



ESA Climate Change Initiative Phase-II

Sea Surface Temperature (SST)

www.esa-sst-cci.org

How uncertainties are currently presented

Chris Merchant and Nick Rayner



Overview

- What does our error model look like?
- The impact on our error model of what we do to make products
- How these uncertainties are communicated in SST CCI products
- How these uncertainties are communicated in Met Office Hadley Centre products



What does our error model look like?

- Observation = true value + errors (due to the conditions under which the measurement was made)
- Observation = true value + systematic error(s) + random error(s)
- Systematic errors can be correlated on:
 - Synoptic space and time scales
 - e.g. some components of retrieval error, bucket biases
 - Larger space and longer time scales
 - e.g. calibration errors
- Random errors can arise:
 - Per observation, e.g. radiometric noise, transcription errors, mis-reading errors, other instrument noise
 - Per instrument, e.g. systematic errors in engine room intake measurements, or buoys























Impact of what we do to create products

- Observations undergo processes to turn them into products, these result in other uncertainties
- For example:
 - Gridding leads to sampling uncertainty since grid boxes are not perfectly sampled
 - Estimation of SST_{depth} from SST_{skin} leads to an uncertainty arising from a synoptically correlated effect
 - Adjustments applied to mitigate the impact of systematic errors, e.g. bucket correction. We treat uncertainties arising from this process as systematic
 - This then leads to further uncertainties, e.g. micro biases, represented in HadSST3 as covariance matrices
 - Creating analyses:
 - If we use EOFs this results in a systematic uncertainty
 - A local OI results in a locally correlated uncertainty
 - SST CCI analysis uncertainties not presently decomposed into systematic and random effects
 - Quality control could lead to systematic errors, e.g. cut-offs at freezing point
 - Inter-satellite harmonisation reduces relative errors between sensors, but leave a residual uncertainty (systematic effect)























How these uncertainties are communicated in SST CCI products

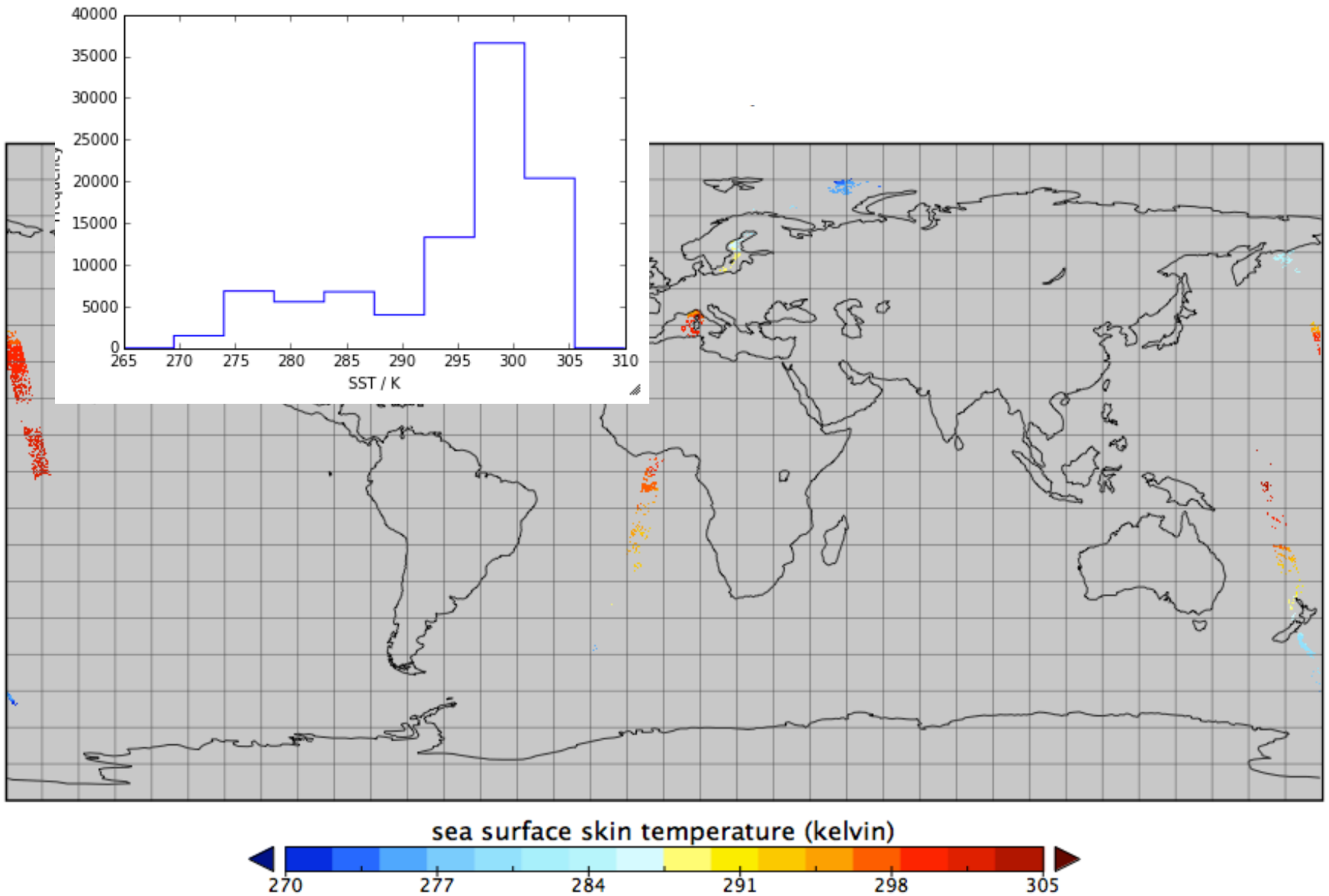
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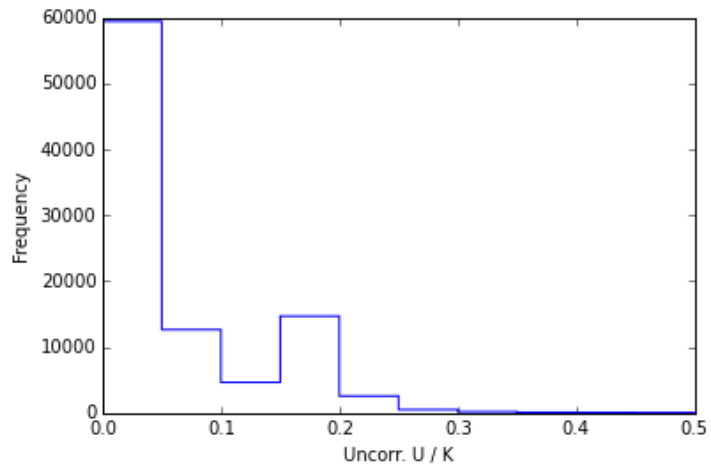


How these uncertainties are communicated in SST CCI products





















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'Noise' in SST

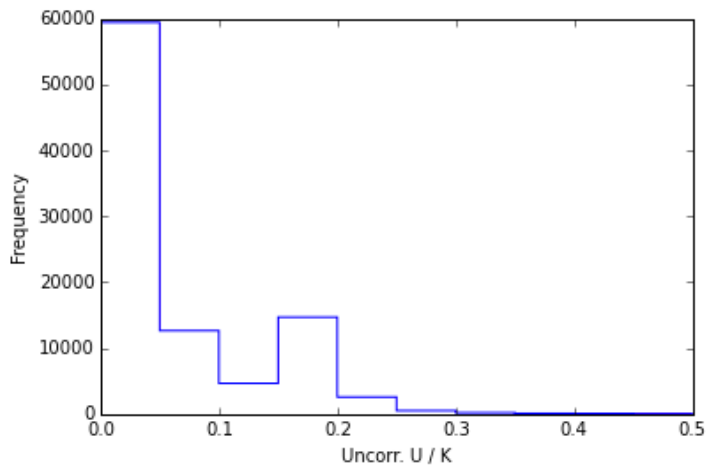


How these uncertainties are communicated in SST CCI products

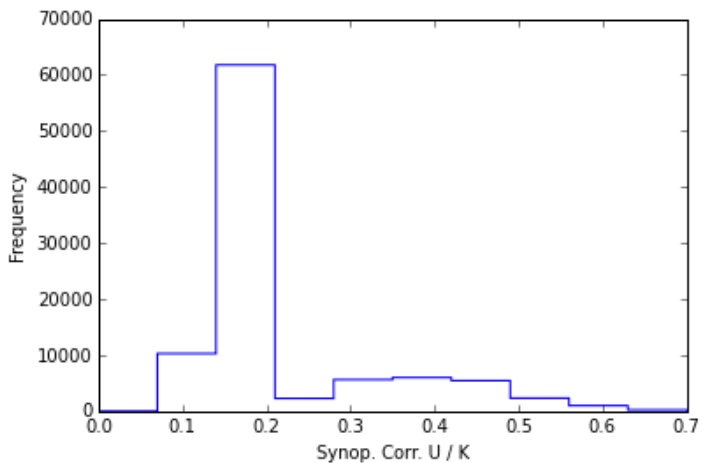
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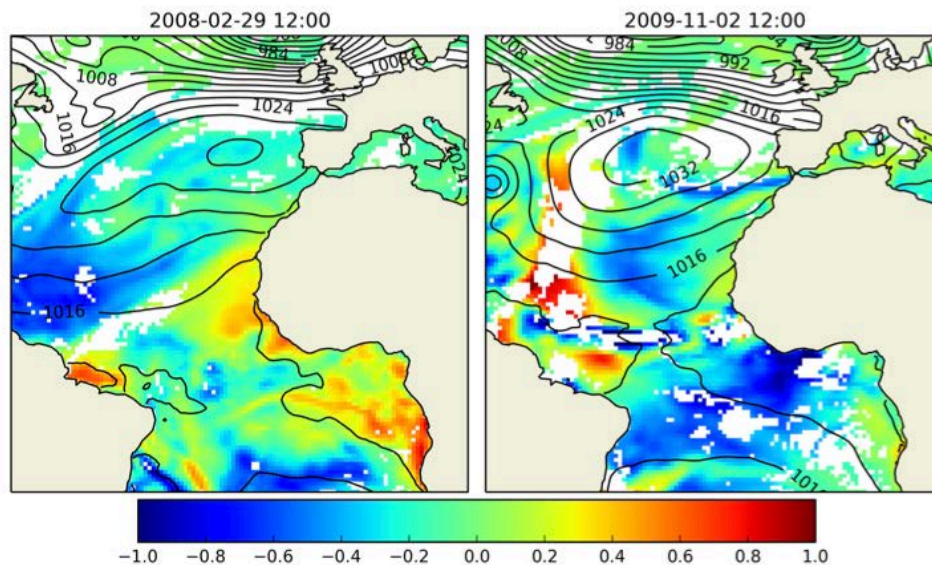
'Noise' in SST (uncorrelated)



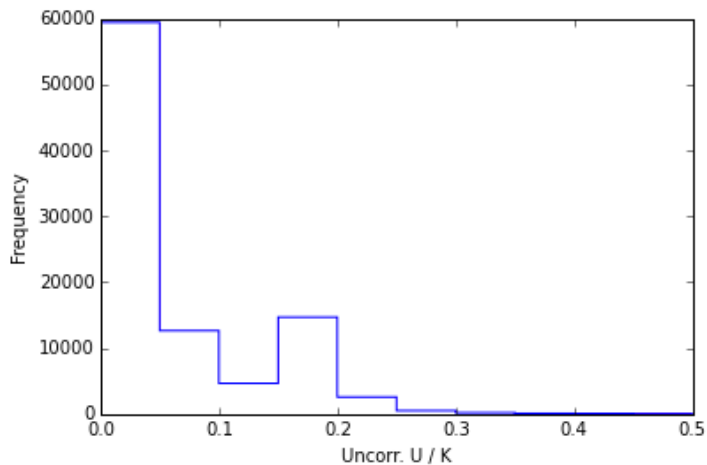
Limitations of algorithm (synop. corr.)



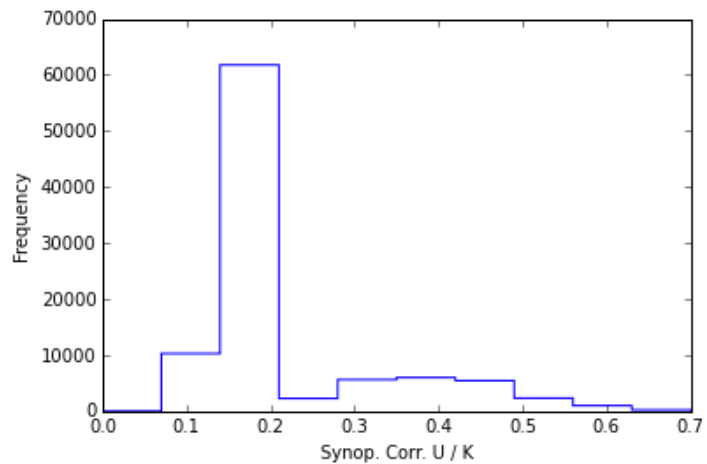
Optical Radiometry for Ocean Climate Measurements (EMPS Vol 47) Chapter 4.3



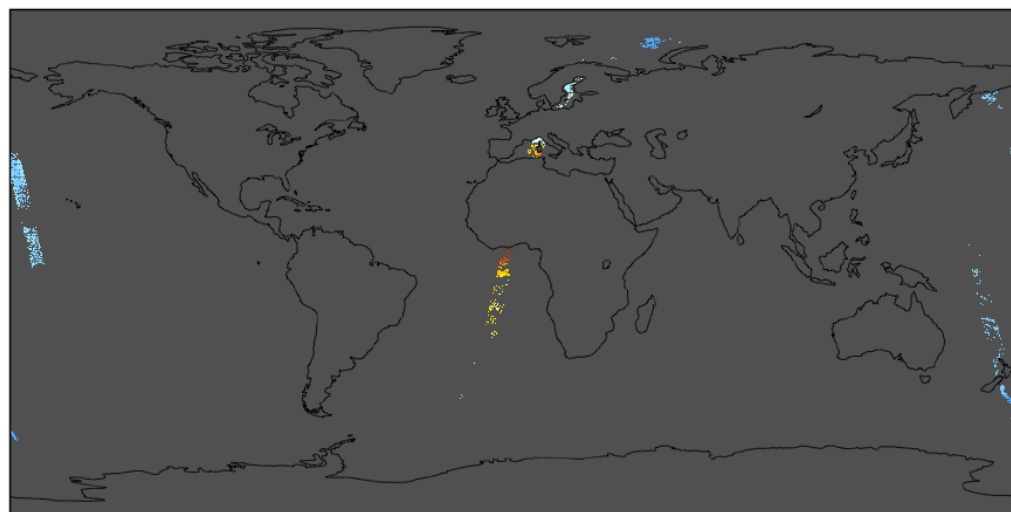
'Noise' in SST (uncorrelated)



Limitations of algorithm (synop. corr.)



Uncertainty from errors likely to be correlated over synoptic scales























Uncertainty from errors likely to be correlated over synoptic scales (kelvin)

0 0.14 0.28 0.42 0.56 0.7

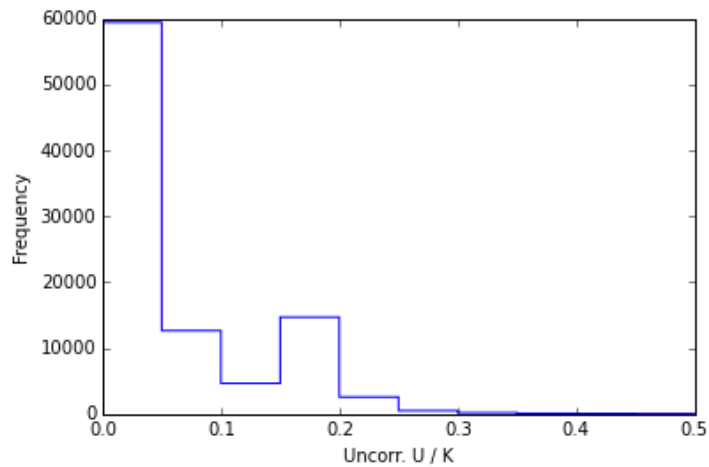
Data Min = 0.1, Max = 0.69

How these uncertainties are communicated in SST CCI products

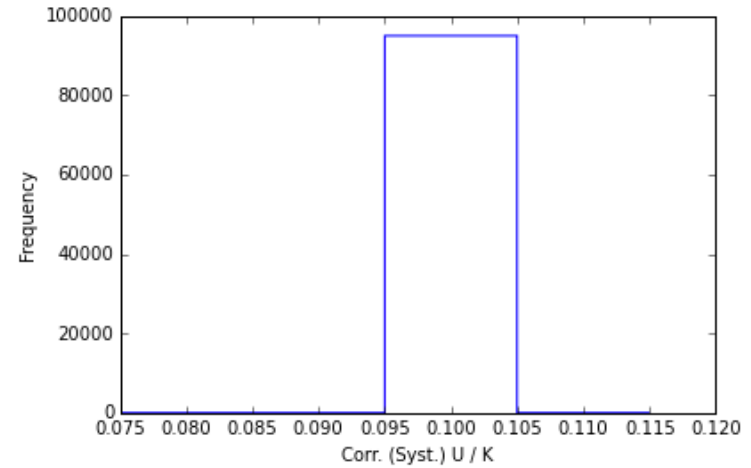
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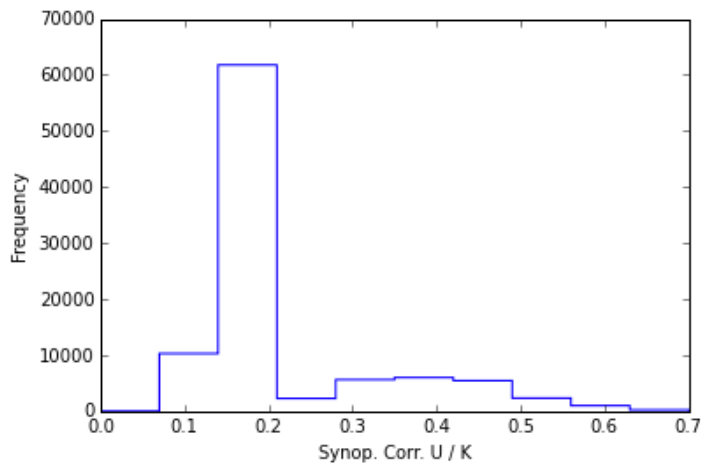
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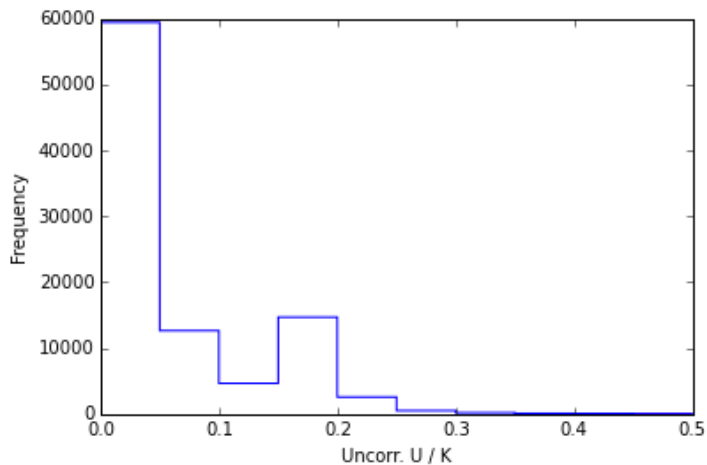
Systematic (large scale correlated)



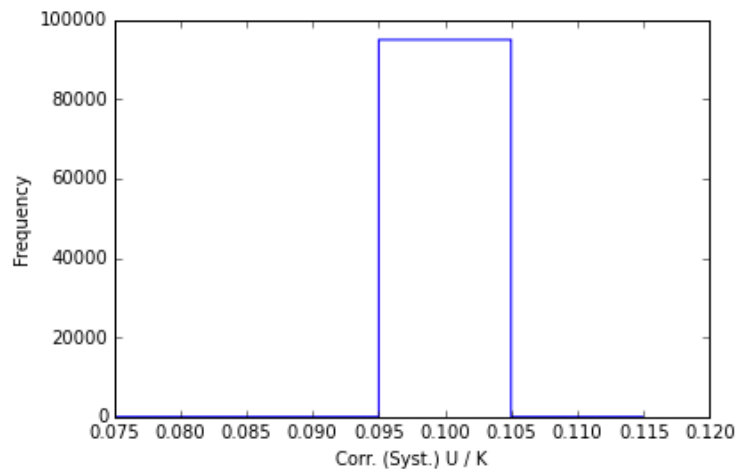
Limitations of algorithm (synop. corr.)



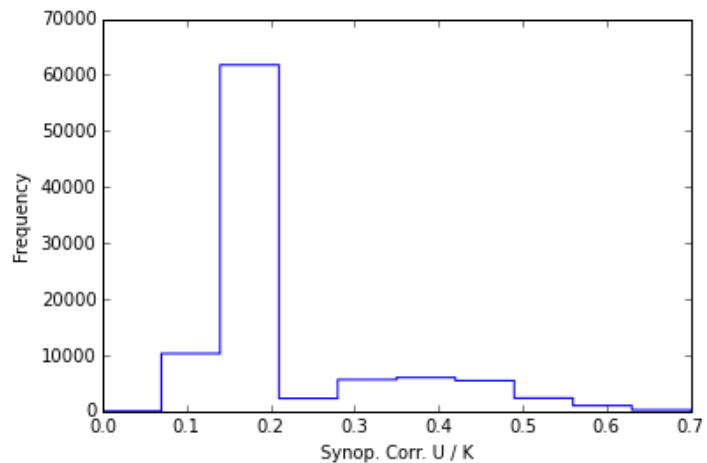
'Noise' in SST (uncorrelated)



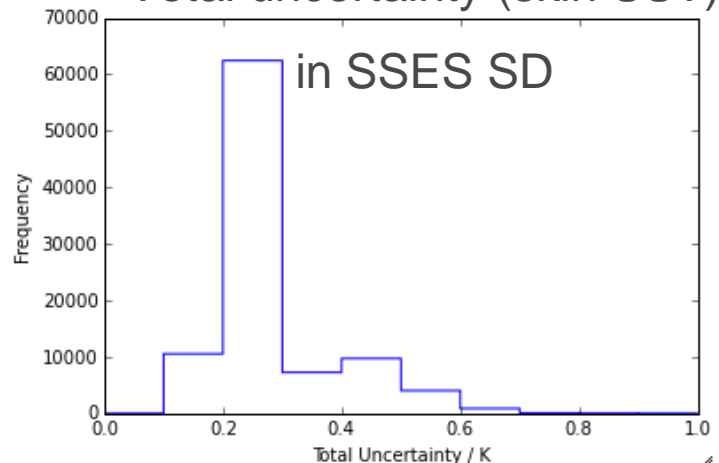
Systematic (large scale correlated)























Limitations of algorithm (synop. corr.)



Total uncertainty (skin SST)























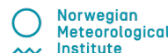
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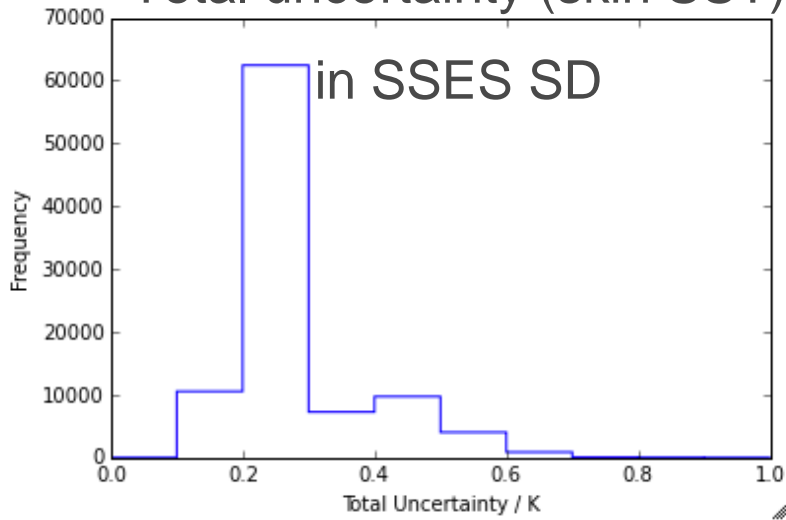


How these uncertainties are communicated in SST CCI products

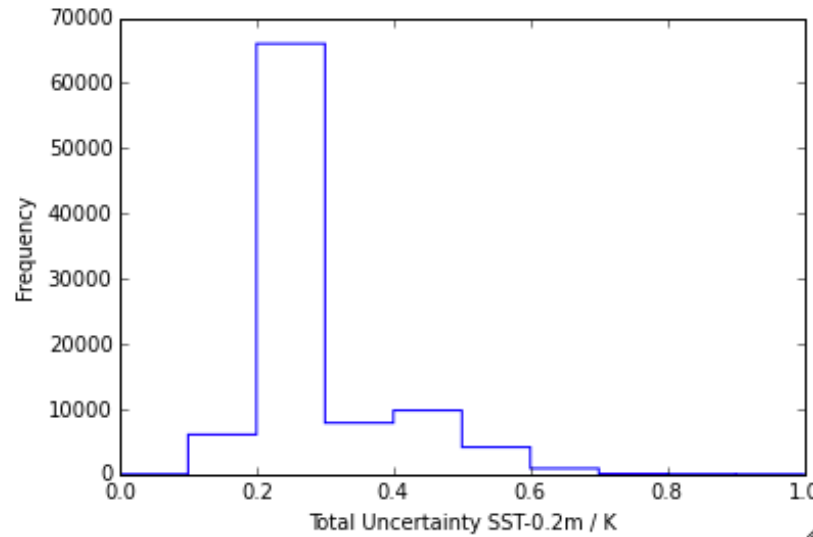
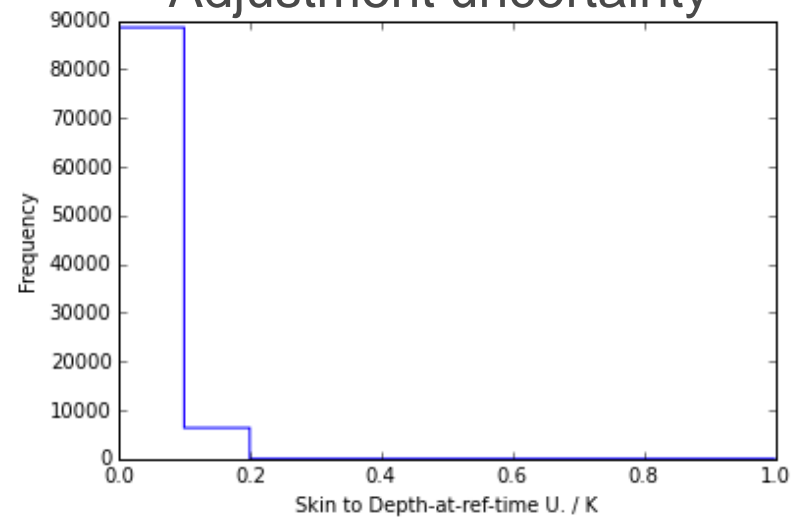
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Total uncertainty (skin SST)



Adjustment uncertainty



Total uncertainty in SST_{0.2 m}



How these uncertainties are communicated in SST CCI products– SST CCI analysis (L4)

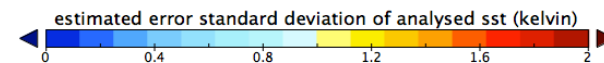
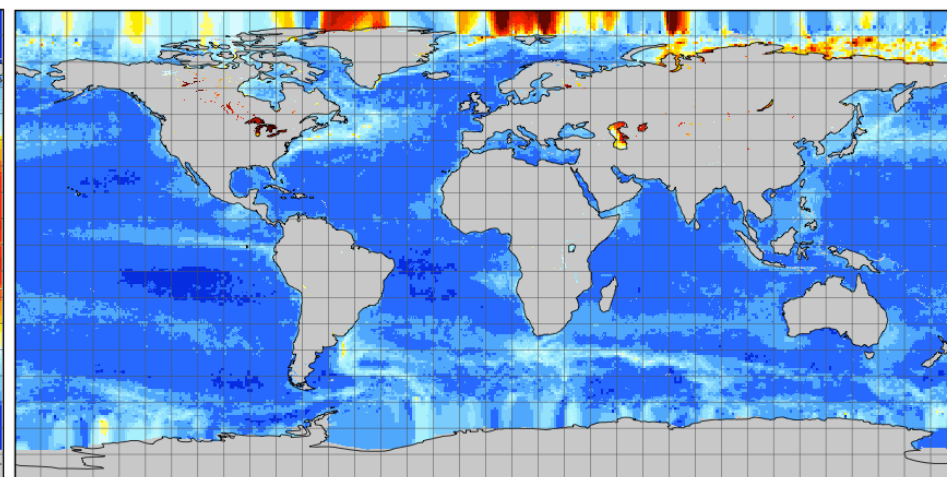
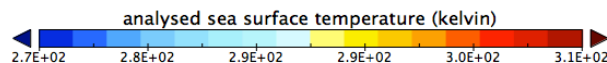
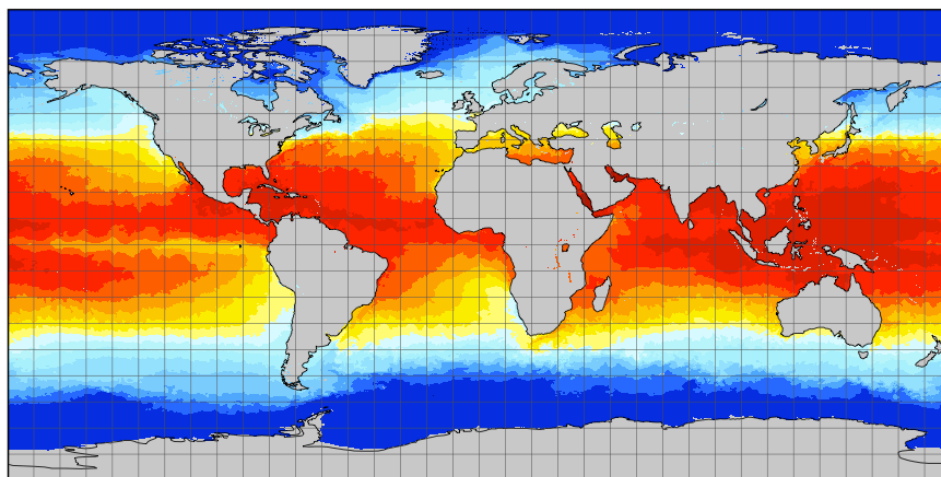
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analysis_error	estimated error standard deviation of a...	[lon][lat]
lat	Latitude	—
lat_bnds	Latitude cell boundaries	—
lon	Longitude	—
lon_bnds	Longitude cell boundaries	—
mask	sea/land/lake/ice field composite mask	[lon][lat]
sea_ice_fraction	sea ice area fraction	[lon][lat]
sea_ice_fraction_error	sea ice area fraction error estimate	[lon][lat]
time	reference time of sst file	—
time_bnds	Time cell boundaries	—

No indication given of the correlation structure or error in product

This is the total uncertainty – not an error estimate

analysed sea surface temperature

estimated error standard deviation of analysed sst



How these uncertainties are communicated in SST CCI products – KEY MESSAGES 1

- Calculate and propagate uncertainties from three classes of effects, classified according to their spatio-temporal correlation properties
- Classes are
 - Random : no correlation between SSTs : “uncorrelated_uncertainty”
 - noise in radiances + sub-sampling errors in case of L3
 - Locally systematic : likely correlation on atmospheric scales : “synoptically_correlated_uncertainty”
 - inverse / algorithmic errors + skin-to-depth-adjustment errors
 - Systematic : correlation across large scales : “large_scale_correlated_uncertainty”
 - calibration + bias in inverse (e.g., from radiative transfer physics)
- Total uncertainties are provided
 - but still using (what we think are) poor “community standard” names for these
 - “ssea_standard_deviation” for skin SST in L2 and L3 products
 - “sst_analysis_error” in L4
- Some components of uncertainty are still “work in progress” in terms of quantitative content



How these uncertainties are currently communicated in Met Office Hadley Centre products

- Since the correlation structure of uncertainties in SST is not simple, we try to embed these uncertainties into ensembles of interchangeable realisations of SST data sets
- We hope that by doing this, users can easily use the ensembles to assess the impact of these uncertainties on their applications, e.g. by rerunning their applications multiple times with different ensemble members



Ensemble of gridded measurements made in situ

- HadSST3 data set is a gridded ensemble of 100 interchangeable realisations
- These realisations arise from uncertainties in the specification of corrections applied to the measurement to mitigate the impact of changes in measurement method through time



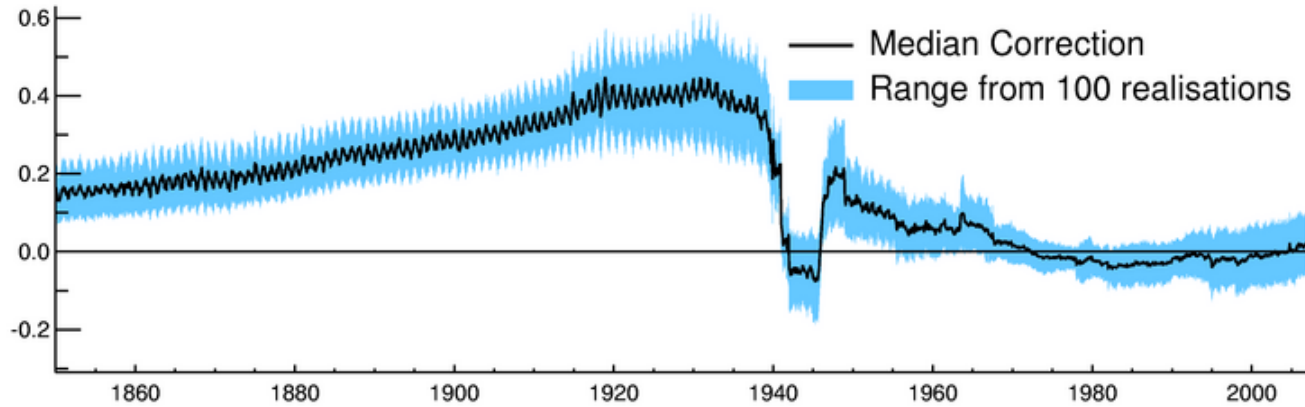
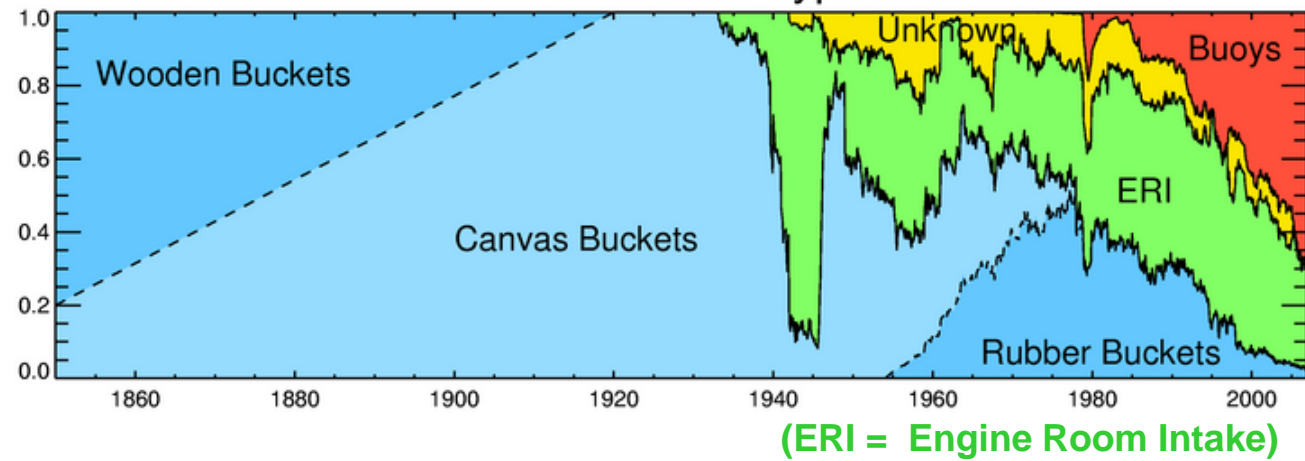


Contribution (fraction) of each measurement method

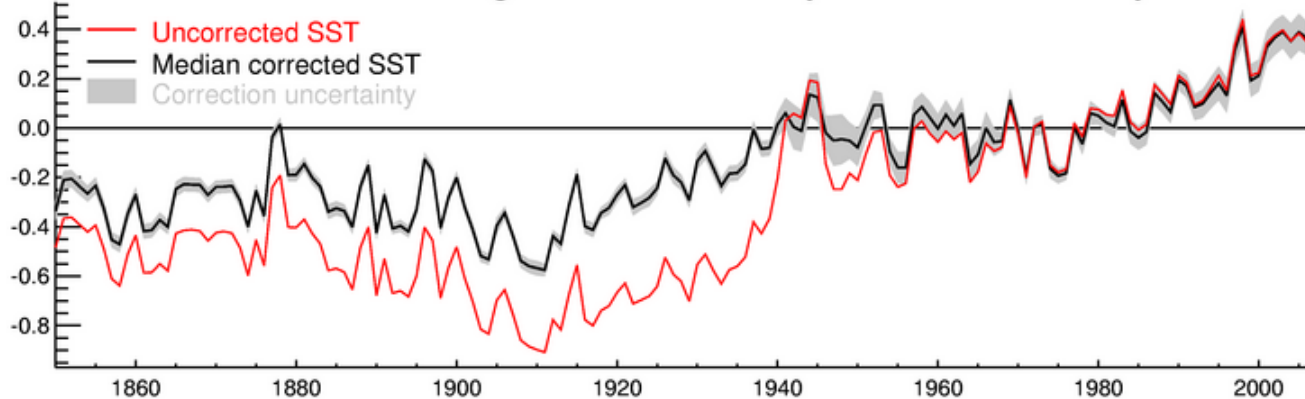
Monthly bias corrections from 100 realisations

Global average annual SST timeseries

Fraction of Measurements from each Type in ICOADS



Corrected Global-Average SST Anomaly and Uncertainty



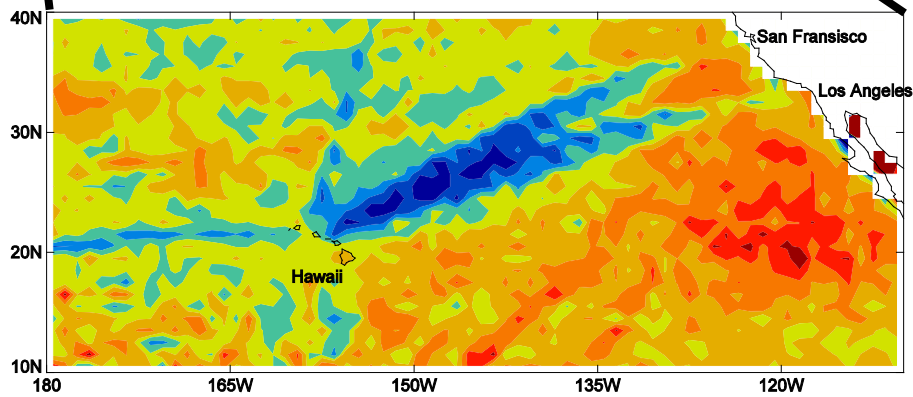
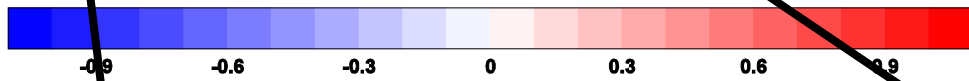
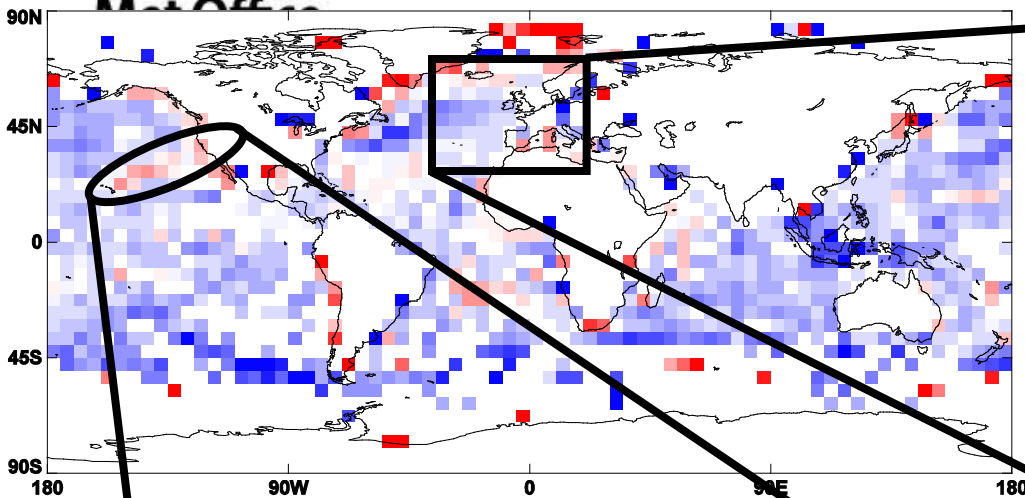
Ensemble of gridded measurements made in situ

- HadSST3 data set is a gridded ensemble of 100 interchangeable realisations
- These realisations arise from uncertainties in the specification of corrections applied to the measurement to mitigate the impact of changes in measurement method through time
- But not all uncertainties are encapsulated in this ensemble – some are provided as covariance matrices

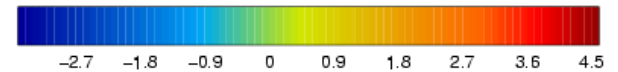
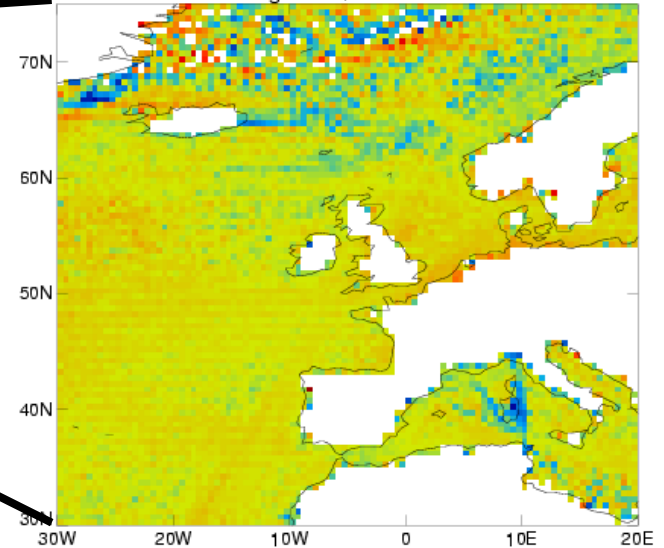




Localised persistent ship biases



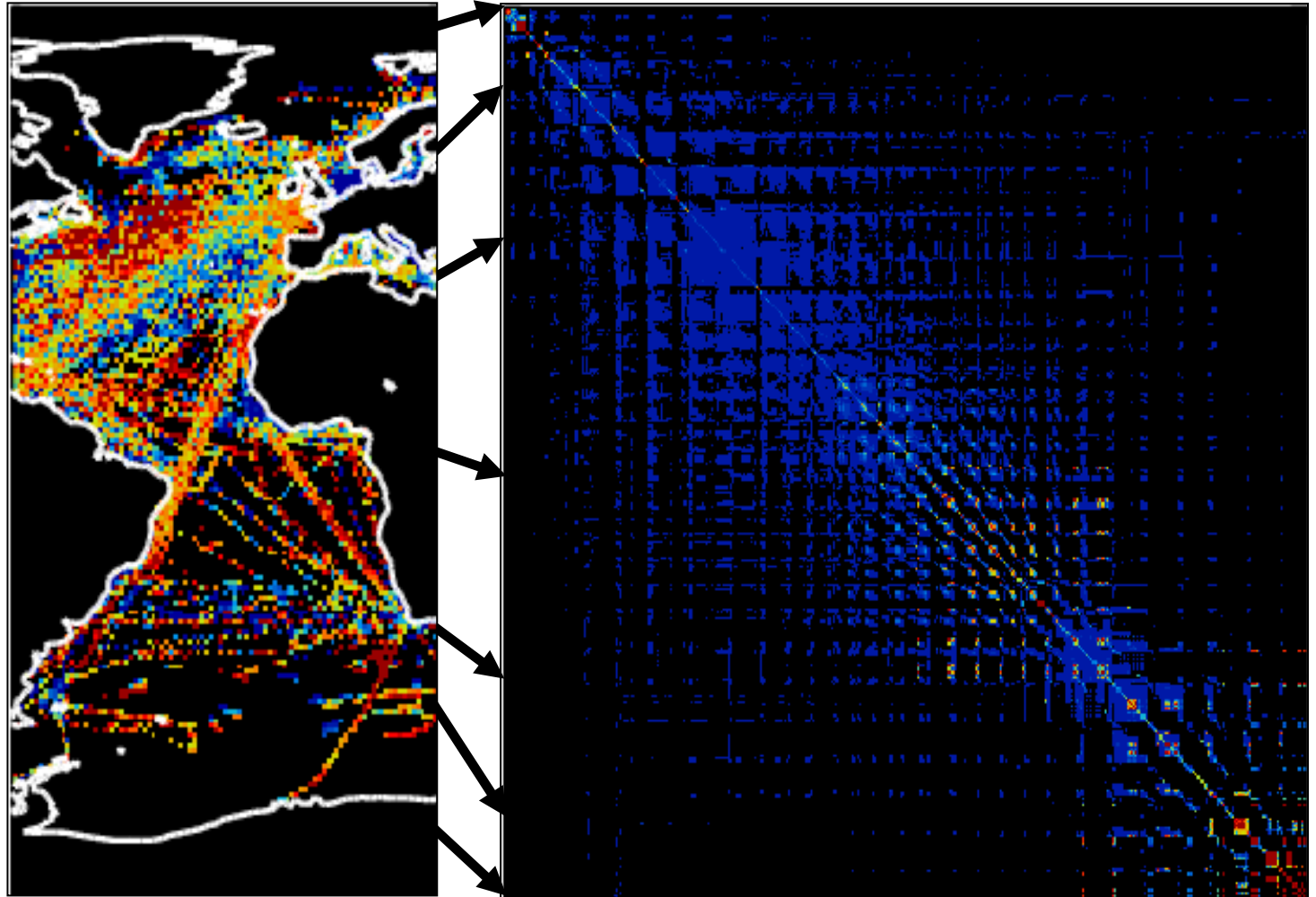
Avg SST 1997-2004



Long term averages highlight ship biases.

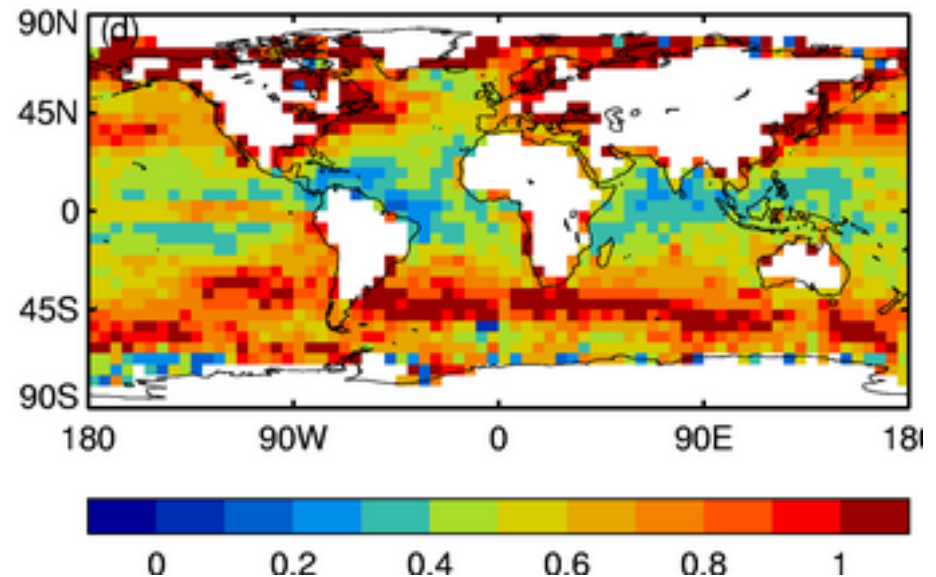
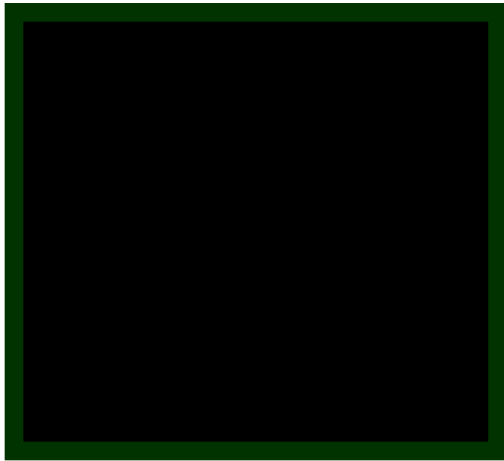
Large local biases due to ERI measurements.

“Micro-biases” (errors due to systematic effects in individual ships’ measurements) are represented in HadSST3 as error covariance matrices



Covariance matrices also include uncertainties due to under-sampling

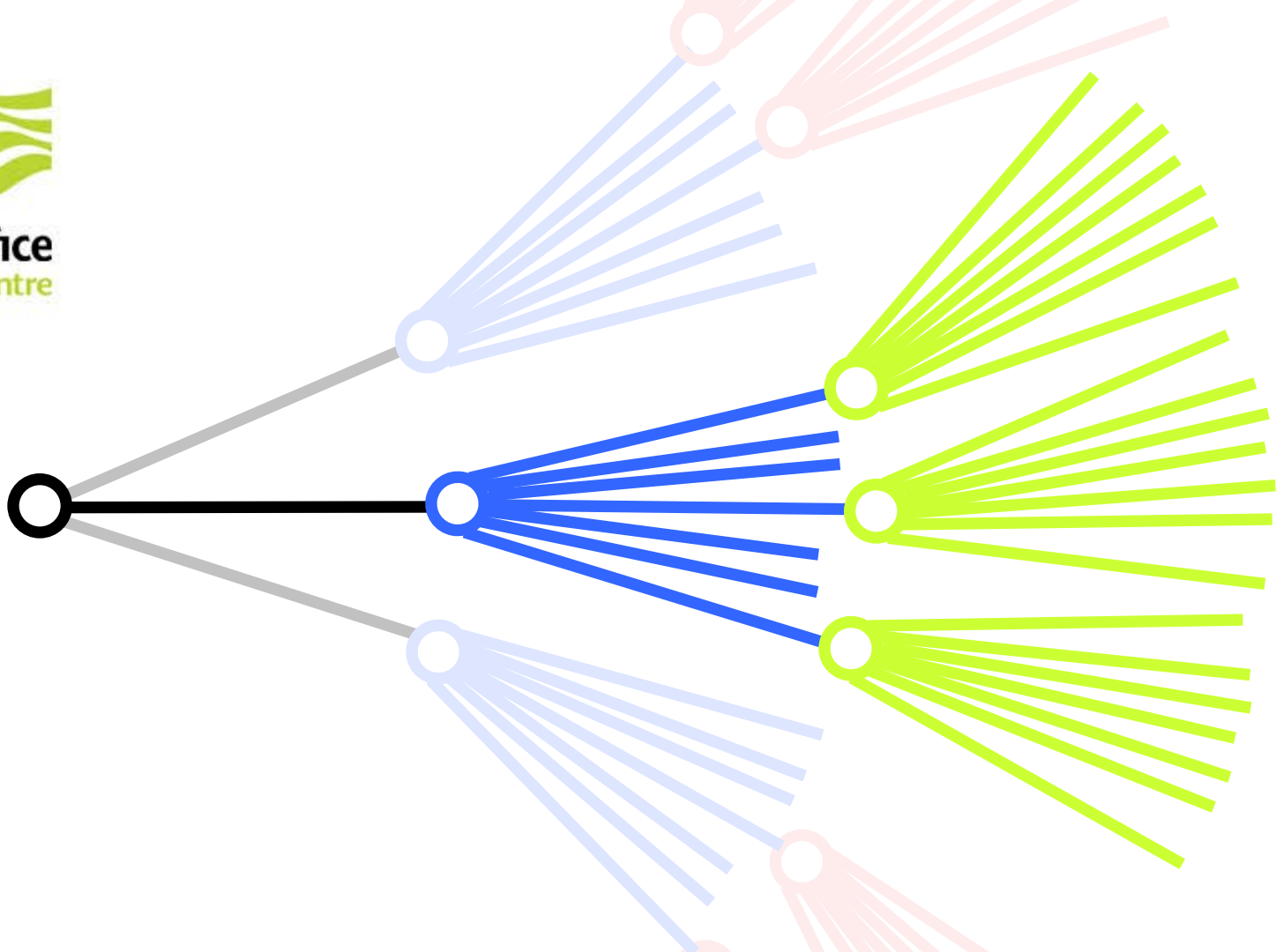
- This is larger in high variability regions



Further ensembles – analysis uncertainty

- HadISST.2.1.0.0 is an ensemble of globally complete fields based on measurements made in situ and satellite retrievals
- Its ensemble is based on that of HadSST3, but also includes uncertainties arising from the analysis techniques used, i.e. vBPCA and OI





**Parametric
uncertainty**

In situ bias adjustment;
number of EOFs used

**Analysis
uncertainty**

Large-scale
reconstruction

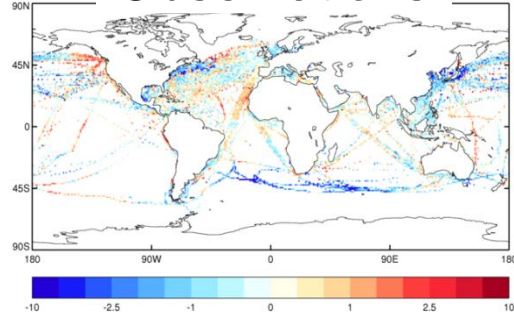
**Analysis
uncertainty**

Local reconstruction

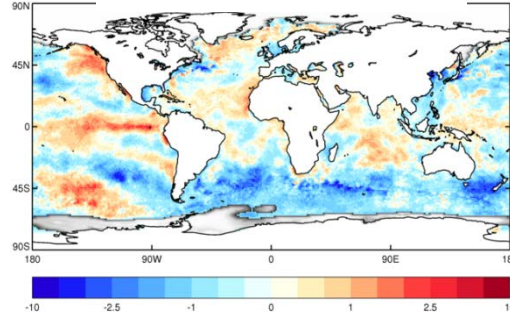


SST anomaly ensemble, January 1926

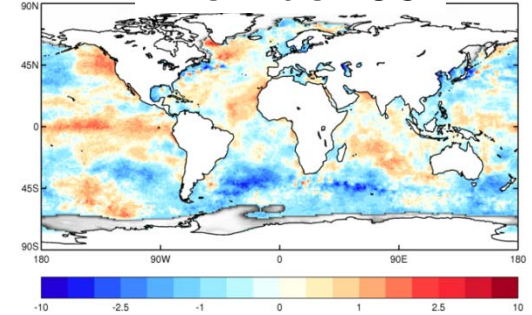
Observations



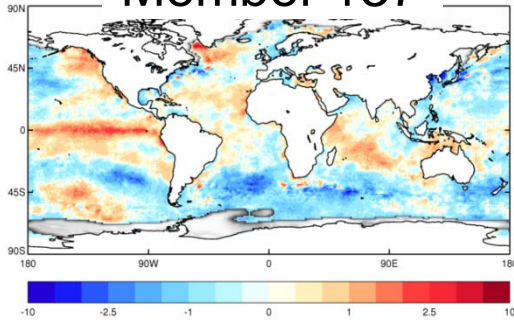
Member 1466



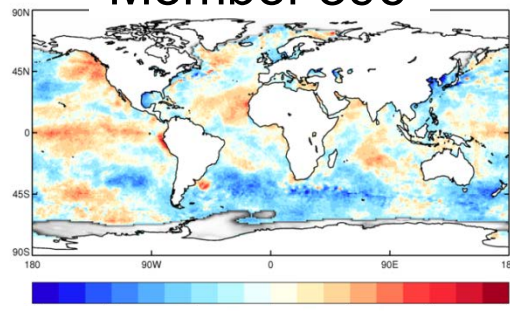
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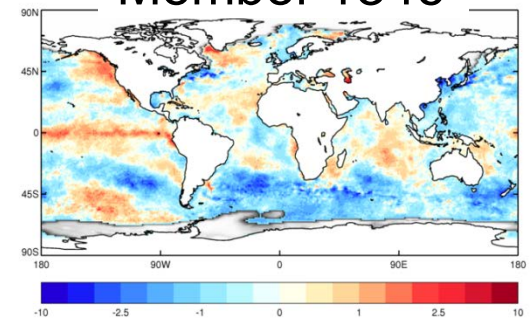
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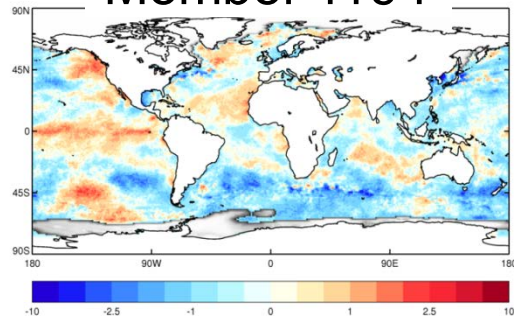
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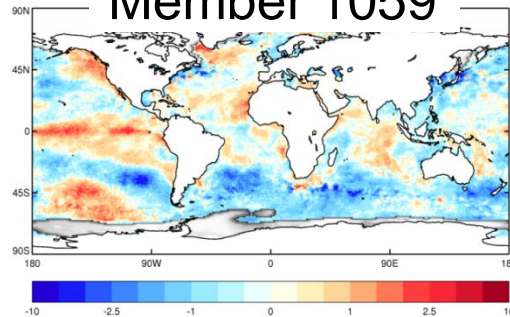
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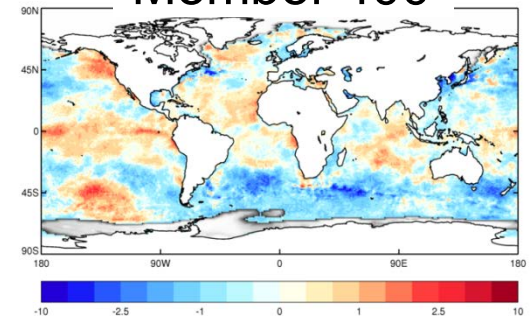
Member 1194



Member 1059



Member 400



-10 -2.5 -1 0 1 2.5 10

Further ensembles – analysis uncertainty

- HadISST.2.1.0.0 is an ensemble of globally complete fields based on measurements made in situ and satellite retrievals
- Its ensemble is based on that of HadSST3, but also includes uncertainties arising from the analysis techniques used, i.e. vBPCA and OI
- This can be used to force an ensemble of atmospheric model simulations, dynamic reanalyses, etc, allowing users to directly explore the impact of SST uncertainties in their applications



Summary

- Uncertainties in SST measurements and analyses are complicated and have different correlations in space and time
- We need to understand how to better represent these to allow users to assess their impact on their applications

