Satellite

Land Surface Temperatures

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Outline

- European Meteorological Satellites
  - Geostationary
  - Polar-Orbiter
- Land Surface Temperature
  - Characteristics
  - Error Sources
  - Validation
- Future Sensors

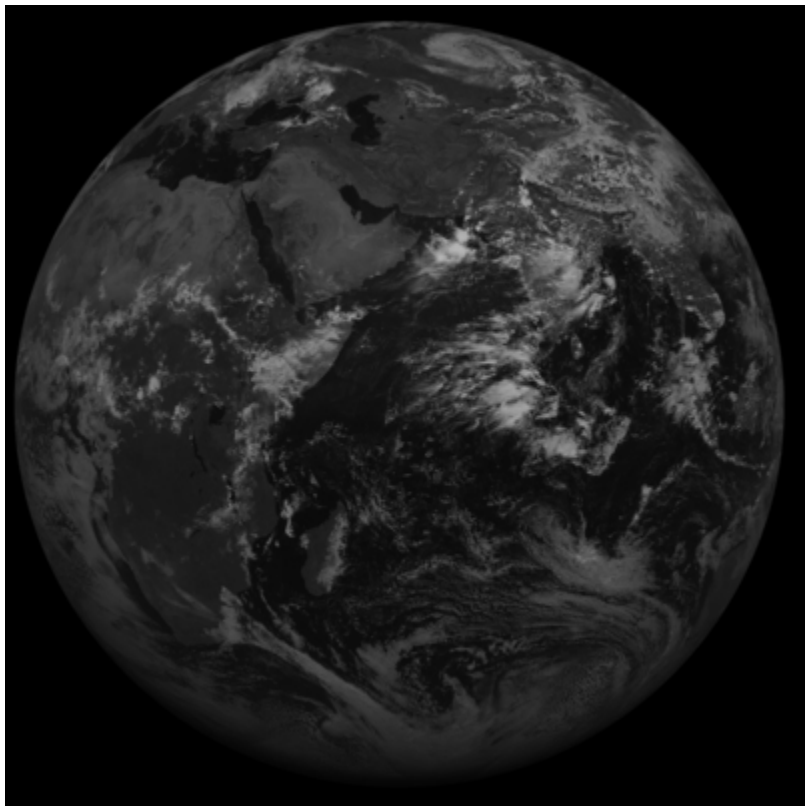
EUMETSAT Satellites - GEO

Meteosat First Generation

- Geostationary orbit
- CURRENT: Nominal sub-satellite point at 57º E
- 0º images available since 1982

(CDRs: LST)

Meteosat-7



3 Channels:

5 km sampling distance at nadir

30 minutes

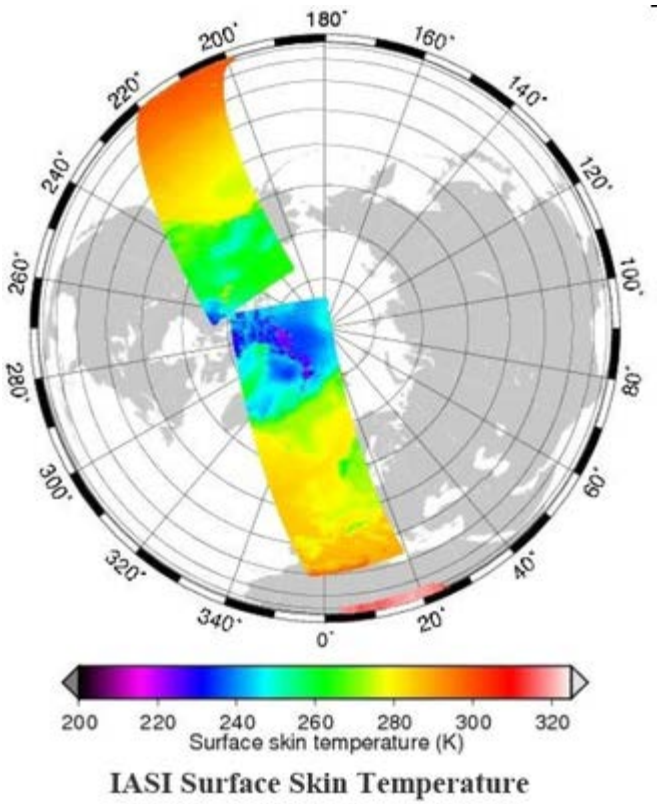
Channel VIS	0.45 – 1.0 μm
Channel WV	5.7 – 7.1
Channel TIR	~ 11.0 μm

EUMETSAT Satellites - LEO

Metop (Polar-Orbit) – Playload:

- AVHRR
- HIRS
- AMSU-A
- MHS
- IASI
- ASCAT
- GOME-2
- GRAS

IASI
~12 km



IASI Surface Skin Temperature

http://www.eumetsat.int

AVHRR

1 km at sub-satellite point

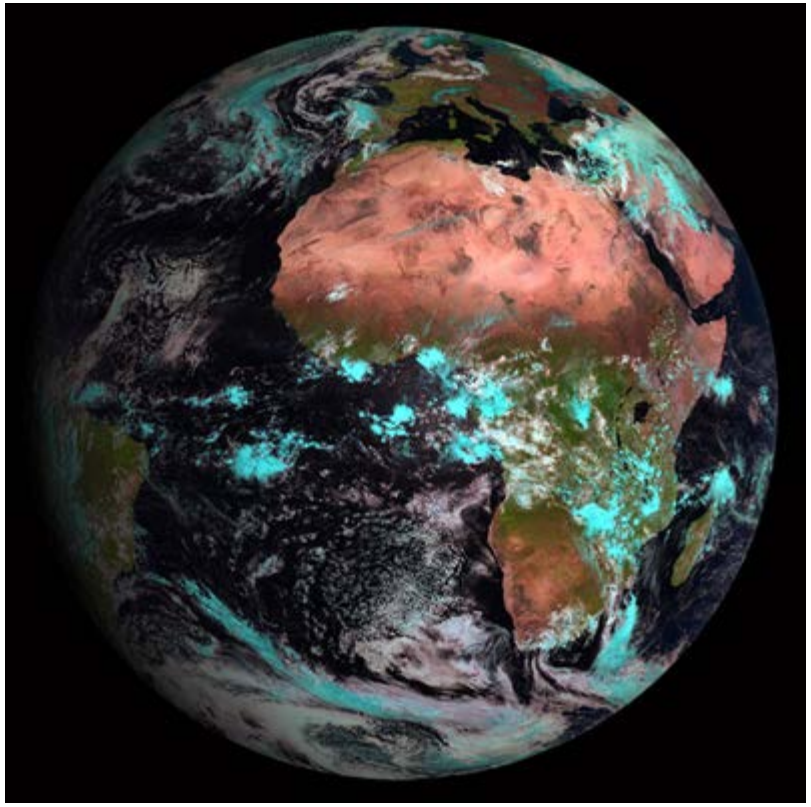
≥ 2 observations / day

Channel 1	0.58 – 0.68 μm
Channel 2	0.725 – 1.0 μm
Channel 3	~ 1.6 (day) / ~3.8 μm (night)
Channel 4	11.3 – 11.3 μm
Channel 5	11.5 – 12.50 μm

EUMETSAT Satellites - GEO

Meteosat Second Generation

- Geostationary orbit
- Nominal sub-satellite point at 0º long



Instruments

Spinning Enhanced Visible and Infrared Imager - SEVIRI

Geostationary Earth Radiation Budget - GERB

- visible-infrared radiometer for Earth radiation budget studies
- 2 broad-band channels (0.32 – 4 μm and 0.32 – 30 μm)
- sub-satellite point at ~45 km; temporal sampling - 15 min

EUMETSAT Satellites - GEO

SEVIRI - Spinning Enhanced Visible and Infrared Imager

11 Channels:

3 km sampling distance at sub-satellite point

15 minutes

High Resolution VIS channel:

1km sampling distance at sub-satellite point

15 minutes

Channel 1 VIS	0.6 μm
Channel 2 VIS	0.8
Channel 3 NIR	1.6
Channel 4 MIR	3.9
Channel 5 WV	6.2
Channel 6 WV	7.3
Channel 7 IR	8.7
Channel 8 IR/O_3	9.7
Channel 9 TIR	10.8
Channel 10 TIR	12.0
Channel 11 IR/CO_2	13.4
Channel 12	HRV

SEVIRI/MSG - LST

Generalised Split-Window → 10.8μm and 12.0μm (Wan & Dozier, 1996)

Trained using CLEAR SKY synthetic SEVIRI/MSG data

$$T_s = (A_1 + A_2 \frac{1-\varepsilon}{\varepsilon} + A_3 \frac{\Delta\varepsilon}{\varepsilon^2}) \frac{T_{10.8} + T_{12.0}}{2} + (B_1 + B_2 \frac{1-\varepsilon}{\varepsilon} + B_3 \frac{\Delta\varepsilon}{\varepsilon^2}) \frac{T_{10.8} - T_{12.0}}{2} + C$$

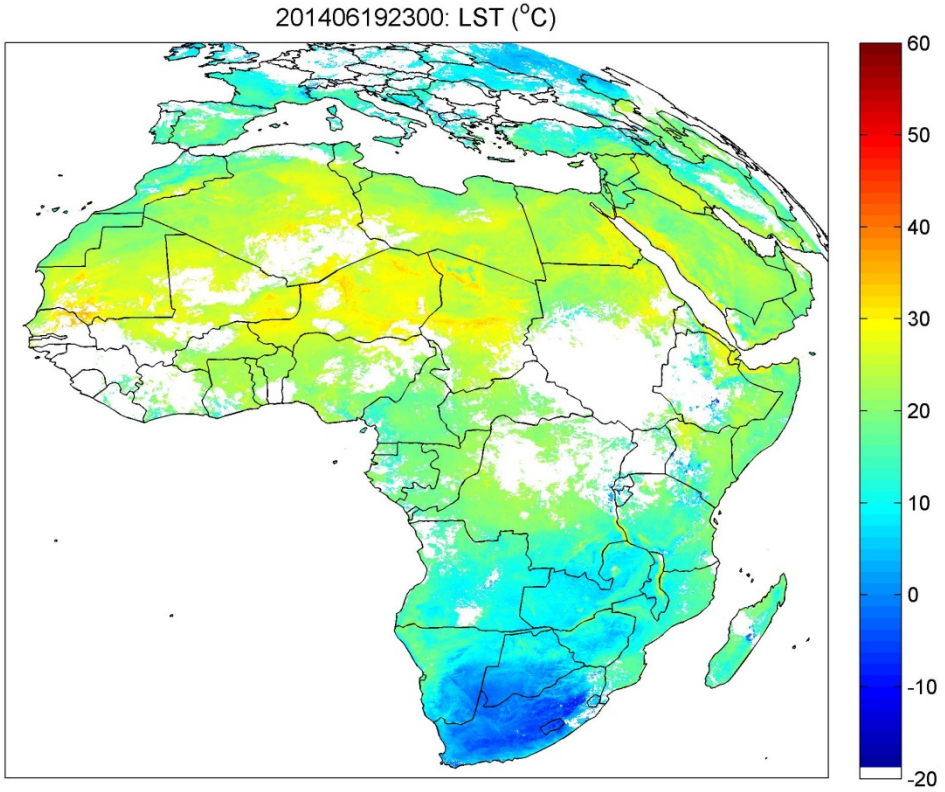
GSW parameters depend on:

- total column water vapour (ECMWF forecasts)
- viewing angle

Channel Emissivity → Fraction Vegetation Cover

Operational LST Product

SEVIRI/MSG - LST



- ✓ 15-min
- ✓ 3 km at sub-satellite point
- ✓ clear sky pixels
- ✓ NRT (EUMETCast)
- ✓ Off-line

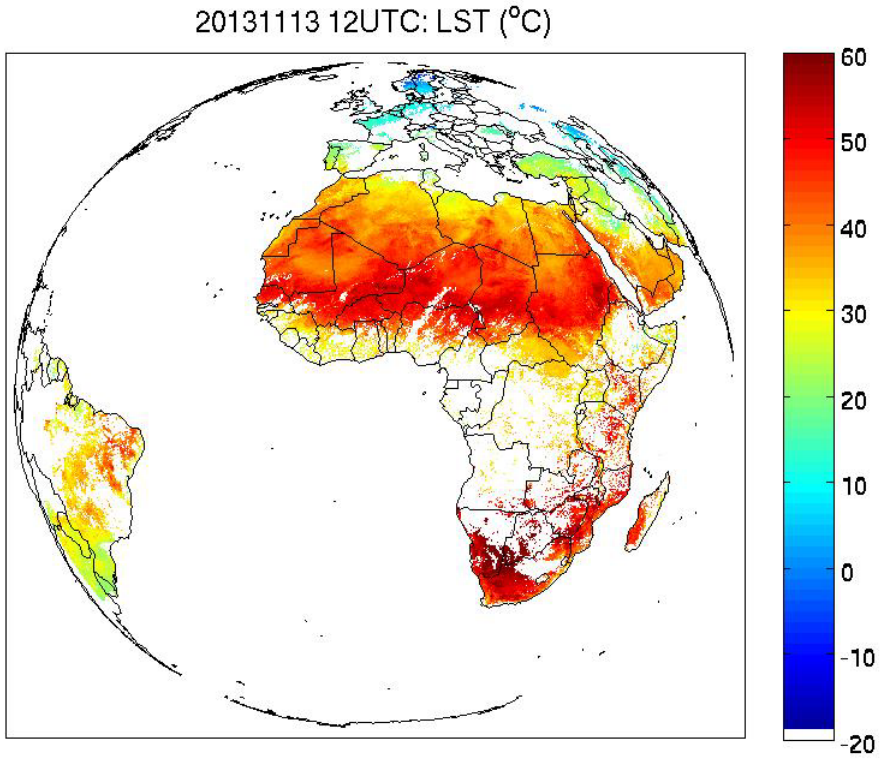
Developer: LSA SAF / IPMA

Trigo et al. (2008) in *J. Geophys. Res.*, DOI:10.1029/2008JD010035

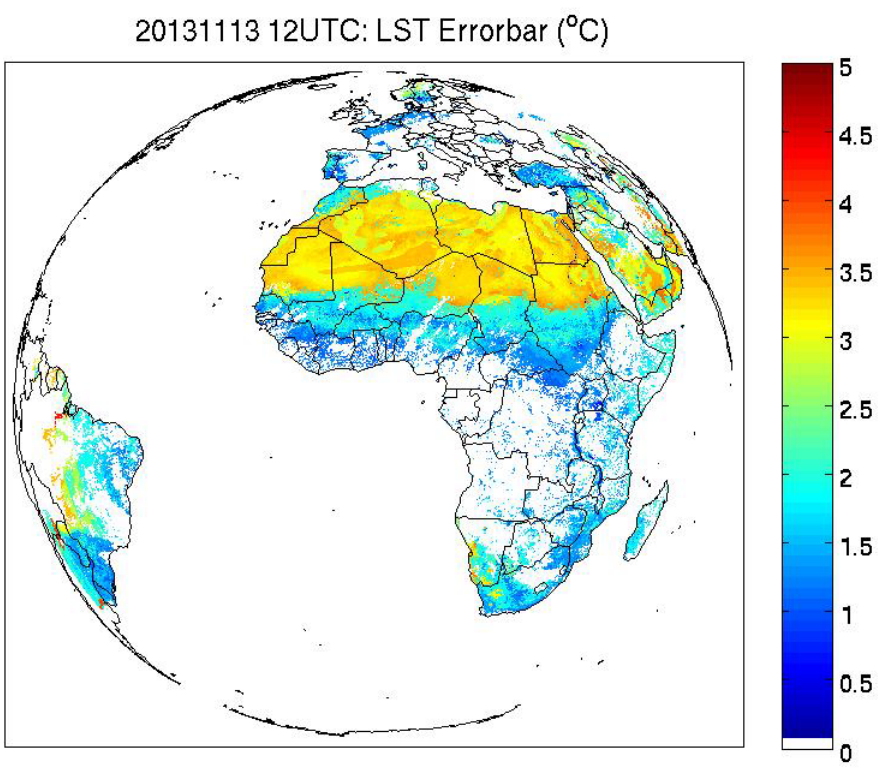
Freitas et al. (2010) in *IEEE Trans Geosc Remote Sens,* DOI: 10.1109/TGRS.2009.2027697.

SEVIRI/MSG - LST

LST



LST uncertainty

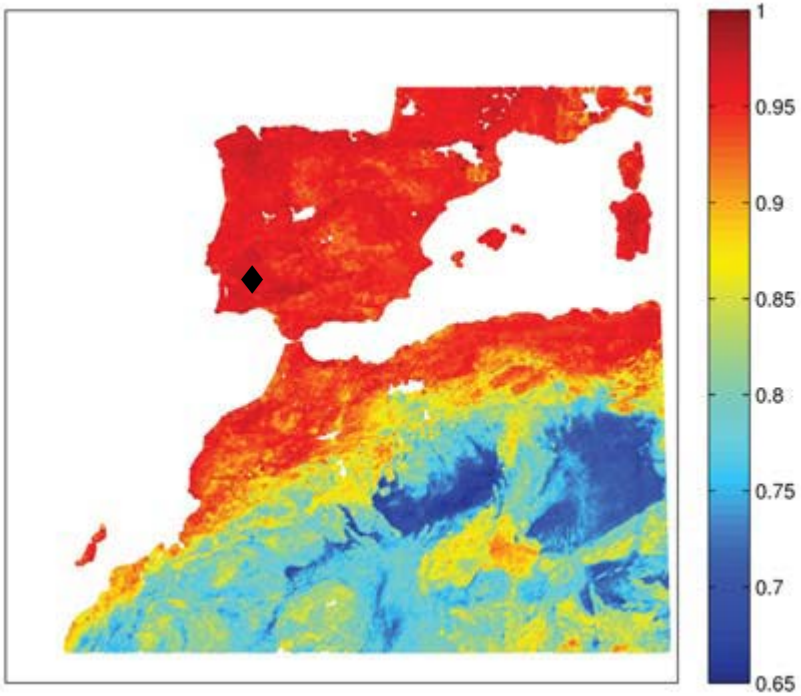


- Temporal sampling: 15 min; poorer under the ITCZ
- Spatial resolution over Africa: 3km up to ~5km
- LST uncertainty highly influenced by emissivity over (semi-)arid regions

Emissivty

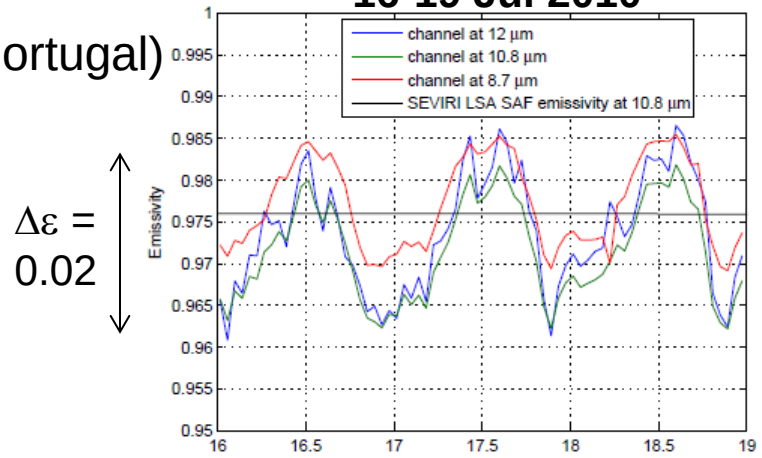
Under Testing: Kalman Filter approach to exploit the high temporal sampling
Channels **8.7, 10.8 and 12.0µm** ⇒ **Emissivity** & LST

1-31 Jul 2010
EMISSIVITY 8.7µm

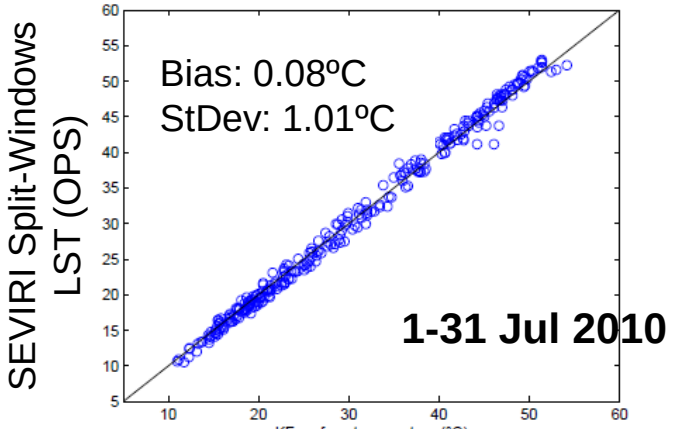


Evora ♦
(Southern Portugal)

16-19 Jul 2010



$\Delta\varepsilon$ = 0.02



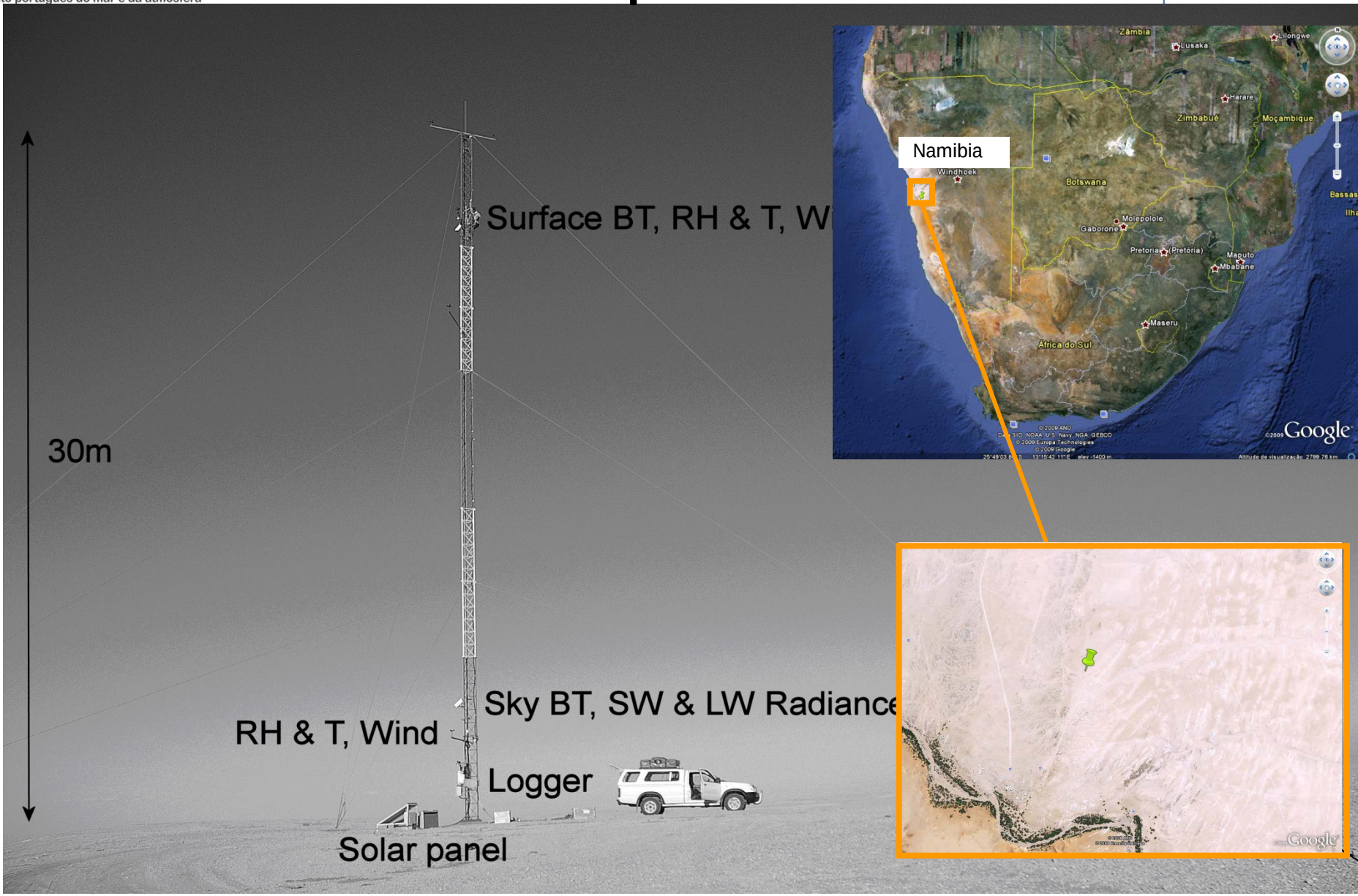
Marsiello et al. (2013) in *Atmos. Meas. Tech,* DOI: 10.5194/amt-6-3613-2013

LSA SAF – Product Validation

LST

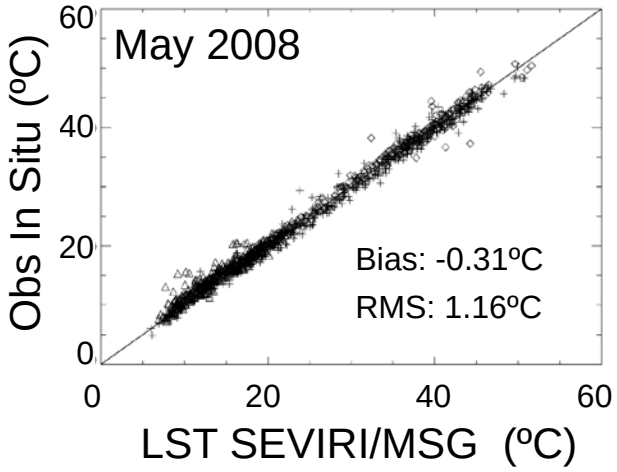
- Intercomparison of satellite derived similar products (MODIS, AATSR, VIIRS, …)
  - Consistency Analysis
- Validation against ground observations - Portugal (Évora), Namibia (Gobabeb, Kalahari), Senegal (Dahra)
  - As an Indenpendent Reference

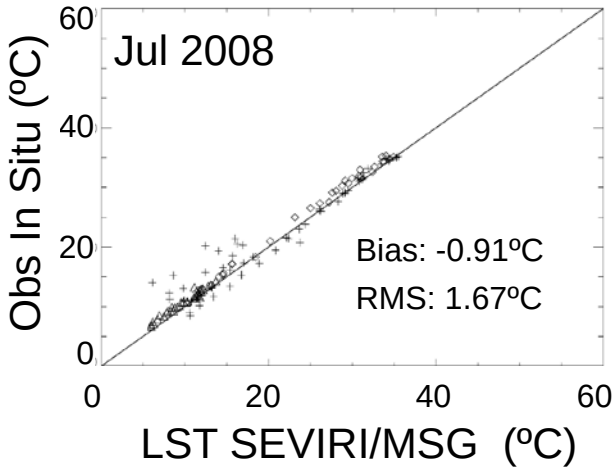
Land Surface Temperature – Validation

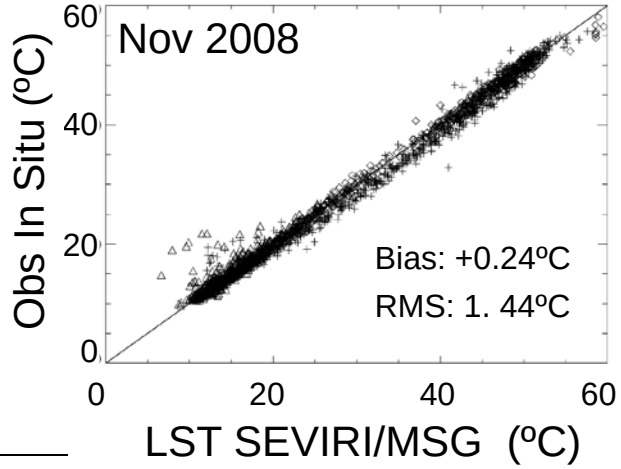


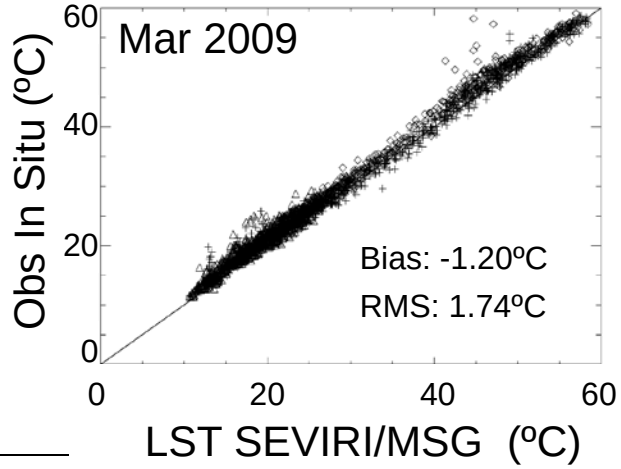
Land Surface Temperature – Validation

T_{sup} MSG/SEVIRI (Land-SAF) versus *in situ* T_{sup}



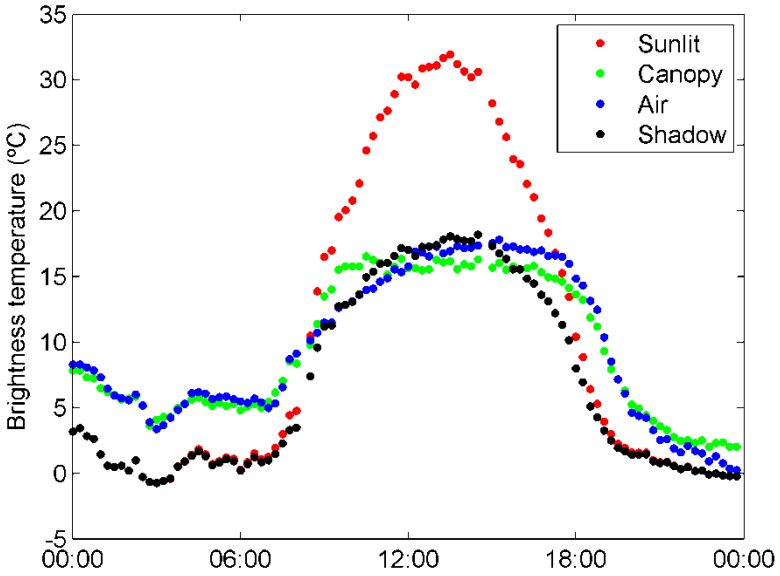






In Situ Observations

LST - Evora



High Variability in Space and Time:

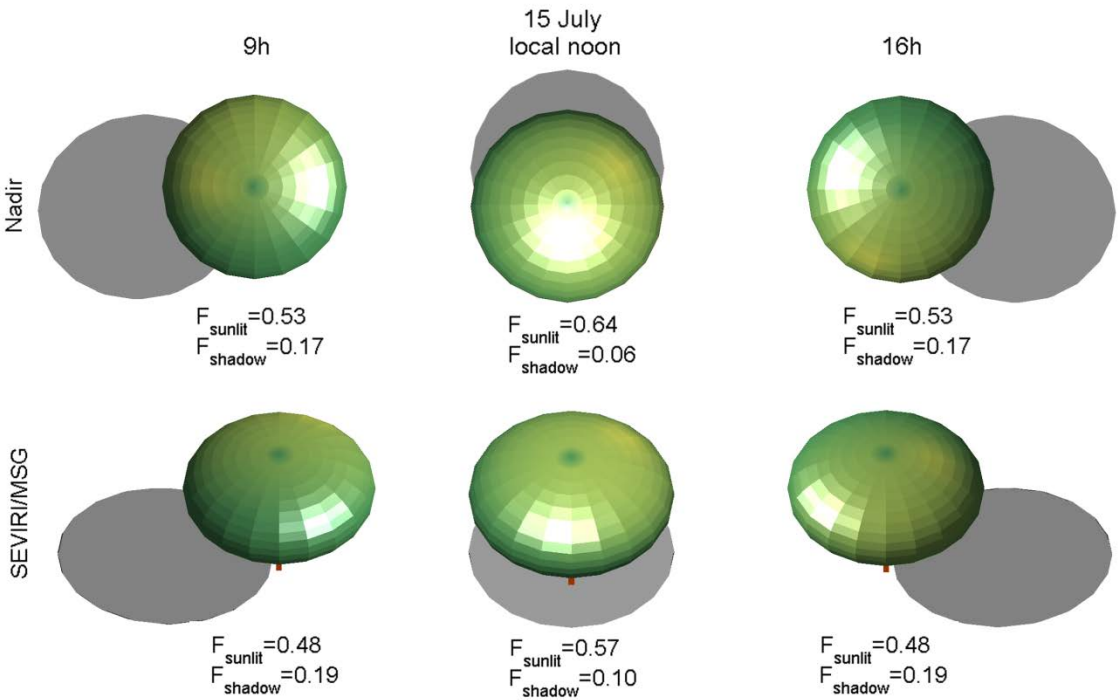
- Impact of view & illumination geometry on retrievals

- Needs to be taken into account when comparing LST products and Ground obs

Directional Effects on LST

Idealized single tree view at Évora:

Nadir & SEVIRI view at different local times in July



Geometric Model – estimate shapes of objects seen by the sensor

Boolean model – derive overlap probabilities and the actual fraction of each end-member

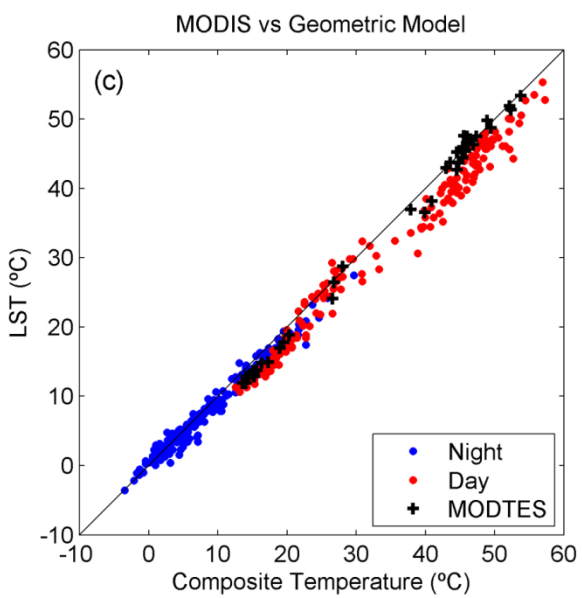
Different Viewing Angles

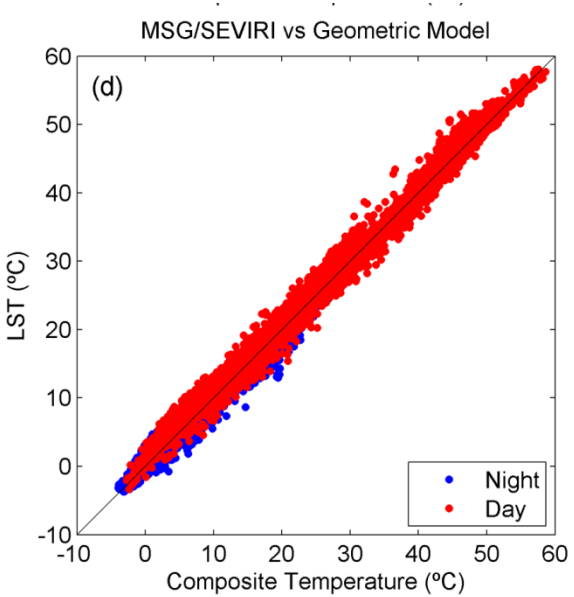
⇓

Different LST

Intercomparison LEO - SEVIRI

LST versus in situ T_{sfc}





Direction effects at Évora

Without Geometric Correction

	Day	Night
MODSW (MOD11)	-5.0/3.1	-0.6/1.2
MODTES (MOD21)	-2.5/1.4	
SEVIRI	-1.2/2.2	-0.1/1.2

With Geometric Correction

	Day	Night
MODSW (MOD11)	-2.7/1.9	-0.7/1.2
MODTES (MOD21)	-0.8/1.3	
SEVIRI	0.5/1.4	0.1/1.2

(Bias/StDev)

Ermida et al (2014) in *Remote Sens Environ*, DOI: 10.1016/j.rse.2014.03.016

EUMETSAT – Future Sensors

Meteosat Third Generation

Playload will be distributed by 2 satellites

Evolution of SEVIRI

MTG-I (launch foreseen for 2018)

Flexible Combined Imager (FCI)

16 channels (1km / 2 km; high-resolution 0.5 km)

10 min

Lightning Imager (LI)

Lightning detection (total - cloud-cloud & cloud-ground)

MTG-S (launch foreseen for 2020 - TBC)

Infrared Sounder (IRS)

800 channels LWIR+ 920 channels MWIR – full disk; 4 km

60 min

Ultraviolet, Visible and Near-Infrared Sounding (Sentinel-4)

UV: 305 – 400 nm; VIS: 400 – 500 nm; NIR: 755 – 775 nm

Europe; 60 min

Summary

- Meteosat Satellites: allow representation of the diurnal LST cycle over **Africa**
  - 1st generation: 30 min, 5km at nadir; 1982 – 2006
  - MSG: 15 min; 3km at nadri; 2004 – present
- Sources of LST uncertainty:
  - Atmospheric Correction
  - Algorithm inaccuracies
  - Sensor Noise / calibration
  - Surface Emissivity
  - Cloud Contamination
  - Aerosol (high loads)
- Directional Effects: LST corresponds to the radiometric temperature of the surface within the sensor FOV.
  - Partially explain differences among satellite products
  - Should to be taken into account when validating with ground data
  - Still to be better understood.