The CM SAF Land Surface Temperature CDR

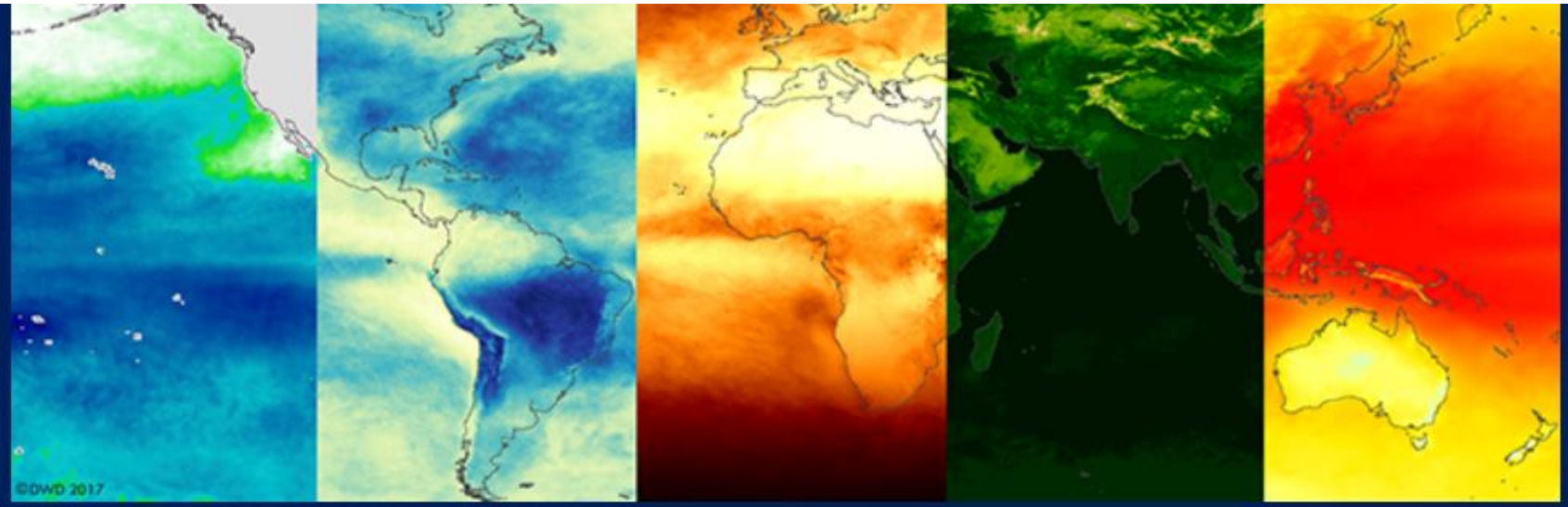
Anke Duguay-Tetzlaff & the CM SAF team

Climate Monitoring Satellite Application Facility
CM SAF

Satellite-derived products and services for climate monitoring.

Our Products

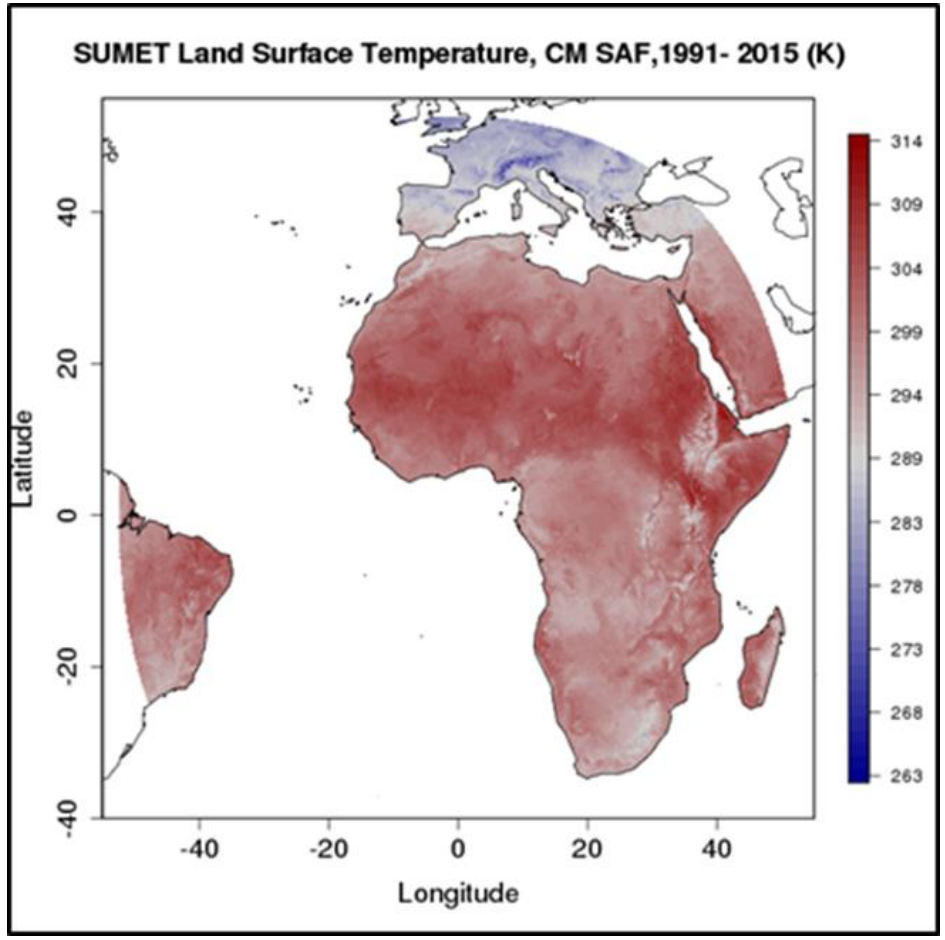
CM SAF products describe important components of the Earth´s Energy budget and its water cycle, i.e. water vapour, cloud properties, precipitation and surface radiation components. Pixel based retrievals as well as spatio-temporal aggregations enable a large variety of applications.



EUMETSAT CM SAF CLIMATE MONITORING

CM SAF Land Surface Temperature CDR

Long-term CDR back to 1991 spanning the two generations of Meteosat sensors.



- Hourly & monthly diurnal cycle
- 5 km x 5 km
- 1991-2015 (2020)
- Clear sky Land Surface Temperature

EUMETSAT CM SAF CLIMATE MONITORING

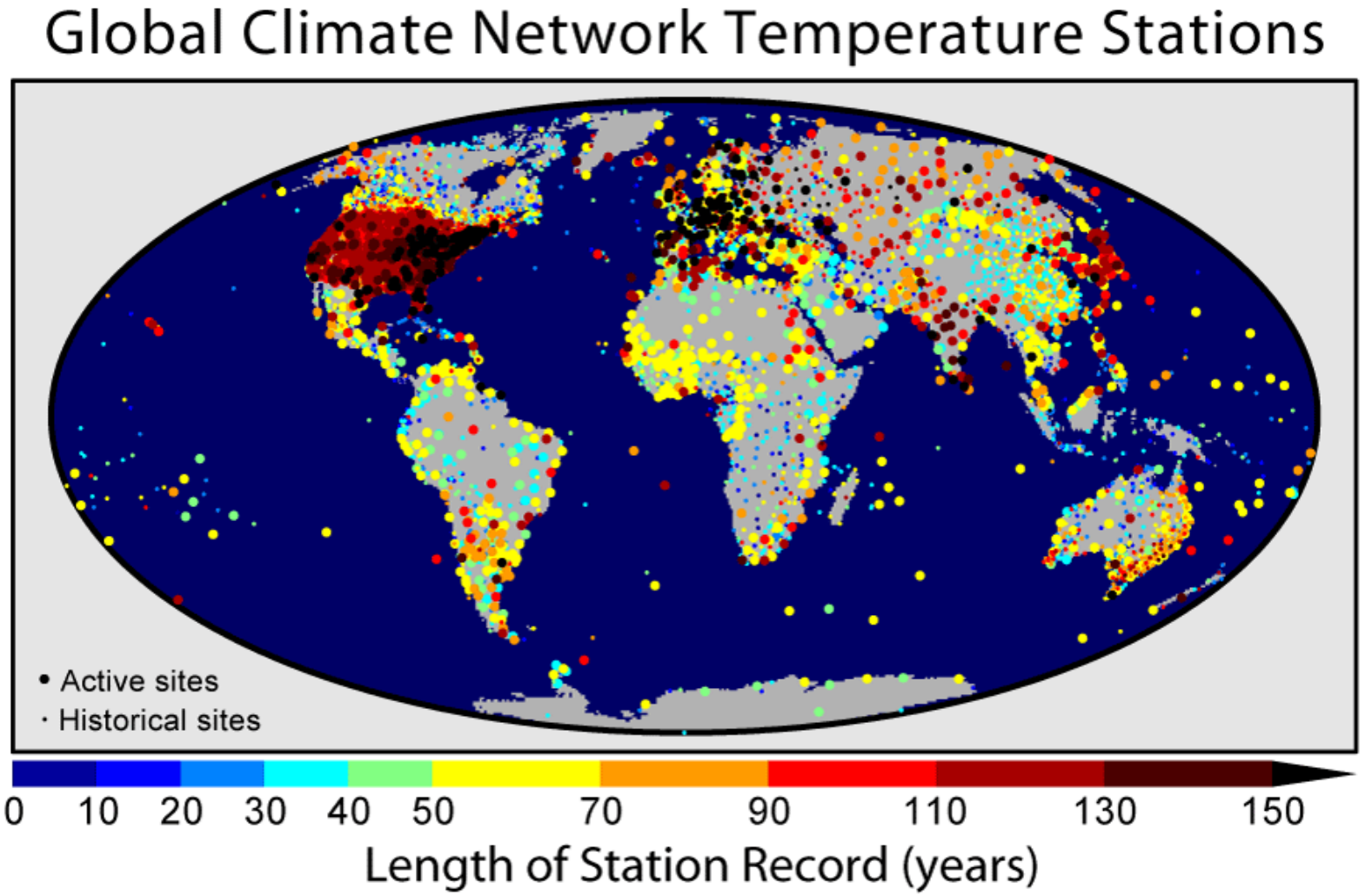
https://www.cmsaf.eu/

Motivation

GCOS ECV Land Surface Temperatur:

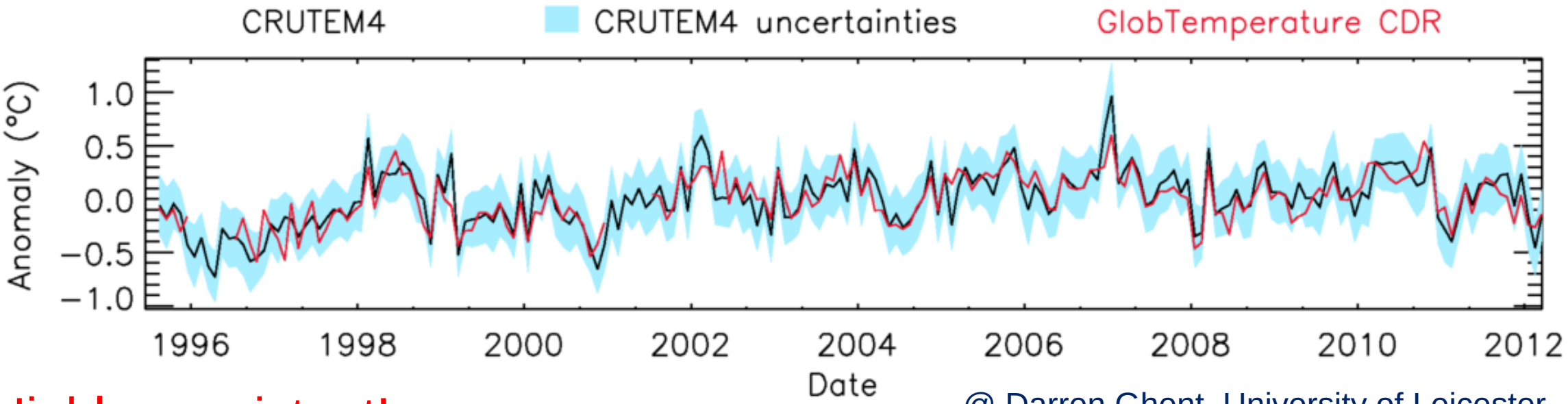
“LST is an independent temperature data set for quantifying climate change complementary to the near-surface air temperature ECVs.”

Motivation


Global Climate Network Temperature Stations
• Active sites
· Historical sites
0 10 20 30 40 50 70 90 110 130 150
Length of Station Record (years)

Motivation

Land Surface Temperature (red) versus Air Temperature (black)



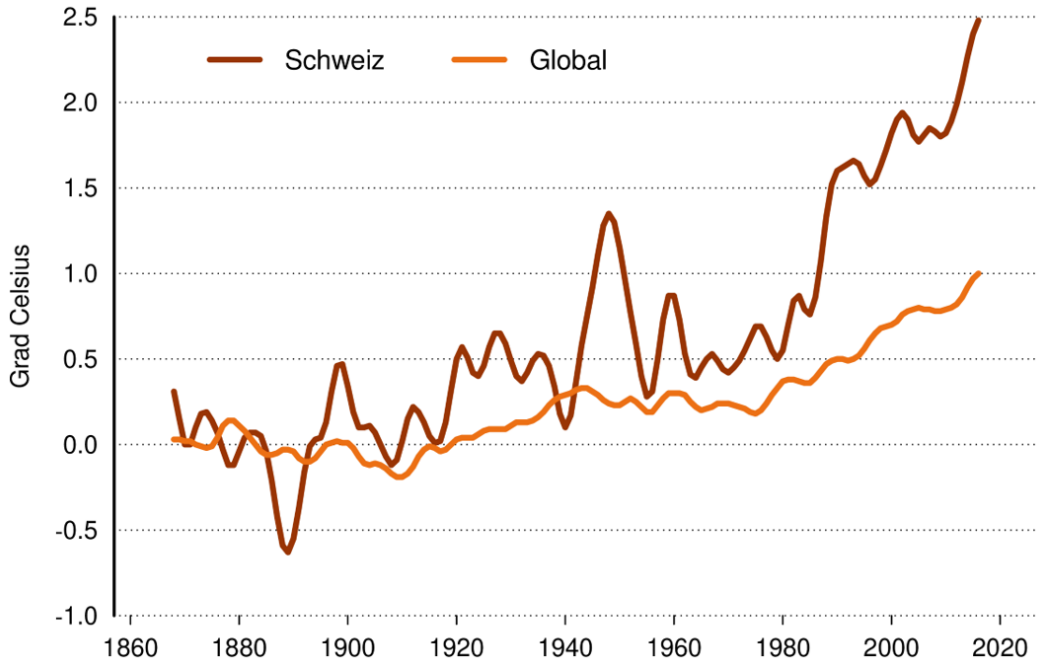
@ Darren Ghent, University of Leicester

Highly consistent!

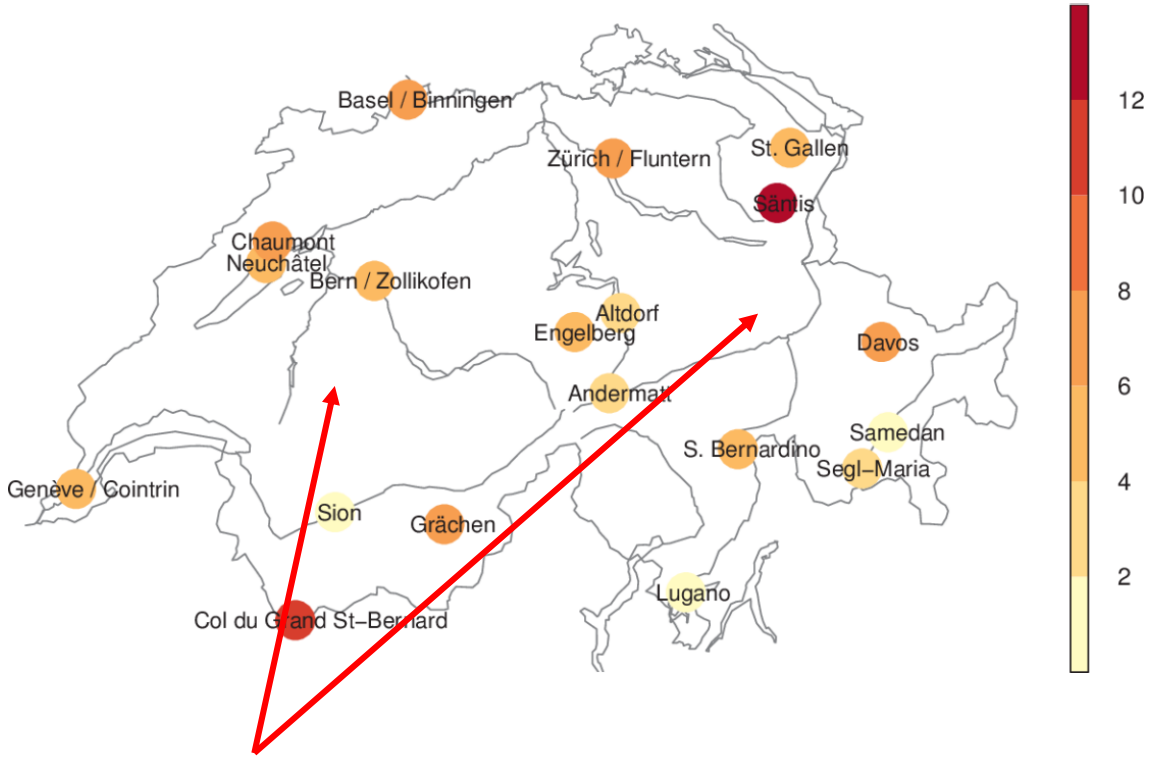
- Anomaly space
- Night-time

Motivation

Climate Change: Air temperatures in Switzerland



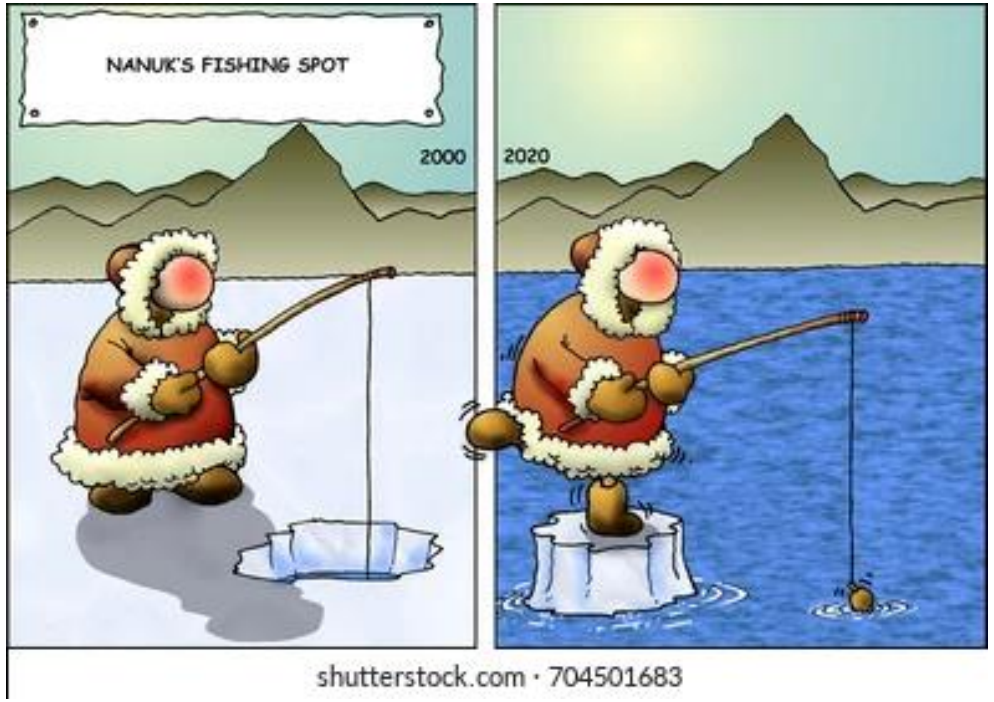
Long term air temperature measurements



Temperature change in Swiss Mountains is not well recorded !

Motivation

WMO New Climate Normal 1991-2020



- benchmark or reference against which conditions (especially current or recent conditions) can be assessed
- they are widely used as an indicator of the conditions likely to be experienced in a given location.

CM SAF LST v2.0 record length covers new WMO Climatological Normal

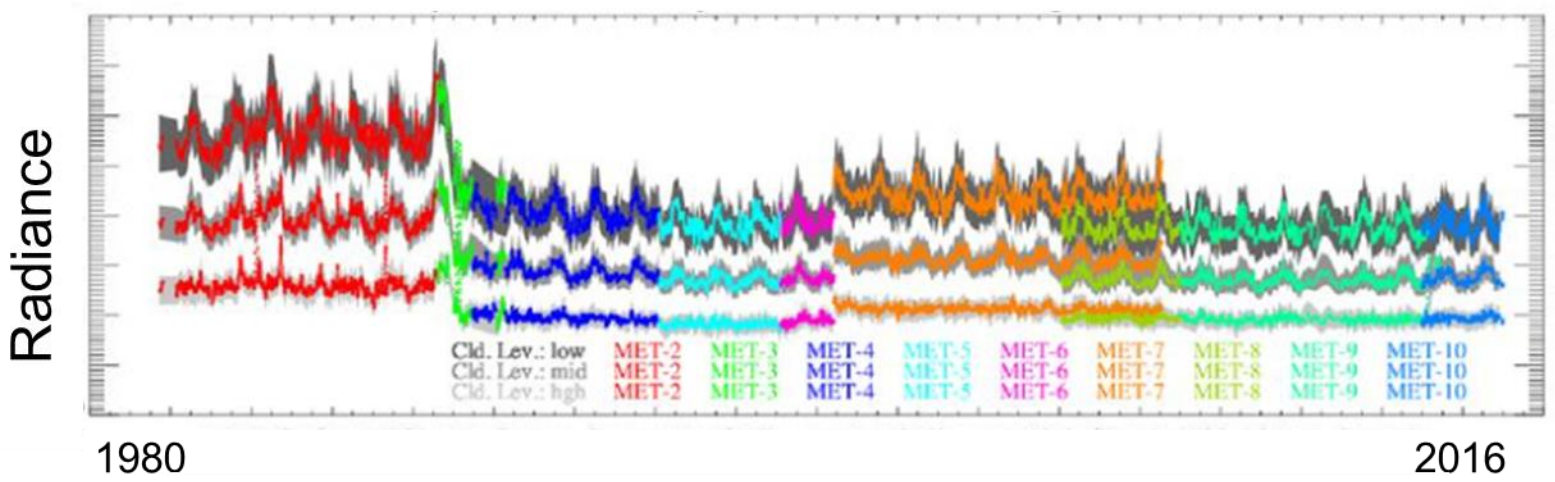
Meteosat First Generation

One of the first Meteosat images in the 80s:

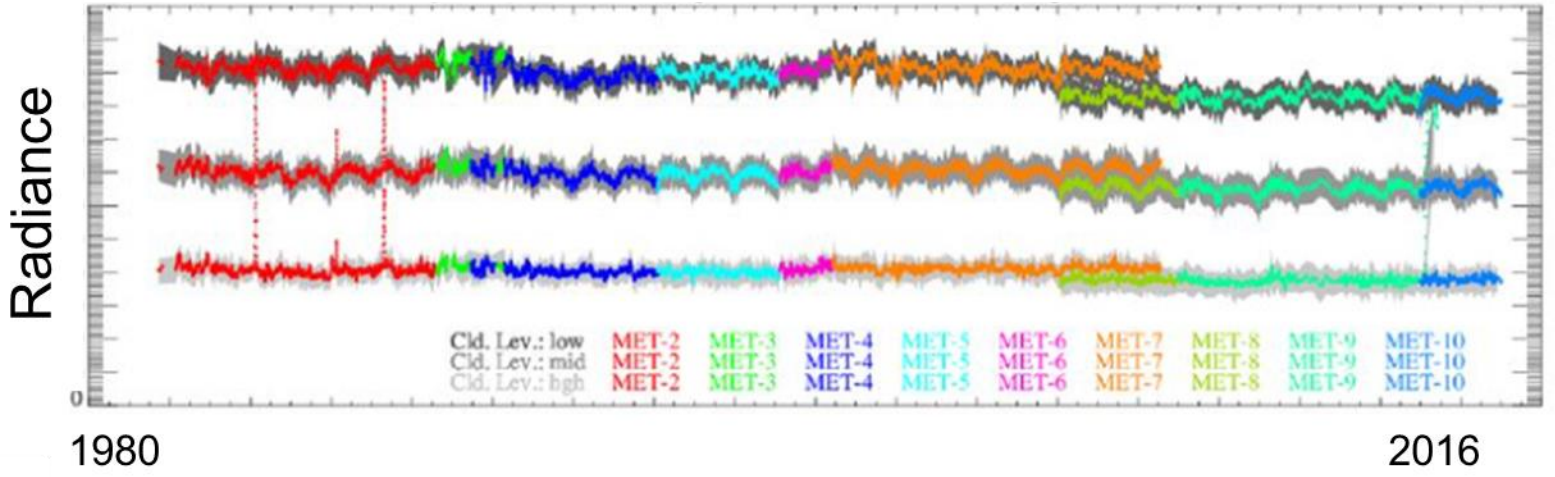
- Ancillary data are missing
- Not all data is stored at EUMETSAT

Challenge MFG and MSG Calibration

Meteosat MVIRI and SEVIRI uncalibrated



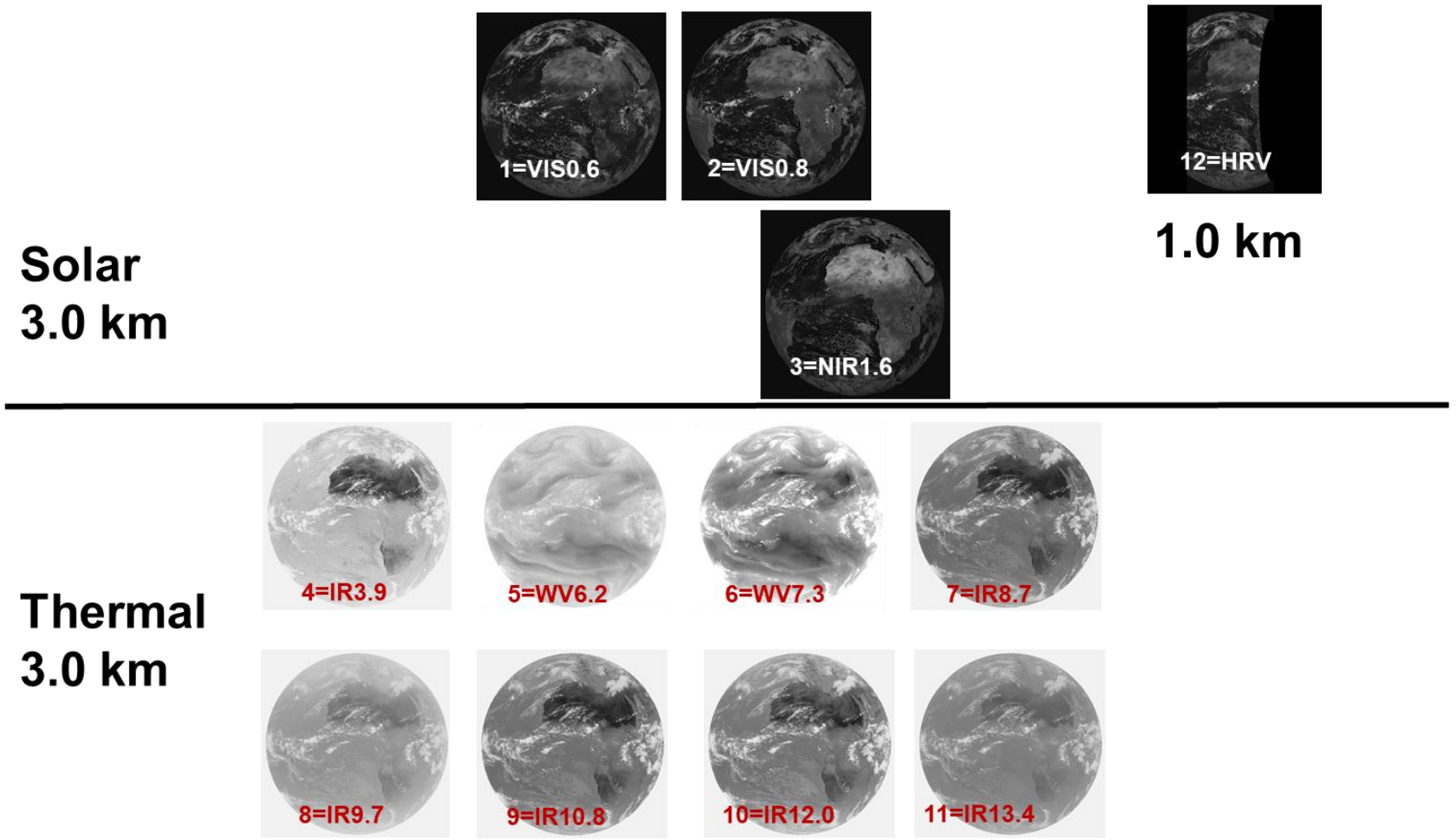
Meteosat MVIRI and SEVIRI calibrated



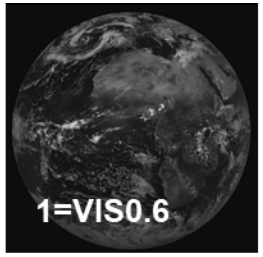
MFG and MSG recalibration by EUMETSAT

@ Viju Johns, EUMETSAT

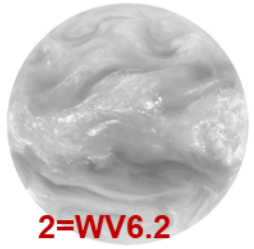
Meteosat Second Generation (since 2004)



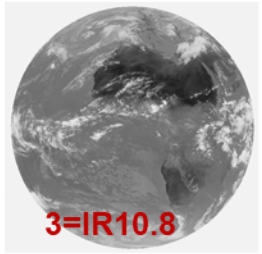
Meteosat First Generation (1983-2004)



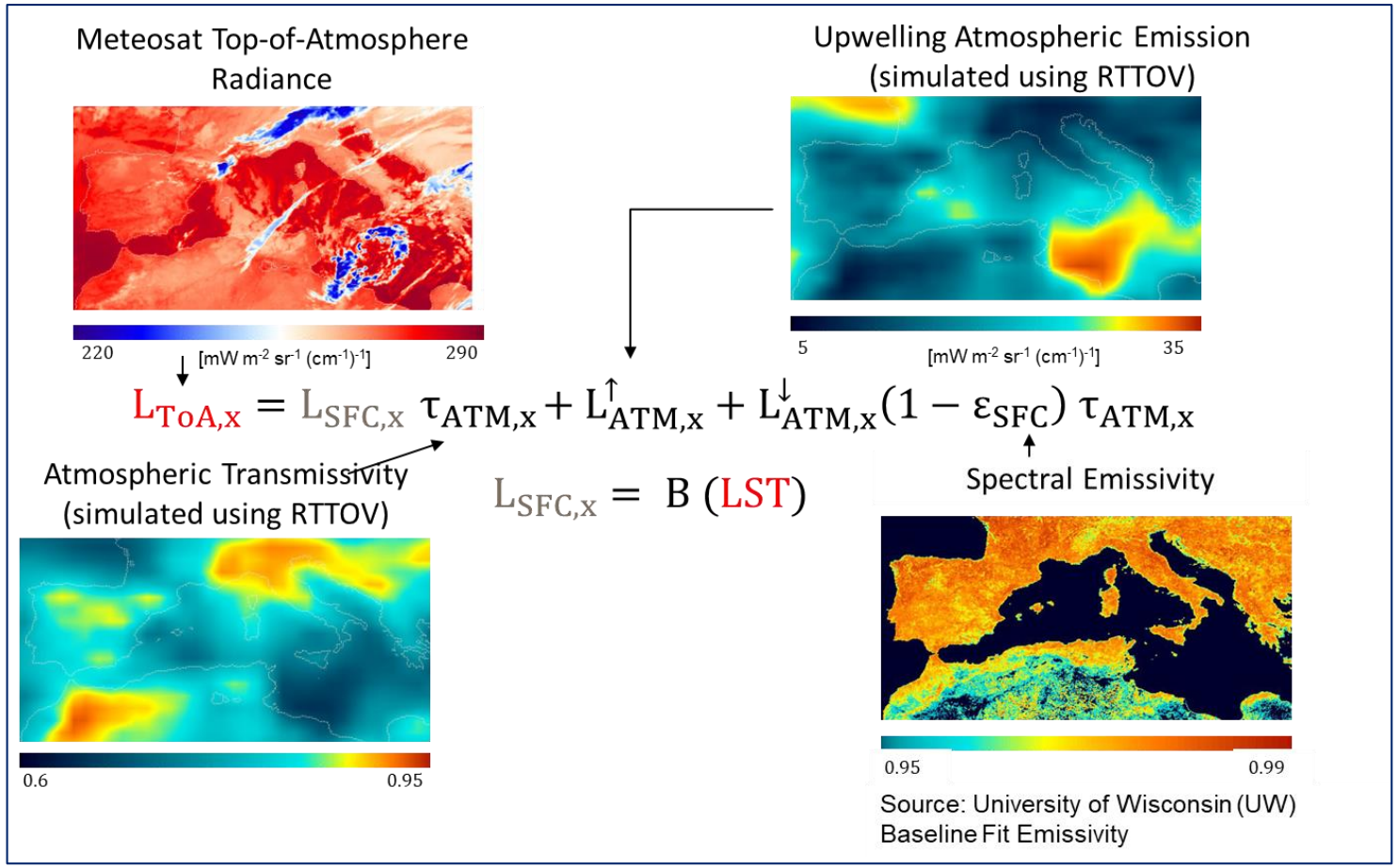
Solar
2.5 km



Thermal
5.0 km



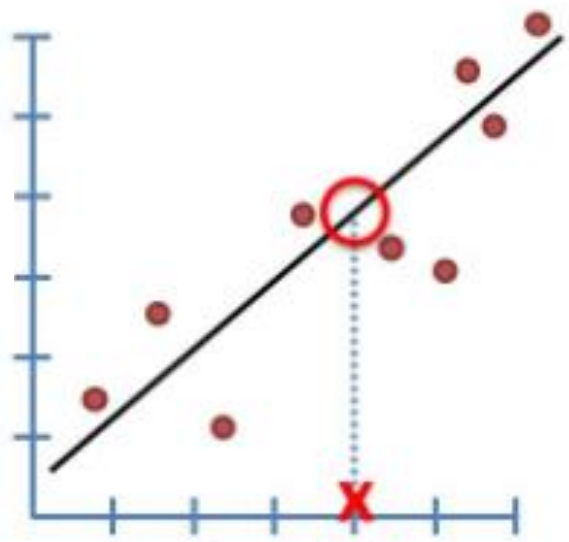
CM SAF LST Algorithm



Single channel LST retrieval for MFG and MSG **to ensure temporal consistency**.

Depends on external fields to estimate the atmospheric state and the surface emissivity.

CM SAF Statistical Mono Window LST Algorithm:

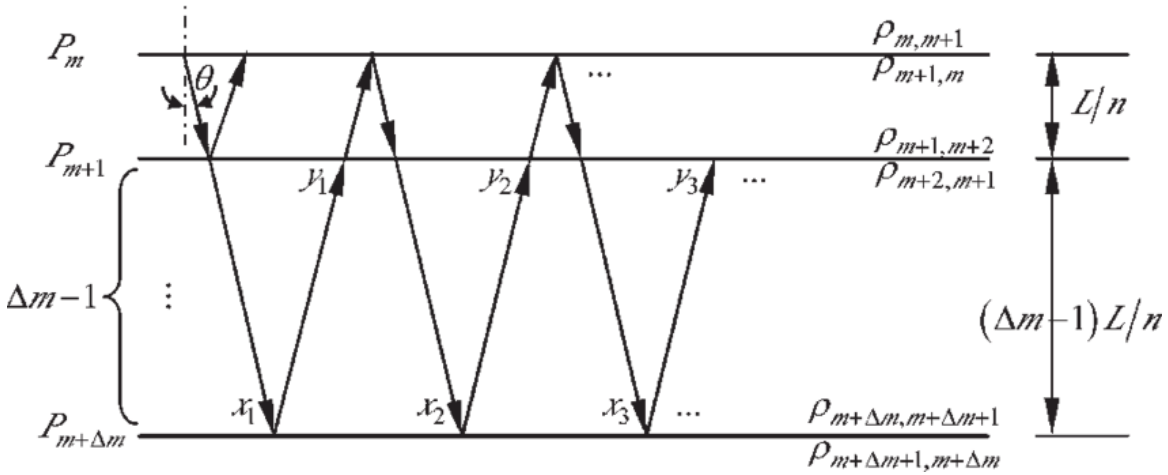


$$T_s = A\ \frac{T_b(\theta)}{\varepsilon_c} + B\frac{1}{\varepsilon_c} + C$$

Statistical approach trained with the LSA SAF data base.

Highest possible consistency with LSA SAF. To be used together with the LSA SAF real time data for climate monitoring.

CM SAF Physical Mono Window LST Algorithm

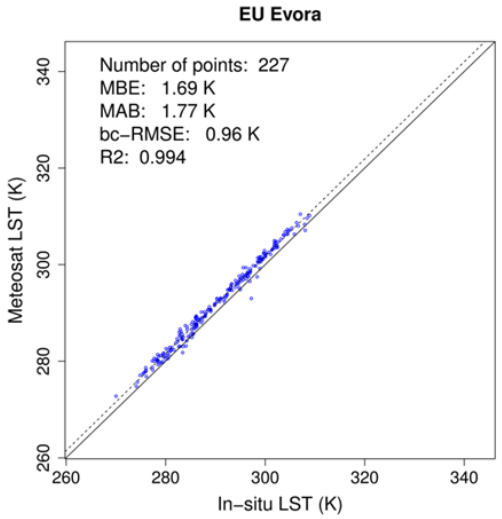


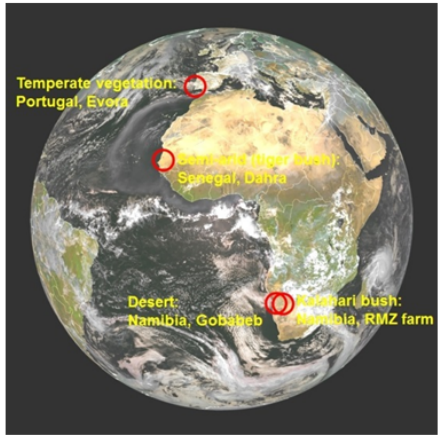
$$T_s \approx \left(\frac{c_2 \nu_c}{\ln\left(\frac{c_1 \nu_c^3 \tau_c(\theta) \varepsilon_c}{L_c(\theta) - L_c^{\uparrow}(\theta) - L_c^{\downarrow}(1-\varepsilon_c)\tau_c(\theta)} + 1 \right)} - \beta \right) / \alpha$$

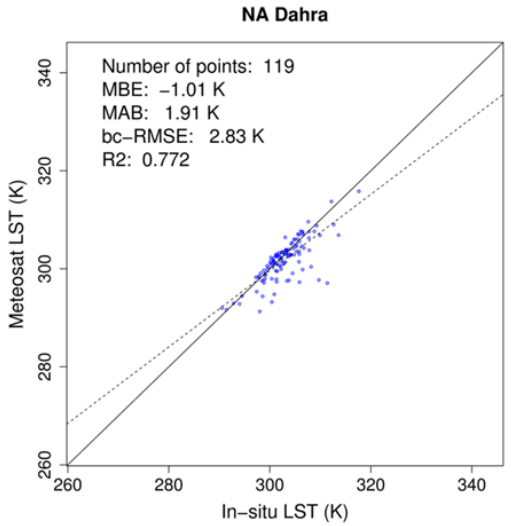
Physical approach based on radiative transfer modelling.

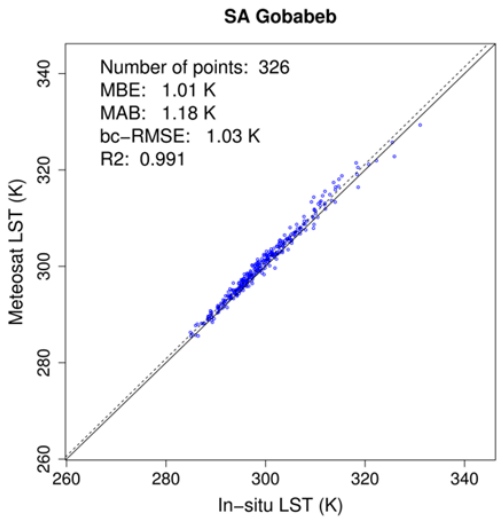
Highest possible accuracy and precision. To be used as stand alone CDR.

CM SAF LST Validation



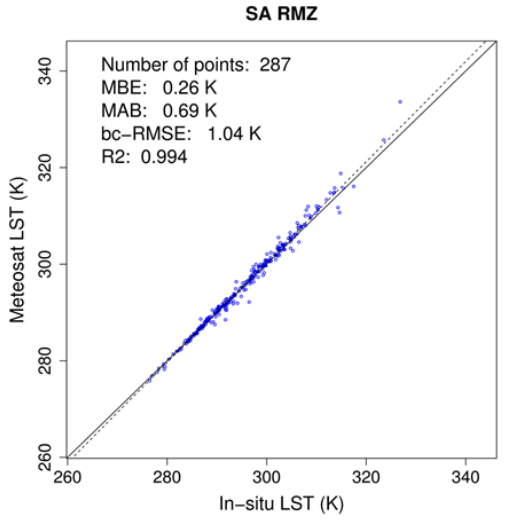






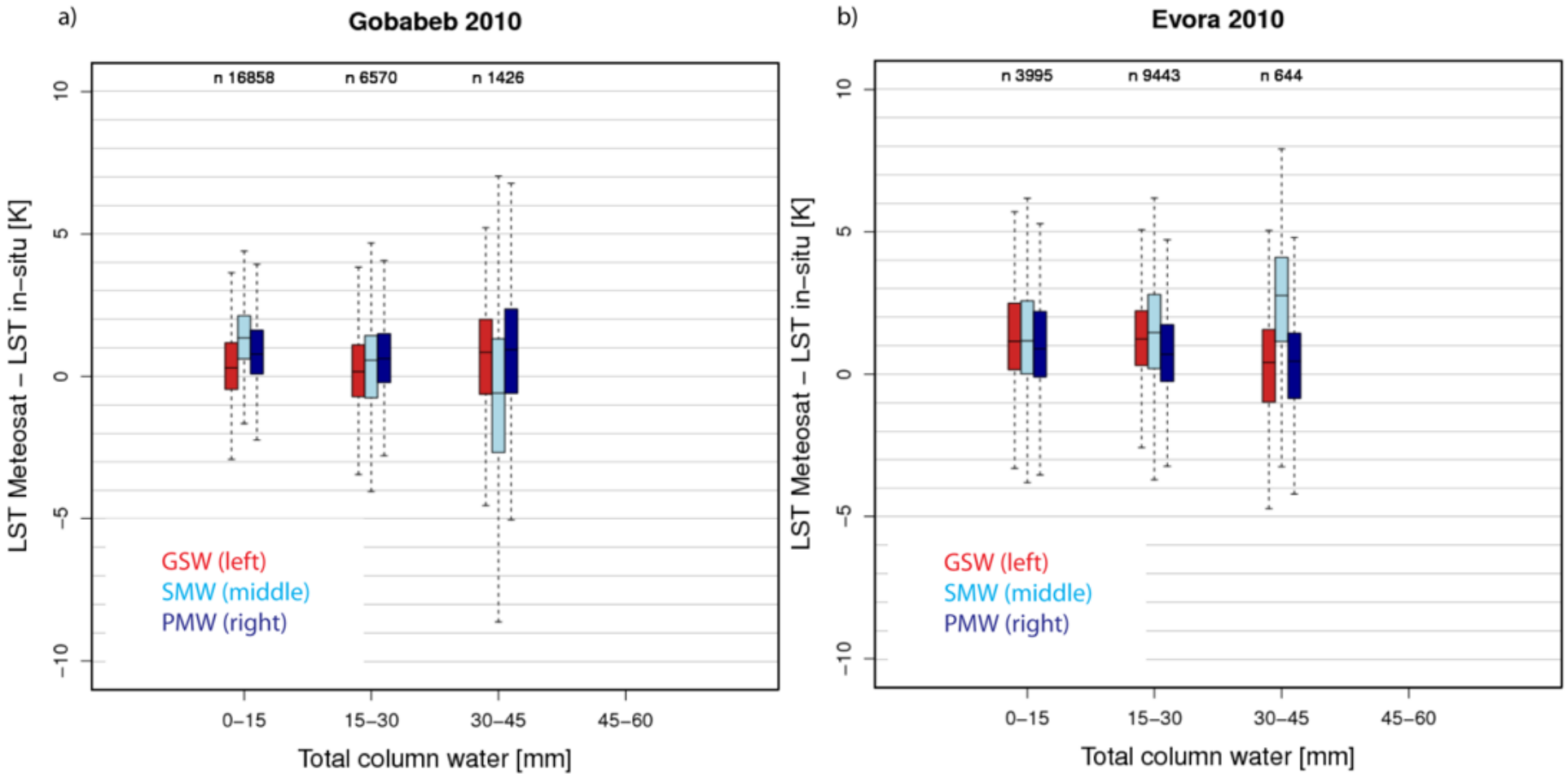
	Achieved Accuracy & Precision Physical LST model		
	Hourly	Daily	Monthly
Bias	0.8 K	0.7 K	0.8 K
Bc-RMS*	1.6 K	1.2 K	0.5 K

*bias-corrected root-mean-square difference

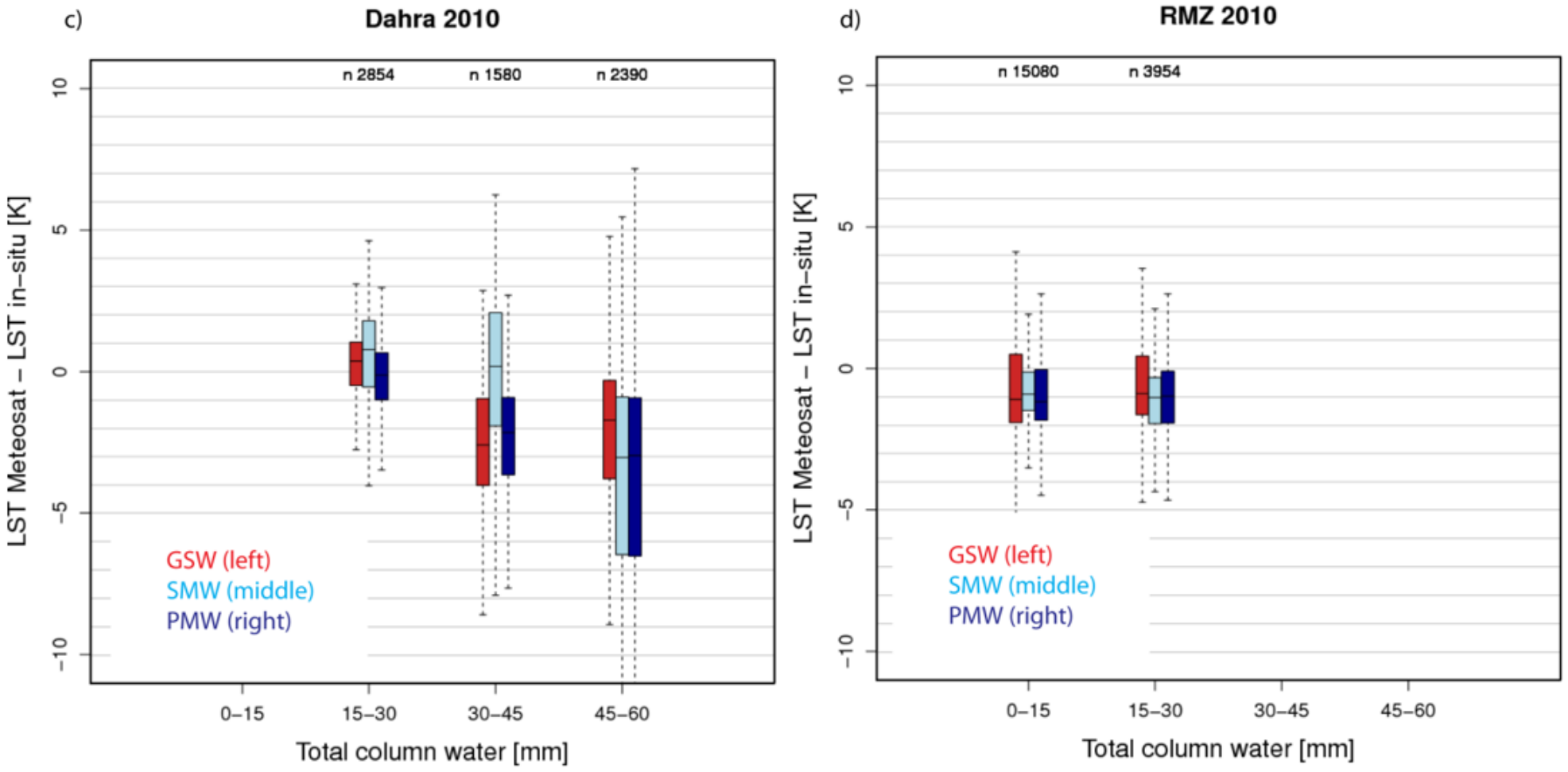


Accuracy and precision < 1.5 K, despite very moist atmospheres and satellite viewing angles.

CM SAF LST Validation

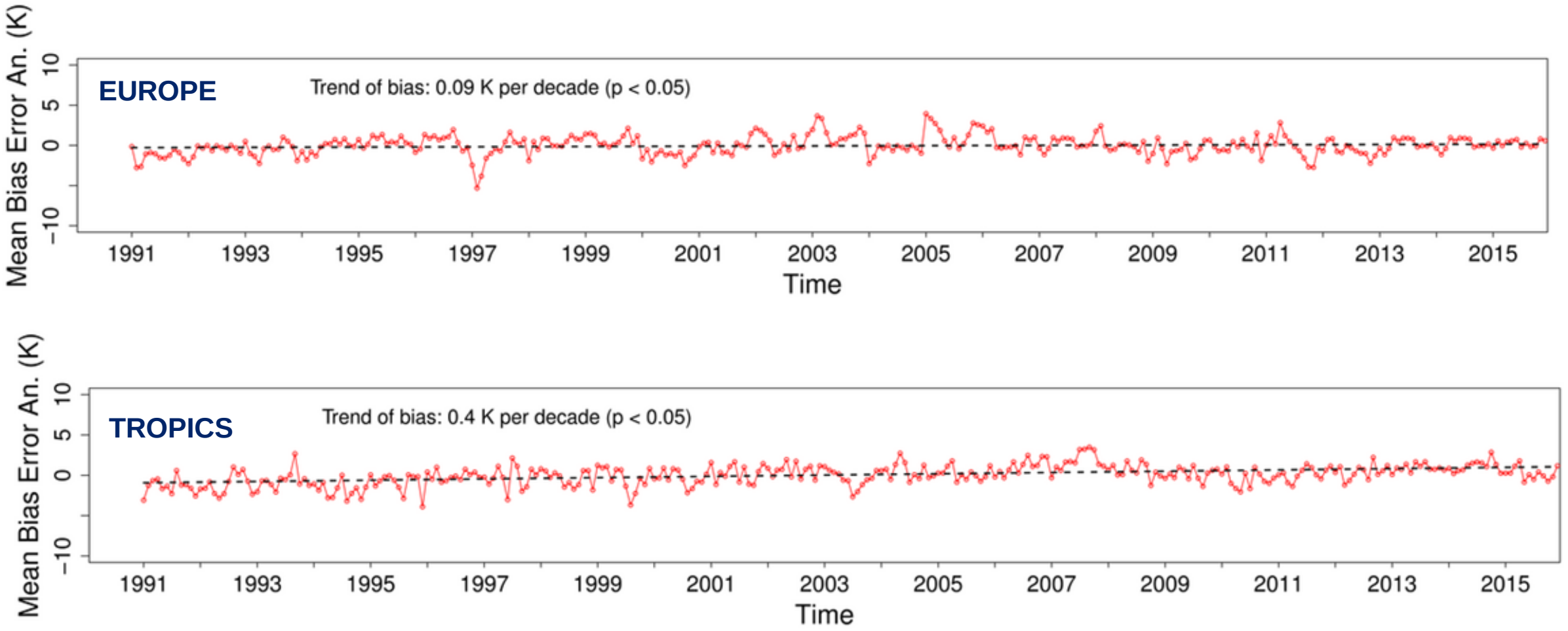


CM SAF LST Validation

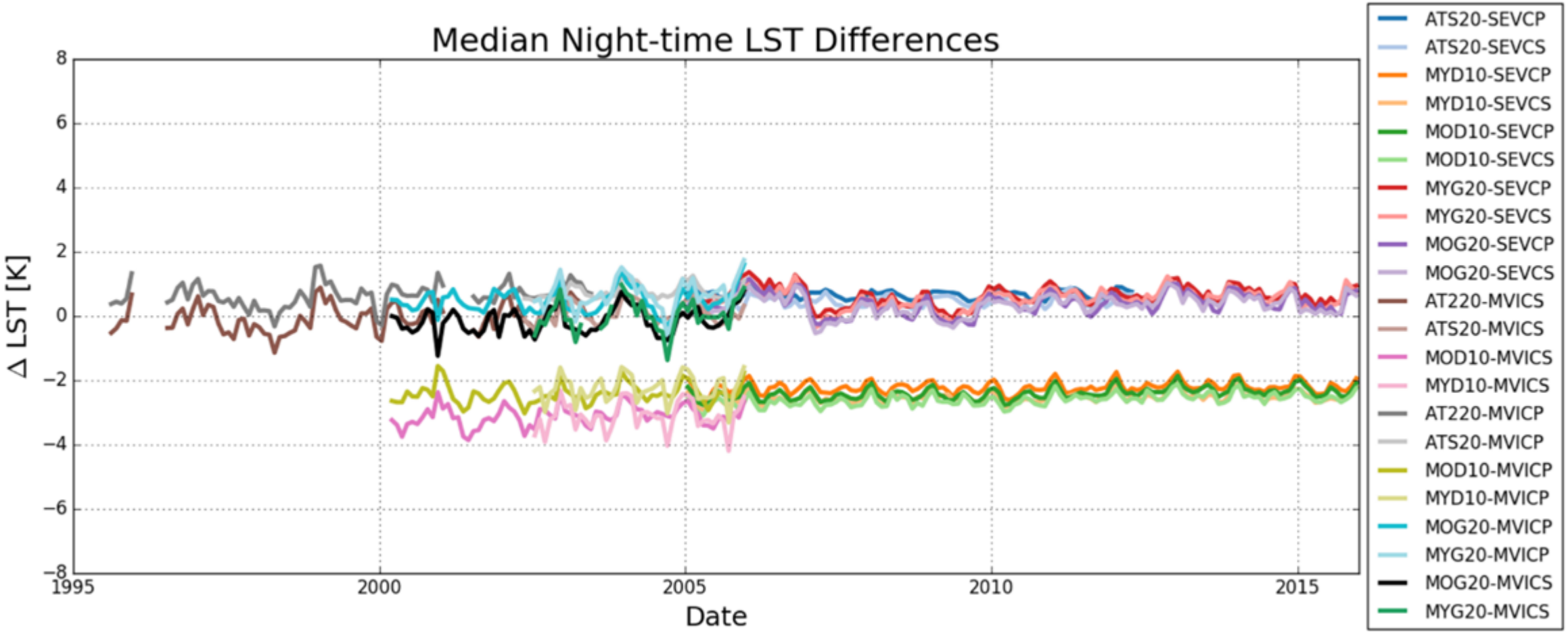


CM SAF LST Validation

Meteosat CM SAF LST minus ECMWF ERA-Interim Skin Temperature



CM SAF LST Validation



Time series of monthly median day/night CM SAF LST differences relative to ATSR2, (A)ATSR and MODIS (Aqua and Terra).

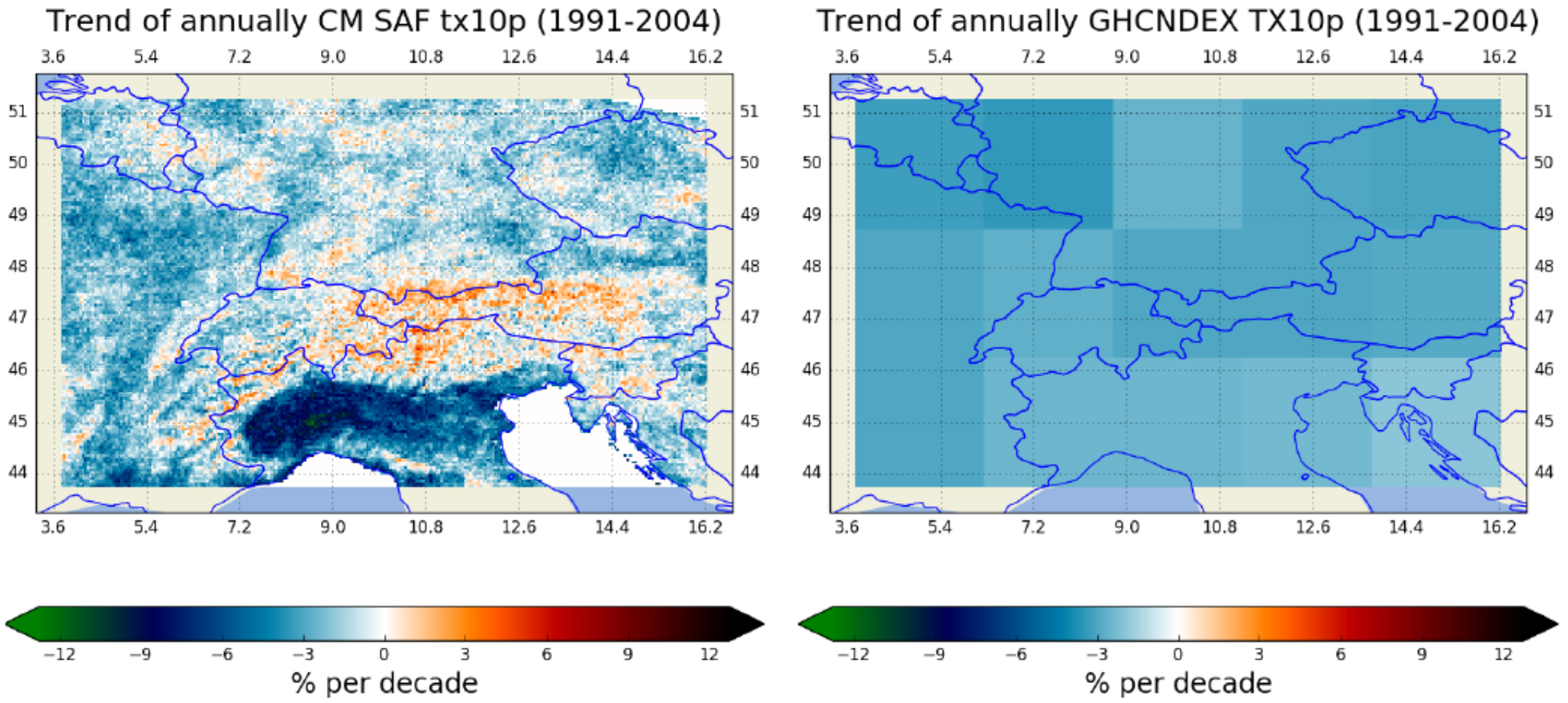
@ Darren Ghent & team, University of Leicester

CM SAF versus LSA SAF

	CM SAF LST	LSA SAF LST
Algorithm	Single Channel LST retrieval	Two Channel LST retrieval
Temporal Resolution	Hourly, back to 1991	Hourly, back to 2004
Spatial Resolution	5 km x 5 km	3 km x 3 km
Accuracy & Precision	< 1.5 K (despite very moist atmospheres)	< 1.5 K
Temporal Stability	0.1 K to 0.4 K/dec.	NN
Limitations	Static Emissivity Data 100% dependency on ECMWF model data for the atmospheric correction	Dynamic Emissivity Atmospheric correction can also be estimated from satellite data

Application: Heat Climate Extrem Indices

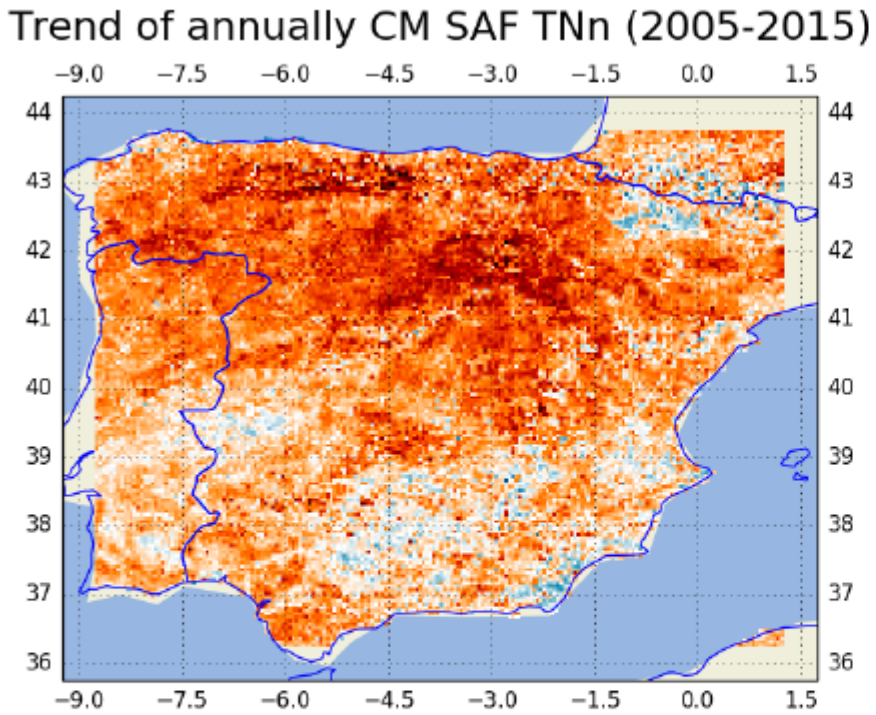
Number of Cool Days (percentage of days when T < 10th percentile)

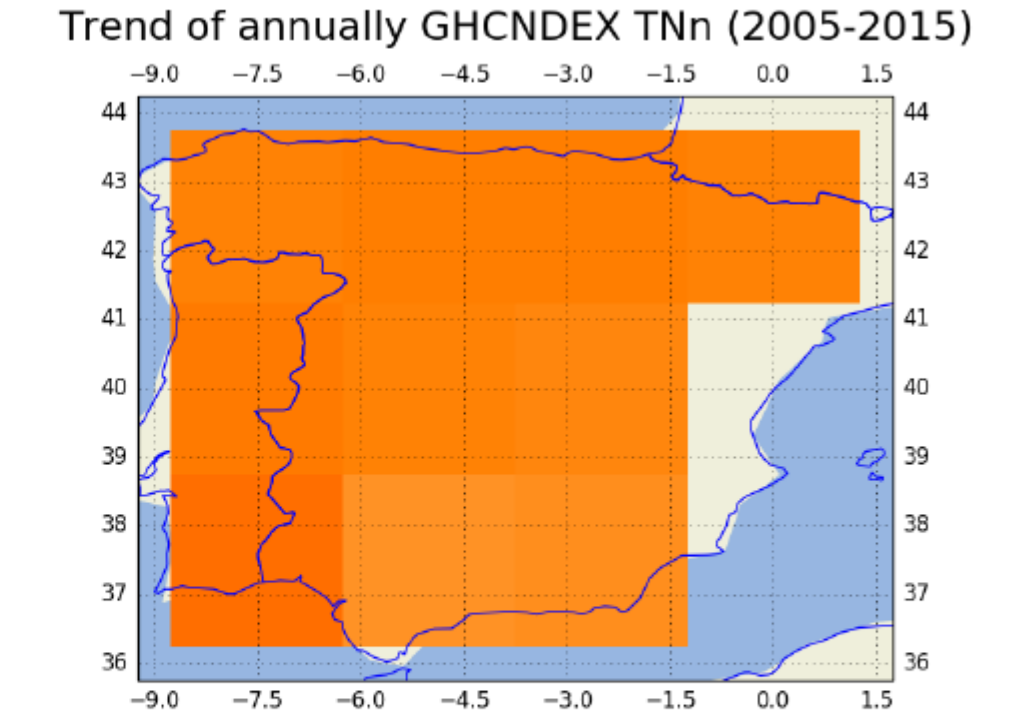


@ Veronika Pörtge, UK MetOffice Hadley Centre

Application: Climate Heat Indicators

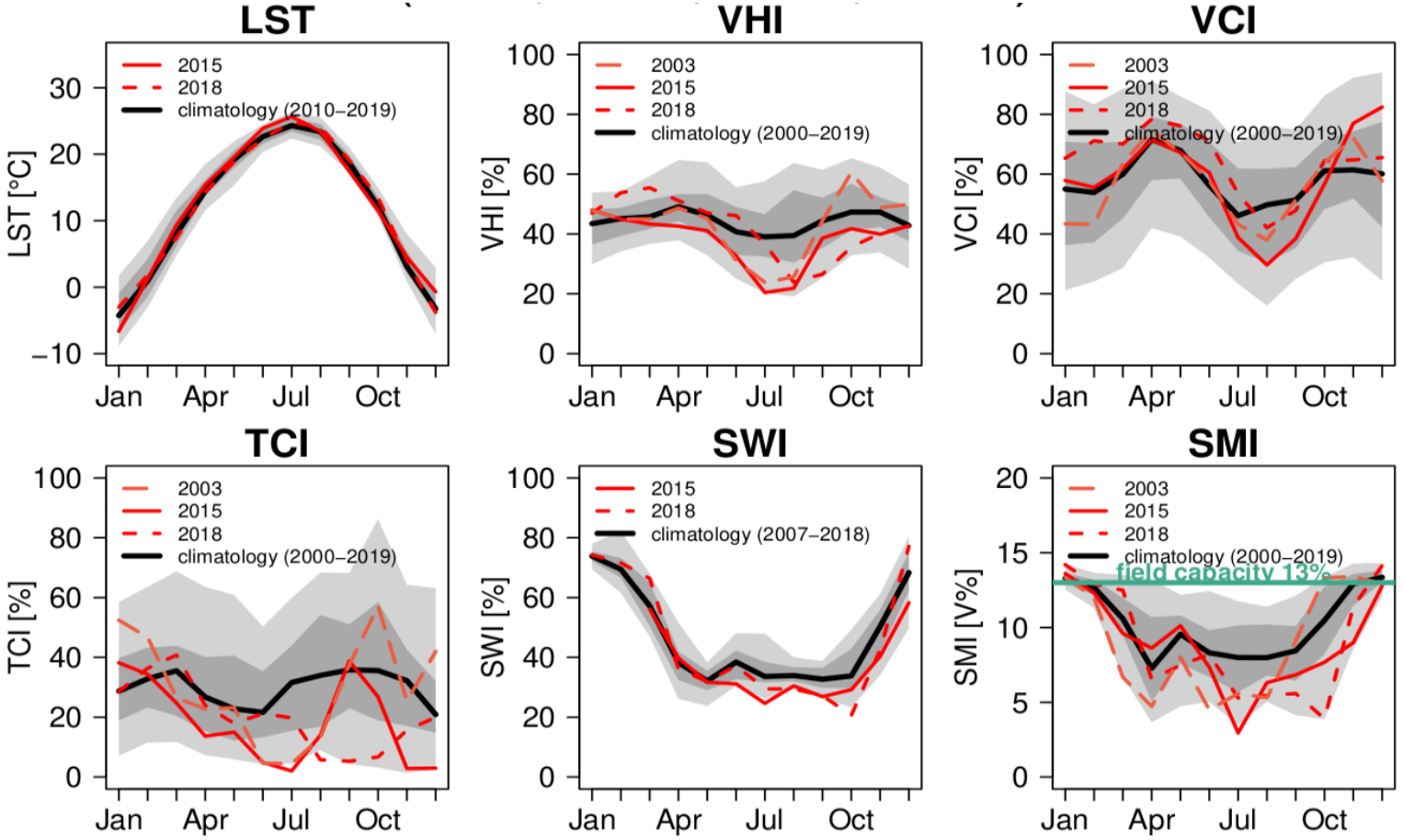
Coldest Daily Minimum Temperature per Year





@ Veronika Pörtge, UK MetOffice Hadley Centre

Application: Drought Monitoring in Switzerland



Different drought indicators during the dry years 2003, 2015 and 2018 (red lines) and their climatology in grey and black (dark grey shading: 25%-75% range; light grey shading: 5-95% range; black line: median).

LST Land Surface Temp.

TCI $$TCI_j = \frac{T_{max} - Ts_j}{T_{max} - T_{min}} \times 100\,\%$$

VCI $$VCI_j = \frac{NDVI_j - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \times 100\,\%$$

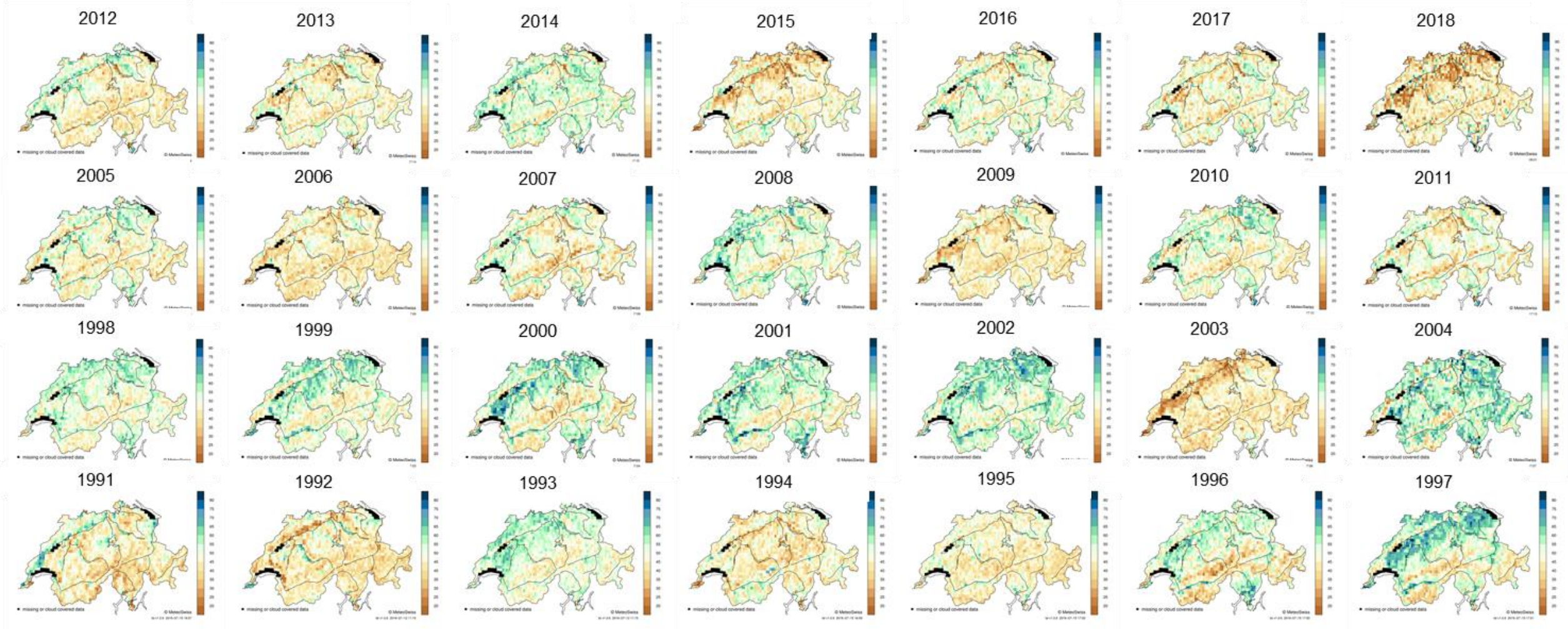
SWI Soil Moisture Satellite

SMI Soil Moisture Ground

@ Annkatrin Burgstall, MeteoSwiss

Application: Drought Monitoring in Switzerland

Vegetation Heat Index (VHI) in Switzerland using CM SAF LST & NOAA NDVI



Outlook: Next project phase (2022 to 2027)

- 2022: Release of the new CM SAF LST TCDR v. 2.0 for the new WMO norm period 1991 to 2020
- Further collaboration with EUMETSAT on Meteosat calibration
- Statistical tuning of the CM SAF MVIRI versus LSA SAF SEVIRI real-time data

Summery

- Long-term LST TCDR based **on MFG and MSG** back to 1991
- CM SAF uses a single channel LST retrieval approach for both MVIRI and SEVIRI to ensure consistency
- Climate applications:
  - Climate indicators for e.g. heat and drought monitoring
  - Climate analysis in anomaly space
- New release in 2022 with improved temporal stability

Wanted

Beta testers for our new CM SAF **long-term** LST CDRs v2.0 from all corners of Europe and Africa!

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