Cloud Occurrence from the level 2B CloudSat-CALIPSO Cloud Mask Data

Jay Mace and Qiuqing Zhang

1. Briefly introduce Geoprof-Lidar Product

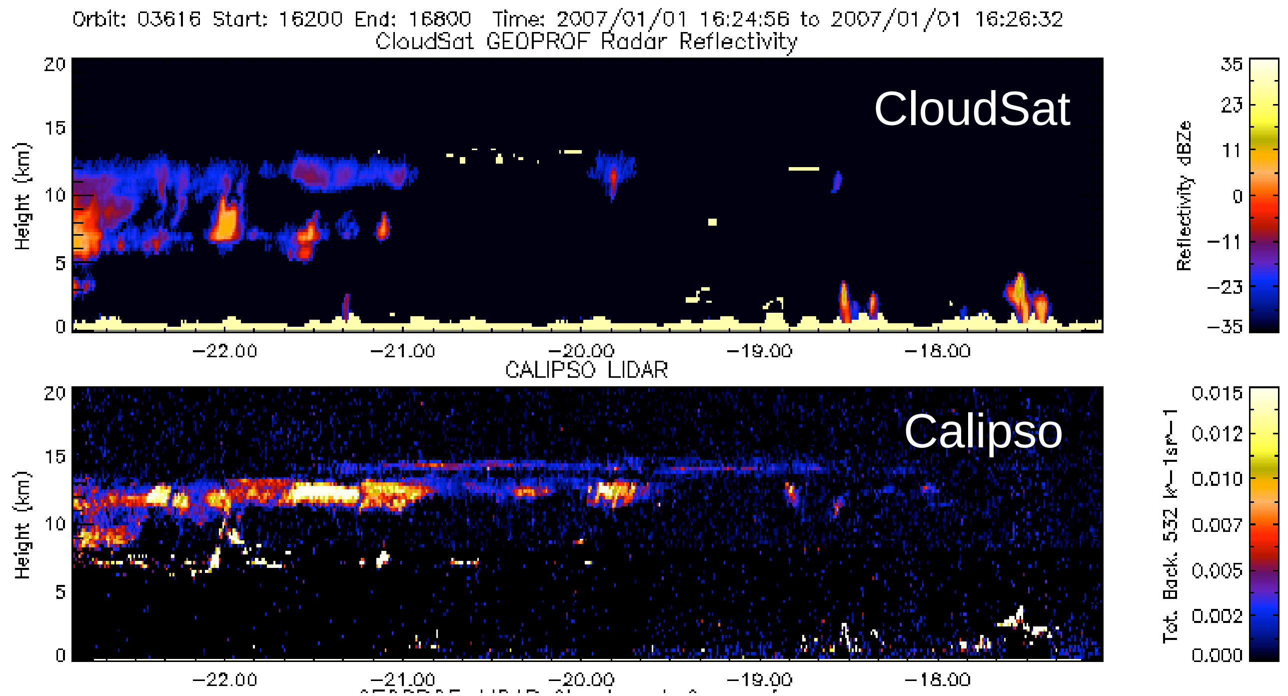
2. Examine the vertical and horizontal distribution of cloud occurrence using Geoprof-Lidar.

3. Compare Geoprof-Lidar statistics to CFMIP GCMs.

2B Geoprof-Lidar Product

CloudSat and CALIPSO are maintained in tight orbital coordination so that they image the same volumes of the atmosphere within 15 s of one another.

Example Case over the Subtropical South Atlantic on 1 January 2007



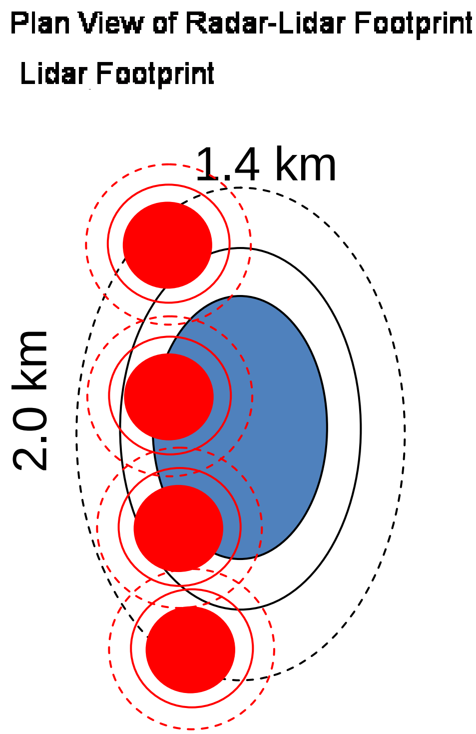
Goal: Merge the CALIPSO lidar cloud mask with the CloudSat cloud mask to create a radar-lidar cloud mask ➔ 2B-Georpof-lidar product

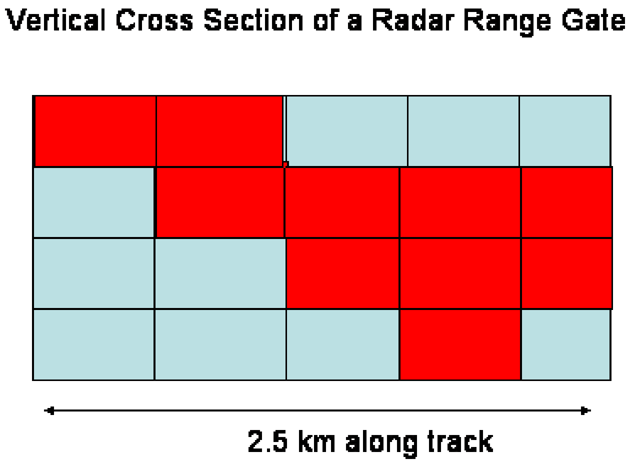
2B Geoprof-Lidar Product

2B Geoprof-Lidar Product:

- Output referenced to Cloudsat footprint as specified in the 2B Geoprof product.
- Approach is to gather the lidar footprints that occur within or near the cloudsat footprint.
- The primary output of this product is a height vs track array that reports the **fraction of the lidar resolution volumes within the radar resolution volume that reports the occurrence of hydrometeors.**

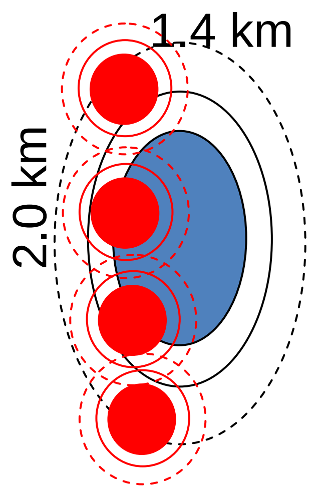
- We also report the layer bases and tops of up to three layers in 1d along track arrays





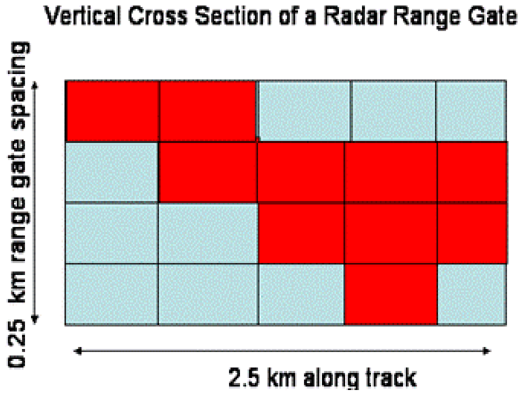
2B Geoprof-Lidar Product

Geoprof-Lidar combines the capacity for millimeter radar to penetrate optically thick hydrometeor layers with the ability of the lidar to detect optically thin clouds .



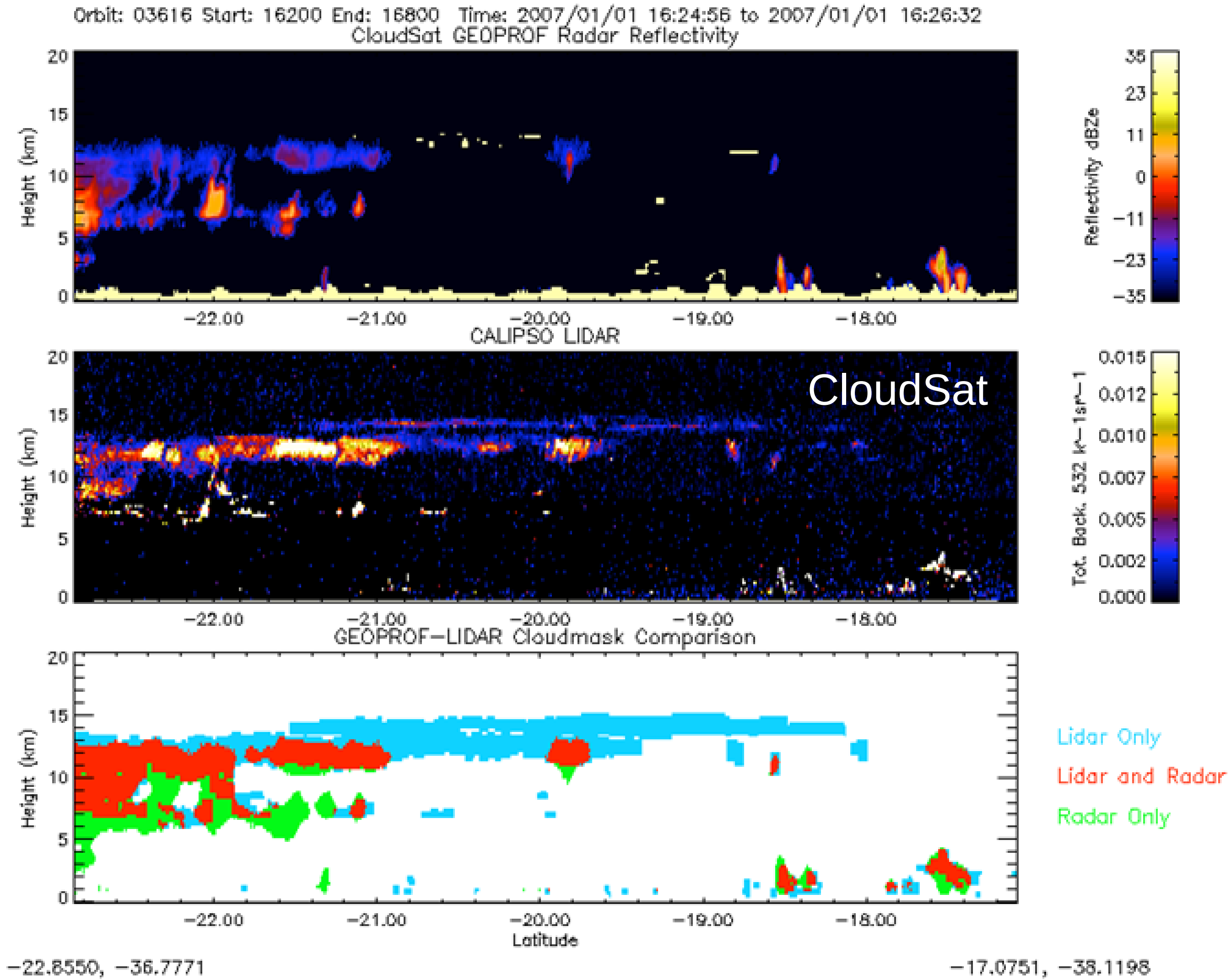
<u>Output of 2B-Geoprof-Lidar Product</u>

- -Cloud Fraction
- -Cloud Layers
- -Layer Base, Layer Top
- -Layer Base Flag, Layer Top Flag
- -1064 nm attenuated backscatter,
- -532 nm total attenuated backscatter
- -532 nm perpendicular attenuated backscatter
- -532 nm extinction coefficient.
- -532 nm total attenuated backscatter (high vertical resolution).



2B Geoprof-Lidar Product

Example Case over the Subtropical South Atlantic on 1 January 2007



Comparison to MOD-35 Along-Track Global Cloud Fraction

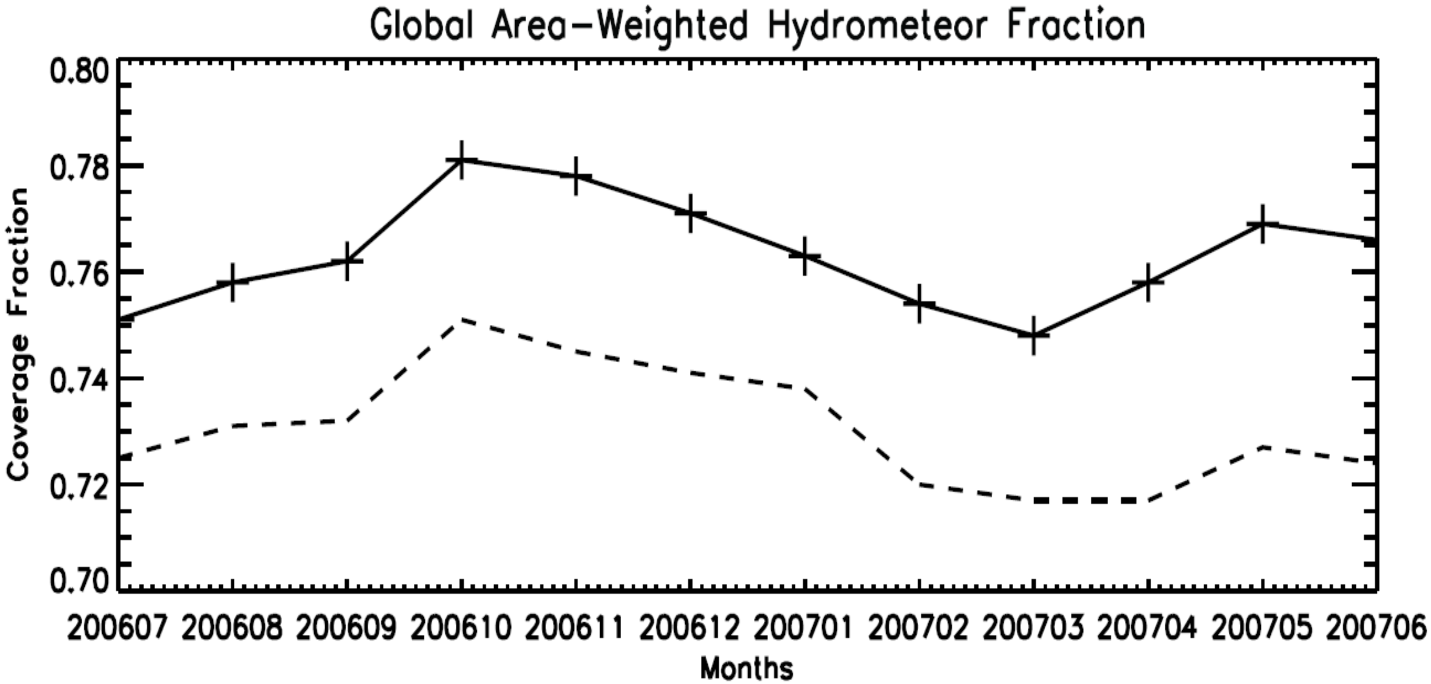
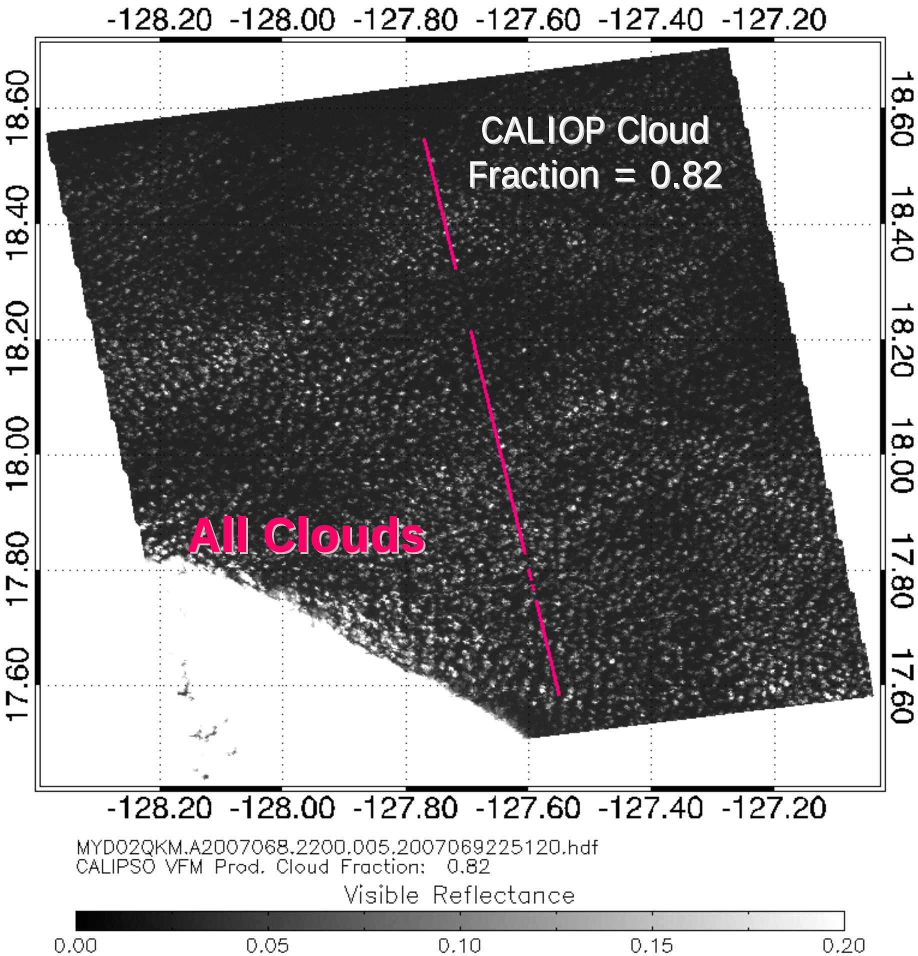
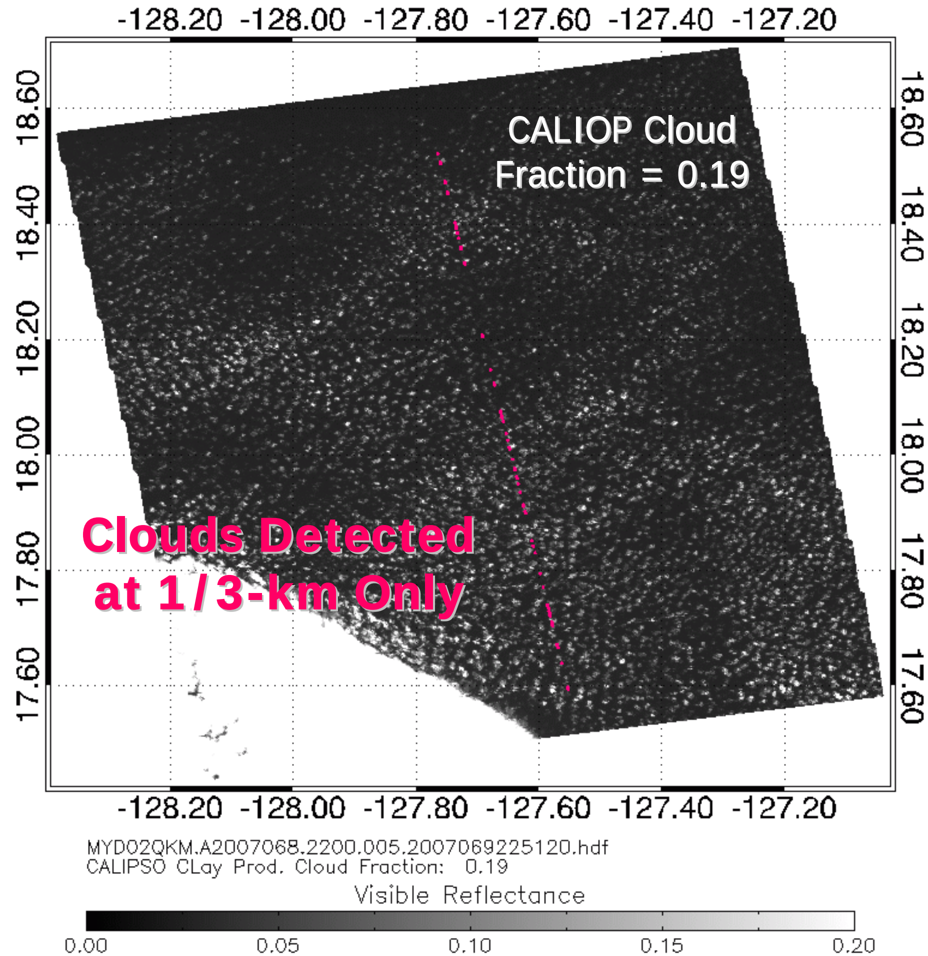


Figure 5. Monthly hydrometeor coverage fraction derived from the merged Cloudsat-CALIPSO data (solid curve) and from the MODIS cloud mask sampled along the Cloudsat-CALIPSO track.

CloudSat/CALIPSO Cloud Cover -- 76%
Modis Cloud Cover – 2% less than CC

Killing the Boundary Layer Cloud Clearing Bug





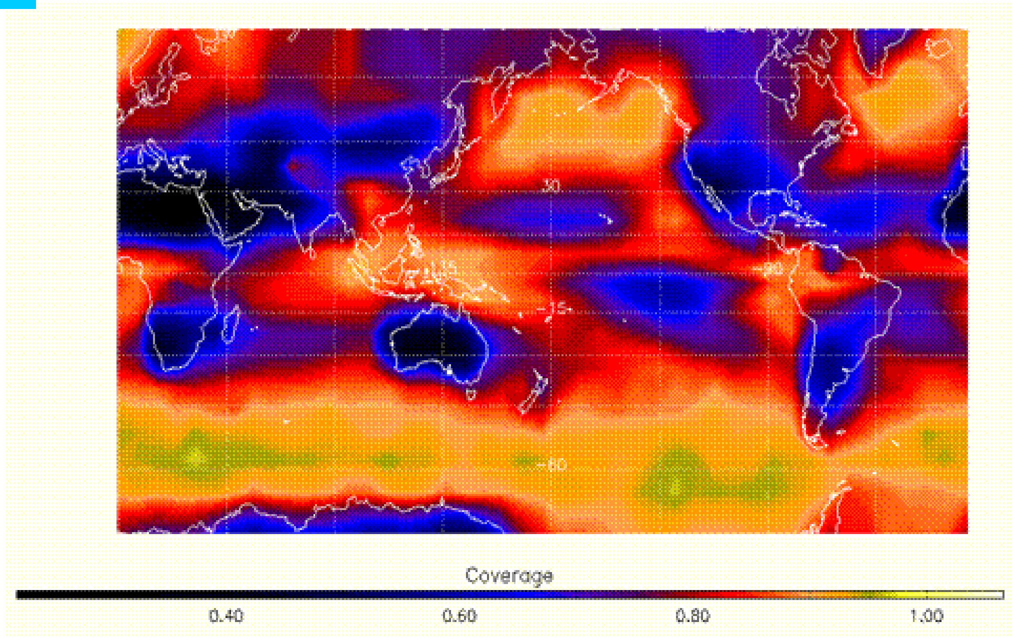
MODIS images courtesy of Chris Yost (CERES)

Slide Courtesy of Mark Vaughan

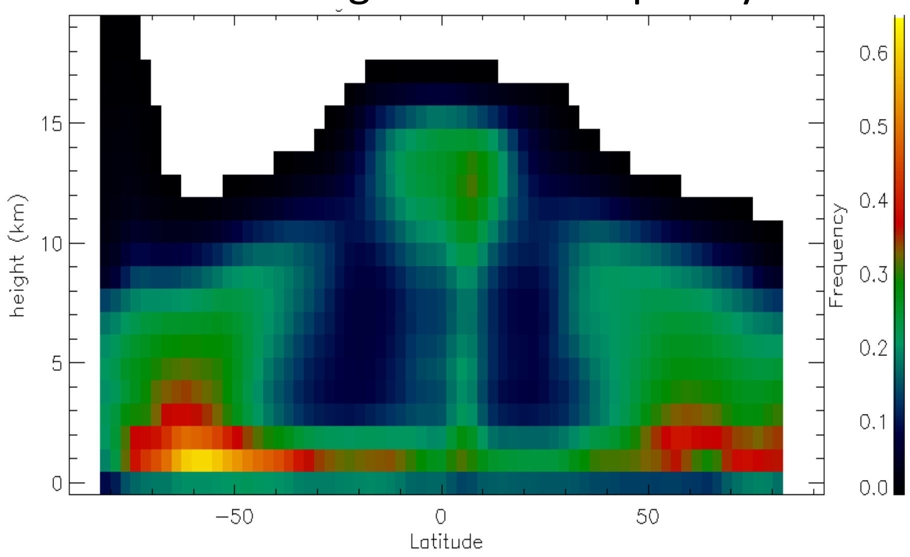
Cloud Coverage

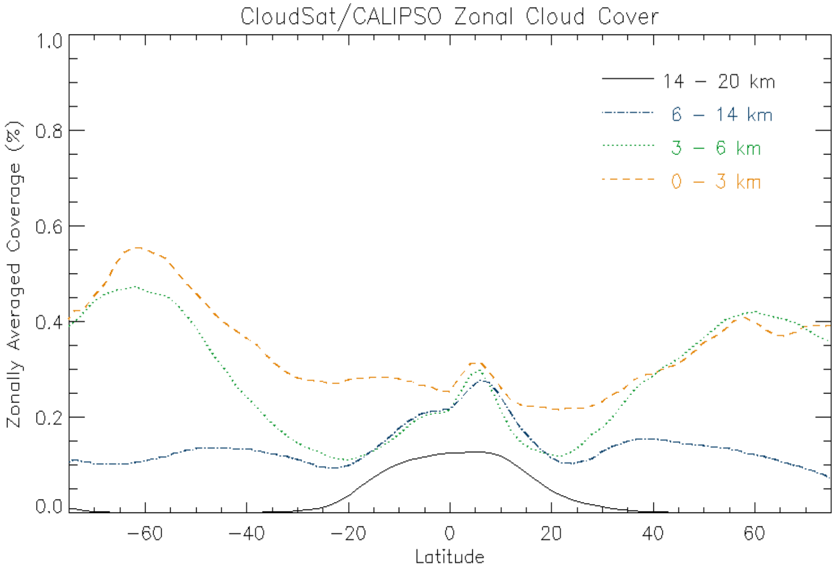
- July, 2006 to February, 2009
- Bases: 0 – 20 km
- Thickness: 0 – 14 km

Global Total Cloud Coverage



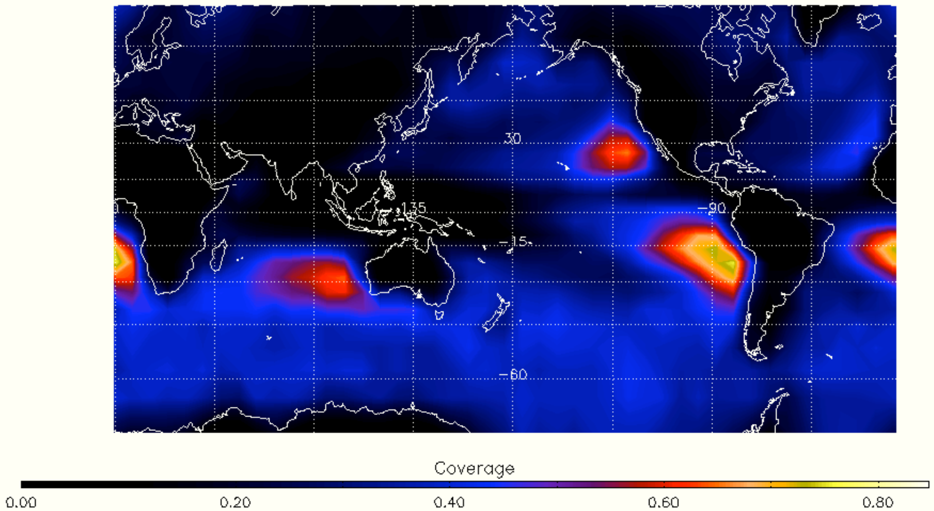
Zonal Averaged Cloud Frequency



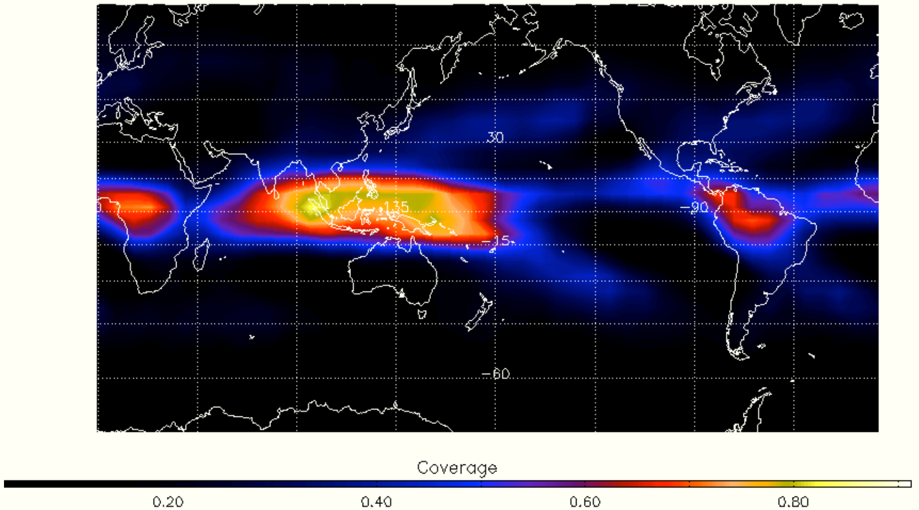


Cloud Coverage --- The View from Above

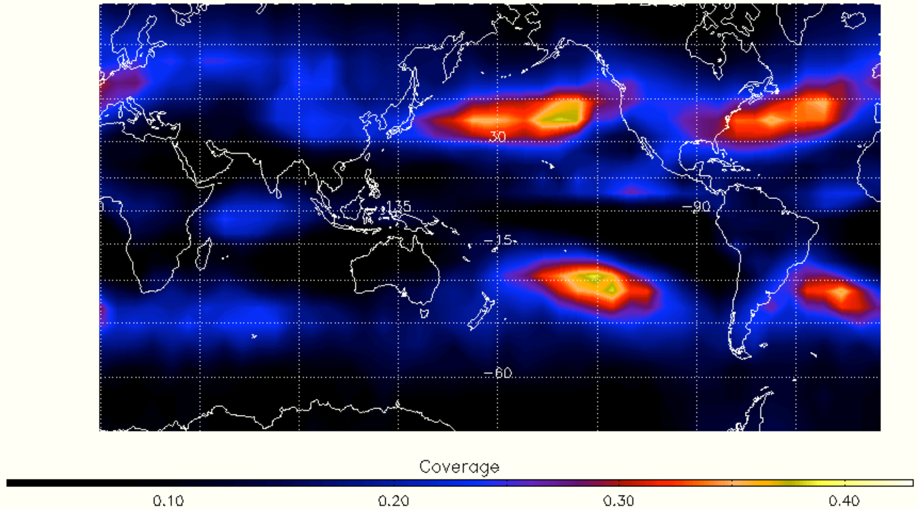
Tops < 3 km (all thickness)



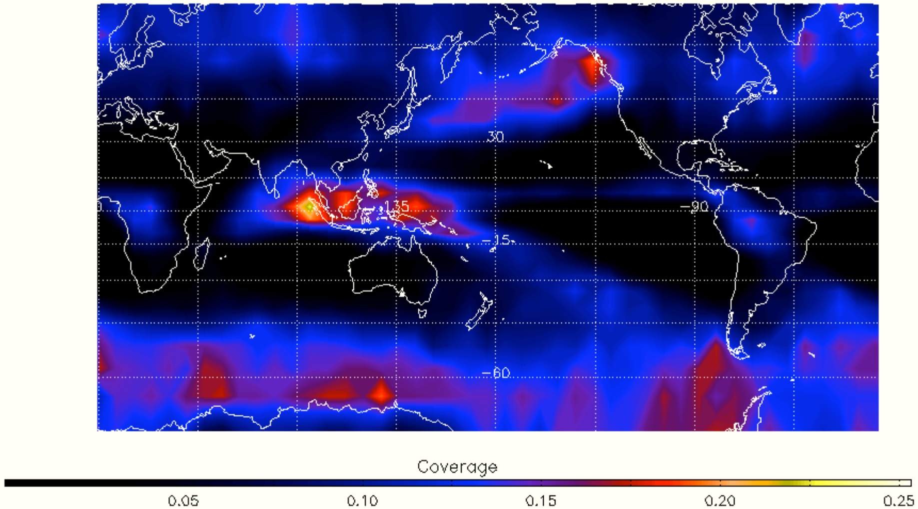
Tops 10-20 km (all thickness)



Tops 10-14 km (all thickness)

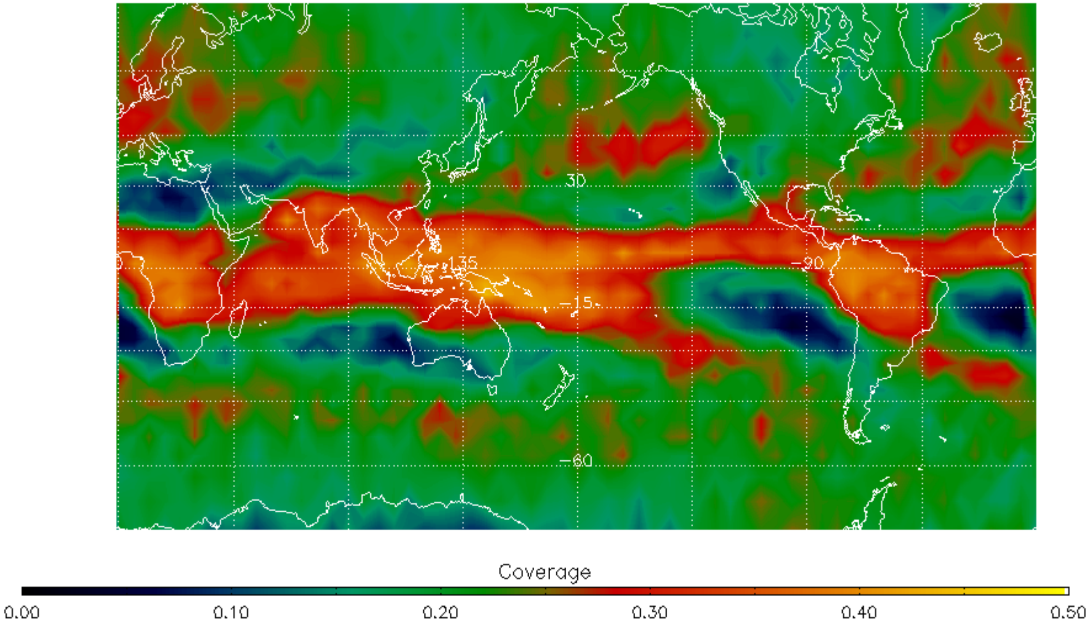


All Tops and Thickness 6-14 km



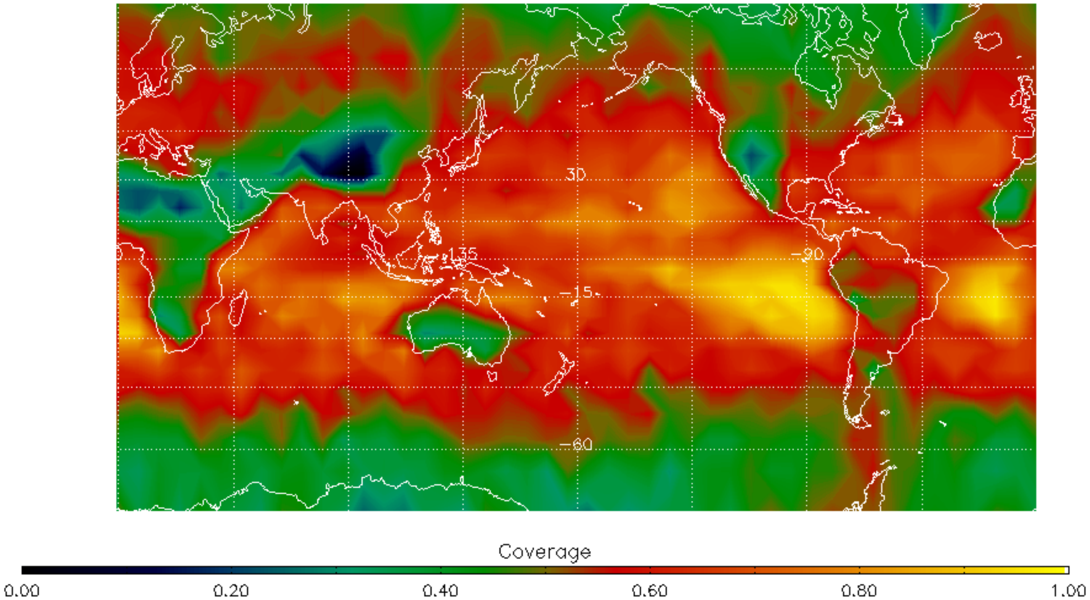
Fraction of all cloudy columns that are multi-layered

The vertical structure of tropical cloud systems are frequently (~ 40%) multi-layered

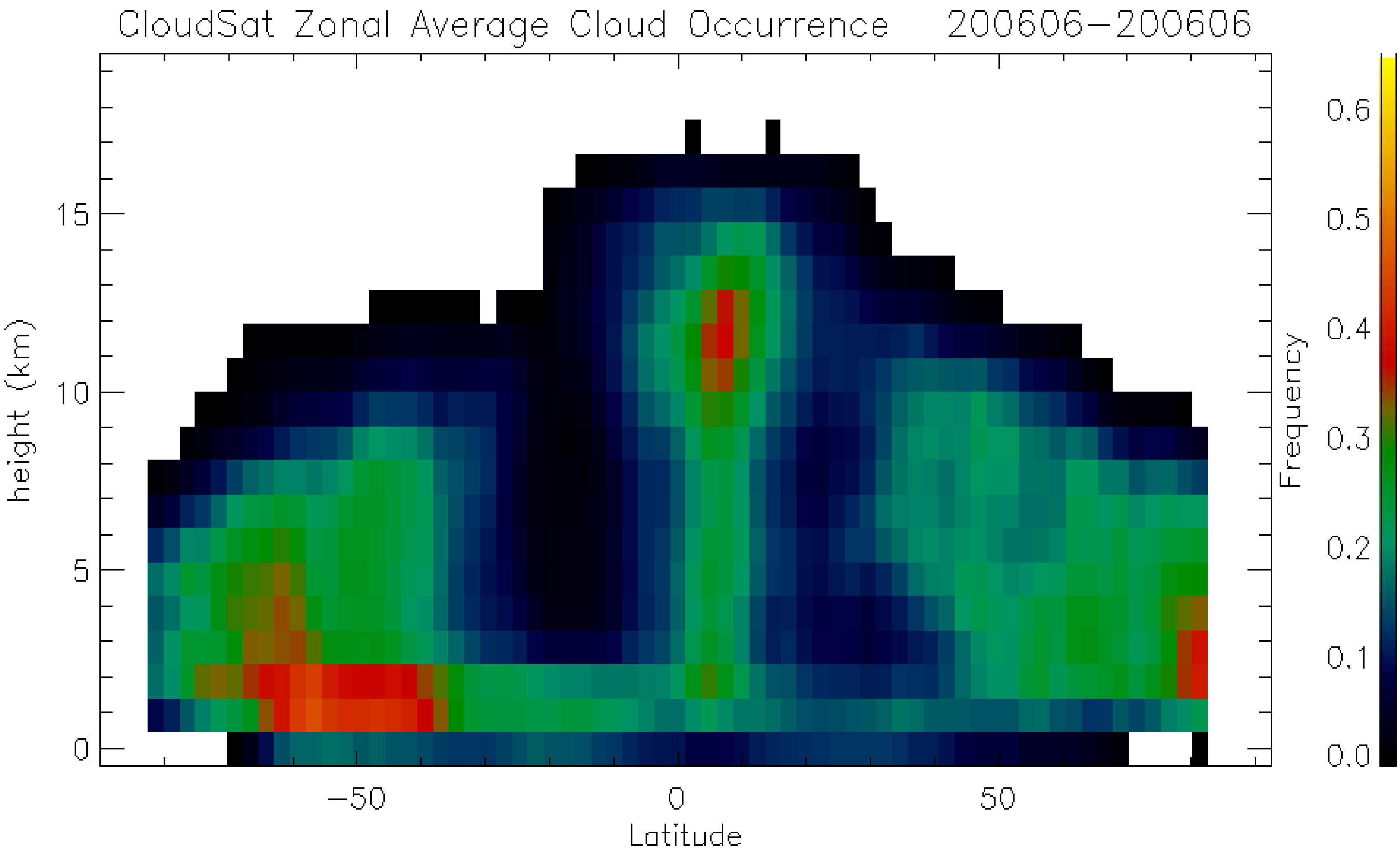


Fraction of all multi-layered columns that are low-based with high-based

Over 60% of multi-layered columns are low-based with high-based



Animation of Zonal Averaged Cloud Occurrence



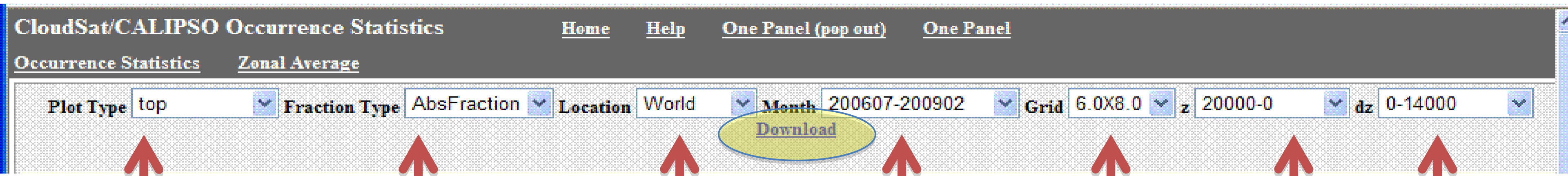
Web-Enabled Gridded CloudSat/CALIPSO Occurrence Statistics

http://meteo04.chpc.utah.edu:8080/qzhang/occ/occ/occ.jsp

- To facilitate use of the data, we are *developing* a utility to view and download gridded occurrence statistics

- Based on pre-computed layer base and top and layer thickness monthly statistics on a 1x1 grid.

Options



Layer base or layer top

Absolute or relative fraction (not yet enabled)

Antarctic, Arctic, Non-Polar

Averaging period – monthly to multi-annual

Grid size (not yet enabled)

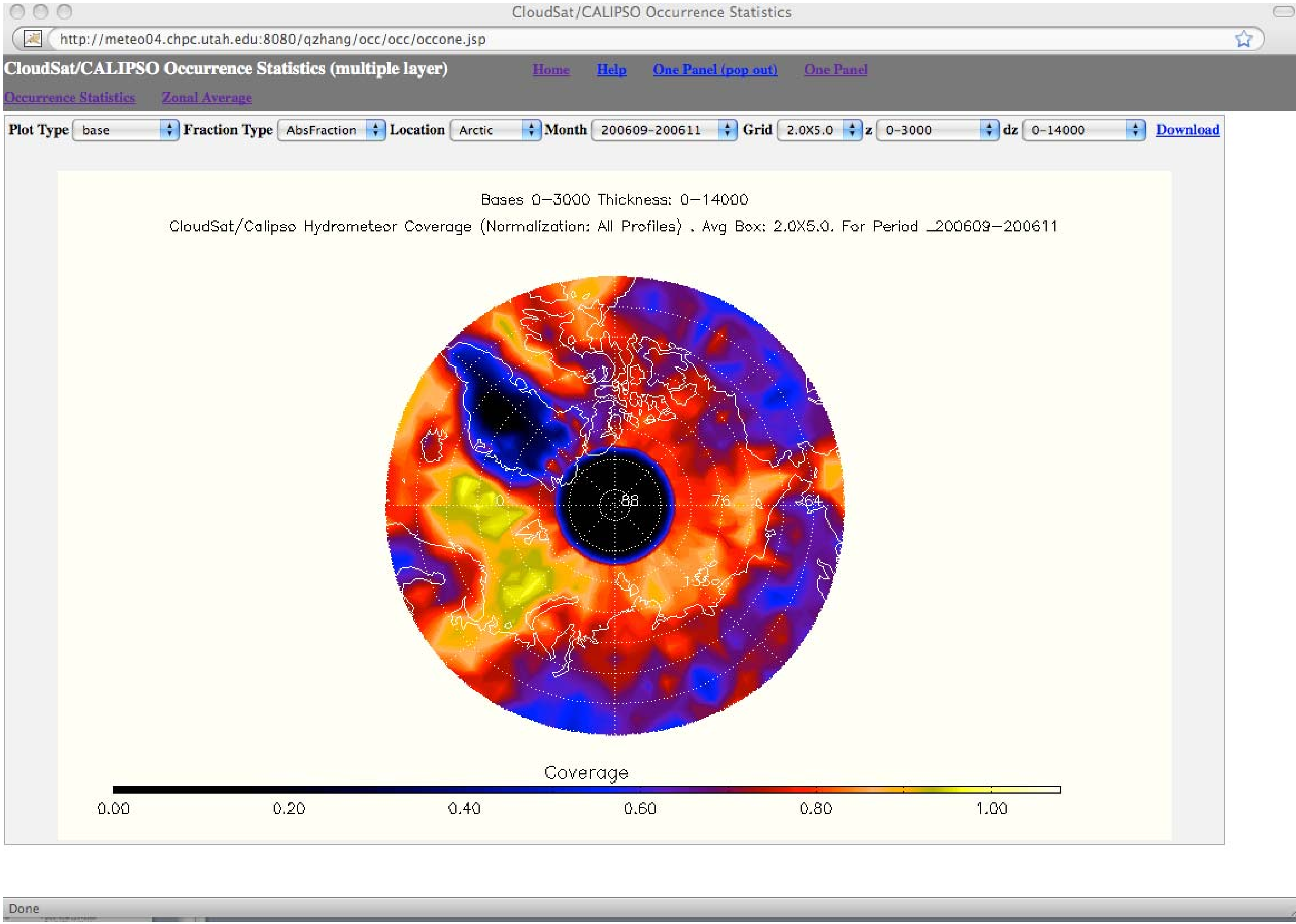
Base or Top height range

Layer thickness range

NetCDF files of gridded stats can be acquired

Web-Enabled Gridded CloudSat/CALIPSO Occurrence Statistics

http://meteo04.chpc.utah.edu:8080/qzhang/occ/occ/occ.jsp



Web Page --- CloudSat/CALIPSO Occurrence Statistics
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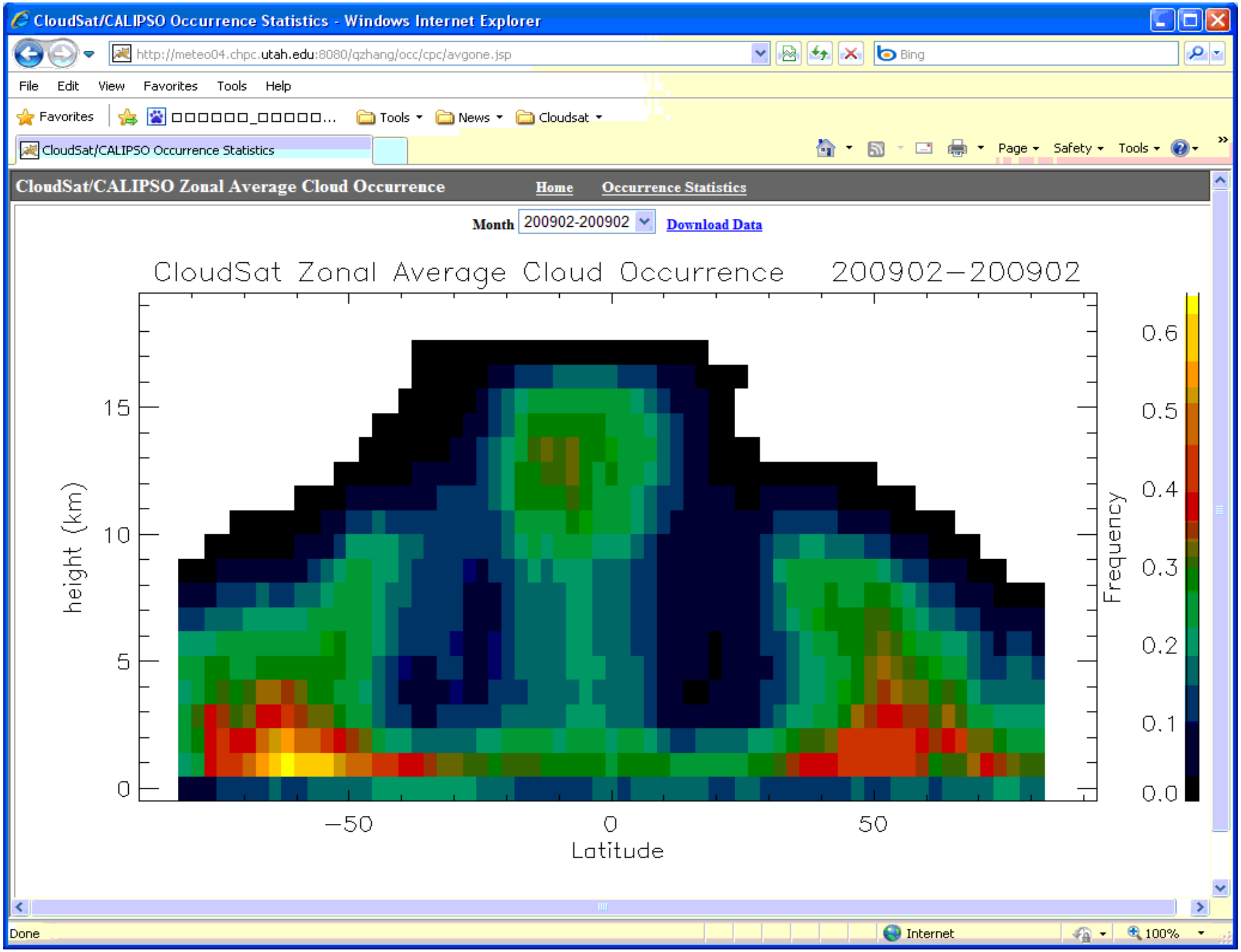


Comparing CloudSat/CALIPSO Measurement with Model Results

- CloudSat/CALIPSO
  - -- Three years measurement (06/2006 – 02/2009)
- Model Data are from CFMIP project :
  - -- Ten years simulation results (1990 – 1999)
  - -- Models:

NCAR CCSM 3.0 Model	*-- Community Climate System Model*
NASA GISS Model	*-- GISS model E20/Russell*
NCAR PCM1 Model	*-- Parallel Climate Model*
NOAA GFDL CM 2.1	*-- GFDL Coupled Climate Model*

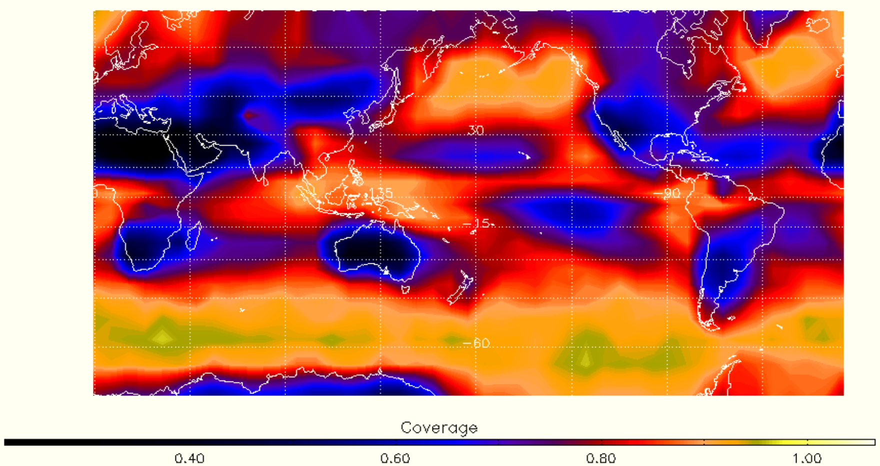
In order to compare with model result, the statistical analyses of radar-lidar cloud occurrence are done with the same method as model output.

--- Volumetric analysis method is used.

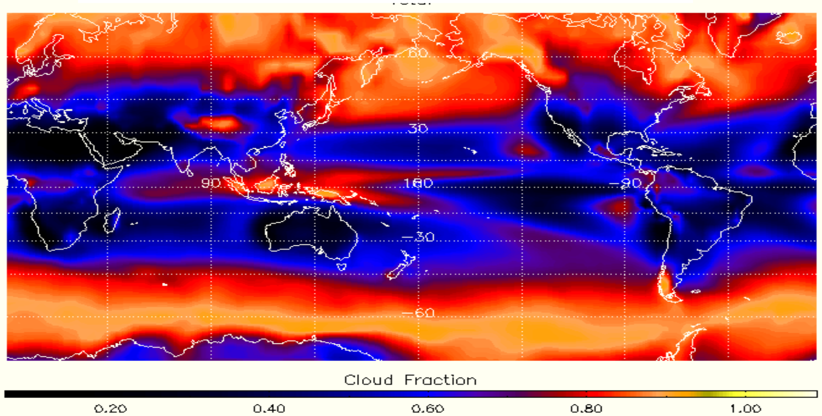
Compare to model results --- Total Clouds

- Models are able to simulate the main systems
- Totally, models simulate less clouds.

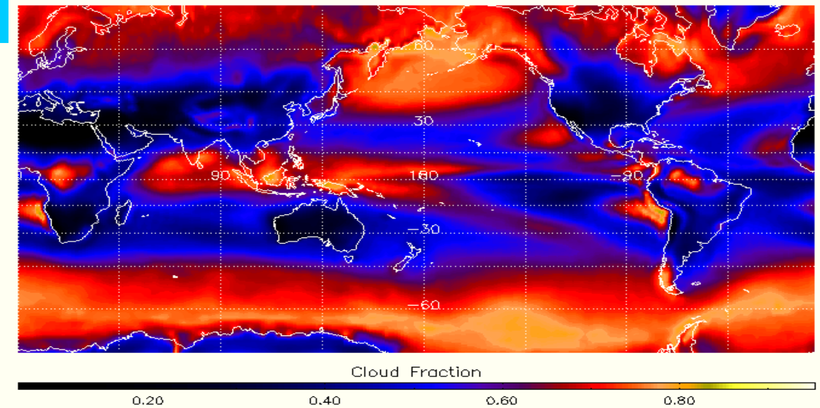
CloudSat/CALIPSO



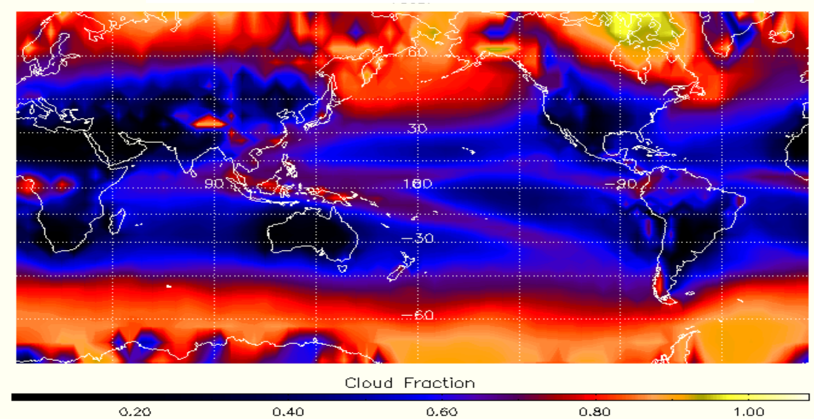
NOAA GFDL CM 2. 1



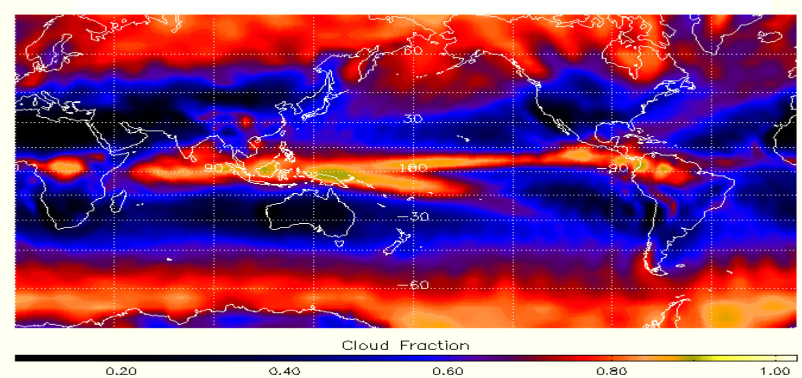
NCAR CCSM 3.0 Model



NASA GISS Model E20/Russell



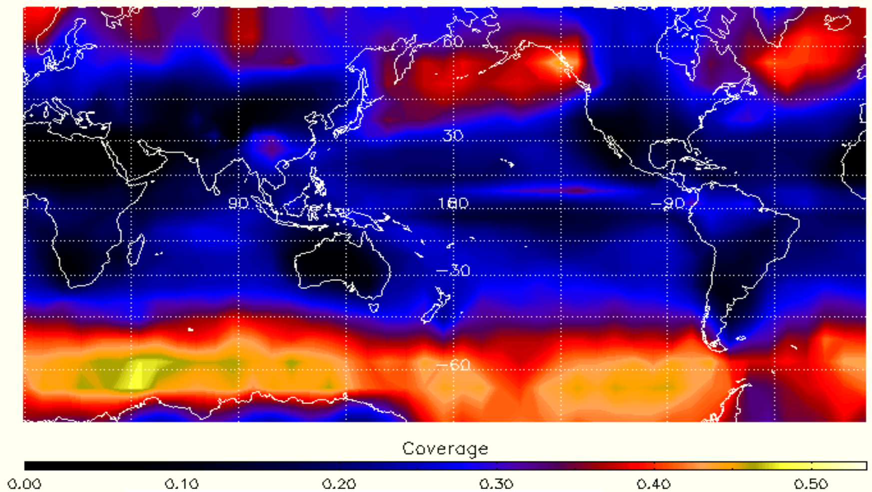
NCAR PCM1 Model



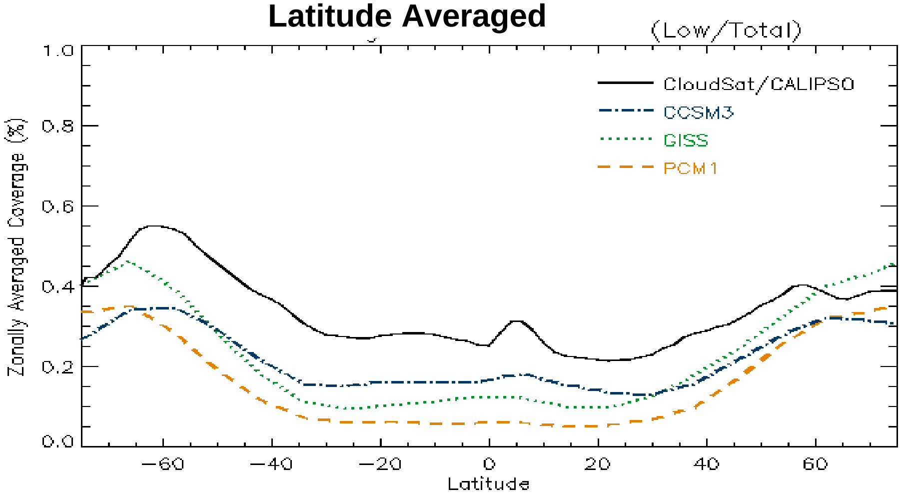
Compare to model results --- Low Clouds

Low clouds: 0 – 3 km
- Models under estimate low clouds
- CCSM: about 10% less than CC measurement.

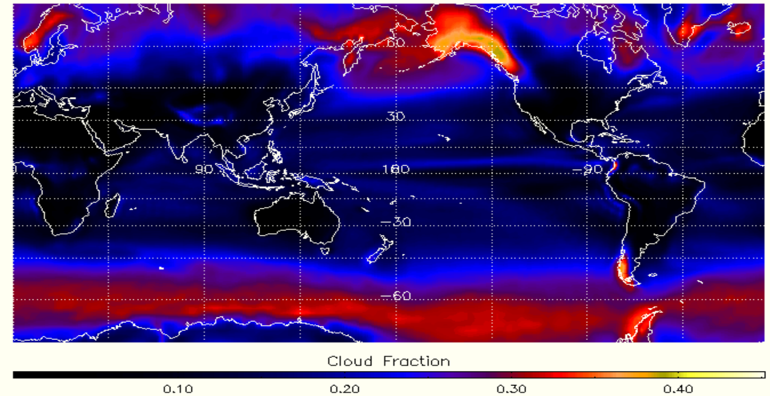
CloudSat / CALIPSO



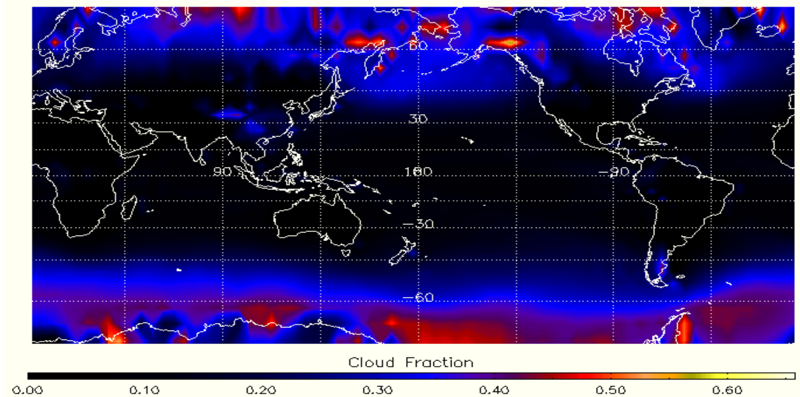
Latitude Averaged



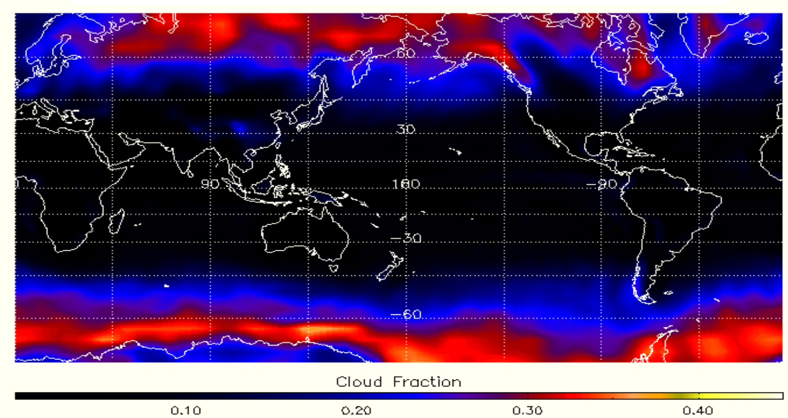
NCAR CCSM 3.0 Model



NASA GISS Model (E20/Russell)



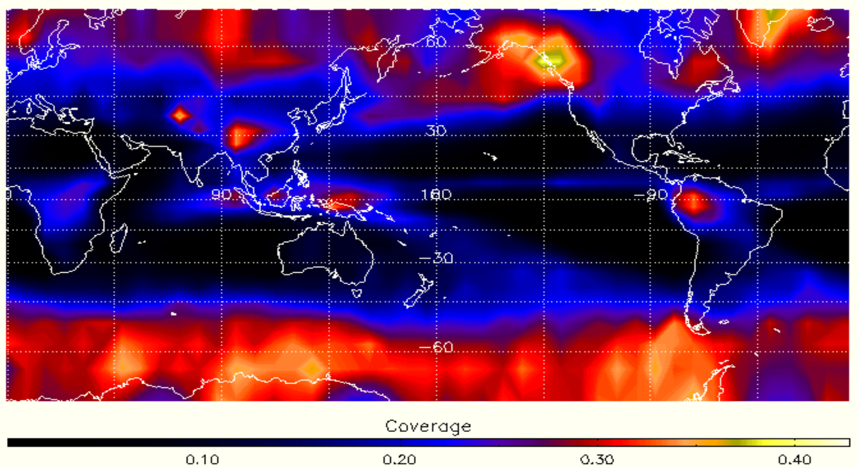
NCAR PCM1 Model



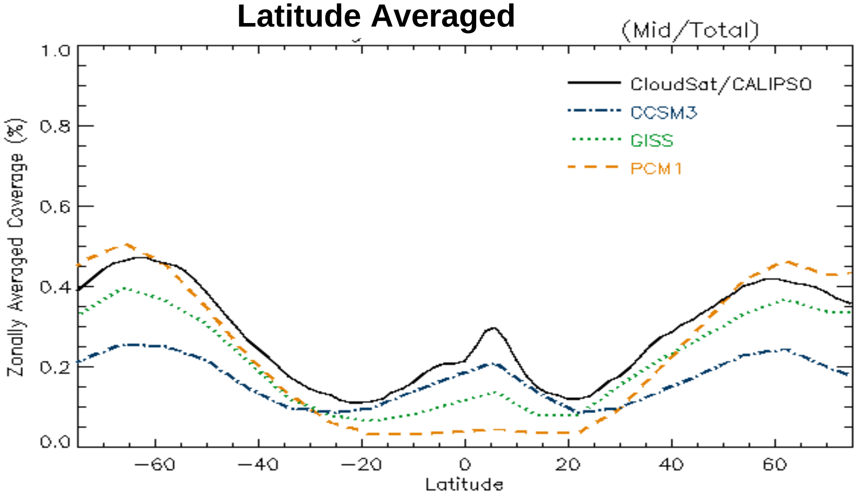
Compare to model results --- Middle Clouds

Middle clouds: 3 – 6 km
- Models under estimate the middle cloud
- CCSM is good at low latitude.

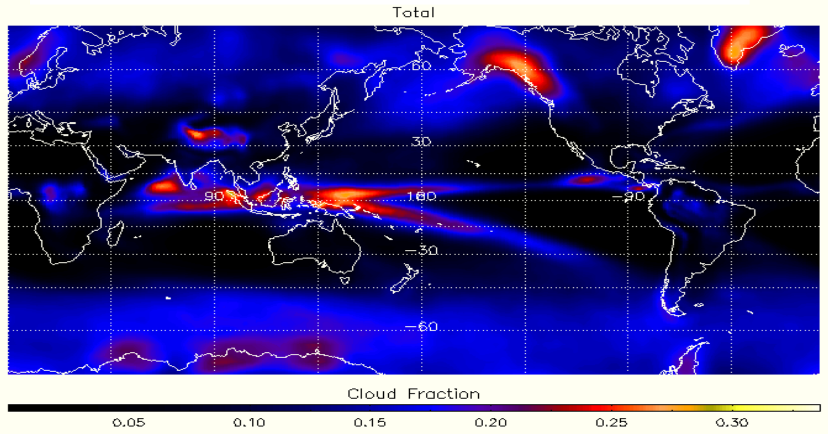
CloudSat / CALIPSO



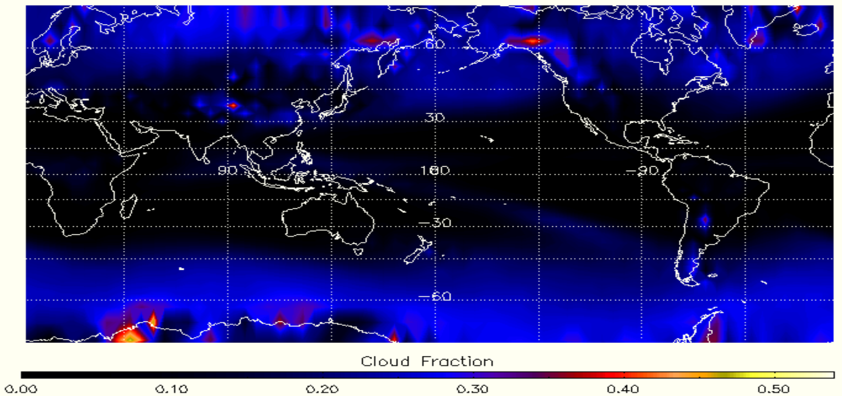
Latitude Averaged



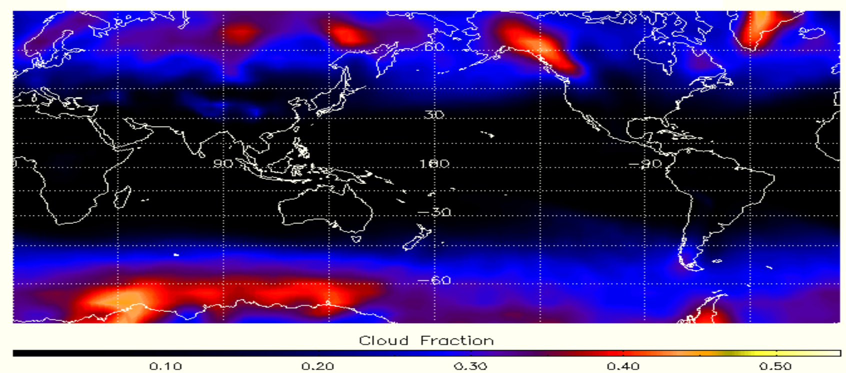
NCAR CCSM 3.0 Model



NASA GISS Model (E20/Russell)



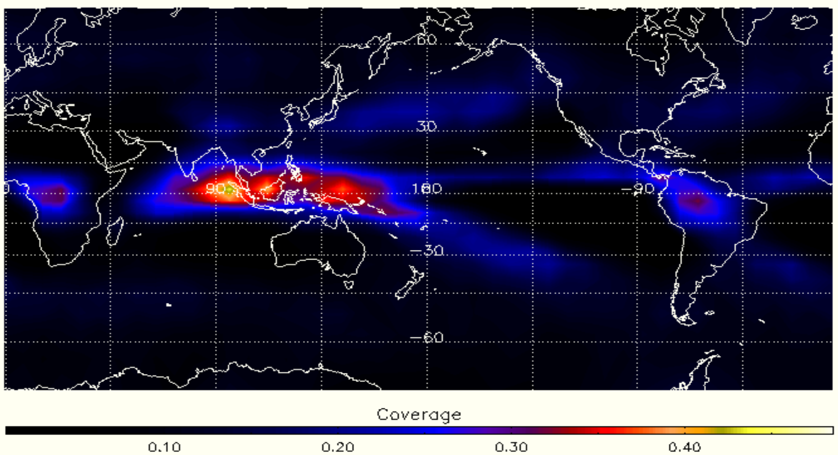
NCAR PCM1 Model



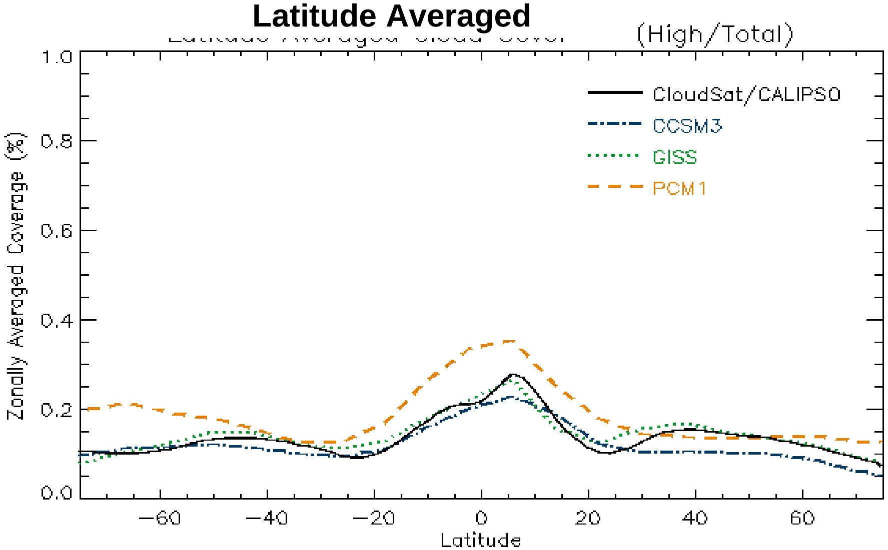
Compare to model results --- High Clouds

High clouds: 6 – 14 km
- CCSM & GISS are very good
- PCM1 over estimates high clouds

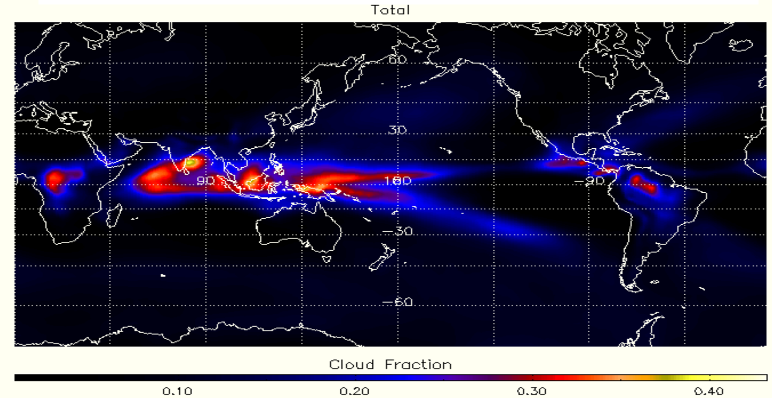
CloudSat / CALIPSO



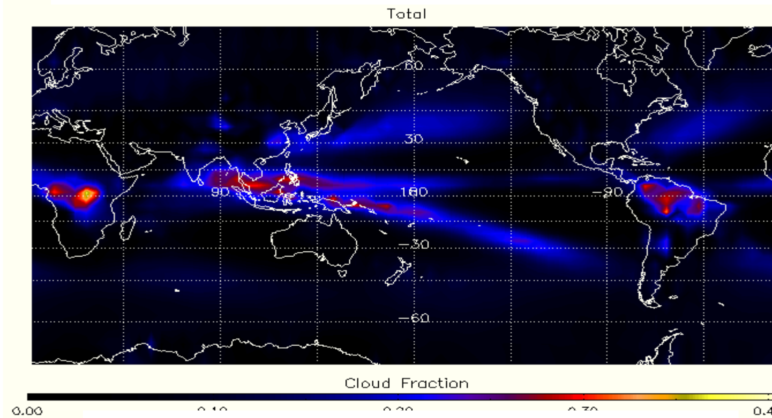
Latitude Averaged



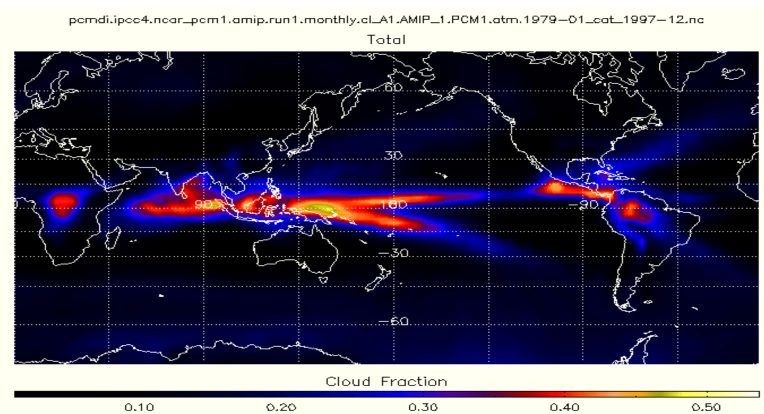
NCAR CCSM 3.0 Model



NASA GISS Model E20/Russell



NCAR PCM1 Model

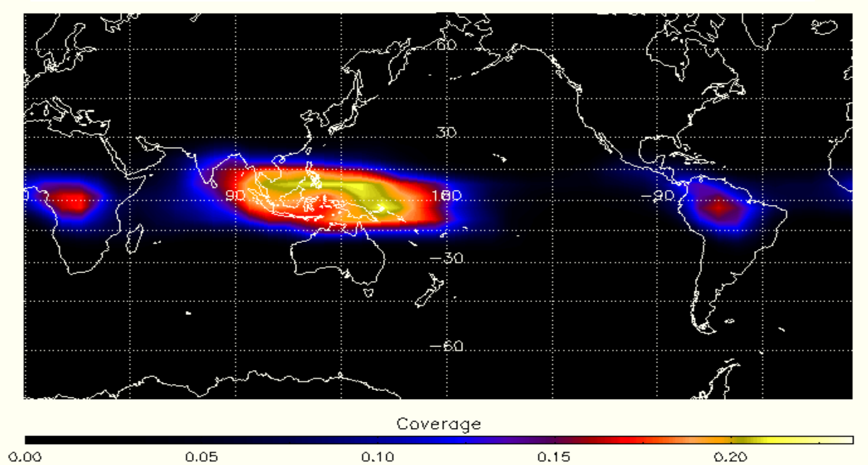


Compare to model results --- Very High Clouds

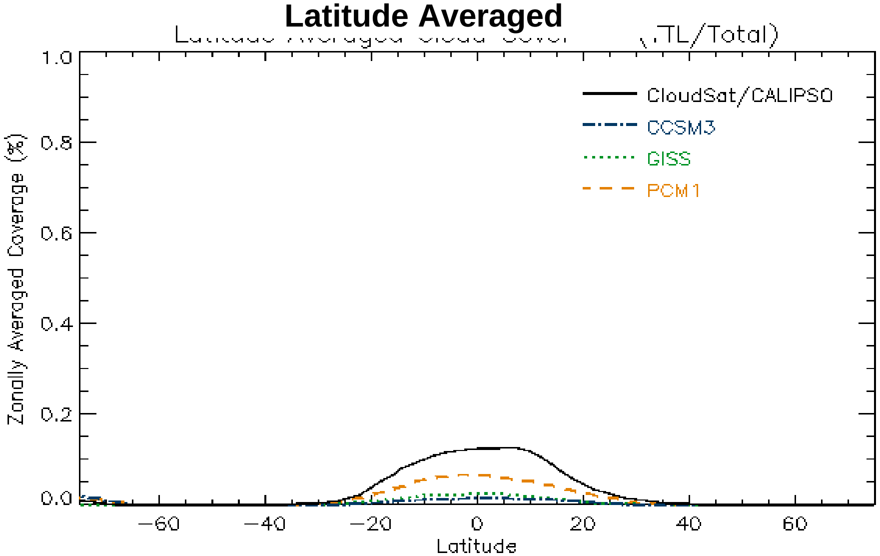
Very High Clouds (TTL): 14-20 km

- Models under estimated

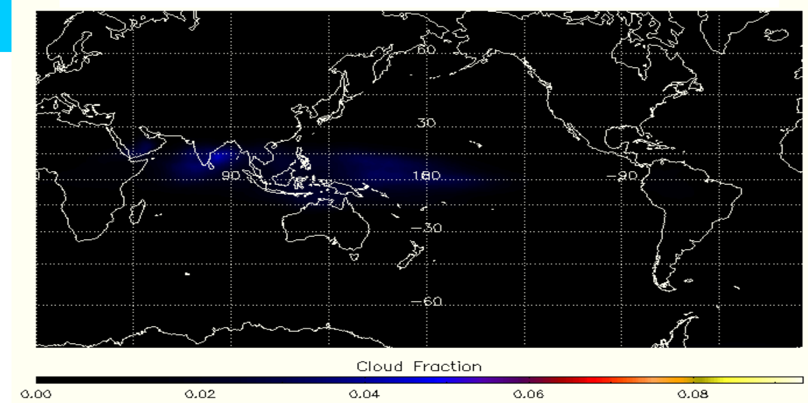
CloudSat / CALIPSO



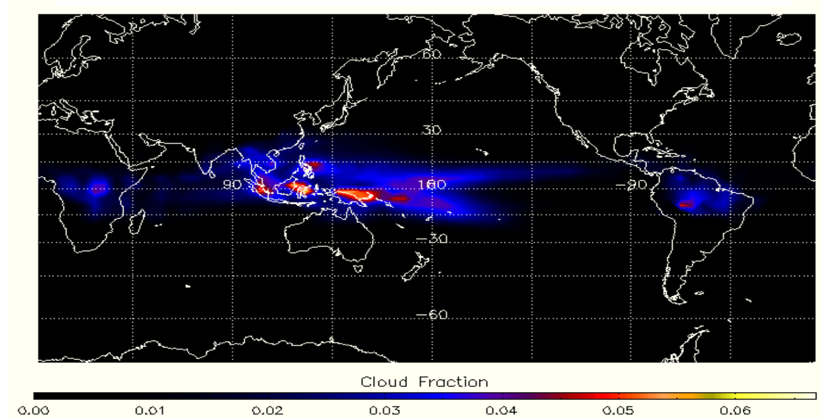
Latitude Averaged



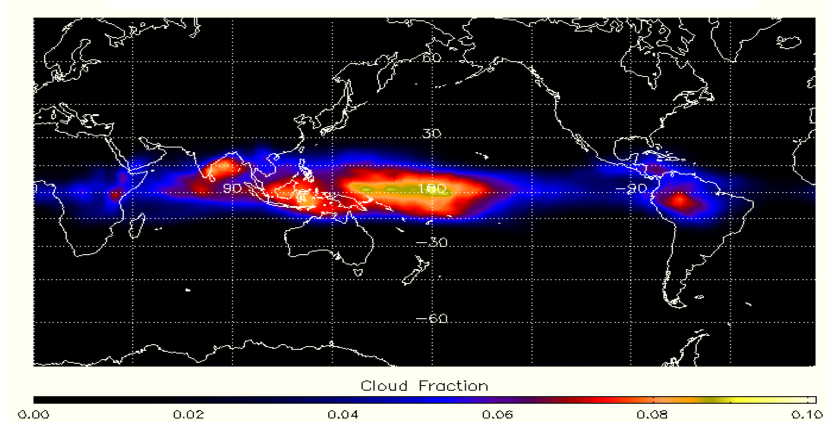
NCAR CCSM 3.0 Model



NASA GISS Model E20/Russell



NCAR PCM1 Model



Summary

- The 2B Geoprof-Lidar dataset provides a unique description of the vertical and horizontal structure of hydrometeor layers by exploiting the synergy between the CPR and Caliop.
- The present data set INCLUDES the Calipso VFM low cloud bug!! Use with caution.
- Plans are to implement either the new version of the VFM or to implement a lidar mask optimized for geoprof lidar. Evaluations are now underway.
- We plan to report on the impact of the low cloud bug in the published cloud statistics at the October Joint A-Train meeting in New Orleans.
- The new version of Geoprof-Lidar (R05) will include Calipso attenuated backscatter information averaged to the radar footprint.
- Preliminary results of model comparison reveal the strengths (high clouds) and weaknesses (low clouds?) of CFMIP GCMs. Work is continuing…