A Statistical Cloud Fraction and Trends from AIRS: Comparison to AIRS L3, MODIS, VIIRS, and (PATMOS)

AIRS Virtual Science Team Meeting

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Introduction

- Cloud fraction trends are considered an extremely important unknown in climate change
- These trends are small, hard to detect, but play a large role in modifying the climate
- Satellite measurements of cloud fraction have existing since the early days of polar imagers
- The climate community is looking for continuity as well as higher quality data
- The PATMOS cloud record (NOAA, based in AVHRR) is the most used record of cloud fraction.

At the May AIRS STM I compared a new AIRS cloud fraction I have developed to PATMOS. Here I compare my results to the AIRS Level 3, MODIS, and VIIRS cloud fraction products.

AIRS PDF-based Cloud Fraction Algorithm

- Extremely simple
- Easy to compute
- But, depends on reasonbly accurate surface temperature and water vapor column, since you need a clear sky B(T) spectrum to generate the cloud fraction

Could this be a viable approach for a long-term cloud fraction record from AIRS that is very simple to compute and maintain?

Dataset

- Full AIRS record equal-area sampled for 1231 and 1228 cm^{-1} channels
- Statistical quantities (Cloud Radiative Forcing, etc. generated for 64° x 120° lat/lon grid for each 16-day interval.
- This data set was a precursor to the AIRS L1c "transposed" data set we hope to produce soon

Approach: Cloud Radiative Forcing (CRF) and BT_{clear}

The AIRS brightness temperature (BT) depression by clouds is one measure of cloud radiative forcing (CRF),

$$CRF = BT_{\text{obs}} - BT_{\text{clear}} \tag{1}$$

We estimate BT_{clear} using (from Aumann)

$$BT_{\text{clear}} = (SST - \Delta BT_{\text{atmosphere}}) \tag{2}$$

where $\Delta BT_{\text{atmosphere}}$ is the BT depression relative to the surface temperature for clear scenes.

$$\Delta BT_{\text{atmosphere}} = \mathbf{F}\left(BT_{1228\ \text{cm}^{-1}} - BT_{1231\ \text{cm}^{-1}}\right). \tag{3}$$

where **F** is a 3rd or 4th order polynomial that is derived from a large set of simulated AIRS spectra using ECMWF model fields.

Approach: Cloud Fraction from PDF of CRF

First generate PDFs of the CRF (Cloud Radiative Forcing). The cloud fraction (CF) is estimated for each grid cell for a 16-day period by summing the CRF PDF from max negative forcing (-140K) to a cutoff denoted as α below,

$$CF = \sum_{\alpha}^{-140K} \mathrm{PDF}_{\mathrm{CRF}}. \tag{4}$$

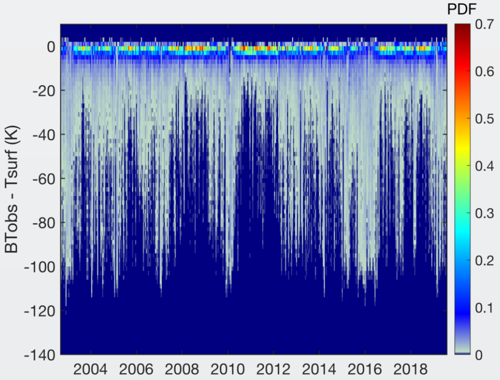
Rreasonable results are obtained using α = -4 to -6K. Comparisons of the AIRS CF to MODIS CF using 1-year averages suggested that α = -4.5K was optimum. (A map of α with range 4.5-9K shows MBL clouds.)

α (K)	Mean CF
0	0.999
-2	0.976
-4	0.770
-6	0.649

If AIRS radiometry drifts by 0.002K/year, we find that this translates into a drift in the CF of ~0.016%/year or 1.2% over 20 years.

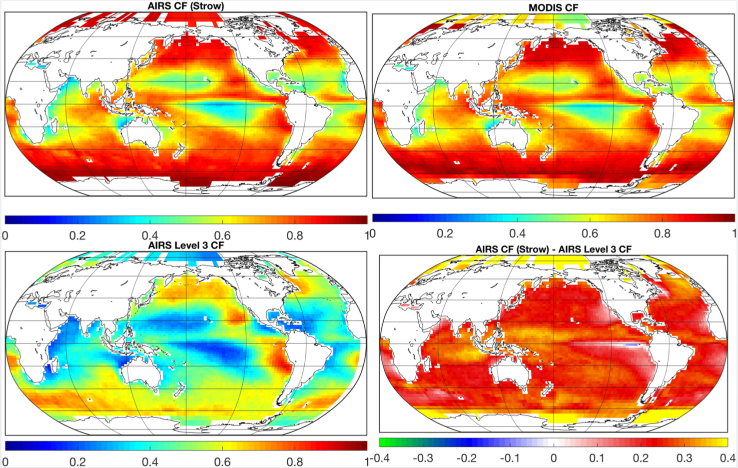
Sample PDFs versus Time

- A sample time series of cloud radiative forcing (CRF) PDFs for a single grid cell in our climatology, located in the Atlantic ocean west of Africa at (1.8,3.0)° lat/lon.



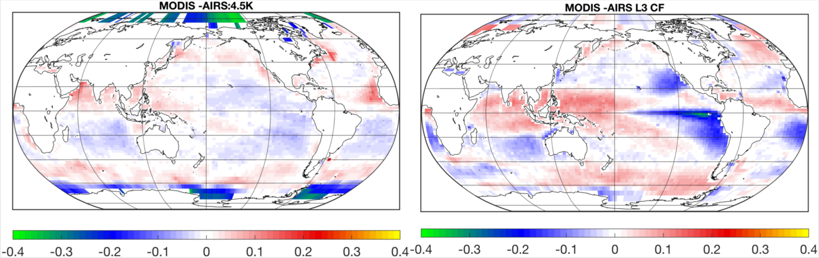
Mean Cloud Fractions

2007 average cloud fraction from this work (AIRS CF (Strow)), MODIS, and the AIRSL3 CF. Bottom right is this work minus AIRS Level 3 CF.

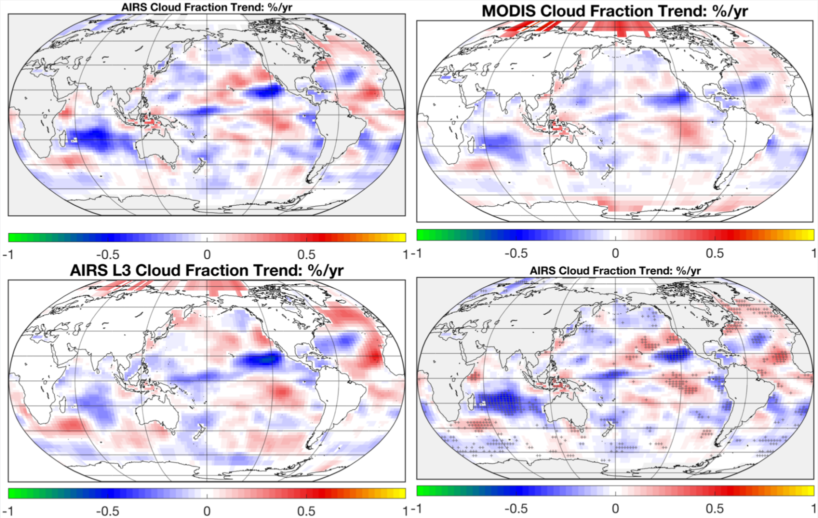


AIRS CF versus MODIS

- I added a δ CF of 0.28 to the AIRSL3 CF
- Compared my CF and this "adjusted" AIRS L3 CF to MODIS
- PDF-based CF appears closer to MODIS than AIRS L3
- Suspect my α cutoff is too large for polar scenes



Cloud Fraction Trends (17 Years)



Lower right panel has + markers for signals > 4-σ uncertainty

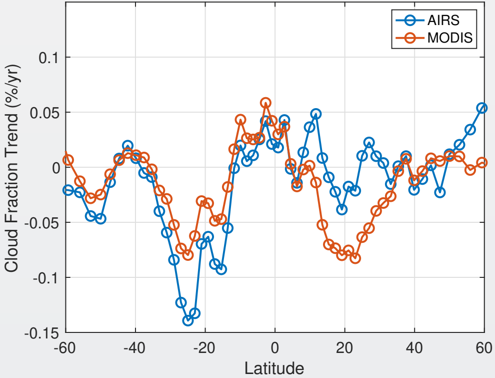
Quantification of Trend Differences

For ± 60°:

- AIRS average CF trend: -0.0177 %/yr
- MODIS average CF trned: -0.0095 %/yr
- MODIS - AIRS = 0.008%/yr, ~2X smaller than our estimated AIRS CF accuracy
- Very small trends, but independently derived. AIRS cloud fraction provides an independent asssessment of MODIS CF trends, adding value.

Zonal Trends

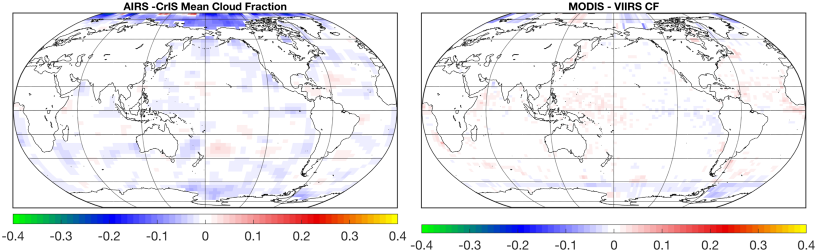
Zonal 17-year CF trends from AIRS and MODIS, in units of percent CF/year.



Both suggest lower cloud fraction in regions of descending air.

Continuity: AIRS vs CrIS, MODIS vs VIIRS

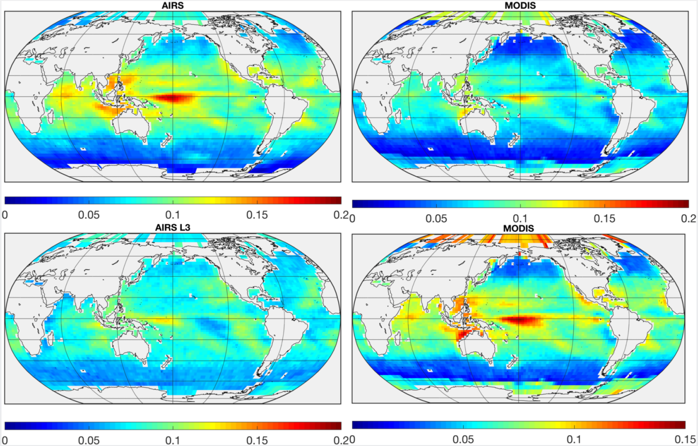
Yearly mean differences in CF between AQUA and NPP instruments. Left: AIRS CF minus SNPP-CrIS CF, Right: MODIS - VIIRS CF.



- MODIS and VIIRS match extremely well!
- AIRS and CrIS agree quite well too, largest differences in Arctic

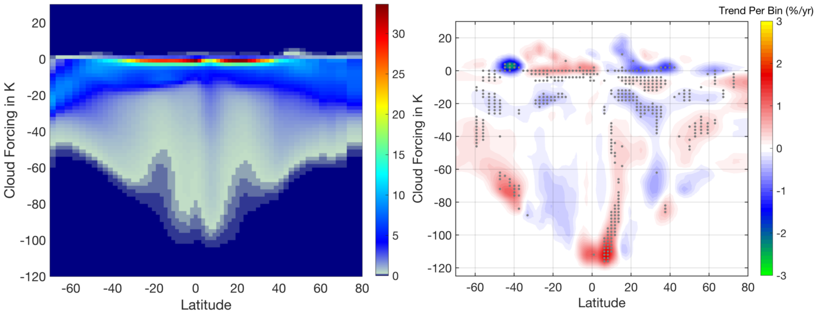
Cloud Fraction Variability

- Showing cloud fraction standard deviations (monthly variability over 17 years)
- The lower right panel the colorscale for MODIS has been compressed by 30% compared to the other panels.



Trends in PDF of Cloud Forcing (Pseudo vertical trends)

Left Panel: Zonal cloud radiative forcing (CRF) PDF yearly means, Right Panel: CRF PDF relative trends per pixel, in %/year. Regions with trends that are 2X the magnitude of the 2-σ trend uncertainties are marked with + signs.



Suggests increased deep convection near the equator.