STAR Supports for JCSDA Development

Fuzhong Weng (PI) and **Yong Han (Co-PI)**
Center for Satellite Applications and Research
and
Quanhua Liu (Dell), Banghua Yan (UMD/ESSIC), Yong Chen (CIRA), Ron Vogel (IMSG), Greg Krasowski (IMSG), Min-jeong Kim (CIRA), Ninghai Sun (IMSG), Sid Boukabara (STAR),Tong Zhu (CIRA), Ellen Liang (IMSG)

In Collaborations with Steve Lord, John Derber, Paul van Delst, Dennis Keyser, and Andrew Collard (EMC)

JCSDA 2010 Science Workshop, UMBC, MD, May 4-5

Focus Areas

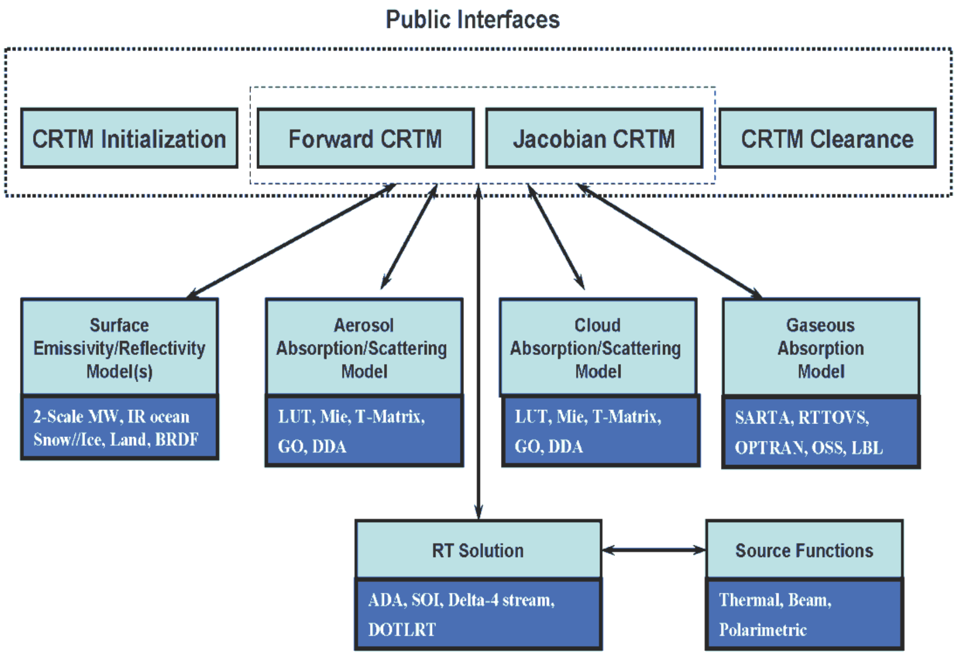
- Develop fast and accurate gaseous, aerosol and cloud optical models for CRTM
- Provide CRTM upgrades with new surface emissivity models and data base (MW vs. IR) (see poster 3.13 by R. Vogel et al)
- Develop, test and integrate new radiative transfer schemes for CRTM applications
- Moisture physics tangent linear and adjoint, and cloudy radiance assimilation (see poster 3.14 by M. Kim et al)
- Prepare CRTM readiness for future instruments (see poster 3.11 by Y, Chen et al)
- Develop and test new quality control and bias correction schemes for microwave instruments (see presentation by Banghua Yan et al)
- Study impacts from new instruments/new products in GFS (also (see presentation by Banghua Yan et al)
- Prepare new data streams for uses by NCEP and other JCSDA partners

National Environmental Satellite, Data, and Information Service

CRTM Software Architecture, Sciences and Physical Processes

- Atmospheric gaseous absorption
  - Band absorption coeff trained by LBL spectroscopy data with sensor response functions
  - Variable gases (H_2O, CO_2, O_3 etc) .
  - Zeeman splitting effects near 60 GHz
- Cloud/precipitation scattering and emission
  - Fast LUT optical models at all phases including non-spherical ice particles
  - Gamma size distributions
- Aerosol scattering and emission
  - GOCART 5 species (dust, sea salt, organic/black carbon,)
  - Lognormal distributions with 35 bins
- Surface emissivity/reflectivity
  - Two-scale microwave ocean emissivity
  - Large scale wave IR ocean emissivity
  - Land mw emissivity including vegetation and snow
  - Land IR emissivity data base
- Radiative transfer scheme
  - Tangent linear and adjoints
  - Inputs and outputs at pressure level coordinate
  - Advanced double and adding scheme
  - Other transfer schemes such as SOI, Delta Eddington

Community Radiative Transfer Model (CRTM)



"Technology transfer made possible by CRTM is a shining example for collaboration among the JCSDA Partners and other organizations, and has been instrumental in the JCSDA success in accelerating uses of new satellite data in operations" – Dr. Louis Uccellini, Director of National Centers for Environmental Prediction

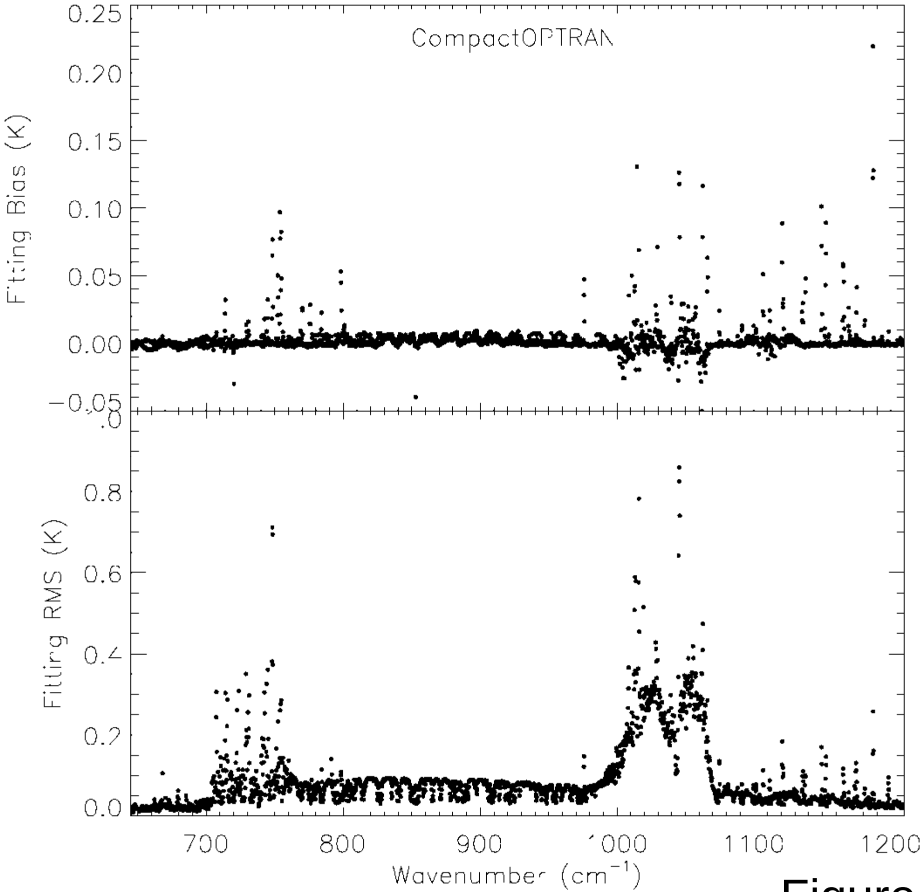
What's new in CRTM v2

- Computational efficiency
  - Improves Forward model speed (by a factor 3 under clear-sky conditions)
  - Improves Jacobian model speed (by a factor 2 under clear-sky conditions)
- Transmittance module
  - Implements Multiple Transmittance Algorithm Framework
    - OPTRAN (current model)
    - ODPS model
    - SSU model
    - SSMIS and AMSUA Zeeman models
- Extends RTSolution module and cloud/aerosol optics LUT to include components for Visible and UV sensors; adds a module for molecular scattering
- Surface emissivity/reflectivity module
  - Adds BRDF for solar reflection over ocean
  - Adds a new IR ocean emissivity model
  - Adds MW snow and ice empirical models for additional sensors
- New instruments: FY3-MWTS,MWHS, MWRI, IRS; DMSP SSMIS

National Environmental Satellite, Data, and Information Service

CRTM Fast Gaseous Absorption Models

Version 1 performance:
Variable gases: H2O, O3
Fixed gas: CO2, CO, CH4, N2O, O2



Version 2 performance
Variable gases: CO2, H2O, O3
Fixed gas: CO, CH4, N2O, O2, CFCs and others

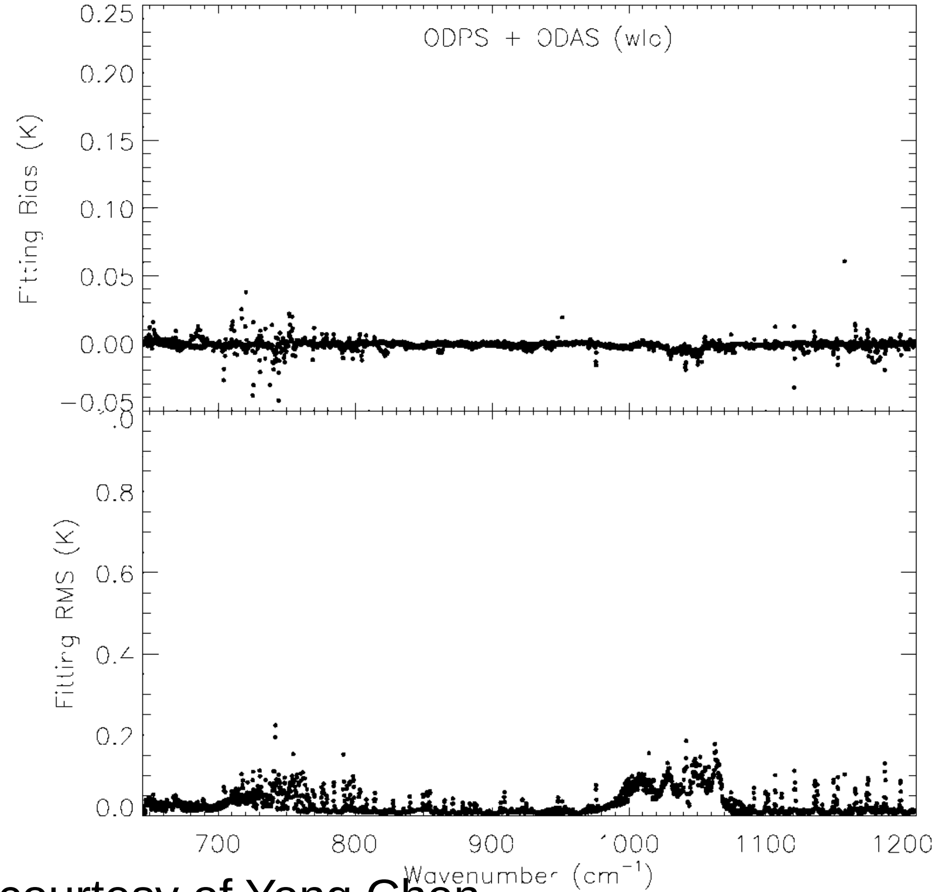
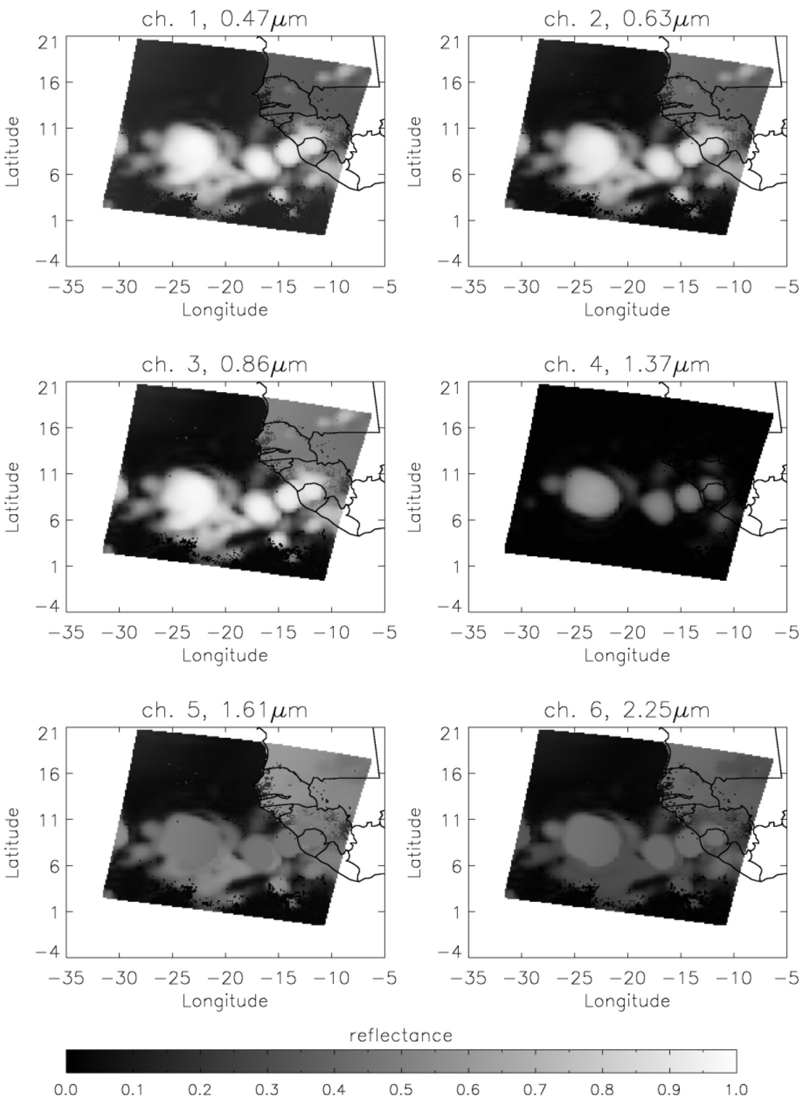


Figure courtesy of Yong Chen

Components for Visible/UV sensors

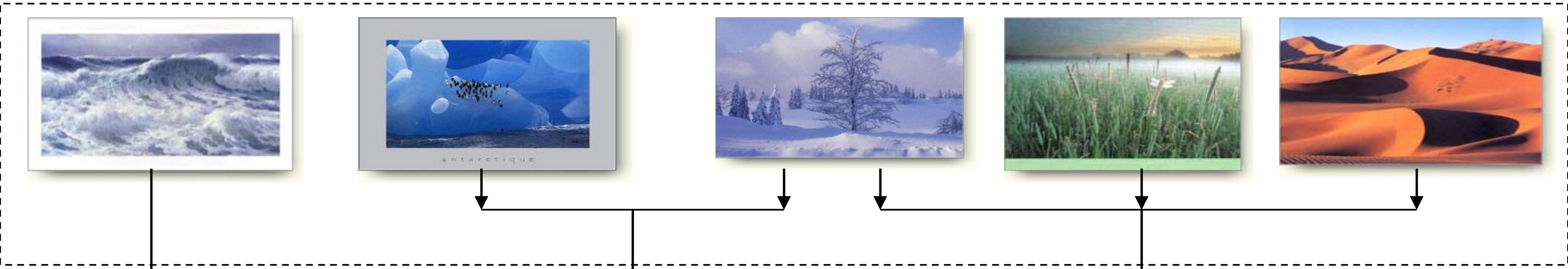
- MoleculeScatter module (new): compute molecule scattering optical properties
- Extension of AtmAbsorption module: compute molecule absorption for Vis/UV sensors
- Extension of CloudScatter and AerosolScatter modules: compute cloud and aerosol optical properties for Vis/UV sensors
- Extension of the Advanced Doubling-Adding (ADA) method: add integratione of the RT solution over Fourier components for azimuth angle



Shown are simulated GOES-R ABI with MODIS terra geometry parameters, GDAS data and GOCART aerosol data.

Surface Emissivity Models

Ocean — Sea Ice — Snow — Canopy (bare soil) — Desert

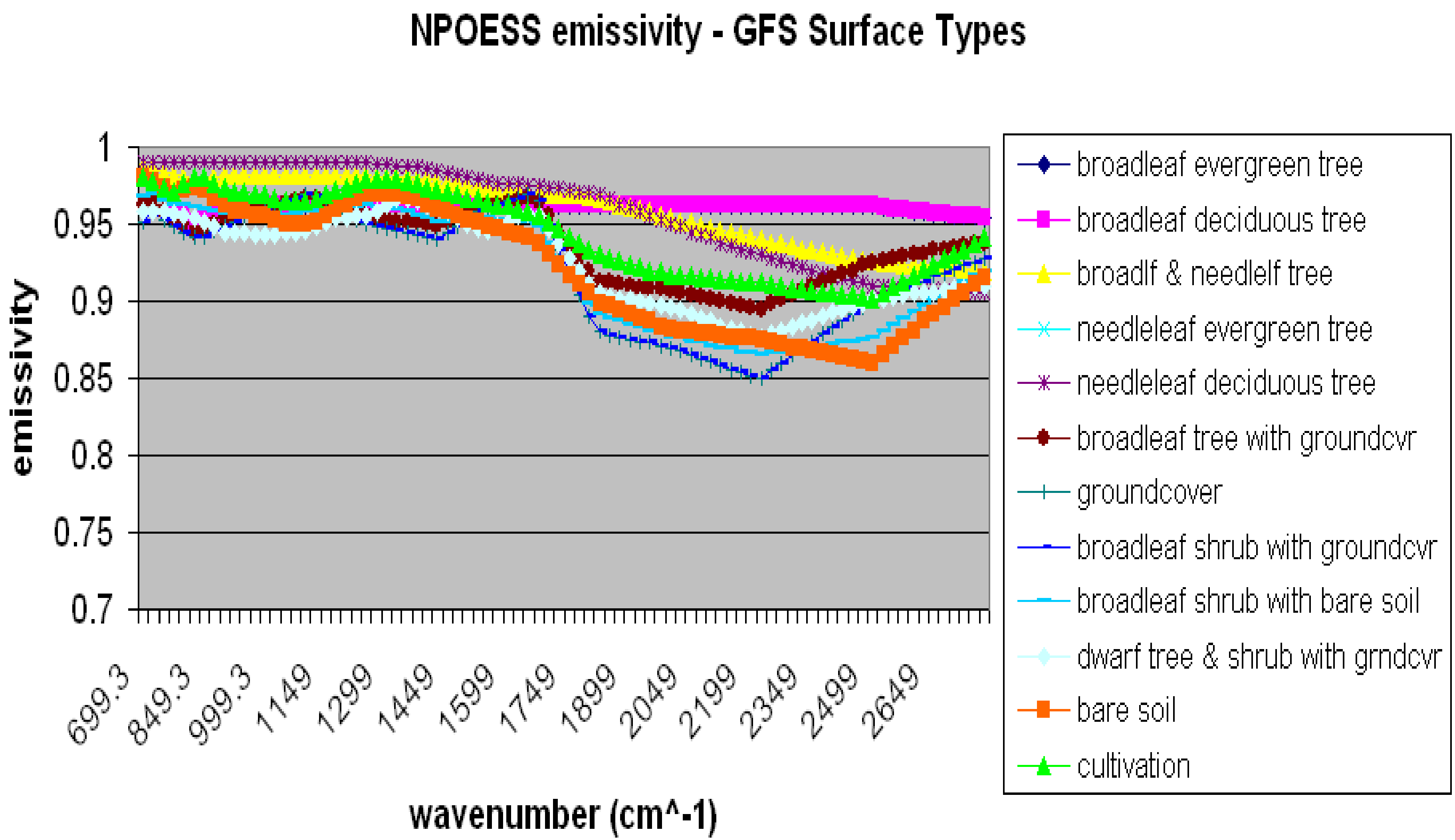


Microwave land emissivity model (Weng et al., 2001) and desert microwave emissivity library (Yan and Weng, 2010)
NPOESS Infrared emissivity data base

Empirical snow and sea ice microwave emissivity data base (Yan and Weng, 2003; 2008)
Two-layer snow emissivity model (Yan, Weng, Liang, 2010)
Fast multi-layer snow emissivity model (Liang, Weng, Yan., 2010)

FASTEM3 microwave emissivity model (English and Hewison, 1998)
IR emissivity model (Wu and Smith, 1991; van Delst et al., 2001)
FASTEM4 microwave emissivity model (Liu, Weng, English, 2010)

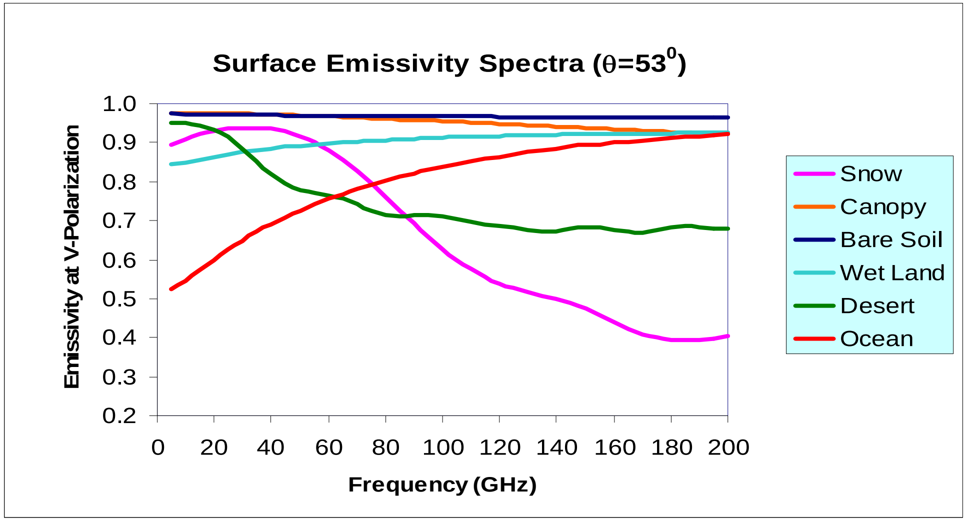
Land Infrared Emissivity Database

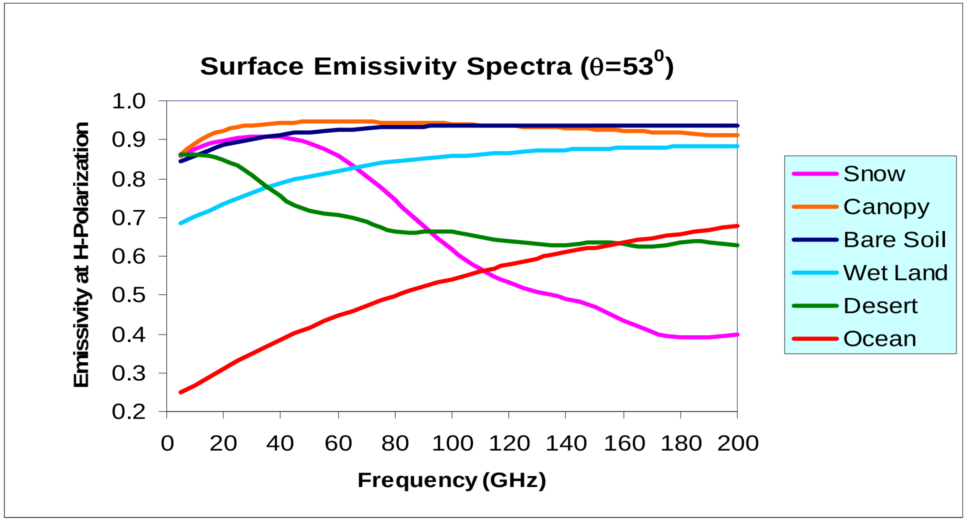


Microwave Surface Emissivity Model

- **Open water** – two-scale roughness theory
- **Sea ice** – Coherent reflection
- **Canopy** – Four layer clustering scattering
- **Bare soil** – Coherent reflection and surface roughness
- **Snow/desert** – Random media

Weng et al (2001, JGR)





Planned Upgrade to CRTM Emissivity Models

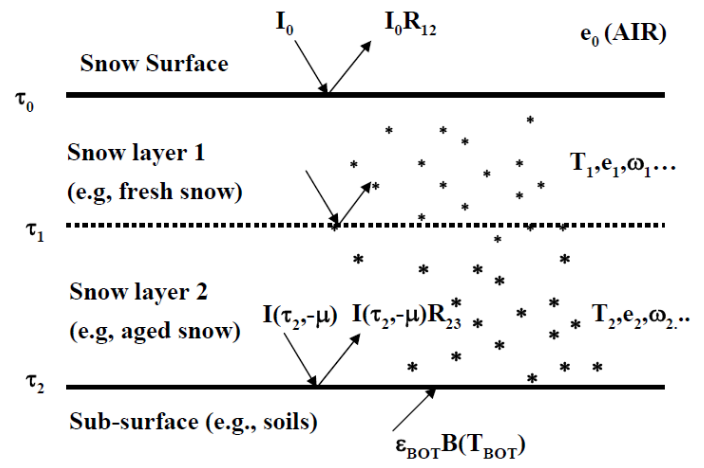
- **Ocean microwave emissivity, FASTEM4**
  - Liu, Weng, and English, TGRS, 2010 (Accepted)
- **Two-layer snow microwave emissivity model**
  - Yan, Weng, and Liang (2010)
- **A fast multi-layer snow microwave emissivity model based on QCA/DMRT model**
  - Liang, Weng, and Yan (2010)
- **Desert microwave emissivity library**
  - Yan and Weng, submitted to TGRS (2010) (revised)
- **IR land emissivity data base derived from MODIS and AIRS emissivity V5.0 L2** (ref. Zhou et al. 2008)

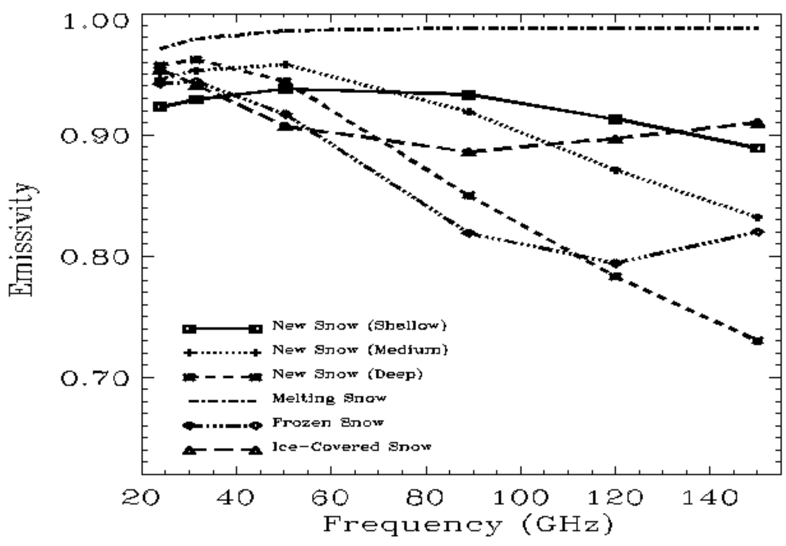
Two-layer Microwave Snow Emissivity Model

- A two-layer snow emissivity model which is derived based on one-layer model in Weng et al. (2001)

- Snow optical parameters are currently computed using an approximate approach from Grody and Weng (2008)

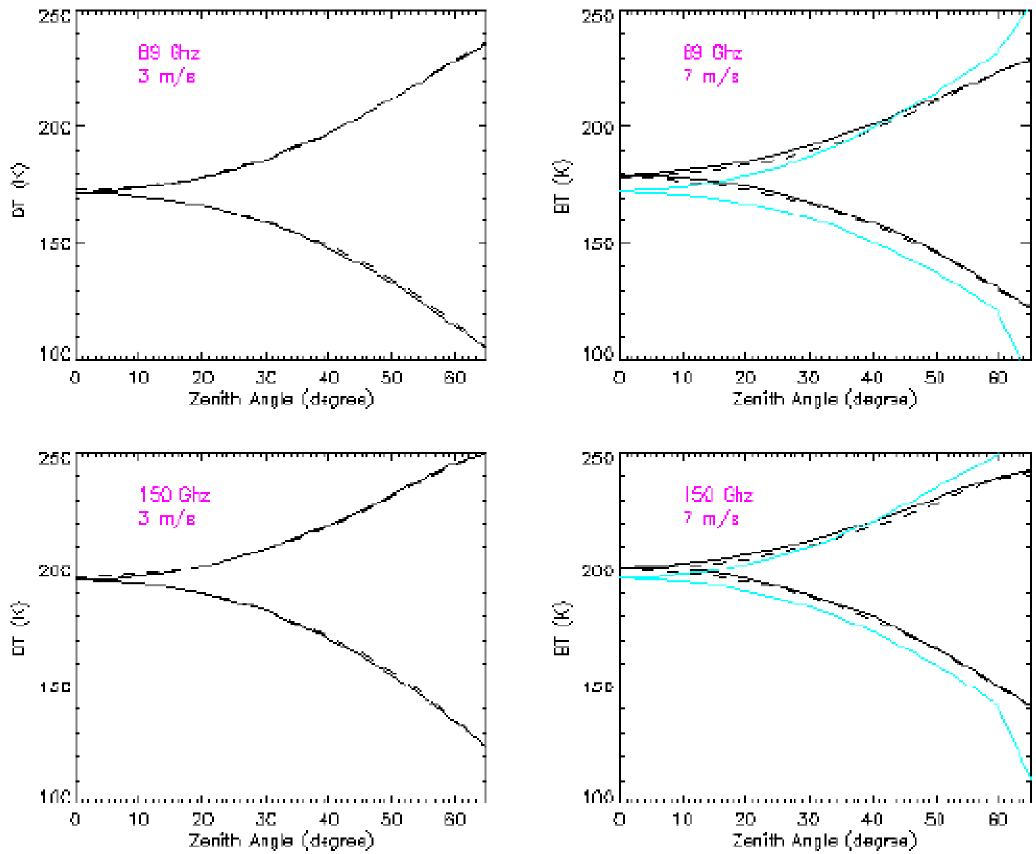
- Snow optical parameter calculations will be updated using a lookup-table from QCA-DMART





New Ocean MW Emissivity Model: FASTEM-4

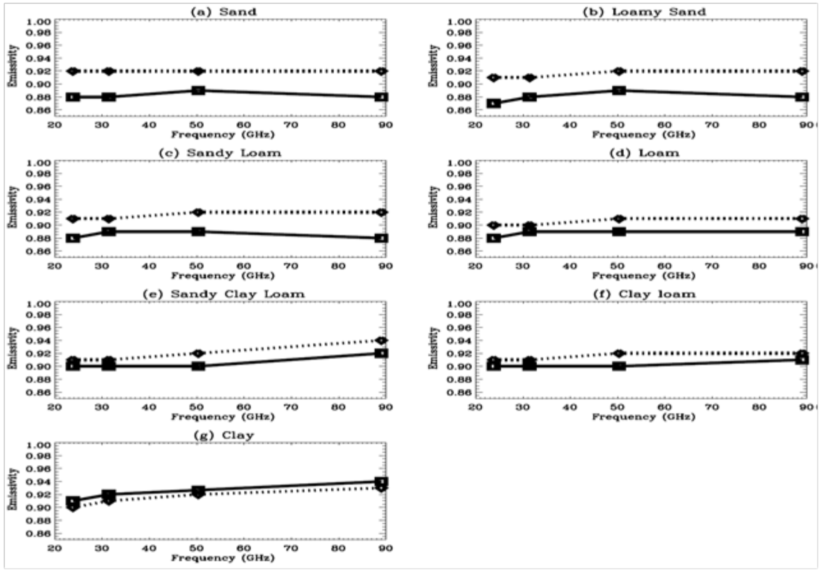
- Revised Double-Debye permitivity model with variable salinity & intermolecular interaction
- A factor 2 of slope variance from Durden and Vesecky spectrum model – upwind and cross-wind slopes
- *Variable foam emissivity depending on angle and polarization (non-unity)*
- Two-scale approximation with an automatic cutoff wavenumber calculation

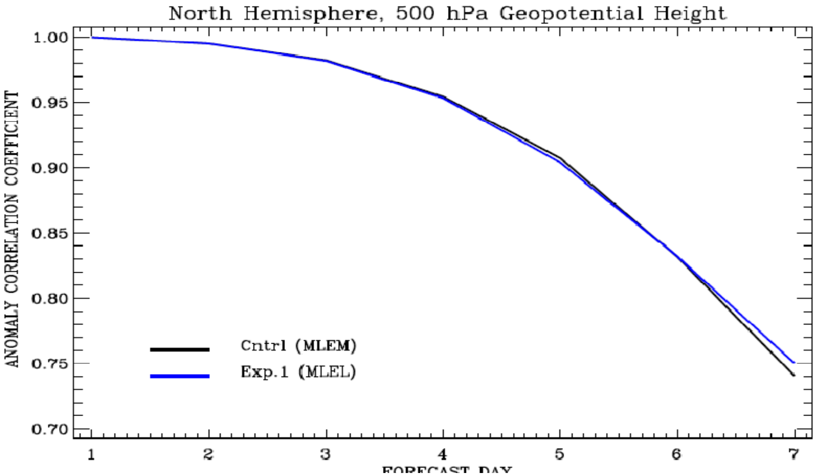


Diamond symbol: Measurement ; Black solid: two-scale simulation, Black dash: FASTEM4, Blue line : FASTEM3

New Microwave Desert Emissivity Library

- Microwave land emissivity library (MLEL) is developed according to soil type from AMSU-A data for improving satellite data assimilation.
- MLEL data results in more data usage in AMSU-A data over desert areas compared to current Microwave land emissivity model (MLEM)
- MLEL data results in a positive impact on global medium-range forecasts in GFS



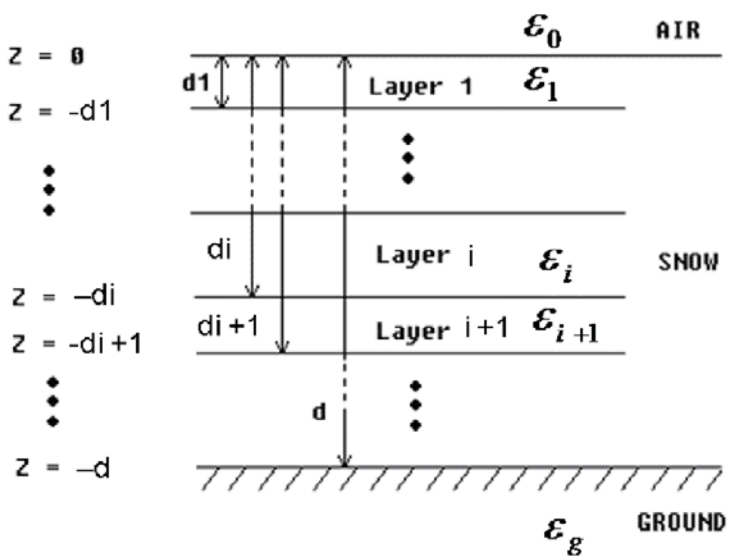


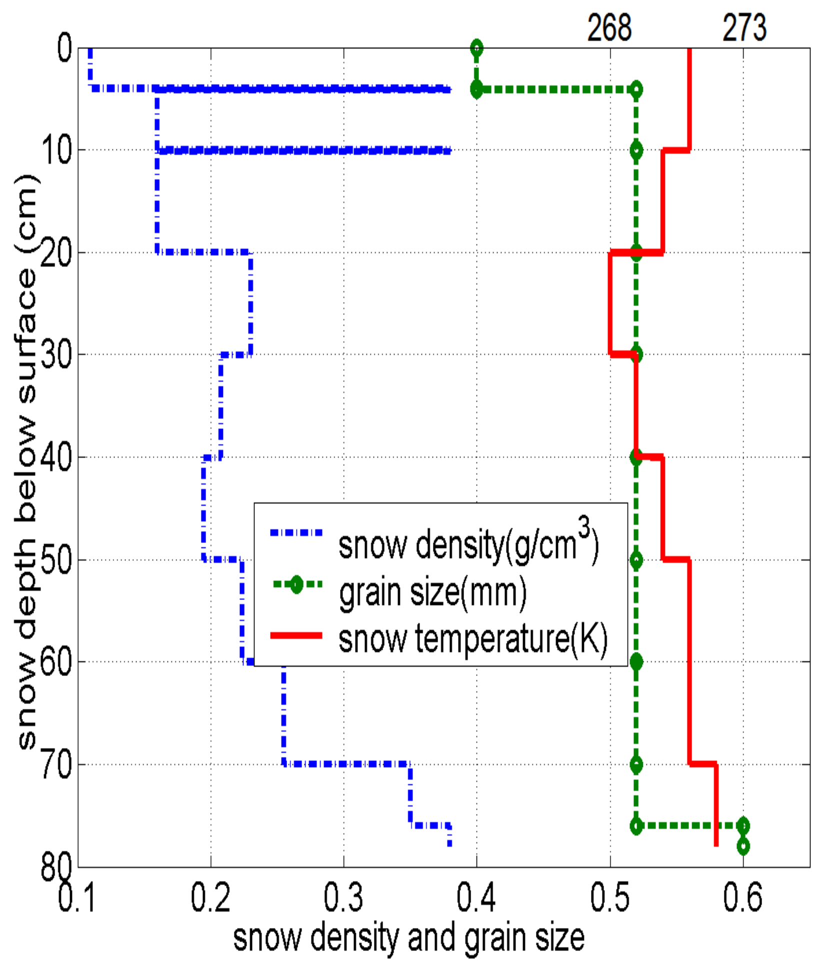
Microwave Emissivity of Layered Snow using QCA/DMRT Approach

Dense media radiative transfer equations in layer i:

$$\cos\theta \frac{d\bar{I}_i(\theta,z)}{dz} = -\kappa_{ei}\cdot\bar{I}_i(\theta,z) + \kappa_{ai}T^i +$$

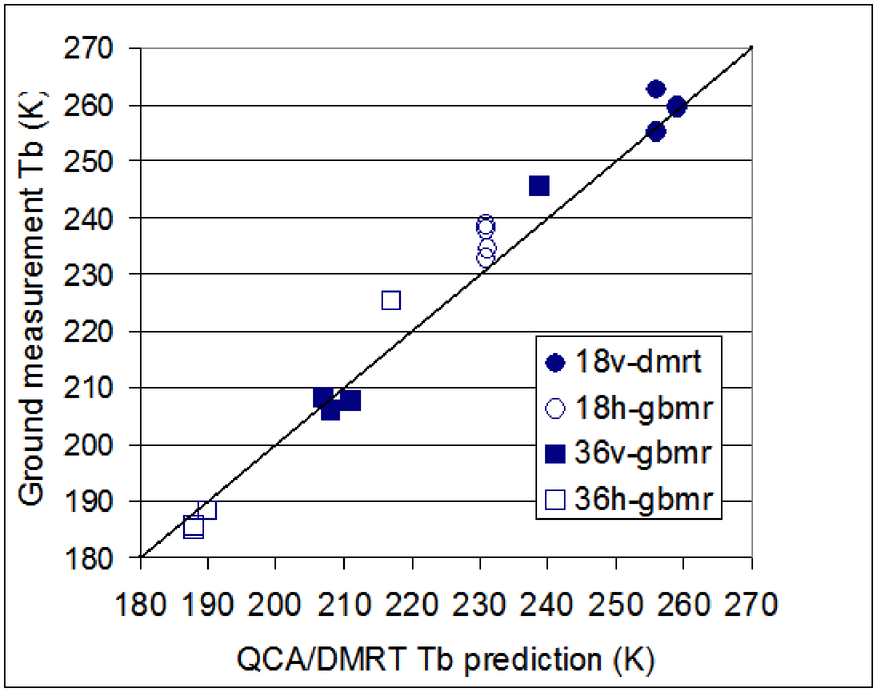
$$\int_0^{\pi} d\theta' \sin\theta' \,\overline{\overline{P}}_i(\theta;\theta')\bar{I}_i(\theta',z)$$



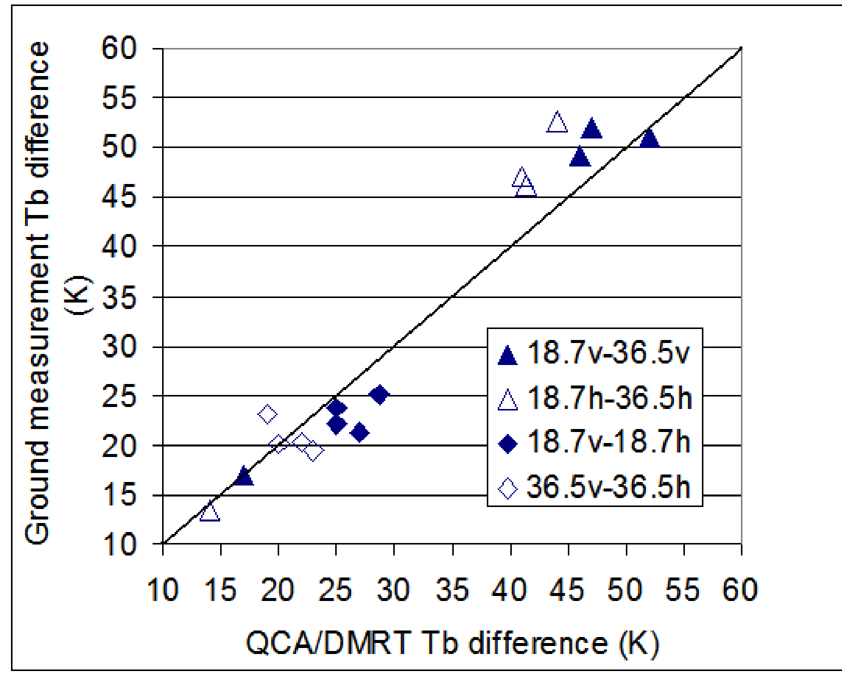


Validation of DMRT Brightness Temperatures

TB comparisons



TB polarization difference comparisons



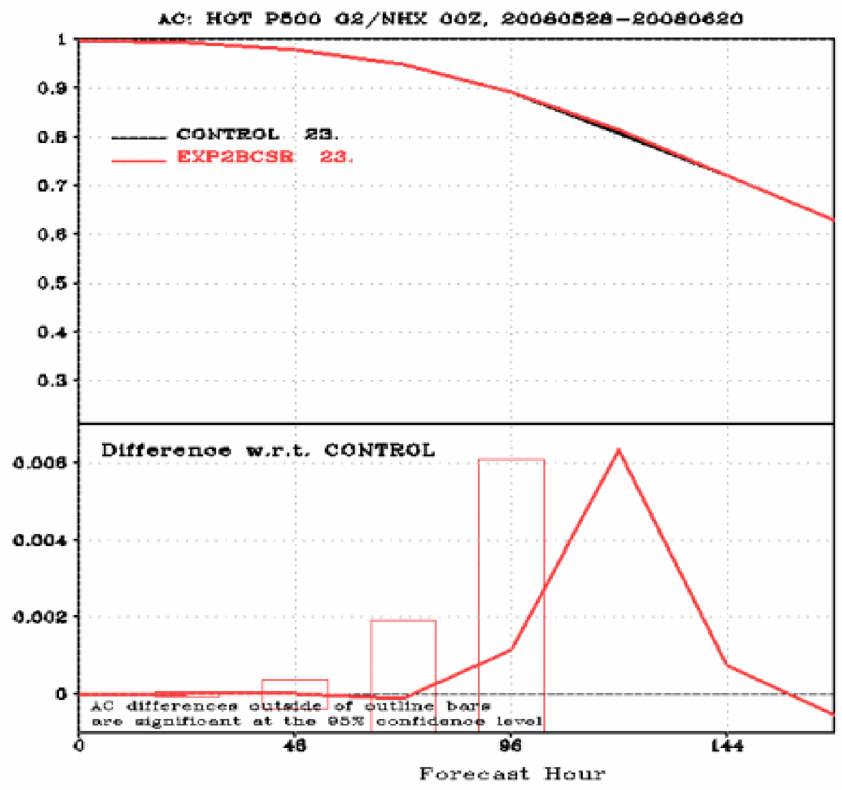
1)The model Tb prediction (left figure) show close agreement with the ground Tb observation.
2)Polarization difference (18.7v-18.7h and 36.5v-36.5h,right figure) predicted by DMRT show close agreement with observations.
3) Frequency dependence(18.7v-36.5v and 18.7h-36.5h, right figure) predicted by DMRT show close agreement with observations.

MSG SEVIRI Data Experiments

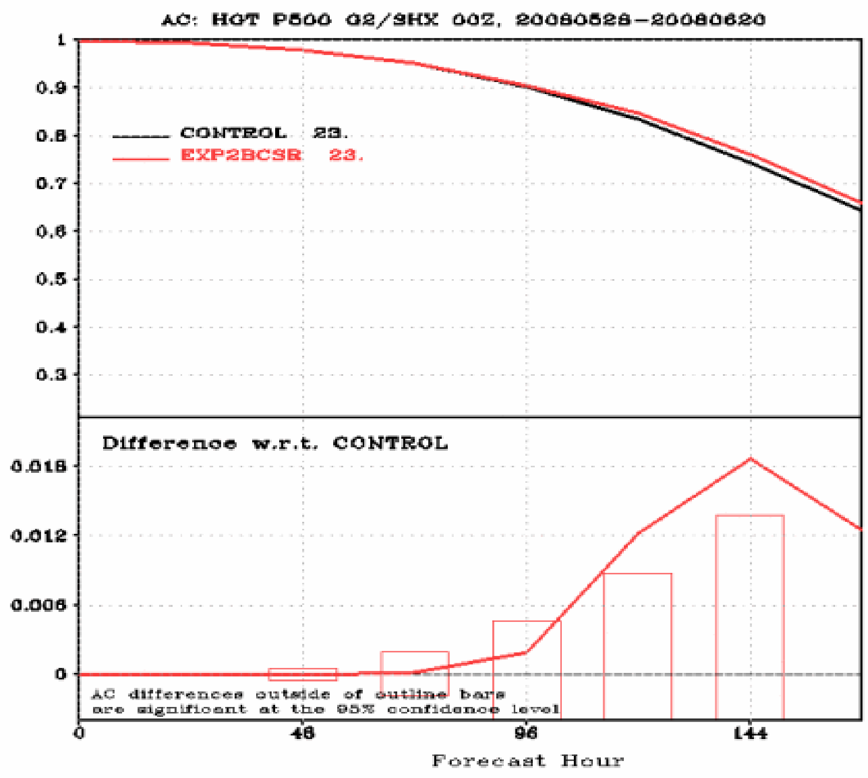
- GSI version with T382 resolution
- Control run: conventional data + all current sensors (e.g. AMSU-A/B, HIRS, AIRS, SSMI, MHS, GOES sounder)
- Exp1 run: control run + SEVIRI 8 IR bands
- Exp2 run: control run + SEVIRI 2 WV bands and CO2 band.
- Quality control: clear sky fraction within FOV > 95%
- Bias correction: GSI bias correction scheme (e.g. scan angle, lapse rate, MW CLW).

Impacts from Assimilation of SEVIRI H2O and CO2 Channel Data

NH 500mb HGT

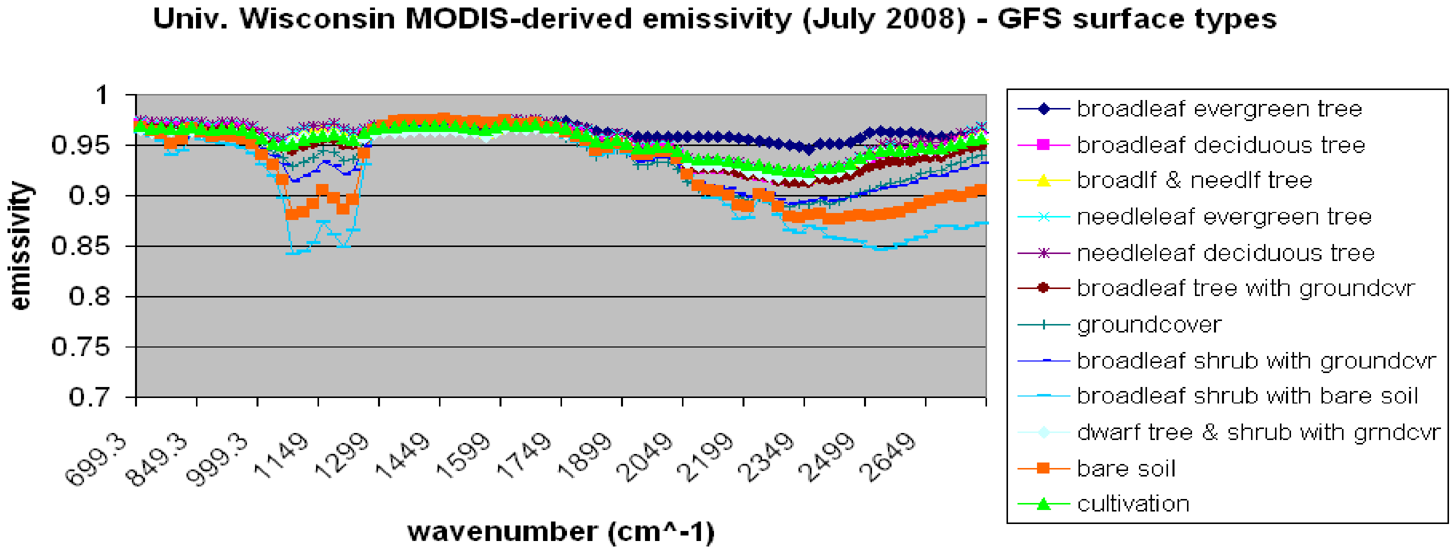


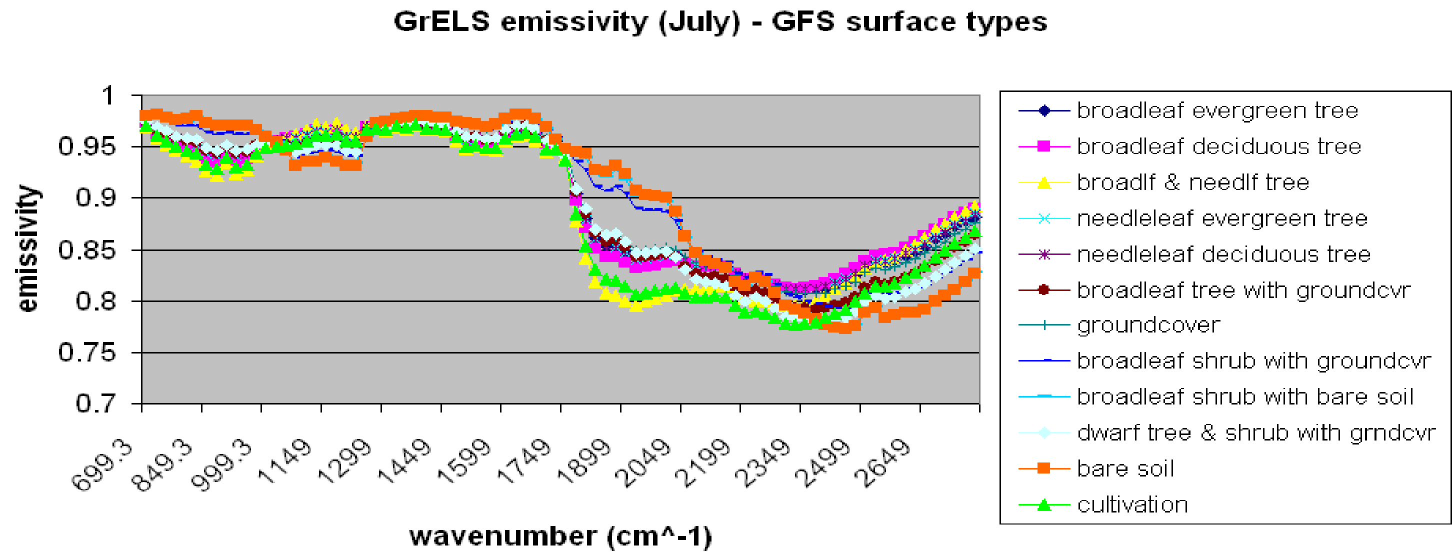
SH 500mb HGT



Some positive impacts are found, especially in Northern Hemisphere when SEVIRI H2O and CO2 channels are assimilated in GFS.

Uses of New Infrared Emissivity in CRTM

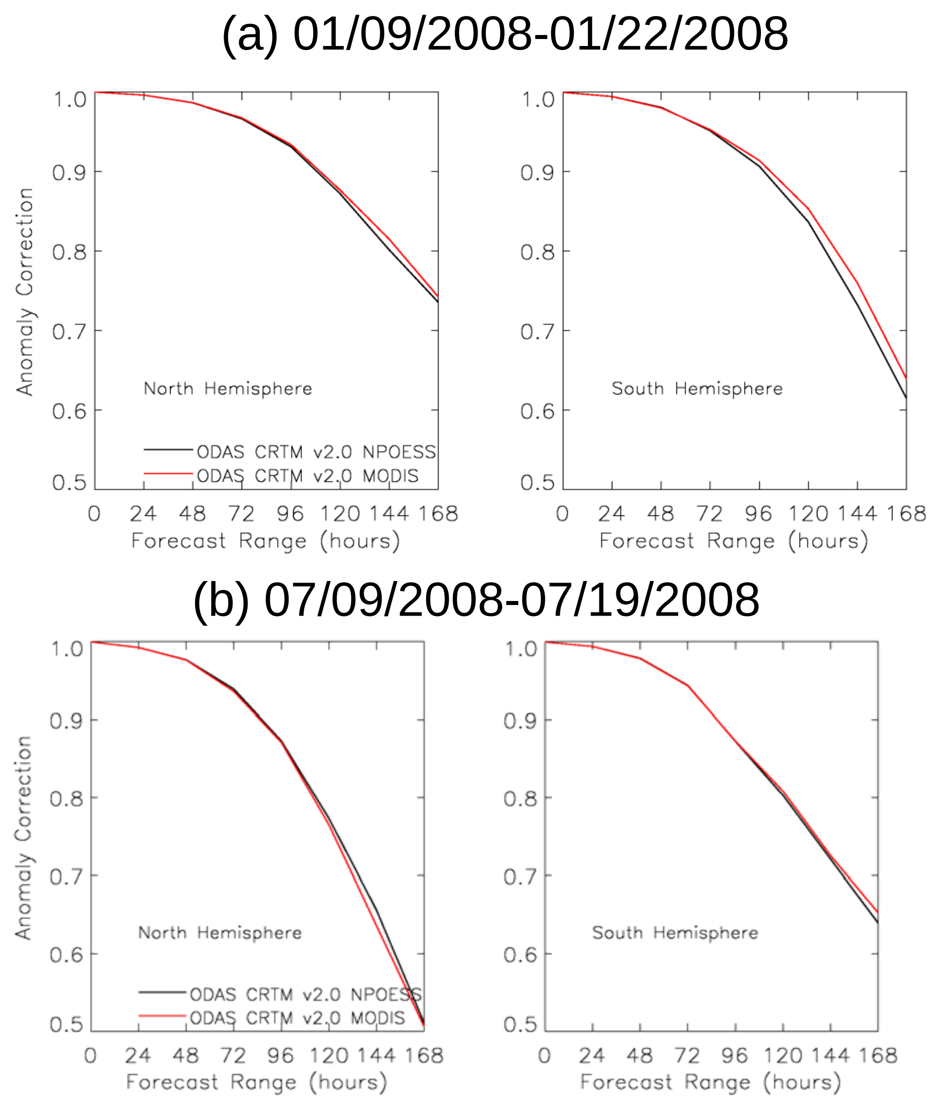




Impacts of UWisc HSR Emissivity Data Base in GFS

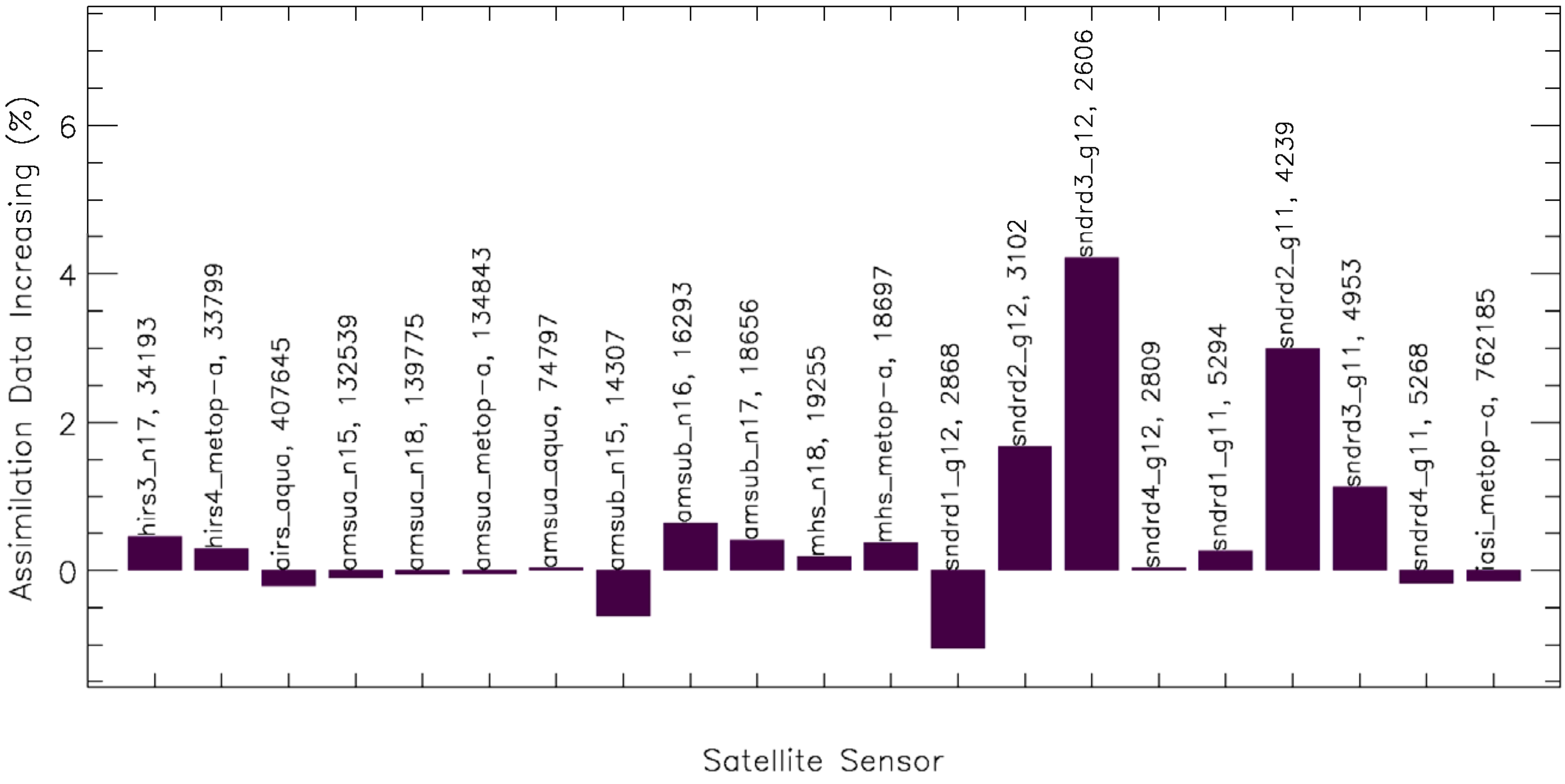
- Experiments are set up in GSI with two months data on 2008 (January, and July), CRTM v2.0 with NPOESS database, and UWIREMIS database

- UWIREMIS database has some positive impact in winter season, especially for south hemisphere. However, it is inferior to the CRTM baseline IR land emissivity in north hemisphere during summer time



National Environmental Satellite, Data, and Information Service

Changes of assimilated data volumes for different sensors (MODIS V.S. NPOESS) on January 22 UTC 00, 2008.



Summary

- CRTM version 2 releases resulted in some significant positive impacts
- New surface emissivity data bases including IR and MW are being assessed in GFS
- Land MW emissivity library has been developed and shows some positive impact on forecast skill
- Several land IR emissivity data bases are tested. MODIS data set has some positive impacts on forecasts during the cold seasons.
- MW ocean emissivity has been updated through FASTEM4 which has significantly improved the emissivity simulations at low and high frequencies
- A two-layer microwave snow emissivity model has been developed to characterize emissivity at a wide frequency range for stratified but shallow snow
- A fast multi-layer microwave snow emissivity model is being developed based on QCA/DMRT model which will be applicable for highly stratified snow.

Other Related Presentations

- STAR JSDI tasks are progressing well and all on-track
- For more detailed presentations: please see STAR/JCSDA posters

3.1 T. Kleespies, Footprint Matching for the Advanced Technology Microwave Sounder

3.2 T. Kleespies, Modeling of Inhomogeneous Surface Properties for the Advanced Technology Microwave Sounder

3. 11 Y. Chen, Preparation of the NPOESS CrIS into GSI System

3.13 R. Vogel: Comparison of infrared land surface emissivity from AIRS and MODIS for improving satellite data assimilation over desert regions

Improvements to infrared land emissivity

3.14 M. Kim: Assimilation of cloud affected MW radiances in GFS

3.15 Q. Liu: An improved FAST Microwave Surface Emissivity Model, FASTEM4