PRECISION REQUIREMENTS FOR SPACE-BASED X_{CO2} DATA

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ABSTRACT

The Orbiting Carbon Observatory (OCO) mission will deliver space-based observations of atmospheric CO_2 with the potential to resolve many of the uncertainties in the spatial and temporal variability of carbon sources and sinks. Our assessments of the measurement requirements for space-based remote sensing of atmospheric CO_2 conclude that the data must support retrievals of the column-averaged CO_2 dry air mole fraction, X_{CO2}, with precisions of 3 to 4 ppm to resolve the annually averaged gradients between the Northern and Southern hemispheres, but higher precision (1 to 2 ppm) will be needed to resolve East-West gradients and questions like the location and spatial extent of the Northern Hemisphere terrestrial carbon sink. These conclusions are derived from the results of observational system simulation experiments (OSSEs) and synthesis inversion models [*Rayner and O'Brien*, 2001; *O'Brien and Rayner*, 2002; *Rayner et al.*, 2002]. The X_{CO2} precision requirements also considered the OCO mission design, the amplitude of X_{CO2} spatial and temporal gradients, and the relationship between X_{CO2} data precision and regional scale surface CO_2 flux uncertainties inferred from X_{CO2} data.

We ingested simulated OCO X_{CO2} data into synthesis inversion models to quantify the dependence of inferred surface-atmosphere CO_2 flux uncertainties on X_{CO2} precision. Regional scale (~10^6 km^2) CO_2 surface flux uncertainties scale almost linearly with the X_{CO2} data precision for X_{CO2} precisions ranging from 1 to 5 ppm (0.3 to 1.4%). The dense, uniform spatiotemporal sampling of the space-based X_{CO2} retrievals will reduce the uncertainties in inferred surface-atmosphere CO_2 fluxes compared to the fluxes inferred from the GLOBALVIEW-CO_2 network [*Schnell et al.,* 2001] even if the space-based X_{CO2} data have precisions on the order of 5 ppm on regional scales. Regional scale X_{CO2} precisions of 1 to 2 ppm (0.3 to 0.5%) are needed to improve our understanding of the temporally varying carbon cycle processes such as the Northern Hemisphere terrestrial carbon sink, fossil fuel and biomass combustion, and the response of land biosphere and ocean to seasonal and interannual climate variability.

Our OSSEs revealed that the impact of systematic X_{CO2} biases on CO_2 flux uncertainties depends on the spatial and temporal extent of each bias since CO_2 sources and sinks are inferred from regional-scale X_{CO2} gradients. Source-sink inversion modeling demonstrated that systematic biases as small as 0.1 ppm could be identified in the X_{CO2} data product. Constant X_{CO2} biases on continental to global scales do not affect the CO_2 flux uncertainties since they introduce no error into the X_{CO2} gradients. Small undetected biases occurring on sub-regional scales (< 10^6 km^2) will appear as small increases in the random noise level and should not affect the CO_2 flux inversions. Persistent geographic biases at the regional to continental scale will have the largest impact on the inferred CO_2 surface fluxes. The design of the OCO validation program has emphasized the capability to identify and correct regional to continental scale X_{CO2} biases.

Several outstanding bias issues remain to be quantified more accurately. The "clear-sky" bias introduced by the OCO sampling strategy must be understood with respect to the CO_2 diurnal cycle and the passage of weather systems through a location between OCO observational revisits. The sampling protocols of the FTS validation network [*Yang et al.*, 2002] and the GLOBALVIEW-CO_2 network will each introduce unique biases into these data; all data must be analyzed in "bias-free" form for accurate inverse modeling [*Olsen and Randerson*, 2004]. Synthesis inversion biases due to inadequate atmospheric transport modeling must also be removed.

A demonstration of the ability of the OCO measurement concept to constrain regional fluxes of CO_2 from Asia of the OCO X_{CO2} data was provided by simulated sampling of the TRACE-P CO_2 data fields [*Suntharalingam et al.*, 2004]. This OSSE quantified the relationship between X_{CO2} data precision and the ability to discriminate surface CO_2 fluxes from 5 distinct regions in East and Southeast Asia. It was found that space-based X_{CO2} measurements with 1 ppm (0.3%) precision constrain carbon fluxes originating from Asia on monthly time scales. These experiments further demonstrate that OCO-like X_{CO2} data can distinguish regional CO_2 fluxes from China and India.

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