An easy recipe for the retrieval of cloud optical thickness over snow and ice surfaces

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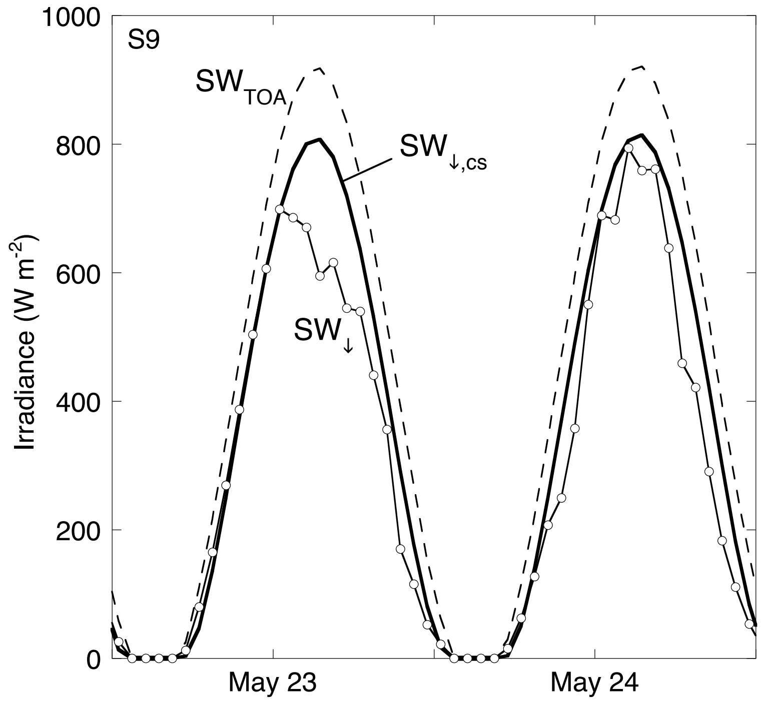
Clouds have a large impact on the radiation budget of glaciers and ice sheets. Cloud optical thickness (COT) is a good measure for the radiative properties of a cloud. But how to obtain a continuous record of COT from (unattended) radiation measurements over snow and ice surfaces? And what can you do with such a COT record?

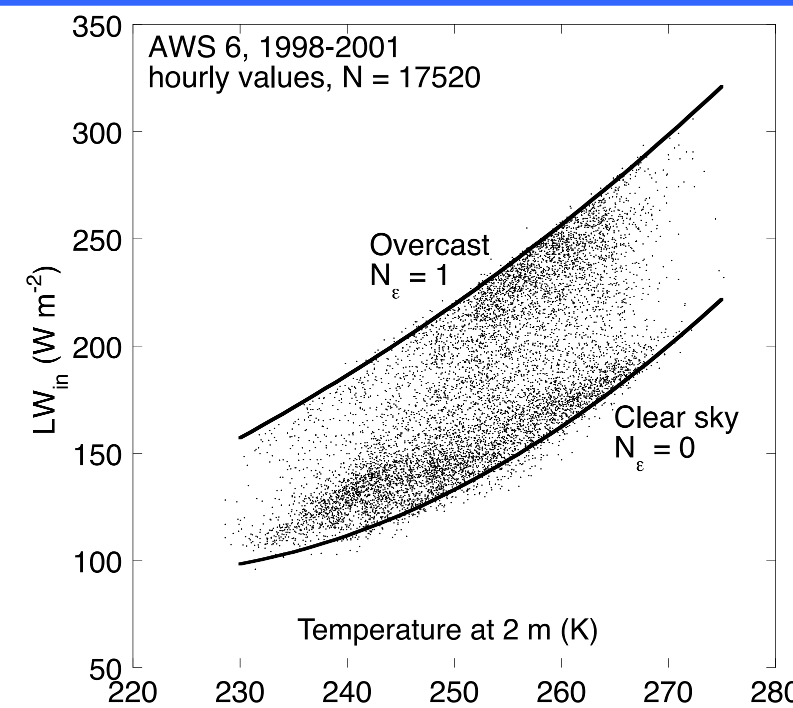
Below, we present a simple 3-step recipe for obtaining a robust, year-round COT record from short- and longwave radiation data over snow and ice surfaces. It allows you (1) to characterize radiative properties of clouds, (2) to distinguish properly between clear and cloudy data, and (3) to validate satellite products of COT.

Step 1: day-time cloud optical thickness



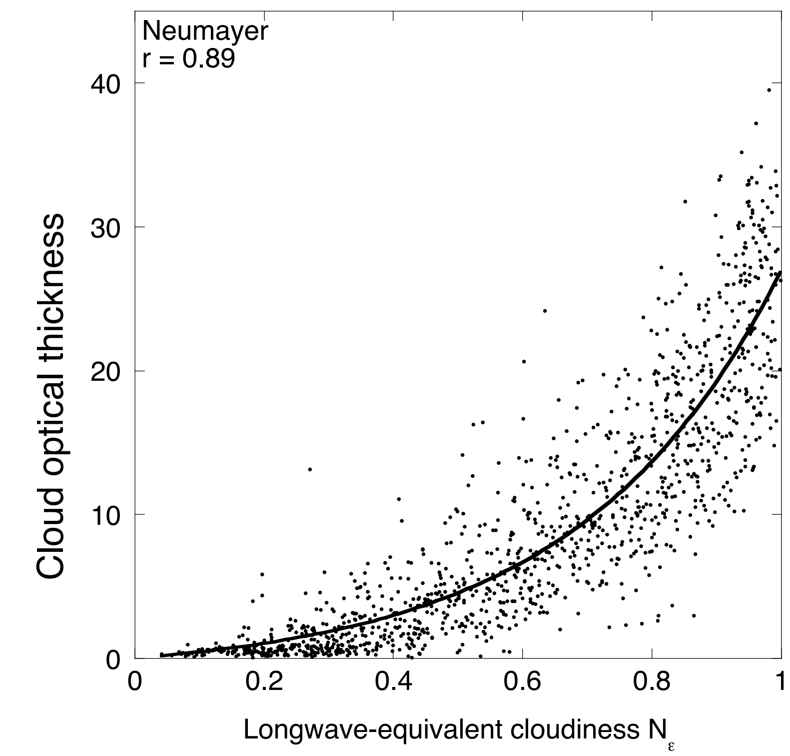
For this step, only shortwave radiation measurements are required. We adopt the method by *Fitzpatrick et al. (2004), J. Clim.* ***17****, 266-275*. From the ratio of clear-sky shortwave radiation ($SW\downarrow_{cs}$) and observed incoming shortwave radiation ($SW\downarrow$), and the observed surface albedo, day-time values of COT are obtained.

Step 2: longwave-equivalent cloudiness



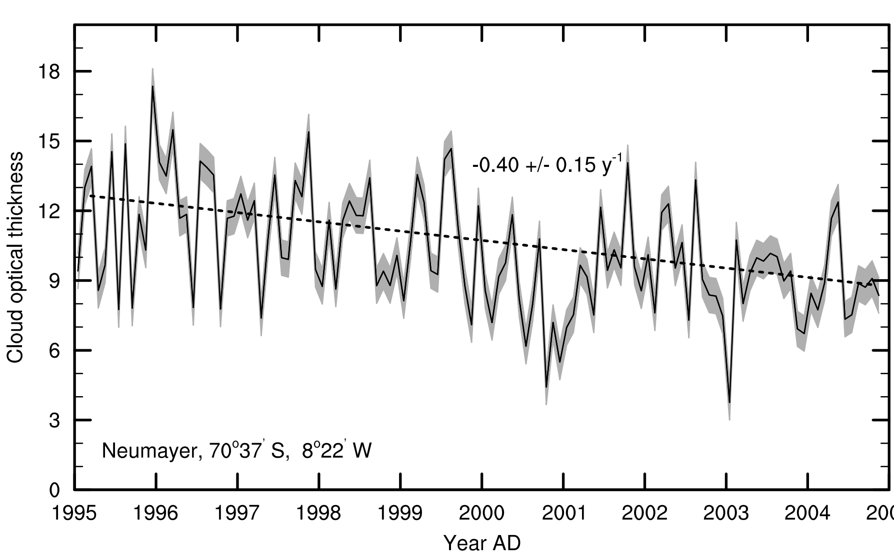
When plotting incoming longwave radiation observations against 2-m temperature, the lower and upper bound of the scatter plot represent clear-sky and overcast data, respectively. Linearly interpolation at a given temperature gives you a longwave-equivalent cloudiness (N_ε) between 0 and 1.

Step 3: continuous cloud optical thickness

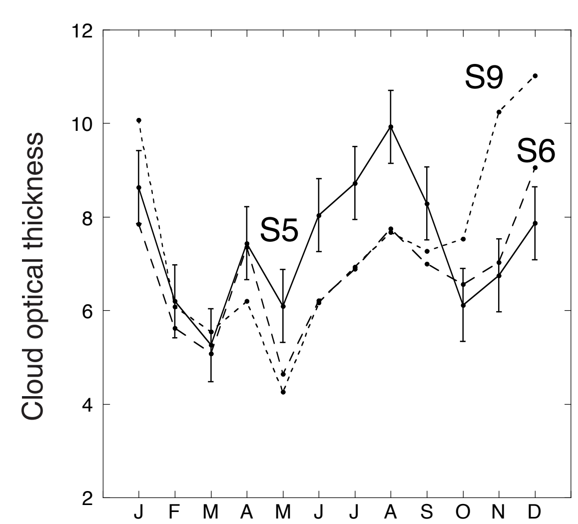


The final step is to relate day-time COT with the longwave-equivalent cloudiness. Fits of the form $COT = c_1(e^{c_2 N_\varepsilon} - 1)$ generally show a good correlation with the data. In this way, you can obtain COT values even at night, in the polar night, or when shortwave sensors fail.

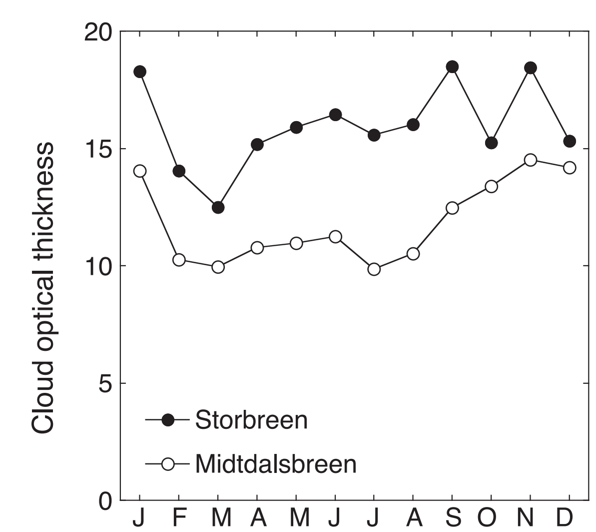
Some examples



Example 1*: Monthly mean COT at Neumayer, coastal Antarctica, between 1995 and 2005. Application of the method reveals a 2σ significant downward trend in cloud optical thickness. Kuipers Munneke et al. (2010), Int. J. Climatol.*



Example 2*: Monthly mean COT (2003-2007) at three locations in the ablation area of the Greenland Ice Sheet near Kangerlussuaq. Note the summer increase. Van den Broeke et al. (2009), JGR(D)* ***113****, D13105.*



Example 3*: Monthly mean COT (2001-2006) at two valley glaciers in Southern Norway. Clouds are thicker and/or more frequent at Storbreen than at Midtdalsbreen. Giesen et al. (2009), The Cryosphere* ***3****, 57-74.*

Kuipers Munneke, P. et al. (2010). Assessing the retrieval of cloud optical properties from radiation measurements over snow and ice. Int. J. Climatol., doi: 10.1002/joc.2114

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