Inferring tropical cirrus optical thickness and frequency fields using MODIS level-3 data

Kerry G. Meyer[a], Ping Yang[a], Bo-Cai Gao[b], Bryan A. Baum[c], and Gerald North[a]
[a] Texas A&M University, College Station, TX; [b] Naval Research Laboratory, Washington, D.C.;
[c]NASA Langley Research Center, Hampton, VA.

I. Introduction

Cirrus clouds have been identified as one of the most uncertain components in the earth's atmosphere. Radiative and microphysical properties, as well as the spatial and temporal patterns, are needed to accurately represent cirrus clouds in general circulation models (GCMs). Recent research has been focused on obtaining cirrus radiative and microphysical properties, such as ice crystal effective size and cloud optical thickness. In the present study, we infer tropical cirrus cloud optical thickness from visible cirrus reflectance data, and obtain the optical thickness and frequency fields of such clouds. We use two and a half years of data obtained from the Aqua MODIS atmosphere product. Seasonal and zonal variations in the optical thickness and frequency fields are investigated. We have also performed a comparison between the present frequency fields with those for "high clouds" obtained from the High resolution Infrared Radiometer Sounder (HIRS) (Wylie et al., 2004).

II. Methodology

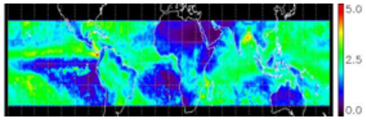
Previously, a method was introduced to retrieve the optical thickness of tropical cirrus clouds using isolated cirrus reflectance in a visible channel (Meyer et al., 2004). This method used MODIS level-1b reflectance data (1 km × 1 km, or 1354 × 2030 pixels) as input. Here, we have modified the algorithm to operate on the MODIS level-3 spatial resolution (1º × 1º, or 180 × 360 pixels). Input data are taken directly from the level-3 daily atmosphere product, and include the average cirrus reflectance (Gao et al, 2002) and solar/satellite view geometries. A cirrus optical thickness archive has been created using two and a half years of Aqua MODIS data, from July 2002 to December 2004. This archive is used for the tropical cirrus analysis, with the following definitions:

$$F_{occc} = \left(N_c / N_t\right) \times 100 \quad \text{and} \quad \tau_{ave} = \tau_c / N_c$$

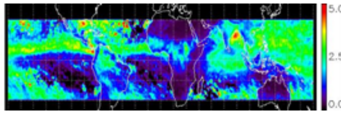
where F_{occ} and τ_{ave} are the frequency of occurrence and average cirrus optical thickness, respectively. N_c is the number of days with cirrus cover (i.e., cirrus reflectance greater than zero), N_t is the total number of days, and τ_c is the sum of the optical thickness for days with cirrus cover. In the present study, we consider only those cirrus clouds located above 440 hPa, following the ISCCP definition of "high clouds."

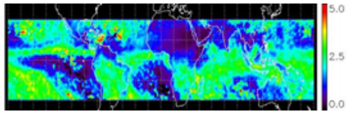
In addition to this analysis, we have also validated our cirrus cloud frequencies with the "high cloud" (cloud top pressure < 440 hPa) frequencies obtained from HIRS (Wylie et al., 2004). Twenty-two years of HIRS data are used, spanning from 1979 to 2001. The HIRS retrieval uses a CO_2 slicing technique for cloud retrieval, without distinguishing between clouds composed of ice or water. We present our results here.

III. Results

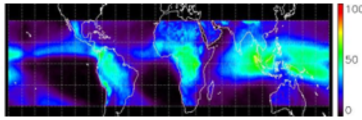


Average cirrus cloud optical thickness for the entire 30-month period. Note the appearance of the Intertropical Convergence Zone (ITCZ), most clearly evident over the Pacific Ocean.

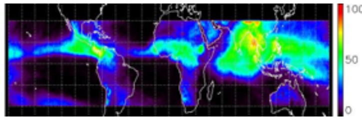




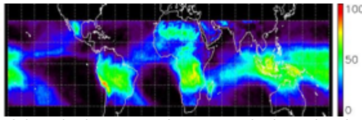
Left Panel: Average cirrus cloud optical thickness for the northern hemispheric summer months of June, July, and August (JJA). Note the ITCZ is clearly evident in this image. Right Panel: Average cirrus cloud optical thickness for the northern hemispheric winter months of December, January, and February (DJF). Note that, compared to the summer image, the ITCZ has shifted southward, especially over continents.



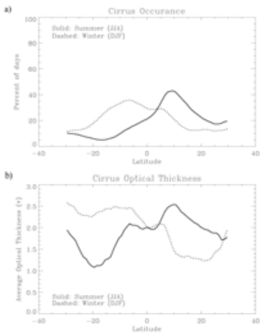
The frequency of cirrus cloud occurrence, from MODIS, for the entire 30-month period. Note the appearance of the ITCZ, as well as various land and orographic effects.



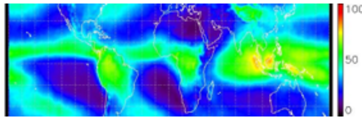
The frequency of cirrus cloud occurrence, from MODIS, for the northern hemispheric summer months (JJA). Note the ITCZ across the center of the image. Also, note the high frequency of occurrence due to the monsoon over southern Asia.



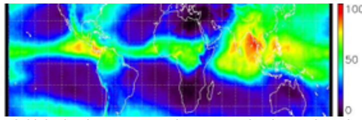
The frequency of cirrus cloud occurrence, from MODIS, for the northern hemispheric winter months (DJF). Note the southward shift of the ITCZ, especially evident over landmasses.



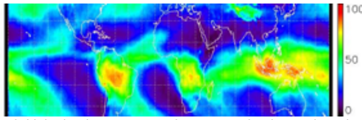
(a) Zonal average of cirrus cloud frequency of occurrence for both the summer (solid) and winter (dashed) months. Note the peak for winter is further south than that for summer. Also, note the secondary peak in the winter plot. This is due to lesser movement of the ITCZ over oceans than over land. (b) Same as (a), but for the zonal average of optical thickness.



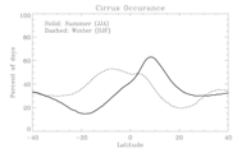
The frequency of "high cloud" occurrence, from HIRS, for the entire 22-year period. Note the appearance of the ITCZ, as well as various land and orographic effects.



The frequency of "high cloud" occurrence, from HIRS, for the northern hemispheric summer months (JJA). Similar to the MODIS image, note the ITCZ across the center of the image, and the high frequency of occurrence due to the monsoon over southern Asia.



The frequency of "high cloud" occurrence, from HIRS, for the northern hemispheric winter months (DJF). Similar to the MODIS image, note the southward shift of the ITCZ.



Zonal seasonal averages of "high cloud" frequencies from HIRS. The pattern is nearly identical to that of the MODIS zonal averages. However, the magnitudes of the frequencies are larger.

IV. Discussion

Comparing the general frequency patterns from our retrieval with those from HIRS reveals remarkable agreement. However, differences do exist, particularly in the magnitude of the frequencies, between our MODIS cirrus retrieval and the HIRS "high cloud" retrieval. These discrepancies may be due to the inclusion of all clouds (both ice and water) in the HIRS retrieval (therefore an overestimation), as well as a lower threshold on MODIS level-2 data that may exclude certain pixels during level-3 averaging (therefore an underestimation).

V. References

B. –C. Gao, P. Yang, W. Han, R.-R. Li, and W. J. Wiscombe, "An algorithm using visible and 1.375-μm channels to retrieve cirrus cloud reflectances from aircraft and satellite data," *IEEE Trans. Geosci. Remote Sensing, 40, 1659-1688,* 2002.

K. Meyer, P. Yang, and B.-C. Gao, "Optical thickness of tropical cirrus clouds derived from the MODIS 0.66- and 1.375-μm channels," *IEEE Transa. Geosci. Remote Sens., 42, 833-841,* 2004.

D. P. Wylie, D. L. Jackson, W. P. Menzel, and J. J. Bates, "Trends in global cover in 22 years of HIRS observations," *J. Climate*, submitted (2004).