Improving the global SST record: estimates of SST biases in the modern era using high quality satellite data

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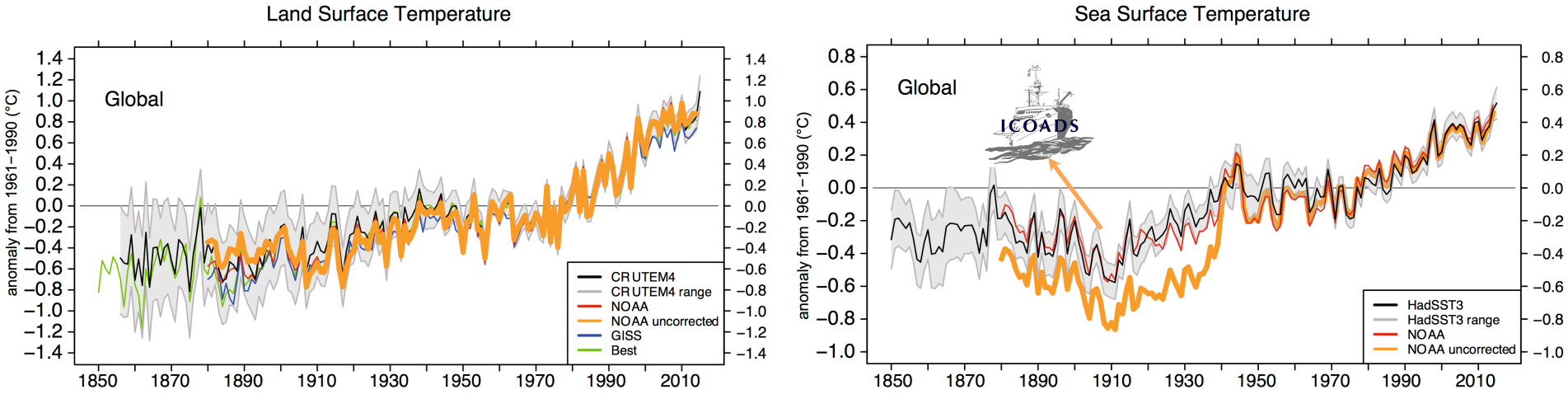
Sea Surface Temperature (SST) adjustments are the largest factor impacting global surface temperature changes, a primary expression of climate change



adapted from Jones 2016, Advances In Atmospheric Sciences **33**, 269–282.

Using only unadjusted data, Karl et al. (2015) show that if the biases and homogeneity issues are ignored, the world would have appeared to have warmed more. This result is primarily due to the SST bucket bias. (Jones 2016)

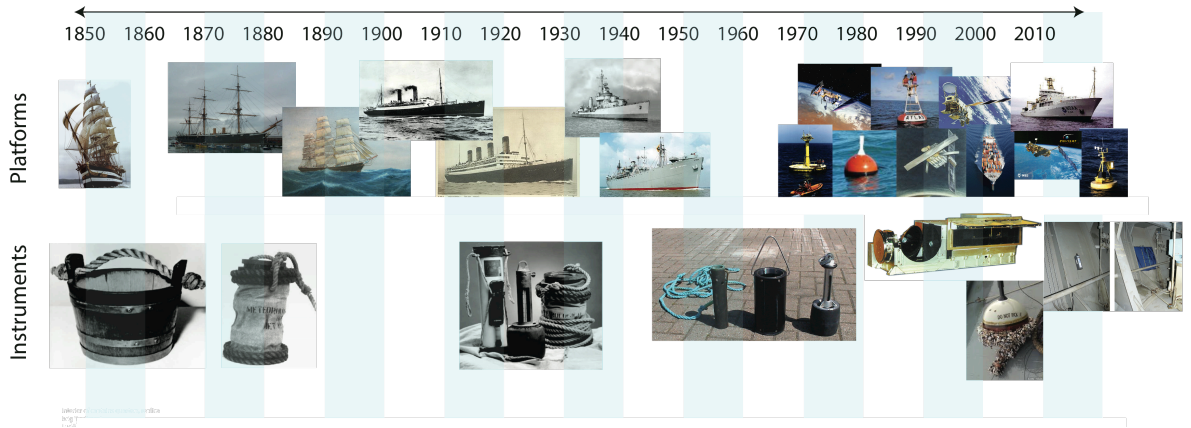
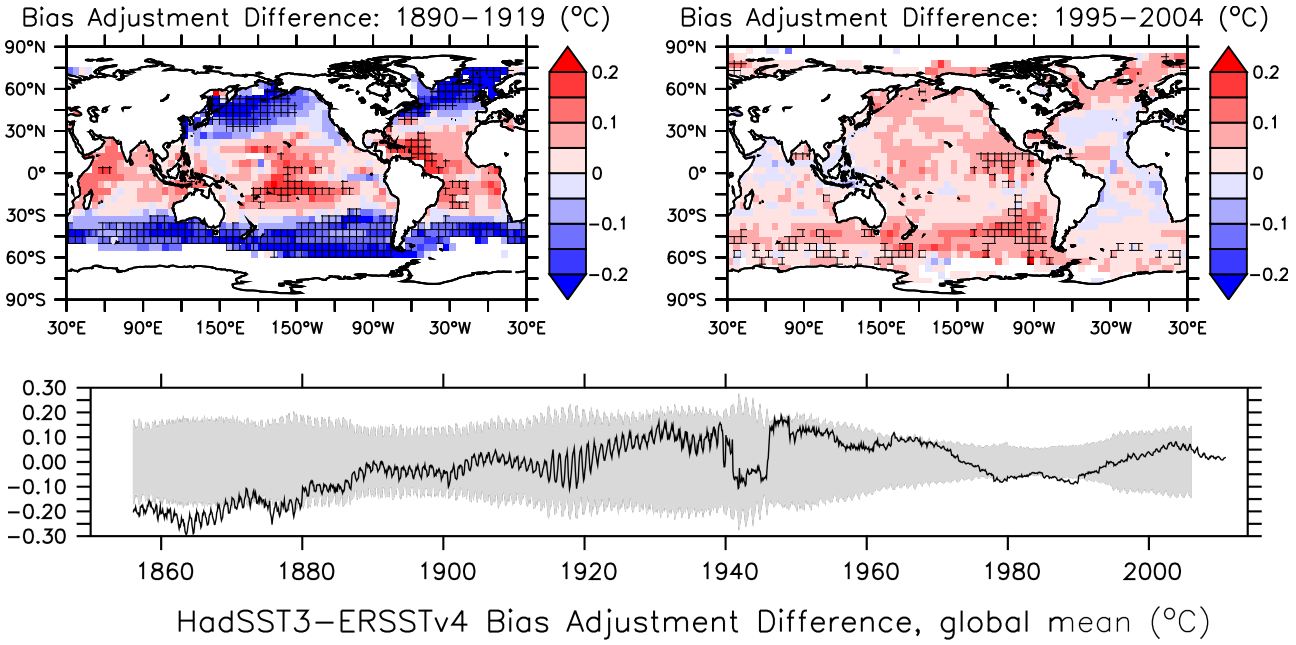


Figure by Elizabeth Kent, NOC.

SST bias estimates agree on the largest space and timescales but regional differences can exceed the estimated uncertainty



adapted from Kent *et al*. 2016, Bulletin of the American Meteorological Society, under review.

Historical **O**cean **S**urface **T**emperatures: **A**ccuracy, **C**haracterisation and **E**valuation

HOSTACE

Historical Sea Surface Temperature (SST) bias adjustments using individual observations and platforms

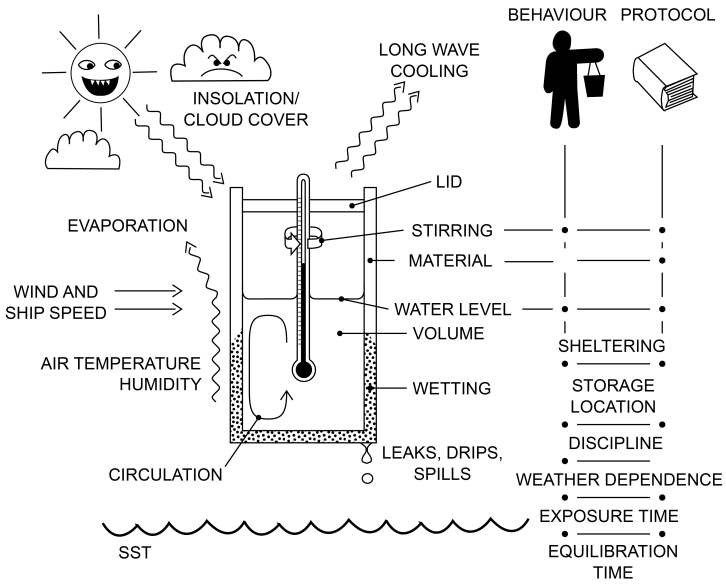
A ship-by-ship approach ideally requires information on the adopted measurement method and its bias characteristics

1. ICOADS information on the adopted measurement type is patchy

2. Factors affecting measurements of SST

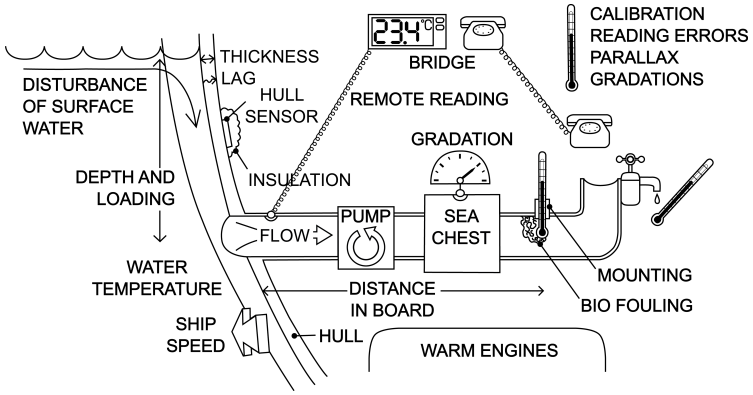
Factors affecting buckets biases

Reasonably well known, although not fully validated against the data



Factors affecting ERI biases

Characteristic of ERI biases are more uncertain
and have not been tackled with physically-based models



Figures by John Kennedy, MET OFFICE.

Improving the global SST record: estimates of SST biases in the modern era using high quality satellite data

Overview

1. Why the modern era: the ESA CCI initiative

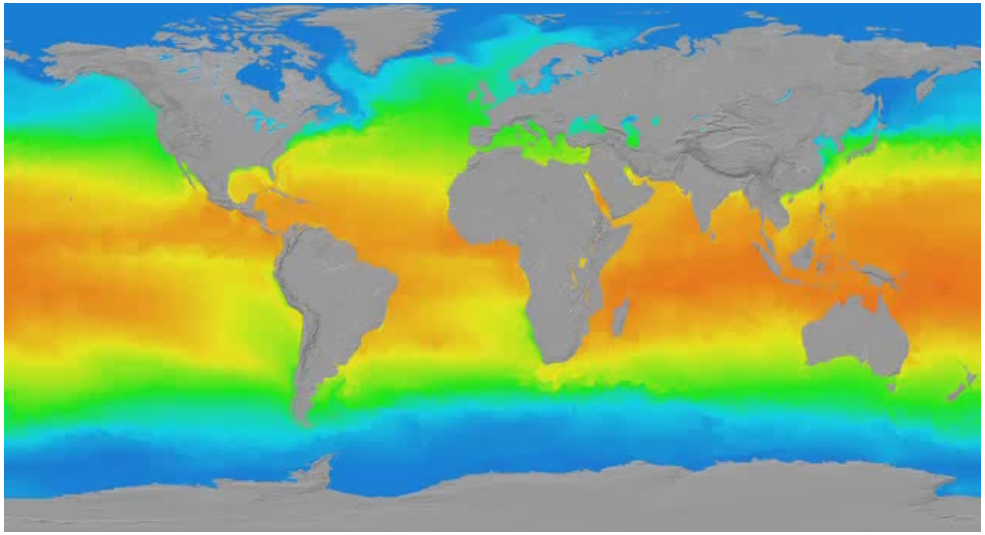
2. Separate observations according to SST measurement methods (buckets, ERI, hull sensors) using characteristic differences in the diurnal cycle

3. Bayesian estimation of SST biases from a reference 'expected' SST

4. Conclusions and future work

ESA CCI SSTs provide high quality satellite data that can be used as a reference to study SST biases from ships observations

Sep 1991 – Dec 2010 ESA CCI SST



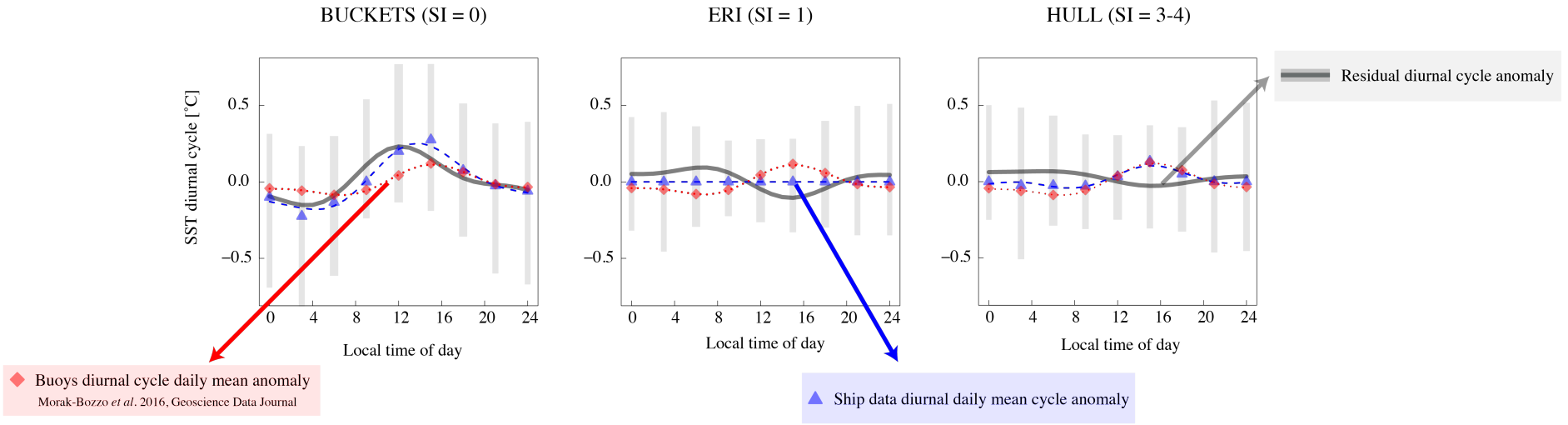
http://www.esa-sst-cci.org/PUG

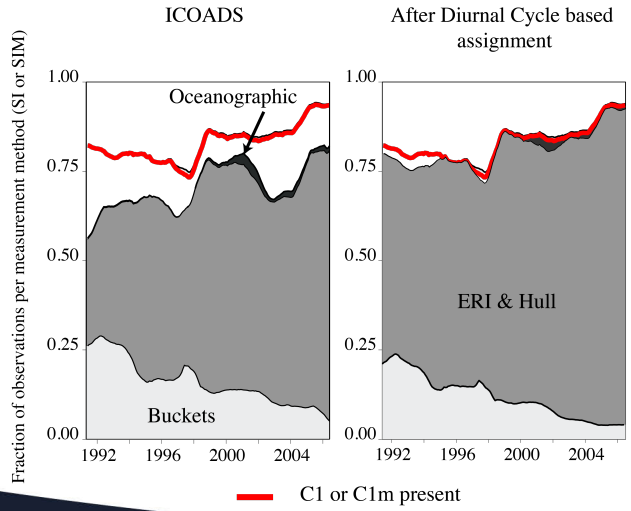
1. Understand SST bias characteristics for each measurement method

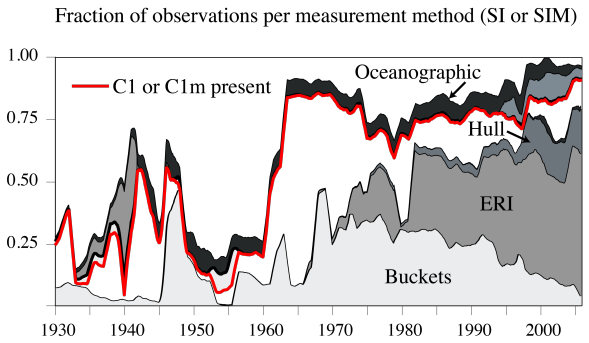
2. Develop a method to adjust SST observations that can be applied to pre - ESA CCI eras

Estimating SST measurement methods using characteristic differences in the diurnal cycle

1991 - 2006 TROPICS





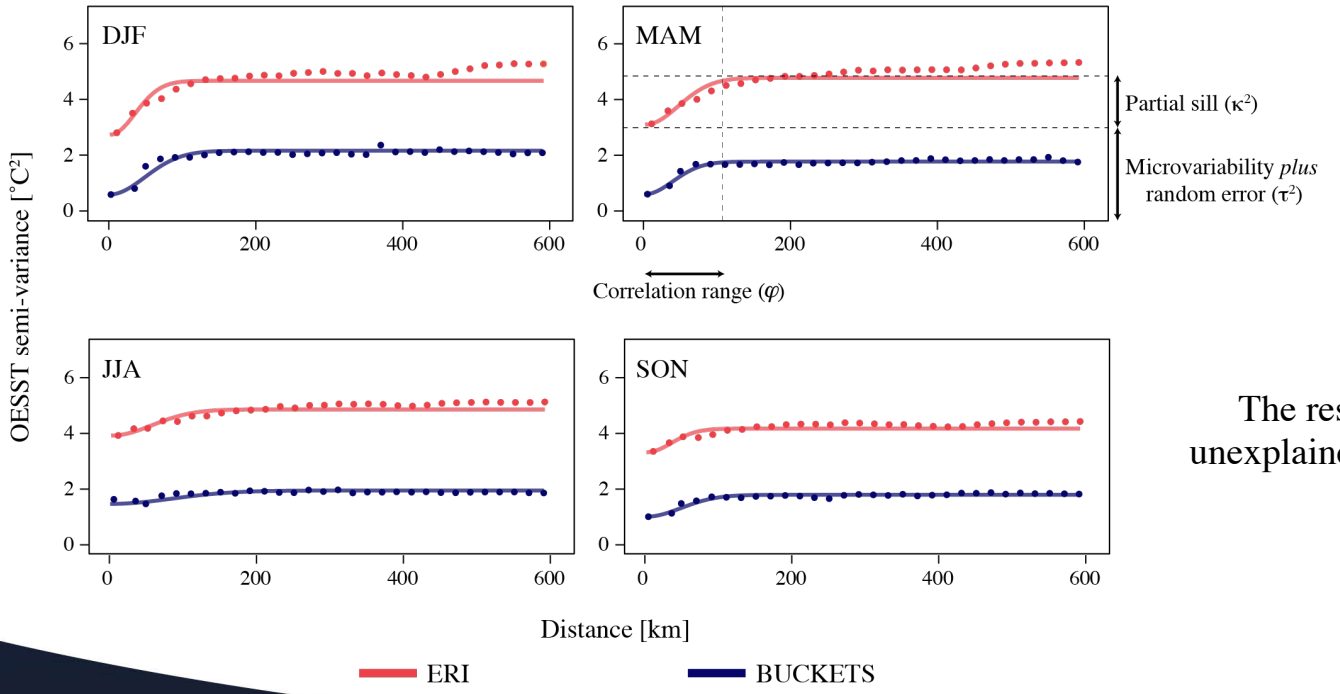


Bayesian estimation of SST biases from a reference 'expected' SST

e.g. ESA CCI SST

$$\underbrace{T_{obs} - \hat{T}}_{\text{OESST}} = bias + \underbrace{N(0,\tau^2)}_{random} + \underbrace{N(0,\kappa^2 + \mathbf{H}(\varphi))}_{spatial}$$

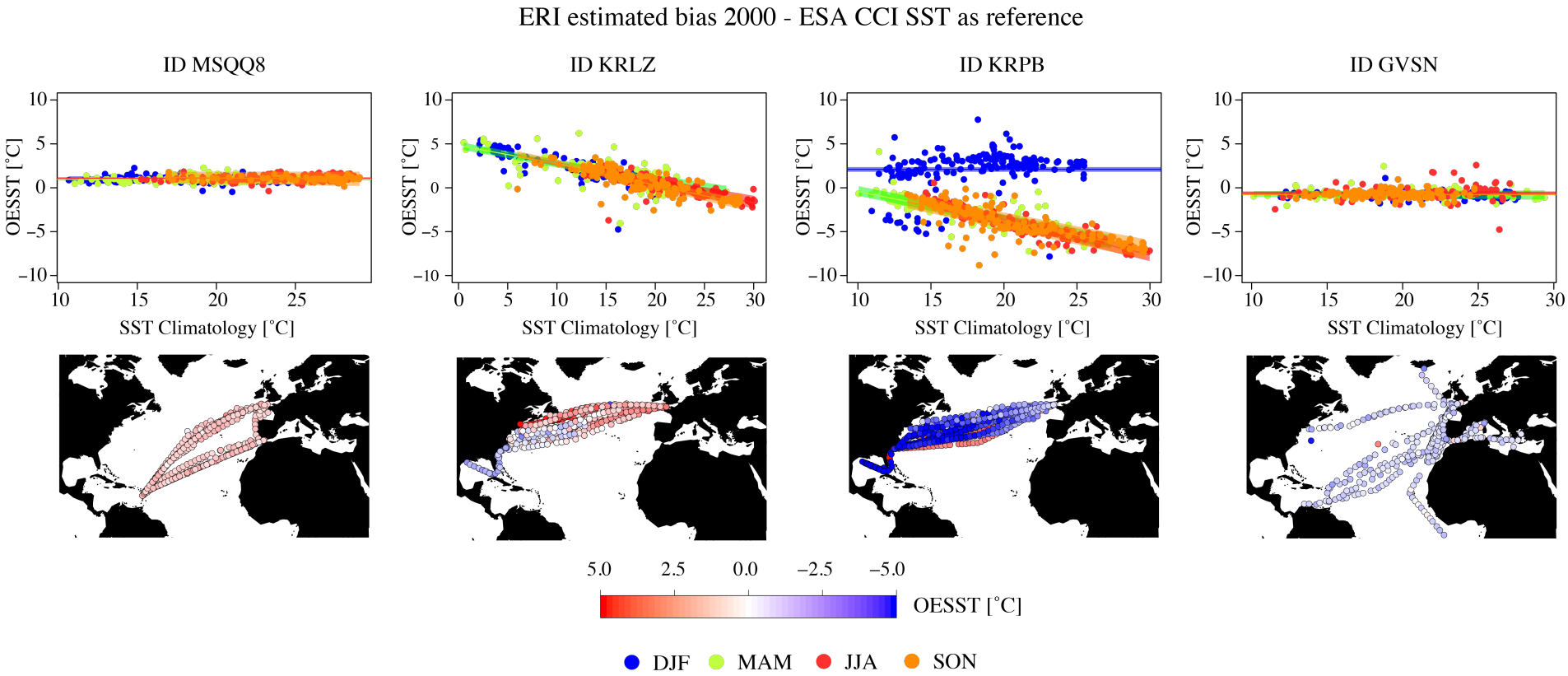
North Atlantic 1994 - 2010, Night time only



The residual spatial pattern captures unexplained variability in the OESST field

SST bias adjustment models will differ for each measurement type

(*a*) ERI $bias = c_0 + c_1 \cdot SST_{clim} \quad c_1 \leqslant 0$

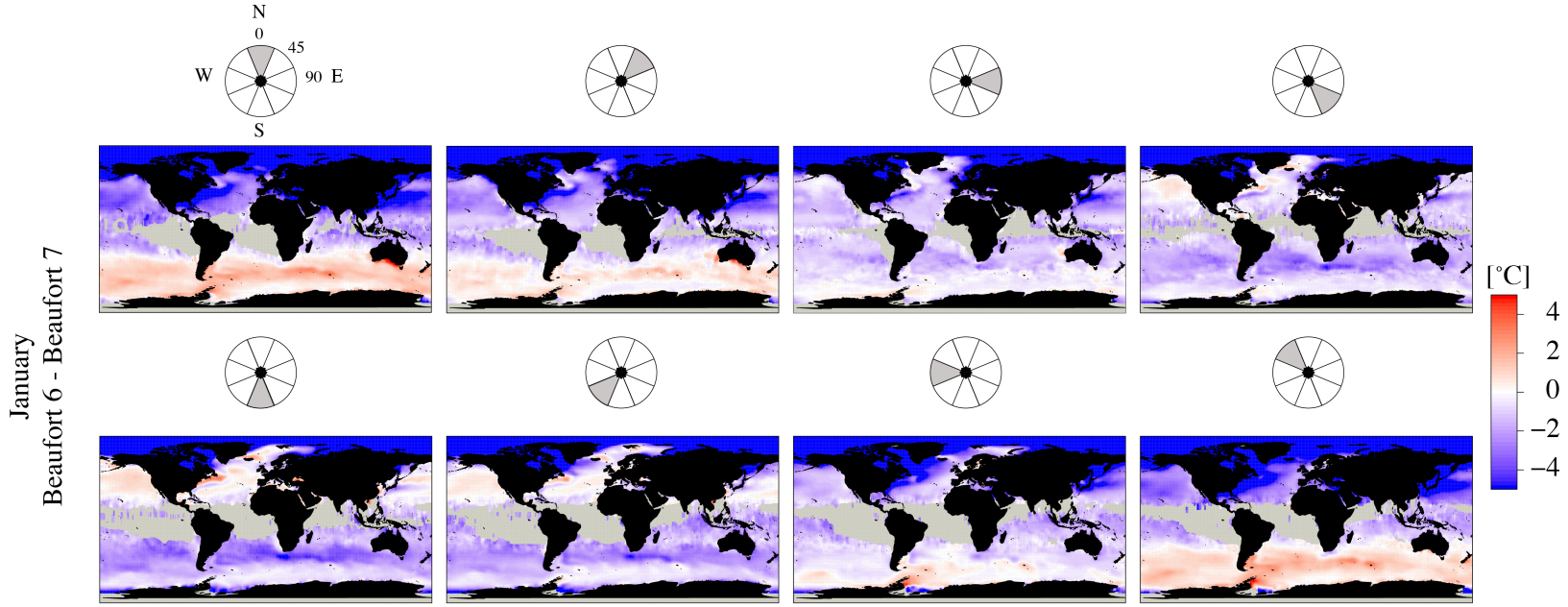


SST bias adjustment models will differ for each measurement type

(*a*) ERI $$bias = c_0 + c_1 \cdot SST_{clim} \quad c_1 \leqslant 0$$

(*b*) Buckets $$bias = c_0 + c_1 \cdot (T_{air} - SST)_{clim} \Big|_{wind} + c_2 \cdot (e_{air} - e_{S_{SST}})_{clim} \Big|_{wind} + c_3 \cdot Q$$

Air *minus* Sea surface temperature climatology (ERA Interim 1985 - 2015)



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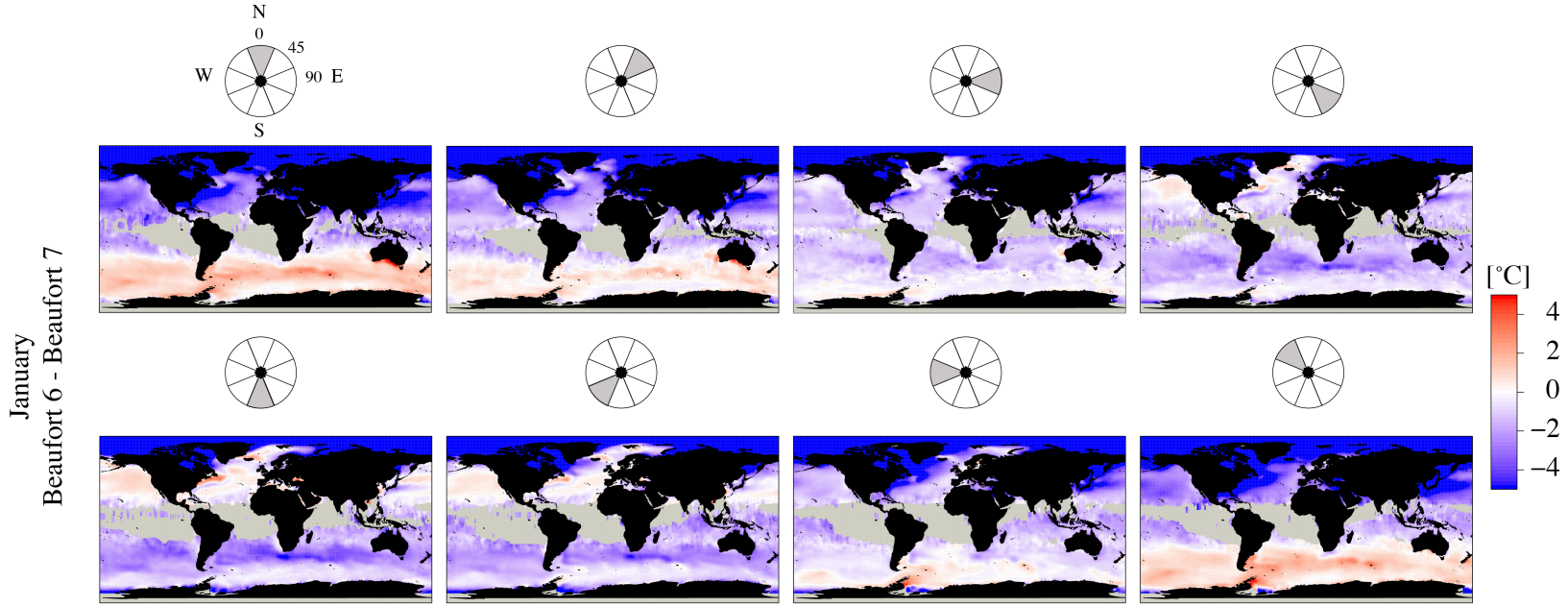

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Small for modern buckets

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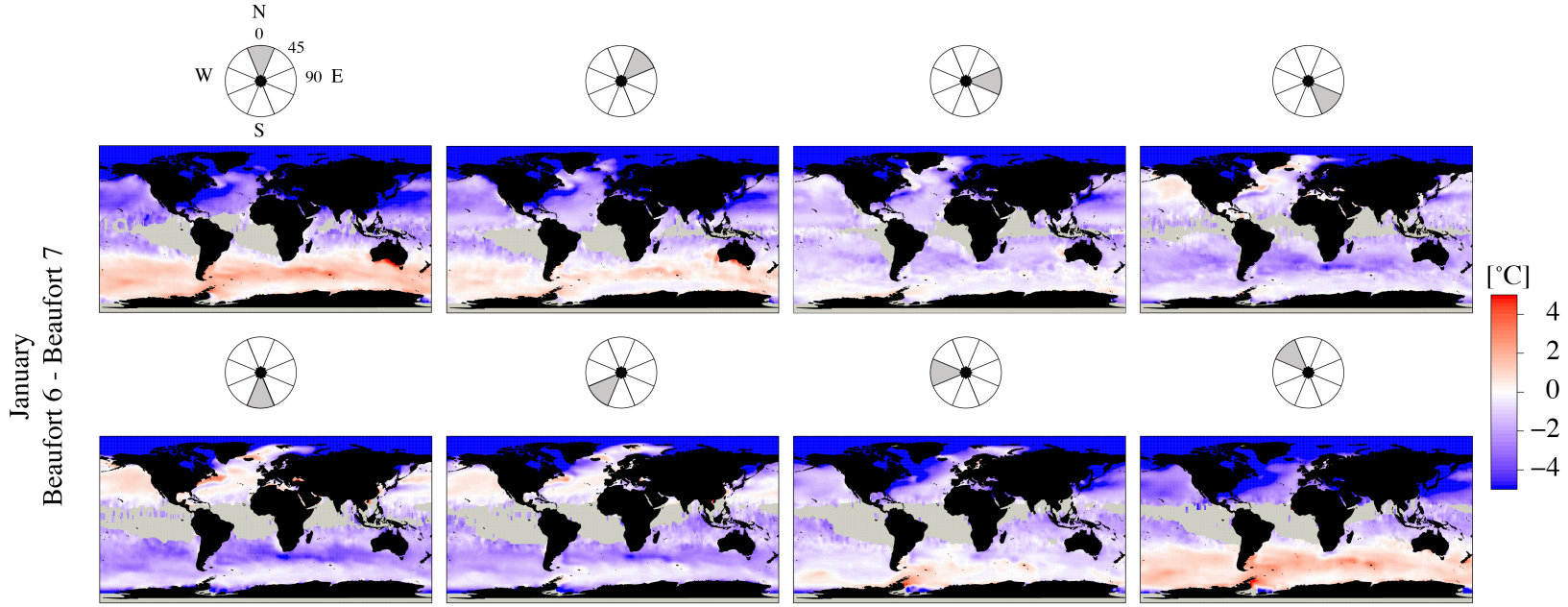

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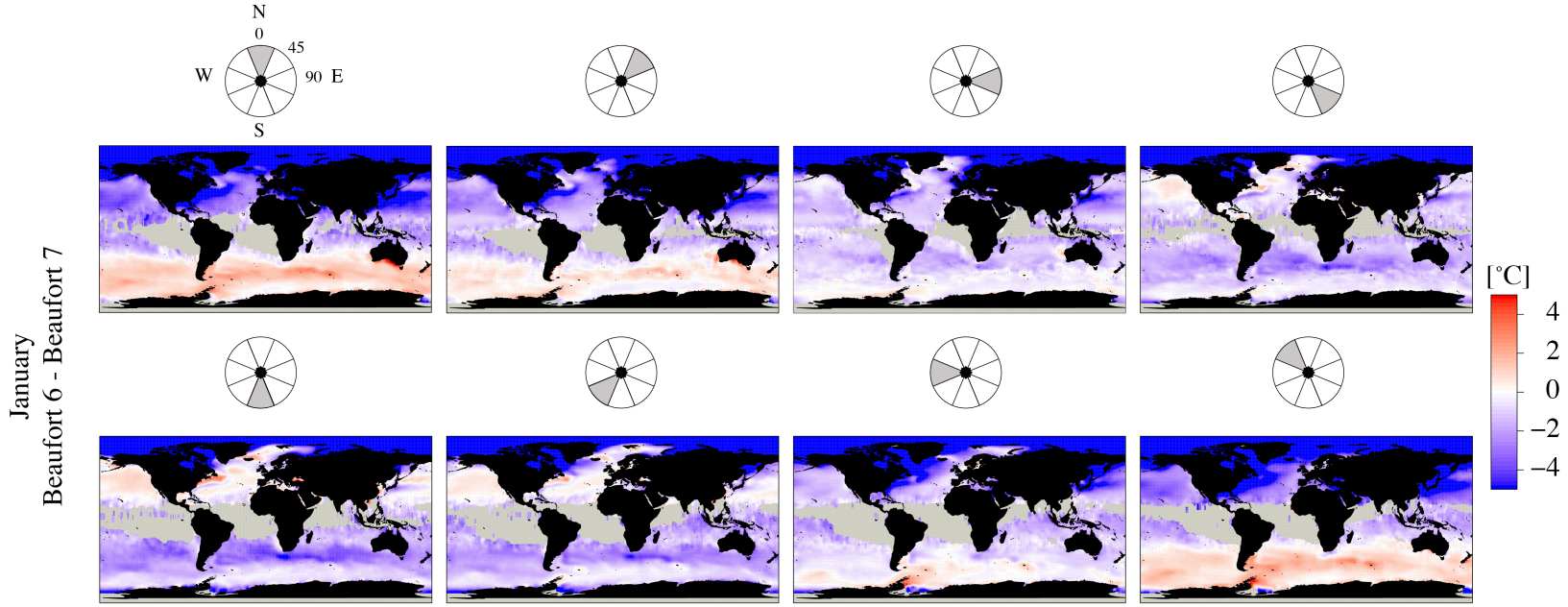
Air *minus* Sea surface temperature climatology (ERA Interim 1985 - 2015)



An estimated bias field can then be produced combining the individual ships biases

SST estimated *bias* 1992 - 2006
ESA CCI SST as reference

(*a*) ERI

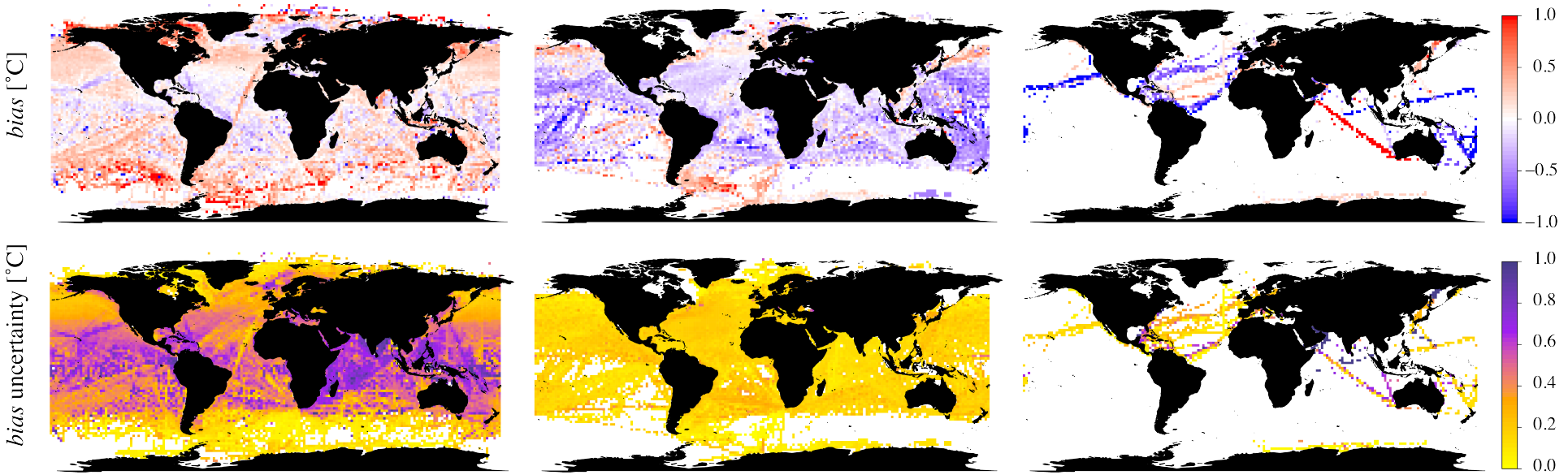
$$bias = c_0 + c_1 \cdot SST_{clim} \quad c_1 \leqslant 0$$

(*b*) Buckets

$$bias = c_0 + c_1 \cdot (T_{air} - SST)_{clim} \Big|_{wind} \quad 0 \leqslant c_1 \leqslant 1$$

(c) Unknown

$$bias = bias_{\text{Buckets}} + bias_{\text{ERI}}$$

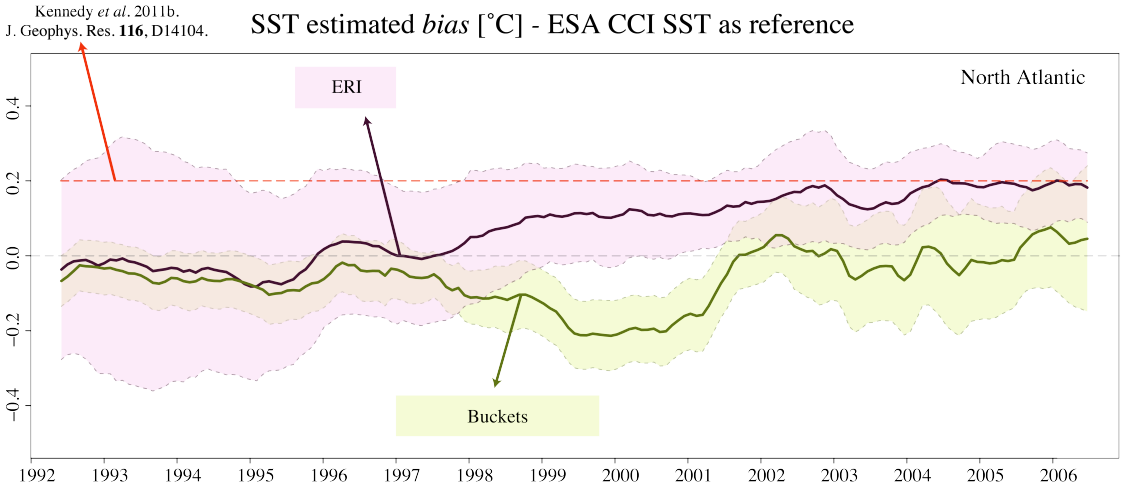


40 % of the observations are significantly correlated with SST climatology ($c_1 \sim -0.09 \pm 0.18$)

$c_1 \sim 0.16 \pm 0.26$ in agreement with Kent & Kaplan 2006

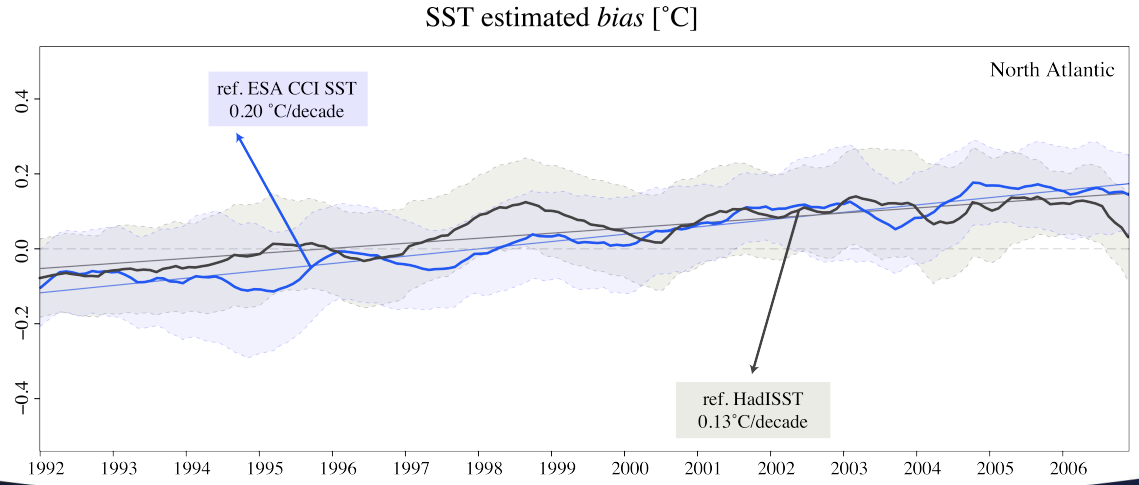
Journal of Atmospheric and Oceanic Technology **23 (3)**, 487-500

The estimated SST *bias* from ships in the period 1992 – 2006 is increasing and on average positive



The average SST bias from ship observations in the period 1992 – 2006 is increasing, contradicting the typical assumption of a mean warm ERI bias falling between 0.1 ˚C and 0.3 ˚C

The uncertainty in the background reference field may be fully represented using different statistically reconstructed SST products



Conclusions

1. Based on characteristic differences in the diurnal cycle, reports with missing measurement indicator were reduced from 15% to less then 0.1% in the period 1992-2006 for observations with country information

2. SST biases from ships were modeled and detected from the data as differences of the observed SST from a reference SST in the context of a Bayesian spatial model

3. Using as a reference high quality SST data from the ESA CCI initiative, for the period 1992-2006 the estimated SST bias is positive (*bias* = 0.08 ± 0.20 ˚C), although shows an increasing trend by 0.07 ˚C/ decade, which can nearly three times larger in the North Atlantic

   - ERI *bias*: Significantly correlated with SST climatology and increasing positive trend. Both these results contradict the typical assumption of a mean warm ERI bias falling between 0.1 ˚C and 0.3 ˚C

   - Bucket *bias*: Mean cold bias in agreement with Kent & Kaplan 2006 and no significant trend

4. Results obtained using HadISST and ESA CCI SST as a reference field show that the global and basin average SST biases agree within their uncertainty range, although regional differences in poorly sampled regions can be large

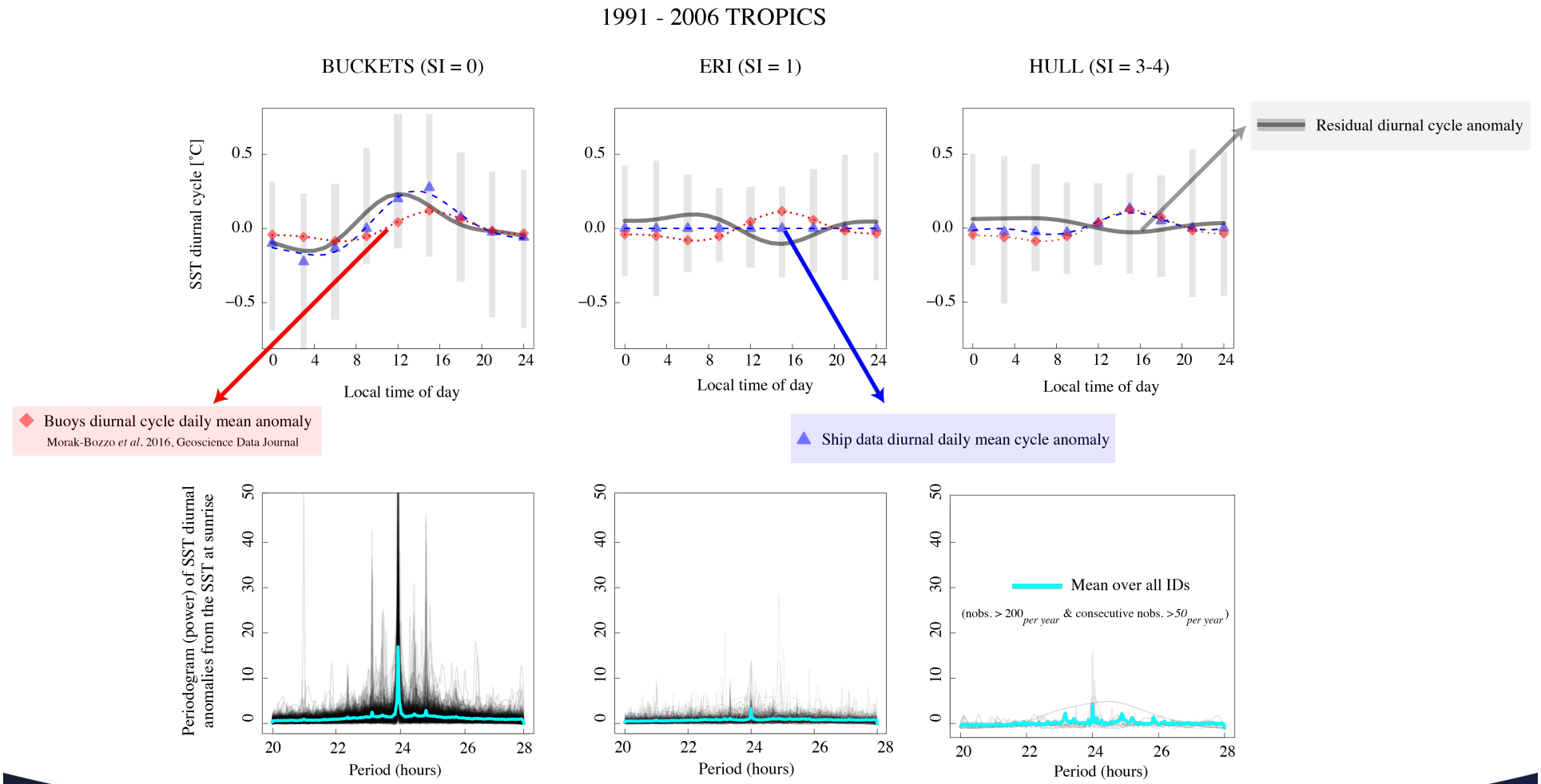
Future work

1. Extend back in time the method to assign measurement practices based on the diurnal cycle, using alternative clustering method when the country information is missing (*e.g.* decks)

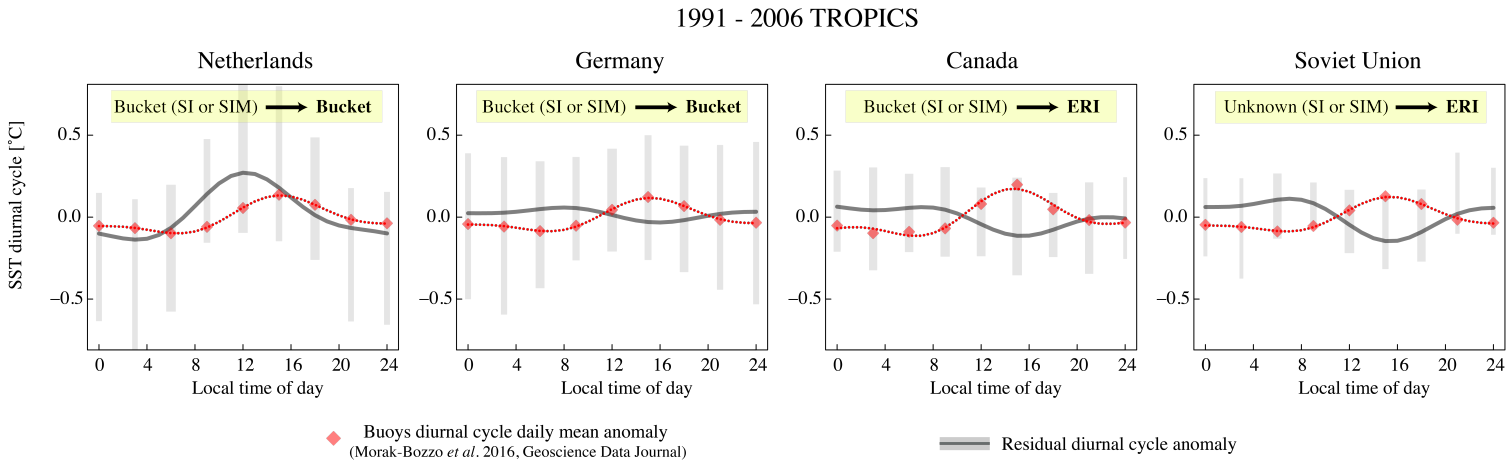
2. Include heat loss from evaporation and solar radiation heating in the SST bias model for buckets

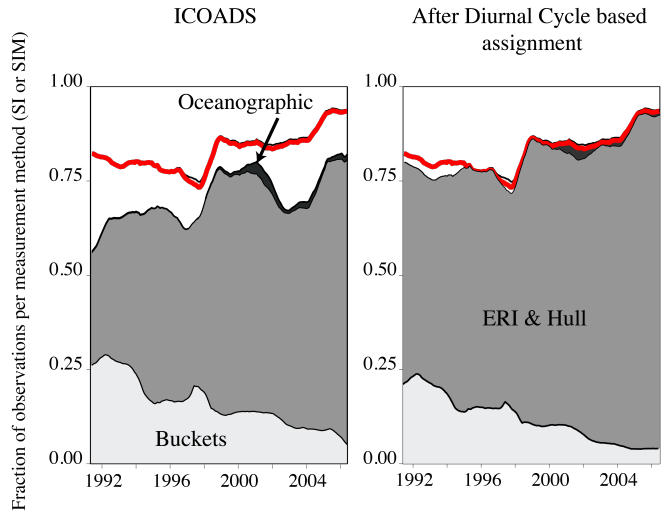
3. Explore the best method to characterize the uncertainty in the SST reference field when high quality satellite date are not available (*e.g.* ensembles of reconstructed SSTs, ocean reanalysis, HadISST with climatology normalized to ESA CCI SSTs)

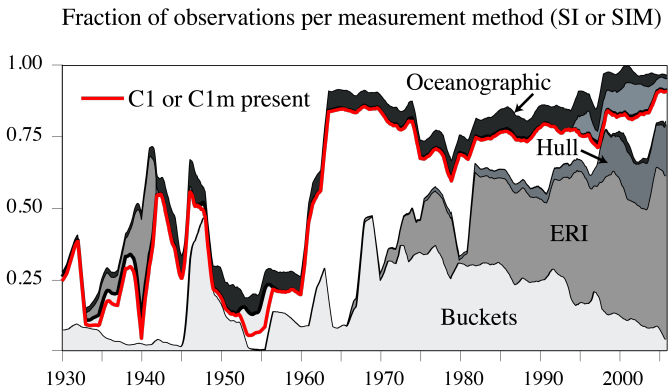
Estimating SST measurement methods using characteristic differences in the diurnal cycle



Differences in the diurnal cycle can be used to attribute a SST measurement method to groups of observations (*e.g.* country)







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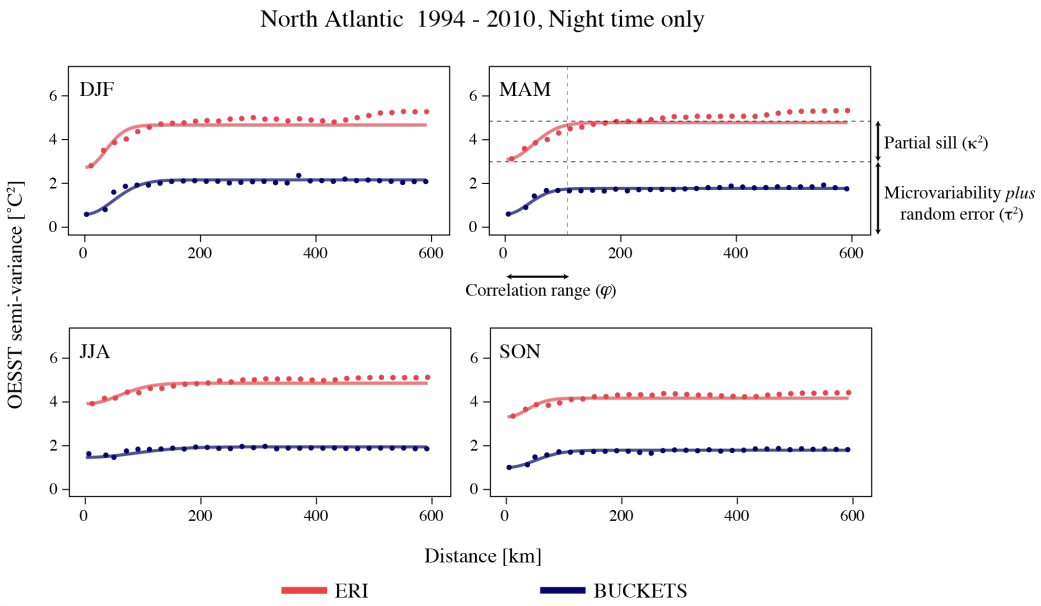
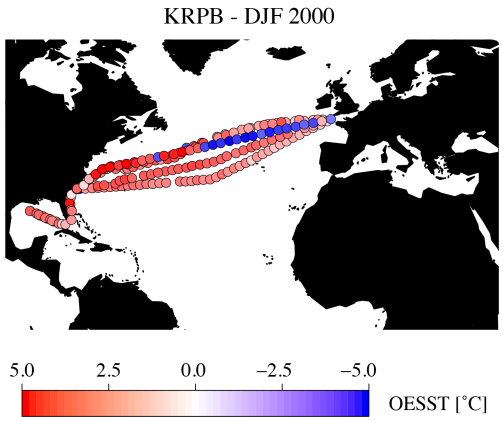
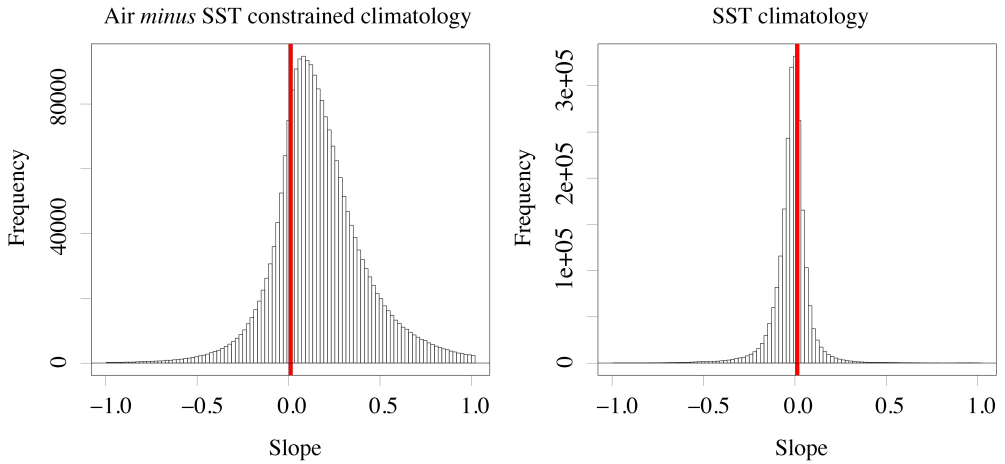


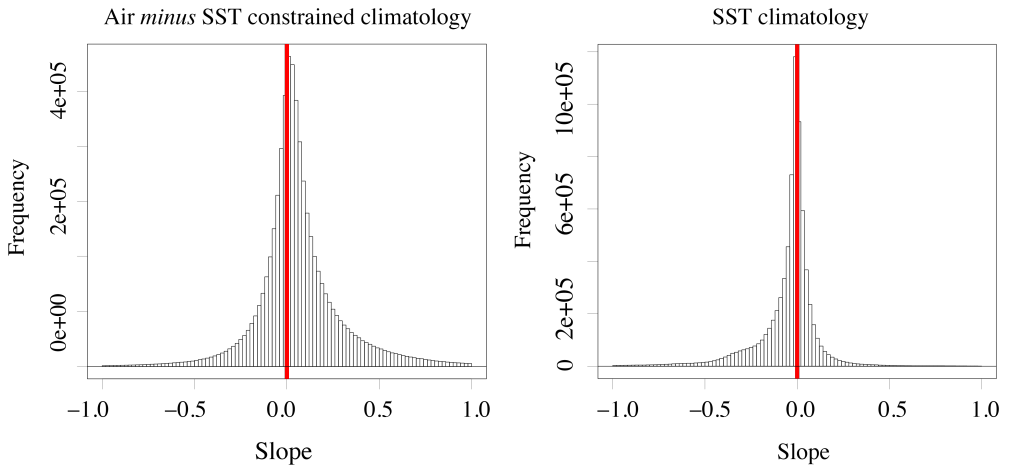


SST unconstrained *bias* coefficients 1992 - 2006
ESA CCI SST as reference

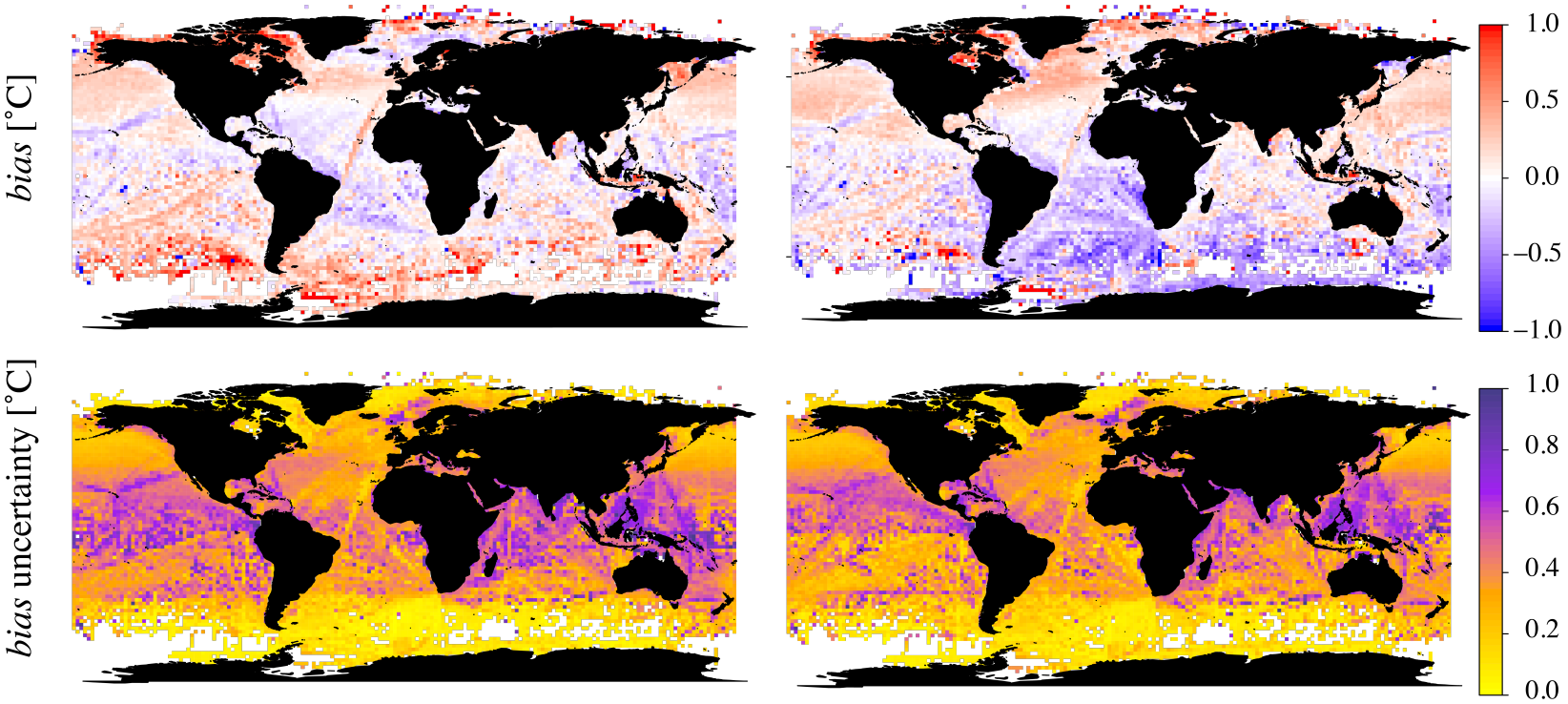
(*a*) BUCKETS (SI = 0), night time only



(*b*) ERI (SI = 1), night time only



SST estimated *bias* 1992 - 2006



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HadISST climatology *minus* ESA CCI SST climatology
1994 - 2010