Interactive comment on "Modelling land atmosphere daily exchanges of NO, NH3 , and CO2 in a semi-arid grazed ecosystem in Senegal" by
Claire Delon et al.

Anonymous Referee #2

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The study on nitrogen and carbon fluxes under grazing in a semi-arid region in Senegal aims to better understand their driver contributions in wet and dry seasons. The authors use field data from the years 2012 and 2013 and apply three models to derive daily time series which are evaluated against the field data. Thus, the work contributes a valuable piece of knowledge in a not-well studied system with measurements under difficult field conditions and the corresponding simulation results to evaluate the representation of processes controlling NO, NH3 and CO2 fluxes under these conditions. The manuscript represents a concise and well-designed piece of knowledge on N and C fluxes in a semi-arid region, is within the scope of BG and is surely worth being published. Before recommending this, a major effort is needed to clarify 1) the structure of the text, 2) the methodological description and 3) the modelling concept. Therefore, I recommend major revisions.

We thank both referees for their careful consideration and comments on the manuscript.
We bring answers to every comment hereafter, and indicate corresponding changes that will be made in our manuscript.

My main concerns are:
1) So far, methods, results and discussion are partly mixed and contain a large number of back and forth references. Please keep the structure more clear. E.g. in section 3.2, the role of the spatial heterogeneity represented in sampling is discussed in relation to the simulations which would better fit in the methods. The results sections contain parts in which the simulations are already discussed which could be moved to the existing discussion sections. Figure 10 is introduced in the discussion and belongs clearly to the results.

The results and discussion sections will carefully be read to avoid mixing results and discussion, and corrected when necessary.
A new point will be added in section 2.2.3 "Measurements of NO, NH3 and CO2 (respiration) fluxes from soil **and physical parameters** " to precise that soil pH and texture measurements will be used in the rest of the manuscript.
The paragraph concerning the spatial heterogeneity in section 3.2 will be moved to section 4.2 in the discussion part, as follows:
"The over or underestimations of NO emissions in the model in Fig. 5 may be explained by the ammonium content shown in Fig. 6. Released N is overestimated during the J13 wet season, and underestimated at the end of the wet season (as N13), when the presence of standing straw may lead to N emissions in addition to soil emissions, not accounted for in the model because litter is not yet buried. The slight underestimation of modelled soil moisture (Fig. 2) at the end of the wet season may also explain why modelled fluxes are lower than measured fluxes. The large spatial heterogeneity in measurements may be explained by variations in soil pH and texture, and by the presence of livestock and the short term history of the Dahra site, i.e. how livestock have trampled, grazed and deposited manure during the different seasons and at different places. This spatial variation is evidently not represented in the 1D model, where unique soil pH and soil texture are given, as well as a unique input of organic fertilization by livestock excreta."

The following paragraphs of section 3.2 will be moved to section 4.2

"With wet season NO fluxes being more than twice higher than dry season fluxes, results emphasize the influence of pulse emissions in that season This increase at the onset of the wet season over the Sahel, due to the drastic change in soil moisture, has been previously highlighted by satellite measurements of the NO2 column, by Vinken et al. (2014), Hudman et al. (2012), Jaegle et al. (2004) and Zörner et al. (2016)."
And
"After the pulses of NO at the beginning of the wet season (Fig. 5), emissions decrease most likely because the available soil mineral N is used by plants during the growing phase of roots and green biomass, especially in 2013, and is less available for the production of NO to be released to the atmosphere (Homyak et al., 2014, Meixner & Fenn 2004, Krul et al., 1982). During the wet season, NO emissions to the atmosphere in the model are reduced by 18% due to plant uptake (compared to NO emissions when plant uptake is not taken into account). Indeed, N uptake by plants is enhanced when transpiration increases during the wet season (Appendix C)."

The following paragraph will be moved from section 3.3 to section 4.2
" the model over-predicts the death rate of microbes and subsequently underestimates the CO2 respired, whereas microbes and residues of roots respiration persist in the field despite low soil moisture. A second explanation of this underestimation might be the lower soil moisture in the model than in measurements at the end of the wet season (Fig. 2)."

Figure 10 will also be mentioned in the result section (paragraph 3.4), and discussed in the discussion section. The following text will be added in paragraph 3.4:
"In Fig. 10a, the total net flux above the canopy in Surfatm results from an emission flux from the soil and a deposition flux onto the vegetation via stomata and cuticles, especially during the wet season. On the contrary, the total flux in Zhang2010 in Fig. 10b results from a strong deposition flux on the soil and a very low deposition flux onto the vegetation. This is explained by a strong contribution of deposition on cuticles in Surfatm (Fig. 10c) whereas it is close to zero in Zhang2010 (Fig. 10d). In Surfatm, emission from stomata also occurs but it is largely offset by the deposition on leaf surfaces which leads to a deposition flux onto vegetation (Sutton et al., 1995). In Surfatm, the deposition on cuticles is effective until the end of the wet season, whereas deposition through stomata lasts until the vegetation is completely dry, i.e. approximately 2 months after the end of the wet season. On the basis of the different averages for each contributing flux in table 4, we estimate that the soil is a net source of NH3 during the wet season, while the vegetation is a net sink in Surfatm, and the soil is a net sink in Zhang2010."

The last paragraph of section 4.3 concerning the lagged correlation between NO and CO_2 fluxes has not been separated between results and discussion to avoid inconsistency in the ideas.

2) The methods section would benefit from an overview of measurements including the temporal resolution of the variables and a correspondence table to the simulations. Here, you could specify which simulations are compared to which measurements and why.

Model (resolution)	Simulated and measured variables (units)	Methods used for measured variables (resolution and reference)
Surfatm (3h)	NH_3 bidirectional fluxes (ngN m^{-2} s^{-1})	Closed dynamic chamber (15 – 20 fluxes a day, Delon et al., 2017)
	Soil surface temperature (°C)	Campbell 107 probe (15min, Tagesson et al., 2015a)
	Sensible and latent heat fluxes (W m^{-2})	Eddy Covariance (15min, Tagesson et al., 2015a)
Zhang2010 (3h)	NH_3 bidirectional fluxes	Closed dynamic chamber (15 – 20 fluxes a day,

	(ngN m^{-2} s^{-1})	Delon et al., 2017)
STEP (day)	NO biogenic fluxes (ngN m^{-2} s^{-1})	Closed dynamic chamber (15 – 20 fluxes a day, Delon et al., 2017)
	CO_2 respiration fluxes (ngN m^{-2} s^{-1})	Closed dynamic chamber (15 – 20 fluxes a day, Delon et al., 2017)
	Ammonium content (%)	Laboratory analysis (6 samples/campaign, Delon et al., 2017)
	Soil temperature at two depths: 0-2cm and 2-30cm (°C)	Campbell 107 probe at 2 depths: 5 and 10 cm (15min, Tagesson et al., 2015a)
	Soil moisture at two depths: 0-2cm and 2-30cm (%)	HH2 Delta probe at 2 depths: 5 and 10 cm (15min, Tagesson et al., 2015a)

Table 1: Summary of different models used in the study, with the variables simulated and compared to measurements. All simulated and measured variables were daily averaged for the purpose of the study.

The reference for this table will be added at the end of section 2.3.2 for STEP model, and at the end of section 2.4.2 for the two models simulating NH_3 fluxes, to specify which models are used, and compared to which measured data.

3) Firstly, it is clear that a model which is already published does not have to be given in detail in a new manuscript. Here, the outcome strongly depends on the details of the models applied and you give a lot of information in the appendix. Please give this information at the beginning of section 2.3 before the details of single processes are described. Here, also try to separate the basic principles from input data and variables calculated within the models. Clarify why there is the double description of resistencies (Ra, Rb, Rc) in 2.4.1 and 2.4.2. Do not mix 'parameters' with 'variables'. Parameters are fixed values in equations whereas variables stand for state variables in the models and measured values. Also here, a better overview of input data (with temporal resolution) and simulated variables is needed.

At the beginning of section 2.3.1, we will add the following sentence:
"STEP model is presented in Appendix A, with forcing variables detailed in Tab. A1, site parameters used in the initialization in Tab. A2, numerical values of parameters used in the equations in Tab. A3, and equations, variables, parameters and constants used in the equations in Tab. A4." Indeed, we prefer to keep this information in Appendix section to avoid too much tables in the main text. The basic principles are described for each model already.
Equations and variables used will be gathered in a single table (Table A4) to make the reading easier, this will clarify between input data (table A1), initialization parameters (table A2), numerical values of parameters used in the equations (Table A3) and equations (table A4) with explanation of variables, constants and parameters used in them.
As Zhang2010 and Surfatm are based on the same resistance analogy, it is indeed not necessary to recall the resistances in section 2.4.2.
Parameters and variables have been differentiated by writing variables in *italics* in table A4.
Input data are already précised in sections 2.4.1 and 2.4.2 for Zhang and Surfatm, and the resolution is 3h (already mentioned). We have also specified that STEP simulations are performed at the daily scale in table A1 where input data are specified for STEP.

General remarks:
1) There are a lot of missing or misleading information on units, scales, subscripts. Unfortunately, typesetting needs more effort.
Typesetting will be carefully proofread. Units will be added in the equations and the tables.

2) The analysis of drivers needs more substance. Relating simulated respiration to simulated soil moisture, this shows that there is a linkage in the model, but not more. In the study region, the variation of soil moisture dominates over the variation in temperature so that this variable is more important for the processes studied. The interesting part would be to see this linkage in measured values as well.

At the end of section 3.3, it is mentioned that "soil field measured respiration show a lower correlation (R^2=0.4 and p=0.09, R^2=0.3 and p=0.1 in J13 and N13 respectively) with surface soil moisture". The analysis of measured fluxes with drivers is comprehensively described in Delon et al., (2017), where weak or non correlations were found between fluxes and environmental variables. In the present paper, we analyze the modeling results, and the role of soil moisture overriding the role of soil temperature is highlighted in the discussion part in sections 4.1 and 4.2, as well as the linkages between environmental drivers and soil fluxes.

3) The text is mostly well-written but please consider to get rid of most of the brackets. These insets can better be integrated into the sentences.

Brackets will be removed every time it is considered as necessary.

Specific remarks:

- In section 3.4, please give all the values in a table.

The values will be moved in a table as follows and the paragraph will be shortened accordingly.

Period / NH_3 fluxes	Measurements (ngN m^{-1} s^{-1})	Surfatm (ngN m^{-1} s^{-1})	Zhang2010 (ngN m^{-1} s^{-1})
J12	1.3±1.1	2.6±2.6	-9.0±0.9
J13	-0.1±1.1	-1.7±2.4	-7.8±2.2
N13	0.7±0.5	-0.2±1.1	-2.8±0.9
2012		-0.9±3.3 (-0.3±1.0 kgN ha^{-1} yr^{-1})	-3.5±4.6 (-0.3±1.0 kgN ha^{-1} yr^{-1})
2013		-2.0±3.7 (-0.6±0.3 kgN ha^{-1} yr^{-1})	-2.7±3.8 (-0.8±1.2 kgN ha^{-1} yr^{-1})
Dry season		-0.2±1.6	-0.9±2.3
Wet season		-4.3±4.8	-8.1±3.2

Table 3: Averaged NH3 fluxes for measurements, Surfatm and Zhang2010 models during specific periods.

- Section 4.1.1 begins with a reasoning that involves something not shown. Please avoid this or give a different reasoning.

The paragraph will be written as follows:

"Dahra is a grazed savanna where the main source of NH_3 emission to the atmosphere is the volatilization of livestock excreta (Delon et al., 2012); the excreta quantity and quality is at a maximum at the end of the wet season, (Hiernaux et al., 1998, Hiernaux and Turner 2002, Schlecht and Hiernaux 2004), because animals are better fed. In August, a strong leaching of the atmosphere occurs which decreases the NH_3 atmospheric concentration (not shown here), compared to July concentration, and the deposition flux decreases as well. Indeed, if the concentration decreases from July to August whereas the canopy compensation point remains stable, the flux will decrease as shown by equation 3."

The title of this paragraph will be modified to "NH_3 deposition flux variation".

- P8L19: Typo in 'Surface-Atmosphere'

Corrected.

- P9L19: sentence, verb missing

The sentence will be modified as follows:
“However, the drying of the layers is sharper in the model than in measurements at the end of the wet season, leading to an underestimation of the model compared to measurements until December each year”

- all figures: please use better colors. Blue and black lines and symbols cannot be distinguished well and having two grey lines as in figure 10 also does not help. Use red color or dashed lines.
In figures 3 and 4, dashed lines will be added for the 1:1 line. In figures 5, 6, 7 and 8, measurements will be colored in red. In figures 9 and 10, grey dashed lines will replace grey lines.

- Fig. 1: This scheme would be a very valuable orientation. Please be more informative here. Include the input data and the variables which are exchanged. It would be good to have such an overview of the other 2 models as well.
Very good schemes are made in the two reference papers for Zhang2010 (Zhang et al., 2010, Fig. 1) and Surfatm (Personne et al., 2009, Fig. 1), and we did not think it was necessary to copy these schemes or try to propose different ones.
In Fig. 1 of the present study, some of the exchanged variables are already included, in reference to the fluxes that are evaluated. The input data for forcing will be added, instead of “meteo forcing”.

- Fig. 3: this shows a consistent underestimation of the latent heat fluxes. This does not fit to the text stating that this is ’giving confidence’.
To moderate the statement, the sentence will be completed as follows:
“The significant correlation between Surfatm and EC latent heat fluxes indicates that the stomatal, aerodynamic and soil resistances are correctly characterized in the model, giving confidence in the further realistic parameterization of NH3 fluxes, despite missing values in intermediate fluxes, due to the criteria applied by the postprocessing (see supplementary material of Tagesson et al. (2015b)).”