climate change initiative

→ SEA SURFACE TEMPERATURE

SST CCI Validation

Owen Embury

sst cci

University of Reading

Met Office

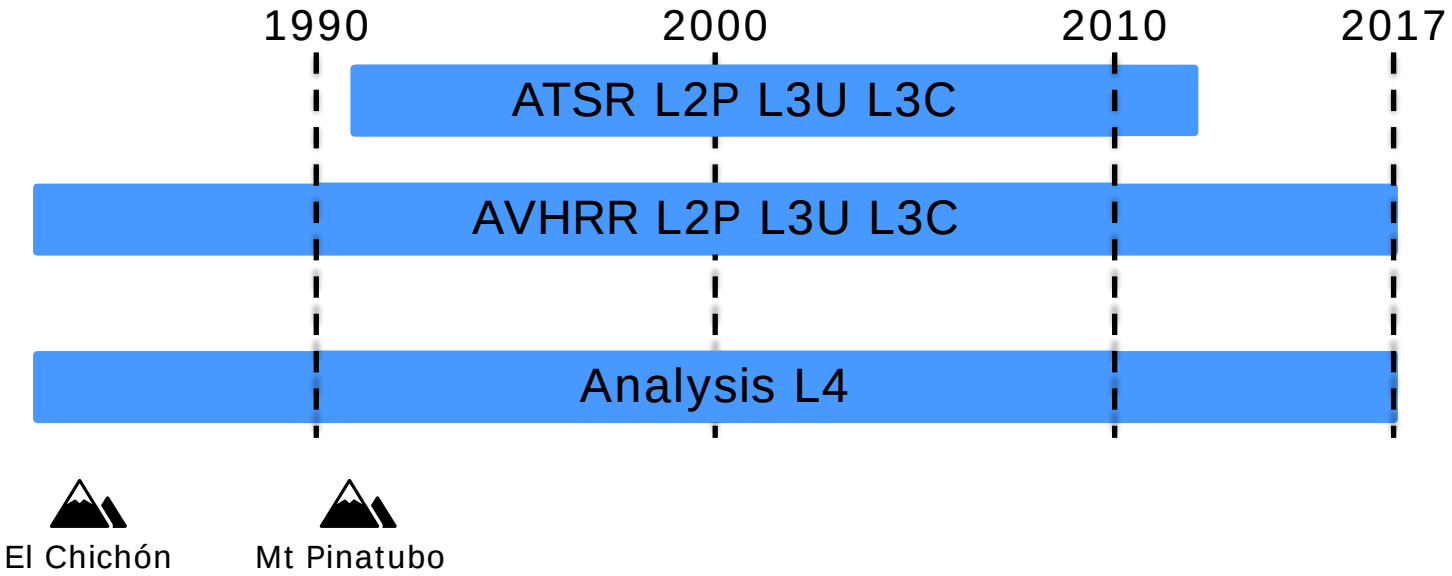
Danish Meteorological Institute

Climate Change Initiative

- ESA Climate Change Initiative (CCI)
  - Programme to produce satellite-based Climate Data Records
  - Targeting multiple Essential Climate Variables (ECVs) including SST
- Climate Data Record (CDR) is:
  - A time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change
- Aims for SST-CCI CDR:
  - **INDEPENDENT** of in situ SST measurements
  - Of useful, quantified **ACCURACY** and **SENSITIVITY**
  - With context-sensitive **UNCERTAINTY** estimates (at all spatio-temporal scales)
  - Harmonised to provide useful **STABILITY**
  - Able to be linked to the longer **HISTORICAL RECORD**
  - Generated by a **ROBUST**, **SUSTAINABLE** processing system

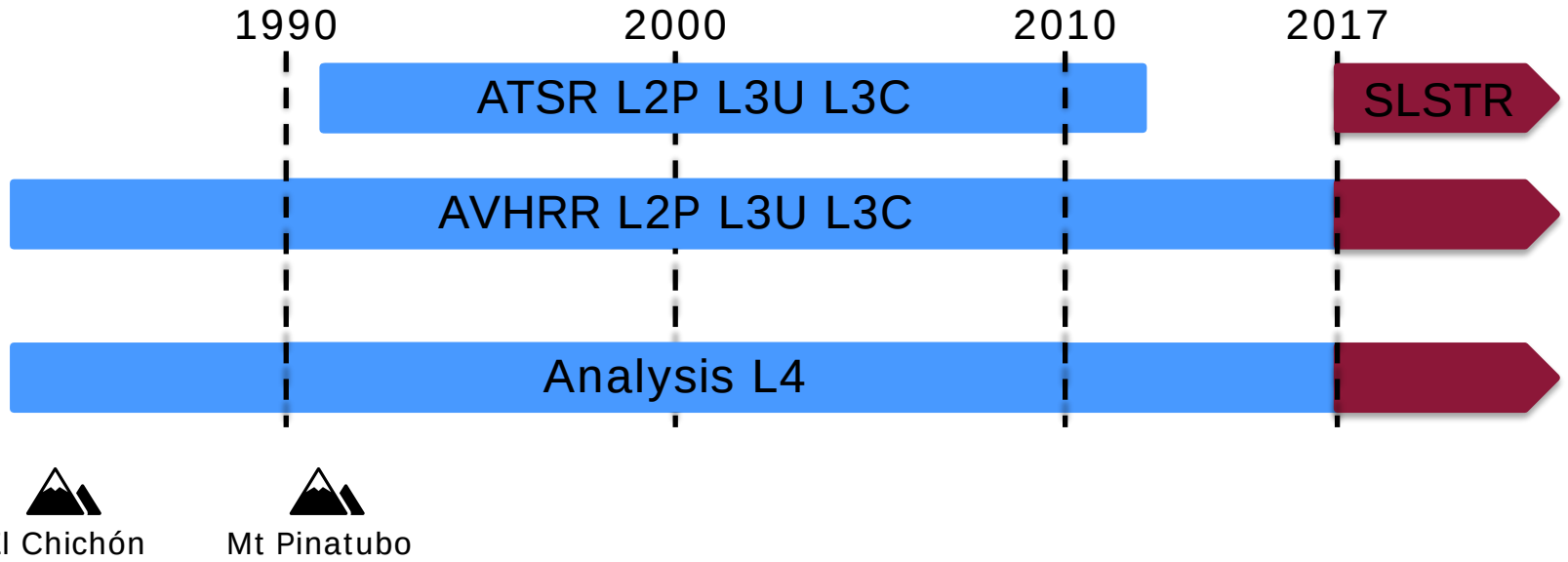
SST CCI CDR v2

- CCI Phase 2 dataset
  - 35 years (September 1981 – December 2016)
  - L2P, L3U and daily L3C for all sensors



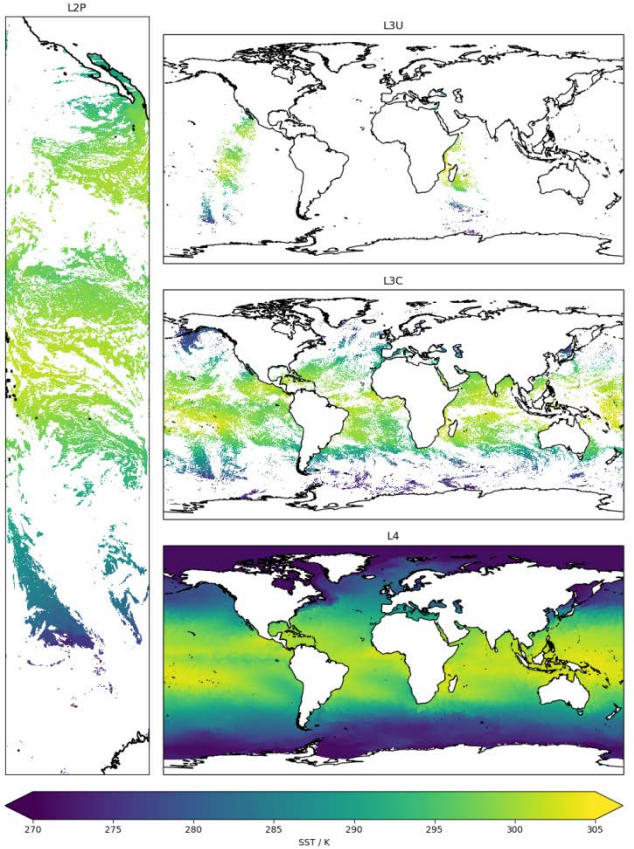
C3S ICDR v2

- Copernicus Climate Change Service (C3S) Interim CDR (ICDR)
  - Extends CCI CDR v2 L3C and L4
  - Data available to end-2019 (currently processing 2020)



SST-CCI Climate Data Record v2

- 35 years (September 1981 – December 2016)
- 18 x 10^{12} satellite radiance measurements
- Single-sensor products:
  - **L2P** swath, **L3U** gridded, and **L3C** daily
  - SST-type:
    - Skin at satellite overpass
    - SST_{20cm} at 10:30 local-time
  - Uncertainties provided:
    - random, correlated, systematic
- Multi-sensor: **L4** CCI Analysis
- Other: GMPE, Climatology

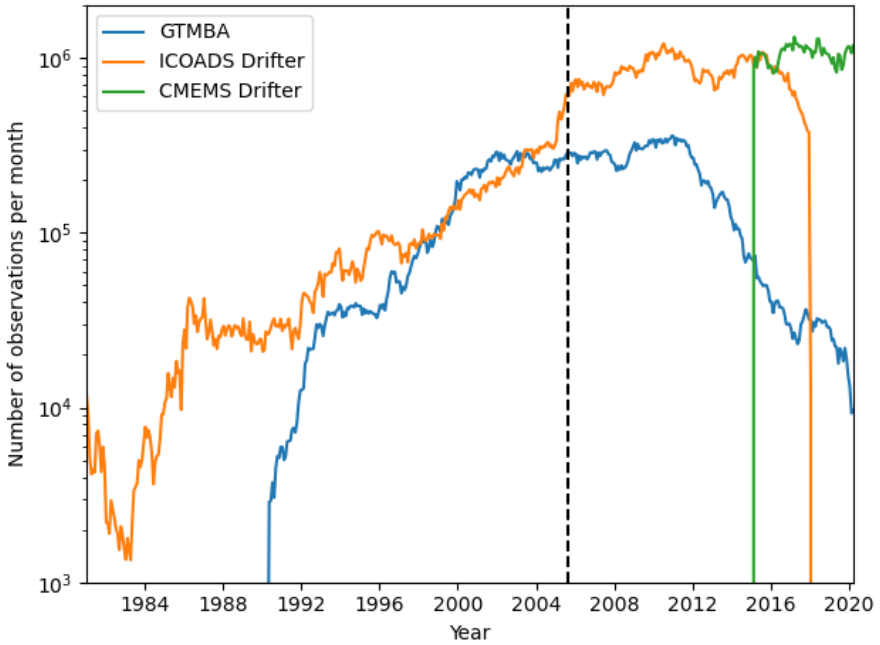


SST CCI Validation

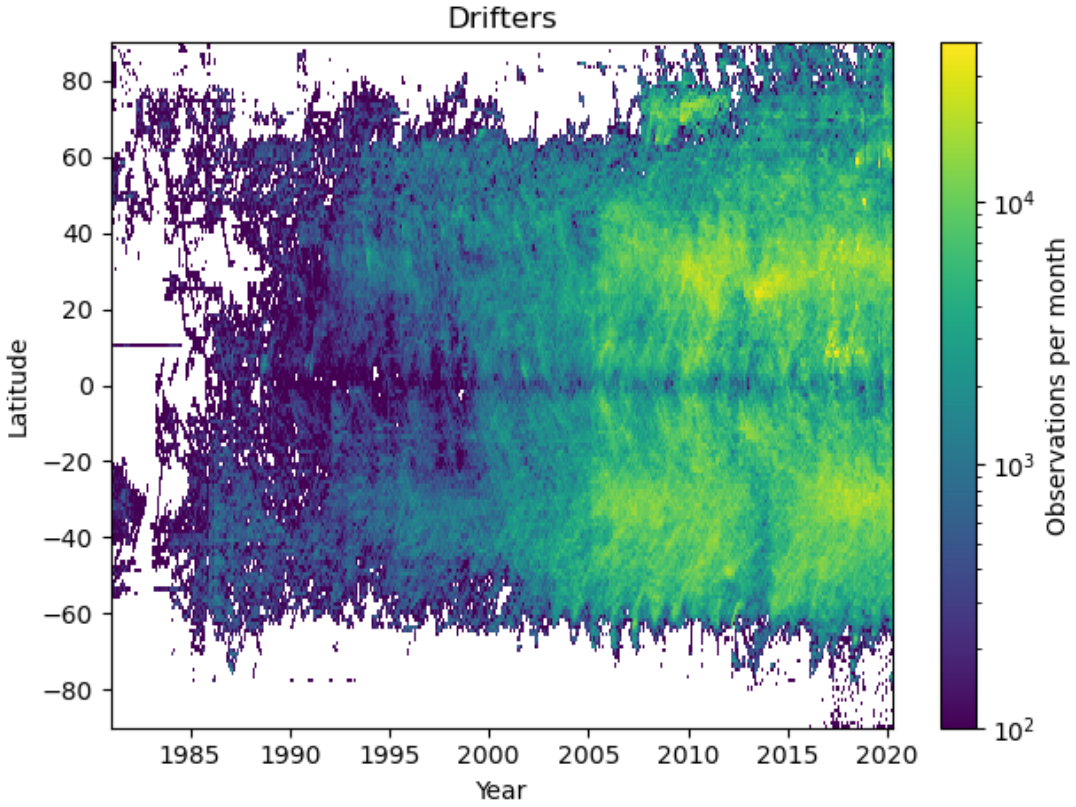
- Reference in situ data supplied by Met Office Hadley Centre
  - Extracted from HadIOD v1.2.0.0
  - We only get SST obs (no salinity)
- Multiple platform types:
  - Drifting buoys (ICOADS and CMEMS)
    - ICOADS record position to 0.01 degree and SST to 0.1 degree
    - CMEMS record position to 0.001 degree and SST to 0.01 degree
  - Global Tropical Moored Buoy Array (GTMBA)
  - Argo Floats
  - Others: Moored buoys (excluding GTMBA); Voluntary observing ships; Animal; Bottles; Conductivity-Temperature-Depth casts (CTDs); Mechanical BathyThermographs (MBTs); eXpendable Bathy Thermographs (XBTs)

SST CCI Validation

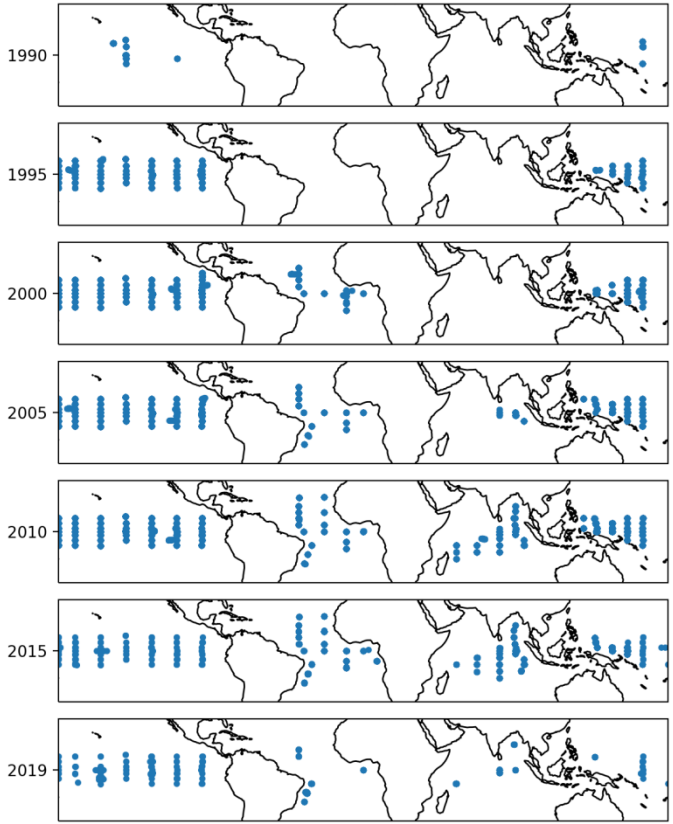
- Drifters provide most “complete” coverage
  - “Full” coverage from Sept 2005
  - Very limited coverage before 1995
  - Need to switch from ICOADS to CMEMS drifters in 2006
  - Note – the “best” satellite retrievals can have lower uncertainties than drifter SSTs
- GTMBA moorings
  - Lower uncertainties than drifters
  - Used for stability analysis
    - See Berry et al. 2018



Distribution of drifter locations



Distribution of GTMBA locations



In situ to Satellite matching

- Multi-sensor Matchup System (MMS)
  - Developed by Brockmann Consult
  - Can produce Matchup Datasets (MD) from various combinations of inputs:
    - Satellite L1b, L2P
    - In situ
    - NWP
  - Examples:
    - ATSR2 – AATSR clear-sky matches (for algorithm development)
    - AVHRR_GAC – in situ all matches (for testing and validation)
- Simple matching for L3 SST products
  - L3 products use regular lat/lon grid so matching process is trival
  - Very quick/easy – used when we only need to validate SSTs

L2/L3 validation against drifters

- Following slides show L2/L3 SST compared to in situ drifters
  - Data up to end-2016 are SST-CCI vs. ICOADS drifters
  - Data from 2017 onwards are C3S-SST vs. CMEMS drifters

- Comparing satellite SST 0.2m against drifter
  - Fairall-Kantha-Clayson model used for time/depth adjustments
  - Code supplied by Met Office

	Level-2				Level-3			
	Day		Night		Day		Night	
	Median	RSD	Median	RSD	Median	RSD	Median	RSD
NOAA-07	**-0.15**	**0.56**	-0.06	0.66	**-0.17**	**0.55**	-0.06	0.68
NOAA-09	-0.07	0.59	+0.02	0.61	**-0.10**	**0.59**	-0.02	0.65
NOAA-11	-0.06	0.52	+0.03	0.49	-0.09	0.51	+0.01	0.47
Metop-A								
ATSR-1	+0.03	0.33	+0.01	0.25	+0.02	0.46	-0.00	0.28
ATSR-2	-0.01	0.26	+0.01	0.20	-0.00	0.27	+0.02	0.21
AATSR	+0.01	0.19	+0.01	0.16	+0.01	0.20	+0.01	0.18
SLSTR-A					+0.02	0.25	+0.00	0.21
SLSTR-B					-0.01	0.25	+0.00	0.19

- NOAA-07 through NOAA-11 are referenced to in situ
  - Ships + subset of drifters used as reference
  - Drifters used for reference are excluded from validation
- ATSR1 is adjusted to drifters (night-only) for 7 months from end-1991
  - These drifters have not been excluded from validation

	Level-2				Level-3			
	Day		Night		Day		Night	
	Median	RSD	Median	RSD	Median	RSD	Median	RSD

- NOAA-12 onwards are referenced to ATSR
- ATSR2 + AATSR are fully independent (no tuning to in situ)

NOAA-12	-0.01	0.51	+0.02	0.44	-0.03	0.50	-0.00	0.45
NOAA-14	-0.03	0.45	-0.00	0.37	-0.05	0.45	+0.01	0.35
NOAA-15	-0.01	0.39	-0.01	0.38	-0.04	0.38	-0.02	0.37
NOAA-16	+0.02	0.36	-0.01	0.33	-0.01	0.37	-0.02	0.32
NOAA-17	+0.01	0.34	+0.02	0.28	-0.02	0.34	+0.00	0.27
NOAA-18	-0.07	0.34	**-0.15**	**0.28**	**-0.11**	**0.34**	**-0.17**	**0.27**
NOAA-19	+0.03	0.34	+0.02	0.29	-0.00	0.33	-0.00	0.27
MetOp-A	+0.01	0.33	+0.04	0.27	-0.02	0.33	+0.02	0.26
ATSR-1	+0.03	0.33	+0.01	0.25	+0.02	0.46	-0.00	0.28
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NOAA-11	-0.06	0.52	+0.03	0.49	-0.09	0.51	+0.01	0.47
NOAA-12	-0.01	0.51	+0.02	0.44	-0.03	0.50	-0.00	0.45
NOAA-14	-0.03	0.45	-0.00	0.37	-0.05	0.45	+0.01	0.35
NOAA-15	-0.01	0.39	-0.01	0.38	-0.04	0.38	-0.02	0.37
NOAA-16	+0.02	0.36	-0.01	0.33	-0.01	0.37	-0.02	0.32
NOAA-17	+0.01	0.34	+0.02	0.28	-0.02	0.34	+0.00	0.27
NOAA-18	-0.07	0.34	**-0.15**	**0.28**	**-0.11**	**0.34**	**-0.17**	**0.27**
NOAA-19	+0.03	0.34	+0.02	0.29	-0.00	0.33	-0.00	0.27
MetOp-A	+0.01	0.33	+0.04	0.27	-0.02	0.33	+0.02	0.26
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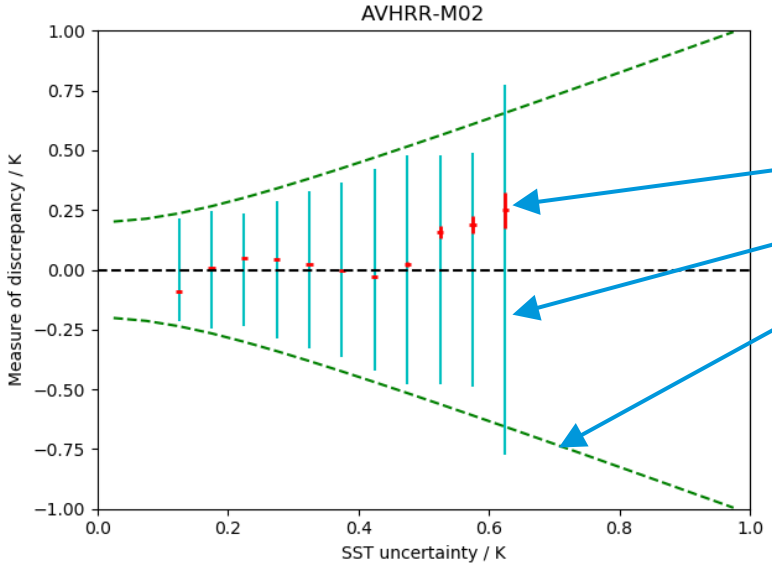
ATSR-2	-0.01	0.26	+0.01	0.20	-0.00	0.27	+0.02	0.21
AATSR	+0.01	0.19	+0.01	0.16	+0.01	0.20	+0.01	0.18
SLSTR-A					+0.02	0.25	+0.00	0.21
SLSTR-B					-0.01	0.25	+0.00	0.19

L2/L3 validation against GTMBA

	Level-2				Level-3			
	Day		Night		Day		Night	
	Median	RSD	Median	RSD	Median	RSD	Median	RSD
NOAA-11	**-0.16**	**0.48**	-0.06	0.40	**-0.26**	**0.47**	-0.09	0.39
NOAA-12	+0.10	0.48	-0.08	0.40	+0.05	0.48	**-0.11**	**0.40**
NOAA-14	-0.02	0.43	-0.04	0.32	-0.06	0.43	-0.07	0.31
NOAA-15	+0.01	0.42	-0.05	0.38	-0.05	0.41	-0.08	0.37
NOAA-16	+0.04	0.40	-0.00	0.31	-0.02	0.39	-0.03	0.30
NOAA-17	+0.00	0.38	+0.00	0.24	-0.05	0.37	-0.02	0.24
NOAA-18	**-0.11**	**0.37**	**-0.16**	**0.27**	**-0.16**	**0.37**	**-0.18**	**0.25**
NOAA-19	+0.04	0.38	-0.02	0.28	-0.01	0.37	-0.05	0.26
MetOp-A	+0.04	0.36	+0.00	0.25	-0.01	0.35	-0.02	0.25
ATSR-1	+0.04	0.29	+0.02	0.11	+0.03	0.45	-0.00	0.14
ATSR-2	-0.01	0.20	-0.01	0.10	-0.01	0.22	-0.01	0.11
AATSR	+0.00	0.18	+0.01	0.11	-0.00	0.19	-0.00	0.13
SLSTRA					-0.03	0.25	+0.00	0.16

Uncertainty Validation

- SST-CCI provides estimate of uncertainty
  - This is an output of the retrieval and is independent of *in situ* data
  - Therefore we can use the in situ data to validate the uncertainty
- Compare the estimated uncertainty against satellite – *in situ* discrepancy



- X-axis: estimated uncertainty
- Y-axis: satellite – *in situ* discrepancy

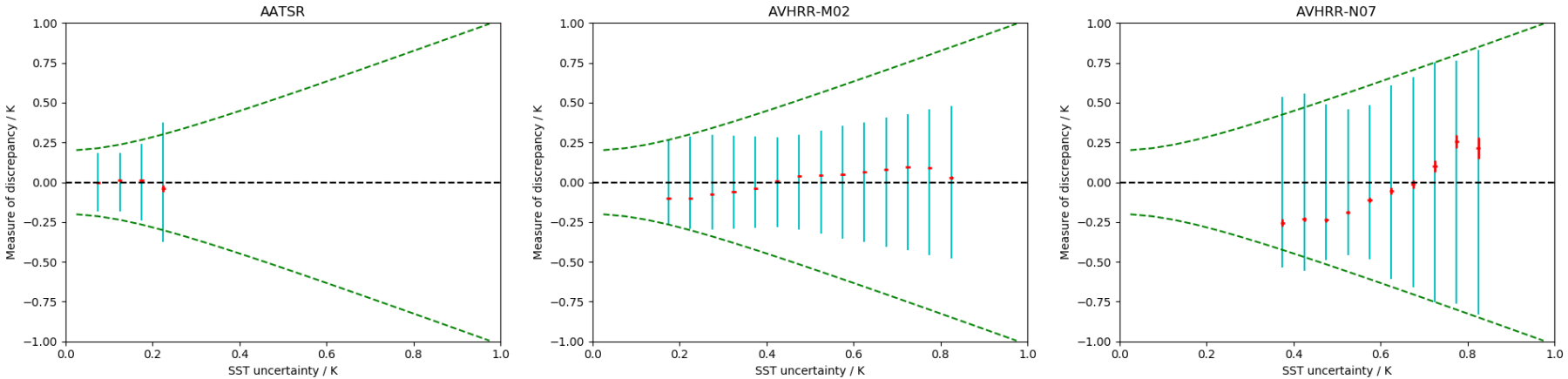
RED: Median discrepancy in bin

CYAN: RSD discrepancy in bin

GREEN: Expected RSD given in situ uncertainty

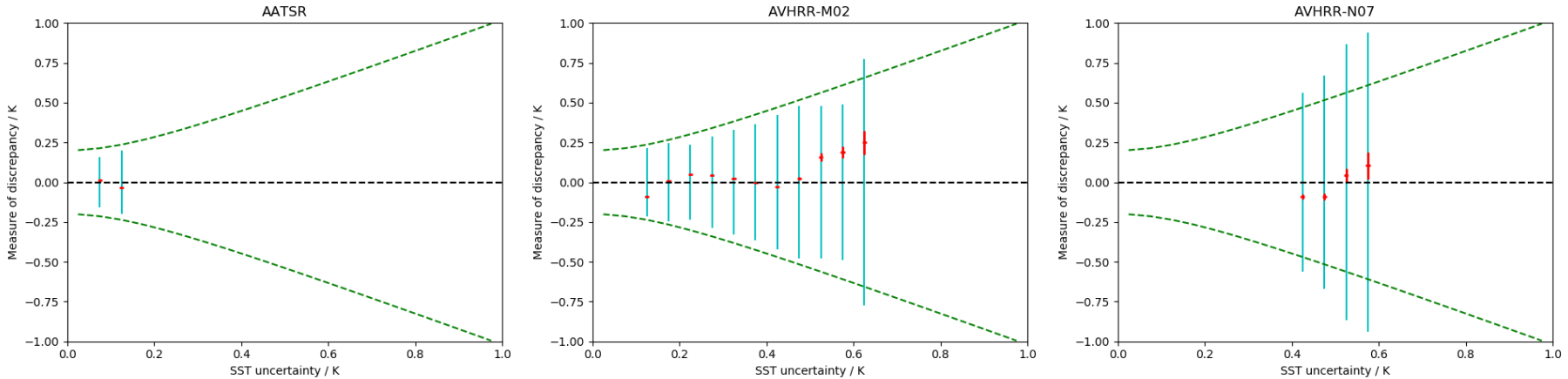
If the vertical lines match the dashed curve the uncertainty estimates are good!

L2P Uncertainty (daytime)



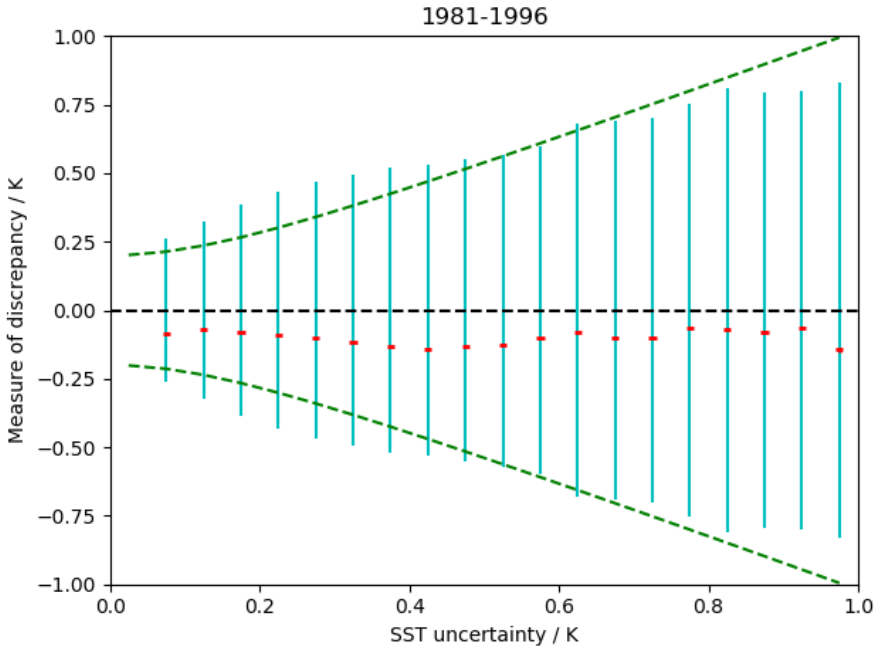
- ATSR uncertainty is good
- MetOp uncertainty is overestimated (also applies to NOAA-12 onwards)
- NOAA-07 uncertainty is good

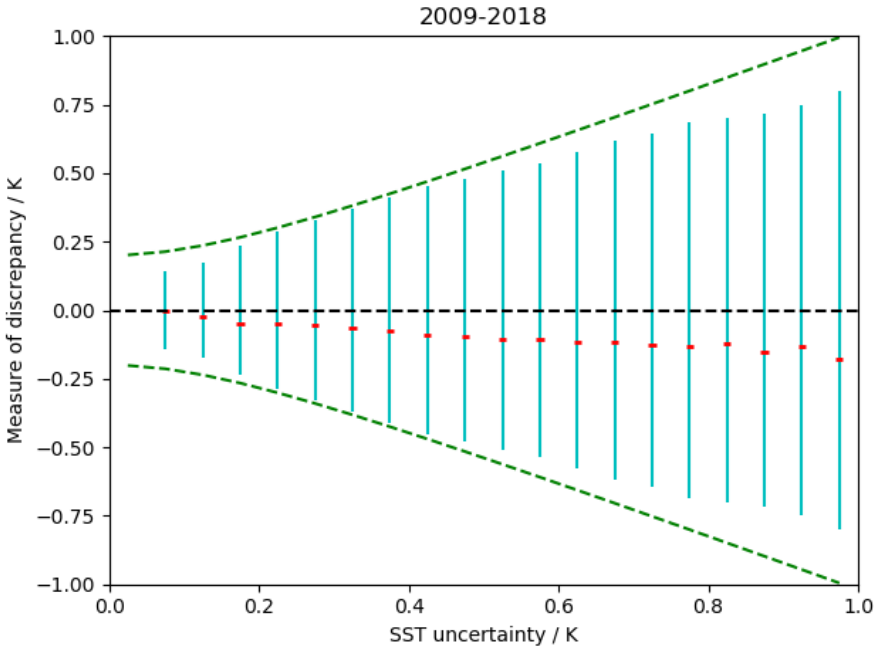
L2P Uncertainty (nighttime)



- ATSR uncertainty is good
- MetOp uncertainty is good (also applies to NOAA-12 onwards)
- NOAA-07 uncertainty is underestimated

L4 Uncertainty





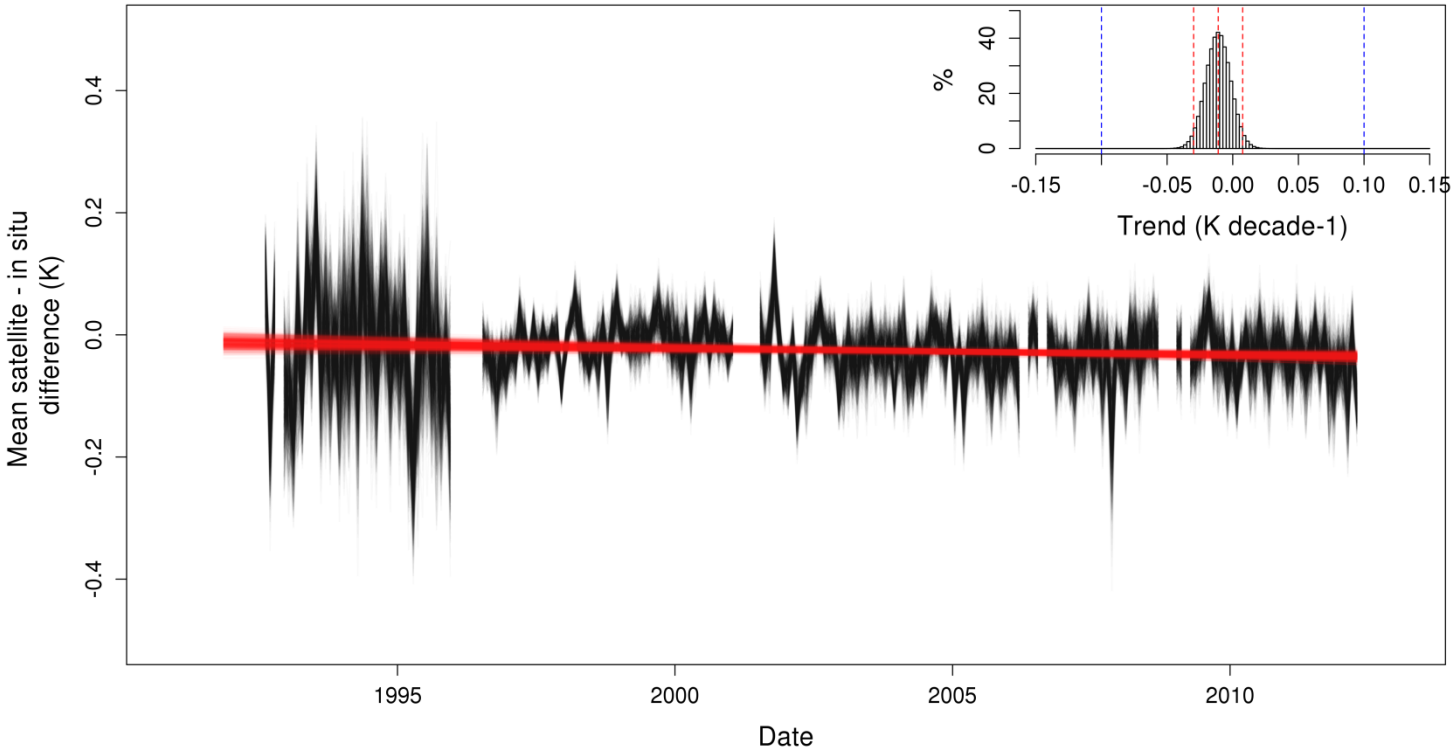
- Some under-estimation at low end for early data
- Some over-estimation at high end for more recent data

Stability Assessment

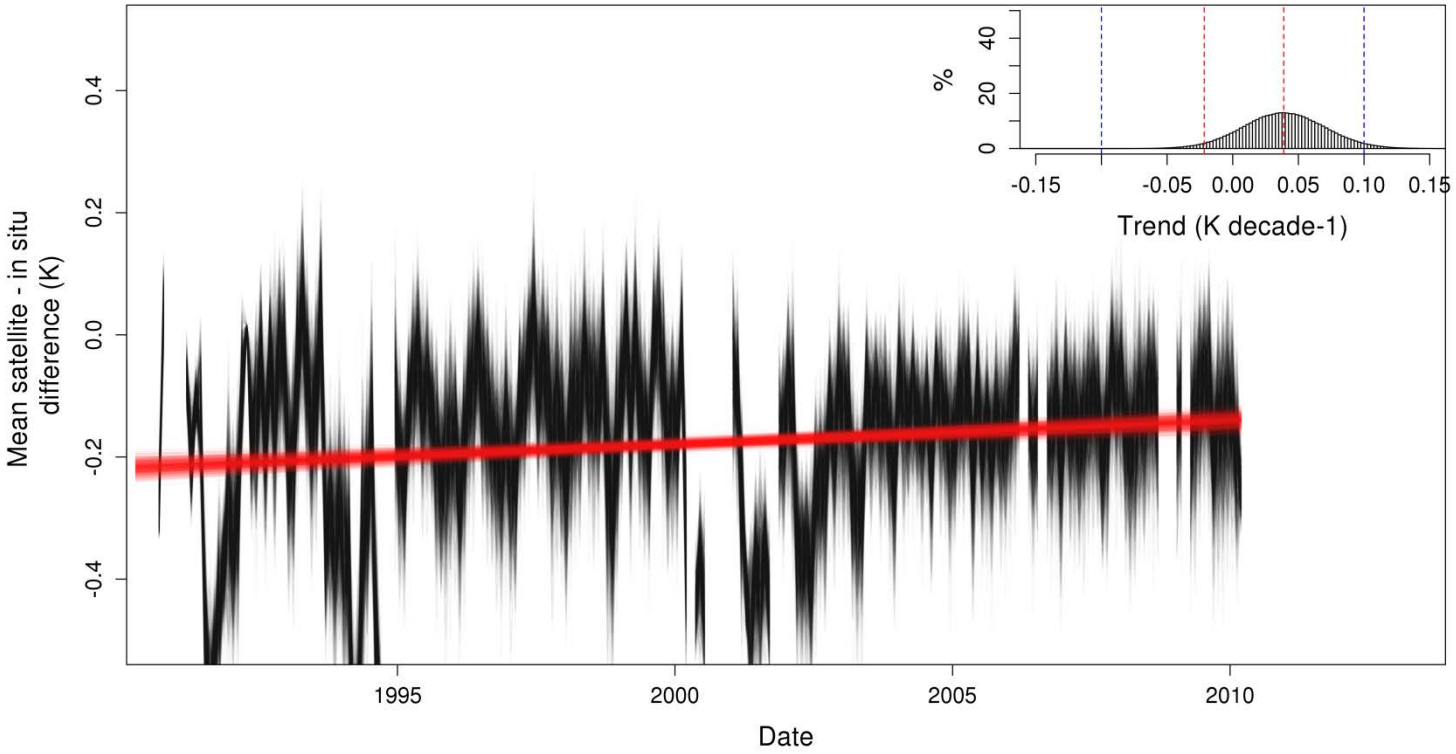
Data	Trend [mK/year]
ATSR (day)	-2.1 < trend < 2.3
ATSR (night)	-2.6 < trend < 0.4
AVHRR (day)	3.6 < trend < 15.5
AVHRR (night)	-2.1 < trend < 9.8
Analysis	-1.51 < trend < -0.05

- See Berry et al. (2018) doi:10.3390/rs10010126
- Stability assessed against long term stable moorings
  - Tropical Pacific (1990 – 2012)
- Trend range is the 95% confidence interval for the relative multi-year trend between satellite SSTs and the Global Tropical Moored Buoy Array
- Aim is trend less than 0.1 K decade^{-1} (or 10 mK year^{-1})

Stability Assessment – ATSR (night)



Stability Assessment – AVHRR (night)



Summary

- SST-CCI CDR v2 is now available
  - http://cci.esa.int/data (Access via FTP, other methods soon)
  - Merchant et al. (2019). Satellite-based time-series of sea-surface temperature since 1981 for climate applications, *Scientific Data*, in prep
- 35-year CDR with ongoing extension via C3S ICDR
  - Data from 1991 onwards referenced to ATSR (independent of *in situ*)
  - 1980s data is referenced to *in situ* SST
- ATSR2 / AATSR (fully independent) global bias $\lesssim$ 0.01 K
- AVHRR 7,9,11 tuned to in situ; AVHRR 12 onwards tuned to ATSR
  - Global bias $\lesssim$ 0.1 K except for AVHRR 7 and 18