Using the CRTM and GOES Observations to Improve Model Microphysics

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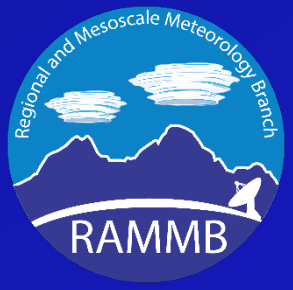


Outline

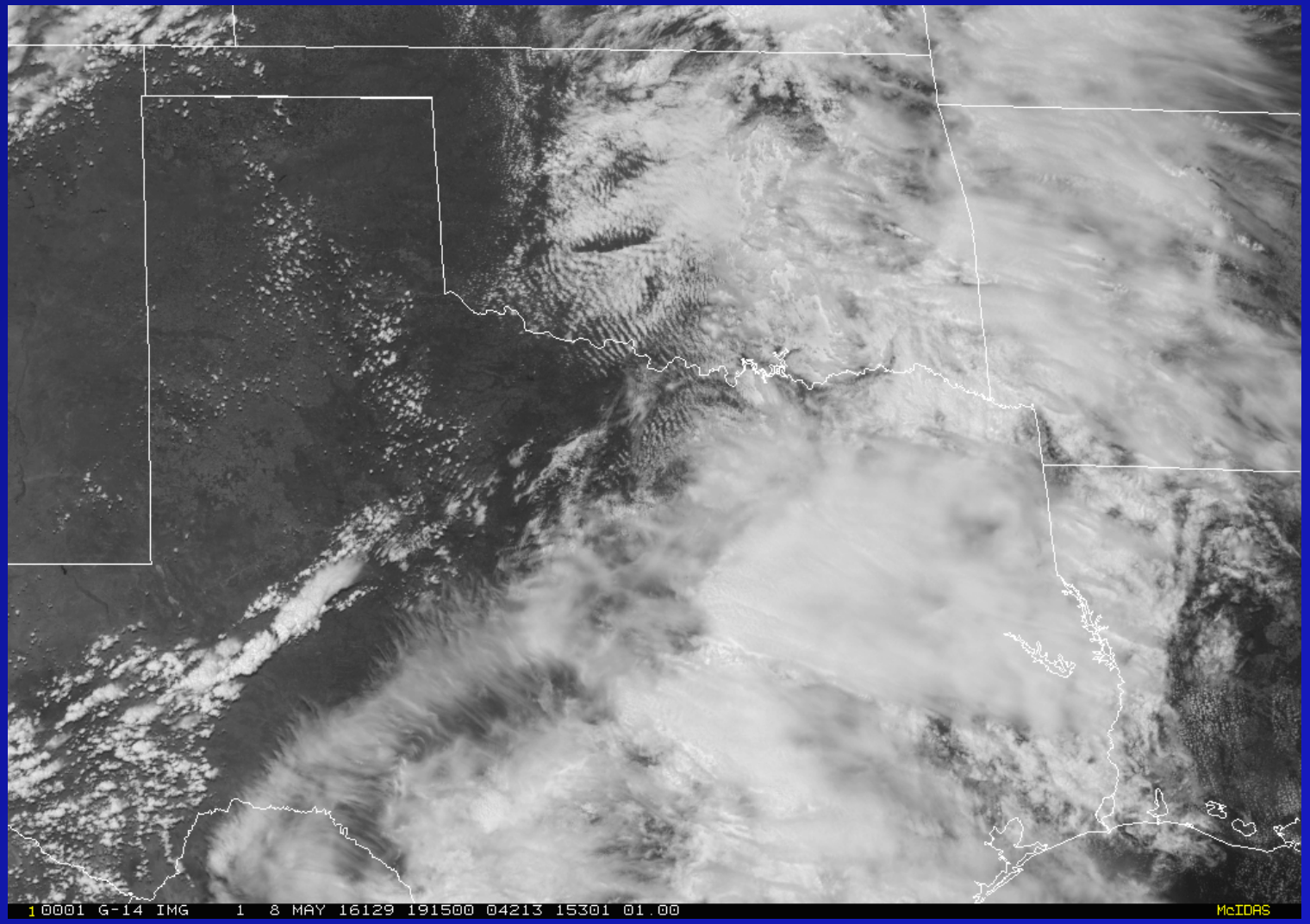
1. New Satellite Observations

2. Synthetic Satellite Imagery

3. CRTM Improvements

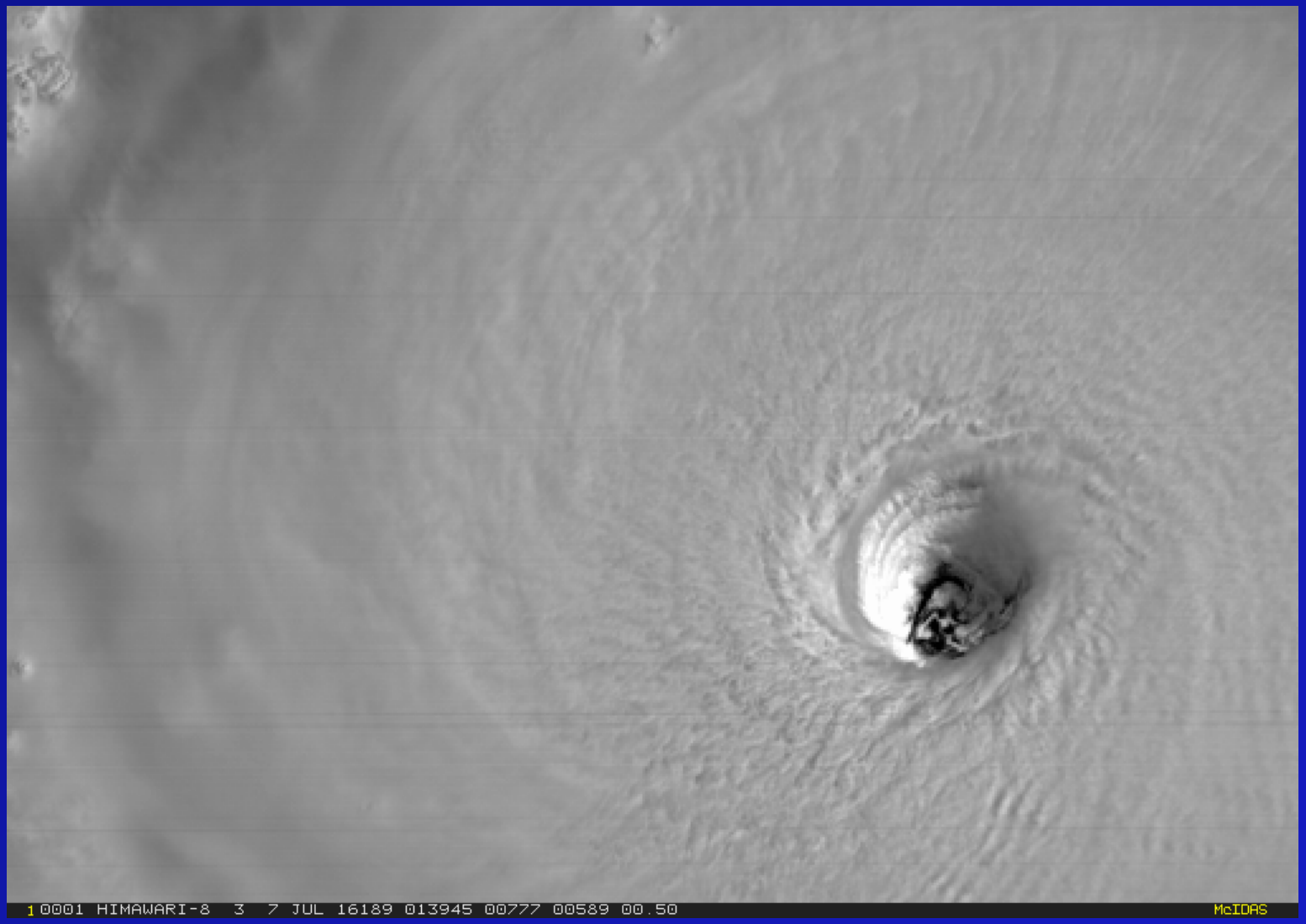
Lockheed Martin

New Satellite Observations



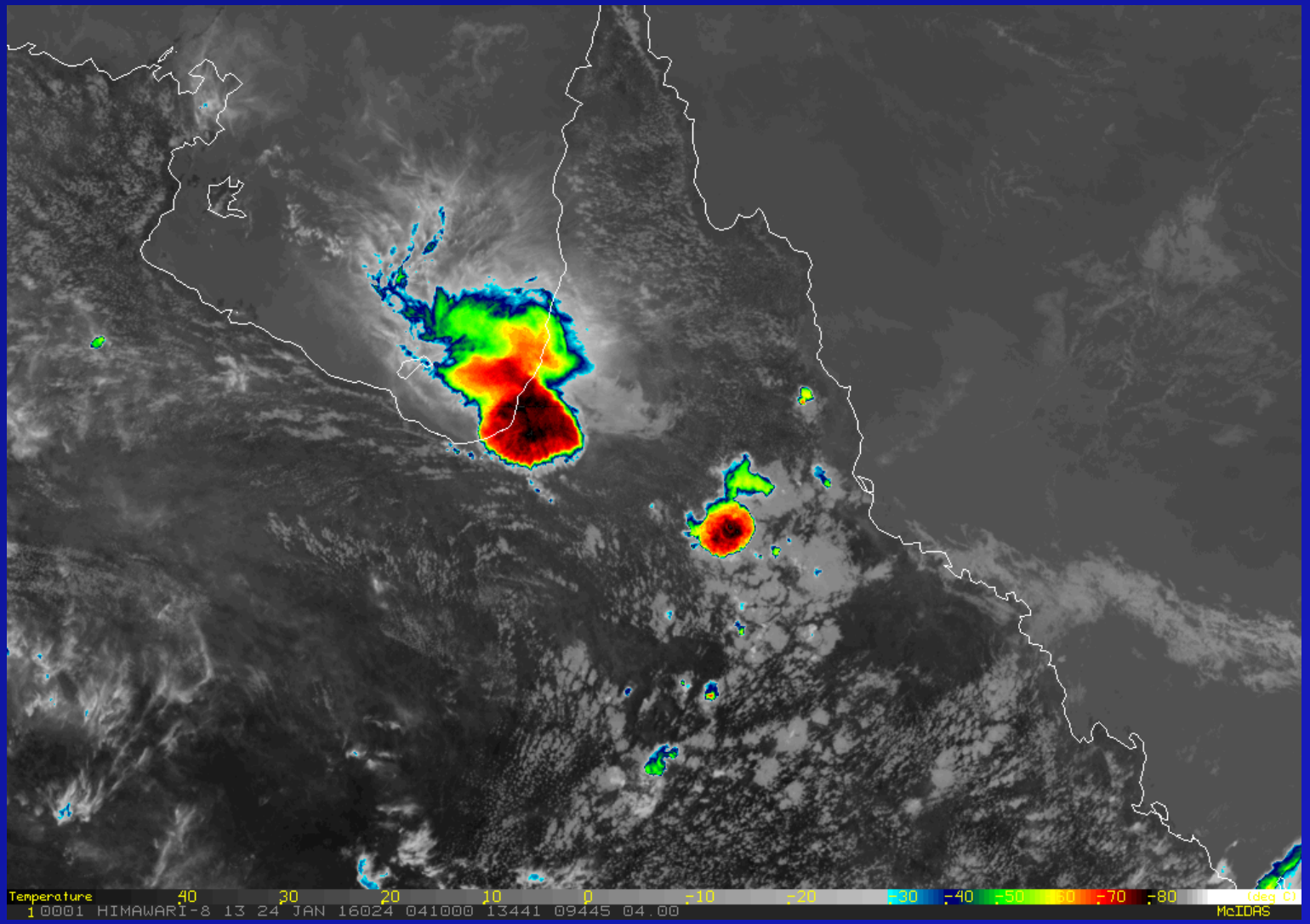
GOES-R will provide 1-min imagery over two mesoscale sectors. GOES-14 has been collecting occasional 1-min data for several years. This example is from 8 May 2016. GOES-R 1-min imagery will have four times better spatial resolution.

New Satellite Observations



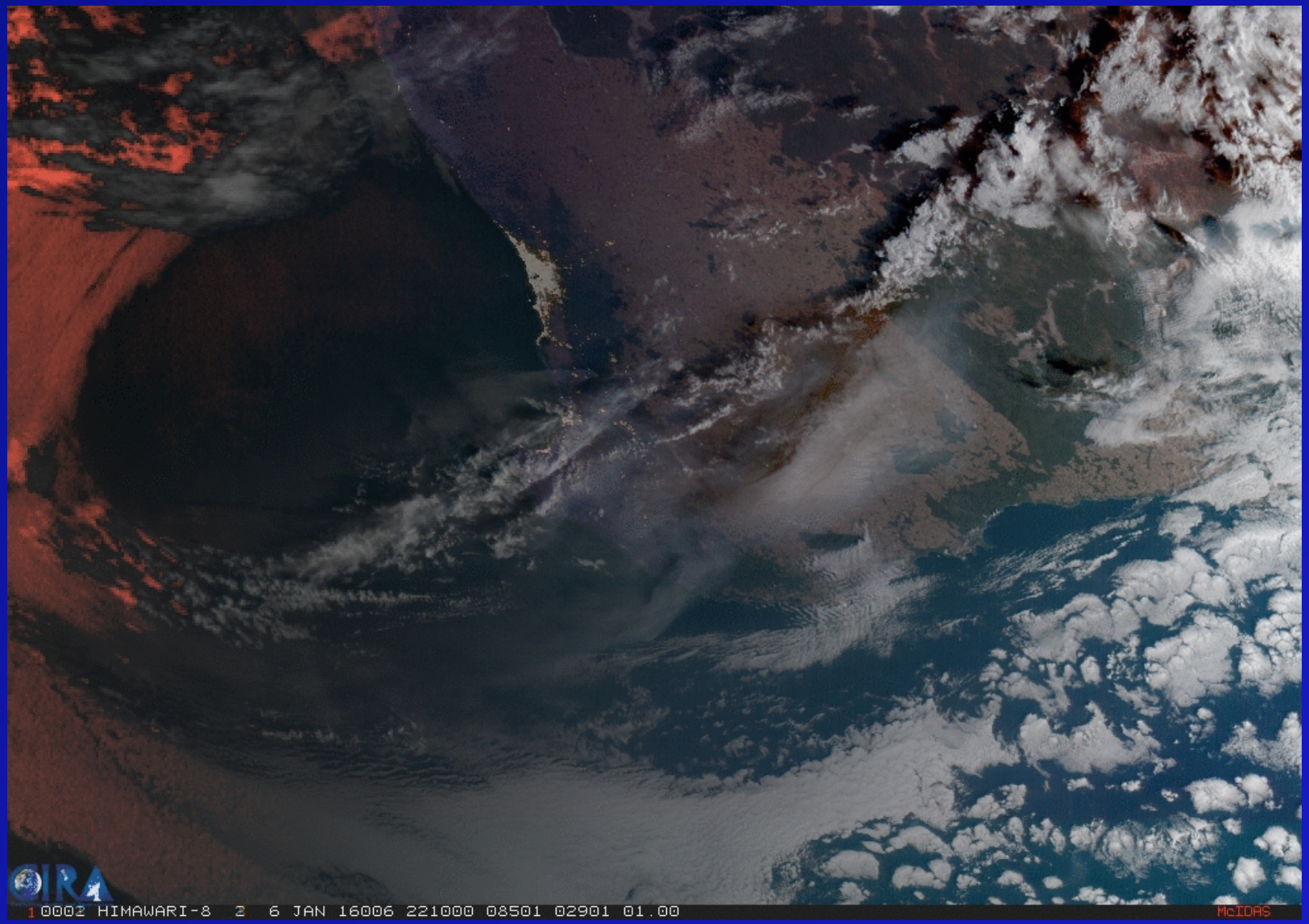
Himawari-8 was launched by the Japanese Meteorological Agency in late 2014. Its imager is quite similar to the GOES-R ABI, and therefore provides the closest proxy to what we'll have over the western Hemisphere in less than a year. This example shows 2.5-min imagery at 500-m resolution of Super Typhoon Nepartak from a couple weeks ago.

New Satellite Observations



This examples shows the Himawari 10.4 µm window IR band (2-km resolution) from 24 Jan. 2016 over northeast Australia

New Satellite Observations



Himawari-8 allows for true color imagery every 10 mins during the day. This example is CIRA's Geocolor product over southwestern Australia on 6 Jan. 2016.

New Satellite Observations

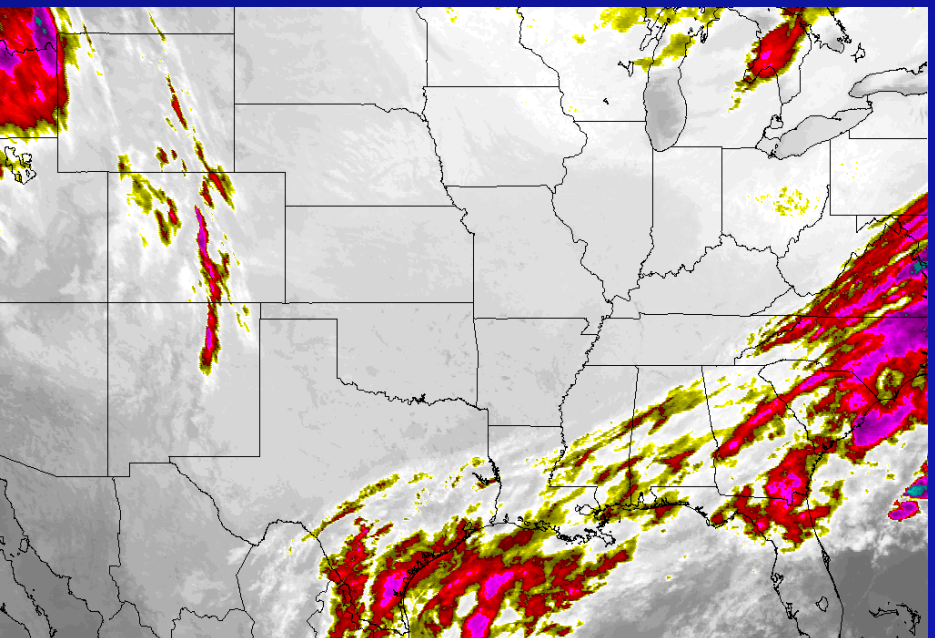
The big question is this:

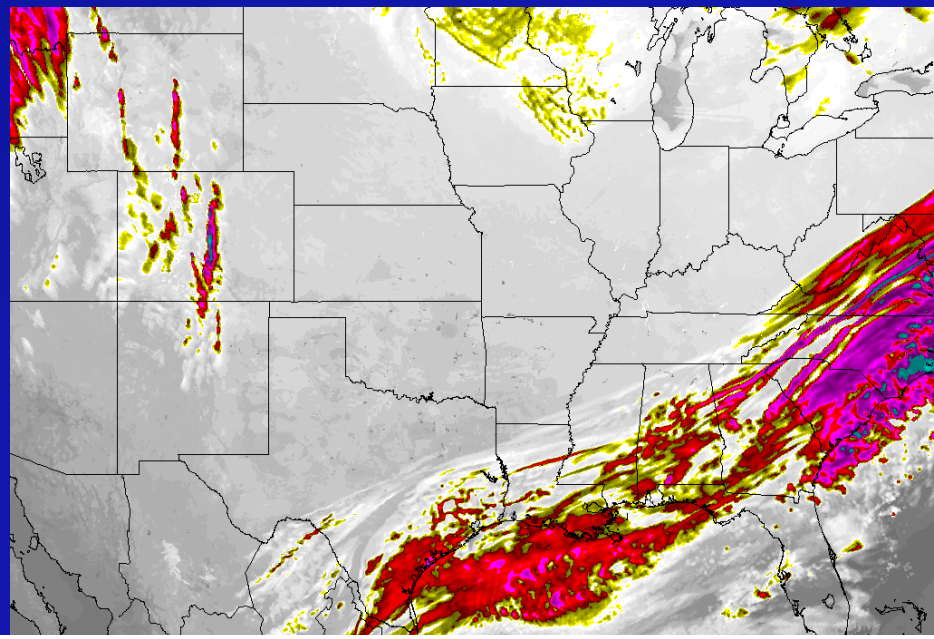
In addition to using these amazing new satellite observations in a qualitative manner, how can they be used *quantitatively* to improve forecasts?

One possible answer: Data Assimilation

- This requires use of a radiative transfer model to simulate what radiance the satellite would see given a particular model-forecast state
- It is critical that the RTM and the model “play well” together

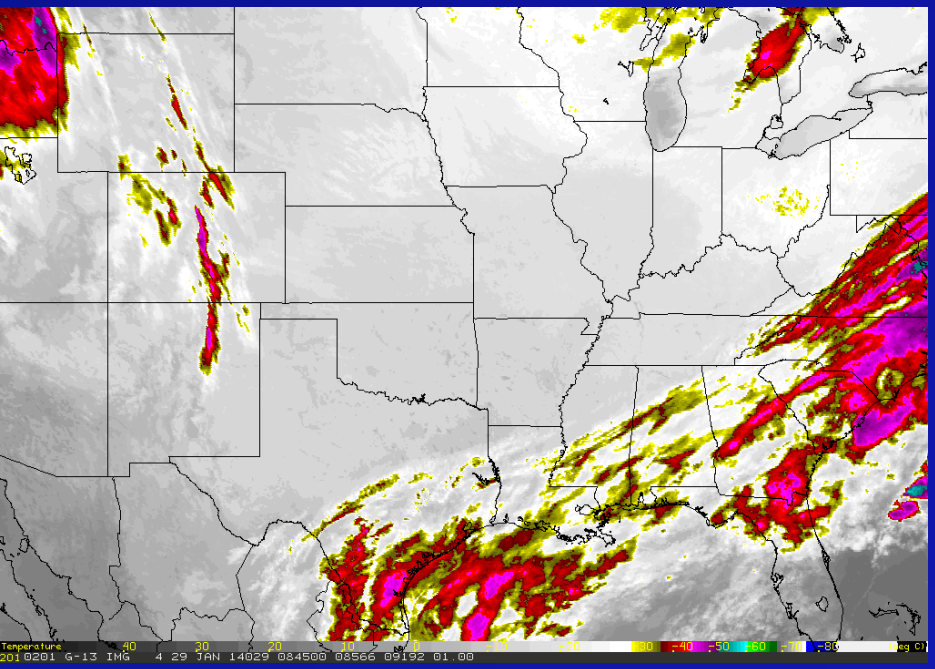
Synthetic Satellite Imagery



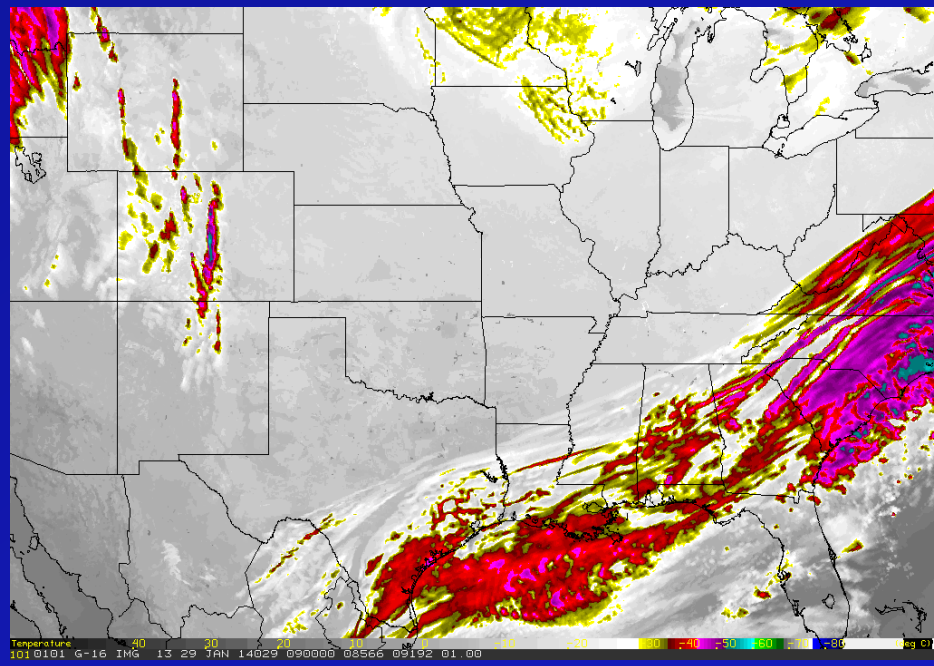


Which of these loops is actual satellite data, and which is simulated imagery based on a model forecast?

Synthetic Satellite Imagery

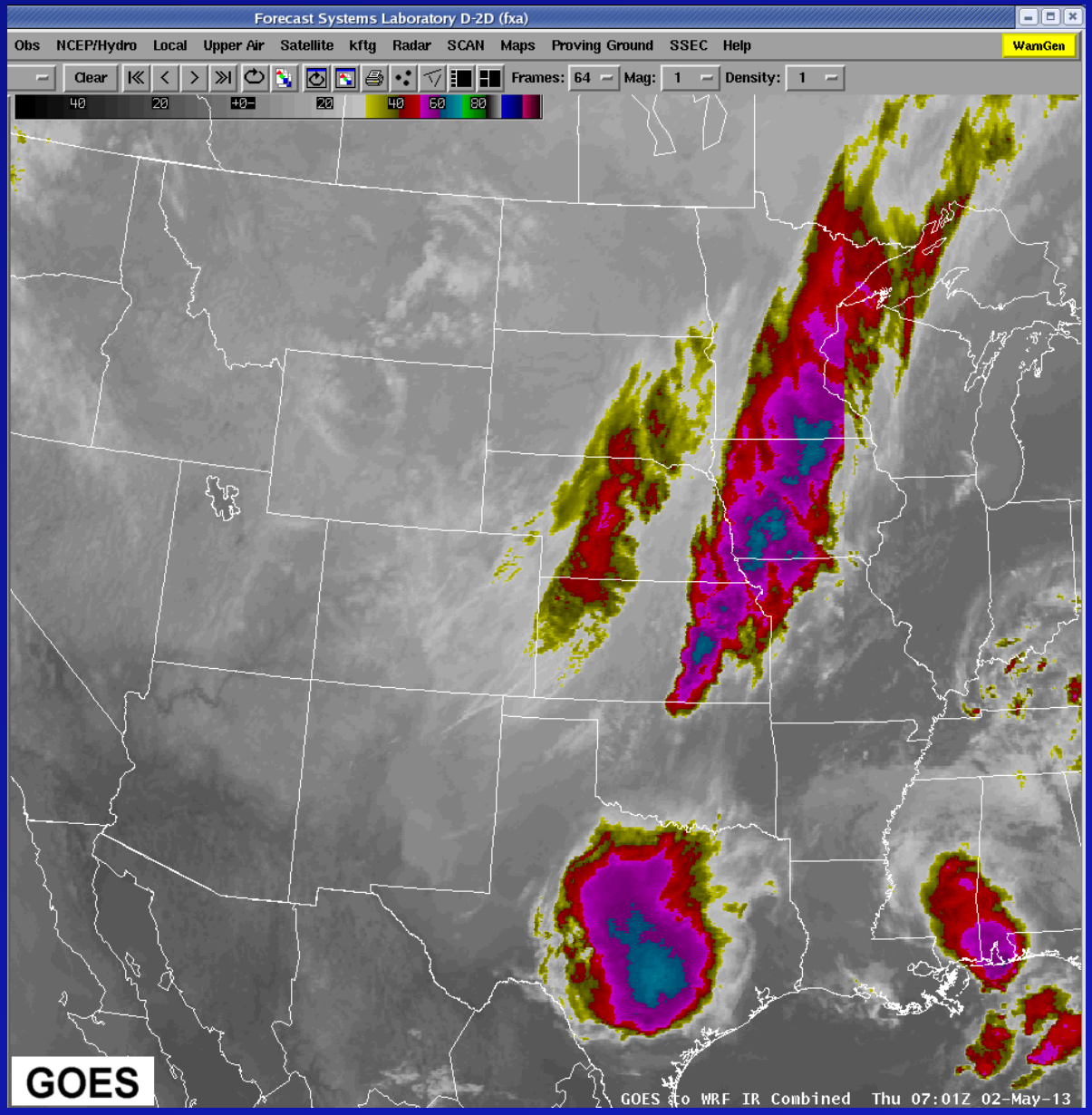


Observed GOES-13 data



Simulated IR Imagery based on a 9- to 23-hour forecast from the NSSL WRF-ARW

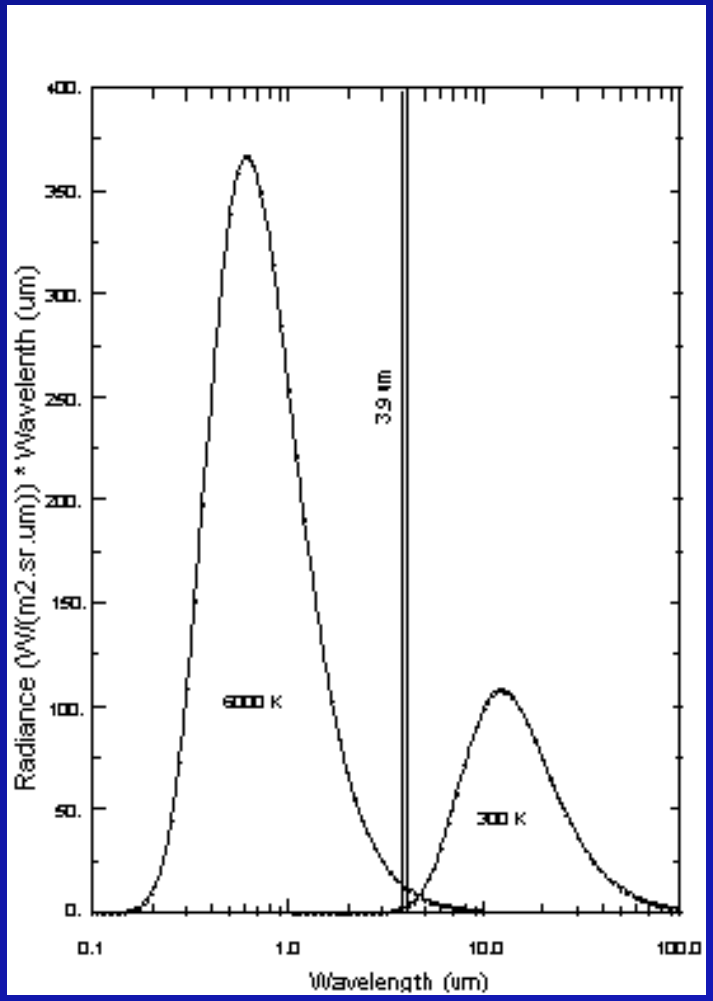
Synthetic Satellite Imagery

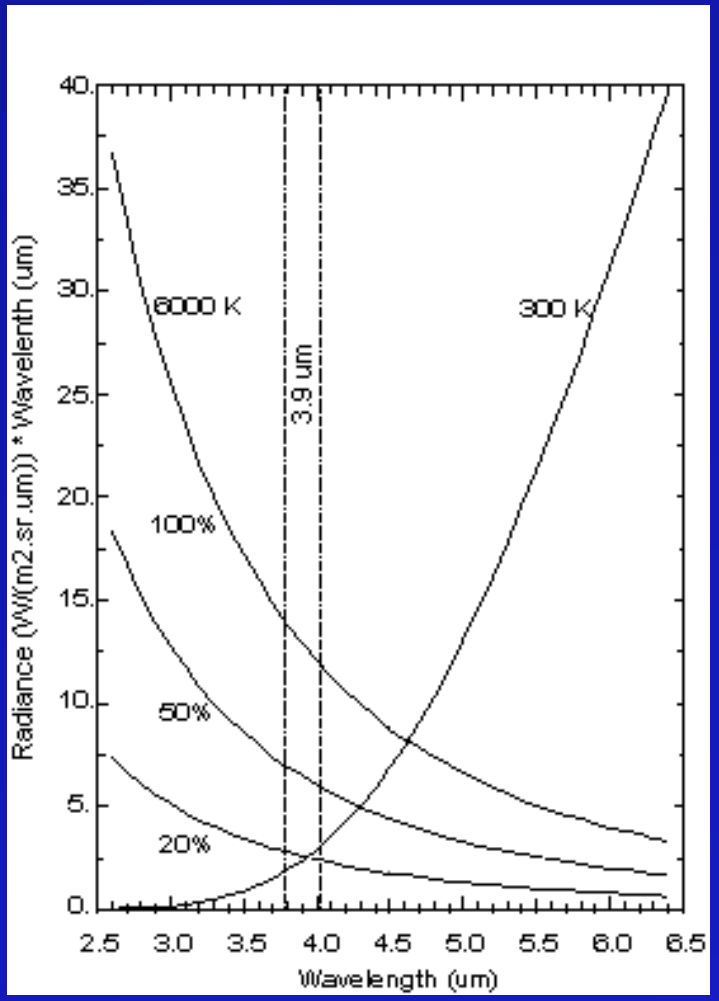


- Running a radiative transfer model using high resolution NWP output to generate synthetic satellite imagery has several applications
- From a forecaster's perspective, the most useful is the ability to view model-forecast clouds in terms of how it would look from GOES

Synthetic Satellite Imagery

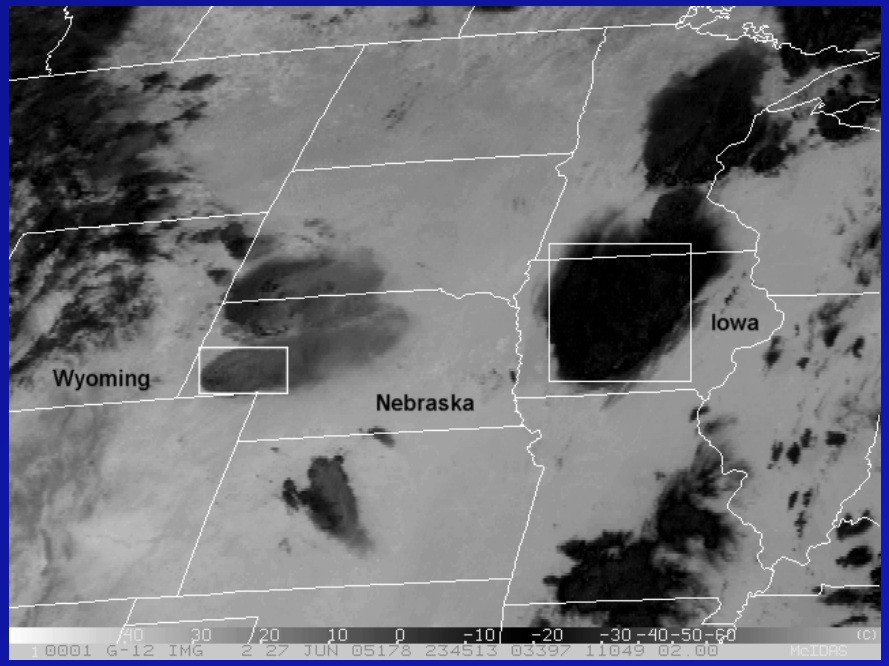
The GOES 3.9 µm Band



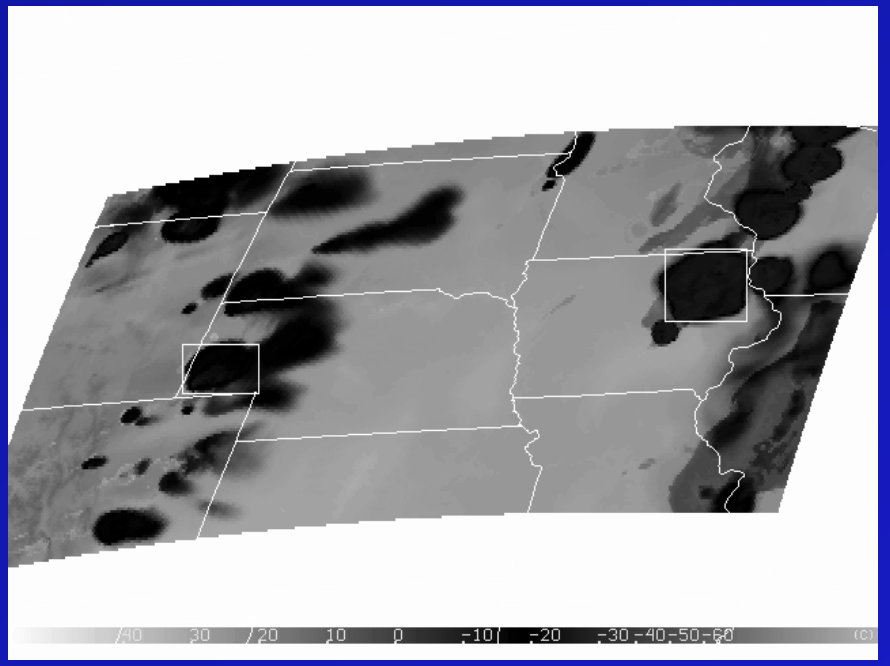


Synthetic Satellite Imagery

- A second benefit of synthetic imagery is to help evaluate NWP microphysics schemes



GOES-12 Observed 3.9 μm, 27 June 20015, 2345 UTC

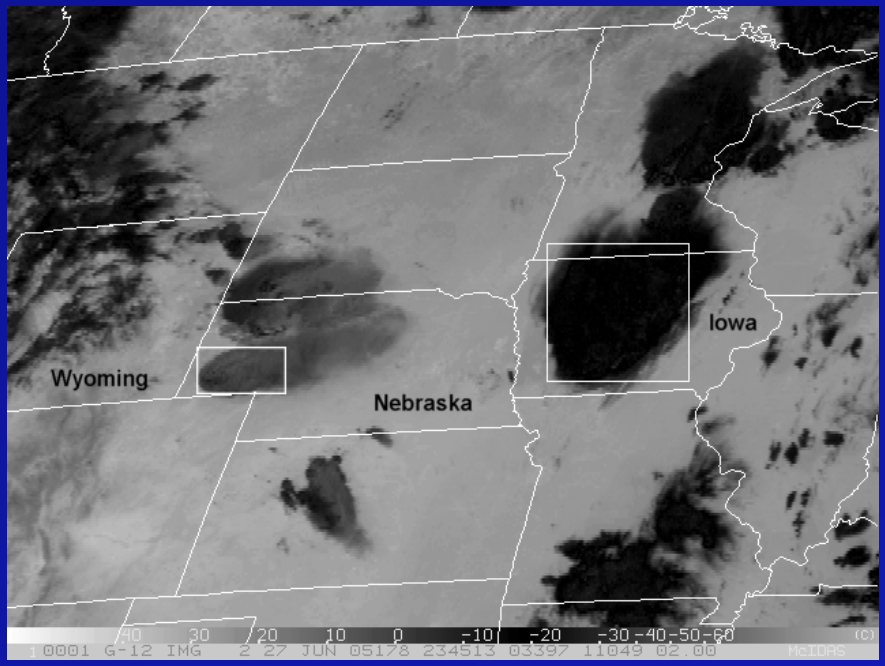


Simulated 3.9 μm based on a RAMS simulation of the 27 June 2005 case, using CIRA's RTM

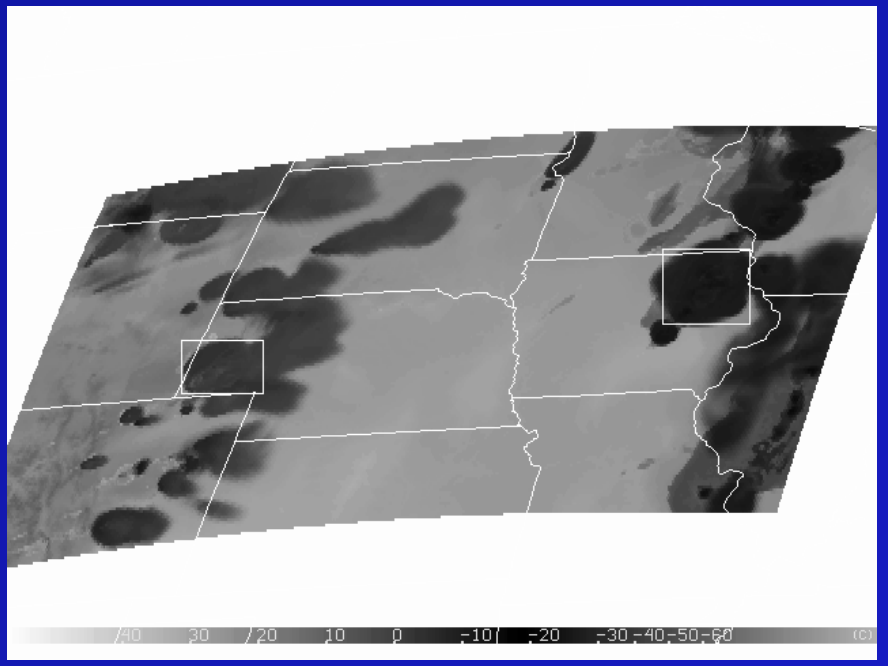
Grasso, L.D., D.T. Lindsey, 2011: An Example of the use of Synthetic 3.9 μm GOES-12 Imagery for Two-Moment Microphysical Evaluation. International Journal of Remote Sensing. 32:8, 2337.

Synthetic Satellite Imagery

- A second benefit of synthetic imagery is to help evaluate NWP microphysics schemes



GOES-12 Observed 3.9 μm, 27 June 20015, 2345 UTC



Simulated 3.9 μm based after fixing the bug discovered in the RAMS microphysics

Grasso, L.D., D.T. Lindsey, 2011: An Example of the use of Synthetic 3.9 μm GOES-12 Imagery for Two-Moment Microphysical Evaluation. International Journal of Remote Sensing. 32:8, 2337.

The Community Radiative Transfer Model (CRTM)

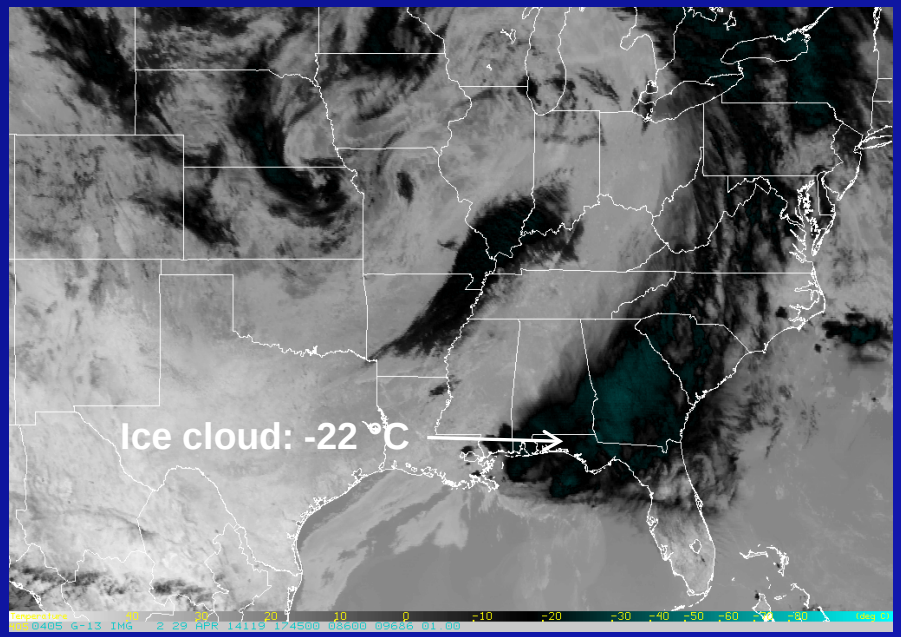
- The CRTM is currently used as part of GSI, the operational data assimilation system used by NCEP
- Although all-sky (including clouds) radiance assimilation is not yet being done in operations, it likely will be in the future
- It is therefore critical that the NWP microphysical output is consistent with that expected by the CRTM – here we investigate this connection

Comparisons between the CRTM (V2.1.3), and GOES-13 Observations

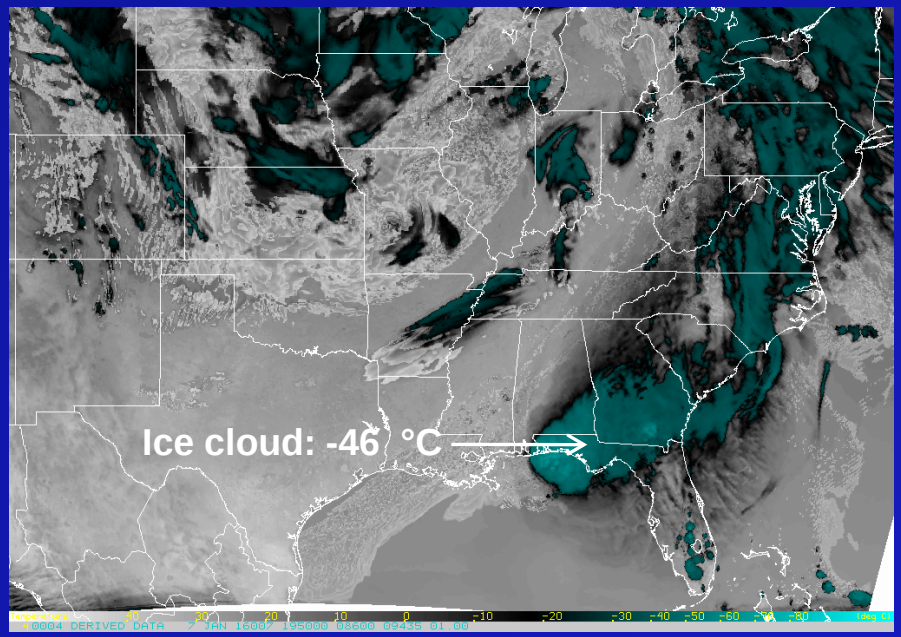
29 April 2014 – 18 Z – based on WRF forecast – Morrison microphysics

3.9 μm ABI band

GOES-13 Observations



CRTM



- The CRTM simulated 3.9 μm band is about 25 °C too cold
- Not enough solar 3.9 μm radiation is being reflected by ice clouds

So why are the CRTM simulated brightness temps too cold?

Possibilities include:

1) Incorrect optical properties of frozen hydrometeors used by the CRTM

2) Model microphysics output inconsistent with the optical properties expected by the CRTM
   - Particles may be too large – that would lead to lower 3.9 μm brightness temps
   - Distribution of the water mass among the ice species may not be supported by observations

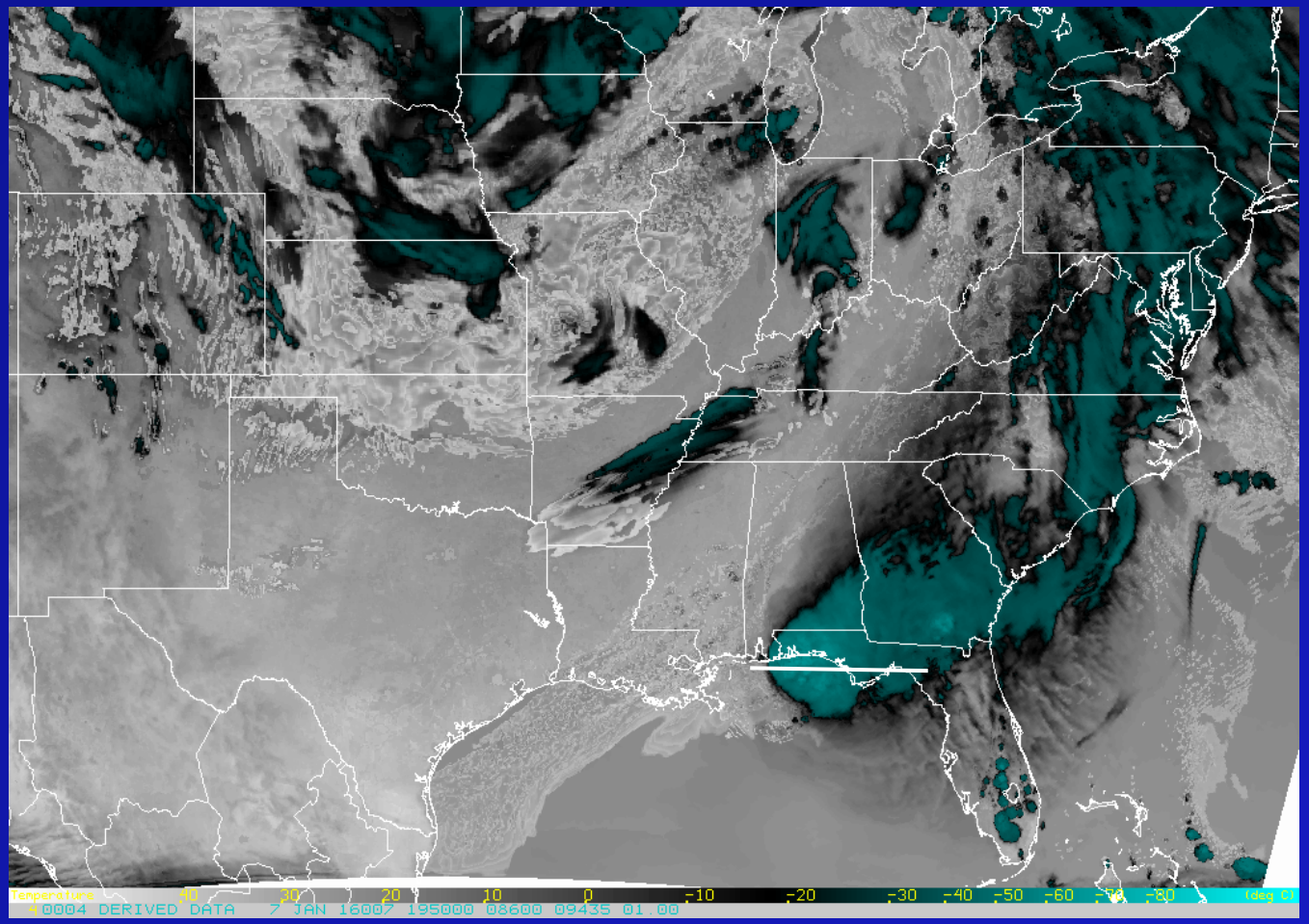
3) A bug in the CRTM solar reflection code

1) Incorrect optical properties of frozen hydrometeors used by the CRTM?

- The CRTM ice scattering table has entries at 3.67 μm and 4.5 μm, but nothing at 3.9 μm. Since the GOES 3.9 μm bandwidth is 3.8-4.0 μm, perhaps interpolation between 3.67 and 4.5 μm is leading to errors
- Tests were performed in which we used recent ice scatting properties from Ping Yang centered at exactly 3.9 μm, and the simulated brightness temps increased by about 3 ºC, not enough to match observations
- It's unlikely that incorrect assumed ice scattering properties is solely responsible for the differences between simulations and observations

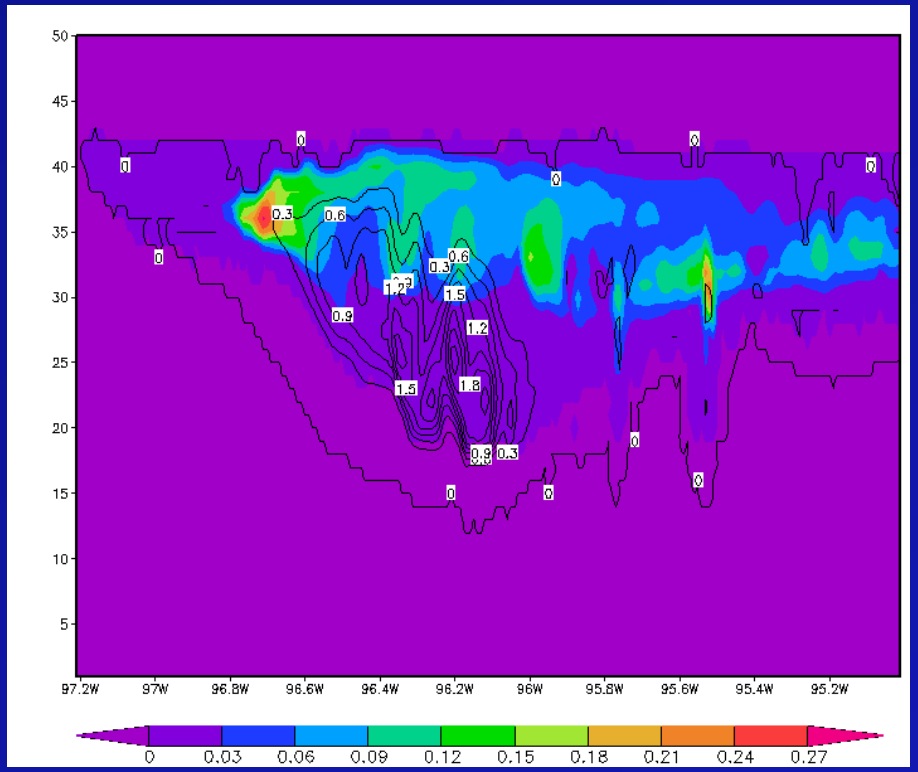
2) Model microphysics output inconsistent with the optical properties expected by the CRTM?

WRF output from the run using the Morrison scheme

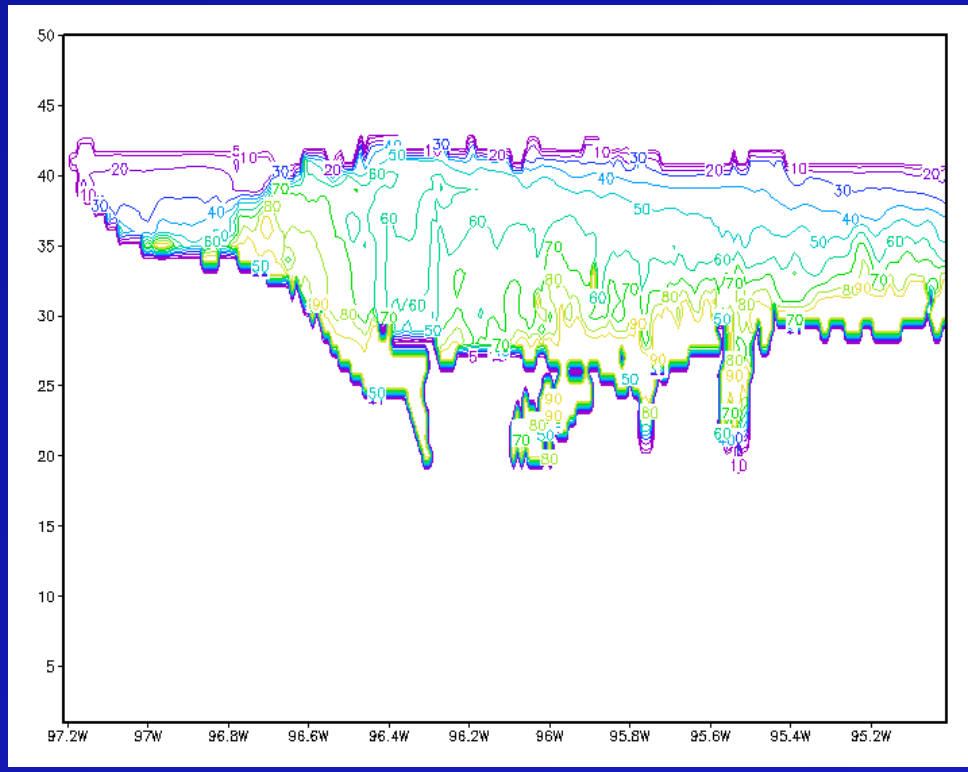


2) Model microphysics output inconsistent with the optical properties expected by the CRTM?

WRF output from the run using the Morrison scheme



Ice mass mixing ratio (colors)
Snow mass mixing ratio (contours)

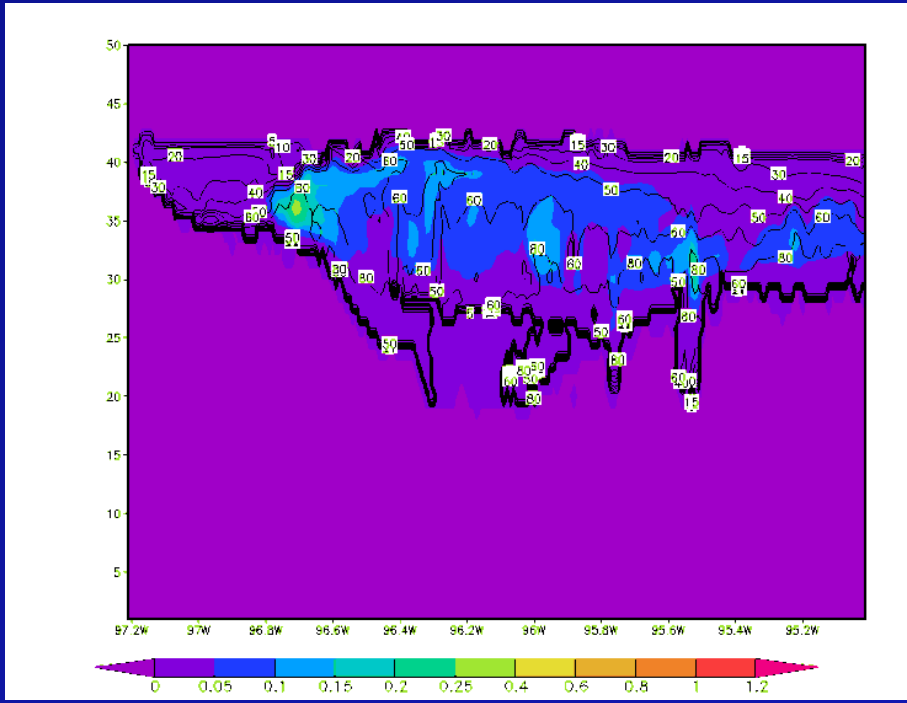


Ice effective radius (μm)

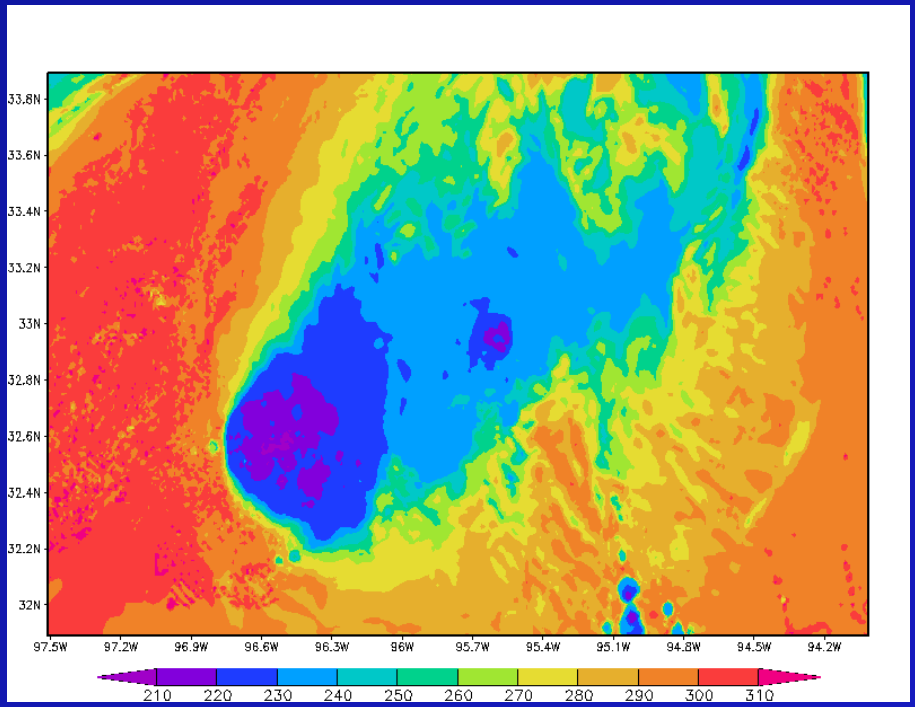
Both in g/kg

2) Model microphysics output inconsistent with the optical properties expected by the CRTM?

Original Run



Ice mass mixing ratio (colors, g/kg)
Ice Effective Radius (contours, μm)

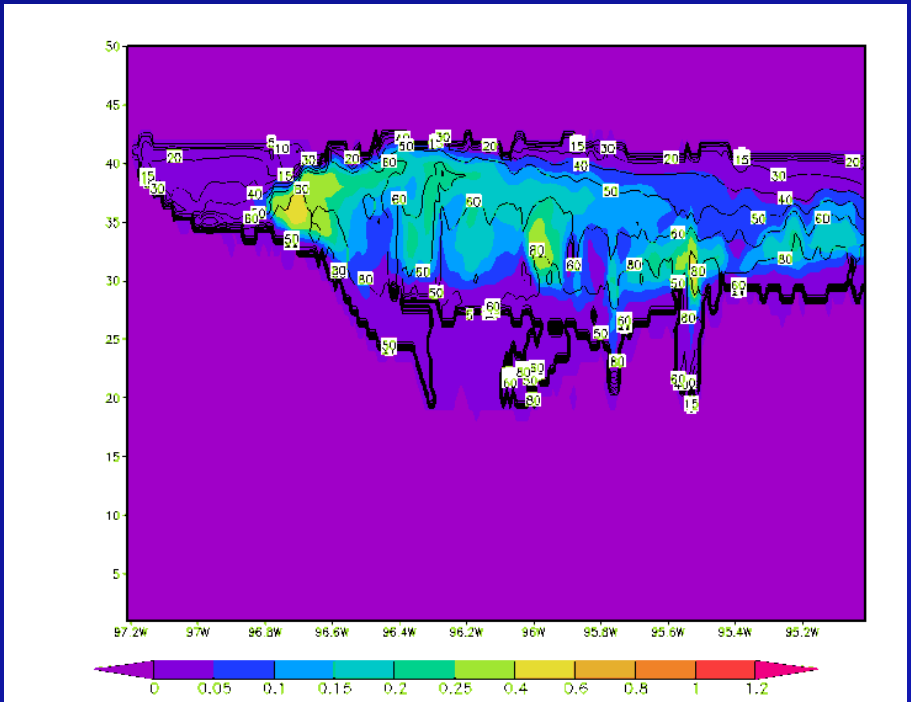


CRTM Simulated Brightness Temperature (K)

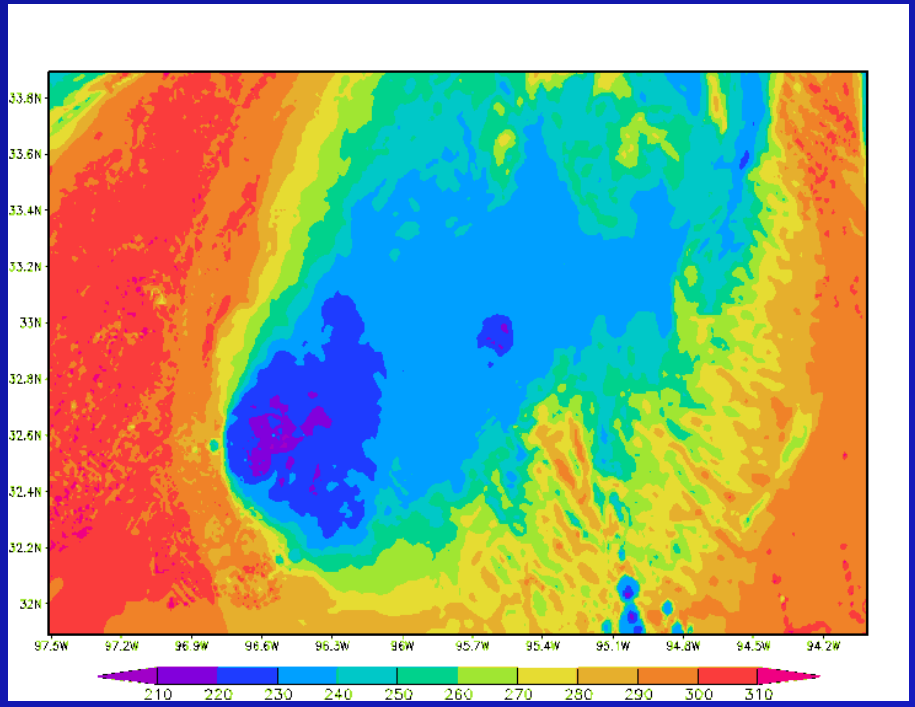
GOES Observations: ~250 K

2) Model microphysics output inconsistent with the optical properties expected by the CRTM?

Double the Ice Mass



Ice mass mixing ratio (colors, g/kg)
Ice Effective Radius (contours, μm)

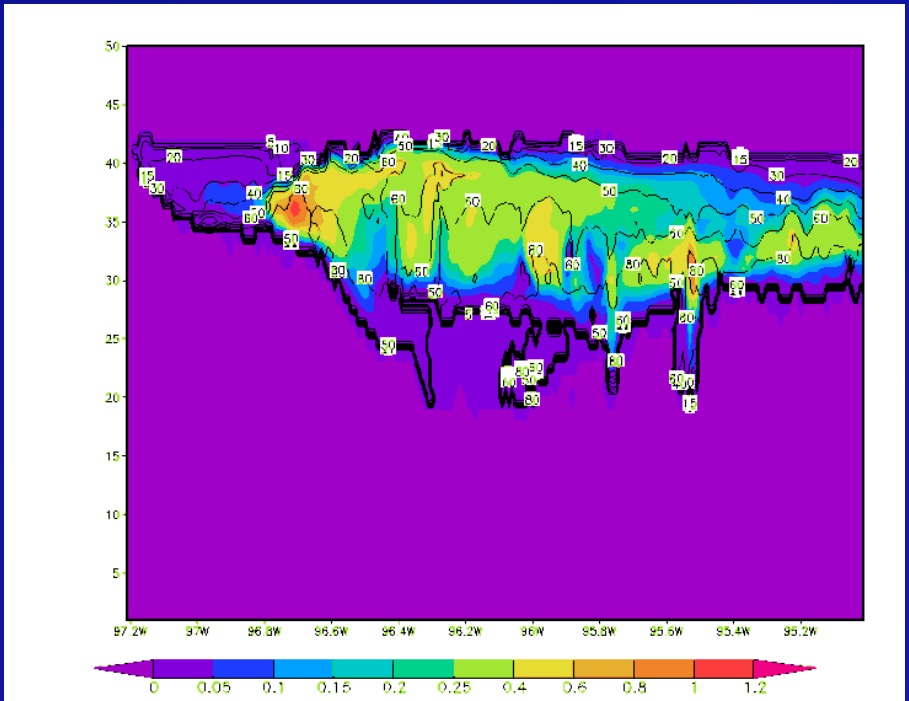


CRTM Simulated Brightness Temperature (K)

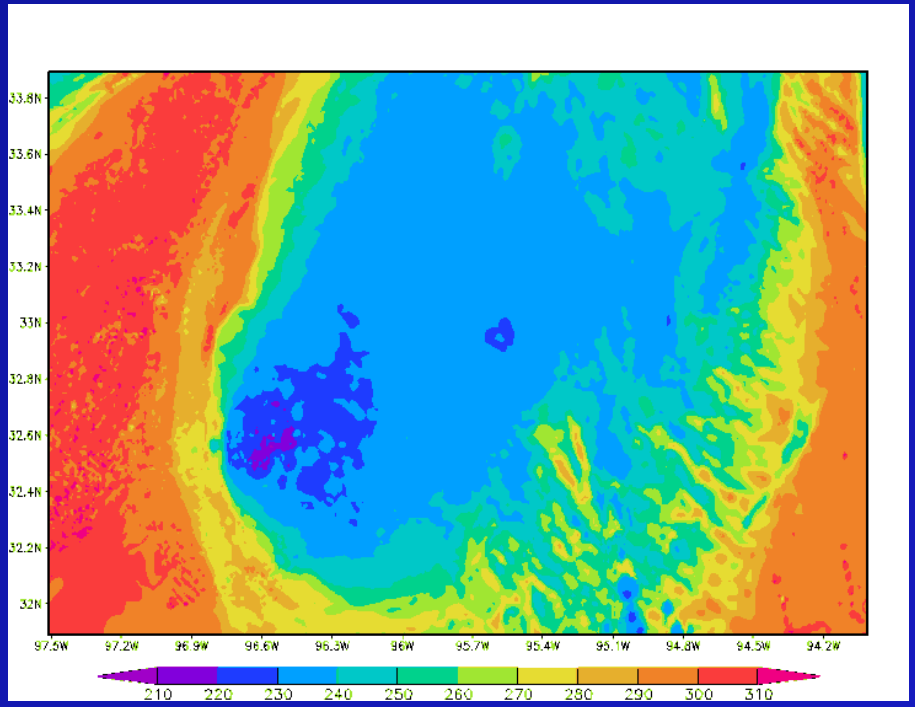
GOES Observations: ~250 K

2) Model microphysics output inconsistent with the optical properties expected by the CRTM?

4x the Ice Mass



Ice mass mixing ratio (colors, g/kg)
Ice Effective Radius (contours, μm)

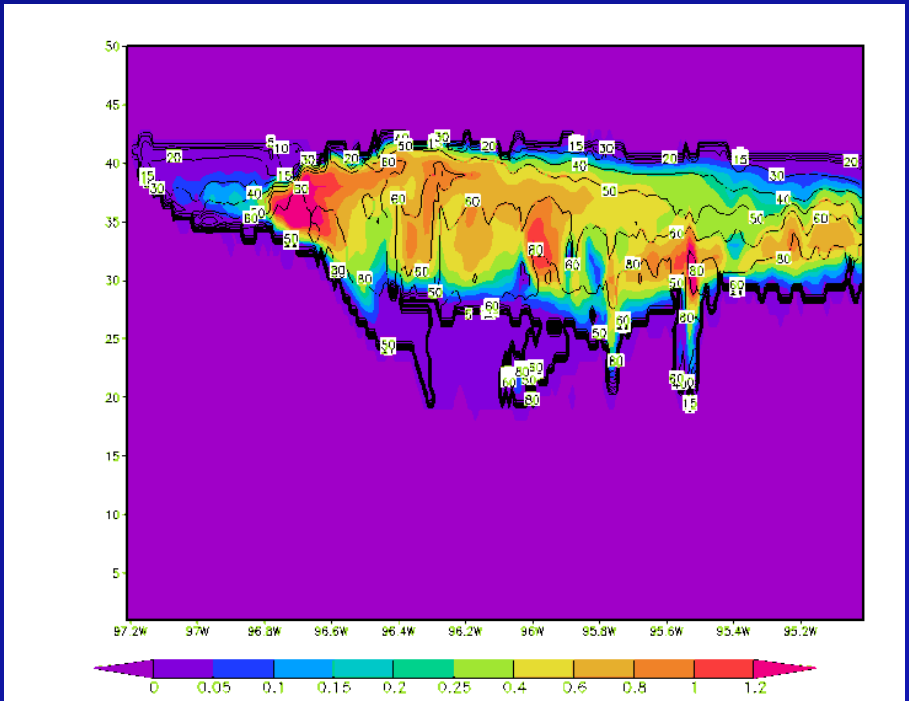


CRTM Simulated Brightness Temperature (K)

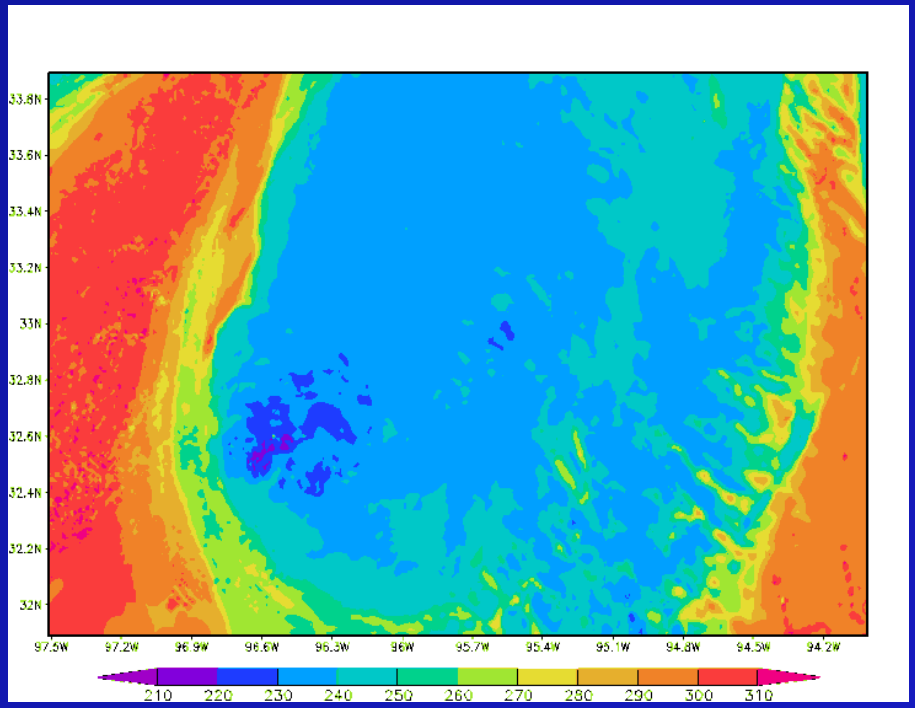
GOES Observations: ~250 K

2) Model microphysics output inconsistent with the optical properties expected by the CRTM?

8x the Ice Mass



Ice mass mixing ratio (colors, g/kg)
Ice Effective Radius (contours, μm)

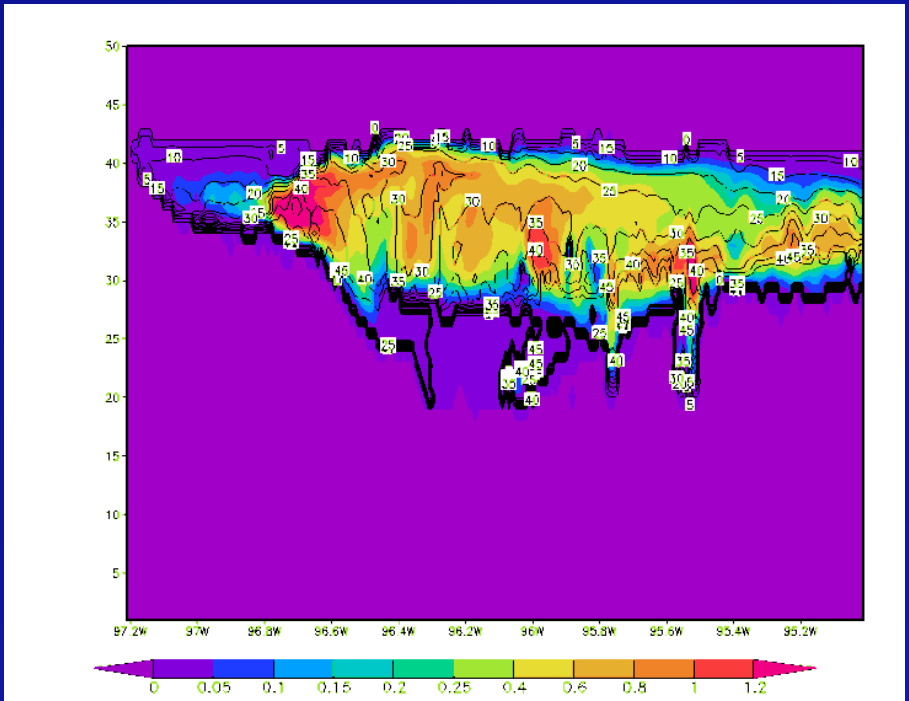


CRTM Simulated Brightness Temperature (K)

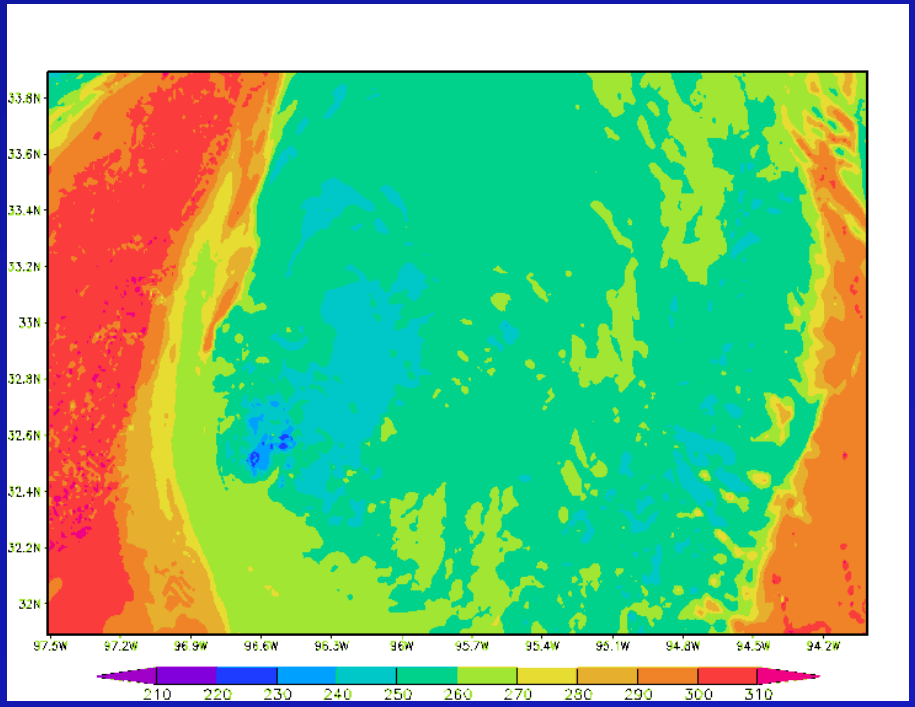
GOES Observations: ~250 K

2) Model microphysics output inconsistent with the optical properties expected by the CRTM?

8x the Ice Mass, Half the Ice size



Ice mass mixing ratio (colors, g/kg)
Ice Effective Radius (contours, μm)

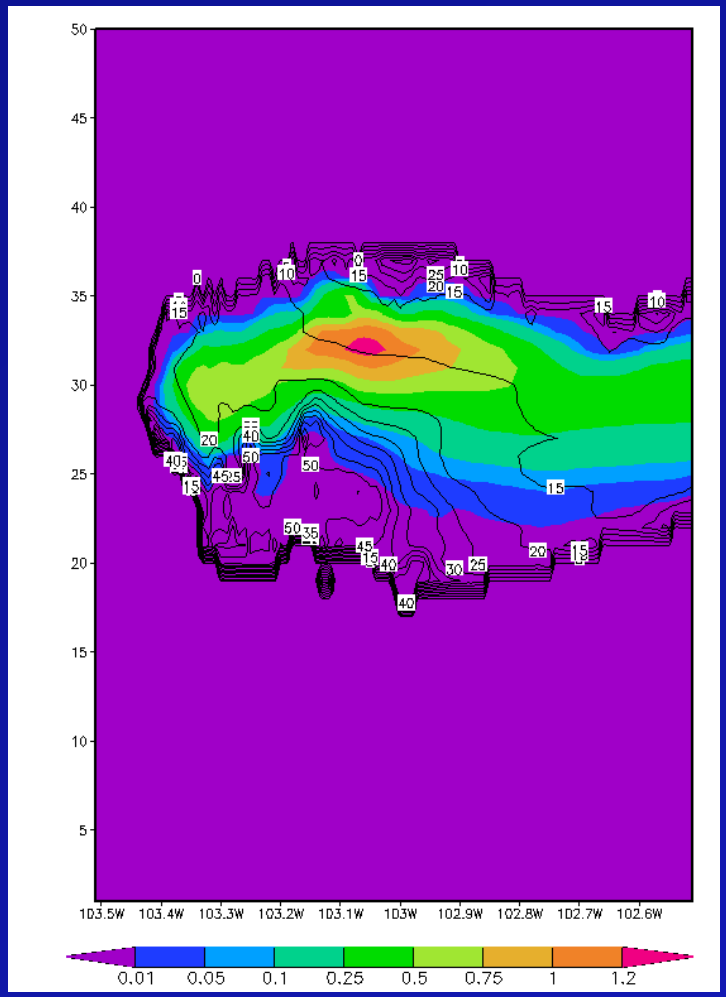


CRTM Simulated Brightness Temperature (K)

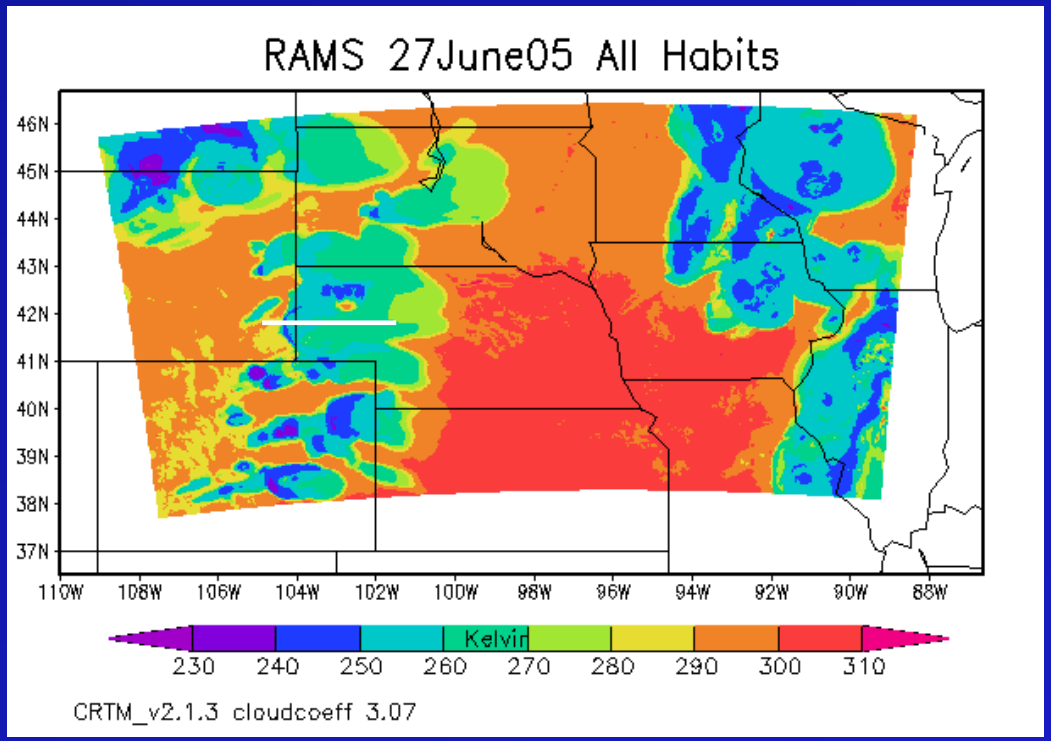
GOES Observations: ~250 K

2) Model microphysics output inconsistent with the optical properties expected by the CRTM?

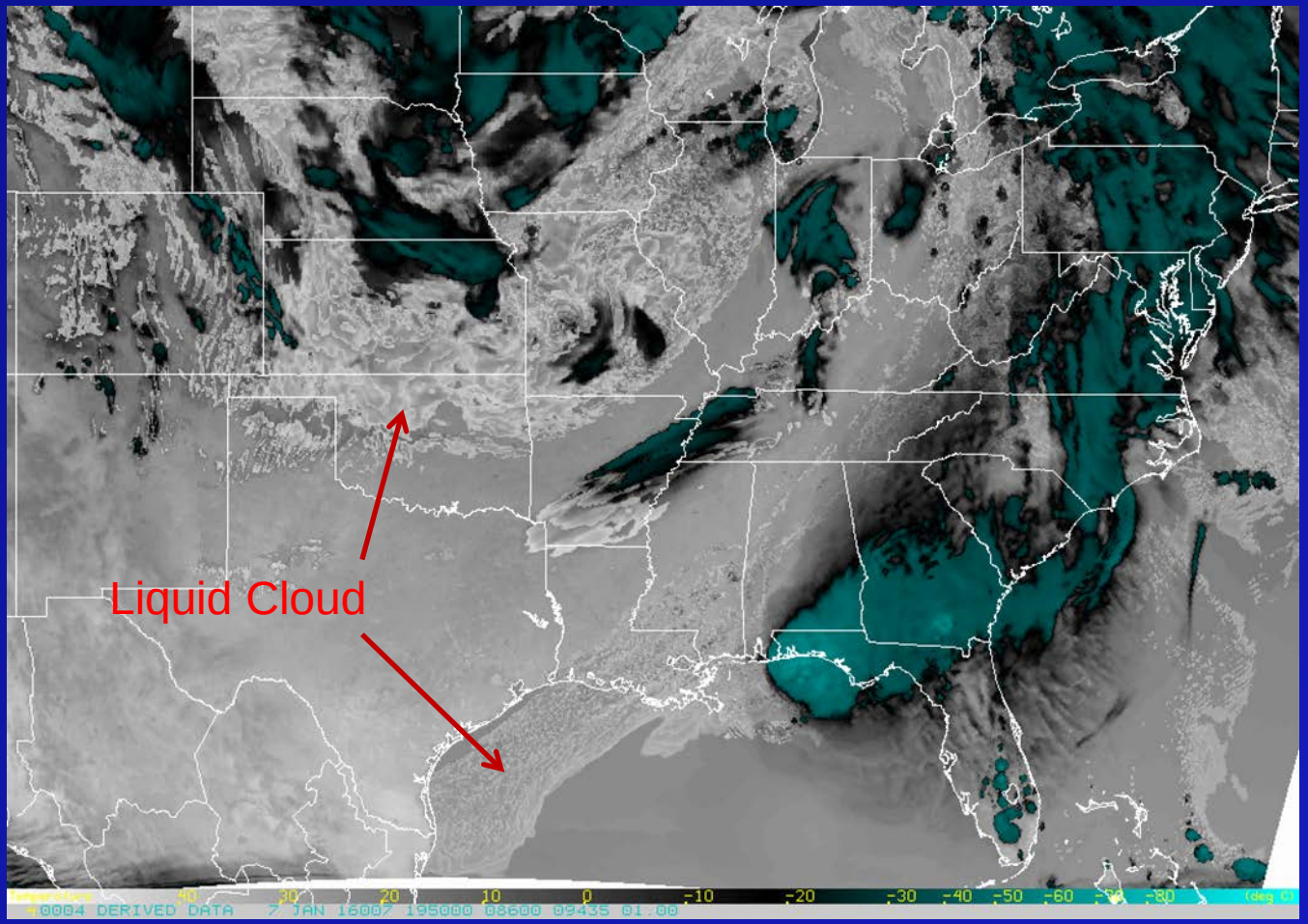
Vertical cross-section through the storm indicated on the right

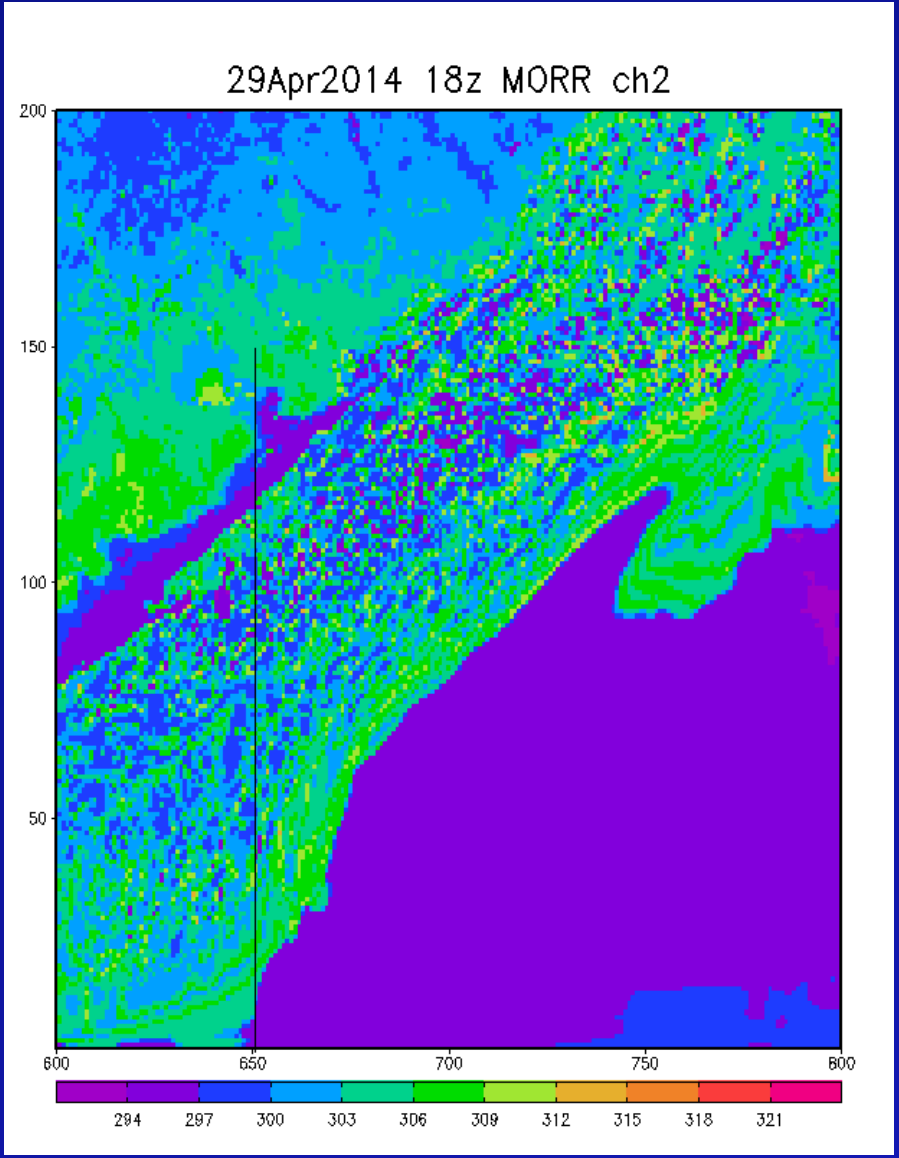


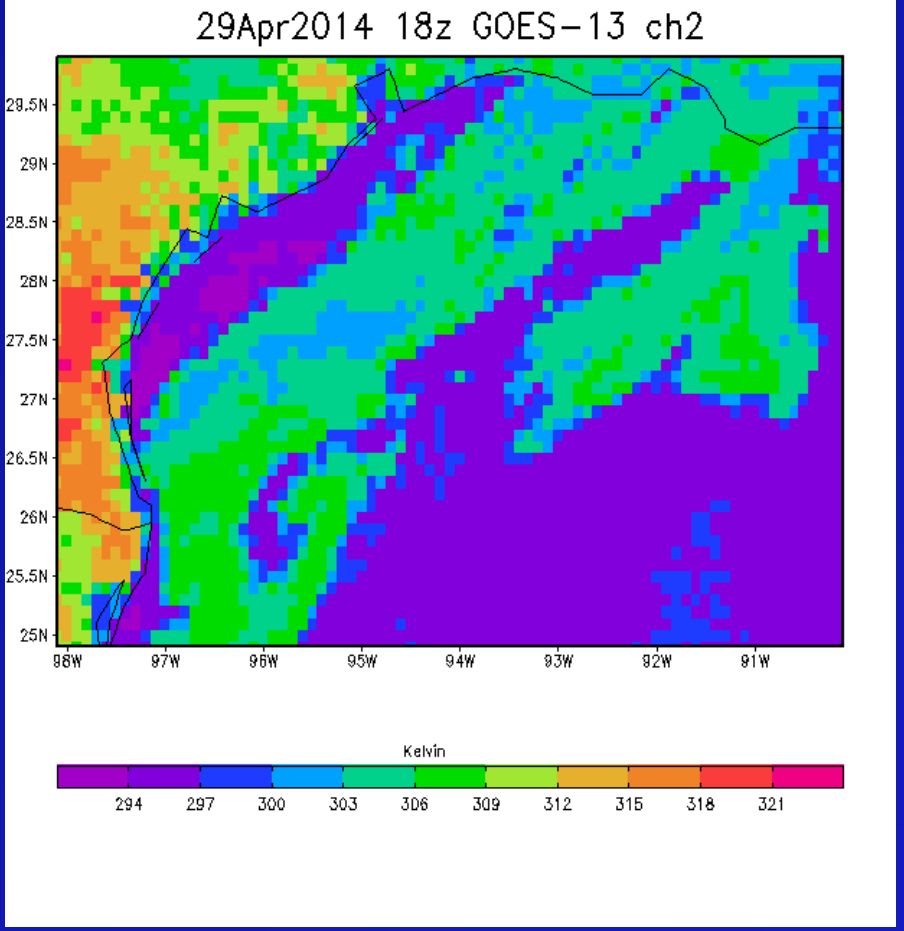
CRTM Simulated 3.9 μm Brightness Temp



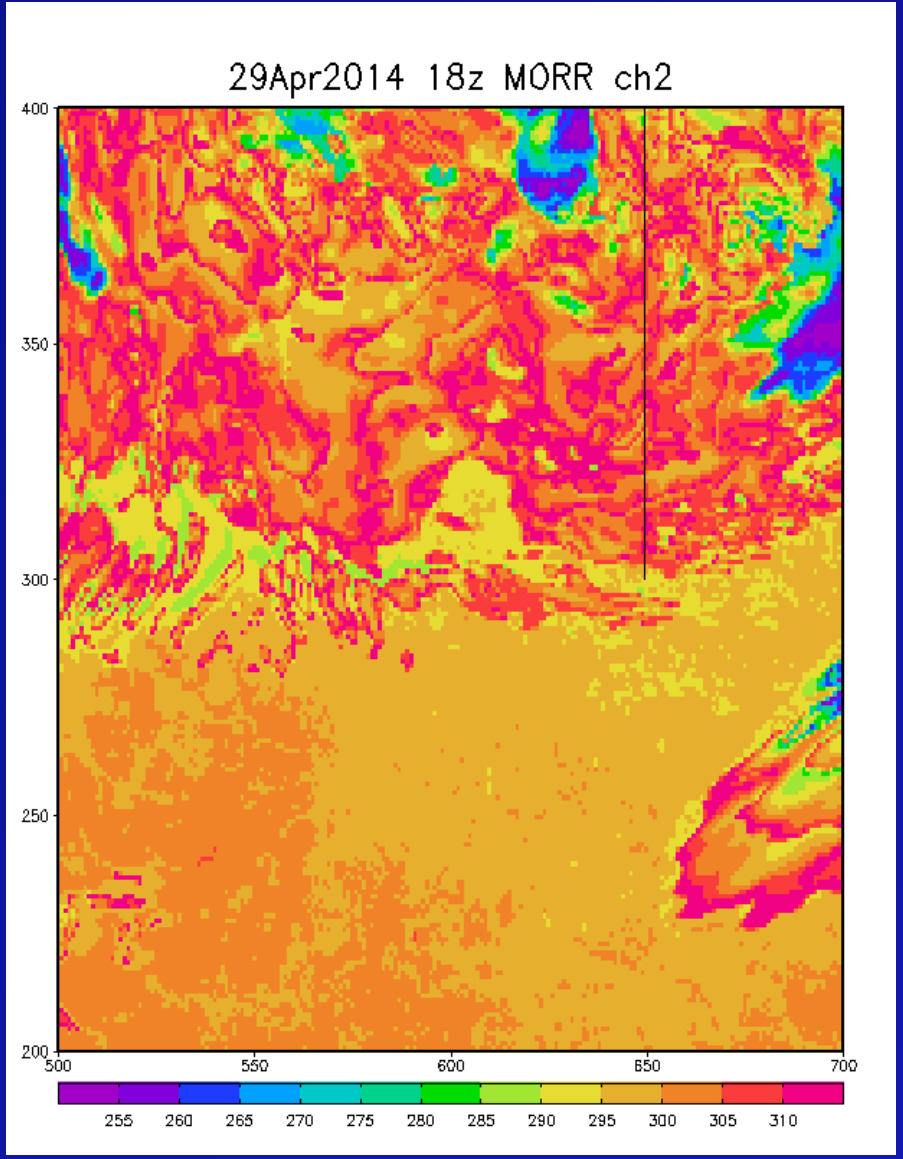
- Ice mass mixing ratio (colors, g/kg)
- Ice radius (contours, μm)

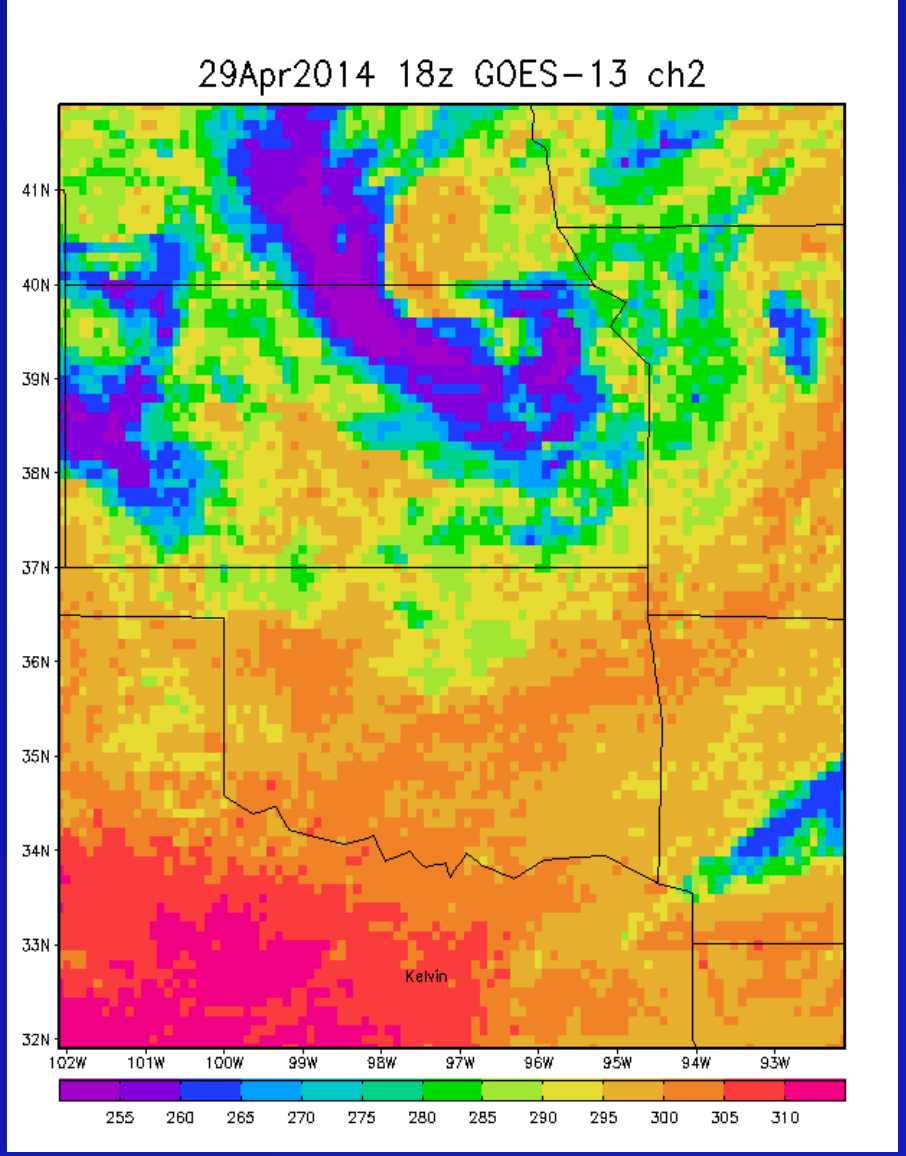

Liquid Cloud
40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 (deg C)
0004 DERIVED DATA 7 JAN 16007 195000 08600 09435 01.00



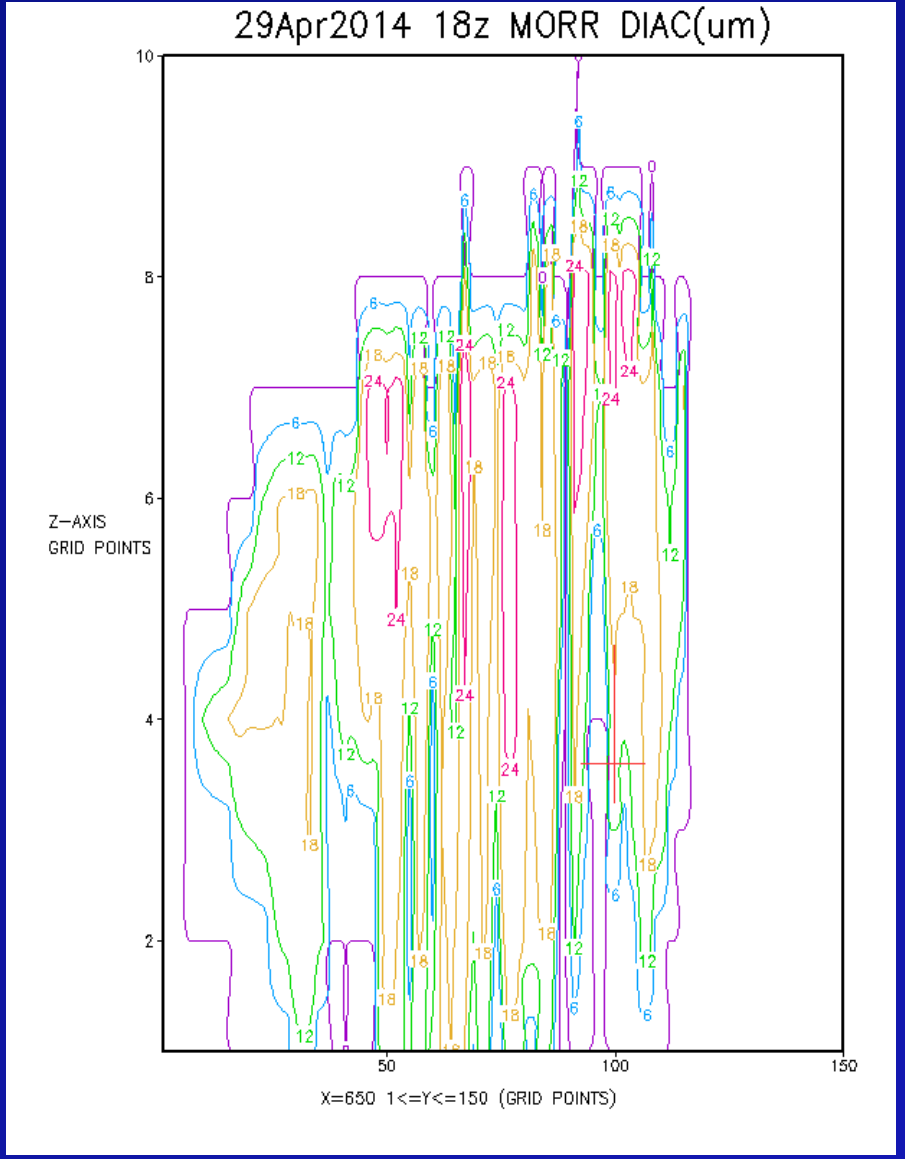


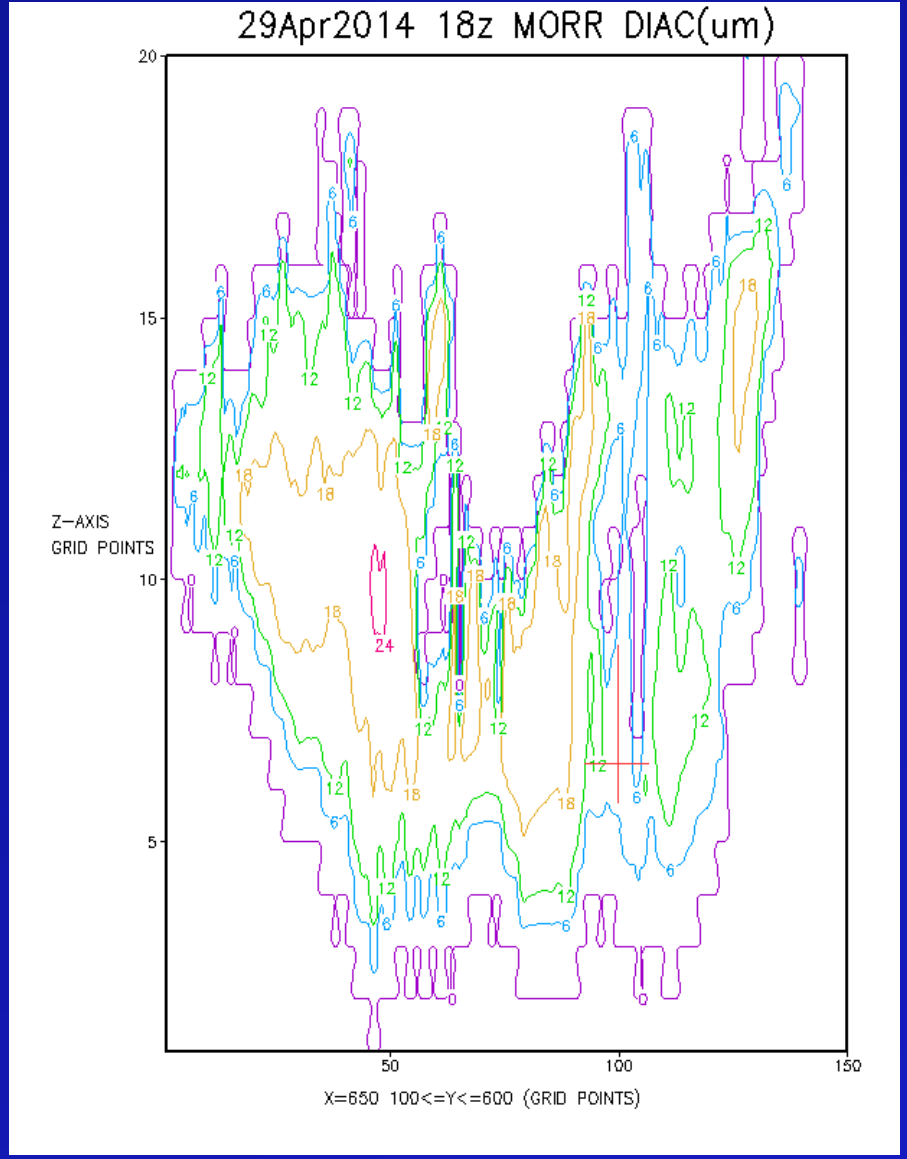
Synthetic (left) and observed (right) GOES-13 imagery at 3.9 of the liquid water cloud just off the Texas coast. Observations supports the CRTM generated brightness temperatures of the liquid water cloud layer. Black vertical line at x=650 (left) is the location of a vertical cross section to be shown very soon.





Synthetic (left) and observed (right) GOES-13 imagery at 3.9 of the liquid water cloud in the central plains. Observations does not support CRTM generated brightness temperatures of the liquid water cloud layer. Black vertical line at x=650 (left) is the location of a vertical cross section to be shown next.





Vertical cross section of simulated cloud droplet diameters (um) for cloud layer located off the Texas coast (left) and the central plains (right). Cloud diameters are smaller at cloud top in the central plains and may be the cause of larger brightness temperatures compared to observations.

Conclusions

- GOES-R will provide unprecedented spatial, spectral, and temporal resolution data
- Data assimilation is necessary to best incorporate some of this information into NWP models
- It's important that the microphysical output from the models is consistent with the fields expected in the CRTM
- Some microphysics schemes tend to make larger ice particles and spread the water mass among other microphysics hydrometeors, like snow
- It appears that the majority of schemes have ice particle sizes that are too large – this can lead to simulated brightness temps that differ from observations

Backup Slides

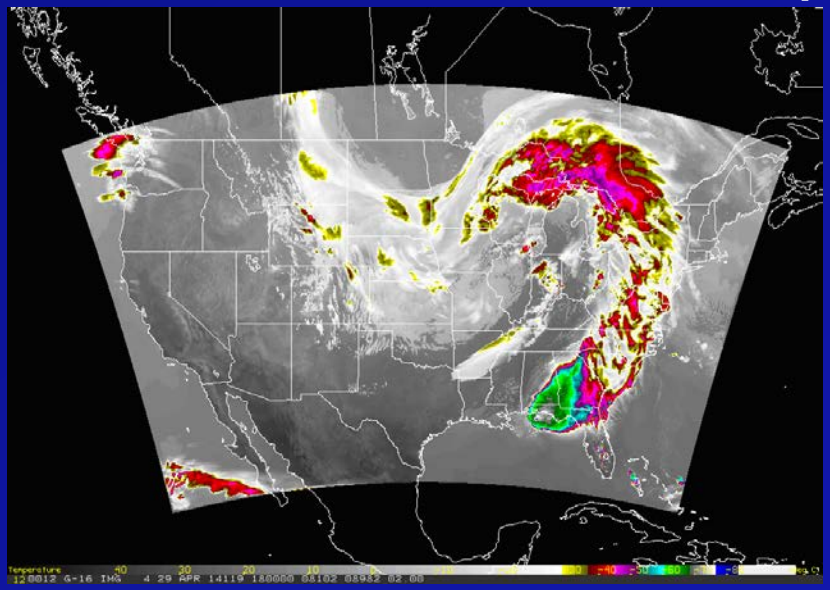
Comparisons between the CRTM (V2.1.3), the CIRA Observational Operator (CIRA-OO), and Observations

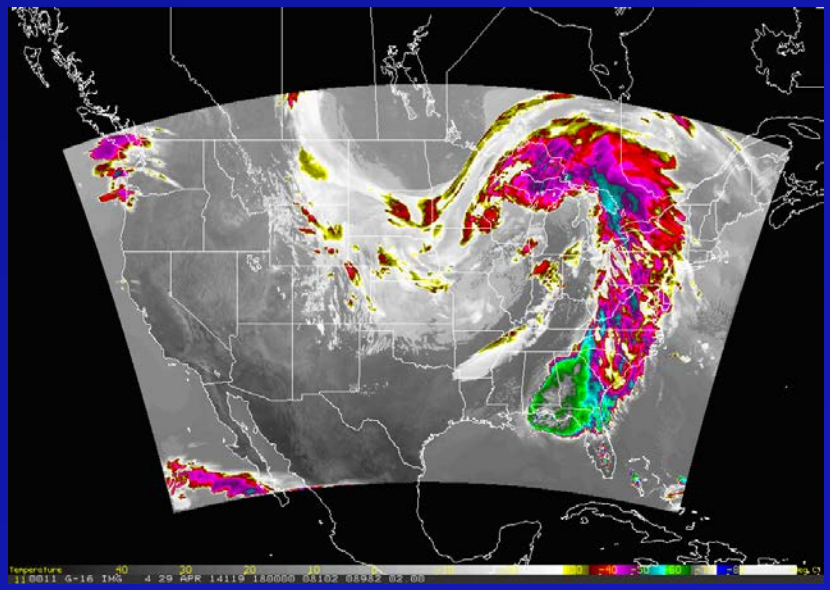
29 April 2014 – 18 Z – based on WRF forecast – Thompson microphysics

CIRA-OO

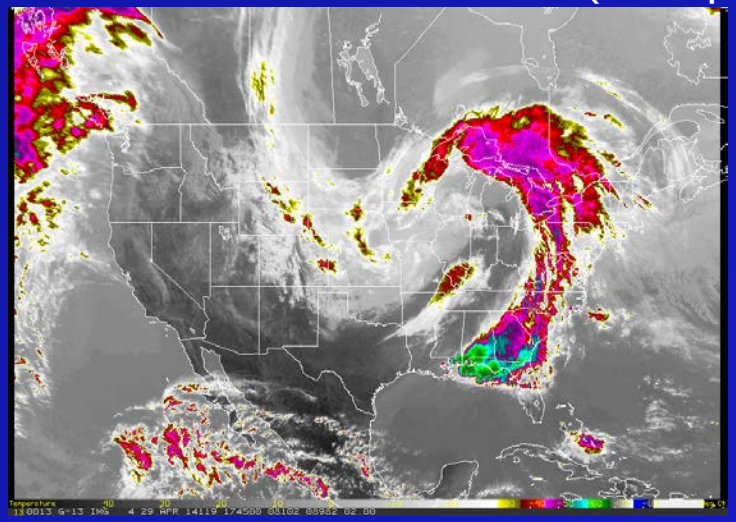
10.35 μm ABI band

CRTM



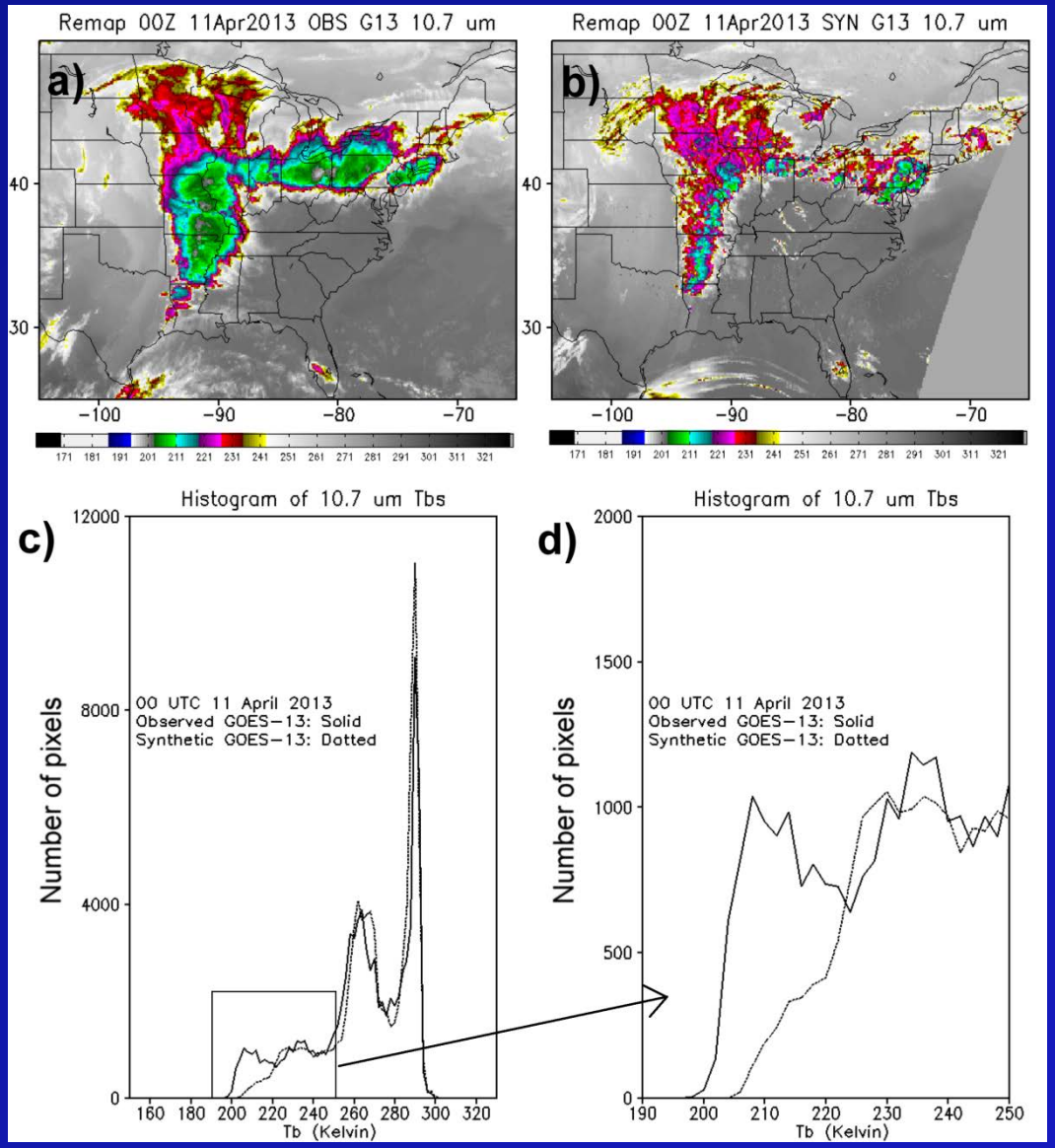


GOES-13 Observations (10.7 μm)



- CIRA-OO and CRTM produced very similar output, and both compare well with GOES observations

Background



Grasso, L., D. T. Lindsey, K.-S. S. Lim, A. Clark, D. Bikos, and S. R. Dembek, 2014: Evaluation of and suggested improvements to the WSM6 microphysics in WRF-ARW using synthetic and observed GOES-13 imagery. *Mon. Wea. Rev*, 142, 3635-3650.