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Validation of the Community Radiative Transfer Model (CRTM) against AVHRR Clear-Sky Processor for Oceans (ACSPO) nighttime radiances for improved cloud detection and physical SST retrievals

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1. Introduction

Developed at NESDIS, the AVHRR Clear-Sky Processor for Oceans (ACSPO) produces clear-sky radiances (CSR) over ocean in all AVHRR bands, sea surface temperatures (SST), and single-channel aerosols. The fast Community Radiative Transfer Model (CRTM) has been integrated into ACSPO and used in conjunction with NCEP/GFS global fields to explore physical SST retrievals, improve cloud mask, and monitor quality of AVHRR CSRs.

2. Objective

This presentation documents CRTM/GFS implementation in ACSPO v.1 and evaluates the "Model minus Observation" (M-O) brightness temperature (BT) biases in three bands (3.7, 11 and 12 μm) of four AVHRR/3 instruments onboard NOAA-16 through 18 and MetOp-A, using one week of global nighttime data from 16–22 February 2007.

3. Methodology

- **Implement** CRTM for accurate BT modeling with different atmospheric and surface states (NCEP/GFS fields, Reynolds v.2 weekly SST, and Black/Fresnel's surface models).
- **Validate** CRTM by analyzing M-O BT biases as functions of environmental parameters (column water vapor, SST, sea-air temperature difference, and wind speed), view zenith angle, and latitude.

CRTM: a "band averaged" RTM

The overbar sign = band averaged; θ = sensor zenith angle

$$\bar{R}(\theta)=\bar{\varepsilon}(\theta)\bar{B}(T_s)\bar{\tau}(\theta)+\bar{L}^{\uparrow}(\theta)+(1-\bar{\varepsilon}(\theta))\bar{L}^{\downarrow}(\theta)\bar{\tau}(\theta) \quad (1)$$

- NCEP/GFS 12h forecast fields are interpolated in time to match AVHRR L1B time by using 5 UTC files per day.
- Simulated BTs with NCEP/GFS 1° spatial resolution are then interpolated in space to match AVHRR L1B 4 km GAC pixel data.

4. CRTM implementation in ACSPO

Treatment of finite layers

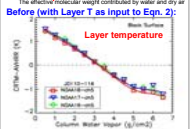
Layer temperature: an average of the two adjacent level temperatures.

Saturation mixing ratio (γ):

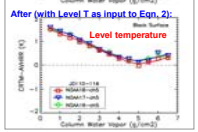
$$\gamma=\varepsilon\frac{MW_{H_2O}}{MW_{air}}\frac{e_s(T)}{P-e_s(T)} \quad (2)$$

The saturation vapor pressure; The effective molecular weight contributed by water and dry air

Before (with Layer T as input to Eqn. 2):



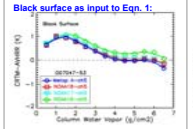
After (with Level T as input to Eqn. 2):



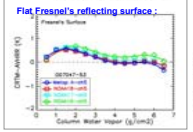
Black vs. Fresnel's model

Using Fresnel's instead of black surface model reduces M-O biases and improves the CRTM accuracies, particularly in low water vapor conditions.

Black surface as input to Eqn. 1:



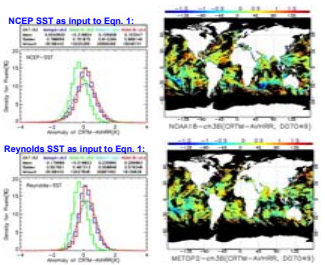
Flat Fresnel's reflecting surface :



NCEP SST vs. Reynolds SST

Using Reynolds SST instead of NCEP SST as input to CRTM improves the M-O statistics. (This is primarily due to the unrealistic low bias in the NCEP SST in the coastal areas.)

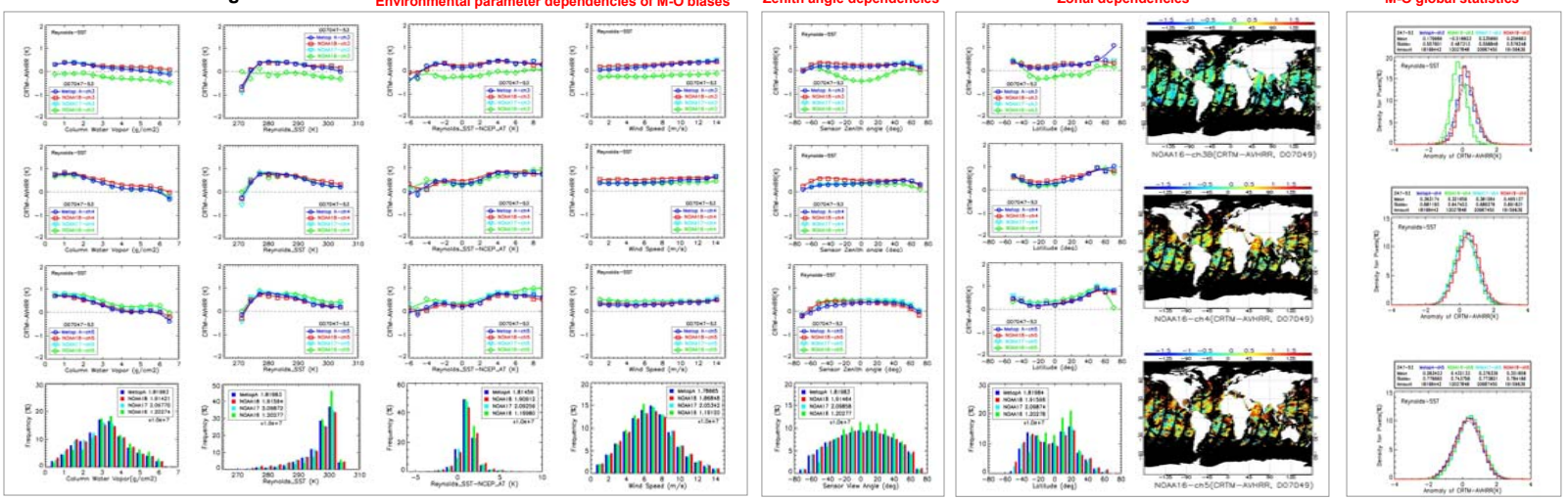
NCEP SST as input to Eqn. 1:



Reynolds SST as input to Eqn. 1:

5. Validation of CRTM against AVHRR

Environmental parameter dependencies of M-O biases | Zenith angle dependencies | Zonal dependencies | M-O global statistics



►Daily 'M-O' biases for this week and their animations are available from http://www.orbit.nesdis.noaa.gov/sod/sst/xliang/

6. Conclusions

- CRTM is computationally efficient.
- M-O bias is significantly reduced by:
  - Consistent treatment of finite GFS layers.
  - Using Fresnel's surface models instead of black.
  - Using Reynolds SST instead of NCEP SST.
- CRTM closely reproduces AVHRR BTs and shows a good cross-platform consistency.
- N16/Ch3B is out-of-family, likely due to its inaccurate response functions.
- The residual warm M-O biases leave margin for future inclusion of aerosols, using skin SST (instead of bulk) and minimizing possible residual cloud in the AVHRR CSRs.

7. Future plans

- Extend validation analyses to include daytime data.
- Add extra-terrestrial radiation to CRTM and evaluate the effect on M-O bias.
- Add global aerosol data to CRTM (from, e.g., GOCART).
- Maintain the web site to publish near real-time results.
- Explore physical SST retrievals using CRTM/GFS.
- Adopt ACSPO and test out CRTM/GFS with MSG/SEVIRI to get ready for GOES-R/ABI.

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