Response to Poulter (Biogeosciences Discuss., 12, C7009-C7011, 2015)

In his comment on the 0.8 ppm 2009-2010 step in the measured Mauna Loa Cape Grim (mlo-cgo) CO_2 difference, Ben Poulter acknowledges the likelihood "that changes in atmospheric transport are largely responsible" for this IHG (interhemispheric gradient) anomaly; however on the basis of the Multivariate ENSO Index timing, regional carbon modelling, remote sensing and covariance measurements, he suggests a contributing role for a Southern hemisphere (SH) land sink. He asks "is the evidence sufficient to discount the role of the terrestrial biosphere in explaining the IHG anomaly?" We offer two arguments, one based solely on the CO_2 data, and the other on modelling of the terrestrial response to climate in 2010/11, to suggest the role of the terrestrial sink is small.

The mlo CO_2 mean seasonal amplitude in baseline data since 1991 is 6.6±0.5 ppm, while at cgo it is 1.1±0.2 ppm, practically identical to that measured at South Pole (spo). The detection of a 0.8 ppm step in annual CO_2 against the seasonal variability is more likely at cgo.

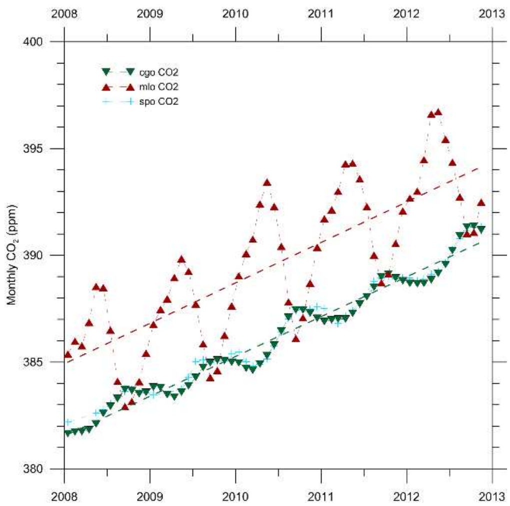

Figure 1: Measured CO_2 concentrations for mlo (dark red), Cape Grim (Green) and South Pole (light blue). Symbols are monthly averages of CSIRO flask data obtained from an 80-day smoothing spline through 2-4 flasks collected in prescribed baseline conditions each month. (For all three sites, the plots are effectively identical to the 6-8 NOAA flasks collected at these sites per month). Linear regressions through 1992-2014 monthly concentrations aid discussion of possible annual step changes.

In Figure 1, an unusual annual decrease of order 0.8 ppm in the cgo or spo data between 2009 and 2010, which would be required if a globally significant Southern Hemisphere sink were responsible for the step, is not evident (marginally larger SH drawdown in early 2010 is followed by a marginally greater release in the late-2010 SH peak amplitude). Instead, there is a clear indication in the mlo data for an increase of the required magnitude to explain the mlo-cgo step.

Accepting the Poulter argument about the timing of a SH terrestrial response to the 2010, 2011 La Niña conditions, the question arises as why is it not recorded in the Cape Grim CO_2 record?

This question was addressed at the 2014 Annual Cape Grim Science Meeting by Xingjie Lu, Ying-Ping Wang and Rachel Law. They used the Community Atmosphere Biosphere Land Exchange model (CABLE, Law 2014) simulations of NEP anomalies over the 2001 to 2012 period, finding SH anomalies (of order 0.5 PgC yr^{-1}) mainly contributed by Argentina and Australia in 2010 and 2011. The timing of their terrestrial response is similar to that of Poulter et al. (2014). They investigated how the inter-annual variability in the CABLE biospheric fluxes affected the IHG using CO_2 response functions from the CCAM atmospheric model (McGregor and Dix, 2008) to reconstruct atmospheric CO_2 concentrations at mlo and cgo. With their permission, the main result is shown in Figure 2.

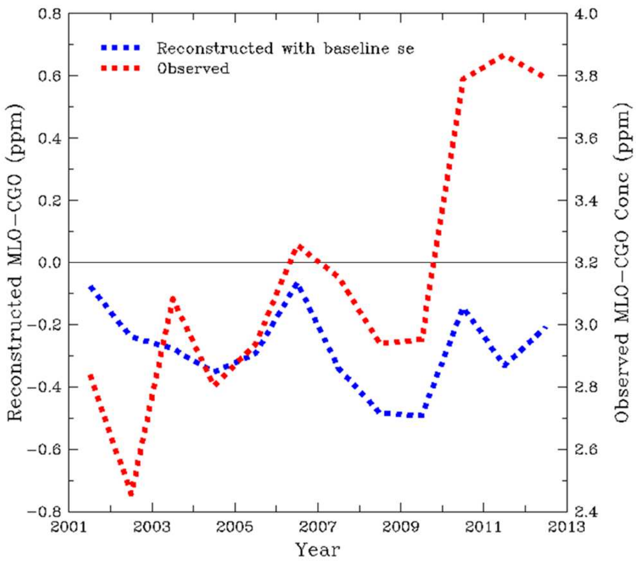

Figure 2: CABLE and CCAM Model results from Lu, Wang and Law (2014) showing reconstructed mlo-cgo annual average differences (blue) and the observed differences from Francey & Frederiksen (red). The blue legend should read "Reconstructed with baseline selection".

There is no significant response to the nearby 2010-2011 terrestrial sink in the reconstruction. A full appreciation of the definition of "baseline" at Cape Grim provides an explanation, since the flask samples are collected in baseline conditions. When the CCAM CO_2 response functions are modified to represent baseline data (at cgo the 20-30% of time with strong winds over the southern ocean) this terrestrial signal is sufficiently diluted into the large well-mixed troposphere at mid-to-high southern latitudes to be unobservable in the reconstructed CO_2 IHG. (Note: When using response functions for all conditions, i.e. including northerly winds carried air from the mainland to Cape Grim, the terrestrial response was visible and a step response in the difference from mlo data between 2009 and 2010 was simulated, but quickly decayed after 2011 unlike the CO_2 IHG). This example highlights the requirement for high time resolution transport modelling coupled with similar resolution when describing the CO_2 data.

As pointed out in the original explanation involving an interhemispheric atmospheric mixing anomaly, such small regional flux anomalies compete with the ~9 PgC yr^{-1} annual injection of mainly NH Fossil Fuel releases and have little impact on IHG.

We particularly acknowledge the guidance of Rachel Law in describing the carbon cycle modelling results.

References

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