Diurnal cycle of the ITD before monsoon onset over Benin: Ground-based measurements and mesoscale modelling

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Introduction

The **annual variation** of the **ITD (Inter Tropical Discontinuity) position** is a crucial process for the West African climate system. The ITD marks the border at the surface between dry harmattan air to the north and the moist monsoon air to the south. The **northward move** of the ITD **preceding the monsoon onset** causes the advection of moist air in the lower troposphere into still very dry areas. It is assumed that this low-level moisture transport is a key factor for the monsoon system in West Africa.

In the frame of the AMMA project, a large set of **ground-based remote sensing instruments** was operated in 2006 in the area of Djougou/Nangatchori (Benin, 9.7°N, 1.7°E). These observations with a high temporal resolution made it possible to describe the ITD (Intertropical discontinuity) structure and dynamics in much detail. They repesent a unique dataset of observations of the diurnal cycle of the ITD.

Study area

In this study a series of simulations over 4 days - between 9 and 12 of April 2006 - was carried out over one domain with a horizontal mesh size of 10 km centered at 9°N and 2°E covering an area of 1000 km x 1000 km from 1.95° W to 6.95° E longitude and from 5.1° N to 13.9° N latitude (Fig. 1).

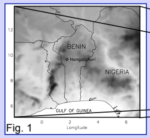


Fig. 1

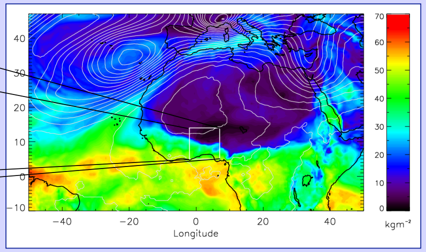
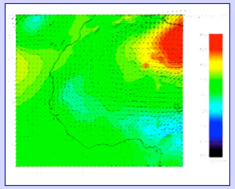


Fig. 2 gives an overview of the water vapour distribution over Africa and the Eastern Atlantic on 11 April 2006, 00 UTC. The sharpest gradient between the moist and dry air masses can be found in the study area. Contours are 500hPa geopotential

Fig. 3 (right) shows the synoptic situation, depicting 925 hPa geopotential height and wind arrows. The ITD lies east-west over West Africa and appears as a minimum in geopotential as well as a convergence line of wind arrows.



References

Pospichal B and S. Crewell., 2007: Boundary layer observations in West Africa using a novel microwave radiometer. *Met. Z.,* **16**, 513-523.

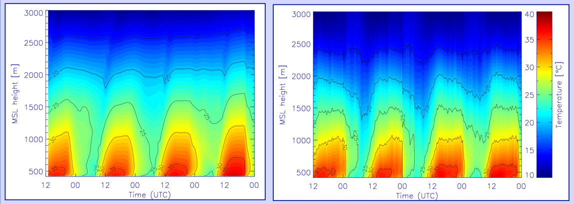
Pospichal B., D. Bou Karam et al., 2008: Diurnal cycle of the inter-tropical discontinuity over Benin from ground-based measurements and mesoscale modelling), *in Preparation*

MesoNH model

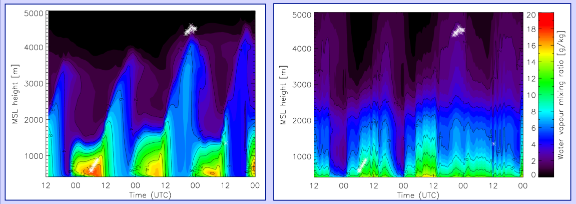
Following the data analysis of boundary layer observations, it was to find out whether a **mesoscale model** is able to reproduce the observed features. For that reason, the non-hydrostatic mesoscale model (MesoNH) has been run with a horizontal resolution of 10 km for a 4-day period in April 2006. The simulation has been initialized by and nudged with ECMWF analyses, the nudging timestep was set to 6 hours.

The distinct diurnal cycle of the ITD position which had been observed and is marked by very sharp gradients in temperature, humidity and wind, was well reproduced by the model.

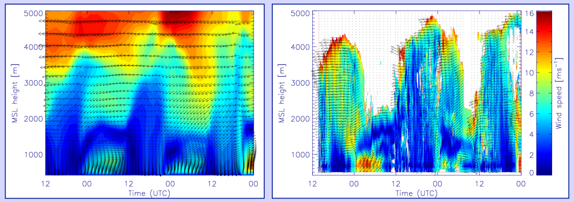
Comparison model – observations



Time series of temperature cross-sections over Nangatchori from 9 April 2006, 12 UTC to 13 April 2006, 00 UTC. Left: MesoNH calculations. Right: HATPRO microwave profiler observations.

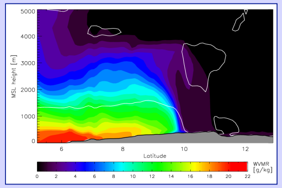


Time-series of water vapour mixing ratio cross-sections over Nangatchori for the same period as above. Left: MesoNH calculations. Right: HATPRO microwave profiler observations. White crosses indicate cloud observation by a ceilometer. Indicating that clouds were present (RH=100% in model!)

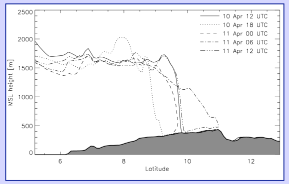


Time series of horizontal wind speed and wind direction, cross-sections over Nangatchori from 10 April 2006, 12 UTC to 13 April 2006, 00 UTC. Wind arrows depict horizontal wind. Left: Meso NH calculations, Right: UHF wind profiler observations. Thanks for wind profiler data to Bernard Campistron (Laboratoire d'Aérologie)

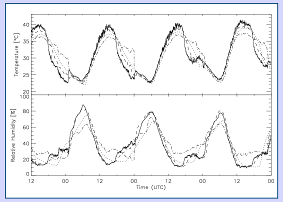
Further modelling results



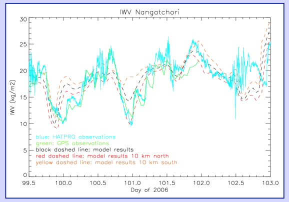
Meridional cross-section of water vapour mixing ratio at 1.8°E on 11 Apr 2006, 00 UTC. White contours represent zero meridional wind speed. The sharp gradient at the ITD position is well represented by the model.



Meridional cross-section of 11 g/kg water vapour mixing ratio contour line. Different times are indicated in the figure. The diurnal cycle can be seen very well. Northernmost position of moist air at 06 UTC.



Time series of temperature (top) and relative humidity (bottom) from 09/04, 12 UTC to 13/04, 00 UTC. Solid: HATPRO temperature and humidity sensor observations (1.2 m above grd). Dashed: Weather station observations in Djougou (2 m above grd). Dash-dotted lines: Lowest level of HATPRO temperature and humidity retrieval (0-25 m above ground). **Dotted lines: MesoNH** results for temperature and relative humidity in 10 m above ground.



Time series of IWV over Nangatchori. HATPRO and GPS observations compared to MesoNH. Dashed lines represent model results on three adjacent gridpoint on a meridional line through Nangatchori. Thanks for GPS data to Olivier Bock (LAREG/IGN and SA/CNRS)

Discussion and Conclusions

- A unique dataset of observations from Central Benin made it possible to observe the diurnal cycle of the monsoon flow at monsoon onset with high resolution, both temporally as well as vertically.
- Moist air is carried northward during the second part of the night in March and April over Nangatchori when the ITD position is about 10°N. During daytime vertical mixing distributes this moisture up to 4 km height and a north-easterly flow brings dry air to the region.
- The MesoNH model was able to capture these features well. Comparison to observations show very good agreement in temperature and humidity. However, the gradient in reality is even stronger and that the low-level wind speed is somewhat underestimated. This might be due to the relatively coarse grid spacing of 10 km.
- Nevertheless, the model proved to be a good means to describe the mesoscale structures of monsoon onset and allows to use model results for gaining deeper insight in atmospheric conditions.

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