Evaluation of modeled diurnally varying sea surface temperatures and the influence of surface winds

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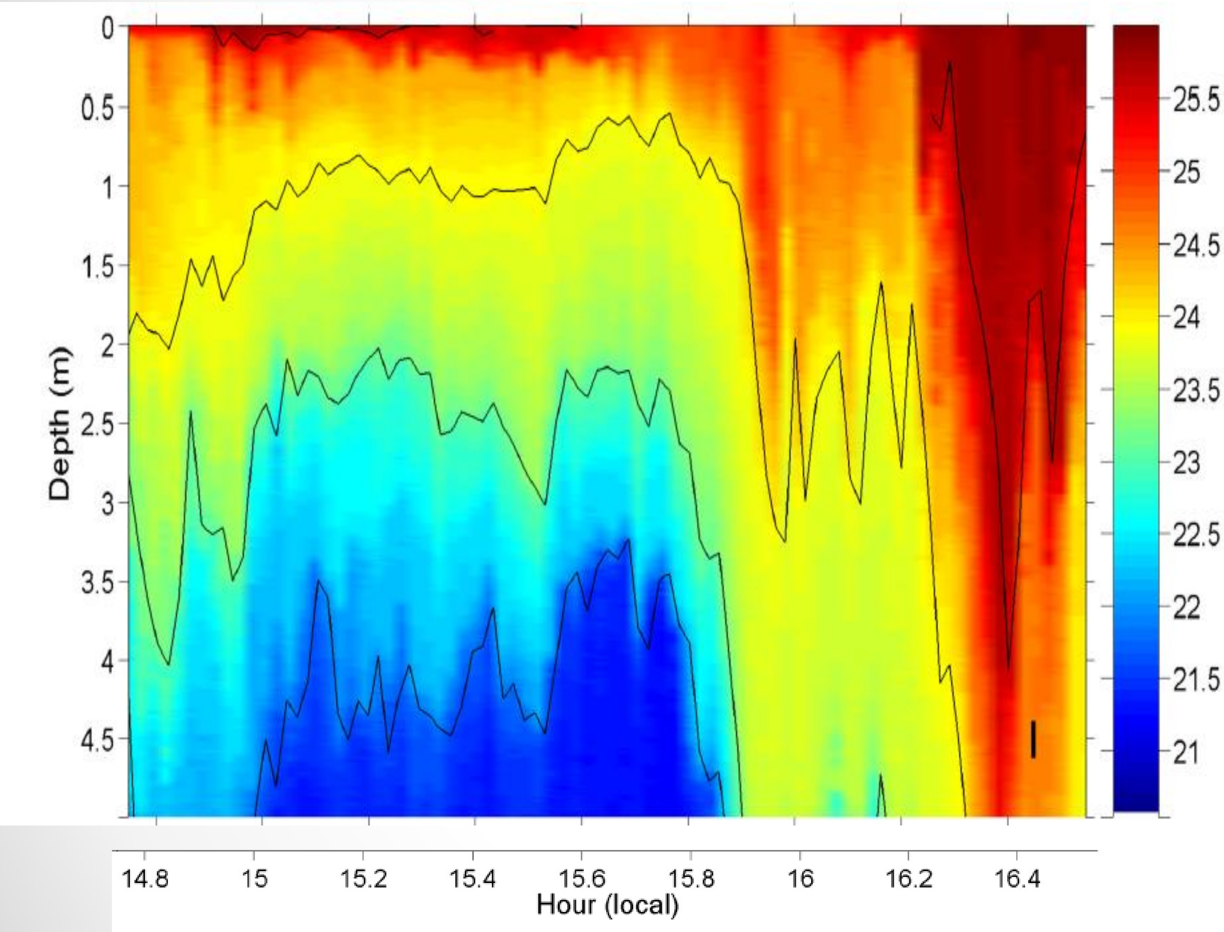
SSTs exhibit diurnal variability



From Ward 2006

- As far as last century, studies have noted ΔT between different depths in upper few meters over course of day
- ΔT can be on the order of 3˚C
- Presence of diurnal warming in certain areas can last throughout the majority of daylight hours.

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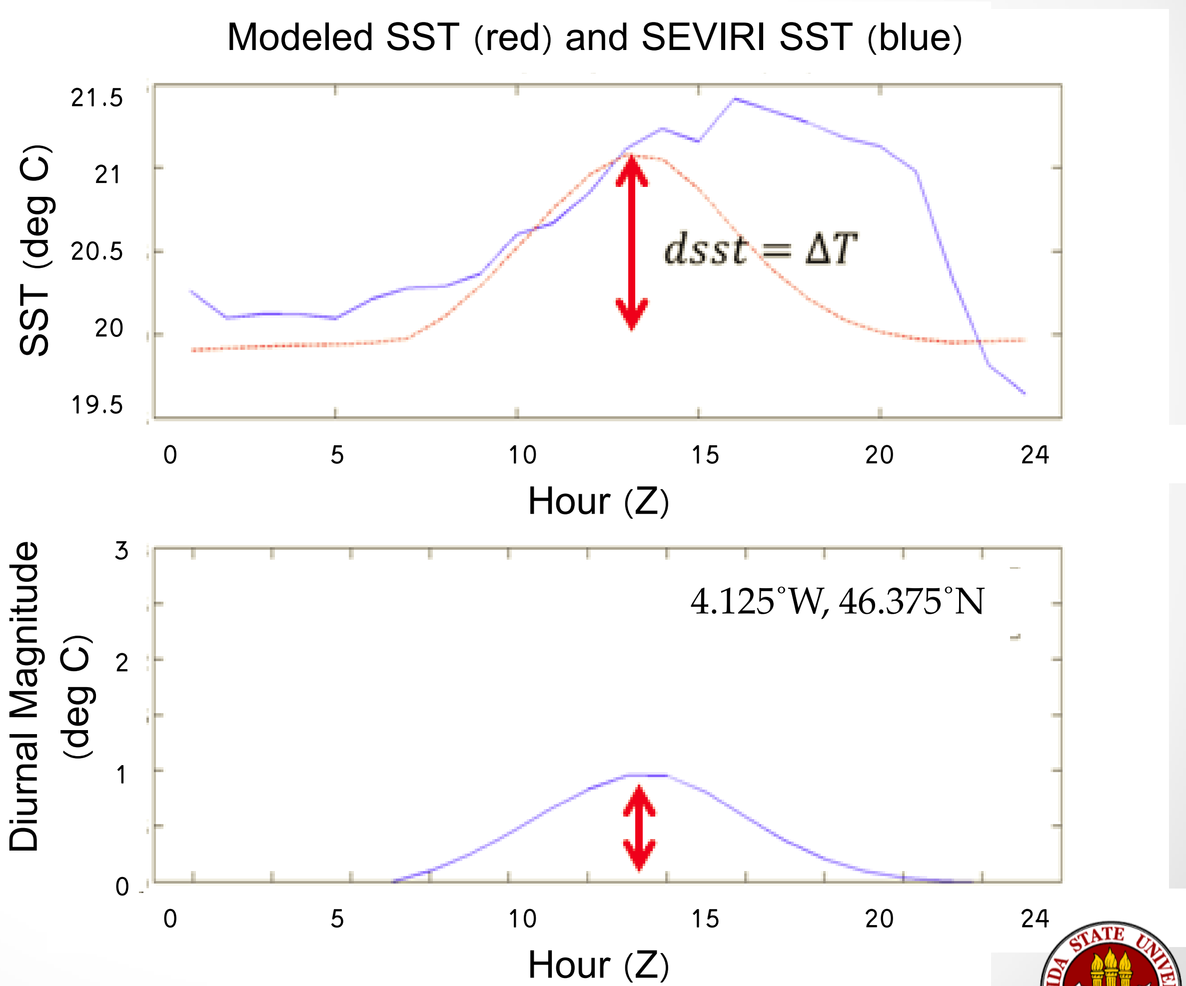
Development of warm surface layer

- Winds are relatively calm (low mechanical turbulence and mixing)
- Ample sunlight absorption into the ocean
- Diurnal cycle observed using model and satellite data



Overview of Research

- Creation of diurnally varying SST dataset using a physical-empirical hybrid model (2000-2004)
- Characterization of diurnal warming in regions of the ocean
  - Diurnal streaks
  - Temporal persistence in Tropics vs. Midlatitudes
- Examine the influence on surface latent and sensible heat fluxes over seasonal time scales
- Analyze sensitivities in model with regard to winds, solar radiation at the surface, and precipitation
- Model evaluation using remotely sensed skin temperature

dSST Product

- **POSH – Profiles in Oceanic Surface Heating Model**
  - Gentemann et al. (2009)
  - Collection of improvements of TOGA-COARE bulk flux algorithm v2.5
    - Fairall et al. (1996)
- **Calculates diurnal warming in a 1-D model at each hour on 0.25° x 0.25° grid**
  - Function of bulk SST and accumulated heat/momentum at each time step.
    - Advection is ignored
    - Ice is excluded
- **Variety of diurnal warming models**
  - Physically based model that captures diurnal warming will likely increase understanding of physical processes of the upper ocean
- **Produced 5 year long dataset (2000-2004)**
  - SST and dSST (magnitude)
  - sensible and latent heat flux with and without a diurnally varying SST
    - using BVW model (Bourassa 2006)

Input Data

- **POSH needs global continuous time series of hourly dat**a
  - atmospheric bulk variables, radiation, and SST_{bulk}
    - U_{10} , V_{10} , Pressure, T_{10} , Q_{10} , SWR, LWR, Precip Rate
- **NASA's MERRA Reanalysis**
  - Provides hourly data on 1/2° x 2/3° grid for entire globe – regridded to 1/4°
- **Bulk SST**
  - Need SST closer to SST_{fnd} (Donlon et. al 2007) unaffected by diurnal heating for total effect
  - Reynolds OI daily SST AVHRR-only (Reynolds et al. 2003)
    - 1/4 °x 1/4 °
    - Uses satellite and in situ measurements for blended product
    - Bias adjusted over seven-day period – eliminates diurnal variability
  - Set to 19 m - theoretical maximum dSST thickness (Gentemann personal communication 2011)

Scaled dSST

- Diurnal warming magnitude

$$dSST(z) = e^{-9.5\left(\frac{z}{D_T}\right)^a}$$

- Diurnal warm layer thickness:

$$D_T = \sqrt{\frac{2R_i c_p}{\alpha g \rho}\frac{\tau_{ac}}{\sqrt{Q_{ac}}}}$$

α water thermal expansion coefficient
ρ density of water
R_i Bulk Richardson Number
C_p Heat Capacity of Water
g Gravitational Acceleration

Wind Speed	a
≤1.5	2
3	3
4.5	5
6	7
≥7.5	9

From Gentemann et al. 2009

Requires bulk Richardson number = 0.65
Assuming a linear temperature profile
Function of accumulated wind stress and accumulated heat

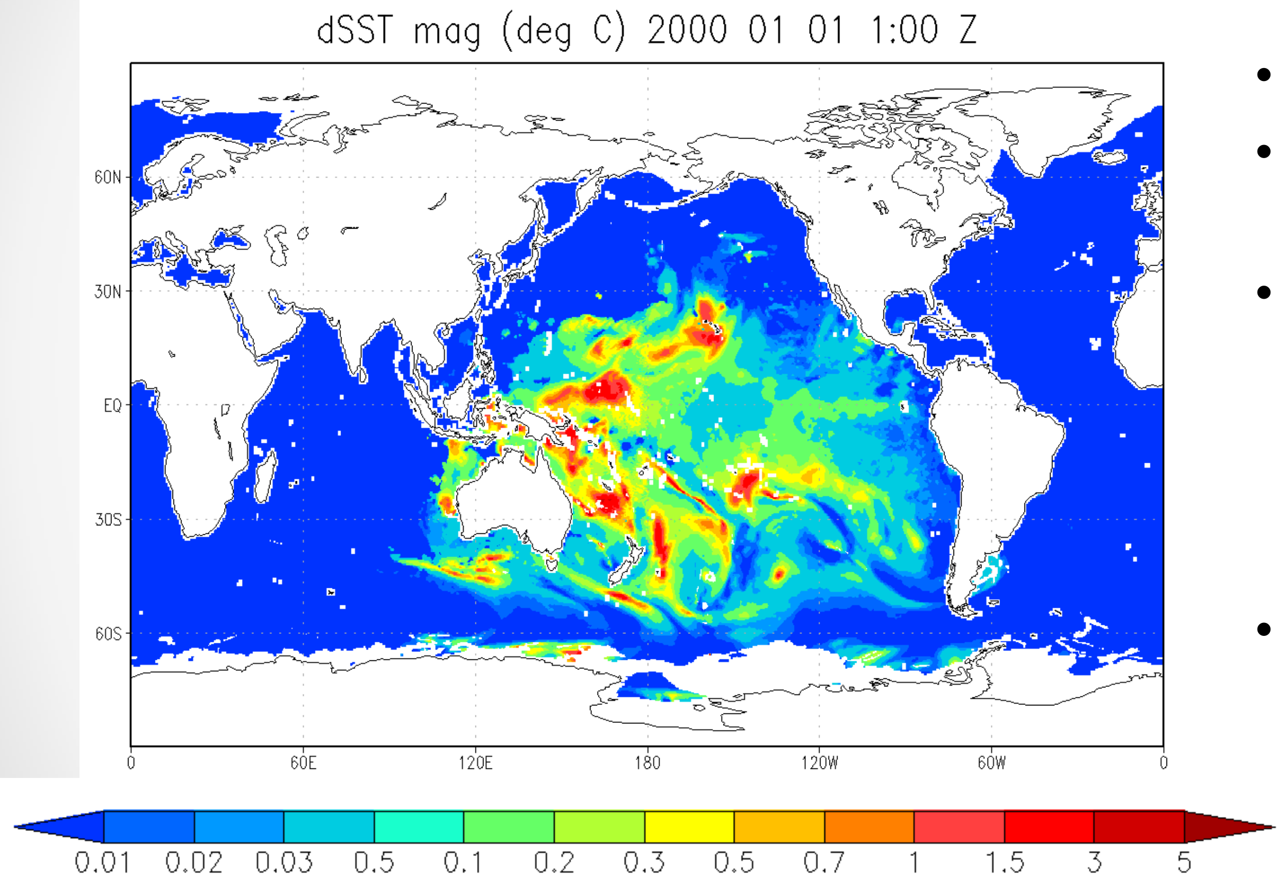
$$\tau_{ac}(t) = (1 - \varepsilon_\tau \Delta t)\tau_{ac}(t - \Delta t) + \tau_{tot}\Delta t$$

$$Q_{ac}(t) = (1 - \varepsilon_\chi \Delta t)Q_{ac}(t - \Delta t) + Q_{tot}\Delta t$$

Dissipation coefficients make diurnal warm layer “interact” with mixed layer and lose heat from bottom DWL

Salinity dependence is not explicit in model

dSST Subdiurnal Spatial Structure



Diurnal warming magnitude (°C)

- Sun synchronous
- Occur at almost all latitudes
- Reflect current meteorological state
  - Cyclones
  - Fair weather features
- Non-linear non-negligible increase in surface heat fluxes

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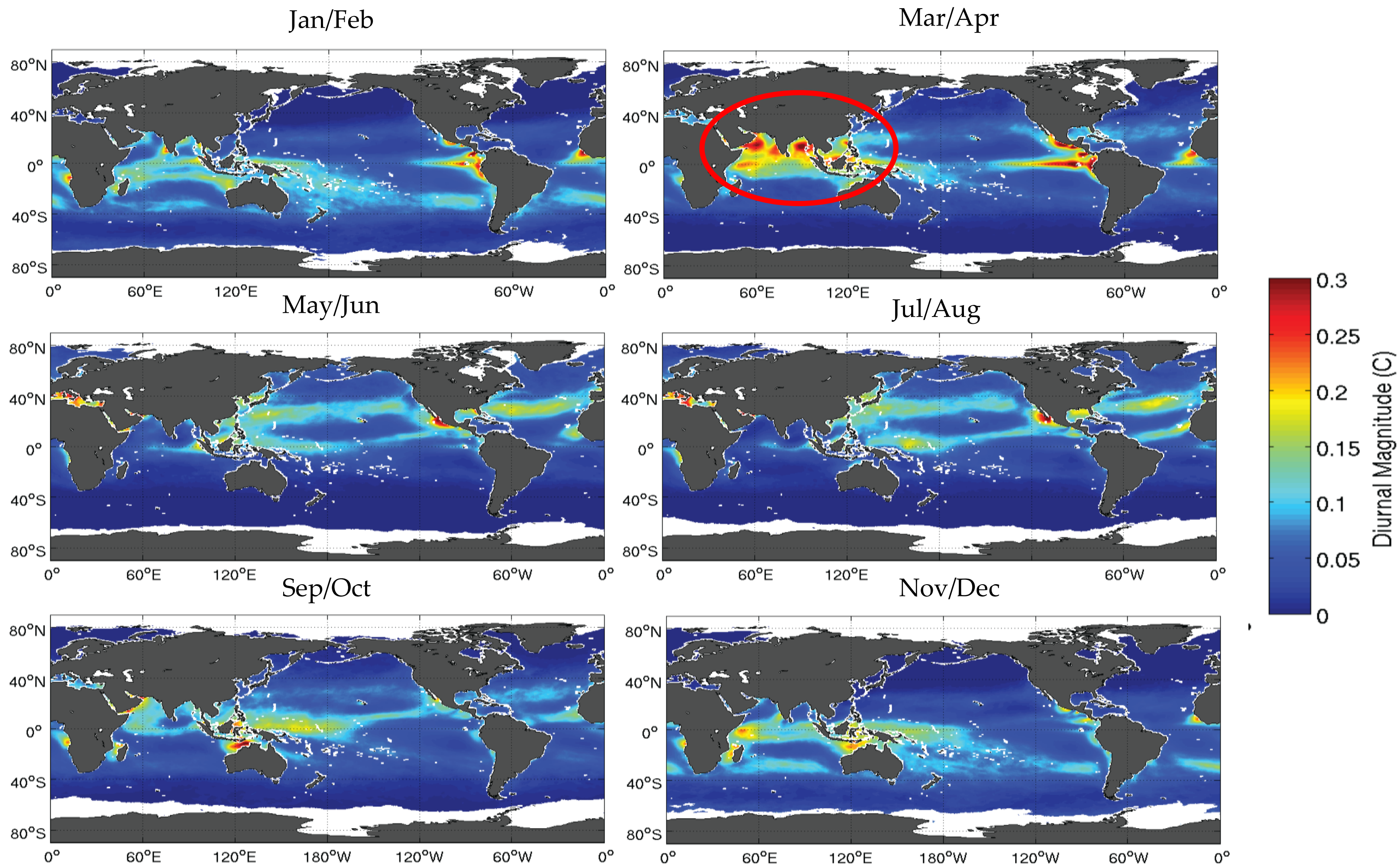
Bimonthly Average dSST



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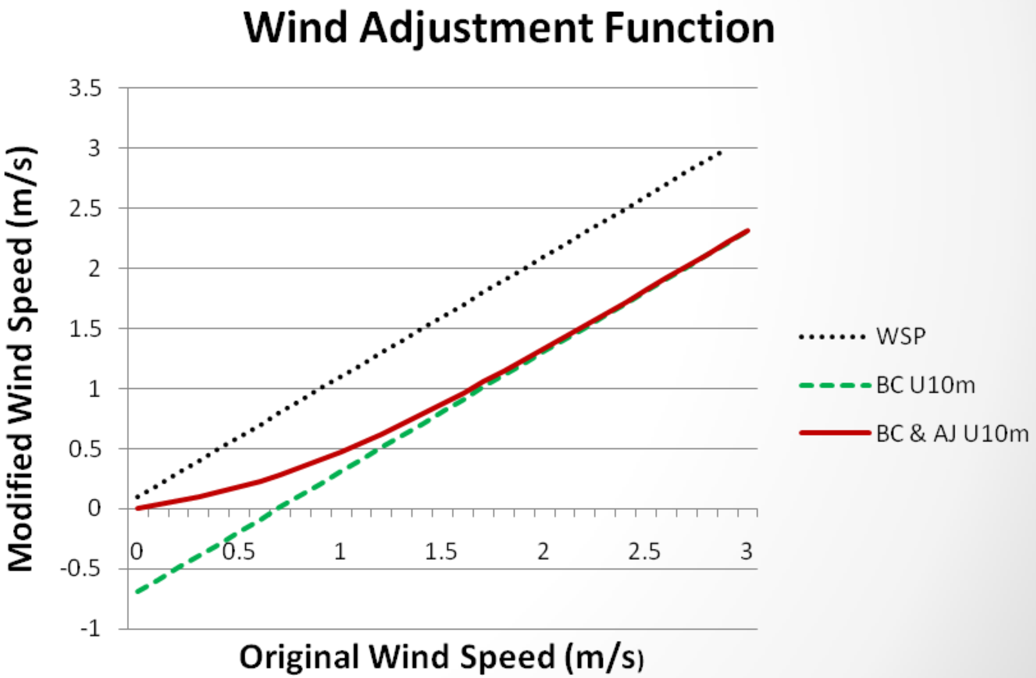
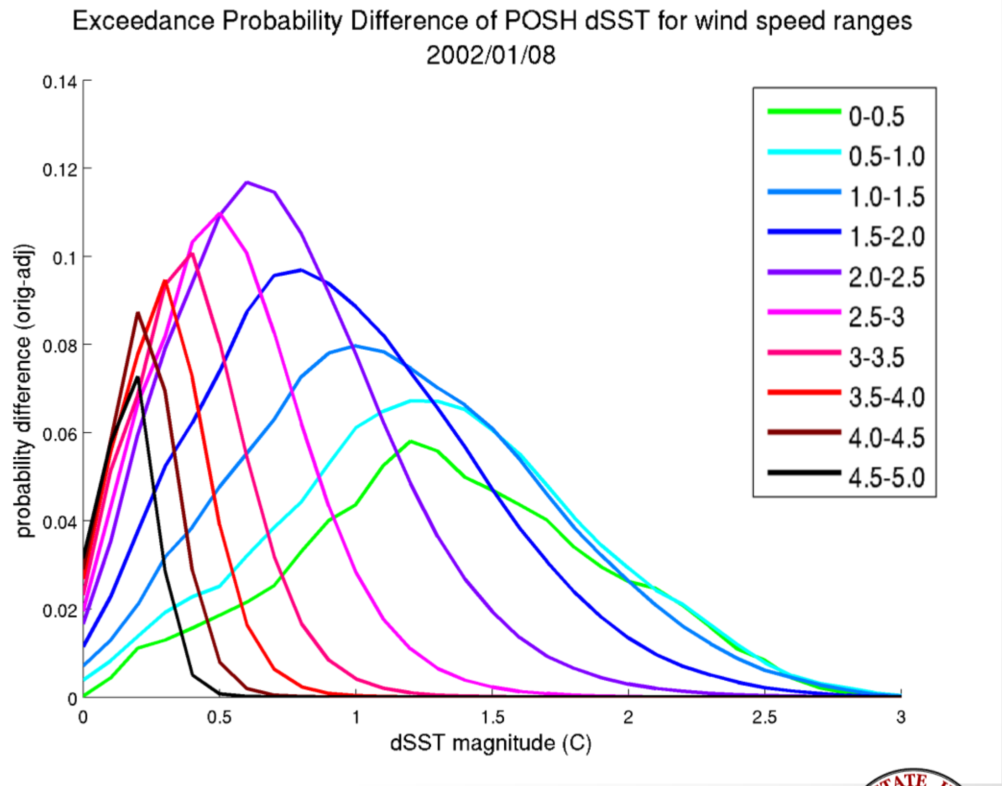
Effect of Potential Biases in Winds

- We can estimate the error associated with biases in the wind speed data
- Roberts et al. [2010] compared MERRA with in situ measurements
  - MERRA had positive bias for entire distribution of winds
- Best guess estimate of systematic bias in winds is 0.69 m/s



Effect of Potential Biases in Winds cont.

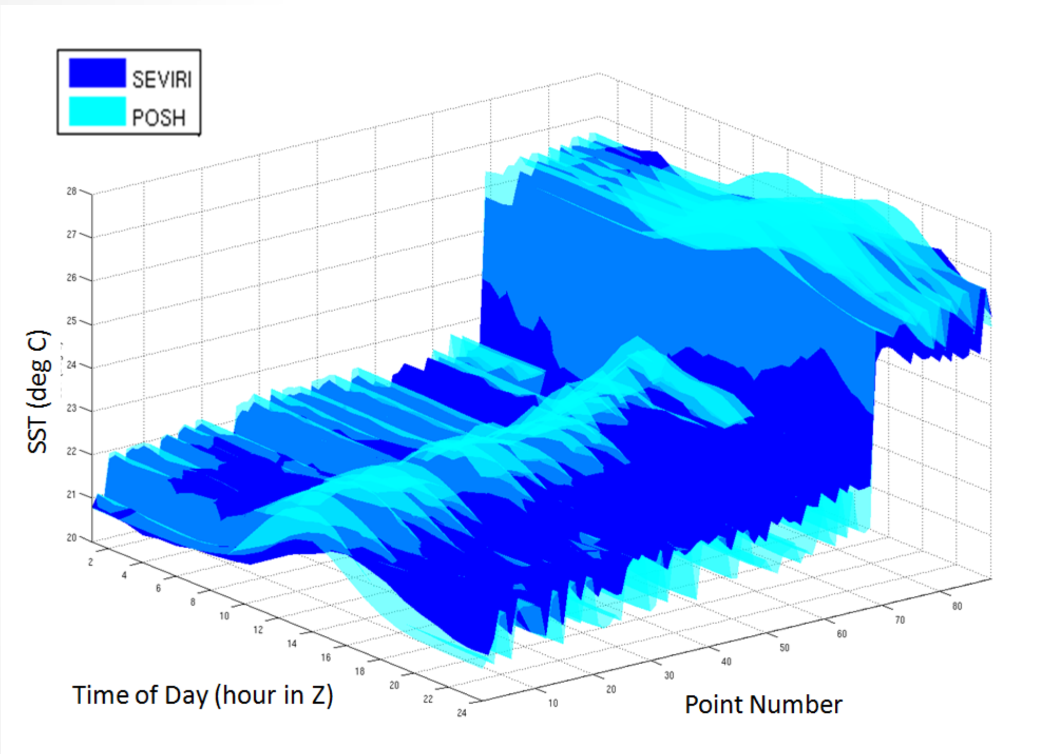
- Potential biases affect the short-term diurnal warming – exceedance curves



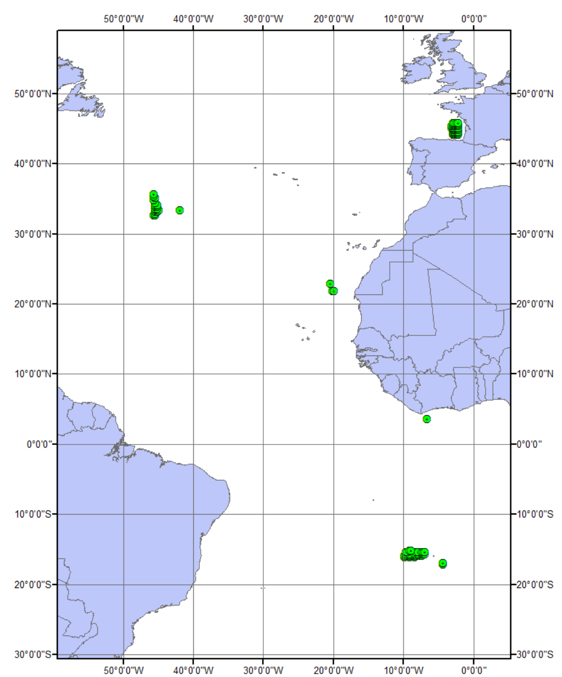
- Differences are +
  - Increased likelihood of dSSTs at all wind speed ranges
- Largest probability increase between winds of 2.0 – 2.5 m/s
  - Lowest wind speed with the largest bias correction value
- Isolated events can be as large as 1˚C
- Bimonthly differences are less than 0.06˚C (not shown)

Time Series of Diurnal Cycles

- Using the best sampled data points on a given day, compare modeled SST to SEVIRI SST at each hour



Sample Locations



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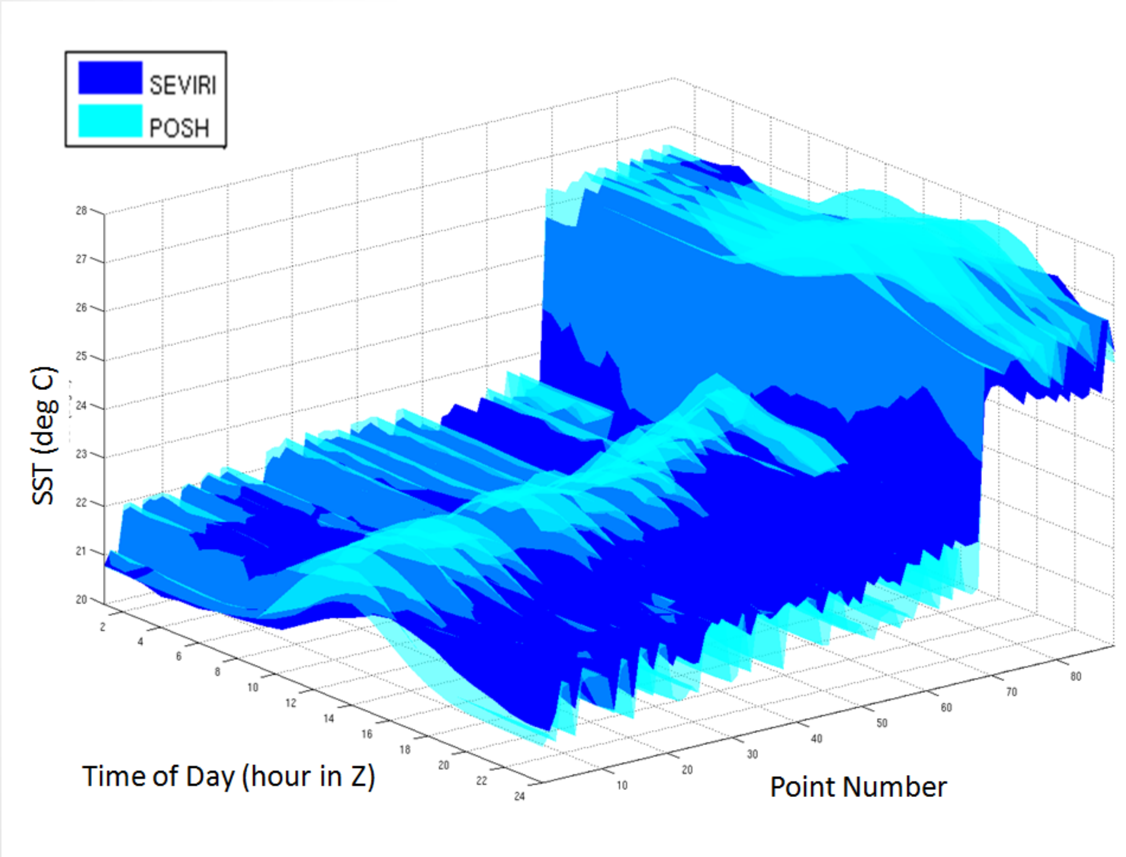

- Reynolds SST estimates foundation temperature reasonably well
- POSH consistently overestimates peak but dissipates heat too quickly for smaller peak SST
  - Tuning of dissipation coefficients for different regions of ocean may prove useful

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Conclusions

- The diurnal cycle of sea surface temperatures is modeled using Gentemann et al.'s POSH model (2009)– a physical-empirical hybrid model based on TOGA-COARE flux model
  - exponential adjustment to the diurnal warm layer thickness;
  - a function of accumulated wind stress and heat adjusted by dissipation coefficients to interact with mixed layer
- Occurs throughout the world's ocean
  - except in areas of ice,
  - sometimes in thousand kilometer streaks
  - Non-linearly affects surface fluxes
- Best guest estimate of bias correction (0.69 m/s) influenced dSST on short timescales but less so on semi-seasonal scales
  - Sensitive to bias adjustment at low wind speeds
- Using regridded SEVIRI SST swath data, selected points based on their sampling were selected to use in a comparison under a best case scenario approach.
- The Reynolds SST was representative of a foundation temperature while the peaks in POSH were consistently overestimated

Future Work

- Couple diurnally varying SSTs to boundary layer model
  - Input from satellite winds, SSTs
  - Varying surface fluxes
  - Potentially with HYCOM
- Examine effects
  - Divergence, wind feedbacks on SST

References

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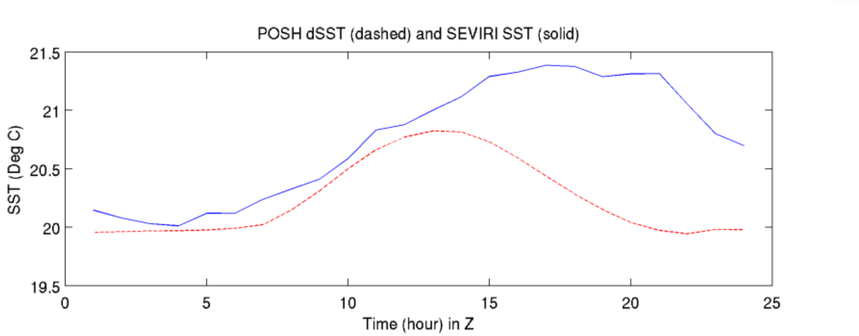
Questions?

Back up slides

Comparison of Modeled Diurnal Cycle to Measurements

- Want an initial assessment of how well POSH represents the diurnal cycle of global SSTs
- Perform a case study
  - Using IFREMER's MSG/SEVIRI hourly skin SST swath data
    - One of the newer instruments; has already been shown to observe diurnal cycle (Le Borgne et al., 2012)
      - Average underestimation of peak dSST by 0.12 K
- Rerun POSH model to match data availability
    - Sample day in July, in Atlantic Ocean
- Differences are function of
  - Foundation offset
  - Shift in onset of warming
  - Hourly/peak offset



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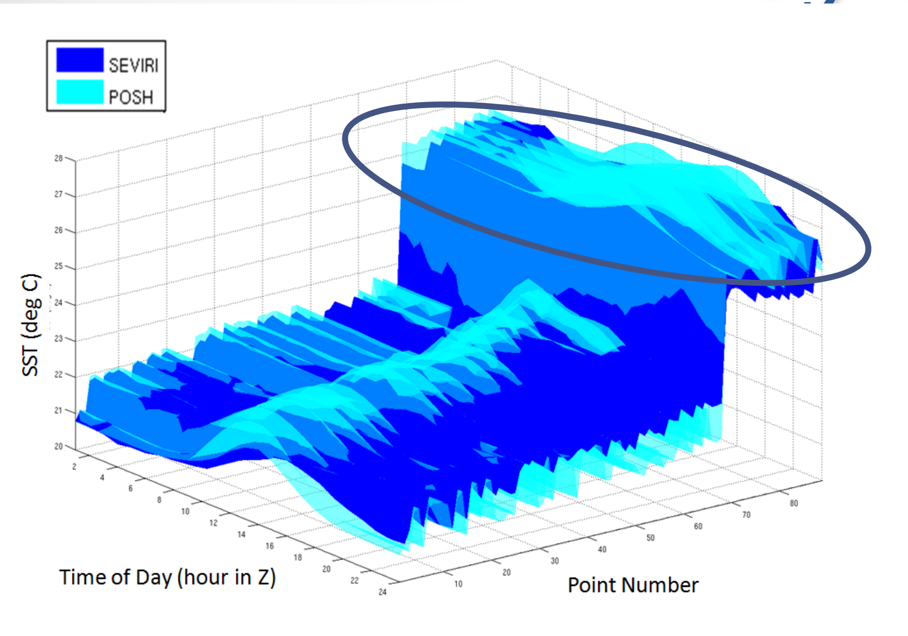

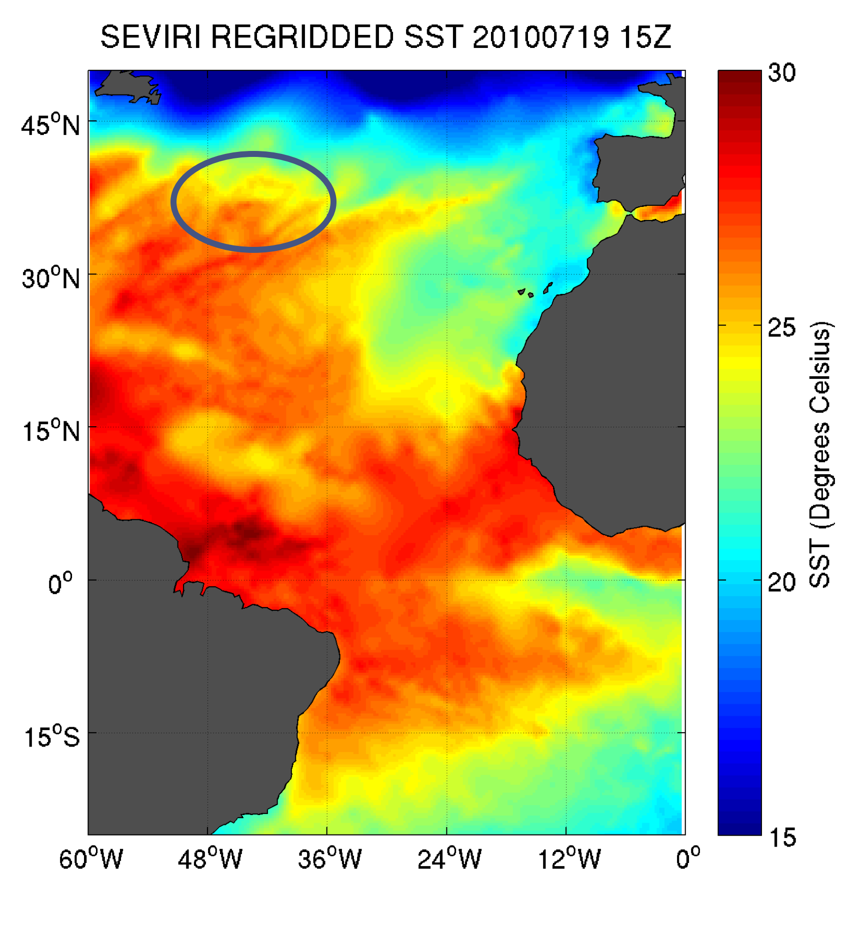

- Areas where SST gradients are large are ambiguous
  - Advection (or large turbulent mixing) may inhibit formation of a classical diurnal warm layer

- Diurnal warming magnitude

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- Diurnal warm layer thickness:

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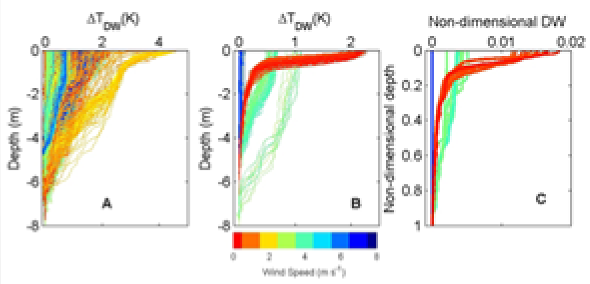

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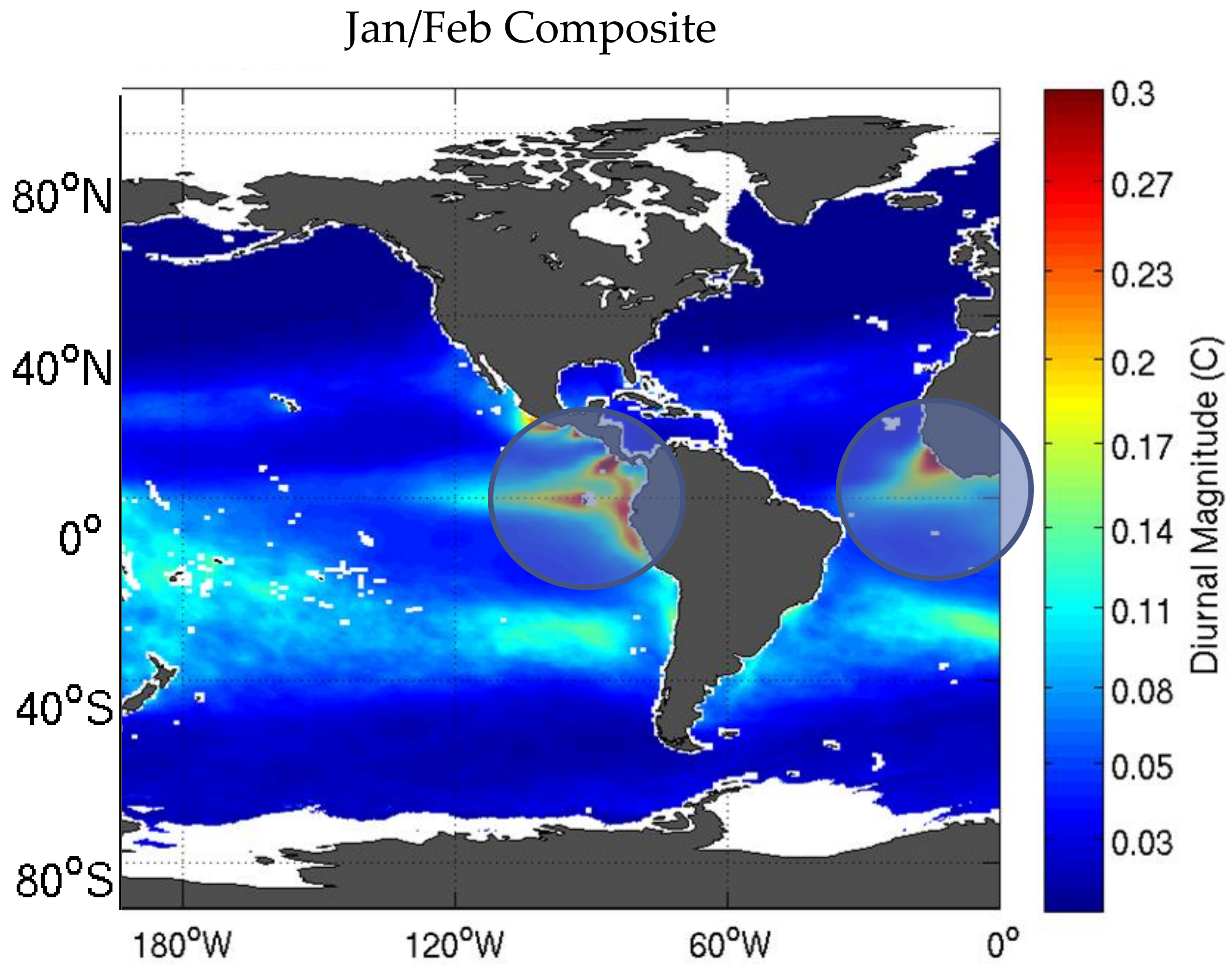
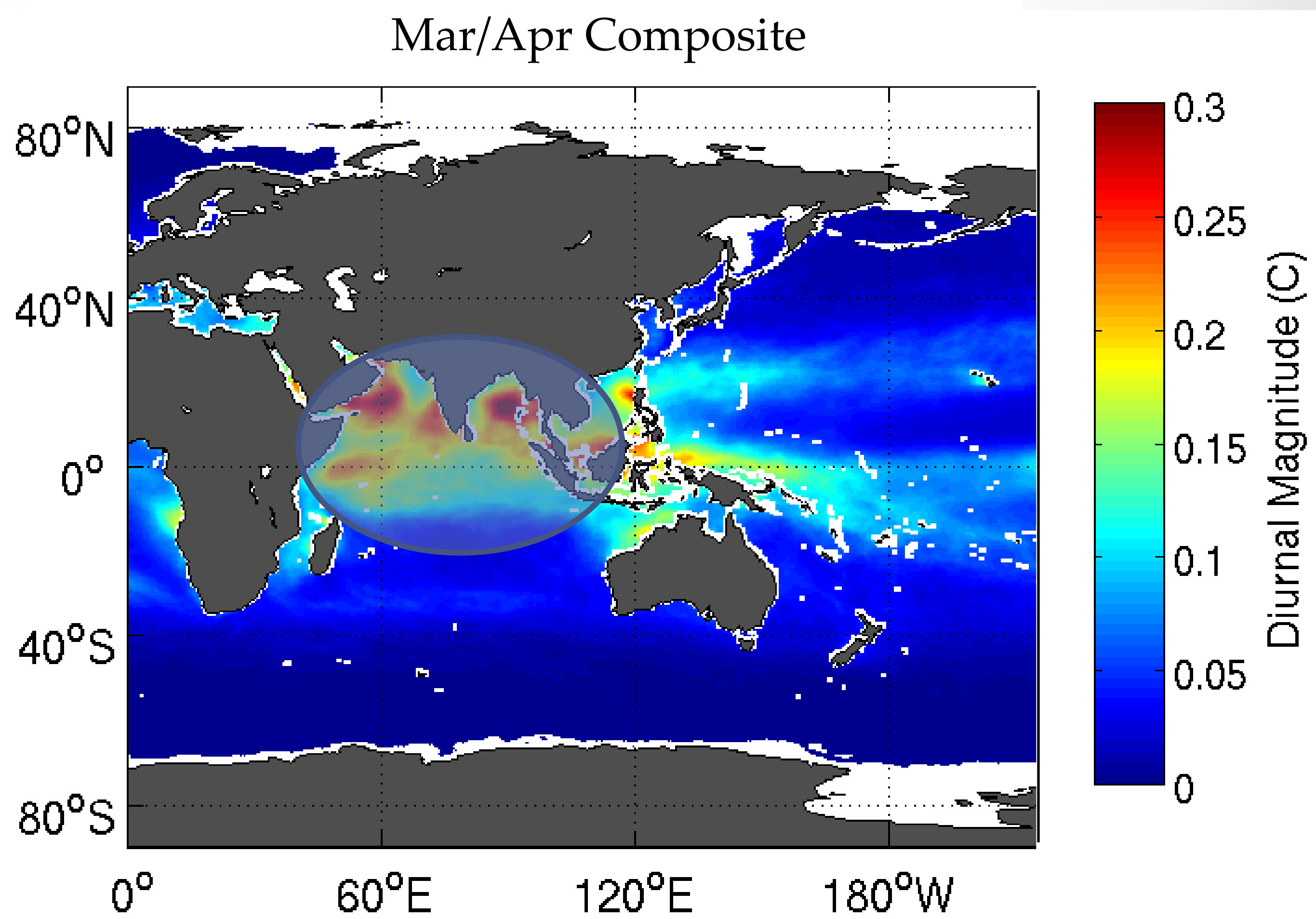
Bimonthly average dSST

- Low level convergence near the ITCZ

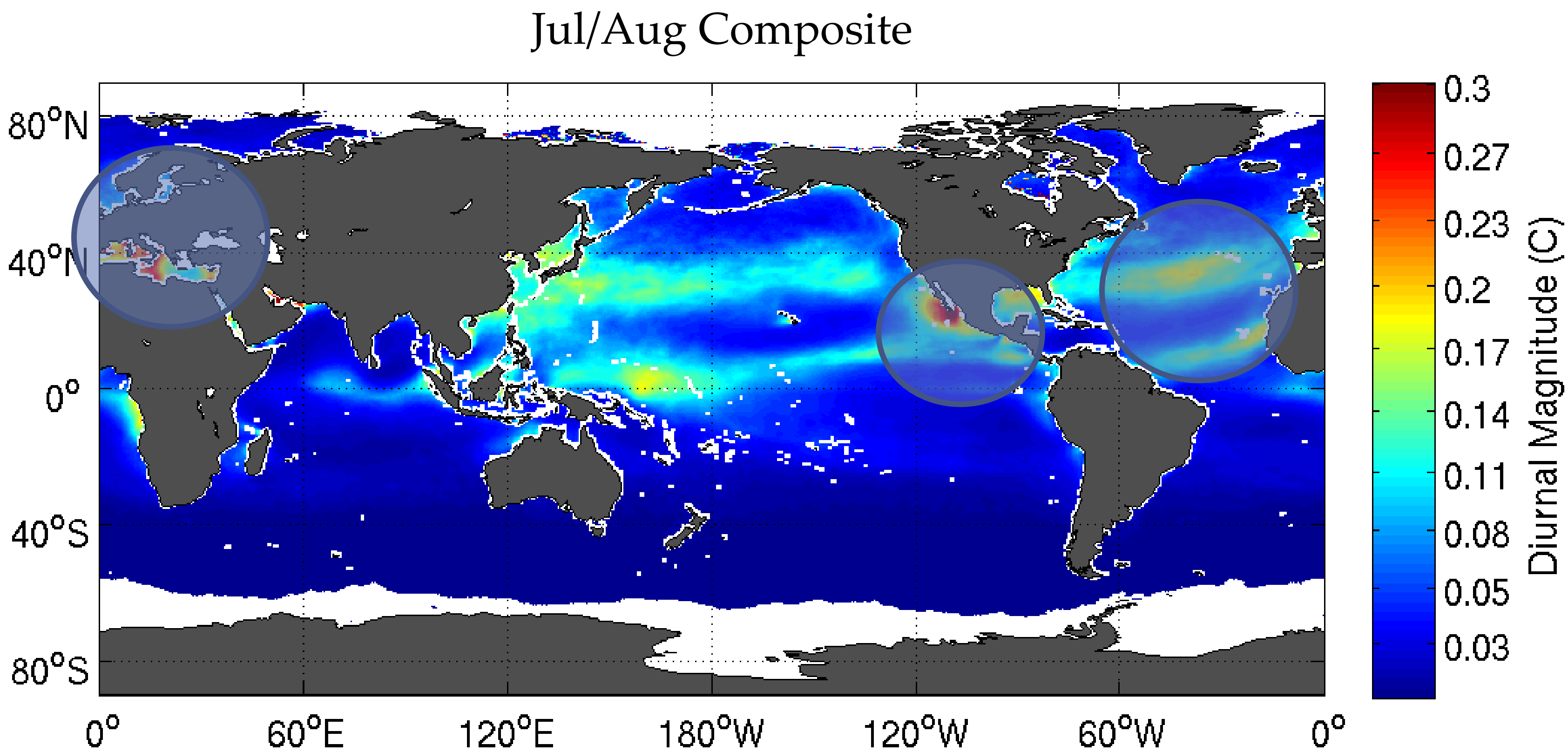


Bimonthly average dSST

- Transitional phase of monsoonal winds

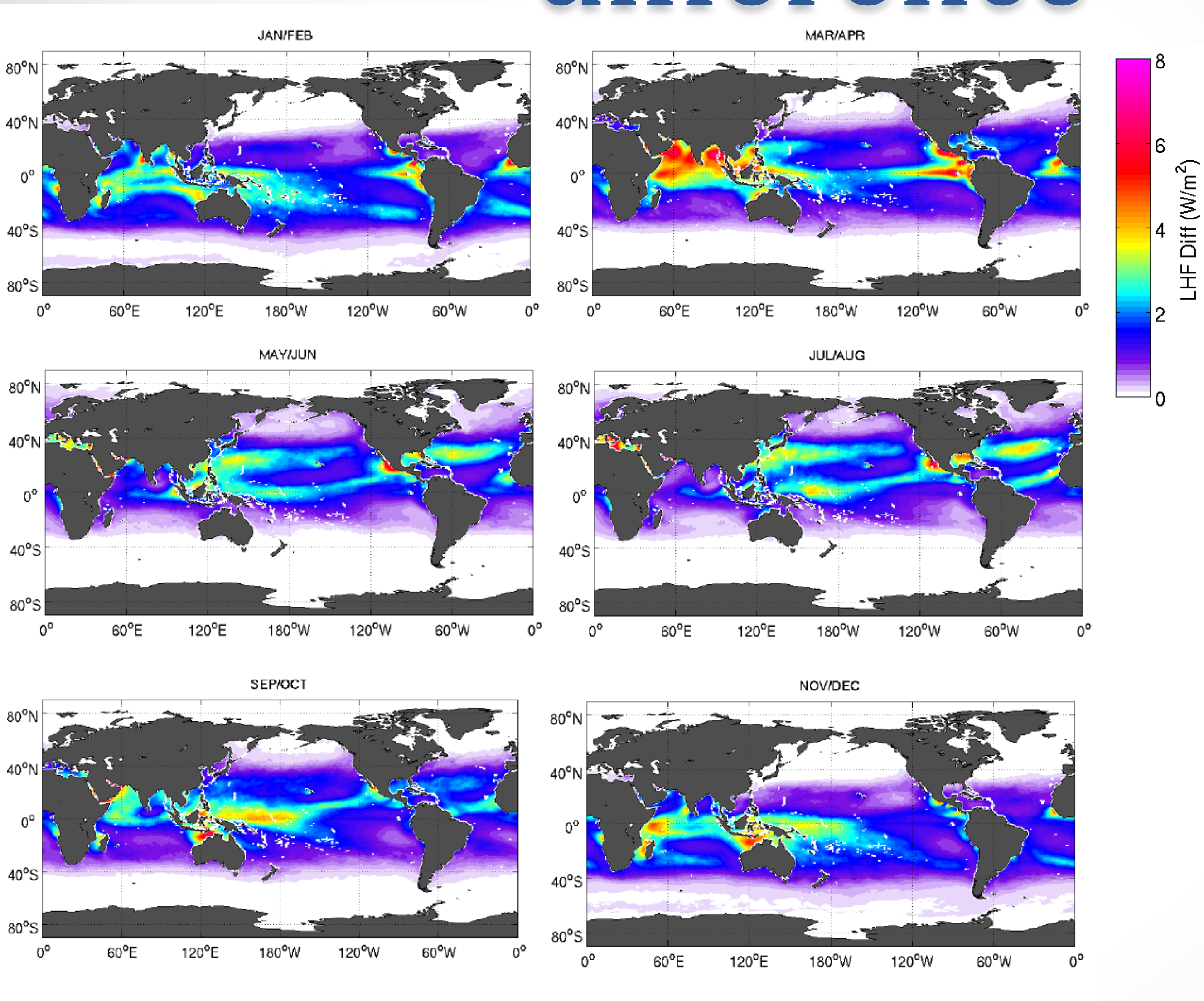


Bimonthly average dSST



- Mountain Barriers
- Mediterranean Sea
- Azores High

Bimonthly average LHF difference

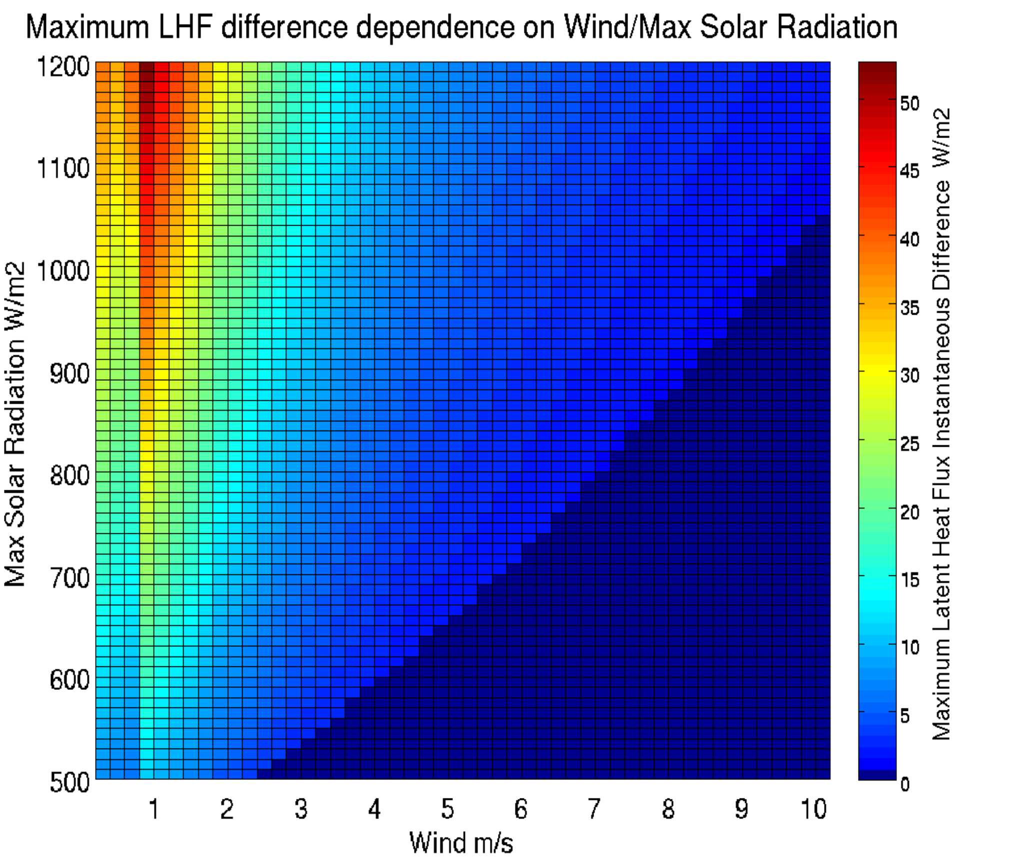


- Latent heat flux accounts for **2/3 of the total net flux***^.
- Heating released to the atmosphere of this magnitude is **considered non-negligible** in terms of response*.
- Supports theory that **diurnal warming can affect convection** in the tropics.

[**Kawai and Wada*, 2007; ^*Bellenger and Duvel*, 2009]

Flux Pt Sensitivity to Wind/SWR ranges

- Flux value at dSST maximum
  - LHF differences expected to increase at dSST increases
  - At wind speed < 0.8 m/s, LHF difference change slows as winds decrease
    - Balance between humidity and wind.
    - Humidity change is less influential to LHF than wind speed.
- Possible consequence largest dSSTs may not correspond to largest LHF deficit.



Max dSST sensitivity to Wind/Precip Ranges

- Similar sensitivity study as Wind/Solar Radiation
  - Precipitation total 0.0 – 30 mm/hr
  - SWR peak is set at 500 W/m² and 700 W/m² for cloudy, rainy conditions