Ocean diurnal variability and coupled surface winds using WRF

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1. Background

- In low surface wind speed environments, diurnal heating of the upper ocean develops as a result of low mechanical mixing in areas where solar radiation absorption is high.
- Diurnal variability of sea surface temperatures increases heat transfer from the ocean to the atmosphere, is rapidly being recognized as a vital component in driving local fluxes and atmospheric circulations in numerical weather prediction (e.g. Noh et al., 2011)
- In specific cases, the SST heating resembles a "diurnal sea surface temperature gradient" (see Fig. 1), where heating appears as thin streaks up to 1500 km long with SST gradients typically less than 1°C/100 km over the course of a few hours (e.g. Stuart-Menteth et al., 2003).

2. Objectives and Methods

- Explore the representation of SST diurnal variability using built-in skin temperature model from Zheng and Beljaars (2005) in the Weather Research and Forecasting Model (WRF)
- Develop empirical model for diurnal SST variability based on high quality satellite SST observations from SEVIRI, shortwave radiation from reanalysis, and calculated wind stress.

Diurnal heating magnitude streak on 2009 07 21

Diurnal warming magnitude (dSST) (deg C)
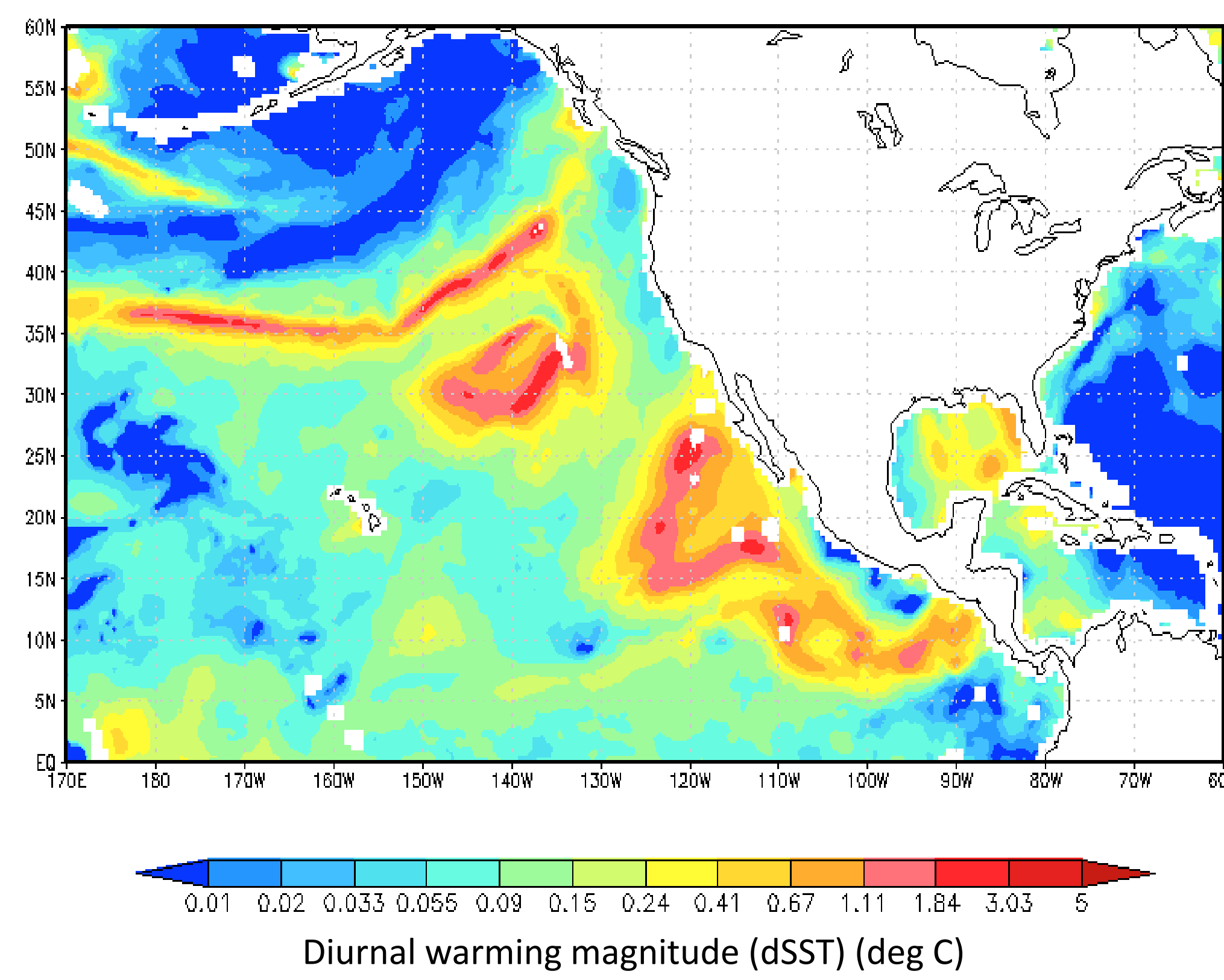0.01 0.02 0.033 0.055 0.09 0.15 0.24 0.41 0.67 1.11 1.84 3.03 5

Figure 1. Diurnal warming magnitudes computed on 21 July, 2009. The diurnal warming magnitude is computed as the temperature difference from Reynolds OI AVHRR-only daily average SST (Reynolds et al., 2007) and the computed skin SST computed POSH model (Gentemann et al., 2009). For more information, see Weihs and Bourassa, 2014 (Accepted to JGR-Oceans)

- We would like to quantify relationships between wind stress, air temperature, boundary layer dynamics, and diurnal SST gradients.

3. WRF Simulations

Specs	Values
Resolution	0.25 deg, hourly simulation
Time Frame	15 July 2009 – 21 July 2009 (7 day simulation)
Input	GFS Final Operational Global Analysis (GRIB1) (1x1 deg, 6hrly)
Domain	North Atlantic Ocean (66°W – 32°W, 20°N – 40°N)

Figure 3. Diurnal amplitudes computed in POSH (left) and WRF with Zheng and Beljaars (2005) model (right). Times are not consistent as POSH peaks earlier than observations.
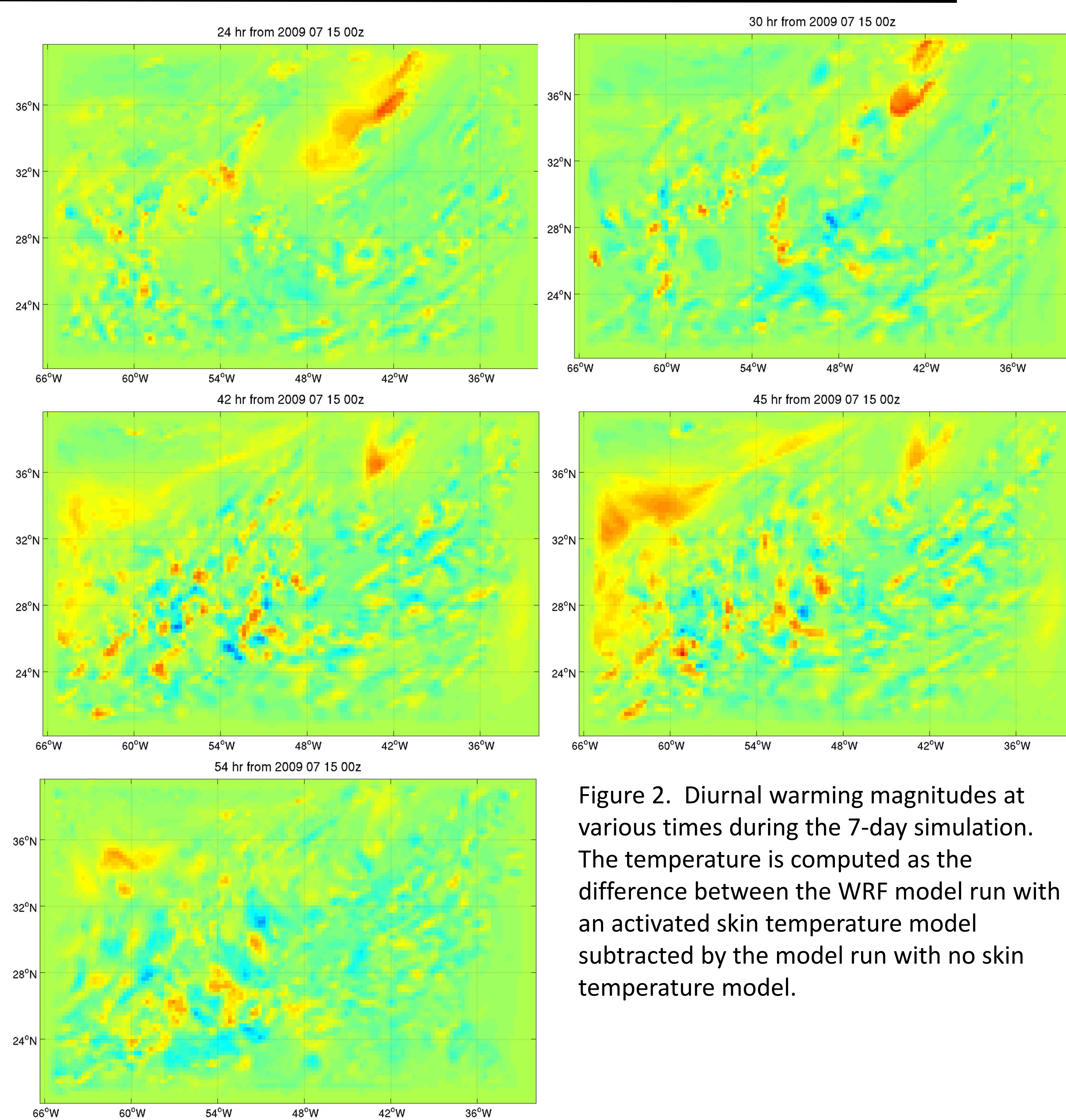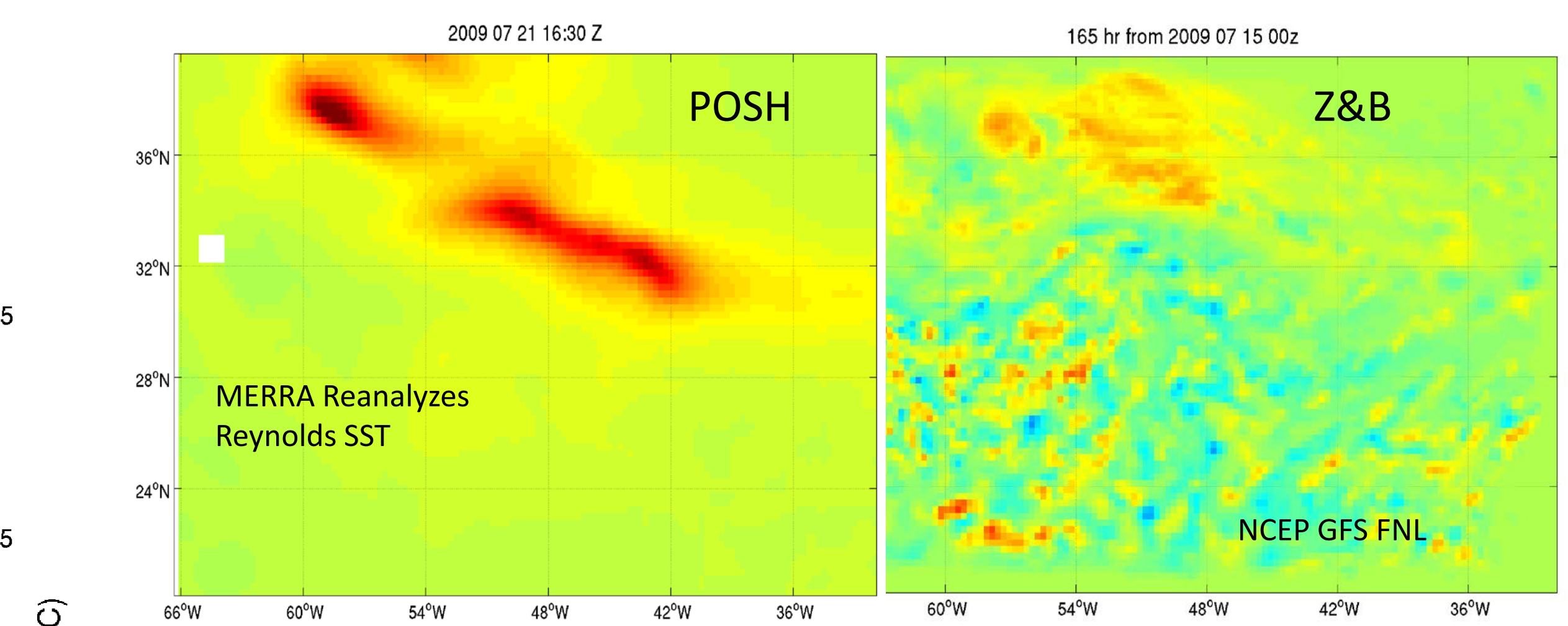

Figure 2. Diurnal warming magnitudes at various times during the 7-day simulation. The temperature is computed as the difference between the WRF model run with an activated skin temperature model subtracted by the model run with no skin temperature model.
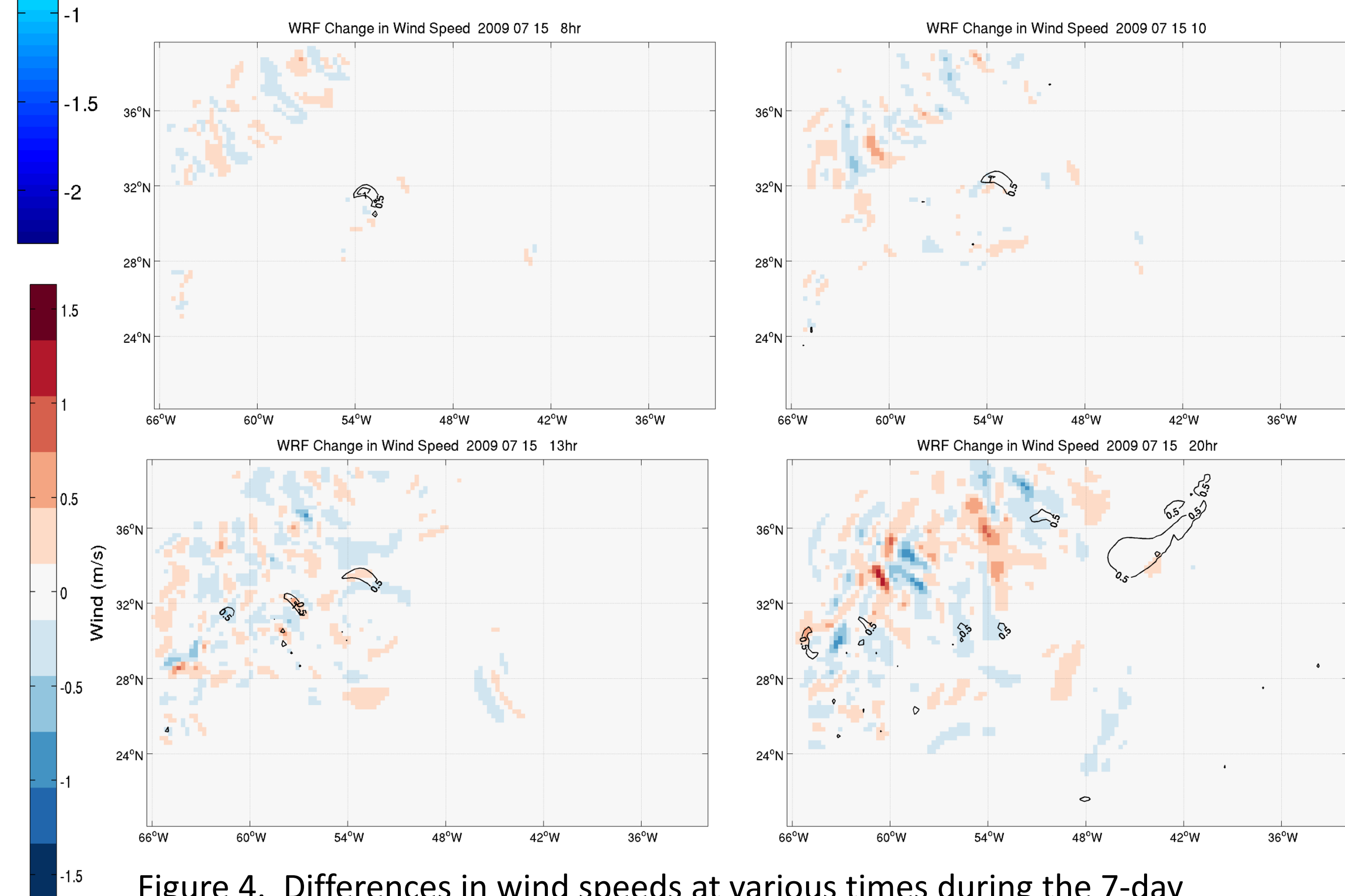

Figure 4. Differences in wind speeds at various times during the 7-day simulation. The difference is computed as the difference between the WRF model run winds with an activated skin temperature model subtracted by the model run winds with no skin temperature model.

Diurnal SST Findings:
- Evidence of diurnal cycle (pulses in SST)
- Some cases no reset in warm layer
- Noise in model result of winds or spatial resolution or SST sloshing

Wind difference findings:
- Gravity wave emanating from first diurnal SST signal
- As diurnal SST field becomes noisier, so do wind differences
- Hard to distinguish between noise and consistent patterns in wind/SST gradient changes

4. New Skin SST model

- Combine SSTs, accumulated wind stress, and shortwave radiation for new empirical model
  - Based on SEVIRI SSTs (EUMETSAT Ocean and Sea Ice Satellite Application Facility experimental SST product from IFREMER)
  - Wind stress via bulk flux algorithm (Bourassa, 2006)
  - Bulk variables taken from NASA's MERRA dataset
  - Will be incorporated into WRF as new skin SST model

    dSST = a1*swr + a2*accum_tau + a3 (linear model)
    Build each coefficient as a function of time (figure 5) and fitted to non-linear function (tau = power function, swr = fourier, yint = sum of sines)
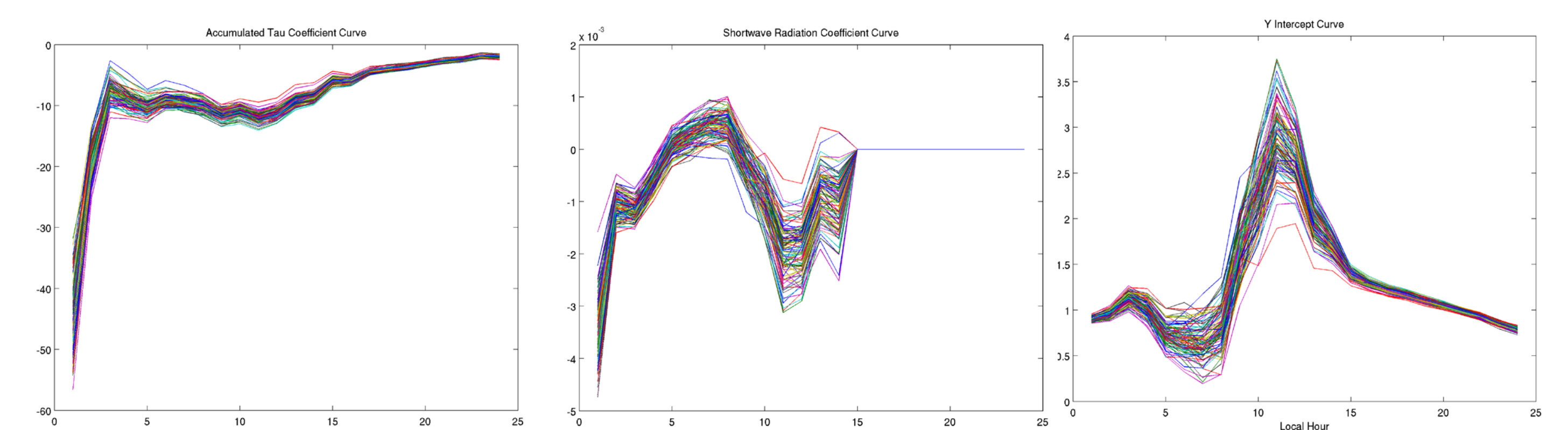

Figure 5. Coefficients of linear relationships of accumulated wind stress (left), shortwave radiation (center), and constant term (right) to SEVIRI diurnal warming magnitude as a function of local time. The diurnal warming magnitude is computed as the difference between a local minimum occurring before dawn and the current SST observation. Each plot contains 99 lines which represent the coefficients derived from 1000 sample time series in July, 2009.

5. Conclusions

- WRF simulations using Zheng and Beljaars model exhibit *some* diurnal variability SSTs; gravity waves generated in winds
- Need to reduce noise in simulations to get clearer result
- New empirical model will be used to simulate skin temperature

References:
Bourassa, M. A. (2006), Satellite-based observations of surface turbulent stress during severe weather, in *Atmosphere-Ocean interactions*, vol. 2, *Adv. Fluid Mech. Ser.*, vol. 39, edited by W. Perrie, pp. 35-52, Wessex Inst. of Technol., Southampton, UK.
Noh, Y., E. Lee, D.-H. Kim, S.-Y. Hong, M.-J. Kim, and M.-L. Ou (2011), Prediction of the diurnal warming of sea surface temperature using an atmosphere-ocean mixed layer coupled model, J. Geophys. Res., 116, C11023, doi:10.1029/2011JC006970.
Stuart-Menteth, A. C., I. S. Robinson, and P. G. Challenor (2003), A global study of diurnal warming using satellite-derived sea surface temperature, J. Geophys. Res., 108, 3155, doi:10.1029/2002JC001534.
Zeng, X. & Beljaars, A. (2005), A prognostic scheme of sea surface skin temperature for modeling and data assimilation. , J. Geophys. Res., 32, L14605, doi:10.1029/2005GL023030.