Simulating Satellite Imagery from High-Resolution WRF Output:

A method for cloud verification?

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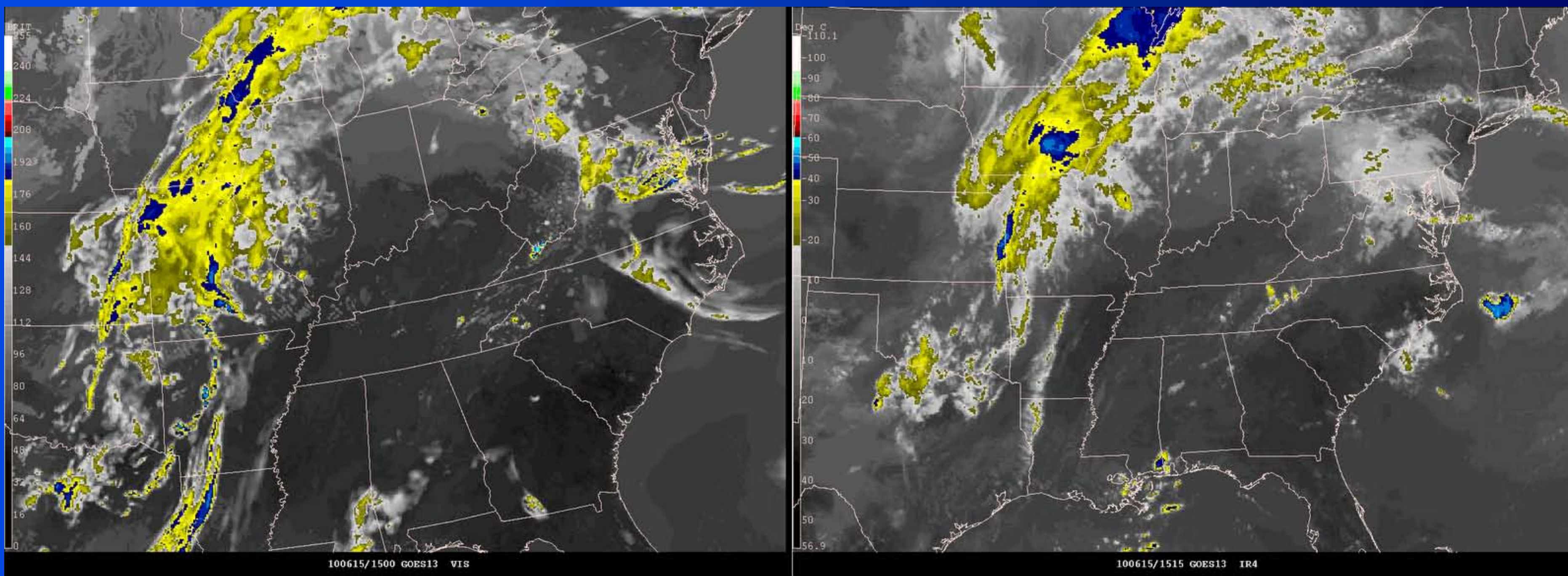
Background

- As part of the 2010 Spring Experiment at the Storm Prediction Center, NSSL and SPC requested that we generate synthetic satellite data from one of their cloud-resolving models



Which of these is real and which is synthetic?

WRF Details

- The model is NSSL’s 4-km WRF-ARW, one of several being evaluated by Spring Experiment participants
  - Ferrier microphysics (1-moment, bulk)
  - They send us the following variables from the model output: pressure, temperature, heights, water vapor, aggregates, cloud water, graupel, pristine ice, rain water, and skin temperature
  - One-moment microphysics means we must specify a number concentration for cloud water and pristine ice
    - Leads to errors in simulated brightness temps, particularly for optically this cirrus
    - Particle sizes are strongly dependent on our specified number concentrations

Creating Synthetic Data

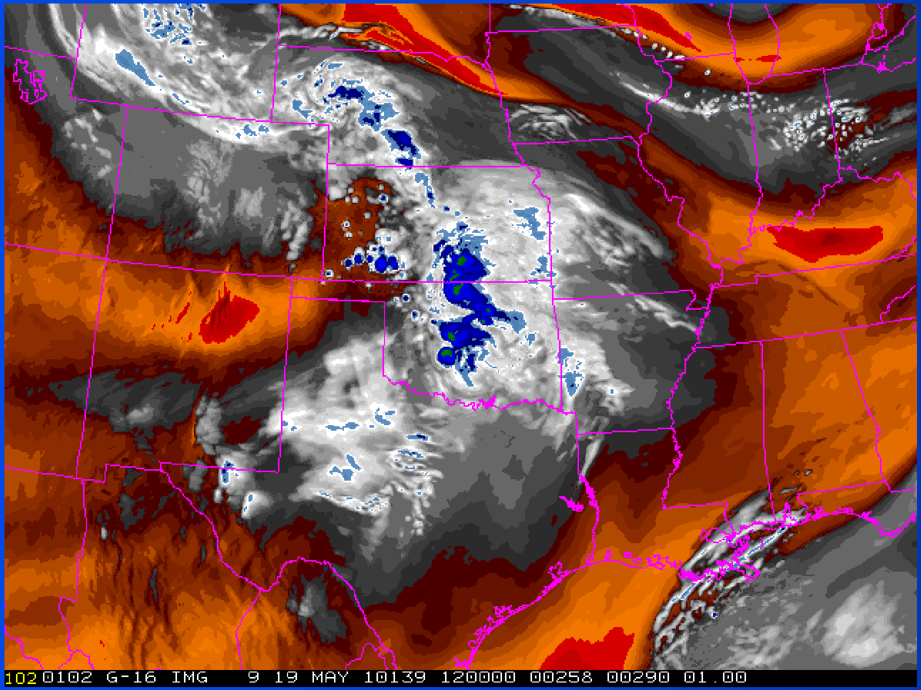
- We use the WRF outputs as inputs to our observational operator that generates synthetic satellite radiances at several GOES-R Band wavelengths
- Community Radiative Transfer Model (CRTM) code used to calculate gaseous transmittances
- Modified anomalous diffraction theory (MADT) is used for cloud optical properties for $\lambda > 3.9$ µm
- Look-up tables for optical properties for $\lambda <= 3.9$ µm
- Delta-Eddington (EDDRT) formulation for IR bands, and the plane-parallel version of the Spherical Harmonic Discrete Ordinate Method (SHDOMPP) for 2.25 and 3.9 µm
- Observational operator is run on a 64-bit cluster with 32 nodes
    - We have recently obtained an upgraded cluster with 36 nodes, and our processing time should decrease by a factor of at least 2

Near Real-Time Imagery Creation

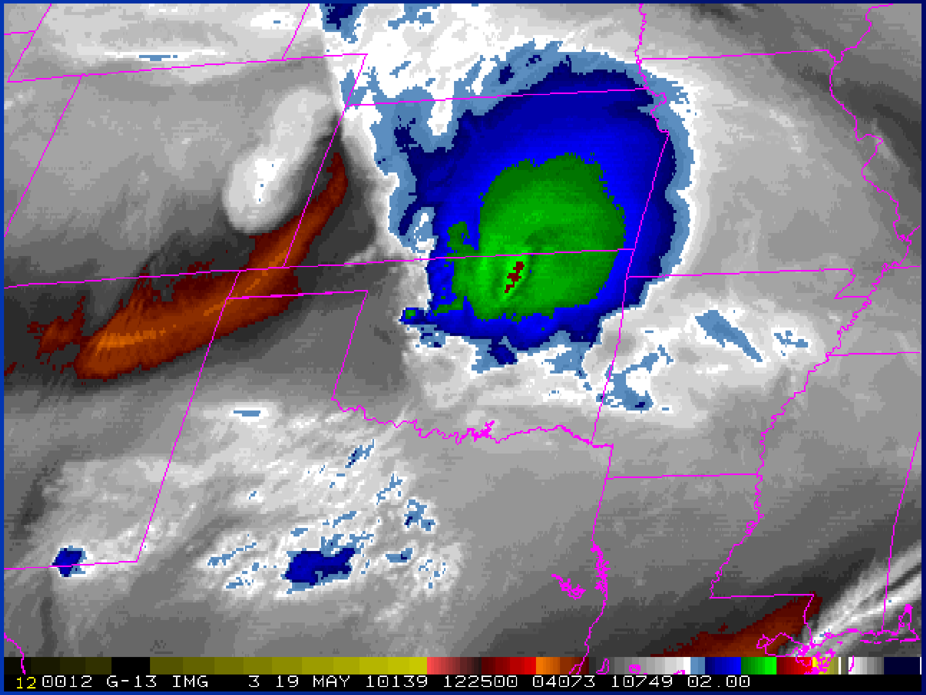
- NSSL's WRF runs each evening at 00Z
- We collect hourly output starting with the 12-hour forecast, out through the 30-hour forecast, so the output is valid from 12Z until 06Z that night
- We're currently providing 2 bands to the SPC and NWS
  - 6.95 µm, a water vapor similar to current GOES' 6.7 µm, but overall warmer
  - 10.35 µm, an IR window band similar to current GOES' 10.35 µm
- The resolution is 4-km to match the WRF resolution, even though GOES-R will have 2-km data
- Real-time examples of the WV and IR forecast loops:
  - ➢ http://rammb.cira.colostate.edu/ramsdis/online/loop_timestamp.asp?data_folder=goes-r_proving_ground/nssl_wrf_synthetic_band9&width=640&height=480
  - ➢ http://rammb.cira.colostate.edu/ramsdis/online/loop_timestamp.asp?data_folder=goes-r_proving_ground/nssl_wrf_synthetic_band13&width=640&height=480

Example – 19 May 2010

Simulated 6.95 µm loop from 12-00 Z

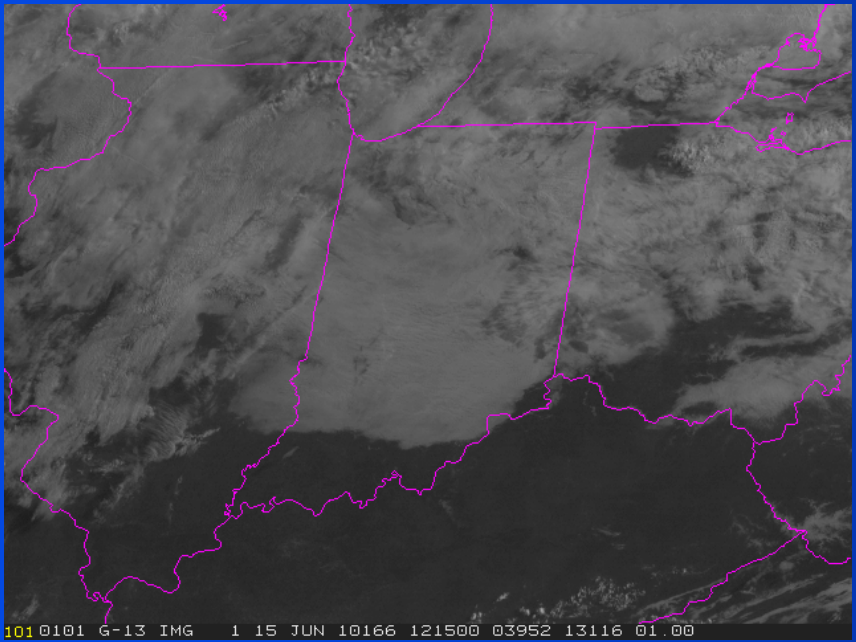


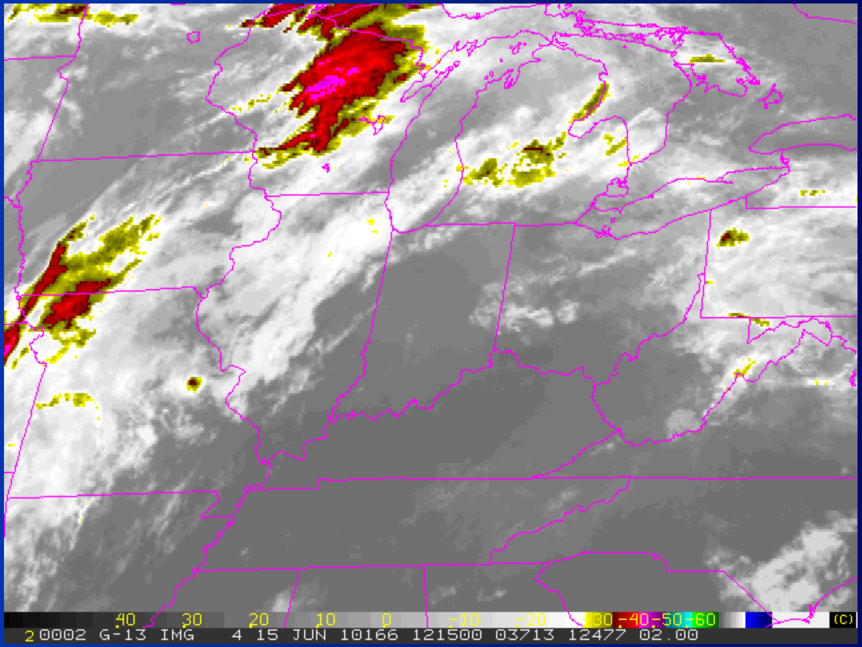
GOES-13 loop from ~12-00 Z



Remember that this is a 12-24 hour forecast!

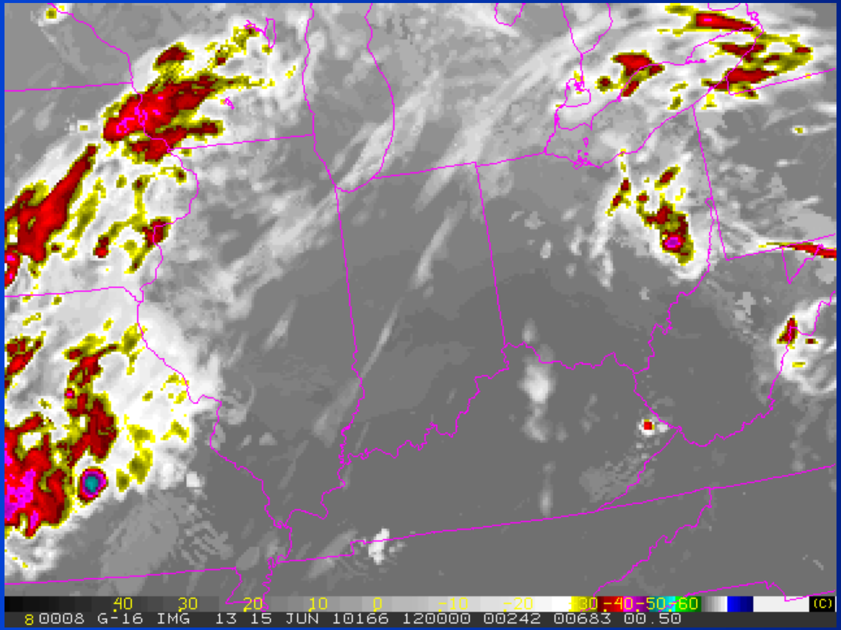
Example – 15 June 2010





GOES-13 VIS

GOES-13 10.7 µm

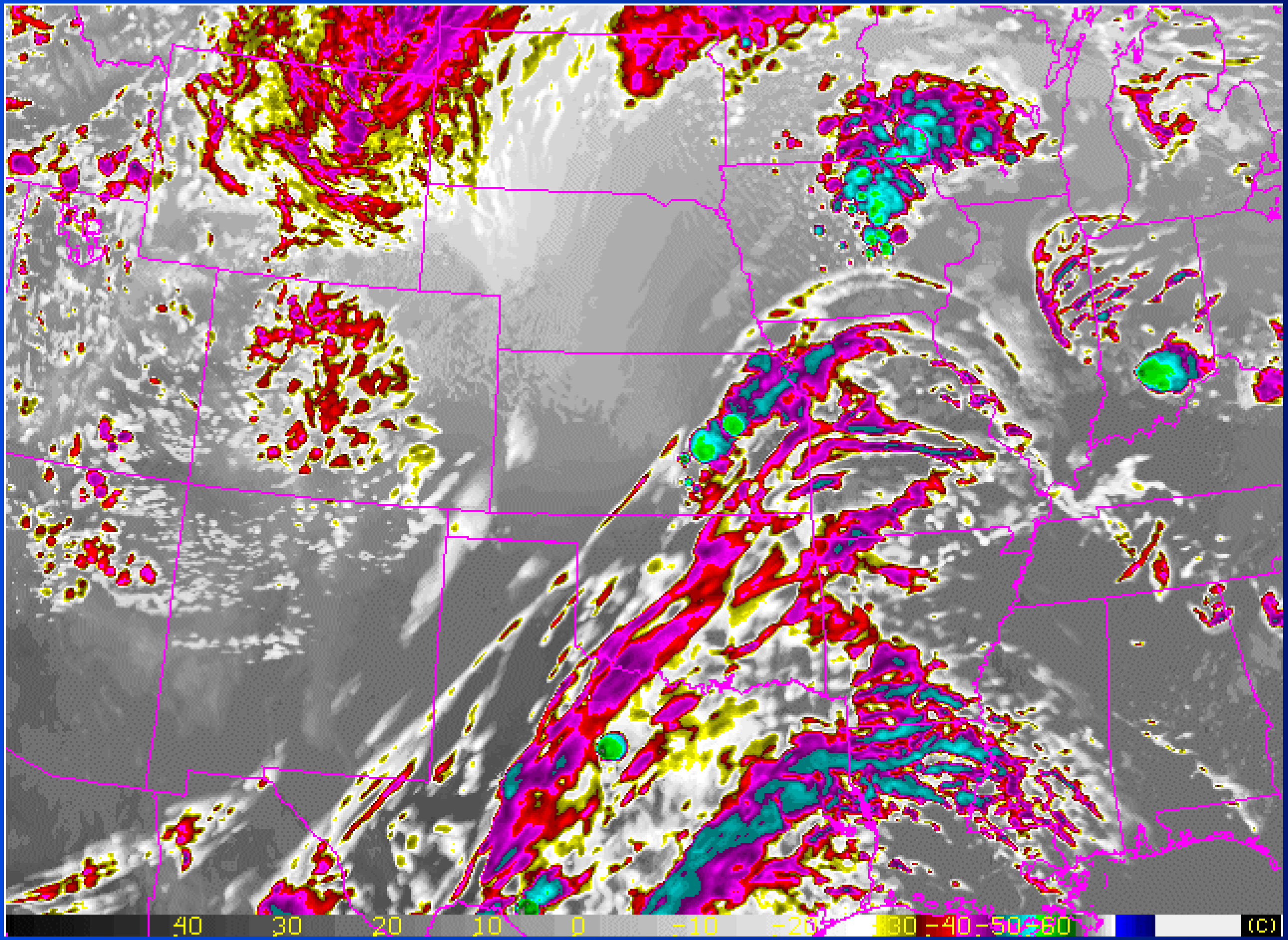


Simulated 10.35 µm

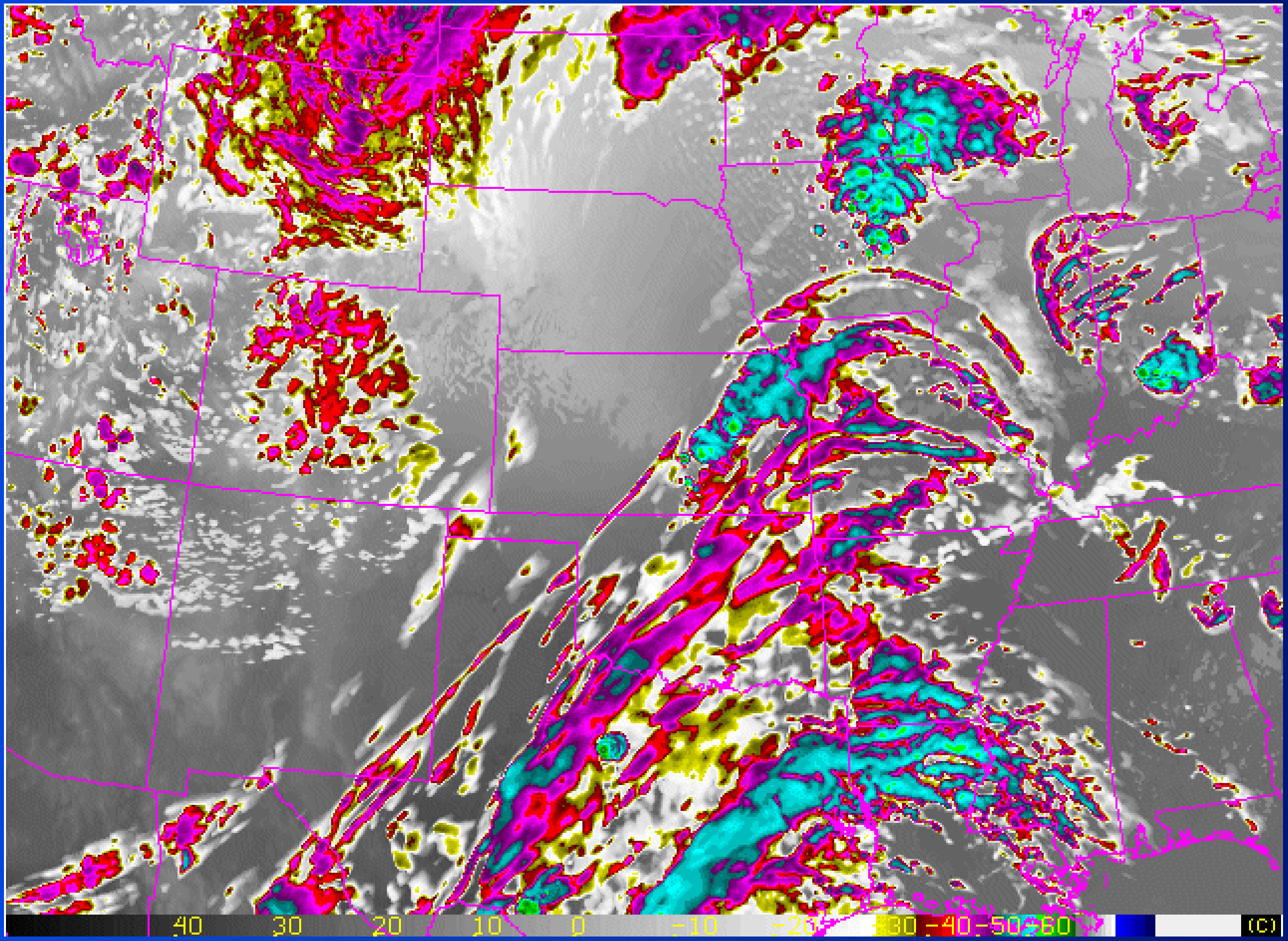
Using Simulated Imagery for Cloud Verification

- Optically thick clouds in the model are relatively easy to verify….simply compare simulated with observed IR window brightness temps
- Spatial differences between simulated and observed clouds more difficult to verify
- Thin clouds (typically thin cirrus) are more problematic, due primarily to the model's 1-moment microphysical scheme
  - ➢ The WRF predicts only ice and cloud water mass, not number concentration, so it must be specified
  - ➢ This leads to errors in the IR brightness temps of thin cirrus, so when verifying thin cirrus, you wouldn't know whether the errors are from the WRF or from the synthetic satellite generation (or both)

Using Simulated Imagery for Cloud Verification



Using Simulated Imagery for Cloud Verification



Summary

- An observational operator is being used to generate synthetic GOES-R imagery in real-time using output from a 4-km version of the WRF
- This output is being provided to the Storm Prediction Center and NWS
- Since clouds are easily inferred from the satellite imagery, they can be compared with GOES observations as a means to verify WRF cloud forecasts
- No formal attempt has yet been made to do this
- We are using simulated brightness temps from HWRF output and comparing it to observations, but results are just now coming in