Low-Level Moisture Transport Associated with West African Monsoon

by

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Diagnostic Time Scales of Atmospheric Moisture Transport over West Africa

<u>Goal</u>: How does atmospheric variability on different time scales affect West African summertime moisture transport?

Atmospheric Moisture Budget

$$\frac{\partial W}{\partial t} + \nabla \bullet Q = E - P$$

W = precipitable water
Q *= vertically integrated (sfc-850 hPa) moisture flux*
q= specific humidity
E= surface evapotranspiration
P= precipitation

Moisture transport can be explored by different time scales, defined as

$$x = \overline{x} + x^c + x^s$$

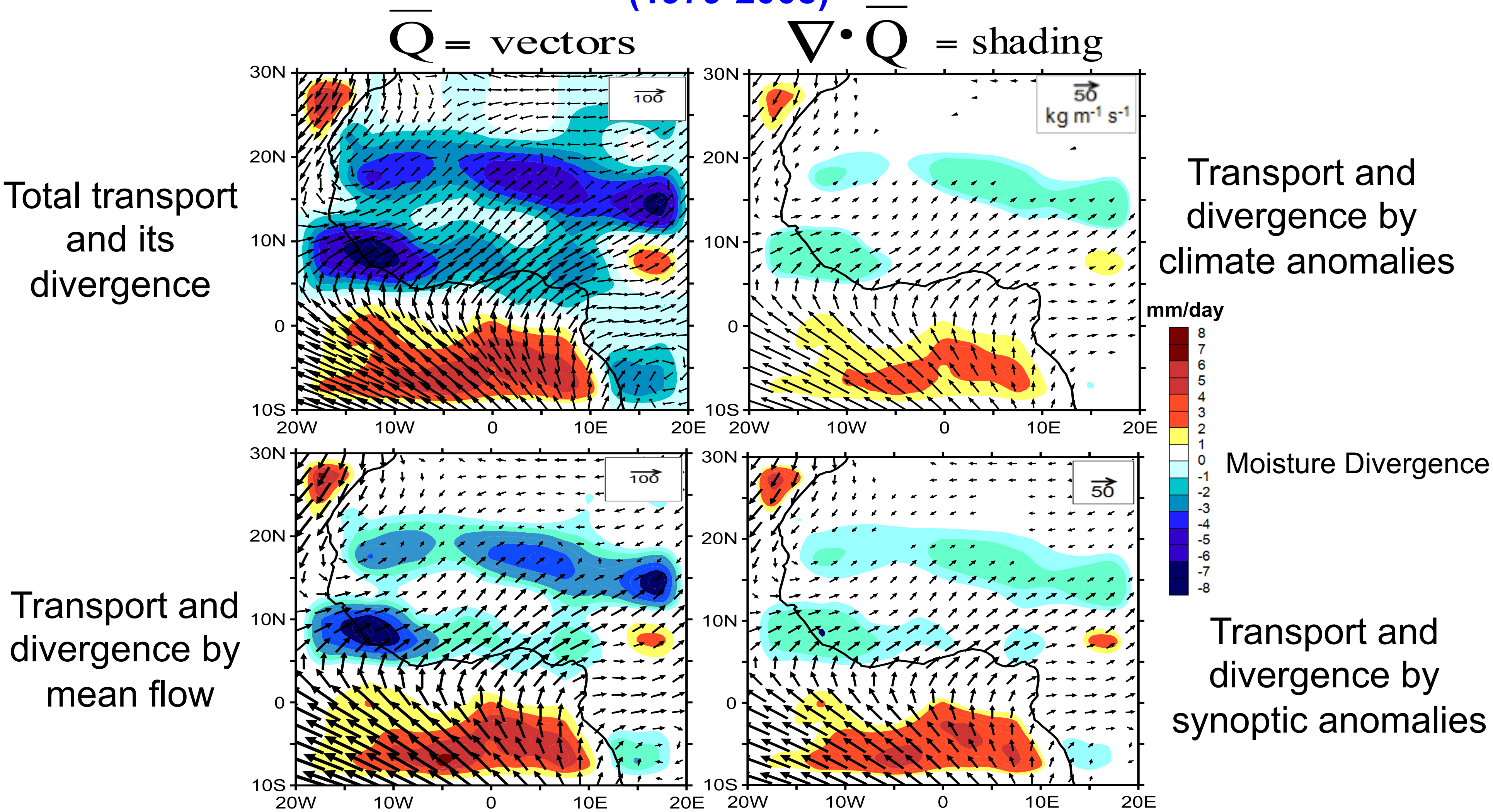
Total = long term mean (1979-2008) + climate anomaly (periods > 10 days) + synoptic anomaly (periods <10 days)

Since $\partial \overline{w} / \partial t = 0$, the mean moisture budget is a balance between moisture flux divergence and the water source/sink :

$$\nabla \bullet \overline{Q} = (\overline{E} - \overline{P})$$ where $$\overline{Q} = \overline{v}\,\overline{q} + \overline{v^c q^c} + \overline{v^s q^s}$$

June-September Moisture Transport and Divergence

(1979-2008)



Mean moisture transport and its divergence is mostly due to transport by the mean flow -- transport by synoptic anomalies is generally greater than transport by climate anomalies, except along the southwest coast

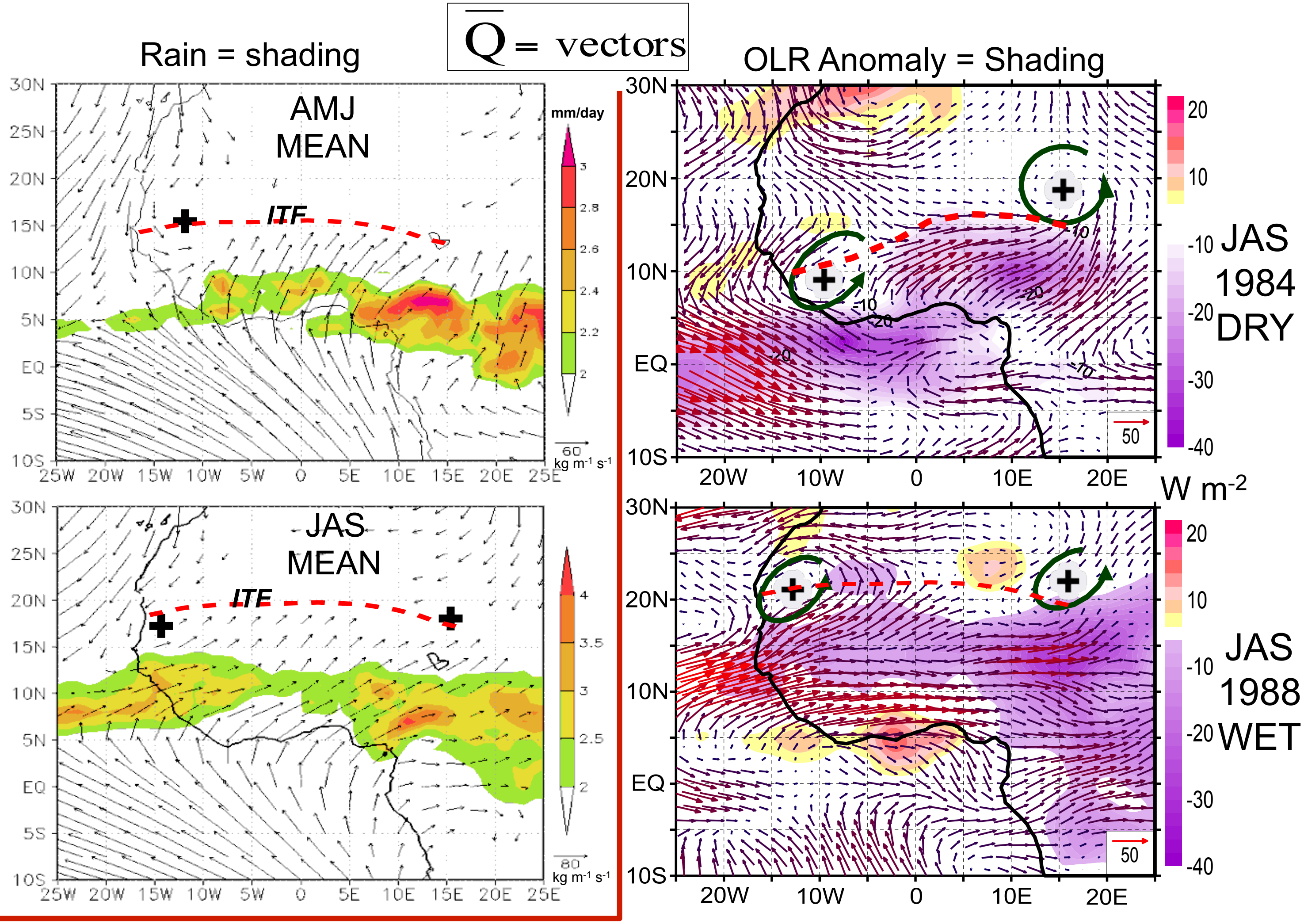
Northward Flux of Moisture into West Africa

- Composites based on $qv_{850} > 1\sigma$ across 5°N (AMJ), and 10°N (JAS) for 15°W-15°E

- Southerly moisture flux originates from the eastern Atlantic and penetrates through the location of the rain-band

- The largest southerly flux magnitude occurred in AMJ rather than JAS

- The northern limit of the flux coincides with the position of the ITF



DRY years → southward flux extent and southward position of the ITF relative to average

WET years → northward flux extent and northward position of the ITF -- strong westerly inflow

Seasonal Cycle of Moisture Transport Averaged across West African Sector

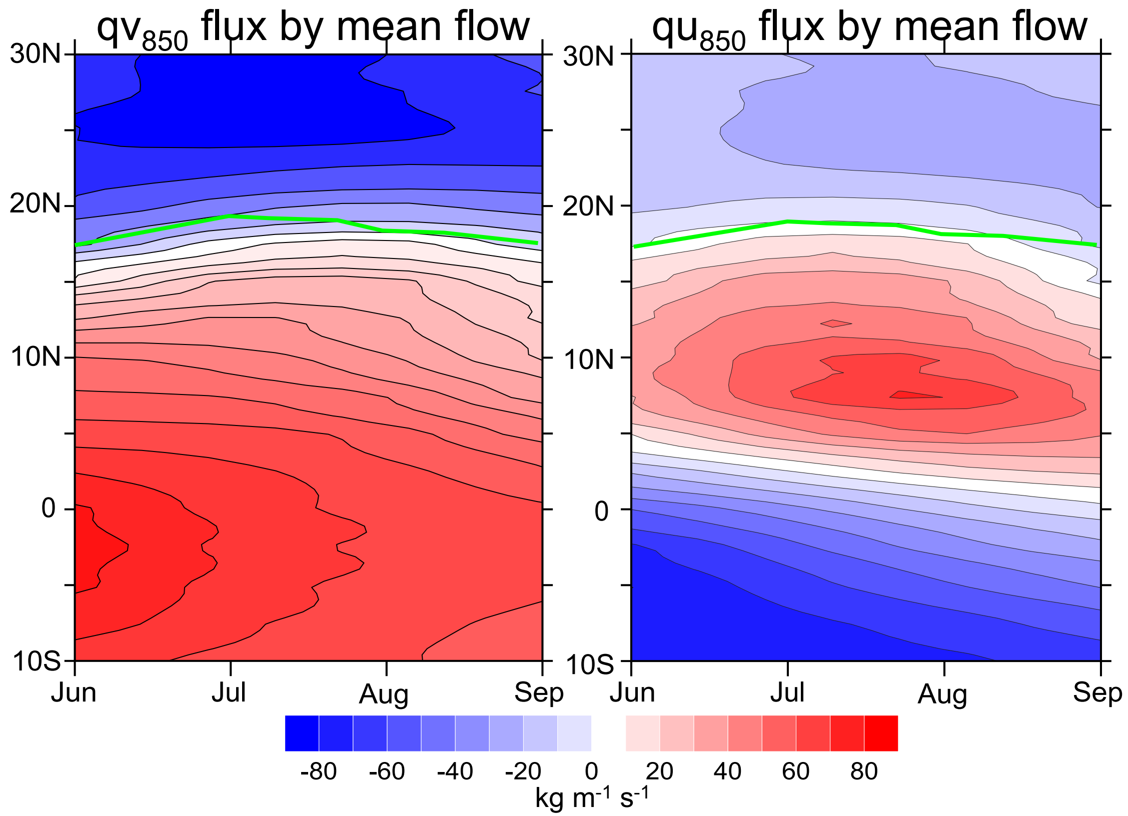
<u>Sahel Zone</u>

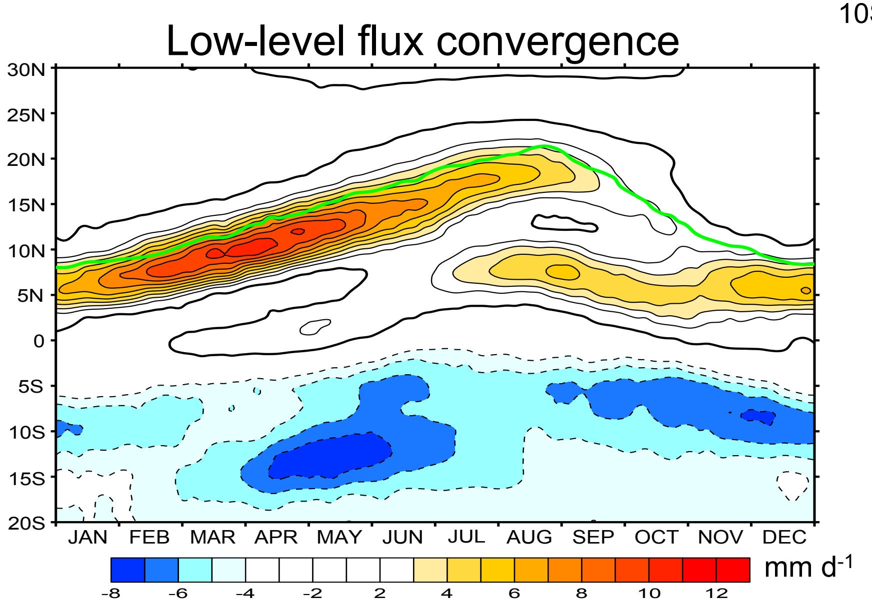
Zonal moisture flux dominated by transport by mean flow

<u>Gulf of Guinea Zone</u>

Meridional moisture flux dominated by transport by mean flow

The position of the zero line of qv_{850} is very close to the mean position of the surface ITF (15^{o}C; green line)





Surface-850 hPa total column flux convergence shows two regions of latitudinal moisture convergence over West Africa

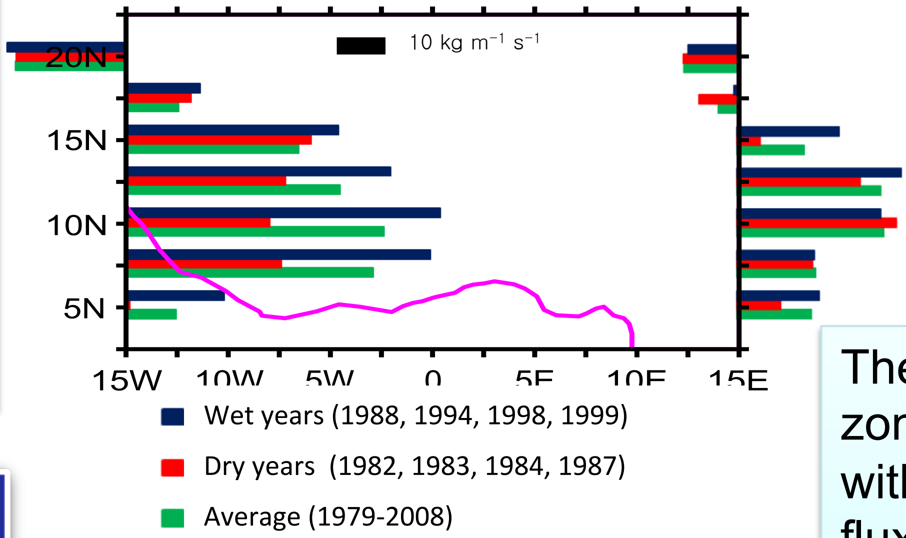
Moisture convergence is stronger during AMJ associated with the northward migration of the ITF

Moisture Flux Variation During Contrasting Years

The bars indicate the magnitude and direction of water vapor flux at region boundaries

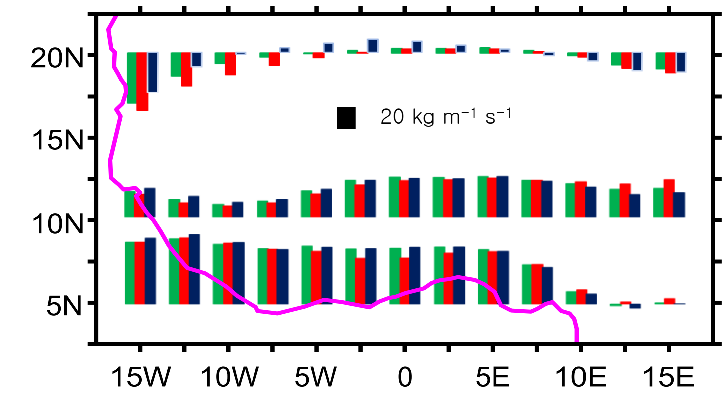
WET years = stronger than average westerly inflow (1988, 1994, 1998, 1999)

DRY years = less than average westerly inflow (1982, 1983, 1984, 1987)



ZONAL

The stronger inward zonal flux compared with the outward zonal flux is observed over the region



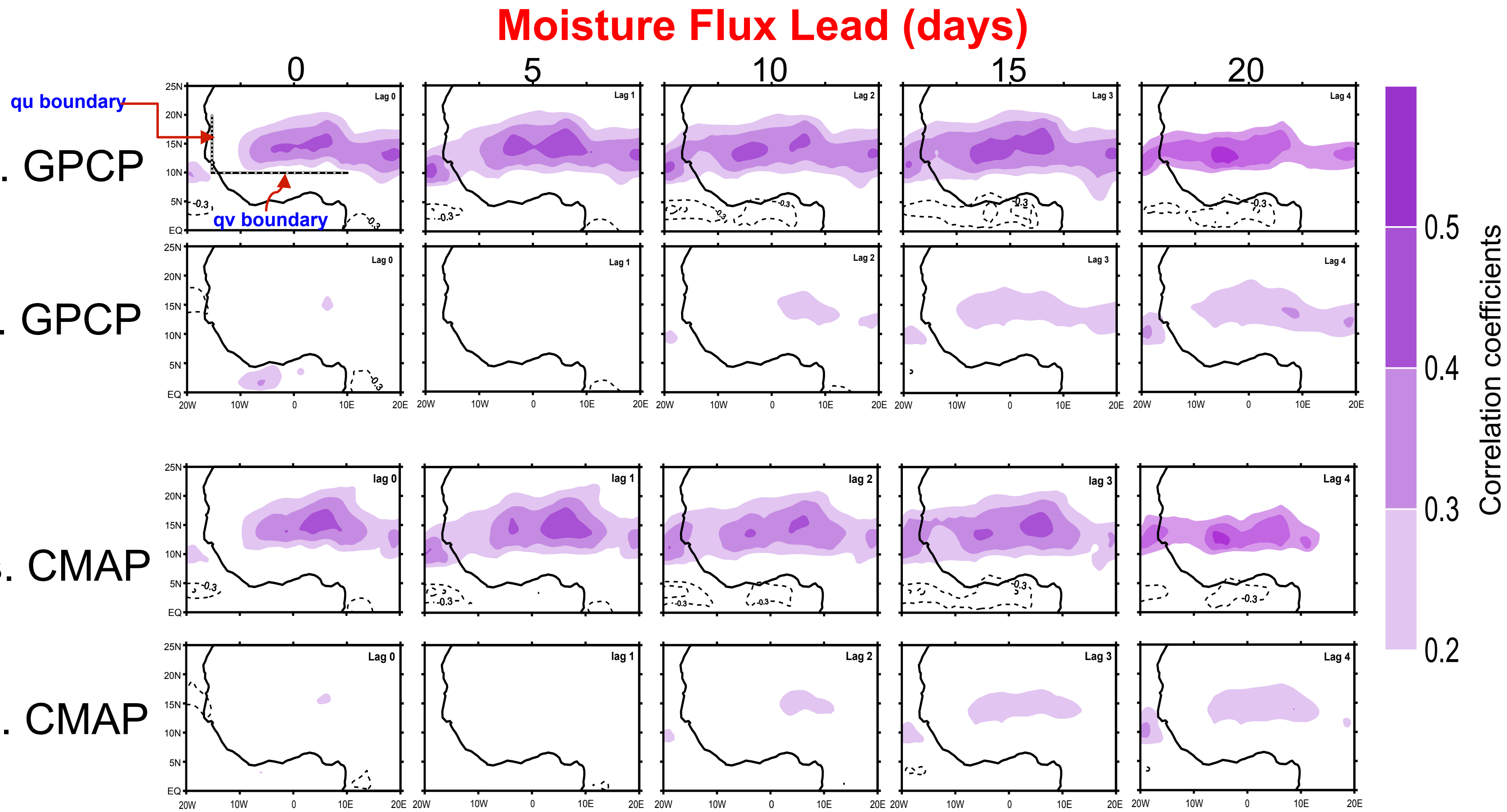
MERIDIONAL

Southerly moisture flux sustained with a slightly decreasing intensity as one goes north regardless of the season

The outward meridional flux is negligible for all composites

Moisture Flux Variation vs. Sahel Precipitation

Lag pentad correlations only with correlation coefficients exceeding 95% confidence level display



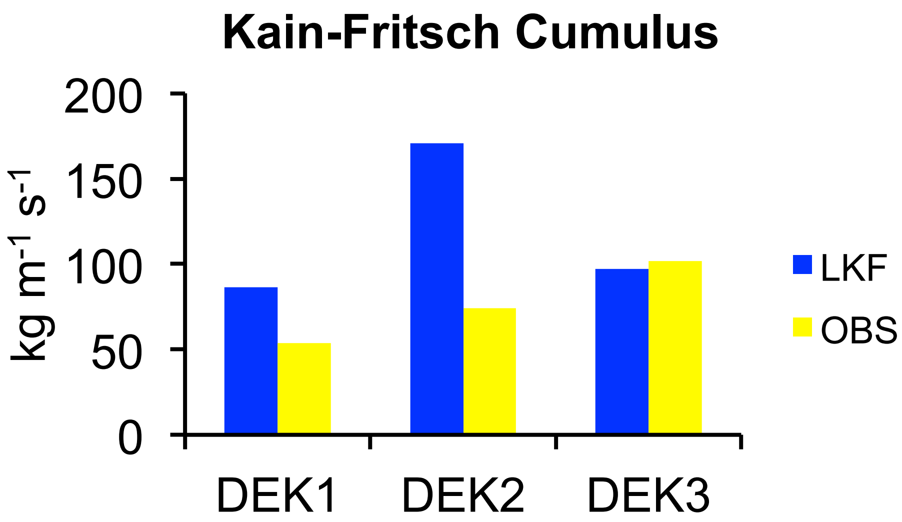
• When qu_{850} leads by 1 to 4 pentads, significant positive correlations extend across the Sahel, suggesting that zonal transport has a significant control on rainfall

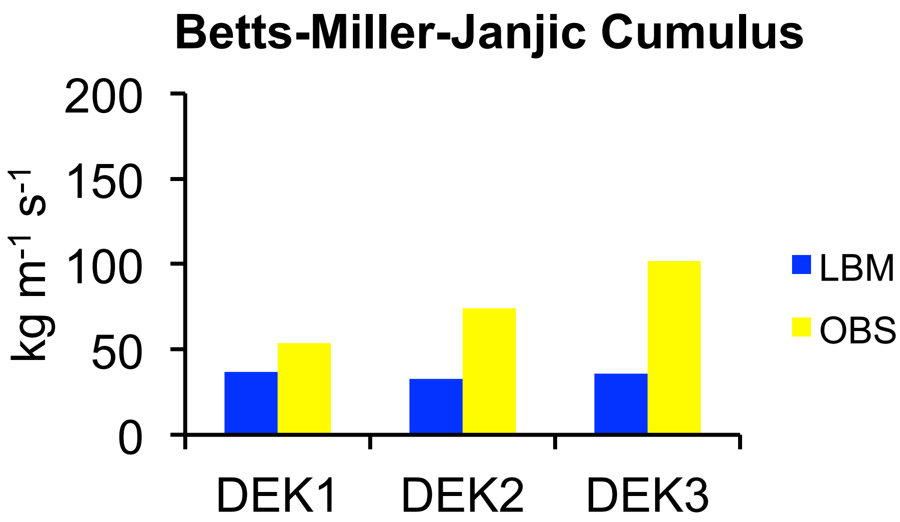
• Significant correlations are depicted with the meridional component starting at lag 3

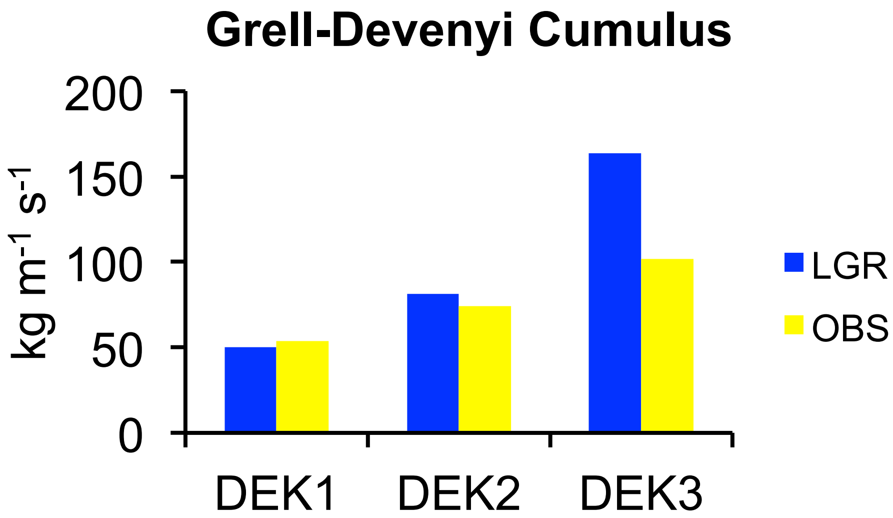
WRF Simulation of Zonal Moisture Flux

August 2006 12 km run

Lin et al. Microphysics



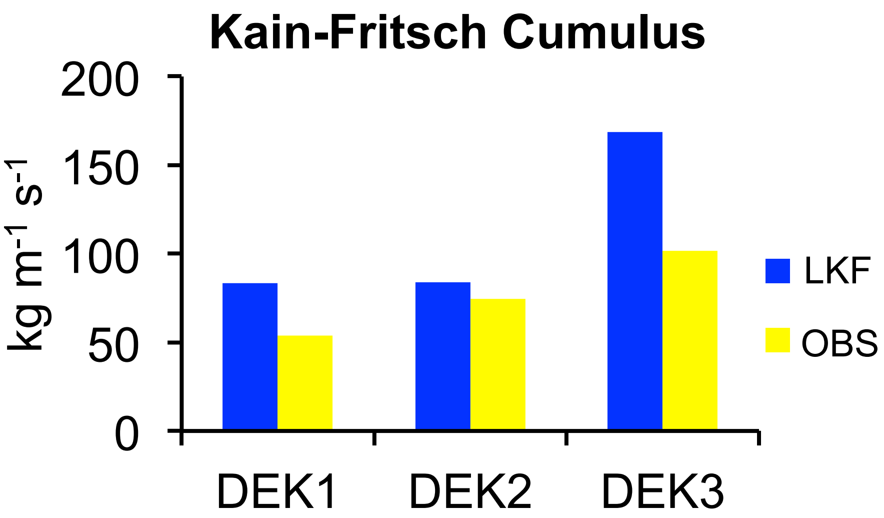


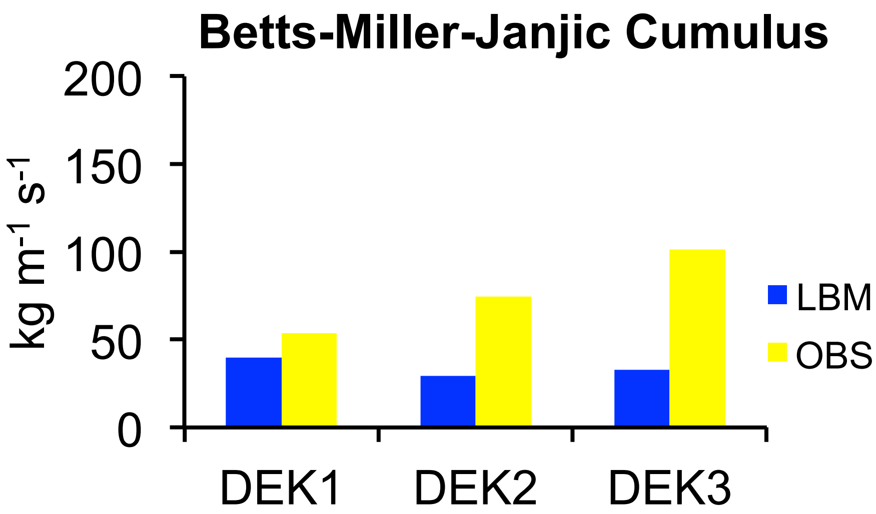


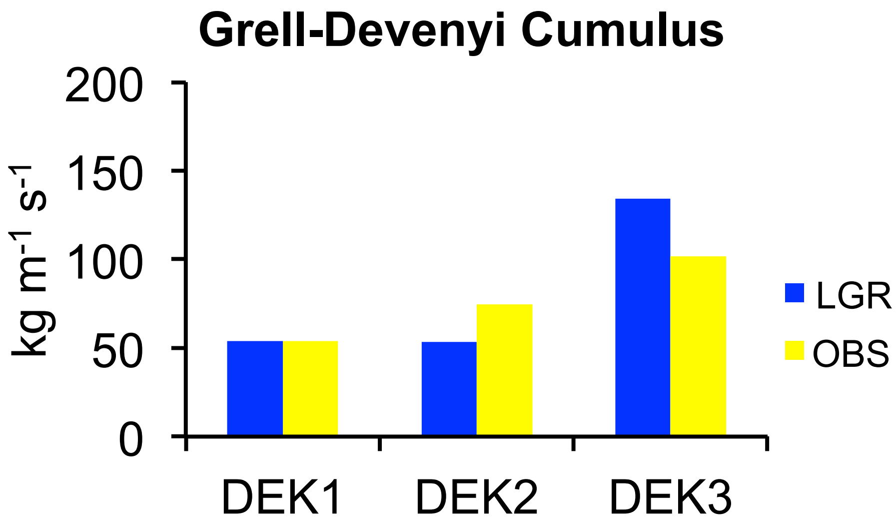
WRF Simulation of Meridional Moisture Flux

August 2006 12 km run

Lin et al. Microphysics







Conclusions

- Monsoonal flow brings moisture from the Atlantic Ocean into West Africa, where it undergoes moist convection

- The ITF is the boundary between the dry Sahara air and the summer moisture flux transport over West Africa. Variations in moisture circulation lead to substantial changes to the Sahel rainfall from year to year.

- The magnitudes of zonal fluxes into the West Africa are larger than that of the southerly fluxes, and the prevailing strong westerly transport extends poleward to the latitude position of the ITF.

- Large scale moisture flux convergence is suggested to be the primary source of water vapor needed to support enhanced convection over West Africa.

- WRF simulation of the meridional and zonal moisture fluxes is quite reasonable compared to observations, in particular when the Lin et al. microphysics is combined with the Grell Devenyi cumulus physics.