Stability Assessment of Satellite Sea Surface Temperature Estimates Using the Penalized Maximal t-Test

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Outline

- Background
- Homogeneity testing
- Results from the (A)ATSR Reprocessing for Climate (ARC) project
- Results from the ESA SST CCI project
- Summary

Background

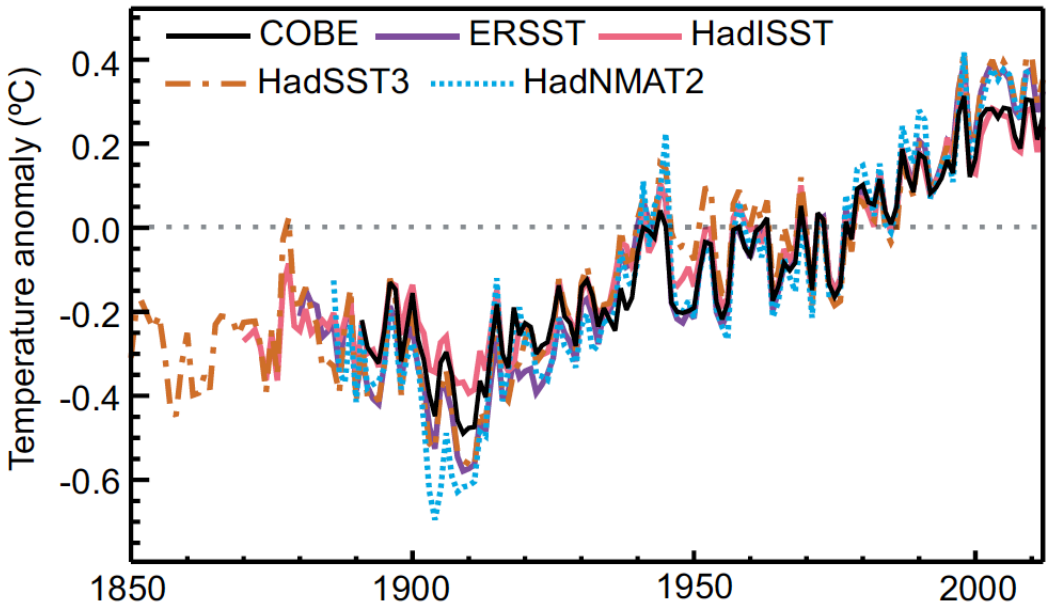
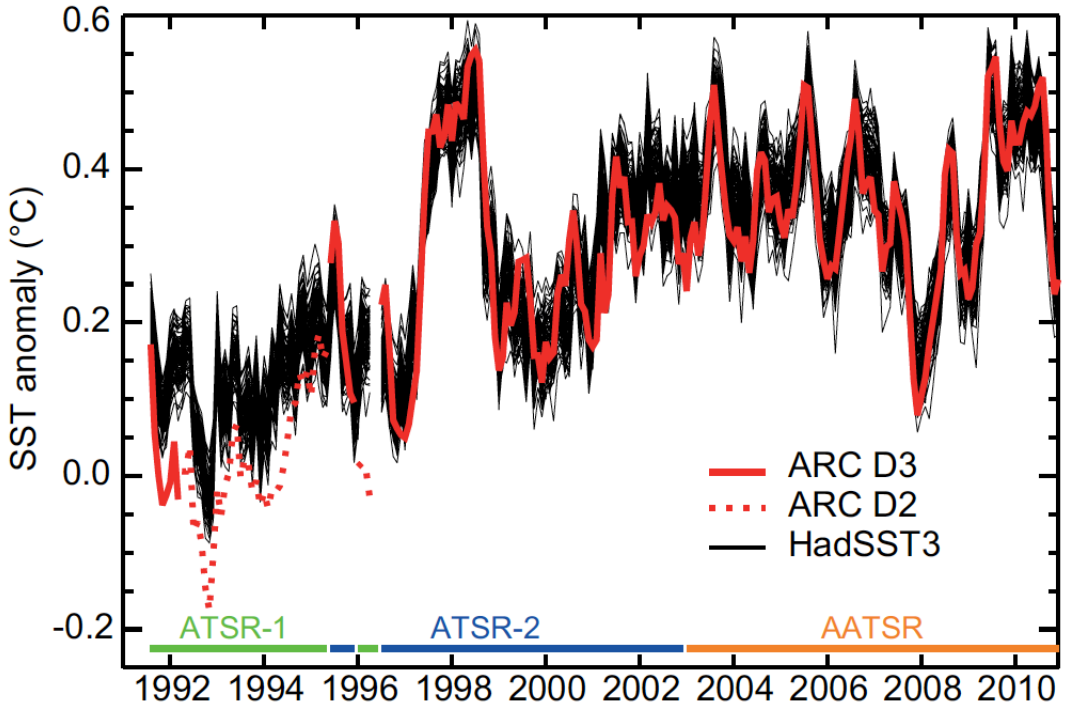


Figure 2.18 | Global annual average sea surface temperature (SST) and Night Marine Air Temperature (NMAT) relative to a 1961–1990 climatology from state of the art data sets. Spatially interpolated products are shown by solid lines; non-interpolated products by dashed lines.

IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

Background



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Standard Normal Homogeneity Test (SNHT) (Alexandersson 1986)

Test for step changes / inhomogeneity in time series.

Developed for precipitation data and ratio between the target series and nearby stations.

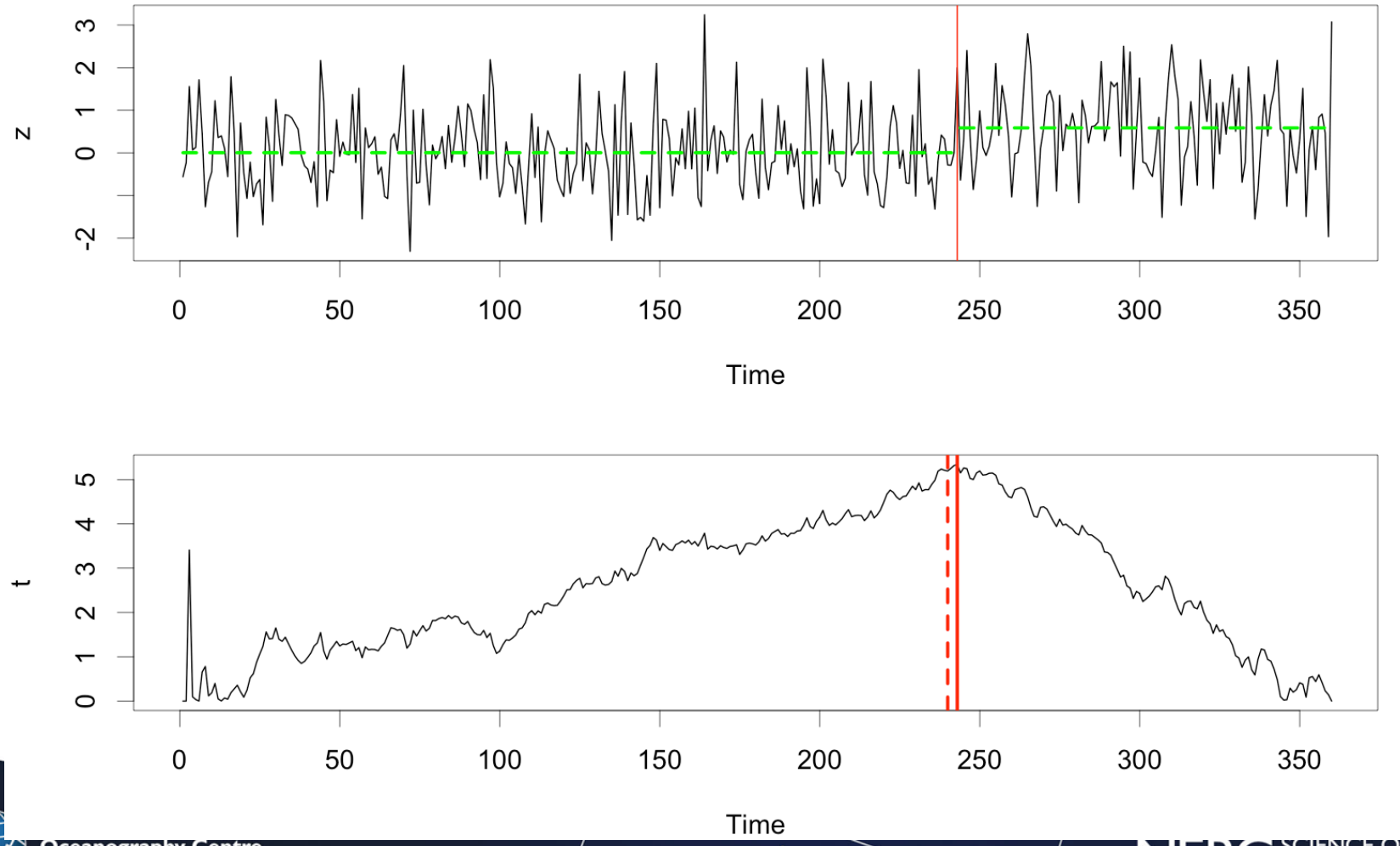
Time series normalised and then each possible break point tested using a test based on the T test.

Breakpoint that maximises test statistic most likely break point.

If greater than critical value (empirically determined) process repeated for each segment until no more breakpoints found.

SNHT example

SNHT example



Penalized Maximal t Test (PMT)

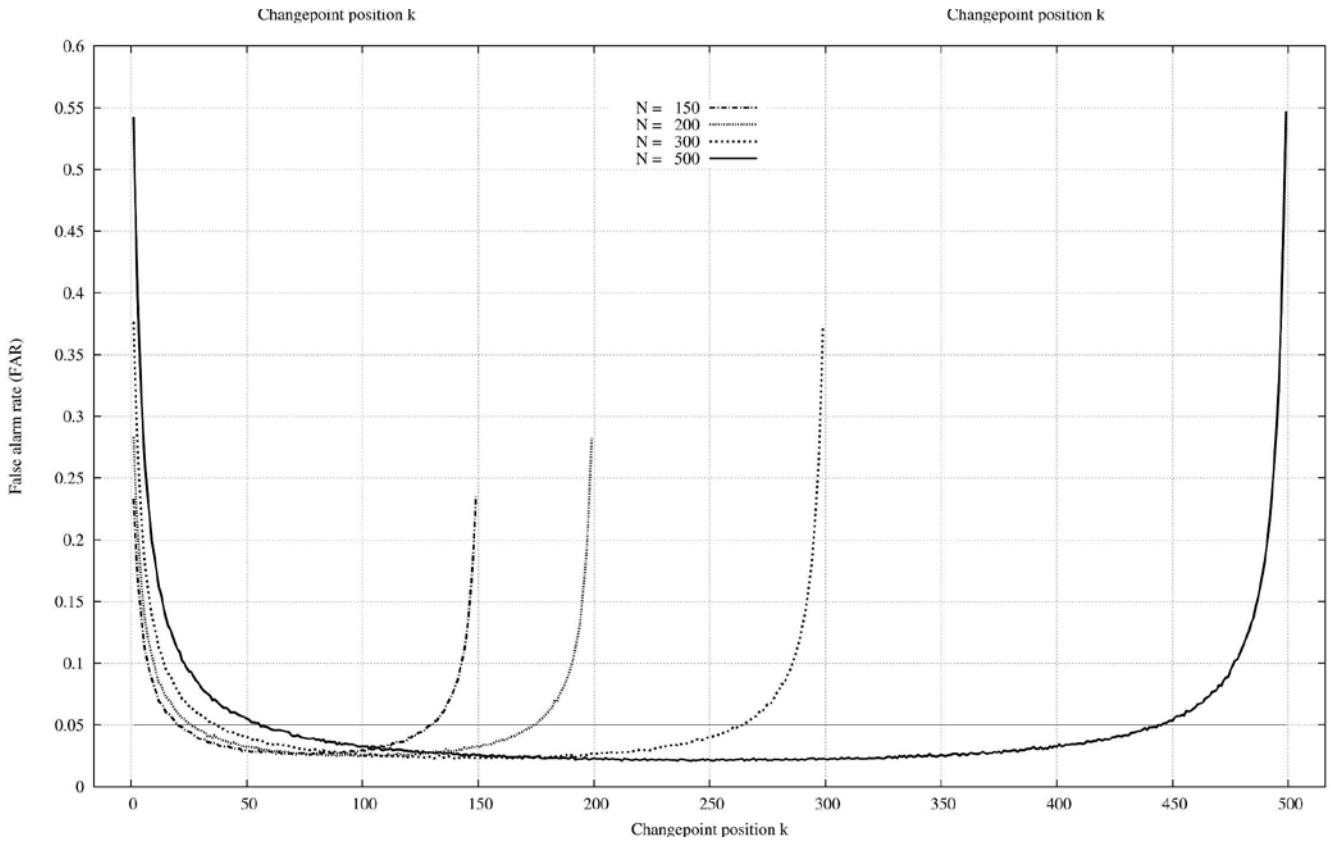
The SNHT, and other tests based on the t test, have an increased false alarm rate (FAR) towards the ends of time series.

This occurs due to the tests being applied to two samples with very different sizes.

The Penalized Maximal t Test (PMT, Wang et al., 2007) corrects for this through empirically modelling the FAR for series of different lengths

Software (RHTest) made available through the joint CCl / CLIVAR / JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI) website

Penalized Maximal t Test (PMT)



Wang, X. L., Q. H. Wen and Y. Wu, 2007: Penalized Maximal t Test for detecting undocumented mean change in climate data series. Journal of Applied Meteorology and Climatology, 46, 916 – 931, DOI: 10.1175/JAM2504.1.

(A)ATSR Reprocessing for Climate (ARC)

ARC project sought to create a climate quality dataset that was independent from the in situ record (consistency between sensors << 0.1°C, artificial trends < 0.05°C/decade).

Individual channels cross calibrated between sensors during overlap periods

Independence from in situ by retrieving SST through full radiative transfer modeling

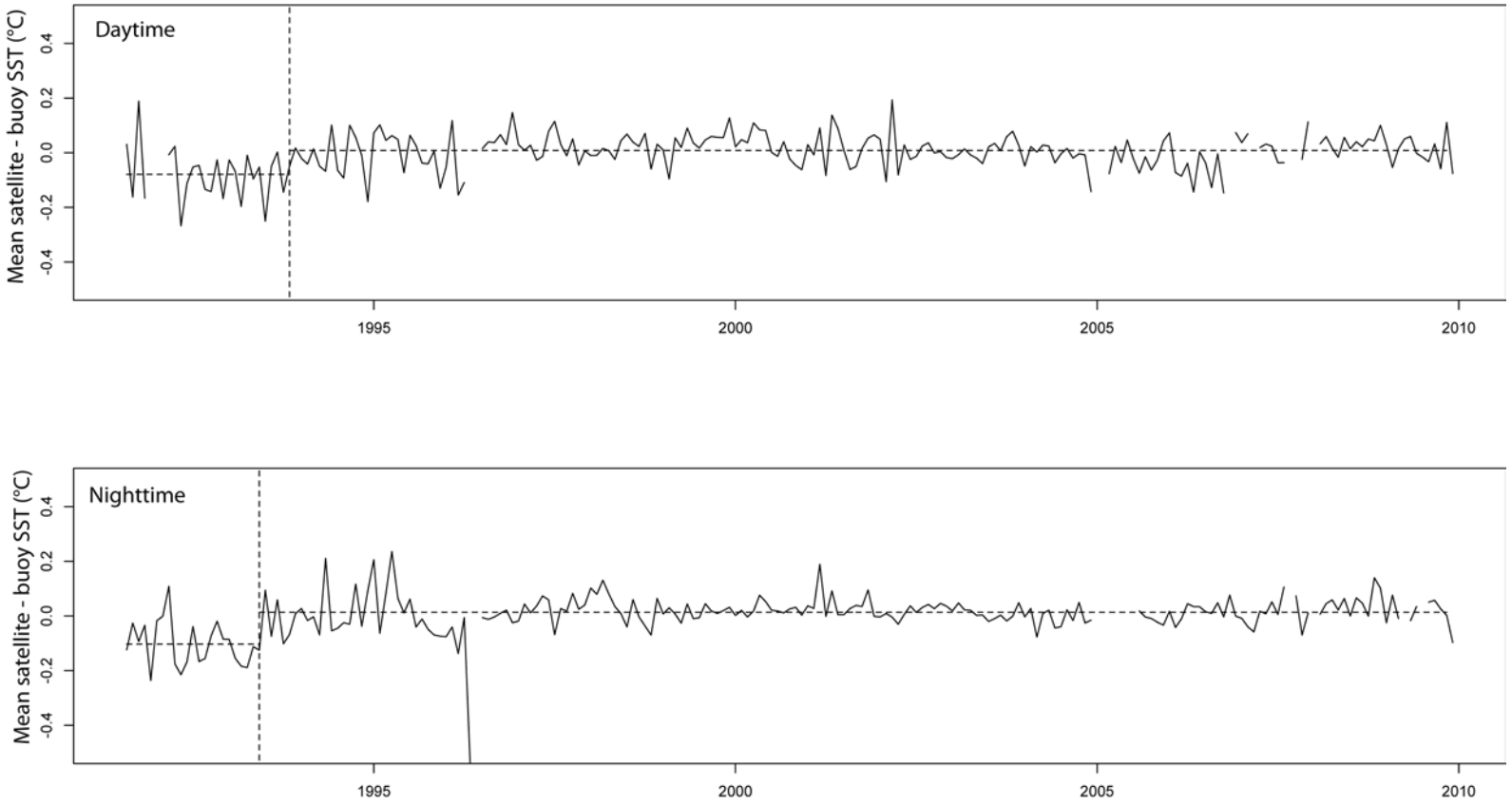
Retrievals adjusted to common overpass time (1030 am/pm), skin and bulk estimated

To assess stability, match-up of (A)ATSR data in tropics to GTMBA SST observations

Composite monthly mean time series created. Impact of errors minimised and sensitivity increased by averaging, error variance in time managed through restricting to only buoys that span full record.

PMT applied to mean difference

(A)ATSR Reprocessing for Climate (ARC)



(A)ATSR Reprocessing for Climate (ARC)

Region	Period	Time of day	Trend (°C decade^{-1})	95% confidence interval (°C decade^{-1})
Tropics	*All (1991 - 2009)*	*Day*	*0.026*	*0.006 < trend < 0.045*
Tropics	*All (1991 - 2009)*	*Night*	*0.044*	*0.020 < trend < 0.069*
Tropics	> 1993	Day	-0.006	-0.026 < trend < 0.015
Tropics	> 1993	Night	0.010	-0.014 < trend < 0.034
Tropics	ATSR2/AATSR	Day	-0.014	-0.037 < trend < 0.009
Tropics	ATSR2/AATSR	Night	-0.002	-0.020 < trend < 0.016

ESA SST CCI

- ARC project (A)ATSR only, ESA project expands this to AVHRR and (A)ATSR sensors.
- Same approach taken:
  - cross calibration of channels during overlap periods
  - RTM used to estimate skin temperature
  - adjustment to 1030 am/pm local time
- Drift in overpass time for NOAA/NASA satellites, AVHRR single view
- RTM dependent on atmospheric profiles from reanalysis model

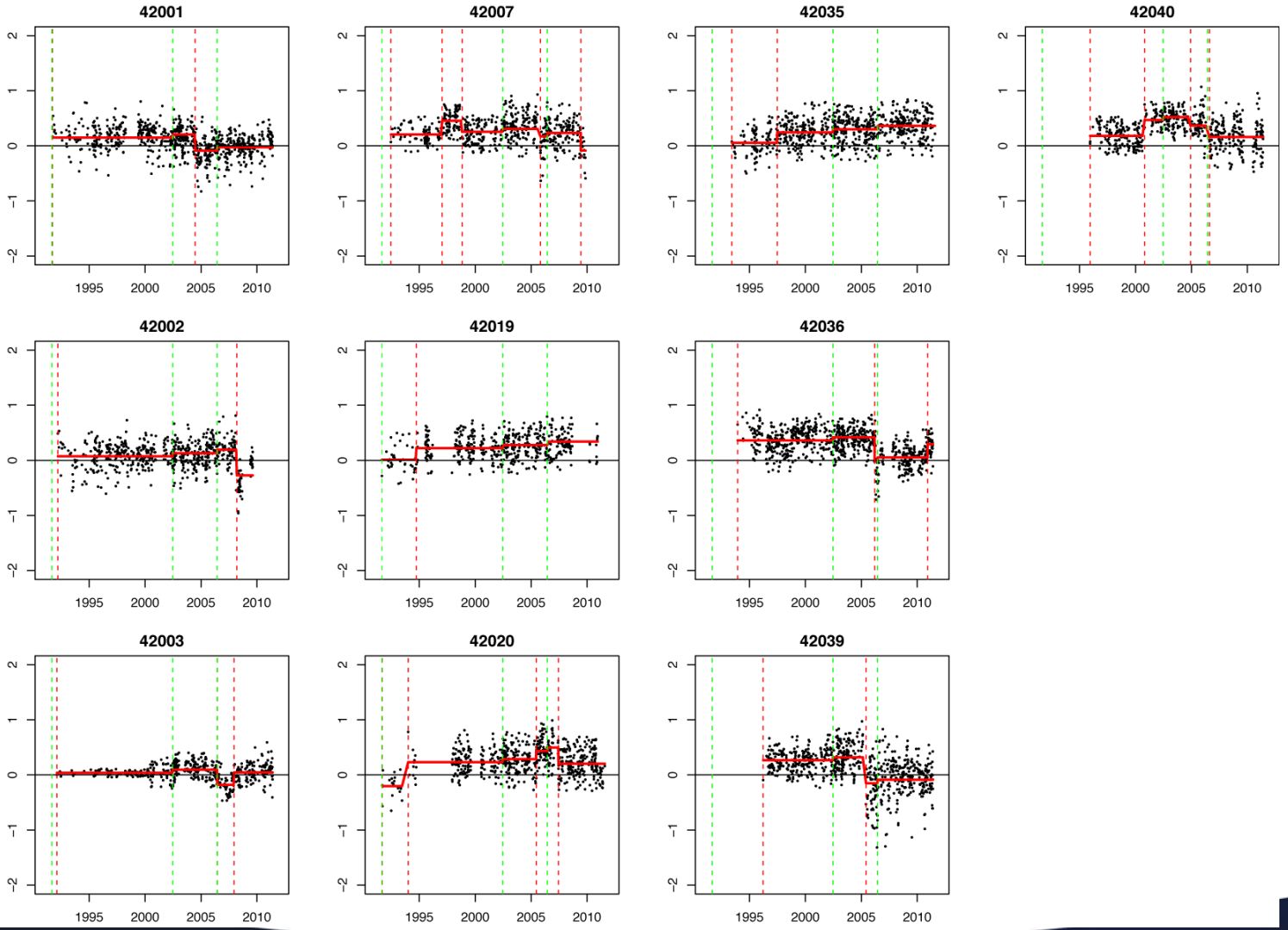
ESA SST CCI

- Similar desire / need for assessment of stability of ESA CCI data
- Also desire to expand to extra-tropics to make assessment global
  - Pairwise comparison attempted using coastal moorings but too little metadata to understand results
  - Instead turned to Argo and drifting buoys

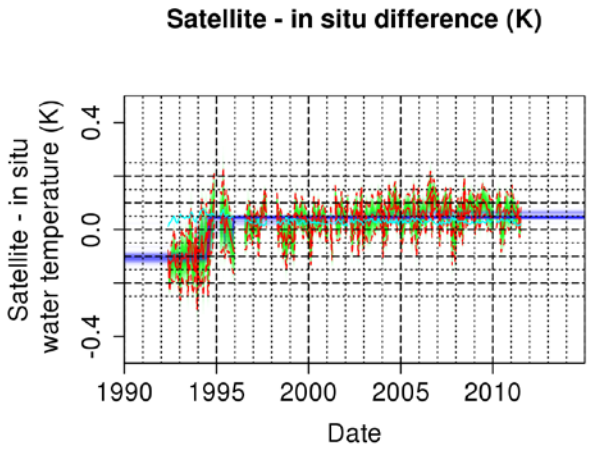
- Similar approach to ARC taken, but this time using moving platforms to assess quality of satellite data

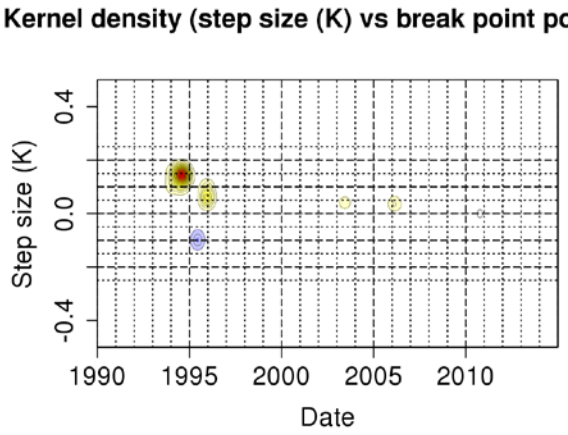
- Ensemble sub-sampling approach taken, again based on PMT
  - Fixed number of match-ups per month randomly selected
  - Aggregate differenced time-series calculated and PMT applied
  - Process repeated to increase sensitivity and minimise impact of outliers

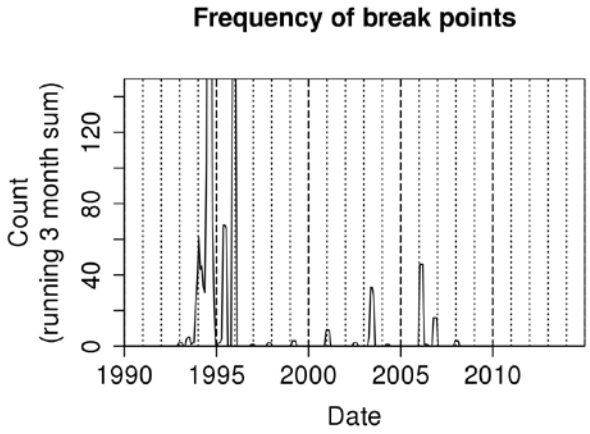
Pairwise comparison

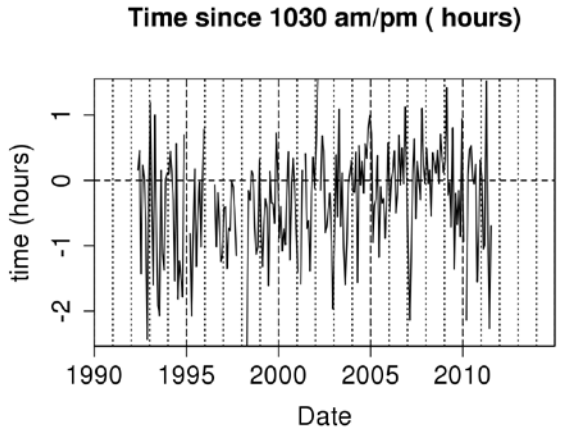


ESA SST CCI: (A)ATSR vs GTMBA

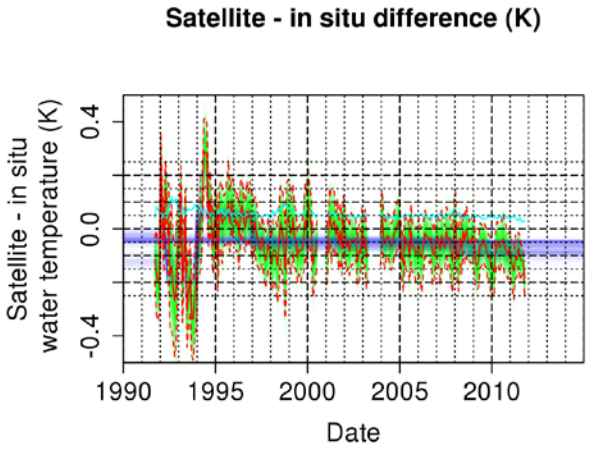


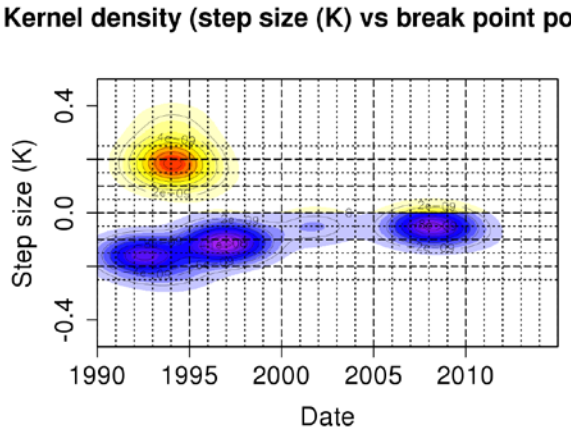


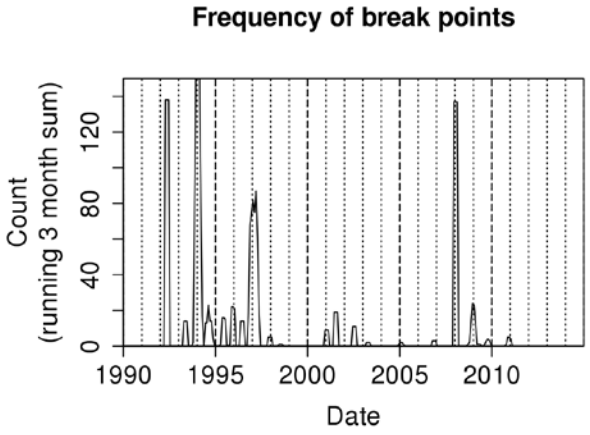


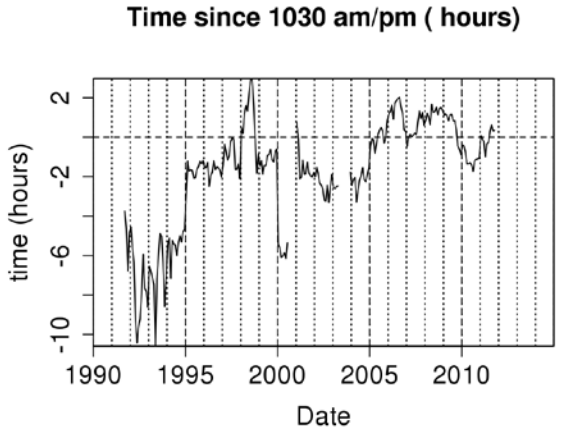


ESA SST CCI: AVHRR vs GTMBA

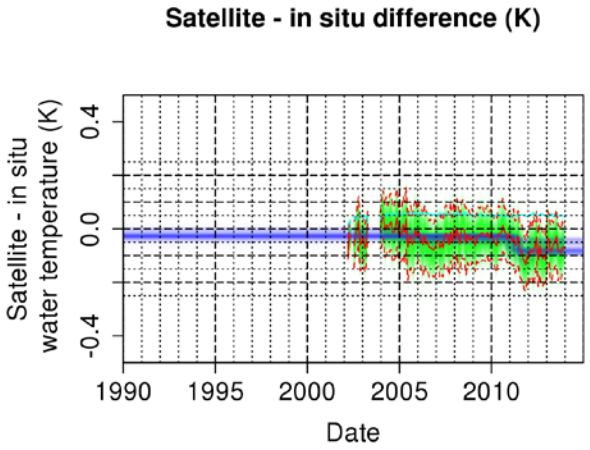


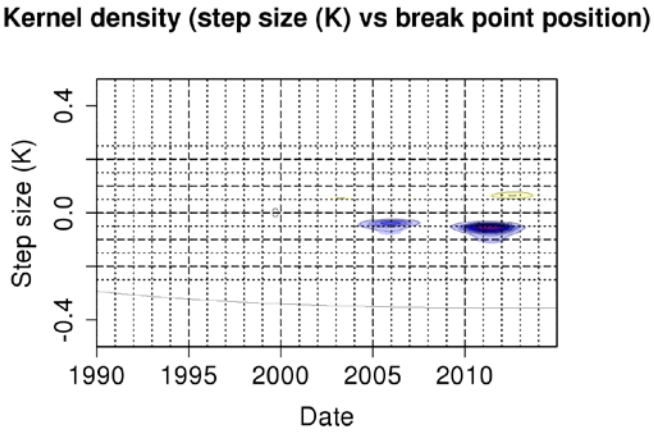


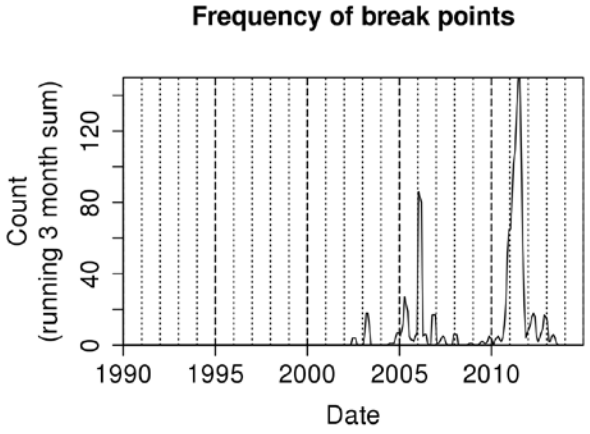


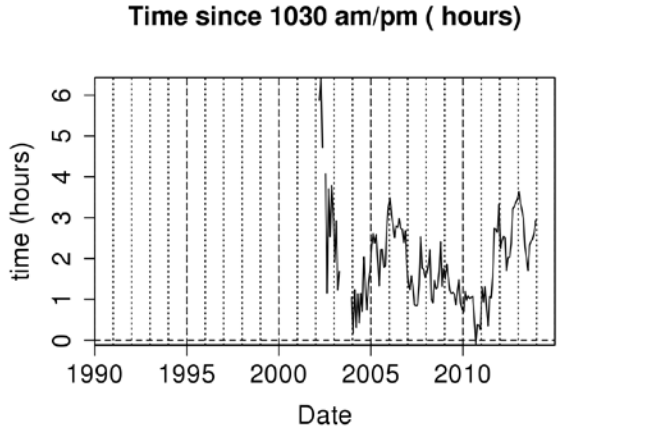


ESA SST CCI: All sensors vs Argo

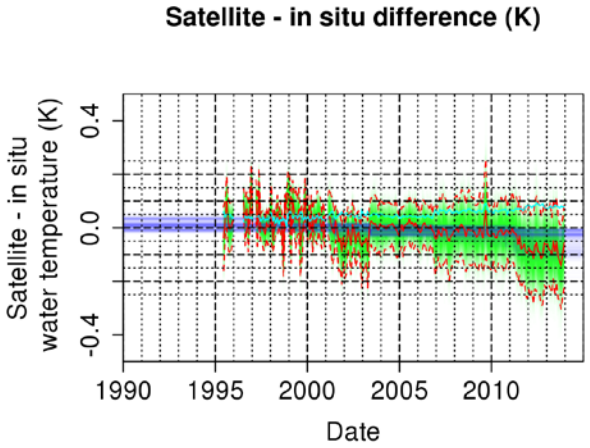


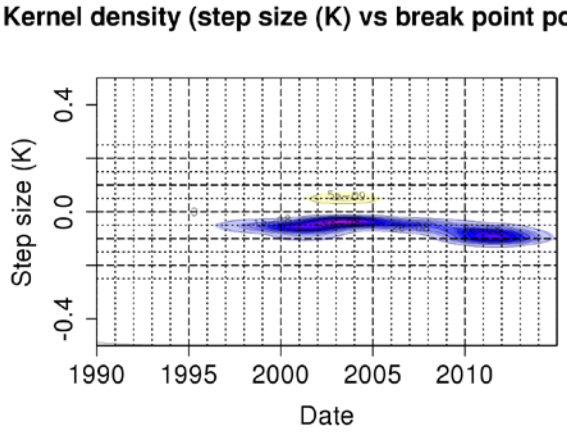


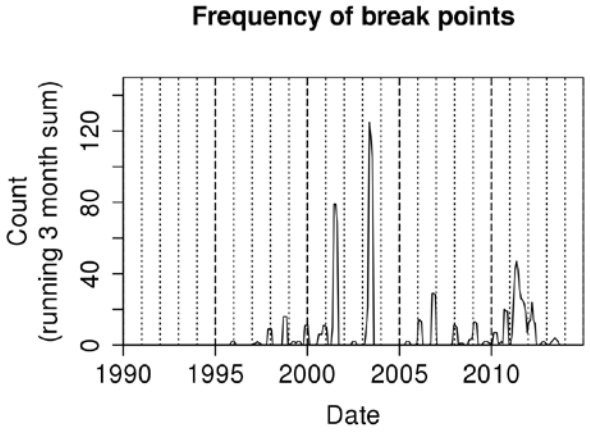


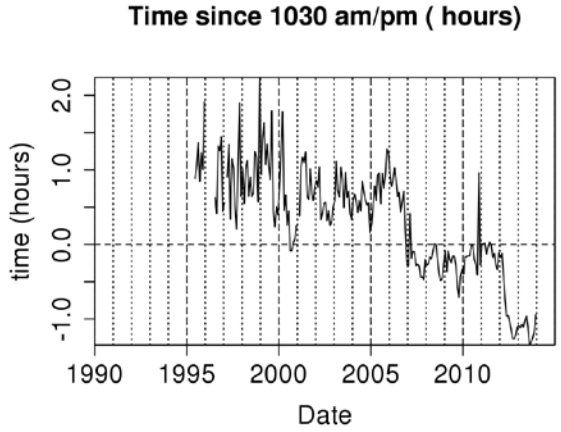


ESA SST CCI – ATSRs + Metop A vs drifting buoys

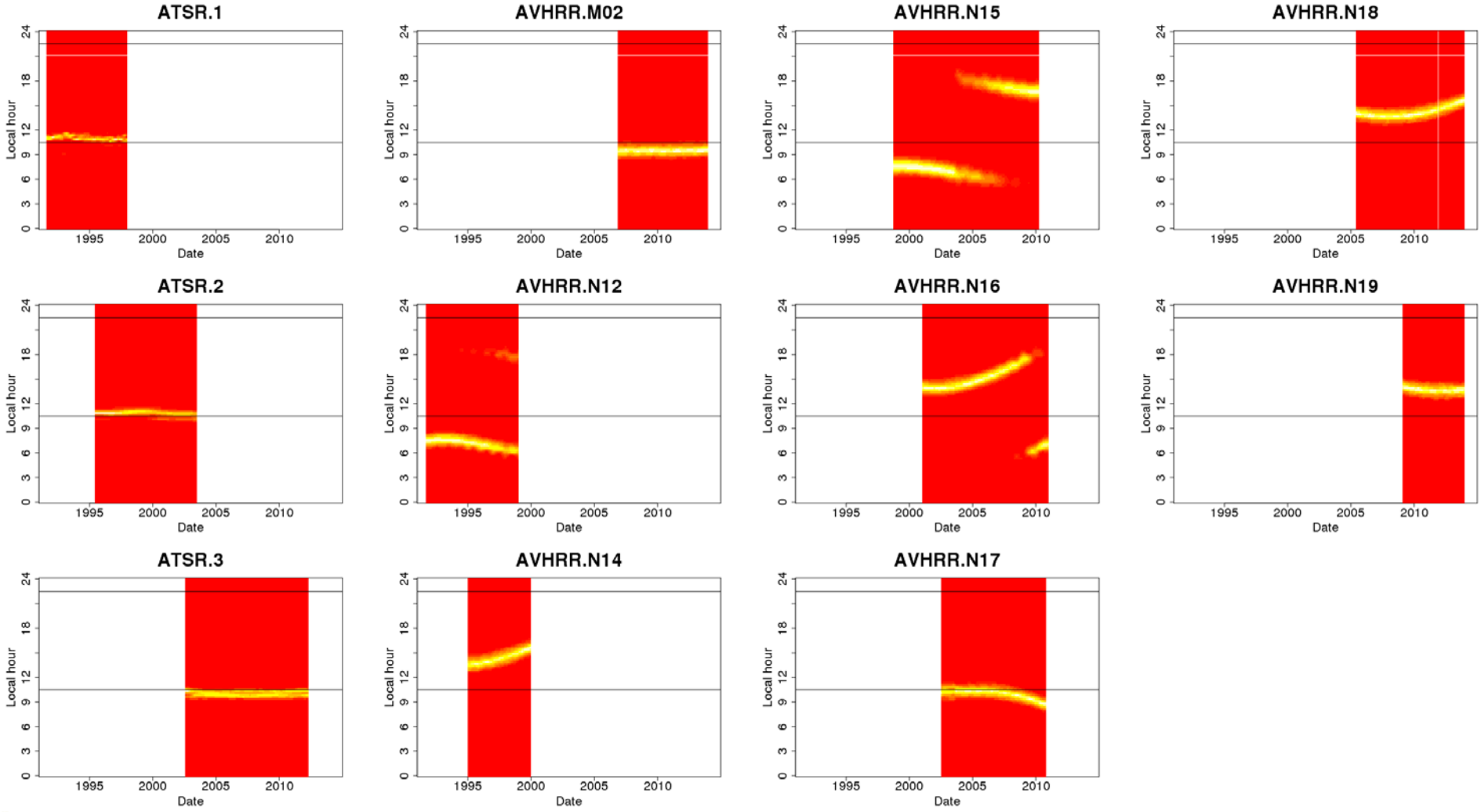








ESA SST CCI – Time of match-up



Summary

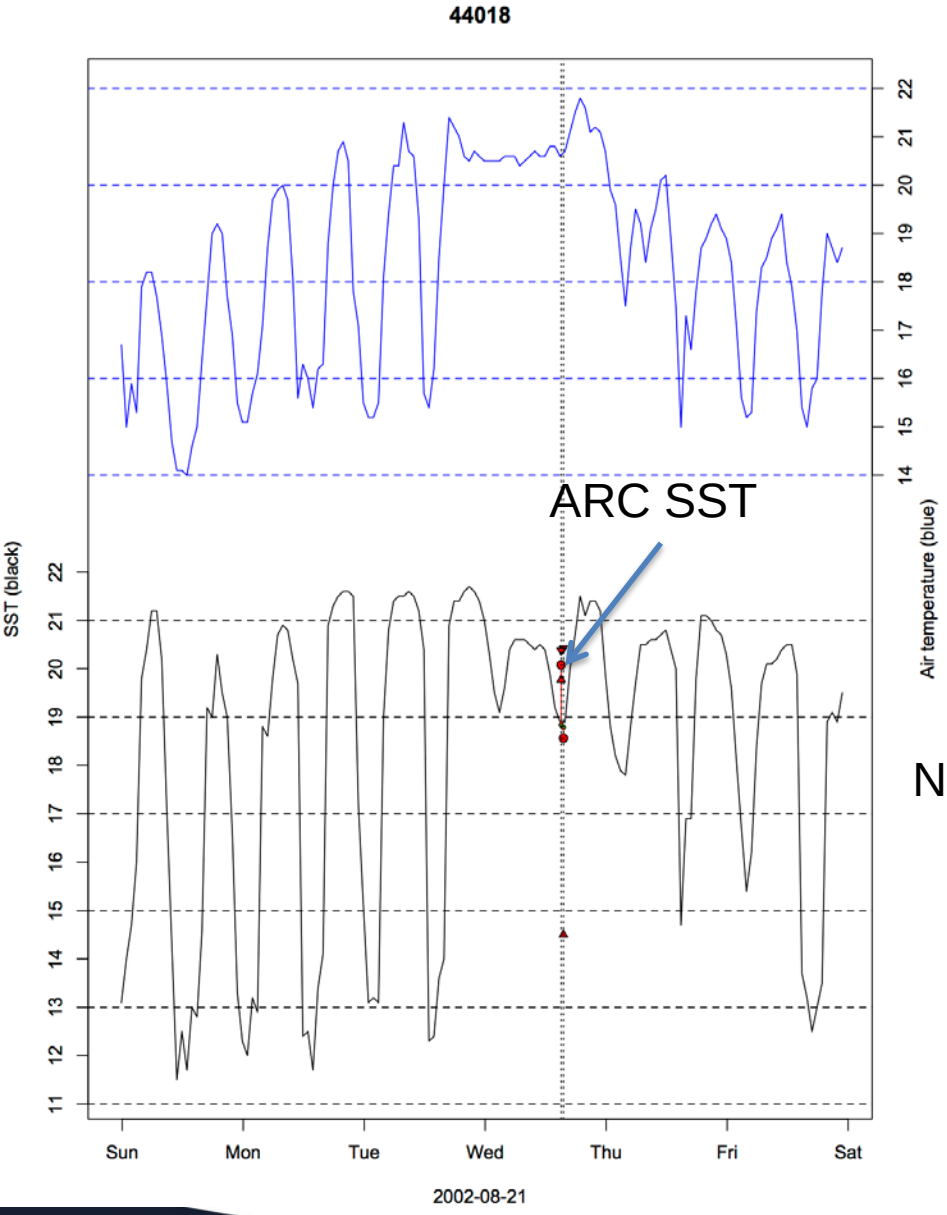
(A)ATSR SST record from ARC project assessed for stability in the tropics through comparison to moored buoy data using PMT (RHTest)

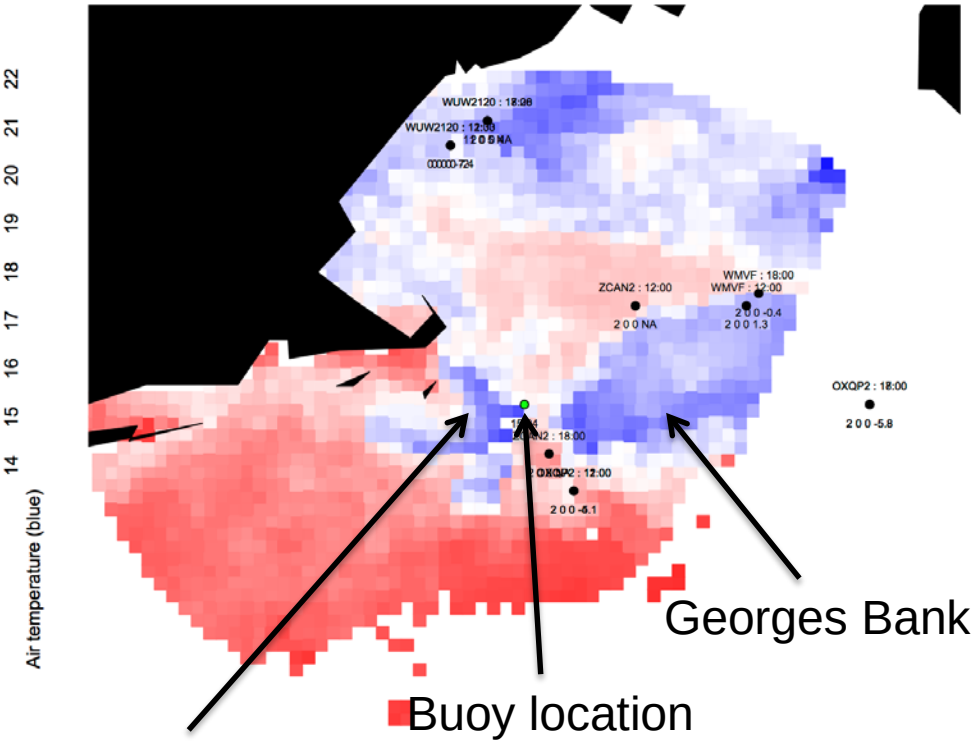
- No step changes after ~1993/1994
- Residual trends < 0.05°C / decade

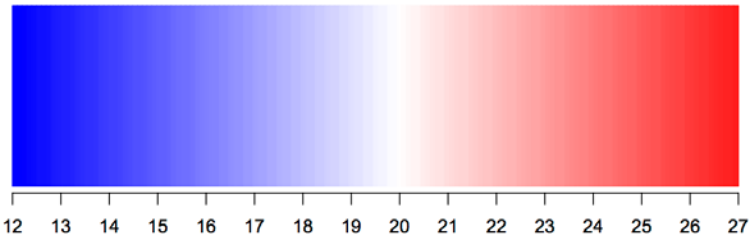
Method developed further and applied to ESA CCI data, Argo and drifting buoys, ensemble approach

- Results broadly comparable in tropics for (A)ATSR + GTMBA
- From 2004 / 2005 onwards possible to use Argo
- From mid to late 1990s possible to use drifting buoys
- Steps evident in both comparisons to Argo and drifting buoys, tend to coincide with change of satellites

However, data not fully adjusted for time of day – comparing 1030 am/pm satellite data with in situ data at time of overpass


44018
SST (black)
Air temperature (blue)
ARC SST
Sun
Mon
Tue
Wed
Thu
Fri
Sat
2002-08-21


Georges Bank
Buoy location
Nantucket Shoals


12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27