Exploring MERRA-2 global meteorological and aerosol reanalyses for improved brightness temperature simulations and SST retrievals in the NOAA ACSPO system

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1. NOAA STAR 2. CSU CIRA

INTRODUCTION

- The NOAA Advanced Clear-Sky Processor for Ocean (ACSPO) SST system is employed for SST retrievals from a number of polar orbiting and geostationary sensors
- ACSPO also calculates the expected top-of-the-atmosphere clear-sky sensor brightness temperatures (BT) using CRTM, in conjunction with first-guess SST (currently, CMC L4) and atmospheric profiles of pressure, temperature, water vapor and ozone (currently, from NCEP GFS).
- To facilitate ACSPO reanalyses efforts (RAN), the Modern-Era Retrospective analysis for Research and Applications v2 (MERRA-2) is explored for improving the modeling of clear-sky satellite IR BTs and SST retrievals from SNPP VIIRS.
- In addition to meteorological fields, MERRA-2 provides global aerosol reanalysis, providing an opportunity to evaluate its potential for accounting for dust-related BT and SST biases.

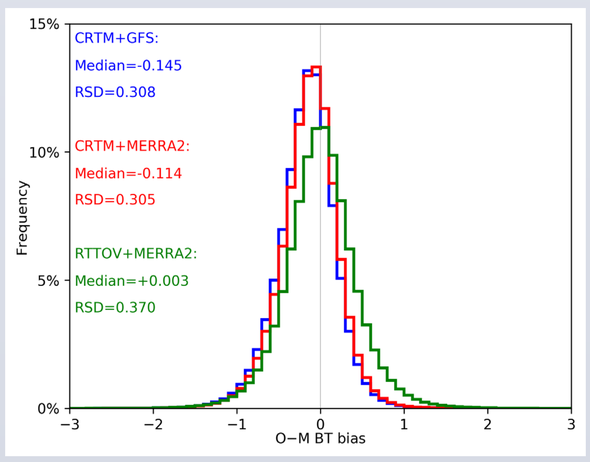
METHODS

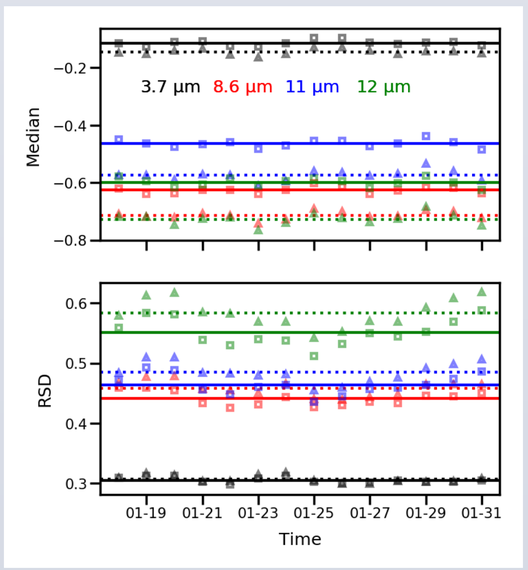
- GFS and MERRA-2 profiles are used in two separate ACSPO (v2.50) simulations, to calculate the VIIRS BTs in the SST bands centered at 3.7, 8.6, 11 and 12 μm, using two weeks (18-21 January 2018) global nighttime data from SNPP VIIRS.
- In addition, two stand-alone (i.e., outside ACSPO) simulations using RTTOV (v12) are conducted over the VIIRS clear-sky ocean pixels under dust-laden and aerosol-free conditions respectively, to compute the effect of dust on VIIRS BTs.
- ACSPO simulations are performed over GFS/MERRA-2 grids, and the results are bilinearly interpolated to VIIRS pixels. In contrast, RTTOV simulations are performed at a pixel level, and only for pixels with AOD>0.02, to save computational cost and to avoid adding noises resulting from uncertain AOD and its vertical placement in MERRA-2.

RESULTS

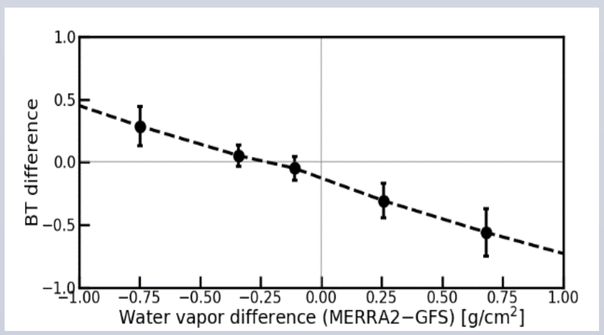
Effects of MERRA2 vs. GFS on Obs. – Model ("O-M") BT biases

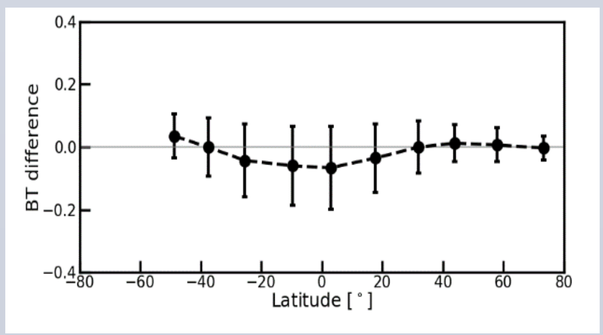
	M12/3.7 μm		M14/8.6 μm		M15/11 μm		M16/12 μm	
(Units = Kelvin)	Median	RSD	Median	RSD	Median	RSD	Median	RSD
CRTM + GFS	-0.15	0.31	-0.71	0.46	-0.58	0.49	-0.73	0.58
CRTM + MERRA-2	-0.11	0.31	-0.63	0.44	-0.46	0.46	-0.60	0.55
RTTOV + MERRA-2	+0.00	0.37	-0.39	0.59	-0.09	0.63	-0.10	0.78





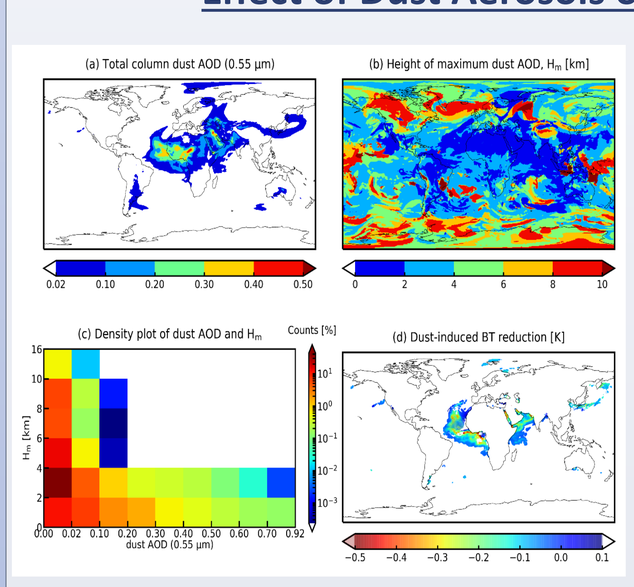
- O-M BT biases are near-Gaussian, and tend to be negative due to e.g. missing aerosols and using foundation SST (rather than cooler skin SST) in "M", and possible residual clouds in "O".
- Both median biases and robust standard deviations (RSDs) are improved, when GFS profiles are replaced with MERRA-2 data. The improvements are consistent in all SST bands, during the two-week period.
- RTTOV O-M biases are all closer to zero compared to CRTM, but with larger RSDs, likely due to increased noise in pixel-level simulations in this study.

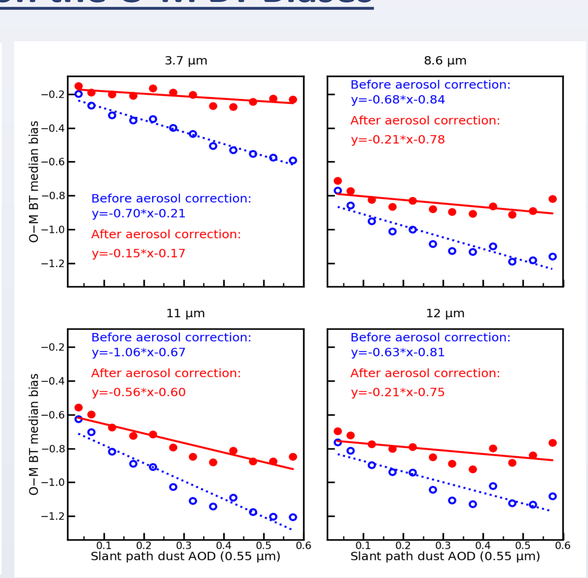




- There is a highly linear relationship between changes in the O–M biases and differences in the water vapor content between MERRA-2 and GFS.
- The reduction in O-M biases is most prominent in the tropics, where water vapor absorption is strongest and sensitivity to its vertical distribution largest.
- Thus, improvement in O-M biases is mostly likely due to more accurate water vapor (both amount and vertical distribution) in MERRA-2.

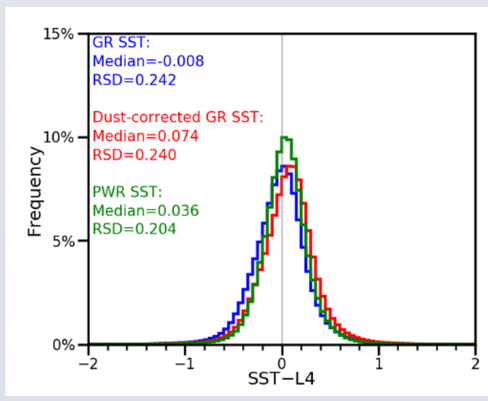
Effect of Dust Aerosols on the O-M BT Biases

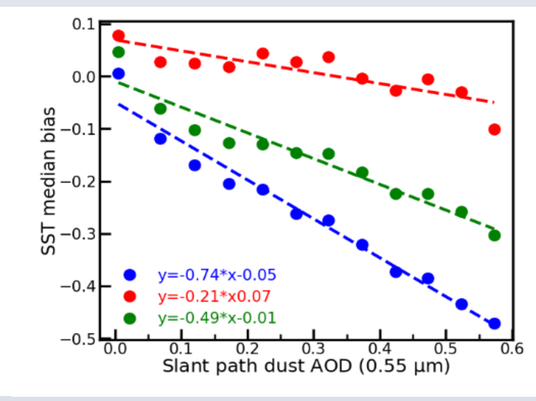




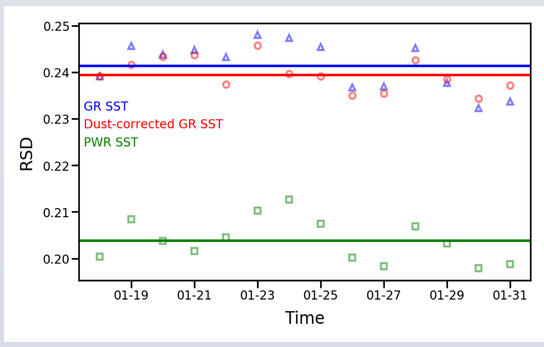
- There are massive dust outflows in the lower troposphere (<4 km) from West Africa and Middle East to the North Atlantic and Arabian, and weaker plumes from Asia to the Pacific, above 6 km.
- Globally, modeled BT in e.g. 3.7 μm is reduced by only -0.07 K. However, the BT reduction is very non-uniform in space, reaching -0.9 K over the North Atlantic.
- After correcting for the dust effect (calculated as the difference between two RTTOV runs, with and without aerosol), the O-M dependence is greatly reduced in all bands, suggesting a statistically significant skill in the MERRA-2 aerosol reanalysis to correct for dust effects on sensor BTs.

Effect of Aerosol Correction on the SST





- Three SST products are compared: ACSPO global regression (GR) SST, GR SST derived from aerosol-corrected VIIRS BTs, and ACSPO piecewise regression (PWR) SST.



- All SST biases are near-Gaussian. The bias of aerosol-corrected GR SST is higher, due to using ACSPO operational coefficients, not optimized for simulation period.
- Aerosol-corrected GR SST has a lower RSD than original GR SST, but remains higher than PWR SST. But, aerosol-corrected GR SST has the most flat dependence on dust AOD.

CONCLUSION & FUTURE WORK

- MERRA-2 is a viable alternative to NCEP GFS for ACSPO reanalyses (RAN) efforts.
- MERRA-2 aerosol reanalysis has potential skill to correct for unwanted dust effects in sensor BTs and SSTs.
- Several correction approaches can be explored, including: implementing MERRA-2 aerosol profiles within ACSPO CRTM for full testing of its potential to reduce the O-M BT biases; or, applying aerosol correction to sensor BTs before using the PWR algorithm, to maximize the atmospheric corrections.

Acknowledgement. This work is supported by the NOAA JPSS, GOES-R and ORS Programs. The views, opinions, and findings in this report are those of the authors and should not be construed as an official NOAA or U.S. government position or policy

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