



# Boundary layer characteristics over West Africa – A comparative study between Niamey and Djougou

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## Introduction

The climate in West Africa is mainly characterized by the strong moisture contrasts between the moist monsoon flow to the south and the dry Harmattan air to the north. The interface between these two flows, called the **Inter-tropical discontinuity (ITD)**, shows a distinct annual cycle (from 6°N in January to 20°N in July). Important factors for the onset of the monsoon season are processes in the planetary boundary layer (PBL). By using a combination of ground-based remote sensing observations it is possible to get a comprehensive and continuous view on PBL temperature, humidity and wind conditions as satellites do not provide satisfactory information of the lowest atmospheric layers.

In the frame of the AMMA project, two supersites were operated continuously during the year 2006:

- **Djougou/Nangatchori** (Benin, 9.7°N, 1.7°E) equipped with a 14-channel microwave radiometer (HATPRO), a lidar ceilometer CT25K, two wind profilers (UHF, VHF), and a low-power vertical Doppler radar (Micro Rain Radar MRR) as well as in situ sensors.
- **Niamey** (Niger, 13.5°N, 2.1°E) hosting the Atmospheric Radiation Measurement (ARM) Mobile Facility (AMF) with similar instrumentation and additional cloud radar and radiosonde launches.

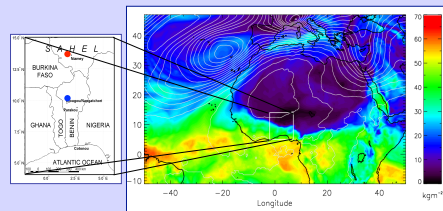


Fig. 1: Left: Location of Niamey and Djougou. Right: Precipitable water (colored) and 500 hPa geopotential (white contours) from ECMWF analysis (11 April 2006, 00 UTC). The strong gradient over West Africa at ~10°N marks the ITD.

## Annual cycle of temperature

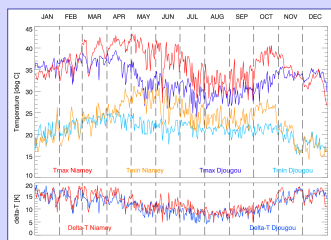


Fig. 2: Top: Annual cycle of daily maximum and minimum temperature for Niamey (red/yellow) and Djougou (dark/light blue). Bottom: Diurnal temperature range

- During the dry season strong radiative heating / cooling of the surface leads to an amplitude of up to 20 K diurnal temperature range.
- The highest maximum temperatures occur in April (Djougou) and early May (Niamey), just before the first moistening takes place.
- Though the diurnal temperature range is similar at both locations maximum and minimum temperatures are higher at Niamey from April to October.

## Water cycle variables

Radiative heating/cooling (Fig. 2) is strongly controlled by the presence of water vapour and clouds. The moistening of the region through PBL transports from the South (Gulf of Guinea) sets the stage for the monsoon onset (Fig. 3). Due to its location about 400 km more to the North **Niamey** stays drier until mid July (onset of peak monsoon) and has **about half of the cloud cover** (Fig. 4). At both locations most of the precipitation occurs in August and receives but Niamey receives only **a third of the yearly precipitation**.

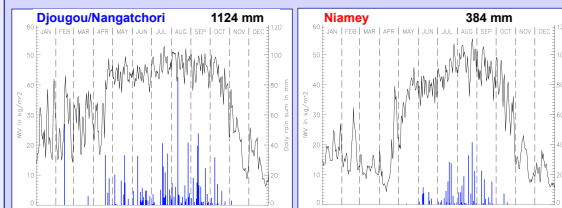


Fig. 3: Annual cycle of daily mean IWV derived from microwave radiometer observations (black; data gaps were filled with GPS observations) and precipitation for Nangatchori (left) and Niamey (right).

### Interannual Variability of Dry Season

**Early 2006** was unusually moist over the region and characterized by several outbreaks of monsoon air from the south (Fig. 3). Peak IWV in February was 42 (32) kg/m<sup>2</sup> at Djougou (Niamey) which is close to monsoon season values. A major rain event on 15 February brought more than 50 mm of rain at Djougou. The driest conditions were present in early April (see also Fig. 1).

The southward retreat of monsoon air started in October and took place much faster than the onset. The last rainfall in Niamey was on 19 October, whereas Nangatchori stayed dry after 2 November.

The dry season **2006/2007** started with a very dry December with several days of IWV values below 10 kg/m<sup>2</sup>. Unlike the year before, in January 2007 very dry conditions and strong Harmattan winds predominated over the whole region.

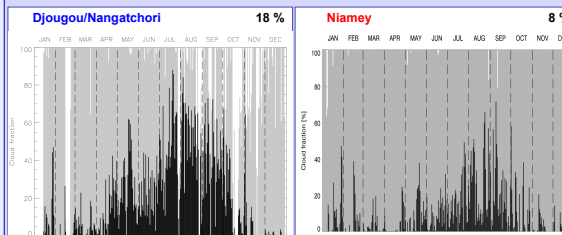


Fig. 4: Annual cycle of cloud occurrence in 2006 (black: percentage of daily cloud cover detected by ceilometer, grey: percentage of days without clouds, white: no data available) for Djougou/Nangatchori (left) and Niamey (right).

*Acknowledgements: Niamey data are from the mobile facility of the U.S. Department of Energy as part of the Atmospheric Radiation Measurement Program. Thanks to Olivier Bock (IGN/LAREG) for GPS IWV data of Niamey and Djougou and to Sylvie Galle (IRD) for Djougou temperature data.*

## PBL Development

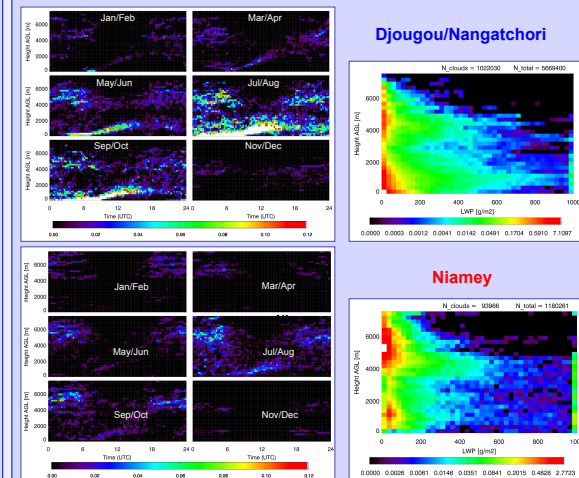


Fig. 5: Diurnal cycle of the lowest cloud base height (as derived from ceilometer) for two months' periods. Colours indicate the relative frequency of cloud base occurrence at a certain height.

- The growth of the convective boundary layer (CBL) is well visible in the diurnal cycle of cloud base particularly in **Nangatchori** (Fig. 5). At the onset of the rainy season (March/April), the CBL becomes more than 2 km deep in the course of the day. July/August show a mean CBL depth of only 600 m with fog frequently occurring in the morning hours.
- Fog is very rare in **Niamey**. Here most clouds about 5 km above ground. These clouds which contain little liquid water path (LWP) are associated with the African Easterly Jet and appear both in Niamey and in Nangatchori (Fig.6). Note that the nighttime maximum of mid-level clouds might be an artefact due to the obscuration by CBL clouds more frequent during daytime.

## Discussion and Conclusions

- The two datasets from Niamey and Djougou/Nangatchori provide unique information about the conditions in the lower atmosphere over West Africa. The one-year deployment gives a very good overview of the annual cycle. However, the dry season in 2006 was unusually moist and the situation in early 2007 was rather different with considerably lower IWV and temperatures.
- The high temporal resolution of these measurements compared to radiosondes allows the analysis of temporal boundary layer development and the passage of fronts.
- Future analysis will connect the information on the water cycle with dynamical structures observed by the wind profiler. In addition the role of radiative processes will be studied in more detail using surface radiation and satellite observations.