NOAA ROSES Semi-Annual Report

Reporting Period: March 2021 – August 2021 (2nd report)

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Project Title: Use of modern geostationary data to improve a global diurnal warming model for multi-satellite data fusion

Executive Summary (1 paragraph max)

Substantial progress has been made on the comprehensive validation of our 1-dimensional turbulence model, with investigations into multiple potential configurations for estimating diurnal warming. Geostationary data from Meteosat-11 SEVIRI, GOES-16 ABI and Himawari-8 AHI have been exploited to construct a comprehensive validation for all seasons. Additional techniques have been developed to improve spatial coverage for validating modelled events. Key turbulence model parameters have been refined for both the original and water vapour dependent insolation schemes, and point the way towards certain aspects of the insolation scheme that will be the focus of investigations in the coming year. All validations datasets and modelling outputs have been made available to the community via web and FTP.

Progress toward FY20 Milestones and Relevant Findings

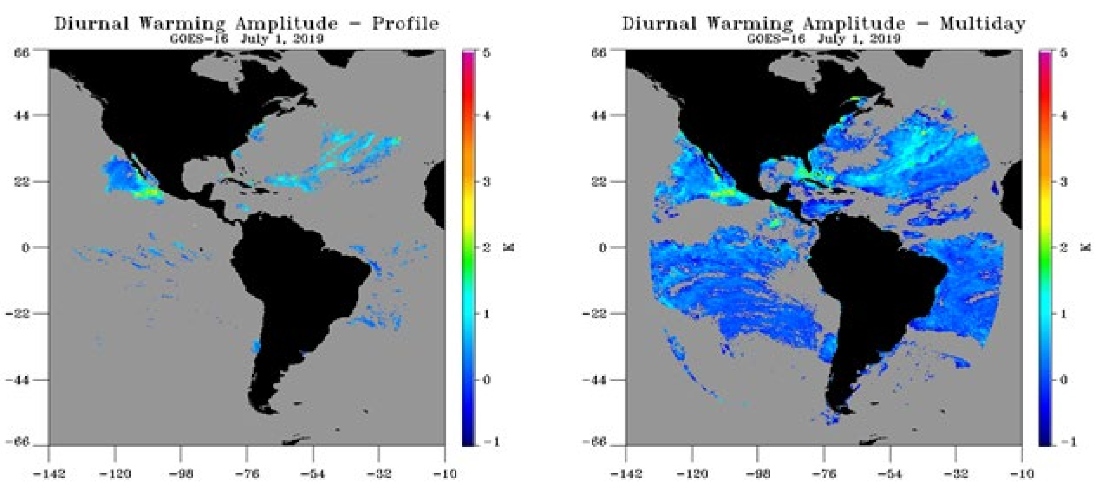

Fig. 1. Daily diurnal warming amplitude estimates for July 1, 2019 derived from GOES-16 using the (a) profile, and (b) multiday methodologies. Gray areas indicate regions outside the satellite disk or with insufficient cloud-free data to retrieve reliable diurnal warming.

Construction of initial satellite validation datasets is complete. Based on Wick and Castro (2020) the “profile” methodology, which derives the warming from a continuous sequence of cloud-free retrievals, is most suitable for validation of modeled warming and is the primary product here. An additional “multiday” technique providing improved spatial coverage by constructing a foundation temperature estimate over multiple days has also been generated. An example of the resulting products for one selected day from GOES-16 are shown in Fig. 1.

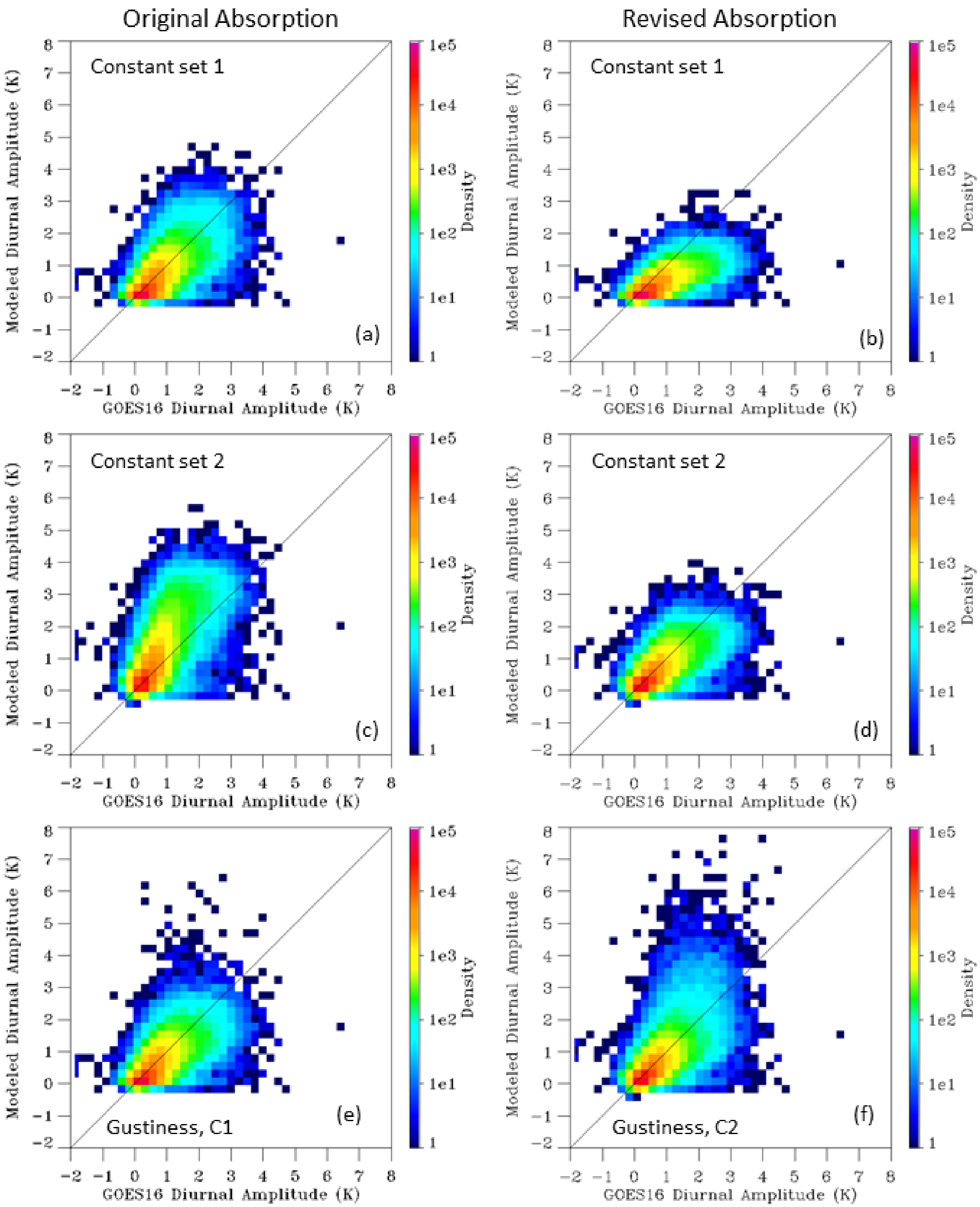

Fig. 2. Comparison of collocated modeled and satellite-derived daily diurnal warming estimates for GOES-16 in July 2019. The left column (a, c, e) shows results using the original insolation parameterization and the right column (b, d, f) shows results from the revised parameterization. Panels a and b use the enhanced mixing parameters (constant set 1) with no gustiness; panels c and d use the reduced mixing parameters (constant set 2) with no

gustiness, and panels e and f employ gustiness and molecular diffusion coefficients with the parameters best fitting the corresponding insolation parameterization.

A detailed validation of multiple potential configurations of the Kantha-Clayson diurnal warming model with wave effects (Kantha and Clayson 1996; Kantha and Clayson 2004) has been completed using both satellite-derived estimates and in situ observations of diurnal warming. The results suggest that favorable predictions of the diurnal warming amplitude can be obtained with both the original and the refined insolation parameterizations, and identify the different preferred model configurations for use with each parameterization.

A sample of the different model predictions compared directly against collocated diurnal warming amplitude estimates from GOES-16 in July 2019 are illustrated in Fig. 2. The results are very similar for the other months and geostationary satellites. The results show that the centroid of the largest density of observations are generally well fit with the enhanced mixing parameters (constant set 1) for the original absorption parameterization (panel a) and the reduced mixing parameters (constant set 2) for the refined absorption parameterization (panel d). The reduced mixing results in overestimates of the warming with the original absorption parameterization (panel c) and the enhanced mixing tends to underestimate the warming with the revised absorption parameterization (panel b). The bottom panels show how molecular background mixing values, coupled with a low level of gustiness, lead to elevated large diurnal warming amplitudes while having less observable impact on smaller warming cases.

As presented in the first 6-month report, the net impact of the new insolation parameterization is to depress diurnal warming relative to the original parameterization with an increased reduction in tropical regions with enhanced water vapor content. The need for reduced mixing with the new insolation parameterization is consistent with this depressed warming. While the slope of the relationship between predicted and observed warming is observed to be generally well-predicted by the model, there is clearly a large amount of scatter and reduced skill for the largest amplitude events. This is not surprising given the forcing with coarse resolution NWP model outputs where the precise geographic positioning of the regions of lowest wind speeds is not assured. To better evaluate the ability of the model to reproduce the accurate range of diurnal warming amplitudes, we look instead at the statistical distribution of the predicted and observed amplitudes.

The model configuration yielding good results with the original insolation parameterization (termed C1 in the plots above) was based on past efforts to validate the model against cruise data and was known to produce good predictions of observed diurnal warming. To conduct an independent validation, new data from the DYNAMO experiment was obtained from the archive at NOAA PSL and the models were tested against multiple days of observations. Results obtained using the original insolation parameterization and same model configuration as above are shown in Fig. 3a. The results show that the same model generally does well at reproducing the observed diurnal warming amplitudes, particularly a extreme, near-three-degree event on day 320. The biggest issue with the model results beyond a tendency to slightly overestimate the diurnal amplitude on some of the later days is the preservation of the warming too far into the evening hours. This has been a known issue with this model.

It was more challenging to obtain good agreement with the observed diurnal warming using the model with the refined insolation parameterization. The configurations tested above generally underpredicted the predicted warming, particularly the three-degree peak. To obtain the more favorable results shown in Fig. 3b, the turbulent parameters had to be significantly altered to turn off all wave mixing effects and utilize molecular background mixing values. While the model with both insolation parameterizations can be forced to provide favorable agreement with in situ observations, use of the revised insolation parameterization required greater changes from the configuration employed with the NWP forcing. Although resorting to molecular diffusion values for background mixing may seem physically reasonable, it is a significant departure from previous practice (the difference is more than 2 orders of magnitude). The implication is that the heating rate in the uppermost part of the ocean (the top few mm to cm) is lower than it should be. The Planck weightings of the original Defant scheme in the IR part of the spectrum (where in-water absorption is strongest) are quite modest, but the values in the new scheme are significantly lower. Our current suspicion is that the wavebands are not correctly defined in the Defant scheme and need to be revisited. This, in turn, will facilitate a better match between the in-water and atmospheric terms for insolation absorption.

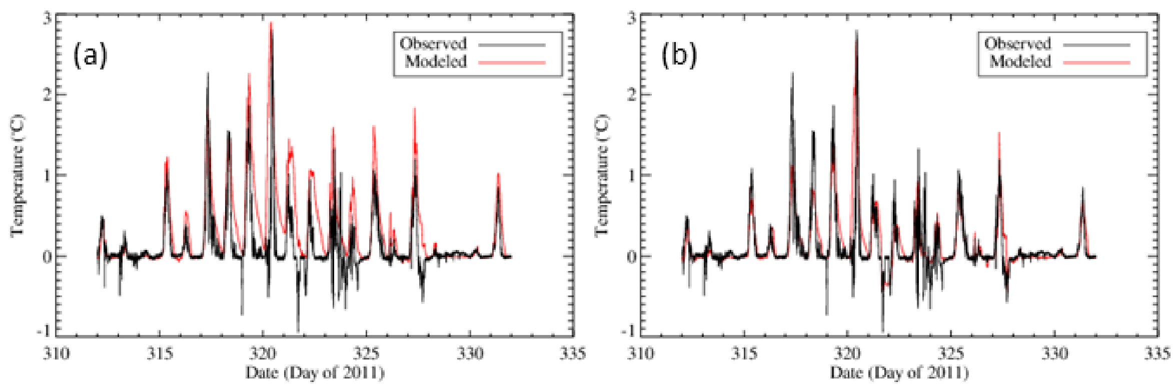

Fig. 3 Comparison of modeled diurnal warming at 5-cm depth (red) with direct observations obtained during the DYNAMO experiment (black). The left panel was obtained using the original insolation parameterization while the right panel was obtained using the revised insolation parameterization.

Initial model-derived daily diurnal warming amplitude estimates using the best-identified model configurations thus far for both the original and refined insolation parameterizations have been made available via ftp at ftp://ftp1.esrl.noaa.gov/et6/sat/diurnal/modeled_dw_amplitude/.

Results are currently available for the four primary validation months described under task 2. For space considerations, only the daily amplitude values are shared at this time. Data are organized by insolation parameterization and by year. A preliminary web site has been implemented for testing at https://psl.noaa.gov/psd2/coastal/satres/data/html/diurnal_sst_analysis.php, and it is currently being populated in near-real-time with an older configuration of the model that has been found through this work to have poorer performance. Once our final recommended model configuration has been confirmed, the contents of the web site will be updated to contain the new model results including hourly graphics and complete hourly data, and the web site will be publicly advertised. The data sharing on the web site has been disabled until we are satisfied with the final quality of the data and model configuration. Interim data from the preferred model configurations are what is available through the ftp site.

Initial satellite-derived diurnal warming datasets have been made available via ftp at ftp://ftp1.esrl.noaa.gov/et6/sat/diurnal/geostationary_dw/.

As described above, daily diurnal warming amplitude estimates have been derived from the geostationary Meteosat-11 SEVIRI, GOES-16 ABI, and Himawari-8 AHI sensors using the “profile,” “filter,” and “multiday” methodologies of Wick and Castro (2020). The multiple months spanning all seasons required for initial model validation have been shared on ftp. The data are currently in a packed binary format. Within the directory structure, the products are grouped first by sensor, then by method, and then by year. Extension of the sharing to the web, additional formats, and for additional months will continue in year 2 and throughout the project.

The current version of the model code, including both the original and refined insolation parameterization, has been shared with both NESDIS and EUMETSAT. Guidance on the preferred configuration will be supplied once that selection has been finalized. The guidance to EUMETSAT will be provided through a formal EUMETSAT-NOAA science cooperation plan on “Joint Product Development and Calibration/Validation Activities of Sea-Surface, Sea-ice and Lake Surface Water Temperature” of which both project PI Harris and collaborator Wick are participants.

Plans for Next Reporting Period

Research effort for the next six months will be directed as follows:

- As a matter of priority, investigate waveband definitions for the insolation scheme and revise accordingly
- Complete and report on insolation modeling to include NWP cloud amount and diffuse radiation
- Optimize band selection based on atmospheric and oceanic absorption effects
- Extend validation activities incorporating additional cruise observations
- Incorporate revisions to the revised insolation model and repeat selected parameter sensitivity studies
- Extend validation activities to further investigate the shape of the modeled temperature profile and temporal evolution of the warming as well as the performance over longer-duration free runs
- Begin formulation of uncertainty statistics on model performance
- Draft manuscript on validation of the baseline model configuration