Evaluation of Sahel ground climatology from 1982 to 1990 based on satellite derived LAI, 200 raingauge stations, and a vegetation model (SSIB)

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EVALUATION OF SAHEL GROUND CLIMATOLOGY FROM 1982 TO 1990 BASED ON SATELLITE DERIVED LAI, 200 RAINGAUGE STATIONS, AND A VEGETATION MODEL (SSIB)

Isabelle Poccard[1]*, Yongkang Xue[1,2]
1 UCLA, Dept. of Geography, Los Angeles, California
2 UCLA, Dept. of Atmospheric Sciences, Los Angeles, California

1. INTRODUCTION

The Sahel has experienced a severe and persistent drought since the beginning of the 1960s. One of causes proposed to explain this dramatic trend includes the land use change, e.g. the land-surface degradation associated with human pressure that dramatically increased during this period (Xue *et al.*, 2003).

Because of the strong social, economic impacts, a number of studies with different models have been conducted to study the role of biosphere feedback of the Sahel drought of the past 20 years (Charney *et al*., 1977; Sud and Fennessy, 1982; Xue and Shukla, 1993; Dirmeyer and Shukla, 1996; Xue, 1997; Zeng *et al*., 1999).

Following these studies, this work evaluates the ground climatology of this region over the 1982-90 period, using observational precipitation data, satellite derived LAI, and an offline version of the SSiB land surface model.

2. DATA AND METHODS

Two hundreds seventeen raingauge stations have been selected (fig. 1) from the IRD daily rainfall database over West Africa, tested and added with other French sources and the Oklahoma database. The choice of the stations is based on three different criteria: (i) the maximization of the spatial coverage (2°N-20°N and 18°W-25°E), (ii) the maximum period length without any gap (1982-90), and (iii) the maximum variation of different associated vegetation types (7 types are included).

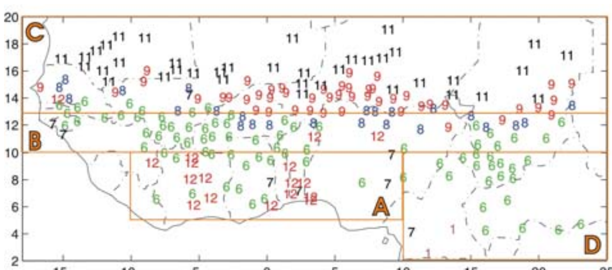

FIGURE 1: *Location of the 217 raingauge stations and associated vegetation type (see Xue et al., 1991 for vegetation type definition). Rectangles represent the 4 selected regions (Label A: 5ºN-10ºN, 10ºW-10ºE, Label B: 10ºN-13ºN, 18ºW-25ºE, Label C: 13ºN-20ºN, 18ºW-25ºE, and Label D: 2ºN-10ºN, 10ºE-25ºE).*

* *Corresponding author address:* Isabelle Poccard, Univ. of California Los Angeles, Dept. of Geography, Los Angeles, CA 90095-1524; mail:ipoccard@geog.ucla.edu

The land cover map used to determine the standard surface parameter values was from the global land cover database of Hansen *et al.* (2000). Leaf Area Index and vegetation cover parameters were derived from AVHRR NDVI satellite data (Los *et al.*, 2001). The remaining forcing variables were derived from NCEP/NCAR Reanalysis data (Kalnay *et al.*, 1996) and interpolated from 6-hour values to hourly values. These forcing data are used to drive an offline version of the model SSiB (Xue *et al.,* 1991) to produce surface meteorological and hydrological variables. The goal of this biophysical model is to consistently and coherently describe the process of water and energy transfer in soil-vegetation complex. The model predicts soil wetness for three layers, temperatures of the canopy, near-surface soil, and deep-soil layers, snow depth on the ground and intercepted water on the canopy.

3. SEASONAL VARIABILITY OF SURFACE WATER AND ENERGY BALANCES

We run the SSiB model with 3 years spinup. The 217 stations have been interpolated into 1°x1° gridboxes using a cubic method. The spatial coverage is even, except the southwest part of the region due to the lag of data in several countries (southwest of Ivory Coast, Liberia, Sierra Leone, west and central Guinea, Guinea-Bissau). In this version of the SSiB, the vegetation type number 12 corresponding to the crops has been replaced with the vegetation type 7 (groundcover only). Because of the unrealistic values of LAI and fraction vegetation cover simulated by the crop code compared with output of a model of agroclimatology for corn filed over Niger, we temporarily decided to use the type 7, which has more closer values. Nineteen main variables have been selected characterizing surface water and energy balances.

Our study investigates the spatial patterns at monthly to seasonal scales, but here we only analyze the results of the month of August due to the scope of this paper, the earth of the rainy season in the Sahel. For temporal patterns of surface fluxes, four regions have been extracted according to the rainfall distribution and the vegetation type (fig. 1).

Figure 2 presents the 1982-90 mean spatial patterns of the precipitation, LAI, latent heat flux and air temperature during august. The precipitation pattern clearly shows the north-south gradient with 2 cores of maximum values (more than 300 mm/month) along the Guinean coast and the dry “corridor” in between. Up to 14°N, the rainfall distribution in almost zonal. In general, the LAI has the similar spatial pattern configuration except in the southeast part of the domain. The core maximum for rainfall and LAI are not located in the same area, depending in particular on the vegetation type and soil moisture in this part of the region.

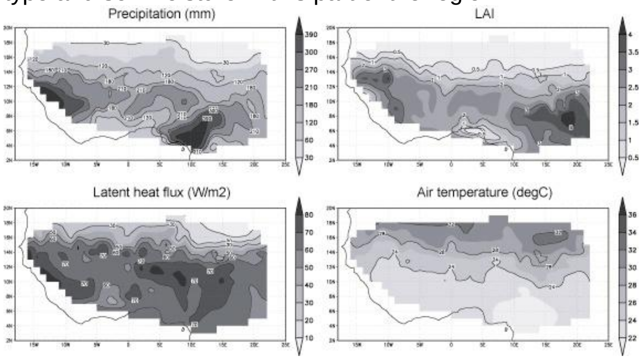

FIGURE 2: *1982-90 August mean of Precipitation, LAI, Latent heat flux and Air temperature.*

The latent heat flux pattern clearly reflects the relationship with the rainfall as well as the photosynthetic activity with a maximum (minimum) in the Guinean (sahelian) zone with a similar south-north gradient. But it shows a complex spatial distribution, which implies complex land/air interactions. The air temperature has a reverse pattern with a maximum in the Sahel zone and the distribution seems to be more uniform than for other variables.

4. INTERANNUAL VARIABILITY OF SURFACE WATER AND ENERGY BALANCES

The analyses of the interannual variability over the Sahel show good relationship between precipitation, LAI and latent heat flux, confirming the good coherence between the variables in the SSiB and thus the consistence of the SSiB model, not only at a raingauge station scale but at a regional scale too. The correlation value of precipitation with latent heat flux reaches 0.94, and with LAI 0.6 without lag and 0.91 with one month lag, highlighting the role of the soil moisture and the time response of the Sahelian vegetation to the precipitation. However, we notice no significant correlation between precipitation and air temperature.

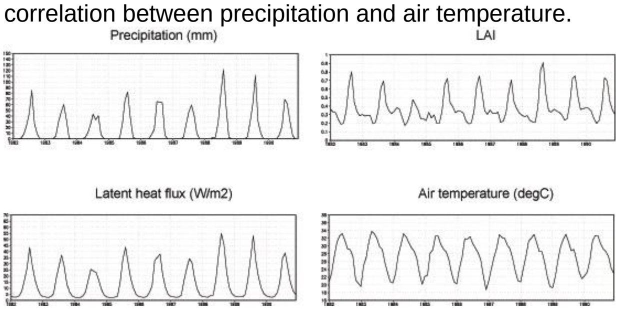

FIGURE 3: *1982-90 mean interannual variability of the Sahelian boxe (C) for precipitation, LAI, latent heat flux and air temperature.*

It is especially true if we consider the years 1984 (relatively dry) and 1988 (relatively wet). A low amount of precipitation in 1984 is associated with less photosynthetic activity, thus less latent heat flux and relatively high air temperature. The opposite behavior is observed in 1988 with consistent response of latent heat flux according to the high rainfall amount and the peak of LAI reaching 0.9. However, there is no significant change in the air temperature value in 1988 regarding to value in 1984. This is a subject that needs further investigation.

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