Long-term Trends of Land Surface Temperature over Europe derived from a daytime normalized AVHRR Time Series

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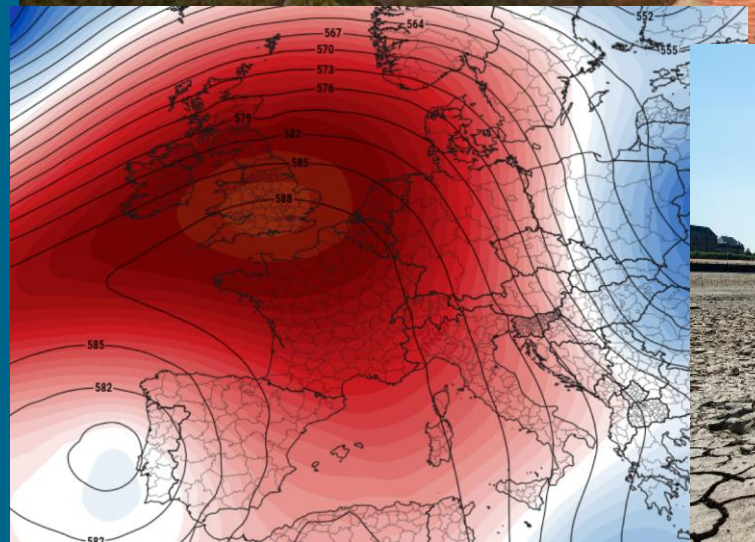
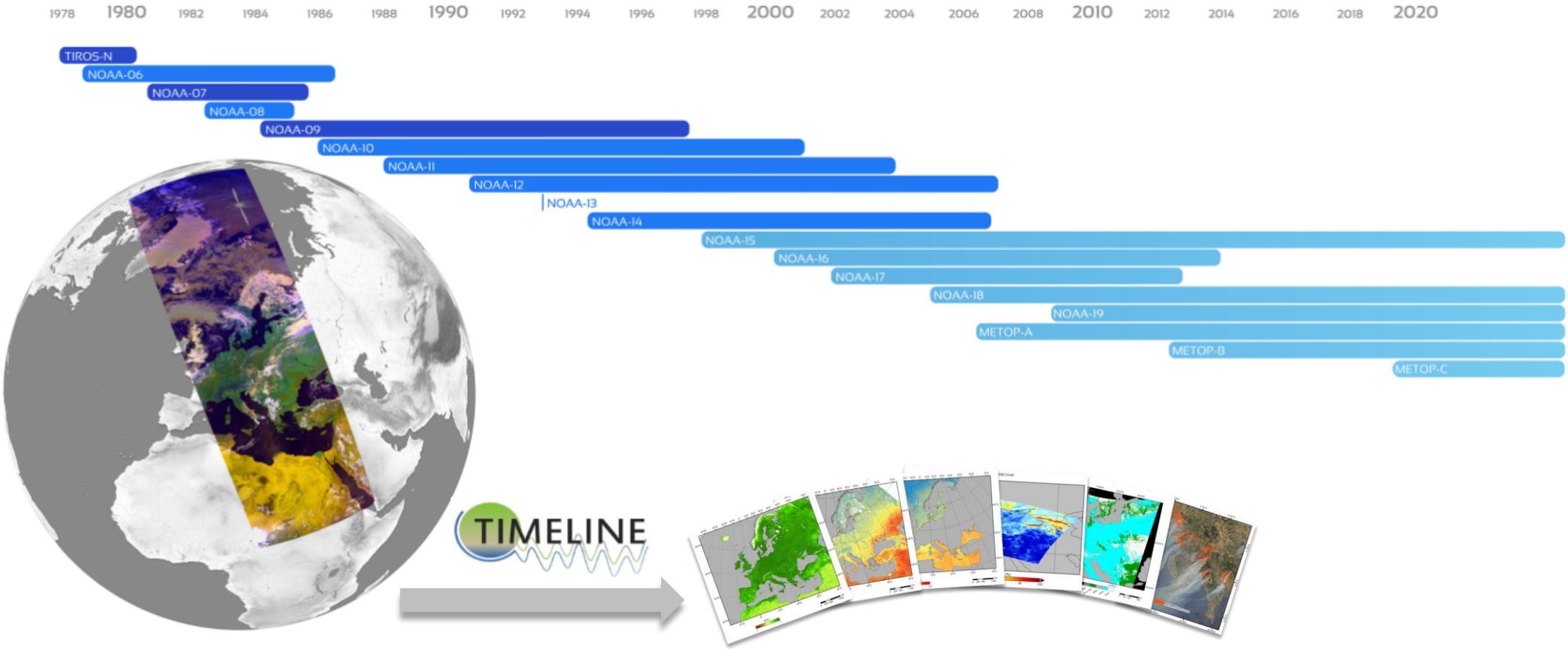
DLR

Climate Change is a serious Thread to Europe...



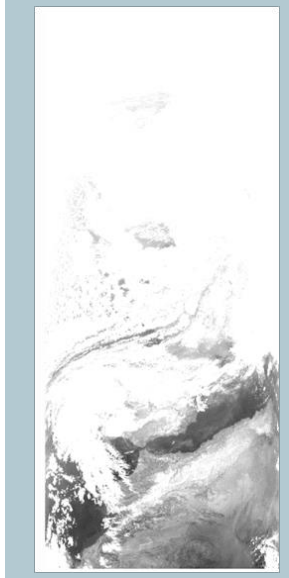
The TIMELINE Project – Geophysical Products over Europe from ~40 Years of AVHRR Data



- **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

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

$$c = \varepsilon_4 \tau$$

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

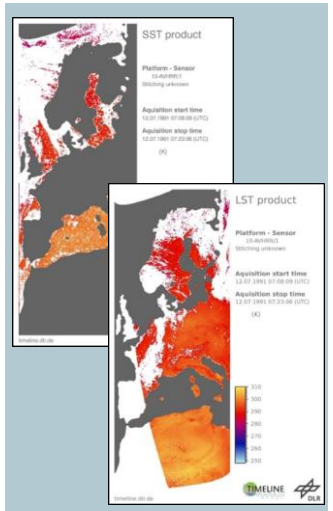
$$\tau = p_0 - p_1 cwv$$

Split window algorithm

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

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

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

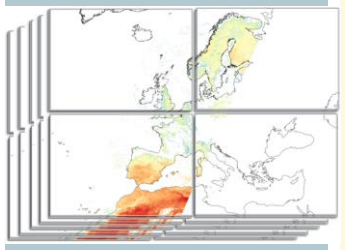


- LST in orbit projection at observation time
- Validated against MODIS LST and in situ LST [2]

L2c

L2c-Processor

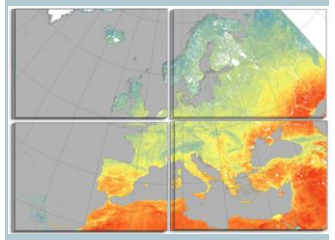
Projection to LAEA Tiles



L3

L3-Processor

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

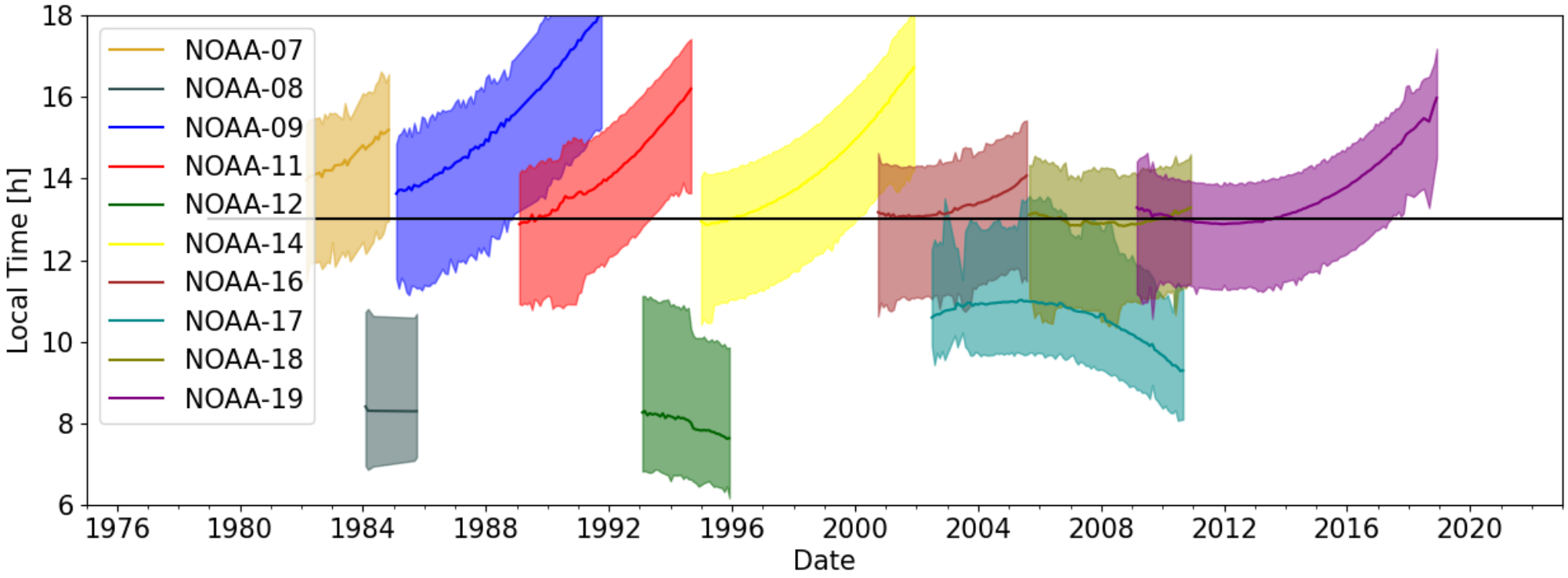


- **Daily:** Best observation of the day (lowest sat zenith angle)
- **10-Daily:** LST stastistics (Max,Mean,Median, Min)
- **Monthly:** LST stastistics (Max,Mean,Median, Min)

[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

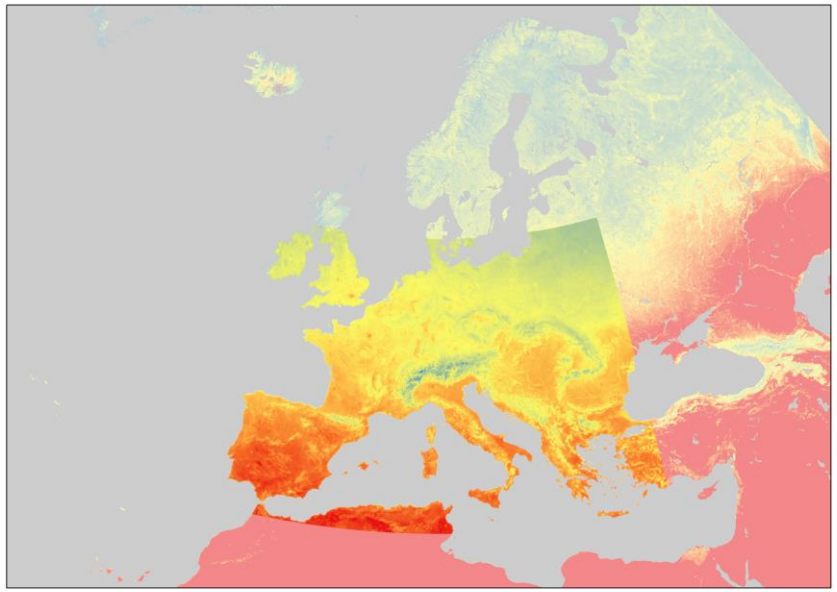
[2] Reiners, P.; Asam, S.; Frey, C.; Holzwarth, S.; Bachmann, M.; Sobrino, J.; Göttsche, F.-M.; Bendix, J.; Kuenzer, C. Validation of AVHRR Land Surface Temperature with MODIS and In Situ LST—A TIMELINE Thematic Processor. *Remote Sens.* **2021**, *13*, 3473. https://doi.org/10.3390/rs13173473

Challenge for LST Time Series: AVHRR Orbit Drift



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

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

$$\Delta LST_2 = LST_{SEVIRI}(13\text{h}, \text{doy}) - LST_{SEVIRI}(t_2, \text{doy})$$

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

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

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

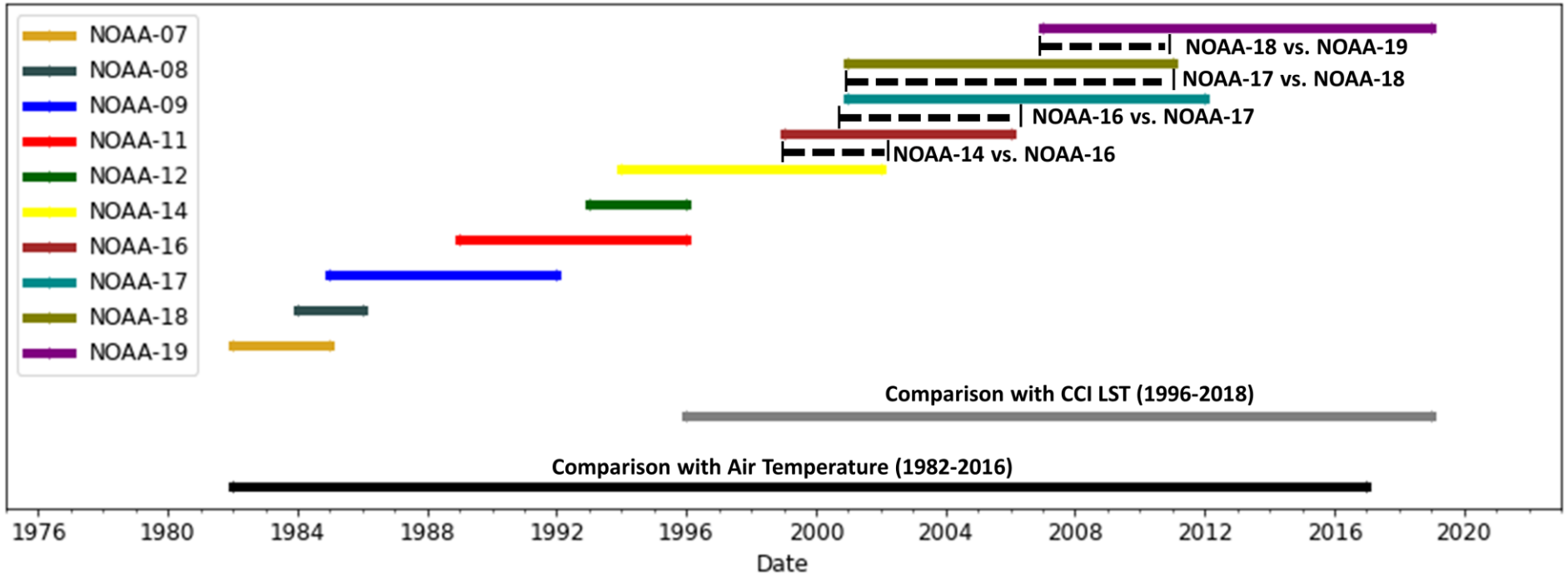
$LST_{AVHRR}(13\text{h})$: AVHRR LST at 13h

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

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

doy = day of the year

Validation of the Daytime Normalized AVHRR LST

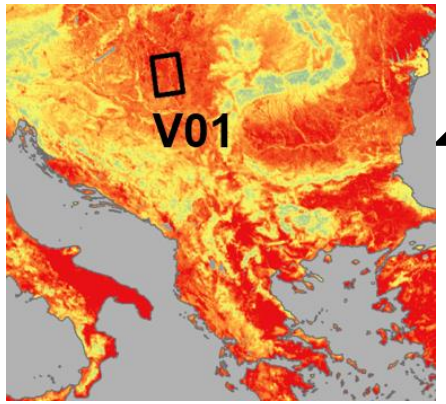


Cross Validation with „Same Day Observations“ from different platforms

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

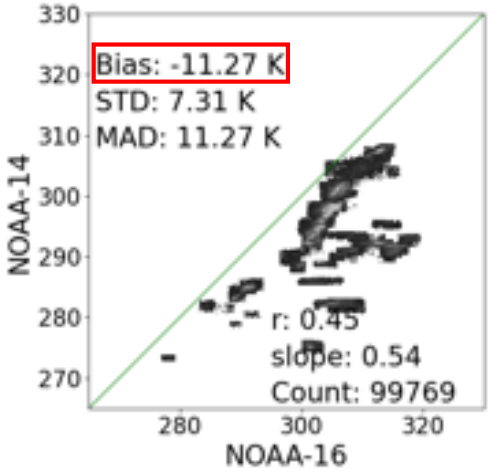
Time Series Comparison with EUSTACE Air Temperature Data (1982-2018)

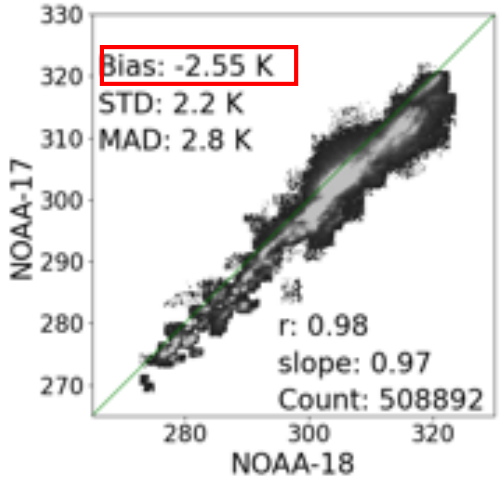
Results for the Cross Platform Validation for Hungarian Plane (V01)



DLR

Before Correction





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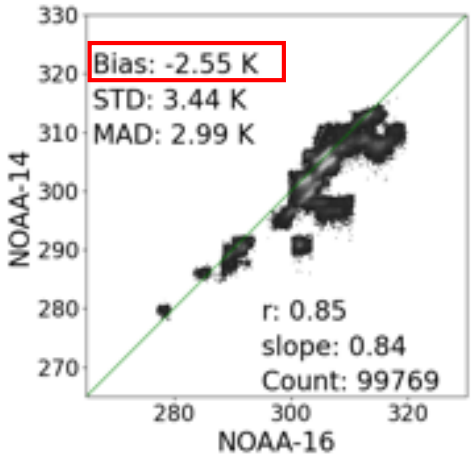
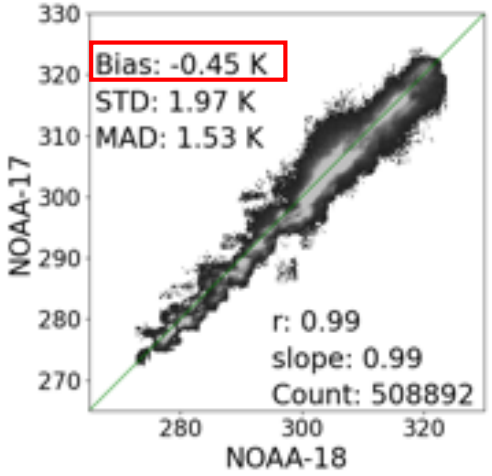
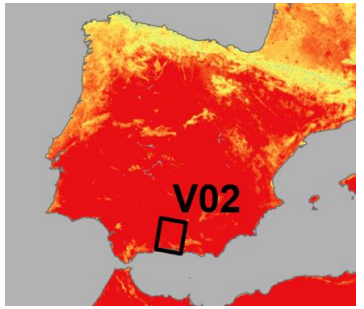


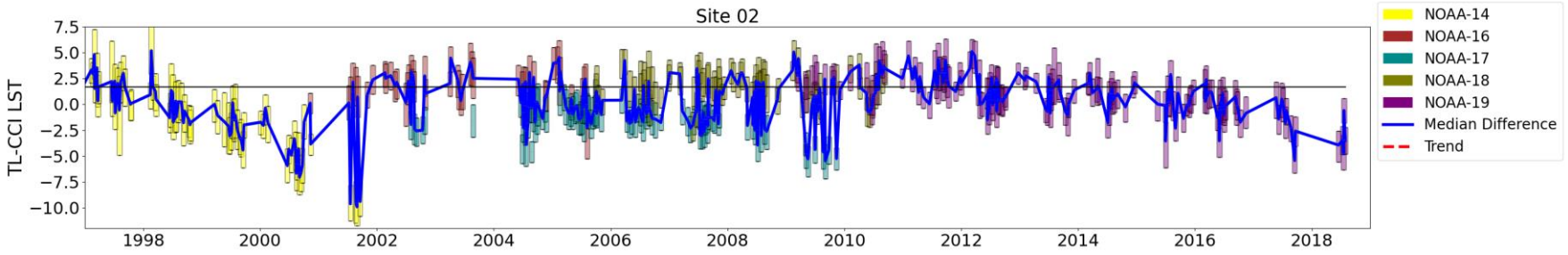


Results for the Comparison with CCI LST for Southern Spain (V02)



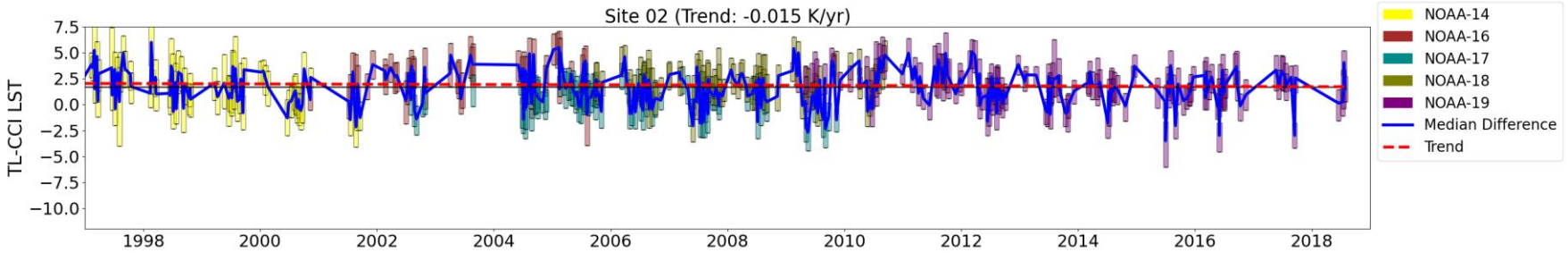
DLR

Before Correction



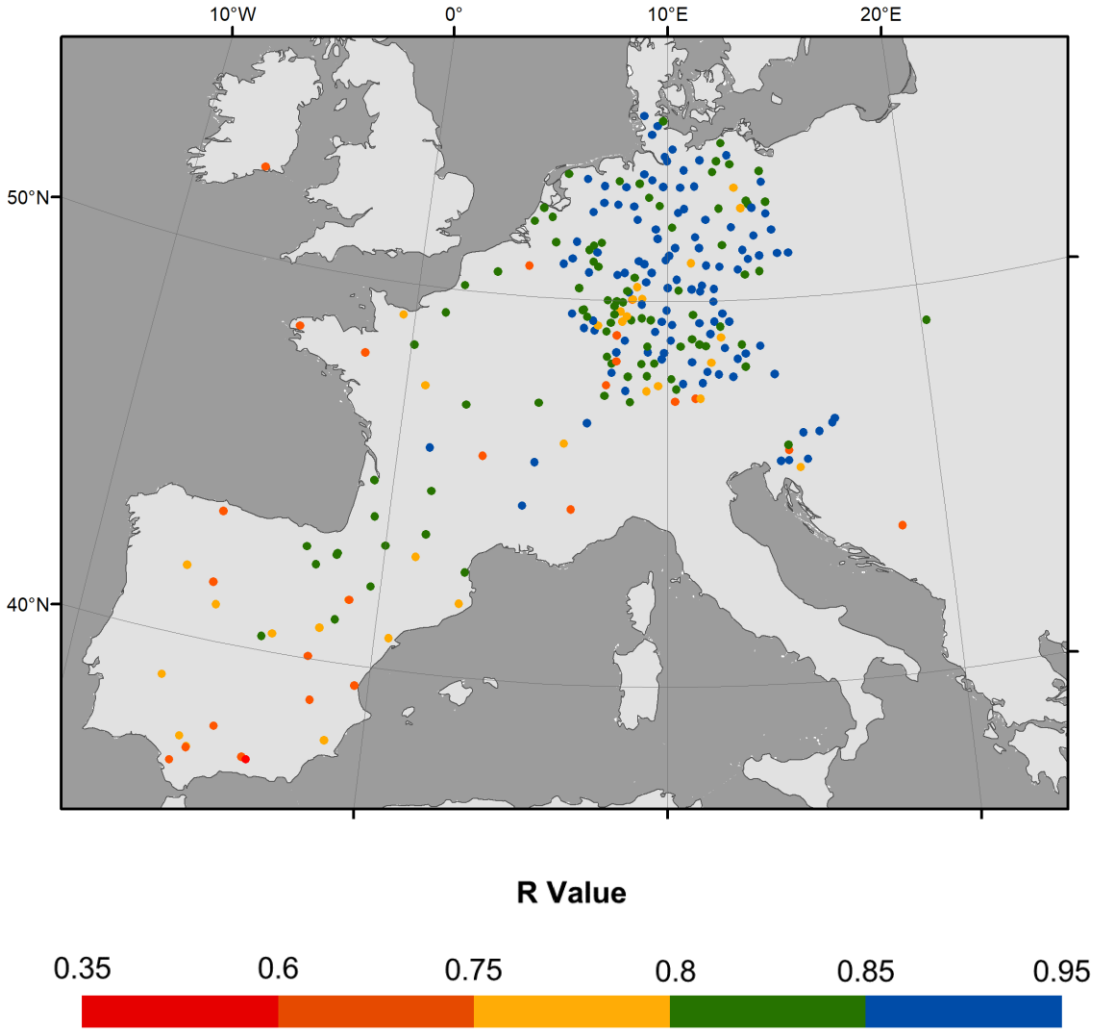
Bias	MAD	Trend
-1.39	2.94	n.s.

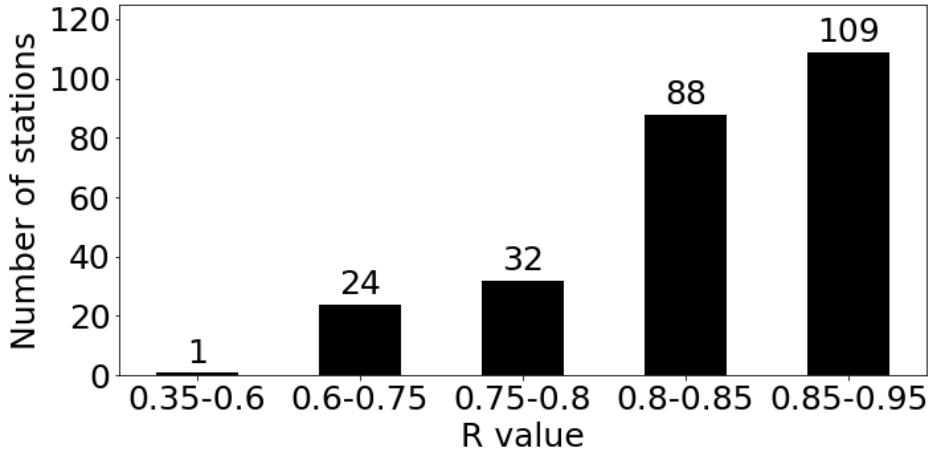
After Correction



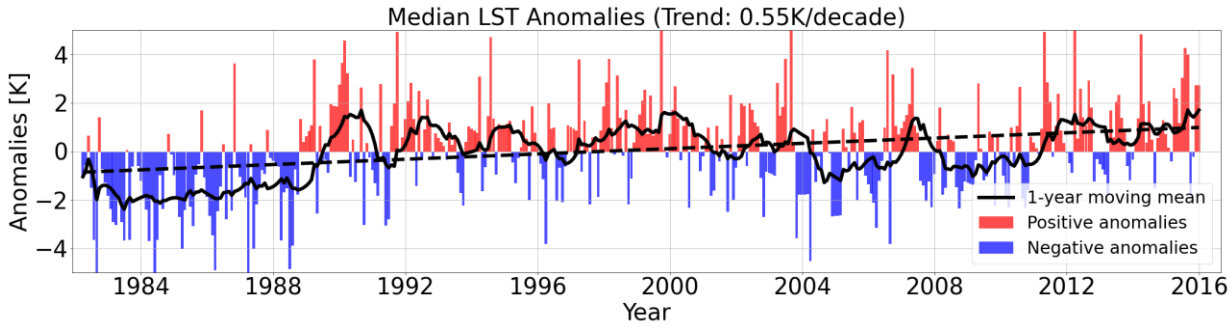
Bias	MAD	Trend
-0.11	2.5	-0.016

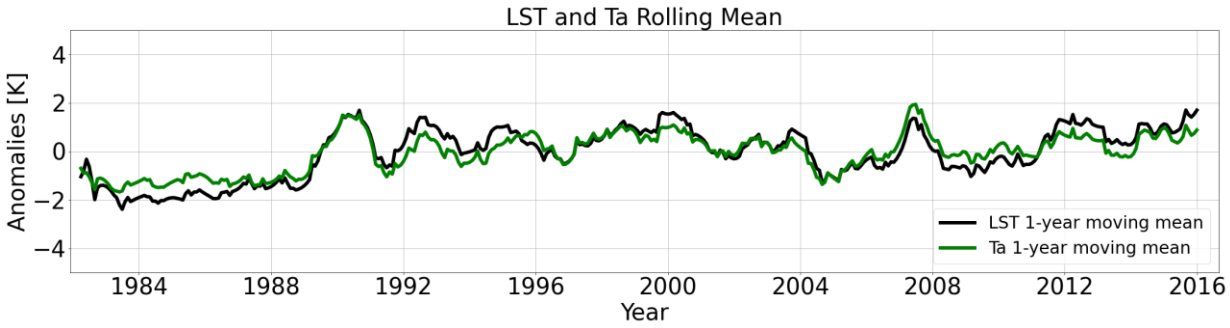
Correlation between LST and Air Temperature Anomalies (1982-2018)

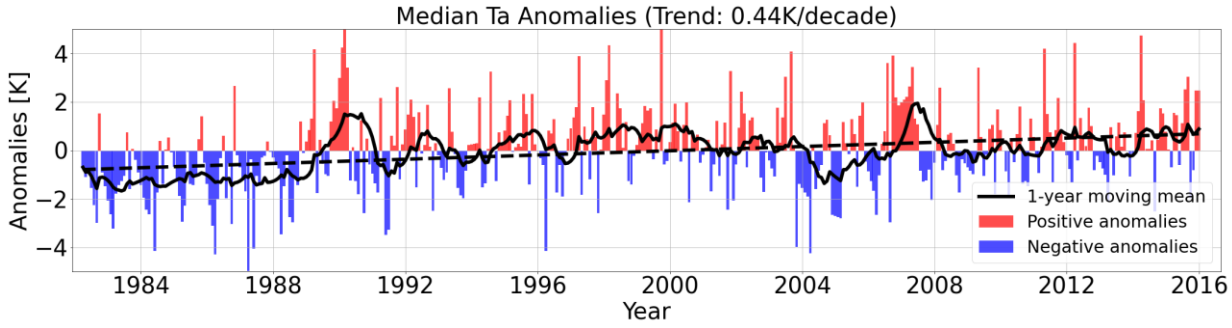


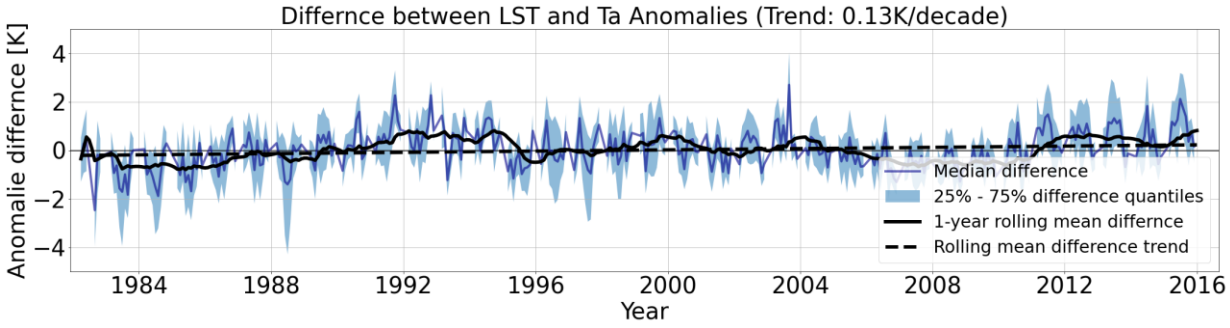


Time Series Comparison between LST and Air Temperature

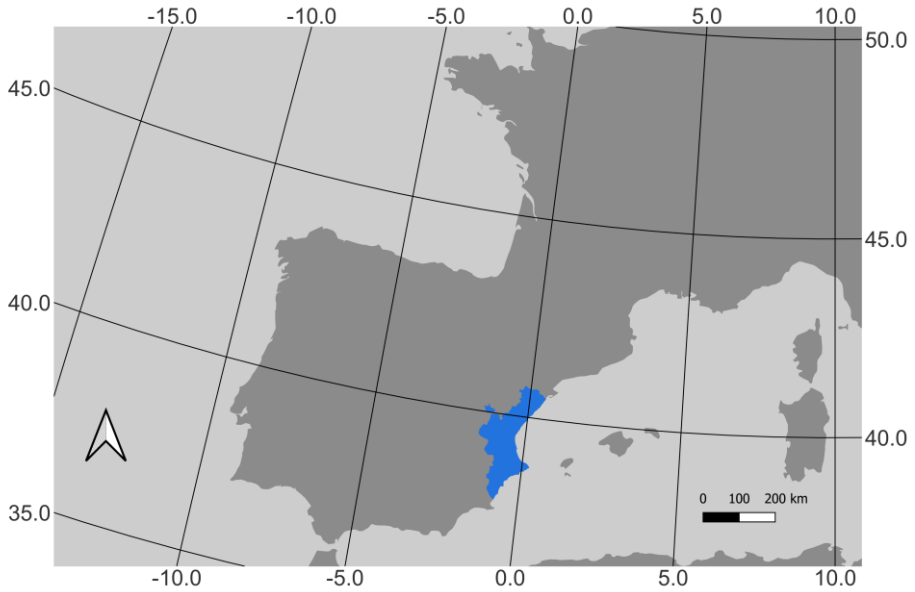


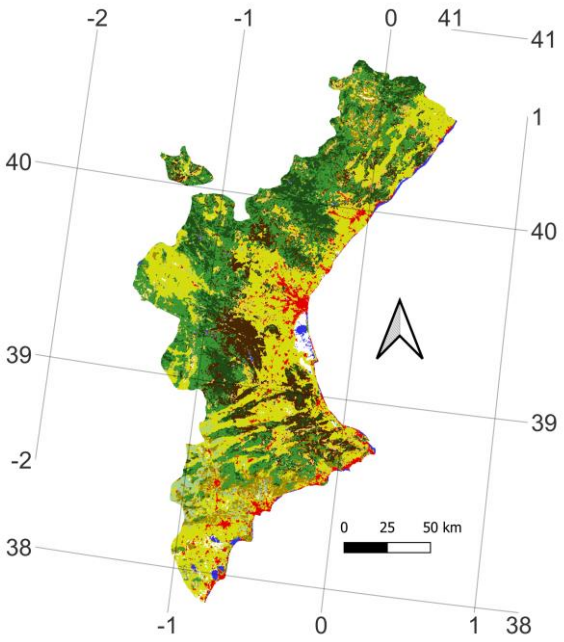


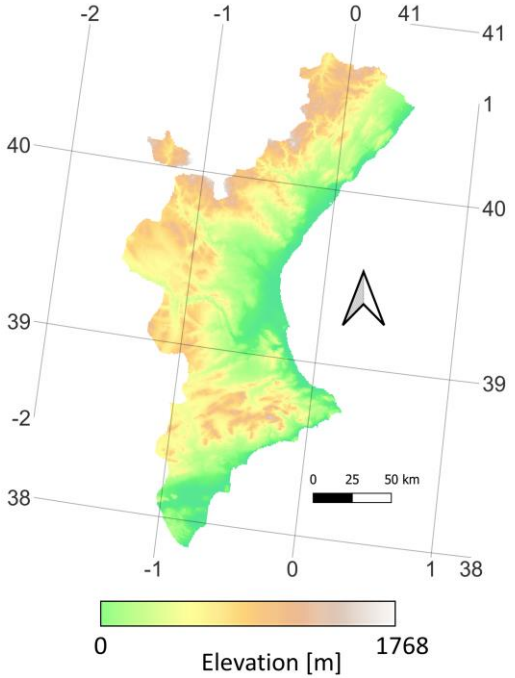




Example Study Area: Valencia Community







Landcover
- Cropland
- Mosaic Cropland
- Broadleaved deciduous Forest
- Needleleaved evergreen Forest
- Mixed Forest
- Shrubs
- Grassland
- Sparse vegetation
- Urban
- Bare Areas

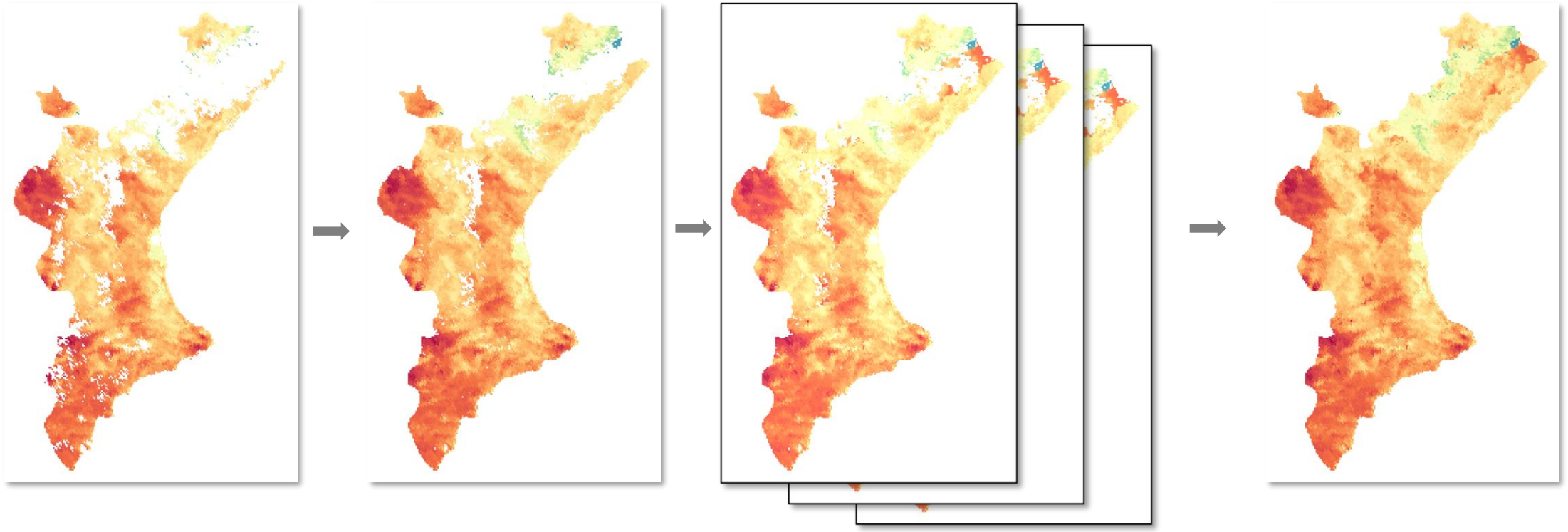
Filling of Cloud Gaps on the 10-daily Products

10-daily maximum LST

1. Spatial Filling

2. Temporal Filling

3. Random Forest Regression Filling

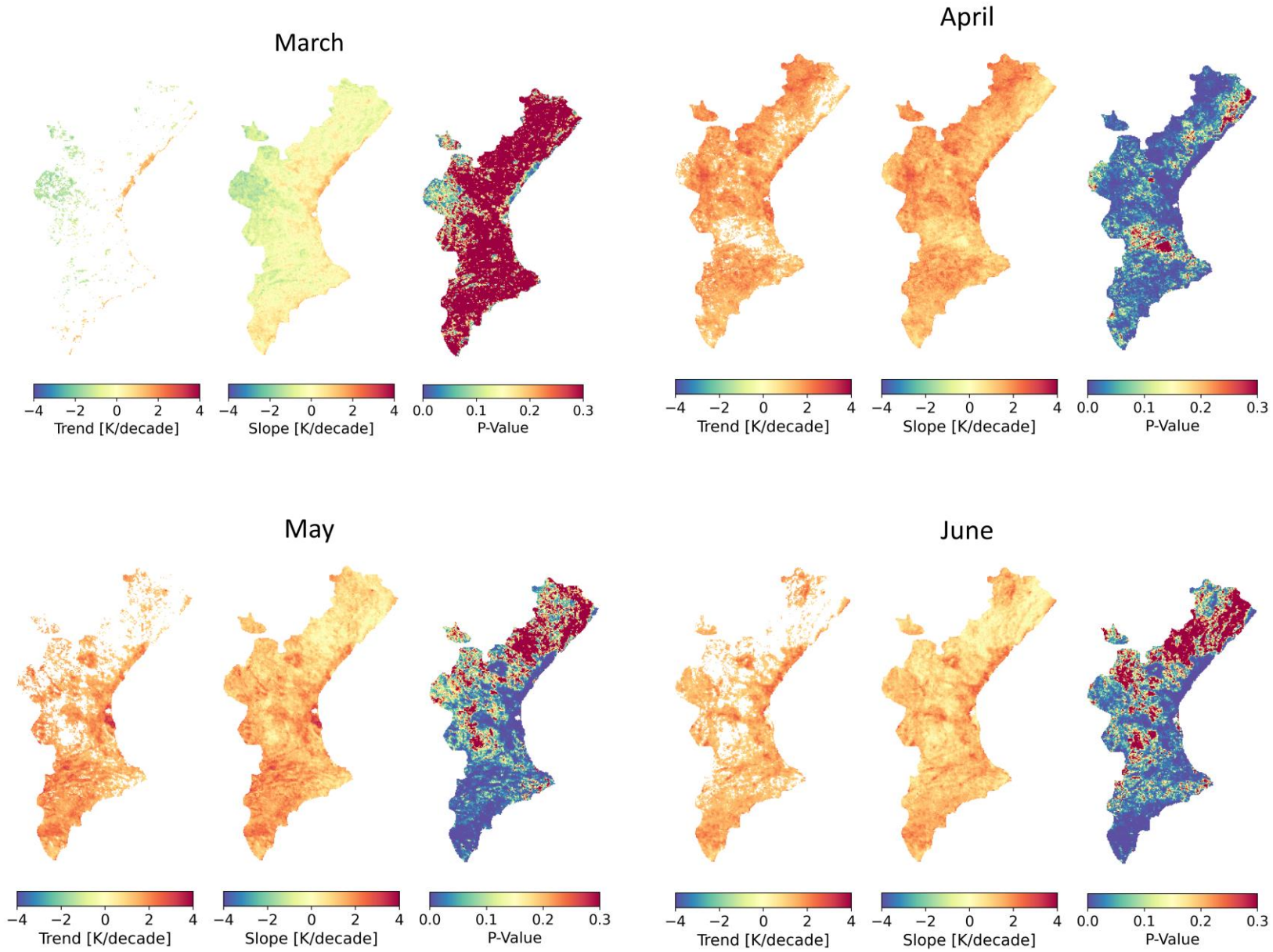


Filled with values within a 10x10 window with similar NDVI and elevation

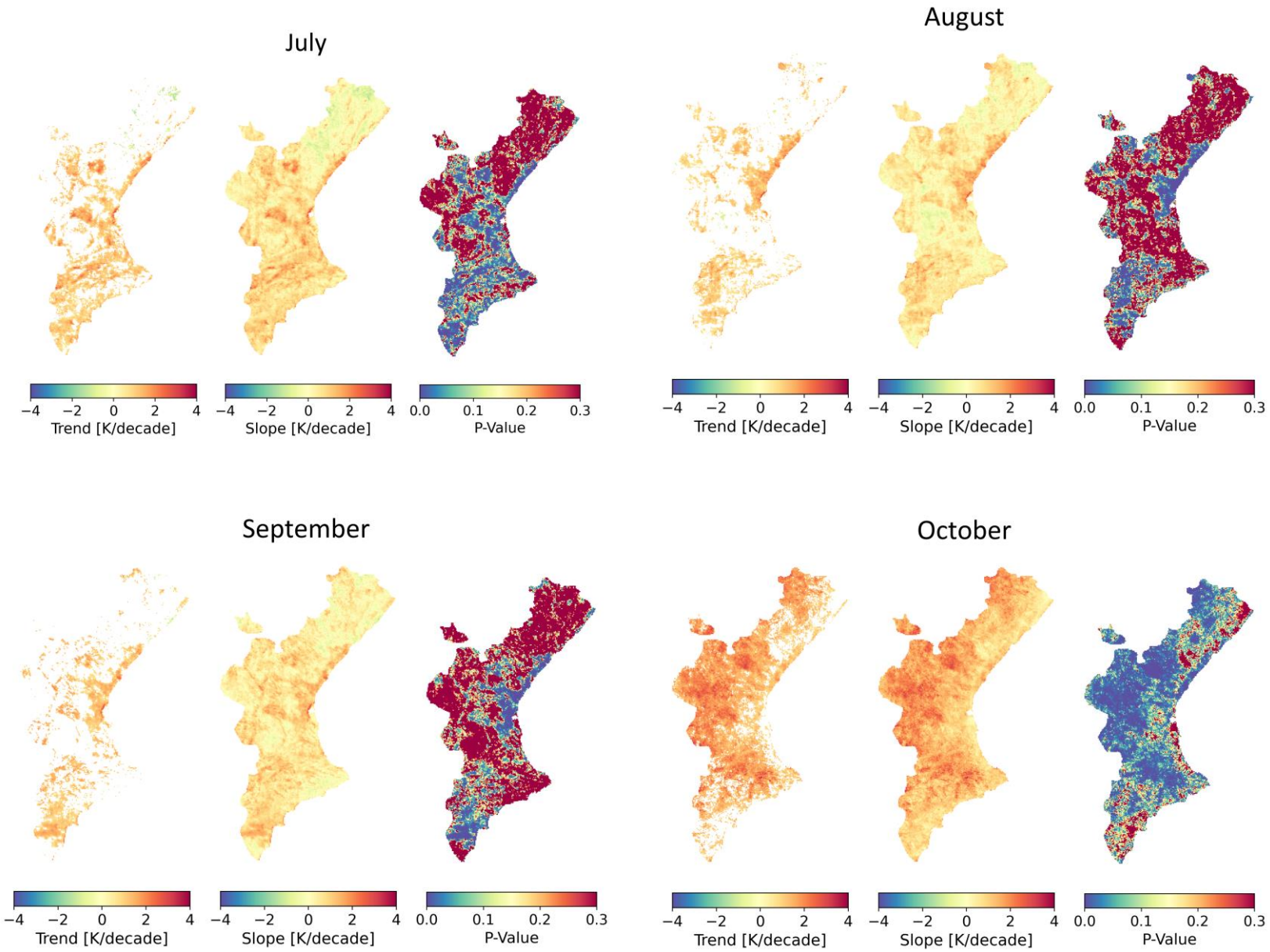
Interpolated between the 10-daily product before and after

Based on 10-daily longterm climatology, NDVI and elevation

Monthly Maximum LST Trends (1982-2018)



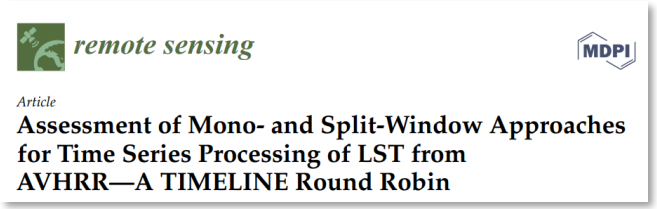
Monthly Maximum LST Trends (1982-2018)



Summary and Outlook

- ✓ Harmonized the spectral response curves of the different NOAA satellites
- ✓ Implemented the correction for emissivity, sensor view angle and water vapor content
- ✓ Validated the instantaneous (Level 2) LST with in situ measurements and MODIS LST
- ✓ Implemented and validated an orbit drift correction by using LST Annual Cycle Parameters (ACPs) from geostationary data
- ✓ Created a long-term daily maximum LST time series (1982-2018) as well as 10-daily and monthly products

- ⚙ Extent the LST time series by incorporating latest NOAA-19 and MetOp data
- ⚙ Further compare the AVHRR LST time series and the LST trends to other available long-term LST sources (e.g. ERA land, CCI products)
- ⚙ Extent the LST trend analysis to other regions in Central and Southern Europe
- ⚙ Extent the LST time series by incorporating latest NOAA-19 and MetOp data
- ⚙ Combine analysis with other variables from the TIMELINE product suite (NDVI, Hot Spot/Burnt Area)

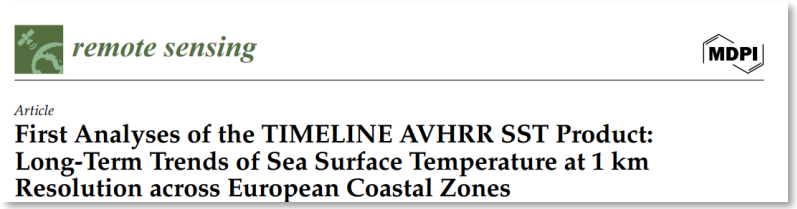

remote sensing

MDPI

Article

Assessment of Mono- and Split-Window Approaches for Time Series Processing of LST from AVHRR—A TIMELINE Round Robin

(Frey et. al., 2017)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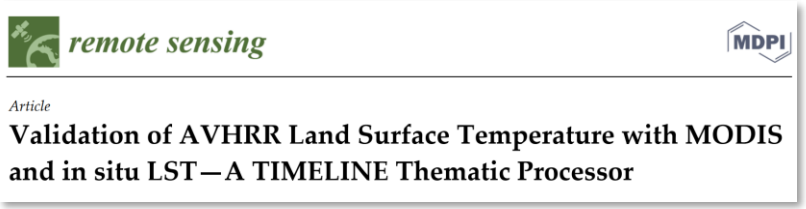
Article

First Analyses of the TIMELINE AVHRR SST Product: Long-Term Trends of Sea Surface Temperature at 1 km Resolution across European Coastal Zones

(Reiners et. al., 2024)

DLR


remote sensing

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Article

Validation of AVHRR Land Surface Temperature with MODIS and in situ LST—A TIMELINE Thematic Processor

(Reiners et. al., 2021)


IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING

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

(Reiners et. al., under review)


remote sensing

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Review

Satellite-Derived Land Surface Temperature Dynamics in the Context of Global Change—A Review

(Reiners et. al., 2023)

www.timeline.dlr.de

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