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

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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 parameterization schemes in the GFS and FV3 models

Project Objectives

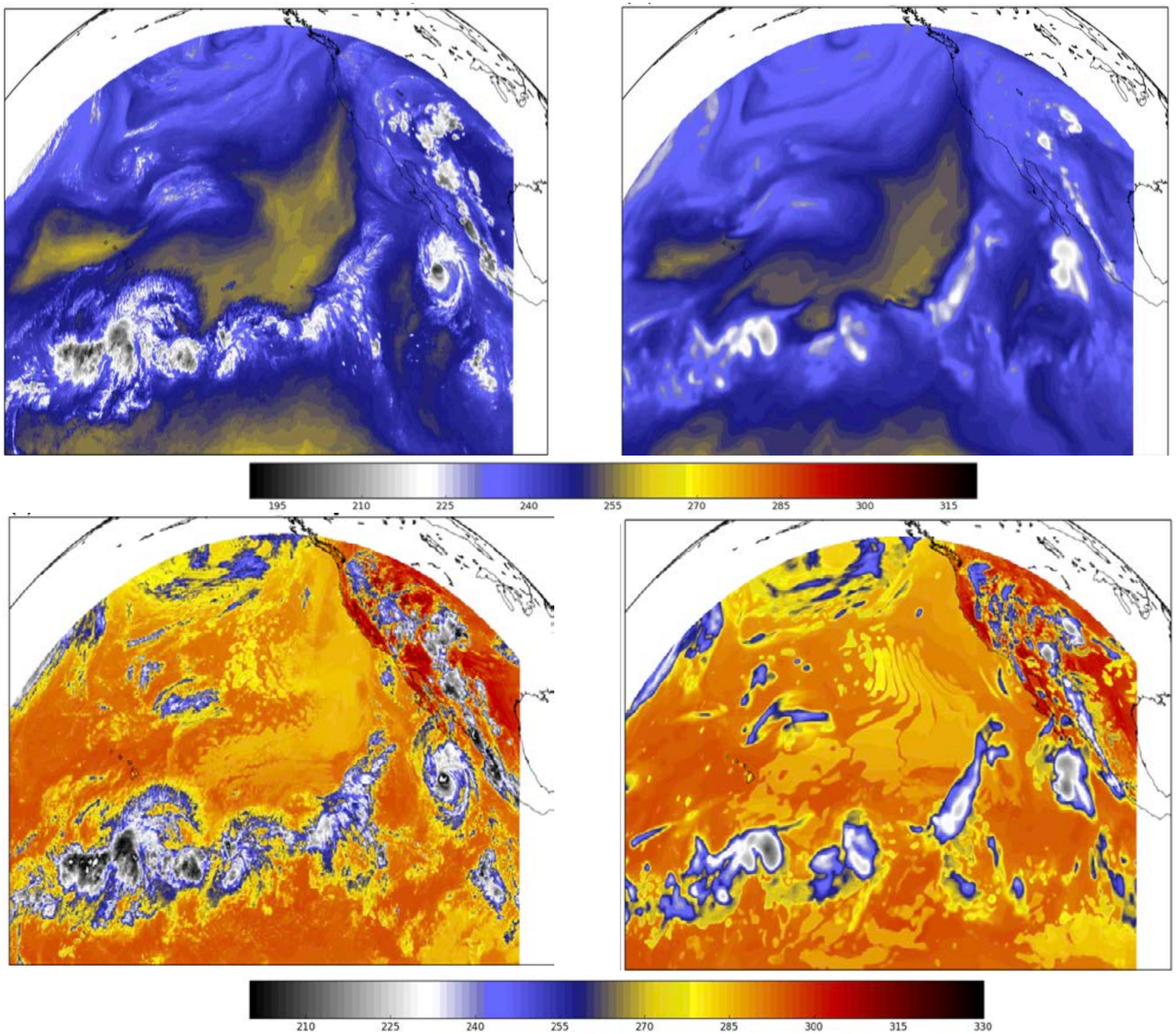
- Enhance the satellite simulator capabilities of the GSI and CRTM in cloudy situations
  - Made changes to interface so that the effective particle diameters are computed correctly for each cloud species
  - Assisting efforts to evaluate new cloud property lookup tables optimized for the GFDL microphysics
- Rigorously evaluate 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

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 microphysics parameterization scheme
  - 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

Example of Model Forecast Bias

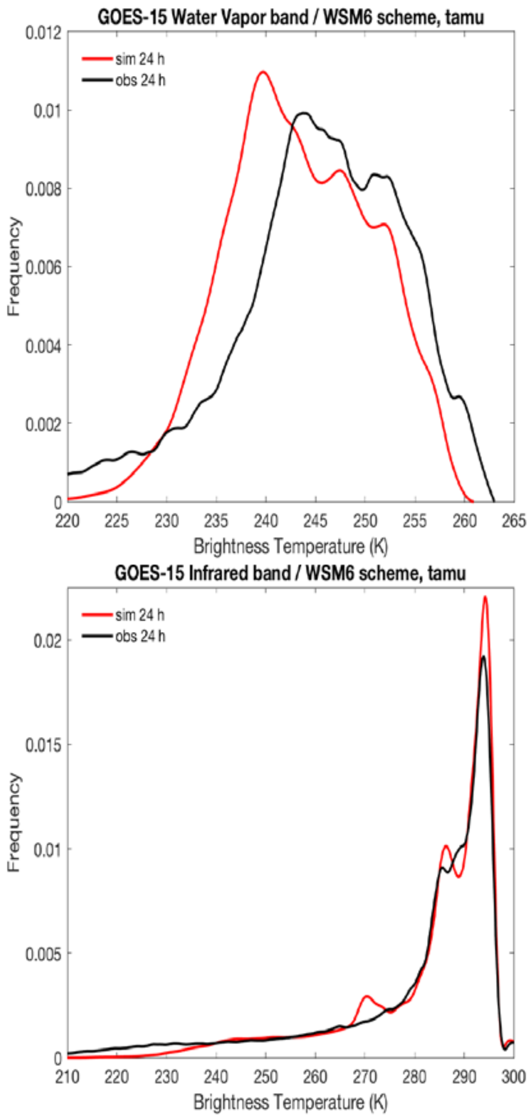
Observed Brightness Temp. Simulated Brightness Temp.



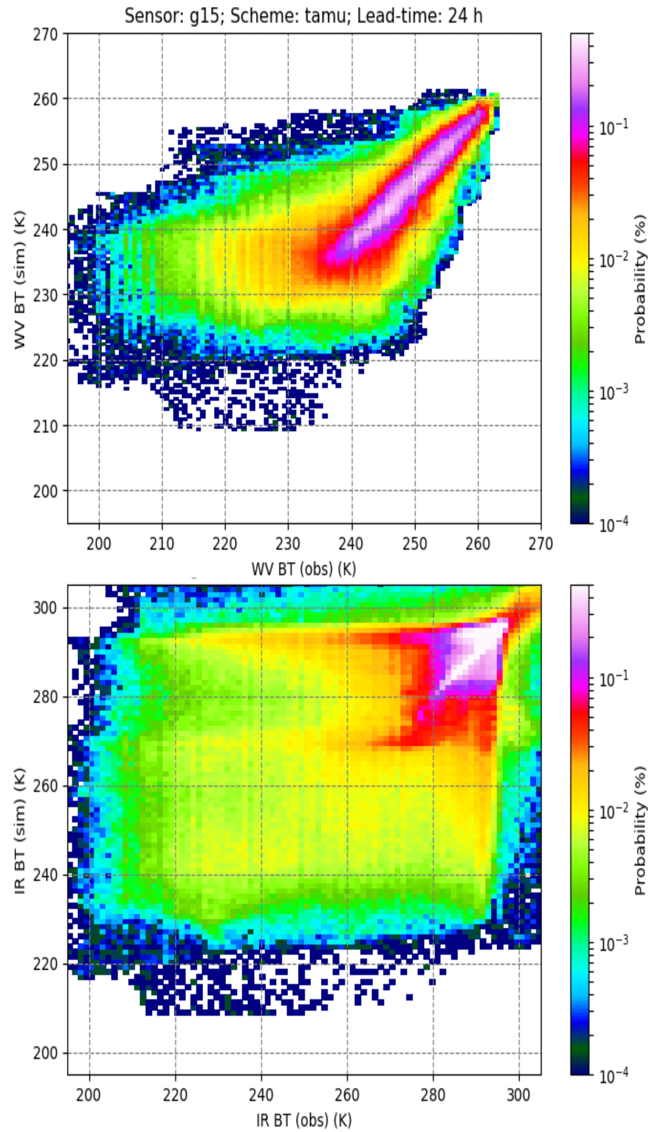
- GOES-15 imagery
- Water vapor band in top panels, with window band in bottom panels
- 24 hour forecast valid at 00 UTC on 28 July 2014
- Moist bias in upper troposphere
- Upper level clouds are too warm
- Clouds are too homogeneous

Histograms Showing Model Forecast Biases

Prob. Dist. Functions

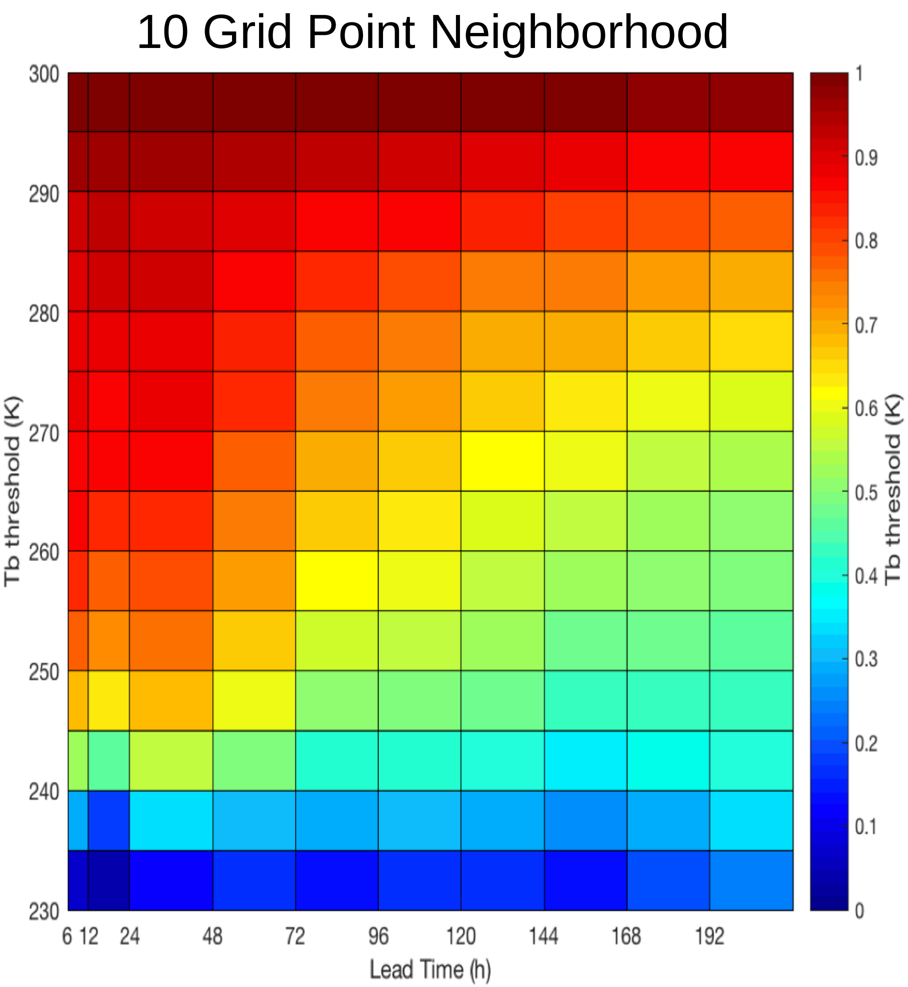


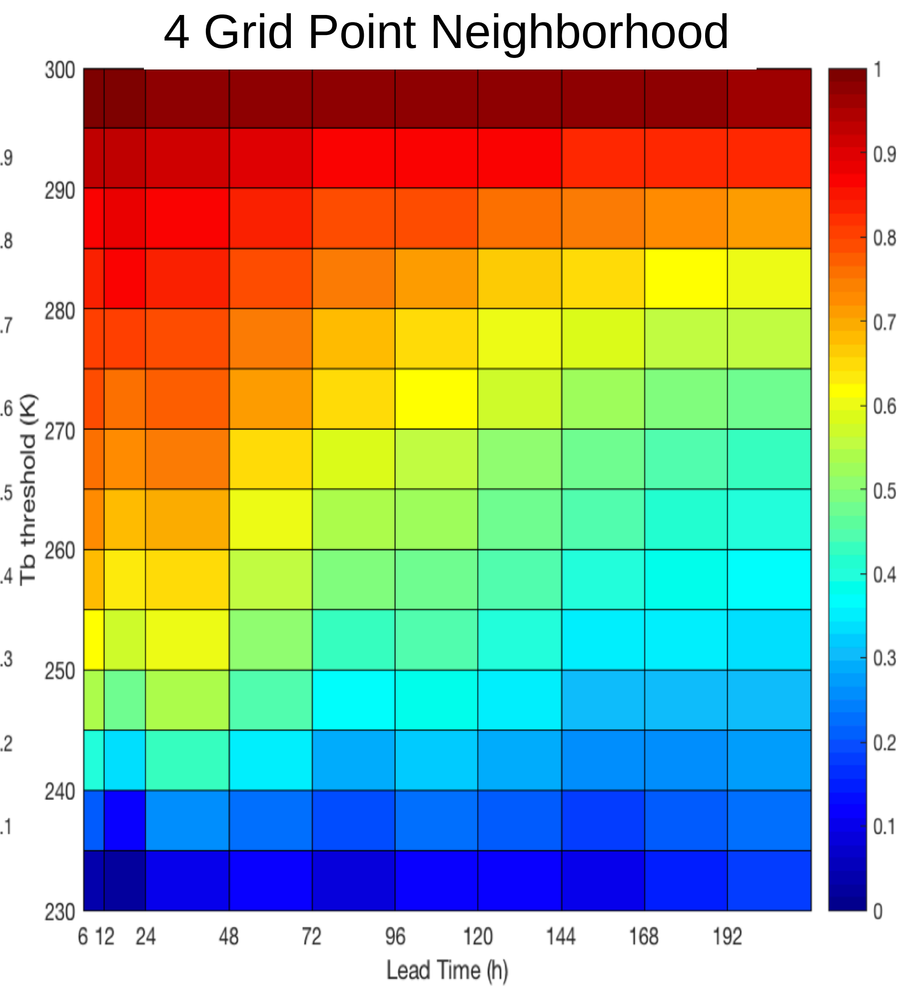
2-d Histograms



- Water vapor band in top panels, with window band in bottom panels
- 24-hr forecasts from 10 days in July
- Leftward shift of red line indicates systematic moist bias in upper troposphere
- Window band brightness temps were more accurate

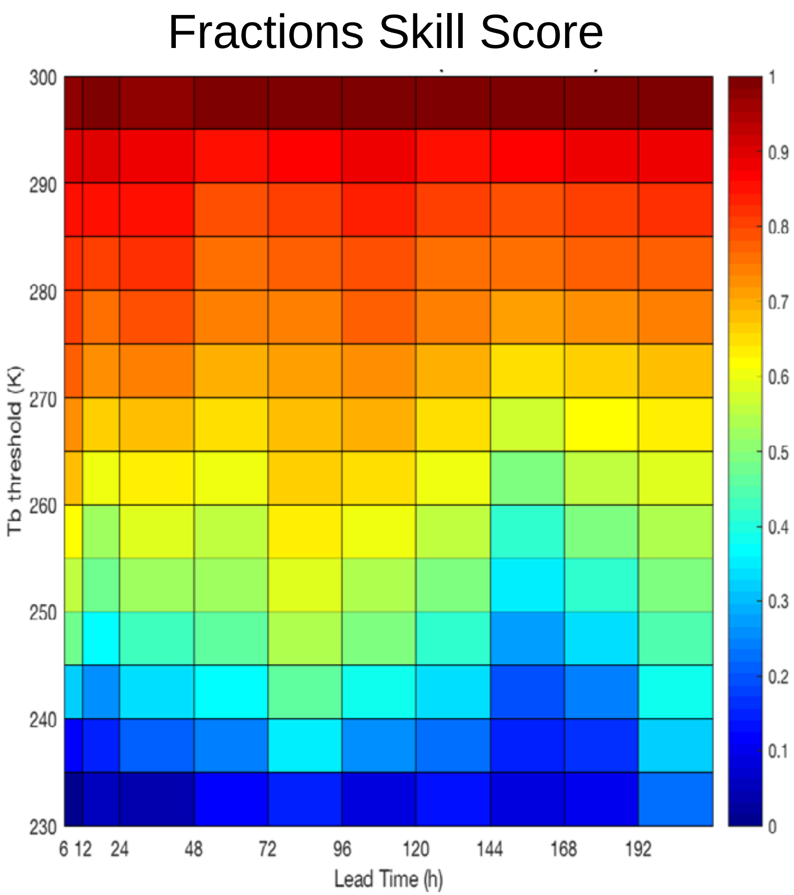
Fractions Skill Score – All Grid Points

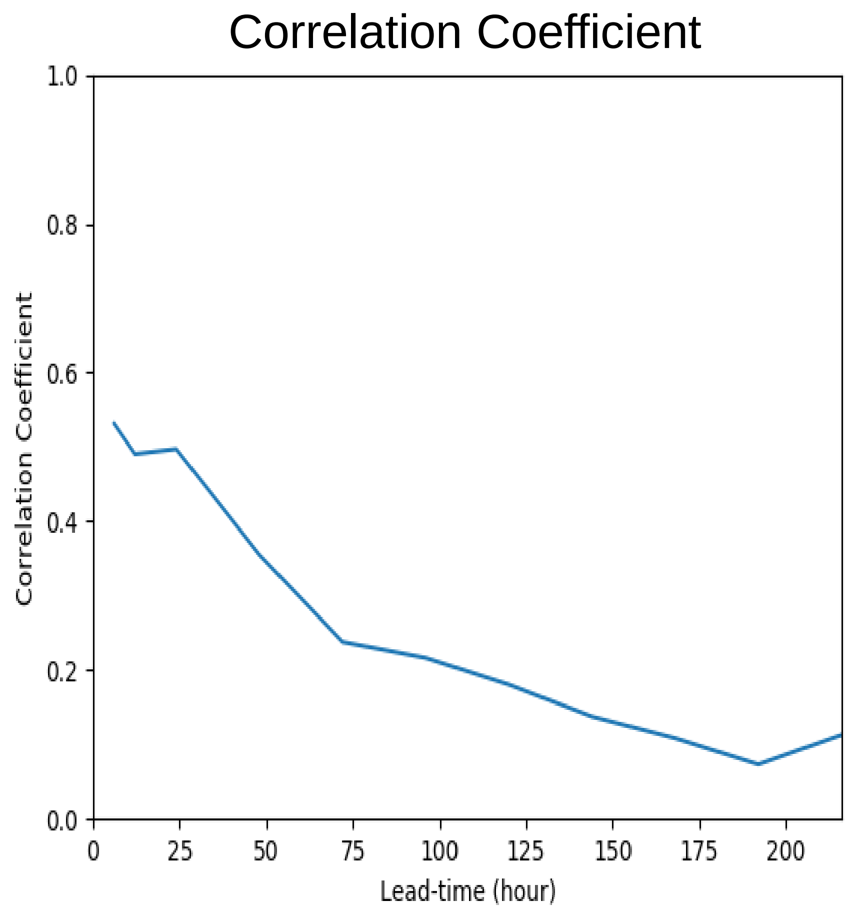




- Analysis method most useful for BT < 270 K
- Some forecast skill in upper-level clouds up to 120 hours

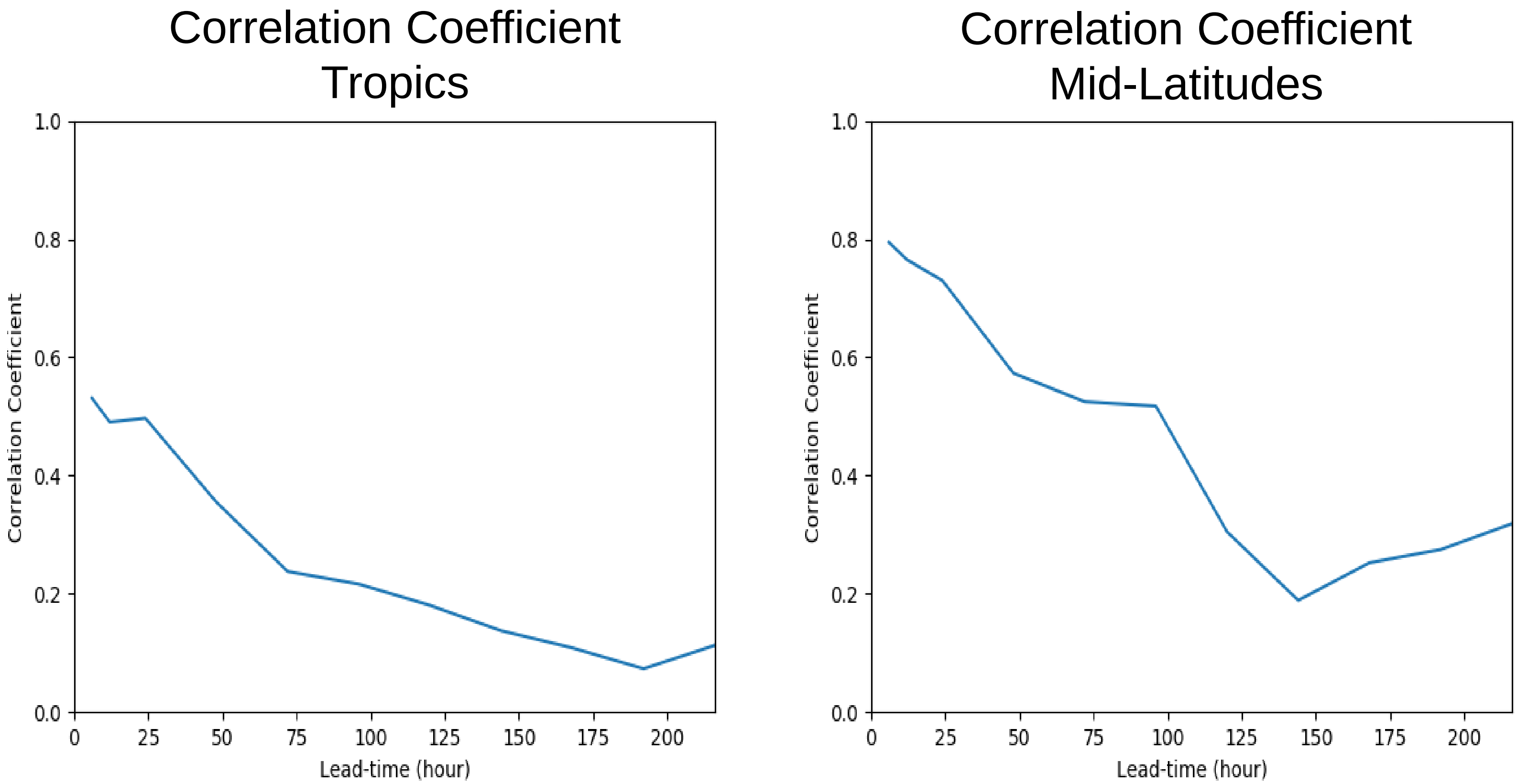
Regional Analysis – Tropics (ITCZ)





- According to FSS, forecast skill remains relatively constant until the 196-hr forecast; however, the correlations decrease with time
- Overall, forecast skill is low due to stochastic nature of convection

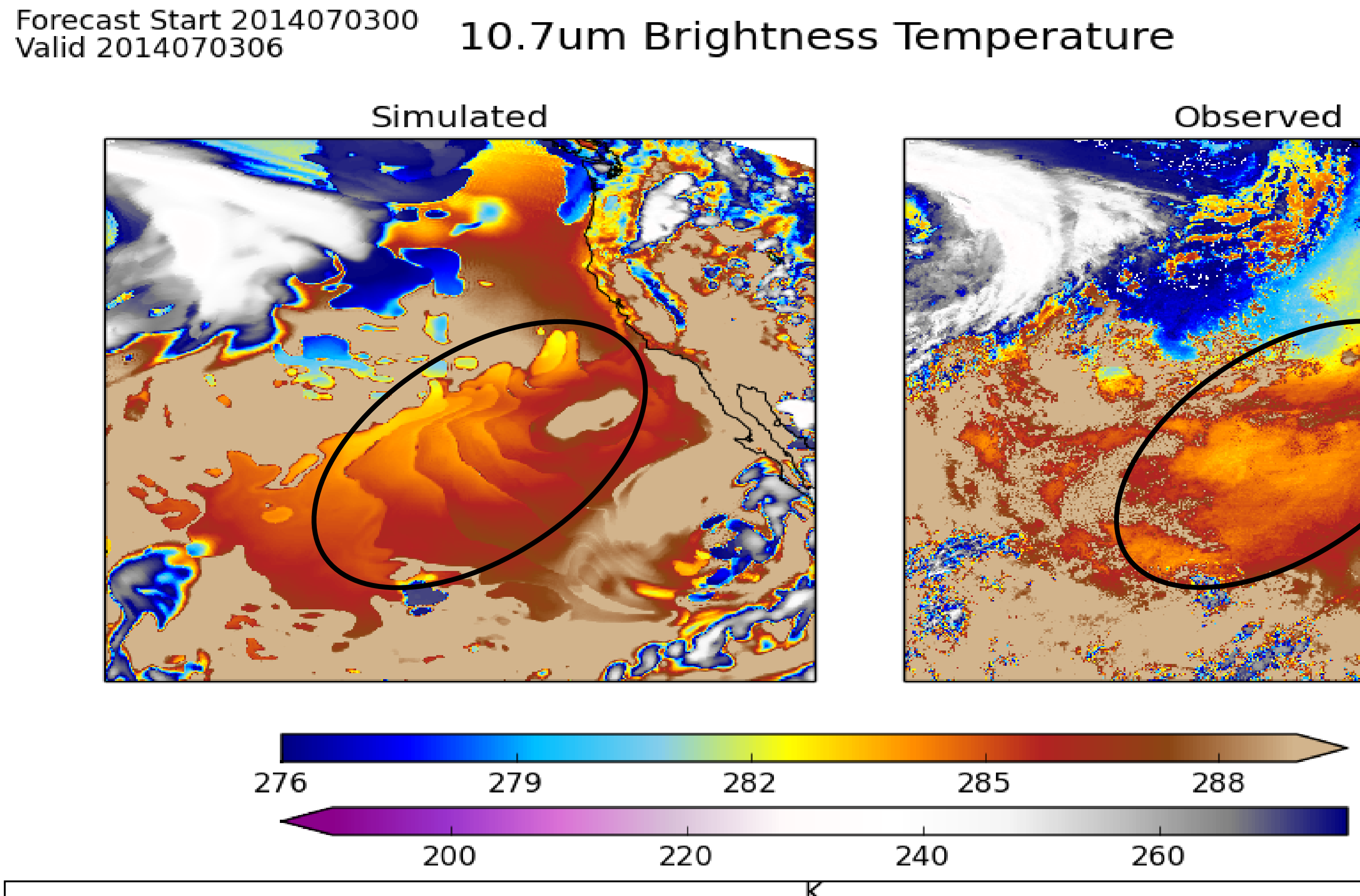
Regional Analysis – Tropics (ITCZ) & Mid-Latitudes



- Correlations show that the cloud field is more accurately forecast in the mid-latitudes than it is in the tropics

- Higher correlations at all forecast lead times in mid-latitudes likely due to greater predictability of extratropical cyclones

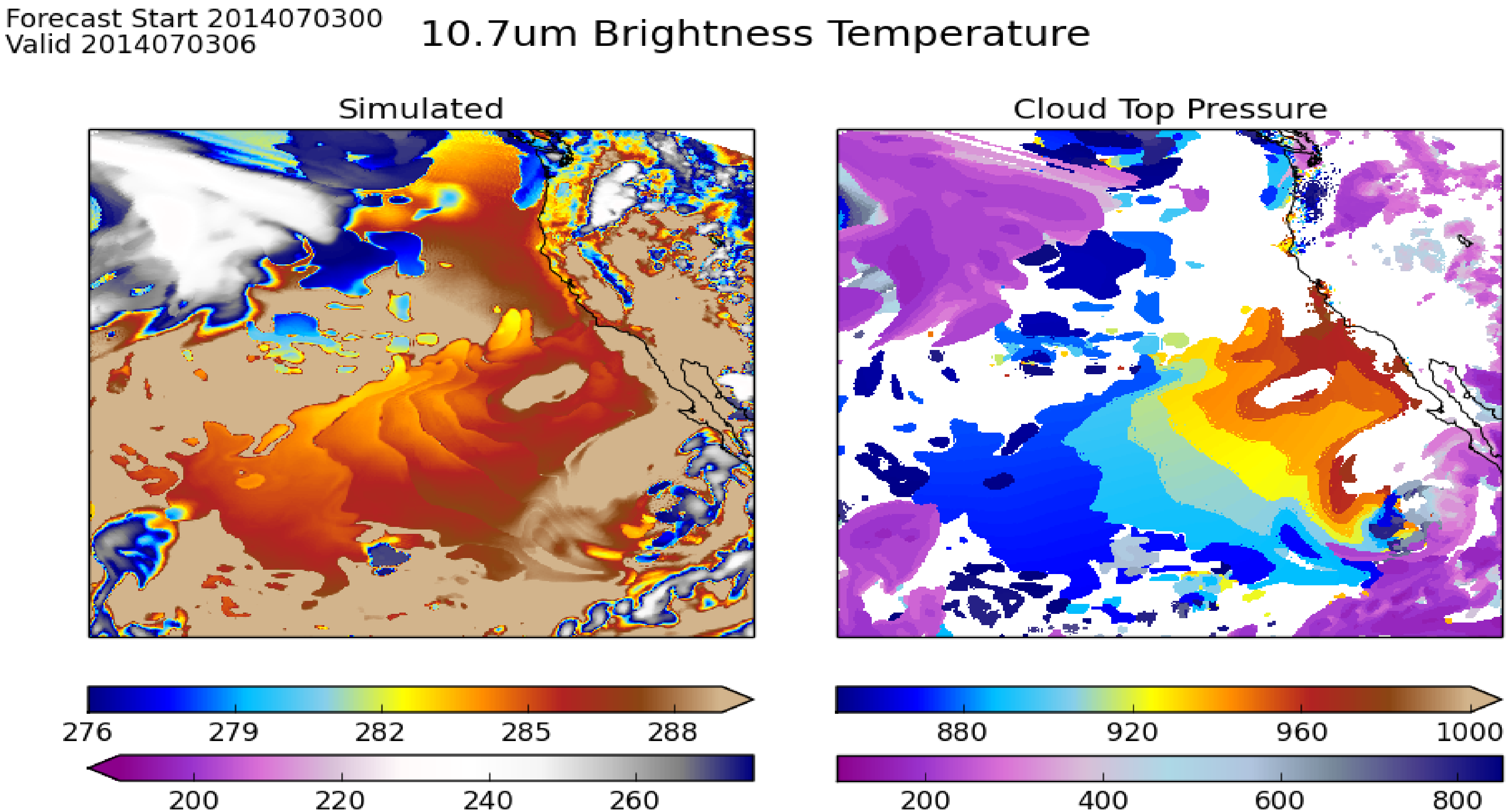
Stratocumulus Cloud Field Errors



- Observed satellite imagery has smooth appearance; however, forecast imagery has discrete jumps in it

- Forecast cloud top temperatures are reasonable if you average across the jumps; however, the jumps themselves are not realistic

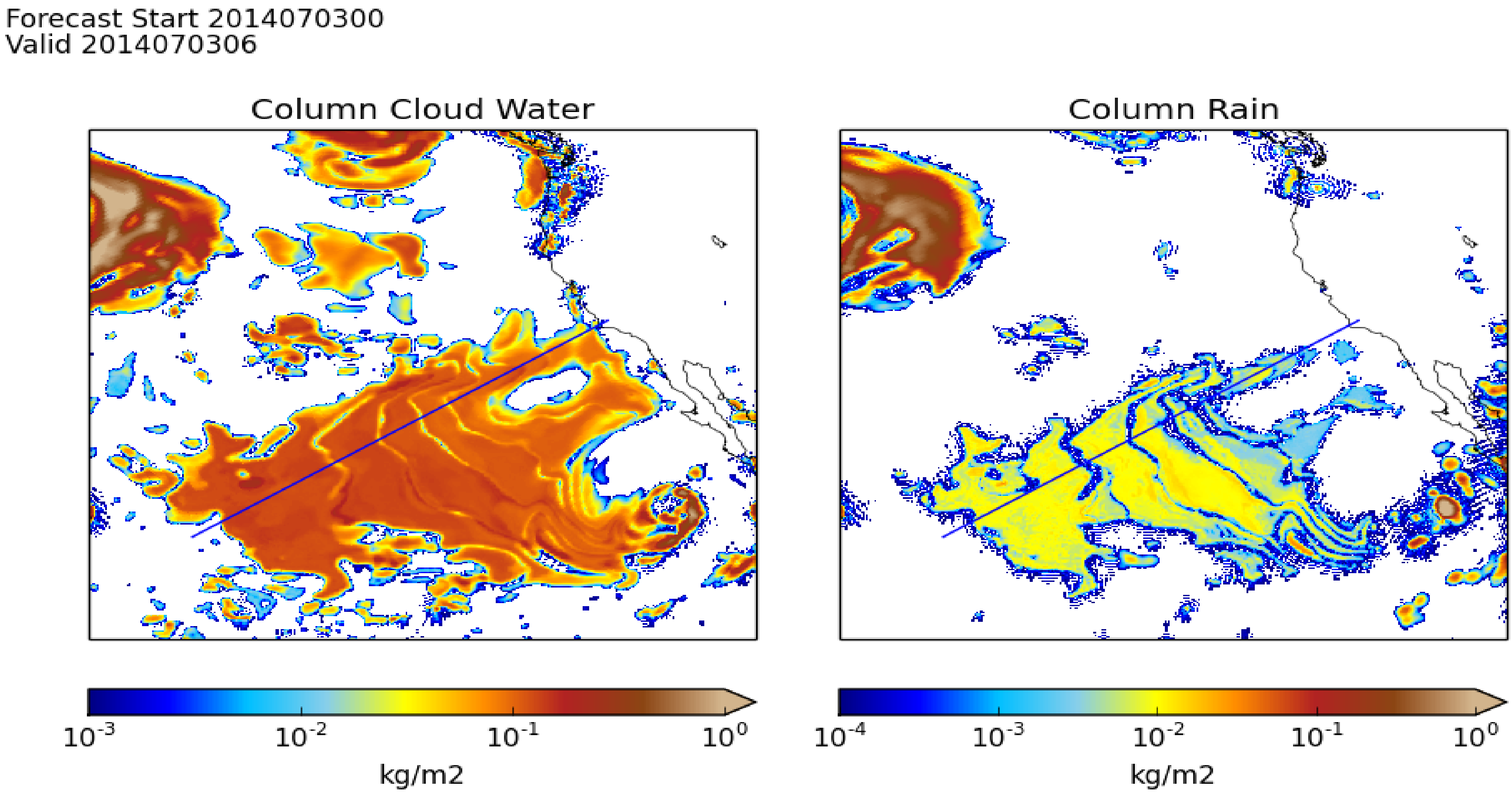
Stratocumulus Cloud Field Errors



- Locations of jumps in brightness temperatures exactly match contours of where the cloud top pressure levels change

- Jumps are directly related to some artifact that arises when the cloud top transitions from one model sigma level to another

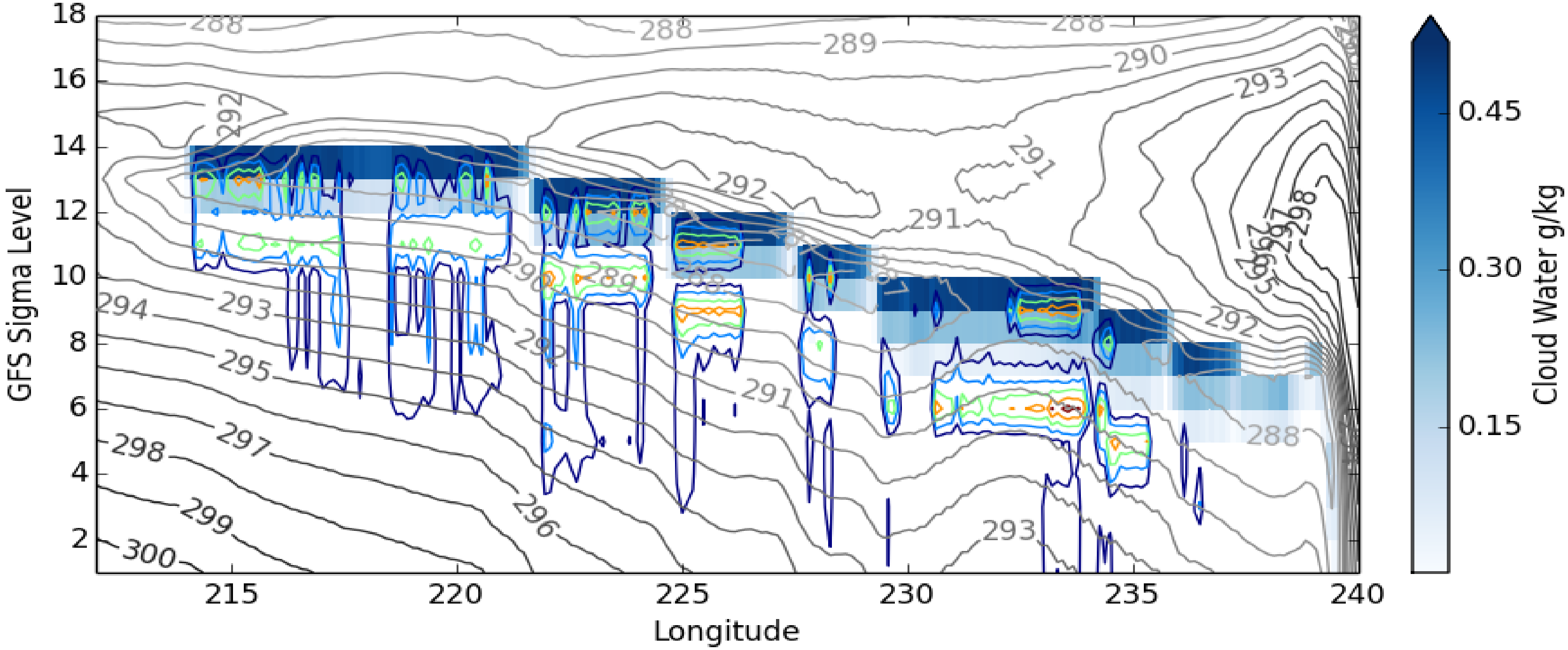
Stratocumulus Cloud Field Errors



- Cloud water and rain water exhibit jumps along these boundaries
- Black line denotes cross-section location shown in next slide

Stratocumulus Cloud Field Errors

Grey Contours: Temperature K
Color Contours: Rain Max=0.02 g/kg
Shaded Contours: Cloud Water

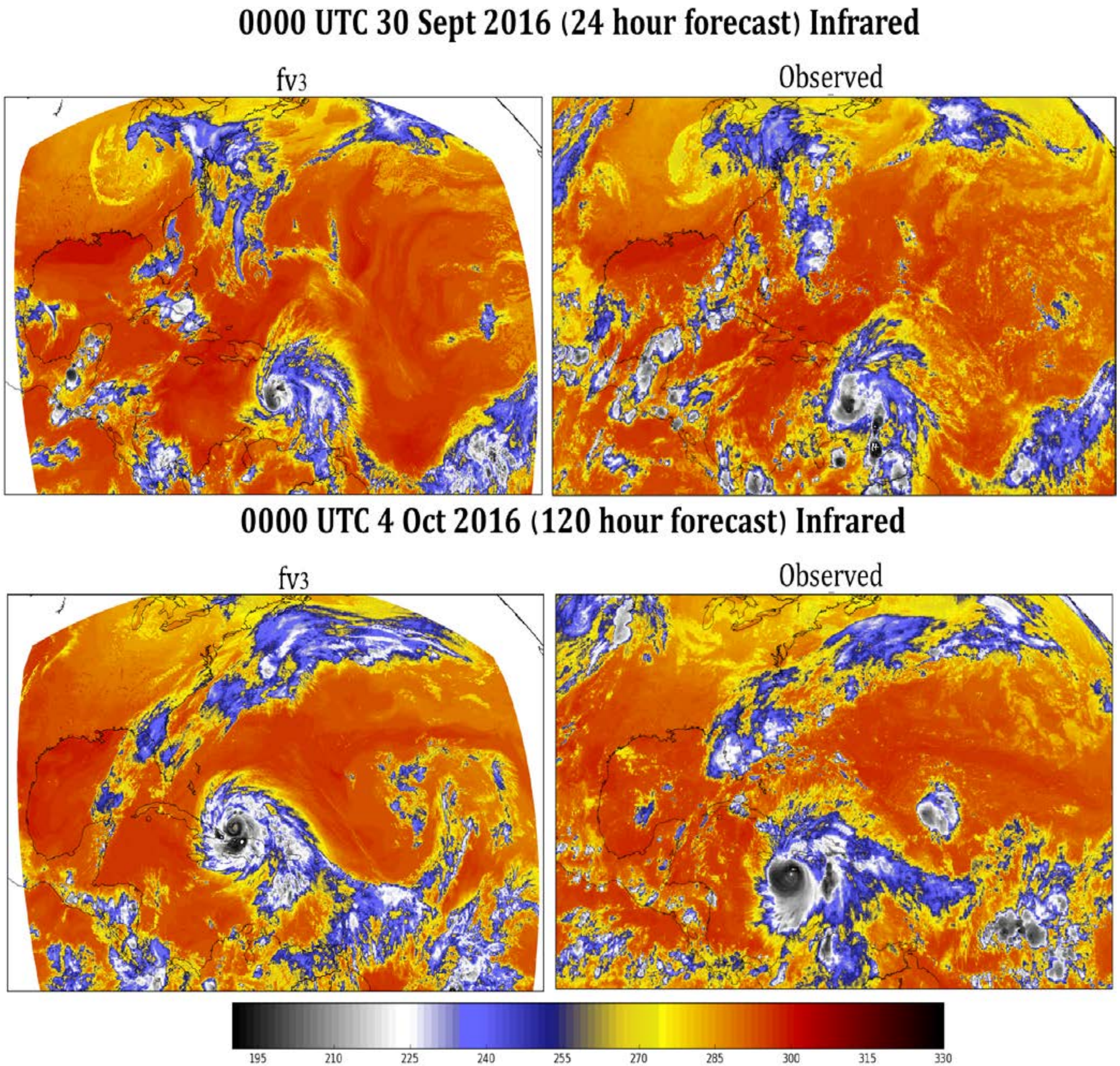


- Wind flow is from right to left across the cross-section
- Could be problem with planetary boundary layer scheme
- Illustrates how satellite-based verification can detect model errors

Collaborations with GFDL

- CIMSS developed a stand-alone CRTM driver to compute simulated brightness temperatures using FV3 output
  - CRTM V2.3
  - netcdf I/O
  - MPI parallelization
  - All sensors supported by CRTM can be simulated, except that polar orbiting sensors have fixed viewing angle
- Delivered to GFDL in April 2018
- GFDL FV3 group is actively using this software

GFDL FV3 Hurricane Matthew Simulation – Infrared



- Forecast cloud fields are realistic in the FV3 simulations when using the GFDL microphysics
- Much more extensive verification is necessary

Future Plans

- Use remaining funds to begin evaluating the accuracy of the cloud and water vapor fields in FV3 forecasts run at GFDL
- Assist efforts at EMC (Emily Liu) to evaluate the impact of using cloud property lookup tables in the CRTM that have been optimized for use with the GFDL microphysics
- Assist efforts by the Model Evaluation Group (MEG) to assess the accuracy of FV3-GFS forecasts