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A radiative transfer based method for accurately calibrating the spectral dependence of satellite radiances using deep convective clouds

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Satellites have measured solar backscattered radiance in UV since 1970. Accurate calibration of these instruments is required in order to derive ozone and the spectral properties of UV-absorbing aerosols. One can achieve 2% accuracy in calibrating top-of-the-atmosphere radiance (TOAR) at 340 nm if the surface reflectivity is known to $\pm$ 0.01 ($\pm$ 20% for a typical reflectivity of 0.05). This is because at 340 nm 90% of the TOAR for a cloud and aerosol-free scene comes from Rayleigh scattering. This method has worked very well for calibrating UV instruments such as SBUV and TOMS. However, the accuracy of this method degrades rapidly as one goes to longer wavelengths, as the Rayleigh contribution decreases. For example at 440 nm 0.01 error in surface reflectance produces 6% error in estimating TOAR. We present a method of translating the high accuracy calibration of TOAR achieved at 340 nm to the longer wavelengths by using deep convective clouds (DCC). Though the reflectance of the DCC in absence of atmospheric scattering is believed to be spectrally invariant in UV and visible, atmospheric scattering can introduce wavelength dependence of TOAR by smearing out the backscattering phase function, the degree of smearing depending upon Rayleigh extinction and the cloud backscattering phase function. We find that for DCC only the ice backscattering phase function model agrees with the data well enough for this method to be used for calibrating satellite radiances. Spectral dependence of TOAR calculated using other models, such as Lambertian reflector model, Deirmendjian's C1 distribution for water clouds, and Henyey–Greenstein phase function do not agree with the data as well. These results indicate that to derive the spectral dependence of TOAR in presence of other cloud types one needs to know the cloud-top height and one needs to consider whether the top of the cloud is in ice or water phase. An important application of this result is to derive the spectral dependence of aerosol absorption optical depth (AAOD) by examining scenes when such aerosols are above a cloud. Spectral dependence of AAOD is not well known, particularly for carbonaceous aerosols containing organics. Such aerosols have important effects on climate and chemistry of the atmosphere.