Strong Observational Constraints on Seasonal Northern Extratropical CO_2 Exchange

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Seasonal CO_2 exchange with northern extratropical terrestrial ecosystems is the largest of all influences on atmospheric CO_2 distribution. Yet, this quantity is remarkable for how poorly it is known. Quantitative estimates of the amount of CO_2 that leaves and enters the Northern Hemisphere extratropical troposphere each year vary by a factor of 4 for state-of-the art prognostic models, and by 50% for global atmospheric inverse models. I will present new estimates of this quantity, based on airborne and ground-based CO_2 observations, that provide valuable constraints on global terrestrial ecosystem models and carbon budgeting exercises. Prognostic models of terrestrial CO_2 exchange have typically been validated by propagation through atmospheric transport models and comparison of the resulting signals to observations from surface stations, making such validations particularly sensitive to the large uncertainties in seasonal vertical mixing in the transport models. Furthermore, global atmospheric CO_2 inverse models with incorrect estimates for this seasonal exchange, or incorrect dilution of northern terrestrial signals in different seasons, will by necessity make biased estimates of the much smaller residual annual-mean fluxes, such as tropical or northern terrestrial net ecosystem exchange.

We use high-resolution airborne CO_2 observations from the HIAPER Pole-to-Pole Observations (HIPPO) campaigns, spanning the Pacific Basin from 67 S to 87 N and the surface to 14 km and collected at 9 different times of year, to provide direct measurements of seasonal hemispheric-scale CO_2 exchange. I use output from the ACTM atmospheric transport model and output from the TransCom 3 collection of models to show that a slice down 180 W provides a very good approximation of zonal mean concentrations, and to establish that the link between extratropical atmospheric molar abundances and extratropical surface fluxes is largely model-independent. I use observations from surface stations and ongoing aircraft vertical profiles to aid interpolation of the 9 HIPPO missions to the full annual cycle and to place these 2009-2011 campaigns in context of longer-term interannual variations. Finally, I will show comparisons of our observations to terrestrial ecosystem fluxes from CMIP5 models and a range of atmospheric inverse results.