Land Surface Temperature, Emissivity and Long-Wave Downwlling Fluxes from MSG Observations: current status and way forward

The EUMETSAT Network of Satellite Application Facilities

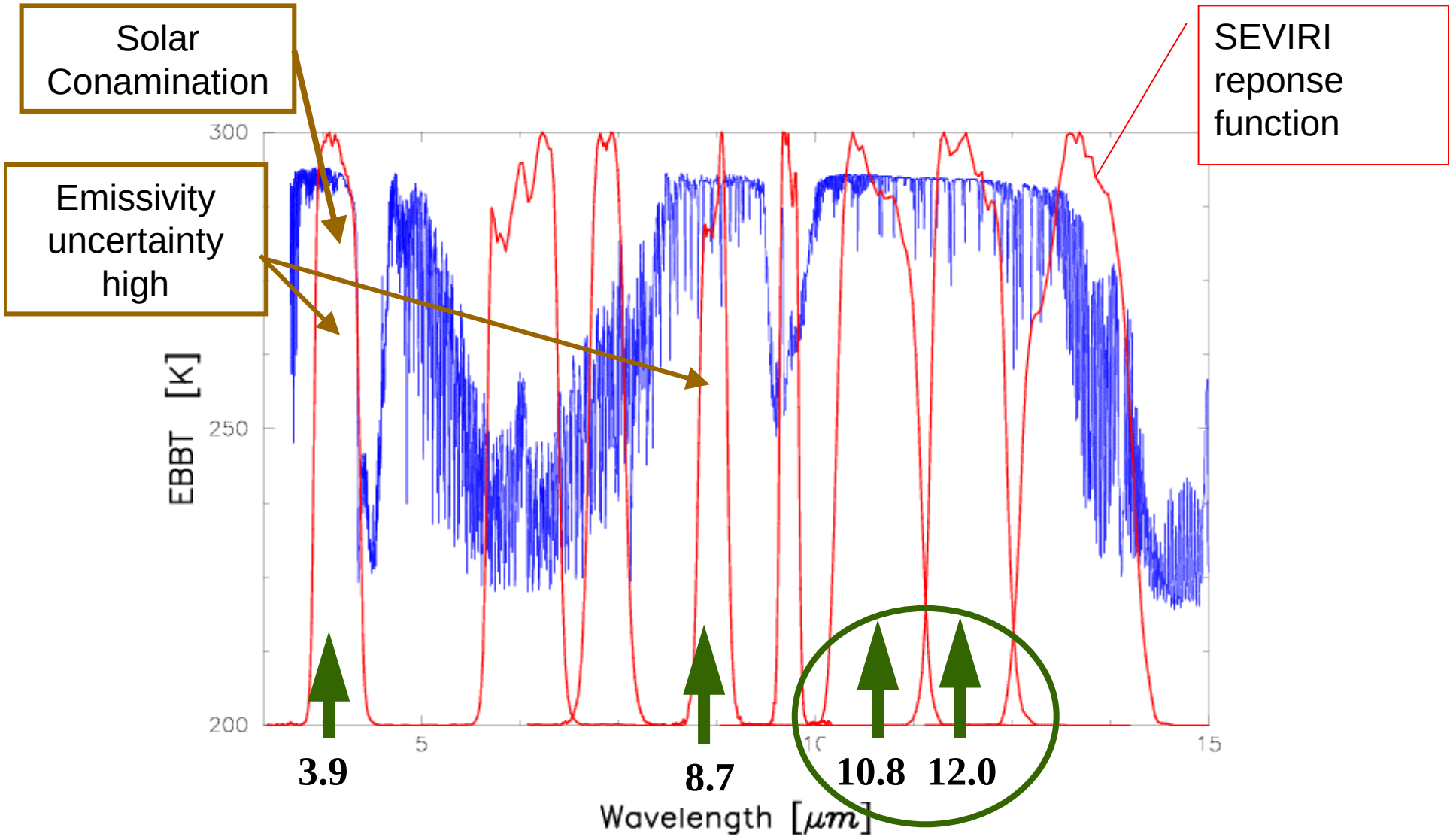
LSA SAF
Land Surface Analysis

Isabel Trigo, Sandra Freitas, Carla Barroso, Isabel Monteiro, Pedro Viterbo

Outline

- **Land Surface Temperature & Emissivity**
  - ✓ Algorithms & Product characteristics
  - ✓ Validation
    - ➢ Strengths and Weaknesses
  - ✓ Developments for CDOP-2
- **Downwelling Sfc Long-wave Flux**
  - ✓ Algorithm & Product characteristics
  - ✓ Validation
    - ➢ against in situ observations and CERES fluxes
  - ✓ Developments for CDOP-2

SEVIRI/Meteosat IR channels & LST



Land Surface Temperature - Algorithm

- Generalised Split-Window → 10.8μm and 12.0μm

Trained using **CLEAR SKY** synthetic SEVIRI/MSG data
(MODTRAN + realistic sfc parameters & atmospheric profiles)

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

GSW parameters depend on:

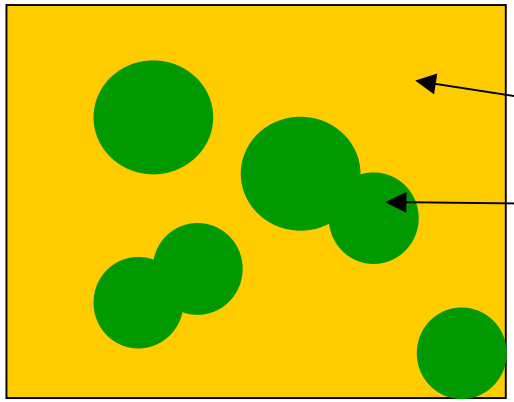
1. total column water vapour
2. viewing angle

ECMWF fc

- Channel Emissivity → Fraction Vegetation Cover

Emissivty

Pixel MSG



$$\varepsilon = \varepsilon_{veg}\,FVC + \varepsilon_{ground}\,(1\text{-}FVC) + \delta\varepsilon$$

LSA SAF Product

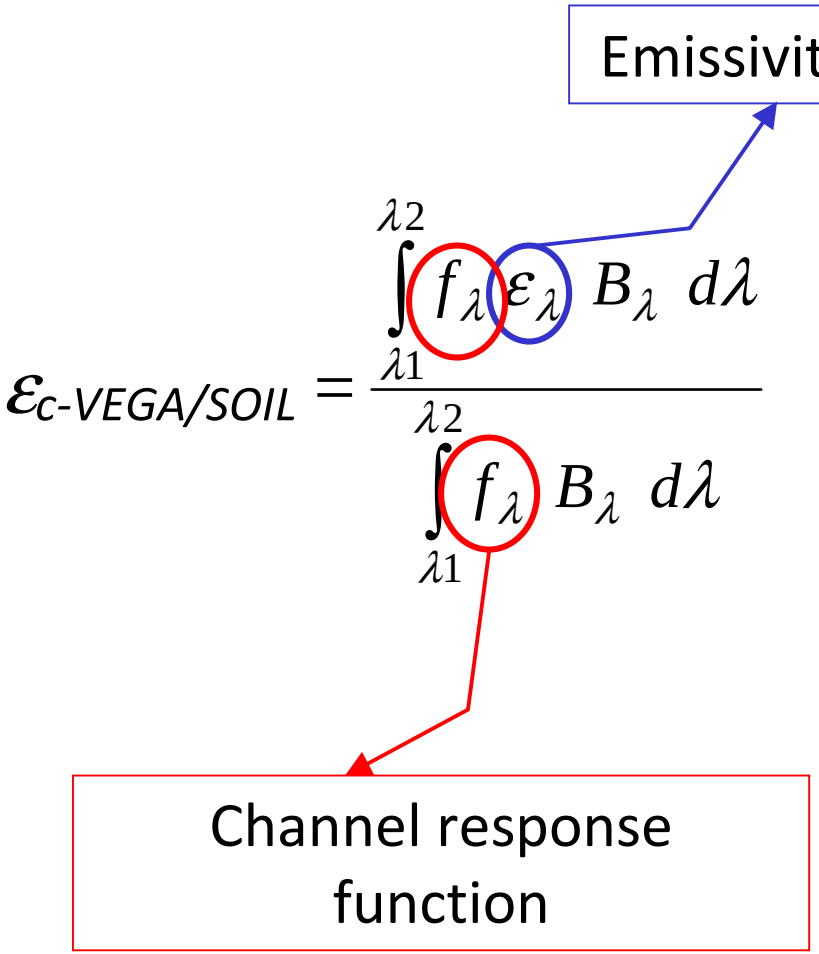
↑

Sfc Reflectances VIS

- Non-accounted effects (multiple reflections at sfc)
- Variability of bare ground/ vega within pixel

Channel Emissivty – Vega/Ground

Band Emissivity for VEGETATION / SOIL classes



SEVIRI/Meteosat Channels

- IR 3.9
- IR 8.7
- **IR 10.8**
- **IR 12.0**

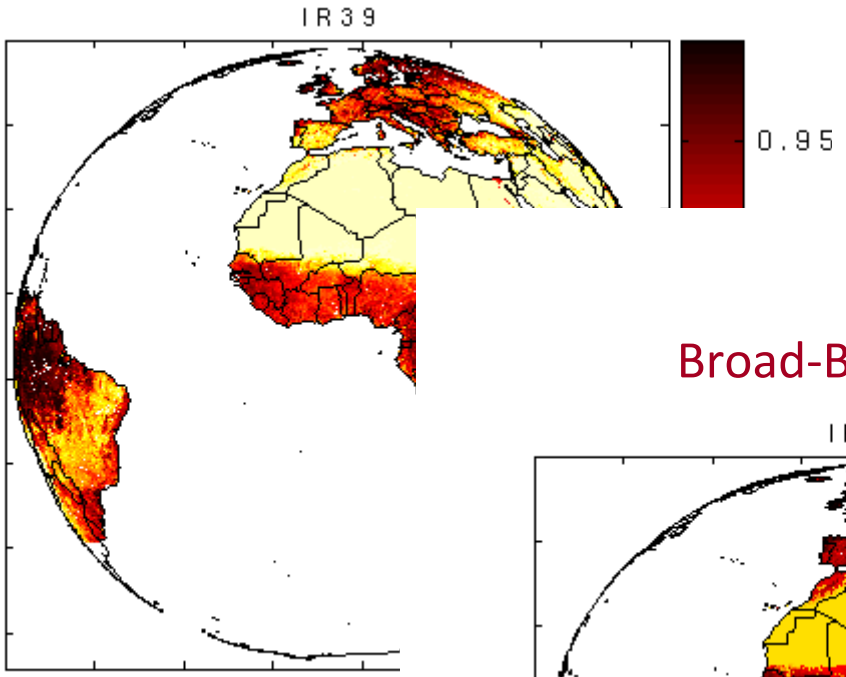
Broad Band

λ1= 3 μm; λ= 14 μm

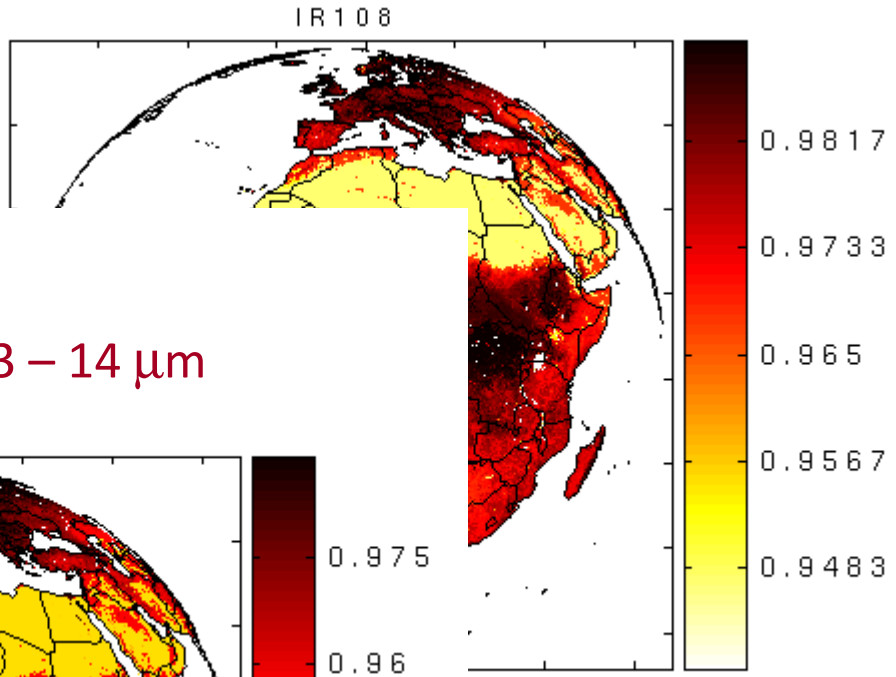
(f_λ=1)

Emissivty

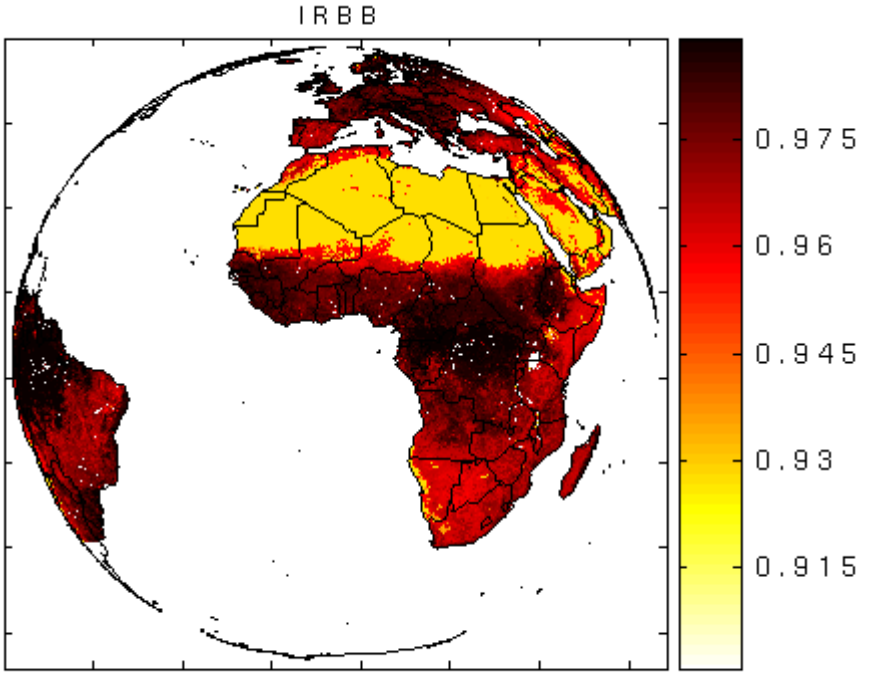
SEVIRI IR3.9



SEVIRI IR10.8

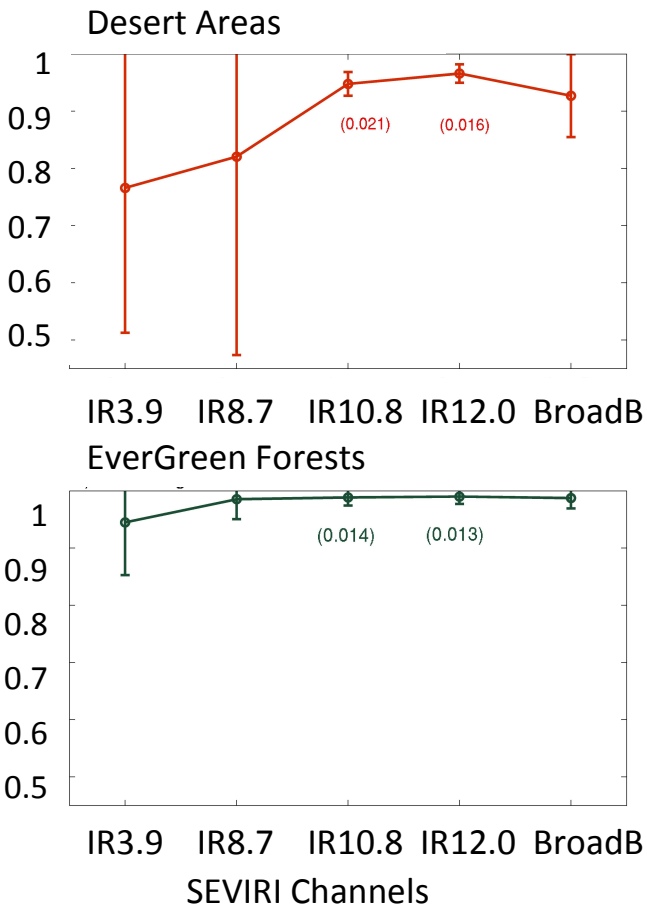


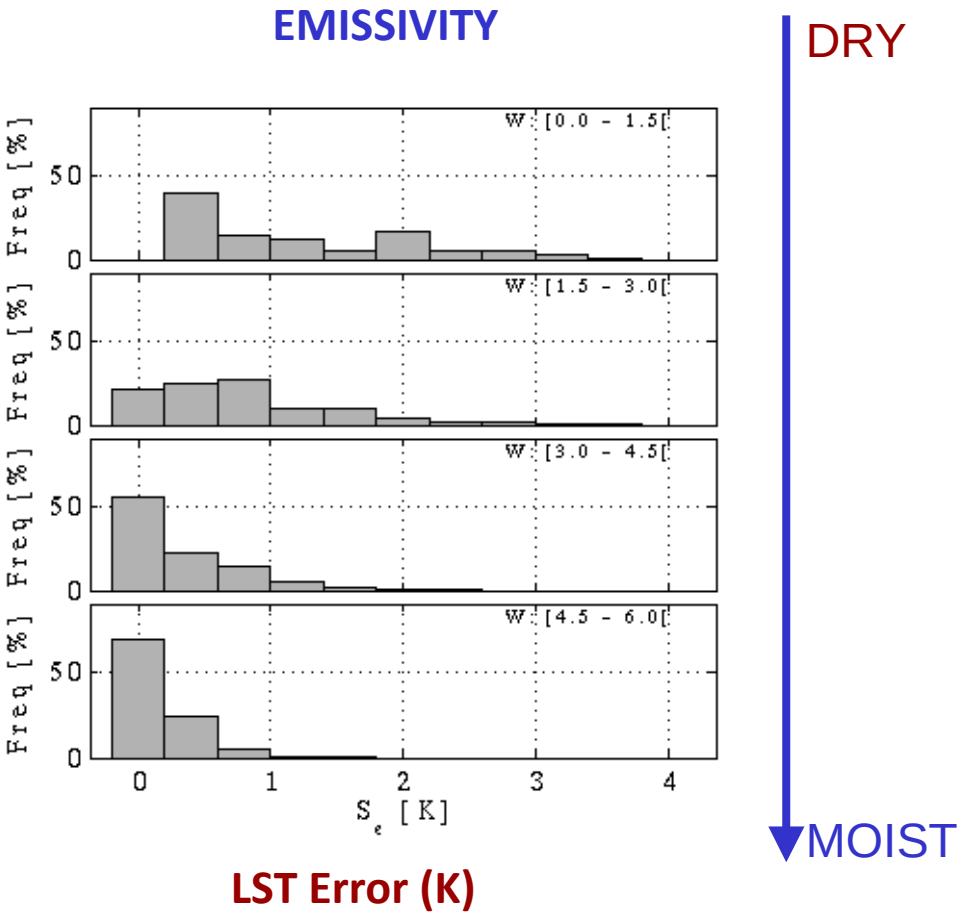
Broad-Band 3 – 14 µm



Updated Daily

Emissivty uncertainty & impact on LST





Emissivty: Next Phase CDOP-2

Improved Emissivity (**EM**) maps

EM (& LST) combination which minimizes:

$$f = \sum [L_{obs} - L_{RTM}(LST, LSE)]_i^2$$

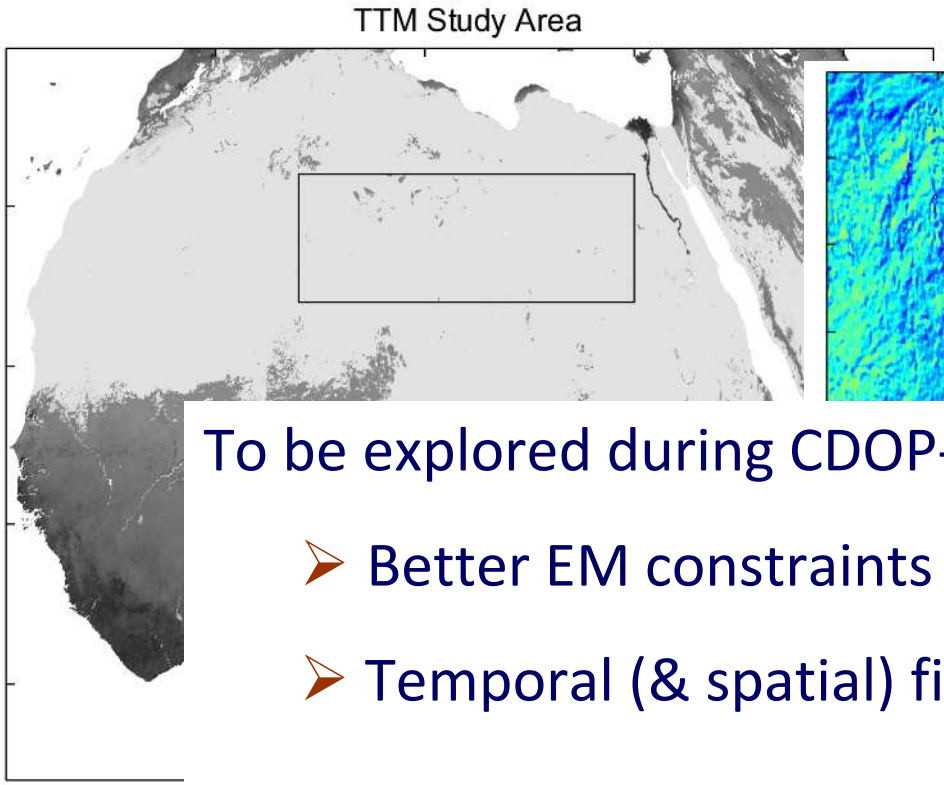
for *i* = channels **IR10.8**, **IR12.0**, **6** and **12 UTC**, assuming **EM** unchanged

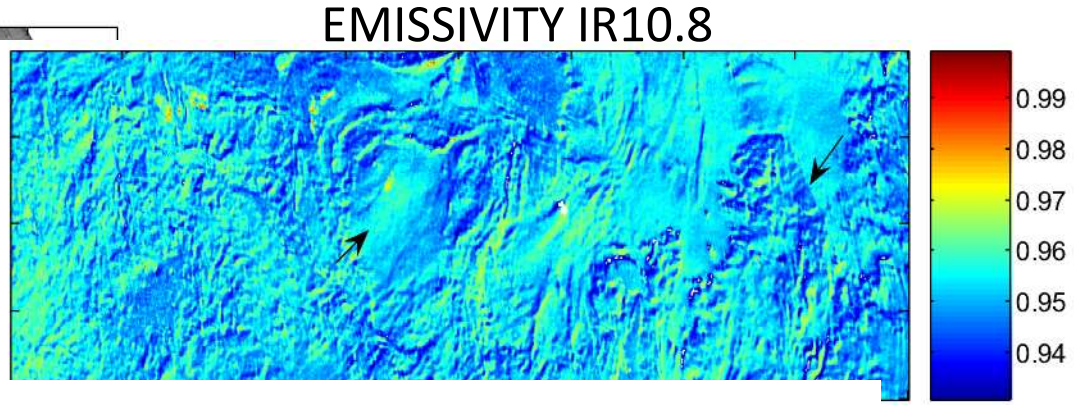
Limited Experience carried out using:

- ✓ LSA SAF **LST** and current **EM** as 1st guess
- ✓ MODTRAN for L_{RTM} ($\rightarrow$ to be replaced by RTTOV)

- Trigo et al (2008) in *IEEE Trans. Remote Sens. Geosc.*
- Peres et al (2010) in *Int J Remote Sens.*

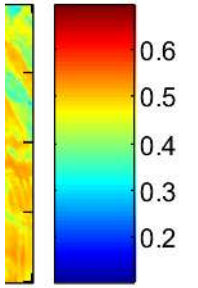
Emissivty: Next Phase CDOP-2

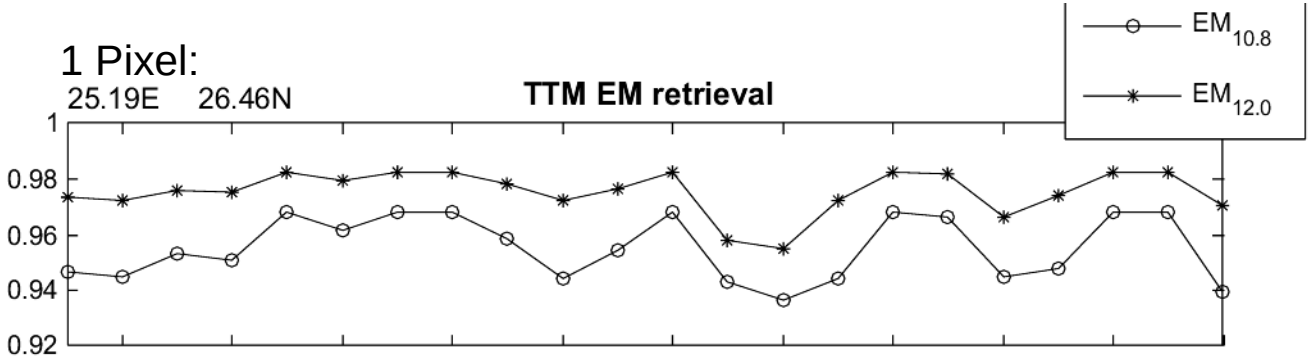




To be explored during CDOP-2:

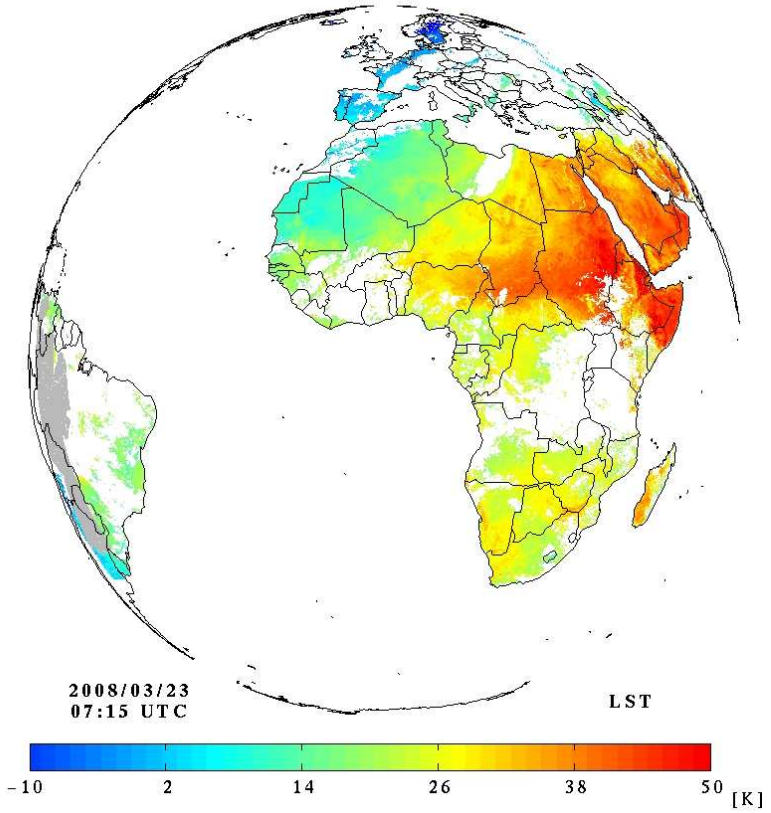
- Better EM constraints among channels
- Temporal (& spatial) filtering





Land Surface Temperature - SEVIRI

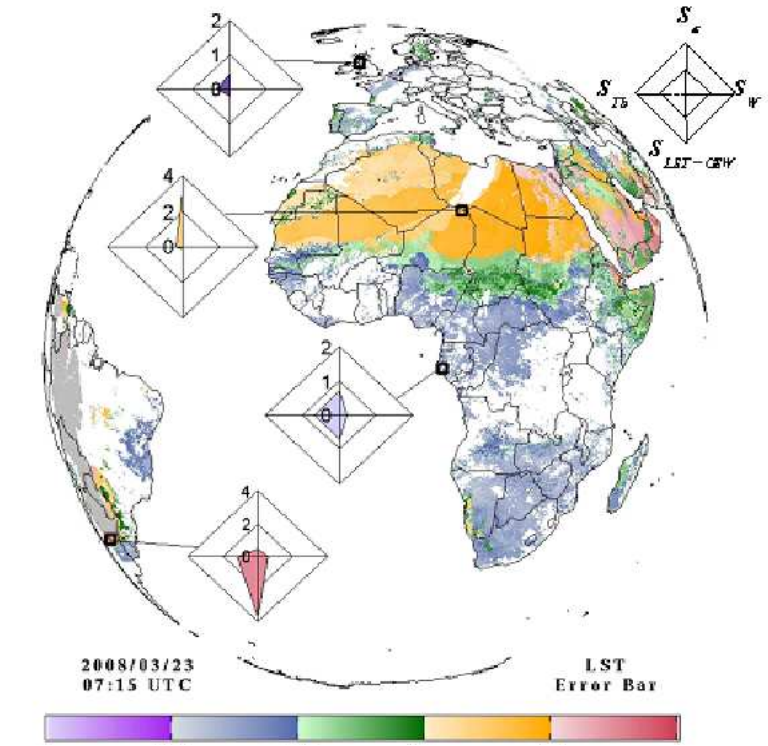
LST



- ✓Generation Frequency - 15 min
- ✓clear sky pixels ...
- ✓ over land ...
- ✓ where estimated errors < 4K
- ✓ Available since
  - ➢ Europe – Feb 2005
  - ➢ Full disk – Jul 2005

Land Surface Temperature - SEVIRI

LST Error Bars



Masked out δLST > 4K

And error bars estimated taking into account:

- ✓ Uncertainty of the GSW regressions
- ✓ Propagation of input uncertainties:
  - Emissivity
  - Sensor noise
  - TCWV ECMWF forecasts

- Trigo et al (2008) in *J. Geophys. Res.*
- Freitas et al (2010) in *IEEE Trans. Remote Sens. Geosc.*

LST - Validation

Validation

- ✓ continuous activity
- ✓ main source of info on product compliance with requiremets

Comparison against in situ observations:

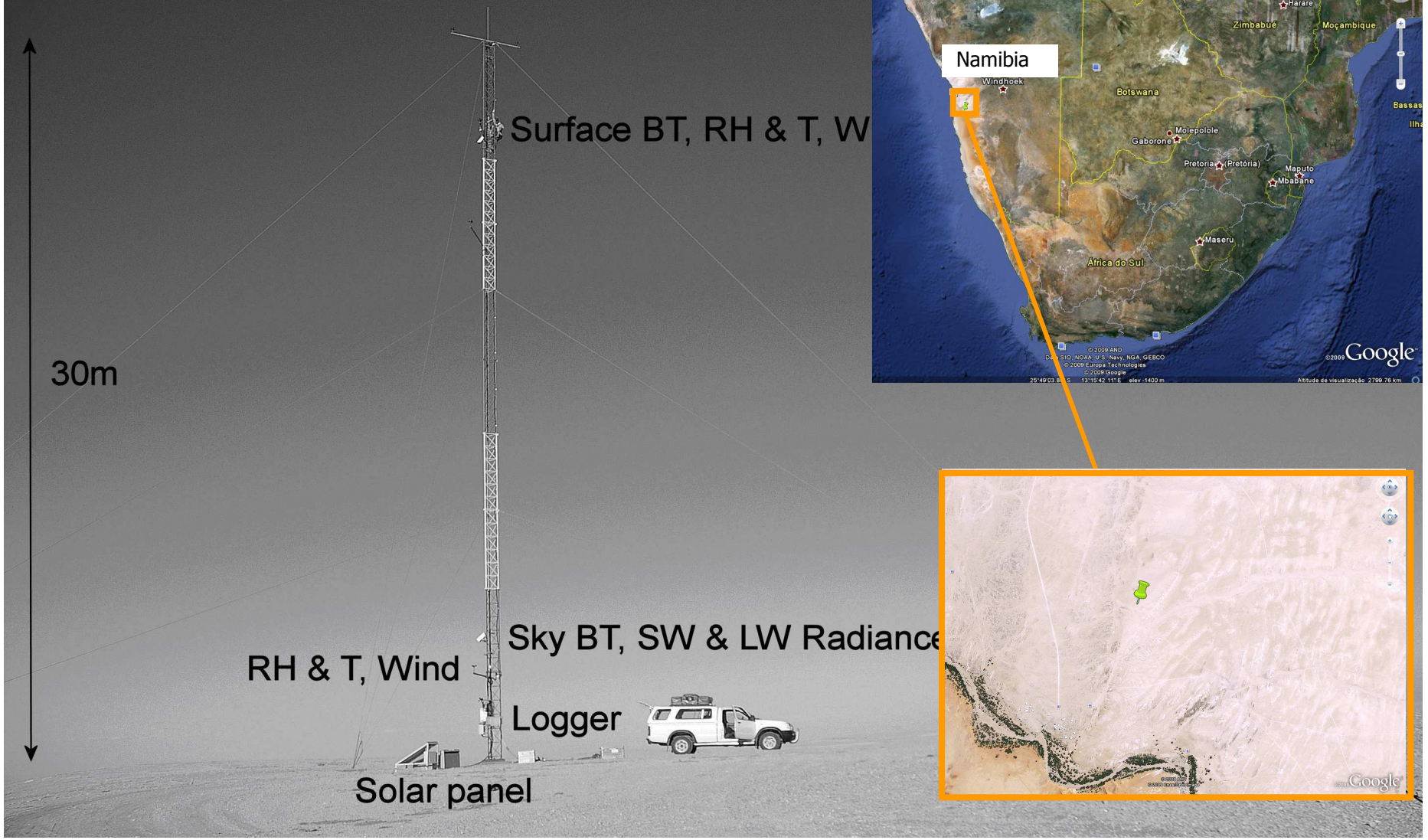
- LSA SAF stations:
  - Portugal (Evora, since 2005)
  - Namibia (Gobabeb + Kalahari farm)
- Field Campaigns (e.g., AMMA)

Comparison with similar products derived from other satellites :

- MODIS
- AATSR

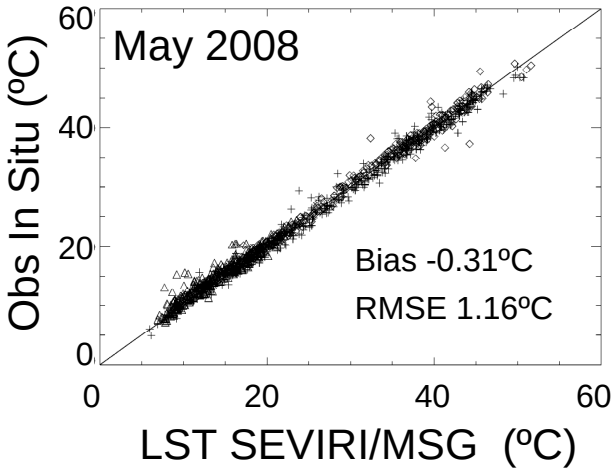
LST - Validation

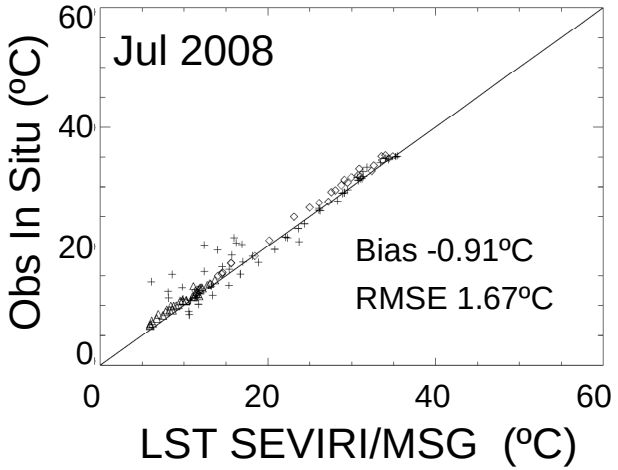
Gobabeb

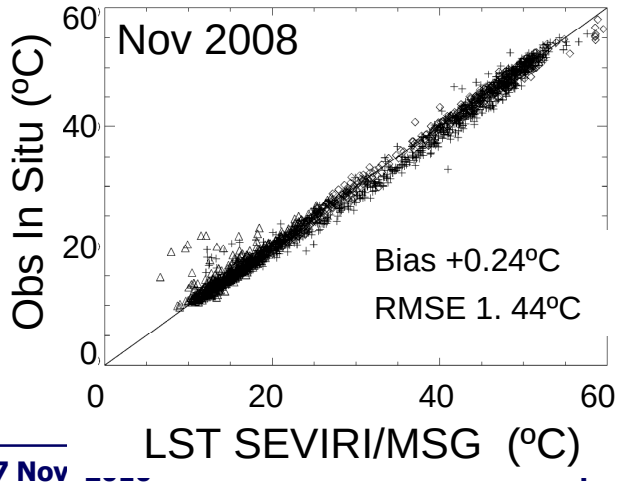


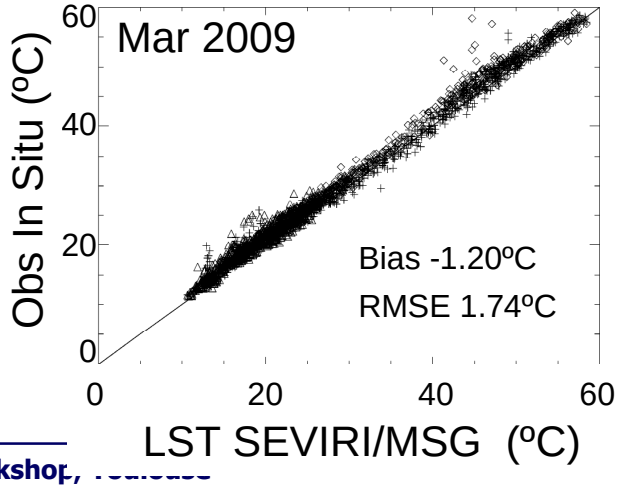
LST - Validation

LST MSG/SEVIRI versus T_{sup} *in situ* at Gobabeb



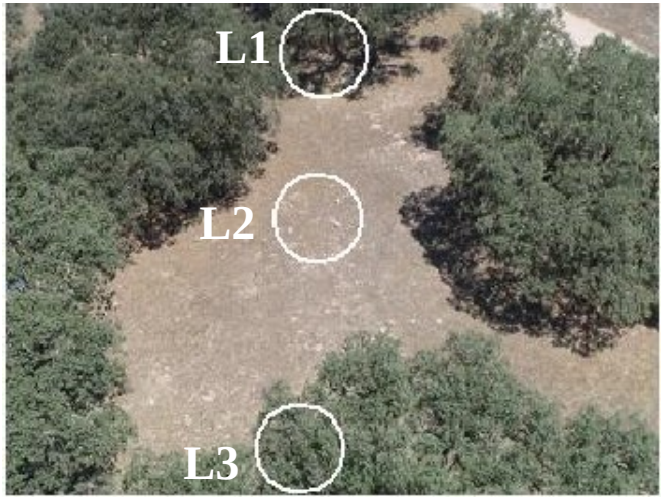






LST - Validation

EVORA



(L1, L2, L3) average

$$L_{RR} = \varepsilon_{RR\_sfc} L_{RR}(T_{sfc}) + (1 - \varepsilon_{RR\_sfc}) L^{\downarrow}_{RR\_atm}$$

scene emissivity

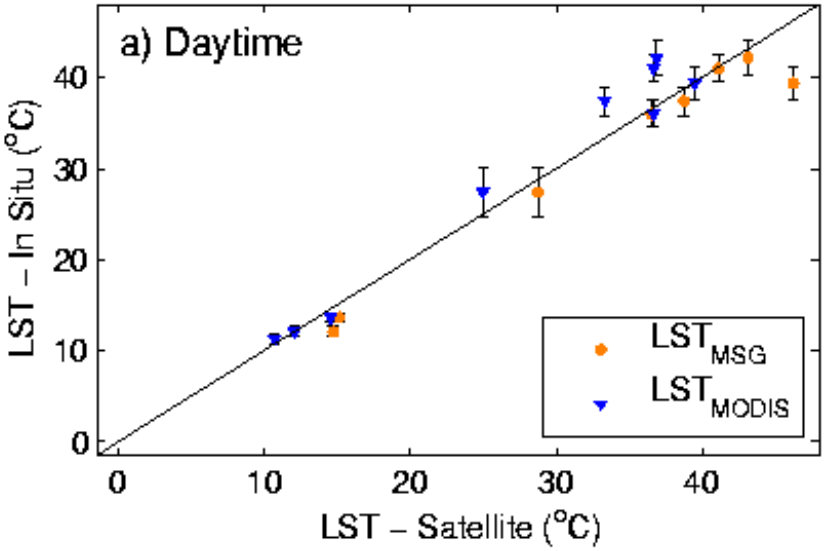
LST_InSitu

downward radiation

$$\delta(LST_{InSitu}) = \left[(\delta LST_{\varepsilon})^2 + (\delta LST_{InSituVarT})^2 + (\delta LST_{InSituVarSp})^2 + (\delta RotRad)^2 \right]^{1/2}$$

LST - Validation

EVORA

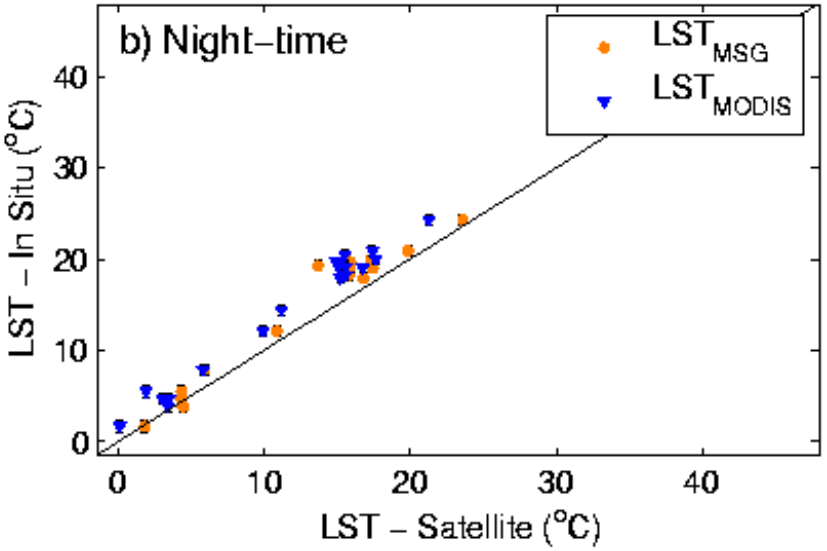


Daytime

(°C)	BIAS	RMSD
SEVIRI	+1.9	2.2
MODIS	-1.8	2.6

Night-time

(°C)	BIAS	RMSD
SEVIRI	-1.7	2.1
MODIS	-2.6	2.7

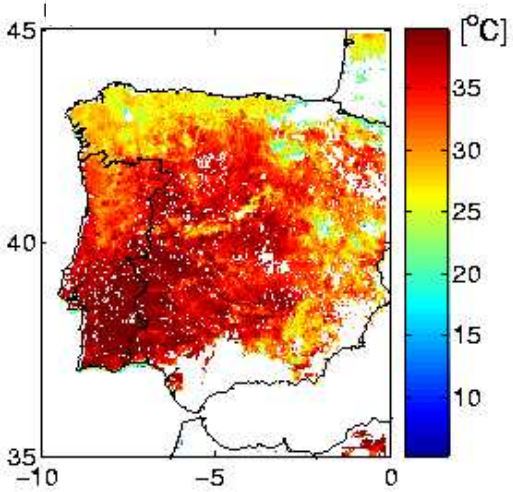


LST - Validation

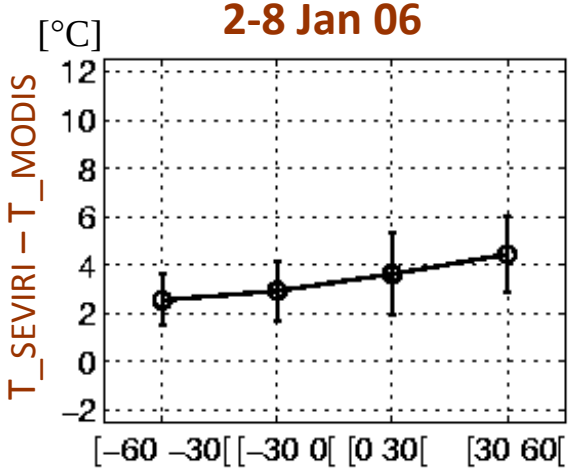
SEVIRI vs MODIS LST

Iberian Peninsula

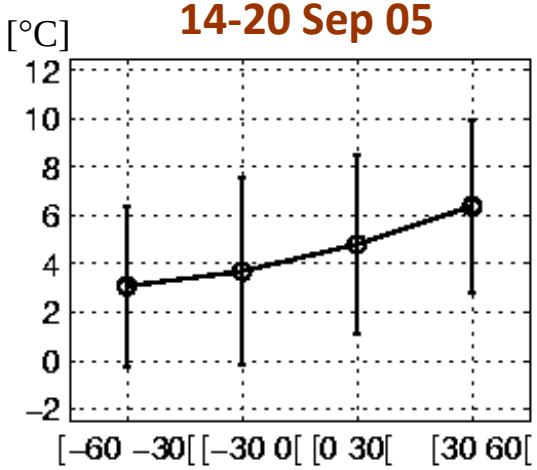
Morning MODIS passage (~11 UTC):



2-8 Jan 06



14-20 Sep 05



MODIS Zenith Angle

Remotely sensed LST is directional variable

Research towards an "isotropic LST" during CDOP-2

Concluding Remarks - LST

- **LST** is generated, archived & disseminated (NRT or off-line) on an operational basis using:
  - ✓ SEVIRI/Meteosat
  - ✓ AVHRR/MetOp

  | Generalized Split-Window

- Validation exercises show that:
  - ✓ LST accuracy depends on retrieval conditions – in accordance to information provided by respective error bars.
    - ➢ CDOP-2: Improve EMISSIVITY
    - ➢ CDOP-2: Revise LST algo for MTG
  - ✓ LST is directional variable
    - ➢ CDOP-2: model of directional effects for different land covers → LST uncertainty; LST correction.

Downwelling Long-wave Flux at the Sfc

DSLF – IR radiation (4 - 100 μm) emitted by whole atmosphere

Bulk Parameterization:

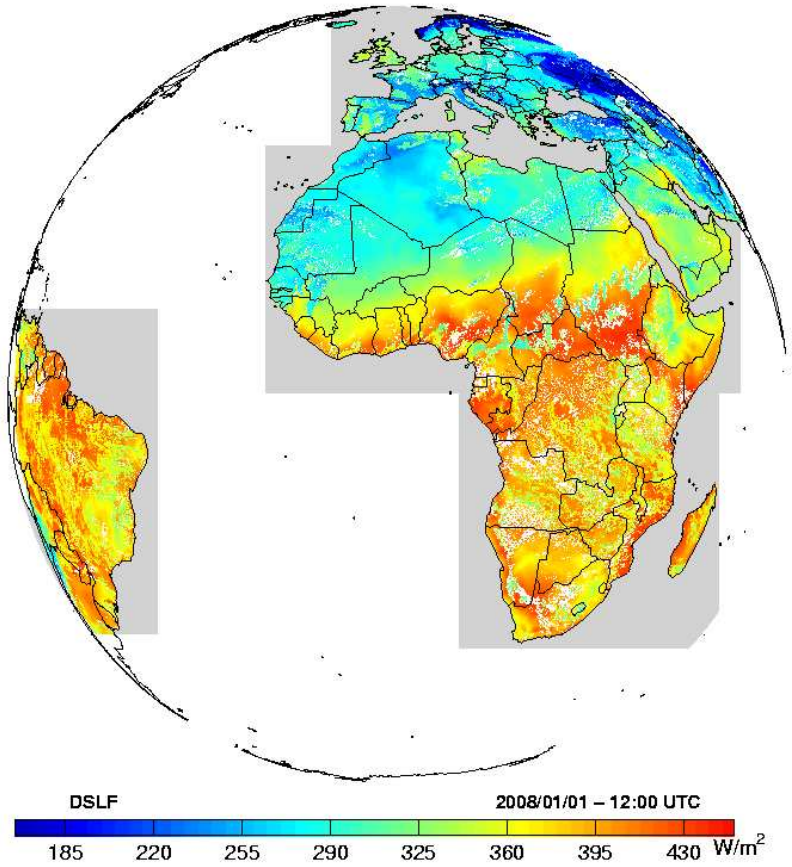
$$F^{\downarrow} = \varepsilon_{sky} \sigma T_{sky}^{4}$$

Temperature & Water Vapour Profiles — **NWP**

Clouds/ Cloud Type — **Remote Sensing**

Trigo et al. (2010) in J Geophys Res., in press

DSLF - SEVIRI

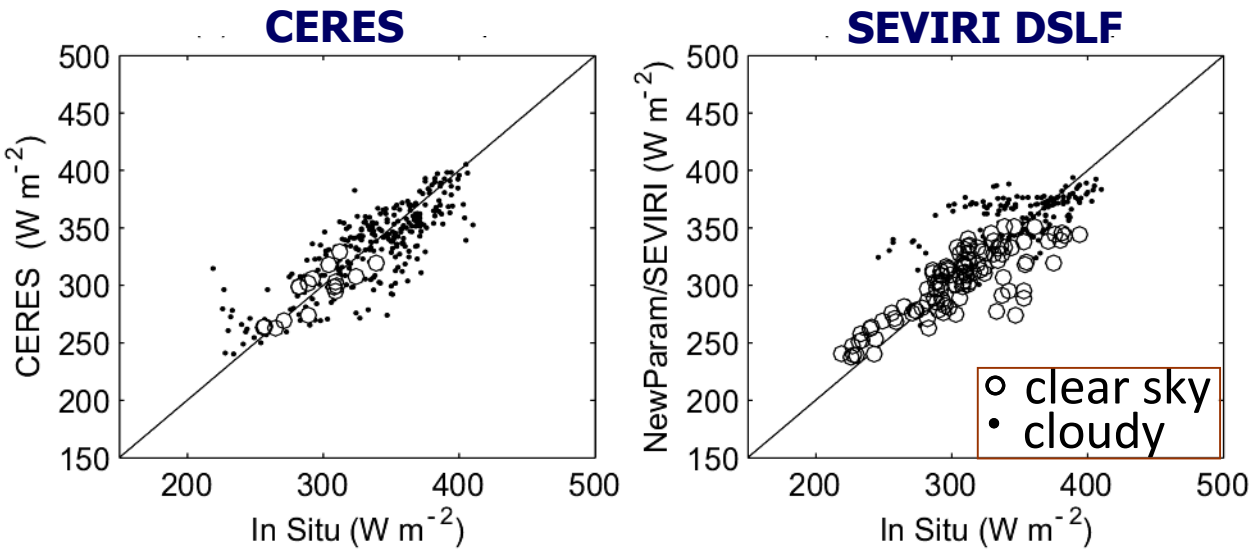


- ✓Generation Frequency 30 min
- ✓ over land pixels
- ✓ available since 2005
  - ❖ with revised algorithm since 2009.

DSLF - Validation

Ground Stations (BSRN) & CERES

Northern Europe Stations



Period

Jan 2006 - Apr 2007

Stations

Cambourne, UK

Lerwick, UK

Toravere, Estonia

	CERES		SEVIRI DSLF	
	Bias	RMSE	Bias	RMSE
Clear Sky	-0.0	12.7	-2.2	22.3
All Sky	-2.1	23.5	3.1	25.3

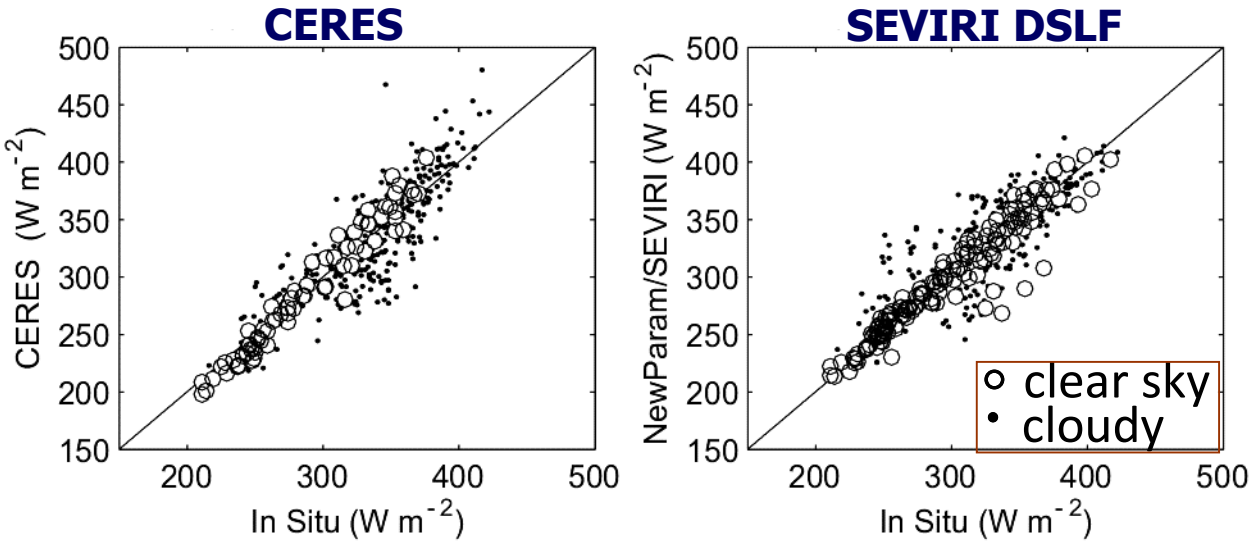
Problems:

- Cloud identification at the edge of Meteosat disk
- DSLF model for ice clouds
- Temperature inversions

DSLF - Validation

Ground Stations (BSRN) & CERES

Central Europe Stations



Period

Jan 2006 - Apr 2007

Stations

Palaiseau, France

Payerne, Swtzerland

Carpentras, France

	CERES		SEVIRI DSLF	
	Bias	RMSE	Bias	RMSE
Clear Sky	-0.9	13.4	0.8	14.5
All Sky	-1.4	22.7	1.6	22.5

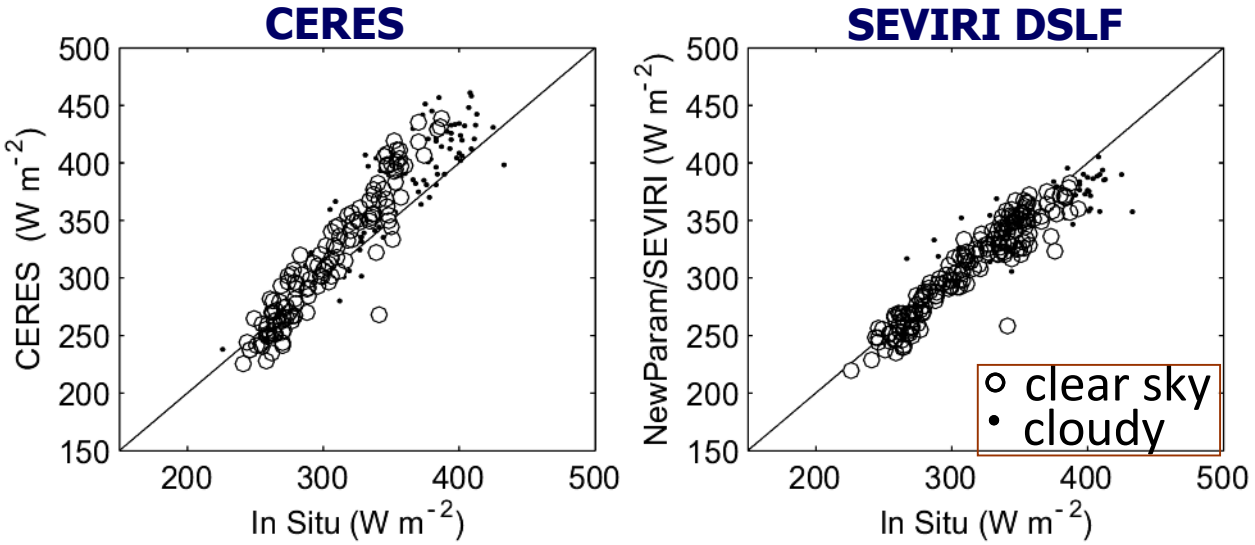
Problems:

- Temperature inversions

DSLF - Validation

Ground Stations (BSRN) & CERES

Semi-Arid & Desert Stations



Period

Jan 2006 - Apr 2007

Stations

Tamanrasset, Algeria

Sde Boqer, Israel

Niamey, Niger

	CERES		SEVIRI DSLF	
	Bias	RMSE	Bias	RMSE
Clear Sky	13.0	26.8	-4.4	14.1
All Sky	17.5	29.6	-5.4	16.9

Problems:

- Impact of high aerosol loads

Concluding Remarks - DSLF

- **DSLF** is generated, archived & disseminated (NRT or off-line) on an operational basis using:
  - ✓ SEVIRI/Meteosat
  - ✓ AVHRR/MetOp

Bulk Parameterization Scheme

- **DSLF** validation against in situ data:
  - ✓ 60-70% of retrievals meet the target accuracy of 10%
  - ✓ low up to mid latitudes – accuracy comparable to CERES downward long-wave fluxes.
    - ➢ CDOP-2: Algorithm development shared within SAF Network, targeting known deficiencies
      - Aerosol, ice clouds, …
      - Review existing dependence on NWP model output.

http://landsaf.meteo.pt