Application of the GOES-R Series Cloud Mask to generate Clear Sky and All Sky Radiance Products for Data Assimilation

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Outline

- Background
  - GOES-R Advanced Baseline Imager (ABI)
  - Clear Sky and All Sky Radiance products for Infrared channels 7-16
- 1st year of effort
  - Define products for data assimilation with collaboration from NWP
  - Validation of the GOES-16 CSR product
- Validation highlights issues with cloud mask. Able to compare cloud masks, show improvement
- Plans for 2nd year of effort
- Summary

Background

ABI Radiance Product for Data Assimilation

- CIMSS, UW-Madison GOES-R Project
- Support product generation at NOAA/NESDIS/STAR by Thomas King, Walter Wolf, Peter Kheen, Qiang Zhao, Priyanka Roy
- From the beginning, have received helpful feedback from NWP to optimize the products usefulness
  - Haixia Liu & Andrew Collard @ NOAA/NCEP/EMC
  - Chris Burrows @ ECMWF
  - Haidao Lin @ NOAA/ESRL/GSD
  - Ben Ruston @ Navy Research Lab
  - Ruth Taylor @ UK Met Office

Background
Review of NOAA Cloud Products

- NOAA runs one set of "**Enterprise**" Algorithms on its GOES-R (ABI) and JPSS (VIIRS) imagers.
- On GOES-R, current operations runs "**Baseline**" older algorithms delivered in 2010. Pilot Projects are underway to test use of Enterprise in GOES-R Ground System.
- Enterprise Algorithm:
  - Cloud Detection is probabilistic (Naive Bayesian).
  - Cloud Top and Cloud Optical/Micro are Optimal Estimation (similar to OCA).
  - Product suite includes standard products of cloud mask, phase, cloud-top pressure, temperature, height, optical depth, particle size and water path.

Background
Geostationary Imager Radiance Products

- SEVIRI Clear Sky Radiance (CSR) products are used by NWP for data assimilation. AHI is under investigation at NOAA/NCEP.
- ECMWF using CIMSS Clear Sky Brightness Temperature (CSBT) from GOES I-P Series Imagers.
- ***GOES-R ABI capability never established***.
- NWP users prefer consistency to simplify software for data ingest and quality control.
- At ITSC-XX, the NWP community stated a preference for the EUMETSAT CSR & All Sky Radiance (ASR) format.

GEO CSR/ASR Product Design

- **SEVIRI** Channels 4-11 L1b 3 km pixels processed with 16x16 pixel processing boxes to define average brightness temperatures using a cloud mask to identify clear and cloudy pixels.
  Two data files are created:
  - **CSR**- Average clear pixel brightness temperature and percent clear in the processing box
  - **ASR**- Average brightness temperature for valid pixels in the box as well as average value of clear, total cloud, low cloud, middle cloud, high cloud, percent of pixels in each sample
- Reduction in data volume with this approach
- User confidence in CSR product to remove cloud contamination with box average approach
- **ABI** Channels 7-16 L1b 2 km pixels processed with 15x15 box and L2 Baseline cloud mask. CSR data is a subset of ASR

SEVIRI & ABI Product Comparison

	SEVIRI	ABI Baseline	ABI Enterprise
IR Pixel Size (km)	3	2	2
Processing Box	16x16	15x15	15x15
Minimum Pixel Sample Size CSR/ASR	8/1	23/23	23/23
Includes Percent Clear	✓	✓	✓
Location: center of box	✓	✓	✓
Time: start of scan	✓	✓	✓
Includes Standard Deviation		✓	✓
Water/Land selective average		✓	✓
Clear Sky Tb Cold pixel outlier check		✓	✓
Channel Dependent Cloud Mask			✓
Cloud Sample Average Emissivity			✓
Cloud Percent Water Phase			✓
Cloud Multilayer Flag			✓

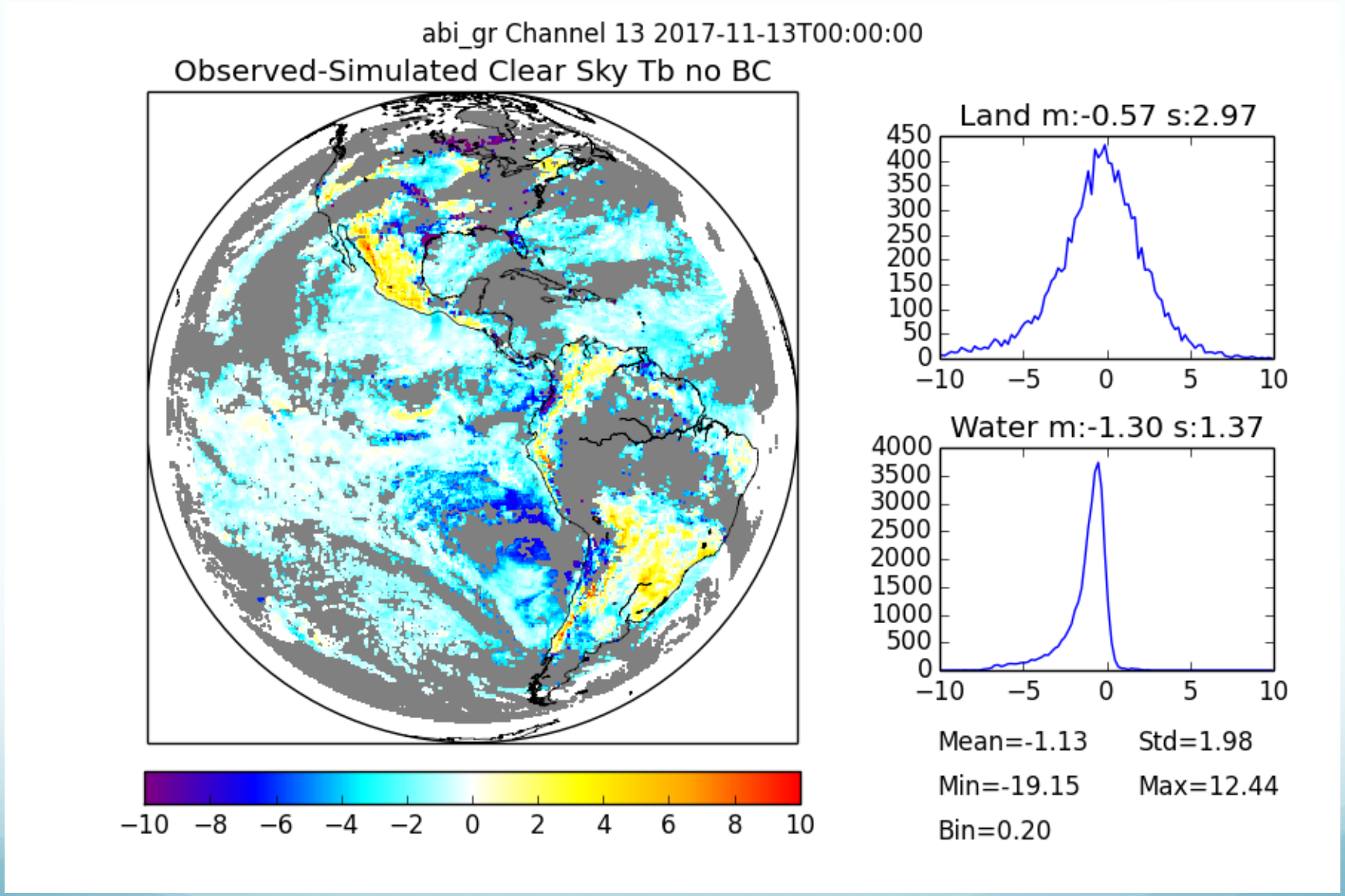
ASR: Cloud top pressure ranges (hPa)

Low	sfc-700
Mid	700-400
High	400-toa

ABI Radiance CSR & ASR Product Validation

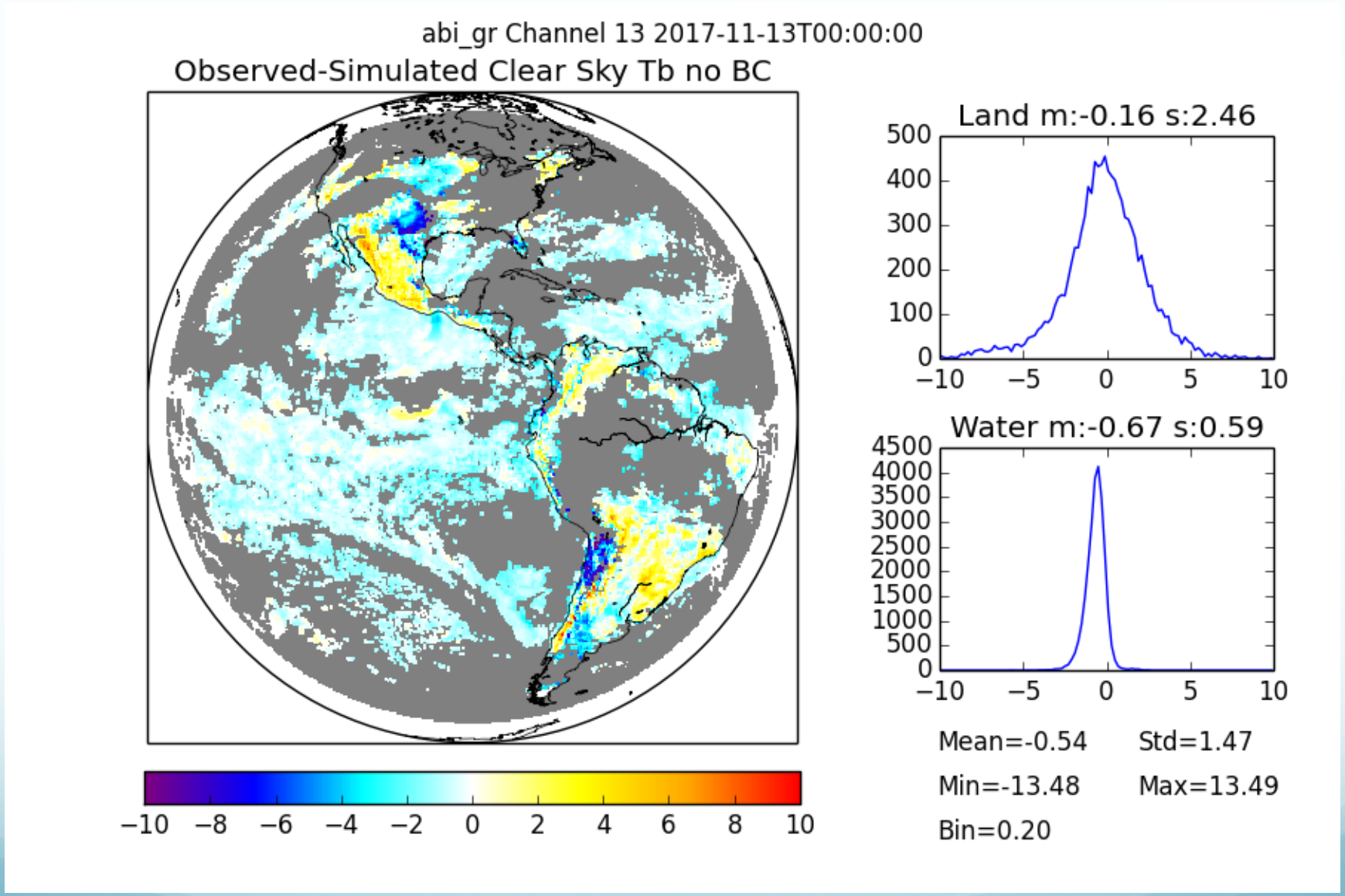
- Validation with the Global Forecast System (GFS) simulated brightness temperatures (background/first guess in analysis cycle) reveal issues with:
  - data bias, cloud mask, need for selective samples around coastlines
  - the CRTM forward model (model temperature & water vapor => brightness temperatures)
- Preliminary data has been generated by NOAA/STAR in NetCDF and BUFR formats for NWP testing
- ECMWF is assimilating the CSR product

10.3µm 15x15 2km Pixel Processing Box – Baseline Cloud Mask



GOES-16 at 85W – Nov 2017, right before move to GOES-East at 75W

10.3µm 15x15 2km Pixel Processing Box – Enterprise Cloud Mask



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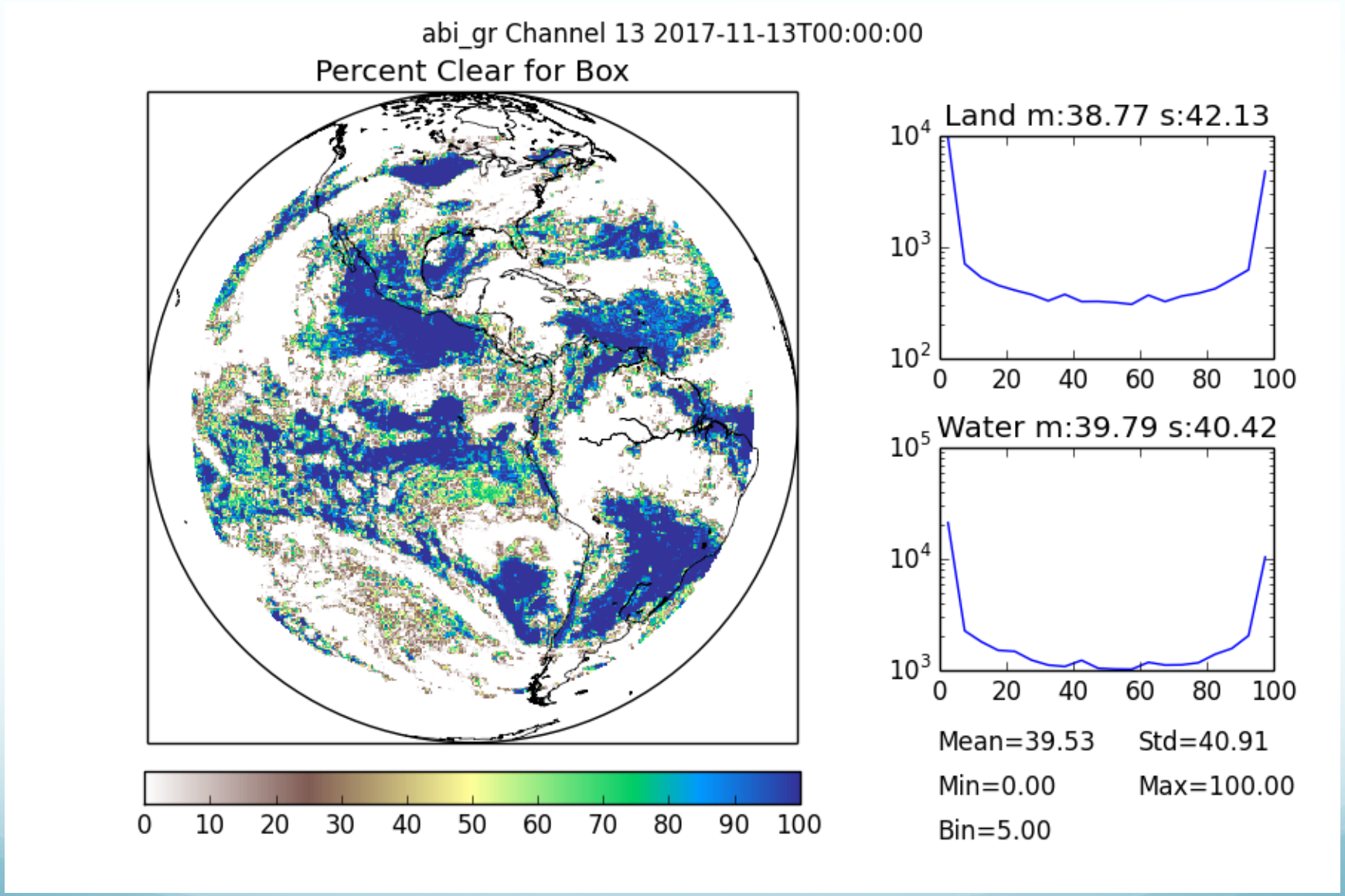

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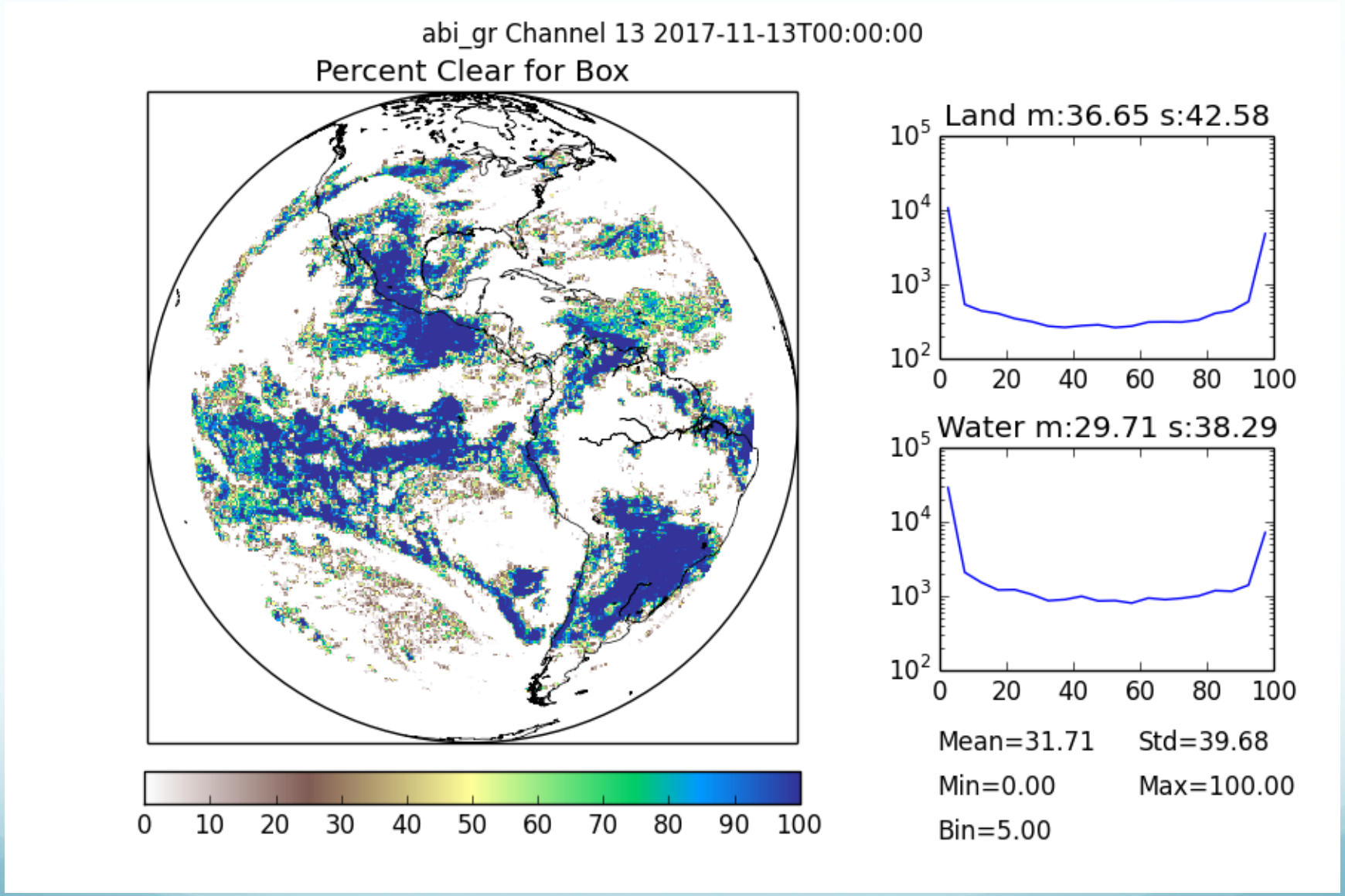
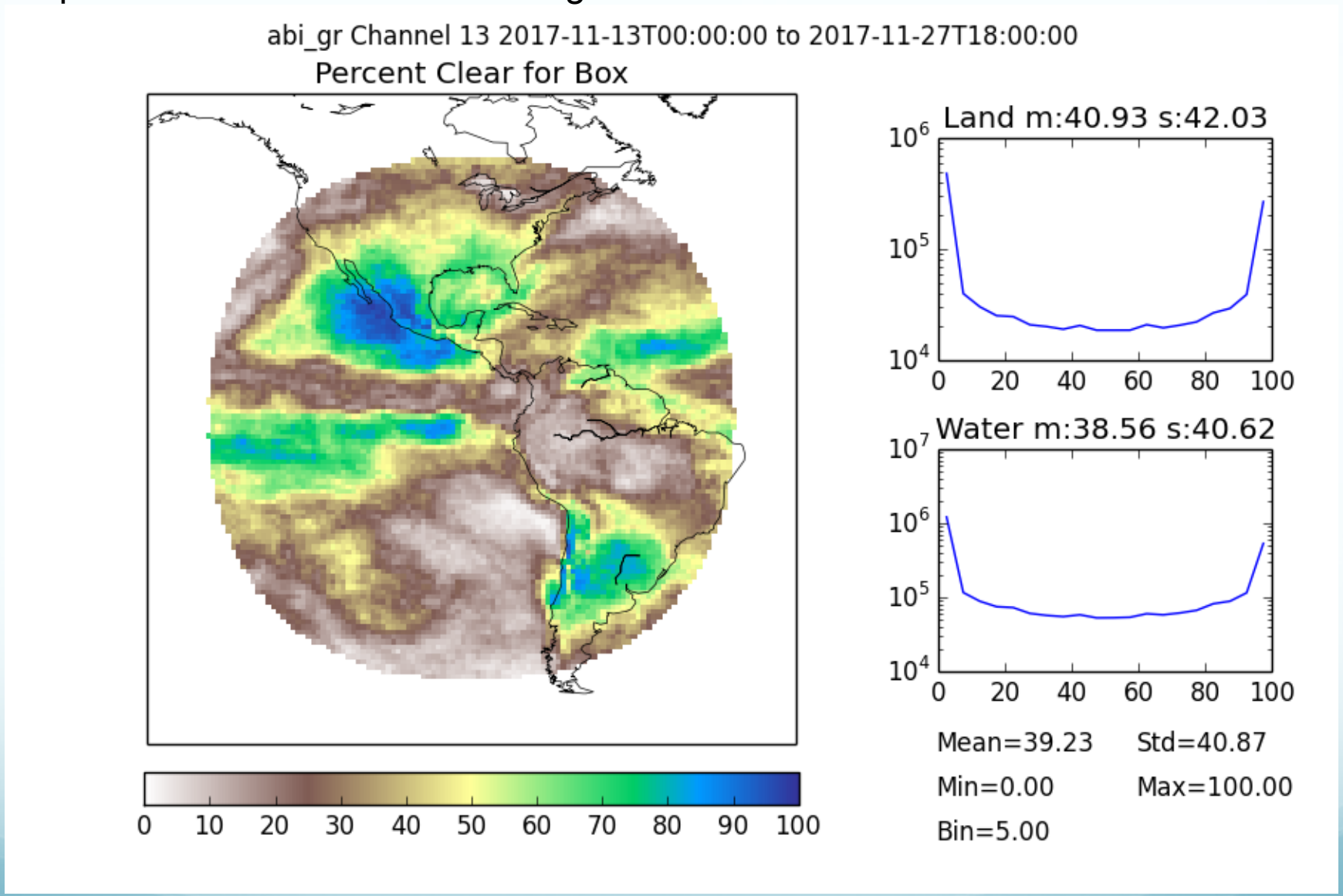


Time Average 0,6,12,18 UTC binned into 2° lat, lon boxes
10.3µm 15x15 2km Pixel Processing Box – Baseline Cloud Mask



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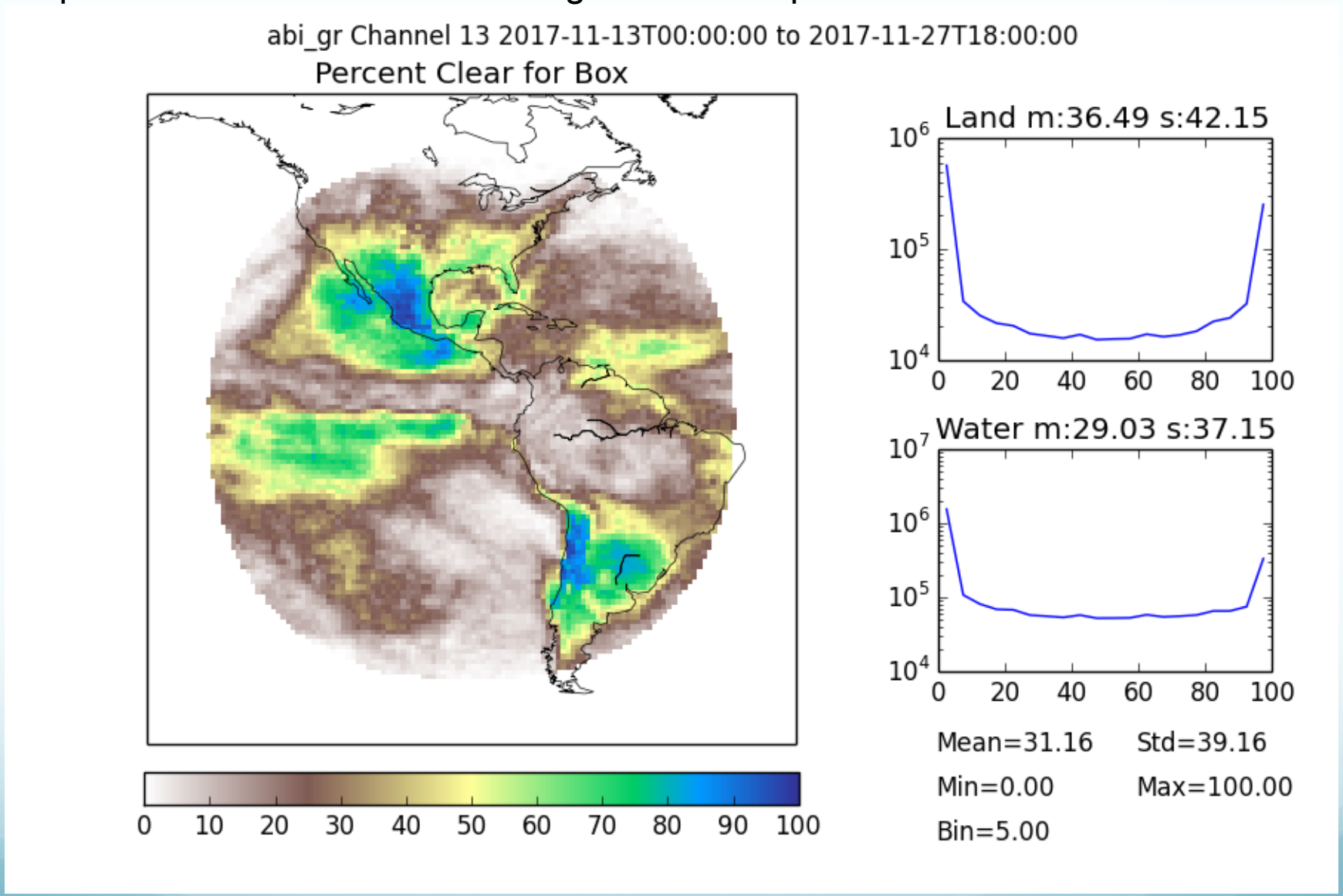

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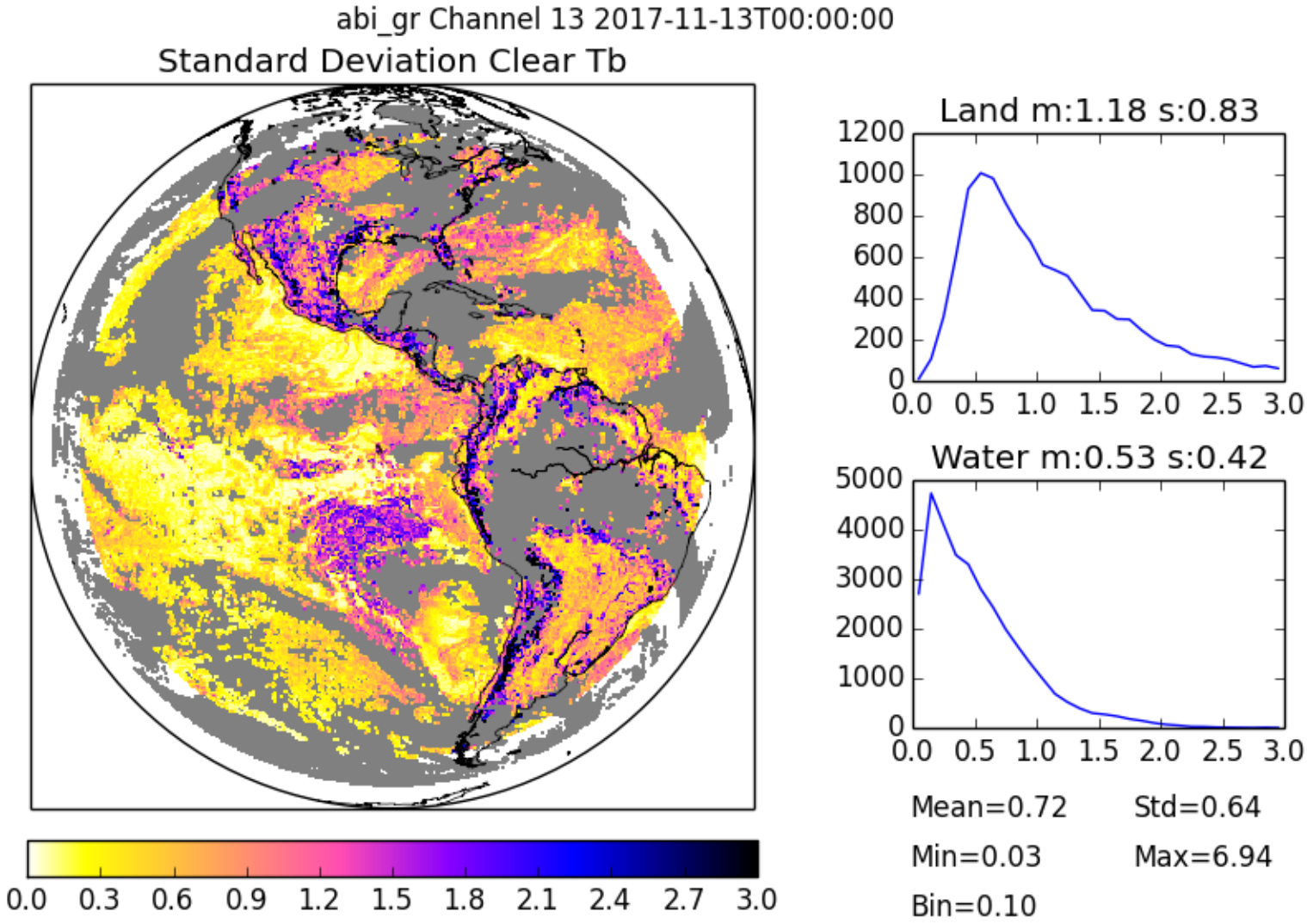
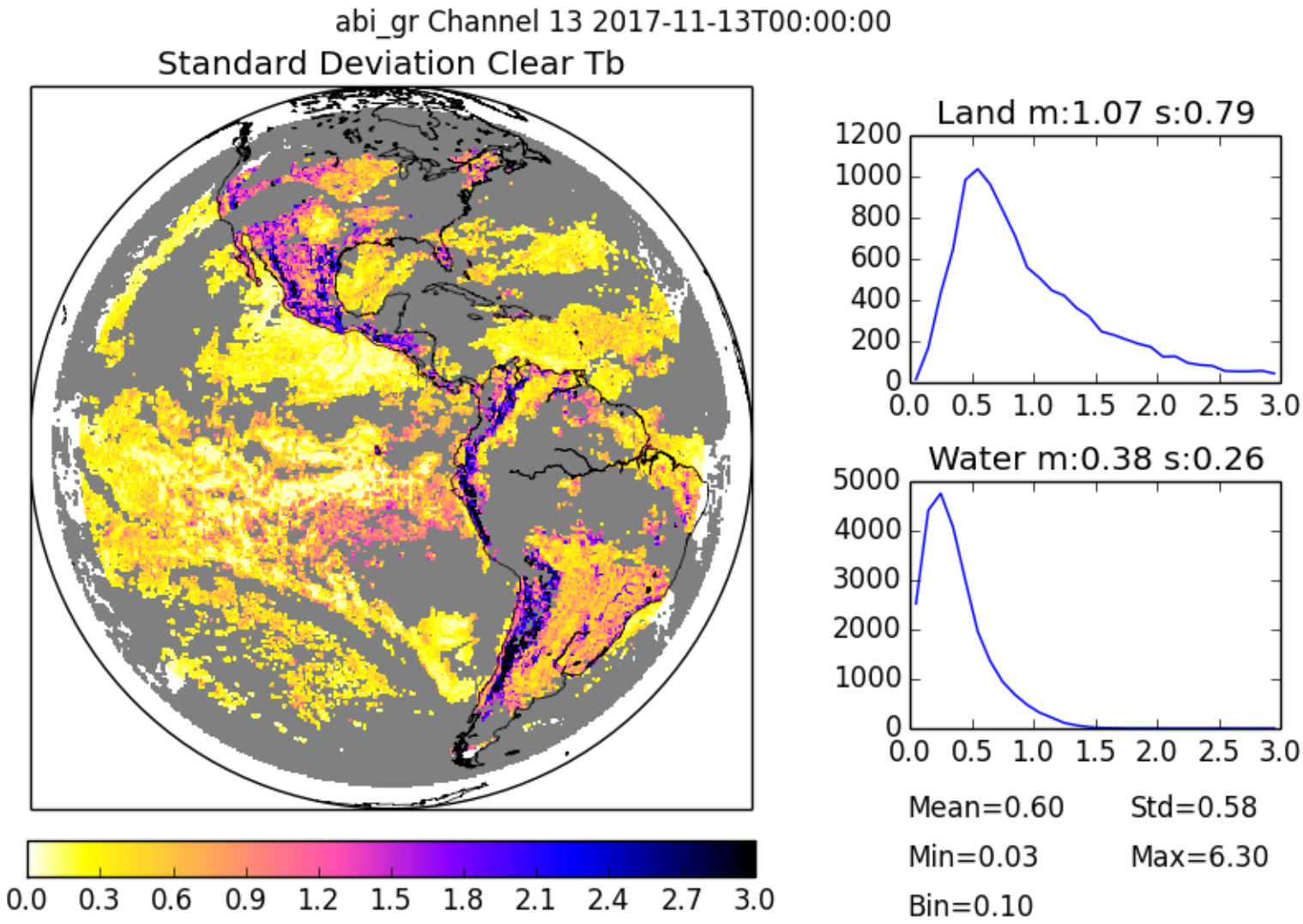
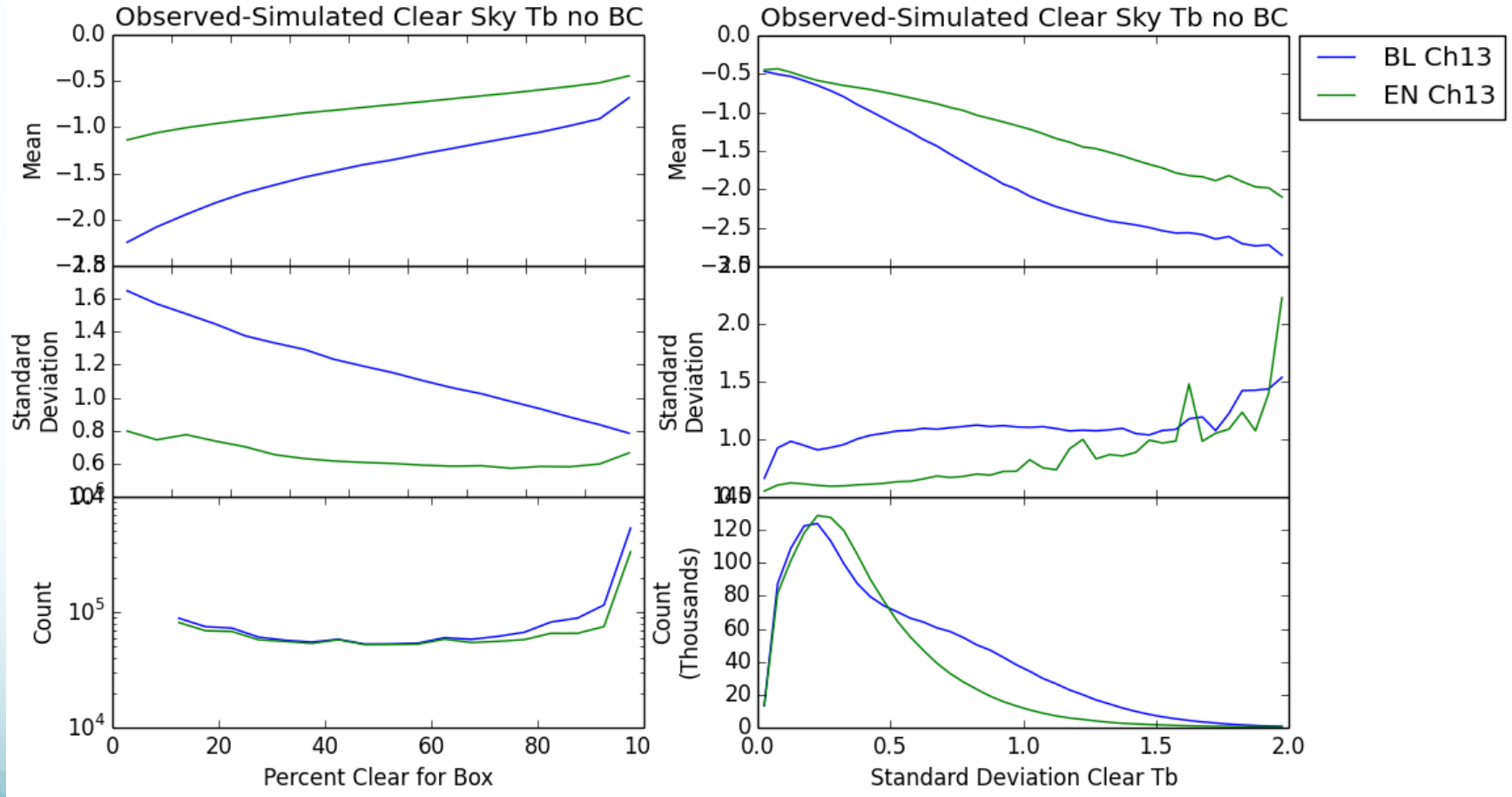


Standard deviation of brightness temperature in the processing box.

10.3µm 15x15 2km Pixel Processing Box – Enterprise Cloud Mask



15x15 2km Pixel Processing Box – Water surface, Satellite Zenith Angle<60°

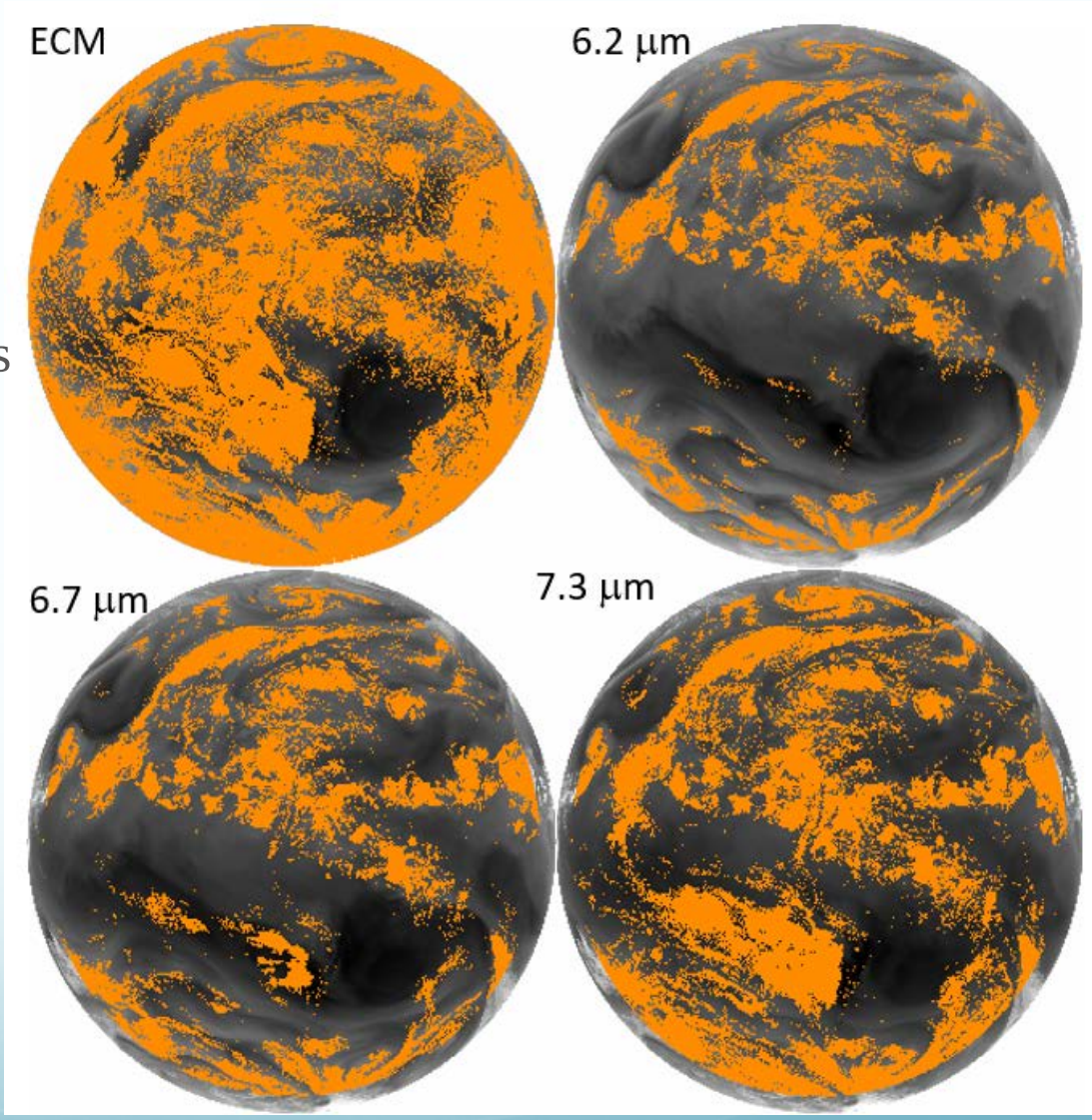


2nd Year Effort

- Complete a longer GFS simulation for Fall 2018
  - Evaluate CSR/ASR products with most recent upgrades to Baseline and Enterprise cloud masks
  - Look at performance for large sensor zenith angles, use standard deviation to identify cloud mask challenges, compare ASR products using Baseline and Enterprise masks
  - Include GOES-17 ABI data if possible
- Channel specific cloud masks
- Include high resolution visible channel

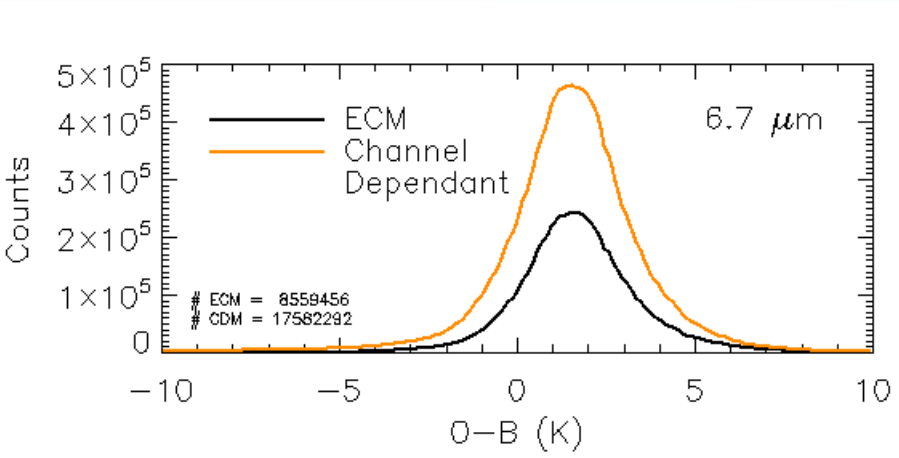
Enterprise Channel Specific Cloud Masks

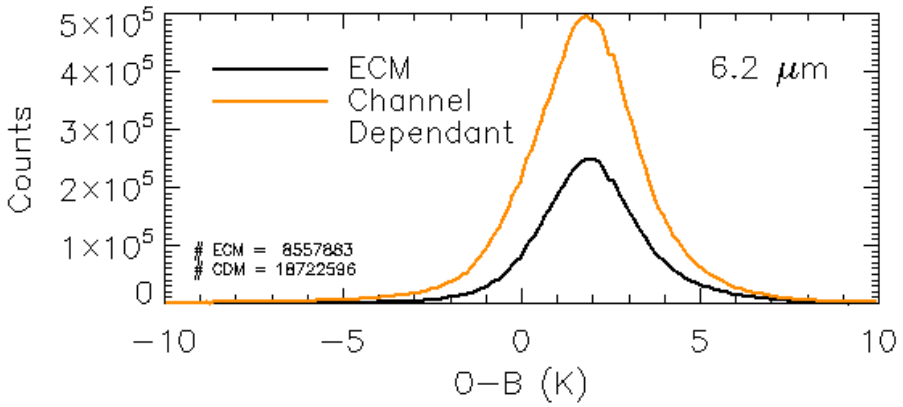
- Enterprise Cloud Mask (ECM) algorithm uses all channels and tries to detect all clouds
- When using IR absorption channels, many lower-level clouds are invisible
- NOAA cloud height product and the NWP profiles are used to modify the mask
- Cloudy pixels with clouds that should be invisible to an IR channel, are reclassified as clear.
- The images on the right show the impact on clear-sky coverage for the 3 water channels on ABI

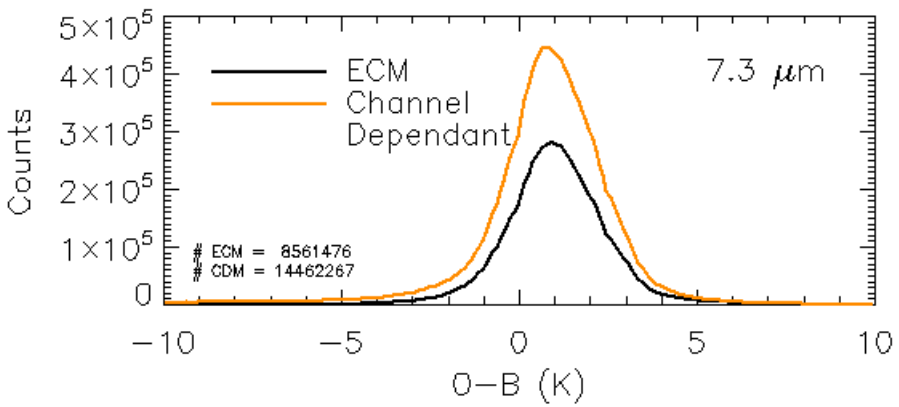


Channel Specific Cloud Masks

- Initial look at ABI CSR - GFS first guess/background (O-B) distributions show little negative impact from using the channel dependant mask.
- Benefits offered by increase in data coverage will be explored.

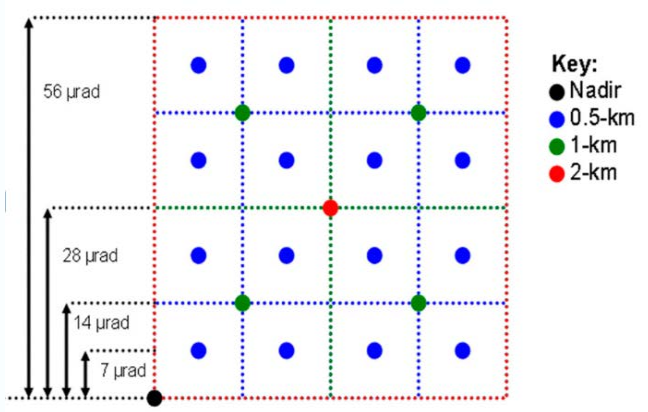




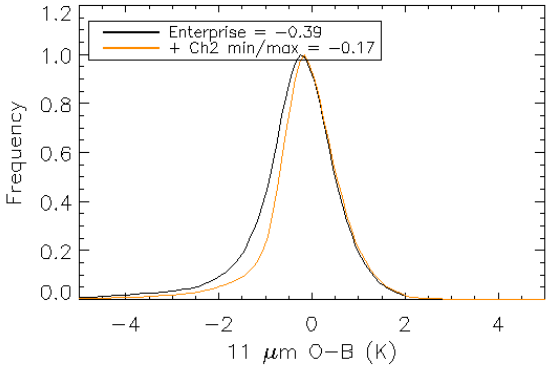


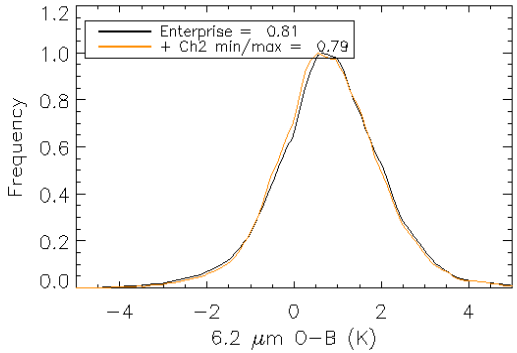
Use of Higher Resolution ABI Channels

- GOES-R ABI cloud products are generated with a resolution of 2 km, the spatial resolution of thermal bands.
- ABI 0.65 µm channel (Ch2) provides 16 values within each 2 km pixel.
- We are exploring inclusion of the Max - Min Reflectance Values into the Enterprise Mask.
- If we add a filter to the ECM on the Ch2 Max-Min, we see a big improvement in 11 µm O-B and less in 6.2 µm.



Layout of 0.64 µm pixels within a 2 km pixel





Summary

- Combining cloud algorithm L2 information with L1b radiance data to provide improved CSR products as well as more detailed ASR data
- GOESR ABI CSR & ASR Radiance Products have consistent approach compared to SEVIRI CSR & ASR Products with added metric of standard deviations of brightness temperatures in the processing box
- Preliminary data has been generated by NOAA/STAR in NetCDF and BUFR formats for NWP testing
- ECMWF is actively assimilating the CSR product
- NWP is requesting Enterprise cloud algorithm to be implemented to improve this product's quality and usefulness
- With Enterprise L2 cloud input, can provide emissivity and multilayer flag to assist in use of cloud information in the future by NWP
- ASR cloud information can be exploited within NWP data assimilation for increasing all sky assimilation capabilities
- Questions and Suggestions? Sharon.Nebuda@ssec.wisc.edu

Extra Slides

Pressure hPa