

## **Response to Anonymous Referee #2 comments to paper “The contribution of soil biogenic NO emissions from a managed hyper-arid ecosystem to the regional NO<sub>2</sub> emissions during growing season”**

*The authors would like to thank Anonymous Referee #2 for his/her constructive and detailed comments as well as his/her very helpful suggestions. In our revised MS, we have performed three major corrections: (1) complete restructuring of the original MS, (2) consideration of the partitioning between NO and NO<sub>2</sub> for the top-down estimates (see Fig. 11), and (3) comparison of bottom-up estimates (see Fig. 11) on top-down estimates taking into account the emission ratio between satellite overpass (at 13:00 LT) and average diurnal emission.*

*We addressed the individual comments (in bold Times Roman) for each reviewer as indicated below (in italics).*

### **Response to the comments as listed:**

**1) I would suggest that the contents (and subtitles) of “Sect. 2 Materials and methods” and “Sect. 3 Results and discussion” be reorganized (and renamed) so that the three different emission estimates (i.e. the bottom-up biogenic NO emission estimates, bottom-up anthropogenic NO<sub>2</sub> emission estimates, and top-down total NO<sub>2</sub> emission estimates) as well as their inter-comparisons could be seen more clearly and followed more easily. For instance, Sect. 2.2 seems to have repeated contents for each of the three estimates and might be skipped with some contents being merged to the subsections for each corresponding estimate.**

*The authors would like to thank Anonymous Referee #2 for his/her very helpful suggestions. With regard to restructuring of the manuscript, the suggestions of Referee #1 and Referee #2 significantly overlap with following aspects:*

- *Scaling of bottom up biogenic NO<sub>x</sub> inventory*
- *bottom-up anthropogenic inventory*
- *bottom-up soil vs. anthropogenic contributions*
- *top-down estimates*
- *bottom-up total soil emissions vs. top-down estimates*

*Given the restructuring of the revised MS, the most part of the GGTP model were transferred to the supplement. With consideration of the suggestions of both Referees and the guidelines of manuscript preparation of ACP (only three levels of sectioning are allowed), the revised MS has now the following sections:*

*Section 1: Introduction*

*Section 2: Materials and methods*

*2.1 Site description and soil sampling*

*2.2 Remote sensing and accompanying data*

*2.3 Bottom-up calculation of biogenic NO emission estimates*

*2.3.1 Laboratory determination of land use type specific net potential NO fluxes*

*2.3.2 Determination of land use types and corresponding soil surface temperatures from Landsat Imagery*

*Land use classification*

*Land surface temperature  $T_s$*

*2.3.3 Temporally high resolution data*

*Soil temperature,  $T_{soil}$*

*Gravimetric soil moisture  $\theta_g$*

Fertilizer factor FF

- 2.3.4 Monthly soil biogenic bottom-up emissions of Tohsun oasis
- 2.4 Bottom-up anthropogenic NO<sub>2</sub> emission estimates
- 2.5. Top-down total NO<sub>2</sub> emission estimates from satellite observations
- 2.5.1 Satellite derived tropospheric VCD<sub>NO<sub>2</sub></sub>
- 2.5.2 Monthly total NO<sub>2</sub> emissions of Tohsun oasis (top-down)

Section 3: Results and Discussion

- 3.1 Bottom-up soil biogenic and anthropogenic emissions from Tohsun oasis
  - 3.1.1 Laboratory derived net potential NO fluxes
  - 3.1.2 Land use type specific net NO fluxes based on soil temperature, soil moisture content, and enhancement by fertilizer application
  - 3.1.3 Monthly soil biogenic emissions of NO and HONO from Tohsun oasis (bottom-up)
  - 3.1.4 Monthly anthropogenic emissions from Tohsun oasis (bottom-up)
  - 3.1.5 Soil biogenic vs. anthropogenic emissions of Tohsun oasis
- 3.2 Top-down satellite derived total NO<sub>2</sub> emissions from Tohsun oasis
  - 3.2.1 Spatio-temporal variation of the tropospheric VCD<sub>NO<sub>2</sub></sub> measured from satellite
  - 3.2.2 Monthly total NO<sub>2</sub> emissions from Tohsun oasis (top-down)
- 3.3 NO<sub>x</sub> emissions of Tohsun oasis: bottom-up vs. top-down

Section 4: 4 Summary

**2) The full name for GGTP does not fully reflect the focus of this study as “the soil biogenic NO emission” is not seen. The soil biogenic NO emission model is an important part of this study, but it appears only in the sub-sub-title (Sect. 2.4.7) of Sect. 2. I would suggest updating Sect. 2.4, first by using some phrase like soil NO emission estimate (or model) for the title. Sect. 2.3 and some contents of Sect. 2.1 might be merged to it. The updated subsection needs to be more concise, e.g. by using citations (if possible) and/or Appendix (or Supplement Information) to describe the validation of soil parameters. The same strategy may be apply for “Sect. 3 Results and discussion” (e.g. Sect. 3.2–3.5).**

*Geoscience General Tool Package (GGTP) was developed to fulfill some requirement of the spatial analysis and digital image interpretation for the study as described in section 2.4 of the original version of our MS. The package was written based on the spatial analysis model facilities in the Geoscience software namely ARC GIS; this is a set of tools that allows the derivation of various environmental parameters. That is why we called it GGTP model.*

*To determine the 2D biogenic soil NO emission source of the oasis at a fine scale matrix (30x30m<sup>2</sup>) the GGTP model was used. This means that the soil biogenic NO emission model is also part of the GGTP model, and that is why it appears in section 2.4.7 of our original MS.*

*Our response to the suggestion of Referee #2 regarding the title updating of sec. 2.4 by using soil emission estimate is as follow:*

*The GGTP model contains more than ten different geoscience spatial tools, and this model runs according to hierarchical routines, and in each step various parameters could be calculated. Within the framework of the GGTP model not only the soil NO emission is derived, but also land surface temperature, and the land use classification the results of which are used for the “bottom-up biogenic emission calculation”. Thus, we prefer to use the title as GGTP model. However, to follow the suggestion of Referee #2 (see above comment 1), the whole GGTP part of the MS (section 2.4), except land use classification and land surface temperature, was moved to the supplement.*

*In our revised MS, the sec. 2.3 (laboratory part) was not merged with the sect. 2.1 (site description part). We think, that the “bottom-up biogenic soil NO estimates” should represent a holistic way. Section 2.3 of the original MS is one of the important parts of the calculation*

*of bottom-up biogenic soil NO estimates, and it appears now as sub-title (2.3.1) of “bottom-up calculation of biogenic NO emission estimates (sec 2.3)” in revised MS.*

*To follow the suggestion of Referee #2 related to an update of section 2.4 of the original MS and to present the objectives in the most coherent way to the reader the calibration and validation of soil parameters sections (2.4.5 and 2.4.6 of original MS) were moved to the Supplement. All related results and discussions in section 3 were also moved to the supplement.*

**3) I would suggest moving the contents on the biogenic emissions from soil in Sect. 2.5. (e.g. the whole Sect. 2.5.2, which introduces the FF and Q10F) to the new section describing the soil biogenic NO emissions (as suggested above). These parts are related to human activities via soil. It would better to include them in the soil NO model to address the soil NO emission variations by ecosystem management. If possible, a sensitivity study can be carried out to investigate such anthropogenic effect by changing FF and Q10F. At the same time, just keep the contents that are related to the anthropogenic emissions from fuel composition. It seems that all the emission factors were taken from the literatures, and thus this section can be more concise by just using citations. The formula (18), Table 1 and Fig. 15 can be omitted, and instead the contributions of industrial and traffic activities to the total anthropogenic emissions may be described.**

*The authors would like to thank Anonymous Referee #2 for his/her suggestions. In our revised MS, we have considered the above comments of Referee #2 concerning the new section. Given the restructuring of the revised MS, the contents on the biogenic emissions from soil were described in a new section (see sec. 2.3 Bottom-up calculation of biogenic NO emission estimates). The impact of the fertilizer application on the NO-fluxes (FF, Q10F) was outlined in the subsection 2.3.4 (page 13 and 14 in revised MS).*

*As described in our original MS (sec. 2.4.7), the areal distributions of NO emissions can be calculated in a fine scale matrix (30x30m<sup>2</sup>) within the framework of the pixel-based soil NO model (see supplement S1.9 of the revised MS). However, these are only “snapshots” (“taken” at 5 10:45 LT of the six selected days). With regards to the suggestion of Referee #2 regarding the ecosystem management in the soil model we give the following responses:*

- the parameters of agroecosystem management such as irrigation regime and fertilizer application must be considered at temporally high resolution (diurnal cycle) since there are large diel to weekly variations of soil moisture and soil nutrient content caused by the applied irrigation and fertilization schedules,*
- 2D soil NO model control runs can not model the applied irrigation (drying-out shape function) and fertilization schedules since the diurnal cycle of the applied irrigation and fertilization schedules can not be taken into account for the corresponding pixel area,*
- however, the diurnal cycle of soil NO emissions with the consideration of the agrosystem management parameters was well represented within the framework of the “bottom-up emission estimates” and not in the scope of the 2D model. It can be emphasized that within the framework of the “bottom-up emission estimates”, the calculation must not take into account the pixel-based model runs, but it required the temporally high-resolution data.*

*The human impacts on soil emissions could be explained by changing FF and Q10F; A sensitivity analysis could investigate the change of the anthropogenic effect that results from changes in the agrosystem management. We appreciate very much the above suggestion of Referee #2 concerning to sensitivity study. However, taking into account the available data of fertilizer application, a sensitivity study by changing FF and Q10F could not be performed, since for the investigation of the anthropogenic effect on soil emissions by changing of FF and Q10F, the long-term trend of the fertilizer application must be considered.*

*Since the study area's anthropogenic emissions predominantly originate from fossil fuel combustion of the energy and traffic sectors, it is necessary to show the emission factors for different economic sectors and fuel types. The anthropogenic NO<sub>2</sub> emissions were calculated based on the equation of 18. (in revised MS Equation S13). Thus, we are convinced that the Equation is relevant for the study. However, to describe the anthropogenic emissions in a concise way, the calculation part was moved to the supplement (S3.4). The contribution of industrial and traffic activities to the total anthropogenic emissions was described as emission source category in economic sector "k" (see page 16, in supplement S3.4).*

**4) I would also suggest removing the contents on the soil biogenic emissions in Sect.2.6. Just focus on the retrieval of regional NO<sub>2</sub> emissions from satellite observations. Are there any advantages or disadvantages in the retrieval of NO<sub>2</sub> emissions from an oasis in comparison with from a city by satellite data? In addition to OMI NO<sub>2</sub> data, were meteorological parameters, such as wind fields, used in the retrieval of this study? The retrieval of regional NO<sub>2</sub> emissions from the oasis by satellite is an important part of this study and needs to be described/discussed more in detail.**

*In our revised MS, we have considered the above comments of Referee #2. Given the restructuring of the revised MS, the contents on biogenic soil emissions (in old sect. 2.6) were moved to the sec. 2.3.4 (page 15). And the retrieval of regional NO<sub>2</sub> emissions from satellite observation is focused on section 2.5.*

*In principle the retrieval of NO<sub>2</sub> emissions over a city or oases is similar. However, usually the emissions from cities are higher and the corresponding enhancements can be better identified compared to the background.*

*We added the following text in the revised MS, sect. 2.5.1, page 18: "Satellite observations reflect contributions from different emission sources. In principle the retrieval of NO<sub>2</sub> emissions over a city or oases is similar. However, usually the emissions from cities are higher and the corresponding enhancements can be better identified compared to the background. In order to establish the relationship between biogenic NO<sub>2</sub> and satellite-derived NO<sub>2</sub>, it is necessary to understand their spatial patterns with respect to the locations and shapes of the potential sources. Thus, four different areas (see Fig. 3) were selected to represent (1) typical agricultural areas (study area) as biogenic source, (2) mixed land use areas (agricultural & small urban) as biogenic and anthropogenic sources, (3) large urban areas as anthropogenic source, and (4) desert area as background source."*

*The meteorological parameters, such as wind fields are not relevant for our top-down emission estimates because we sum up all satellite measurements for an area, which does not only cover the oasis but also the area with enhanced NO<sub>2</sub> VCDs. Thus we can assume that almost all (>90%) of the emitted NO<sub>2</sub> is destroyed before it is blown out from the considered area. We added this information to section 2.5.2, page 19.*

#### **Technical/Specific comments:**

**1. P34534, L7-9: It might not be necessary to emphasize the scaling from annual to monthly values. Instead, the anthropogenic NO<sub>2</sub> emissions from fuel composition might be mentioned.**

*Since the anthropogenic NO<sub>2</sub> emission inventories are available only on an annual basis, we feel that it is necessary to mention the scaling approach. In our revised MS, the anthropogenic emissions from fuel composition were described in more detail in section 2.4.*

**2. P34534, L12: are equal to?**

*"until" was changed "to".*

3. **P34534, L25: NO<sub>x</sub> = NO + NO<sub>2</sub>**  
*„ NO + NO<sub>2</sub>“ was added.*
4. **P34538, L11: county?**  
*„country“ was changed to „county“*
5. **P34547, L9: replace “proposed” with “used” because so many studies are cited.**  
*“proposed” replaced by “used”.*
6. **P34547, L23: I do not understand the word “space” here.**  
*The word “space” means here the shape between Ts and NDVI.*
7. **P34549, L11-12: Wagner et al. (1989) and Mallick et al. (2009) cannot be found in the Reference.**  
*Many thanks for Anonymous Referee #2. These references were added (in supplement).*
8. **P34551-34552, Sect. 2.4.5: no validation and calibration are presented.**  
*In revised MS, the validation and calibration of satellite-derived surface temperature and soil moisture data are presented in the supplement (S2, page 11-12; in Figure S4).*
9. **P34558, L9, the title for Sect. 2.5.3: it might not be suitable to use “assimilation” at least for the method of deriving monthly values of anthropogenic NO<sub>2</sub> emissions.**  
*The data of section 2.5.3 of the original MS were collected in various way such as modeling, temporal upscaling, personal communication and adapting. This type of data estimation which combine the model and accompanying data could be simplified by the term of “assimilation”. We added this information to supplement S3.*
10. **P34561, L27-28: there could be dust aerosols over the desert region.**  
*Yes, the reviewer Referee #2 is right. We added additionally “except sporadical dust”.*
11. **P34569, L2-4: The NO fluxes as function of theta cannot be found in Fig.9.**  
*There was a simple typo, Fig.8 instead of Fig. 9.*