Evaluation of the Daytime corrected AVHRR Land Surface Temperature Time Series

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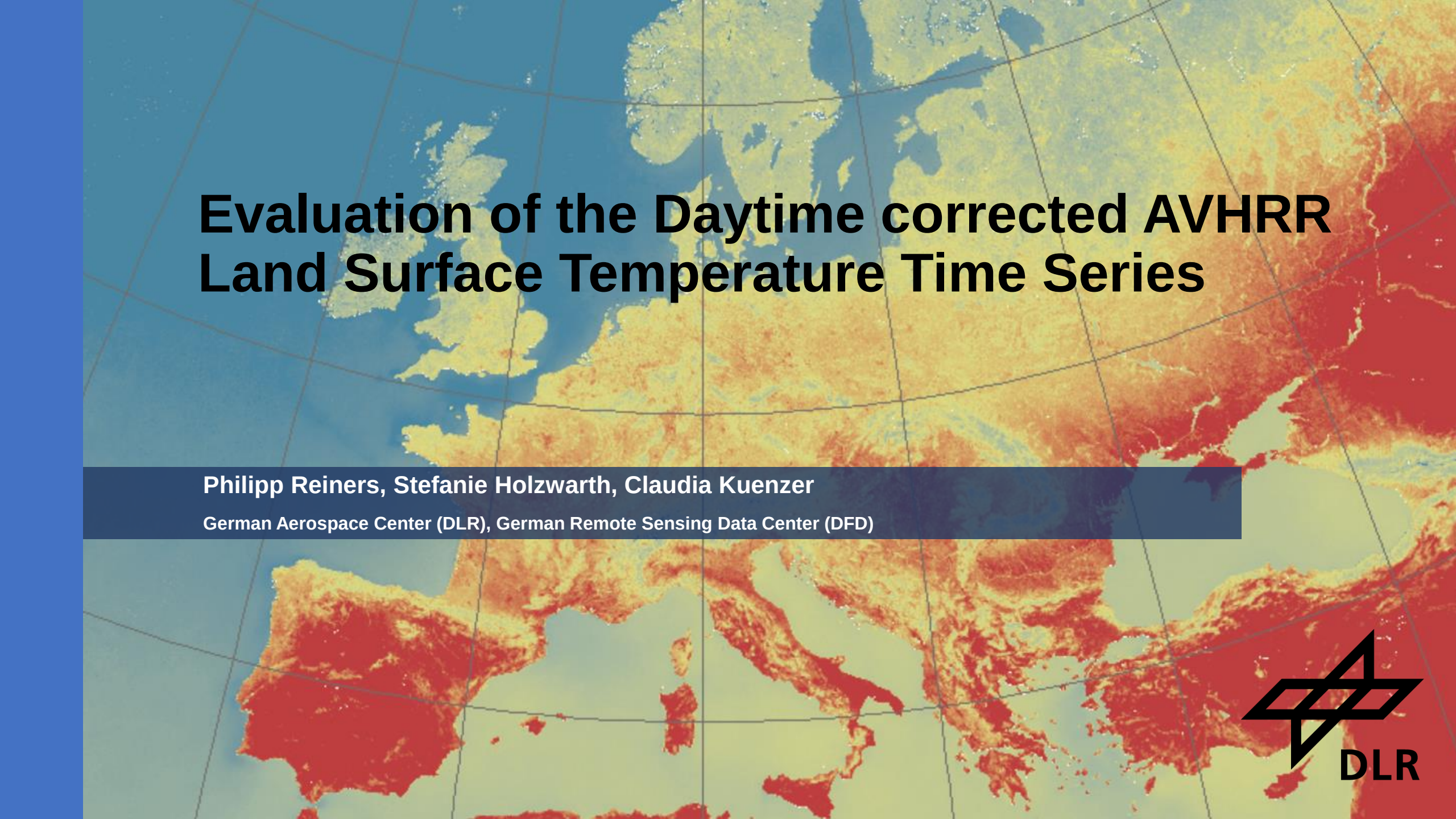
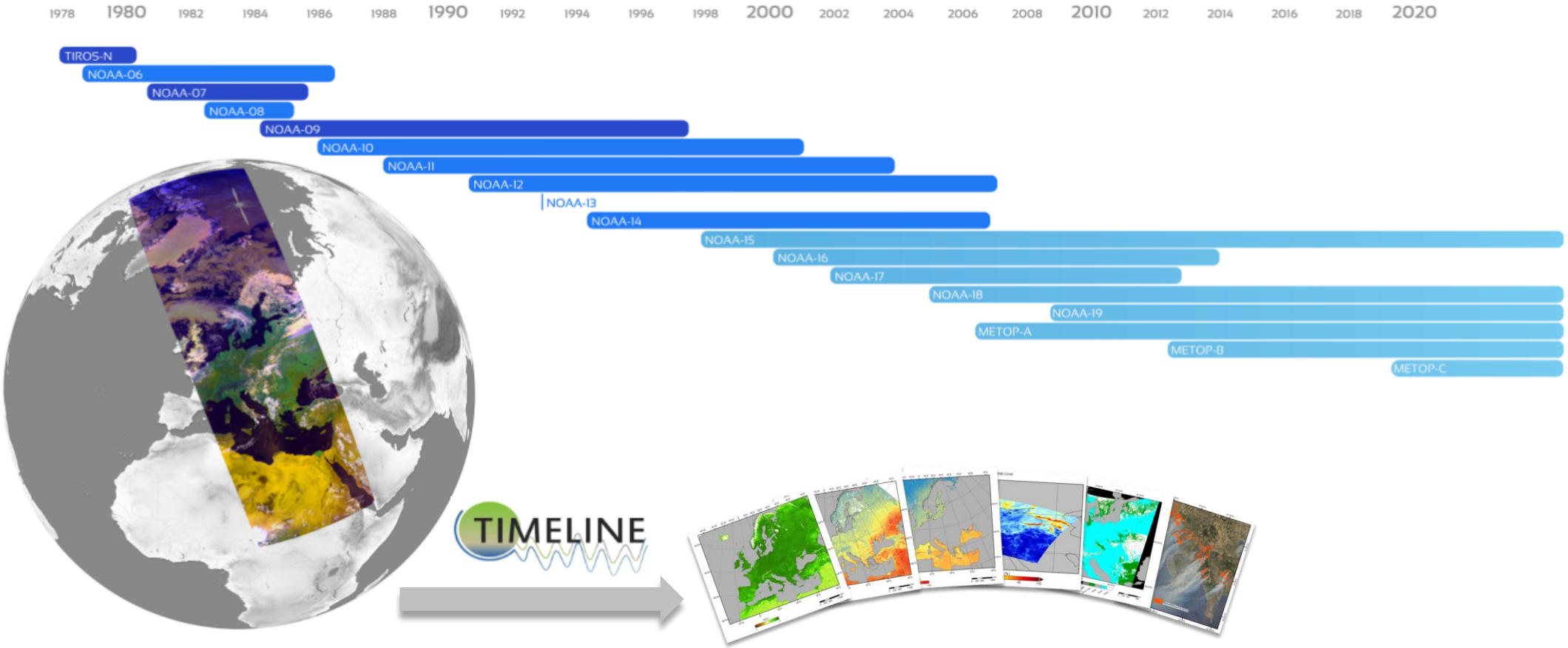


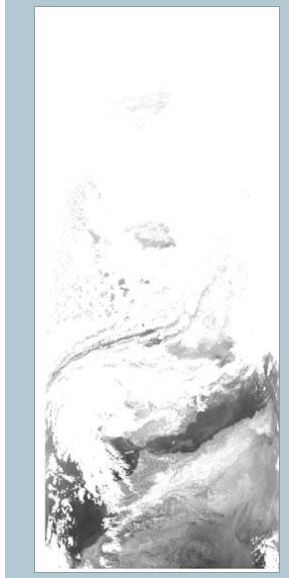
The TIMELINE Project – Geophysical Products over Europe from ~40 Years of AVHRR Data



- **Sensors:** AVHRR-1 (4 Channels), AVHRR-2 (5 Channels) & AVHRR-3 (6 Channels) onboard NOAA 7 - 19 [integrated] and MetOp-A, -B, & -C [being integrated]
- **Resolution:** 1 km (LAC + HRTP data)
- **Coverage:** Europe and North Africa

TIMELINE LST Product Generation Overview

L1B



AVHRR Brightness Temperatures

L2

L2-Processor [1,2]

Vegetation Cover Method

$$\varepsilon_k = \varepsilon_{kv}\, f + \varepsilon_{kg}\, (1-f) + 4 < d\varepsilon_k > f\, (1-f)$$

Mono window algorithm

$$LST = \frac{1}{c}(p_2(1-c-d) + t_3(p_1(1-c-d) + c + d) - dT_{atm})$$

$$c = \varepsilon_4 \tau$$

$$d = (1-\tau)(1+\tau(1-\varepsilon_4))$$

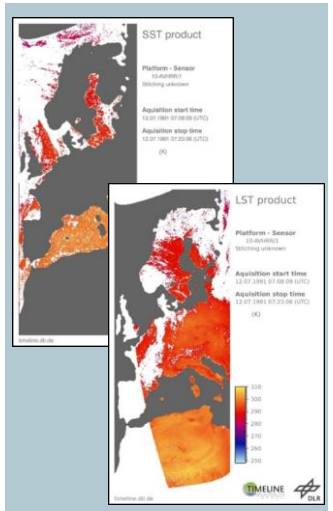
$$\tau = p_0 - p_1 cwv$$

Split window algorithm

$$\alpha = 1 + p_1 \frac{1-\varepsilon}{\varepsilon} + p_2 \frac{d\varepsilon}{\varepsilon^2}$$

$$\beta = p_3 + p_4 \frac{1-\varepsilon}{\varepsilon} + p_5 \frac{d\varepsilon}{\varepsilon^2}$$

$$LST = p_0 + \alpha\left(\frac{t4+t5}{2}\right) + \beta\left(\frac{t4-t5}{2}\right)$$

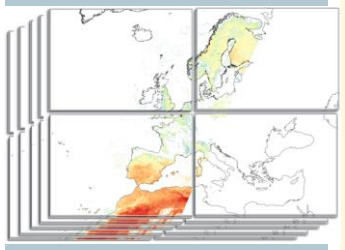


- LST in orbit projection at observation time
- Validated against MODIS LST and in situ LST [2]

L2c

L2c-Processor

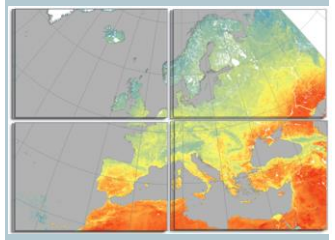
Projection to LAEA Tiles



L3

L3-Processor

- Pixel-based filtering of the monthly time series (1.5*stdev)
- Compositing

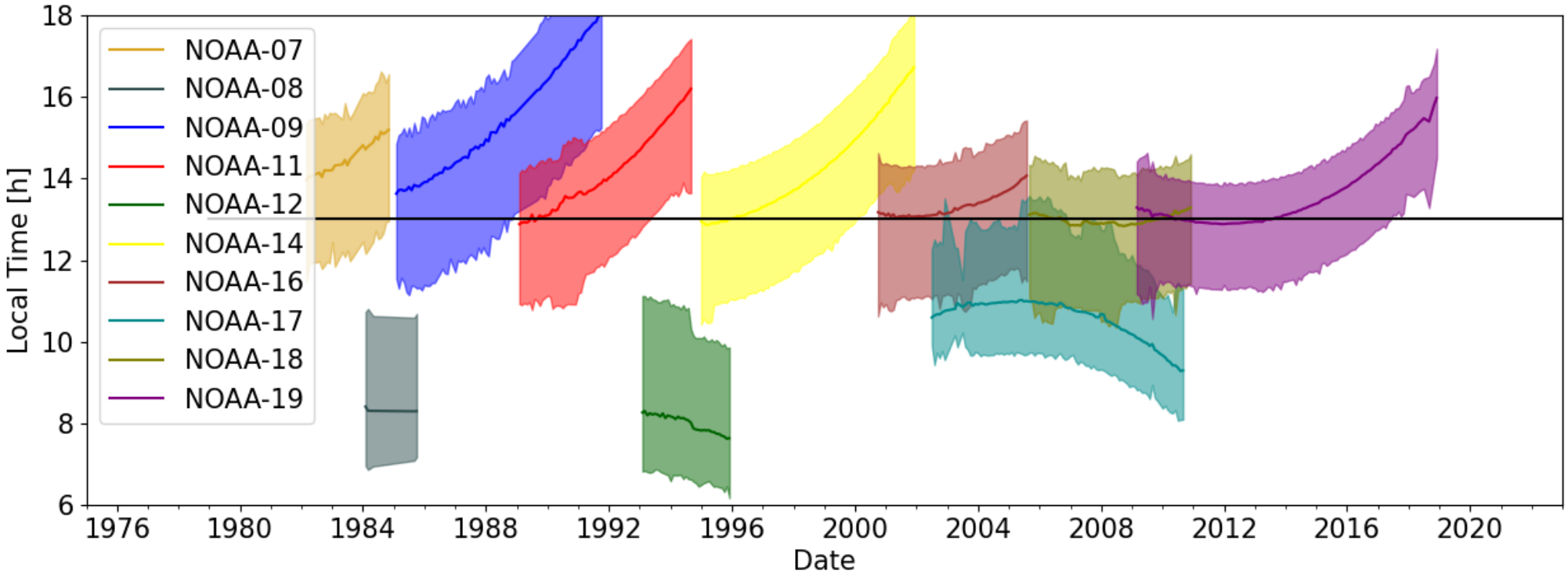


- **Daily:** Best observation of the day (lowest sat zenith angle)
- **10-Daily:** LST stastistics (Max,Mean,Median, Min)
- **Monthly:** LST stastistics (Max,Mean,Median, Min)

[1] Frey, C.M.; Kuenzer, C.; Dech, S. Assessment of Mono- and Split-Window Approaches for Time Series Processing of LST from AVHRR—A TIMELINE Round Robin. *Remote Sens.* **2017**, *9*, 72. https://doi.org/10.3390/rs9010072

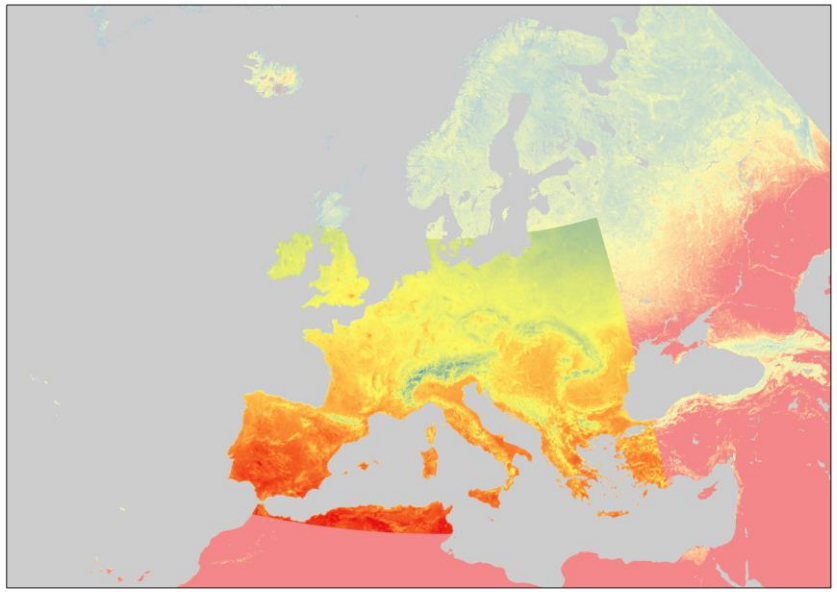
[2] Reiners, P.; Asam, S.; Frey, C.; Holzwarth, S.; Bachmann, M.; Sobrino, J.; Göttsche, F.-M.; Bendix, J.; Kuenzer, C. Validation of AVHRR Land Surface Temperature with MODIS and In Situ LST—A TIMELINE Thematic Processor. *Remote Sens.* **2021**, *13*, 3473. https://doi.org/10.3390/rs13173473

Generation of Daily Minimum and Maximum LST



AVHRR observation times over Europe

Fusion of SEVIRI continuous LST with AVHRR LST



Available Area for diurnal LST cycles from SEVIRI

- LST model parameters derived from Seviri LST by Sismanidis et al (2021)
- 1 km resolution Dataset containing the annual LST cycle parameters (ACPs) on a pixel level for every 30 min interval of the day

⟶ Can be used to calculate gap free LST in 30 min resolution

$$\Delta LST_1 = LSTS_{EVIRI}(13\text{h}, \text{doy}) - LST_{SEVIRI}(t_1, \text{doy})$$

$$\Delta LST_2 = LSTSE_{VIRI}(13\text{h}, \text{doy}) - LSTS_{EVIRI}(t_2, \text{doy})$$

$$\Delta LST = \Delta LST_1 + (t - t_1) * \frac{\Delta LST_2 \_ \Delta LST_1}{t_2 - t_1}$$

$$LST_{AVHRR}(13\text{h}) = LSTAV_{HRR}(t) + 0.75 * \Delta LST$$

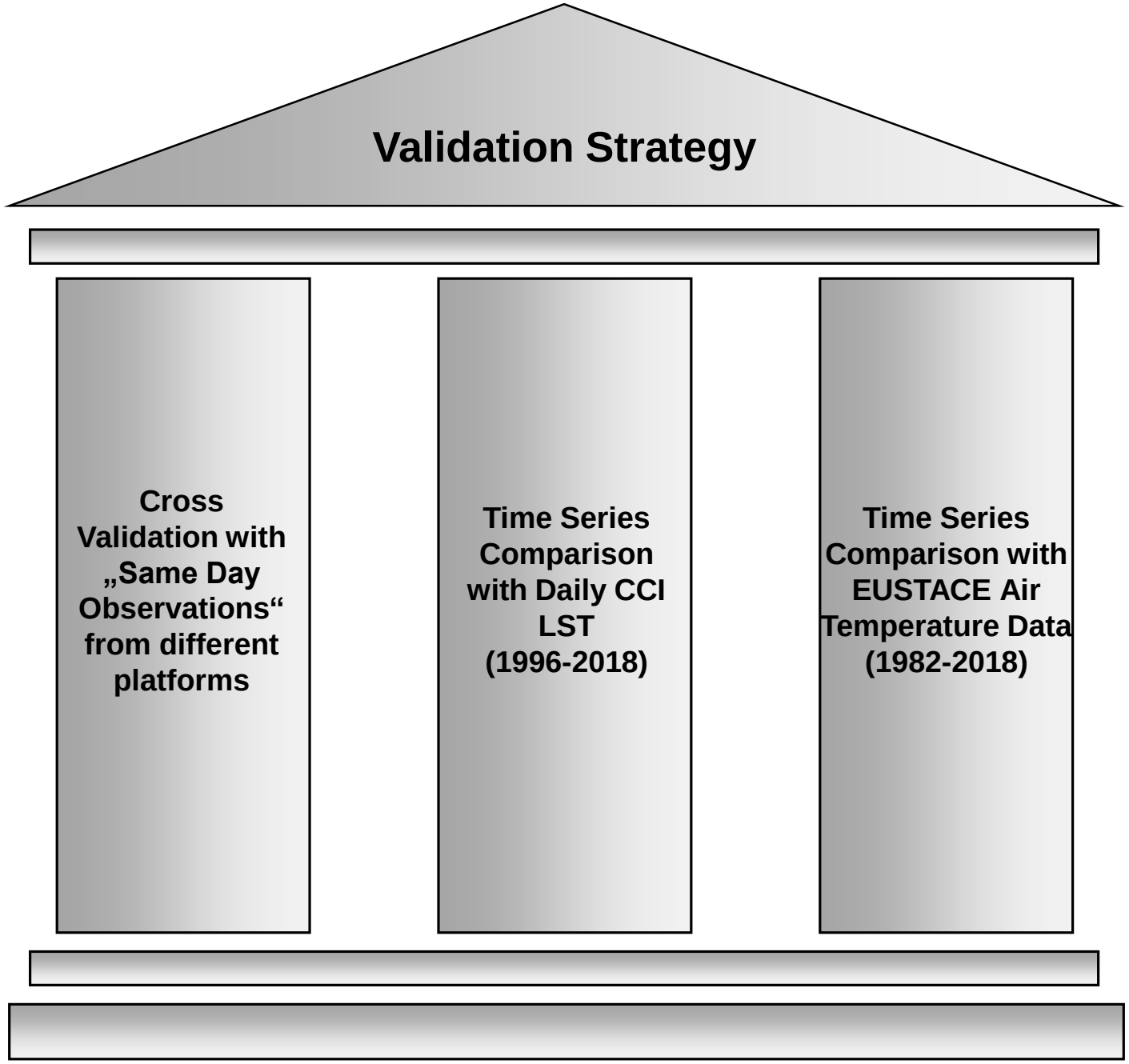
$LST_{AVHRR}(t)$: AVHRR LST at observation time

$LST_{AVHRR}(13\text{h})$: AVHRR LST at 13h

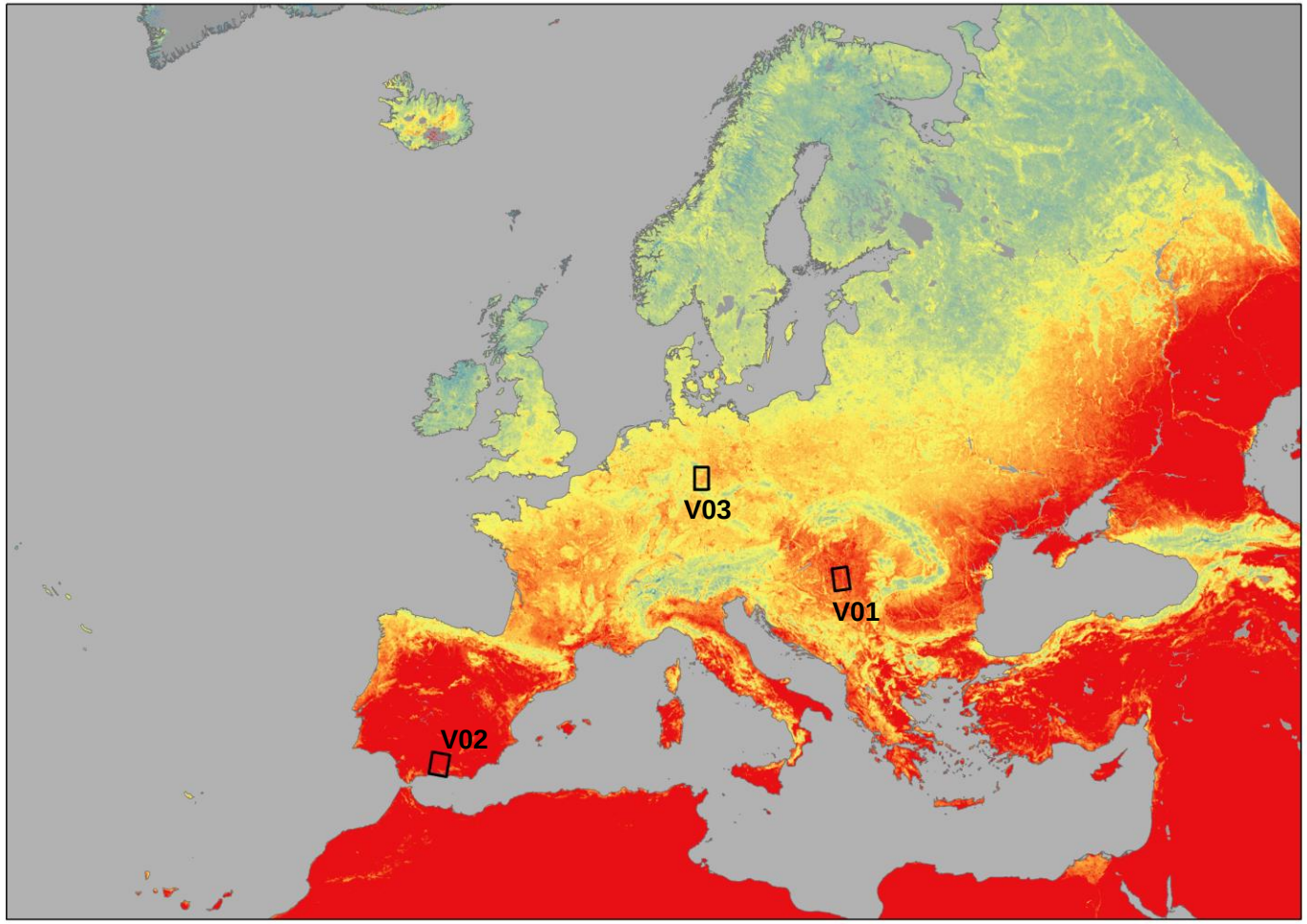
$LST_{SEVIRI}(t_1, t_2)$: Modelled SEVIRI LST at nearest times to t

$LST_{SEVIRI}(13\text{h})$: SEVIRI LST at 13h

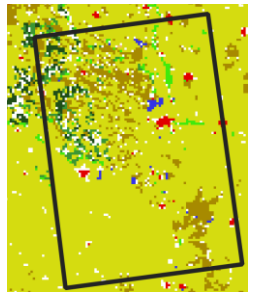
doy = day of the year


Validation Strategy
Cross Validation with „Same Day Observations“ from different platforms
Time Series Comparison with Daily CCI LST (1996-2018)
Time Series Comparison with EUSTACE Air Temperature Data (1982-2018)

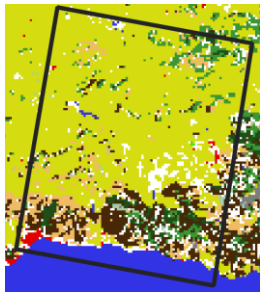
Validation Areas



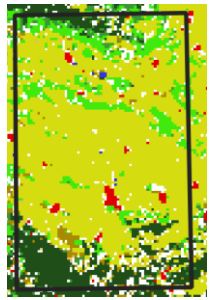
V01 (Hungarian Plain)



V02 (Spain)

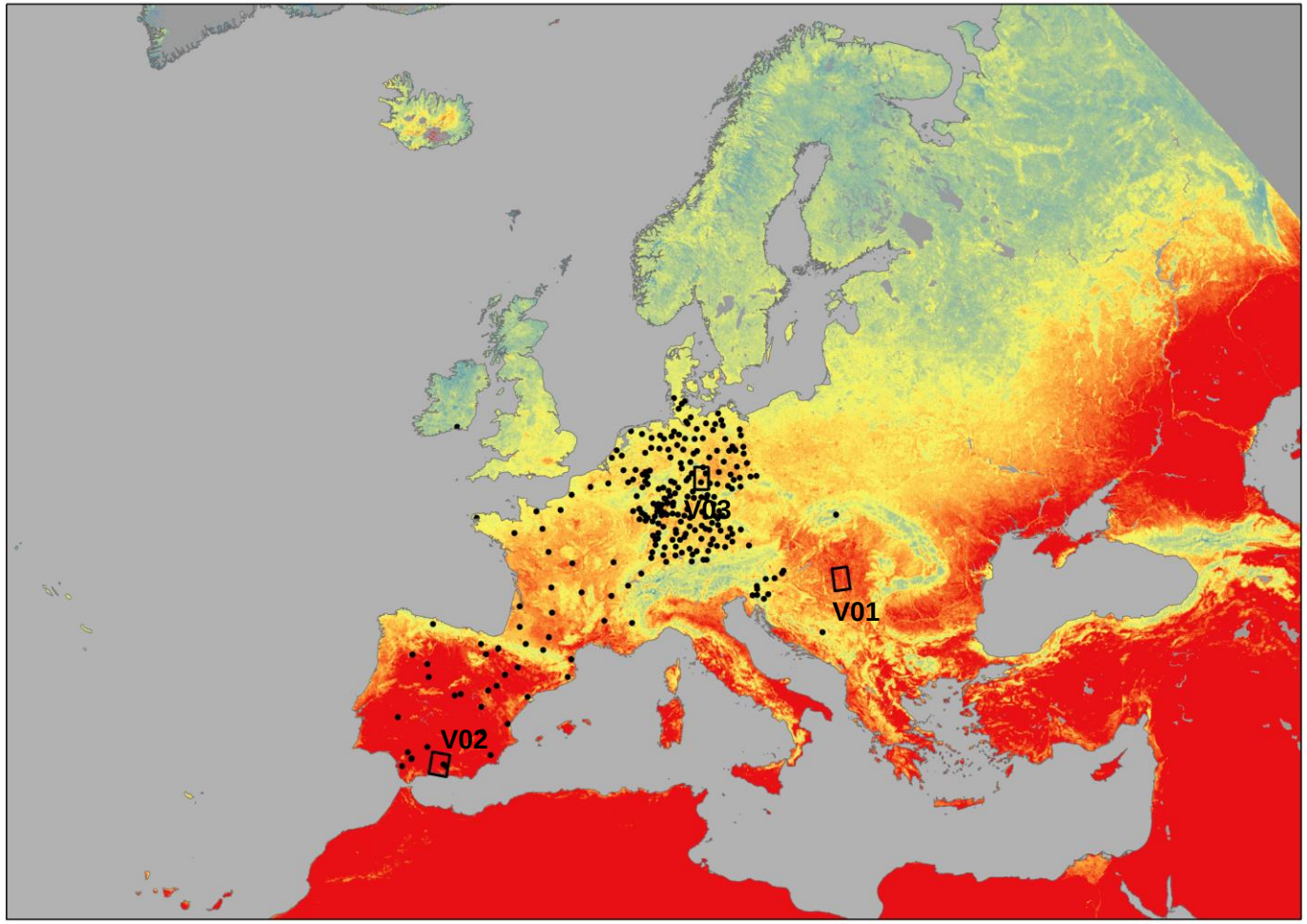


V03 (Germany)

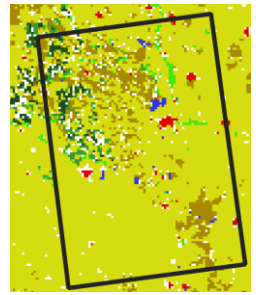


- Cropland
- Mosaic Cropland
- Broadleaved deciduous Forest
- Needleleaved evergreen Forest
- Mixed Forest
- Shrubs
- Grassland
- Sparse vegetation
- Urban
- Bare areas
- Water
- Snow & Ice

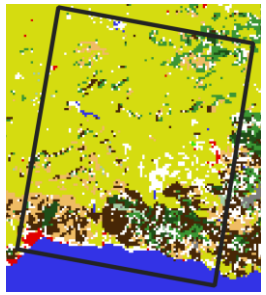
Validation Areas – Air Temperature Measurement Stations



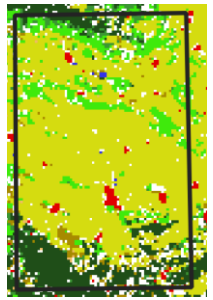
V01 (Hungarian Plain)



V02 (Spain)



V03 (Germany)



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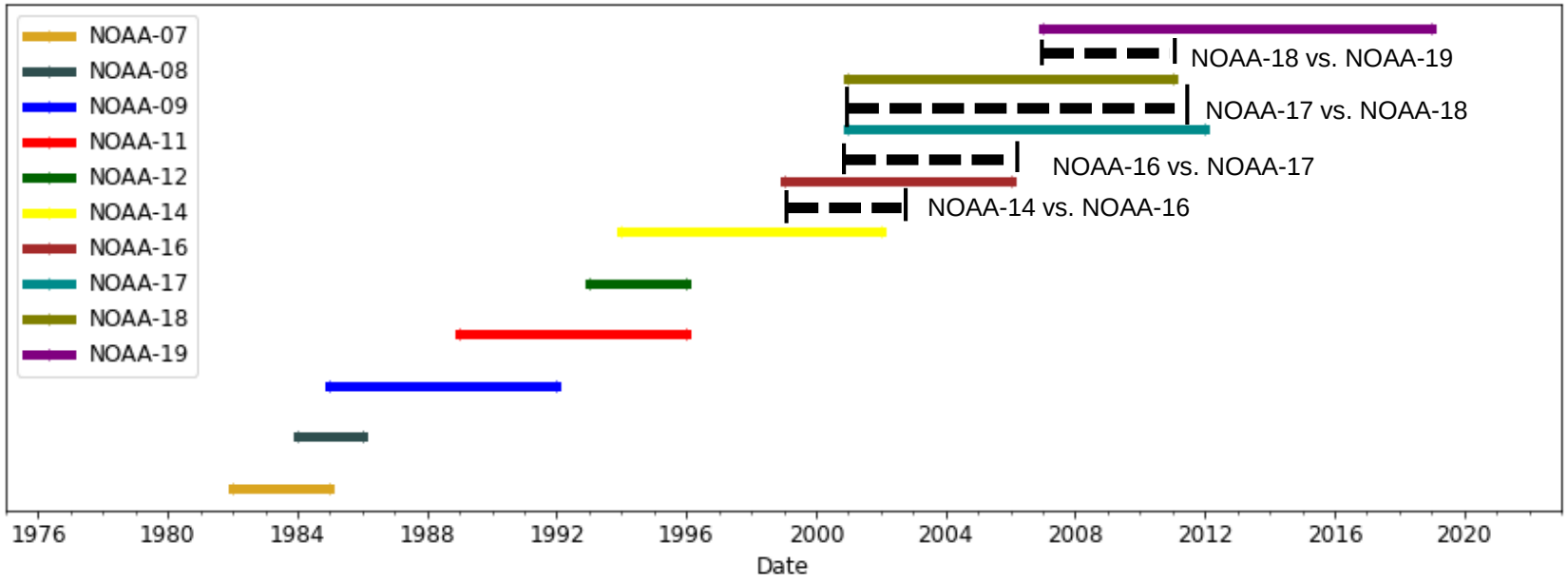
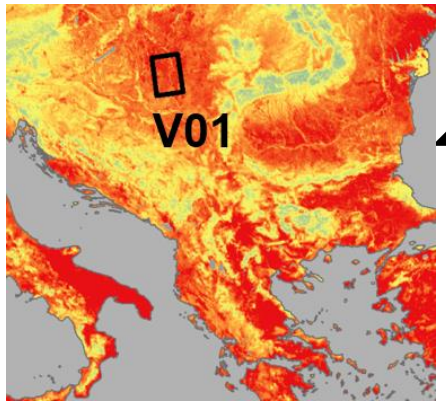
Cross Validation with „Same Day Observations“



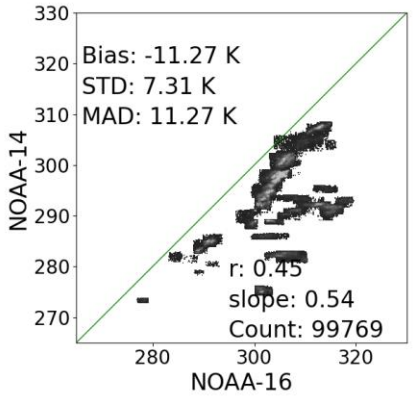
- Direct comparison of observations from the same day but from different platforms
- Assumption: Differences only occur because of the different daytime of the observations and should be eliminated through the Orbit Drift correction

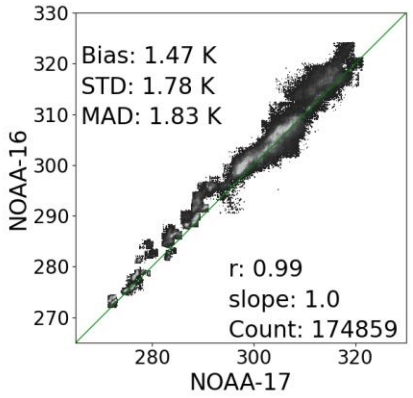
Results for the Cross Validation for V01

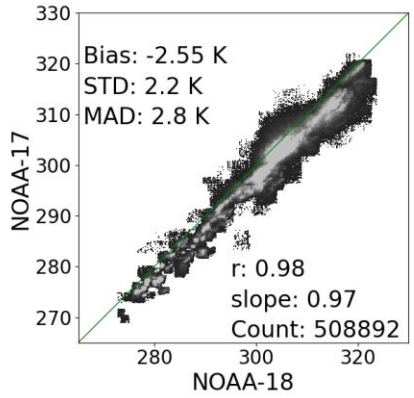


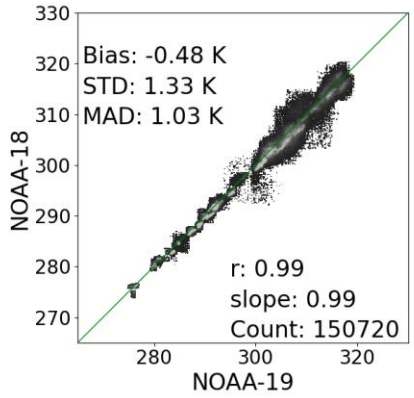
DLR

Before Correction

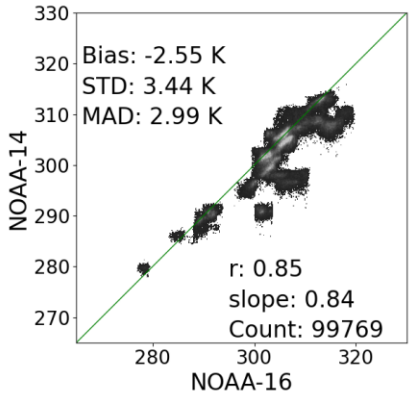


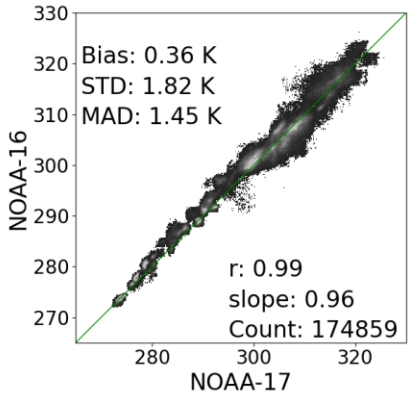


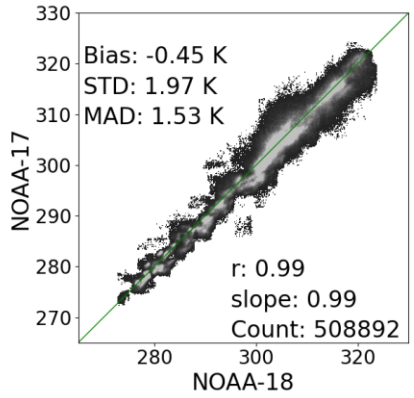


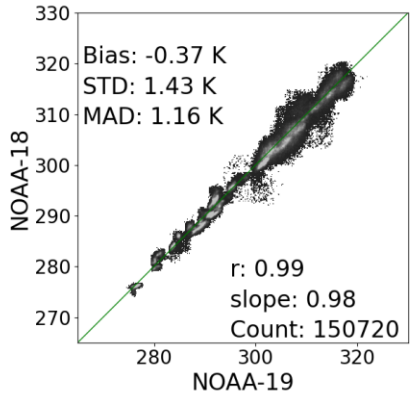


After Correction

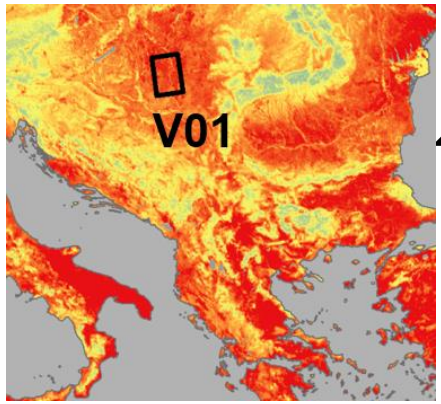






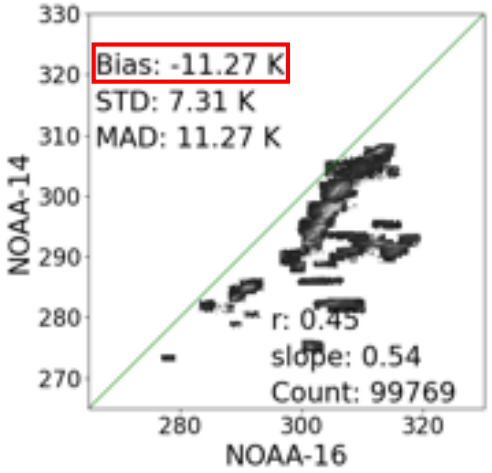


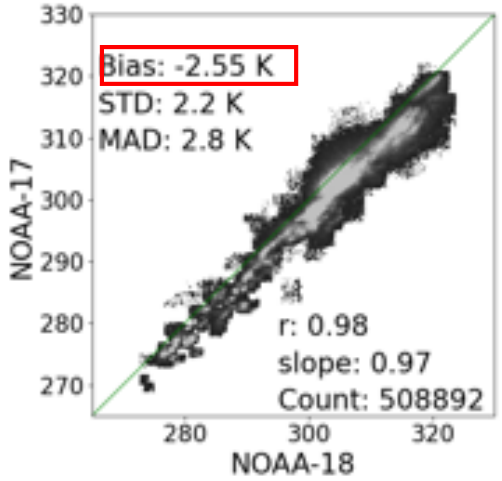
Results for the Cross Validation for V01



DLR

Before Correction





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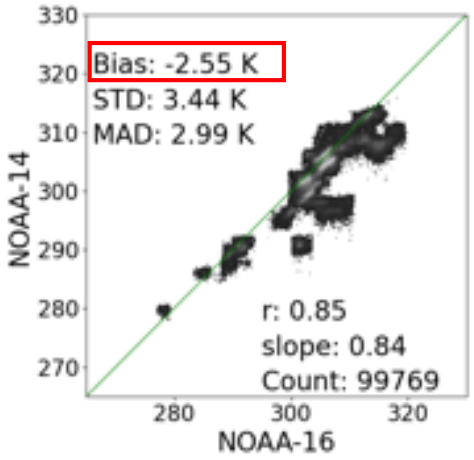
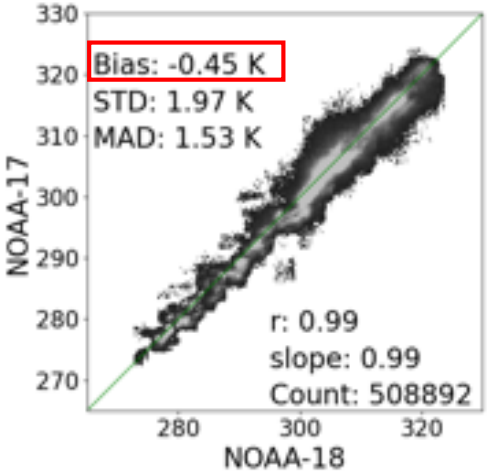
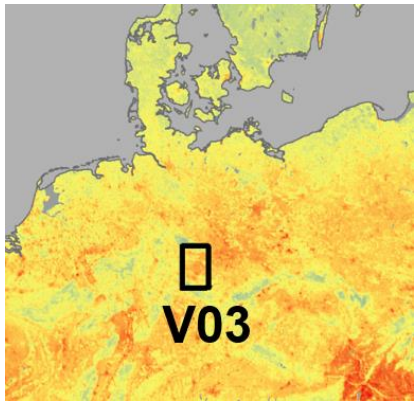


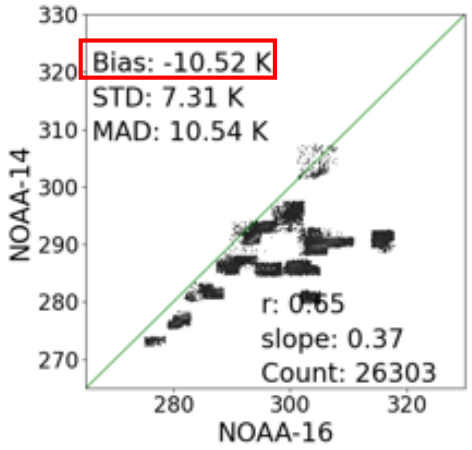


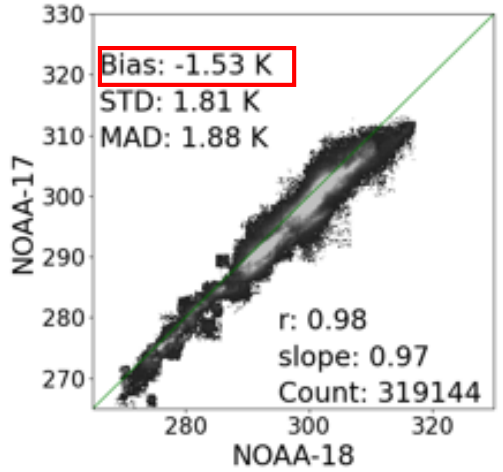
Results for the Cross Validation for V03



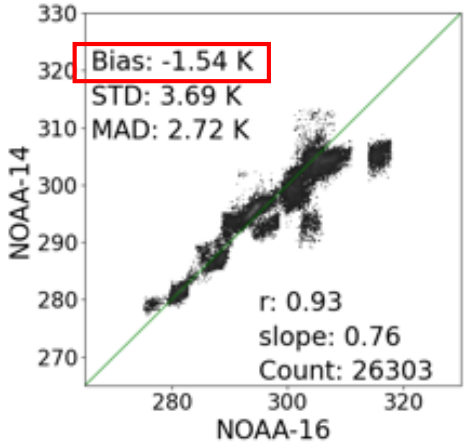
DLR

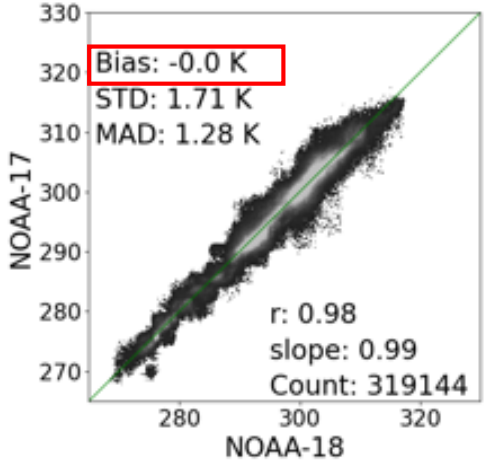
Before Correction



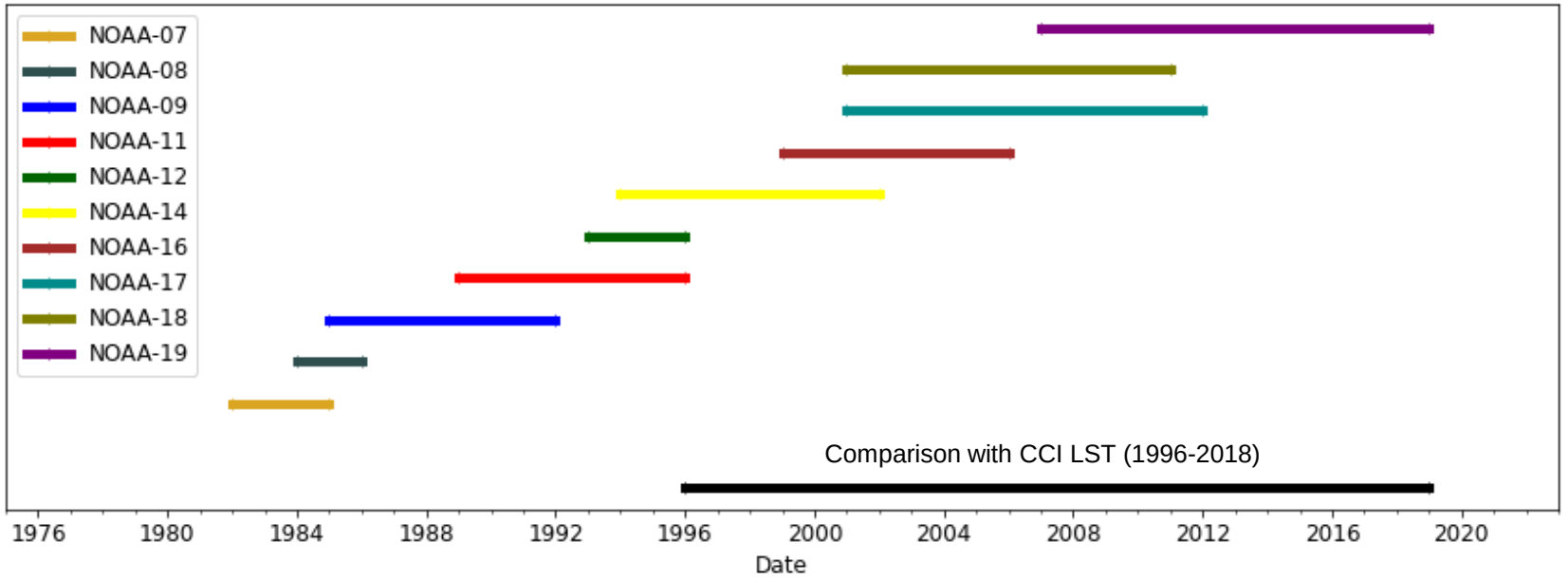


After Correction



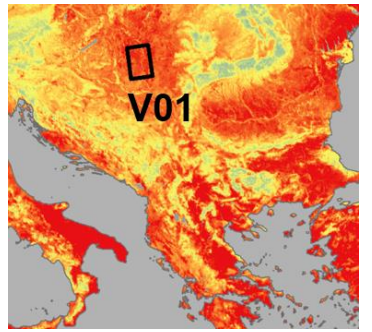


Time Series Comparison with Daily CCI LST (1996-2018)

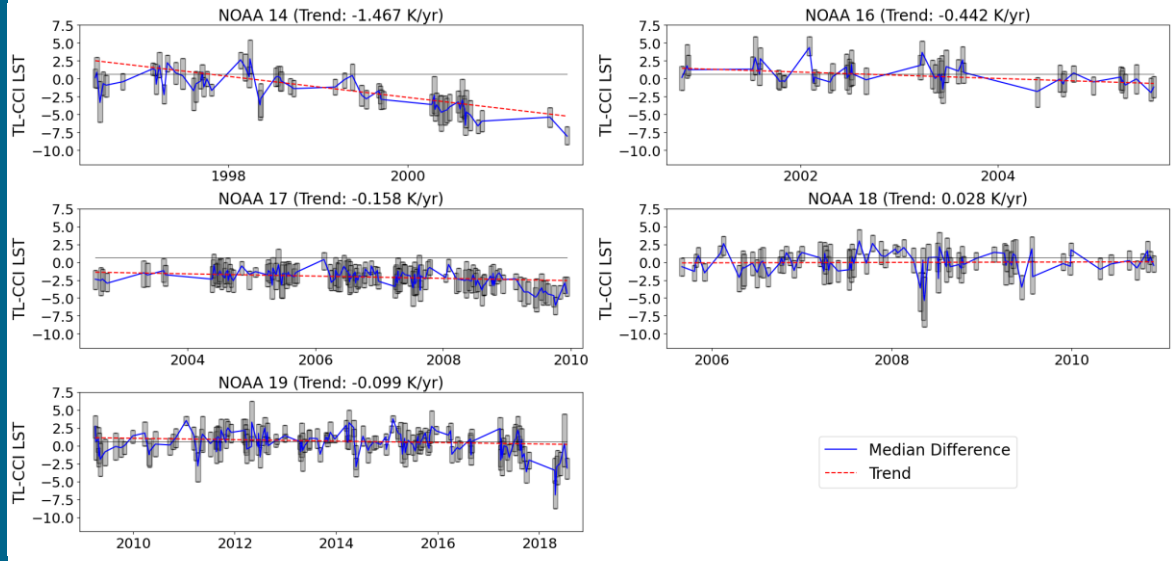


- **CCI L3S LST:** Harmonized LST dataset derived from ATSR-2, AATSR, Sentinel 3A, and MODIS Data
- Dataset corresponds to 10:30h local time
- Daytime normalization should remove trends in the differences between TIMELINE and CCI LST

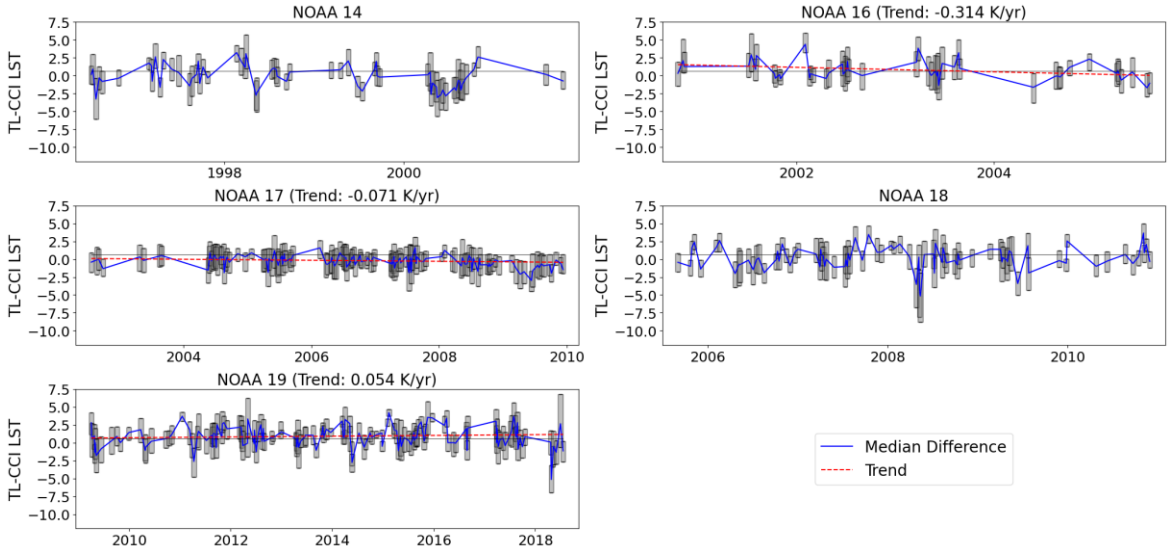
Results for the Cross Validation for V01



Before Correction



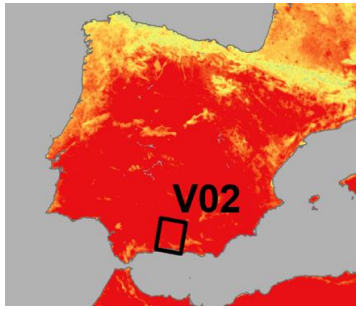
After Correction



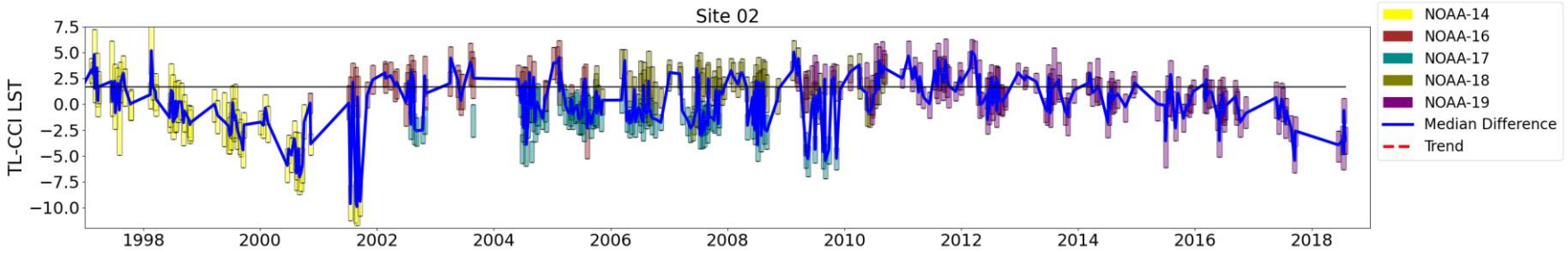
Platform	Bias	MAD	Trend
NOAA-14	-2.62	3.61	-1.467
NOAA-16	-0.25	2.29	-0.414
NOAA-17	-2.9	3.21	-0.156
NOAA-18	-0.68	2.18	0.03
NOAA-19	-0.32	2.07	-0.095

Platform	Bias	MAD	Trend
NOAA-14	-0.79	2.42	0.009
NOAA-16	-0.01	2.25	-0.296
NOAA-17	-0.96	2.03	-0.073
NOAA-18	-0.48	2.23	0.03
NOAA-19	0.16	2.01	0.086

Results for the Cross Validation for V02

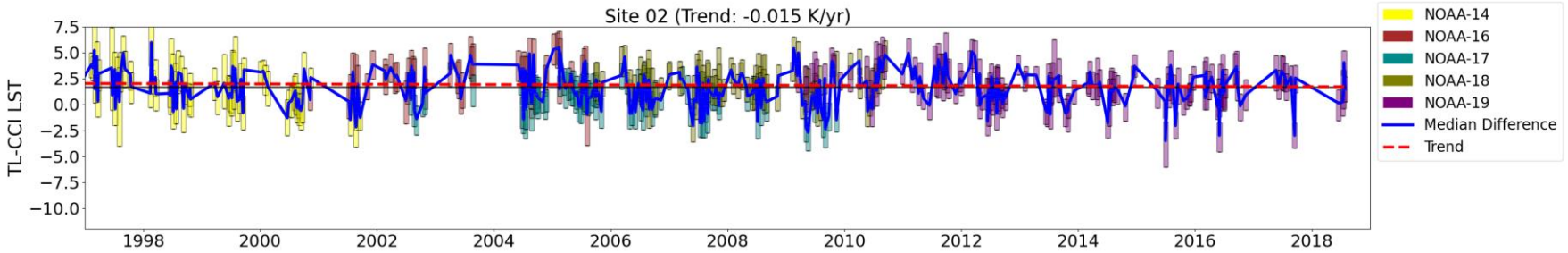


Before Correction



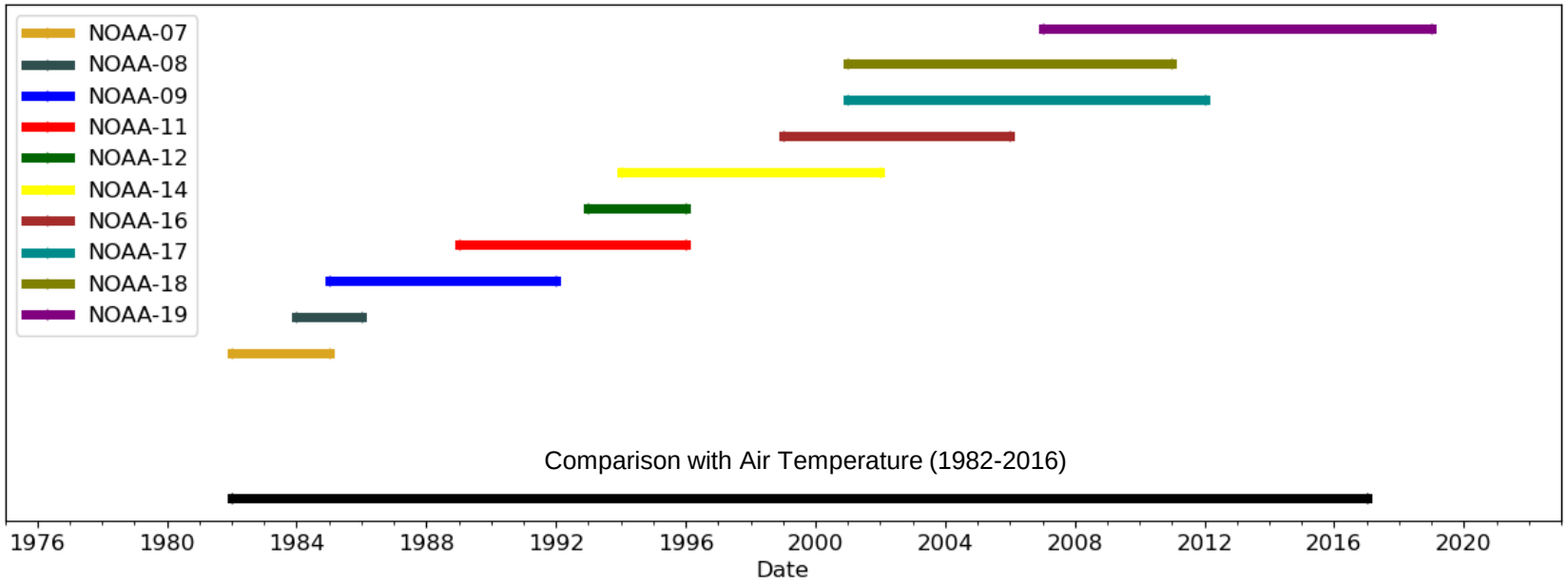
Bias	MAD	Trend
-1.39	2.94	n.s.

After Correction



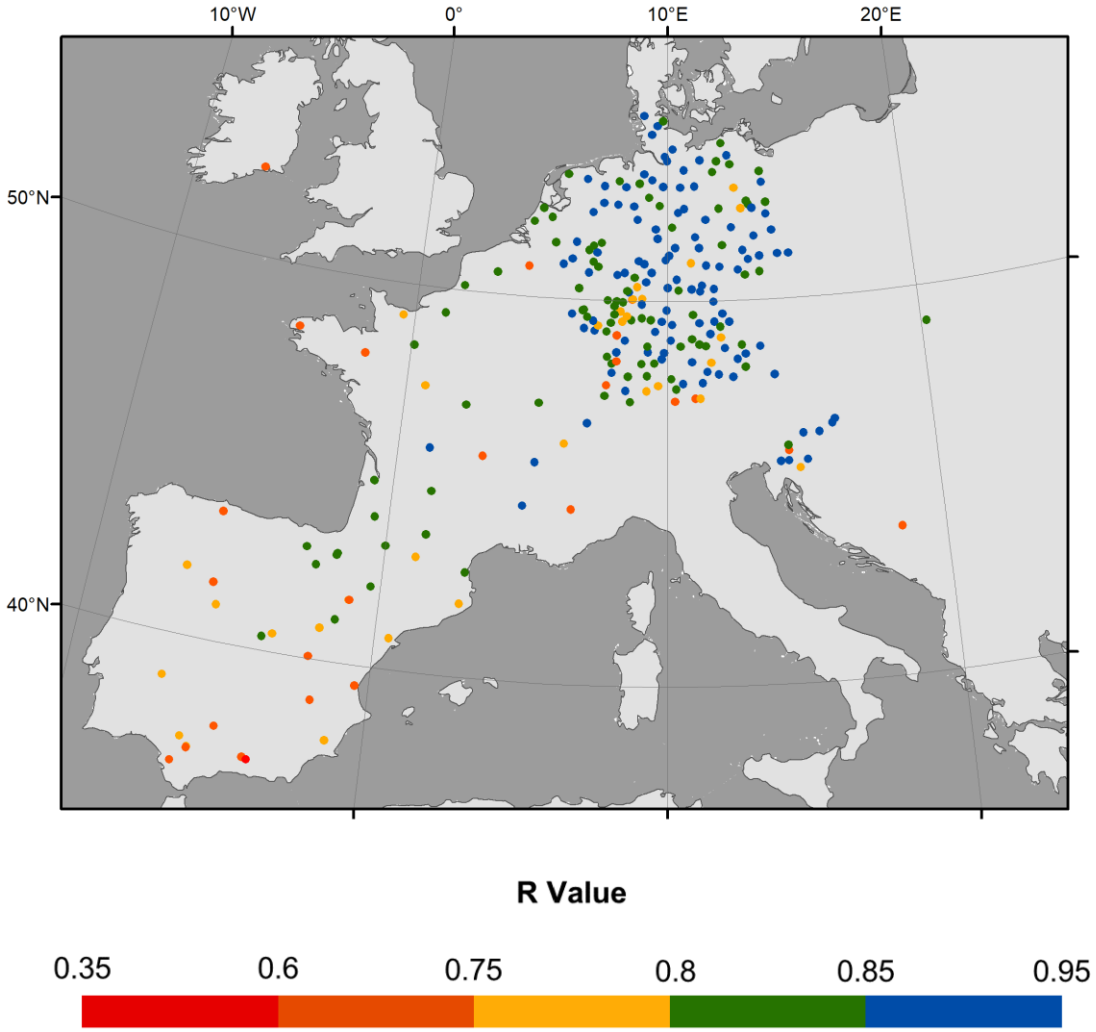
Bias	MAD	Trend
-0.11	2.5	-0.016

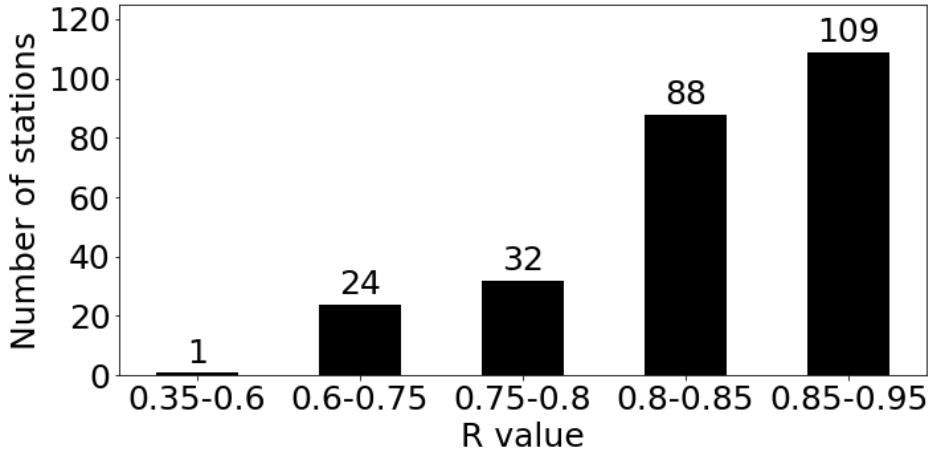
Time Series Comparison with EUSTACE Air Temperature Data (1982-2018)



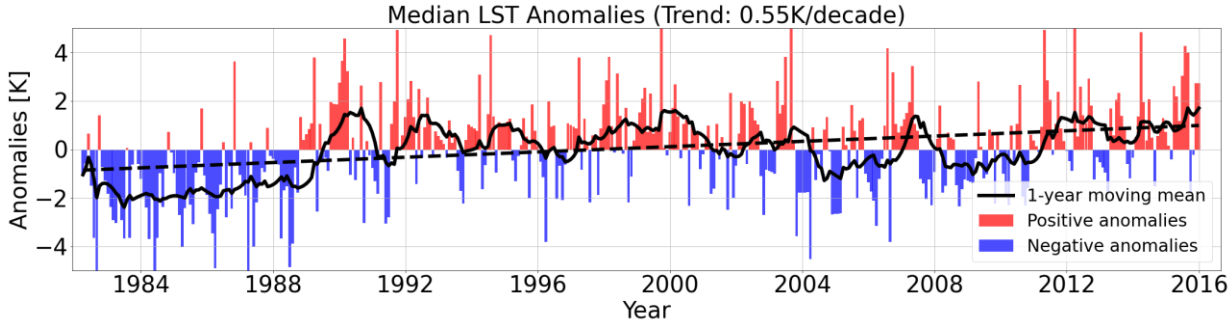
- Comparison between monthly LST and air temperature anomalies at 300 measurement stations
- Correlation between the anomalies and comparison between LST and air temperature trends

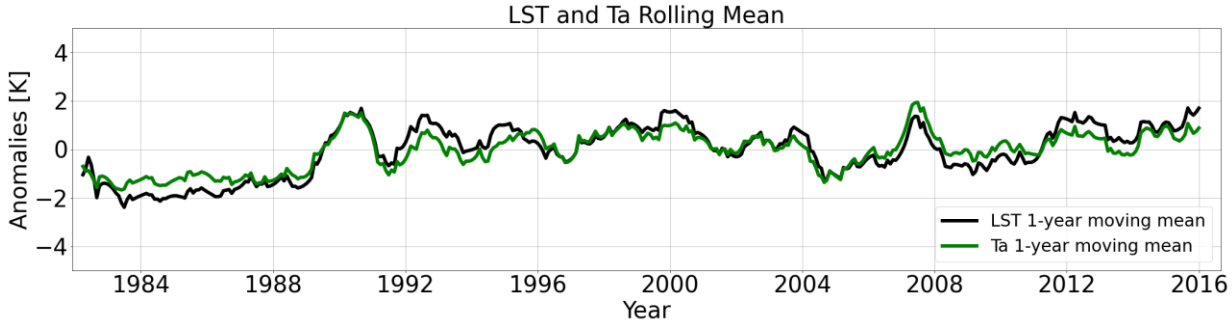
Correlation between Orbit Drift corrected Land Surface Temperature and Air Temperature

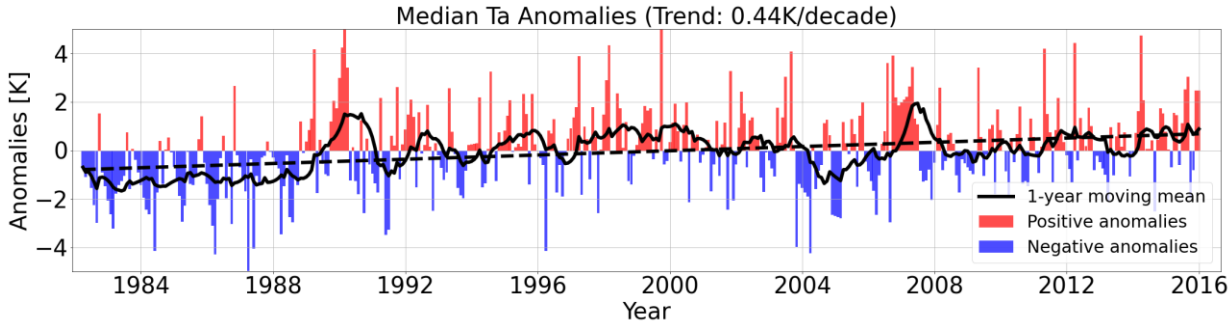


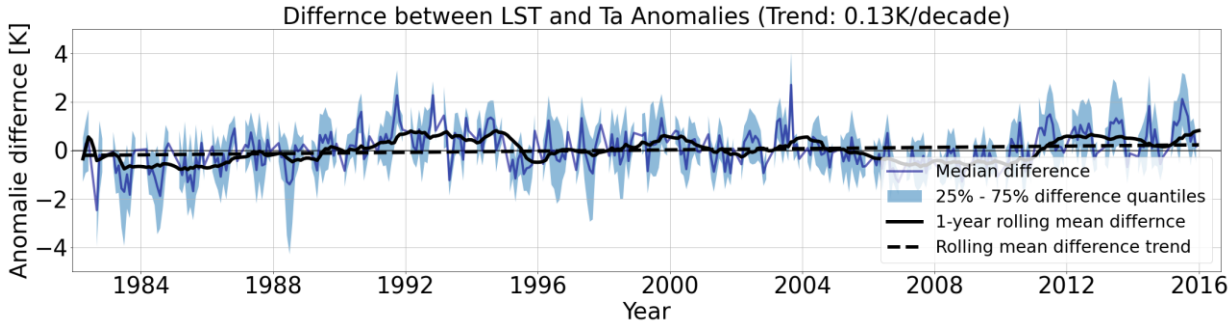


Time Series Comparison with Air Temperature









Conclusions

- Fusion with SEVIRI LST enables daytime normalization of the AVHRR LST
- Daytime Normalization reduces biases between the LSTs of different NOAA platforms
- Daytime Normalization reduces spurious trends in the comparison with CCI LST
- Daily maximum AVHRR LST anomalies show high correlation with air temperature anomalies
- Therefore, this time series can be used to map global and climate change in Europe in 1 km resolution

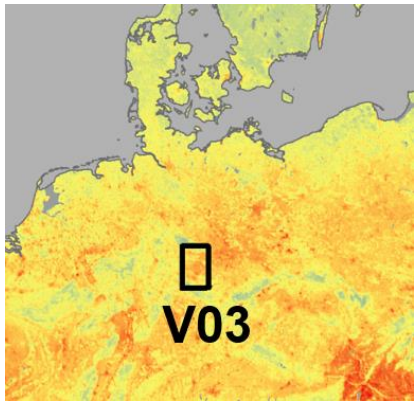
In preparation of publication (2024):

Fusing AVHRR LST with geostationary SEVIRI LST to create a long-term daily Maximum LST Time Series over Europe

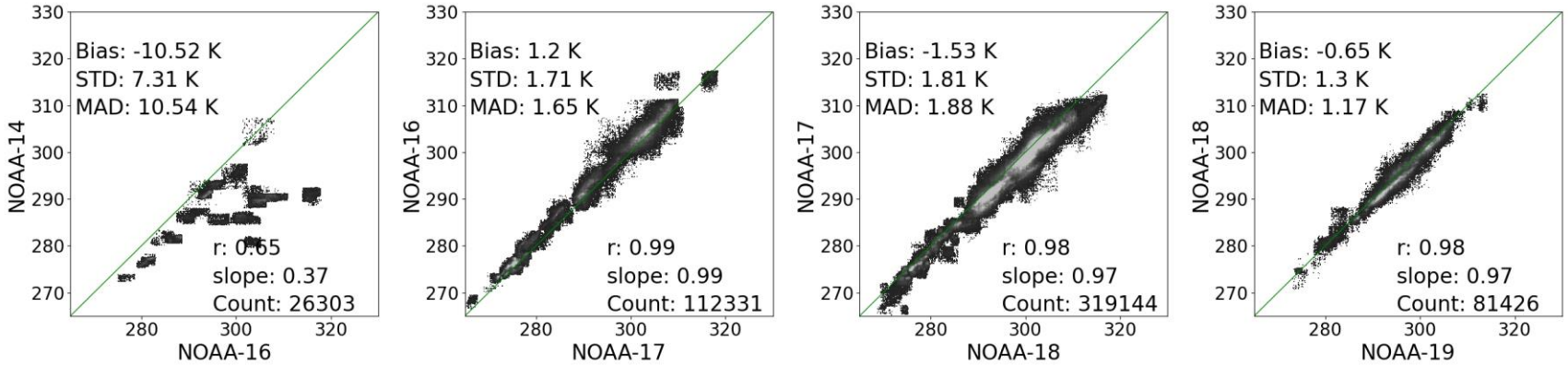
Thank you for your Attention ☺

Corresponding: Philipp.Reiners@dlr.de

Results for the Cross Validation for V03



Before Correction



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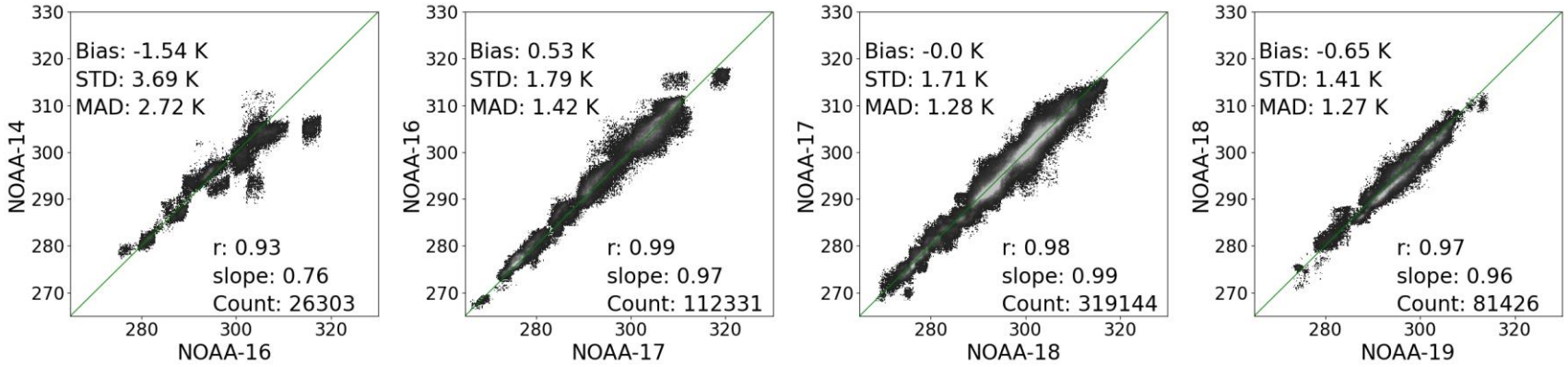
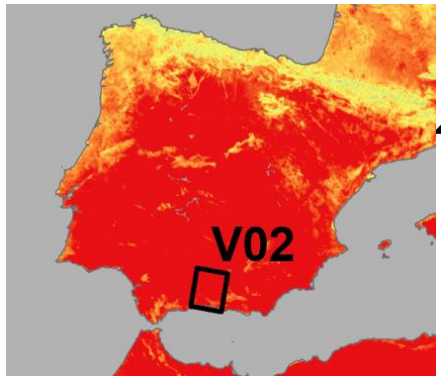
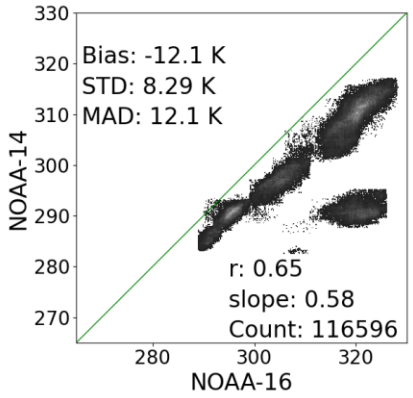


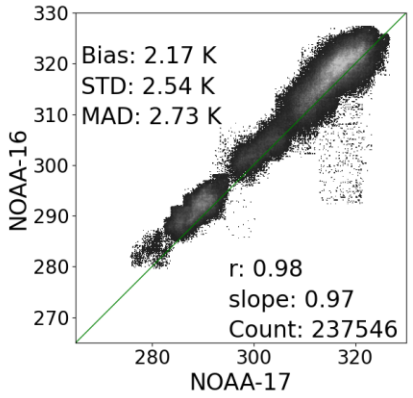
Results for the Cross Validation for V02

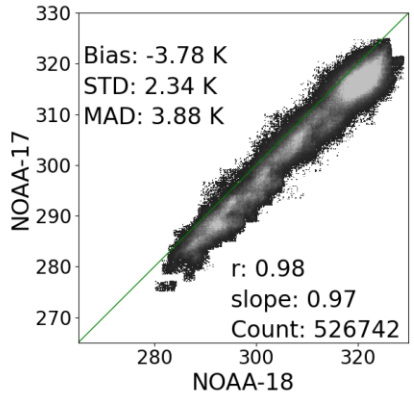


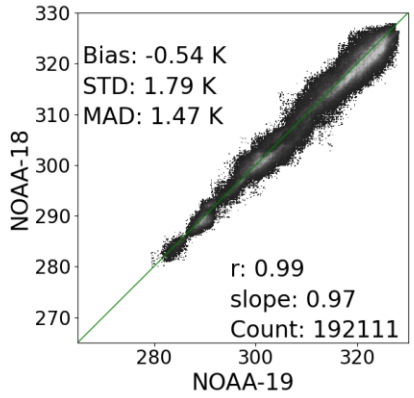
DLR

Before Correction









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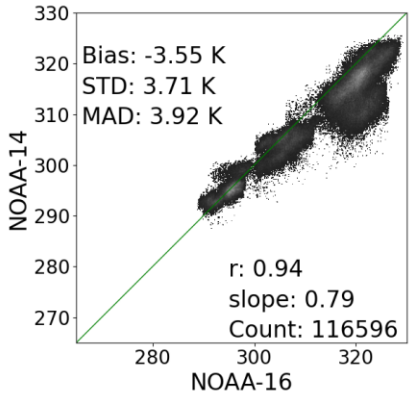
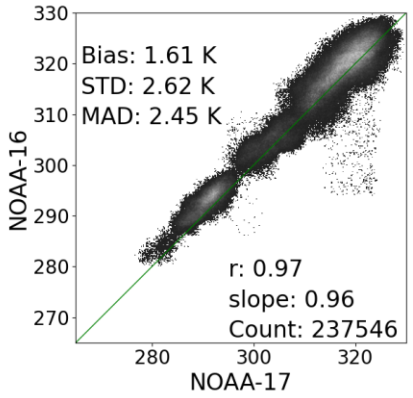
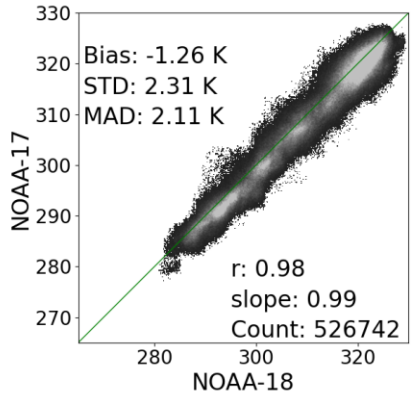
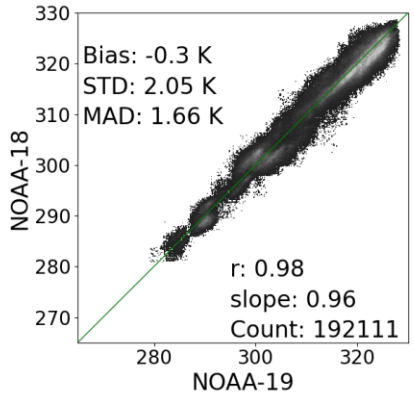
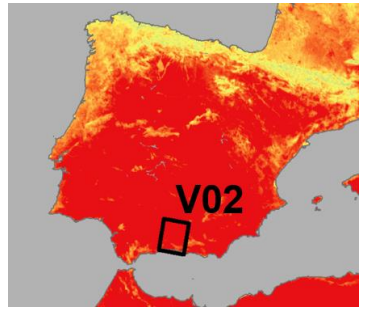








Results for the Cross Validation for V02



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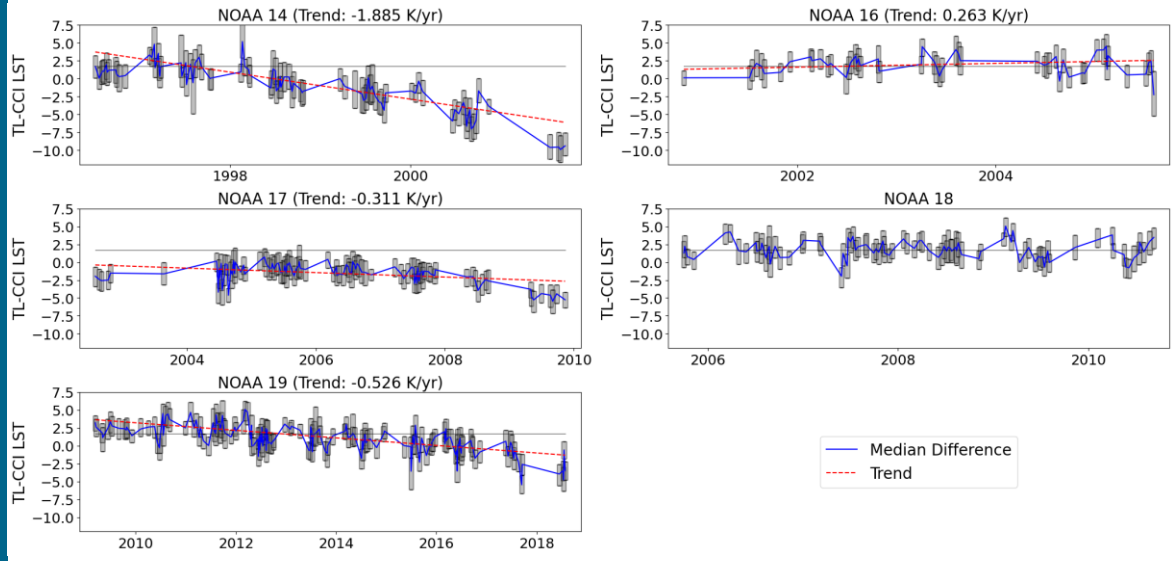

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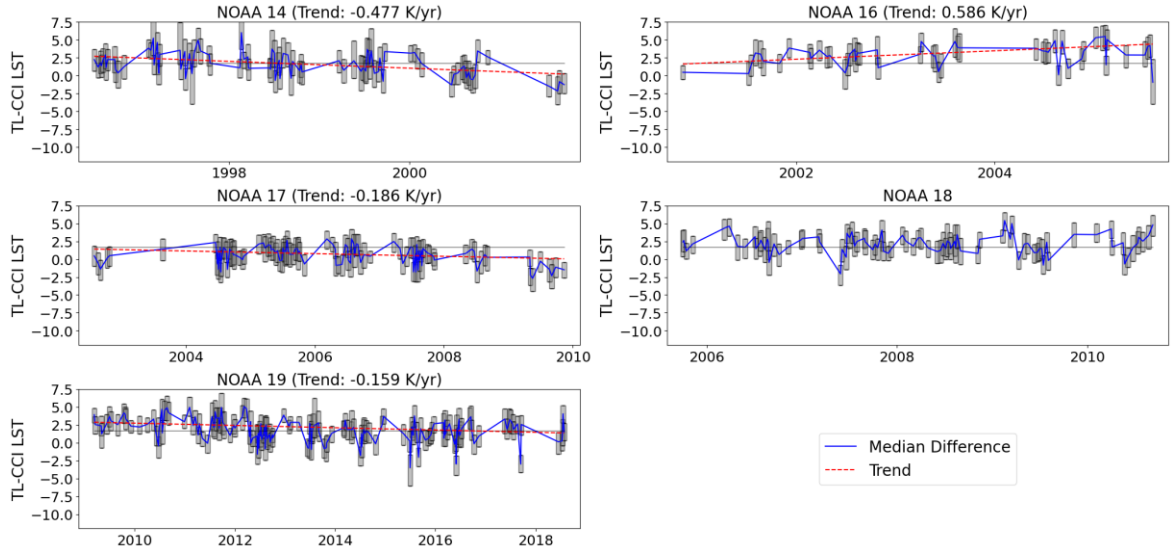
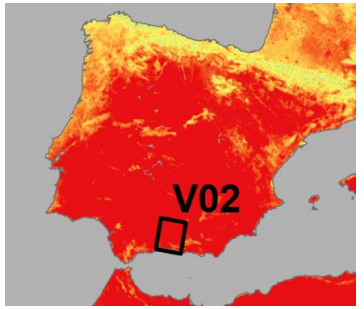


Platform	Bias	MAD	Trend
NOAA-14	-2.9	4.09	-1.557
NOAA-16	-0.09	2.44	0.206
NOAA-17	-3	3.44	-0.328
NOAA-18	0.02	2.29	0.102
NOAA-19	-0.8	2.56	-0.499

Platform	Bias	MAD	Trend
NOAA-14	-0.29	2.79	-0.286
NOAA-16	0.85	2.68	0.554
NOAA-17	-1.09	2.41	-0.122
NOAA-18	0.35	2.36	0.167
NOAA-19	0.02	2.41	-0.135

Results for the Cross Validation for V02



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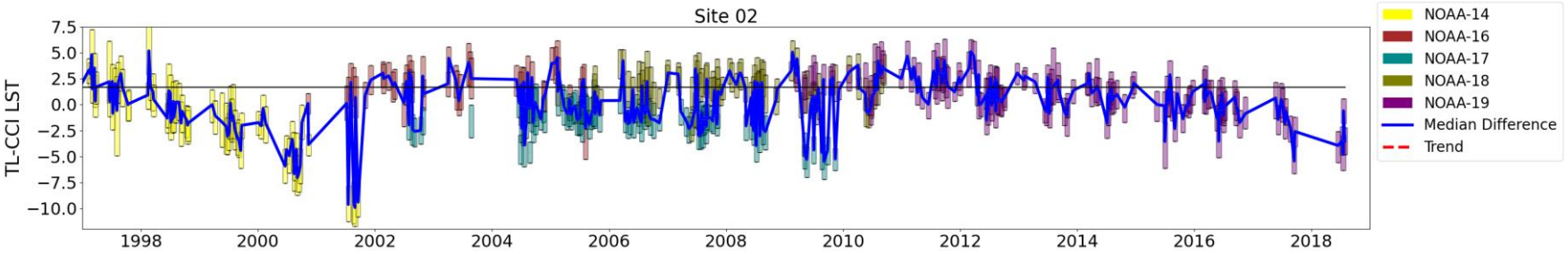
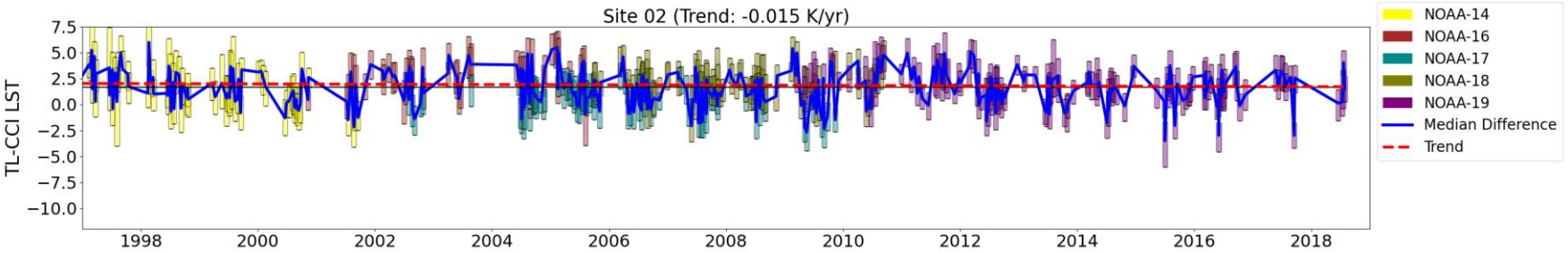


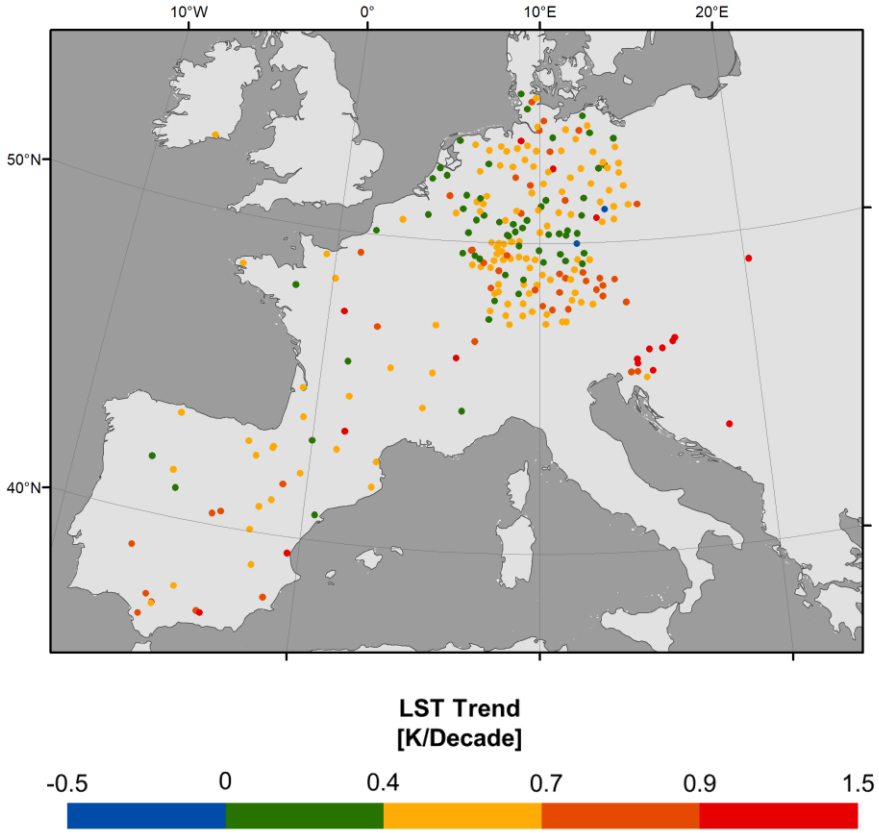
Bias	MAD	Trend
-1.39	2.94	0.005

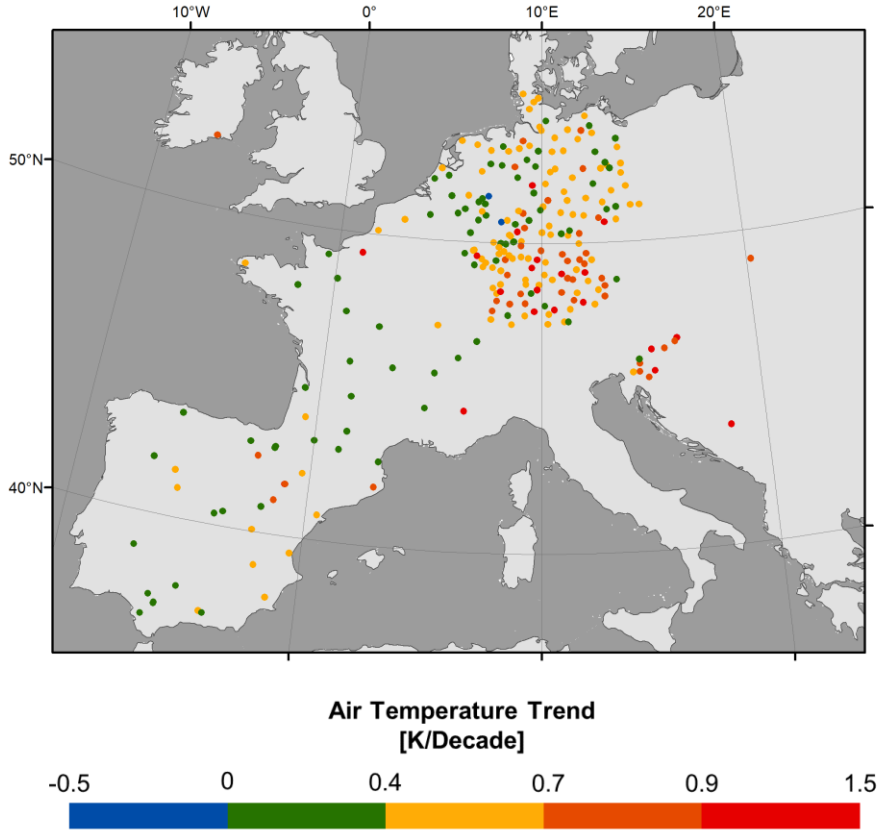
After Correction



Bias	MAD	Trend
-0.11	2.5	-0.016

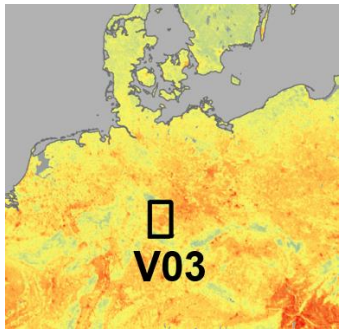
Spatial Distribution of significant LST and Air Temperature Trends





South Germany shows a cluster of high LST and air temperature trends.

Results for the Cross Validation for V03



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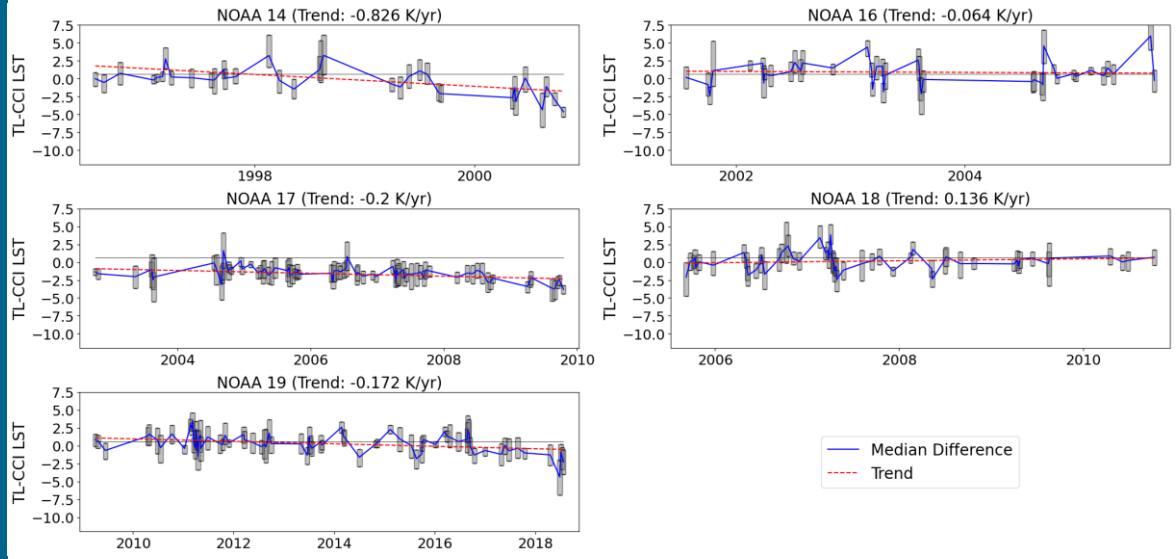

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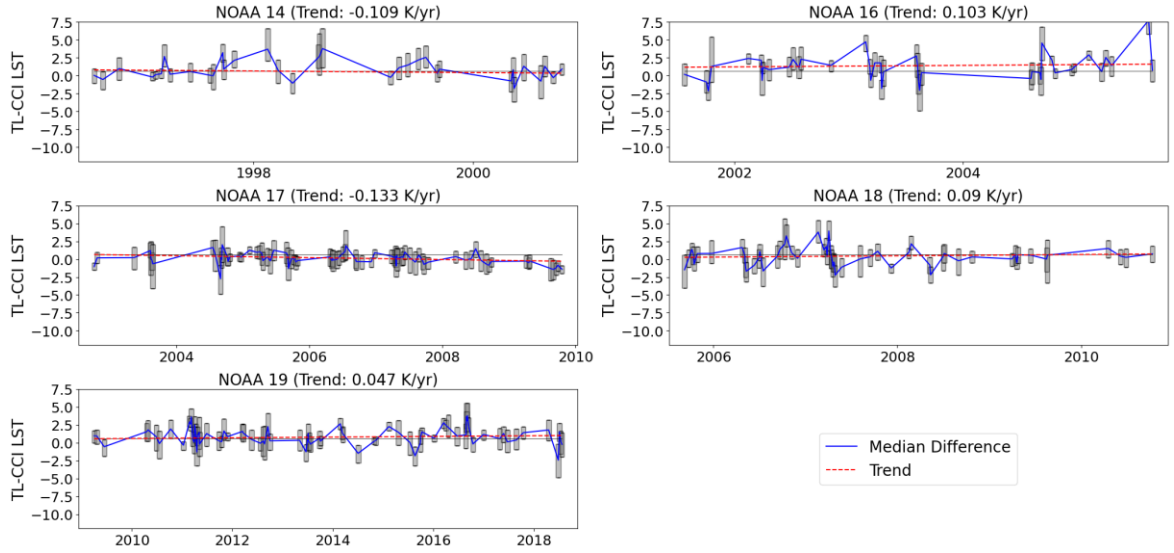
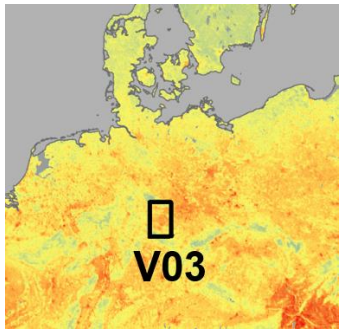


Platform	Bias	MAD	Trend
NOAA-14	-1.11	2.41	-1.146
NOAA-16	0.03	2.15	-0.273
NOAA-17	-2.44	2.75	-0.161
NOAA-18	-0.69	1.89	0.115
NOAA-19	-0.26	1.9	-0.138

Platform	Bias	MAD	Trend
NOAA-14	0.16	2.09	0.123
NOAA-16	0.35	2.2	-0.258
NOAA-17	-0.82	1.79	-0.142
NOAA-18	-0.49	1.89	0.059
NOAA-19	0.24	1.89	0.066

Results for the Cross Validation for V03



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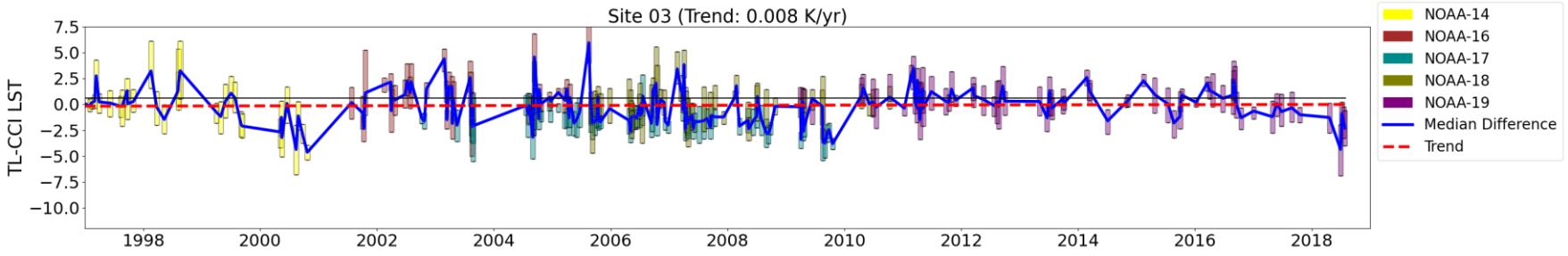
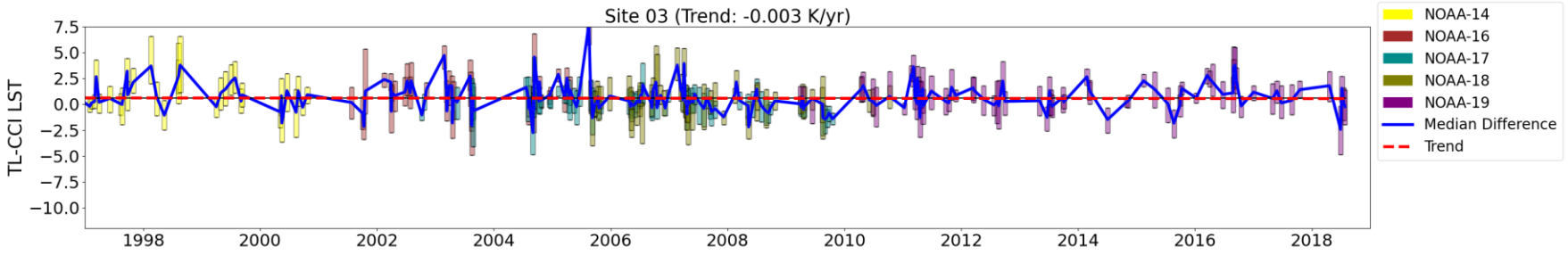


Bias	MAD	Trend
-1.02	2.23	0.005

After Correction



Bias	MAD	Trend
-0.19	1.93	-0.007