Improving the use of surface-sensitive radiances in the GMAO Hybrid-4DEnVar system

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Abstract

The planetary boundary layer (PBL) was designated as an incubation-class targeted observable (TO) in the 2018 Decadal Survey. As no single instrument source will provide enough information to constrain the global PBL, the assimilation of a wide range of observations in data assimilation (DA) systems will play a critical role, and GMAO has put in efforts to enhance surface-sensitive radiance assimilation. Although a vast number of microwave radiance observations are used in the GEOS global DA system, very few surface-sensitive radiances are currently used over land due to large uncertainty of land surface emissivity in the CRTM as well as cloud detection issue. Dynamically varying emissivity is retrieved from observations of window channels in the GEOS system for non-scattering FOVs and applied to sounding channel assimilation. Moreover, the original radiance bias correction is found not to work well over land, and shows drifting bias when the original emissivity sensitivity bias predictor with a dynamically varying emissivity retrieval is used. Hence, the radiance bias correction has been modified, and the quality control procedure has been adapted accordingly. Cycled experiment results show improvement in the temperature forecast at lower model levels; further refinement of this system continues.

1. Current status of surface-sensitive WV radiance usage in the GEOS system

- AMSU-A and ATMS
  - AMSU-A ch 1-3 & 15, ATMS ch 1-4 & 16: not used over either ocean or land
  - AMSU-A ch 4-5, ATMS channels 5-6, 17-22: very limited radiances data are used over land
  - Clear-sky approach: Only clear-sky radiances and radiances affected by thin clouds are assimilated
- No GMI and AMSR2 data are used over land
- No MHS window channels are used

Fig. 1 , ATMS channel 6 weighting function and used data counts over ocean and land

Challenges:

- Uncertainties of land surface state properties
- Large uncertainties of the land physical surface emissivity model in the CRTM

Objectives:

Improve the assimilation of surface-sensitive radiances from AMSU-A channels 3-5 and ATMS channels 3-6, 17-22 over land by improving emissivity

2. Methodology and quality control of dynamically varying emissivity retrieval in the GEOS

For a scattering-free atmosphere, assuming a flat and specular surface, observed brightness temperature BT can be expressed as:

$$BT_{obs} = \varepsilon\, T_s\, \Gamma + BT_{up} + \Gamma\,(1 - \varepsilon)\, BT_{down}$$

where BT_{up} and BT_{down} are atmospheric upwelling and downwelling radiations, Γ atmospheric surface-to-space transmittance, and T_s surface skin temperature. Surface emissivity can be calculated as:

$$\varepsilon = \frac{BT_{obs} - BTup - BTdown\,\Gamma}{(T_s - BTdown)\,\Gamma}$$

Quality control of emissivity

- First guess scattering check
- Observations scattering check
- Transmittance check
- Emissivity retrieval range check
- Low emissivity value check

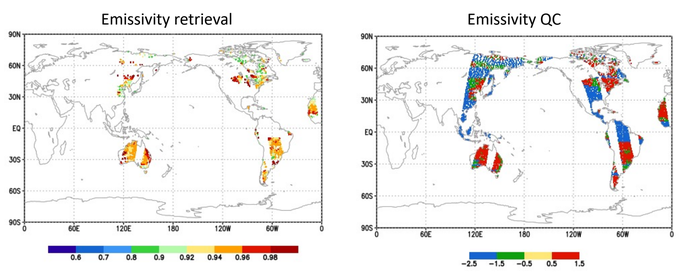

Fig. 2, An example of Emissivity QC: Used, Excluded (fg scattering, low transmittance, observation scattering),

Monthly-mean of emissivity

- **CRTM physical emissivity model shows significant differences from climatology in several regions**
- **Dynamically varying emissivity retrieval in the GEOS has similar patterns as TELSEM[2]**

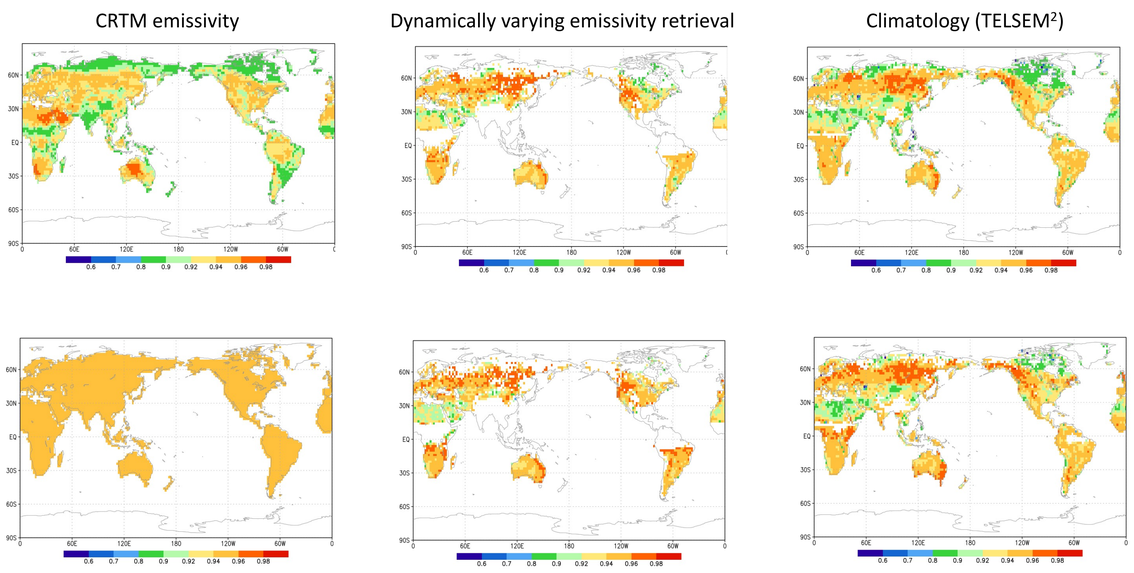

Fig. 3, Monthly-mean emissivity for ATMS NPP channels 2 (upper row) and 16 (lower row) for July 2019: CRTM physical land surface emissivity model (left), dynamically varying emissivity retrieval in the GEOS (middle), TELSEM[2] (right).

3. Impact of using emissivity retrieval on OmF

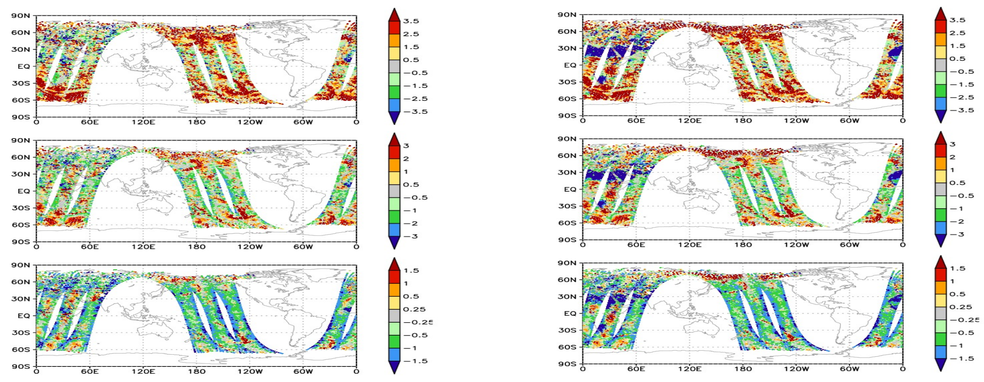

Fig. 4, ATMS NPP OmFs before bias correction for channles 3 (top), 4 (middle), and 5 (bottom): using CRTM physical emissivity model (right) and using dynamically varying emissivity retrieval over land (left).

4. Issues with radiance bias correction

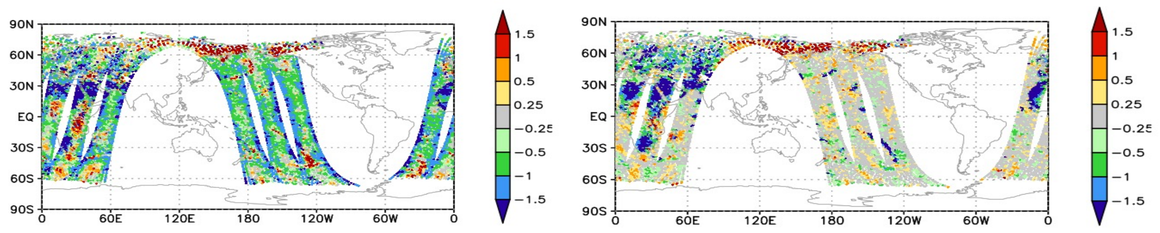

Fig. 5, ATMS NPP channel 5 OmF before (left) & after (right) bias correction in CTL using CRTM emissivity.

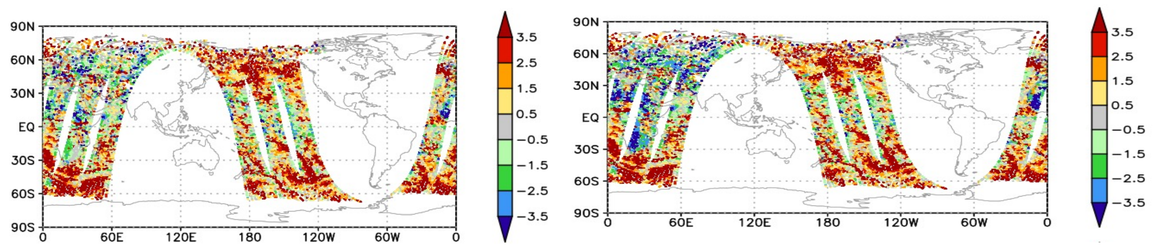

Fig. 6, After one-week cycled run using emissivity retrieval for radiance simulation, ATMS NPP channel 3 OmF after bias correction with (right) and w/o (left) the original emissivity sensitivity bias predictor.

- Radiance bias correction works well over ocean, but OmFs become worse over land after bias correction in the original system
- When emissivity retrieval is used in the GEOS, radiance bias correction is noticed to drift if the original emissivity sensitivity bias predictor is used
- When the original bias correction is modified: emissivity sensitivity bias predictor is removed; a separate constant bias predictor is applied for non-water FOVs

5. Experiment results and future plan

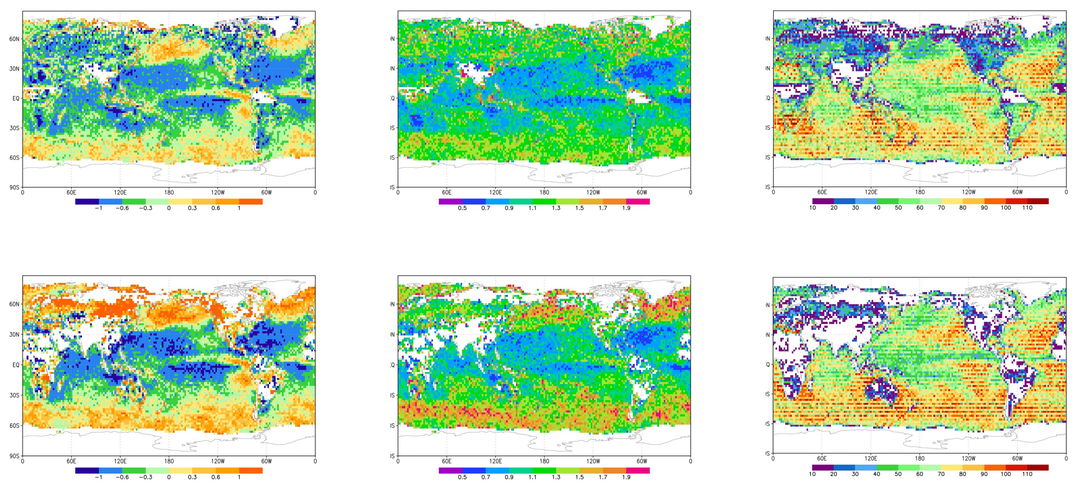

Fig. 7, Monthly-mean of used ATMS NPP channel 4 in July 2019 for experiments using dynamically varying emissivity retrieval (upper row) and CRTM emissivity (lower row) over land: OmF mean (left), OmF STDV (middle), and data count (right).

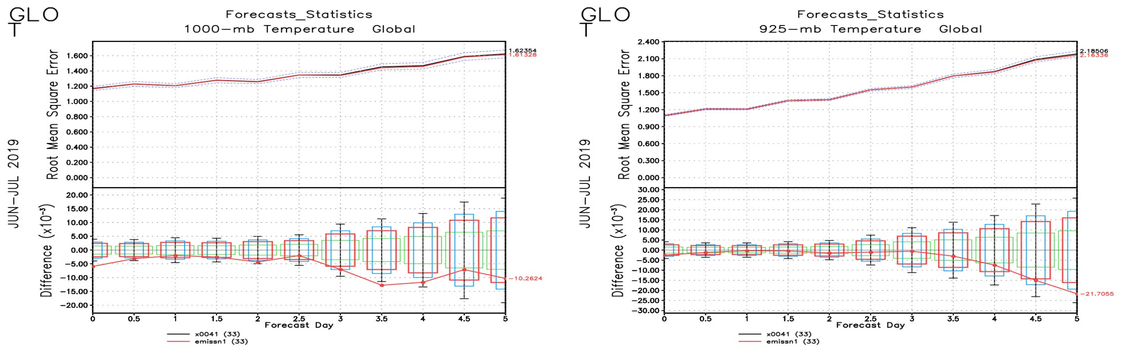

Fig. 8, RMSE statistics of temperature forecasts at 1000mb (left) and 925mb (right) verified against ECMWF analysis.

Summary:

- **Dynamically varying emissivity is retrieved from the AMSU-A and ATMS window channels and applied to sounding channel assimilation**
- **The monthly-mean GEOS emissivity retrieval is shown to have similar patterns as TELSEM[2] climatology**
- **The use of the emissivity retrieval improves the data usages over land, which improves temperature fields at lower model levels**
- **Future plan: improve data usage of surface-sensitive radiances from MHS, GMI, AMSR2, etc**

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