Soil moisture-precipitation feedback in West Africa

E. Orlandi [1] ***F. Fierli*** [2] *S. Davolio* [2] *O. Drofa* [2] *P. Malguzzi* [2] *A. Buzzi* [2]

1 Institute of Geophysics and Meteorology, University of Cologne, Germany.

2 Institute of Atmospheric Science and Climate, ISAC-CNR, Bologna, Italy.

MOTIVATION

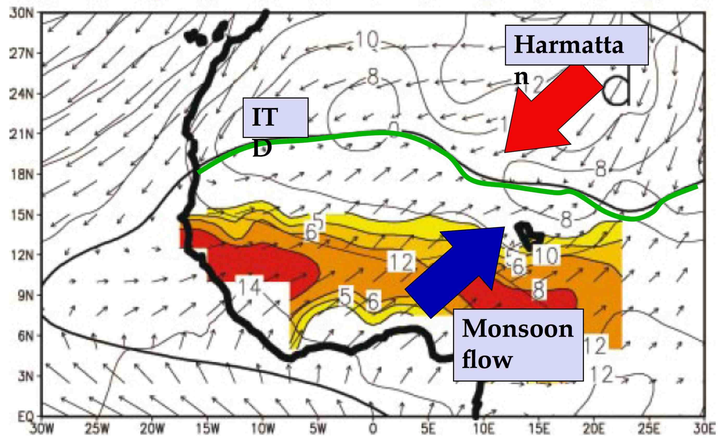
Land-atmosphere feedbacks are complex and act over a wide range of scales, having an impact on local and regional climate. In the transition zones between wet and dry climate, precipitation forecasts has been recognized to be highly sensitive to changes in soil moisture (Koster et al., 2004). In the Sahel, the transition area between the dry Sahara desert and the wetter Guinea coast, 90% of the precipitation is produced by mesoscale convective systems whose evolution and development is highly sensitive to soil moisture distribution.

Meynadier et al. (2010) showed that even the most up to date general circulation models' analyses fail in reproducing the correct seasonal water budget over West Africa. Improvements and tuning of land-atmosphere coupling over Africa are thus needed.

In this work we present a preliminary study on the sensitivity of land-surface model (LSM) and land/atmosphere coupling (e.g., fluxes of water and energy) to soil moisture initial condition and LSM parameters. This could indicate the best way to improve LSM.

Northern Hemisphere rainy season in Africa

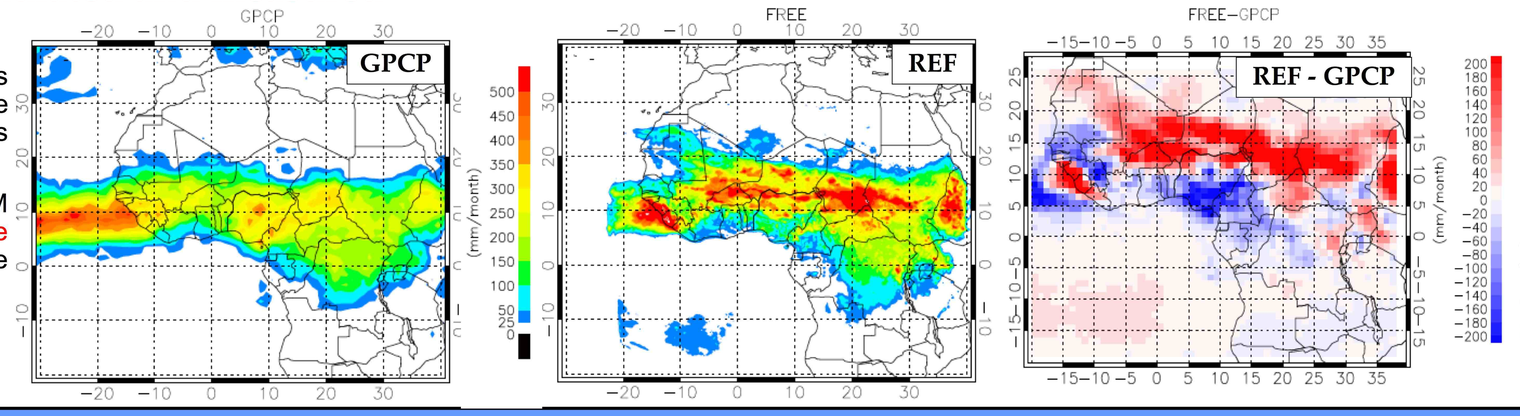
- Period: June-September
- Monsoon: low level circulation due to temperature gradient between sea and land
- African Easterly Jet(AEJ): thermal wind altitude 600 hPa, latitude 15°N
- Inter-tropical discontinuity (ITD): interface between wet and cold monsoon flow and dry and warm Harmattan



Mean 1968-1990 rainfall (mm/day) and NCEP Wind (m/s) at 925 hPa averaged from 16 Jul-31 Aug. Sultan B. and Janicot S., J.Clim., 2003

1. PRECIPITATION: Simulated and measured

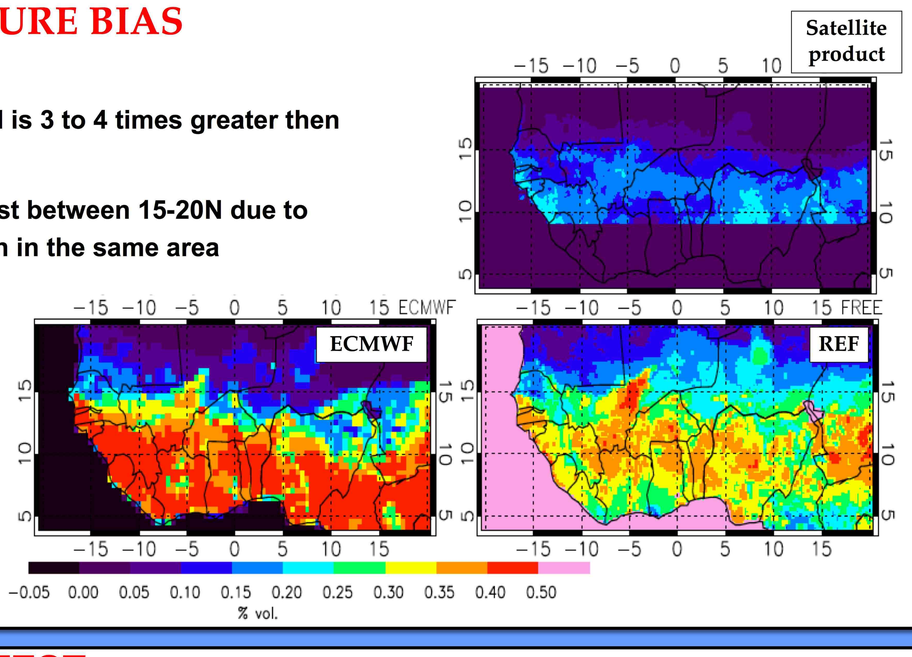
- BOLAM model overestimates monthly mean precipitation in the Sahel (10-20N) while underestimates precipitation in the Guinean area.
- In West Africa (10E-10W) BOLAM simulates the centre of the precipitation band at 15N while in the measurements it is found at 10N.



Accumulated precipitation for August 2006. GPCP (left), BOLAM (centre) and BOLAM-GPCP (right).

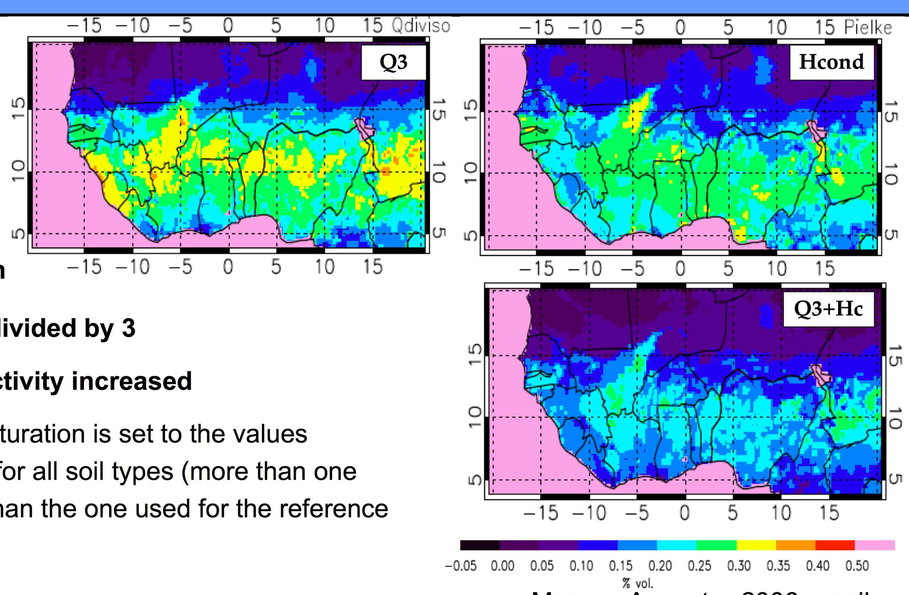
2. SOIL MOISTURE BIAS

- **Soil moisture in model is 3 to 4 times greater then observed**
- **BOLAM: high soil moist between 15-20N due to unrealistic precipitation in the same area**



Mean August 2006 soil moisture at 5 cm (m3/m3).

3. SENSITIVITY EXPERIMENTS



REF- reference simulation

Q3 - initial soil moisture divided by 3

Hcond - hydraulic conductivity increased

Hydraulic conductivity at saturation is set to the values proposed by Pielke (2002) for all soil types (more than one order of magnitude larger than the one used for the reference simulation).

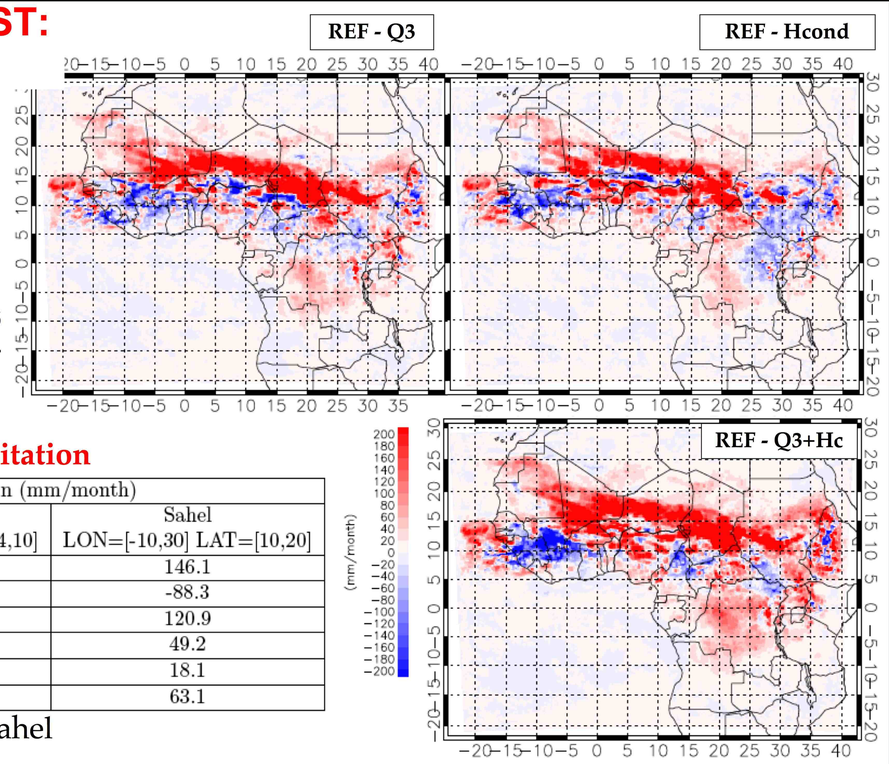
Q3+Hcond - both

Mean August 2006 soil moisture at 5 cm (m^3/m^3).

4. SENSITIVITY TEST: Precipitation bias

- **Precipitation is most sensitive to changes in soil moisture content in Sahel**

Difference in total August 2006 precipitation. Reference - sensitivity



Mean August 2006 precipitation

August precipitation (mm/month)	Guinea Coast LON=[-10,10] LAT=[4,10]	Sahel LON=[-10,30] LAT=[10,20]
GPCP	168.6	146.1
bias ECMWF	18.5	-88.3
bias REF	-80.5	120.9
bias Q3	-61.9	49.2
bias Q3+Hc	-66.8	18.1
bias Hcond	-78.1	63.1

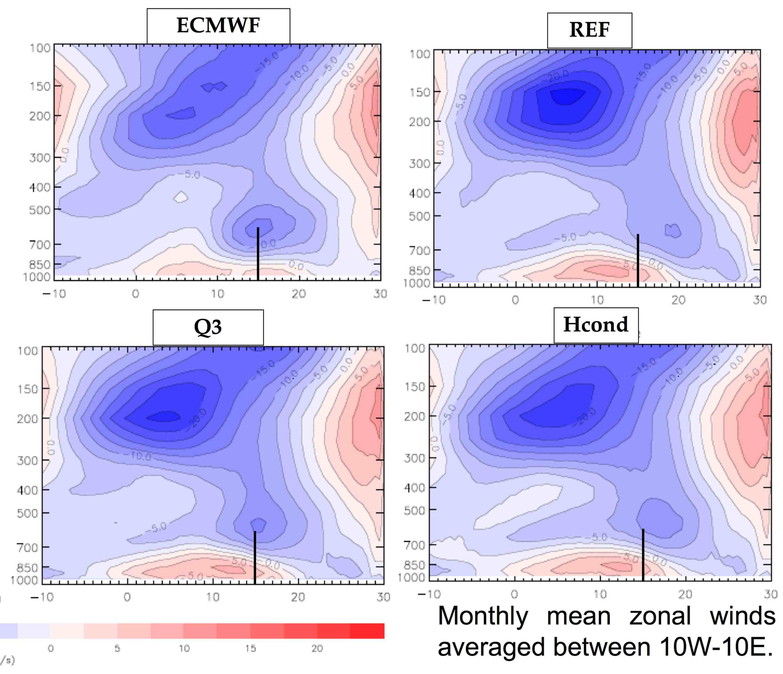
Q3+Hcond best score in Sahel

5. SENSITIVITY TEST: Dynamical features

- **REF simulation**: weak and northward displaced of AEJ.

Observational studies find this situation when rainfall in Sahel is above average and soil moisture too high.

- **Sensitivity sim.: improved AEJ position and intensity**



Monthly mean zonal winds averaged between 10W-10E.

CONCLUSIONS

- **Monthly mean simulated precipitation is overestimated in Sahel during the monsoon season**
- **A possible explanation of rain excess is the overestimation of the mean soil moisture in region**
- **Sensitivity tests reducing soil moisture result in a precipitation reduction and improved circulation**

BOLAM simulations

- BOLAM is a limited-area meteorological model based on the primitive equations in the hydrostatic approximation.
- The microphysical scheme has five prognostic variables.
- Deep convection is parameterized with the scheme of Kain-Fritsch.
- Further details of the model are provided in Malguzzi et al. 2006.

Model set-up

- Simulated period: 1- 31 August 2006
- Initial and boundary conditions: ECMWF AMMA reanalysis
- Grid: 38 vertical levels, 24 km horizontal resolution

Satellite RAINFALL product

GPCP-1DD: The Global Precipitation Climatology Project algorithm combines precipitation estimates from several sources, including infrared (IR) and passive microwave (PM) rain estimates and rain gauge observations. PM data are used within the framework of the threshold-matched precipitation index to delineate rain areas in the IR data. Gauge data was involved indirectly to scale the 1DD product so that monthly accumulations matched the monthly GPCP product.

RESOLUTION: 1°, Daily

Satellite SOIL MOISTURE product

- Soil moisture maps are initially produced using rainfall estimation based on Meteosat measurements.
- A microwave emission model is used to simulate the emission from wet soil.
- An assimilation scheme is then used to minimize the difference between AMSR-E C-band measurements and simulated brightness temperature. Pellarin et al. (2009)

RESOLUTION: ~10 km, 30 minute

References

Koster RD et al., 2004, Regions of strong coupling between soil moisture and precipitation, Science, 305:1138–1140.
Malguzzi P. et al., 2006, The 1966 "century" flood in Italy: A meteorological and hydrological revisitation, JGR, 111:D24106.
Meynadier R. et al., 2010, West Africa Monsoon water cycle: 2. Assessment of numerical weather prediction water budgets, JGR, 115:D19107
Pellarin T. et al., 2009, Soil moisture mapping over West Africa with a 30-min temporal resolution using AMSR-E observations and a satellite-based rainfall product, HESS, 13:1887-1896
Pielke R.A., 2002, Mesoscale Meteorological modelling, International Geophysics Series volume 78, Academic Press.

Contact: Emiliano Orlandi <eorlandi@meteo.uni-koeln.de>