Several recent studies have concluded that coupled climate models should utilize a diurnally varying SST to examine the details of the boundary layer response and ensuing air-sea interactions. The global distribution of diurnally varying SST is clearly linked to wind speed and will therefore respond to the climatic distributions and seasonal or anomalous changes in wind speed, as shown by the response to ENSO wind speed anomalies. The Subtropical High regions in each ocean basin, and the Tropical Indian and Western Pacific Oceans have the largest regions of diurnal warming, as expected from the stability of the boundary layer and atmospheric convection. Since the tropical convection is an important driver of global atmospheric circulation, this example of ocean-atmospheric feedback underscores how diurnal warming of the ocean surface may influence larger scale weather patterns and climate. Results from several satellites show significant diurnal warming present over large regions. Several models (both empirical and physical) of diurnal SST variability have been developed, but show little agreement with each other. Comparisons of data and models will be used to discuss the global spatial-temporal distribution of diurnal warming and how accurately we actually understand it.

### 1. Characteristics of diurnal warming from observations and a model

Using data from 2002-2010, the observed mean and maximum diurnal warming is shown in Figures 1 and 2. Figure 1 shows AMRR-E (A) diurnal warming to be less than MODIS (B), but the CG04 model primarily because it was developed using microwave SST data from TMI. While there is significant, widespread diurnal warming in the tropical Pacific and Indian Oceans, this is also considerable warming in the midlatitude low wind regions. There are large day-night differences in MODIS at high latitudes that are likely not diurnal warming. Figure 2 shows the maximum diurnal warming, showing warming events of ~5°C as the Equatorial cold tongue, and midlatitude low wind regions. Although the mean diurnal warming is not large in the mid-latitude regions, it is important to recognize that these regions have large, but sporadic warming events. The model (Figure 2C) does not capture the large events well.

These results show the difficulty in understanding diurnal warming. The warming measured depends on instrument, spatial resolution, time of observation, and the modelled diurnal warming depends on modelized and data inputs. It is likely that there is no single answer for how to model diurnal warming, and each model has a different answer for each specific question. To remove diurnal warming from observations and calculate a ‘foundation’ or diurnally-corrected SST, it may be best to use a model developed from the maximum diurnal warming, showing warming events of ~5°C as a climate model, it is necessary to understand whether a skin or 1-m model of diurnal amplitudes and what is the spatial resolution of the model is.

### 3. Characteristics of extreme diurnal warming events (>5°C)

Diurnal warming events between 5 and 7 K, spatially coherent over large areas (~1000 km), are observed in independent satellite measurements of ocean surface temperature. The majority of the large events occurred in the extra-tropics. Given sufficient heating (from solar radiation), the location and magnitude of these events appears to be primarily determined by large-scale wind patterns. The amplitude of the measured diurnal heating scales inversely with the spatial resolution of the different sensors used in this study. These results indicate that predictions of peak diurnal warming using wind speeds with a 25 km spatial resolution available from satellite sensors and those with 50-100 km resolution from Numerical Weather Prediction models may have underestimated the warming. Thus, the use of these models in modeling diurnal effects will be limited in accuracy by both the temporal and spatial resolution of the wind fields. Failure to account for a diurnal cycle in sea surface temperatures (SST) can lead to errors in determining surface fluxes for Numerical Weather Prediction (NWP) and climate models (Webster et al., 1996; Woods et al., 1984). These large diurnal events are not well reproduced by any existing physical or empirical model.

Three independent satellite datasets were used to investigate large diurnal warming events. The AQUA satellite carries both the Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) and Moderate Resolution Imaging Spectroradiometer (MODIS), providing independent contemporaneous microwave (MW) and infrared (IR) measurements. The AQUA satellite was launched in May 2002 into a polar, sun-synchronous orbit, with a LECT (Local Equator Crossing Time) of 1:30 AM/PM. Over much of the Atlantic Ocean, the geostationary METEOSAT-8 Second Generation (MSG) Spinning Enhanced Visible and Infrared Imager (SEVIRI) provides hourly data. While both MODIS and SEVIRI provide IR radiances, the SEVIRI instrument and viewing geometry is different than MODIS and is therefore independent.

The SEVIRI day-night differences were examined for spatially coherent large positive differences over 5 K, 595 events were found (Figure 2). Low wind speeds occur more frequently when there are large diurnal warming events. The wind field over large regions was shown to have afternoon biases (which is the IR SSTs) and this has masked and reduced large warming events. Images of the daily diurnal events are available as auxiliary materials for the model. The large events were identified in the SEVIRI data, verification using other sensors was completed.

### 4. Air-Sea interactions: Diurnal warming and ENSO

Diatoms models all depend strongly on wind speed. At low wind speeds, small changes in wind speed will result in a large change in diurnal warming amplitudes. To illustrate this, this data from a location in the Equatorial Cold Tongue where the wind speed is strongly controlled by the stability of the boundary layer and SST (Chelton et al., 2001). Using a time series of SSM/I wind speeds, we calculated daily diurnal warming at 12 PM (the peak value for CG04 model). The Multivariate ENSO Index (MEI) (Wolter and Timlin, 1999) is a measure of the strength and timing of ENSO events. Figure 4 shows the MEI in the background El Niño or La Niña in blue). The CG04 modelled diurnal warming is shown by the line. The heavy black lines is a long-lead estimate of the diurnal warming annual/biannual magnitude. This fit to the diurnal amplitudes was completed to allow for comparison of the usual diurnal warming modelled, versus the warming during ENSO. In non-ENSO years, there is normally a cold tongue of water in the Eastern Pacific and the wind speeds in the Eastern Pacific are larger than their climatological value. Conversely, during a La Niña the cold tongue is larger than normal and the wind speeds are less than their climatological value. The cold tongue influences the wind speed (Figure 5 by increasing the stability of the boundary layer and thereby decreasing the vertical transfer of momentum (Chelton et al., 2001). The cold tongue is clearly seen in both the SST and the surface wind stress. Figure 5 shows that during the El Niño phase, the diurnal warming is significantly less than during the warmer ocean temperatures during the El Niño, resulting in higher wind speeds and less diurnal warming.