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Answers to Referee #2

Thank you very much for your comments and suggestions on our study. Below we have inserted, in italics, explanations and clarifications to all the points you raised and describe how we have the revised the manuscript accordingly.

General comments:

- Title: The title doesn't clearly reflect the content of the manuscript. Indeed, this work is not only a modelling exercise, with the objective to provide isoprene emission estimates for one particular region, but really focuses on emission sensitivity and model evaluation, which I think is important to underline in the title. I would therefore suggest to reinforce the title to include these aspects of your study.

Following your comment and suggestion, we have changed the title to "Isoprene Emission Estimates for West Africa: MEGAN model evaluation and sensitivity analysis".

- Abstract: Comparing calculated emission fluxes with measured mixing ratios provides a qualitative, rather than a quantitative, model evaluation, and though valuable, also has some limitations. This kind of exercise on its own can't be a complete model evaluation, but is definitely an important step, complementary from other methods. I think it is important to include these aspects in the abstract. On the other hand, the sensitivity of isoprene emissions to changes in LAI and EF is demonstrated in the study, but could be quantified (in the abstract, and also in the text and conclusion when addressed), so that the abstract does not only reflect the general objectives of the study but also the important results (how much change related to LAI/EF, compared to temperature and radiation, min/max and mean for example).

A sentence in the Abstract has been re-written to emphasis the qualitative nature of the model evaluation when using the observed isoprene concentrations.

"These data have been used to make a qualitative evaluation of the model performance."

Further a sentence which quantifies the impact of the LAI and EF accordingly to the sensitivity analysis performed has also been added to the abstract.

"It was concluded that changes in EF and LAI may lead to emission differentials ranging from -85 to 158% and from -86 to 181% respectively."

We have carefully considered the referees comment and tried to come up with a sentence quantifying the sensitivity of the emissions to the EFs and LAI, but in the end decided that it would require too much explanation to be meaningful and this did not seem appropriate for the Abstract. We have however provided more quantification in the text – see below.

- Section 2, page 6927, lines 14-26: the discussion about how reasonable it is to compare observation distribution of isoprene concentrations with calculated emission fluxes is confusing, mixing altogether different aspects of the problem, and not completely convincing, to me. I think it is really important to make this discussion clearer, as it justifies the approach used later on in the study. For example, lines 21-24: "isoprene was transported around 1_. . .., but that its mixing ratios had declined to around a third": what does that imply for the comparison? Which range of uncertainty?

We have reworded the text in this section 1) to make the discussion clearer by not mixing the discussion on day and night time together, but to have one after the other 2) to state how much of the data was actually collected during the day to strengthen the justification of its use for *emission model validation 3) to summarise by explaining the scales at which a comparison of observed concentrations and modelled emissions is justifiable and 4) to point to a further discussion of difficulties of comparing observed concentrations and modelled emissions on smaller scales in a later section. In revising this text we have also moved a couple of sentences that were previously in section 3.1 to this paragraph.*

"Figure 1 presents the portions of the flight tracks of the BAe-146 below 700 m above sea level and respective isoprene concentrations observed during the AMMA field campaign. In using these observed concentrations to evaluate modelled emissions one has to apply some caution as transport, dilution and chemical transformation may impact atmospheric concentrations. It is therefore important to consider the nature of the observed data and how this might limit any emission model evaluation. These measurements were almost entirely taken during the daytime (98.4%) when an altitude of 700 m was within the boundary layer and when isoprene has an atmospheric lifetime of around 1-2 hours during the daytime, so cannot be transported far from its source. The typical wind speed in the boundary layer was around 10 km hr^{-1} such that advection would only have displaced the emissions by about 10 km before the isoprene concentrations would have been reduced considerably through chemical reaction. A small percentage of the data (1.6%) were collected at night when 700m would have been above the nocturnal boundary layer and when the chemical lifetime of isoprene would have been longer. Measurements in the evening (Flight B219, 25th July) and early morning (B232, 14th August) show that the isoprene was transported around 1º of latitude (60 nautical miles or 120 km) northwards in the nocturnal flow, but that its mixing ratios had declined to around a third of their afternoon values. Therefore when looking at monthly patterns and at scales of a few 10s of km, it is reasonable to assume that the observed distribution of isoprene concentrations gives a good indication of the spatial distribution of emissions and as such provides a useful evaluation the model performance. When considering case studies of individual flights (even daytime flights), local environmental factors will affect observed concentrations and thus impact their comparison with modelled emissions, as discussed further in section 5."

- Section 3, page 6928, lines 8-9: which other gases and aerosols are calculated by MEGAN?

MEGAN calculates emissions for several gases and aerosols in a total of 138 species. However, in this study, we have just analysed the isoprene emission estimates.

Which MEGAN version and parameterisation have been used for this study?

MEGAN v2.04 has been used in this study in its default setup, i.e., production and loss within plant canopies and soil moisture correction factor are assumed equal to one.
The first lines of section 3 now read:
"The Model of Emissions of Gases and Aerosols from Nature, MEGAN v2.04, has been applied to estimate the isoprene emissions over West Africa for July and August 2006.
MEGAN is an emissions model that estimates the net emission rate of isoprene and other trace gases and aerosols from terrestrial ecosystems into the above-canopy atmosphere at a specific location and time [Guenther et al., 2006]. Figure 2 presents its input/output structure.
MEGAN, in its default setup, requires two types of inputs:"

- Section 3, page 6928, lines 20-23: for this study, did you use for PFT-specific emission factors or pre-determined standard EFs? Crops are mentioned several times in the paper but doesn't appear in the EF category: have they not been taken into account specifically for EF?

We have used pre-determined standard EFs. Specifically we have used the area average EFs database available at Megan Community Data Portal that considers a single EF for each location and it accounts for the emission activity of each type of vegetation (PFT) present in each referred location.
Lines 21 to 24 on page 6928 were revised accordingly:
"The emission factors can be considered within MEGAN as a function of the PFT at each location (PFT-specific emission factors) or pre-determined standard EFs for each location, based on each type of vegetation (PFT) present, can be supplied as input."

- Section 3.1, page 6929, lines 18-24: what is the MCDP LAIv datasets based on? Again crops are not mentioned for the PFT distribution: were they not considered?

This is version 2.0 of the MEGAN LAIv global dataset available at the Megan Community Data Portal and described in Guenther et al. 2006. LAIv are averaged over vegetation covered surfaces.
The standard MEGAN global classification scheme includes seven PFTs: broadleaf evergreen trees, broadleaf deciduous trees, needle evergreen trees, needle deciduous trees, shrubs, crops, and grass. However, the PFT database used for the simulations considers the herbaceous PFT including grassland and cropland. This was made clearer in the revised manuscript. In section 3, where MEGAN inputs are described (point 1) Landcover data) one can read now:
"Four different PFTs are considered by default in MEGAN – broadleaf trees, needle leaf trees, shrublands and herbaceous (including grass and crops)."

- Section 3.1, page 6930, lines 15-16: I don't understand the sentence "High values of EF are given for some northern parts of this region, consistent with the LAIv fields": to me there's no reason why EF and LAI should vary the same way along the region studied, but is this linked to the way average values are calculated?

As mention above, the pre-determined EFs are based on vegetation cover, and LAIv values also reflect the vegetation cover of a specific location. This explains why EF and LAI may vary the same way along certain areas of the study region.

- Section 3.1, page 6931, lines 1-5: were nocturnal measurements also considered for this comparison? If transport, in this case, doesn't affect strongly isoprene concentrations, what about other parameters mentioned such as dilution and chemical transformation?

Yes, all measurements were considered. We haven't removed night-time data from Fig 1 but they represent less than 2% of the measurements. We have moved the sentences in these lines to section 2 where we have a more complete discussion of the comparison between observed concentrations and modelled emissions. There we describe the observed change in the concentration distributions between day and night. These will be affected by transport, dilution and chemical transformation (i.e. not just transport). We hope that in the re-writing of section 2 (as described above) we have made a clear justification for the way we have then, in section 3.1, used the observed concentrations to evaluate the model.

- Section 3.1, page 6931, line 10-11: which LAI is used by Muller et al. (2007) and how can you explain the differences between both studies?

Muller et al. (2007) have used LAI from MODIS satellite data. This information was added in the revised manuscript in the sentence:
"Their calculation was driven by LAI from MODIS and meteorological fields (air temperature, cloud cover, downward solar irradiance, wind speed, volumetric soil moisture in 4 soil layers) provided by analyses of the European Centre for Medium-Range Weather Forecasts (ECMWF)."
We believe the differences between Muller's and our study are mainly due to the different meteorological inputs (ECMWF and WRF, respectively) as referred to on page 6931, line 18, and also the different spatial resolutions: 0.5º and ≈ 0.36 (40 km) respectively.

- Section 3.1, page 6931, line 24-27: Shorten or cut the sentence to make it clearer. You mention processes or factors that could affect the comparison: which ones for example?

"There may be other factors (e.g. soil moisture, other meteorological parameters, ...) which are not taken into account by MEGAN that altered the rates of isoprene emissions between July and August. Further the lifetime of the isoprene make been different between the two months, which would have affected the observed concentrations."

- Section 3.2: page 6932, line 10-15: "The EFs and the LAI clearly have the greatest impact. . .": as it is not very clear to differentiate different percentages from the figure, could you give min/max/mean (some of them) values for the impact of the different variables on emissions?

We have considered the referee's comments. Whilst we agree that it would be good to provide some numbers, we do not consider that mean, min and max values are particularly useful. However, we do use these plots to demonstrate how the spatial patterns of the EFs and LAI affect the latitudinal gradient of the calculated emissions, in particular the transition at 12 ºN. We have therefore adjusted the text to read as follows:
"The EFs and the LAI clearly have the greatest impact on the spatial distributions of the monthly averaged emissions, with emission differentials ranging from -85 to 158% and from -86 to 181% respectively. They both contribute to the strong gradient observed around 12 ºN, with mean and standard deviations of the percentage differences north (south) of 12 ºN of -2±32% (55±25%) and -32±35% (61±40%) for the EFs and LAI, respectively. It is the EFs that are responsible for the band of enhanced emissions centred around 16 ºN, which do not correspond to observed concentrations of isoprene. This band of enhanced emissions, together with the surrounding reduced emissions, leads to the mean percentage impact of the variability of the EFs on the calculated emissions north of 12 ºN being close to zero (i.e. -2%)".

- Section 3.3, page 6932, line 21-27: What are the main differences between WRF and MM5 meteorological conditions for this region? As temperature and radiation are strong drivers in isoprene emissions, any change in meteorological conditions and model could strongly affect the emissions, and therefore make any emission change more difficult to understand. Why not using the same model to provide meteorological conditions at every different resolution, to by-pass the emission change related to meteorological model change? Couldn't WRF be run at higher resolution of MM5 at lower?

You are right it would be easier to evaluate the emission change due to meteorological conditions if the same meteorological model had been used. When this work started our idea was to try to use meteorological simulation results already available within the scientific modelling community of AMMA Project and thus skipping the step of doing the meteorological simulation which was not the main objective, just a required input. Once we analysed the results of this coarser resolution application we realized that it was important to increase the spatial and temporal resolution to attain the goal of comparing observed and simulated data. We have run MM5 for this purpose because one of the authors has previous experience with MM5 model and that was the only meteorological model we had available to run by that time. We realise that this model change adds additional variables to the comparison between the low and high resolution simulations, but this is as a consequence of the data that was available to us during the project.

- Section 3.3, page 6934, lines 8-23: To add quantitative information, could you precise the total isoprene emissions for the whole region studied in the different simulations, for July and August?

As suggested by the referee the total isoprene emissions for both simulations were calculated for July and August, considering the area of WA2 domain. The following sentence was added in line 13 of page 6933:

"The total monthly isoprene emissions estimated were higher for the higher resolution application: 0.43 Tg as opposed to 0.10 Tg for July, and 0.31 Tg versus 0.12 Tg for August, for the area of WA2 domain (≈ 825 000 km2)."

Specific comments:

- Introduction page 6926, line 2: remove “the” in the sentence “a relatively clean environment in which to the study biogenic emissions”.

There was a typo in this sentence. We have deleted “the” so that the sentence now reads:

“Thus the West African Monsoon provides a relatively clean environment in which to study biogenic emissions and their regional effects on tropospheric chemical composition.”

- Section 2, page 6927, line 3: replace “5 research aircraft” by “5 research aircrafts”

Aircraft is also plural so I would prefer not to make this correction

- Section 2, page 6927, line 7: remove fullstop in “measured above the UK. Facility”

This was corrected in the revised manuscript.

- Section 3, page 6928, line 17: replace “LAI values are needed for the months of the model simulation and the preceding month” by “LAI values are needed for the month of the model simulation and for the preceding month”

This was corrected in the revised manuscript.

- Section 3, page 6929, line 5-6: replace “isoprene emissions estimates” by “isoprene emission estimates”

This was corrected in the revised manuscript

- Section 3.1, page 6931, line 11: replace “Further MEGAN gives slightly..;” by “Furthermore, MEGAN gives slightly. . .”

This was corrected in the revised manuscript

- Conclusion, page 6938, line 8: replace “provides insight into the model behaviour” by “provides insight on the model behaviour”

This was corrected in the revised manuscript

- Conclusion, page 6938, line 16: replace “which point to the need for improvements to the emission factors” by “which point out the need to improve the emission factors”

This was corrected in the revised manuscript and the sentence now reads:
“which point to the need to improve the emission factors in this region.”

Tables and Figures:
- Figure 2: right-hand of the figure replace “PTF” by “PFT”
- Figure 4: make sure the figure appears bigger when published
- Figure 9: To make it easier to analyse, could you add the flight track in the temperature and radiation figures as well?

These corrections have been made in the figures of the revised manuscript, and hence different panels of figures 3 to 10 were numbered a, b, c... to be read easier.