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Quantification of the aerosol direct radiative effect from smoke over clouds using passive space-borne spectrometry

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A new method is presented to quantify the solar radiative absorption by smoke layers above clouds, using passive satellite spectrometry from the ultraviolet (UV) to the shortwave infrared (SWIR). UV-absorbing aerosols have a strong signature that can be detected using UV reflectance measurements, even when above clouds. Since the aerosol extinction optical thickness decreases rapidly with increasing wavelength for biomass burning aerosols, the properties of the clouds below the aerosol layer can be retrieved in the SWIR, where aerosol extinction optical thickness is sufficiently small. Then, using radiative transfer computations, the contribution of the clouds to the reflected radiation can be modeled for the entire solar spectrum. In this way, cloud and aerosol effects can be separated for a scene with aerosols above clouds. Aerosol microphysical assumptions and retrievals are avoided by modeling only the pure (aerosol-free) cloud spectra. The method can be employed to derive the aerosol direct radiative effect (DRE) over marine clouds, where the surface albedo from the ocean is low, creating a strong contrast between the cloud reflectance and the clear-sky reflectance. The global aerosol DRE over clouds is largely unstudied, because the retrieval of aerosol parameters over clouds using satellite instruments is difficult. Furthermore, modelled aerosol DRE is strongly dependent on retrieved or assumed aerosol parameters. The method presented here is independent of aerosol parameter retrievals, significantly improving the current accuracy of aerosol DRE estimates. Only cloud parameters are needed to model the aerosol-unpolluted cloud reflectance, while the effects of the aerosol absorption are in the aerosol-polluted cloud reflectance measurements.

An algorithm was developed using the space-borne spectrometer Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY). The aerosol DRE over clouds over the South Atlantic Ocean west of Africa, averaged through August 2006 was found to be 23 $\pm$ 8 Wm-2 with a mean variation over the region in this month of 22 Wm-2. The largest aerosol DRE over clouds found in that month was 132 $\pm$ 8 Wm-2. SCIAMACHY has been measuring successfully since mid-2002, which can be used to retrieve time series of the aerosol DRE over clouds and relate this to changes in cloud cover and aerosol presence. SCIAMACHY does not have an optimal spatial resolution and global coverage is reached only once every six days. However, to retrieve the aerosol DRE at a higher spatial resolution, the method presented here for SCIAMACHY may be applied to any instrument, or a combination of instruments, that measures UV, visible and SWIR reflectances at the top of the atmosphere (TOA) simultaneously. For example, MODIS and OMI, flying in the A-Train constellation, may be used to retrieve cloud parameters in the SWIR (from MODIS), while spectral UV reflectance measurements from OMI can be used to determine the aerosol absorption. We show that this would produce aerosol DRE estimates with unprecendented accuracy and spatial resolutions.