climate change initiative

→ SEA SURFACE TEMPERATURE

A 35 year SST Climate Data Record from the ESA Climate Change Initiative

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sst cci

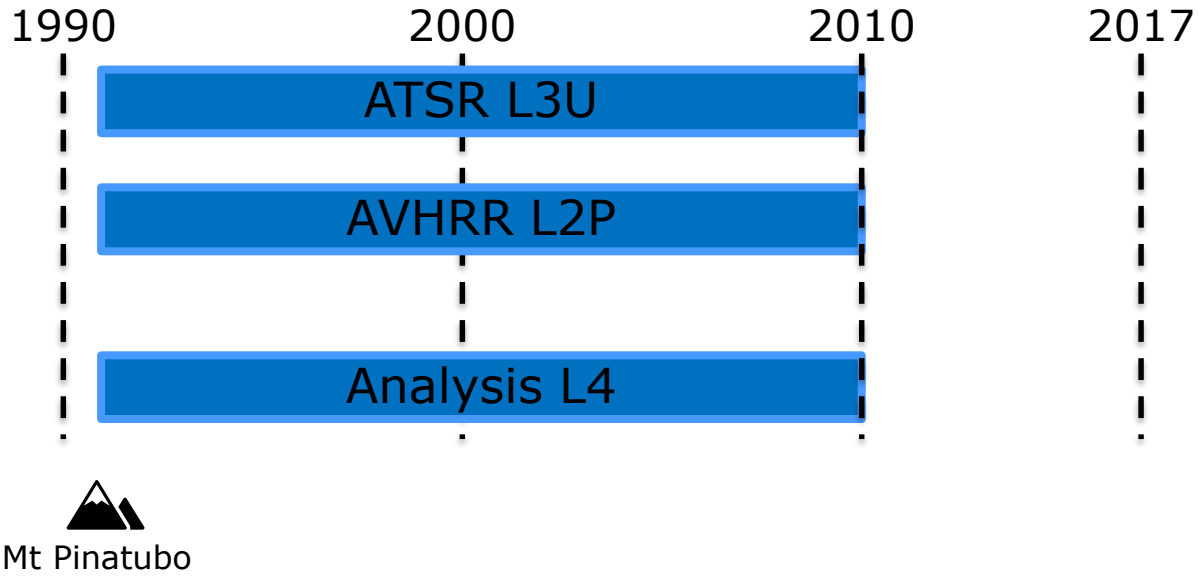
University of Reading | Met Office | Brockmann Consult | DMI | University of Leicester | Météo France | Norwegian Meteorological Institute | National Oceanography Centre | Space ConneXions

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

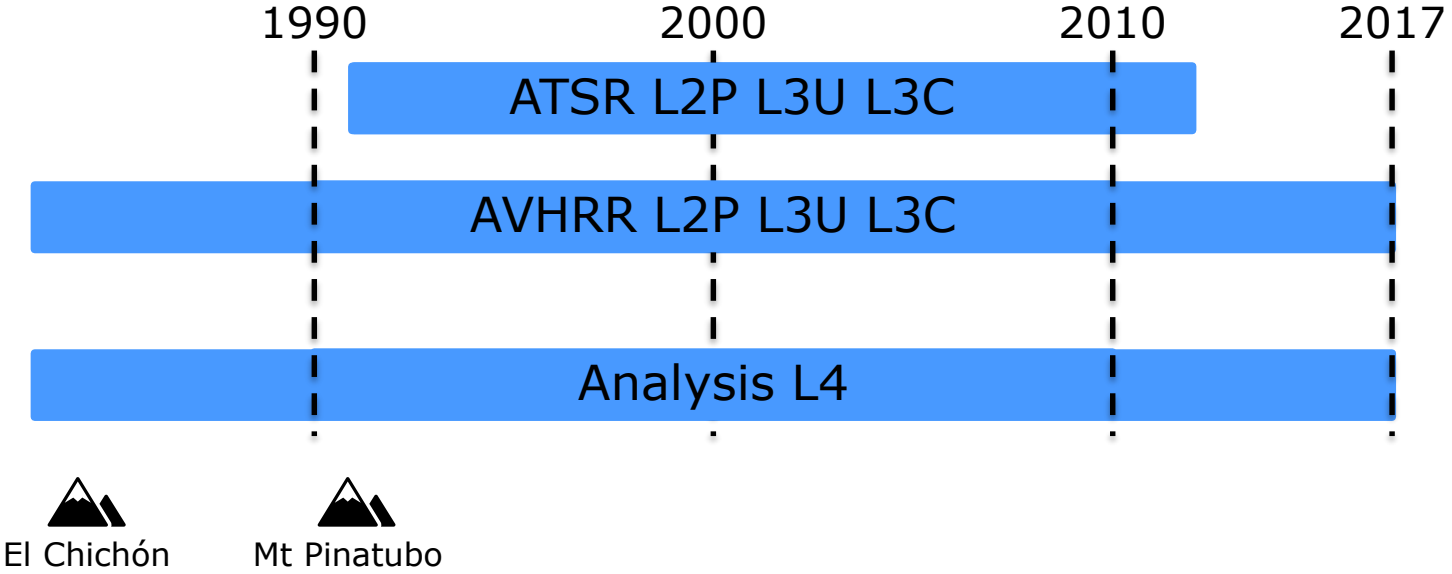
SST CCI CDR v1

- CCI Phase 1 dataset
  - 19 years (September 1991 – December 2010)
  - Released 2014



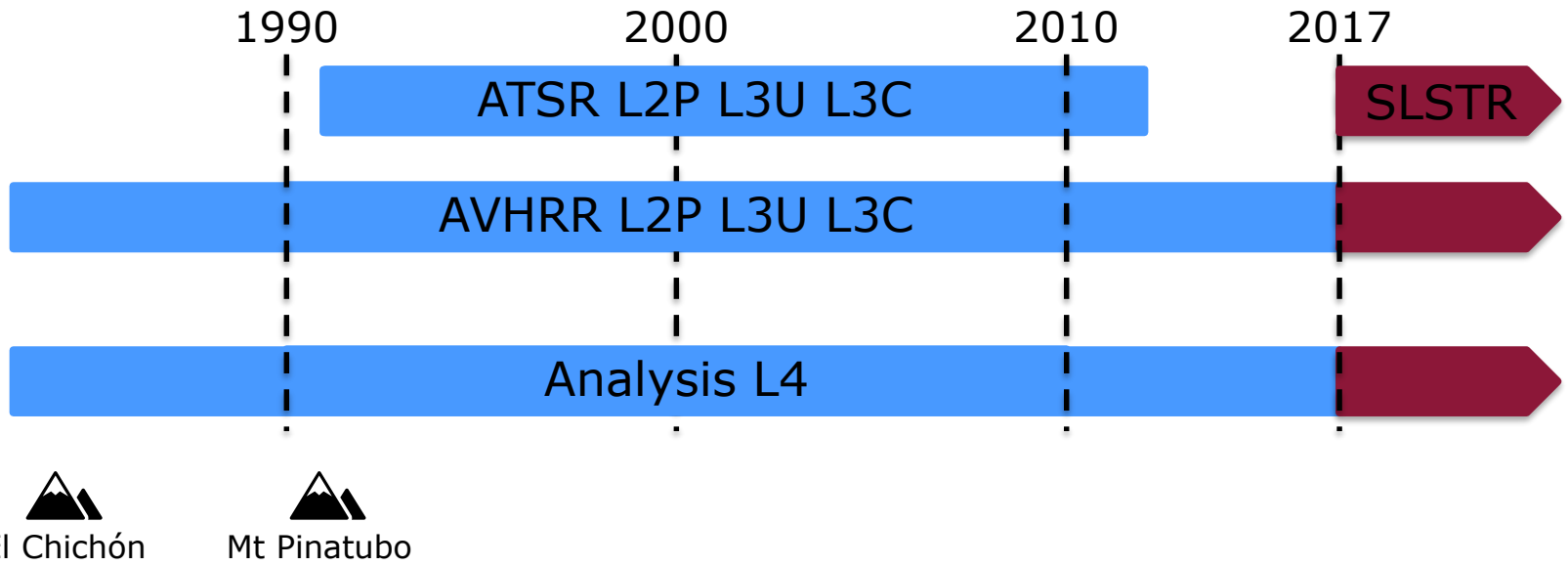
SST CCI CDR v2

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



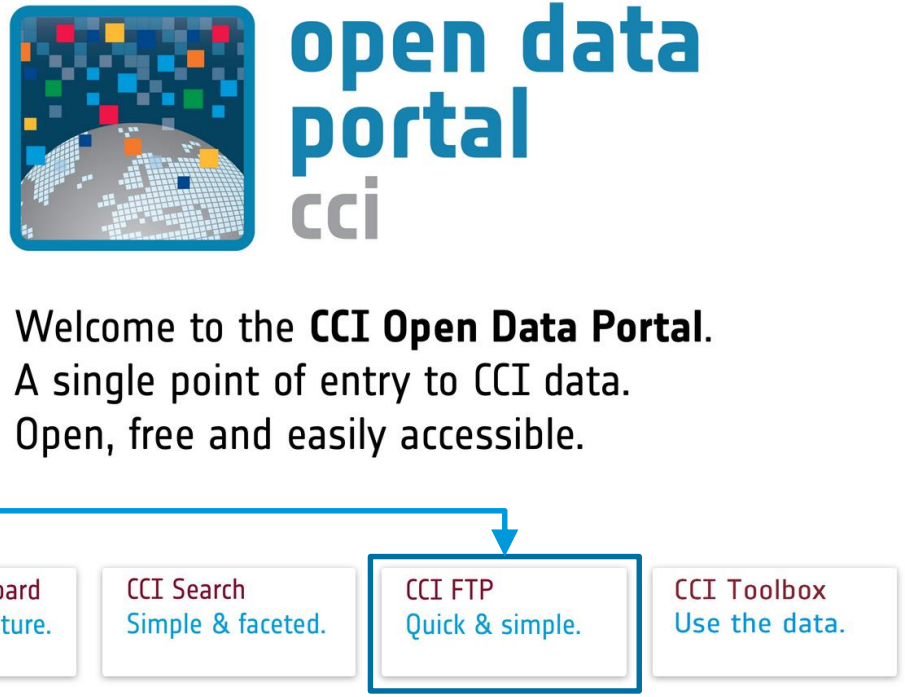
C3S ICDR v2

- Copernicus Climate Change Service (C3S) Interim CDR (ICDR)
  - Extends CCI CDR v2
  - Monthly updates ~9 months behind present



Data Access – Open Data Portal

- Data are online, but catalogue records are in progress
- Open Data Portal:
  - http://cci.esa.int/data
  - Use the FTP link:
  - Others will work soon…



Merchant et al. (2019). Satellite-based time-series of sea-surface temperature since 1981 for climate applications, *Scientific Data*, in prep

Data Access – Climate Data Store

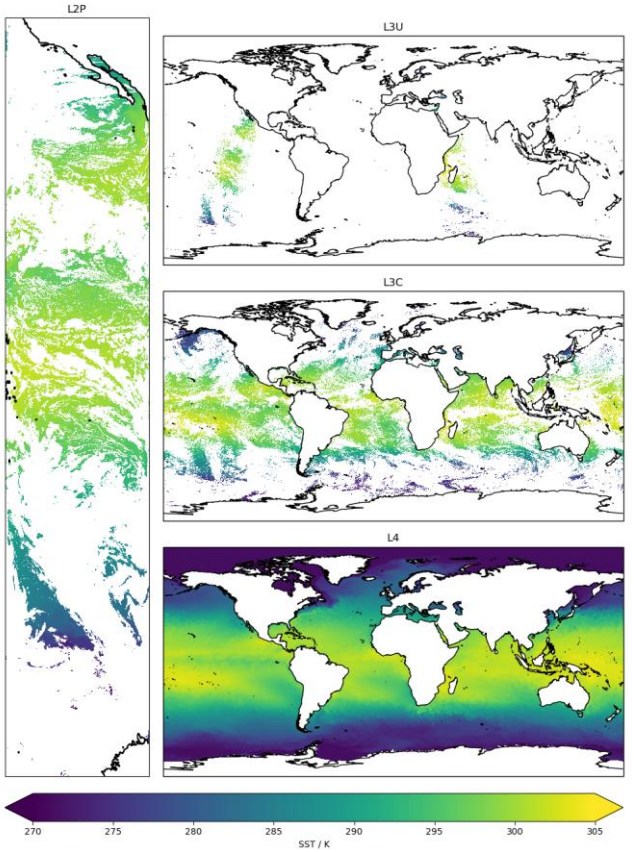
- Seamless web and API-based access climate data and information
- Copernicus Climate Data Store (CDS):
  - https://cds.climate.copernicus.eu
  - Currently only CCI CDR v1 accessible
  - Will allow seamless access to CCI CDR + C3S ICDR

In progress

Merchant et al. (2019). Satellite-based time-series of sea-surface temperature since 1981 for climate applications, *Scientific Data*, in prep

SST-CCI Climate Data Record v2

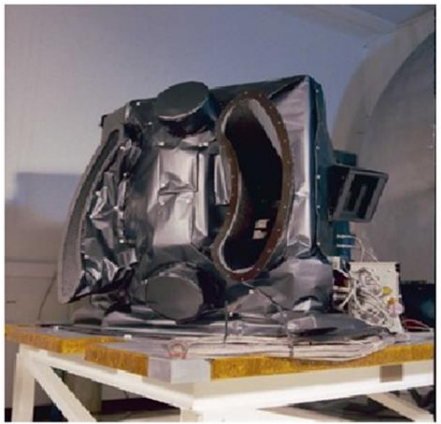
- 35 years (September 1981 – December 2016)
- 18 x 10^{12} satellite radiance measurements
- Single-sensor products:
  - **L2P** swath, **L3U** gridded, and **L3C** daily
  - SST-type:
    - Skin at satellite overpass
    - SST_{20cm} at 10:30 local-time
  - Uncertainties provided:
    - random, correlated,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



SST-CCI Input Sensors

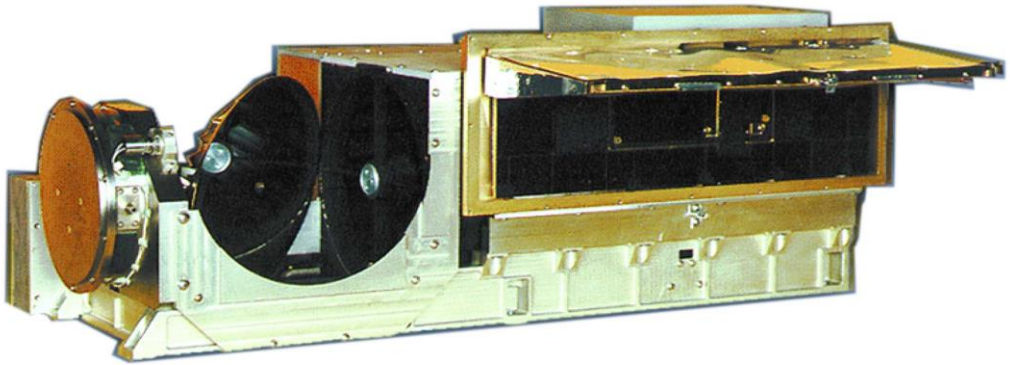
ATSR

- Dual-view reference sensor
- Exceptional calibration
- Aerosol-robust
- Independent SST retrieval
  - Physical retrieval based on Radiative Transfer modelling

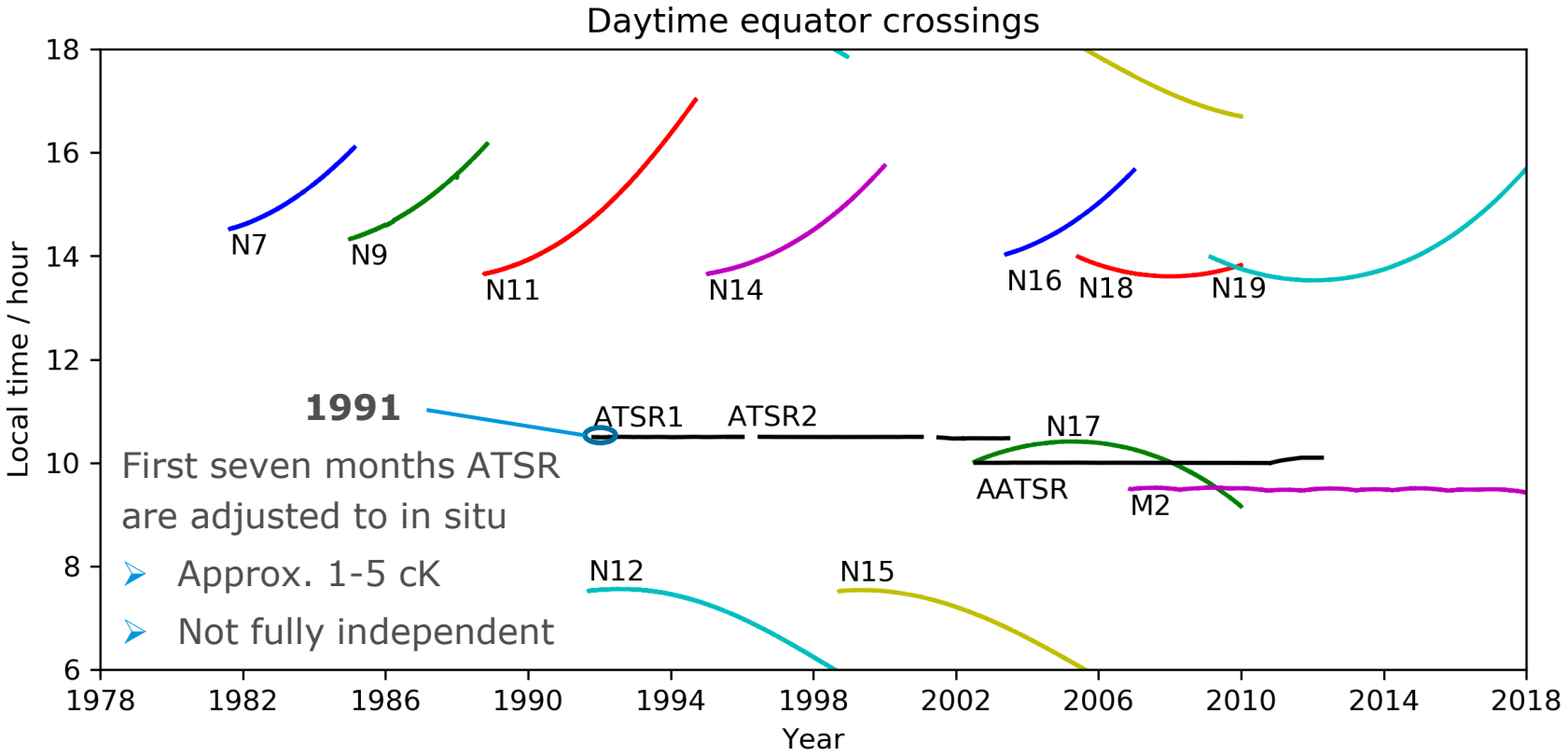


AVHRR

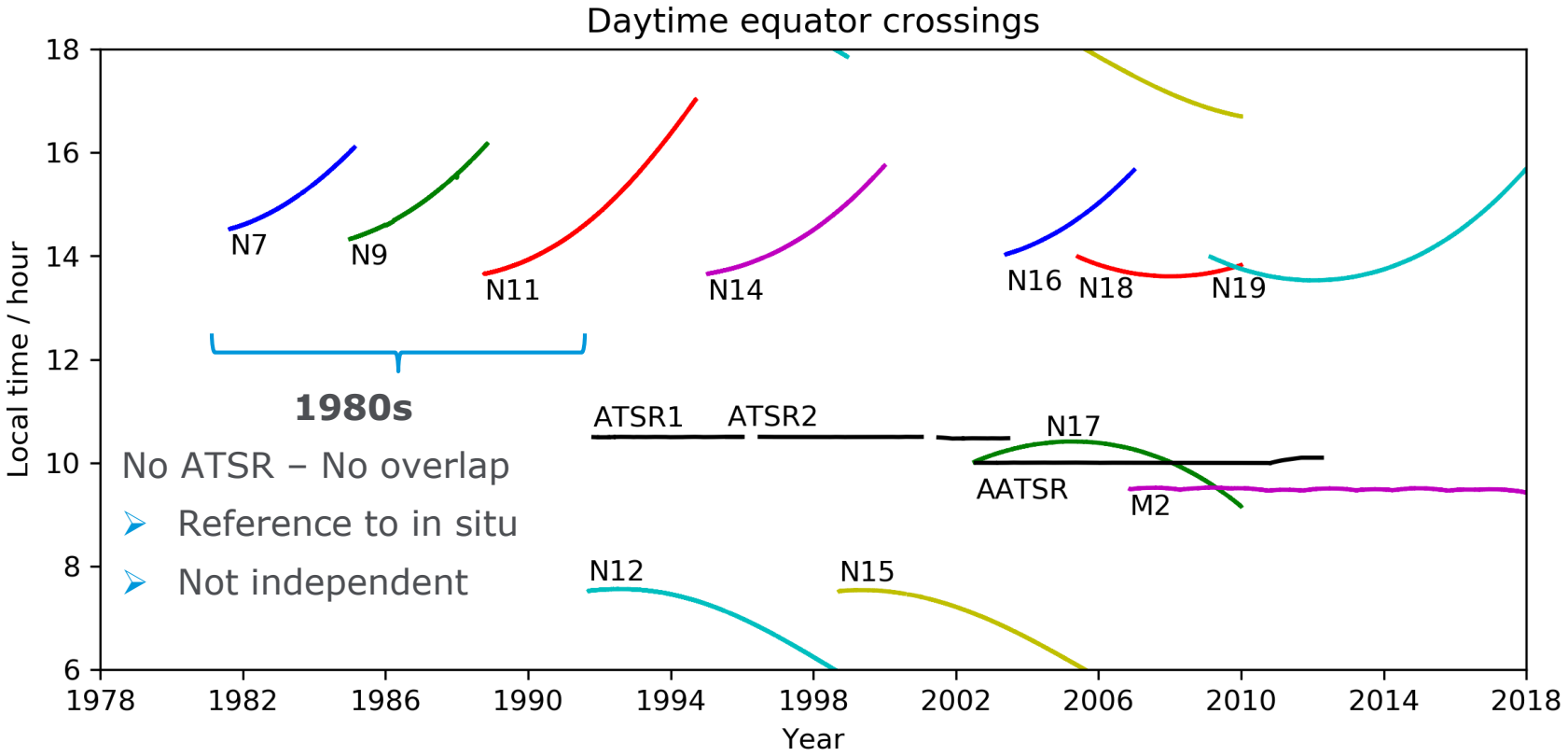
- Single-view meteorological sensor
- Variable calibration
- Not aerosol robust
- Optimal Estimation SST
  - Bias adjusted to match ATSR reference



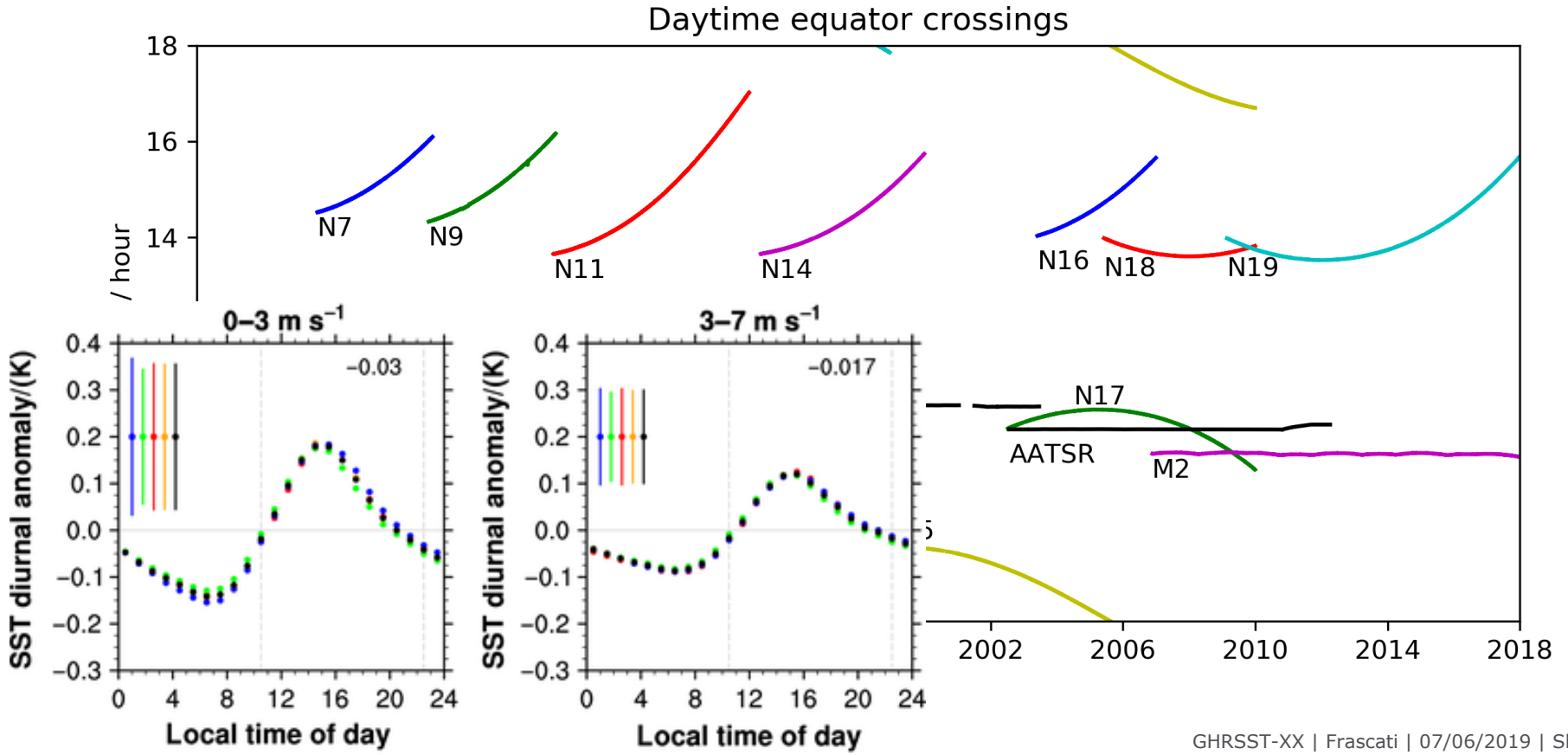
SST-CCI Input Sensors



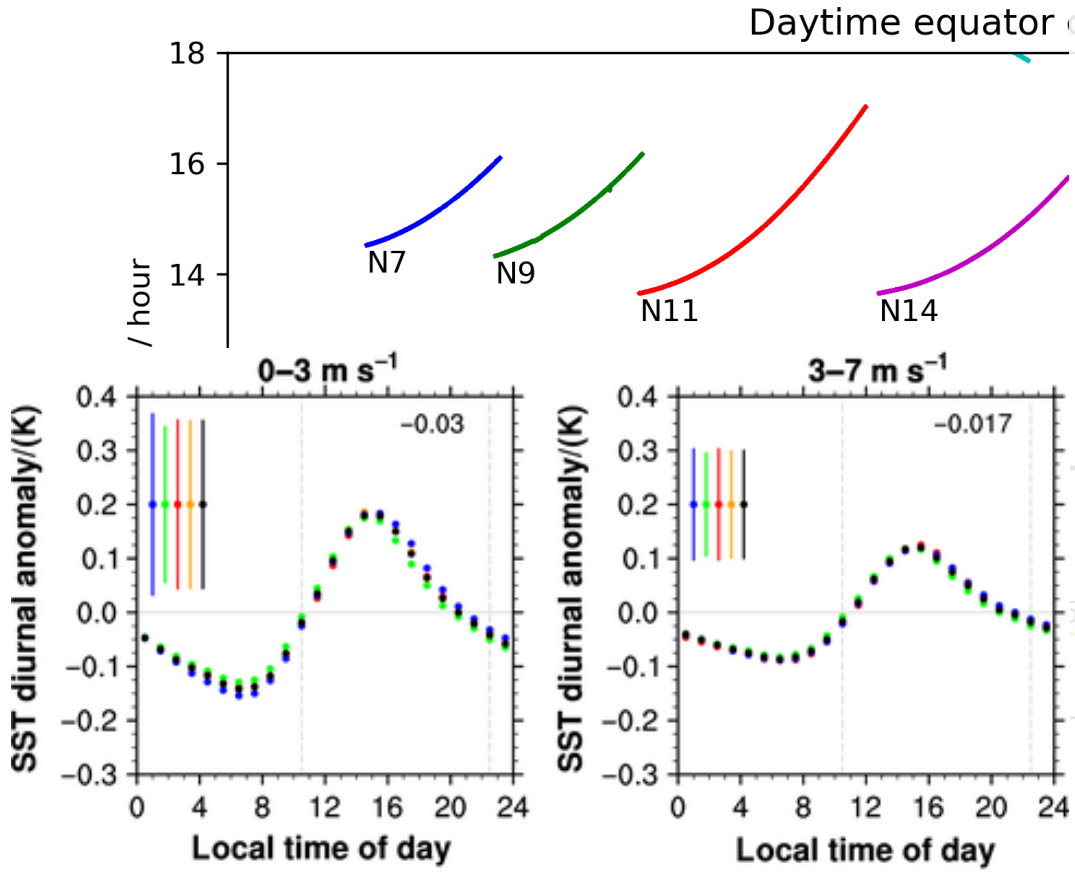
SST-CCI Input Sensors



Diurnal Variability



Diurnal Variability



- SST changes throughout day
- Drift in LECT can be aliased into SST record
- Adjust to standard time of day
  - 10:30 local time
  - Equivalent to daily mean SST
- Adjustment based on
  - Fairall-Kantha-Clayson
  - Met Office code

L2/L3 validation against drifters

	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

- 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

L2/L3 validation against drifters

	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
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

L2/L3 validation against drifters

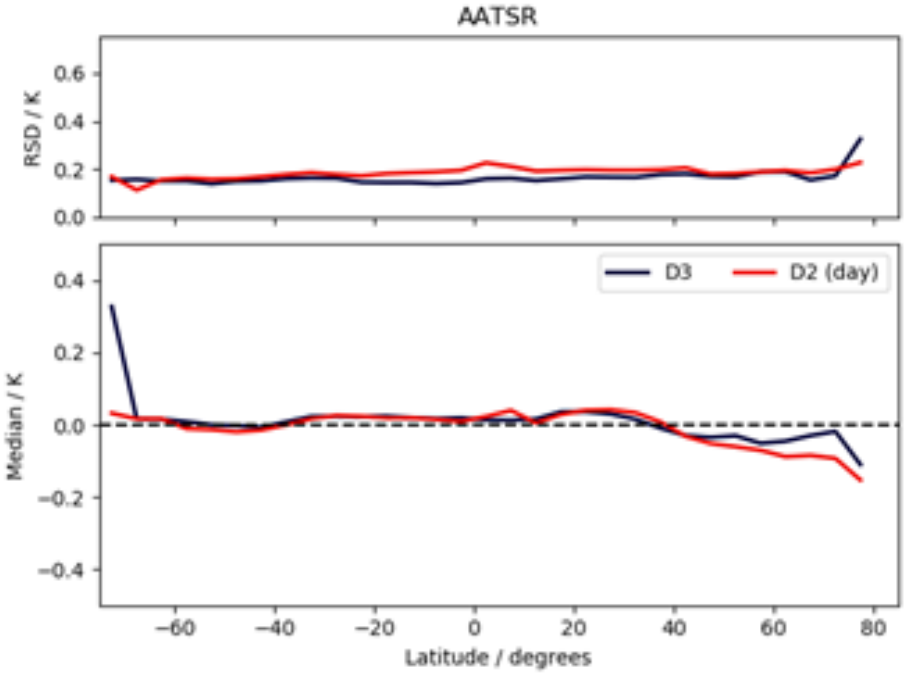
	Level-2				Level-3			
	Day		Night		Day		Night	
	Median	RSD	Median	RSD	Median	RSD	Median	RSD
NOAA-07	**-0.15**	**0.56**	-0.06	0.66	**-0.17**	**0.55**	-0.06	0.68
NOAA-09	-0.07	0.59	+0.02	0.61	**-0.10**	**0.59**	-0.02	0.65
NOAA-11	-0.06	0.52	+0.03	0.49	-0.09	0.51	+0.01	0.47
NOAA-12	-0.01	0.51	+0.02	0.44	-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
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

L2/L3 validation against GTMBA

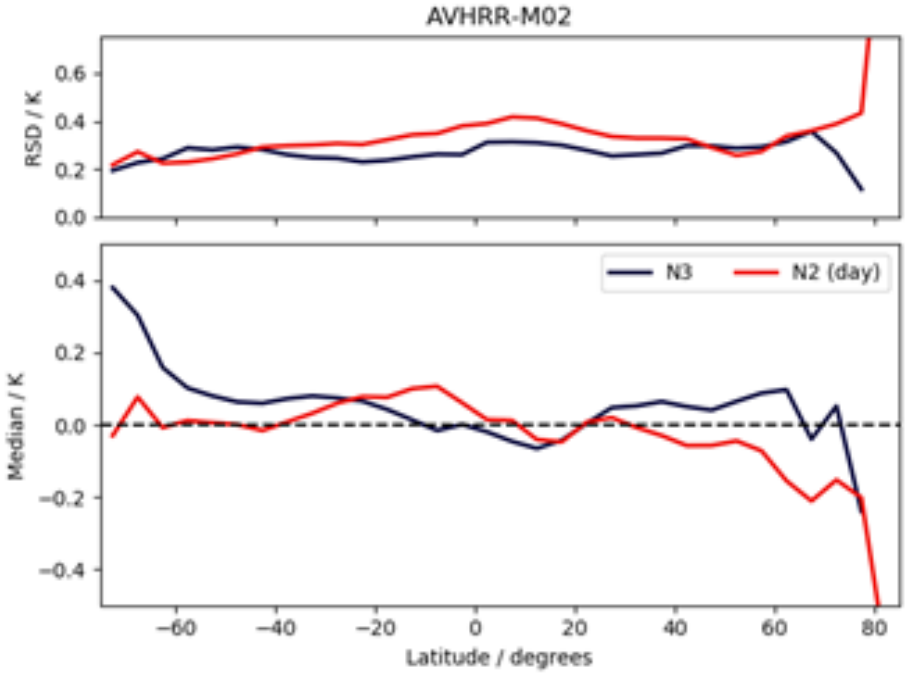
	Level-2				Level-3			
	Day		Night		Day		Night	
	Median	RSD	Median	RSD	Median	RSD	Median	RSD
NOAA-07								
NOAA-09								
NOAA-11	**-0.16**	**0.48**	-0.06	0.40	**-0.26**	**0.47**	-0.09	0.39
NOAA-12	+0.10	0.48	-0.08	0.40	+0.05	0.48	**-0.11**	**0.40**
NOAA-14	-0.02	0.43	-0.04	0.32	-0.06	0.43	-0.07	0.31
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

Spatial comparison against drifters

SST CCI AATSR L2P

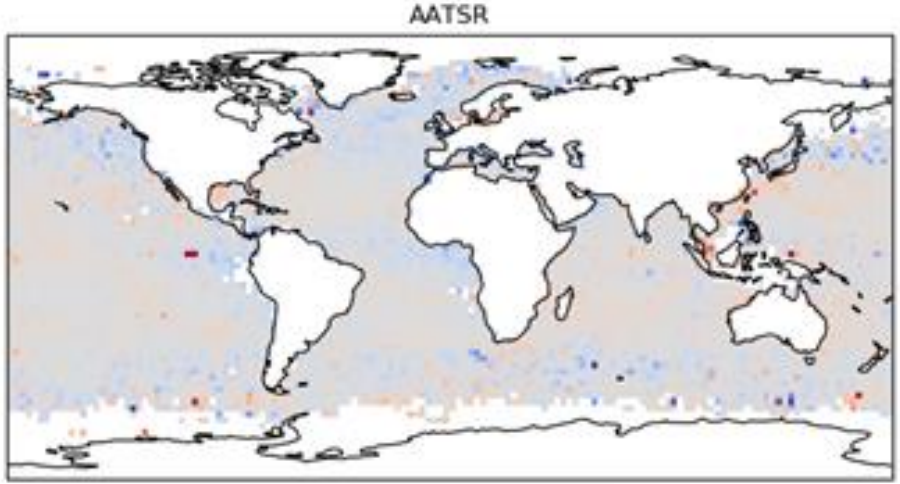


SST CCI AVHRRMTA_G L2P

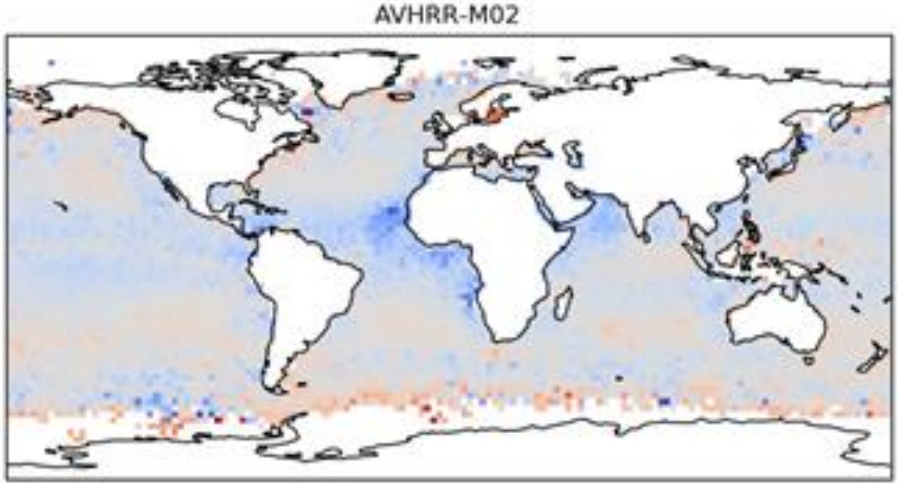


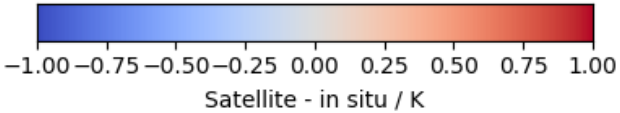
Spatial comparison against drifters

SST CCI AATSR L2P



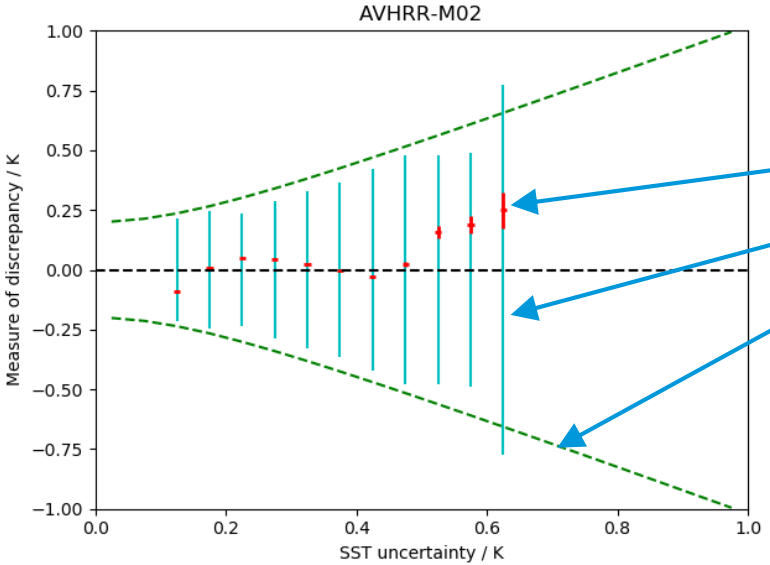
SST CCI AVHRRMTA_G L2P





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

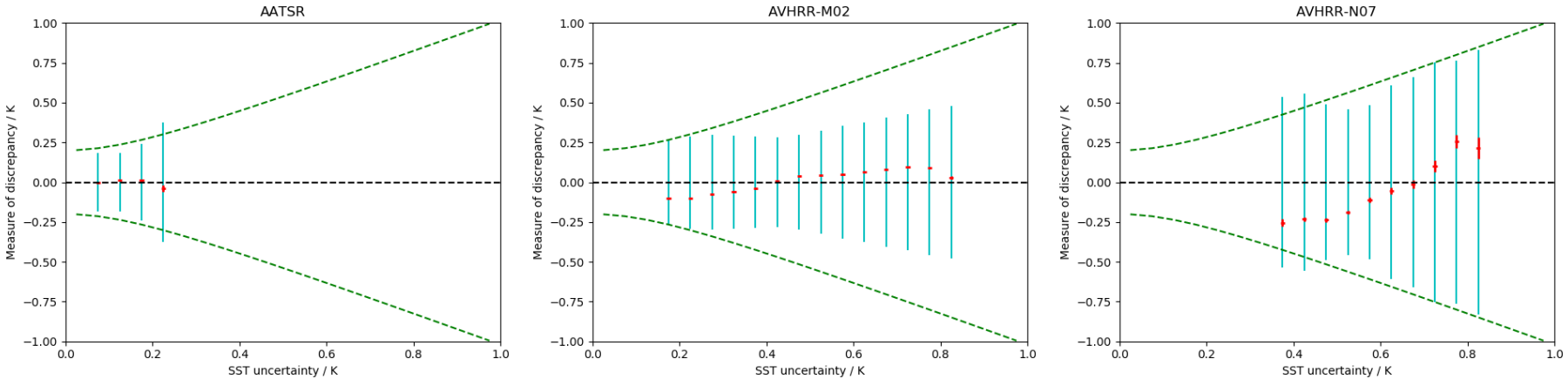
RED: Median discrepancy in bin

CYAN: RSD discrepancy in bin

GREEN: Expected RSD given in situ uncertainty

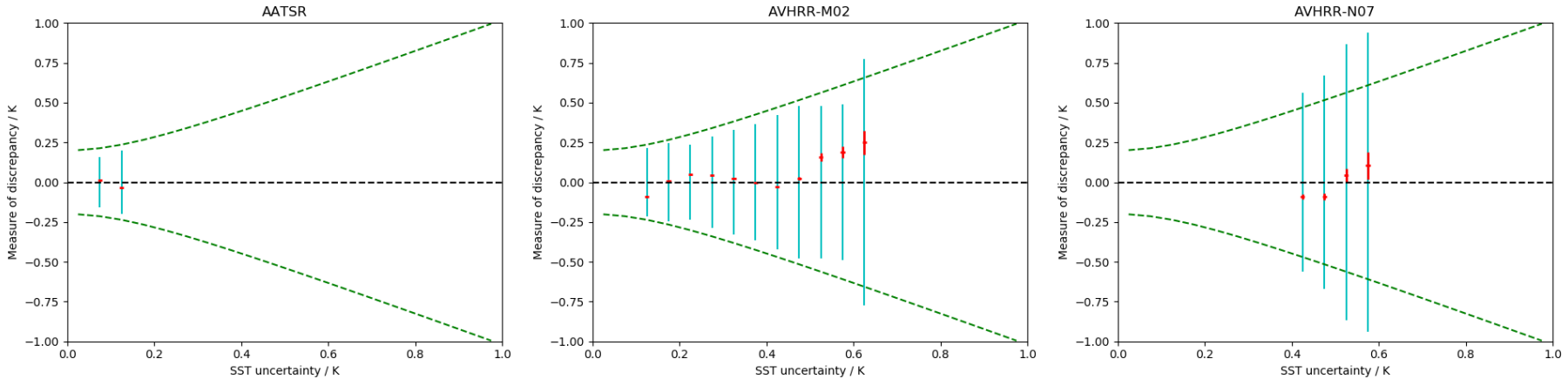
If the vertical lines match the dashed curve the uncertainty estimates are good!

L2P Uncertainty (daytime)



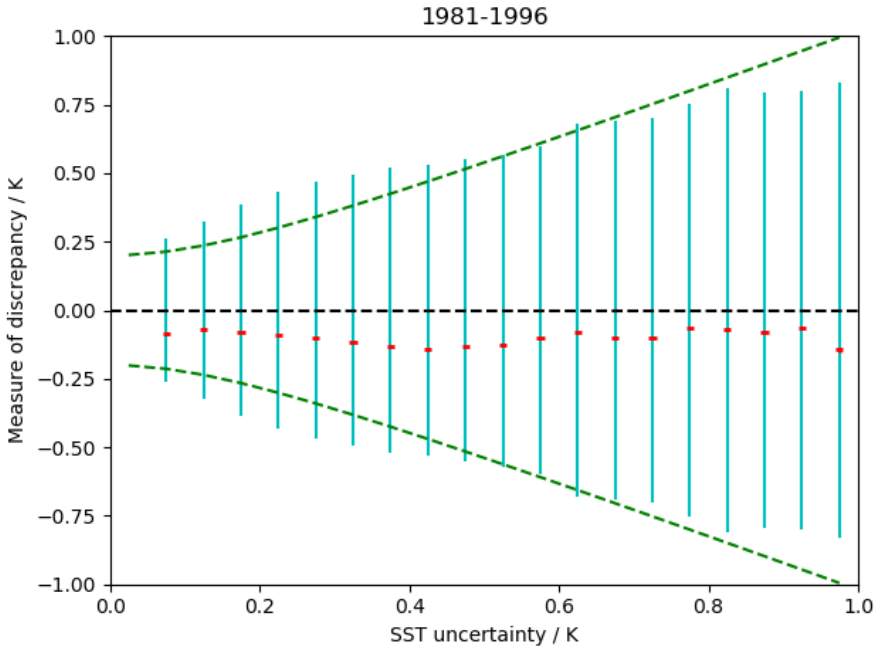
- ATSR uncertainty is good
- MetOp uncertainty is overestimated (also applies to NOAA-12 onwards)
- NOAA-07 uncertainty is good

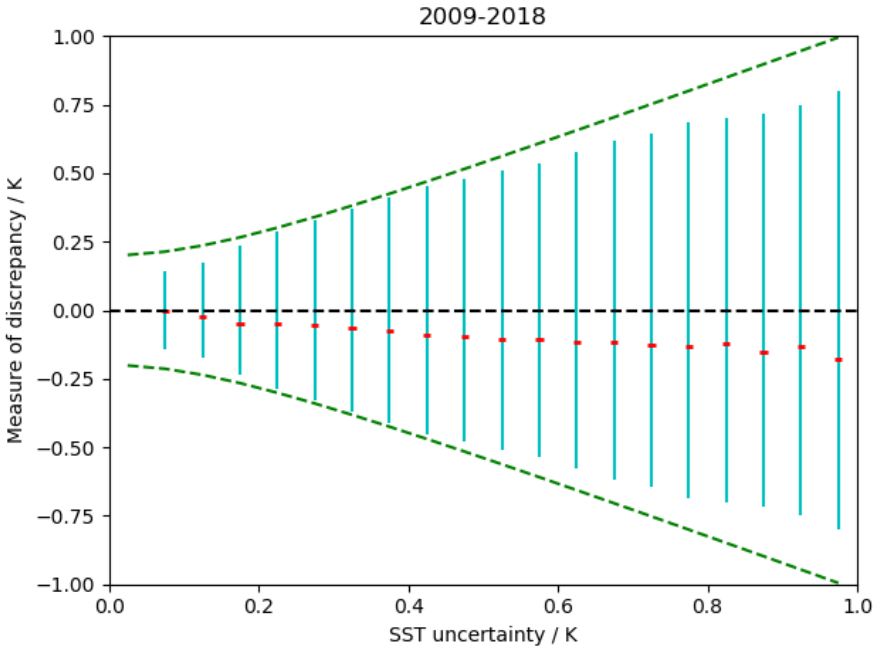
L2P Uncertainty (nighttime)



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

L4 Uncertainty





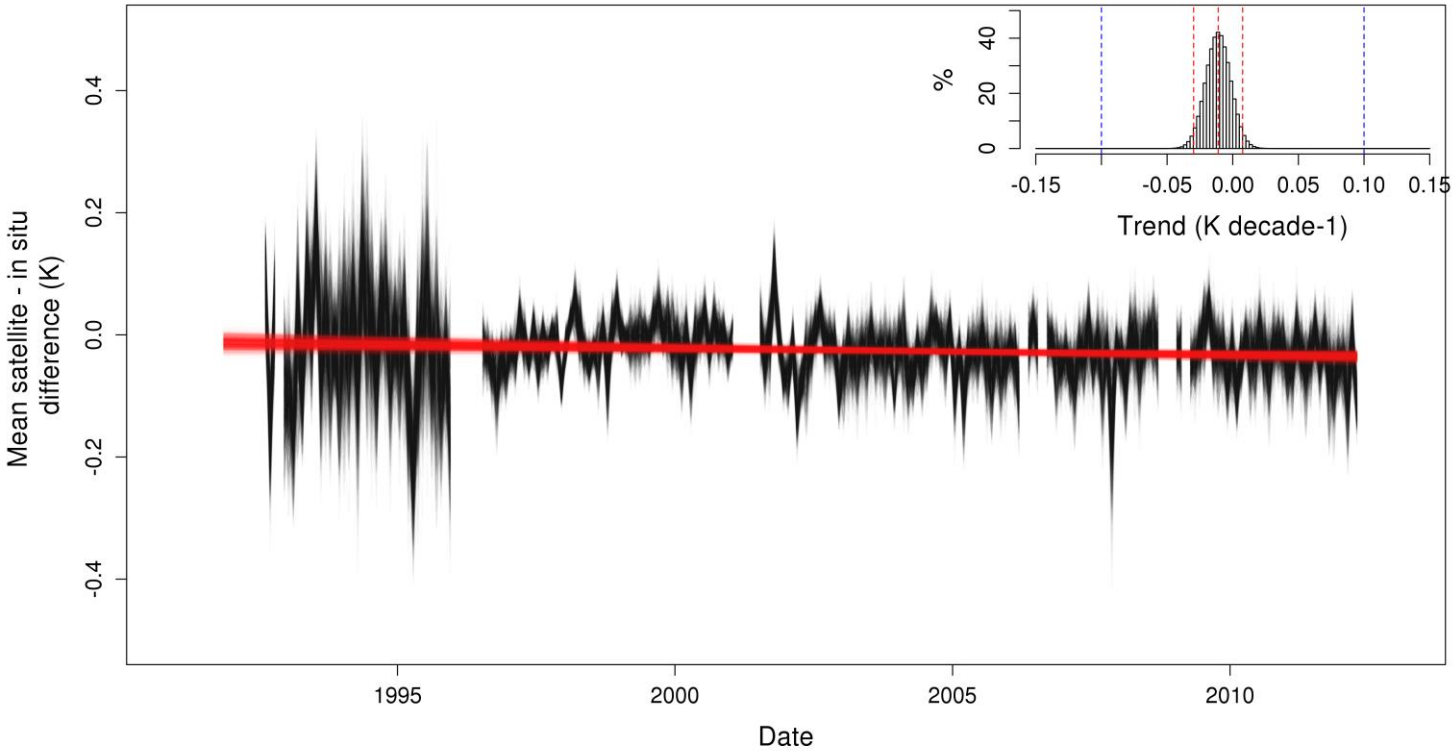
- Some under-estimation at low end for early data
- Some over-estimation at high end for more recent data

Stability Assessment

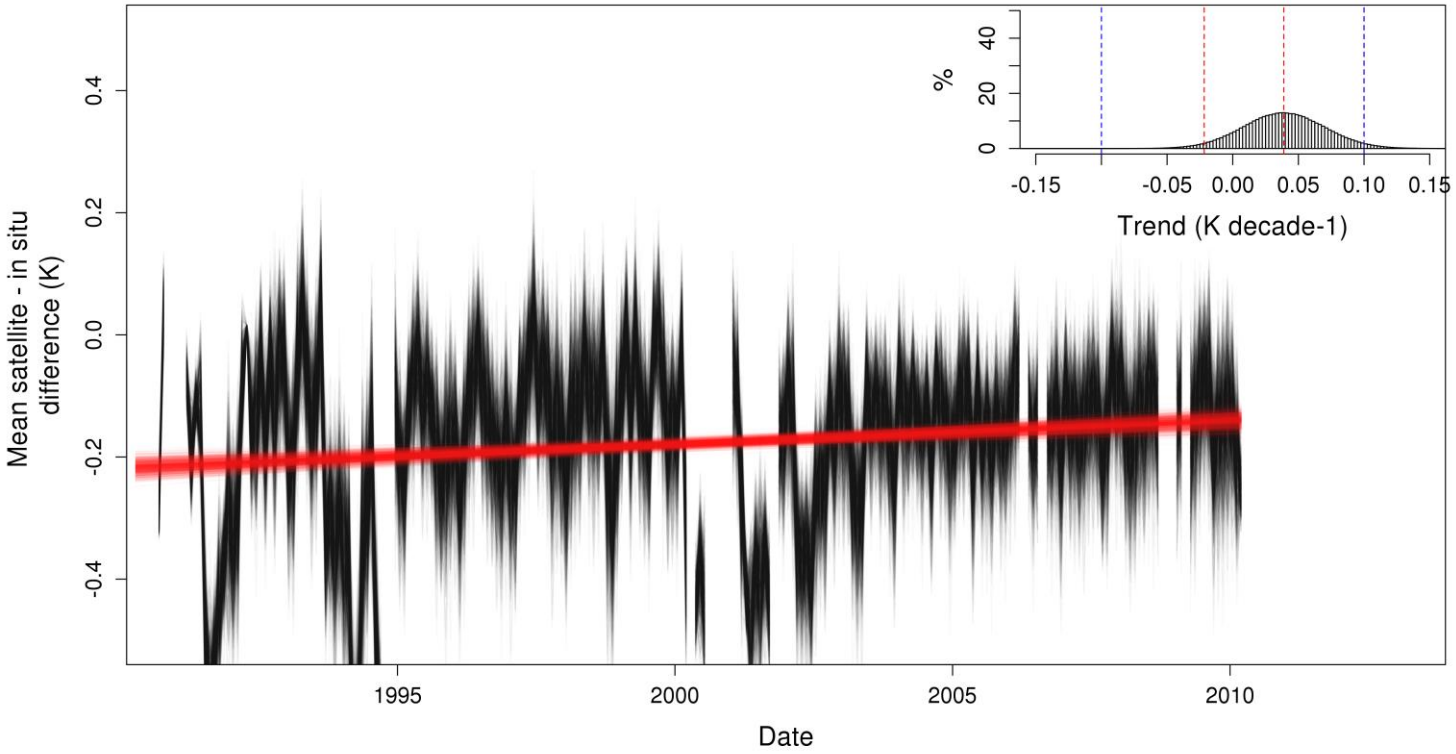
Data	Trend [mK/year]
ATSR (day)	-2.1 < trend < 2.3
ATSR (night)	-2.6 < trend < 0.4
AVHRR (day)	3.6 < trend < 15.5
AVHRR (night)	-2.1 < trend < 9.8
Analysis	-1.51 < trend < -0.05

- 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)

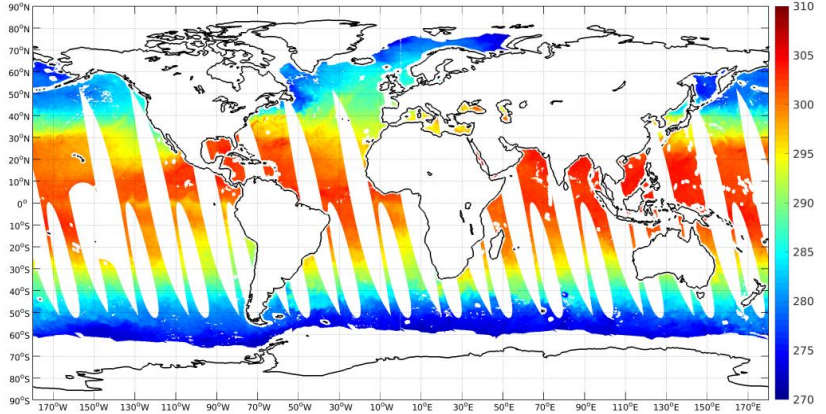


Passive Microwave Retrieval

- Work continues on PMW retrieval
- Available as separate “PMW2.0” products
  - AMSRE / AMSR2 **L2P**
  - **L4** CCI Analysis
- Allows inter-comparison with IR-only CDR
- Arriving at the Open Data Portal soon…

PMW Developments

- Consistent AMSR-E and AMSR2 SST + wind speed products in L2P (2002-2017)
- Used statistical retrieval + RFI/QC filtering
- Validated uncertainties
- L4 IR+PMW (2002-2016)
- See poster by Jacob Høyer



L2P Validation

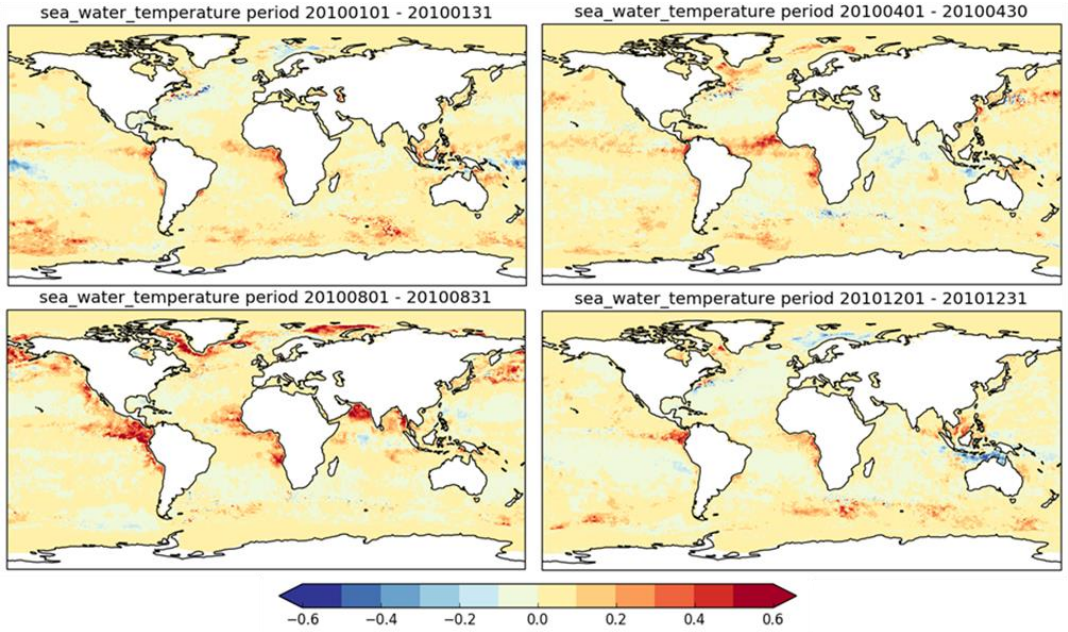
Sensor	Quality level	Mean Drifter (K)	Std Drifter (K)	No. of matchups	Mean Argo (K)	Std Argo (K)	No. of matchups
AMSR-E	4-5	-0.02	0.46	7,153,519	-0.01	0.44	108,956
	5	**-0.03**	**0.37**	**2,753,625**	**-0.02**	**0.36**	**48,558**
AMSR2	4-5	0.00	0.45	4,550,286	0.01	0.43	117,432
	5	**-0.00**	**0.35**	**2,000,938**	**0.00**	**0.34**	**60,089**

Impact on ESA CCI L4

- PMW L2P included in test run with ESA CCI L4
- Compared with IR only reference run
- Significant improvements against Argo floats
- Spatial resolution maintained
- See poster by Mark Worsfold

Right: Monthly SST difference

IR+PMW – IR-only control



OSTIA L4: CCI/C3S vs CMEMS

CCI/C3S L4

- Intended for Climate applications
  - Short-delay product
- Satellite-only **CCI** SST inputs
  - All L2/L3 generated by CCI
- Daily average SST_{20cm} analysis

CMEMS

- Intended for operational applications
  - Operational NRT product
- Various NRT SST inputs + ***in situ***
  - No L2/L3 generated by CMEMS
- Foundation SST analysis

Shared OSTIA developments

- Met Office OSTIA system used for both CCI/C3S and CMEMS products
- Developments from one project will benefit the other
  - e.g. SST-CCI work on improved feature resolution

Future Work

C3S

- Focus on ongoing production
- System evolutions
  - Use ERA5 / ERA5T NWP
  - Add MetOp-B / SLSTR-B
  - Improve timeliness
- Will update science (reprocess) with CCI product release

CCI Phase 3

- Continue PMW work
  - Aim is to include PMW in CDR
- SLSTR as a reference sensor
- Focus on historical record
  - HIRS-AVHRR synergy
  - Primary aim 1980s improvement
  - Aerosol conditions
  - Period with no ATSR reference
- Will take C3S processor updates

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
- Future development shared between:
  - CCI – science improvements to: PMW, historical record, SLSTR as reference
  - C3S – system evolutions and extending current record