

Climatic impacts of irrigated afforestation of the Sahara in a complex Earth System Model

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Key Questions

- 1 What are the local changes?
- 2 What are the global impacts?
- 3 How is the West African Monsoon influenced and how is this connected to the Afforestation of the Sahara?

Model & Experimental Design

- Model: CESM-WACCM (Marsh et al., 2013)
- atm: 1.9°lat x 2.5°lon; ocean: 1°x1°
- 20 yrs spin up + 30 yrs analysis data
- Fixed 1960 greenhouse gas concentrations
- Modified interactive irrigation model CLM4
- Sahara afforestation run: with afforestation (green area)
Control run: without afforestation

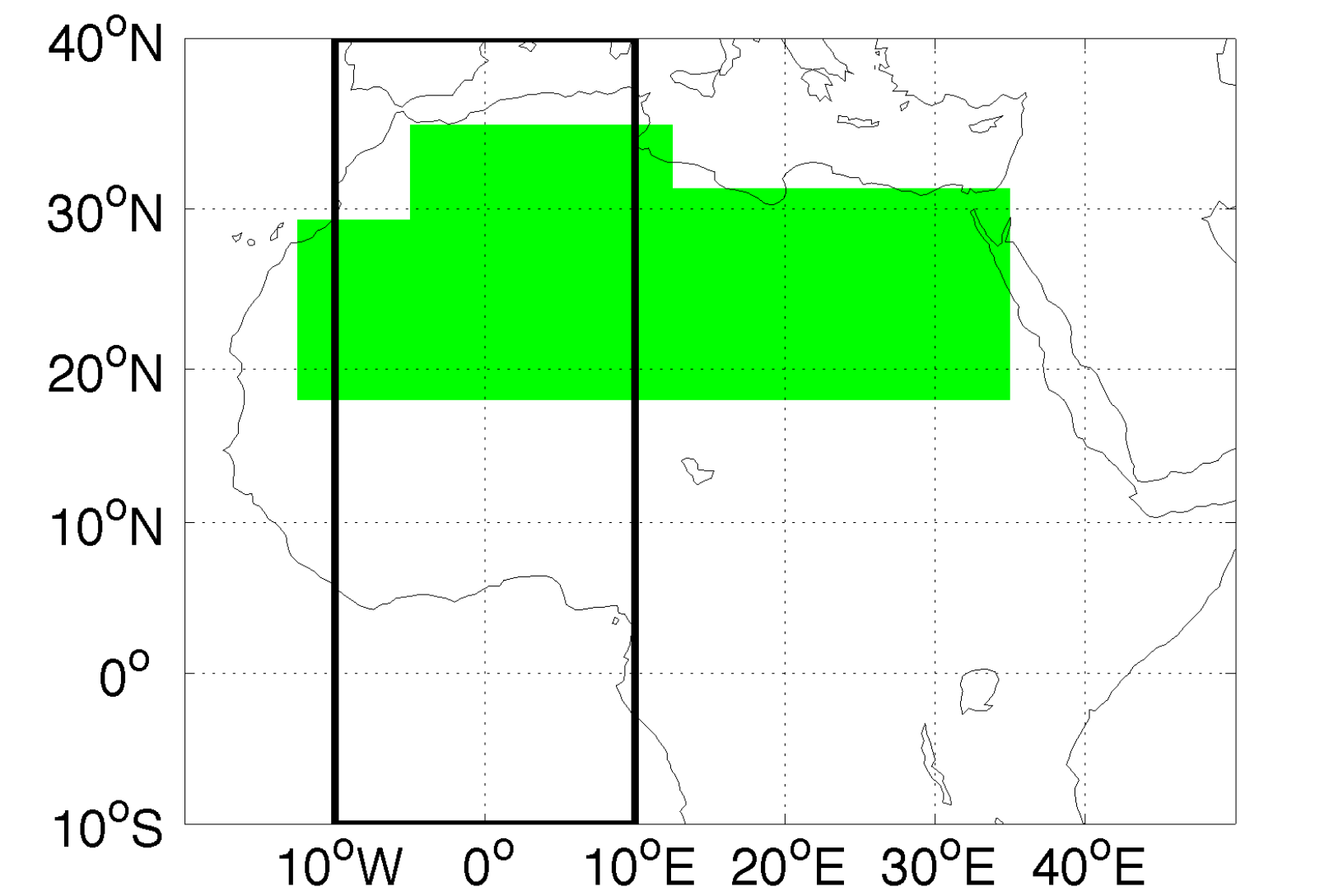


Figure 1. Afforested area (green) and area of interest (black box)

1 Local Changes

Main factors changing surface air temperature in the Sahara

Surface air temperature is decreasing by 8°C

Cooling:

- Irrigation enhances latent heat flux by 94 W/m²
- Increasing cloud cover reduces incoming SW radiation at the surface by 50 W/m²

Warming:

- Remaining albedo effect on absorption of SW radiation +19 W/m²
- Greenhouse effect +11 W/m²

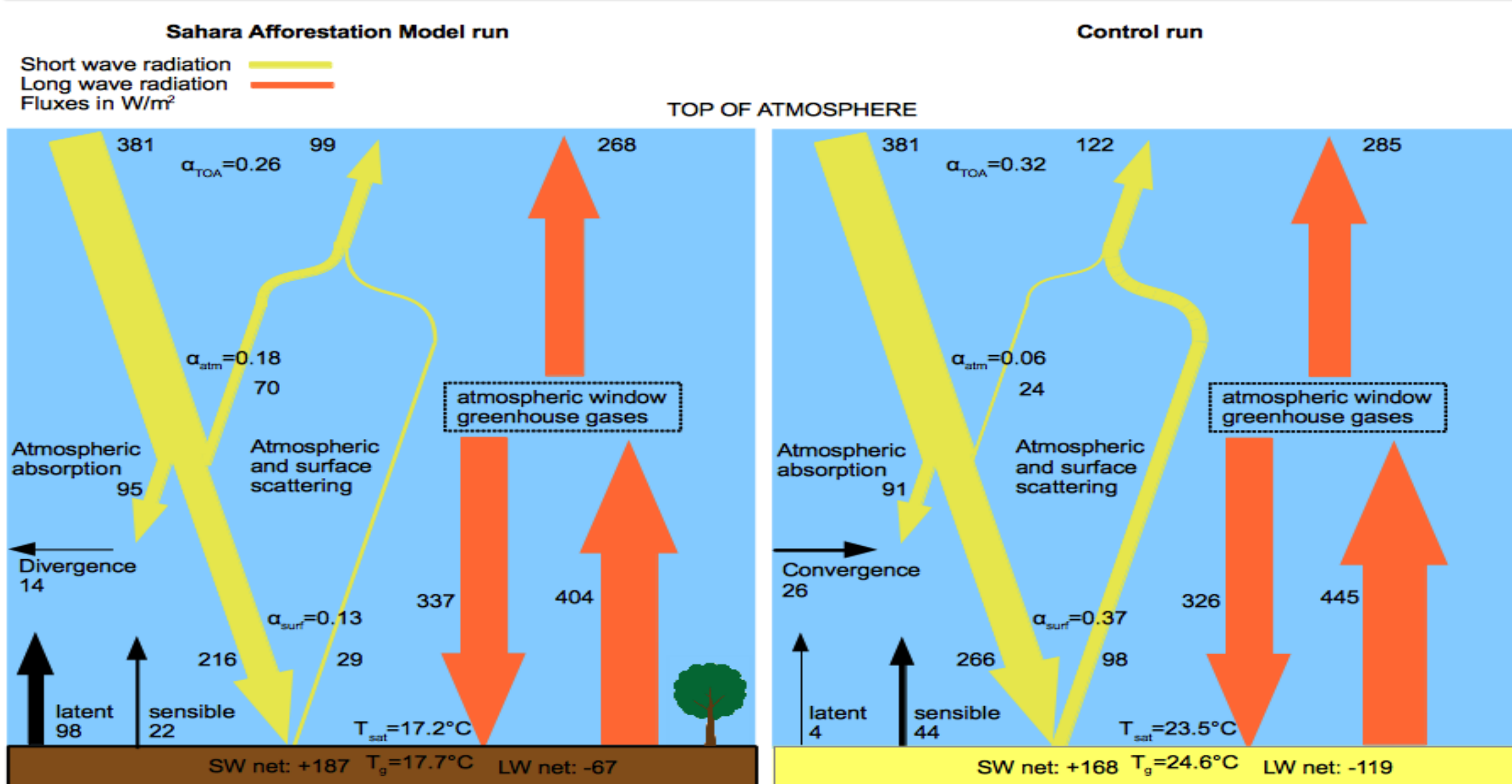


Figure 2. Heat flux balance (annual averages) for the afforested Sahara (left) and for the control run (right) computed from 30 years of model data.

Atmospheric available H₂O is lost by advection

- Evapotranspiration 1236 mm/yr
- 26% recycled locally as rain
- 74% lost to adjacent regions by advection

Advection of moisture to the Sahel zone intensifies the West African Monsoon (see also figure 5)

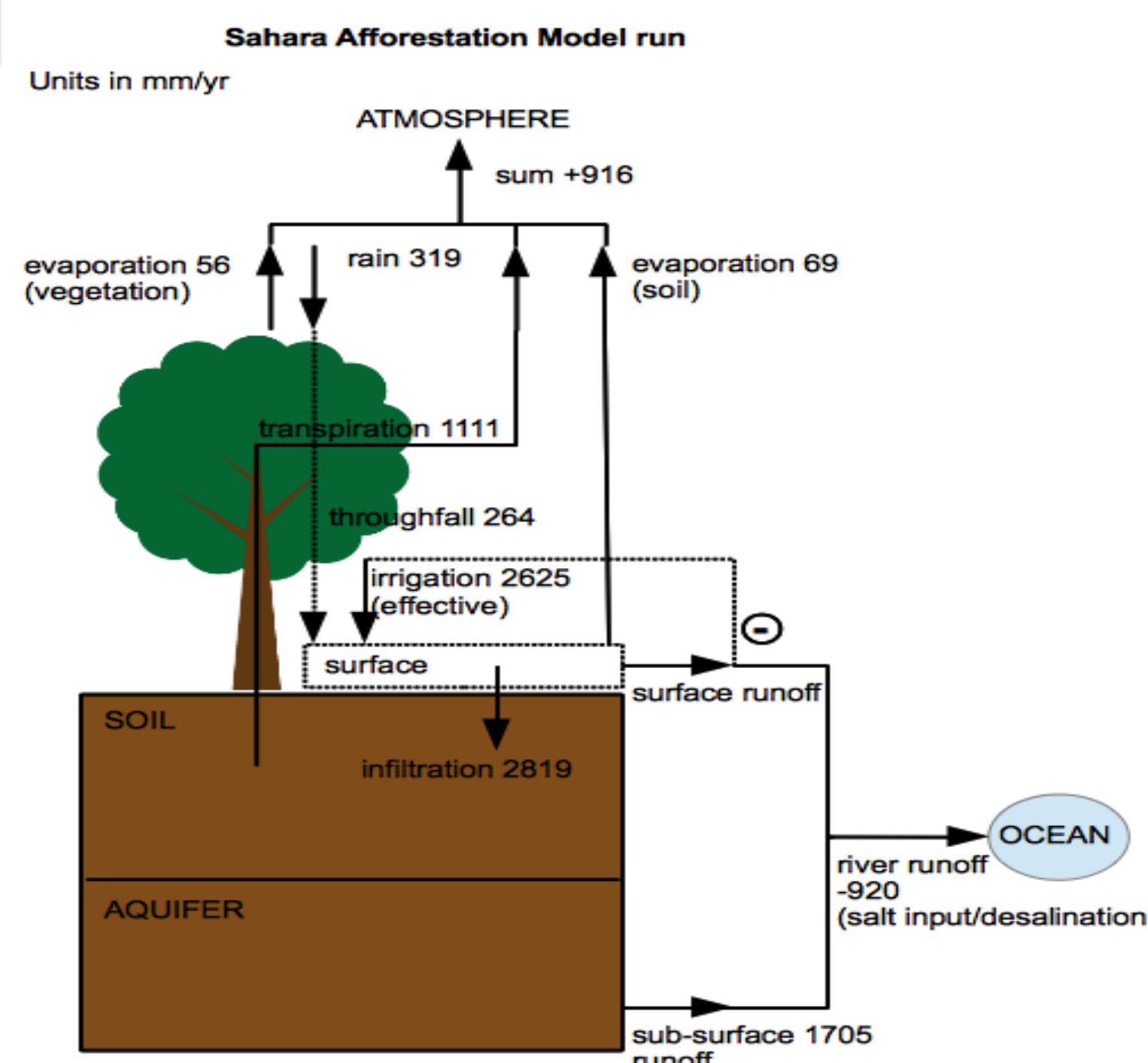


Figure 3. Water balance (annual averages) for the afforested Sahara computed from 30 years of model data.

2 Global Impacts

Teleconnections to the tropics

- ENSO influenced by the afforestation of the Sahara?
- Global cooling by 0.04°C

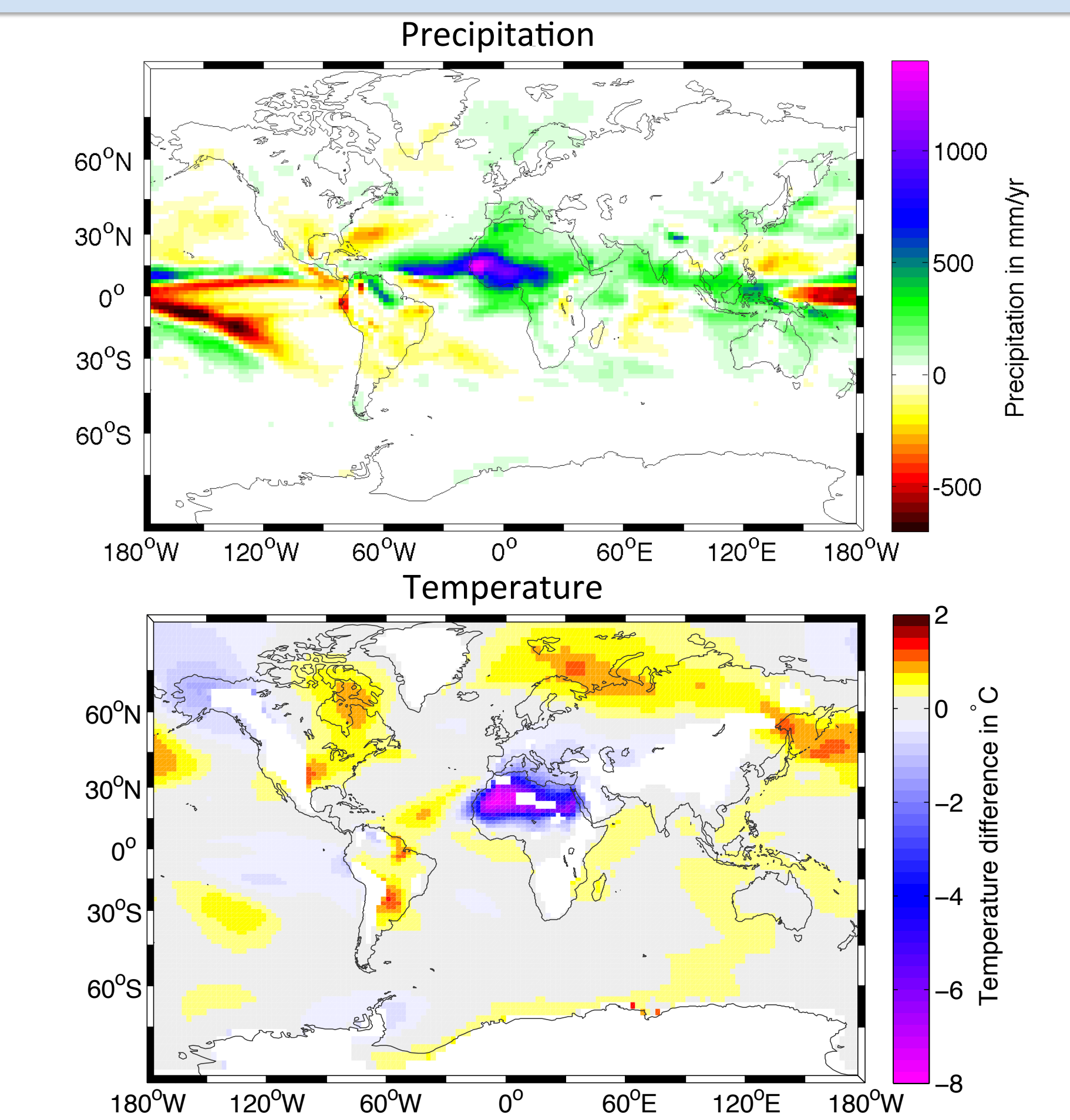


Figure 4. Changes in precipitation (top) and precipitation (bottom). 30 year average, annual mean, Afforested Sahara minus Control run.

3 West African Monsoon

Intensification of the West African Monsoon

- Large scale afforestation as a climate engineering option affects non local monsoon dynamics
- West African Monsoon starts already in April, moves northward and intensifies

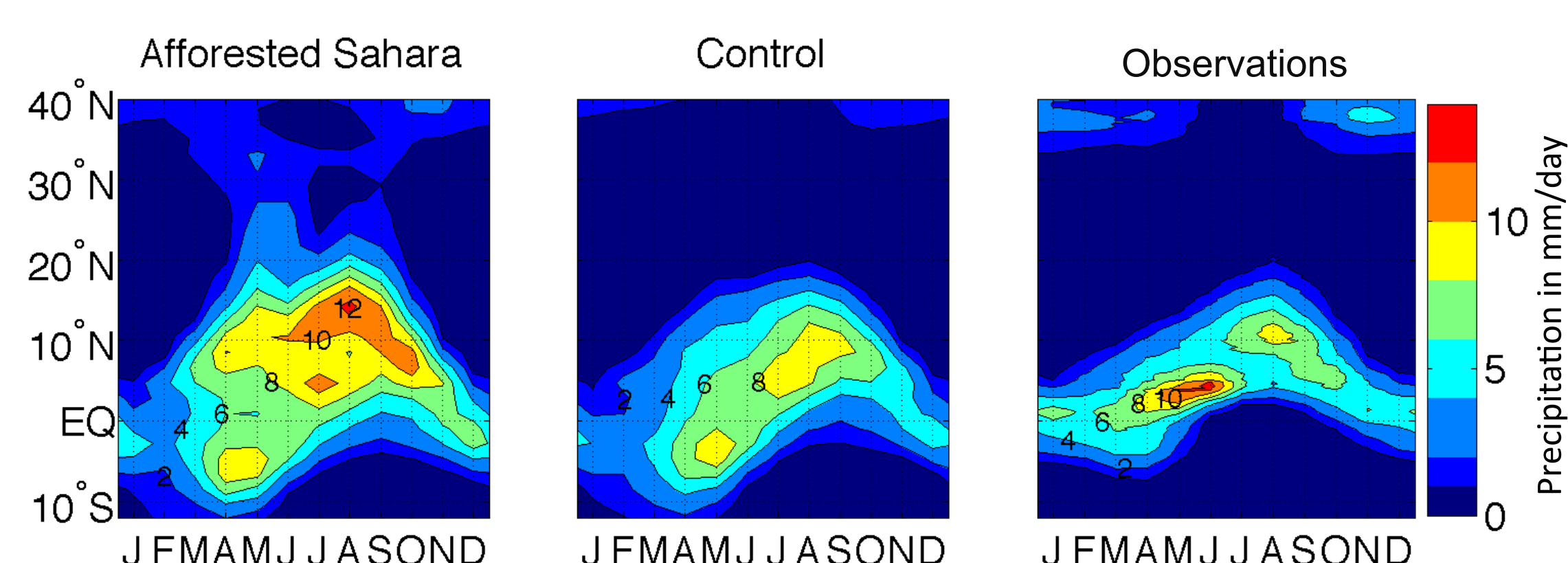


Figure 5. Seasonal cycle of precipitation zonally averaged from 10°W to 10°E for an afforested Sahara (left) and for the control run (middle) computed from 30 years of model data. Observation from the Tropical Rainfall Measuring Mission (right).

Local atmospheric temperature profile controls zonal wind system

- Thermal wind changes zonal circulation
- Weakening of the African Easterly Jet (AEJ)
- Strengthening of the Tropical Easterly Jet (TEJ)
- Impact of the AEJ, TEJ dynamics on the precipitation (see also figure 7)

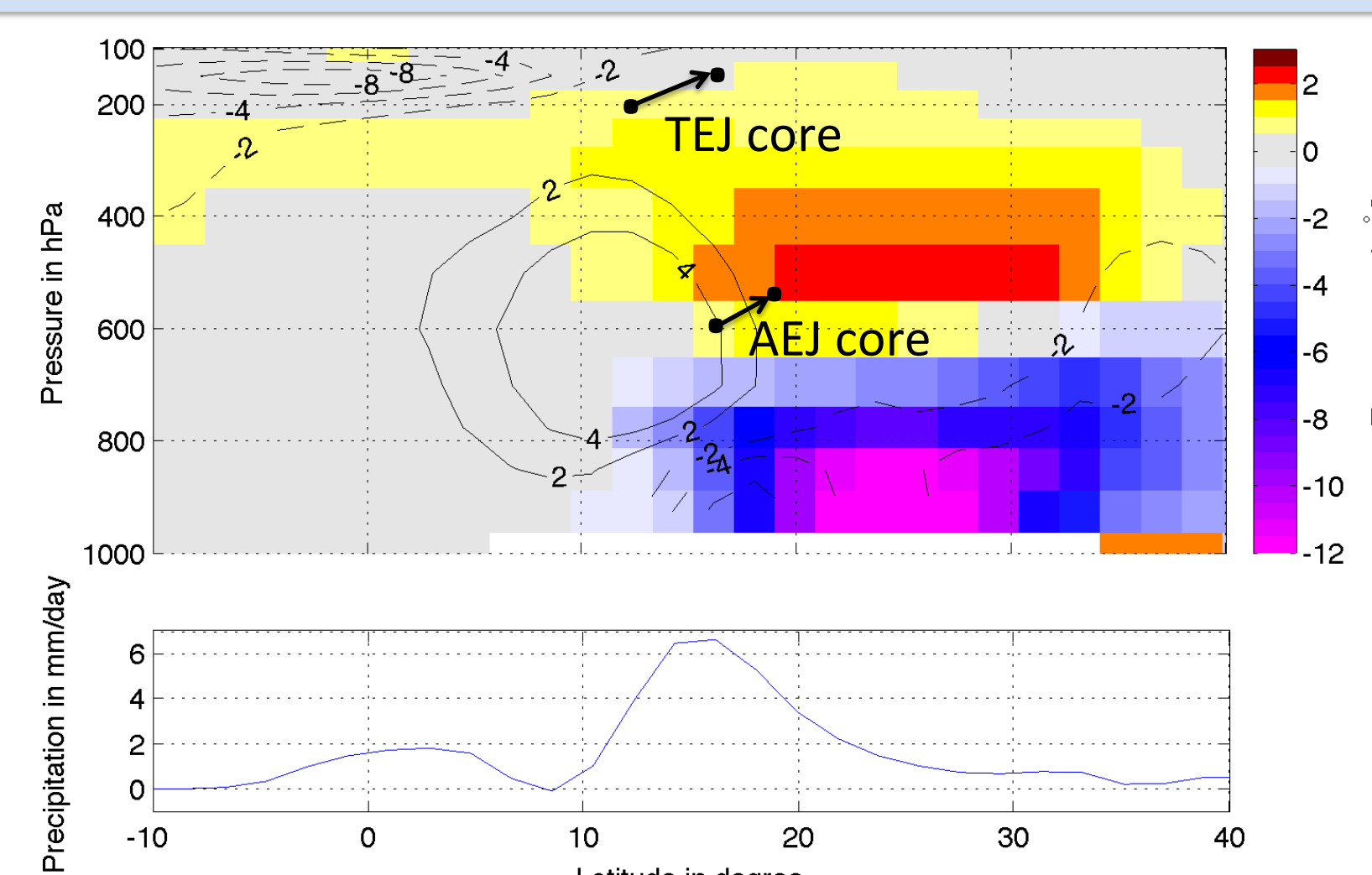


Figure 6. Changes in temperature (top, colors) zonal windspeed (top, contour lines, m/s) and precipitation (bottom). 10°W to 10°E 30 year average, August, Afforested Sahara minus Control run.

Sensitivity of non-local precipitation to the TEJ and AEJ variability

- A weaker AEJ increases precipitation over the Sahara and in the Sahel zone (red regions, left)
- Stronger TEJ intensifies Sahel rainfall during the monsoon (blue regions, middle)

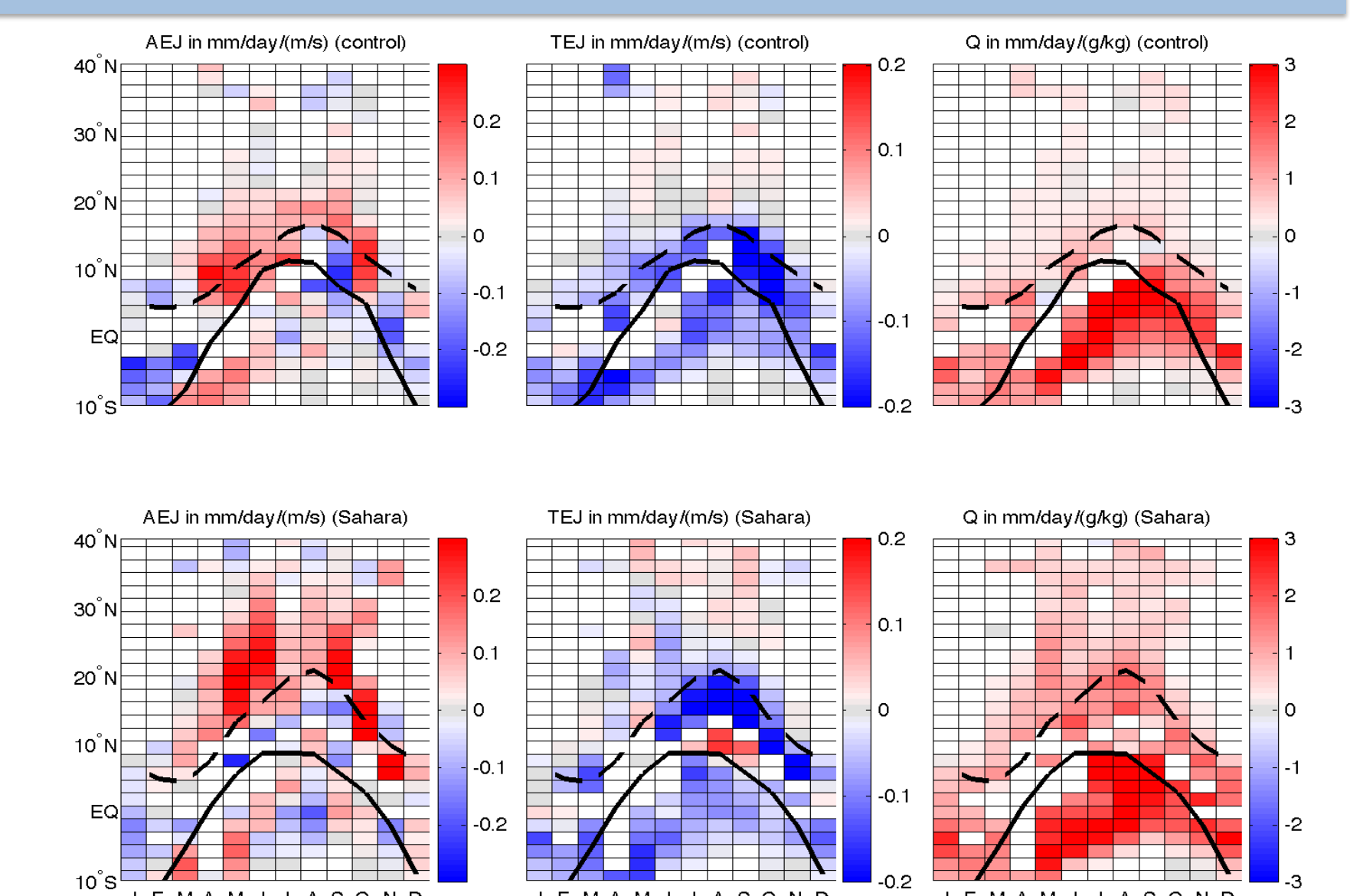


Figure 7. Coefficients of multivariate linear regressions of local precipitation on the AEJ core velocity (left), TEJ core velocity (middle) and local humidity (right). Position of the TEJ core (solid line) and AEJ core (dashed line). 99% significance level, climatology of 50 years data, 10°W to 10°E.