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Interactive comment on "A dual-pass carbon cycle data assimilation system to estimate surface CO_2 fluxes and 3D atmospheric CO_2 concentrations from spaceborne measurements of atmospheric CO_2" *by* Rui Han and Xiangjun Tian

Anonymous Referee #2

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Referee Comments on Han & Tian, "A dual-pass carbon cycle data assimilation system to estimate surface CO2 fluxes and 3D atmospheric CO2 concentrations from spaceborne measurements of atmospheric CO2"

This paper presents a new version (v1) of the Tan-Tracker carbon data assimilation system. The previous version (v0), as detailed in Tian, et al. (2014), was a forward-running filter with a 5-7 week assimilation window similar to the CarbonTracker scheme (Peters et al. 2005), with both CO2 flux and CO2 concentrations being solved for simultaneously. This version splits this into a two-step process, with CO2 concentration being

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estimated first across a 3-day window, then CO_2 fluxes inferred from those across a 2-week window.

Since the chief problem with these forward-running assimilation schemes in the past has been the shortness of the assimilation window, which truncates the span across which the dynamical constraint between fluxes and concentrations provided by the atmospheric transport model can operate, it is not clear what benefit is gained by both shortening this assimilation window and removing the flux constraint in the first step of the assimilation. The explanation given in the text for this ("to reduce the influence of the background flux on the initial CO_2 concentration") does not make sense to this reviewer: it would seem more logical to use a longer assimilation window, so that the background fluxes (those before the start of the assimilation window) play less of a role, being further back in time with respect to the measurements being assimilated in the window. Given these issues, I am perplexed that the OSSE results presented show that this newer approach is somehow giving results that are closer to the truth than before – I would have thought that a properly-designed OSSE would show the opposite.

Measurement information in this scheme, as in CarbonTracker, can only be propagated backwards to previous times as far as the length of the assimilation window (here, two weeks (or 3 days?), in v0 5-7 weeks, in CarbonTracker 5 weeks, though this has been increased to 3-6 months in the latest annual release). The measurement information can only modify fluxes within this window – any corrective information coming from earlier fluxes is then mis-attributed to fluxes inside this span. This attribution or localization error grows worse as the assimilation window is shortened. In the past when only in situ data (mostly at the surface) was available, this was a significant problem: in many areas of the world, CO_2 fluxes would not be "seen" at the measurement sites until many weeks, or even months, had transpired (think fluxes from the tropical land regions, the effect of which would be transported up due to the mainly convective transport there and not be seen until it came down later at higher latitudes or else got lucky enough to

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be observed by an airplane before then). In this case, the localization of these far-field fluxes to the near-field around the measurements would cause large flux errors. Now, with satellite data this is less of an issue (there is generally an overpass of the satellite within 400 km of any spot on the globe at least once a week), but clouds and high aerosol conditions in the tropics reduce coverage there and suggest an assimilation window of at least several weeks would still be wise; the ability of the satellites to see a signal anywhere in the column both helps see the influence of the surface fluxes but also hurts by making it more difficult to say where the signal came from. And systematic errors (biases) in the satellite data further limit its usefulness. Given this, I would think that the powerful dynamical constraint provided by the transport models should not be cast aside by using assimilation windows as short as is done here. (Yes, the transport models have their own inaccuracies, but one can always use several of them to get an idea of their influence.)

The estimation of the CO2 fields and CO2 fluxes in two steps also seems problematic to me. Estimating the CO2 fields first without the flux constraint seems to allow one to throw out the mass balance imposed by the transport model for the previous fluxes completely. The error caused by this should them project into the second step in which the fluxes are estimated. The two-step process would seem to eliminate the ability to solve for correlations between errors in the fluxes and errors in the initial concentration field.

In my view, the direction taken here towards shorter assimilation windows and a looser constraint from the transport model seems to be misguided. I would be more interested in the OSSEs quantifying the truncation errors incurred from these short windows, rather than what is shown here (I can't understand why the OSSEs give better results and I am suspicious that the OSSE setup does not capture all the relevant errors). I would not be surprised if CO2 flux results obtained with this new v1 TanSat system are similar to those given by the old "mass-balance" methods of 20+ years ago: noisy to the point of making it difficult to identify the actual flux signal beneath the noise.

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