Land Surface Temperature Observations

&

Assessment of Land Surface Parameterizations

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Thanks to: I. Sandu, S. Boussetta, G. Balsamo (ECMWF) et al.

The EUMETSAT Network of Satellite Application Facilities

LSA SAF Land Surface Analysis

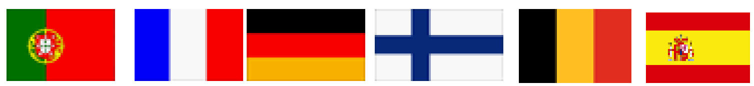
Outline

- The Satellite Application Facility on Land Surface Analysis (Land-SAF) – overview of products and services
- Land Surface Temperature – SEVIRI retrievals
  - Algorithm
  - LST uncertainties
  - Validation
    - In-Situ observations
    - LST MODIS
  - LST as a Model Diagnostic tool
    - ECMWF model: Past & present
    - Vegetation – monthly climatologies of LAI
    - Surface parameterization – aerodynamic resistance
- Concluding Remarks

The LSA SAF

The **Land Surface Analysis Satellite Applications Facility**, is dedicated to algorithm development, validation and operational production of **land surface related products** based (primarily) on European meteorological satellites (MSG and METOP)

- ✓ Funded by **EUMETSAT**
- ✓ 7 Institutes in 6 countries



- ➢ Real time operations (i.e., some products are available every 15 min, ~2-3 hours after observed)
- ➢ Reviewed (~annually) by technical and scientific review panels
- ➢ Most products can be used for verification & monitoring of NWP
- ➢ A few products can be used for surface data assimilation

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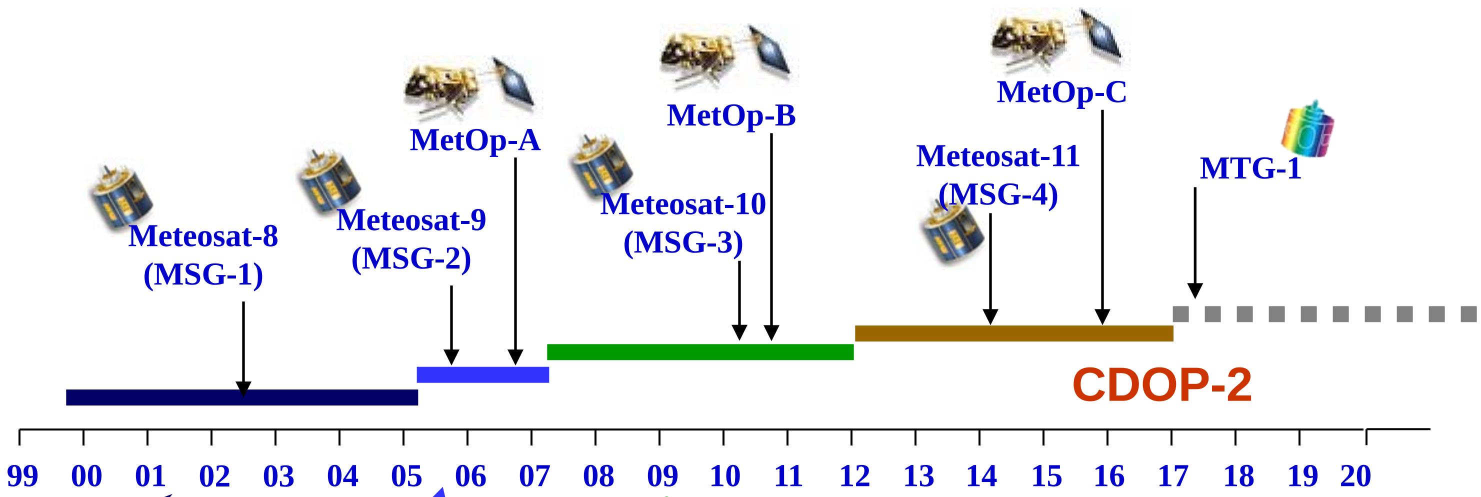
LSA SAF - Chronogram



Development Phase:
Sep 99 – Jan 05

Initial Operations Phase:
Feb 05 – Feb 07

Continuous Development & Operations Phase I:
Mar 07 – Feb 12

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Land-SAF – Perspective for CDOP-2

LSA SAF

Surface Radiation

- LST
- ↓LongWave Flux
- ↓ShortWave Flux
- Albedo

Vegetation

State

- Fraction Veg Cover
- LAI
- fAPAR
- NDVI

Water stress

- Evapotranspiration
- Reference Evap

Wild fires

- Fire Detection
- Fire Radiative Power
- Fire Risk (Europe)

Increased level of maturity →

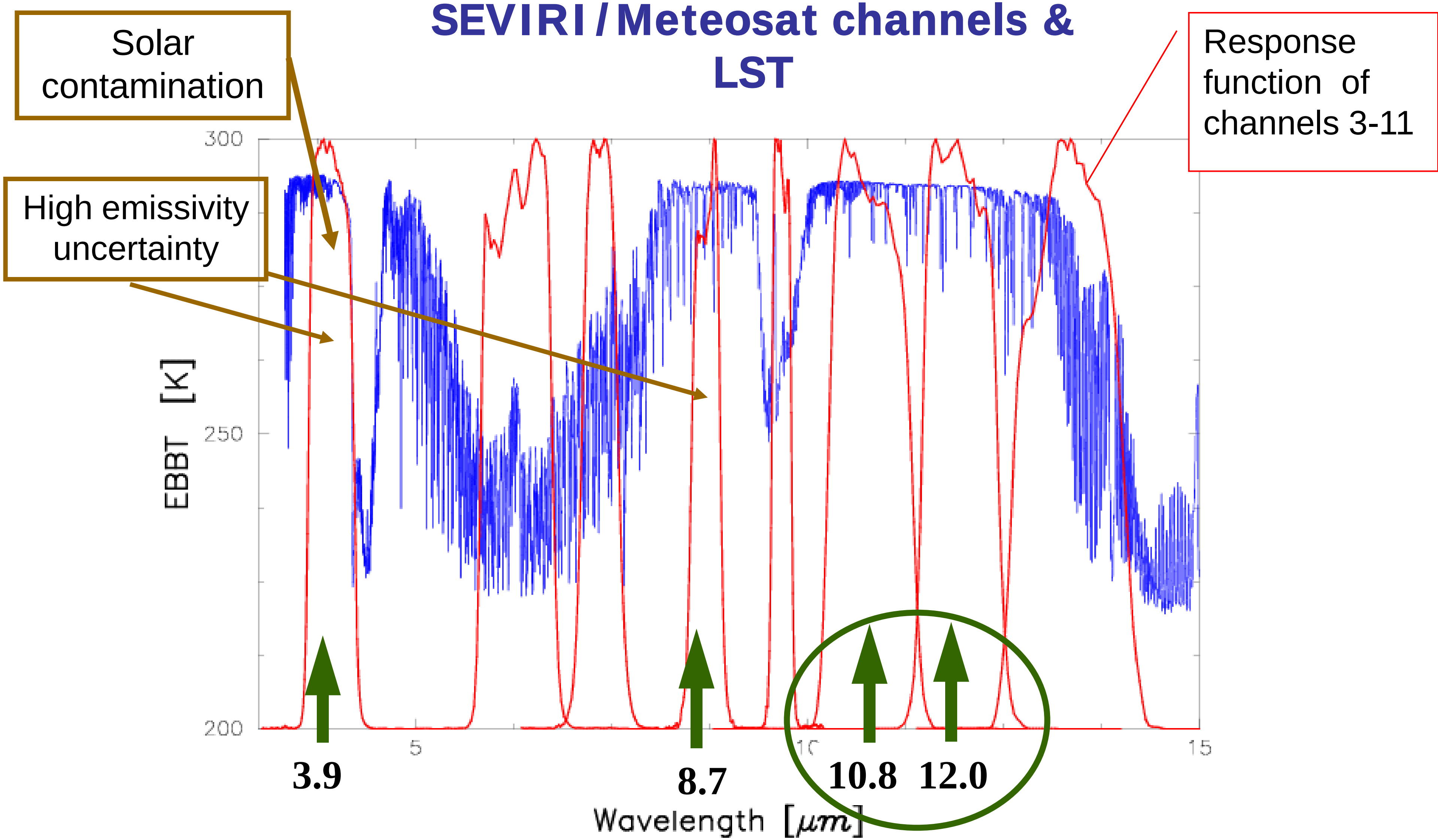
MSG

Metop

LST Algorithm Requirements:

- ✓ Maximize the use of available channels, in order to …
- ✓ Minimize the incertainty of the retrievals, and …
- ✓ being Computacionally Efficient.

SEVIRI / Meteosat channels & LST



LST from SEVIRI / Meteosat

- 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:

1. total column water vapour
2. viewing angle

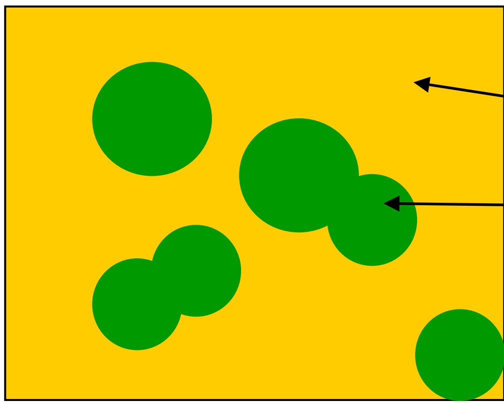
ECMWF fc

- Channel Emissivity → Fraction Vegetation Cover

Emissivty

VEGETATION COVER METHOD

Pixel MSG



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

LSA SAF Product

↑

Sfc Reflectances VIS

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

Generalized Split-Windows - LST Errors

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

Input errors

↓

Sensor noise; emissivity

Algorithm uncertainty

↓

Retrieval conditions

Model parameters/ Implicit input variables

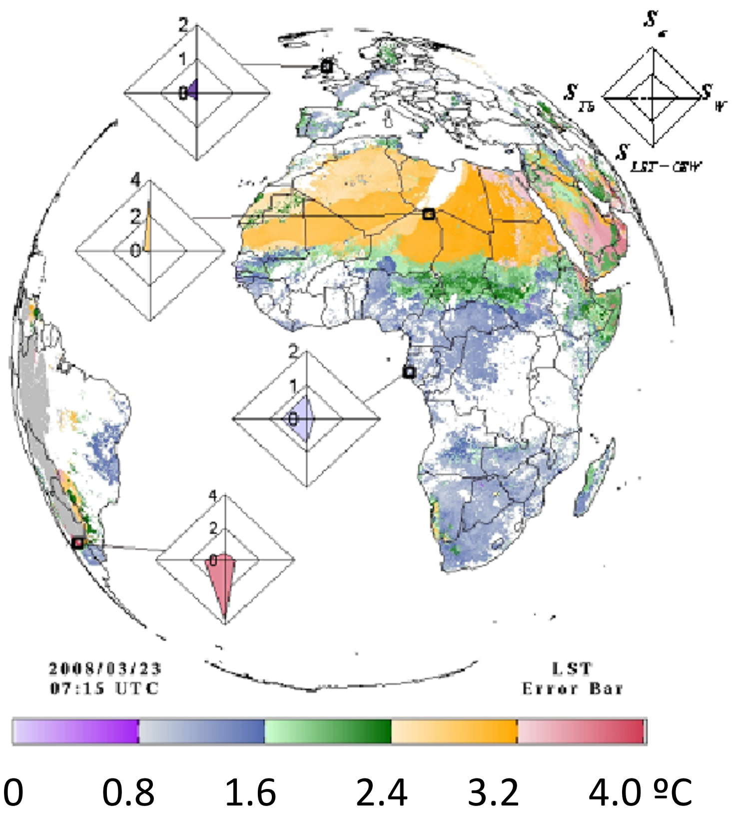
↓

TCWV (ECMWF); view angle

Land Surface Temperature - SEVIRI

LSA SAF

LST Error Bars



Masked out δLST > 4K

And error bars estimated taking into account:

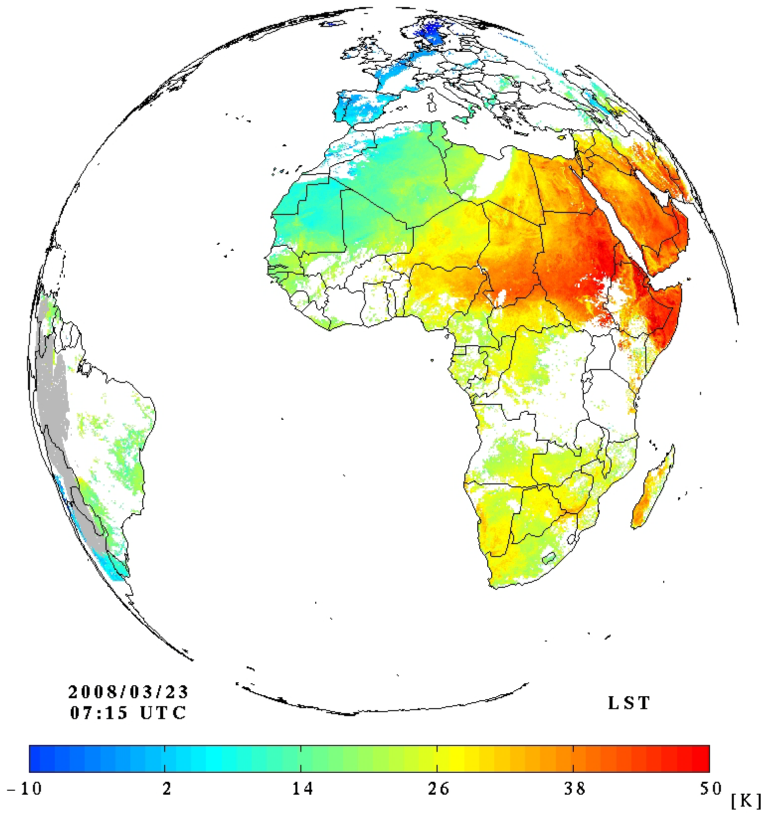
- ✓ Uncertainty of the GSW regressions
- ✓ Propagation of input uncertainties:
  - Emissivity
  - Sensor noise
  - TCWV ECMWF forecasts

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

Land Surface Temperature - SEVIRI

LSA SAF

LST



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

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

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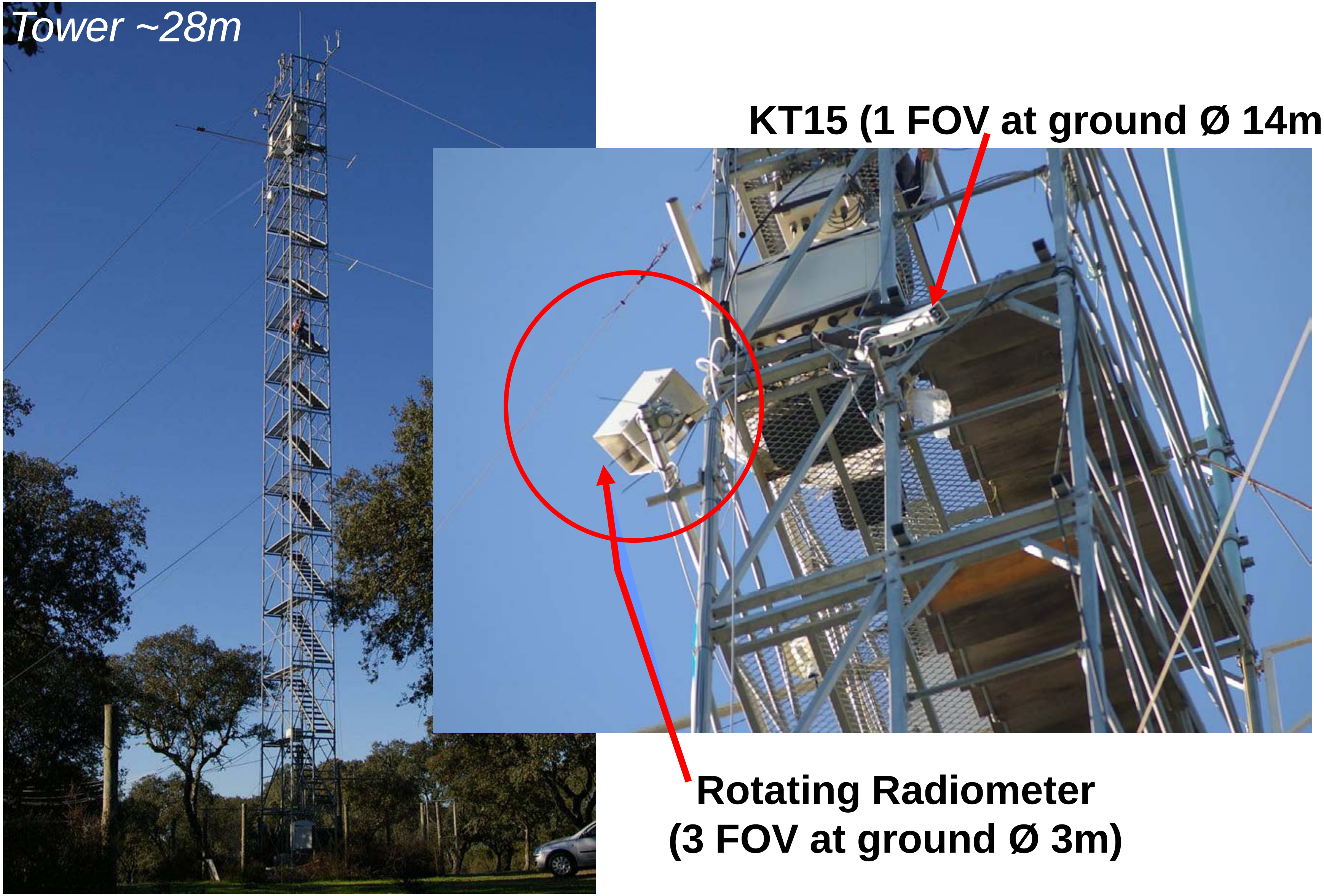
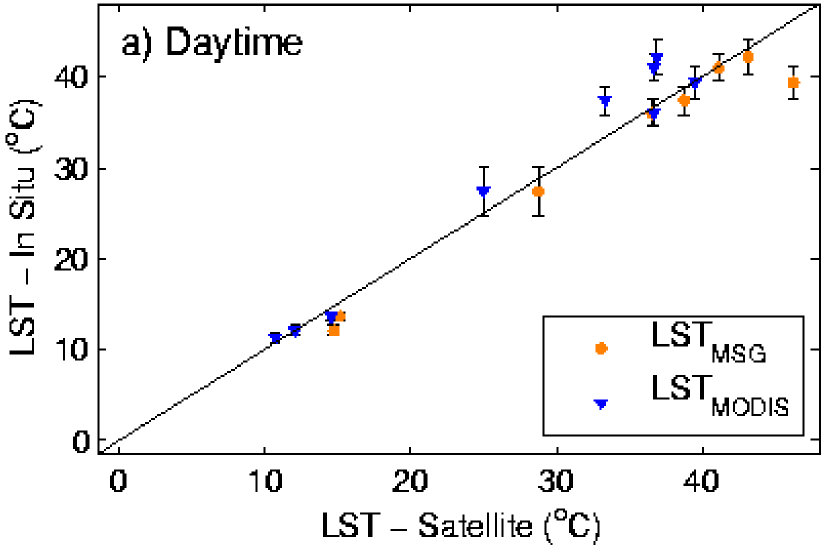
EVORA


Tower ~28m
KT15 (1 FOV at ground Ø 14m
Rotating Radiometer
(3 FOV at ground Ø 3m)

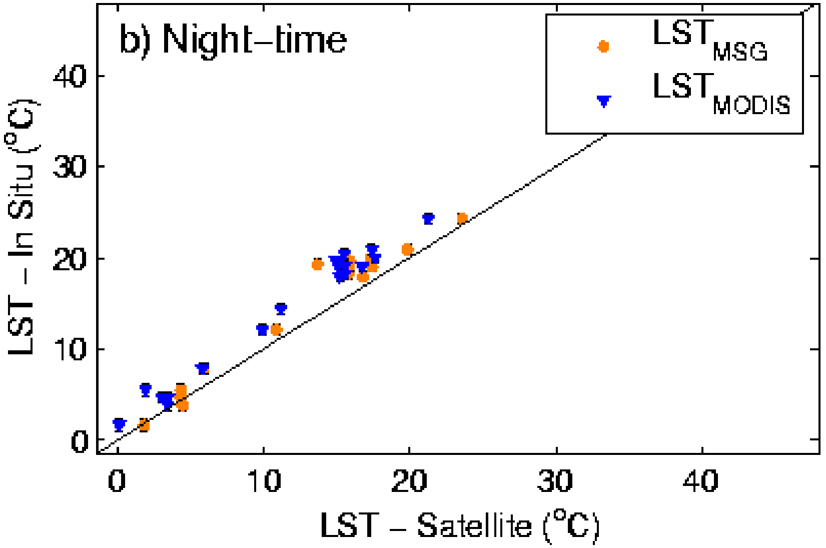


Daytime

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

Night-time

(ºC)	BIAS	RMSD
SEVIRI	-1.7	2.1
MODIS	-2.6	2.7



Trigo, I. F., I. T. Monteiro, F. Olesen, and E. Kabsch, (2008) *in* J. Geophys. Res., 113

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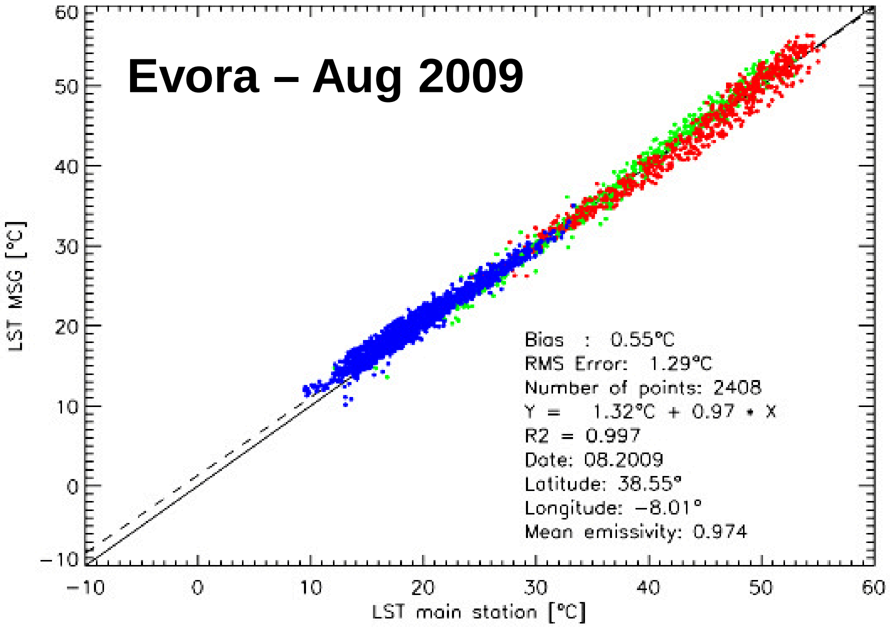
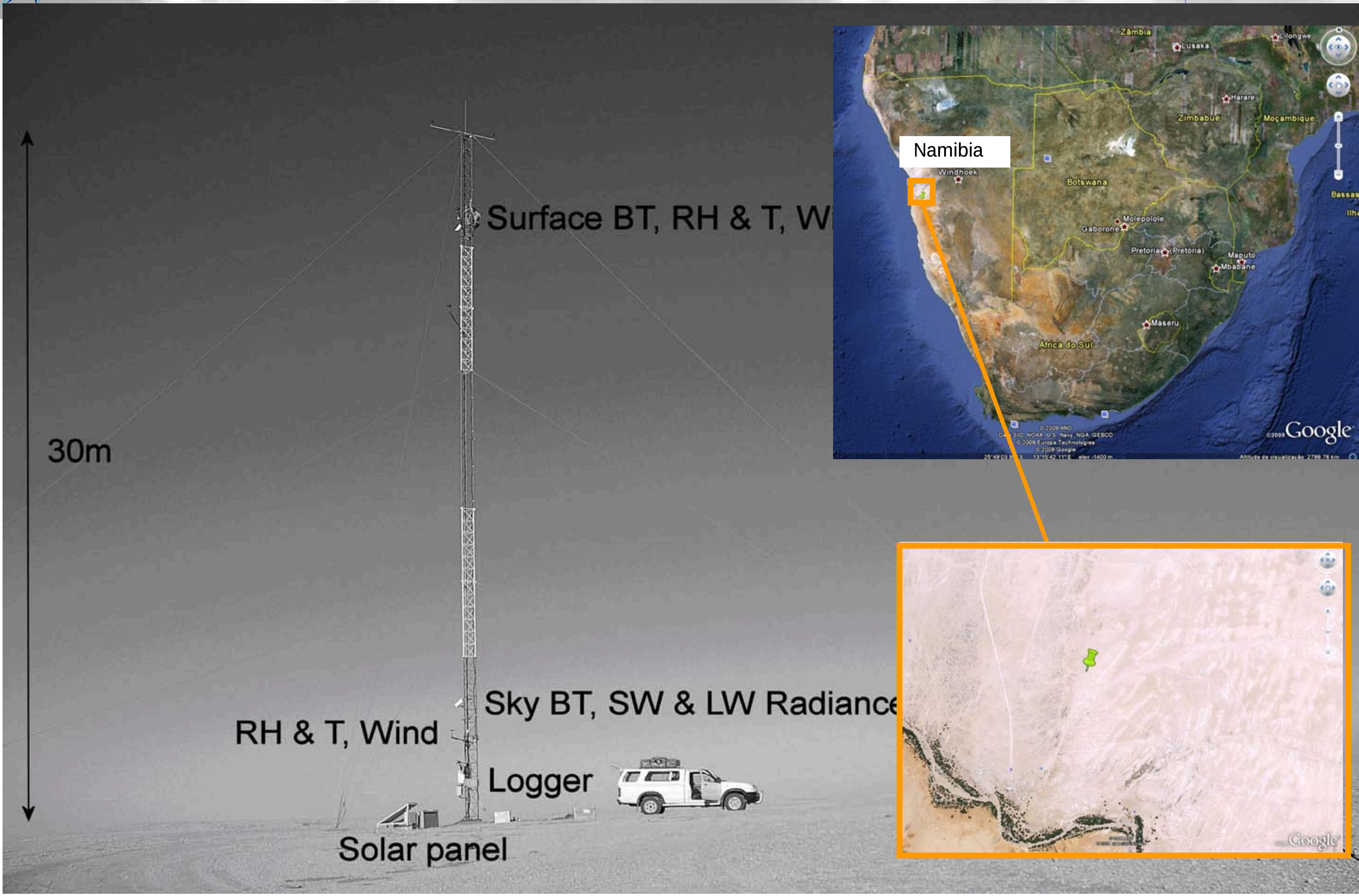
Improvements in SEVIRI/MSG LST

- Correction in level 1.5 processing at EUMETSAT (May 2008): conversion of digital counts to effective radiances (impact small, but reaching significant values for high brightness temperatures); ...
- Generalized Split-Windows – wider calibration dataset; treatment of input unceratainties and impact on LST errors.

Morning – green; afternoon – red; night - blue



Land Surface Temperature – Validation



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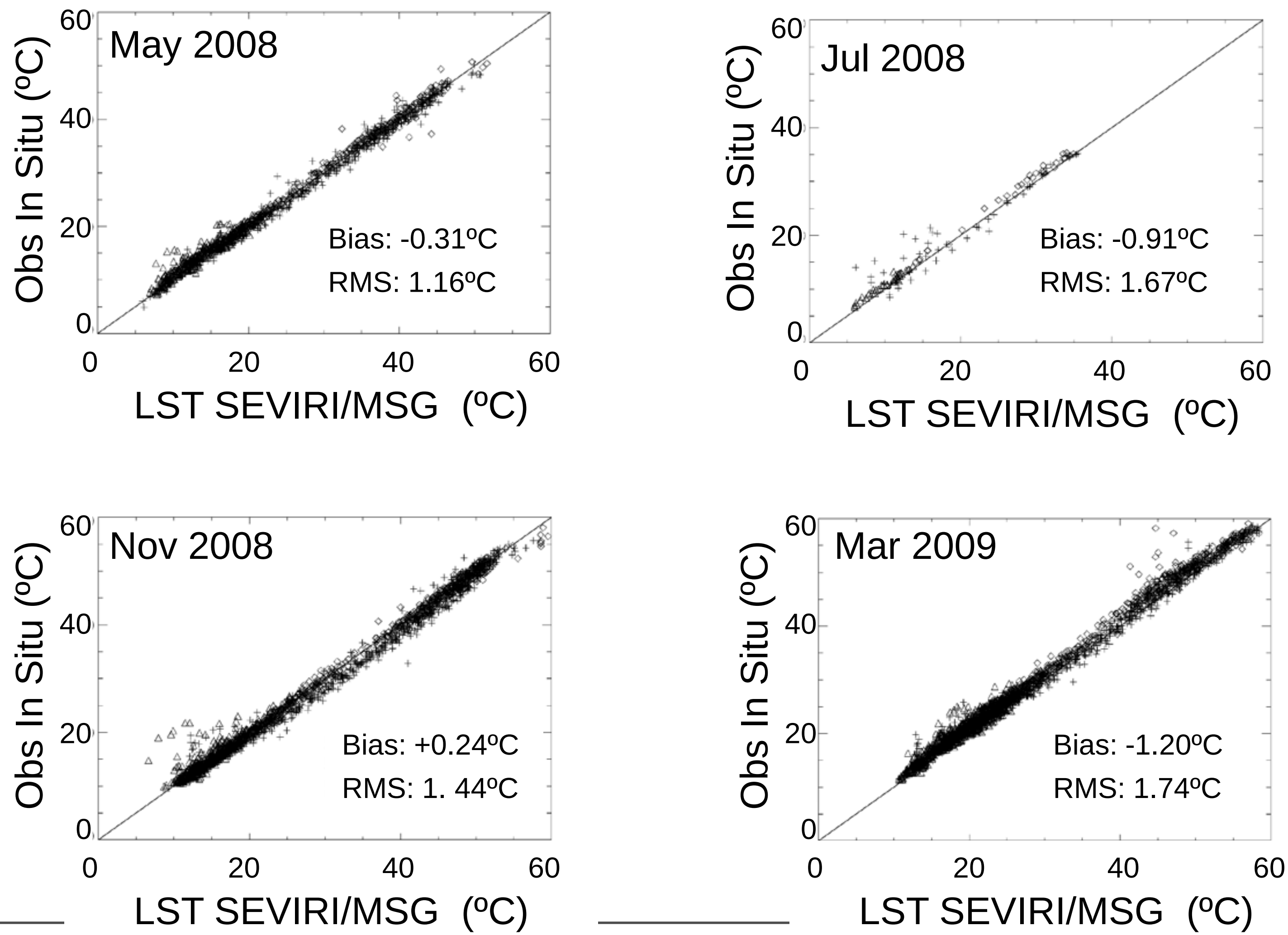
Land Surface Temperature – Validation

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



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LST and Models

As a diagnostic tool

Model Skin Temperature depends on:

- local effects – land cover, vegetation state, soil moisture, terrain charateristics and near surface wind;
- the surface scheme (and impact on, e.g., soil moisture); land surface parameters such as roughness lengths for momentum and heat.

The assessment of model temperature provides useful information on the impact of changes in surface modelling.

2001

Comparison of Meteosat and ECMWF TOA brightness temperatures as a proxy for LST versus skin temperature

Window Channel (10.50 – 12.50 μm)

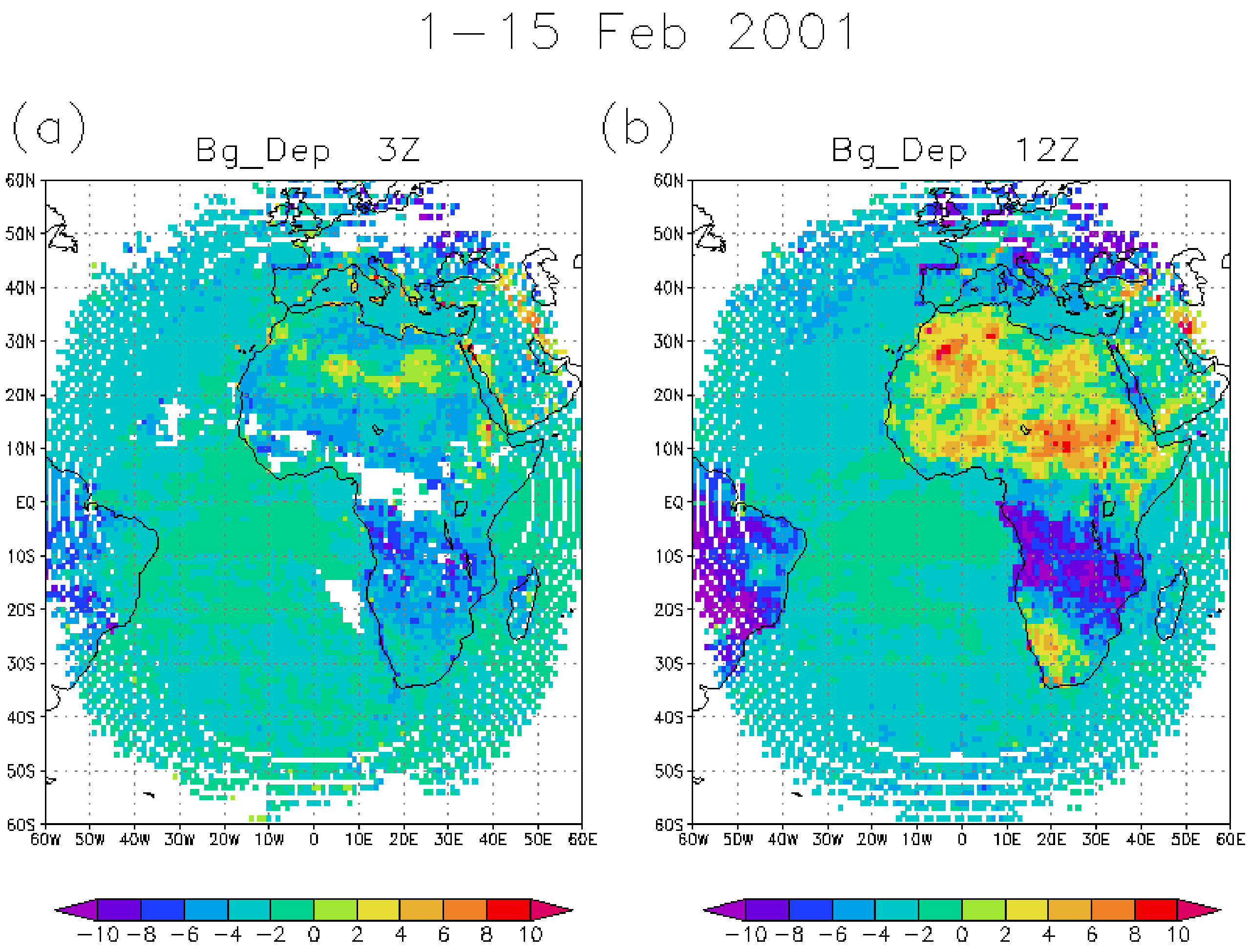
METEOSAT – 7 clear sky .... Tb_OBS

ECMWF model equivalent .... Tb_ECMWF

To assess the quality of modelled land surface temperature.

To monitor the quality of the observations by identifying gross errors / systematic problems in the data.

2001

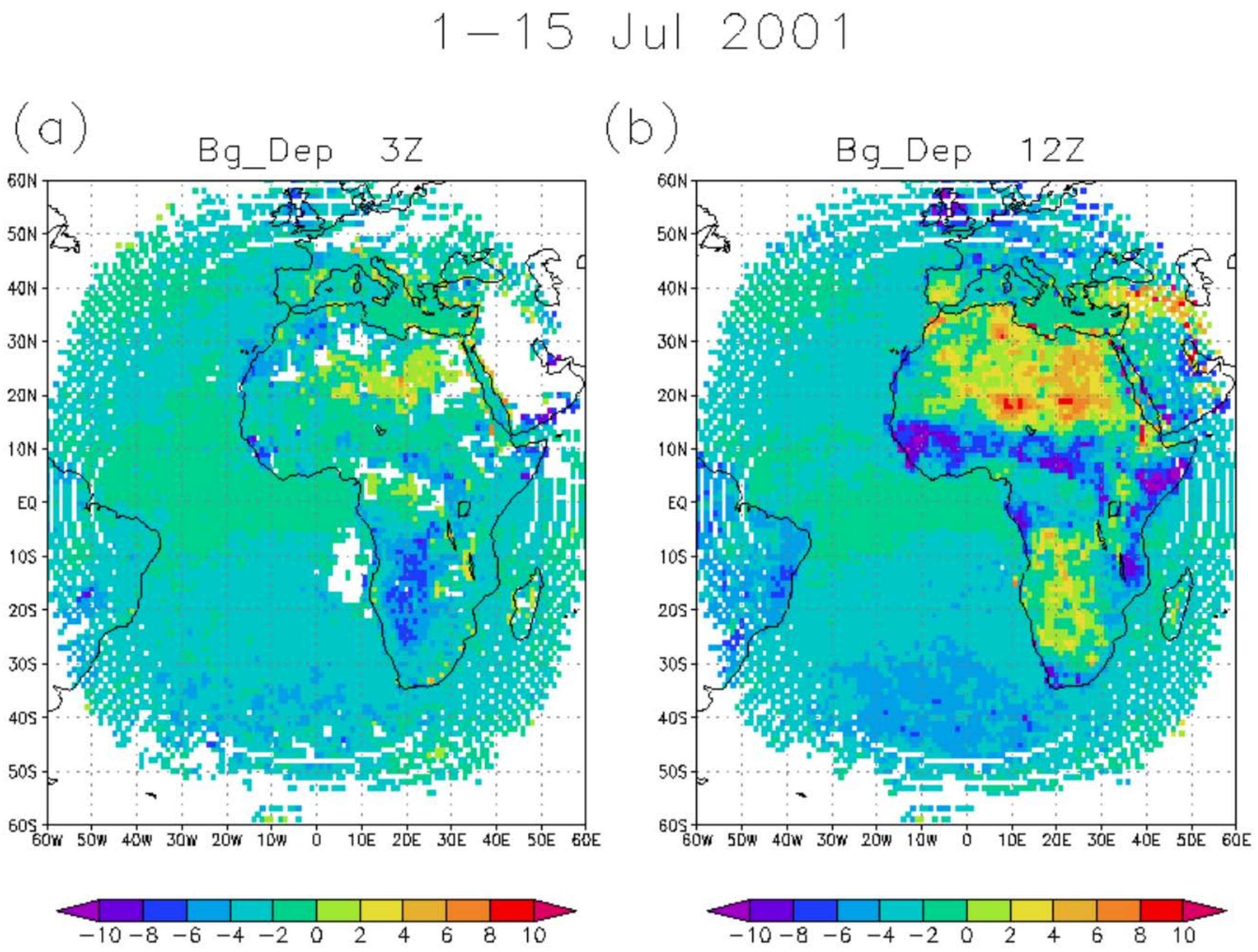


Tb_obs – Tb_ECMWF

Averaged for 1-15 Feb 2001

LST and Models

2001



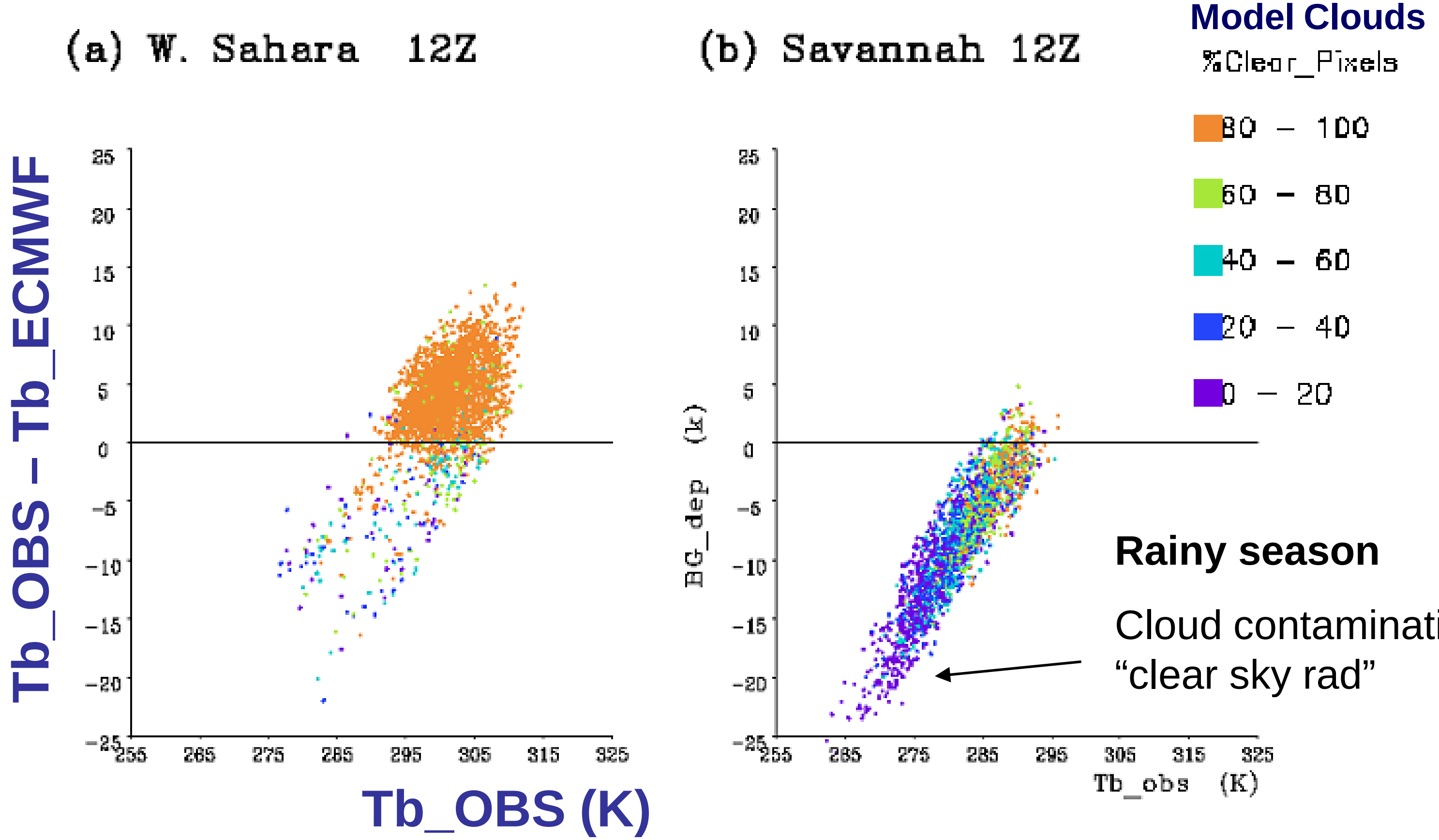
Tb_obs – Tb_ECMWF

Averaged for 1-15 Jul 2001

LST and Models

2001

Feb 2001



Rainy season

Cloud contamination of "clear sky rad"

Sources of Window channel Tb Systematic Errors (in 2001)

(i) cloud screening of the observations ...

⇓

- MSG allows more accurate cloud masks.

(ii) underestimation of modelled diurnal amplitudes of Tb_ECMWF in clear sky conditions

⇑

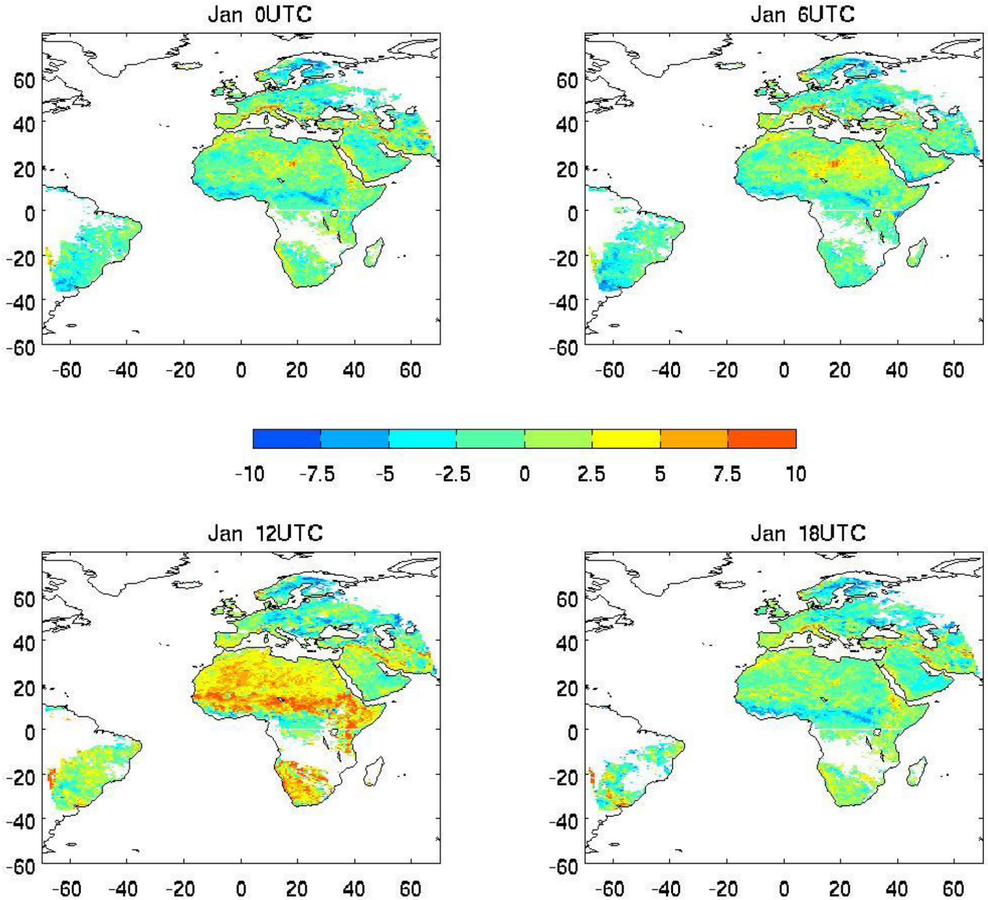
underestimation of skin temperature diurnal cycle
(particularly over arid and semi-arid regions)

LST and Models

LST_SEVIRI – ECMWF skin Temp 1-15 Jan 2009

2009

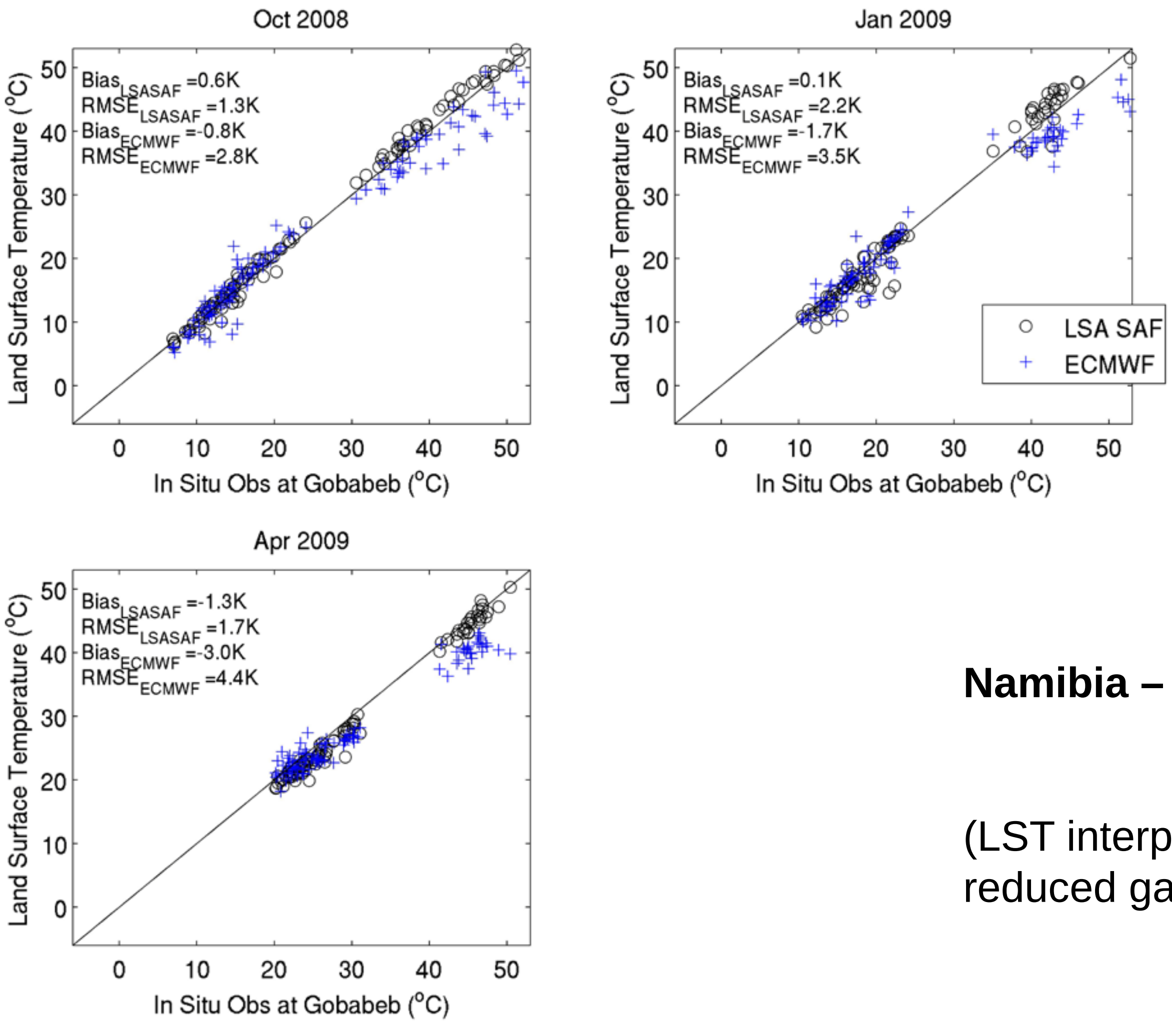
(only cases with model TCC < 10% - **always from now onwards**)



Many of the features found 8-year before are still present in the operational model in 2009:

- Good agreement of night-time temperatures;
- Underestimation of daily amplitudes – particularly in semi-arid /sparsely vegetated regions.

LST and Models



Namibia – gravel plains

(LST interpolated to model reduced gaussian grid)

Changing the ECMWF model Vegetation

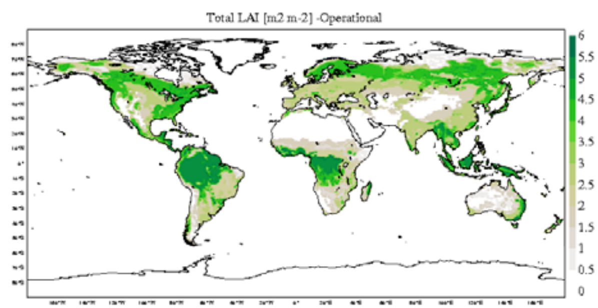
Suite of forecast experiments

CTL: Constant LAI

LAI_MOD: monthly climatology LAI - MODIS

LAI_rsmin: LAI MODIS climate + reduction of minimum stomatal resistance

Boussetta et al., 2011

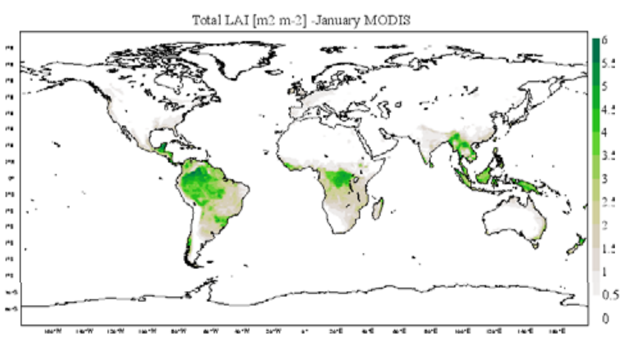


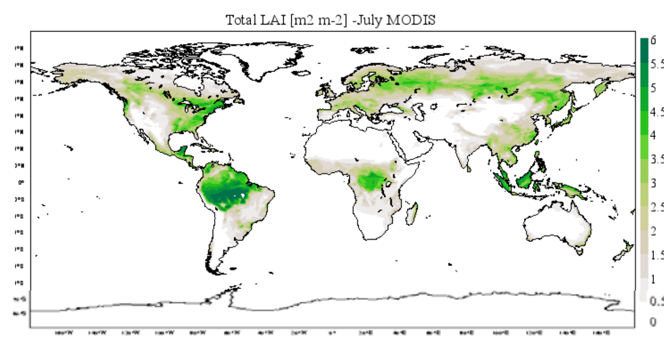
Constant LAI

January

LAI MODIS climate

July



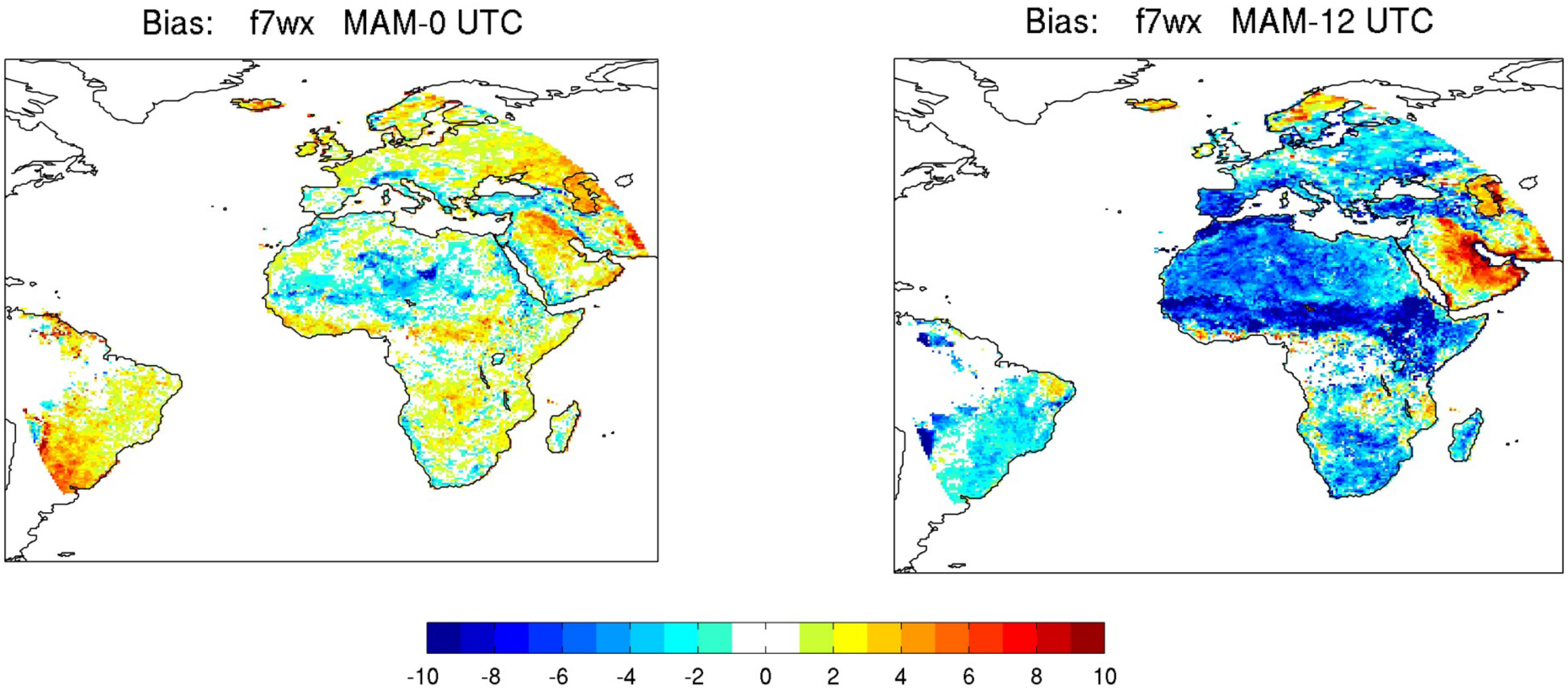


Bias of control: Model Skin Temp – LSA SAF LST

Tsk_CTL – LST

00 UTC

12 UTC



- ✓ Good agreement of night-time temperatures;
- ✓ Underestimation of daily amplitudes, particularly in semi-arid and/or sparsely vegetated regions.

Impact and sensitivity: Vocabulary

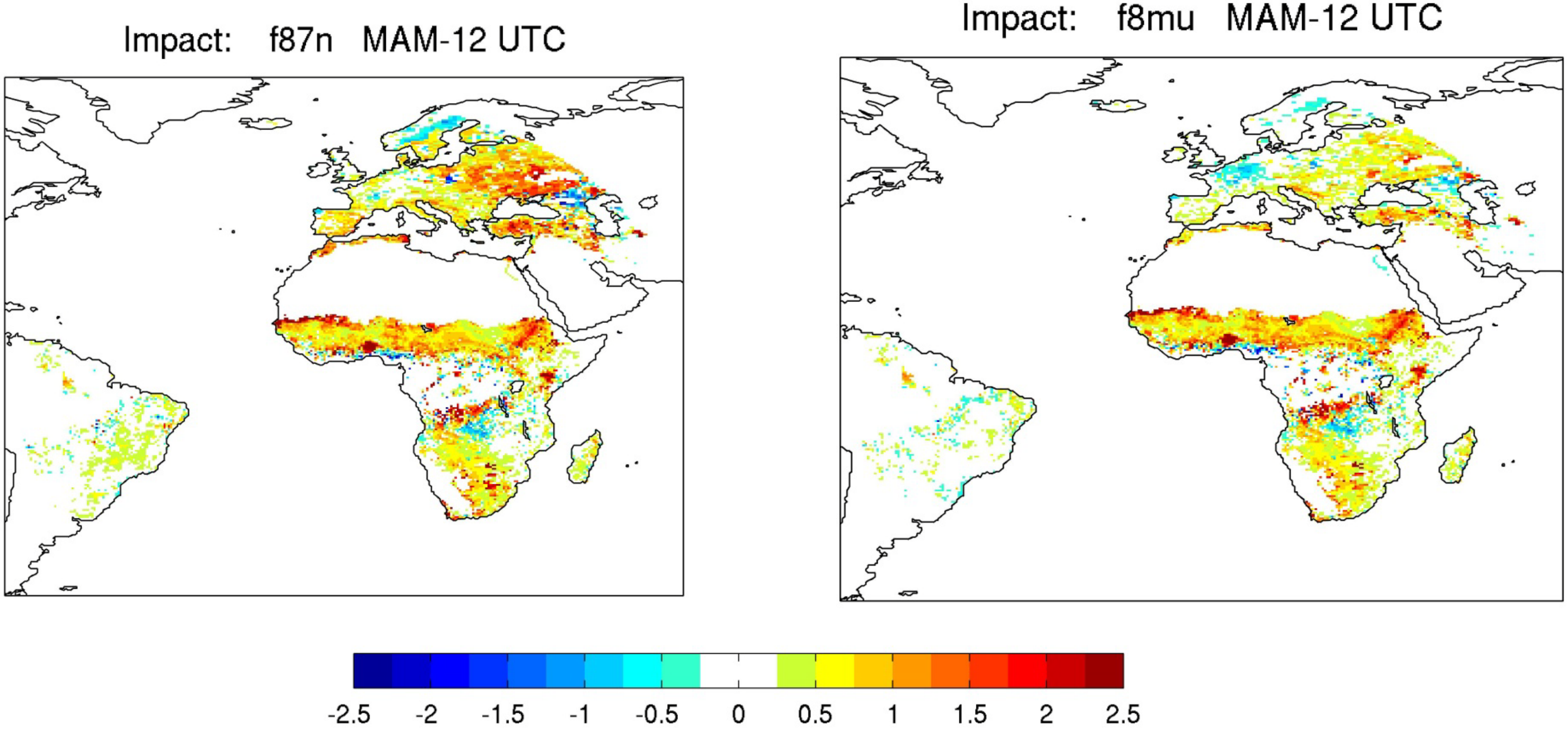
Impact on variable X: │X_CTL – X_obs│- │X_MOD – X_obs│

Sensitivity of variable Y: (Y_EXP – Y_CTL)

MODIS LAI and LAI_rsmin: Impact on Tsk

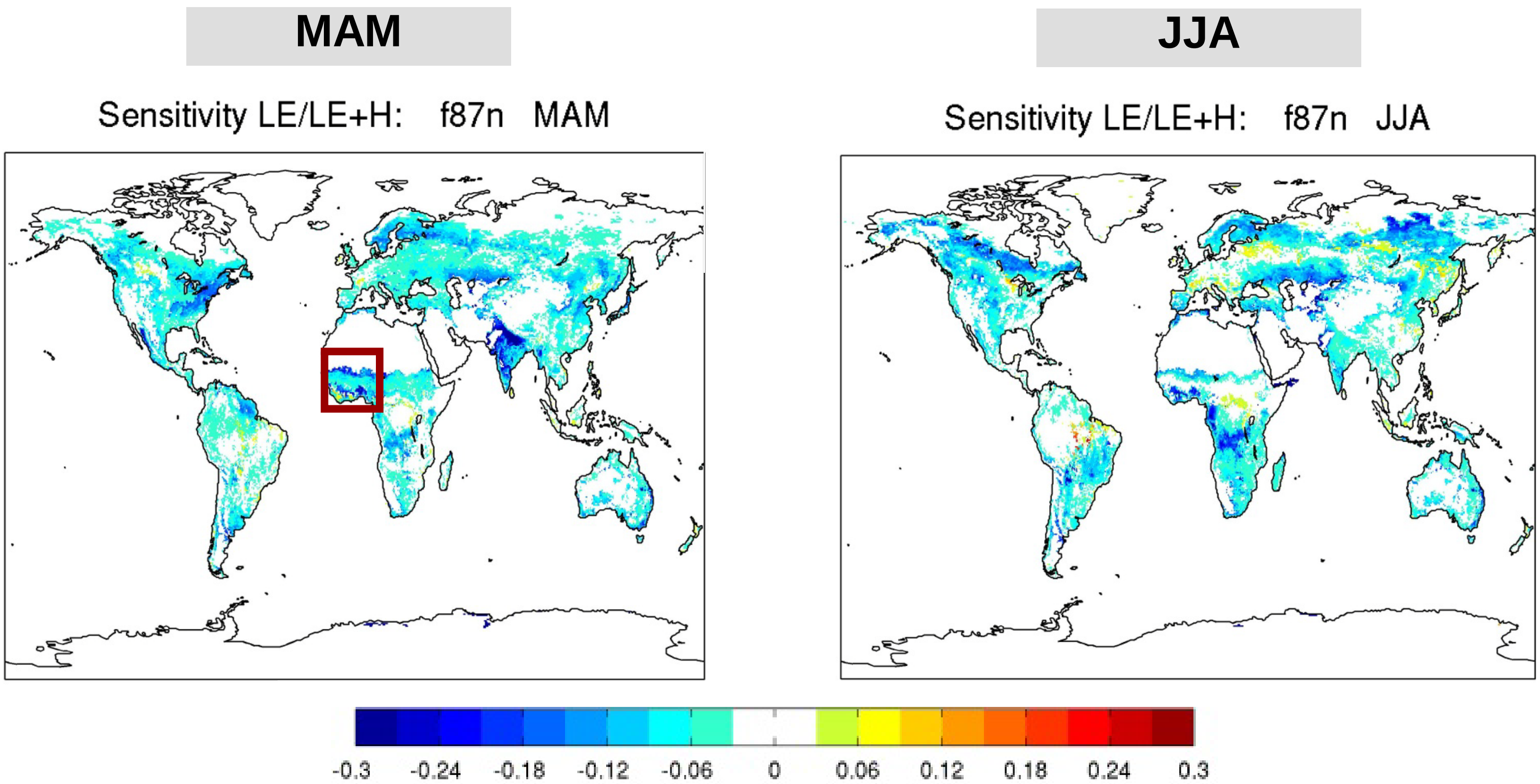
12 UTC

MODIS LAI | **MODIS LAI_rsmin**



- ✓ There is a positive impact of the MODIS LAI in MAM and JJA. The decrease in stomatal resistance compensates for the decrease in LAI and therefore reduces the impact on LST
- ✓ The impact on skin temperature over Europe is negative in summer (not shown) when the minimum stomatal resistance is reduced for needle-leaf trees.

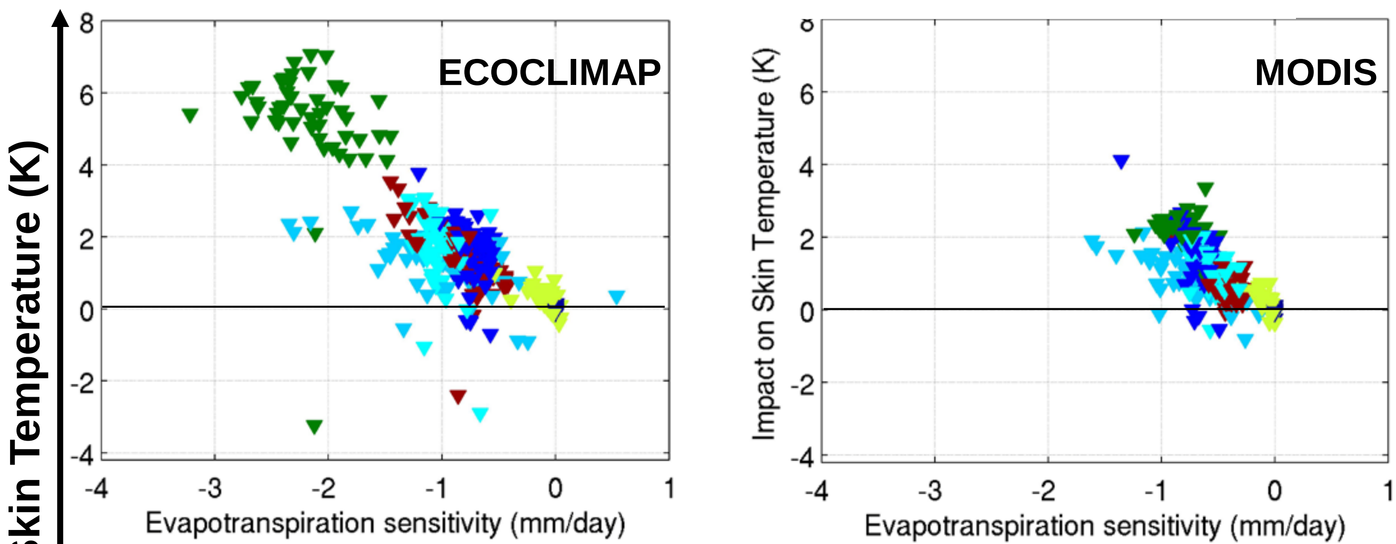
MODIS LAI: Sensitivity of Evaporative Fraction

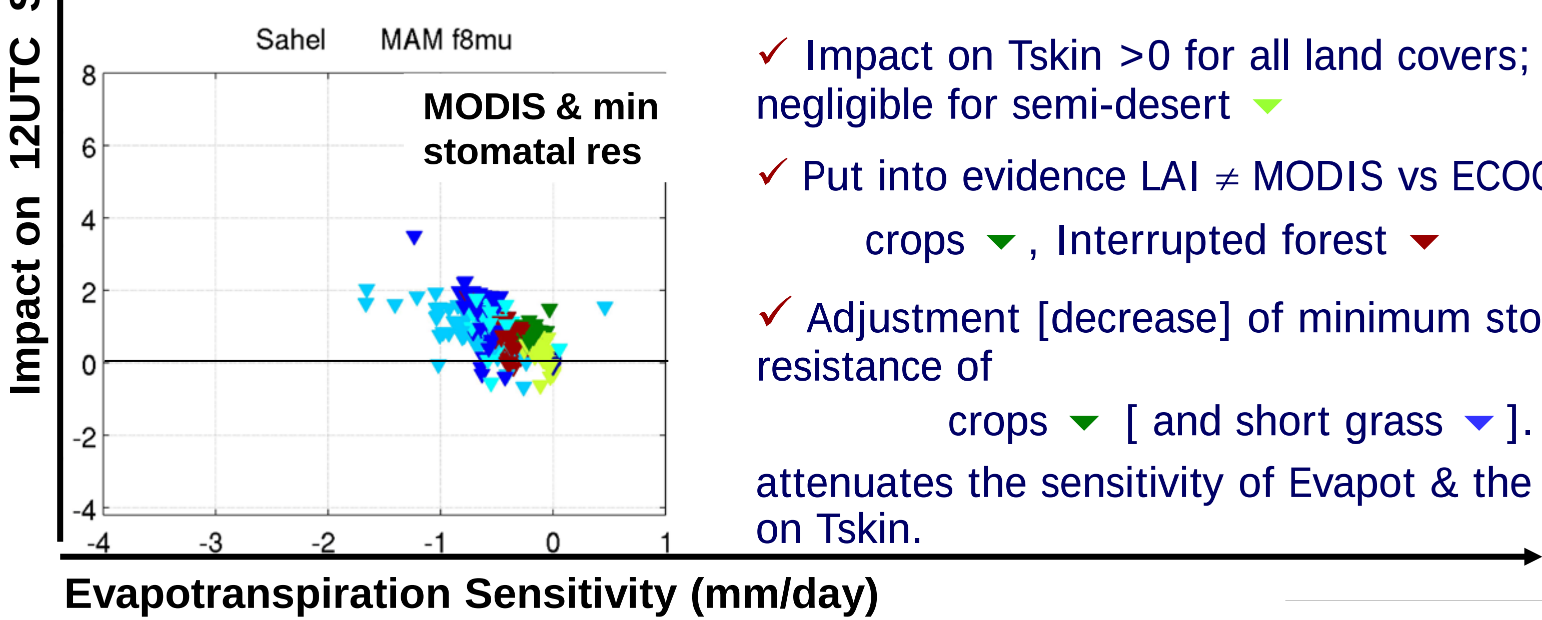


- ✓ The increase in temperature seems to be associated to a decrease in evaporative fraction (evaporation).

LAI: Tskin versus Evapotranspiration

Sahel MAM



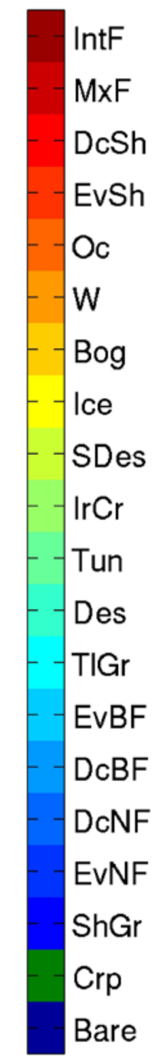


- ✓ Impact on Tskin >0 for all land covers; negligible for semi-desert ▼
- ✓ Put into evidence LAI ≠ MODIS vs ECOCLIMAP:

  crops ▼, Interrupted forest ▼
- ✓ Adjustment [decrease] of minimum stomatal resistance of

  crops ▼ [and short grass ▼].

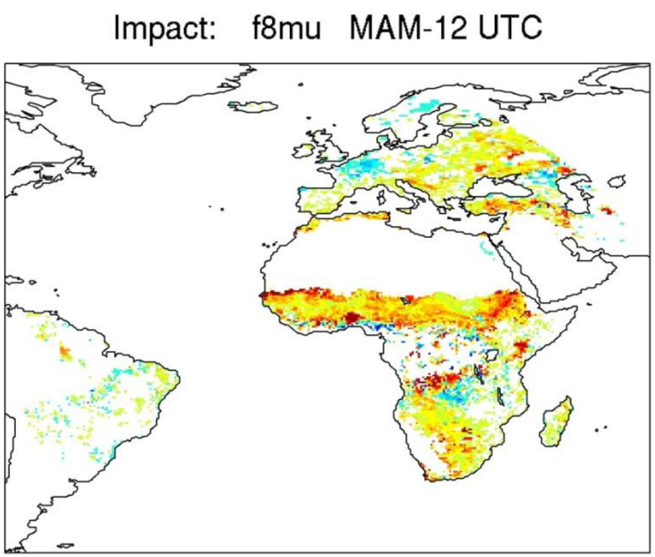
  attenuates the sensitivity of Evapot & the impact on Tskin.



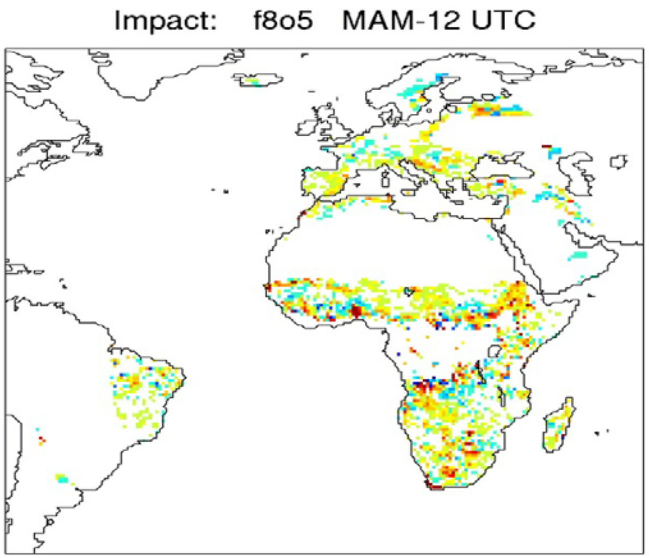
MODIS_LAI: Impact on forecast + data assimilation

- In all previous forecast experiments, the initial soil moisture is the same in EXP and CTL;
- Data assimilation + forecast experiments produce an evolved soil moisture responding to the evaporative changes.

MODIS LAI rsmin, FC only



MODIS LAI_rsmin w/ data assimilation



- Impacts in experiments including data assimilation are attenuated;
- During the assimilation there is less evaporation resulting in wetter soil moisture for the next background; the wetter soil partly compensates the model induced changes in Evapo.

Aerodynamic Resistance

Forecast Experiments

(Thanks I. Sandu)

Roughness length for heat

$Z_{oM\_ctl} / Z_{oH\_ctl} = 10$

$Z_{oM\_exp} / Z_{oH\_exp} = 100$

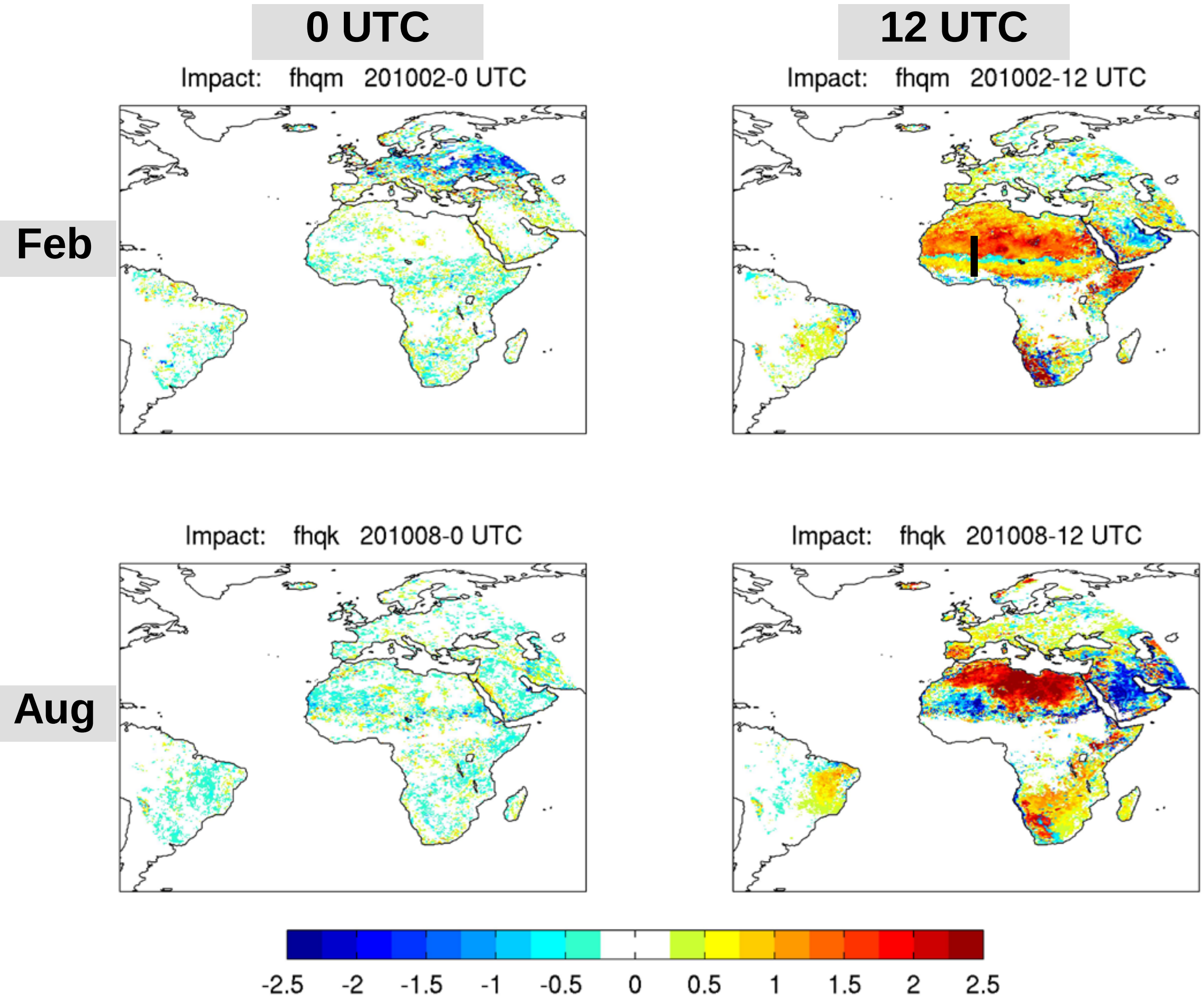
(except forests, ice-caps)

Roughness length for Momentum

$$Z_{oM\_exp} = \begin{cases} Z_{oM\_Ctl} & \text{(e.g., baresoil, desert, forests)} \\ \alpha . Z_{oM\_Ctl}, \quad 2 < \alpha < 5 & \text{(e.g., grass, semi-desert, shrubs, crops, ...)} \end{cases}$$

- Increase resistance to sensible heat flux
- Reduce aerodynamic resistance where Z_{oM} ↗ (decrease in near sfc wind)

Roughness Lengths: Impact on Tsk



- ✓ Negligible impact at night-time;
- ✓ Impact > 0 over semi-arid regions during daytime.
- ✓ Feb: sharp north-south gradient matches the transition between land-cover classes.
- ✓ Aug: > 0 over most Northern Africa, Europe;

  < 0 over Western Sahara associated to particularly cloudy period.

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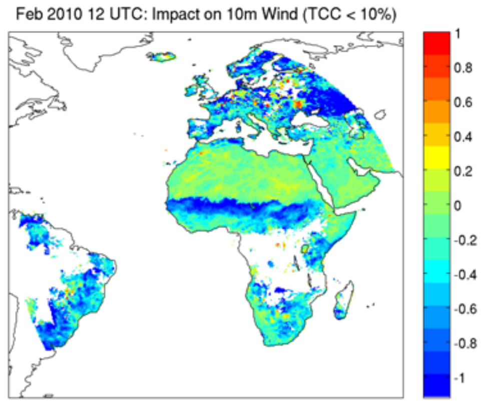
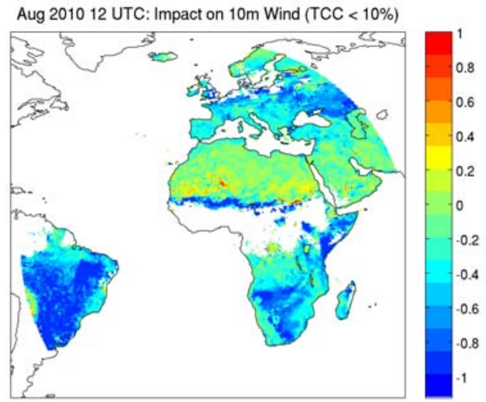
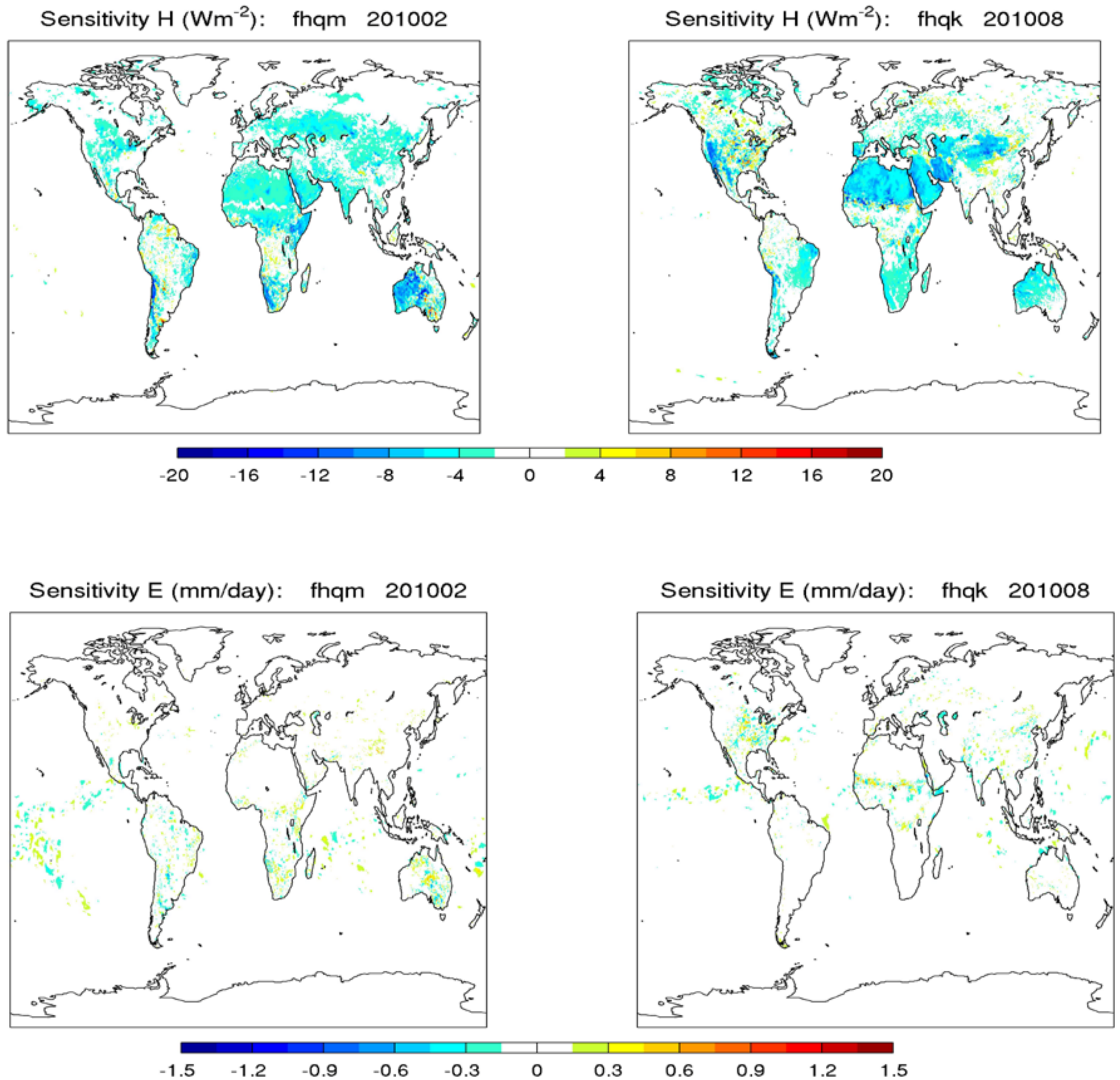
10m wind speed at 12 UTC (only cases with TCC at 12 UTC < 10%)





- ✓ Lower wind speeds at 12 UTC over regions where Z_{0M} is increased

Roughness Lengths: Sensitivity of Heat Fluxes



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OBSERVATIONS: LST/SEVIRI

• SEVIRI/MSG based LST is estimated using a split-windows algorith, trained to SEVIRI response functions. The Land-SAF produces, archives and distributes

LST & **δLST** (15 min; 3 km at nadir; Meteosat disk)

• The analysis of LST uncertainties is complemented with validation against **independent data sources** (in situ + other satellites):

✓discrepancies generally ≤2K, within uncertainty computed in Near Real Time.

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ECMWF Model

• ECMWF **underestimates daytime skin temperature** – Tskin diurnal cycle – particularly in arid / semi-arid regions: Northern Africa, Sahel, Southern Europe (summer), ...

• More realistic representation of **vegetation seasonal variability** contributes to correct this effect:

- ✓ Forecast experiments: Positive impact on daytime Tskin associated to a decrease in evapotranspiration
- ✓ Assimilation experiments: the impact is considerably attenuated

• The adjustment of Roughness Lengths for heat and momentum leads to a overall positive impact on daytime Tskin:

- ✓ Generally associated to a reduction of sensible heat flux (lower values of Z_{oH}).

http://landsaf.meteo.pt

Publications

Download Data

Documentation (User Manuals, Validation Reports)

Helpdesk