Response to Editor

Thank you for your careful consideration of the previous round of referee comments. The manuscript is substantially improved. However, I agree with the referee reports that further revision is required. Please consider the comments raised by the referee's in this latest round of reports. In particular, please address the comments related to the uncertainty in the trends.

Response: Dear editor, thank you so much for your precious time and great works. In this round, we provided plenty of additional analysis to address the reviewers' concerns. Some analysis is only provided in this response file not in the revised paper since these contents are mostly for addressing the reviewers' questions. In addition, we followed the reviewers' comments and modified the title and the conclusions of the paper, which can better conclude the content of the current manuscript.

We also changed the name of the authors' institution #1 in the paper from "College of Global Change and Earth System Science, Joint Center for Global Changes Studies, Beijing Normal University, Beijing 100875, China" to "College of Global Change and Earth System Science, Beijing Normal University, Beijing 100875, China" because the "Joint Center for Global Changes Studies" has been canceled recently.

Response to Referee #1

First, thanks to the authors for the great efforts in revising the manuscript. I saw many places that have been changed, including newly-added tables and uncertainty discussion etc.

Response: Thank you so much for you precious time and constructive comments. We already revised the paper following your comment, and the point-by-point responses have been given as below.

The title of this study is "Land cover change dominates decadal trends of biogenic volatile organic compound (BVOC) emission in China". However, in this new version of figure 4, there is no clear trend in the total emissions (see S1 in Figure 4d), so for me, then the current title is misleading. This also goes to the descriptions in the abstract (Line 20-21). The significant trend found in S2 is with the fixed climate inputs to 2001, but cannot represent the modelled total emissions (i.e., S1).

Response: Thank you so much for your comment. We agreed with your suggestion, and the new title as "A long-term estimation of biogenic volatile organic compound (BVOC) emission in China during 2001-2016: the roles of land cover change and climate variability" according to the current content of manuscript.

Then, my another concern with Figure 4 is that if we remove the first two years (i.e., 2001 and 2002), can we still see the increase trend for S2 and S5? If not, what does that mean? Does that mean the land use management mainly occurs before the year 2003 nationalwide? And are these two years dominating the trend you actually detect for the whole time series? Or can you see the gradual changes from 2003 also contribute to the trend? Response: Thanks for your comment. The reviewer raised a very interesting question, so we analyzed the results without considering the first two years. As shown in Figure R1, after removing the first two years, the scenarios other than S2 didn't show statistically significant trends for most of species as expected by the reviewer, however, the scenario S2 with the fixed climate inputs of 2001 and the annually updated land cover still showed statistically significant increasing trends for all species, which means the change of land cover is not dominated by the first two years. We can further take a look at the horizontal distribution of changing rate. Figure R2 presented the horizontal distributions of BVOC emission trends in different scenarios since 2003. In the revised manuscript, we presented the same figure but with the data starting from 2001. A nationwide significantly increasing trend caused by the vegetation development can be found in scenario S2 (c, i, o and u in Figure R2), and it is very close to the situation we found in the original figure with the data starting from 2001. In addition, the analyses for hot-spot regions in the revised paper also indicate that the first two years are not the dominate factor of increasing trend in these regions. For instance, as shown in Figure R3 (Figure 7 in the revised manuscript), we found that the LAIv as well as the tree cover fraction (broadleaf + needle leaf) in these regions are still in an increasing trend if we ignored the first two years. Therefore, we can't say that this land cover change occurred before 2003, and it is long-term change between 2001 and 2016.



Figure R1. Annual BVOC emissions in China during 2003 to 2016 for five scenarios. The increasing trends and the probabilities (p) using the Mann-Kendall test are shown in the legend.



Figure R2. The horizontal distributions of isoprene, monoterpenes, sesquiterpenes and total BVOCs emissions of China in 2003 are shown in figure (a), (g), (m) and (s), respectively. The rest of the columns of figures present the changing trend of isoprene (b-f), monoterpenes (h-l), sesquiterpenes (n-r) and total BVOCs (t-x) in S1, S2, S3, S4 and S5, respectively, from 2003 to 2016. The Mann-Kendall test was used to mark the grids where the p is smaller than 0.1.



Figure R3. The annual changes of PFTs, the annual emission amount of BVOC and LAI in (a) northeastern China, (b) Beijing and its surroundings, and the (c) Qinling mountains. The solid, dashed and marked line represents the mean emission flux rate of total BVOC in S1, S2 and S5, respectively.

On the same topic, now if we have a look at the significant trend of isoprene and HCHO in this study (figure 9), there are very few dots on both maps, meaning the majority does not have significant changing trend (not even mentioning increasing trend), right?

Response: Thank you so much for your comment. Firstly, we need to mention that the OMI HCHO product starts from 2005, so the results we presented in Figure 9 are from 2005 to 2016. We compared the results from the full scenario S1 with the OMI HCHO product. The trend of isoprene in S1 is also affected by the variability of climatic conditions, therefore, it is not as strong or significant as the increasing trend in S2.

Then just curious what causes the large decrease in emissions in Jiangxi, Hunan and Fujian areas.

Response: Thank you so much for your comment. The decrease of BVOC emission in Jiangxi, Hunan, Fujian and Zhejiang Provinces is caused by the variability of meteorology. As shown in Figure R4, the decreasing trends of BVOC emission are relatively more obvious in the scenarios of S1, S3 and S4, and these scenarios all considered the variability of meteorology. Temperature and downward shortwave radiation also indicate a decreasing trend in the same region as presented in Figure R5 (Figure 3 in the revised paper). Especially, the downward shortwave radiation is showing a significantly decreasing trend, which is caused by the variability of total cloud cover (He and Wang, 2020). In addition, the decreasing trend in these provinces is also found in other similar studies as we presented in the revised paper (Figure 10 and Figure 11 in the revised paper), and the climatic variability is the main driver of variation of BVOC emission in these studies.



Figure R4. Spatial distribution of BVOC emission in 2001 (a) and the changing trends of annual BVOC emission flux in different scenarios (b-f). The Mann-Kendall test was used to mark the grids where the p is smaller than 0.1.



Figure R5. The trend of growing season averaged 2-meter temperature (T2) and downward shortwave radiation (DSW). (a) and (b) are for in-situ T2 and DSW, respectively, and the sites with statistically significant trend are marked by black circles. (c) and (d) are for the WRF simulated T2 and DSW, respectively, and the regions with statistically significant trend are illustrated by shadow.

I still think there should be a table that lists emission factors for those included compounds and for available PFTs. It provides basic information for readers to understand emission differences among different PFTs.

Response: Thank you for your comment. As mentioned in our previous response, we adopted the default emission factors for different PFTs in the MEGAN model (Table 2 in Guenther et al. (2012)). We already have a lot of figures in the manuscript, so we added this table to the supplement and revised the corresponding description in the revised manuscript as: "We adopted the default emission factors for PFTs described in Guenther et al. (2012), which have been presented in the Table S4 in the supplement."

It is difficult to remember what processes are included or excluded for S1-S5, and I would suggest to use more meaningful names for these scenarios. Furthermore, it will be a good practice that all abbreviations in figures are explained in the caption.

Response: Thank you for your comment. We will follow your suggestion and add the full name of abbreviations in the captions. About the name of scenarios, we reconsidered your suggestion. If we use other longer and more informative names to represent these scenarios instead of using the short names, the whole article may become lengthy. Since we already provided a table (Table 1) to present the configuration of different scenarios, and our discussions are mostly based on S1 and S2. Therefore, we will continue to adopt the current way to represent different scenarios.

Then about paper structure, the usage of HCHO is to evaluate the isoprene emission variability and trend, and for this, this should somehow present before analyzing the spatial and temporal changes of different scenarios.

Response: Thank you so much for your comment. About your suggestion, we reconsidered the structure of the current paper, and we finally decided that we would keep the current structure. Because we already found some in-situ flux measurements published in recent years and compared them with our results. If we continue to use the comparison between the HCHO data and the isoprene emission estimated in this study as a validation or evaluation, it may confuse readers when they read the later part.

P10, L8-9, "The interannual variability of isoprene emission estimated in this study ..." so do you mean that the modelled annual isoprene emission is evaluated with JJA HCHO data? Why not look at the same months?

Response: Thank you so much for your comment. Actually, we compared the JJA averaged isoprene emission with the JJA HCHO data. We feel sorry that we misled you at this place and we already revised this sentence as:

"The interannual variability of isoprene emission estimated in this study was evaluated by comparing the summer (June-August) averaged isoprene emission with the summer averaged HCHO VC."

P10, L23, "low anthropogenic influence", is there any reference that can back up this? As far as I know, some of these areas are highly developed and with heavy industry. Then the sentence after, I would also argue that this non-correlated area could be potentially linked to the less-constrained emission factor for crop PFTs, right?

Response: Thank you so much for your comment. We agree that some regions are highly developed and with heavy industry. As mentioned in revised paper, the comparison between the isoprene emission and the HCHO data is also affected by the absence of some physical and chemical processes, including transportation, diffusion, and chemical reactions. However, the general pattern in Figure 9 shows that the regions with high LAI have positive correlation between the HCHO data and the isoprene emission. In addition, the spatial distribution of

anthropogenic VOC emission can further illustrate this. Figure R6 shows the spatial distribution of anthropogenic VOC emissions in China estimated by Wu et al. (2016), and the regions with high anthropogenic VOC emissions are also the regions with high HCHO concentration (Figure 9 in revised paper) and low correlation coefficient. The reviewer also mentioned the impact of the less-constrained emission factors for crop PFTs, but we think the impact of anthropogenic VOCs are more dominant in these regions. The distribution of crop in China is shown in Figure 1 in the revised paper, and the regions like North China Plain have very high crop cover rate as well as strong anthropogenic emission, and the spatial pattern of HCHO has illustrated that the anthropogenic emission that dominate the precursors of HCHO not the isoprene from crop in the regions like North China Plain.



Figure R6. The spatial distribution of anthropogenic VCO emissions in China at a resolution of 36x36 km for 2008-2012 (Wu et al., 2016).

P10, L33, when talking about the increasing trend, did the author only refer to the significant ones (dots in figure)? There are very few points are actually significant, even using the p threshold value of 0.1. Then I did not get what does the sentence starting with "the increasing trend pattern of isoprene emissions ... " mean?

Response: Thank you so much for your comment. Here we referred to the grids with a positive trend in this region. Although only a few grids passed the significant test with p < 0.1, the general pattern is showing an increasing trend. We agreed with the reviewer that the current expression is too bold. So, we rephased this paragraph as:

"For HCHO, developed regions such as the North China Plain have an increasing trend because of the increase of human activities (Smedt et al., 2010), there is also an obvious increasing trend of HCHO VC at Yunnan and Guangxi provinces in the south of China. Moreover, these regions,

especially Guangxi province also show a statistically significant positive correlation between isoprene emission and HCHO VC as presented in Figure 9d. This implies that biogenic emissions might be the main driver of the increased HCHO in Guangxi province, however, the absence of the physical and chemical processes like transport led to a large uncertainty to this conclusion. Here we conducted a primary comparison between HCHO VC and isoprene emission, and a more thorough study by using chemical transport model may help to further explain the relationship between the variability of HCHO VC and the isoprene emission."

What is the main reason for selecting different sizes of six regions to compare?

Response: Thank you so much for your comment. Our selection is based on the changing trends we found from Figure 5 and Figure 6 in the revised paper. Therefore, we didn't use the geographical boundaries as the criteria to select the regions of interest, and we chose the hotspots with positive trends and investigated the drivers of trends.

Response to Referee #2

The revised manuscript by Wang and co-workers is clearly improved and the majority of my previous concerns have been adequately addressed.

Response: Thanks for your precious comments. We have revised the paper following your comment. The point-by-point responses are list as follows.

I have however doubts regarding (i) the high magnitude of the LULC-induced isoprene trends derived from this study, as illustrated in Figure 4; (ii) the fact that adding up the trends due to LULC (0.64%/yr, S2), LAI (+0.21%/yr, S5), and meteorology (-0.08%/yr in S3 or -0.01%/yr in S4), does not result in the trend of the full model simulation (0.64%/yr, S1), as one would expect. Regarding the first point, the authors should include additional evidence for the very strong trend LULC by e.g. providing MODIS LULC trend maps. Response: Thanks for your comment. We think the changing trend (0.69%/yr in S1) of isoprene in the full scenario cannot be got from the linear summation of trends in other one factor scenarios. Firstly, the response of isoprene emission to meteorological conditions are nonlinear (Guenther et al., 1993). In addition, our estimations considered the spatial variability of vegetation types and meteorological conditions, therefore, the calculation of national scale total emission amount is affected by the spatial variabilities of vegetation types as well as climatic conditions and should not be a linear combination of two aspects. For example, as shown in Table 4, the changing trend of BVOC emission in S2 driven by LULC solely is about 0.04 g m⁻² y^{-1} (p<0.01) in Yunnan province region, and it increases to 0.1 g m⁻² y⁻¹ (p<0.01) in the full scenario of S1 by considering the impact of meteorology additionally. While in northeastern China, the changing trend of BVOC emission in S2 is about 0.02 g m⁻² y⁻¹ (p<0.01), but it decreases to 0.01 g m⁻² y⁻¹ after considering the impact of meteorology. Therefore, for some

regions, the meteorology condition is playing a favorable role but for somes are not. We already provided the trend maps of main PFTs in the previous version revised paper (Figure 6 in the revised paper and Figure R7 in this response file), and the PFTs as input for MEGAN model are derived from MODIS LULC data in IGBP classification system. The trend maps of the tree type cover fraction in MODIS MCD12C1 dataset are also shown in Figure R8 in original IGBP classification system. As shown in Figure R8, the MODIS MCD12C1 LULC product shows a increasing trend of forest in the regions like northeastern, central and south China, and the changing trend of forest is coincident with the increasing trend of BVOC emission estimated in S2 (Figure R7).



Figure R7. Spatial distribution of BVOC emission in 2001 (a) and the changing trends of annual emission flux (S1, S2 and S5), cover fractions of main PFTs and LAIv. The Mann-Kendall test was used to filter the grids where the p is greater than 0.1.



Figure R8.The changing trends (p<0.1) of tree type cover fraction in original 5km grids in MODIS MCD12C1 datasets.

The second point casts doubt on the interpretation of the results and the conclusions drawn. These two points need to be better explained and clarified in the next version.

Response: Thanks for your comment. We have revised the conclusion part, and we removed some inappropriate interpretation of the results and added more discussion about the uncertainties of the results. The conclusion part now is as:

"Satellite observations have shown that China has led the global greening trend in recent decades (Chen et al., 2019). In this study, we investigated the impact of this greening trend on BVOC emission in China from 2001 to 2016. We used long-term satellite vegetation products as inputs in the MEGAN. According to the estimation of model, we found the greening trend of China is leading a national scale increase of BVOC emission. The BVOC emission level in 2016 can be 11.7% higher than that in 2001 because of higher tree cover fraction and biomass. The comparison among different scenarios showed that vegetation changes resulting from land cover management is the main driver of BVOC emission change in China. Climate variability contributed significantly to interannual variations but not much to the long-term trend during the study period."

"We used the long-term record of satellite HCHO VC from the OMI sensor to assess our estimation of isoprene emission in China during 2005-2016. The results indicated statistically significant positive correlation coefficients between the isoprene emission estimate and satellite HCHO VC in summer over the regions with high vegetation cover fraction including the northeast, central and southern China. In addition, isoprene emission and HCHO VC both had a statistically significant increasing trend in the south of China, mainly Guangxi Province, where there was a statistically significant positive correlation supporting the estimated variability of BVOC emission in China. However, the absence of the physical and chemical processes, e.g. transport, led to a large uncertainty to this conclusion, and a more thorough study by using chemical transport model may help to further explain the relationship between the variability of HCHO VC and the isoprene emission."

"We conclude that uncertainties of this study mainly come from the emission factor, PFT and LAI inputs through comparing our results with other studies and flux measurements during 2010-2016 in China. The validation with flux measurements suggested that using the observation-based emission factor could largely improve the performance of model, but it also requires more much more efforts. Our results suggest that the continued increase of BVOC will enhance the importance of considering BVOC when making policies for controlling ozone pollution in China along with ongoing efforts to increase the cover fraction of forest."

Another question concerns the trends in surface temperature and radiation and their comparison to the trends at the sites shown in Figure 3. The upper panels of this figure are not very clear and the comparison is not quantitative. I recommend to provide a more quantitative comparison, as e.g. time series of modelled and observed temperature and radiation fluxes averaged over different large regions. In addition, you should compare the respective trends quantitatively, averaged over the same regions.

Response: Thank you so much for your comment. As shown in Figure R9, we defined five subregions to validate the meteorological inputs separately, and they are Northeastern China (40-54N, 118-135E), Central China (28-40N, 105-113E), Eastern China (28-40N, 113-123E), Southeastern China (20-34N, 95-105E) and Southern China (18-28N, 105-123E).



Figure R9. The trend of growing season averaged 2-meter temperature (T2) and downward shortwave radiation (DSW). (a) and (b) are for in-situ T2 and DSW, respectively, and the sites with statistically significant trend are marked by black circles. (c) and (d) are for the WRF simulated T2 and DSW, respectively, and the regions with statistically significant trend are illustrated by shadow. The boxes represent the sub-regions chosen for the regional validation of meteorology.

The validations of the region averaged 2-meter temperature (T2) and downward shortwave radiation (DSW) are presented in Figure R10 and Figure R11, and the corresponding correlation coefficient, mean bias (MB), mean error (ME) and root mean square error (RMSE) are presented in Table R1 and Table R2. The simulated temperature shows a large underestimation (MB=-4.70 °C) in southeastern China, which is caused by the complex topography there. For other regions, the WRF model shows a good performance high R values (about 0.99), and the MBs in these regions are in the range of -0.80~0.50 °C. The WRF model shows an overestimation for the

DSW simulation, and the MBs in these regions are in the range of 21.93~63.26 W m⁻². The reasons of this underestimation may be the misrepresentation of the radiative effect of the subgrid scale cumulus clouds (Ruiz-Arias et al., 2016) and the lack of physical processes for aerosol radiation effect (Wang et al., 2011;Situ et al., 2013). In addition, we can see that the performance of model is better in the north part than in the south part of China. The south of China has higher frequency of precipitation and clouds, which may amplify the defect of model on the sub-grid scale cloud simulation. We already added Figure R10, Figure R11, Table R1 and Table R2 in the revised paper, and the corresponding description is as:

"The regional scale validation was also conducted in five main regions (Figure S1) by comparing the averaged values of the observation and the simulation among the sites in the regions we defined, and the results (Figure S2 and Figure S3) and statistical parameters (Table S5 and Table S6) can be found in the supplement."



Figure R10. Validations of the daily 2-meter temperature in different regions.

Table R1. The statistic parameters for the validation of the region averaged 2-meter temperature in different regions. MB, ME and RMSE are shorts for mean bias, mean error and root mean square error, respectively.

| | R | MB(°C) | ME(°C) | RMSE(°C) |
|-----------|------|--------|--------|----------|
| Northeast | 0.99 | -0.71 | 1.31 | 1.60 |
| Centre | 0.99 | -0.89 | 1.12 | 1.42 |
| East | 0.99 | 0.50 | 0.95 | 1.13 |





Figure R11. Validations of the daily downward shortwave radiation in different regions.

Table R2. The statistic parameters for the validation of the region averaged downward shortwave radiation in different regions. MB, ME and RMSE are shorts for mean bias, mean error and root mean square error, respectively.

| | R | MB (W m ⁻²) | ME (W m ⁻²) | RMSE (W m ⁻ |
|-----------|------|-------------------------|-------------------------|------------------------|
| | | | | ²) |
| Northeast | 0.96 | 21.93 | 24.94 | 35.37 |
| Centre | 0.95 | 53.60 | 53.66 | 59.66 |
| East | 0.95 | 48.99 | 49.01 | 54.34 |
| Southeast | 0.87 | 31.91 | 37.61 | 46.38 |
| South | 0.90 | 64.26 | 64.51 | 71.13 |

The comparisons of the monthly anomalies of DSW and T2 are presented in Figure R13 and Figure R12, respectively, and the model captured the variabilities of DSW and T2 in these regions. The T2 observation shows a significant increasing trend in Southeastern China (0.0021 °C month⁻¹ with p < 0.05), and the model also shows an increasing trend (0.0013 °C month⁻¹) in the same region with p value of 0.19. The DSW observation shows a significant

increasing trend in Northeastern China (0.05 W m⁻² month⁻¹ with p < 0.001), Central China (0.05 W m⁻² month⁻¹ with p < 0.05) and Southeastern China (0.05 W m⁻² month⁻¹ with p < 0.05). The model also shows a significant increasing trend in Southeastern China (0.03 W m⁻² month⁻¹ with p < 0.1), but it missed the increasing trend in Northeastern and Central China, which may be induced by the simulation bias we mentioned above.



Figure R12. The comparisons of monthly anomaly of 2-meter temperature between the observation and the model simulation in different regions. The unit of trend is °C month⁻¹.



Figure R13. The comparisons of monthly anomaly of downward shortwave radiation (DSW) between the observation and the model simulation in different regions. The unit of trend is W m⁻² month⁻¹.

Specific comments/Language corrections

p.3, l.33: Add references, e.g. Palmer et al. (2003), Marais et al. (2012), Stavrakou et al. (2009), see below.

Response: Thanks for your comment. We have added these references in the revised paper as: "Since HCHO is an important proxy of isoprene in forest regions with no significant anthropogenic impact, satellite HCHO columns are widely used to derive isoprene emission at regional to global scales (Palmer et al., 2003; Marais et al., 2012; Stavrakou et al. 2009; Stavrakou et al., 2015; Kaiser et al. 2018)."

p.6, l.6-14: Most of this text can be found in Table 1, could be shortened

Response: Thanks for your comment. We have revised this part as:

"We designed five scenarios (S1-S5) to investigate the impact of land cover change and climatic conditions on BVOC emission. The configurations of the five scenarios are shown in Table 1: 1) S1 was considered as the standard or full scenario.

2) S2 was used to investigate the impact of the ecosystem and land cover variability on BVOC emission;

3) S3 and S4 characterize the effect of climate variability and compare the difference of BVOC emission induced by vegetation change between 2001 and 2016;
4) S5 investigate the contribution of LAI trend to BVOC emission trend solely;"

p.6, l.17: Replace 'which means the meteorological' by 'which means that the meteorological'.

Response: Thanks for your comment. We have followed your suggestion.

p.6, l.15-19: 'is not considered in this study' is mentioned twice in the same paragraph. Check and rephrase.

Response: Thanks. We have followed your suggestion.

p.6, l.23-24: Provide reference for the Theil-Sen and Mann-Kendall estimation methods.

Response: Thank you for your comment. We have added the references for Theil-Sen trend estimation method and Mann-Kendall trend test method.

p.7, l.19: Add 's' in 'demonstrate'

Response: Thank you so much. We have followed your advice.

p.7, l.5: Here and elsewhere 'didn't' should read 'did not'

Response: Thanks. We have followed your comment.

p.8, l.2: 'national wide' should be 'nationwide', here and elsewhere

Response: Thanks for your comment. We have followed your advice.

p.8, l.6: 'comparing to S2', read 'compared to S2'

Response: Thank you for your comment. We have revised in this part in the paper.

p.8, 1.7-9: Something is missing in this sentence. Reread and rephrase.

Response: Thanks for your comment. We have revised this sentence as: "The spatial patterns of changing trends of total BVOC emission and landcover parameters are presented in Figure 6. The cover fraction of broadleaf trees shows a strong increasing trend in the regions including northeastern, central and southern China. Meanwhile, the grass and crop cover fractions show a decreasing trend in these regions."

p.8, l.12: 'faction', should be 'fraction'

Response: Thanks for your comment. We have revised in this part in the paper.

p.8, l.17: read 'six regions of interest', and 'the six regions include'

Response: Thanks for your comment. We have followed your suggestion.

p.8, l.29: 'at a rate'

Response: Thanks for your comment. We have followed your advice.

p.9, l.13: Correct 'significantly trend' by 'significant trend'

Response: Thank you so much. We have followed your advice.

p.9, l.19: 'comparing that', replace by 'compared to that'

Response: Thanks for your comment. We have followed your advice.

references: use abbreviations of journal names

Response: Thanks for your comment. We have updated the format of references.

figure 5 caption: 'the rest columns', read 'the rest of the columns'; replace 'showed' by 'shown'; replace 'test were used' by 'test was used'

Response: Thanks for your comment. We have followed your advice.

References

Marais, E. A., Jacob, D. J., Kurosu, T. P., Chance, K., Murphy, J. G., Reeves, C., Mills, G., Casadio, S., Millet, D. B., Barkley, M. P., Paulot, F., and Mao, J.: Isoprene emissions in Africa inferred from OMI observations of formaldehyde columns, Atmos. Chem. Phys., 12, 6219-6235, https://doi.org/10.5194/acp-12-6219-2012, 2012.

Palmer, P. I, D. J. Jacob, A. M. Fiore, R. V. Martin, K. Chance, T.P. Kurosu: Mapping isoprene emissions over North America using formaldehyde_column observations from space, J. Geophys. Res., 108, D6, 4180, doi:10.1029/2002JD002153, 2003.

Stavrakou, T., Müller, J.-F., De Smedt, I., Van Roozendael, M., van der Werf, G. R., Giglio, L., and Guenther, A.: Evaluating the performance of pyrogenic and biogenic emission inventories against one decade of space-based formaldehyde columns, Atmos. Chem. Phys., 9, 1037-1060, https://doi.org/10.5194/acp-9-1037-2009, 2009.

Guenther, A. B., Zimmerman, P. R., Harley, P. C., Monson, R. K., and Fall, R.: Isoprene and monoterpene emission rate variability: Model evaluations and sensitivity analyses, Journal of Geophysical Research: Atmospheres, 98, 12609-12617, doi:10.1029/93JD00527, 1993.

Guenther, A. B., Jiang, X., Heald, C. L., Sakulyanontvittaya, T., Duhl, T., Emmons, L. K., and Wang, X.: The Model of Emissions of Gases and Aerosols from Nature version 2.1 (MEGAN2.1): an extended and updated framework for modeling biogenic emissions, Geoscientific Model Development, 5, 1471-1492, 10.5194/gmd-5-1471-2012, 2012.

He, Y., and Wang, K.: Variability in Direct and Diffuse Solar Radiation Across China From 1958 to 2017, Geophysical Research Letters, 47, e2019GL084570, 10.1029/2019GL084570, 2020.

Ruiz-Arias, J. A., Arbizu-Barrena, C., Santos-Alamillos, F. J., Tovar-Pescador, J., and Pozo-Vázquez, D.: Assessing the Surface Solar Radiation Budget in the WRF Model: A Spatiotemporal Analysis of the Bias and Its Causes, Monthly Weather Review, 144, 703-711, 10.1175/MWR-D-15-0262.1, 2016.

Situ, S., Guenther, A., Wang, X., Jiang, X., Turnipseed, A., Wu, Z., and Bai, J.: Impacts of seasonal and regional variability in biogenic VOC emissions on surface ozone in the Pearl River delta region, China, Atmospheric Chemistry and Physics, 13, 11803-11817, 2013.

Wang, X., Situ, S., Guenther, A., Chen, F. E. I., Wu, Z., Xia, B., and Wang, T.: Spatiotemporal variability of biogenic terpenoid emissions in Pearl River Delta, China, with high-resolution land-cover and meteorological data, Tellus B, 63, 241-254, 10.1111/j.1600-0889.2010.00523.x, 2011.

Wu, R., Li, J., Hao, Y., Li, Y., Zeng, L., and Xie, S.: Evolution process and sources of ambient volatile organic compounds during a severe haze event in Beijing, China, Science of The Total Environment, 560-561, 62-72, https://doi.org/10.1016/j.scitotenv.2016.04.030, 2016.