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Cloud top height retrieval using the imaging polarimeter (3MI) top-of-atmosphere reflectance measurements in the oxygen absorption band

Alexander Kokhanovsky and Rose Munro
EUMETSAT, Darmstadt, Germany (alexander.kokhanovsky@eumetsat.int)

The determination of cloud top height from a satellite has a number of applications both for climate studies and aviation safety. A great variety of methods are applied using both active and passive observation systems in the optical and microwave spectral regions. One of the most popular methods with good spatial coverage is based on the measurement of outgoing radiation in the spectral range where oxygen strongly absorbs incoming solar light. Clouds shield tropospheric oxygen reducing the depth of the corresponding absorption line as detected by a satellite instrument. Radiative transfer models are used to connect the solar light reflectance, e.g., in the oxygen A-band located around 761nm, and the cloud top height. The inverse problem is then solved e.g. using look-up tables, to determine the cloud top height. In this paper we propose a new fast and robust oxygen A-band method for the retrieval of cloud altitude using the Multi-viewing Multi-channel Multi-polarization Imaging instrument (3MI) on board the EUMETSAT Polar System Second Generation (EPS-SG). The 3MI measures the intensity at the wavelengths of 410, 443, 490, 555, 670, 763, 765, 865, 910, 1370, 1650, and 2130nm, and (for selected channels) the second and third Stokes vector components which allows the degree of linear polarization and the polarization orientation angle of reflected solar light to be derived at up to 14 observation angles. The instrument response function (to a first approximation) can be modelled by a Gaussian distribution with the full width at half maximum (FWHM) equal to 20nm for all channels except 765nm, 865nm, 1370nm, 1650nm, and 2130nm, where it is equal to 40nm. The FWHM at 763nm (the oxygen A-band location) is equal to 10nm. The following 3MI channels are used in the retrieval procedure: 670, 763, and 865nm. The channels at 670 and 865 nm are not affected by the oxygen absorption. The channel at 763nm is affected by the oxygen concentration vertical profile. The higher clouds will screen the oxygen below them and have larger value of ratios x=R(763nm)/r(763nm) as compared to the lower clouds. Here r(763nm) is the value of reflectance at 763nm for the artificial atmosphere free of oxygen. This value can be derived by the linear extrapolation of reflectances at 670 and 865nm as measured by 3MI over ocean. Over land this technique requires a modification.We assume that the top of atmosphere reflectance in the oxygen A-band can be presented in the following way: R(763nm)=r(763nm)T, where the transmittance term can be derived using the radiative transfer theory. The algorithm is validated using synthetic 3MI measurements. It has been found that the retrieval technique can be used for clouds with cloud top heights in the range 0.5-10km and cloud optical thicknesses above 5.0. For lower cloud optical thicknesses, the cloud is inhomogeneous on a scale of the 3MI pixel (4x4km) and the assumption used in the calculation of the transmittance term T (a horizontally homogeneous cloud layer) is no longer valid. The technique can also be applied to heavy aerosol events such as dust outbreaks, smoke, and volcanic eruptions.