Exploring the EUMETSAT Land Surface Temperature Data Records

19 May 2021, Anke Duguay-Tetzlaff, João P. Martins

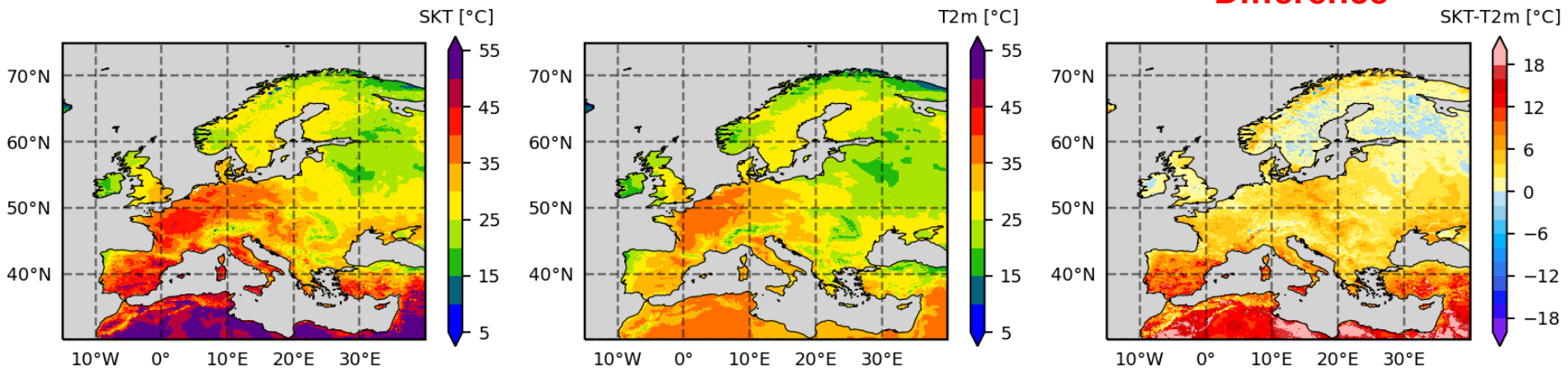
What is exactly Land Surface Temperature (LST)?

- Land Surface Temperature is the temperature we would feel if we *touch* the surface.
- Most climate studies use 2m-temperature. Although strongly correlated, these two temperatures may differ up to 10's of °C.
- EUMETSAT distributes satellite-retrieved LST datasets. These timeseries are becoming long enough to be suitable for climate applications

Figure from Göttsche et al 2016

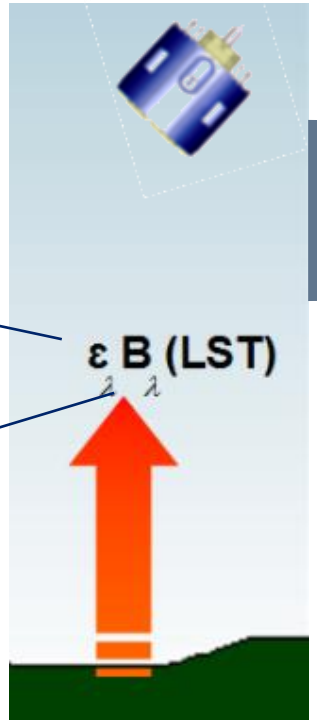
ERA-5 Land data for 25/07/2019 12UTC

Difference



How do we measure LST from space?

- **Land Surface Temperature (LST) is the radiative *skin* temperature of the land surface**
  - Corresponds to thermal emission from the top thin layer of a few micrometers on the surface (up to 50 µm).
- **Satellite sensors can measure this "skin" temperature by measuring the infrared radiance emitted by the surface**



Surface emissivity (assumed to be known)

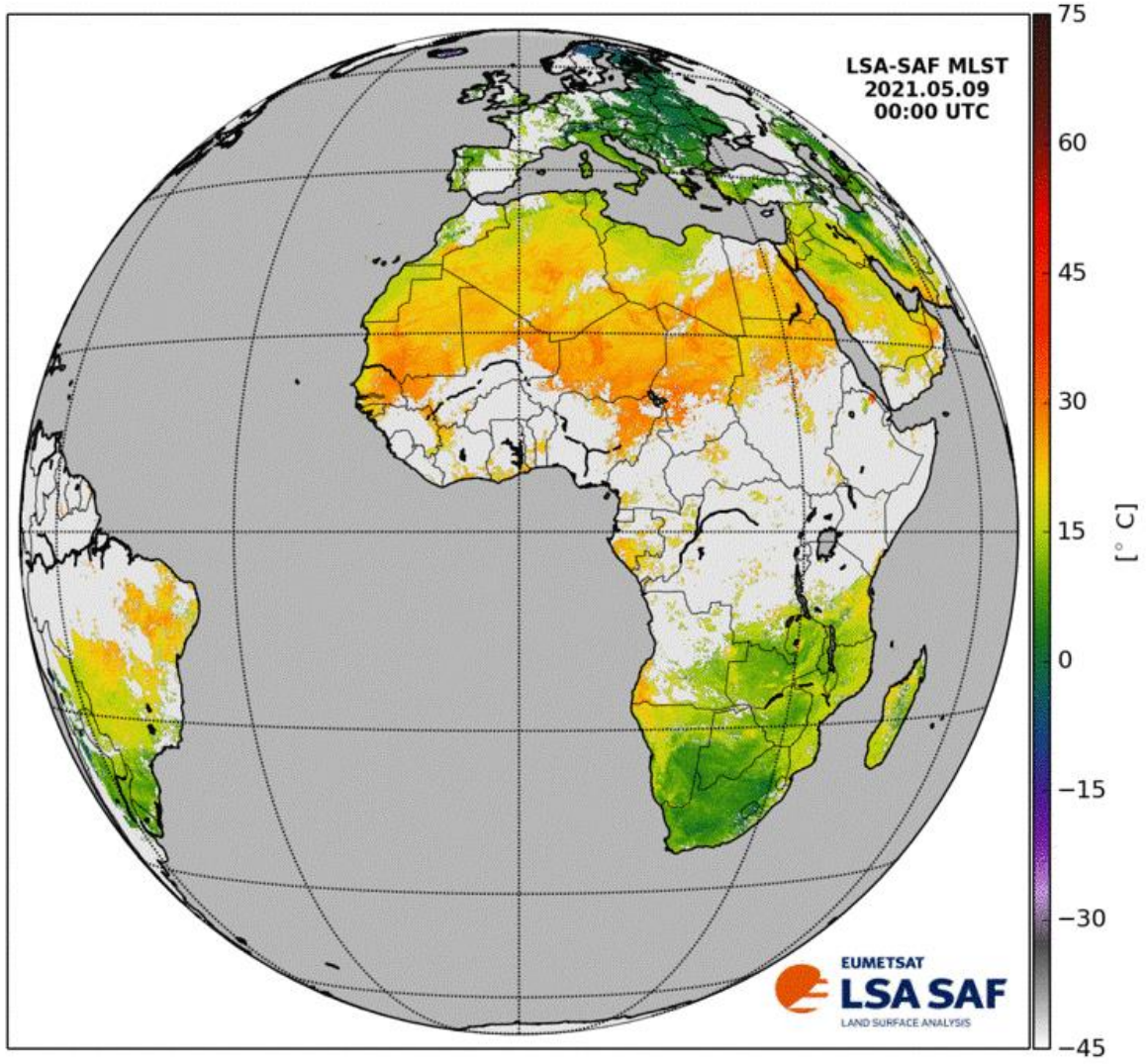
Radiance of a blackbody at temperature *LST*

The effect of the atmosphere needs to be corrected

LSA SAF LST retrieval

- "Generalized Split-Window" (GSW) formulation first developed for MODIS and AVHRR by Wan and Dozier (1996):
  - **$LST = f (Tb_{10.8}, Tb_{12.0}, \varepsilon_{10.8}, \varepsilon_{12.0}, \dots)$**
- Maximizes the use of satellite channels with thermal information from the surface
- Helps further correction of atmospheric effects

LST at the Land Surface Analysis SAF (LSA-SAF)



Main LST product at LSA SAF:

- LSA SAF LST is generated on an operational basis with 15 min frequency from 2004 onwards
- Based on SEVIRI observations (onboard Meteosat Second Generation)

- Retrieved for **clear-sky** conditions (Infrared sensors are not able to see through clouds – most LST products are limited to clear sky pixels)

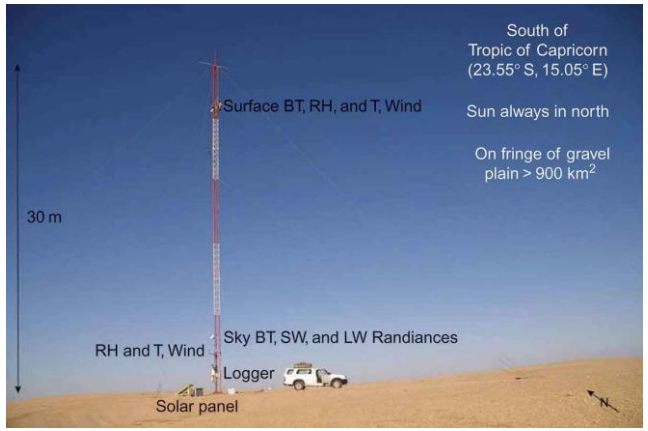
Other LST products from LSA-SAF include (available in NRT):

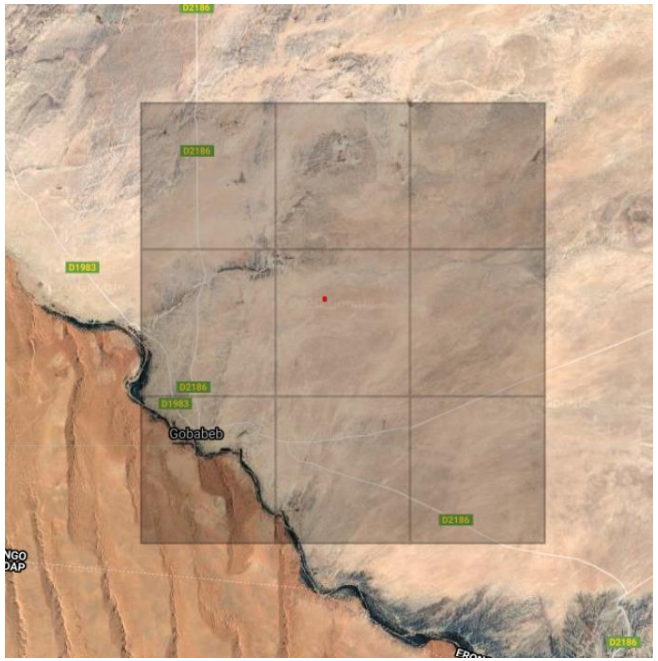
- LST from AVHRR on MetOp (polar orbiter - global, twice daily)
- LST from SEVIRI on Indian Ocean Data Coverage (IODC) mission
- All-sky LST from SEVIRI on MSG
- A new layer on the nominal NRT LST product correcting for directional effects

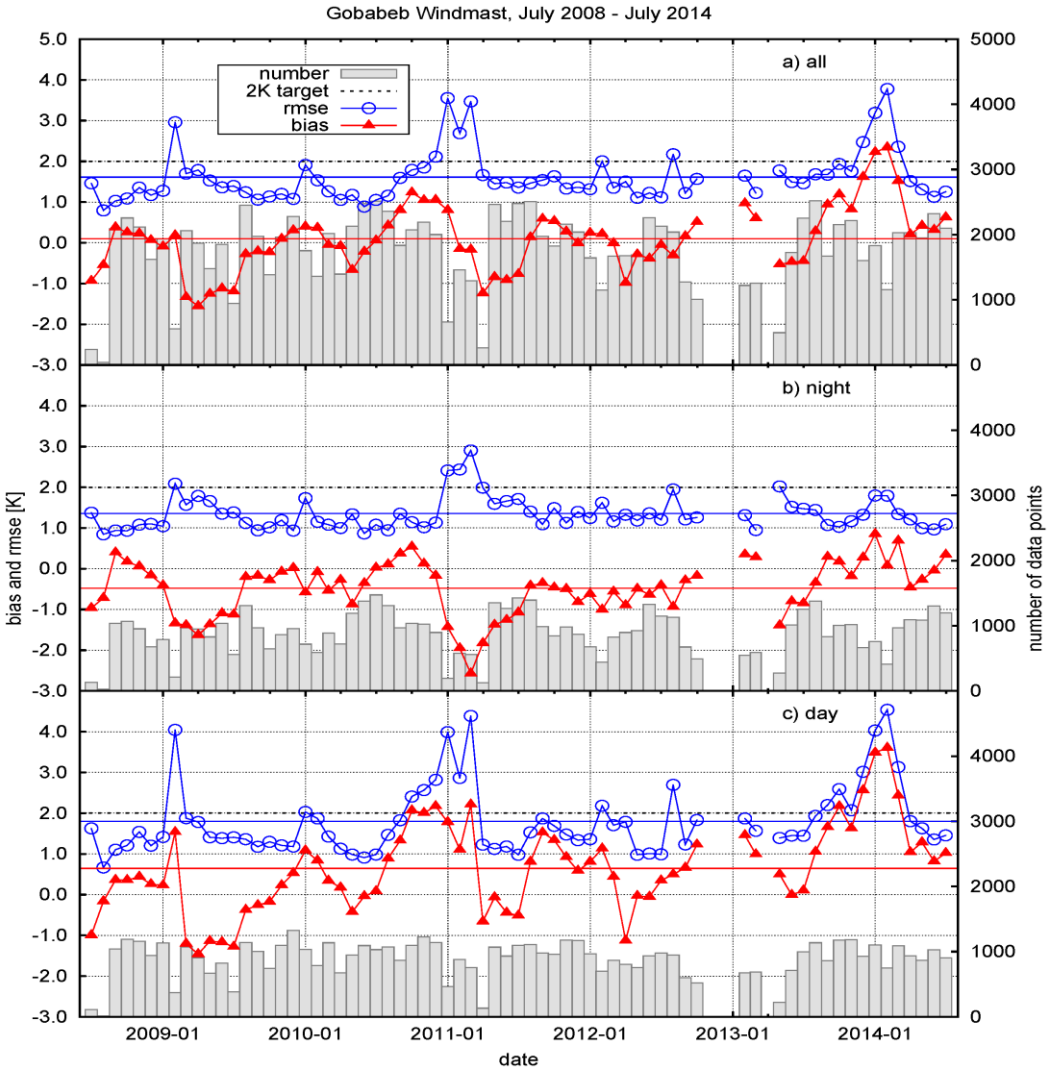
LST Climate Data Record Quality

Accuracy and Precision

- Accuracy requirement: below 2 K.
- LST is rather difficult to validate. Stations are rarely over highly homogeneous landscapes.





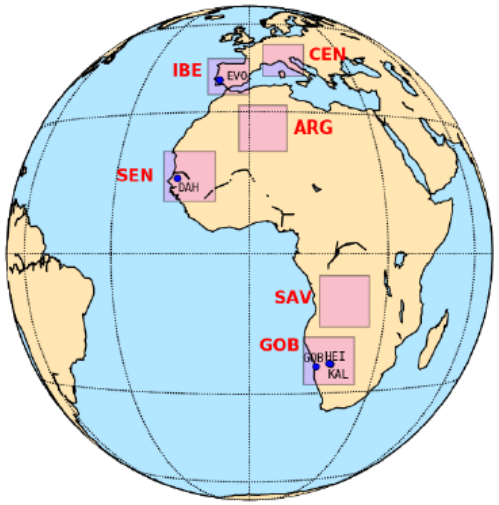


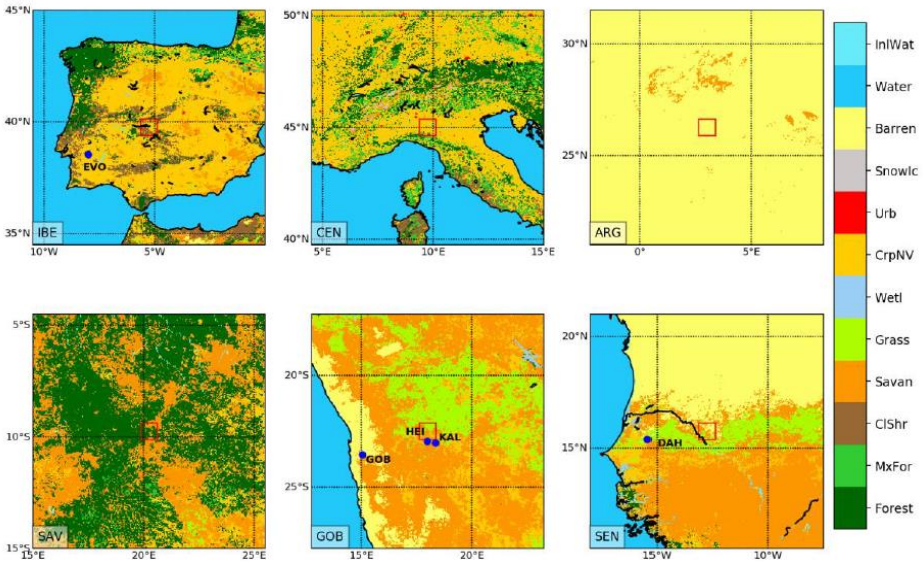
From: Göttsche et al. (2016)

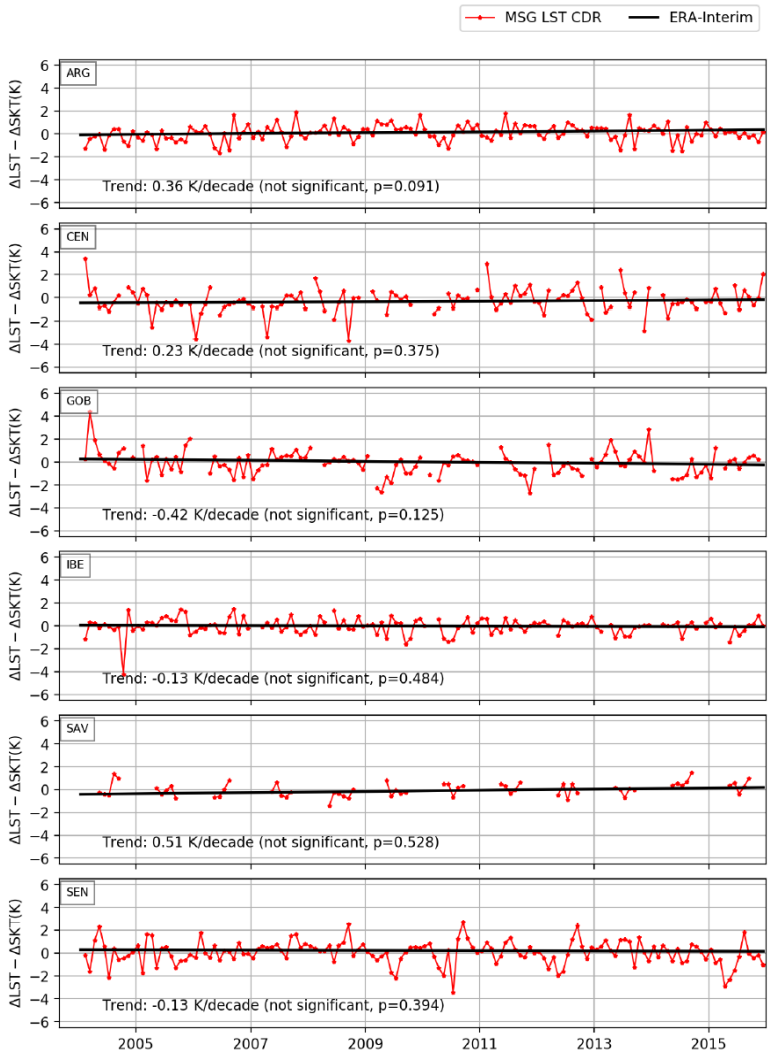
LST Climate Data Record Quality

Temporal Stability

- Check for tendencies in the differences between the LST CDR and an alternative product (ERA-Interim)
- Requirements defined by the WMO (threshold 0.3 K/decade)





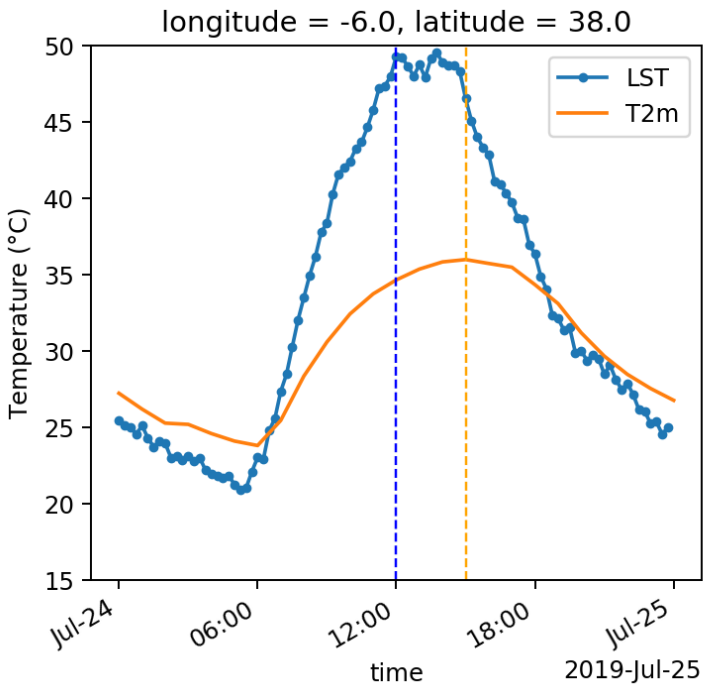


Differences between LST and 2m-temperature

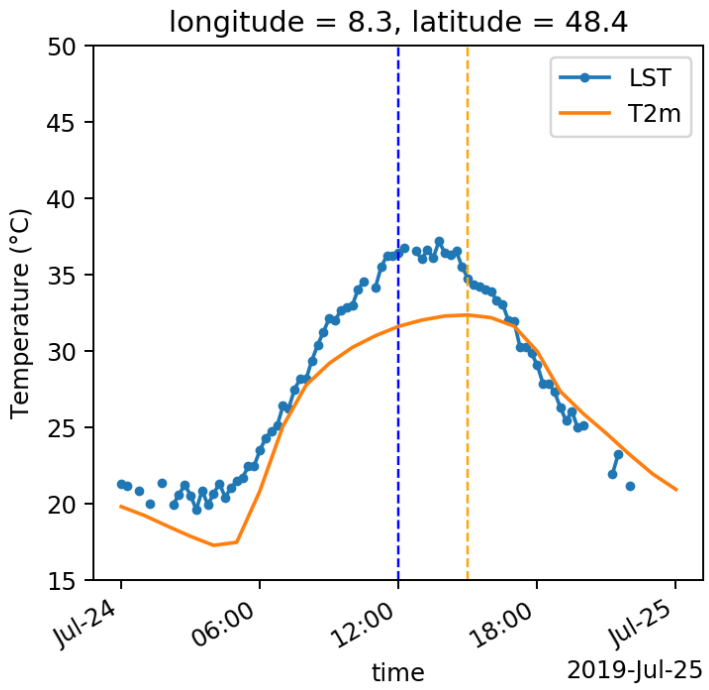
- These two temperatures have different diurnal cycles.
  - LST responds rapidly to insolation – maximum around noon;
  - T2m keeps increasing past noon, as surface fluxes transfer energy from the surface to the low-atmosphere – maximum in mid-afternoon
  - LST diurnal amplitude is larger over drier areas, and decreases over vegetated areas (plants can control their own temperature through evapotranspiration)

→ To make climate indexes comparable, we may use daily maximum (or daily mean) temperatures

Southern Spain

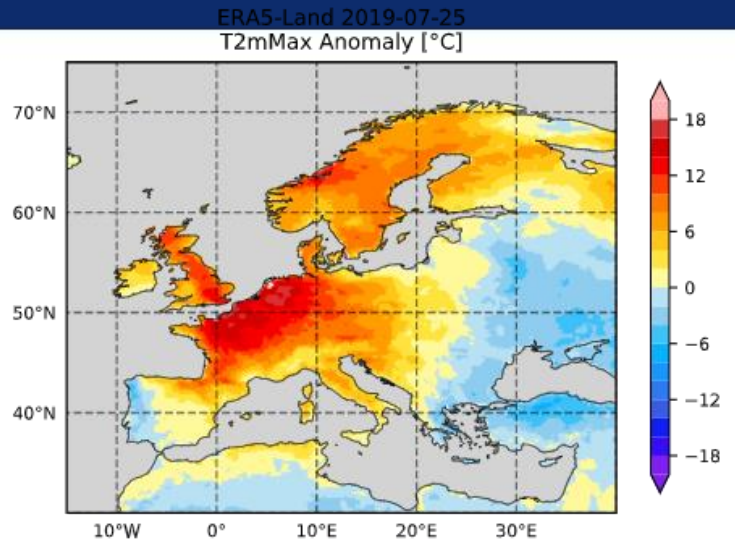


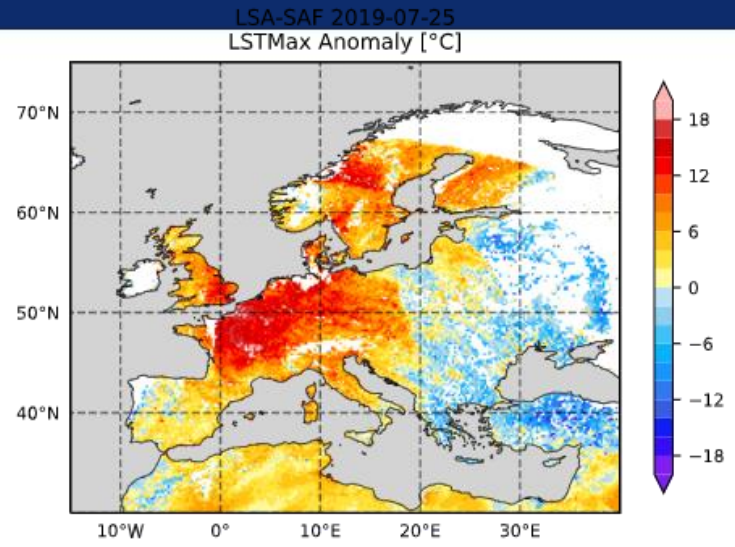
Black Forest (Germany)



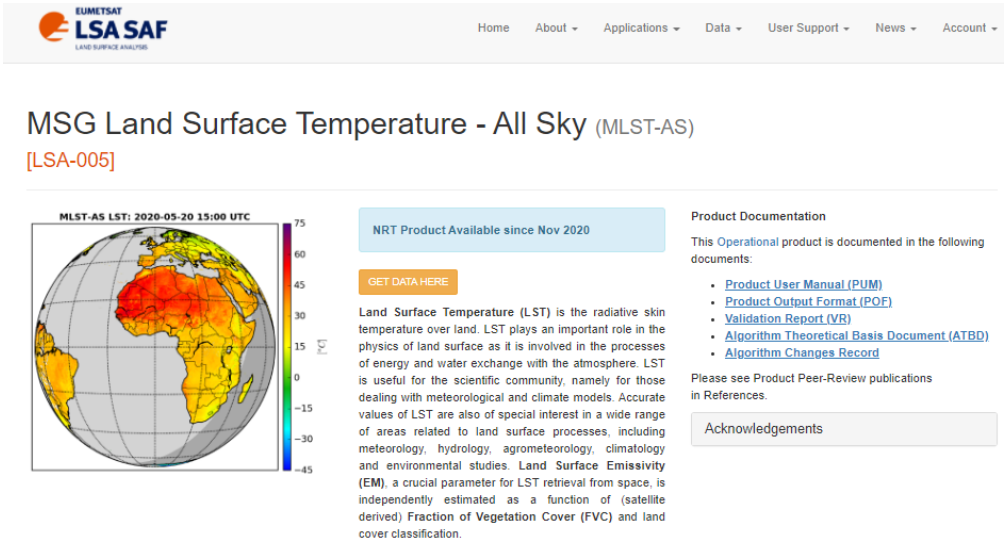
Can we use LST for climate applications?

- Computed daily maximum of:
  - T2m (ERA5-Land)
  - LST (LSA-SAF)
- Median of the reference period
- Both anomalies for 27/07/2019 show the same overall patterns and magnitudes for the European Heatwave event of July 2019
- Patchy measurements over cloudy areas



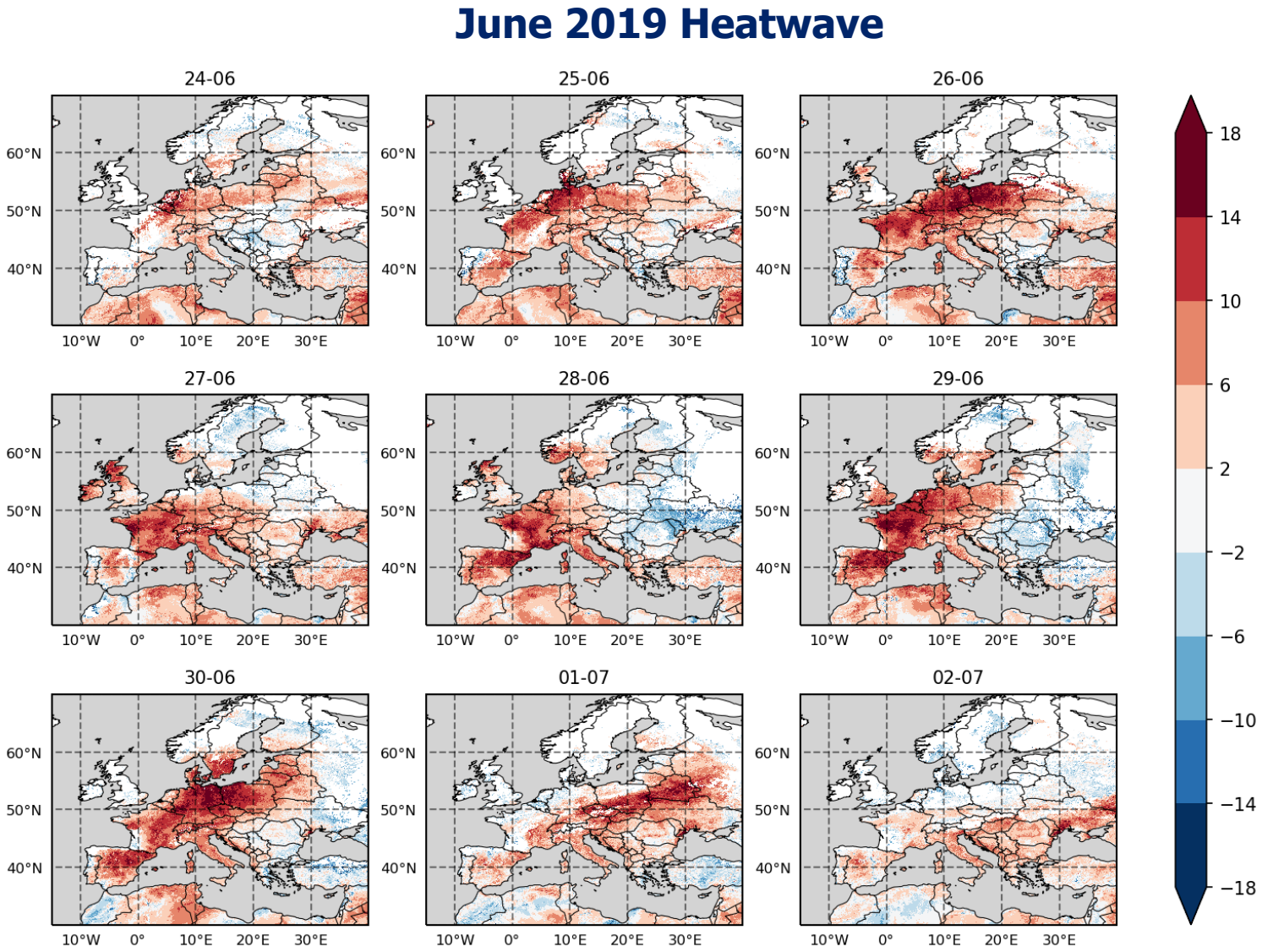


- (note) Check the new product from LSA-SAF: all-sky LST!



Heat wave monitoring

- In the end of June 2019 a significant heatwave affected most of West / Central Europe
- LST anomalies (with respect to the 2004-2020 median) illustrate the spatial extent, duration and intensity of the event
- Several LST anomalies up to ~20 °C were observed over Germany and France



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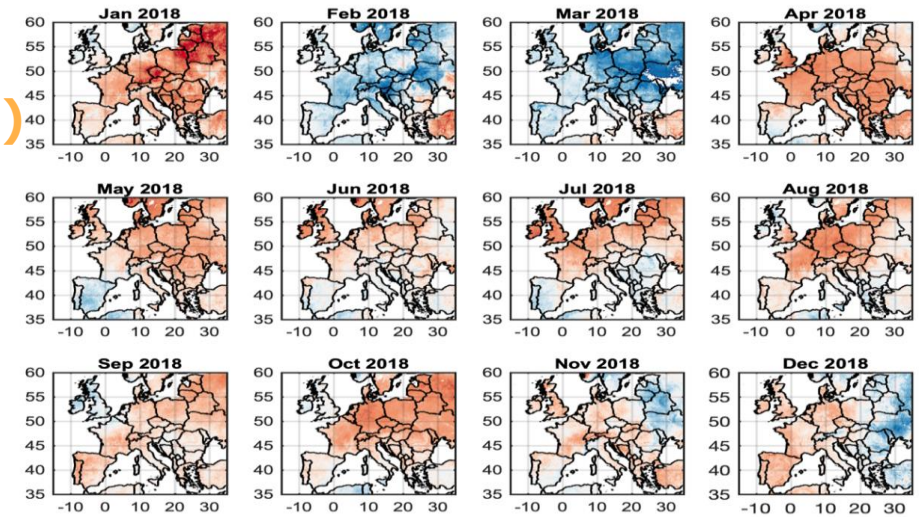
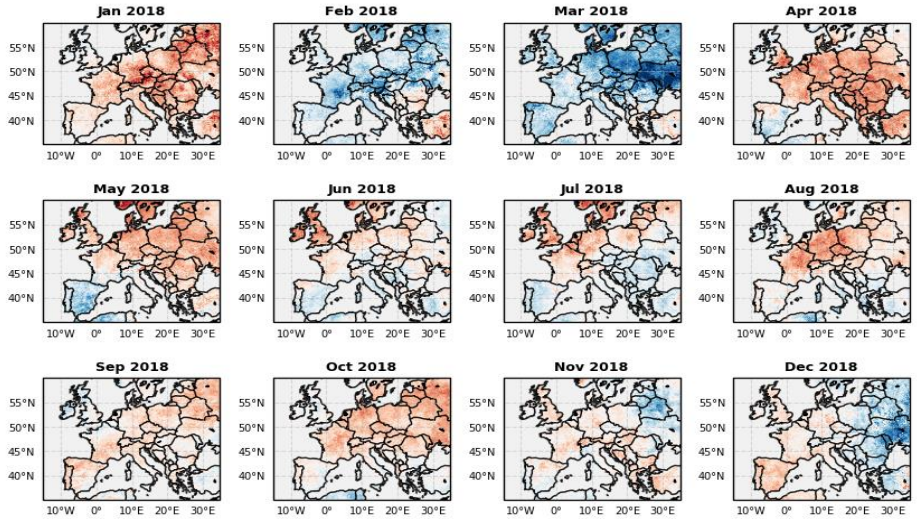
Comparison with other datasets

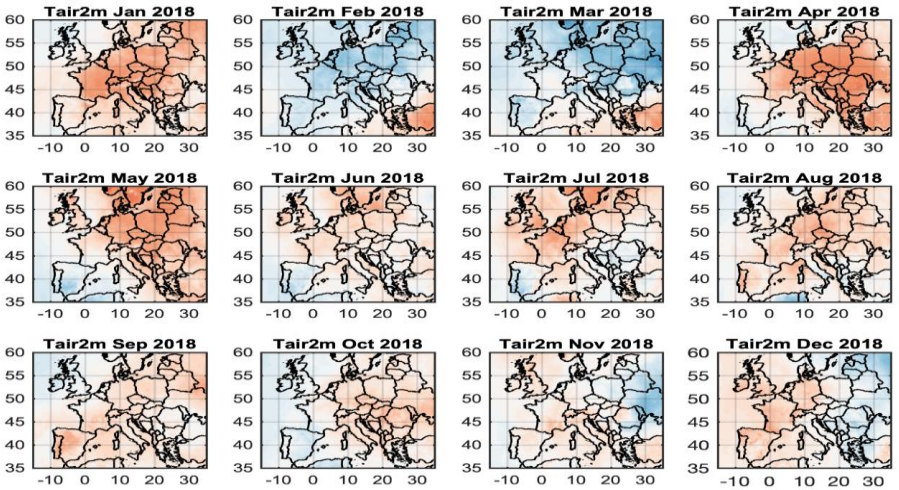
LST (SEVIRI)



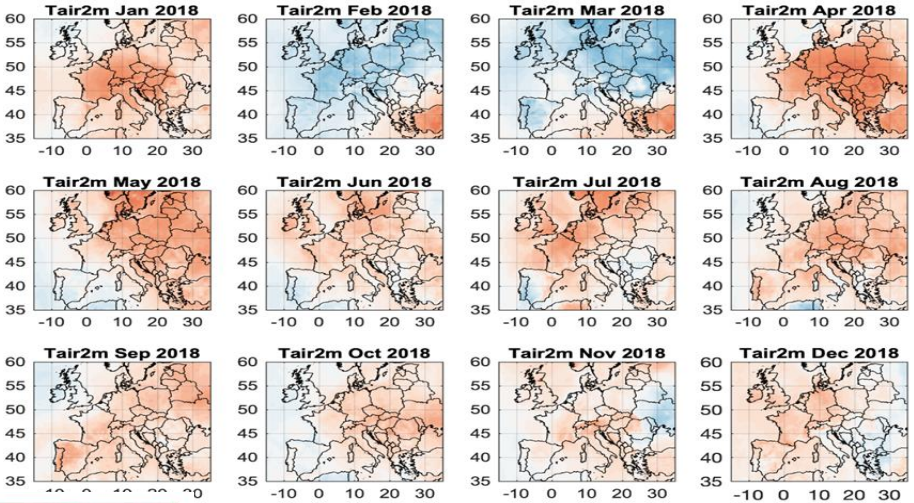
LST (MODIS)



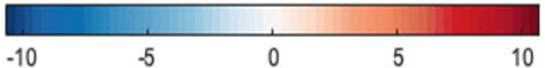
Tair 2m (ERA5)
2004-2019



Tair 2m (ERA5)
1979-2019



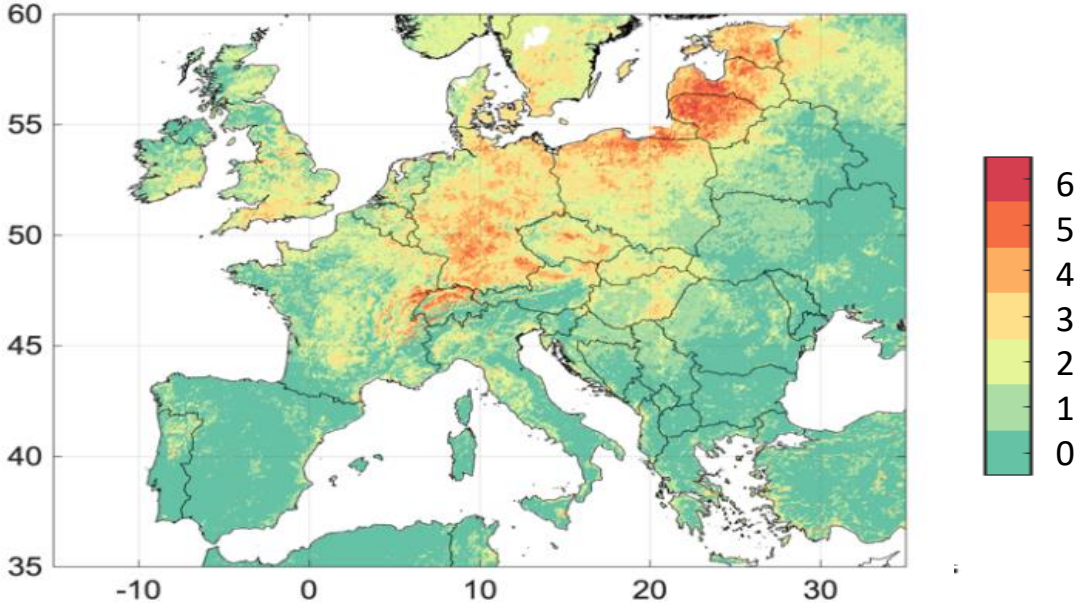
Extended reference period



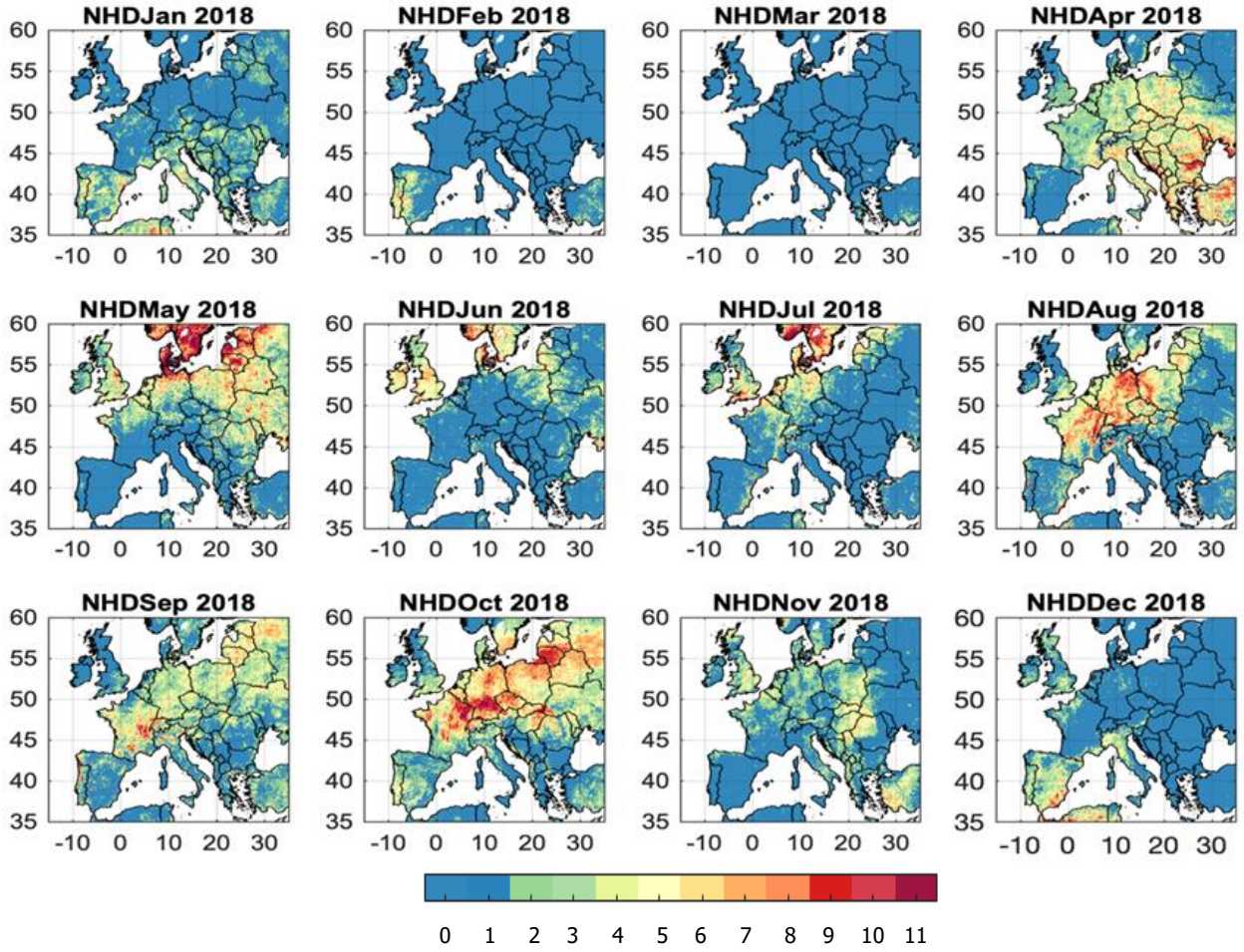
Gouveia et al., 2021 (in preparation)

Heat wave indices (under development)

Number of months in 2018 where maximum LST records were observed



Number of Hot Days (LST > $p90_{2004\text{-}2019}$)



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Thermal signature of wildfire scars

- Wildfires introduce dramatic changes to the land surface
- Changes in
  - Vegetation properties (FVC↓, LAI ↓, FAPAR ↓)
  - Surface Albedo ↓
  - Evapotranspiration ↓
- Surface energy balance occurs at higher LSTs ($LW_{up}\uparrow$, $H\uparrow$)

Fig. 29 – Incêndio "Catraia-Tavira", julho 2012.
Fotografia: cedidada pelo Serviço Municipal de Proteção Civil de Loulé.

***Fig. 29** – Forest fire "Catraia-Tavira", July 2012.*
Photography: ceded by the Loulé Municipal Service of Civil Protection.

Fig. 30 – Árvores queimadas e cenário pós-incêndio.

***Fig. 30** – Burned trees and post-fire scenario.*

Catraia Wildfire (south Portugal, July 2012)

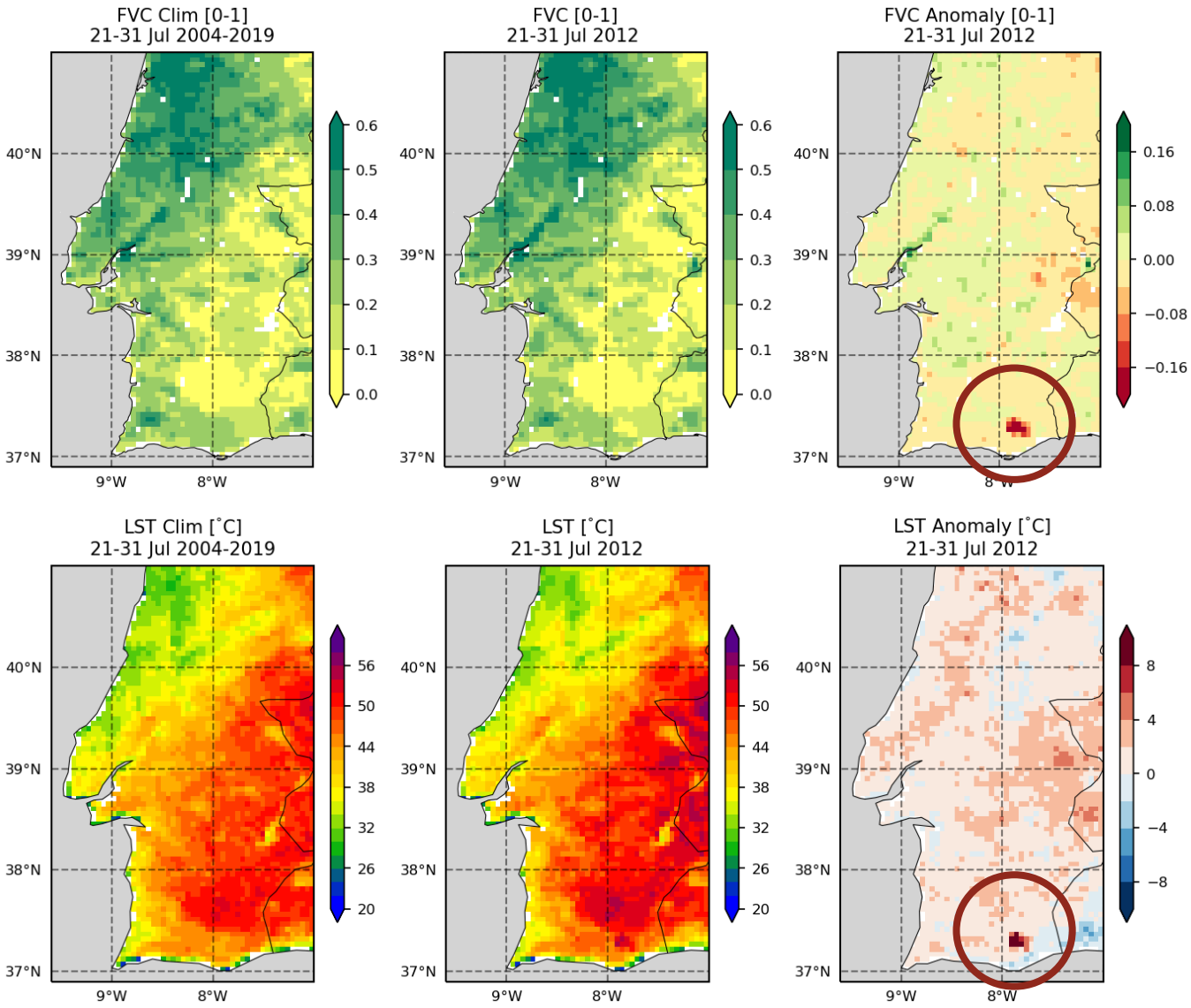
- Burned area: ~250 km^2
- 18-21 July 2012

- Climate Data Records of Land Surface variables allow detailed inspection of the anomalies and their spatial extent
- Compare timeseries extracted within the scar and right next to the scar (unperturbed)

Burned areas for 2012
Source: Portuguese Forest Institute (ICNF)

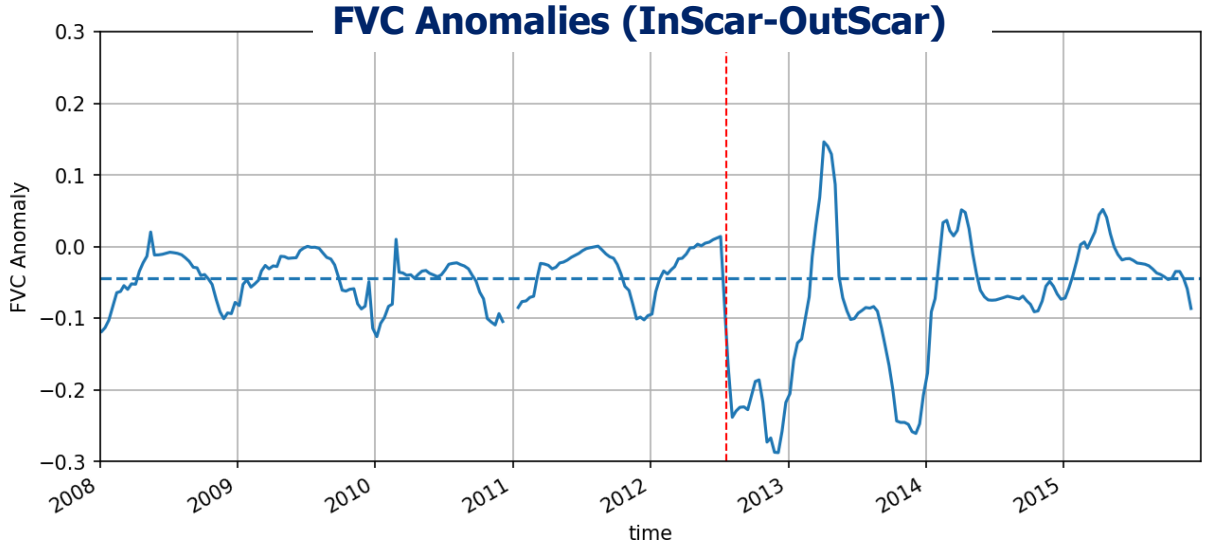
Catraia Wildfire – spatial patterns

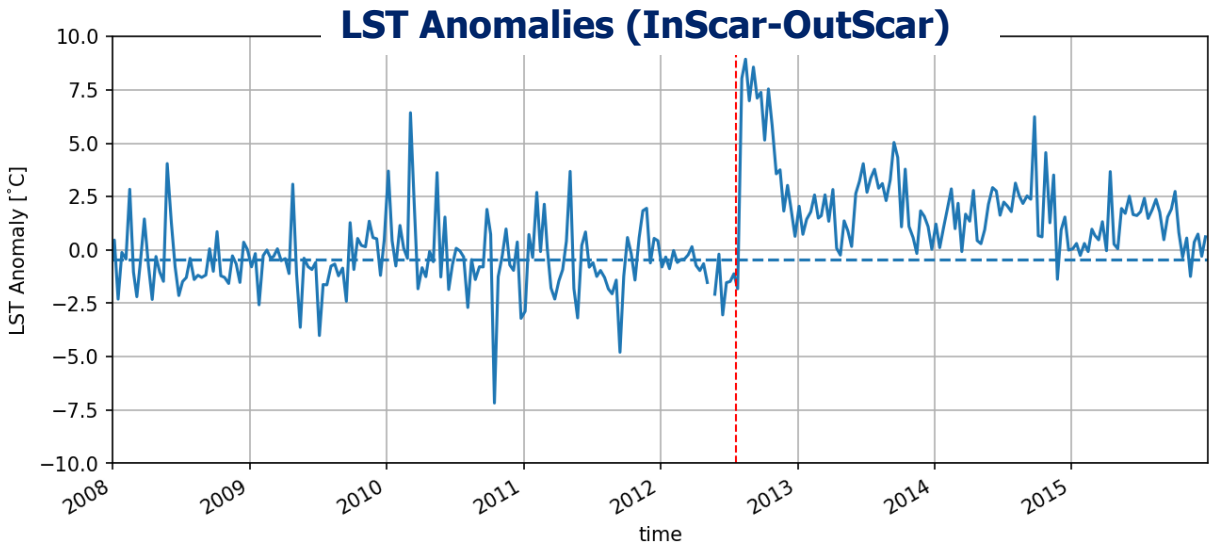
- Wildfires have clear signatures in most land surface variables
- Northwest Portugal has denser vegetation. Most of the south vegetation dessicates over the summer (savanna-like)
- FVC pronounced negative anomaly (~-0.4)
- LST pronounced positive anomaly (up to 10 °C) within the scar). Notice the overall positive anomaly.

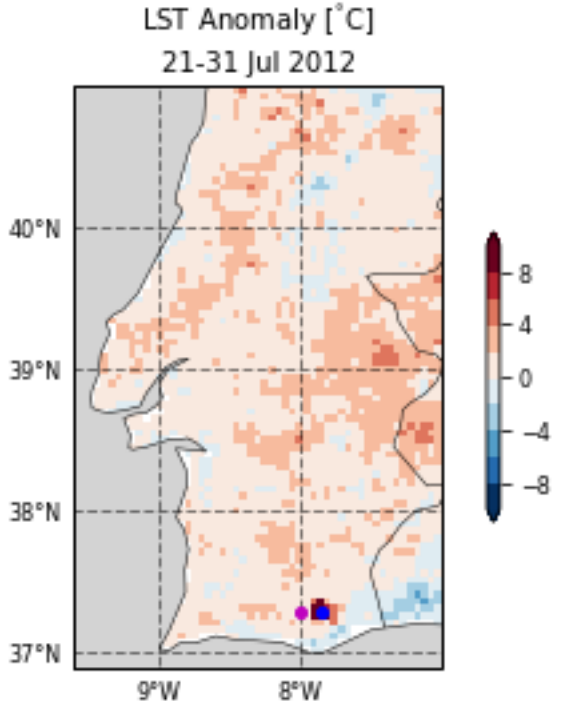


Evolution of Anomalies (FVC and LST)

- Large anomalies caused by fire are alleviated with the winter rains
- Low vegetation grows after the first winter and partly dessicates in the following summer
- After 3 years vegetation nearly returns close to its original state
- We may use CDRs to monitor vegetation recovery over fire scars







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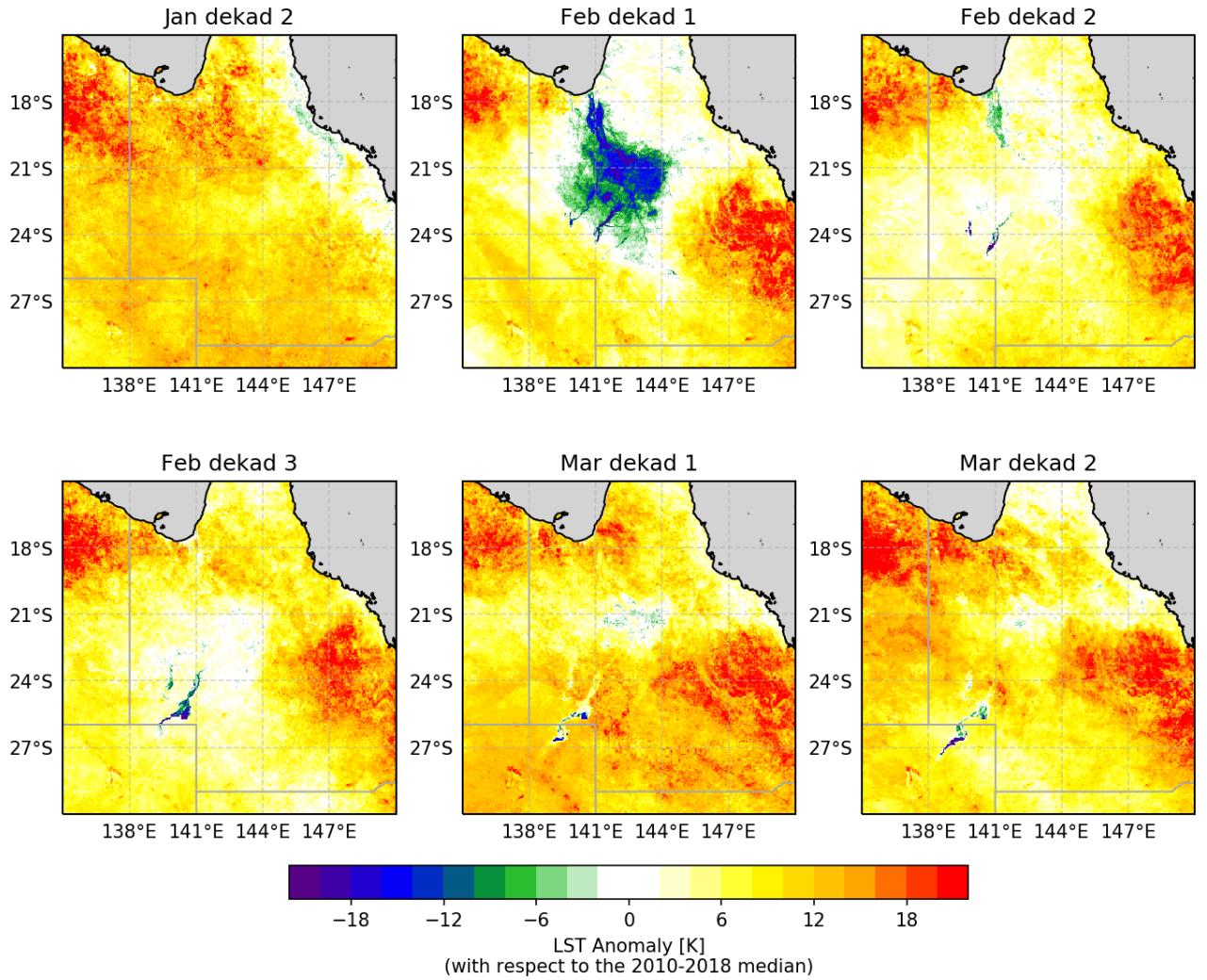
Floods

- Heavy rains hit North Queensland (Australia) in January 2019
- Flood warnings were issued for the Flinders, Leichhardt, Norman, Nicholson, Gregory, and Gilbert rivers, whose flows essentially merged. Reports stated these were the worst floods in 50 years.
- Flooding introduces a negative LST anomaly into an otherwise very warm landscape
- It is possible to follow the river discharges in their way to Lake Eyre in the following weeks

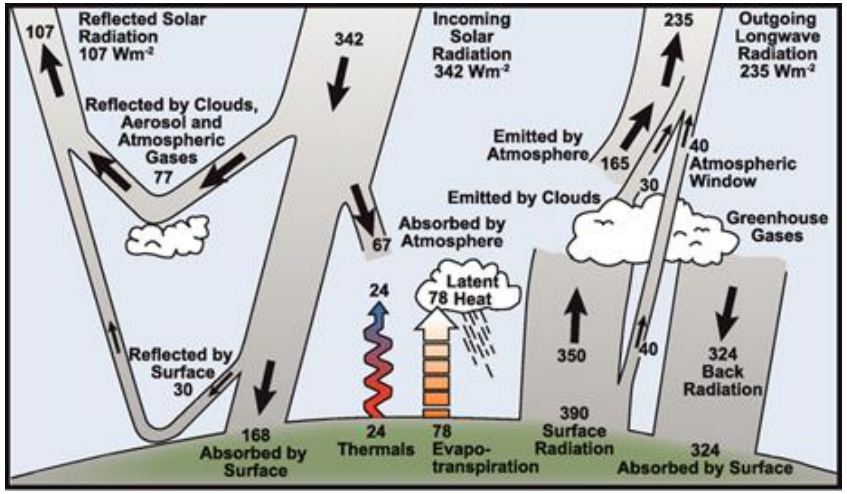


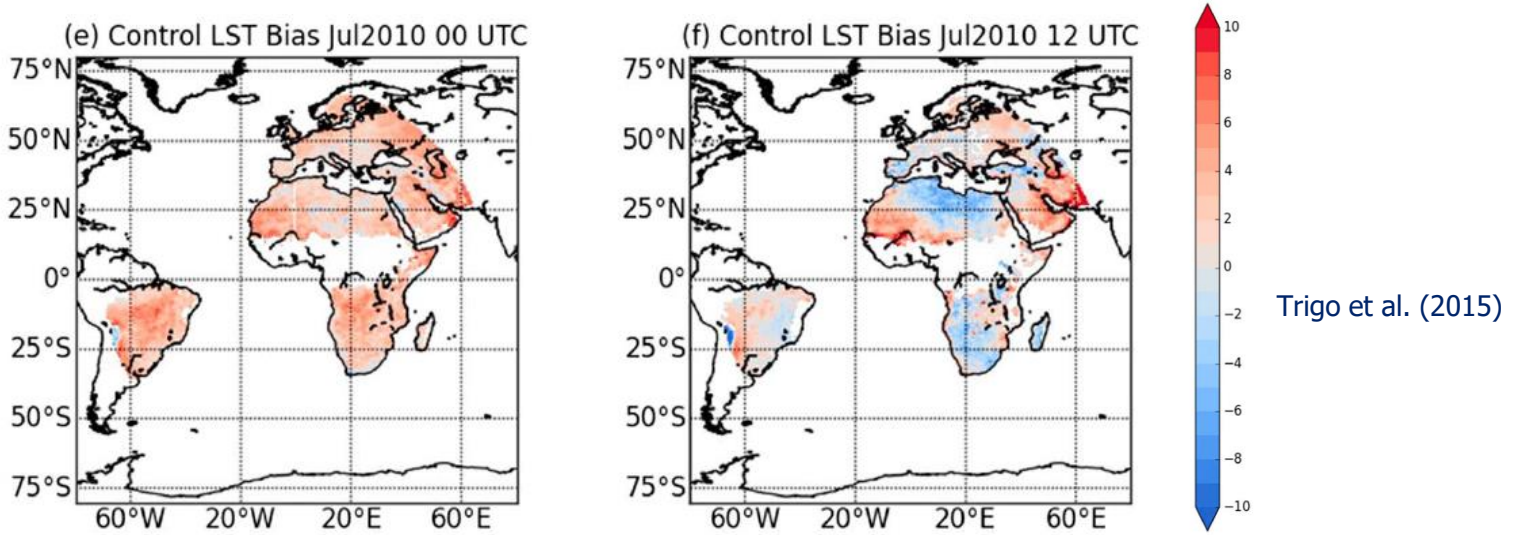
Source: Copernicus Global Land – Land Surface Temperature Scientific Quality Assessment Report (2019)

Improvement of NWP / Climate Models

- LST is a good indicator for the performance of the land surface scheme, as it may be regarded as an integrated metric of the processes regulating the land surface energy balance, e.g.:
  - Radiative fluxes
  - Vegetation (evapotranspiration)
  - Conduction into the ground
  - Albedo

- Trigo et al. (2015) identified significant LST biases in simulations from the ECWMF surface model HTESSEL using the LSA SAF LST





Trigo et al. (2015)

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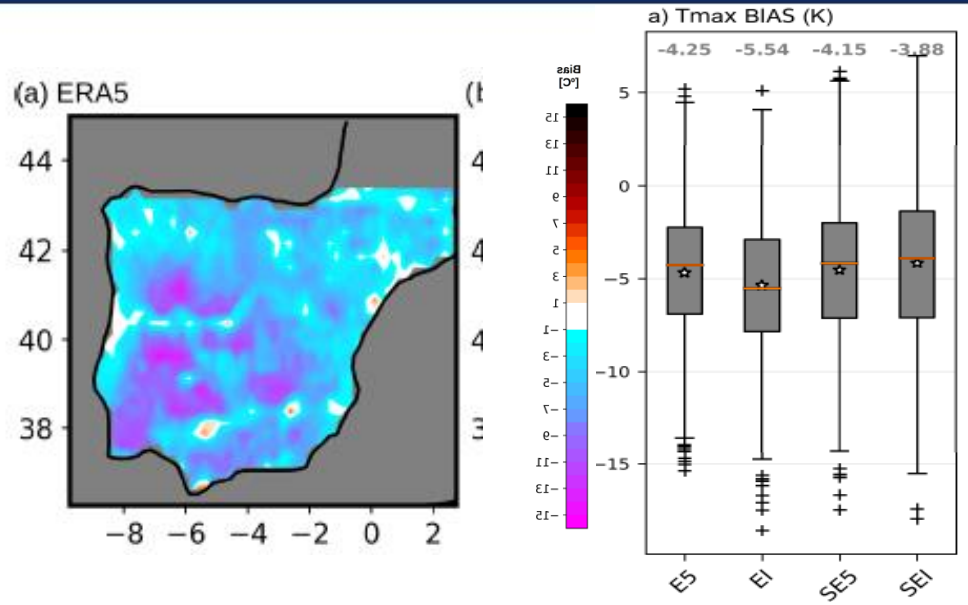
Improvement of NWP / Climate Models

- Johanssen et al (2019) and Nogueira et al. (2020) focused on the Iberia cold bias and proposed several improvements to the model
- They detected that vegetation was poorly represented in the HTESSEL scheme, and most of the errors in LST could be associated to errors in vegetation cover



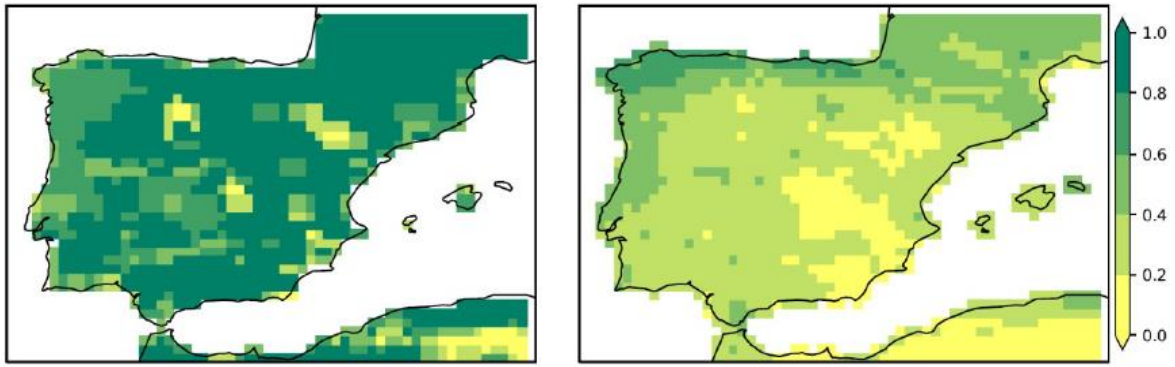
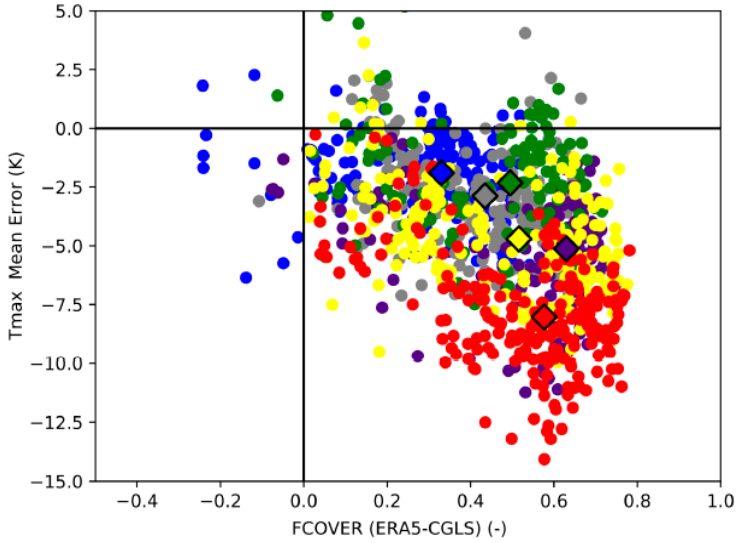


Figure S3. ERA5 Total Vegetation Cover (TVC, left) and the mean 1999-2018 CGLS FCover (right).

From: Johanssen et al (2019)



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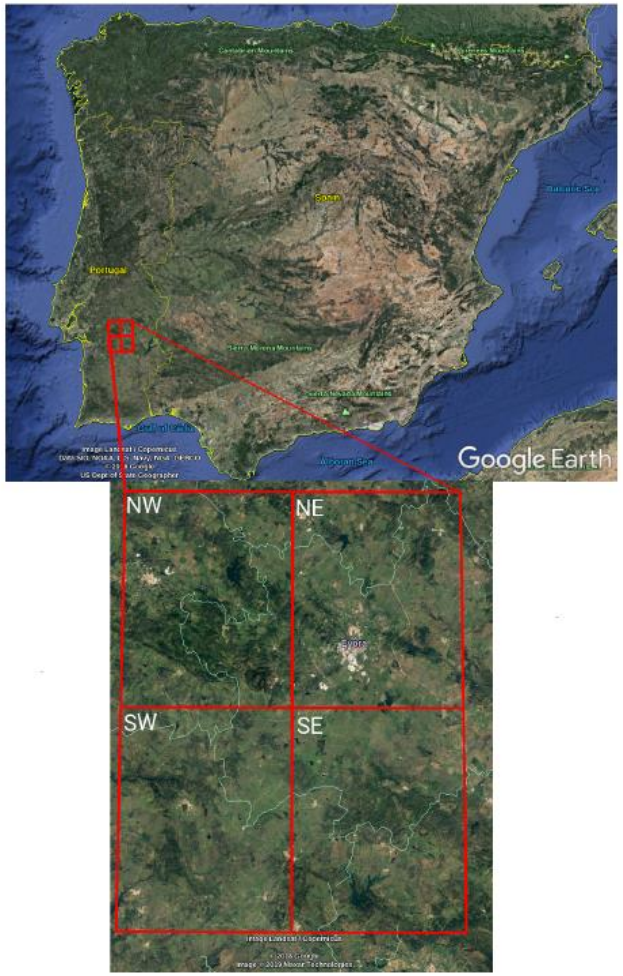
Improvement of NWP / Climate Models



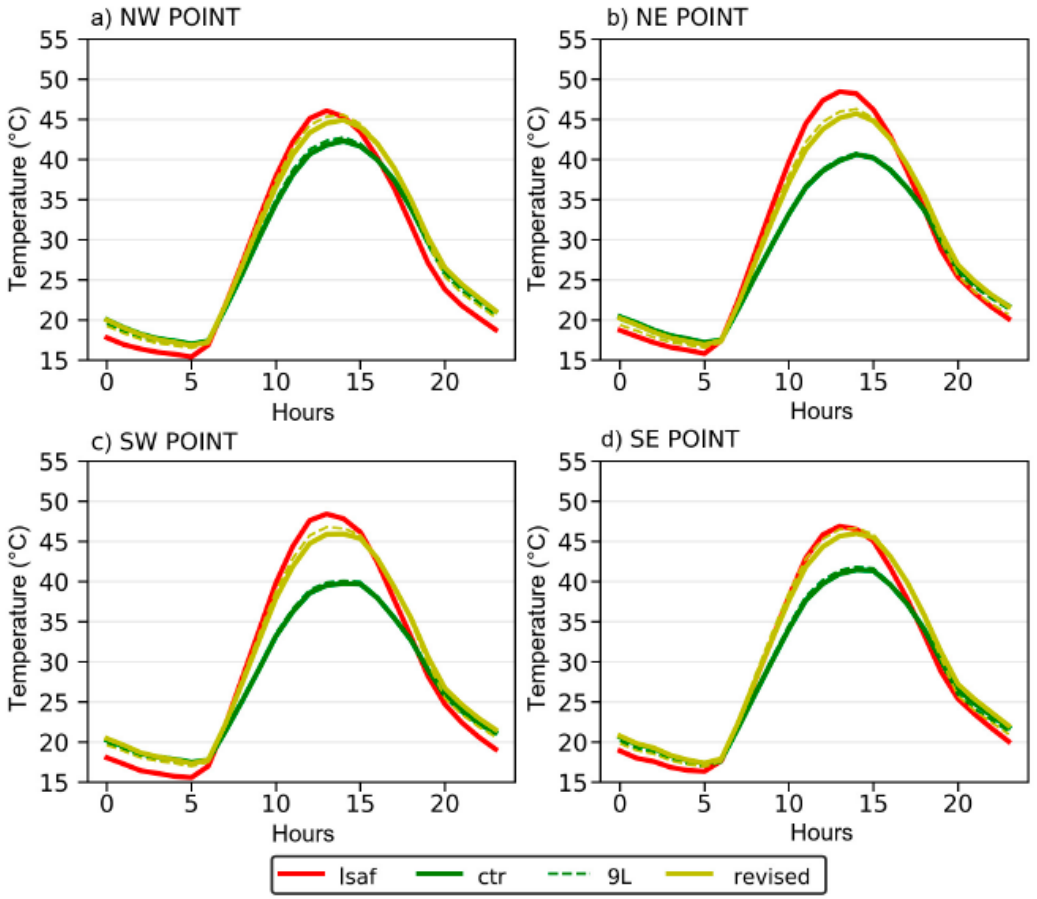


Figure 8. Mean diurnal cycle of temperature (2010 Summer) in the 4 points of the Southern Portugal domain (a) North West, (b) North East, (c) South West (d) South East (see Figure S1) comparing the satellite LST (red), and the LST in the control simulation (green), and control with 9 soil layers (dashed green) with the simulation using ESA-CCI vegetation cover (revised in yellow, and with the 9 soil layers dashed yellow).

Advantages / Disadvantages of the LSA-SAF LST CDR

- A more accurate algorithm using two channels; assumes known emissivity
- Higher resolution (spatial, temporal)
- Available in NRT (useful for monitoring)
- Full description of the diurnal cycle (as opposed to polar orbiter-based LST products)
- Will be available through the EUMETSAT Datacube (easier access through a THREDDS server)

- Not so useful for long term trends (yet!)
- “Climate reference” period is less robust – WMO requires length > 20 years for CDRs