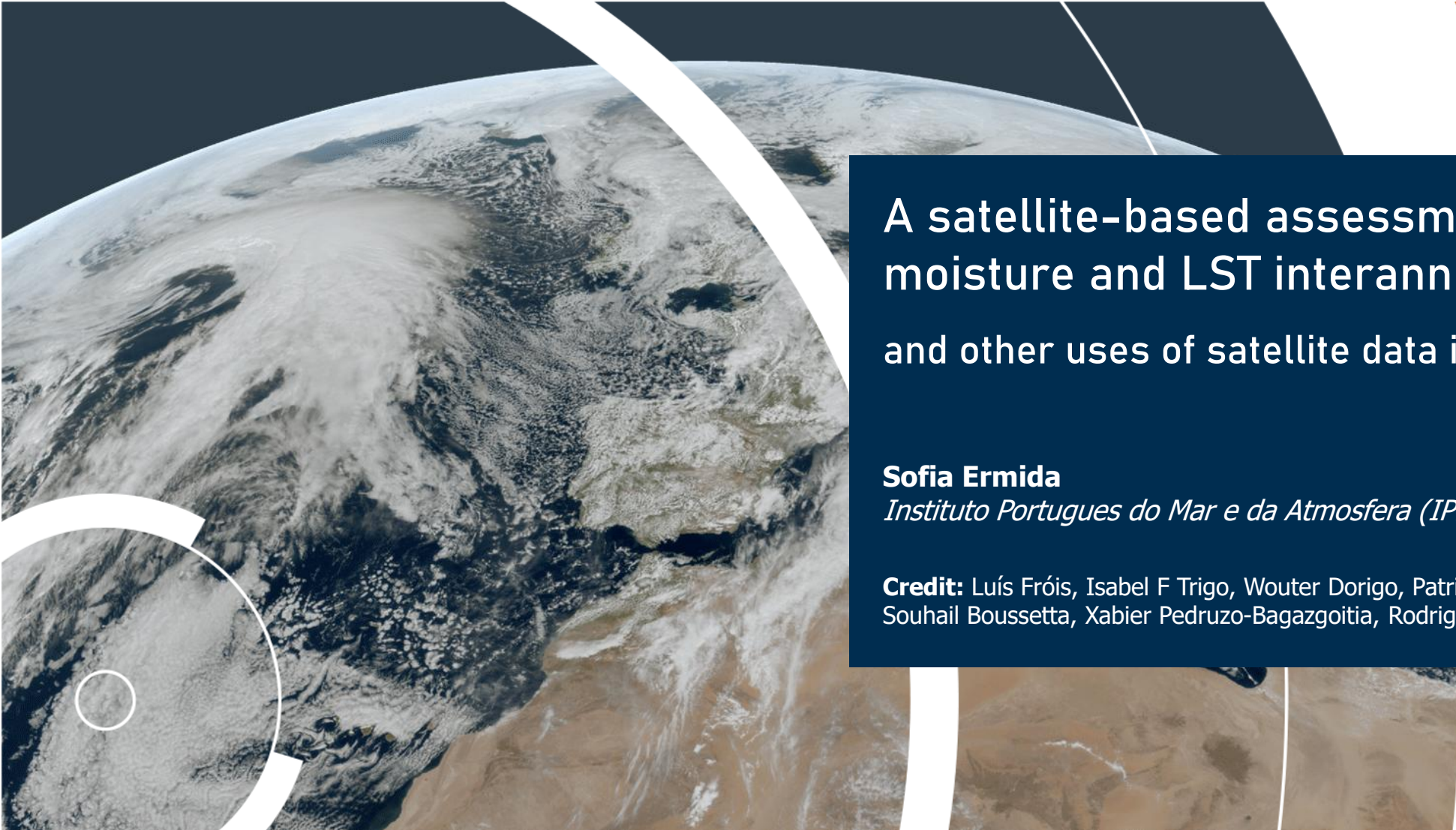




A satellite-based assessment of ERA5 soil moisture and LST interannual co-variability and other uses of satellite data in model development

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Credit: Luís Fróis, Isabel F Trigo, Wouter Dorigo, Patricia de Rosnay, Emanuel Dutra, Souhail Boussetta, Xabier Pedruzo-Bagazgoitia, Rodrigo Capitão, Gabriele Arduini



- Can we enhance the use of Earth Observations (EO) in land surface model development ?
- Routine use of **LST** for **model** and **ancillaries** evaluation? Can it guide model development?
- **Soil moisture, vegetation state and LST** are strong modulators of the surface energy balance?
 - How can we use this information from Earth Observations?



- Satellite:
 - LST: LSA-SAF MSG (15 min, 3km)
 - FVC: LSA-SAF MSG (daily, 3km)
 - SM: C3S combined (passive+active) product (daily, 25km)
- ERA5:
 - Skin temperature
 - soil water content (first model soil layer)

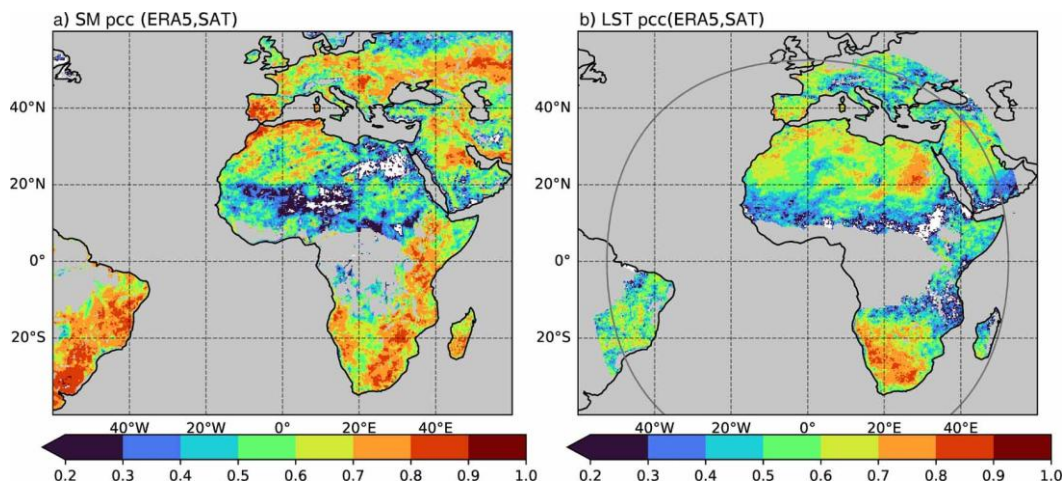
Methods:

- Monthly mean diurnal cycle of LST: monthly mean maximum – monthly mean
- Computed monthly anomalies using the 2004-2023 normal
- Correlation weight score: monthly Spearman's rank correlations + statistical significance
 - **Ncovar**: number of months with significant interannual correlation between LST and SM

Frois et al. (2026): A satellite-based assessment of ERA5 soil moisture and land surface temperature interannual co-variability, Environ. Res. Lett. 21 024024. <https://10.1088/1748-9326/ae3789>

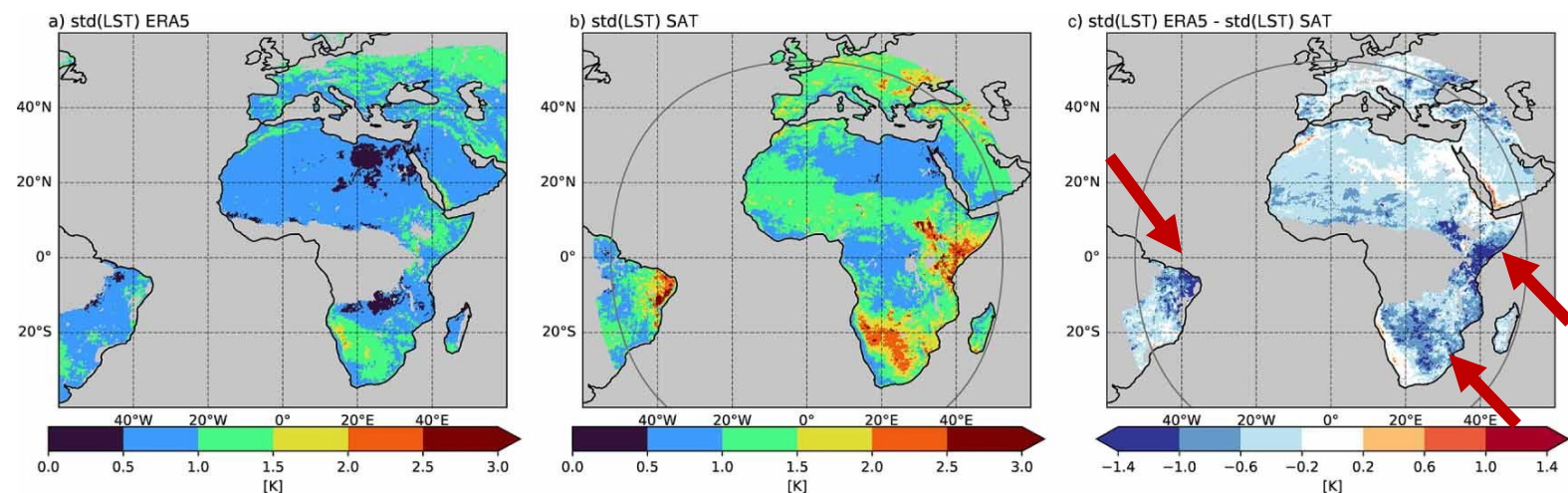


Correlation between ERA5 and SAT monthly anomalies



- Correlations mostly above 0.6
- Correlations of LST tend to be lower than those of SM

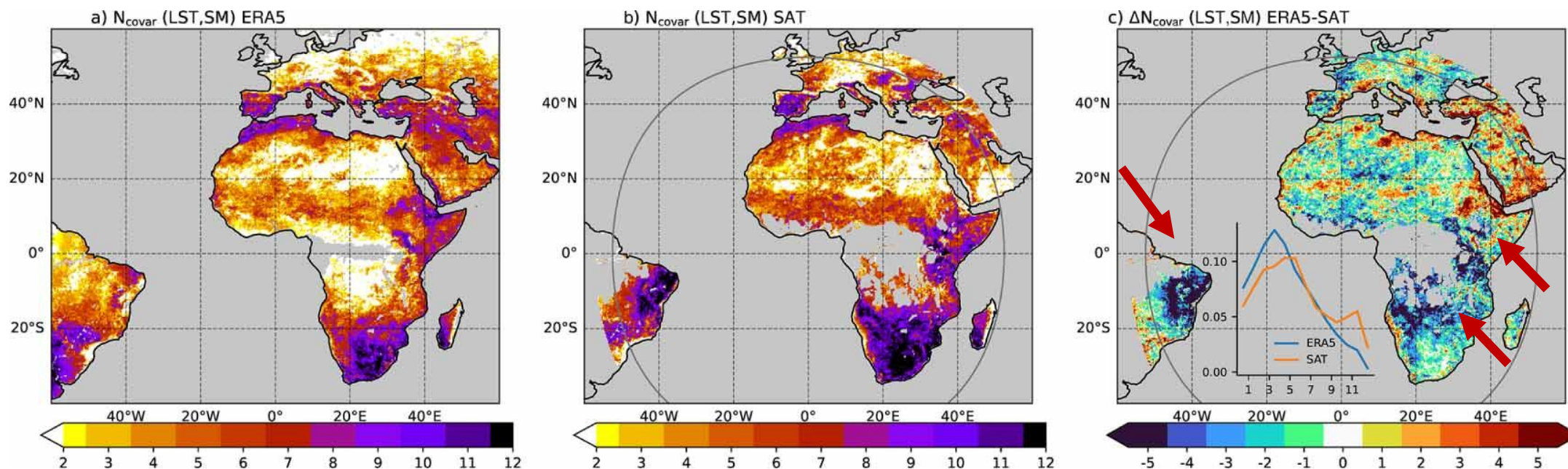
Standard deviation of LST monthly anomalies



- Interannual variability of ERA5 LST is lower than the satellite



Ncovar: LST-SM interannual co-variability (ERA5 vs SAT)



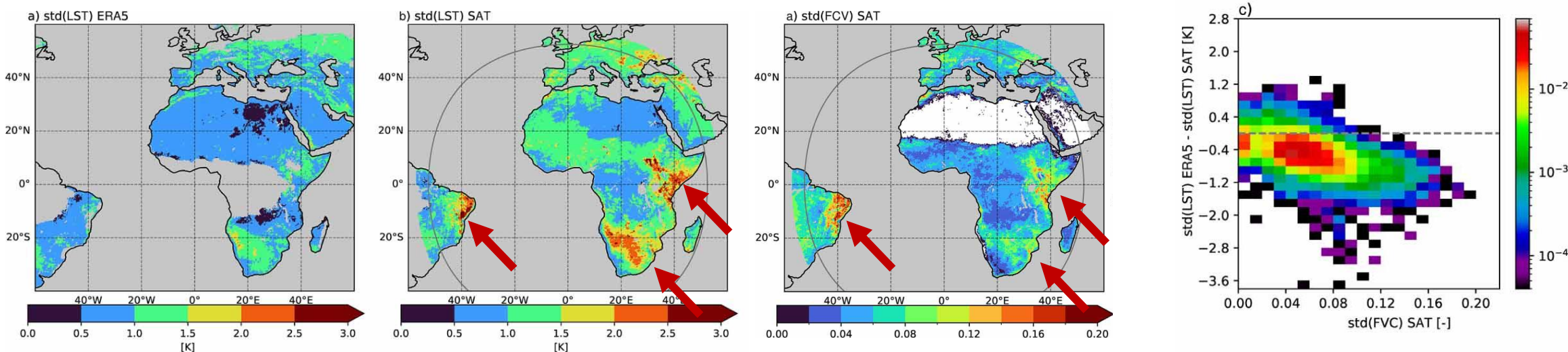
- Good overall agreement between ERA5 and Satellite
- Strong underestimation of Ncovar by ERA5 in some regions. Why?

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How relevant is the representation of Vegetation Interannual Variability?

Standard deviation of LST and FVC monthly anomalies



- Hot spots of vegetation interannual variability:
 - Lower variability of ERA5 LST amplitude
 - Weaker coupling between ERA5 SM and LST
- Discrepancies in Ncovar could be related to the absence of vegetation interannual variability in ERA5

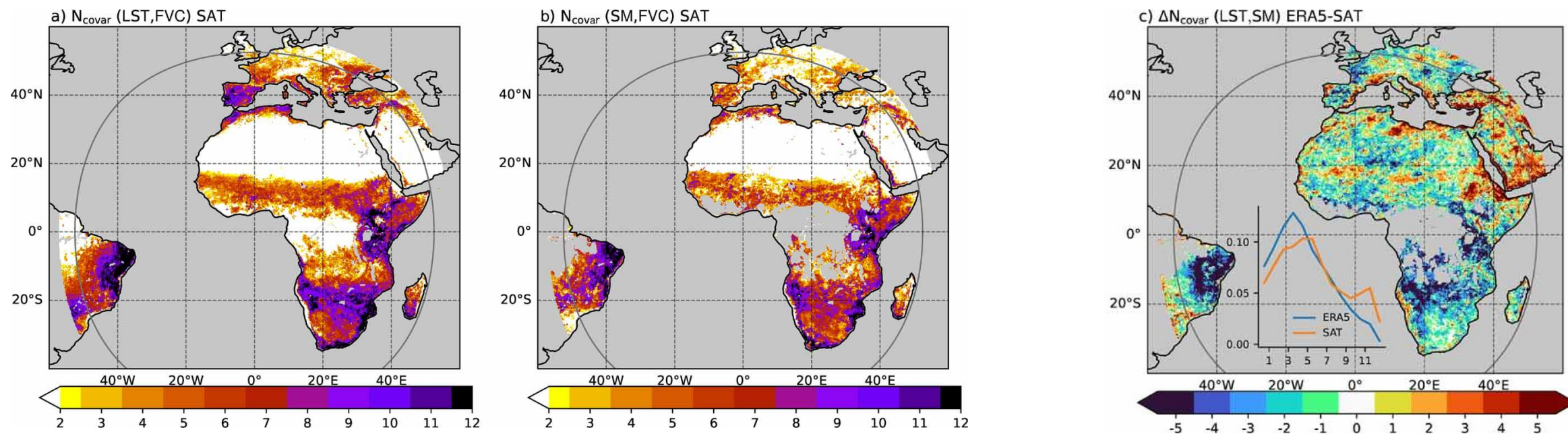
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Vegetation, soil moisture and LST co-variability



Ncovar: LST-FVC and SM-FVC interannual co-variability (SAT)



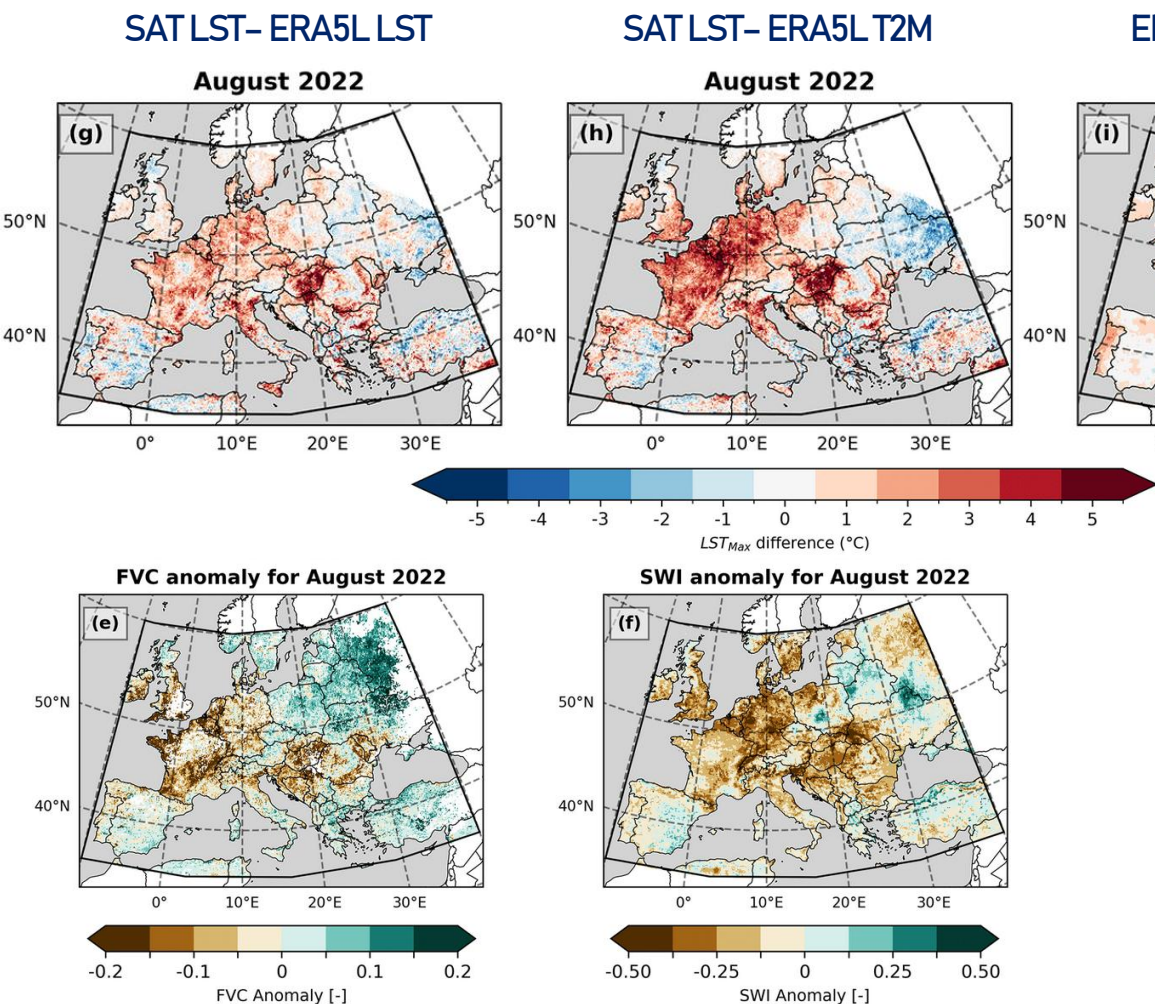
- High co-variability of FVC and LST/SM over the same regions where we see underestimation of LST and SM co-variability by ERA5
- Consistency between the results obtained with satellite data for different pairs of variables supports the robustness of results

Frois et al. (2026): A satellite-based assessment of ERA5 soil moisture and land surface temperature interannual co-variability, Environ. Res. Lett. 21 024024. <https://10.1088/1748-9326/ae3789>



How relevant are these limitations in ERA5?

Martins et al. (2024): A satellite view of the exceptionally warm summer of 2022 over Europe, Nat. Hazards Earth Syst. Sci., 24, 1501–1520, <https://doi.org/10.5194/nhess-24-1501-2024>



- Amplification of LST anomalies linked to vegetation anomalies
- ERA5 Land underestimates the amplitude of the heat wave signal



Using satellite LST to assess model developments

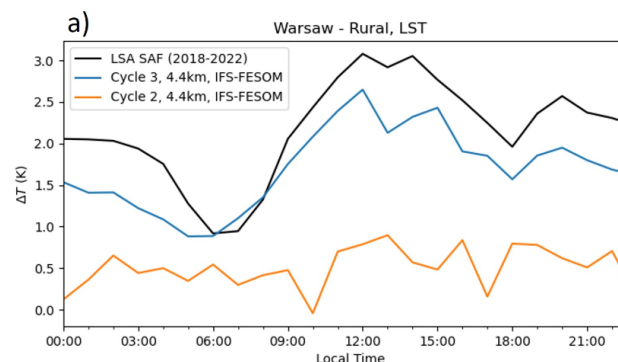
- NextGEMS is building prototypes for a new generation of storm-resolving earth system models'



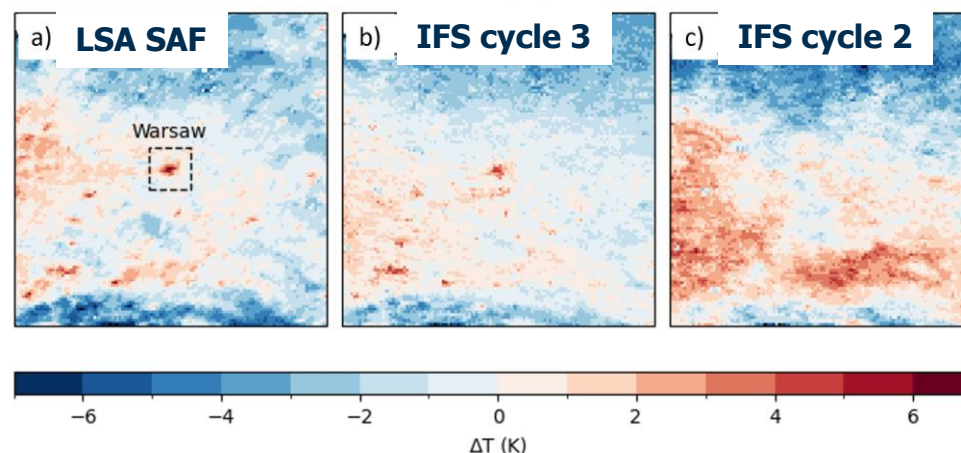
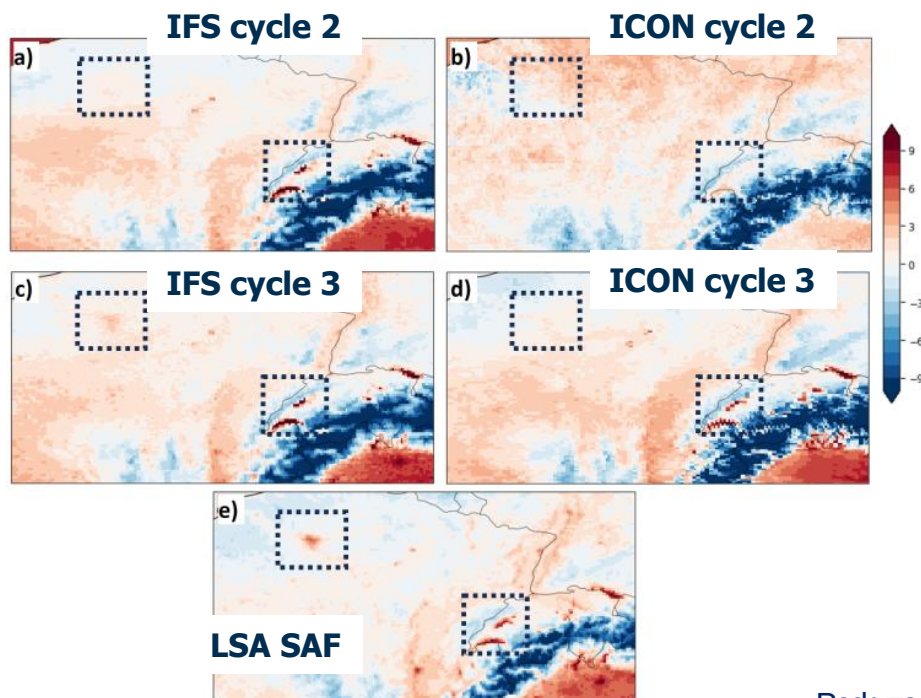
IFS Ecland model upgrade Cycle 2- > Cycle 3

- Urban scheme
- High-res LU/LC

Surface Urban Heat Island



Clear added value of updated land-cover & urban scheme in cycle 3 vs cycle 2

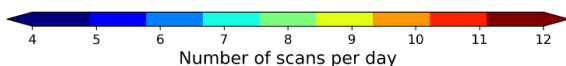
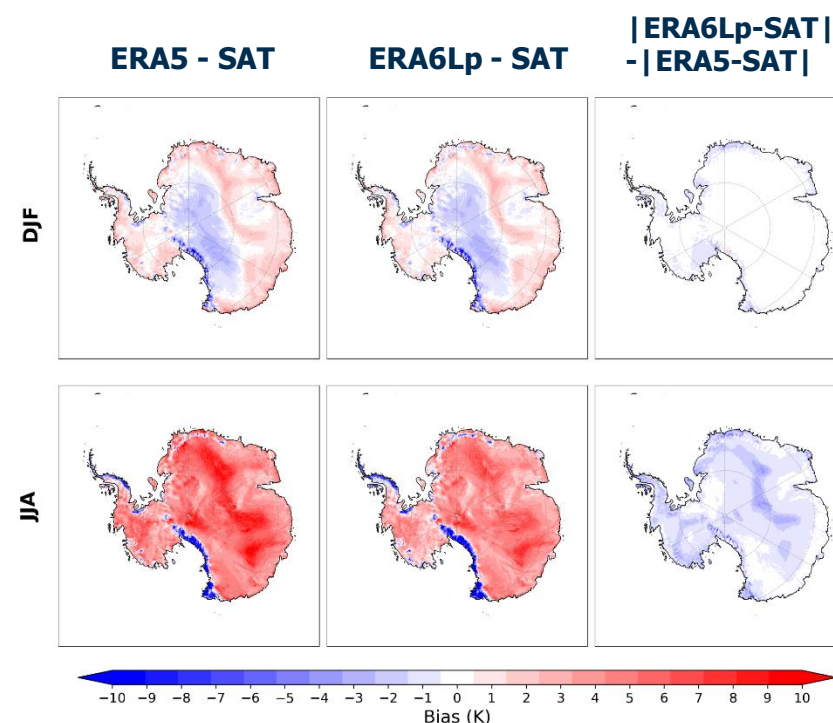
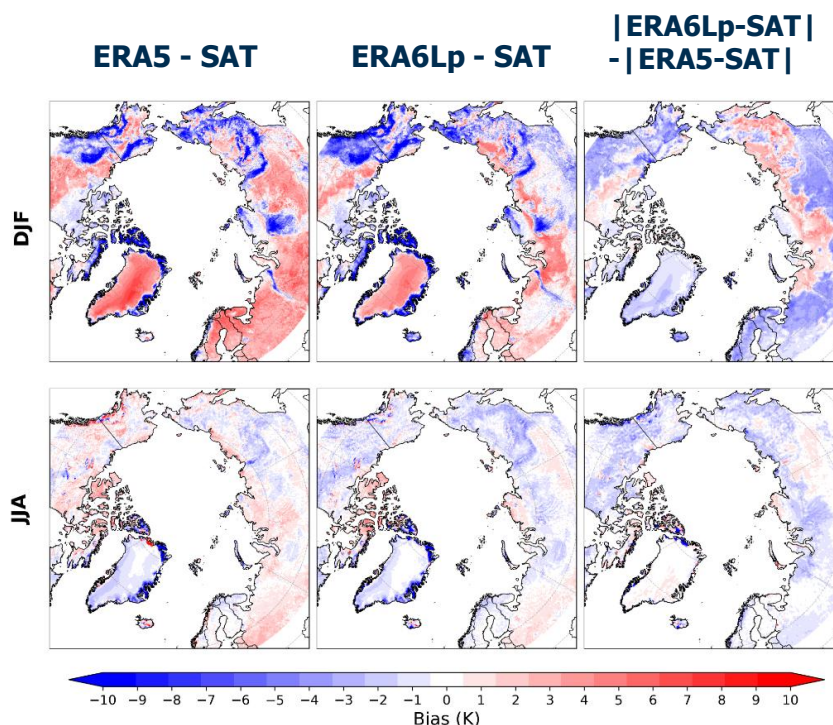
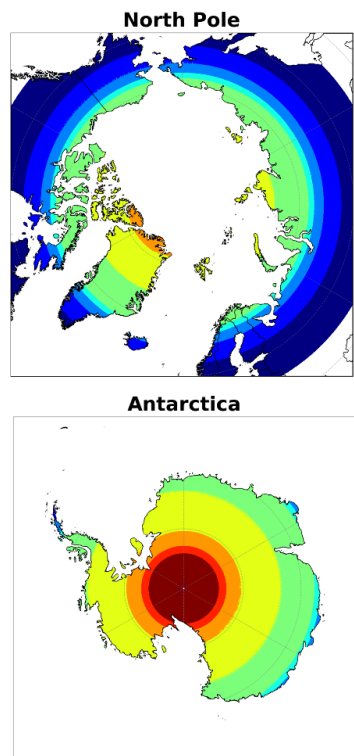


Pedruzo-Bagazgoitia et al. (2025): Unlocking Urban Climate Change Analysis in Global Kilometre-Scale Climate Simulations, ESS Open Archive. 12 December 2025. <https://doi.org/10.22541/essoar.176555751.17883296/v1>



Using satellite LST to assess model developments

- THAWIMPACT project: Antarctic Peninsula permafrost under a changing climate: sensitivity, fate and impacts
- The LSA-SAF developed a high frequency product over the poles based on Metop/AVHRR



ERA6Lp: ERA6-Land Prototype with new multi-layer snow surface scheme



Can we enhance the use of Earth Observations (EO) in land surface model development ?

- **Globally consistent EO data records, +15 years, of LST, vegetation state, soil moisture, etc** are paramount to identify process oriented constraints for model's evaluation
 - **EO** medium resolution is ok **~25km**; High resolution **~1-5km** EO also very important, with at least a few years (**~5**)
- Use of Earth Observations products is not simply “**plug and play**” - the model needs to be “**ready**” for that data.
- EO can help guide surface model **direct improvements** such as **land cover/vegetation** representation and resolution, but is also relevant to **evaluate the representation of surface processes** such as temperature-vegetation-water coupling or radiative cooling