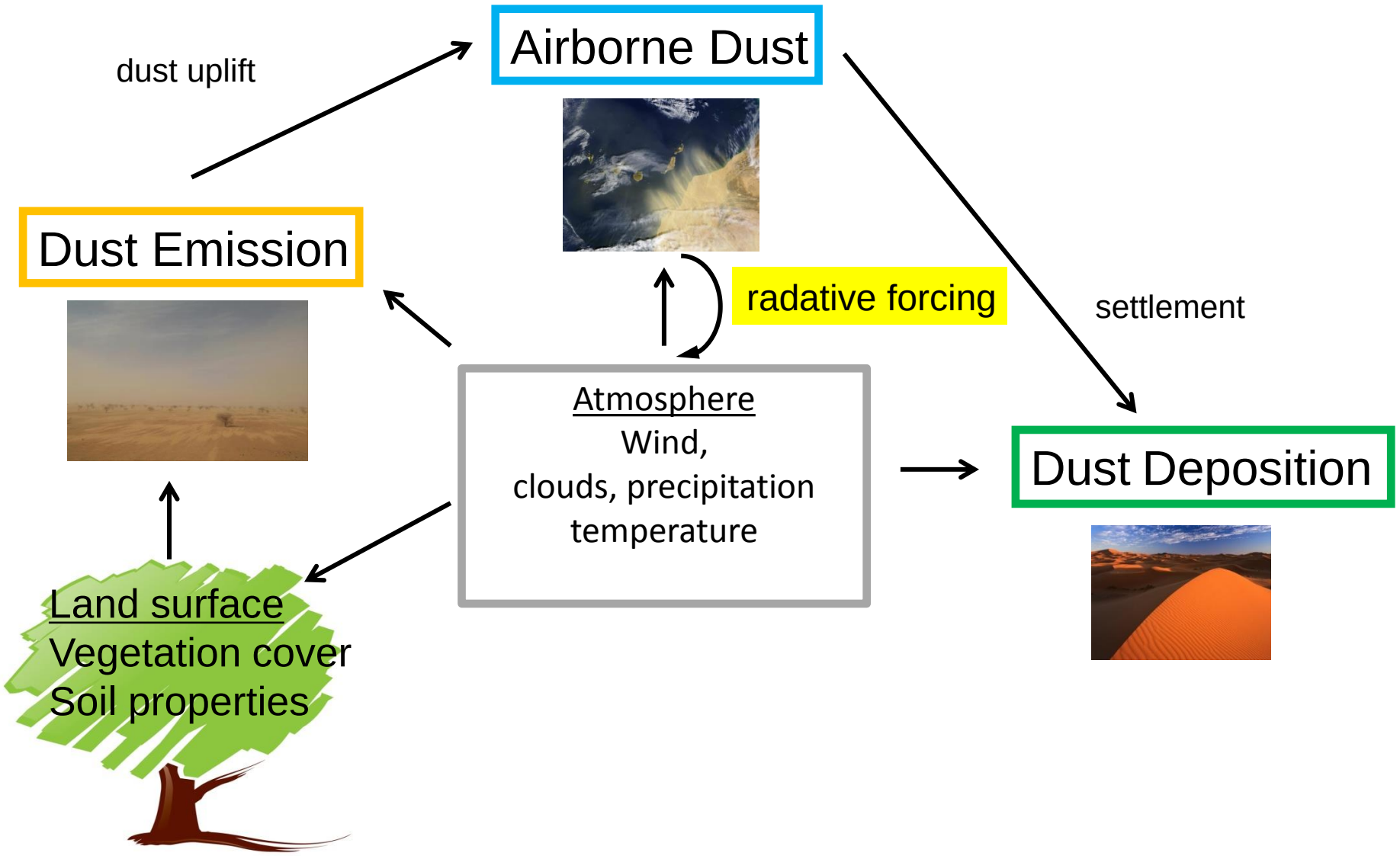
Dust Emission

settlement

Dust Deposition

Land surface
Vegetation cover
Soil properties

Mineral dust as a global player



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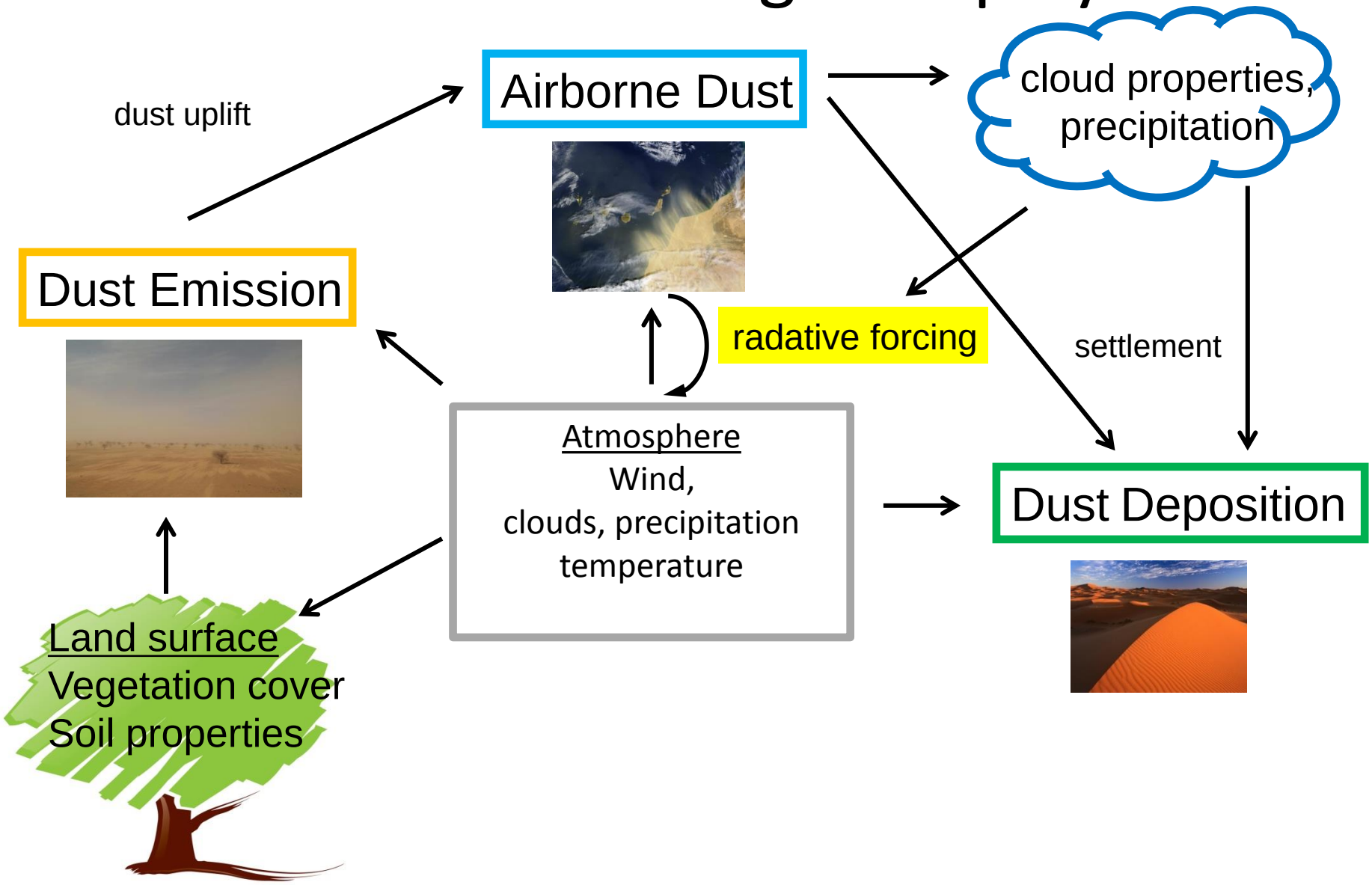

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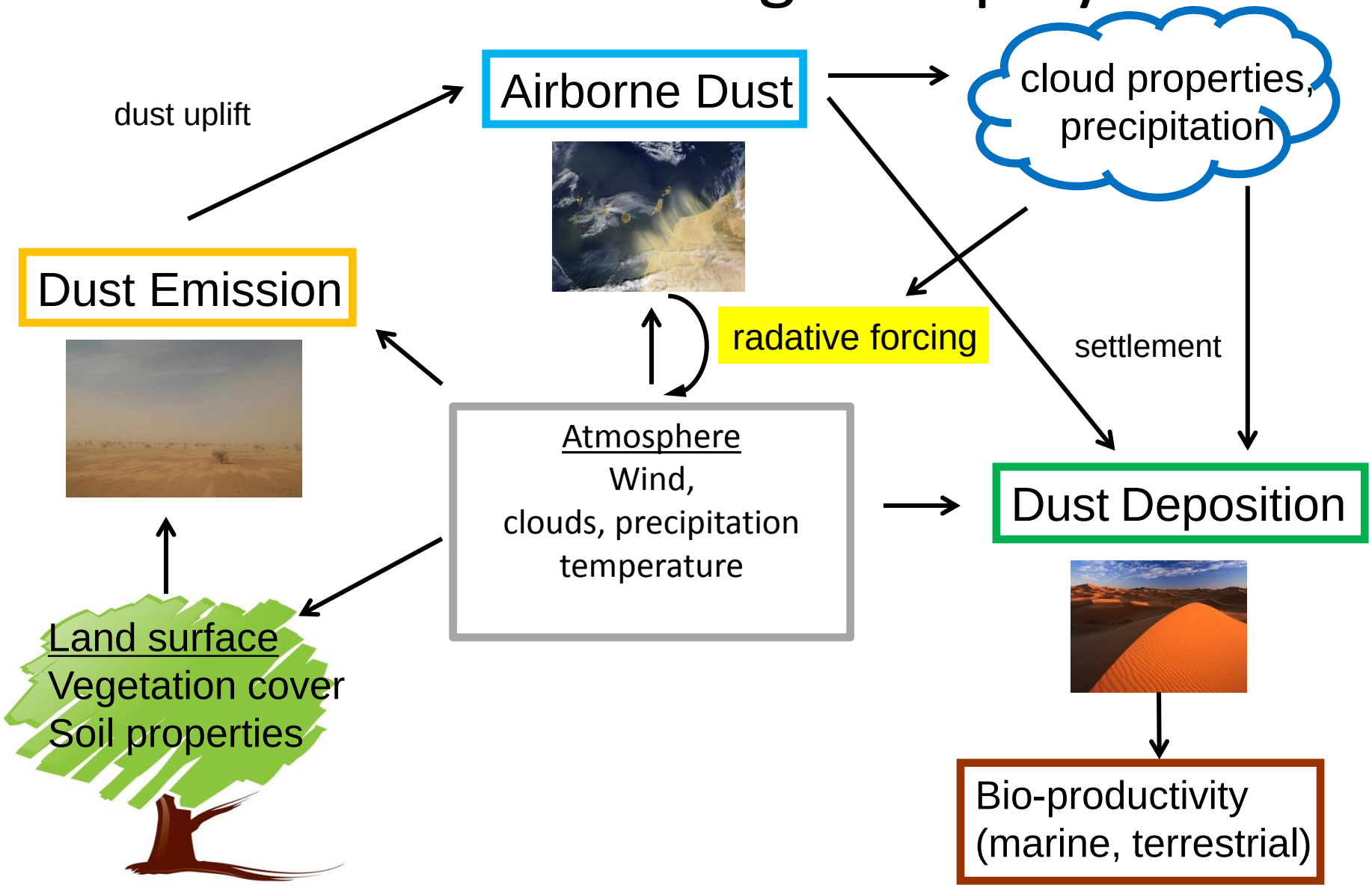

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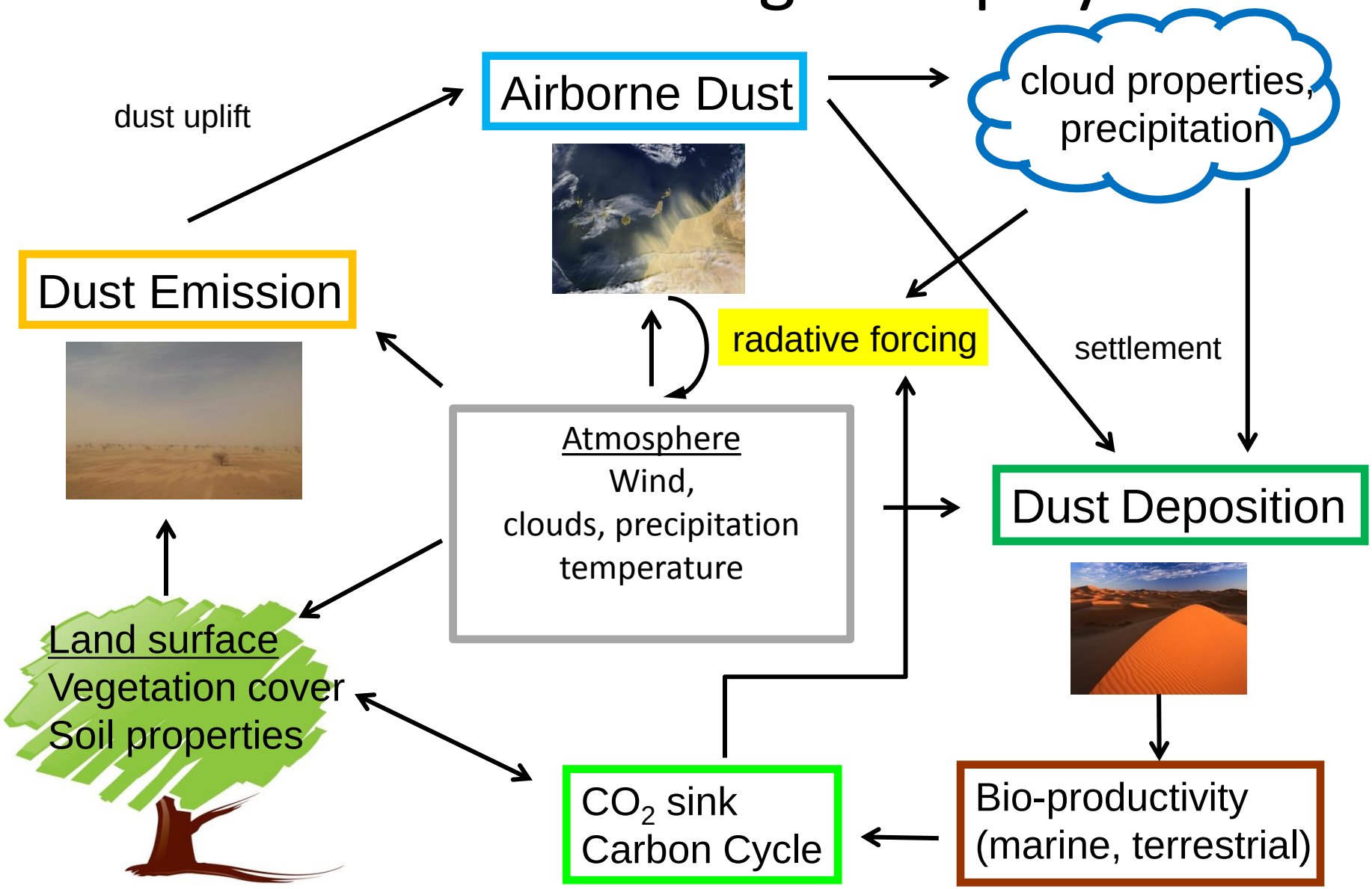
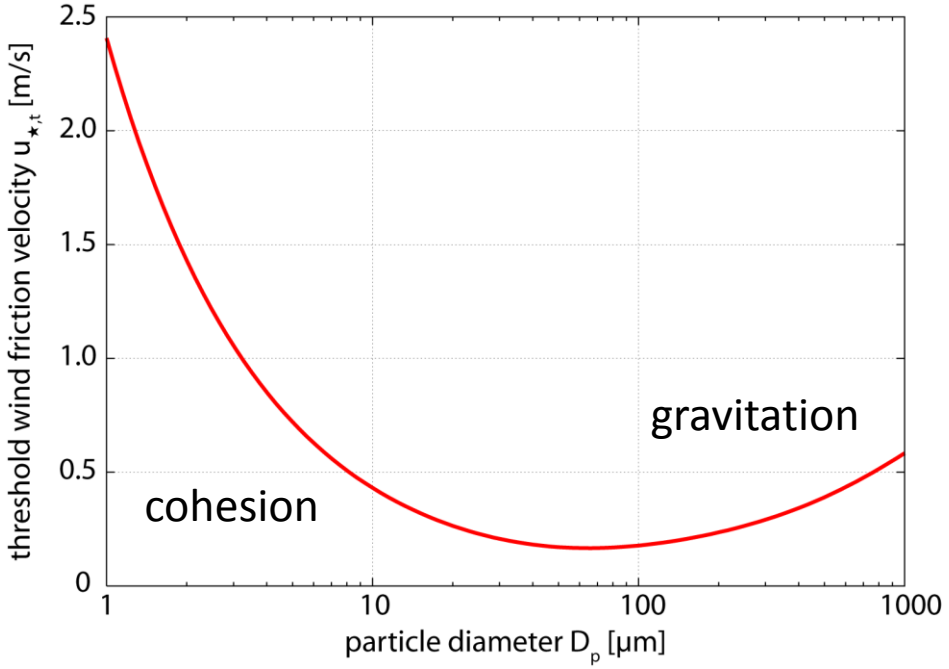


Dust Mobilisation

- **Transport of momentum** from the atmosphere to soil surface
- Soil moisture, vegetation, and surface texture affect **Aeolian erosion** (threshold problem)
- Size distribution of mobilized dust particles depend on **cohesion and gravitation**
- Mobilisation of small particles for long-range transport by **saltation**



The ideal dust source ...

... is characterized by a mixture of fine (suspension) and coarse (saltation) sediment

... is free of vegetation or at least almost barren.

... shows a low soil moisture content.

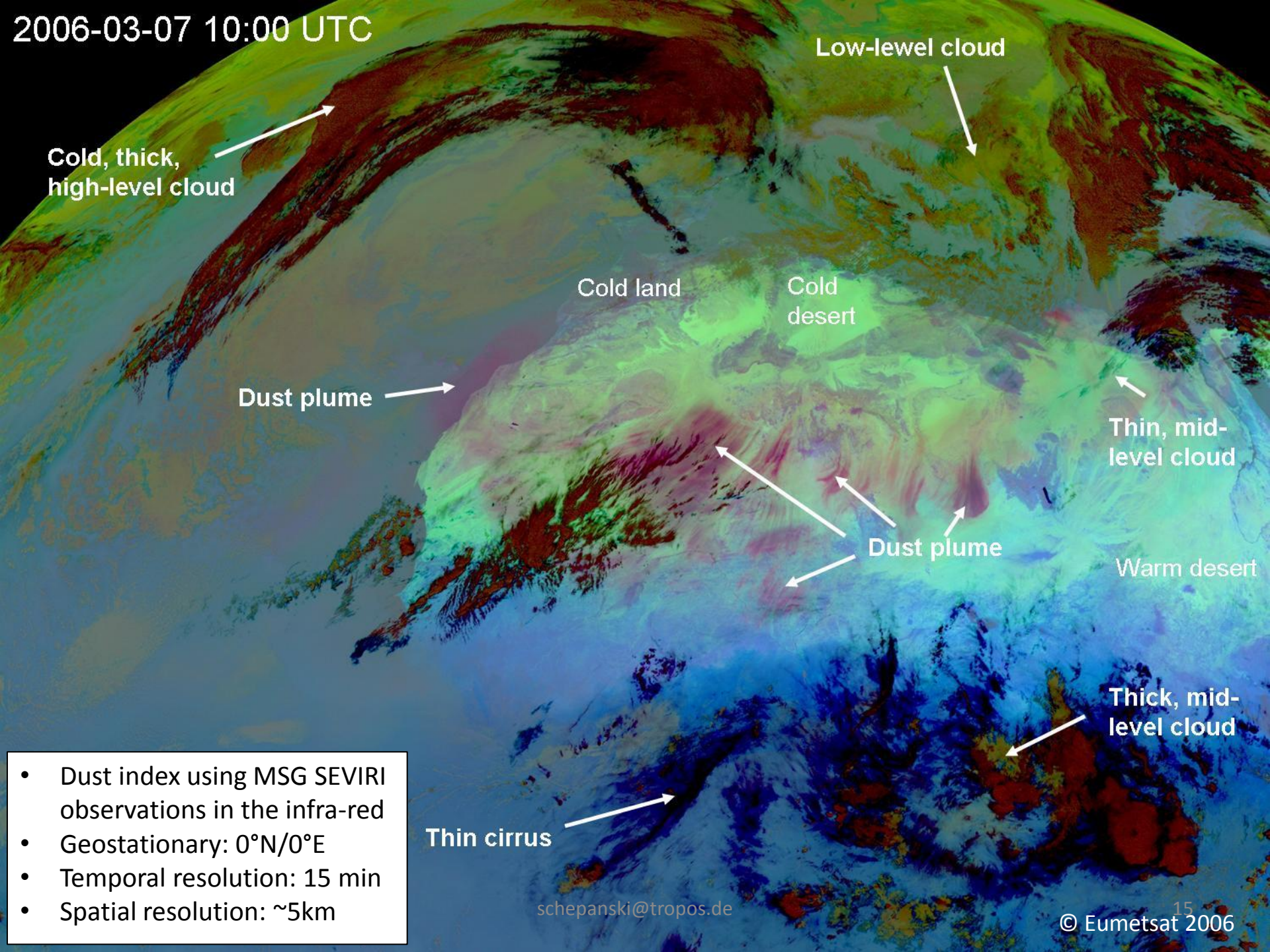
... has no or is only locally covered by crusts.

... is located in a place where wind speeds > 6 m/s occur.

... is situated in desert regions – or the farm land next door.

Identification of dust sources

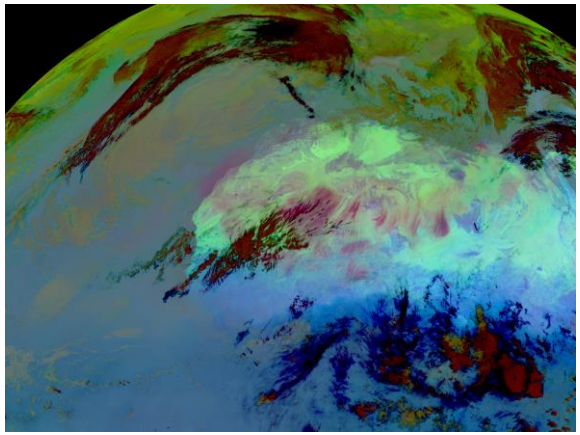
- Knowledge of dust source regions and meteorological processes forcing dust emission important for modelling
  - Spatial and temporal distribution of dust source regions
  - Precondition for accurate description of atmospheric dust life-cycle and dust feedbacks
- Satellite observations suitable data set for inferring active dust source regions
  - Spatial coverage
  - Availability



- Dust index using MSG SEVIRI observations in the infra-red
- Geostationary: 0°N/0°E
- Temporal resolution: 15 min
- Spatial resolution: ~5km

Mapping North African Dust Sources

Tri-spectral IR dust index, 15 min



Determination of single dust sources

R: BT(12.0 µm)-BT(10.8 µm)
G: BT(10.8 µm) -BT(8.7 µm)
B: BT(10.8 µm)

Program-Routine

IR difference dust index

visual analysis

redish color

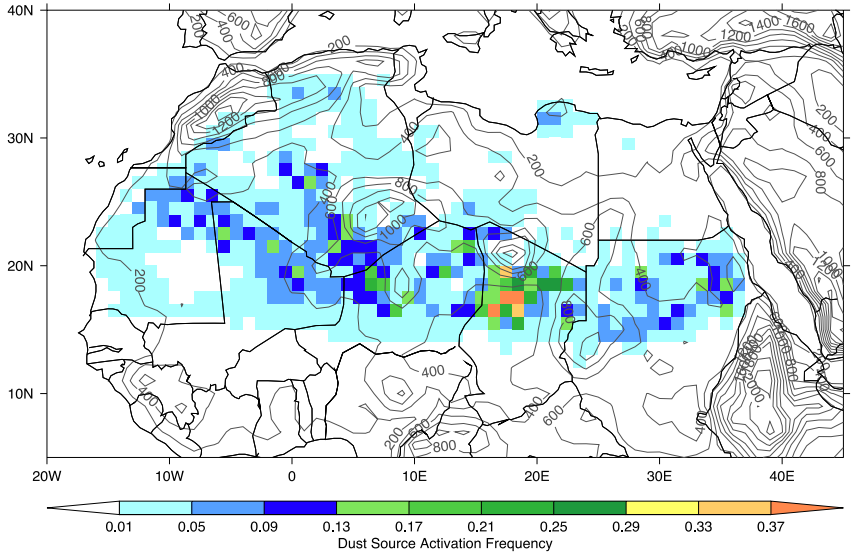
Movement

differentiation between surface and dust

source area = area of fist occurrence of redish color

marking source area on 1°x1° map

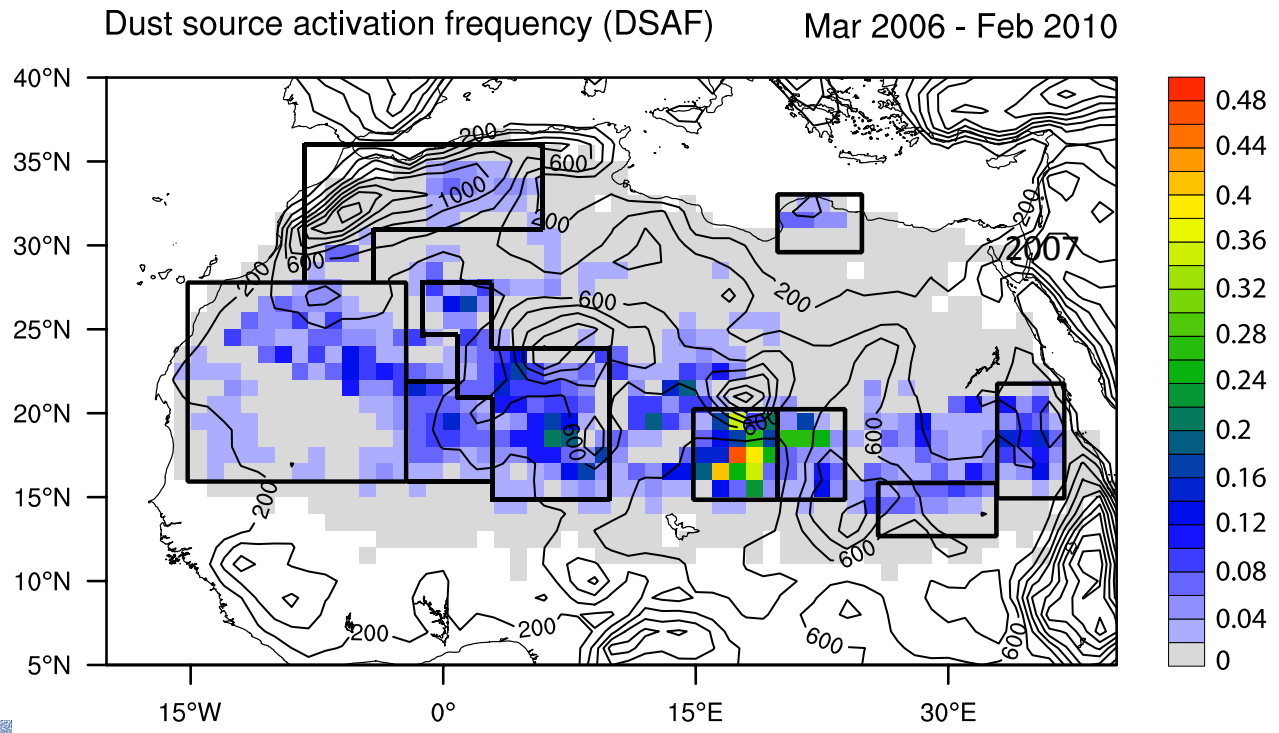
Dust source activation frequency, 03/2006-02/2010



[Schepanski et al., 2007]

Time-of-day of dust source activation

- Mapping active dust sources
  - Dominant dust sources are located in desert valleys
  - Most dust sources become active during the morning



00-12 UTC

12-00 UTC

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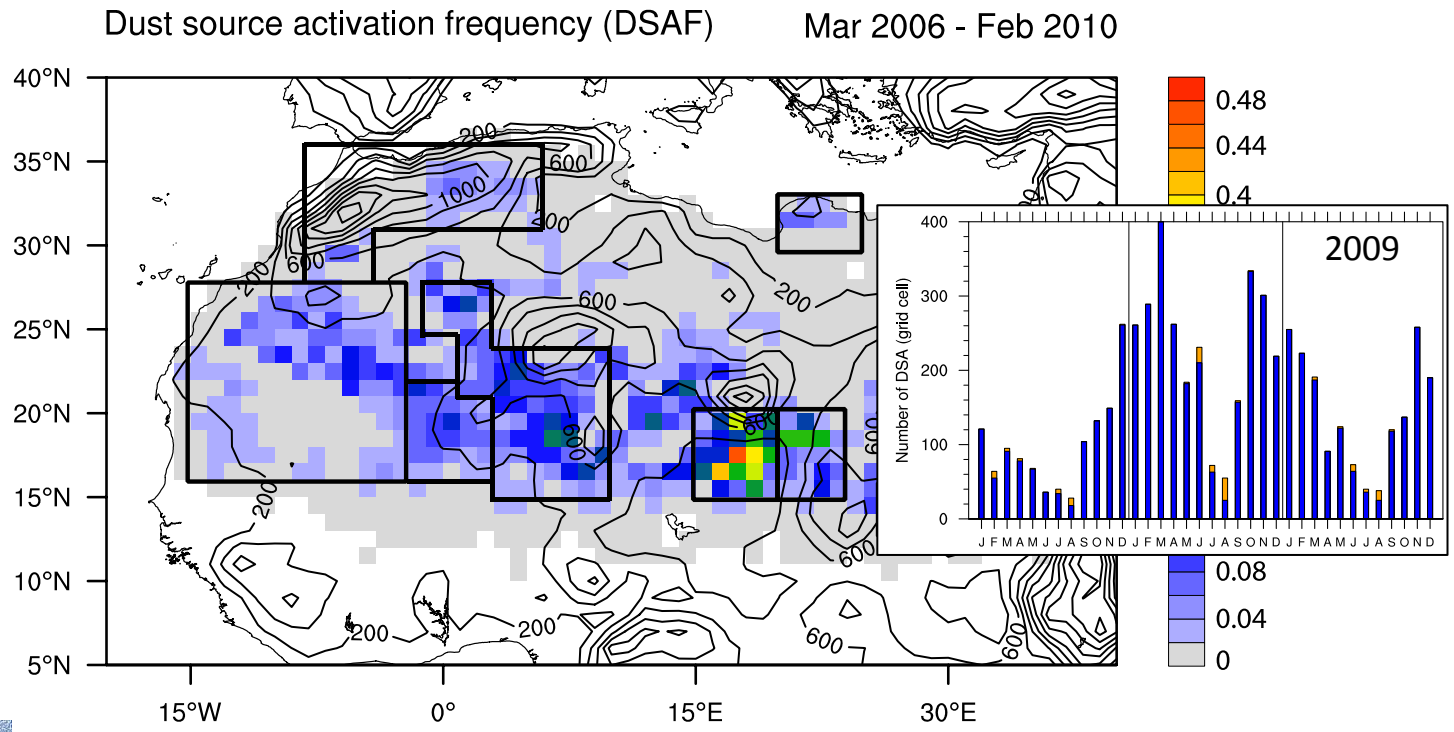

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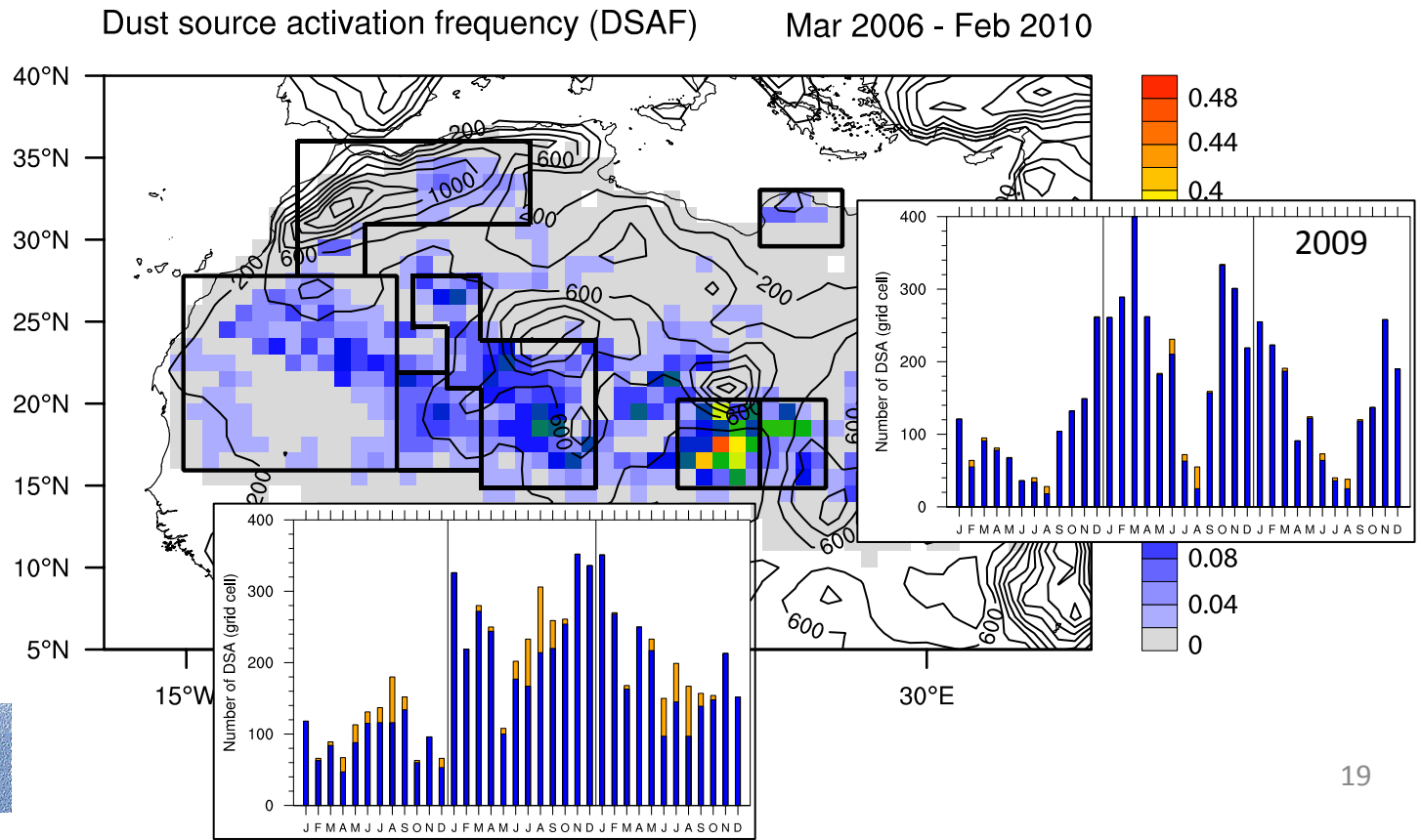

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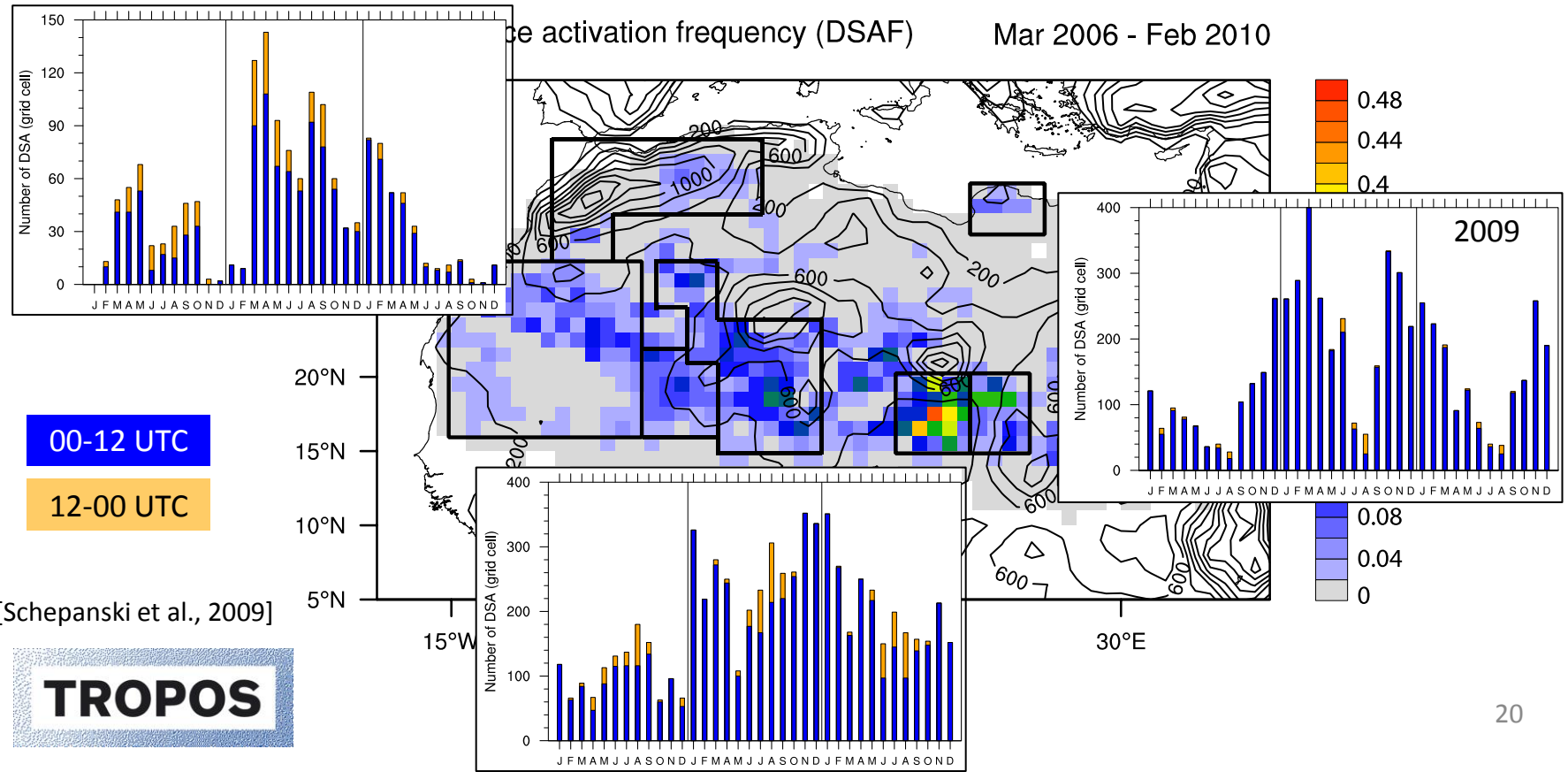

[Schepanski et al., 2009]

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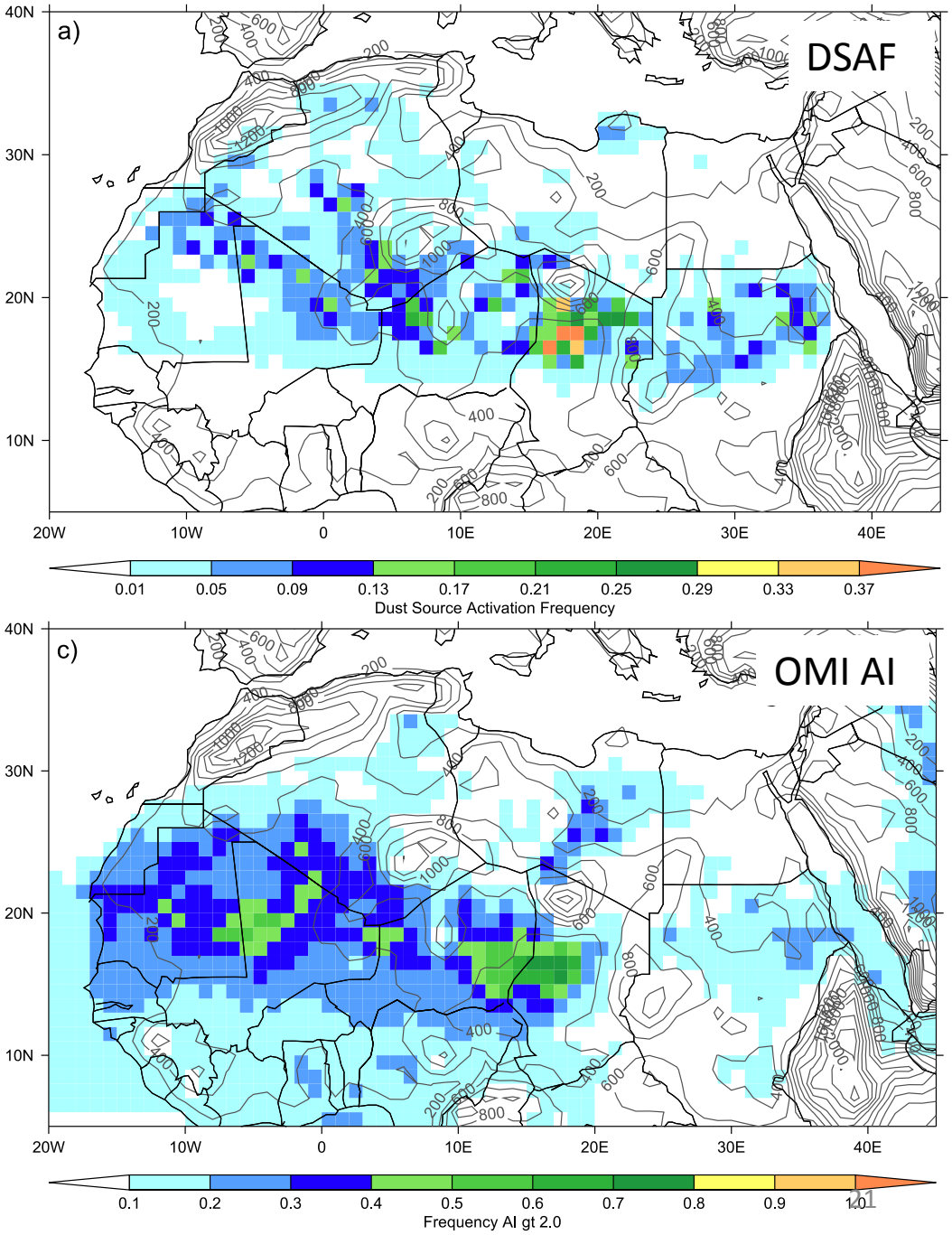
Identification of dust sources

'Types' of Identification:

- Origin of dust plume
- Occurrence frequency of dust loading
  - Frequency of threshold exceedance, e.g. AI > 2.0
  - High dust load over sources



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Schepanski et al., 2012

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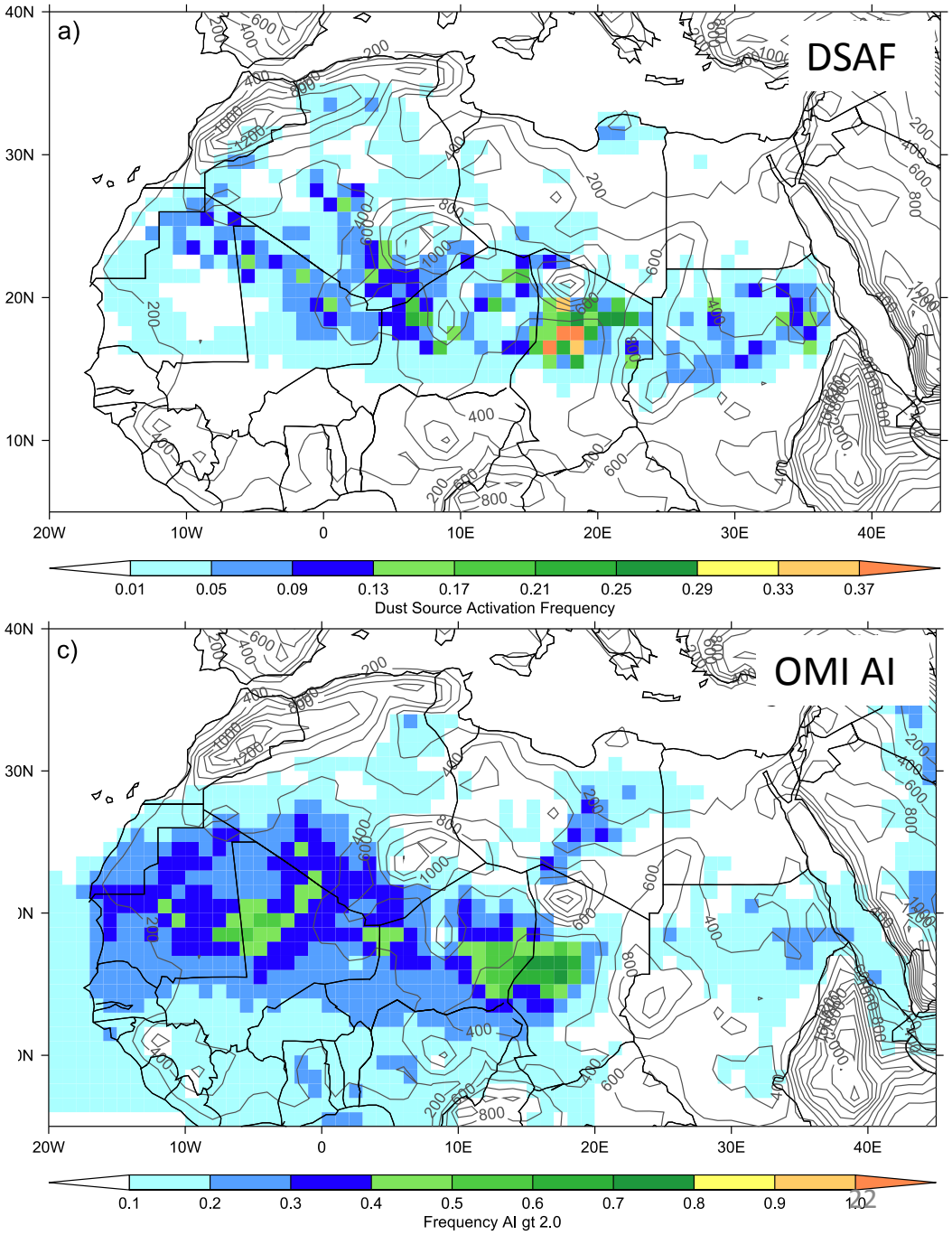

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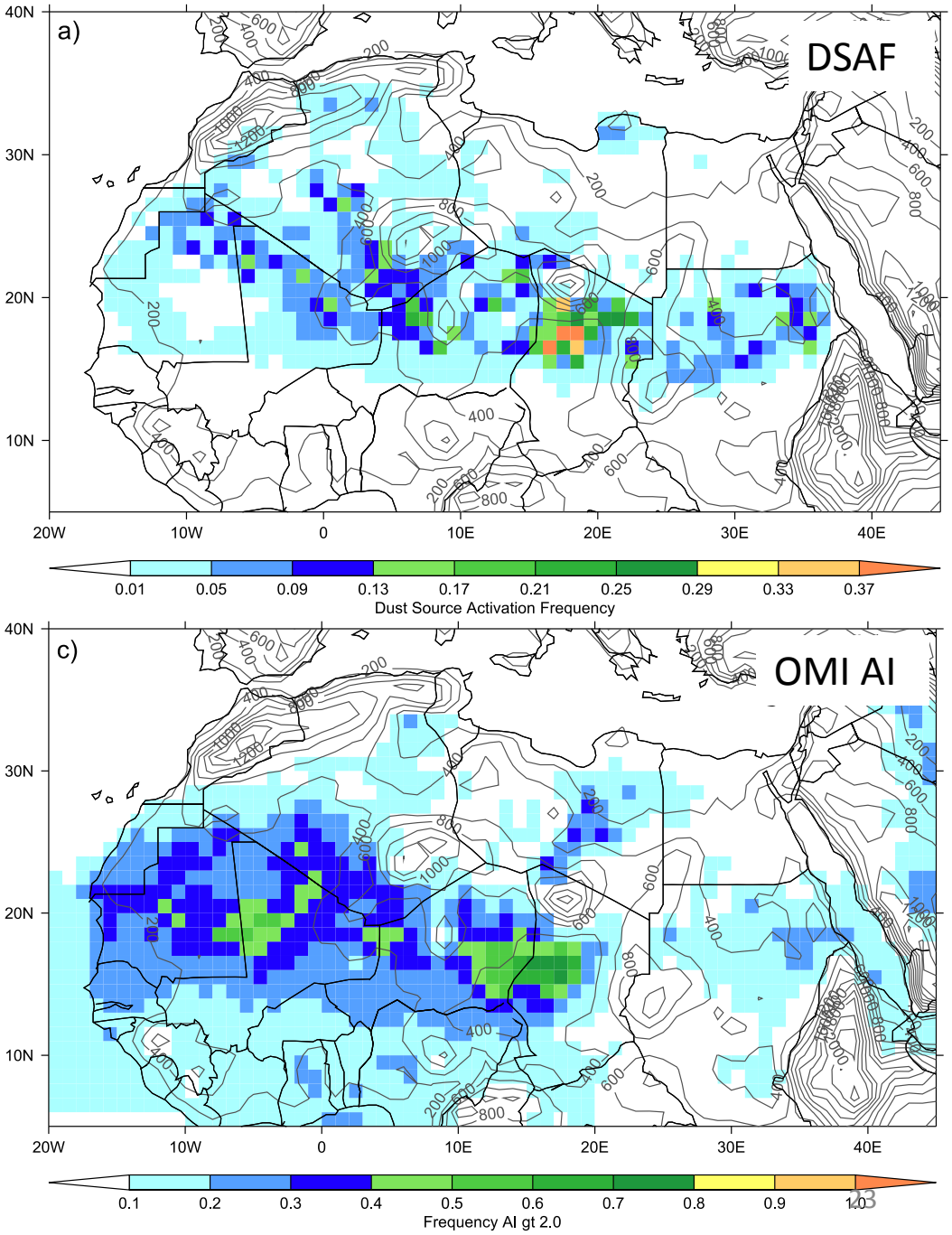
Model input commonly bases on limited temporal resolution.



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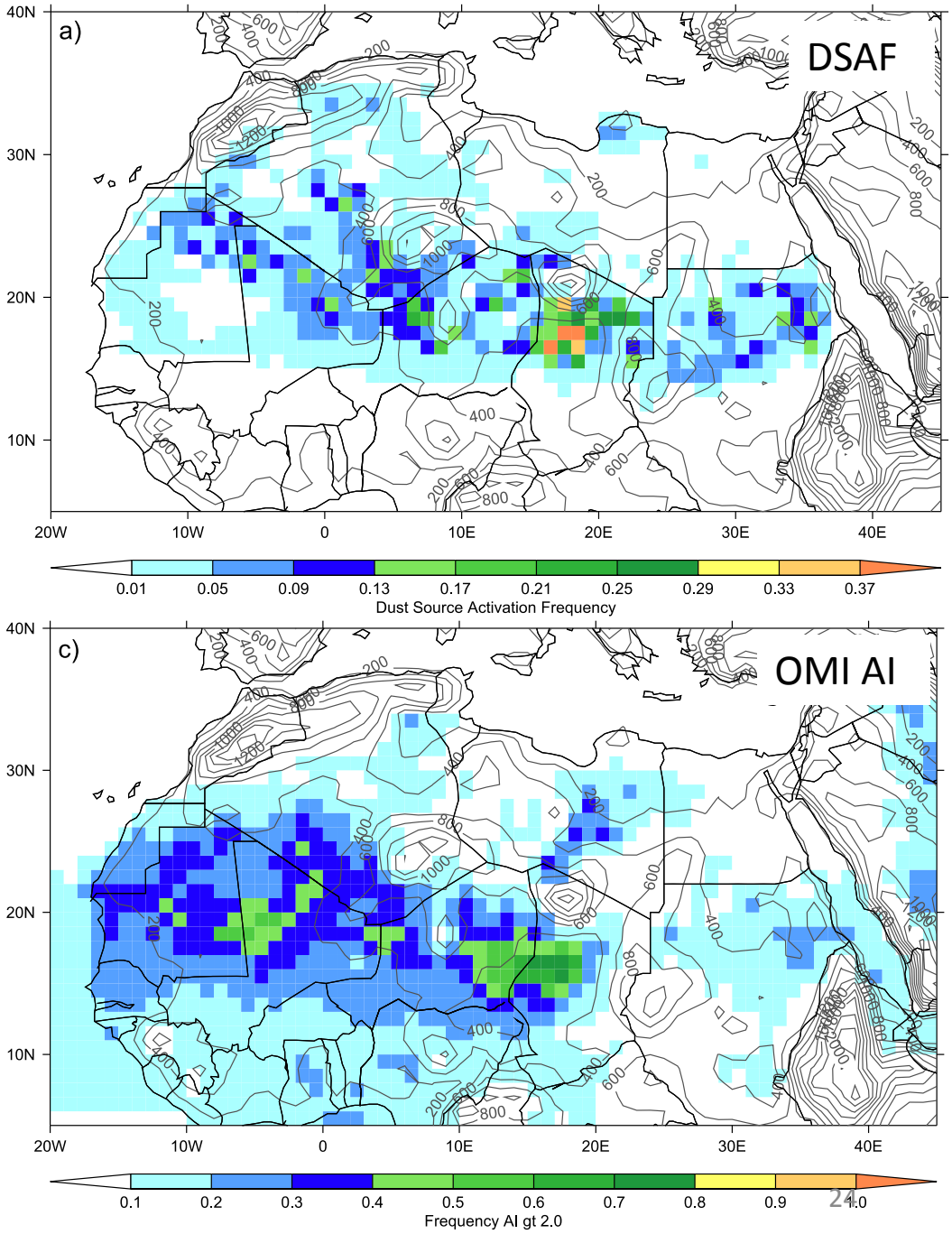
Schepanski et al., 2012

Timing of observation

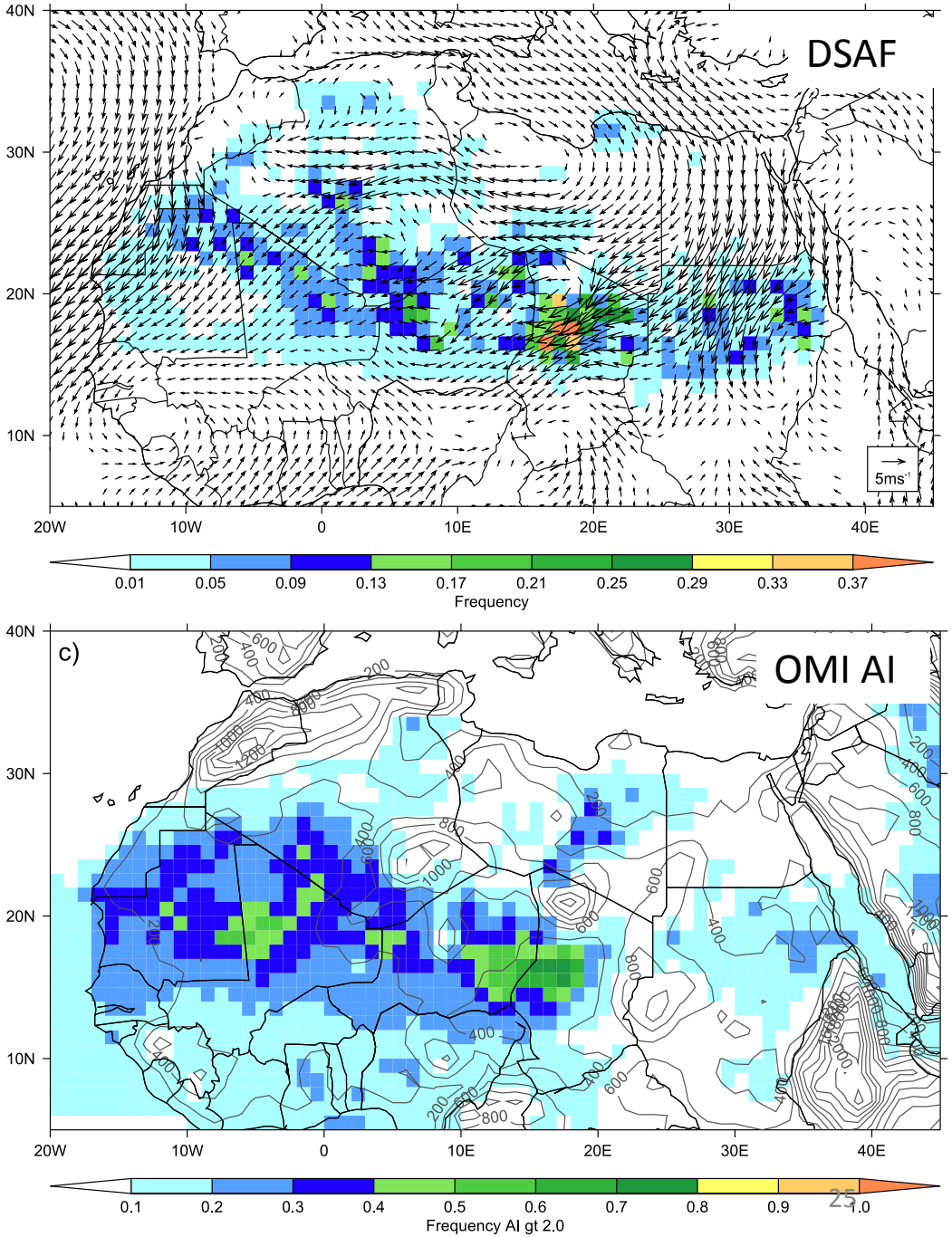
- Temporal resolution of satellite data determines retrieved dust source locations



Schepanski et al., 2012

Timing of observation

- Temporal resolution of satellite data determines retrieved dust source locations
- Temporal difference between on-set of dust emission and satellite observation leads to downwind shift of dust hot spot
  - Wind transport
  - Accumulation of airborne dust in topographic depressions
  - Altitude of dust plume impacts on sensor sensitivity (e.g. OMI)



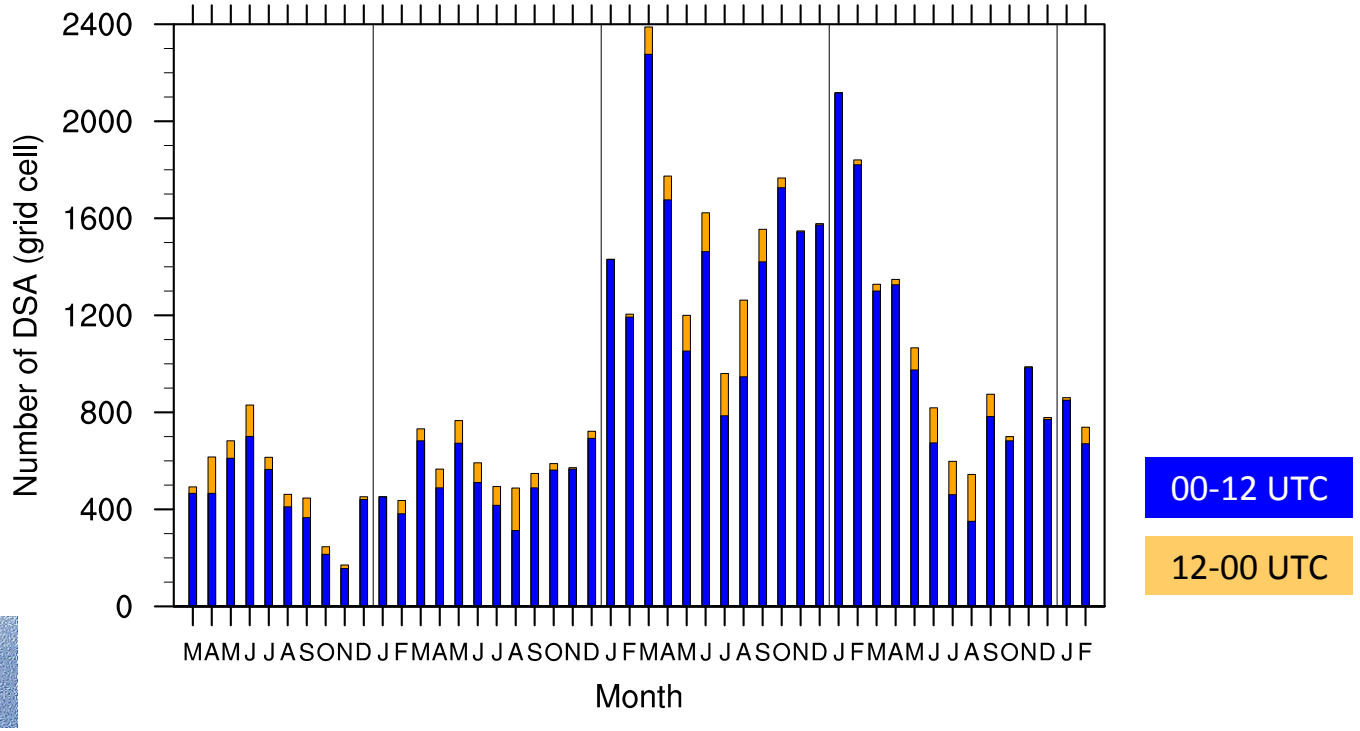
Schepanski et al., 2012

Application to Models

- Maps of dust sources are used as mask of potential dust sources in dust models
- Time-of-day of dust source activation points towards meteorological conditions fostering dust emission
  - Models can provide complementary studies on atmospheric processes involved
  - Models can provide estimates on relevance and feedback mechanism

Meteorological driver

- Mapping active dust sources
  - Dominant dust sources are located in desert valleys
  - Most dust sources become active during the morning
- Synoptic situations linked to time-of-day



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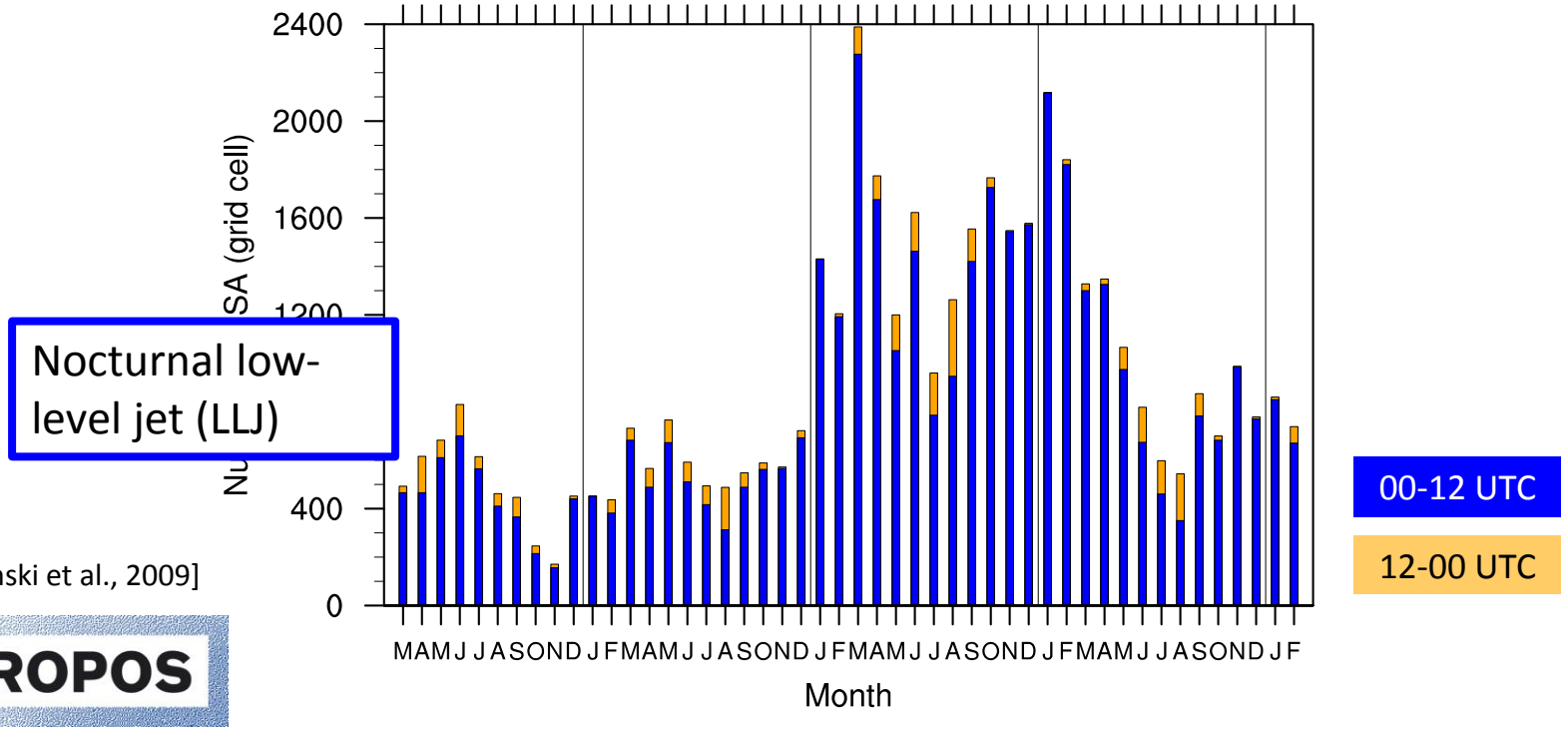

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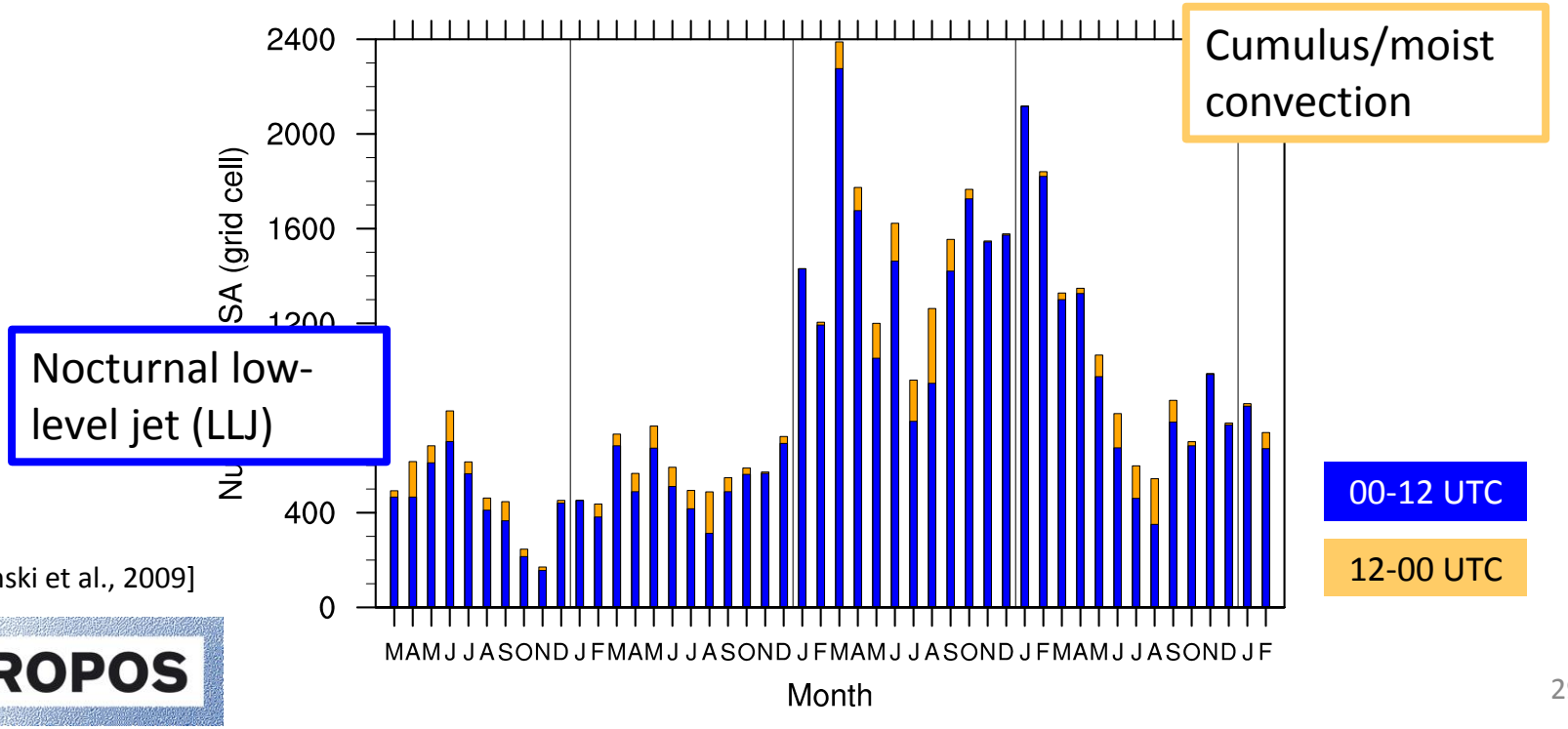

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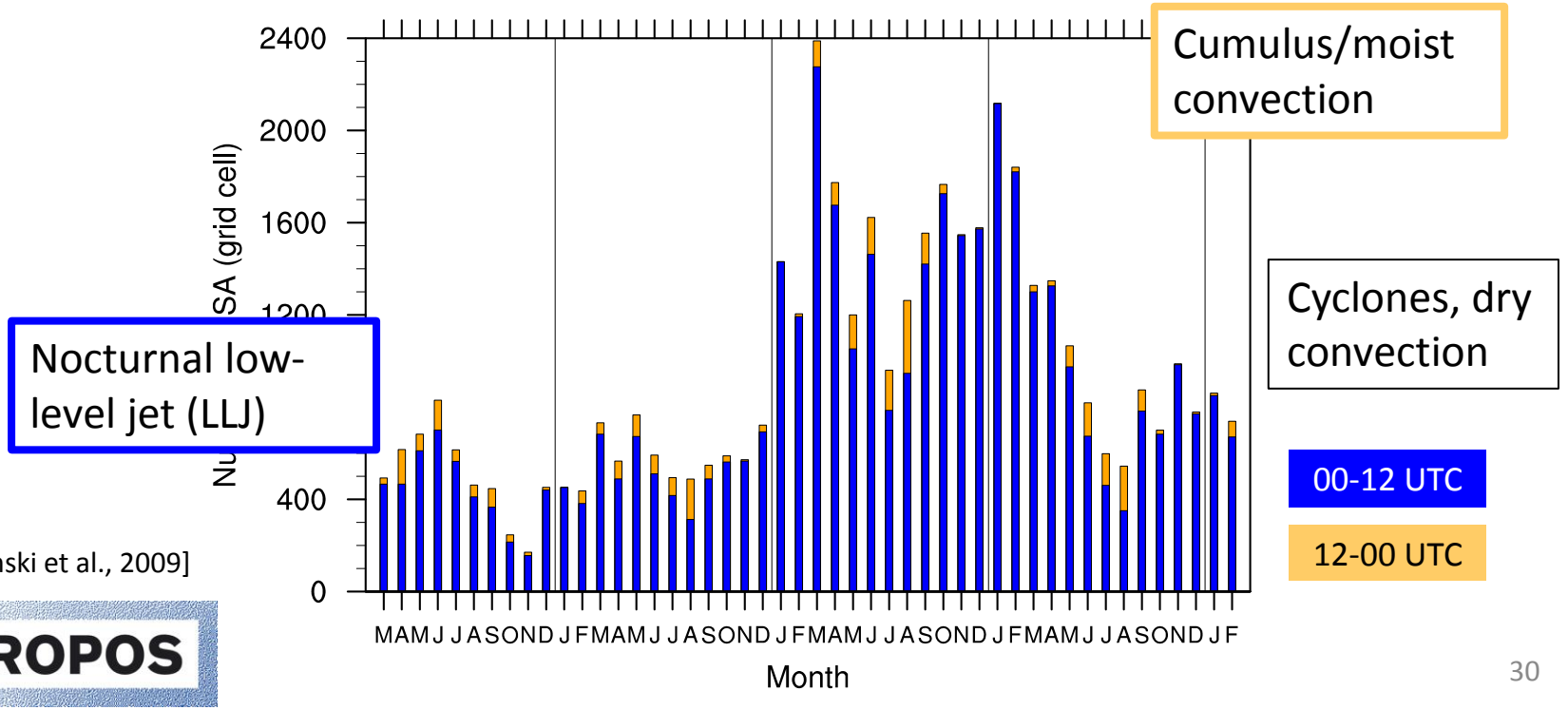

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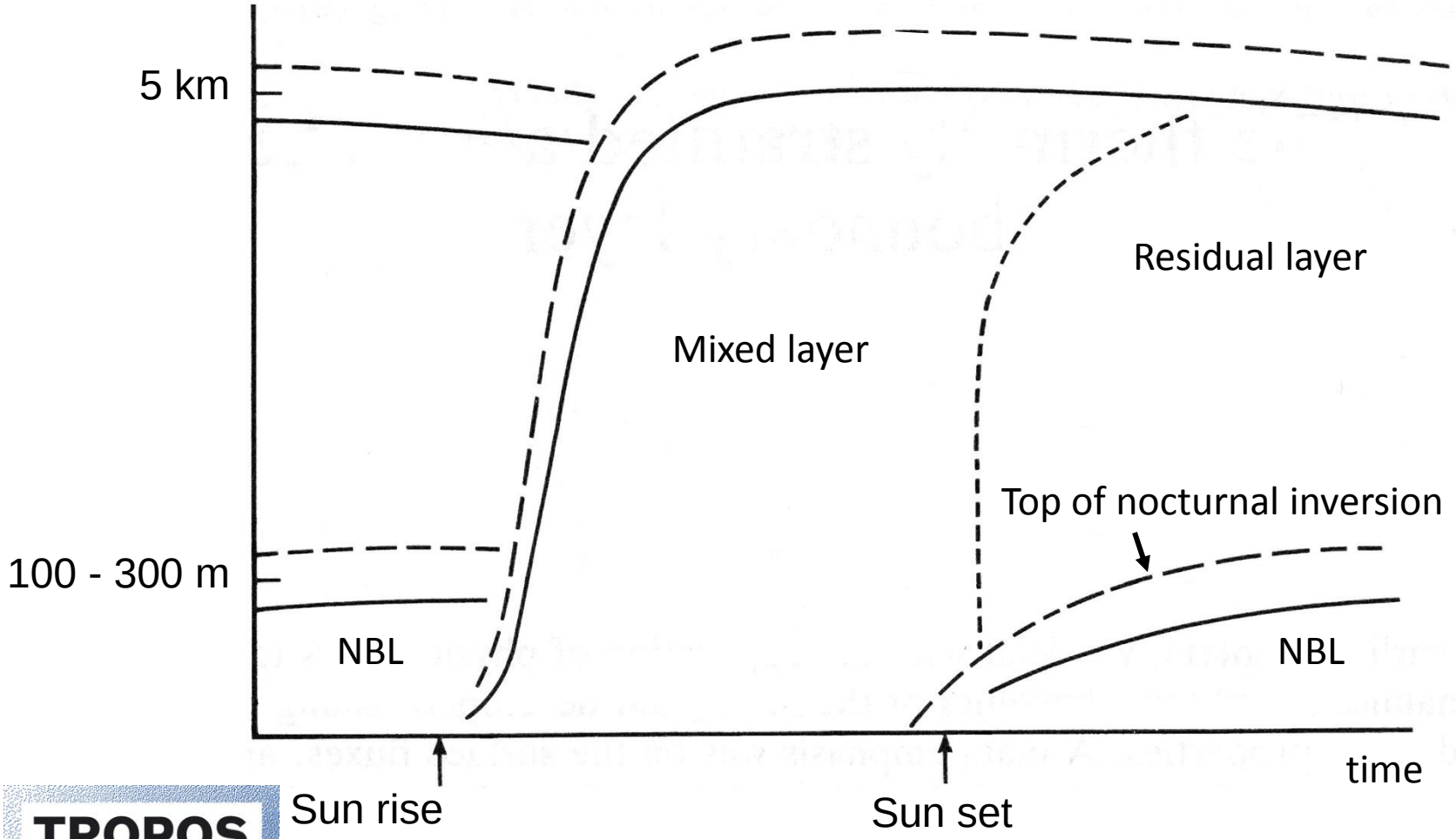
The nocturnal low-level jet (LLJ)

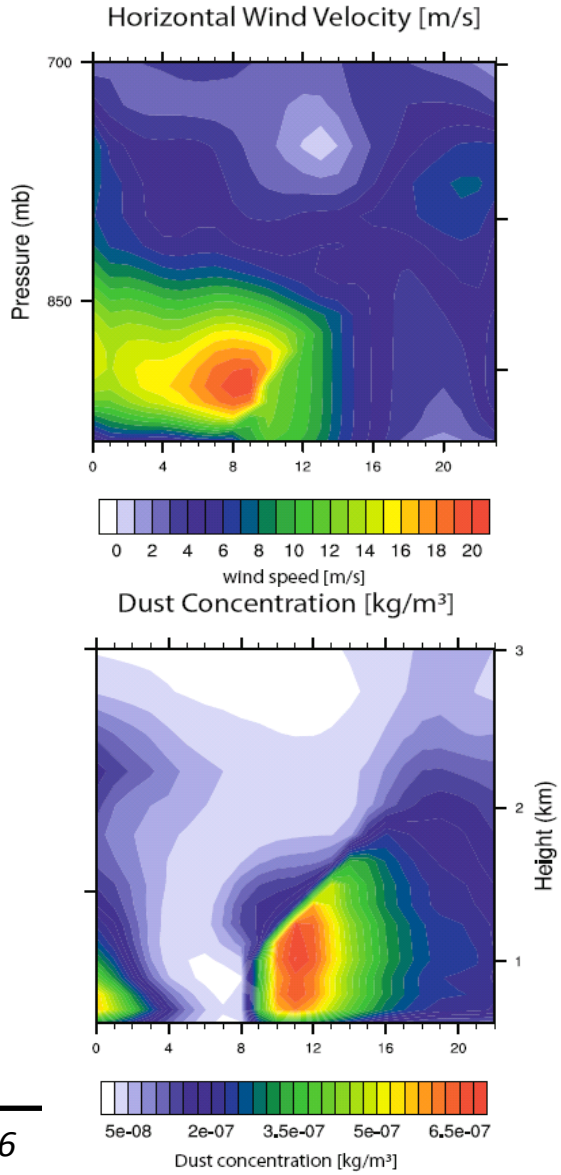
Temporal evolution of the boundary layer, technical terms



[after Garrett, 1992]

The nocturnal LLJ

- Decoupling of the residual layer from the surface due to the formation of the nocturnal boundary layer (NBL).



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COSMO-MUSCAT simulation, 22.25°N, 3.5°E, 10 Mar 2006

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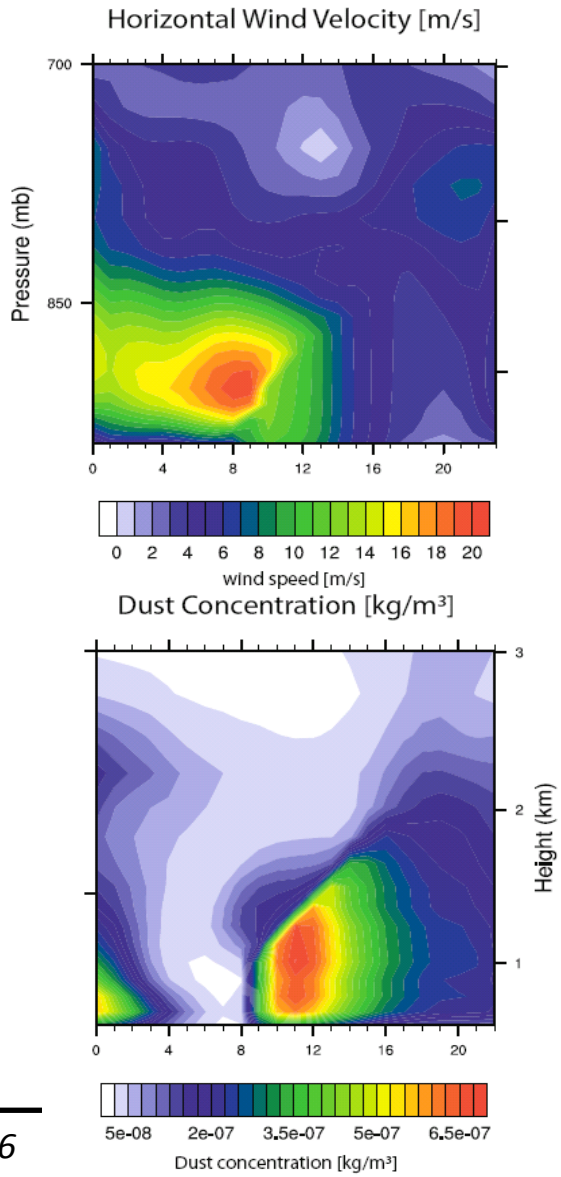

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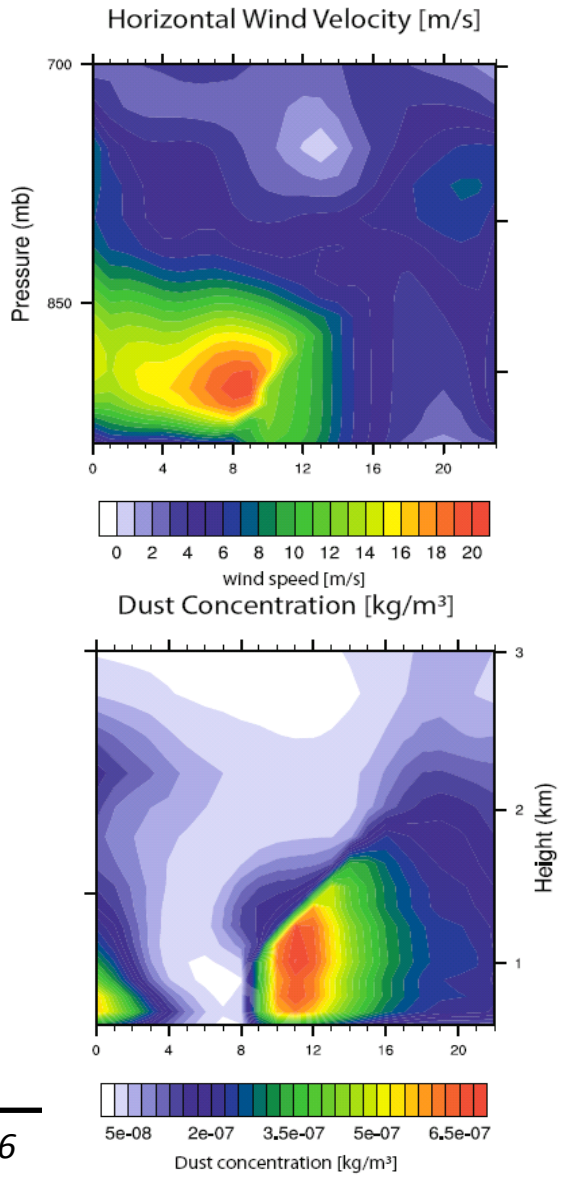
- Shortly after sun rise, the convective mixed layer grows, and the residual layer including the LLJ erodes.



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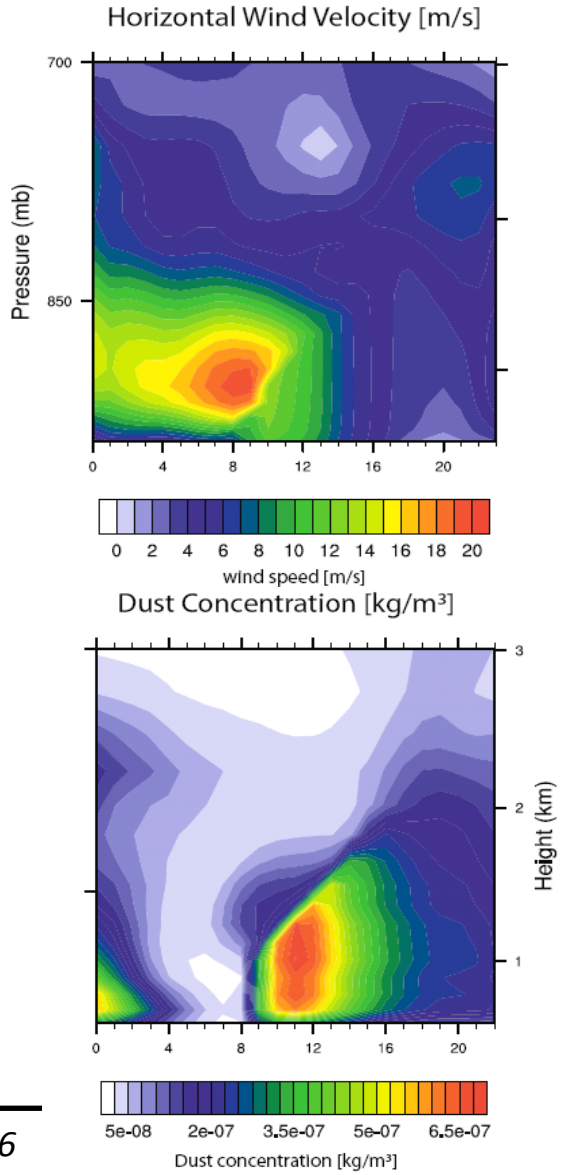
- Acceleration of winds above the top of the NBL within the residual layer: low-level jet.
- Shortly after sun rise, the convective mixed layer grows, and the residual layer including the LLJ erodes.
- Momentum from the LLJ is distributed over the growing mixed layer resulting in an increase of wind speed.



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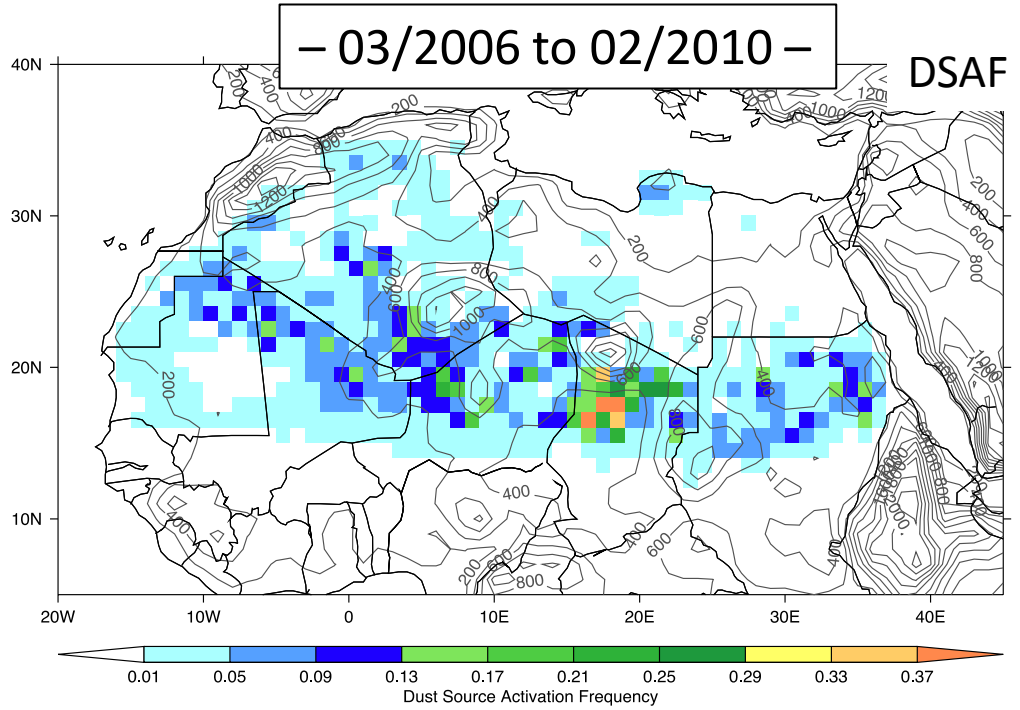
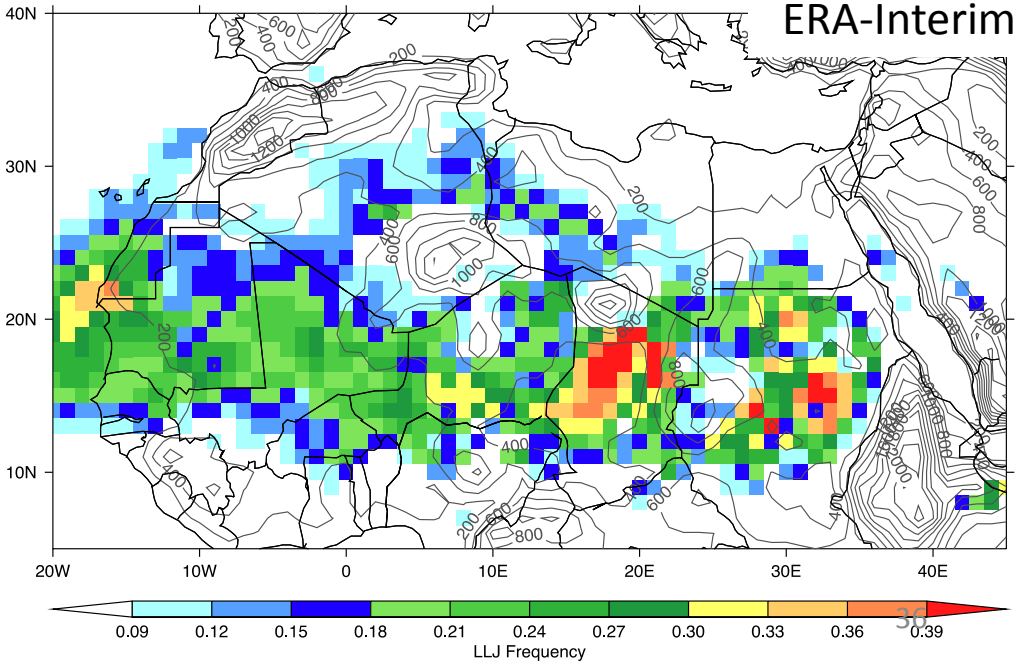
COSMO-MUSCAT simulation, 22.25°N, 3.5°E, 10 Mar 2006

Role of LLJ for dust emission

- Many observed dust source areas show high frequencies of LLJ occurrence
- Margins of the Saharan Heat Low, West African monsoon circulation, inflow regions of maritime air masses
- Seasonality is evident





LLJ identification based on wind speeds difference (≥ 6m/s) at pressure level corresponding to LLJ core height (dependent on terrain height) and wind speed minimum above [Schepanski et a., 2009; Crouvi et al., 2012].

Summary

- Identification of active dust sources from satellite observations
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  - By tracking-back individual dust plumes to their point of origin
  - By assuming frequent high dust loading over source regions
- Temporal resolution and time of observation with regard to time of dust source activation is crucial for inferring maps on dust sources
- Time of day of dust source activation provides implicitly information on meteorological drivers
  - Most dust sources over the Sahara are activated during the morning hours; LLJs are prominent drivers
- Satellite & Models in concert:
  - Input data on potential dust sources for dust models
  - Allow for comprehensive interpretation of data