IRS2012-146
International Radiation Symposium 2012
Dahlem Cube, Berlin, Germany, 06 – 10 August 2012

Aerosol effects on the cloud optical depth retrieval from atmospheric transmittance

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Optical characterization of clouds is of interest for climatic studies. Among the cloud properties, cloud optical depth (COD) is particularly useful to describe the cloud, and can be determined from surface measurements of the total atmospheric transmittance in some shortwave bands. Various methods have been proposed, which take into account or not the effect of the aerosol load of the atmosphere on the cloud optical depth determination. Here we use a very simple two-stream treatment of the radiative transfer to show how cloud optical depth determinations could be affected by various aerosol properties: the aerosol optical depth (AOD), the single scattering albedo (SSA) and the asymmetry parameter (g). With this aim, the total transmittance is calculated for conditions with both cloud and aerosol, and then the method is inverted to obtain an estimation of COD assuming that no aerosol is present.

Results show how, in connection with the fact that cloud drops and aerosol particles have different optical properties, the AOD has an effect considerably higher than it could be expected. For example, for an actual COD of 20 combined with an AOD of only 0.2, and a surface reflectivity of 0.04, the retrieved COD by inversion of the treatment is 20.75, corresponding to a relative error introduced of about 4%. Thus for these conditions AOD has an effect 4 times its value. This amplification factor increases both with COD, AOD and the surface reflectivity, reaching values well above 4. Relative error decreases with COD, reaching values close to 1% for very thick clouds, whereas increases with AOD. Beside its dependence on COD and AOD, the retrieval errors (and thus the amplification factor) are also affected by other cloud and aerosol properties as the effective radius of the droplets and the SSA and g of the aerosol. Likewise, the effect of all these properties on the amplification factor are addressed. Both the relative error in the retrieval and the amplification factor decrease when SSA or g increase.

These results are compared with simulations performed with a more rigorous (but still one-dimensional) radiative transfer code. The analysis is done considering a horizontally homogeneous single layer cloud above an aerosol layer, for the 415 nm wavelength, corresponding to the first channel of the Multifilter Rotating Shadowband Radiometer. For the reference case described above, a COD of 21.16 should be introduced to obtain the same transmittance, for the sun in the zenith. For a solar zenith of 60º, the COD should be 21.30. These values correspond to errors of 5.8% and 6.5% respectively. Effects of other aerosol properties on the retrieval are also addressed. It is found that the two-stream method considered can roughly reproduce the results obtained using more rigorous treatments. The general conclusion is that aerosol optical properties are very important and thus they must be taken into account when retrieving cloud optical properties.