NOAA ROSES Semi-Annual Report

Reporting Period: September 2020 – February 2021 (1st 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)

The project has been placed on a firm footing and research is proceeding according to the work plan described in the proposal, and a number of useful initial results have been forthcoming. Tasks during year one at the University of Colorado have focused on local implementation of the diurnal warming (DW) model with revised insolation absorption scheme, verification of proper execution, and initiation of a comprehensive validation of potential model configurations against observations of DW from geostationary satellites. Tasks at UMD have focused on investigations into potential refinements to the fundamental insolation parameterization.

Progress toward FY20 Milestones and Relevant Findings (with any Figs)

Model Implementation

Milestones

- DW model with revised solar absorption scheme successfully ported to the University of Colorado
- Global forcing data from NWP model outputs obtained and configured for ingestion
- Model run daily for six different configurations (Table 1) starting June 2019; 3 months complete, more ongoing (example output in Fig 1)
- Different configurations found to have significant impact on how much the new absorption scheme alters predicted amplitudes from the baseline scheme (Fig. 2)

The one-dimensional Kantha-Clayson DW model with wave effects incorporating an implementation of the revised model for solar absorption was ported to our group at the University of Colorado. The configuration of the model initially implemented is designed to run independently on a series of grid points to provide predictions of diurnal warming over a global domain. Forcing at each point is obtained from global numerical weather prediction (NWP) and wave model outputs. Along with the model, all required forcing was obtained and configured for model ingestion. For initial testing, the forcing is taken from the NOAA operational Global Forecast System (GFS) and Wave Watch III model outputs.

For validation against geostationary satellite observations (described in more detail below), the model is being run daily on a 0.5-degree global grid from 60°N to 60°S starting in June 2019. This period corresponds to the availability of previously validated geostationary diurnal warming retrievals and the operational implementation of a major upgrade to the GFS model. On each day, the model is run for a two-day period with validation performed using the outputs from the second day. The modeled temperature is output hourly at multiple depths and, for initial testing, the DW is taken as the difference between the surface temperature and that at 25-m depth. From the hourly outputs, a daily peak DW amplitude can be derived as shown in Fig. 1.

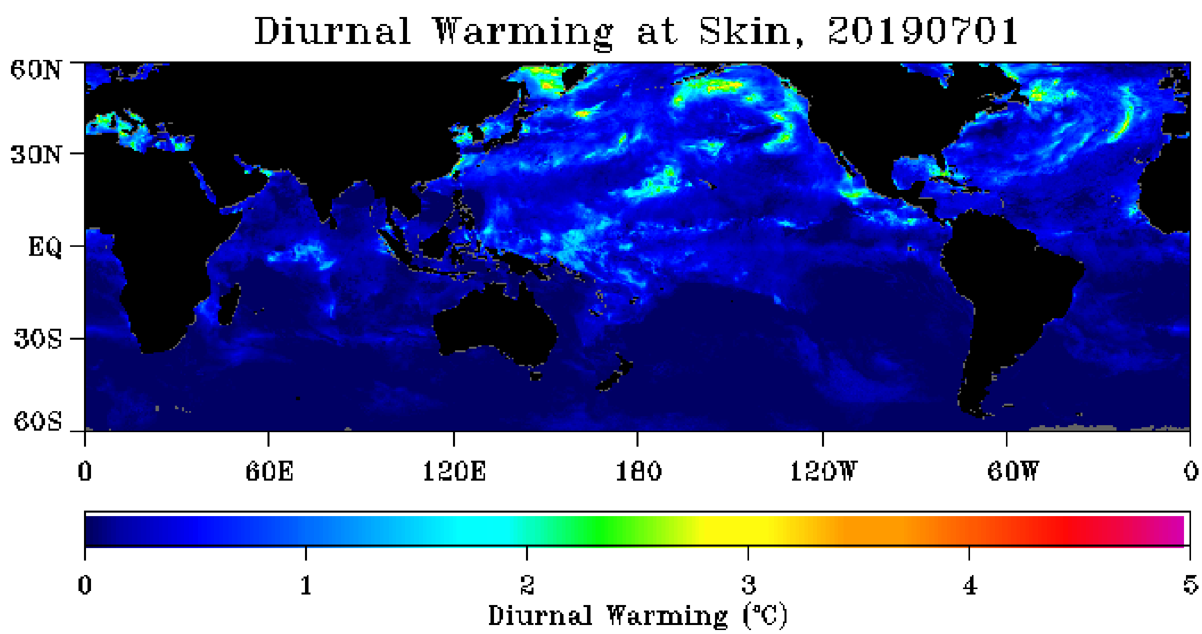

Figure 1. Simulated diurnal warming amplitude for July 1, 2019 generated using the no-gustiness, constant set 2 configuration. The result confirms proper execution of the model and illustrates simulation of physically reasonable amplitudes.

The model incorporates multiple adjustable parameters that can be evaluated for best correspondence with predicted DW against observations. Factors include different coefficient sets for the turbulence closure equations and a gustiness factor introduced to treat potential issues associated with sustained low wind speeds when forcing data are available only every six hours. Initial testing has considered four different configurations as highlighted in Table 1. Global runs have been completed for three months with each of these configurations.

The new absorption scheme results in a depression of predicted DW relative to the baseline scheme that varies with the atmospheric water vapor content. The zonally averaged depression for two configurations is shown in Fig. 2. The results confirm consistency obtained with the new model runs at CU and demonstrate the significant impact the configuration choice has on the predicted warming. Detailed validation is required to determine the most applicable model configuration for the specific forcing content and resolution.

Table 1. Model configurations tested using the revised solar absorption model.

Name	Gustiness	Coefficient set
FULLGUST, C1	1.0	1
FULLGUST, C2	1.0	2
HALFGUST, C1	0.5	1
HALFGUST, C2	0.5	2
NOGUST, C1	0.0	1
NOGUST, C2	0.0	2

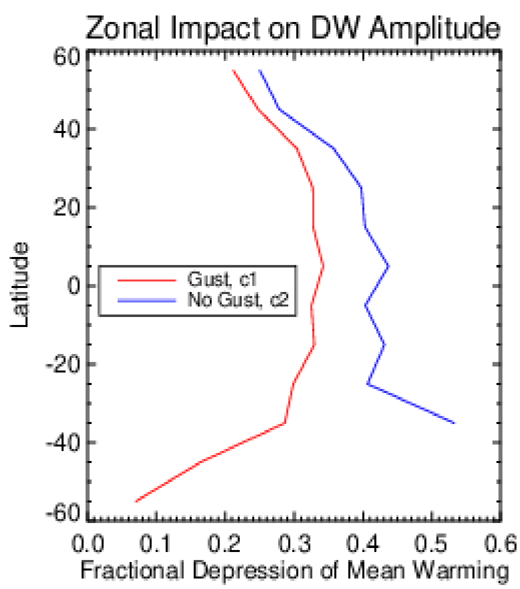

Figure 2. Average zonal impact of the new absorption scheme in depressing the simulated DW amplitude relative to the baseline scheme for multiple model configurations computed for July 2019. The depression is generally greatest at mid-latitudes with increased water vapor as expected, but the model configuration has a significant impact on the depression.

Model Validation

Milestones

- Obtained validation DW amplitude data from the geostationary Meteosat-11 SEVIRI, GOES-16 ABI, and Himawari-8 AHI for June – August 2019 based on past study demonstrating reliability
- Extension of DW amplitude retrievals to additional seasons to present date underway
- Compared simulated DW amplitudes for multiple model configurations against retrieved geostationary DW amplitudes
- Initial comparison of zonally averaged amplitudes (shown in Fig. 3 for July 2019) shows the revised absorption scheme has the potential to improve the simulation of both DW amplitudes and their zonal distribution over the baseline absorption configuration and the large potential impact of selected model configuration
- Comparison of distributions for collocated DW estimates and observations on a common grid help inform what model configuration is best suited to the new solar absorption model and highlight remaining issues requiring further testing (Fig. 4)

Description

Initial work has begun on a comprehensive validation of multiple potential model configurations against a broad range of diurnal warming observations derived from recent geostationary satellite data. Satellite data has been selected for this validation to provide observations for the broadest range of potential conditions. A key objective of the revised absorption model is to resolve potential zonal biases resulting from inadequate treatment of variations in absorption resulting from differing total water vapor content. To evaluate the impact, adequate observations are required across a large range of latitudes. Available in situ observations are still too limited in this scope. More detailed tuning of model configurations will be conducted using in situ observations in later stages of the project.

Wick and Castro (2020) demonstrated that, with appropriate care, the current set of operational SST retrievals from the Meteosat-11 SEVIRI, GOES-16 ABI, and Himawari-8 AHI, can be used to derive reliable estimates of large diurnal warming. The results of that study with derived DW amplitudes for June-August 2019 have been used for initial testing. The “profile” methodology which derives the warming from a continuous sequence of cloud-free retrievals was determined to be most reliable (though with more limited spatial coverage) and is being used here. The methods developed in the study are being used to extend the available validation data from September 2019 to the present.

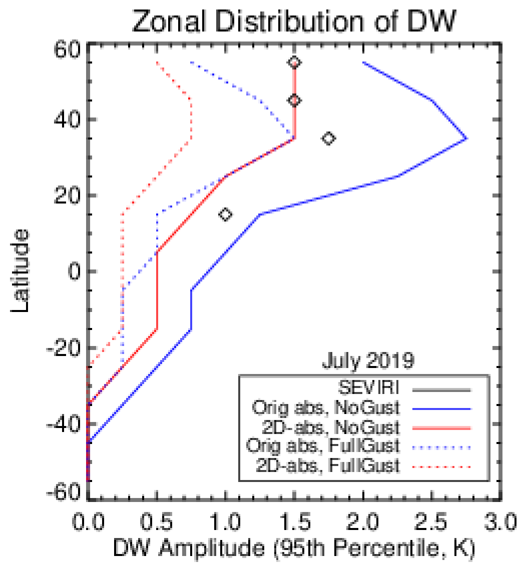

Figure 3. Zonal distribution of the DW amplitude predicted with multiple model configurations compared against retrieved amplitudes from SEVIRI during July 2019. Limited zonal bands are represented in the SEVIRI data due to the reduced data density for the amplitude methodology employed.

Various comparisons between the satellite-derived DW amplitudes and the simulated results from the multiple model configurations are now being conducted. Because of uncertainties associated with the precise positioning of the lowest wind speeds within the NWP model outputs, the comparisons are focused on the probability distributions of the DW amplitudes. Example results from July 2019 are shown in Fig. 3 for the zonal distribution of observed DW amplitudes over the SEVIRI domain as compared with the simulated amplitudes for two different model configurations applied to the new and baseline solar absorption schemes. The results suggest that use of the refined solar absorption model provides the potential to better simulate both the absolute DW amplitudes and their zonal distribution. With the baseline absorption scheme, introduction of a gustiness factor is required to avoid overprediction of the DW amplitude, but the model fails to capture the proper zonal distribution. With the new absorption scheme, the zonal distribution of DW amplitude is generally well reproduced without inclusion of gustiness.

Focusing on application of the refined solar absorption scheme, additional tests are being performed that more directly compare the results obtained from different model configurations and collocated satellite-derived DW amplitudes. The fractional distribution of simulated DW amplitudes with and without gustiness are compared with the collocated SEVIRI, ABI, and AHI observations for July 2019 in Fig. 4. While the no gustiness

configuration better predicts the moderate DW amplitudes up to around 2 K consistent with Fig. 3, the model has difficulty reproducing the largest observed amplitudes particularly as encountered in the Mediterranean Sea.
Ongoing model evaluations will explore the ability to capture these extremes without degrading the ability to reproduce the remainder of the distribution.

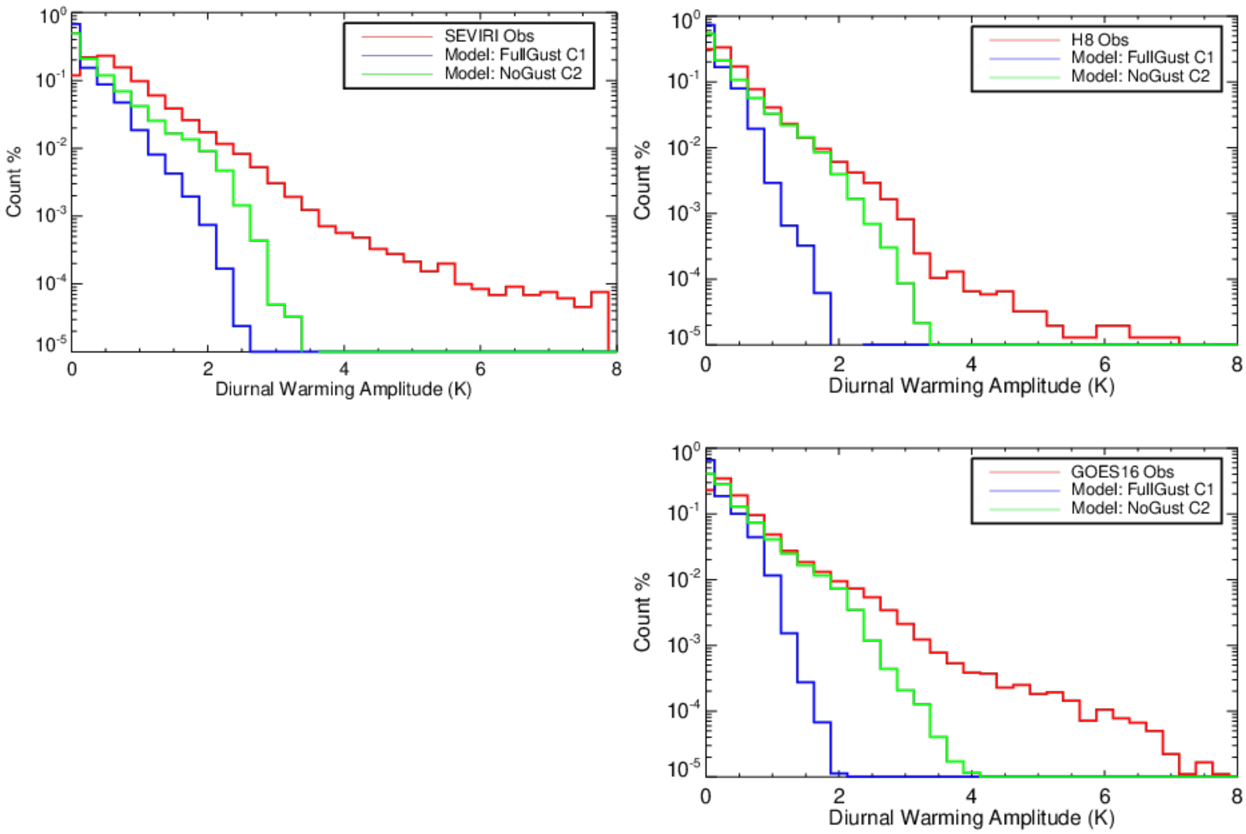

Figure 4. Comparison of the distribution of daily DW amplitude accumulated over the month of July 2019 derived from multiple model configurations using the revised solar absorption model and available collocated (clockwise from top-left) Meteosat-11, HIMAWARI-8, and GOES-16 observations.

Optimize band selection

This project arose from recognition of the existing deficiency in parameterization the fundamental source term for heat within the water column, which led to the development of the 2-dimensional insolation parameterization. While the changes in model warming response have already been substantial, there is an undoubted need to ensure that any new parameterization of the primary forcing term is optimal. Our initial research is focusing on examining the nature of the atmospheric and in-water insolation absorption at high resolution. While this is far more detailed than would be feasible for implementation in any operational environment, it allows assessment of the likely “minimum complexity” of any practical parameterization.

Figure 5 shows both terms on the same scale, along with the *e*-folding scales and Planck weights for the 9-band Defant model that has formed the basis of numerous previous modeling schemes. (Note that these same wavelength bands have been used in the development of the current 2-d insolation scheme that is being tested and validated in the work described above.) The following features can be discerned:

- The crossover from 1/*e* depths greater than 1 cm to less than 1 cm is largely in agreement between the coarse 9-band Defant and the high-resolution Segelstein
- The 1/*e* depths for higher frequencies seem to be overestimated in the 9-band Defant model. Since the Segelstein parameterization is for pure water, addition of biological elements will only serve to exacerbate this difference
- The 1/*e* depths display notable variation (more than an order of magnitude) within at least some of the Defant bands
- The variations in insolation due to atmospheric water vapor do not necessarily correspond with Defant band selections, or features in the high-resolution in-water 1/*e* parameterization

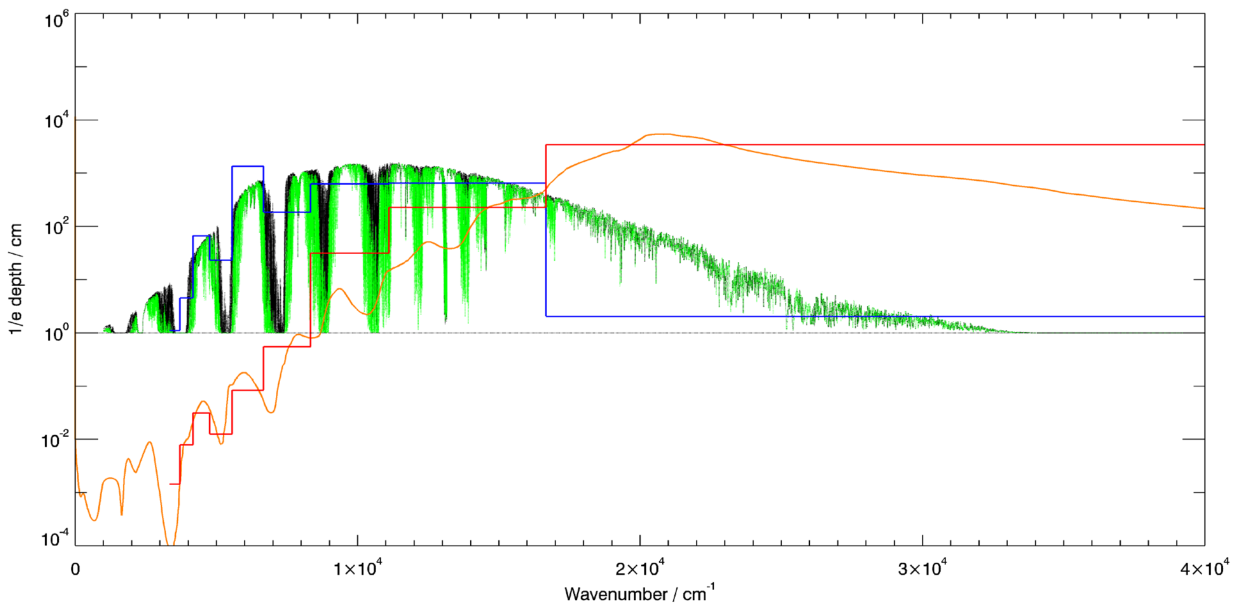

Figure 5. 1/e absorption depths for 9-band Defant (red) and high-resolution Segelstein (orange). Corresponding Planck weights for Defant bands are shown in blue, along with Modtran insolation for low (black) and high (green) water vapor atmospheres. (N.B. The units for the radiance calculations and Planck weights have been exponentially scaled to allow for correct representation on the same logarithmic scale as the 1/e depths.)

The first implication of the above findings is that any revised parameterization that uses explicitly defined wavelength bands will need to be more complex than the 9-band Defant model. The increase in complexity is likely to be approximately a factor 2-3, which, although more burdensome in computational terms (previously, modelers would consider the 9-band Defant something an extravagance, and sought to implement less complex schemes), should be within the scope of modern processing capability, especially when considering the “trivial” nature of parallelization for 1-d mixing schemes. However, computational efficiency will come into play for large-scale ocean modeling, especially in long climate runs. Reconciling this requirement with the somewhat complex nature of the atmospheric and in-water absorption relationships implies the need for derivation of a statistical parameterization (*i.e.* not using explicit wavebands), and investigations into this will be reported on in due course.

Plans for next reporting period

Since progress has been proceeding in broad accordance with the original project plan, we anticipate reporting on the following activities:

- More detailed analysis of findings from validation
- 1st cut revision of model mixing parameters
- 1st cut refinement of insolation parameterization
- Assess impact of cloudiness on insolation parameterization
- Updates to operational diurnal modeling code as indicated by research results

Reference

Wick, G. A., and S. L. Castro, Assessment of extreme diurnal warming in operational geosynchronous satellite sea surface temperature products, *Remote Sensing*, **12**, 3771; doi:10.3390/rs12223771, 2020.