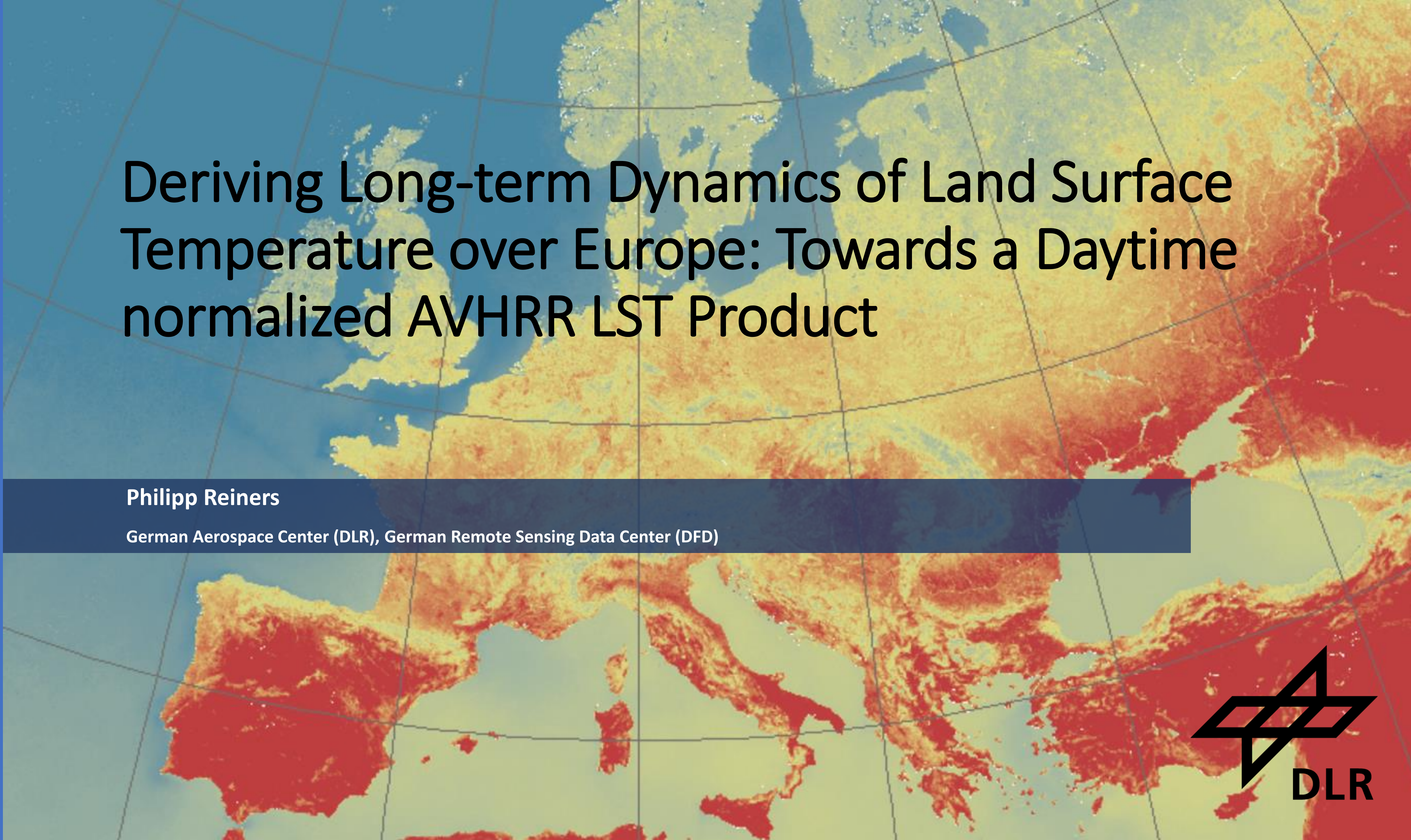


Deriving Long-term Dynamics of Land Surface Temperature over Europe: Towards a Daytime normalized AVHRR LST Product

Philipp Reiners

German Aerospace Center (DLR), German Remote Sensing Data Center (DFD)

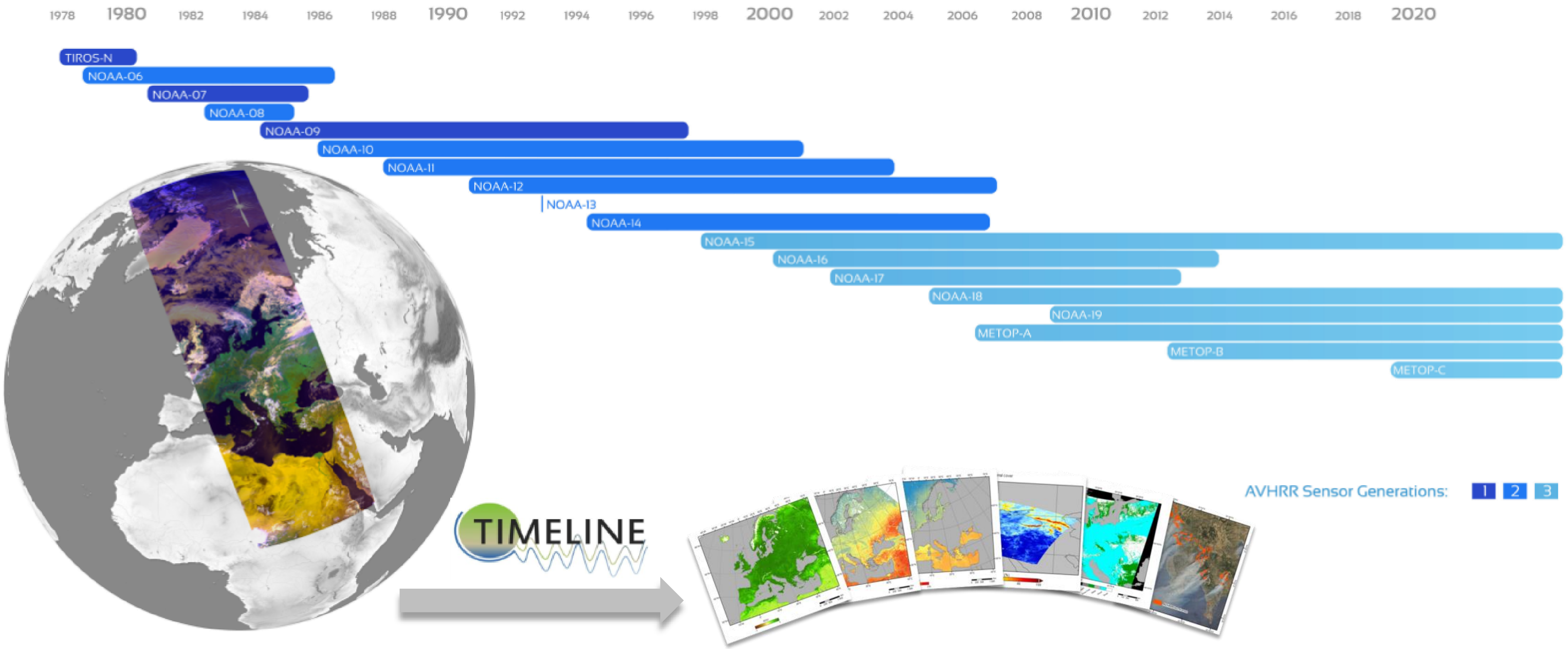
DLR

Land Surface Temperature – A key Parameter in the Earth's System

- Land Surface Temperature (LST) is a key parameter for tracing the impact of changing climate conditions
- Long-term changes of LST reflect global warming as well as land surface processes such as deforestation and urbanization
- LST changes on the other hand can change local climate




Mapping 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:** 1km (LAC + HRTP data)
- **Coverage:** Europe and North Africa

TIMELINE LST Product Generation Overview

L1B → L2 → L2c → L3

AVHRR Brightness Temperatures

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

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

$$c = \varepsilon_4 \tau$$

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

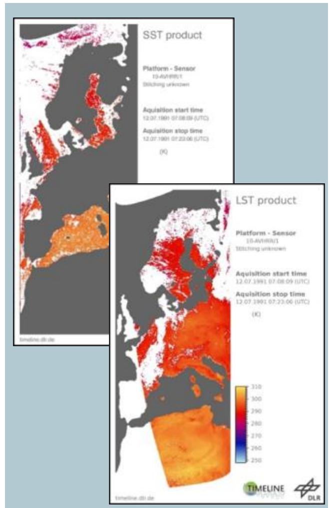
$$\tau = p_0 - p_1 cwv$$

Split window algorithm

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

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

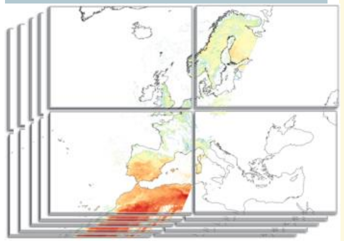
$$LST = p_0 + \alpha\left(\frac{t4+t5}{2}\right) + \beta\left(\frac{t4-t5}{2}\right)$$



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

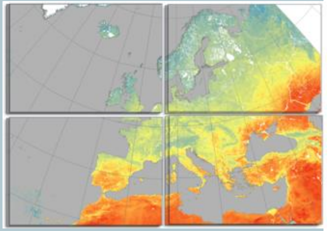
L2c-Processor

Projection to LAEA Tiles



L3-Processor

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

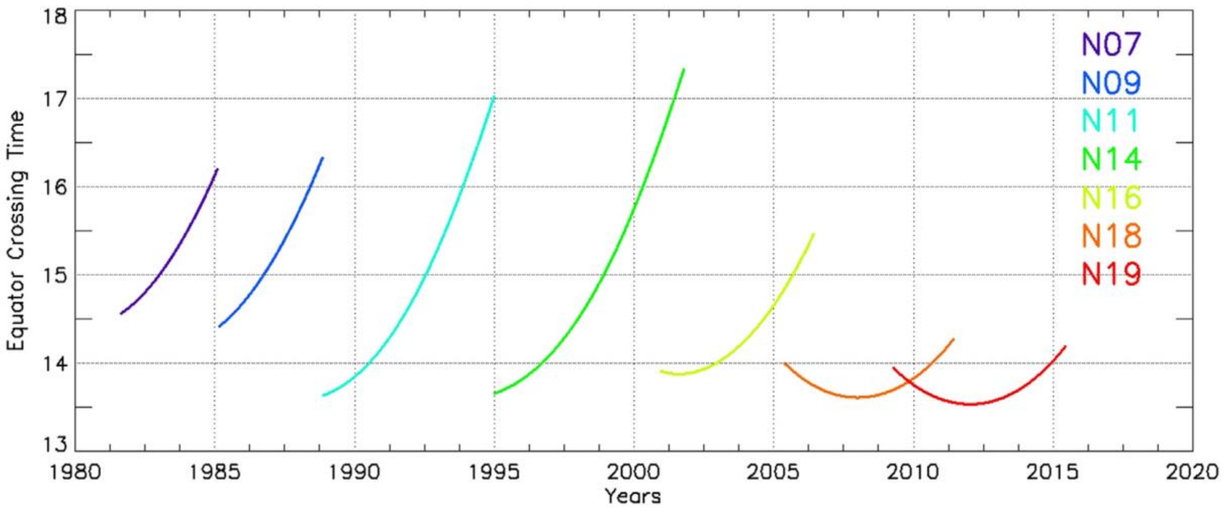


- **Daily:** Best observation of the day (lowest sat zenith angle)
- **10-Daily:** LST stastistics (Max,Mean,Median, Min)
- **Monthly:** LST stastistics (Max,Mean,Median, Min)

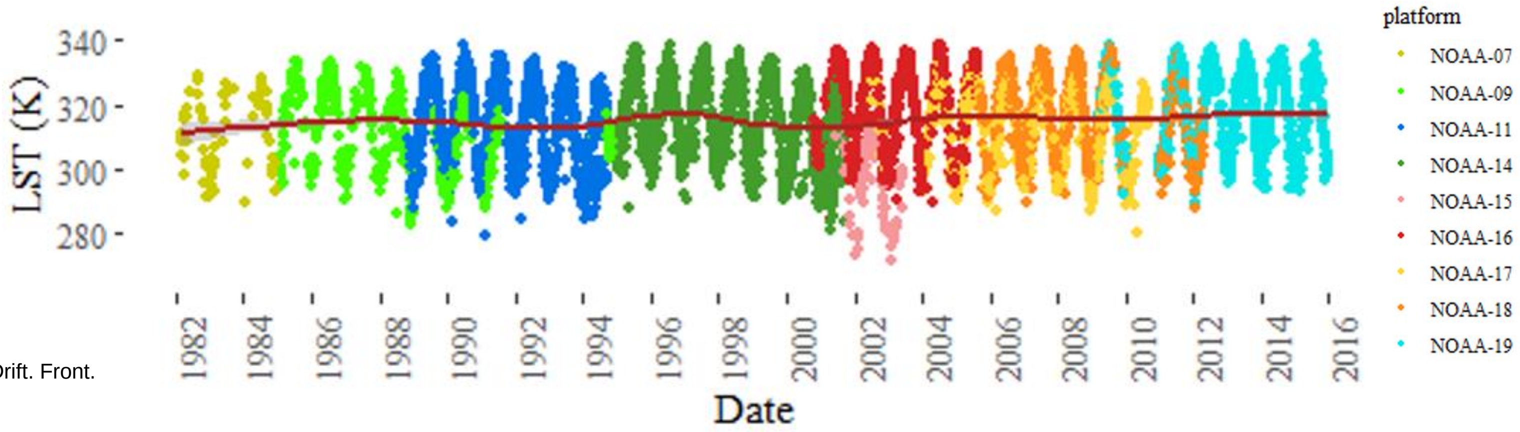
[1] Frey, C.M.; Kuenzer, C.; Dech, S. Assessment of Mono- and Split-Window Approaches for Time Series Processing of LST from AVHRR—A TIMELINE Round Robin. *Remote Sens.* **2017**, *9*, 72. https://doi.org/10.3390/rs9010072
[2] Reiners, P.; Asam, S.; Frey, C.; Holzwarth, S.; Bachmann, M.; Sobrino, J.;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

AVHRR Orbit Drift

Equator crossing times of the NOAA sensors [3]



Drifted Timeseries of TIMELINE LST at the PICS site Algeria 3



[3] Julien Y and Sobrino JA (2022) Toward a Reliable Correction of NOAA AVHRR Orbital Drift. Front. Remote Sens. 3:851933. doi: 10.3389/frsen.2022.851933

Methods for Correcting the Orbital Drift

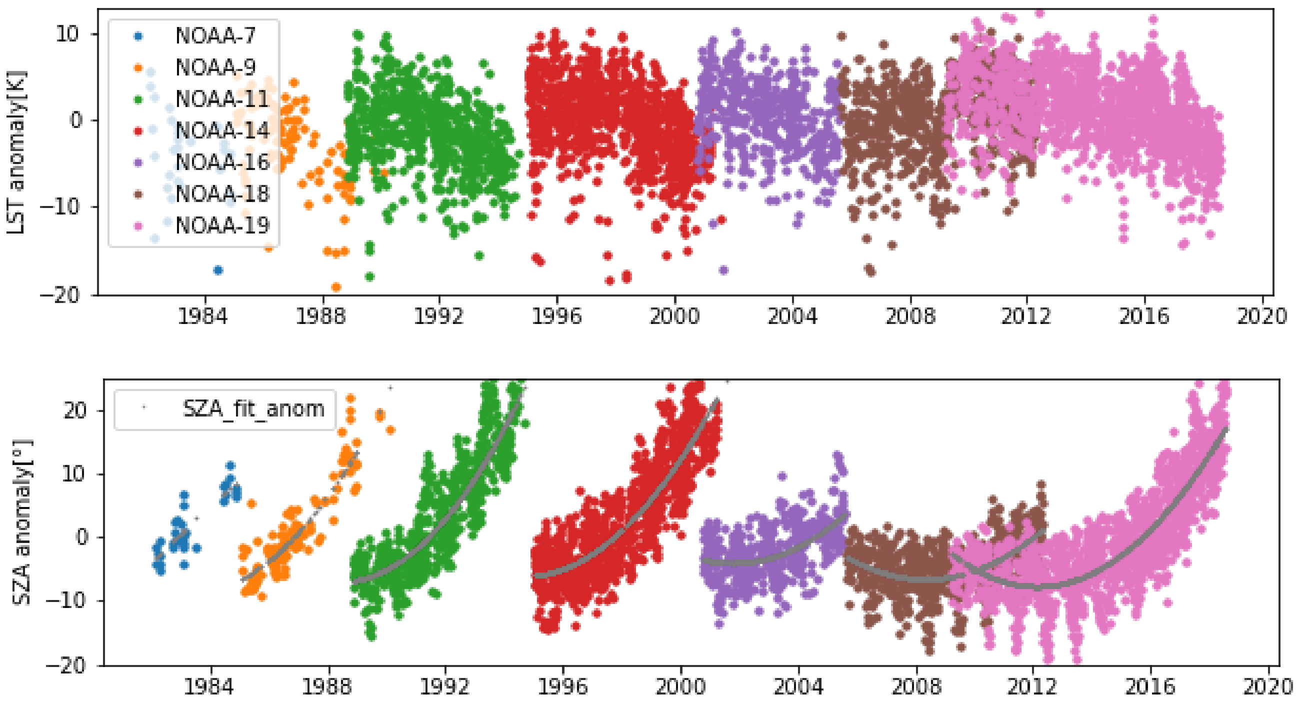
- Sun Target Sensor Geometry Modelling
  - ➢ Relying on Vegetation Structure Models
  - ✚ Take into account the viewing geometry
  - ▬ Rely on many pre-assumptions

- Diurnal Temperature Cycle (DTC) Reconstruction
  - ➢ DTC Modelling from several measurements throughout the day or from neighbouring LSTs
  - ✚ Models have a physical meaning.
  - ▬ Only few measurements per day » dependency on auxiliary data.

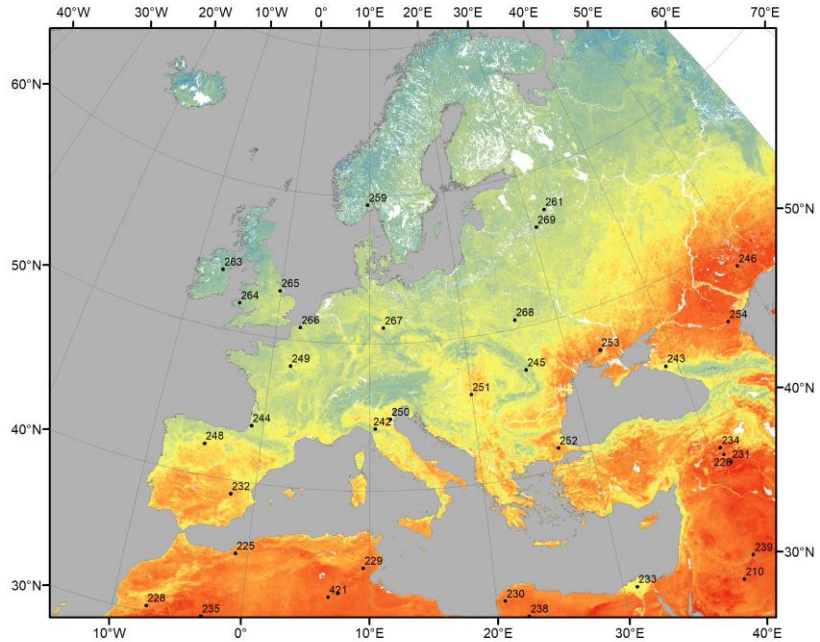
- Statistical Methods
  - ➢ Regression between LST anomalies and anomalies in observation time or sun zenith angle.
  - ✚ No auxiliary data needed.
  - ▬ Distinction between orbit drift signal and “real” temperature trends.

LST and Sun Zenith Angle Regression Method
adapted from Julien & Sobrino [3,4,5]

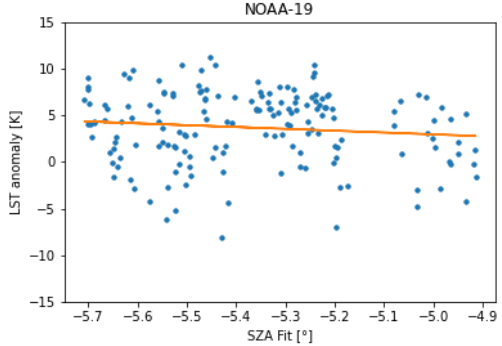
LST and SZA anomalies at the BELMANIP site 235



BELMANIP sites within the TIMELINE project area



LST anomalies against SZA_anom_fit for NOAA 19 at BELMANIP site 235



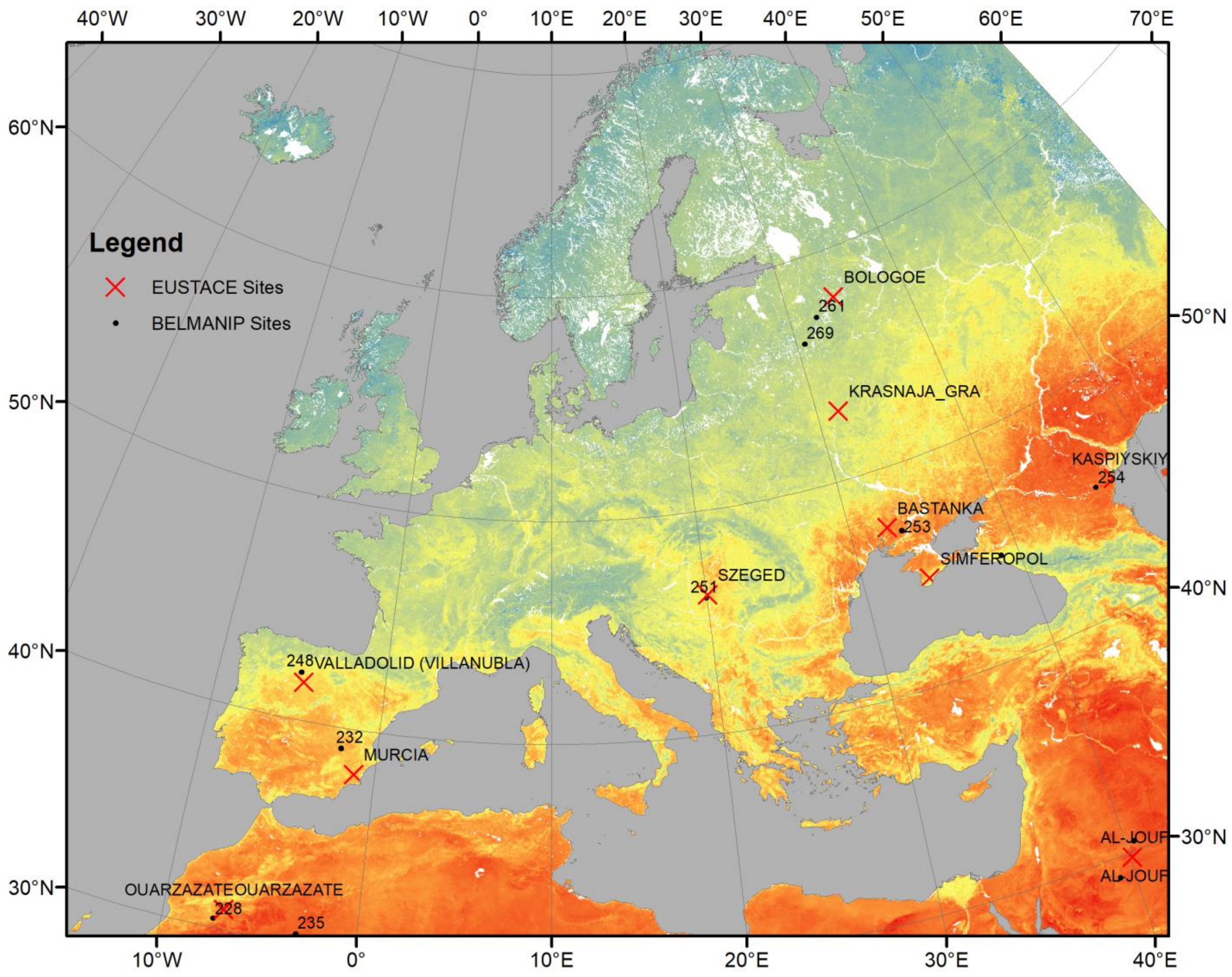
$$Orbit\ Drift\ Signal = a_i * SZA\_anom\_fit_i\ \{SZA\_anom\_fit_i > 0\}$$

[3] Julien Y and Sobrino JA (2022) Toward a Reliable Correction of NOAA AVHRR Orbital Drift. Front. Remote Sens. 3:851933. doi: 10.3389/frsen.2022.851933
[4] Julien, Y.; Sobrino, J.A. NOAA-AVHRR Orbital Drift Correction: Validating Methods Using MSG-SEVIRI Data as a Benchmark Dataset. Remote Sens. 2021, 13, 925. https://doi.org/ 10.3390/rs13050925
[5] Julien, Yves & Sobrino, Jose. (2012). Correcting AVHRR Long Term Data Record V3 estimated LST from orbital drift effects. Remote Sensing of Environment. 123. 207-219. 10.1016/j.rse.2012.03.016.

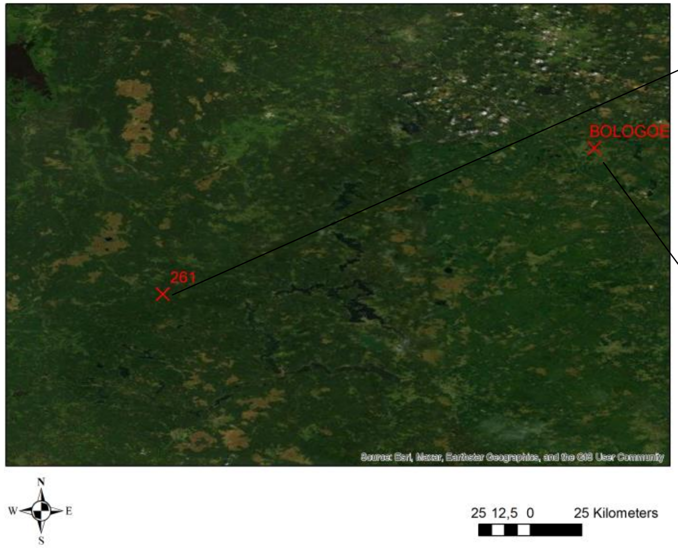
Study sites from BELMANIP and EUSTACE network

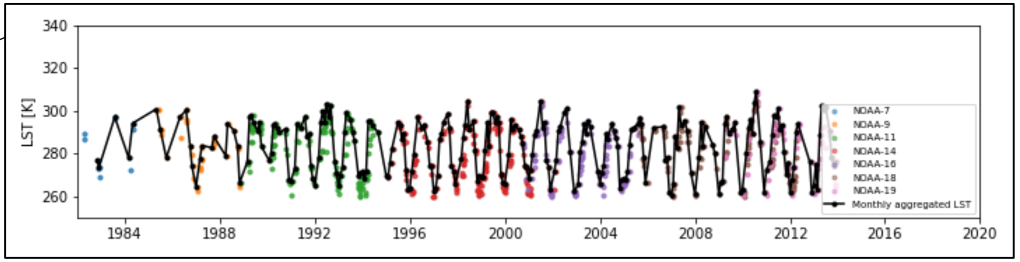
BELMANIP Site	EUSTACE Site	Distance [km]	Landcover
210	AL-JOUF	115.7	Desert
228	OUARZAZATE	71.6	Desert
232	MURCIA	141.6	Croplands
235	OUARZAZATE	367.8	Desert
239	AL-JOUF	79.7	Desert
243	SIMFEROPOL	376.8	BroadDec
248	VALLADOLID (VILLANUBLA)	52	OpenShrub
251	SZEGED	19.6	Croplands
253	BASTANKA	73.5	Croplands
254	KASPIYSKIY	101.4	Grassland
261	BOLOGOE	132.7	MixedForest
269	KRASNAJA_GRA	368.6	Urban

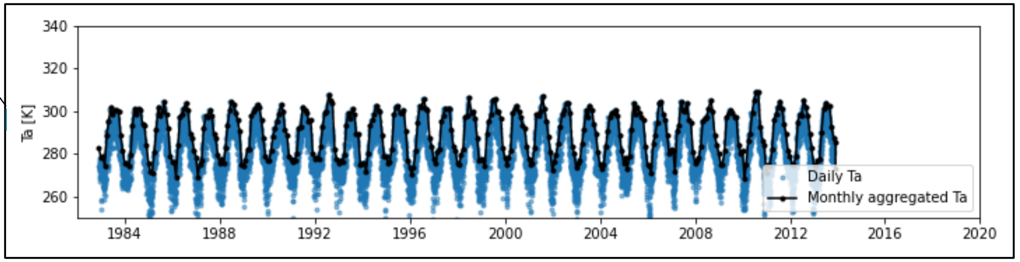
BELMANIP sites for this study and matching EUSTACE sites

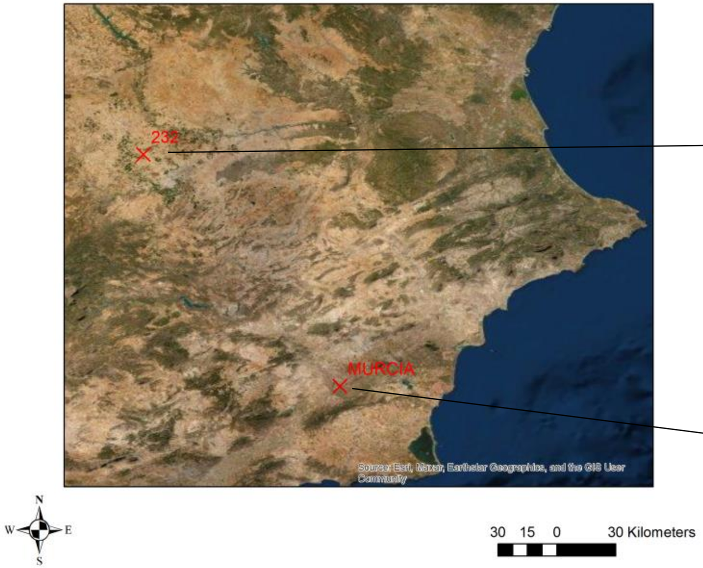


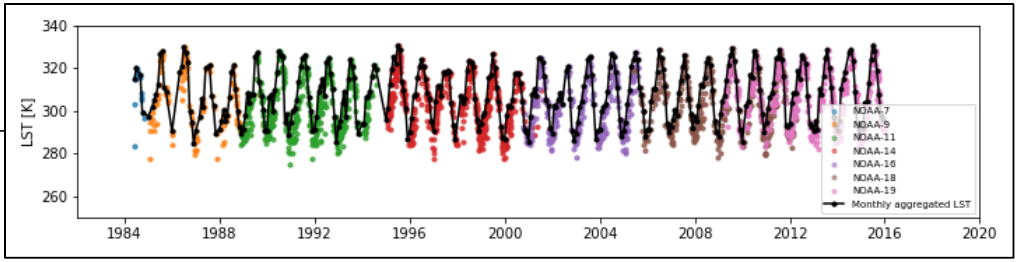
Uncorrected LST and Ta at the sites 261 (Siberia) and 232 (Spain)

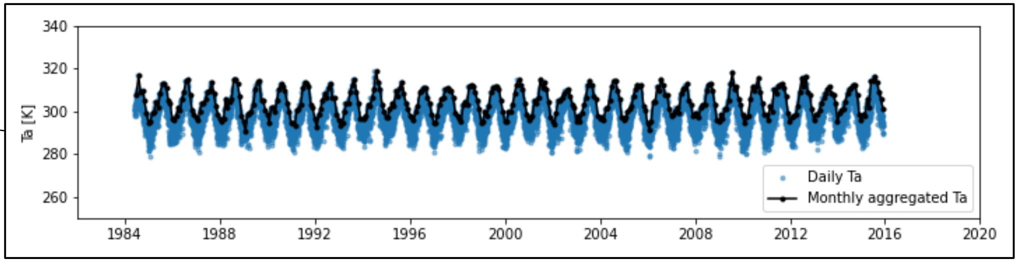




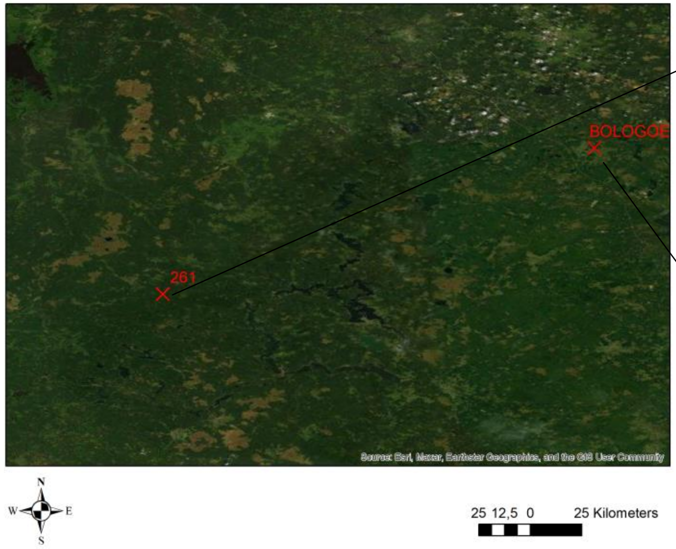


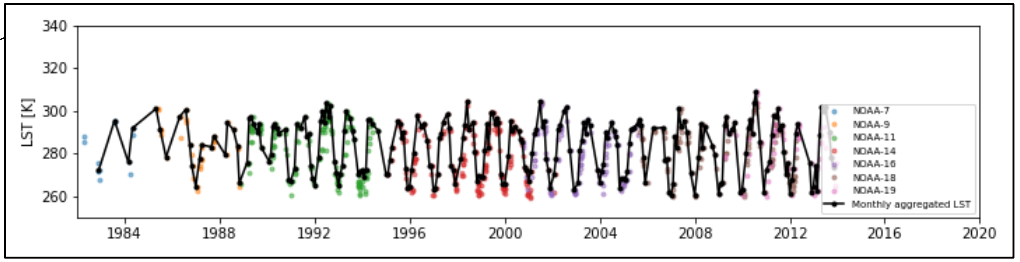


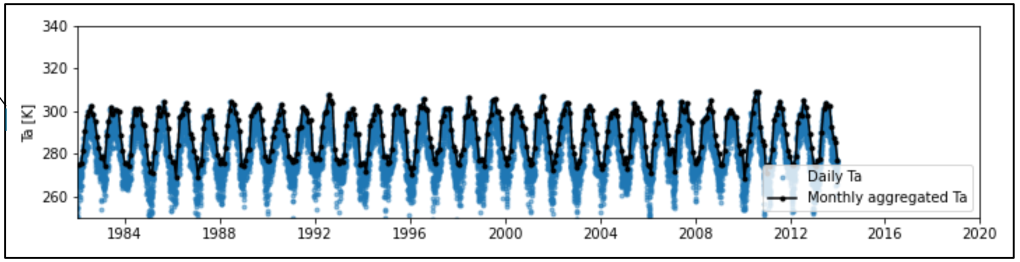


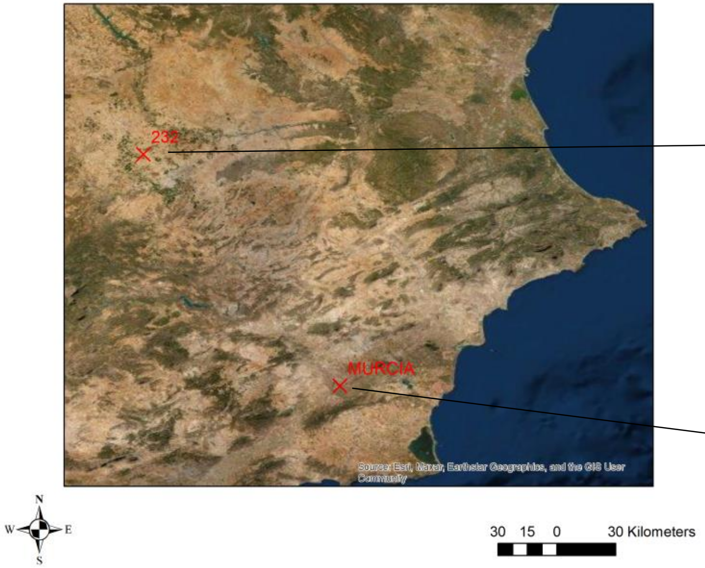


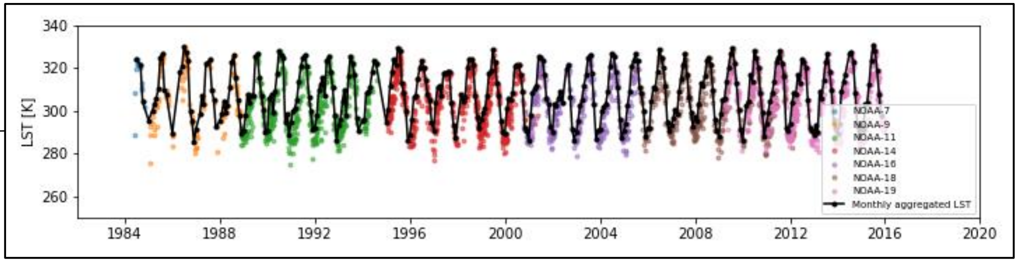
Corrected LST and Ta at the sites 261 (Siberia) and 232 (Spain)

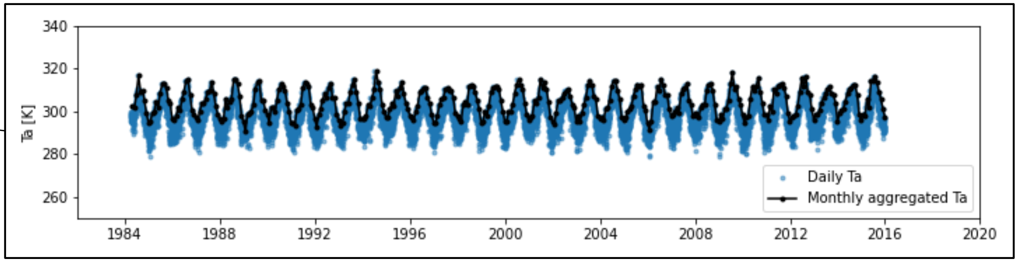




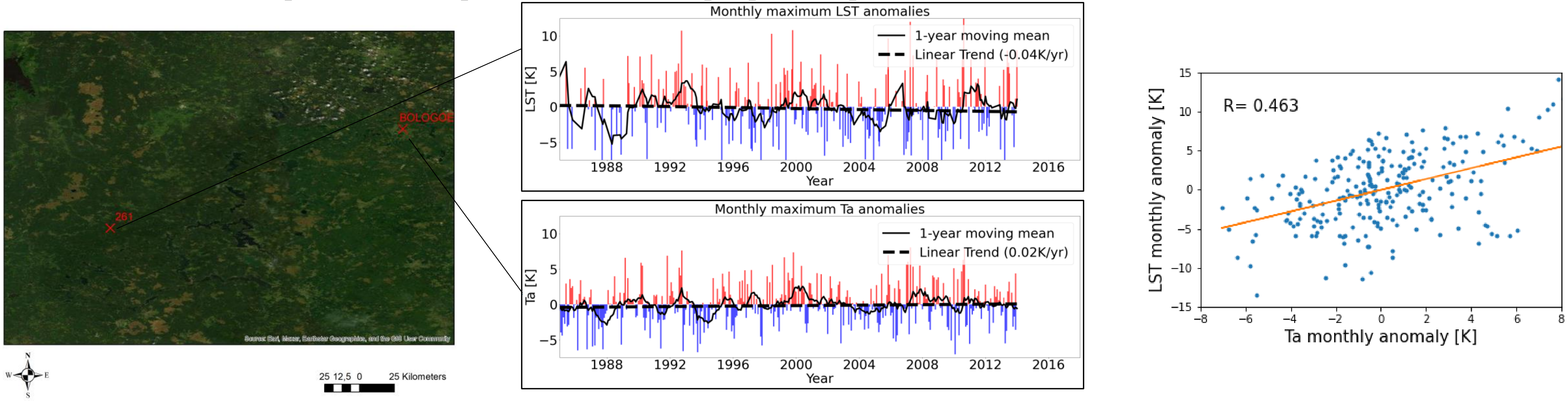


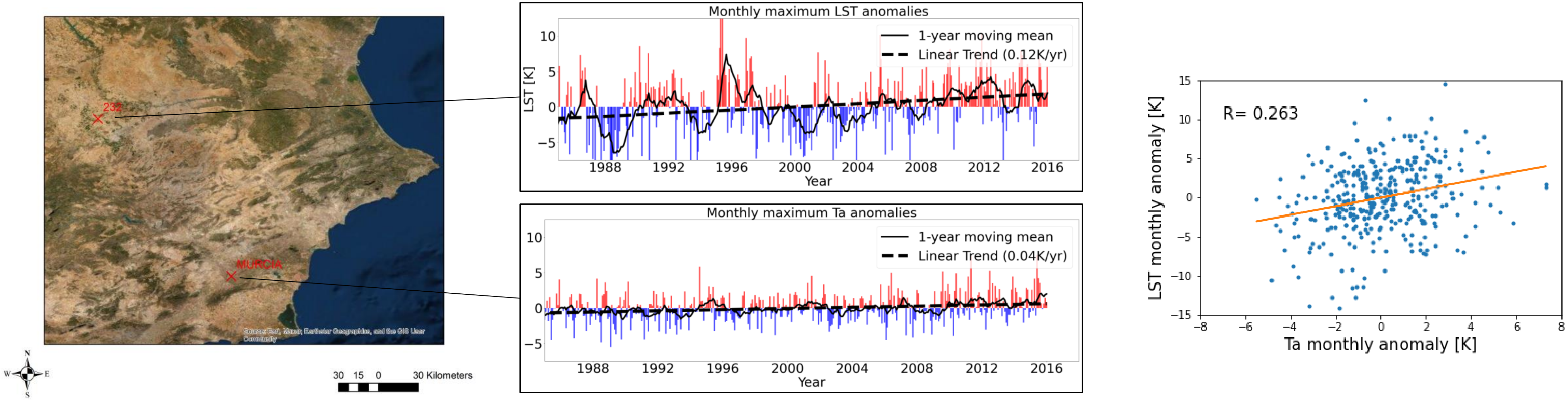






Uncorrected LST and Ta monthly anomalies at the sites 261 (Siberia) and 232 (Spain)





Results of the Orbit Drift Correction

R
between monthly Ta anomalies and monthly LST anomalies

Trend [K/yr]

BELMANIP site	Landcover	Original	Corrected	Change [%]	Orginal LST	Ta	Corrected LST
210	Desert	0.26	0.269	3.5	0.22	0.05	0.07
228	Desert	0.321	0.37	15.3	0.11	0.07	0.07
232	Croplands	0.263	0.277	5.3	0.12	0.04	0.04
235	Desert	0.29	0.299	3.1	0.2	0.05	0.13
239	Desert	0.358	0.404	12.8	0.2	0.04	0.07
243	BroadDec	0.407	0.423	3.9	-0.03	0.04	-0.04
248	OpenShrub	0.435	0.462	6.2	0.06	0.02	0.01
251	Croplands	0.518	0.518	0.0	0.13	0.04	0.06
253	Croplands	0.357	0.395	10.6	0.14	0.12	0.02
254	Grassland	0.374	0.332	-11.2	0.13	0.06	0.01
261	MixedForest	0.477	0.463	-2.9	-0.04	0.02	-0.06
269	Urban	0.38	0.362	-4.7	0.11	0.04	0.01

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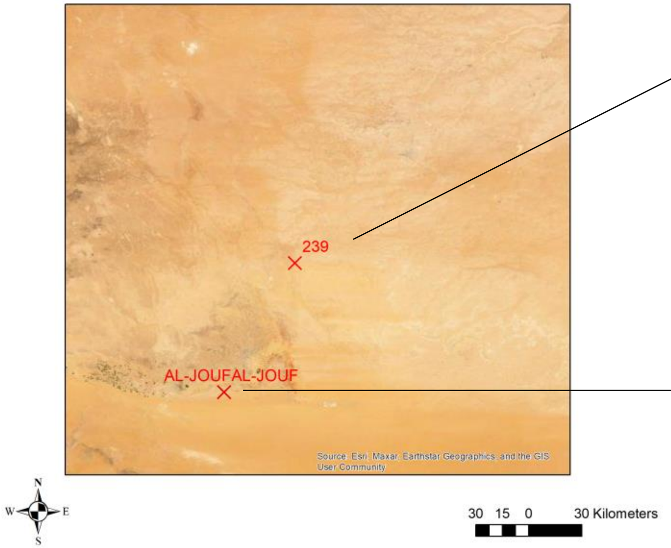
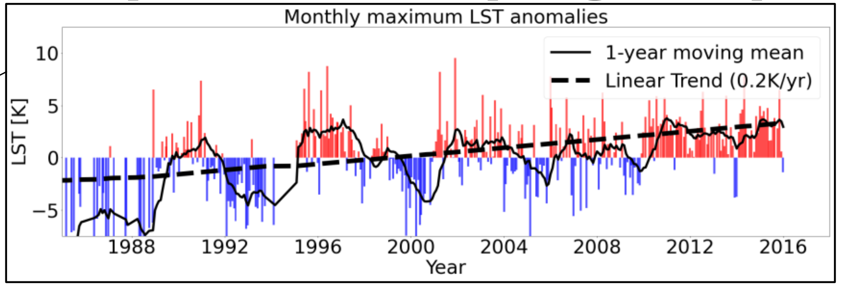
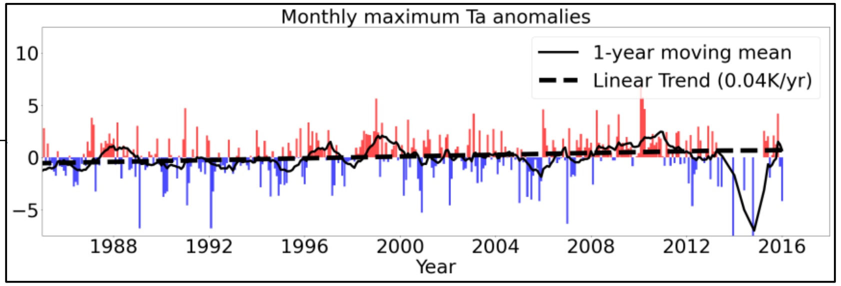
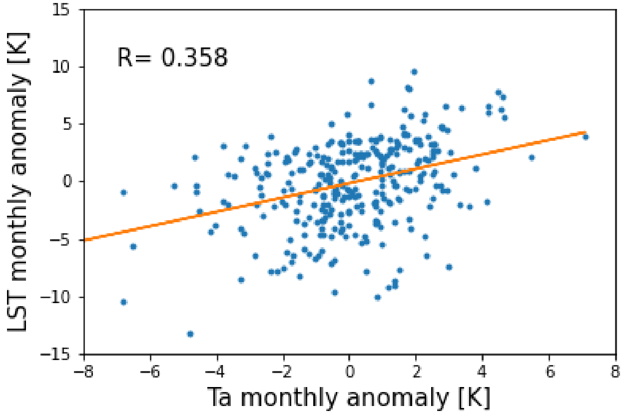
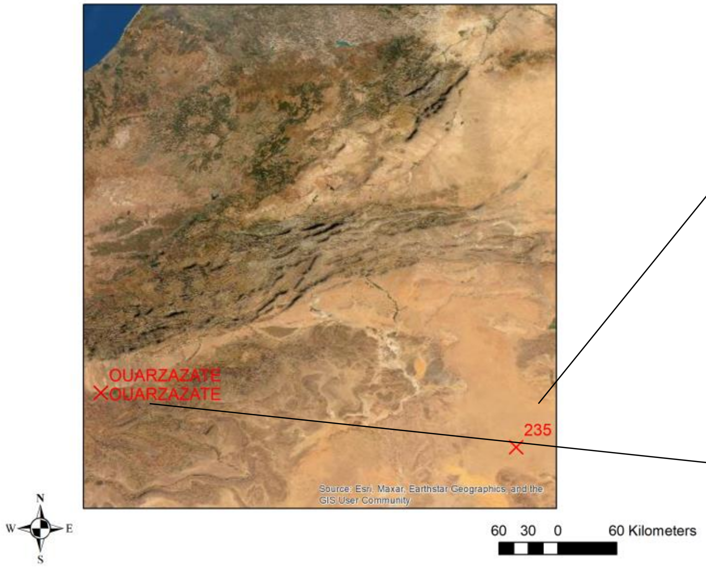
Uncorrected LST and Ta monthly anomalies at the sites 239 (Saudi-Arabia) and 235 (Algeria)

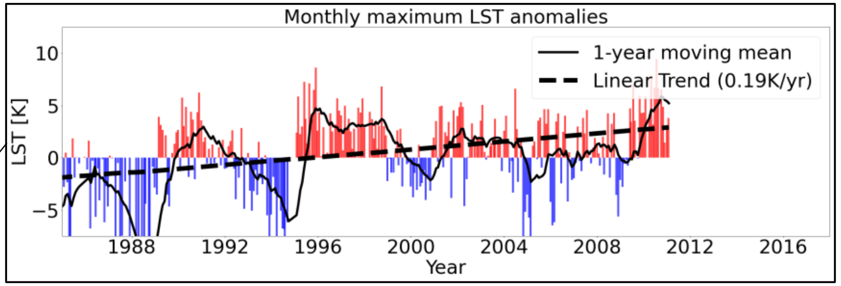


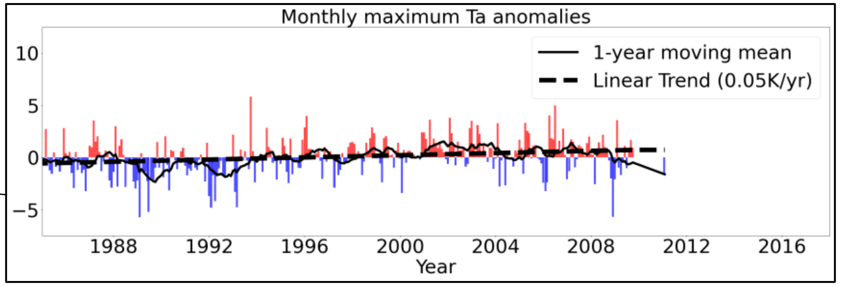


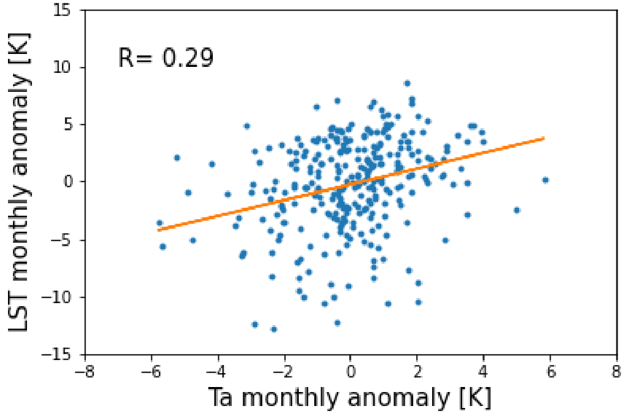












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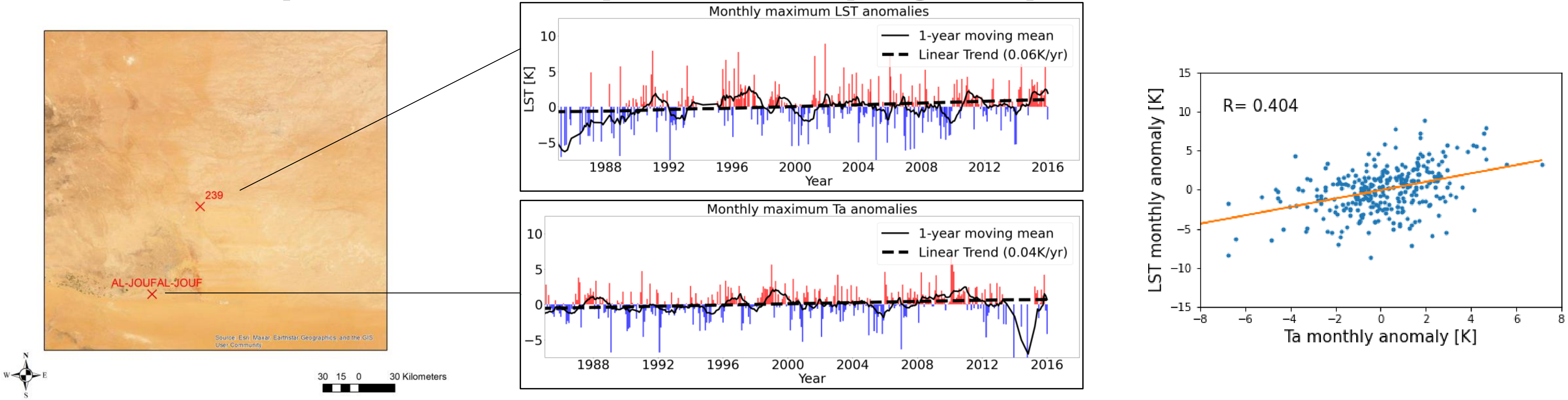

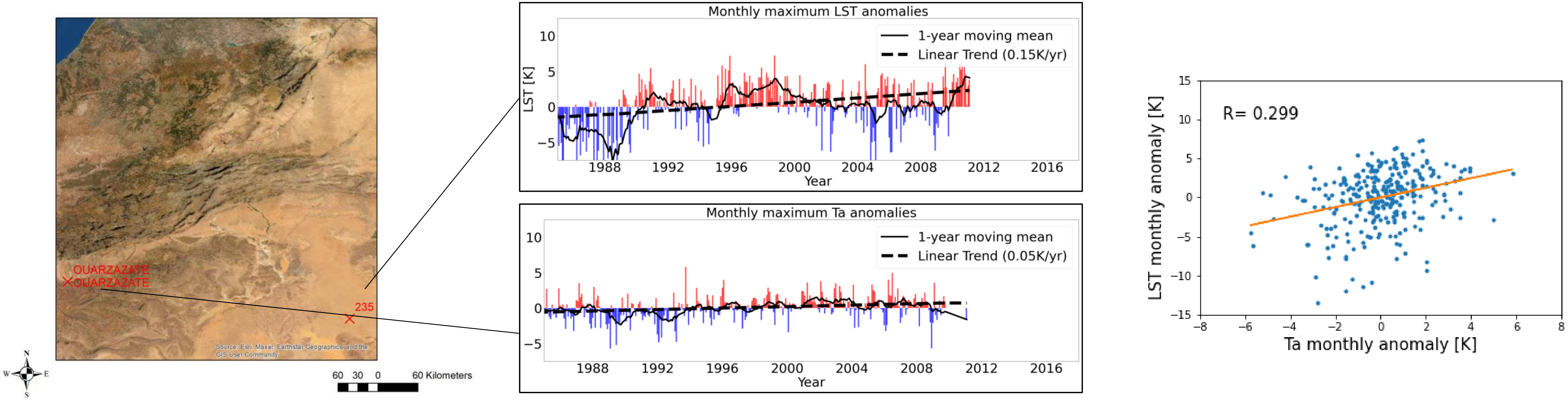

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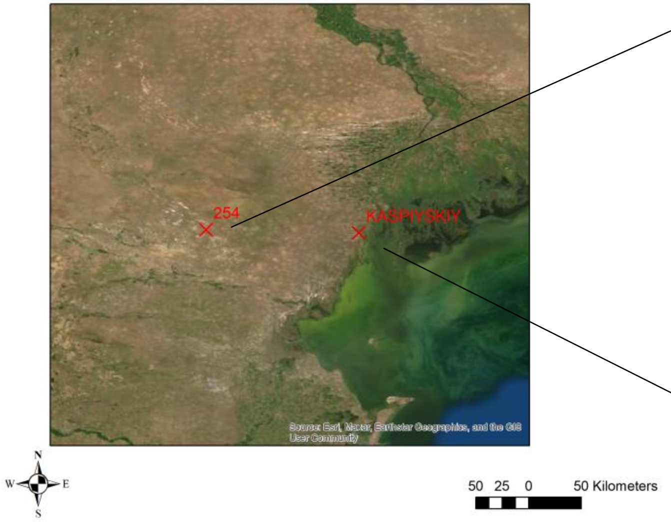
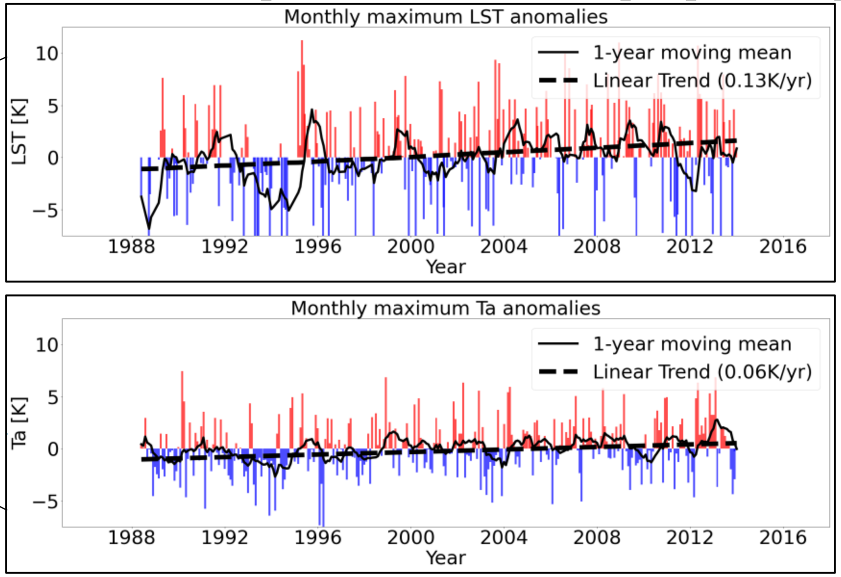
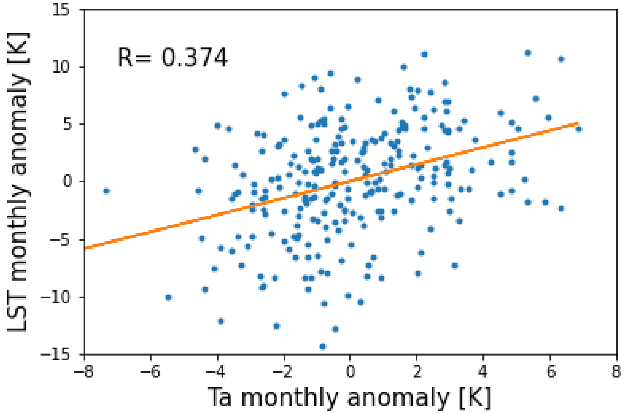
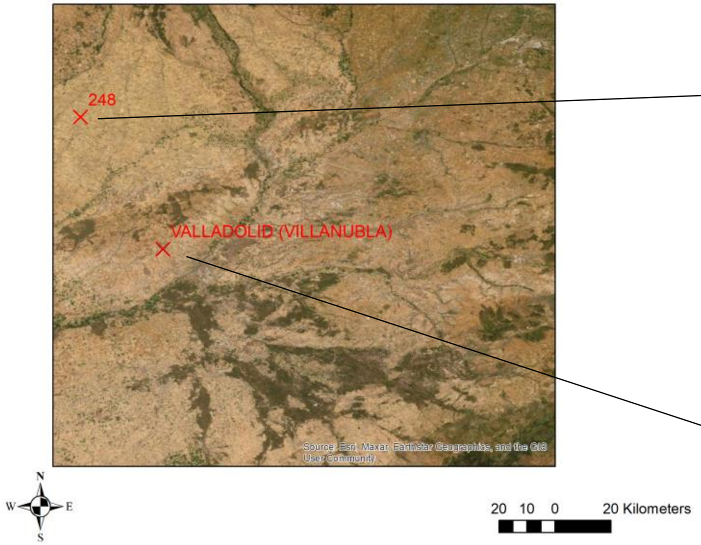
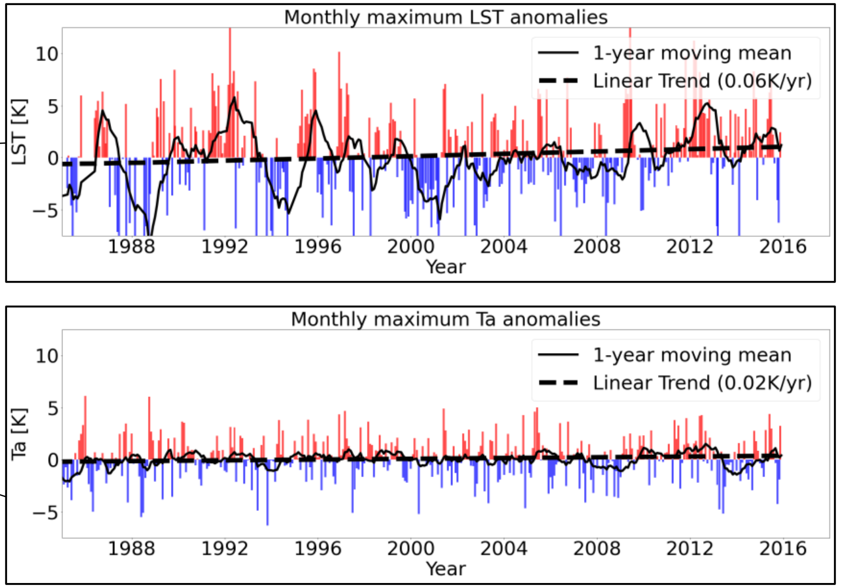
Uncorrected LST and Ta monthly anomalies at the sites 254 (Southern Russia) and 248 (Spain)

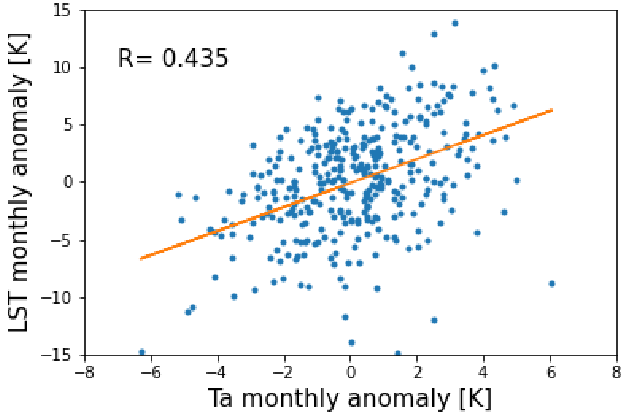




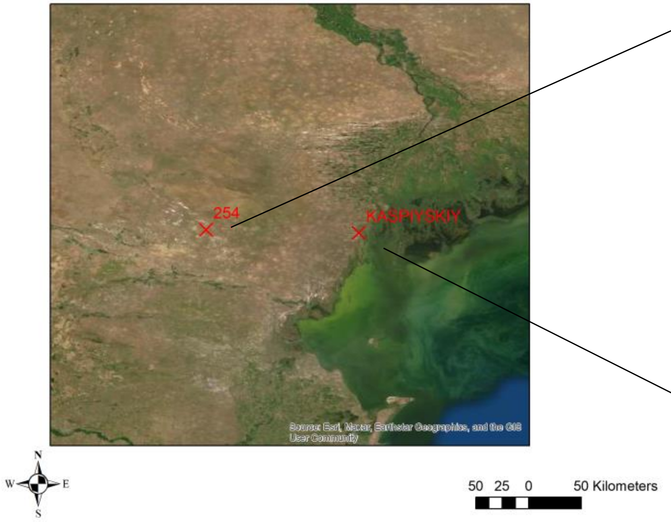


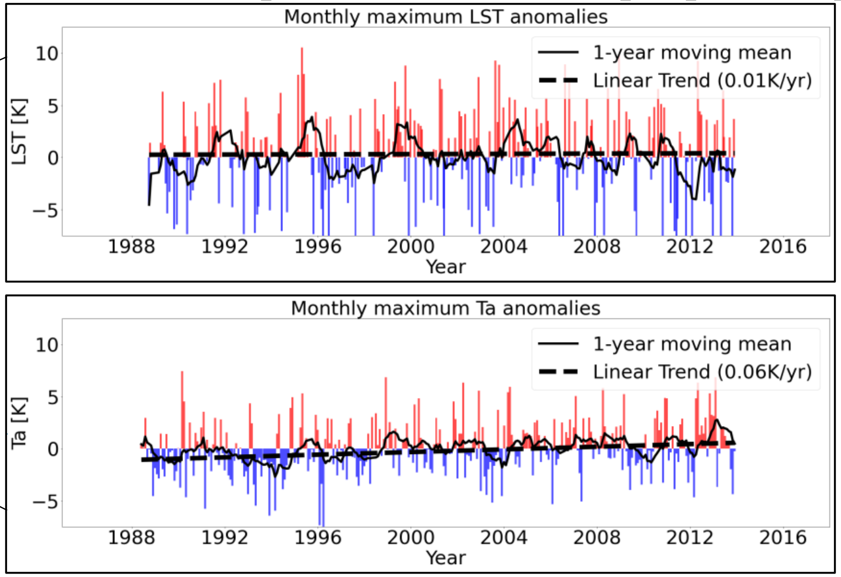


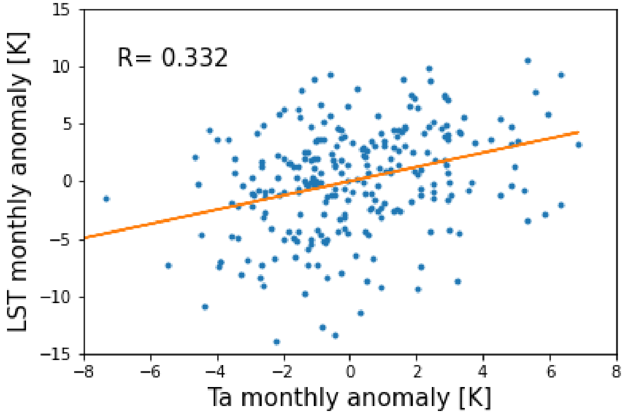


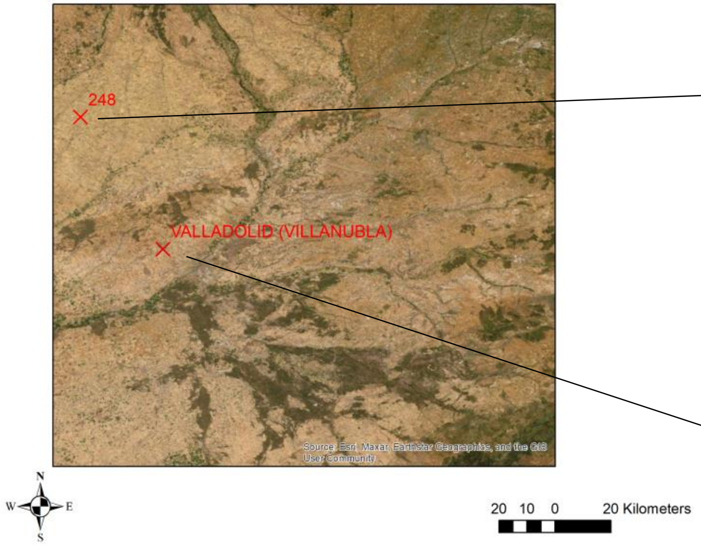


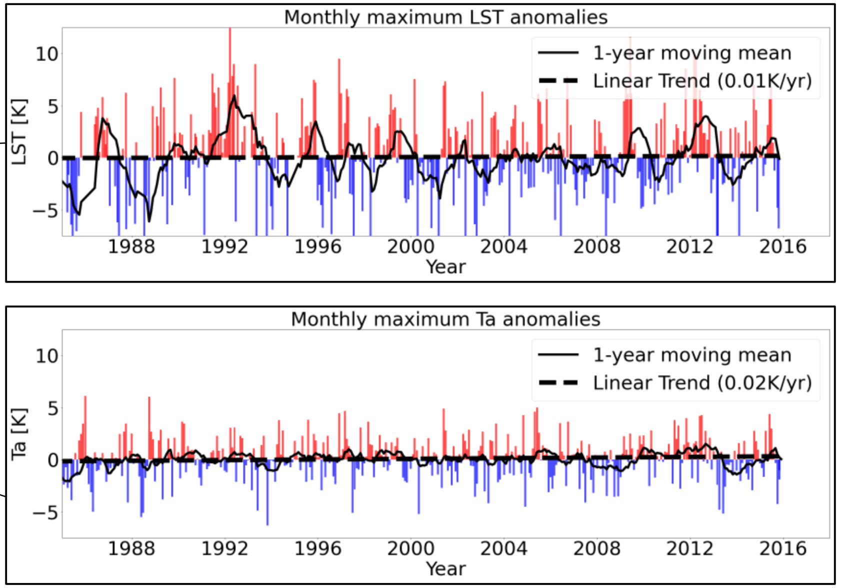
Corrected LST and Ta monthly anomalies at the sites 254 (Southern Russia) and 248 (Spain)

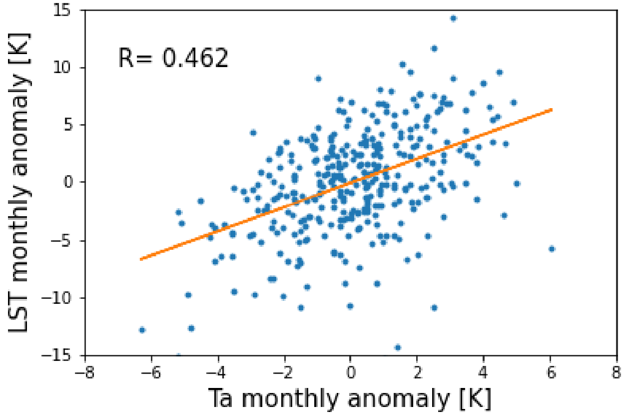












Conclusions and Outlook

- Statistical Orbit drift correction significantly improved the R between the monthly anomalies of LST and Ta at most of the study sites
- Statistical Orbit drift correction leads to more realistic long term trends of LST
- Statistical Orbit drift correction mostly preserves climatological events in the LST time series
- Statistical Orbit drift correction relies on a simple linear relationship. Therefore it has the potential to be applied on a continent-wide LST dataset
- Further validation and improvements are necessary to build an extensive climatologically meaningful LST dataset

Impressum

Topic: **Deriving Long-term Dynamics of Land Surface Temperature over Europe: Towards a daytime normalized AVHRR LST Product**

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Author: Philipp Reiners

Institute: German Aerospace Center (DLR), German Remote Sensing Data Center (DFD)

Corresponding: Philipp.Reiners@dlr.de