# CRTM and Data Assimilation activities at STAR supporting JPSS


Kevin Garrett[1]

*CRTM Federal Manager*

*NESDIS Associate Director for the Joint Center for Satellite Data Assimilation*

Tong Zhu[1,2], Ming Chen[1,3], Biljana Orescanin[1,3], Yingtao Ma[4]



Acknowledgments: Jean-Luc Moncet[4], Mark Liu[1], Benjamin Johnson[5], Hui Shao[5]



1: NOAA/NESDIS/STAR 2: CIRA 3: CICS 4: AER, Inc. 5.UCAR/JCSDA

# Outline

- CRTM
  - Status
  - Cal/Val and algorithm support
  - Current and future development

- Data Assimilation
  - Current activities
  - STAR plans/priorities

# CRTM activities

# CRTM development history

## Impacting JPSS Applications

| CRTM Version | Date | Enhancements |
|---|---|---|
| 2.0/2.0.5 | 12/2011 | • New user interface |
| 2.1/2.1.1 | 3/2012 | • SOI solver<br>• Fastem5<br>• MW Land Surface Emissivity Model<br>• NLTE Correction |
| 2.1.3 | 6/2013 | • Implement reflection correction in Fastem (use clear-sky trx)<br>• Enhanced absorption coefficients (6 absorbers)<br>• Solar irradiance in spectral coefficient files (CrIS)<br>• IRSSEM improvements |
| 2.2.1 | 4/2015 | • Enable reflection correction for non-scattering clouds<br>• Fastem6<br>• Revert to box car SRF for SNPP ATMS |
| 2.2.3 | 8/2015 | • IRRSEM improvements |
| 2.3 (current) | 11/2017 | • NOAA-20 coefficients<br>• ATMS snow and sea-ice emissivity models<br>• Cloud fraction capability<br>• Reflection correction (use cloudy trx) |

# CRTM Cal/Val and algorithm support

## Applications applied to JPSS data

| Algorithm | CRTM v. | Current use | Some desired enhancements? |
|---|---|---|---|
| ICVS | 2.0.5-2.3 | Forward operator, clear-sky, ocean | Ocean emissivity/reflectance modeling |
| MiRS | 2.1.1 | Forward operator, K-matrix, all-sky variational retrieval | Hydrometeor handling (scattering properties) |
| ACSPO | 2.1.3 | Forward operator, clear-sky, ocean | IRSSEM, reflectance enhancements, aerosol handling (species, scattering) |
| Enterprise Cloud Products | 2.1.3 | Long-wave IR clear-sky transmittance profiles | Shortwave IR transmittance, cloudy transmittances |
| Enterprise Volcanic Ash | 2.1.3 | Long-wave IR clear-sky transmittance profiles | Shortwave IR transmittance, cloudy transmittances |

*All applications could benefit from improved efficiency

# CRTM current development

## Expected to have impacts on JPSS sensors

- JCSDA partners collectively manage CRTM development (B. Johnson lead)
- STAR-led contributions to JCSDA CRTM project
  - Code management, new sensors, testing & maintenance, package/delivery of software
  - Surface emissivity modeling, BRDF improvements (CSEM)
  - Modernization of LBLRTM with through the Community Line-By-Line Model (CLBLM)
  - Extension to UV sensors
- Summary of other JCSDA projects
  - Fast solvers for scattering
  - Full Stokes polarization
  - Improvements to aerosol/hydrometeor scattering properties/LUTs
  - Improved code efficiency (vectorization/OpenMP)
- Next release is v3.0 ~Jan/Feb 2019

# CRTM current developments

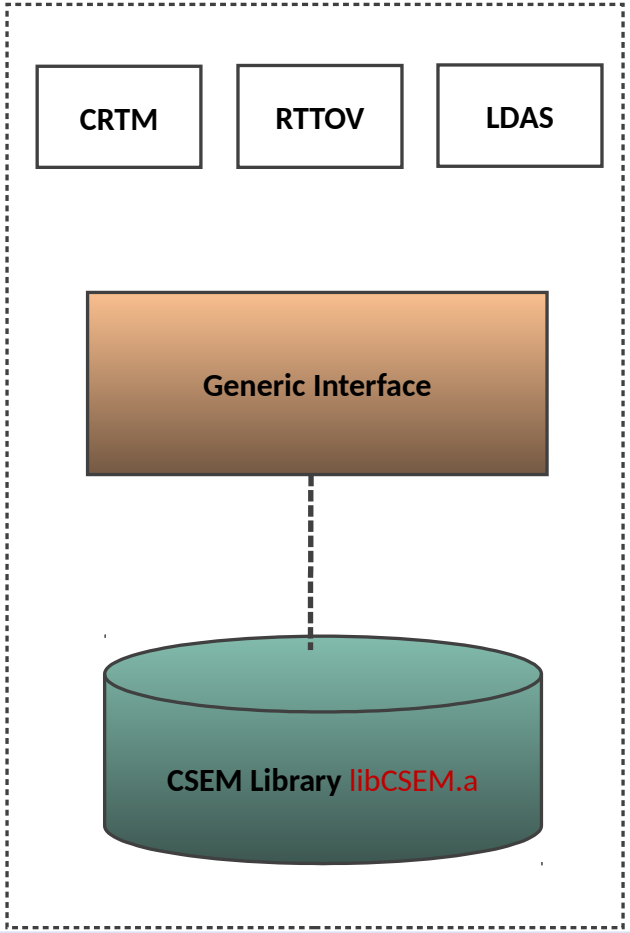
## The Community Surface Emissivity Model (CSEM)

**Objective: Release of the CSEM package and integration into CRTM**

- CSEM is OOP-based system to compute emissivity and BRDF over all surfaces, in the MW, IR and Vis
  - Easy to integrate and test new emissivity models
  - Easy to interface with other tools (e.g. CRTM)
  - Includes tangent-linear and adjoint

**Enhancements over existing CRTM surface emissivity models**

| Microwave | Vis/IR |
|---|---|
| Improved NESDIS Land Phys. Model | UW IR Emissivity Atlas (SEEBOR) |
| Semi-physical ATMS Snow Model | UW Vis/NIR BRDF Atlas (Vidot & Borbas) |
| Semi-Physical ATMS Sea-ice Model | |
| TELSEM 1, 2 (climatology) | |




CSEM can be used as a stand-alone package or interface with other tools

# CRTM current developments (CSEM)

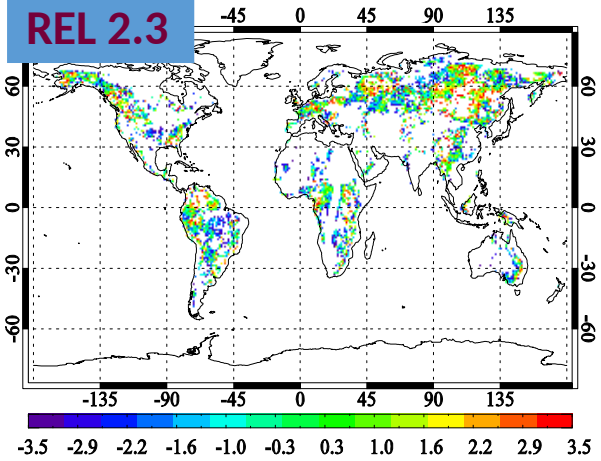
## The Community Surface Emissivity Model (CSEM)

**O-B over land using NESDIS Land Physical Model (TOP: CRTM 2.3) (Bottom: CSEM)**

**O-B over sea-ice for 50.3 GHz (TOP: TELSEM) (Bottom: CSEM)**

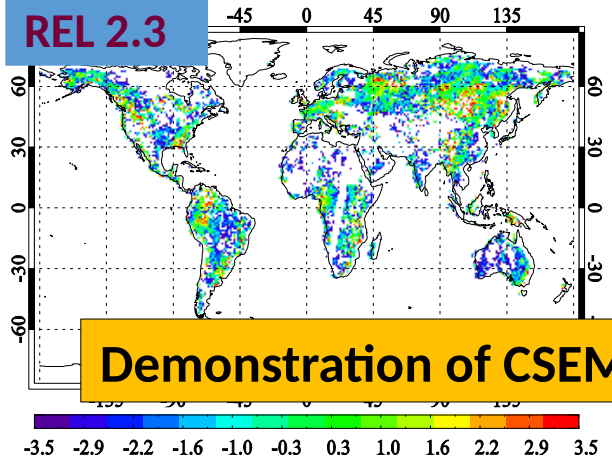
23.8GHz

REL 2.3

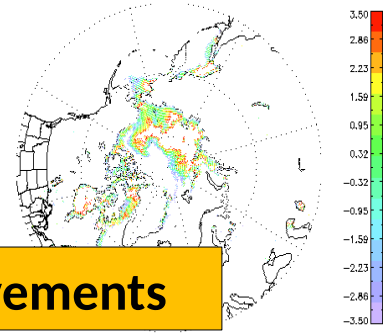


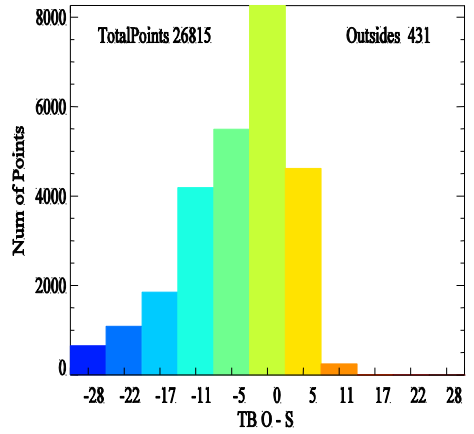

50.3GHz

REL 2.3



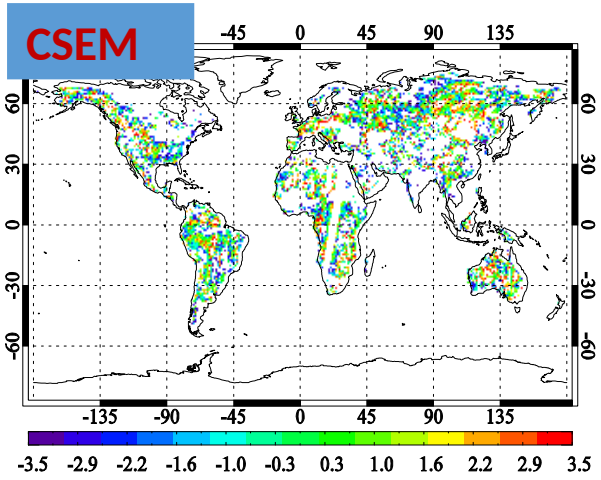

TELSEM



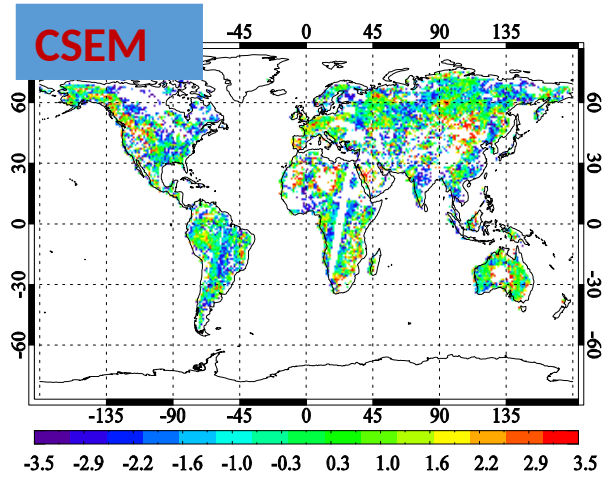




**Demonstration of CSEM improvements**

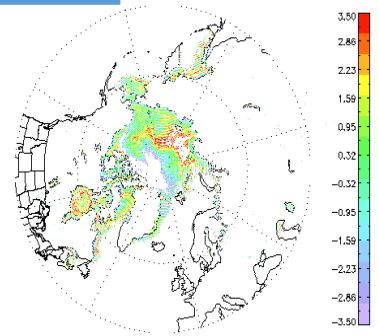
CSEM

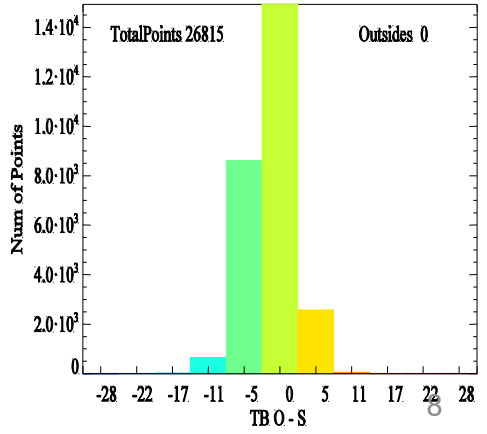



CSEM




CSEM



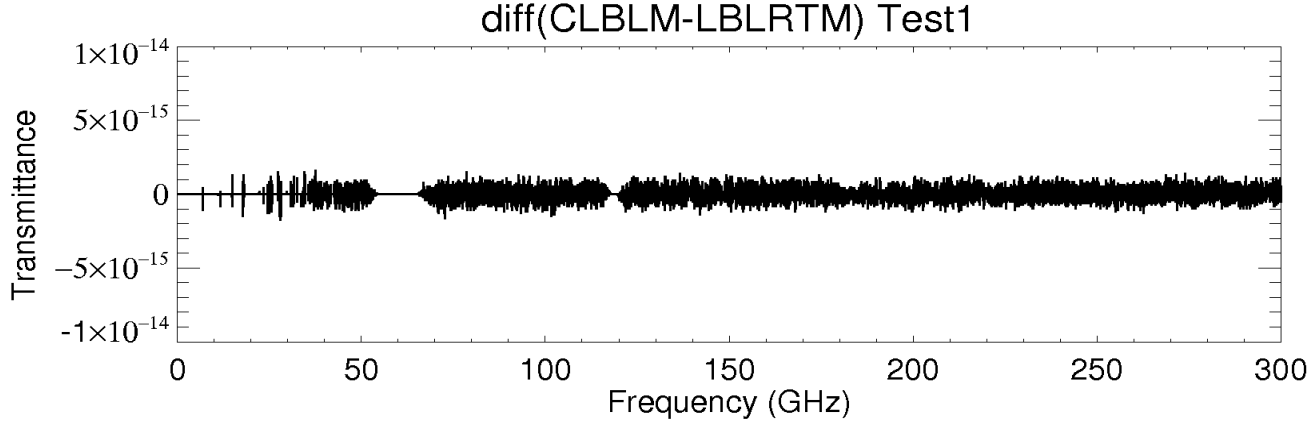
# CRTM current developments

## The Community Line-By-Line Model (CLBLM)

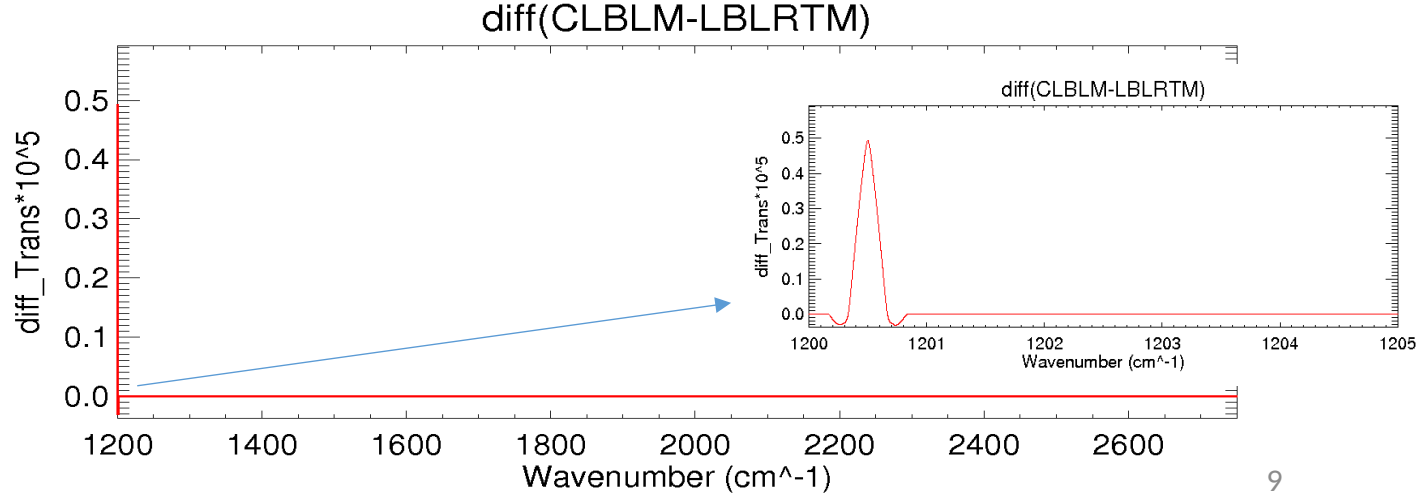
**Objective: Development/release of the Community Line-By-Line Model (CLBLM)**

- Monochromatic RTM to train CRTM fast model
- Modernization of heritage LBLRTM
  - Refactored/modular code
  - Improved I/O
  - Redesigned RT/Jacobian routines
  - Double line-shape convolution scheme for improved narrow-lines
- CLBLM Alpha released 1/2018
- CLBLM v1.0 released 8/2018

**Transmittances over MW Spectrum**




**Transmittances over IR Spectrum**



# Data assimilation activities

# Data assimilation activities

## ATMS surface-sensitive radiance assimilation

**Objective: Increase the number and quality of ATMS surface-sensitive (non-ocean) observations assimilated (NOAA GDAS/GFS)**

- Requires accurate forward operator
- …which requires accurate surface characterization (e.g. emissivity)

**Implement in 2 phases**

- Improve the background surface emissivity
- Implement surface emissivity as a control variable in the GSI

**Compare Current Land Model in CRTM and TELSEM2 for background**

| | CRTM | TELSEM 2 |
|---|---|---|
| Surface type | All | Land & sea-ice only |
| Frequency | 3 – 190 GHz | 10 – 700 GHz |
| Polarization | H + V | H + V |
| Spatial Resolution | 0.25° | 0.25° |
| Temporal Resolution | Instantaneous | Monthly |
| Base | “Physical” | Empirical |

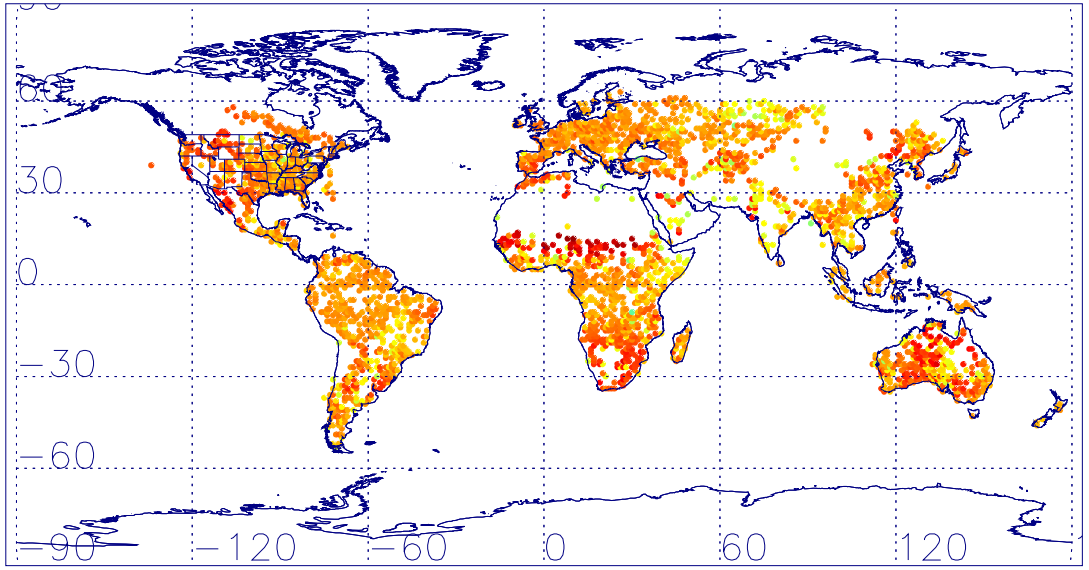
CSEM improved Land Emissivity physical model will also be tested

# Data assimilation activities

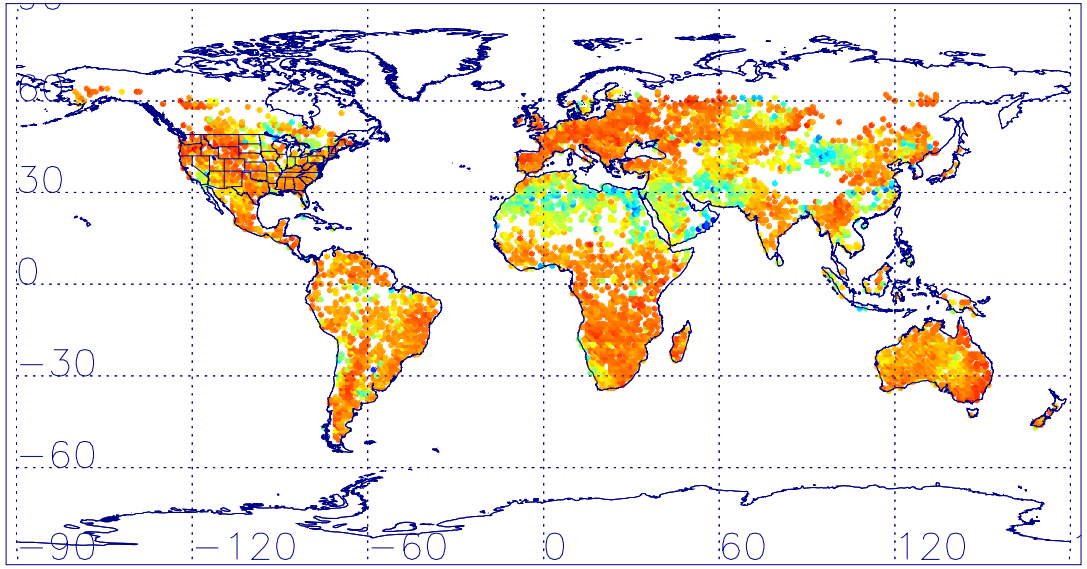
## ATMS surface-sensitive radiance assimilation

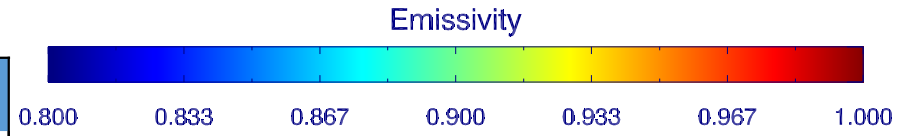
### Improving the background: 31 GHz Emissivity from 2 GDAS Cycles

CRTM




TELSEM 2



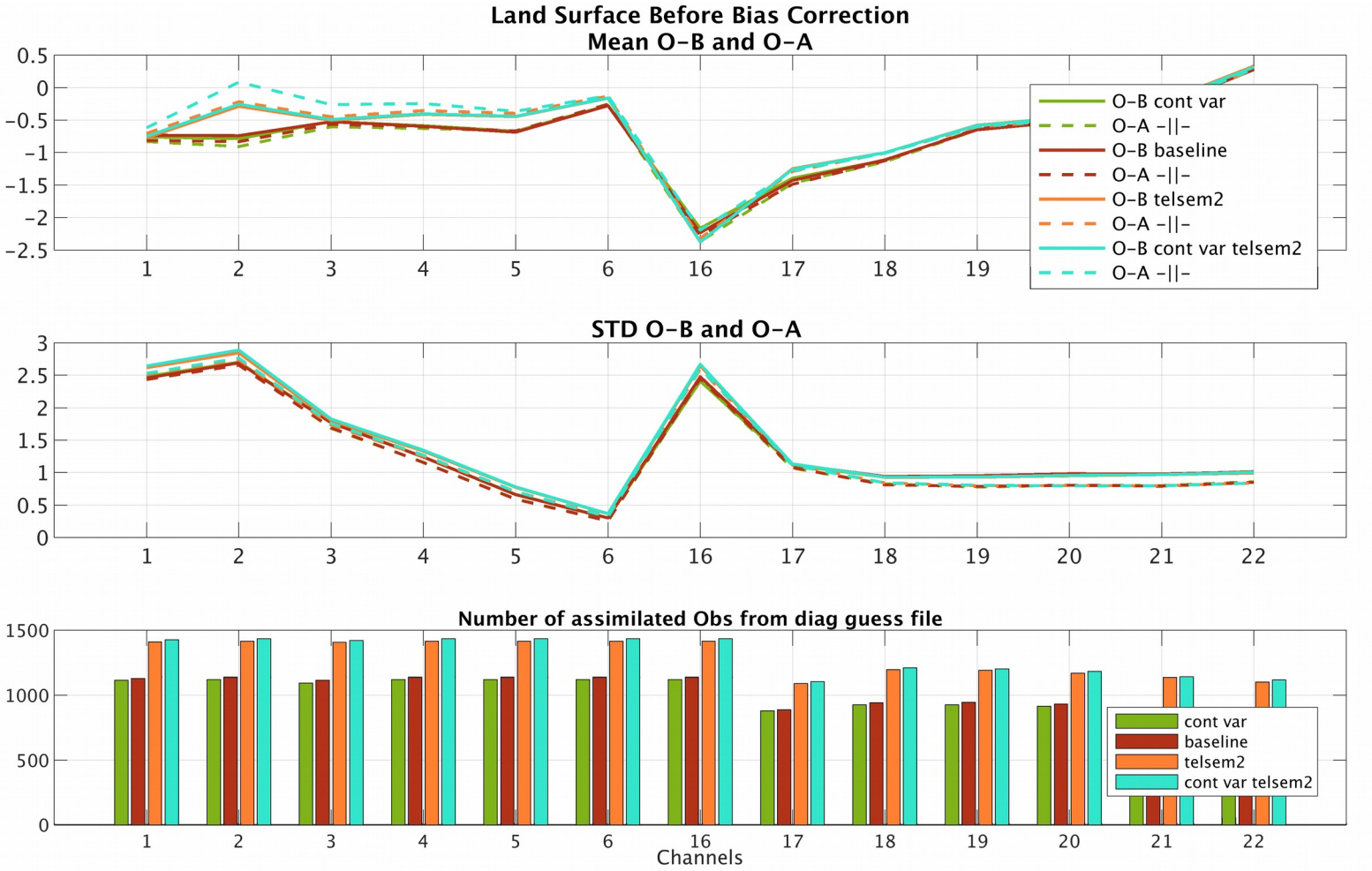

| O-B Stats | CRTM | TELSEM 2 |
|---|---|---|
| **Number count** | **4104** | **8050** |
| Bias | -0.4 | 0.05 |
| Std. dev. | 2.0 | 1.9 |

**Replacing the background to use TELSEM2 increases x2 the number of observations assimilated (from 2 GDAS cycles)**

# Data assimilation activities

## ATMS surface-sensitive radiance assimilation

### Improving the analysis: O-B, O-A, and Obs Count from 9 GDAS Cycles




**While replacing the background (orange) improves the observation count, implementing emissivity as control variable improves the analysis.**

**Further improvement can be realized:**

- **Use off-diagonal elements of emissivity covariance matrix**
- **Improve bias correction over land**

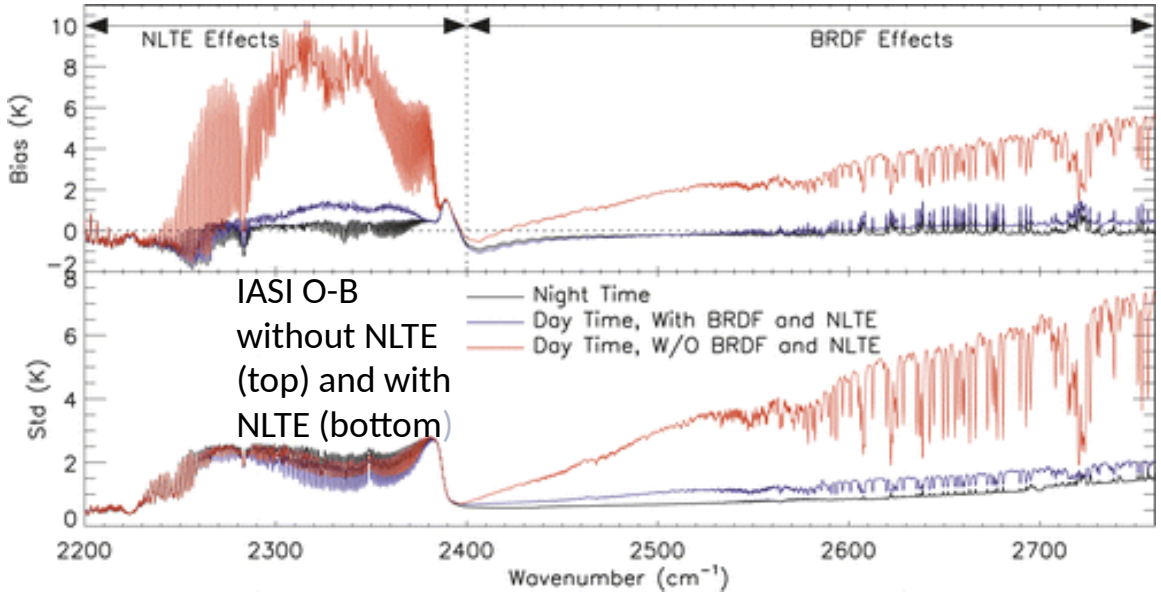
# Data assimilation/CRTM activities

## Other efforts at STAR

### CrIS and IASI shortwave IR 4 µm band assimilation

**(Boukabara, Ide, Garrett, Barnet)**

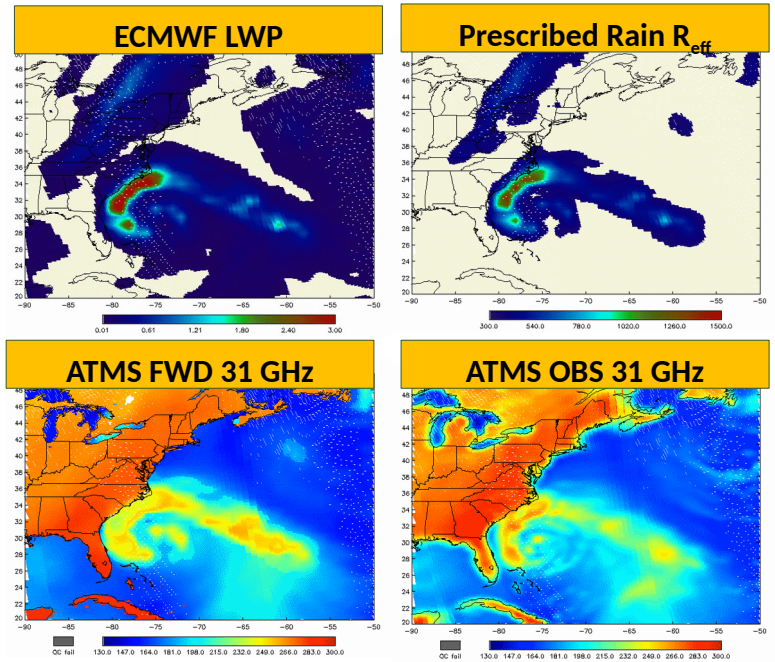
- Assess CRTM capability
  - NLTE, shortwave reflectance
- Extend global DA
  - Dynamic CO2/N2O, obs errors, etc.
- Assess analysis and forecast impact vs longwave IR




Chen et al. 2013

### Improve PMW all-sky radiance retrieval/assimilation

- Utilize datasets like GPM 2BCSATGPM
  - Quantify accuracy of CRTM in precip for ATMS
- … or GPROF
  - Training set to improve a-priori of hydrometeor microphysical properties



# Summary

## Focus on Future Efforts

### Cal/Val Systems and Science Support from CRTM

- Address priorities and needs of STAR EDR, Cal/Val teams
  - Science needs, e.g. improvements to quality of output
  - Technical needs, e.g. supporting transitions to new versions

### Science/Coordination Support for Data Assimilation

- Address priorities across STAR, NESDIS (program offices)
  - Assimilation of land EDRs (LST, GVF, soil moisture)
  - Assimilation of ocean EDRs (SST, color)
  - Assimilation of cryospheric products (IST, SIC, Snow Cover/SWE)
  - Assimilation of trace gases, aerosol (V8Tot/Pro, AOD)