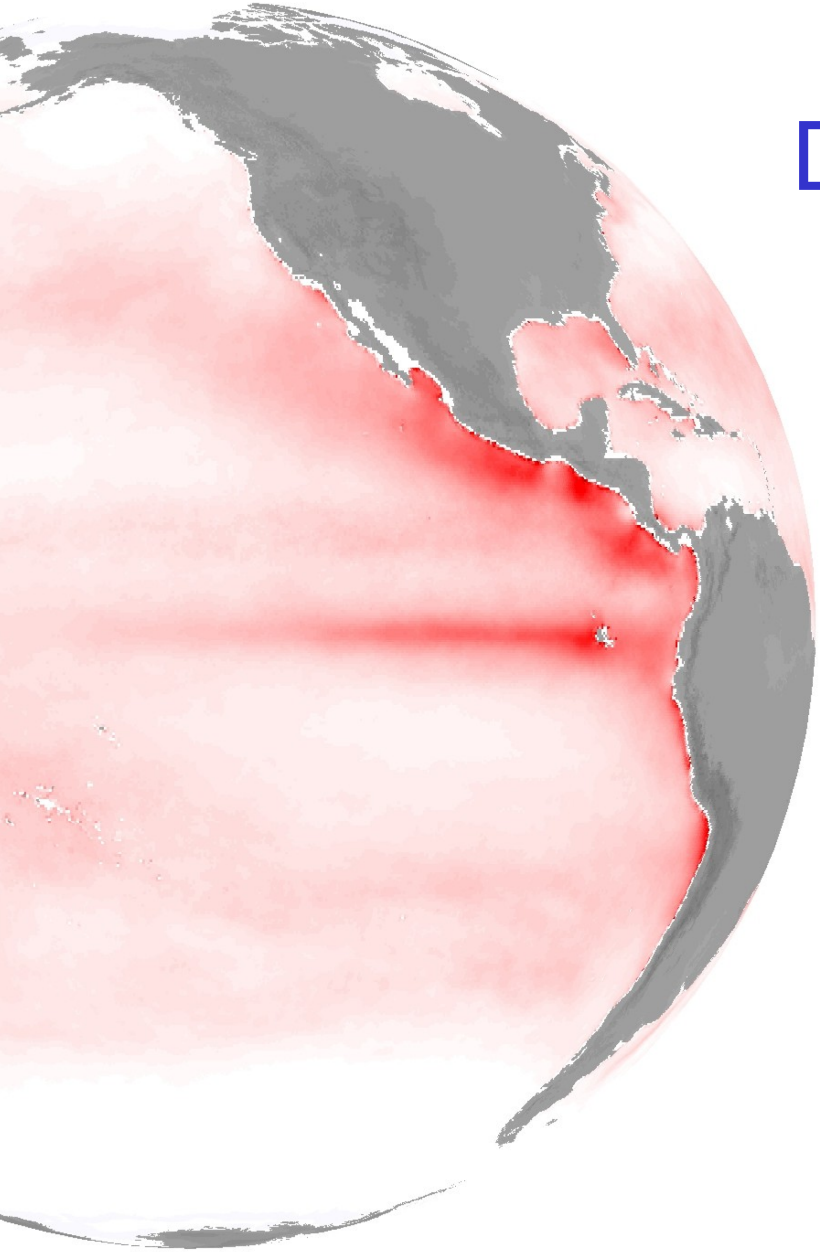

Diurnal variability in the upper ocean

Chelle L. Gentemann
Peter J. Minnett

Satellite measurement
Radiometric measurements
Models
Global distribution
Air-sea interactions
Conclusions

RSMAS

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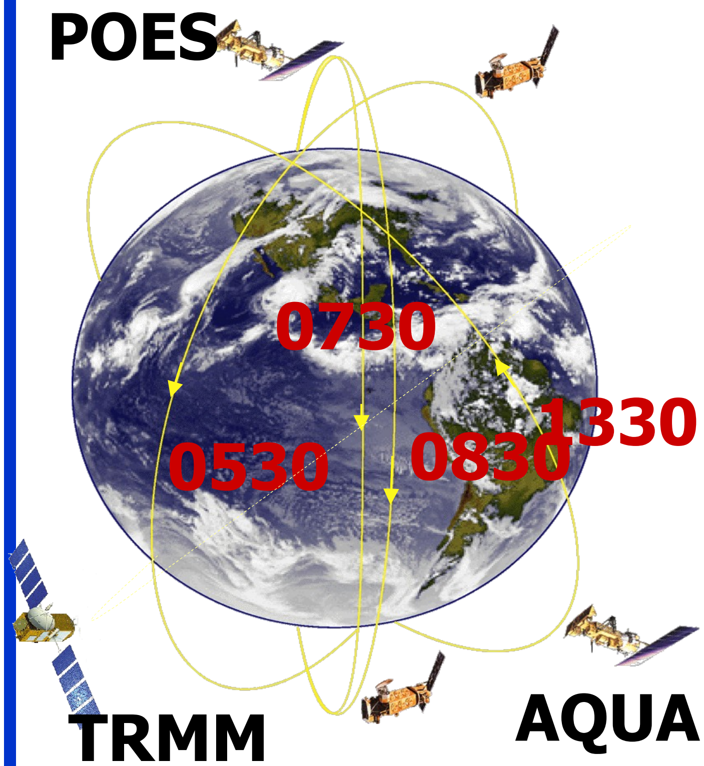
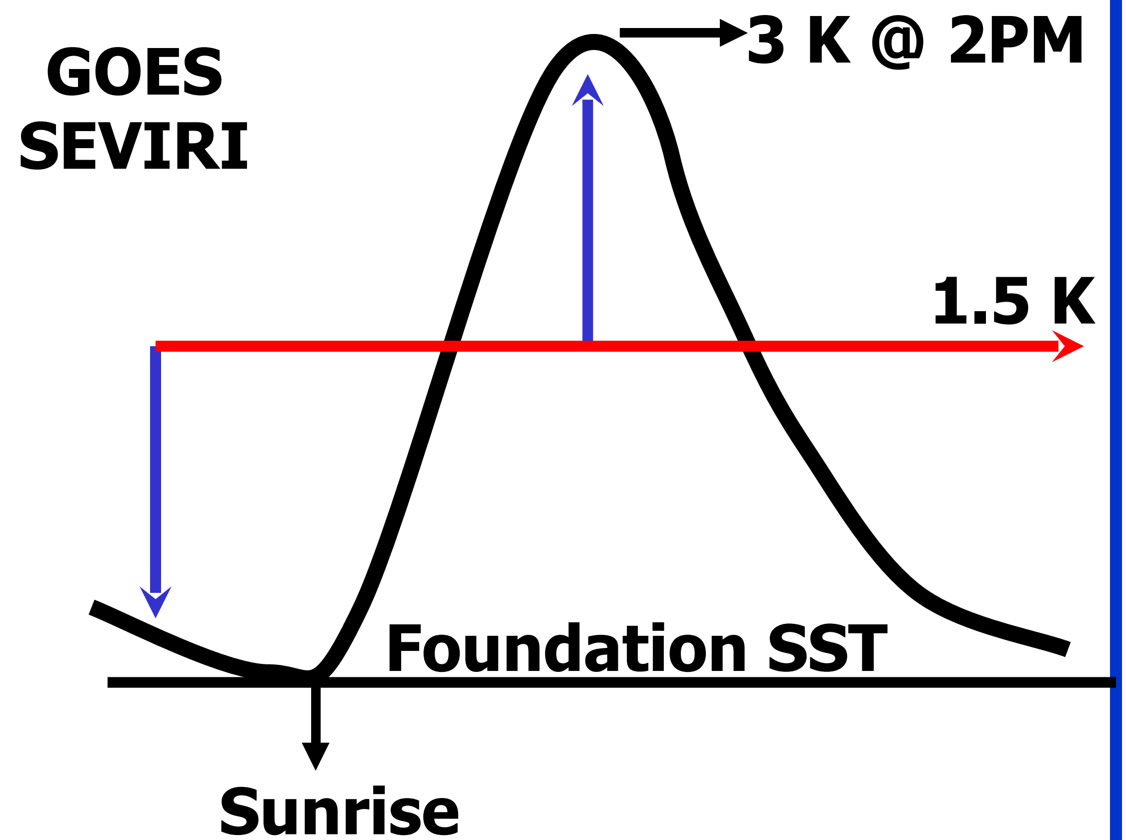
What is a daily SST?





Diurnal warming aliased onto SST time series (CLIMATE)

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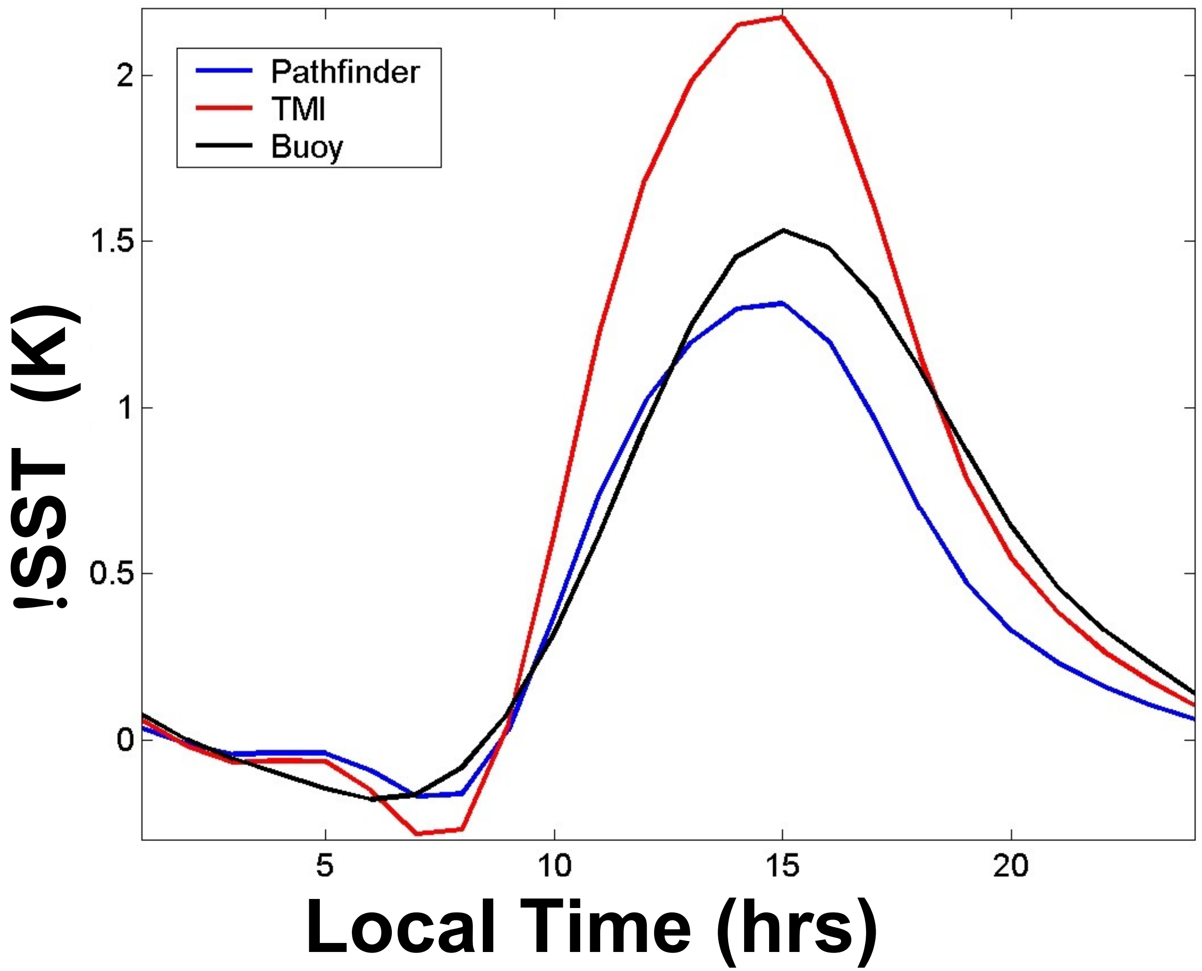
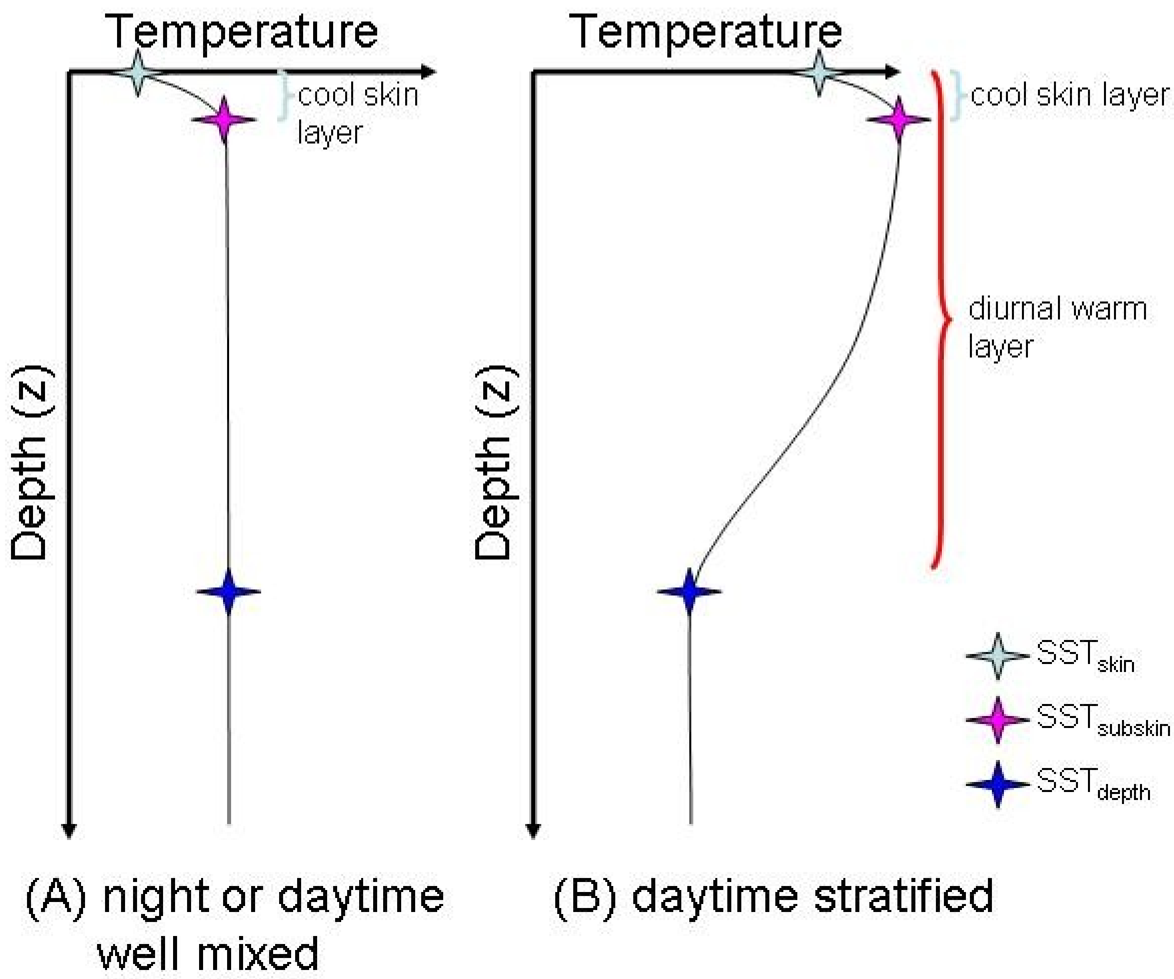


Upper Ocean Thermal Structure



Foundation SST

Summary of empirical models

Model	Inputs	Output	Max (K)	Min (K)
L91	$u\ C_f$	DW_{peak}	2.4	0.75
W96	$u_{av}\ Q_{max}\ P$	DW_{peak}	2.4	-0.30
KK02 skin	$u_{av}\ Q_{max}$	DW_{peak}	13.5	0.0
KK02 bulk	$u_{av}\ Q_{max}$	DW_{peak}	2.8	0.0
CG03	$U_{inst}\ Q_{av}$	DW(t)	2.8	0.0
ASM sub-skin	$u_{0\text{-}6}\ u_{8\text{-}12}\ u_{12\text{-}15}\ u_{16\text{-}24}\ Q_{6\text{-}12}\ Q_{12\text{-}18}$	DW(t)	14.5	0.0
ASM bulk	$u_{0\text{-}6}\ u_{8\text{-}12}\ u_{12\text{-}15}\ u_{16\text{-}24}\ Q_{6\text{-}12}\ Q_{12\text{-}18}$	DW(t)	4.0	0.0

- Bulk – no vertical structure, fast
- Turb. Models – vertical structure, slow

Measurements at the ocean surface

- Few measurements of diurnal warming at the air-sea interface exist
- Most research / model development use in situ observations at depth or extrapolated from 0.5m or 1.0 m to the ocean surface
- Extrapolation done using bulk (PWP, Fairall, Kraus-Turner, or turbulence closure models (Mellor,Yamada / Kantha/Clayson)

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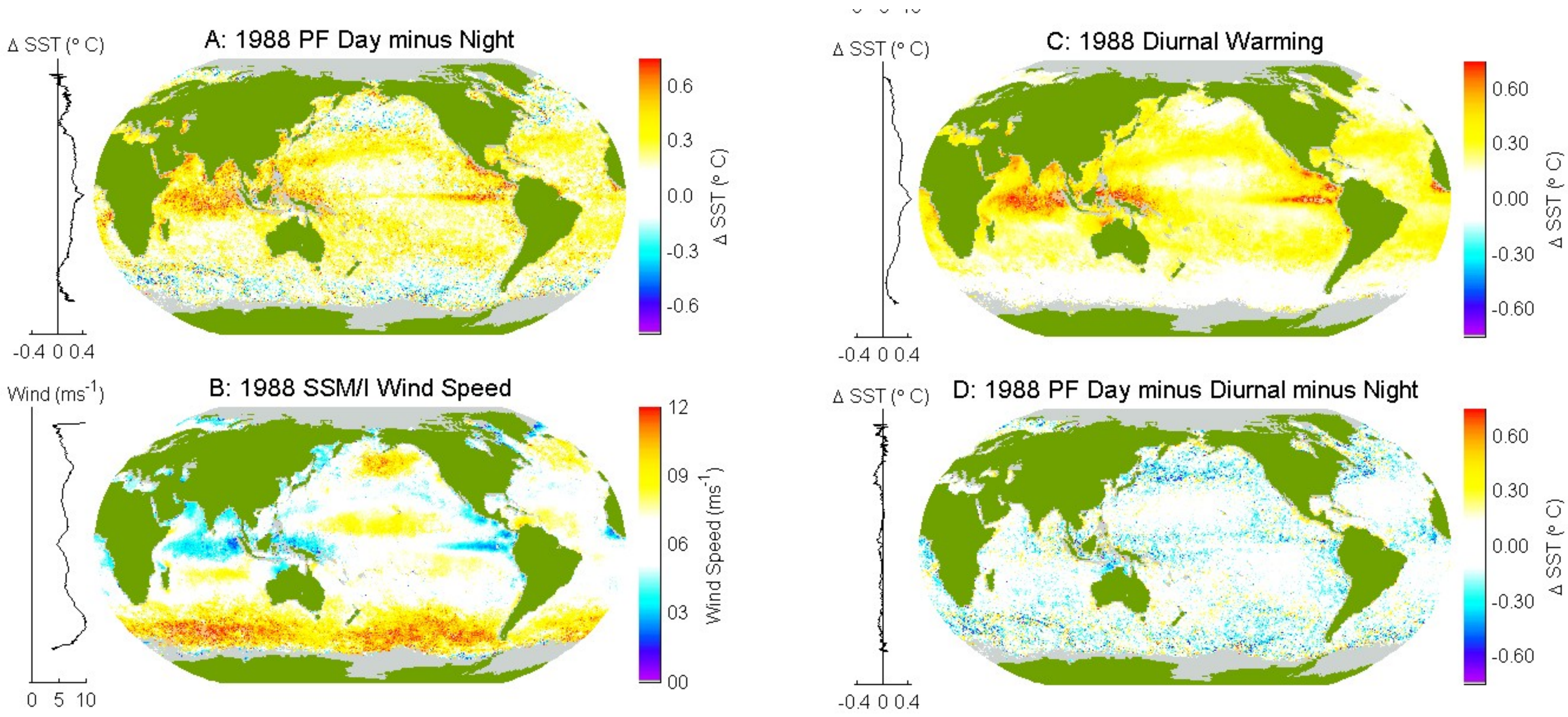
AVHRR diurnal warming



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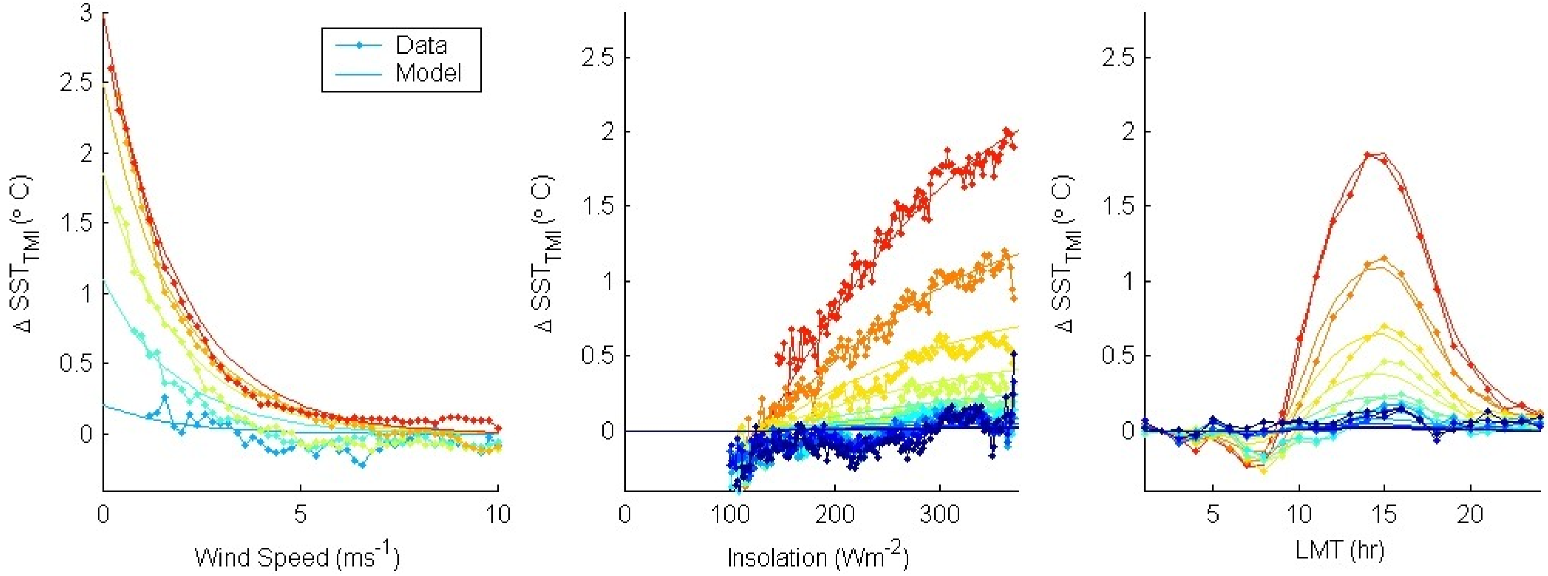
CG

$$\Delta SST_{tmi}(t,Q,u) = f_1(t)[(Q - Q_o^t) - 9.632\times 10^{-4}(Q - Q_o^t)^2]e^{-0.44u}$$

Q = insolation ; t = local time ; u = wind speed ; $f(t)$ = truncated Fourier Series

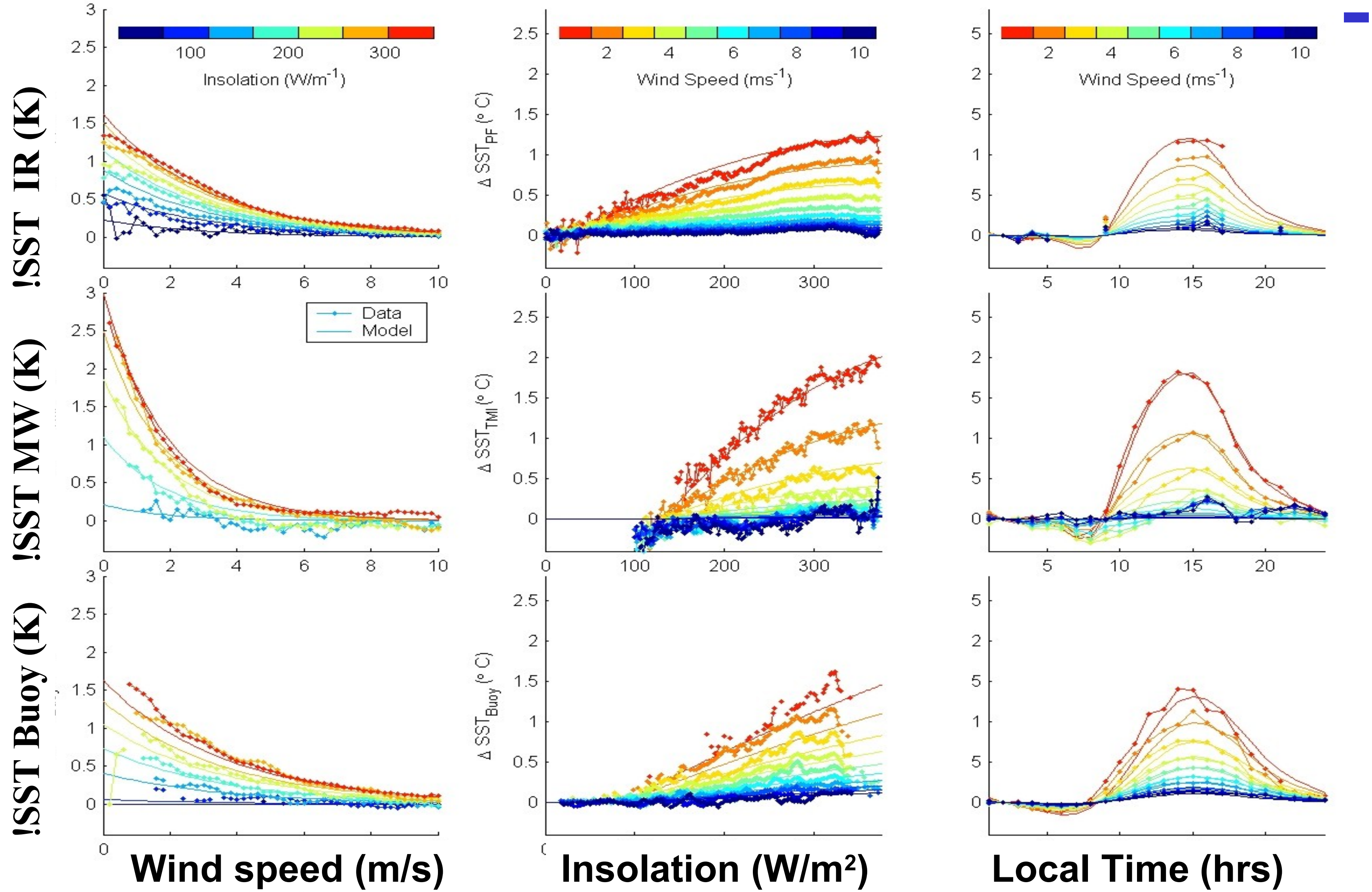
as wind increases, equation approaches 0

$Q < Q_0$, equation = 0



Gentemann, C. L., C. J. Donlon, et al. (2003). "Diurnal signals in satellite sea surface temperature measurements." Geophysical Research Letters 30(3): 1140.

TMI/PF Model and Data



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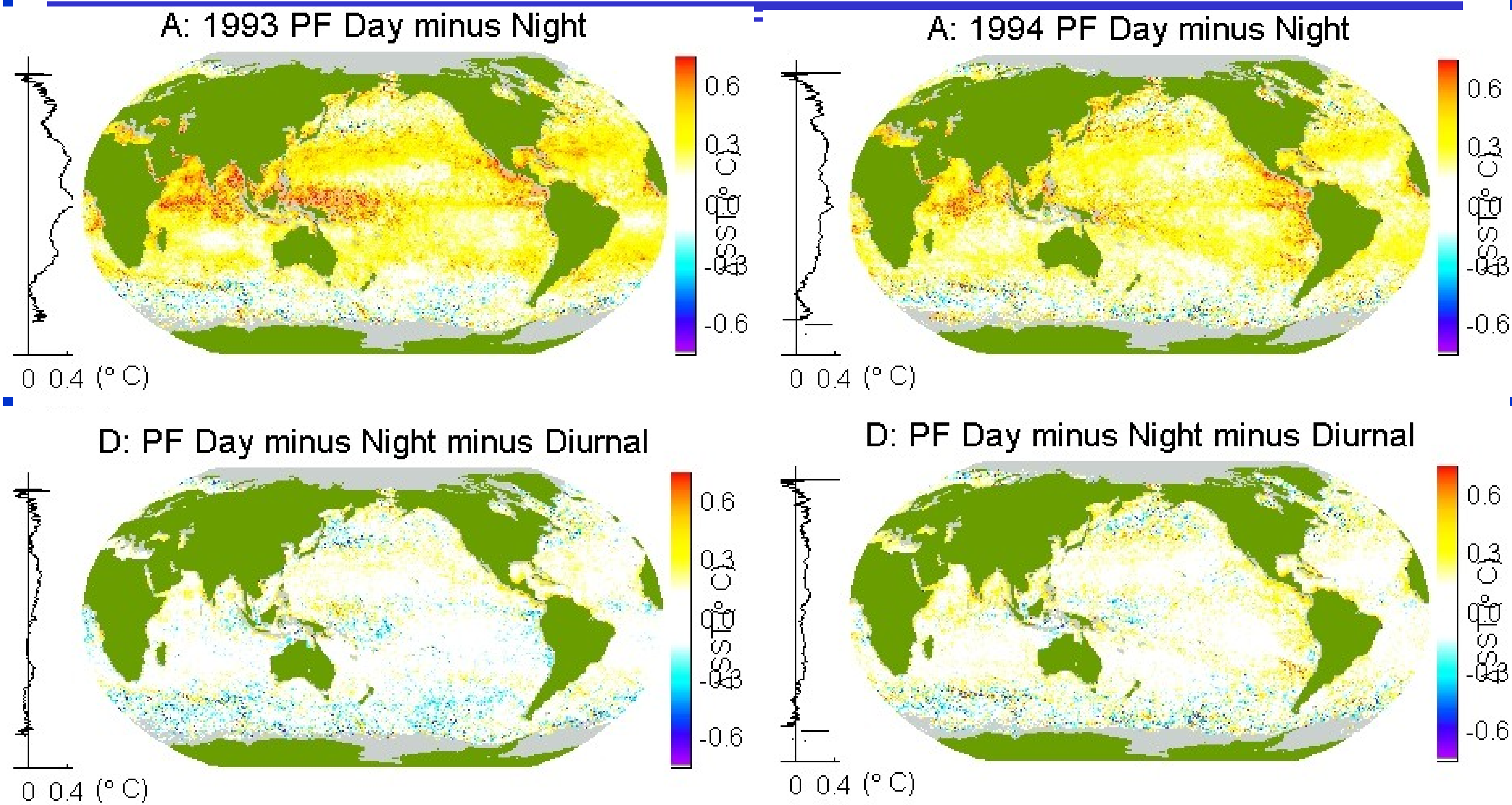
Global Correction



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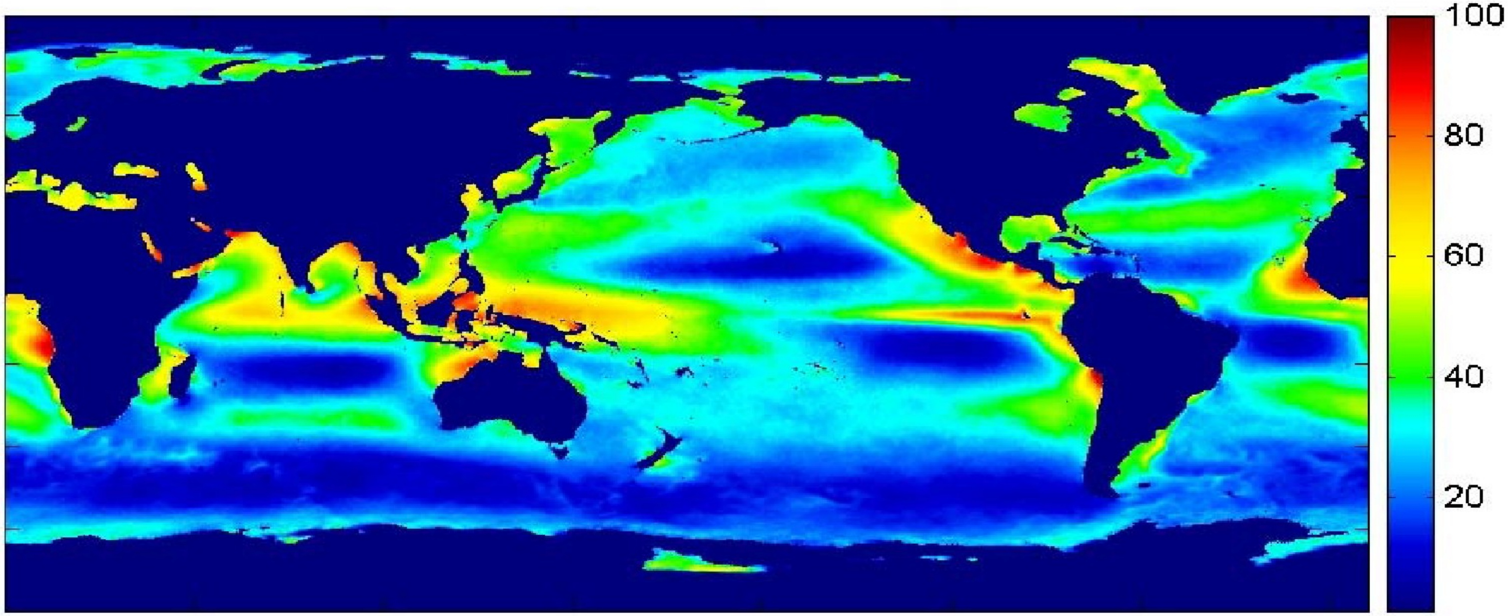
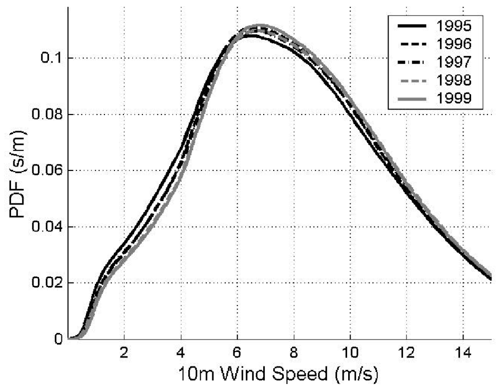
Low winds



SSM/I wind speeds 1995-1999 highlight regions where indirect validation should be targeted. Average wind speed is 8.3 m/s and 30% of winds are < 6 m/s. 3% of winds are less than 2 m/s.



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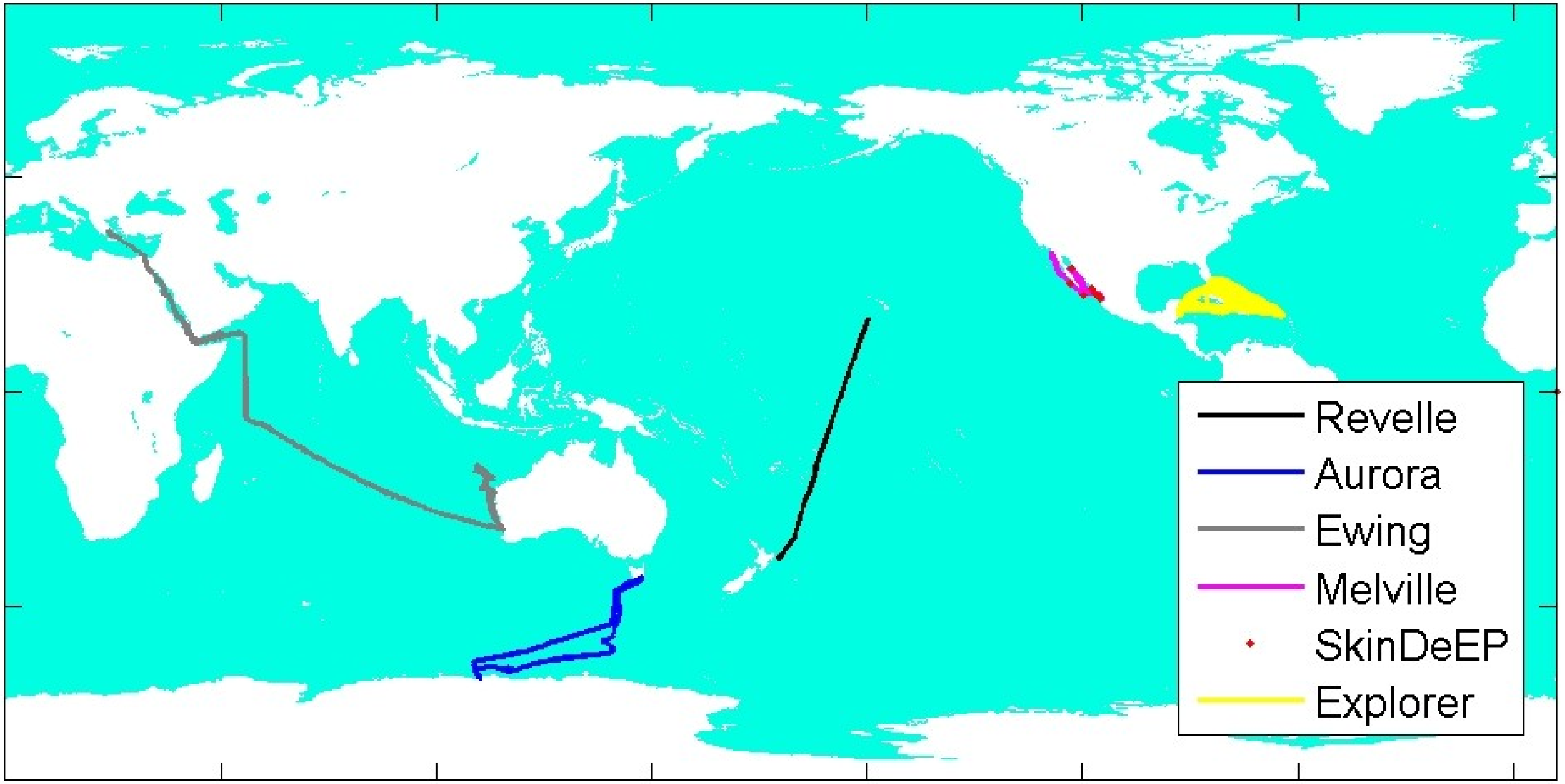
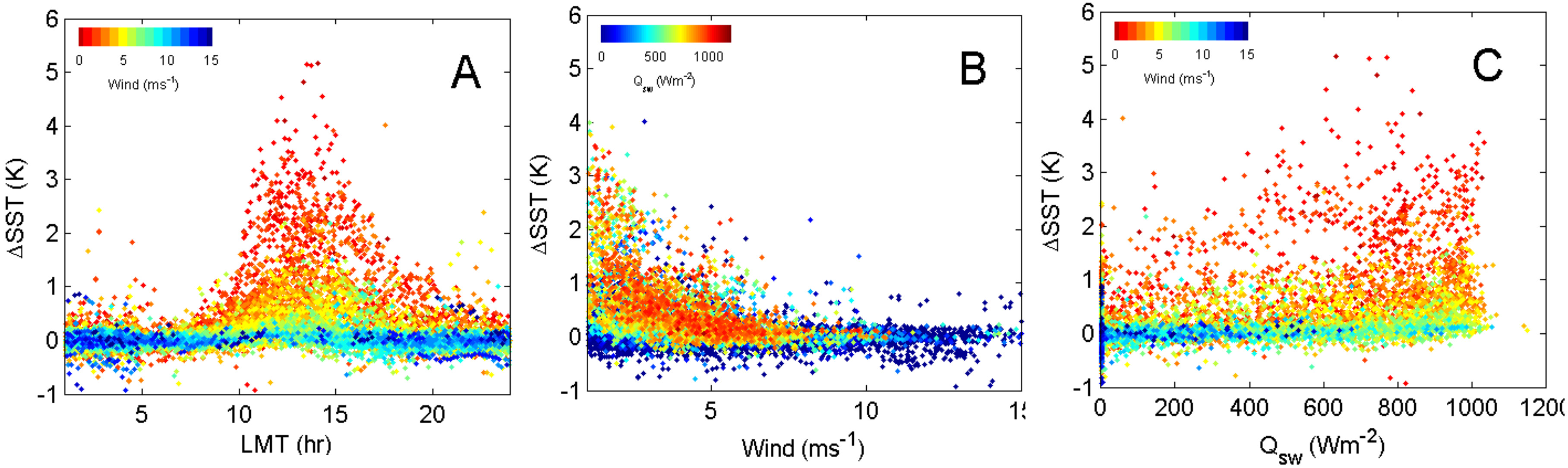
4 research cruises + Explorer



All M-AERI DW

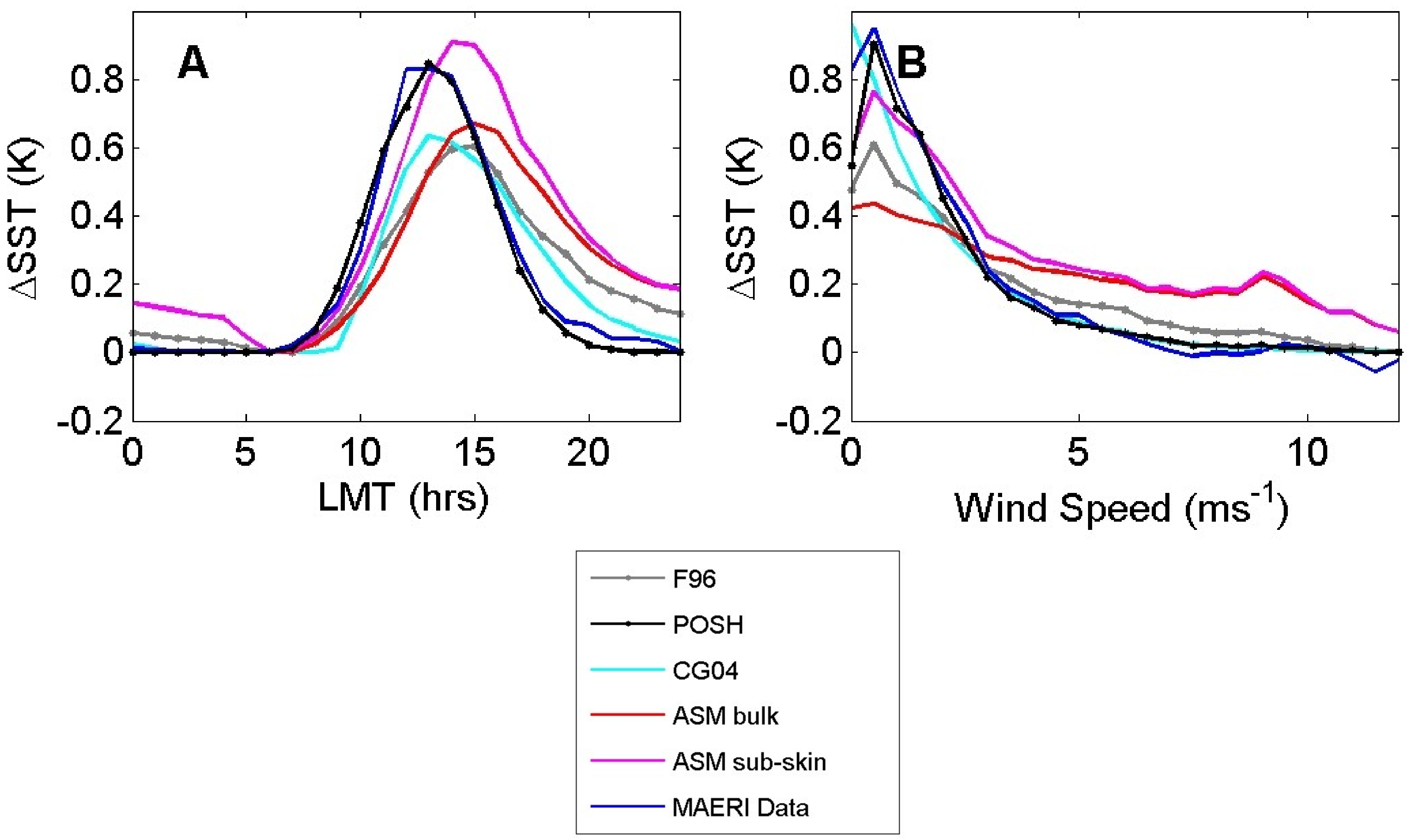


72 days with diurnal warming

All DW > 4 K from Melville cruise in Gulf of California

Peak warming not at peak insolation

Compare data & models



TOGA-COARE (F96)

$$T_w = \frac{2I_s}{\rho c_p D_T}$$

$$D_T = \sqrt{\frac{2R_i \rho c_p}{\alpha g}} \frac{I_\tau}{\sqrt{I_S}}$$

Static stability and mixed layer stability are enforced, but not shear layer instability

Once incoming (solar and LW) heat flux exceeds the outgoing heat flux (sensible, latent, LW radiation, the diurnal warm layer forms a separate layer within the mixed layer

Surface inputs of heat and momentum are confined within this layer.

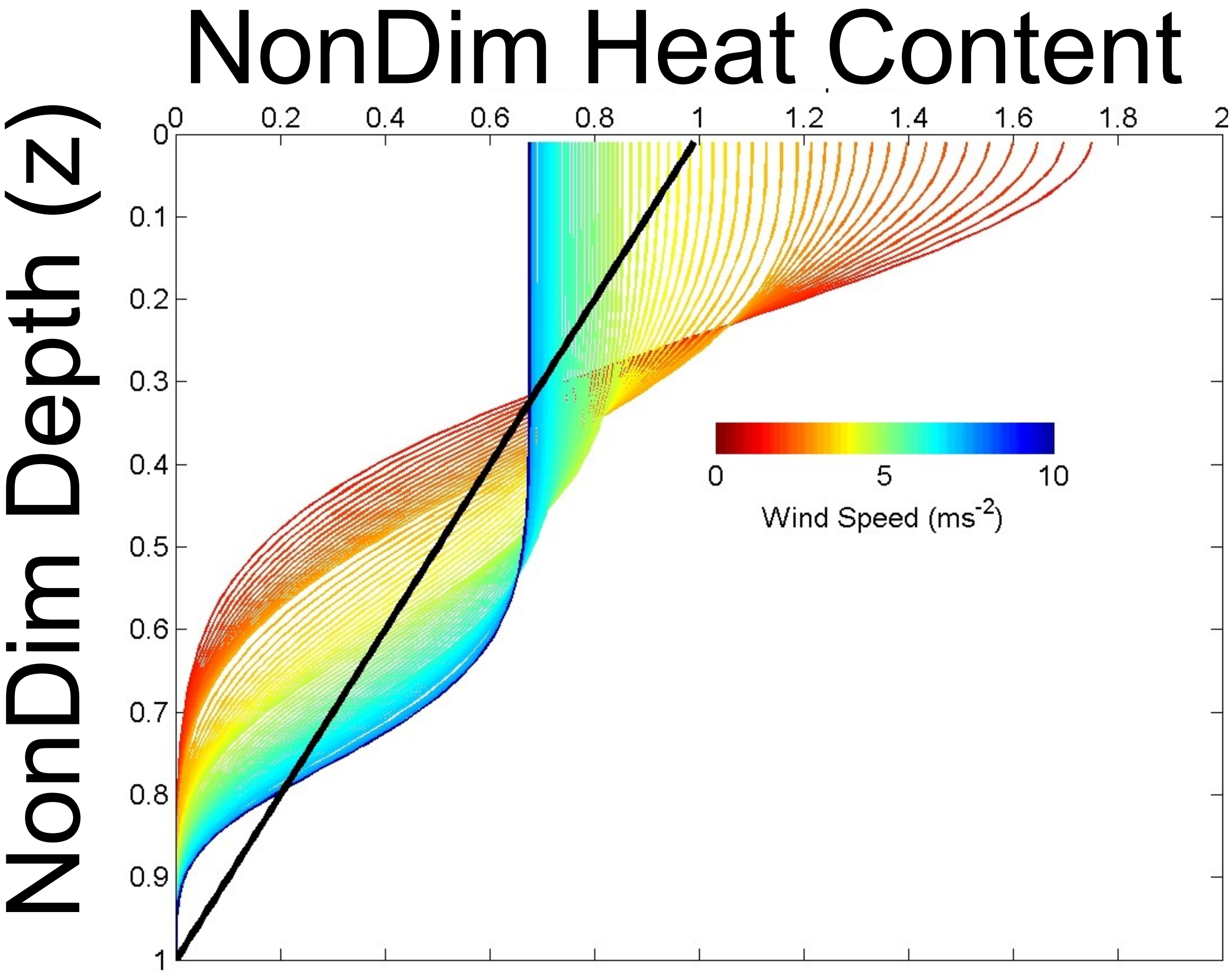
Using the 1D heat & equation of state you can determine the diurnal heating at the surface

Require the bulk Ri to be 0.65, to determine the depth of the warm layer

POSH

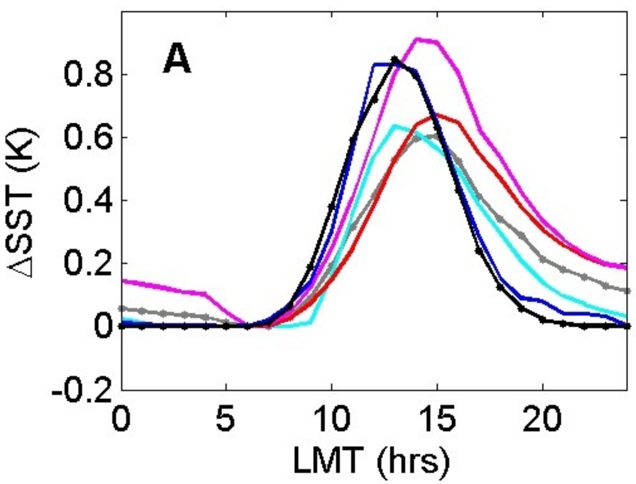
- Profiles of Surface Heating (POSH)
  - F96
  - Absorption
  - Dissipation of heat/momentum
  - **Structured profiles** of temperature within the warm layer (CG empirical or Kantha/Clayson (WICK) profiles)

Dimensionless DW profile

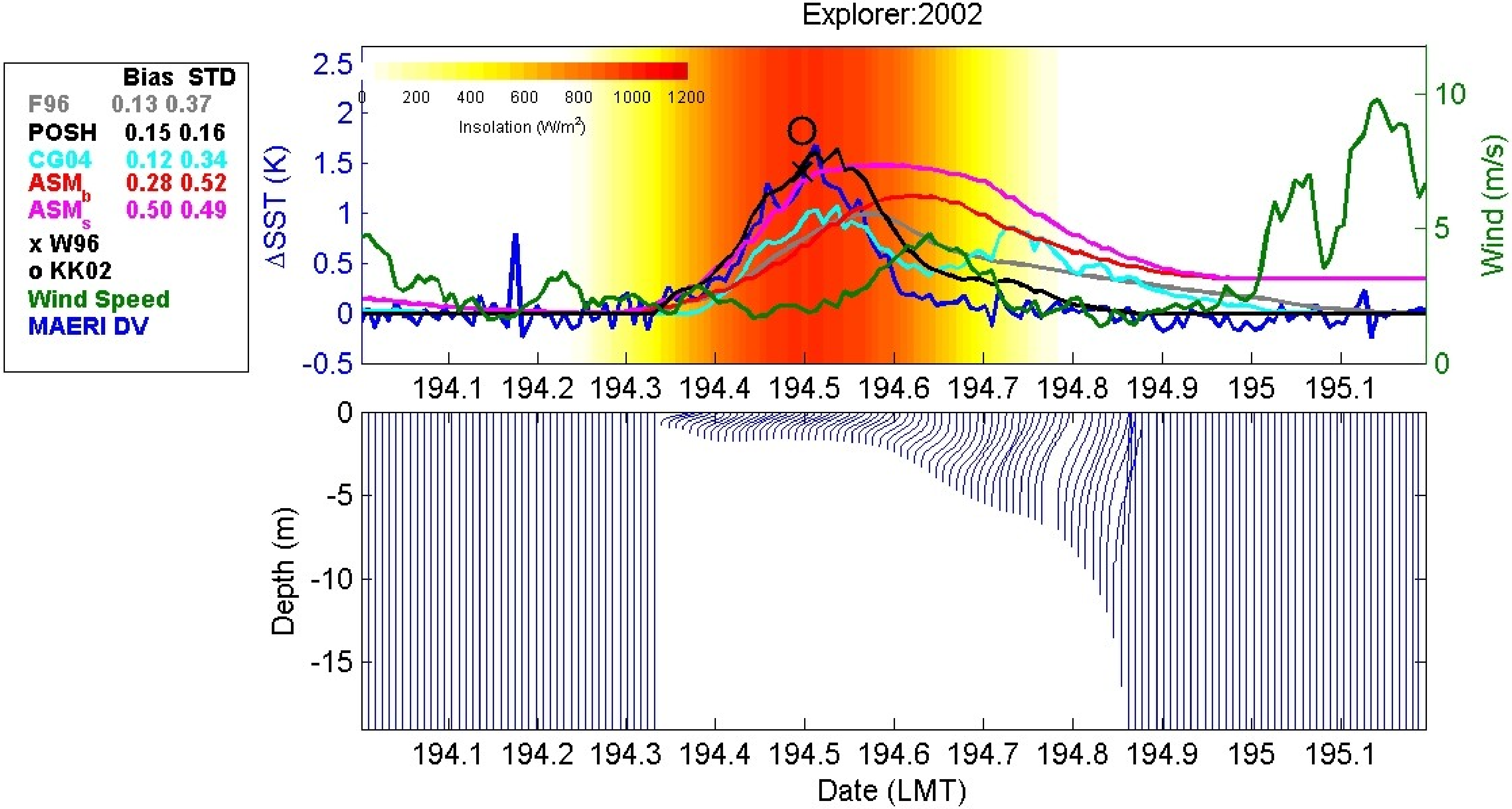


Comparison throughout the day

Comparison	Mean Bias (K)	STD (K)	Number Obs
F96-MAERI	-0.00	0.42	9680
POSH-MAERI	-0.07	0.36 ←	9680
CG04-MAERI	-0.04	0.37	9680
ASM bulk – MAERI	0.05	0.47	9680
ASM sub-skin – MAERI	0.13	0.44	9680

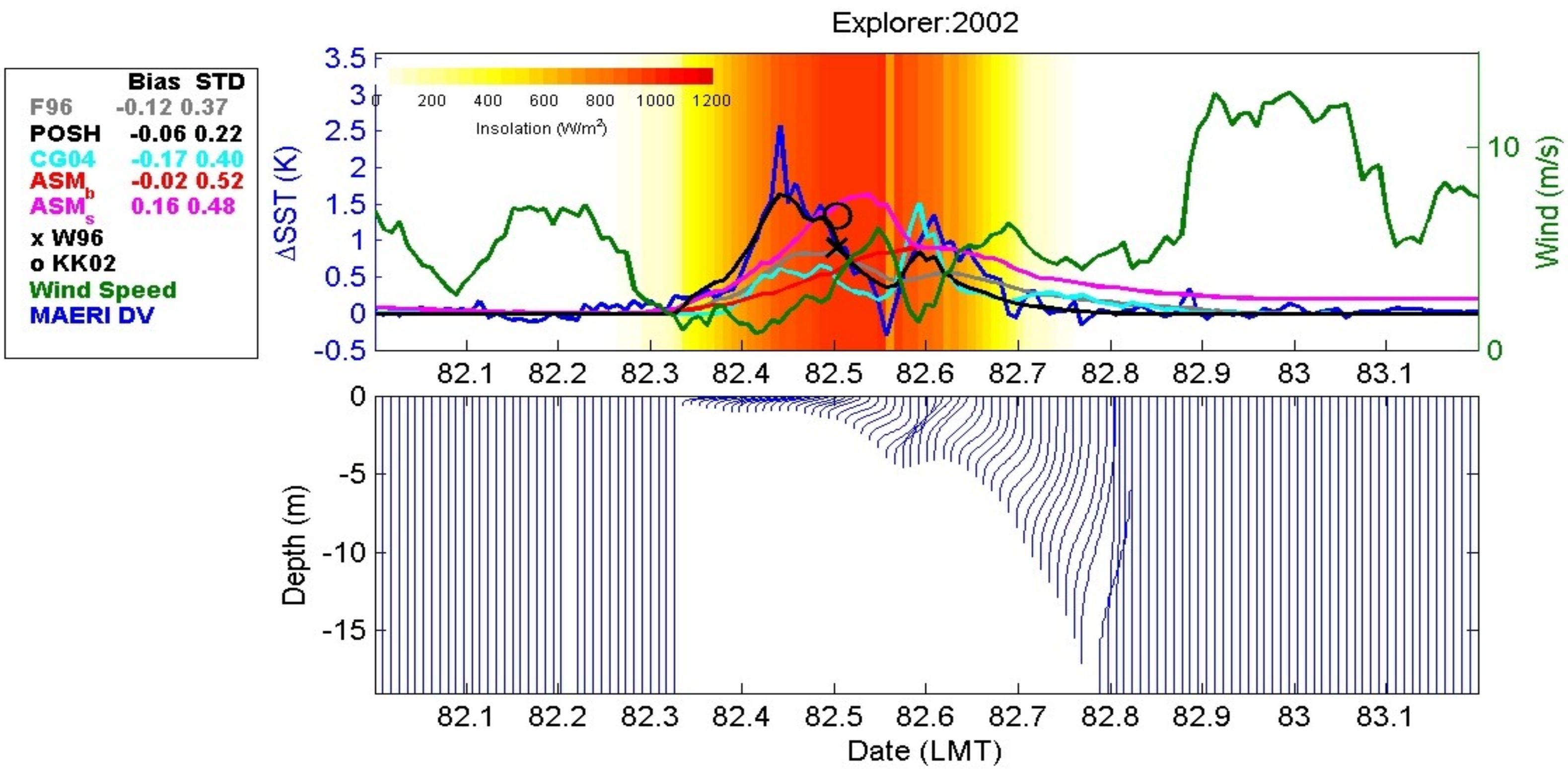


Peak at solar noon



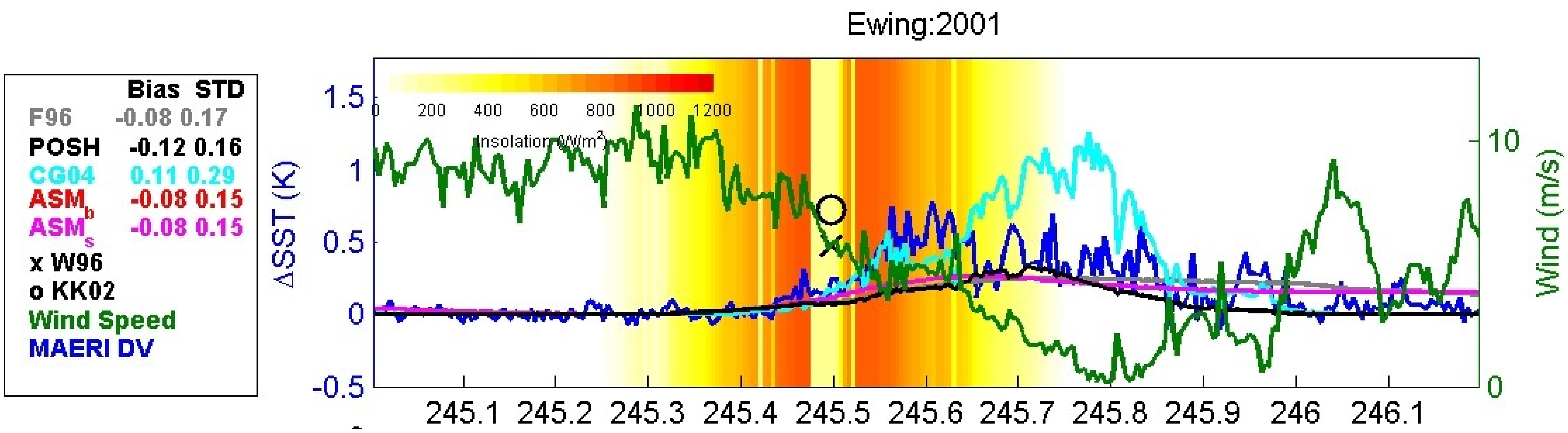
Conclusions

- The variability in warming and total daily heat available from the surface are not well represented by a single point such as the KK02 or K96 models



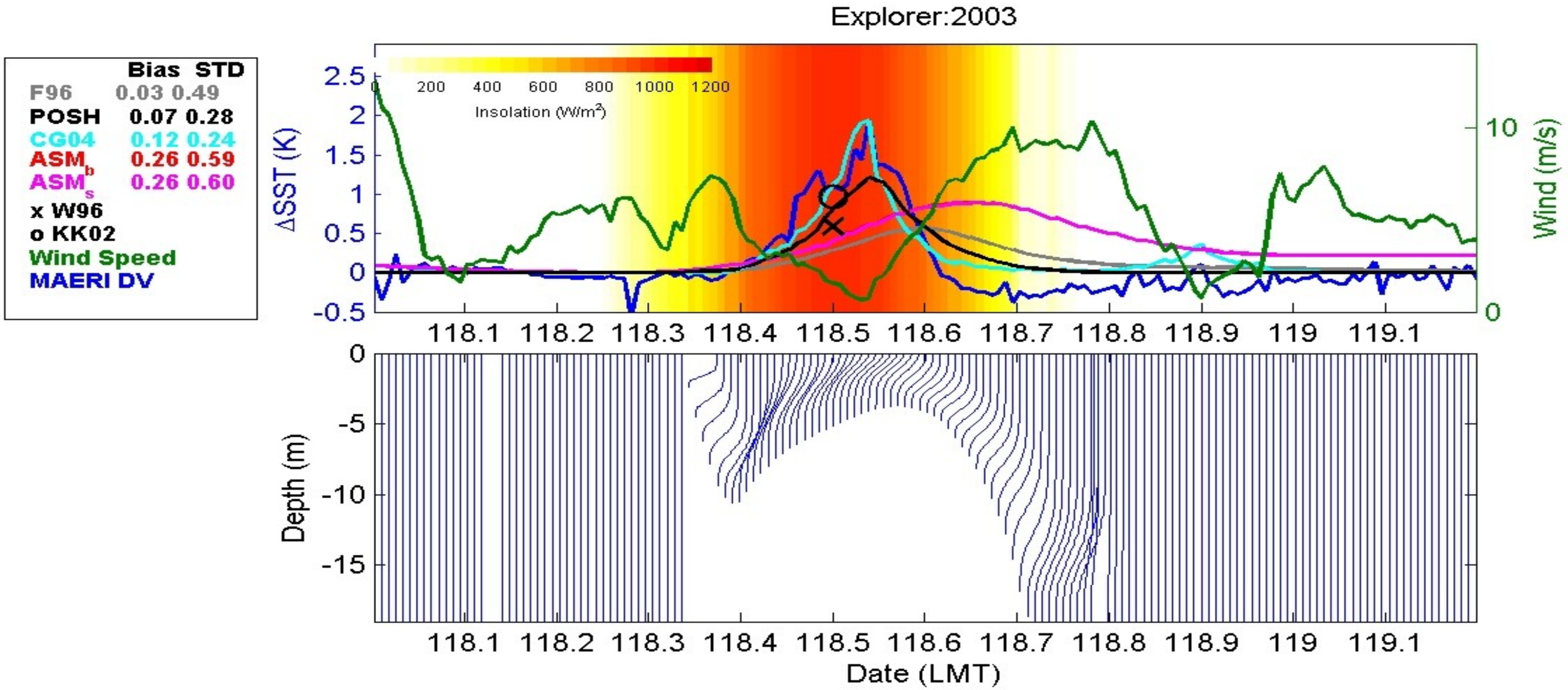
Conclusions

- CG04 model has largest errors in the late afternoon or evening when there is a sudden drop in wind speed. Diurnal warming is then over estimated by CG04 model



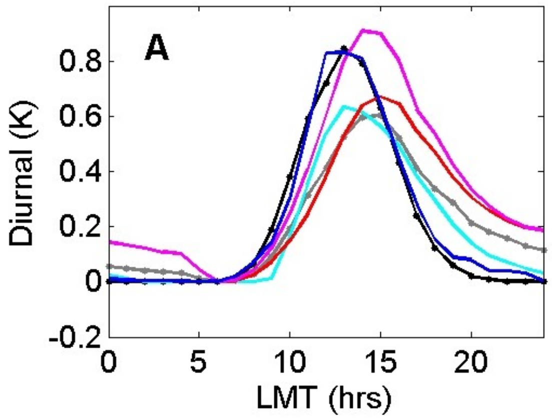
Conclusions

- F96 model is too small and tends to overestimate warming in afternoon (due to the accumulation of heat)
- POSH model responds rapidly to the onset of warming and decreases realistically in afternoon. Additionally model returns information on warming profile within the warm layer



Conclusions

Comparison	Mean Bias (K)	STD (K)	Number Obs
PWP-MAERI	-0.47	0.66	72
PWP3-MAERI	-0.32	0.55	72
CG03-MAERI	-0.34	0.61	72
ASM_bulk – MAERI	-0.51	0.77	72
ASM_skin – MAERI	-0.27	0.63	72
W96 – MAERI	-0.13	0.76	72
KK02 – MAERI	0.18	0.78	72



Comparisons at solar noon: models do not model variability well

Conclusions

- Accuracy of CG04 model indicates that it is useful, especially for for polar orbiters w/ 2AM/PM LECT while POSH more useful for geo-stationary satellites, understanding intra-day variability, and vertical structure.

Comparison	Mean Bias (K)	STD (K)	Number Obs
F96-MAERI	-0.00	0.42	9680
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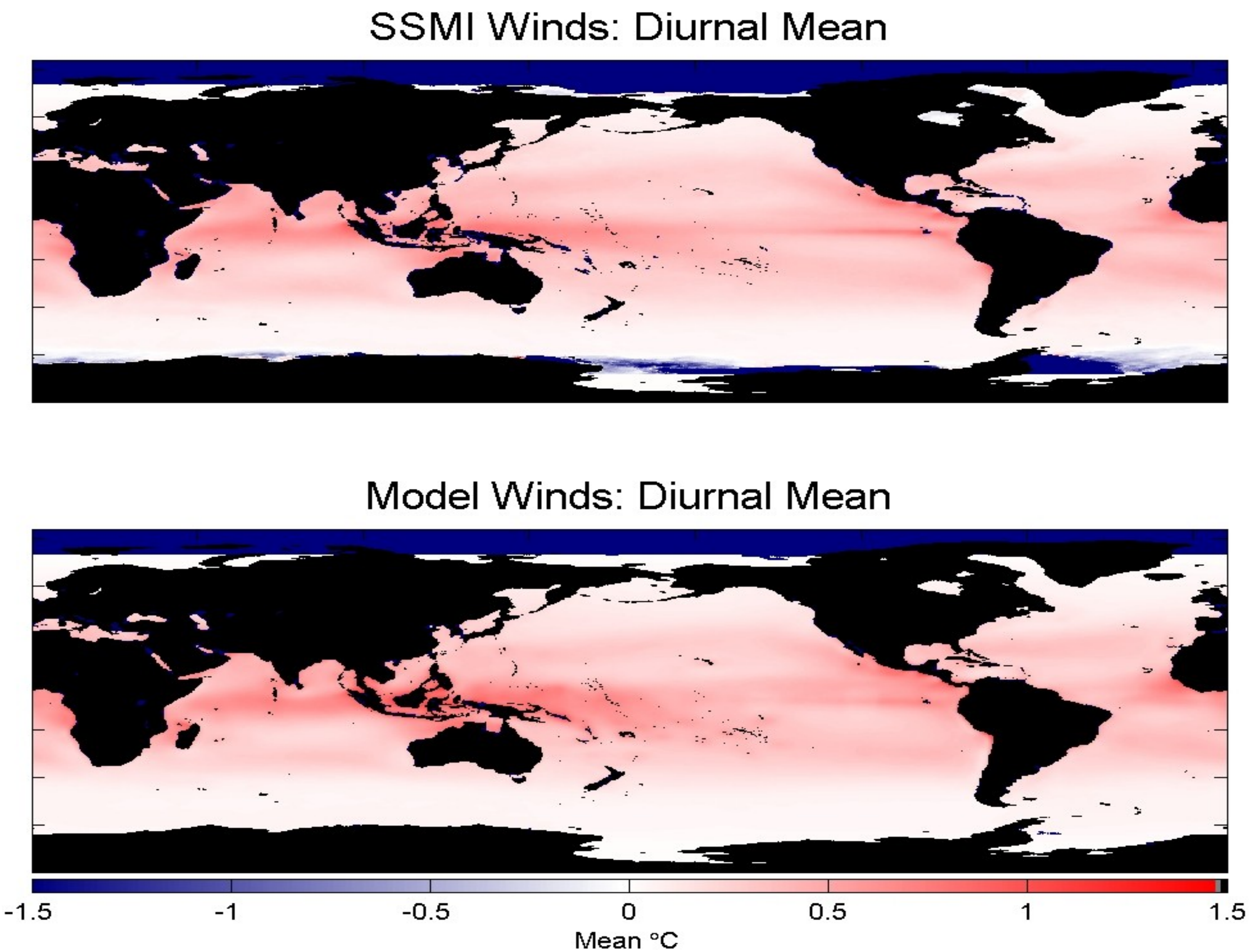
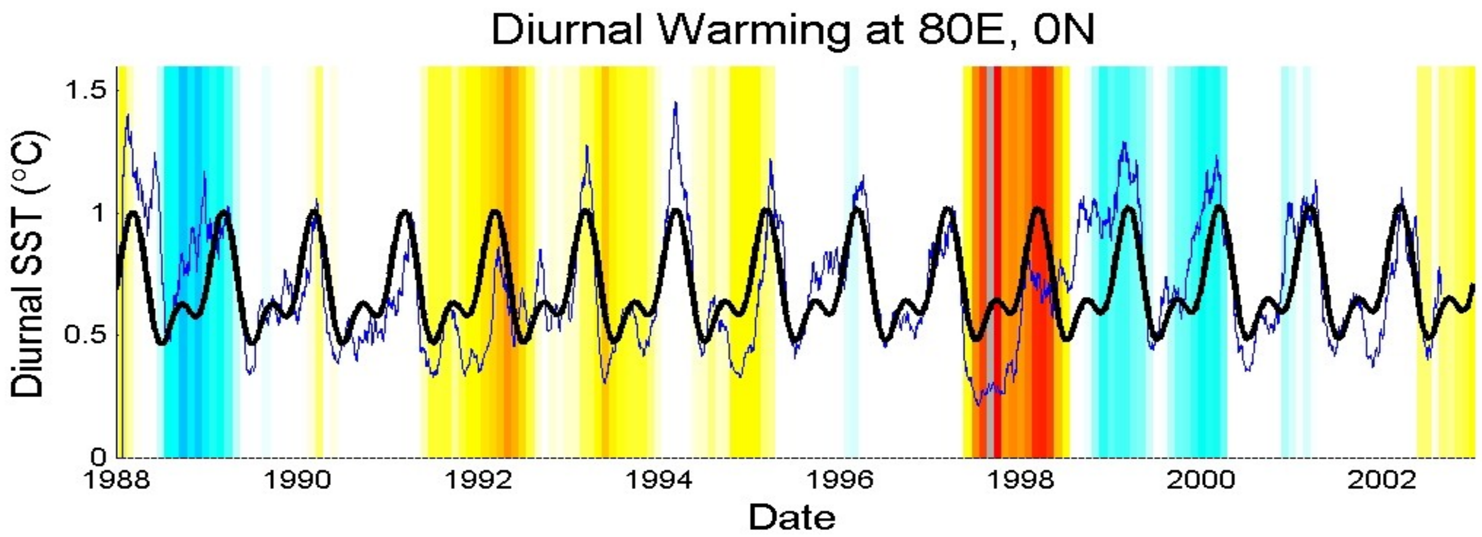
Global distribution



Diurnal Time series



- El Nino warm pool / stronger equatorial winds
- La Nina cold tongue / weaker equatorial winds

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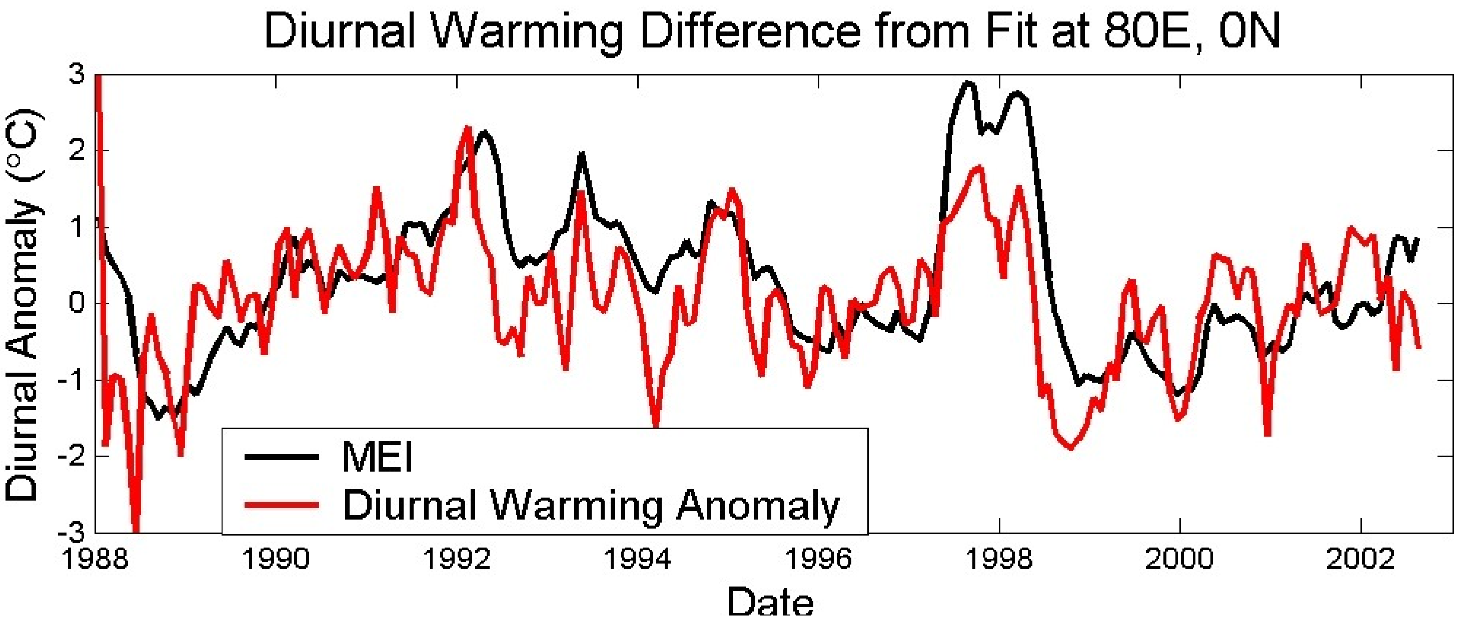
Diurnal Time series



- El Nino warm pool / stronger equatorial winds
- La Nina cold tongue / weaker equatorial winds

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Change

- Change in wind patterns lead to changes in the vertical structure of surface heating
- Heat available to atmosphere
- Clouds/convection/feedbacks

Conclusions

- Look at wind fields to understand diurnal variability
- There are air-sea feedbacks: cold SSTs stabilize the MBL, lower wind speeds at surface, which result in more surface warming, destabilizing MBL, increasing winds…..

conclusions

- In the tropics it is highly likely that in situ observations are affected by diurnal warming.
- We see in ALL buoy arrays clear warming