Advancing Forecast Verification and Model Development Efforts through Development of a Flexible Satellite-Based Verification System for the Global Forecasting System

Jason Otkin and Sharon Nebuda

University of Wisconsin-Madison, CIMSS/SSEC

Chris Rozoff

National Center for Atmospheric Research

Ruiyu Sun, Andrew Collard, Emily Liu, and Vijay Tallapragada

NOAA/NCEP/EMC

Michelle Harrold and Ligia Bernardet

Developmental Testbed Center

Project Motivation

- Accurate depiction of the cloud and water vapor fields is necessary for NWP models to produce skillful forecasts
- Cloud and precipitation processes are very complex and often difficult to accurately represent in NWP models
- Errors in water vapor distribution and interactions between parameterization schemes compound these uncertainties
- Clouds and water vapor are highly variable in space and time and poorly sampled by conventional observations
  - Satellite brightness temperatures sensitive to clouds and water vapor can fill in this observing gap

Project Motivation

- Satellite radiances (visible, infrared, microwave) are the only observations that can provide information about the cloud and water vapor fields over the entire globe
- Use "model-to-satellite" approach to convert model data into simulated brightness temperatures
- Methodology provides an effective way to assess forecast accuracy over large spatial domains
- Provides valuable opportunity to evaluate the performance of new parameterization schemes in the GFS model (and eventually the FV3 model)

Project Objectives

- Enhance the satellite simulator capabilities of the GSI and CRTM in cloudy situations
  - Made changes to interface so that the effective particle diameters are computed correctly for each cloud species
- Rigorously evaluate the accuracy of the forecast cloud and water vapor fields through comparisons of observed and simulated satellite brightness temperatures
- Provide guidance to operational model developers concerning which schemes produce the most accurate cloud and water vapor fields

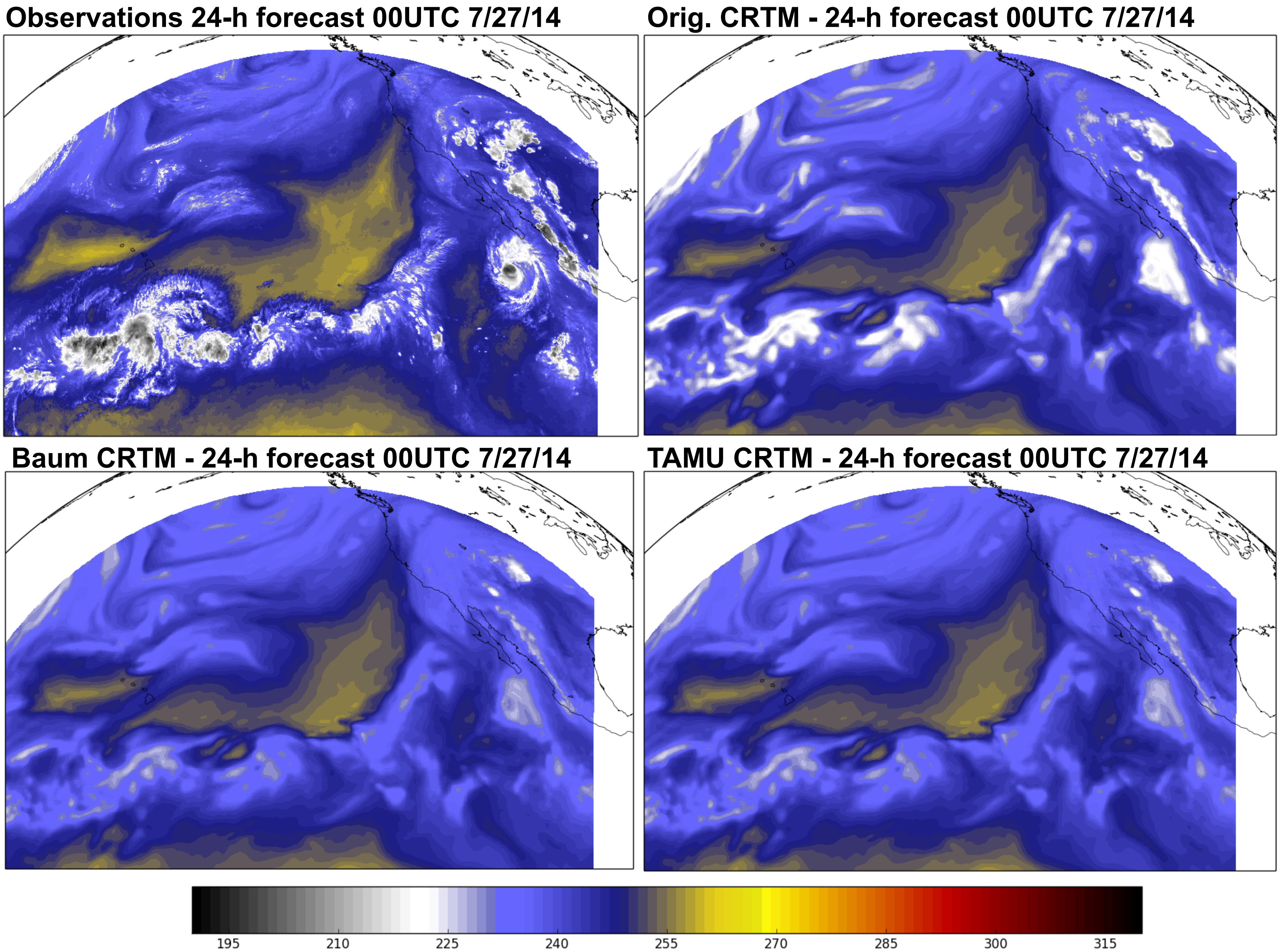
Project Objectives

- Assessed impact of using different ice cloud property lookup tables (CloudCoeff.bin) in version 2.2.3 of the CRTM
  - Original version (identified as release 3, version 4)
  - New TAMU version (identified as release 3, version 6)
  - Created new version based on Baum et al. (2013)
- Important task given its impact on the verification results
  - Challenging problem because the sensitivity varies with model resolution and microphysics scheme
- Will be discussing both general model errors and the impact due to the lookup tables

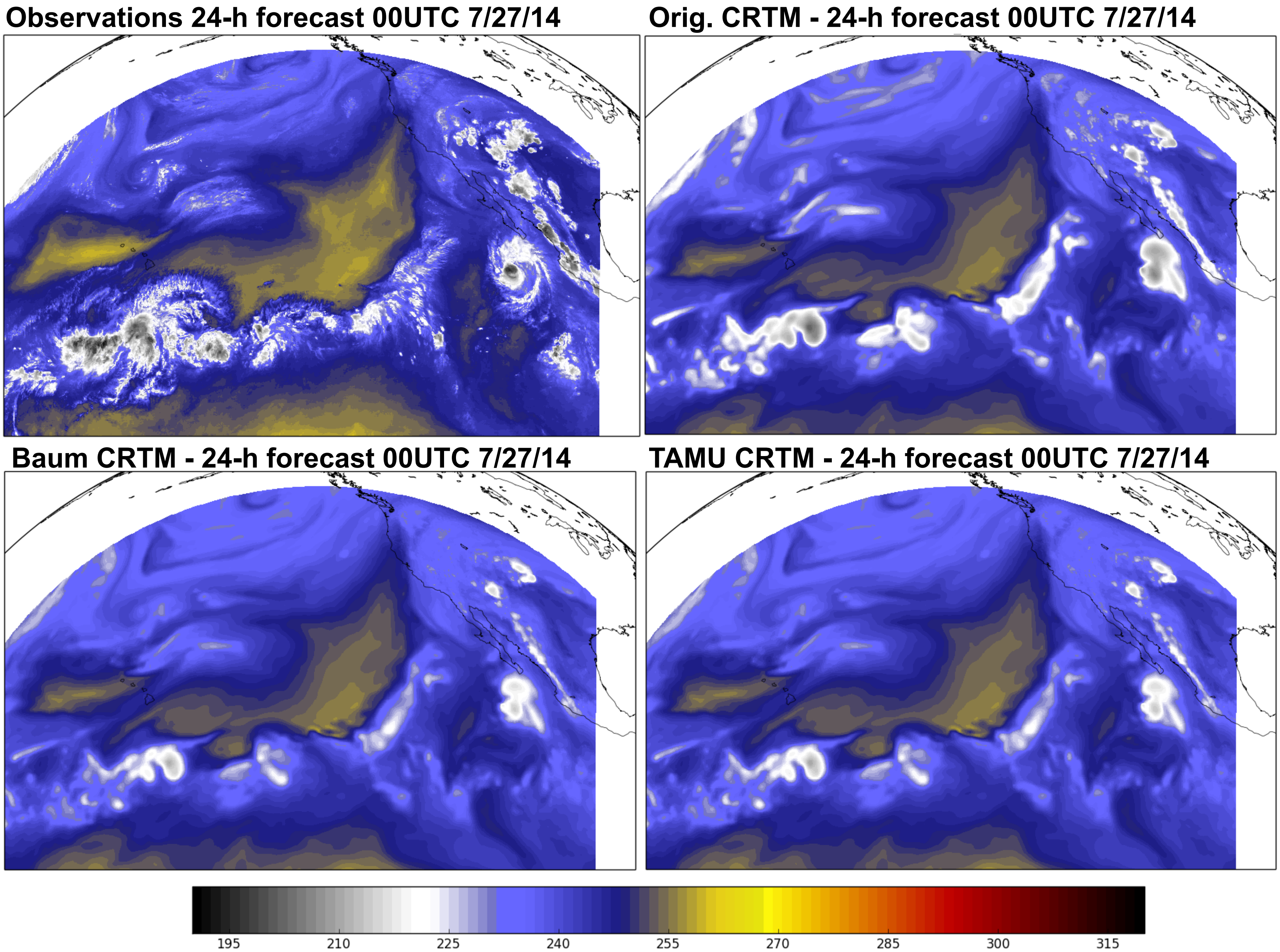
Full Resolution GFS Simulations

- GFS model at T1534 resolution (~13-km resolution)
  - Model simulations performed by Ruiyu Sun (NCEP/EMC)
  - Simulations performed using the WSM6 and Thompson cloud microphysics parameterization schemes
  - Forecasts were generated for several days during July and December 2014 prior to start of this project
- Simulated satellite brightness temperatures generated using the GSI in "single-cycle" mode
  - Provides collocated observed and simulated brightness temperatures for both GEO and LEO satellites

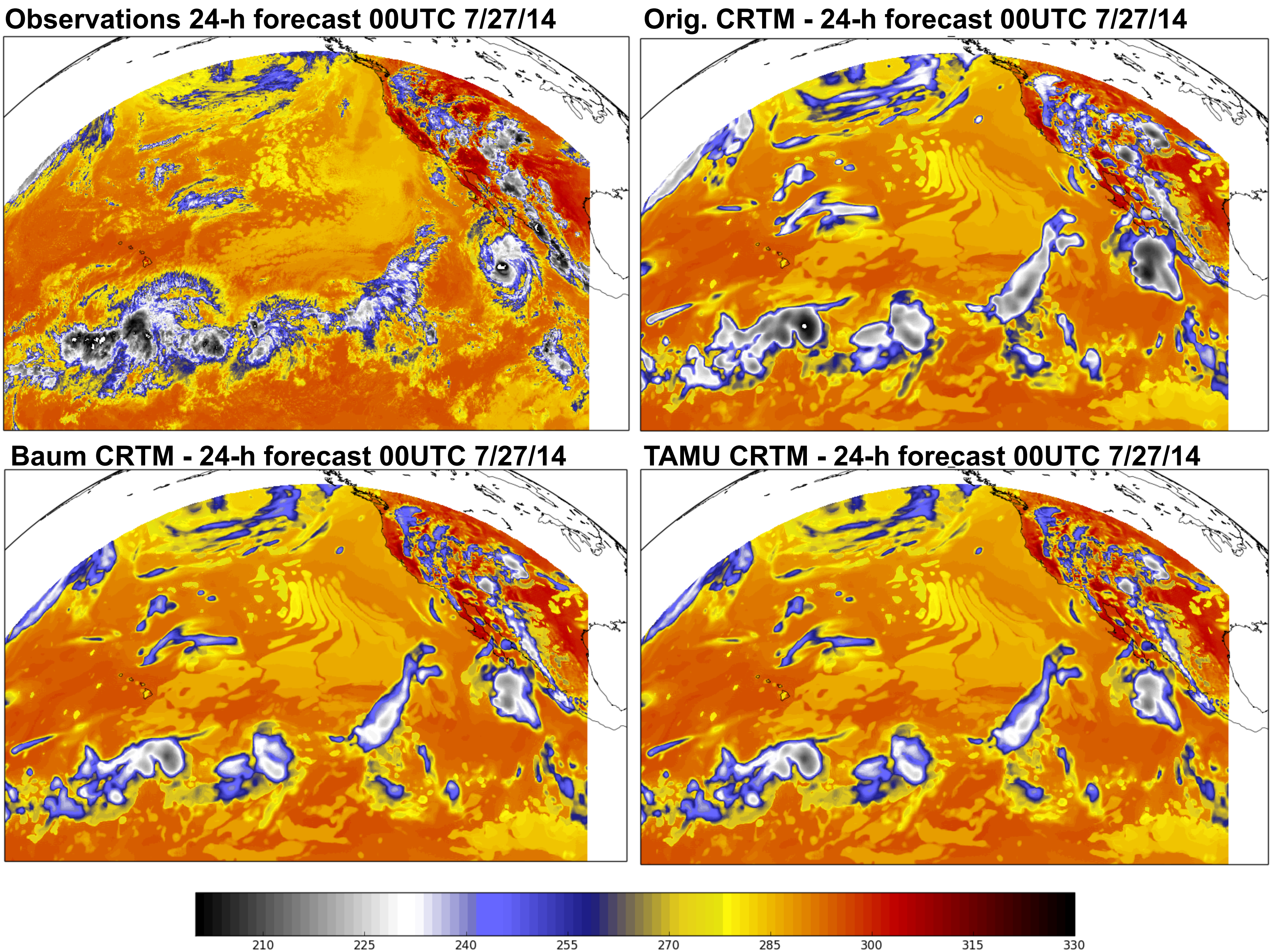
Thompson Scheme WV (6.5 μm) Imagery – GOES-15



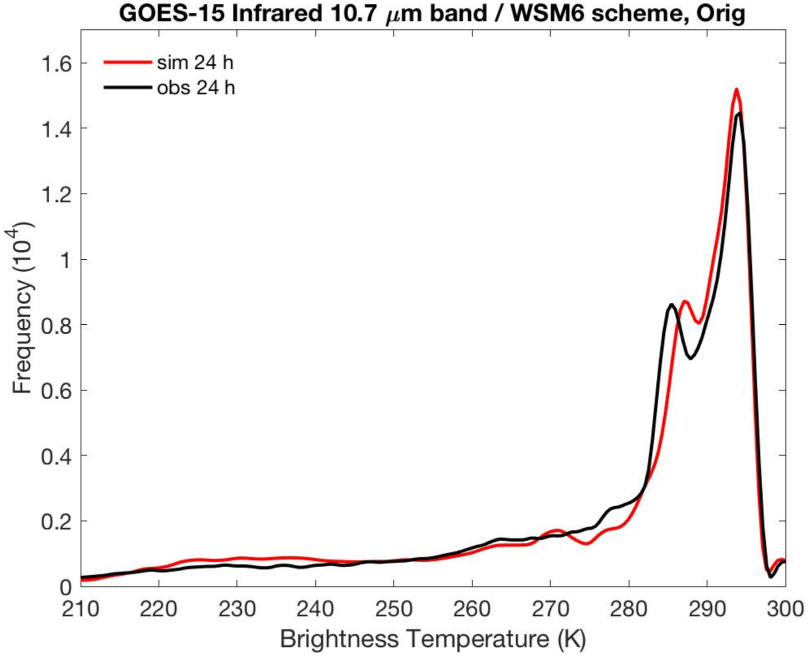
WSM6 Scheme WV (6.5 μm) Imagery – GOES-15



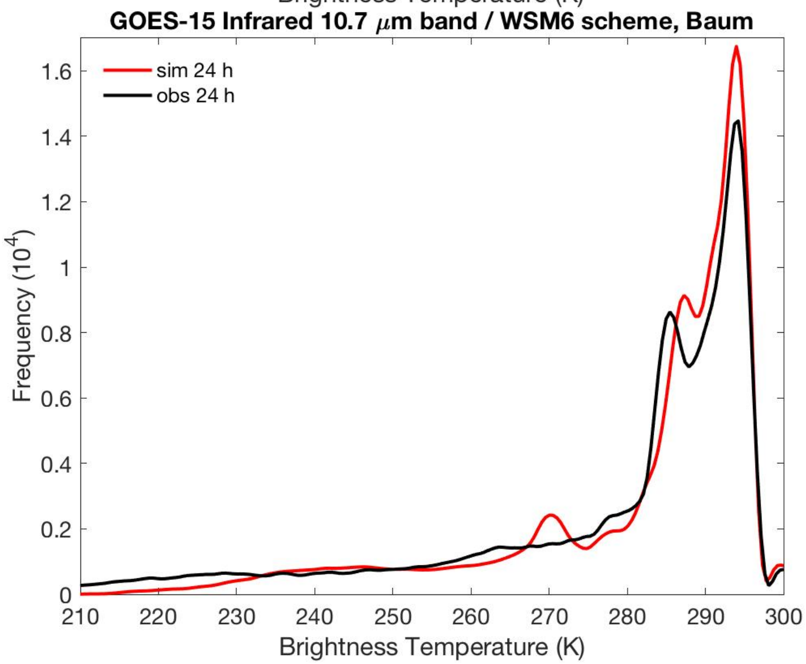
WSM6 Scheme IR (10.7 μm) Imagery – GOES-15

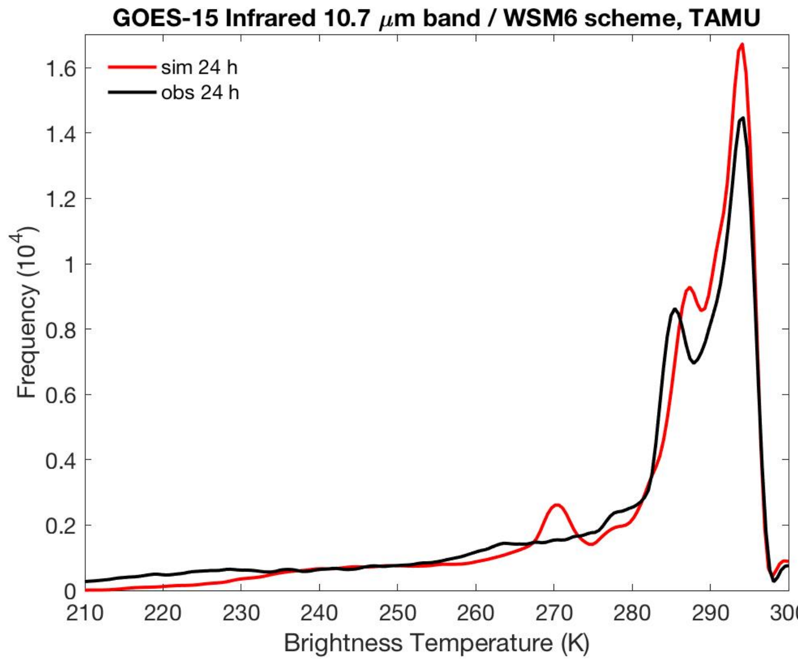


WSM6 Scheme IR (10.7 μm) PDFs – GOES-15



- Too many clear grid points (295 K) and secondary peak (285 K) is shifted to the right
- Original CRTM ice lookup tables produce a more accurate depiction of the clouds than the newer tables





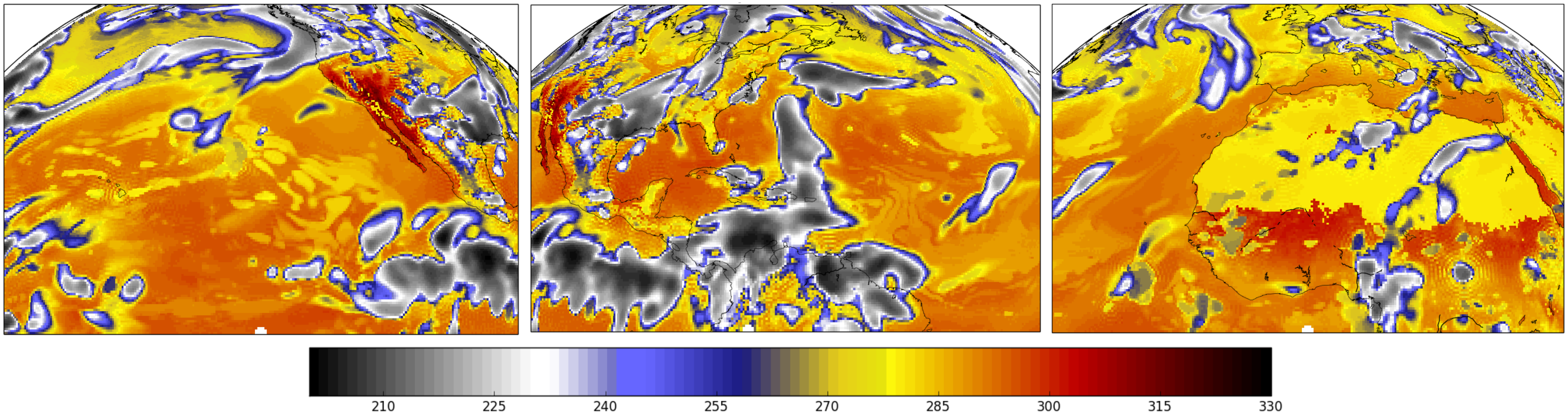
Coarse Resolution GFS Model Simulations

- GFS model forecasts at T574 resolution (~27-km horizontal grid spacing)
  - Model simulations performed by DTC collaborators
  - Results will be used as a proxy for evaluating the accuracy of the cloud and water vapor fields in the ensemble members
- Analysis could be very useful given increased emphasis on all-sky satellite radiance assimilation
  - Ability of the future hybrid data assimilation system to assimilate cloudy observations is highly dependent on the ability of the ensemble to produce realistic clouds

Coarse Resolution GFS Model Simulations

- Another objective of this effort is to assess the accuracy of different cumulus parameterization schemes
- Assessing SAS and Grell-Freitas cumulus schemes
- Simulated infrared brightness temperatures generated from GFS pressure-level data using UPP/CRTM
- Post output includes simulated infrared brightness temperatures for GOES-13/15, and MSG SEVIRI

GOES-15 10.7 μm　　GOES-13 10.7 μm　　SEVIRI 10.8 μm

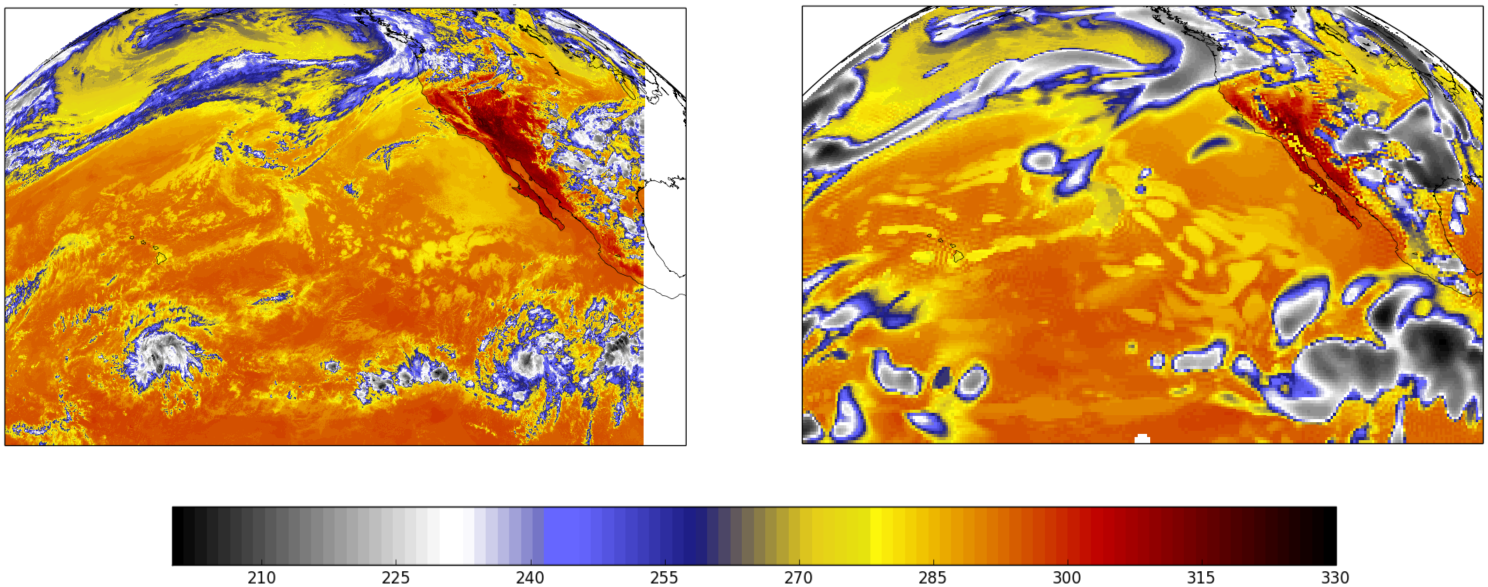


Coarse Resolution GFS Model Simulations

Simulation using SAS cumulus scheme and the original CRTM lookup table

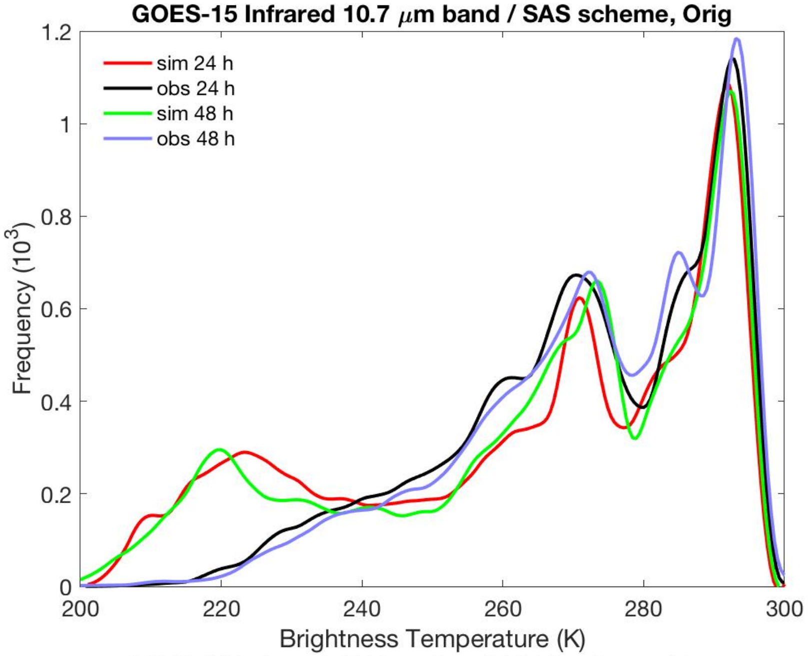
Observed GOES 10.7 μm

Simulated GOES 10.7 μm

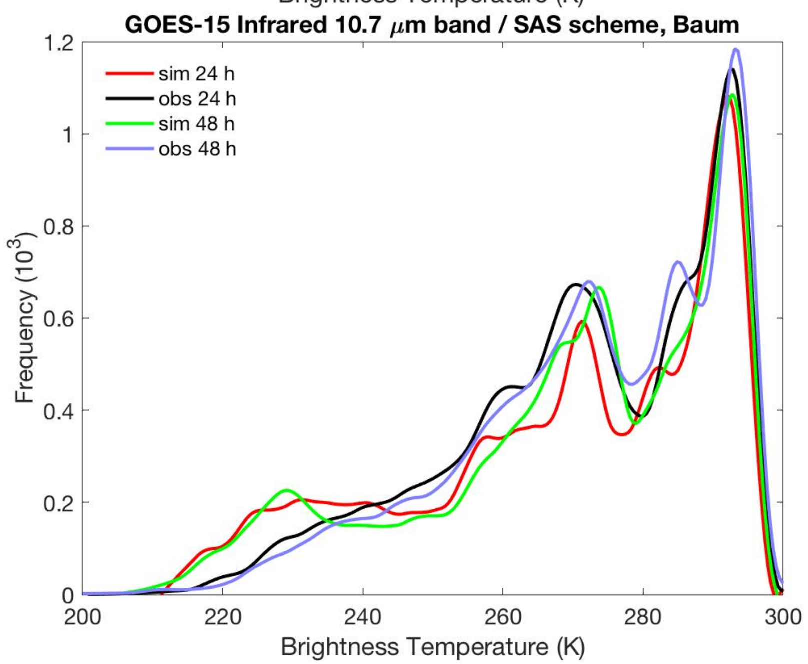


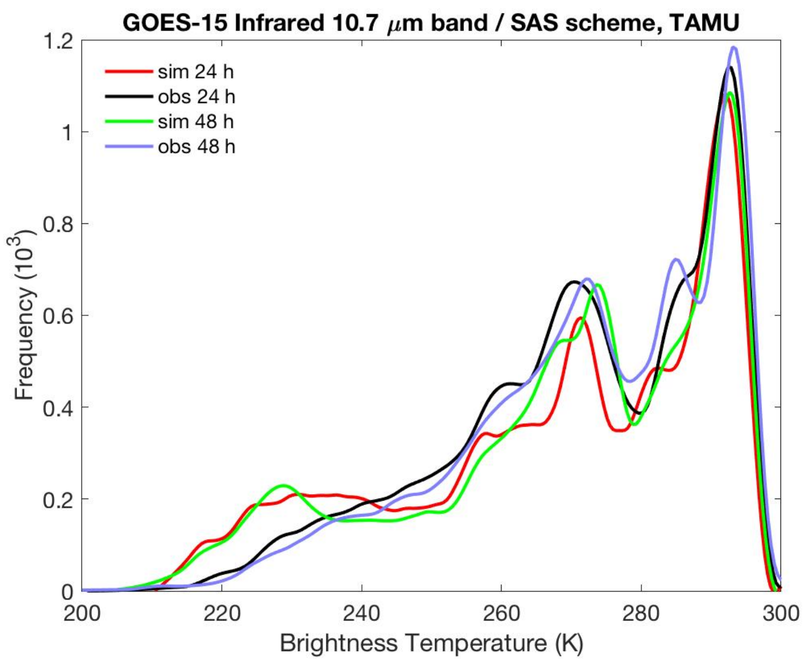
- Representative comparison from a 24 hour forecast
  - Simulated clouds have a more uniform appearance – likely due to coarse model resolution
  - Large cold bias in cloudy regions – could be due to use of simple cloud scheme or the CRTM

Coarse Resolution GFS – GOES-15 10.7 μm PDFs



- Observations were averaged to model resolution
- Results are much better for cold clouds when using the newer ice cloud property lookup tables
- Compensates for lack of partial cloudiness option





CRTM Ice Cloud Property Lookup Table Summary

- The newer Baum and TAMU ice cloud property lookup tables led to warmer brightness temperatures
- Generally a good thing at coarse resolutions but leads to excessively warm brightness temperatures at higher resolutions
- Conclusions are made more complicated by our need to leverage simulations performed by other groups
  - Different parameterization schemes employed in the coarse- and high-resolution simulations
- Additional experiments are necessary to reach a more definitive answer concerning which table provides the most accurate results

Outcomes Delivered to Operations

- Added a routine to the GSI so that the effective particle diameters are computed correctly for each cloud species
- Collocation of model forecast to the observation location
  - Added capability to use nearest neighbor in space and/or time versus weighted average when choosing the vertical profiles to be used by the CRTM
- Share GSI modifications with NCEP/EMC for use by the wider GSI community
  - Changes available through GSI Community Repository & Redmine Issue (ticket) documentation

Final Plans and a Request for Datasets

- Plans for the next year include continuing to develop a flexible satellite-based analysis system that can be easily adapted to work with other schemes and with the FV3
  - Use a variety of statistical methods to assess impact of the various parameterization schemes being considered for inclusion in future model versions
- One final request – please let us know if you have model forecasts that you would be willing to share with us
  - We may be able to assess their accuracy using our satellite-based verification system