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## ***Interactive comment on “An integrated assessment modelling framework for uncertainty studies in global and regional climate change: the MIT IGSM-CAM (version 1.0)” by E. Monier et al.***

**E. Monier et al.**

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### **Authors' Response to Anonymous Referee #1**

We appreciate the comments by the referee #1. We respond point by point to the comments.

### **Major concerns**

**-The modeling framework represents a single model and therefore a single model structure. I'm concerned that potential biases and model errors within CAM are simply being propagated across the entire IGSM ensemble. Perhaps coupling**

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**IGSM to a different atmospheric model would result in entirely different projected ranges. I think the authors should address these issues a bit more in the text. It could also be useful to compare the IGSM-CAM results with coupled CCSM3 or CESM, which also uses CAM as its atmosphere component (though the authors never explicitly state in the ms which version of CAM they are using). This could at least provide some information about whether the biases are shared between this modeling framework and NCAR's coupled GCM.**

The author agree with the reviewer that, if the IGSM were linked to a different atmospheric model, it would likely lead to different textures in the model bias and errors – and propagate into the range of projections. It will be mentioned more clearly in the revised manuscript. A comparison of the IGSM-CAM to the CCSM3 will be added in Figure 4 and Figure 5 to add more context to this issue of propagation of the potential biases and model errors within CAM. Finally, the version of the CAM model is given on page 2219, line 4.

**- I gather from the text that the coupling between IGSM and CAM is one-directional, in that SST, land use change, GHGs/aerosols simulated by IGSM are used as input to CAM. It would be interesting to check the consistency between the modeled state of CAM and IGSM's 2D atmosphere for overlapping periods. How do the zonal averages compare between the models? Is the mean state and projected trends preserved? The authors show that 2100 global projections of SAT and precip are consistent between previous IGSM runs and the IGSM-CAM model, but some additional diagnostics looking at spatial aspects of the agreement (zonal averages) would perhaps provide insight into the capability of the model to simulate regional changes... in particular for the hindcast period as well.**

The author will include an analysis that compares the IGSM-CAM zonal mean with the IGSM 2D atmosphere for the observed record and for the projections and a discussion and interpretation will be provided.

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- A central focus of the paper is on evaluating IGSM-CAM projections based on agreement with CMIP5 projections. I don't really see the value of these comparisons, since the forcings (emissions) are not the same between IGSM and CMIP5, as well as other limitations such as the aerosols not being spatially resolved in IGSM, which makes regional comparisons problematic. In order to evaluate the model's usefulness for projections, it would probably be better to focus more on evaluating the model against the historical record. This is done somewhat in Figures 4 and 5, but I think more diagnostics would greatly benefit the ms. Does the model reproduce past changes in emissions? What about model error for different time periods? Can it reproduce the mean state, seasonal cycle, and observed trends over the past 50 years? I think these types of comparisons would provide more insight into the model's utility and better highlight its strengths and weaknesses, particularly at the regional scales.

The authors believe that the comparison between the IGSM-CAM and CMIP5 projections is useful because it shows that within a single modeling framework (relying on a single 3D atmospheric model), the range of future changes exhibited by more than 20 models can be largely encompassed by sampling the climate system response. This indicates that structural uncertainty is not the largest and sole source of uncertainty in climate projections. This will be emphasized in the revised manuscript. However, the authors realize that more diagnostics would greatly benefit the manuscript. For this reason, the revised manuscript will include more evaluation of the IGSM-CAM against observations.

#### Specific Comments:

##### **P2214,L7: Which version of CAM?**

The version of CAM used in the IGSM-CAM framework is given on page 2219, line 4. We will reiterate the version several other times within the revised manuscript.

##### **P2215,L13: How does IGSM enable structural uncertainties to be treated as para-**

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**metric uncertainties? What do the authors mean by structural uncertainties?**

The Webster and Sokolov (2000) study describes the framework upon which structural uncertainties may be represented parametrically. In particular, it was shown that uncertainty in climate sensitivity associated with differences in parametrizations of physical processes used in different GCMs can be treated as an uncertainty in cloud feedback adjustment factor.

Webster MD, Sokolov AP (2000) A Methodology for Quantifying Uncertainty in Climate Projections. *Climatic Change*, 46(4), 417-446. Doi: 10.1023/A:1005685317358

**P2216,L6-7: How do the authors quantify "efficient"?**

The efficiency of the framework will be explained in the revised manuscript. There are two ways that make the IGSM-CAM an efficient framework: first, the atmospheric chemistry is resolved by the IGSM 2D zonal mean chemistry model, thus taking less computational time than full 3D chemistry; then, the IGSM-CAM makes use of the IGSM probabilistic ensemble projections and can then subsample them at key quantile values (i.e., 5th and 95th percentile, median) to obtain a first order assessment of regional uncertainties without necessarily having to run the entire set of members (400) from the IGSM ensemble.

**P2219,L25-27: The authors state that a bias is present in the seasonal cycle of SST, but anomalies agree with observations. What kind of anomalies are the authors referring to? Is the model capable of simulating realistic variability (anomalies) in eastern equatorial Pacific (ENSO), which can remotely affect regional climate through teleconnections? Further, how well does IGSM-CAM simulate ENSO variability and the associated teleconnections? This is important for assessing the model's skill at simulating regional surface temperature and precipitation.**

The anomalies refer to differences between an IGSM historical simulation and an IGSM

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control simulation corresponding to pre-industrial forcing. In addition, as stated in response to the major concerns, the revised manuscript will include more diagnostics and evaluation of the IGSM-CAM against observations – particularly with respect to natural variability.

**P2220,L3: The statement that IGSM-CAM does not account for spatial distribution of aerosols is troubling, given the potential impacts of aerosols on regional climate through dynamic feedbacks, such as linkages to the monsoonal circulations (e.g. ramanathan et al., 2005–pnas; Meehl et al., 2008–journal of climate). Can the authors reconcile this limitation in using the model to address regional climate change?**

The authors do not state that the “IGSM-CAM does not account for spatial distribution of aerosols”. As stated on page 2220, lines 3-4: “the IGSM-CAM does not consider potential changes in the spatial distribution of aerosols and ozone”. However, the authors realize that this is a strong limitation and in the future, the distribution of ozone and aerosol will be modified spatially as a function of the change in distribution of emissions (computed in the human system component of the IGSM-CAM).

**P2222, L24-26 – (Description of Figure 4): The comparison between IGSM-CAM error and the CMIP ensemble mean error is not particularly useful. It could be helpful to also see the direct comparison between IGSM-CAM with CESM (CMIP5) or CCSM3 (CMIP3), which uses CAM as the atmosphere component. Do these models share the same biases? However, such a comparison may also be problematic depending on which version of CAM is being used, and the stand-alone version of CAM may be optimized to different parameter values than the coupled version.**

As stated in response to the major concerns, a comparison the CCSM3 will be added to Figure 4 and Figure 5.

**P2222, L24-26: Figure 4– the relatively large error over North America and Eu-**

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rope for IGSM-CAM is particularly concerning, since the paper's focus is on regional scale climate projections. Do the authors have any explanation for the lack of agreement in these areas? P2223, L7: How do the precip biases in IGSM-CAM compare with the NCAR model?

Figure 4 and Figure 5 in revised manuscript will include a comparison with CCSM3 and an associated discussion. The bias over North America is likely caused by the inaccurate representation of the Hudson Bay in the IGSM 3-dimensional ocean.

**P2223, L22-23: I don't think Figure 5 makes the case that IGSM-CAM's skill in simulating precipitation is "reasonably good". A more fair assessment would probably be that it shares many of the same limitations as other CGCMs.**

The statement "Compared with the IPCC AR4 models, the skills of the IGSM-CAM framework in simulating present-day annual mean precipitation are reasonably good" will be changed to "The IGSM-CAM framework share the same limitations as the IPCC AR4 models in simulating present-day annual mean precipitation".

**P2225, L19-22: I'm skeptical about the claims of local extreme temperature changes, given these regions also coincide with large model biases compared to observations of around 3-4C for the mean annual temperature (Figure 4). More evaluation of the model in the context of the observational record is needed to make these claims more plausible. It could be helpful to show seasonal model/data agreement for different time periods (do the model errors and biases change with time and forcings?).**

The revised manuscript will include a comparison of past regional changes with observed trends and an associated discussion. It should be noted that a model does not require a realistic simulation of the present mean state to accurately simulate past (and future) trends. The authors will add the following citation to substantiate this statement:

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E, Drijfhout SS, Edwards NR, Eliseev AV, Feulner G, Fichet T, Forest CE, Goosse H, Holden PB, Joos F, Kawamiya M, Kicklighter D, Kienert H, Matsumoto K, Mokhov II, Monier E, Olsen SM, Pedersen JOP, Perrette M, Philippon-Berthier G, Ridgwell A, Schlosser A, Schneider von Deimling T, Shaffer G, Smith RS, Spahni R, Sokolov AP, Steinacher M, Tachiiri K, Tokos K, Yoshimori M, Zeng N, Zhao F (2013) Historical and Idealized Climate Model Experiments: An EMIC Intercomparison. *Clim. Past*, 9, 1111-1140, doi:10.5194/cp-9-1111-2013

**P2226,L18: It would be good to also see hemispheric comparisons in plots 9 and 10**

This will be added in the revised manuscript.

**P2226,L25: How many CMIP5 models are used in making these plots?**

The authors used the models that had archived the necessary data at the time of the analysis. This corresponds to 22 models. A list will be provided in the supplementary documentation.

**P2226,L29: "CMIP5 model" should be "CMIP5 models"**

This will be changed in the revised manuscript.

**P2227,L12: The large disagreement between precip in CMIP5 and IGSM-CAM is startling. Is it possible to decipher how much of this is due to differences in emissions versus using the CAM model? Is there perhaps some regional differences due to the fact that IGSM does not contain spatially resolved aerosols? I don't think agreement between IGSM-CAM and CMIP5 is necessary, since this constitutes a different modeling framework (with an additional human component and thus different forcings), but some additional discussion is warranted here.**

The authors agree with the reviewer that "I don't think agreement between IGSM-CAM and CMIP5 is necessary, since this constitutes a different modeling framework (with

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an additional human component and thus different forcings)". The disagreement likely suggests that there exist a large uncertainty in precipitation changes in regions like South America or Africa. However, additional discussion will be included. In addition, the authors want to emphasize once again that the IGSM does contain spatially resolved aerosols, however it does not include potential changes in the spatial distribution of aerosols.

**P2228,L17: The authors repeatedly state that the model is more computationally efficient, but they never explain or quantify this statement.**

This statement will be explained (see one of the previous comments).

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Interactive comment on Geosci. Model Dev. Discuss., 6, 2213, 2013.

**GMDD**

6, C1169–C1176, 2013

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