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ORGANIZED STRUCTURES IN THE SAHELAN BOUNDARY LAYER DURING THE TRANSITION PERIOD BETWEEN THE WET AND DRY SEASONS: IMPACT ON FLUX MEASUREMENTS

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1. Introduction

AMMA (African Monsoon Multidisciplinary Analysis) will have French ATR-42 and British BAe-146 aircraft flyying in the low and mid-troposphere and measuring heat fluxes above various vegetation-typed surfaces and within very different flows such as monsoon or Harmattan.

During HAPEX-SAHEL experiment that took place in 1992 in Niger near Niamey, two French aircraft flew at low altitudes to measure fluxes in the lower troposphere. Organized structures were often detected, along with skewed water vapor mixing ratio. Links were raised between the structures, dry intrusions (entrainment) and shear. The surface fluxes deduced from the aircraft measurements were most of the time smaller than the estimates made from the ground measurements. We suspect the organized structures and dry intrusions to be part of the explanation for this underestimation and for error in flux estimates in general.

Organized structures and other type of anisotropy associated with the mixing processes within the PBL (Planetary Boundary Layer) can make the estimation of fluxes - based on the assumption of a fully homogeneous turbulent medium - a very difficult challenge (Lohou et al., 2000). Here we use one real case of HAPEX-SAHEL experiment simulated with a meso-scale model at 250 m horizontal resolution to show further evidence of the impact of the coherent structures on aircraft flux measurements.

2. Numerical and experimental data

A numerical simulation of the real case of October 8 1992 was made for the purpose of studying the PBL during the transition period between wet and dry seasons. Three simulations were made at 5 km, 500 m and 250 m horizontal resolutions within the squared degree of Niamey with the non-hydrostatic mesoscale model Meso-NH. Here we mainly consider the numerical simulation at 250 m resolution made in a 50 km by 50 km domain.

During this day ARAT aircraft flew at around 300 m between 0930 and 1200 UTC. All stabilized legs were divided into 30-km segments to estimate the statistical moments of the components of the wind (u,v, w), the potential temperature ( ) and the water vapor mixing ratio (q) from the highest sampling rate data (16Hz). A high pass filter at 5 km was used to remove the mesoscale trend.

Before using the numerical simulation to show the impact of thermals and dry intrusions, we validated it by comparing the surface energy budget, the profiles of mean meteorological variables, their horizontal gradients and the distributions of their fluctuations. We found a good fit between the numerical simulation and what was observed with the aircraft.

Figure 1 shows the distribution of water vapor mixing ratio observed along the twenty four 30 km-long legs of the ARAT aircraft, and that observed in the modeled 2D field at the same height. The observed distribution fits surprisingly well within the minimum and maximum envelops simulated over the duration of the flight. In particular, the negative skewness observed with aircraft measurement of water vapor mixing ratio (-0.9 here) is also found in the model (-0.6). This negative skewness.increasing with height.is likely due to descents of dry air from the free troposphere into the PBL through entrainment process as shown in figure 4. During HAPEX, it was observed that the more negative the skewness, the larger the under-estimation of aircraft-measured fluxes.

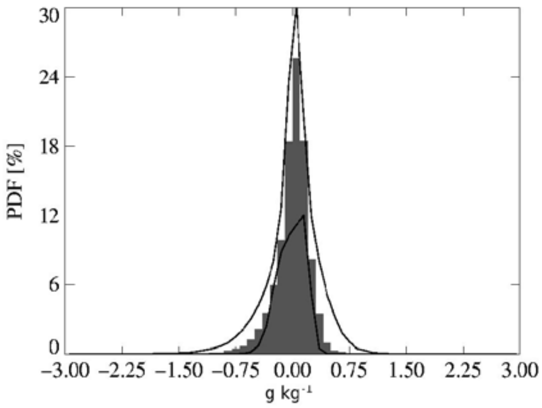

Figure 1: . *Distribution of water vapor mixing ratio observed with the aircraft (bars) and that found in the modeled 2D field at the same height over the duration of the flight (two envelops, for the two extreme distributions). For aircraft data, all 30-km segments are considered. Only scales ranging between 250 m and 5 km are considered for both types of data.*

3. <u>Organized structures and dry intrusion in the Sahelian boundary layer</u>

The numerical simulation showed very nice coherent structures in the morning, organized in lines at 1000 UTC and in cells later in the morning. These 'no-cloud streets' observed at 1000 UTC are shown in figure 2 for water vapor mixing ratio, with a separation distance of around 2.5km in the model.

Even if the measurements of the aircraft did not show structures as organized as in the model, it was still obvious that there were effectively organizations during the flight. Especially, an auto-correlation analysis of the water vapor mixing ratio modeled series at the same position and time of the aircraft showed similar caracteristic scale. Since only two 30-km segments were in the domain of the high resolution simulation, a direct comparaison could no be done at small scale.

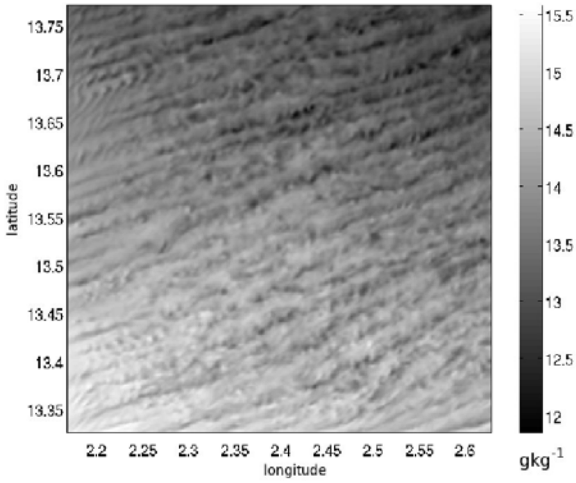

Figure 2: *Horizontal cross section 300m above the ground of water vapor mixing ratio in models 2 and 3.*

Such a field of organized structures can make the 1D sampling of the aircraft measurements unsufficient for several reasons: one is that the scale of the coherent structures is too large to be well sampled by a 30km-long leg. The other is that the line sampled by the aircraft may result in a bias depending on which direction it is flown.

Figure 3 shows the effect of filtering scales larger than respectively 1, 2, 4, 5 km on the flux estimate. The calculation of the latent heat flux profiles shown here was made from the 2D fields of fluctuations at each level of the simulation, after removing the 2D sliding mean. It demonstrates that when the scales of the structures (2.5 km) are not taken into account in the flux computation, the total flux is not totally retrieved. Whereas filtering at cut-off scales larger than the scale of the structures does not make any change.

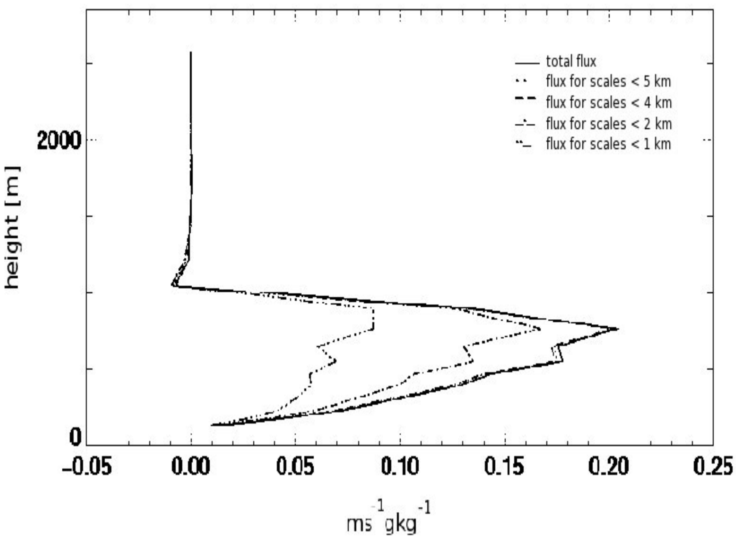

Figure 3: *Vertical profile of modeled covariance between vertical velocity and water vapor mixing ratio for different ranges of scales (larger scales removed).*

From the numerical simulation, flux measured from 1D series of fluctuations seemed to depend on the direction of the leg, because the reference mean removed from the signal can be higher or smaller than the 2D field average, and the resulting fluctuations smaller. This happens in particular if the leg is longitudinal to the alignment of the structures, while it would not if it is transverse. This effect was seen in the numerical simulation for the sensible heat fluxes, with only 5% decrease of the 1D flux relative to the 2D-computed flux. It was not seen on the latent heat flux, likely because of dry intrusions. However, we need to pursue this study to confirm the result and we also plan to verify wether the 1D-measurement can introdude a significant error depending on the type of organizations (rolls or cells). Using LES with higher resolution will help.

Dry intrusions (descents) from the top of the PBL were observed during HAPEX-SAHEL as shown in figure4. They are responsible for the negative skewness of the distribution of water vapor mixing ratio. Those dry intrusions were also well seen in the numerical simulation and contributed significantly to the total heat flux. Close to neutral free tropospheric profiles favor rapid growing of the PBL. This has a positive feedback on entrainment and dry subsidences and makes the PBL still more heterogeneous and flux measurement more difficult. This explanation is supported by a larger under-estimation of the aircraft fluxes later in the period, when the neutral conditions above the PBL top are more frequent.

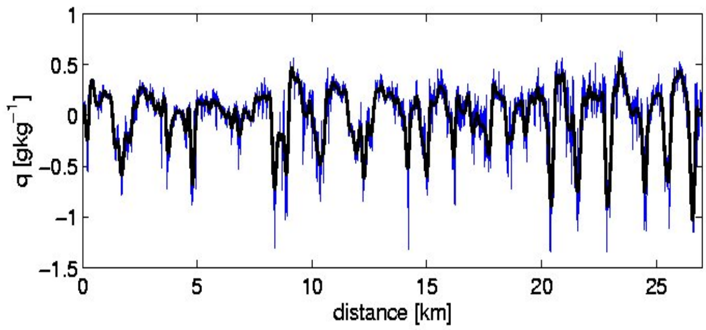

Figure 4: *Time series observed with aircraft showing subsidence of dry air. The black line stands for a series obtained after a 250 m low pass filter.*

4. Conclusions

Coherent structures and dry intrusions contribute significantly to the fluxes of the PBL. However, their scale of a few km raises sampling issues: numerous and long enough legs are necessary to obtain a statistical representation of the structures Lenschow and Stankov (1986) and these organized structures along with dry intrusions introduce heterogenities in the PBL that make the basic assumption of turbulence incorrect. We plan to pursue our investigation about the differences that may exist between 2D versus 1D methods for flux estimations. A study of the variation of the scales involved with time and along vertical will also be made. We also are pursuing our investigation on this issue with a LES simulation of IHOP (International H20 Project) that allows us to better understand the relative role of these structures and that of turbulence. This was not allowed with the simulation at 250 m resolution considered here.

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Convective wind system with aerosols, named “haboob”, Hombori in Mali, West Africa.