Biogeosciences

Discussions

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Interactive comment on "Simulating the atmospheric CO$_2$ concentration across the heterogeneous landscape of Denmark using a coupled atmosphere-biosphere mesoscale model system" *by* Anne Sofie Lansø et al.

Anonymous Referee #2

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This paper presents a coupled land-atmosphere model developed to simulate atmospheric CO2 mixing ratios over Denmark at high resolutions (here 5.6 km). The system includes a chemical transport model (DEHM) and a vegetation model (SPA) in addition to parameterized coastal fluxes and prescribed anthropogenic emissions of CO2. The evaluation of the SPA vegetation model was performed using eddy-covariance flux towers located across various ecosystems, while the simulated CO2 mixing ratios were compared to observations made at the Risø tower on the shore of Roskilde Fjord. The overall paper is well-written and the evaluation of the SPA model is well-documented.

Overall, the modeling system and more specifically the coupling between DEHM and SPA is well-described, with a tile approach similar to other systems (e.g. SiB-RAMS). The development of mesoscale systems for regional carbon studies is important to better understand the surface exchange of CO2 at finer scales. However, information related to the atmospheric model (here WRF), driving the DEHM chemical transport model, is completely absent. No information related to the WRF configuration is provided, and no evaluation of the model is included. This part of the system is critical, especially if this coupled system is intended to be used in regional inversions in the near-future. Even if not, the ability of the system to match the observed mixing ratios requires careful consideration of the meteorological performances. The paper has an extensive description and evaluation of SPA. The same should apply to the atmospheric model.

For this reason, the study requires a major revision with a dedicated section on the atmospheric model performances, and more specifically looking at the variables related to the transport of CO2 across the domain (i.e. wind speed and direction near the surface and above, and mixing heights). Because the Risø tower is located on the shore, an assessment of the land-sea air circulation should be a primary focus of this evaluation. The complexity of mesoscale circulation in cold waters and contrasted surface energy balance is challenging for meteorological models, and could impair the ability to simulate CO2 mixing ratios. With a description of the WRF simulations and an evaluation of the performances, this study would be suited for publication.

Another missing element for the SPA model evaluation is the absence of figures such as Taylor diagrams, or an illustration of the performances of SPA with different parameter values. A figure would help the reader to see the impact of your parameter optimization.

Additional comments are listed hereafter:

P1 – "Surface heterogeneity can be challenging to fully encompass by modelling

studies of CO2 surface exchanges, especially when it comes to land-sea boarders." Strange construction and confusing. Re-phrase. The first sentence should introduce the broader context of your study, and possibly the objectives in a broader context. Why do you need to understand the complexity of the land-sea border?

P1: "exploits" – Do you mean "explores"?

P1: "experienced" – showed, generated

P2: "These difficulties in simulating the local impact from the Roskilde Fjord might arise from" – What is the difference between (i) and (ii)? Isn't (ii) part of (i)? The third solution is not a difficulty but a possible physical reality. You should re-phrase the beginning of the sentence. And a fourth solution could be that the fluxes from the Fjord are small, hence not detectable.

P2 L10 – Eliminate is impossible. Any physical quantity has an associated uncertainty. What are these uncertainties? Cite studies that demonstrated our current uncertainties in the present carbon cycle are too large.

P2 L16 – Add references. Which surface observations are missing? All of them? Flux towers? Biomass measurements? Soil samples?

P2 – "These atmospheric inversions are capable of capturing the year to year changes in natural surface fluxes, the magnitude and distribution of regional fluxes, and distinguish between land and ocean fluxes (Le Quéré et al., 2015)." Several inter-comparison studies have shown large differences among inverse estimates. The study cited here is using aggregated inverse fluxes over large latitudinal bands or a land-ocean separation. This statement is very optimistic and very likely over-confident. See Peylin et al., (2013) for more details on global inversions.

P2: "atmospheric inversions are limited by the availability of atmospheric measurements" – And erroneous prior fluxes, errors in transport models, and simplified error covariances. Add citations related to limitations in inversions. Increasing the resolution

C3

and denser networks do not fix all the problems encountered by global inversions.

P2 L32: "advantageous" – Do you mean "necessary" or "required"?

P3 L6-14: Most studies have ignored coastal fluxes because flux measurements and model estimates suggest that coastal fluxes are negligible compared to terrestrial fluxes in most areas. A brief comparison of existing studies to provide a range of coastal fluxes would be useful. While very large amount of carbon will be transported from the land to the deep ocean, the net surface fluxes remain small. You should justify better why you expect significant fluxes in your case.

P4: "such different things as" - delete.

P4 L6: "it's" – should be "its"

P4: You need to describe briefly the nesting. And DEHM is a chemical transport model using existing meteorological fields. These input fields come from a simulation or an existing product. In your case, if you used WRF simulations, you need to describe these as well, including WRF configuration and the domain setup.

P4: "towards the Southern Hemisphere"- Very confusing. What do you mean here? You have not coupled the full boundaries of your simulation domain? How are CO2 mole fractions coupled to your simulations?

P4 L19-21: This description is too succinct. You need to develop that part significantly. Describe the physical schemes used in WRF, the domain, and simulation period (re-initalizations or continuous run?)

Figure 1: Add the vegetation type next to the name of the site. How did you calculate the standard deviation? Is it the STD using 30-min fluxes? or from the parameter calibration? Provid more details on your shaded areas (STD's) for both model and data.

P6 For the Skjern Enge site, the uptake seems over-estimated by the model, as you

C4

pointed out in the text. How much excess in uptake would that correspond to? You noted in the results, later in the paper, and in the abstract, how grassland plays a critical role in the annual uptake. Is it over-estimated by the SPA model?

P6 L27-28: Technically, the meteorological drivers come from the WRF model and not DEHM, to make it clear to the readers.

Section 2.3: This section is too succinct and provides very little details on the measurements. Which Picarro instrument was used? How often was it calibrated? Which standards did you use? Any publications looking at the data? Without a careful calibration, CRDS instruments from Picarro are not accurate enough to be used for CO_2 studies. You need to document your measurements here.

P7 L9: This sentence is confusing. You can write instead "As shown in Figure 2, the SPA model simulates an east-west gradient..."

P7: "their grow patterns" – Unclear. Do you mean seasonal cycle? plant phenology?

P7: "population density" – Do you mean that the vegetation is less dense because of urbanization?

P7: "In winter, GPP is highest for evergreen, grassland and agricultural other." – Respiration is higher during that time of year. Why do you focus on GPP in winter? What about the net positive flux?

P7: "Respiration is less concentrated for individual land-use classes and the individual monthly contributions vary much less for respiration than GPP throughout the year" – How different are your parameter values for respiration across land use classes? Could you explain why? Is it a reasonable result?

P8: The Danish CO_2 budget needs to be completed. When considering the total CO_2 budget of a country, one needs to include the lateral fluxes (export/import) of agricultural production, and include all the sources of CO_2 including animal livestocks. Otherwise you simply remove carbon from the country or from the food chain which

creates artificially a local sink in agricultural land not compensated by the emissions. If you want to discuss the national Danish CO_2 budget, you need to consider all the components of the problem. I would suggest you simply remove this part, unless you want to develop it with the other exchanges of CO_2.

P8: "Overall the model simulates the atmospheric CO_2 quite well, indicating that the simulated surface exchange of CO_2 is acceptable." Acceptable for what goal? How did you define the statistical success of your model? You need to discuss here what you want to accomplish with your system, and how you defined success.

P9: Autotrop[h]ic, heterotroph[h]ic

P10 L1-2: The range in values is so broad that the model can hardly fail. This is not very convincing to evaluate your simulated fluxes. Provide metrics instead (e.g. annual differences).

P10: "However, improvements to the evergreen plant functional type in SPA are needed" – Confusing. The model is fine (following the previous lines) but it needs improvement. Clarify why the model has to be improved.

P11: The discussion on the national CO_2 budget is weak. As noted above, this part needs to be extended to the entire nation including all the components, as you noted in the discussion.

P11: The "land-sea signals" discussion seems to argue that fjord fluxes are still important despite the limited impact on the modeled concentrations. If the tower location is a problem, you can sample your model in an optimal location to compute the maximum influence of the fjord on the CO_2 mole fractions. You can look at the potential impact on the potential measurement locations. In any case, the fluxes are small. Is it really important at the annual scale? You need to provide numbers to demonstrate this statement. The section argues that fjords are important for the CO_2 budget but without a clear demonstration.

P12: "to repeatedly simulate atmospheric transport to robustly quantify the impact of flux uncertainties on atmospheric CO2 concentrations due to their computational requirements." – Clarify. Why is SPA involved in atmospheric transport? What computational requirements?

P12: [at] a satisfactorily level

P12: "a satisfactorily level" – Again, you need to define why this is satisfying.

P12: "The usage of satellite retrievals by data assimilations systems and their accompanying improvements moreover highlights the future enhancement to the current modelling framework, where satellite products could be utilized for upscaling reducing the related error." – Very confusing sentence. Re-phrase. Which satellite data? What are the accompanying improvements? Future enhancements of what?

P12: "could be utilized for upscaling reducing the related error" – Which error?

P12: "while the choice of surface map could change the study region from an annual sink to source of atmospheric" – You need to clarify two things here. First, if you remove land from your map, you will make the fjord or the coast more important. What do you mean by "change the study region"? And second, even if you double your coastal flux, what would be the conclusions compared to the biosphere and the fossil fuel emissions? Globally, it matters, but regionally, aren't the conclusions unchanged?

Conclusions: Are there any measurements available to evaluate your coastal fluxes? Fig 2: Fonts are too small.

Fig 3: Your caption should include more information. Which driver data? at what resolution? and which formulation did you use?

Fig 4: "annual mean values" – Did you compute a running mean for each day of the year? or a trend?

Fig 6: Are these concentrations at the exact hour or hourly averages?

Fig A1: Fonts are too small. Caption needs additional information. Which model was used? At what resolution? . . .

Table 1: The references should list papers instead of data bases. Are there any papers documenting the flux data you used?