Updated Microwave Land Emissivity Calculation in the CRTM

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Motivation:

Problem about the surface sensitive channels:

Much less satellite data (IR/MW) is assimilated over land than over ocean. In particularly, satellite data is rarely used over arid/desert regions in GSI/CRTM (e.g. W. CONUS and N. Africa)

(a) Substantial cold bias of land surface skin temperature (LST) in GFS.

(b) Inaccurate emissivity calculation for MW over land in GSI/CRTM.

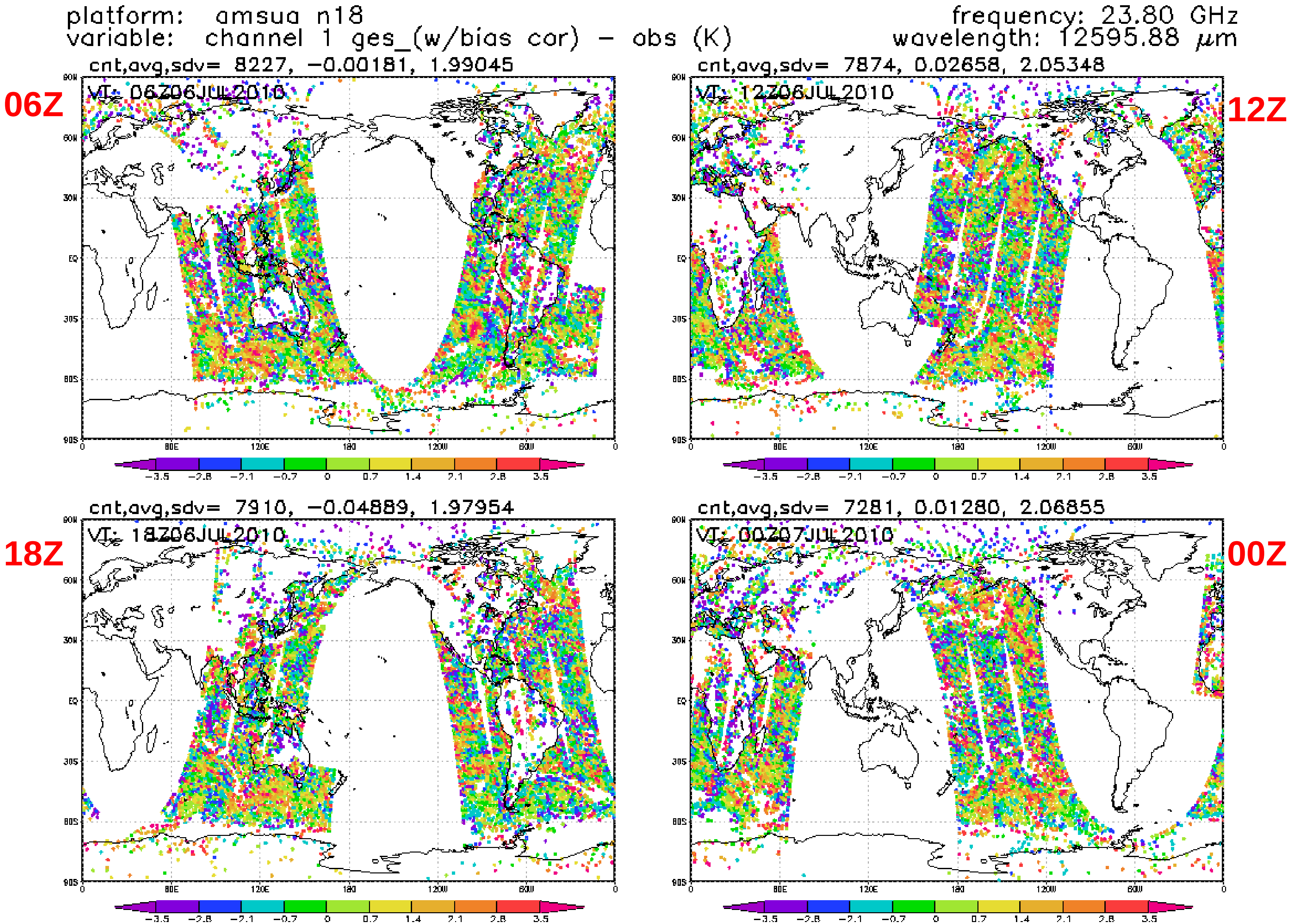
Approaches:

(a) New formula for momentum and thermal roughness lengths (Zom,Zot) (Zeng et al., U. of Arizona)

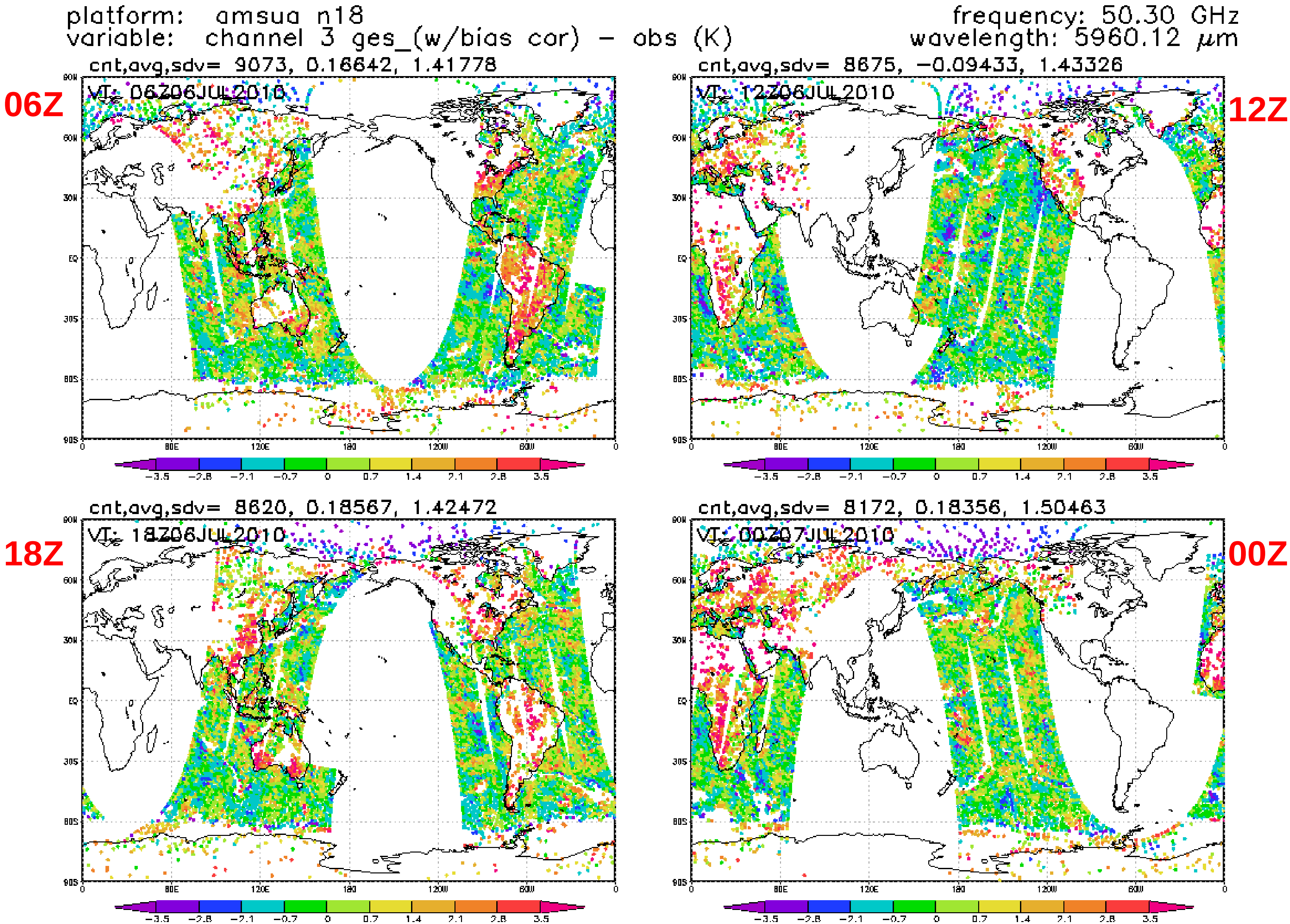
(b) Improvement of MW land emissivity model (Weng et al., 2001)

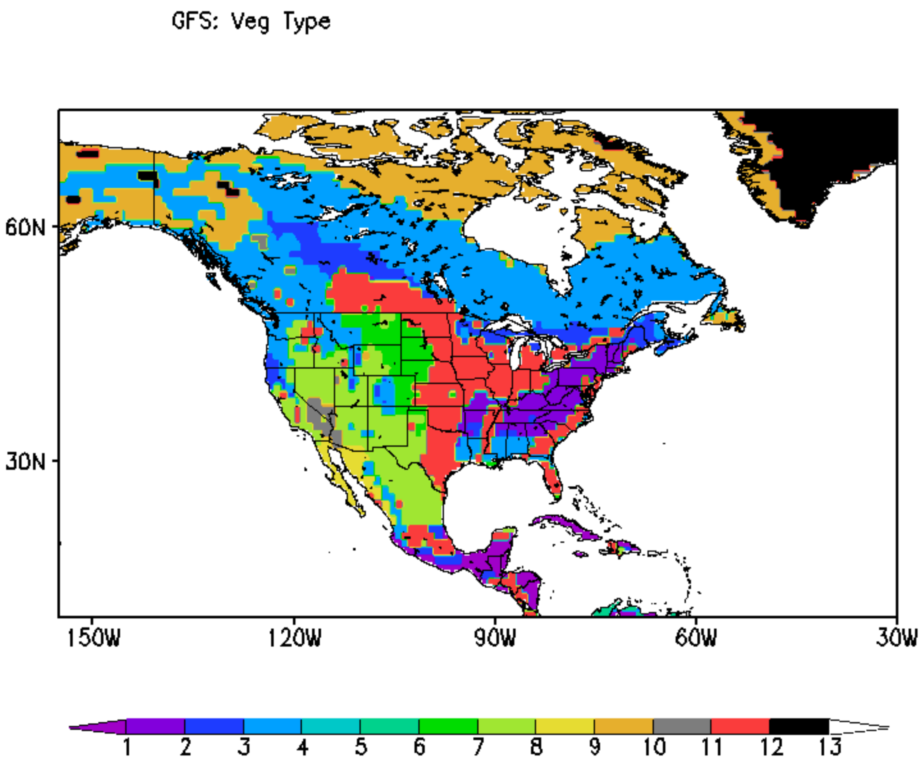
Case: 1-31 July, 2010

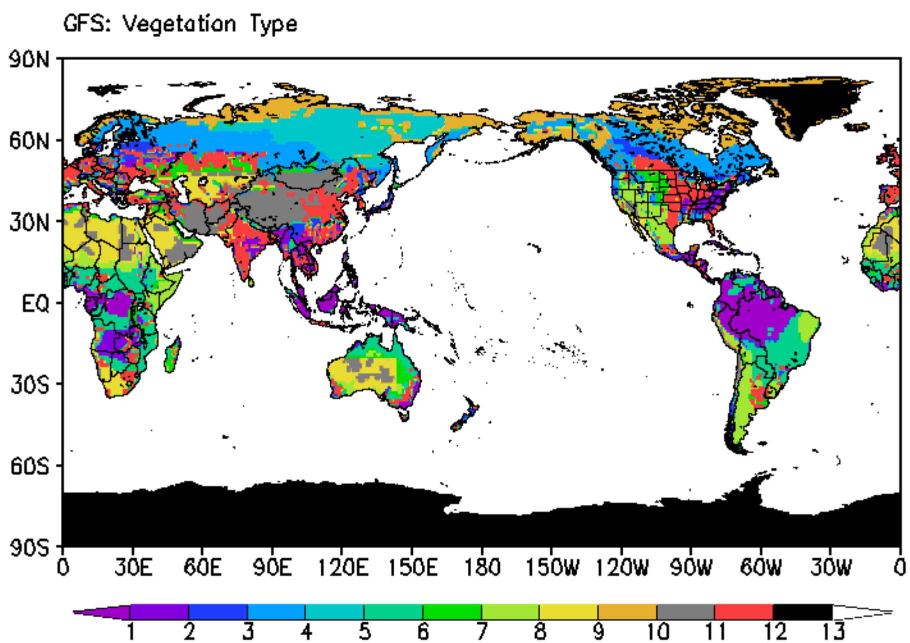
Operational Monitoring Plots: NOAA-18 AMSU-A, *Ch1* 06 July 2010



Operational Monitoring Plots: NOAA-18 AMSU-A, *Ch3* 06 July 2010







Vegetation Type

Veg_1: Broadleaf-Evergreen (Tropical Forest)

Veg_2: Broad-Deciduous Trees

Veg_3: Broadleaf and Needleleaf Trees (Mixed Forest)

Veg_4: Needleleaf-Evergreen Trees

Veg_5: Needleleaf-Deciduous Trees (Larch)

Veg_6: Broadleaf Trees with Ground Cover (Savanna)

Veg_7: Ground Cover Only (Perennial)

Veg_8: Broad leaf Shrubs w/ Ground Cover

Veg_9: Broadleaf Shrubs with Bare Soil

Veg_10: Dwarf Trees & Shrubs w/Ground Cover (Tundra)

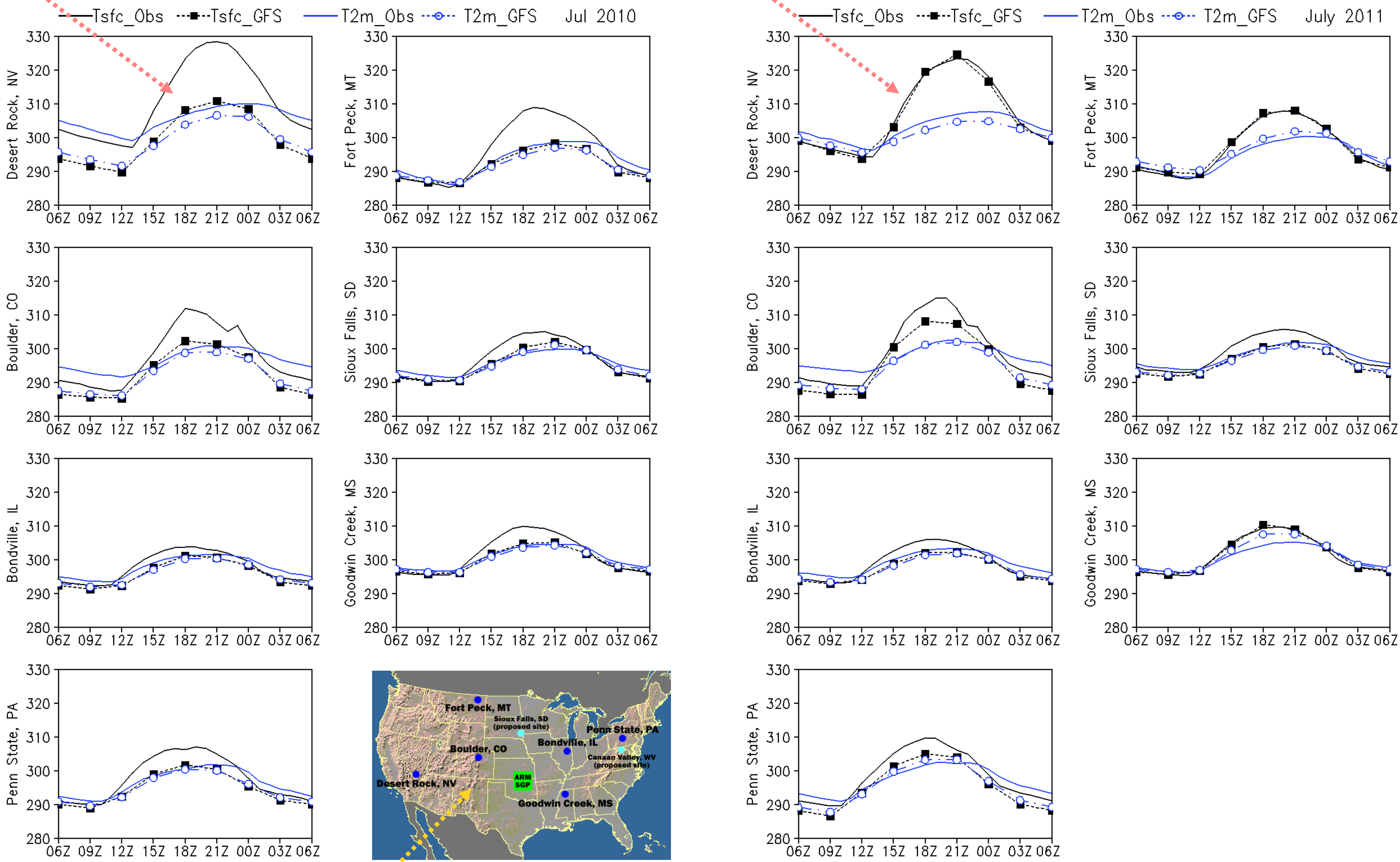
Veg_11: Bare Soil

Veg_12: Cultivations

Veg_13: Glacial

Diurnal variation of T_{sfc} and T_{2m} Verified with SURFRAD Observation Network

Large cold bias ***July 2010*** **Improved !** ***July 2011***



http://www.srrb.noaa.gov/surfrad **New z_{ot} and z_{om} *implemented* in NCEP Ops GFS on May 9, 2011.**

Schematic representation

Radiative transfer process for microwave scatting and emission material on land surface

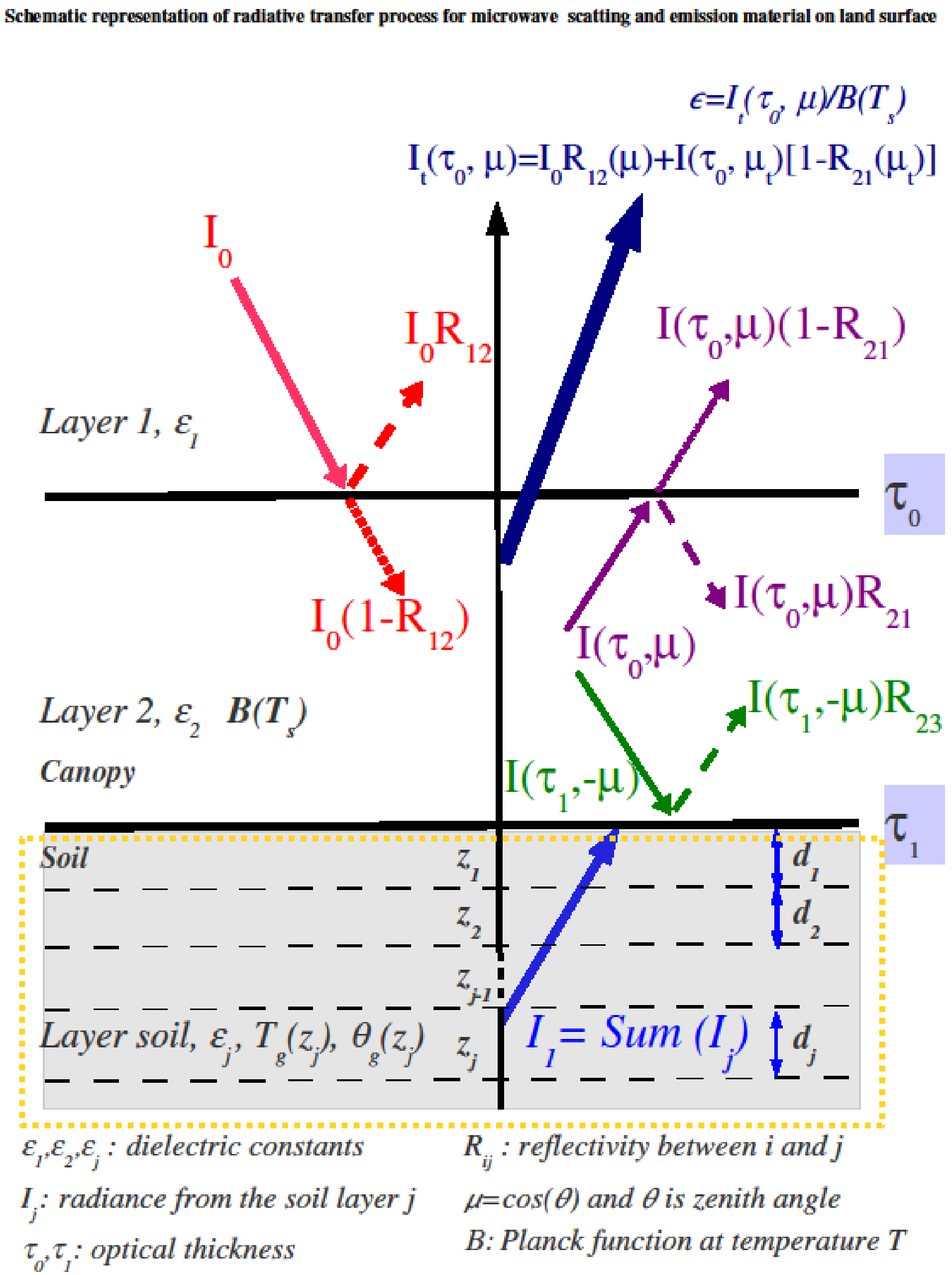
Enhancement of soil and vegetation description:

(a) Soil type

(b) Vegetation types

(c) Non-isothermal surface

Under working for the multi-layer soil algorithm



Radiative transfer process for microwave scatting and emission material on the land surface.

The radiative transfer equation (Weng et al, 2001) is

$$\mu \frac{dI(\tau,\mu)}{d\tau} = I(\tau,\mu) - \frac{\omega(\tau)}{2}\int_{-1}^{1} \boldsymbol{P_s}(\tau,\mu,\mu')d\mu' - [1-\omega(\tau)]B(T)$$

I: radiance,
Ω(τ): single-scattering albedo,
Ps(τ,μ,μ'): phase function,
B(T): Planck function,
T: thermal temperature,
τ: optical thickness,
μ: cosine of incident zenith angle,
μ' : cosine of scattering zenith angle.

Total upwelling radiance from the surface:

$$I_t(\tau_0,\mu) = \frac{B(T_s)(1-\beta)[1+\gamma e^{-2\kappa(\tau_1-\tau_0)}]}{(1-\beta R_{21})-(\beta-R_{21})\gamma\, e^{-2\kappa(\tau_1-\tau_0)}} + \frac{[I_0(1-R_{12})][\beta-\gamma e^{-2\kappa(\tau_1-\tau_0)}]}{(1-\beta R_{21})-(\beta-R_{21})\gamma\, e^{-2\kappa(\tau_1-\tau_0)}} + \frac{(1-R_{23})[B(T_g)-B(T_s)]\gamma_m e^{-\kappa(\tau_1-\tau_0)}}{(1-\beta R_{21})-(\beta-R_{21})\gamma\, e^{-2\kappa(\tau_1-\tau_0)}}$$

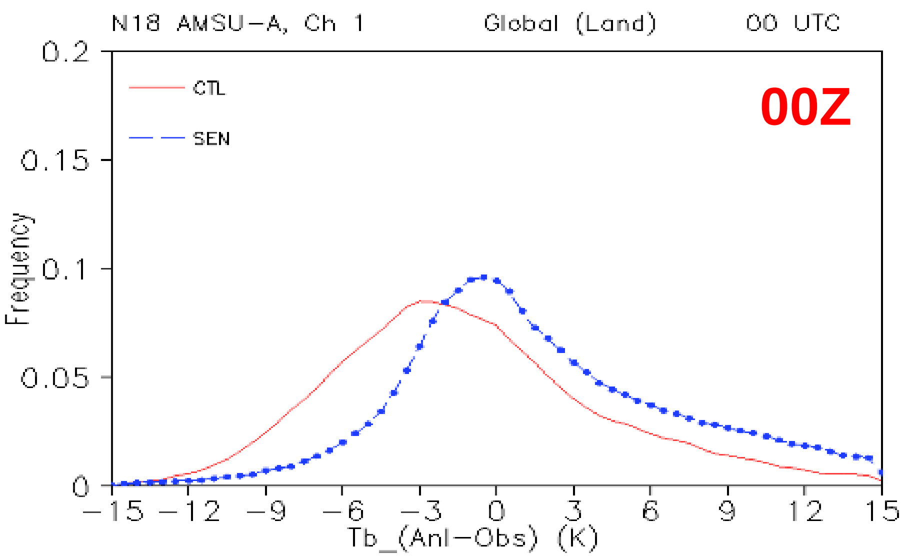
Downwelling radiance at τ_0 ***Upwelling radiance at τ_1***

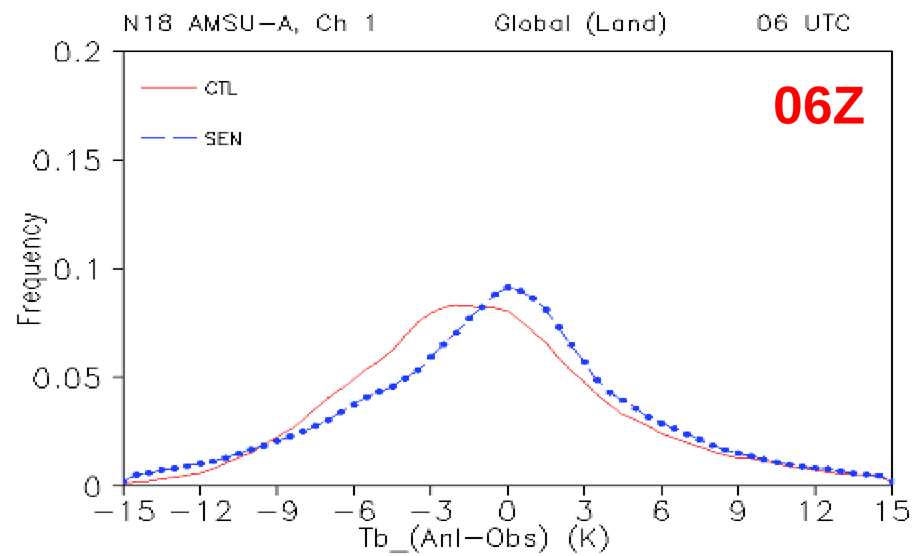
I_{middle} I_{top} I_{bottom}

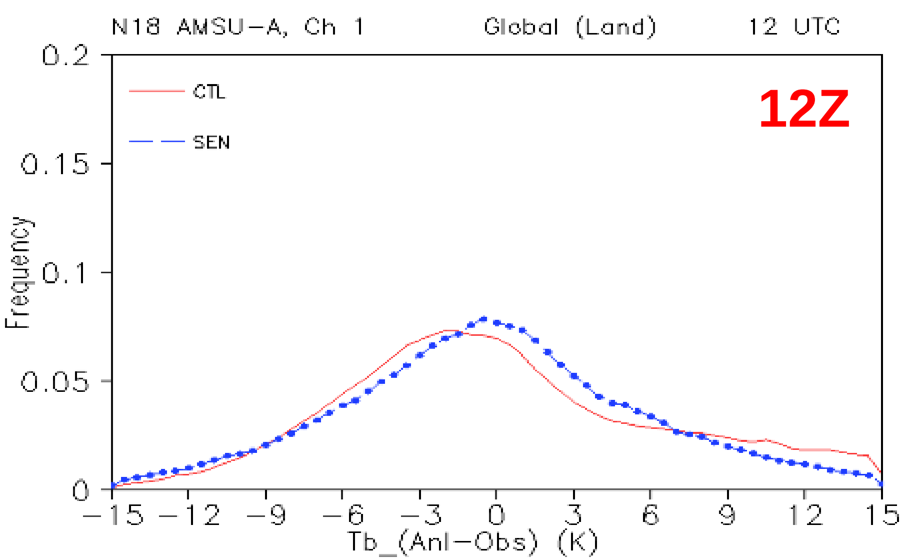
Daytime : $T_g < T_s$, so $I_{bottom} < 0$, $I_t(\tau_0,\mu)$ decreases;

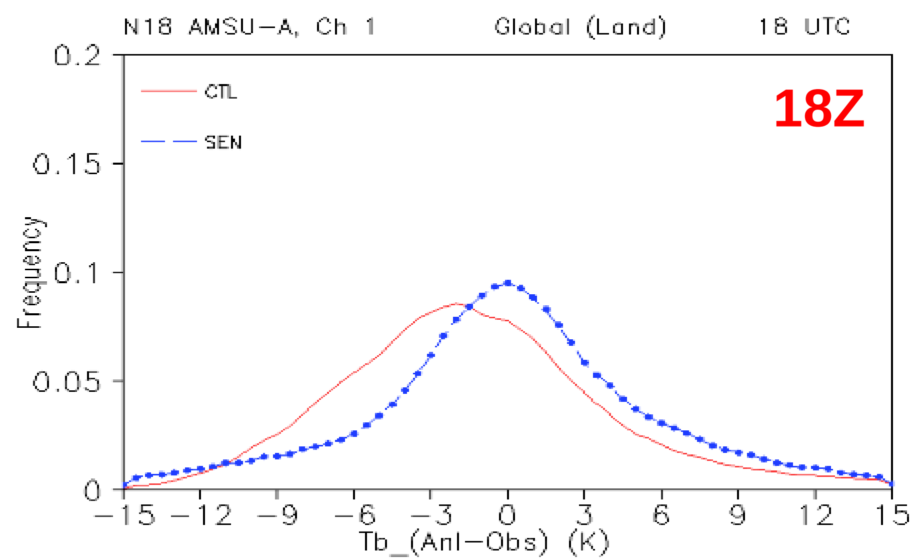
Nighttime: $T_g > T_s$, so $I_{bottom} > 0$, $I_t(\tau_0,\mu)$ increases.

Frequently distribution of T_b bias (Ch1) in 1K bins for all clear sky pixels



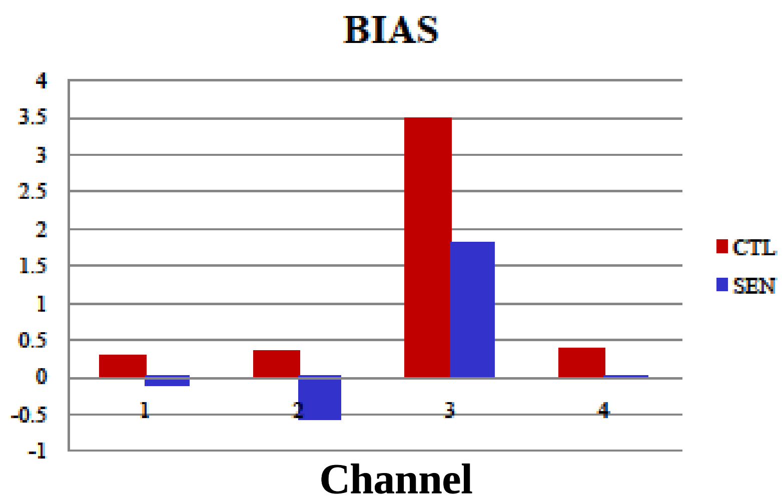


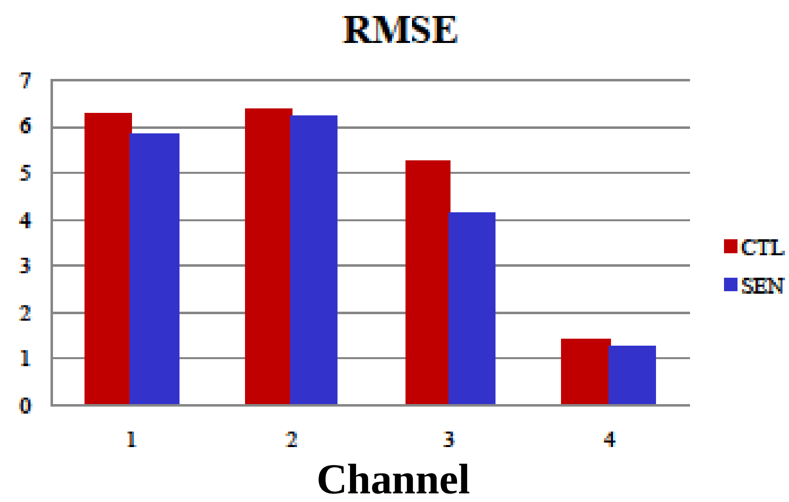


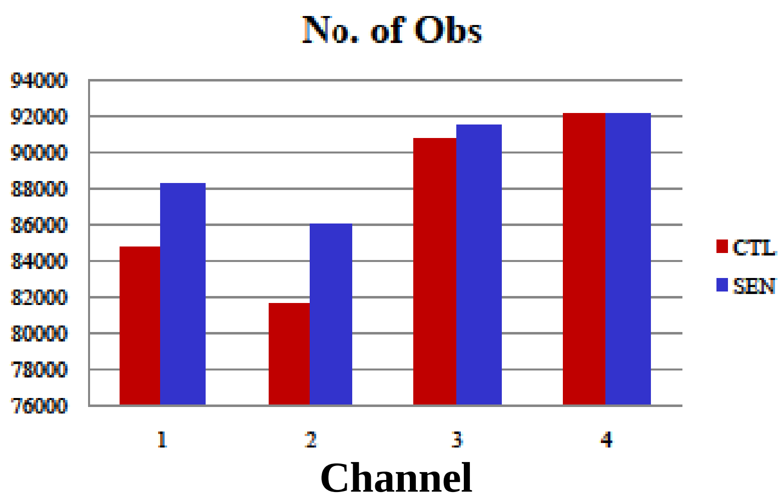


Comparisons of Tb bias and rmse and the number of obs assimilated in GSI

T_b BIAS, RMSE and No. of Obs assimilated in GSI: 12Z (Ave: 01-31 July 2010)





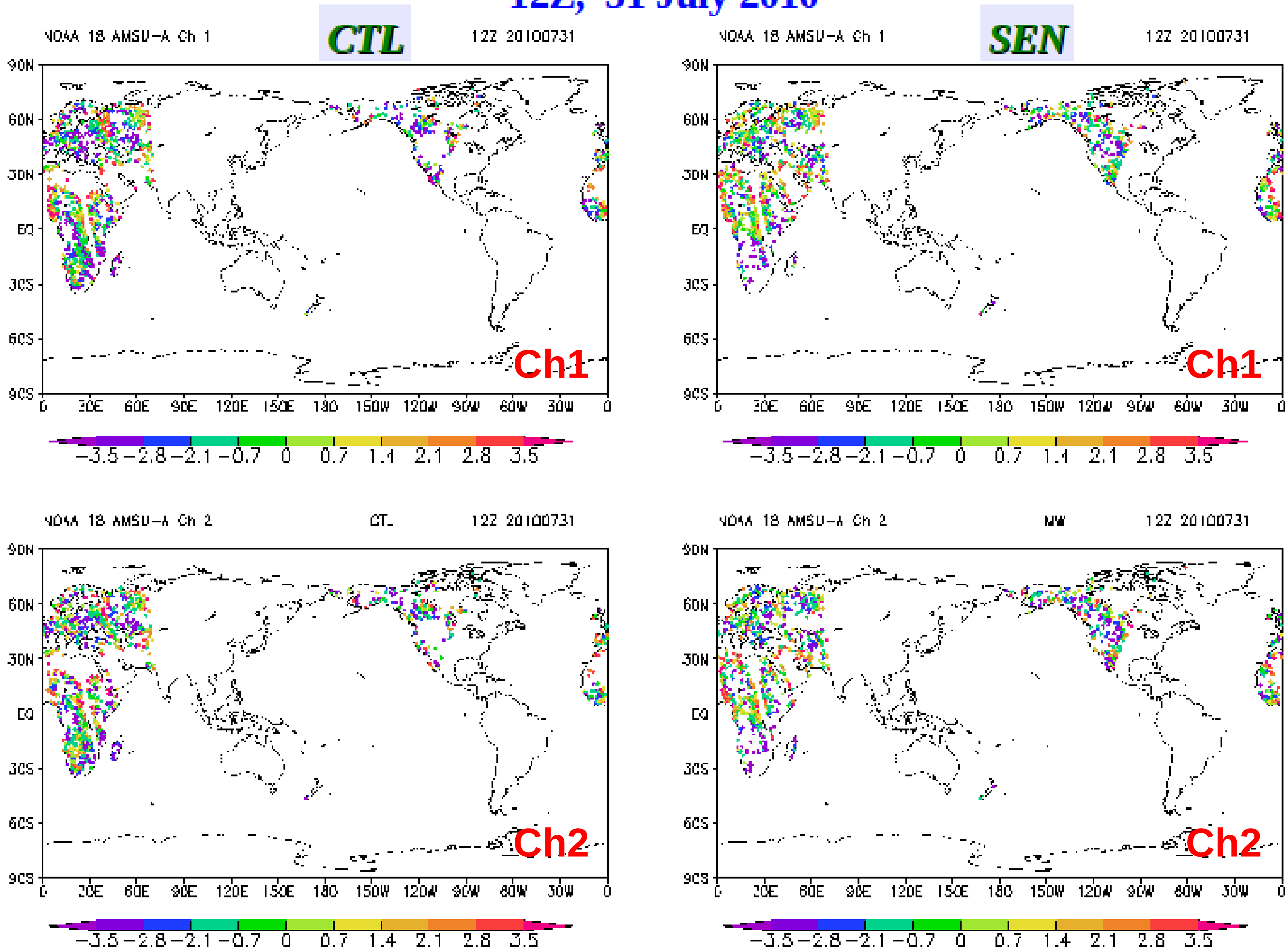


Red: CTL

Blue: SEN

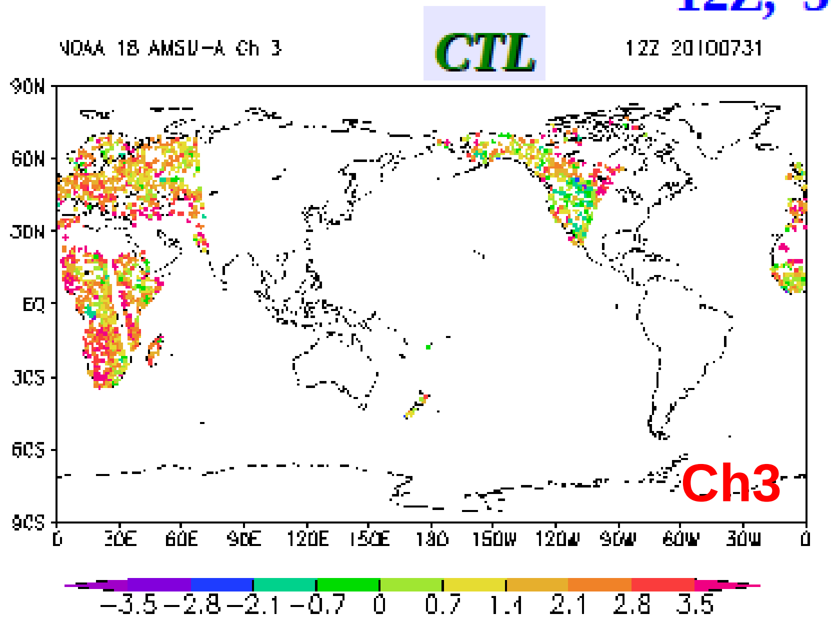
Spatial distribution of satellite data assimilated: Ch 1 and Ch 2

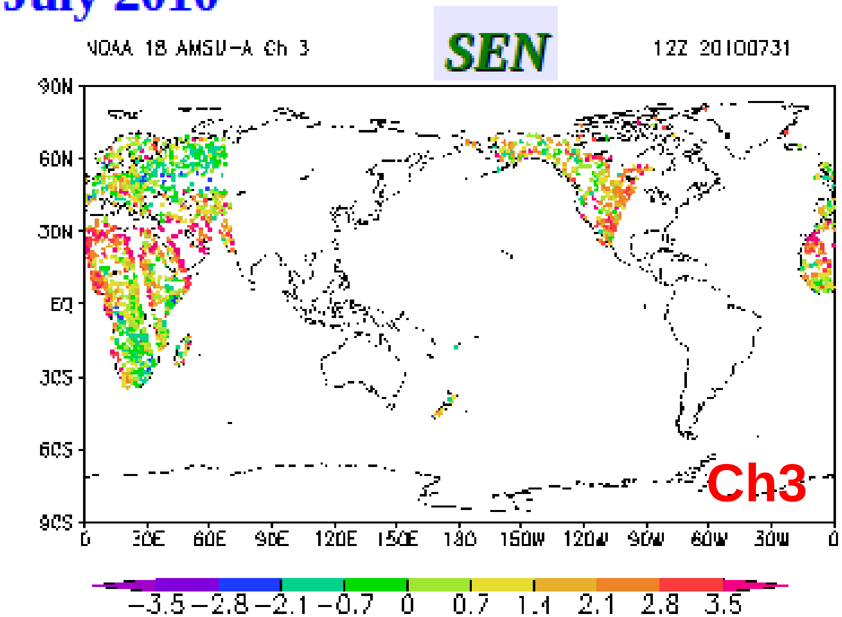
12Z, 31 July 2010

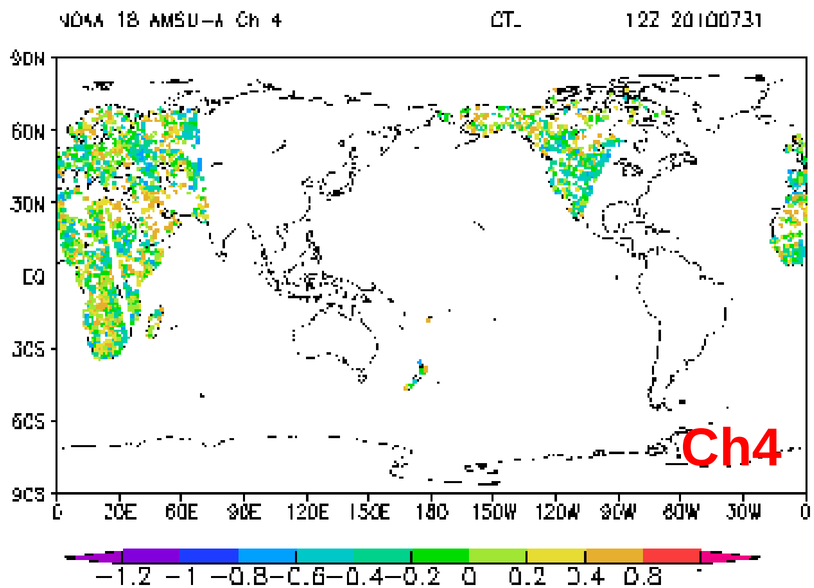


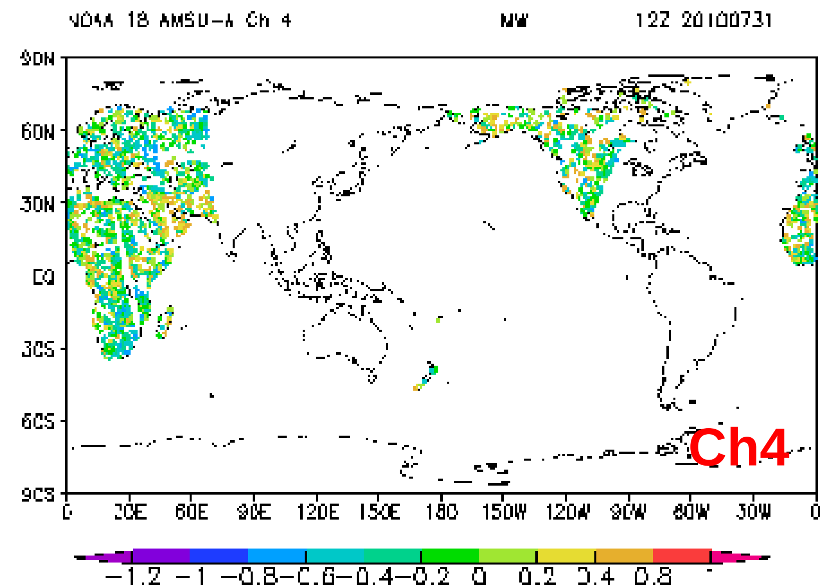
Spatial distribution of satellite data assimilated: Ch 3 and Ch 4

12Z, 31 July 2010









Summary:

1) The microwave land emissivity model was updated with more accurate land surface parameters, canopy optical parameters and alternative dielectric constant calculation.

2) Based on the three-layer medium model, the more accurate formula of total upwelling radiance emanating from the surface was derived, considering impact of ground upwelling radiance which is important for low microwave frequency channels, especially for the desert and semi-arid regions.

3) The sensitivity experiments with GFS-GSI show a reduction of errors in simulated brightness temperature, as well as an increase in the number observations assimilated in the GSI, compared to the results using a previous land surface emissivity scheme.

4) The updated microwave land emissivity model was implemented in the CRTM version 2.1.

5) The multi-layer soil algorithm was tested and will be implemented into the CRTM.