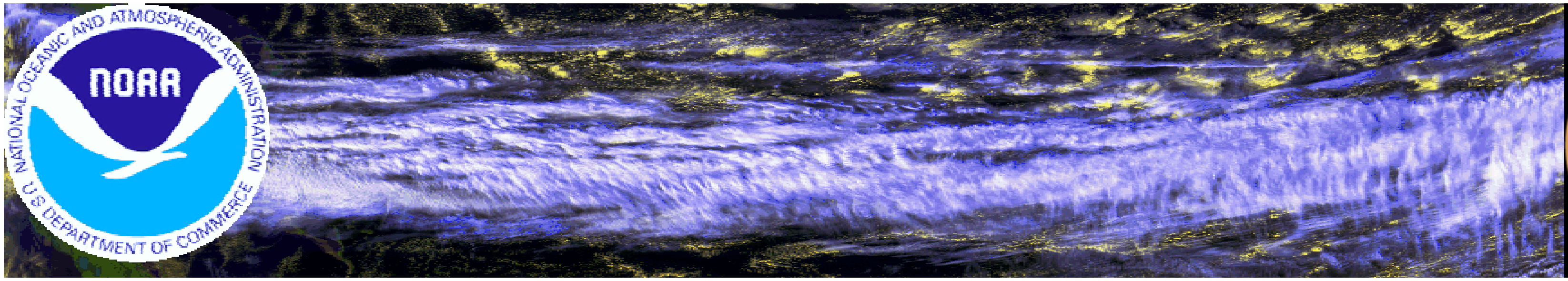


# Expected Operational (*Cirrus*) Cloud Observation Improvements with VIIRS on NPP/NPOESS



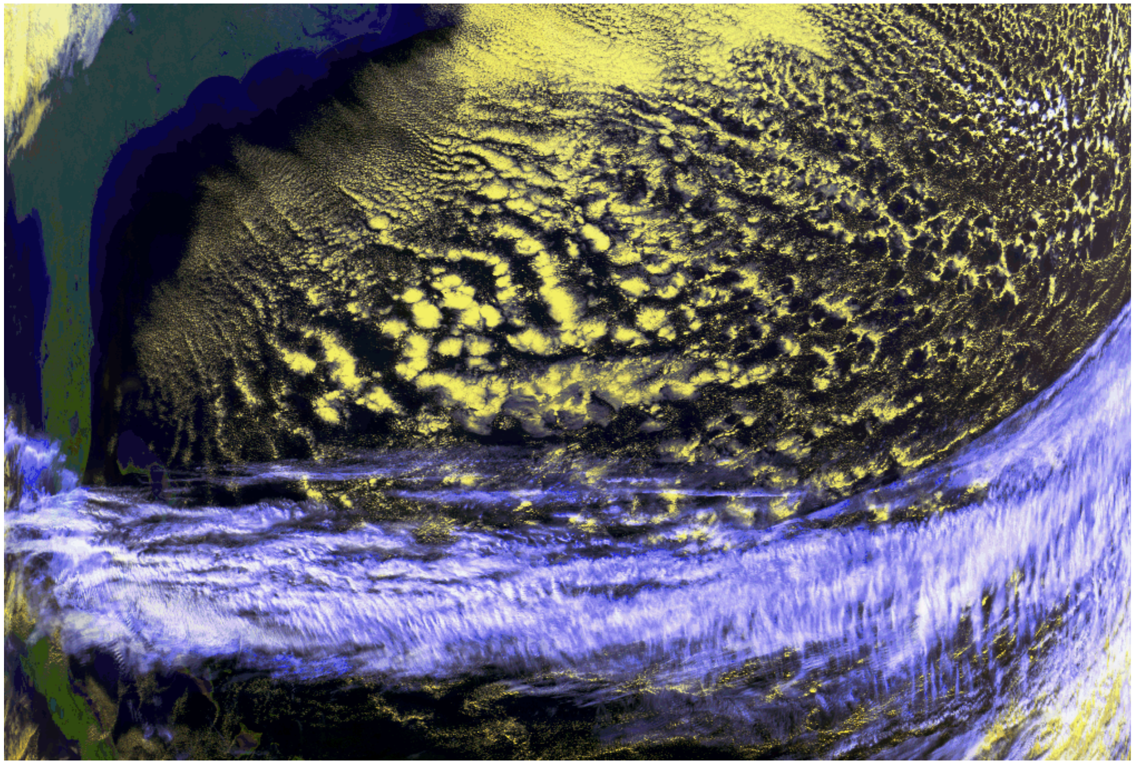
Andrew Heidinger
NOAA/NESDIS/STAR
Madison, Wisconsin

And others

January 20, 2010

AMS Annual Meeting, Atlanta, Georgia  January 17-22, 2010

# Motivation



• cirrus cloud are high (upper troposphere) semitransparent ice clouds

• dominant players in radiative forcing and climate change feedbacks

• The thinnest of cirrus are not observable by microwave sensors or radars.

• IR measurements provide good sensitivity to cirrus and provide the global and diurnal coverage needed.

•Modeling and Interpretation of IR observations is less challenging than VIS observations because of the presence of less scattering and overall smoother phase functions.

• Cirrus exhibit high spatial variability that requires fine spatial resolution observations offered by IR imagers such as VIIRS (complements the information from sounders).

# Outline

- Overview of VIIRS for cloud remote sensing.
- Impact of the not having IR absorption channels on VIIRS.
- Benefits for cirrus remote sensing using VIIRS over AVHRR.
- Summary

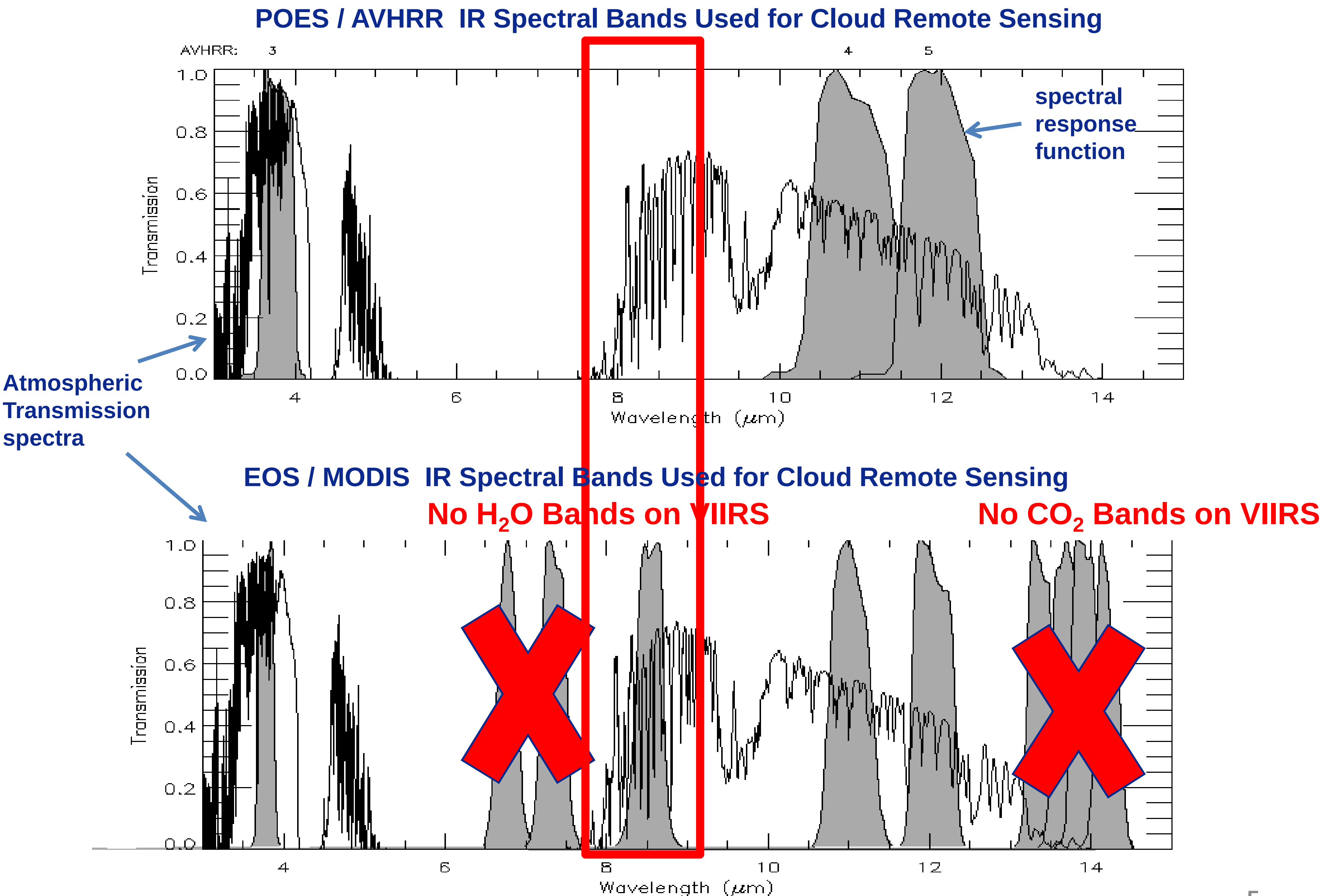
# Overview of VIIRS for Cloud Remote Sensing

- The VIS/NIR approaches used to derive daytime optical depth and particle size on MODIS will live on with VIIRS.

- Most of the MODIS cloud mask methodology will translate to VIIRS.  The exception being polar cloud detection using IR bands.

- VIIRS differs most from MODIS in the Infrared (IR) channels and this will be the focus of this talk.

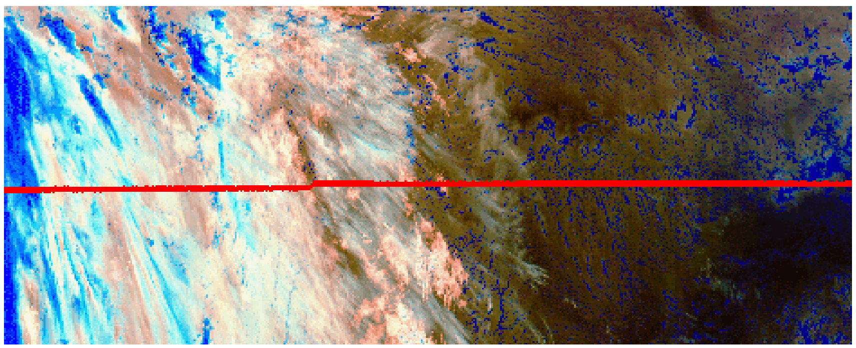
# VIIRS Infrared Observations for Cloud Remote Sensing

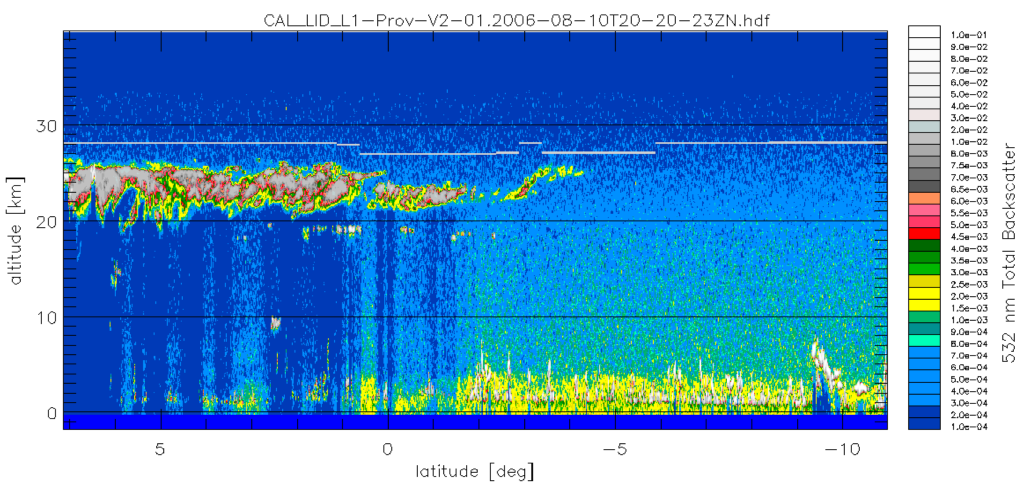


## Impact of no $CO_2$ channel(s) on VIIRS (A Bad Story for Cloud Height Retrievals).

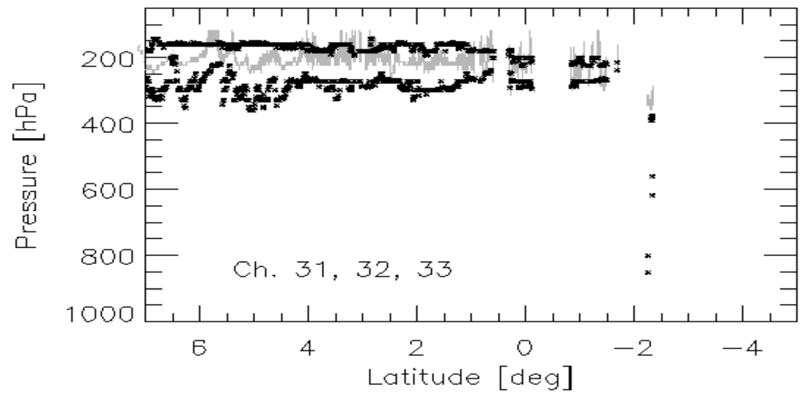
**Following images show an example calculation using MODIS where a cloud could exist in a atmosphere and match the observations used in the cloud height retrieval (grey region). Black lines are cloud boundaries from CALIPSO.**

**Inclusion of the 13.3 $\mu$m channel with the 11 and 12 $\mu$m channels on the GOES-R ABI shrinks the region where a cloud could exist significantly (25 mb). Note, even with multiple window channels, VIIRS can not provide a confident value of cloud pressure.**

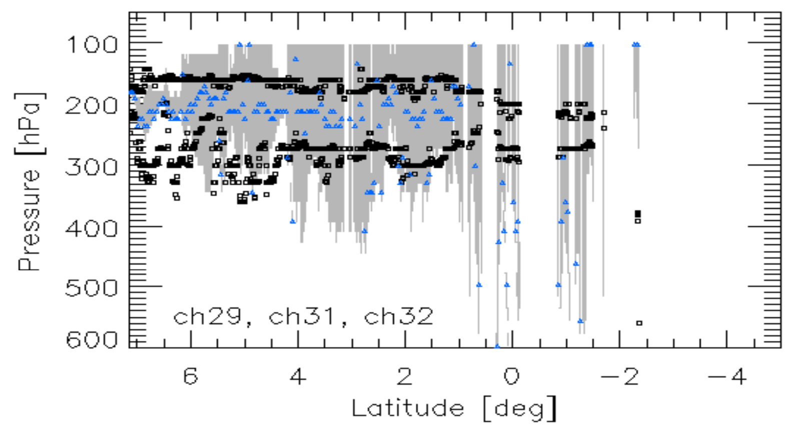





**GOES-R**




**VIIRS**



# Impact on the 8.5 μm channel on Cloud Microphysical Retrievals (A Good Story)

- **The AVHRR provides 2 channels in IR window (11 and 12 μm).**

- **VIIRS will provide a third channel at 8.5 μm.**

- **While VIIRS won't do much better than AVHRR at determining the height of thin cirrus, *it will provide more information on cirrus microphysics.***

- **Traditionally cloud algorithms generate**
  - **cloud optical depth – a measure of integrated extinction**
  - **cloud effective radius – a measure of bulk particle size**

- **The 8.5 μm channels provides one more piece of information that can be *used to infer information on ice crystal habit*.**

# Methodology of Deriving Cirrus Properties from IR channels

- If you know or model the clear-sky radiative transfer, you can take a cloud height and the 8.5, 11 and 12 $\mu$m radiances and compute cloud emissivities ($\varepsilon$) at each channel.

- You can then compute $\beta$ values for a channel pair which we know are directly related to the single scattering properties

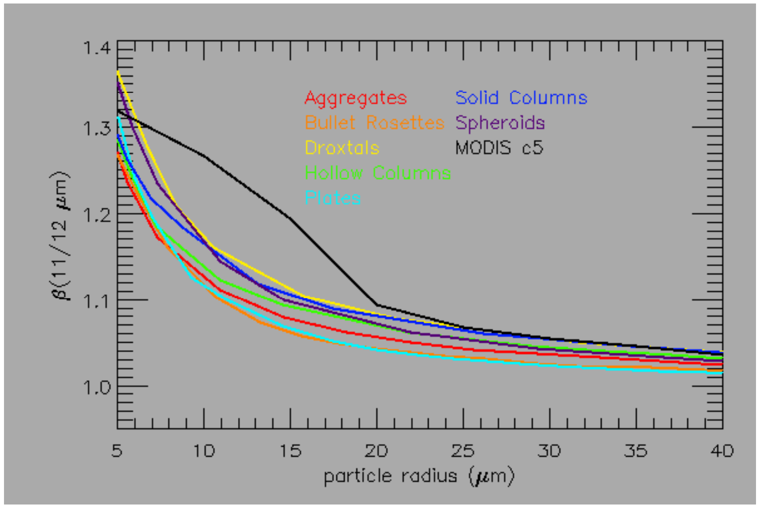
$$\beta = \ln(1-\varepsilon_y) / \ln(1-\varepsilon_x) = ((1-\omega_{o,x}\, g_y)Q_y) / ((1-\omega_{o,x}\, g_x)\, Q_x)$$

- We know that the single properties ($\omega_o$, g and Q) are related directly to particle size and habit (shape).

- For each habit, we can compute a particle size (see figure).

- We choose the habit that gives particle sizes that match between the two $\beta$ values

- Knowing the habit and particle size, we can then compute optical depth from any one of the emissivities.



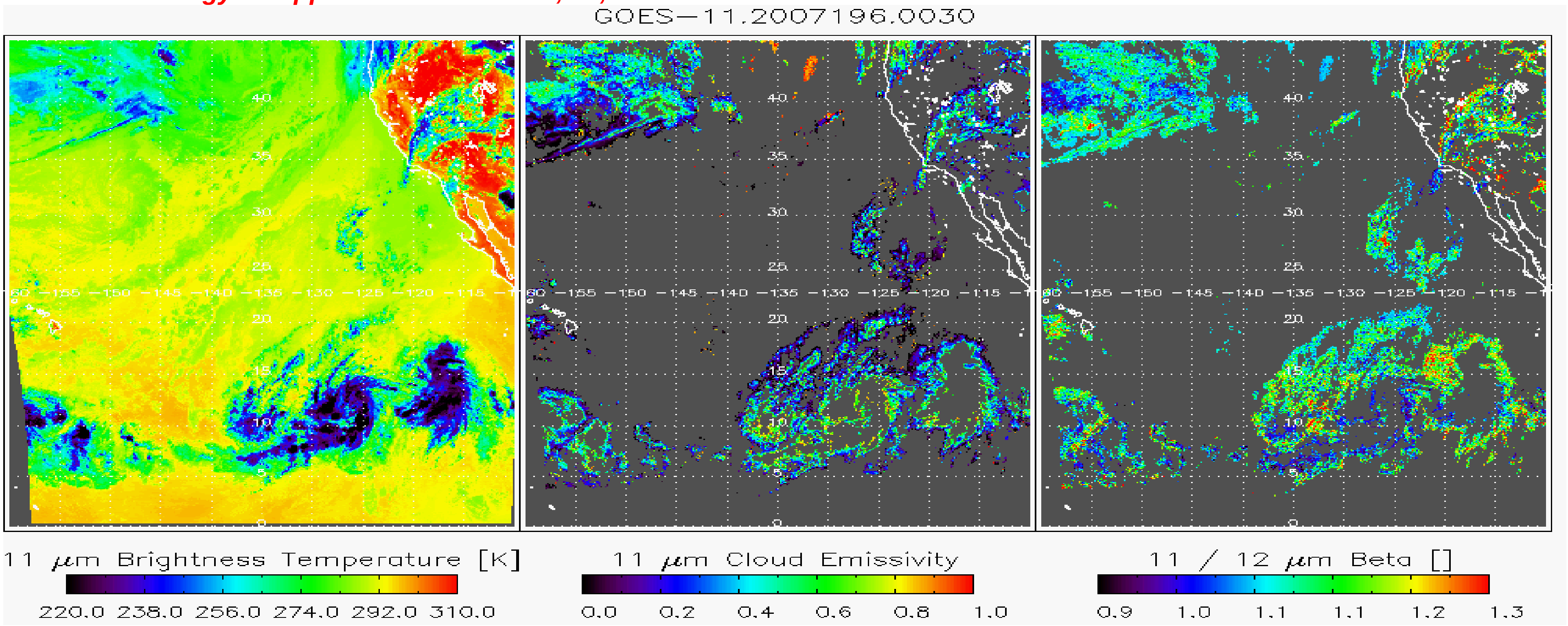
# Illustration of Cirrus Properties from 11 and 12 microns (GOES-11)

- **As mentioned VIIRS cloud height performance for thin cirrus should be more similar to AVHRR than MODIS.**

- **But as pointed out in Heidinger and Pavolonis (2009), you don't need to know the height accurately to extract microphysical information about cirrus.**

- **To illustrate this point, the images below show cirrus properties from split-window measurements from GOES-11.**

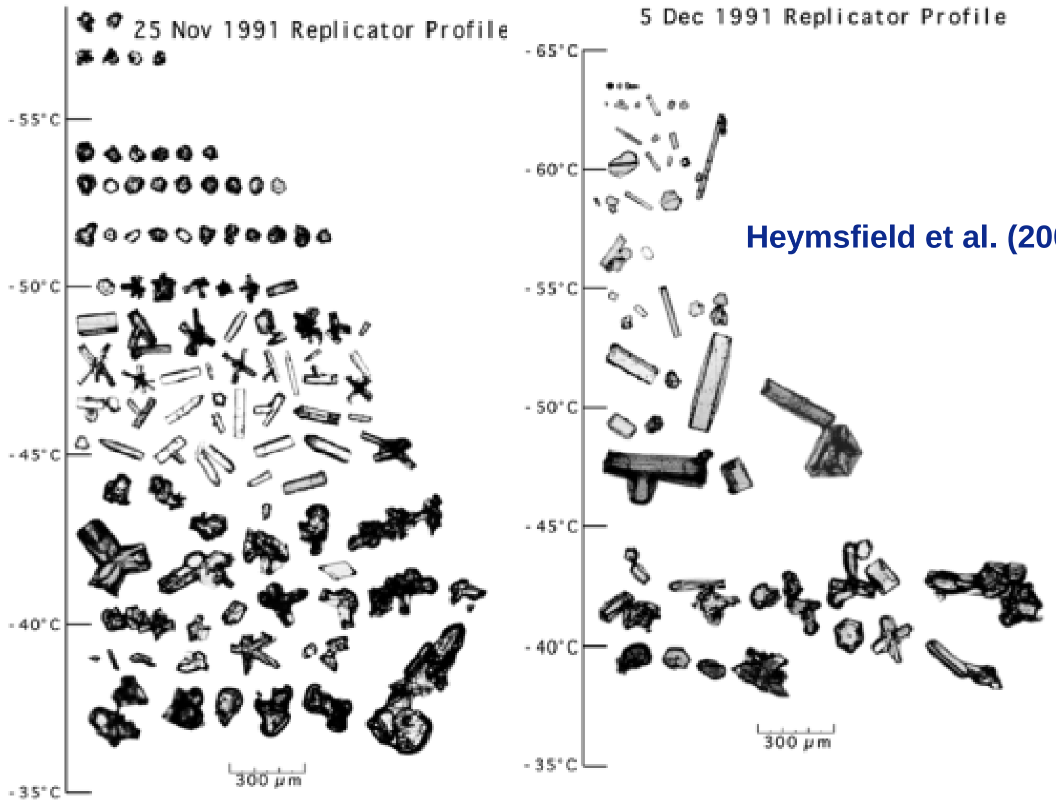
*Heidinger, A.K., and M.J. Pavolonis, 2009: Gazing at Cirrus Clouds for 25 Years through a Split Window. Part I: Methodology. J. Appl. Meteor. Climatol., 48, 1100–1116*.



# What does having 8.5 μm observations give us?

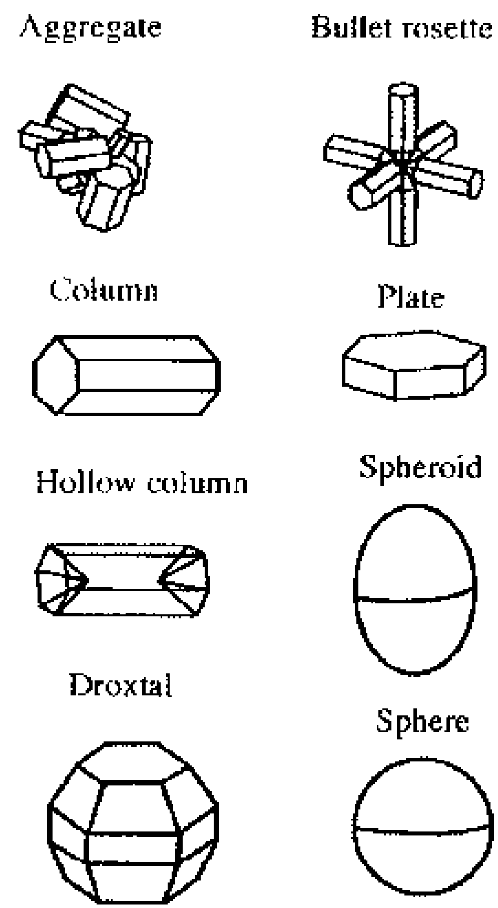
- The ability to go beyond the traditional measures of optical depth and particle size and to begin to infer information on the dominant ice crystal habit.

**Real Ice Crystals**




**Heymsfield et al. (2002)**

**Modeled Ice Crystals**




**Yang, P., *H. Wei, H.-L. Huang, B. A. Baum, Y. X. Hu, G. W. Kattawar, M. I. Mishchenko, and Q. Fu, 2005: Scattering and absorption property database for nonspherical ice particles in the near- through far-infrared spectral region, *Appl. Opt., 44, 5512-5523.***

# Global Distribution of Dominant Cloud-top Ice Crystal Habit

- MODIS/AQUA observations used to estimate cirrus properties for 10 days in August 2006.

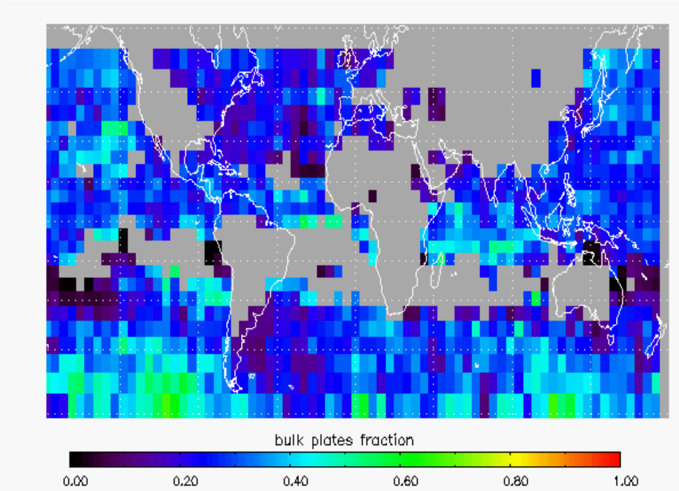
- Patterns are coherent and pervasive over the 10 days studied.

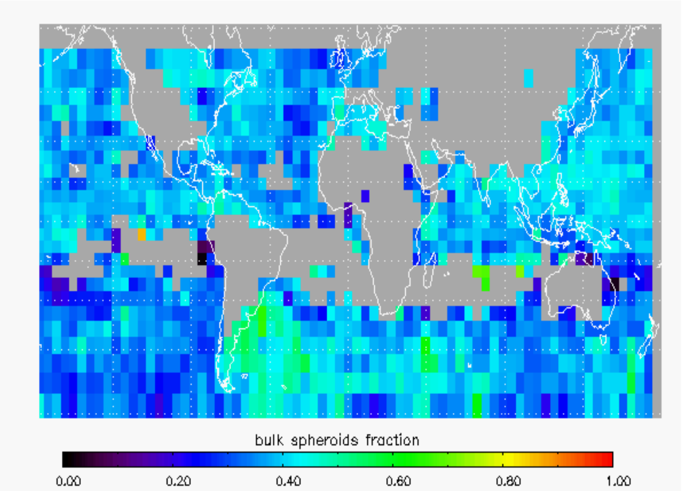
- Columns are dominant in Southern Tropics.

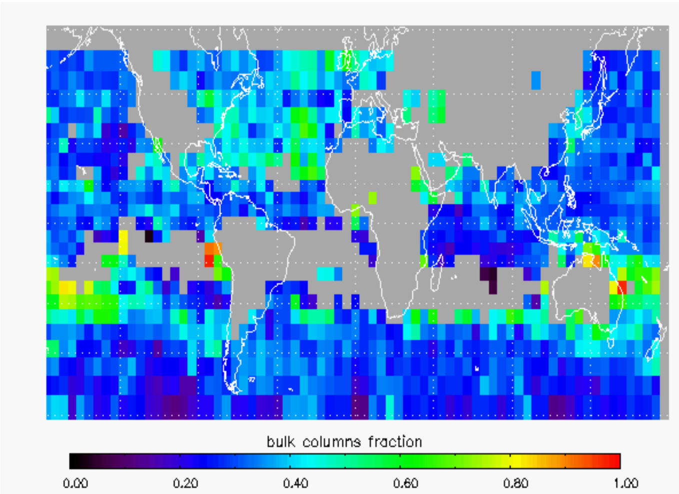
- Plates are common in southern latitudes.

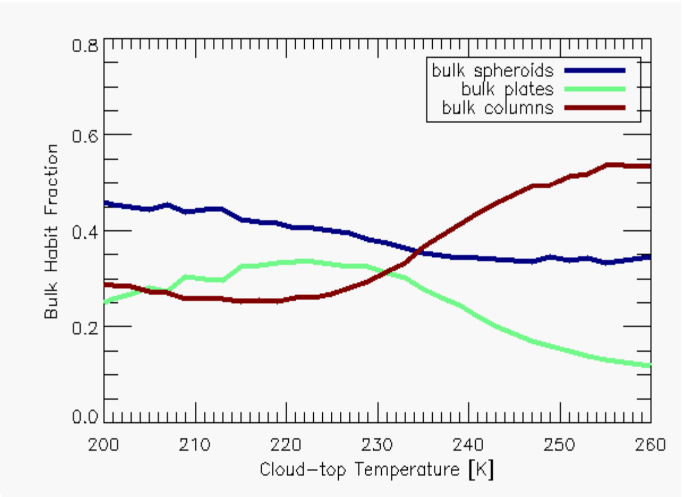
- Spheroids are common everywhere.

- The habit mixture used in the MODIS processing (C5) does not appear to be dominant in any region and tends to mimic columns.



# Why Does Habit Matter?

- It is a ***fundamental property of cirrus*** that impacts fluxes, lifetimes and other important cloud characteristics.

- There is also a long-standing ***inconsistency between solar-reflectance (VIS) and IR*** estimates of cirrus properties.

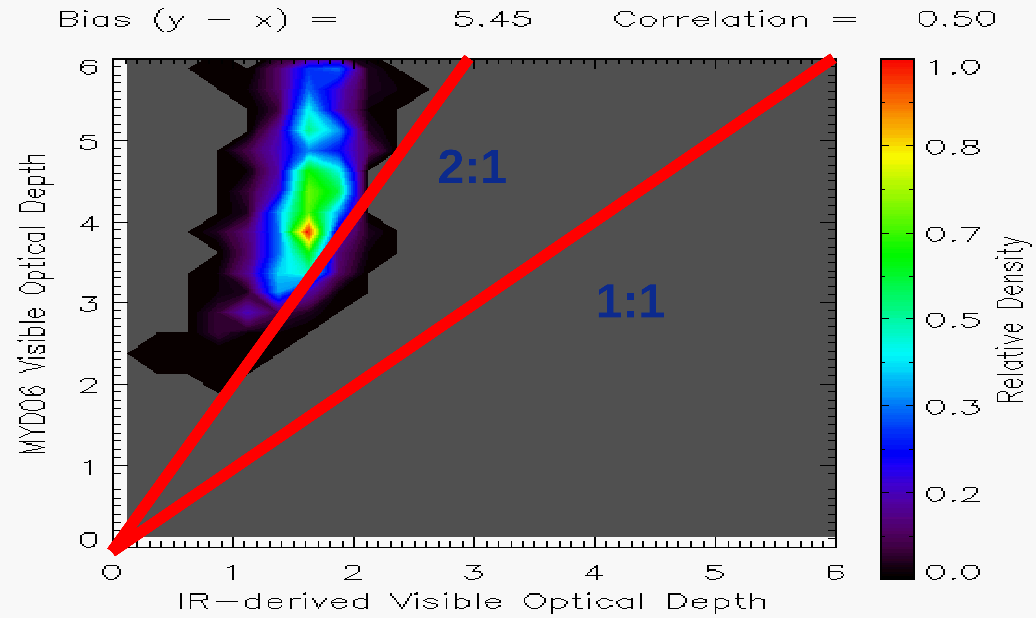
- VIS optical depths are about twice what the IR says for thin cirrus.

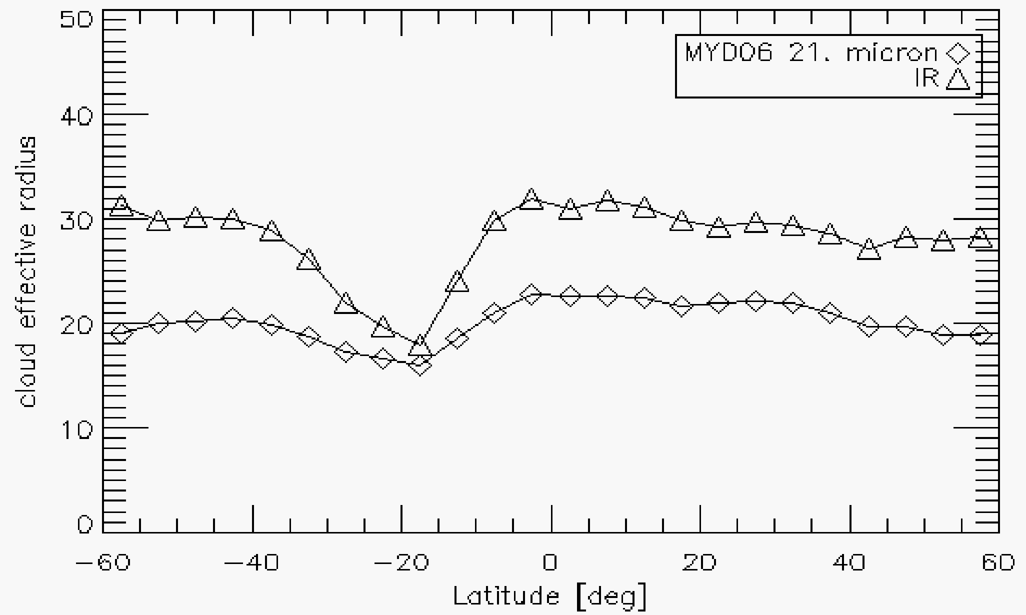
- **CALIPSO (a lidar) results also show a similar discrepancy** with the VIS results.

- IR particle sizes tend to be larger than the VIS results (at least for MODIS MYD06).

- These results can be used to make new scattering models that are consistent in both spectral regions.

- If this is accomplished, we can employ ***approaches that utilize all the VIIRS and GOES-R information***. Now, we have to restrict our spectral ranges to get convergence.



## Conclusions

- The absence of IR absorption channels on VIIRS does negatively impact our ability to estimate cloud height relative to MODIS and GOES-R. (Performance is more similar to AVHRR than MODIS)

- However, the additional 8.5 μm channel on VIIRS relative to AVHRR greatly improves VIIRS capabilities to observe cirrus.

- The 8.5 μm channel gives another piece of microphysical information that we argue gives information on the dominant ice crystal habit at cloud top. [*in the context of P. Yang's scattering database*]

- Knowledge of ice habit can lead to a better physical understanding of the spectral inconsistency between VIS and IR cloud properties.

- With the 8.5 μm channel, VIIRS can derive cirrus properties that are day/night independent and suffer no terminator effects.

- This use of 8.5, 11 and 12 μm data is similar to that in the GOES-R AWG cloud algorithms. Our goal is implement this on VIIRS and ***provide a seamless set of cirrus observations.***