Geosci. Model Dev. Discuss.,
https://doi.org/10.5194/gmd-2017-169-RC2, 2017

Geoscientific Model Development Discussions

Interactive comment on "Coupling the Canadian Terrestrial Ecosystem Model (CTEM v. 2.0) to Environment and Climate Change Canada's greenhouse gas forecast model" *by* Bakr Badawy et al.

Anonymous Referee #2

Received and published: 16 October 2017

General comments

This paper addresses the challenge of coupling a terrestrial ecosystem model to an NWP model that has been adapted to forecast CO2 for the purpose of estimating CO2 fluxes using a flux inversion analysis system. This coupling is required in order to provide boundary conditions to the forward CO2 model and prior estimates for the flux inversion system. The main challenge stems from the differences in timescales required for the TEM to spin up and the short timescales used in NWP. The paper

presents an alternative configuration for the spin up suitable for the NWP model and compares the results with the standard spin up procedure. The results emphasize the large impact of meteorological biases on the biogenic CO2 flux biases, in particular over the tropics. Although there is a small impact on the estimation of CO2 growth rate when these fluxes are used as priors in flux inversion systems, there is a significant impact on the spatial distribution of the optimized fluxes, particularly in the tropics. All these aspects addressed are relevant scientific modelling questions within the scope of GMD, which are important to advance the use of earth system models to monitor the climate change.

The paper is well written and well structured. The methods used are valid and clearly outlined and the results are based on sound simulations with independent validation based on observations. However, the validation could be expanded to make better use of observations in the identification of regional biases both for the forward model and the optimized fluxes (see specific comments below). Test of statistical signficance would also be highly recommended in order to strengthen the conclusions drawn from the results.

Specific Comments

- Page 2, line 31: The sentence "Theoretically, in CCDAS, parameters of a TEM can also be optimized..." is a bit confusing. Isn't that what CCDAS aims to do?
- Page 3, line 2: The limitations of CCDAS should also be mentioned (e.g. inability to correct for model structure and missing processes).
- Page 3, line 9: Shouldn't "reduced CO2" be "increased CO2"?
- Page 6, line 15: Please remove sentence "(e.g. Agusti-Panareda et al. (2016) also had similar issues)". The TEM used in Agusti-Panareda et al. (2016) doesn't

have carbon stocks, so it does not require a spin up period.

- Page 7, line 29: Note that the TCCON observations and HIPPO data in free troposphere are not ideal to assess impact of fluxes because their sensitivity to the surface fluxes is small compared to in situ surface stations. Why weren't surface stations used for validation?
- Page 12, line 19: "the range of the other *model* estimat (Melton and Arora, 2014, Table 2)".
- Page 15, line 2: Why are only 2 sites used in the evaluation of the forward model? This evaluation is not enough to draw conclusions on the impact of the coupled fluxes on the atmospheric CO2 spatial/temporal variability at global scale. Please consider using more sites, if possible one site per TransCom region.
- Page 15, line 22: I do not agree with this statement. The differences between red and blue lines can be substantial in summer and autumn as shown in Figure 10. Please also consider the use of more sites for the validation to make the results more robust in terms of spatial distribution (see previous comment).
- Page 15, line 23-24: Again, I don't think one can say that the forward runs with the CTEM and the posterior fluxes are similar in Figure 10 when the different are around 5 ppm both at both Alert and Mauna Loa during spring, summer and autumn.
- Page 16, lines 10,11: There are significant differences in CTEM-based posterior estimates both in phase and amplites for NAmerica, Europe and Asia.
- Page 16, line 24: A small flux increment does not necessarily mean a more accurate posterior estimate. In order to conclude that it is necessary to compare

the resulting posterior estimate with independent observations of fluxes or compare posterior atmospheric CO2 concentrations with independent observations at sites that are sensitive to the biogenic fluxes.

- Page 17, line 26: Are these small differences in RMSE statistically significant?
- Page 18, lines 1,2 : These statement should be supported with a significance test of the error differences.
- Page 18, line 26: ".. datasets of analyses are simply not possible to obtain" unless re-analysis datasets are used.
- Page 19, lines 28-30: It is still not clear if the small differences in the error resulting from using CTEM-GEM or CTEM-CRUNCEP are statistically signficant. Unless this is shown, this statatement should not be used. Also, there is not explanation as to why one would expect the CTEM-GEM to provide a better constraint than CTEM-CRUNCEP for the inversion system.
- Page 19, line 31: This study provides insight into the deficiencies attributed to errors in the meteorological forcing (e.g. dry bias in precipitation over the tropics). It is not clear where is the insight into the deficiencies in the model.
- Page 19, line 33: It is not clear how can the approach in this paper help improve the performance of CLASS-CTEM. Please provide an example.
- Page 21, line 6: Please update the reference.
- Figure 8 shows a larger impact from meteorological forcing than from model formulation in NH summer, tropics and SH. This message should be emphasized in the paper.
- Figure 13 shows a large difference of NEE budget in Europe between CTEM-GEM and CTEM-CRUNCEP. This is not mentioned in the paper.

- Table 4: Please show station to station error (e.g. std of station bias) in order to evaluate the spatial variability of posterior CO2. This is commonly done in evaluation of CO2 satellite data. The ability of reproducing the global mean does not reflect the impact that the prior has on the posterior regional patterns.
- Table 5: The error with respect to the HIPPO data could be stratified in latitude bands in order to evaluate the interhemispheric gradient.

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