RETRIEVAL OF CLOUD OPTICAL DEPTH FROM GROUND BASED MEASUREMENTS OF SOLAR RADIATION IN BROAD AND PHOTOSYNTHETIC BANDS

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1 Summary

Cloud optical depth is the main optical variable to treat the atmospheric radiative transfer for overcast skies. Modeling studies show that, for a broad range of cloudy conditions, **cloud optical depth and the inverse of the atmospheric transmittance are linearly correlated**. Linear correlation parameters depend mainly on solar altitude, surface albedo, and effective drop radius **(Section 2.1)**. Dependence on other atmospheric factors and cloud geometry is less important. Here, we present a first approach to a simple method to retrieve cloud optical depth at 550 nm from surface irradiance measurements. The method is based on an **iterative algorithm (Section 2.2)**. First, a guess value for cloud optical depth is introduced into a **plane-parallel radiative transfer model** (SBDART, which uses the discrete ordinate code) to obtain an estimation of the atmospheric transmittance for the selected band. After comparing this estimate with the actual atmospheric transmittance (from the irradiance measurements), a new guess for the cloud optical depth is derived and introduced in a new run. This process is successively applied until the desired agreement is reached. The potential usefulness of the method has been analyzed, by modeling, for various bands including the 415 nm band of the MultiFilter Rotating Shadowband Radiometer. The method has been applied to **ground based measurements of solar horizontal irradiances in broad and photosynthetic** bands **(Sections 2.3 and 2.4)**. **Overcast conditions** have been selected a posteriori from the whole database by **visual inspection** of the time evolution of measured irradiances. This selection has been confirmed by **inspection of images** taken every minute by a whole sky camera.

2 Method and Results

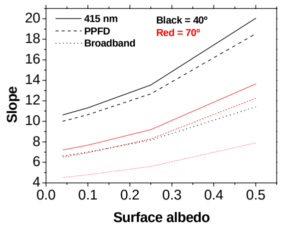
2.1 Sensitivity of the linear relationship

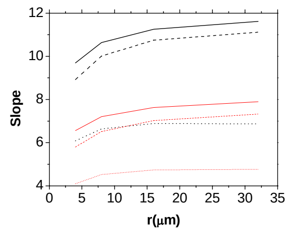
We take advantage of the near linear relation between the cloud optical depth (for a horizontally homogeneous layer) and the inverse of the atmospheric transmittance, for a broad range of conditions. The linear parameters depend mainly on solar zenith angle (SZA), surface albedo (the top figure is for a drop radius of 8 μm) and effective drop radius (the bottom figure is for surface albedo 0.04). This linear relation is valid for various bands, including those where absorption is present. We have analyzed the following bands:

1) **415 nm**, used by the Multifilter Rotating Shadowband Radiometer (MFRSR), with FWHM = 10 nm

2) **Photosynthetic band**, between 400 and 700 nm, measured by silicon sensors. PPFD is the Photosynthetic Photon Flux Density

3) **Broad band**, measured by pyranometers





2.2 Iterative procedure

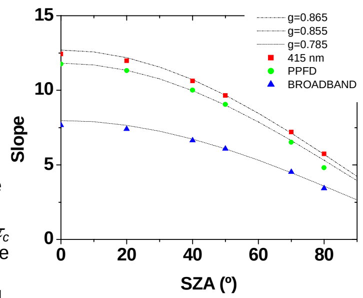
1. Calculate a guess value for the cloud optical depth (τ_c), by using the following expression, which can be obtained from the approximation to the asymptotic relations presented by Kokhanovsky et al (2003):

$$\tau_c \approx \frac{4(1+2\mu)}{7(1-g)}\frac{1}{T} - \frac{1.07}{0.75(1-g)} \qquad (1)$$

where μ=cos(*SZA*), *g* is the asymmetry parameter, and *T* is the atmospheric transmittance in the considered band. The effective values for *g* have been here obtained by modeling, for each band, the slope of the linear relation between the cloud optical depth and the inverse of the atmospheric transmittance (see figure). A representative case with fixed surface albedo (0.04) and effective drop radius (8 μm) has been used. We have obtained *g*=0.865, 0.855 and 0.785 for 415 nm, PPFD and broadband, respectively.

2. Introduce the cloud optical depth at 550 nm in SBDART (Ricchiazzi *et al.*, 1998) and obtain the atmospheric transmittance for the selected band. Note that albedo, effective radius or any other atmospheric or cloud parameter could also be introduced if available

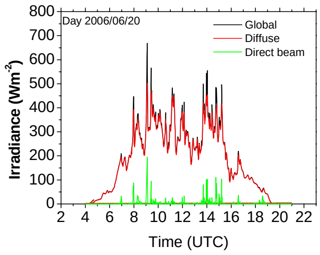
3. Obtain a new value for τ_c by using the slope from (1) and the obtained transmittance to correct the previous τ_c to obtain a new value for τ_c, and iterate until the measured inverse of the atmospheric transmittance is obtained within 0.01



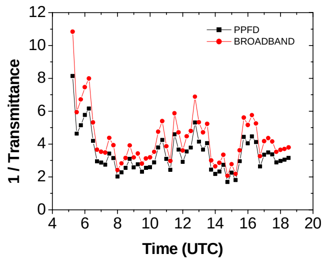
2.3 Measurements

Broadband irradiance has been measured by a pyranometer Kipp and Zonen CM11, whereas photosynthetic photon flux density (PPFD) has been measured by a quantum sensor Li-Cor LI190. Measurements are routinelly taken in Girona (NE of the Iberian Peninsula) every second, and then averaged over 1-minute intervals.

Overcast conditions have been selected a posteriori from the whole database by visual inspection of the time evolution of measured irradiances.

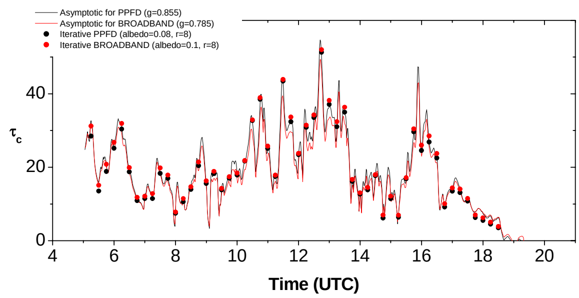


This selection has been confirmed by inspection of images taken every minute by a whole sky camera (Long *et al*, 2006)



The inverse of the atmospheric transmittance has been obtained for every 15 minutes

2.4 Results



Cloud Optical Depth retrieved from PPFD and Broad bands. Results for asymptotic approach (0 iterations) are also shown.

3 Concluding remarks

The simple method presented can be applied on several bands to estimate cloud optical depth. Here, application to PPFD and broad band has produced very similar results. This gives a feel of the robustness of the method. The main factors affecting the accuracy of the method are surface albedo and effective drop radius, which can be obtained by alternative concurrent measurements. Any other variable describing atmospheric or cloud properties can be introduced, if available, for a more accurate retrieval, as easily as the radiative transfer model allows. Asymptotic relations, which depend only on solar altitude and the asymmetry parameter, can be used for less accurate, but very fast, retrieval. We prescribe some values for the asymmetry parameter for various bands. These values are tuned for particular, but representative, conditions. The iterative procedure is efficient: in most cases, only two to four iterations are needed to reach an inverse transmittance stable within 0.01. This corresponds to an intrinsic error below 0.2% for the cloud optical depth. Further work: comparison with alternative methods of obtaining cloud optical depth.

4 References

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Acknowledgements

This work has been funded by the Spanish Ministry of Science and Education in the framework of the project NUCLIER (CGL 2004-02325)

Design: Jordi Badosa