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Interannual variability of surface radiative fluxes and rainfall in the semi-arid Sahel

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In the Sahel, interannual variability of rainfall is known to be strong, from meso- to continental spatial scales. This is associated with changes in surface radiative fluxes. The actual role played by surface fluxes on the interannual variability of rainfall has been much debated, especially within the context of the major regional scale, multi-decadal West African drought which started at the end of the 1960's (e.g. changes in surface albedo, Charney et al. Science 1975). The significance of conclusions that have been drawn, essentially from modelling approaches, is however limited because of weaknesses in models (e.g. parametrizations of rainfall and clouds, vegetation and aerosols) coupled to a lack of data for assessing the relevance of theories or hypotheses put forward on such bases.

The present study aims to quantify and to analyse the interannual variability of surface radiative fluxes and rainfall measured with ground-based automatic weather stations (AWS) for seven years. The AWS are located in the Malian Gourma, from the semi-arid Central Sahel (15°N, 1.5°W) to Northern Sahel (17°N, 1°W), on the border of the Sahara, over the dominant Sahelian surface type (sandy soil). The variability displayed by satellite estimates SRB over this area is also presented and discussed.

This study is linked to another one presented in the session AS1.14, African Monsoon Multidisciplinary Analysis (AMMA) by Guichard et al. "Couplings between the seasonal cycles of surface thermodynamics and radiative fluxes in the semi-arid Sahel" (see also Guichard et al. J. Hydrology 2009, AMMA-Catch special issue, http://dx.doi.org/10.1016/j.jhydrol.2008.09.007)

The large interannual variability of annual rainfall sampled by AWS (less than 200 mm to more than 400 mm) is associated with an equally significant variability of surface net radiation Rnet. It is the more pronounced during the core of the monsoon season. More rainy monsoon seasons are characterized by higher Rnet; the difference can reach up to 30 W.m-2 on average over the month of August.

This difference in Rnet is not related to an enhancement of the incoming longwave flux, LWin actually fluctuates by less than 5 W.m-2. More rain in August is associated with less incoming shortwave radiation, with a difference of about 10W.m-2. At this monthly time scale, variations of Rnet are more largely explained by changes in surface properties. This involves the vegetation dynamics, which accounts for large interannual fluctuations of albedo (Samain et al., J. Geophys. Res. 2008, http://www.agu.org/pubs/crossref/2008/2007JD009174.shtml).

However, the processes accounting for the interannual variability of the upwelling longwave flux, LWup, are found to be at least as important as albedo effects when accounting for changes in Rnet. LWup decreases sharply in response to the succession of rainfall events in this region where soil temperature reaches very high values in Spring. At larger time scale (June to September average), LWup and rainfall are also found to be strongly and consistently related.

As the interannual variability of shortwave incoming and upwelling flux partly balance each other, the upwelling longwave flux LWup appears as a major driver of the interannual variability of Rnet.

These results emphasize the strong couplings taking place in the Sahelian climate between surface radiation, energy fluxes and the water cycle. They point to the significance of a variety of processes, among which aerosols and vegetation-related processes cannot be neglected. Finally, they provide valuable guidance for models over an area where interactions among processes are complex and climate projections currently very uncertain.