COMPARISON OF UNIVERSITY OF WISCONSIN HIRS, MODIS, AND ISCCP D2 CLOUD STUDIES

W. Paul Menzel
NOAA/NESDIS
Madison, Wisconsin 53706 USA

Donald P. Wylie and Richard A. Frey
Cooperative Institute for Meteorological Satellite Studies
University of Wisconsin-Madison
Madison, Wisconsin 53706 USA

1. UW HIRS CIRRUS CLOUD TRENDS

Seasonal changes in semi-transparent or cirrus global cloud cover have been monitored with multispectral observations with the polar orbiting HIRS (High resolution Infrared Radiation Sounder) since June 1989. The HIRS measurements in the carbon dioxide absorption band at 15 microns are used to detect cloud and calculate both cloud top pressure and effective emissivity from radiative transfer principles. The technique and details of its application with HIRS data are described in Wylie et al. (1994) and Wylie and Menzel (1999). The HIRS data have a higher sensitivity to semi-transparent cirrus clouds than visible and infrared window techniques; the threshold for detection appears to be at IR optical depths greater than 0.05.

Global UW HIRS cloud statistics since June 1989 are shown in Table 1. They are separated by cloud type into clear sky ($\tau_{IR} < 0.05$), thin ($\tau_{IR} < 0.7$), thick ($\tau_{IR} > 0.7$), and opaque ($\tau_{IR} > 3.0$) clouds and separated by level in the atmosphere above 6 km, between 3 and 6 km, and below 3 km. On the average for summer and winter, HIRS finds thin clouds in 23% of all observations, thick clouds in 22%, and opaque clouds in 29%. Thus these HIRS observations imply that clouds are found in 74% of all HIRS observations from 65 S to 65 N latitude.

Trends in cloud cover are inferred from monthly averages of the cloud frequencies for each satellite and plotted as one continuous record (see Figure 1). The annual cycle of all cloud cover is very noticeable in the northern mid-latitudes; an annual cycle for high clouds is somewhat apparent in the northern mid-latitudes. It is not apparent in either the tropics or the southern mid-latitudes. High clouds increased until 1993 and then gradually decreased back to 1989 levels. There are about 6 to 8% more high clouds in the tropics than in the northern or the southern mid-latitudes. All clouds stayed relatively constant until 1995 and then decreased to below 1989 levels; the decrease is most noticeable in the northern mid-latitudes (especially in the winter months).

Table 1: UW HIRS cloud statistics from 11 years of global near nadir HIRS measurements for the boreal summers and winters from June 1989 through February 2000 between 65 N and 65 S

	Boreal Summer (June-August)				Boreal Winter (December-February)			
	All Clouds	Thin Clouds	Thick Clouds	Opaque Clouds	All Clouds	Thin Clouds	Thick Clouds	Opaque Clouds
High >6km	36%	16%	15%	5%	36%	16%	16%	4%
Mid 3-6 km	25%	9%	11%	5%	30%	9%	11%	9%
Low <3 km	45%	2%	0	44%	44%	0	2%	42%
All Clouds	73%	23%	21%	29%	75%	22%	24%	29%

Frequency of cloud observations in a given level of the atmosphere are percentages of observations only to that level. Effective emissivity refers to the product of the fractional cloud cover, N, and the cloud emissivity, ε, for each HIRS observational area (roughly 20 km resolution). Thin clouds have $N\varepsilon < 0.5$ and IR optical depths <0.7. Thick clouds have $0.5 < N\varepsilon < 0.95$ and IR optical depths from 0.7 to 3.0. Opaque clouds are opaque to the IR window with $N\varepsilon > 0.95$ and IR optical depths > 3.0. Comparisons with 1 km AVHRR data have indicated that the FOV is totally obscured by cloud when $N\varepsilon \geq 0.5$ and 72% obscured by cloud when $N\varepsilon < 0.5$. 6 km averaged 441 hPa in pressure height; 3 km averaged 665 hPa in pressure height.

Table 2: Global averages of the detection frequency for All Cloud and High Cloud as well as the cloud IR effective emissivities from UW HIRS and ISCCP. The differences in the last column are HIRS minus ISCCP values.

	UW HIRS	ISCCP	Difference
Total (All Clouds)			
January	73%	67%	+6
July	71	66	+5
High Clouds			
January	34%	19%	+15
July	34	20	+14
Infrared Emissivity			
January	68%	76%	-8
July	68	73	-5

Table 3. UW HIRS and MODIS Cloud Statistics for 29 August 2000 between 65 N and 65 S

	UW HIRS				MODIS			
	All Clouds	Thin Clouds	Thick Clouds	Opaque Clouds	All Clouds	Thin Clouds	Thick Clouds	Opaque Clouds
High <400hPa	21%	10%	5%	6%	19%	4%	11%	5%
Mid <700hPa	37%	14%	14%	9%	47%	10%	22%	15%
Low <1000hPa	52%	0%	2	50%	42%	9	14%	19%
All Clouds	76%	21%	17%	38%	75%	16%	35%	25%

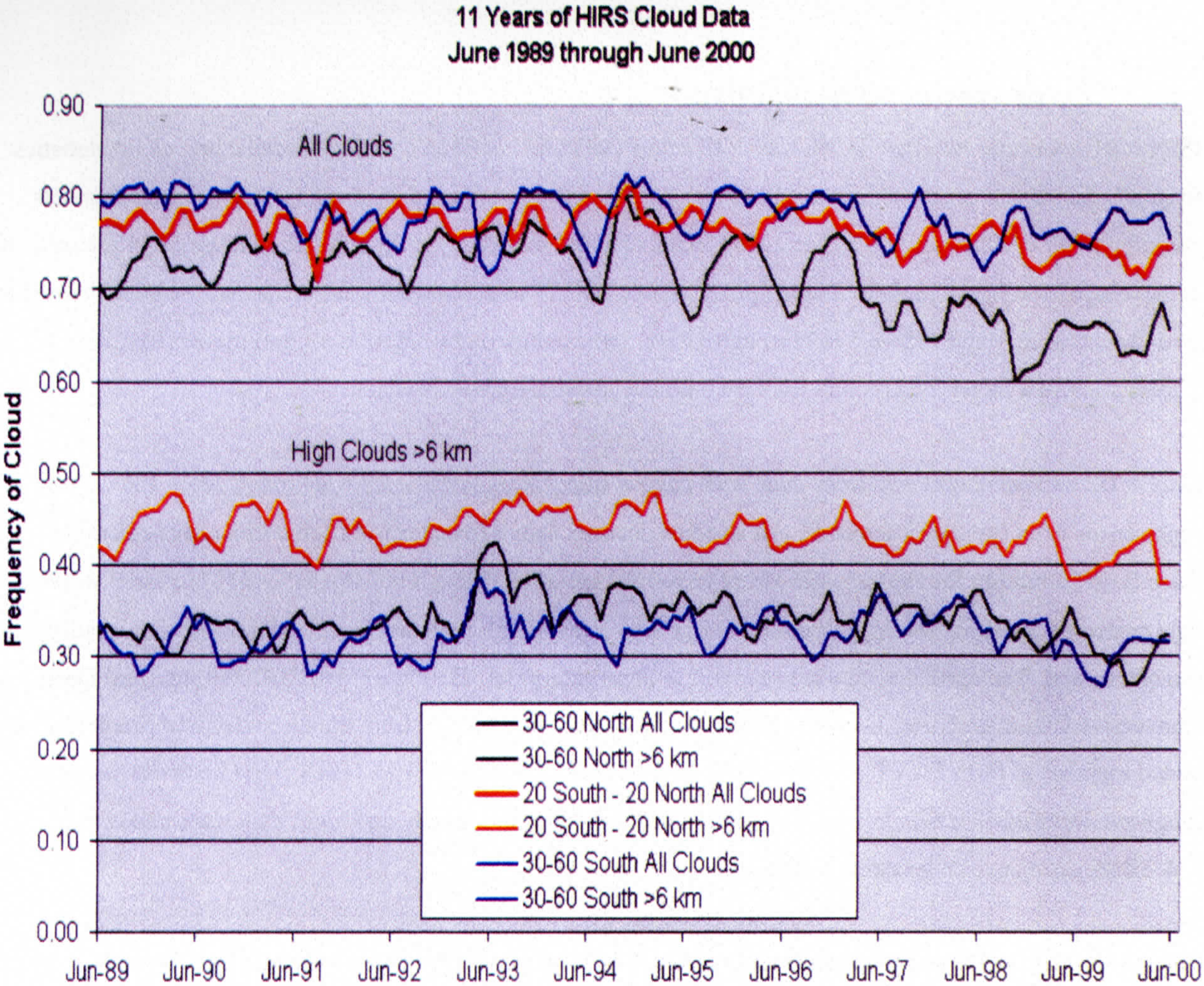

Figure 1. High cloud and all cloud observations found in HIRS measurements from June 1989 through June 2000. Polar orbiters NOAA 10 through 15 are part of this data set. NOAA 12 replaced NOAA 10 in September 1991, and NOAA 14 replaced NOAA 11 in April 1995. NOAA 15 replaced NOAA 12 in October 1998. Cloud observations over land from NOAA 11 are discarded because of the influence of the orbit drift.

2. COMPARISON WITH ISCCP D2

ISCCP (Rossow and Schiffer, 1999) was initiated in 1983 and has been continually collecting cloud statistics from all operational geostationary and polar orbiting weather satellites since then. ISCCP uses the channels common to all weather satellites - the visible channel at 0.6 microns and the infrared window at 11 microns - to detect clouds and measure their visible optical depths. ISCCP and UW HIRS cloud data sets were compared for five years (January and July in 1989 through 1993). This comparison is a follow-on to the work of Jin et al. (1996); we use a larger data set and ISCCP cloud data after algorithm revision.

ISCCP D2 data were obtained from their Web page at http://isccp.giss.nasa.gov/dataview.html. ISCCP detects high clouds from (a) only infrared 11 μm window channel data where it misses some thin cirrus clouds because there is no correction for the transmission of terrestrial radiation through the clouds; and (b) infrared window data corrected for cloud semi-transparency using the solar reflection measurements at 0.6 μm with a radiative transfer model. The corrected data are reported in three categories: Daytime Cirrus, Cirrostratus, and Deep Convective Cloud Amounts. For this comparison, the cloud frequencies from the three daytime categories were added together to form ISCCP's best estimate of high cloud frequency. UW HIRS cloud detection uses four longwave infrared channels from 13-15 μm to detect thin cirrus; both day and night data were added to form UW HIRS estimate of high cloud frequency.

The average frequencies of total cloud (also called All Clouds) and high clouds reported by UW HIRS and ISCCP are shown in Figure 2; there is general agreement at most latitudes. The exceptions occur in the tropics and the polar regions. UW HIRS finds more thin cirrus in the tropics, as noted by Jin et al. (1996). In the polar regions, ISCCP finds more total cloud in the winter hemisphere while UW HIRS reports more in the summer hemisphere.

Several differences in the cloud detection techniques cause different reports of cloud frequency. First, ISCCP uses solar reflectance and thus encounters more difficulty in finding thin cirrus clouds where the solar illumination angle is small (as in the winter hemisphere). Second, ISCCP uses a 3.7 μm channel near the poles and increases cloud detection mainly in the polar winter. Third, UW HIRS uses surface temperature data for separating clear and cloudy HIRS data while ISCCP examines spatial and temporal variances in infrared window data using statistical tests; UW HIRS has difficulties in high altitude mountains and polar regions, where there are few or unrepresentative surface temperature data. Fourth, ISCCP requires that a cloudy pixel be 4 K colder over land; UW HIRS uses 2.5 K (after adjustment for water vapor attenuation) and ignores the night and sunrise data where the surface temperature data is unreliable. Fifth, ISSCP sensors have field of view (FOV) sizes of 5-8 km diameter, while UW HIRS is 19 km diameter.

Over all, UW HIRS averaged 6% more Total Cloud detection than the ISCCP (Table 2). The High Cloud frequencies also are shown in Figure 2 and Table 2. UW HIRS is consistently higher than the ISCCP at mid- and tropical latitudes. The greatest differences occur in the Intertropical Convergence Zone (ITCZ) from 10° S to 10° N reaching 27%. UW HIRS and ISCCP High Cloud detections differed by an average of 16% over all latitudes. This is close to the 12-16% previously reported by Jin et al. (1996).

ISCCP reports the cloud optical depth extracted from solar reflection measurements in a visible channel at 0.6 µm. UW HIRS does not use any visible reflectance data; it derives the infrared effective of semitransparent cirrus clouds from IR window (11 µm) upwelling radiance measurements (Wylie et al., 1994). To compare ISCCP and UW HIRS data, ISCCP visible optical depths were converted to infrared emissivities (visible optical depths are halved to infer IR optical depths from which effective emissivities are derived). The latitudinal averages (not shown) are similar except for the ITCZ and summer midlatitudes where the ISCCP effective emissivity values are 10-15% higher. In the ITCZ, UW HIRS detects more high clouds than ISSCP; the colder temperatures of higher altitude cloud reports result in lower effective emissivity values. This reasoning may also explain differences found in the summer extra-tropical latitudes. Over all latitudes ISCCP effective emissivity averaged 5-7% higher than UW HIRS (see Table 2).

3. INTRODUCING MODIS

With the successful launch in December 1999 of the Moderate resolution Imaging Spectro-radiometer (MODIS) cloud fields and properties are being determined using visible, near IR, and IR cloud detection techniques (Ackerman et al., 1998) and CO2 slicing techniques. The 1 km data are being averaged to 5 km resolution and cloud properties are being processed at that resolution. Initial comparison of the MODIS and HIRS cloud data for 29 August 2000 reveals that total cloud determinations are in good agreement (Table 3). However MODIS finds more mid and high level thick clouds and less low level opaque; this is likely due to more CO2 slicing determinations at 5 km resolution and less IR window opaque cloud estimates.

When the MODIS 5 km data set was sampled at 20 km, the MODIS cloud statistics stayed nearly the same (within 1 % in all categories). Global cloud formations seem to be adequately sampled at 20 km, but the best spatial resolution of the sample still needs to be investigated. More global comparisons of UW HIRS and MODIS cloud statistics are pending.

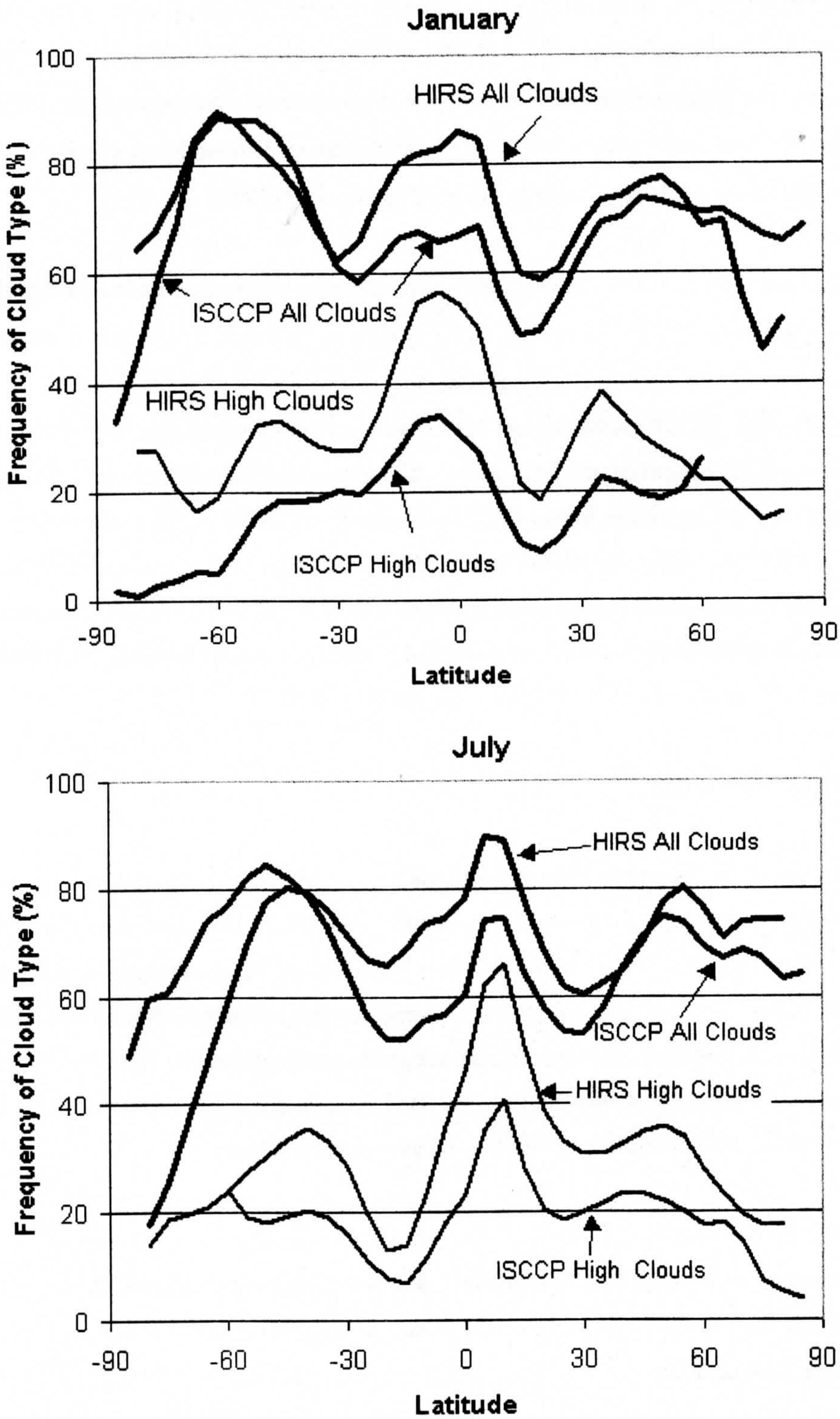

Figure 2: The frequency of detection of all clouds (total cloud) and high cloud (above 440 hPa) for the UW HIRS and the ISCCP analyses. ISCCP high clouds are the sum of cirrus, cirrostratus, and deep convective cloud frequencies. (top) Results from four Januarys in 1990-93 were averaged. (bottom) Results from five Julys in 1989 – 1993.

4. CONCLUSIONS

Eleven year trends in UW HIRS cloud statistics reveal that high clouds increased until 1993 and then gradually decreased back to 1989 levels. There are about 6 to 8% more high clouds in the tropics than in the northern or southern mid-latitudes. All clouds stayed relatively constant until 1995 and then decreased to below 1989 levels; the decrease is most noticeable in the northern mid-latitudes (especially in the winter months).

UW HIRS reported 6% more total cloud and 16% more high cloud than ISCCP D2. The largest differences found were in the ITCZ and the regions affected by polar winter. High cloud detection differences peaked at 5° N in July, averaging 27%. These results are similar to Jin et al. (1996) with a smaller data set.
ISSCP cloud infrared emissivities (converted from visible optical depths) were 5 to 7 % larger than UW HIRS; the most significant differences occurred in the ITCZ and the regions affected by polar summer. Some of these differences may be ascribed to the UW HIRS higher sensitivity to high thin cirrus clouds than ISSCP.

Initial comparison of the MODIS and UW HIRS cloud data for one day reveals that total cloud determinations are about the same. MODIS finds more mid and high level thick clouds and less low level opaque; this may be due to the high signal to noise and the high spatial resolution of the MODIS data. More global comparisons of UW HIRS and MODIS cloud statistics are pending.

5. ACKNOWLEDGMENTS

This work was supported by NASA Contract NAG1-2196.

6. REFERENCES

Ackerman, S. A., K. I. Strabala, W. P. Menzel, R. A. Frey, C. C. Moeller, and L. I. Gumley, 1998: Discriminating clear-sky from clouds with MODIS. J. Geophys. Res., 103, D24 , 32141-32158.

Jin, Y., W. B. Rossow, and D. P. Wylie, 1996: Comparison of the climatologies of high-level clouds from HIRS and the ISCCP. *J. Climate*, **9**, 2850-2879.

Rossow, W. B., and R. A. Schiffer, 1999: Advances in understanding clouds from the ISCCP. *Bull. Amer. Meteor. Soc.*, **80**, 2261-2287.

Wylie, D. P., and W. P. Menzel, 1999: Eight years of high cloud statistics using HIRS. *J. Climate*, **12**, 170-184.

Wylie, D. P. W. P. Menzel, and K. I. Strabala, 1994: Four years of global cirrus cloud statistics using HIRS. *J. Climate*, **7**, 1972-1986.

TECHNICAL PROCEEDINGS OF THE ELEVENTH INTERNATIONAL ATOVS STUDY CONFERENCE

Budapest Hungary

20-26 September, 2000

Edited by

J.F. Le Marshall and J.D. Jasper

Bureau of Meteorology Research Centre, Melbourne, Australia

Published by

Bureau of Meteorology Research Centre

PO BOX 1289K, GPO Melbourne, Vic., 3001, Australia

June 2001