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XCO_2 Retrieval Errors from a PCA-based Approach to Fast Radiative Transfer

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Multiple-scattering radiative transfer (RT) calculations are an integral part of forward models used to infer greenhouse gas concentrations in the shortwave-infrared spectral range from satellite missions such as GOSAT or OCO-2. Such calculations are, however, computationally expensive and, combined with the recent growth in data volume, necessitate the use of acceleration methods in order to make retrievals feasible on an operational level.

The principle component analysis (PCA)-based approach to fast radiative transfer introduced by Natraj et al. 2005 is a spectral binning method, in which the many line-by-line monochromatic calculations are replaced by a small set of representative ones. From the PCA performed on the optical layer properties for a scene-dependent atmosphere, the results of the representative calculations are mapped onto all spectral points in the given band.

Since this RT scheme is an approximation, the computed top-of-atmosphere radiances exhibit errors compared to the “full” line-by-line calculation. These errors ultimately propagate into the final retrieved greenhouse gas concentrations, and their magnitude depends on scene-dependent parameters such as aerosol loadings or viewing geometry. An advantage of this method is the ability to choose the degree of accuracy by increasing or decreasing the number of empirical orthogonal functions used for the reconstruction of the radiances.

We have performed a large set of global simulations based on real GOSAT scenes and assess the retrieval errors induced by the fast RT approximation through linear error analysis. We find that across a wide range of geophysical parameters, the errors are for the most part smaller than $\pm$ 0.2 ppm and $\pm$ 0.06 ppm (out of roughly 400 ppm) for ocean and land scenes respectively. A fast RT scheme that produces low errors is important, since regional biases in XCO_2 even in the low sub-ppm range can cause significant changes in carbon fluxes obtained from inversions (Chevallier et al. 2007).