Using Satellite (Imager) Cloud Observations to Diagnose Cloud Forecasts

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Outline

- Review of the NESDIS Operational Cloud Products
- Simulating Satellite Observations using GFS forecasts
  - Differences between observed and modeled 11 μm observations
- Comparisons of the cloud vertical structure
  - 2D histogram of Cloud Temperature and 11 μm Temperature
  - Occurrence of multilayer clouds
- Future Work

Review of NESDIS Operational Cloud Products

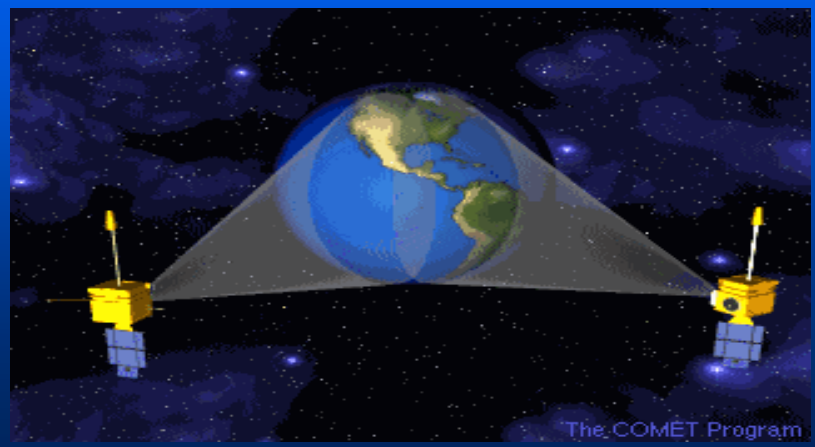
- AMSU / MSPPS: Cloud Liquid Water Paths (LWP) and Ice Water Paths (IWP)

- HIRS / ATOVS: Cloud Top Pressure and Emissivity

- AVHRR / CLAVR-x: Cloud Mask, Type, Temperature, Emissivity, LWP, IWP, Cloud Amounts (H/M/L).

- GOES Imager / GSIP / CSBT: same products as CLAVR-x

- GOES Sounder: Cloud Top Pressure and Emissivity



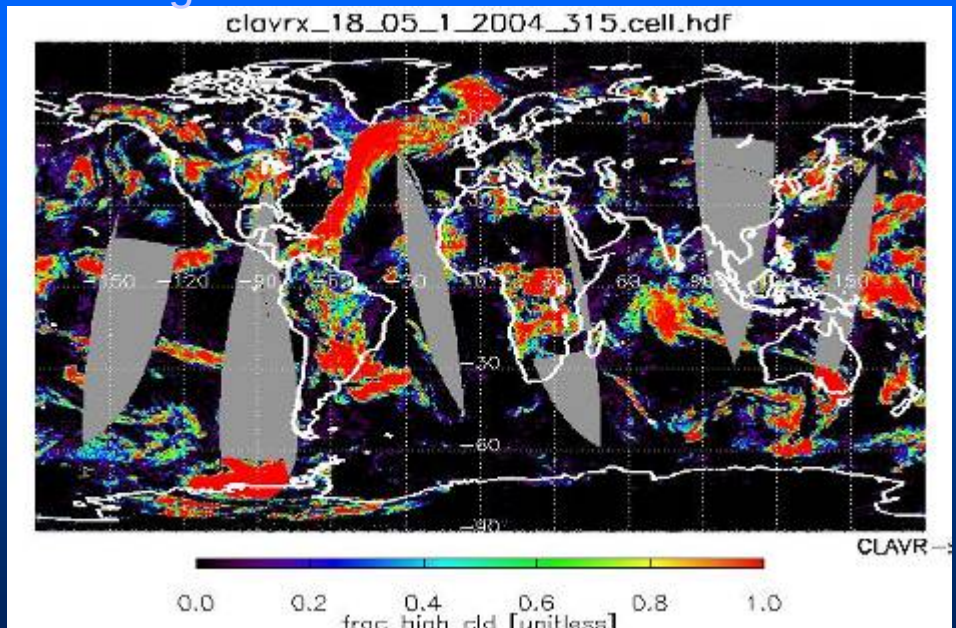
Clouds from AVHRR Extended (CLAVR-x) Products

- Pixel level cloud mask is available in the 1b data stream

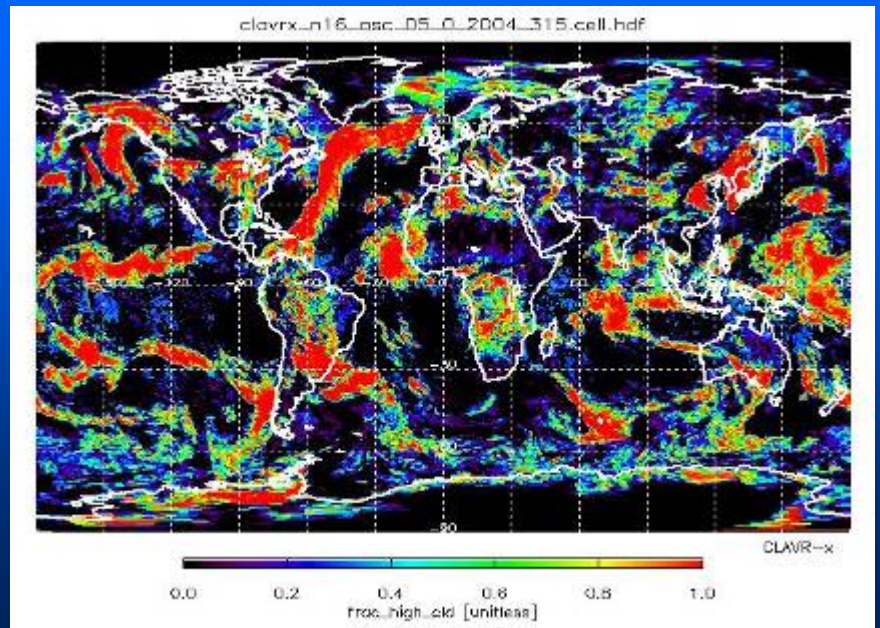
- Cloud products are similar to those from MODIS. Standard products are on a 55 km grid. Pixel products are not part of the standard operational suite, but they can be. AVHRR will soon provide global 1km data.

- We make daily fields from one satellite and at model forecast times (0,6,12 and 18Z) from multiple satellites.

High Cloud at 18Z from 3 AVHRRs



High Cloud from Asc Node from 1 AVHRR



Comparison of NESDIS (CLAVR-x) Real-Time Cloud Products with other Satellite-Derived Cloud Products (Total Cloud Amount)

- The AVHRR (CLAVR-x) products can be compared to those from MODIS, and GLAS (a LIDAR) in addition other POES sensors (AMSU and HIRS)

- NCEP has shown most interest in CLAVR-x cloud amount (H/M/L) so far.

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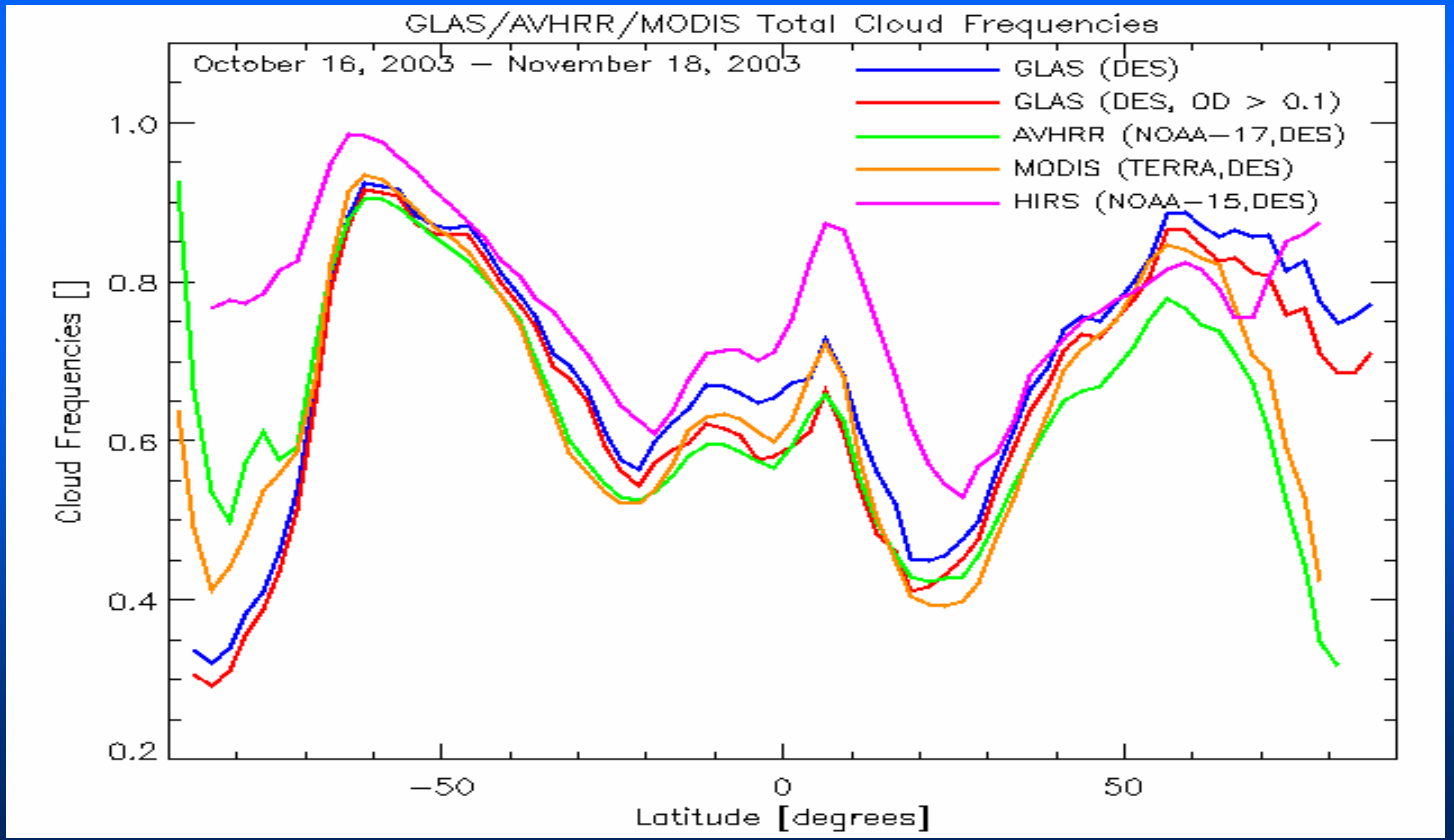
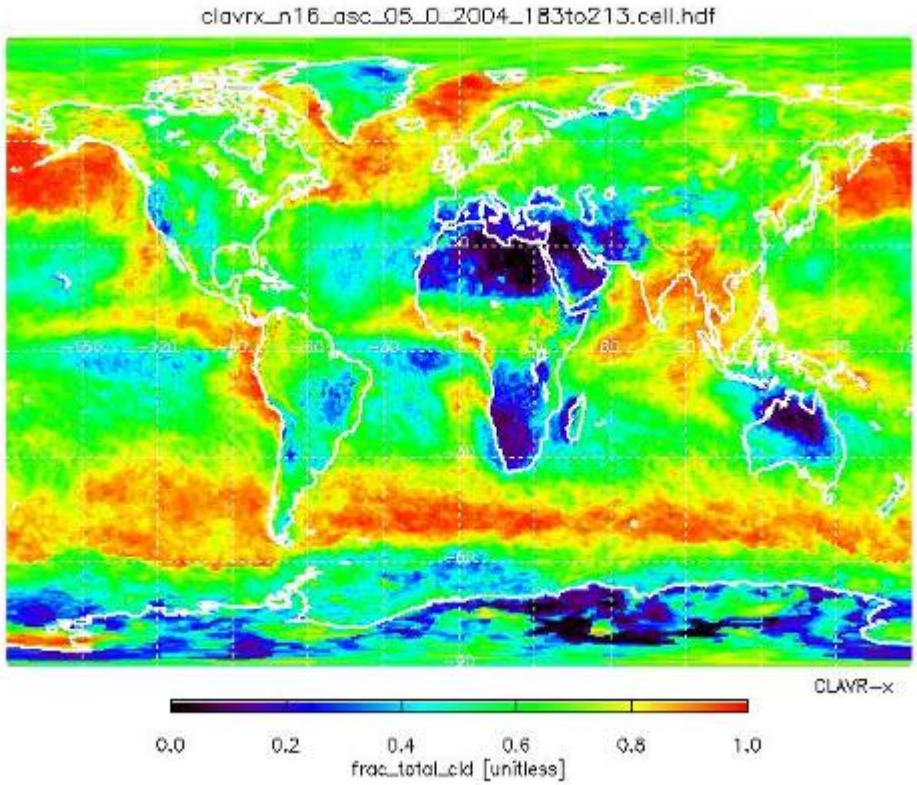
- GLAS provides profiles of cloud optical depth so that we can estimate at what optical depth are clouds not detected by different passive sensors. HIRS seems to detect the most cloud while AVHRR and MODIS are good agreement for many zones



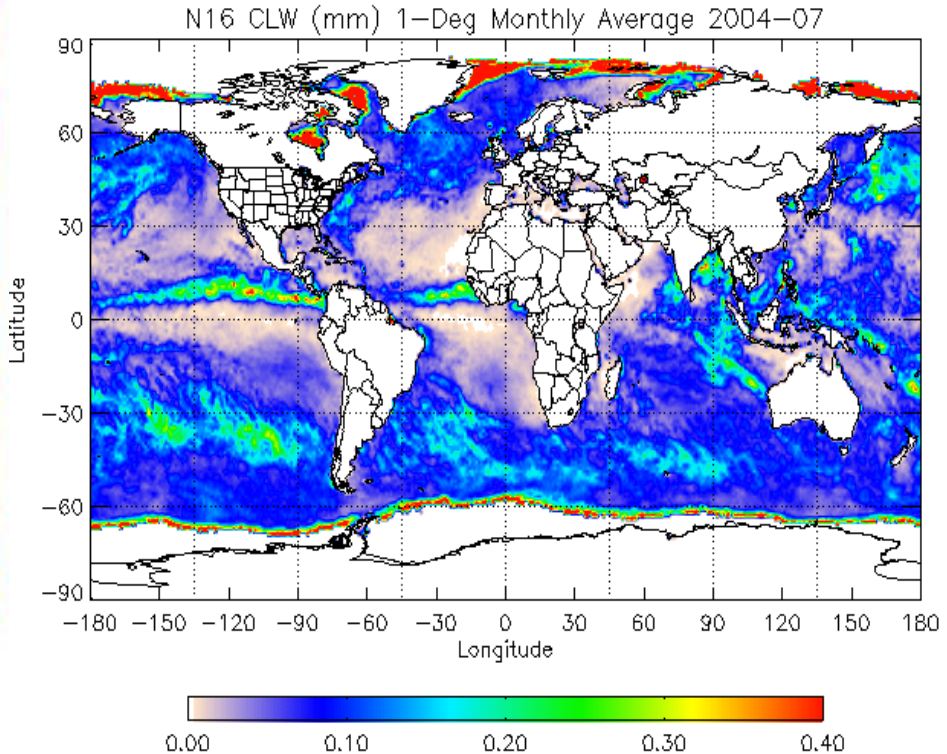
Cloud Climatologies Available from NESDIS Products

- It is important to note the many of the real-time products are available historically from climate-algorithms. *(ISCCP is not only source of climate data)*
- MSPPS has made pentad and monthly composites. (2000-2005)
- AVHRR Pathfinder Atmospheres Extended (**PATMOS-x**) provides climatologies of the CLAVR-x data (1981-2005)
- These products benefit from improved algorithms and calibration

PATMOS-x Monthly Cloud Amount



MSPPS Monthly CLW Frequency



Simulating Satellite Radiances using GFS Output

Motivation:

•NCEP has expressed an interest in developing this capability with NESDIS

• Comparison of modeled and observed radiances removes some of the ambiguities in comparing modeled and retrieved cloud products.

•11 and 12 μm infrared radiances offer information on cloud height and transparency. A good starting point for comparisons.

•Actual methodology is applicable to any satellite IR or μ–wave obs.

Methodology

• 12 Hr 1 degree GFS forecast products were used (T(z), q(z), and CLWMR (z)). Cloud amount was not computed.

•We assumed 10 μm water particles and 30 μm ice particle radii and a linear with temperature phase relationship (provided).

• The pCRTM (van Delst) routines were used for non-cloud transmittances.

• The method of Successive Orders of Interaction (SOI) was used to simulate cloudy radiances. This method includes multiple scattering and is very fast and can achieve a high level of accuracy. (Method developed with JCSDA funding at AOS/CIMSS/NESDIS). Will be incorporated into CRTM.

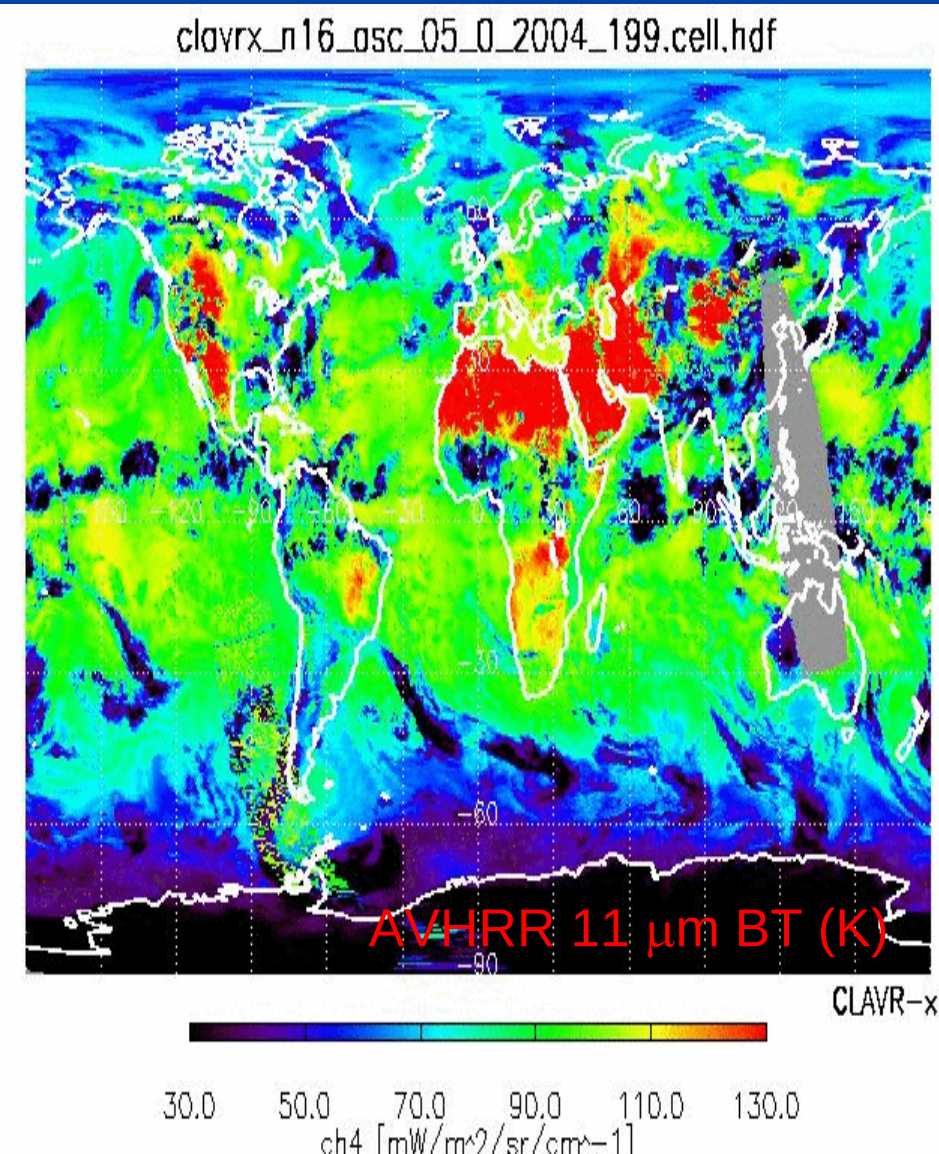
SOI described in following papers under review:

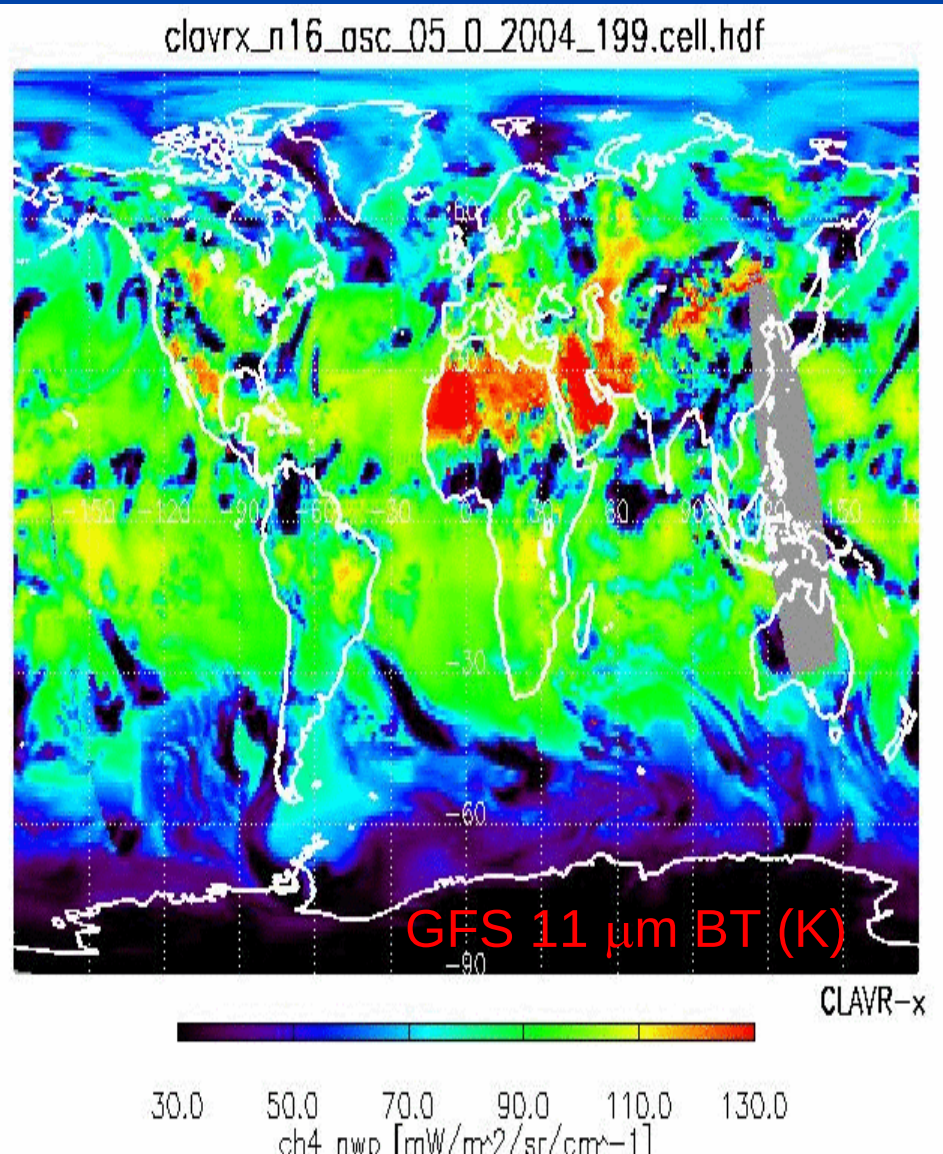
Heidinger, A. K, C. O'Dell, T. Greenwald, and R. Bennartz, 2005: The Successive Orders of Interaction Radiative Transfer Model, Part I: Model Development, *submitted to JAM*.

O'Dell, C, A. K. Heidinger, T. Greenwald, and R. Bennartz, 2005: The Successive Orders of Interaction Radiative Transfer Model, Part II: Model Performance and Applications, *submitted to JAM*.

Comparison of ascending data from AVHRR Ch 4 on NOAA-16 for July 2004

We have started with analyzing 11 μm radiances because of their sensitivity to cloud height / opacity and due to their abundance (all imagers/sounders)



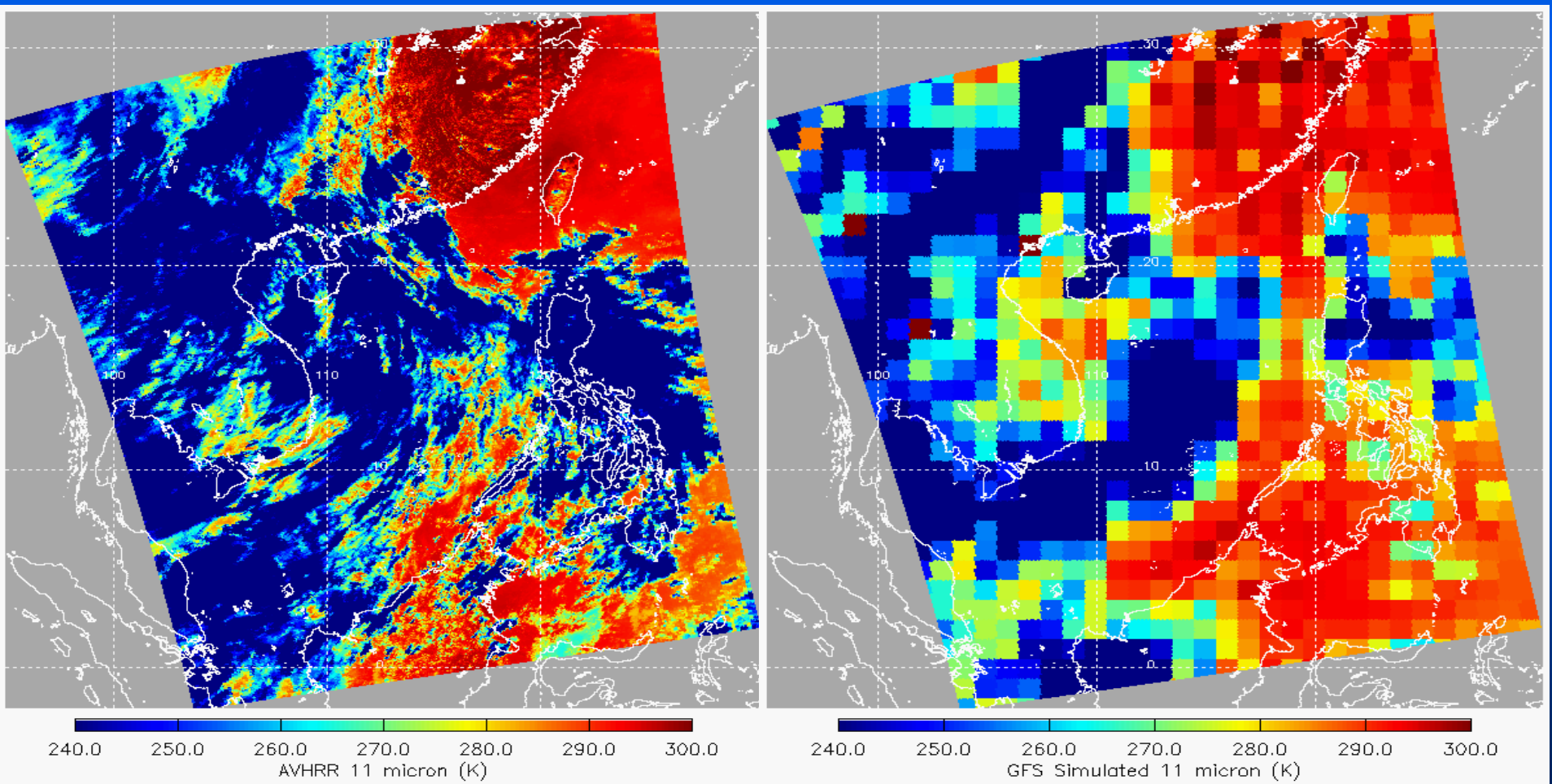


Regional Scale Comparisons of Satellite and GFS 11 μm Brightness Temps.

While the global comparison indicate agreement on the synoptic scales, there are difference revealed in smaller scales.

AVHRR 11 μm BT at 6Z

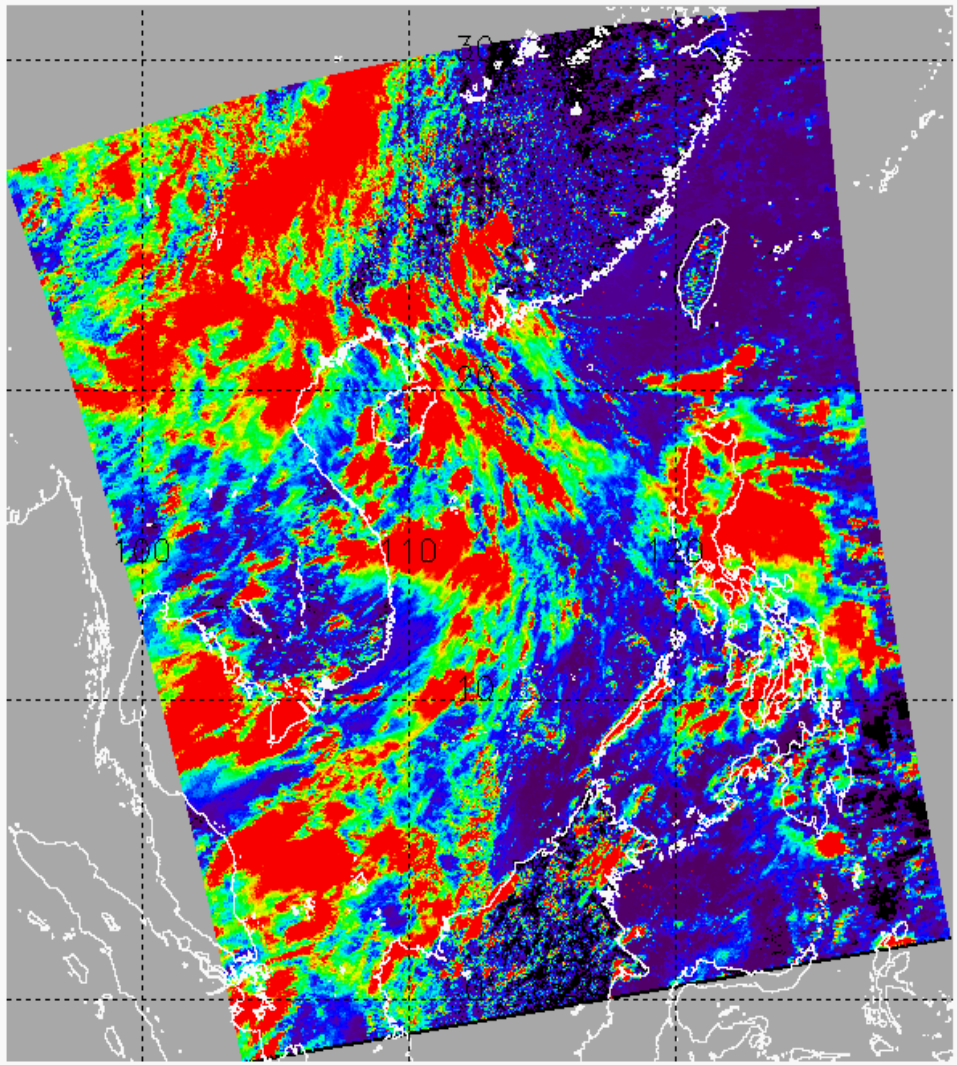
GFS Simulated 11 μm BT at 6Z

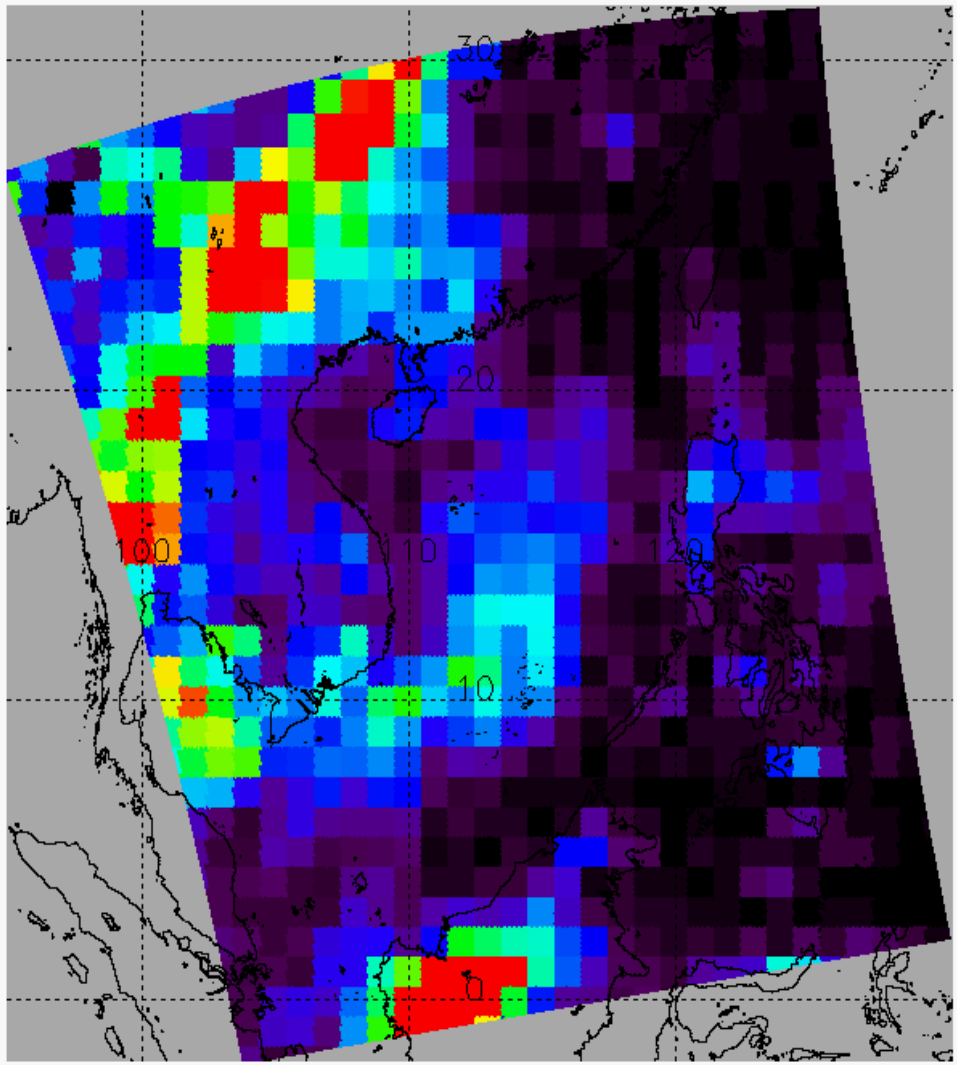


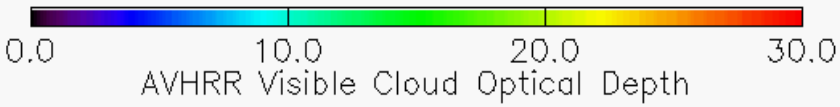
Comparison of products can explain differences noticed in 11 μm radiances

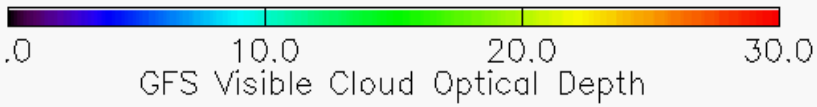
CLAVR-x Optical Depth

Derived GFS Optical Depth



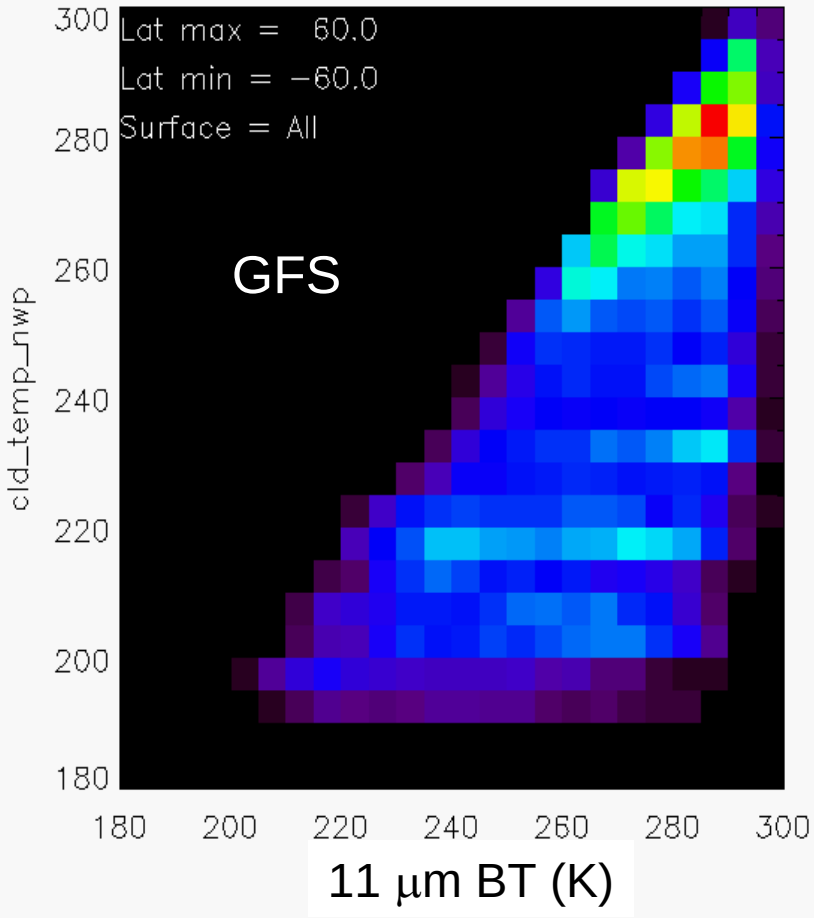


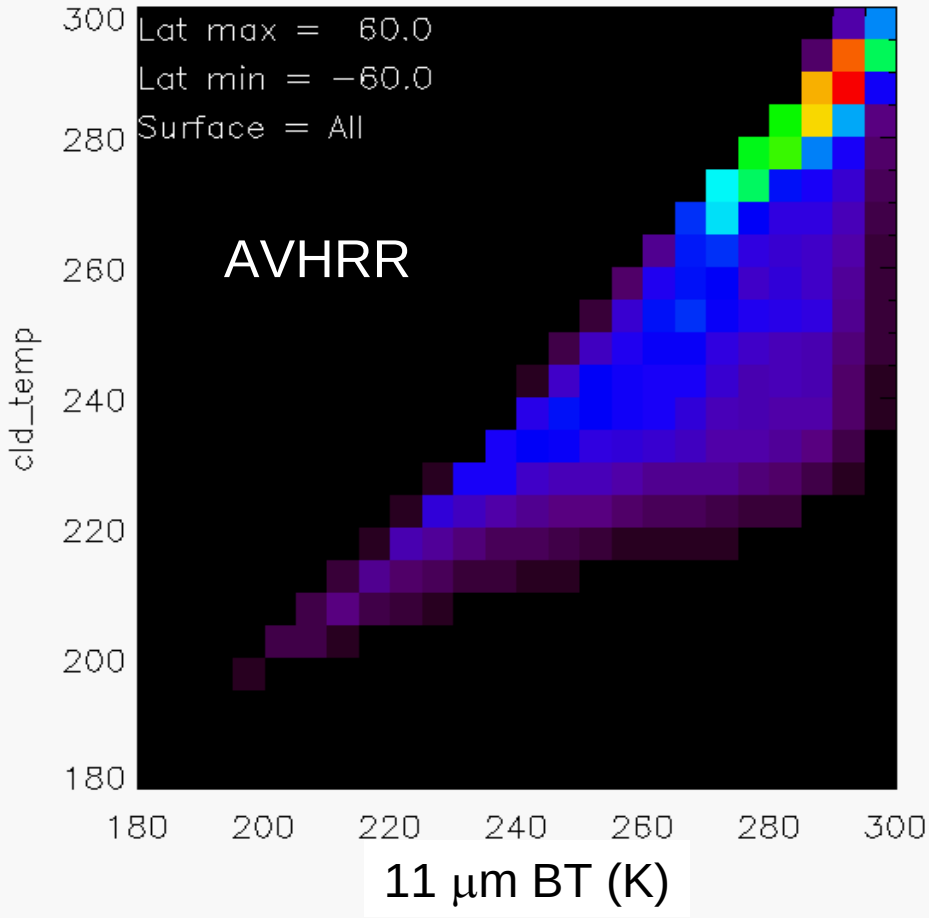




Comparison of the 2d Histograms of Cloud Top Temperature and 11 μm Brightness Temperature

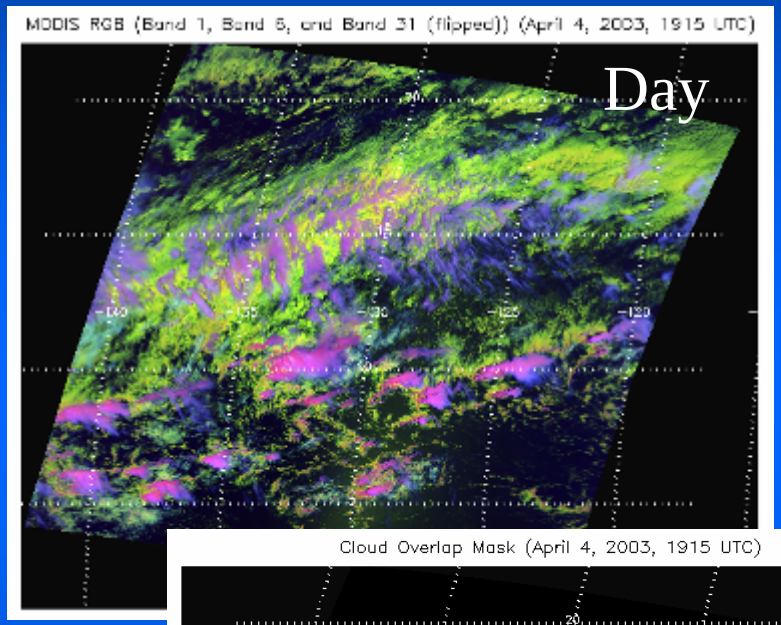
Results show that GFS has more high thin cloud than seen in satellite. This may be a limitation of satellite and/or difference in physical of observed and modeled cloud temperatures. MODIS is more similar to AVHRR. These results are preliminary.

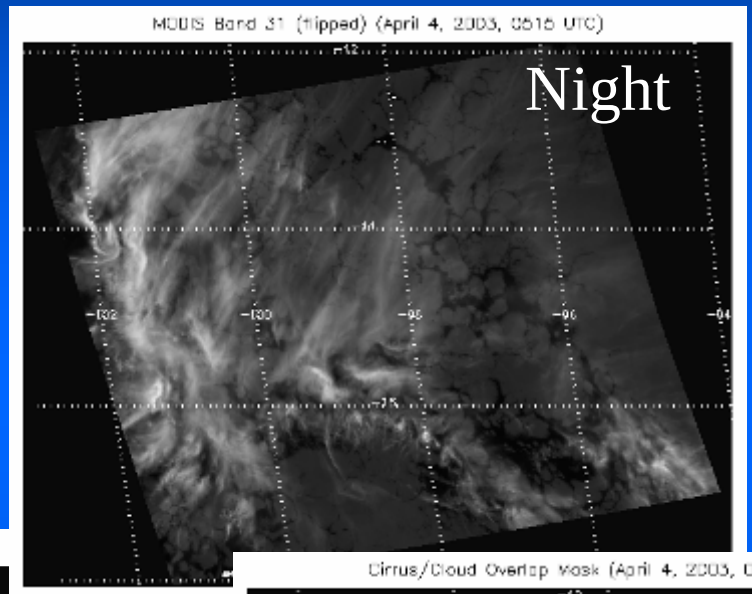


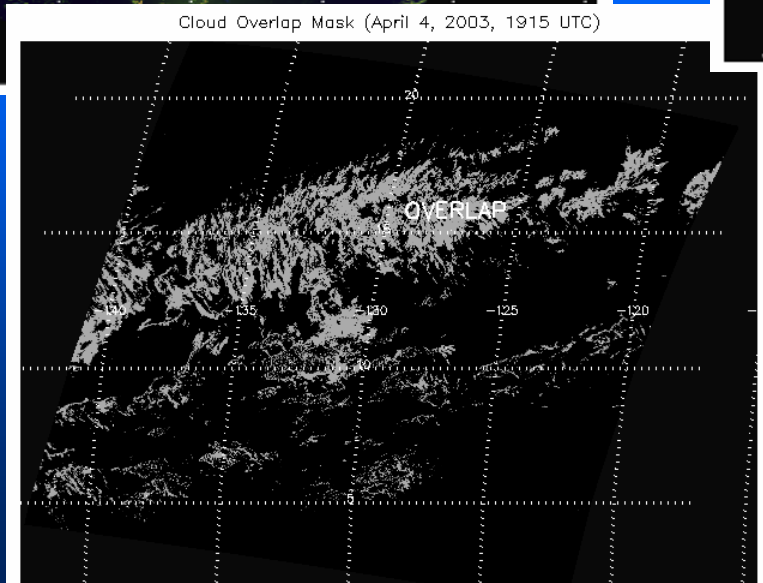


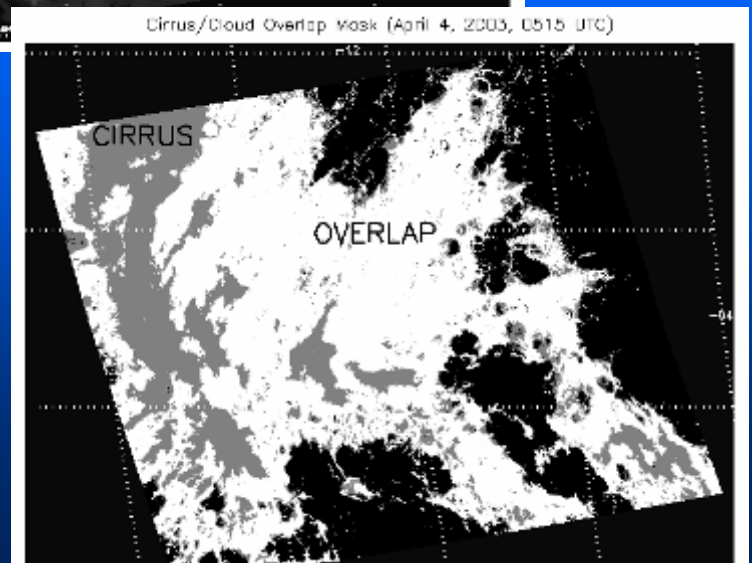
Comparison of GFS Cloud Vertical Structure

CLAVR-x employs an algorithm that can detect a subset of multi-layer cloud (high over low) both day and night. Performance improves on MODIS and VIIRS.

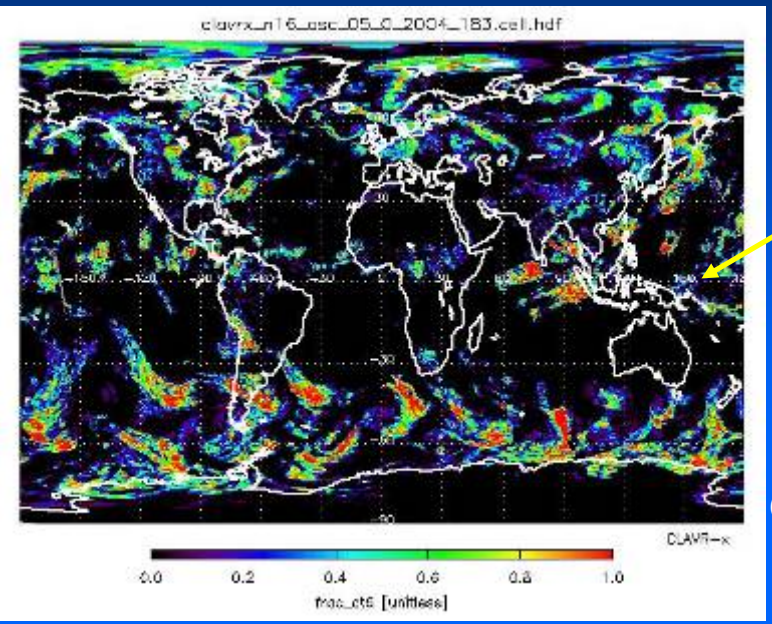






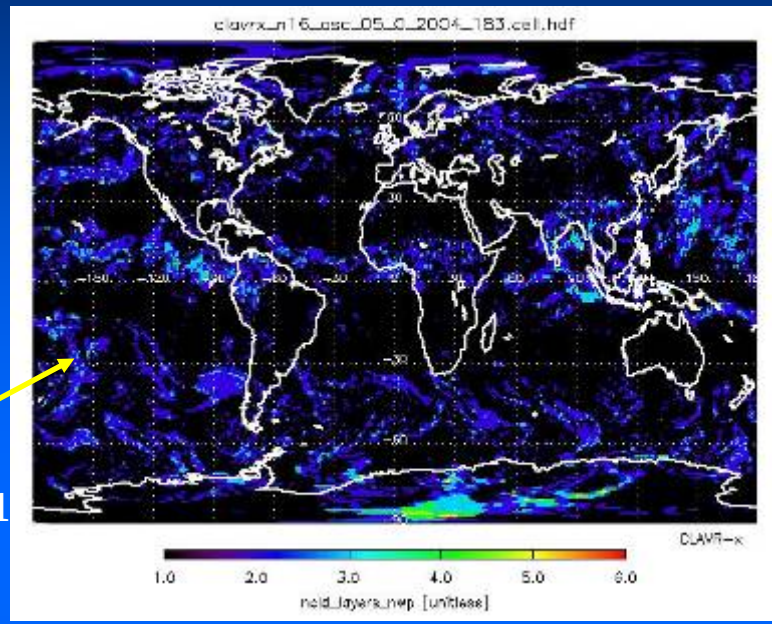


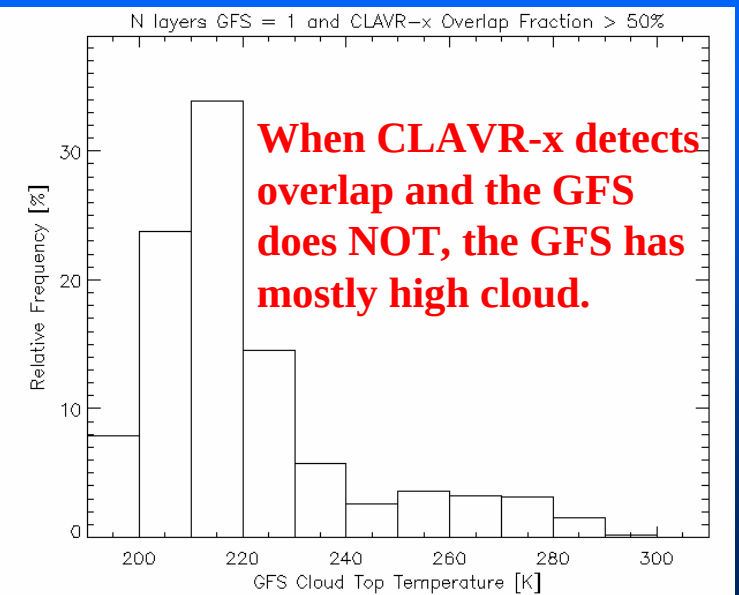
CLAVR-x / GFS Multi-layered Cloud Comparisons



CLAVR-x overlap fraction

GFS cloud layers > 1



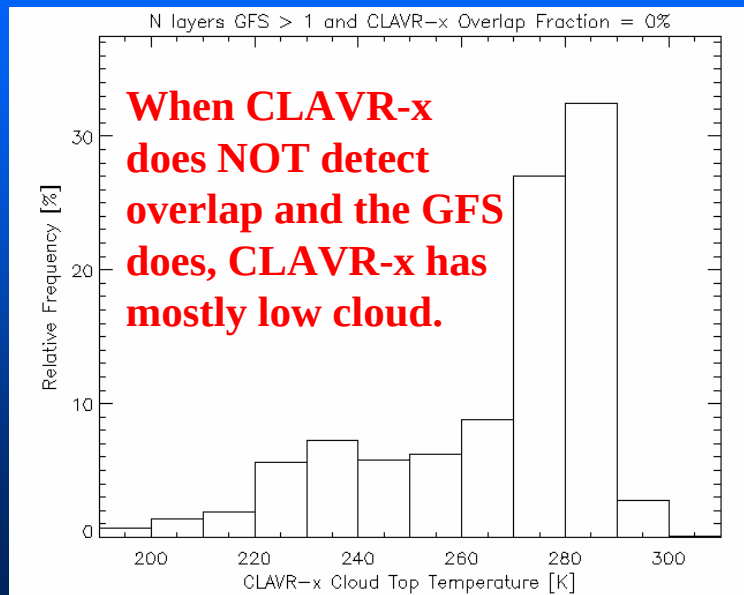


When CLAVR-x detects overlap and the GFS does NOT, the GFS has mostly high cloud.

Single

vs

Multi-layered



When CLAVR-x does NOT detect overlap and the GFS does, CLAVR-x has mostly low cloud.

Conclusions / Future Work

- NESDIS makes a full suite of real-time and climate cloud products (CLAVR-x, MSPPS and ATOVS) and welcomes more collaboration with NWP.

- Motivated by NCEP interest, we have developed a capability to simulate infrared radiances (6.7, 11 and 12 μm) from imagers from the GFS forecasts.

- We plan to develop methods to use the simulation satellite radiances to diagnose the performance NWP cloud forecasts. We also will continue to compare the derived products (occurrence of multi-layer cloud) to forecasted GFS cloud fields.

- We plan to propose to extend this work to the NAM / GOES imager for higher temporal resolution over North America.

- Changes in forecast product outputs could greatly aid this comparison. (Provide instantaneous values as opposed to time averaged)

- CloudSat, Calipso and other missions (sub-millimeter?) will soon greatly expand our ability to use satellites to diagnose NWP cloud forecasts.

We seek feedback and guidance from the NWP community.