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Interactive comment on "Carbon Monitoring System Flux Net Biosphere Exchange 2020 (CMS-Flux NBE 2020)" *by* Junjie Liu et al.

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Dear Dr. Marshall, We appreciate very much your comments. Please see our responses below.

Original: My first hesitation is based on the appropriateness of publishing optimized fluxes in ESSD. These are not measurements, but rather, by definition, a model-based interpretation of measurements. In the description of the Aims and Scope of the journal it states that: "Any interpretation of data is outside the scope of regular articles." On some level this is a philosophical distinction, and it seems this article has made it through the first quick review process, so I have to assume that the editor does not see a major problem here.

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Discussion paper

Response: This is a reanalysis dataset, not a pure model simulation. It is a combination of observations and an apriori based on their respective error statistics. Reanalysis products have been used more broadly in research than the raw observations. For example, the meteorology reanalysis data sets (e.g., MERRA and ERA-5) have many more users than weather station data or satellite radiances.

Original: My next hesitation is on the criterion of "Completeness". This is one of the categories reviewers are asked to assess, stating that: "A data set or collection must not be split intentionally, for example, to increase the possible number of publications. It should contain all data that can be reviewed without unnecessary increase of workload and can be reused in another context by a reader." The current paper seems to be a classic case of withholding part of the dataset to release it in a future publication. The modelling system used has been well-documented in its ability to (quoting from the Introduction): "resolve regional fluxes, and also disentangle net biosphere exchange (NBE) into constituent carbon fluxes including plant gross primary productivity (GPP) and biomass burning through solar-induced fluorescence and carbon monoxide proxies, respectively (Bowman et al, 2017, Liu et al., 2017)." So is that what is reported here? No, they have decided to only report NBE, stating that" Subsequent papers will present the partitioning of the NBE into constituent gross fluxes." This seems like a clear infringement of the "Completeness" criterion. My recommendation would be to include the optimized GPP, biomass burning, and respiration fluxes in the same data release, and have an accompanying analysis paper (in another journal) that goes into the interpretation of the retrieved signals. One of the unique strengths of the CMS is its partitioning of the net land biosphere fluxes, which most modellers do not claim to be able to do with any confidence. It is this partitioning that would make the resultant fluxes more interesting for comparison against other approaches.

Response: We respectfully disagree that the data is incomplete per ESSD guidance. The NBE can be reviewed independently of component fluxes and can be re-used in many applications by the reader, e.g., comparison to DGVM output, understanding the

carbon-climate feedbacks etc. We agree that NBE can be more richly understood by partitioning it into component fluxes. However, there are multiple ways that this can be done, whether through independent data streams additional data streams (e.g., Liu et al., 2017; Bowman et al., 2017) or through a more sophisticated land-surface assimilation, e.g., Quetin et al, 2020. We do not want to prejudge that methodology or the additional data that might be used.

With respect to NBE, we report all the elements from the inversion system, including gridded fluxes, uncertainties, and regionally aggregated fluxes. We evaluate both the mean fluxes and the uncertainty estimates with independent observations.

We will modify the introduction to reflect the fact that we have not withheld dataset.

G. R. Quetin, A. A. Bloom, K. W. Bowman, A. G. Konings, Carbon Flux Variability From a Relatively Simple Ecosystem Model With Assimilated Data Is Consistent With Terrestrial Biosphere Model Estimates. J Adv Model Earth Sy. 12 (2020), doi:10.1029/2019ms001889.

Original: Finally, my third hesitation is related to the data quality. This is not related to anything that the authors themselves have done wrong, but there are (still) clear limitations to using only satellite data in an inversion. This has been well documented in the literature (e.g. Basu et al., 2013; Chevallier et al., 2014), and leads to an unexpectedly high source in northern Africa (and perhaps a too-large sink in Europe) that is hard to reconcile with bottom-up fluxes and inversions based on surface/in-situ measurements. The magnitude of this potential bias has decreased in more recent retrieval versions but has not disappeared. This discrepancy is clearly seen in the limited validation that is presented here, when the optimized concentrations are compared to the Atlantic ATom-1 and -2 flights. At least this inconsistency with independent data is documented: hopefully potential users of this dataset will not assume that their model is wrong simply because it disagrees with the CMS fluxes. One potential improvement here would be to include also fluxes optimized based on surface-based measurements,

to give some idea of the uncertainty in the fluxes as a result of the choice of input data. (The estimated fluxes will most likely not agree within the stated uncertainties.) This is downplayed by comparing the global land biosphere budget to widely accepted values from the Global Carbon Project (Friedlingstein et al., 2019), rather than the regional breakdown. Comparing to Figure 8 of Friedlingstein et al. (2019) it seems that the tropics are a more substantial source and the extratropics a more substantial sink than is seen within the spread of inverse models included in the GCP analysis.

Response: We agree with Dr. Marshall that the satellite-based NBE product is not perfect. However, neither is a surface-based inversion product nor is any assimilated product, e.g., ERA5. In particular, surface-based information used in the GCP analysis provide limited information on the tropics. Satellite-based NBE estimates have provided many new insights on the carbon cycle. For example, Basu et al. (2014) studied the flux seasonal variation over tropical Asia with top-down flux estimates based on GOSAT observations. Detmers et al. (2015) studied the 2011 anomalous carbon sink over Australia using NBE estimates based on GOSAT observations. Liu et al, 2018 CMS-Flux results showed excellent agreement with the North American carbon balance changes with in-situ approaches from Wolf et al, 2016. A snapshot of the differences between inversion systems has been documented in Crowell et al, (2019). Those differences will evolve even as a number of these systems converge on their inferences, (e.g., Gaubert et al, 2019)). Sharing the data with broader community will accelerate its use in scientific exploration, and at the same time, will help identify possible deficiencies that further feeds back on future development.

In this paper, we evaluate the reported fluxes and corresponding uncertainties with independent aircraft observations using rigorous methodology. As noticed by Dr. Marshall, we also point to any possible deficiencies in the products based on these evaluations.

Basu, S., Krol, M., Butz, A., Clerbaux, C., Sawa, Y., Machida, T., Matsueda, H., Frankenberg, C., Hasekamp, O. P., and Aben, I. (2014), The seasonal variation of the

CO2 flux over Tropical Asia estimated from GOSAT, CONTRAIL, and IASI, Geophys. Res. Lett., 41, 1809– 1815, doi:10.1002/2013GL059105. Detmers, R. G., Hasekamp, O., Aben, I., Houweling, S., van Leeuwen, T. T., Butz, A., Landgraf, J., Köhler, P., Guanter, L., and Poulter, B. (2015), Anomalous carbon uptake in Australia as seen by GOSAT, Geophys. Res. Lett., 42, 8177– 8184, doi:10.1002/2015GL065161.

Crowell, S., Baker, D., Schuh, A., Basu, S., Jacobson, A. R., Chevallier, F., Liu, J., Deng, F., Feng, L., McKain, K., Chatterjee, A., Miller, J. B., Stephens, B. B., Eldering, A., Crisp, D., Schimel, D., Nassar, R., O'Dell, C. W., Oda, T., Sweeney, C., Palmer, P. I., and Jones, D. B. A.: The 2015–2016 carbon cycle as seen from OCO-2 and the global in situ network, Atmos. Chem. Phys., 19, 9797–9831, https://doi.org/10.5194/acp-19-9797-2019, 2019.

J. Liu, K. Bowman, N. C. Parazoo, A. A. Bloom, D. Wunch, Z. Jiang, K. R. Gurney, D. Schimel, Detecting drought impact on terrestrial biosphere carbon fluxes over contiguous US with satellite observations. Environ Res Lett. 13, 095003 (2018).

B. Gaubert, B. B. Stephens, S. Basu, F. Chevallier, F. Deng, E. A. Kort, P. K. Patra, W. Peters, C. Rödenbeck, T. Saeki, D. Schimel, I. V. der Laan-Luijkx, S. Wofsy, Y. Yin, Global atmospheric CO2 inverse models converging on neutral tropical land exchange, but disagreeing on fossil fuel and atmospheric growth rate. Biogeosciences. 16, 117–134 (2019).

S. Wolf, T. F. Keenan, J. B. Fisher, D. D. Baldocchi, A. R. Desai, A. D. Richardson, R. L. Scott, B. E. Law, M. E. Litvak, N. A. Brunsell, W. Peters, and I. T. van der Laan-Luijkx. Warm spring reduced carbon cycle impact of the 2012 US summer drought. Proceedings of the National Academy of Sciences, 113(21):5880–5885, 2016. doi: 10.1073/pnas.1519620113. URL http://www.pnas.org/content/113/21/5880.abstract.

Original: Another potential limitation to the usefulness of the data is the underwhelming resolution. Monthly fluxes at 4 x 5 degree resolution are no longer really state-of-the-art. One of the arguments for using satellite measurements is the higher spatial

resolution of the signals that can be resolved compared to the rather sparse surface-based network. This dataset is not exploiting to this strength.

Response: We chose 4 x 5 to reflect the information content of the current available space-based CO2 data, rather than an arbitrary grid scale, and we note this spatial resolution has already been scientifically successful (e.g., Liu et al., 2017; Bowman et al., 2017; Liu et al., 2018; Sellers et al., 2018). Before the launch of GOSAT and OCO-2, the tropics has been basically treated as a whole (e.g., Gurney et al., 2002; Baker et al. 2006; Schimel et al., 2015). The 4 x 5 resolution has both scientific value and manageable uncertainty. The estimated posterior flux uncertainty reflects the actual uncertainty as shown in the comparison to aircraft CO2 observations (Figure 9 in the text). Publishing the dataset will make the dataset easily accessible to more specific regional studies, and thus facilitate rapid progress.

Liu, J., Bowman, K. W., Schimel, D. S., et al. (2017). Contrasting carbon cycle responses of the tropical continents to the 2015–2016âĂŁEl Nino. Science, 358 eaam5690.

Sellers, P. J., D. S. Schimel, B. Moore, J. Liu, and A. Eldering, Observing Carbon Cycle-climate feedbacks from space, Proceedings of the National Academy of Sciences Jul 2018, 115 (31) 7860-7868; DOI: 10.1073/pnas.1716613115

J. Liu, K. Bowman, N. C. Parazoo, A. A. Bloom, D. Wunch, Z. Jiang, K. R. Gurney, D. Schimel, Detecting drought impact on terrestrial biosphere carbon fluxes over contiguous US with satellite observations. Environ Res Lett. 13, 095003 (2018).

Gurney KR, Law RM, Denning AS et al. (2002) Towards robust regional estimates of CO2 sources and sinks using atmospheric transport models. Nature, 415, 626– 630.

Baker, D. F., et al. (2006), TransCom 3 inversion intercomparison: Impact of transport model errors on the interannual variability of regional CO2 fluxes, 1988–2003, Global Biogeochem. Cycles, 20, GB1002, doi:10.1029/2004GB002439.

Schimel D, Stephens BB, Fisher JB. 2015. Effect of increasing CO2 on the terrestrial carbon cycle. Proceedings of the National Academy of Sciences, USA 112: 436– 441.

Bowman, K. W., Liu, J., Bloom, A. A., Parazoo, N. C., Lee, M., Jiang, Z., ... Wunch, D. (2017). Global and Brazilian carbon response to El Niño Modoki 2011–2010. Earth and Space Science, 4, 637– 660. https://doi.org/10.1002/2016EA000204

Original: Other comments: Regarding the completeness of the dataset presented, I had some minor concerns.I tried to check the availability of the datasets linked to here, and found that I was not sure which version of the ECCO-Darwin fluxes had been used: the data portal lists several different options. I was not even entirely sure if the ocean fluxes had been optimized, but the netCDF gridded fluxes describe the ocean fluxes as "posterior ocean fluxes,2010-2014 constrained by GOSAT, 2015-2018 constrained by OCO2", so I assume that they are not identical to the prior. In any case, this could be clarified.

Response: We optimize ocean fluxes along with land fluxes. We will clarify the link of ECCO-Darwin fluxes and the inversion setup in the revision.

Original: Similarly, the paper mentions that FLUXCOM-GPP is one of the inputs to CARDAMOM, but there is more than one version of this product as well. Even CARDAMOM comes in different flavours, I believe, based on the documentation in the cited papers. For completeness it would be suitable to include all the prior and posterior fluxes in the dataset - including the anthropogenic fluxes which are not optimised. Only then can the full budget be assessed.

Response: In the revision, we will specify the exact version of CARDAMOM and FLUXOM-GPP. We will also provide fossil fuel fluxes along with natural carbon fluxes.

Original: I do not see the purpose of providing the monthly fluxes (with uncertainty) at 13 different FLUXNET sites. As far as I can tell, these are extracted directly from the model, and do not represent additional downscaling or enhanced temporal resolution.

The benefit of this (and the rationale for the selection of these specific sites) is not clear to me. The measured monthly mean NBE at these sites is not included for comparison, nor is any validation using FLUXNET sites provided in the manuscript. It seems redundant.

Response: We will remove the monthly fluxes at 13 different FLUXNET sites.

Original: I was surprised by the choice of the masks used for aggregation of fluxes. If two masks are included, why not include the broadly-applied TransCom mask? The benefit of such a common mask is the ease of comparison. Yes, a user may apply his or her own mask to the data, but it really does not add much in terms of space (22 regions with monthly resolution), and would facilitate comparison with already available model output. This is likely of more general application than the two custom masks given here.

Response: We will replace the mask that is based on latitude with TransCom mask. Correspondingly, we will provide NBE and uncertainties at TransCom regions.

Original: Minor/typographical comments: L29: “from Greenhouse” -> “from the Greenhouse” L30: remove “the” before NASA Response: We will correct the grammar.

Original: L49: Crowell et al. 2019 is an odd choice as an example of inversions based on surface CO2 observations, as this was explicitly not the focus of the publication.

Response: we will remove the reference.

Original: L55: The NBE are far -> NBE is far L108: suggest “ North America (NA)” -> “North American” (abbreviation is established elsewhere, and adjectival form fits better here) L122: Section 8 is -> Section 8 describes the L128: “that no” -> “no” L151: its -> their L161: from2010 (missing space) L169: CARDAMON -> CARDAMOM L184: by ACOS -> by the ACOS L185: maximize -> maximizes L193: land nadir good quality observations -> land nadir observations flagged as being of good quality L221: of OCO-2 -> of the OCO-2 L272: over Pacific, and -> over the Pacific, but L277: its ->

their L279: each nine -> each of nine L283: fractions sampled at ith aircraft locations -> fraction sampled at the ith aircraft location L285: of mean -> of the mean L287: either posterior fluxes or transport -> either the posterior fluxes or the transportPrinter-friendly version Discussion paper L288: posterior fluxes -> the posterior fluxes (twice) L315: of RMSE to posterior flux using GEOS-Chem -> of the RMSE to the posterior flux using the GEOS-Chem âËŸA ´l L342: Please rewrite the first sentence. L355 & L366: by NOAA -> by the NOAA L360: of posterior -> of the posterior L371: calculate -> calculated L375: with GCP -> with the GCP (or, "with the range estimated by the GCP,") L382: shows large -> shows that large L382: Southern -> the Southern L383: eastern -> the eastern L409: or weakly -> or are weakly L410: during 2015 -> during the 2015 L415: Pouter -> Poulter L416: capitalisation weird in "tropical south America Savanna"âËŸA ´l L440: above planetary -> above the planetary L446: used NOAA -> used the NOAA L448: is equal or above -> is greater than or equal toâËŸA ´l L450 & L482 & L497: Southern Ocean -> the Southern Ocean (as an aside: the weaker seasonality certainly plays a role, but this was also a "problem region" in comparison to Atom-1 measurements, so perhaps there is something else going on there: : :)

Response: thanks for all the editorial suggestions. We will incorporate these comments in the revision.

Original:: Figure 2: It is really difficult to tell the regions apart on this map. The blues in North America, for instance, really blend together.

Response: we will remake Figure 2. n paper Original: Figure 9: This figure seems unnecessarily cramped. Perhaps split it into two? For instance, I could barely tell that the bars were really blue without zooming way in, as they are so tiny.

Response: we will remake Figure 9.

Original: General figure comment: Something is a bit off with the rendering of the digits in your colour bars, making the bottom bar of "2"s disappear and making a gap in the bottom of round digits.

Response: we will make sure at the color bar is clear.

Original:{ L466: from Monte -> from the Monte L478: What is meant here? “either transport or low of posterior flux uncertainty estimates”: Perhaps, “either transport errors or too low values for posterior flux uncertainties”? L480: of flight -> of the flight L493: defined -> as defined L496: These -> The, also, specify which ratio you mean “between RMSE and RMSEMC“ L500: Pacific -> the Pacific L503: these -> the L504: with 4_ x 5_ resolution transport model -> using a transport model with only 4_ x 5_ resolutionâËŸA ´l L513-515: A bit awkward, please rephrase. L516: indicates small -> indicates a small L518: of posterior -> of the posterior L533: to FLUXSAT -> to the FLUXSAT L541: “needs caution” -> perhaps better: “calls for caution” L556: by GCP -> by the GCP L562: atmospheric -> the atmospheric L563: level -> levels L576: provide support the monitoring of the regional contributions to the changes inÂËŸaatmospheric: : : I’m not sure about this, perhaps: “support the monitoring of the regional (biospheric) contributions to changes in atmospheric: : :”? L580 & L582: data is -> data are L582: ensemble posterior -> ensemble of posterior Interactive comment on Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2020-123, 2020.} Response: Thanks again. We will incorporate all these editorial suggestions.

Interactive comment on Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2020-123, 2020.