CRTM at the JCSDA
Status Report

Paul van Delst (CIMSS)

Small selection of people involved

- JCSDA
  - Yong Han, Quanhua Liu, Paul van Delst(CIMSS), Russ Treadon, John Derber, Masahiro Kazumori(JMA), Yoshihiko Tahara(JMA), David Groff, Roger Saunders(MetOffice)
- NESDIS/ORA
  - Banghua Yan, Fuzhong Weng, Yong Chen, Nick Nalli
- NASA/GSFC
  - Clark Weaver
- UW/AOS, CIMSS/SSEC
  - Ralf Bennartz, Tom Greenwald, Chris O'Dell, Bryan Baum
- AER
  - Jean-Luc Moncet, Gennady Uymin, Sid-Ahmed Boukabara (now at NESDIS)
- IT Help
  - Tim Wait, Jason van Houten, SSEC Unix Admin folks

Major Milestone

- The CRTM has been integrated into the GSI at NCEP/EMC (Dec 2005).
- Initial results and tests have focused on achieving similar results as the protoype CRTM, pCRTM. (Note: This is *not* Xu Liu's principal components RTM!)
- The CRTM in this mode is a bit faster than pCRTM.
- Testing is ongoing.

CRTM Framework

- The CRTM is basically a big bucket for the various components involved in simulating satellite radiance measurements for data assimilation.
- Four main components
  - Atmospheric gaseous absorption (AtmAbsorption)
  - Scattering and absorption by clouds and aerosols (AtmScatter)
  - Surface optics; emissivity and reflectivity (SfcOptics)
  - Radiative transfer solution (RTSolution)
- Four models
  - Forward ⇒ used operationally
  - Tangent-linear
  - Adjoint
  - K-Matrix ⇒ used operationally
- The ultimate goal was to make various implementations of the components easily replaceable. Mostly true.

AtmAbsorption

- CompactOPTRAN is the current AtmAbsorption algorithm in use.
- Other algorithms:
  - OPTRAN v7. Implemented, but the OD coefficient S/W still needs some tuning.
  - SARTA. In the process of being integrated. (Yong Chen)
  - RTTOV. In the process of being integrated. (Roger Saunders)
  - OSS. Implemented, but some software components need updating to latest CRTM release.
- OSS. Significant changes to CRTM framework required for implementation.
  - AER in the process of delivering the software package to generate the OSS IR LUTs. Testing has started at JCSDA.
  - MW component on its way.
- Investigating the implementation of multiple, concurrent AtmAbsorption algorithms.

AtmScatter

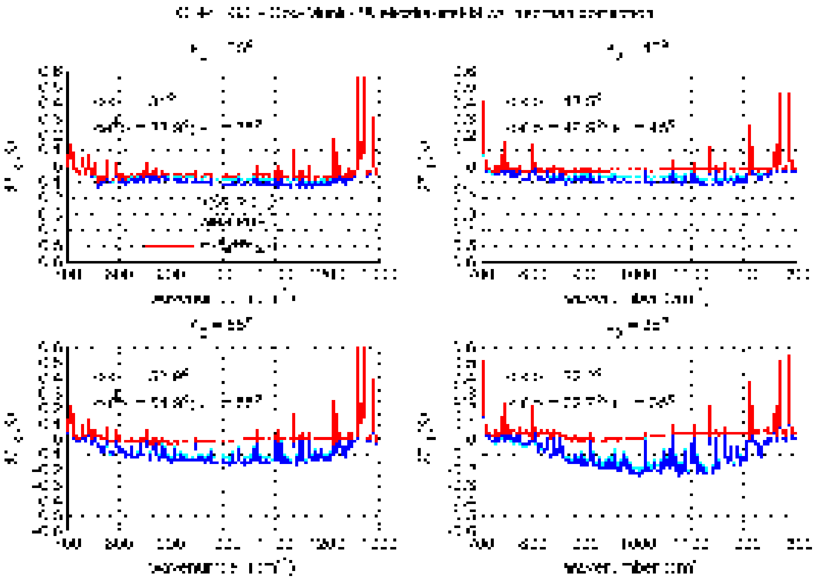
- Encompasses both cloud and aerosol scattering and absorption.
- **CloudScatter**
  - Six cloud types: water, ice, rain, snow, graupel and hail.
  - LUT for mass extinction coefficient, single scatter albedo, asymmetry factor and Legendre phase coefficients.
  - IR: spherical particles for liquid water and ice cloud; non-spherical ice cloud tables.
  - MW: spherical particles for rain drops and ice and snow clouds. Rayleigh approximation for liquid and ice clouds.
  - Parameters are obtained from LUT via cloud type, particle effective radius, and cloud water content.
- **AerosolScatter** (still being implemented)
  - Seven aerosol types: dust, sea salt, dry/wet organic/black carbon, sulfate.
  - LUT of absorption properties based on aerosol type, particle effective radius, and concentration.

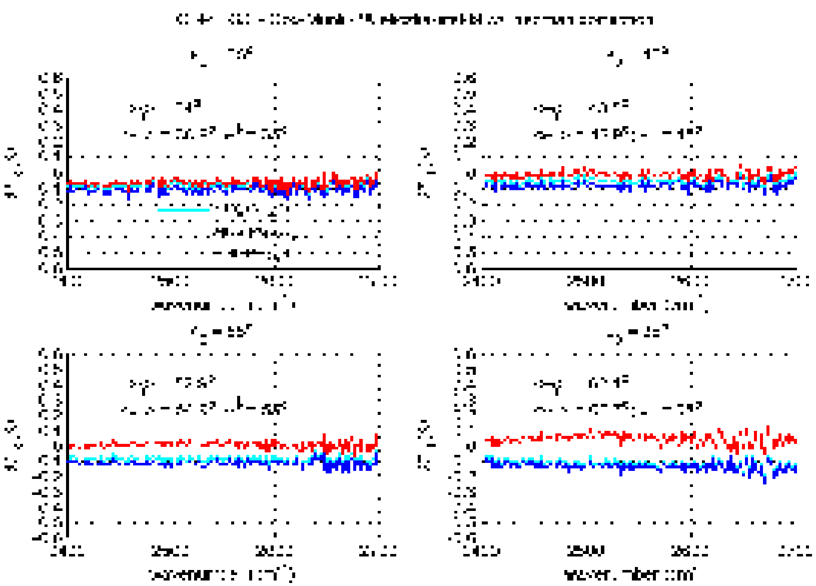
SfcOptics

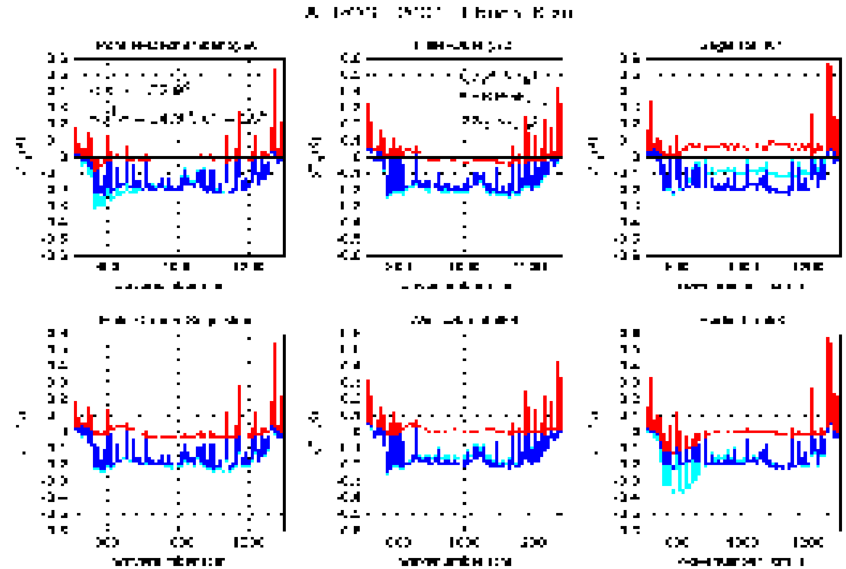
- Infrared and microwave models for four different surface types: land, water, snow, and ice.
- **Infrared- water**
  - Currently, IRSSE is a LUT based on Wu-Smith model (ensemble mean of 1-r) generated at high resolution. LUT parameters are view angle, surface wind speed, and frequency.
- Nick Nalli's ensemble mean surface geometry model.
  - Work beginning on integration into the CRTM
  - Properly accounts for reflected downwelling radiance. Conventional approach to modeling IR surface-leaving radiance results in systematic underestimation of surface leaving radiance.
  - Preliminary approach shows good agreement with M-AERI from CSP and AEROSE. Amounts to a 0.15-0.3% correction in emissivity; 0.1-0.2K correction in bias

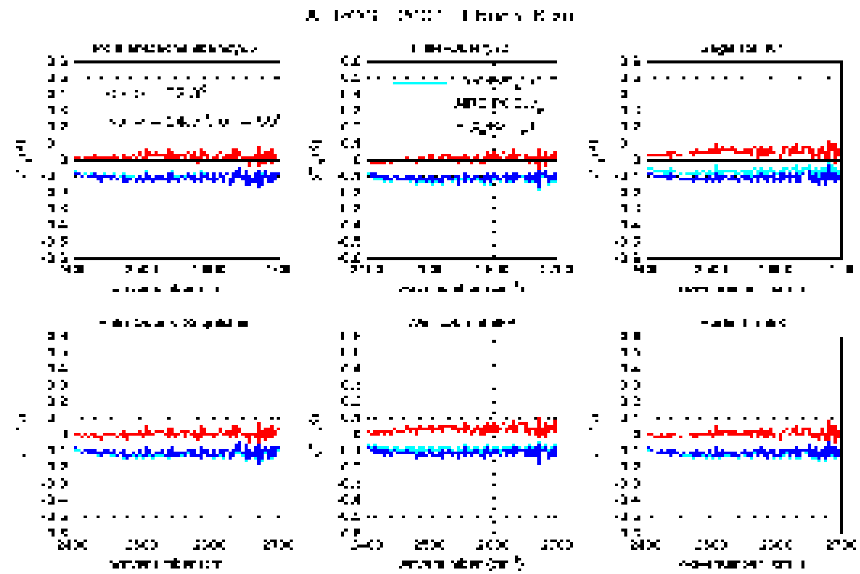
1996 CSP

2004 AEROSE







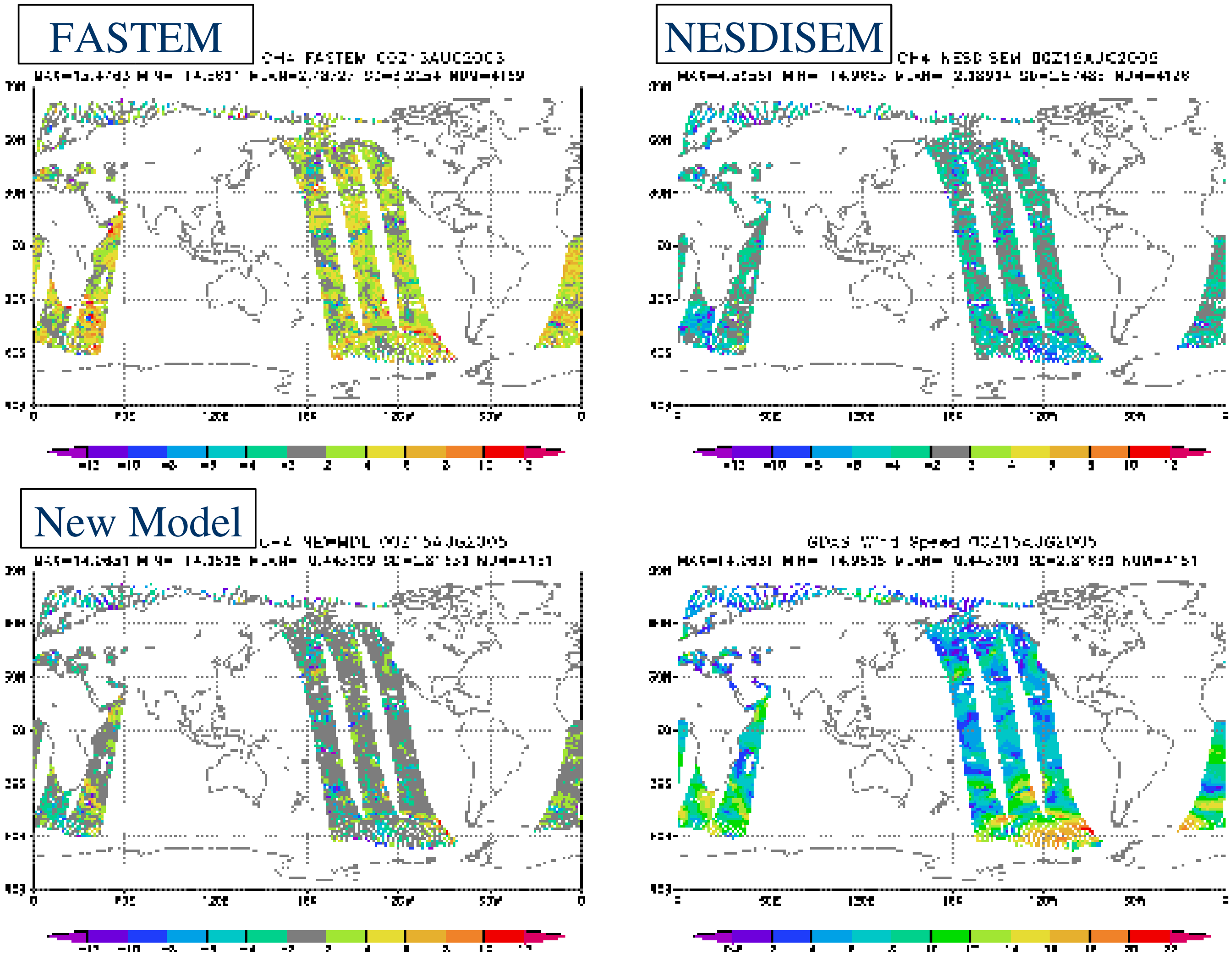


SfcOptics

- **Infrared- land,snow,ice**
  - Currently, IRLSE is a LUT based on a database. The measurement database is for various land, snow and ice surface types. 24 surface types in total (NPOESS Net Heat Flux ATBD, 2001)
- **Microwave- water**
  - FASTEM-1 (English, 1998). Other wind speed dependent models are being investigated (NESDIS model). Also, wind vector dependent models.
  - Masahiro Kazumori is working on AMSR-E radiance assimilation and has developed a water surface emissivity model for that instrument.
- **Microwave- land,snow,ice** (Weng and Yan)
  - Land: Physical model when $f<80$GHz, $e=0.95$ for $f\geq80$GHz.
  - Snow: Empirical models (using window channels) for AMSU, AMSR-E, MSU, and SSM/I. Physical model for other sensors when $f<80$GHz, $e=0.9$ for $f\geq80$GHz.
  - Ice: Empirical models (using window channels) for AMSU, AMSR-E, MSU, and SSM/I. $e=0.92$ for other sensors.

AMSR-E radiance assimilation in GSI

Simulated TB - Observed TB   AMSR-E 10.65GHz(H)



AMSR-E radiance at low frequency contains signature on surface wind speed and temperature over Oceans.

Surface emissivity plays an important role in direct radiance assimilation.

The new emissivity model reduces the error in model radiance simulation.

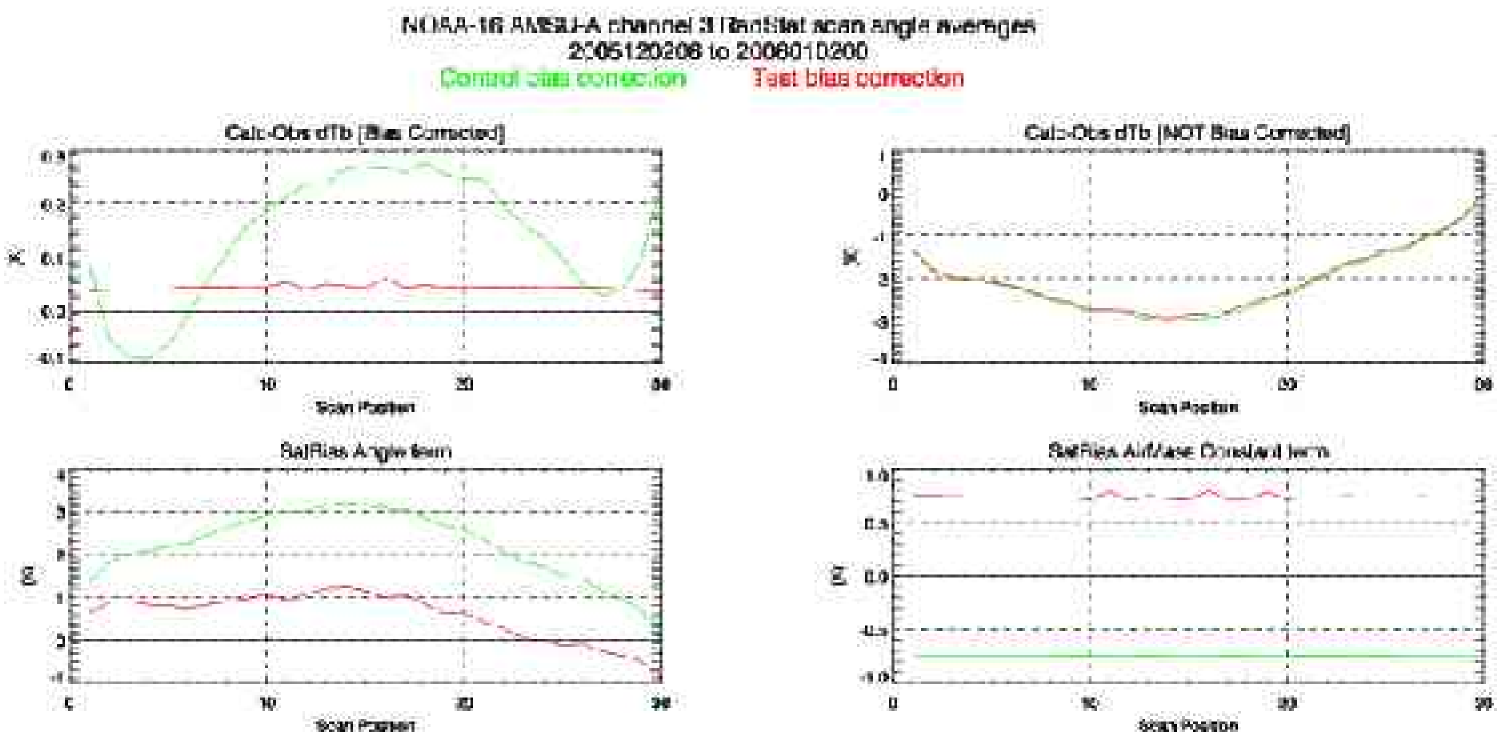
Masahiro Kazumori, JMA/JCSDA

RTSolution

- Two radiative transfer solvers.
  - NESDIS advanced doubling-adding (ADA) algorithm. Fully implemented.
  - UW/AOS/CIMSS successive order of interaction (SOI) algorithm. Partially implemented.
- Fast RT algorithm for SSMIS channels affected by Zeeman-splitting.
  - Has been developed, but attention/effort required to integrate into CRTM.
- No handling of nonLTE yet. Affected channels in operations (e.g. AIRS 4.3um) are not assimilated.

Bias Correction

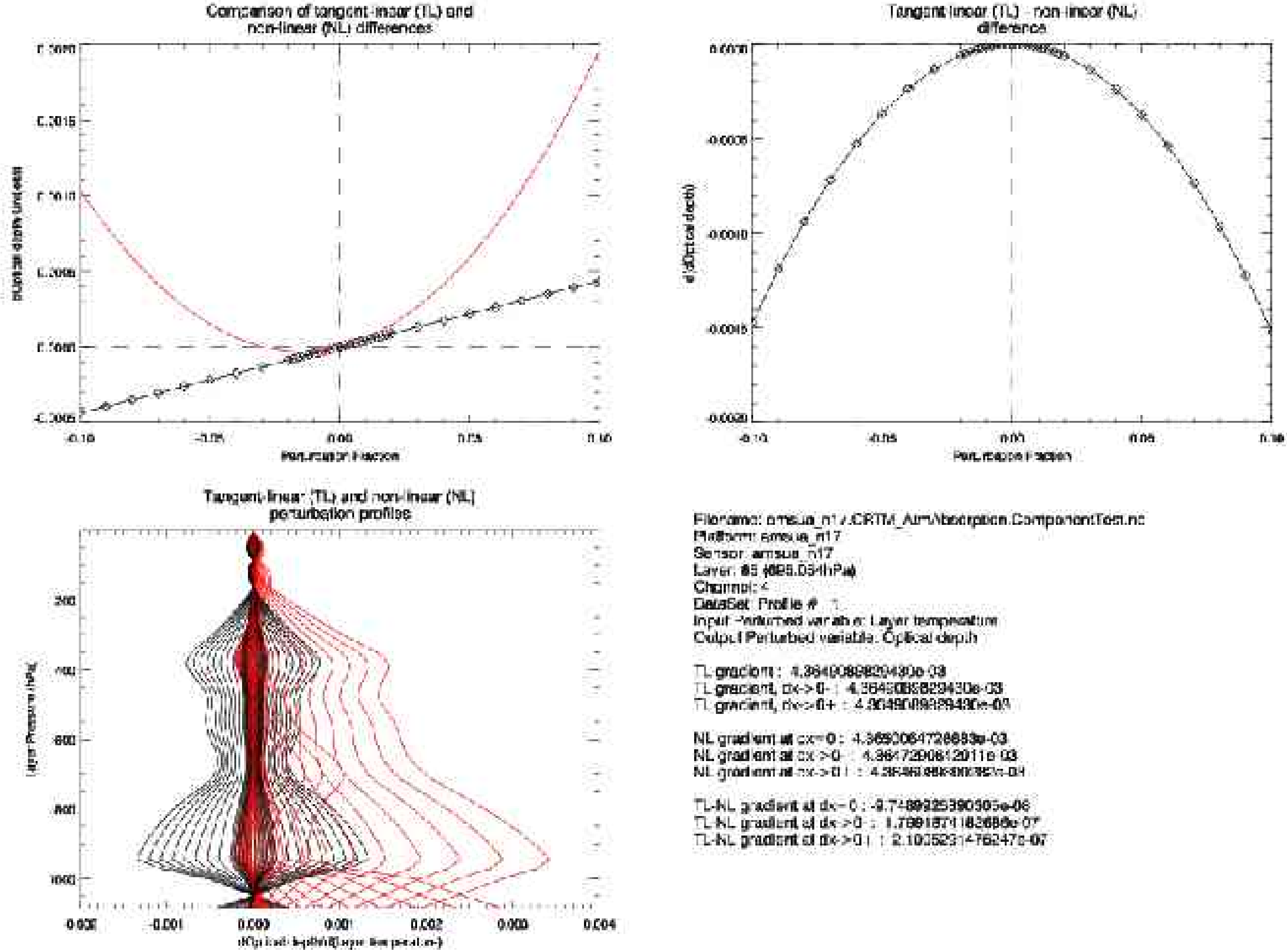
- Bias correction in GSI consists of two parts.
  - Slowly varying scan dependence.
  - Predicted air mass dependence (variational).
- CRTM requires new bias correction procedures.
- Preliminary results are encouraging. Real test is when clouds and aerosols are turned on.



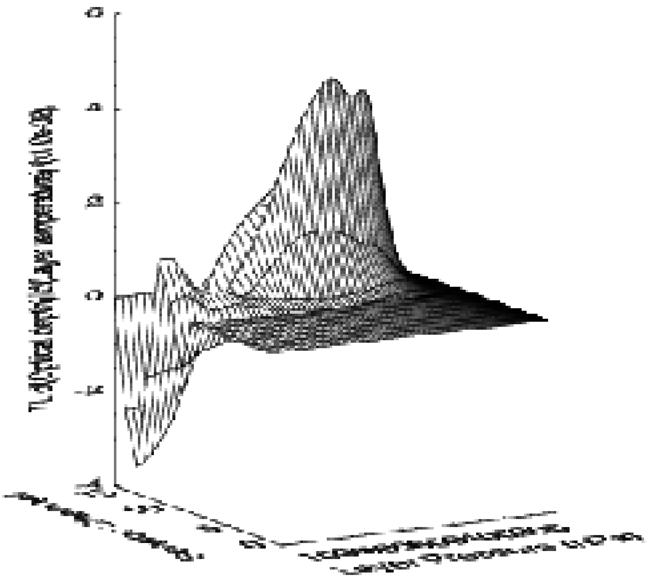
Consistency Testing

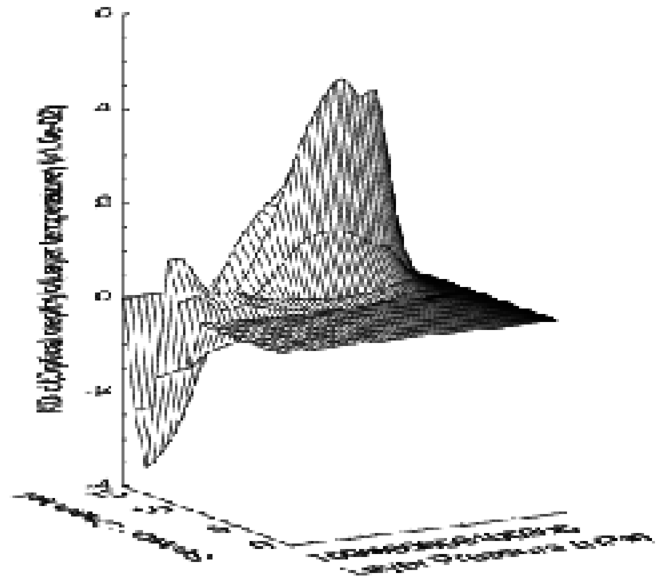
- Testing the consistency of FWD/TL/AD/K models is now being focused on.
- Important for code to be used in assimilation systems.
- Currently only the AtmAbsorption (Compact OPTRAN) and the CloudScatter components have been tested for FWD/TL/AD consistency.
- Some issues have come up with regards to the CloudScatter testing.
- David Groff will be constructing and running the tests for the other components (AerosolScatter, SfcOptics, "RTSolution")

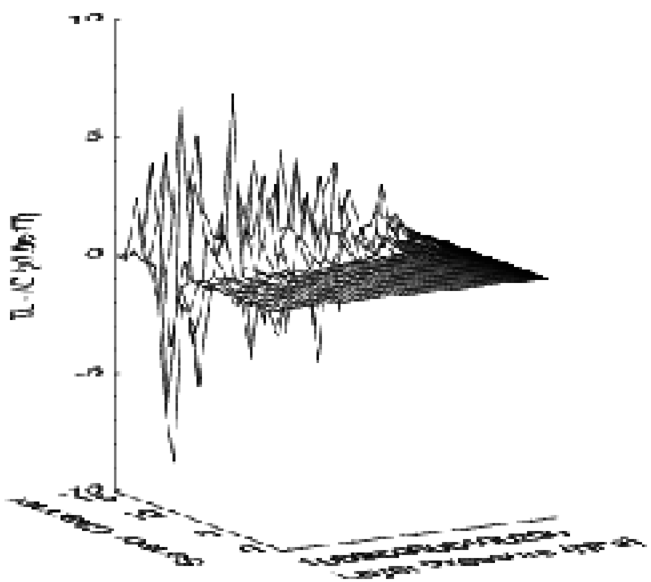
AtmAbsorption(Compact OPTRAN) FWD/TL Test



AtmAbsorption(Compact OPTRAN) TL/AD Test

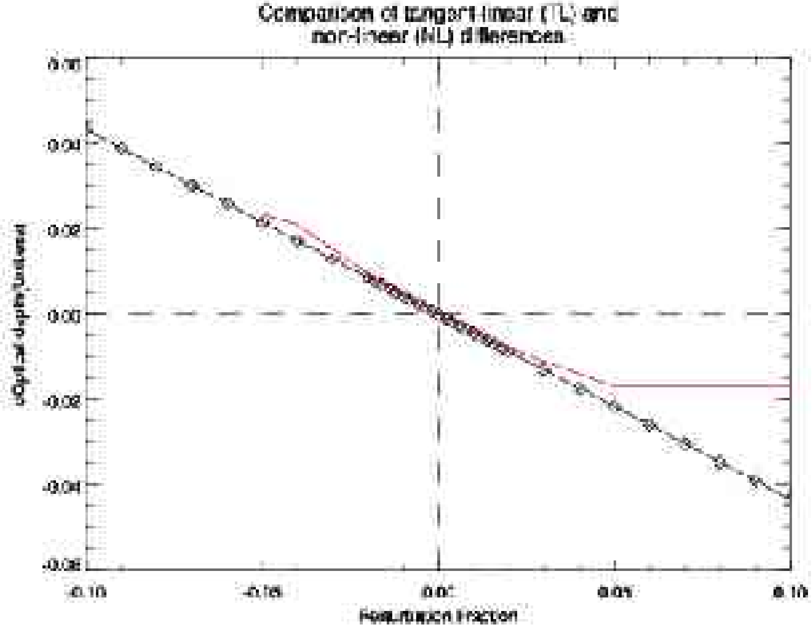


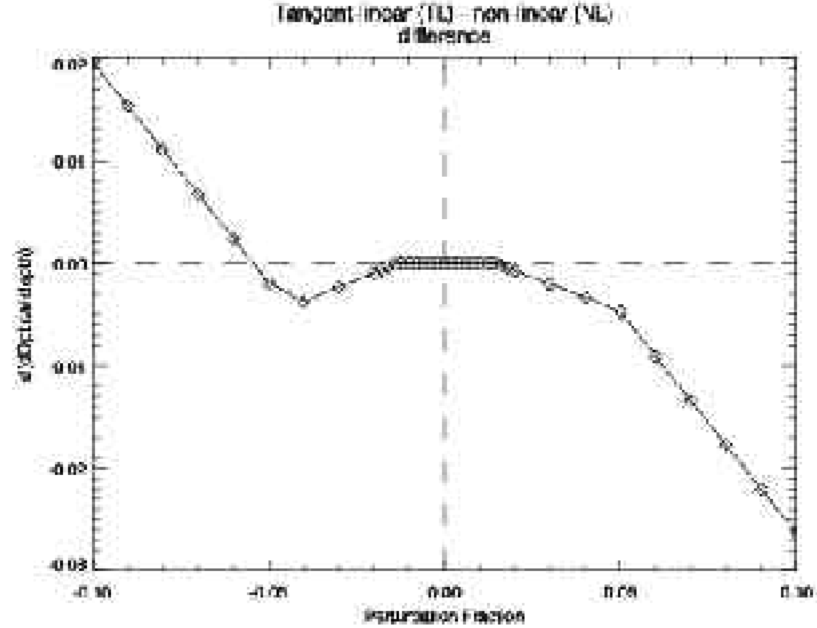


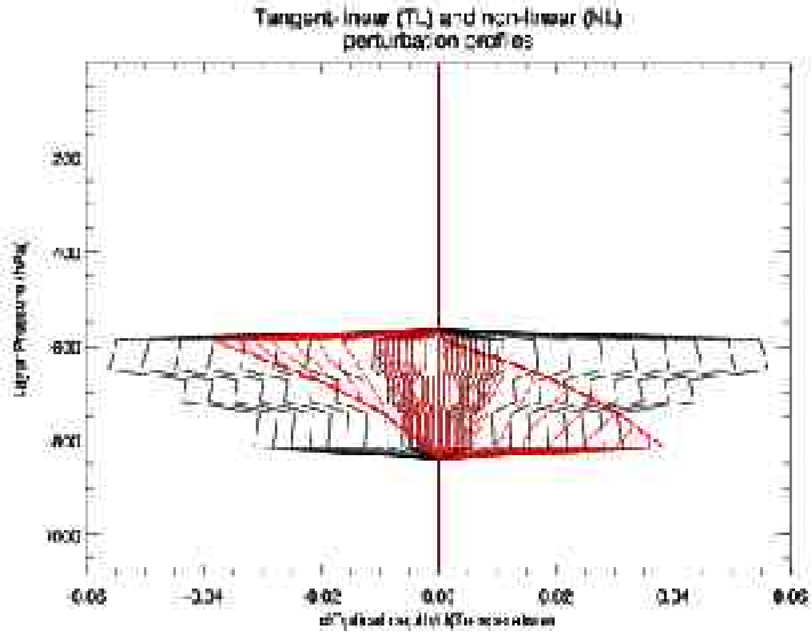


Filename: amsua_n17.CRTM_AtmAbsorption.ComponentTest.nc
Platform: amsua_n17
Sensor: amsua_n17
Channel: N/A
DataSet: Profile # 42
Variable: d(Optical depth)/d(Layer temperature)

CloudScatter FWD/TL Test: dOD/dT







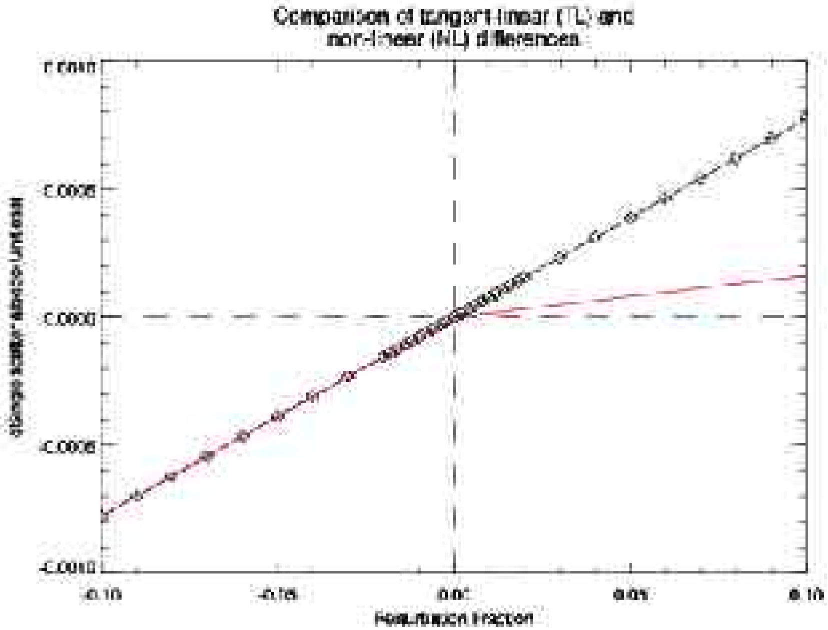
Filename: amsua_n17.CRTM_CloudScatter.ComponentTest.nc
Platform: amsua_n17
Sensor: amsua_n17
Layer: 85 (885.054hPa)
Channel: 1
DataSet: Profile # 1, Selected cloud: Water
Input Perturbed variable: Temperature
Output Perturbed variable: Optical depth

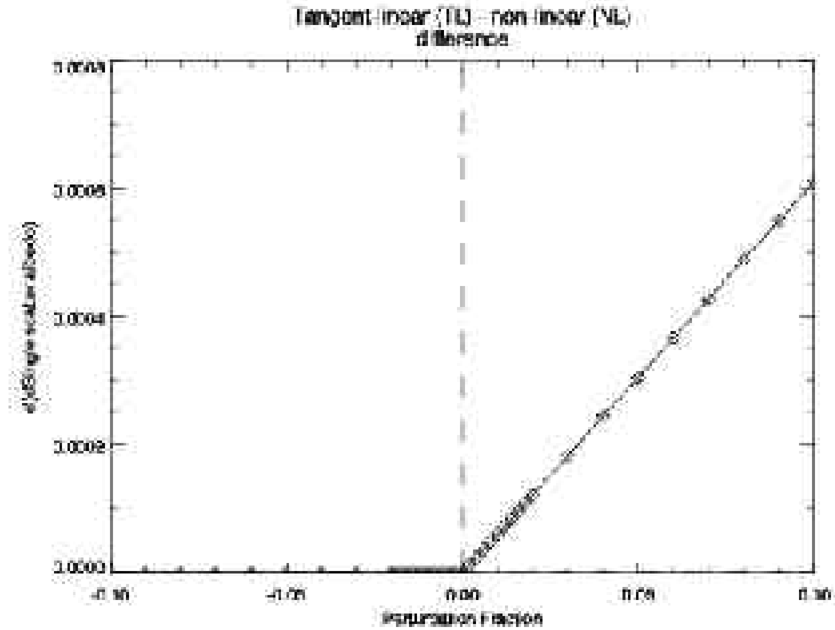
TL gradient : -4.31752104196933e-01
TL gradient, dx->0+ : -4.31752104196933e-01
TL gradient, dx->0- : -4.31752104196082e-01

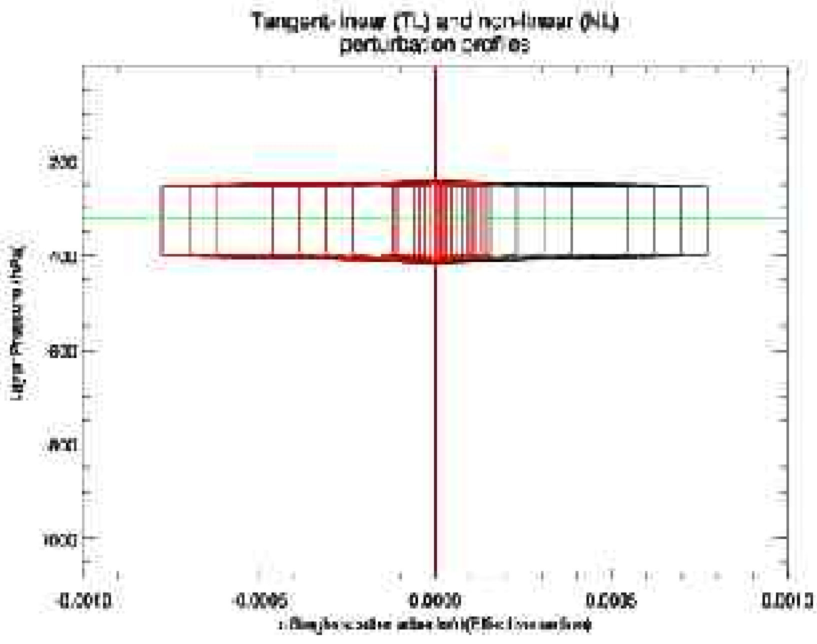
NL gradient at dx=0 : -4.31752104196651e-01
NL gradient at dx->0+ : -4.31752104196795e-01
NL gradient at dx->0- : -4.31752104196679e-01

TL-NL gradient at dx=0 : -2.24820162458659e-14
TL-NL gradient at dx->0+ : -4.60790617986751e-14
TL-NL gradient at dx->0- : -4.60196436486650e-14

CloudScatter FWD/TL Test:dRe/dSSA







Filename: amsua_n17.CRTM_CloudScatter.ComponentTest.nc
Platform: amsua_n17
Sensor: amsua_n17
Layer: 65 [321.351hPa]
Channel: 4
DataSet: Profile # 30. Selected cloud: Snow
Input Perturbed variable: Effective radius
Output Perturbed variable: Single scatter albedo

TL gradient : 7.7540457002783e-03
TL gradient, dx->0+ : 7.7540457002783e-03
TL gradient, dx->0- : 7.7540457002783e-03

NL gradient at dx=0 : 4.6907747694169e-03
NL gradient at dx->0+ : 7.7540457002478e-03
NL gradient at dx->0- : 1.6277028884884e-03

TL-NL gradient at dx=0 : 3.0632709308581e-03
TL-NL gradient at dx->0+ : 2.6153460401664e-14
TL-NL gradient at dx->0- : 6.1266418517147e-03

FWD/TL/AD Testing Results

- AtmAbsorption results are good for most channels. Some water vapour channels are suspect but I think that’s an issue with the Compact OPTRAN algorithm itself, not the TL/AD code. Repeat tests with OPTRANv7.
- CloudScatter results are technically correct, but not ready for operational use.
- CloudScatter issues are:
  - Temperature range of lookup table (LUT).
  - Interpolation performed between LUT entries. Currently it’s linear.
    - Must separate out the interpolation routine from the CloudScatter code for replacement. Currently it appears to be tightly coupled with the code.
    - The current IRSSE also does this linear interpolation between LUT entries in three dimensions and needs to be replaced.
    - Use the same interpolation functions for all CRTM components where they are needed.