The effect of dust absorption on Sahel precipitation

Session: **Natural Aerosols in Climate Change** (AS3.7/CL3)

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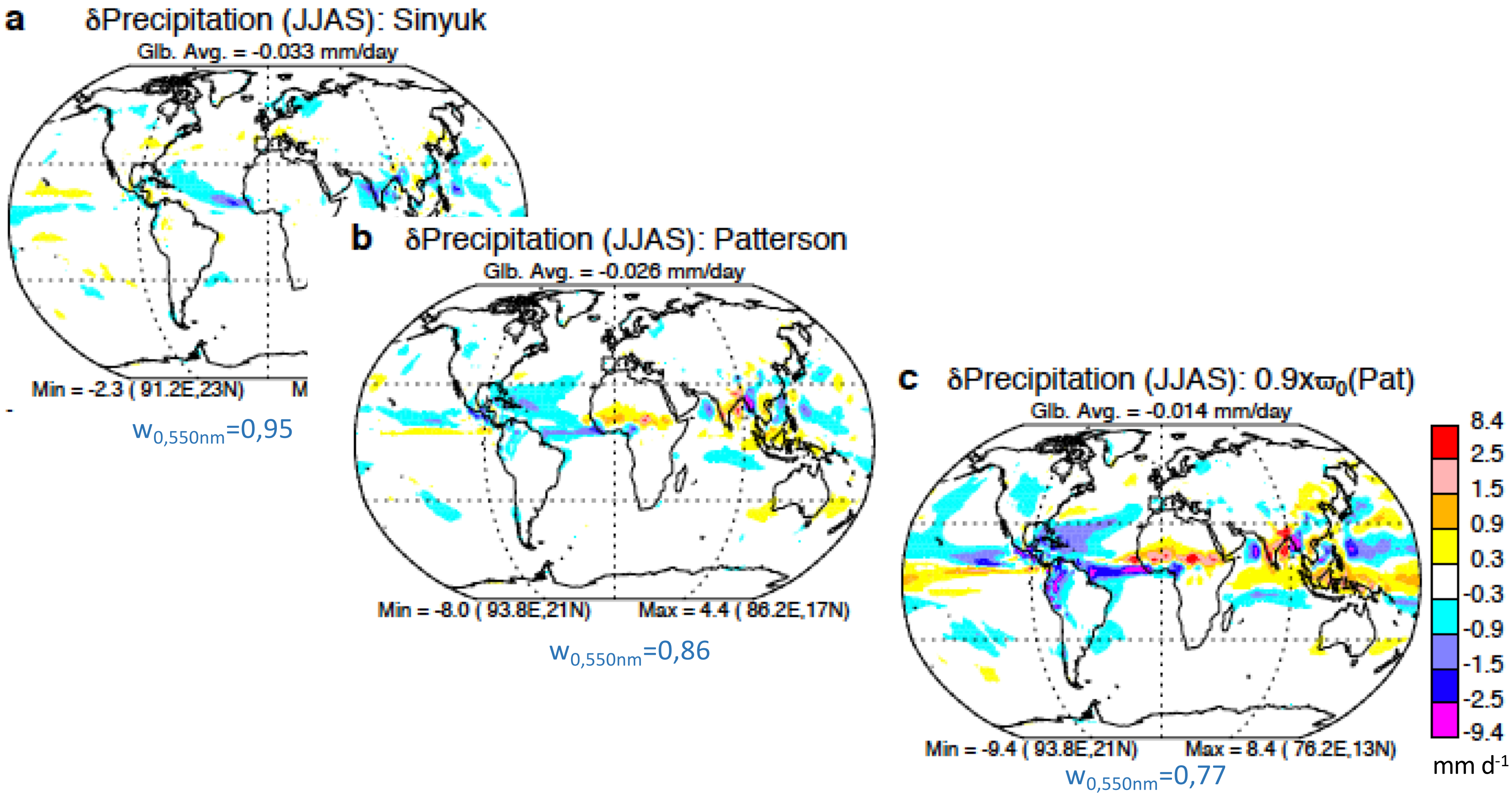
Plan

- Why are dust particles influencing precipitation?
- Mineralogy and dust particle size
- Analyzing the variables influenced by the presence of dust

Existing literature on dust/precipitation connection

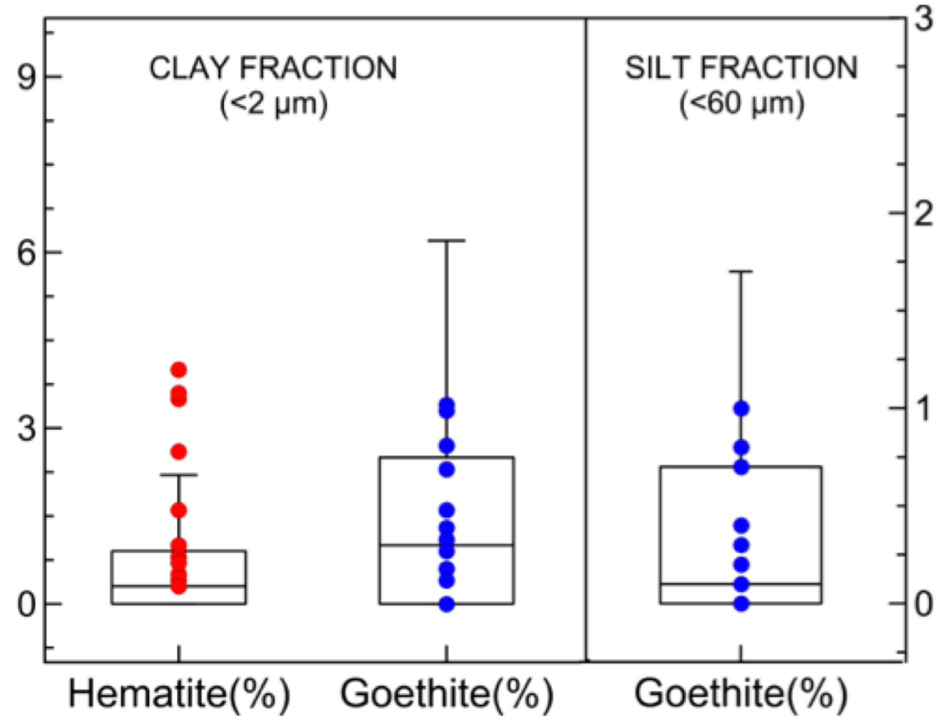
- Miller et al. 2004
- Miller et al. 2011
- Yoshioka et al. 2009
- Solmon et al., 2008

Change in precipitation due to dust (Miller et al., 2014)



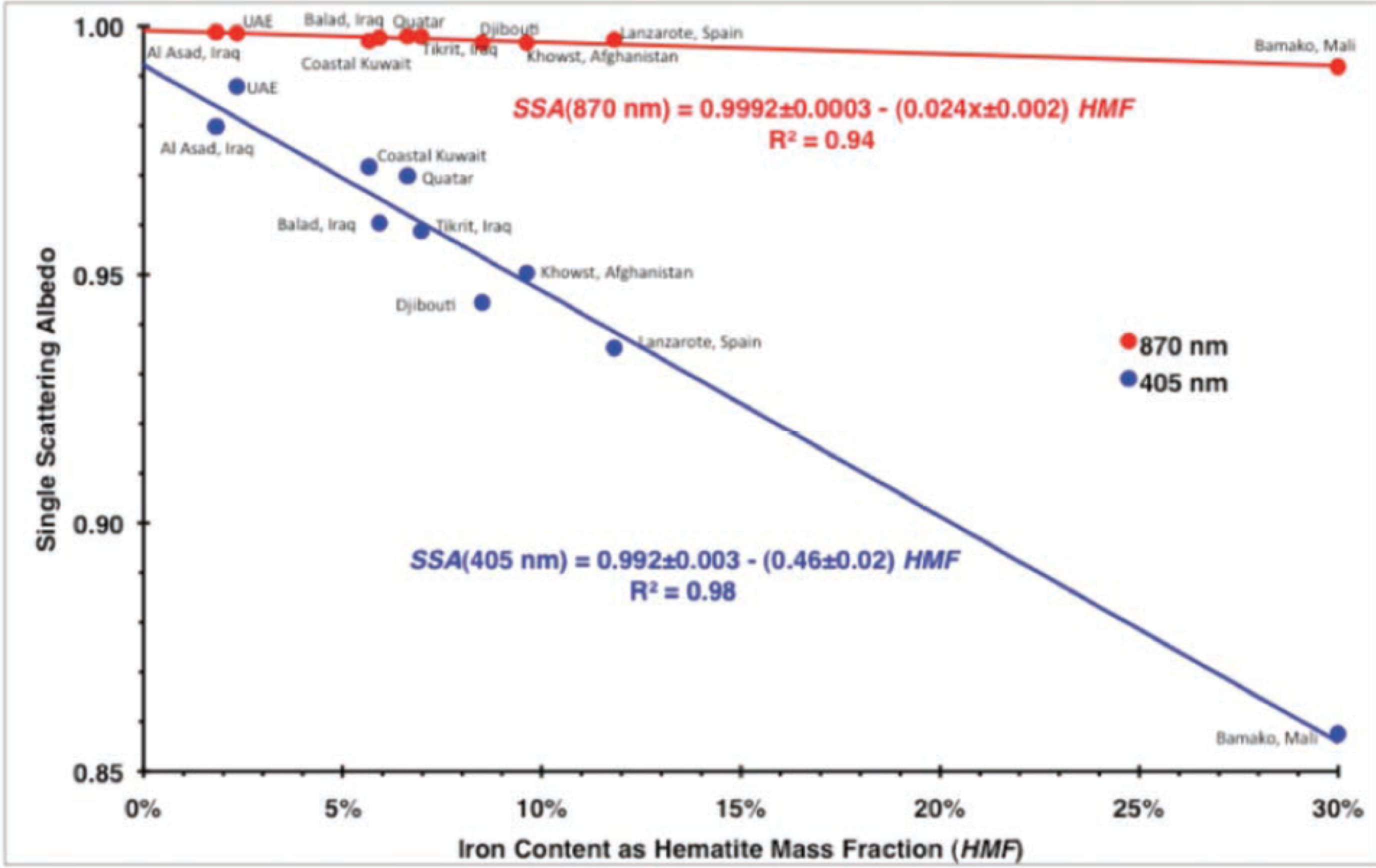
- Over Sahel summer dust absorption reaches 36 $W.m^{-2}$ over the Sahel region (see Slide 13)
- Absorption of dust depends on its mineralogy and is mostly driven by the dust iron oxide content
- Large dust particle absorb much more than smaller particles

Goethite and hematite mass fractions (%) measured in the CESAM aerosol chamber for dust samples from major source areas



Di Biagio et al., 2019

Relationship Between Hematite Content and Single Scattering Albedo



Single scattering albedo (*SSA*) as function of iron content at wavelengths of 405 and 870 nm for ten entrained dust samples demonstrating and quantifying a strong linear correlation between the two.

Moosmuller et al., 2012

Computation of the refractive index computed for a mineral assemblage

- We account for six minerals: Kaolinite, Illite, Montmorillonite, Quartz, Calcite et hematite
- An optical model is used in which we vary the iron oxide content to represent respectively: 0.9 1.5 2.7 5.0 10 et 15% of the total volume of the particles.

Step 1: Each mineral is associated with a VOLUME content of respectively: 0.9 1.5 2.7 5.0 10 et 15% using the Maxwell-Bruggeman approximation

Step 2: The combination kaolinite-hematite is associated with illite_hematite

Step 3: The combinaison kaolinite-illite-hematite is associated to montmorillonite-hematite

Step 4: The combinaison kaol-illi-montmo-hema is associated to quartz_hematite

Step 5: The combinaison kaol-illi-montmo-hema-quartz is associated to calcite_hematite

Step 6:: The refractive index of kaol-illi-montmo-hema-quartz-calcite-hematite is obtained

Absorption increase (imaginary part of ref. index) as a function of hematite content

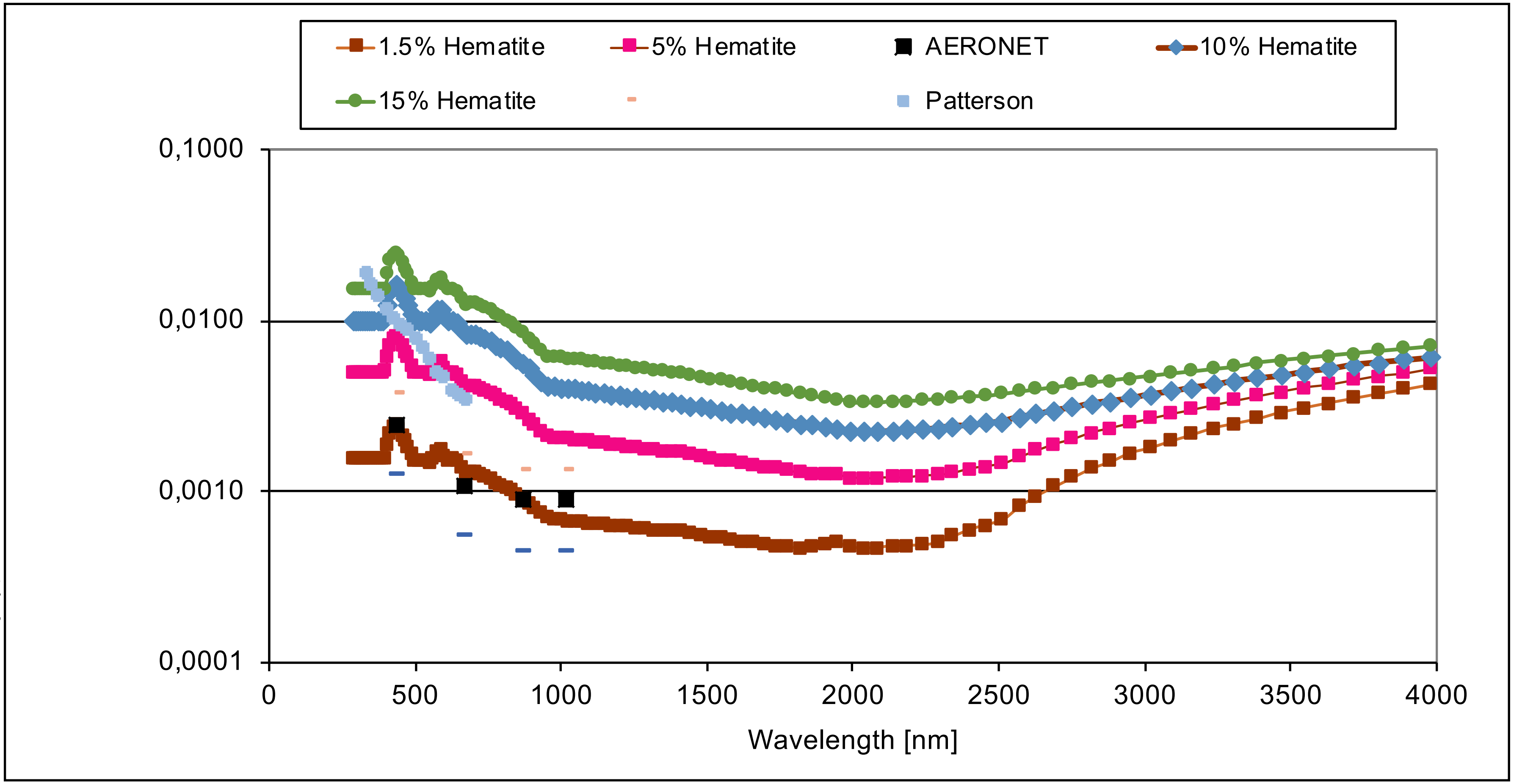
Hematite 1,5%
$\omega_{0,550nm}$=0,906

Hematite 5%
$\omega_{0,550nm}$=0,879

Hematite 10%
$\omega_{0,550nm}$=0,807

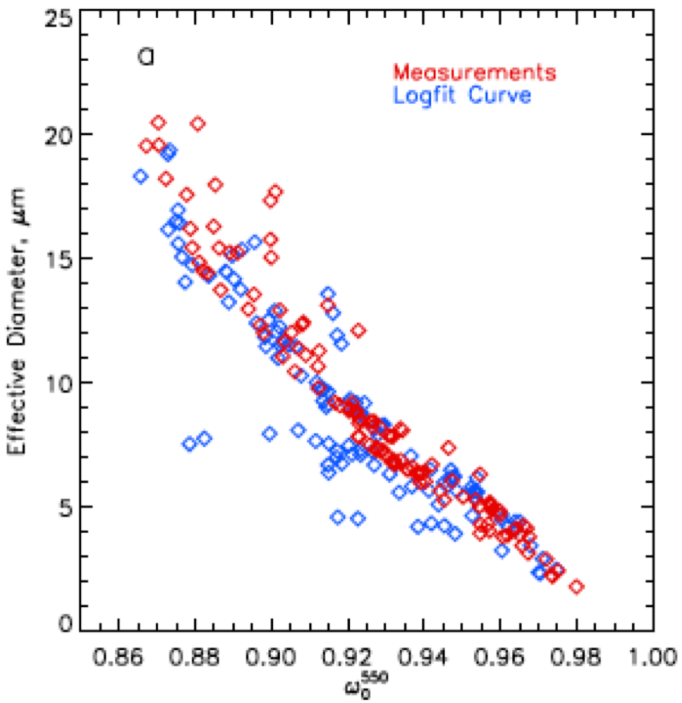
Hematite 15%
$\omega_{0,550nm}$=0,757

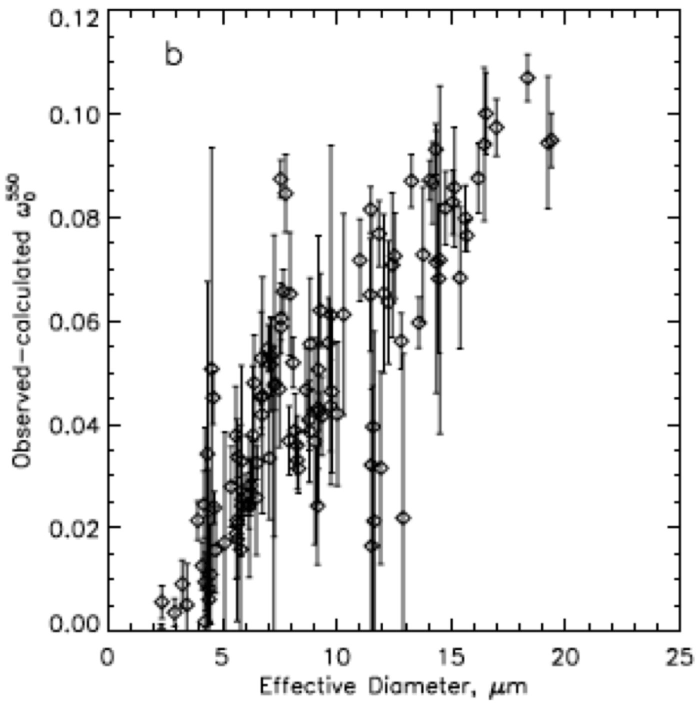
Patterson-Volz
$\omega_{0,550nm}$=0,857



Observations of Dust Single Scattering Albedo (SSA) as a function of particle size during the AER-D campaign

Ryder et al., 2013





Description of the simulations

- We modeled the Dust size distribution with either 1 or with 4 modes.

- When 1 mode (MMD=2.5 um) is used absorbing dust contains 5% hematite, when 4 modes are used (MMD= 1, 3.5, 7 and 22 um) the same absorption is reached with only 3.5% hematite

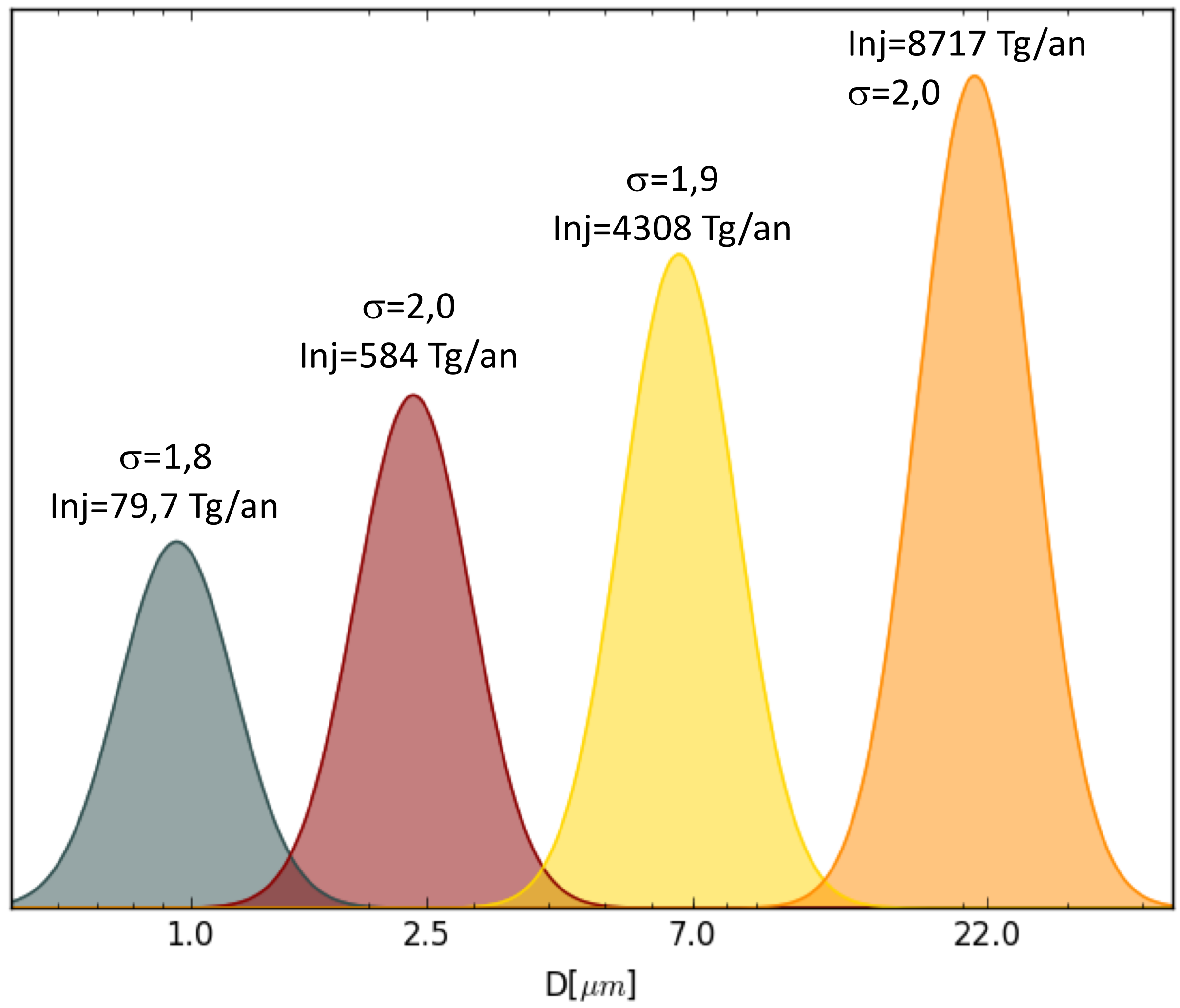
- We made 2 long simulations:

    Simulation 1 with fixed SSTs for 18 years (1980 to 1997)

    Simulation 2 with a fully coupled model for 100 years (1915 to 2014)

The analysis is made by comparing these simulations to a control with NO Dust

Global Emissions derived from observational constraints for 4 Modes of Dust



After Di Biagio et al, 2020

JJA Average Dust SW Radiative Effect for 5% hematite

top panel: Top-of-Atmosphere, middle panel: Atmospheric absorption; bottom panel: Surface

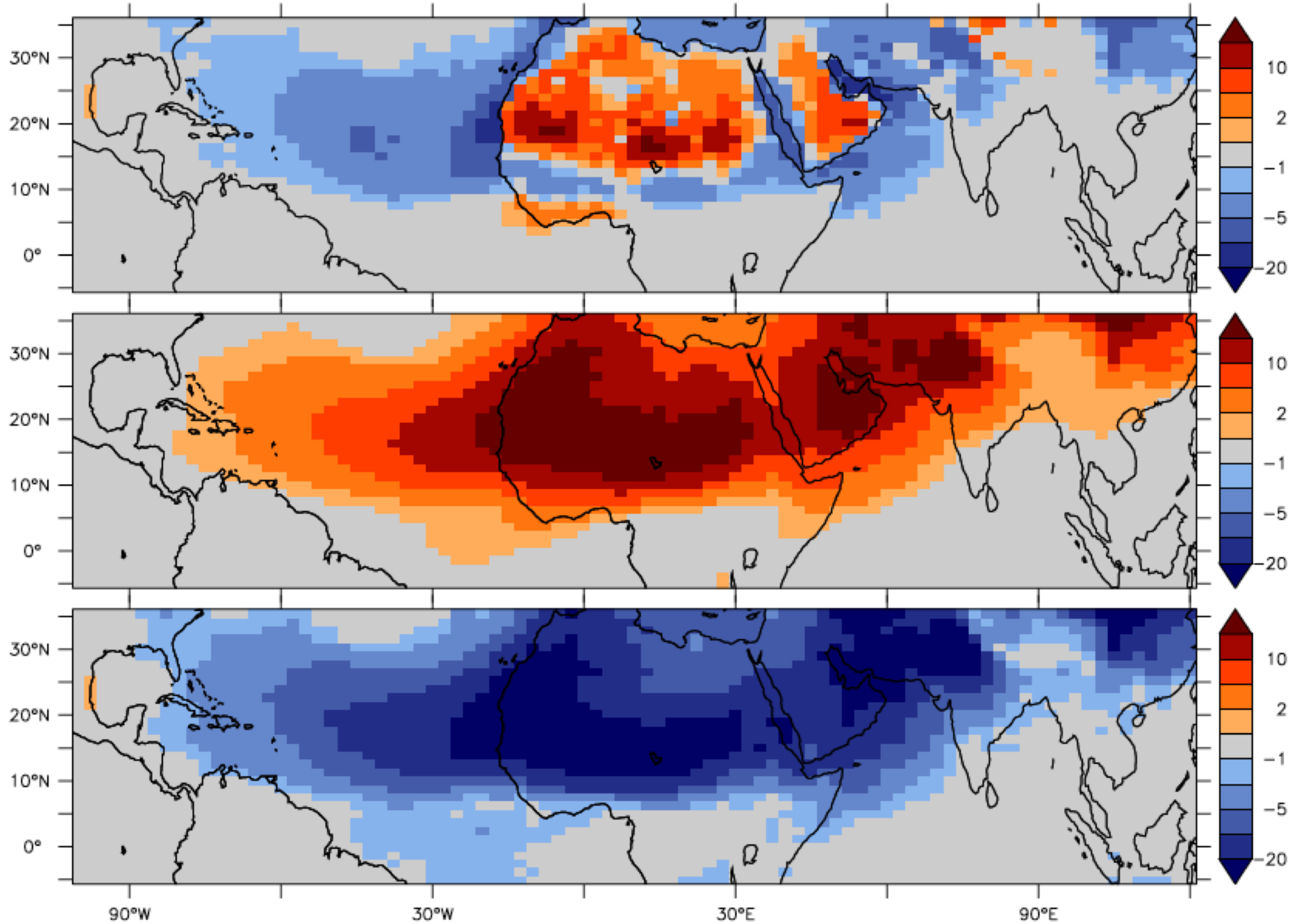
Sahel TOA = +4,4 $W.m^{-2}$

SAHEL area: 16W:36E, 10N:20N

Atm. Absorption = +36 $W.m^{-2}$

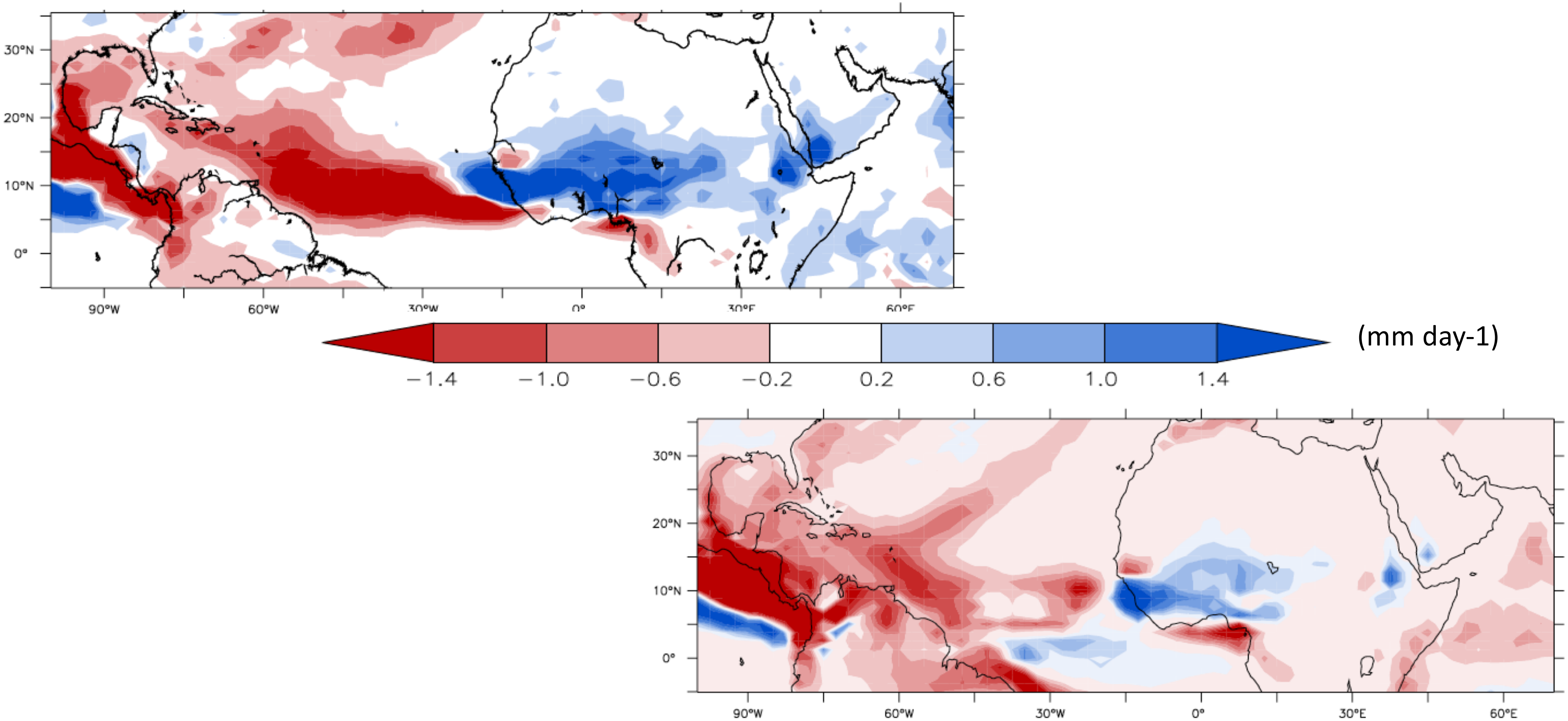
(Sahel area)

Sahel Surface = -31.6 $W.m^{-2}$



Precipitation change – Dust with 5% hematite versus No Dust

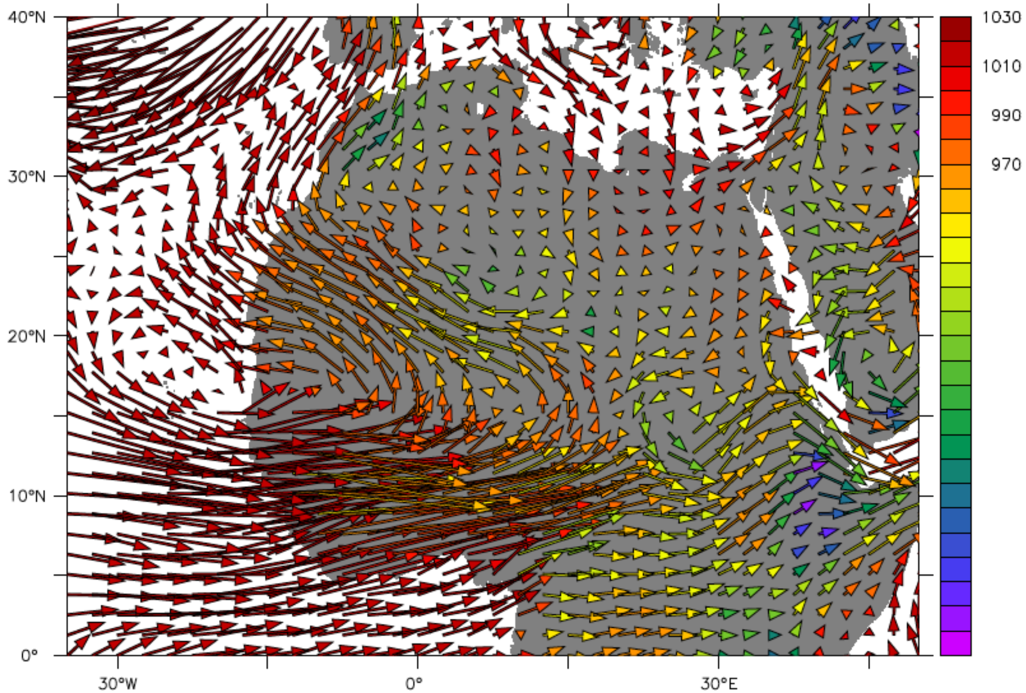
Model with fixed SST 18y mean



Fully Coupled Model 100y mean

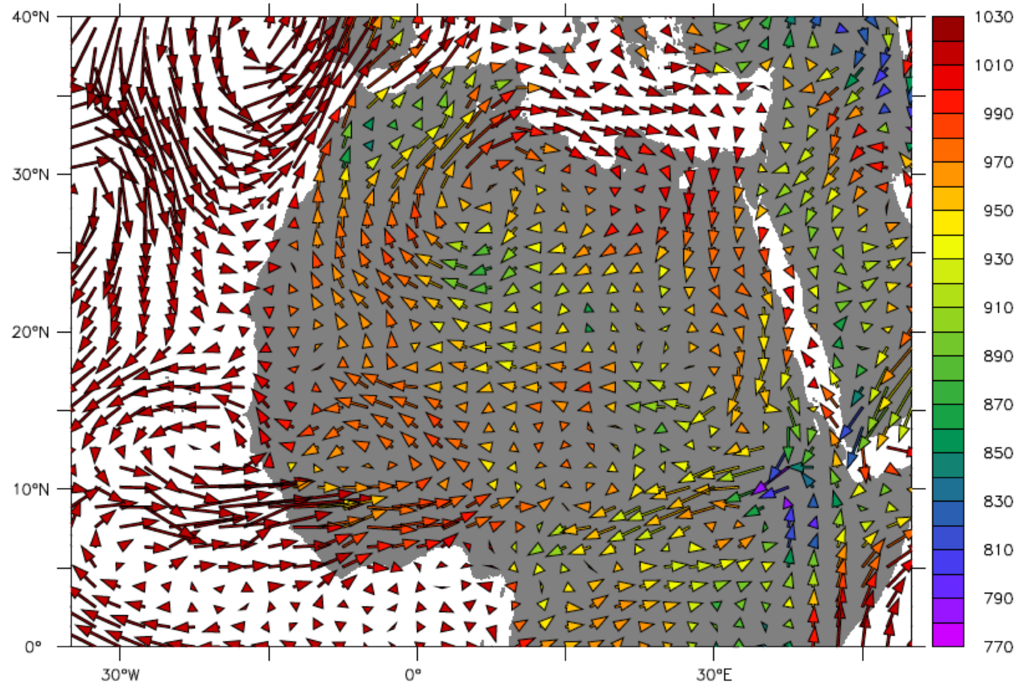
Change in Humidity transport at the surface – vector (uq,vq)

Forced Model JAS 1989

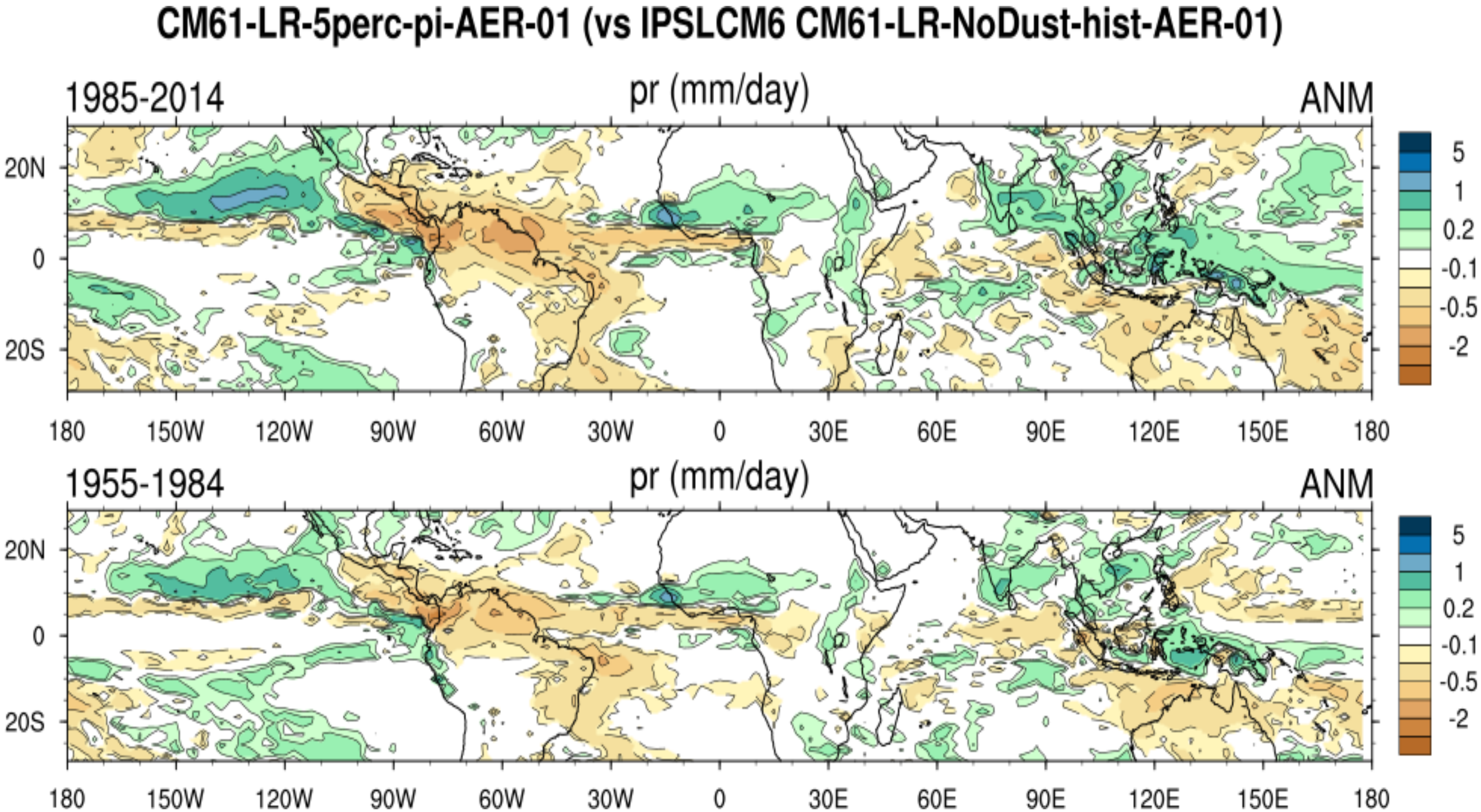


50 (m s^{-1} . RH)

Coupled Model JAS 1924

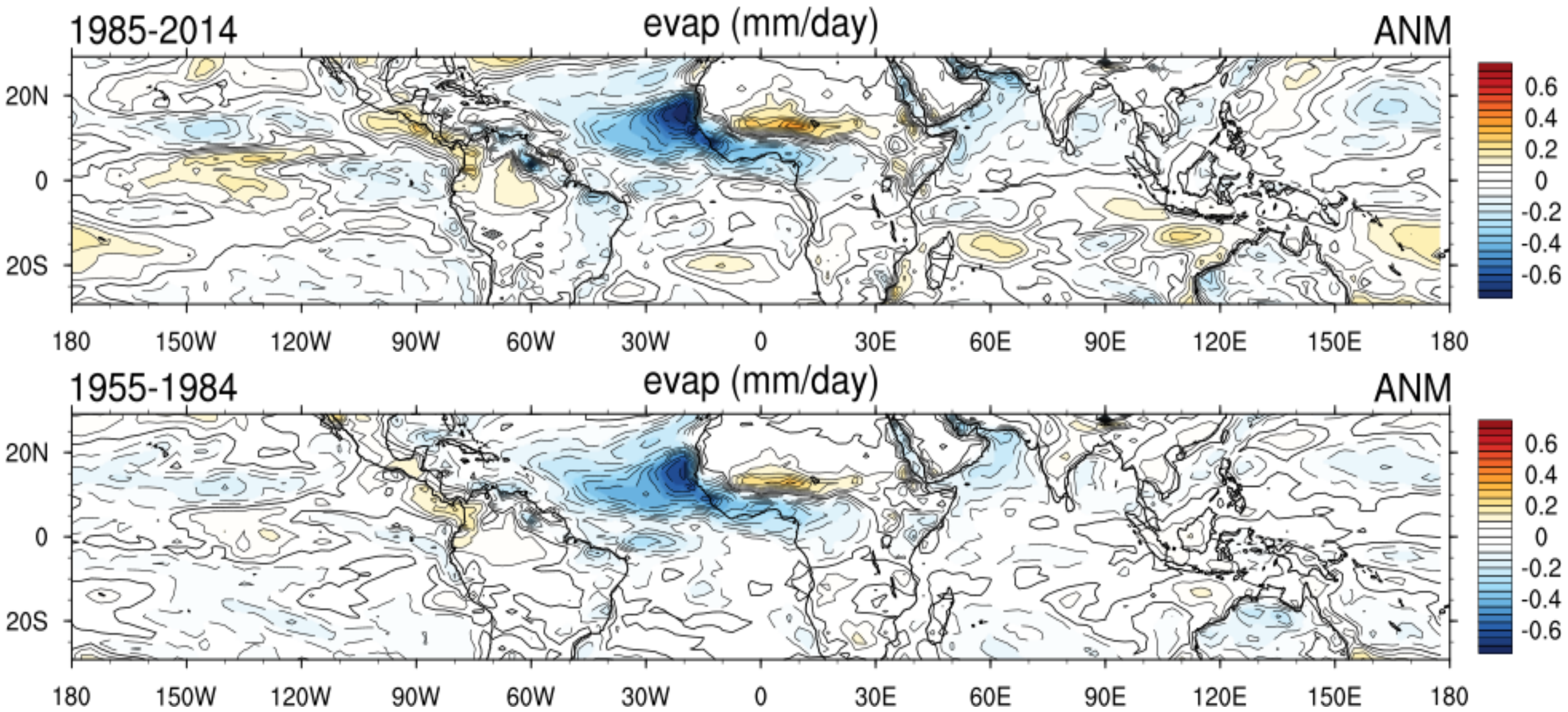


Precipitation change for the periods 1985-2014 and 1955-1984

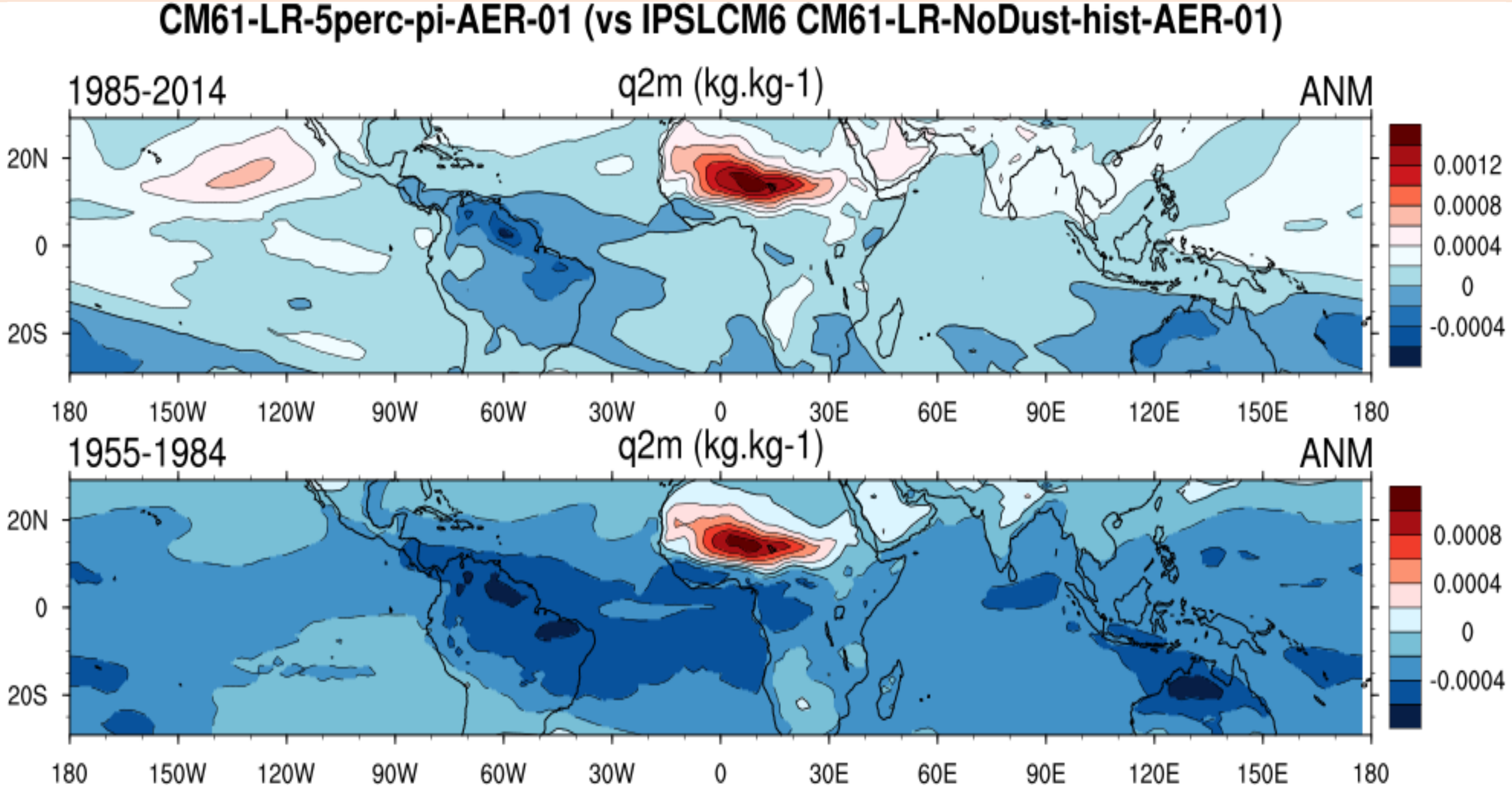


Evaporation change for 1985-2014 and 1955-1984 periods

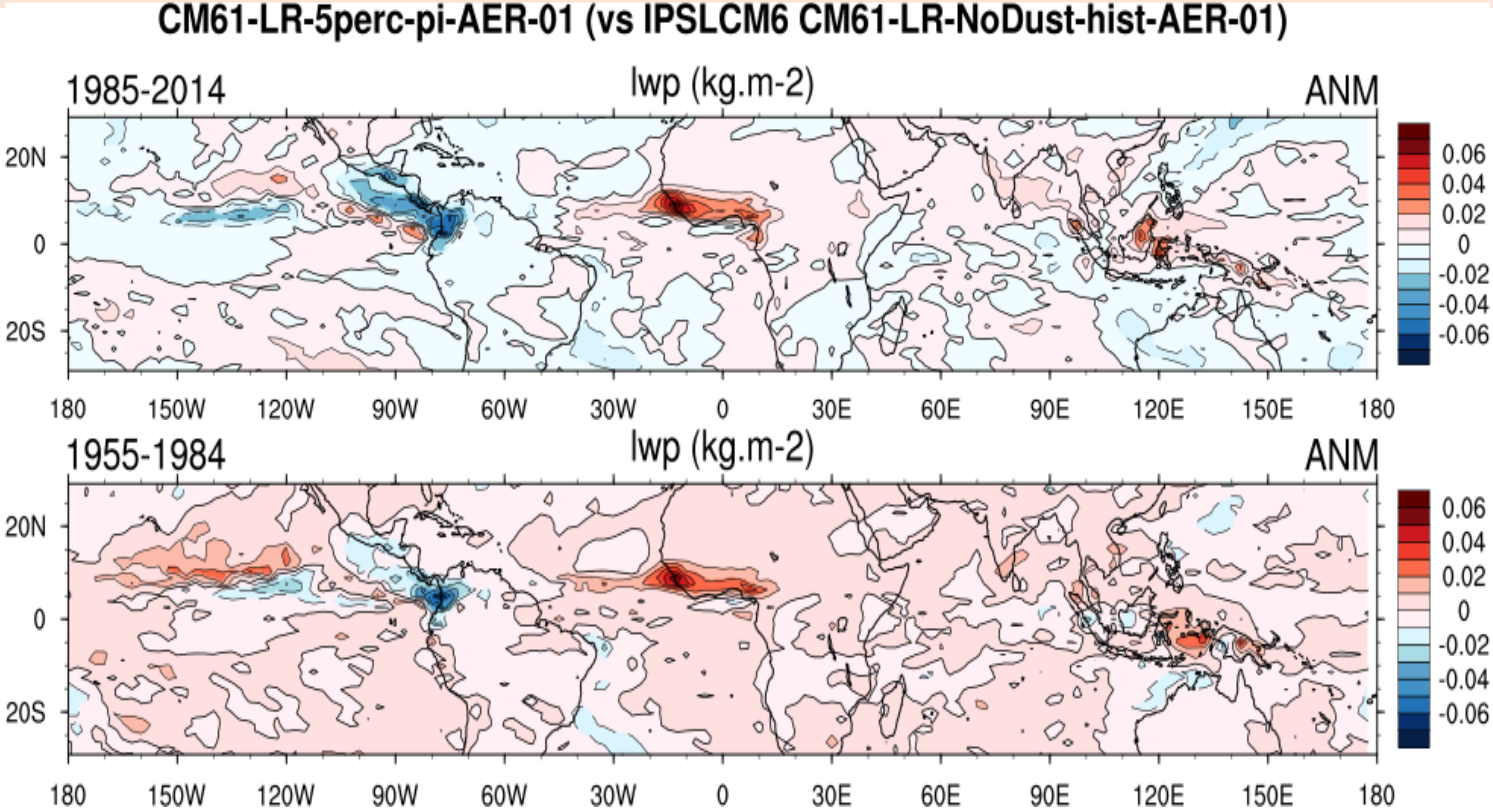
CM61-LR-5perc-pi-AER-01 (vs IPSLCM6 CM61-LR-NoDust-hist-AER-01)



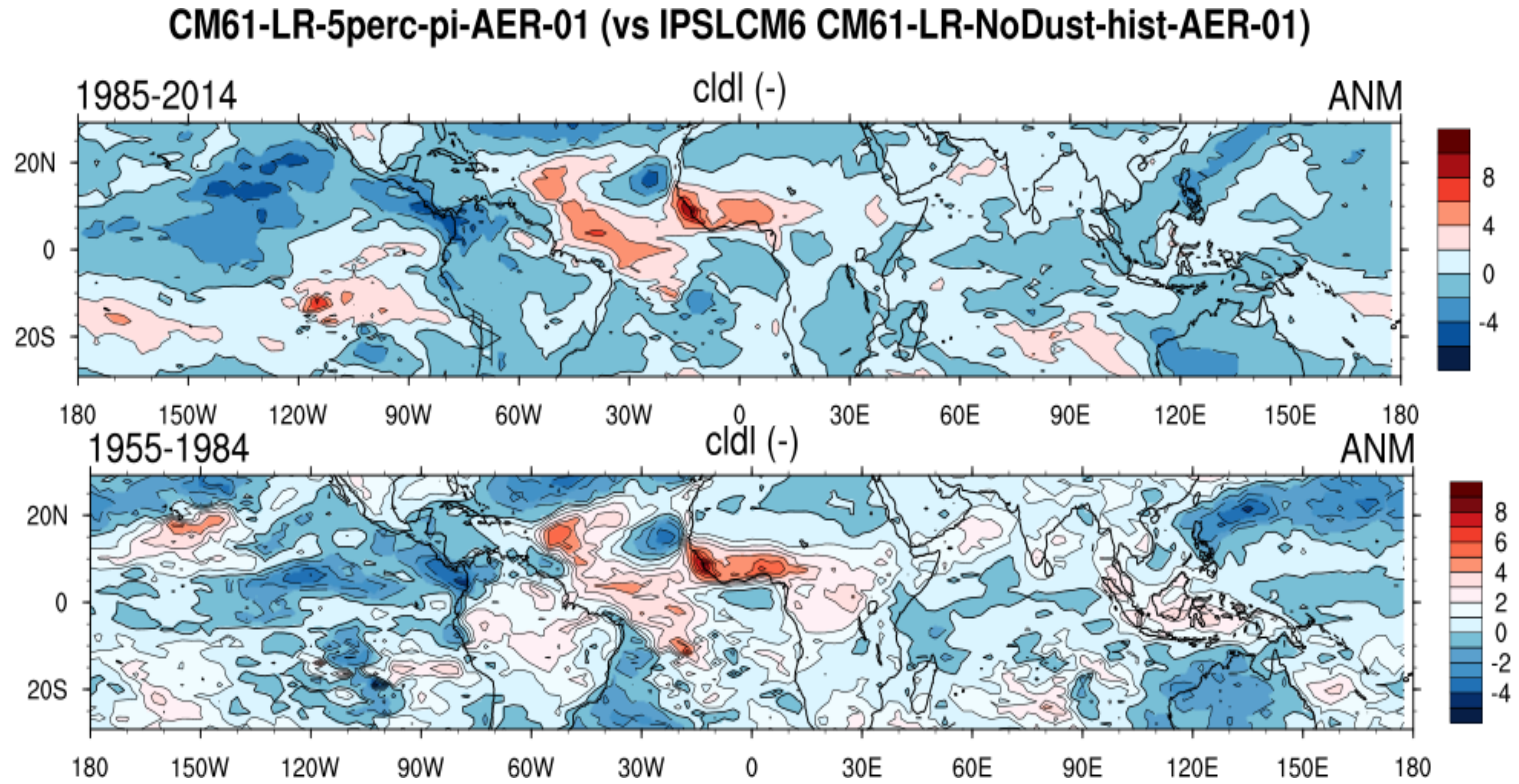
Relative humidity (at 2m) change for 1985-2014 and 1955-1984 periods



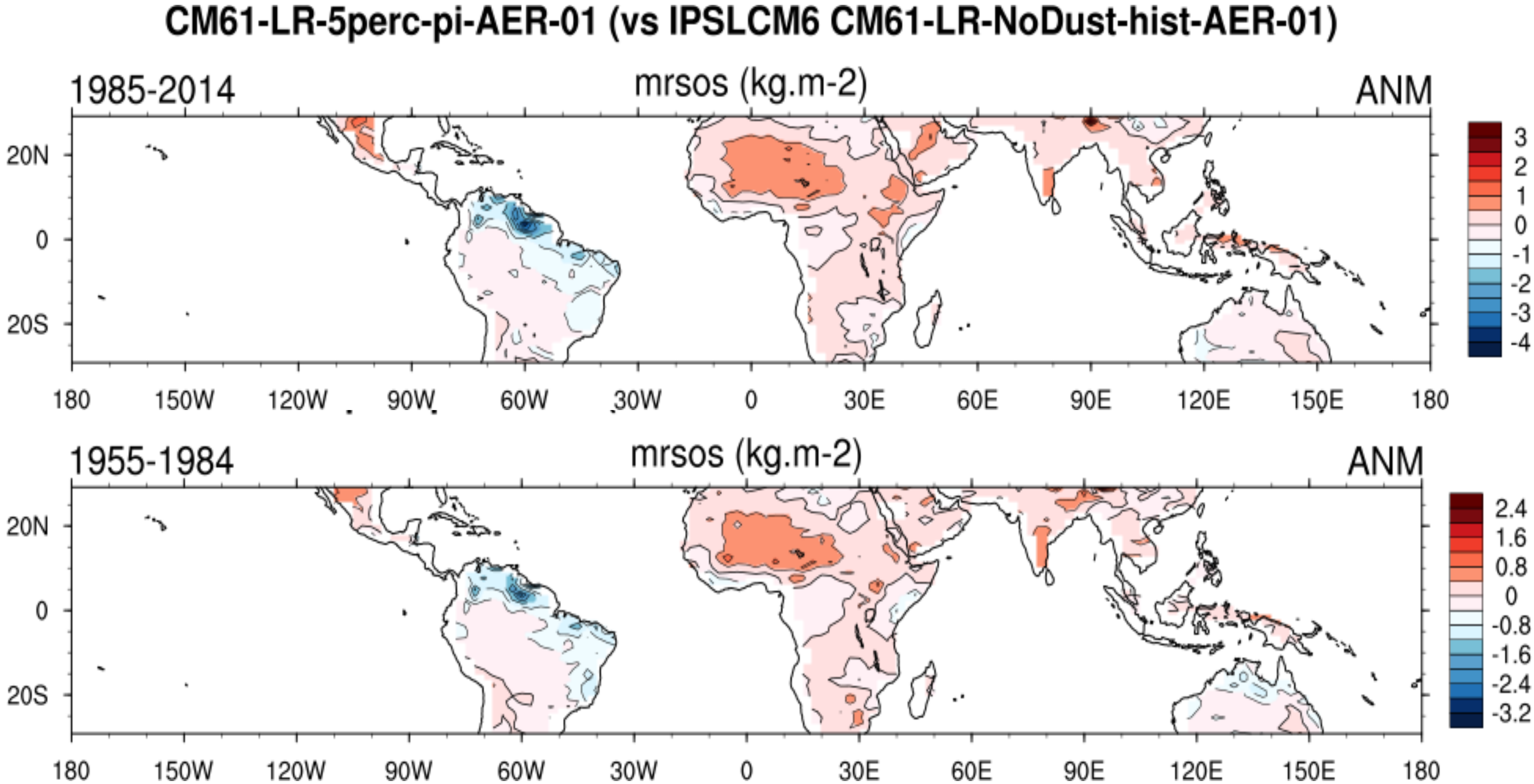
Liquid Water Path change for 1985-2014 and 1955-1984 periods



Low Clouds change (%) for 1985-2014 and 1955-1984 periods



Total soil water content change for 1985-2014 and 1955-1984 periods



Conclusions

- Absorbing dust strongly influences Sahel summer precipitations
- Two factors control this absorption: the iron oxide content and the particle size (absorption increases with particle size)
- We ran a fully coupled Earth System Model with and without dust for 100 years over the period 1915 to 2014
- Over Sahel, the energy absorbed can be as high as +36 $W.m^{-2}$ for the JJA period
- We analyzed changes in water vapor budget in response to changes in this energy
- This analysis will be prolonged by the analysis of the moist static energy