Applications of remotely sensed Land Surface Temperature Products

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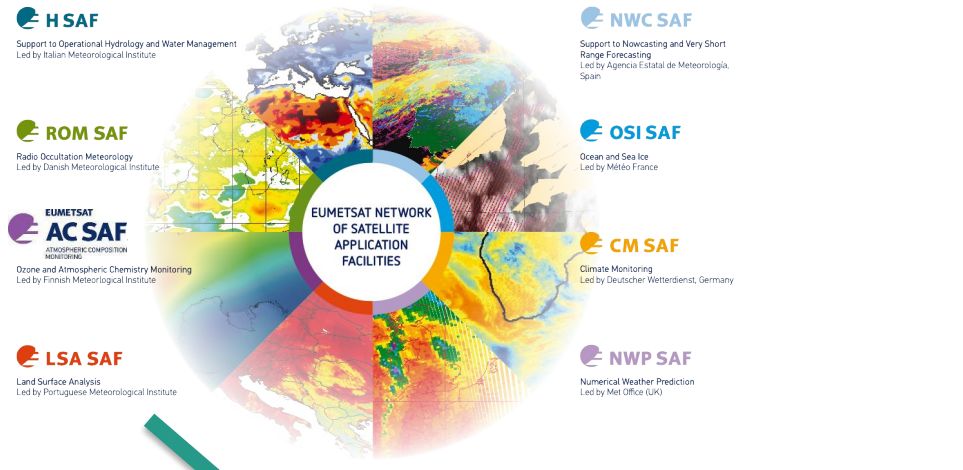
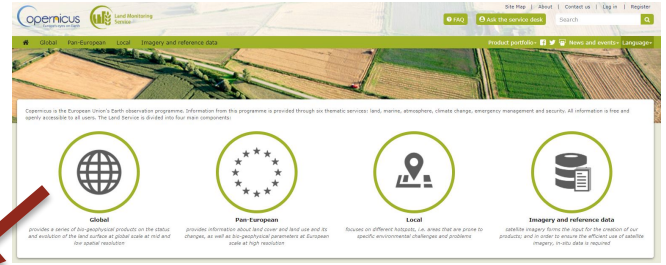
Remote Sensing of the Land Surface – IPMA's role

- Space Agencies divide their ground segment work by the member-states / areas;
- **IPMA**:
  - ✔ **LSA-SAF** leader (production / distribution; product developer)
  - ✔ **Copernicus Global Land** (product developer);
  - ✔ **ESA CCI** (product developer);
  - ✔ **CAMS** (product developer)



https://landsaf.ipma.pt

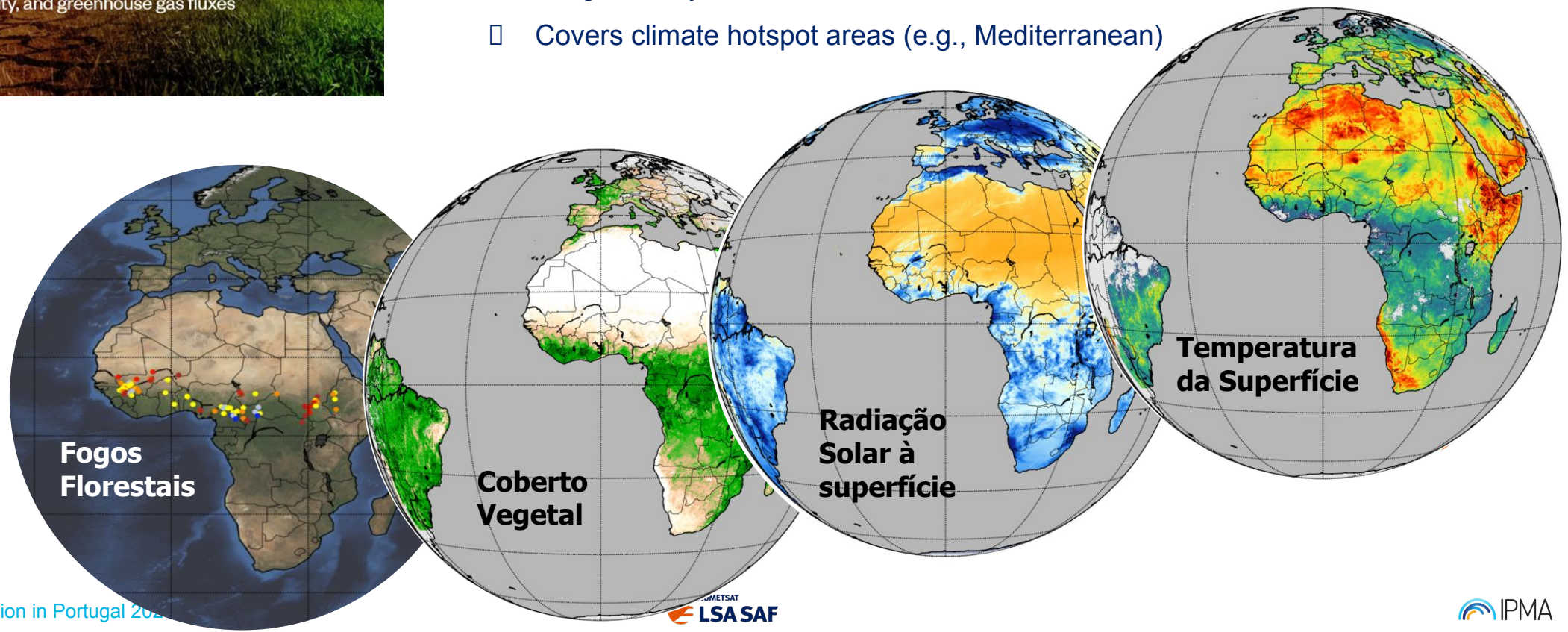
Satellite Application Facility on Land Surface Analysis (LSA-SAF)



https://land.copernicus.eu/global/

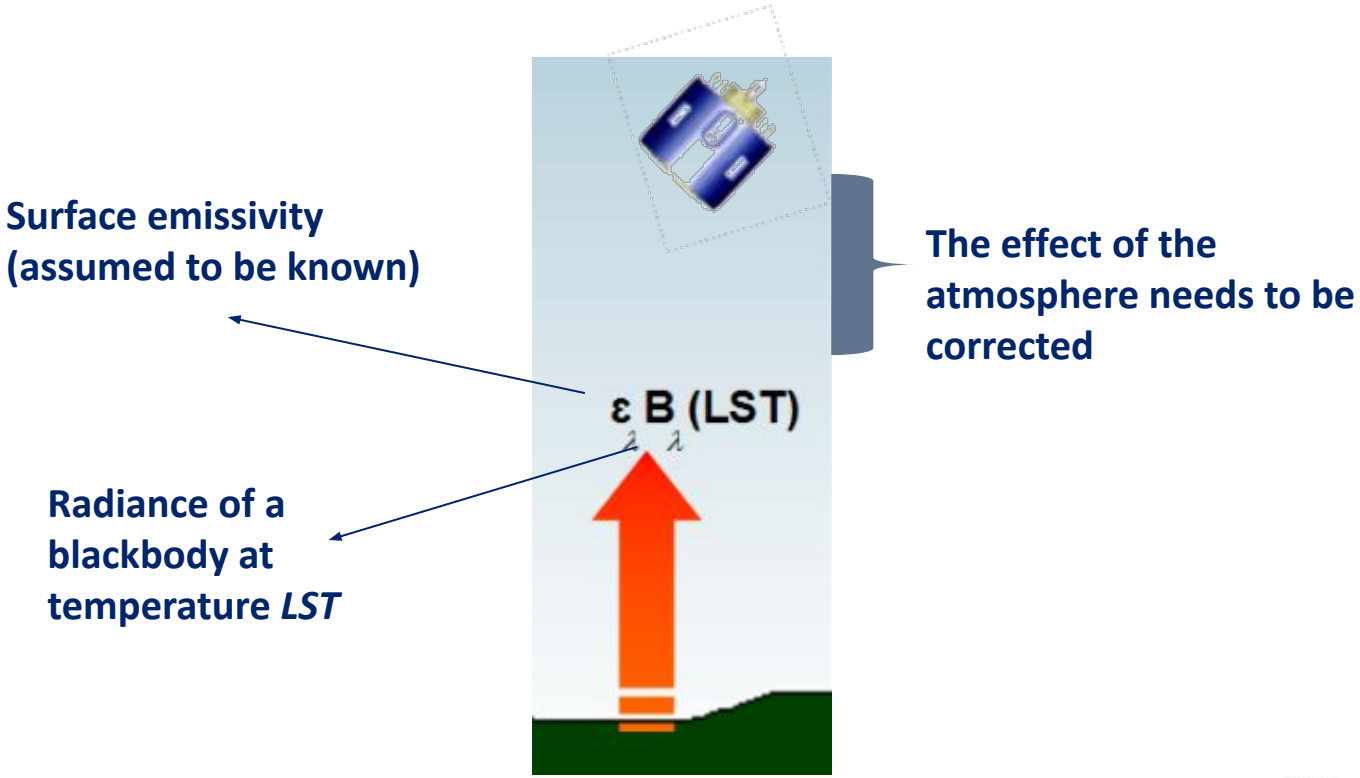
Remote Sensing of the Land Surface

- Satellite observations provide **support for decision-makers** (e.g., IPCC, JRC, etc.), and are useful for **operational monitoring**
- LandSAF: data cubes with SEVIRI/MSG data (2004-today):
  - 12 channels (VIS and IR)
  - Images every 15 min
  - Covers climate hotspot areas (e.g., Mediterranean)



How do we measure LST from space?

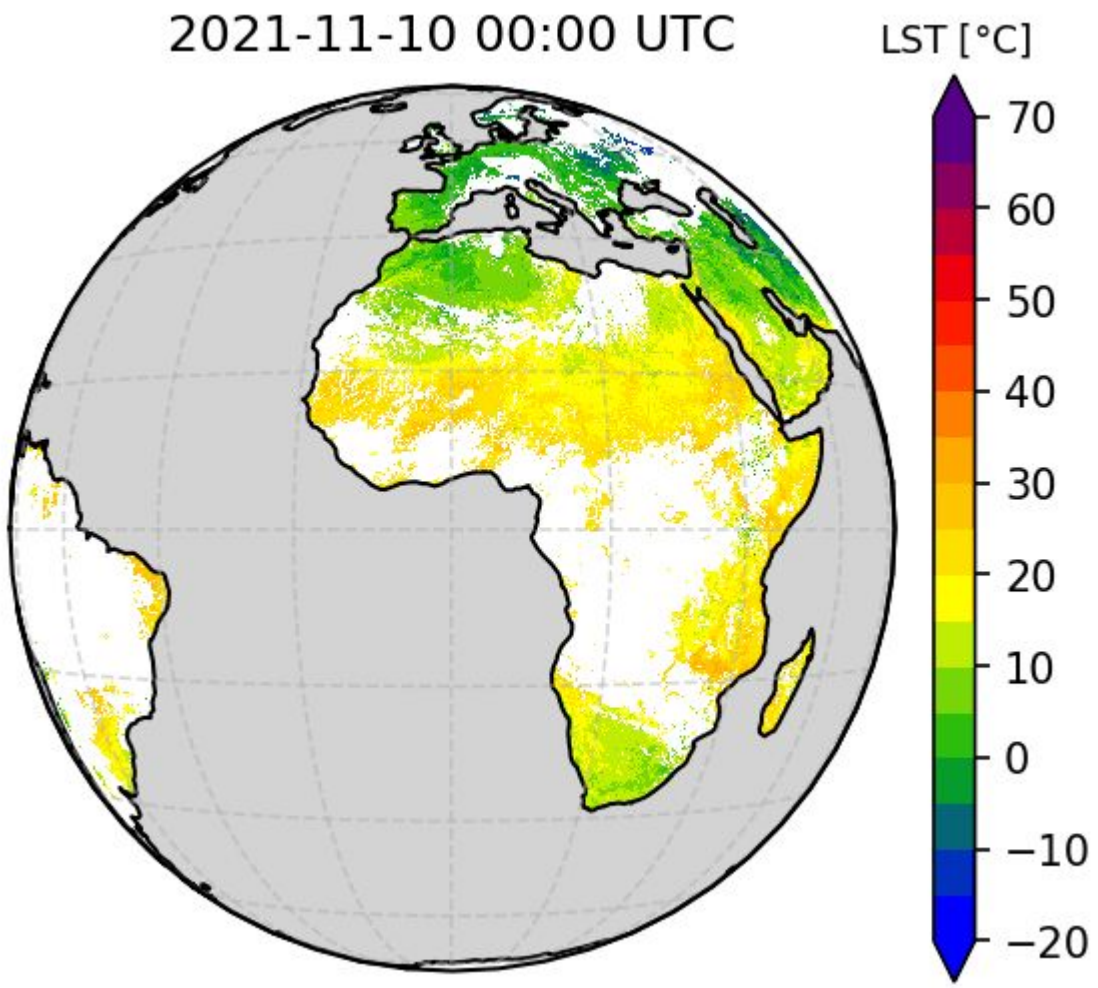
- **Land Surface Temperature (LST) is the radiative *skin* temperature of the land surface**
  - Corresponds to thermal emission from the top thin layer of a few micrometers on the surface (up to 50 µm).
- **Satellite sensors can measure this "skin" temperature by measuring the infrared radiance emitted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



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

All-Sky LST

Clear sky LST

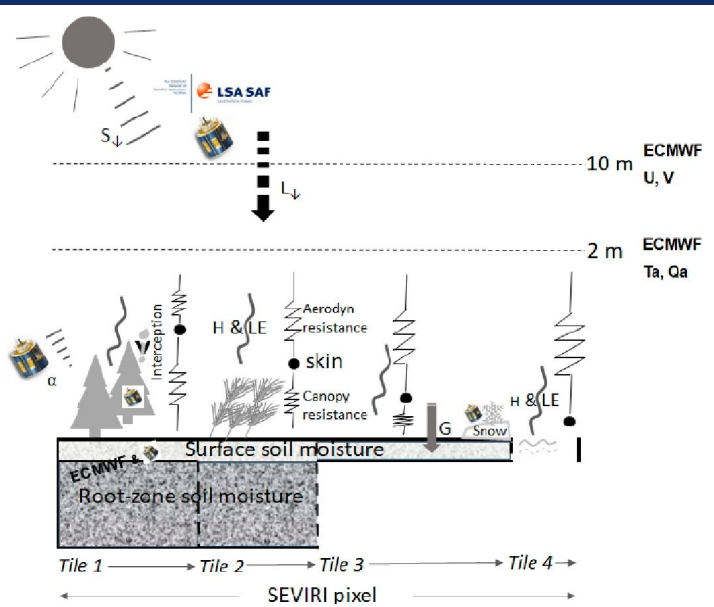
IR retrievals for clear sky (Generalized Split-Windows Algorithm, standard L2 LST for SEVIRI)

Cloudy Sky LST

Skin temperature from a surface energy balance model, forced by LSA-SAF products and ECMWF meteorological data

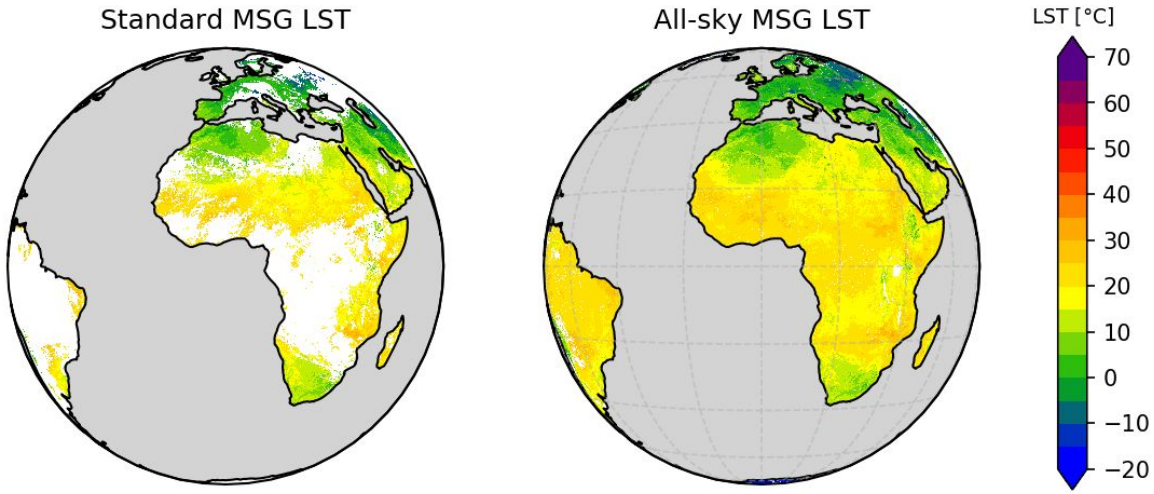
Outputs:

- *H, LE* (and evapotranspiration) and ***SKT***

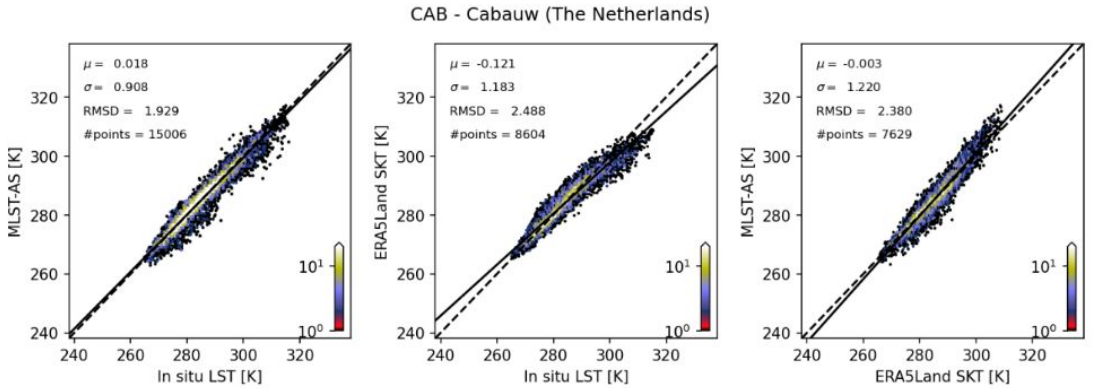


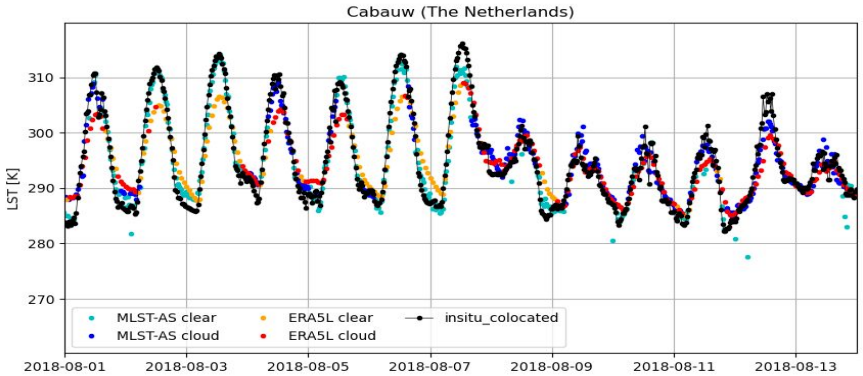
- **Maximizes use of remote sensing data (mostly LSA-SAF)**
- **Scheme based on the H-TESSEL surface model (ECMWF)**
- **Runs every 30 min**

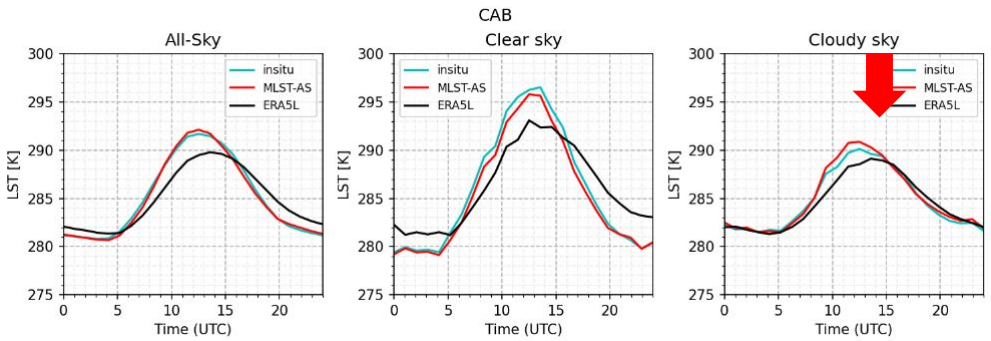
2021-11-10 00:00 UTC



All-Sky LST - validation







Overall stats for the 33 stations (BSRN + EFDC + KIT)

	MLSTS – in situ			ERA5-Land – in situ			MLSTS – ERA5-Land		
	All	Clear	Cloudy	All	Clear	Cloudy	All	Clear	Cloudy
	0.0	**-0.2**	**0.2**	0.2	0.1	0.3	-0.2	-0.2	-0.2
	1.5	1.4	1.5	1.6	2.1	1.3	1.7	2.1	1.2
RMSD (K)	2.9	2.8	2.8	2.9	3.3	2.6	3.1	3.5	2.4

- **Compares very well with in situ estimates**
- **Statistics for cloudy sky estimates are similar to clear sky**
- **Compares well to ERA5-Land**
- **Some problems in the representation of the diurnal cycle (phase shift, amplitude)**

EUMETSAT LSA SAF

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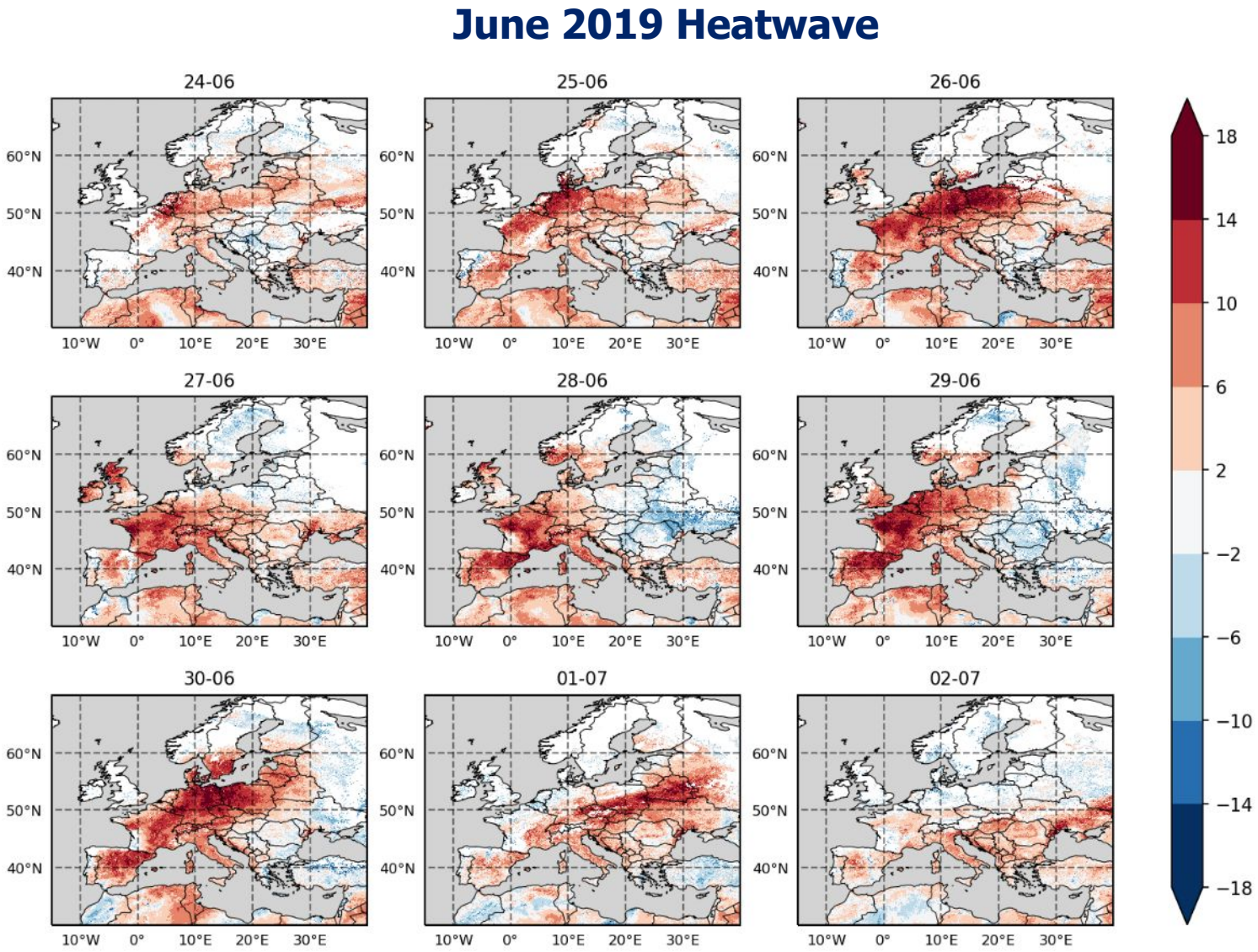
Applications: Heat wave monitoring

- 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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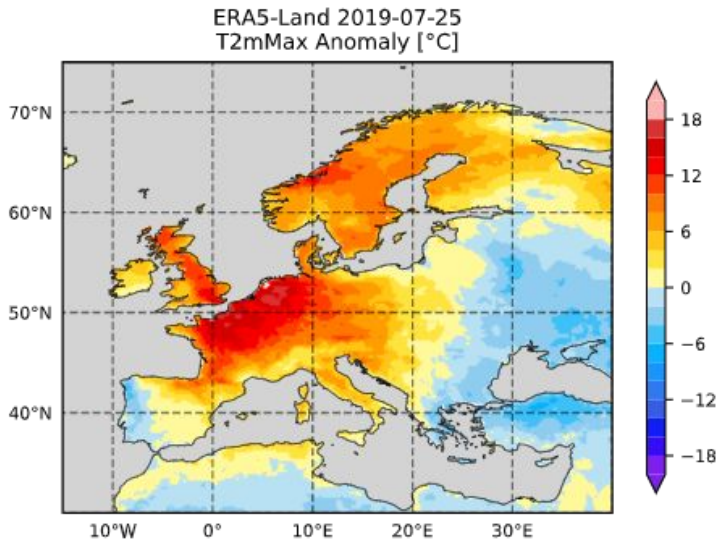
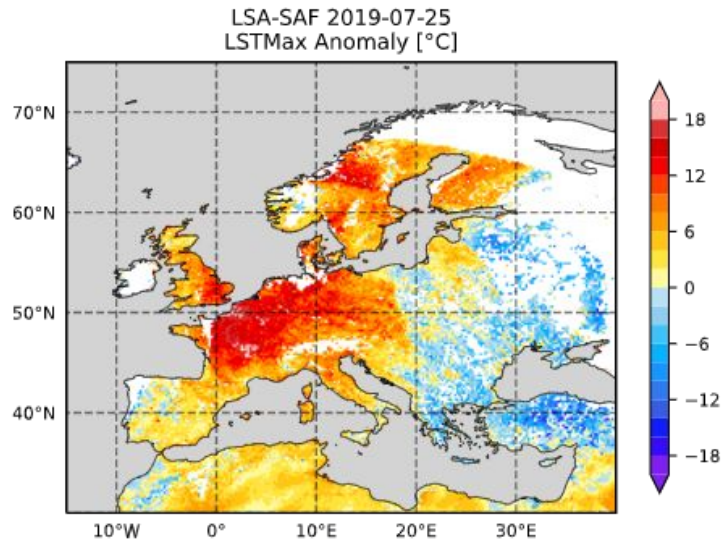
LST vs. T2m for heatwave monitoring

- 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





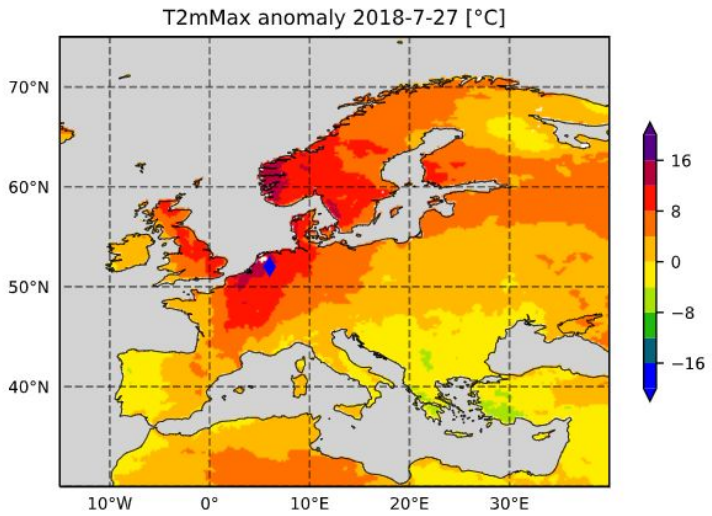
Heatwave Magnitude Index (Russo et al, 2015)

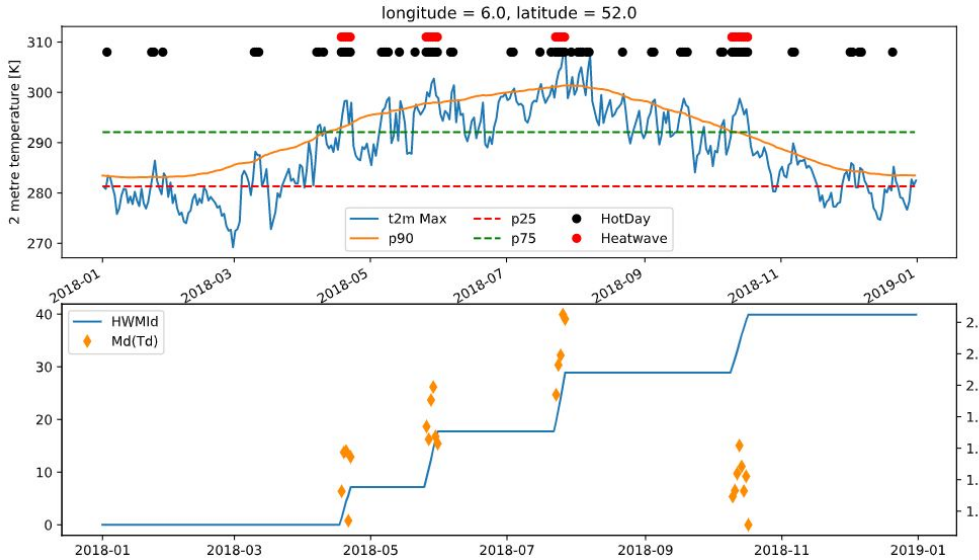
- Heatwave: 5+ days above T_{p90};
- Daily heatwave magnitude:

$$M_d(T_d) = \begin{cases} \dfrac{T_d - T_{30y25p}}{T_{30y75p} - T_{30y25p}} & \text{if } T_d > T_{30y25p} \\ 0 \quad \text{if } T_d \leqslant T_{30y25p} \end{cases}$$

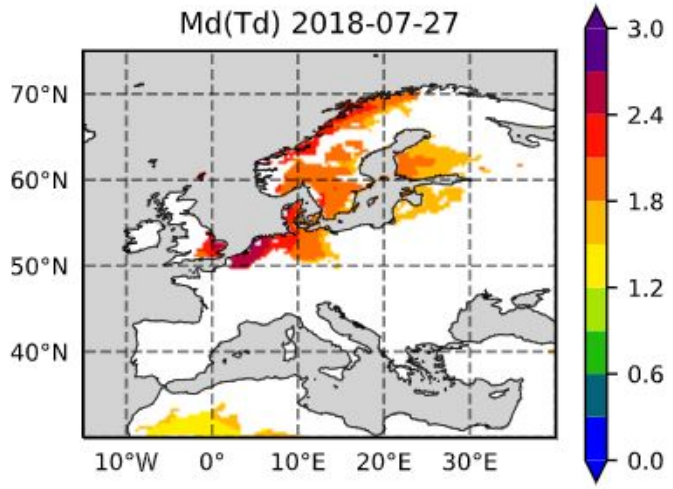
- Heatwave Magnitude Index (*HWMId*): sum of $M_d(T_d)$ for the whole heatwave
- *HWMId* "unit": heatwave day, whose daily magnitude with respect to T_{p25} is equal to the *IQR*.

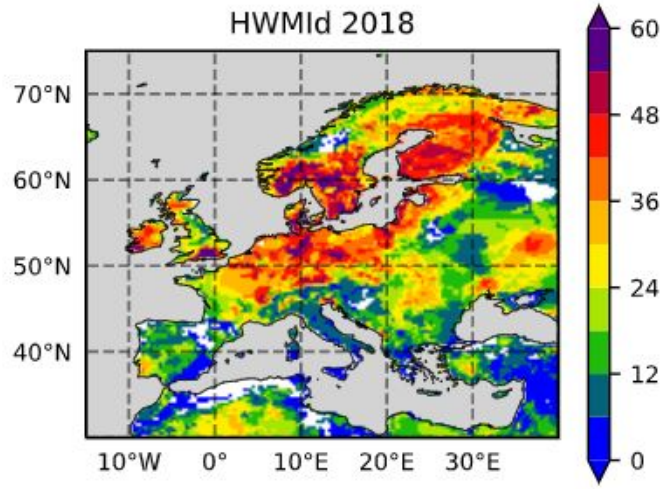
Please check Sara Caetano's poster!





Data from ERA5-Land
Reference period 1981-2020





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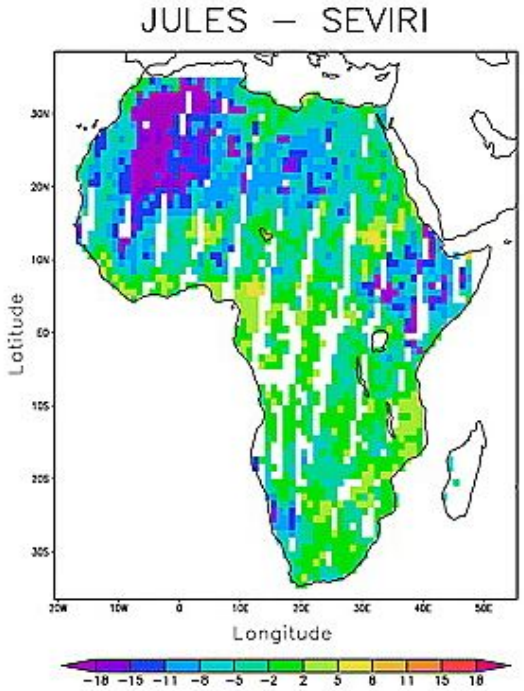
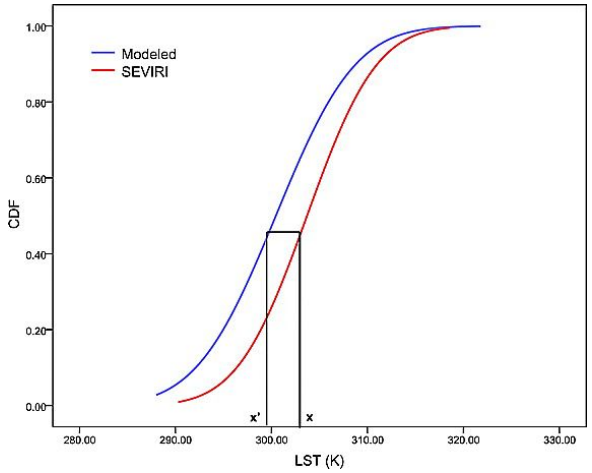
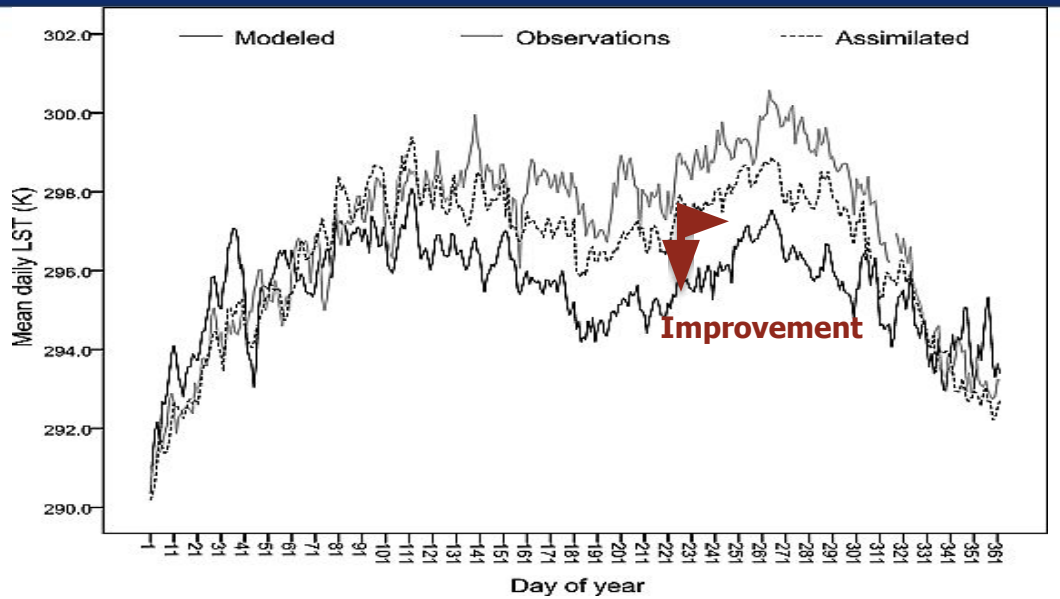
Applications: LST assimilation

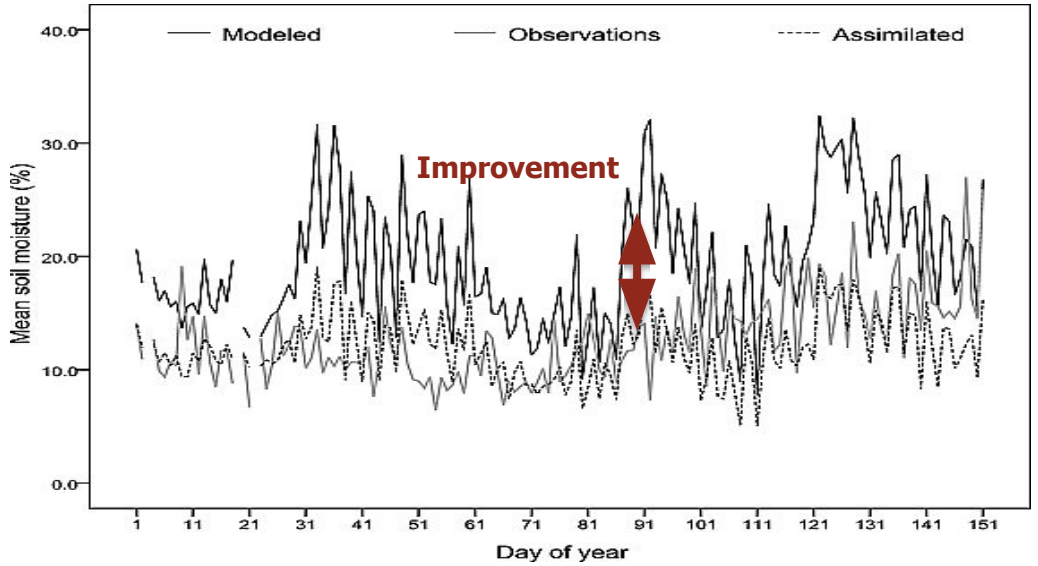
Ghent et al. 2010

- Assimilation of LSA-SAF LST into JULES Surface Model
- Uses EnKF
- CDF bias correction (Reichle and Koster [2004])
- Leads to general improvement of simulation of surface temperature and soil moisture







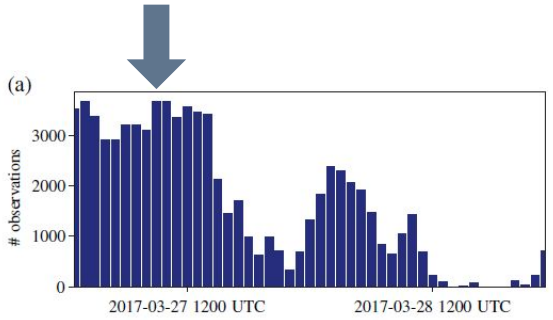


LST assimilation

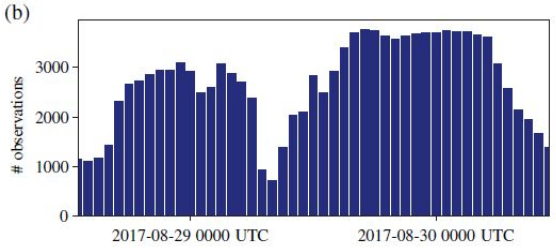
Sgoff et al et al. 2020

- Assimilation of synthetic LSTs into COSMO coupled land + atmosphere model
- Uses Local Ensemble Transform Kalman Filter (LETKF; Hunt et al., 2007)
- Assumes LST from a clear-sky situations of a model “nature run” + random noise of 1-2 K as “truth” – mimics LSA SAF LST, *no bias (!)*

More data – greater impact
Greater positive impact around noon

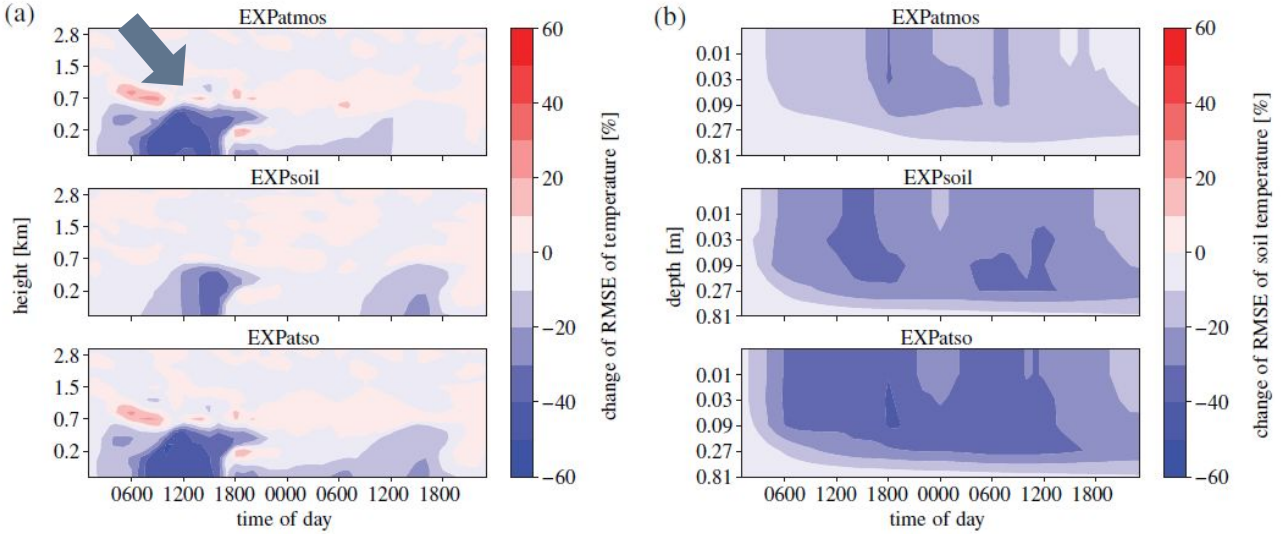


Negative impact over the afternoon transition to nocturnal stable PBL – less surface coupling

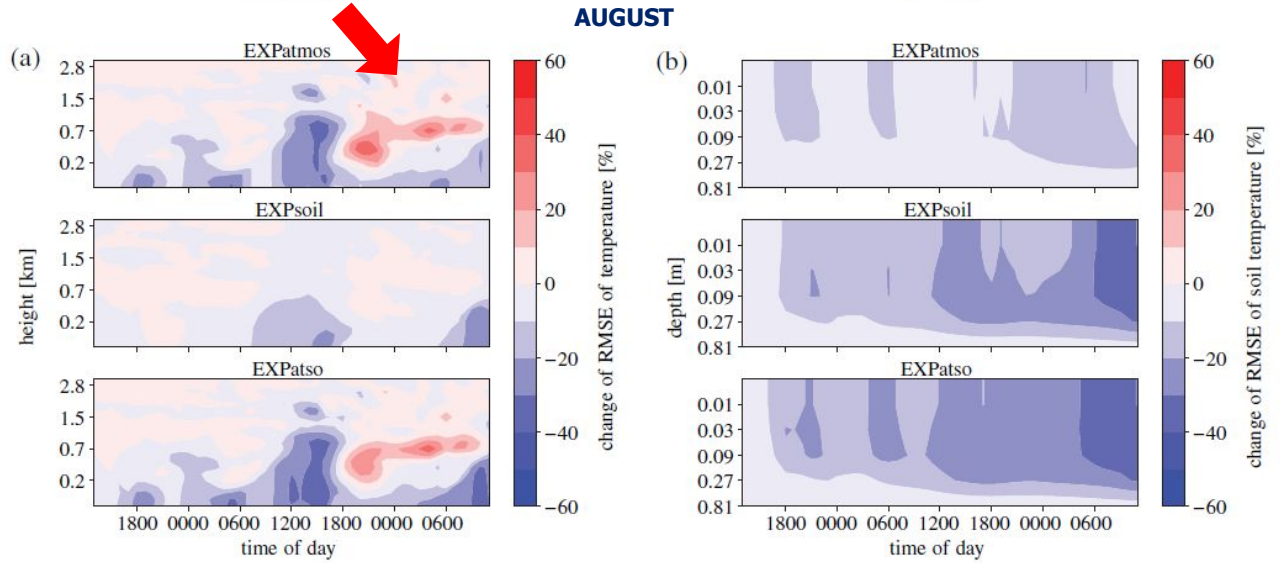


Soil has more memory than the atmosphere

PBL T change in RMSE **MARCH** **Soil T change in RMSE**



AUGUST



LSA SAF

IPMA

Concluding Remarks

- LSA-SAF provides temporally stable products using a relatively accurate algorithm using two infrared imager 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)
- LSA-SAF catalogue is continuously improving
  - All-sky LST now provides reliable LSTs even for cloudy pixels
  - LST-based Heatwave magnitude Indexes are under development
- Number of dataset applications is increasing
  - Data assimilation; NWP model improvement (check Emanuel Dutra tomorrow)
  - Climate extremes; Drought; Post Wildfire vegetation recovery; Urban Heat Islands (see Alexandra Hurduc); Land Cover / Land Use change, etc.