Data Assimilation Efforts – Microwave Over Land

Biljana Orescanin[1,2], Kevin Garrett[2], Hui Shao[3] and Kayo Ide[4]

[1]Cooperative Institute for Climate & Satellites-Maryland (CICS-MD)/ESSIC; [2]NOAA/NESDIS/Center for Satellite Applications and Research(STAR)

[3]Joint Center for Satellite Data Assimilation (JCSDA)/UCAR; [4]University of Maryland

Overview

Data assimilation over land, particularly in the microwave spectrum, has been hampered by poor representation of surface emissivity variability. This often results in rejection of satellite observations over land surfaces. Current research at NOAA/NESDIS and Joint Center for Satellite Data Assimilation (JCSDA) seeks to extend and improve NOAA's efforts to assimilate satellite radiance data over land through the study of surface emissivity simulation and improved Quality Control (QC) using the NCEP operational data assimilation system – Gridpoint Statistical Interpolation (GSI) system.

This effort includes:

(1) Enabling the GSI system to use emissivity background from:

- The Community Radiative Transfer Model (CRTM), and
- The Tool to Estimate Land Surface Emissivity at Microwave frequencies - version 2 (TELSEM2).

(2) Employing emissivity in GSI system as a control variable

(3) Implementing new QC

Preliminary results show promising improvement over land using the control variable approach with TELSEM2 as background.

Emissivity Background

TELSEM2 atlas is a monthly-mean climatology of emissivity calculated by averaging 15 years of Special Sensor Microwave Imager (SSM/I) observations (Aires, et al. 2011).

CRTM, serving as a radiative transfer model in GSI system, in its current version (2.3.0) uses its own "Two Stream Solution" subroutine to calculate emissivity in the microwave spectrum.

	CRTM	TELSEM 2
Surface type	All	Land & sea-ice only
Frequency	1 – 300 GHz	10 – 700 GHz
Polarization	H + V	H + V
Spatial Resolution	Satellite FOV	0.25°
Temporal Resolution	Instantaneous	Monthly
Base	"Physical"	Empirical

Analytical emissivity is used here to define surface-sensitive channels emissivity-QC criteria, it is defined as surface emissivity derived relying on a simplified microwave radiative transfer (RT) equation inverted to solve the emissivity term analytically:

$$\varepsilon = \frac{T_b - T_u - T_d\,\Gamma}{(T_s - T_d)\,\Gamma}$$

Γ – Atmospheric Transmittance
T_b – Observed Brightness Temperature
T_s – Skin Temperature
T_u – Upwelling Tb
T_d – Downwelling Tb

Emissivity as a Control Variable

Implementation of emissivity as a control variable into GSI:

$$J(x,\beta)=\frac{1}{2}[x-x_b]^T B_x^{-1}[x-x_b]+\frac{1}{2}[\beta-\beta_b]^T B_\beta^{-1}[\beta-\beta_b]+$$
$$+\frac{1}{2}[y-h(x)]^T R^{-1}[y-h(x)]+\frac{1}{2}[y_{Tb}-h_{Tb}(x,\beta)]^T R_{Tb}^{-1}[y_{Tb}-h_{Tb}(x,\beta)]$$

$$e=\beta\, e_{crtm}$$

$$\beta=\begin{pmatrix}\beta_1 & \beta_2 & \cdots & \beta_N\end{pmatrix}^T$$

$$B_\beta=\begin{pmatrix}\sigma^2_{\beta_1} & 0 & & 0\\ 0 & \sigma^2_{\beta_2} & & \\ & & \ddots & \vdots\\ 0 & & \cdots & \sigma^2_{\beta_N}\end{pmatrix}$$

- x - control variable
- y - other observations
- h - observation operator of other observations
- R - observation error covariance
- B_x - forecast error covariance of standard control variables
- h_{Tb} - forward CRTM radiative transfer operator from model space to brightness temperature; brightness temperature observation operator is a function of both x and β
- y_{Tb} - brightness temperature observation
- R_{Tb} - brightness temperature observation error covariance
- e - emissivity; e_{crtm} emissivity from our background (crtm or telsem)
- β - Multiplicative emissivity parameter in observation space
- N - total number of channels
- B_β - error covariance of parameter β. Without knowing cross correlations between channels, the initial choice for parameter error covariance is a diagonal matrix. σ is the standard deviation of the emissivity parameter, currently determined based on TELSEM2.

Experiment design

Using the GSI system and the NCEP GFS model, two experiments are carried out:

- Cntr_modelEm: Emissivity computed using CRTM-v2.3.0 (red)
- **Exp_con_tel**: Emissivity computed via the developmental approach using the emissivity as a control variable in the minimization scheme and TELSEM2 as the background (green)

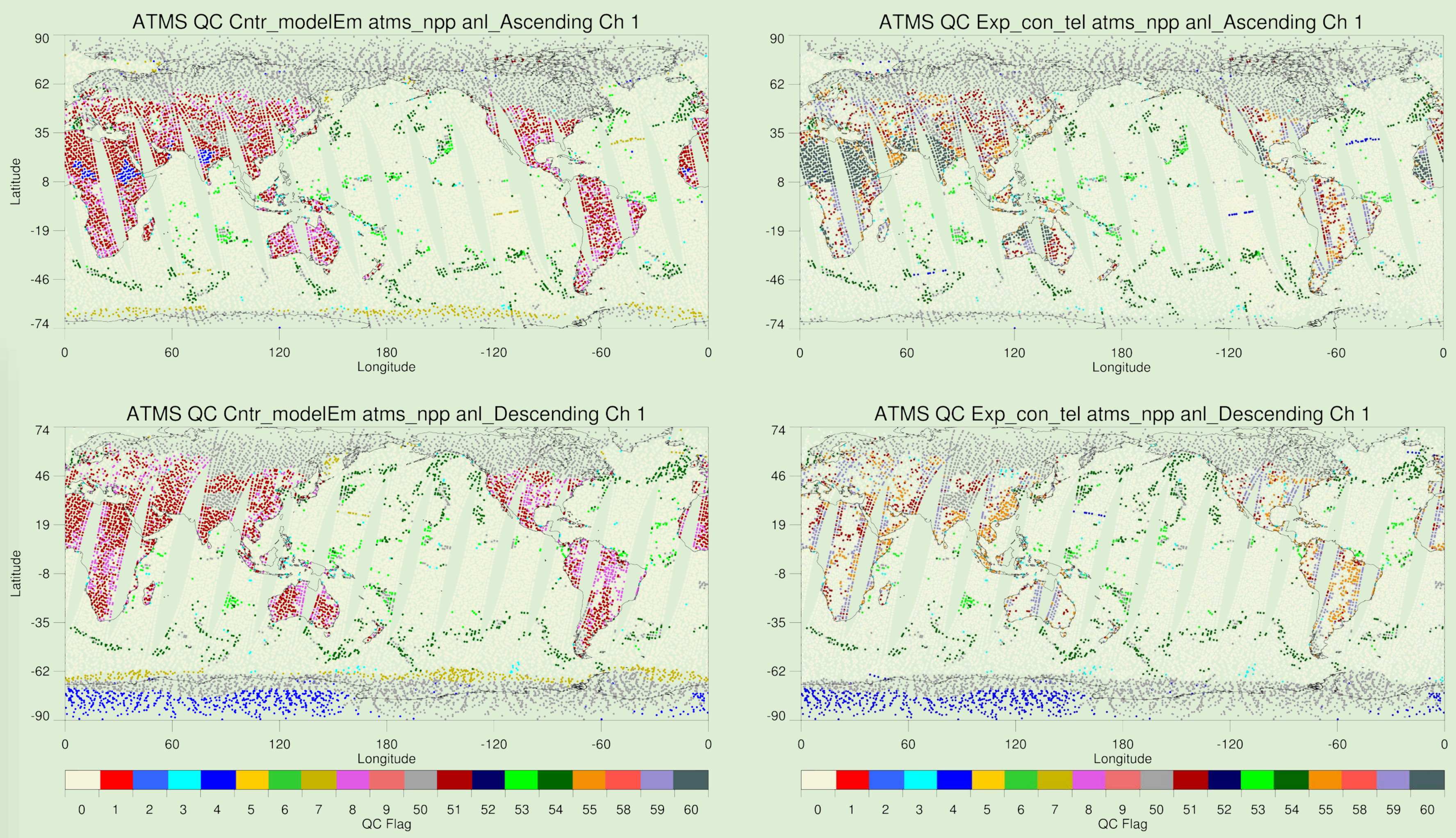
The new approach is implemented for all microwave sensors. Results shown here are for Advanced Technology Microwave Sounder (ATMS) radiance assimilation only.

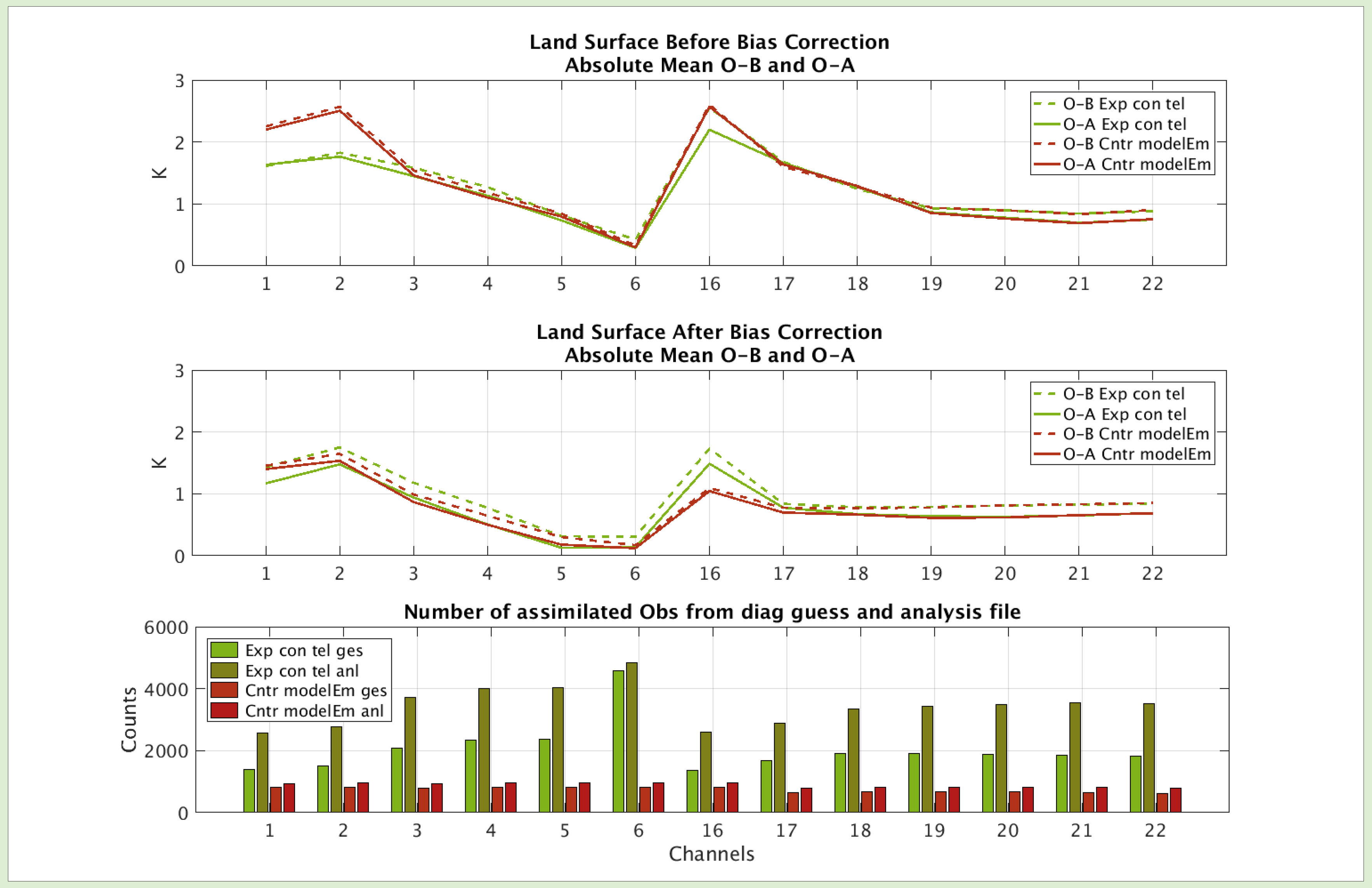
Preliminary Results with New QC

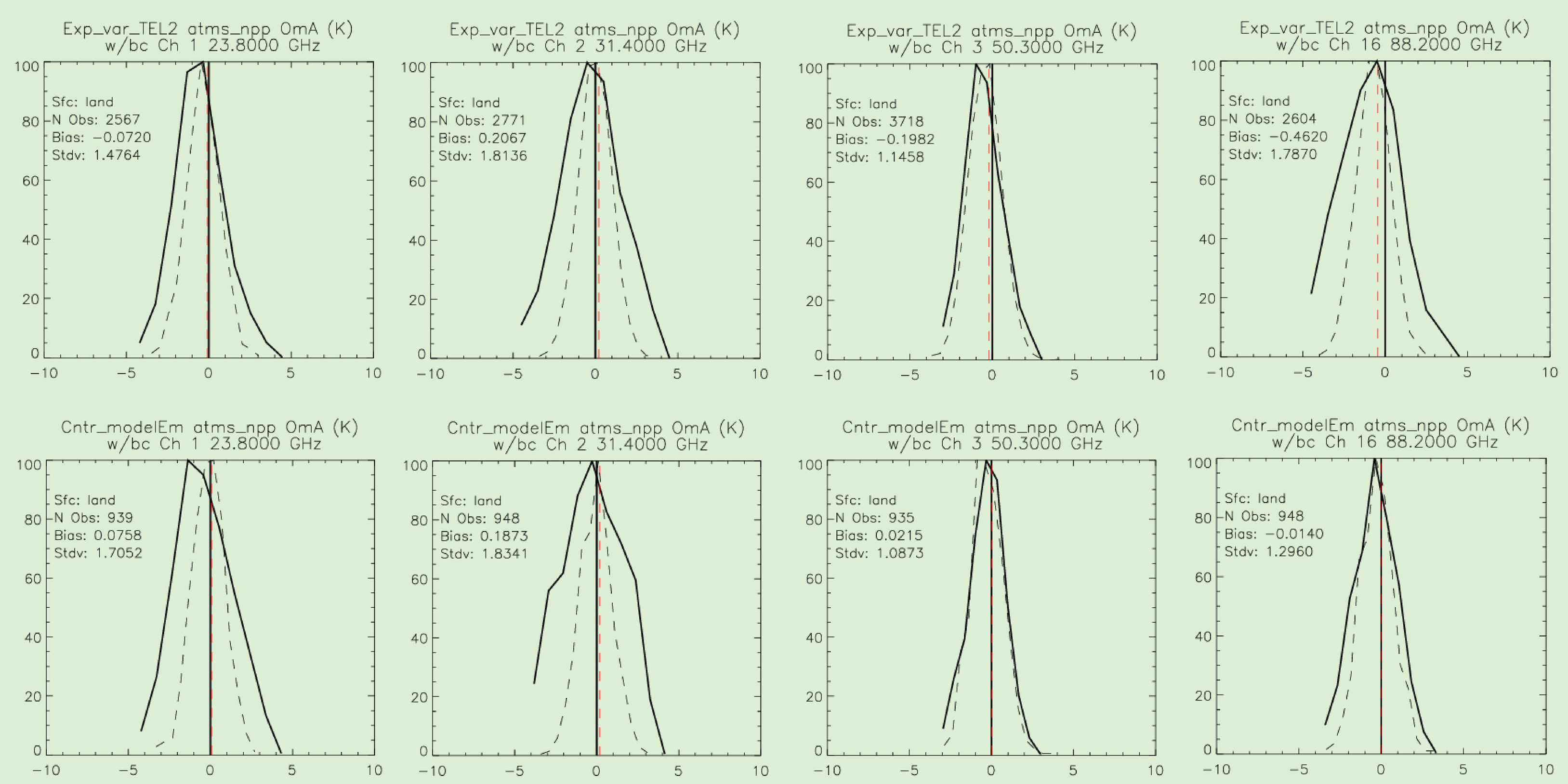
To maximize the already positive impact the implementation of TELSEM2 and emissivity control variable has brought to the system, we re-evaluate the existing QC criteria seeking potentially better, physically-based observation quality screening.

The new QC for ATMS over land is based on 4 types of screening: Precipitation, T-skin, CLW, and Emissivity

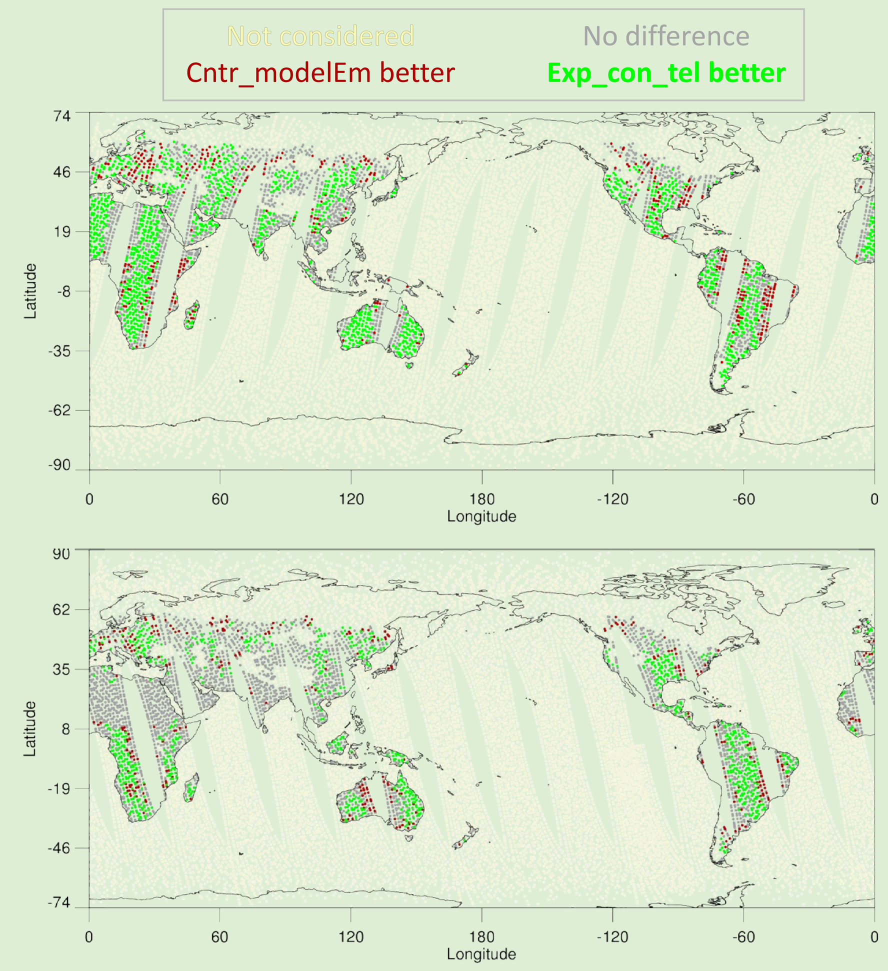
QC Flags
51- Cloud Liquid Water
55 - Precipitation
59 - Emissivity difference
60 – Tskin difference



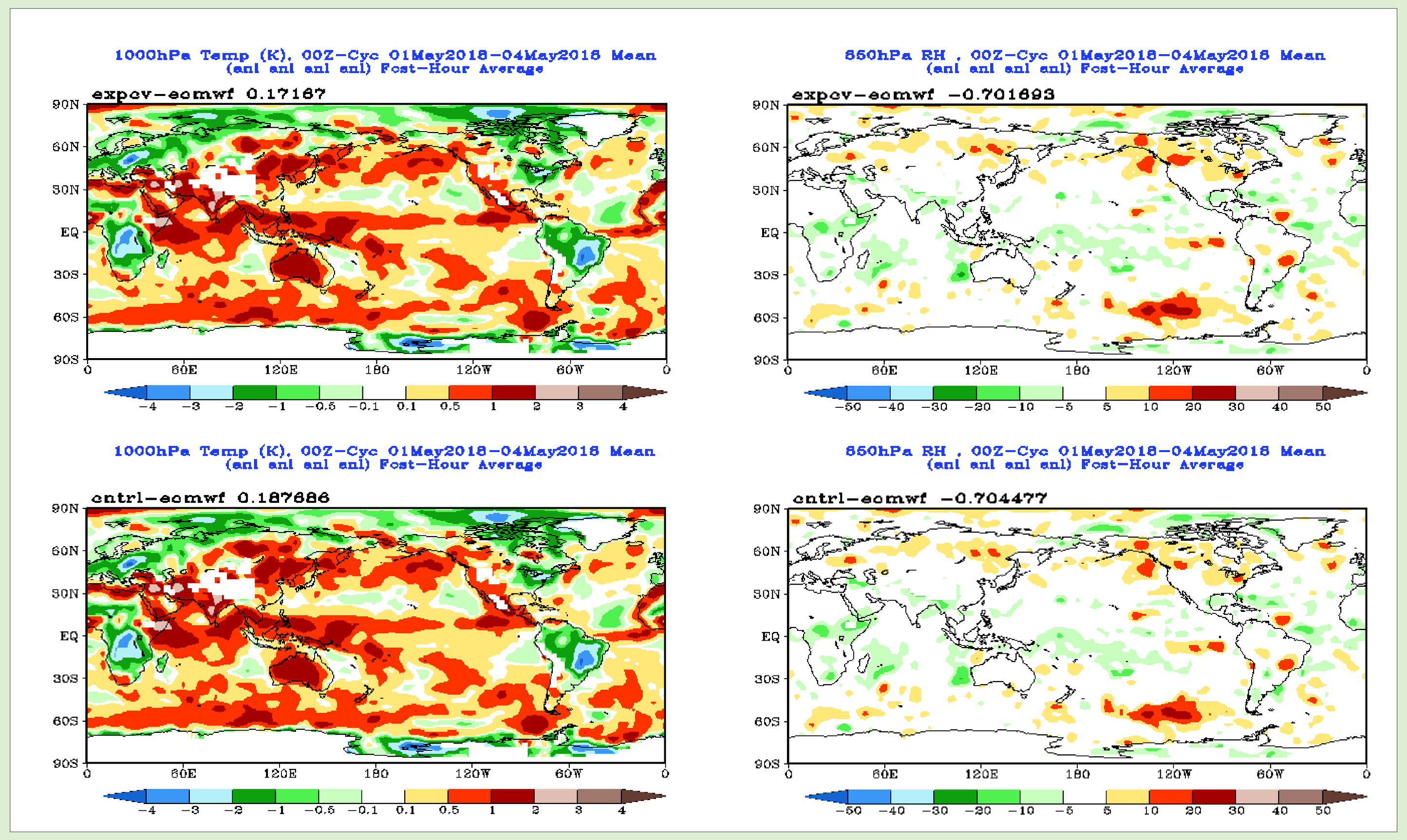




Evaluation



- Comparisons of OmA fields at surface sensitive channels indicate improvement over all land surfaces in descending, and most land surfaces in ascending orbits (distribution for channel 1 given in maps on the right)
- Swath edges and deserts, although improved, still appear to be a major challenge
- Using ECMWF as a reference, 1000-mb and 850-mb temperature and relative humidity increments from the two experiments are assessed (maps at the bottom show few days of comparisons after the spin up period)



Conclusions

- A new approach for treating emissivity in the GSI system is developed using the TELSEM emissivity background and the emissivity control variable in the minimization.
- Use of the new approach over land in place of physical model emissivity has shown an increase in the number of assimilated observations and a better detection of land features.
- Currently, testing for extended periods is being performed with the goal of providing more robust results.

Future Work

- Optimization of QC and observation errors in the GSI for land surface sensitive microwave brightness temperatures assimilation.
- Optimization of surface emissivity background error covariance and background emissivity.
- Bias correction over land area requires further investigation. Land-specific bias correction factors and parameters might be necessary.
- Modifications will be made for a dynamic emissivity update based on surface types/locations. Currently, the emissivity control variable provides a global update to each channel.
- Emissivity analysis demonstration and inter comparison.
- JCSDA is developing the Community Surface Emissivity Model (CSEM), which will be coupled with CRTM. Impacts of the CSEM emissivity will be evaluated together with the control variable approach.
- Impact assessment on analysis and forecast assimilating land surface sensitive microwave brightness temperatures.

Acknowledgments

Funding for this project was provided by the NOAA grant NA14NES4320003. Calculations were carried out at the S4 Supercomputing Facilities of the University of Wisconsin Madison, and the authors gratefully acknowledge the facility staff for their help and assistance.

Reference

Aires, F., Prigent, C., Bernardo, F., Jiménez, C., Saunders, R. and Brunel, P. (2011), A Tool to Estimate Land-Surface Emissivities at Microwave frequencies (TELSEM) for use in numerical weather prediction. Q.J.R. Meteorol. Soc., 137: 690–699. doi:10.1002/qj.803