

climate change initiative

→ **SEA SURFACE TEMPERATURE**

# Validation of the ESA SST CCI data using the Met Office SIRDS dataset

Owen Embury, Chris Merchant, Simon Good, Jacob Høyer,  
Nick Rayner, Tom Block, Craig Donlon





- ESA Climate Change Initiative (CCI) has produced two previous SST Climate Data Records (CDR):
  - Version 1: September 1991 – December 2010 (19 years)
  - Version 2: September 1981 – December 2016 (35 years)
- Version 3:
  - CDR: January 1980 – December 2021 (42 years)
  - Interim-CDR (ICDR) 2022 to present at ~3 weeks latency



## Improved AVHRR SST especially 1980s:

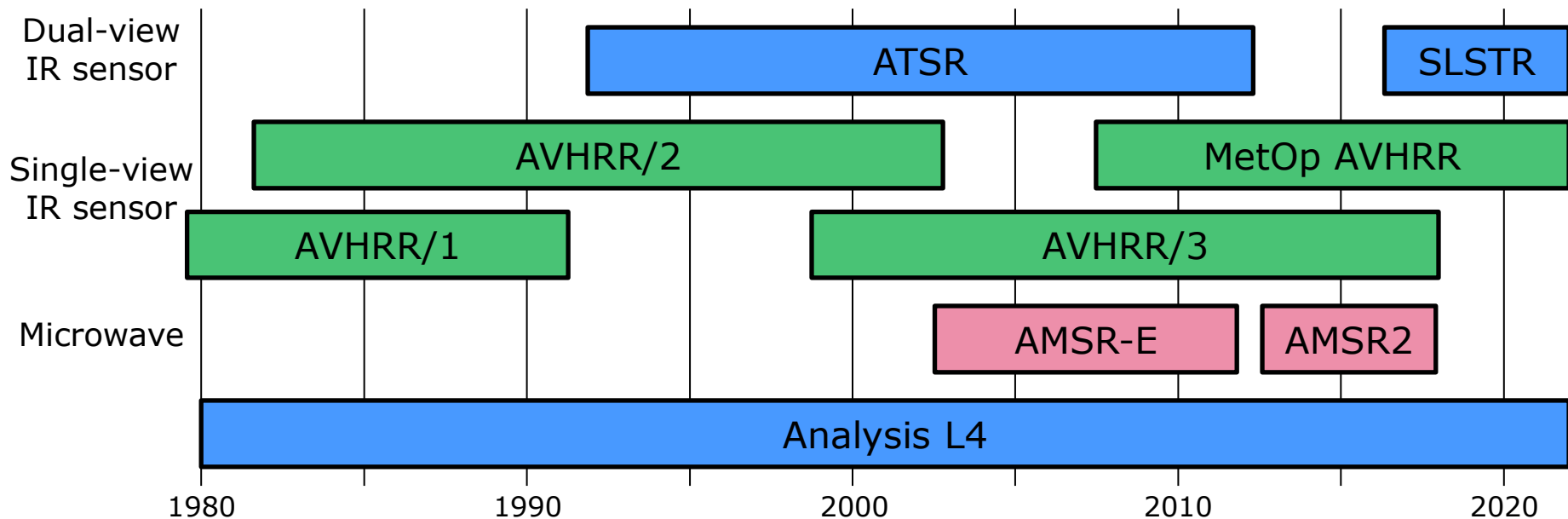
- Addition of AVHRR/1 from NOAA-6, -8, and -10
- Reduce 1980s data gaps
- Reduce desert-dust related biases
- New bias-aware optimal estimation retrieval

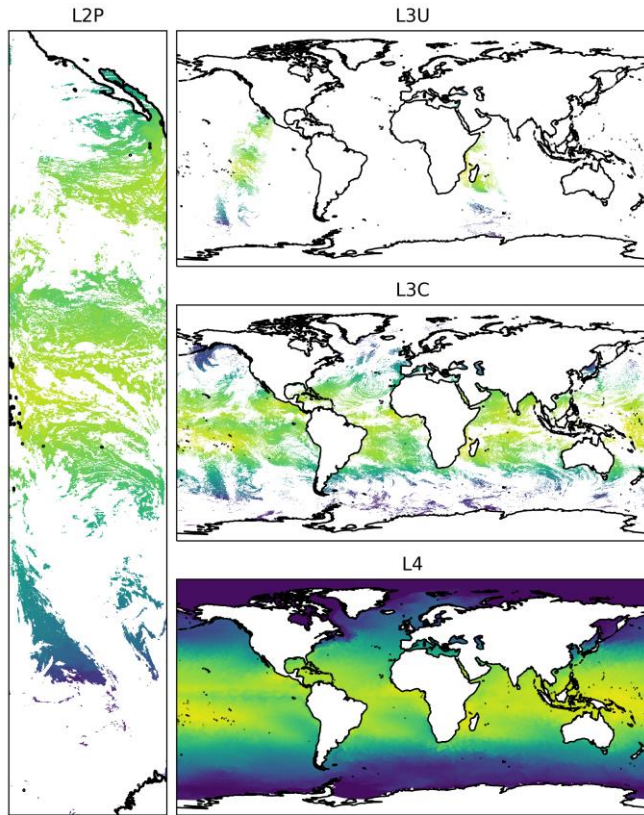
## New:

- Full resolution MetOp AVHRR
- SLSTR
- Passive Microwave SST from AMSR-E and AMSR2



- Includes products at L2P, L3U, L3C, and L4
- $SST_{skin}$  at satellite overpass;  $SST_{20cm}$  at 10:30 local time
- Multi-sensor L4 Analysis generated using Met Office OSTIA system





SST is provided at four “product levels”:

- **L2P**: data on the Level 1 grid – i.e. satellite swath projection
- **L3U**: (uncollated) Level 2 data remapped to global latitude / longitude grid
- **L3C**: (collated) single-sensor observations for a fixed period (daily)
- **L4**: multi-sensor observations blended to a global gap-free product

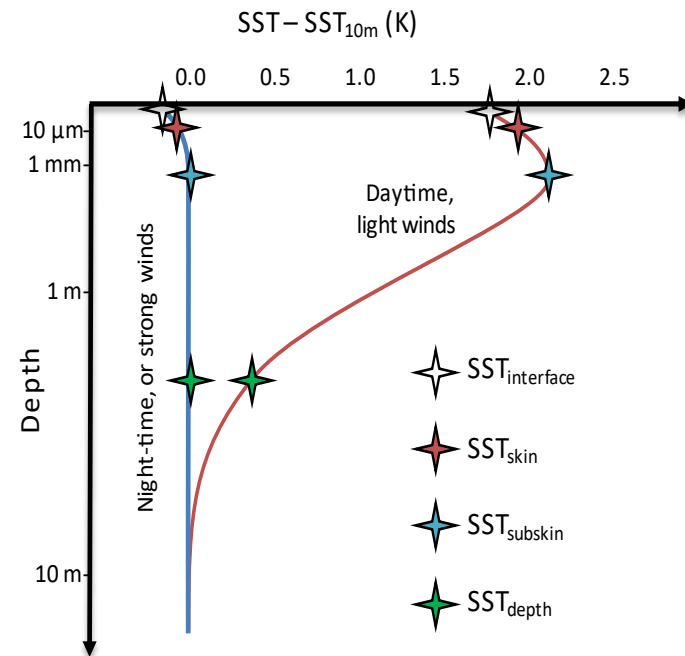


# SST Type



SST can refer to anything between the interface and  $\sim 10$  m, which varies due to heat flux through the surface.

- **SST<sub>int</sub>** – is a hypothetical temperature at the exact air-sea interface.
- **SST<sub>skin</sub>** – the skin temperature measured by an infrared radiometer, corresponds to a depth of  $\sim 10$ - $20 \mu\text{m}$ . This is typically  $\sim 0.2$  K cooler than in situ measurements (depending on wind speed).
- **SST<sub>subskin</sub>** – the sub-skin temperature. For practical purposes the sub skin can be approximated as the temperature observed by a microwave radiometer.
- **SST<sub>depth</sub>** – temperature measured at any depth below the surface (e.g. SST<sub>0.2m</sub>), used for the majority of *in situ* measurements (e.g. drifting buoys, ships etc.)

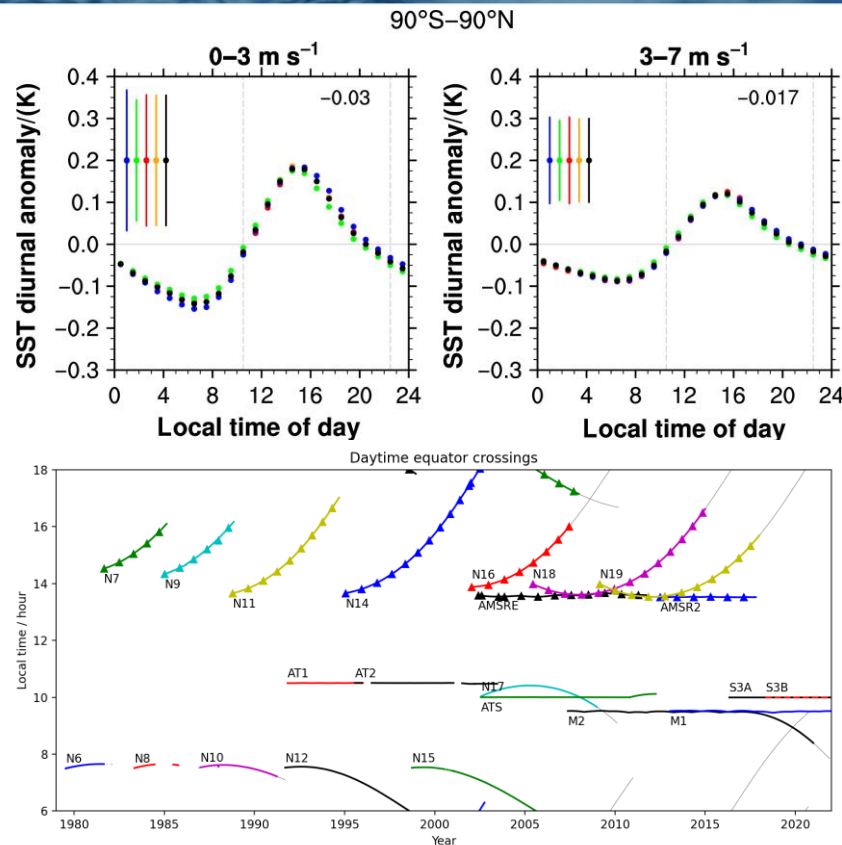




# Diurnal Variability



- SST varies through the day as it is warmed by the sun, and cools at night
  - Typical diurnal cycle is 0.1 – 0.5 K
  - Can be over 5 K in extreme cases (low wind, strong sun)
- Satellites observe at various local times of day
- Some satellites are in drifting orbits
  
- Climate Data Record needs to use standard time of day to avoid aliasing diurnal cycle
- SST CCI uses 10:30 or 22:30 local time
- Diurnal anomaly is closest to zero, SST is good approximation for daily average SST



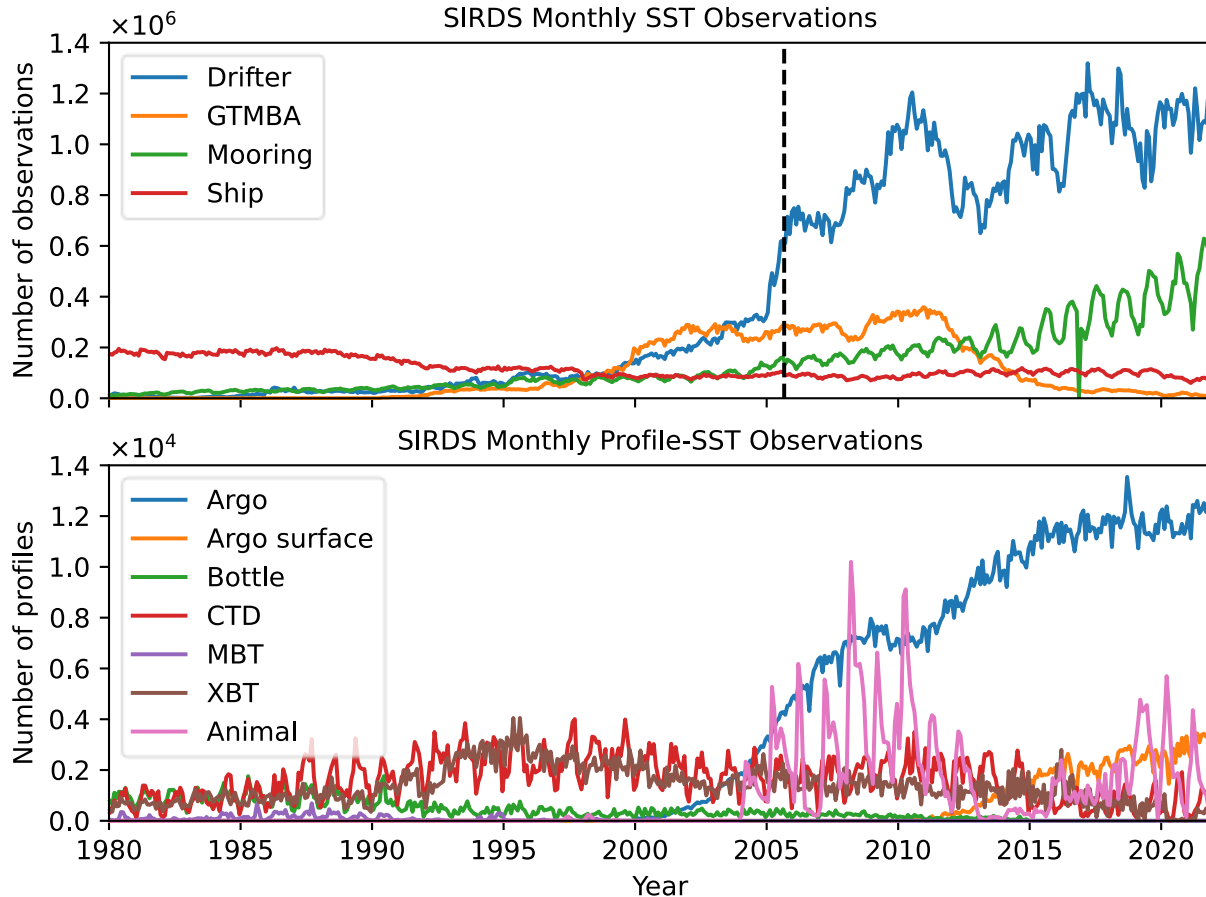


## SST CCI Independent Reference Data Set (SIRDS)

- Based on Met Office Hadley Centre Integrated Ocean Dataset (HadIOD)
- <https://www.metoffice.gov.uk/hadobs/hadiod/sirds.html>
- Includes: drifters, gtmba, moorings, ships, argo, bottle, ctd, mbt, xbt, ...
- Variable coverage over CDR period
- Ships provide best coverage in 1980s, but highest uncertainty – typically larger than satellite uncertainty
- Drifters provide majority of obs. since early 2000s, but very limited spatial coverage in 1980s



# SST CCI Independent Reference Data Set



Monthly count of in situ SST observations

Top: surface platforms

Bottom: sub-surface profiling platforms

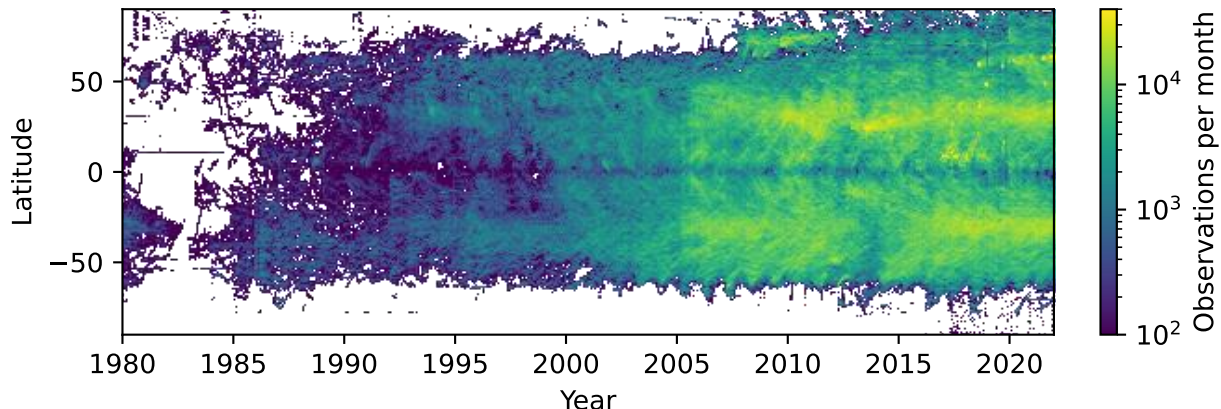




# SST CCI Independent Reference Data Set



Drifters

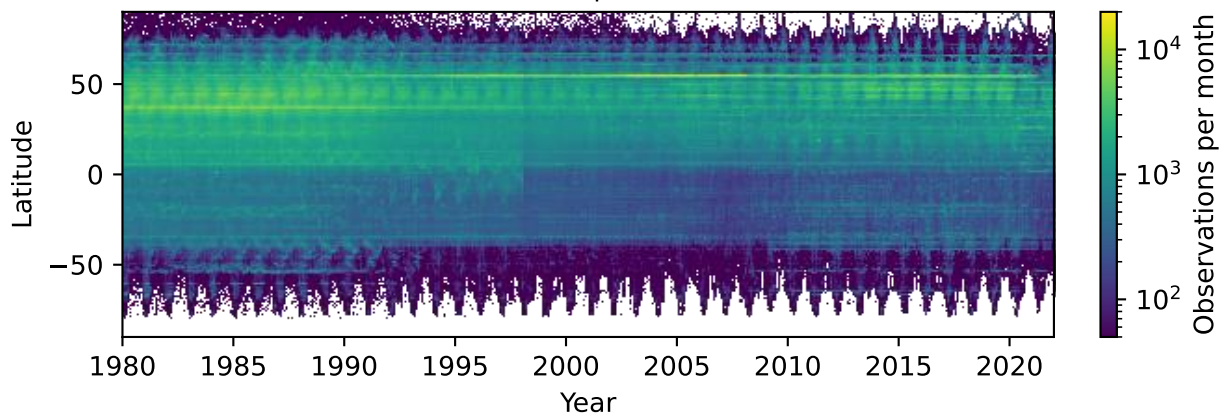


Hovmöller distribution of  
in situ observations

Top: drifters

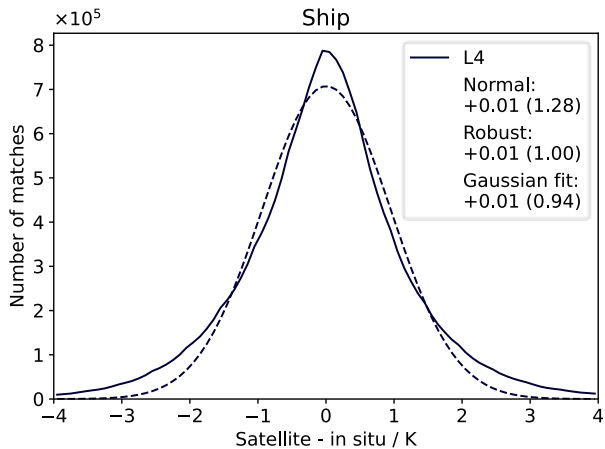
Bottom: Voluntary  
observing ships

Ships





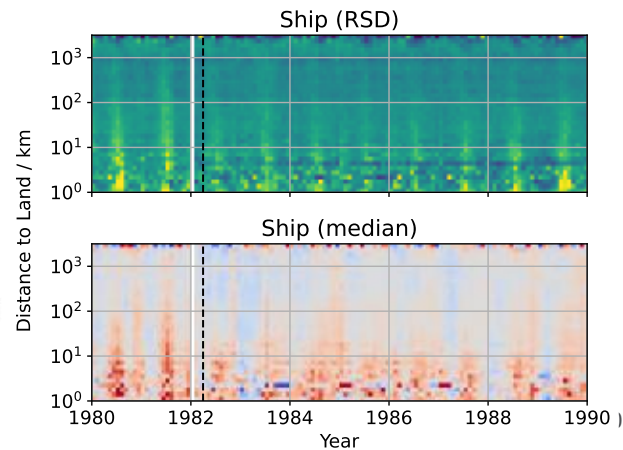
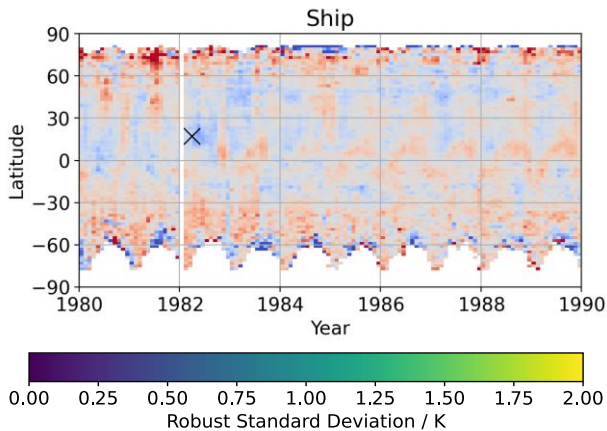
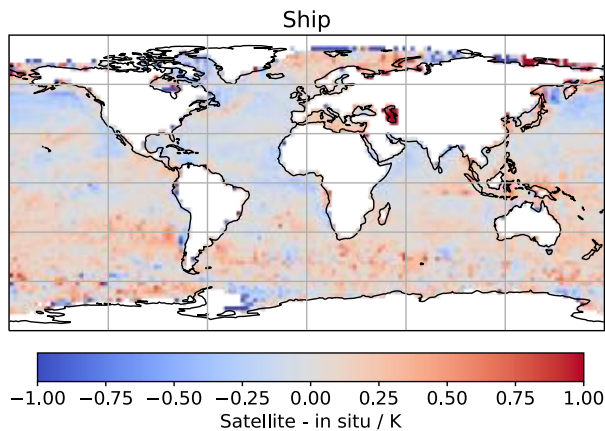
# Validation of Level 4 SST (1980s) - ships



Comparison against ships (VOS)

High standard deviation (1.28 K), RSD (1.00 K)

Note - early in situ locations only recorded to  $0.1^\circ$  precision, so distance-to-land plot is not accurate below  $\sim 10$  km



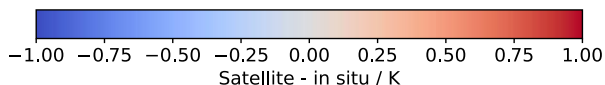
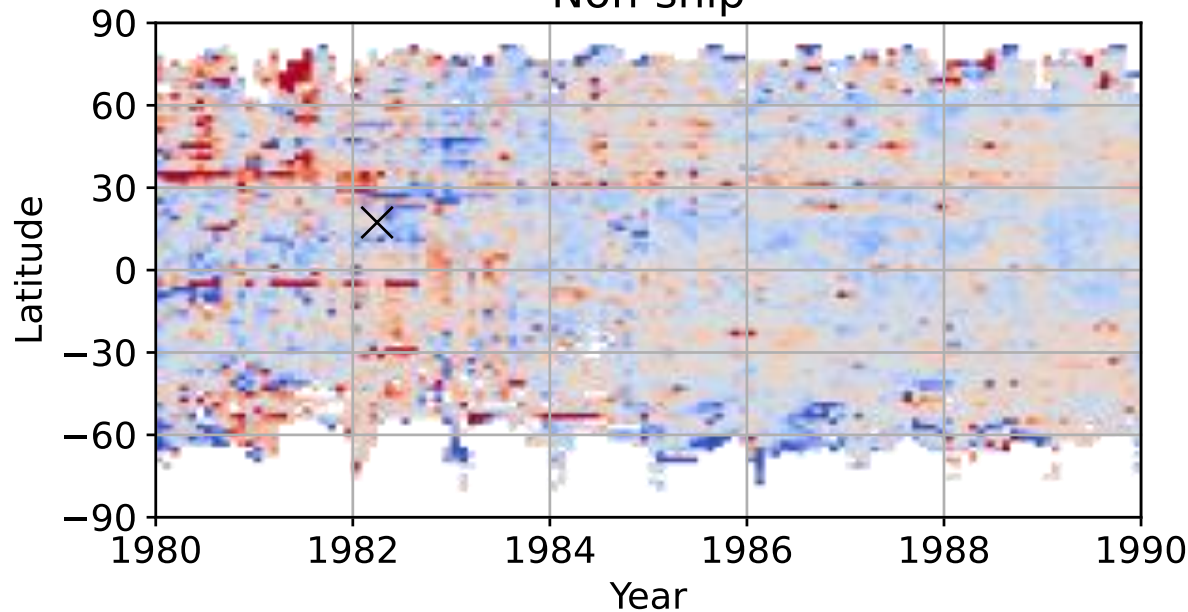


# Validation of Level 4 SST (1980s)



- Initial validation of SST CCI products used all “non-ship” platforms up to 1995
  - i.e. bottle, CTD, Drifter, MBT, Mooring, and XBT

## Non-ship



Hovmöller distribution of Level 4 SST0.2m minus reference in situ difference during 1980s

Several horizontal artefacts can be seen where satellite and in situ SST differ at fixed latitudes



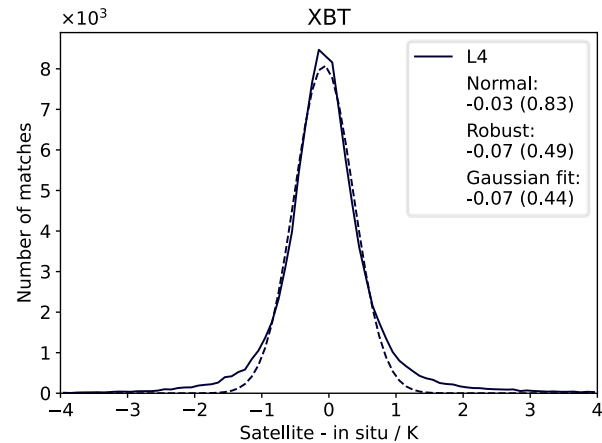
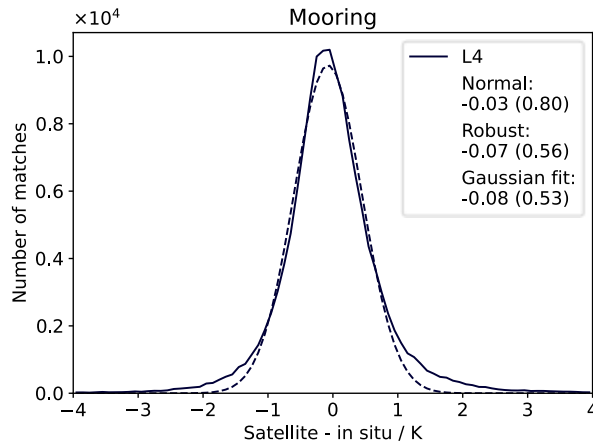
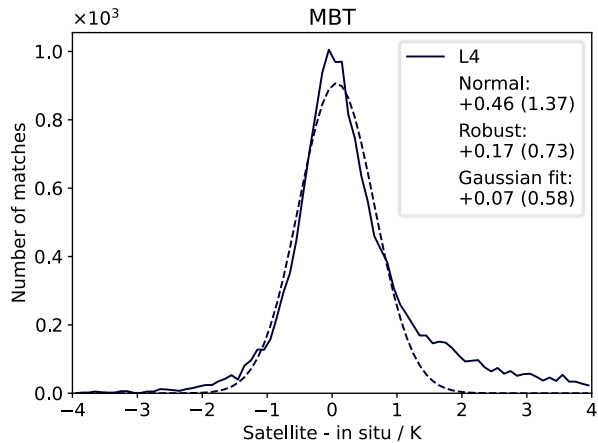
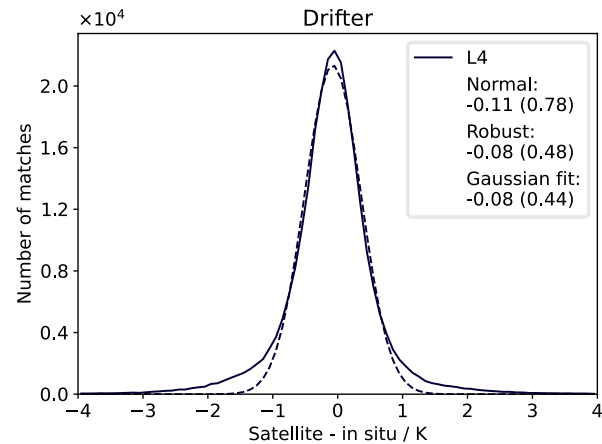
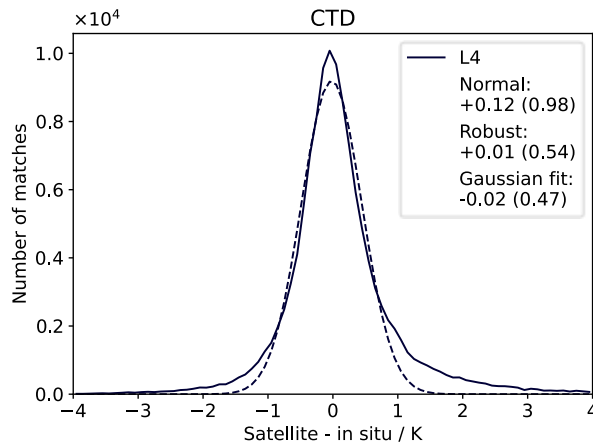
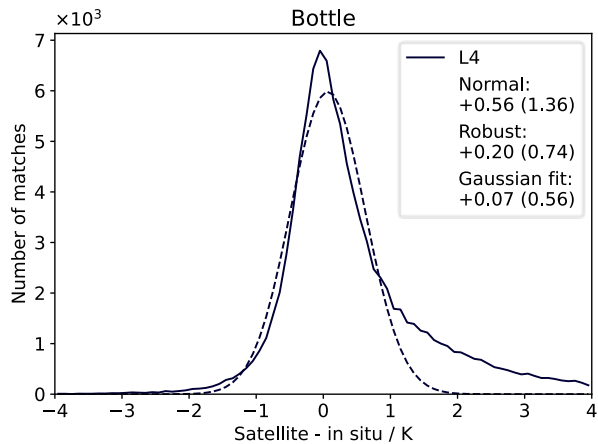
# Validation of Level 4 SST (1980s)



	Global			Ocean (over 10 km from land)		
In situ type	Number	SD / K	RSD / K	Number	SD / K	RSD / K
Bottle	103005	1.36	0.74	67909	1.06	0.56
CTD	123814	0.98	0.54	104339	0.90	0.51
Drifter	257794	0.78	0.48	253766	0.75	0.47
MBT	15892	1.37	0.73	14199	1.29	0.69
Mooring	139118	0.80	0.56	125561	0.79	0.55
XBT	99045	0.83	0.49	96861	0.82	0.48
Ship	18055483	1.28	1.00	17508166	1.27	1.00

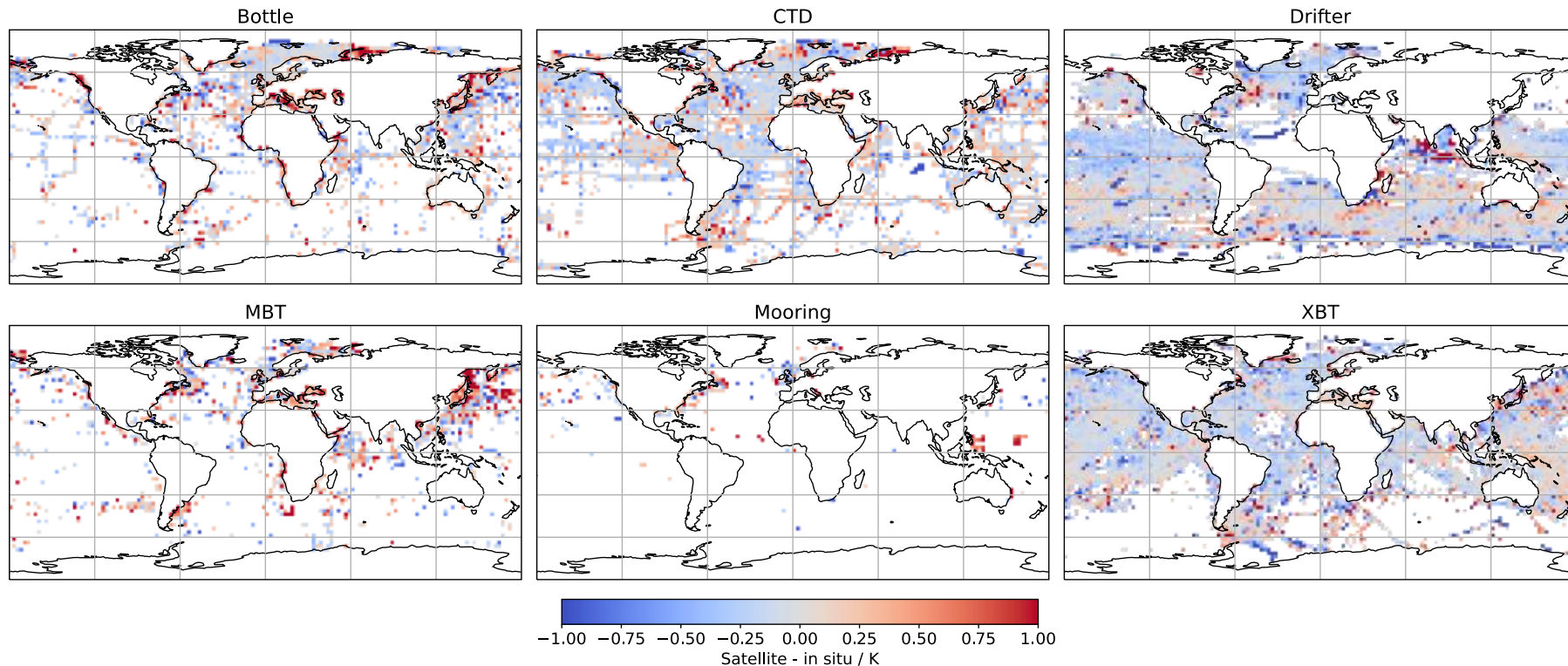


# Validation of Level 4 SST (1980s)



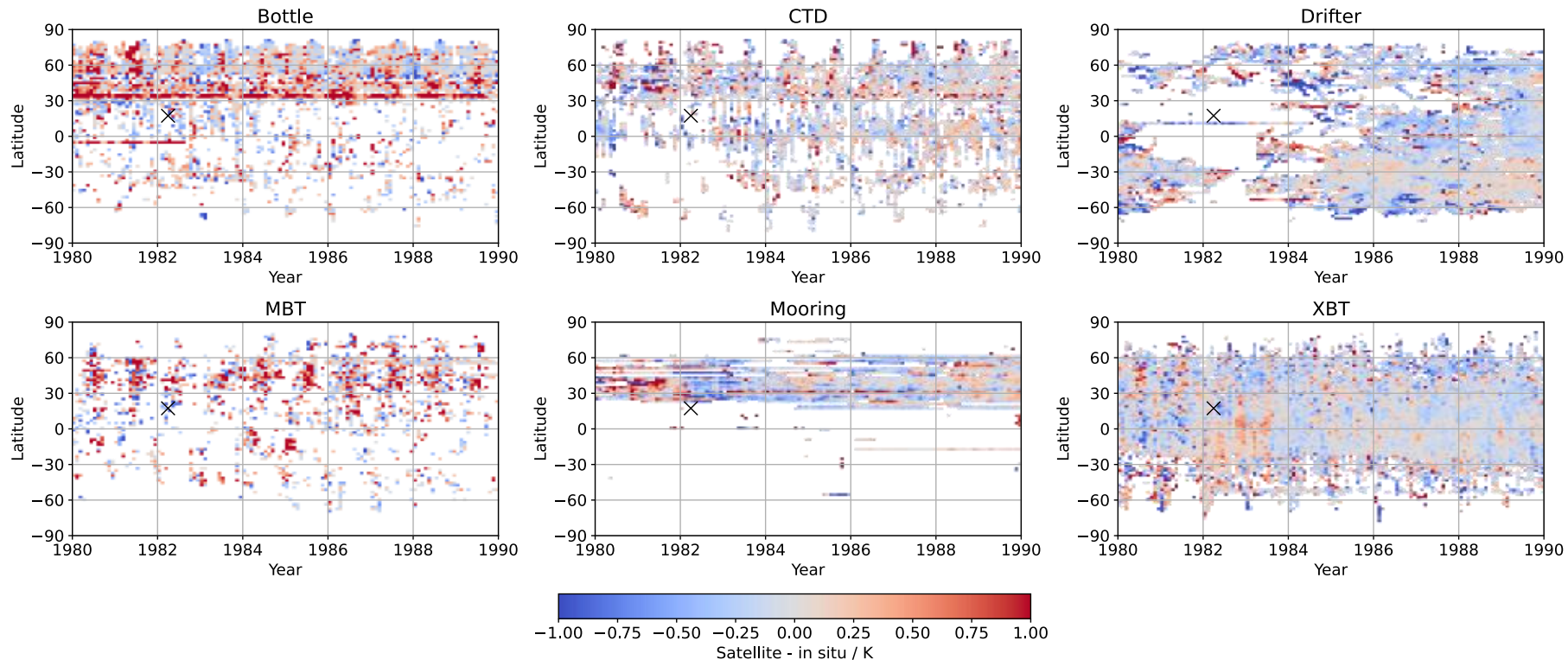


# Validation of Level 4 SST (1980s)



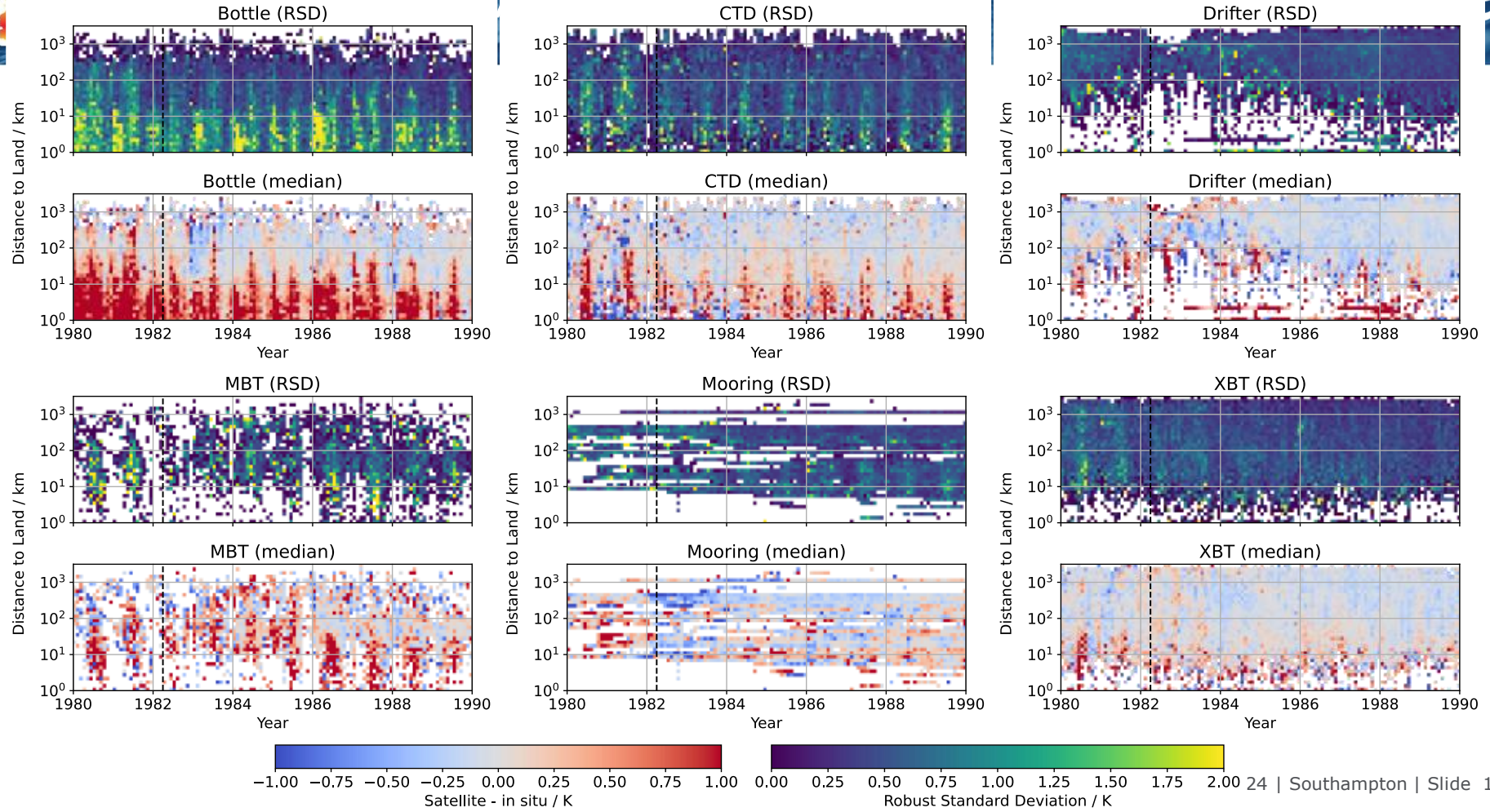


# Validation of Level 4 SST (1980s)





# Validation of Level 4 SST (1980s)





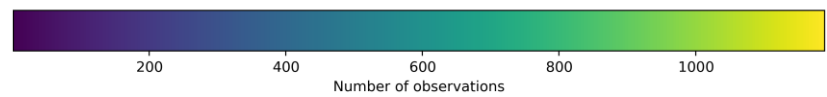
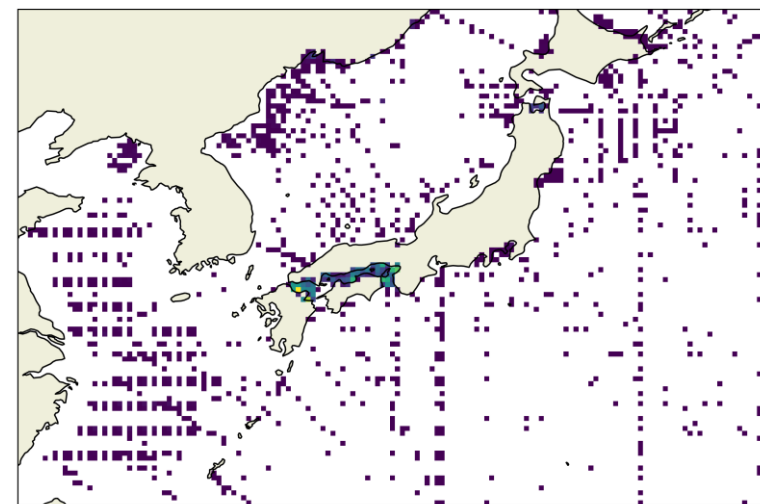


# Spatial Sampling



- 34% of bottle in situ within  $\sim 10$  km of land
- Most of these are in Seto Inland Sea
  - Too small to be adequately resolved in 1980s
  - AVHRR GAC pixels are  $\sim 4 - 15$  km
  - Level 4 will be extrapolating from Sea of Japan / Pacific
- Will exclude bottle and MBT from main validation results
- Also split into ocean ( $> 10$  km) and coastal ( $< 10$  km)

Location of Bottle observations

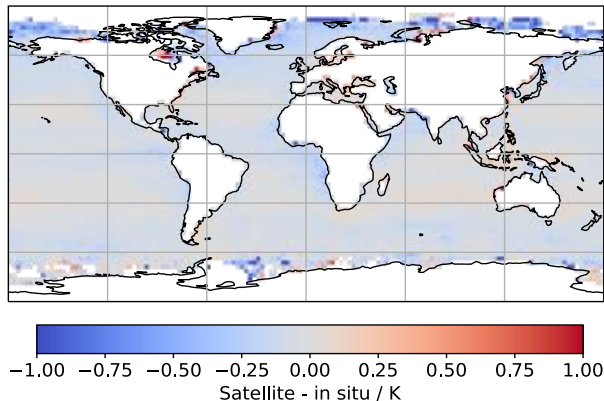




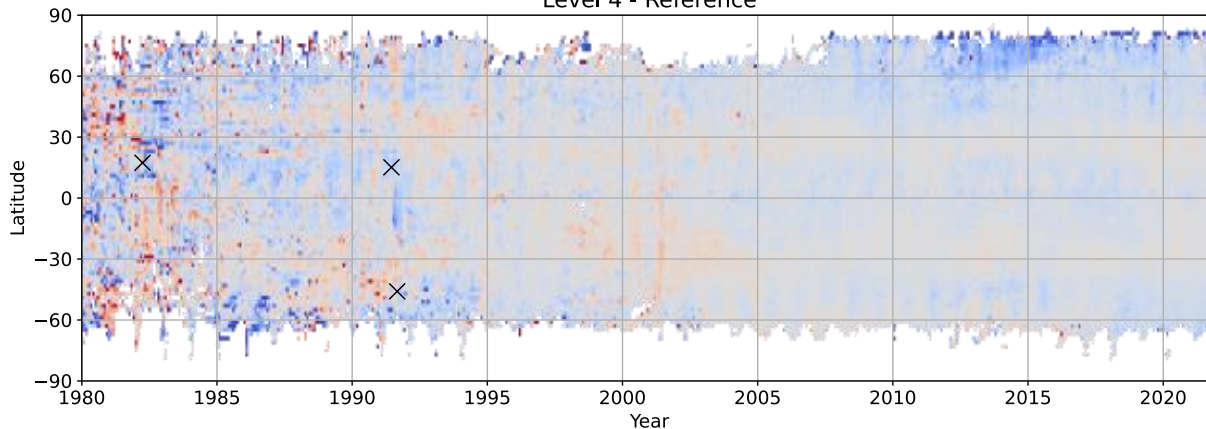
- Validation against reference in situ:
  - CTD, drifter, GTMBA, moorings, and XBT up to end-1995
  - Drifter-only from 1996 onwards

	Ocean (over 10 km from land)			Coastal (under 10 km from land)		
In situ type	N / million	SD / K	RSD / K	N / million	SD / K	RSD / K
<b>Reference</b>	10.81	0.49	0.25	0.54	0.96	0.46
Ship	45.03	1.22	0.89	3.23	1.25	0.88

Level 4 - Reference



Level 4 - Reference

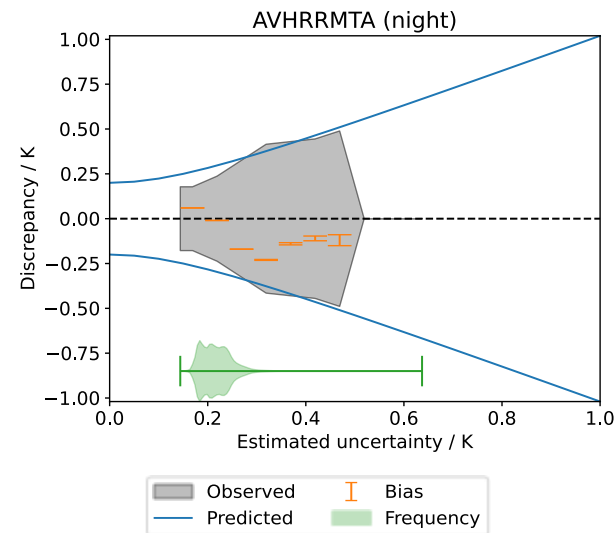




- Uncertainties can be validated using *in situ* data

**Right:** discrepancy (satellite – *in situ*) against estimated uncertainty

- Grey area shows robust standard deviation (RSD) of discrepancy
- Blue line shows expected dependency from assumed *in situ* uncertainty (0.2 K for drifters)
- Green violin plot shows distribution of data

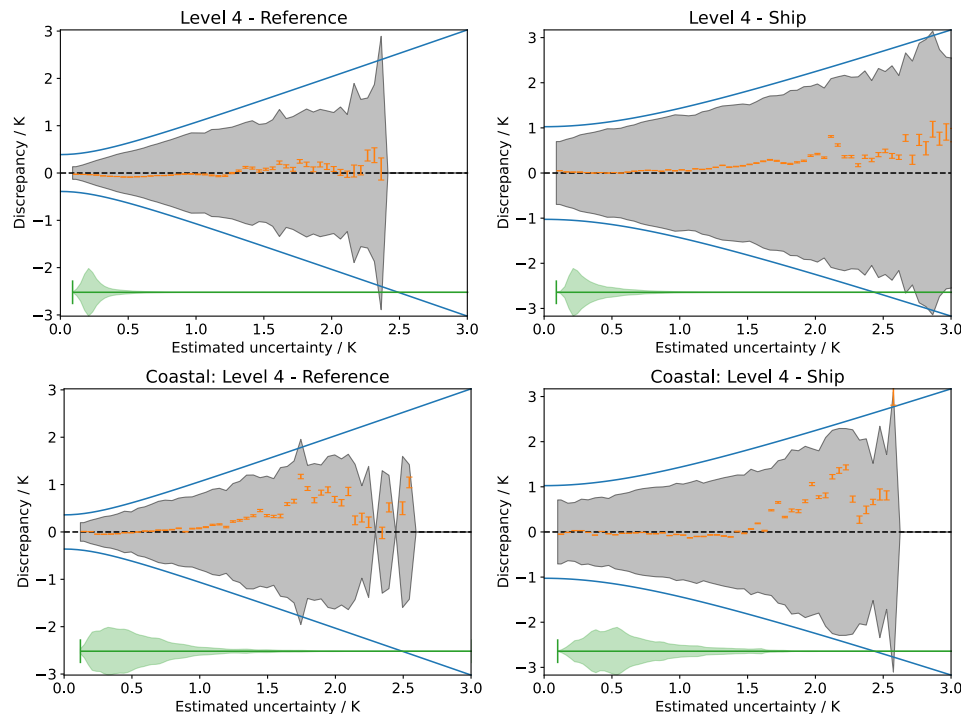




# Uncertainty Validation



- Level 4 analysis uncertainty are slightly over-estimated
- Maybe partly related to *in situ* data – reference data had a median reported uncertainty of 0.39 K
- Majority of data have estimated uncertainty < 0.5 K
- Data are more uncertain in coastal regions





# Summary

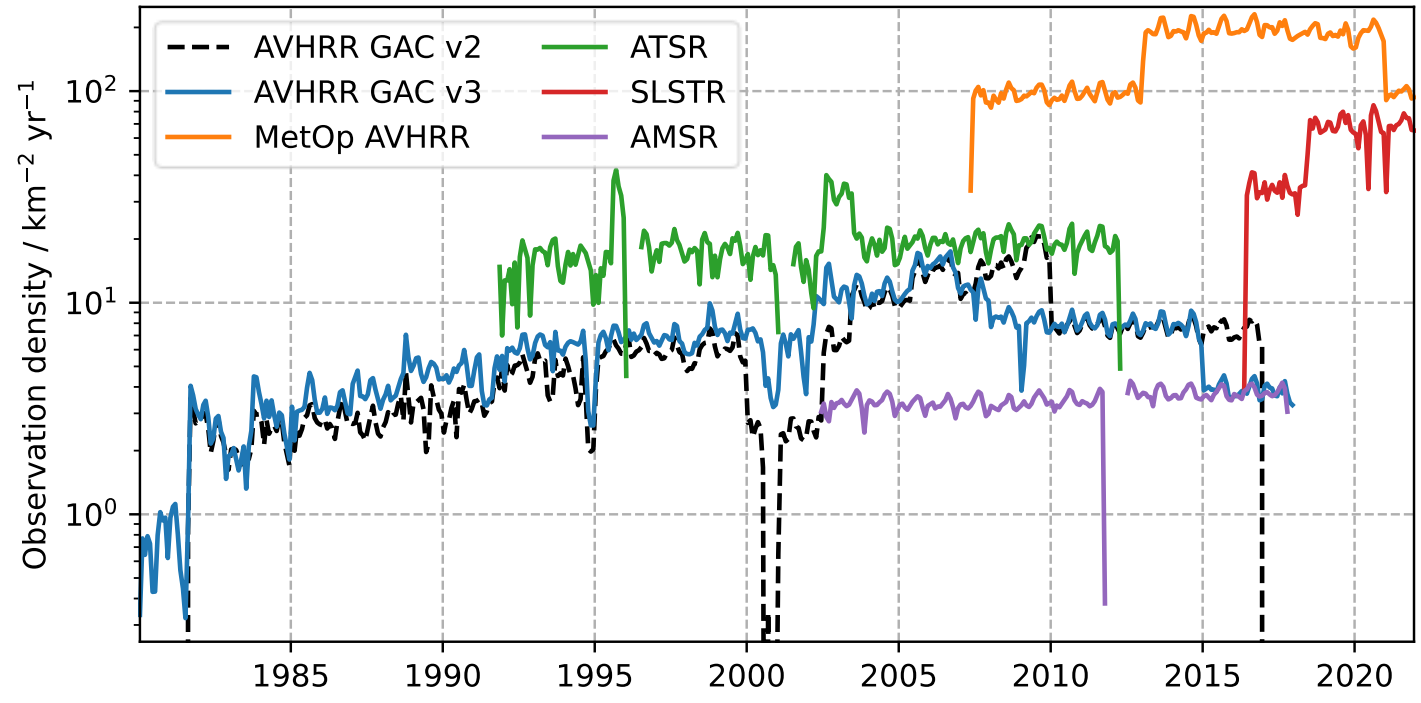


- 42-year CDR from 1980 to end-2021
  - Adds AVHRR/1, Passive Microwave, full-resolution MetOp, and SLSTR
  - New bias-aware OE retrieval and reduced desert-dust related biases
  - Interim-CDR to provide ongoing extension at 2-3 weeks latency
    - 2022: C3S. 2023 onwards: UK funding EOCIS / UKMCAS
- Data available from:
  - <https://climate.esa.int/en/projects/sea-surface-temperature/>
- Regional and re-gridded data products will be available next month:
  - <https://surftemp.net/>
- Embury et al. (**2024**). Satellite-based time-series of sea-surface temperature since 1980 for climate applications. *Sci Data* 11, 326. <https://doi.org/10.1038/s41597-024-03147-w>





# Single-Sensor Data Density



## New in CDRv3

- MetOp AVHRR
- SLSTR
- AMSR

## AVHRR GAC

- More data in 1980s / 1990s
- v2 included MetOp as GAC from 2007
- 1980 is NOAA-06 only



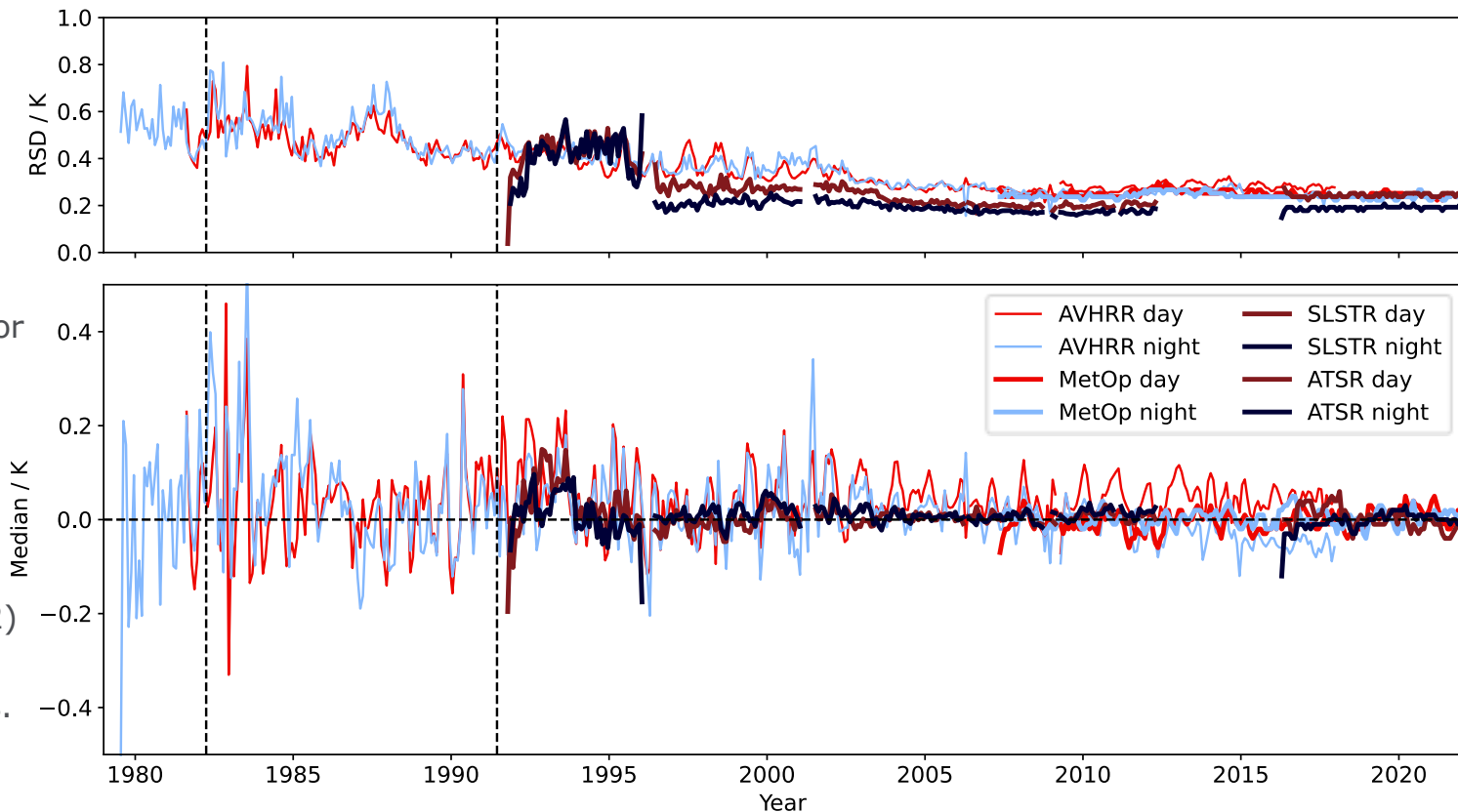
# Time series of IR validation against in situ



SST<sub>0.2m</sub>@10:30  
compared to *in situ*

- *In situ* includes all non-ship data up to NOAA-12
- Drifters-only used for NOAA-14 onwards.

Vertical dashed lines show time of El Chichón (April 1982) and Mount Pinatubo (June 1991) eruptions.







# Summary of IR validation against *in situ*



	Day		Night	
	Median	RSD	Median	RSD
NOAA-06			+0.02	0.55
NOAA-07	+0.00	0.53	+0.07	0.53
NOAA-08			+0.02	0.57
NOAA-09	+0.02	0.49	+0.02	0.51
NOAA-10			-0.04	0.52
NOAA-11	+0.07	0.43	+0.05	0.41
NOAA-12	+0.02	0.40	-0.00	0.41
NOAA-14	+0.04	0.37	+0.02	0.38
NOAA-15	+0.03	0.32	+0.03	0.34
NOAA-16	+0.05	0.30	-0.03	0.29
NOAA-17	+0.07	0.25	+0.06	0.26
NOAA-18	+0.03	0.28	-0.02	0.27
NOAA-19	+0.05	0.28	-0.03	0.25

Reference *in situ* includes all non-ship data up to NOAA-12

Drifters-only used for NOAA-14 onwards



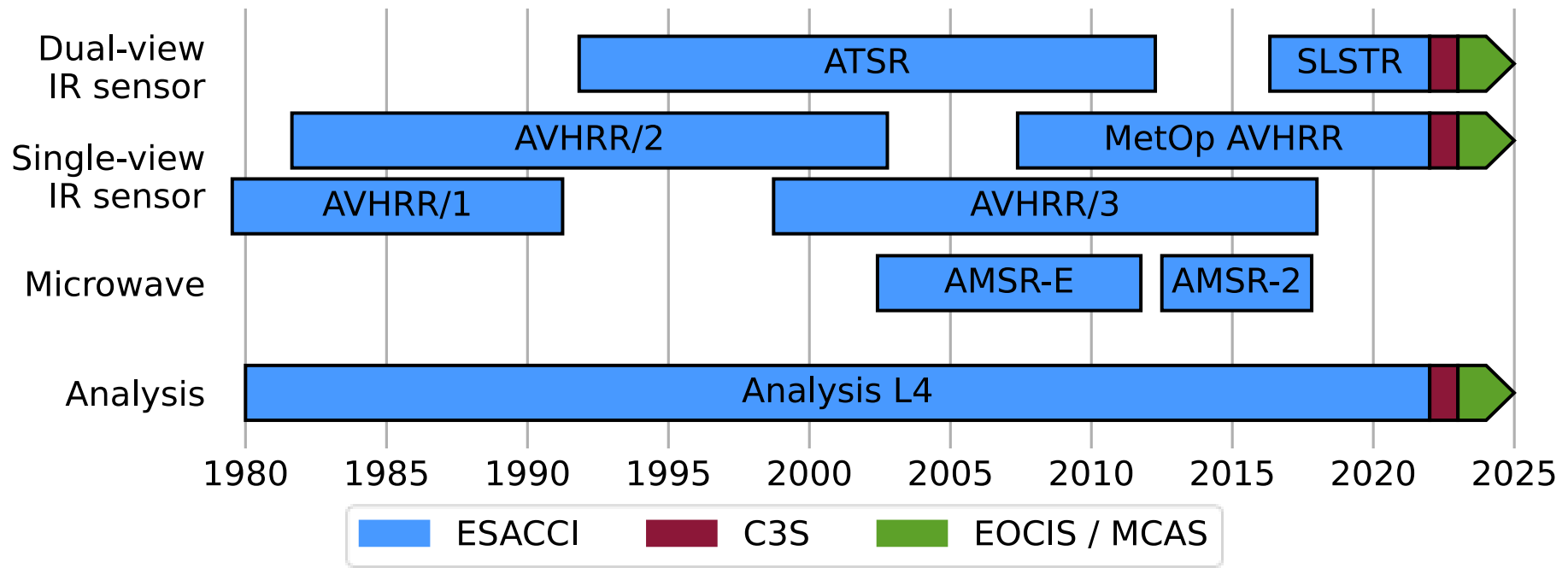
# Summary of IR validation against *in situ*



	Day		Night	
	Median	RSD	Median	RSD
MetOp-A	-0.01	0.25	-0.01	0.24
MetOp-B	+0.01	0.25	+0.02	0.24
ATSR-1	+0.04	0.45	+0.01	0.45
ATSR-1 (d3)			+0.00	0.26
ATSR-2	-0.00	0.28	+0.02	0.21
AATSR	+0.01	0.21	+0.01	0.18
SLSTR-A	+0.02	0.25	+0.00	0.19
SLSTR-B	-0.03	0.24	-0.01	0.19



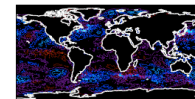
- Ongoing extension of SST-CCI CDR produced using the same software
  - Uses ECMWF ERA5-T as prior rather than ERA5 (CDR)
  - 2-3 weeks behind present
- With version 3 both CDR and ICDR will be accessed as a single dataset via CEDA
- 2022 funded by Copernicus Climate Change Service (C3S)
- 2023 onwards funded by:
  - UK Earth Observation Climate Information Service (EOCIS) – Level 2/3 production (Reading)
  - Marine Climate Advisory Service (MCAS) – Level 4 production (Met Office)





- Steady stream of requests from users with less compute capability to deal with full SST CCI archive data on CEDA
- For flexible low-resolution and extraction requests: <https://surfTemp.net/>
- Region, time period and resolution requested are ordered, and users download from a link after creation
- Regridded uncertainties are also estimated
- Made under NCEO funding
- 77 subscribed users plus many anonymous

## Sea Surface Temperature Data



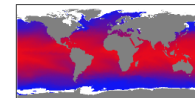
The data available here is made available by the [Surface Temperature Group at the University of Reading, UK](#).

To obtain the data upon which these services are based, see [data used by this service](#).

### Available services

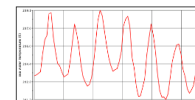
#### Re-gridding Service

Obtain L4 sea and ocean surface temperature datasets in your chosen spatial and temporal resolution



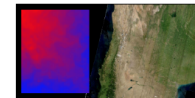
#### Time-series Service

Obtain L4 sea and ocean timeseries for a particular bounding box



#### Region Service

Obtain L4 sea and ocean data at 0.05 degree resolution for a particular bounding box



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# Mean Global SST (ESA CCI v3.0)

