Decadal Cloud Trends as Measured by Three Generations of Hyperspectral Infrared Sounders, AIRS, IASI and CrIS

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Objectives and Method

We examine a decade of global statistics in cloud height and frequency as measured by all three polar-orbiting hyperspectral sounders, **AIRS** (Atmospheric Infrared Sounding Spectrometer), **IASI** (Infrared Atmospheric Sounding Interferometer) and **CrIS** (Cross-track Infrared Sounder). We highlight the continuity that can be achieved in cloud products from these different instruments to allow a decadal global trend assessment. We then compare hyperspectral trends in cloud height and frequency with those derived from **HIRS** (High-Resolution Infrared Radiation Sounder) and **ISCCP** (International Satellite Cloud Climatology Project).

Accumulate all observations (per day, per instrument) by aggregating to nearest grid cell (1 x 1 degree resolution, global dimension is 180 x 360). If desired data can be filtered by viewing angle, day/night, land/ocean. Here all the data is used, i.e., a 'daily mean' includes measurements from both ascending and descending orbits at all viewing angles.

Daily cloud frequency	$freq_d$ = cld_obs/all_obs
Daily high cloud (<440 hPa) frequency	$hfreq_d$ = high_cld_obs/all_obs
Daily mean of CTOP	$ctop_d = mean(ctop)$

Monthly mean of cloud frequency	$freq_m = mean(freq_d)$
Monthly mean of high cloud frequency	$hfreq_m = mean(hfreq_d)$
Weighted monthly mean of CTOP	$ctop_m = \Sigma(freq_d * ctop_d)/\Sigma(freq_d)$

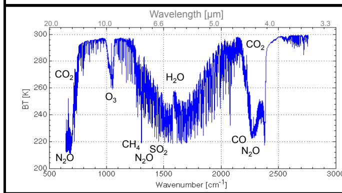
Multi-Instrument Retrieval Algorithm

The **Dual-Regression (DR) retrieval algorithm** (released under the University of Wisconsin-Madison Community Software Processing Package, **CSPP**, http://cimss.ssec.wisc.edu/cspp/) is a stand-alone tool designed to retrieve profiles of temperature, H_2O, surface & cloud properties, as well as trace gases (O_3, CO, CO_2) from space-based hyperspectral infrared sounders (Smith et al. 2012; Weisz et al. 2013)

The DR algorithm is (i) fast (for real-time application and reprocessing of decadal data records) and (ii) has multi-instrument capability to enhance data continuity and fusion.

Multi-Instrument Aggregation Algorithm

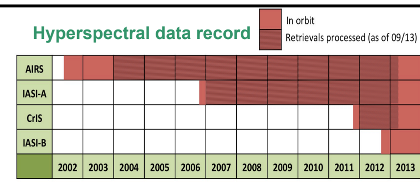
Cloud Top Pressure (CTOP) from all three instruments were aggregated in exactly the same way using the **UW Space-Time-Gridding algorithm** (Smith et al. 2013)

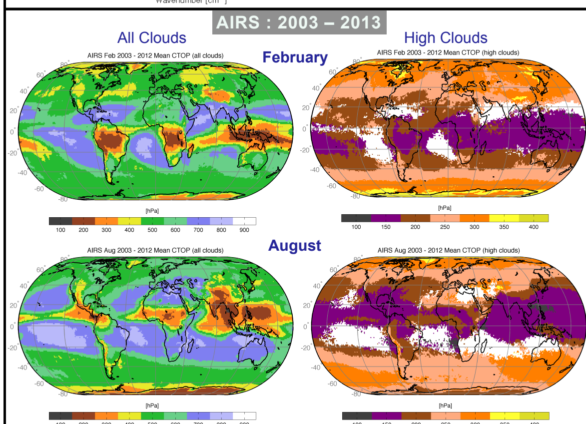


Hyperspectral Infrared spectrum have several thousand spectral channels that measure the atmospheric column with high vertical resolution.

Sounders are able to detect thin cirrus clouds with higher accuracy

Satellite	Instrument	Spatial resolution	Spectral resolution	Spectral Range	Spatial Sampling
Aqua (1330 LST)	**AIRS (2002 -)**	3x3 13.5-km (50 km)	~1200 resolving power	645-2700 cm^{-1}	Contiguous Cross-track scan
Metop-A/B (0900/0930 LST)	**IASI (2006 -)**	2x2 12.0-km (50 km)	0.25 cm^{-1}	645-2760 cm^{-1}	Contiguous Cross-track Scan
SNPP (1330 LST)	**CrIS (2011 -)**	3 x 3 13-km (50 km)	0.6 cm^{-1}	645-2700 cm^{-1}	Contiguous Cross-track Scan





Clouds are found in roughly 80 % of AIRS observations from 2003–2012. Occurrence of high clouds is ~ 40%.

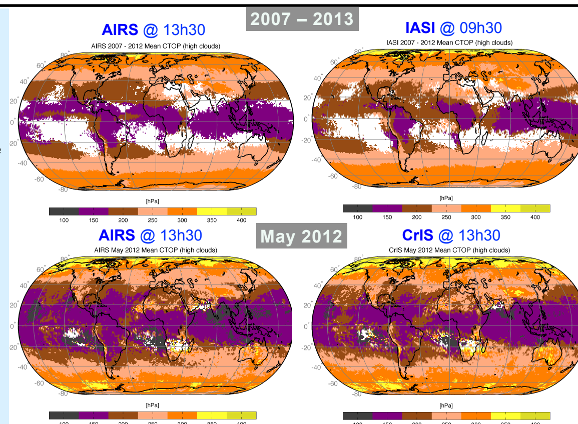
In the tropics ~75% of all observations are clouds, with 40% indicating high clouds. Tropical high clouds are more frequent in February than August.

Highest clouds are found in the ITCZ, where clouds are also most frequent.

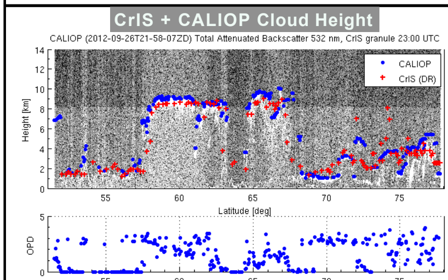
Cloud cover exhibits latitudinal movement with the seasons.

No significant trend can be deduced so far.

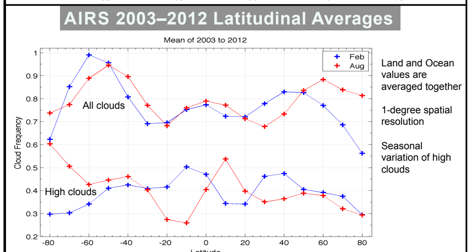
Good agreement among AIRS, IASI and CrIS across space and time.



CrIS + CALIOP Cloud Height



AIRS 2003–2012 Latitudinal Averages



Land and Ocean values are averaged together

1-degree spatial resolution

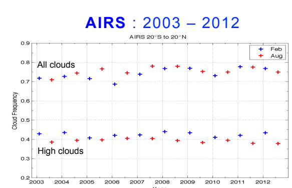
Seasonal variation of high clouds

Future work

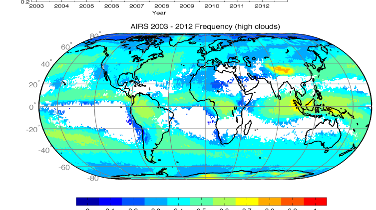
1. Filter by day/night, land/ocean, viewing angle, El Niño years, etc.
2. Study other parameters like cloud optical thickness and cloud emissivity.
3. Compute other statistical quantities (standard deviation, correlation, probabilities …) and define uncertainties.
4. Investigate instrument differences and synergistic use of all instruments.
5. Compare long-term trends with other (non-hyperspectral) instruments (e.g. MODIS)
6. Continue to extend HIRS data continuity and analysis.

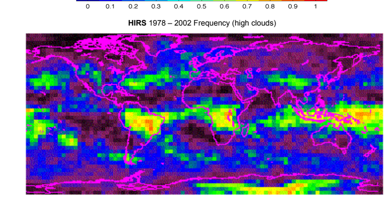
AIRS + HIRS + ISCCP

AIRS : 2003 – 2012



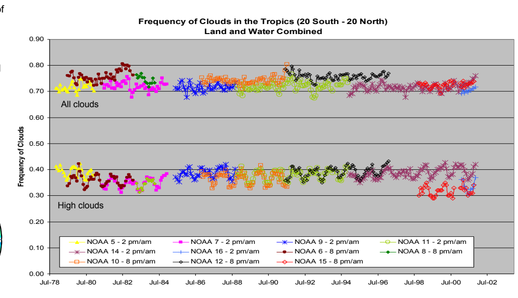
Decadal mean of AIRS cloud frequency for all clouds is ~80% (MODIS=67%, HIRS=75%) and for high clouds, ~40%.



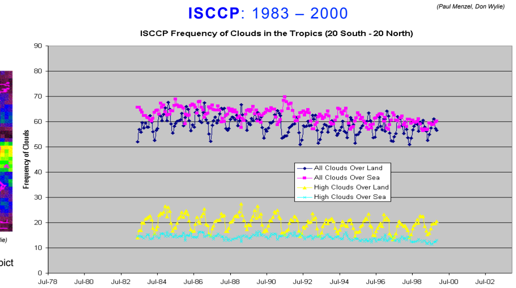


The AIRS record is comparable to the multi-decadal HIRS record. Both records depict more upper-tropospheric clouds than the ISCCP record. This can be explained by spectral differences between imager and sounder measurements.

HIRS: 1978 – 2002



ISCCP: 1983 – 2000



- There are four hyperspectral sounder instruments in Polar orbit at present spanning a decade of measurements.
- These four sounders provide high vertical resolution measurements of coincident soundings and cloud parameters with which climate trends can be measured globally at consistent temporal and spatial intervals.
- Given a single retrieval algorithm (i.e., Dual-Regression) instrument differences can be understood and minimized to allow data continuity among different generations of sounders for the assimilation of climate data records.

References:

-Smith et al. (2012) "Dual-regression retrieval algorithm…" *JAMC* 51(8): 1455–1467
-Smith et al. (2013) "A uniform space-time gridding algorithm…" *JAMC* 52:255–268
-Weisz et al. (2013) "Advances in…parameter regression" *JGR doi:10.1002/jgrd.50521*