Ongoing and planed CRTM development

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List of Ongoing Projects

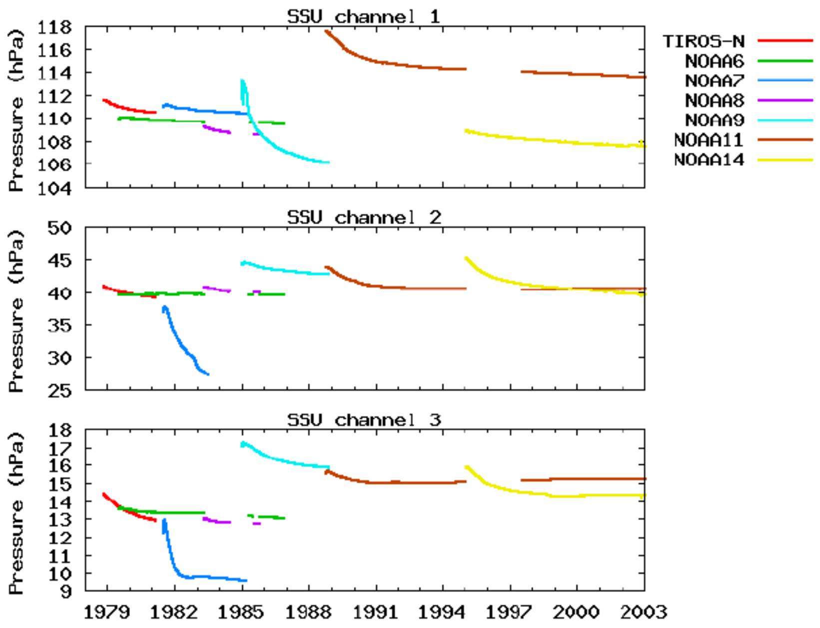
- Implementation of the transmittance model for SSU that takes the leakage of the CO2 cell pressure into account (Q. Liu): preliminarily implemented; being used in the NCEP reanalysis
- Improvements in the CompactOPTRAN transmittance model (Y. Chen/Y. Han):
- Implementation of multiple atmospheric transmittance algorithms – CompactOPTRAN, OPTRAN-V7, RTTOV and SARTA (Y. Chen / P. vanDelst): the framework is implemented.
- Implementation of the fast radiative transfer model that takes the Zeeman effect into account (Y. Han/P. vanDelst): preliminarily implemented.
- Investigation of a new infrared land surface emissivity model from NRL (R. Vogel): Completed a comparison between the current CRTM and the NRL model for the AVHRR sensor (3 IR channels).
- Implementation of a new low-frequency microwave sea surface emissivity model (P. vanDelst)
- Improvement in computational efficiency for the Advanced Doubling-Adding (ADA) radiative transfer solver (Q. Liu): completed optimization design for computational efficiency.
- CRTM test and validation (D. Groff, Y. Chen, P. vanDelst)

Planned Development

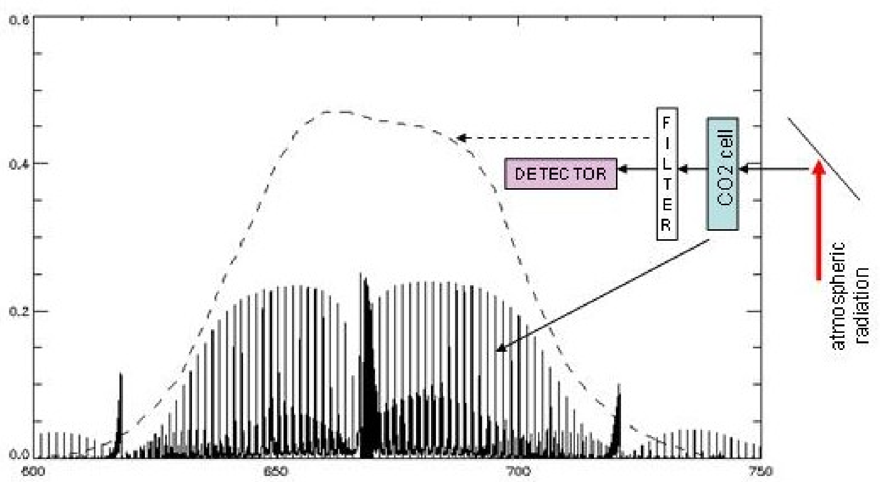
- Implementation of the Successive Order of Interaction (SOI) radiative transfer solver developed at the University of Wisconsin (Y. Tahara/P. vanDelst):
- Implementation of the AER generalized OSS algorithm.

Implementation of SSU transmittance model that takes the leakage of the CO2 cell pressure into account

- The transmittance model is preliminarily implemented
- The CRTM-SSU model is being used in the NCEP reanalysis
- The transmittance model is a series of CompactOPTRAN transmittance coefficient sets conditioned at different CO2 cell pressure level; The transmittance set at the required time is an interpolation from the transmittance series.
- The current implementation needs to be merged into the operational code



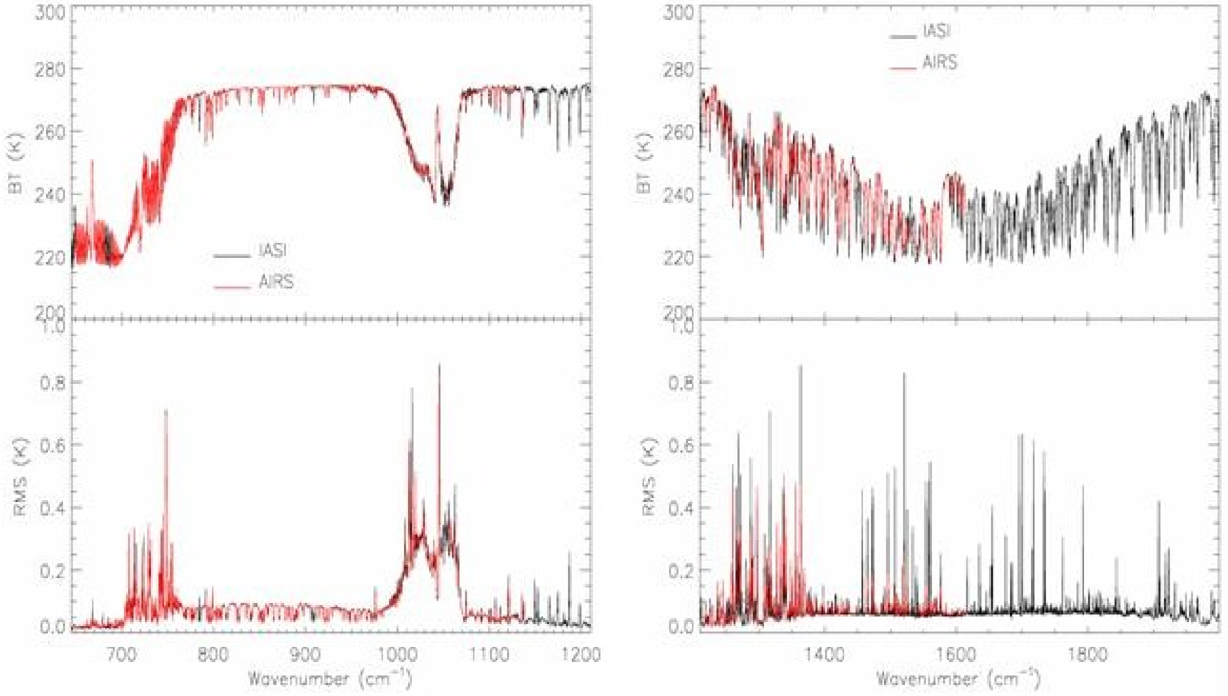
CO2 cell pressure leakage from Dr. Shinya Kobayashi at ECMWF.



SSU instrument filter function (dashed line) and CO2 cell absorption spectrum (solid lines).

Improvements in the CompactOPTRAN transmittance model

- The figure show below indicates there are a significant number of channels having transmittance model errors large than 0.1 K
- Work to improve the model:
  - Adopt approaches from OPTRAN-V7, RTTOV and SARTA
  - Create a new transmittance coefficient training software package
  - Modify CRTM transmittance module



Computed IASI (black line) and AIRS (red line) spectra (upper panel) and the fitting errors – the difference between CRTM and a line-by-line model (lower panel).

Algorithm of new microwave ocean emissivity model (1)

developed by Masahiro Kazumori, visiting scientist from JMA

Two-Scale Ocean roughness model

–Small Scale correction (Liu1998, Bjerkaas1979)

–Large Scale correction (Modified Storyn1972)

–Foam emissivity and foam fraction (Modified Storyn1972,Rose2004)

$$|R_{\mathrm{v}}|^2 = |R_{\mathrm{v,Fresnel}}|^2 \underline{\exp(-4k^2\varsigma_{\mathrm{R}}^2\cos^2\theta)} + \underline{(a_1 + a_2\theta + a_3\theta^2)W_s f(\nu)} \qquad f(\nu) = \frac{\nu}{c_1 + c_2\nu}$$

$$|R_{\mathrm{h}}|^2 = |R_{\mathrm{h,Fresnel}}|^2 \underline{\exp(-4k^2\varsigma_{\mathrm{R}}^2\cos^2\theta)} + \underline{(b_1 + b_2\theta + b_3\theta^2)W_s f(\nu)} \qquad a_1 = b_1$$

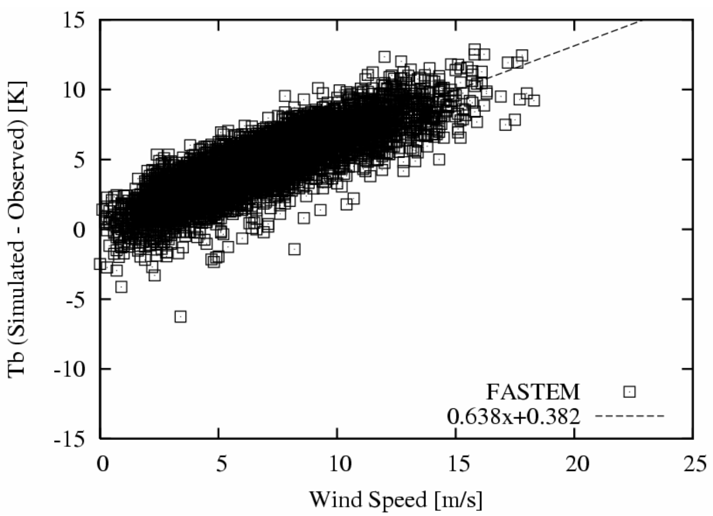
Small scale correction Large scale correction

Coefficients were obtained from the fitting to the satellite measurements (AMSR-E,SSMI and AMSU-A)

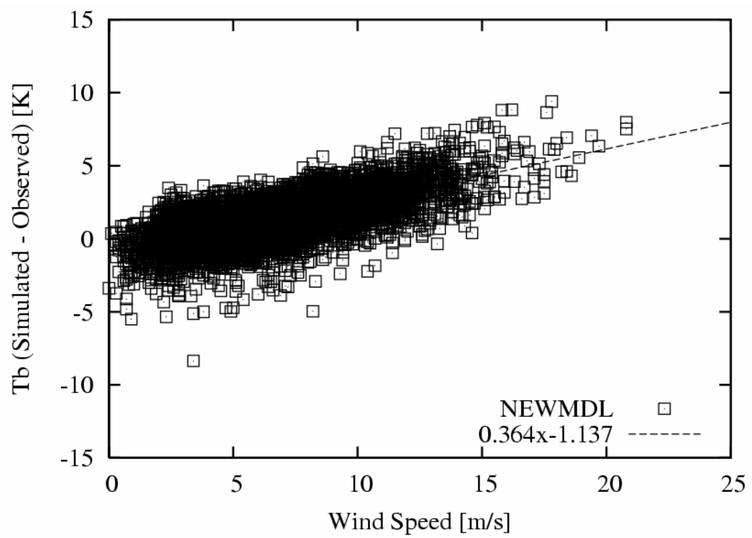
Algorithm of new microwave ocean emissivity model (2)

Tb_{cal}-Tb_{obs} vs Wind SpeedAMSR-E 10.65 GHz (H)

FASTEM
(used in the current CRTM)



LowFrequency_MWSSEM
(new EM model)



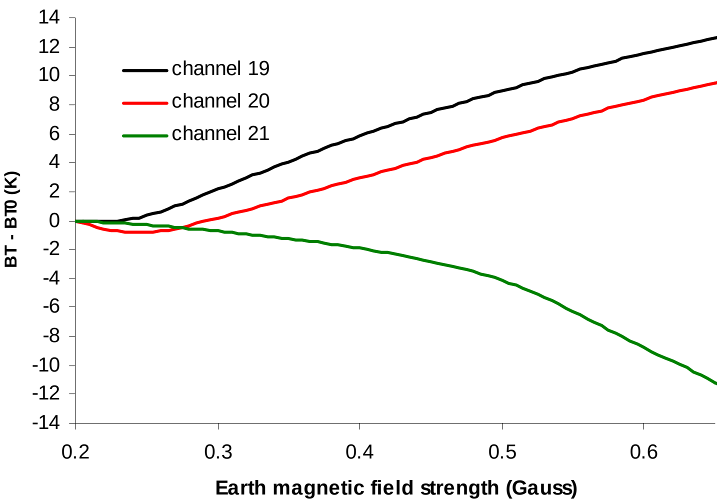
Bias is dependent on surface wind speed.

New model has smaller bias than the operational (FASTEM-1).

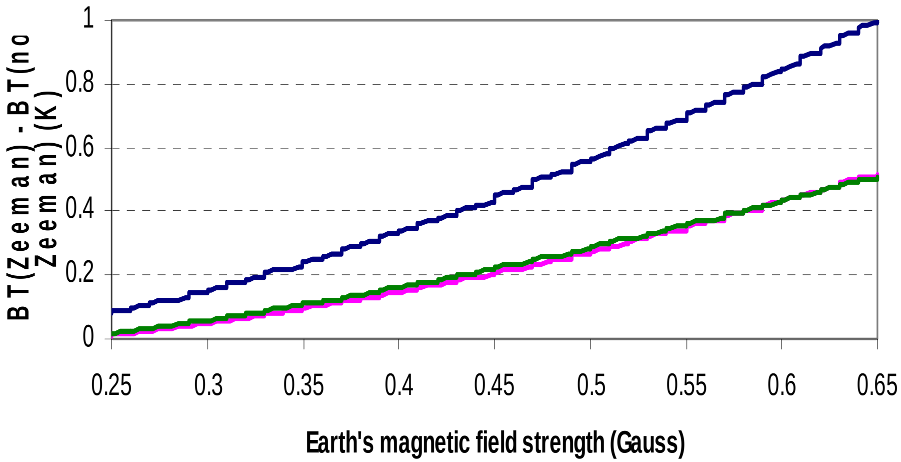
Implementation of the fast radiative transfer model that takes the Zeeman effect into account

- Radiances of SSMIS channels 19 -22 and AMSU-A channel 14 are affected by Zeeman-splitting
- Fast model for these channels has been developed
- The model has been preliminarily implemented in the CRTM:
  - A separate transmittance module has been created for SSMIS channel 19-22
  - A separate transmittance coefficient file has been created

The dependence of the radiance on the Earth's magnetic field



Simulated Tb – Tb0 as a function of the Earth's magnetic field strength for SSMIS channels 19 - 21



Simulated Tb(Zeeman) – Tb(no Zeeman) for AMSU-A channel 14 as a function of the Earth's magnetic field strength

Efficient improvement for Cloud Radiance Assimilation (1)

Cloud radiance assimilation is challenging because

1. unlike temperature, water vapor and trace gases, cloud is a discontinuity medium in horizontal, vertical, and time domain.
2. large uncertainties in cloud microphysics, such as particle size, shape, …
3. expansive computation resource demanded because of multiple scattering in the cloud and between clouds as well as between surface and clouds.

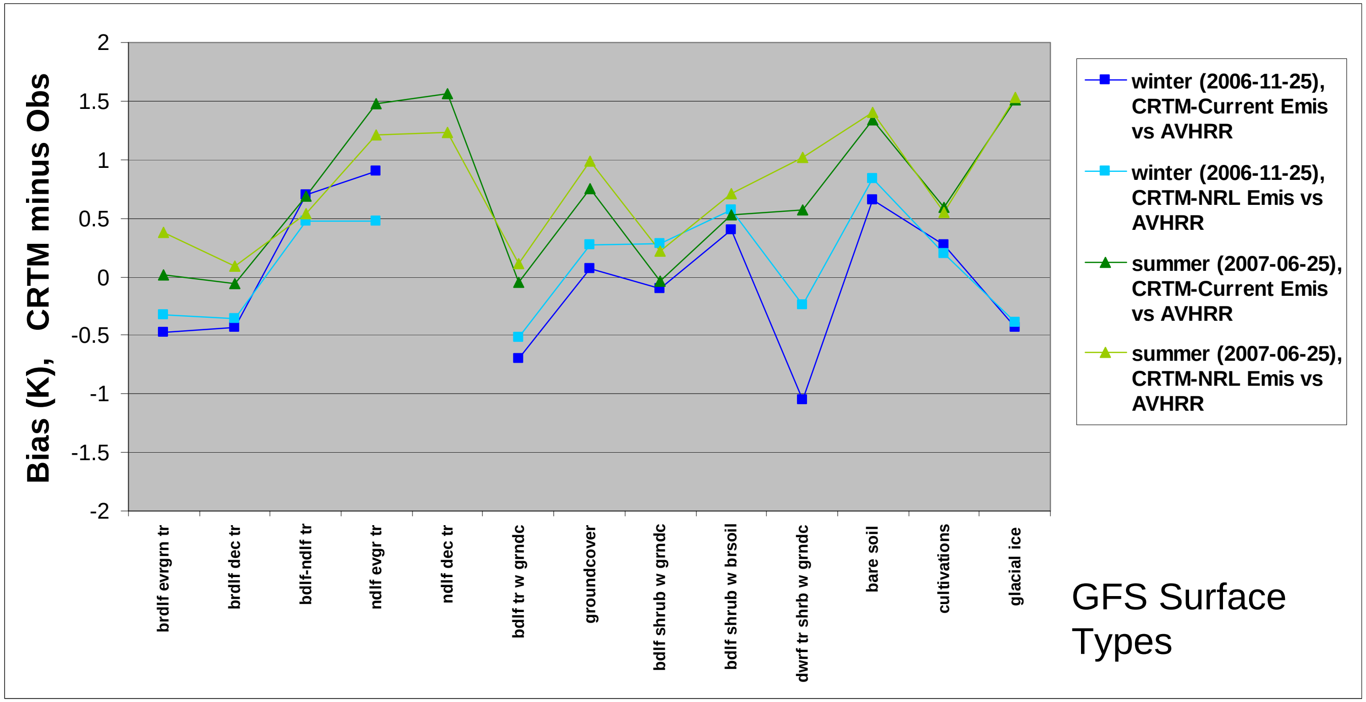
Efficient improvement for Cloud Radiance Assimilation (2)

- The CRTM uses a generic multiple steam scheme (advanced doubling-adding method). The scheme takes absorption, multiple scatterings, and surface polarization into account.
- The CRTM has been intensively tested for clear-sky simulations. The CRTM needs to be tested and optimized under cloud conditions. For example:
  - Cloud radiance derivative cutoff at the top of 10 hPa (allow PSC).
  - Optimize current code for fast 2 or 4 streams calculation.
  - Minimize the number of legendre expansion term in cloud LUT for less stream.
- Listen to community's requirements: speed factor (comparison to clear-sky), accuracy.

IR surface emissivity model investigation (1)

- CRTM run with 2 different emissivity models and compared to AVHRR channels 3, 4, 5.
  - Model 1) **NPOESS static reflectance spectra (CRTM's current model)**
  - Model 2) **NRL "Indexed Emissivity" model**
    - Takes seasonal vegetation dynamics into account
    - Sub-gridcell surface characterization
    - Higher spectral and spatial resolution
  - Days 2006-11-25 (winter), 2007-06-25 (summer)
  - Cloud-free, land surface pixels only (also, coastal pixels excluded)
- NRL model shows improved bias in wintertime for majority of GFS surface types (bands 4, 5)

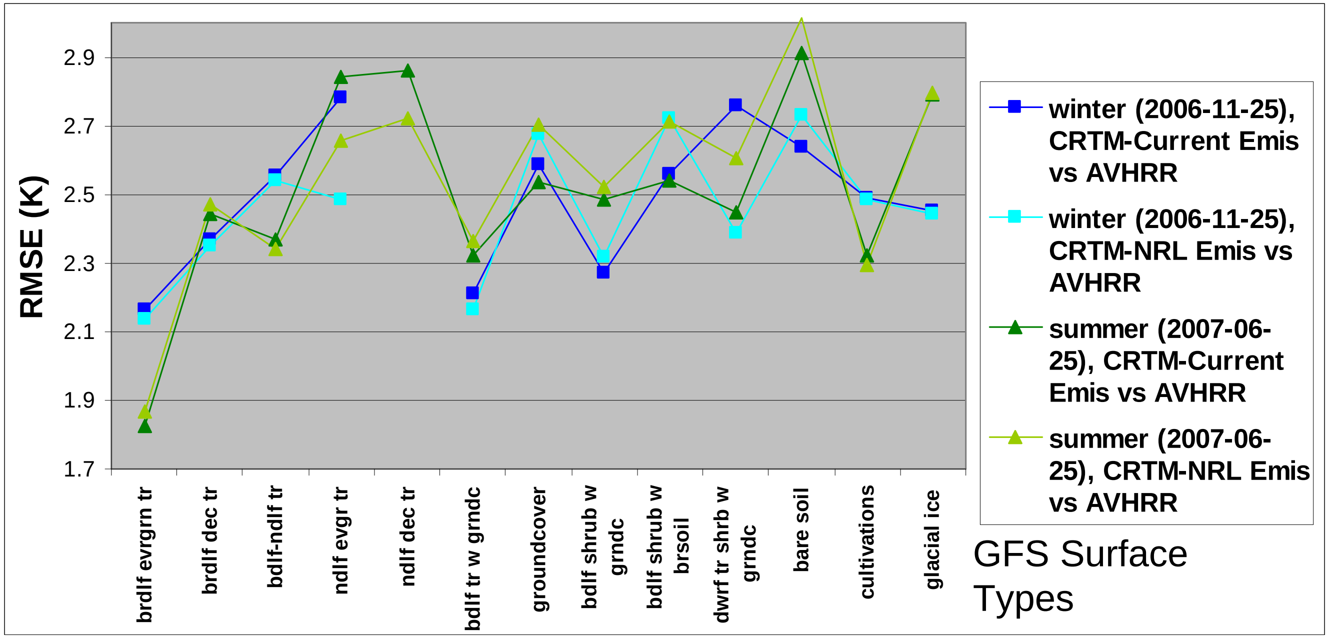
AVHRR Band 4



IR surface emissivity model investigation (2)

- Issues
  - RMSE high for both models: 2 - 3 K
    - Reasons: accuracy of GDAS surface temperature unknown, land surface characteristics highly variable, need higher emissivity accuracy?
  - Implementation: model modularized to run with CRTM (speed improved), requires 20-30MB on-disk memory
  - Steps ahead:
    - Emissivity sensitivity in CRTM
    - Comparison of CRTM with HIRS, other sensors (AIRS, MODIS ?)

AVHRR Band 4



GFS Surface Types

Implementation of AER generalized OSS algorithm

- Background
  - In the past three years, the AER and JCSDA teams worked together to transfer the OSS technology to JCSDA
  - The OSS model was compared with OPTRAN-v7 and the results showed the OSS model was superior in accuracy
  - The localized OSS algorithm was preliminarily implemented into CRTM
  - The OSS training software package was delivered to JCSDA
  - Issue: the CRTM OSS code could be slow in cloudy radiance calculations and in applications when only a small channel subset of the hyperspectral sensors was used.
- Implementation of the generalized OSS algorithm
  - The generalized OSS algorithm may address the above issue and more importantly it may allow assimilation of all channels for the hyperspectral sensors by applying the PC concept.
  - Implementation issue: need to allocate manpower to do the work.

Implementation of the Successive Order of Interaction (SOI) radiative transfer solver

- The SOI model was contributed by the University of Wisconsin
- The code, including FW, TL and AD, was delivered to JCSDA
- It is planned to be implemented into CRTM by Y. Tahara (JMA scientist)