PATMOS-x:
Cloud Cover, Layers, Temperatures and Emissivities

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What is PATMOS-x?

-An AVHRR based cloud climatology. We run algorithms that share much physical consistency with the MODIS-ST where possible.

-Data record spans from 1981 to the present and should extend to 2020.

- Effort underway to go back in time on AVHRR/1 (back to 1978) and forward in time on NPOESS VIIRS.

- Level-3 products are generated at 0.5 degree resolution using an equal-area (ISCCP-like) grid.

- Level-2b products are now generated which provided sampled pixel-level results with a 0.1 degree equal-angle grid.

Data available at http://cimss.ssec.wisc.edu/patmosx/

Latest Papers that Include or Describe PATMOS-x

Heidinger, A.K. C. Molling, W. Straka, J.T. Sullivan, and X. Wu, 2010: Deriving an Inter-sensor Consistent Calibration for the AVHRR Solar Reflectance Data Record. Accepted to IJRS.

Heidinger, A.K. and M. Pavolonis, 2009: Gazing at Cirrus Clouds for 25 Years through a Split Window. Part I: Methodology. JAMC, 48, 1100-1116.

Foster, M. J., R. Bennartz, and A. K. Heidinger, 2010: Estimation of Liquid Cloud Properties that Conserve Total-scene Reflectance Using Satellite Measurements, Submitted to *Journal of Applied Meteorology and Climatology*.

Rausch, J., R. Bennartz and A. Heidinger, 2010: Global assessment of marine boundary layer cloud microphysical properties using the PATMOS-x dataset. Submitted to JGR.

Eliasson, S., Buehler, S. A., Milz, M., Eriksson, P., and John, V. O.: Assessing modelled spatial distributions of ice water path using satellite data, Atmos. Chem. Phys. Discuss., 10, 12185-12224, doi:10.5194/acpd-10-12185-2010, 2010.

+ 2 others submitted using PATMOS-x cloud amounts

PATMOS-x Cloud Climate Products

• Largely due to the need to make modified Level-3 data for this GEWEX effort, we have rethought the PATMOS-x data products.

• We now make a level-2b product that consists of sampled (not averaged) products at relatively high spatial resolution (0.1 or 0.2 degree). There are much fewer level2b products than level3 products. (i.e. no H/M/L separation needed).

• Level2b maintains the flexibility to conduct any analysis including any LEVEL-3 data-set or multi-dimensional histograms.

• Our plan is make level2b available online and to allow sub-setting in space and time to make the data-set optimal for a users specific application.

• Andi Walther has developed tools to go from Level-2b to the GEWEX LEVEL-3 data.

• We plan to continue to make these GEWEX Level3 netcdf data and/or provide the tools.

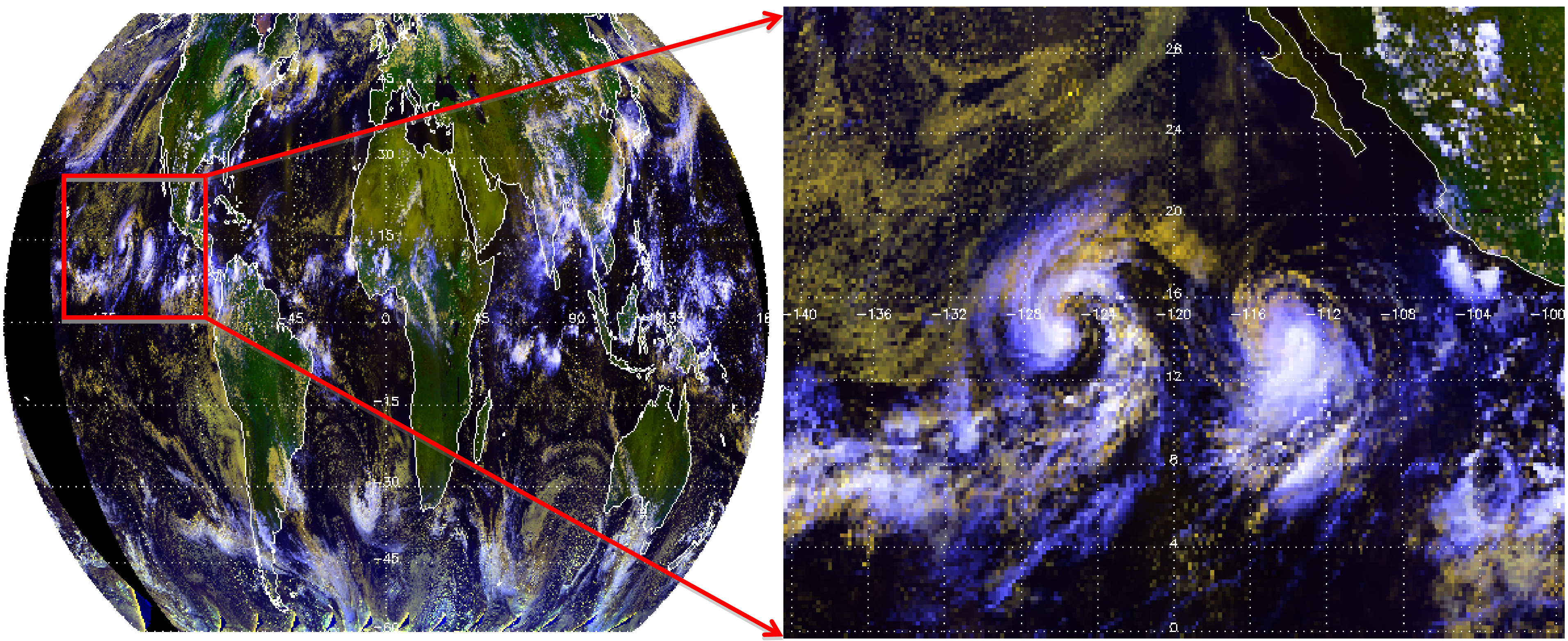
• In addition, we will offer diurnally corrected Level-3 data. For example, products adjusted to 13:30 or diurnally averaged.

LEVEL-2b PATMOS-x example (0.2 degrees)

Level-2b consists of sampled pixel-level results and allows for flexible analysis – like arbitrary 2d histograms

patmosx_n18_asc_2008_180.level2b

patmosx_n18_asc_2008_180.level2b



False Color Image
Red=0.63μm, Green = 0.86μm, Blue = 11μm (reversed)

False Color Image
Red=0.63μm, Green = 0.86μm, Blue = 11μm (reversed)

Level-2b being proposed for inclusion in future MODIS-ST product versions.

PATMOS-x Improvements in Cloud Cover and Cloud Heights

• Most of algorithmic effort is now spent on the GOES-R program. I chair the Cloud Application Team which includes members from NOAA, NASA and Academia.

• Over the past three years, we have developed tools to utilize co-located CALIPSO/CALIOP observations for algorithm refinements and characterization.

• PATMOS-x has benefited from these efforts. Notably…

- ✓ Naïve Bayesian Cloud Mask derived using CALIPSO Cloud Layer Product
- ✓Prior information used in cloud height optimal estimation approach taken from global CALIPSO analysis. (our first guess comes from a CALIPSO analysis).

• The overall agreement between PATMOS-x and CALIPSO shown here is therefore not coincidental.

Bayesian Cloud Detection in PATMOS-x

• We have continued to develop our ability to co-locate CALIPSO observations with passive satellites (AVHRR, MODIS, SEVIRI …)

• While this was done initially for validation, we decided to explore using CALIPSO colocations for deriving a naïve Bayesian cloud Mask.

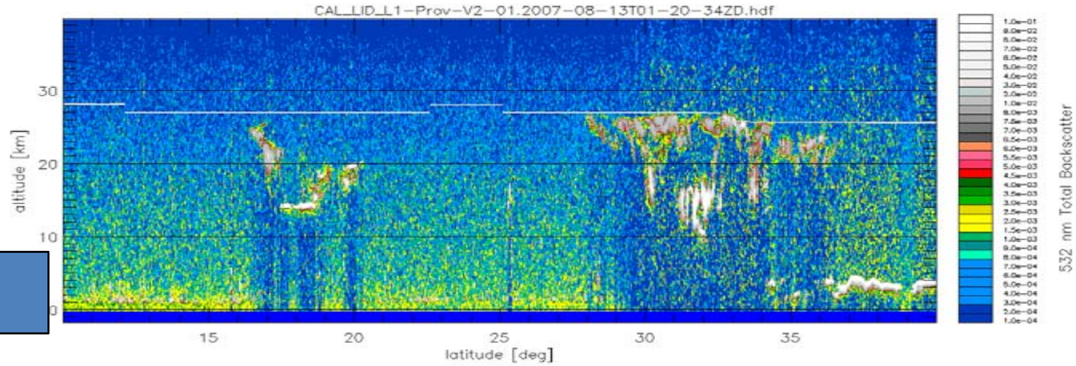
• The cloud tests are the same as those used in previous data-set.

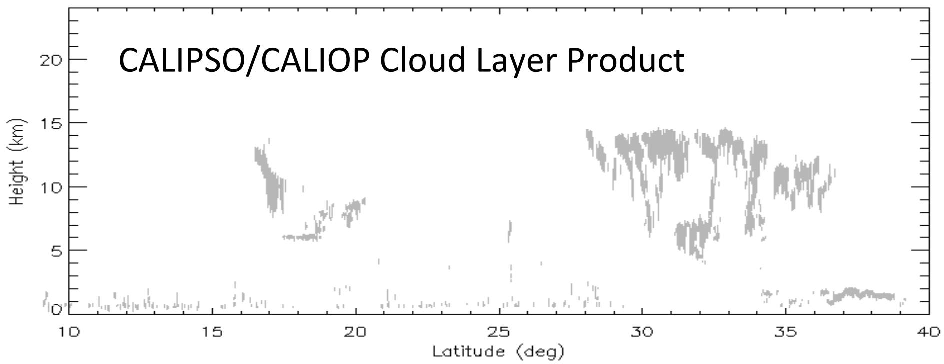
• The Bayesian mask has removed the need to specify thresholds for cloud detection.

• Currently, we have derived Bayesian classifiers for several surface types (Deep Ocean, Shallow Water, Land, Snow-covered Land, Sea Ice, Antarctica+Greenland & Deserts).

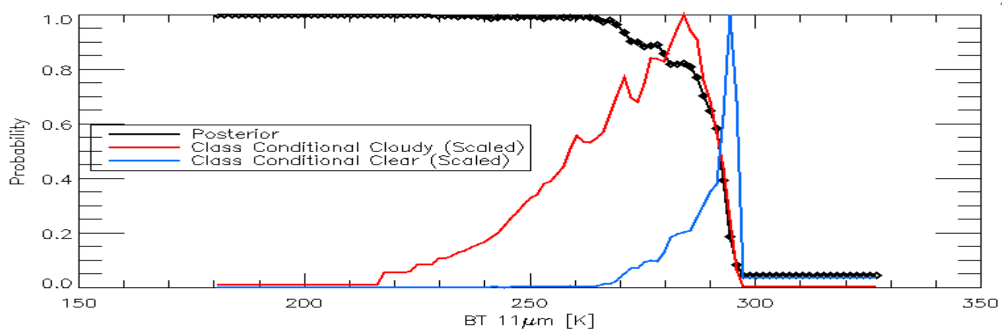
Using CALIPSO to Derive a Bayesian Cloud Mask

CALIPSO/CALIOP 532 nm Total Backscatter

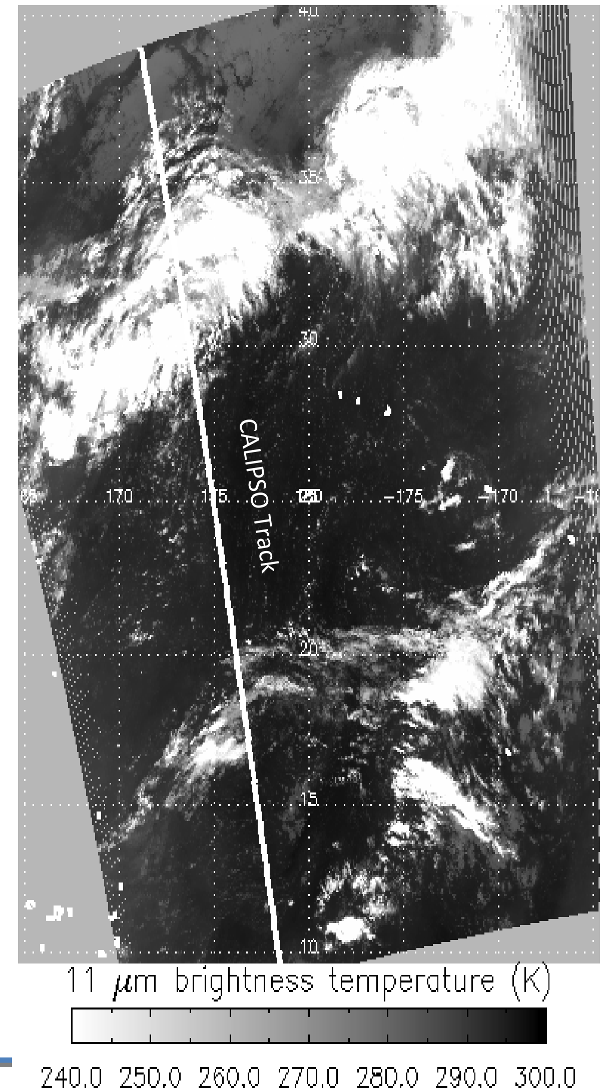




Distribution of Clear and Cloudy AVHRR 11 μm BT

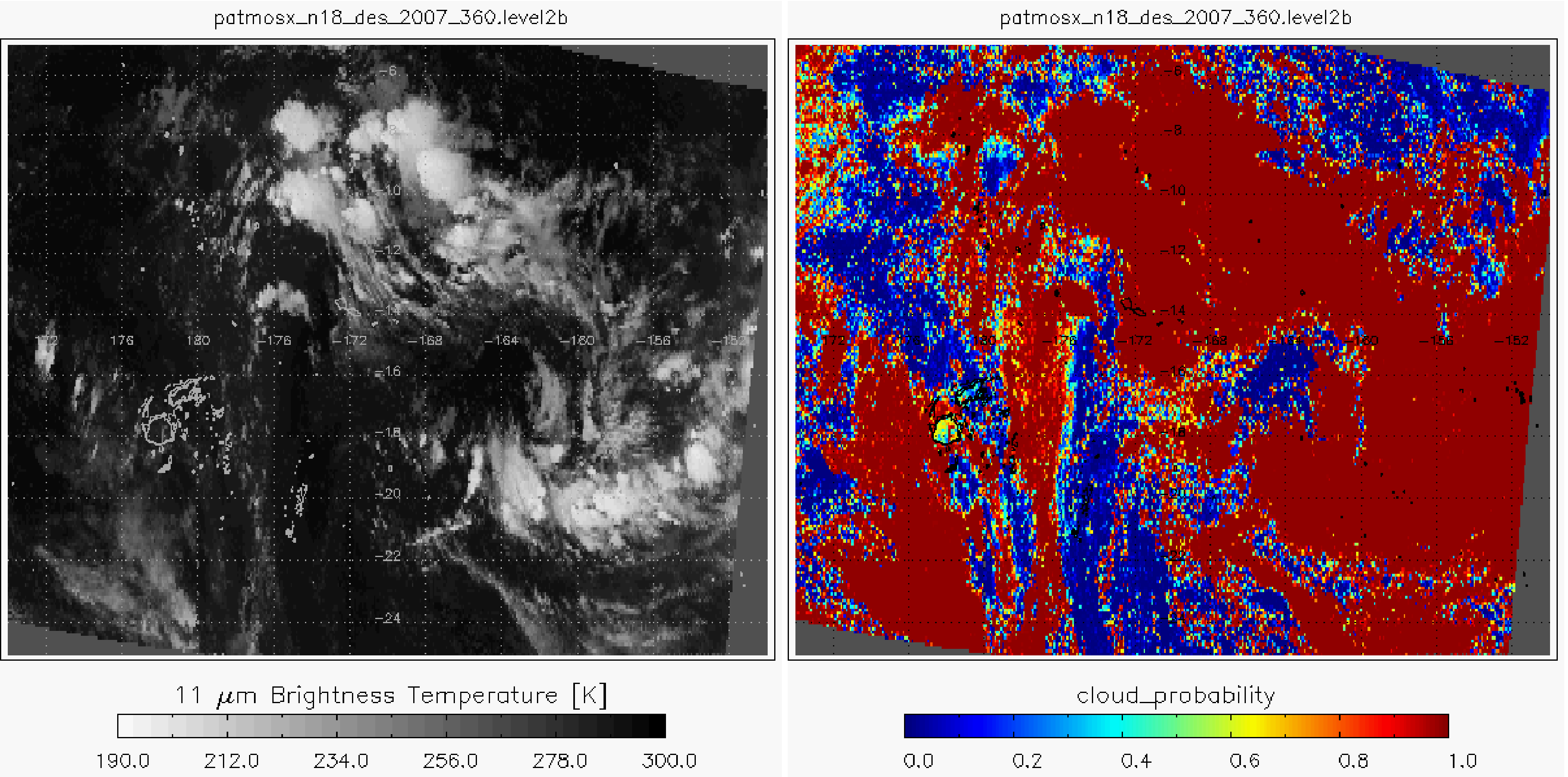


AVHRR Image



Bayesian Cloud Detection

Example of Resulting Naïve Bayesian Cloud Probability in PATMOS-x Level2b Data.



Naïve Bayesian Cloud Mask Statistics

Using the NCEP Renanalysis – which is done in PATMOS-x

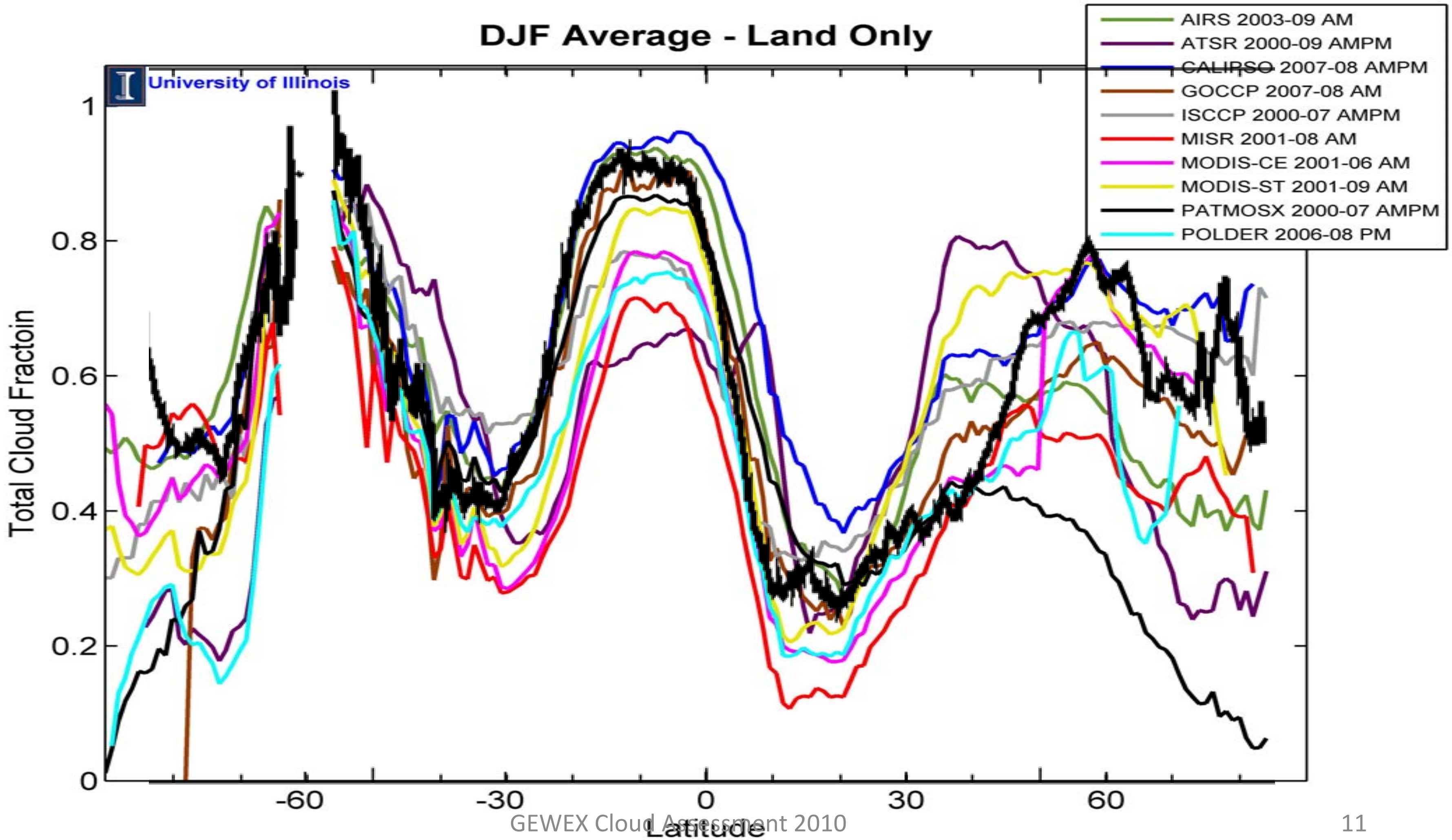
	Deep Ocean	Shallow Water	Land	Snow Covered Land	Sea-Ice	Antarctica	Deserts
POD	0.917	0.908	0.887	0.796	0.730	0.649	0.898
SKILL	0.823	0.808	0.771	0.626	0.480	0.343	0.747
FALSE	0.017	0.0285	0.0397	0.0456	0.0708	0.0774	0.0478
MISSED	0.066	0.0632	0.0735	0.158	0.199	0.273	0.0541

Using the NCEP GFS Forecast – which is done in our real-time processing at NOAA

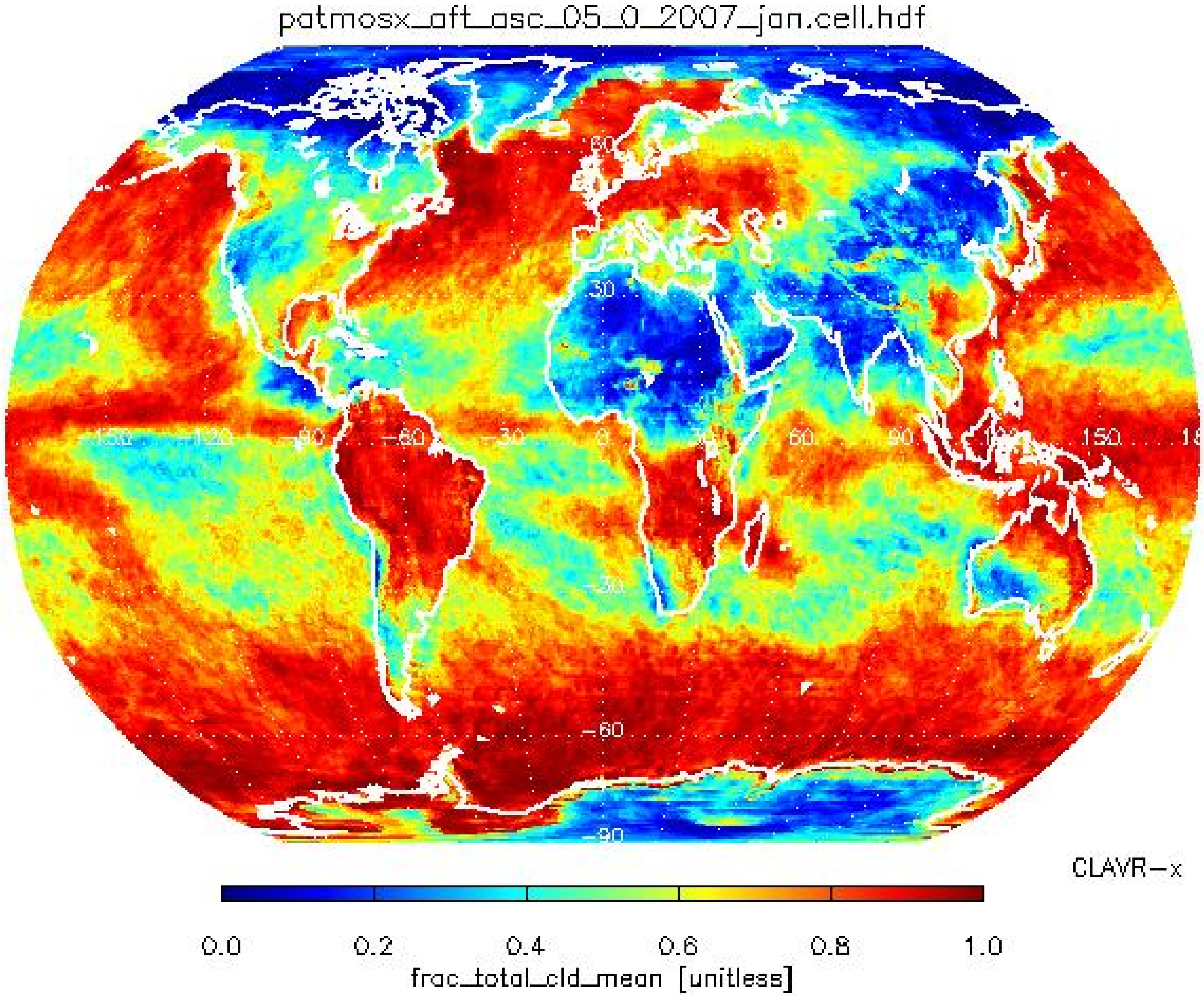
	Deep Ocean	Shallow Water	Land	Frozen Land	Sea-Ice	Antarctica	Desert
POD	0.929	0.913	0.890	0.808	0.745	0.663	0.907
SKILL	0.842	0.808	0.780	0.641	0.500	0.364	0.765
FALSE	0.0173	0.031	0.0368	0.048	0.0716	0.0887	0.0401
MISSED	0.0534	0.0577	0.073	0.144	0.183	0.255	0.053

Impact of Bayesian on PATMOS-x Cloud Amounts

The previous GEWEX analysis that PATMOS-x cloud amounts over cold land ere too low. The Bayesian mask appears to have brought PATMOS-x "back in line"

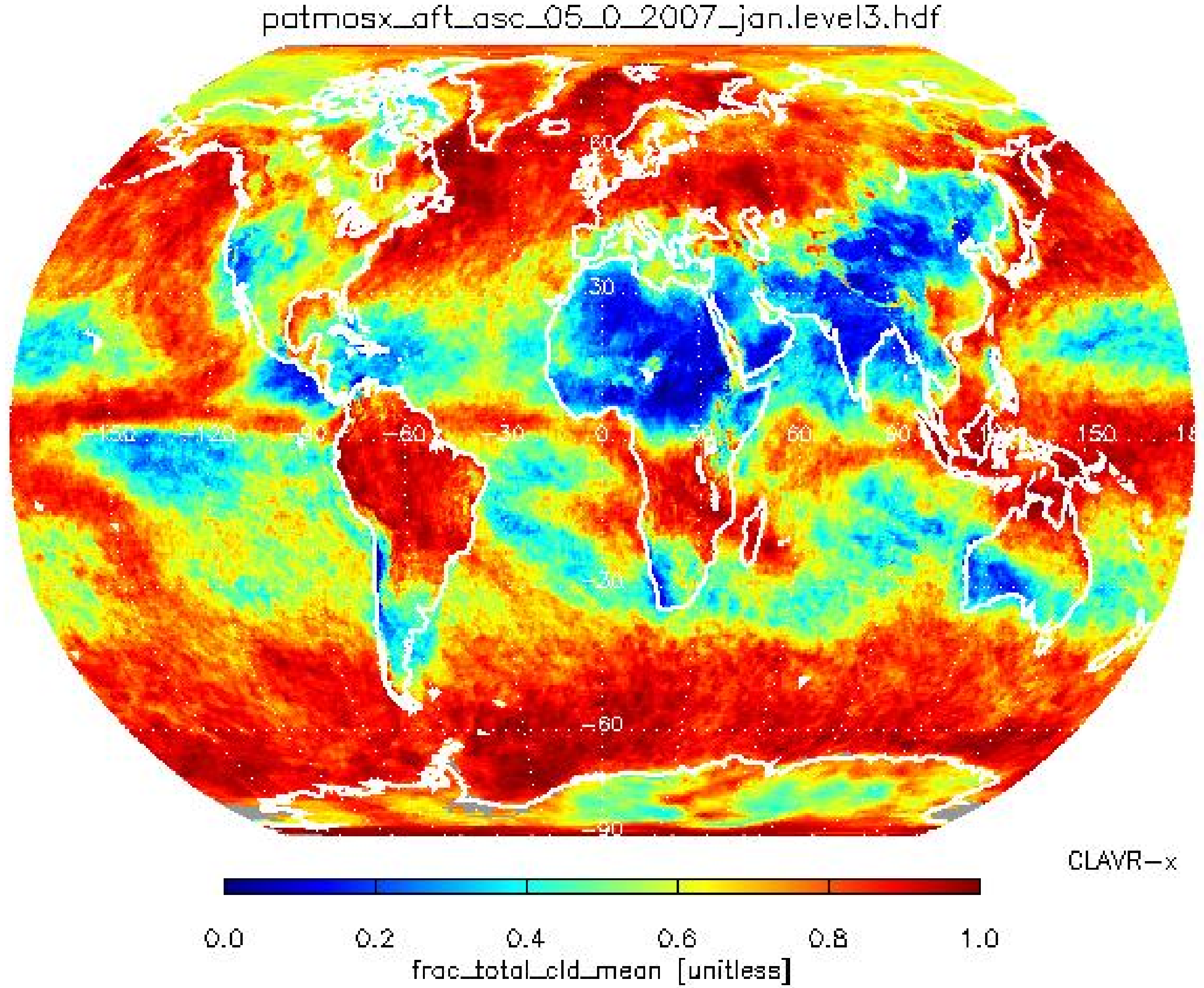


OLD



patmosx_aft_asc_05_0_2007_jan.cell.hdf
CLAVR−x
0.0
0.2
0.4
0.6
0.8
1.0
frac_total_cld_mean [unitless]

NEW



patmosx_aft_asc_05_0_2007_jan.level3.hdf
60
30
-150
-120
-90
-60
-30
0
30
60
90
150
-30
-60
-90
CLAVR-x
0.0
0.2
0.4
0.6
0.8
1.0
frac_total_cld_mean [unitless]

PATMOS-x Cloud Height Algorithm

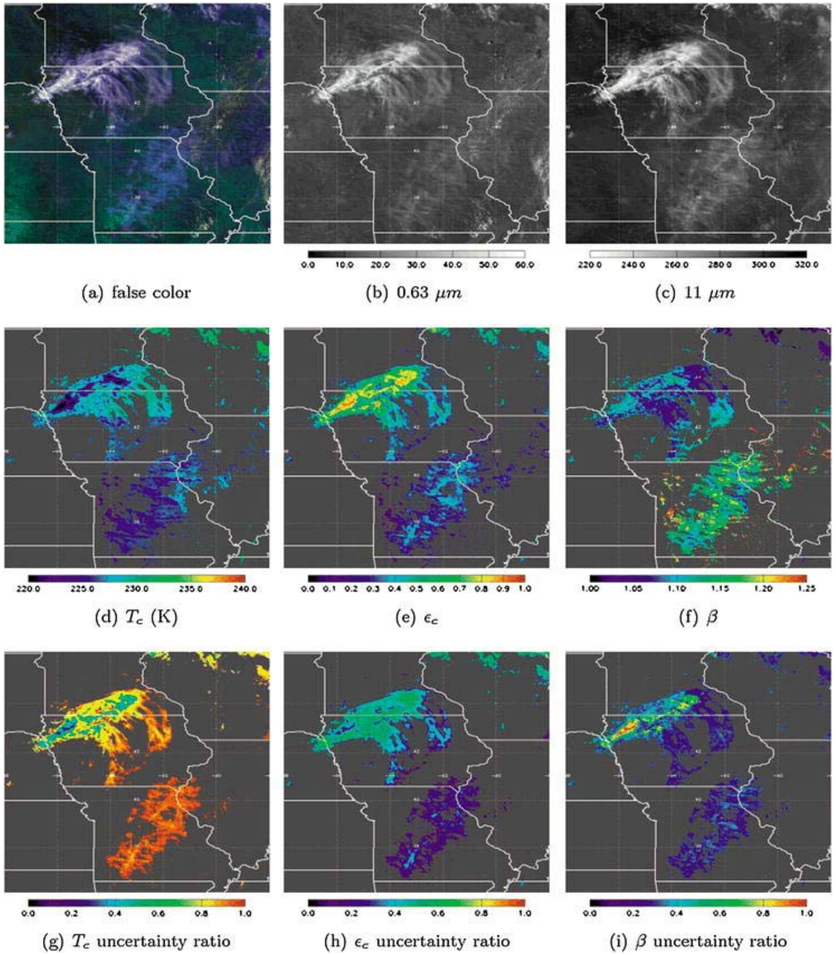
• PATMOS-x uses a split-window based approach for deriving cloud-height, pressure, temperature, emissivity and particle size.

• We use an optimal estimation approach

• Prior information from CALIPSO/CALIOP is used in the OE algorithm.

• Our analysis indicates large uncertainties in cloud temperature for thin cirrus.

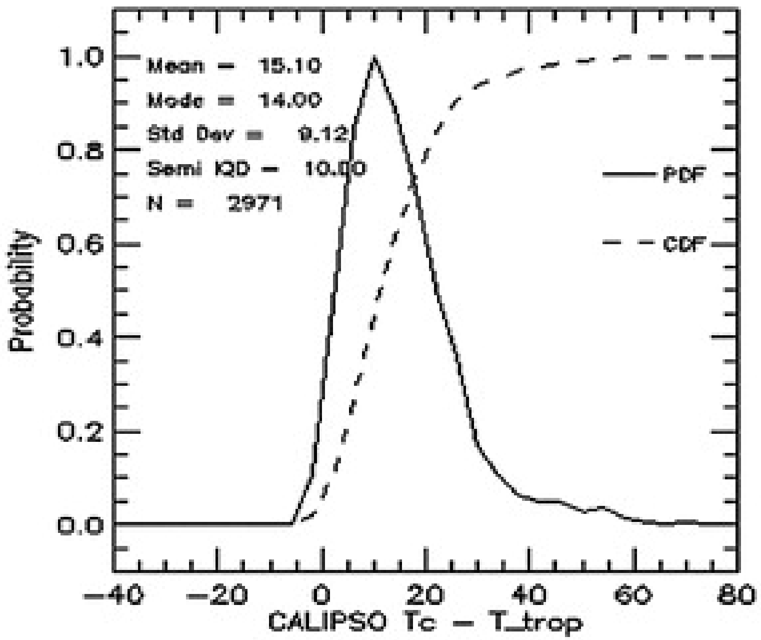
•However, cirrus emissivity and particle size are accurate for thin cirrus.



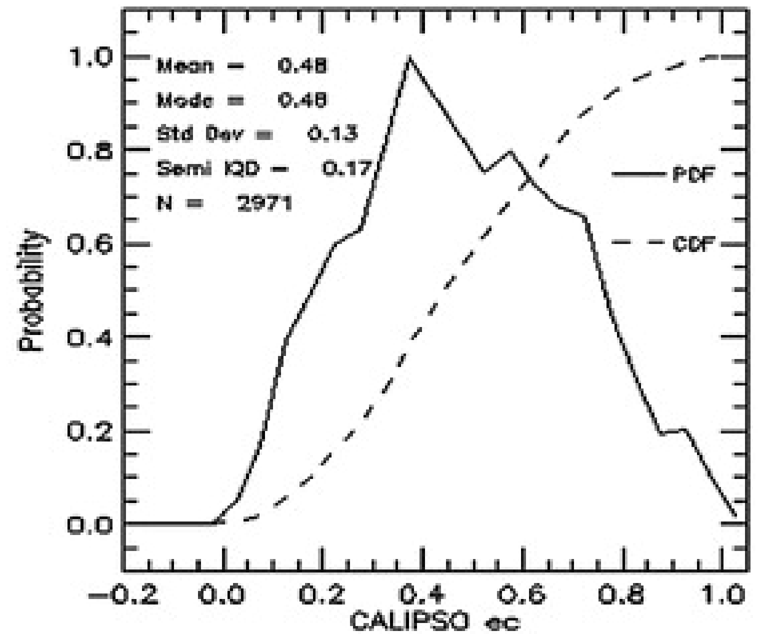
Heidinger, Andrew K. and Pavolonis, Michael J.. Gazing at cirrus clouds for 25 years through a split window, part 1: Methodology. Journal of Applied Meteorology and Climatology, Volume 48, Issue 6, 2009, pp.110-1116. Call Number: Reprint # 6079

PATMOS-x Cloud Height Algorithm

- *a priori* values are taken from CALIPSO
- These are the values used for cloud we typed as cirrus.



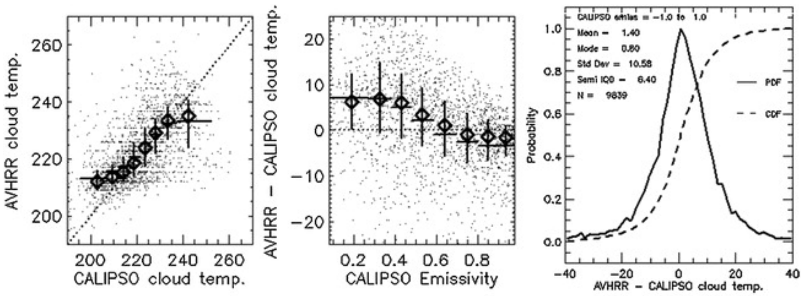
(a) T_c - T_{tropo}



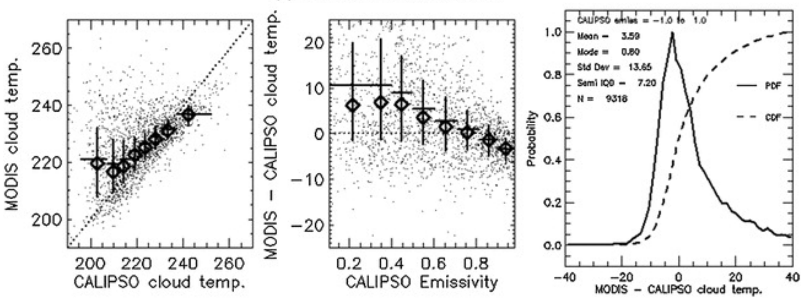
(b) ϵ_c

Level-2 comparisons of cloud temperature and emissivity from PATMOS-x, MODIS-T and CALIPSO (Heidinger et al. 2009)

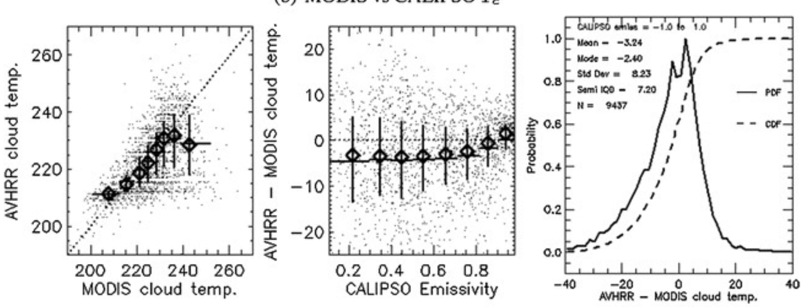
Note, our Level-2 comparisons are more favorable than our GEWEX Level-3 Analysis



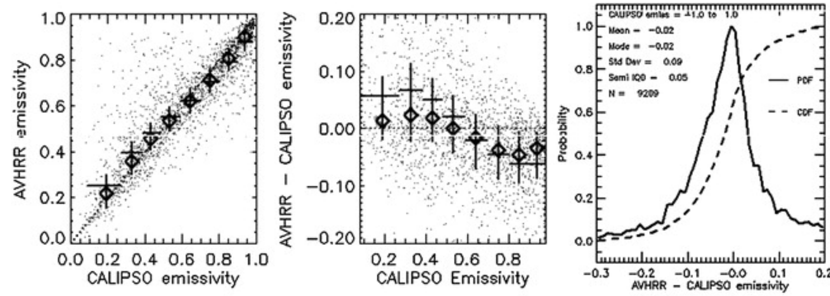
(a) AVHRR vs CALIPSO T_c



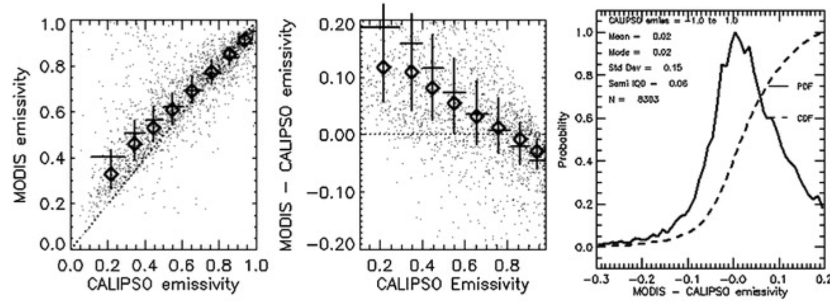
(b) MODIS vs CALIPSO T_c



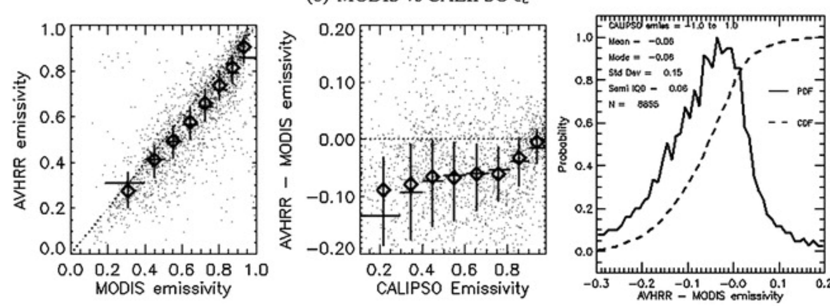
(c) AVHRR vs MODIS T_c



(a) AVHRR vs CALIPSO ϵ_c



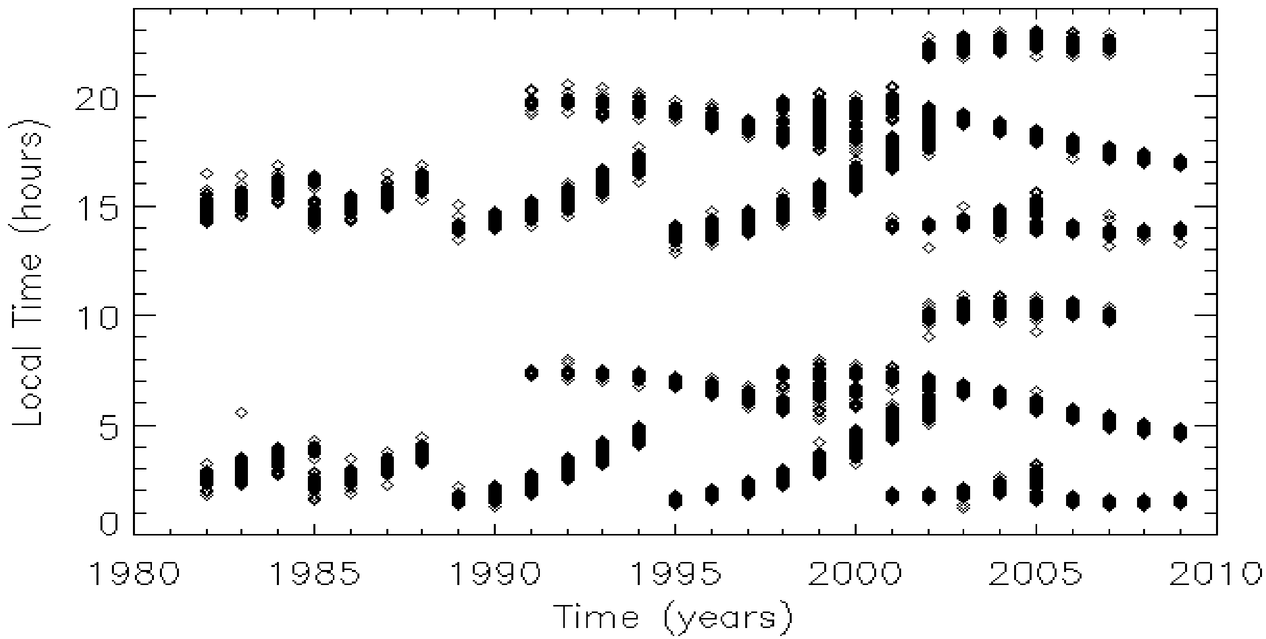
(b) MODIS vs CALIPSO ϵ_c



(c) AVHRR vs MODIS ϵ_c

Accounting for the Diurnal Cycle

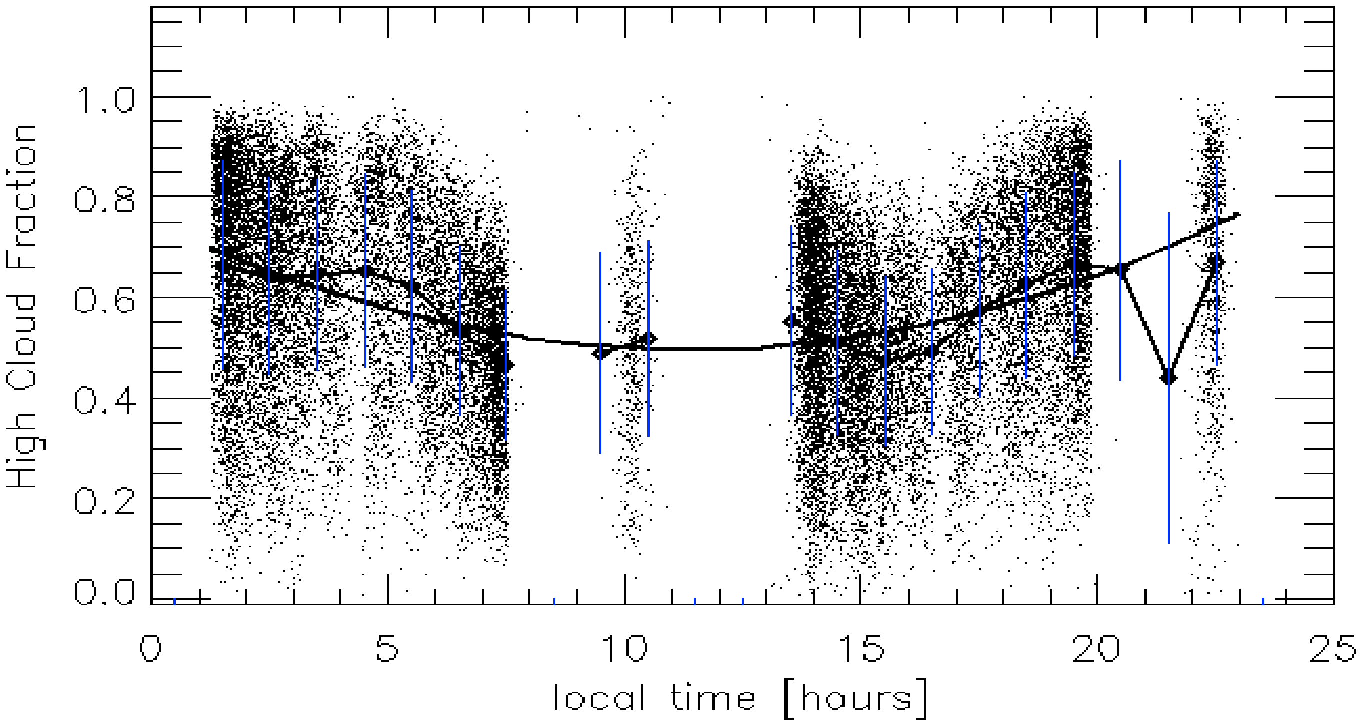
Illustration of Local Time Variation within PATMOS-x



- Over 30 yrs, PATMOS-x sees the earth at almost every hour in the day.
- We are using this information to derive “climatological” diurnal cycles and using them to correct Level-3 time-series to any local time.

Accounting for the Diurnal Cycle

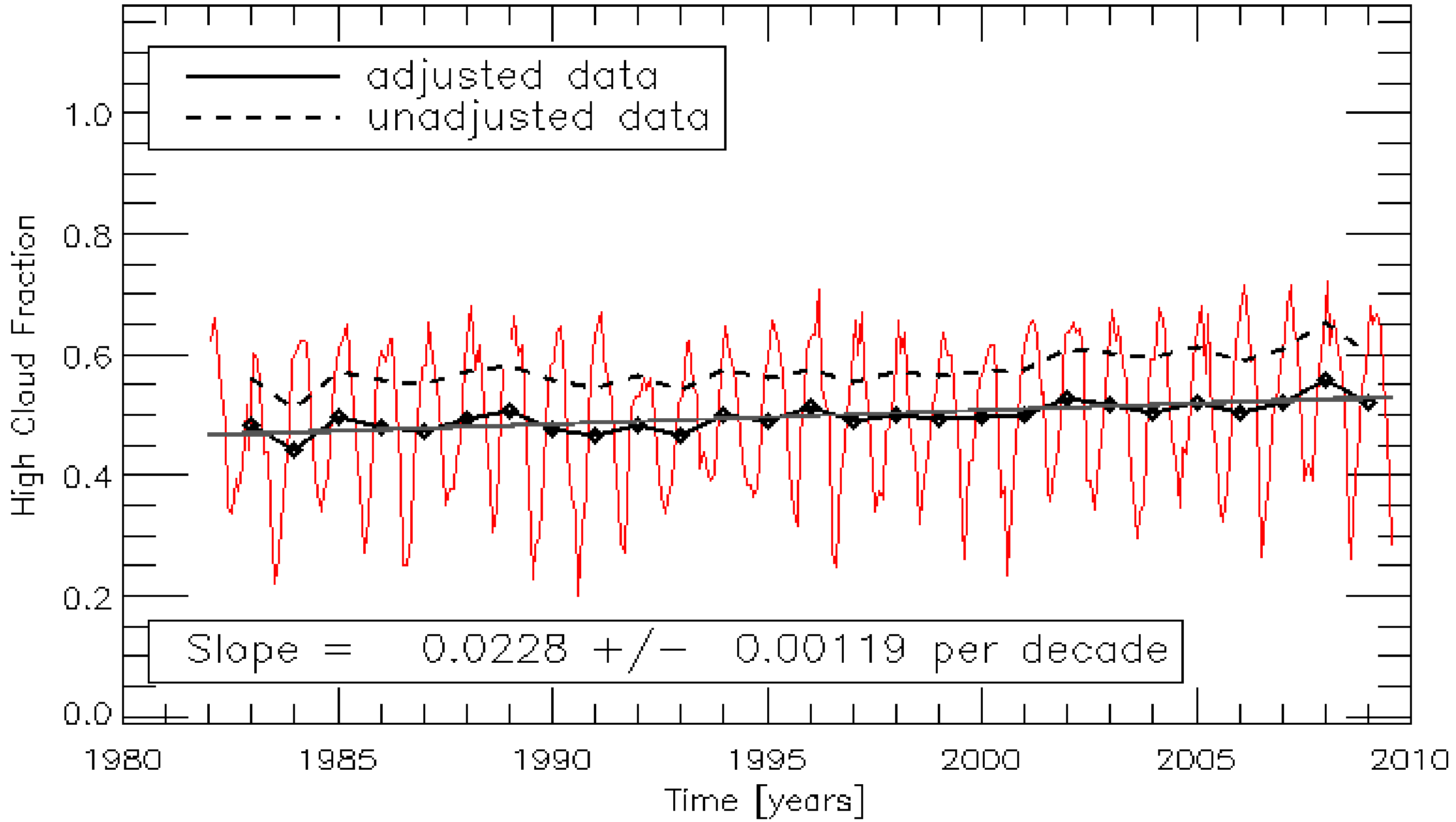
- We derive a mean diurnal cycle by taking all measurements, plotting as a function of local time and fitting a polynomial to it.
- With this polynomial, we can adjust any time-series to a time-series with a fixed local-time (say 13:30 or 1:30 + 13:30).
- The big assumption is that the diurnal cycle remains constant.



Accounting for the Diurnal Cycle

- Time series was adjusted to 13:30 local.

- Since 13:30 is near the minimum in the diurnal cycle, the adjusted time series is lower.



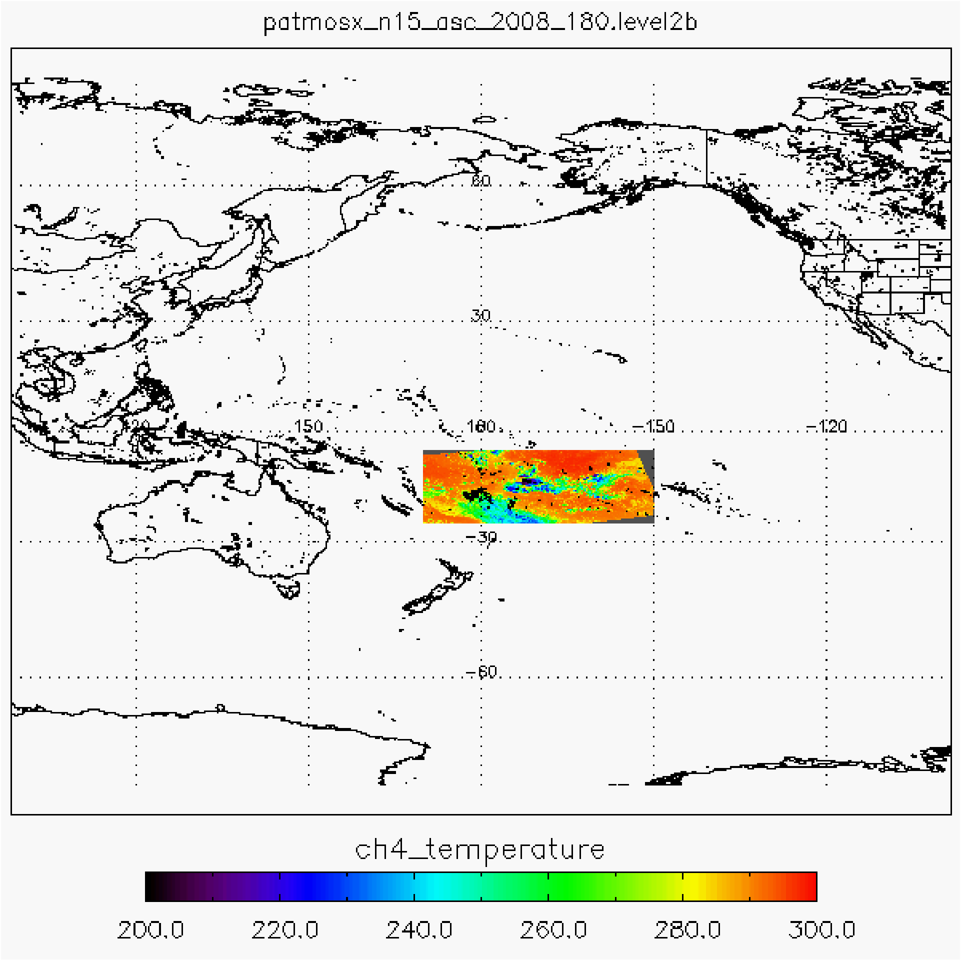
Study of Long-Term Time Series over the Tropical Western Pacific

•Most of the time-series shown here where for the Western Tropical Pacific Region show on the right.

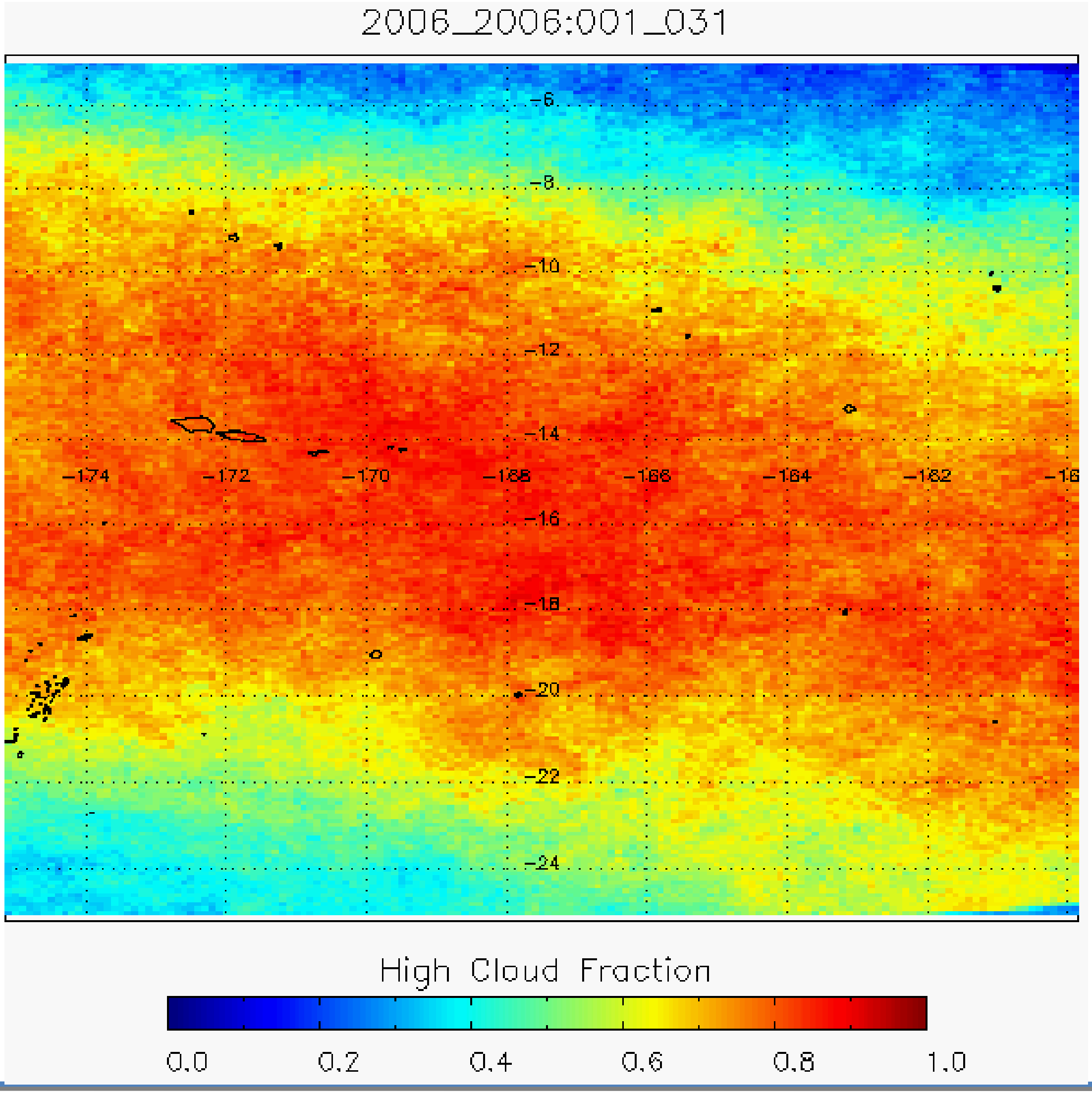
•This was done for simplicity and to avoid mixing results from different surface types and cloudiness regimes.

• Results from the entire Tropics are similar.

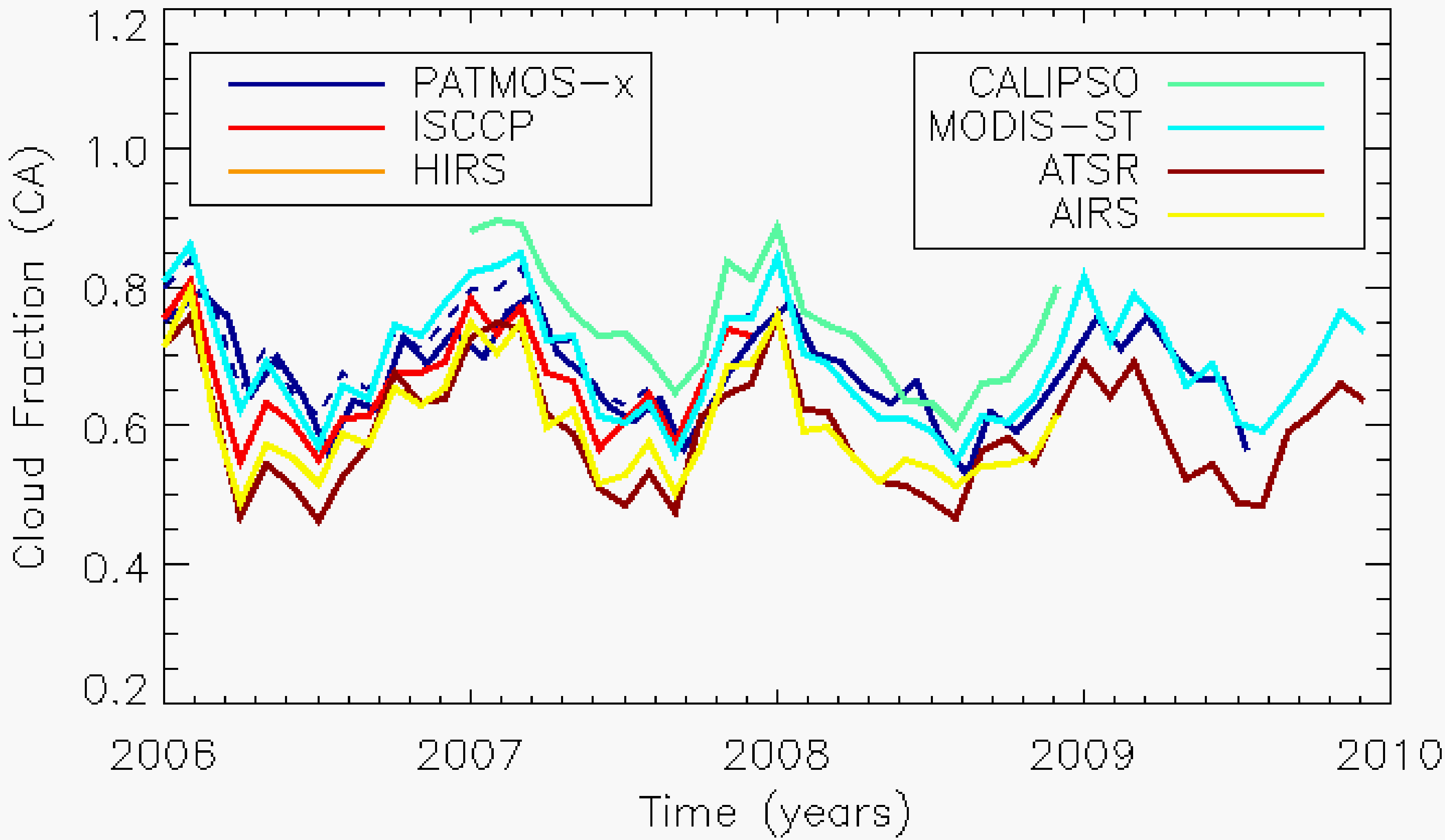
• Small region allowed for running of PATMOS-x V5 for this meeting.



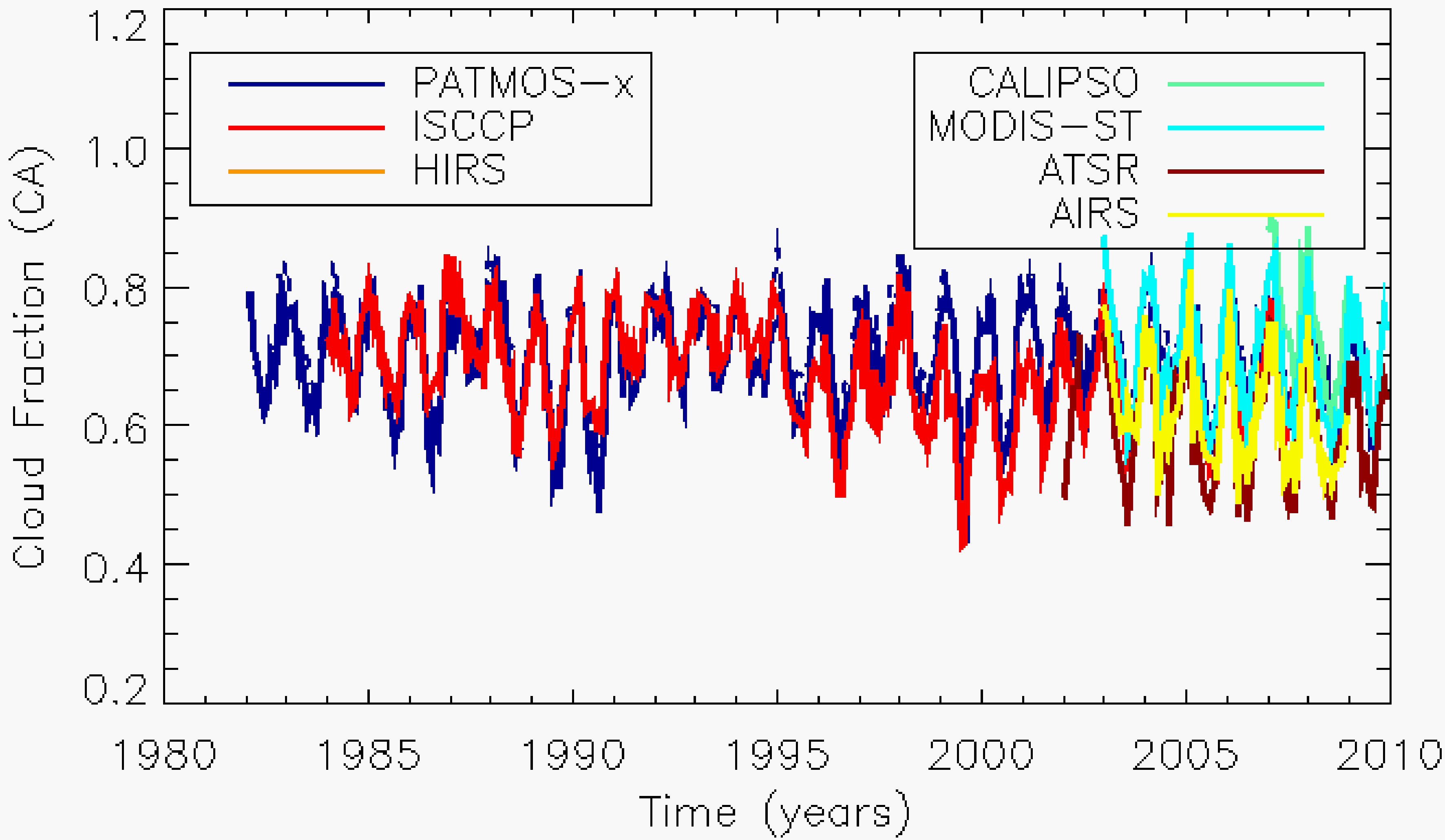
Diurnal Variation of High Cloud Amount over this Region 2006-2007



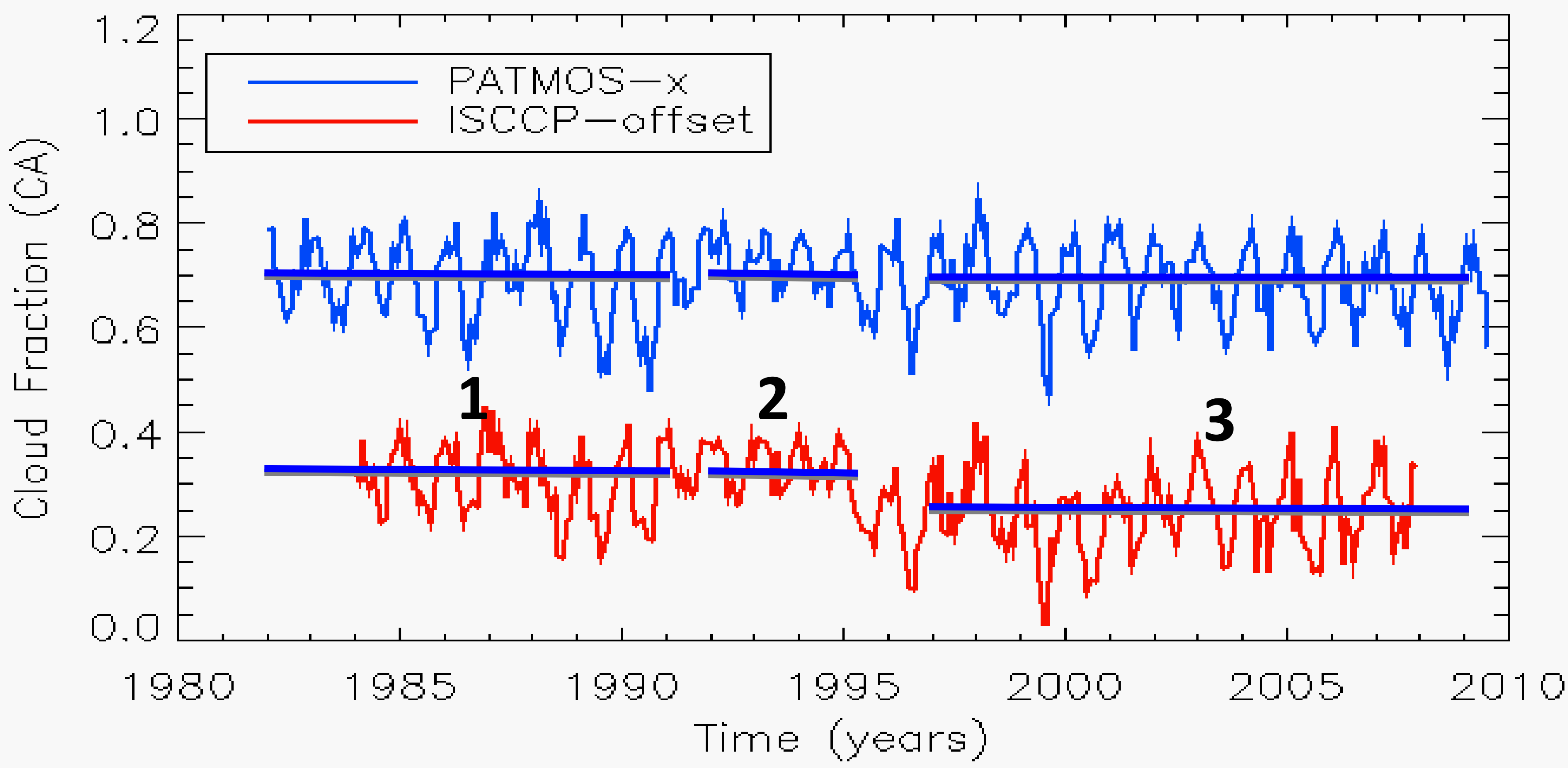
Cloud Amount Comparison



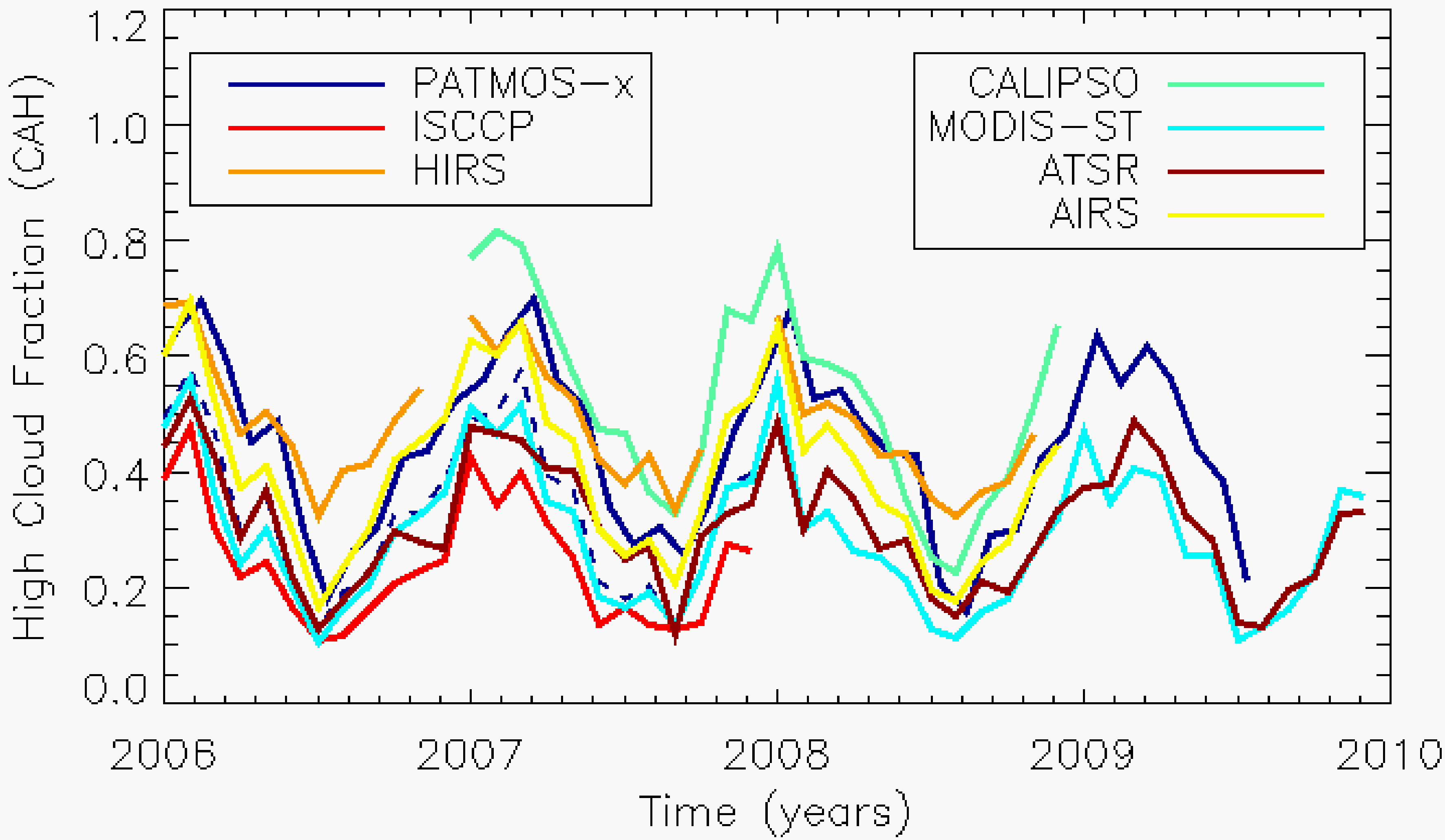
Cloud Amount Comparison

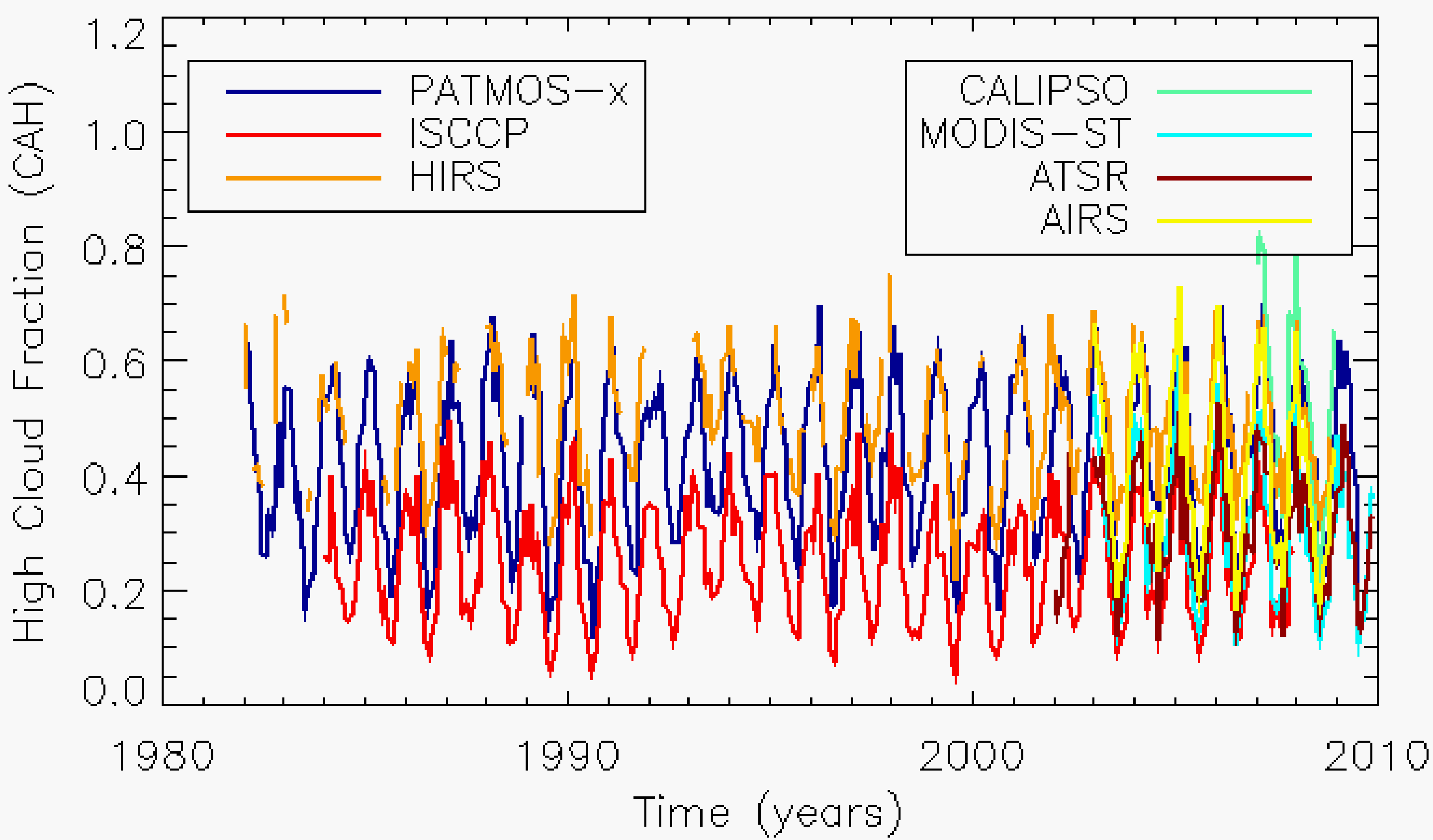


Cloud Amount Comparison



High Cloud Amount Comparison




1.2
1.0
0.8
0.6
0.4
0.2
0.0
High Cloud Fraction (CAH)
PATMOS−x
ISCCP
HIRS
CALIPSO
MODIS−ST
ATSR
AIRS
1980
1990
2000
2010
Time (years)

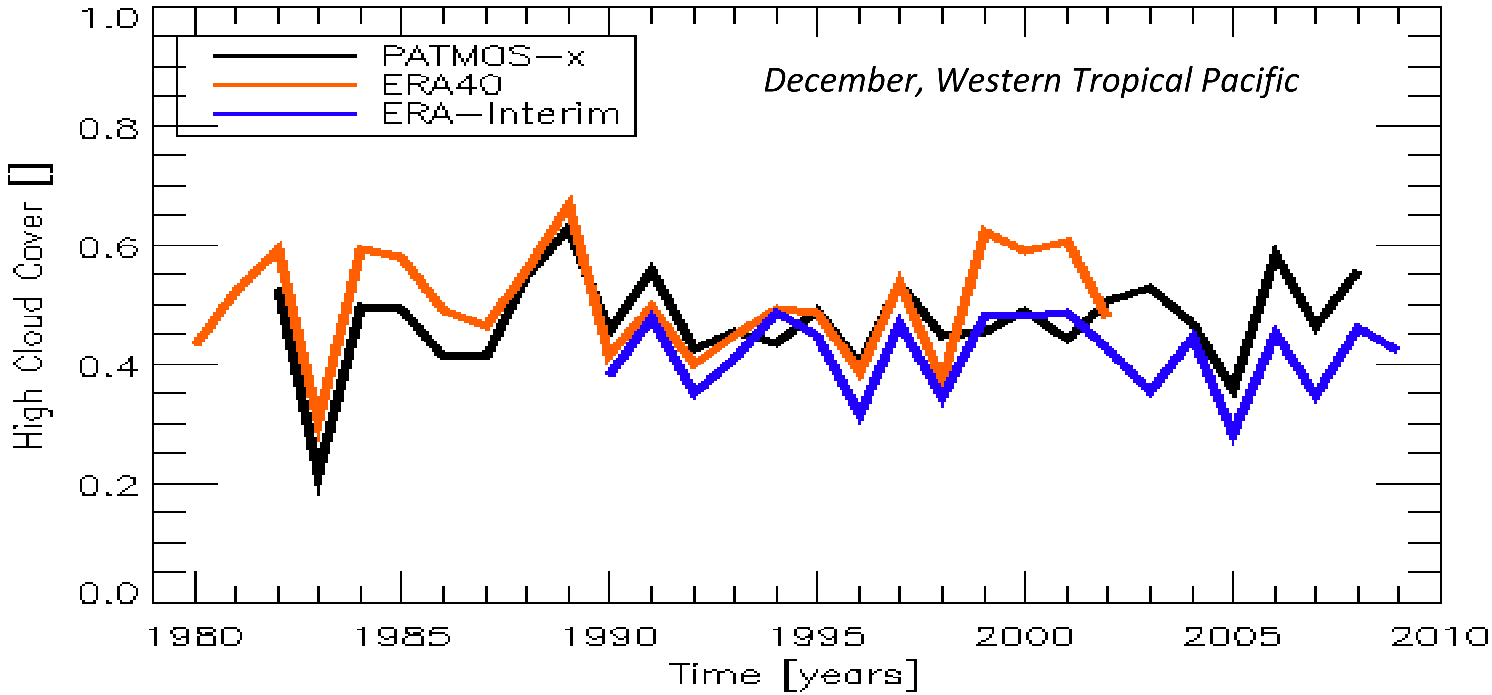
High Cloud Amount Comparison

•We assume that reanalysis data should capture well the large scale dynamical and thermo-dynamical features that drive large scale cloudiness.

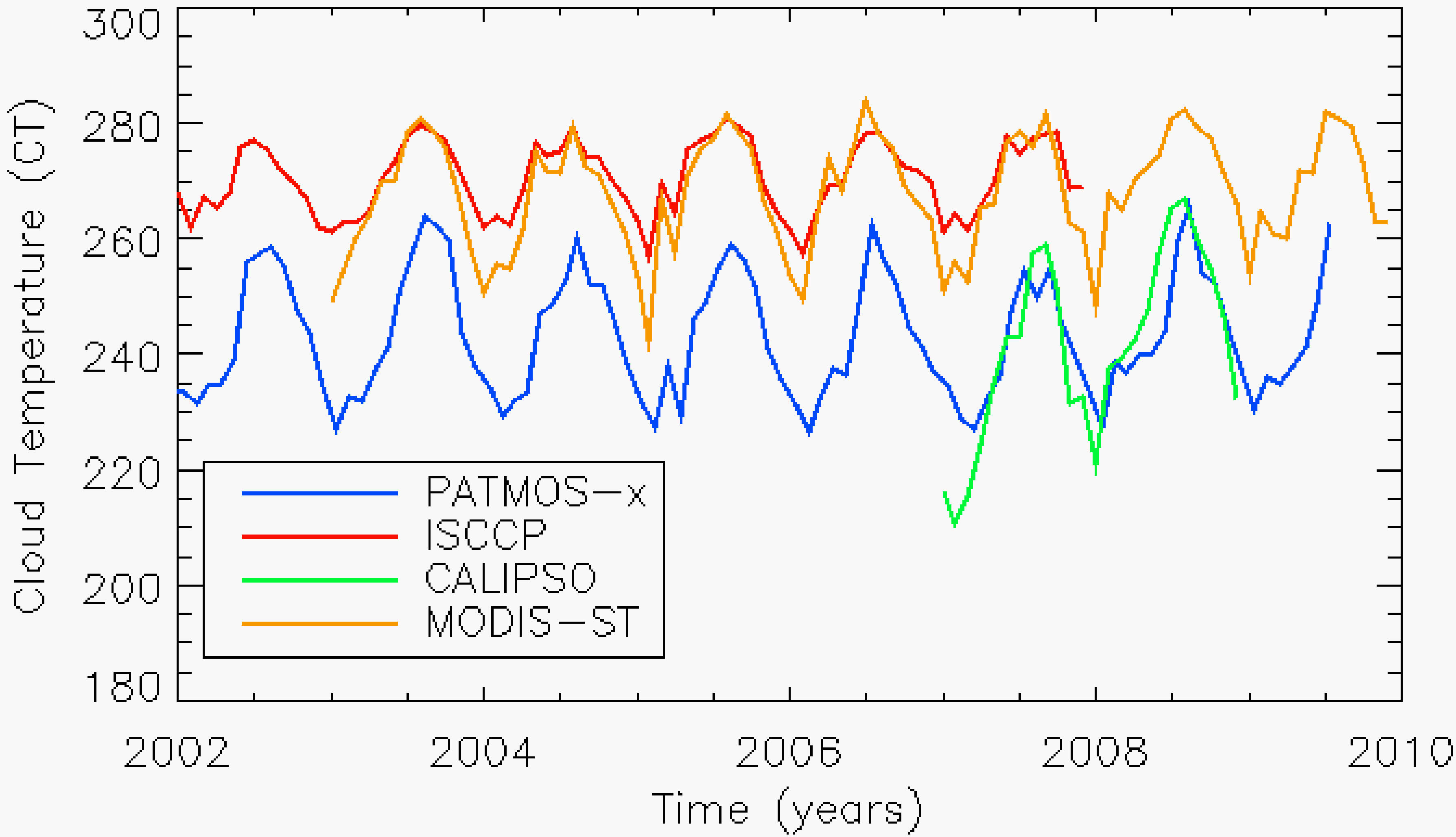
•Therefore, interannual variation of high cloud amount in the reanalysis data should be a good metric for comparison.

•Agreement of inter-annual variation (1983 anomaly) gives us confidence that our climatology is capturing natural variability and that ***inter-annual variability is not dominated by satellite to satellite transitions***.

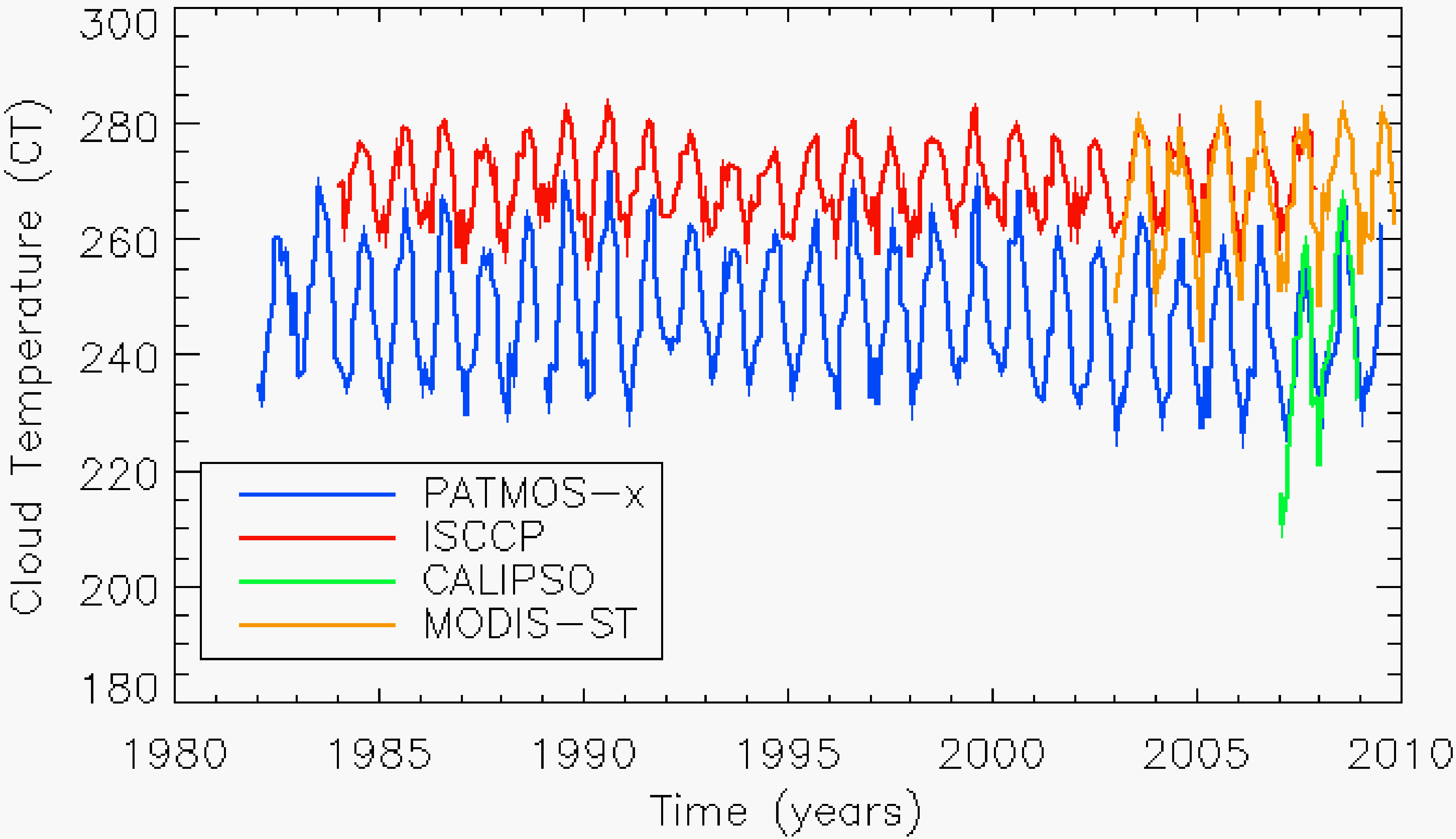
•CM-SAF time series comparisons will be done when possible.



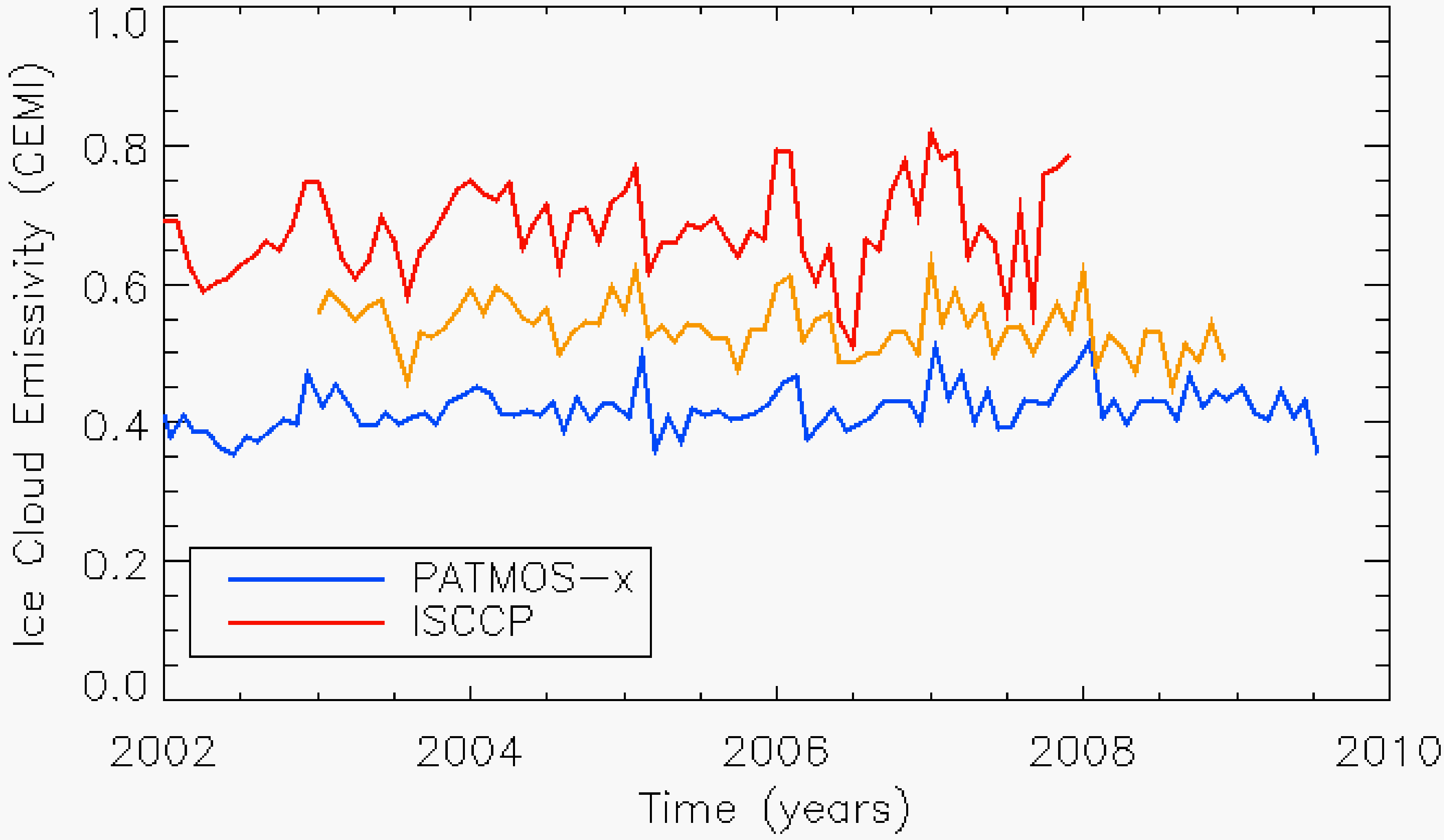
Cloud Temperature Comparison



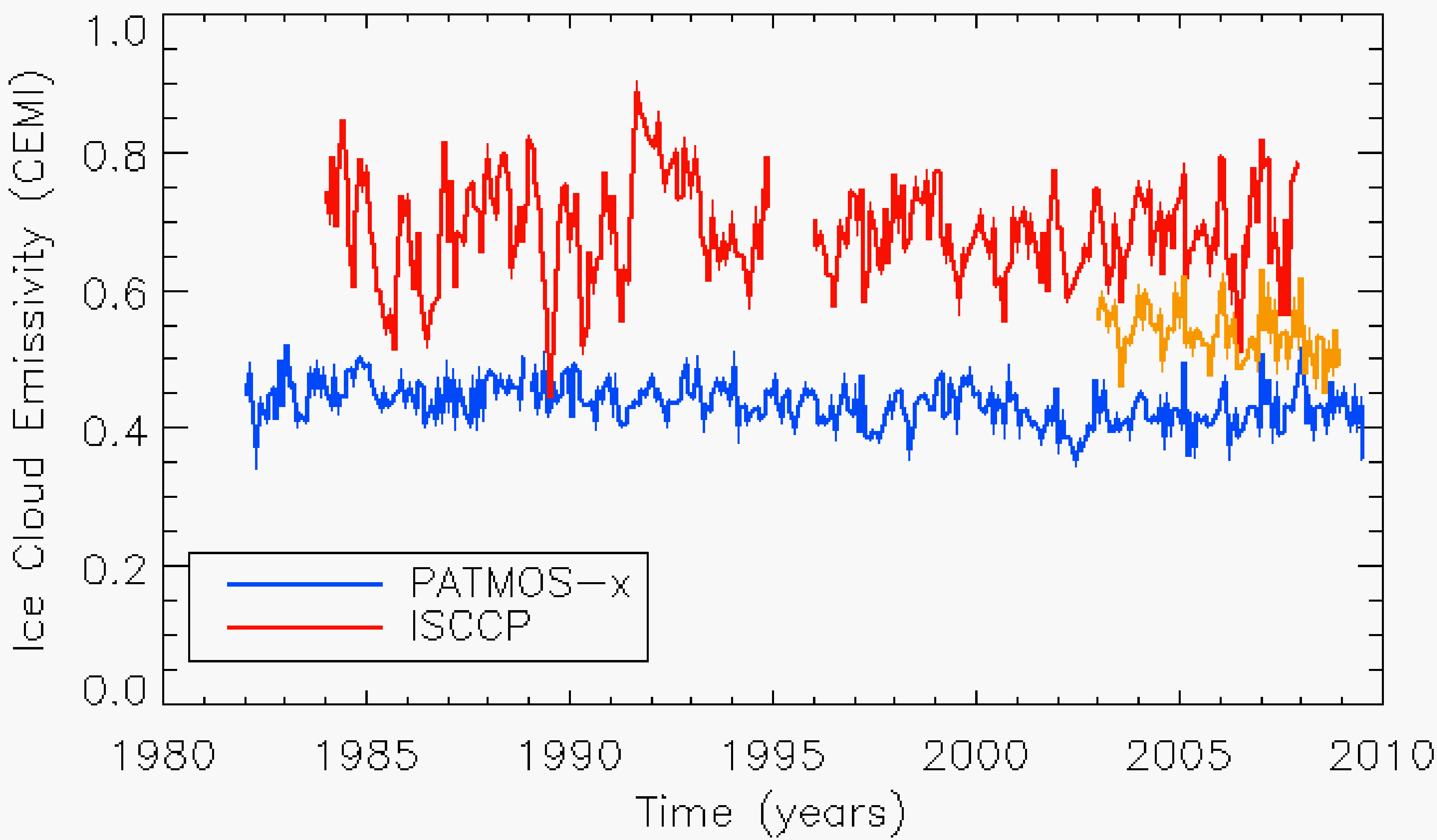
Cloud Temperature Comparison



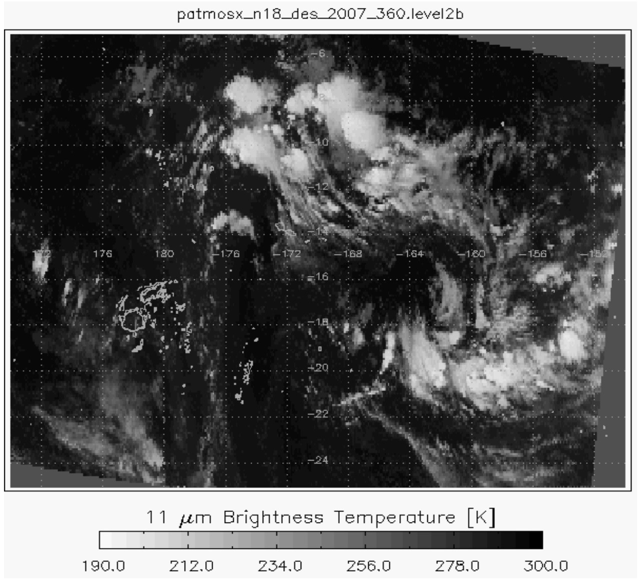
Ice Cloud Emissivity

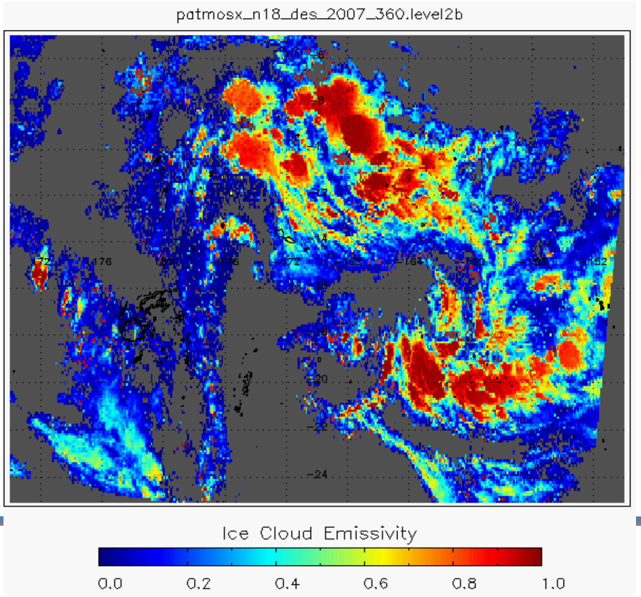


Ice Cloud Emissivity

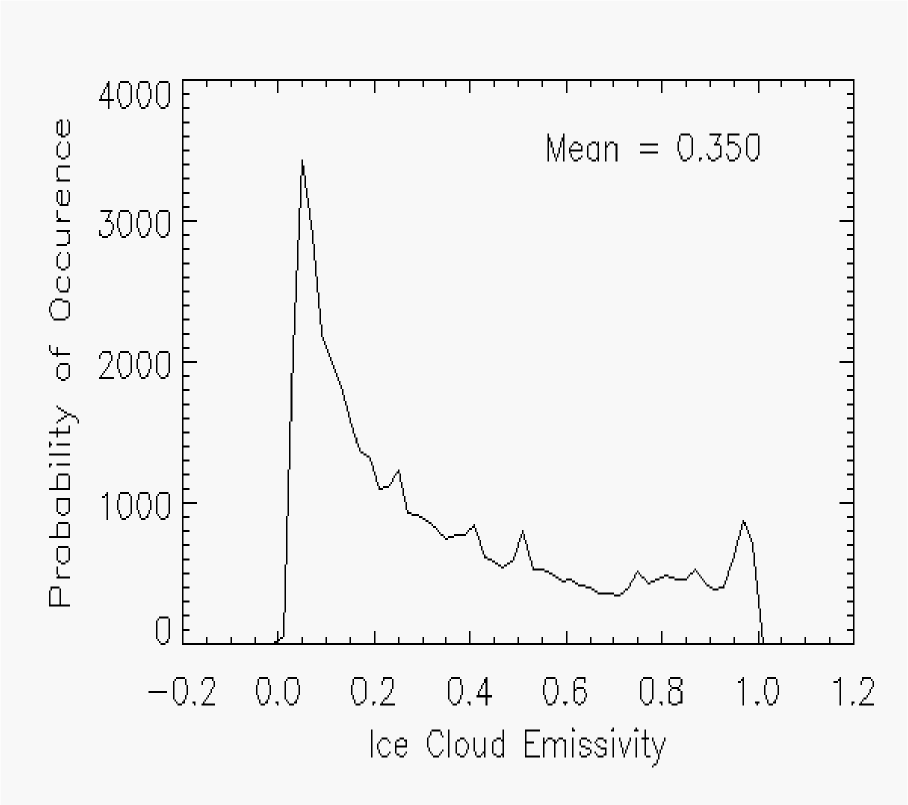


Ice Cloud Emissivity





A closer look at PATMOS-x ice cloud emissivities.



Are we really too thin? – No obvious at this point.

Conclusions

- PATMOS-x has benefited greatly from CALIPSO analysis over the past three years.

- CALIPSO-derived Bayesian Mask appears to remedy main artifact in PATMOS-x cloud amount values.

- Use of CALIPSO prior information in optimal estimation cloud height algorithm has positively impacted our cloud height, temperature and emissivities.

- Tropical Cloud Amounts are very similar. PATMOS-x and ISCCP are highly correlated though ISCCP shows a drop in the 2000's not seen in PATMOS-x

- MODIS-ST, ATST and ISCCP high cloud amounts are similar. PATMOS-x is more similar to AIRS & HIRS which are more similar to CALIPSO.

- PATMOS-x and CALIPSO cloud temperature are similar and colder than the MODIS-ST and ISCCP. PATMOS-x ice cloud emissivities are lower in the Tropics that AIRS and ISCCP. I assume this is driven by differences in ice cloud detection.

- Our level 3 analysis often does not agree with previous level-2 analysis. PATMOS-x level2b data may offer level-2 like analysis for long-term climate products.