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Application of Principal Component Analysis for Narrow and Broadband Radiance and Flux Calculations

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Radiative transfer (RT) computations are an essential component of many remote sensing retrieval algorithms and climate models. In retrieval applications, RT models are required for the generation of simulated radiances from satellite, ground-based and other platforms. For climate models, RT calculations are required for the generation of surface and top of the atmosphere radiative fluxes in the longwave and shortwave spectral regions, especially for aerosol-laden scenarios. In many inverse-modeling applications, RT models are also needed to calculate Jacobians (partial derivatives of radiances with respect to atmospheric, surface or other parameters). However, full treatment of RT processes is computationally expensive, prompting usage of simplifications (such as two-stream approximations in operational climate models). Furthermore, new-generation low-Earth orbit and geostationary satellite instruments coming up for launch in the next decade will be generating data at rates that current computing power is unlikely to match. For these and other reasons, there is a pressing need for RT performance enhancement for a wide range of applications.

Over the years, several techniques have been proposed to enhance the speed of RT modeling; these include correlated-k methods, spectral binning, optimal spectral sampling, asymptotic methods for semi-transparent media, low-stream interpolation methods, and low-orders of scattering approximations.

In prior work, we have demonstrated the ability of a technique using principal component analysis (PCA) to speed up scalar RT simulations. In the PCA method for RT performance enhancement, empirical orthogonal functions are developed for binned sets of inherent optical properties that possess some redundancy; costly multiple-scattering RT calculations are only done for those (few) optical states corresponding to the most important principal components, and correction factors are applied to approximate radiation fields.

Here, we extend the PCA method to a much wider set of applications in remote sensing retrievals and climate modeling. We will present results for applications involving extended backscatter simulations over the ultraviolet and visible ranges, and over spectral ranges requiring treatment of thermal emission (alone) and coupled scattering/emission. We will also show results for broadband radiances and fluxes in a spectral region covering the ultraviolet, visible and near infrared. The PCA-based technique will be shown to provide accurate radiance and flux estimates (maximum errors < 1% and root mean square errors less than 0.1% compared to exact line by line calculations over a wide variety of scenarios) at speeds comparable to two-stream models.