Improvement of Satellite Data Utilization in NCEP Operational NWP Modeling and Data Assimilation Systems

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Motivation

- ***Problems:*** **Satellite data (IR/MW) is rarely used over arid/desert regions in GSI (e.g. W. CONUS and N. Africa)**
  - **Substantial cold bias of land surface skin temperature (LST) in GFS.**
  - **Inaccurate emissivity calculation for MW over desert in GSI/CRTM**

- **Improvement of land surface skin temperature (LST) in GFS**
  - **New formula for momentum and thermal roughness lengths (Zom,Zot) (X. Zeng et al)**

- **New emissivity calculation for MW in GSI/CRTM**
  - **Empirical emissivity algorithm over desert region (B. Yan and F. Weng).**

Tb Simulation in GSI:

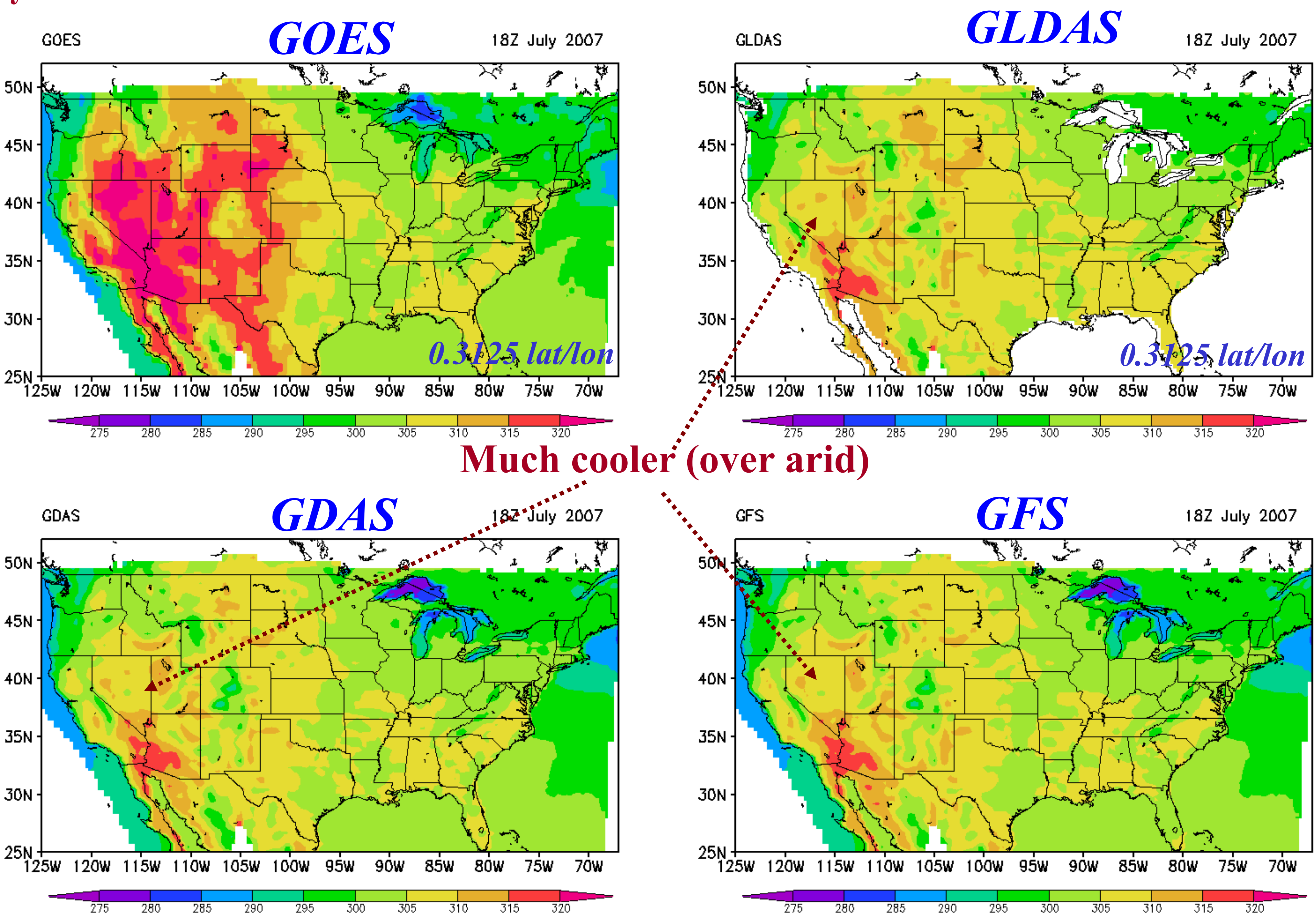
IR **NOAA-17 HIRS3:** ***Ch8: 11-micron***

MW **NOAA-18 AMSU_A:** ***Ch1: 23.8 Ghz ;*** ***Ch15: 89.0 Ghz ;***

Summer

Monthly Mean 18Z LST [K] July 2007

Daytime



GDAS/GFS/GLDAS have a large cold bias over western CONUS (Arid area).

LST in NCEP NWP models

Upward longwave radiation: $LW\uparrow = \varepsilon \sigma (T_{skin})^4$

Sensible heat flux: $SH = \rho C_p C_h (T_{skin} - T_{air})$

Ch (m/sec) = (Ch*) x lVl = aerodynamic conductance

Ch* is non-dimensional surface exchange coefficient and a function of momentum and thermal roughness lengths (***Zom*** and ***Zot)***

lVl is the wind speed at same level as T_{air}

T_{skin} is land surface skin temperature (**LST**)

- **Errors in Ch and T_{skin} can offset each other to still yield reasonable sensible heat flux SH**
- **But CRTM surface emission module cannot tolerate large error in LST.**

Kenneth Mitchell

New z_{0t} formula in GFS:

Xubin Zeng et al. (U. Arizona)

$$\ln(z_{0m} / z_{0t}) = (1 - GVF)^2\, Czil\, k\, (u_* z_{0g}/\nu)^{0.5}$$

z_{0m} : the momentum roughness length specified for each grid,

z_{0t} : the thermal roughness length,

GVF: the green vegetation fraction,

Czil : a coefficient to be determined and takes 0.8 in this study,

k: the Von Karman constant (0.4),

ν: the molecular viscosity ($1.5\times10^{-5}\ m^2\ s^{-1}$),

u_* : the friction velocity,

z_{0g} : the bare soil roughness length for momentum (0.01 m).

OPS: $z_{0t} = z_{0m}$

Effective z_{0m} is used as follows:

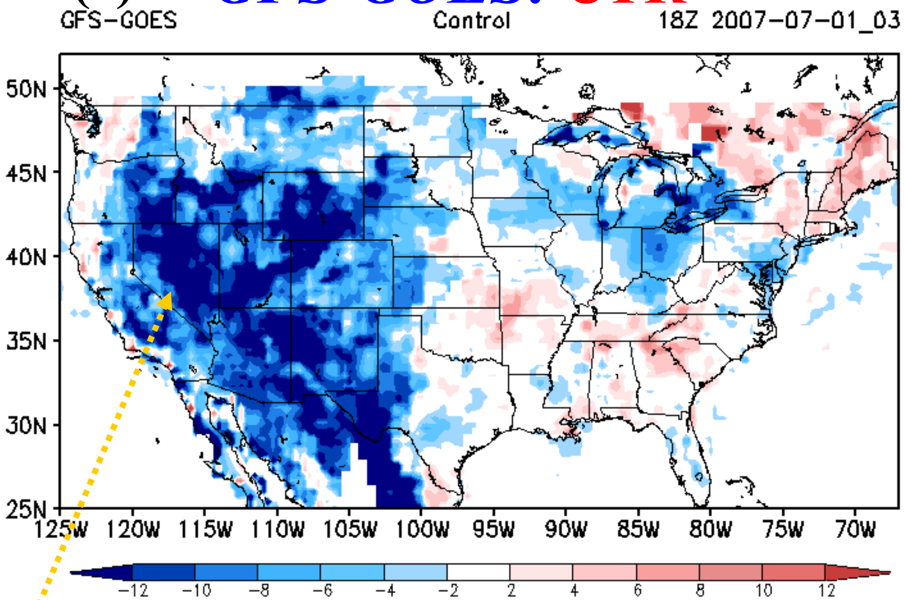
$$\ln(z_{0m}) = (1 - GVF)^2 \ln(z_{0g}) + [1 - (1 - GVF)^2] \ln(z_{0m})$$

Note: LST is related to ***Aerodynamic conductance (then*** surface exchange coefficient) which is a function of Zom and Zot

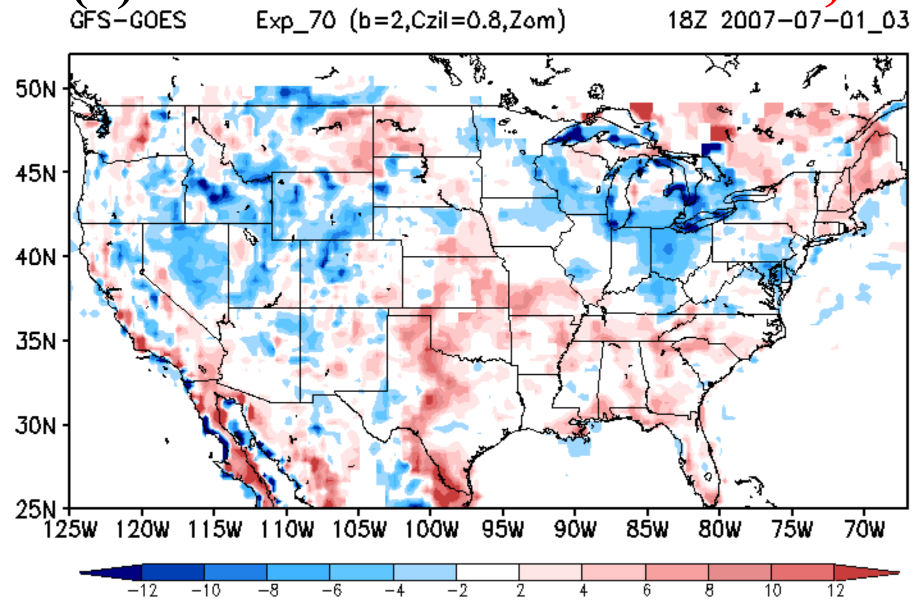
LST [K] Verification with GOES and SURFRAD

3-Day Mean: July 1-3, 2007

(a) ***GFS-GOES: CTR***

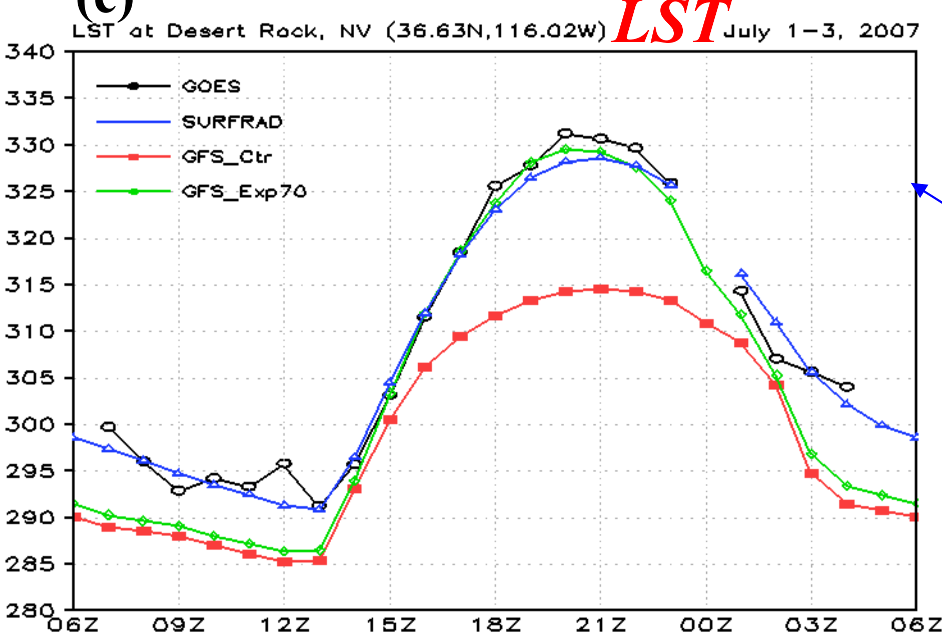


(b) ***GFS-GOES: New Zom,t***



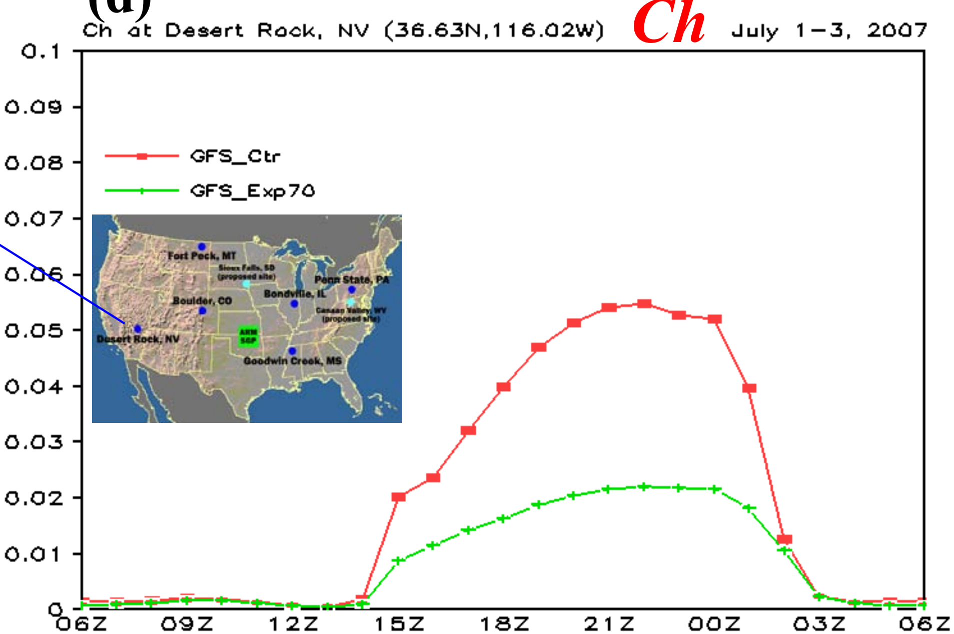
Large cold bias

(c) ***LST***



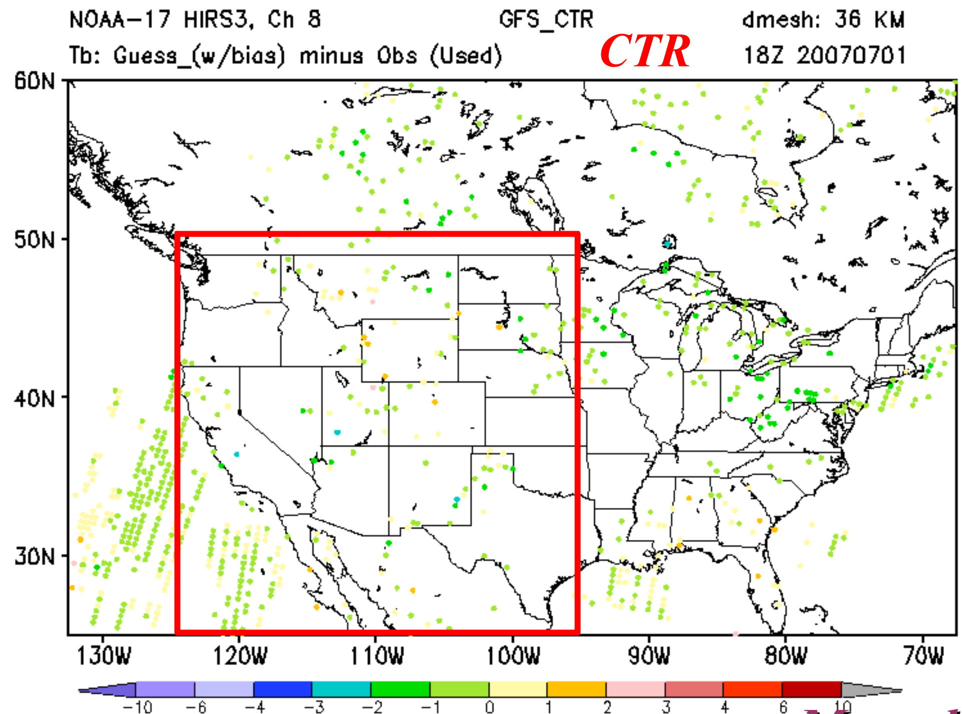
Improved significantly during daytime!

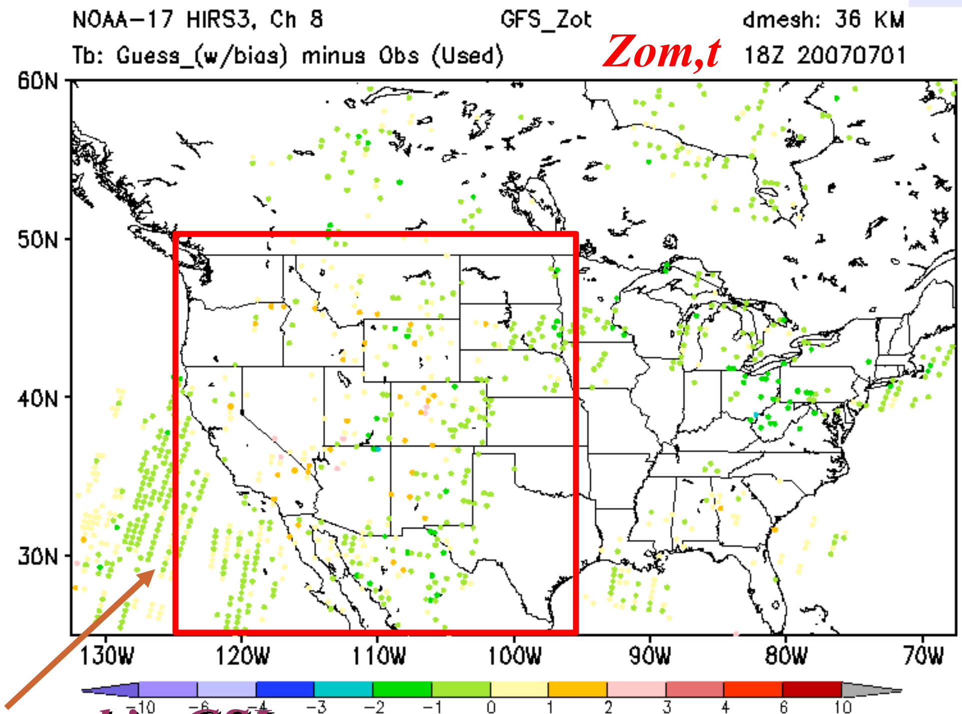
(d) ***Ch***



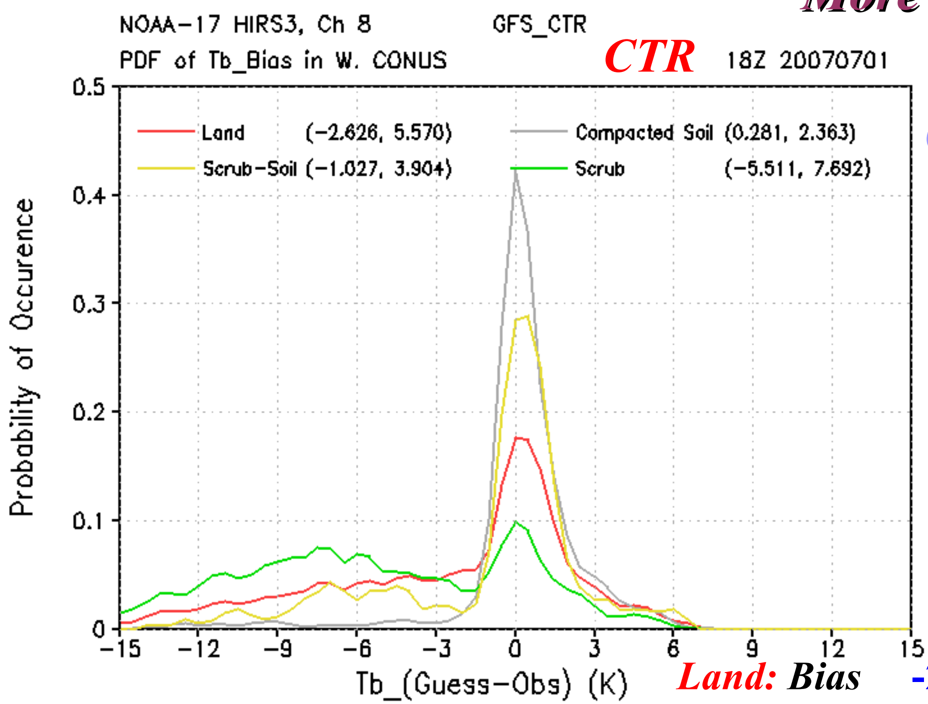
Aerodynamic conductance: CTR vs Zom,t

Tb Simulation in GSI: NOAA-17 HIRS3 *Ch8: 11-micron* *Used in GSI* IR

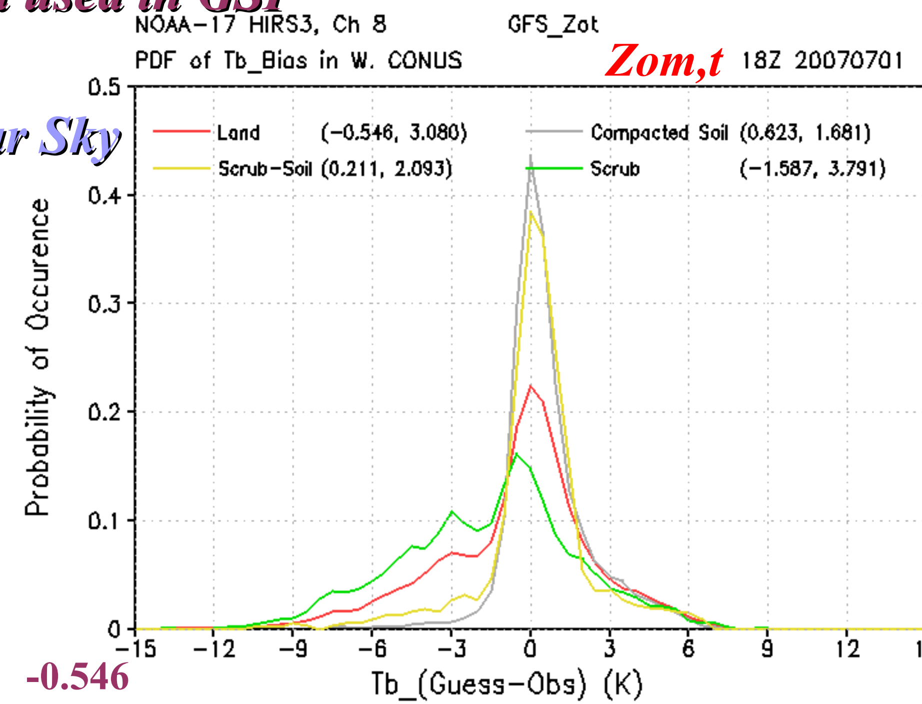




More data used in GSI



Clear Sky

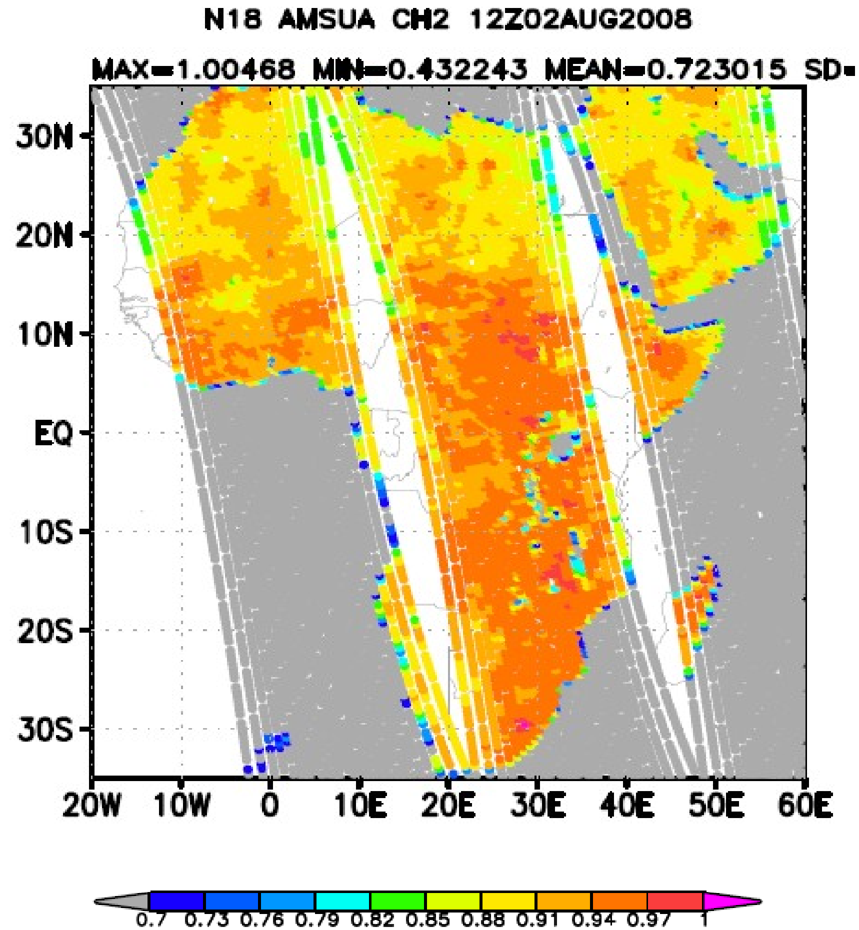


Land: ***Bias*** **-2.626** **-0.546**

rmse **5.570** **3.080**

New Microwave Desert Empirical Algorithm

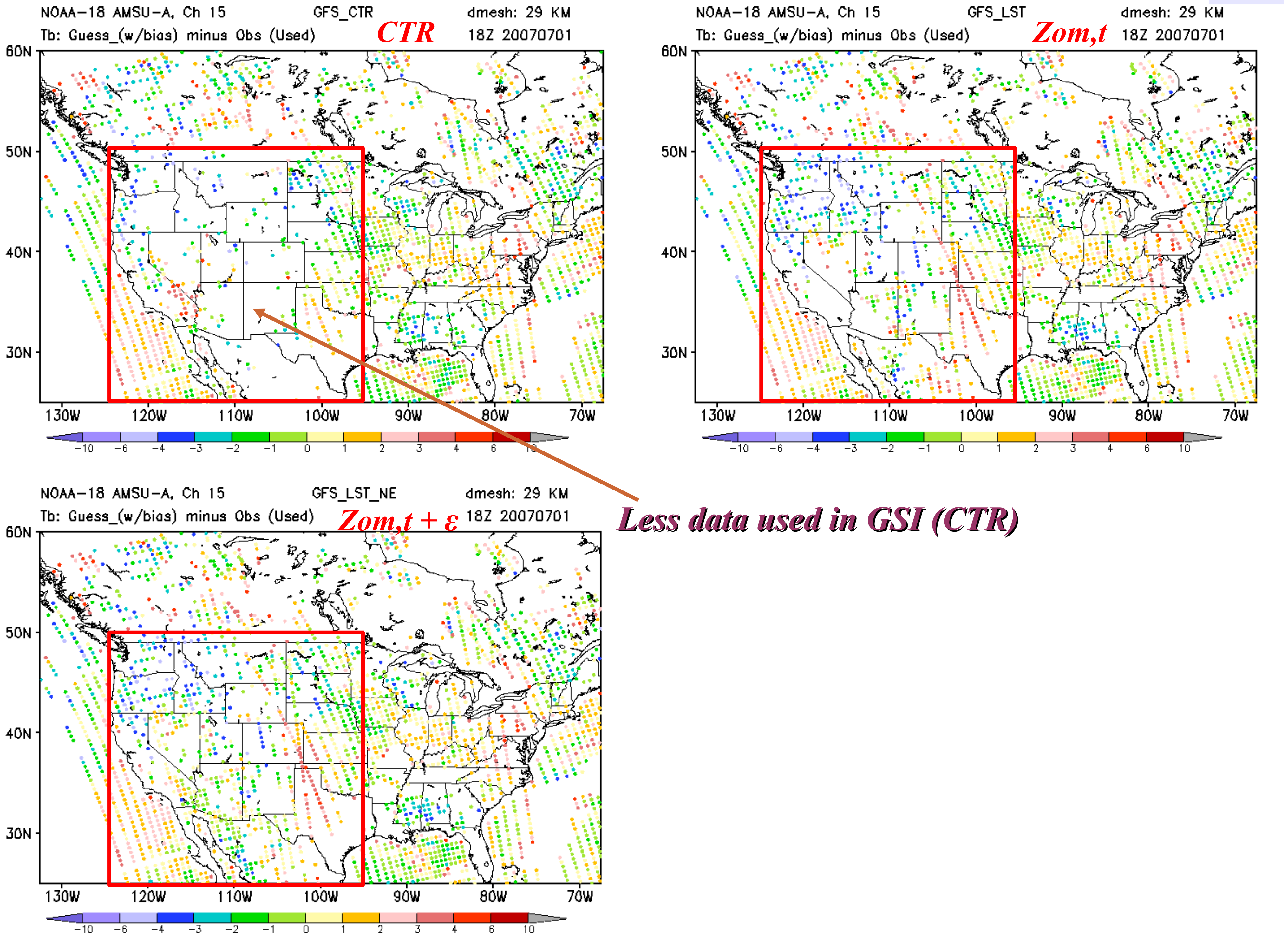
- **Generate desert emissivity training data bases at window channels using JCSDA-CRTM under microwave clear sky conditions**
- **Derive fitting coefficients for emissivity estimate at window channels from the training data set**
- **Interpolate emissivity at other frequencies according to a series of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



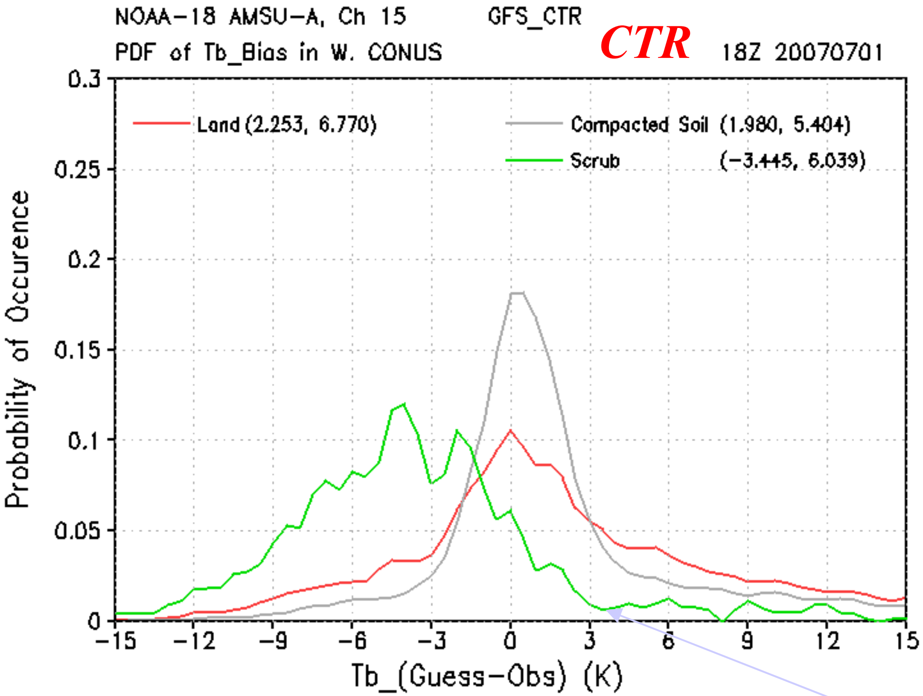
Reference: Yan and Weng (2009)

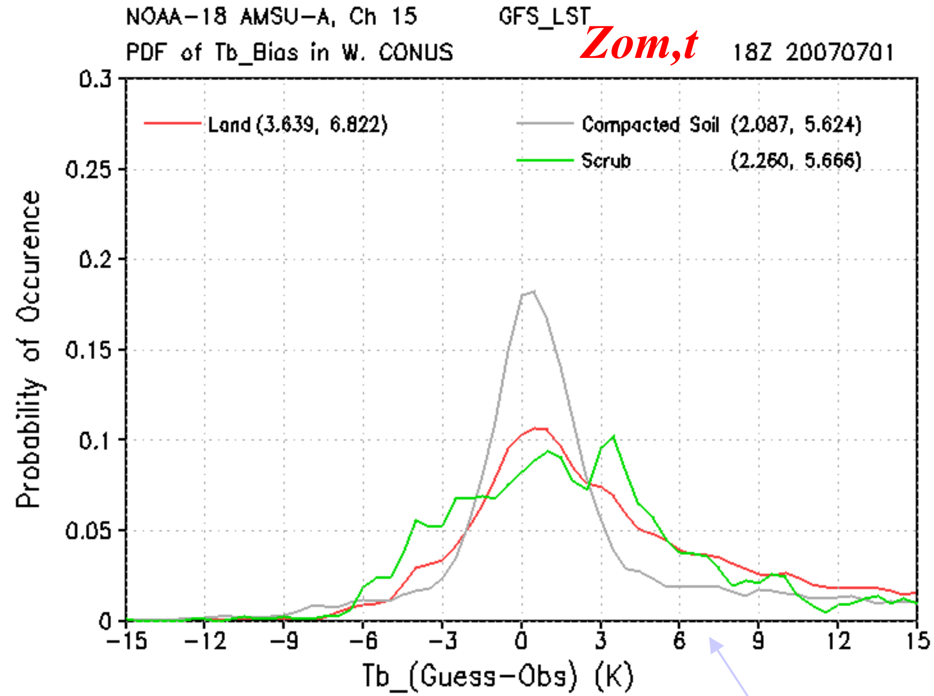
Tb Simulation in GSI: NOAA-18 AMSU_A Ch15

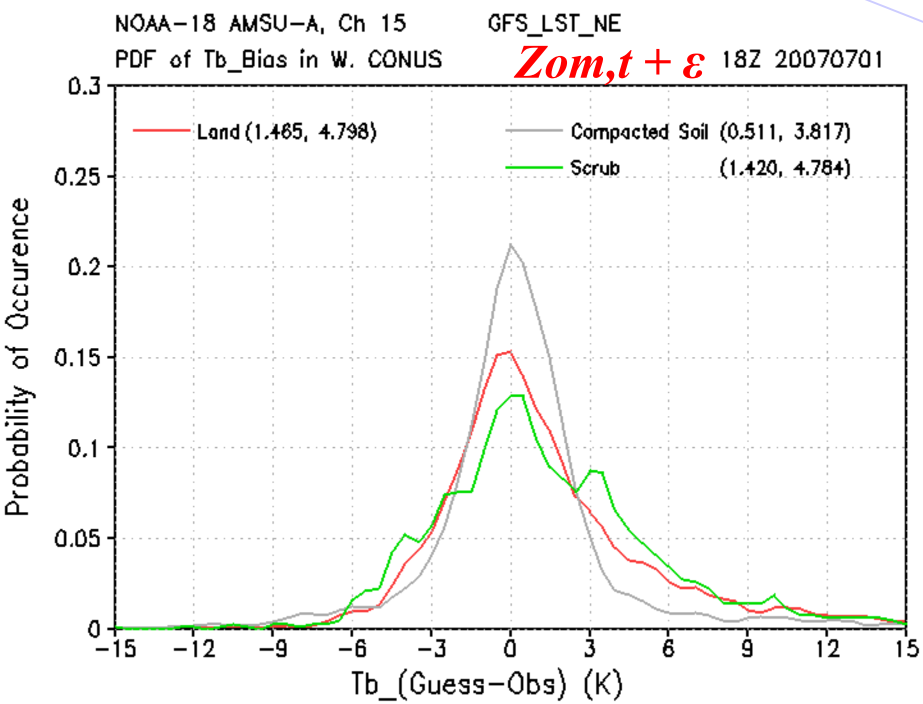
MW



PDF distribution, Bias and RMSE: Land, Compacted Soil & Scrub







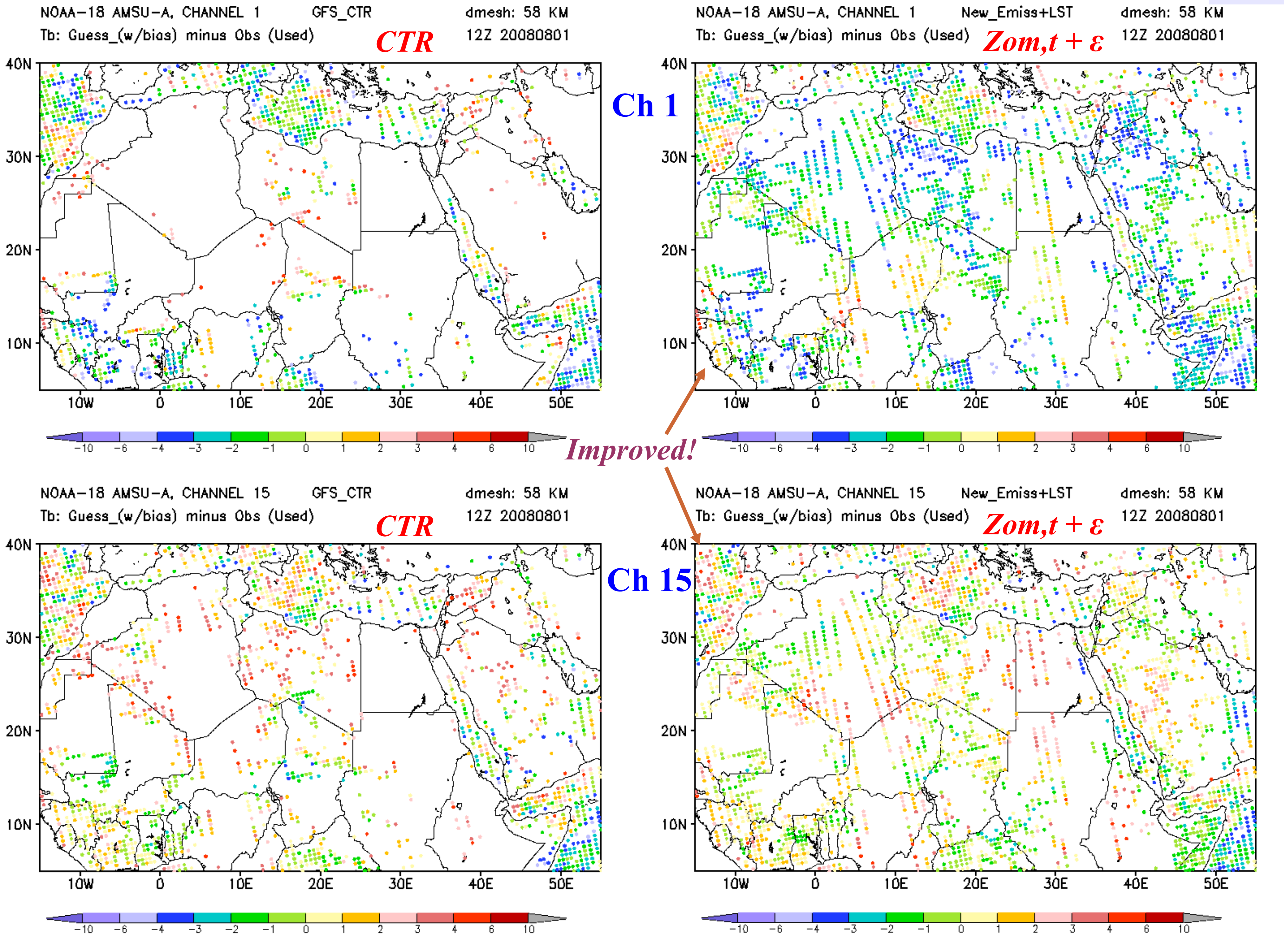
Cold bias for Scrub

Improved for Scrub

W. CONUS		*CTR*	*Zom,t*	*Zom,t+ ε*
Scrub:	*Bias*	**-3.445**	**2.260**	**1.420**
	rmse	**8.039**	**5.666**	**4.784**

Most part of W. CONUS is covered by "Scrub".

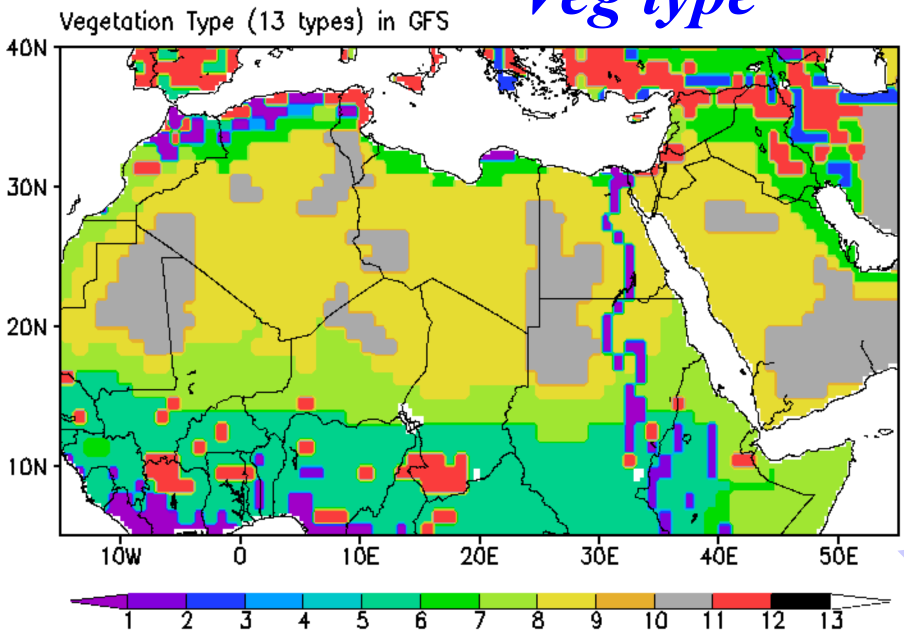
Tb Simulation in GSI: NOAA-18 AMSU_A *PHY_CTR vs EMP_LST* MW



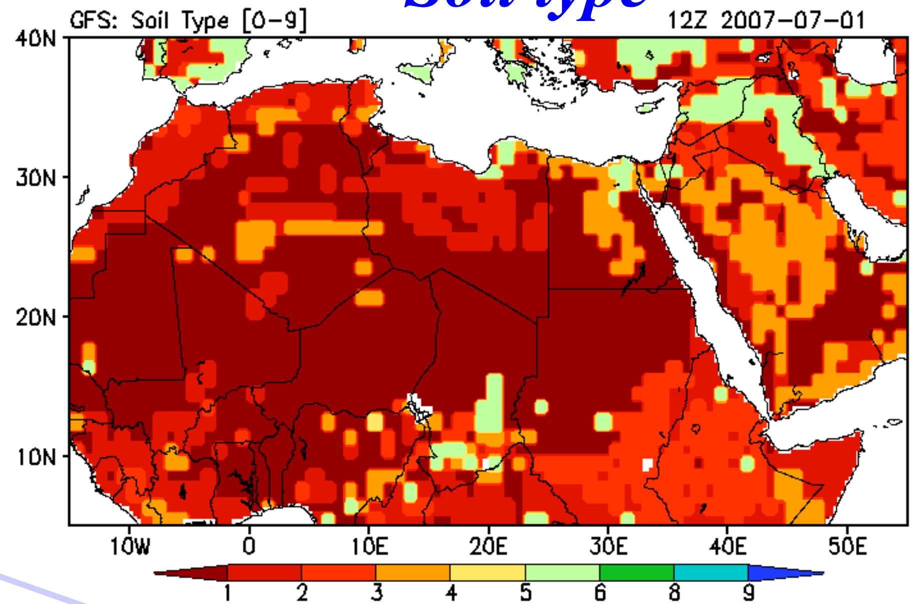
Case: 12Z, 20080801

Vegetation type, soil type and Green Vegetation Fraction (GVF)

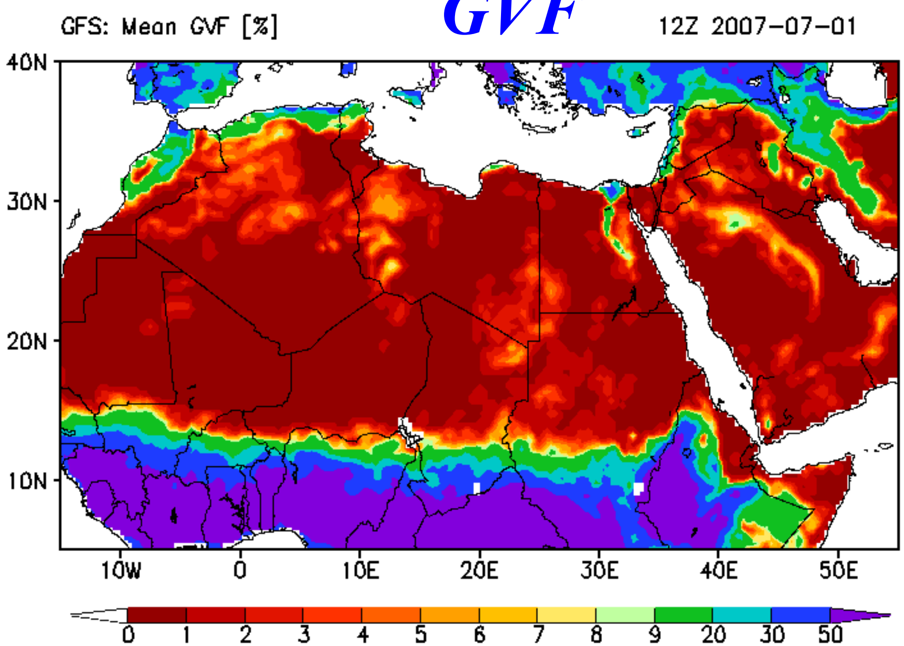
Veg type



Soil type



GFV



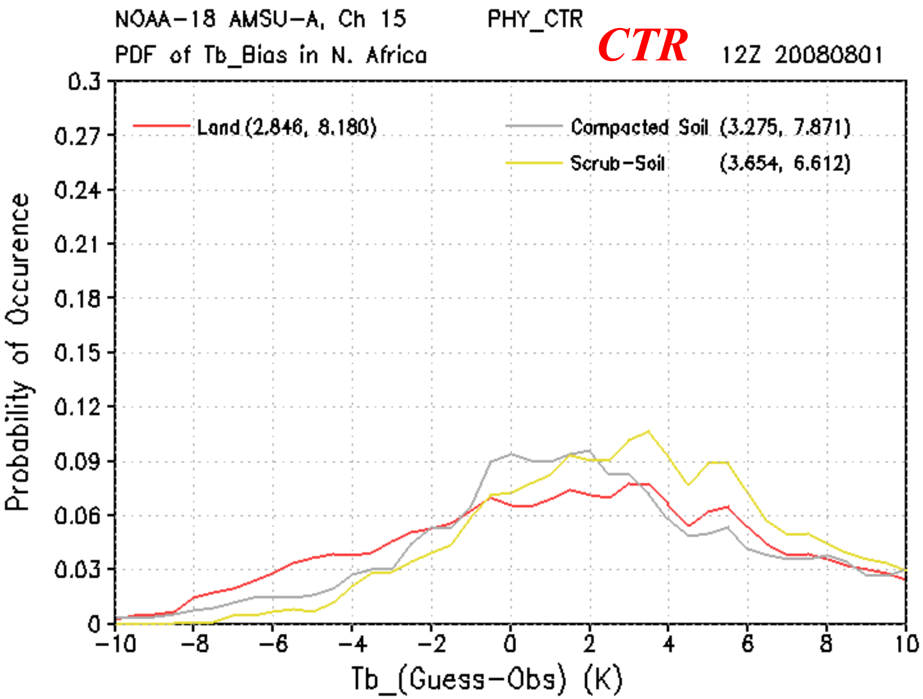
Vegetation Types

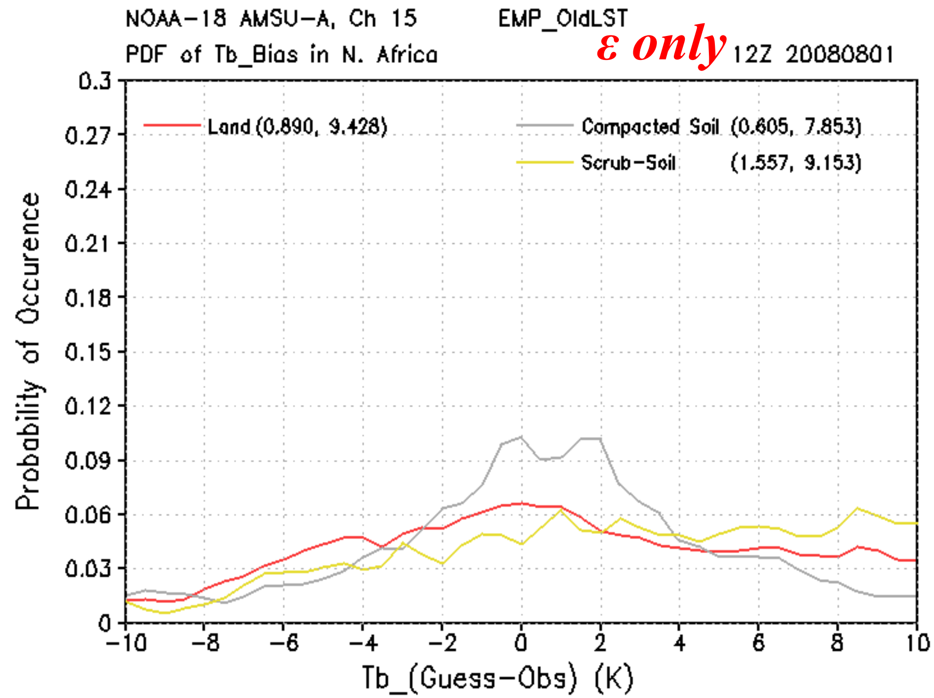
GFS		CRTM
Veg_7:	Ground Cover Only (Perennial)	(Scrub)
Veg_8:	Broad leaf Shrubs w/ Ground Cover	(Scrub)
Veg_9:	Broadleaf Shrubs with Bare Soil	(Scrub-Soil)
Veg_11:	Bare Soil	(Compacted Soil)

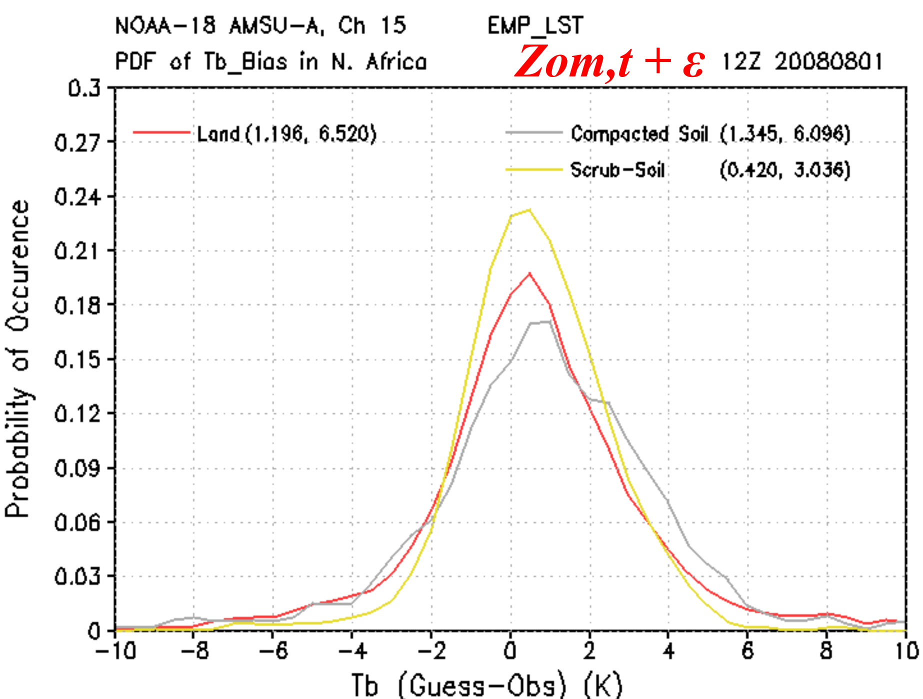
Unlike W. CONUS, most part of N. Africa is desert.

PDF distribution, Bias and RMSE: Land, Compacted Soil & Scrub-Soil

Ch 15 MW







N. Africa		*CTR*	*ε only*	*Zom,t+ ε*
Land:	*Bias*	**2.846**	**0.890**	**1.196**
	rmse	**8.180**	**9.428**	**6.520**

Improved significantly

Summary

- **New formula for momentum and thermal roughness lengths (Zom,Zot) as a function of green vegetation fraction was tested in the NCEP GFS model to reduce a substantial cold bias of land surface skin temperature over arid and semi-arid regions during daytime in the warm seasons.**

- **The new empirical MW emissivity model, developed by B. Yan and F. Weng at NESDIS, corrected unreasonable MW surface emissivity calculation over desert regions in the CRTM .**

- **With new roughness changes and new emissivity MW model together, obvious reduction of large bias of the calculated brightness temperatures was found for infrared or microwave satellite sensors at window or near window channels, so that much more satellite measurements can be utilized in the GSI data assimilation system.**