Comparison of ECMWF model skin Temperature with SEVIRI LST

How satellite-based skin temperature can support model development?

Isabel F. Trigo, Souhail Boussetta, Pedro Viterbo, Gianpaolo Balsamo, Anton Beljaars, and Irina Sandu, JGR 2015
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Outline

- Comparison of ECMWF Skin Temperature and SEVIRI/ Land-SAF Land Surface Temperature estimates to assess changes in:
  - Model representation of vegetation – LAI
  - Model Surface roughness – Aerodynamic Resistance
  - Parameter controlling ground flux – skin conductivity

Land surface model status at ECMWF and evolution since ERA-Interim

- **H**ydrology-**TESSEL**

  Balsamo et al. (2009)
  van den Hurk and Viterbo (2003)

  Global Soil Texture (FAO)

  New hydraulic properties

  Variable Infiltration capacity & surface runoff revision

- **NEW SNOW**

  Dutra et al. (2010)

  Revised snow density

  Liquid water reservoir

  Revision of Albedo
  and sub-grid snow cover

- **NEW LAI**

  Boussetta et al. (2013)

  New satellite-based

  Leaf-Area-Index

- **SOIL Evaporation**

  Balsamo et al. (2011),

  Albergel et al. (2012)

- **H_2O / E / CO_2**

  Integration of

  Carbon/Energy/Water

  Boussetta et al. 2013

  Agusti-Panareda et al. 2015

- **Flake**

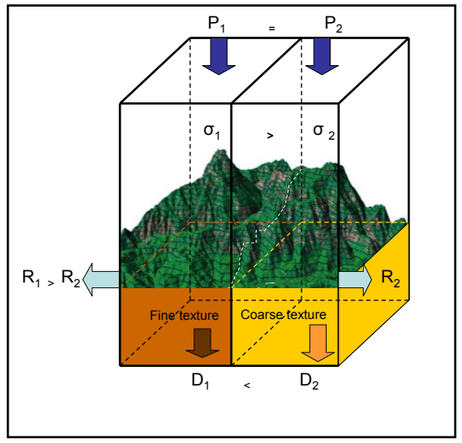
  Mironov et al (2010),

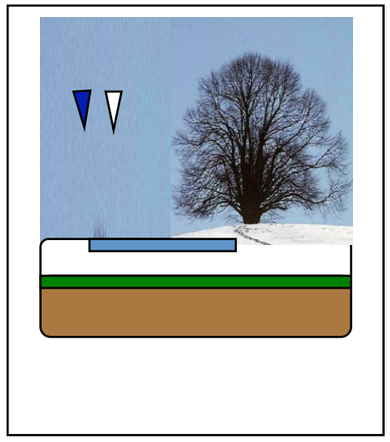
  Dutra et al. (2010),

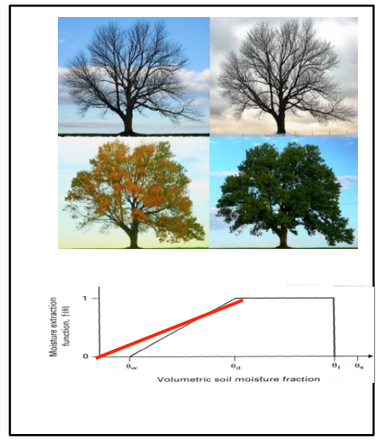
  Balsamo et al. (2012, 2010)

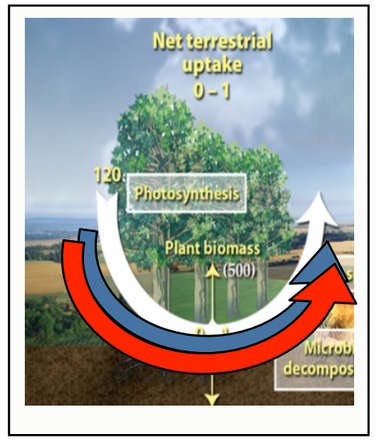
  Extra tile (9) to
  for sub-grid lakes and ice

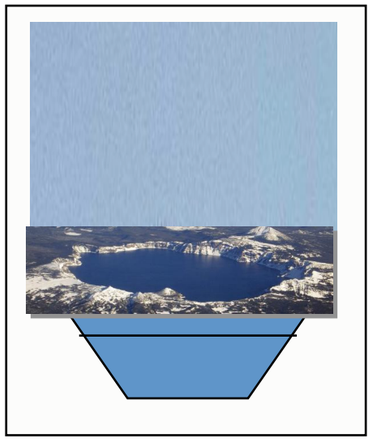
  LW tiling (Dutra)











Satellite Land Surface Temperature (LST)

As a model diagnostic tool

ECMWF Skin Temperature:

- Corresponds to a thickness-less surface, close to the radiometric temperature that is obtained from thermal infra-red channels
- Plays a role in the partitioning between latent and sensible heat fluxes at surface;
- Its diurnal cycle is associated to the degree of coupling between the land and the atmosphere that is shown to vary greatly across models.

Model deficiencies in skin temperature

- provide an indication of problems in surface energy fluxes and soil moisture …
- with impact on predictability of NWP / Earth System Models at medium and monthly-range.

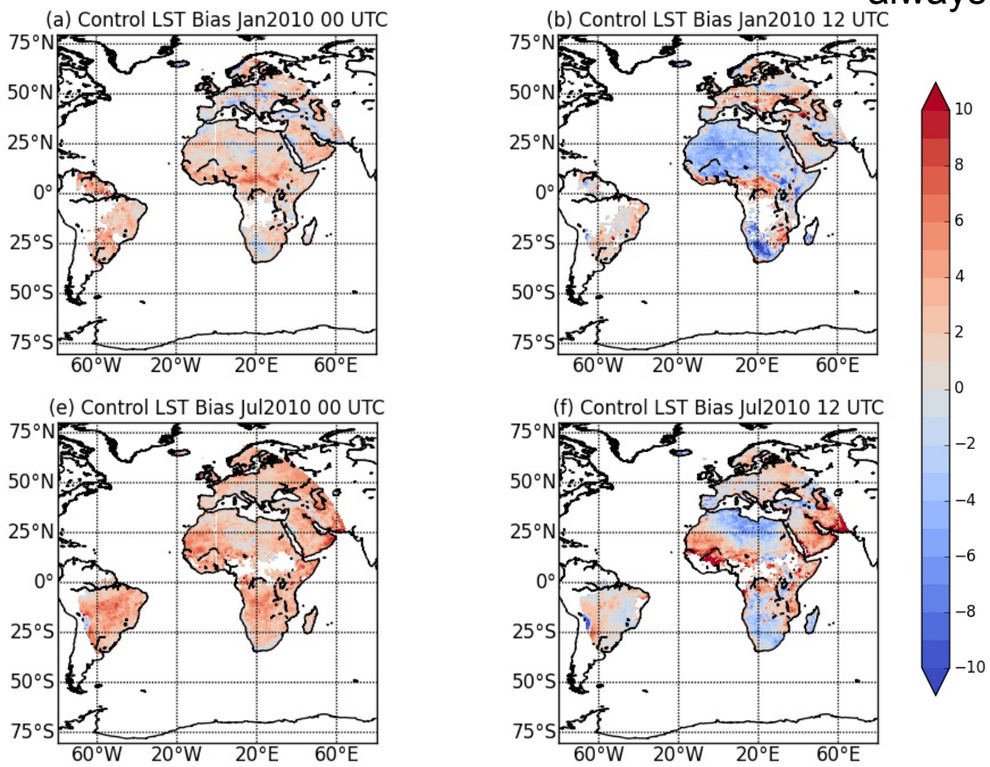
ECMWF Tskin and SEVIRI LST

Tskin (ECMWF) – LST (SEVIRI)

Clear sky cases only: ECMWF TCC < 10% always!

Jan 2010

Jul 2010

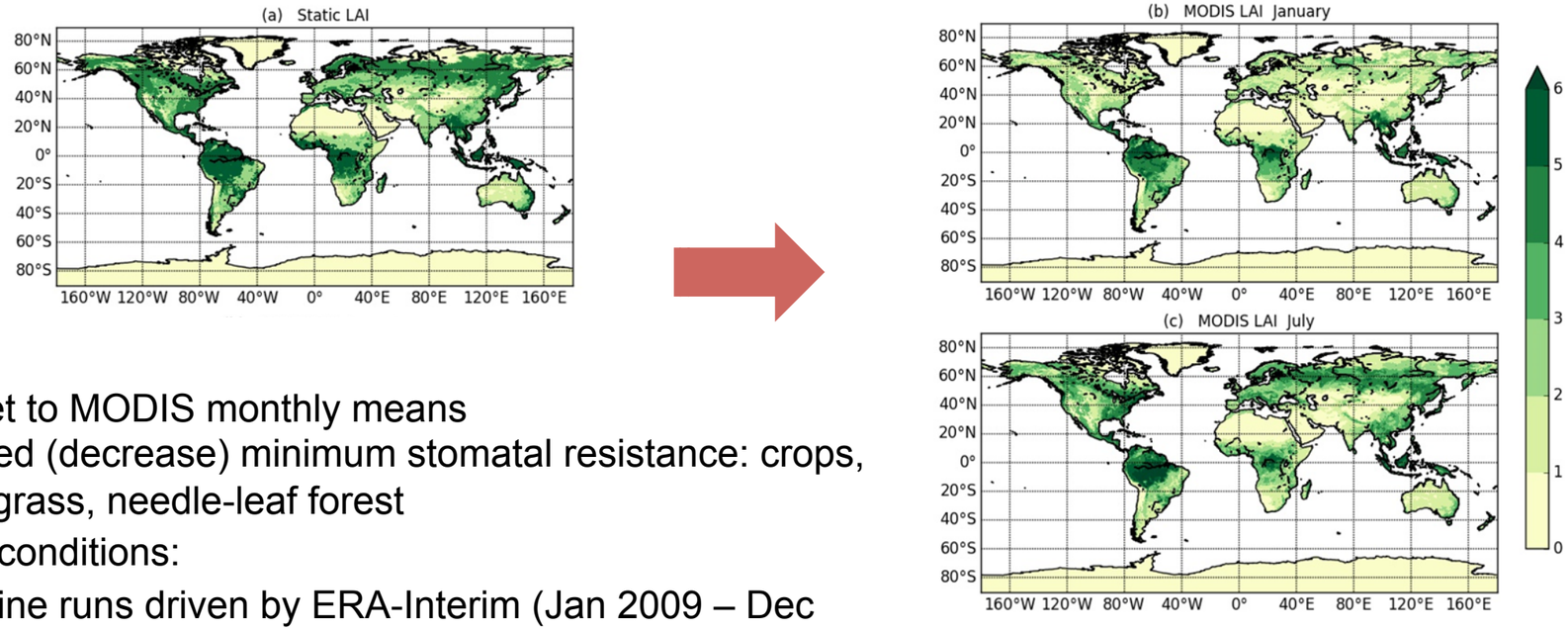


- Cool bias during daytime (12 UTC panels) over most of Africa and Europe
- Warm bias, although generally less pronounced, during night-time, i.e., ….
- Underestimation of daily amplitude of Tskin, particularly in semi-aird regions

- Different pattern over subtropical regions (during the wet season)

ECMWF: Moving towards more realistic LAI

Results shown in previous slide: run (**control**) with the prescription of a single static LAI (used in ECMWF IFS until November 2010)



- LAI set to MODIS monthly means
- Revised (decrease) minimum stomatal resistance: crops, short grass, needle-leaf forest
- Initial conditions:

  Off-line runs driven by ERA-Interim (Jan 2009 – Dec 2010) + LAI / stomata changes

ECMWF: Montly LAI

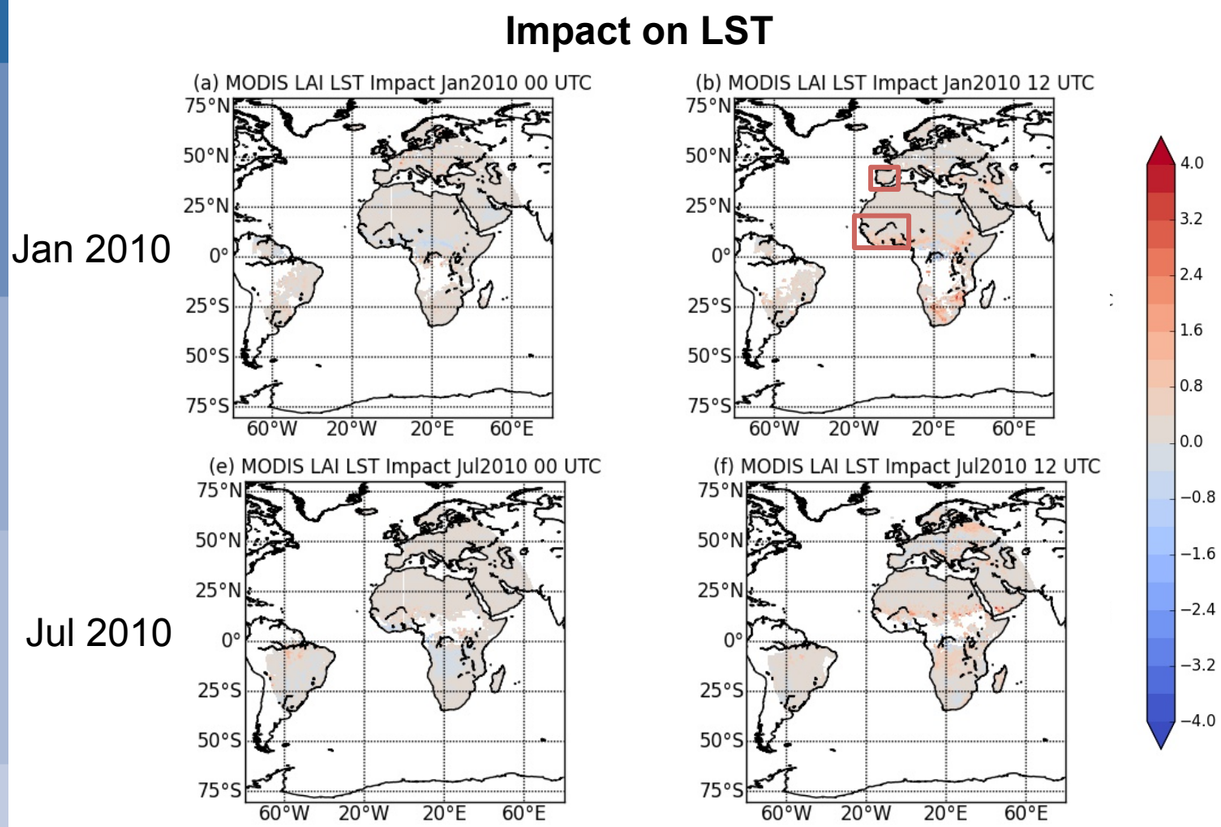
Impact on Tskin is measured as Mean Absolute Error (MAE) reduction:

$$|\text{Tskin\_CTL} - \text{LST\_SEVIRI}| - |\text{Tskin\_exp} - \text{LST\_SEVIRI}|$$

Sensitivity of variable Y is measured as simple difference:

$$\Delta = (\text{Y\_EXP} - \text{Y\_CTL})$$

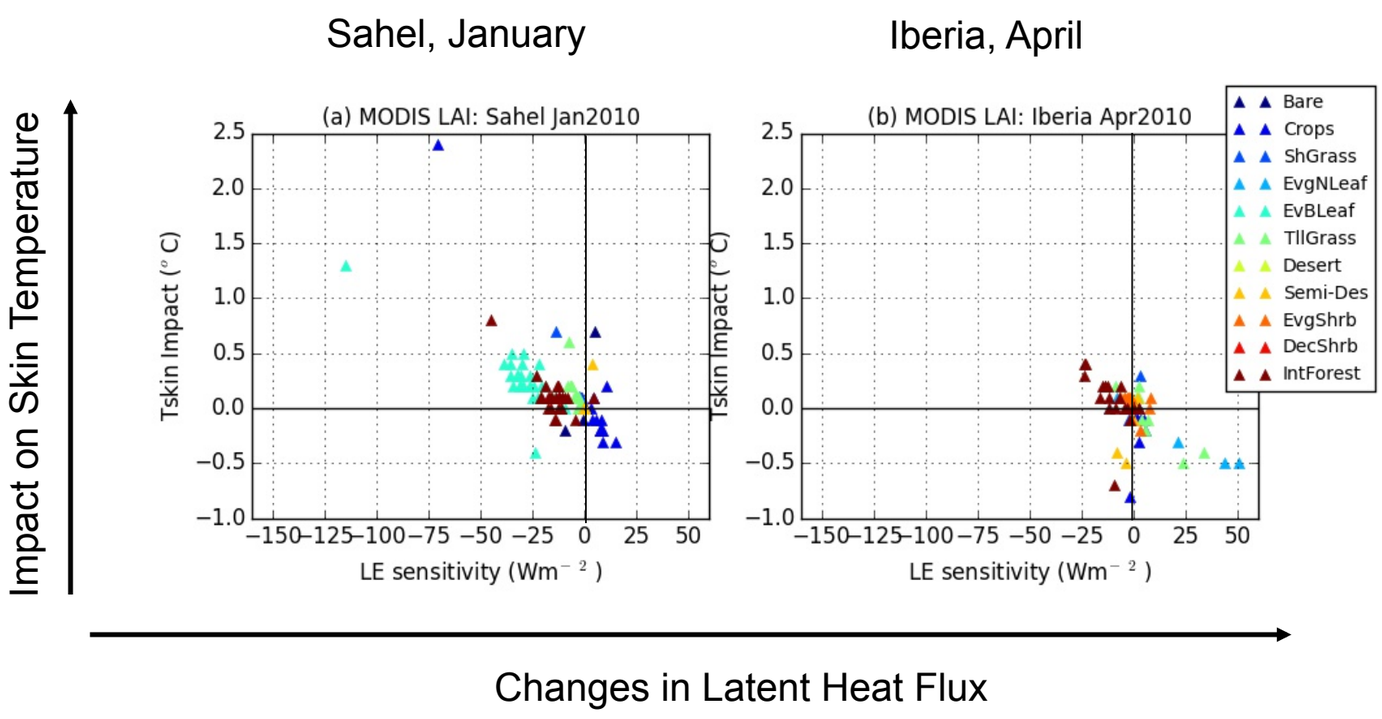
ECMWF: Montly LAI



Reduced LAI + seasonal variability

- 00 UTC: neutral impact.
- 12 UTC shows positive impact over limited areas: Sahel in January and July; Europe and Middle East in April (not shown)

ECMWF: Montly LAI

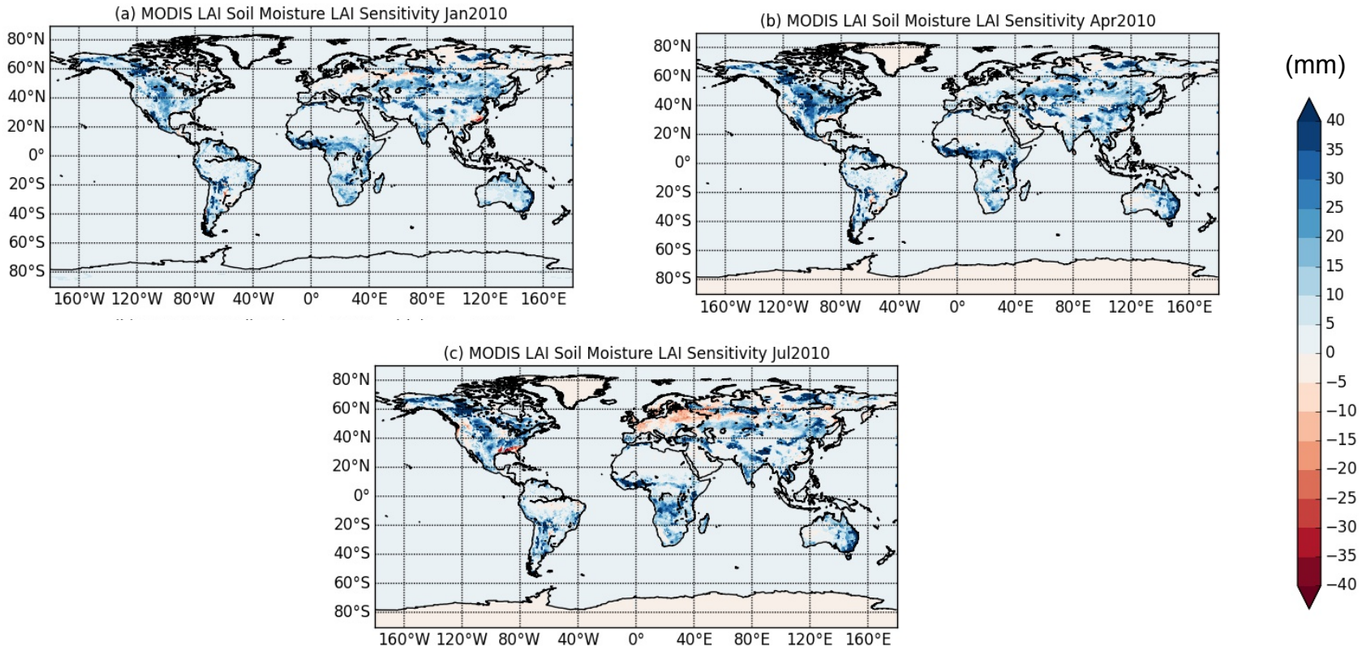


- Positive impact for land-cover types where LE decreases:
  - Tall grass;
  - Interrupted Forest;
  - Evergreen Broad-leaf Forest

- Why not more widespread?

ECMWF: Montly LAI

Changes in Soil Moisture – top 1m of soil



- “LAI MODIS” simulations present higher soil moisture.

⇑

- Lower LAI in the offline run (which sets up initial conditions) leads indeed to less evaporation in most places, and therefore to higher SM.

- A wetter soil compensates for lower of evaporation and limits the impact on skin temperature.

ECMWF: Aerodynamic Resistance

Roughness Length for Momentum (ZoM)
Roughness Length for Heat (ZoH)

Control sensible heat flux: directly or via the near surface wind profile

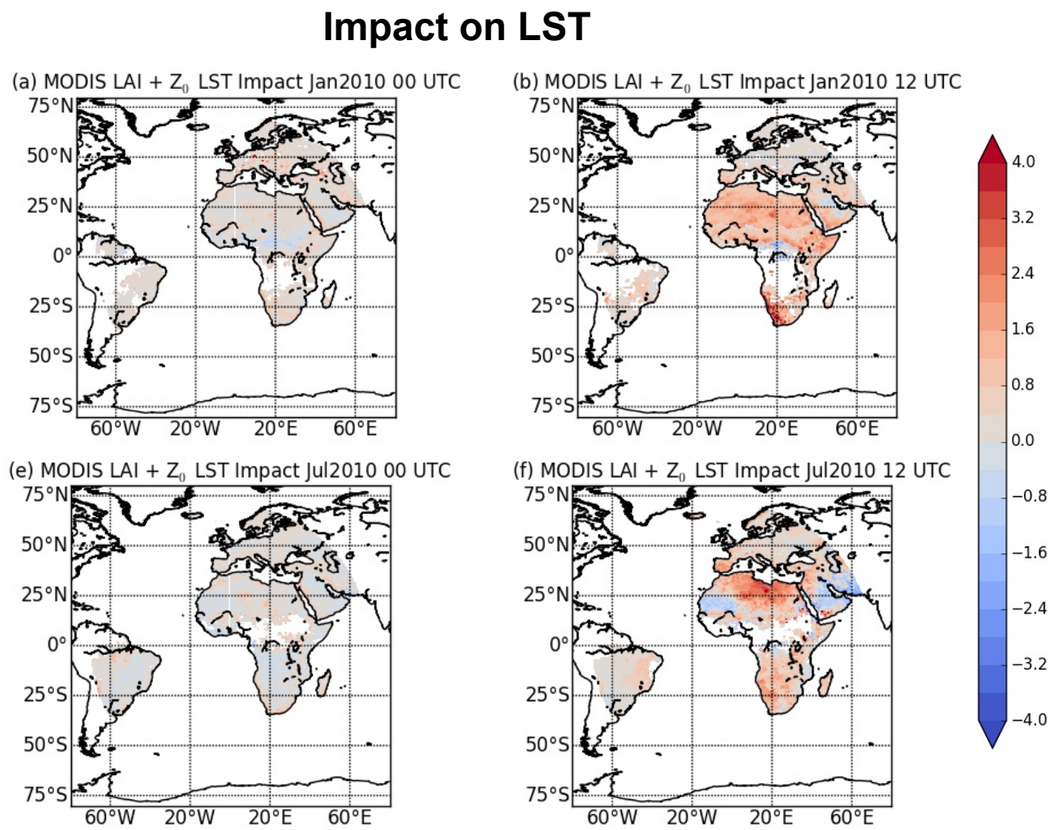
- ✓ **ZoM**: revised in Nov 2011 to compensate an overestimation of 10m wind over a wide range of landcover types
  (increase in ZoM in grass, semi-desert, shrubs, crops, ...)

- ✓ **ZoH**: were revised to balance the increase in ZoM, and

  $Z_{oM} / Z_{oH} = 10$ is set to $Z_{oM} / Z_{oH} = 100$ for (nearly) all surface types …

  … leading to an increased resistance to heat transfer almost everywhere.

ECMWF: Revised LAI + ZoM and ZoH

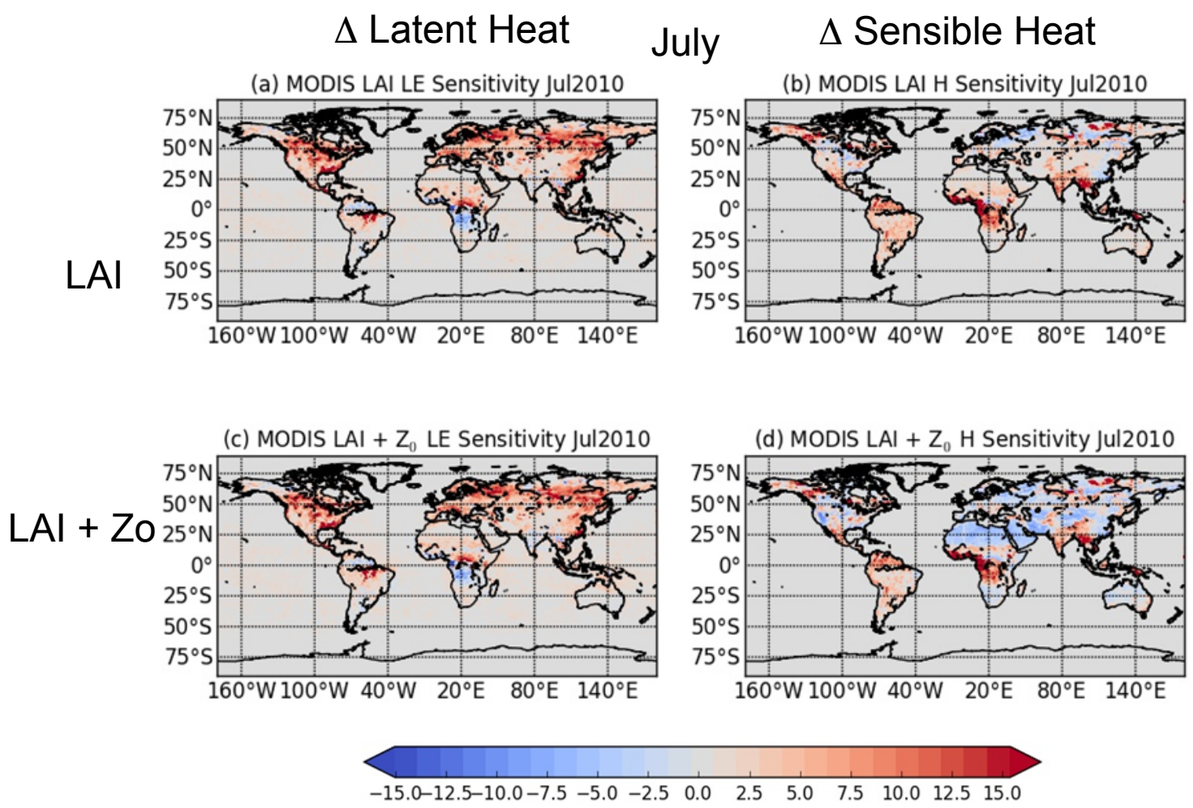


Jan 201(

Jul 201(

- 00 UTC: neutral impact.
- 12 UTC shows wider areas of positive impact over limited areas: Most of northern Africa, southern Europe
- The impact also complements the (smaller) impact induced by the revised LAI

ECMWF: Revised LAI + ZoM and ZoH



- **LAI:**
  - Generalized increase in Latent Heat Flux (coinciding with the wetter soil);
- **LAI + Zo:**
  - Lower Sensible Heat: compatible with revised ZoH, complementing the changes induced by LAI alone.

ECMWF: Skin Conductivity

- For completeness we assess the sensitivity of model skin temperature to surface conductivity, Λ_{skin}.

$$\Lambda_{skin} \Rightarrow \Lambda_{skin} / 2$$

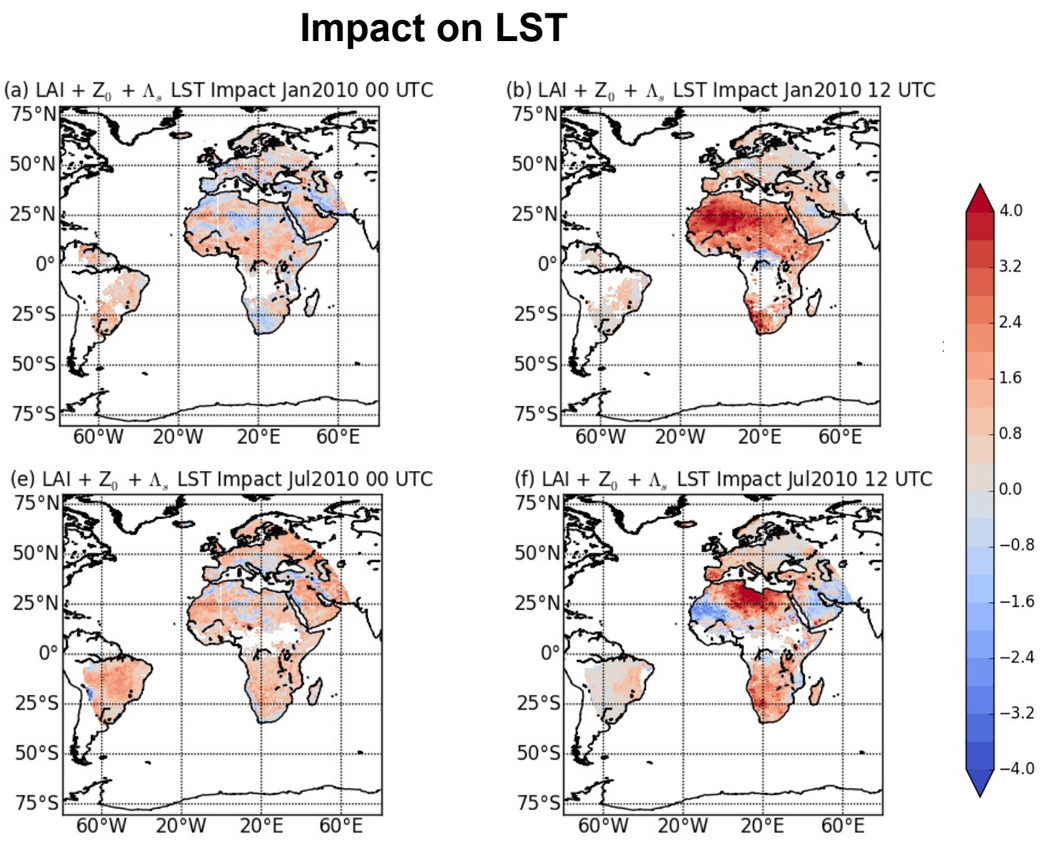
- Λ_{skin} controls the heat transfer to the ground by diffusion

- A first approach to test the use of remotely sensed LST to estimate surface parameters, otherwise difficult to prescribe.

ECMWF: Revised LAI + Zo + Λskin

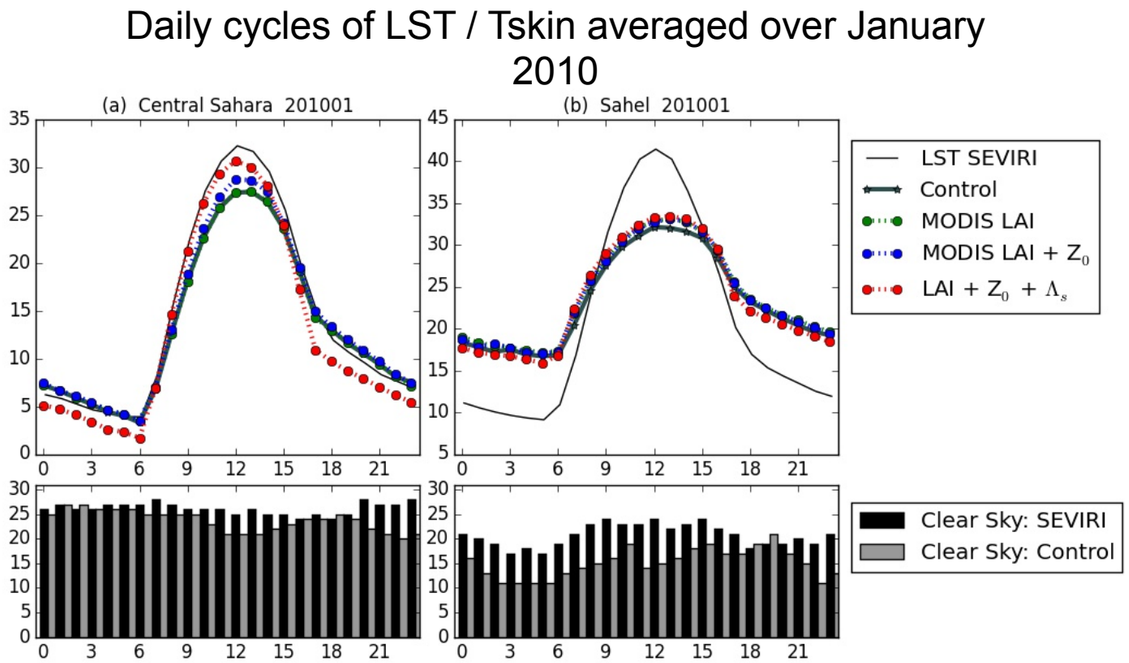
Jan 2010

Jul 2010



- 00 UTC: less neutral than in previous experiments
- 12 UTC shows stronger positive impact on Tskin over a large part of the disk.

ECMWF: Revised LAI + Zo + Λskin



- Figure illustrates well the impact of the various changes introduced in ECMWF surface scheme.
- Points out discrepancies in the phase between model and satellite (besides daily amplitude), which also need to be addressed.

Conclusions and Remarks

- Several studies reported **cold biases** in **model surface temperatures** when compared to **satellite LST's** - particularly daytime over arid regions, when compared either to satellite estimates.
- Biases of this type also identified in the ECMWF model. **LST** was then used to assess the **impact of sfc parameters on mode skin temp & sfc fluxes**.
- Changing **static to monthly LAI**: showed **a limited impact on the model Tskin**, with a **slight improvement over semi-arid / sparsely vegetated regions** (e.g., Sahel, Iberian Peninsula). The new (mostly lower LAI) leads **higher soil moisture**; this is the result of a new equilibrium reached by the model during the long integration with lower Evapotranspiration.
- The **adjustment of ZoM and ZoH** leads to an overall **positive impact on daytime skin temperature**, generally associated to a **reduction of sensible heat flux** (lower values of Z_{oH}). The impact is particularly relevant in non-vegetated areas that remained unaffected by the changes in the vegetation representation.
- The **reduction of skin conductivity** is shown to **further strengthen the positive impact on model Tskin**. A complete analysis of changes/ tuning of this parameter in other surface fluxes and other surface variables is still needed.