Third CWG meeting agenda
July 31(Thursday), 2008 at 2:30pm EDT

2:30pm: Review of CWG-M2 action items - Y. Han/P.vanDelst (10 min)

2:40pm: Updates to spectroscopy for radiative transfer models - V. Payne (15 min)

2:55pm: Updates on the work at ESRL/GSD in using the CRTM - D. Birkenheuer (5 min)

3:00pm: Improvement of land skin temperature in GFS and simulation of brightness temperature with GSI/CRTM - W. Zheng (15 min)

3:15pm: CRTM public repository status and implementation of the improved low-frequency MW sea surface emissivity model - P.van Delst (15 min)

3:30pm: Systematic Differences in LBLRTM-derived optical depths - D. Groff (10 min)

3:40pm: Update on microwave surface emissivity model - B. Yan (10 min)

3:50pm: CRTM aerosol look-up table - Q. Liu (10 min)

4:00pm: RMS differences between model and measurements – B. Ruston (5 min)

4:05pm: Update on implementation of the multiple transmittance algorithm framework - Y. Han (5 min)

4:10pm: Short work updates and discussions – all attendees

4:30pm: Adjourn

CWG Meeting-2 Action Items Review

- Item#1: Obtain more accurate information on the set of SSMIS SRFs
  - We have obtained two sets of SRFs for the SSMIS sensor with serial # N2:

    SN2RECPB.DAT – data assuming a rectangular oassband shape

    SN2ffPB.DAT – data after Fourier filtering to the measurements by a spectrum analyzer
  - We should use the SN2ffPB data as they have been referred in the two Journal papers by Swadely et al. (2008) and Kerola (2006).
- Item#2: Update and improve CRTM user guide for broader users

  Paul van Delst is working on a wet based user guide

- Item#3: Provide a CRTM version plan (1)
  - CRTM current version 1.1
  - Next update: version 1.2 (Mid August)
    - MWSSE improvement
    - Improvement of interpolation scheme for cloud/aerosol LUTs
  - Date file update (4^{th} Quarter)
    - Transmittance coefficients using the latest spectroscopy (LBLRTM for IR and MonoRTM for MW)
    - Transmittance coefficients for new sensors, such as CrIS, GOES-14, ATMS, SSMIS f17 and f18.

- Item#3: Provide the CRTM version plan (2)
  - CRTM version 2.0 (2nd Quarter, 2009)
    - Multiple transmittance algorithm framework
    - Zeeman algorithms for SSMIS UAS channels and AMSU-A channel 14
    - ODCAPS transmittance algorithm
    - ODPS algorithm
    - Height dependent zenith angles (for the Earth curvature effect)

Atmospheric and Environmental Research, Inc.

Updates to spectroscopy for radiative transfer models

JCSDA CRTM Working Group telecon

July 31 2008

Status of microwave updates

- **MonoRTM: new release pending**
  - Anticipated release date**: 1st September**

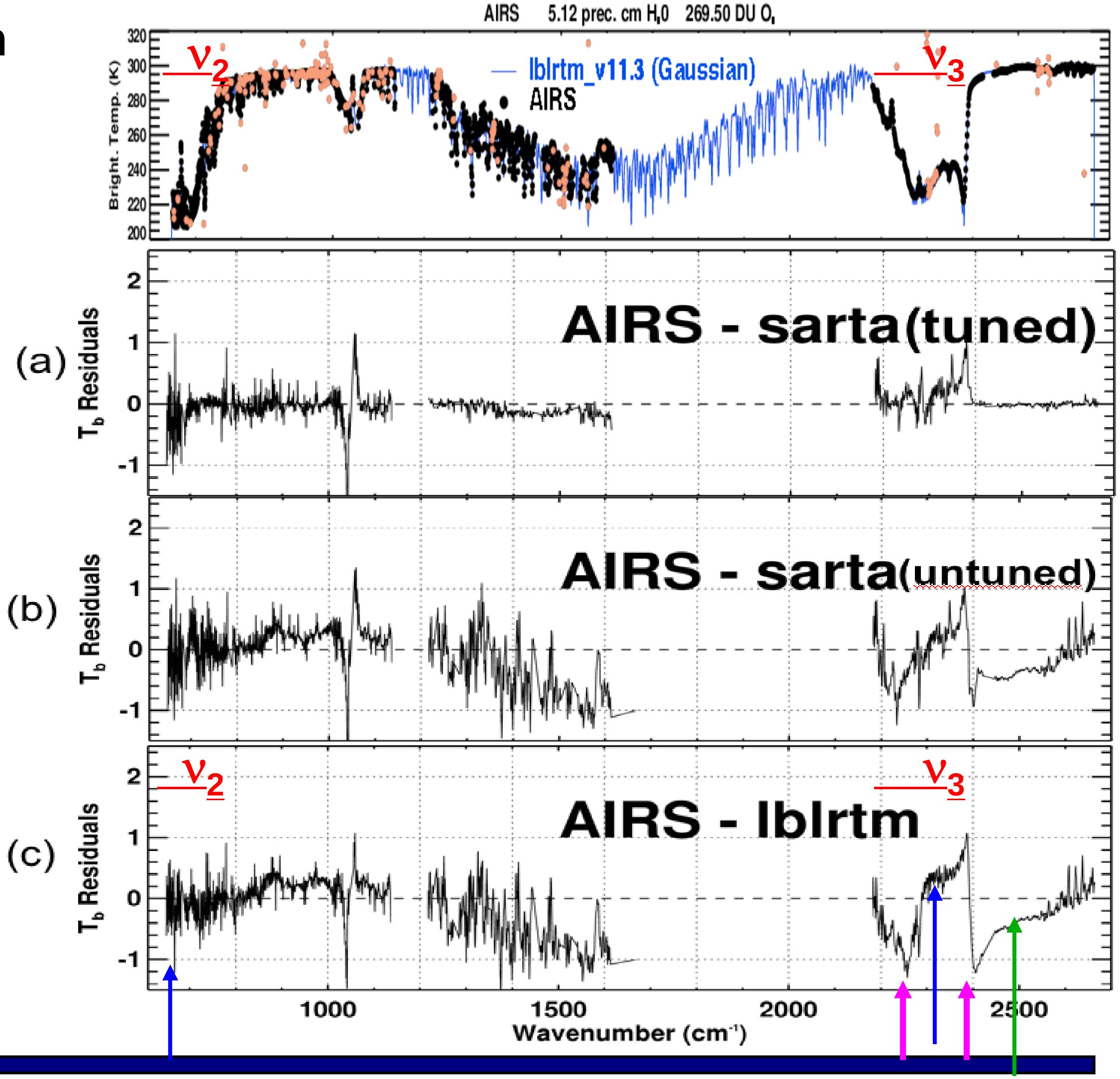
- **Update to MT_CKD water vapor continuum in microwave**
  - Based on ARM ground-based radiometer data
  - Preliminary numbers for changes:
    - » ~10 % decrease in foreign
    - » ~20 % increase in self

- **Additional features:**
  - Extension beyond microwave region
  - Improved consistency with LBLRTM in terms of coding and databases
    - » Will facilitate future updates to the models

Status of infrared spectroscopy: CO_2 (1)

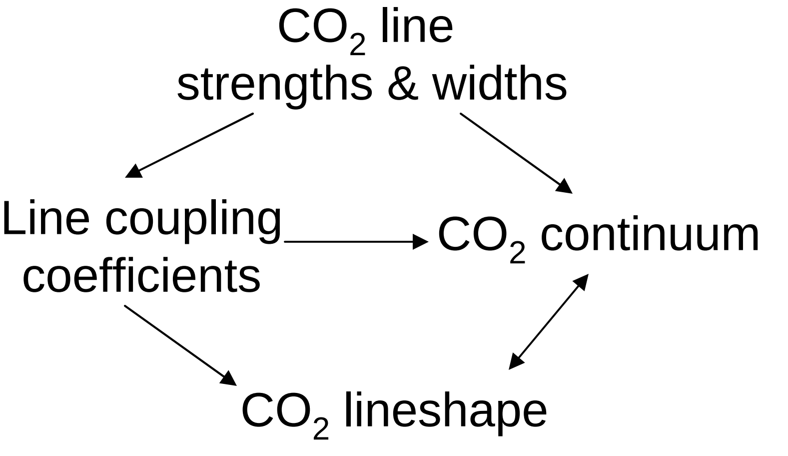
- **Improvements in LBLRTM have been obtained by implementation of P&R branch line coupling**
  – Niro, Hartmann et al. (2005)
- **CO_2 ν_2 and ν_3 residuals are not yet fully consistent**
- ν_2 region: good agreement with sondes in troposphere
- **Outstanding issues:**
  – **Edges of ν_3 band**
    » Tropospheric temperature information
  – **“Stratospheric” parts of ν_2 and ν_3 regions**
    » Essentially unvalidated
  – **2500-2600 cm^{-1} region**
    » Information close to surface
    » CO_2 and or H_2O continuum absorption

39 ARM TWP cases: Profile inputs and “SARTA” results supplied by L. Strow and S. Hannon.



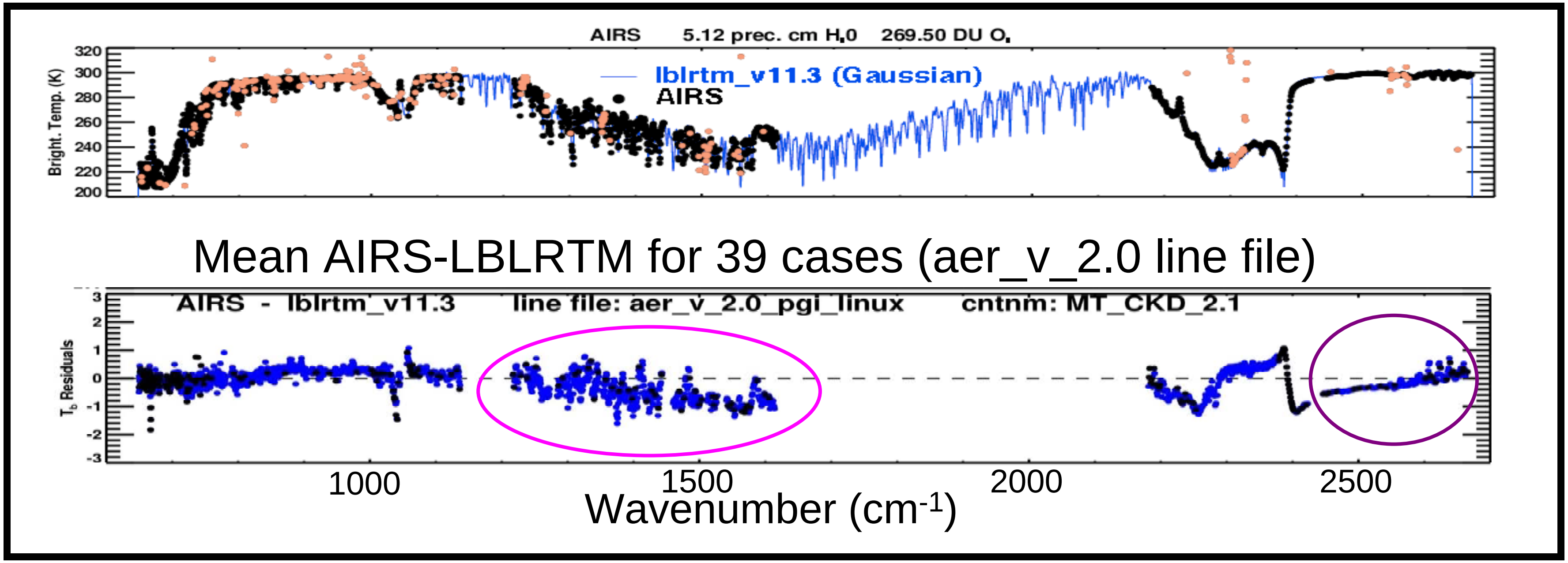
Status of infrared spectroscopy: CO_2 (2)

- **Consistency between CO_2 ν_2 and ν_3 regions:**
  - Have acquired new CO_2 ν_3 line strengths, widths
    - » from S. Tashkun (via MIPAS team).
  - **Next:**
    - » Recalculate line coupling coefficients
      - Use code supplied by J-M. Hartmann.
    - » Recalculate CO_2 continuum
    - » Reassess CO_2 χ-factor (lineshape)
    - » Careful validation
      - AIRS
      - IASI
      - AERI

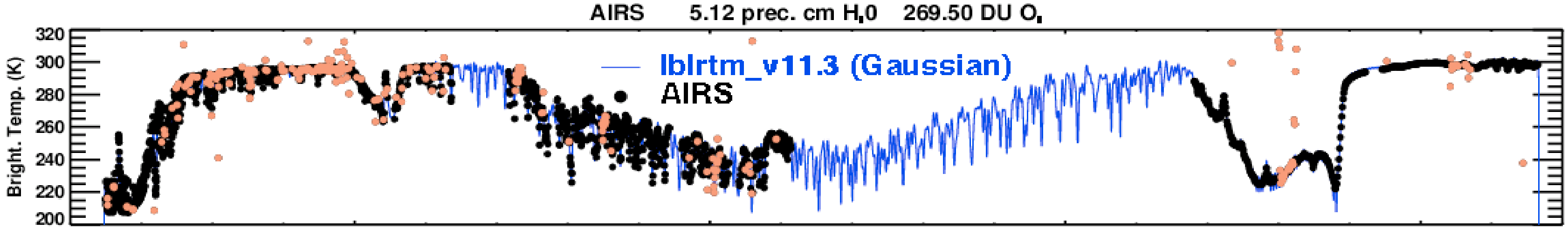


Status of infrared spectroscopy: H_2O

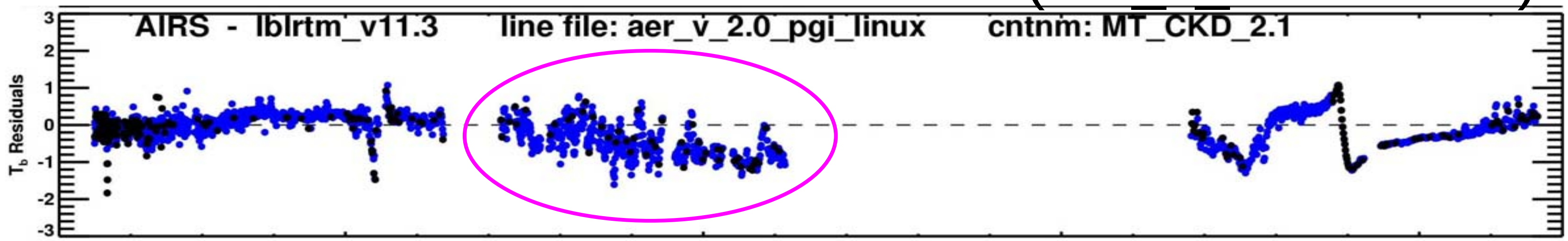
- Outstanding issues for H_2O spectroscopy:
  - **Residuals in H_2O ν_2 (1200-2100 cm^{-1}) region**
  - **Residuals in 2500-2600 cm^{-1} region**



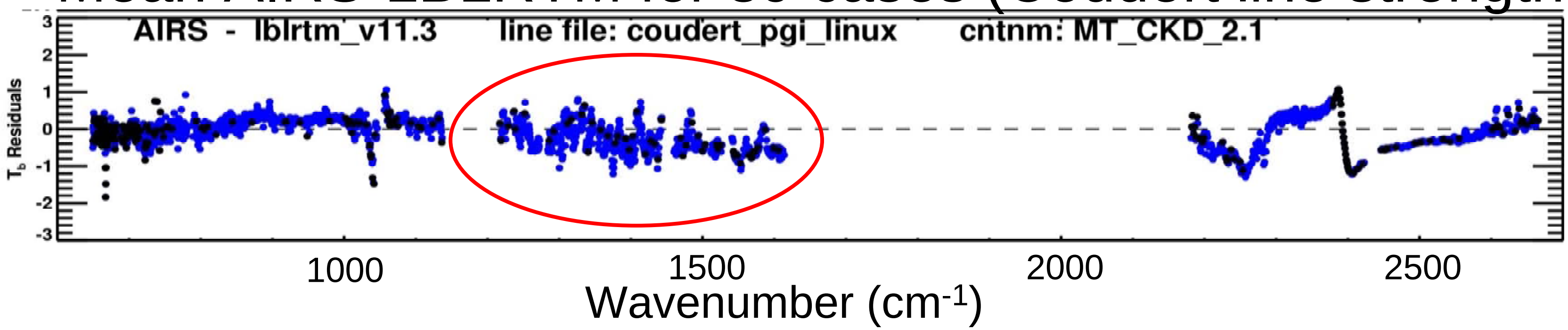
- Things to try:
  - Line strengths from Coudert et al. (2008)
  - Temperature dependence of widths from Gamache
  - Analyze self-broadened continuum in 2500 cm^{-1} region



Mean AIRS-LBLRTM for 39 cases (aer_v_2.0 line file)



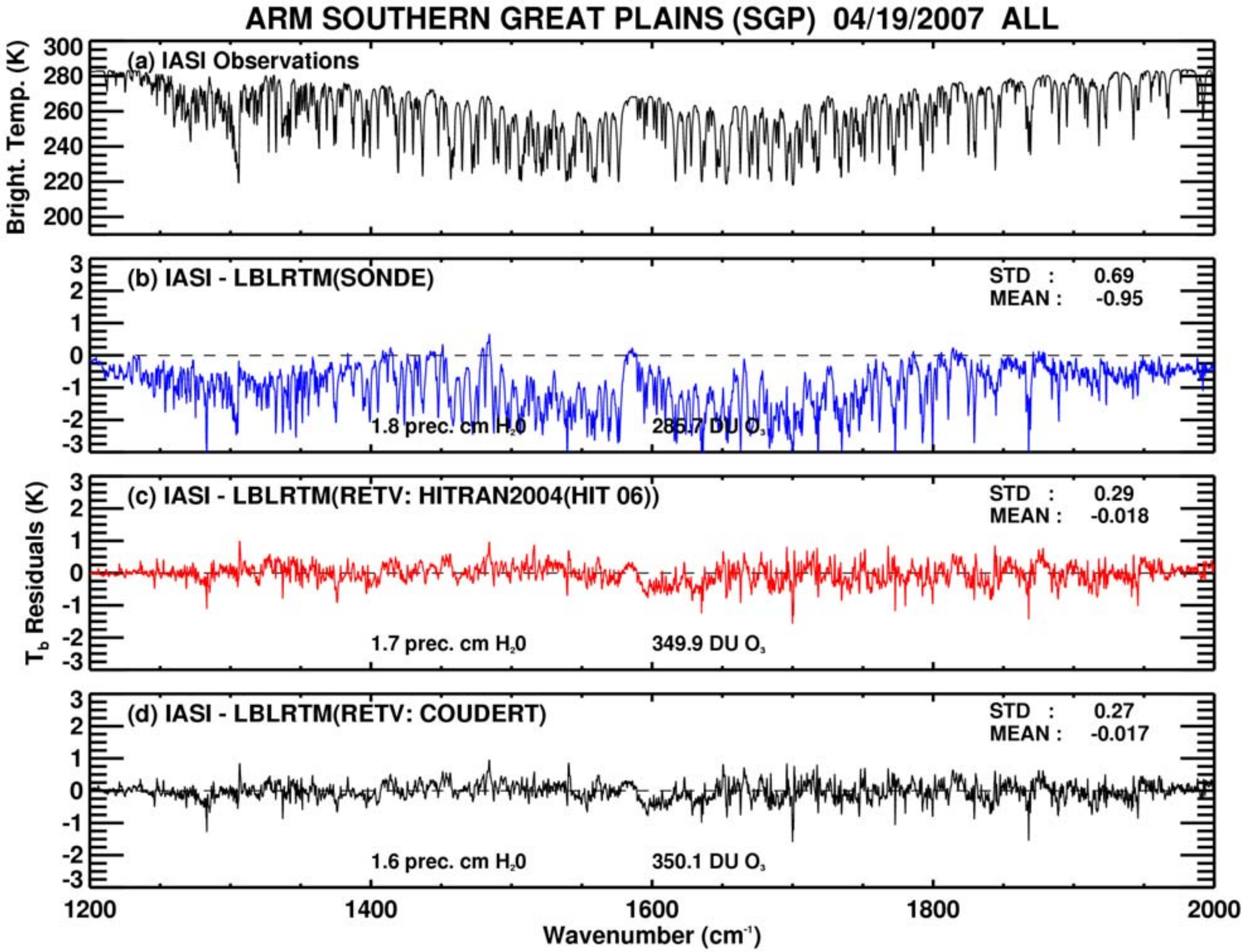
Mean AIRS-LBLRTM for 39 cases (Coudert line strengths)

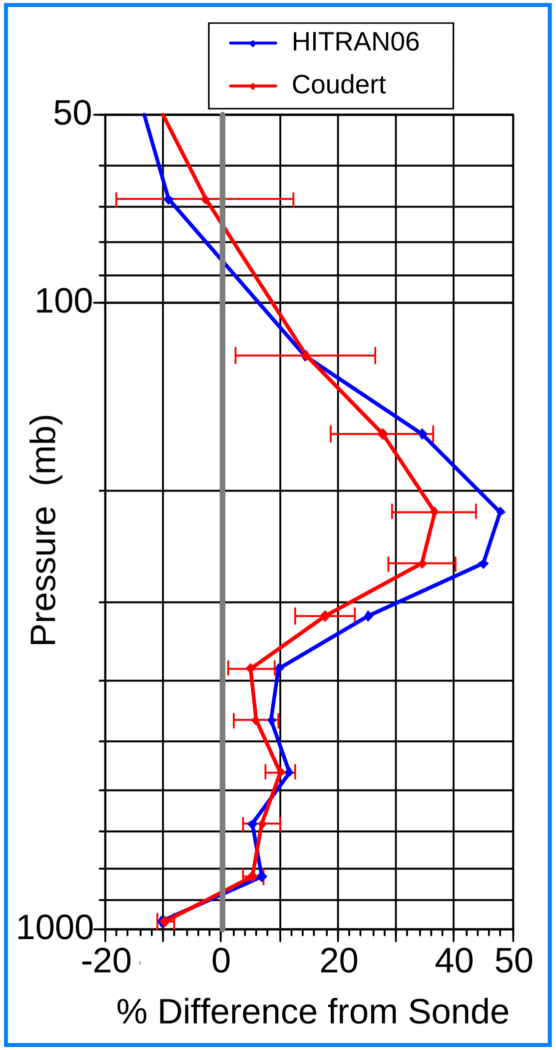


- Coudert's strengths improve residuals in H_2O ν_2 region
- We expect Gamache's width temperature dependences to improve "peak to valley" issues

Water Vapor v_2 Region : Impact of Coudert Intensities

IASI retrieval





Tony Clough and Mark Shephard
(presented at HITRAN meeting, June 2008)

~10 % diff in upper trop!

Future work: Priorities

- **Current top priorities (IR/MW) in order of priority:**

- **MonoRTM release (1st September)**
- **CO_2: consistency between ν_2 and ν_3 regions**
  - Update ν_3 line parameters, line coupling, CO_2 continuum and lineshape
  - Assess impact on temperature retrievals
- **H_2O line parameters in 1200-1600 cm^{-1} region**
  - Implement Coudert H_2O line strengths
    - » Demonstrated impact on retrievals of upper tropospheric H_2O
  - Assess new width temperature exponents from Gamache
    - » Expected impact on mid- to upper tropospheric H_2O

Future work: Priorities

- **Other future work (IR/MW, in no particular order of priority)**

- Zeeman splitting in MonoRTM
- Stratospheric validation
  - For example, use of COSMIC data to validate strong CO_2 lines
- Parameterization of 667 cm^{-1} Q branch line coupling
- Non-LTE
- Spectroscopy for MW limb calculations (e.g. for assimilation of MLS radiances?)
- O_3 spectroscopy?
- Other molecules? (e.g. CH4, CO…..)
- Residuals in 2500 cm^{-1} region
  - Validation of CO_2 and H_2O continuua in this region

Questions for JCSDA

- **How would you order the items listed in “Future Work” in terms of priority?**

- **What means do you have of judging one model against another?**

Updates on the work at ESRL/GSD in using the CRTM

D. Birkenheuer

Improvement of Land Skin Temperature in GFS and Simulation of Brightness Temperature with GSI/CRTM

Weizhong Zheng and Ken Mitchell
(NOAA/NCEP/EMC)

Third CRTM Working Group Meeting
July 31, 2008

LST in NCEP NWP models

Kenneth Mitchell

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

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

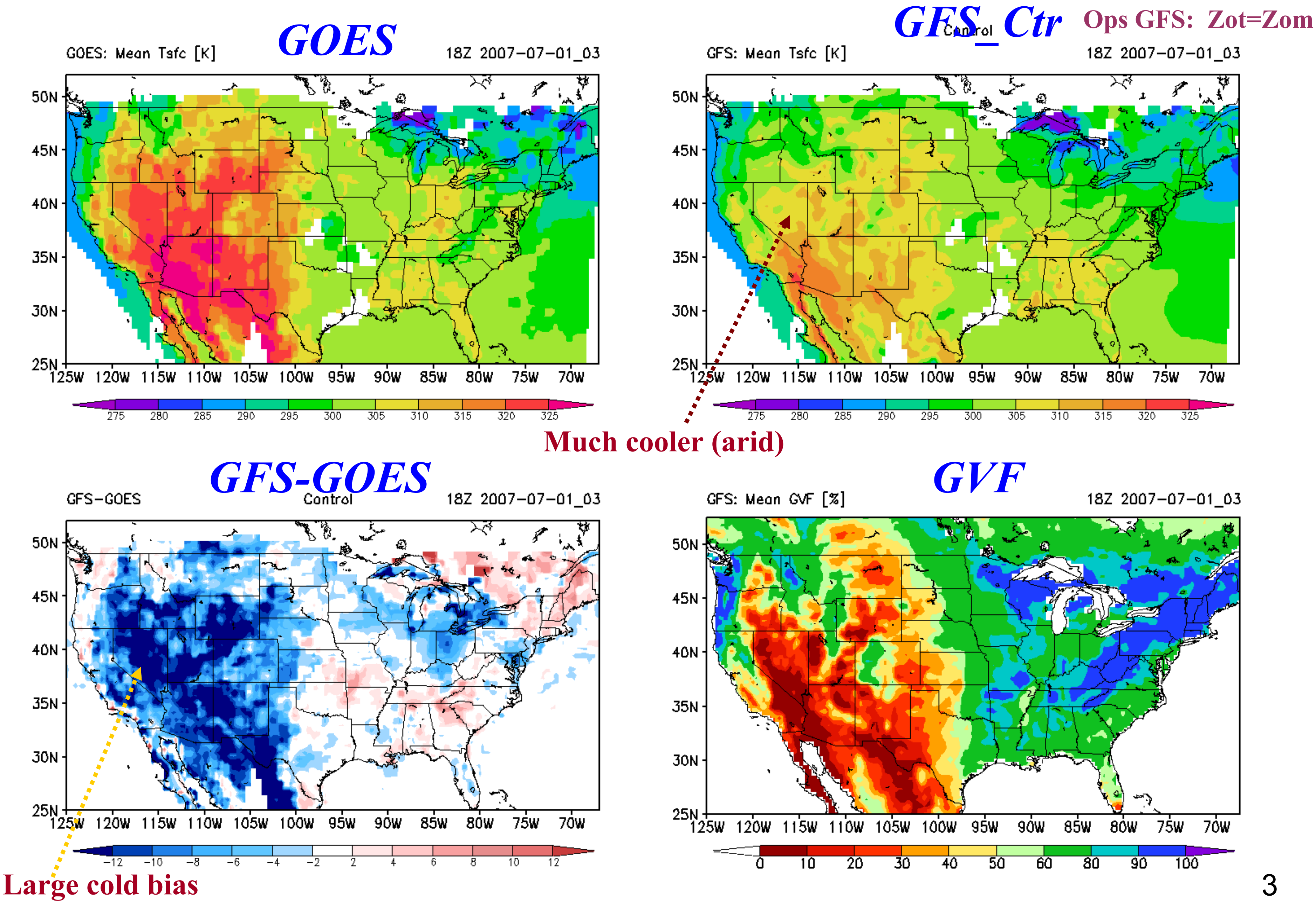
lVl is the wind speed at same level as T_{air}

Tskin is land surface skin temperature (LST)

- **Errors in Ch and T_{skin} can offset each other to still yield reasonable sensible heat flux**
- **But CRTM surface emission module cannot tolerate large error in LST.**
- **In Ops GFS, use Zot=Zom to calculate Ch.**

Mean 18Z LST [K] July 1 - 3, 2007

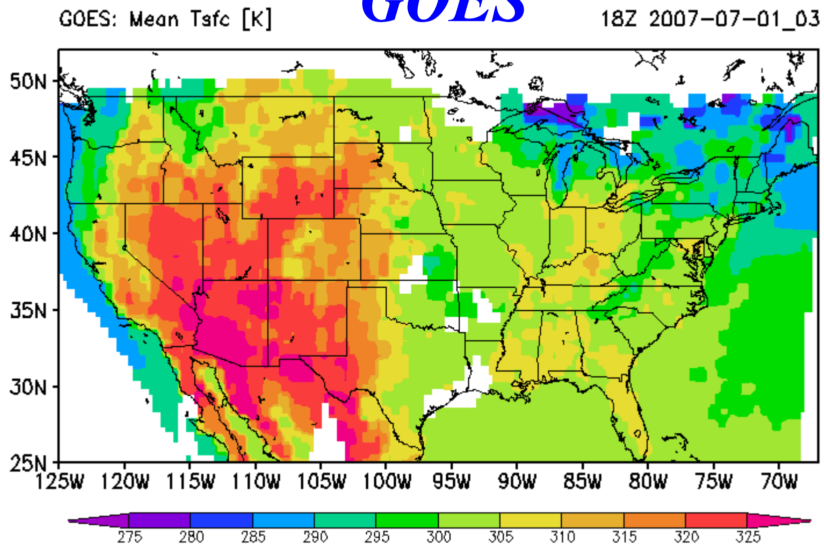
3-Day Mean



Mean 18Z LST [K] July 1 - 3, 2007

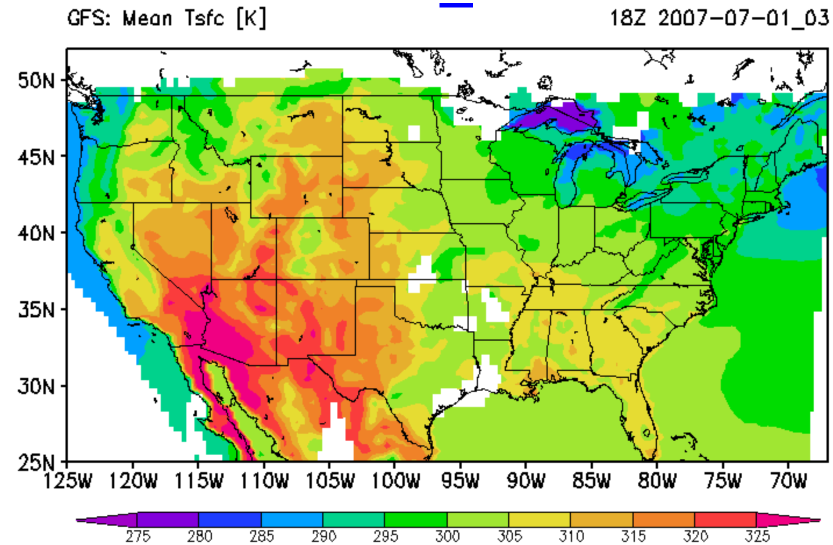
3-Day Mean

GOES

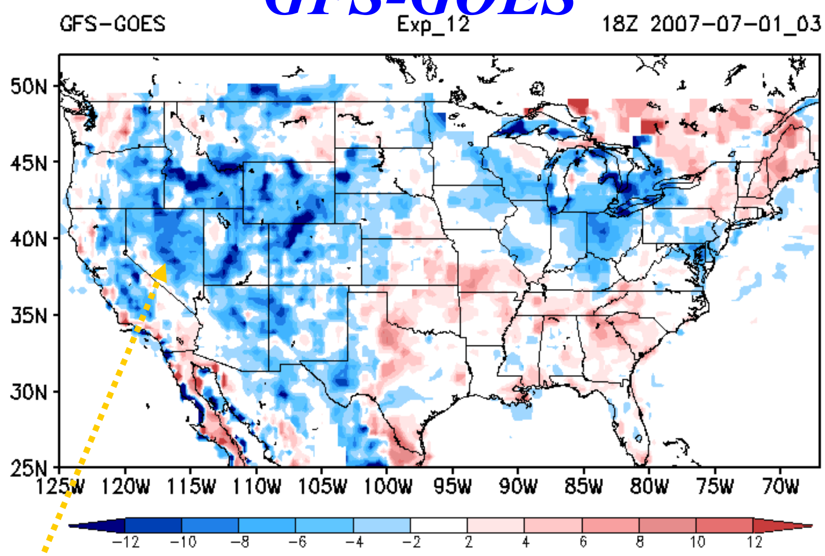


GFS_E12

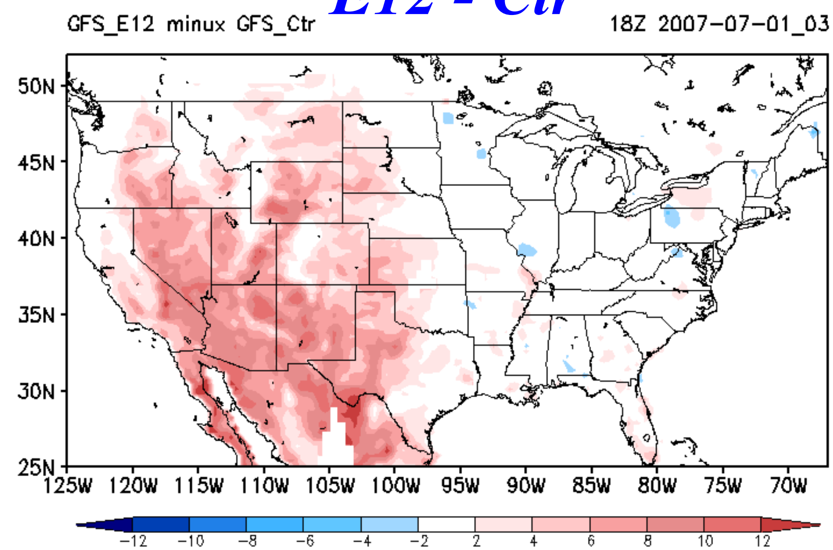
New Zot (X. Zeng)



GFS-GOES



E12 - Ctr

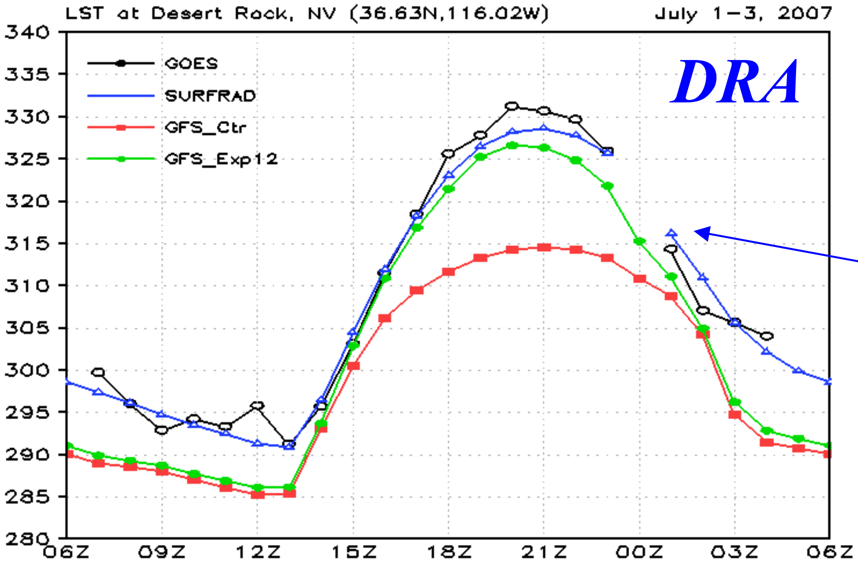


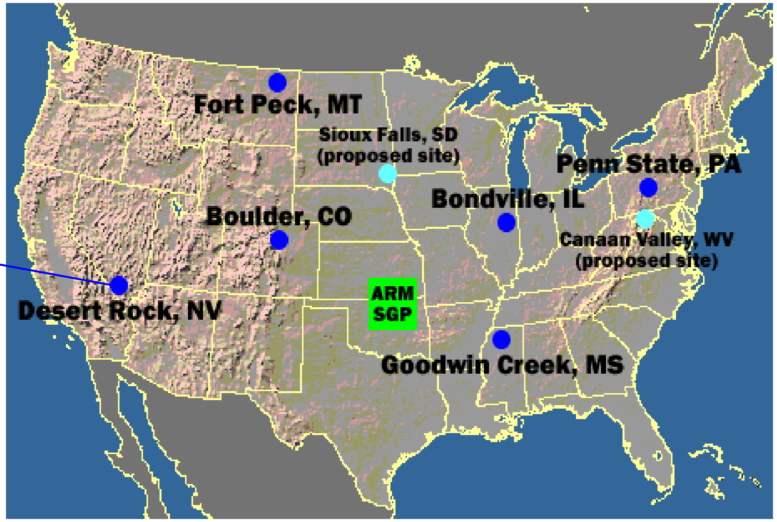
Large cold bias reduced significantly

LST [K] Verification at SURFRAD Site

3-Day Mean

Case: July 1-3, 2007





SURFRAD Network

Improved significantly during daytime!

Next slides show Tb simulation for NOAA-17 HIRS3 and NOAA-18 AMSU_A with GSI/CRTM

Experiment: Control and sensitivity runs

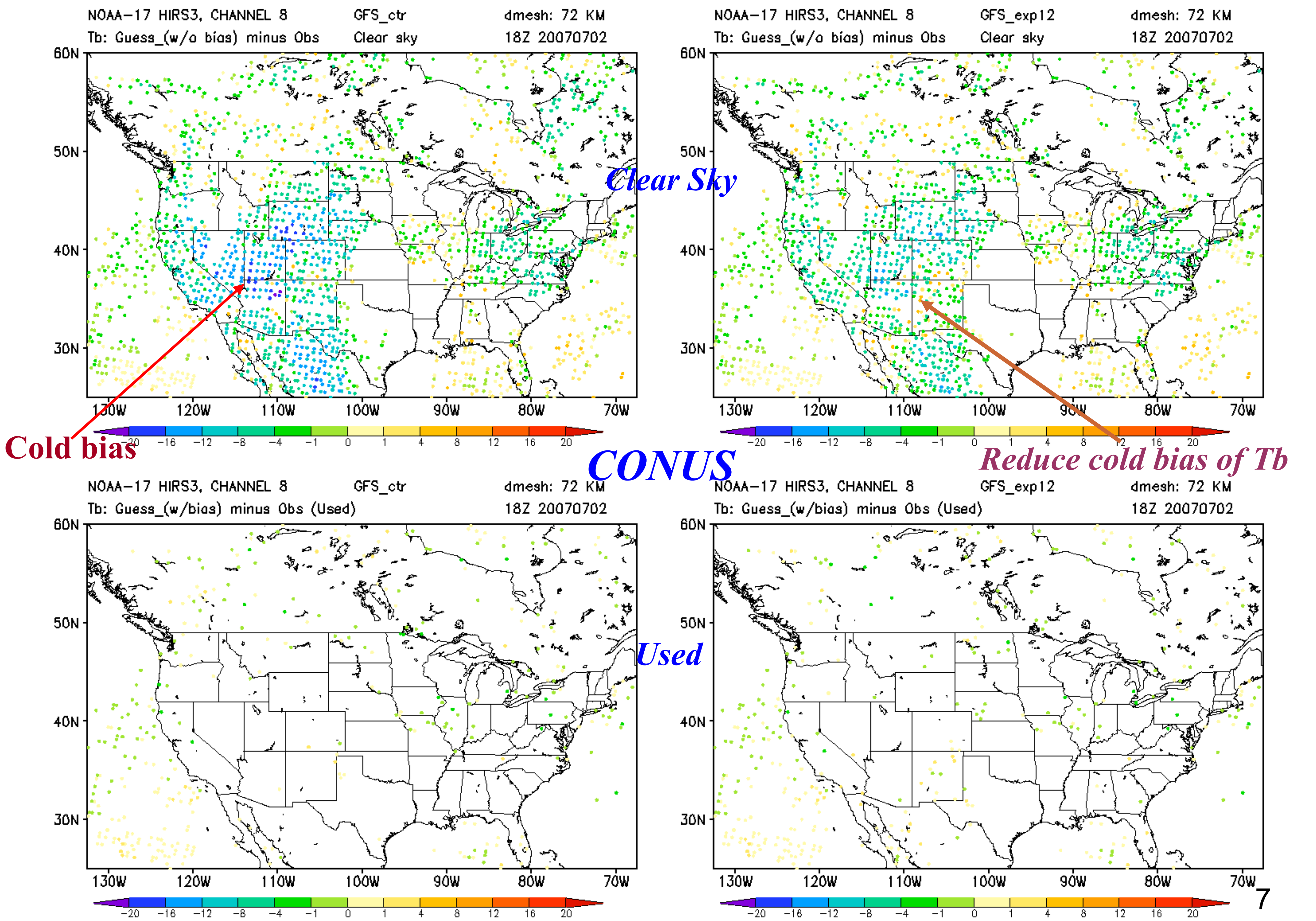
Case: Daytime, July 2, 2007

Area: CONUS / North Africa

Channel: HIRS3 Ch8; AMSU_A Ch15

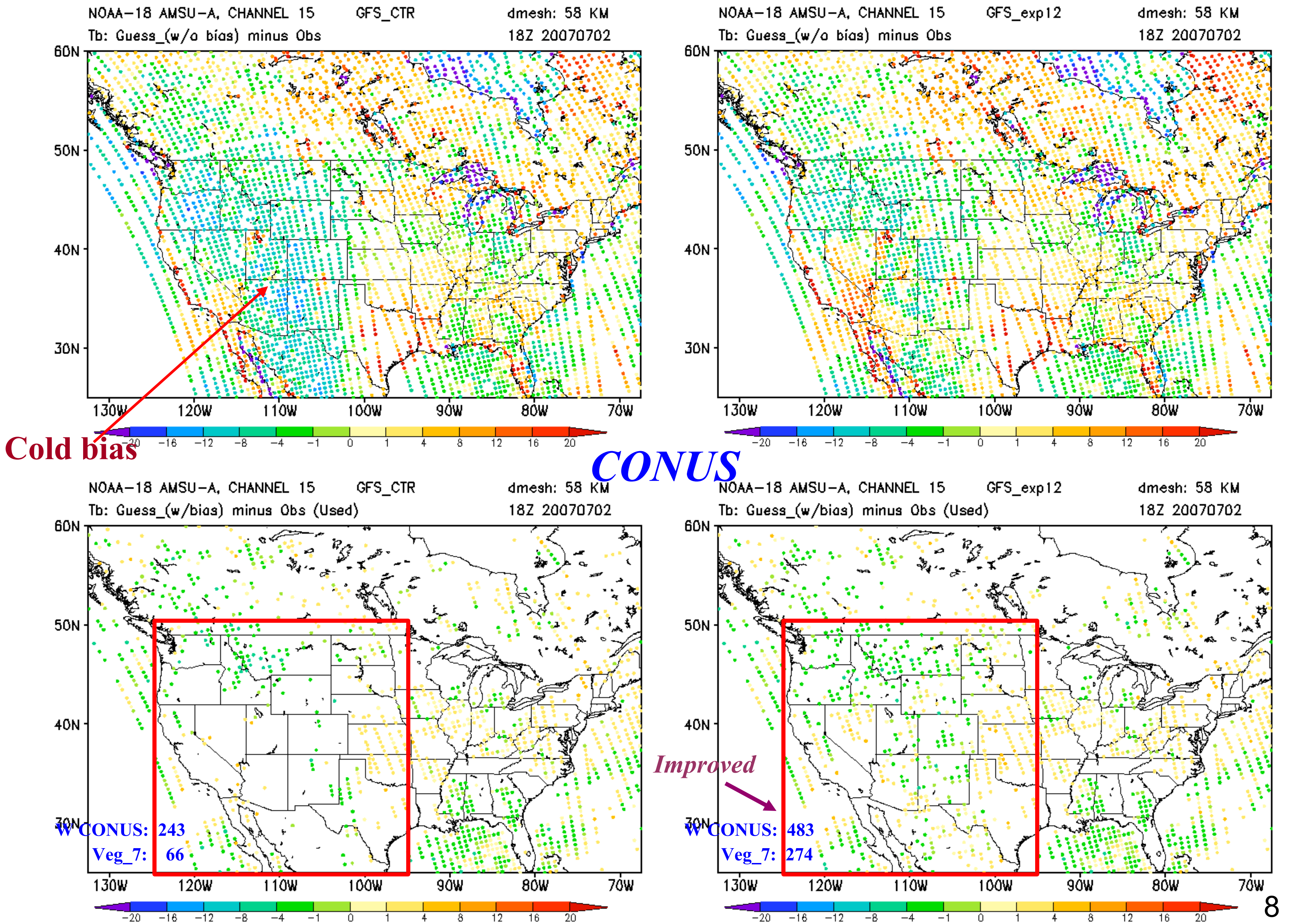
Tb Simulation from HIRS3: “w/o bias” vs “Used (w/bias)”

Case: 18Z, 20070702



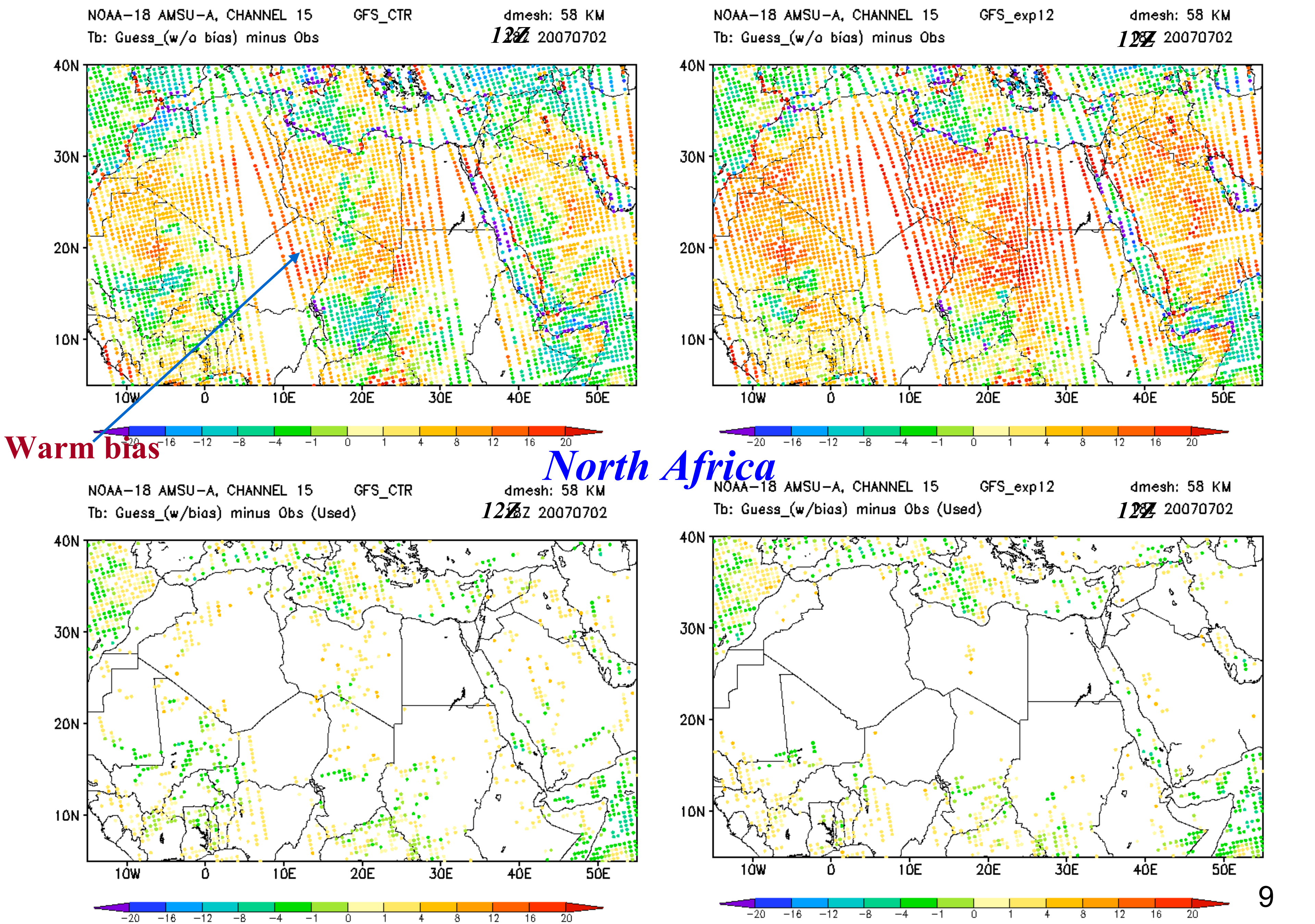
Tb Simulation from AMSU_A: "w/o bias" vs "Used (w/bias)"

Case: 18Z, 20070702

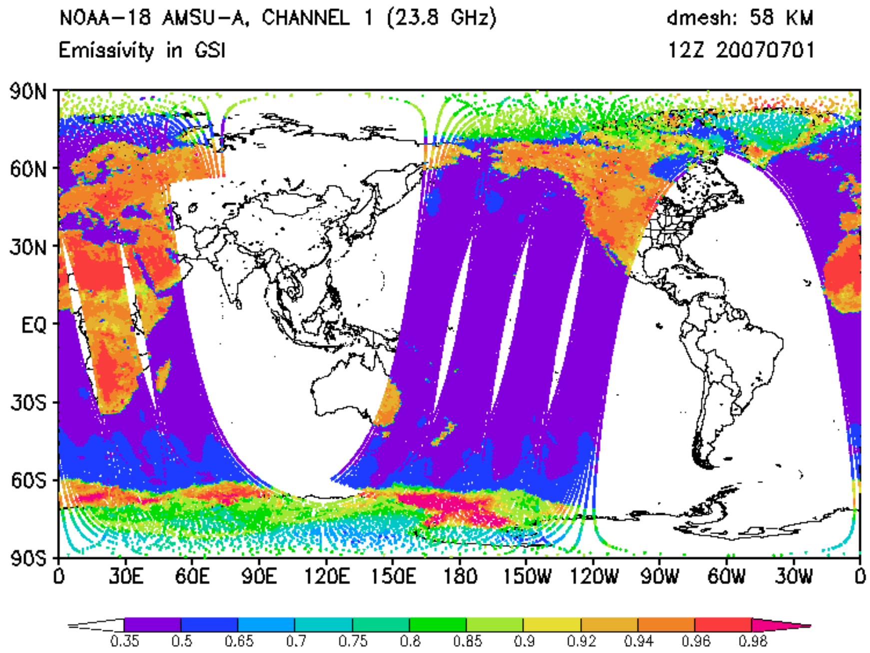


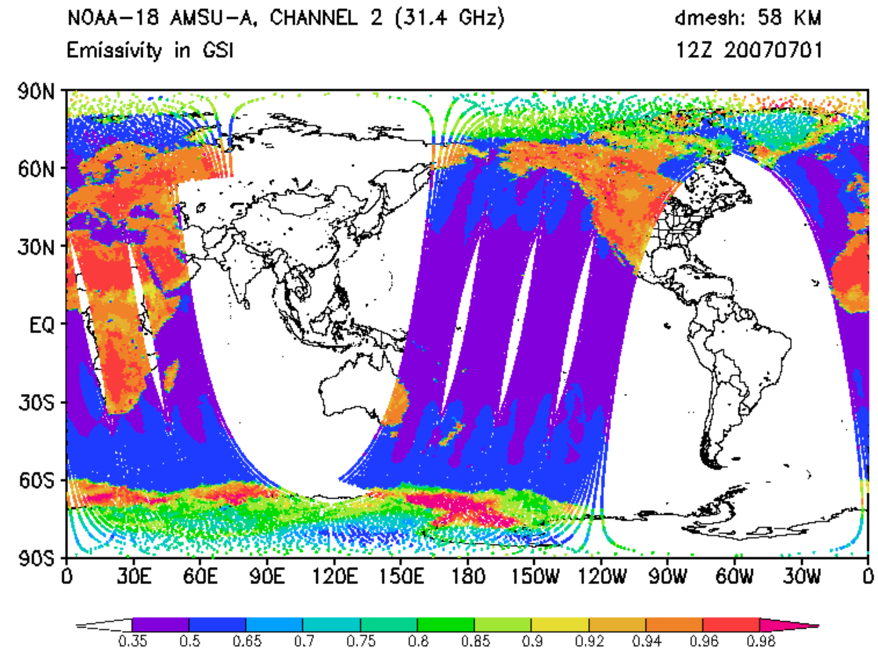
Tb Simulation from AMSU_A: "w/o bias" vs "Used (w/bias)"

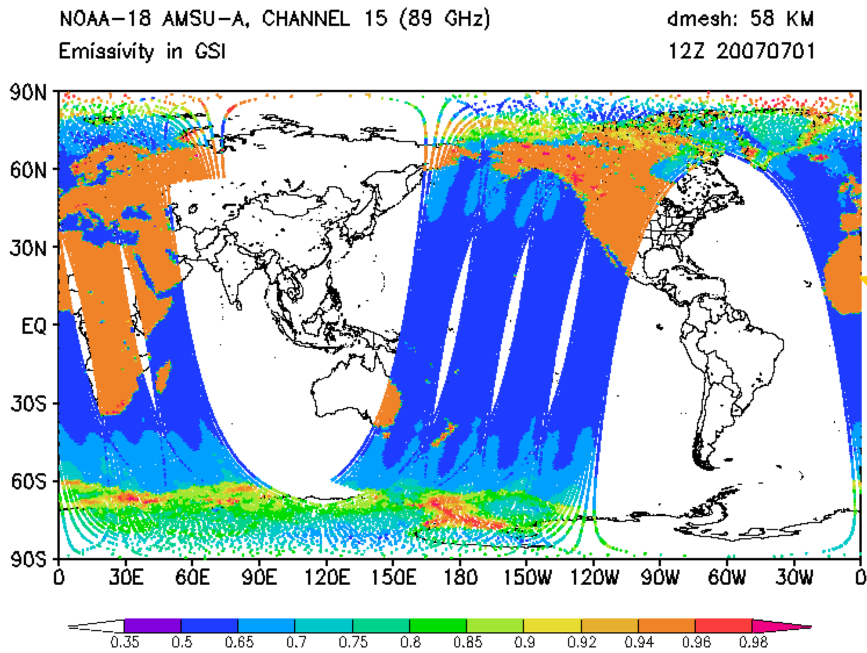
Case: 12Z, 20070702



Global Emissivity NOAA-18 AMSU_A: Ch1, Ch2 and Ch15 *Case: 12Z, 20070701*







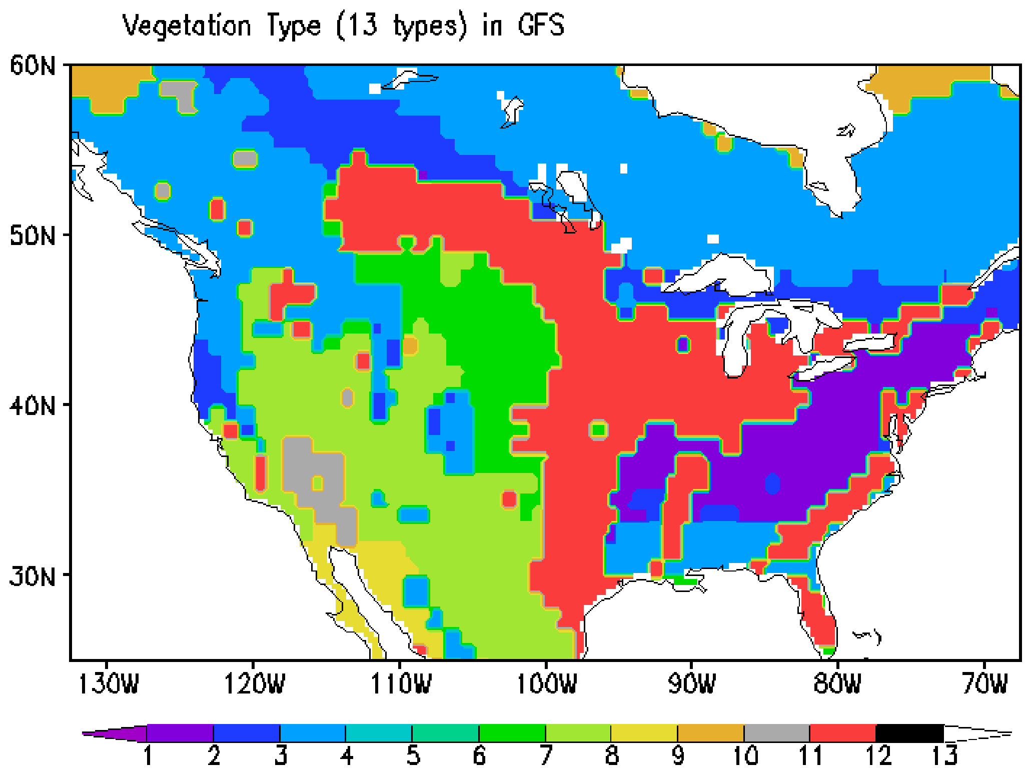
ε=0.95 ?

Summary

- **LST is important to remote sensing and data assimilation, and a critical factor to determine Tb for satellite surface sensitive channels.**
- **New Zot scheme can improve GFS LST significantly over arid region in warm season during daytime. Moreover, LST beyond arid region as well as other fields such as surface air temperature, whose biases are small in current Ops, are not much affected.**
- **Improved LST can also improve IR Tb simulation but quite different effects for MW.**
- **Further analysis shows there exists emissivity issue for MW over desert (bare soil) areas in CRTM. Improvement of emissivity calculation over desert is necessary in order to improve Tb simulation.**

Vegetation Type: CONUS

Backup



Vegetation Type

Veg_1: Broadleaf-Evergreen (Tropical Forest)

Veg_2: Broad-Deciduous Trees

Veg_3: Broadleaf and Needleleaf Trees

Veg_4: Needleleaf-Evergreen Trees

Veg_5: Needleleaf-Deciduous Trees

Veg_6: Broadleaf Trees with Ground Cover

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

Veg_11: Bare Soil

Veg_12: Cultivations

Veg_13: Glacial

CRTM Working Group Meeting
July 31, 2008

Paul van Delst, JCSDA/EMC/SAIC

- Subversion server
- Updated microwave sea surface emissivity model

Subversion Server

- Hardware (ordered months ago, still waiting for delivery)
  1. Dell PowerEdge 2950 (2) - one primary and one backup server
  2. Dell PowerVault MD1000 (2) - one for primary and backup server storage
  3. Current Subversion server
- Script to copy all data to the backup server after each commit operation.
- Incremental backups nightly. Full backups weekly. Month of backups kept online (and possibly written to HPSS on IBM supercomputers).
- A web based form will be created that will be open to the public to request a User ID for access.
- The current subversion server will be used for additional web services such as a web forum, wiki, etc, since the server is not a vital operation to the Subversion systems.

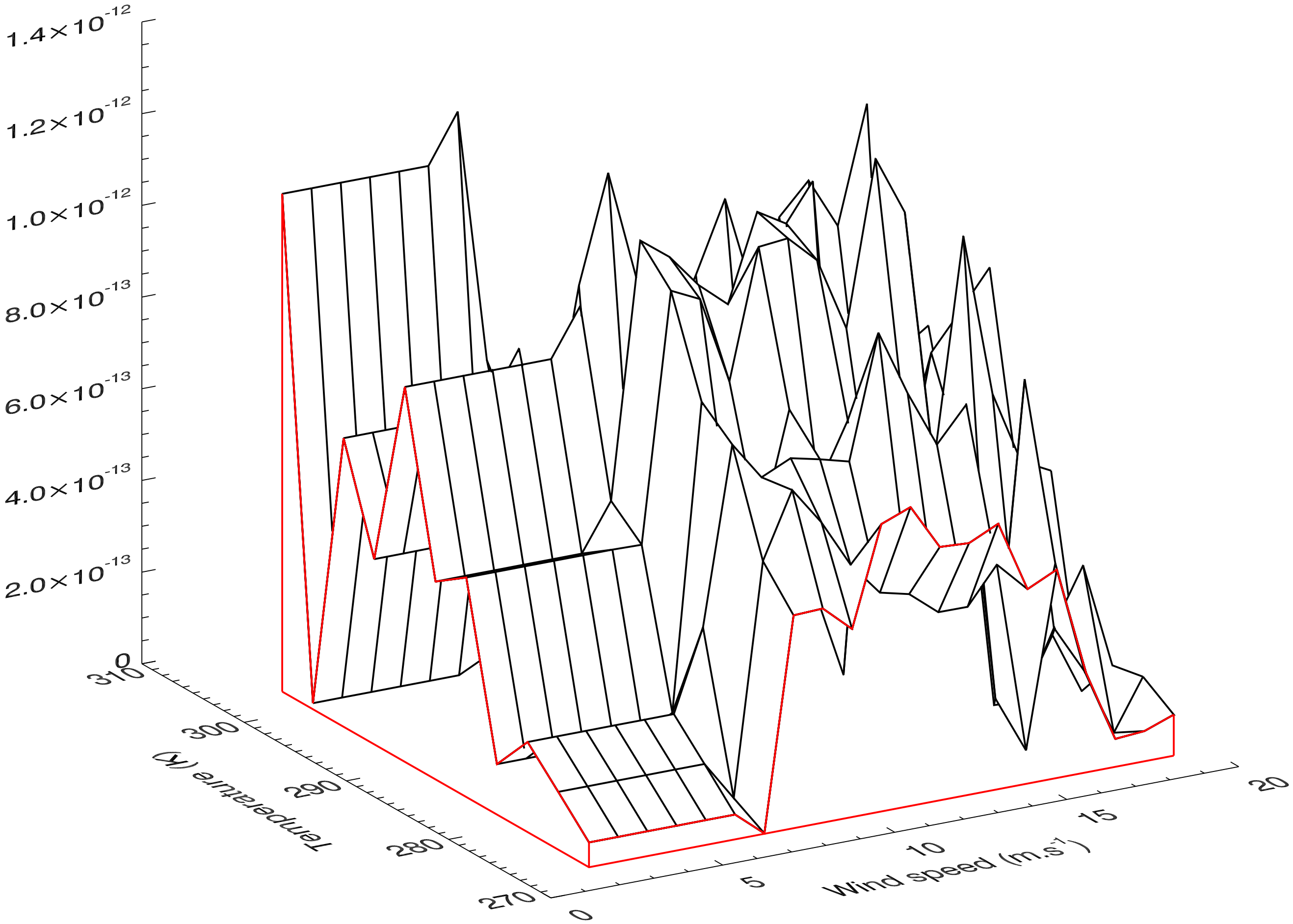
Updated microwave sea surface emissivity model

- For $f < 20$GHz, M. Kazumori's model. For $f \geq 20$GHz, Fastem3.
- Fixed some potential bugs (e.g. complex conjugates), standardised constants (e.g. permittivity in vaccum) across permittivity models.
- FWD/TL tests passed, but no objective method. Visual inspection of results required. Ocean height variance issue.
- TL/AD tests passed to within numerical precision.
- Separate module created for permittivity models. Also ran through their own set of FWD/TL and TL/AD tests.
  1. Guillou *et al.*, 1998
  2. Ellison *et al.*, 2003 (no salinity parameterisation)
- Separate module created for Fresnel reflectivity. Also ran through their own set of FWD/TL and TL/AD tests.

Forward/tangent-linear test result

f=7GHz, S=35ppt, θ=30°

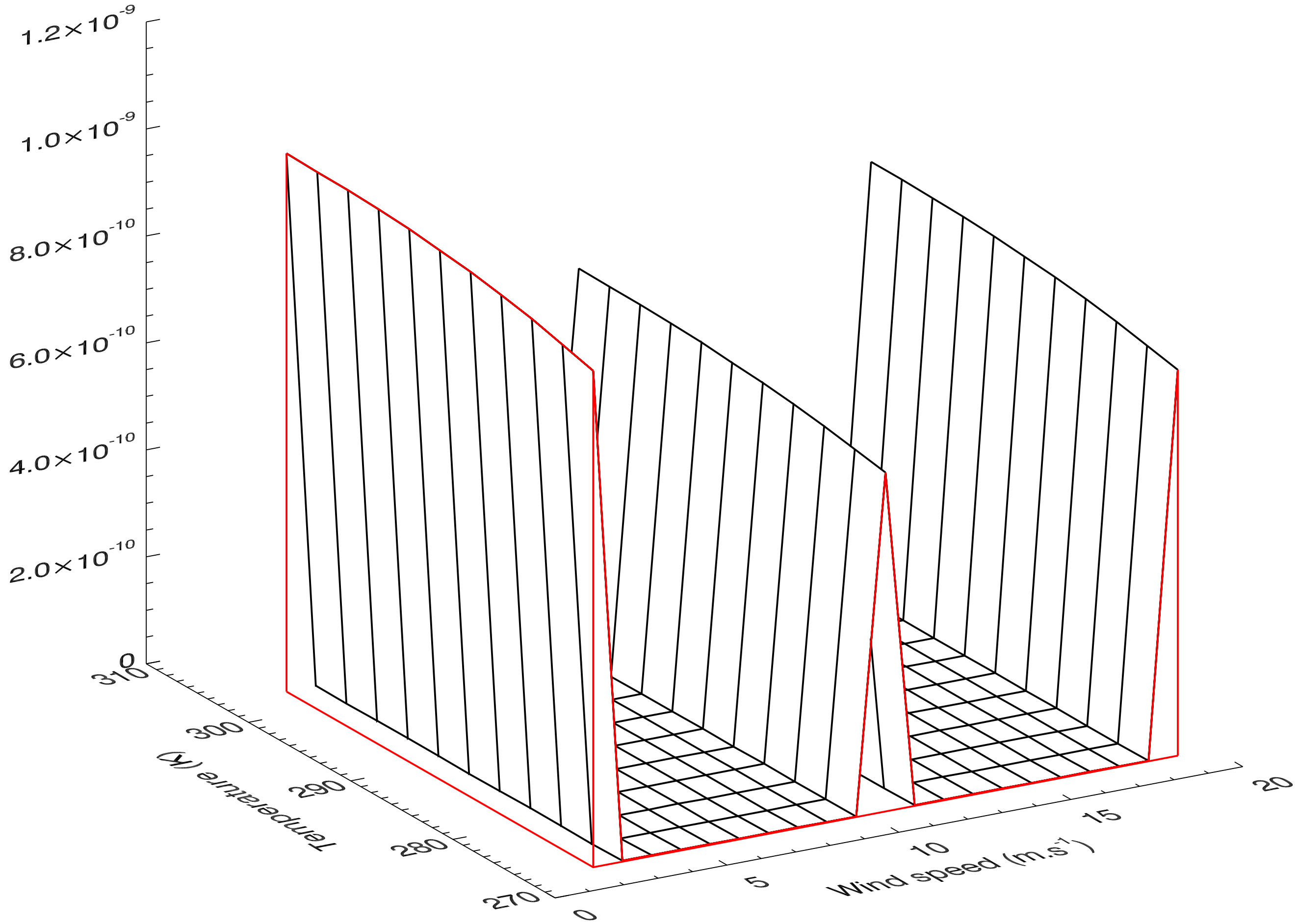
$$|\Delta e_v - \delta e_v|$$



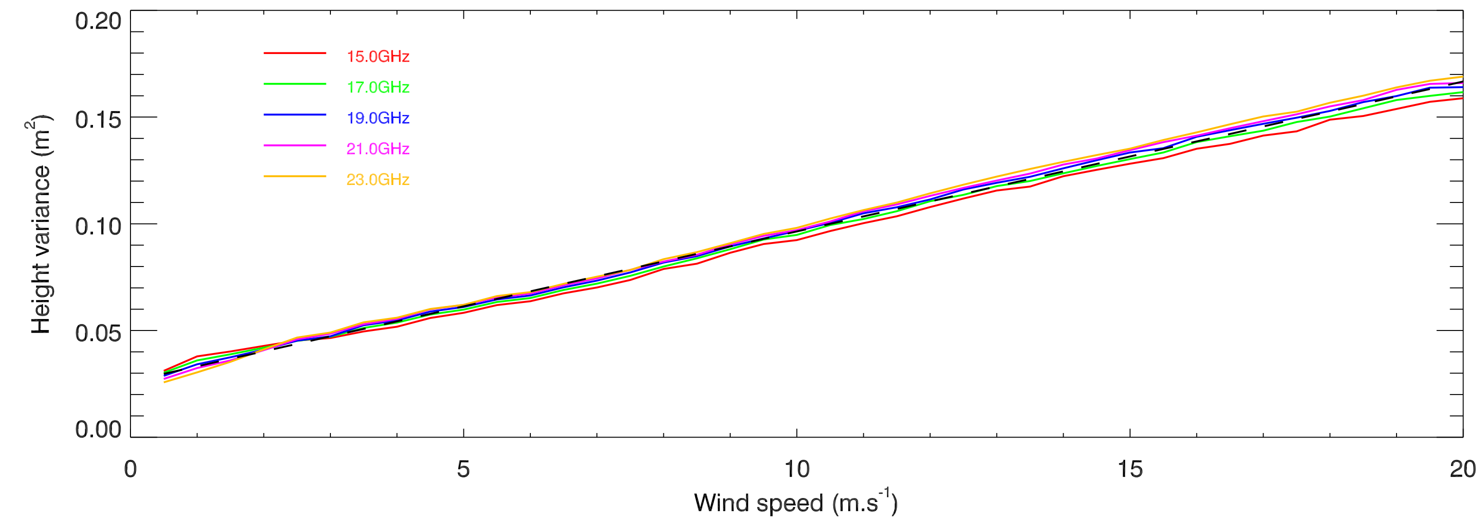
Forward/tangent-linear test result

f=19GHz, S=35ppt, θ=30°

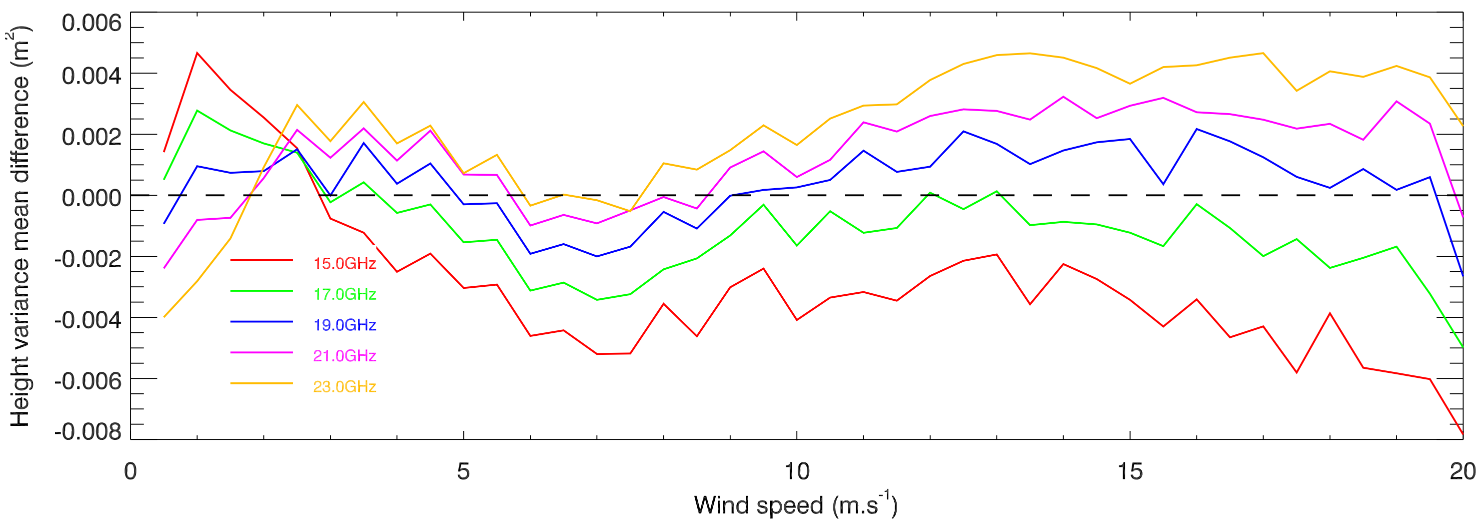
$$|\Delta e_v - \delta e_v|$$



Ocean height variance $(4k^2\zeta_R^2)$ wind speed spectra



Ocean height variance $(4k^2\zeta_R^2)$ mean difference wind speed spectra

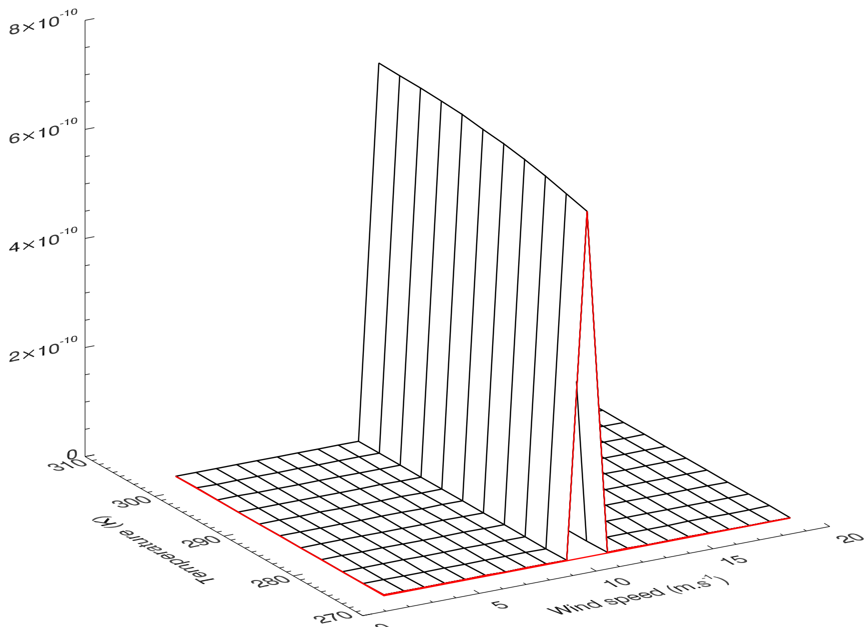


Forward/tangent-linear test result

f=19GHz, S=35ppt, θ=30°

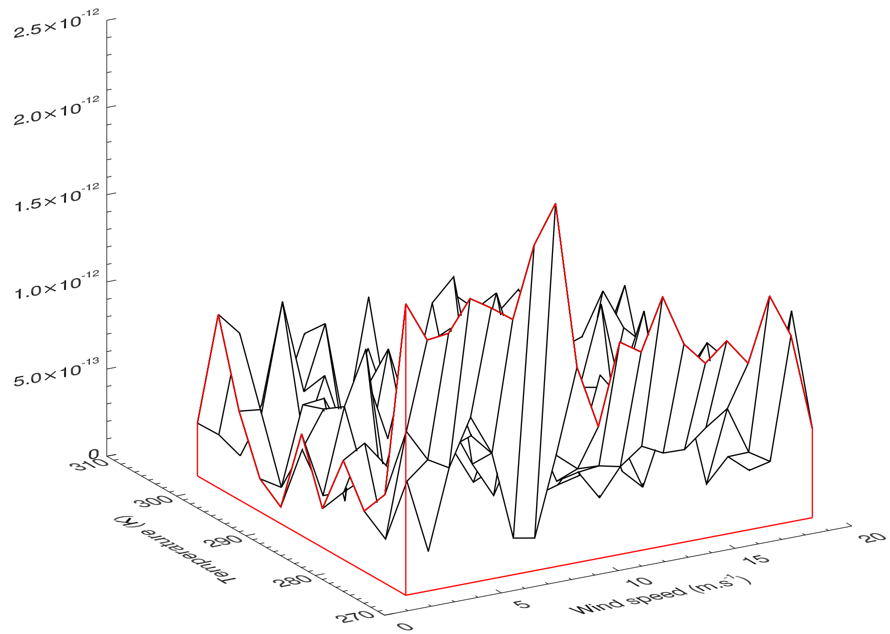
Wind speed test gridpoint at

LUT hingepoint of 10.5ms^{-1}



No wind speed test gridpoint

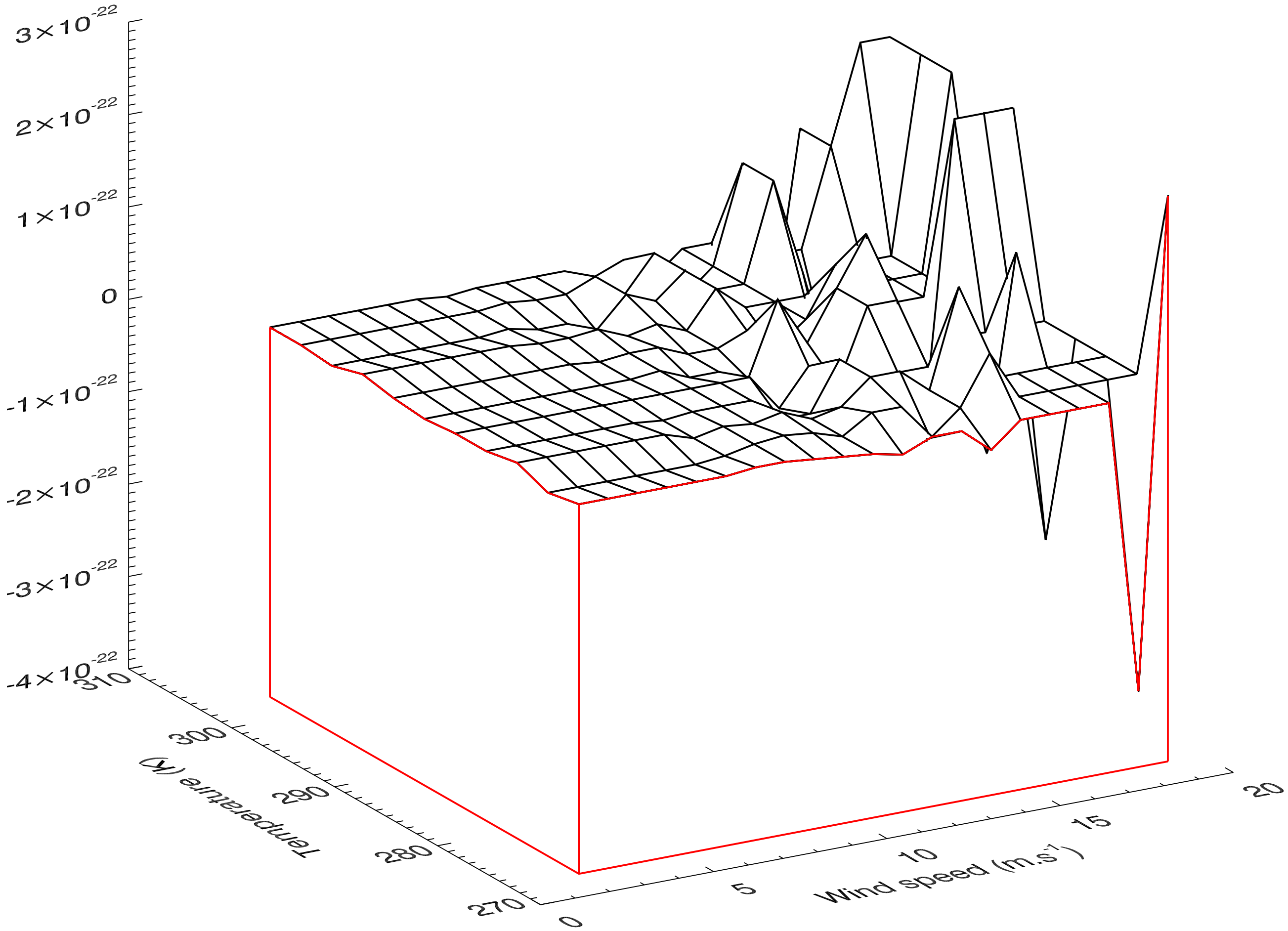
corresponds with LUT hingepoints



Tangent-linear/adjoint test result

f=7GHz, S=35ppt, θ=30°

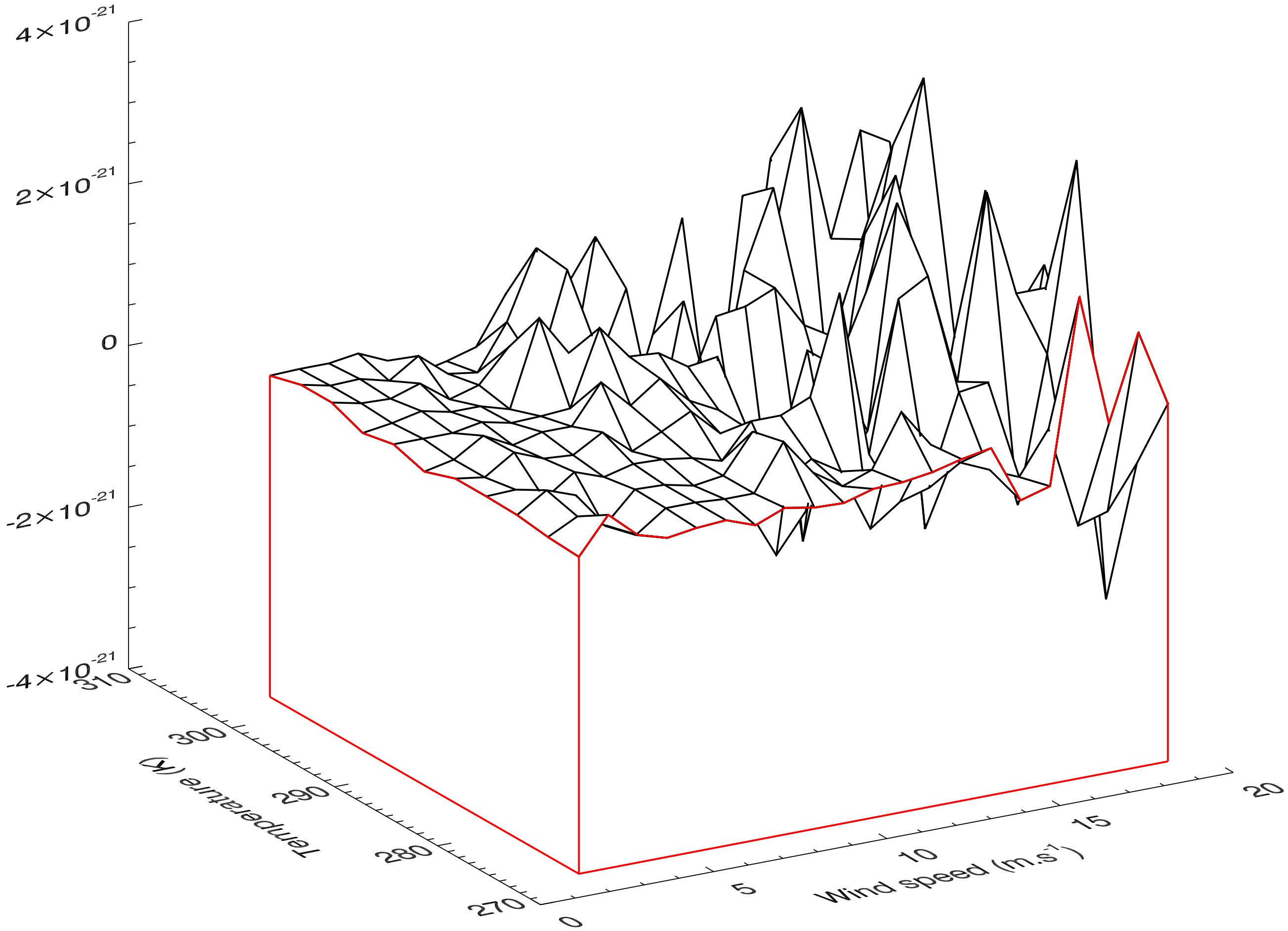
$$\mathbf{TL}^T\mathbf{TL} - \delta\mathbf{x}^T\mathbf{AD}(TL)$$



Tangent-linear/adjoint test result

f=19GHz, S=35ppt, θ=30°

$$\mathbf{TL}^T\mathbf{TL} - \delta\mathbf{x}^T\mathbf{AD}(TL)$$



Systematic Differences When Running LBLRTM

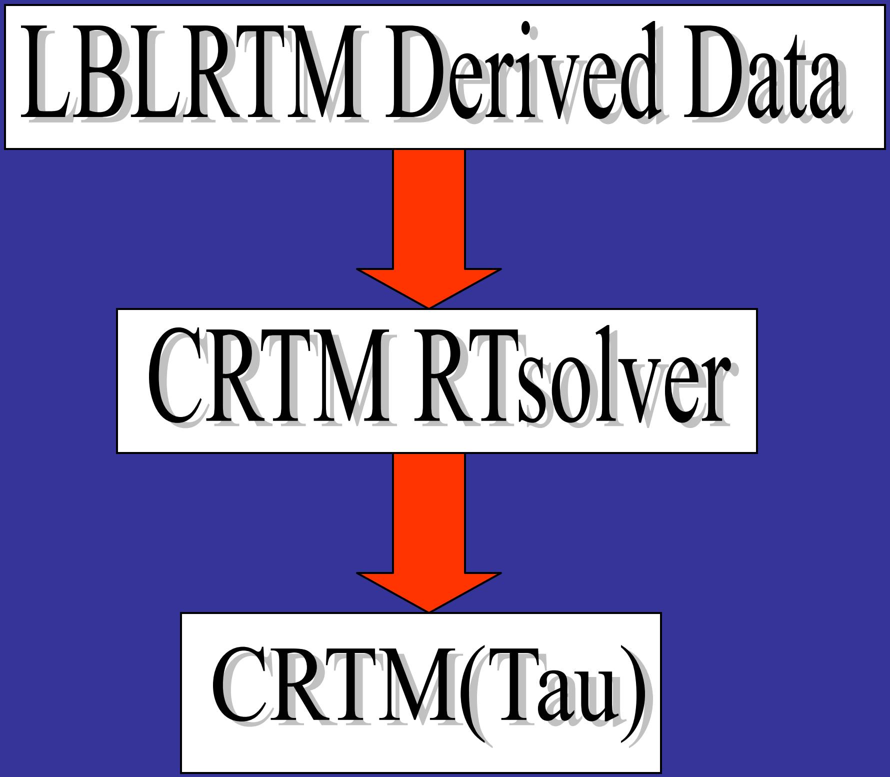
Presented by: David N. Groff
(SAIC)

Background

- Working on project to compare components of CRTM with components of LBLDIS RT model

- For clear sky these components are the radiative transfer solvers and the methods for handling gas absorption.

Obtaining Component Differences



CRTM(Tau) - LBLDIS = RTsolver Difference

CRTM(Tau) - CRTM = Gas Absorption Difference

Specifications for Current LBLRTM Transmittances

- Geometry set to nadir

- 3 band ranges:

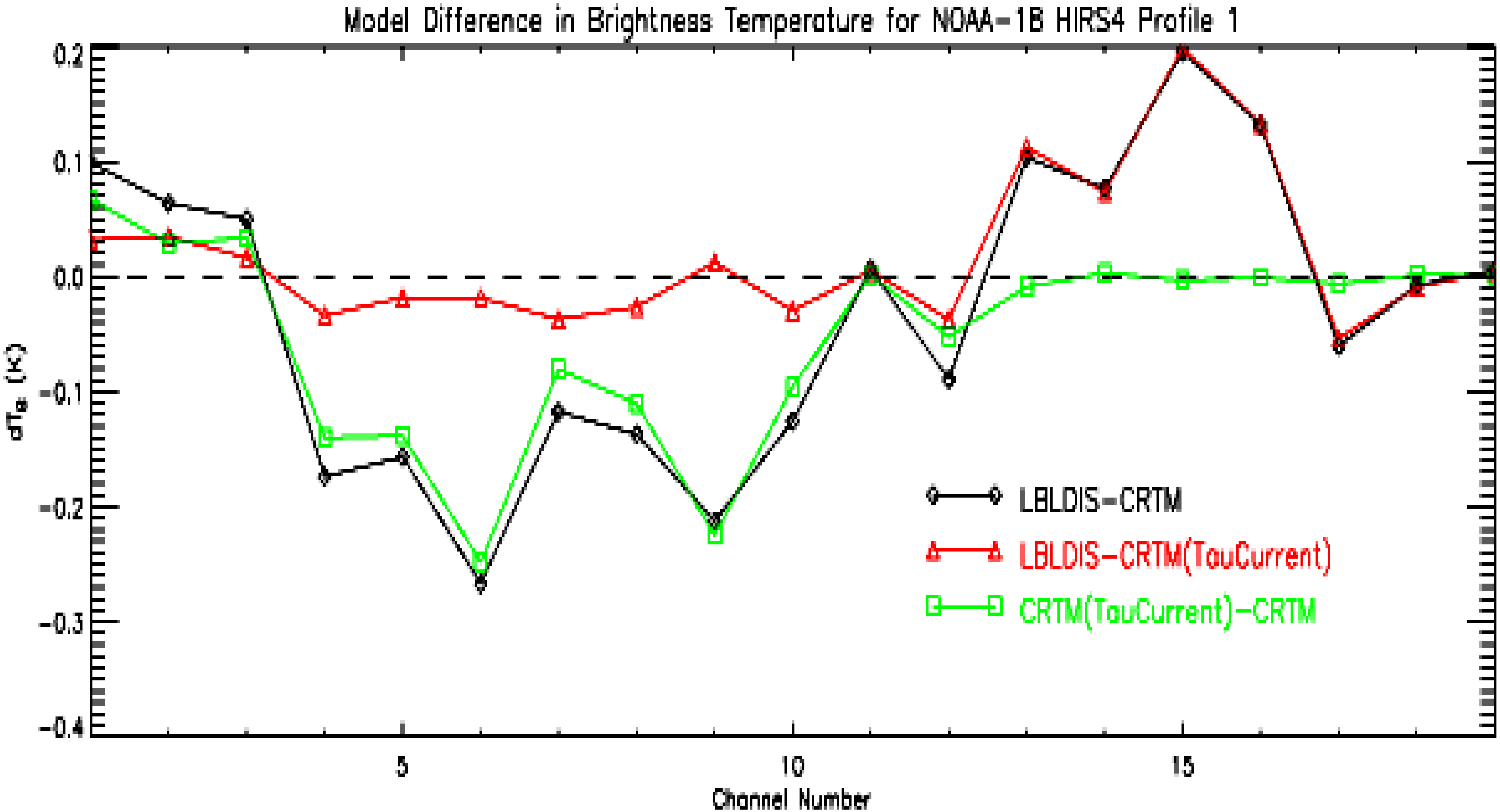
  1) 649-1101 cm^-1

  2) 1299-1601 cm^-1

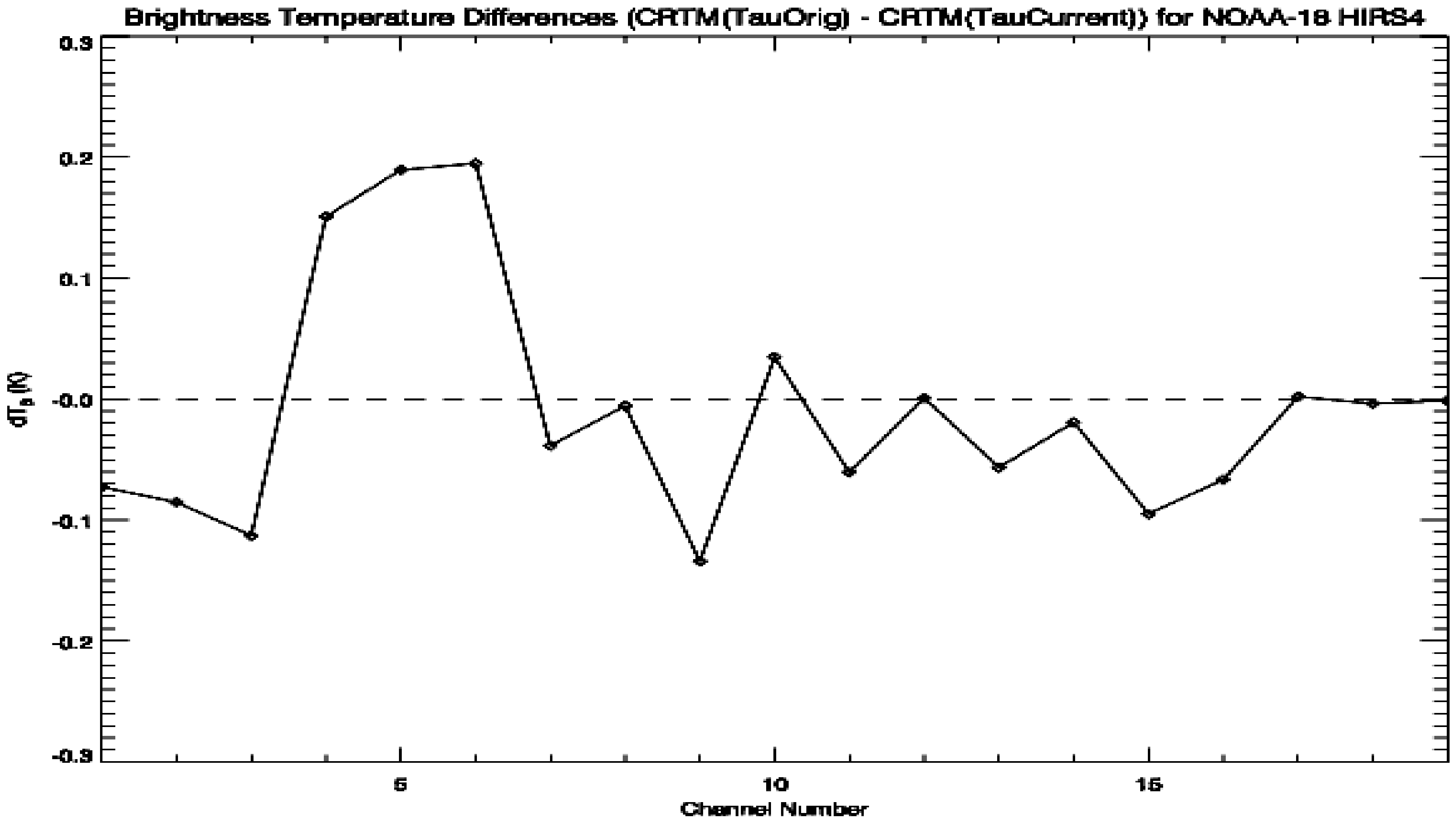
  3) 2099-2801 cm^-1

- For the scan merge: HWHM = 0.05 cm^-1

Dependent Set Results



CRTM(TauOrig) - CRTM(TauCurrent)



Why The Difference?

- LBLRTM bandwidth for original:

  (10 bands in blocks of 250 cm^-1 used to span spectrum from 499 cm^-1 to 3001cm^-1)

- Scan merge for original:

  (HWHM was set to 0.1 cm^-1)

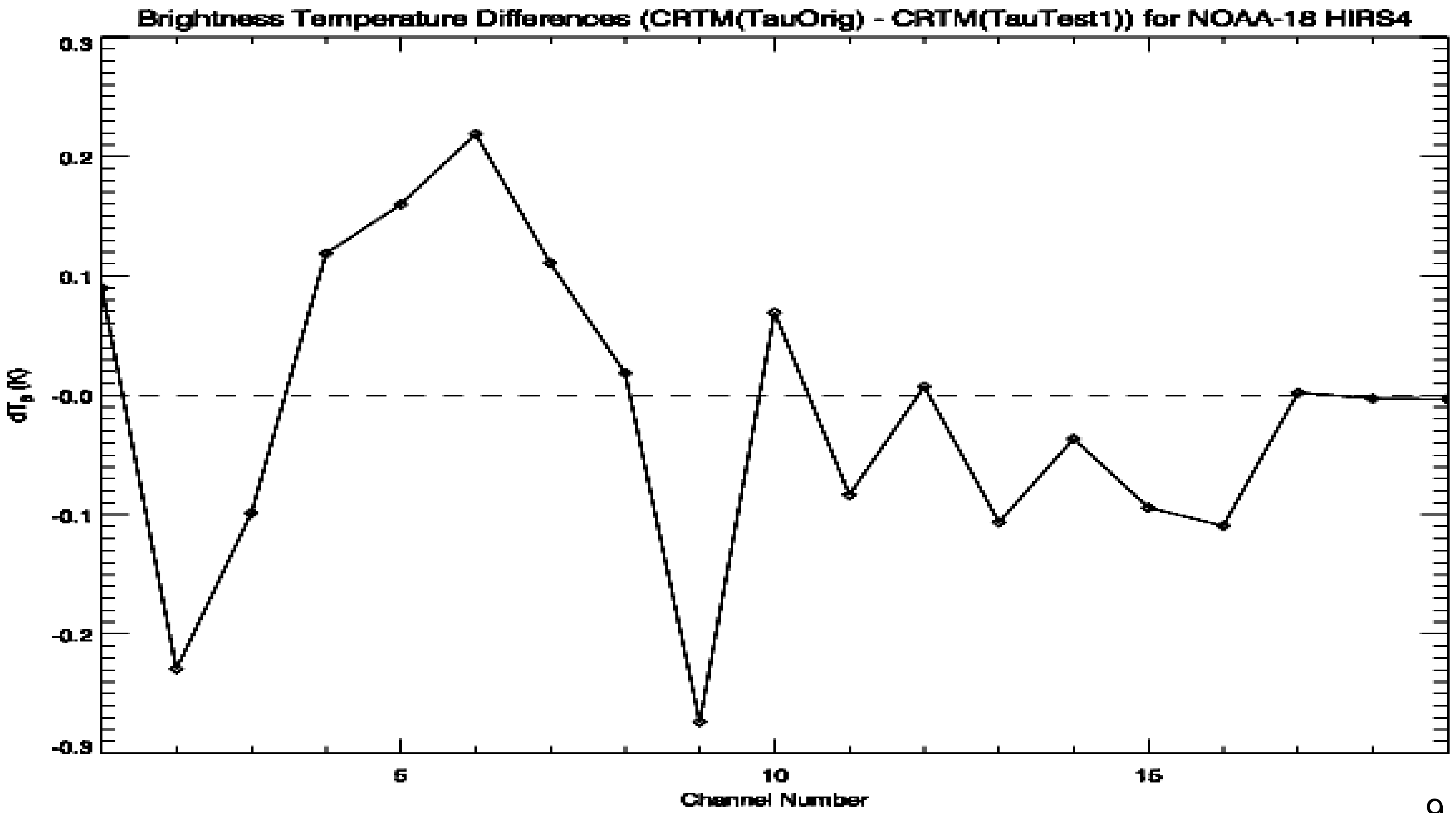
Tests

- Test1: HWHM = 0.1 cm^-1, 3 bandwidths

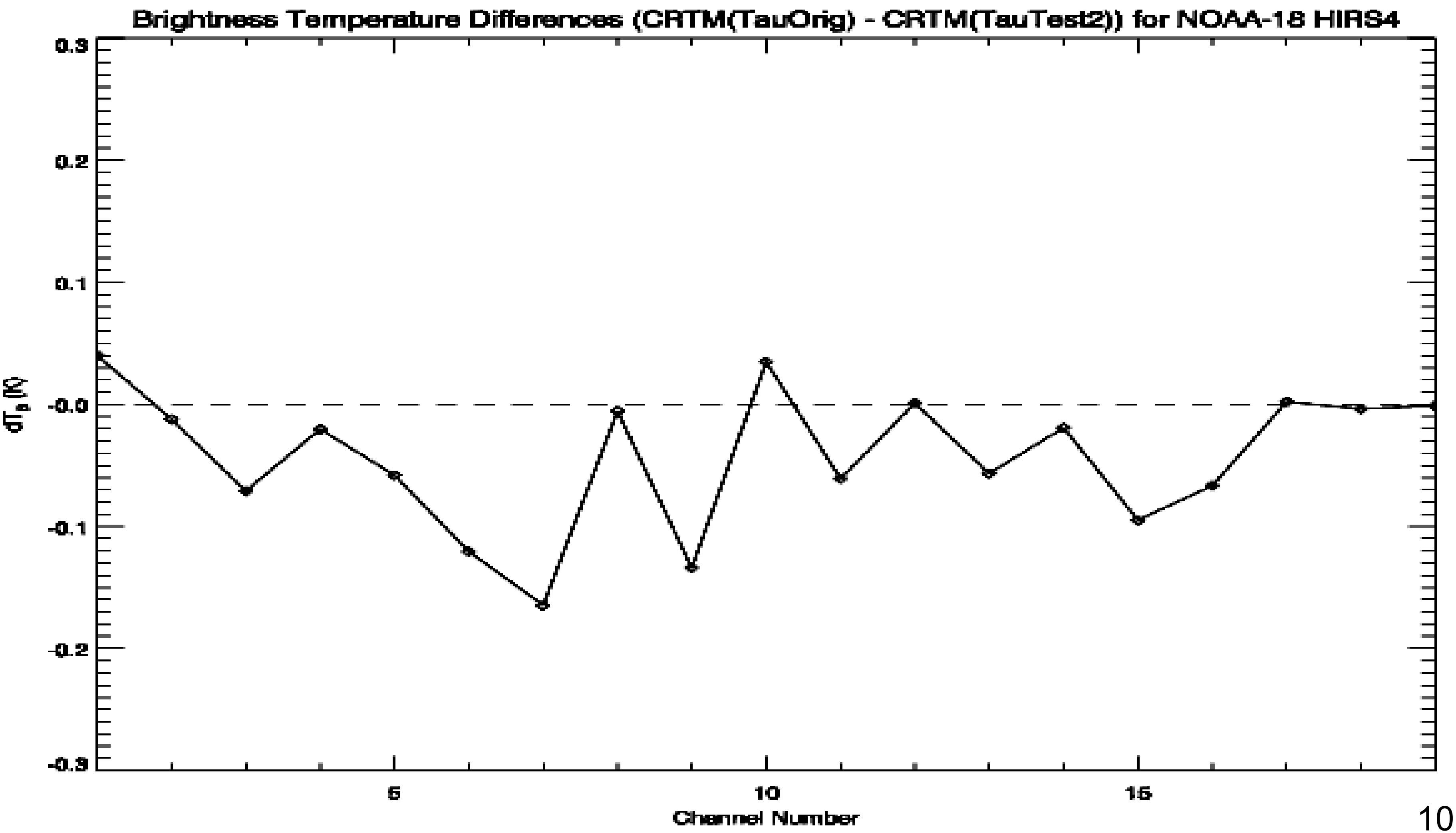
- Test2: HWMH = 0.05 cm^-1, 10 bandwidths

- Test3: HWHM = 0.1 cm^-1, 10 bandwidths

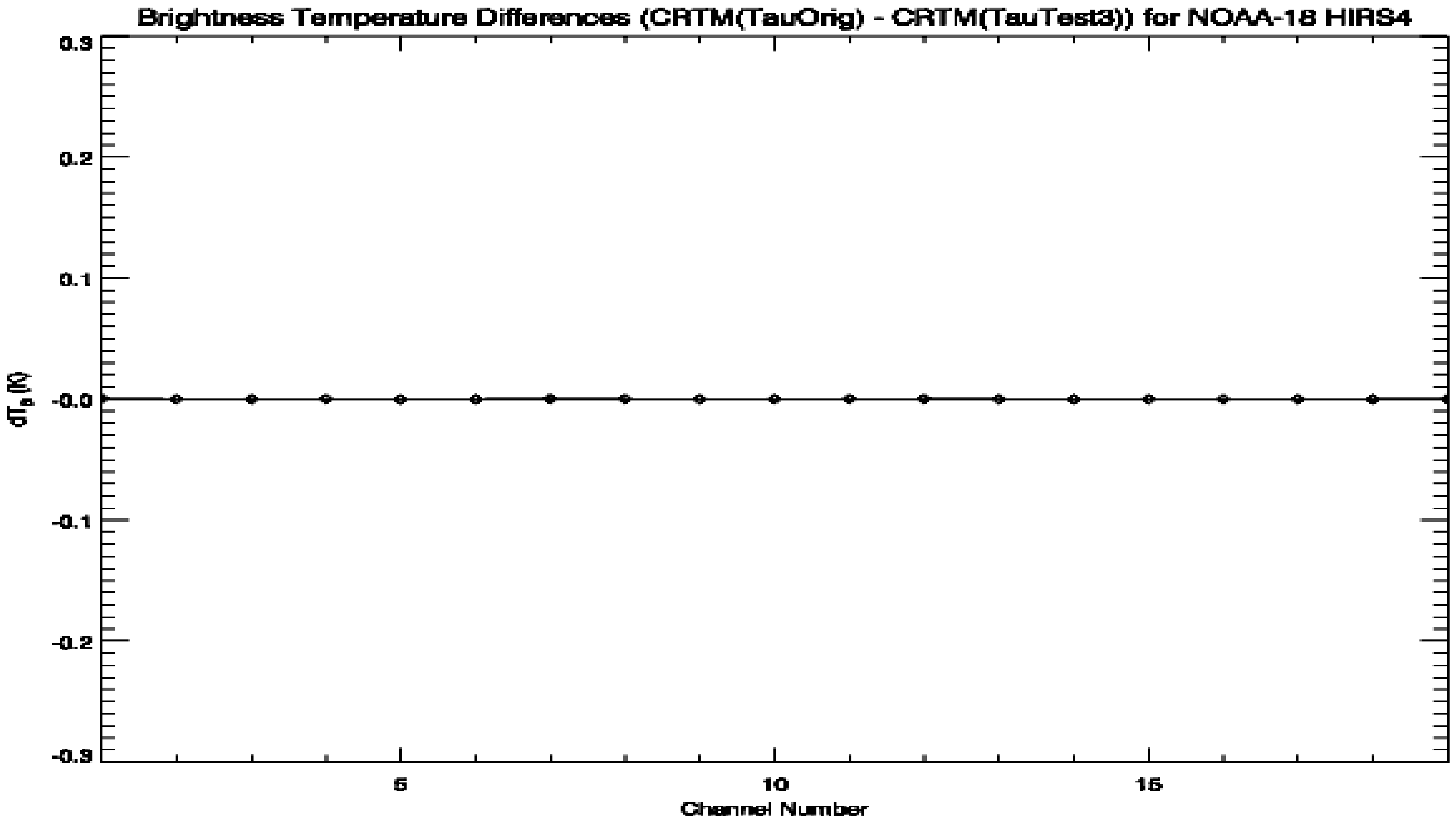
CRTM(TauOrig) - CRTM(TauTest1)

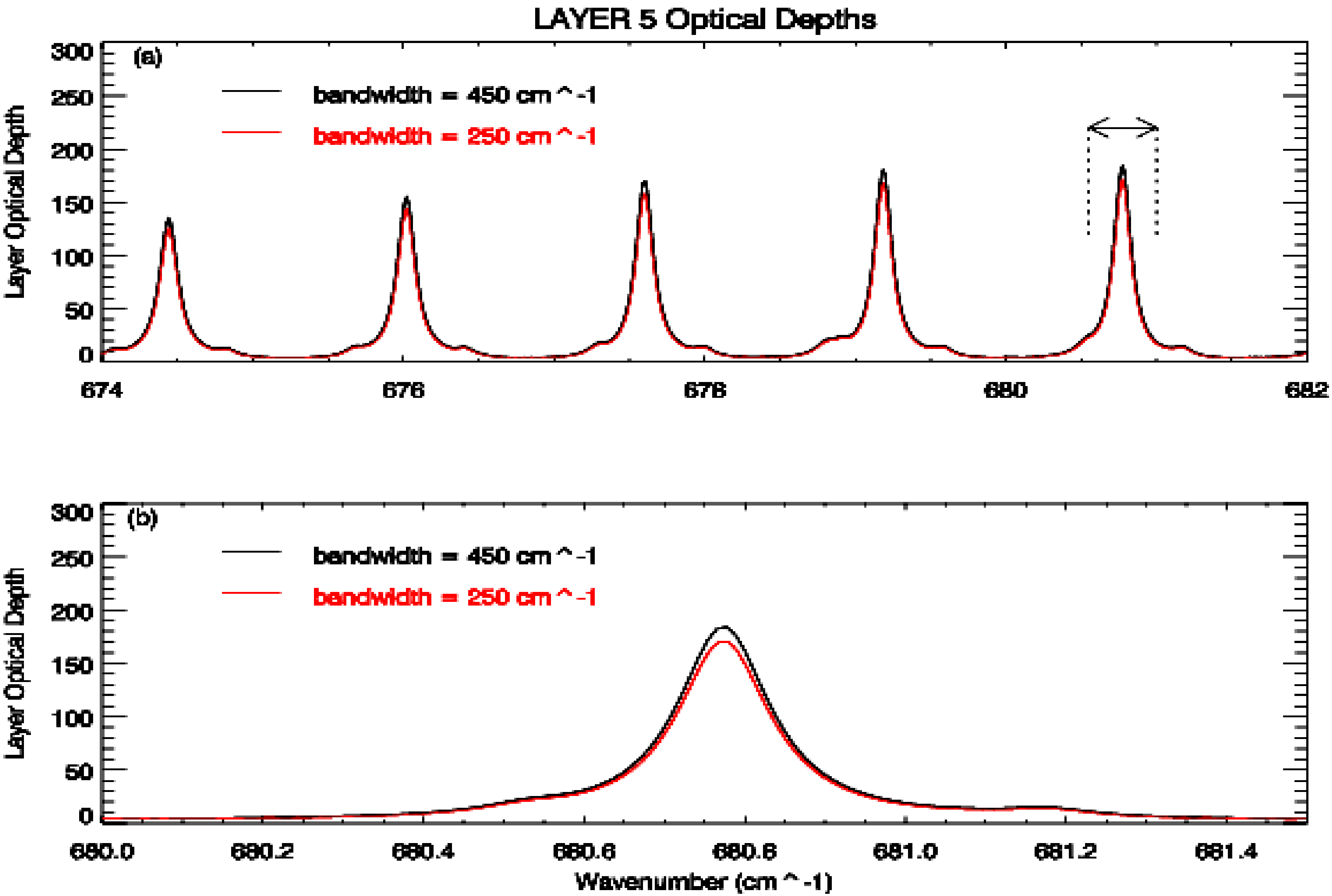


CRTM(TauOrig) - CRTM(TauTest2)



CRTM(TauOrig) - CRTM(TauTest3)





LAYER 5 Optical Depths
(a)
bandwidth = 450 cm ^ -1
bandwidth = 250 cm ^ -1
Layer Optical Depth
0
50
100
150
200
250
300
674
676
678
680
682
(b)
bandwidth = 450 cm ^ -1
bandwidth = 250 cm ^ -1
Layer Optical Depth
680.0
680.2
680.4
680.6
680.8
681.0
681.2
681.4
Wavenumber (cm ^ -1)

Conclusion

- LBLRTM optical depth calculations are dependent on bandwidth

Microwave Emissivity Model Update

Banghua Yan[1], Fuzhong Weng[2], John Derber[3]

1. Joint Center for Satellite Data Assimilation
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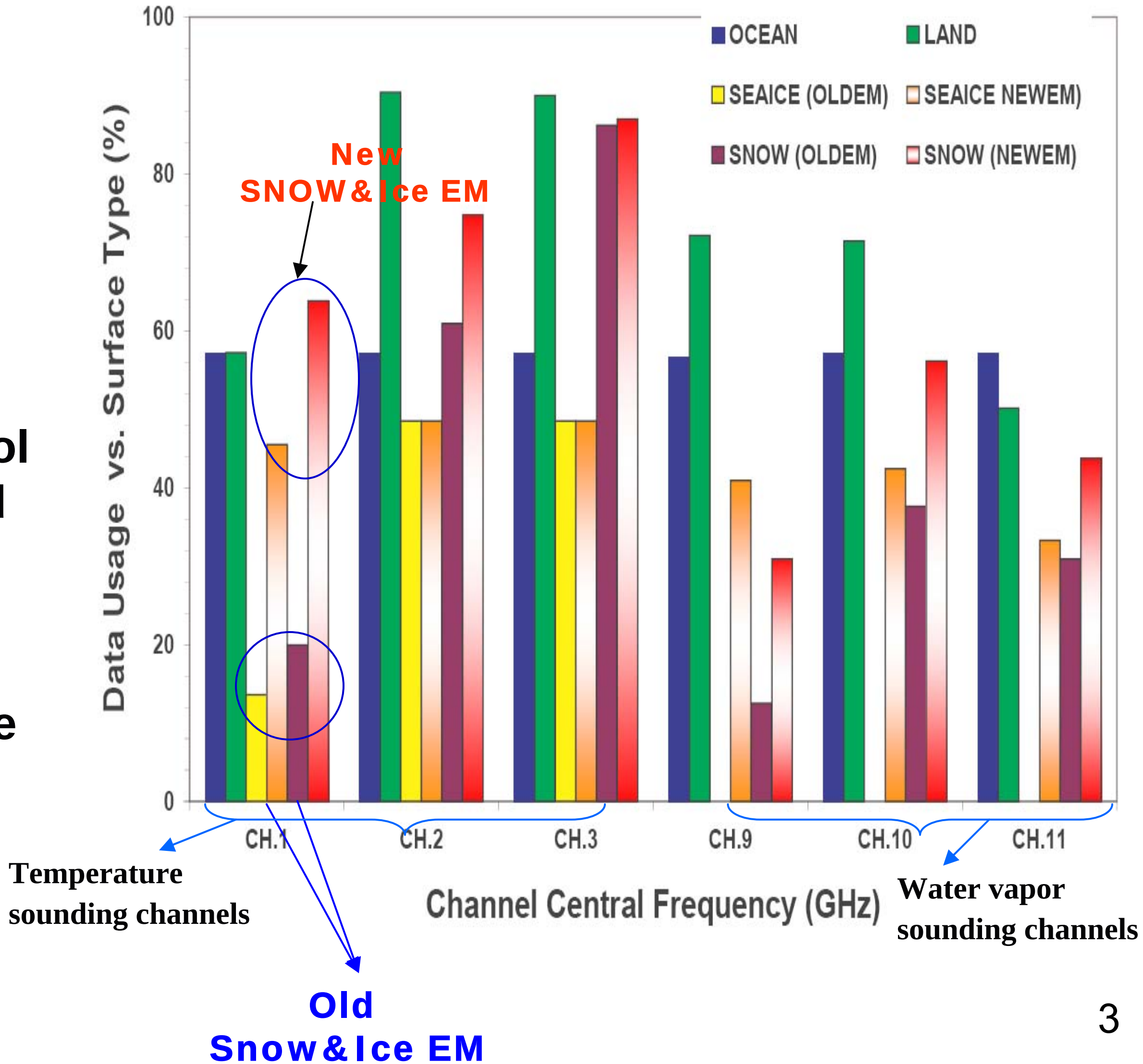
3rd CRTM Tel-conference, July 31, 2008

Part One: Applied the AMSU snow and sea ice emissivity empirical algorithms to MHS and SSMIS

Impact of Improved Snow and Sea Ice Emissivity at SSMIS Channels on F16 SSMIS Data Usage

- Several SSMIS sounding channels are sensitive to highly variable emissivity especially over snow and sea ice conditions
- Only about 20% SSMIS data passed quality control in NCEP/GSI using the old models
- Around 50% SSMIS data passed quality control due to improved SSMIS snow and sea ice emissivity simulations



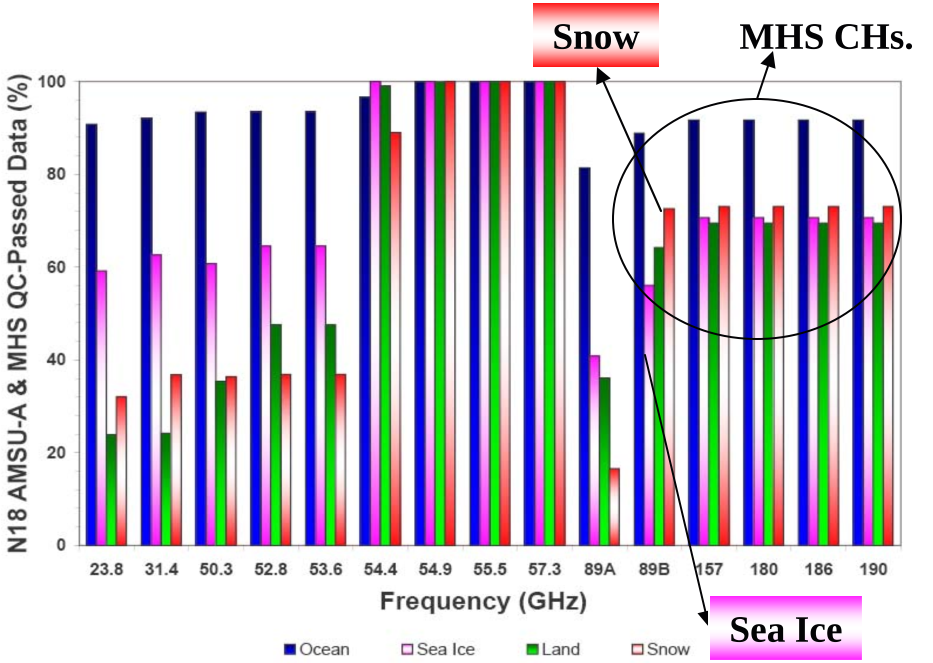
Improved Snow and Sea Ice Emissivity Simulations Increases use of MHS Data in NCEP GFS

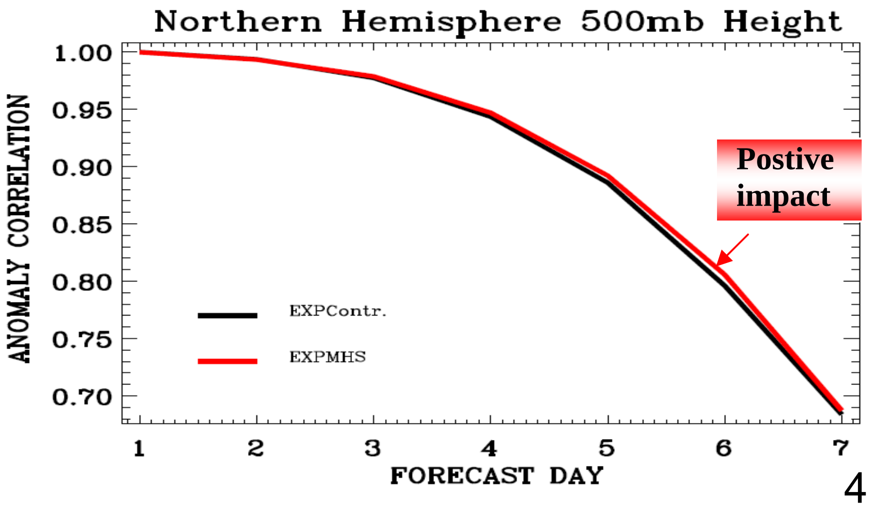
- MHS, especially over snow and sea ice conditions, can be highly affected by variable emissivity

- Currently, only 20-30% MHS data at some sounding channels 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 positive

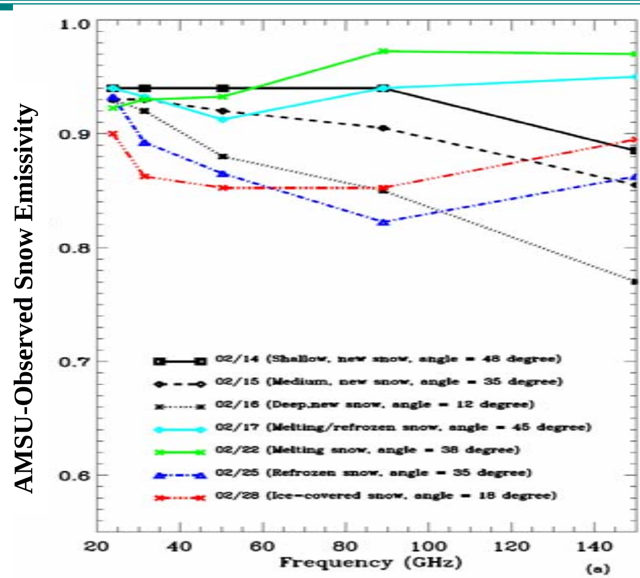




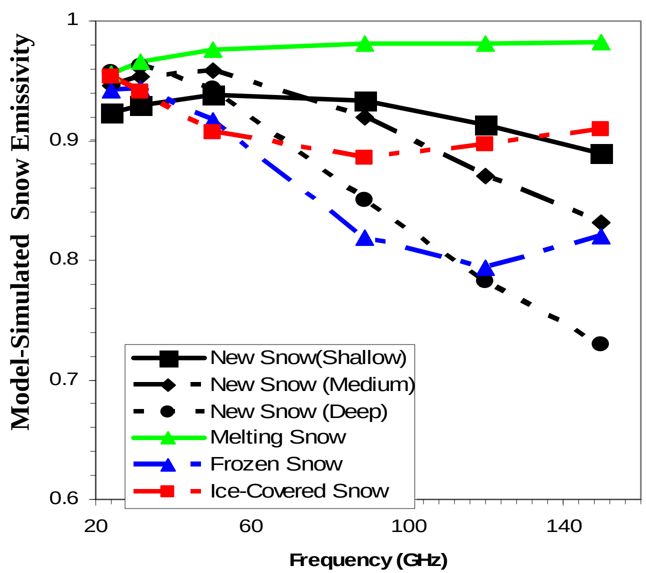
Part Two: Developed a new two-layer microwave snow emissivity physical model

Comparison of Simulated and Observed Snow Emissivity Spectra

AMSU Observations

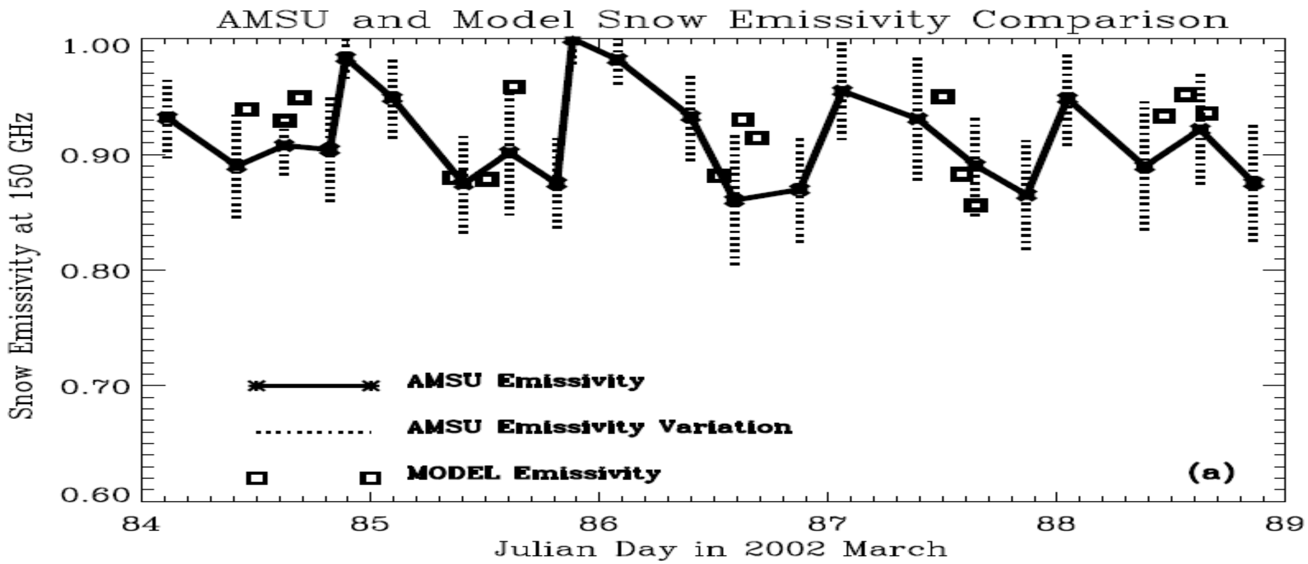


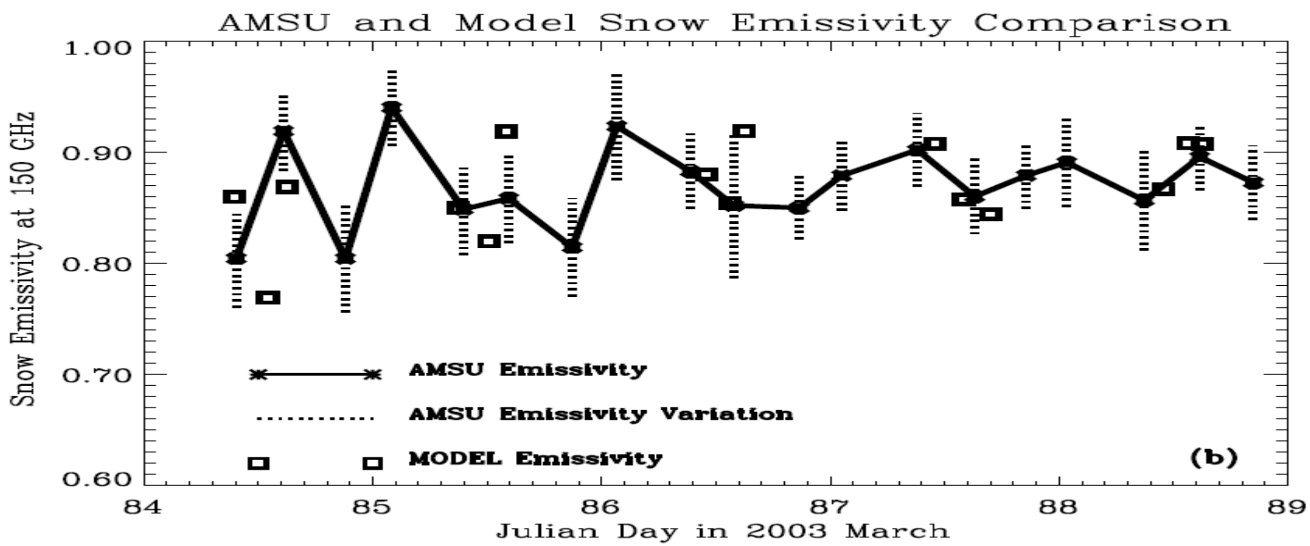
SnowEM Model Simulations



- Seven types of snow events are observed at Hagerstown, Maryland in February 2003
- Observed emissivity is retrieved using AMSU brightness temperatures (Yan et al., JGR, 2008)
- Spectral feature of simulated snow emissivity is qualitatively consistent to the satellite-observed emissivity

AMSU and Model Snow Emissivity Comparison at 150 GHz of Snowpacks in March 2002 and 2003





Model-simulated and AMSU-observed Emissivity Comparisons of Snowpacks: Statistical Analysis

Table 1 Mean bias and standard deviation of the microwave snow emissivity model-simulated emissivity in comparison with AMSU-retrieved emissivity for observed mountain snowpacks at CLPX LSOS in Northern Colorado

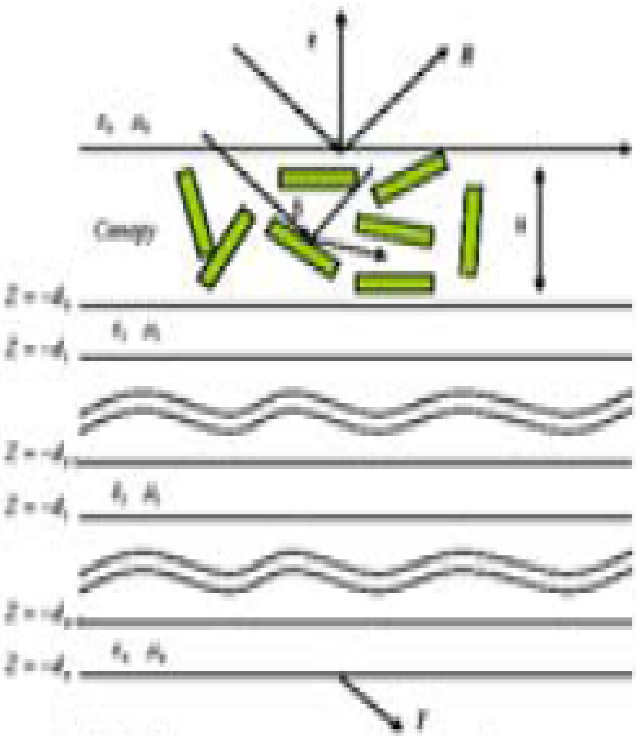
Freq. (GHz)	February 2002			March 2002			February 2003			March 2003		
	bias	σ_1	σ_2	bias	σ_1	σ_2	bias	σ_1	σ_2	bias	σ_1	σ_2
23.8	-0.007	0.002	0.006	-0.069	0.004	0.007	-0.053	0.007	0.009	-0.009	0.002	0.009
31.4	0.000	0.001	0.014	-0.079	0.007	0.012	-0.054	0.013	0.019	0.015	0.001	0.011
50.3	-0.046	0.004	0.021	-0.100	0.012	0.017	-0.113	0.022	0.024	0.006	0.003	0.014
89	-0.117	0.003	0.049	-0.096	0.010	0.038	-0.132	0.018	0.044	-0.011	0.004	0.038
150	-0.061	0.002	0.049	-0.055	0.009	0.041	-0.076	0.015	0.043	0.006	0.003	0.039
Note	1) bias: emissivity (AMSU) and emissivity (MOD) mean difference 2) σ_1 denotes the standard deviation of the emissivity model mean biases 3) σ_2 denotes the standard deviation of the AMSU emissivity due to spatial inhomogeneity											

- New multi-layer snow emissivity model simulated emissivity from 23.8 to 150 GHz is well agreeable to AMSU-observed emissivity. The mean difference is usually smaller than 0.07
- Spatial and temporal resolution differences (point and satellite scales) also contribute to the model and AMSU emissivity differences (~0.03)

Part Three: Developed a new multi-layer microwave canopy/bare soil emissivity physical model (F.Weng et al.,2008)

Multilayer Soil/Vegetation Emissivity Model

1. Model Description



d - leaf thickness
H - canopy height
LAI - leaf area index
Md - dry matter content
β - leaf orientation angle
θ - incident angle of EM wave

l - layer number
ε - dielectric constant
μ - magnetic permeability

Soil dielectric model:

Dobson et al. (1985) developed a mixing rule for soil dielectric constant (Weng et al., 2001) which is

$$\epsilon_m^\alpha = 1 + \frac{\rho_b}{\rho_s}(\epsilon_s^\alpha - 1) + m_v^\beta \epsilon_w^\alpha - m_v, \tag{5.21}$$

where m_v is the soil volumetric moisture, ϵ_s is the dielectric constant of solids, and ρ_b is the density of soil, ρ_s is the density of solids, which are calculated from sand and clay fraction. The exponents, α, β are depending on soil type.

$$\alpha = 0.65 \tag{5.22}$$

$$\beta = 1.09 - 0.11S + 0.18C \tag{5.23}$$

$$\epsilon_s = (1.01 + 0.44 * \rho_s)^2 - 0.062 \tag{5.24}$$

Vegetation dielectric model:

$$\begin{aligned} \epsilon_{veg} &= 1.7 - (0.74 - 6.16 m_g) m_g + m_g * (0.55 m_g - 0.076) \\ &\quad [4.9 + 75.0/(1 + y_i) - y_i] + \\ &\quad 4.64 m_g^2/(1 + 7.36 m_g^2)[2.9 + 55.0/(1.0 + \sqrt{y_i})] \end{aligned} \tag{5.16}$$

$$y_i = i\nu/18.0$$

where y_i is a complex value, m_g is the gravimetric water content (g/kg), ν is the frequency in GHz.

A mixing formula was also derived and validated for leaves (Mätzler, 1994a) having a higher gravimetric water content (e.g. > 0.5) which is

$$\epsilon_{veg} = (0.52 - 0.69 m_d)\epsilon_w + 3.84 m_d + 0.51, \tag{5.17}$$

where m_d is the dry matter content and ϵ_w is the dielectric of water.

Weng et al. (ITOVS, 2008)

Multilayer Soil/Vegetation Emissivity Model

2. Simulated Brightness Temperature from Soil **(Weng et al., ITOVS, 2008)**

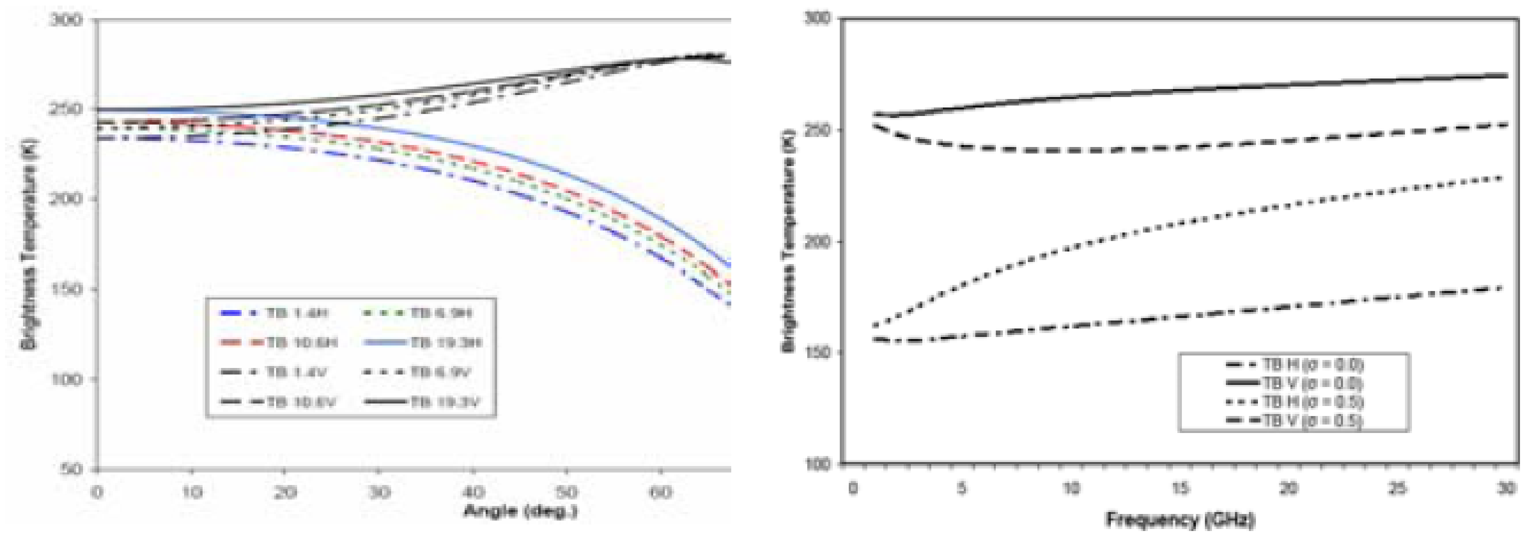
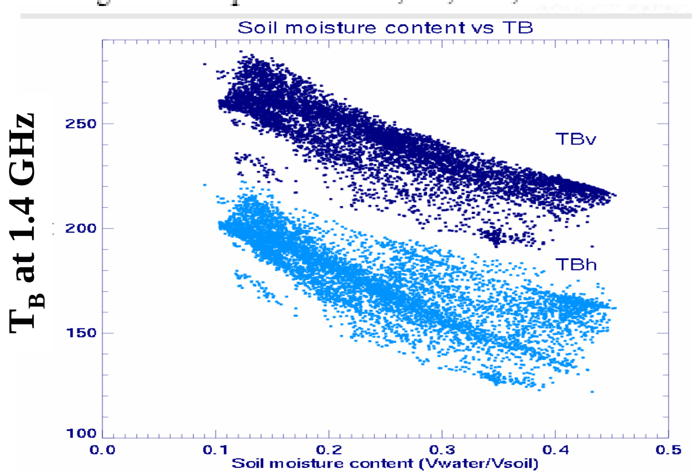
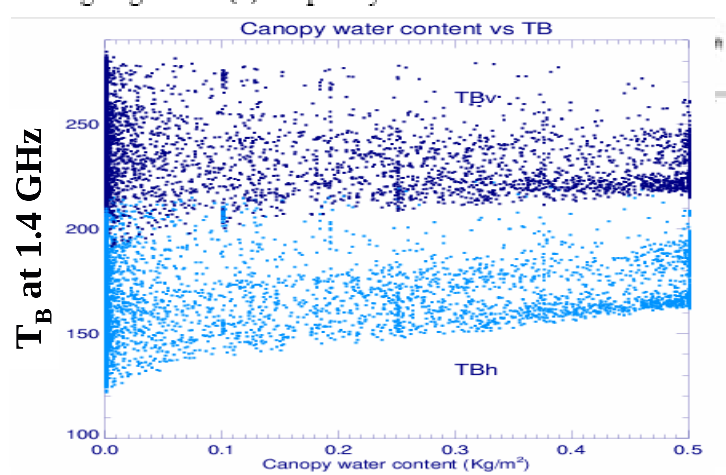


Figure 1. Brightness temperature at 1.4, 6.9, 10.7, and 19.3 GHz vs. (a) viewing angle and (b) frequency





Future Plans

- Continue to validate both microwave multilayer snow and soil/vegetation emissivity physical models
- Assess assimilation impacts of the updated microwave snow, and soil/vegetation emissivity physical models on GDAS and GFS
- Update CRTM microwave emissivity models

Aerosol Look-up Tables in the CRTM

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Joint Center for Satellite Data Assimilation

July 31, 2008

Aerosol Models-GOCART, completed

Global Model, Goddard Chemistry Aerosol Radiation and Transport (GOCART)

Species	Aerosol types in the CRTM
Dust	dust
Sea salt	sea salt ssam
	sea salt sscm
Organic carbon	dry organic carbon
	wet organic carbon
Black carbon	dry black carbon
	wet black carbon
Sulfate	sulfate

Lognormal size distribution, 35 size bins

Aerosol Models-GOES-R, working on

GOES-R aerosol model is similar to MODIS model.

Land

Aerosol Model	Mode	Volume median radius r_V
Generic	Fine	$0.145+0.0203*\tau_{550}$
	Coarse	$3.1007+0.3364*\tau_{550}$
Urban	Fine	$0.1604+0.434*\tau_{550}$
	Coarse	$3.3252+0.1411*\tau_{550}$
Smoke	Fine	$0.1335+0.0096*\tau_{550}$
	Coarse	$3.4479+0.9489*\tau_{550}$
Dust	Fine	0.14
	Coarse	2.30

Ocean

4 fine modes

5 coarse modes

CMAQ, Aerosol Models, under consideration

Table 1. Aerosol Species[a]

	Abbreviation	Description
{a1}	ASO4J	Accumulation mode sulfate mass
{a2}	ASO4I	Aitken mode sulfate mass
{a3}	ANH4J	Accumulation mode ammonium mass
{a4}	ANH4I	Aitken mode ammonium mass
{a5}	ANO3J	Accumulation mode nitrate mass
{a6}	ANO3I	Aitken mode aerosol nitrate mass
{a7}	AORGAJ	Accumulation mode anthropogenic secondary organic mass
{a8}	AORGAI	Aitken mode anthropogenic secondary organic mass
{a9}	AORGPAJ	Accumulation mode primary organic mass
{a10}	AORGPAI	Aitken mode mode primary organic mass
{a11}	AORGBJ	Accumulation mode secondary biogenic organic mass
{a12}	AORGBI	Aitken mode biogenic secondary biogenic organic mass
{a13}	AECJ	Accumulation mode elemental carbon mass
{a14}	AECI	Aitken mode elemental carbon mass
{a15}	A25J	Accumulation mode unspecified anthropogenic mass
{a16}	A25I	Aitken mode unspecified anthropogenic mass
{a17}	ACORS	Coarse mode unspecified anthropogenic mass
{a18}	ASEAS	Coarse mode marine mass
{a19}	ASOIL	Coarse mode soil-derived mass
{a20}	NUMATKN	Aitken mode number
{a21}	NUMACC	Accumulation mode number
{a22}	NUMCOR	Coarse mode number
{a23}	SRFATKN	Aitken mode surface area
{a24}	SRFACC	Accumulation mode surface area
{a25}	AH2OJ	Accumulation mode water mass
{a26}	AH2OI	Aitken mode water mass

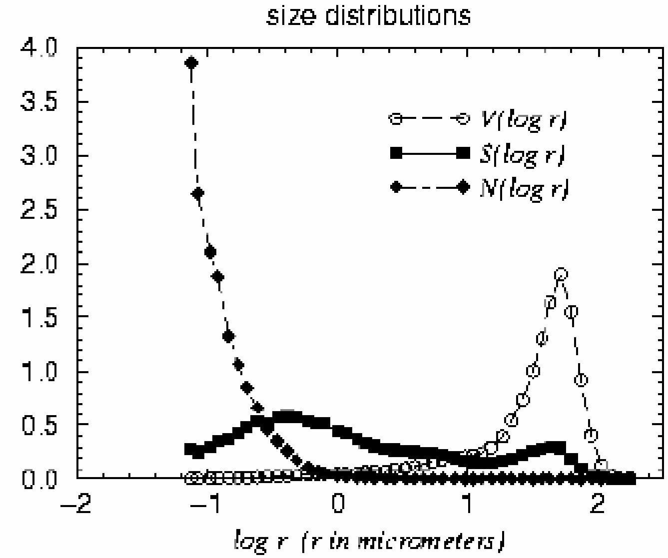
[a]Concentration units: mass [$\mu g\ m^{-3}$], number [m^{-3}].

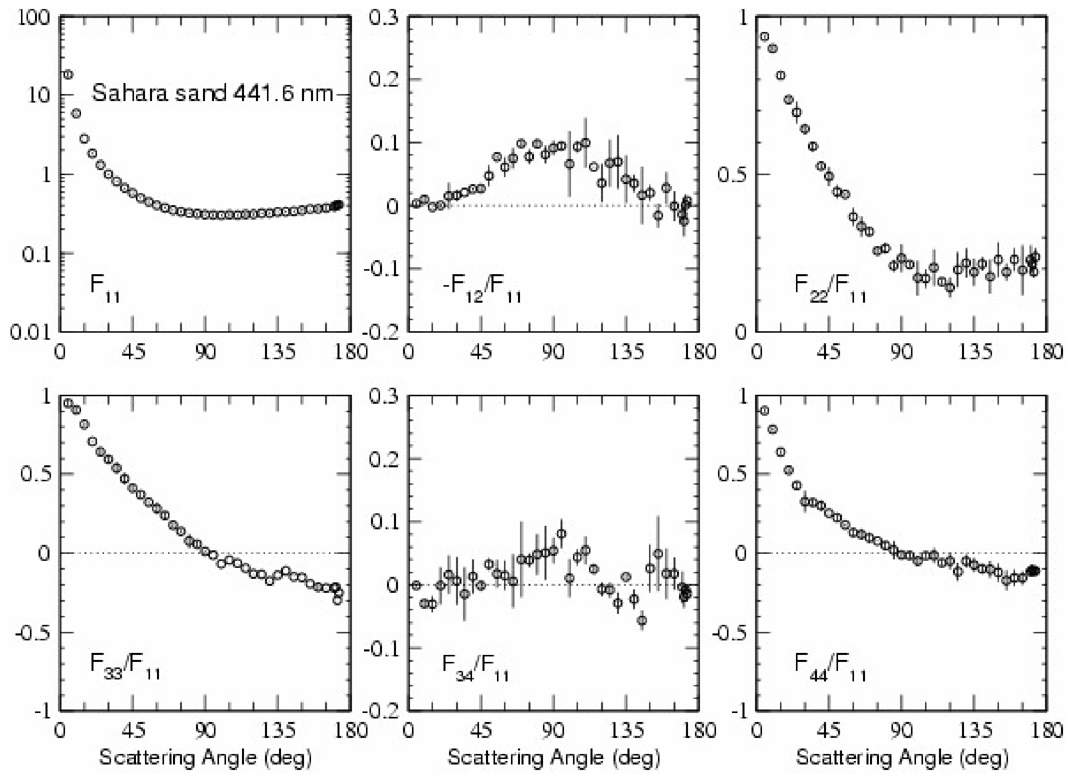
$$\begin{aligned}\beta_{sp}\left(km^{-1}\right) = 0.003f(RH)\ &[ammonium + sulfate + nitrate]\\ &+\ 0.004\ [all\ organic\ species]\\ &+\ 0.01\ [elemental\ carbon]\\ &+\ 0.001\ [unspeciated\ PM_{2.5}].\end{aligned}$$

Binkowski, F.S., Roselle, S.J., 2003

Sahara Dust (Ping Yang)

Sahara sand





Phase functions

From Amsterdam Light Scattering Database

CRTM Extension, Baseline Solver +solar radiation

(Advanced Doubling-Adding, ADA)

1. Compute layer transmission and reflection (loop i from 0→ n-1)

$$\mathbf{r}(\delta_0) = \delta_0 \boldsymbol{\beta} \qquad \mathbf{t}(\delta_0) = \mathbf{E} + \boldsymbol{\alpha}\,\delta_0 \qquad \delta = \delta_n = 2^n \delta_0$$

$$\mathbf{r}(\delta_{i+1}) = \mathbf{t}(\delta_i)[\mathbf{E} - \mathbf{r}(\delta_i)\mathbf{r}(\delta_i)]^{-1}\mathbf{r}(\delta_i)\mathbf{t}(\delta_i) + \mathbf{r}(\delta_i) \qquad \mathbf{t}(\delta_{i+1}) = \mathbf{t}(\delta_i)[\mathbf{E} - \mathbf{r}(\delta_i)\mathbf{r}(\delta_i)]^{-1}\mathbf{t}(\delta_i)$$

2. Compute layer source functions

$$\mathbf{S}_{\mathbf{u}} = [(\mathbf{E} - \mathbf{t} - \mathbf{r})B(T_1) - (B(T_2) - B(T_1))\mathbf{t} + \frac{B(T_2) - B(T_1)}{(1 - \varpi g)\delta}(\mathbf{E} + \mathbf{r} - \mathbf{t})\mathbf{u}]\boldsymbol{\Xi} \quad + \frac{\varpi F_0}{\pi}\exp(-\bar{\tau}_{k-1}(\mu_0))[(\mathbf{E} - \mathbf{t}\exp(-\bar{\delta}(\mu_0))\Psi_u - \mathbf{r}\Psi_d]$$

$$\mathbf{S}_{\mathbf{d}} = [(\mathbf{E} - \mathbf{t} - \mathbf{r})B(T_1) + (B(T_2) - B(T_1))(\mathbf{E} - \mathbf{r}) + \frac{B(T_2) - B(T_1)}{(1 - \varpi g)\delta}(\mathbf{t} - \mathbf{E} - \mathbf{r})\mathbf{u}]\boldsymbol{\Xi} \quad + \frac{\varpi F_0}{\pi}\exp(-\bar{\tau}_{k-1}(\mu_0))[(\exp(-\bar{\delta}(\mu_0))E - \mathbf{t})\Psi_d - \mathbf{r}\exp(-\bar{\delta}(\mu_0))\Psi_u]$$

$$\begin{bmatrix}\Psi_d \\ \Psi_u\end{bmatrix} = -\frac{\varpi F_\lambda}{(1 + \delta_{0m})\pi}\begin{bmatrix}\boldsymbol{\alpha} + E/\mu_0 & \boldsymbol{\beta} \\ -\boldsymbol{\beta} & -\boldsymbol{\alpha} + E/\mu_0\end{bmatrix}^{-1}\begin{bmatrix}\phi(\mu_i, \mu_0) \\ \phi(-\mu_i, \mu_0)\end{bmatrix}$$

The above pseudo-spherical approximation enables us to do simulation for large sun zenith angles.

3. Vertical integration

$$\mathbf{I}_{\mathbf{u}}(n) = \varepsilon B(T_s) \quad + \frac{F_\lambda \exp(-\bar{\tau}_N(\mu_0))}{(1 + \delta_{0m})\pi} R_s(\mu_0)$$

$\mathbf{R}(n)$ **the surface reflection matrix, loop k from n → 1**

$$\begin{aligned}\mathbf{I}_{\mathbf{u}}(k-1) &= \mathbf{S}_{\mathbf{u}}(k) + \mathbf{t}(k)[\mathbf{E} - \mathbf{R}(k)\mathbf{r}(k)]^{-1}\ \mathbf{R}(k)\mathbf{S}_{\mathbf{d}}(k) + \mathbf{t}(k)[\mathbf{E} - \mathbf{R}(k)\mathbf{r}(k)]^{-1}\ \mathbf{I}_{\mathbf{u}}(k) \\ &= \mathbf{S}_{\mathbf{u}}(k) + \mathbf{t}(k)[\mathbf{E} - \mathbf{R}(k)\mathbf{r}(k)]^{-1}\ [\mathbf{R}(k)\mathbf{S}_{\mathbf{d}}(k) + \mathbf{I}_{\mathbf{u}}(k)]\end{aligned}$$

$$\mathbf{R}(k-1) = \mathbf{r}(k) + \mathbf{t}(k)[\mathbf{E} - \mathbf{R}(k)\mathbf{r}(k)]^{-1}\mathbf{R}(k)\mathbf{t}(k)$$

4. Final TOA radiance $\quad \mathbf{R}adiance = \mathbf{I}_u(0) + \mathbf{R}(0)\mathbf{I}_{sky}$

UV+VIS Transmittance Model, working on

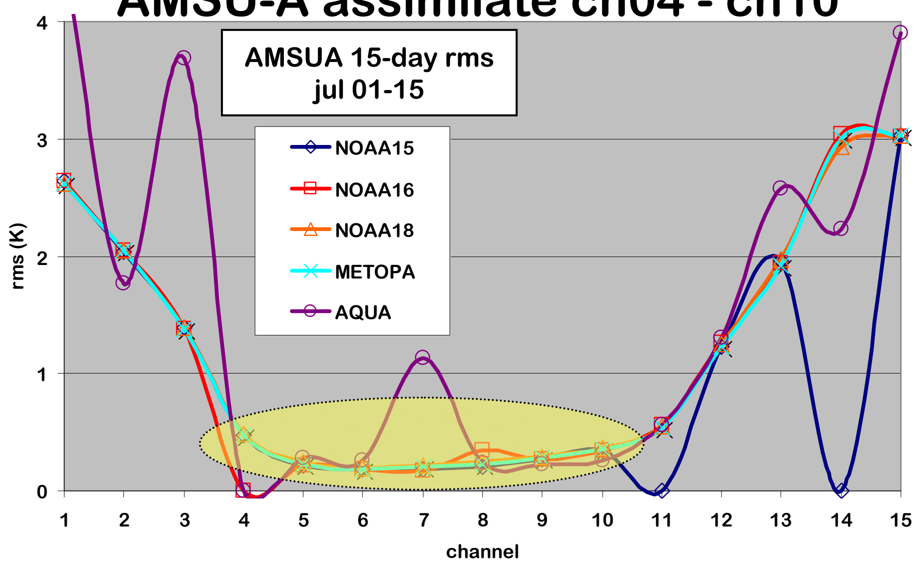
Operational CRTM is for IR and MW where source is the thermal emission. To extend CRTM for UV+VIS, solar source has to

be included. For speed consideration, we will test

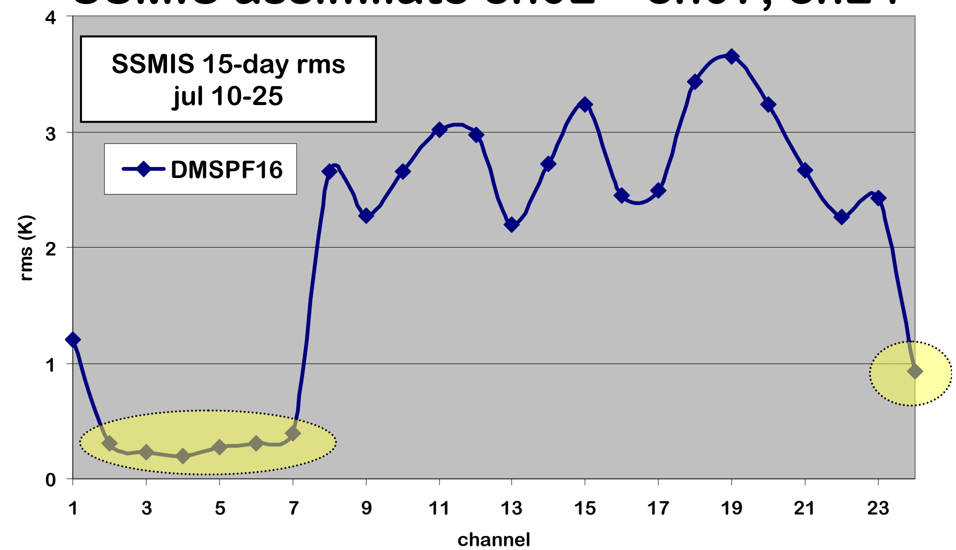
OPTRAN-like model

B. Ruston

AMSU-A assimilate ch04 - ch10



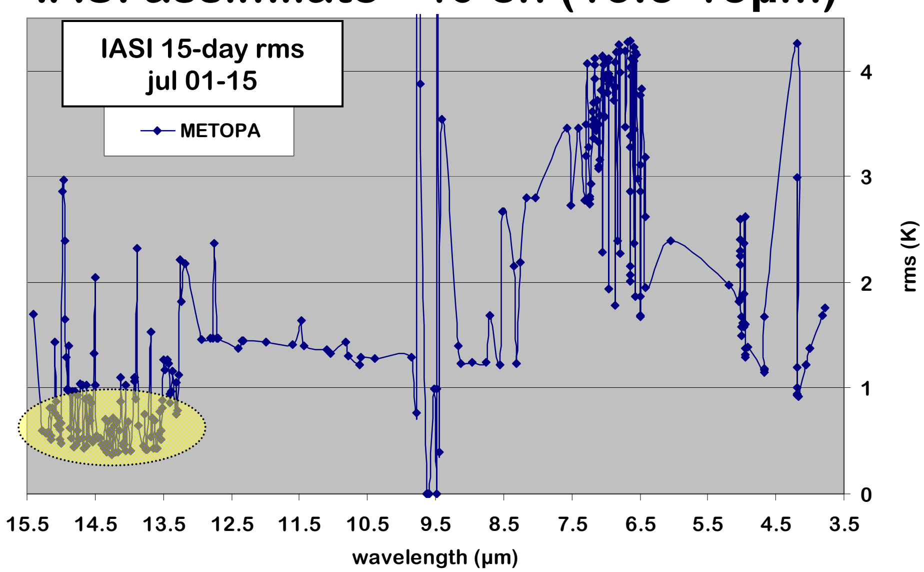
SSMIS assimilate ch02 – ch07, ch24



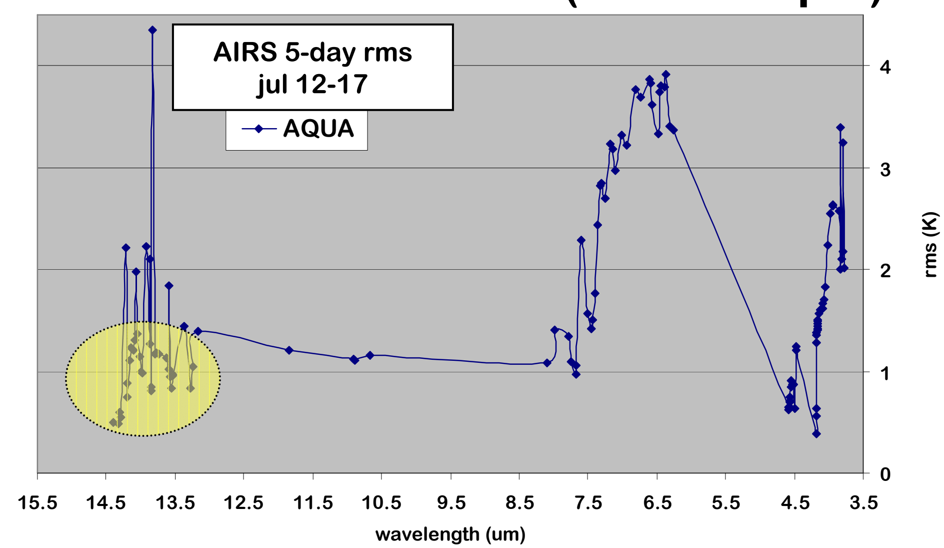
All "live" in NAVDAS-AR beta except AQUA AIRS/AMSU
AQUA qc being reformed AMSU-A ch4 out; ch07&ch15 noisy

CRTM-WG use
please don't distribute

IASI assimilate ~40 ch (13.5-15μm)



AIRS assimilate ~20 ch (13.5-14.5μm)

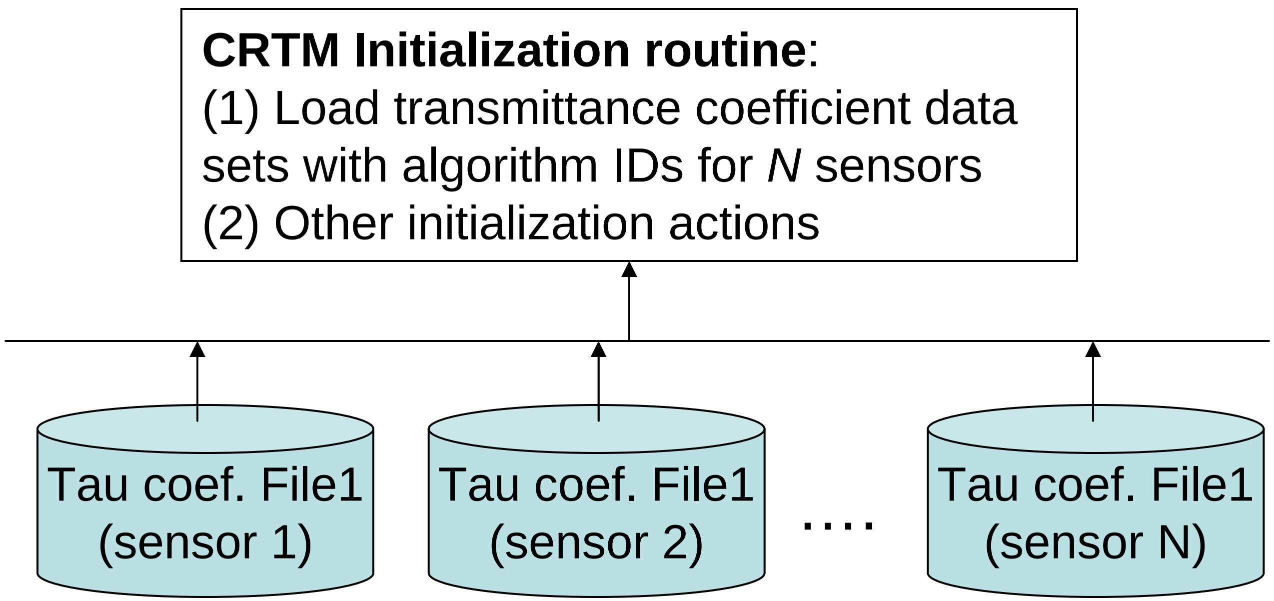


Implementation of Multiple Transmittance Algorithm Framework (completed)

Yong Han

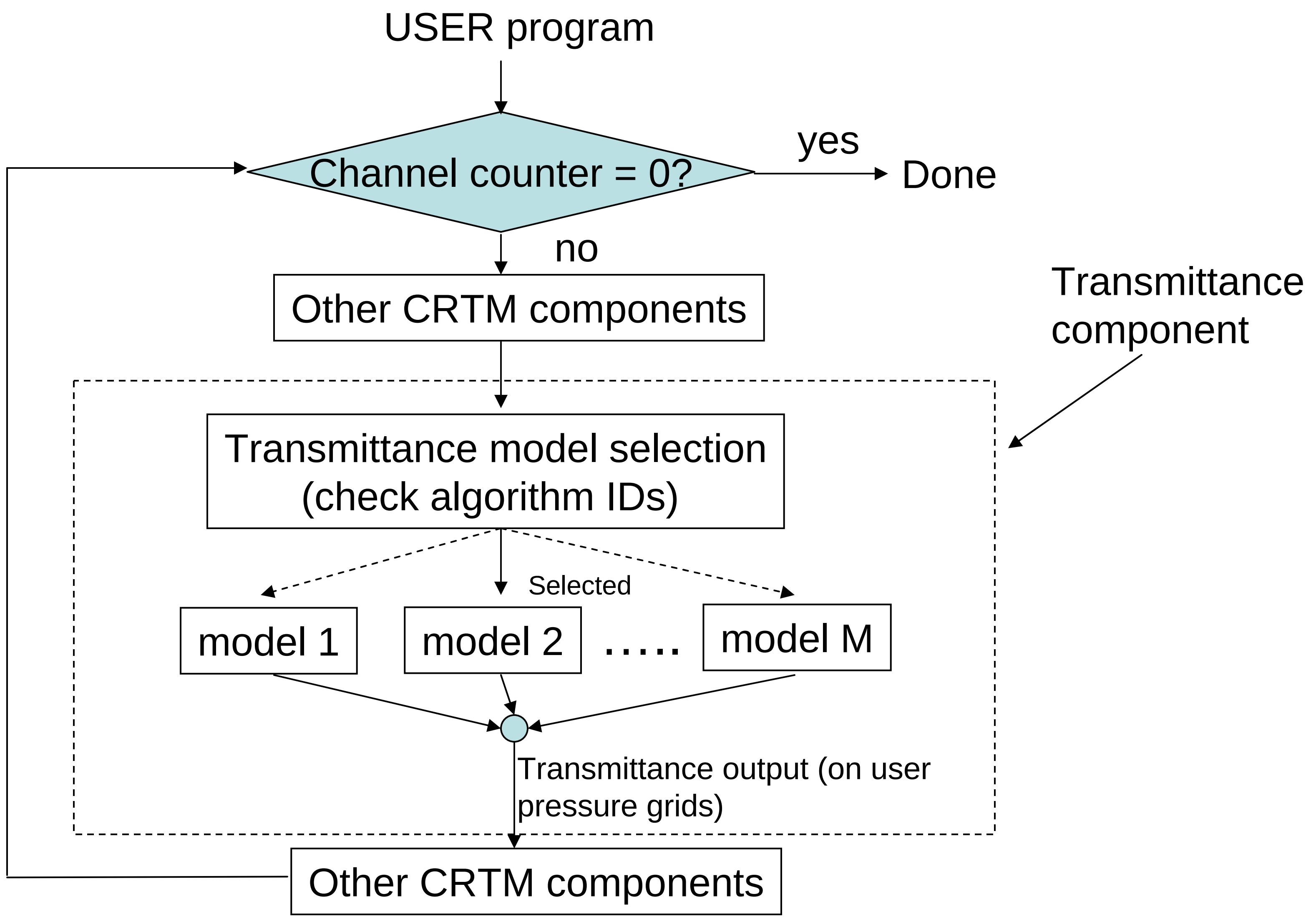
Implementation (1)

CRTM initialization is called (only once) by the user to load coefficient data for a set of sensors (determined by the user)



Each file contains an algorithm ID, a set of transmittance coefficients and data structure specific to the algorithm

Implementation (2)



- Algorithms currently implemented in the framework
  - Compact OPTRAN
  - SARTA transmittance model (Y. Chen)

Next steps

- Completion of the ODPS transmittance model and implementation of this model into the framework
- Implementation of the Zeeman models into the framework
- Implementation of the SSU transmittance model into the framework (Quanhua Liu)