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Tethered balloon profiles in the nocturnal boundary layer and CO2 fluxes in Sahelian Mali.

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Very few CO2 flux measurements are carried out in Africa to date. This is a clear limitation to our understanding of CO2 exchanges between vegetation canopies and the atmosphere, because surface flux measurements provide a strong basis for vegetation mechanistic modelling. Indeed vegetation dynamics (growth and functioning), which is an important actor of the West African monsoon system, is largely controlled by the interactions between the CO2, water and nutrients cycles. In addition to the scarcity of data, a second problem arises from the strong spatial heterogeneity characterising terrestrial ecosystems, which requires measurements at different scales, whereas mostly local data are collected.

In this context, we present estimates of night-time CO2 exchanges derived from concentration profiles in the nocturnal boundary layer. Assuming that vertical mixing is limited under stable conditions (calm nights), the accumulation of CO2 in the lowest atmospheric layers is mostly due to surface CO2 fluxes, when advection is negligible.

CO2 concentration profiles between 0 to 200 m have been acquired with a tethered balloon for 7 nights in August 2004 in Hombori (Mali, 15.5 °N, 1.5 °W). Air pressure, temperature, relative humidity, wind speed and direction were recorded with an AIRS sonde. Air was pumped through a tube down to the ground and flown through a LiCor infrared gas analyser. The Hombori supersite is dominated by herbaceous vegetation growing on sandy dunes and bare soil areas with scattered trees. Transects of soil CO2 fluxes from chamber measurements and soil moisture were also performed at the same

site, as well as measurements of leaves respiration rates, biomass and tree cover.

The profiles revealed the development of relatively shallow stable boundary layers at night (˜100 m or less). The dominant wind was from south-west to south. Wind speed varied significantly from night to night. A few profiles acquired during the calmer nights show the development of a nocturnal low level jet (caution led us not to raise the balloon up to the altitude of the low level jet maximum under too windy conditions). Several measurement nights were also interrupted by the arrival of convective systems.

On calm nights, the CO2 flux estimate was 4 to 5 micromoles m-2 s-1. Such a high CO2 flux rate is consistent with chamber measurements of soil respiration, on the order 3 micromole m-2 s-1, and leaf respiration rates. A simple scaling based on back trajectories and MODIS vegetation index showed that these ground measurements were most of the time representative of the balloon footprint. No accumulation was recorded when the wind exceeded 7 m/s at 100 m agl, probably because of shear driven turbulence and vertical mixing.

Our data, collected shortly after significant rain events, support the hypothesis that semi-arid Sahelian ecosystems display large CO2 respiratory fluxes during the rain season, despite a rather low vegetation density and a low annual rainfall. Such fluxes are detectable with nocturnal budget methods, which had been applied to tropical and boreal forests thus far.

In the overall context of the AMMA program, balloon-based experiments proved to be suitable to scale-up surface CO2 fluxes as well as to document the low-level atmosphere (moisture advection, nocturnal jets) by allowing high-frequency soundings.