Response to Referee 2 (Referee's comments in blue, response in black)

It is a well-know problem that current chemistry models are unable to represent the magnitude of carbon monoxide (CO) in the northern hemisphere, particularly in winter and spring. This paper addresses this problem and highlights the sensitivity of modeled CO to emissions and hydroxyl radical (OH) concentrations. They then go on to provide a valuable insight into the importance of model biases in ozone, water vapor and nitrogen oxide emissions in driving possible biases in simulated OH concentrations. The paper is well presented and scientifically relevant and is well suited for publication in ACP after the relatively minor corrections that are listed below.

We thank the Referee for the positive review. We incorporated the specific comments as described below.

Main comments:

One of my main questions is why you use a chemistry climate model with free-running meteorology instead of a model with specified dynamics as your primary model. You show that when you use specified dynamics in the CO-only runs you reduce the model bias so I wonder what results you would get in section 3.4 if you also try a run with SD? It would be useful to give a brief description of why you employed each model version under section 2.2, as you have done for the CO-OH option on page 20312, L17.

Our goal is to understand the CO bias in free-running CCMs, since they are used to predict past and future changes in methane lifetime and other trace gas concentrations. We added the following explanation of this choice in Section 3.2.4: "The simulations discussed so far are free-running CCM simulations driven by SSTs, since our goal is to understand the biases seen in CCM studies such as ACCMIP." Following the reviewer's suggestion, we also added an explanation of what we use each chemistry option for to the explanation of the GMI chemistry and CO-only chemistry options in section 2.2, to match what we did for the CO-OH option: "We use the GMI chemistry option to quantify the impact of changes in CO emissions on methane, OH, and ozone." and "We use the CO-only option to calculate the influence of specific sources on CO concentrations, and to isolate the impact of specific changes in OH on CO."

Under section 2 give a brief description of how you change emissions, transport and OH prior to describing results. (Just simply by saying you apply scaling factors to emissions/OH and by switching between free-running and SD meteorology).

We added a paragraph describing this to section 2.2:

"We use a series of sensitivity studies to analyze the role of CO emissions, OH concentrations, and transport. Two methods are used to examine the sensitivity of

CO concentrations to CO emissions from different sources: scaling up the CO emissions, and scaling up CO tracers tagged by source. We quantify the sensitivity of CO to OH concentrations by applying scaling factors to the OH field. We analyze the sensitivity to transport by comparing a free running CCM simulation with a simulation that has prescribed meteorology. Several different chemistry options within the GEOSCCM framework are used to isolate specific processes."

Table 2: Add CO-only option for the OH information. It is useful to see what the OH looks like in the CO-only run and whether it differs from the CO-OH model. Consider also adding zonal mean plot of OH for CO-only simulation to figure 1.

The CO-only run uses the OH field generated by the RefGMI simulation. We do not show it in the table or figure because it would be identical to the RefGMI OH, which is already shown. We modified the wording in section 2.2.2 to clarify that the OH in the RefCOonly simulation is from the RefGMI simulation.

Figure 3: Can you show bias instead of absolute concentrations – may be easier to see differences between the runs?

We prefer to show the absolute concentrations so that we can also show the observations.

Pg20314 L9-11 – How different are the NOx, NMHC and CH4 archived fields used for the CO-OH runs compared to those calculated within the RefGMI run? Does this explain the OH differences or is it something else?

The archived NO_x, NMHC, and CH_4 archived fields are taken from the RefGMI run, so this does not explain the OH differences. We clarified that these are fields are from the RefGMI run in section 2.2.3.

Pg 20316, L8: Why exclude COnaa and CObio? Move this sentence to L13, after you've highlighted problems in increasing these regional emissions.

Done

Pg 20319, Section 3.3: How do you sample the model for comparison to the MLS/OMI total column ozone. Does the instrument see the full total atmospheric column of ozone? Do you remove any model data when there is missing observations? Are there any limitations that will have an impact on your results?

We now mention in section 3.4.1 that "No scaling is applied where the TCO data is missing". We added to Section 2.1: "The observations are cloud-filtered, so there is sensitivity throughout the troposphere, although there is some reduction in retrieval efficiency in the lower troposphere. "

Minor Corrections:

Pg 20306, L14 – Add reference for CO as primary sink for OH. Methane is also important, please change sentence to reflect this.

We reworded this sentence and added citations: "Carbon monoxide (CO) is an ozone precursor and a major sink of the hydroxyl radical (OH) in the troposphere [Logan et al., 1981; Spivakovsky et al., 2000]."

Pg 20313, L22-24: In figure 2 are the surface obs averaged over 1999-2009 also? Please indicate years used for each site.

Yes, except for Trinidad Head, which is averaged over 2002-2009, since earlier data was not available. We added the year information to the text.

Pg 20315, L17: Define IHG. Currently defined lower down in paragraph.

Done

Pg20315, L23: global mean. -> global mean concentration? Or global mean bias?

Global mean bias. We corrected this text to say "in the global mean".

Pg 20317, L16: Remove first sentence as repetitive and seems out of order. You state this lower in the paragraph.

Done

Technical corrections:
Pg 20311, L20: The simulation in pulled -> The simulation is pulled

Done

Pg 20312, L15: COonly -> CO-only

Done