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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Atmospheric nitrogen budget in Sahelian dry savannas" *by* C. Delon et al.

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The authors thank the reviewer to have raised a number of questions in the work presented in the above referenced manuscript. We have considered the review, and we would like to propose a revised version of the work, with changes in the deposition fluxes calculation.

First of all, it is necessary to precise the height of concentration measurements at the IDAF stations: the passive samplers are situated 1.5m above ground. In that case, the application of the inferential method is possible, since at this height the chemical transformations are not affected by turbulence. De Arellano et al. (1992) state that for the NO-O3-NO2 system in the surface layer, this only holds when chemical species are near ground level. The inferential method is used for the calculation of NO2, HNO3

and NH3 deposition fluxes. However, the case of NH3 is more complicated than the case of NO2 and HNO3: the concentrations of these 2 compounds near the ground is null, the net flux is only a deposition flux, whereas NH3 is both emitted and deposited. The direction of the net flux will depend on the strength of the volatilization process and environmental conditions. The NH3 compensation point has been widely studied for temperate climate vegetation (Sutton et al., 2007 and references therein), Trebs et al. (2006) have also described a detailed N budget in a tropical pasture site in Brazil, but once again the lack of data in the Sahel prevents from parameterizing and estimating, for example, stomatal emissions, cuticular desorption emissions, cuticular recapture of stomatal emissions (Sutton et al., 1998), key points for the compensation point concept. As mentioned by the reviewer, the compensation point is partially considered by the applied NH3 volatilization rate. Both deposition and emission fluxes are evaluated independently in the manuscript, assuming that the resulting net flux will not be as sophisticated as with a detailed mechanistic model of NH3 surface-atmosphere exchanges.

1/ We agree that the concept of using constant deposition velocities is not satisfying. Therefore, we have used deposition velocities calculated by the ISBA-SURFEX model. In the model the general resistance parameterization for dry deposition velocities of Wesely and Hicks (1977) has been introduced. The surface resistance incorporates both the physical and biological surface characteristics together with the solubility of deposited species (Baer and Nester, 1992). For vegetated surfaces (Wesely, 1989), one further considers the relative contributions of stomata, mesophyllic tissues, and cuticle whereas for liquid surfaces, the parameterization of Erisman and Baldocchi (1994) is used. For the cuticle and soil resistances, the parameterization developed in Zhang et al. (2003) has been used. These parameterizations have been included in ISBA and coupled with the 255 surface classification types. ISBA calculates such evolving parameters as aerodynamical, quasi-laminar, stomatal resistances, and drag coefficients for different vegetation types. Chemical dry deposition velocities evolve at each time step together with surface wind, turbulent conditions and chemical parameters. Meteorological conditions are provided by the forcing, derived from satellite data, and developed in the ALMIP project. Validation of surface temperature and moisture have been made within the ALMIP project (Boone et al., 2009). In the present work, we have calculated monthly means of deposition velocities for NO2, HNO3 and NH3, in order to reproduce the seasonal cycle of the deposition process. The monthly means deposition velocities range from 0.1 to 0.35 cm/s for NO2, from 0.35 to 0.7 cm/s for HNO3 and from 0.08 to 0.4 cm /s for NH3.

2/ For NH3 and HNO3, the deposition velocity (cm/s) is multiplied by the concentration (in molecules/cm3) to obtain the deposition flux (in molecules.cm-2.s-1). In the text, the flux is further converted to kgN.ha-1.yr-1. For NO2, an additional term has been added, to estimate a potential chemical loss of NO2 by reaction with OH (Stewart et al., 2008):

FNO2 = [NO2] * (Vd + H*k*[OH])

Where H is the height of measurements in cm, in our case H=150, k=1.19$\times$10$-$11 cm3.molec$-$1.s$-$1 and [OH] = 1.106 to 1.107 molecules.cm-3, to give a variation range of deposition fluxes. However, there is no significant difference between fluxes if the OH concentration changes from 1.106 to 1.107 molecules.cm-3, and the difference in fluxes when we apply the first equation (F = C*Vd) or the second one (with chemical loss) does not exceed 10%.

3/ New estimates of organic fertilization have been made with the new Glipha database: http://kids.fao.org/glipha/, Global Livestock Production and Health Atlas. Livestock population for each administrative region in each country is given in head/sqkm. Therefore, the N input for the calculation of NO emissions from soils has been modified (though modifications in that case are not significant in the Sahel), as well as the emission of NH3 by volatilization processes. Considering that the rate of volatilization is a large source of uncertainties, two different rates have been applied (30% and 50%) to give a range of values for the N emission.

4/ A new window is proposed for the Sahel region: 15°W-10°E, 12°N-18°N, which gives 2434700.4 km2. As a consequence, the budget for the Sahel region is reduced compared to the previous study, and ranges from 1.3 to 2.1 TgN/yr for N deposition, and from 1.5 to 3.7 TgN/yr for N emissions.

5/ Biogenic NO fluxes during the dry season have been corrected.

6/ As mentioned by the reviewer, no micrometeorological measurements have been done in the IDAF stations, in parallel with concentration measurements. No field campaign is planned for the time being. However, thanks to the meteorological forcing developed in the ALMIP project, deposition velocities have been calculated and are not taken from other studies any more. One of the major purposes of this paper was also to show that the concentrations measured in dry savannas by the IDAF network were not over estimated, and could be explained by the emission processes implicated in these regions.

We are aware that quantifying the Nitrogen budget between atmosphere and biosphere is extremely difficult, due to the lack of measurements in the region we consider, and due to the wide variety of N forms that have to be considered. According to the present review, a better quantification of the uncertainties has to be made, to give a range of emission and deposition fluxes. Not all the questions raised by the reviewer are addressed in this response, but the authors wanted first to show that a lot of work has been done to try to improve the previous manuscript, considering the comments of reviewer #1, while waiting for those of reviewer #2.

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