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Diagnostics and Modelling of the Spatial Rainfall Variability on Intraseasonal to Decadal Time Scales

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Objectives:
The three main goals of this subproject are:

- to establish a monitoring system that quantifies rainfall and its variability in Benin
- to understand the mechanisms that control rainfall variability
- to provide high-quality meteorological products for all related activities in IMPETUS

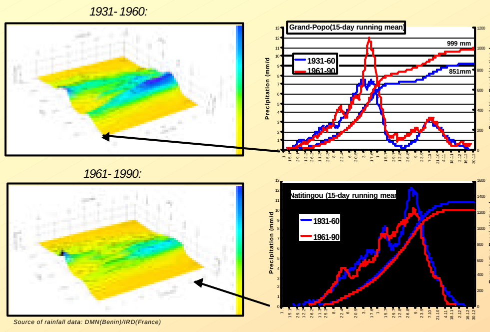
An integrated approach based on both observational and model studies is chosen to pursue these objectives .

Results:
Analysis of precipitation trends reveals no return to normal or above-normal monsoon rains in all climatic zones of West Africa. During recent dry decades, shortfalls at the height of the rainy seasons were the major cause for the annual rainfall deficits in central-north Benin. In this region, African easterly waves (AEWs) were found to be a major trigger mechanism for squall lines (SLs) at the peak of the rainy seasons 1998 and 1999.

A monthly rainfall climatology based on a combination of in-situ and remote sensing data has been established and a passive microwave rainfall algorithm has been successfully calibrated.
Model studies reveal a remarkable forecast potential of large-scale predictors for Benin rainfall. On the regional scale, the effect of land use changes on individual precipitation systems was successfully modelled.

Outlook:
A scale-comprehensive assessment of rainfall reduction risks in Benin induced by future changes in the relevant global and regional processes that determine rainfall variability is now possible. The establishment of corresponding scenarios and the coupling of hydrological models to the meteorological model chain will be flanked by continuous model improvement and validation with data of the meteorological monitoring network.

Changes in the seasonal cycle, 1931-60 vs. 1961-90



Seasonality

Coast: bi-modal, 1st peak largest
~8°N: tri-modal, 3rd peak largest
HVO: bi-modal, 2nd peak largest
North: uni-modal

Trends 1961-1990

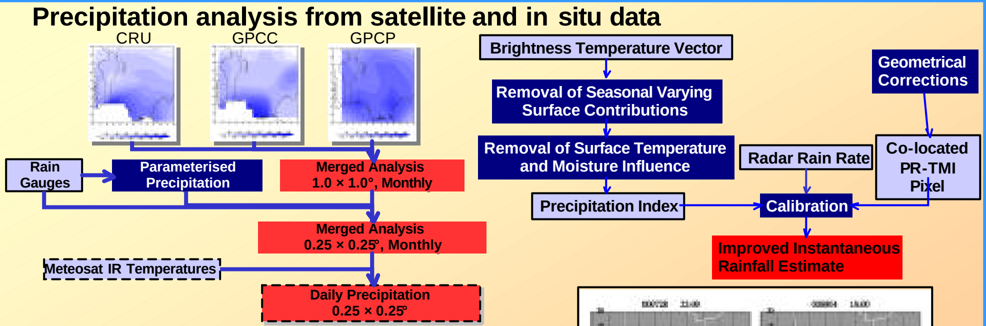
Coast: wetter 1st rainy season, wetter little dry season, (5-10% increase)
HVO: drier 2nd rainy season, (5-10% decrease)

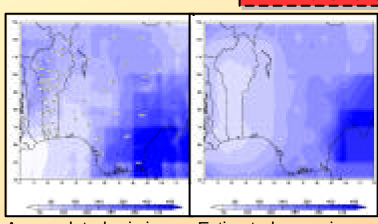
Moister 1961-90 period at the Guinea Coast is biased by 3 excessive rainy years in the 1960s (1968, 1963/62)

Drier 1961-90 period in central-north Benin is mainly a result of poor rains at the peak of the rainy season in Aug-Sept.

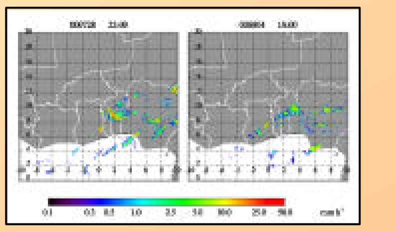
One current research focus: Causes for dry synoptic disturbances (AEWs) at the height of the rainy season

Precipitation analysis from satellite and in situ data



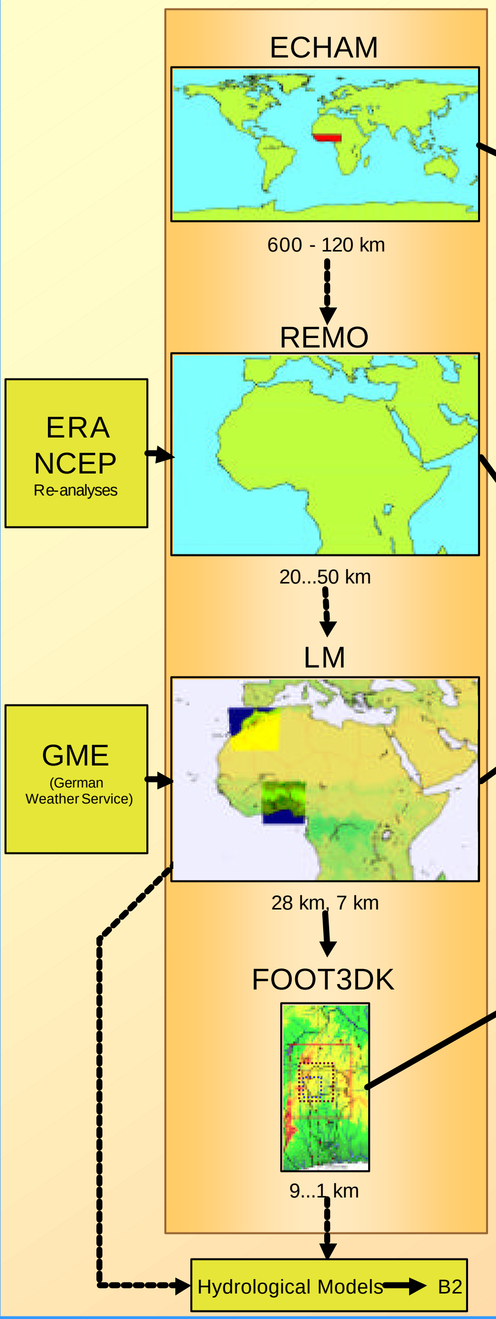


Accumulated rain in mm Estimated errors in mm



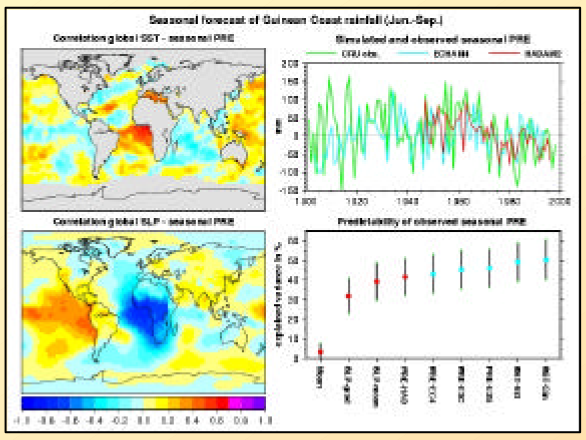
TMI retrieval scheme and application to two orbits in 2000. Rainfall over sea is TRMM standard product 2A12.

Atmospheric Model Chain



Seasonal forecast potential of large-scale predictors for West African rainfall

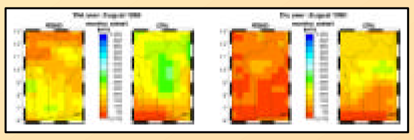
Rainfall variability over the Guinea and Sudan zones is largely induced by global sea surface temperature (SST) and embedded in the global tropical teleconnections. Seasonal precipitation anomalies can be predicted from SST-driven global climate model experiments. Here, the seasonal forecast potential of observed Guinean coast rainfall is quantified by using multi-model output statistics, based on SST, sea level pressure (SLP) and simulated rainfall. The predictor time series are derived from the global correlation patterns on the left panels, revealing the tropical Atlantic and Pacific SST and SLP to be linked to interannual rainfall fluctuations.



Simulated rainfall from different climate models also correlates with observed interannual variability (top right panel) and thus can be linked to further predictors. The forecast potential amounts to more than 50% of total inter-annual rainfall variability (bottom right panel), whereas only the first four predictors are ensured to be physically relevant according to cross validation analysis. Actually, the meridional gradient and the mean state of SLP over the tropical Atlantic contribute most to rainfall predictability over the Guinean coast region. The forecast may even be improved when midtropospheric dynamics is included.

Simulation of interannual rainfall variability with a regional climate model

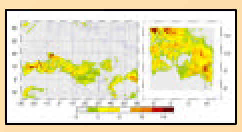
It is of major interest to understand the synoptic and larger-scale processes which drive the strong interannual variability of Benin rainfall. Therefore, the regional climate model REMO is run in a 0.5° resolution over West Africa, providing case studies



of wet and dry years over Benin. As it is shown in the figures, REMO in fact reproduces the relative anomalies in August 1988 and 1990, whereas the rainfall amount itself is slightly underestimated.

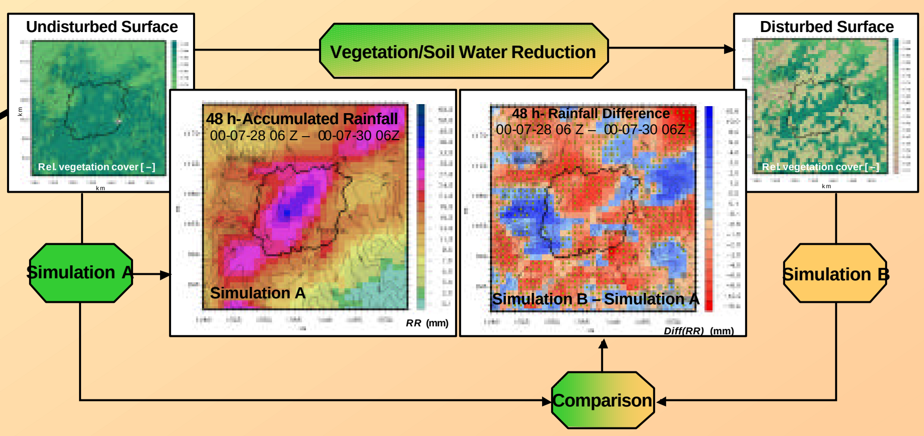
Case studies on interactions between synoptic and mesoscale processes

African weather systems are multiscale phenomena. The *Lokalmodell*, with its ability to perform simulations on the synoptic scale as well as on the mesoscale, is used to investigate scale interactions between synoptic scale forcing,



e.g. from AEWs and mesoscale precipitation systems like sqall lines. The figure shows convectively generated rainfall in two simulations for July 30, 2000 on different scales. The largest differences can be seen near the model boundaries.

Sensitivity of an individual rainfall event to hypothetical land use changes in the Upper Ouémé Valley



- The interplay of surface-atmosphere interactions, convection and larger-scale atmospheric flow generates a distinct pattern of both positive and negative rainfall anomalies.
- The pattern establishes during the first day and is intensified on the second day of the simulation. Its persistence corresponds well with pronounced surface-precipitation feedbacks.

- Sensitivity analyses of single rainfall events will be incorporated into a statistical-dynamical approach to assess rainfall reduction risks by regional land use changes.

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