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MedCLIVAR Workshop on: "Scenarios of Mediterranean Climate Change under Increased Radiative Active Gas Concentration and the Role of Aerosols

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African monsoon and Mediterranean climate: the role of mineral dust aerosol from Saharan desert

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African monsoon and Mediterranean climate: the role of mineral dust aerosol from Saharan desert

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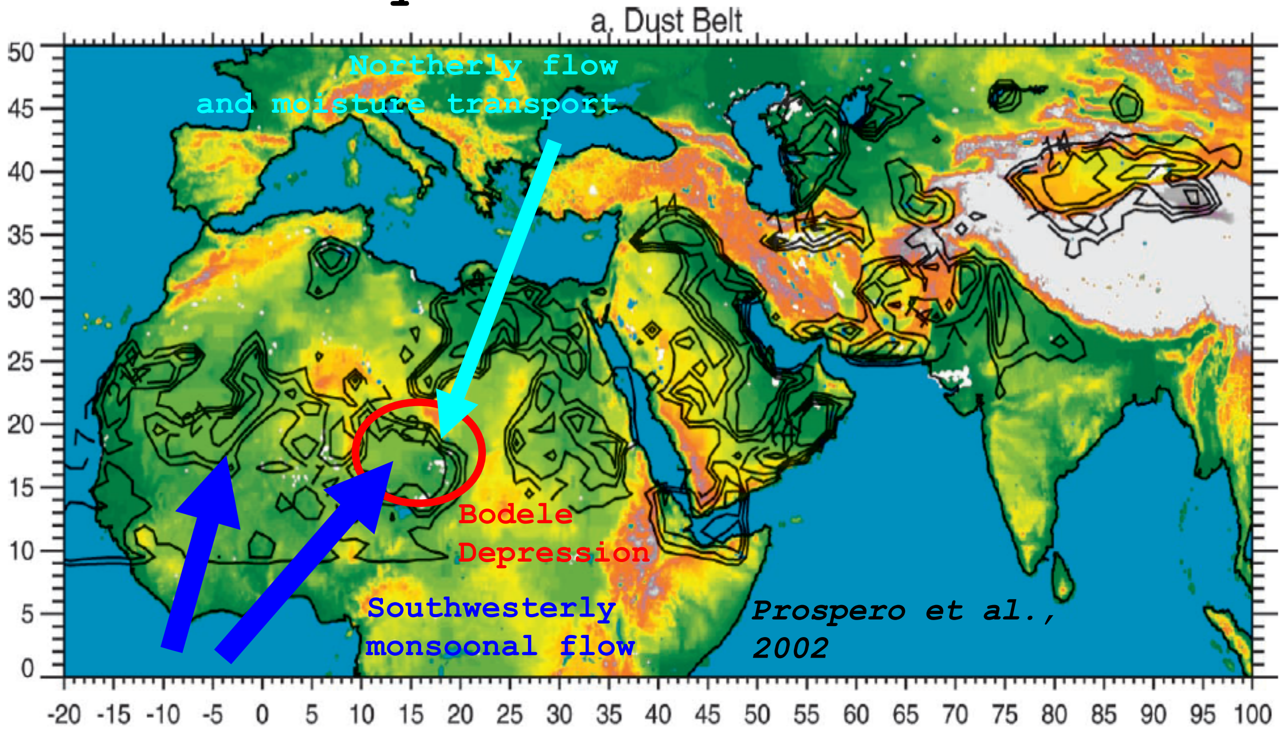
Outline

1. Motivations & objectives
2. Med-Sahel and Saharan dust observation
3. Dust transport simulation
4. Conclusions and perspectives

1 Motivations & objectives

- **Med-Sahel interaction:** a warm Med sea positively affects the Sahel precip in JAS, through an intensification of the northerly flow and moisture transport across the Sahara desert, toward the monsoonal front (Rowell, 2003; Fontaine et al., 2010; Gaetani et al., 2010).

- **The Bodele Depression,** north of Lake Chad, is a large source of dust (Washington et al., 2006), and it is under the influence of the northerly flow from the Med and the southwesterly monsoonal flow.



- Complicated feedbacks between mineral aerosols and climate: impact on cloud properties and radiative forcing, suppression of precip (Mahowald & Kiehl, 2003).

- A reduction of precip is observed in Sahel related to the increase of aerosols concentration (Kluser & Holzer-Popp, 2010).

- Sahel precip reduction: Atlantic SST changes, 50%; aerosols increase, 30%; vegetation loss, 10% (Yoshioka et al., 2007).

Objective:

investigate the potential role of the Saharan dust emission/transport, within the Med-Sahel interaction, in modulating the Sahel precipitation.

Methodology:

- 2 case-studies, 1987 & 1988;
- observational data analysis;
- regional modeling.

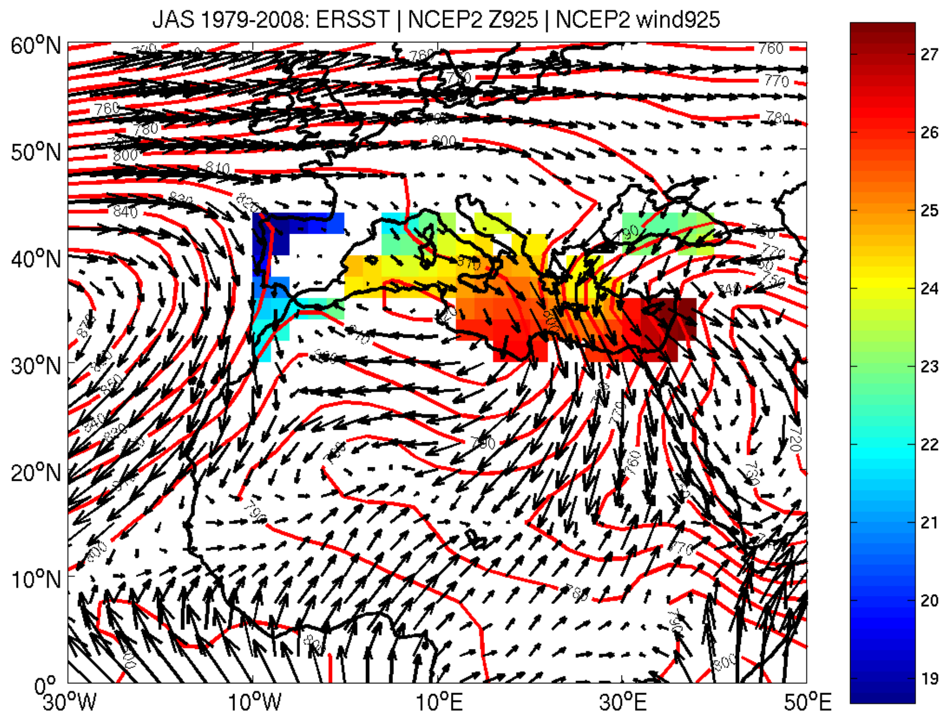
Observational data:

- NOAA Extended Reconstructed SST, 1854-present, 2° lat-lon res;
- CPC Merged Analysis of Precipitation, 1979-2009, 2.5 lat-lon res;
- NCEP-DOE Reanalysis 2, 1979-2008, 2.5 lat-lon, 17 vertical levels;
- NASA-GSFC Total Ozone Mapping Spectrometer, Aerosol Index (Earth Probe, Meteor3, Nimbus7, OMI, 1978-present)

AI = 100*log(I_obs(UV) / I_Ray(UV))

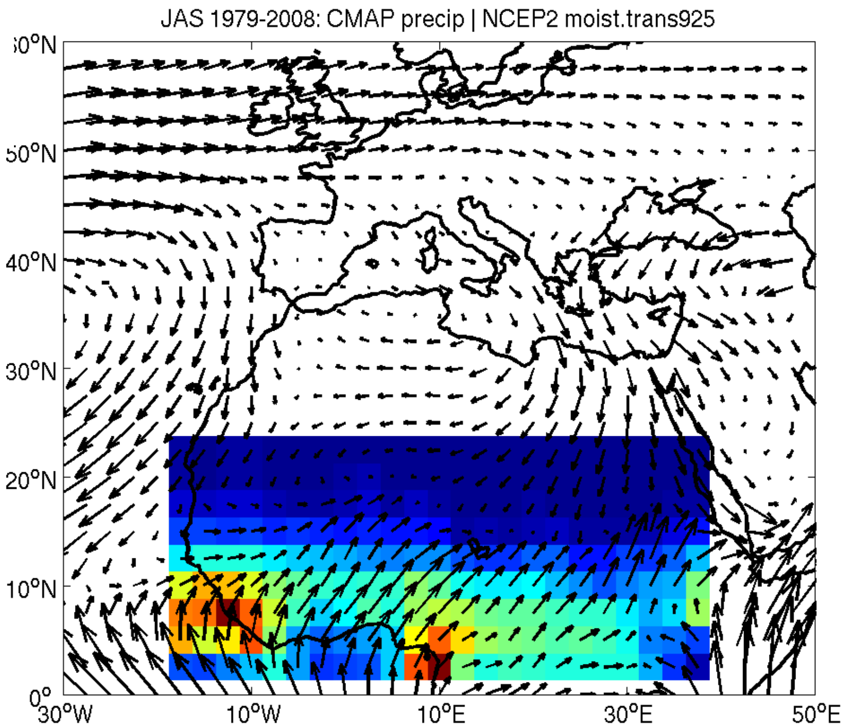
2 Observations

Climatology 1979-2008 JAS

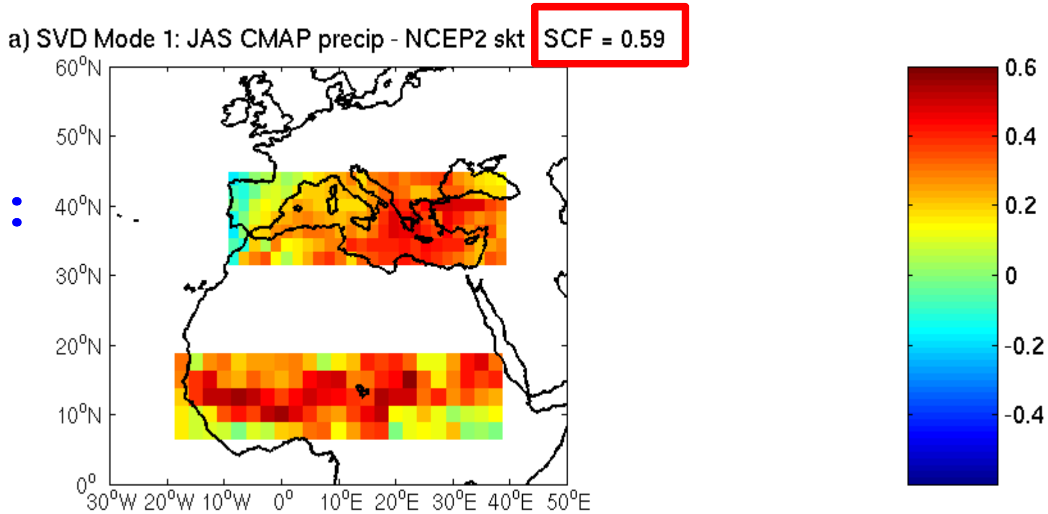


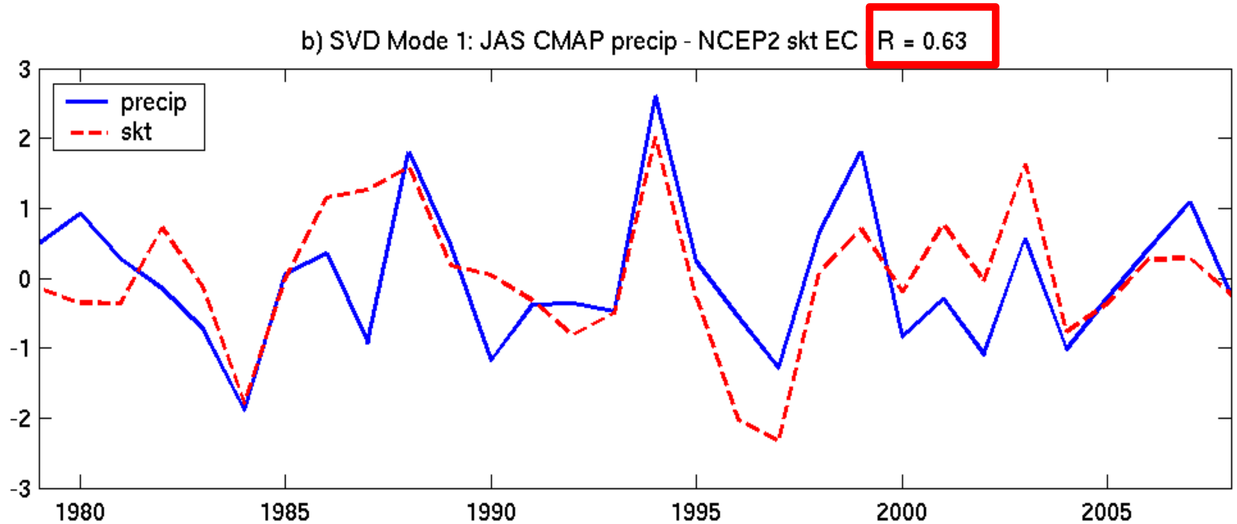
SST, Z925, wind925

Precip, moist.trans925



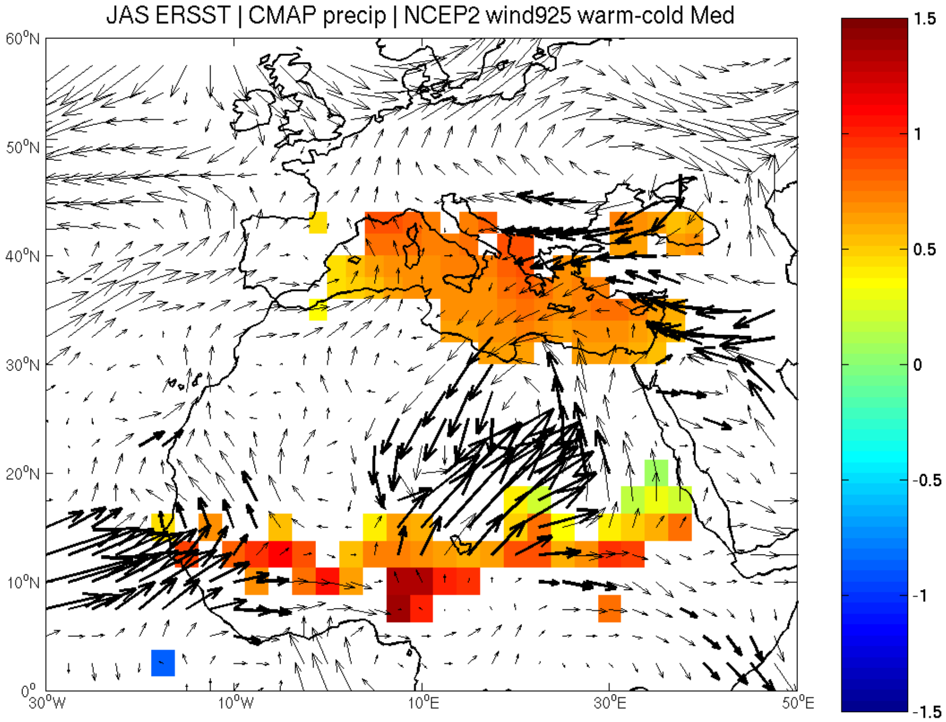
Covariance analysis:
Med surface temp
vs. Sahel precip,
1st mode





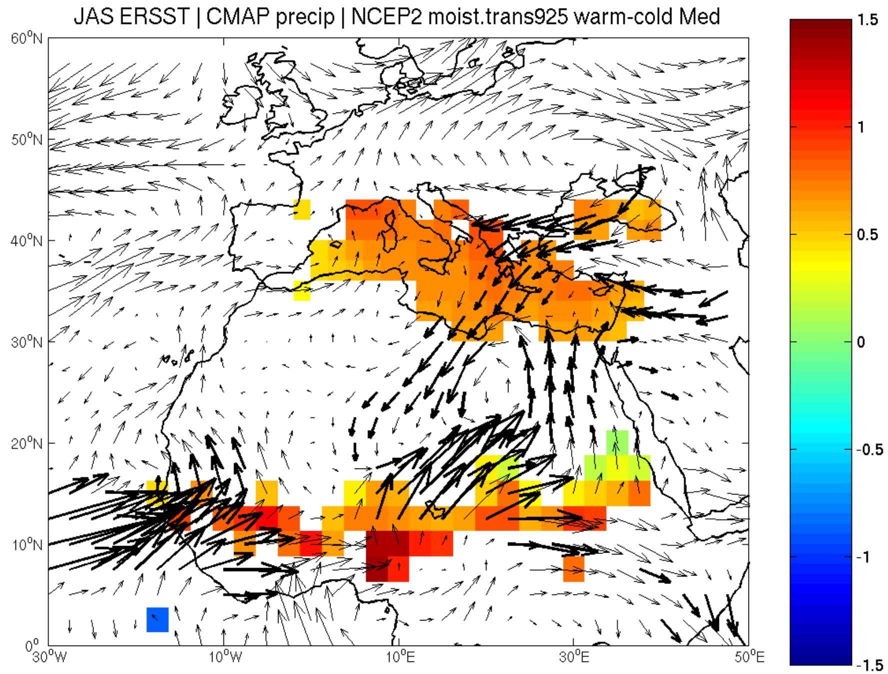
2 Observations

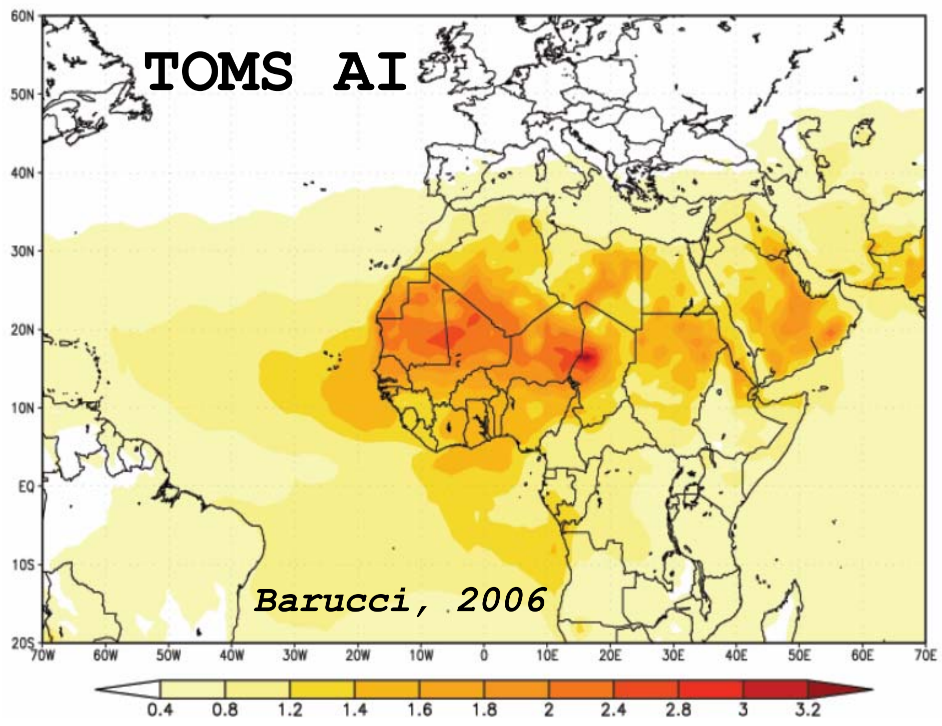
JAS Med warm-cold differences

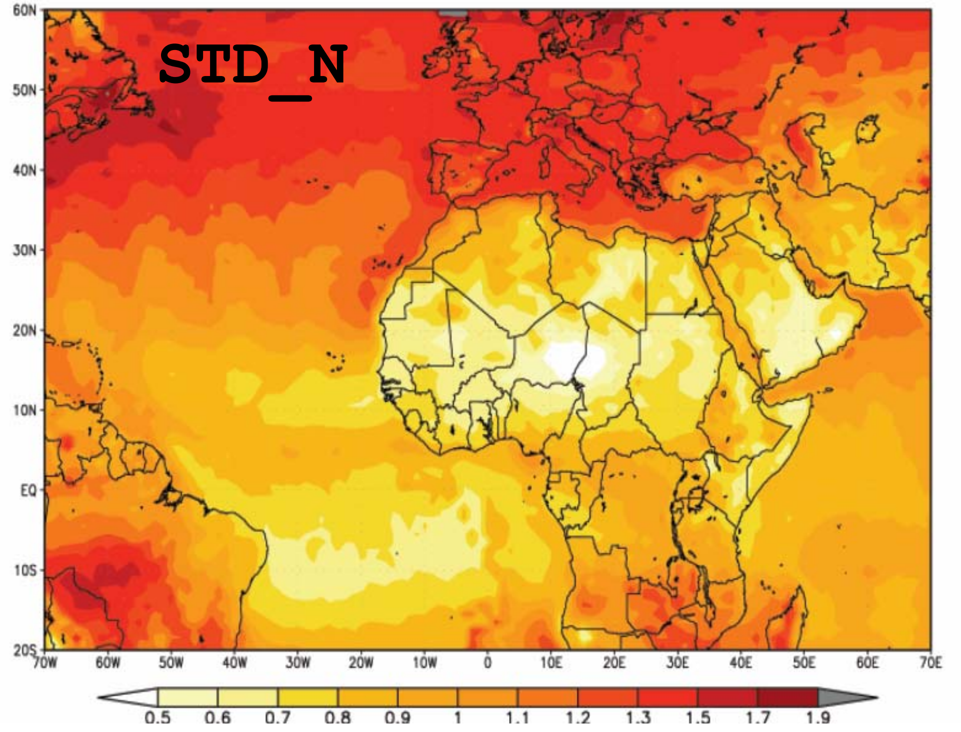


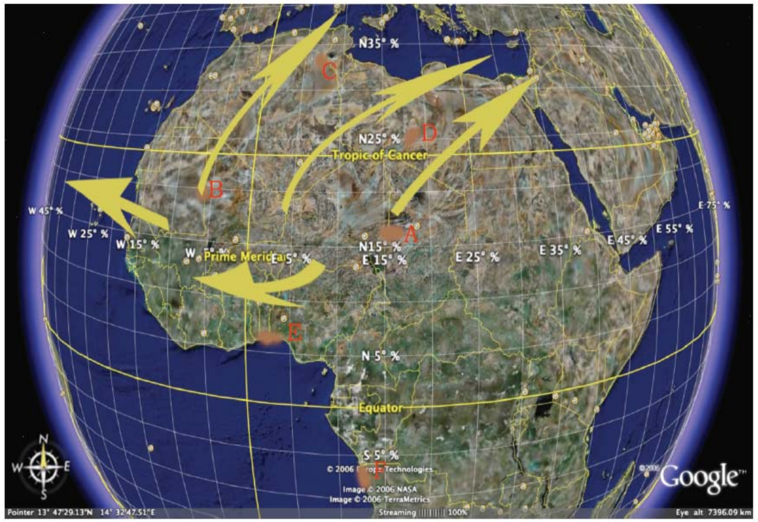
Med SST, Sahel precip, wind925

Med SST, Sahel precip, moist.trans925





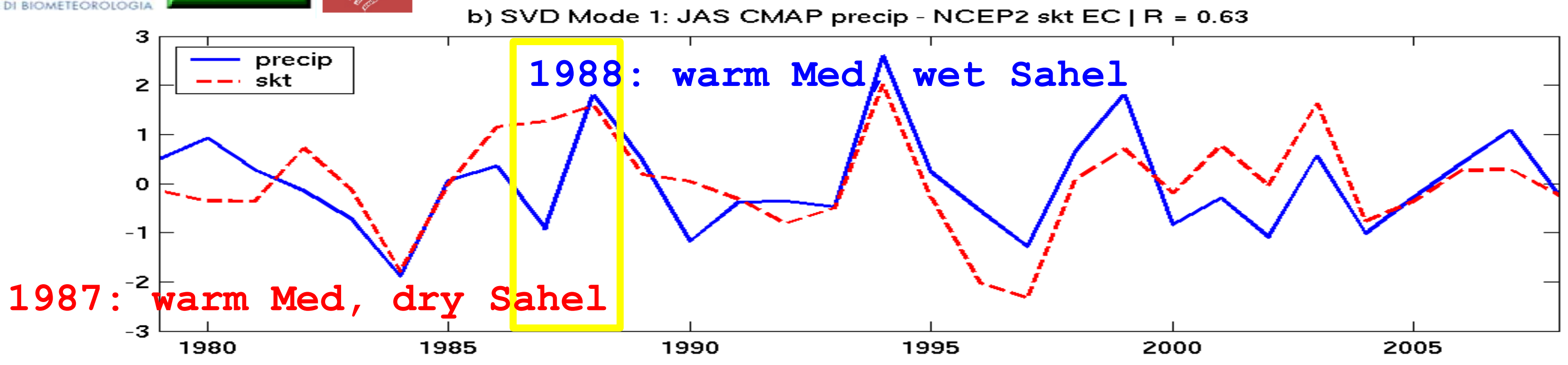


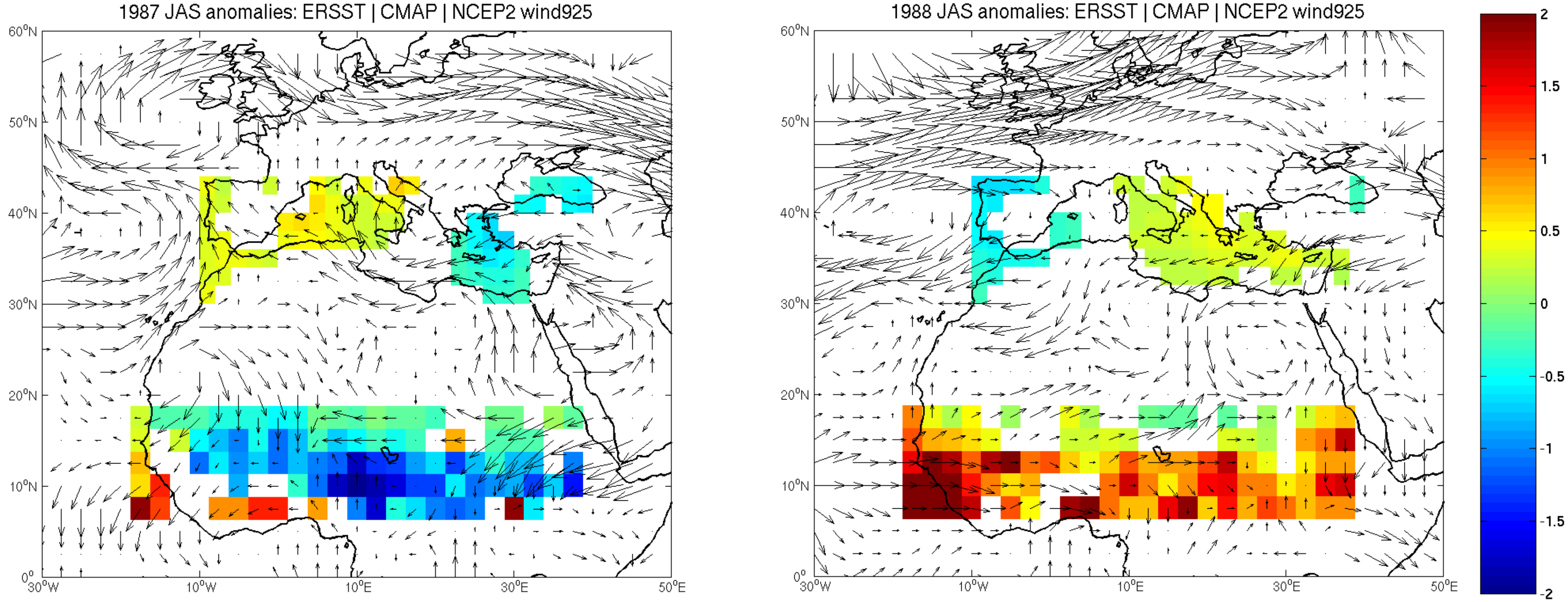


Main transport directions

TOMS Aerosol Index, annual mean

Source stability, STD_N=STD(AI)/<AI>





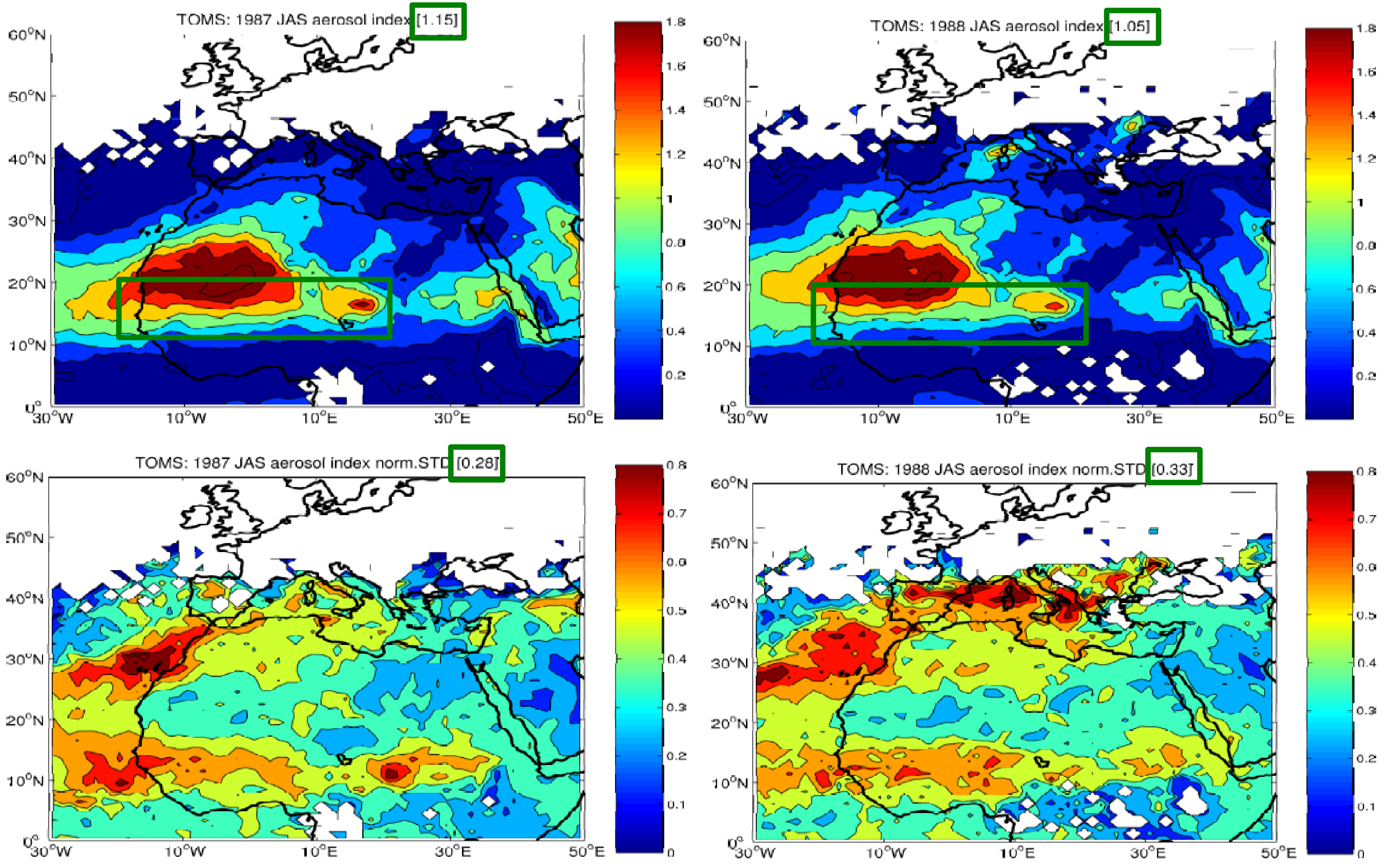
1987: reduced SST gradient,
reduced northerly flow, enhanced easterlies.

1988: enhanced SST gradient,
increased northerly flow, enhanced convergence.

TOMS JAS Aerosol Index and norm.STD

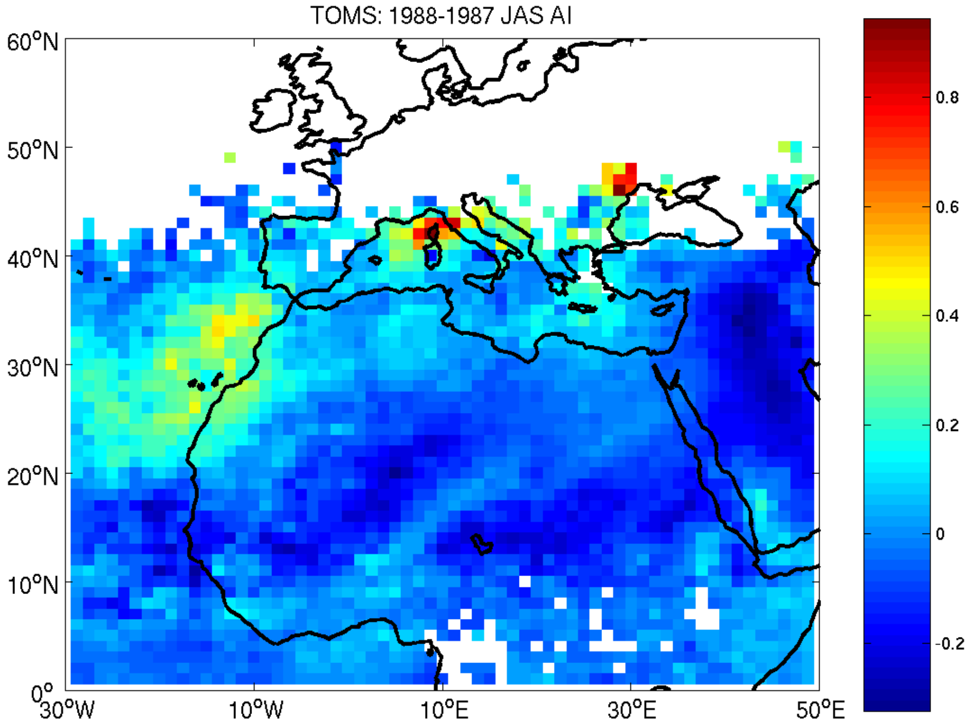
1987, warm Med, dry Sahel

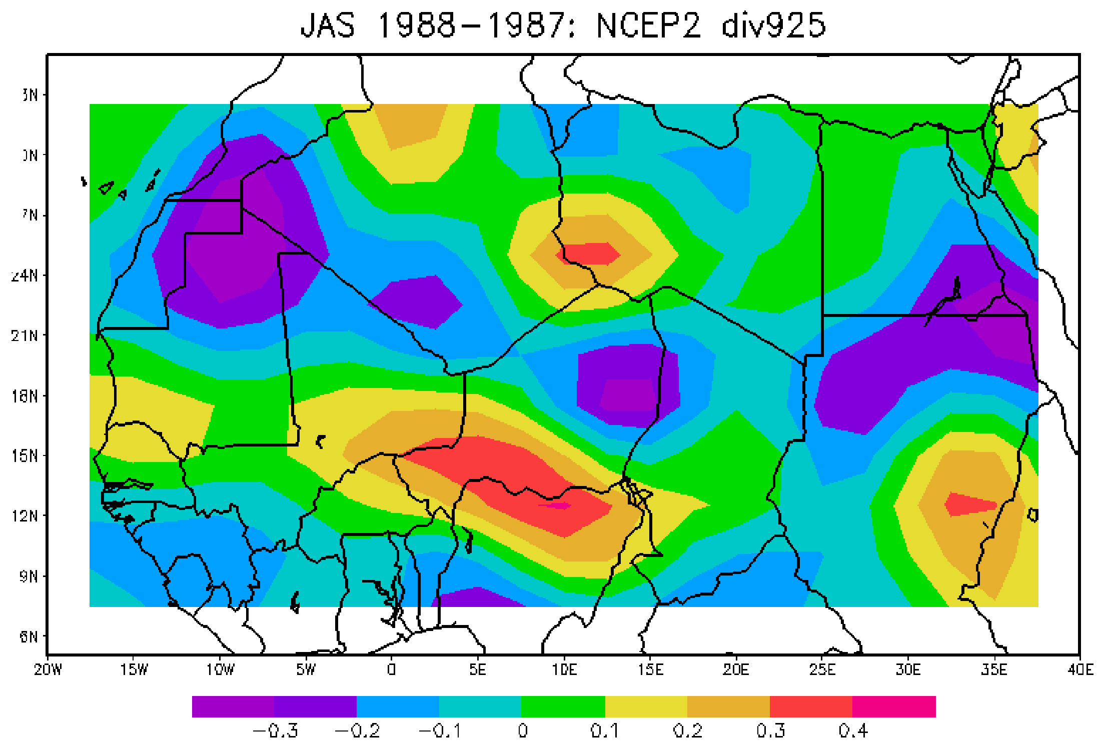
1988, warm Med, wet Sahel



2 Observations

1988-1987 JAS difference: TOMS AI and NCEP2 div925





Observational evidences:

- the intensity of the west-east SST gradient in the Med drives the northerly flow toward the Sahel;
- 1987, warm Med, dry Sahel: weak SST gradient => weak northerly flow => reduced convergence => easterly anomalies => enhanced dust emission/transport;
- 1988, warm Med, wet Sahel: strong SST gradient => strong northerly flow => enhanced convergence => southwesterly anomalies => reduced dust emission/transport.

Limitations:

- TOMS: coarse time-space resolution and coverage;
- NCEP2: coarse space-time resolution; poor description of the surface-atmosphere interaction.

A regional modeling approach is required

3 Numerical simulations

The modeling system is based on three different modules:

1. atmospheric (RAMS);
2. dust emission (DUSTEM);
3. dust transport/deposition (CAMX).

The Regional Atmospheric Modeling System (RAMS), forced by NCEP2 and HadSST, provides input data for the other modules.

The Dust Emission Model (DUSTEM) simulates the emission of four particle categories (clay, small-silt, large-silt, sand) from the Saharan desert, forced by soil moisture and u* (RAMS), land cover (GLC 2000), soil textural class (FAO).

The dispersion model (Comprehensive Air quality Model with extensions; CAMX), takes the meteorological inputs from RAMS and the emission amount from DUSTEM.

Domain: northern Africa & Europe

Horizontal resolution: 30 km

Vertical resolution: 18 levels, 10-10500 m

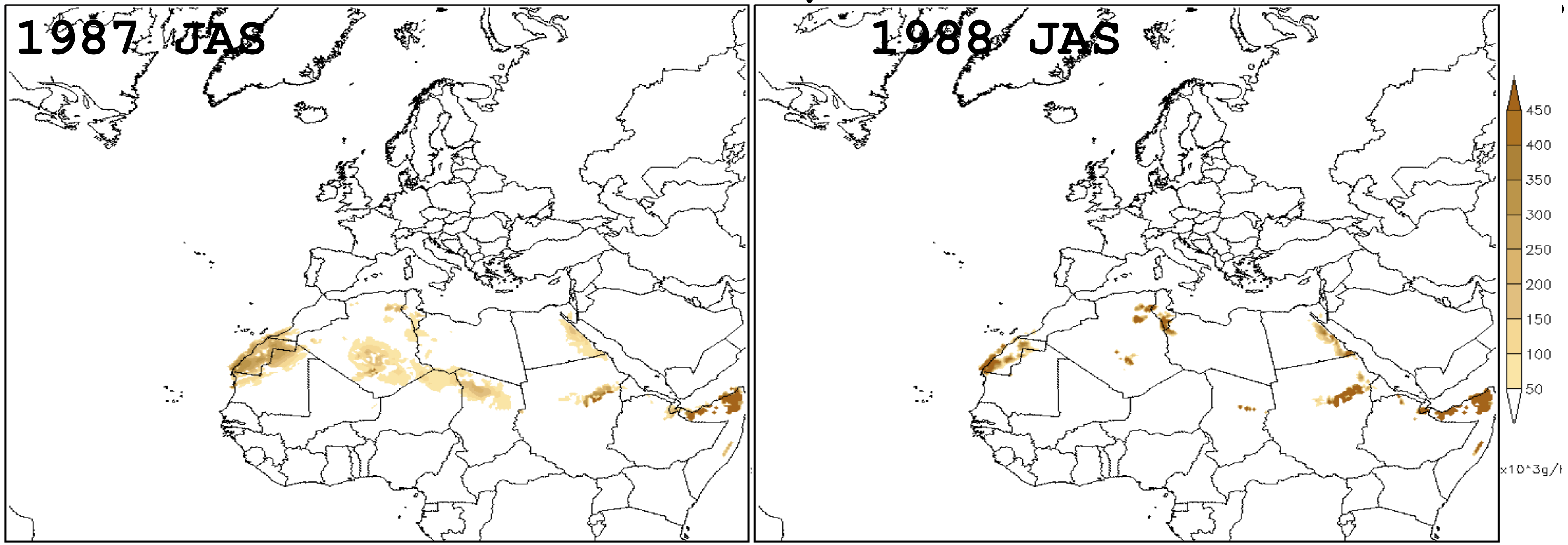
Time resolution: 1hr

Simulations: 1987, 1988, April to October

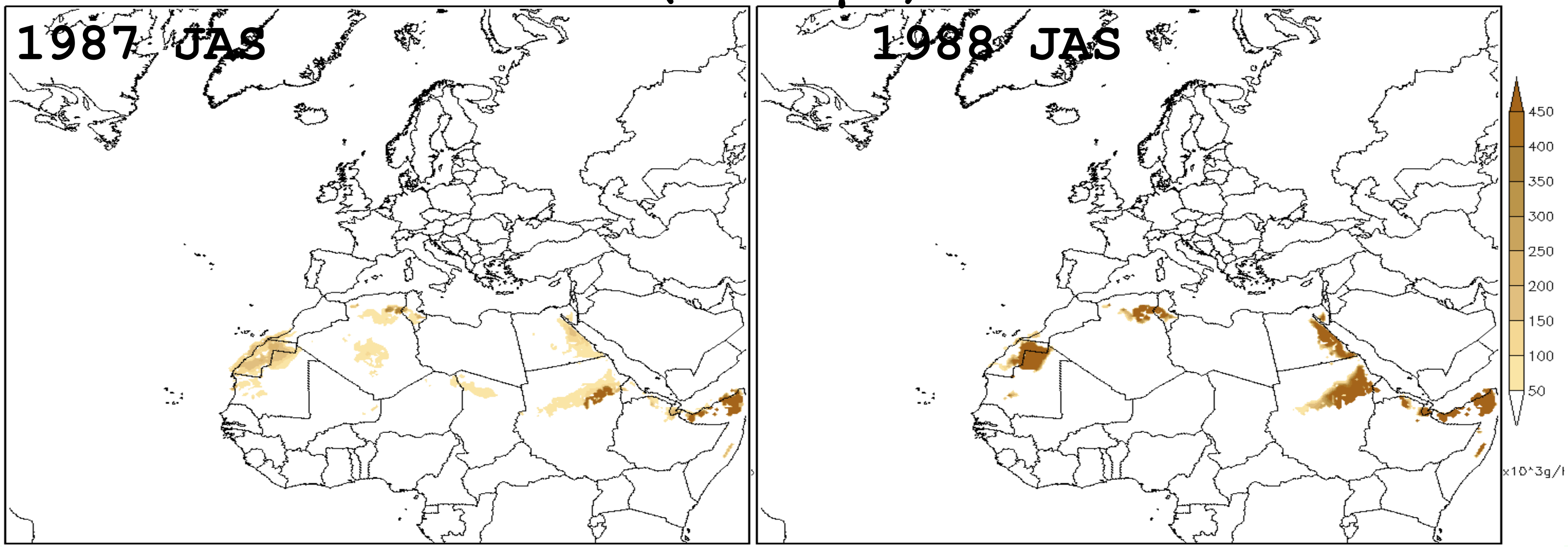
CAMX outputs: coarse crustal, CCR1 (1-2 µm) and CCR2 (2-20 µm) concentration (µg/m3)

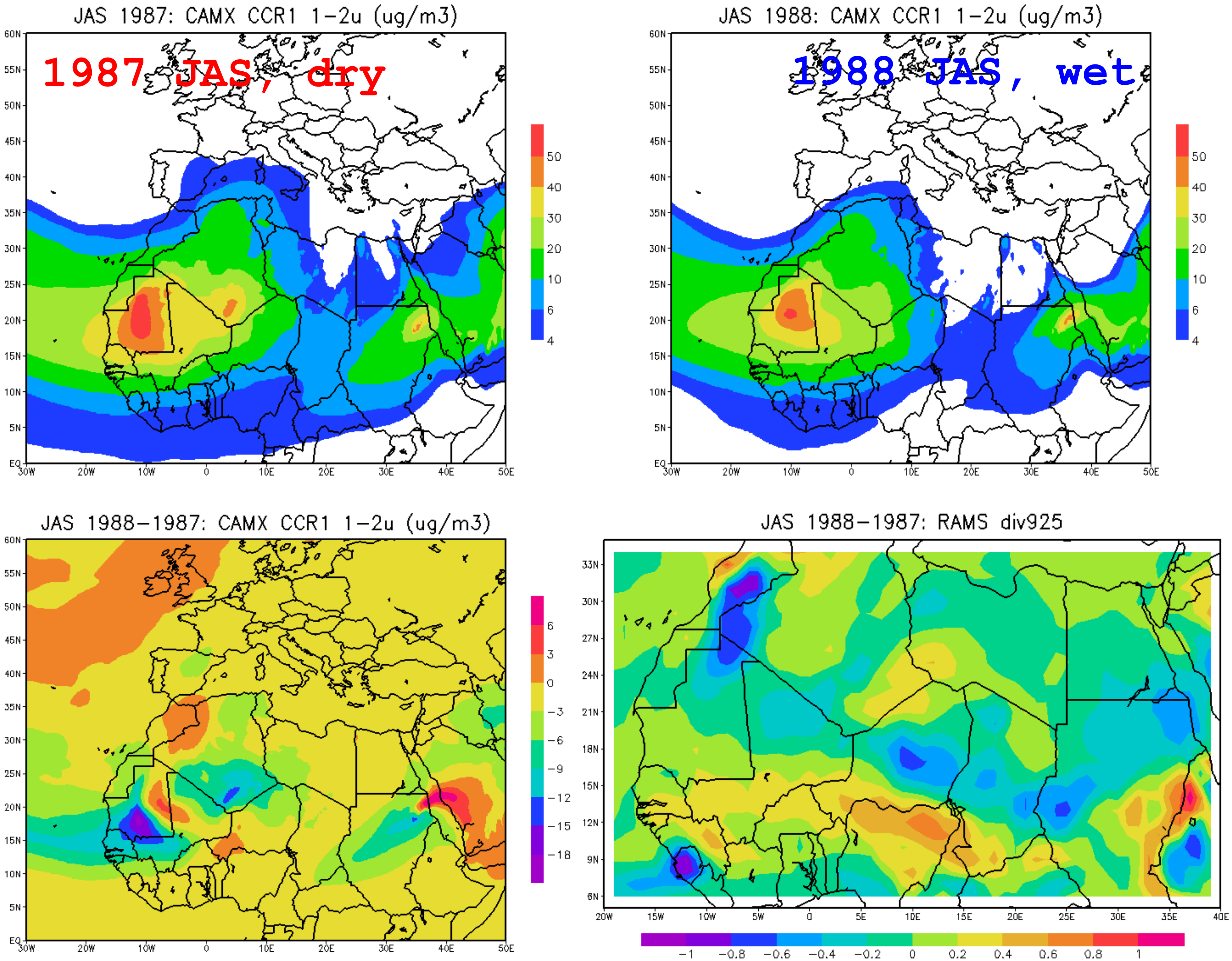
Note: dust in not interacting with the atmosphere microphysics

DUST EMission: CCR1 (1-2 μm)

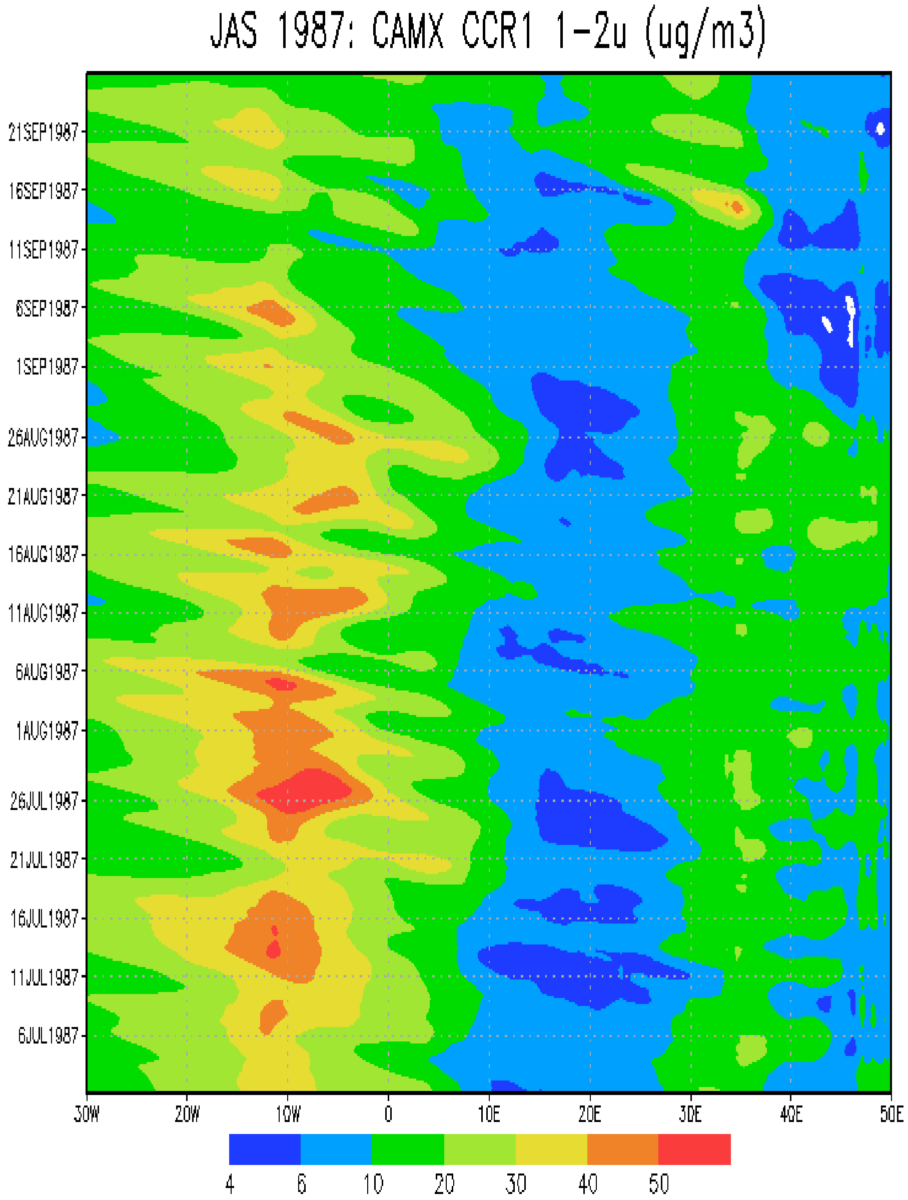


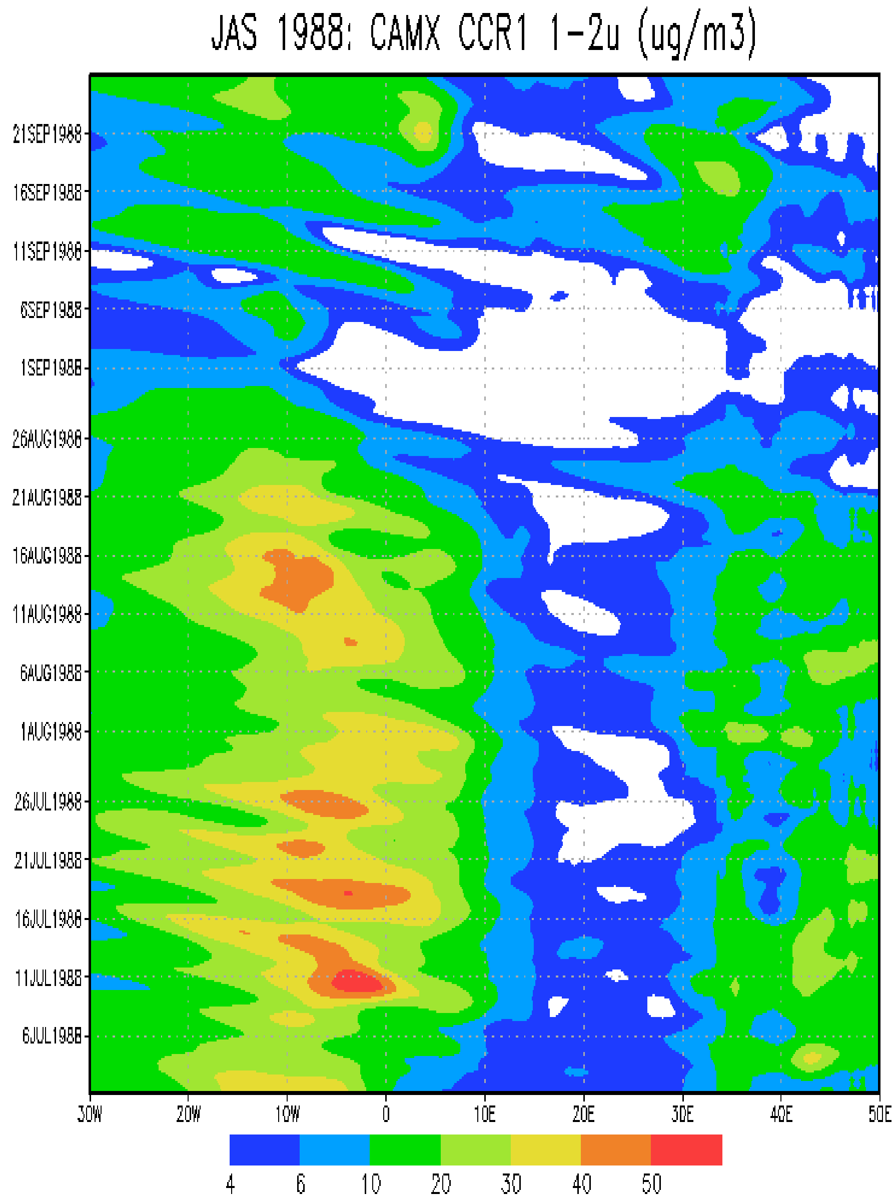
DUST EMission: CCR2 (2-20 μm)

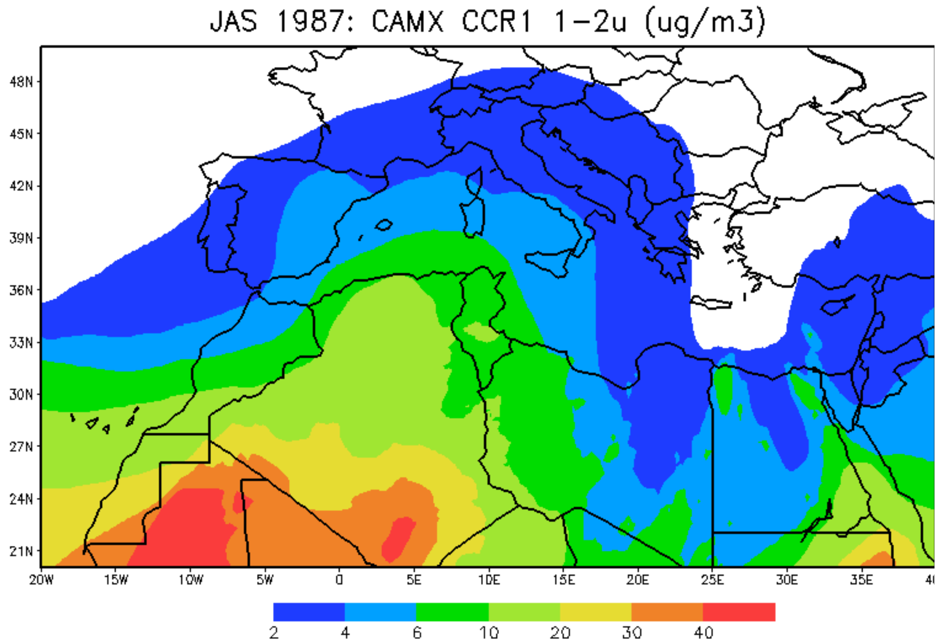


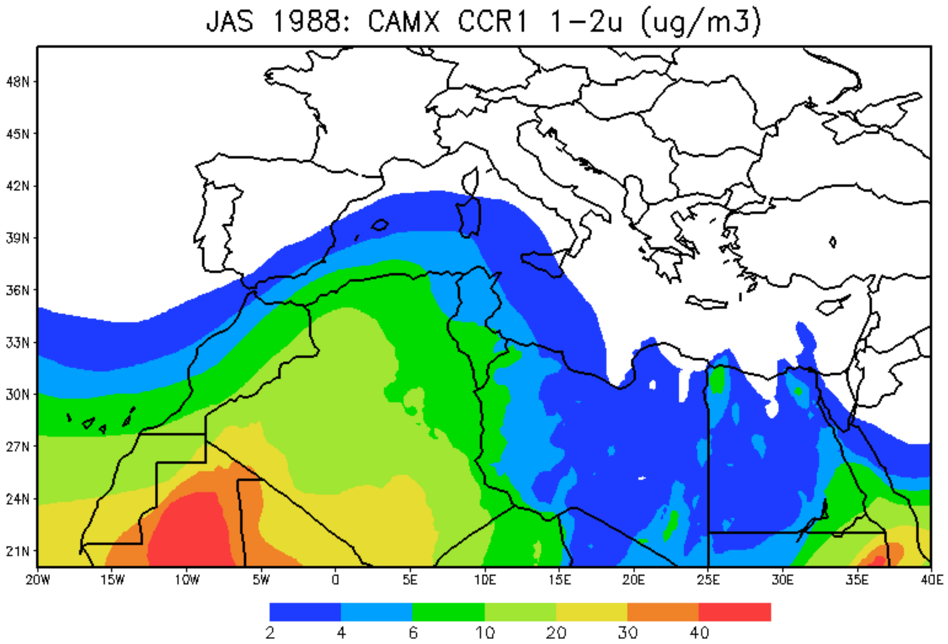

JAS 1987: CAMX CCR1 1-2u (ug/m3)
1987 JAS, dry
JAS 1988: CAMX CCR1 1-2u (ug/m3)
1988 JAS, wet
JAS 1988-1987: CAMX CCR1 1-2u (ug/m3)
JAS 1988-1987: RAMS div925
4 6 10 20 30 40 50
-18 -15 -12 -9 -6 -3 0 3 6
-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1

Sahel 10-20N, surface-10km



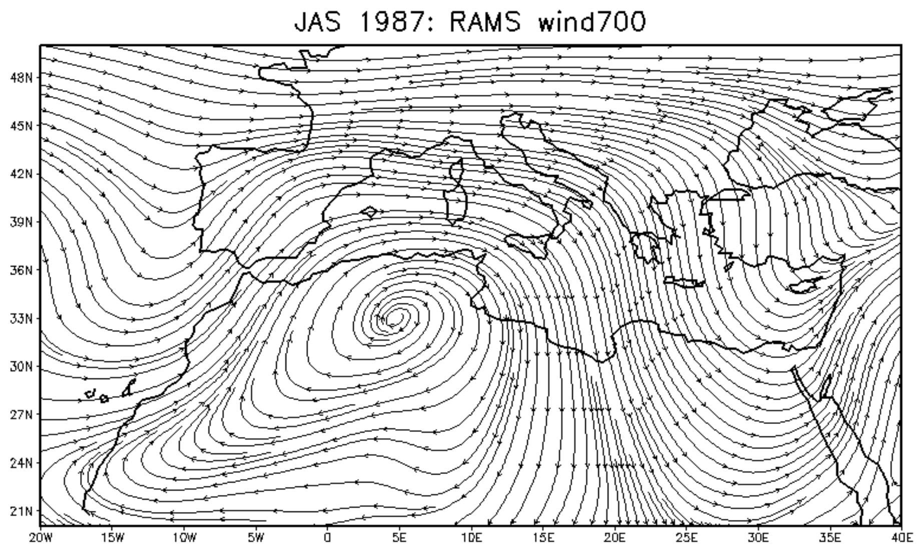


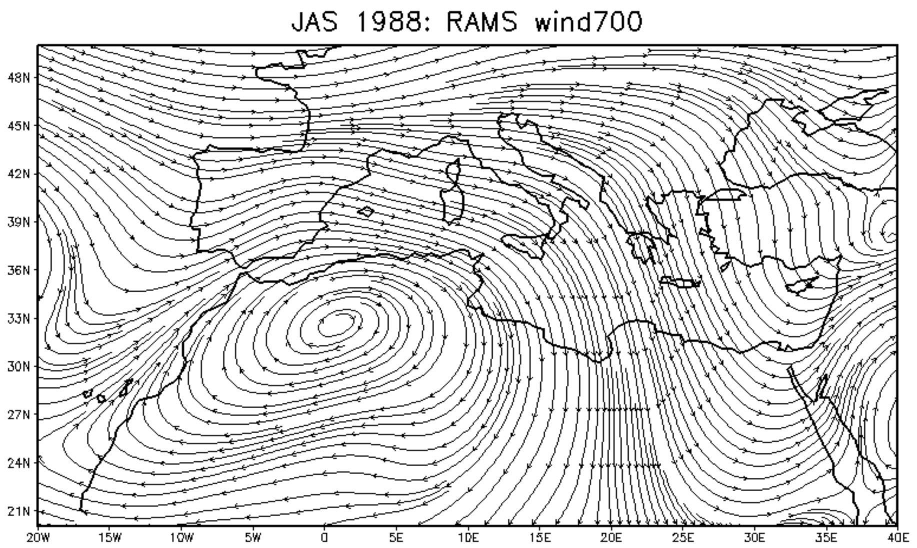




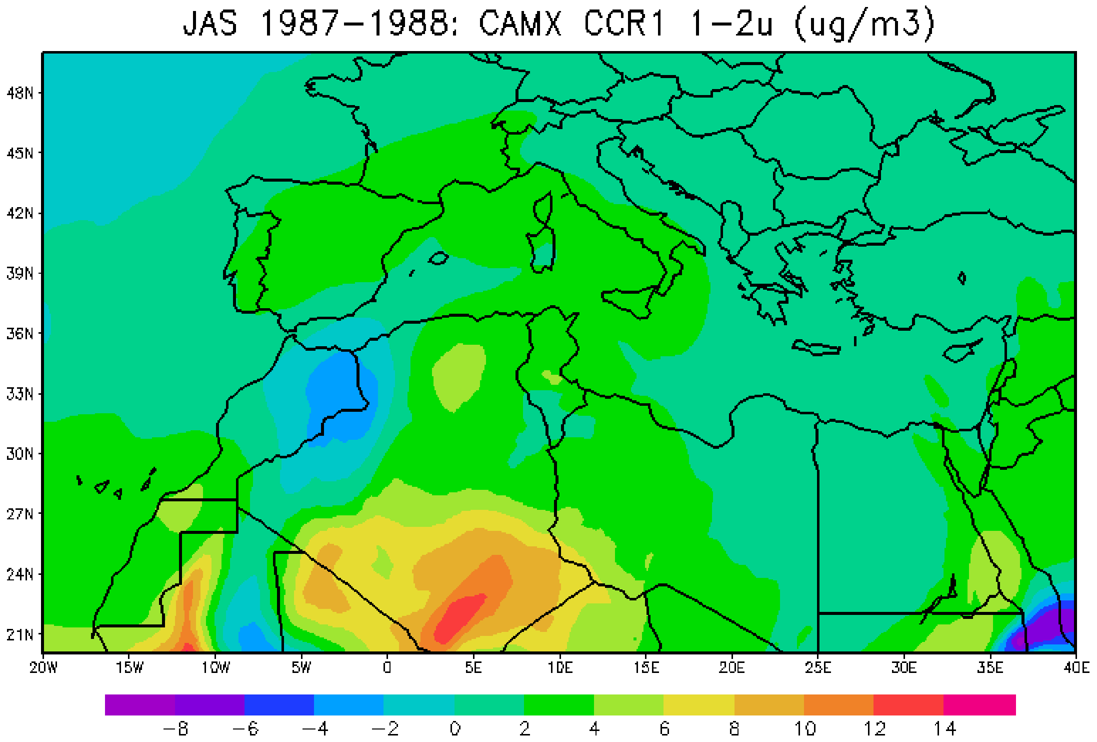
1987 JAS, weak SST gradient

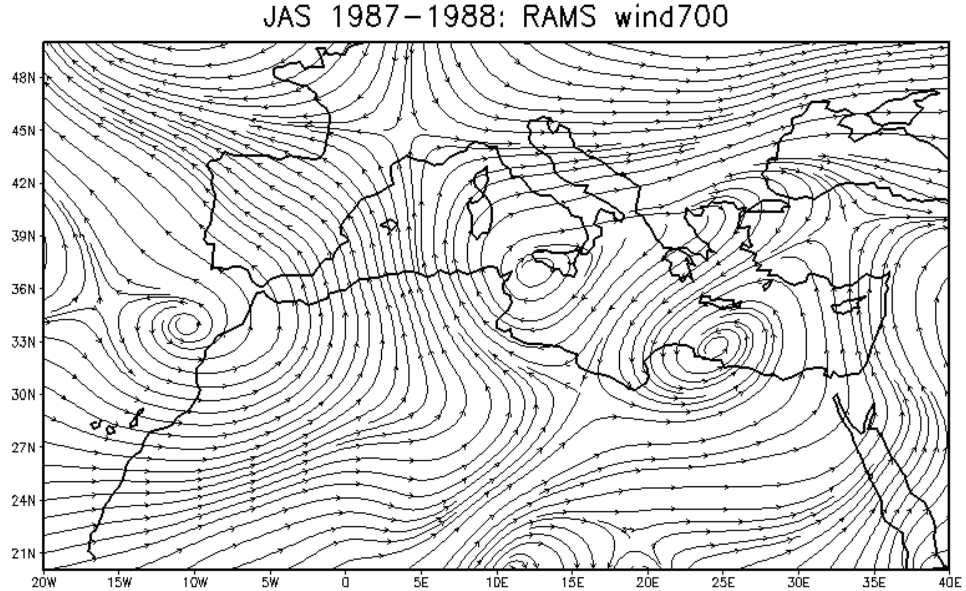
1988 JAS, strong SST gredient





1987-1988 JAS difference: CAMX CCR1 and RAMS wind700





- The intensity of the west-east SST gradient in the Med drives the northerly flow toward the Sahel:
  strong (weak) SST gradient => (wet) dry Sahel.

- Possible relationship between the Med-Sahel dynamics and the Bodele Depression dust emission/transport:
  enhanced (reduced) convergence => lower (higher) emission/transport.

- Potential contribution of the Bodele Depression dust emission/transport to the Sahel precip variability:
  lower (higher) emission/transport <-> (wet) dry Sahel.

- Potential feedback between the Med SST gradient and the dust transport through the Med.

- RAMS/DUSTEM/CAMX effectiveness in describing the dust dynamics in the Afro-Med region, specifically at the sub-seasonal time-scale.

- Future work:
  - build a “model climatology”;
  - analyze more case studies;
  - focus on the effects of dust on the radiative balance, exploiting the CAMX capability in describing the chemical aerosol interactions.

Thank you !

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