# Comparison of Physically Consistent Cloud Products from CFSR and PATMOS-x


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## INTRODUCTION

- Most NWP reanalysis data span more than 30 years.
- Satellite climate records (PATMOS-x, ISCCP) now also span more than 30 years.
- Both Reanalysis and Satellite climate data are dependent on each other.
- This poster attempts a physical comparison of the NOAA/NESDIS PATMOS-x data based on the MODIS sensor to cloud products derived from NOAA/NCEP CFSR.
- The goal is to see if analysis methods can be used to generate products that be compared meaningfully.
- The long term goal is explore and motivate the use of satellite cloud climate records in future reanalysis efforts.

## PATMOS-x (the satellite cloud data)

- PATMOS-x is a NOAA/NESDIS Project developed at CIMSS.
- PATMOS-x AVHRR Radiometric and Cloud Climate Data Records (CDRs) are hosted at NCDC.
- PATMOS-x MODIS and GOES Data will be available via CIMSS Climate Data Portal. (see SSEC booth exhibit)
- Reference: *Andrew K. Heidinger, Michael J. Foster, Andi Walther, and Xuepeng (Tom) Zhao, 2014: The Pathfinder Atmospheres–Extended AVHRR Climate Dataset. Bull. Amer. Meteor. Soc., 95, 909–922.*

## CFSR (the reanalysis data)

- The National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) is generated from 1979 to the present.
- For more information about CFSR, please see http://rda.ucar.edu/#!pub/cfsr.html.
- Reference: *Saha, Suranjana, et. al., 2010: The NCEP Climate Forecast System Reanalysis. Bull. Amer. Meteor. Soc., 91(8), 1015-1057*

## ANALYSIS

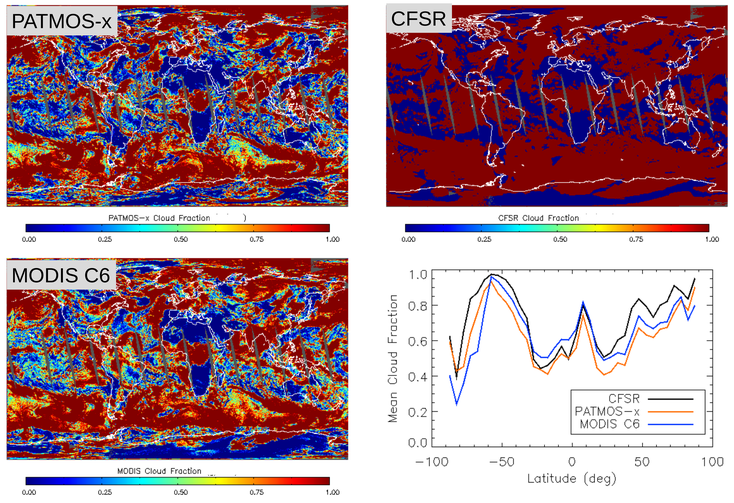
- PATMOS-x run on AQUA/MODIS 5km data (MYD02SSH).
- 0.5º CFSR data was temporally interpolated from each 6 hour cycle to the time of the MODIS observations.
- ***The Cloud Liquid Water Mixing Ratio (CLWMR) profiles from the CFSR are used for this analysis.***
- PATMOS-x uses some CFSR profiles for clear-sky radiative transfer (but not those compared in this study).
- The CLWMR profiles are vertically integrated to generate a cloud water path (CWP) that can be compared to PATMOS-x.
- Any CLWMR profiles with CWP values < 5 g/m^2 were considered clear. This corresponds with the suspected cloud detection sensitivity threshold of PATMOS-x.
- To estimate cloud-top pressure (CTP), the effective emission level of the clouds were computed from CLWMR profiles to simulate what an InfraRed retrieval (like that used in PATMOS-x) would generate.
- Therefore, the CFSR products are not those made available from the CFSR diagnostic schemes.
- ***These products are adjusted so as to be physically similar to the satellite products to allow for more meaningful comparisons.***
- ***This is similar in concept to that of a satellite simulator***.

## Data Used

- The data holdings of PATMOS-x and CFSR span many years.
- However, the systematic features of this analysis did not change dramatically for any one scene.
- We found analysis from a single day provided the most easily explained results.
- Therefore the examples shown here (except for the cloud fraction time-series) are daytime data from one day (June 28, 2013).

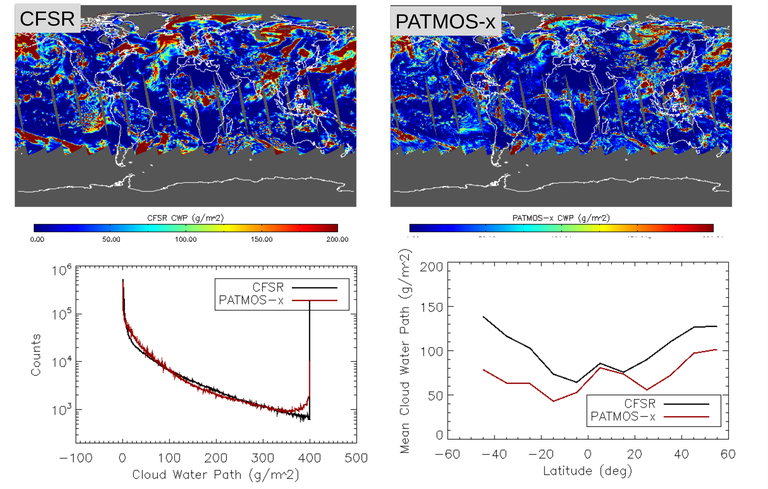
## Comparison of PATMOS-x Cloud Fraction to that derived from CFSR CLWMR:

Images below show the cloud fractions from PATMOS-x and the Official NASA MODIS C6 cloud detection schemes. Also shown is the cloud fraction from CFSR computed by applying a 5 g/m^2 threshold for clear/clear using the integrated CFSR Cloud Water Paths. 5 g/m^2 is an estimate of the cloud sensitivity threshold of the satellite retrievals. The CFSR cloud fraction is therefore only 0 or 1. CFSR cloud fraction is therefore a maximum value and is not the CFSR Total Cloud Fraction which is diagnosed from relative humidity. Zonal fractions show good agreement between all 3 data-sets.



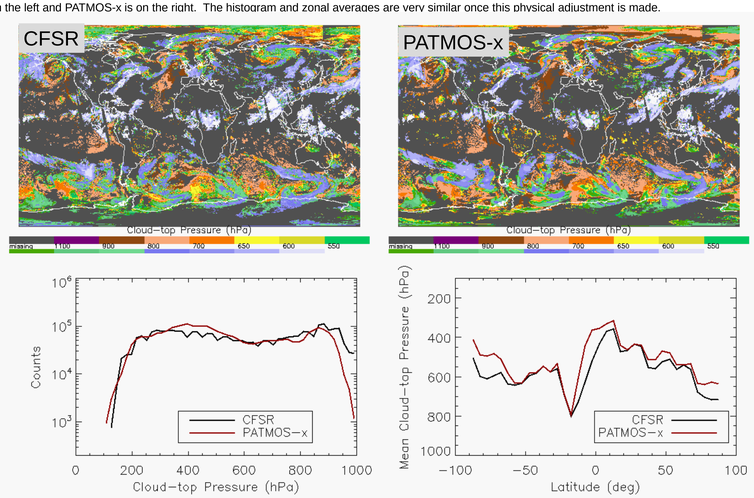

## Comparison of Cloud Water Path:

Cloud water path is the integrated amount of cloud water in the column. The top two images show the CWP from CFSR (left) and PATMOS-x (right). Both have a resolution of 0.5º. Satellite retrievals suffer from two issues. 1) No sensitivity to liquid cloud under ice cloud. 2). VIS/NIR retrievals saturate at about 400 g/m^2. In this analysis, all CFSR and PATMOS-x values greater than 400 g/m^2 are set to this value. Histogram of global values shows good agreement for values less than 350 g/m^2 and shows CFSR to have more values > 400 g/m^2. Zonal patterns shows CFSR > PATMOS-x which is likely due to lack of sensitivity at high values for PATMOS-x (or any VIS/NIR retrieval).



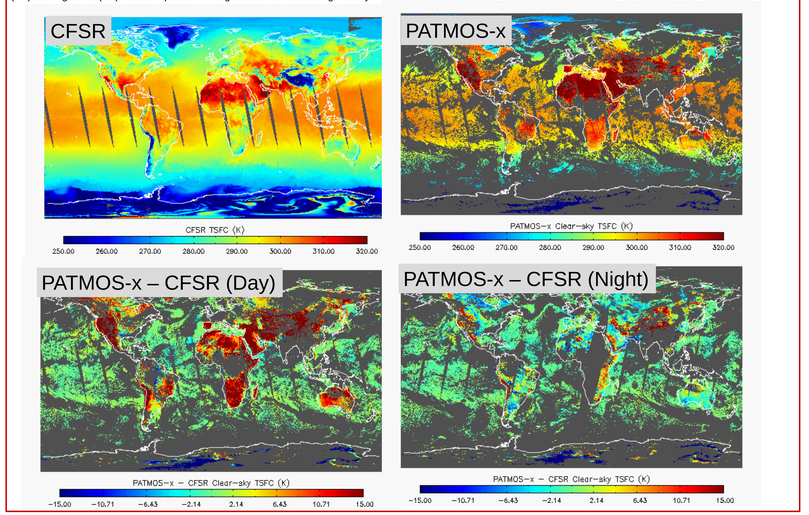

## Comparison of Cloud-top Pressure:

Cloud-top Pressure (CTP) is the pressure of the highest cloud in the column, PATMOS-x uses an IR algorithm and it therefore measures the cloud-top pressure of the effective level of emission. IR theory says this should occur at an IR optical depth of 1 into the cloud or roughly 18 g/m^2 into the cloud. We computed the CTP using this definition for each CFSR CLWMR profile. CFSR results are on the left and PATMOS-x is on the right. The histogram and zonal averages are very similar once this physical adjustment is made.




## Comparison of Surface Temperature:

Surface Temperature (TSFC) is a key climate parameter generated by the CFSR and PATMOS-x. The top figures show the CFSR (right) and PATMOS-x (left) values for the ascending data (daytime). The bottom images show PATMOS-x – CFSR for daytime (left) and nighttime (left). Bias maps show a large bias over land during the day with PATMOS-x – CFSR > 10 K over arid regions. Biases over ocean and at night are less.




## CONCLUSIONS

- By accounting for cloud detection sensitivity, cloud water path saturation and effective level of emission, the CFSR cloud products derived from the CLWMR profiles are very similar to those of PATMOS-x.
- Surface temperature differences over arid land are significant.
- Hopefully, this analysis may spur the use of satellite cloud products (such as PATMOS-x) in future NCEP reanalysis.
- Long-term comparisons of cloud fraction (TCDC) show good correlation for inter-annual variation over the regions studied. However, CFSR does show a strong change in cloudiness off the Coast of California after 1995 that is missing in PATMOS-x and ERA-Interim.
- This is only a first step in this analysis and we welcome suggestions to explore this further.

## Long-Term Cloud Fraction Comparisons:

For this analysis, we use the diagnosed cloud fraction from CFSR (and ERA Interim) compared to the AVHRR PATMOS-x data. This allows for multi-decadal comparisons.

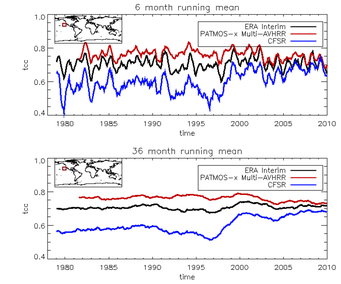
We chose two regions for this comparison. One in the North Pacific off the coast of California which is dominated by stratus clouds. The other, the Tropical Pacific in the region of American Samoa is dominated by deep convection and the annual cycle of the ITCZ. *We show 6–month and 36–month running means to highlight both the inter-annual and the long-term variations.*

### California Stratus

Inter-annual correlation is high. For the 6 month running mean, the values are as follows:

- correlation of PATMOS-x with ERA-Interim = 0.67
- correlation of PATMOS-x with CFSR = 0.65
- correlation of ERA-Interim with CFSR = 0.61

In the 36-month running figure, CFSR shows a dramatic increase after 1998 not seen in the others. ***While PATMOS-x does use CFSR fields, it does not show this feature.***

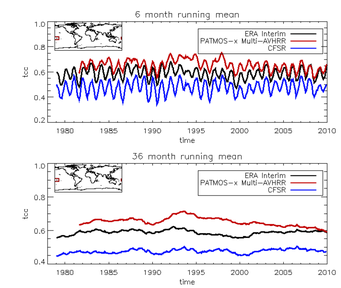



### Tropical Pacific Near Samoa

With a vey regular annual cycle, the Inter-annual correlations are higher. For the 6 month running mean, the values are as follows:

- correlation of PATMOS-x with ERA-Interim = 0.86
- correlation of PATMOS-x with CFSR = 0.84
- correlation of ERA-Interim with CFSR = 0.91

In the 36-month running figure, CFSR *DOES NOT* show the dramatic increase after 1998 seen in the California Stratus Analysis.




**Get PATMOS-x AVHRR Data (1979-2014) at NCDC: http://www.ncdc.noaa.gov/cdr/operationalcdrs.html**

**Check out CIMSS Climate Data Portal at UW/SSEC Booth!**

## References


PATMOS-x: Andrew K. Heidinger, Michael J. Foster, Andi Walther, and Xuepeng (Tom) Zhao, 2014: The Pathfinder Atmospheres–Extended AVHRR Climate Dataset. Bull. Amer. Meteor. Soc., 95, 909–922.

Cloud Water Path: Andi Walther and Andrew K. Heidinger, 2012: Implementation of the Daytime Cloud Optical and Microphysical Properties Algorithm (DCOMP) in PATMOS-x. J. Appl. Meteor. Climatol., 51, 1371–1390.

Cloud Fraction: Andrew K. Heidinger, Amato T. Evan, Michael J. Foster, and Andi Walther, 2012: A Naive Bayesian Cloud-Detection Scheme Derived from CALIPSO and Applied within PATMOS-x. J. Appl. Meteor. Climatol., 51, 1129–1144.

Cloud-top Pressure:Andrew K. Heidinger, Michael J. Pavolonis. (2010) Gazing at Cirrus Clouds for 25 Years through a Split Window. Part I: Methodology. Journal of Applied Meteorology and Climatology 48:6, 1100-1116.