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Impact of Missing Absorption Channels on Infrared-based Cloud-Pressure Retrievals on VIIRS Relative to MODIS *(& GOES-R)*

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Goal

• Answer the question. What are the consequences on the cloud-top pressure estimation uncertainty on the IR channels used on VIIRS relative to MODIS and GOES-R?

• Conduct this analysis in a way that is insensitive to any particular algorithm.

Motivation

• Cloud vertical extent (Height/Pressure/Temperature) is a often studied parameter in various cloud climatologies.

• It's important in predicting the IR radiative budget of clouds

• Cloud-top pressure from MODIS and GOES is being assimilated in multiple NWP models.

•CrIS is available for half of the VIIRS data but at a lower spatial resolution. VIIRS 1km cloud height products remain important.

Outline

- Review of the VIIRS IR spectral information for cloud remote sensing relative to that from MODIS.

- Methodology for computing the solution space for IR cloud height algorithms

- Demonstrate impact of absorption channels on the cloud pressure solution space for one scene.

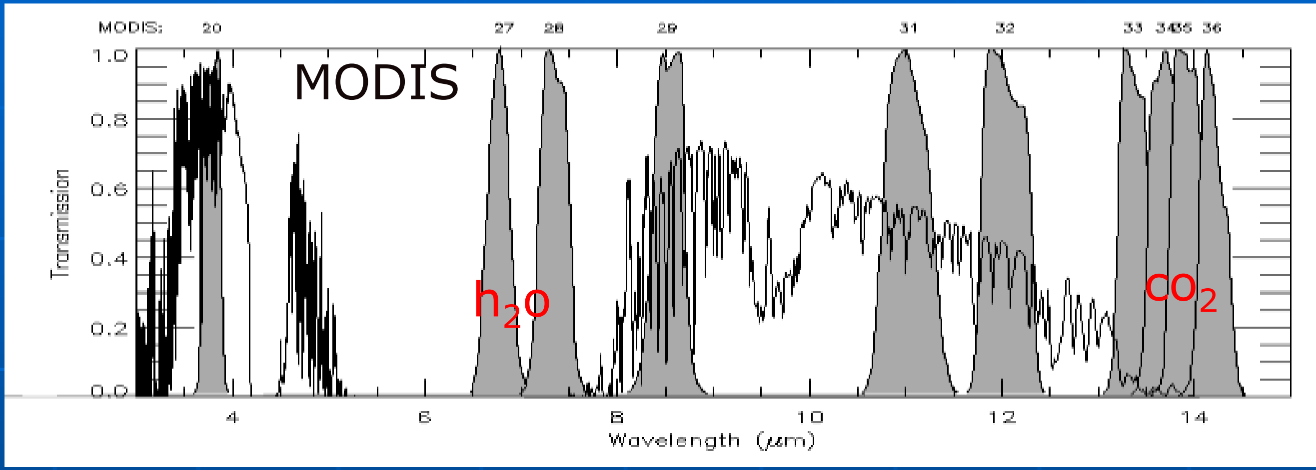
- Conclusions

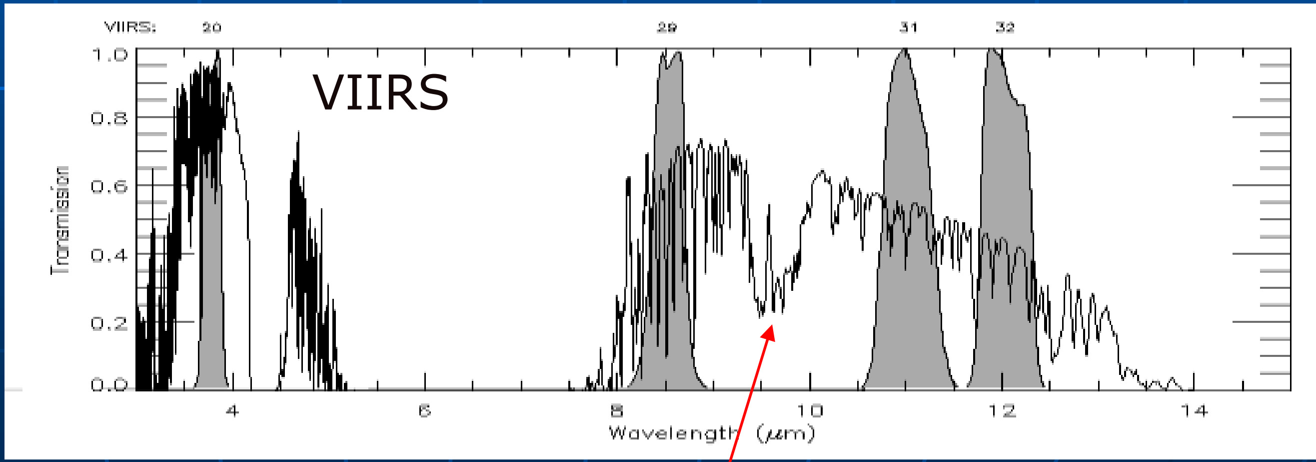
Spectral Differences in IR bands used for Cloud Remote Sensing

- MODIS 06 cloud top pressure was derived using the 15 μm CO2 channels 33-36 and channel 31 (11 μm)

- VIIRS was designed without any channels situated in CO_2 or H_2O IR absorption bands. VIIRS specs for cloud-pressure are 40-65 hPa.

- GOES-R ABI will provide one CO_2 channel similar to Channel 33 on MODIS and three H_2O IR bands.

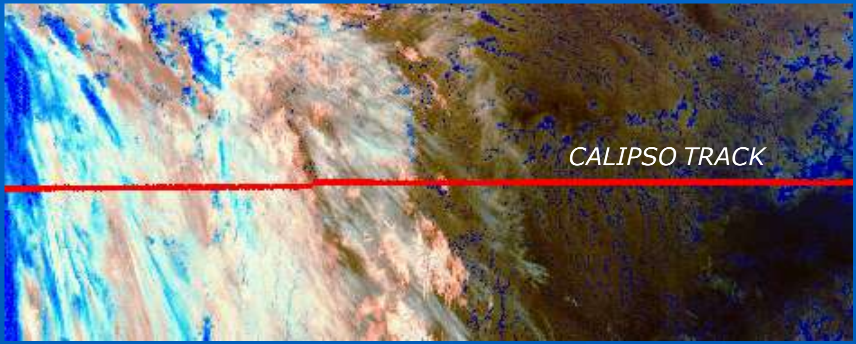




Nadir clear-sky transmission

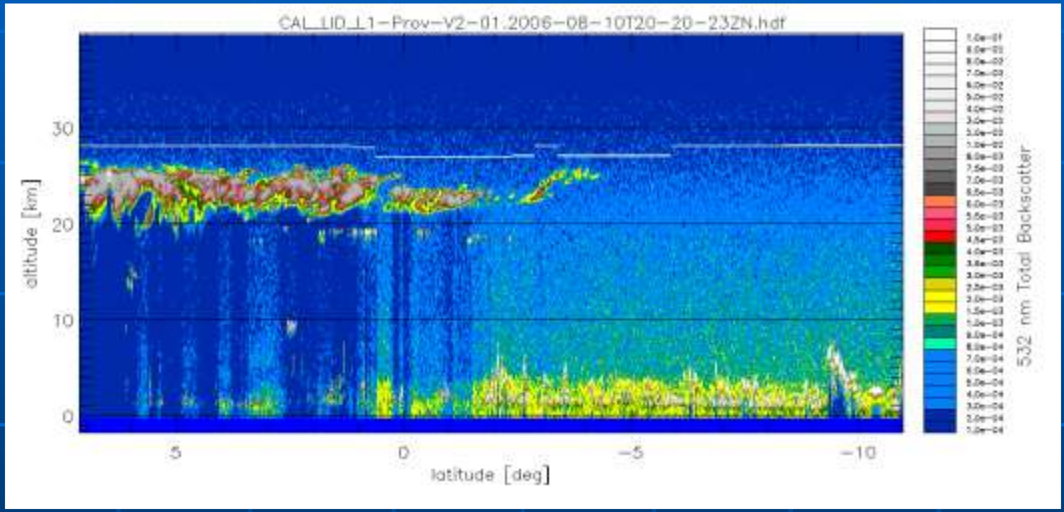
Data

To illustrate the solution space offered by the VIIRS and other infrared cloud height approaches, we focus our attention on one arbitrary nighttime granule from AQUA/MODIS during the CALIPSO era. (*August 10, 2006 20:35 over the Indian Ocean*)

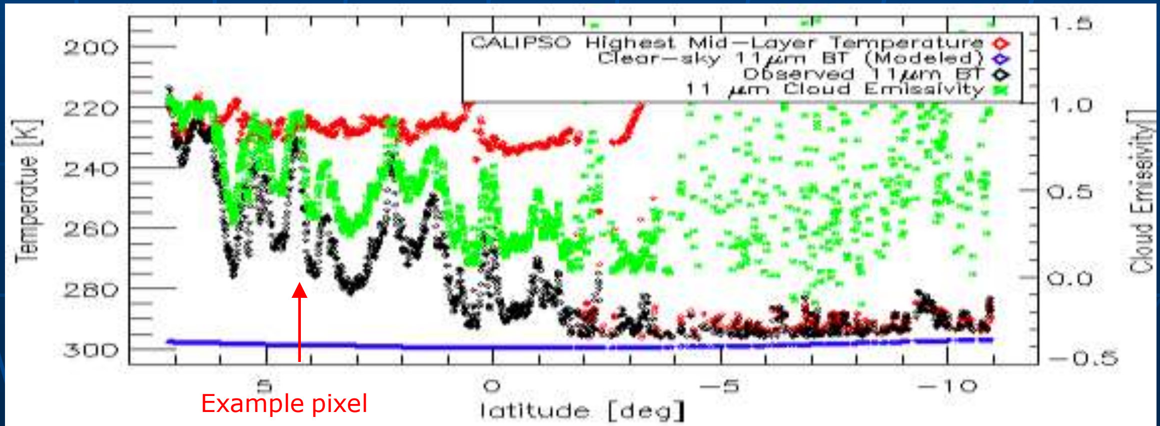


• False color image using 3.75, 11 and 12 μm observations (*cirrus are whitish*)

• 532 nm total backscattering image



•cross-section of CALIOP cloud temperature, observed 11 μm BT, clear-sky 11 μm BT and derived 11 μm cloud emissivity using CALIOP cloud boudaries.



•We focused on ice clouds here only. We used the MYD06 IR phase product to accomplish this.

•CALIPSO co-locations and data provided by the Atmospheric PEATE (Bob Holz and Fred Nagle)

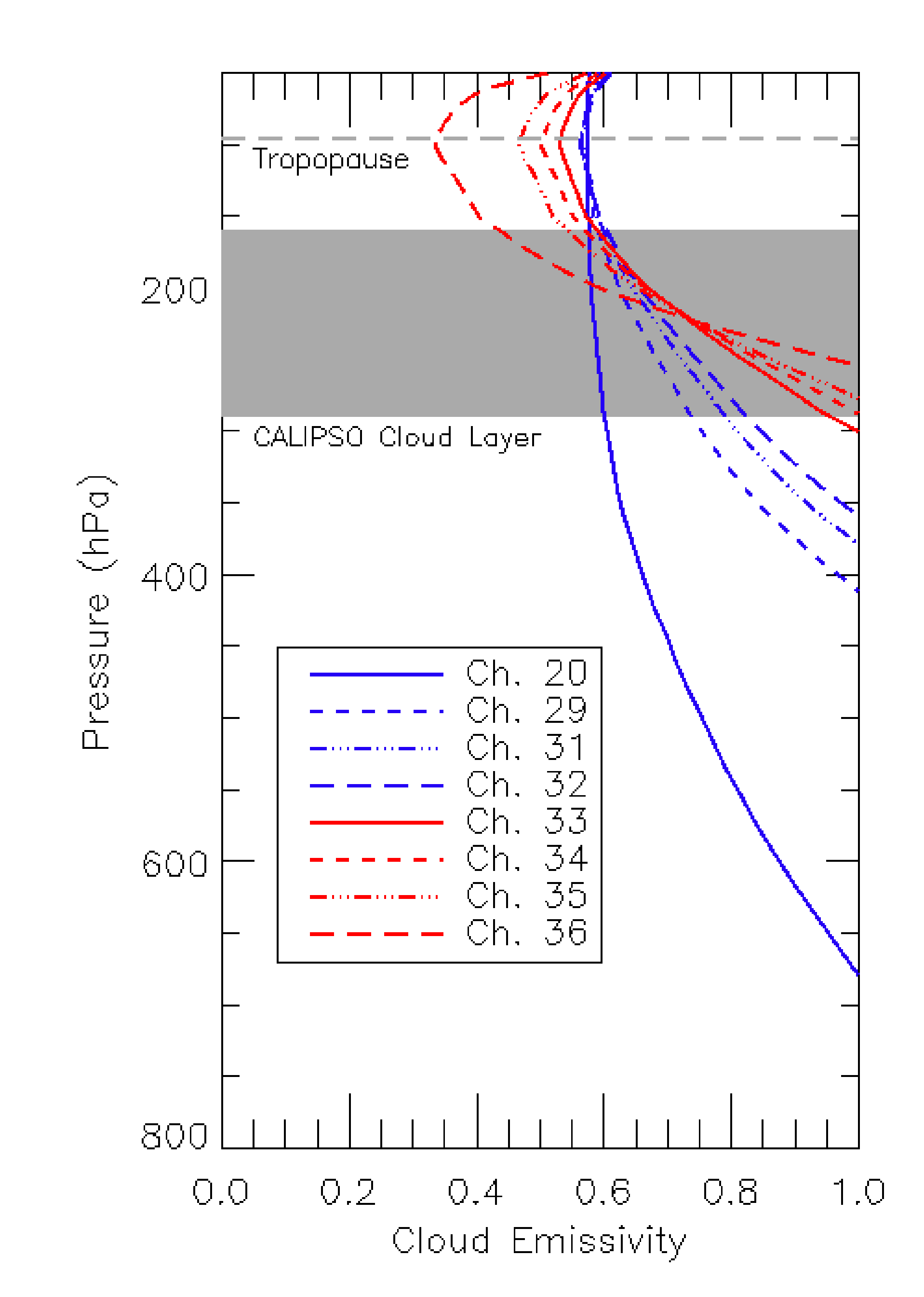
Methodology Part 1

- The following slides demonstrate a methodology to define the solution space (*region of the atmosphere*) where a cloud can be placed and match all of the observations used in the particular retrieval.

- These results are for one pixel in the previous granule along the CALIPSO track where CALIPSO detected a cloud between 160 and 290 hPa and derived 11 μm emissivity was about 0.6.

- For an individual channel, the cloud pressure solution space is defined as any pressure where the cloud emissivity profile is between 0 and 1.

$$e_c(p) = \left(I - I_{clr}\right) \Big/ \left(I_{bb}(p) - I_{clr}\right)$$



Methodology Part 2

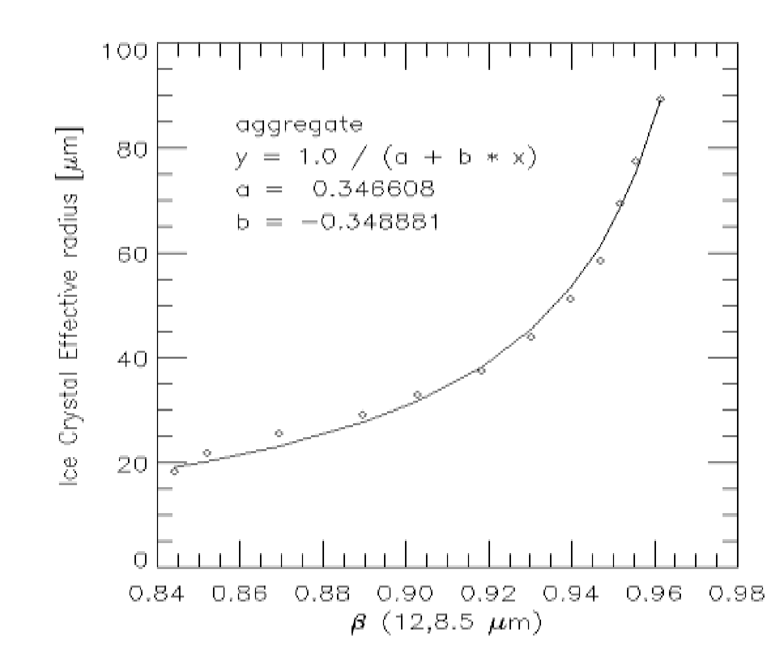
• Emissivities from multiple channels can be related to each other using the β parameter (analogous to the Angstrom Exponent) which is commonly used in IR remote sensing and is defined as:

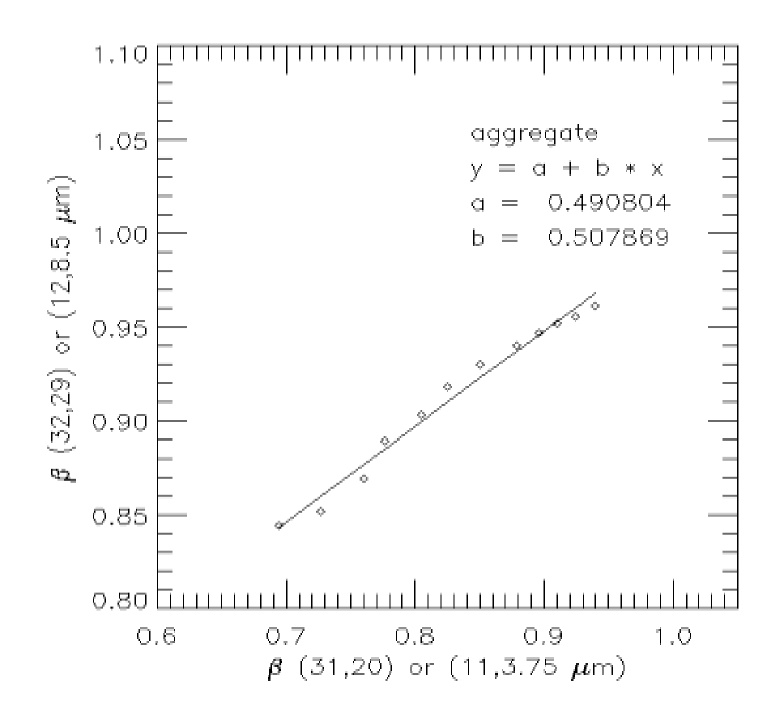
$$\beta_{x,y}(p) = \ln(1-e_{c,y}(p)) \Big/ \ln(1-e_{c,x}(p))$$

• β is solely a function of single scattering properties and is therefore directly related to particle size given an assumption of the crystal habit.

• We assume aggregates and use the IR scattering properties from Professor Ping Yang of TAMU.

• Once a scattering model is assumed (i.e. a habit or mix of habits), β values from different channel combinations are constrained to follow a predetermined relationship.





Methodology Part 3

- The VIIRS approach uses the 3.75, 8.5, 11 and 12 μm channels on VIIRS which are similar to Channels 20, 29, 31 and 32 on MODIS

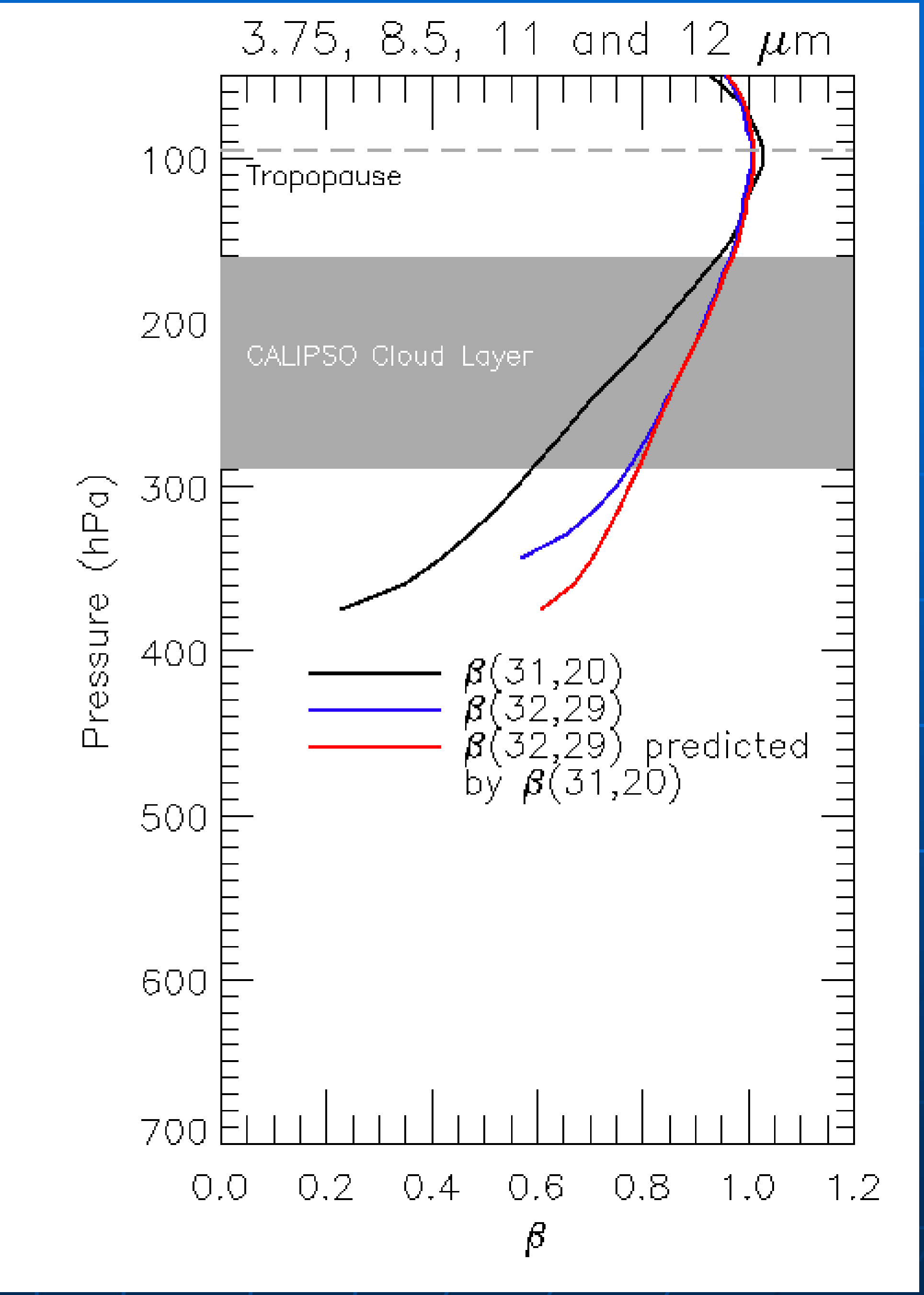
- The NGST approach uses a β value based on channels 31 and 20 and a β value based on channels 32 and 29.

- The image on the left shows the β profiles computed from the emissivity profiles on the previous slide.

- Using the β relationships predicted for aggregates, we can used the β(31,20) profile to predict what the β(32,29) profile should be.

- Where the predicted and observed β(32,29) profiles agree defines the cloud pressure solution space. This shown where the blue and red lines are close to each other.

- Within this space, all of the derived channel emissivities are valid and the β values are consistent with the chosen microphysical model.

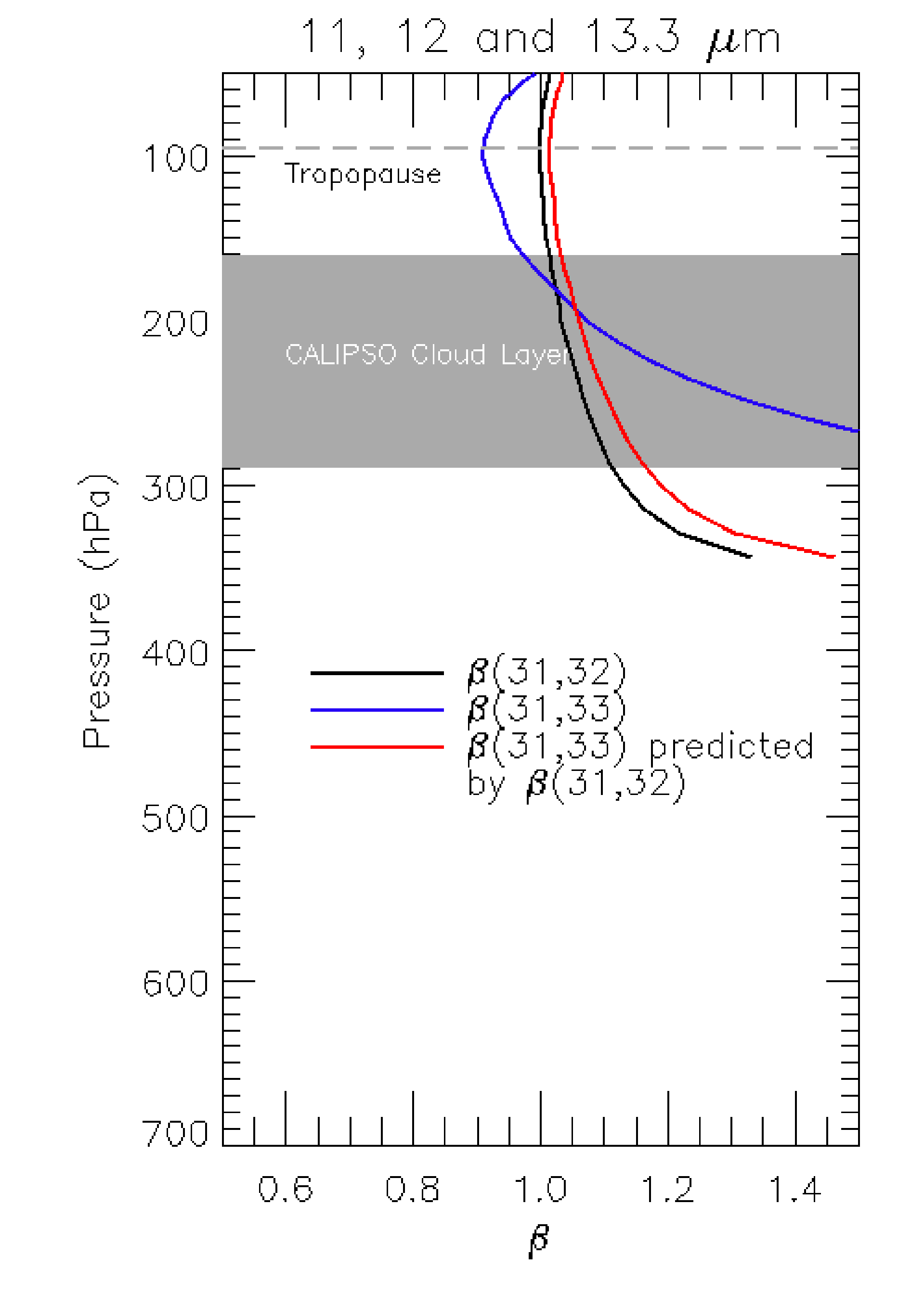


Methodology Part 4

- In contrast to the VIIRS channel set which only uses IR window channels, when a absorption channel is used, the solution space shrinks (which is good).

- In this example, the 11, 12, and 13.3 mm or MODIS channels 31,32 and 33 are used.

- Here, the observed (red) and predicted (blue) β curves are close together over a smaller solution space.



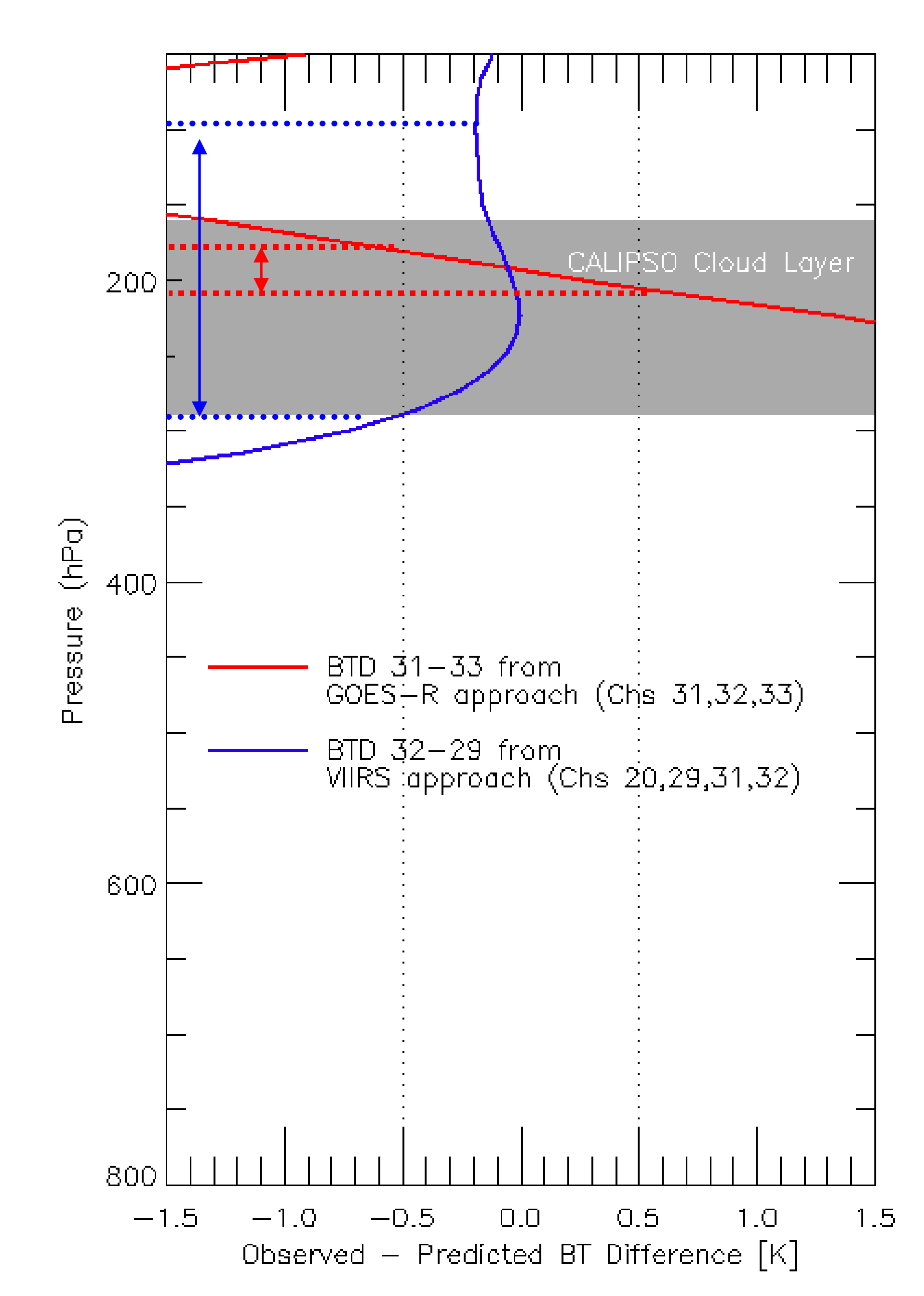
Methodology Part 5

- A small solution space means that the channel set is very sensitive to variations in cloud pressure (good)

- To objectively compute the cloud pressure solution space, we defined the solution space as the region where the predicted brightness temperature difference was within 0.5K of the level where it agreed most with the observations.

- For the example on the right, the solution space spanned by the GOES-R approach is much smaller than that spanned by the VIIRS approach.

- The 0.5K is arbitrary



Depth of Solution Space Compared to CALIPSO Cloud Boundaries

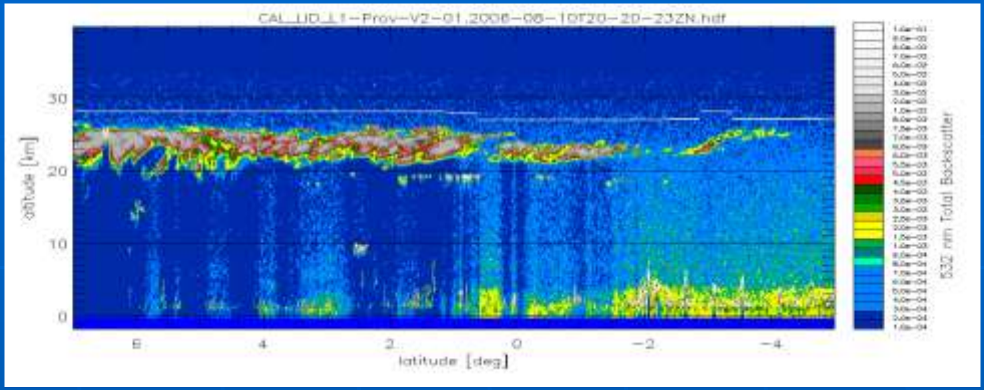
- The figures on the right show the variation in the pressure depth of solution space for ice cloud portion of the granule shown previously.

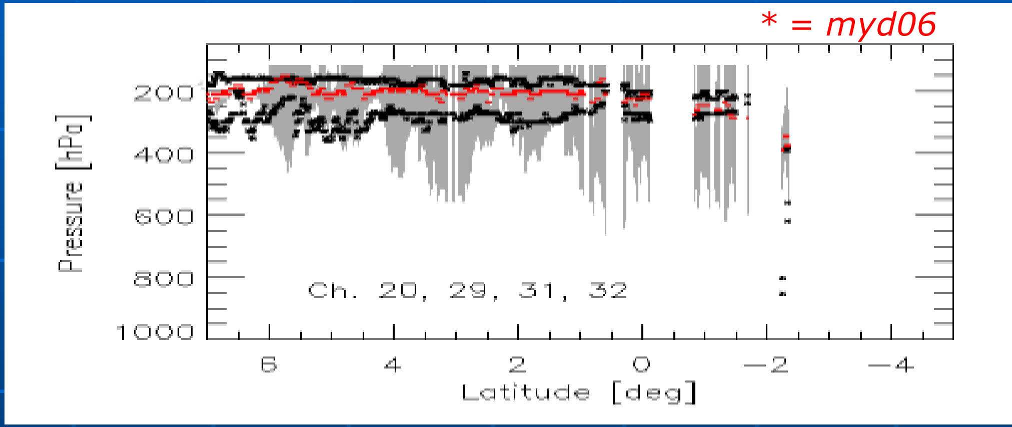
- The grey regions are those that are within the solution space spanned by the particular channel set.

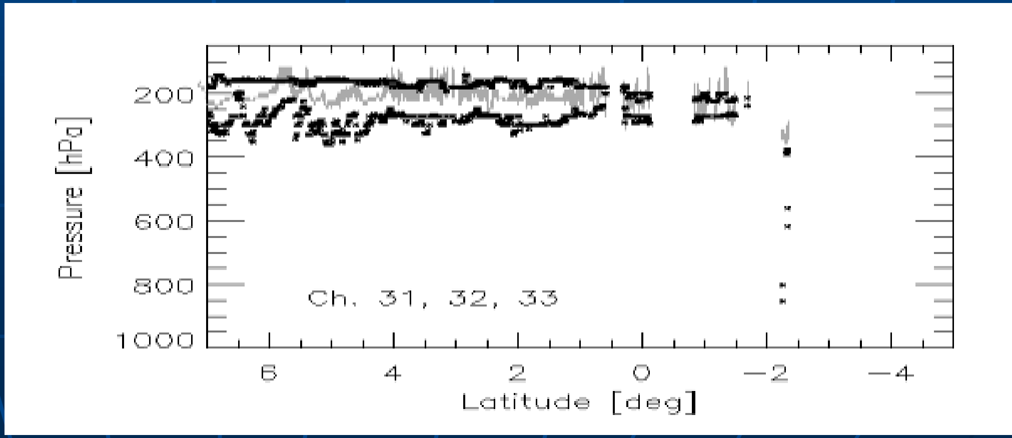
- The CALIPSO cloud boundaries of the highest cloud layer are plotted as the black symbols.

- Based on this data, the depth of the solution space offered by the GOES-R ABI (Ch 31,32,33) channels is much smaller than offered by the VIIRS channels (Chs 20, 29, 31,32)

- This analysis applied to the individual CO_2 slicing pairs give similar results to the GOES-R channels.





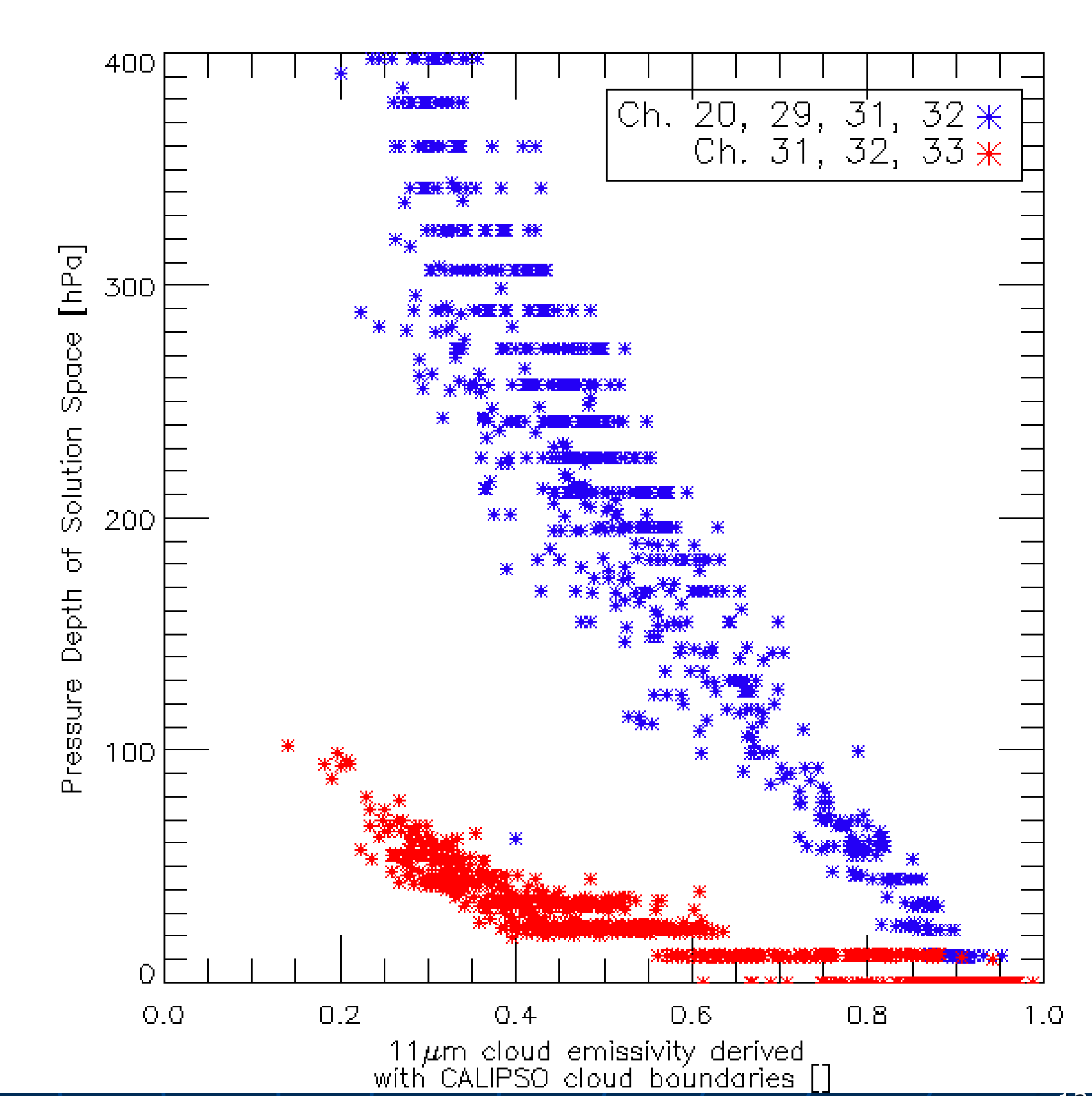


Correlation of Depth of Solution Space with Cloud Emissivity

- As expected, the pressure depth of the solution space is highly correlated with the cloud emissivity.

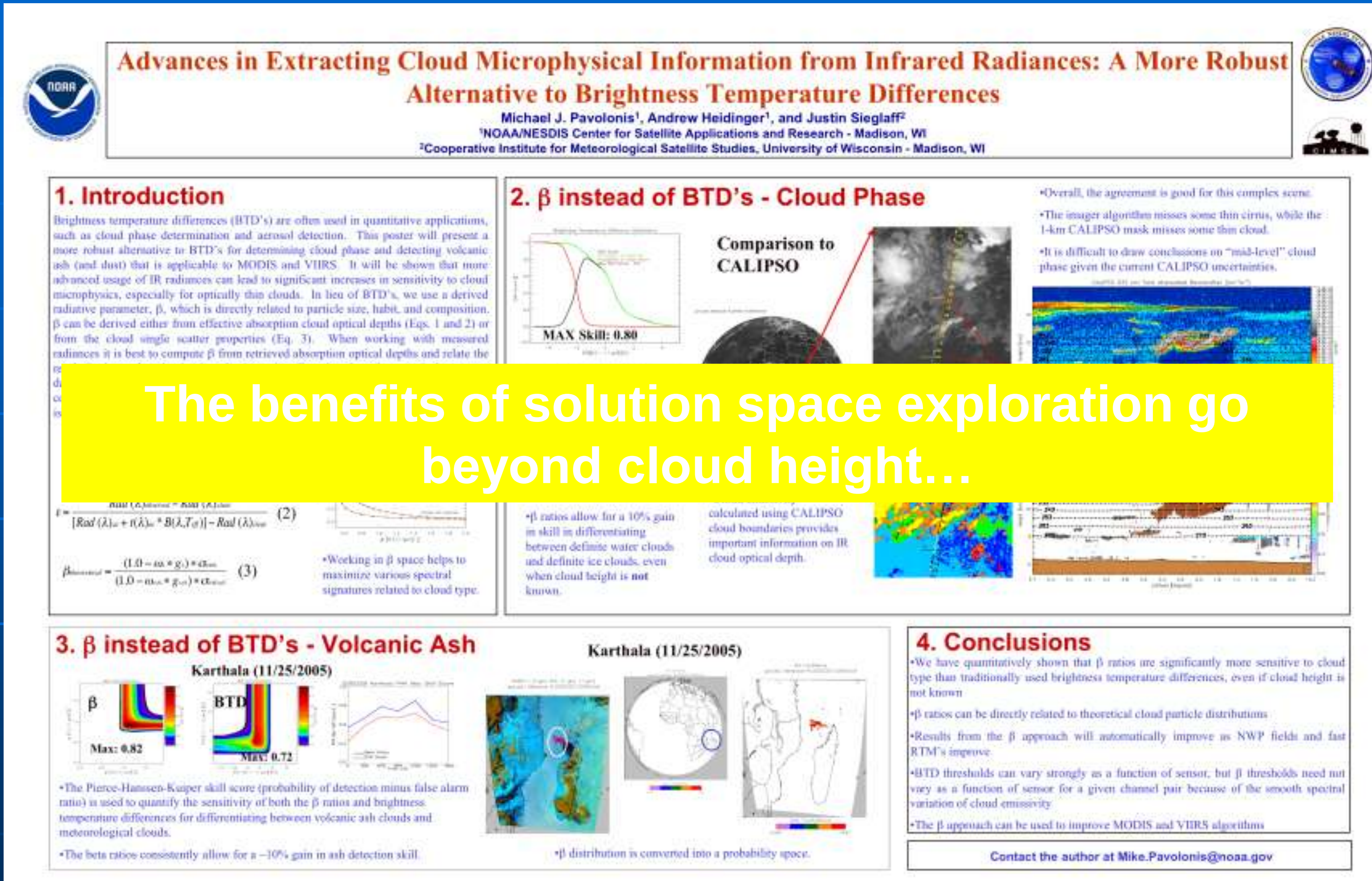
- Cloud emissivity was derived using the MODIS Ch 31 radiance, clear-sky radiance estimates and the CALIPSO cloud boundaries.

- This analysis points to lack of cloud height sensitivity for window-based solutions for optically thin clouds.



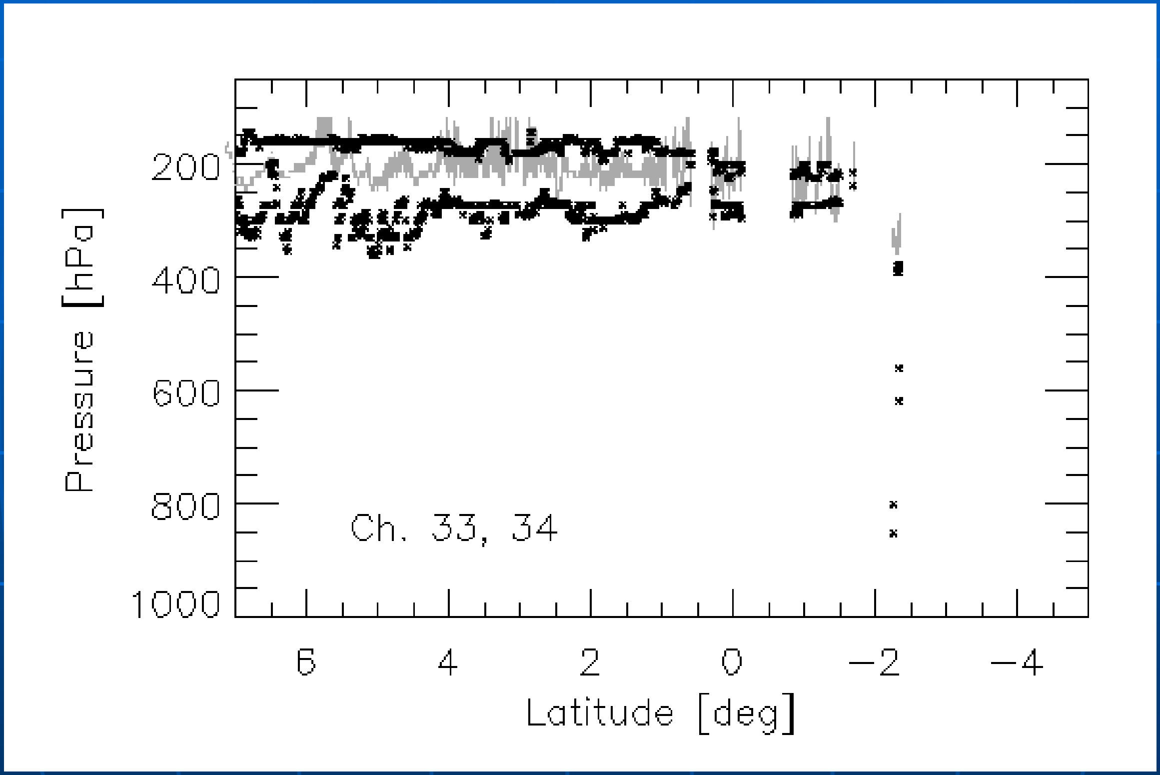
Conclusions

- The lack of IR channels in absorption bands has a large impact on the sensitivity to cloud height provided by VIIRS.
- The inclusion of a single (*albeit weak*) 13.3 CO_2 absorption channel on the GOES-R ABI greatly increases the sensitivity to cloud height. MODIS with multiple CO_2 channels is even more sensitive.
- Therefore, expect a large discontinuity in the cloud vertical extent climate record from MODIS to VIIRS. VIIRS will look more like AVHRR than MODIS in this respect.
- The 3.75 μm channel did not seem to help narrow the VIIRS solution space. Therefore, an algorithm that can run with 8.5, 11 and 12 μm channels in day/night consistent manner may be preferable.
- Note this analysis is purely looking at the information content from a single pixel. ***Algorithms can do better than the performance shown*** here by using other information (channels from a sounder, spatial statistics etc).
- While cloud height sensitivity is small, the IR ***window channels do provide very good measures of emissivity and microphysics***. We are developing ways to do this for the MODIS record from our support from NASA/ROSES which commences this summer.



The benefits of solution space exploration go beyond cloud height…

End of Presentation


Pressure [hPa]
200
400
600
800
1000
Ch. 33, 34
6
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