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LOW-FREQUENCY RAINFALL VARIABILITY IN NORTHWEST AFRICA AND THE SAHELIAN AND SUDANIAN ZONES

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1. INTRODUCTION

Much of West Africa experiences significant interannual and interdecadal variability of rainfall. The German IMPETUS ("An Integrated Approach to the Efficient Management of Scarce Water Resources in West Africa") project has compiled and quality-checked precipitation data from networks of rain gauges in various climate regions of West Africa from a variety of sources. Particular attention is given to the climates of Benin and Morocco, as these are the locations of the field campaigns for the IMPETUS project.

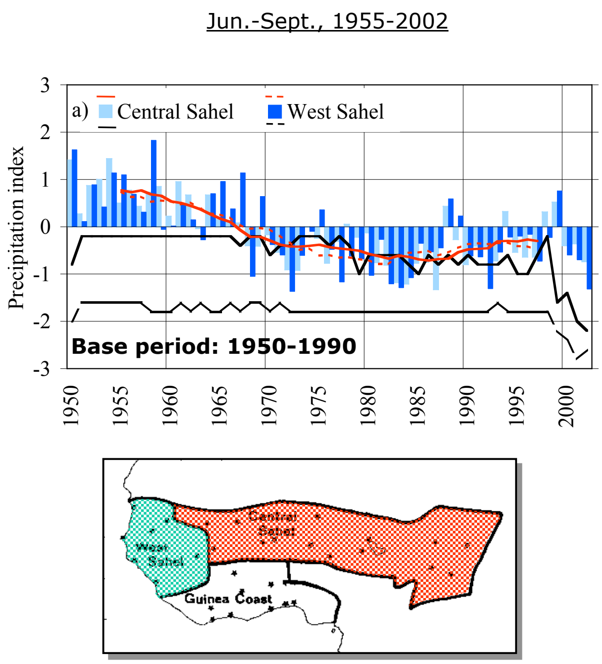

Figure 1. Annual precipitation index anomalies for the Central and Western Sahel (top). Data processing: 1950-1998, Chris Landsea (NOAA AOML), 1999- present, IGM Cologne.

As seen in Fig. 1, broad regions of the Sahel had above normal precipitation from 1950-1970, but have seen unrelenting dry conditions since 1970. The longer climate records in Benin (Fig. 2) also exhibit this trend, with another period of wet (dry) conditions from 1920-1935 (1935-1950), although the time series for the entire Sahel (Fig.1) show considerably more year-to-year persistence.

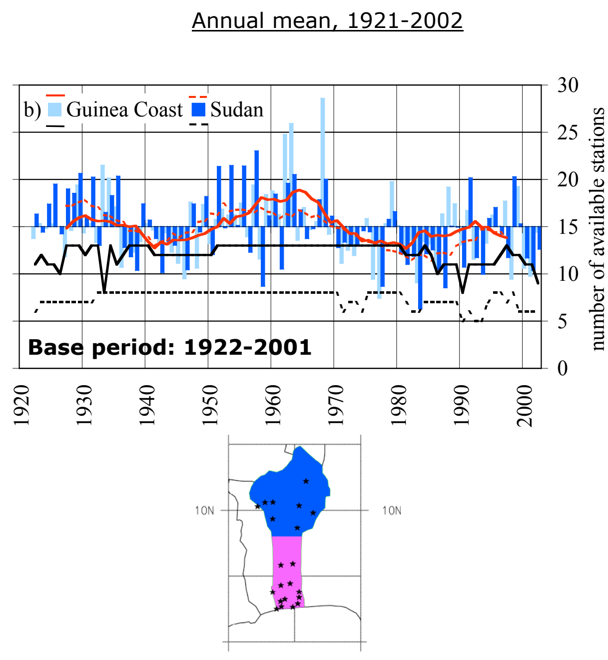

Figure 2. Annual precipitation index anomalies for the Guinea Coast and Sudanian climate regions of Benin. Data source: National Meteorological Service, Benin. Data processing: IGM Cologne

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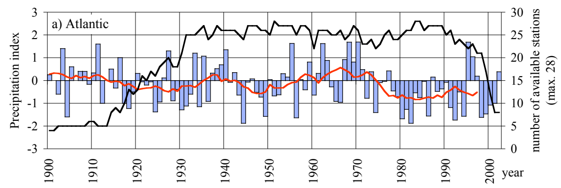

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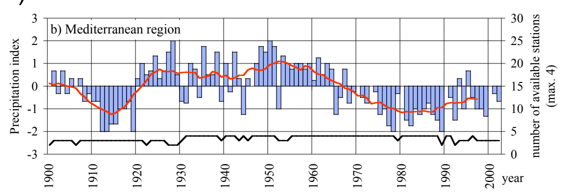

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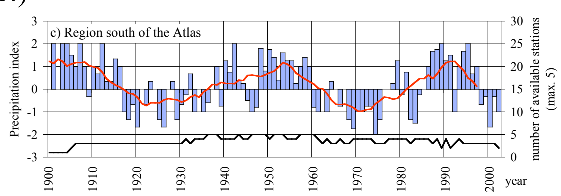

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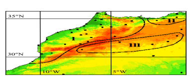

Figure 3. Time series of annual (September-October, hydrological year) precipitation index anomalies for three climate zones of northwest Africa: (a) the Atlantic—region I (ATL), (b) the Mediterranean Coast—region II (MED), and (c) South of the Atlas Mountains—region III (SOA). For more details, see Knippertz et al. (2003a) Climate regions are indicated in panel (d).

For northwestern Africa (Fig. 3), the variability is highly interannual along the Atlantic coast, while highly interdecadal in the Mediterranean region. Despite this difference in character, however, both regions exhibit considerably reduced rainfall totals since the late 1970s, with the exception of a few wet years in the mid-1990s along the Atlantic coast. The region south of the Atlas mountains experienced wet conditions from the mid 1980s through the mid 1990s.

2. Relation to NAO and ENSO indices

Of primary interest to this study is the nature of the association between the precipitation in each climate region and two year indices of global climate variability: NAO-G and the Niño3 sea surface temperatures (SSTs). Knippertz et al. (2003a) demonstrated that rainfall anomalies in the Atlantic region can be understood from meridinal shifts in the Atlantic storm track in December, January, and February (DJF). Therefore, they are strongly correlated to indices of the North Atlantic Oscillation (NAO). It will be shown that about 50% of the rainfall variance in the Moroccan Atlantic region during DJF can be explained by the NAO-G index calculated from the standardized mean sea-level pressure differences between Iceland and Gibraltar (NAO-G). The same index explains less than 9% of the rainfall variability in the other two regions. The lacking NAO influence can be understood from the major rainfall producing circulation patterns; Knippertz et al. (2003a) showed that rainfall along the Mediterranean Coast is largely related to weak lows in the western Mediterranean Sea, whereas precipitation events occurring south of the Atlas Mountains in the transition seasons are often related to tropical-extratropical interactions (Knippertz et al., 2003b). Figure 4 illustrates the 25-year running correlations between NAO-G and the precipitation indices for the three climate regions of Morocco. The strong negative correlation between the NAO-G and Moroccan rainfall in the Atlantic climate zone persisted throughout the 20th century.

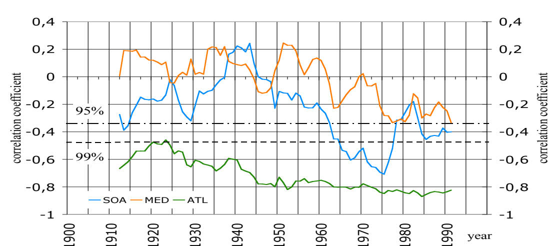

Figure 4. Twenty-five year running correlations between NAO-G index and December-January-February (DJF) precipitation in the Atlantic (green), Mediterranean (red), and South of Atlas Mountains (blue) Moroccan climate zones.

Knippertz (2003c) also investigated the influence of ENSO on rainfall in northwest Africa. A correlation analysis between the seasonal precipitation indices and the DJF Niño3-index revealed a small negative correlation for spring (March–May, MAM) and a small positive correlation for autumn (September–October, SON). However, as evident in Fig. 3 (a slightly modified version of Fig. 6.2 in Knippertz, 2003c) the MAM correlations were not stable in the course of the 20th century. Especially between the mid-1930s and 1960 the influence of ENSO on spring rainfall north of the Atlas Mountains was insignificant.

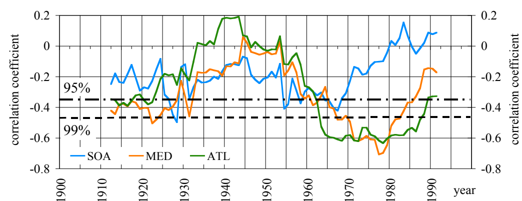

Figure 5. As in Fig. 4, except for one-season lagged correlation between Niño-3 SSTs and Moroccan climate zones.

As can be seen from Fig 6 rainfall in the Sahelian regions were significantly (95% level) correlated with the DJF Niño3-index after the drought commenced about 1970. In contrast, ENSO seems not to influence the rainfall along the Guinea Coast (Fig. 6). In the latter region low-frequency variations of rainfall are largely determined by anomalies of sea-surface temperatures in the Gulf of Guinea and the tropical Atlantic.

a.)

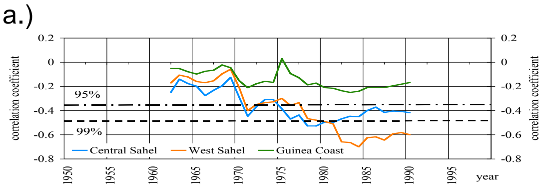

Figure 6. Twenty-five year running lagged correlation between Niño-3 SSTs and precipitation totals for three West African climate zones.

3. Concluding remarks

Our preliminary analysis of the role of teleconnections for rainfall north and south of the Sahara yielded two noteworthy results. Firstly, a discernible influence of ENSO on springtime rainfall in subtropical northwest Africa and on monsoon rainfall in the Sahel was restricted to the periods after the 1960-1970s and, at least for Northwest Africa, to before 1930. What may have caused these changes over time in the teleconnection patterns? In a recent paper, Knippertz et al. (2003d) show different correlation patterns between the Niño3-index and the mean sea-level pressure (MSLP) over the North Atlantic Ocean for the periods 1900-1925, 1931-1956 and 1962-1987 that may help to explain the time-varying influence of ENSO on European and Northwest African springtime precipitation. In this context, it is interesting to note the results of Goldenberg et al. (2001) with respect to the decadal fluctuations of the interhemispheric SST dipole in the Atlantic Ocean. From 1930–1970 the North Atlantic Ocean was anomalously warm, while the South Atlantic Ocean was colder than normal. Our preliminary analyses suggests that during this period, an ENSO influence on rainfall is not evident from the precipitation time series at neither margin of the Saharan desert. It is speculated that during these decades the forcing from the Atlantic region was dominant and/or the strength of the ENSO events was generally weaker.

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