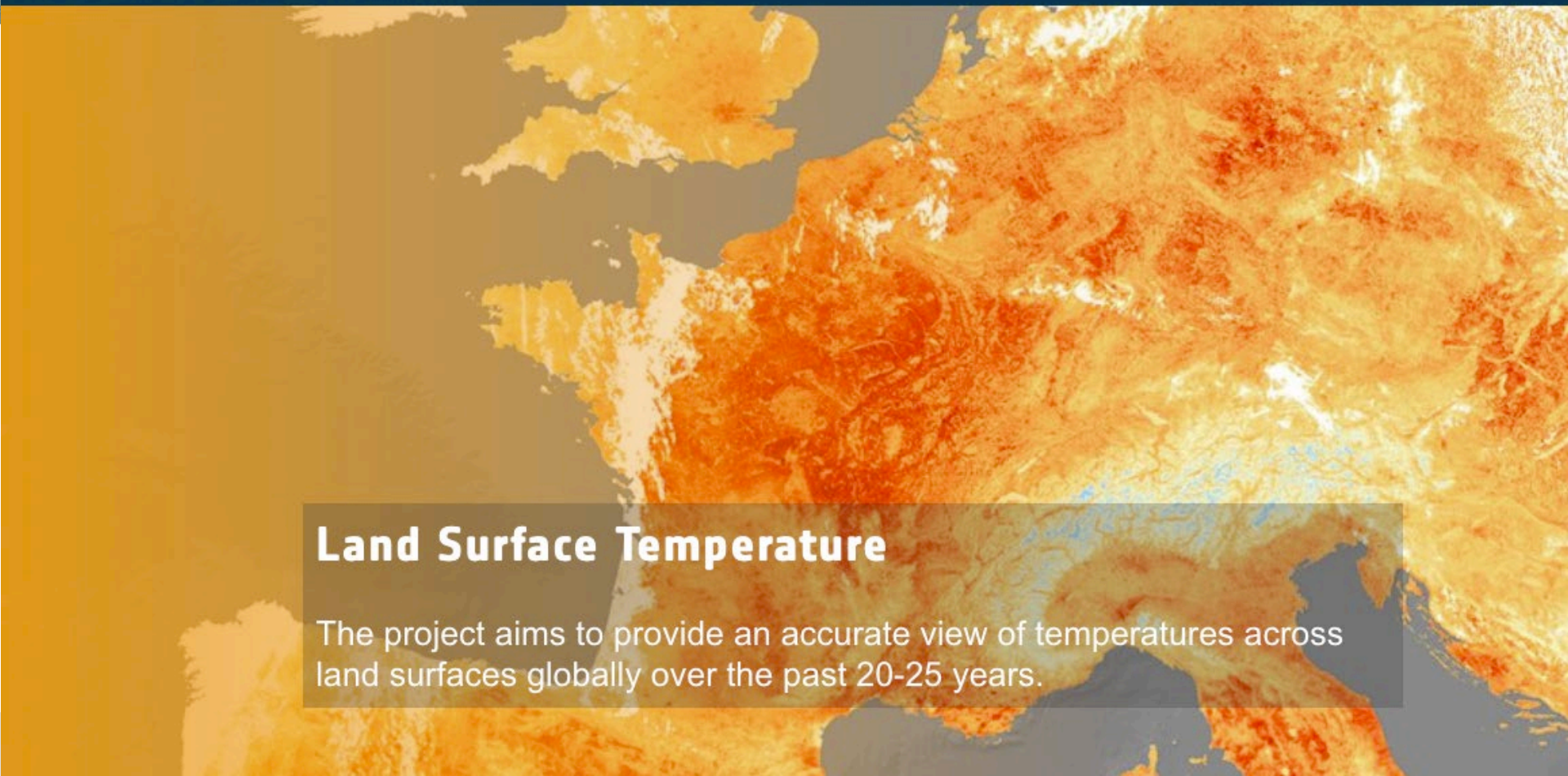
climate change initiative

→ LAND SURFACE TEMPERATURE

A GLOBAL DATA RECORD OF 'ALL WEATHER' LAND SURFACE TEMPERATURE (LST) FROM THE ESA CLIMATE CHANGE INITIATIVE (CCI)

land surface temperature cci

Carlos Jimenez, Catherine Prigent, Samuel Favrichon



Land Surface Temperature

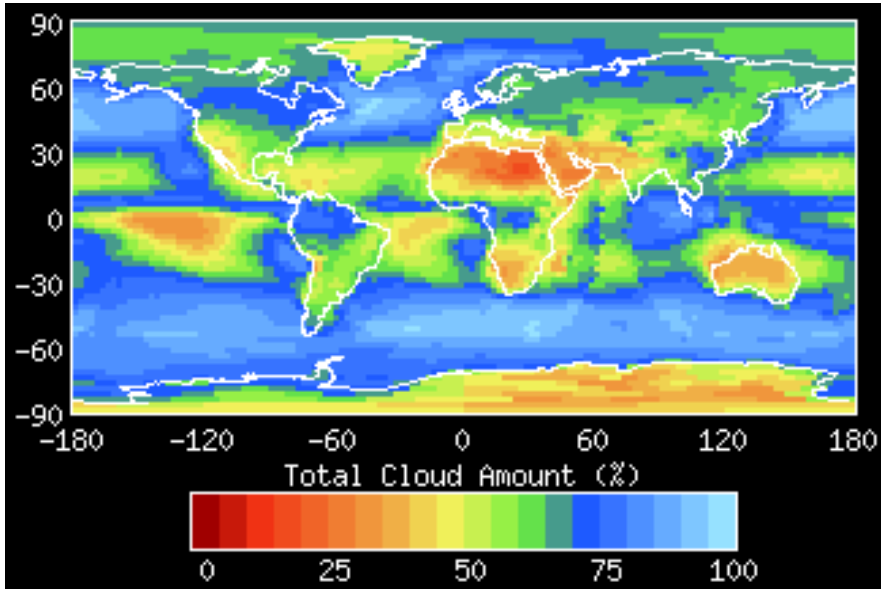
The project aims to provide an accurate view of temperatures across land surfaces globally over the past 20-25 years.

LST-CCI MW Product: **Motivation**

- How to obtain reliable estimates of all-weather LST?

  - No routine in situ measurements of land surface skin temperature (LST)
  - LST traditionally measured from thermal infrared
    - the most direct estimate
      ~ e_{IR} LST^4
      with emissivity e_{IR} close to 1
      (varying on a rather limited range)

    but, measurements are
    <u>not possible below clouds</u>



[ISCCP, Rossow and Schiffer, BAMS, 1999]

LST-CCI MW Product: **Challenges**

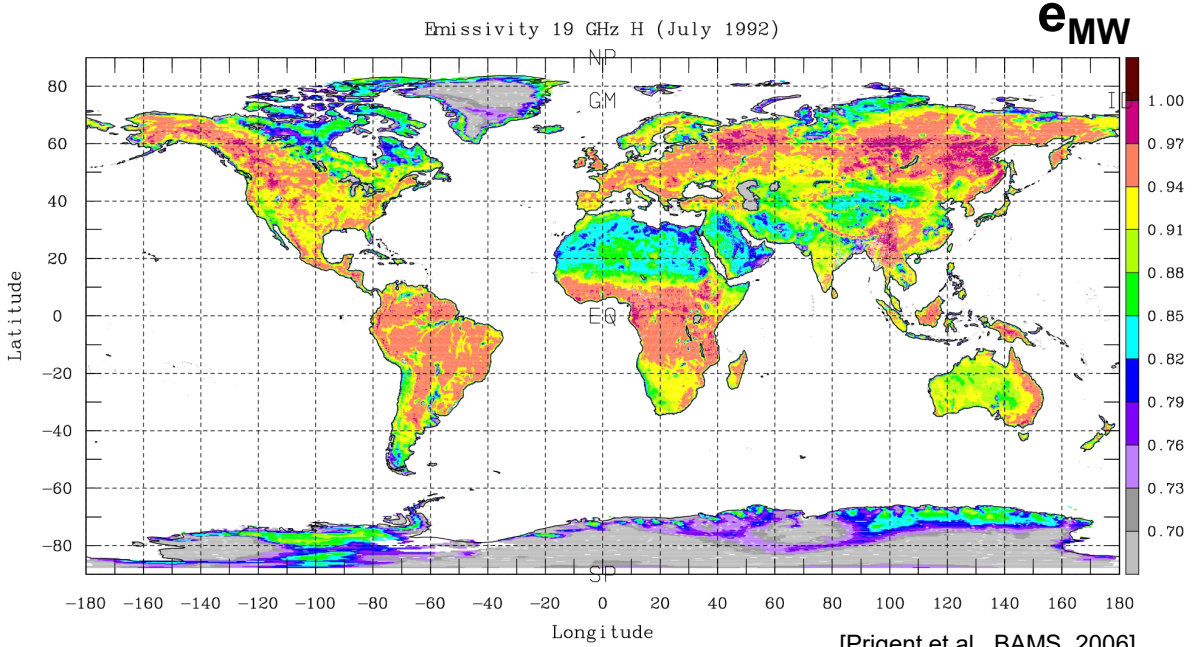
- How to obtain reliable estimates of all-weather LST?

▪ Passive microwaves in window channels can see through most clouds, but

(1) Microwave frequencies have a larger sensitivity to the **emissivity** e_{MW},

$Tb \sim e_{MW}\ LST$

and the emissivity e_{MW} varies with vegetation, soil moisture, snow…



[Prigent et al., BAMS, 2006]

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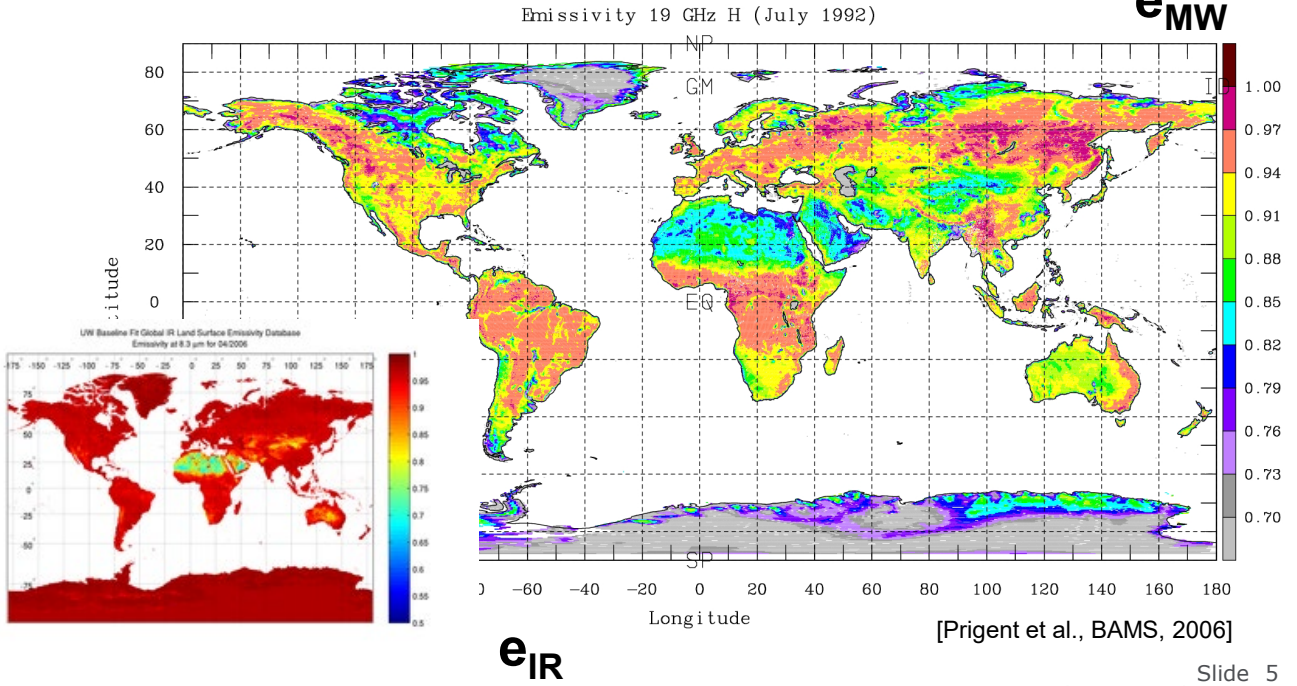


e_{MW}

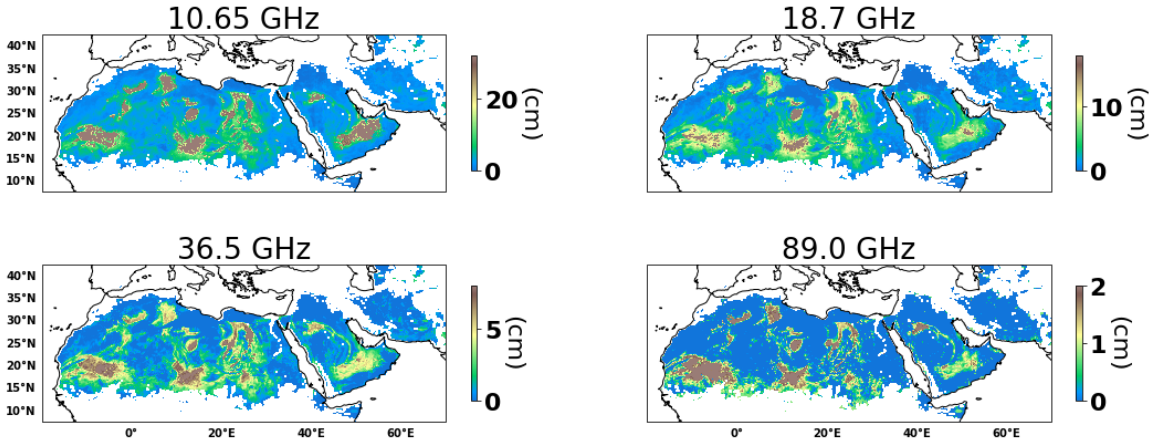
e_{IR}

[Prigent et al., BAMS, 2006]

- How to obtain reliable estimates of all-weather LST?

▪ Passive microwaves in window channels can see through most clouds, but

(2) Lower microwave frequencies have **larger penetration depth.** In that case, it is not the skin temperature that is measured but a depth-integrated LST.



Estimation of the penetration depth of the microwave signals, over North Africa, from a combination of ERA5 reanalysis and GMI observations

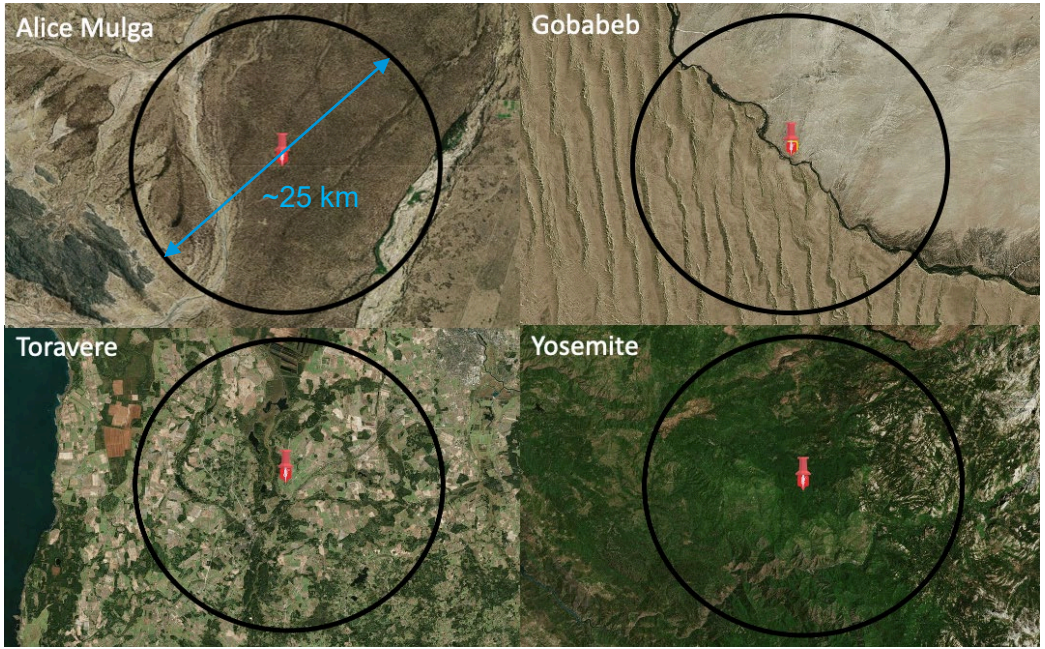
[Favrichon, PhD thesis, 2021]

LST-CCI MW Product: **Challenges**

- How to obtain reliable estimates of all-weather LST?

▪ Passive microwaves in window channels can see through most clouds, but

(3) Larger wavelengths have **coarser spatial resolutions.** The measurement integrates emission from different surface conditions.



Examples of typical footprints of a MW instrument (SSM/I) around 4 sites measuring in-situ LST

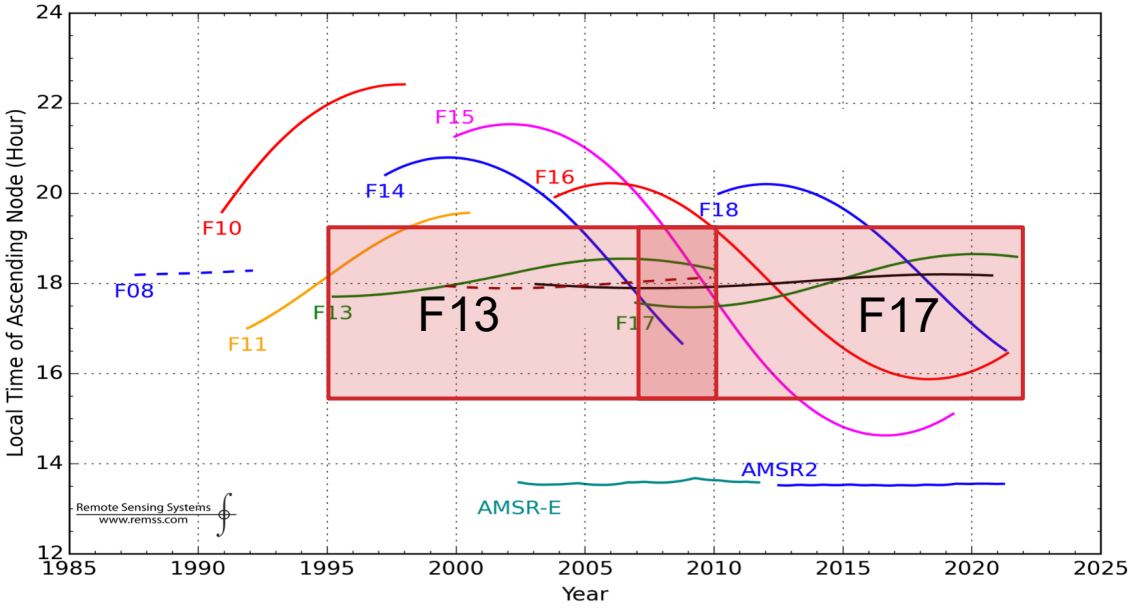
LST-CCI MW Product: **Developments**

- Building a long data record of MW LST for climate applications

The Special Sensor Microwave/Imagers (SSM/I) and the Special Sensor Microwave Imager Sounder (SSMIS) instruments are selected to provides a first 25-year record of "all weather" LST.

SSM/I (F13) – SSMIS (F17)

CHALLENGE: These sensors are operational weather satellites not originally designed with the instrumental and orbital stability constrains required to study decadal climate trends.



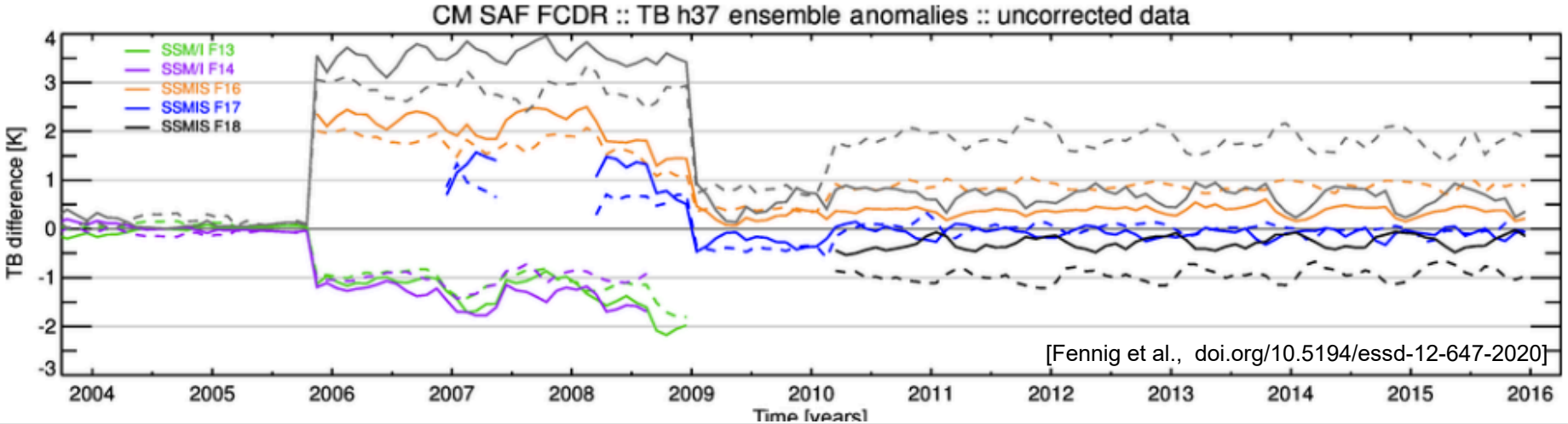
LST-CCI MW Product: **Developments**

- Building a long data record of MW LST for climate applications

(1) Brightness temperatures

Need to have inter-calibrated sensors with known calibration anomalies and instrumental issues corrected.

The Fundamental Climate Data Record (**FCDR**) of Microwave Imager Radiances from the EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) is adopted.



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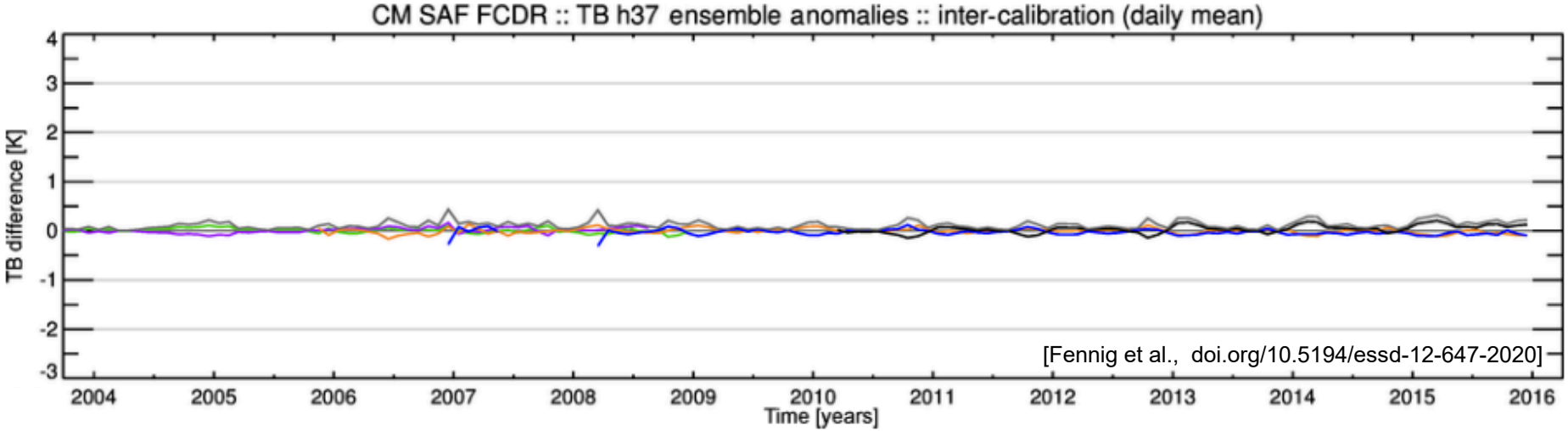


LST-CCI MW Product: **Developments**

- Building a long data record of MW LST

(2) Retrieval algorithm

- The inversion of radiances is based on a fast neural network (NN) algorithm trained on a database of detailed inversions of real observations.
- Inputs to the NN are the observed L1 radiances at 18, 22, 36, and 89 GHz, along with the precalculated emissivities. The NN outputs are the retrieved L2 LST and corresponding uncertainty in the observation swath.

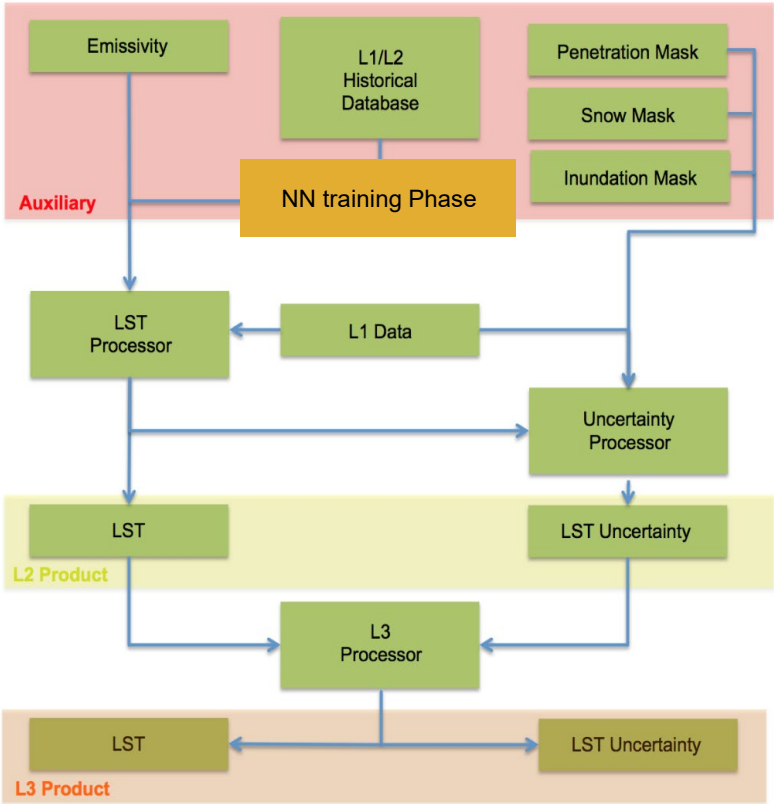
L2P product

- The L2 LST is then remapped to a regular 0.25x0.25 degrees and distributed.

L3C product

Only using radiances and and pre-calculated emissivities to reduce the dependence on **ancillary data** inhomogeneities and artifacts.

[Prigent et al., JGR, 2016; Jimenez et al., JGR, 2017; Ermida et al., JGR, 2017]

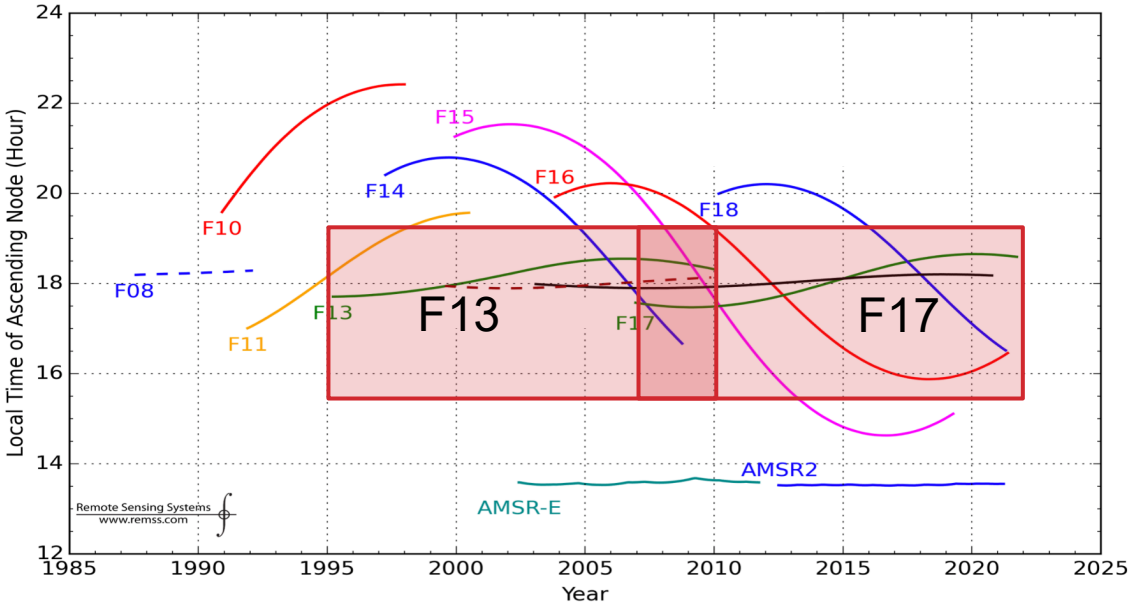


- Building a long data record of MW LST for climate applications

(3) Time correction

The orbital drift of the satellite platforms results in variations of the overpass local time during the lifetime of the instrument.

To facilitate climate studies, a temperature adjustment is available to have all LST estimates corrected to a fixed local time **6AM/6PM**.

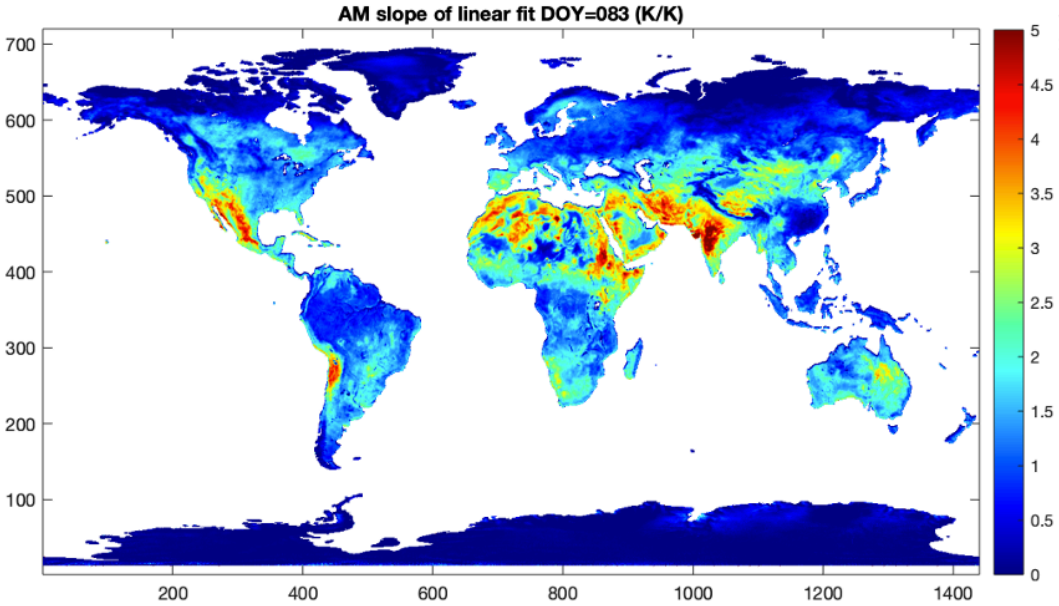


LST-CCI MW Product: **Developments**

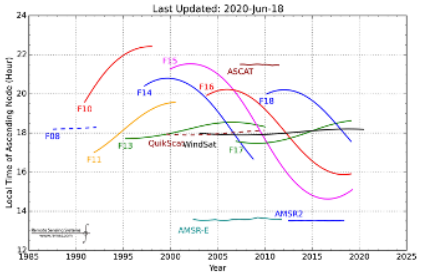
- Building a long data record of MW LST for climate applications

(3) Time correction

The time correction is based on calculating for each day-of-year and location an averaged slope from the F16-F13 and F16-F17 LST differences. LST offset available in L3 product.



processing LST for F16 **(1)**



calculating SLOPE **(2)**

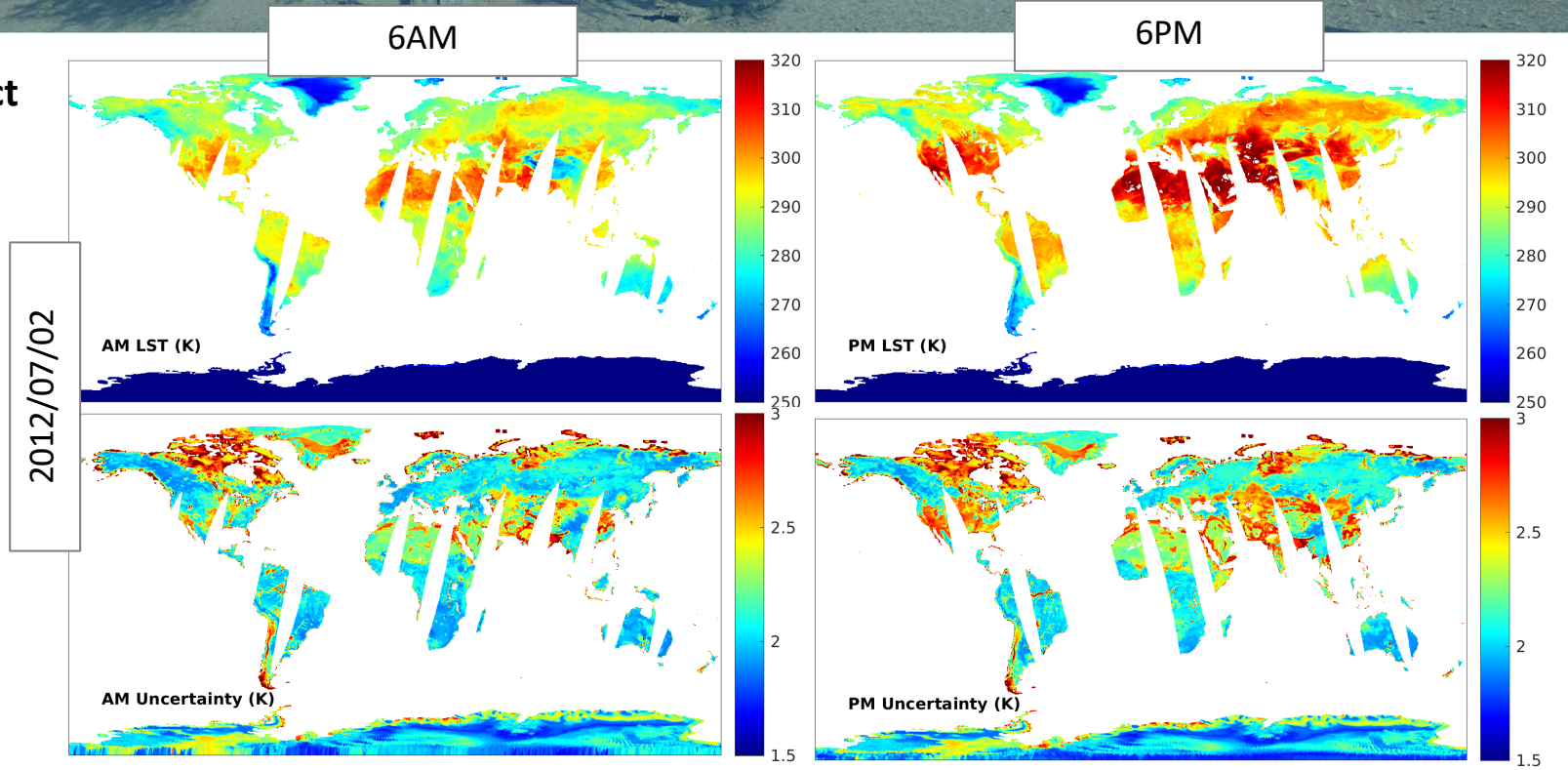
$$\frac{\blacktriangle LST}{\blacktriangle time}\ (LON,LAT,DOY)$$

F16-F13/F16-F17

correcting F13-F17 LST to 6 AM/PM **(3)**

LST-CCI MW Product: **Example**

L3C daily product



Larger **uncertainty** at locations with more challenging retrievals (e.g., varying emissivity, water presence, surface penetration)

L2P product– comparing with in situ LST from the GBVO of Copernicus Land Global Products [2016-2019]

Ground-Based Observations for Validation (GBOV) of Copernicus Global Land Products

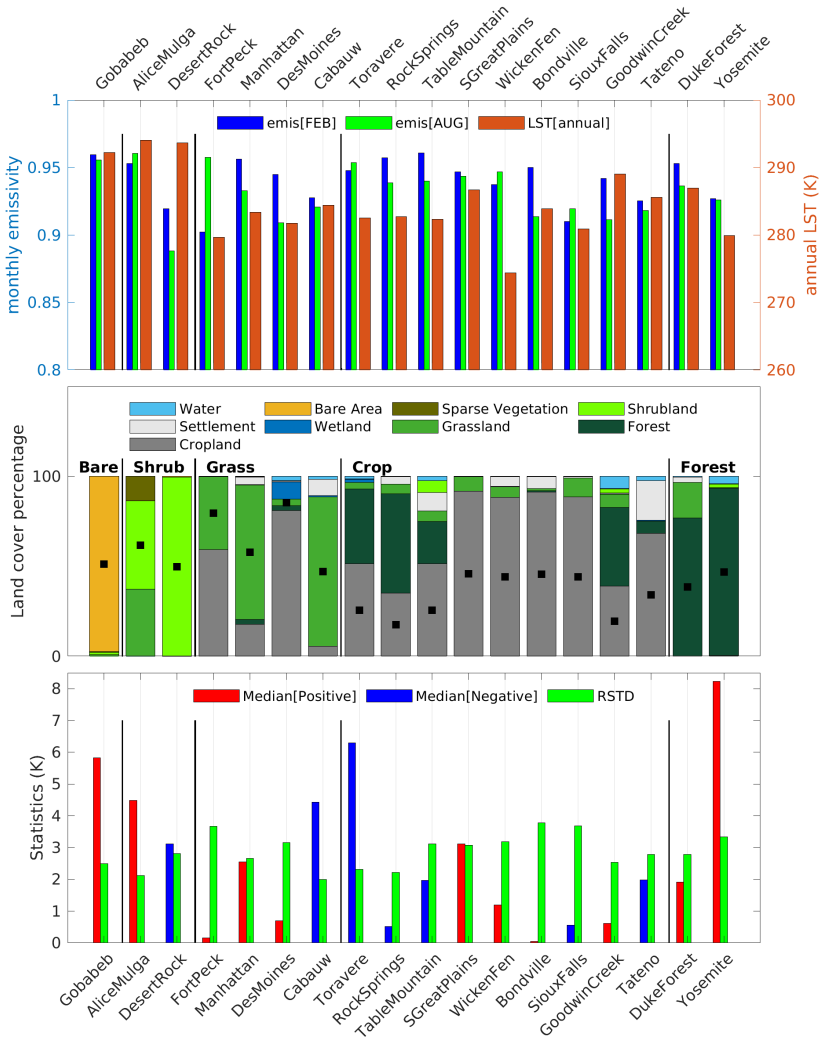
- 22 stations available, but 4 close to coastline removed.

LST-CCI MW Product:
Evaluation

- Statistics of the difference **$LST_{station}$ - LST_{MW}**
  [4 km max separation between station and L2 swath position]
  - Large surface inhomogeneity at the satellite footprint affects the comparisons.
  - Reasonable standard deviations, in the range ~2-4 K.
  - Large biases at some stations can indicate retrieval issues for specific conditions.

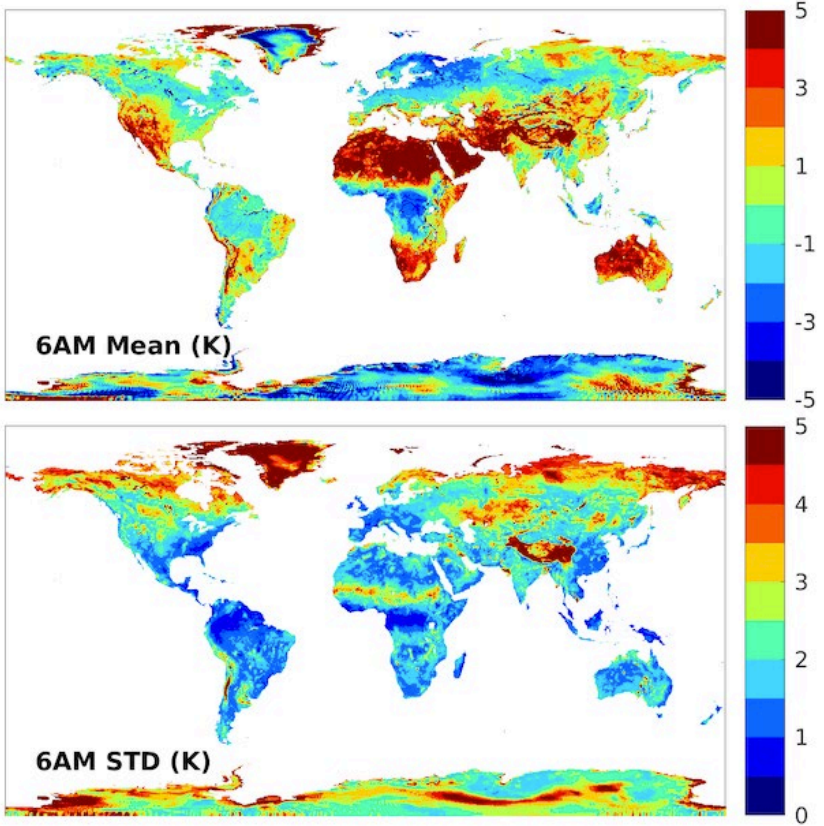
Informative evaluation, but **larger scale evaluation**, in time and space, is also needed to test the stability of the data record for climate studies.

[Jimenez et al., JGR, 2017]



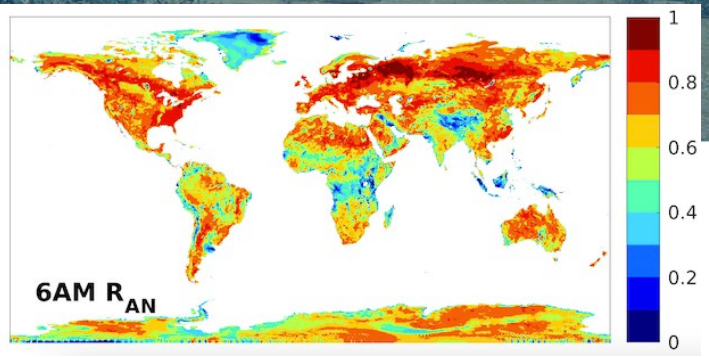
LST-CCI MW Product:
Large scale evaluation

- **L3C product [6AM/PM] –** comparing with reanalysis skin temperature from ERA5 [1996-2020]

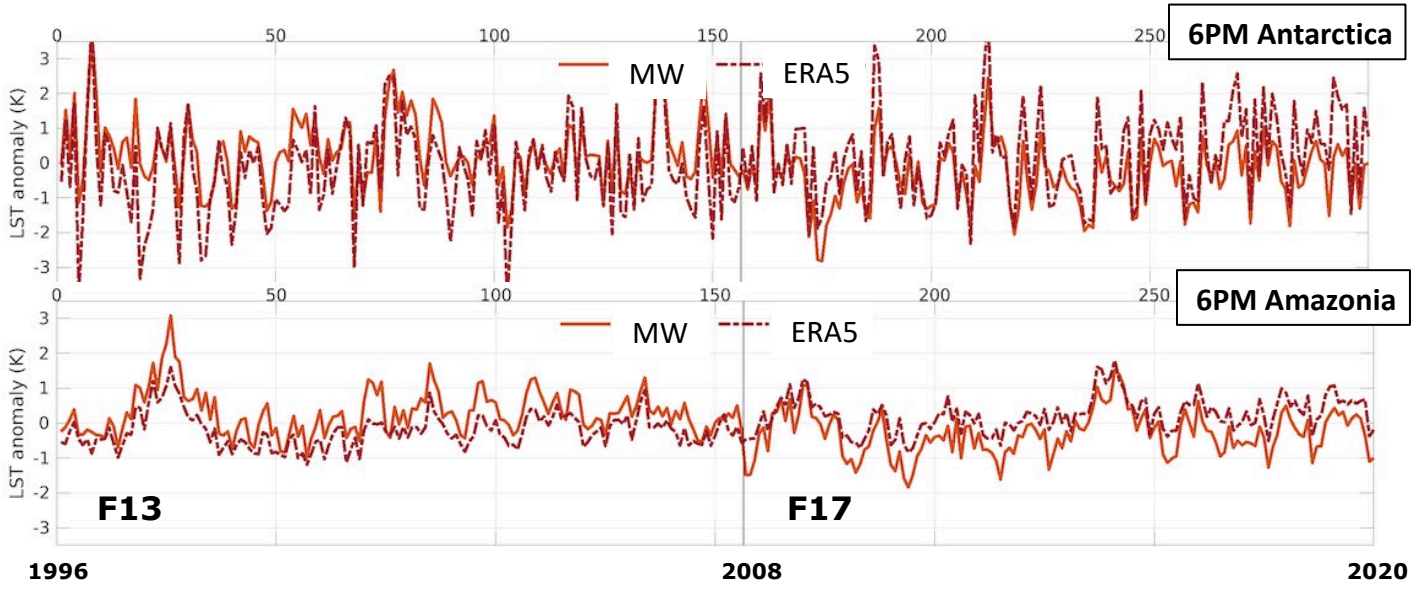


- Mean and STD of the MW LST and ERA5 SKT differences are reasonable, compared with other differences between satellite LST and SKT.
- Larger differences can be signaling potential issues either in the MW LST or in the reanalysis SKT (e.g., large biases in deserts).

LST-CCI MW Product:
Large scale evaluation



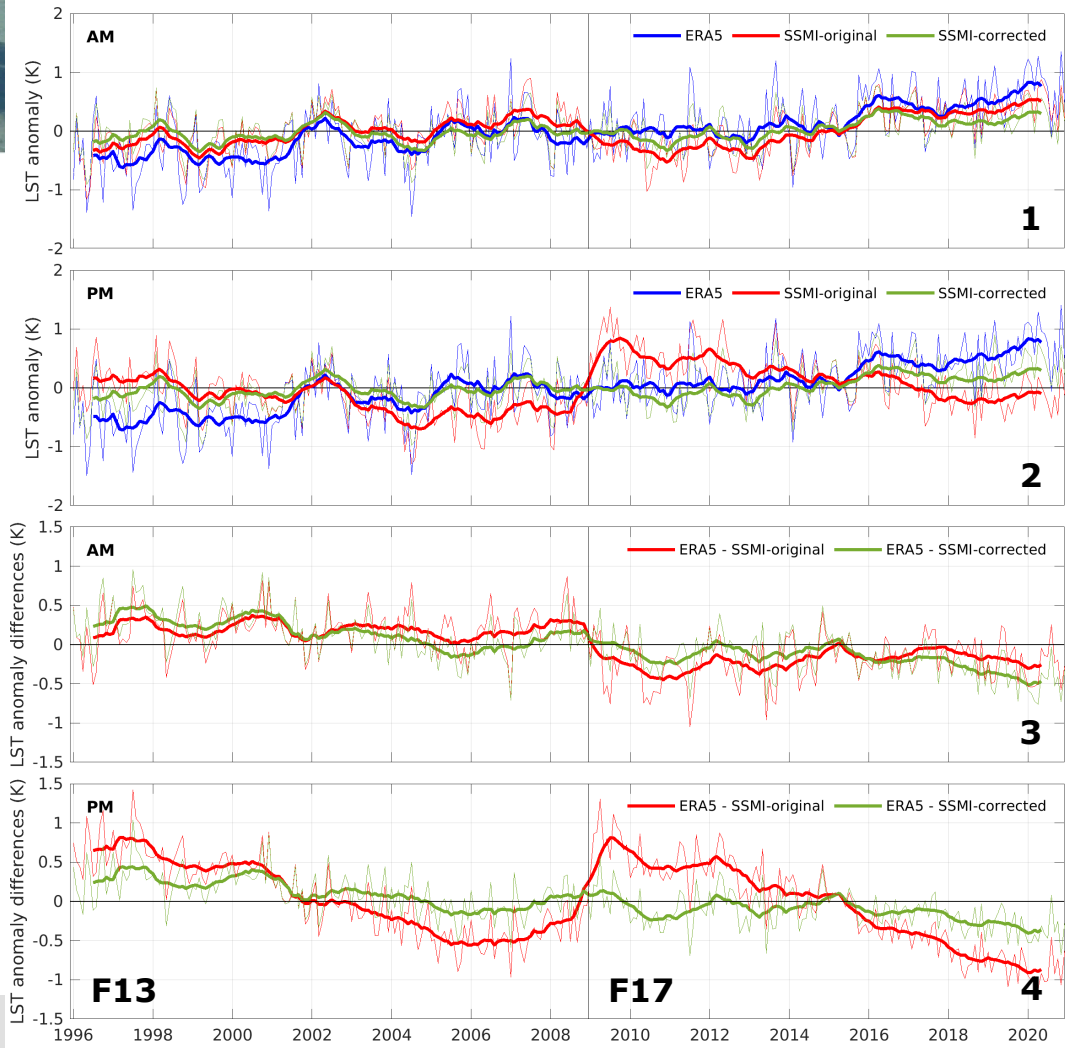
- **L3C product [6PM] –** comparing with reanalysis skin temperature from ERA5 [1996-2020]
  - Correlations on the anomalies (R_{AN}) suggest that inter-annual climate variability is well captured by the MW LST.



LST-CCI MW Product:
Large scale evaluation

- **L3C product [6AM/PM] –** comparing with reanalysis skin temperature from ERA5

- Calculating global LST and SKT anomalies (1,2) and their difference (3,4) to test **stability** of data record.
- Much more stable LST after time correction, but statistical tests still cannot discard the presence of non-climatic variations (taking ERA5 as reference).



LST-CCI MW Product: **Status**

- **Current activities** focus on extending the MW LST data record to also include AMSR ~1.30 AM/PM observations to allow sampling the diurnal cycle 4 times per day, improving the spatial resolution, and the long term stability,to facilitate climate applications.

- The product is publicly available from the **ESA Climate Office Open Data Portal**, together with the LST-CCI infrared products

  https://climate.esa.int/en/odp/

- All product information (methodology, uncertainty, evaluation) is available at the **ESA LST-CCI documents** site:

  https://climate.esa.int/en/projects/land-surface-temperature/key-documents/

- For any queries about the product, please contact **carlos.jimenez@estellus.fr**