PATMOS-X

Microphysical Parameters

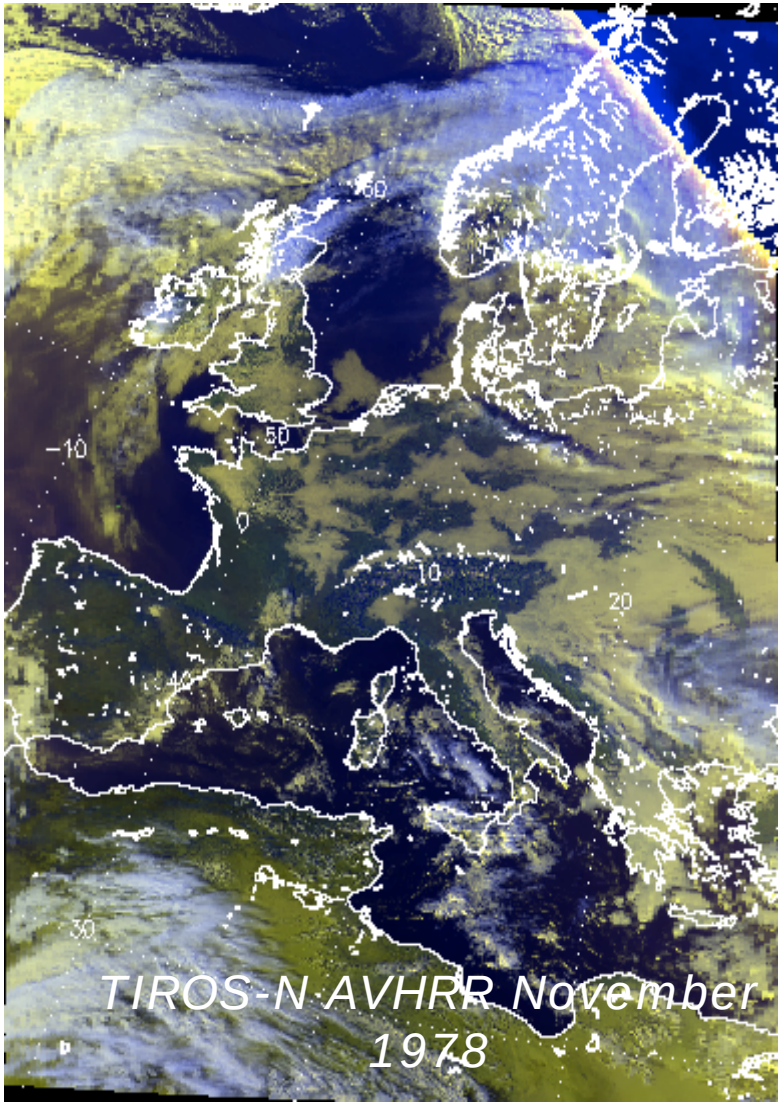
Andi Walther[1]
Andrew Heidinger[2] Michael Foster[1]

1 CIMSS University of Wisconsin-Madison,
2 NOAA/NESDIS, Madison, WI

What is PATMOS-x?

PATMOS-x

- is a *global cloud climatology*
- AVHRR **Pat**hfinder At**mos**pheres – E**x**tended
- is an unique long-term satellite-based data set (almost 30 years)
- includes over 120 parameters including radiance, cloud and surface products in a HDF format.
- consists of twice daily fields from all AVHRR/2 and AVHRR/3 data from 1981
- Data can be obtained via http://cimss.ssec.wisc.edu/patmosx/



PATMOSX Version 5 era started

PATMOSX version 5 replaces version 4 from 2006. The main updates are:

- Introducing Bayesian Cloud Mask
- Major changes in daytime microphysical properties retrieval
- New, more flexible, convenient data level “level-2b”, which allows fast level-3 generation for decades of data.
- Full global data set 1980-2010 will be completed by September.

PATMOS-x Data levels

In past versions, we have generated 0.5° (55 km) resolution level-3 files that included the statistics (mean and standard deviation) for all pixels within the grid cell. (daily and monthly). Data basis was level2 data with GAC resolution (5km), which had to be deleted after level3 processing due to high data amount.

PATMOS-x level3 results have appeared in 2006-2008 BAMS State of the Climate Reports, the GEWEX Cloud Climate Assessment Reports and in several journal articles (Heidinger and Pavolonis, 2005; Zhao et al, 2008, Evan et al., 2006, 2008, 2009).

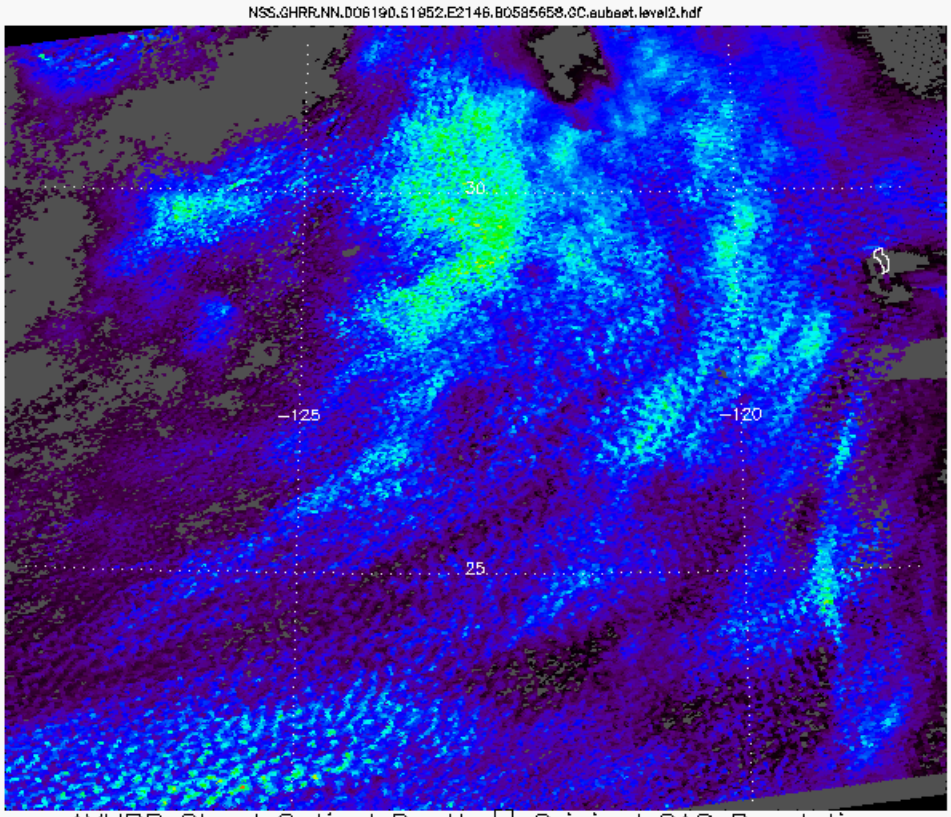
The level-3 data is of limited utility for study many cloud characteristics and we have adopted an additional output format (**level-2b**) with provides a sampled pixel-level results at a resolution of 0.1° (11 km)

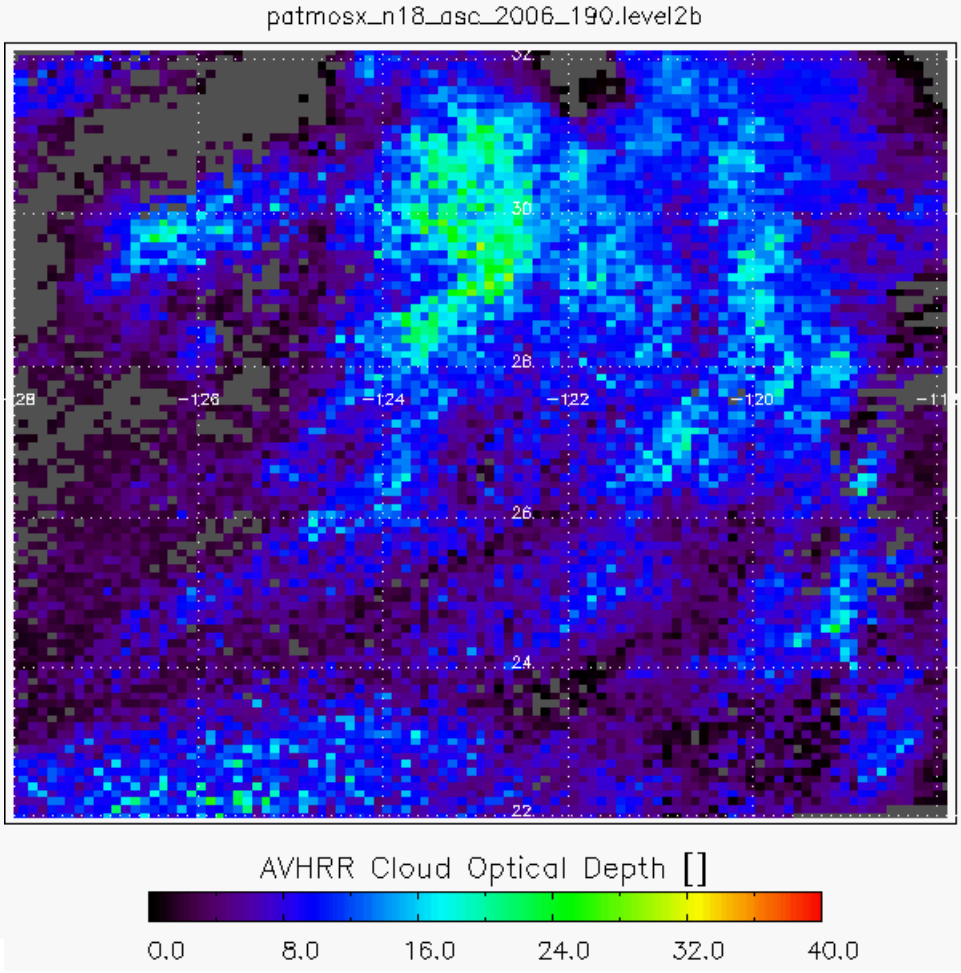
25 scientific parameters in a level2b file. The yearly data amount for compressed data is approx. 20 GB for one sensor.

We are currently generating a full 30-year set of global level2b data.

Recently, we have implemented a GAC subsetting capability that allows use to generate 30 year high resolution time series over any one region in two days on a desktop workstation.

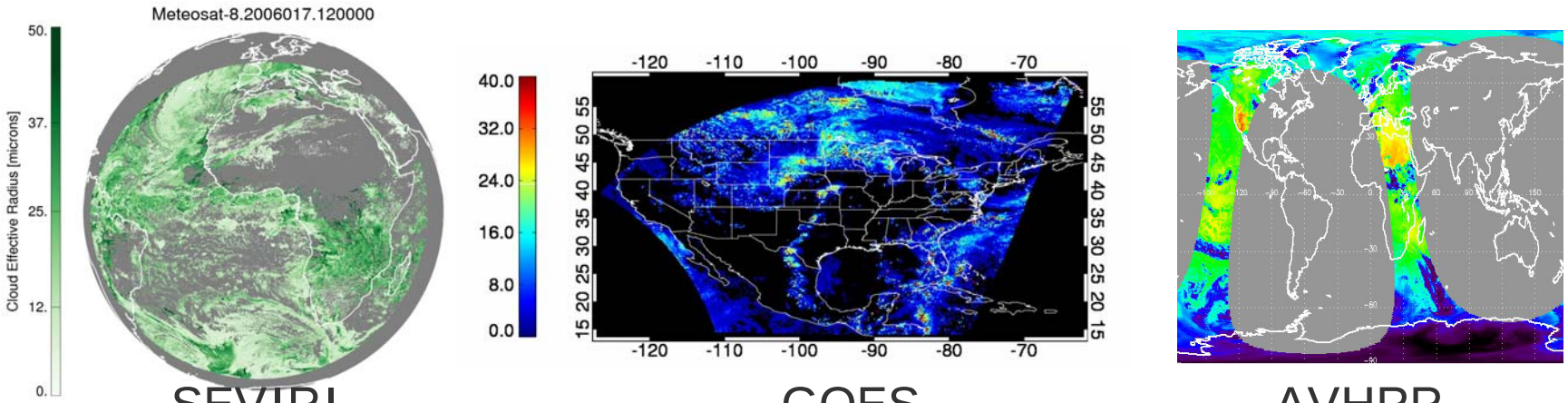
Level2b Data Example





Microphysical cloud parameter retrieval at our group

- Cloud optical depth, Effective Radius and cloud water content (liquid and ice)
- LUT approach for daytime retrievals for optical depth and particle size applying simultaneous measurements in one VIS and NIR channel.
- Algorithms for *SEVIRI, GOES* (inclusive the future *GOES-ABI*), and *AVHRR* (PATMOS-X) differ only in radiative transfer model in respect to the exact spectral position of the channels
- No differences in design and generation of LUTs, inversion technique and auxiliary data (e.g. surface parameters and NWP).
- Use of the same FORTRAN code with different *include* files for input of LUT and auxiliary data.
- Consistent data set that combines advantages of SEVIRI (high temporally and spatially resolved data over MSG disk), GOES (same for the Americans) and AVHRR (long-term time series, no static observation angles and global view).



SEVIRI GOES AVHRR

Microphysical cloud parameters - Retrieval

Ozone correction using NWP (NCEP) data

Aerosol correction using (still) a global value for AOT (0.1)

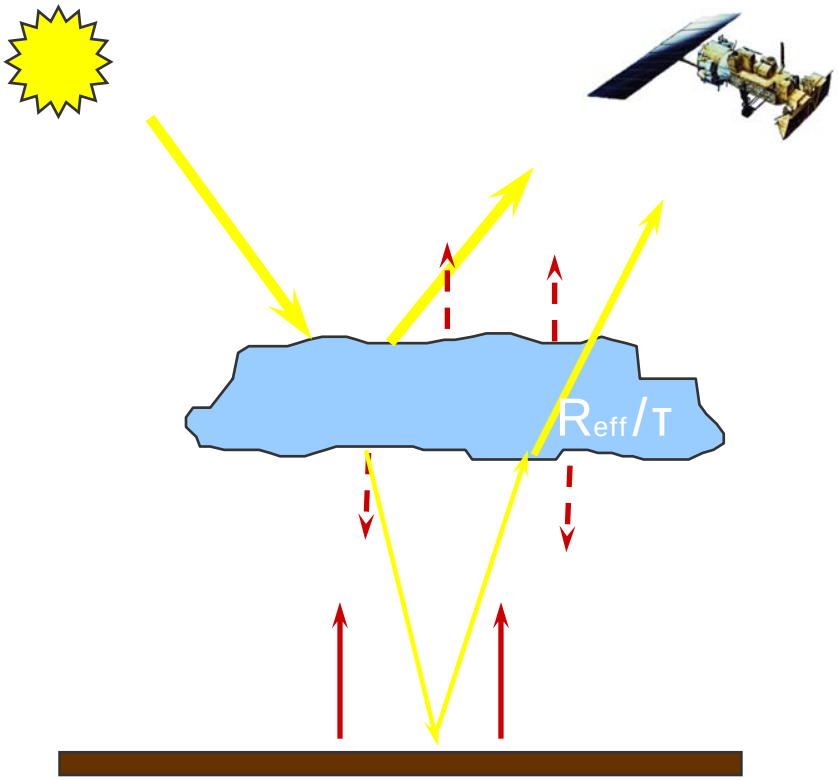
Water vapor correction with NWP re-analysis data

Rayleigh correction with single scattering assumption

Land surface albedo and snow map by 16- day climatology from MODIS

Default values for **sea albedo**

0.6µm / 3.75µm
More than 2 yrs NOAA-16 -> 1.6µm
SEVIRI 0.6µm/1.6µm



Cloud mask. Cloud Phase and **Cloud height** from CLAVR-X retrieval

Reflectance Temperature

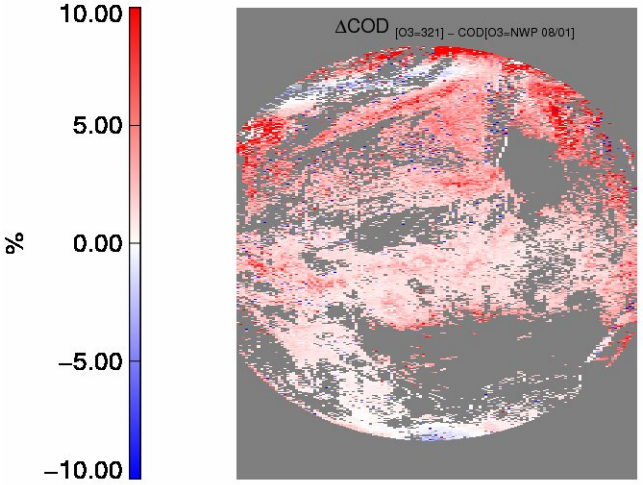
Inversion

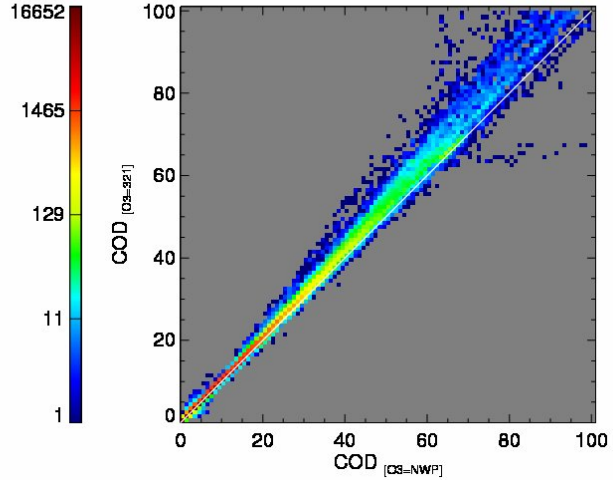
Forward model (RTM) results are stored in Look-Up-Tables for ice and water clouds

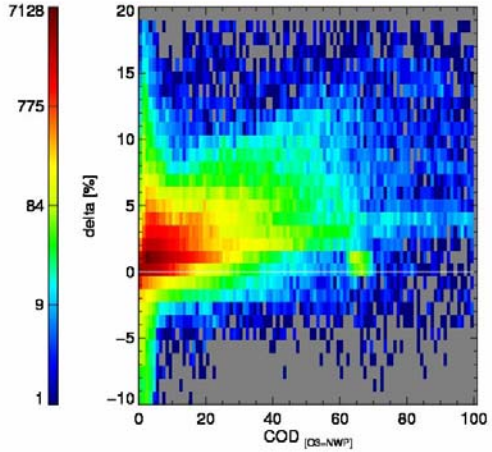
Cloud properties
R_{eff}/T

Example: Ozone correction

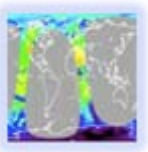
Error by using a global default error (321dobson) instead of NWP re-analysis information for one scenene☐







Microphysical cloud parameters: What is new in PATMOSX version 5



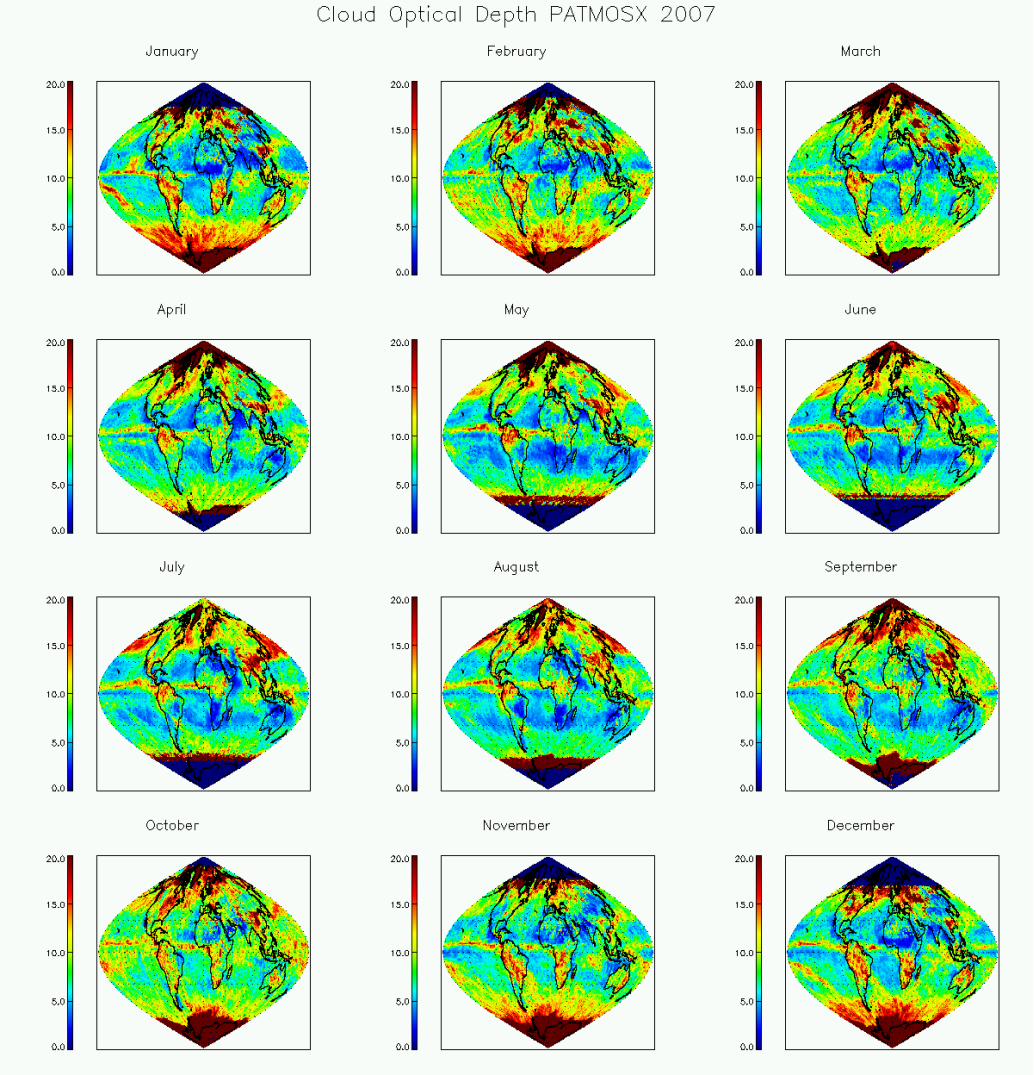
There are major changes in the COD/REF algorithm from version 4 to version 5:

- Reconstruction of LUT design.
- Updated ice phase functions from Baum/Yang
- Revised optimal estimation inversion technique. New a-priori assumption parameters. We give the measurements more trust (lower error covariance values for a-priori) than in version 4
- Use of MODIS land surface white sky albedo climatology instead of default values
- Including and improving Rayleigh, water vapor and ozone atmospheric correction.
- Bringing AVHRR software code in consistency to SEVIRI and GOES algorithms.
- Validation of level 2 products.
- Bringing almost 30 years of data to gridded level2B 0.1 degree data set. (in progress, will be done by September). This will allow fast analysis of several climate aspects of clouds.
- Results are also affected by updates of other cloud retrievals in version 5, such as new (Bayesian) cloud mask and cloud top pressure retrieval.

Microphysical cloud parameters: What is new in PATMOSX version 5

COD PATMOSX version4:

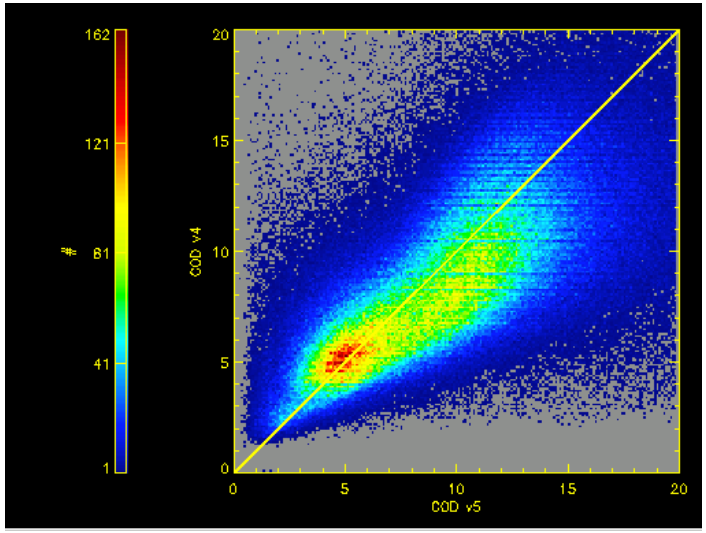
- Image shows COD version4 for PM and AM data for NOAA15 and NOAA18

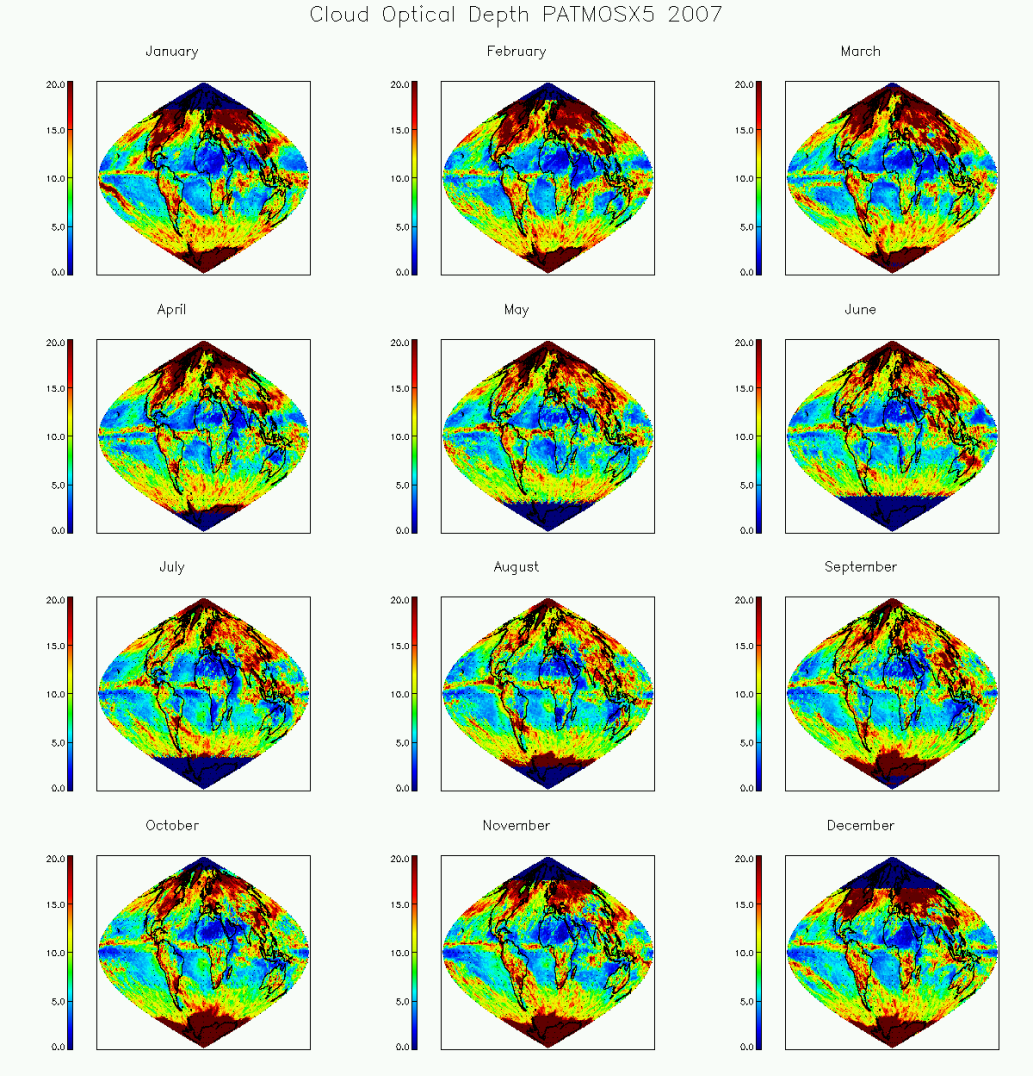


Microphysical cloud parameters: Comparison

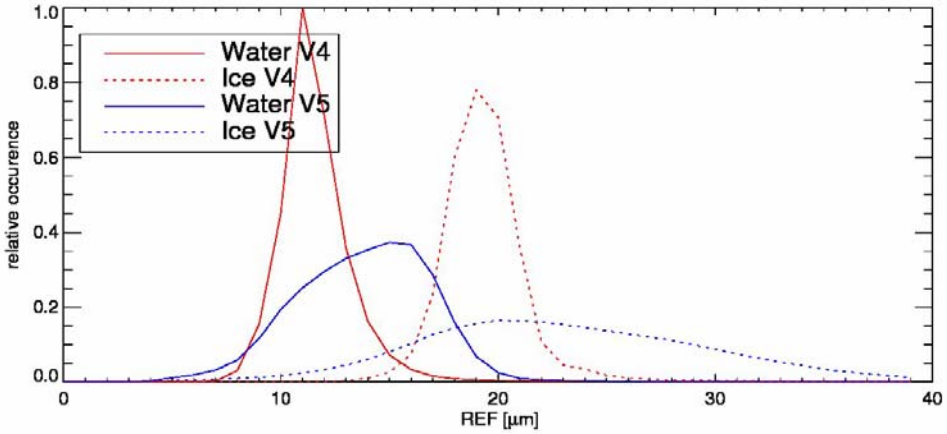
Change from version4 to 5:

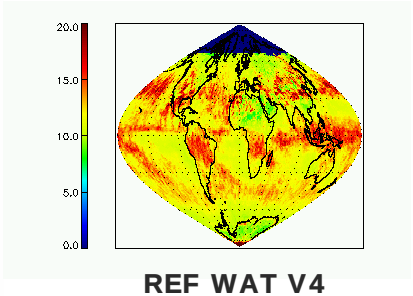
- Image shows COD version5 for PM NOAA18.

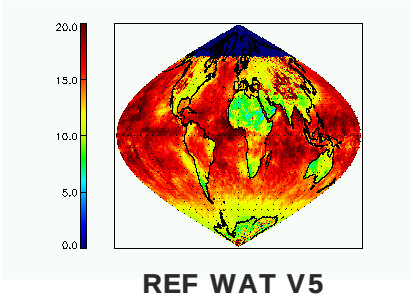


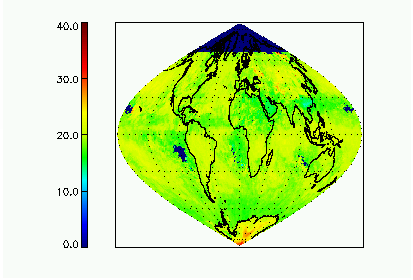


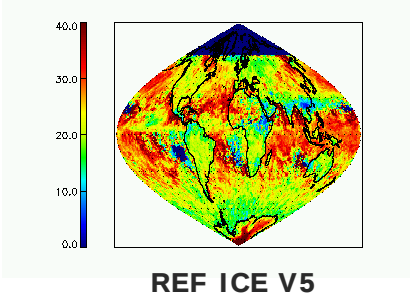
Microphysical cloud parameters:











- The differences between COD/REF algorithm V4 and V5 are significant
- We delivered V4 data from 1990-2007 and one year V5 (2007)
- Full V5 data set for all years will be ready by September

Performance estimates with MODIS

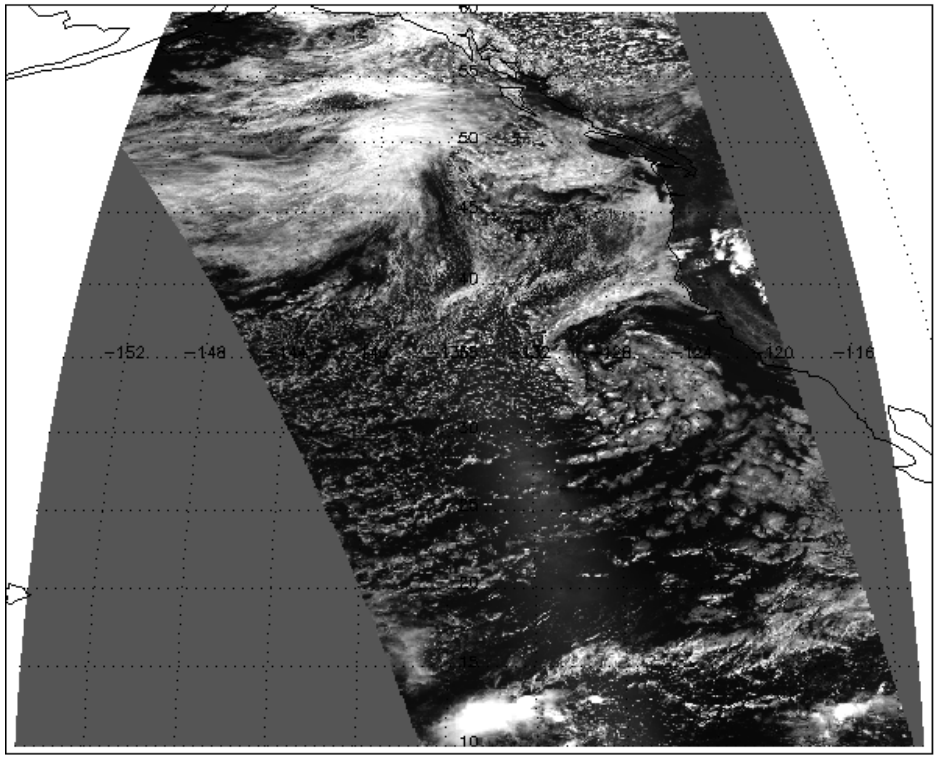
•AQUA and NOAA-18 were roughly 1 minute apart on 6th AUG 2006.

• Periodically, the ground tracks of NOAA-18/AVHRR and AQUA are in close proximity in time and space

• The occurrences of happen for large parts of an orbital node and therefore provide observations outside of the high latitudes. This allows for comparison of cloudy products in a regions where we know they perform well (unlike the high latitudes)

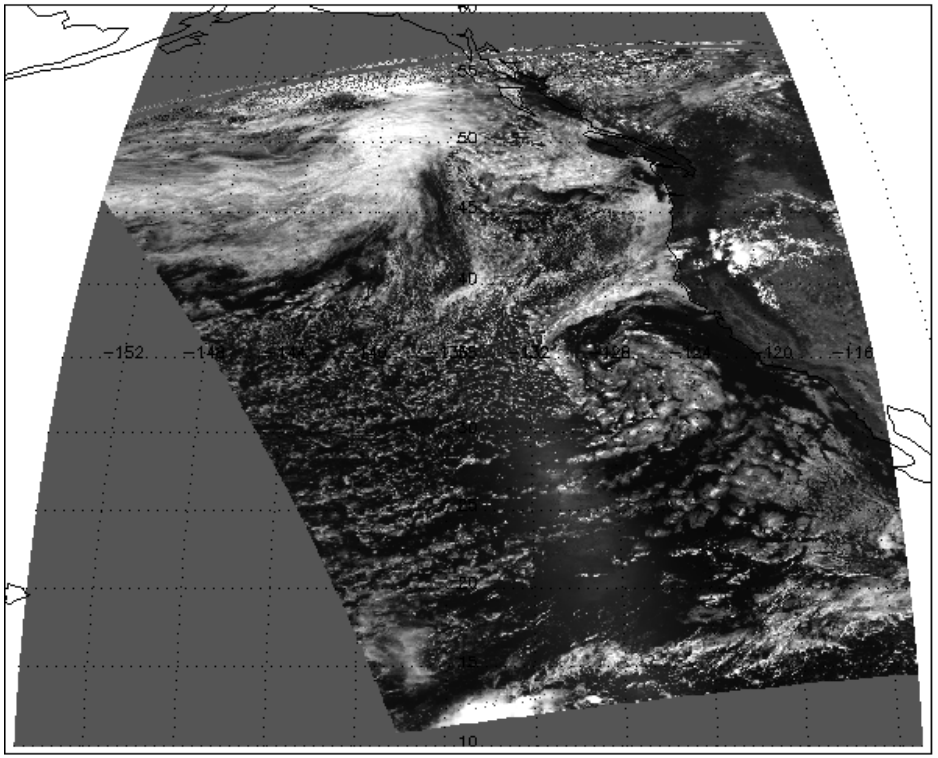
•In this analysis, we remapped the AVHRR and MODIS data to a 0.01 degree resolution. We took the closest AVHRR or MODIS pixel to each 0.01 grid point. This resolution has not been optimized.

• This provided roughly 644,000 co-located pixels for this one analysis.



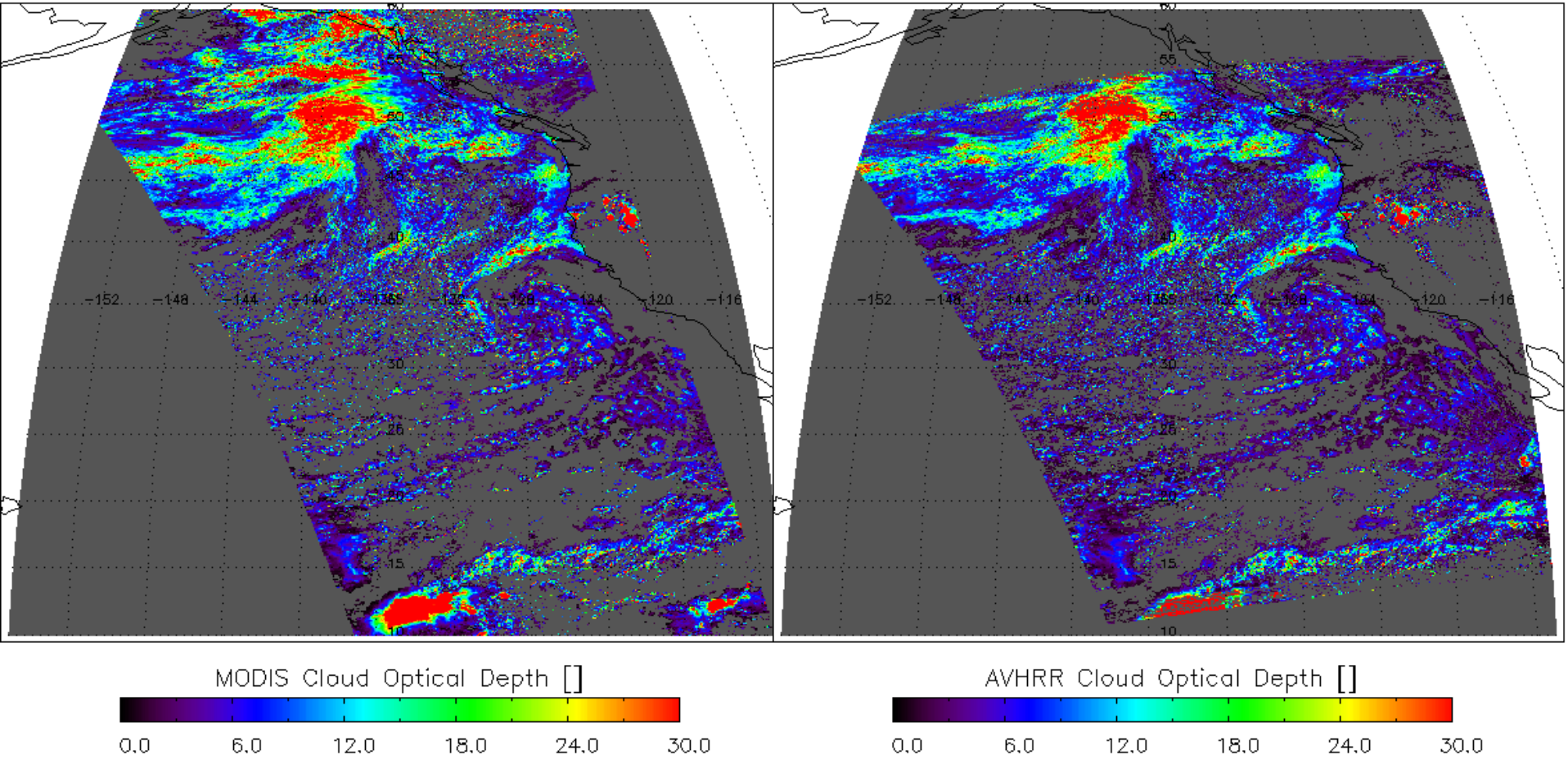
MODIS 0.65 micron Refl (%)

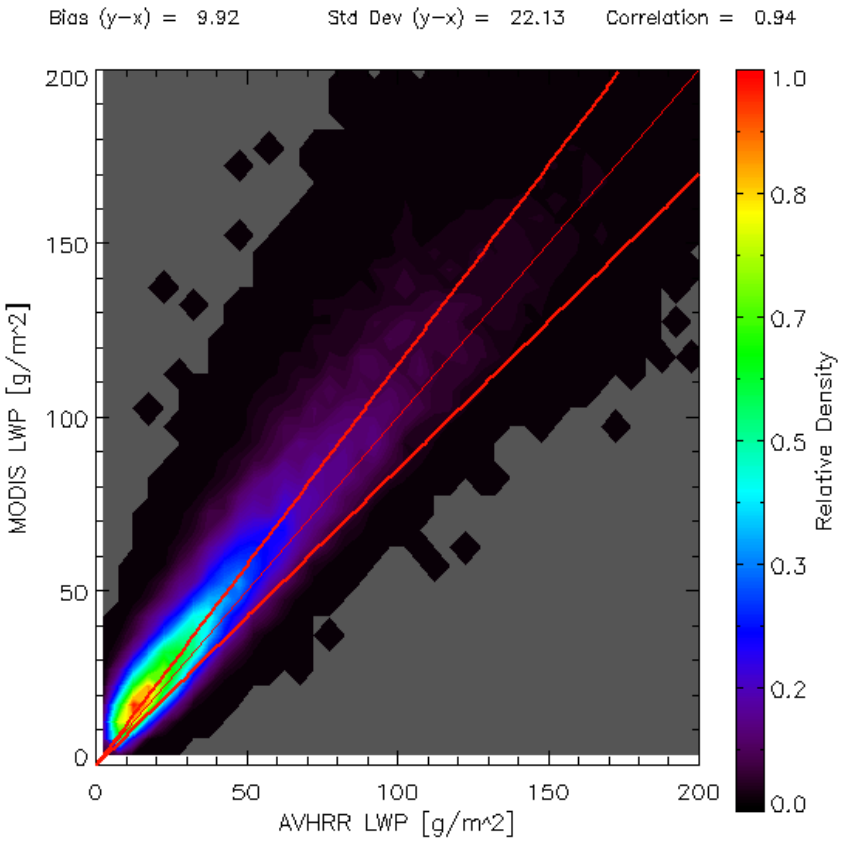
0.0 16.0 32.0 48.0 64.0 80.0

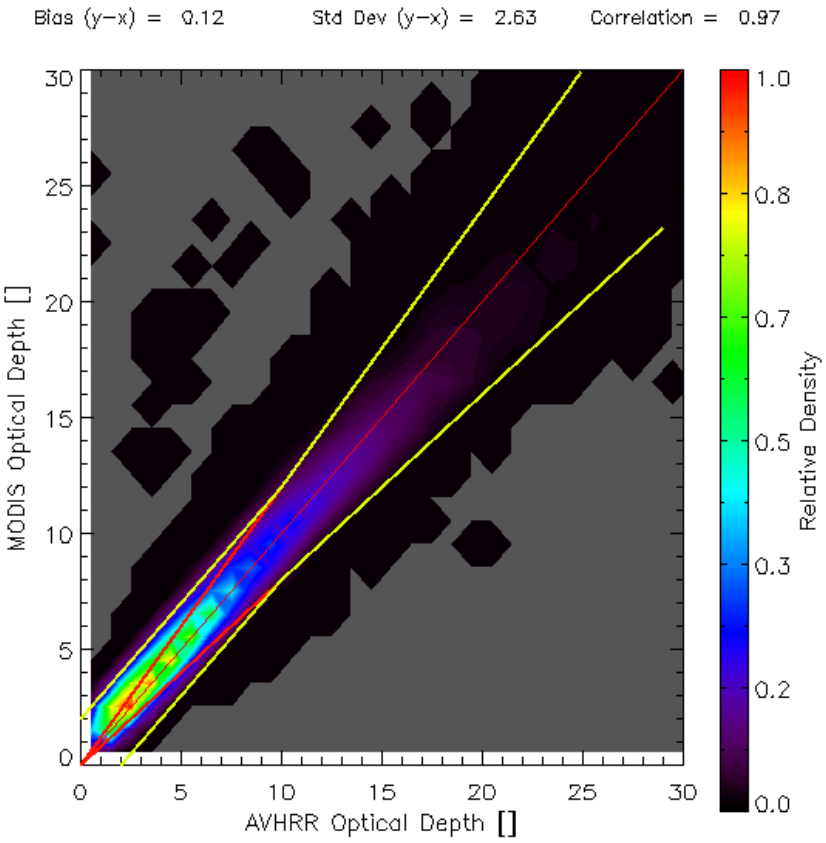


AVHRR 0.65 micron Refl (%)

0.0 16.0 32.0 48.0 64.0 80.0


MODIS Cloud Optical Depth []
0.0
6.0
12.0
18.0
24.0
30.0
AVHRR Cloud Optical Depth []
0.0
6.0
12.0
18.0
24.0
30.0


Bias (y−x) = 9.92
Std Dev (y−x) = 22.13
Correlation = 0.94
MODIS LWP [g/m^2]
AVHRR LWP [g/m^2]
Relative Density
0
50
100
150
200
0.0
0.2
0.3
0.5
0.7
0.8
1.0


Bias (y−x) = 0.12
Std Dev (y−x) = 2.63
Correlation = 0.97
MODIS Optical Depth []
AVHRR Optical Depth []
Relative Density
0
5
10
15
20
25
30
0.0
0.2
0.3
0.5
0.7
0.8
1.0

Comparison of the SEVIRI algorithm with CLOUDSAT, MODIS and AMSR-E

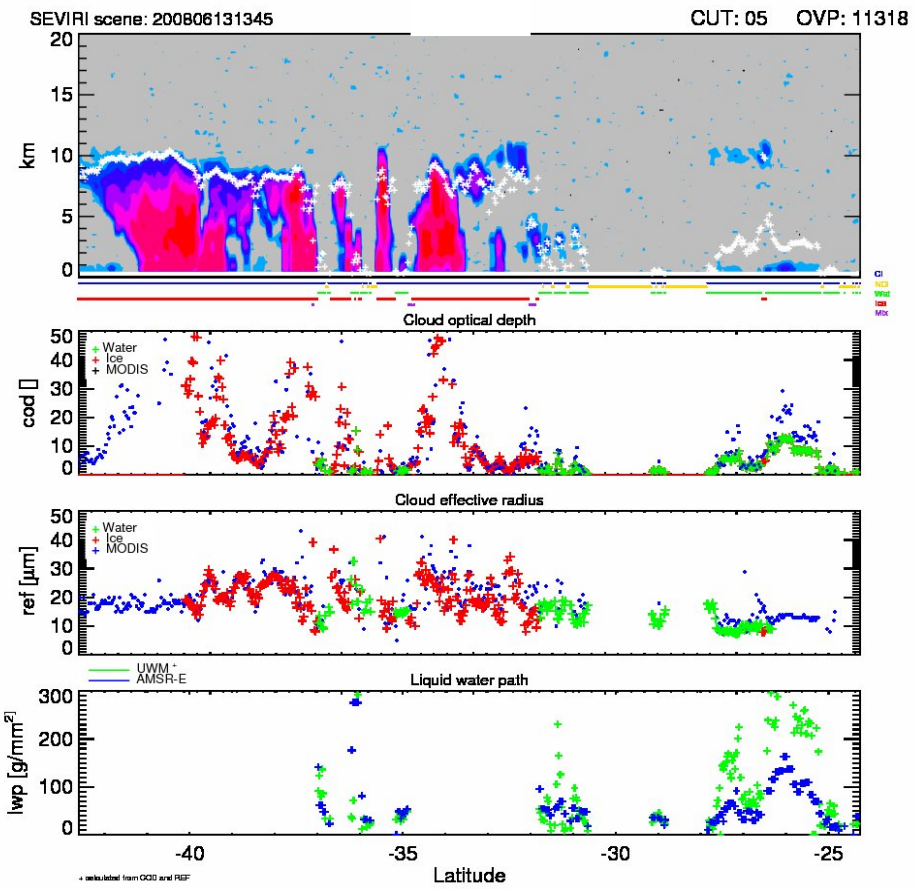
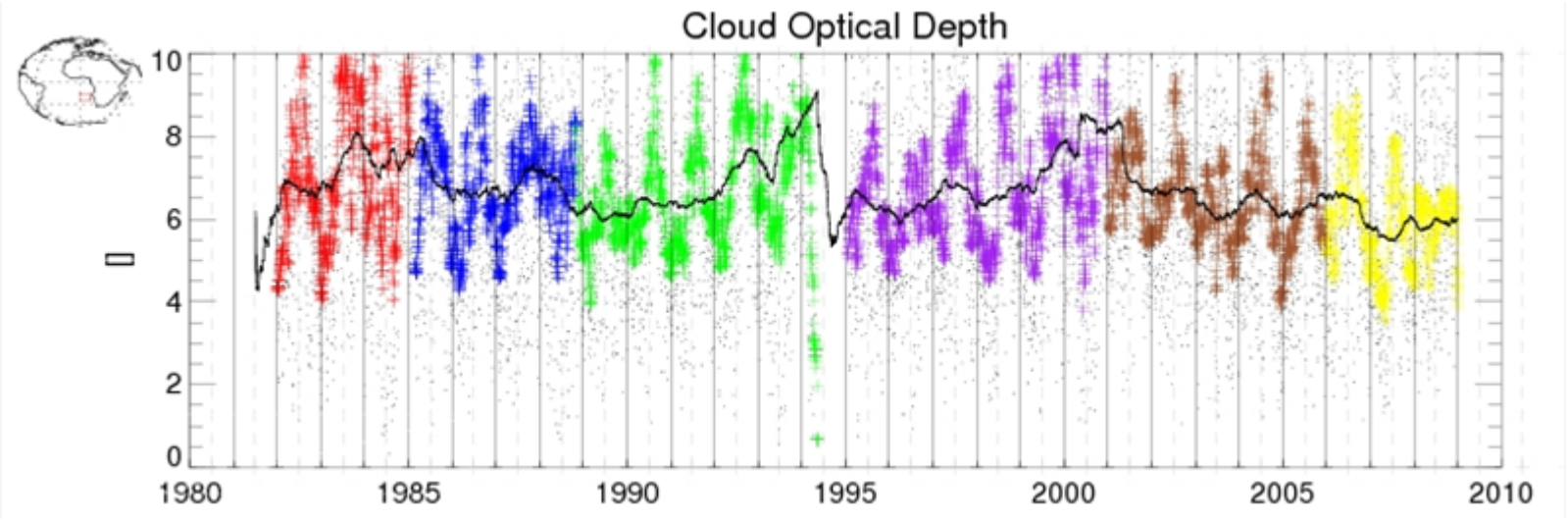


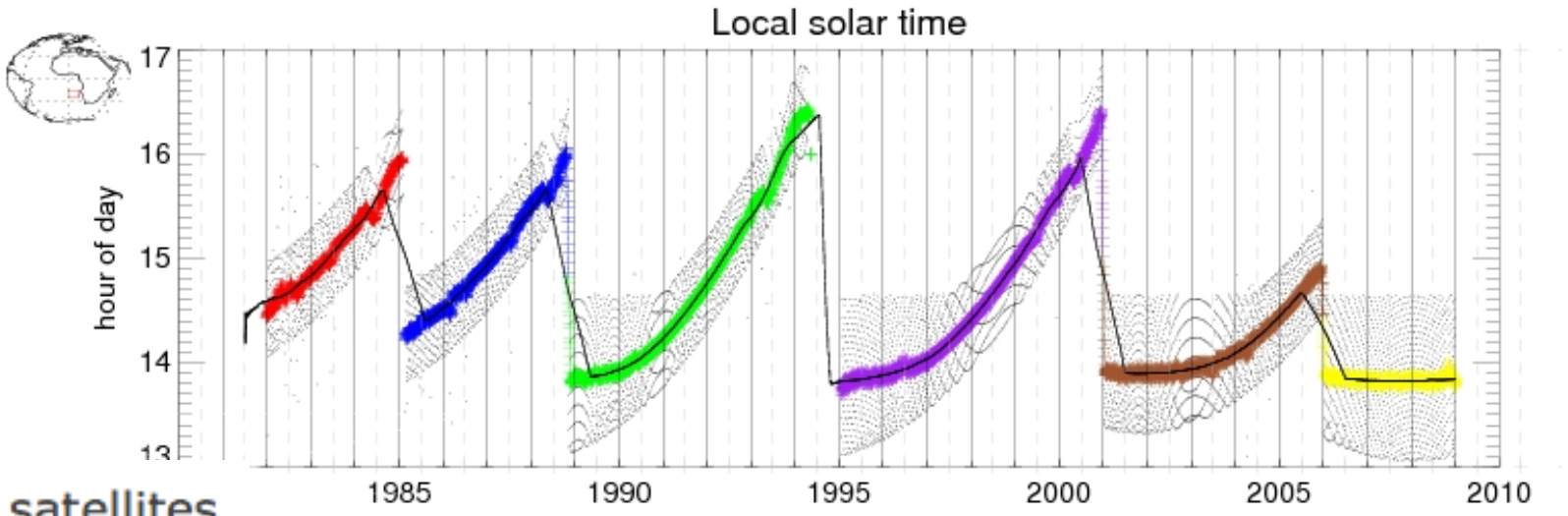
Fig. : Comparison of AWG (University of Wisconsin-Madison) cloud properties Cloud Top Height, Cloud Optical Depth, Cloud Effective Radius and Liquid Water Path with CLOUDSAT, MODIS and AMSR-E (CUT-05)

Along track evaluation with CLOUDSAT, MODIS and AMSR-E

17

Time series South Atlantic

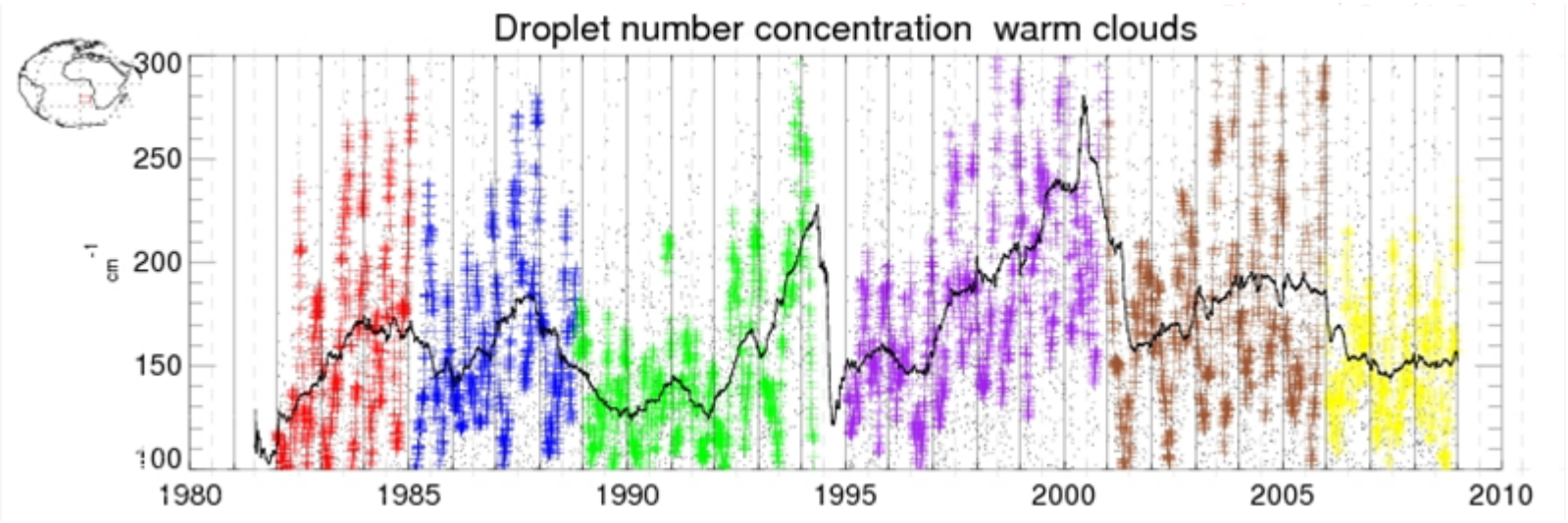


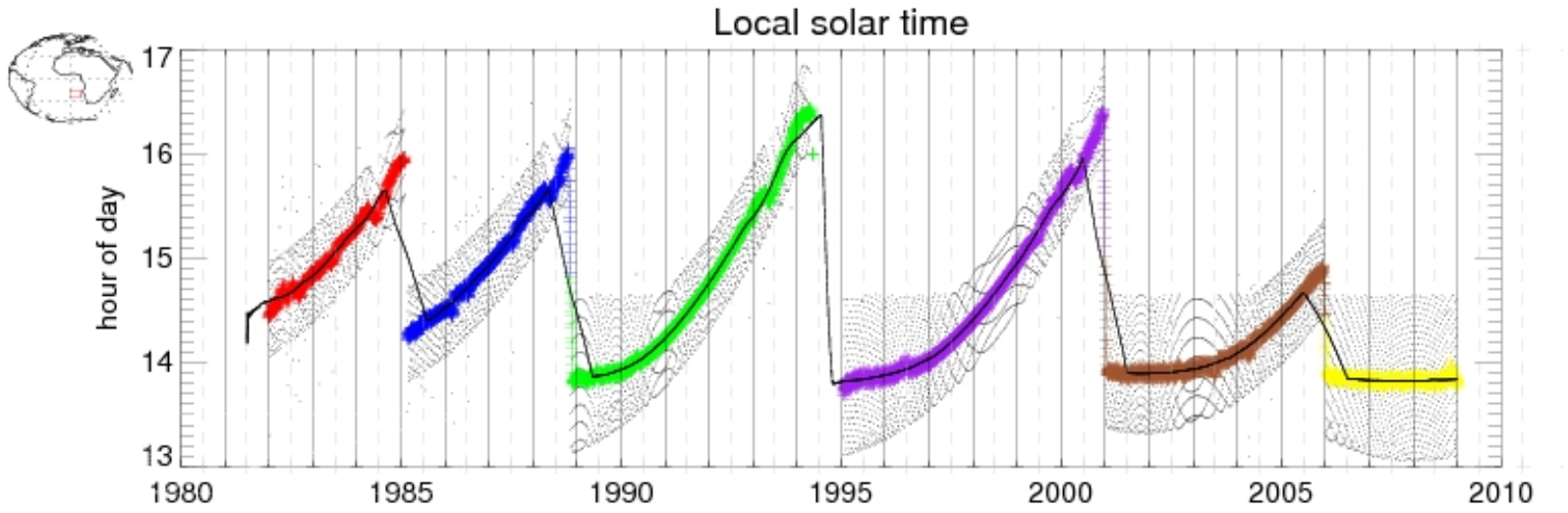


NOAA- satellites

7 9 11 14 16 18

Time series (South Atlantic)





Time series

- NOAA satellite orbits shift during their lifetime.
- Microphysical properties have diurnal cycle, so that time-series are not consistent over the years. Matching with SEVIRI or GOES will help to research the diurnal cycle and to correct the level-3 data by adjusting to one hour of day, such as 13:30.
- We intend to provide correction coefficients in the future.

Time series

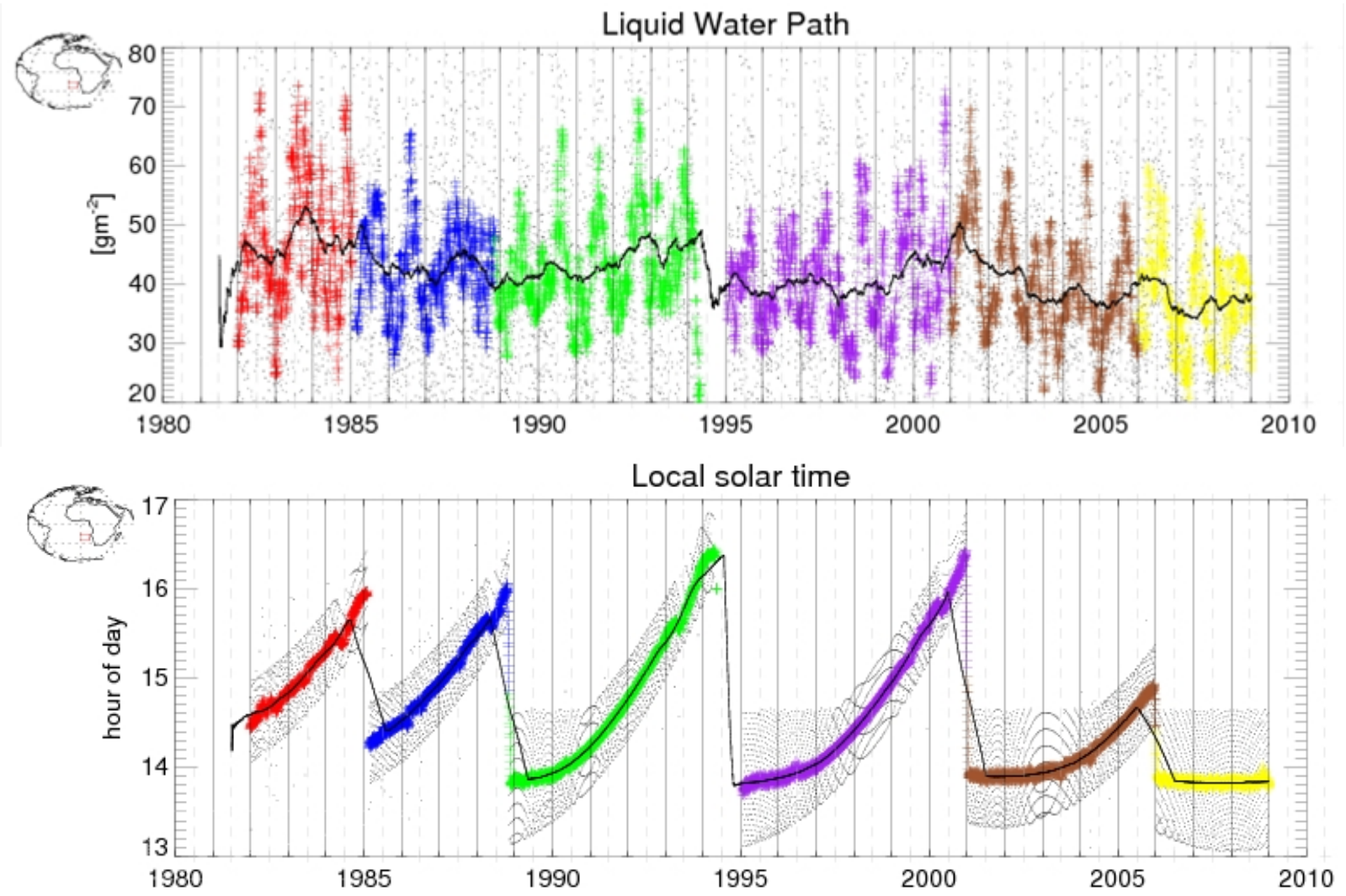
• However, retrieval has to be proofed to be invariant to observation geometry. There are many parts in the retrieval, those are highly sensitive to observation geometry, such as atmospheric correction.

•Question is: Are the abrupt changes in the time series a result of real diurnal cycle of COD or is it an artifact of the retrieval in respect to solar zenith angle or of the?

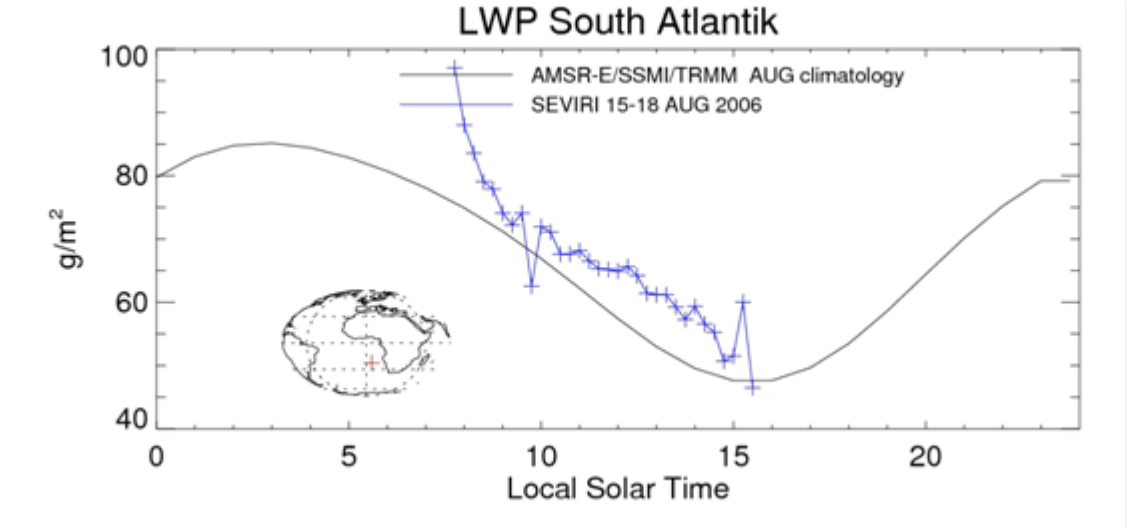
• There are no appropriate comparison data set for COD to answer this question directly, since geostationary sensors use similar principles. (MODIS observes under the same sun angle)

• Way to go: Liquid water path can be measured by microwave sensors.

Time series of liquid water path

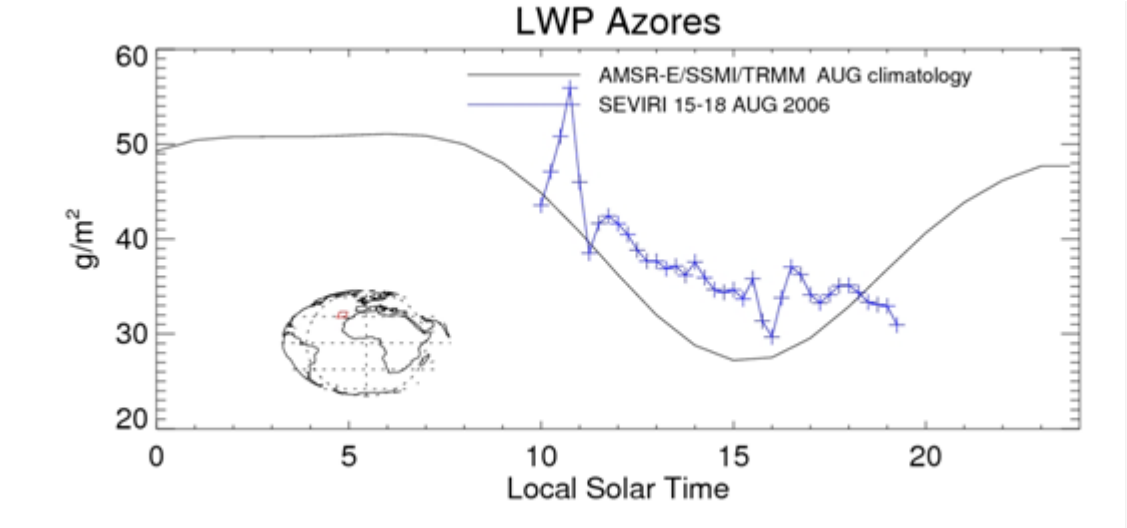


Microphysical parameters in PATMOS-x



- Satellite-based microwave (MW) observations are the only source for totally independent validation studies for cloud-optical properties for larger areas.
- Limitations are different spatial resolutions and the applicability only for liquid clouds over sea surface.
- MW sees also water below ice clouds, that SEVIRI/AVHRR can not.
- Chris O'Dell's liquid water path climatology combines AMSR-E, SSM-I and TRMM observations.

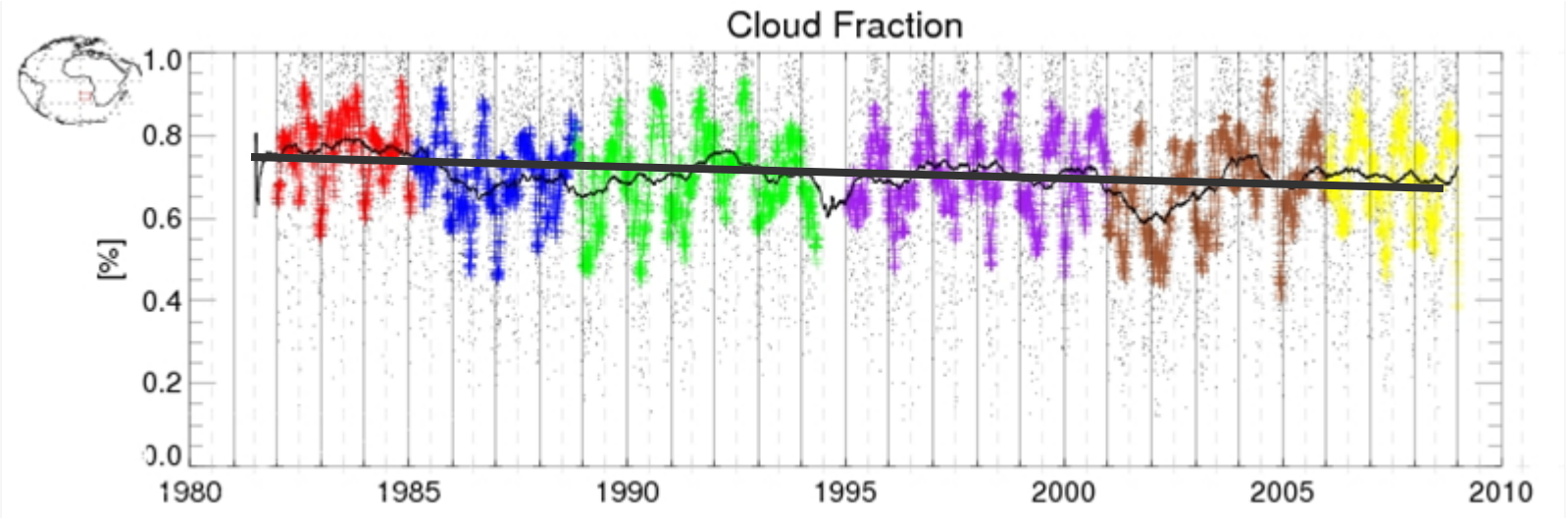
Microphysical parameter in PATMOS-x



First impressions are good.

But more analysis are needed to validate the retrievals to the aspect of observation geometry.

Time series (South Atlantic)

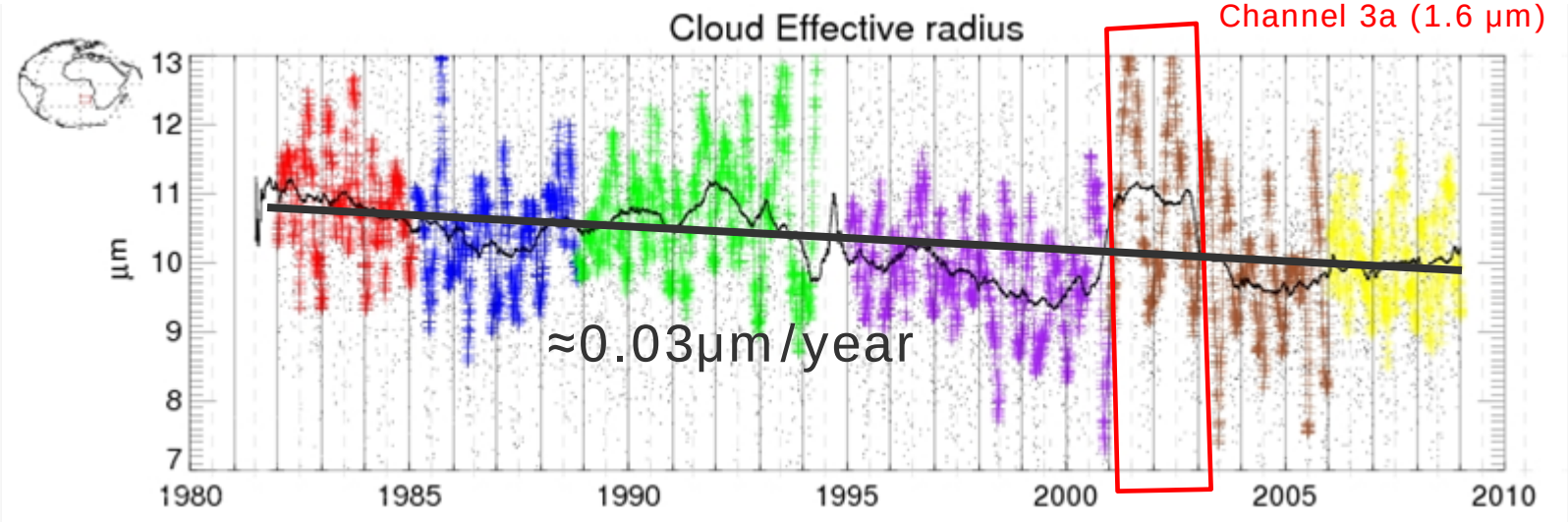


NOAA- satellites

7 9 11 14 16 18

Further questions one could analyze with PATMOS-X: Is there a trend in cloud cover?

Time series (South Atlantic)

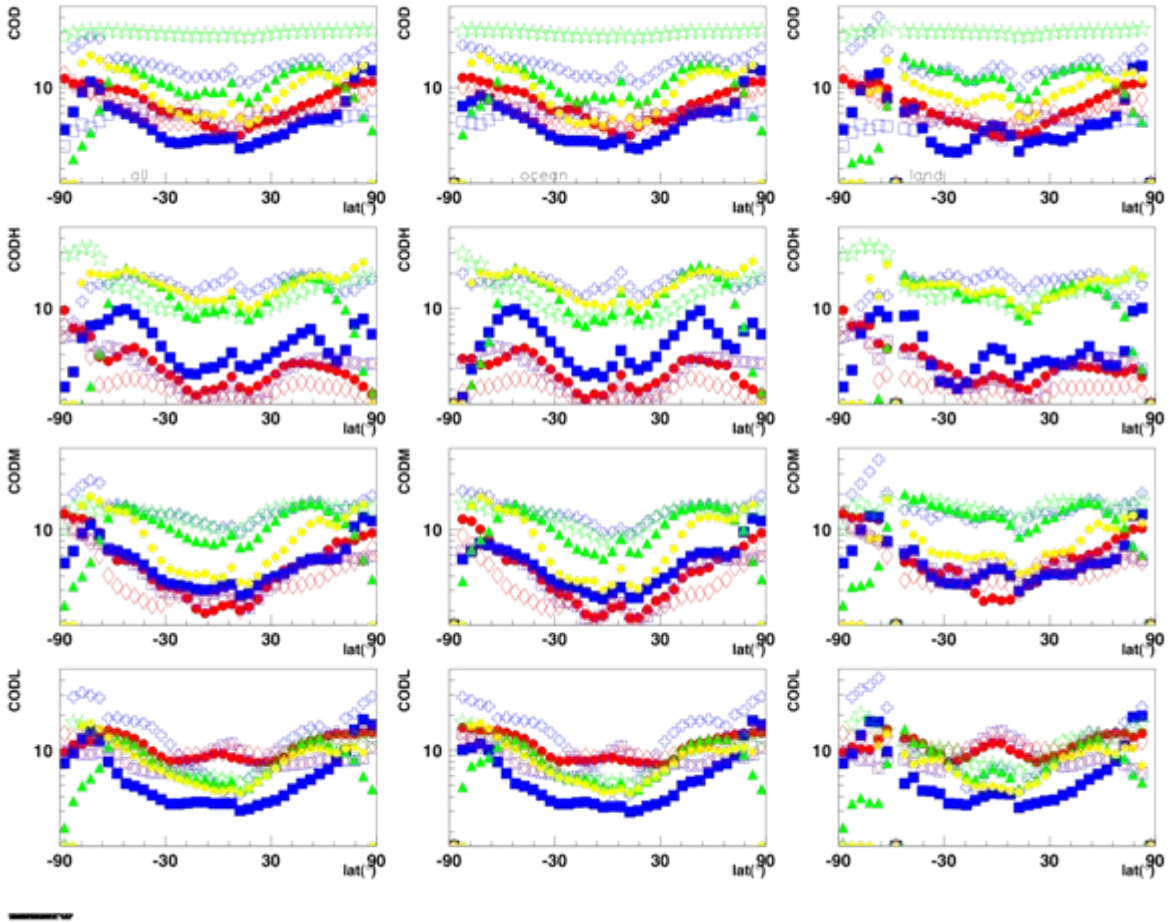


Determination of a long-term trend is pending.

Evaluations of COD/REF

Data set	Products	Histograms	Sat	
AIRS-LMD	COD	COD-CP	AQUA	
ATSR-GRAPE	COD/REF/LWP	COD-CP	ATSR/ENVISAT	
ISCCP	COD	COD-CP empty	geostationary	
MODIS-CE	COD/REF/LWP		AQUA/TERRA	
MODIS-ST	COD/REF/LWP			
PATMOSX	COD/REF/LWP	COD-CP	NOAA	Unit space
POLDER	COD	COD-CP		Av log space
TOVSB	COD			
TOVSR	COD			

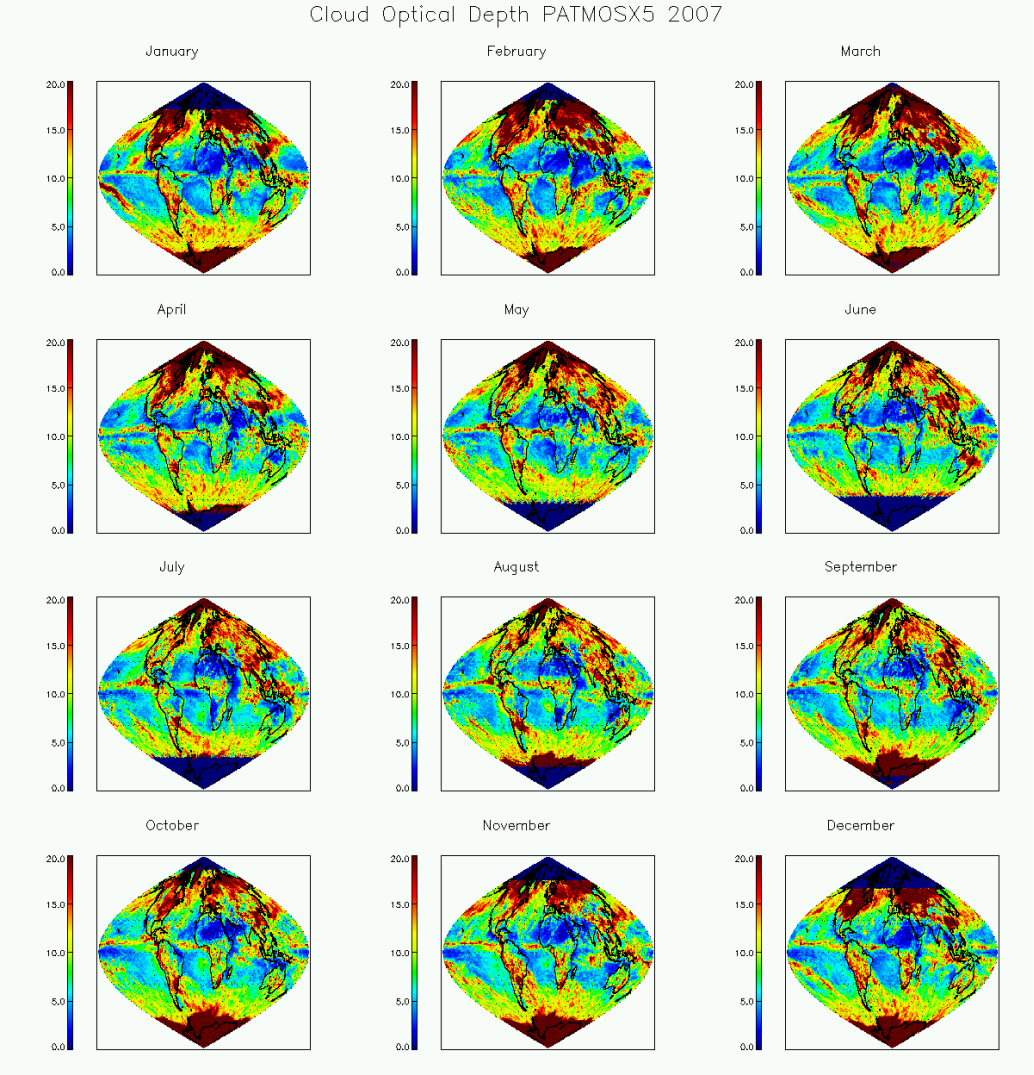
Zonal mean


COD
CODH
CODM
CODL
10
-90
-30
30
90
lat(°)
all
ocean
land
AIRS
TOVS
MOD-CE
MOD-ST
ISCCP
PATMOS
ATSR
MISR
POLDER
CALIPSO
GOCCP

Microphysical cloud parameters: Comparison of Cloud Optical Depth

COD PATMOSX v5:

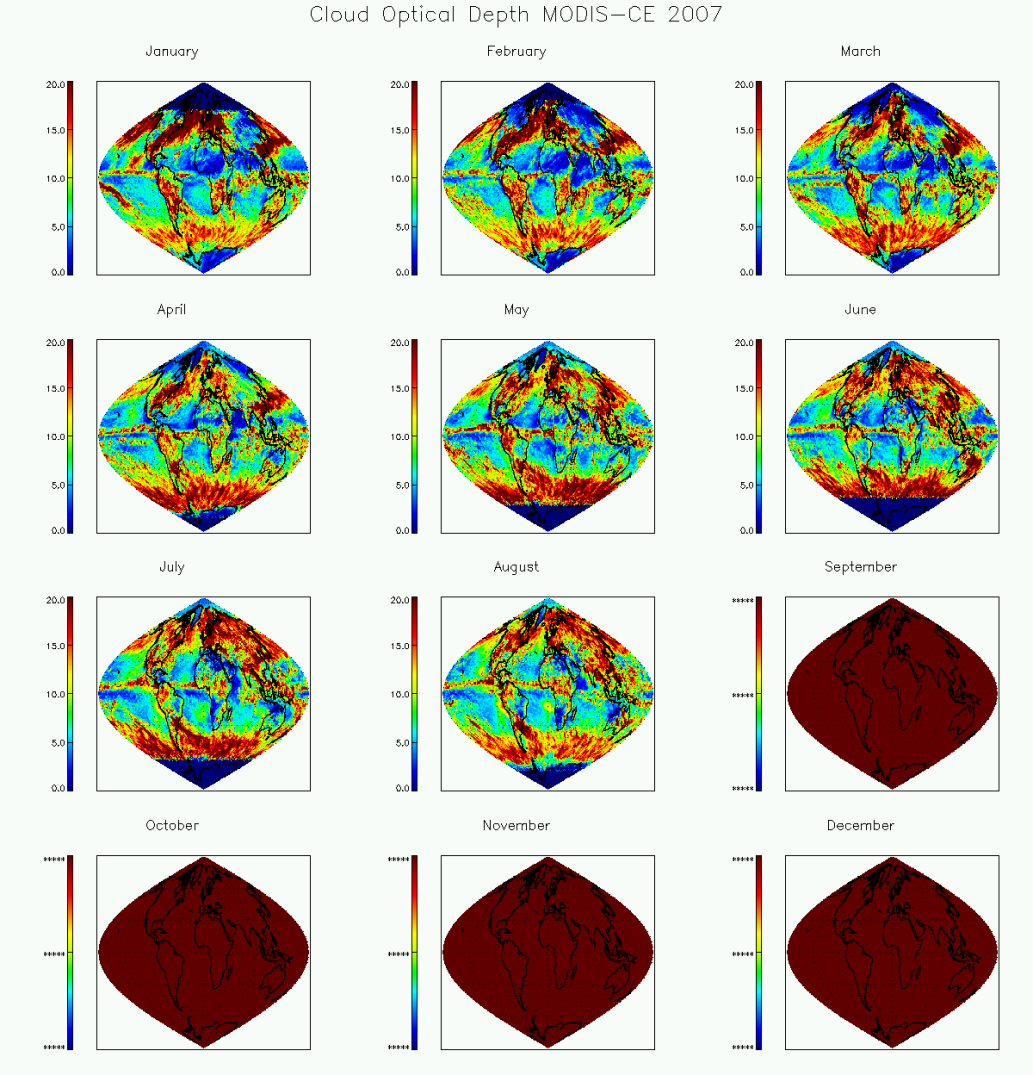
- Image shows COD version5 for PM NOAA18.



Microphysical cloud parameters: Comparison

MODIS-CE:

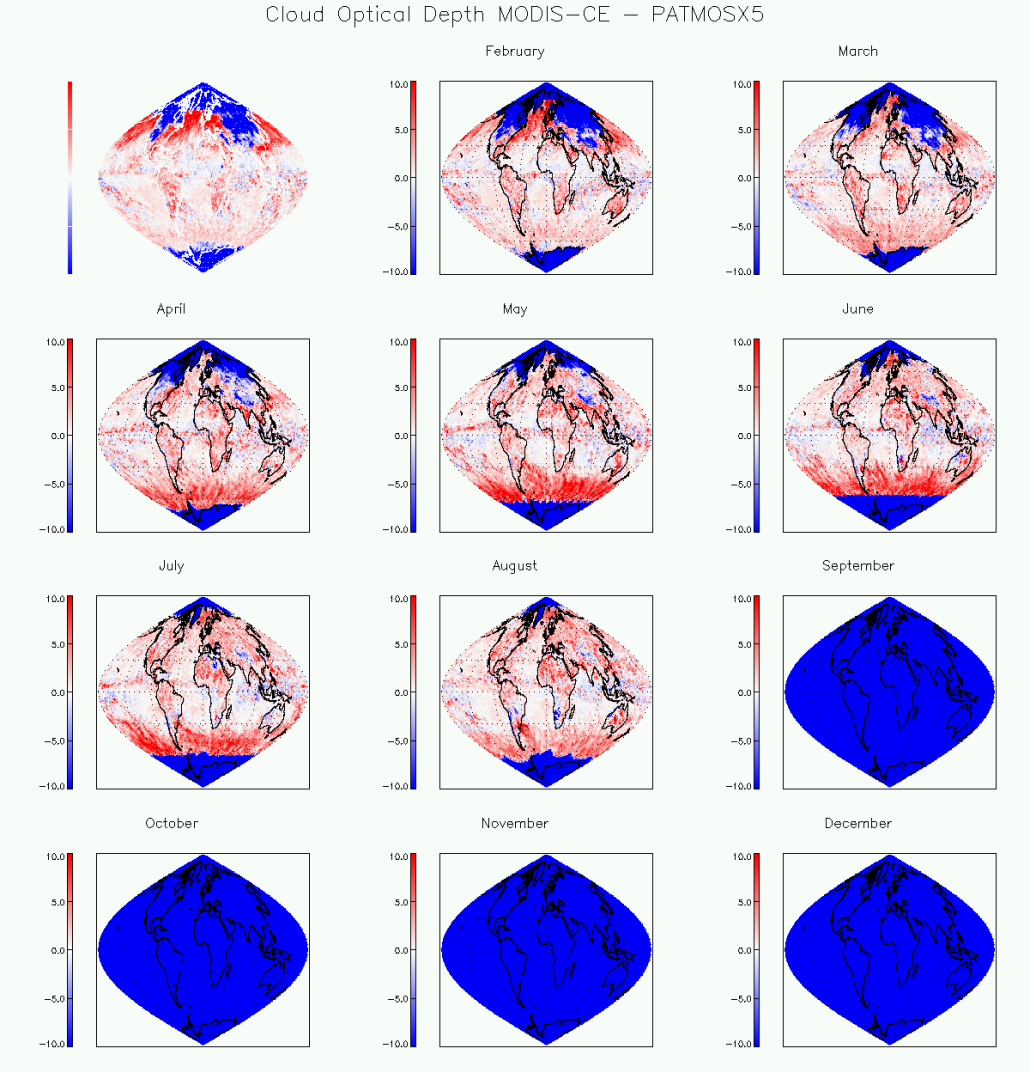
- Image shows COD MODIS AQUA PM.



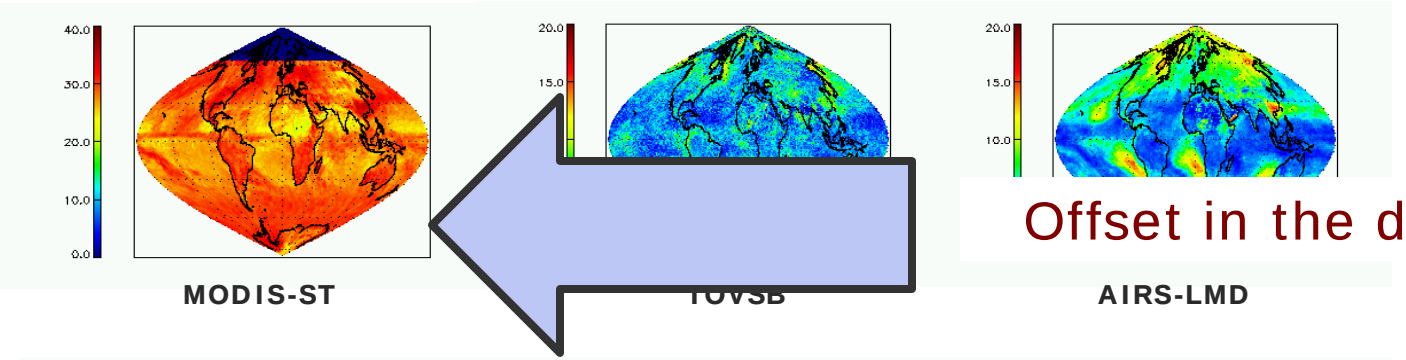
Microphysical cloud parameters: What is new in PATMOSX version 5

MODIS-CE:

- Image shows COD Difference Plot between MODIS AQUA PM and PATMOSX-v5 NOAA18 PM.

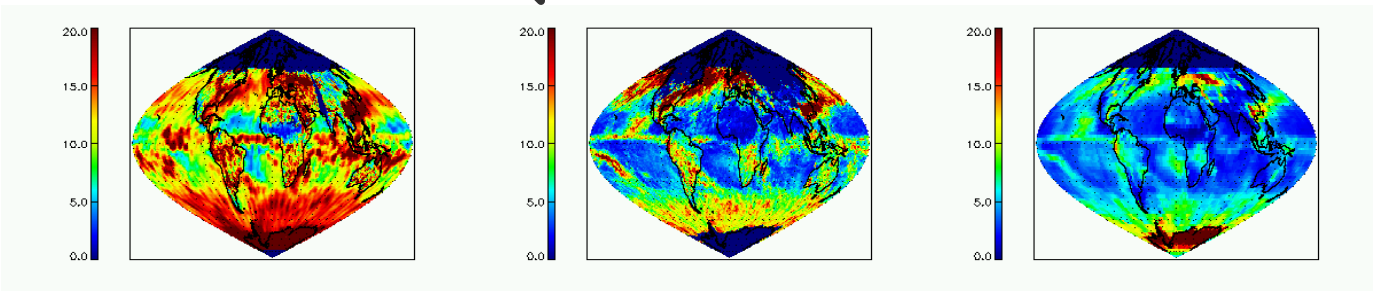


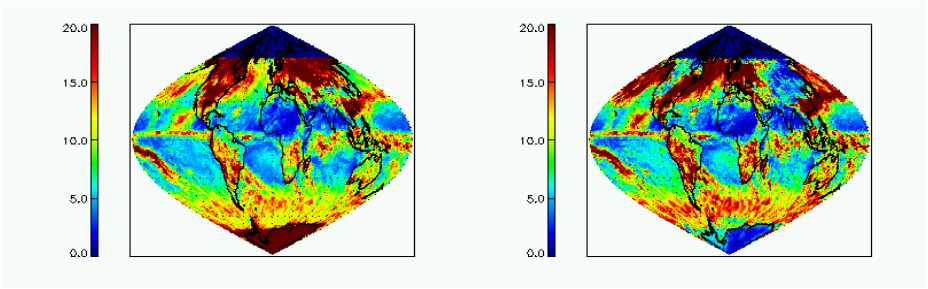
Microphysical cloud parameters: Cloud Optical Depth



Offset in the data?

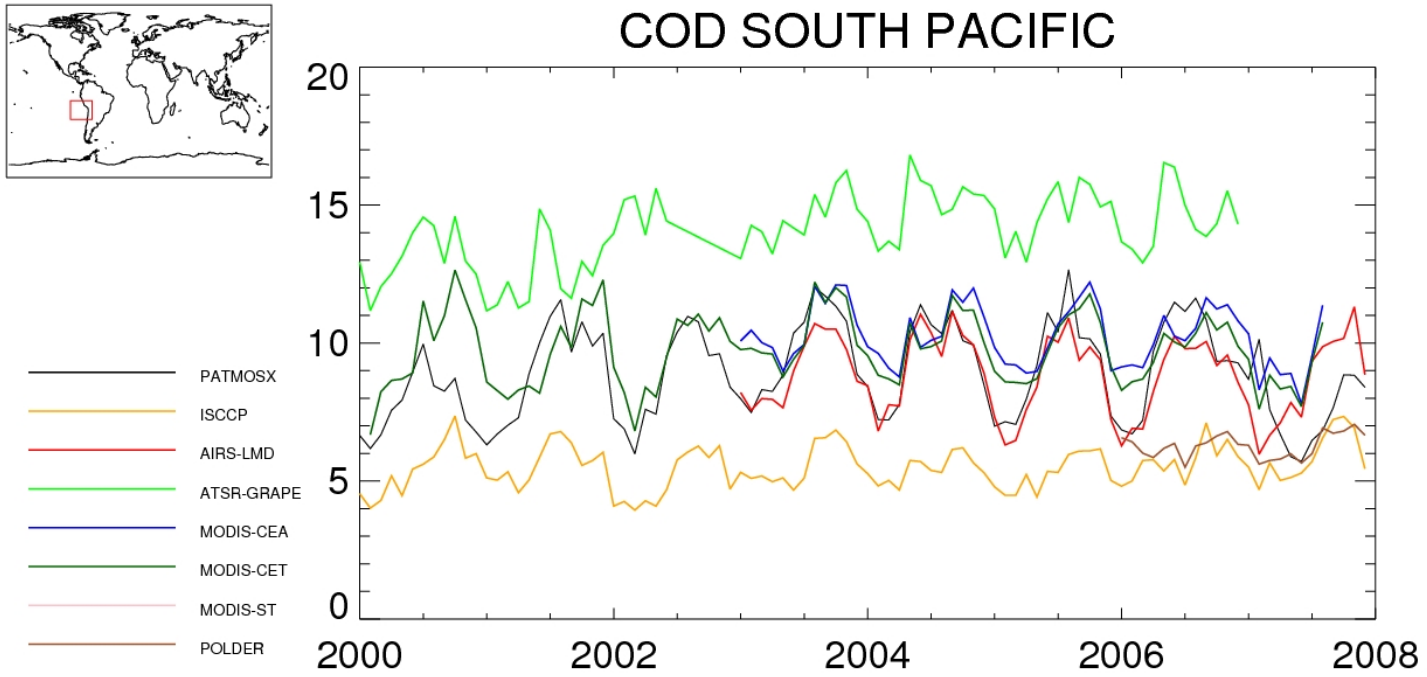
Image shows exemplarily 2007 COD data.



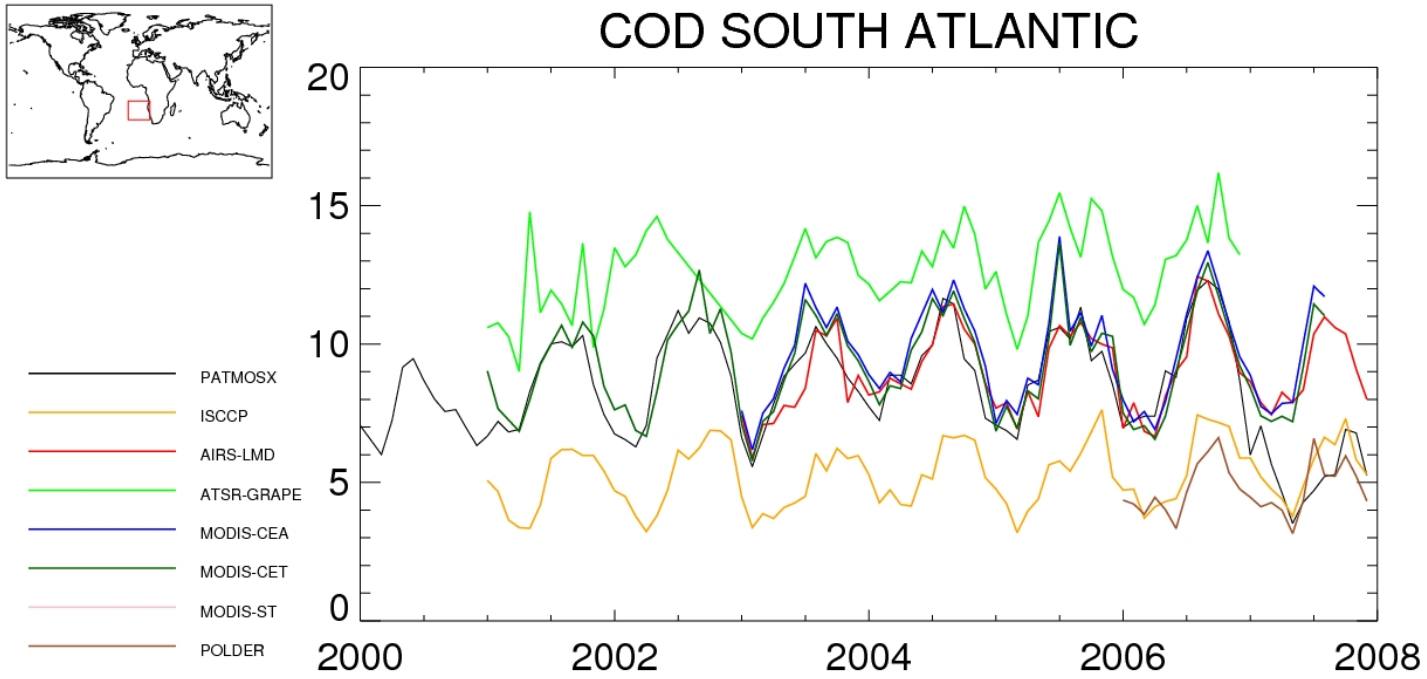


In which data space was averaged? (log or linear?)

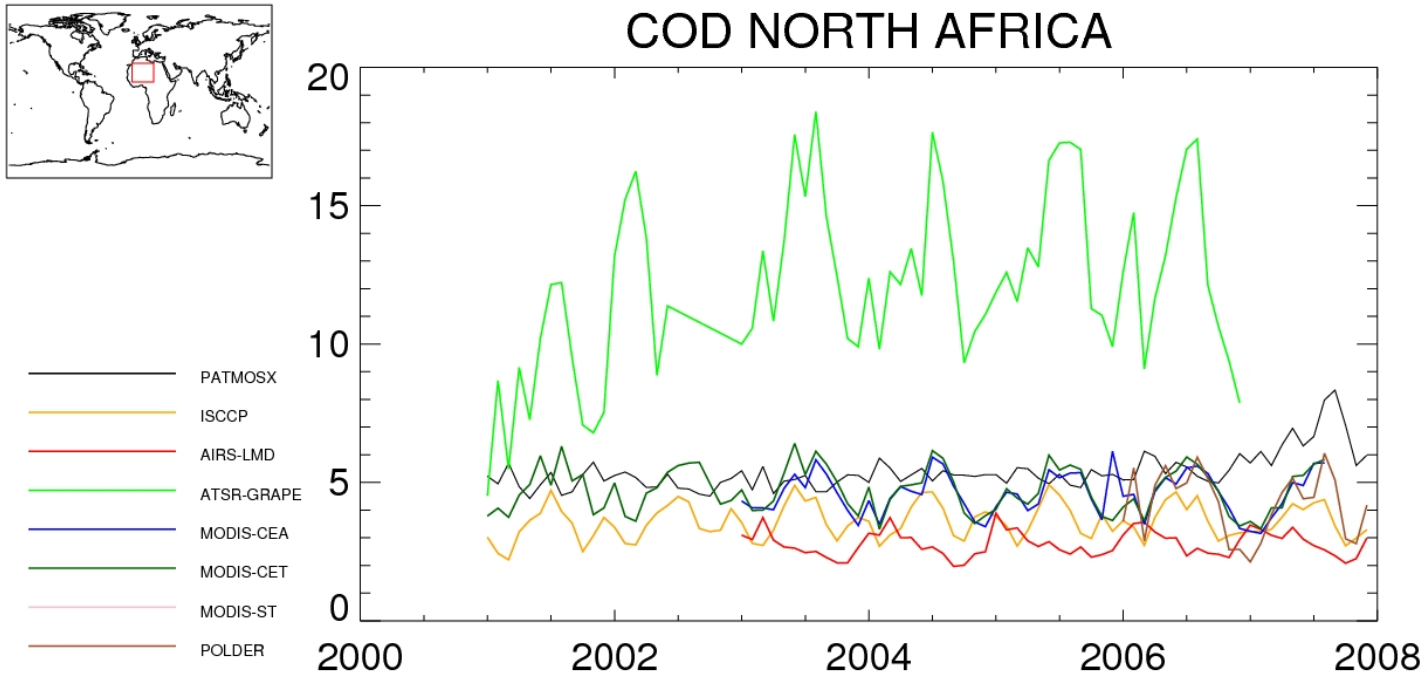
Microphysical cloud parameters:



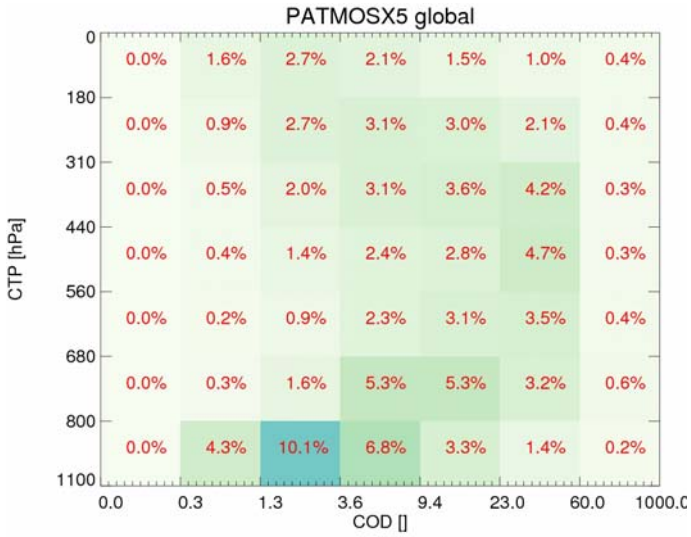
Microphysical cloud parameters:

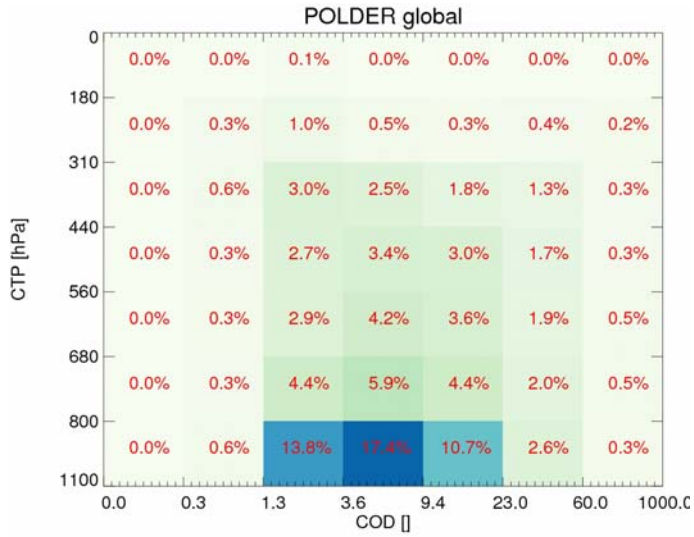


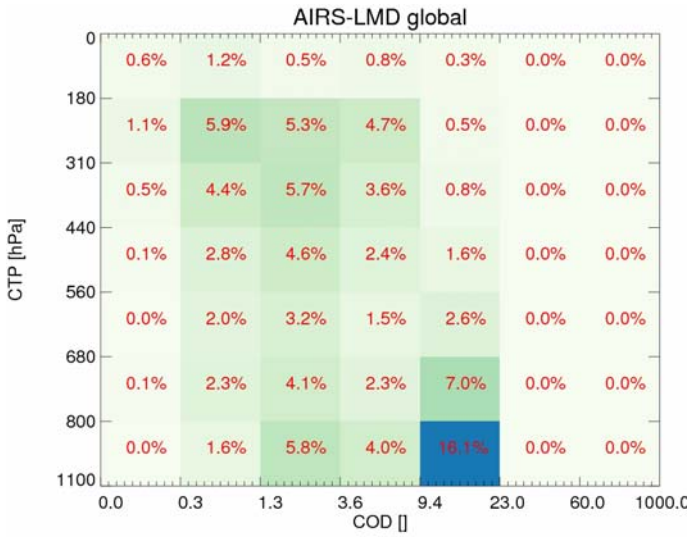
Microphysical cloud parameters:

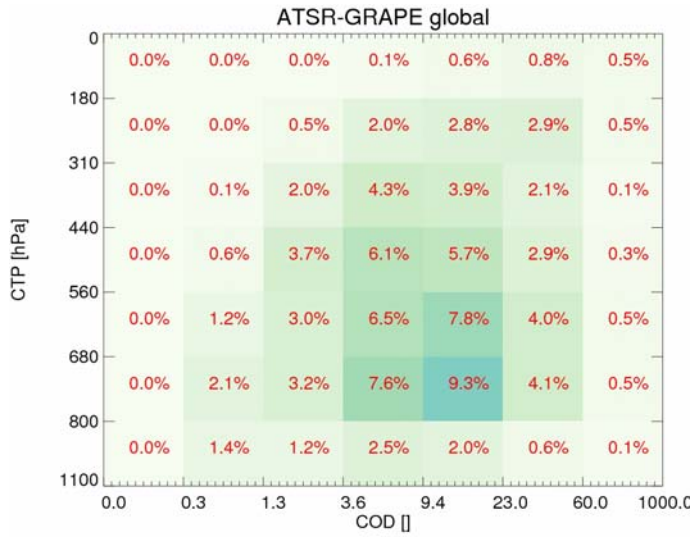


COD-CP histograms: Global Data

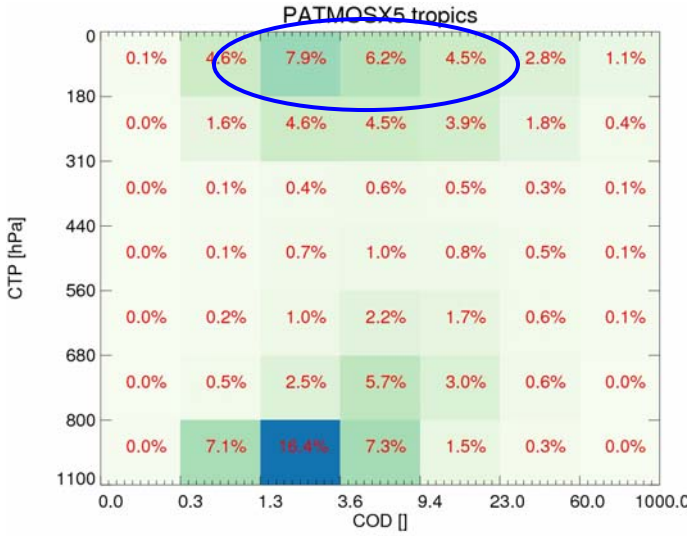


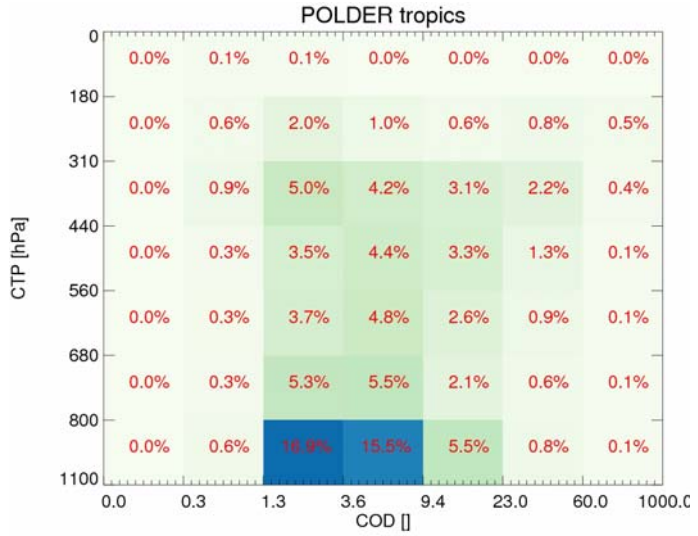


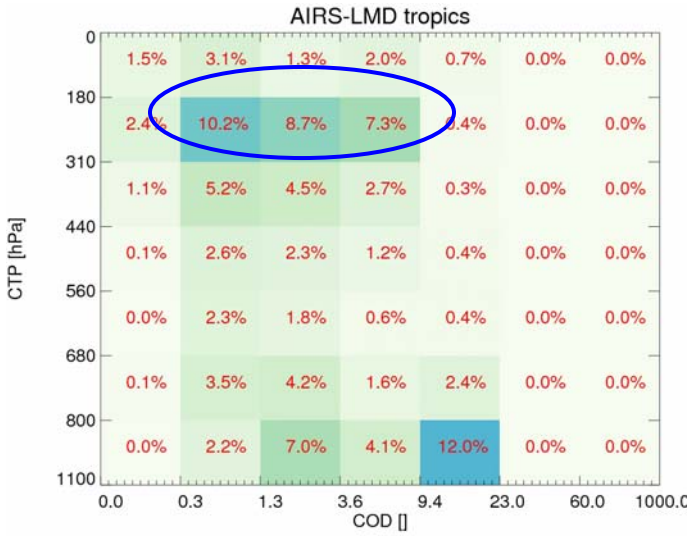


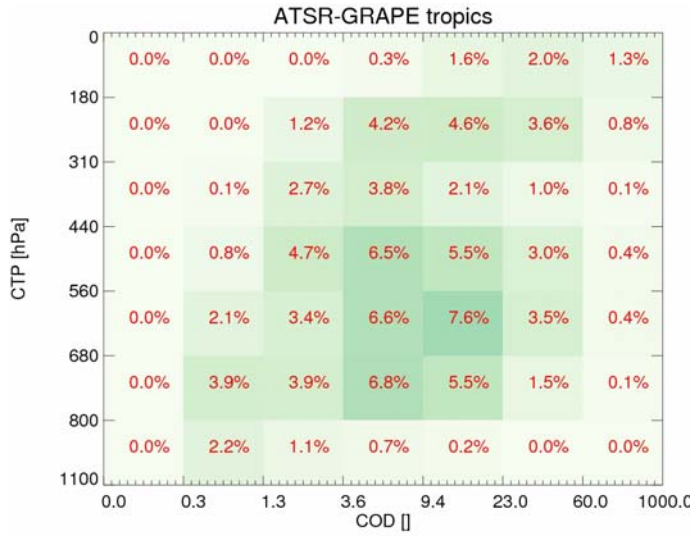


COD-CP histograms: Tropics (30S – 30N)

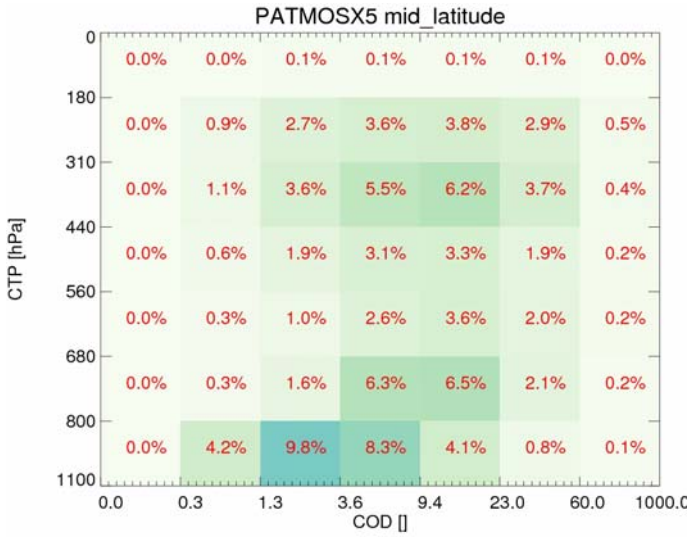


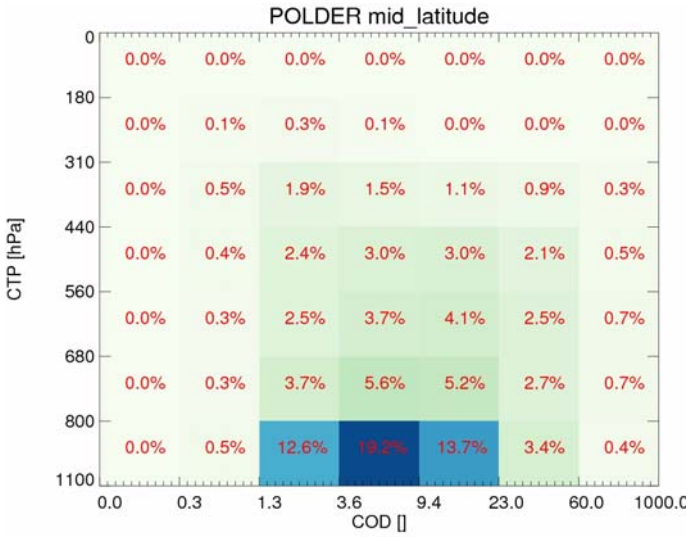


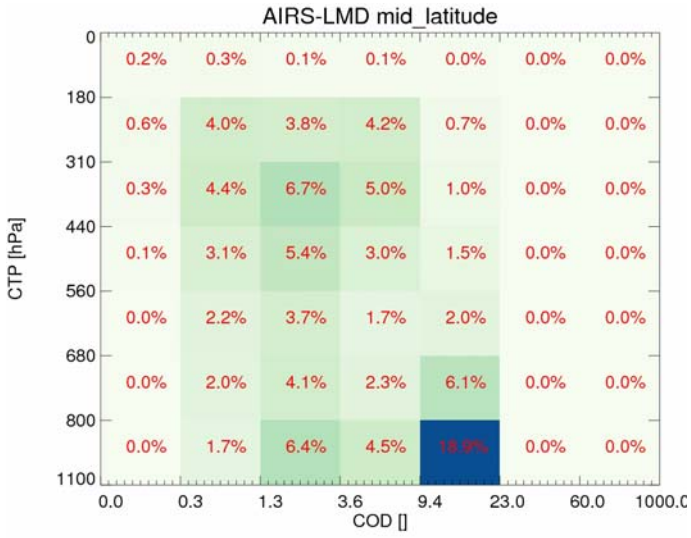


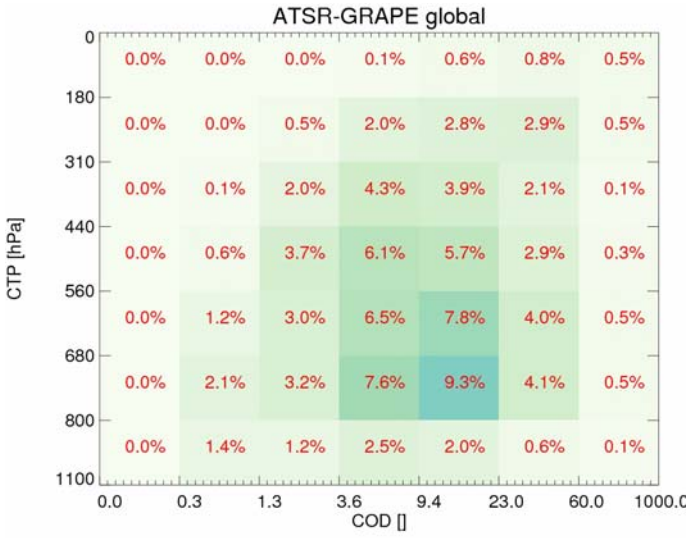


COD-CP histograms: Mid Latitudes (30S/N – 60S/N)

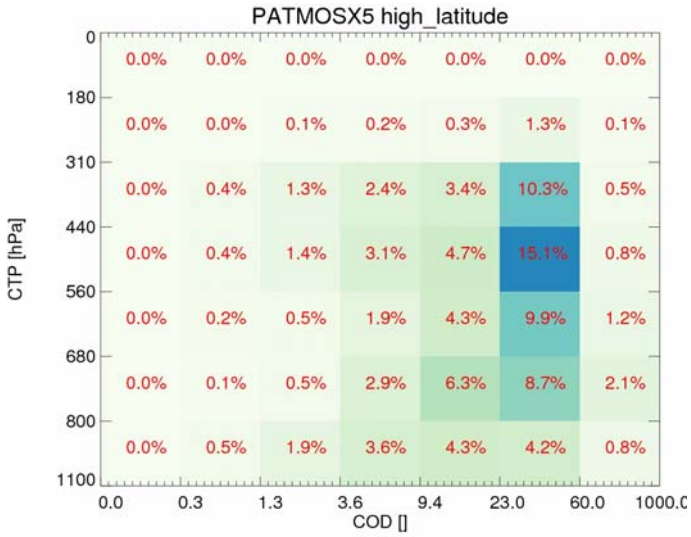


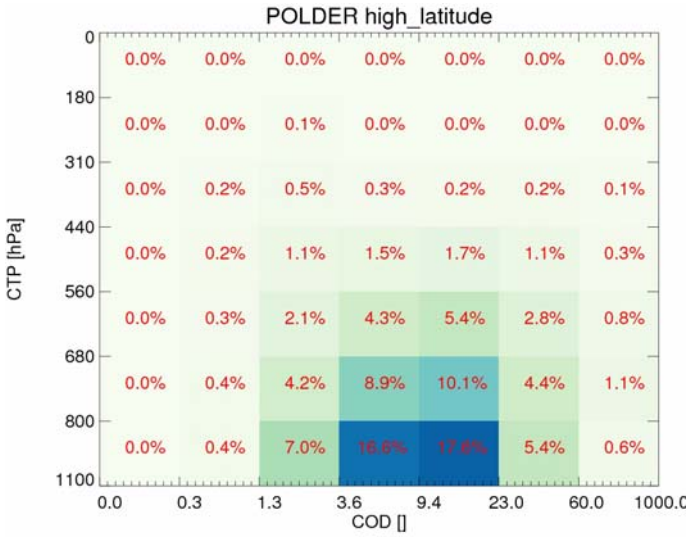


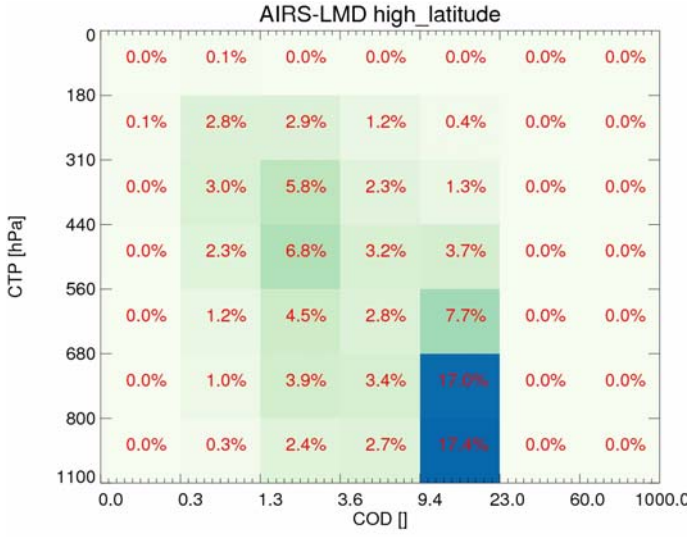


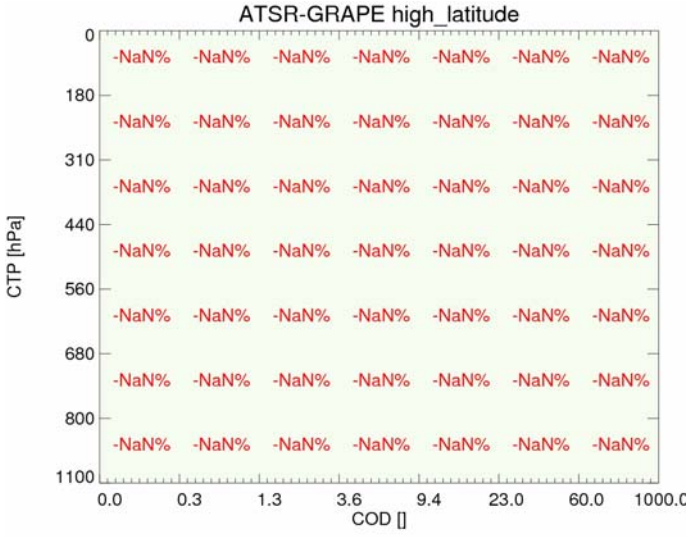


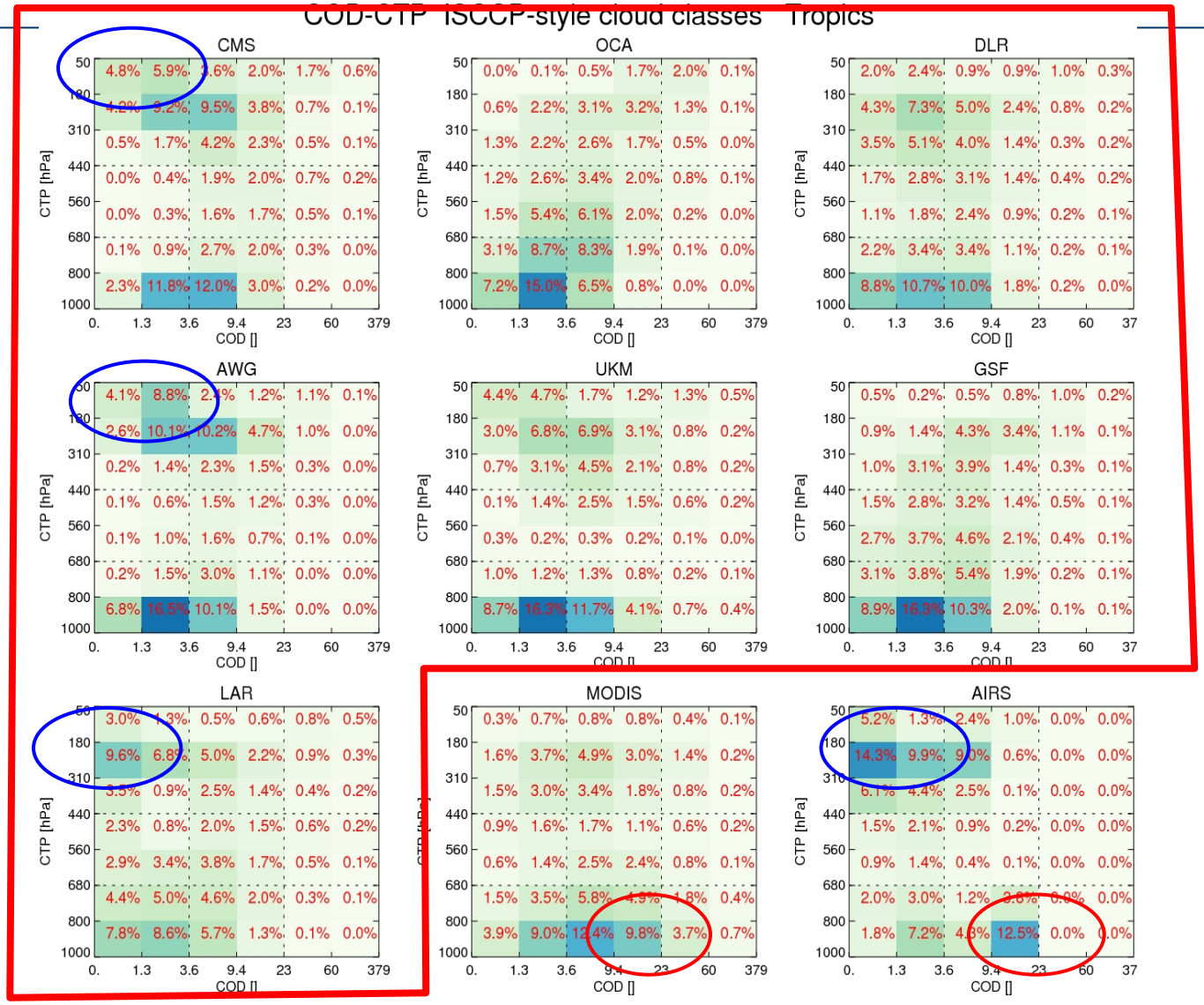
COD-CP histograms: High Latitudes (> 60S/N)





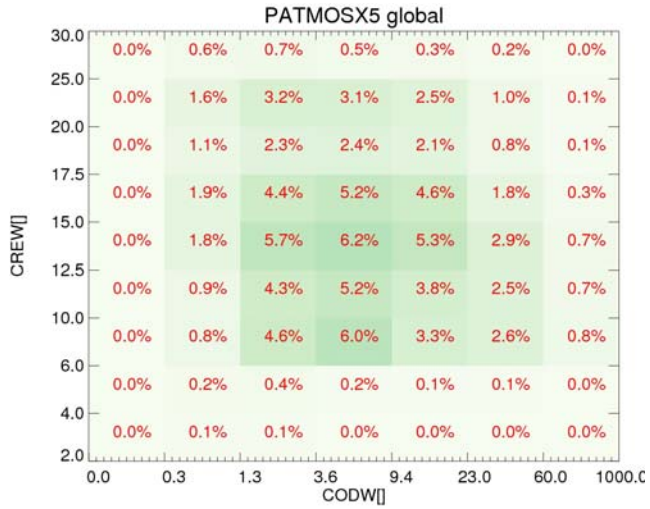


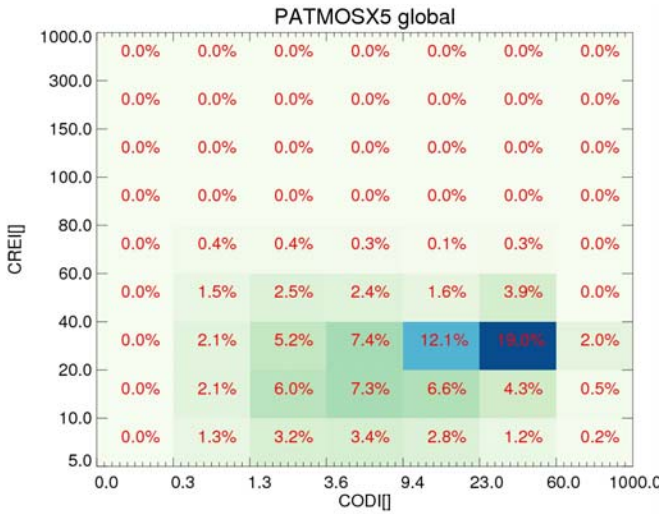




7 SEVIRI algorithms for scenes of one day

Microphysical cloud parameters:

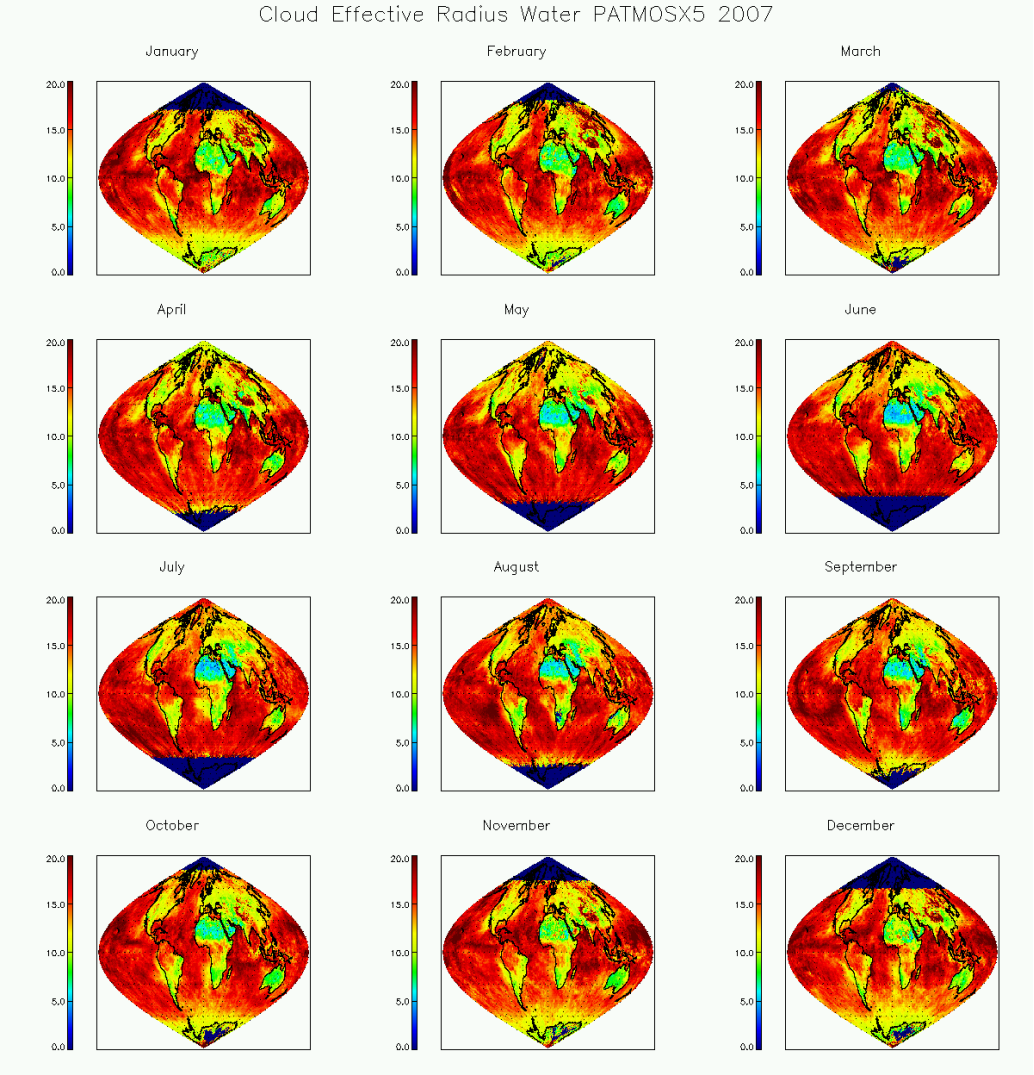




Microphysical cloud parameters: Cloud Effective Radius Water

CREW PATMOSX Version 5:

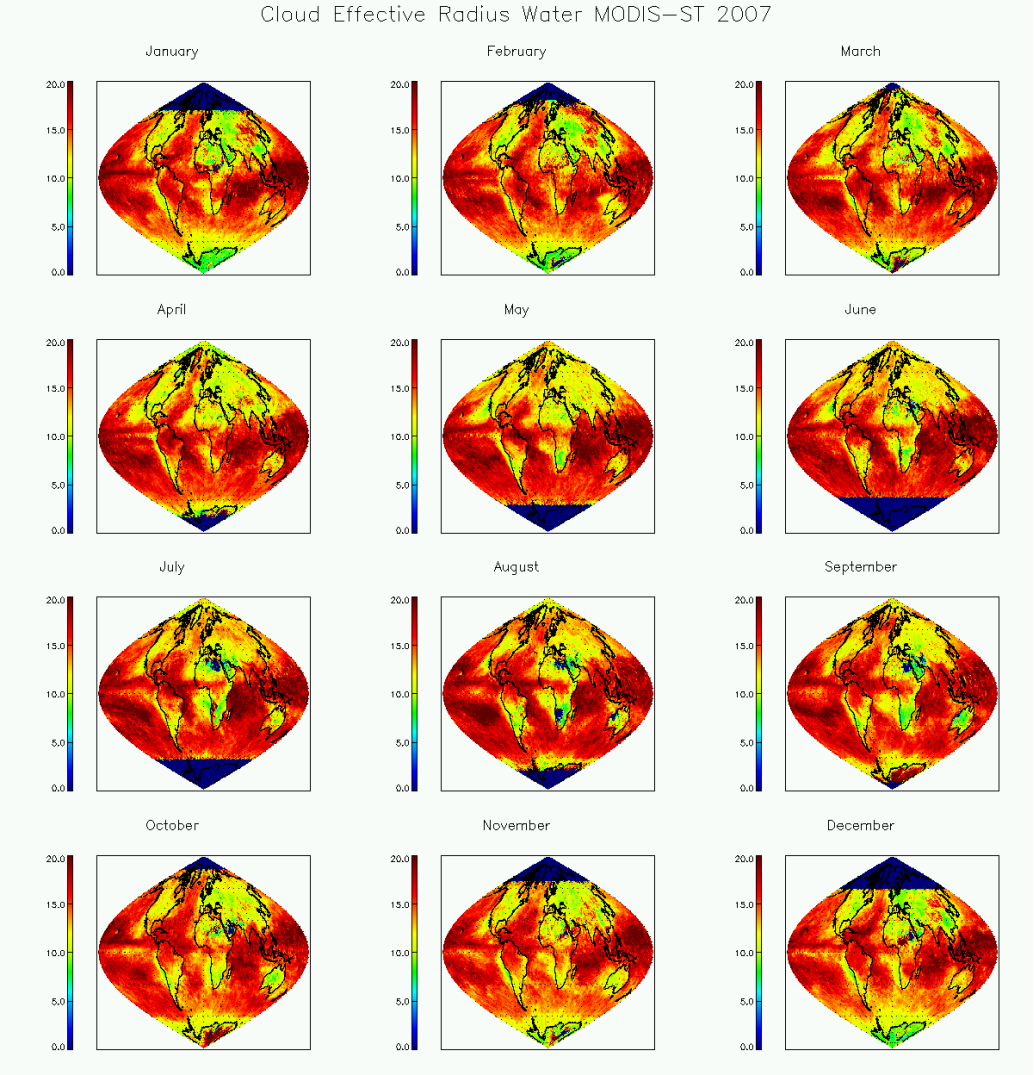
- Image shows REF version5 for PM NOAA18.



Microphysical cloud parameters: Cloud Effective Radius Water

CREW MODIS-ST:

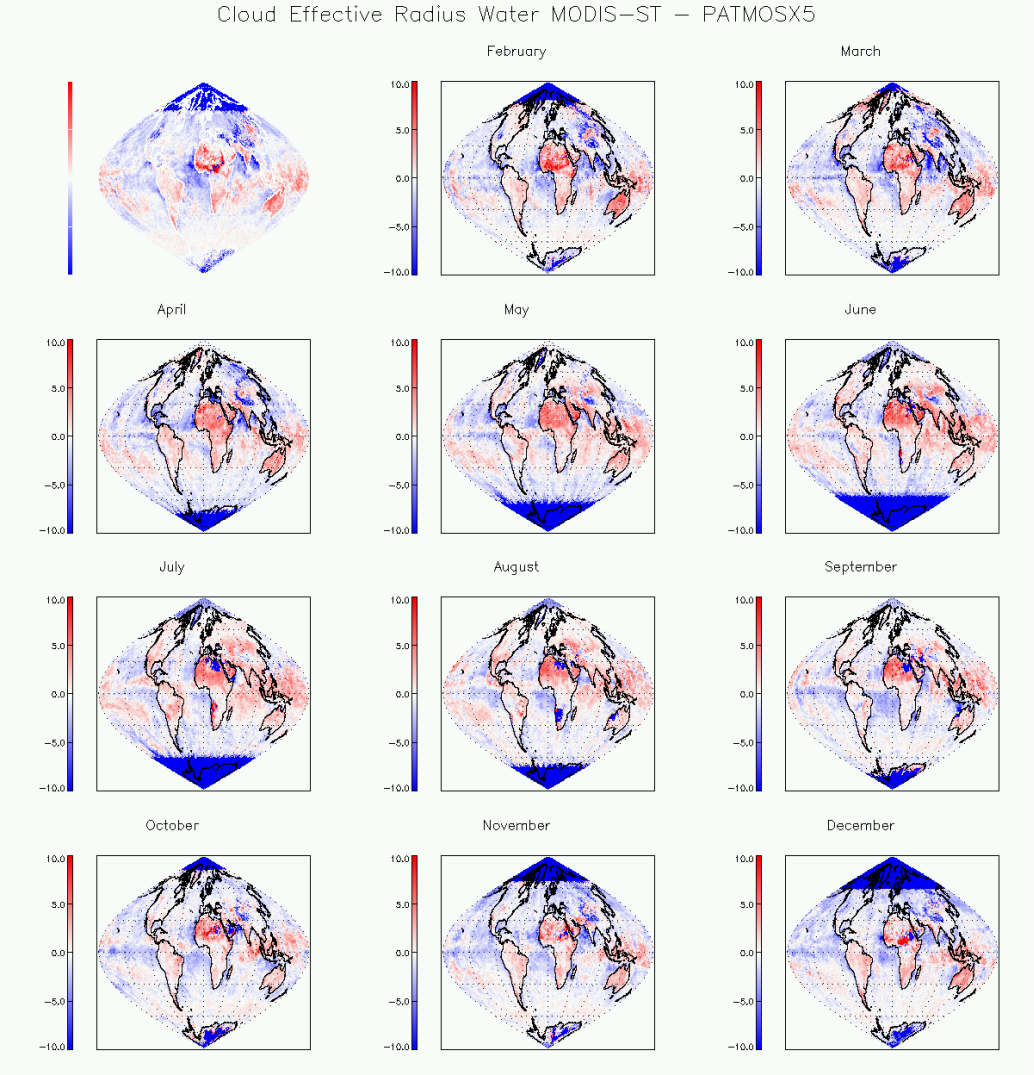
- Image shows REF MODIS-ST AQUA PM .



Microphysical cloud parameters: Cloud Effective Radius Water

CREW: MODIS-ST – PATMOSX v5

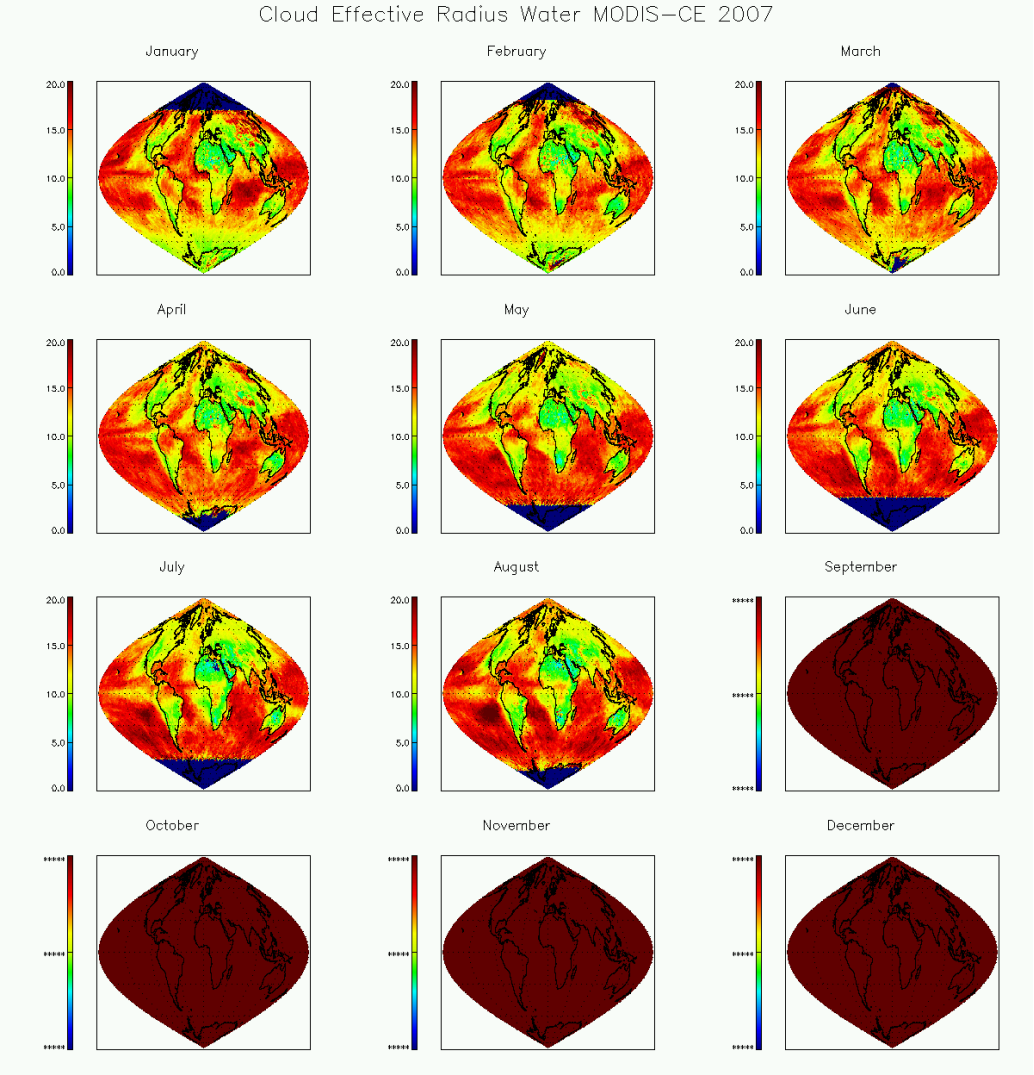
- Image shows REF MODIS-ST AQUA PM .



Microphysical cloud parameters:

Version 5:

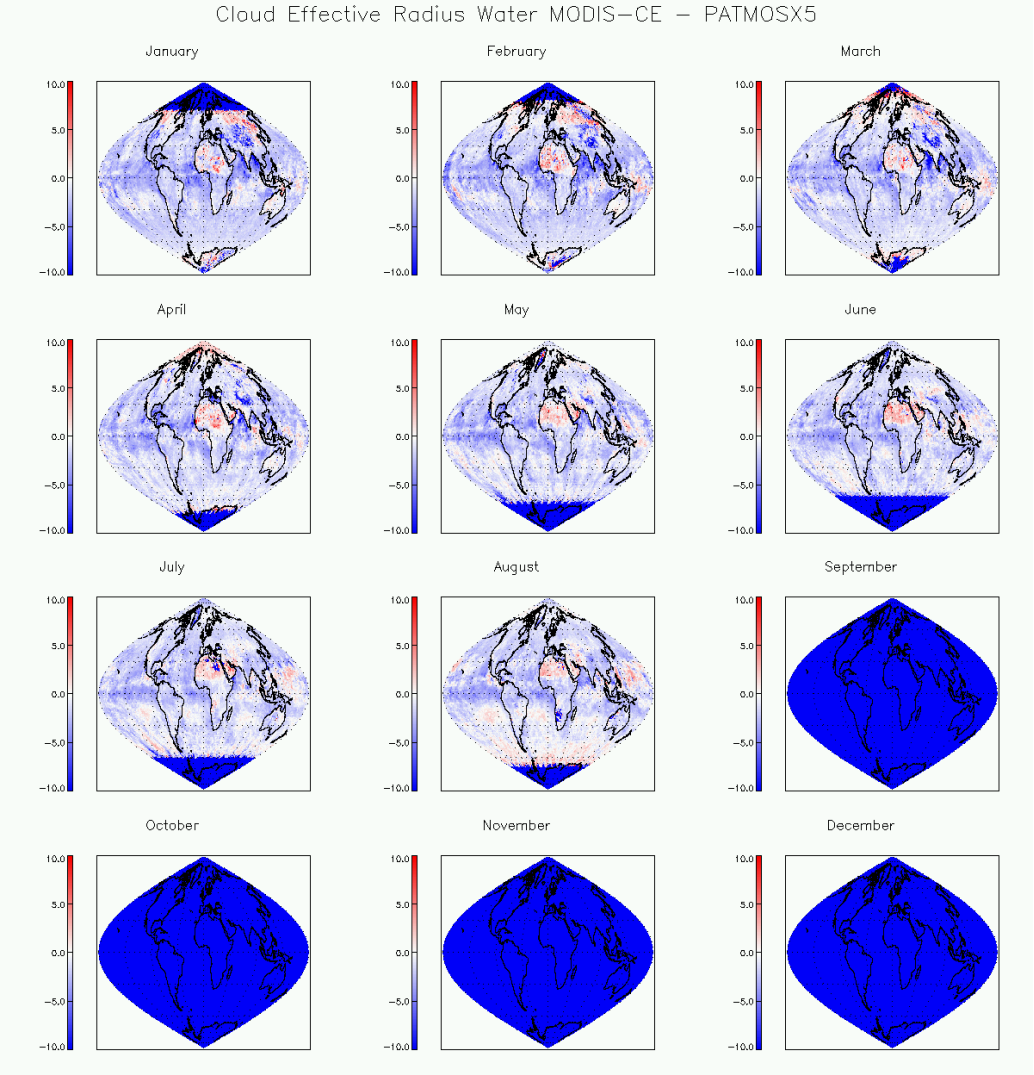
- Image shows REF MODIS AQUA PM .



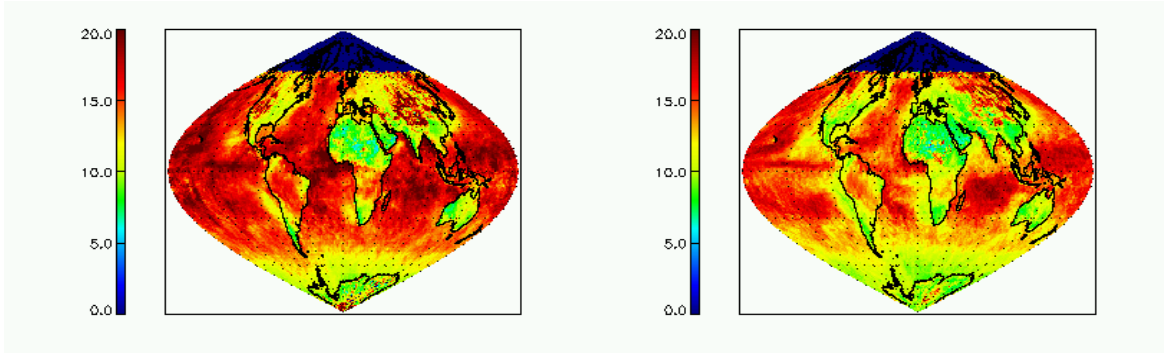
Microphysical cloud parameters: What is new in PATMOSX version 5

REF MODIS-CE:

- Image shows REF MODIS-CE AQUA PM difference plot to PATMOSX v5.

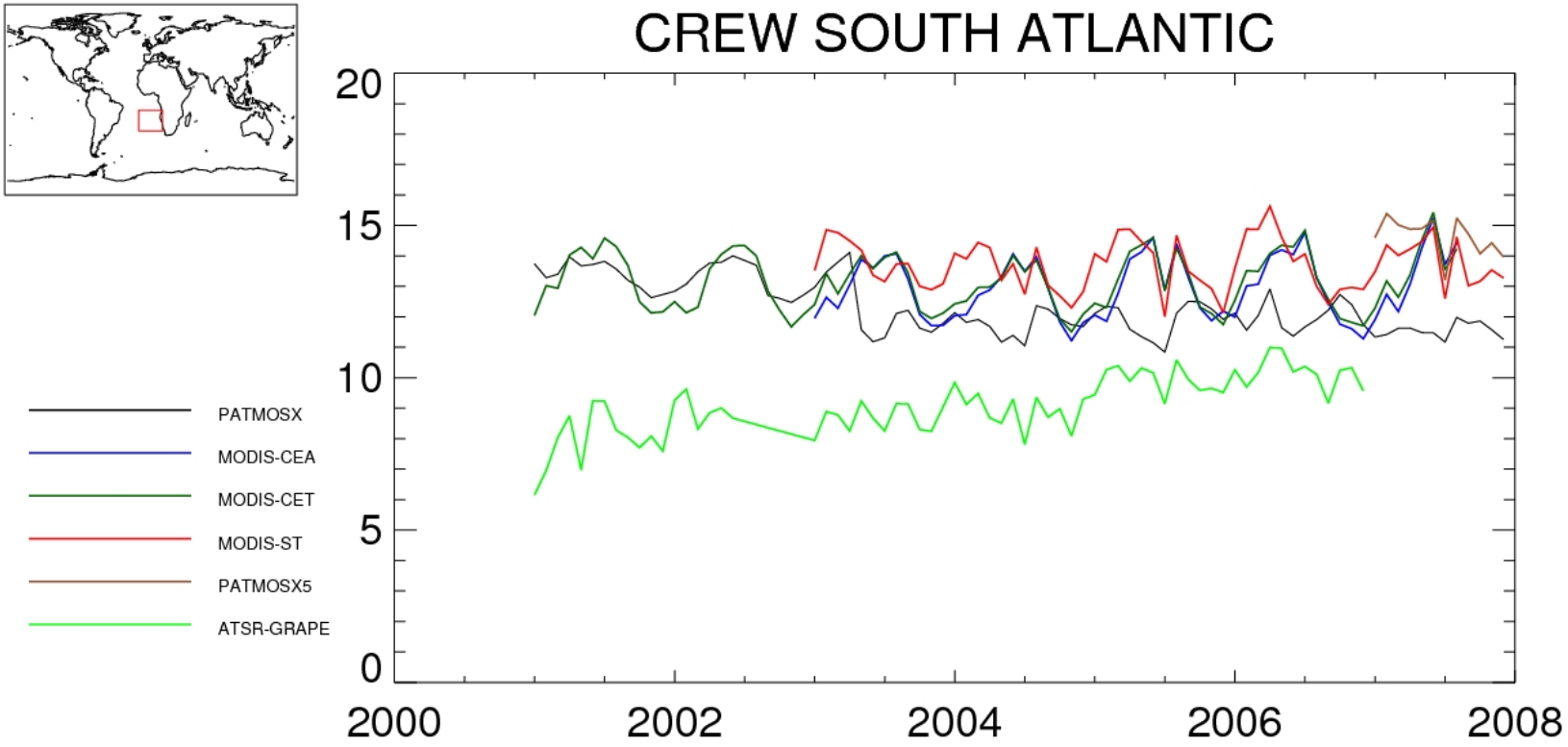


Microphysical cloud parameters: Cloud Effective Radius Water



Good agreement to MODIS retrievals!

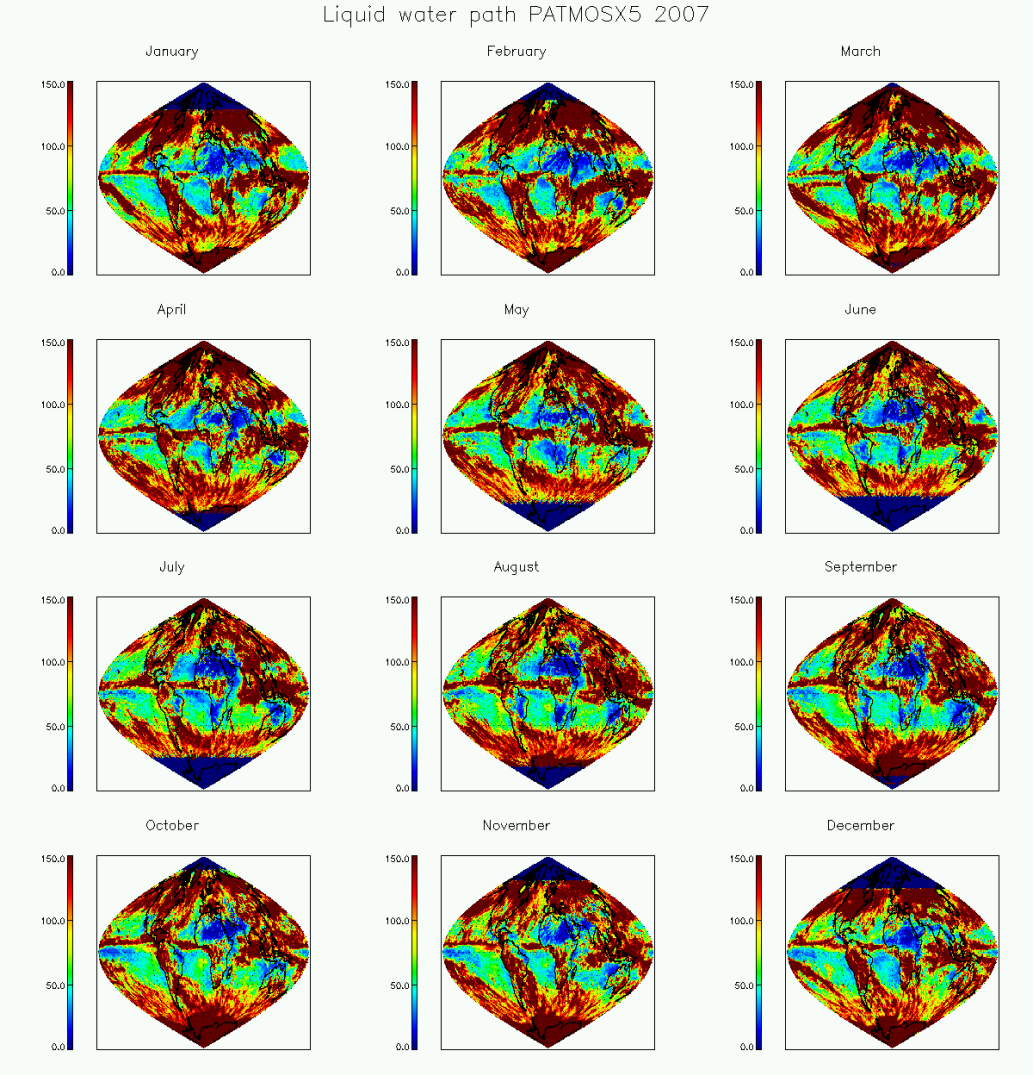
Microphysical cloud parameters:



Microphysical cloud parameters:

LWP PATMOSX v5:

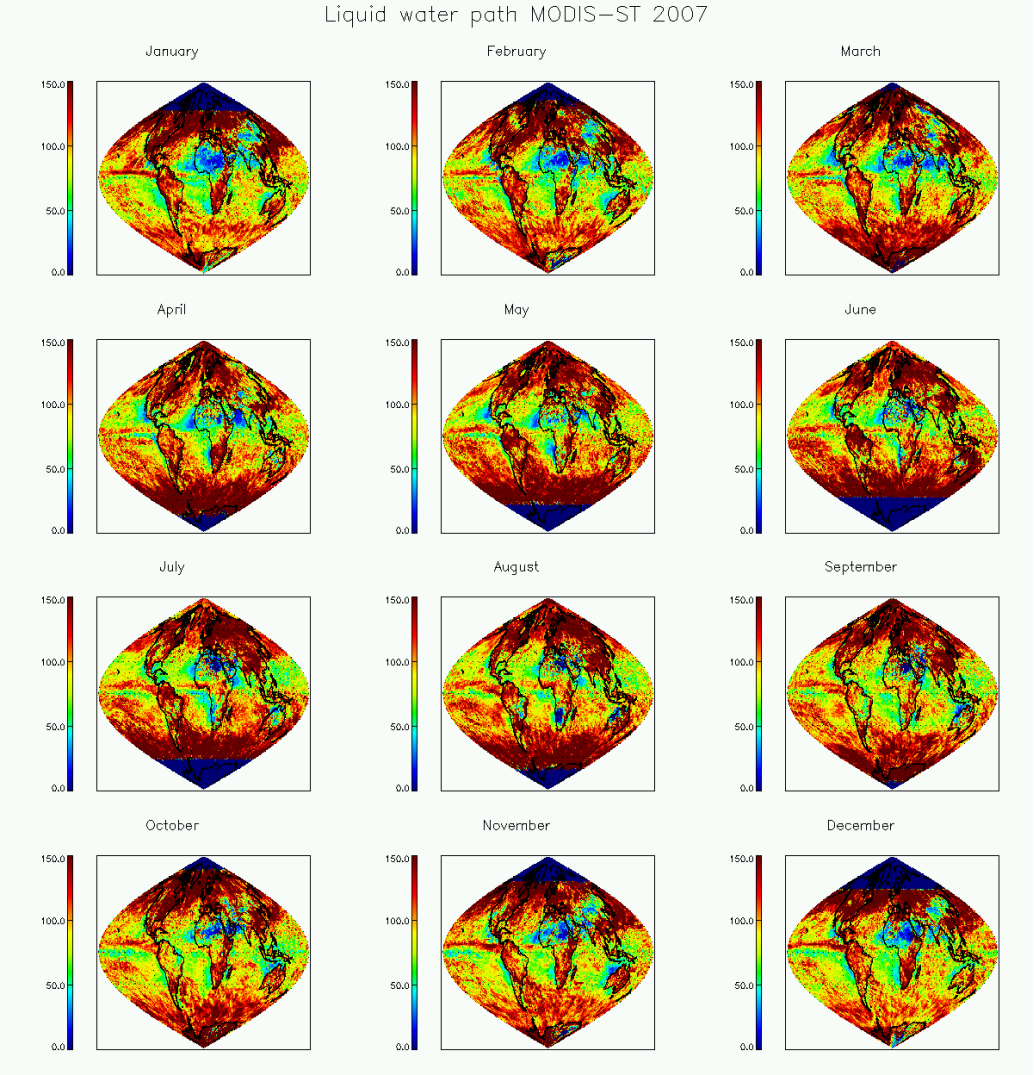
- Image shows Liquid Water Path PATMOSX v5 PM .
- Average over all cloudy pixels in a grid box.



Microphysical cloud parameters:

MODIS-ST:

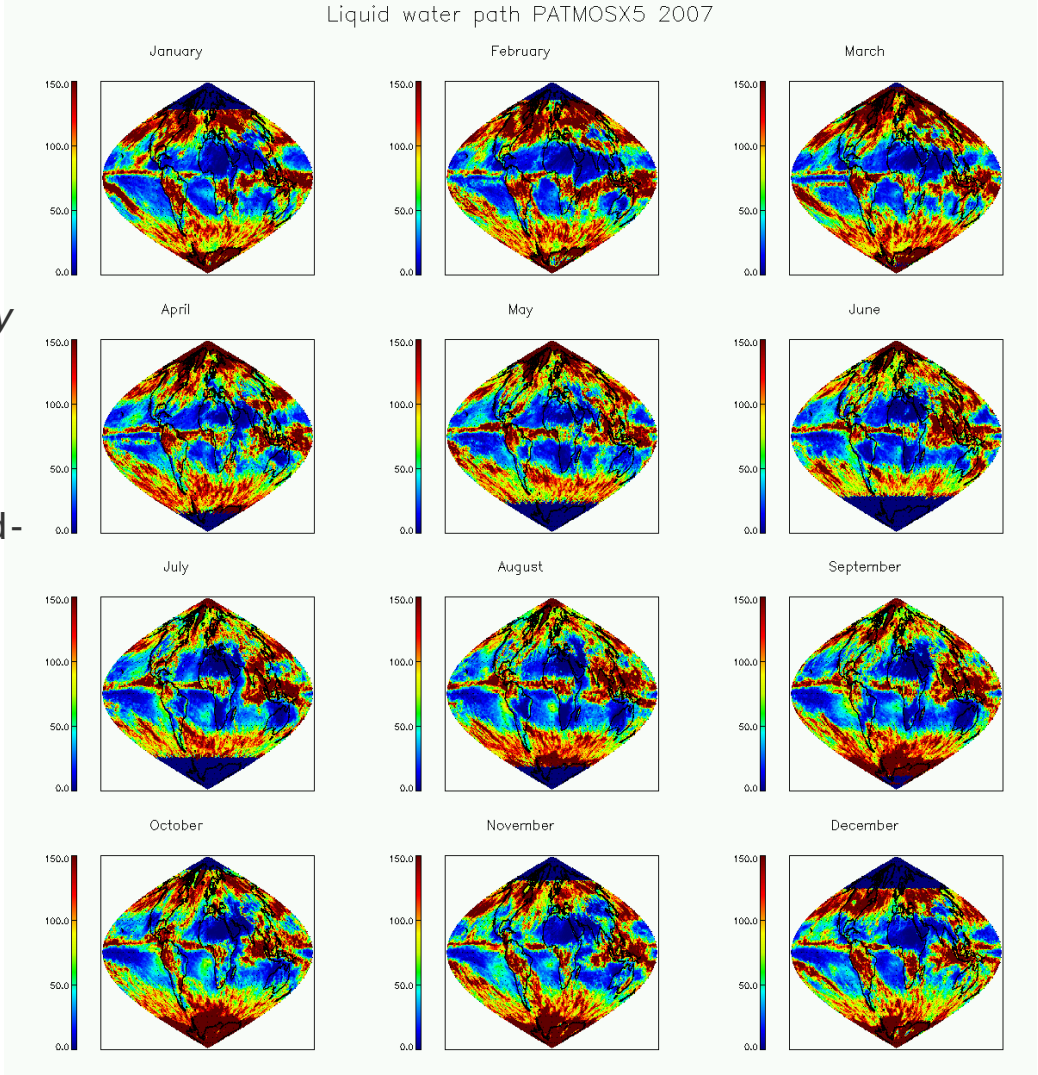
- Image shows Liquid Water Path MODIS-ST v5 PM .



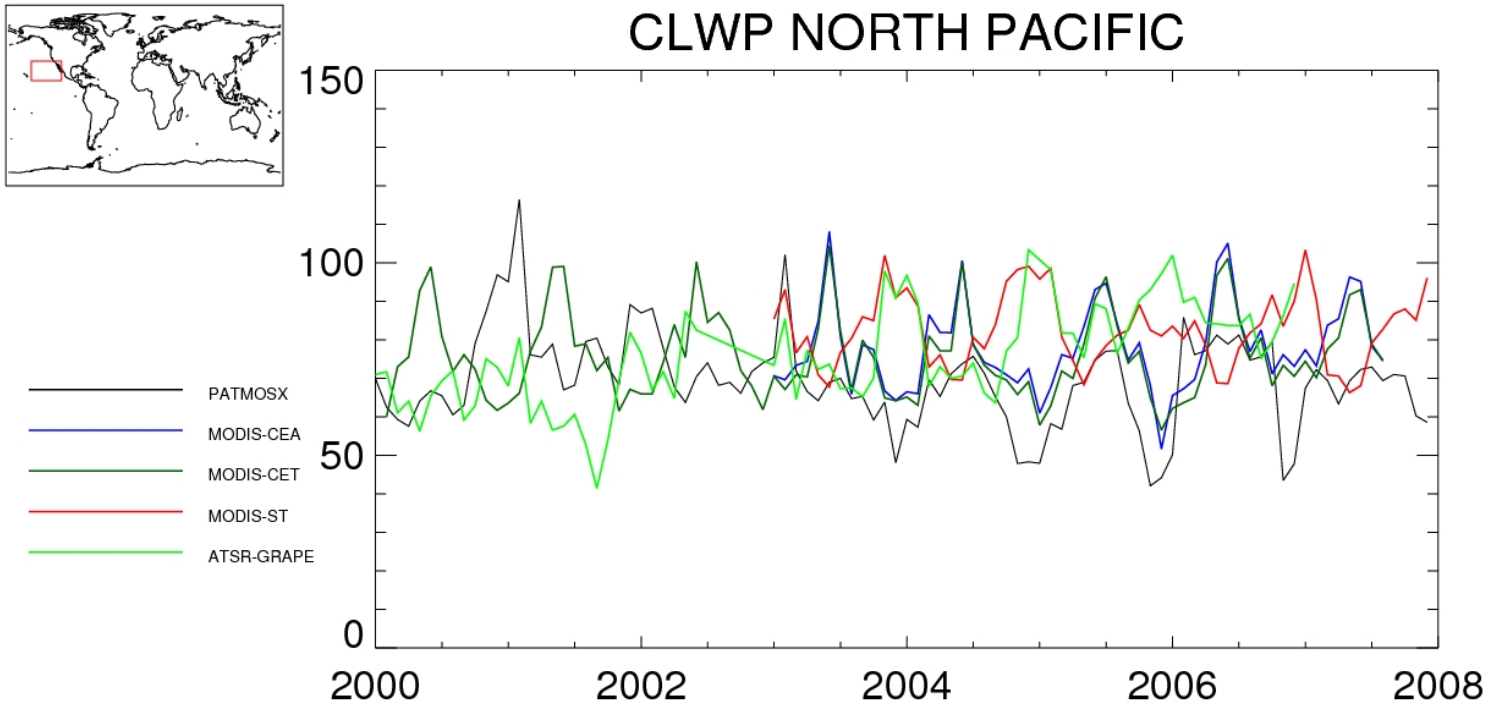
Microphysical cloud parameters:

LWP PATMOSX v5 :

- Picture shows an all-pixel average, that means it represents the total cloud water mass in a grid box.
- Treat LWP as an *extensive property* (capable of being totaled) in this way
- Controversial pixel (cloudy or cloud-free) are mostly thin clouds and contributes only a with a small amount to the overall water content.
- Data of different sample size are comparable.

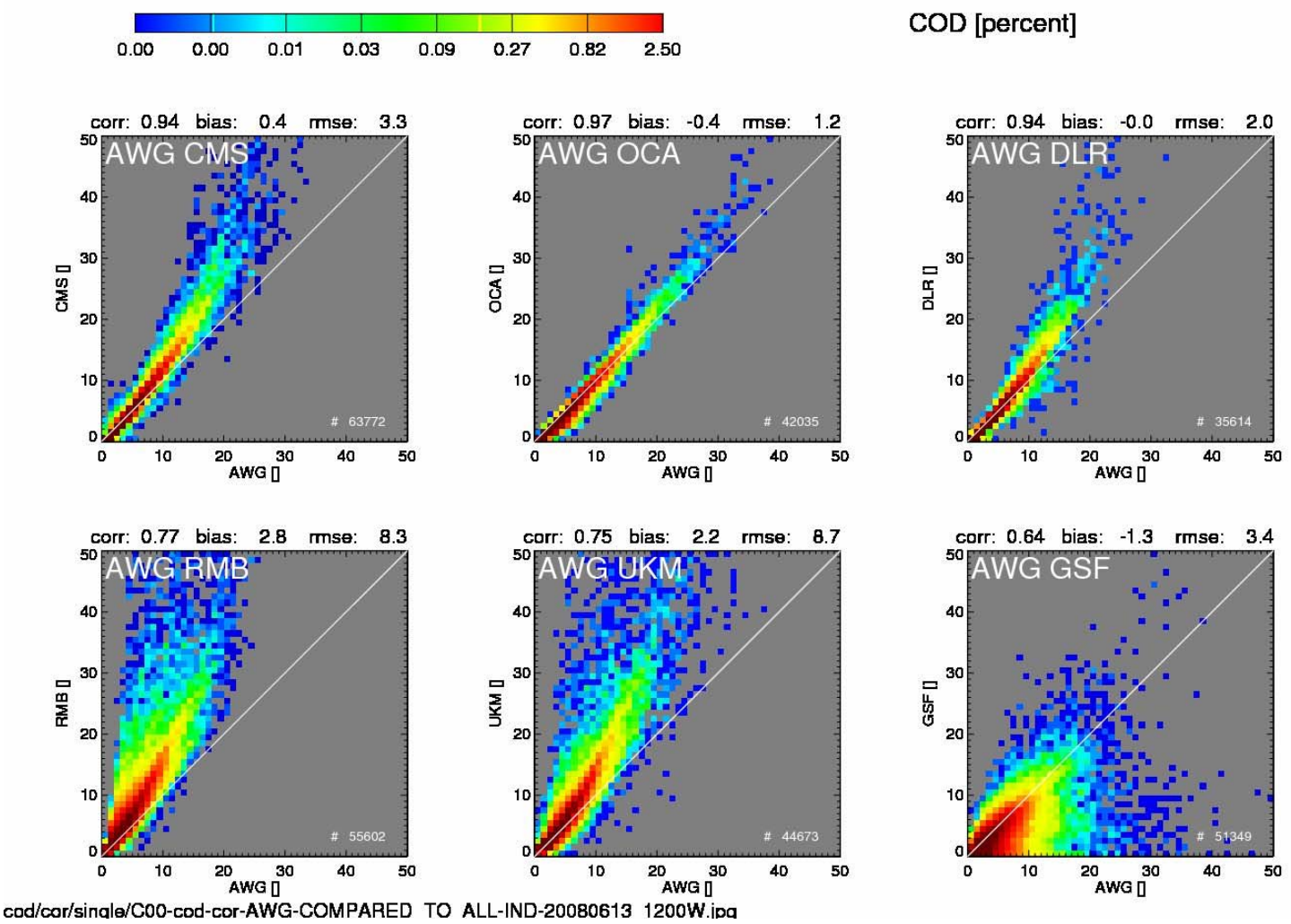


Microphysical cloud parameters: Cloud Liquid Water Path



Summary

- PATMSOSx is a stable, well-calibrated long-term cloud data set.
- Version 5 started recently.
- Level 2B sampled data maintains more flexibility to conduct long-term analysis.
- COD/REF retrieval level-2 products shows good agreement to other retrievals.
- PATMOSx
- The global view of Level-3 products shows big differences between algorithms.
- Regions with homogeneous cloud conditions show partly good agreement.


COD [percent]
0.00 0.00 0.01 0.03 0.09 0.27 0.82 2.50
corr: 0.94 bias: 0.4 rmse: 3.3
AWG CMS
CMS []
AWG []
63772
corr: 0.97 bias: -0.4 rmse: 1.2
AWG OCA
OCA []
AWG []
42035
corr: 0.94 bias: -0.0 rmse: 2.0
AWG DLR
DLR []
AWG []
35614
corr: 0.77 bias: 2.8 rmse: 8.3
AWG RMB
RMB []
AWG []
55602
corr: 0.75 bias: 2.2 rmse: 8.7
AWG UKM
UKM []
AWG []
44673
corr: 0.64 bias: -1.3 rmse: 3.4
AWG GSF
GSF []
AWG []
51349
cod/cor/single/C00-cod-cor-AWG-COMPARED TO ALL-IND-20080613 1200W.jpg

Cloud workshop Locarno 2009: Results