Modelled feedback of observed inter-annual vegetation changes on the West African monsoon

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Motivation

Vegetation changes driven by climate on decadal scales or by anthropogenic land use at continental scales can modulate the extent and the amount of West African monsoon rainfall [1,2]. However, the effect of natural year-to-year changes of vegetation (Fig. 1) on rainfall and the related operating processes in that region has received less attention.

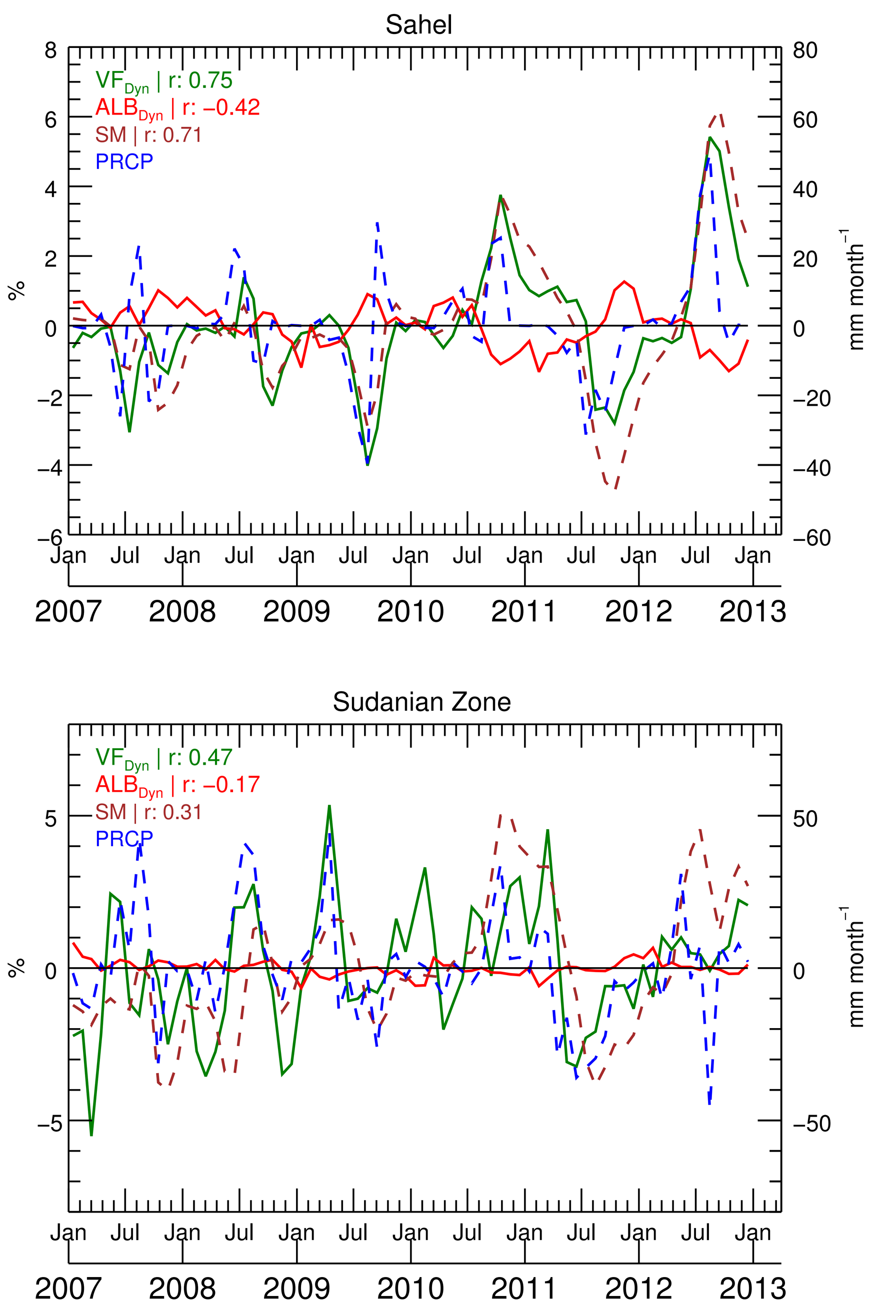


Figure 1: Monthly anomalies of the dynamical albedo (ALB_{Dyn}) and vegetation fraction (VF_{Dyn}), soil moisture (SM) and precipitation (PRCP: TRMM) with respect to the average annual cycle for 2007-2012. Correlations (r) represent +1 month time-lagged correlations with PRCP.

Study area and method

Experimental set-up

Weather **R**esearch and **F**orecasting model:
- 7 km horizontal resolution
- August-September 2009/2010
- Dynamic and static land surface description
- Inter-annual change: ΔY = 2010-2009

Reduction of internal model variability

Four-member ensembles per year: perturbed initial conditions (-0,-1,-2,-3 days). The result are sixteen different ΔY.

Removal of the large-scale signal

DYN: satellite-derived ALB (monthly), LAI and VF (10-daily) + new land-use map
CLIM: WRF default parameters with fixed annual cycle + standard tables [5]

Vegetation-induced surface signal from DYN and CLIM ensemble means:
$\Delta Y_{Srfc} = \Delta Y_{Dyn} - \Delta Y_{Clim}$

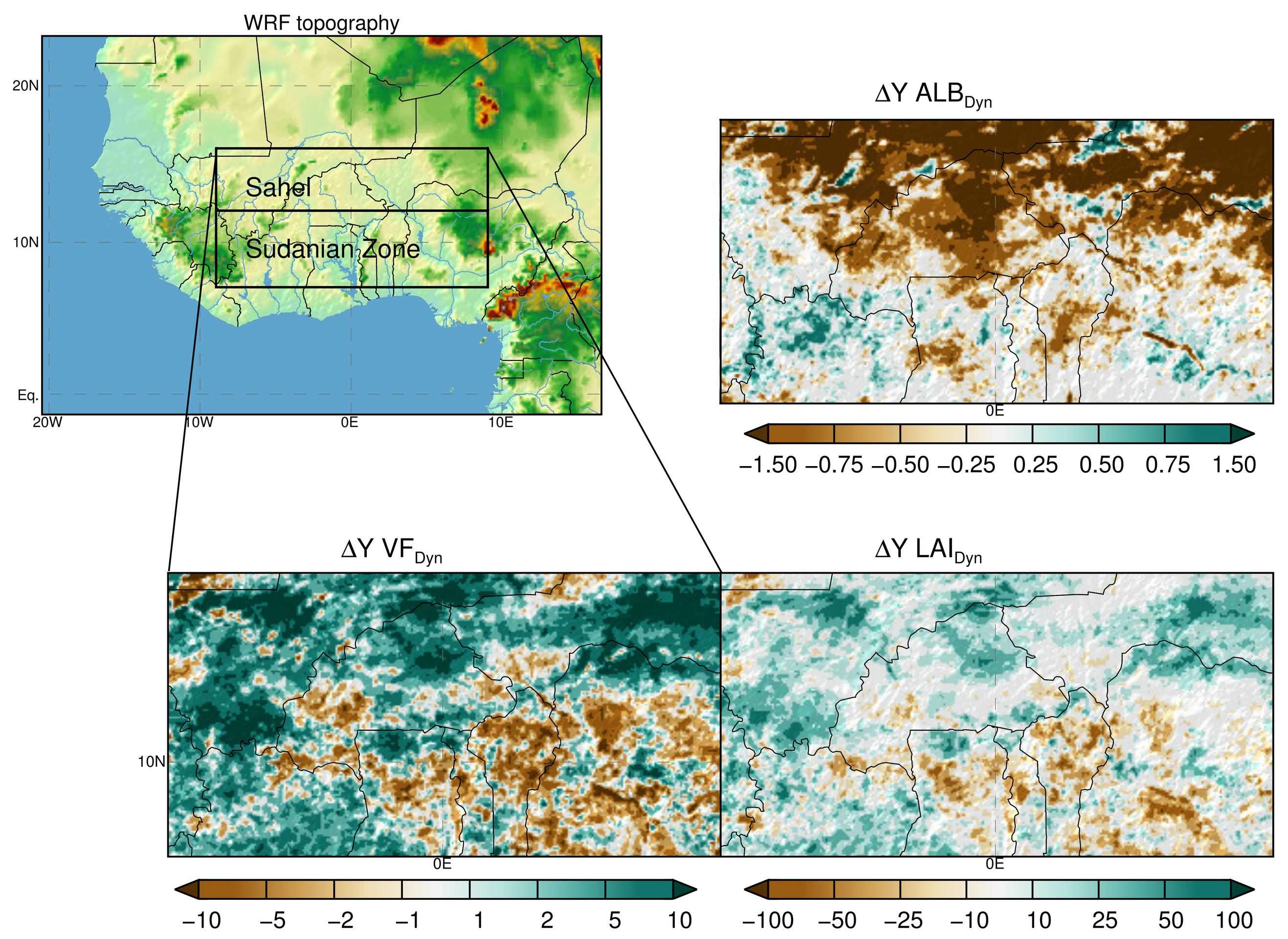


Figure 2: WRF domain with indicated study region and sub-regions in the box (9°W-9°E, 7-16°N) and the ΔY (%) for the dynamical satellite-derived datasets for green vegetation fraction (VF), albedo (ALB) and leaf area index (LAI).

The atmospheric footprint of vegetation

Vegetation induced circulations

(a,b) Convergence (divergence) of moist air over higher (lower) temperatures. Higher (lower) PBL heights favour (inhibit) the initiation of deep convection in the afternoon

Different behaviour during night and day

(c,d) Decrease (increase) of rainy hours over regions with higher (lower) VF during the day and vice-versa during the night.

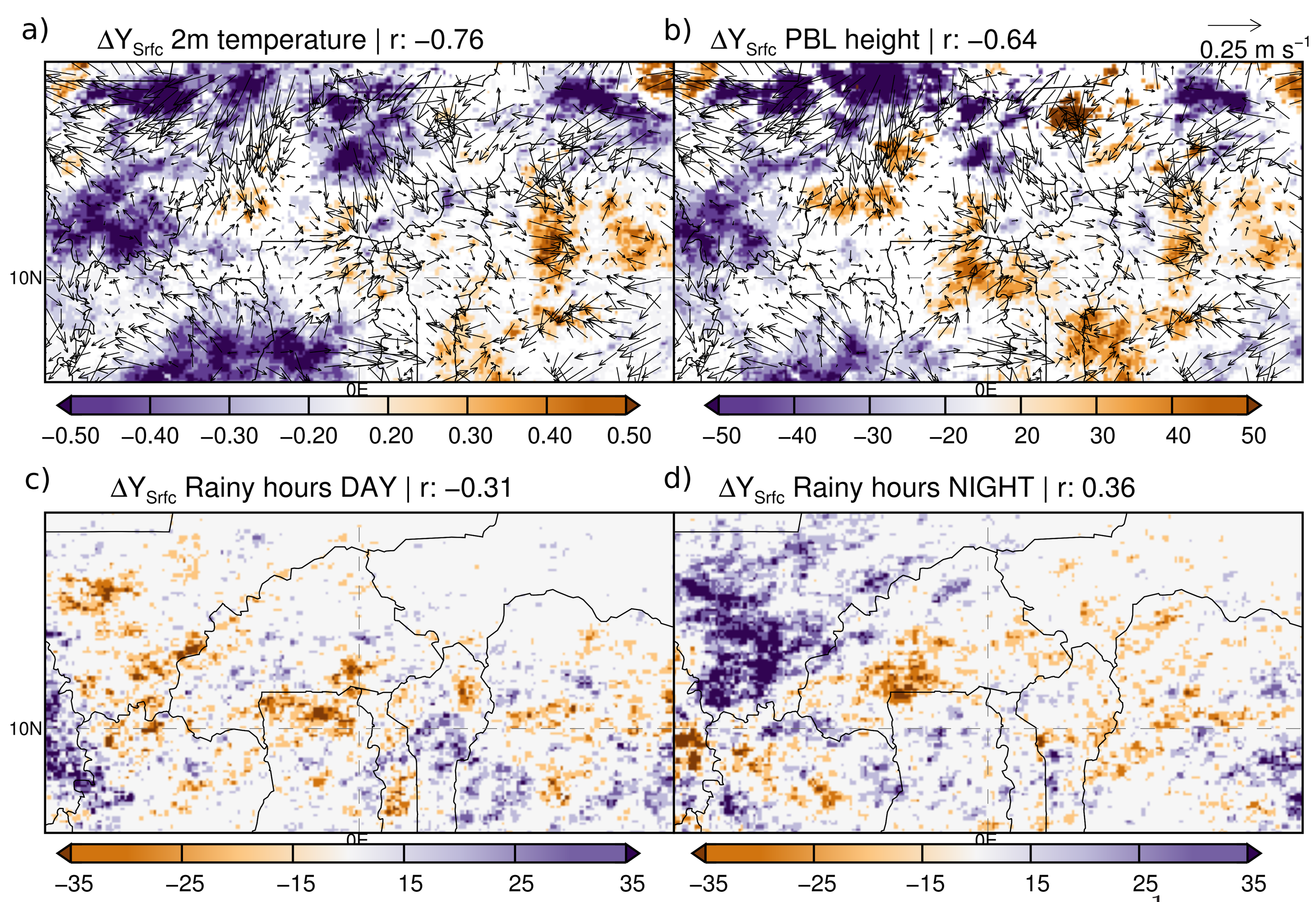
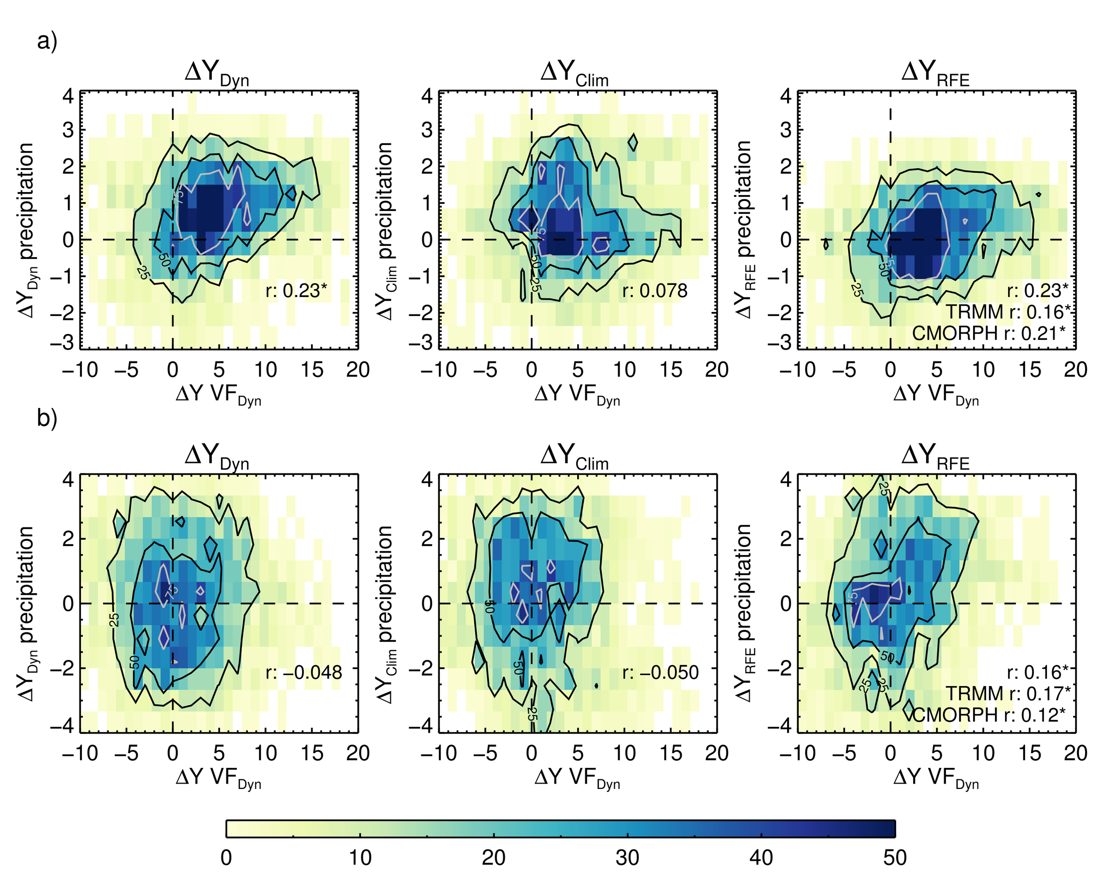


Figure 3: **(a,b)** 2m temperatures (K) and PBL heights (m) with ΔY_{Srfc} 10m wind vectors (m s^{-1}). **(c,d)** Daytime (0700-1800 UTC) / nighttime rainy hours. Spatial correlations (r) are with respect to $\Delta Y\ VF_{Dyn}$ (c.f. Fig. 2).

Observed feedback



Signal only detectable in Sahel

Observed correlation between precipitation and vegetation changes (~0.2) captured with DYN.
→ not explained by large-scales (CLIM ~0.08)

Dominance of the monsoon dynamics inhibits signal detection in Sudanian Zone: no correlation in WRF. The observed correlations of ~0.15 represent the precipitation-vegetation feedback only.

← **Figure 4:** AS density scatterplots between $\Delta Y\ VF_{Dyn}$ and the ΔY of precipitation (mm day^{-1}) for DYN and CLIM in comparison to RFE[3] (TRMM[1], CMORPH[2]) for average daily rainfall **(a)** in the Sahel, **(b)** in the Sudanian zone. Significant r are marked with a star. Contours indicate the 75th, 50th and 25th percentile of the maximum density.

1: TRMM: NASA Tropical Rainfall Measuring Mission 3B42 V7, 0.25°
2: CMORPH: CPC Morphing technique, 0.25°
3: RFE: Africa rainfall estimates 2.0, 0.1°

Conclusions

Precipitation-vegetation correlation peaks with a time-lag of one month with **implications for seasonal predictions** (Fig. 1)

The modelled feedback corresponds to preceding studies in the region [3,4] (Fig. 3):
- **vegetation breeze**: negative feedback
- **enhancement of mature convective systems** during the night: positive feedback

Biggest potential for model **improvement at the northern and southern extent of the monsoon rainband** or drier months (Fig. 4)

Need for analysis methods based on observations without the need to remove a large-scale signal

References

[1] Alo CA, Wang G (2010) Role of dynamic vegetation in regional climate predictions over western Africa. Clim Dyn 35:907-922

[2] Kucharski F, et al. (2012) A further assessment of vegetation feedback on decadal Sahel rainfall variability. Clim Dyn 40:1453-1466

[3] Taylor CM, et al. (2012) Afternoon rain more likely over drier soils. Nature 489:423-6

[4] Garcia-Carreras L, et al. (2011) What is the Mechanism for the Modification of Convective Cloud Distributions by Land Surface-Induced Flows? J Atmos Sci 68:619-634.

[5] Skamarock WC, et al. (2008) A Description of the Advanced Research WRF Version 3.

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