CRTM Working Group

14 January 2011 Meeting

Community Radiative Transfer Model
Working Group Meeting

Friday, January 14, 2011, 12:00-1:30 p.m. (EST)
NOAA Science Center (World Weather Building)

Agenda

1. Opening comments (Paul, Yong)

2. Introductions (All)

3. Review and discuss recent and planned activities (All)
   - JCSDA CRTM Developers Reports
     - Ping Yang (TAMU) – CRTM Validation
     - Tom Greenwald (CIMSS) – SOI status; Scattering Index
     - Zhiquan Liu (NCAR) – Assimilation of MODIS AOD
     - Tomoko Koyama (ESRL) – CRTM Validation
     - Vivienne Payne (AER) – OSS; LBLRTM and spectroscopy
   - JCSDA CRTM Team Reports
     - Paul van Delst – FASTEM4, VIIRS SRFs
     - Yong Han – NLTE
     - Quanhua Liu – CRTM AOD module
     - David Groff – SOI
     - Tong Zhu – IR land emissivity
     - Yong Chen – Earth curvature and CFC impact; New sensor coefficients
     - Weizhong Zheng – MW land emissivity
   - User Concerns and Questions

4. Identify action items and next steps (Paul, Yong)

5. Identify when we will have our next meeting/conference call (Paul, Yong)

Ping Yang (TAMU)

Validation of the Community Radiative Transfer Model

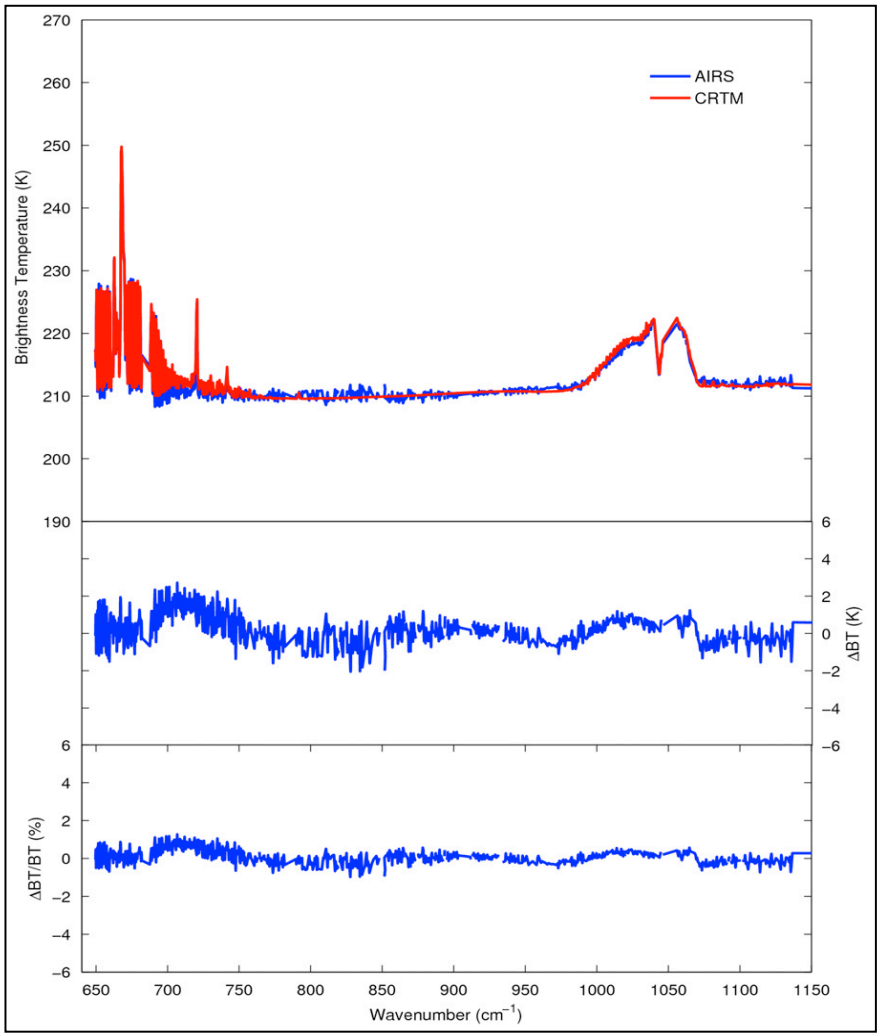
PI: Ping Yang

Team member: S. Ding

Department of Atmospheric Sciences
Texas A&M University
College Station, TX 77843
Email Address: pyang@tamu.edu

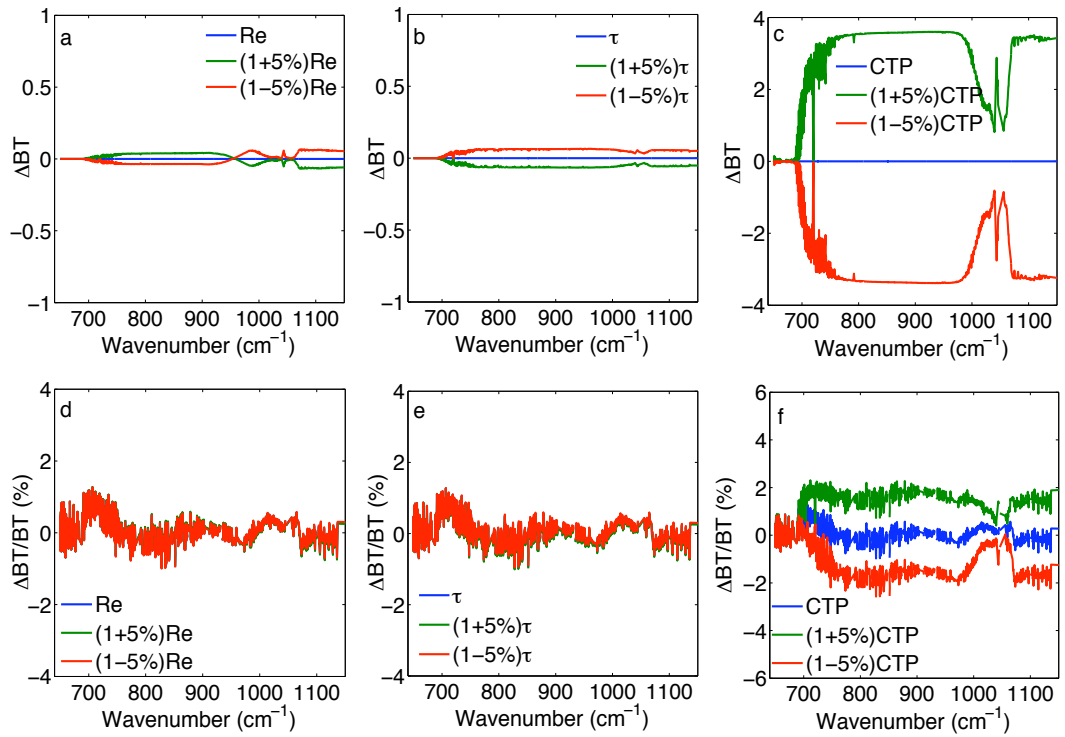
Accomplishments

To validate the CRTM, in our previous effort we used the AIRS profile products and MODIS cloud properties as inputs for CRTM and compared the simulated spectra with the AIRS counterparts. To be more objective, in our new effort we compared CRTM simulated brightness temperatures (BTs) with the AIRS level 1B radiance data by using the MODIS cloud products and ECMWF atmospheric profile as input.



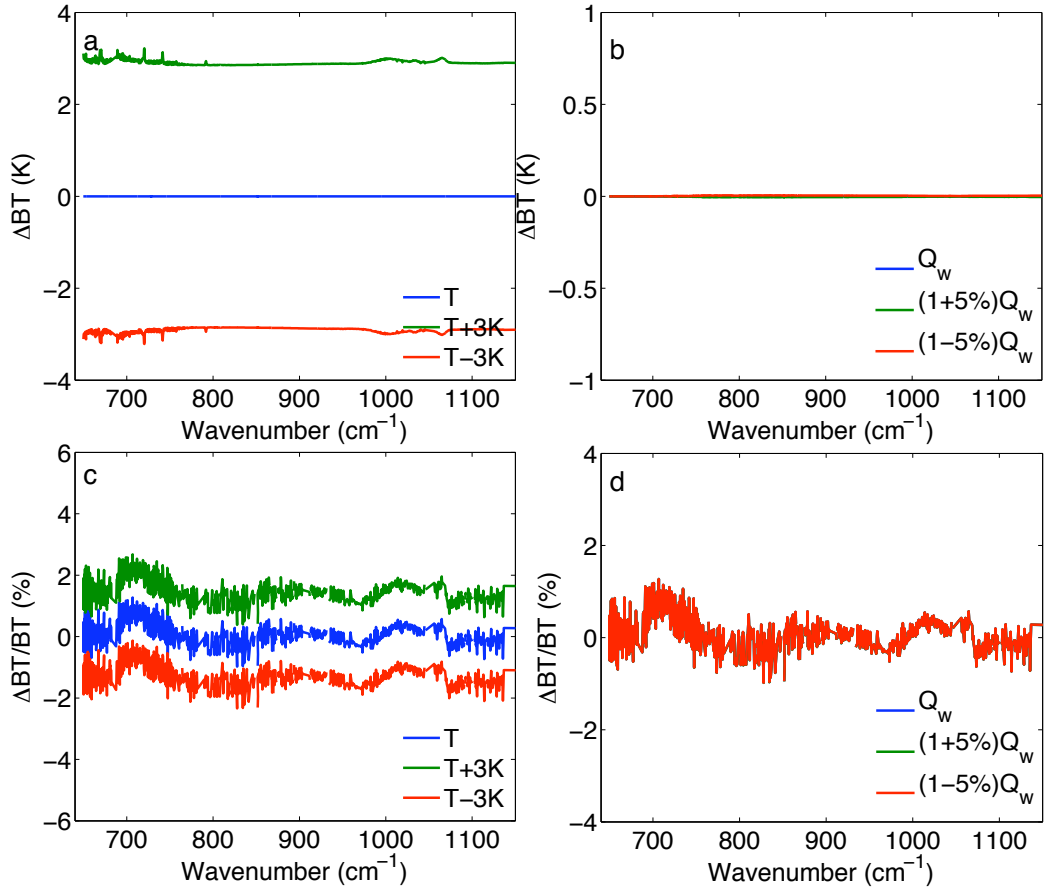
Comparison between the spectral BTs simulated from the CRTM and those observed by AIRS for a MODIS ice cloud pixel with a large optical thickness.

Sensitivity and Uncertainty Studies (1/2)



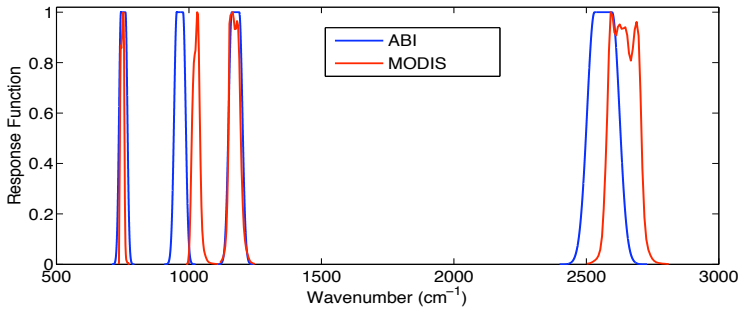
The CRTM-based brightness temperature differences associated with the perturbation of the various ice cloud properties for an optical thick cloud case.

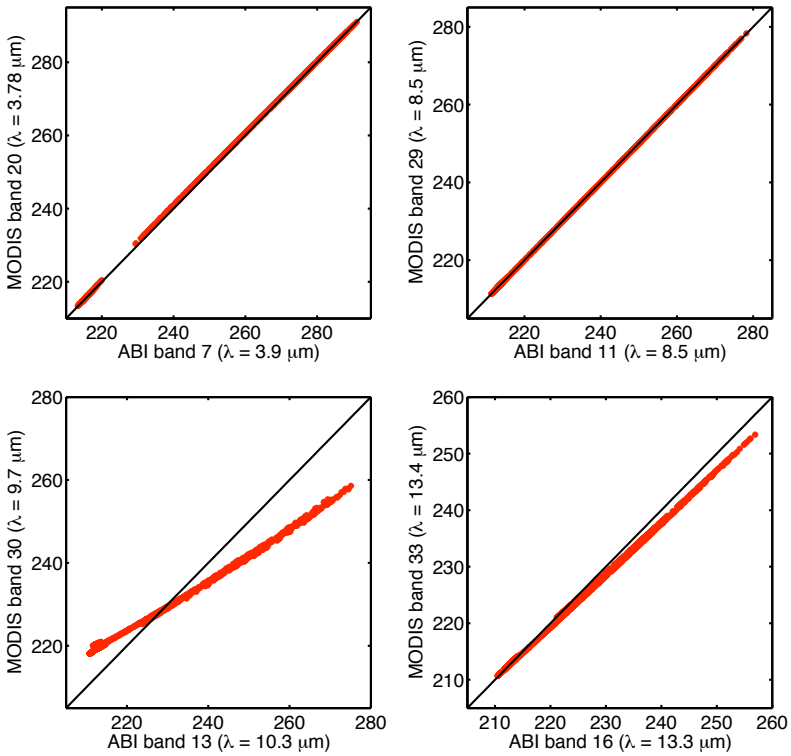
Sensitivity and Uncertainty Studies (2/2)



The CRTM-based brightness temperature differences associated with the perturbation of atmospheric profile for an optically thick cloud case.

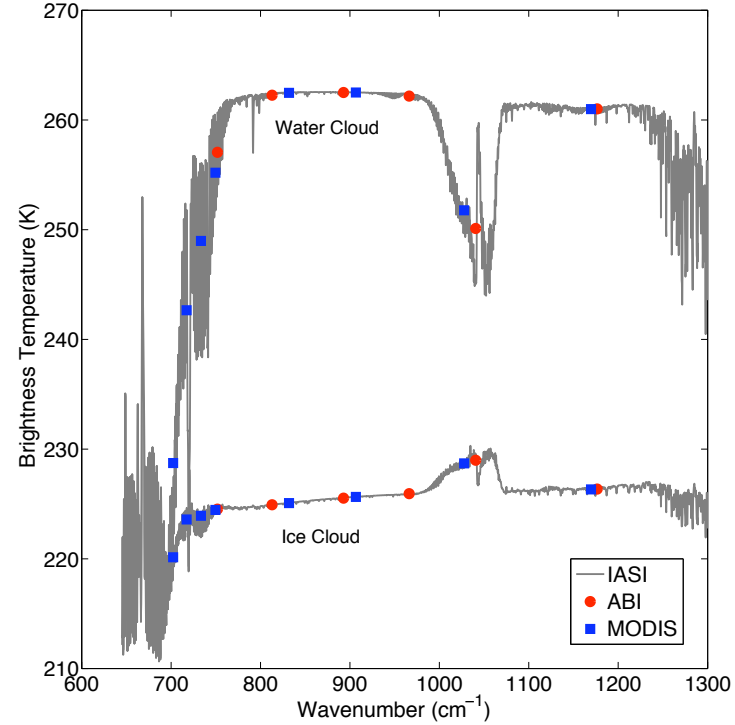
Spectral response function





Comparison of Brightness Temperatures simulated for the MODIS and ABI selected bands

The simulation from the CRTM for water and ice clouds



Future Plan

To continue validating the CRTM, we will use the MODIS and CALIPSO cloud products and the European Center for Medium-range Weather Forecasting (ECMWF) atmospheric profiles as the CRTM inputs to simulate the upwelling radiances and to compare them with the MODIS measurements.

Tom Greenwald (CIMSS)

CIMSS/UW Progress Report

Tom Greenwald and Ralf Bennartz

SOI Status

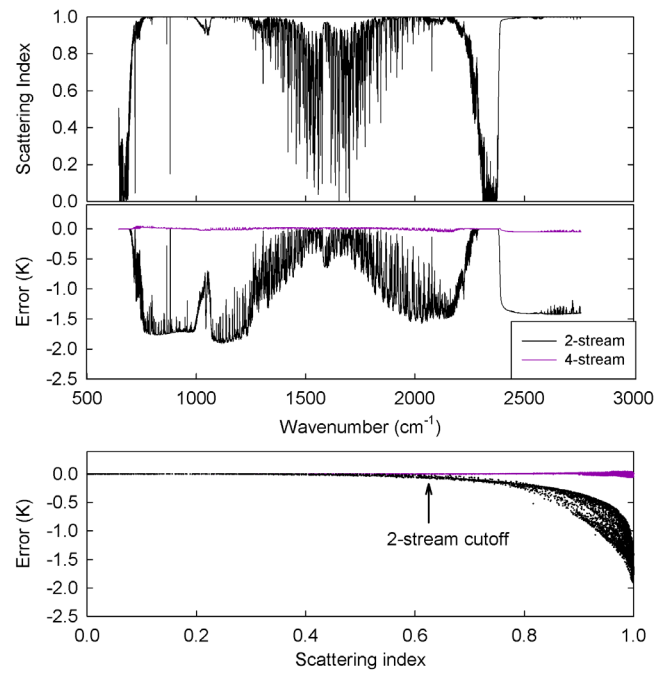
- Adjoint model written
- Issue migrating from V1.2 to V2.0; resolved by increasing maximum number of doubling steps
- FWD/TL test code written (D. Groff)
- **Plans:** Write adjoint test code; test

Channel selection

- Select AMSU channels best suited for cloud-affected radiance assim.
- Received sample GDAS analysis data from Min-Jeong Kim
- **Plans:** Do adjoint analysis for AMSU-A; arrange March visit

New task: Scattering Index (Nstreams)

- Tested on IASI channels for optically thin ice cloud at 300 hPa
- **Plans:** Extend to aerosols and other sensors (including microwave, visible)



Current CRTM:
6-strm (100%)

SI cutoff = 0.62
4-strm: (88%)
2-strm: (12%)

Zhiquan Liu (NCAR)

Variational Assimilation of MODIS AOD with GSI/CRTM/WRF-Chem

Zhiquan Liu (liuz@ucar.edu)

Collaborators:
Quanhua Liu (JCSDA)
Hui-Chuan Lin, Craig Schwartz (NCAR/MMM)
Jeff Lee (NCAR/ACD)

NCAR is sponsored by the National Science Foundation

Key Features for our AOD DA with GSI

- Direct 3D aerosol DA with one-step procedure of variational minimization
  - Compare to 2D-OI/2DVAR first, then adjust profile vertically

- Use CRTM as AOD observation operator, including both forward and Jacobian (or TL/AD) models
  - developed by Dr. Quanhua Liu, JCSDA

- Allow simultaneous assimilation of meteor. Observations
  - Though not well tested yet

In addition to CRTM-AOD interface, many other related development work needed for having AOD DA work though not detailed here.

黄色预警

新一轮沙尘又来了

今日春分恐难觅春色

A dust&sand storm case over East Asia

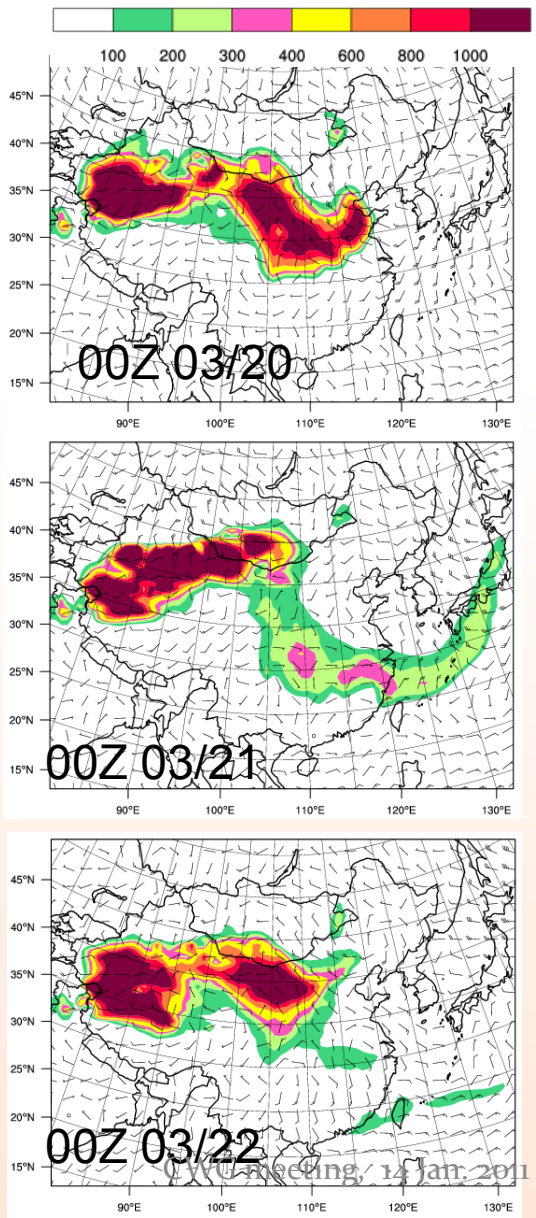
虽然袭击我国 13 个省市区的沙尘暴昨天傍晚基本结束，但中央气象台首席预报员林建提醒：受另一股冷空气影响，新一轮沙尘天气会接踵而至。昨天下午，中央气象台已继续发布了沙尘暴黄色预警。

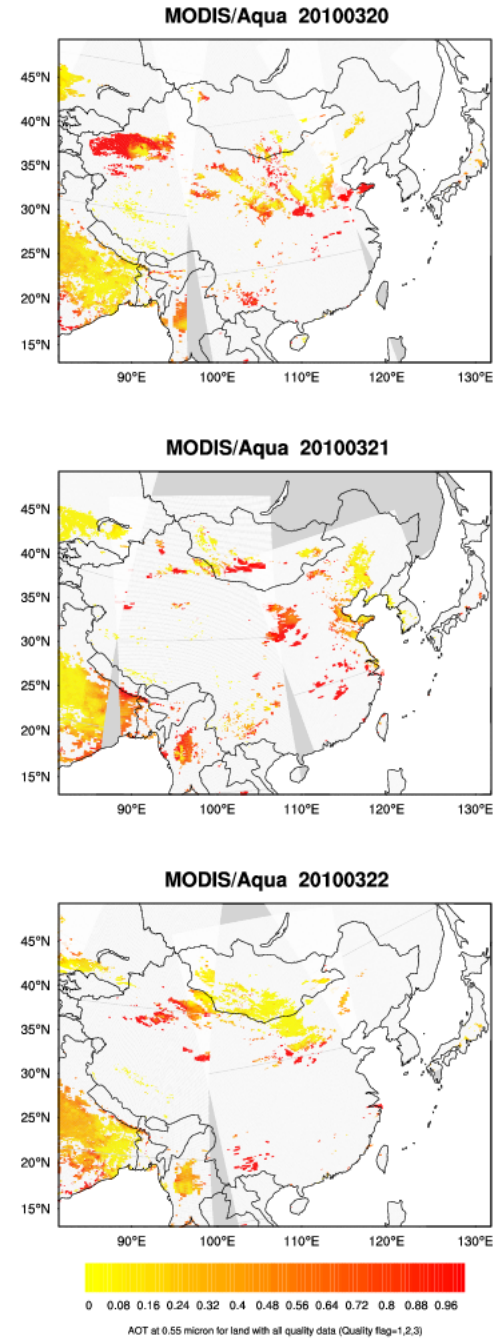
20 日晨，一场大范围的沙尘天气席卷我国北方大部地区。据中央气象台预计，21 日，南疆盆地、甘肃、青海、内蒙古、华北等地还将持续沙尘天气。今年春分时间是 3 月 21 日 1 时 32 分，“春分”节气将难觅盎然春色。据悉，这次 2009 年以来影响范围最大，强度最强沙尘天气过程，其中，内蒙古呼和浩特、吉兰太出现了强沙尘暴。虽然刚刚结束的强沙尘暴天气过程让人心有余悸，但另一场沙尘天气又虎视眈眈地从新疆奔赴而来。中央气象台昨天下午继续发布沙尘暴黄色预警：受蒙古气旋和冷空气影响，20 日 20 时至 21 日 20 时，南疆盆地、甘肃中西部、青海柴达木盆地、内蒙古西部、宁夏中北部等地有沙尘天气，其中，南疆盆地中东部、内蒙古西部等地的部分地区有沙尘暴，上述地区并将伴有 5~6 级偏北风，阵风风力可达 7 级。 中广 中新

昨天北方沙尘来到南京，使南京蒙上灰蒙蒙的“沙帐”。张筠 摄

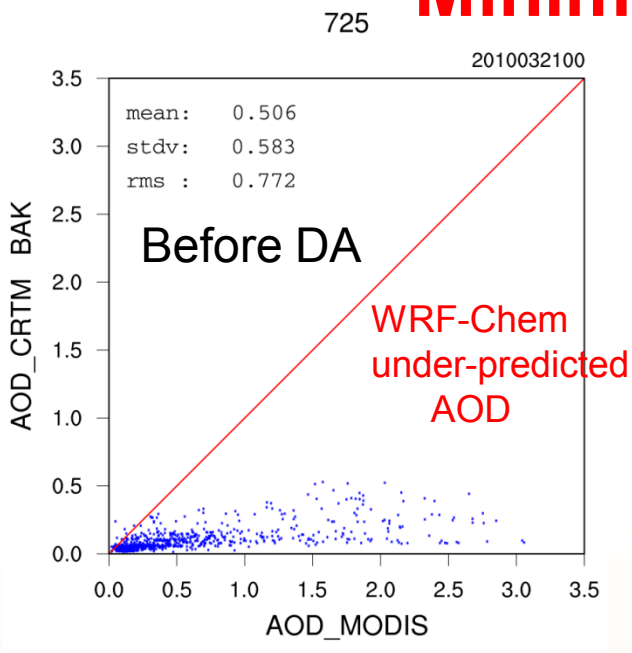
Dust Storm Simulation over East Asia

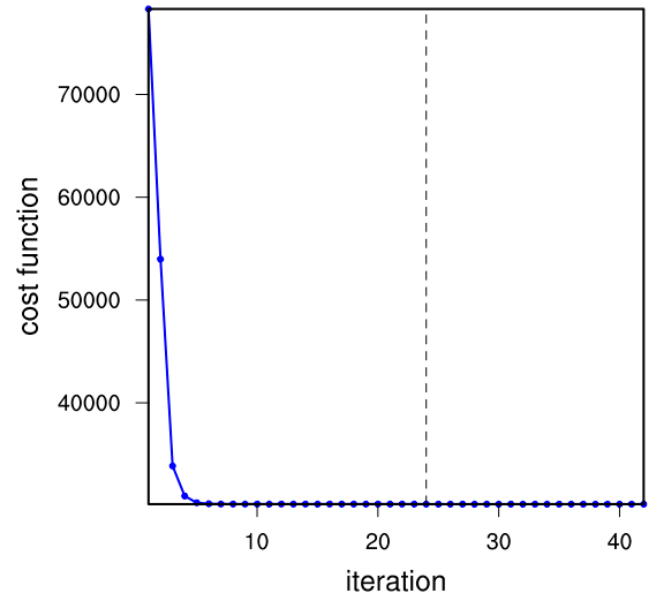
WRF-Chem prediction of surface dust

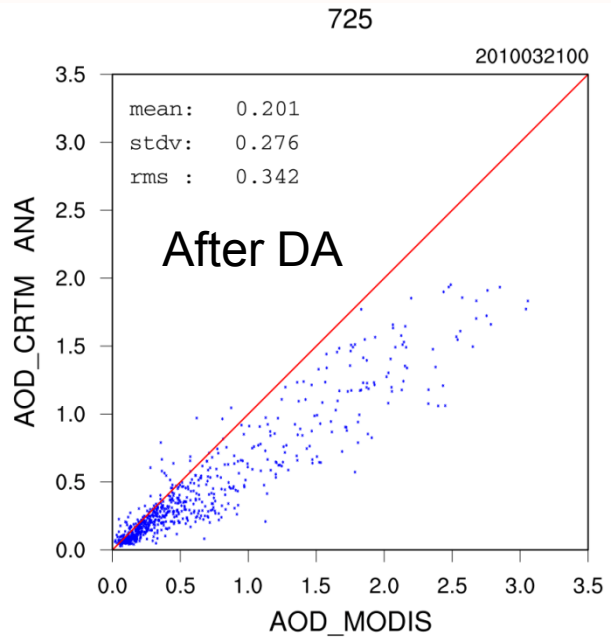


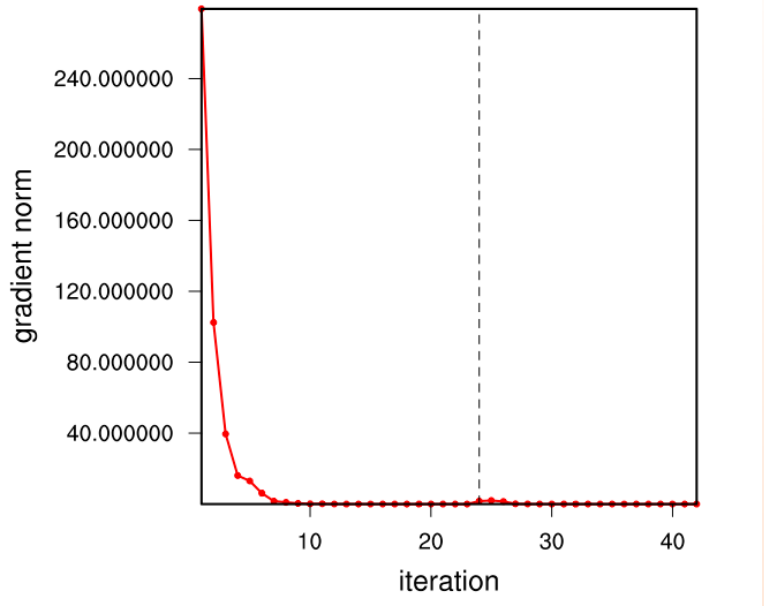


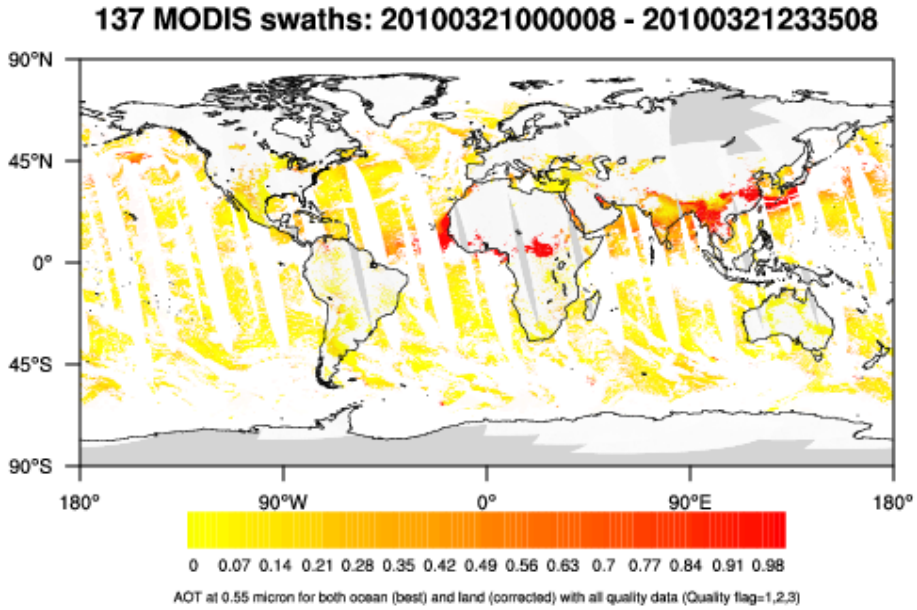
Minimization works!!





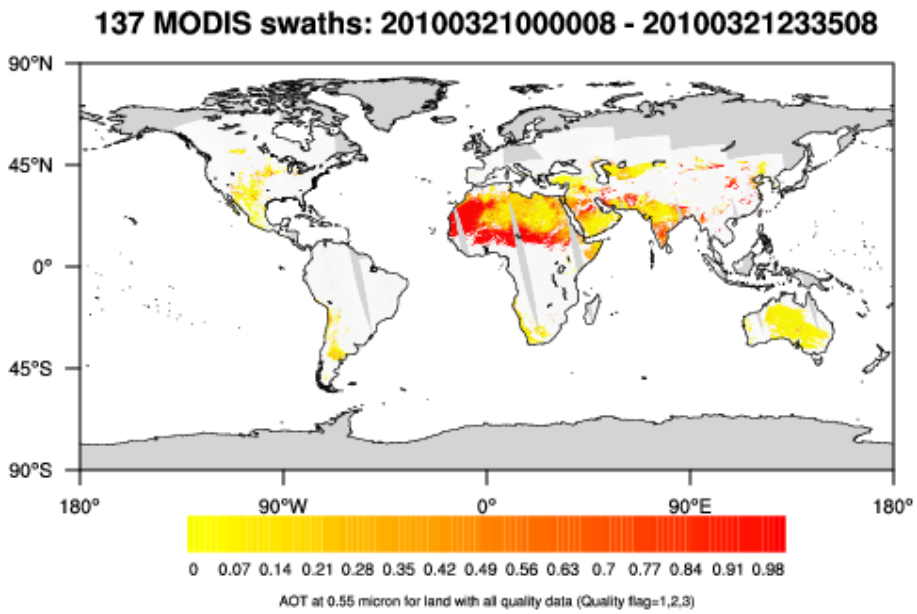






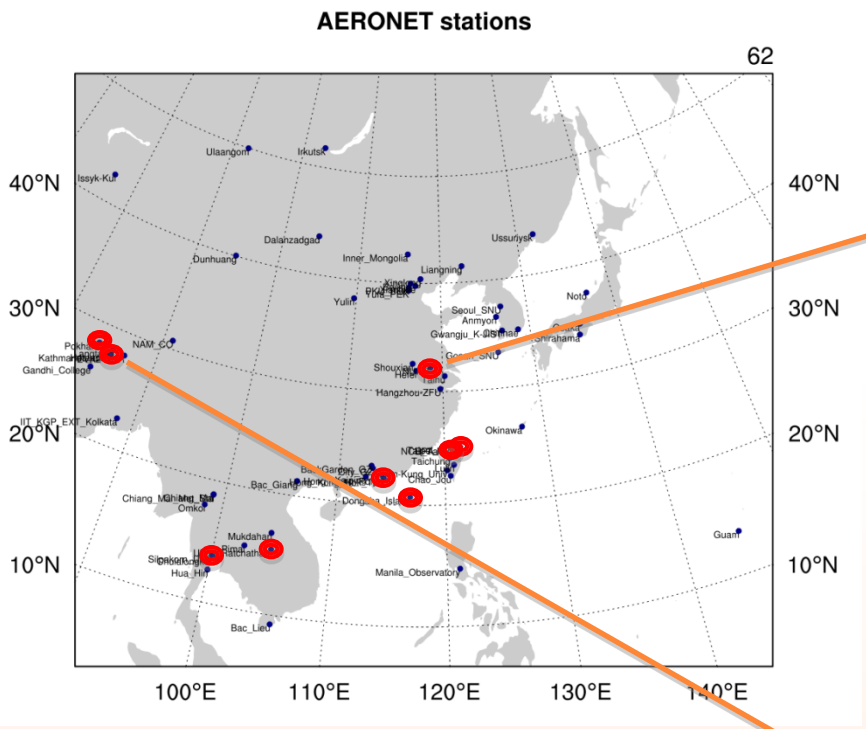
Standard AOD product over ocean & land

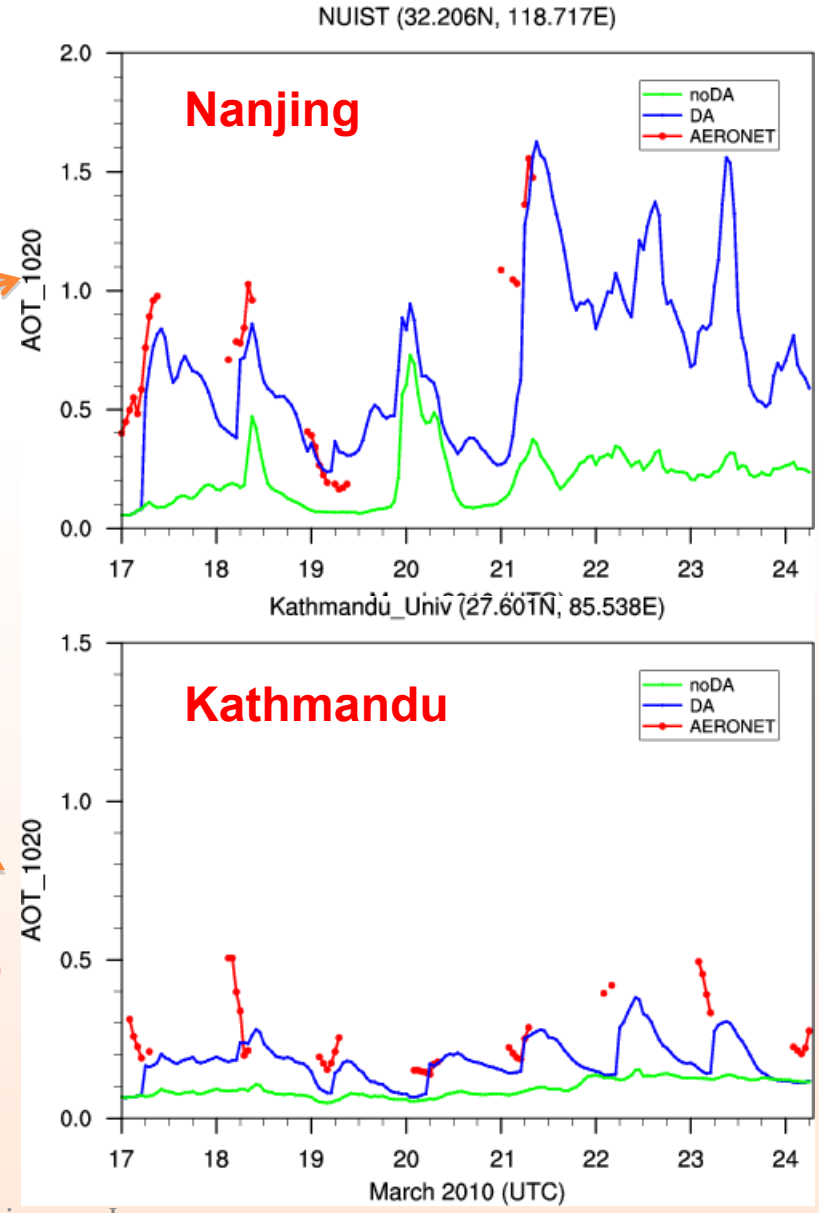
Only 0.55um AOD Assimilated.



"Deep Blue" AOD product over bright land surface

Validation with AERONET AOD data





These are 6-hour cycling experiments.

Future Work

- Other applications:
  - biomass burning, air quality, volcanic ash
- Simultaneous DA of MET+Aerosol
- Direct radiance DA for aerosol
- Other data source
  - AVHRR, GOES ……
- Combine surface PM2.5/PM10 network
- Profile Validation/Assimilation
  - Lidar network, CALIPSO
- Pre-operational test at AFWA

Tomoko Koyama
(ESRL/GSD/FAB)

Progress using CRTM at ESRL/GSD/Forecast Applications Branch

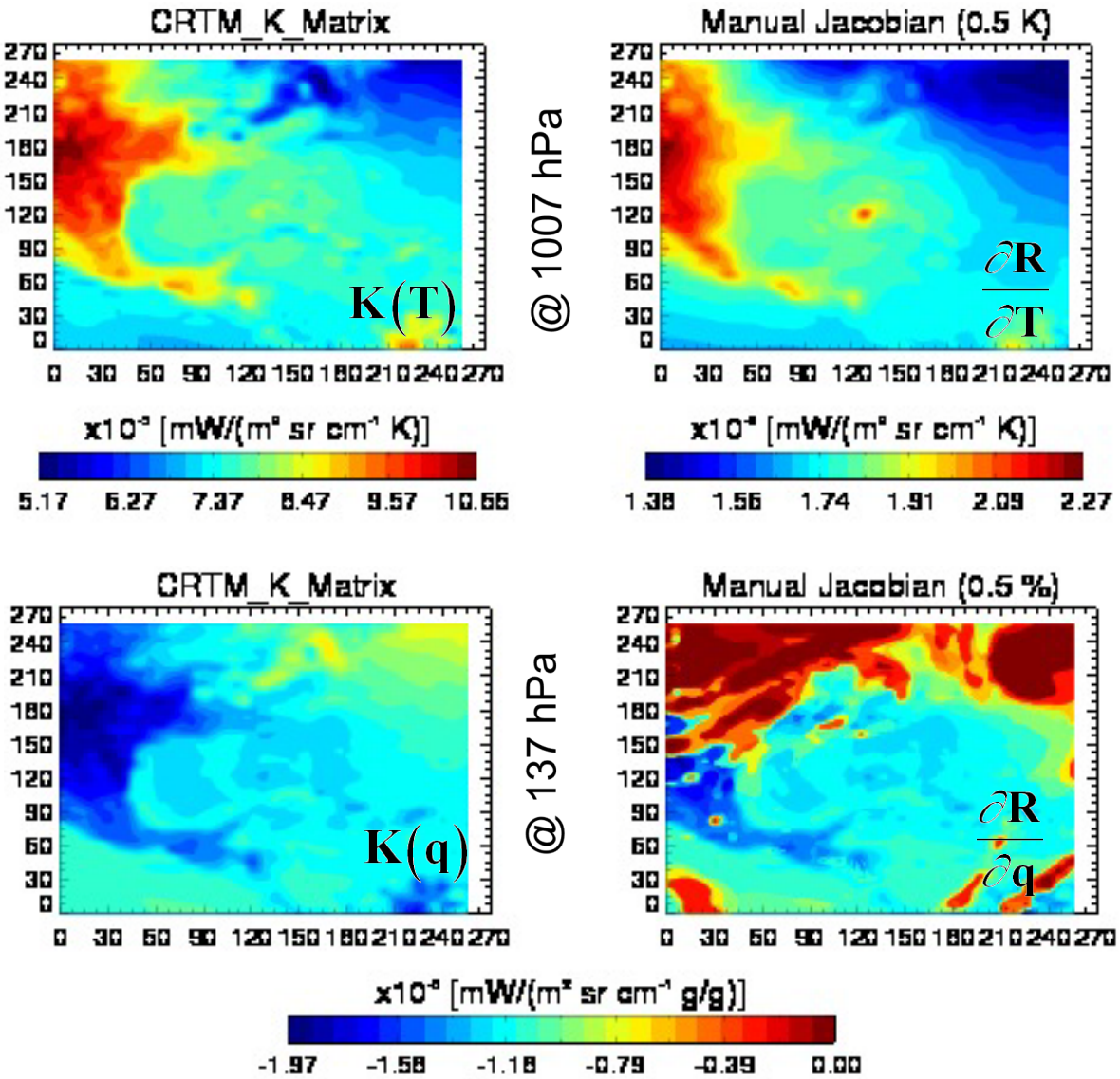
Tomoko Koyama, Yuanfu Xie, and Dan Birkenheuer

14 Jan 2011

Overview

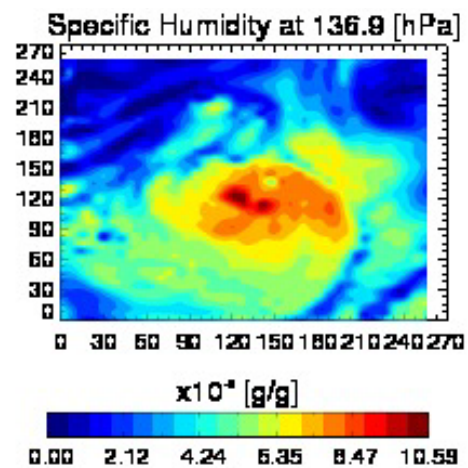
- K-Matrix checkout
- Near IR day/night inconsistencies
- Future Work

Checkout of the K-Matrix



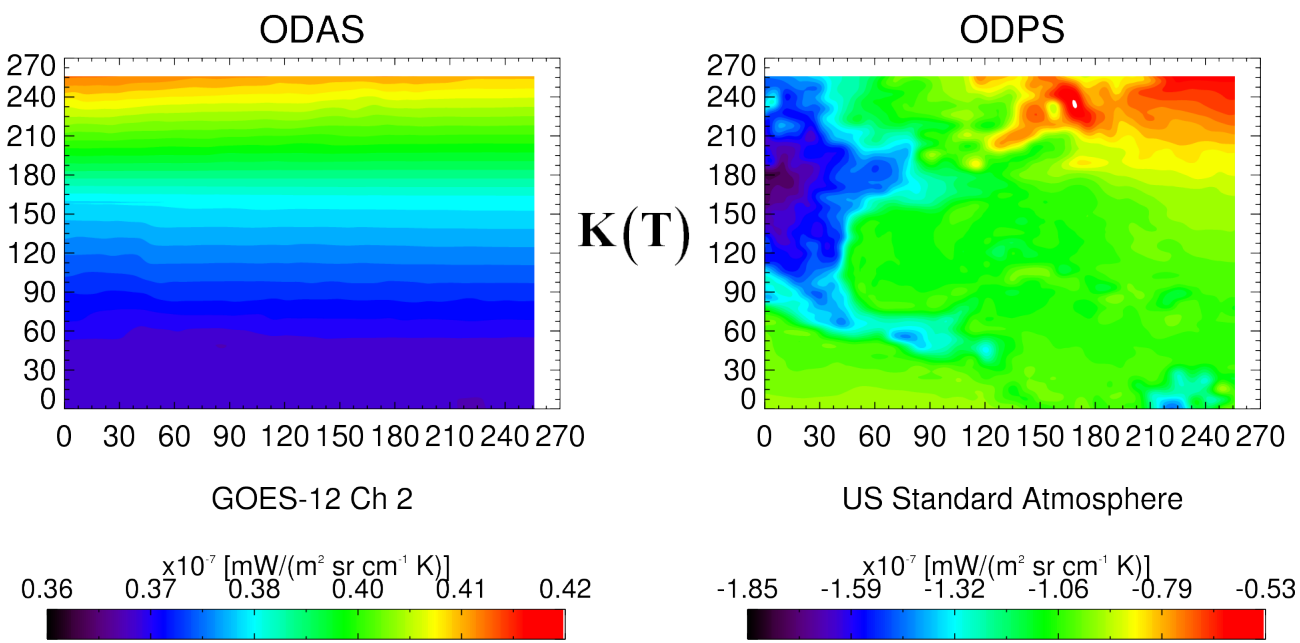
- The CRTM K-matrix performs well for Jacobians WRT temp perturbations.

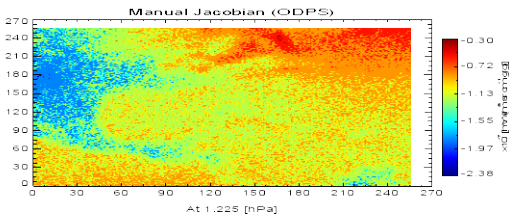
- Jacobians WRT moisture perturbations, the K-matrix performance seems promising. Further study is preferable.



Transmittance Algorithms

The CRTM K-matrix function occasionally shows lateral stripes at higher levels when the Optical Depth in Absorber Space (ODAS) model is selected. On the other hand, the Optical Depth in Pressure Space (ODPS) model shows reasonable patterns at the same levels.



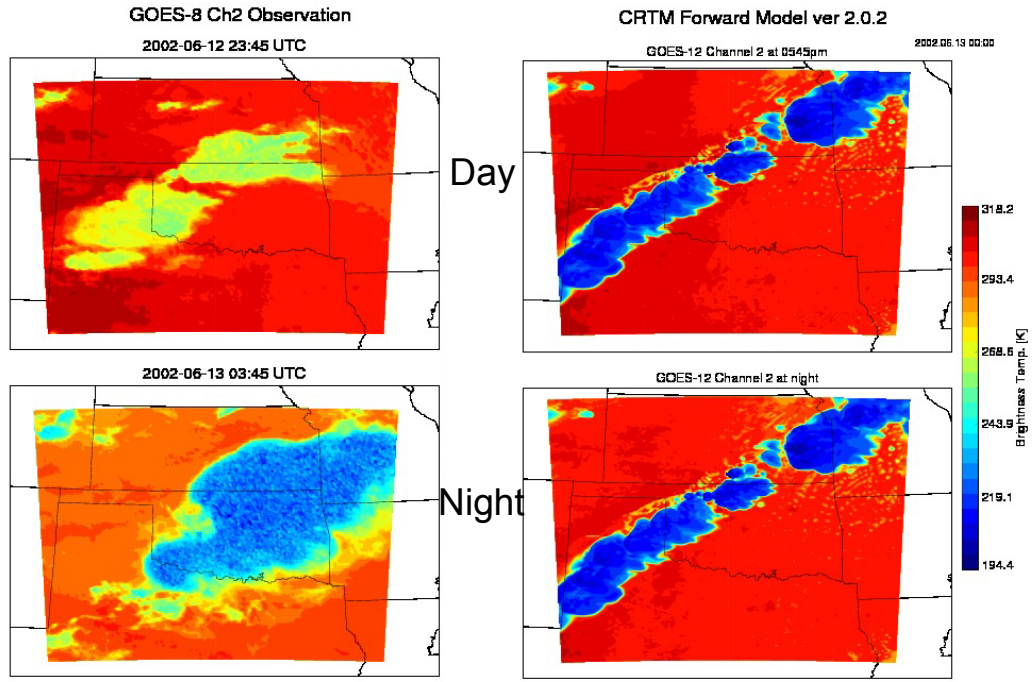


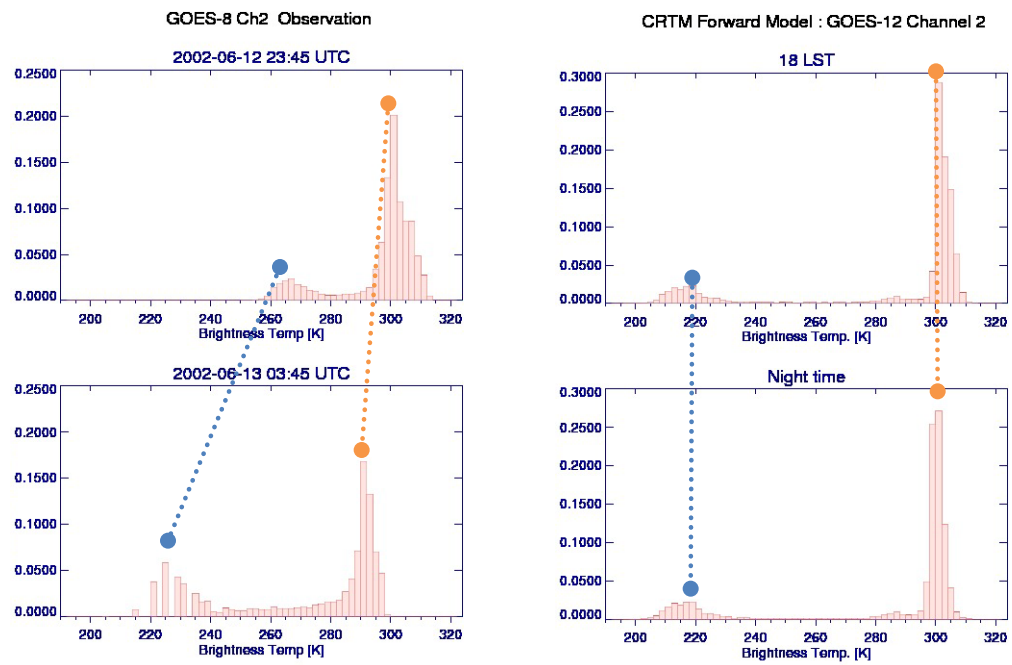
$$\frac{\partial \mathbf{R}}{\partial \mathbf{T}}$$

GOES-12 CH2
@ 1.225 hPa

Near-IR day/night Inconsistencies

Solar reflectance (BRDF) computation within CRTM 2.0 is still questionable. Simulated radiances with the forward model in the day time are lower than the equivalent observation.





Peak of Cloud-top Radiances

Peak of Ground Radiances

Future Work

- Adjustments to cloud microphysics

- Examine the CRTM forward and K-matrix functions in the microwave and visible wavelengths.

- Minimization of the cost (penalty) function using a limited memory quasi-Newtonian (L-BFGS) method within the IR range (starting with full-cloud advancing to partly cloudy problems).

$$J = \frac{1}{2}\sum_{i}\left[F\left(T_i, q_i\right) - R_i^{(obs)}\right]^2$$

Jean-Luc Moncet,
Vivienne Payne
AER Inc.

Implementation of OSS in CRTM

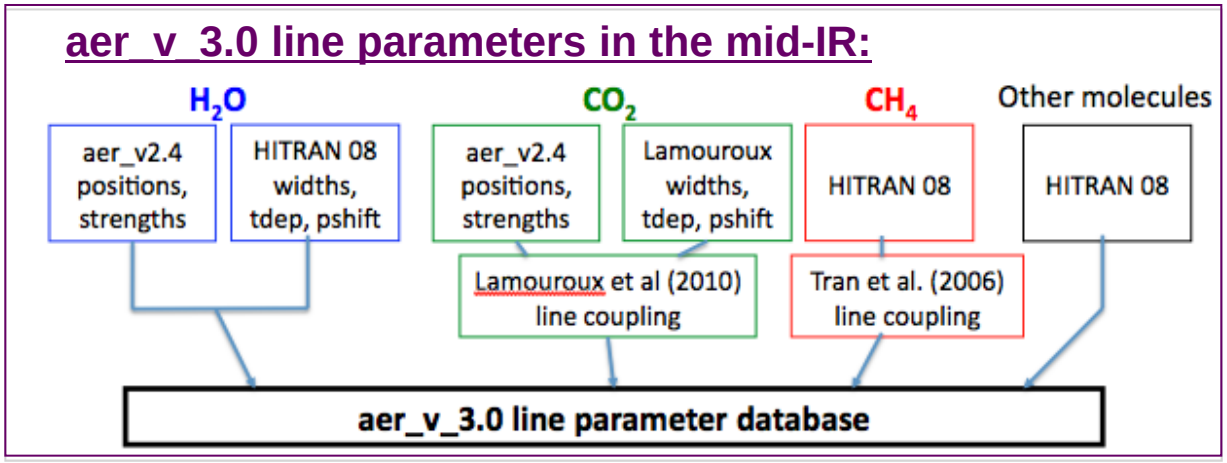
- **First phase of integration nearly complete (IR only/single sensor)**
  - **Created an OSS specific version of**
    - CRTM_Compute_Predictors (to produce average layer temperature and molecular amounts as well as interpolation coefficients and indices for the absorption look-up tables)
    - CRTM_Compute_AtmAbsorption (OSSTRAN)
    - OSS initialization function OSS_INIT moved into CRTM_LoadCoeff
    - Inserted node loop and node-to-channel (or node-to-PC)mapping function inside CRTM _Forward_Module
    - CRTM RT solvers, Cloud and Surface modules left unchanged
  - **Adapted existing structures (now called OSS_Predictor_type) to pass OSS specific data/arguments to the Absorption and RT modules**
- **Clear-sky Testing**
  - **Code successfully compiled and run**
  - **CRTM-OSS radiance output is being compared to AER's standalone OSS RT model**
    - Sources of difference:
    - Assumed dependence of temperature and mixing ratios on pressure in atmospheric path calculations
    - Differences in treatment of Planck function in RT modules
  - **CRTM_OSS only 25% slower than AER's model**
    - Believed to be due to differences in treatment of Planck function (not explicitly computed for each node in AER's model)

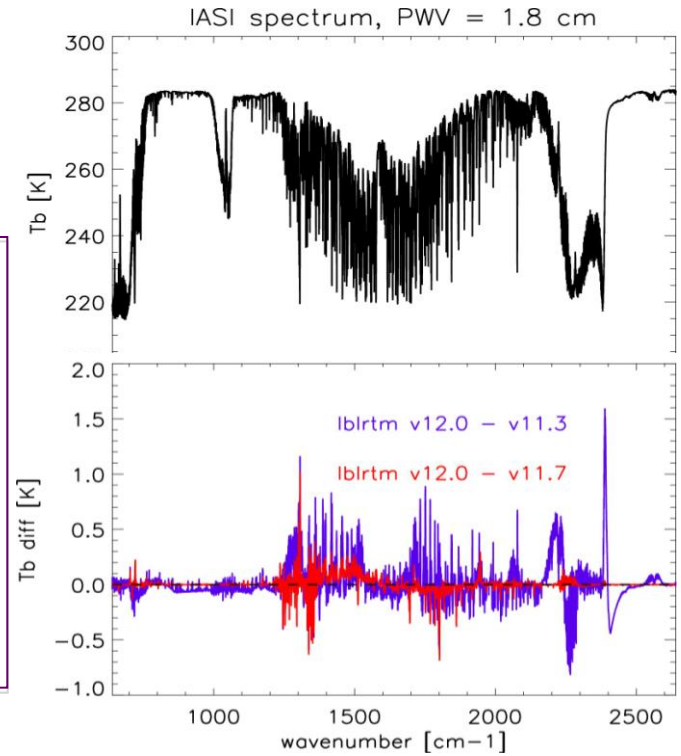
Implementation of OSS in CRTM

- **Next steps**
  - **Complete clear-sky testing in infrared and document changes**
  - **Test model in scattering environment**
  - **Jacobians**
    - Combine adjoint and analytical optical depth derivatives???
  - **Add multi-sensor capability**
  - **Add microwave specific capability**

Line by line modeling / spectroscopy

- **LBLRTM v12.0** release imminent
  - Supplied with mt_ckd 2.5.2 continuum and **aer_v_3.0 line parameter database**
  - Line parameter database based on **HITRAN 08**, with notable exceptions
    - H_2O and O_2 in the MW, H_2O and CO_2 in the IR
    - aer_v_3.0 contains **line coupling** coeffs
      - HITRAN database does not





  - Updates to **non-LTE** in LBLRTM v12.0
    - Capability to apply different vib. temp. profiles for minor isotopologues
    - Differences ~0.2 K at AIRS spectral res. for strong non-LTE conditions

Paul van Delst

MWSSEM, SRFs, and Surface Optics

- Microwave sea surface emissivity model update (under review)
  - Implementation of FASTEM4, developed by Q.Liu and S.English, in CRTM.
  - Updated the main CRTM unit test to properly exercise the surface optics modules.
- VIIRS NPP SRF analysis.
  - Converted the raw ASCII datafiles into our standard netCDF format.
  - Developed templates for future processing so generating the netCDF files shouldn't take as long.
  - Detector-to-detector variations noted, but no quantitative analysis done (Q.Liu has undertaken that task). We will add that capability to the standard SRF preprocessing.
- Surface optics (SfcOptics) structural changes for v3.0 are taking shape.
  - Based on work being done by W.Zheng (MW land surface emissivity) and D.Liang (MW snow surface emissivity).
  - Main CRTM interface will change:
    - Split the current surface structure into separate Land, Snow, Ice, and Water structures.
    - Allow specification of additional LUT files for the various IR/MW/VIS models.

Yong Han

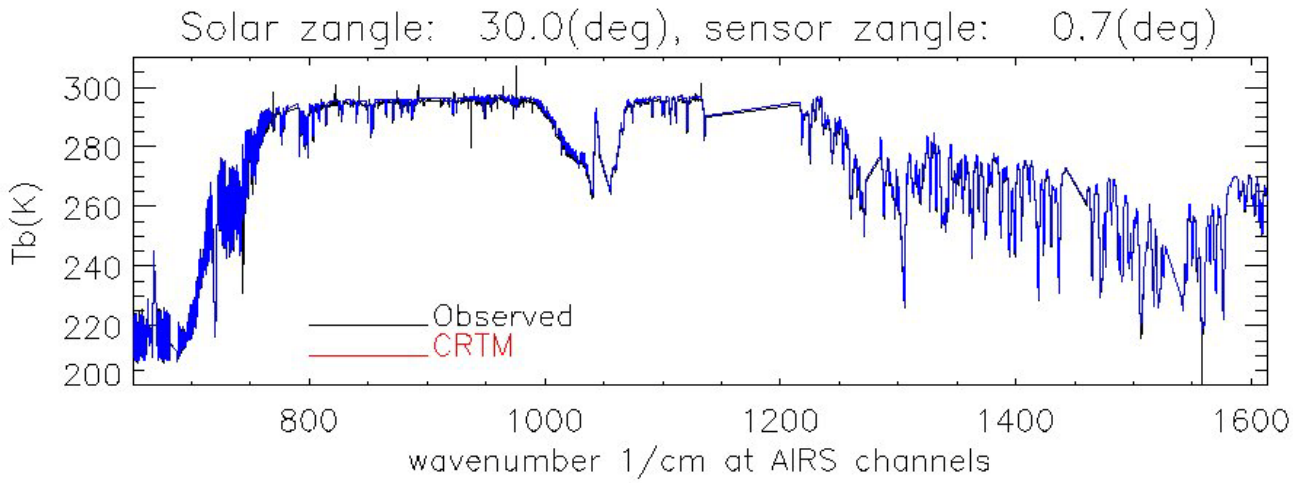
NLTE Model Implementation (CRTM v2.1)

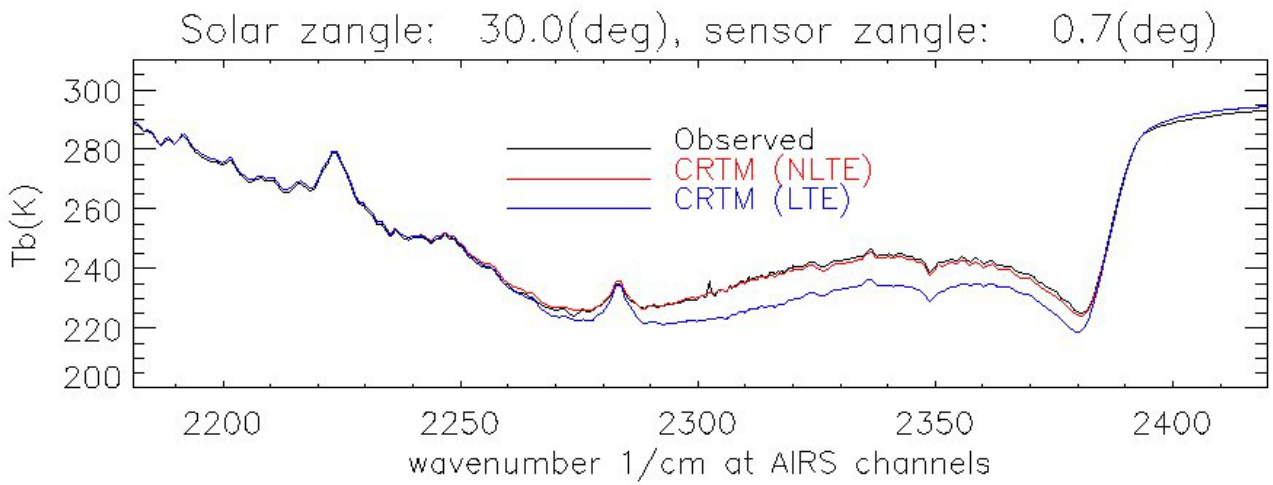
Yong Han, Yong Chen and Paul VanDelst

- The NLTE model is to predict the difference between the LTE and NLTE radiances and the difference is used to correct the LTE radiance either from the ODPS or ODAS transmittance model.
- Initial implementation and tests have been done (in CRTM NLTE branch); it is to be included in CRTM v2.1.
- Coefficients are generated for AIRS, IASI and CrIS; LBLRTM v11.7 is used for the training.
- Remaining work: reconfiguring the NLTE coefficient structure to be a substructure in the SpcCoeff structure and creating software to generate the NCDF file to hold the NLTE coefficients for archive and to create the SpcCoeff file with the NLTE data in it.
- Remaining issues: ~1.5K residual error (see next slides).

CRTM NLTE simulation vs observation example 1
Solar zenith angle = 30°, sensor zenith angle = 0.7^o

AIRS

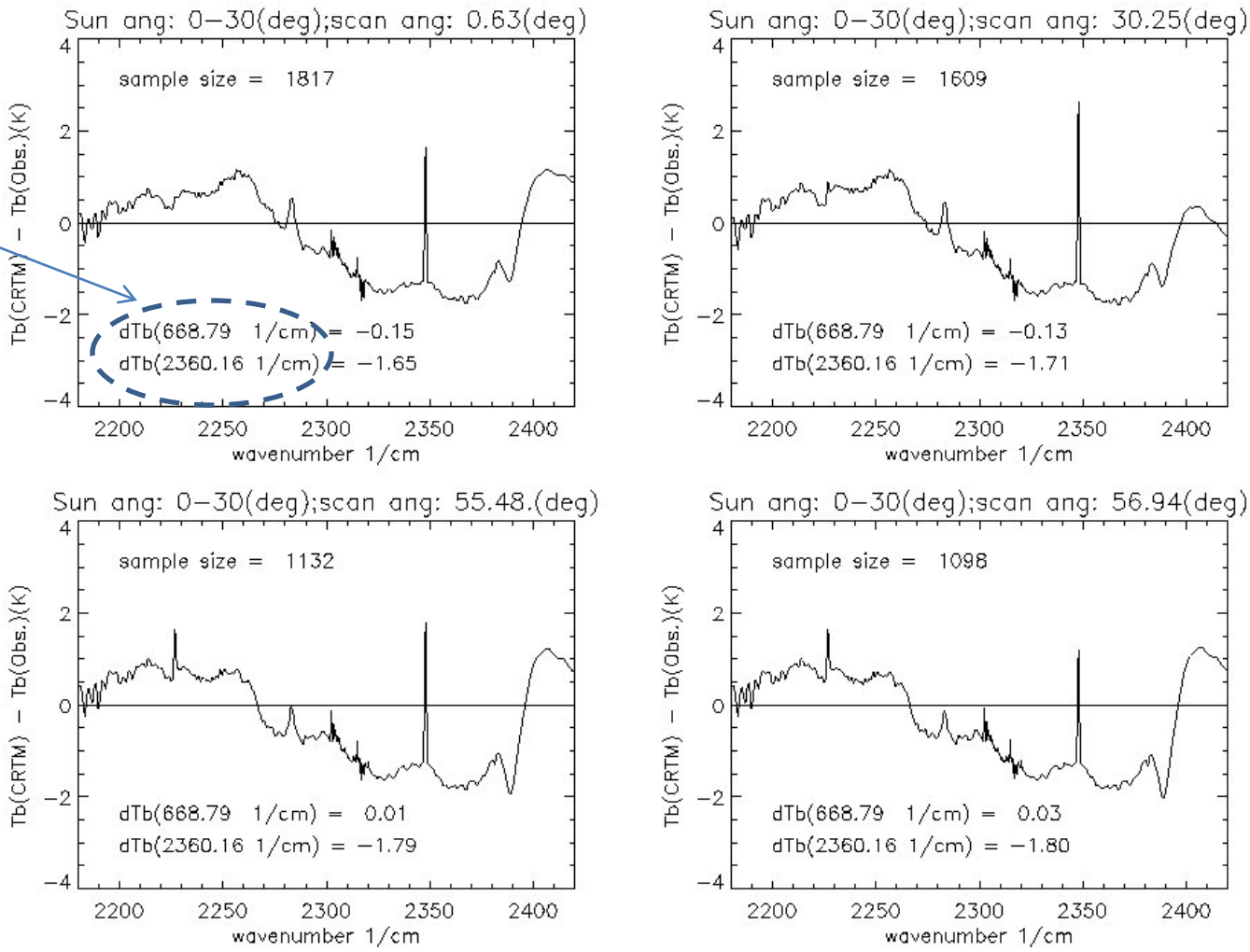




Differences of simulated and observed radiances in solar zenith angle range from 0° to 30° at four sensor scan angles

The two channels have similar weighting functions

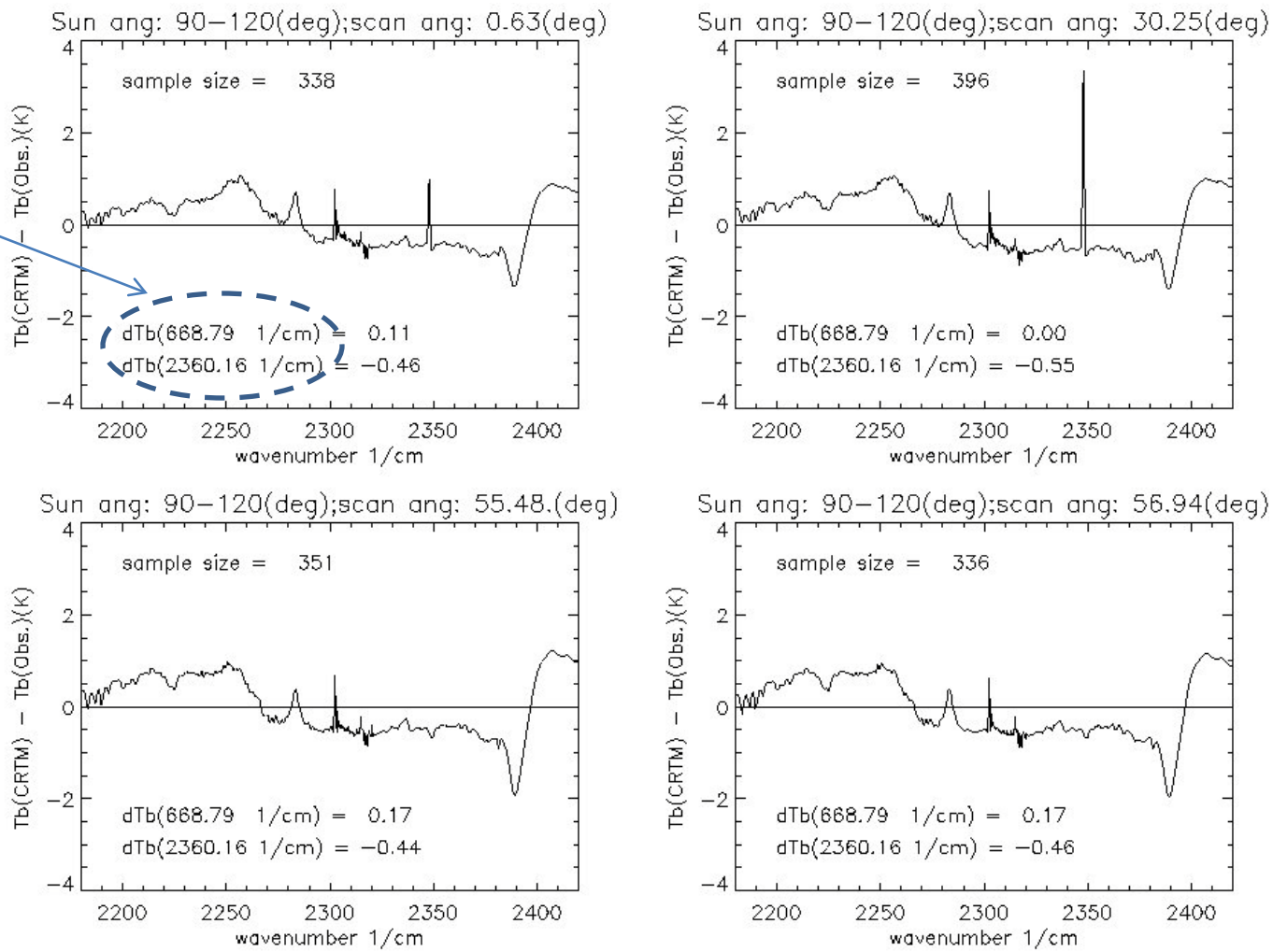
Daytime



Differences of simulated and observed radiances in solar zenith angle range from 90° to 120° at four sensor scan angles

The two channels have similar weighting functions

Night Time



Summary

- The NLTE can have a huge effect (~10K) in daytime.
- The fast NLTE model will significantly improve the accuracy of daytime shortwave radiance calculations.
- The CRTM/NLTE model underestimates the NLTE affected radiance by about 1.5 K.
- We are closely working with AER to address the remaining errors.
- Possible error sources (from Vivienne):
  - LBLRTM (v11.7) does not take into account that different isotopologues have different vibrational temperature profiles (up to 0.2K).
  - LBLRTM CO2 v3 line strength error as suggested by the nighttime AIRS M-O spectral difference.

Quanhua Liu

CRTM Module Aerosol Optical Depth Calculations

Quanhua (Mark) Liu

Joint Center for Satellite Data Assimilation

January 14, 2011

Module CRTM_Aerosol_AOD

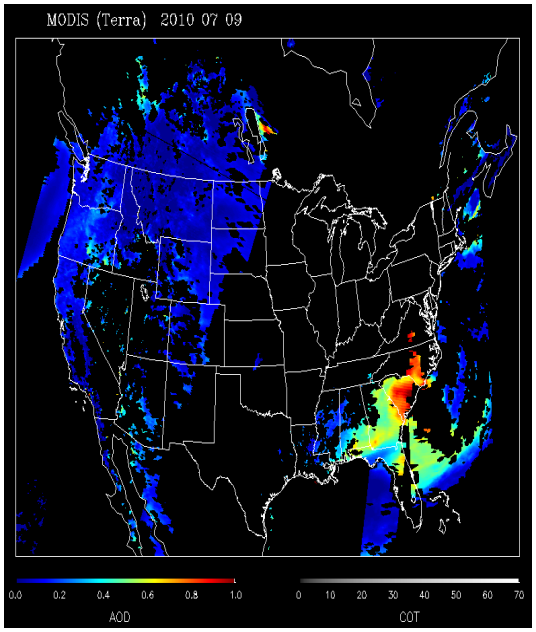
- Compute Layer Aerosol Optical Depth

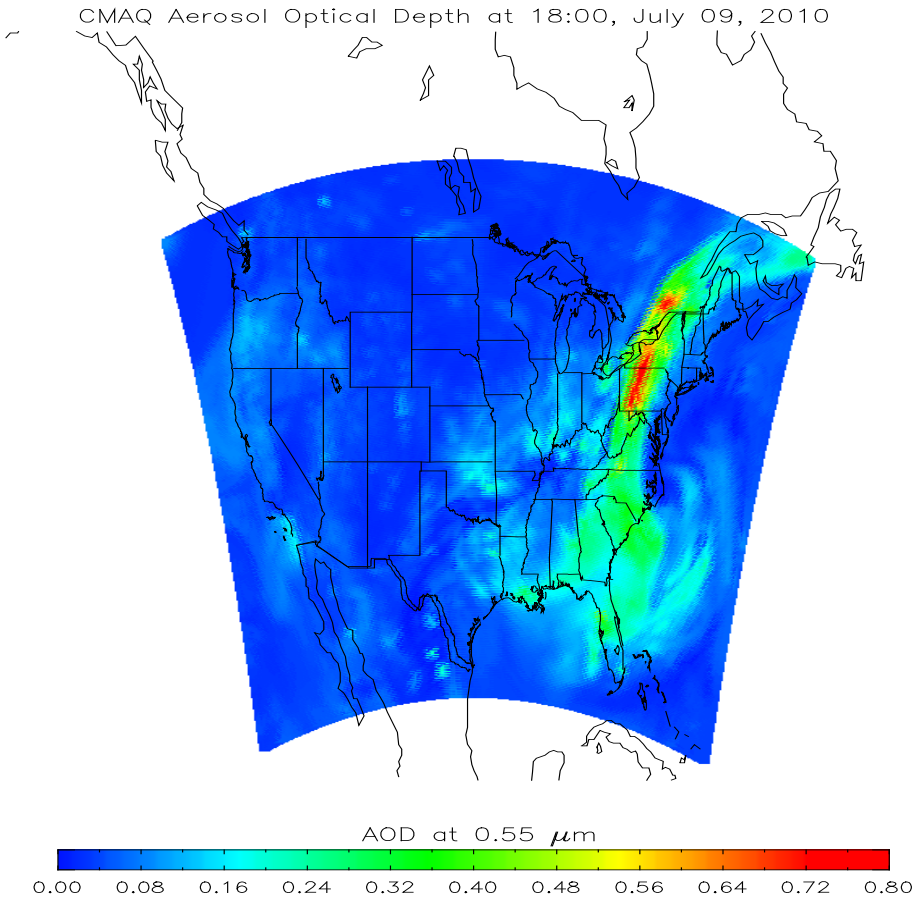
Error_Status = CRTM_Aerosol_AOD
(Atmosphere,ChannelInfo,RTSolution)

Change to (?)

Error_Status = CRTM_Aerosol_AOD
(Atmosphere,Wavelength,Aerosol_AOD)

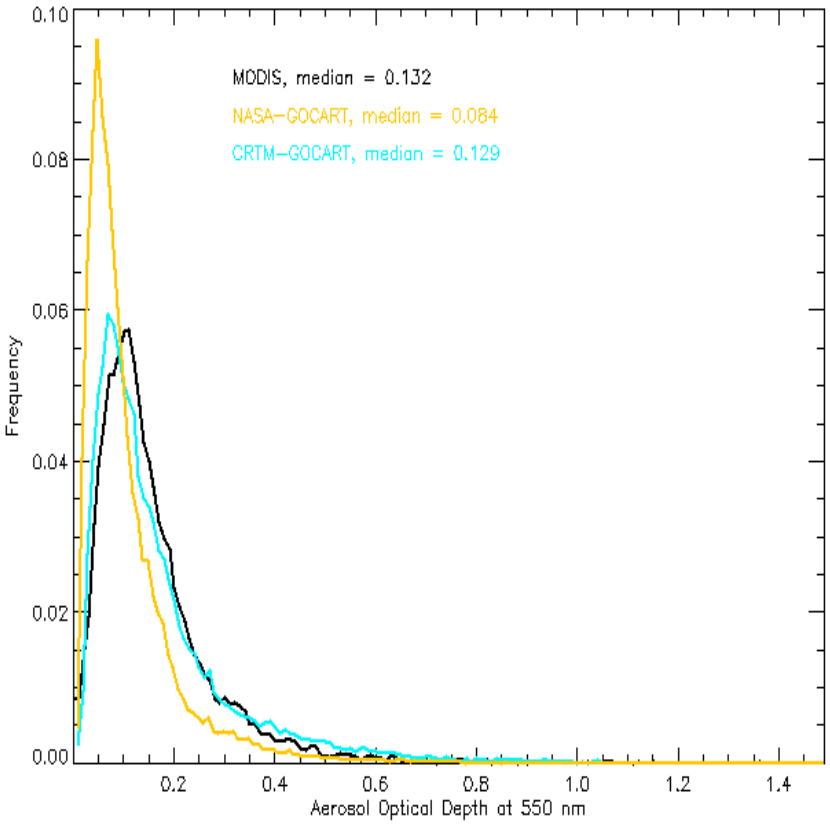
MODIS AOD and CMAQ surface layer aerosol

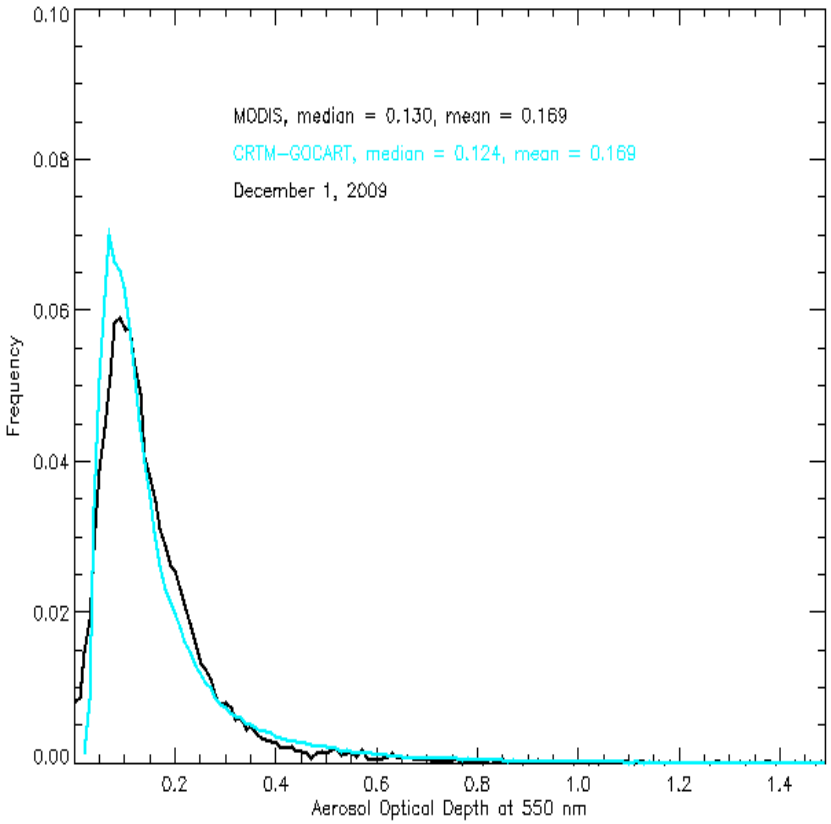




Left and middle panels are the MODIS and the CRTM aerosol optical depth (AOD) and the right panel is CMAQ surface aerosol concentration.

AOD Comparisons





Left panel is for Dec. 1, 2007.

David Groff

SOI Implementation

- The CRTM_RTSolution.f90 module in the EXP-SOI branch is being refactored to be a wrapper for algorithm specific RTSolution modules.

- The refactor of CRTM_RTSolution.f90 will allow there to be a well defined process for implementing RTSolution algorithms in the future.

- Unit tests are being written for the RTSolution algorithms in the EXP-SOI branch. Tom Greenwald will be using these unit tests as a reference when making future changes to SOI_Module.f90.

- The SOI RTSolution algorithm is scheduled for inclusion in CRTM release 2.1.

Tong Zhu

IR land emissivity - Tong Zhu

Things completed, or nearly so:

- Analyzed one year monthly IASI land surface emissivity data set. Convolved high spectral resolution IASI emissivity to broadband SEVIRI emissivity. It was found that seasonal variation is significant over Sahara Desert. Diurnal change of the emissivity can also be found in desert region.
- Analyzed AIRS Version-5 globe surface emissivity. There are three kind of time scale data sets, daily, 8-day, and monthly. It was found that there are a lot of missing data over desert region even in AIRS monthly emissivity data.

Things still to do/being done:

- Study the impacts of IASI emissivity on the CRTM simulation of SEVIRI IR radiance. We will focus on the performance over North Africa desert region, and will test three kinds of emissivity data sets, i.e. daytime, nighttime, and combined emissivity data sets.
- Study the improvement of CRTM simulation by using a new emissivity and land surface temperature (LST) together.
- Access the IASI emissivity impacts on GFS forecast. A series of control and sensitive runs will be conducted by assimilating SEVIRI CSR, GOES Imager and other IR sensors with and without new IR emissivity and LST.

Yong Chen

Earth Curvature and CFCs Absorption Impacts on AVHRR radiances (CRTM v2.0.2)

Yong Chen and Yong Han

- The current CRTM v2.0.2 includes two transmittance models ODAS, and ODPS. ODAS assumes plane-parallel atmosphere with constant local path angle, while ODPS considers the curvature of earth, local path angle changing with altitude. This difference results in surface zenith angle is larger for ODPS than ODAS for the same TOA zenith angle. For the same surface zenith angle, the ODPS has larger BT due to smaller zenith angle at higher levels compared to ODAS.

- ODPS was training with LBLRTM v11.3 but add other 10 trace gases (NO, SO_2, NO_2, HNO_3, OCS, N_2, CCl_4, CCl_3F (CFC-11), CCl_2F_2 (CFC-12),and CCl_2FCClF_2 (CFC-113)), in addition to H_2O, CO_2, O_3, N_2O, CO, CH_4, and O_2 as in ODAS. AVHRR3 channel 4 and 5 are greater impacted by CFCs absoption, on average about 0.3 K, 0.2 K smaller respectively.

- Comparison results between observations and CRTM simulations over ocean have verified the findings.

New Coefficients Generation

Yong Chen

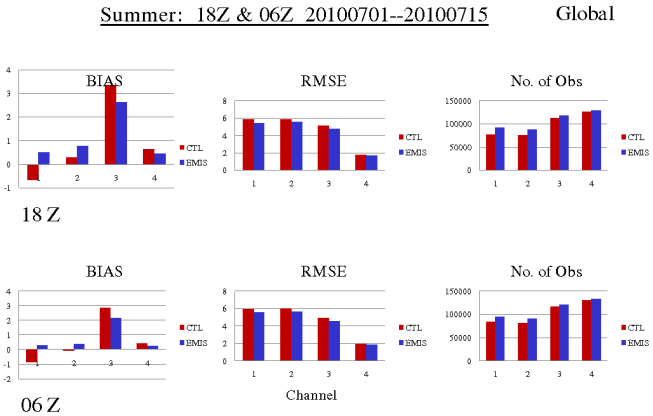
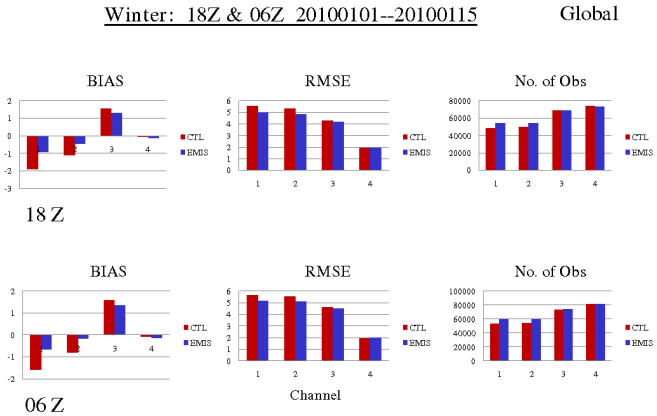
- VIIRS (imager channel 4 and 5, moderate spatial resolution sensor channels M12-M16) transmittance coefficients for both ODAS and ODPS.
- GOES 15 imager and sounder transmittance coefficients for both ODAS and ODPS.
- GOES 13 imager, GOES 14 imager and sounder transmittance coefficients regeneration based on new update SRF.
- TMI on TRMM, and GMI on GPM transmittance coefficients are updated to correct center frequencies for channels 8 and 9 (from 85.0 GHz to 85.5 GHz) for tmi_trmm, and channel 4 (from 19.7 GHz to 18.7 GHz) for gmi_gpm.

Weizhong Zheng

MW Land Emissivity Calculation in CRTM

Weizhong Zheng and Michael Ek

NOAA/NCEP/EMC

CWG Telecon., Jan.14, 2011

- **Continue to improve MW land emissivity calculation and its implementation;**
- **Enhancement of soil and vegetation description; An alternative vegetation dielectric constant and improvement of canopy optical parameters calculation;**
- **Established sets of soil and vegetation parameters required for the new emissivity calculation;**
- **Sensitivity tests with the GSI/CRTM show reduction of bias and rmse of Tb simulation and increase of number of observations assimilated, especially over forest areas;**
- **Some areas (like desert, etc.) still have problems, so further study is needed.**