Assimilation Impact Study of Microwave Land Emissivity on NCEP Global Forecast System

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Key Things for Assimilation of Satellite Data into NWP Model

No. 1 Satellite calibration anomaly and/or bias corrections

↓ Unbiased data

Challenging areas:

Desert:
Sahara, Gobi
Great Sandy, etc
Snow-covering areas:
Greenland,
Antarctic,
Tibet, etc

No. 2 Cloud detection (only non-cloud impacted satellite data is assimilated)

↓ High quality of non-cloud affected data

No. 3 Accurate surface emissivity information for T_B simulations for channels sensitive to surface

↓ **Goal:** QC-passed high quality data (e.g., reliable RTM simulations)

NWP Models

AMSU-A Data Utilization in Lower Tropospheric Sounding Channels

- Brightness temperature departure (ΔT_B) at 50.3 and 52.8 GHz for used data in Northern Africa from August 1 to August 15, 2008
- Most of the AMSU-A data at 50.3 and 52.8 GHz is removed from the NCEP global data assimilation system due to large ΔT_B
- This large ΔT_B is caused by large emissivity simulation error and large Tsfc errors from the existing physical land emissivity model and land surface model

Few data is used in Northern Africa desert areas due to inaccurate emissivity simulation & skin temperature

Used data at 50.3 GHz

Used data at 52.8 GHz

Major Approaches for Microwave Land Emissivity Simulations

- <u>Mean emissivity spectra,</u> e.g., a series of microwave mean emissivity spectra associated with land type

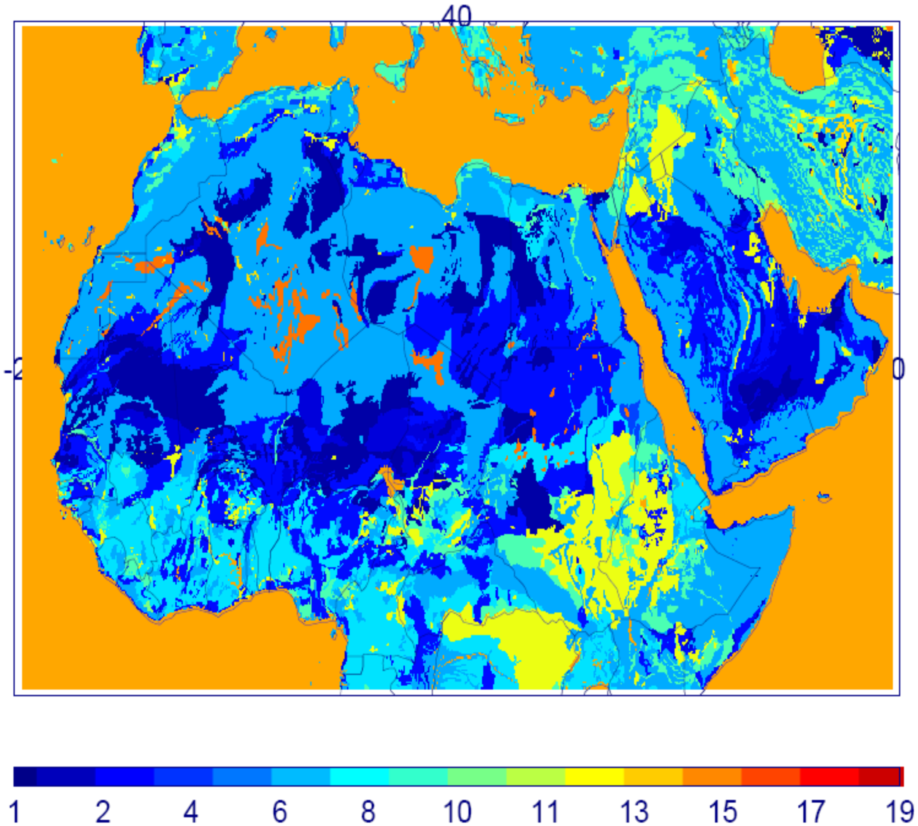
- <u>Weekly (bi-weekly, monthly) composite emissivity data base</u>

- <u>Empirical algorithm</u>, e.g., the regression snow/seaice/desert emissivity algorithms derived from window channels of brightness temperatures (Yan and Weng, 2003; 2008; 2009)

- <u>Physical model</u>, e.g., the microwave land emissivity model by Weng et al. (2001)

etc.

Soil Texture Class Distribution in Northern Africa



1 Sand	6 Loam	11 Silty Clay	16 Land-Ice
2 Loamy Sand	7 Sandy Clay Loam	12 Clay	17 Playa
3 Sandy Loam	8 Silty Clay Loam	13 Organic Materials	18 Lava
4 Silt Loam	9 Clay Loam	14 Water	19 White Sand
5 Silt	10 Sandy Clay	15 Bedrock	

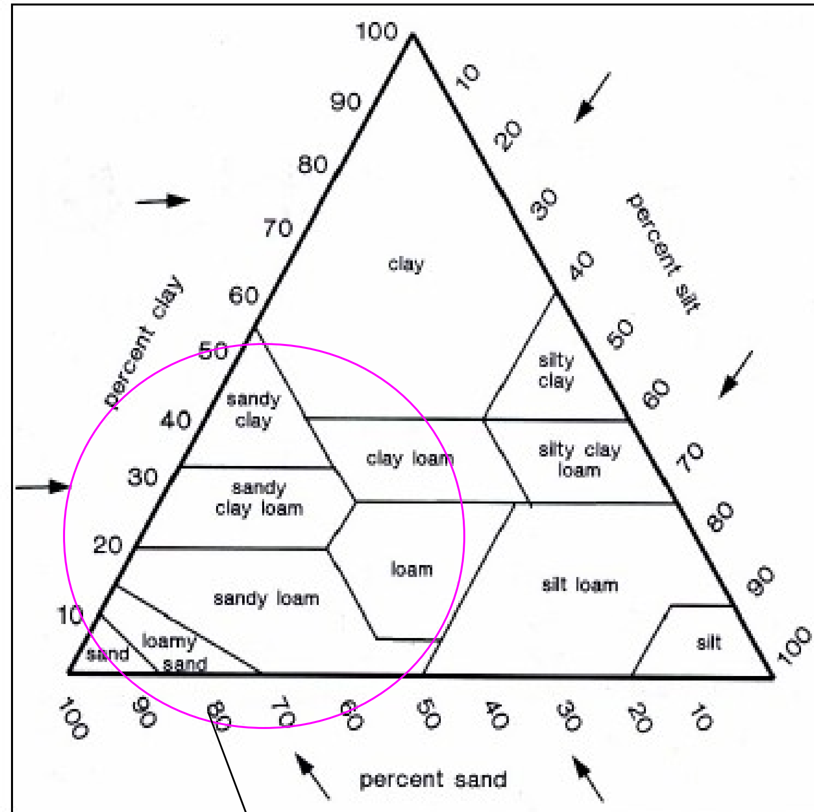


Figure 1: A soil textural triangle is used to determine soil textural class from the percentages of sand, silt, and clay in the soil.

Major sub-desert types:
sand, loamy sand,
sandy loam,
loam, sandy clay loam,
clay loam, clay, etc.

(Reference: **http://www.emc.ncep.noaa.gov/mmb/gcp/sfcimg/soiltex/index.html**)

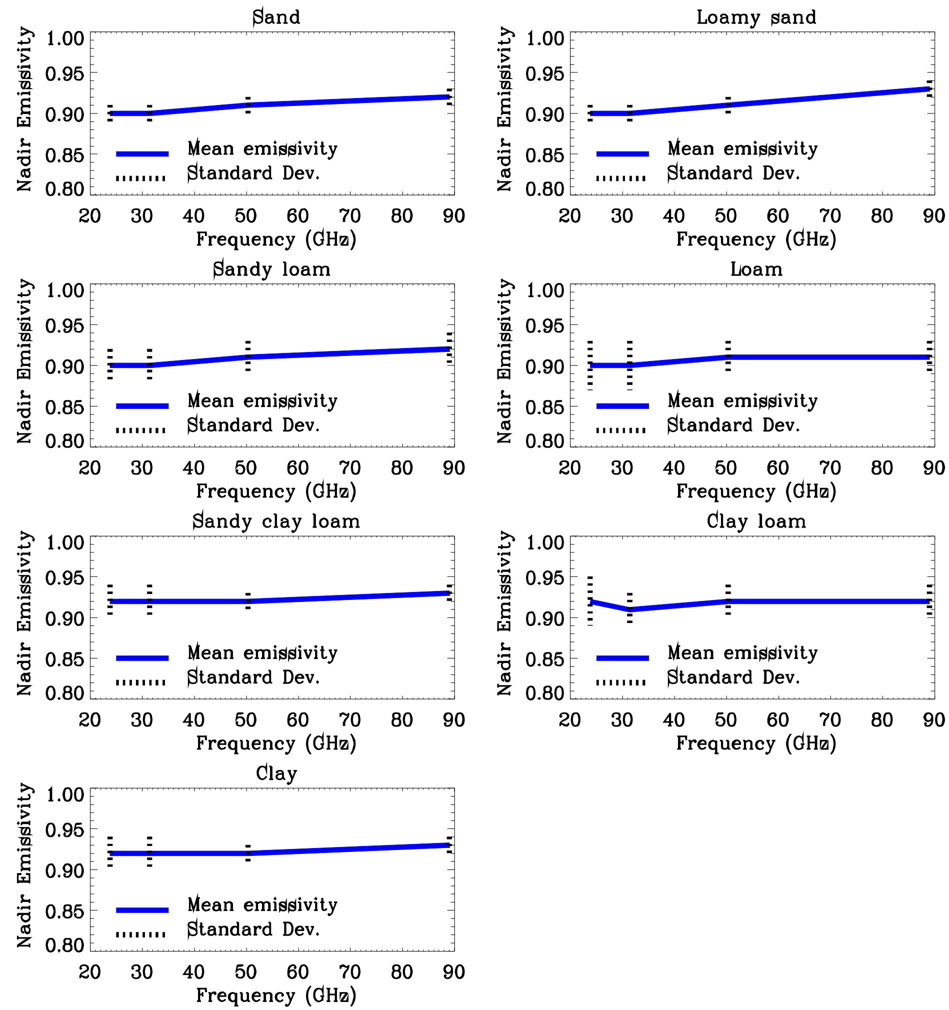
(Thanks also go to W. Zheng, M.Ek and V. Wong in EMC for their help in getting this information)

Mean Emissivity Spectra at Nadir from 23.8 to 89 GHz along Each Sub-Desert Type

- JCSDA-CRTM is used to calculate land emissivity from NCEP improved GDAS products from NCEP land data assimilation group

- Seven major sub-desert types: sand, loamy sand, sand loam, loam, sand clay loam, clay loam, slay

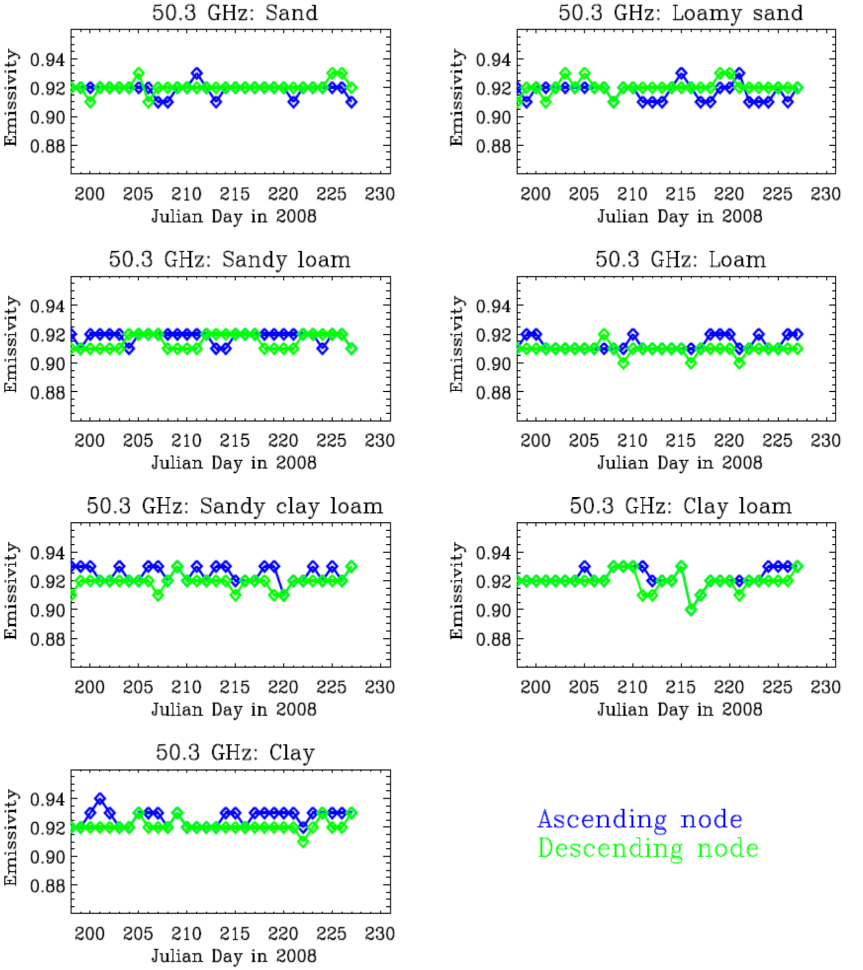
- Desert emissivity spectrum at nadir direction may vary with sub-desert type, but not much as snow emissivity does with sub-snow type



(Thanks go to W. Zheng, M.Ek and H. Wei in EMC for their help in getting improved GDAS data for our emissivity calculations)

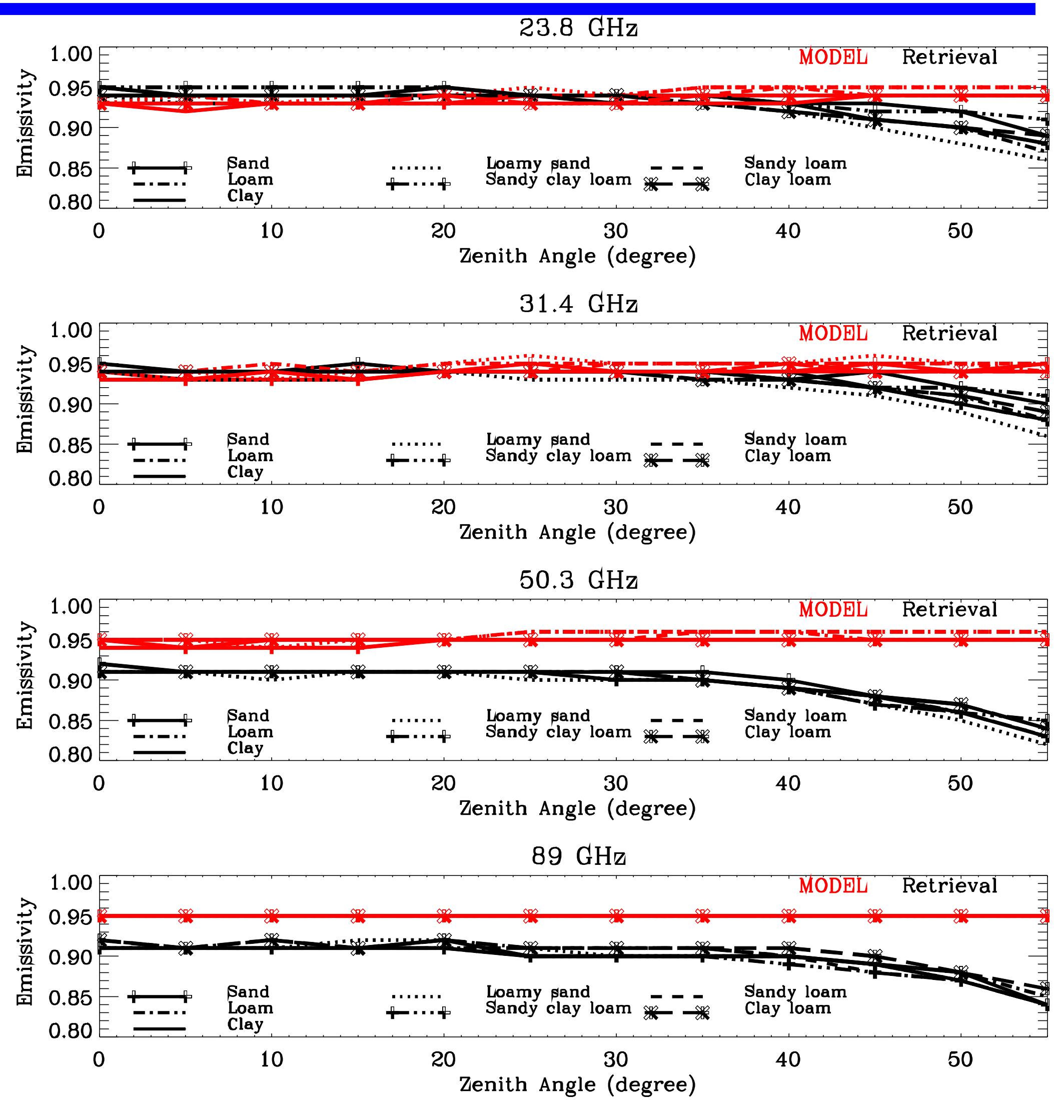
Time Series of AMSU Desert Emissivity

- Desert emissivity from July 16 to August 16, 2008 as retrieved from NOAA-18 AMSUA ascending and descending observations
- Emissivity retrievals display obvious diurnal variation



Angle Dependency of Desert Emissivity

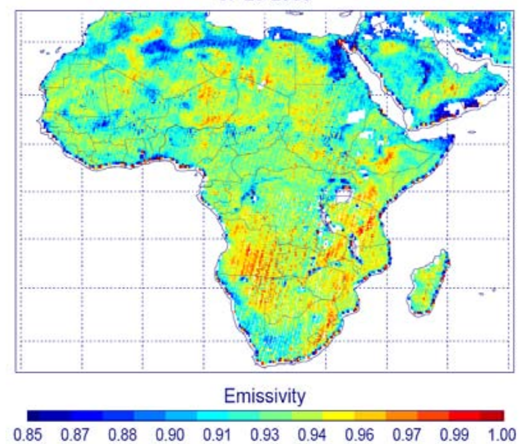
- Microwave land emissivity model by Weng et al. (2001)
- Retrieved emissivity is obtained using NOAA-18 AMSU-A brightness temperatures
- Satellite retrievals of emissivity display stronger angle dependency than the mode simulation



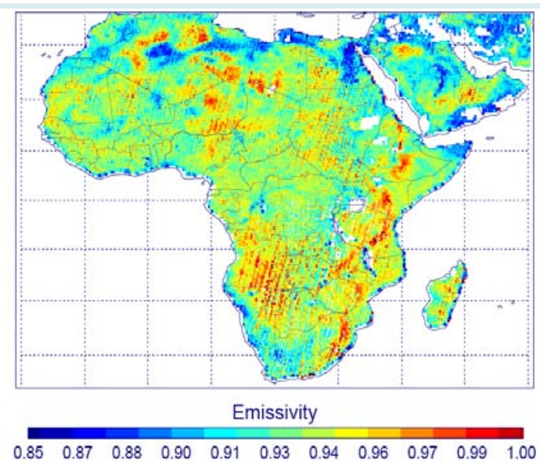
Weekly Composite Desert Emissivity

- Weekly composite land emissivity data at nadir is generated based on seven days of emissivity data under microwave-clear sky conditions
- Cloud detection over land is made using a new empirical algorithm
- JCSDA-CRTM is used to calculate land emissivity from NCEP GDAS products
- Angle-dependency of emissivity is adjusted using fitting angle dependency function

(a) Weekly composite emissivity at nadir (31.4 GHz)
(7/16 – 7/23, 2008)

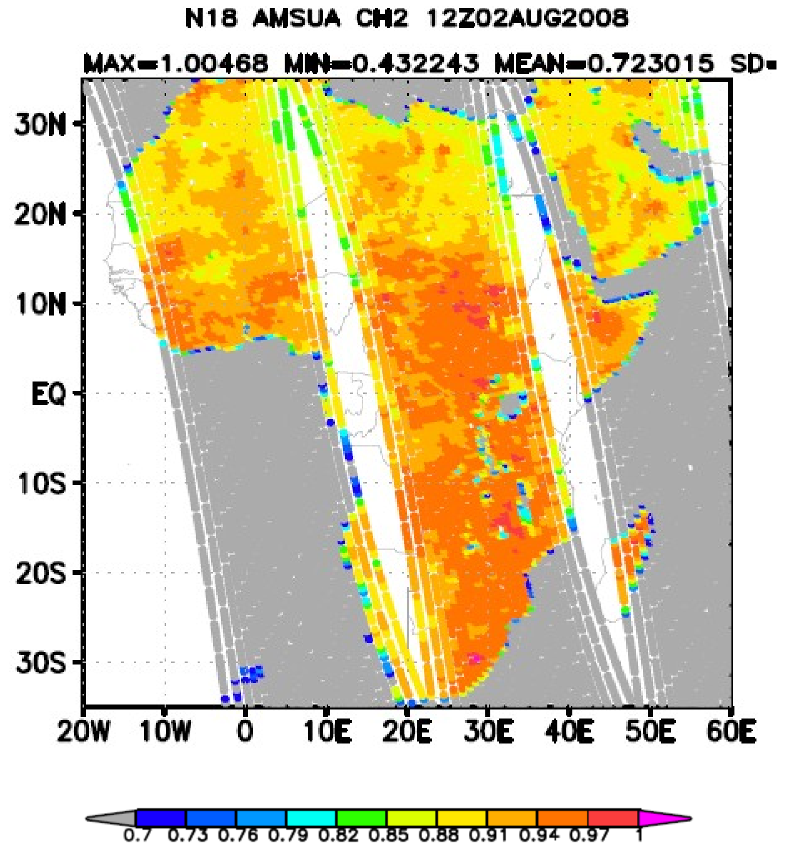


(b) Weekly composite emissivity at nadir (50.3 GHz)
(7/16 – 7/23, 2008)

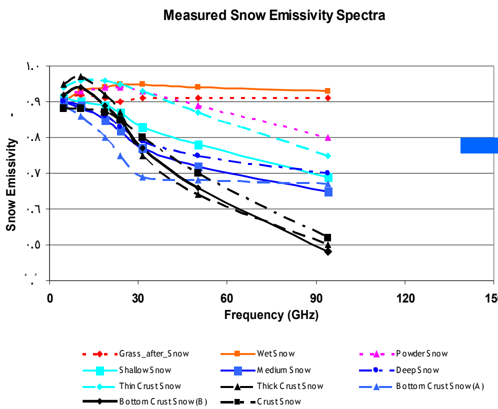


Microwave Desert Empirical Algorithm

- Generate desert emissivity training data bases at window channels using JCSDA-CRTM under microwave clear sky conditions
- Derive fitting coefficients for emissivity estimate at window channels from the training data set
- Interpolate emissivity at other frequencies according to a series of mean emissivity spectra along sub –desert type
- Calculate emissivity polarization using the existing physical model (Weng et al., 2001) if needed



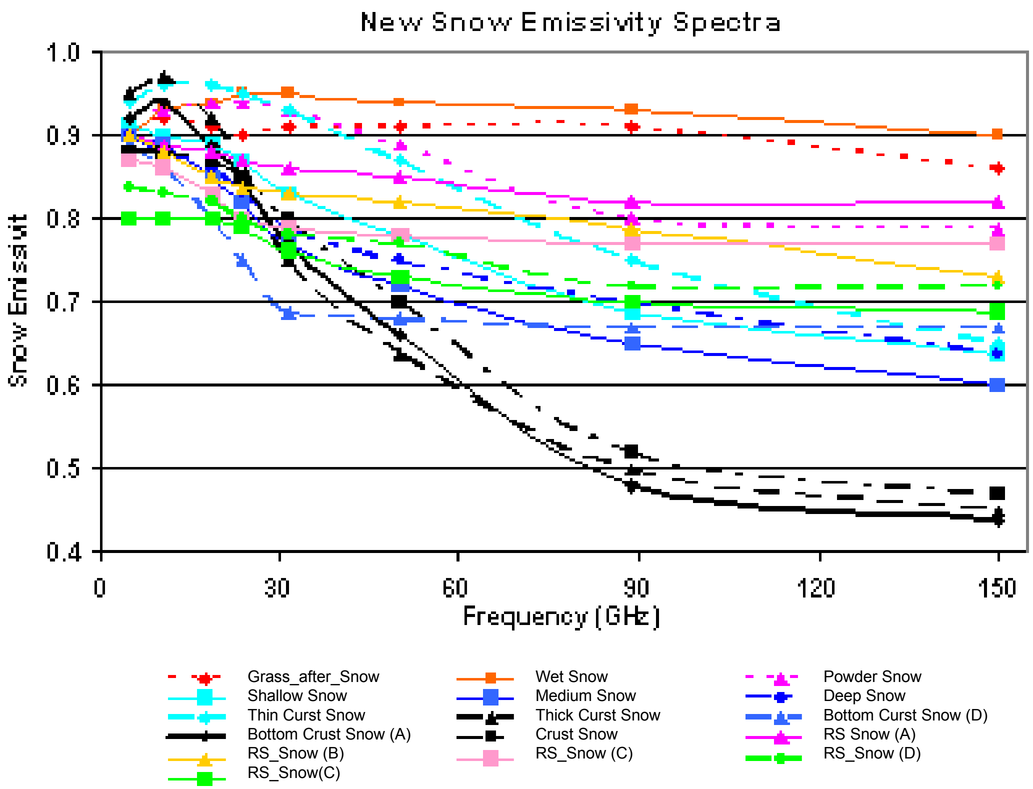
Microwave Spectra of Snow Emissivity along Sub-snow Type



11 Ground-measured emissivity

Of snow emissivity (4.9~94 GHz)

(Mätzler, C., 1994)

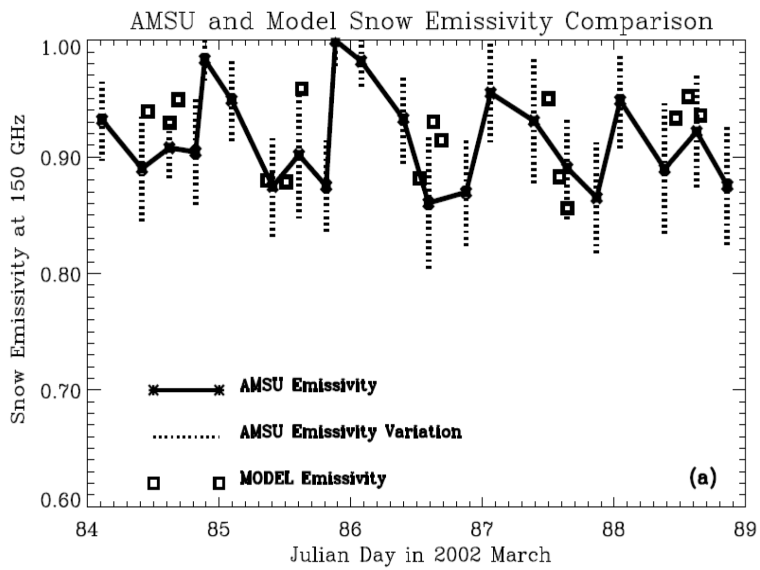


New various snow emissivity spectra based upon satellite-retrieved and ground-measured data of snow emissivity (4.9 ~ 150 GHz)

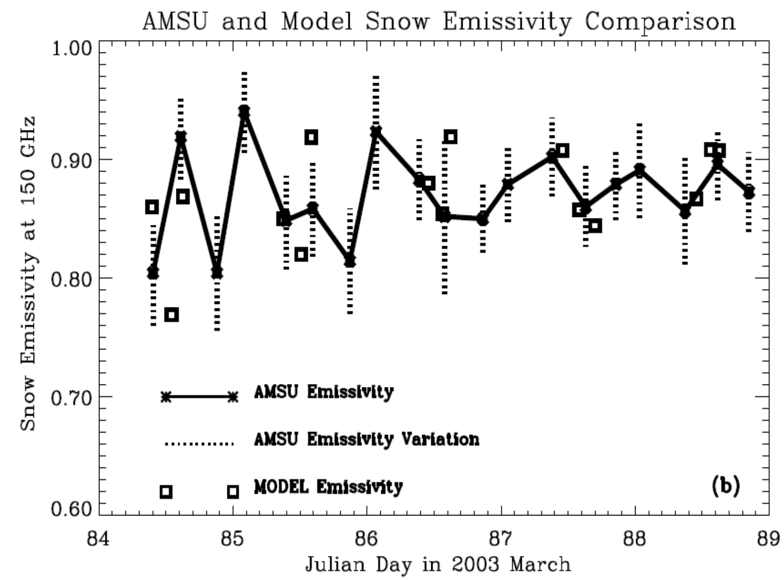
(Yan et al., 2004)

Snow Emissivity Time Series at 150 GHz (Rocky Mountains, 39.9° N, 105.9° W)

March 2002



March 2003



Here, the model simulation is mad using new two-layer snow emissivity model by Yan and Weng.

Snow emissivity varies significantly with time, the variation being around 6 % compared to its daily mean emissivity

(Yan et al., 2008)

Experiment Designs for Desert Emissivity Assimilation Impact

- Analysis: GSI 3D-Var (Q1FY09 version)
- Resolution: T382L64
- Assimilation Period: July 16 – Aug. 31, 2008
- Only non-cloud affected data are used
- Bias correction scheme (i.e. Derber and Wu, 1998)
- Experiment Legend:

Contrl.: all operational data (physical model for N18 AMSUA data)

AMSUA1: Contrl. except for mean emissivity spectra for N18 AMSUA data

AMSUA2: Contrl. except for weekly emissivity data base for N18 AMSUA data

AMSUA3: Contrl. except for empirical algorithm for N18 AMSUA data

(Here, the physical model is the microwave land emissivity model by Weng et al. 92001)

Experiment Designs for Snow Emissivity Assimilation Impact

- Analysis: GSI 3D-Var (July 2007 version)
- Resolution: T382L64
- Assimilation Period: July 1 – Aug. 31, 2007
- Only non-cloud affected data are used
- Bias correction scheme (i.e. Derber and Wu,1998)
- Experiment Legend:

Contrl.: all operational data (physical model for N18 MHS data over snow and sea ice surfaces)

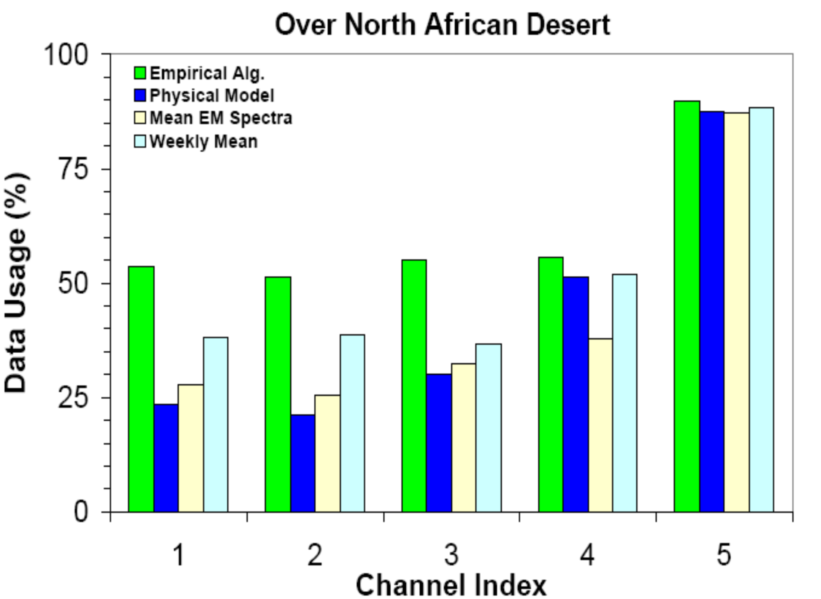
MHS: Contrl. except for empirical algorithm for N18 MHS data over snow and sea ice surfaces

(Here, the physical model is the microwave land emissivity model by Weng et al. 92001)

Comparison of Data Utilization at N18 AMSU-A Channels Sensitive to Surface Using Four Emissivity Approaches

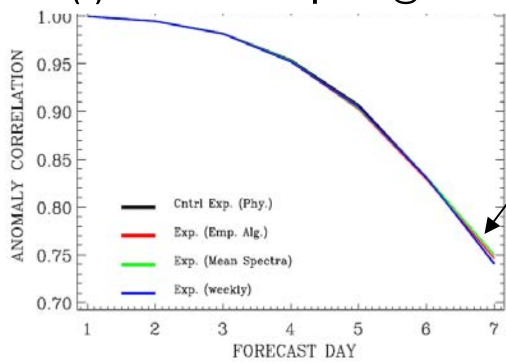
- **Four approaches for emissivity simulation:**
  (1) Empirical emissivity algorithm
  (2) Physical model: Microwave land emissivity model by Weng et al., 2001
  (3) Mean emissivity spectra along sub-desert type
  (4) Weekly composite emissivity data base

- **Impact:**
  New desert emissivity algorithm doubles data utilization at N18 AMSU-A channels sensitive to surface compared to that using the physical model



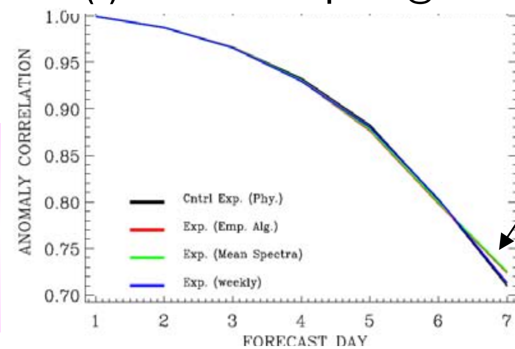
Assimilation Impact of AMSU-A Desert Emissivity on GFS Forecast Skill

(a) Northern Hemisphere @ 500mb



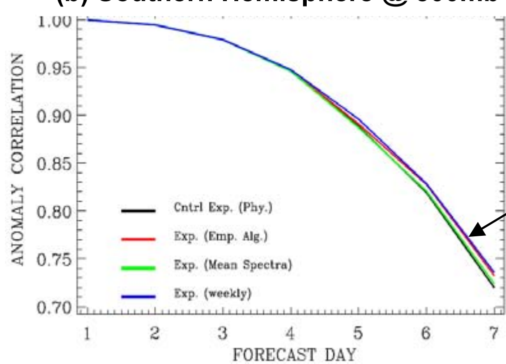
Positive impact from the alg., and mean empssivity approaches

(c) Northern Hemisphere @ 1000mb



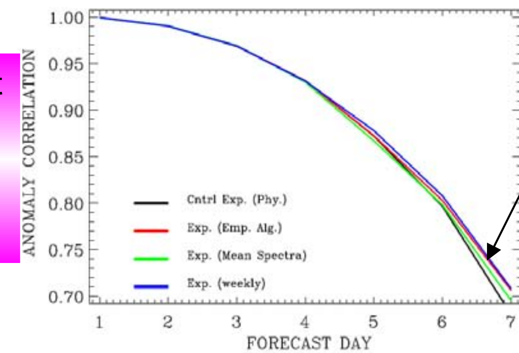
Positive impact from the alg., and mean empssivity approaches

(b) Southern Hemisphere @ 500mb



Positive impact from the alg., and weekly empssivity approaches

(d) Southern Hemisphere @ 1000mb

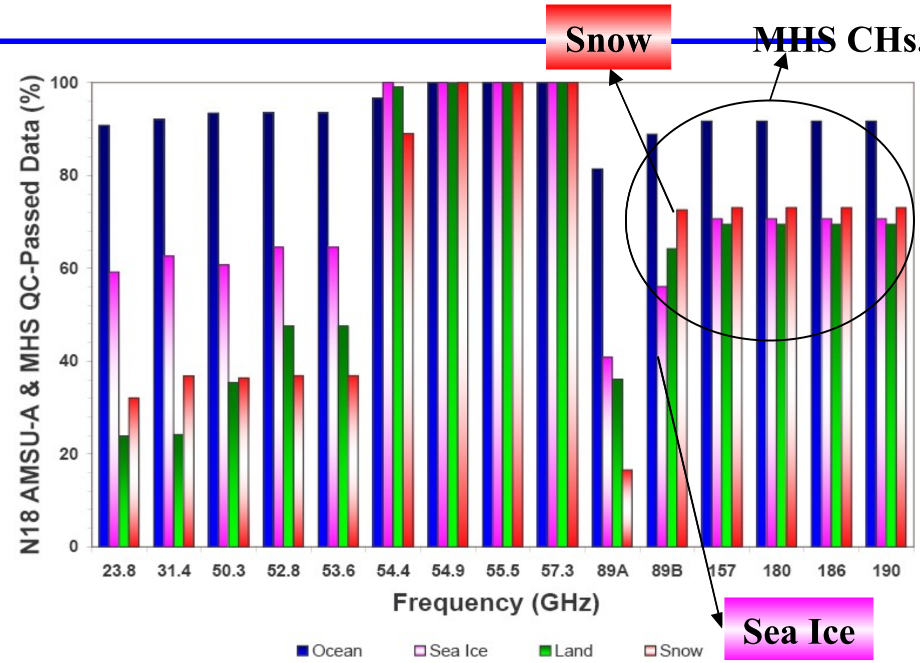


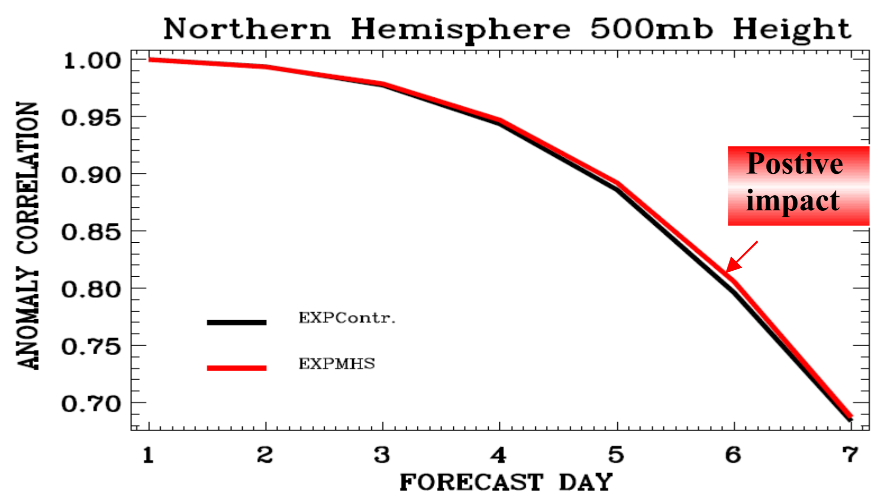
Positive impact from the alg., weekly and mean empssivity approaches

- Desert emissivity from the empirical algorithm demonstrates a more stable and positive impact on the GFS than the other three emissivity approaches
- Weekly composite emissivity produces positive impact similar to the empirical algorithm on the GFS over Southern Hemisphere
- Mean emissivity spectrum approach produces positive impact similar to the empirical algorithm on the GFS over Northern Hemisphere

Improved Snow and Sea Ice Emissivity Simulations Increases use of MHS Data in GFS

- MHS, especially over snow and sea ice conditions, is highly affected by variable emissivity
- Currently, only 20-30% MHS data passed quality control in NCEP/GSI
- Improved MHS snow and sea ice emissivity models results in more than 60% data passing QC
- The impact of the MHS data using the new emissivity model is slightly positive





Summary and Conclusions

- New AMSU-A empirical desert emissivity algorithm, mean emissivity spectra along sub-desert type, weekly composite desert emissivity data bas have been developed based on desert emissivity characterization analysis.

- Among the above three approaches and the existing microwave land emissivity model by Weng et al. (2001), **the empirical algorithm results in the greatest data utilization in the GFS assimilation for lower tropospheric sounding channels**

- **Empirical algorithms** for desert/snow surface emissivity simulation can produce **a stable and positive impact** on the GFS forecast skill over both Southern and Northern Hemisphere

- Weekly composite desert emissivity data base and mean emissivity spectra approaches can result in neutral or positive impacts on the GFS over either Southern or Northern Hemisphere, **which is primarily due to relatively stable surface properties in the desert**

On-Going Work

- Study assimilation impact of land emissivity during other seasons (e.g., winter season)
- Assess assimilation impact of snow emissivity using the mean emissivity spectra and weekly composite emissivity approaches
- Study assimilation impact of the land emissivity data base generated by Prigent et al. (2008)