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Supplement of

Drivers of column-average CO_2 variability at Southern Hemispheric Total Carbon Column Observing Network sites

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Supplement to "'Drivers of column-average CO_2 variability at Southern Hemispheric total carbon column observing network sites"'

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1 Variability in co-located near-surface CO_2 concentrations

In this supplement, we analyse the various model simulations of CO_2 in the surface layer at the three southern hemisphere TCCON sites and present our corresponding conclusions regarding additional, complementary information that column measurements could provide. Figure 1 shows a comparison between the MSCs decomposed by process for the surface layer and the column for each site. The seasonal cycle amplitude for the surface is considerably larger than for the column, and also dominated by the terrestrial biosphere signal. For Darwin, the phasing of the processes is very similar between the surface and the column, perhaps an indication of the role of convection in ensuring a relatively uniform vertical distribution throughout the column. For Lauder and Wollongong the phasing is shifted in the surface relative to the column.

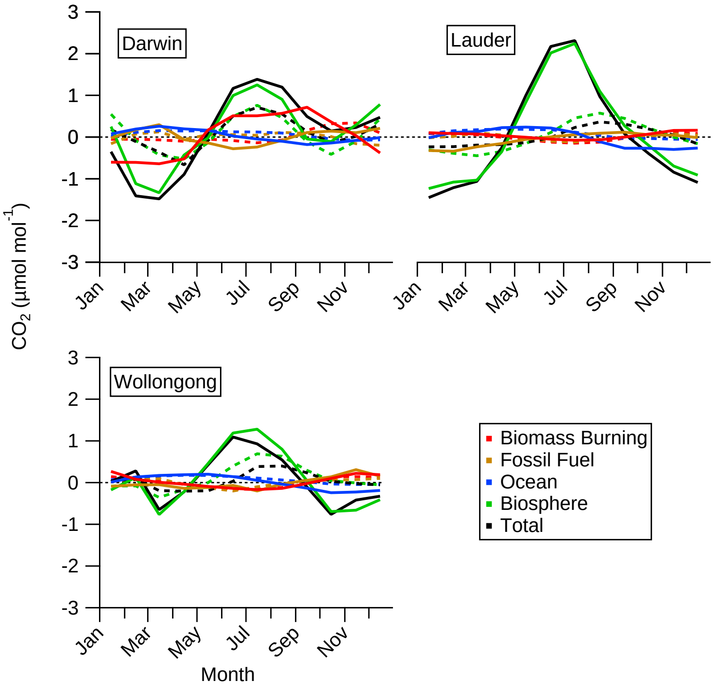

Figure 1: Mean seasonal cycles in the CT2011oi simulation for the surface at the southern hemisphere TCCON sites Darwin (top left), Wollongong (bottom) and Lauder (top right), decomposed by source process: total (black), biomass burning (red), ocean (blue), terrestrial biosphere (green) and fossil fuel (brown). The solid lines depict the MSC in the surface layer at the site, the dashed lines those for the column, as per the figure in the main manuscript.

Figures 2, 3 and 4 show the mean CO2 seasonal cycles at the surface for Darwin, Lauder and Wollongong, respectively. In each case there are MSCs corresponding to three model simulations - CT2011oi (in TM5), CT2011oi fluxes in TM3 and SiB terrestrial biosphere in TM3, at three vertical levels (ground upwards from thickest to thinner lines). Note that the vertical resolution of the models is different, therefore the CT2011oi levels displayed here have been vertically interpolated to match those from TM3. All simulations have been sampled at 0000UT to coincide with when we sampled TM3 for the column studies. These figures show that within a model run, the seasonal cycle amplitude is sensitive to the model level, getting smaller further from the surface, but with a phasing that does not vary greatly. The differences between simulations are much larger, even when using the same fluxes (TM3 vs CT2011oi). The surface is therefore much more sensitive to this type of effect than the column, for which there was good agreement between TM3 and TM5 when using the same fluxes. This suggests that the column measurements are better suited to validating simulations of fluxes without potentially introducing model-dependent biases.

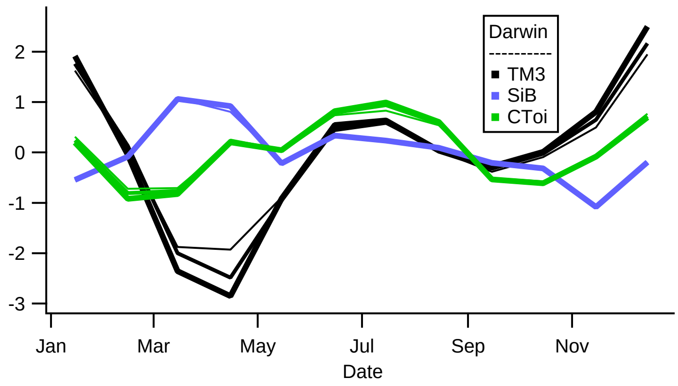

Figure 2: Mean seasonal cycles in the surface simulations at Darwin based on CT2011oi itself (green), the CT2011oi fluxes in TM3 (black) and SiB replacing the optimised CT2011oi terrestrial biosphere flux in the TM3 run (blue). The first three vertical levels for each simulation are shown, from thick (lowest) to thin (third level). For CT2011oi, the levels are vertically interpolated in pressure to match those from TM3.

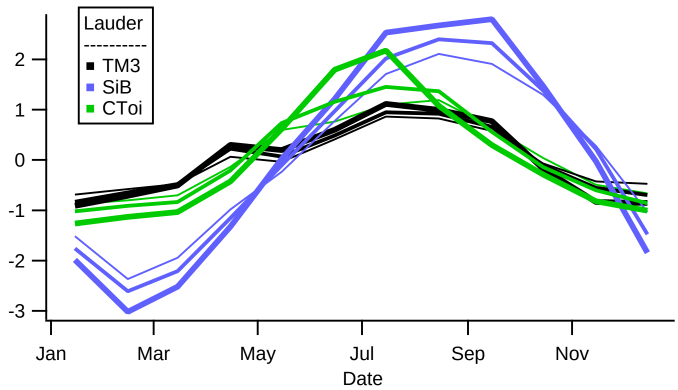

Figure 3: As for Figure 2 but for Lauder.

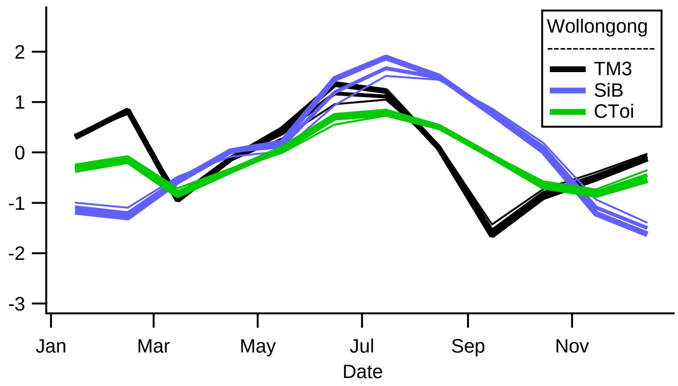

Figure 4: As for Figure 2 but for Wollongong.

Despite the disagreement between the model simulations based on the optimised CT2011oi fluxes, the TM5 and TM3 simulations with these fluxes show better agreement to each other in phasing and magnitude than with the TM3 SiB simulation. The SiB runs show a larger seasonal amplitude at Wollongong and Lauder, and a relatively small seasonal amplitude at Darwin. The phasing at the extra-tropical sites also suggests a later peak in CO_2 in the SiB simulations at these sites, while at Darwin the peak occurs at the time that CT2011oi flux simulations suggest a minimum.

The lack of agreement between TM5 and TM3 simulations based on identical fluxes means that the tagged tracer decomposition at the surface is highly sensitive to the choice of atmospheric transport model. This contrasts to what we see with the column, where the TM5 and TM3 simulations show excellent agreement, even for the individual processes. We therefore only use the tagged tracer decomposition in a qualitative fashion, to examine the regions responsible for the expected signals in the surface time series and this phase shift. These are shown for the terrestrial biosphere in Figure 5. In each case the dominant signal at a site comes from the most local region, and this dominates the seasonal variability. Compared to the column, the magnitude of the influence from the northern hemisphere is very similar, an indication that the northern hemispheric signal is well-mixed throughout the column by the time it reaches these sites.

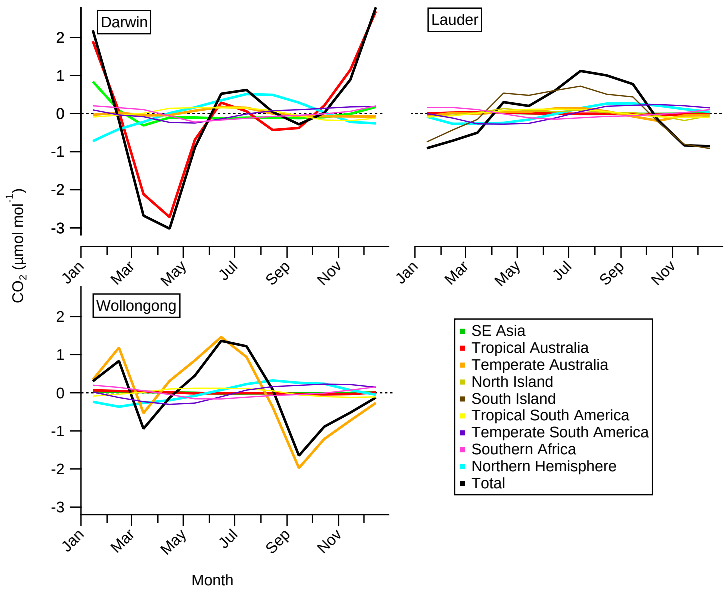

Figure 5: Mean seasonal cycles in the CT2011oi simulation of the terrestrial biosphere tracer for the surface layer at the southern hemisphere TCCON sites Darwin (top left), Wollongong (bottom) and Lauder (top right), decomposed by source region.

Figure 6 shows the terrestrial biosphere decomposition by region for the SiB fluxes. In comparison to Figure 5, the largest differences occur in the regions local to the sites, for example for Tropical Australia at Darwin. The remote regions show very good agreement between the CT2011oi and SiB simulations. The differences between the SiB and CT2011oi-based simulations at the surface are therefore driven by flux differences from tropical and extra-tropical Australasia.

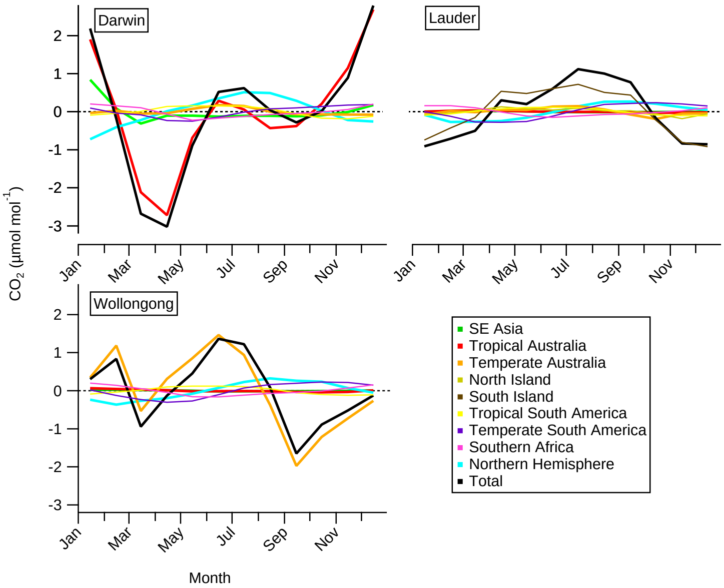

Figure 6: Mean seasonal cycles in the SiB simulation of the terrestrial biosphere tracer for the surface layer at the southern hemisphere TCCON sites Darwin (top left), Wollongong (bottom) and Lauder (top right), decomposed by source region.

2 Conclusions

Analysis of simulations of co-located surface and column concentrations show that the column seasonal cycles agree well between models when using identical surface fluxes. However, the analysis of drivers in the co-located surface CO_2 concentrations is complicated by inter-model differences that result in identical fluxes yielding different mean seasonal cycles in the concentrations. The column measurements could offer more robust validation of model flux simulations without introducing potential model-dependent biases. The largest influence on surface variability comes from the terrestrial biosphere in the region surrounding each site, with relatively smaller remote influences. In contrast, the relative contribution of remote regions to the column variability is larger, though of a similar magnitude. The column measurements could therefore offer complementary information to those made at the surface.