Response to Referee #2

We are grateful to the reviewer for their helpful comments and guidance that have led to important improvements of the original manuscript. Our point-by-point responses are listed below. Reviewer's comments are in italic font, and authors' responses are in dark blue font. Page and line numbers refer to discussion paper *Atmos. Chem. Phys. Discuss., 15, 11763–11797, 2015*.

1. Major comments.

I agree with all the points of Referee #1 with some additional comments:

Reviewer 1's concerns about the "observed" GPP are well founded. What are the meteorological drivers being used to determine fluxnet-GPP? Are the results just a comparison of different meteorological drivers? I don't believe so, but this should be addressed. I also don't understand how global fluxnet-GPP can be calculated from 1982 onwards when the only long-term flux sites were established in the 1990s.

Response: (1) The meteorological drivers being used to determine FLUXNET-GPP mainly include the fraction of absorbed photosynthetically active radiation (fAPAR), precipitation, temperature, sunshine hours, relative humidity, potential evaporation, etc. There are 29 explanatory variables in total used in the upscaling process (Jung et al., 2011). (2) The MLR analysis is applied to determine the relative importance of meteorological drivers in different regions and different seasons, which is then used to help explain the GPP-HCHO correlations and evaluate the global Earth system model. (3) The global FLUXNET-GPP dataset was generated using a machine learning technique: the model ensemble trees (MTEs) are firstly trained by GPP and site-level explanatory variables, and then globally gridded datasets of the same explanatory variables are applied to obtain global GPP estimates. The latter step does not require site-level observations. Therefore, this upscaling process is not necessarily required to be within the exact same time period as the flux tower site observational collection period. The FLUXNET-GPP dataset is available from 1982 when reliable satellite-data became extensively available to support the meteorological reanalysis used in the upscaling.

We made the following modifications of the original manuscript to state the above points more clearly.

At 11767/16, we added a description of the generation of the MTE FLUXNET-GPP: "The main steps of the upscaling procedure are processing FLUXNET observational data and calculating GPP for each site, training model-tree-ensembles (MTEs) for each GPP using site-level explanatory variables, and applying the established MTEs using global gridded dataset of the same explanatory variables to get global GPP estimates (Jung et al., 2011). Twenty-nine explanatory variables are used to train the MTE, including the fraction of absorbed photosynthetic active radiation (fAPAR), precipitation, temperature and other climate and land cover data (Jung et al., 2011)."

At 11774/22, we added: "We perform a multiple linear regression analysis of

FLUXNET-derived GPP and OMI-retrieved HCHOv against major meteorological variables to examine their climatic covariance and to determine the most important meteorological drivers in different regions and different seasons."

As stated by Reviewer 1, there needs to be a systematic discussion of the uncertainties inherent in both the fluxnet-GPP and the HCHO variability. What are the model uncertainties? Are they of a similar order of magnitude to the fluxnet-GPP and HCHOv? Was the model calculated GPP ever compared to the fluxnet-GPP? If not, then there needs to be a short discussion why.

Response: Please see response to reviewer 1, we added discussion of the uncertainty analyses at several points in the manuscript and have added the direct observationally-derived – model data comparisons in the supplementary materials.

CO2 has risen appreciably since 1982, could the fluxnet-GPP/HCHOv relationship have changed in this time? Use of fluxnet-GPP comparable in time to the HCHO time series should address this problem. Do the MLRs change when using only co-sampled (or close in time) data? Is Section 3.2 using only 2005-2011 data for both HCHOv and fluxnet-GPP?

Response: The reviewer raises an interesting question. The original MLR analysis uses monthly mean GPP data from 1982 to 2011, and HCHO data from 2005 to 2013, which are the complete available time ranges of each dataset. In response to the reviewer's question, we tested the MLR of GPP and HCHOv both using 2005-2011 data, and the results are very similar, the conclusions do not change in any way. Therefore, we chose to retain the original MLR using 1982-2011 for GPP and 2005-2013 for HCHOv in the manuscript because the longer periods facilitate assessment of statistical significance.

To avoid confusion, at 11774/24, we added: "MLR of GPP and HCHOv using 2005-2011 data (the overlapped time range) yields very similar results. A provocative implication is that the effects of decadal climate change (e.g. the rapid global rise in atmospheric CO_2 since 1982) do not appear to influence GPP's and HCHOv's seasonal climatic covariance in the contemporary period."

The discussion/conclusions are very short. I second Reviewer 1's suggestion of extending the discussion of soil moisture control on isoprene.

Response: Please see the response to reviewer 1.

Minor comments In Sentence 1: "radiative forcing of global climate change" doesn't seem like a complete sentence.

Response: We confirm that it is a complete sentence and the correct way to use the "radiative forcing" terminology.

Pg11766 line5. What are the other sources of HCHO? Can the destruction of HCHO be tied to precipitation by limiting O1D/OH?

Response: At 11766/5, we added: "Other HCHO sources include oxidation from CH_4, which provides a slowly varying background of HCHO, oxidation from other volatile organic compounds (VOCs), and direct emission from fires. Precipitation might affect HCHO indirectly by removing reactive carbon, nitrogen oxides and oxidants, thus dampening atmospheric photochemistry."

We also made some modifications in the results section to discuss the factors controlling HCHO column variability. At 11778/22, we added: "Precipitation may dampen photochemistry by limiting OH and O(1D) concentration, thus may have an indirect impact on both formation and destruction of HCHO."

At 11778/24, we added: "New research is showing that HCHO column variation reflects variation of OH production rather than isoprene emission variability, especially in low OH regions (Dr. L. Valin, Columbia University, personal communication)."

Pg 11769 line 1: Is surface temperature the air temperature at some height close to the ground (if so, what height) or the soil surface temperature (or if lower, what depth). These are two very different variables.

Response: We clarify: "surface skin temperature".