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SPRING TO SUMMER CONTRASTED TRANSITIONS IN THE WEST AFRICAN MONSOON

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1. INTRODUCTION

In coherency with the conceptual framework of Emanuel, 1995; and Eltahir and Gong, 1996; Fontaine and Philippon [2000] have shown the role of the horizontal energy gradients in northern spring for the West African monsoon dynamics in summer and hence for seasonal rainfall prediction. This note focuses on the spring to summer transition of the West African monsoon through diagnostics from the NCEP/NCAR (USA) reanalyses, 8 AGCM (ARPEGE-Climat, France) long-term simulations over the period 1968-1998 and in-situ observations from the CRU (UK) dataset. The selected NCEP variables are the monthly temperature, humidity, geopotential and the 3 wind components on 11 standard isobaric levels in the troposphere (1000hPa-100hPa), the radiative (long and short wave) and heat (sensible and latent components) fluxes at the surface, and the soil moisture (surface and deep reservoirs).

2. MAIN RESULTS

These atmospheric diagnostics refer mainly to the spring /summer transitions occurring before the abnormally wet and dry July-September rainy seasons using several simulated and observed rainfall indexes. Fig. 1 presents the mean March to May and July to September values (a-b) of the vertical velocity in Pa/s (ϖ) along with the spring (c) and summer (d) Wet minus Dry composites (W-D) (see captions). Negative (positive) values of ϖ correspond to upward (downward) motion. Similarly, Fig. 2 focuses on the moist static energy (MSE) content, defined as: MSE = gZ + CpT + Lq where g is the gravitational acceleration, Cp the specific heat of dry air at constant pressure and L the latent heat of evaporation, gZ the geopotential energy, CpT and Lq the respective sensible and latent energy components.

The statistical signature in ϖ (Fig.1) indicates that overturning in the monsoon circulation increases (decreases) before and during the wettest (driest) Sudan-Sahel rainy seasons and is linked to specific changes in MSE atmospheric content during spring. One can notice that, at the beginning of spring, the Moist Static Energy (MSE) meridional gradients are the strongest over the continent and are maintained by sensible heating and cooling (Fig. 2a). Then they relax and the monsoon air mass is transported northward into the continent (Fig. 2b). However, such a relaxation tends to occur later (earlier) and to be more (less) abrupt before wet (dry) years as shown by the significant negative MSE differences in Fig. 2f (to be compared with Fig. 2c).

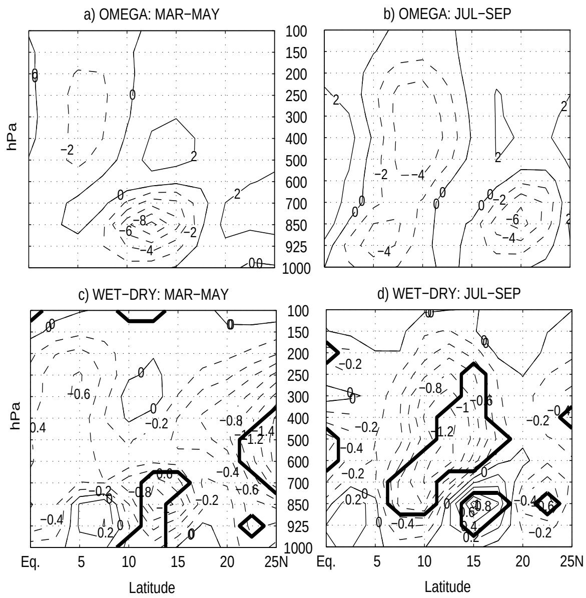

FIGURE 1. Vertical sections of Omega (vertical velocity expressed in Pa/s *100) over West Africa as a function of latitudes and averaged over 10°W-10°E: March-May (a) and July-September (b) mean values and their respective Wet minus Dry differences (c,d) for the period 1968-1998. Wet years: 1969 70 71 73 74 75 76 78 85 89; Dry years: 1977 80 83 86 91 92 93 94 95 97. Bold lines locate the significant differences in means regarding a Student t-test at p=0.1.

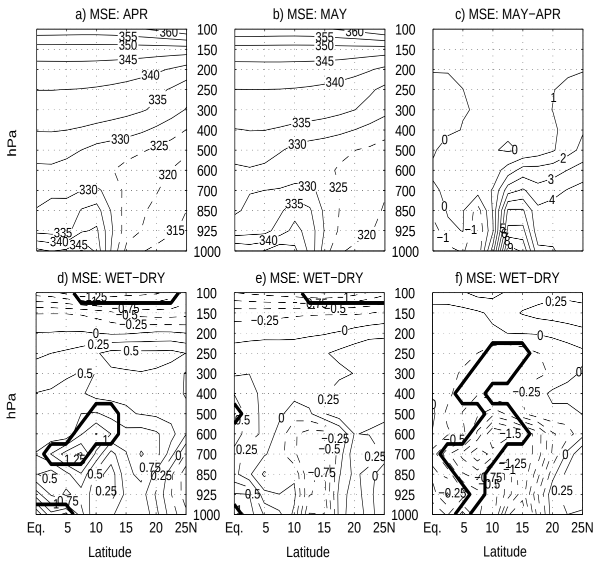

FIGURE 2. As figure 1, except for MSE contents (KJ/Kg) in April (a,d), May (b,e) and May minus April differences (c,f).

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Such changes are first sensitive to land moisture since soil moisture is linked to the convergence of the humidity fluxes (Cook, 1994). But they are also directly linked to observed or modeled continental rainfall (Figs. 3,4.). Fig 3 displays the monthly means (a-b) and the W-D (c-d). One can notice that horizontal (mostly meridional) energy gradients in the boundary layer control significantly the spring to summer changes in monsoon dynamics but are mainly controlled at regional scale by the seasonal evolution of precipitation and soil moisture fields. For example, the W-D differences (Fig.4c-d) show that before an abnormally wet JAS season (i.e. by May-June), precipitation and soil moisture anomalies are negative over Sudan-Sahel. This means a later (an earlier) African monsoon with a more (less) sudden northward migration of the system in wet (dry) years.

As a quasi-independent validation Fig.4 presents the annual evolution of W-D referring to simulated July-September Sahelian rainfall (1968-1997) from a 8-member ensemble of ARPEGE-Climat simulations forced by observed SSTs over the period 1948-1997 [Cassou and Terray, 2001]. The wettest rainy seasons (significant positive values north of 10°N in summer) in the model are preceded by a dipolar pattern in spring (significant positive values south of 7°N and negative values northward): all conditions being the same, this means a later and more abrupt onset of the monsoon season (and inversely in dry situation).

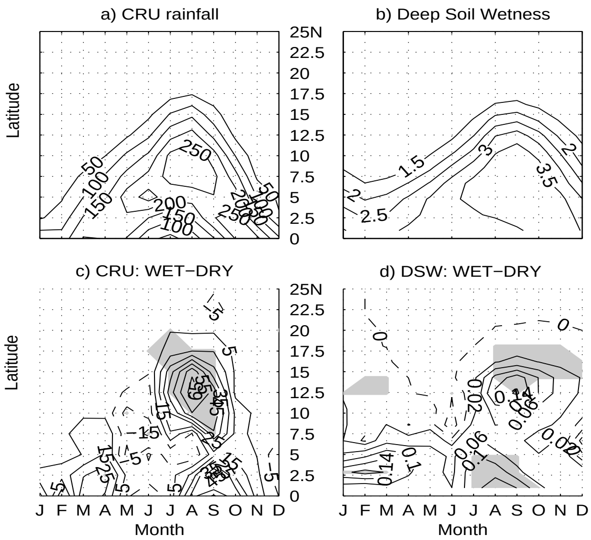

FIGURE 3.. Annual evolutions as a function of months and latitudes (15°W-25°E) of 2 selected variables linked to the water cycle in West Africa (period: 1968-1998): (a) mean CRU observed rainfall; (b) NCEP/NCAR Deep Soil Wetness (30-200cm) and the respective Wet minus Dry differences (c,d). Shadings refer to significant differences in means regarding a Student t-test at p=0.1.

3. DISCUSSION AND CONCLUSION

Due to the scarcity of in-situ data the statistical results and hypotheses proposed have to be verified first through new diagnostics and new modeling approaches. However, the course of events can be summarized as follows:

- Before an abnormally wet (dry) rainy season, negative (positive) rainfall and soil moisture anomalies are normally observed over Sudan-Sahel: this maintains stronger than normal MSE and humidity gradients between the Sahelian and Guinean areas in late spring
- The MSE meridional gradients tend to be significantly stronger (weaker) and to relax later (earlier) but more (less) intensely in summer. This increase (decrease) monsoon dynamics as tested through the aforementioned atmospheric indicators and rainfall indexes.

This could explain why, for improving significantly (~20% of explained variance), rainfall predictions over West Africa, numerical simulations must prescribe an interactive (dynamical) soil moisture all along the time integration (Douville and Chauvin, 2000) while statistical approaches have just to take into consideration the atmospheric MSE contents in spring (Philippon and Fontaine, 2001).

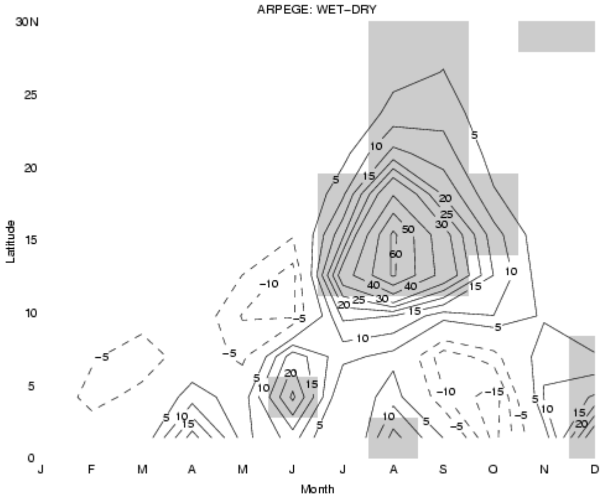

FIGURE 4.: Annual evolution of the Wet minus Dry composites (referring to simulated July-September Sahelian rainfall) in the 8-member ensemble of ARPEGE-Climat simulation forced by observed SSTs (1968-1997). Shadings refer to significant differences in means regarding a Student t-test at p=0.1.

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