Land Surface Temperature from Geostationary Satellites

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The EUMETSAT Network of Satellite Application Facilities

geoland2

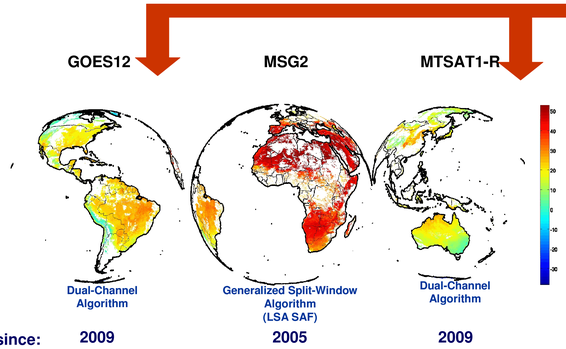
LSA SAF Land Surface Analysis

Introduction

Land Surface Temperature (LST) presents high variability in space and time, particularly over land surfaces. Geostationary satellites are well-suited to describe the daily cycle of LST and present spatial resolutions of the order of 3-to-5 km at sub-satellite point, acceptable for many applications. The EUMETSAT Satellite Application Facility on Land Surface Analysis (LSA SAF) provides operational retrievals of LST from SEVIRI on board Meteosat Second Generation (MSG) with a 15-minute temporal frequency. In order to increase spatial coverage, MSG-based LST is complemented with estimations from GOES-W and MTSAT data, which cover North and South America, and Eastern Asia and Australia, respectively. Hourly LST fields are then regularly estimated using GOES and MTSAT top-of-atmosphere observations disseminated via EUMETCast, as part of Geoland-2 demonstrational service.
Different LST algorithms were trained to the relevant infra-red channels available for each sensor, described the table below.
Product uncertainty is assessed taking into account the propagation of (realistic) input errors and the expected performance of the algorithms. LST estimations are validated through comparisons against independent sources, i.e., other satellite retrievals and ground measurements.

Channels / Resolution	SEVIRI	GOES Imager	MTSAT
Middle IR	3.5 – 4.4 μm	3.8 – 4.0 μm	3.5 – 4.0 μm
Thermal IR 1	10.0 – 11.5 μm	10.2 – 11.2 μm	10.3 – 11.3 μm
Thermal IR 2	11.2 – 12.8 μm	-	11.5 - 12.5 μm(*)
Spatial sampling(**)	3 km	5 km	5 km
Temporal sampling	15 min	1 h	1 h

(*) Not disseminated via EUMETCast
(**) At sub-satellite point



Dual-Channel

Applied when only one thermal infrared channel is available

Daytime

Mono-Channel →10.7 μm

$$LST = C_1 + C_2 T_{10.7}$$

Nighttime

Two-Channel →10.7 μm & 3.9 μm

$$LST = C_1 + C_2 T_{10.7} + C_2 (T_{10.7} - T_{3.9})$$

Parameters C_k depend on:

- Total Column Water Vapour — From Numerical Weather Prediction Models (ECMWF)
- Landcover
- Satellite View Angle

(Adapted from Sun et al., 2004 to **IMAGER-GOES** & **JAMI-MTSAT** channels – Freitas et al., 2012)

Generalized Split-Window

Applied when two thermal infrared channels are available

Daytime & Nighttime

Two-Channel →10.7 μm & 12.0 μm

$$LST = (A_1 + A_2 \frac{1-\varepsilon}{\varepsilon} + A_3 \frac{\Delta\varepsilon}{\varepsilon^2}) \frac{T_{10.8} + T_{12.0}}{2} +$$

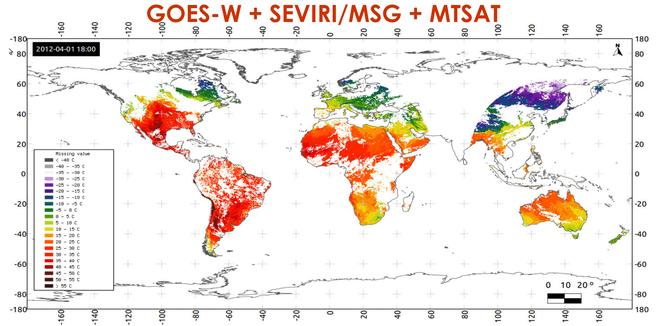
$$(B_1 + B_2 \frac{1-\varepsilon}{\varepsilon} + B_3 \frac{\Delta\varepsilon}{\varepsilon^2}) \frac{T_{10.8} - T_{12.0}}{2} + C$$

Parameters A_k, B_k & C depend on:

- Total Column Water Vapour — From Numerical Weather Prediction Models (ECMWF)
- Satellite View Angle

(Generalized Split Window - Wan and Dozier, 1996; adapted to **SEVIRI-MSG** – Freitas et al., 2010)

GOES-W + SEVIRI/MSG + MTSAT

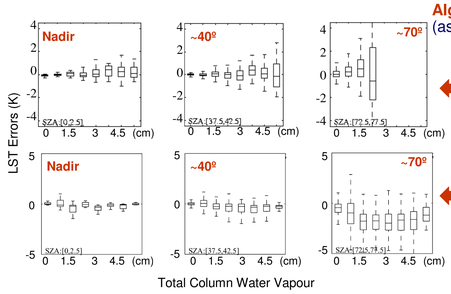


LST field (ºC): 1st April 2012, 18 UTC

LST Uncertainty

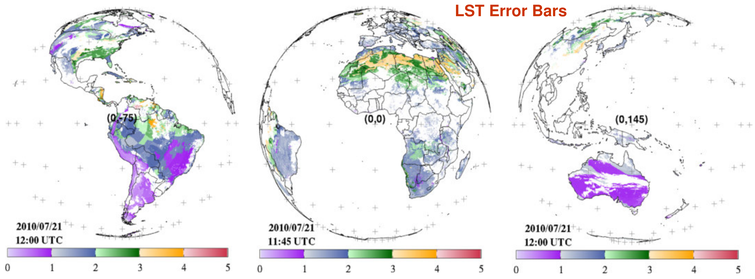
$$S^2_{LST} = \sum_i \left(\frac{\partial f}{\partial X_i}\right)^2 \sigma^2_{X_i} + \sum_j \left(\frac{\partial f}{\partial \theta_j}\right)^2 \sigma^2_{\theta_j} + \Delta LST^2$$

- **Algorithm uncertainty** [depend on retrieval conditions → total optical path]
- Errors in algorithm parameters [depend on implicit input variables → column water vapour; view angle; land cover]
- Errors in explicit algorithm inputs [sensor noise; emissivity]



Algorithm Uncertainty (assessed using simulated radiances)

- Generalized Split-Windows (SEVIRI; LSA SAF)
- Dual Channel (GOES/ MTSAT; Geoland-2)

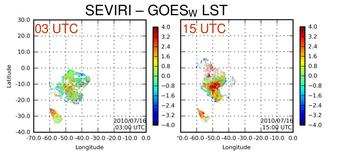


LST Error Bars (K) estimated taking into consideration: (i) algorithm uncertainty; (ii) sensor noise; (iii) channel emissivity uncertainties; (iv) expected forecast errors of water vapour.

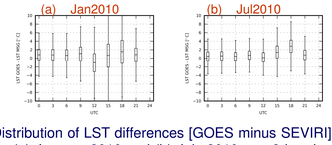
Validation

Comparison among satellite retrievals

GOES-W & MSG overlapping region

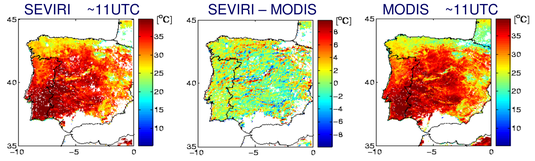


Differences (ºC) between MSG/SEVIRI and GOES-W LST for the overlapping area between the 2 disks (both projected onto a regular 0.05ºX0.05º grid): **16 Jul 2010** at 03 and 15 UTC.



Distribution of LST differences [GOES minus SEVIRI] (ºC) for (a) January 2010 and (b) July 2010, per 3-hourly slots. The boxplots show the lower quartile, median and upper quartile, respectively, while whiskers extend to remaining data.

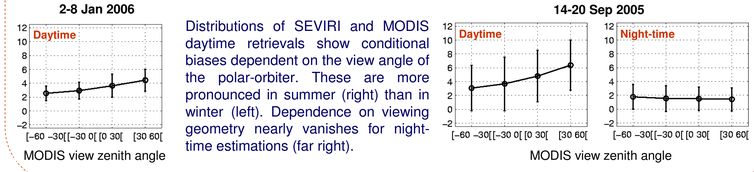
SEVIRI/MSG versus MODIS



LST fields over the Iberian Peninsula from SEVIRI (left) and MODIS (right), collocated in space and time, for the MODIS morning passage on 14 Sep 2005. Differences are shown in the central panel.

Most differences within -2 to +2 ºC; heterogeneity is high.

Distribution of LST differences: SEVIRI/MSG – MODIS (ºC)

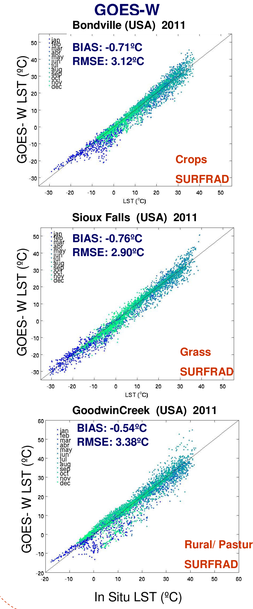


Distributions of SEVIRI and MODIS daytime retrievals show conditional biases dependent on the view angle of the polar-orbiter. These are more pronounced in summer (right) than in winter (left). Dependence on viewing geometry nearly vanishes for night-time estimations (far right).

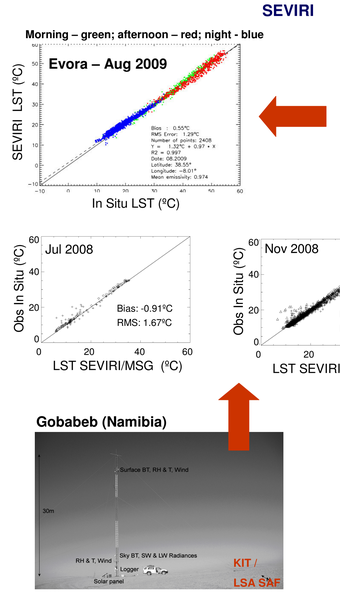
Comparison with In Situ Observations

- ✓ Comparisons with **Ground Measurements** avoids assumptions about performance of other LST products.
- × Difficult to find sites with skin temperature observations, which are **representative** of pixel scale.

GOES-W



SEVIRI



MTSAT

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Acknowledgments

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