Southampton Oceanography Centre
UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL

Correction of Daytime Marine Air Temperatures for Climate Studies

David I. Berry, Elizabeth C. Kent and Peter K. Taylor
Southampton Oceanography Centre, UK

This work has been partially funded by the Hadley Centre

CLIMAR-II, Second JCOMM Workshop on Advances in Marine Climatology, Brussels, 17-22 November, 2003.

Outline

- Introduction
  - Voluntary Observing Ship (VOS) air temperature observations
  - Example of heating errors
- Marine Air Temperature (MAT) Correction
  - Heat budget for a VOS
  - Solution of the heat budget
- Initial Results
  - Impact on marine air temperatures
- Summary

VOS observe marine air temperature (MAT) using either screens or psychrometers

Wooden Screen

Whirling psychrometer

However, the instrument exposure can vary greatly from ship to ship

Well exposed screen

Poorly exposed screen

VOS Marine Air Temperatures and Heating Errors

- Heating errors in the daytime Marine Air Temperature (MAT) observations from merchants ships have been well documented, e.g.
  - Dietrich, G., 1950: Systematic errors in the observed surface water and air temperature at sea and their effect on the determination of heat exchange between sea and atmosphere. *D. Hydrogr. Z.*, **3**, 314 - 324.
  - Glahn, W., 1933: False measurements of air temperatures on ships. *Der Seewart*, **2**, 250 - 256.
  - Goerss, J. S. and C. E. Duchon, 1980: Effect of Ship Heating on Dry-Bulb Temperature Measurements in GATE. *J. Phys. Ocean.*, **10**, 478 - 479.
  - Folland, C. K., 1971: Daytime temperature measurements on weather ship 'Weather Reporter', *Meteorological Magazine*, **100**, 6 - 14.
  - Hayashi, S., 1974: Some problems in marine meteorological observations, particularly of pressure and temperature. *Journal of Meteorological Research*, **26**, 84 - 87.
  - Kent, E. C., P. K. Taylor, B. S. Truscott and J. S. Hopkins, 1993: The accuracy of voluntary observing ships' meteorological observations - Results of the VSOP-NA. *J. Atmos. Oceanic Technol.*, **10**, 591 - 608.

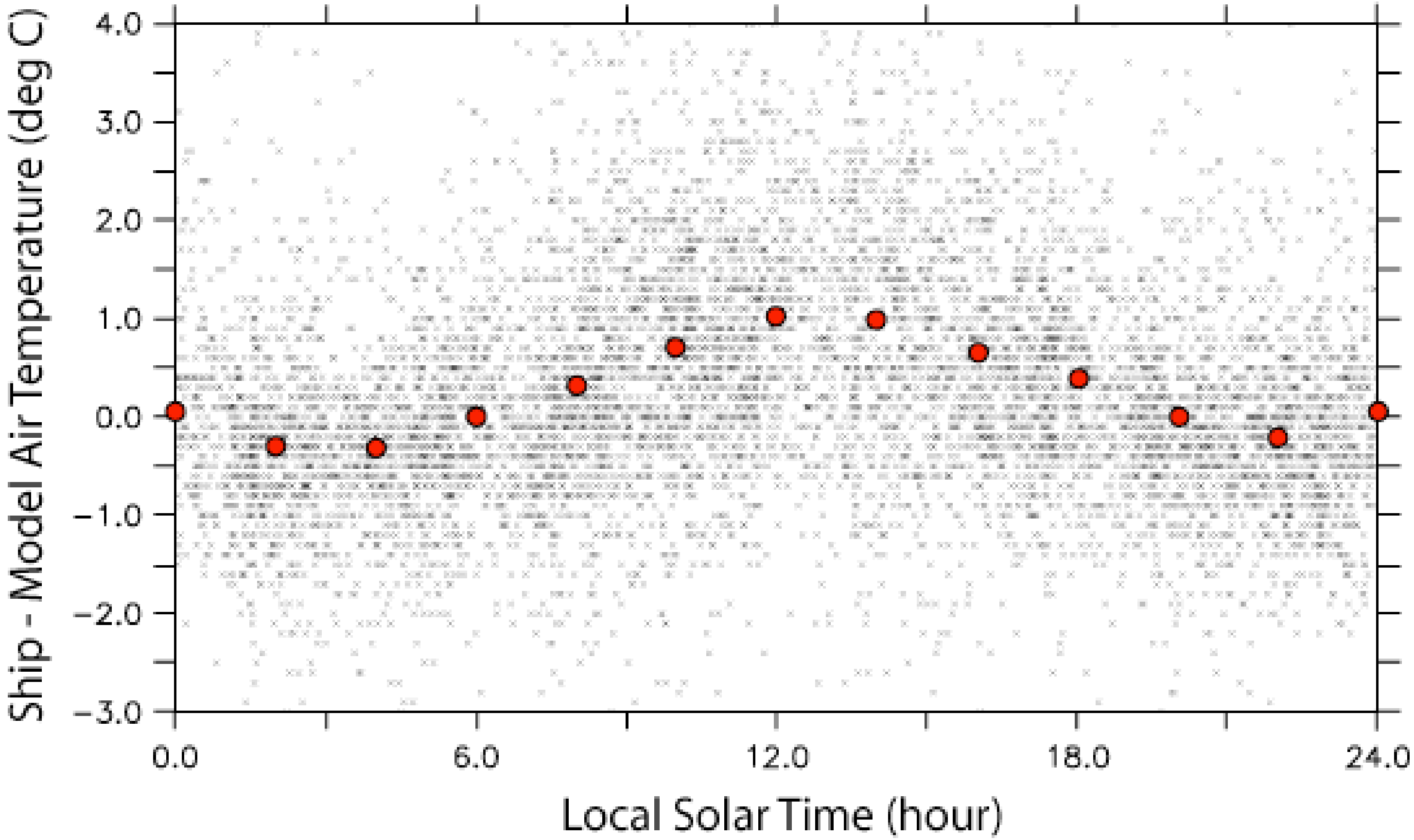
VOSClim Heating Errors

- VOSClim project contains co-located VOS observations and Numerical Weather Prediction Model output.
- Data available for the period November 2001 - present distributed globally.
- Errors estimated as the difference between the observed air temperature and the model air temperature.

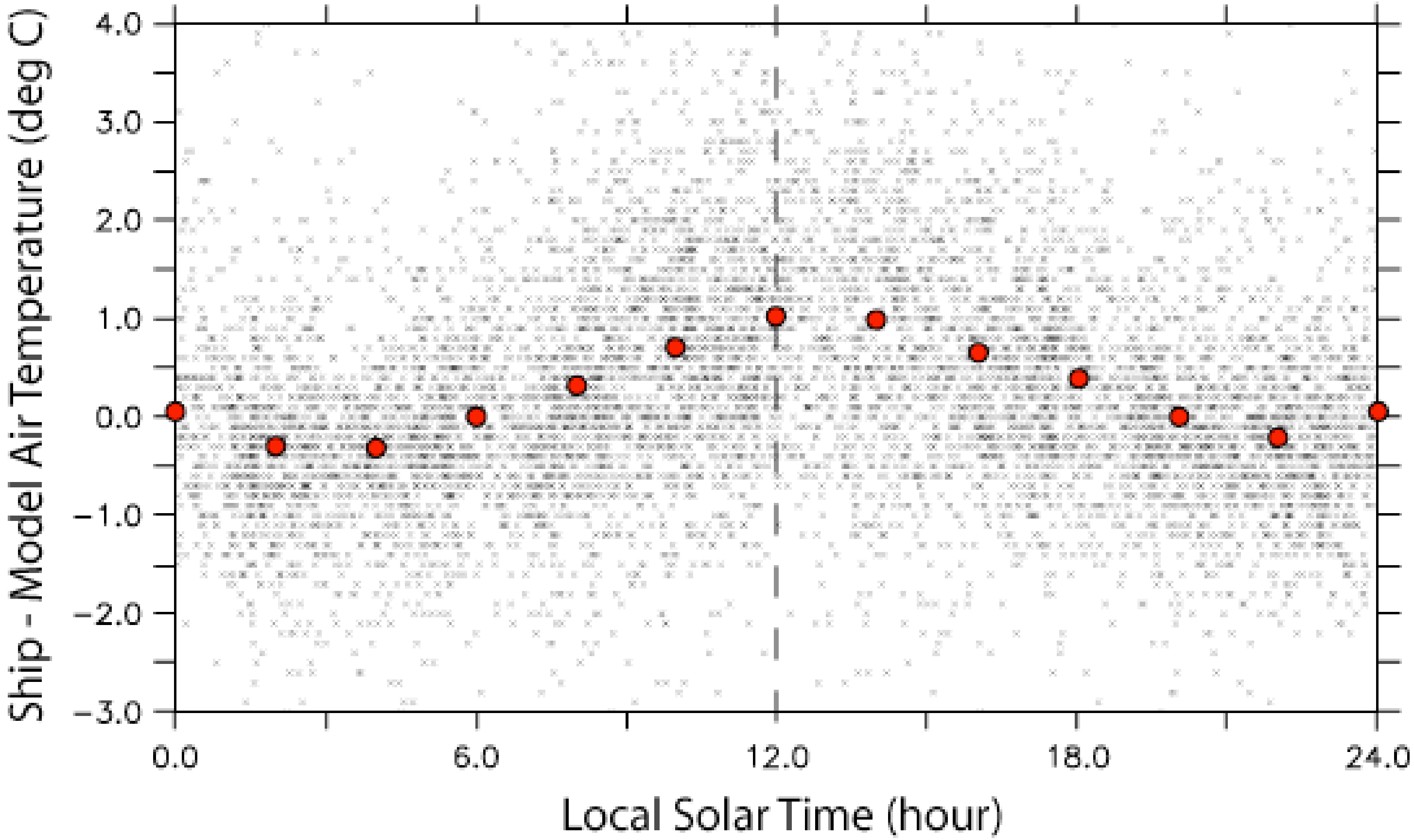
Data available from:

http://www.ncdc.noaa.gov/oa/climate/vosclim/vosclim.html

VOSClim Heating Errors



VOSClim Heating Errors



Errors asymmetrical about midday

Development of Correction

1. Determine heat budget for ships environment

2. Parameterize different components of heat budget

3. Solution of heat budget

4. Fit solution of heat budget to estimated errors

Background

- Correction based on work of Anderson and Baumgartner (1998, AB98) who correct buoy MAT observations for heating errors by balancing heat budget of instruments

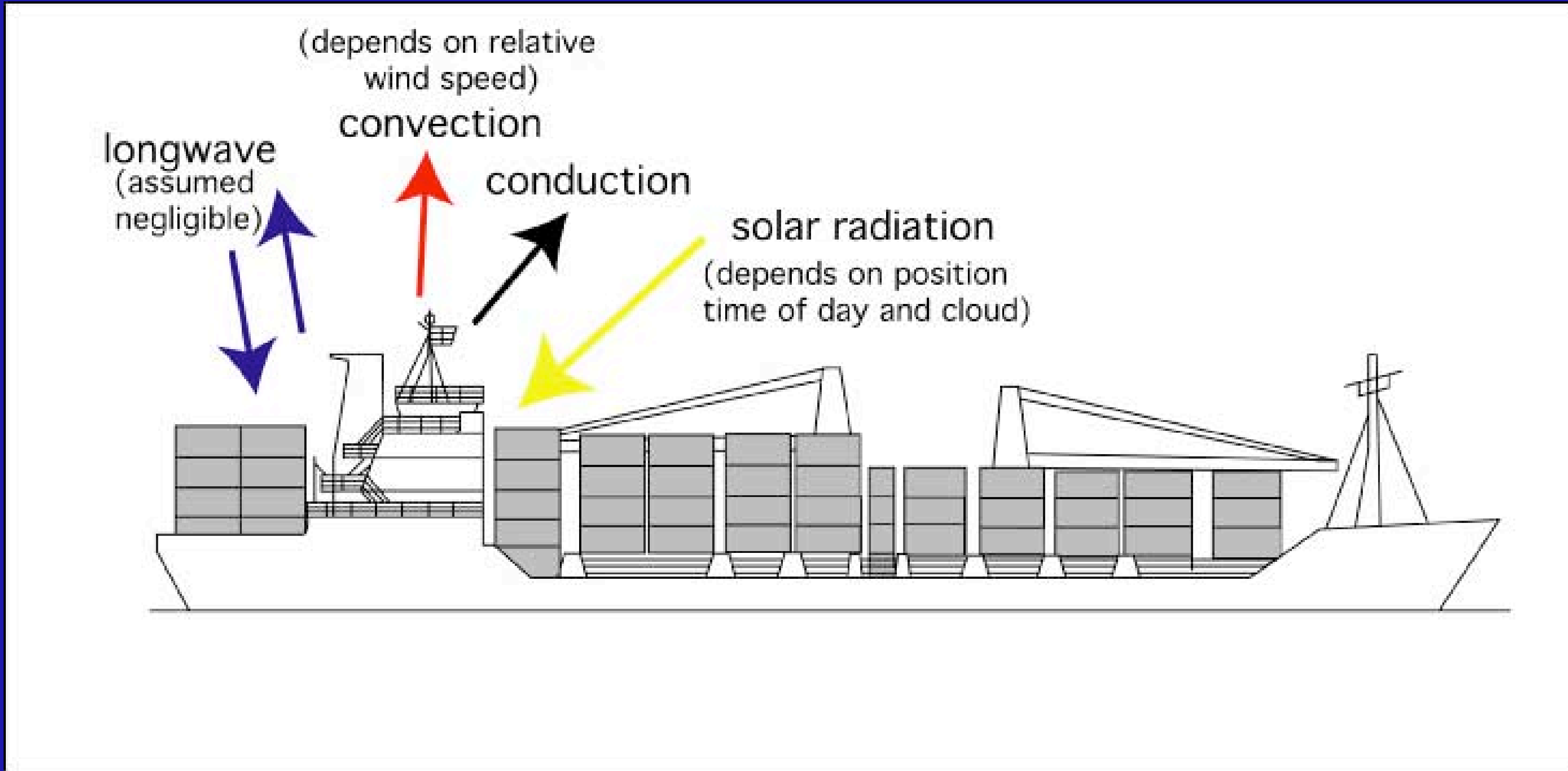
- We’ve determined heat budget of ships environment rather than instruments

- We’ve also extended the model to allow a storage of heat by the ships environment

- However, we’ve used the same convective and conductive cooling scheme as AB98

•Anderson, S. P. and M. F. Baumgartner, 1998: Radiative heating errors in Naturally Ventilated Air Temperature Measurements Made from Buoys. *J. Atmos. Oceanic Technol.*, **15**, 157 - 173

The Heat Budget



Longwave modeled but found to have negligible impact on results

The Heat Budget

- Approximating the ships environment as a simple homogenous system the heat budget can be expressed as;

$$mc\frac{dT_{ship}}{dt} = Q_{SW} + \cancel{Q_{LW}} + Q_{CONV} + Q_{COND}$$

m = Mass of ship [Kg]

c = Specific heat capacity of ship [J Kg^{-1} K^{-1}]

T_{ship} = Temperature of ship [K]

t = Time [s]

Q_{SW} = Rate of solar energy absorbed [W]

Q_{LW} = Net transfer of thermal energy [W] (assumed negligible)

Q_{CONV} = Heat transfer between atmosphere and ship due to convection [W]

Q_{COND} = Heat transfer between atmosphere and ship due to conduction [W]

The Heat Budget

- Using the Okta model (Dobson and Smith, 1988) to estimate the incident shortwave radiation and making a number of approximations the heat budget can be expressed as

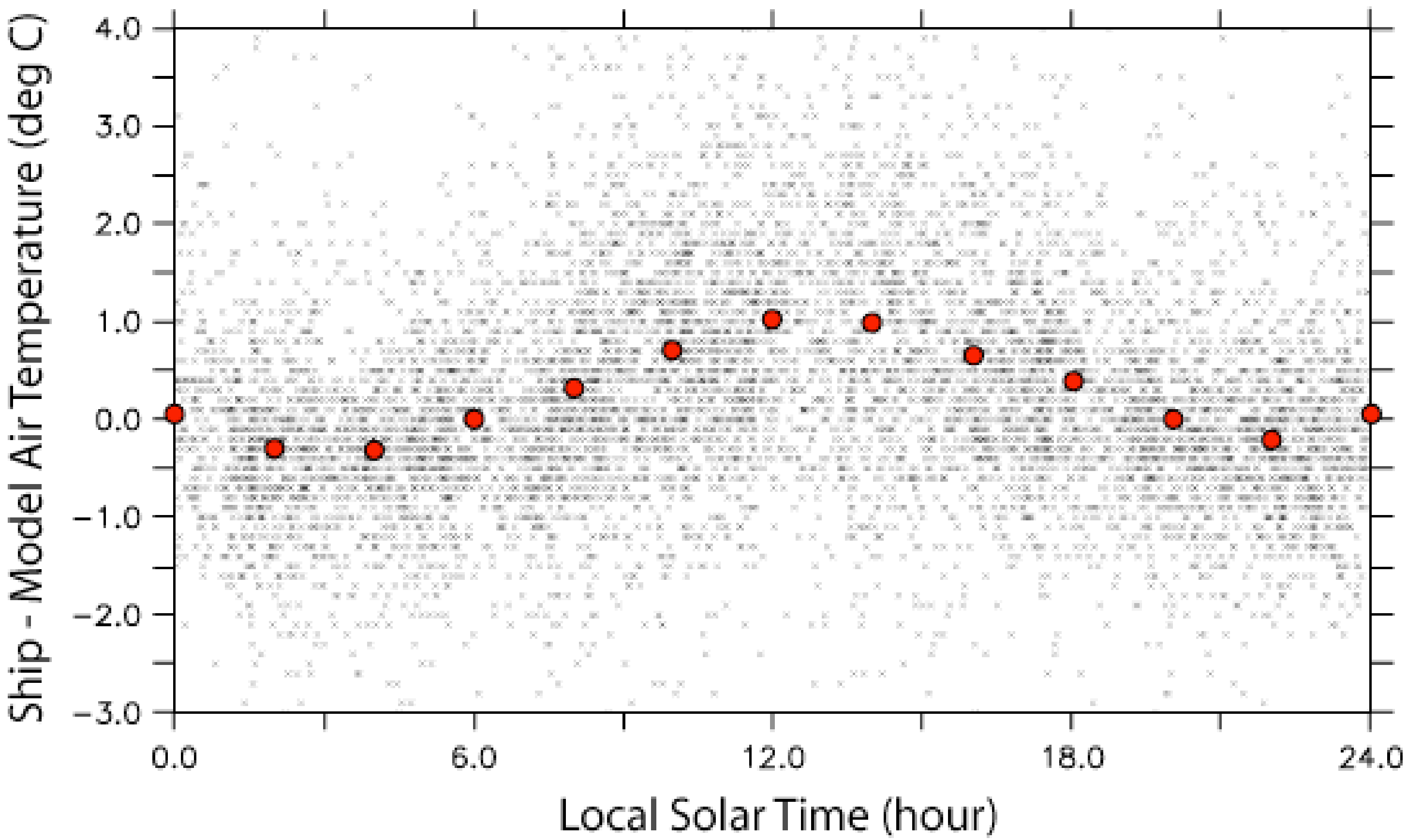
$$\frac{d(T_{air})}{dt} + \frac{d(\Delta T)}{dt} + \underbrace{x_2(x_3 V^{x_4} + x_5)\Delta T}_{Q_{CONV} + Q_{COND}} = \underbrace{x_1 R_{top}(a + b\sin\theta)\sin\theta}_{Q_{SW}}$$

(after Anderson and Baumgartner, 1998)

- Where ΔT = Radiative heating error
  - $\sin\theta$ = Sine of solar elevation (function of time and latitude)
  - a,b = Coefficients for the Okta model
  - V = Relative wind speed
  - x_1-x_5 = Coefficients to be determined empirically

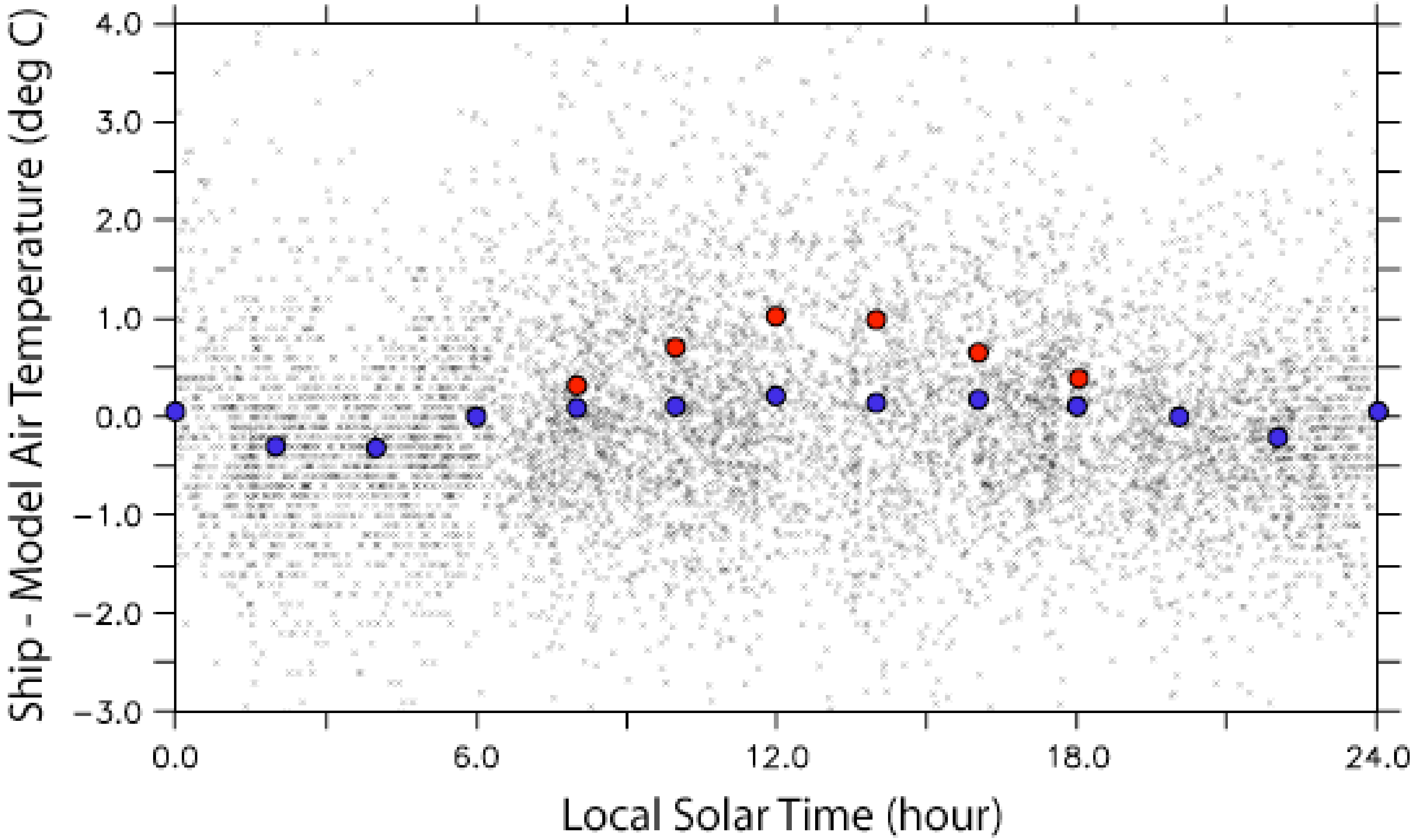
•Dobson, F. W. and S. D. Smith, 1988: Bulk Models of Solar Radiation at Sea, *Quart. J. Roy. Met. Soc.*, **114**, 165 - 182.

VOSClim Heating Errors



Same as slide 6

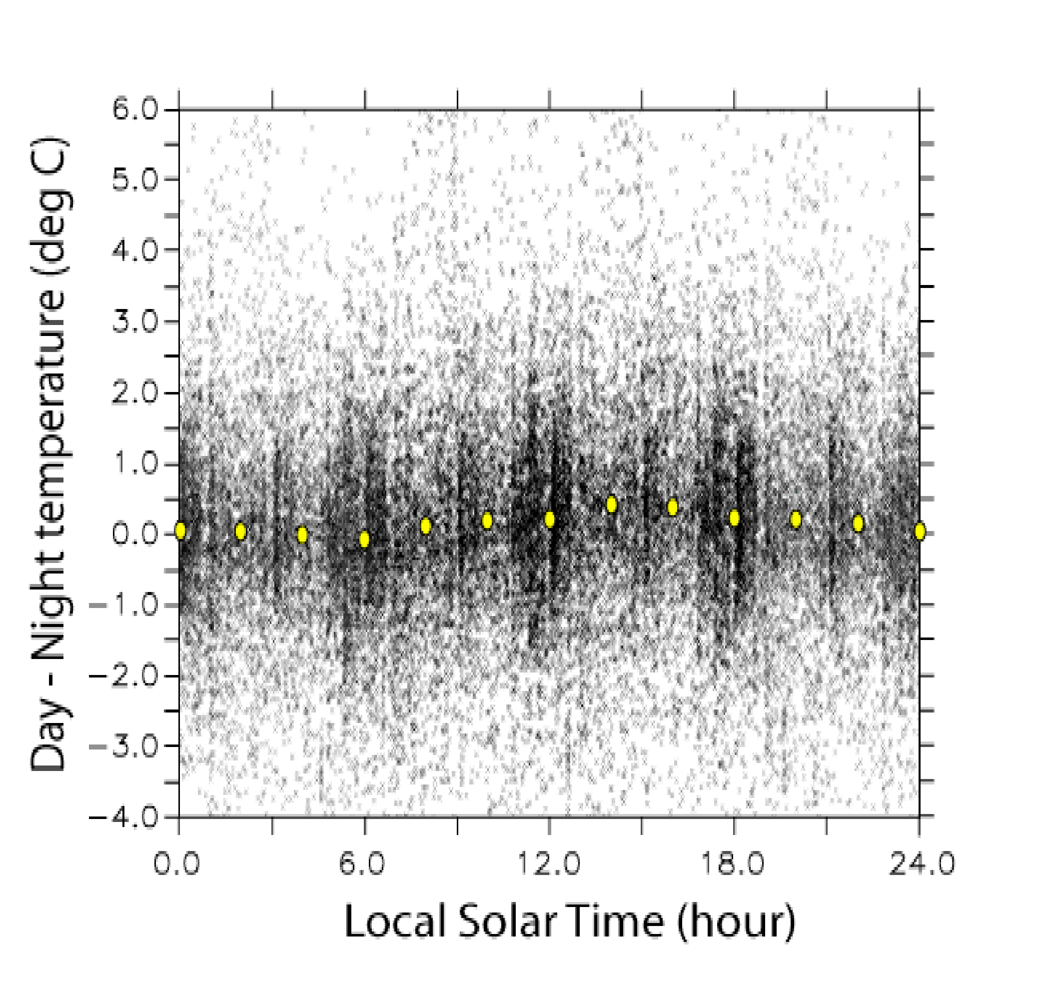
VOSClim Heating Errors



Corrected data (blue)

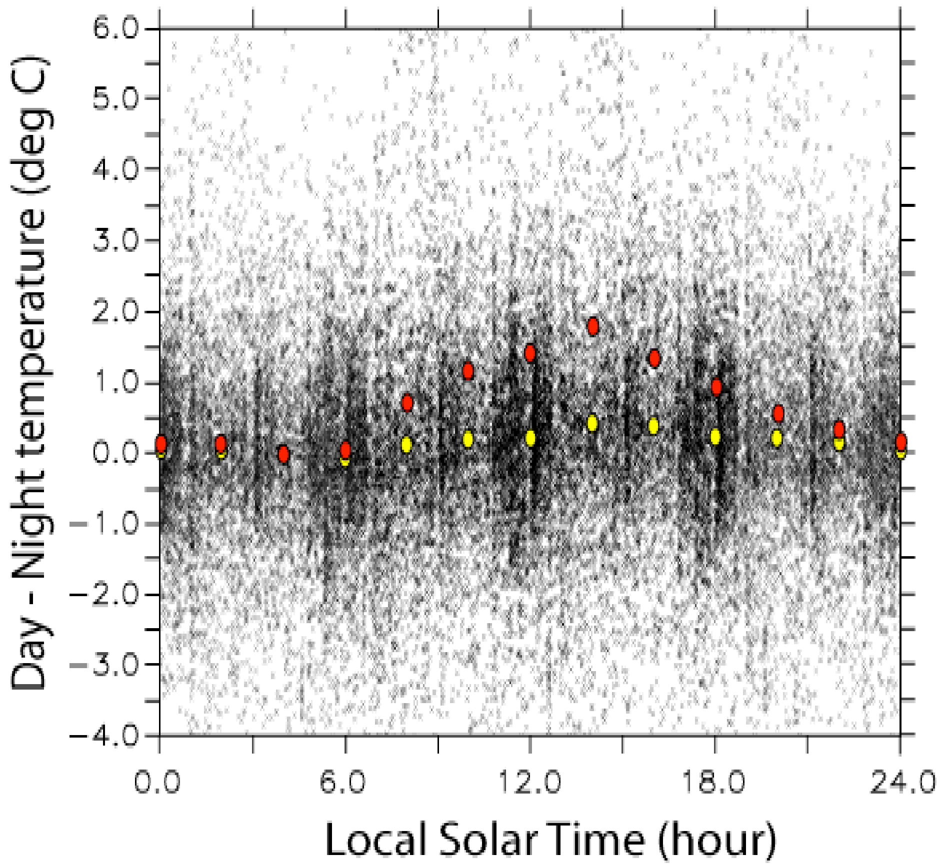
Note reduced diurnal cycle

Diurnal cycle of SST (yellow) and MAT (red) for the North Atlantic, July 1988



- Expect diurnal cycle of MAT to be smaller than diurnal cycle of SST

Diurnal cycle of SST (yellow) and MAT (red) for the North Atlantic, July 1988

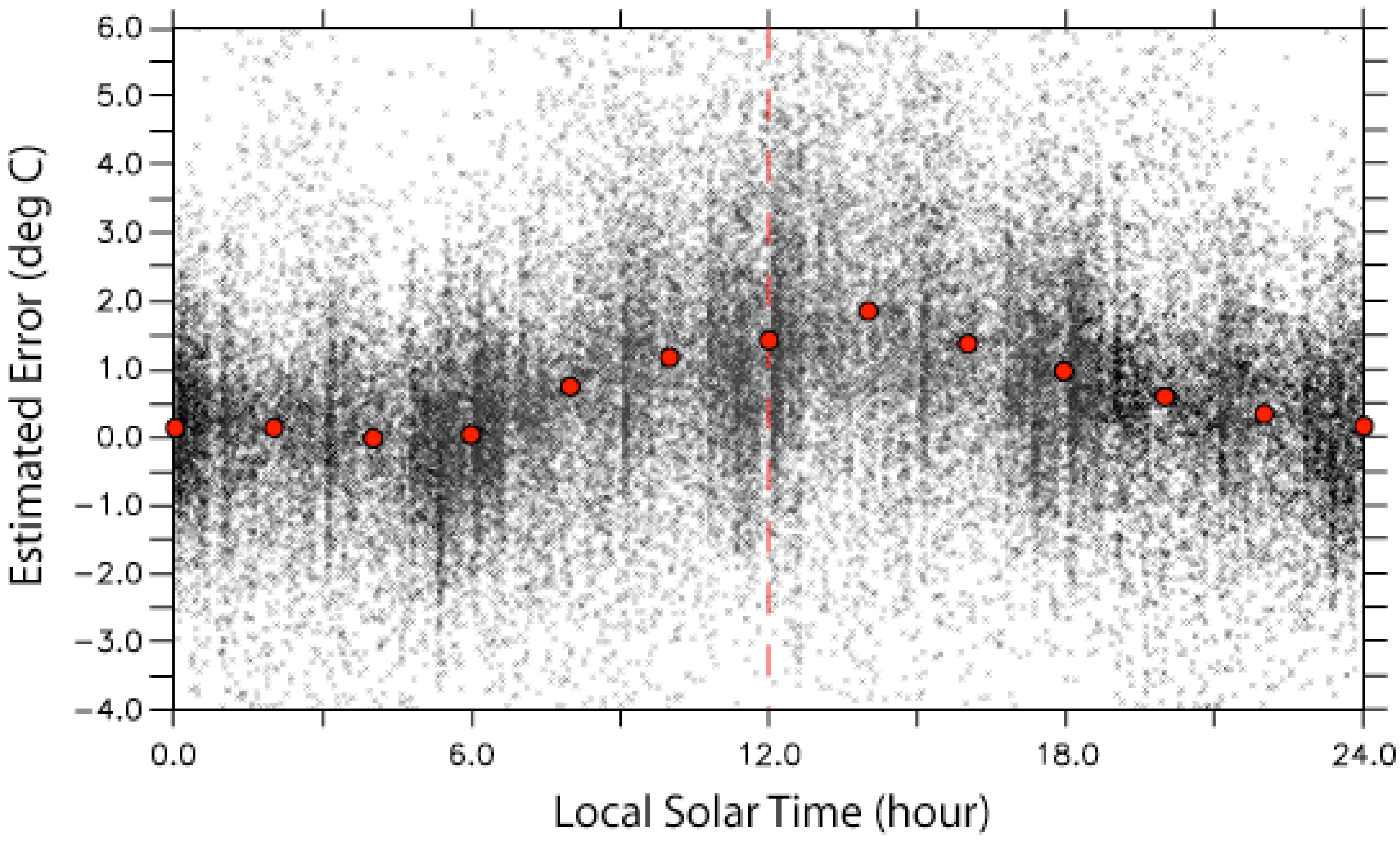


- Expect diurnal cycle of MAT to be smaller than diurnal cycle of SST
- However, the MAT show a much larger diurnal cycle

Estimation of heating errors using I-COADS

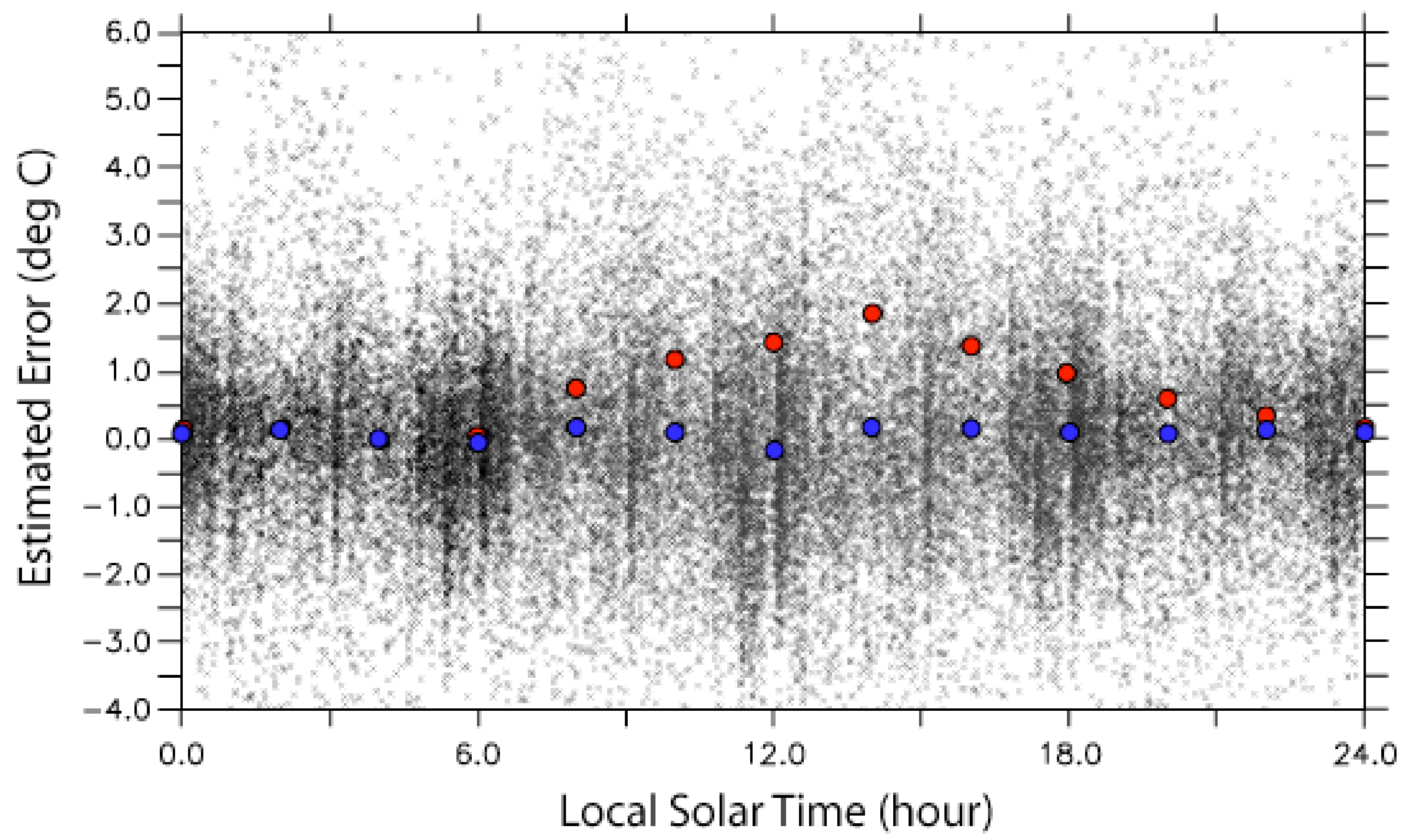
- Hence, we can use the observed minus night time MAT as a good 1st approximation of the heating errors
- This will provide an upper limit on the estimated heating errors
- Similar results can be shown using the observed minus night time air - sea temperature difference
- Using the observed minus night time air - sea temperature difference provides a lower limit on the estimate of the heating errors

Estimated Errors for the North Atlantic (July 1988)



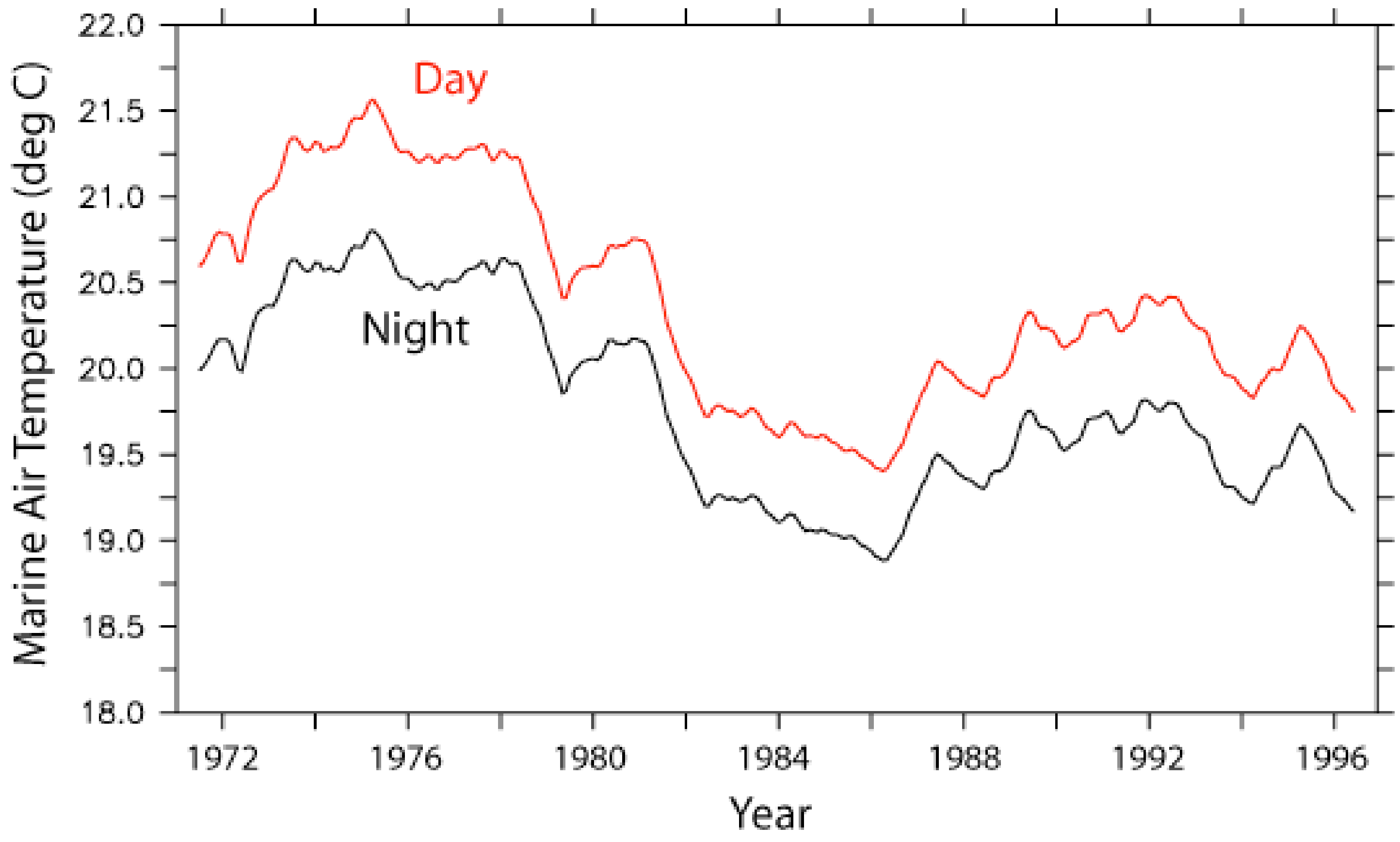
Estimated errors calculated using day - night MAT

Estimated Errors for the North Atlantic (July 1988)



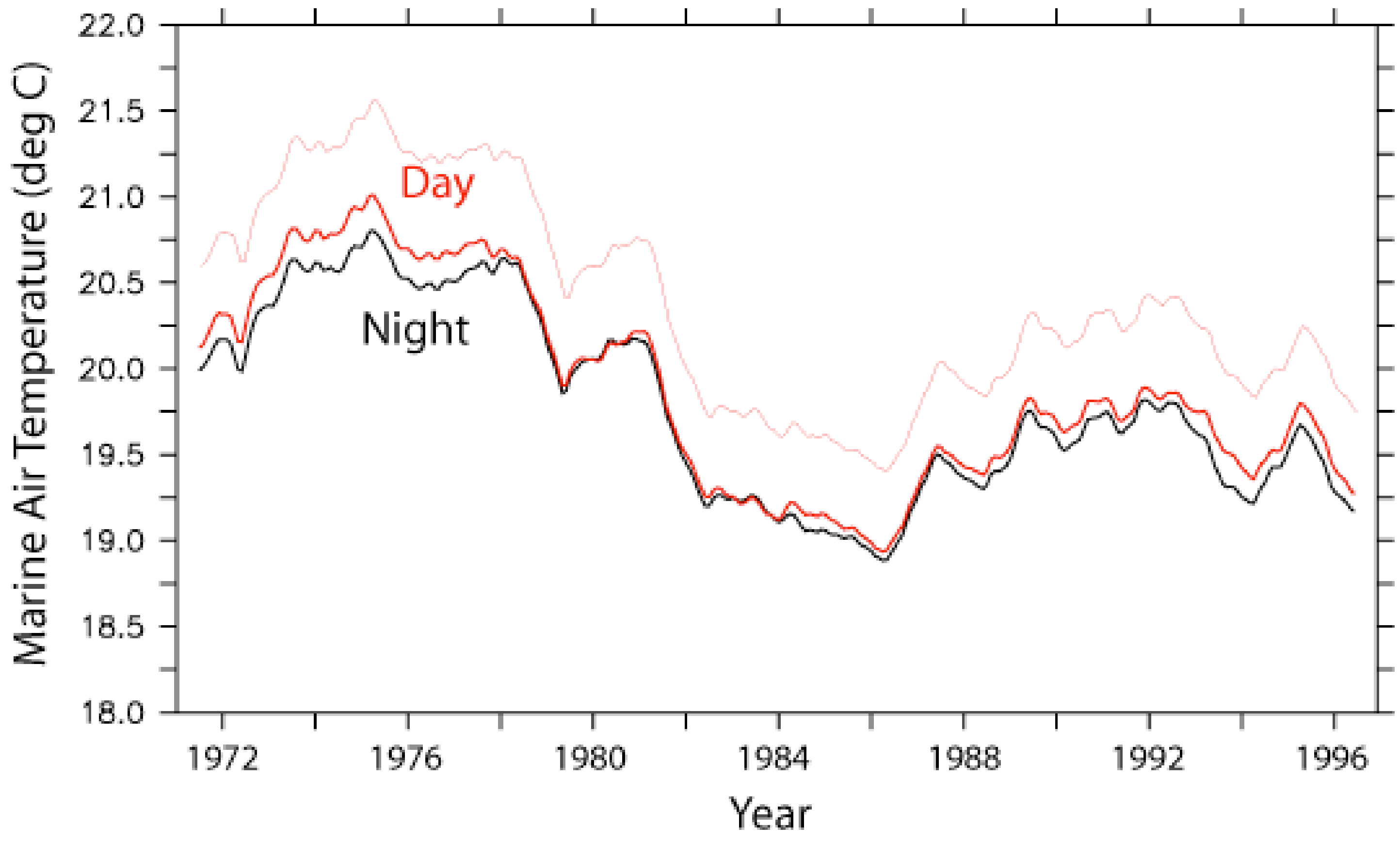
Corrected data (blue)

North Atlantic Marine Air Temperature (12 month running mean)



Approximately 0.6 - 0.7 C difference between day and night MAT averaged over the North Atlantic. We'd expect differences of 0.2 - 0.3 C at most based on SST

North Atlantic Marine Air Temperature
(12 month running mean)



Correcting the data brings the day and night time values into much better agreement.

Summary and Further Work

- VOS MAT observations contain large heating errors
- These errors are asymmetrical about midday, suggesting a storage of heat by the ships environment
- We can model these heating errors using an analytical model of the heat budget of the ships environment
- Further work includes
  - examine heating errors and correction by subset, e.g. country of recruitment, instrument type, ship type etc.
  - Use VOSClim data and metadata to examine the relationship between the heating errors, correction and fitted coefficients and the exposure of the instruments.

Southampton Oceanography Centre
UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL

Correction of Daytime Marine Air Temperatures for Climate Studies

David I. Berry, Elizabeth C. Kent and Peter K. Taylor
Southampton Oceanography Centre, UK

This work has been partially funded by the Hadley Centre

CLIMAR-II, Second JCOMM Workshop on Advances in Marine Climatology, Brussels,
17-22 November, 2003.