The Community Radiative Transfer Model Ocean Emissivity Modeling Overview

Core Team:

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In-Kind Contributors*:*
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Other Collaborators:
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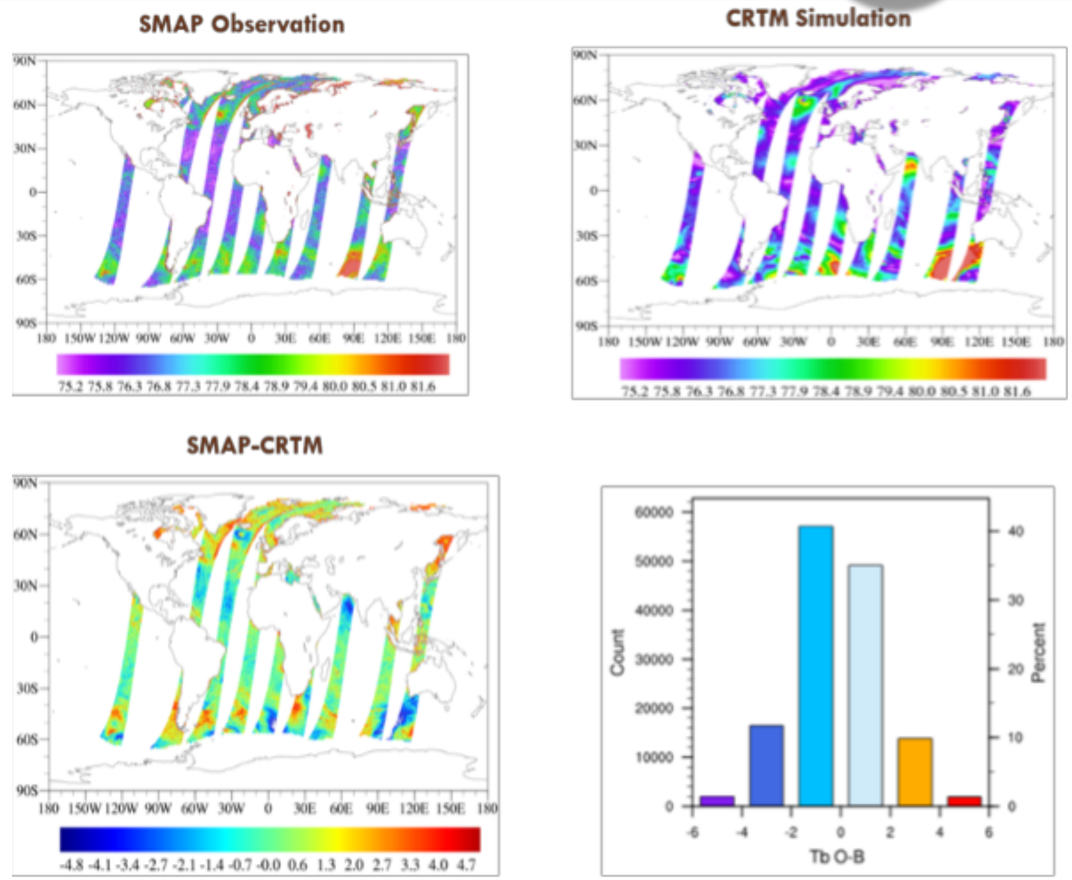
Introduction

- Requirements for fast models
  - fast vs. accurate
  - missing elements (BRDF, Polarization, ICI, UV)
- Community Surface Emissivity Model (CSEM, Ming Chen)
- IRSSE (Nick Nalli)
- Reflection Correction (Emily Liu, Ming Chen)
- SMAP SSS Analysis (Hamideh Ebrahimi)
- IRRTM

CSEM :: Surface Emissivity (Chen, Nalli)

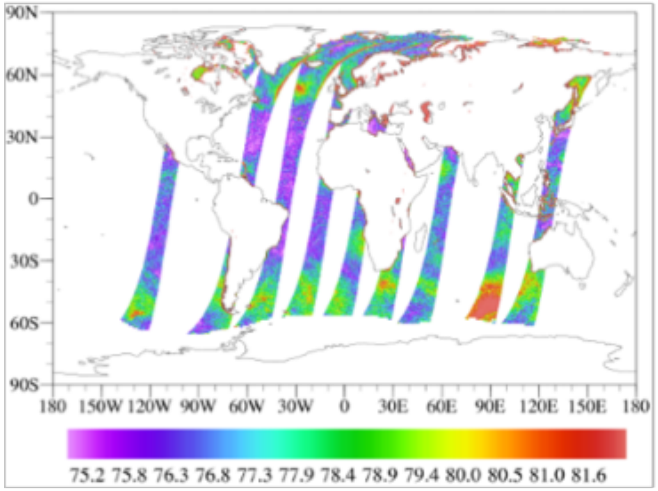
<u>Highlights</u>:

1) IRSSE model upgrade (Nalli)
2) CSEM top-down interfaces were refined to support upper-level vectorised RT solvers.
3) Integrated CRTM-CSEM version was successfully implemented in ProdGSI
4) The tangent linear and adjoint modules of the physical MW land model implemented.
5) Implementation of L-band in CRTM has been tested with the integrated CRTM-CSEM.
6) The testing of CRTM-CSEM in FV3 GFS/GSI is in progress.
7) Implementation of the JPL SMAP Level-3 monthly sea surface salinity (SSS) atlas into CSEM to account for the impact of SSS on the forward Tbs simulation and to improve the first guess accuracy in DA, especially for the L-band Tb.

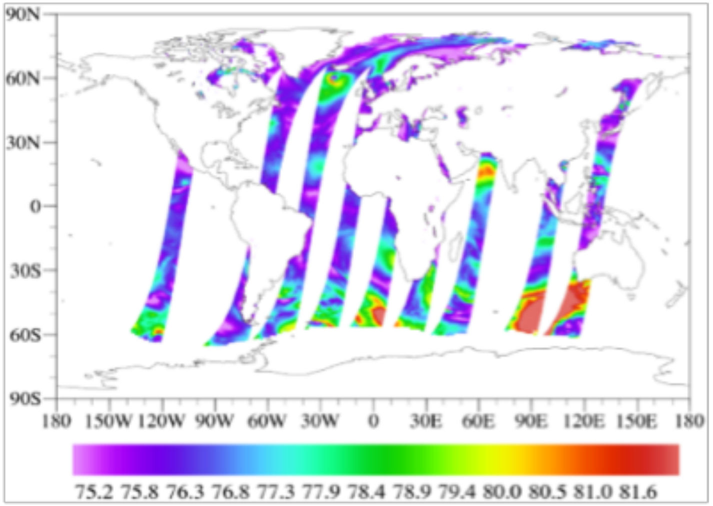


CSEM :: Surface Emissivity (M. Chen, Y. Zhu)

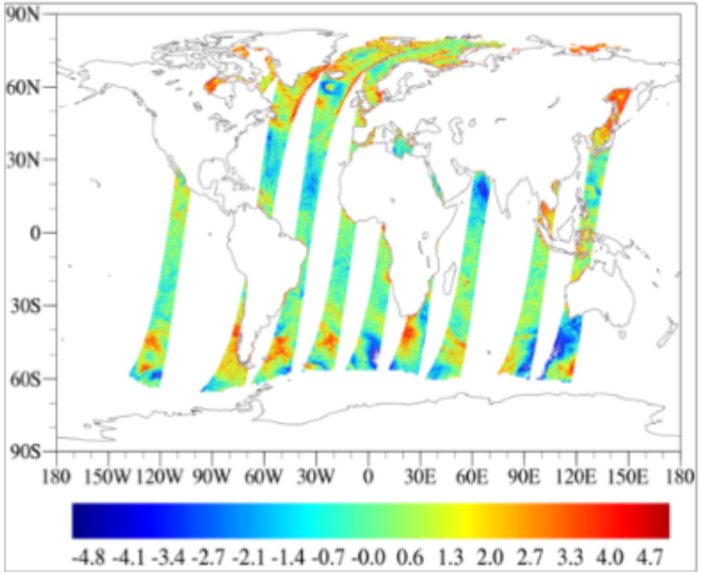
SMAP Observation

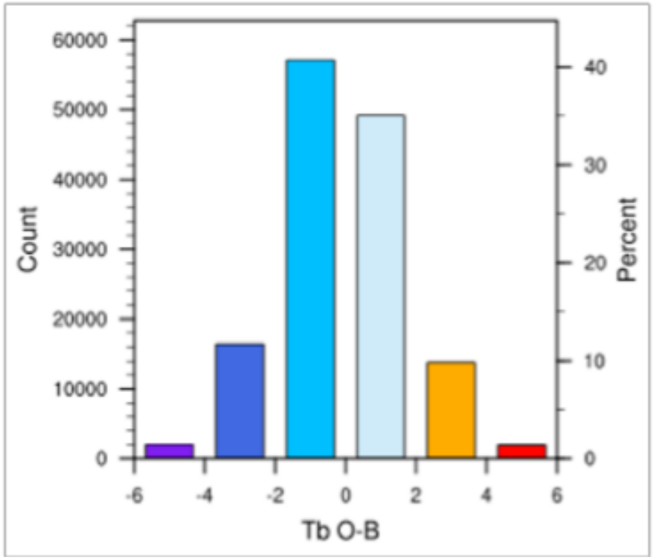


CRTM Simulation



SMAP-CRTM





Comparison of MW Ocean Model (theta=30°)

A new FASTEM version (NFASTEM) has been developed to cover L-band to submillimeter channels.

It agrees very well with FASTEM 6 at channels lower than 200GHz, as well as with TESSEM at channels over 200GHz.

FASTEM-6 limits:

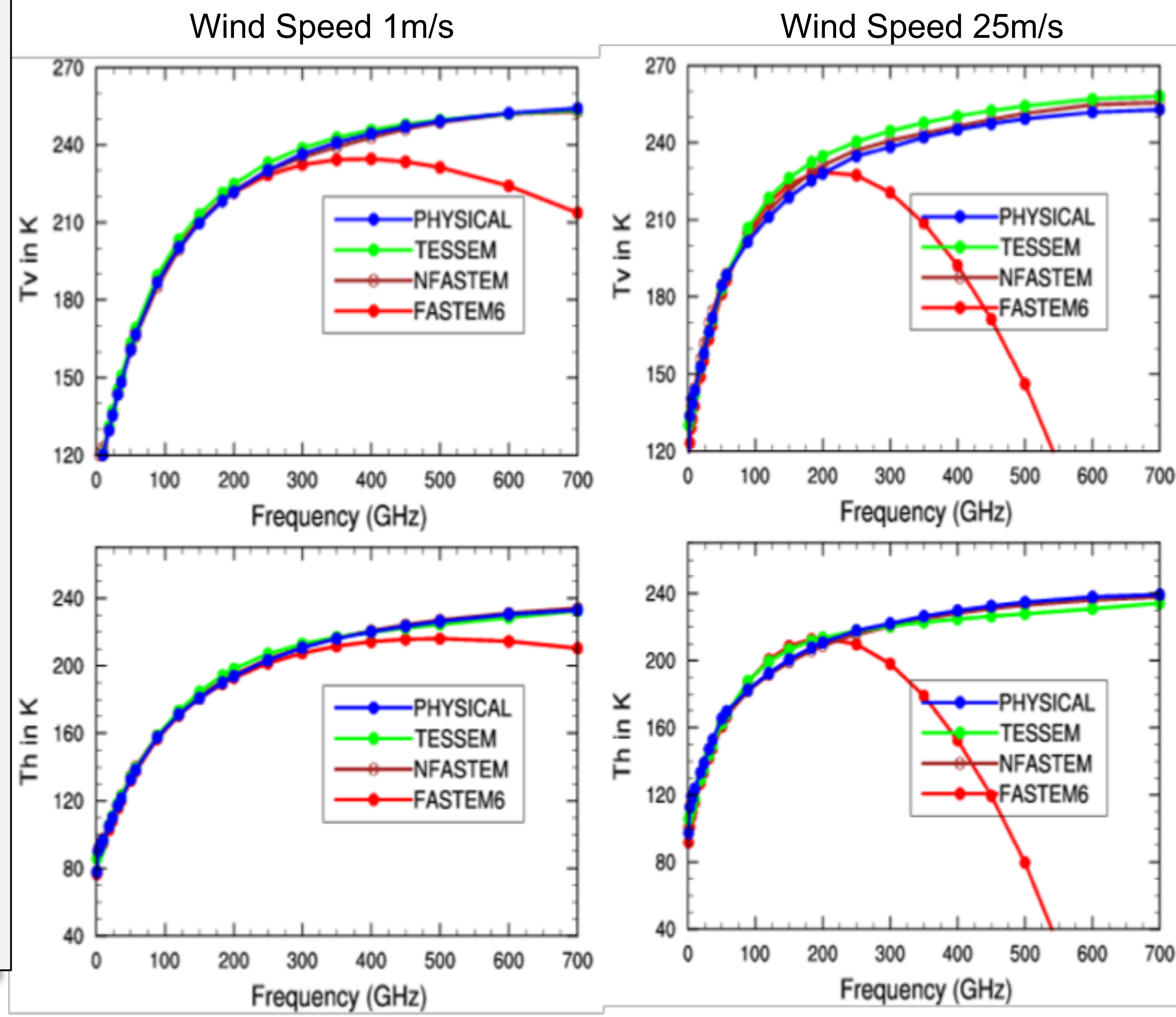
- 19GHz to 200GHz
- View angle < 60°
- Only V-pol and H-pol

RTTOV-TESSEM limits:

- 19GHz to 700GHz
- Only V-pol and H-pol

NFASTEM limits:

- 1GHz to 700GHz
- View angle < 85°
- Full Stokes

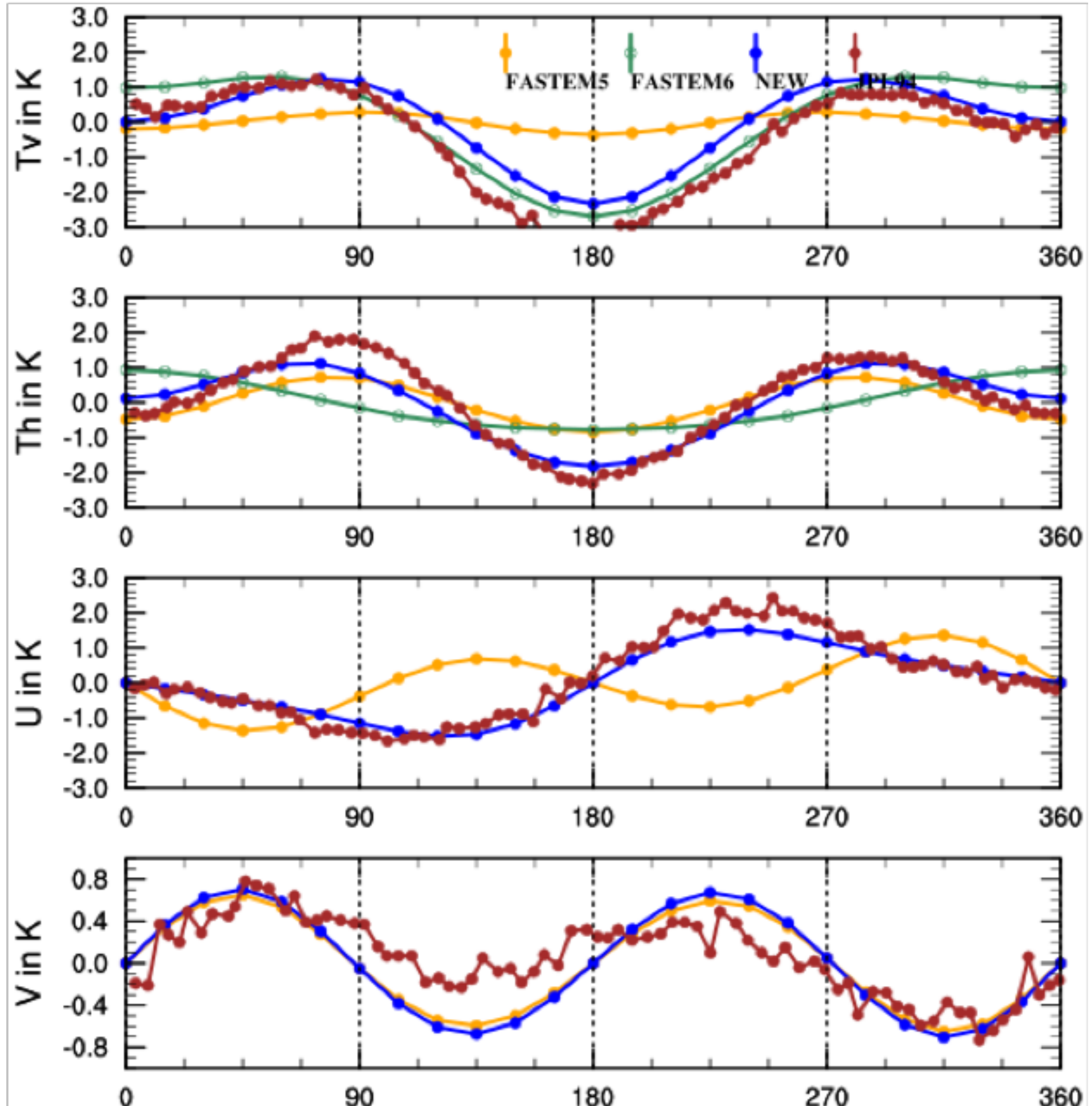


Ming Chen, ESSIC/UMD @ STAR

Comparison of FASTEM with JPL WINDRAD Observations (theta=65°)

In general, the previous FASTEM versions were developed for zenith/view angles less than 60 degree. FASTEM 6 also turned off the 3rd and 4th Stokes components. TESSEM is similar to FASTEM 6 except for the frequency extension to submillimeter channels.

The **NFASTEM provides full-Stokes component calculations**. The azimuthal variations in NFASTEM now agree well with the observations (Red) in both magnitude and phase change.



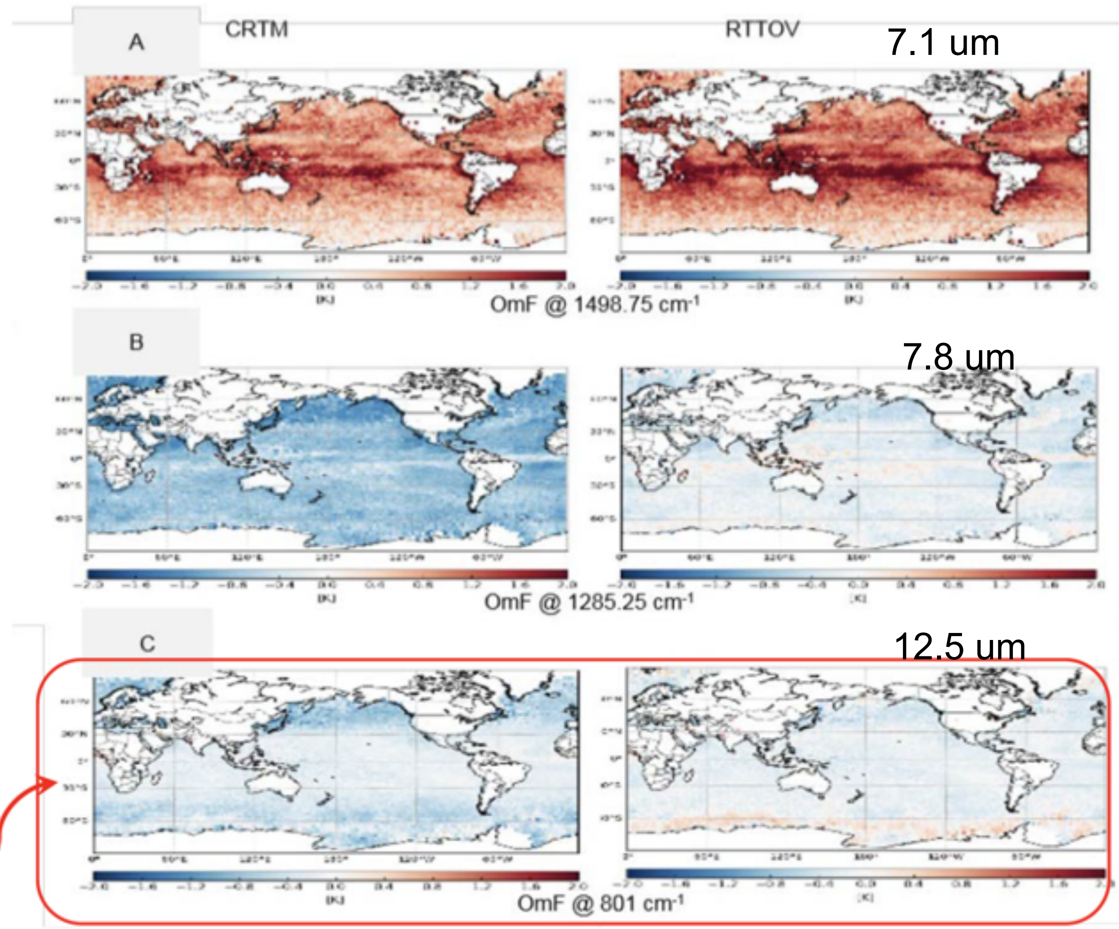
Ming Chen, ESSIC/UMD @ STAR

IR Sea Surface Emissivity [Nick Nalli (STAR)]

Temperature Dependence Found in Global Data

- **We were aware in 2008** of the **temperature dependence** of the **IR optical constants on IRSSE**
  - *Nalli et al.* (2008b): "In agreement with other recent work on the subject, we found a significant temperature dependence, which, if unaccounted for, can lead to spectral SLR errors of the same order of magnitude as those we have sought to correct. Therefore, additional work is desirable to derive an optimal seawater refractive index dataset…"
  - Unfortunately, however, this work was **not supported** at the time
- However, **recent findings of *Liu et al.* (2019)** have shown a significant **systematic bias** (on the order of **0.5 K**) on a **global scale**, thus bringing this issue back into focus for support

***From Liu et al.* (2019)**



-2.0 K to 2.0 K

-2.0 K to 2.0 K

IR Sea Surface Emissivity [Nick Nalli]

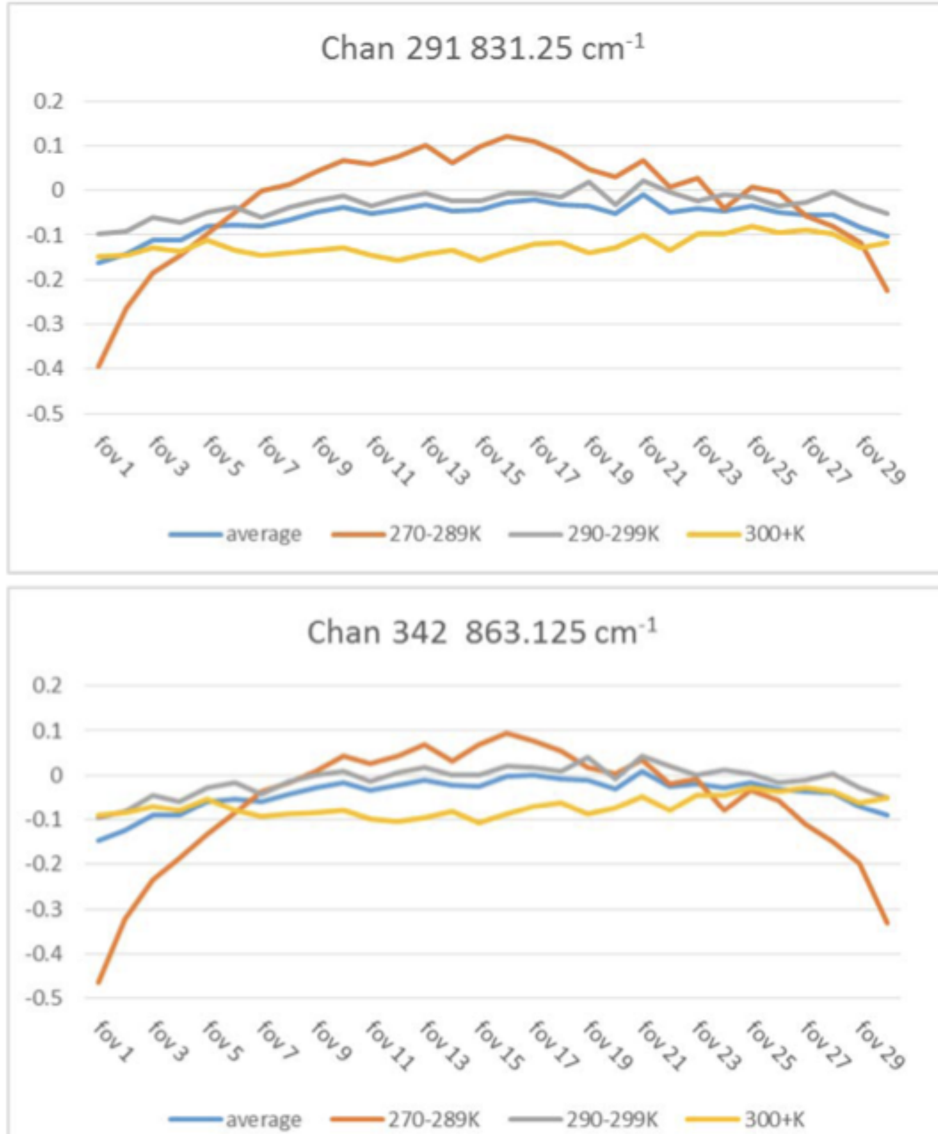
- **2-weeks global NOAA-20 CrIS data (OBS) versus CRTM model calculations (CALC)**

- Shown are microwindow-channel double-differences of OBS – CALC in regions of varying surface temperature dependence observed in the IR spectrum

- The **double-differences** serve to place control on the unknown atmospheric path uncertainties (e.g., model bias, cloud contamination, H_2O errors, etc.)

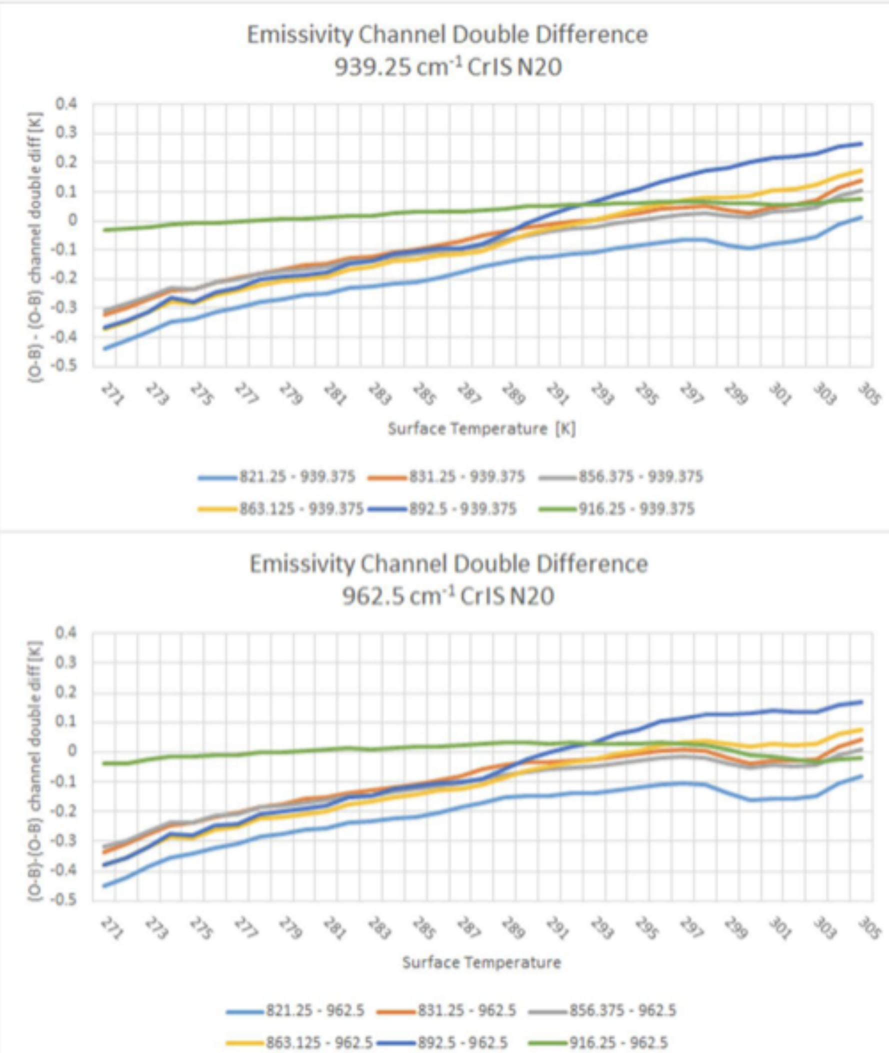
- **Significant surface-temperature dependence** is clearly visible **on the order of >0.5 K**
  - This is of **first order significance** within the context of the total forward model uncertainty

Observed Angular Dependence

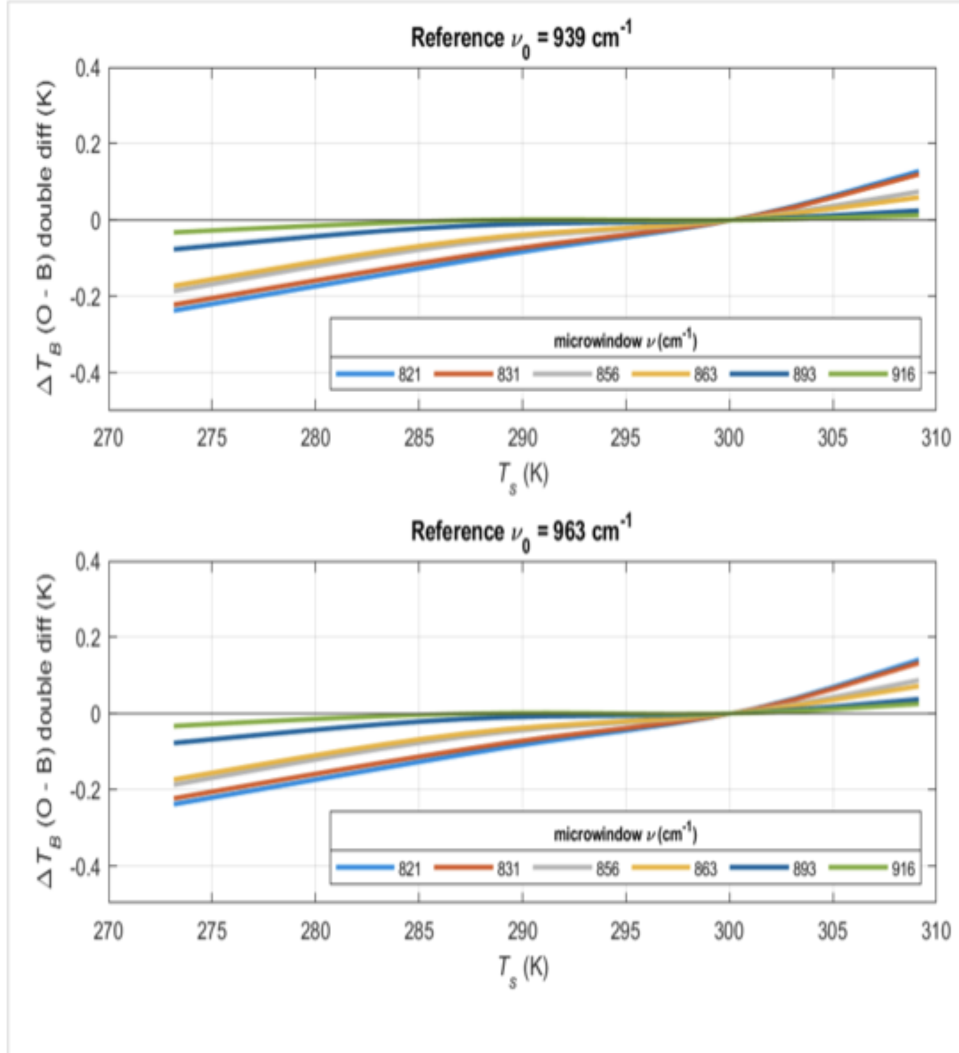


IR Sea Surface Emissivity [Nick Nalli]

Observed SST Dependence

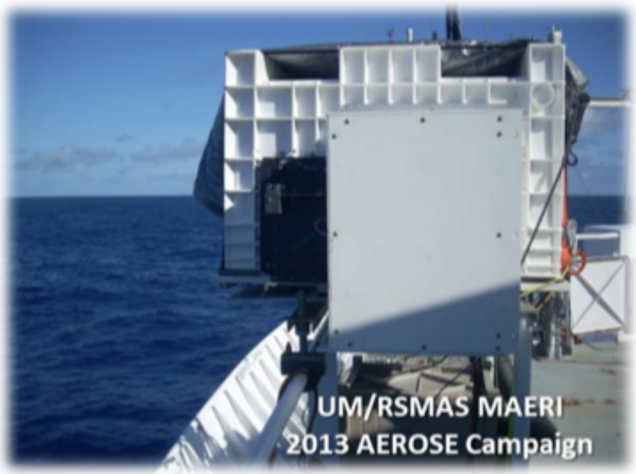


Modelled SST Dependence

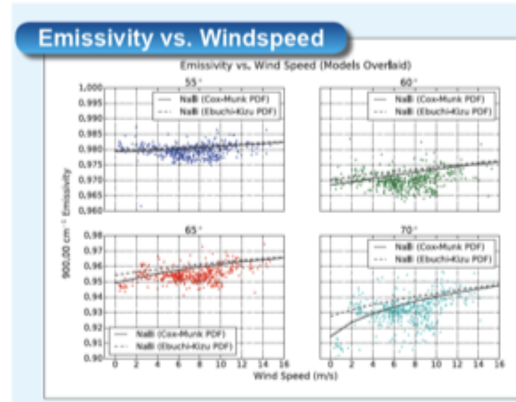


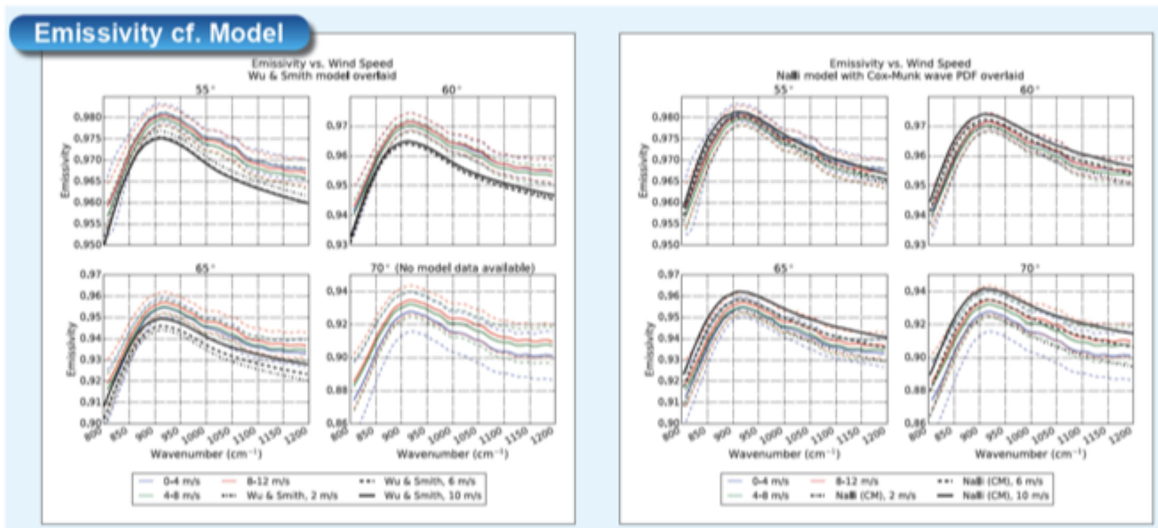
IR Sea Surface Emissivity [Nick Nalli]

IRSSE Model Validation Plan

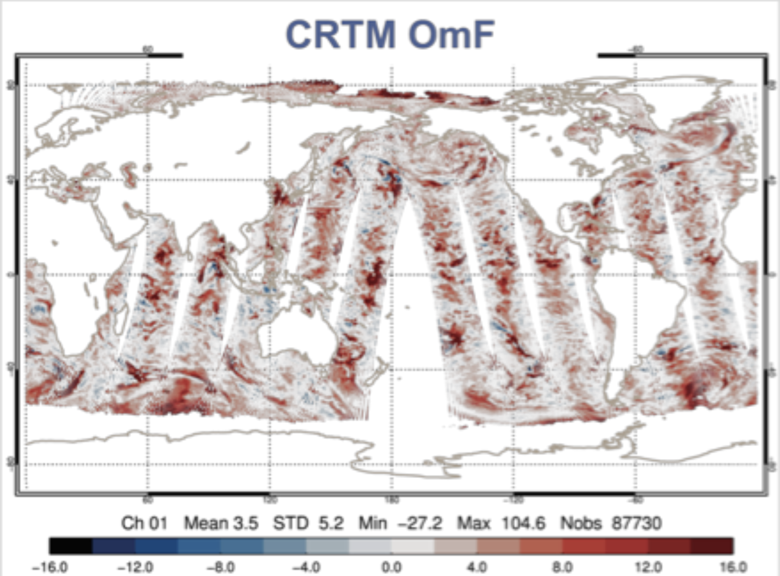


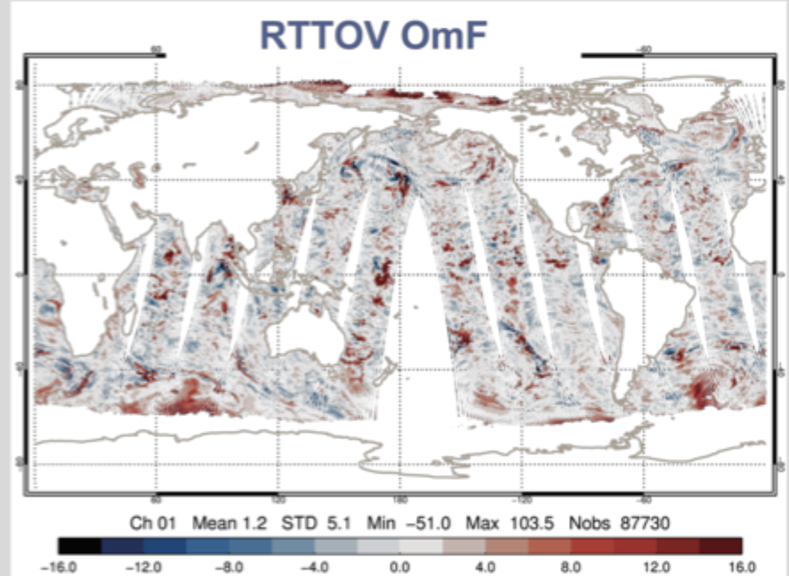
From *Gero et al.* AGU Fall Meeting (2016)



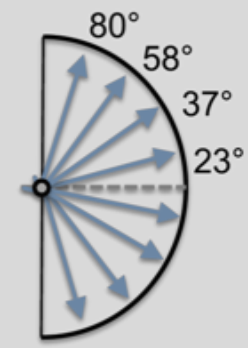


Issue – CRTM Simulated BTs are too cold in general





- CRTM is a multi-stream radiative transfer solver using Advanced Doubling Adding (ADA) scheme
- It is found that the off-diagonal terms of the surface reflectivity matrix is zero so that there is no diffuse radiation being reflected towards the viewing direction



8-stream Approximation

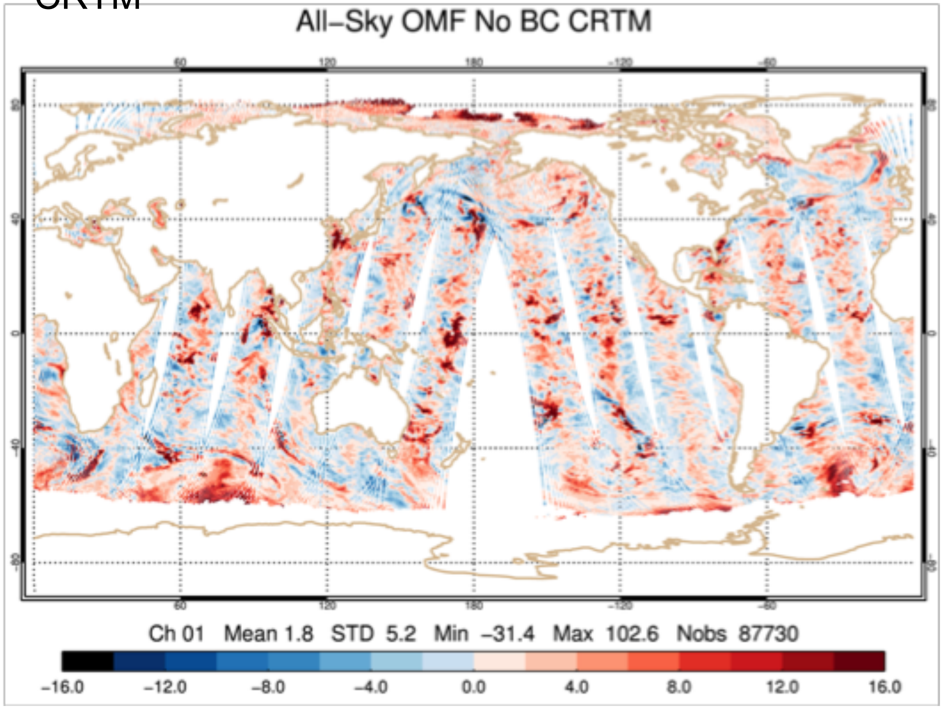
$$L_\nu(\mu,0) = \varepsilon_{\nu,sfc}\cdot B_\nu(T_{sfc}) + \rho_{\nu,sfc}\cdot R^{\downarrow}_{\nu,sfc} + \rho_{\odot,\nu,sfc}\cdot R^{\downarrow}_{\odot,\nu,sfc}$$

Boundary Condition | Surface Emission | Downward Radiation Reflected at Surface | Downward Direct Solar Radiation Reflected at Surface

Fixed O-F, no BC

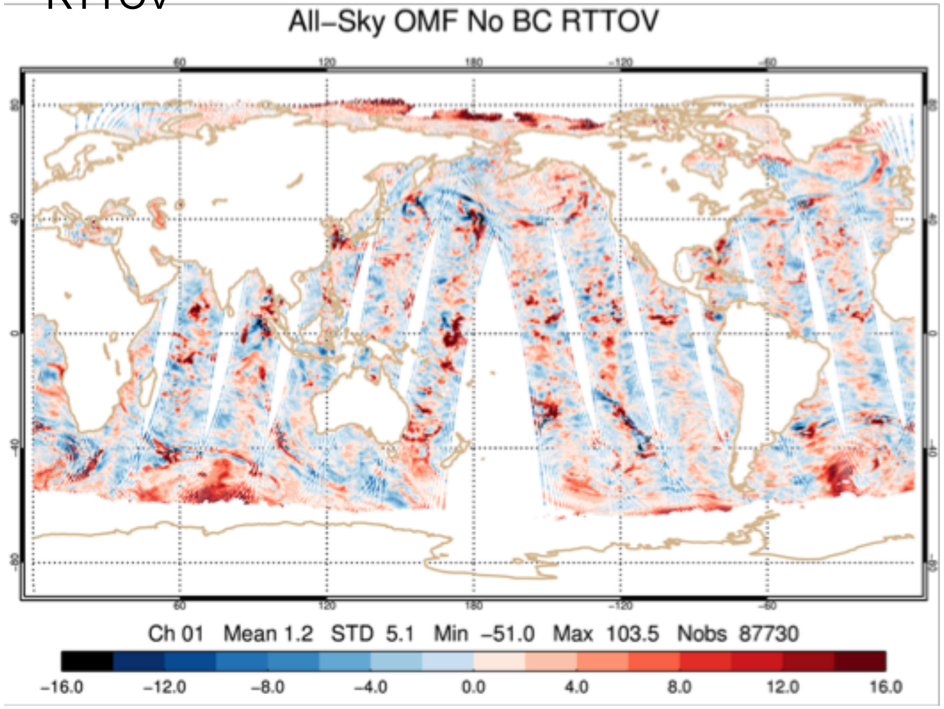
Channel 1 AMSU-A (23.8 GHz)

CRTM



-16 K to 16 K

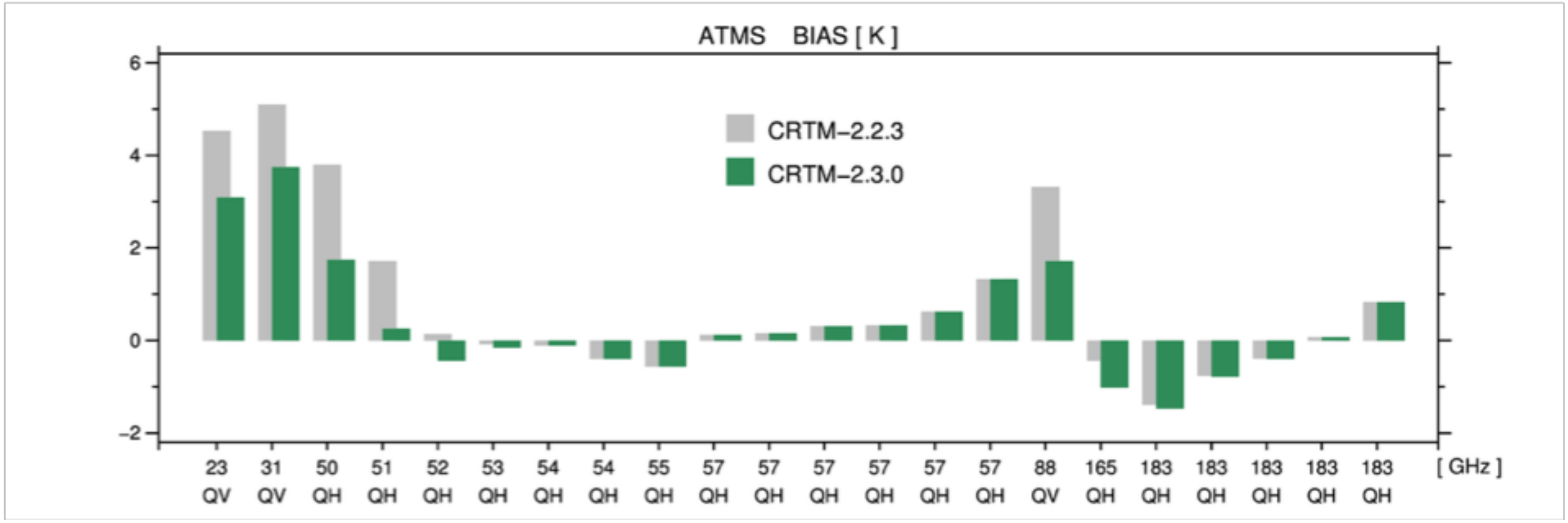
RTTOV

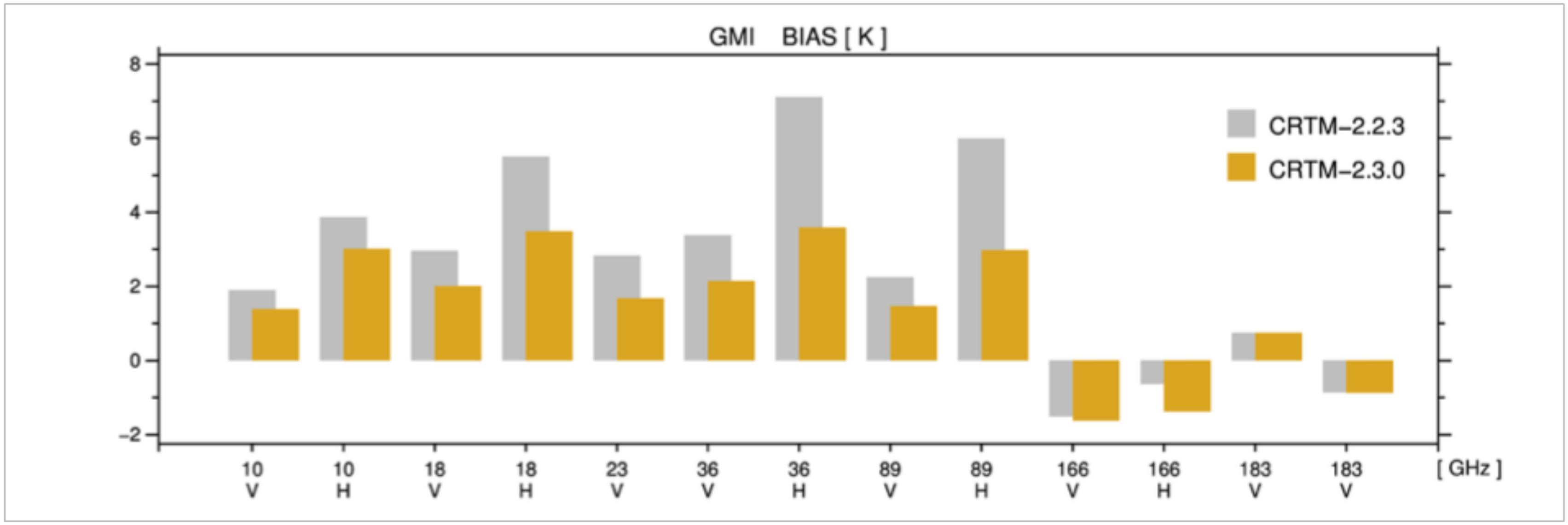


-16 K to 16 K

Emily Liu (EMC), Ming Chen (STAR)

Impact of Scattering Correction





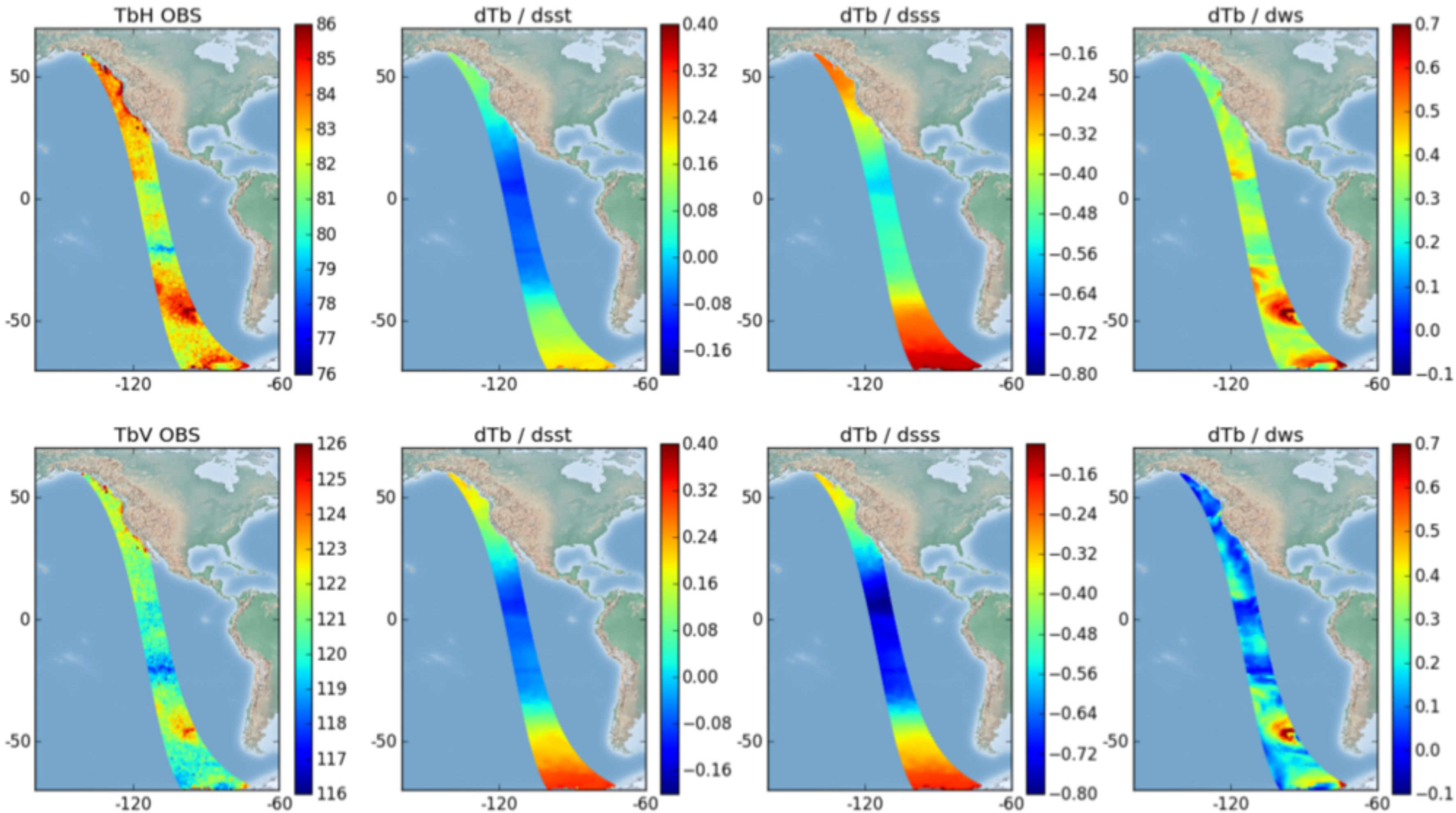
Emily Liu (EMC), Ming Chen (STAR)

Impact of SSS on CRTM H(x) for SMAP

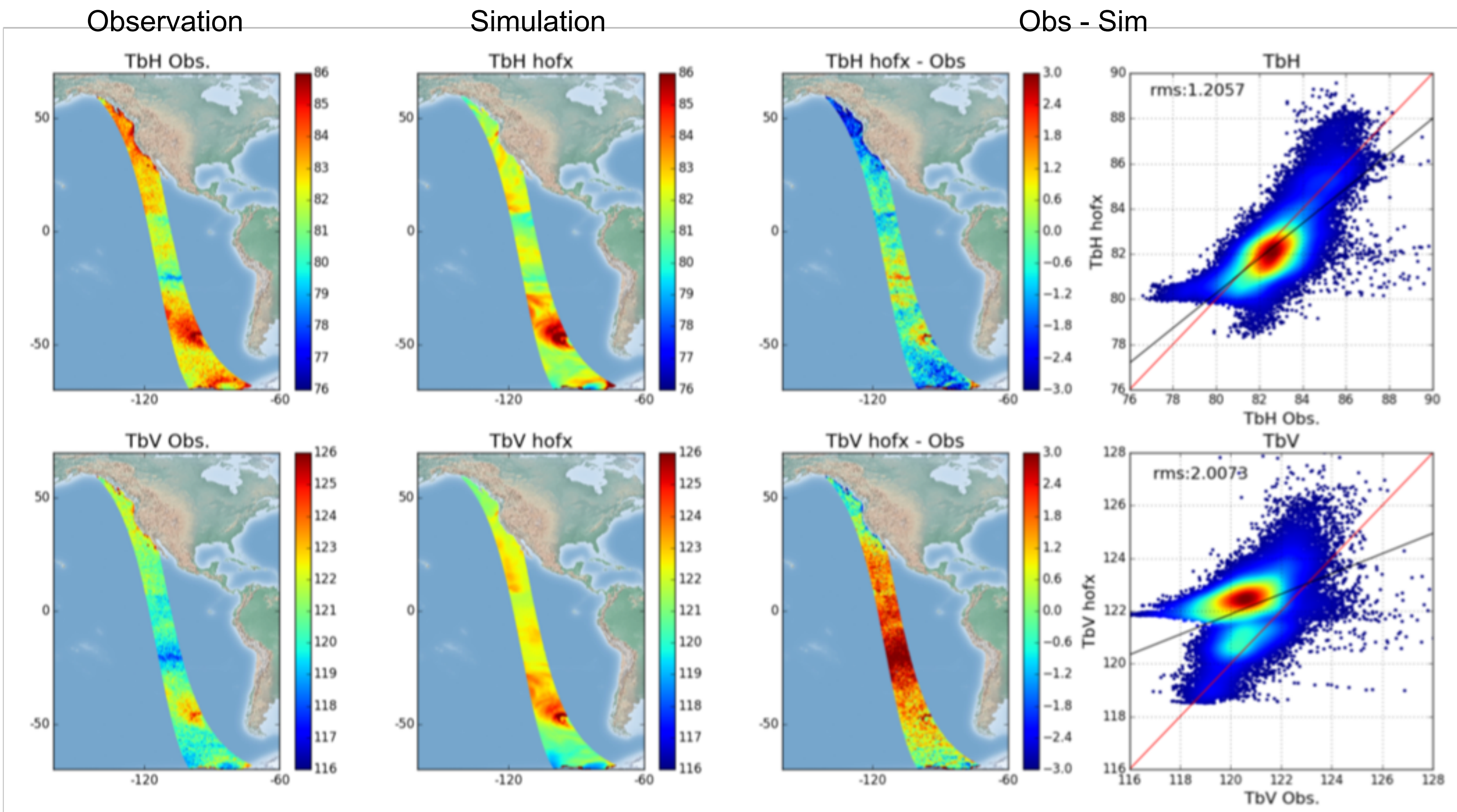
Hamideh Ebrahami (JCSDA@GMAO), Guillaume Vernieres (JCSDA@EMC)

SMAP Jacobians

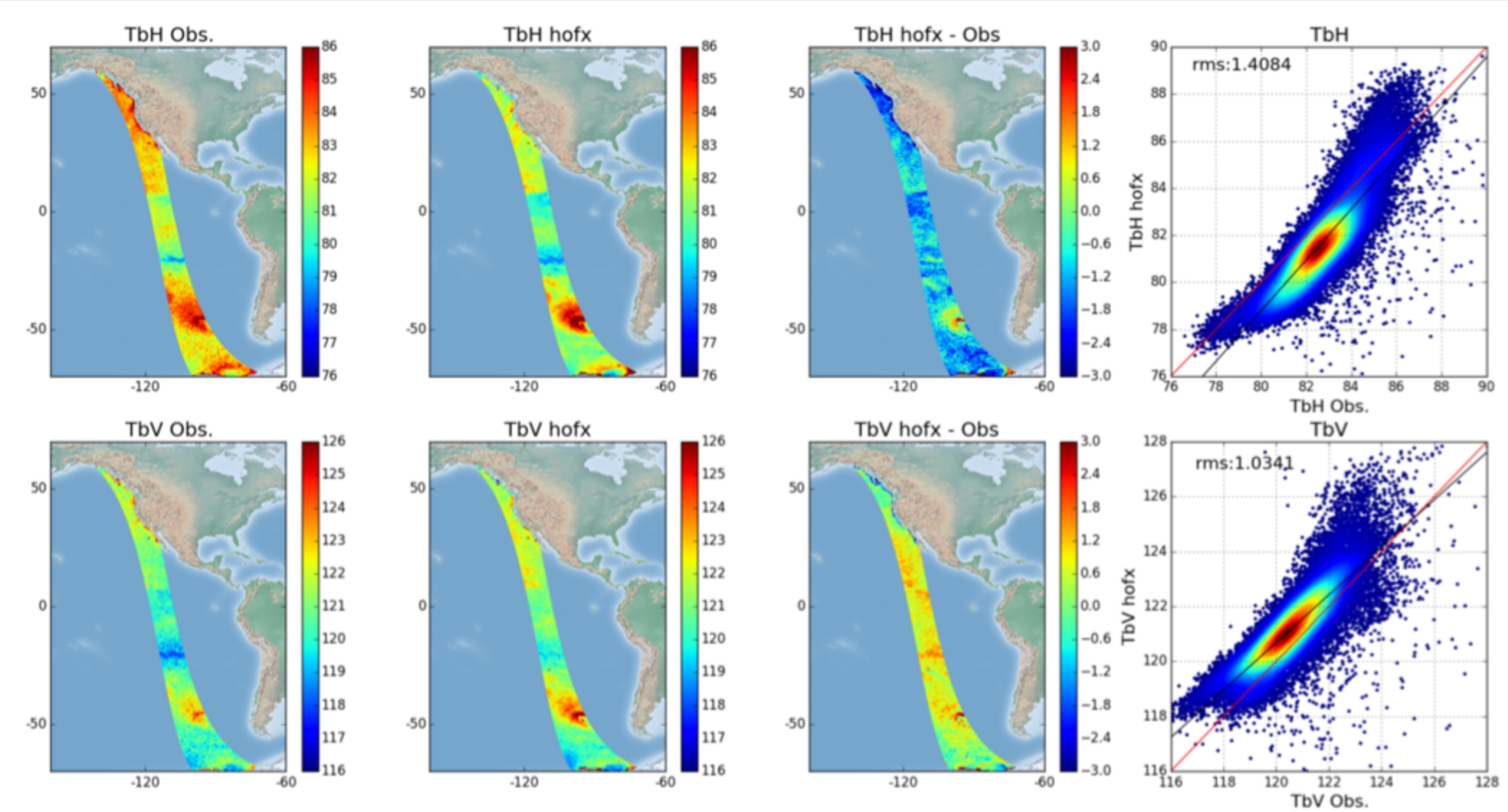
SST SSS Wind Speed



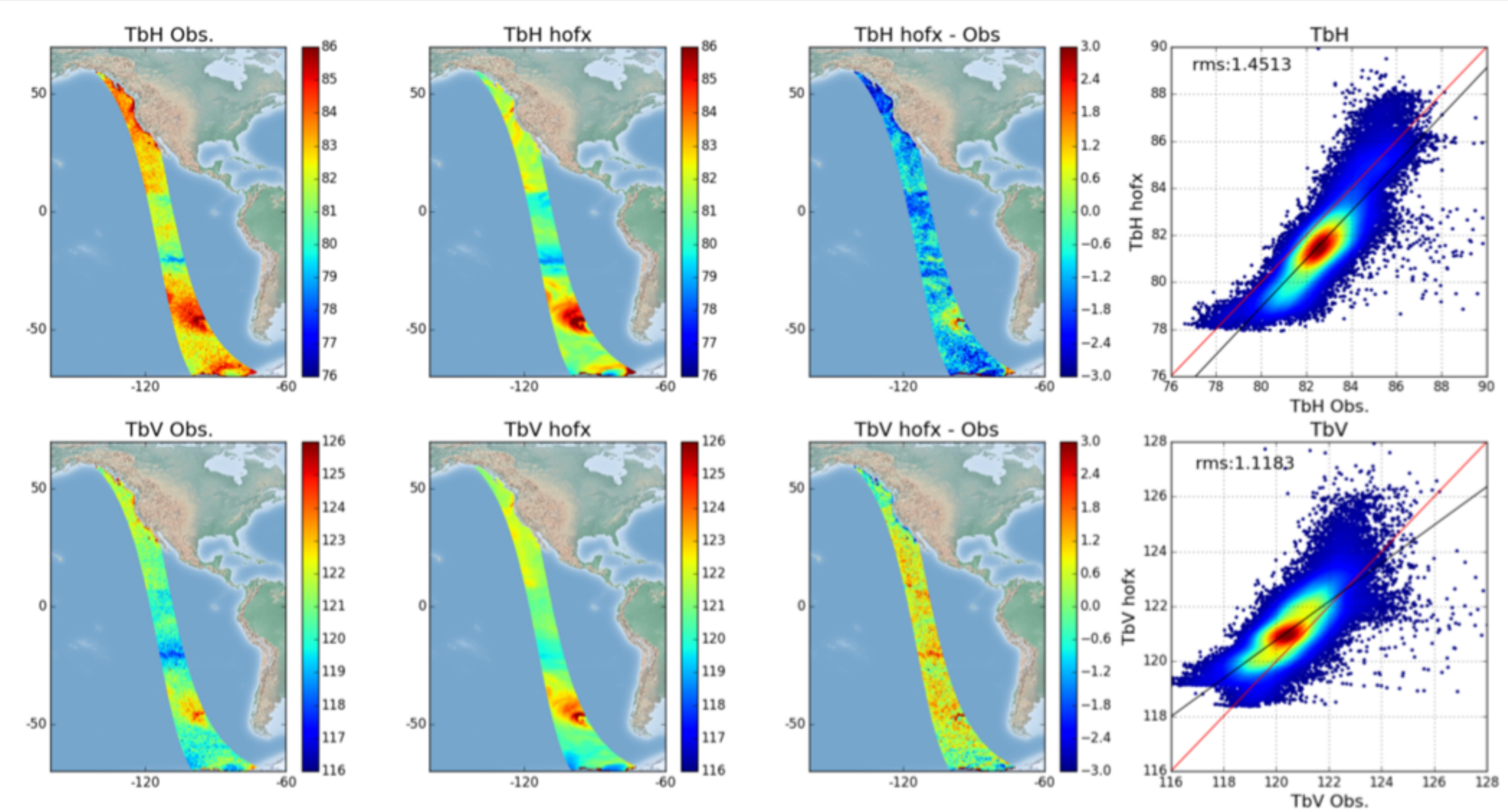
SMAP, GFS H(x) using FASTEM with **SSS=33**



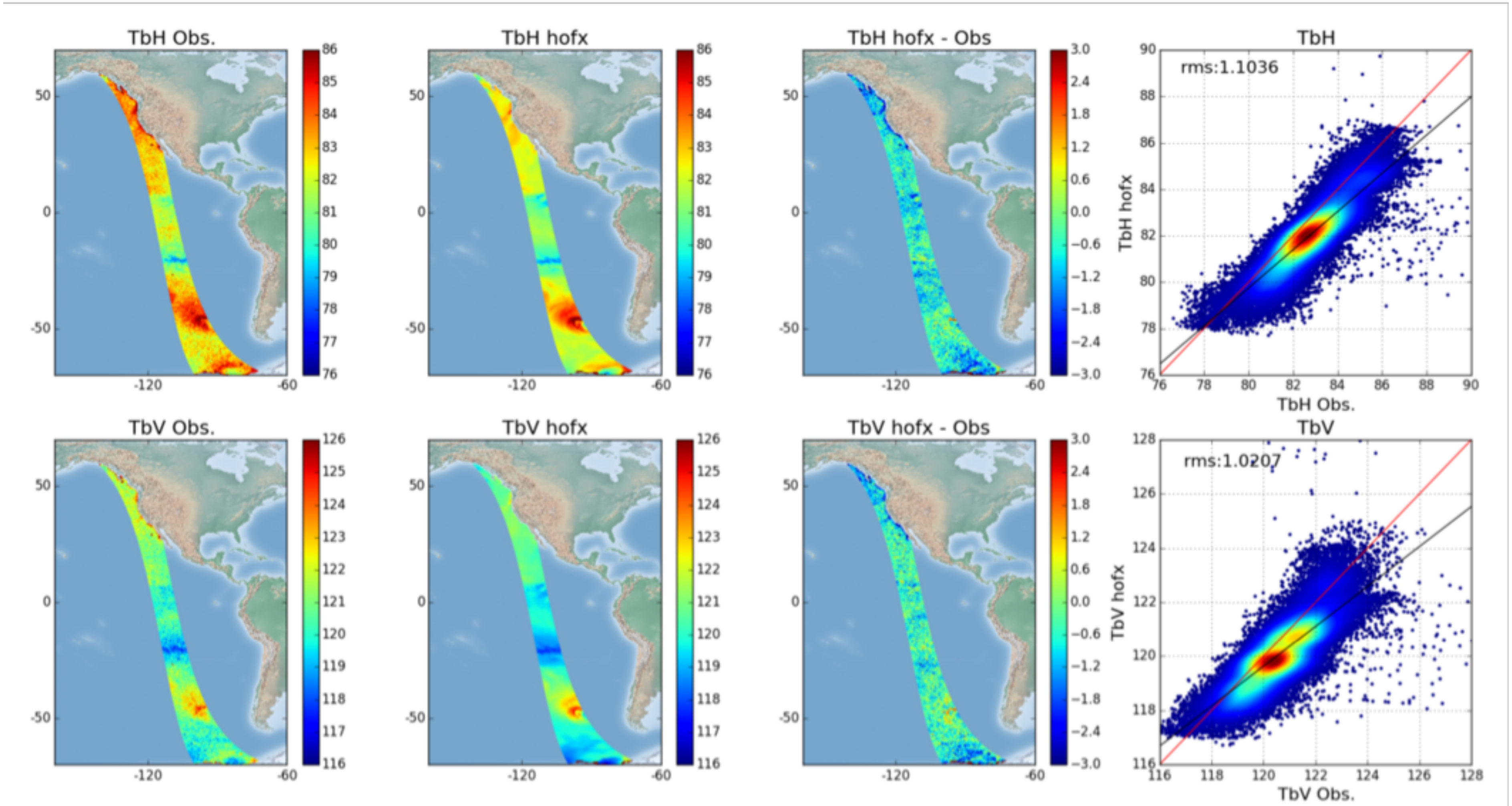
SMAP, GFS H(x) using FASTEM with **HYCOM SSS**



SMAP, GFS H(x) using FASTEM with **World Ocean Atlas SSS**



SMAP, GFS H(x) using **RSS model** with **WOA SSS**



Future Work (near term)
Ongoing tasks toward CRTM 3.0 [1/2]

- **Cloudy Radiance** (P. Stegmann, E. Liu, Johnson)
  - Adding backscattering coefficients for CRTM active sensor capability.
  - Produce (Polarized) CRTM Scattering Coefficients from BHMIE and T-Matrix spheroids in binary and NetCDF
  - Start systematic investigation of "optimal" single-scattering properties for CRTM applications
- **Surface** (M. Chen, Y. Zhu)
  - Test CRTM-CSEM in GFS/GSI, focusing on the comparisons among model options.
  - Analyze and document the tests of CRTM-CSEM in GFS/GSI.
  - Initial implementation of MW ocean surface BRDF model.
  - Continued testing of CSEM in GSI
- **Full Polarization Solver Capability** (T. Greenwald, Q. Liu, B. Johnson, C. Cao)
  - UV capable solver + polarization support under development
  - Need to touch each element of CRTM to support UV capabilities – still establishing scope of effort required.

Future Work (near term)
Ongoing tasks toward CRTM 3.0 [2/2]

- **NLTE corrections** (Z. Li)
- **SW / IR improvements in CRTM**
  - IR Sea surface emissivity improvement (N. Nalli, M. Chen)
  - Aerosol + solar impacted IR (expert needed!)
- **Aerosols update** (Johnson, Stegmann, S. Lu, M. Pagowski, B. Scherllin-Pirscher, A. Naeger, NRL, GMAO, others).
  - Update of CHYM to work with aerosol tables (Johnson, Stegmann)
  - Improved aerosol indices of refraction (via D. Turner and J. Gasteiger)
  - Update toward CMAQ specifications (Team)
  - Improve Lidar backscattering and attenuation calculations (Pagowski, Scherllin-Pirscher)
- **Fast coefficient generation** (Johnson, Stegmann, Moradi, Q. Liu)
  - Modernized physically-based approach
  - AI / Machine Learning-based approach

Questions / Comments?

Please join our new CRTM google groups:

Developer Discussion:
https://groups.google.com/forum/#!forum/crtm-developers

Support:
https://groups.google.com/forum/#!forum/crtm-support

New support email:
crtm-support@googlegroups.com

This will post to the support forum, so anything you email will be available to the members of the support group.

Email: Benjamin.T.Johnson@noaa.gov for direct support, questions, and comments

CRTM 2.3.0 Status

Released November, 2017

1. **All-Sky radiance simulation under cloud_fraction conditions.**
2. Use of **all-sky transmittances in FASTEM-X reflection correction.**
3. **Improve surface reflectance for Microwave under scattering conditions.**
4. Add **ATMS SeaIce emissivity** module.
5. Fixed the simulation near **3.9 micron by adding solar contribution** in ADA_Module.
6. Updates of **CRTM Coefficients for ABI_GOES-R, AHI_Himawari-8.**
7. Updates of **CRTM antenna correction coefficients for MHS_N19/Metop-a.**
8. Update **AIRS coefficients for including NLTE correction.**
9. Add **new coefficients** for: CrIS-fsrB1/B2/B3_NPP, CrIS*_N20, CrIS-fsr431_npp/n20, AHI_Himawari-9, ABI_G16, VIIRS-JPSS1, ATMS_N20, ATMS_N20-SRF, COWVR, tropics_designed_v1.

In this release, there is a new feature for the simulation of all-sky (cloudy) radiance, which utilizes Fortran class function, and now CRTM will be supported by advanced compilers with class function, such as ifort 14.0+, 15.0+, 16.0+, 18.0+, gfortran (gcc 4.8.5, 5.4, 6.4, 7.2, 8.2), pgi/15.1, 16.5, 17.3, 18.5, ftn/2.3.0.

CRTM 2.3.1-beta Status

December 28, 2018:

*** New/Updated Coefficients:**

1. Earth Observing Nanosatellite-Microwave: eon_mw.v1
2. Sentinel-3A Sea and Land Surface Temperature Radiometer: slstr_sentinel3a
3. Meteosat-11 SEVIRI: seviri_m11
4. New coefficient for ABI_G17, and updated IDs from ABI_GR to ABI_G16
5. New coefficients for Metop-C sensors: AVHRR3_Metop-C, IASI(b1,b2,b3)_Metop-C, IASI300_Metop-C, IASI316_Metop-C, IASI616_Metop-C
6. L-Band sensors at 1.413 GHz: SMAP and SMOS (V, H, 3rd, 4th Stokes)
7. Tempest-D_cubesat: 5 microwave bands at 87, 164, 173, 178, and 181 GHz
8. Updated for a shifted WV band SRF of MI-L_COMS.v2

*** Integrated Bug fixes:**

1. Bug in CRTM_CloudCover_Define.f90, fixing "Intent(in)" to "Intent(inout)" error for using gfortran compiler.
2. Bug in CRTM_CloudCover_Define.f90, when using the "Maximum-Random" scheme to calculate Total Cloud Cover.
3. Bug in ATMS_SnowEM_module, commented out uninitialized (also unused) variables and calculations.
4. Fix a CRTM_AtmOptics_type uninitialized error in CRTM_AtmOptics_Define.f90.
5. Update the libsrc/make.dependencies file for using make -j option.
6. Fix a bug in Common_RTSolution.f90, for calculating surface emissivity Jacobian.