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Radiative Transfer Modeling of AVHRR Brightness Temperatures for Improved Sea Surface Temperature Retrievals: Initial Results

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OBJECTIVE Establish forward radiative transfer model (RTM) for high-accuracy SST applications and validate against AVHRR

METHODOLOGY Forward model: MODTRAN-4.2 with NCEP GDAS input coupled with Fresnel's surface. Global AVHRR clear-sky nighttime brightness temperatures (BT) were simulated for 18 February 2007 for 5 AVHRR sensors. 'Model' (M) BTs were compared against 'Observed' (O) BTs in AVHRR channels 3B, 4, 5 and 'M-O' Bias was analyzed.

1. Global Radiative Transfer Model (RTM)

Input to forward RTM

- Reynolds & Smith analysis SST
- Fresnel's flat reflective surface
- NCEP GDAS Global Profiles (T, P, RH, GP)

Top-of-atmosphere Channel Clear-Sky Radiance Calculation

Step 1: Simulations at 1 cm^{-1} spectral intervals:

$$R_\nu^{TOA} = B\left(\nu, T_{sfc}\right)\cdot\varepsilon\left(\nu,\theta\right)\cdot\tau^{\uparrow}\left(\nu,\theta\right) + L^{\uparrow}\left(\nu,\theta\right) + L^{\downarrow}\left(\nu,\theta\right)\cdot\left(1-\varepsilon\left(\nu,\theta\right)\right)\cdot\tau^{\uparrow}\left(\theta\right)$$

Step 2: Convolve with RSR for channel radiances:

$$R_{channel}^{TOA} = \sum_{\nu=\nu_1}^{\nu_2} R_\nu^{TOA}\cdot\Phi_\nu \Big/ \sum_{\nu=\nu_1}^{\nu_2}\Phi_\nu$$

2. Validation of forward RTM: Collocation with AVHRR Observations

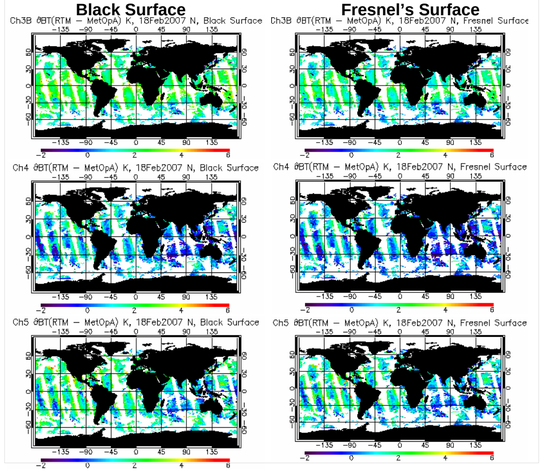
For 3 AVHRR channels (3B: 3.7 μm, 4: 10 μm, 5: 11 μm) onboard 5 platforms (NOAA 15-18, MetOp-A) :

- Resample one full-day (18 February 2007) AVHRR Data to NCEP GDAS 1° resolution, along with ancillary information
- For corresponding average satellite zenith angle, simulate TOA BT for 5 UTCs
- Interpolate RTM Brightness Temperatures (BT) in time to match average AVHRR retrieval time per grid

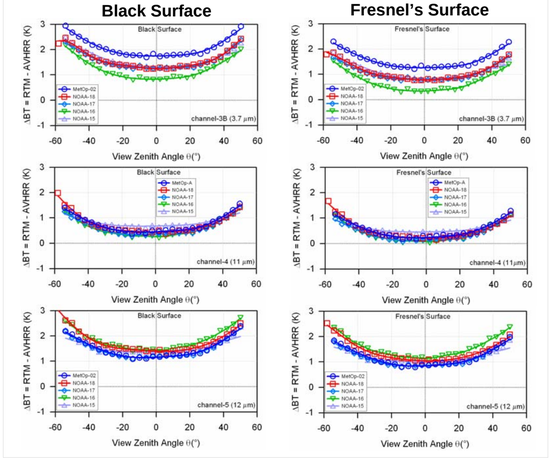
Collocated Model (M) and Observation (O) BTs have been statistically compared. The 'M-O' Bias was analyzed as a function of observational and retrieval conditions: View Zenith Angle, Column Water Vapor, Air-Sea Temperature difference, # of obs. per grid.

3. Validation Results: 'Model - Observation' (M-O) Bias: Dependence on Observational and Geophysical variables

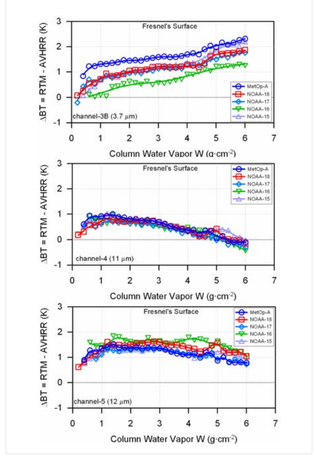
Global 'M-O' Bias Maps



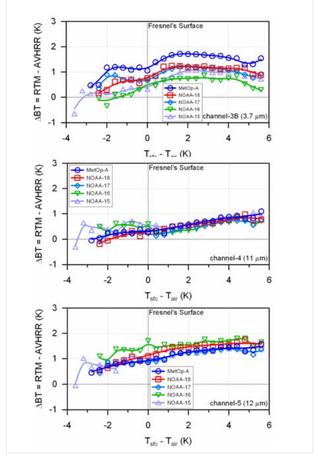
Global 'M-O' Bias vs. Zenith Angle



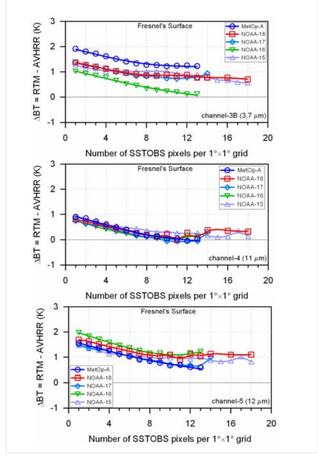
Global 'M-O' Bias vs. 'W'



Global 'M-O' Bias vs. 'T_{sea}-T_{air}'



Global 'M-O' Bias vs. #Obs/Grid



RTM vs. AVHRR: Overall agreement
On an average, RTM is warmer than AVHRR. Bias is smallest in channel 4, and larger in channels 5 and 3B. Adding more water vapor or aerosol would reduce this bias.

Effect of surface emissivity
For all bands and all sensors, including emissivity in RTM improves agreement with AVHRR. However this improvement is insufficient to fully reconcile Model and Observations.

Cross-platform consistency
All five AVHRRs onboard different platforms show excellent consistency. Exception to this rule are MetOp-A and NOAA-16, whose Ch3B's are "out-of-family". Analyses are underway to resolve observed sensors anomalies.

References
- Berk *et al.*, 2000, MODTRAN4 Users Guide.
- Segelstein, 1981, Refractive index of water.
- Ignatov *et al.*, 2004, Global SST/Aerosol from AVHRR. 13th AMS conf. Sep 2004.

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CONCLUSION Forward RTM tested in this study (MODTRAN + NCEP GDAS + Fresnel's surface) does not reproduce spectral, angular and water vapor structure observed in AVHRR TOA BTs. The bias decreases towards confidently cloud-free conditions but it never fully vanishes. Errors in the input GDAS fields could not reconcile spectral structure of the bias. Improvements to RTM are thus needed for high-accuracy SST applications.

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