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LSA-SAF All-Weather Land Surface Temperature – validation and uncertainty estimates

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Introduction

The Satellite Application Facility on Land Surface Analysis (LSA-SAF, http://lsa-saf.eumetsat.int) has been providing land surface temperature (LST) estimates using SEVIRI/MSG on an operational basis since 2006. The LSA-SAF service has since been extended to provide a wide range of satellite-based quantities over land surfaces, such as emissivity, albedo, radiative fluxes, vegetation state, evapotranspiration, and fire-related variables. Being based on infra-red measurements, the SEVIRI/MSG LST product is limited to clear-sky pixels only. Several all-weather LST products have been proposed by the scientific community either based on microwave observations or using surface models to fill the gaps caused by clouds. The goal of this work is to provide a nearly gap-free operational all-weather LST product and compare with alternative approaches.

LSA-SAF All-Weather LST

Clear sky:

The Generalized Split-Windows (Wan and Dozier, 1996; Freitas et al, 2010) is used:

$$LST = \left(A_1 + A_2\frac{1-\epsilon}{\epsilon} + A_3\frac{\Delta\epsilon}{\epsilon^2}\right)\frac{T_{IR1}+T_{IR2}}{2} + \left(B_1 + B_2\frac{1-\epsilon}{\epsilon} + B_3\frac{\Delta\epsilon}{\epsilon^2}\right) + C$$

- *TIR1* and *TIR2* are the brightness temperatures at the split-window channels (10.8 and 12.0µm for SEVIRI),
- *ε* and *Δε* are their spectral emissivity average and difference, respectively. The retrieval of ε is based on the Vegetation Cover Method (described in Trigo et al. (2008b)).;
- *Ai*, *Bi* and *C* are the model coefficients. These coefficients are determined a priori by class of viewing angle and Total Column Water Vapor.

Cloudy Sky:

In order to provide estimates of evapotranspiration, the surface radiative balance is solved every 30 min using the LSA-SAF ET v2 algorithm:

$$Rn_i = H_i + LE_i + G_i$$

Where Rn_i is the net radiation, H_i is the sensible heat, LE_i is the latent heat and G_i is the ground conduction for i-th tile of each pixel. All these terms are parameterized as a function of a number of other variables (details may be found in the product ATBD):

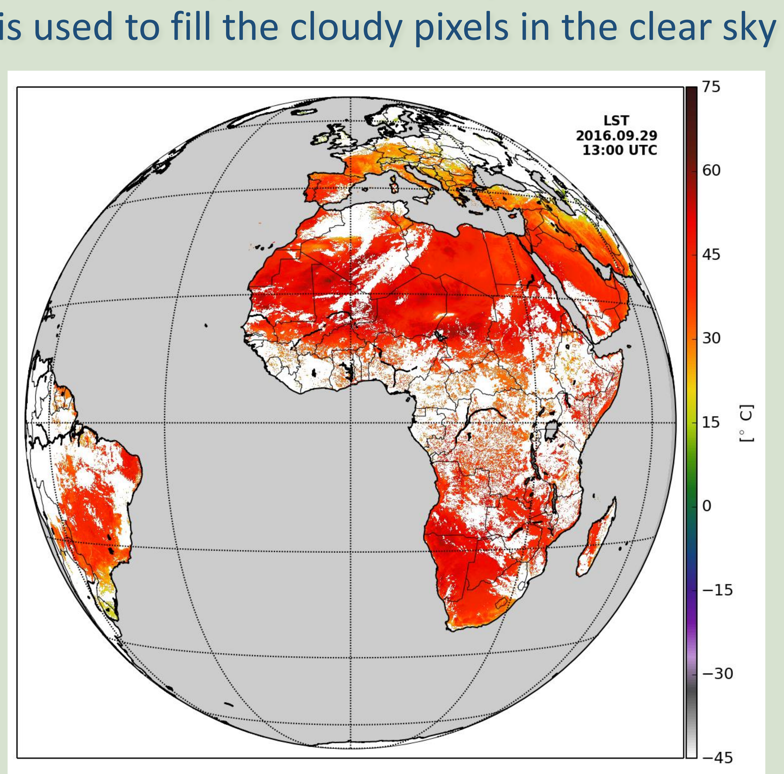
$$G_i = \beta_i R_{n_i}$$

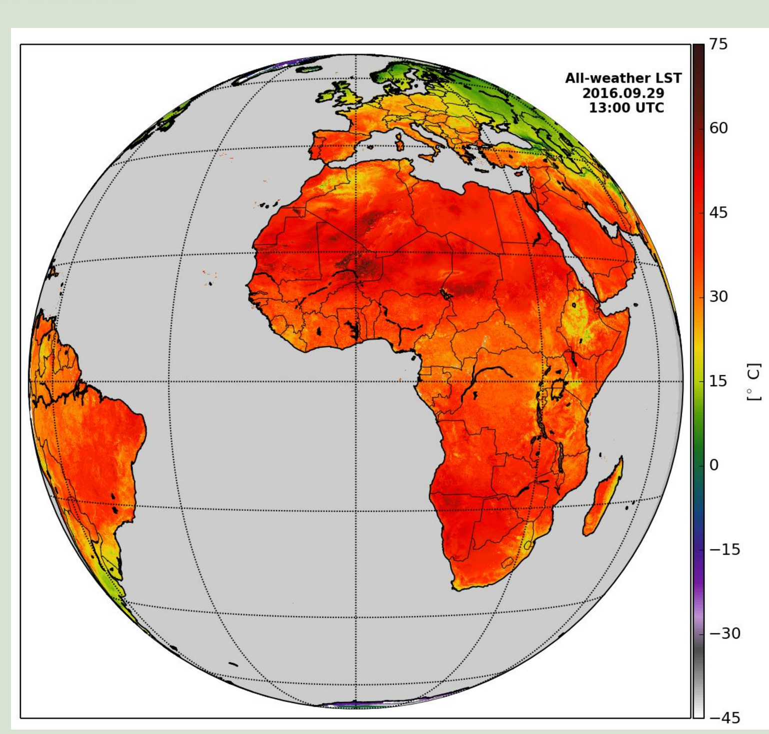
$$H_i = \frac{\rho_a}{r_{a_i}}\left[c_p\left(T_{sk_i} - T_a\right) - gz_a\right]$$

$$LE = \frac{L_v \rho_a}{r_{a_i} + r_{c_i}}\left[q_{sat}\left(T_{sk_i}\right) - q_a(T_a)\right]$$

$$H_i = \frac{\rho_a}{r_{a_i}}\left[c_p\left(T_{sk_i} - T_a\right) - gz_a\right]$$

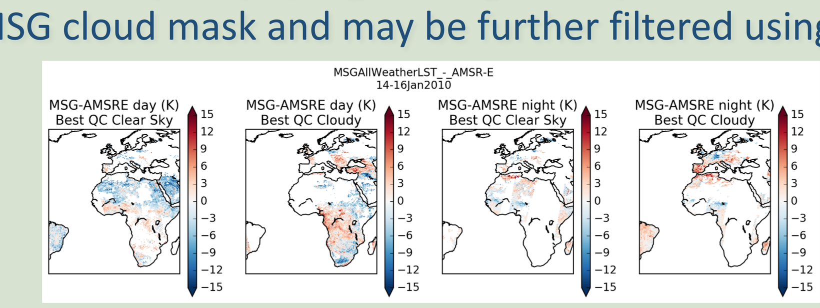
The system is solved iteratively due to the non-linear interdependence of the variables and a T_{sk} is produced as a byproduct in the process. This skin temperature is produced for all weather conditions and is used to fill the cloudy pixels in the clear sky LST product.

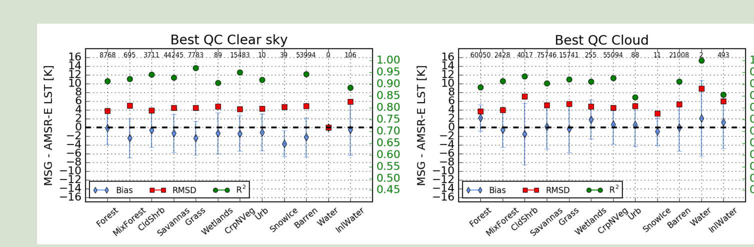




MW LST from AMSR-E

- Passive MW measurements are much less affected by clouds than IR observations.
- MW emissivities have large variability (soil moisture, vegetation cover, presence of snow).
- Spatial resolution and atmospheric effects depend on the used frequency.
- MW radiation can emanate from subsurface layers, not from the surface skin.
- LST may be estimated from passive MW imagers (Aires et al., 2001; Jimenez et al, 2017), using a neural network inversion, trained with a large data set of simulated radiances. The method has been applied to the NASA AMSR-E measurements, and LST was estimated with a spatial resolution of 0.125°x0.125°, twice daily.
- Poor quality data may be filtered using quality control flags for 1) Coastal pixels 2) Snow/Ice 3) Poor inversion quality 4) High MW ground penetration 5) Flooded terrain. Cloudy pixels are selected using the MSG cloud mask and may be further filtered using a convection activity flag in the AMSR-E data.





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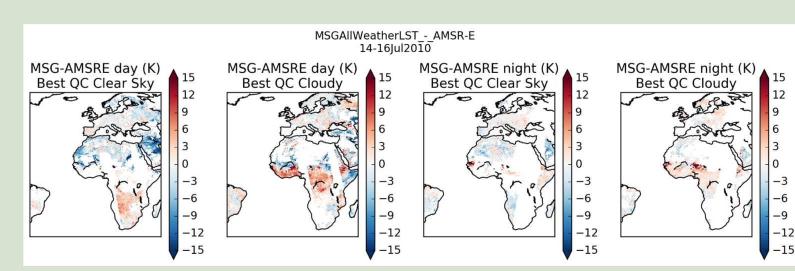

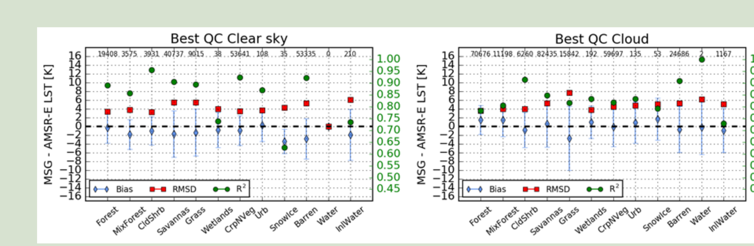

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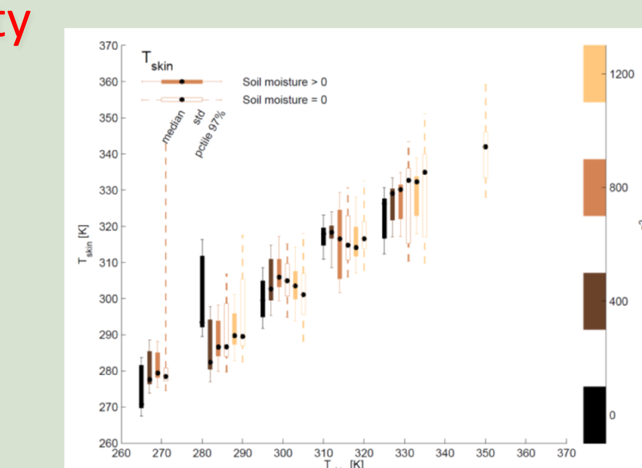
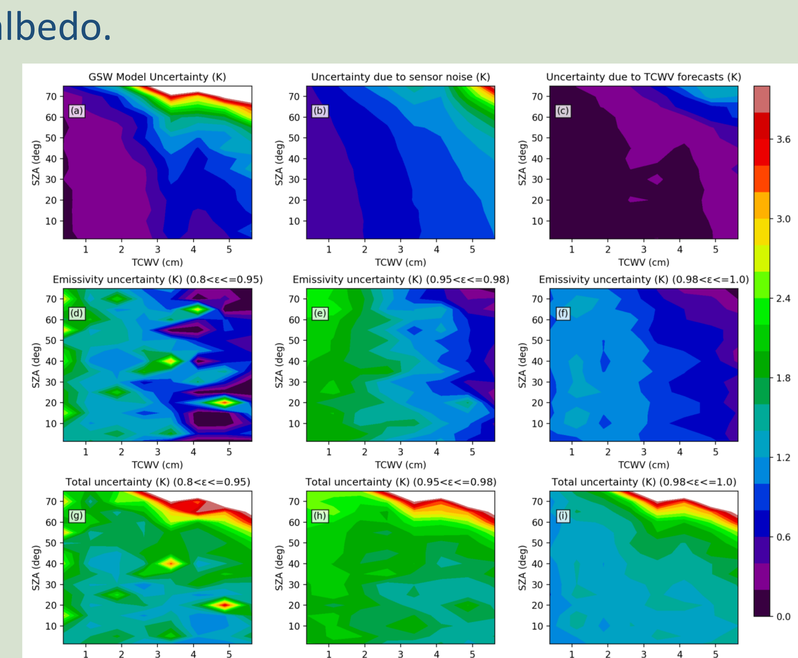
All-weather LST Uncertainty

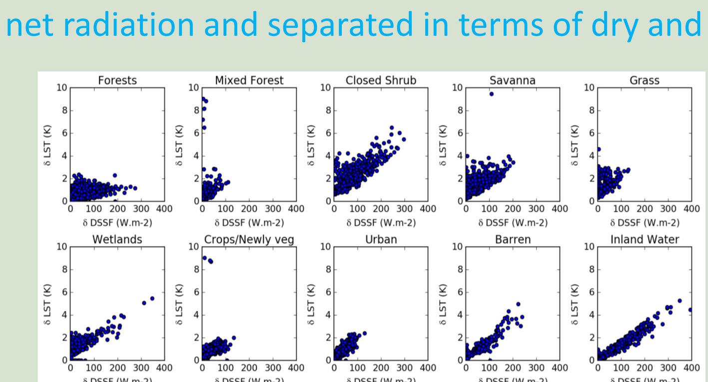
Monte Carlo methods are used to estimate uncertainties due to input variables for the clear and cloud sky components of the product. The clear sky uncertainty depends on the sensor noise, total column water vapour and surface emissivity. The cloudy sky depends on the radiative fluxes (LW and SW), soil moisture and albedo.



Uncertainty of skin temperature as a function of skin temperature. The boxplots are coloured according to the surface net radiation and separated in terms of dry and wet soils.

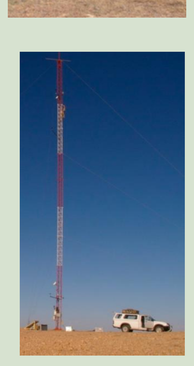


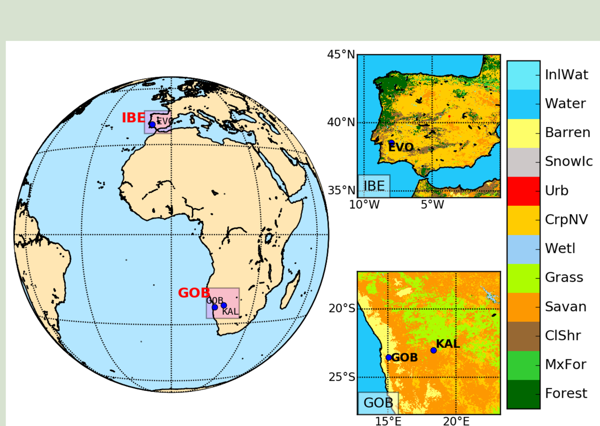
Uncertainty assessment for the clear sky component

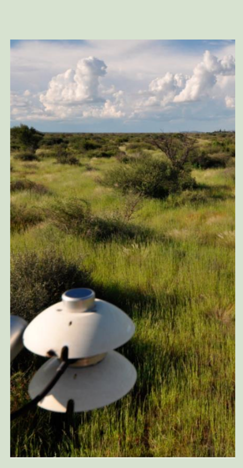


ET T_{sk} spatial standard deviation dependence on the spatial standard deviation of DSSF

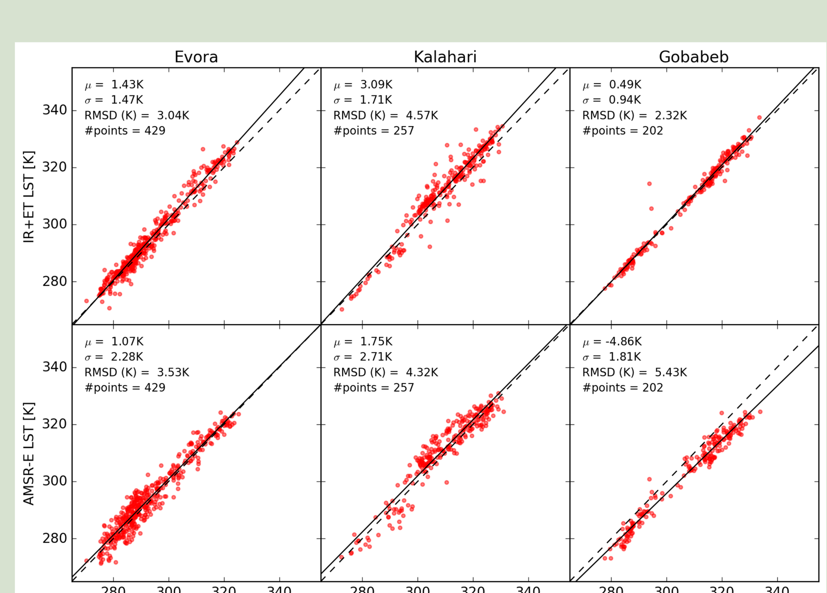
Comparison of the LSA-SAF all-weather LST to dedicated in situ stations (full year 2010)







	Median error (Accuracy) (K)	Median of the absolute residuals (Precision) (K)	Root-Mean Square Difference (Uncertainty) (K)
ET T_{Sk} (clear sky)	0.4	2.2	3.8
ET T_{Sk} (cloudy sky)	-0.2	2.1	3.8
IR LST	0.1	1.0	2.1
All-weather LST	0.1	1.2	2.7

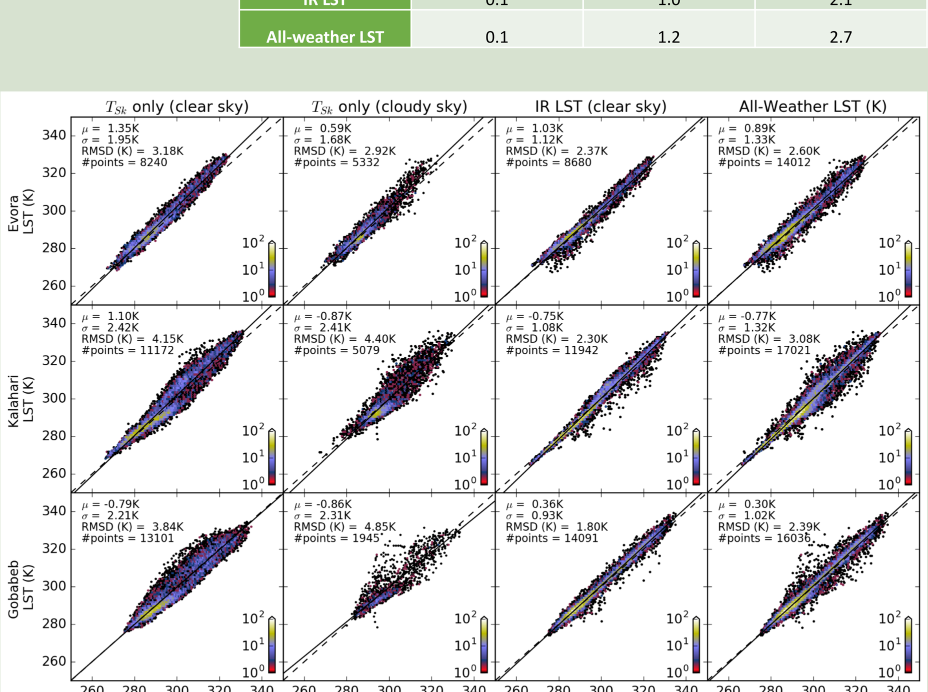


AMSR-E and LSA-SAF All-Weather LST vs in-situ

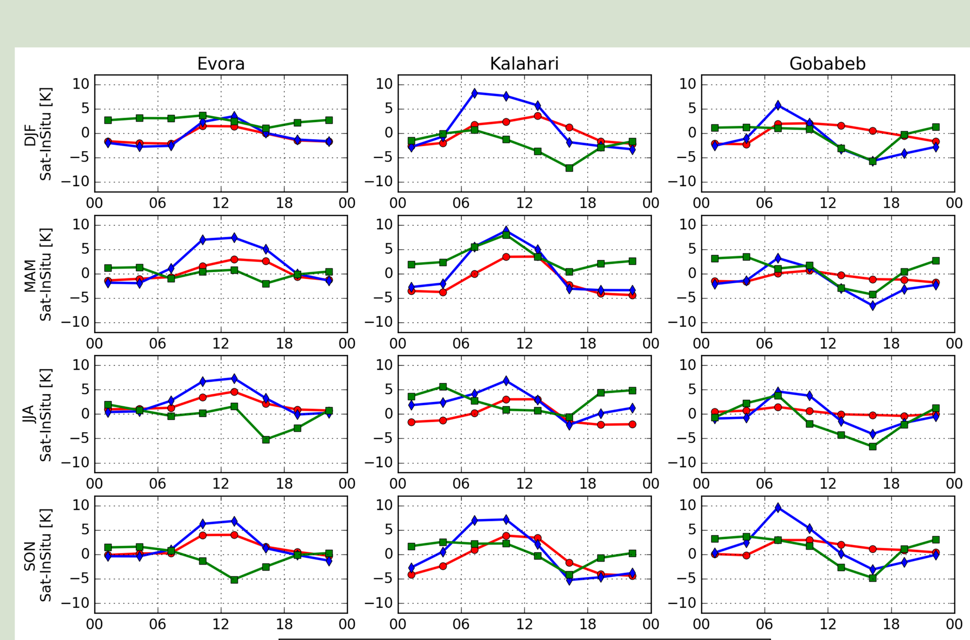
- Both the LSA-SAF LST and the AMSR-E LST were colocated with in situ measurements taken at 3 dedicated stations operated by the LSA-SAF / KIT. A nearest neighbour technique was used for the spatial and temporal interpolations. The insitu data was available every minute.
- IR LST (clear sky) always outperforms the other estimates. The ET Tskin has similar performances for clear or cloudy cases (in terms of RMSD).

  The ET Tskin shows a pronounced diurnal cycle of its error in less vegetated áreas, more pronounced in cloudy conditions.

  AMSR-E shows comparable results, when compared to the LSA-SAF All-weather LST, except for Gobabeb.



LSA-SAF All-Weather LST vs in-situ (every 30 min)



Error diurnal cycle for the LSA-SAF All-Weather LST components

Conclusions

- A new all-weather LST product is presented, with a much more comprehensive spatial coverage compared to conventional IR-based LST produts, with 30min temporal sampling.
- These results show that although the ET-based all-weather LST product is slightly less precise, it shows better accuracy and much better time sampling
- Still, the diurnal cycle is not well represented by the model in certain locations especially in cloudy situations.
- Preliminary comparison with microwave LST (all-weather) shows large differences in the deserts and in the tropics during daytime. Further tuning of both products is under investigation before operational production.

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