7.1 **Water management in a semi-arid region: an analogue algorithm approach for rainfall seasonal forecasting**

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1. INTRODUCTION

In a semi-arid region, like those of Sub-Saharian Africa, water and crop management is a fundamental tool to avoid serious health problem (famine, epidemic, etc.). But in order to obtain the best results from such policies information on precipitation and temperature must be available a few months before. Thus, the use of seasonal forecasts tends to assume a relevant role, despite of the large uncertainties still present. At the same time, methods and results of this recent branch of atmospheric sciences must be the most simple and accessible as possible. For this reason, the Institute of Biometeorology, (part of the National Research Council, http://www.ibimet.cnr.it), has developed a physically-based statistical approach to obtain seasonal forecasts, regarding rainfall precipitation, over Sahel region.

The method is based on the "similarity" conditions of the sea surface temperature (SST) in three areas of the world defined as: Niño-3 (5S-5N;150W-90W), Guinea Gulf (10S-5N;20W-10E), Indian Ocean (5S-15N;60E-90E) which, in literature, are indicated as the most important areas to drive the precipitation patterns (Indian Ocean and Southern Atlantic with regards of the trend of precipitation and Niño-3 with regards of the interannual time scale).

The importance of the sea surface temperature to force the long-term atmospheric anomalies, at least at a regional scale, is recognized with a particular attention to the Pacific area affected by El-Niño Southern Oscillation (Dalu et al, 2005).

Many atmospheric Research Centers have developed their own method to derive seasonal forecasts, based on the results of a large number of simulations of a Global (GCM) or a Regional (RCM) Circulation Model, namely "Ensemble Forecasts", or on statistical algorithms that relate the most important atmospheric variables, or both (see for example: http://www.ecmwf.int or http://iri.columbia.edu/).

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This work describes a statistical method that relates the SST of three oceanic areas with the precipitation in the semi-arid region called Sahel. The chance of forecasting a reliable rainfall fields is, in many parts of Africa, dependent on prevailing patterns of sea surface temperature, atmospheric circulations, the El Niño Southern Oscillation and regional climate fluctuations in the Indian and Atlantic Oceans. A brief summary of scientific background of the method is in the following list:

- West African Monsoon variability is strongly forced by the sea surface temperatures standardized anomaly (SSTAs) of the Gulf of Guinea. Warm Gulf of Guinea SSTAs generates a rainfall increases along the Guinean coast while the precipitation decreases over the Congo Basin. These features can be understood through the dynamical response of a Kelvin wave along the equator and a Rossby wave to the west of the SSTA. The first is associated with a weakening of the Walker circulation, while the latter tends to strength the West African Monsoon and the upward vertical velocity. The effects of Cold SSTAs are opposite, but weaker (Vizy and Cook, 2001).

- The monsoon circulation influences the precipitation over the Sahel, in particular southern Sahel (10N-15N), in two main ways. The moisture is transported by the low-level southerly flow. The proximity of the monsoon circulation and circulation over Sahara generates a strong low-level convergence to force air parcels to rise vertically until the level of free convection (Vizy and Cook, 2002).

- Positive SST anomalies in the Eastern Pacific and in the Indian Ocean, negative in the northern Atlantic and in the Gulf of Guinea are related with droughts conditions over all the West Africa (Fontaine and Janicot, 1996).

- Droughts limited to Sahel are due to a positive SST anomaly northward in the southern Atlantic and a negative pattern in the northern Atlantic. Floods along the West Africa are associated with positive anomalies in the northern Atlantic, while the floods limited to

Sahel are related to different forcing: northward expansion of negative SST anomalies in the southern Atlantic, positive SST departures in the northern Atlantic, and development of negative SST anomalies in the eastern Pacific (Fontaine and Janicot, 1996).

- The Principal Components Analysis (PCA) performed on the summer precipitation in the Sahel region, demonstrates that the two leading principal components (PCs) explain almost the half of the variability of the precipitation. Moreover two main patterns are present: the first along the Gulf of Guinea coast, between the equator and 10°N, dominated the interannual variability, the second associated with the continental convergence in the Sahel (between 10°N and 20°N) affected by the interdecadal variability. The decomposition of these two leading PCs into high and low-frequency components shows the role of the SST of the Southern Atlantic and Indian Ocean for driving the long-term variability, while the interannual variations are driven by the ENSO (Giannini et al. 2003).

2. METHOD AND DATASETS

In the method each "month" is defined by six variables: three are SSTAs while the other three take into account their respective tendencies (namely "Change Rate" or CRs). The CRs are defined as the difference between the current SSTAs and those of the previous month. The standardization is obtained with the subtraction of the 1979-2003 climatological mean and the division by the 1979-2003 climatological standard deviation. The "similarity" to the current SST conditions is evaluated by means of the minimization of the Euclidean distance to find the most similar year (namely analogue) and assign the values observed in that year to the forecast rainfall field. Precipitation anomaly and percentage anomaly are then computed, compared with the 1979-2003 climatological mean.

Due to the specific dynamical behavior of the West African Monsoon this simple analogue characterization is able to catch main features of rainfall precipitation patterns during the JJA period and a validation of this approach, through analysis of forecast skills, shows encouraging results.

SST used in the method are from three oceanic areas: the Niño-3 area (5N, 5S; 150W, 90W), the Guinea Gulf (5N, 10S; 20W, 10E), the Indian Ocean (15N, 5S; 60E, 90E).

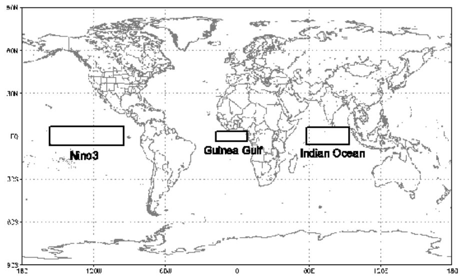


Fig.1 Oceanic areas from which SST A have been computed to be used in the method.

The SST data have been obtained by the NCEP/NCAR Reanalisys dataset (2.5°x2.5° Lat-Lon, Kalnay et al, 1996; Kistler et al, 2001) while the precipitation data have been derived from the Global Precipitation Climatology Project (GPCP, Xie and Arkin, 1996; Huffman et al., 1997; Xie et al., 2003) on a 2.5°x2.5° Lat-Lon grid.

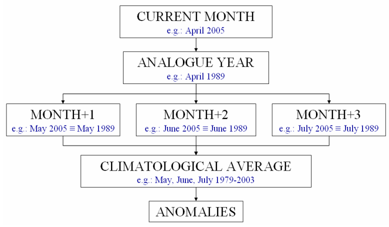
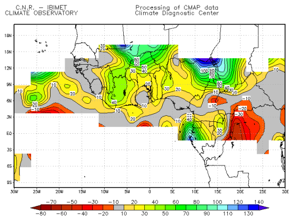
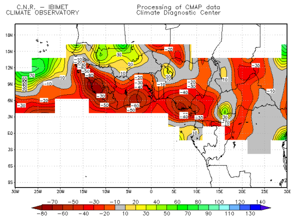
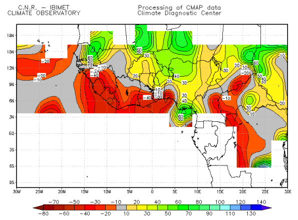
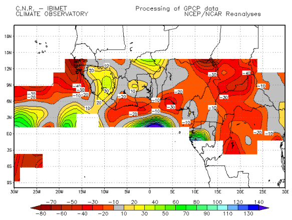
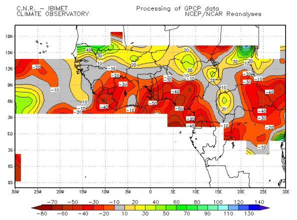
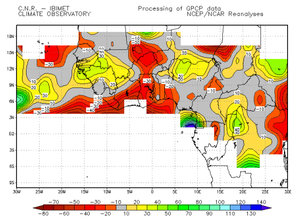
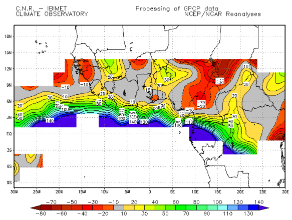
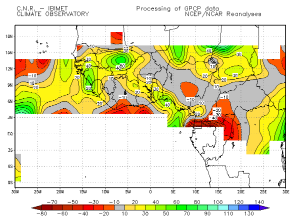
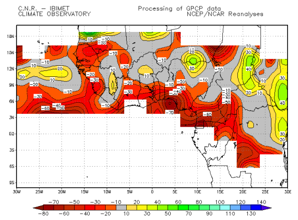
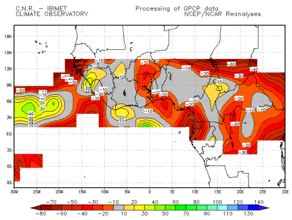
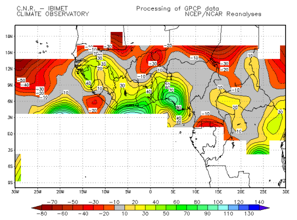
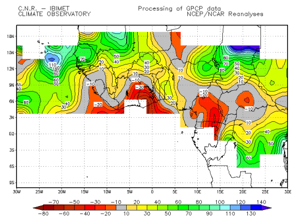


Fig.2 An example of the logical scheme applied for each precipitation grid point in order to derive the "Analogue" year.

For each month and for each grid-point, the precipitation time series has been correlated to the SST time series, in order to have the relative weight of the three different oceanic areas with regards of the precipitation. Based on these weights and on the six variables defined above. The method searches for the most similar SST conditions in the past (the year obtained is called "Analogue Year"), assigning the values observed in the closest year to the forecasts. Using 1979-2003 climatology, precipitation anomaly and percentage anomaly are then computed. The first is derived by means of the subtraction of the climatological mean from the forecast precipitation. The latter is obtained from the former, dividing for the climatological mean and it's represented as a percentage.

The dry regions of the world, identified by a monthly cumulated precipitation under 30mm, are blanked to avoid large values of anomalies and percentage anomalies.

	June 2003	July 2003	August 2003
OBS CMAP			
Forecast issued 1 month before			
Forecast issued 2 months before			
Forecast issued 3 months before			

Tab.1 An example of forecast maps of percentage anomaly for the year 2003 with the correspondent observed values from CMAP (http://www.cdc.noaa.gov/cdc/data.cmap.html) Janowiak and Xie 1999: for each month, June, July and August, forecasted maps have been shown with different time lags.

3. CONCLUSIONS

The weather prediction are today established on solid theoretical and practical bases, their reliability and accuracy are steadily increasing and their usefulness is widely recognized in a variety of fields and applications, often in the frame of automatic integrated prediction systems.

The today state of the art of the weather forecasts allows the short-term prediction of rare and dangerous local events such as rainstorms, frost with high reliability and accuracy and very high spatial resolution, as well as the accurate medium range prediction. The role of conventional weather forecasts is precisely defined as a strategic one, and as such are considered the national as well as the regional weather services.

Having information on the future trend of precipitation three months or more in advance could have an extreme importance in many fields of large economic, social, environmental and strategic relevance: agriculture and forestry, land and landscape management (to forecast droughts or heat waves for example), international cooperation and catastrophes management (i.e. food shortages, droughts, production and distribution of energy).

Seasonal forecasts could answer these questions but not with the same efficiency, accuracy and reliability of the meteorological forecasts. Although many enhancements have interested this branch of atmospheric science in the last decade, large errors and uncertainties still affect this type of products. At the same time, seasonal forecasts have assumed a relevant role for planning and decision making.

Authors would underline the experimental character of the results of the method. They must be used just as an indication of the possible future trend of the precipitation.

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