FINAL REPORT PROGRAM LEFE

Program LEFE/ action(s) LEFE-IMAGO et EC2CO	Project Title Recent trends of hydrometeological hazards in the Sahel : detection and elements of attribution	Years 2015 – 2016

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Context

The hydro-climatic hazard has increased during the last twenty years in the Sahel, causing severe damage to populations notably vulnerable to extreme events. So far, the increase in extreme floods in the Sahel has mainly been attributed to the modification of land use but recent results (e.g. Panthou et al., 2014) have shown a significant intensification of the precipitation regime which calls into question this thesis and raises new questions about the role of global warming on the Sahelian hydro-climatic regime.

Objectives / scientific questions

The project aim was to provide an integrated atmosphere-surface view for detecting recent hydro-climatic trends in the Sahel and to improve our capacity to attribute them to natural and/or anthropogenic factors.

Main results

Detection of trend in rainfall

The project showed that the intensification of daily rainfall identified by Panthou et al. (2014) on the central Sahel is visible throughout the Sahel (Panthou et al., submitted). There are, however, some regional contrasts since in the Western Sahel intensification is slightly less marked and has occurred later than in the Central Sahel (Panthou et al., submitted). Contrasts are also characterized by smaller and/or less propagating storm systems in the western Sahel, whereas in the central Sahel storm systems tend to be larger and/or more propagative (Vischel et al., 2018; Blanchet al., 2018).

Elements of rainfall trend attribution

From the analysis of a composite event representative of the 20 strongest events recorded in Ougadougou since 1998, the project has shown that intense rainfall events occur during the concomitance of an intense monsoon flow from the south and the passage of an intense African Easterly wave which, by creating a vortex with strong vertical extension (C2 in Fig. 1b), blocks the propagation of the convective systems (Fig.1b, c) (Budiarti, 2015, Vischel et al., 2018). This situation corresponds to a generalization of Lafore et al. (2017) on the unique case of the 1st of September 2009 in Ouagadougou.

A study published in Nature (Taylor et al., 2017) involving two people from the consortium also pointed out the major role of the Saharan warming, in link with anthropogenic GHG emissions, on the increase of the occurrence of extreme rainfall in the Sahel.

Detection of trend in floods

The evolution of floods was analyzed in the three main Sahelian tributaries of the Niger river and in three rivers in the Senegal basin. The analysis shows that the increase in extreme floods has been initiated the 1970s on the tributaries of Niger, with an accentuation since the mid-1980s (Wilcox et al., In prep). On the Senegal River, the evolution of floods has also been rising since the beginning of the 1980s, but it follows a sharp decline in the 50s to 70s.

Elements of flood trend attribution

On the basis of large-scale hydrological simulations (all Sahelian tributaries of the Niger River - ~100 000km²), Cassé et al. (2016) showed that the increase in floods on the Niger River in Niamey since the 1980s is mainly driven by an increase of rainfall. On the other hand, only a soil degradation following the droughts of the 1970s can explain the difference in response between the 1950s and recent years (Figure 2). At a finer-scale, a rainfall-runoff model has been implemented on the Dargol catchment (tributary to the right bank of the Niger River, 7000 km ²) and fed by hydrodynamic parameters measured in-situ. The model has made it possible to estimate that if the basins modeled

were covered with 100% surface area encrusted, the runoff would increase by 10 to 30% compared to the current state. This increase is not enough to explain the recent increase in Niger's floods in Niamey. This suggests that further investigations are required to identify other drivers of hydrological intensification based on field and modelling experiments.

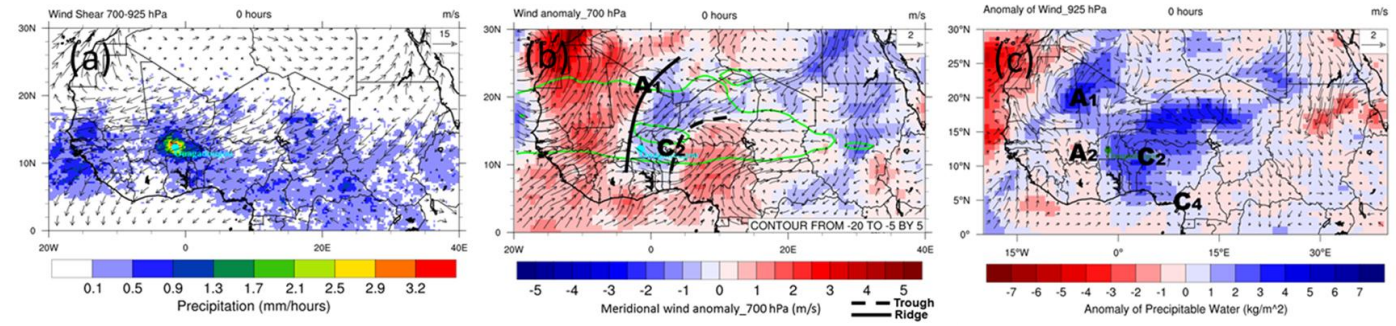

Figure 1 Horizontal structure of the composite extreme event at Lag 0 for : (a) TRMM precipitation (mm h^{-1}, shaded) and 700-925 hPa wind shear (m s^{-1}, vectors) ; (b) 700 hPa wind anomaly (m s^{-1} , vectors) and 700-hPa meridional wind anomaly (m s^{-1}, shaded); (c) Column water vapor anomaly (kg/m^2, shaded) and 925-hPa wind (m s^{-1} ,vectors); (d) Lag – longitude composite structure averaged over 12°-16°N of (a) column water vapor anomaly (kg/m^2, shaded). In (b) the green line represents the core of the African Easterly jet, the solid (dashed) line indicates the through (ridge) of the African Easterly wave. In (c) the symbols A and C indicate the anticyclonic and cyclonic circulations.

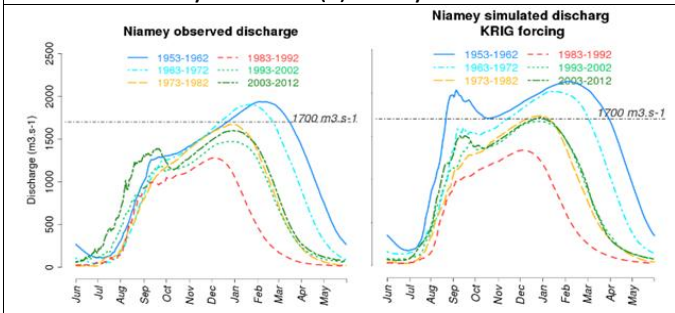

Figure 2 Evolution of the Niger hydrograph in Niamey since 1953: Mean decadal hydrographs observed (left) and simulated (right) with ISBA-TRIP forced by observed rainfall (rain gauges + kriging). The figure shows the capacity of the model, with vegetation/land cover corresponding to the current one, to reproduce the increase in red flood since the 1970s.

Future of the project :

Future scientific directions relate to: (i) the extension of the analyzes of evolution of the rainfall and hydrological regimes on the southern regions of West Africa characterized by a Sudano-Guinean climate, (ii) the identification of the synoptic atmospheric factors responsible for certain regional contrasts in the evolution of the rainfall regime (for example between the western Sahel and the central Sahel), (iii) the quantitative impact of extreme rainfall, endorheism breaks and sandy storage in drains on the hydrological response. These elements will contribute to the attribution issues and by extension to the simulation of future hydro-climatic projections.

Part of these actions will be carried out within the AMMA2050 project funded until 2019. Others will have to find their own framework to make progress, especially those related to field activities and those relating to statistical attribution issues.

Nombre de publications, de communications et de thèses

Casse, C., Gosset, M., Vischel, T., Quantin, G., Tanimoun, B.A., 2016. Model-based study of the role of rainfall and land use–land cover in the changes in the occurrence and intensity of Niger red floods in Niamey between 1953 and 2012. Hydrol Earth Syst Sci 20, 2841–2859.

Lafore, J.-P., et al., 2017. A multi-scale analysis of the extreme rain event of Ouagadougou in 2009: High-impact weather system, West Africa, African Easterly Waves. Q. J. R. Meteorol. Soc. https://doi.org/10.1002/qj.3165

Panthou, G., Lebel, T., Vischel, T., Quantin, G., Sané, Y., Ba, A., Ndiaye, O., Diongue-Niang, A., Diop Kane, M., submitted. Rainfall intensification in tropical semi-arid regions: the Sahelian case. Environ. Res. Lett.

Taylor, C.M., Belušić, D., Guichard, F., Parker, D.J., Vischel, T., Bock, O., Harris, P.P., Janicot, S., Klein, C., Panthou, G., 2017. Frequency of extreme Sahelian storms tripled since 1982 in satellite observations. Nature 544, 475–478.

Vischel, T., Panthou, G., Peyrillé, P., Roehrig, R., Quantin, G., Lebel, T., Wilcox, C., Beucher, F., Budiarti, M., 2018. Precipitation extremes in the West African Sahel: recent evolution and physical mechanisms, in: Tropical Climate Extremes: Natural Variability and Trends.