Monitoring vegetation with satellite observations assimilated in the ECMWF modelling system

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ECMWF

Why?

- Vegetation was shown to be of critical importance under the NWP framework:
  - Evapotranspiration
  - Boundary layer developement
  - Cloud and precipitation ...
- Vegetation directly affect the global carbon cycle
- LSM has evolved to better represent vegetation and its dynamic
- Satellite observation are becoming more and more available with higher resolution
- ➔ Assimilation of vegetation related observations would allow:
  - to seek eventual improvement in the near surface atmosphere.
  - to understand and adjust process developpement within LSM
  - to better monitor the actual vegetation status and its dynamic
  - To better represent land biogenic fluxes

The data:

The GEOV1 LAI/albedo product is based on observations from the VEGETATION sensor on board of SPOT satellite. ➔ Global coverage with 1km resolution and 10 day temporal resolution

Produced in the framework of the Copernicus Initial Operation and ***Freely available***.

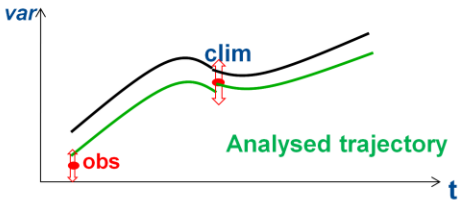
The model:

The ECMWF LSM (CTESSEL) coupled within the Integrated Forecasting system IFS

The analysis system:

The analysis procedure is an optimal combination of the satellite observations and derived climatology, depending on their associated errors σo and σc.

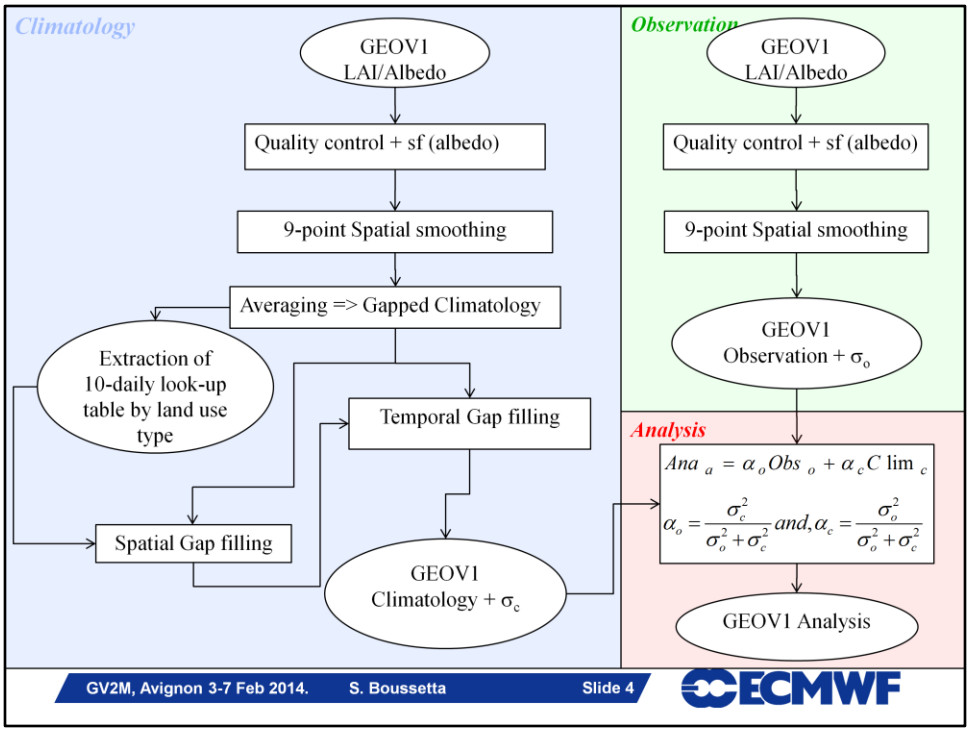
➔ Suitable for NWP framework and consistent with actual method used for slow evolving variables.



$$\text{var}_a = \alpha_o \, \text{var}_o + \alpha_c \, \text{var}_c$$

where

$$\alpha_o = \frac{\sigma_c^2}{\sigma_o^2 + \sigma_c^2} \; and, \alpha_c = \frac{\sigma_o^2}{\sigma_o^2 + \sigma_c^2}$$


Climatology
GEOV1 LAI/Albedo
Quality control + sf (albedo)
9-point Spatial smoothing
Averaging => Gapped Climatology
Extraction of 10-daily look-up table by land use type
Temporal Gap filling
Spatial Gap filling
GEOV1 Climatology + σc
Observation
GEOV1 LAI/Albedo
Quality control + sf (albedo)
9-point Spatial smoothing
GEOV1 Observation + σo
Analysis
$Ana_a = \alpha_o Obs_o + \alpha_c C\lim_c$
$\alpha_o = \frac{\sigma_c^2}{\sigma_o^2+\sigma_c^2} and, \alpha_c = \frac{\sigma_o^2}{\sigma_o^2+\sigma_c^2}$
GEOV1 Analysis
GV2M, Avignon 3-7 Feb 2014. S. Boussetta Slide 4
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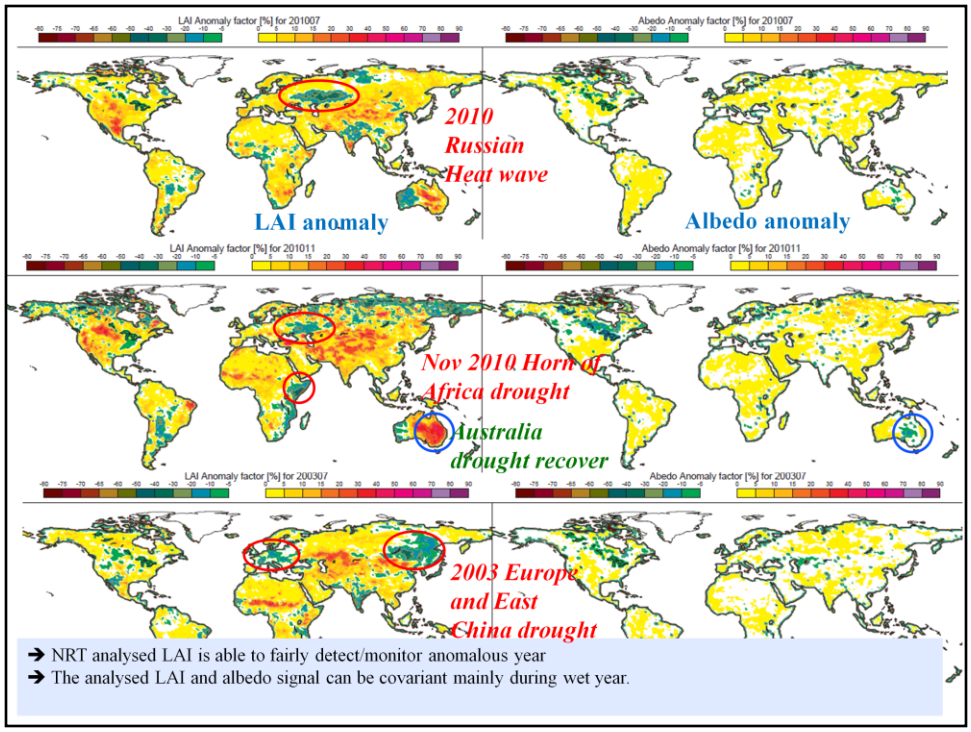


The analysis procedure not only allow to produce data with smooth temporal evolution suitable for NWP application and environmental prediction but the analysis product are also able to detect/monitor extreme event such us the:

1) Summer 2010 Russian heat wave

2) November 2010 Horn of Africa Drought and also the beginning of the Australian drought recover (Wet)

3) 2003 Europe and East China drought

The albedo anomaly signal is very mild during drought event but quit pronounced in wet event

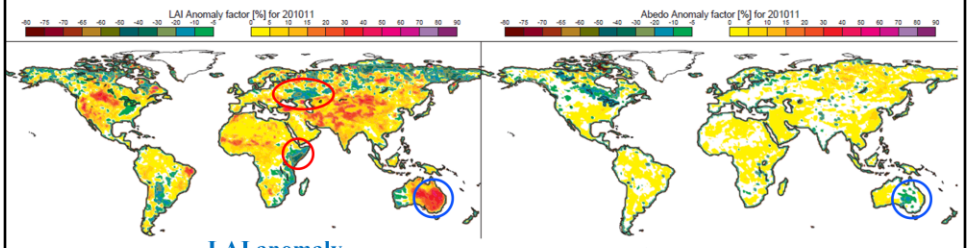
The offline surface simulation setup:

To seek the impact of the NRT analysed data four offline LSM nudging experiments are performed

Period: 1999 – 2012
Coverage: Global
Spatial resolution: T511 (~40km)

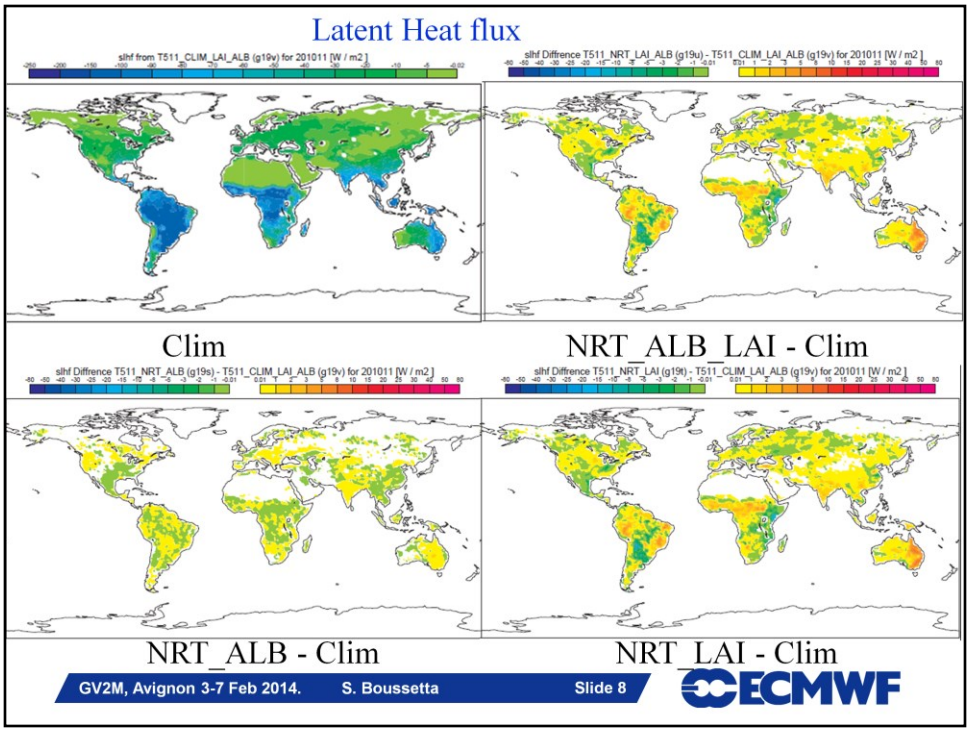
- Control: LAI+albedo climatology are used
- LAI_ALB_NRT: LAI nrt data + albedo nrt
- LAI_NRT: LAI nrt data + albedo climatology
- ALB_NRT: LAI climatology + albedo nrt

Horn of Africa drought & Australia drought recover



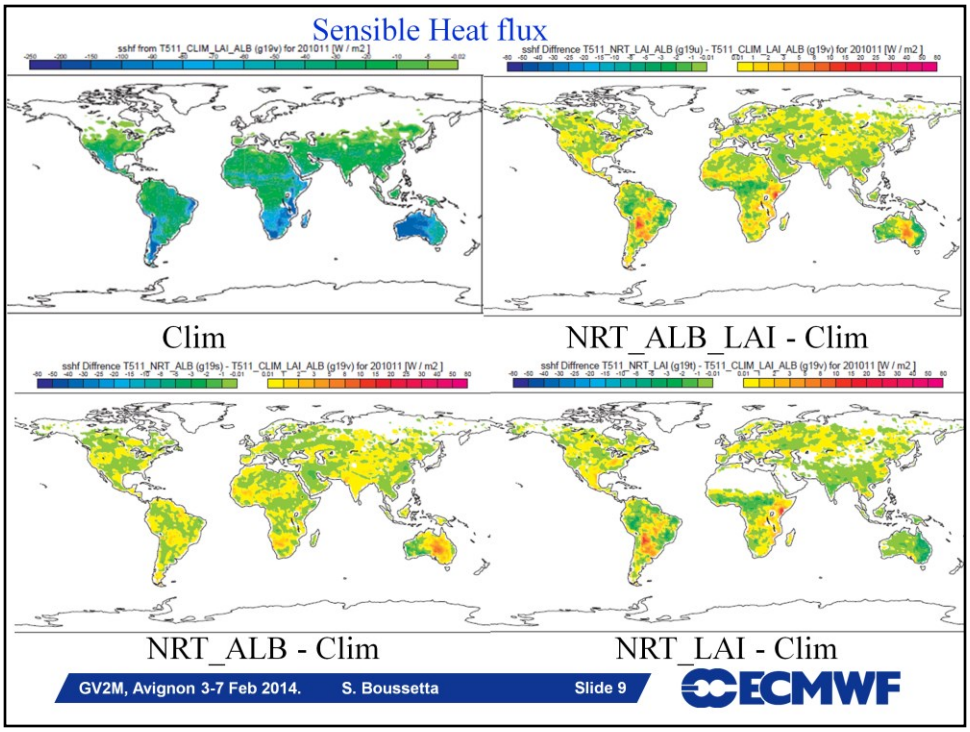
LAI anomaly

Albedo anomaly



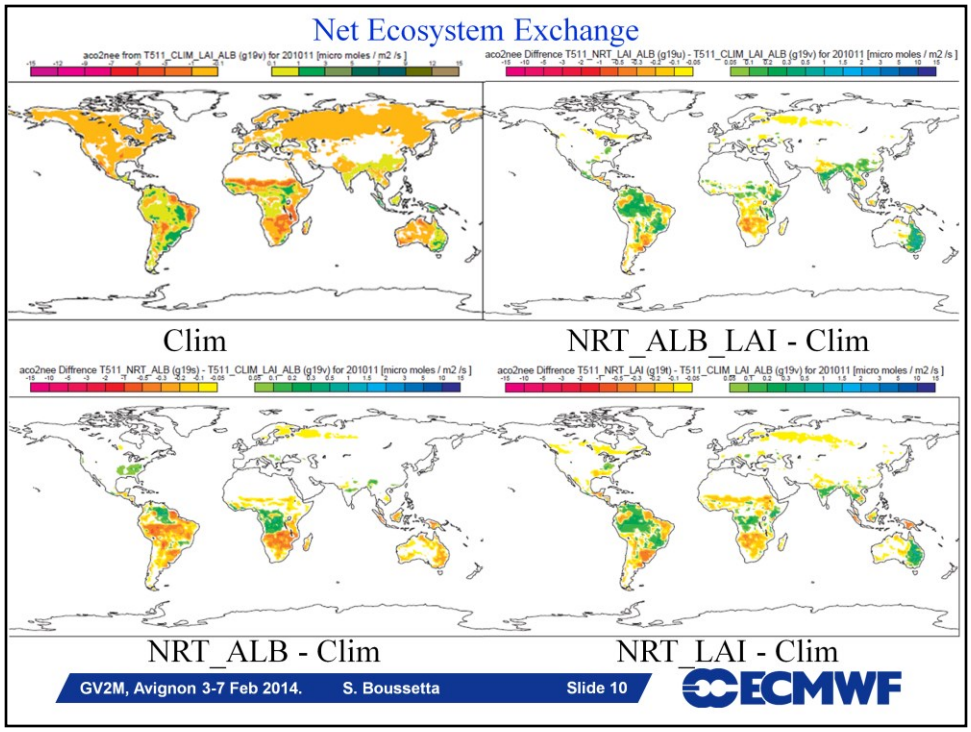
1) For the horn of Africa drought, when only the NRT albedo is nudged the impact on the Latent heat flux is very mild but when combined with the LAI NRT, the NRT albedo tend to strengthen the anomaly signal of the latent heat (given the slight increase of the albedo resulting on less net energy available at the surface).

2) For the Australia wet case (drought recover), the NRT LAI has a positive anomaly resulting in a higher evapotranspiration. On the other hand, the NRT albedo was shown to decrease due to the darkening of the surface (soil moisture and vegetation) allowing more energy to be available at the surface, this has increased the signal of the positive anomaly at the eastern part of Australia.



1) For the Horn of Africa, the slight positive NRT albedo anomaly resulted in less energy available at the surface and thus a decrease in the sensible heat, but when combined with the NRT LAI which has a more pronounced negative anomaly, the albedo anomaly effect was masked by the LAI anomaly effect which resulted in increased sensible heat due to the decrease of latent heat.

2) For Australia the albedo decrease (negative anomaly) enabled more energy to be available at the surface then an increase in the sensible heat acted in the opposite direction compared to the decrease of sensible heat given the positive LAI anomaly (increase) leading to higher evapotranspiration.



Australia (NEE positive :photosythesis)

decrease in albedo => decrease in photosyntheis

Increase in LAI => increase in photosynthesis

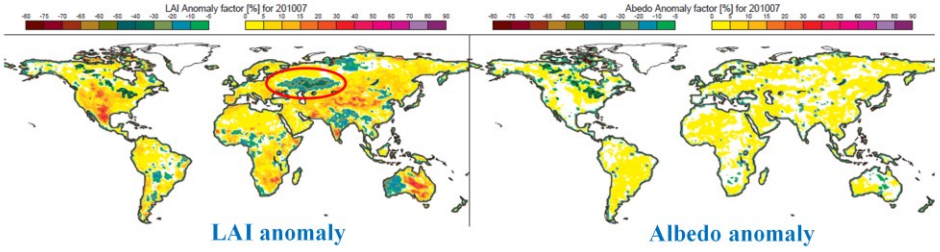
Horn of Africa (NEE negative: respiration)

decrease in LAI => increase in respiration

mild increase in albedo => slight increase in radiative forcing (photosynthesis) => decrease in respiration

Decrase in LAI + increase in albedo => the additional energy coming from the albedo anomaly would be converted in an increase of surface temperature => enhance respiration

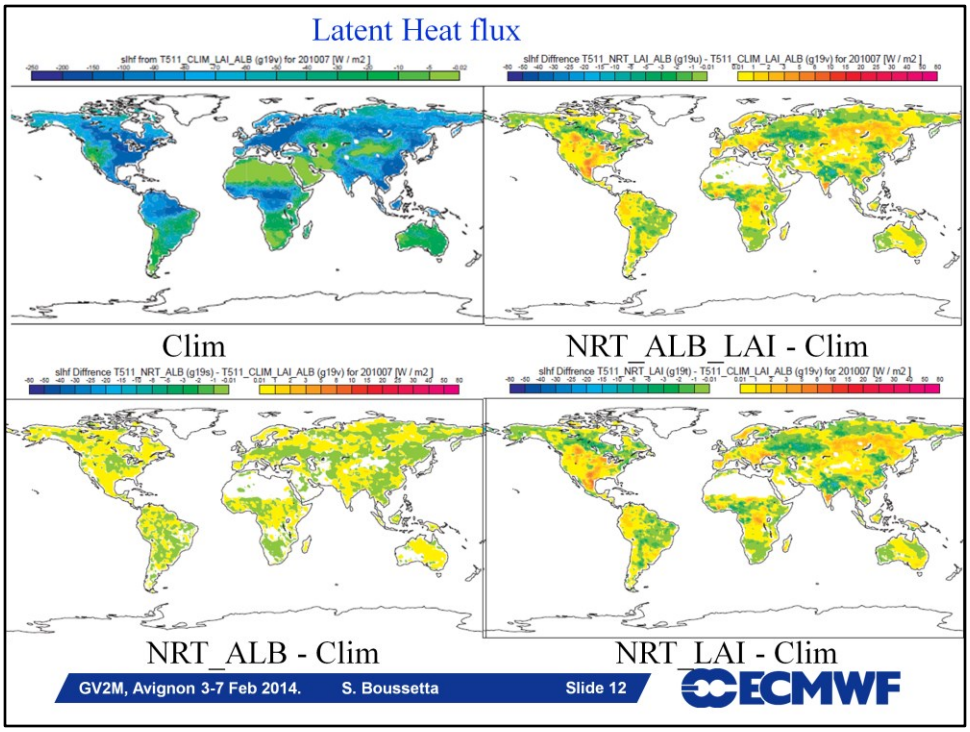
2010 Russian Heat wave



LAI anomaly

Albedo anomaly

ECMWF


Latent Heat flux
slhf from T511_CLIM_LAI_ALB (g19v) for 201007 [W / m2]
slhf Diffrence T511_NRT_LAI_ALB (g19u) - T511_CLIM_LAI_ALB (g19v) for 201007 [W / m2]
Clim
NRT_ALB_LAI - Clim
slhf Diffrence T511_NRT_ALB (g19s) - T511_CLIM_LAI_ALB (g19v) for 201007 [W / m2]
slhf Diffrence T511_NRT_LAI (g19t) - T511_CLIM_LAI_ALB (g19v) for 201007 [W / m2]
NRT_ALB - Clim
NRT_LAI - Clim
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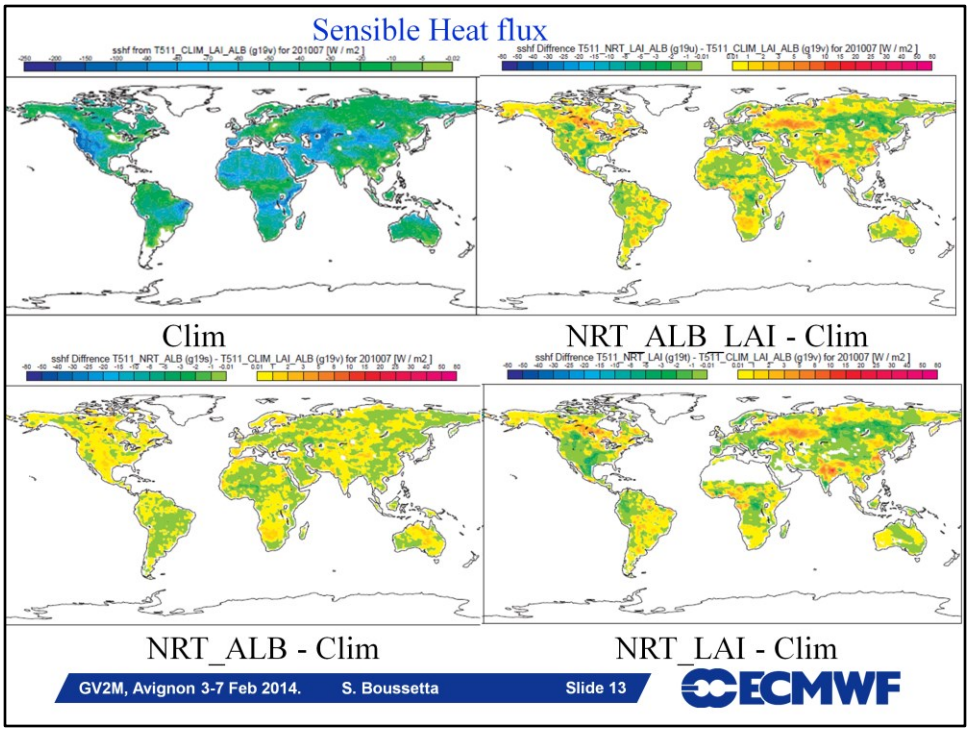
Sensible Heat flux
sshf from T511_CLIM_LAI_ALB (g19v) for 201007 [W / m2]
sshf Diffrence T511_NRT_LAI_ALB (g19u) - T511_CLIM_LAI_ALB (g19v) for 201007 [W / m2]
Clim
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sshf Diffrence T511_NRT_ALB (g19s) - T511_CLIM_LAI_ALB (g19v) for 201007 [W / m2]
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NRT_ALB - Clim
NRT_LAI - Clim
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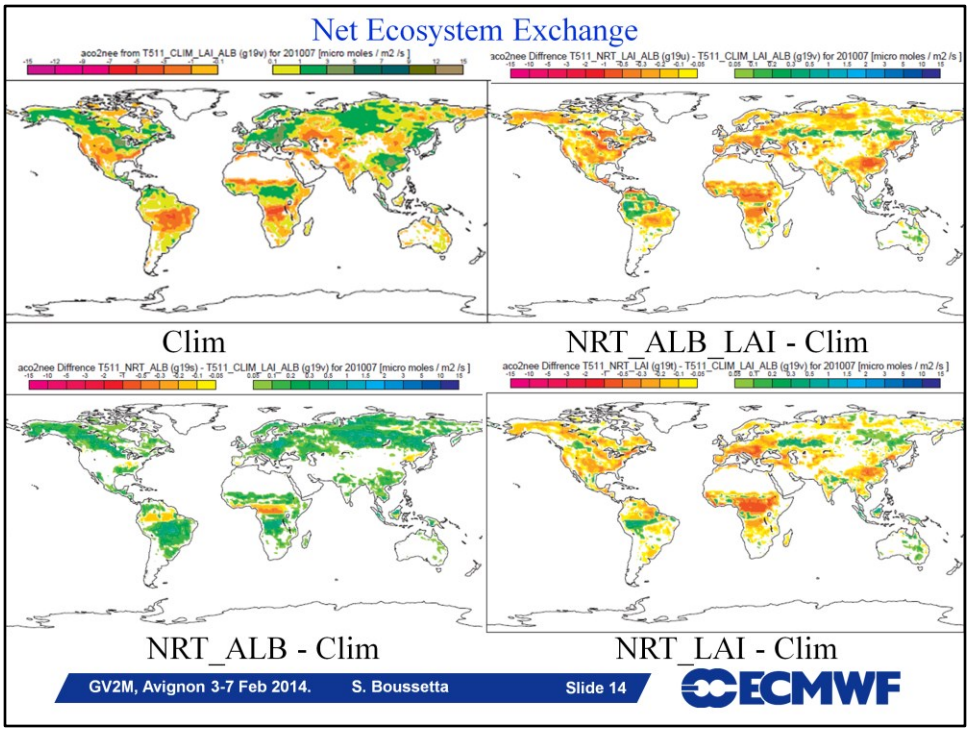
Net Ecosystem Exchange
aco2nee from T511_CLIM_LAI_ALB (g19v) for 201007 [micro moles / m2 /s]
aco2nee Diffrence T511_NRT_LAI_ALB (g19u) - T511_CLIM_LAI_ALB (g19v) for 201007 [micro moles / m2 /s]
Clim
NRT_ALB_LAI - Clim
aco2nee Diffrence T511_NRT_ALB (g19s) - T511_CLIM_LAI_ALB (g19v) for 201007 [micro moles / m2 /s]
aco2nee Diffrence T511_NRT_LAI (g19t) - T511_CLIM_LAI_ALB (g19v) for 201007 [micro moles / m2 /s]
NRT_ALB - Clim
NRT_LAI - Clim
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Coupled experiments

Setup:

-10 days fc every 10days in 2010

-2 experiments: * Control CLIM

* NRT LAI NRT

➔Check the T 2m and RH on short term forecast fc+36 valid 12 UTC

Sensitivity = (NRT –CLIM),

if >0 => warming/adding moisture,

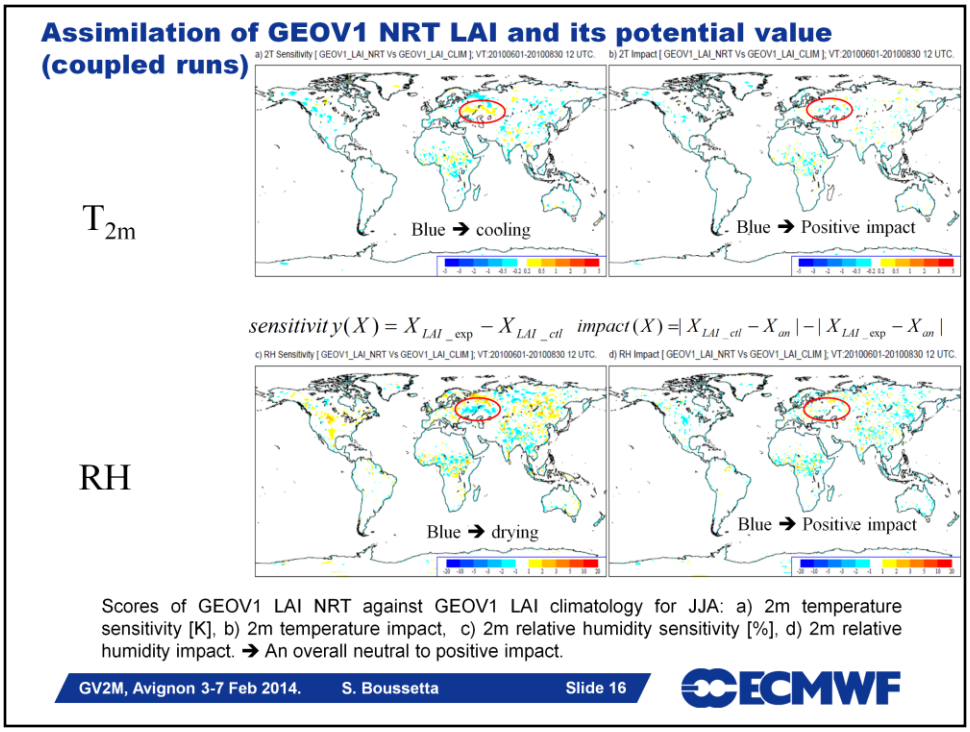
if <0 => cooling/removing moisture

And

Impact = |CLIM – oper_analysis| - |NRT – oper_analysis| ,

if >0 => relative error reduction from the analysis (positive impact)

if <0 => relative error increase from the analysis (negative impact)



- The negative NRT LAI anomaly resulted in a warming in the T2m and drying in the Rh2m,
- While the temperature warming had a positive impact with reference to the operational analysis, the drying impact was quite neutral.

➔ Assimilating NRT LAI has potential to improve the near surface atmospheric prediction, although these results need further confirmation with other cases.

Conclusions & Outlook

❑The analysis process resulted in products with smooth temporal evolution, which makes them more appropriate for environmental prediction than the original data.

❑The analysed NRT LAI is able to fairly detect/monitor anomalous year.

❑The analysed NRT albedo signal can be covariant with the NRT LAI mainly during wet year despite the compensation effect that may occur between vegetation and bare-ground albedo.

❑ GEOV1 NRT LAI/albedo showed potential for heat waves and drought monitoring also through its impact on energy and carbon Fluxes.

❑Introducing NRT LAI in coupled runs is physically justified and has an overall neutral to positive impact on forecasted screen level variables.

❑Additional testing is still needed to seek the impact of the NRT albedo in coupled mode.

❑Parameterizing a more explicit link between albedo and LAI would increase the model sensitivity to vegetation dynamics.

Acknowledgment:

* To the Copernicus Global Land team for their effort in generating and providing the LAI and albedo raw data.

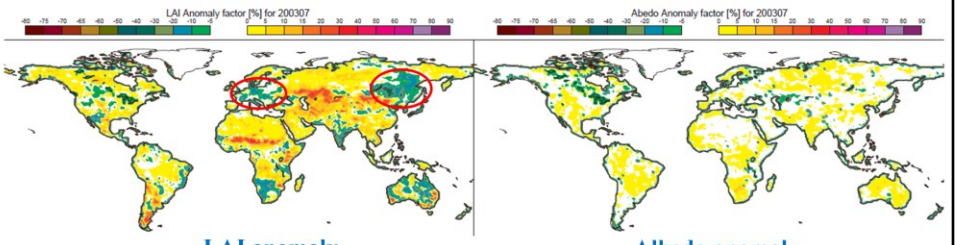
*This study is conducted under the framework of the ImagineS project.

http://fp7-imagines.eu/

Thank you for your attention

Contact: souhail.boussetta@ecmwf.int

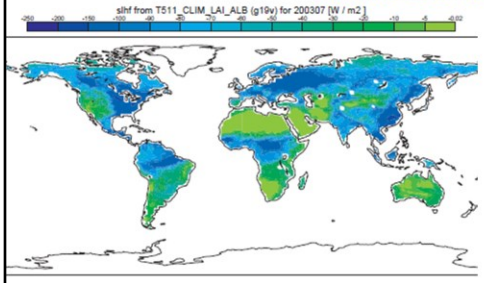
2003 Europe and East China drought



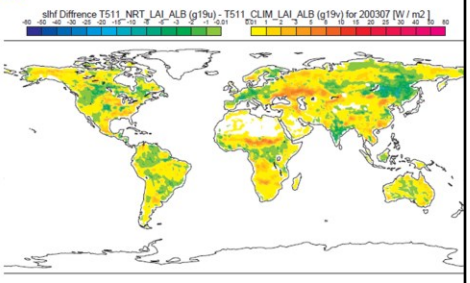
LAI anomaly

Albedo anomaly

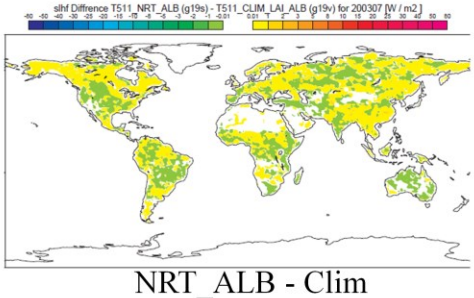
Latent Heat flux



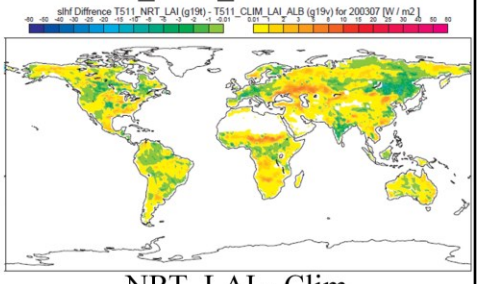
Clim



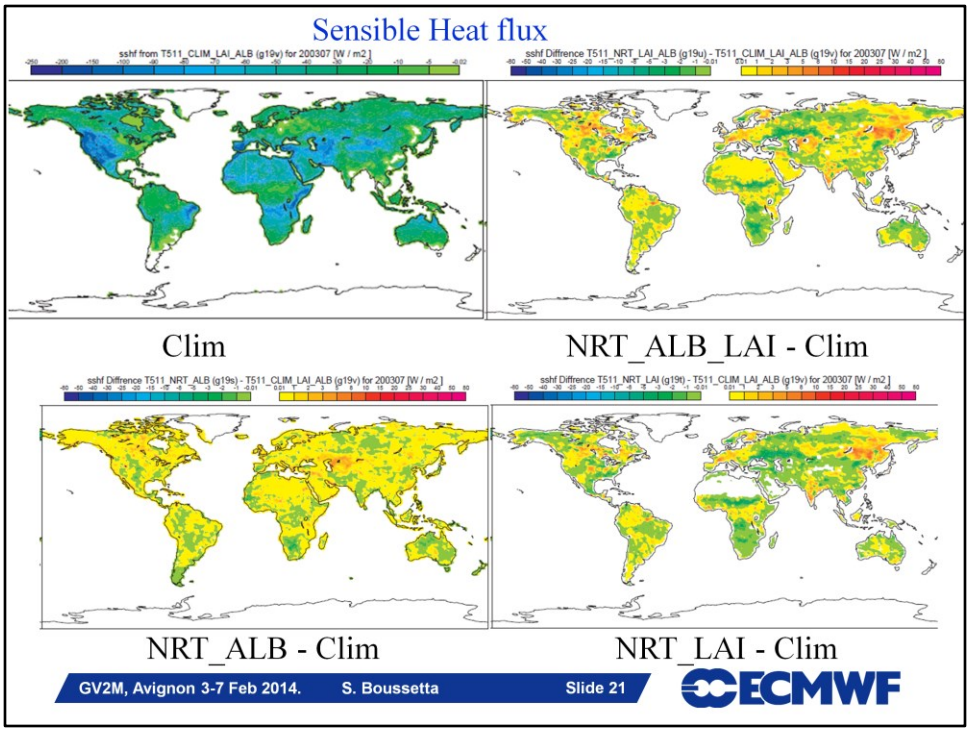
NRT_ALB_LAI - Clim



NRT_ALB - Clim



NRT_LAI - Clim


Sensible Heat flux
sshf from T511_CLIM_LAI_ALB (g19v) for 200307 [W / m2]
sshf Diffrence T511_NRT_LAI_ALB (g19u) - T511_CLIM_LAI_ALB (g19v) for 200307 [W / m2]
Clim
NRT_ALB_LAI - Clim
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NRT_ALB - Clim
NRT_LAI - Clim
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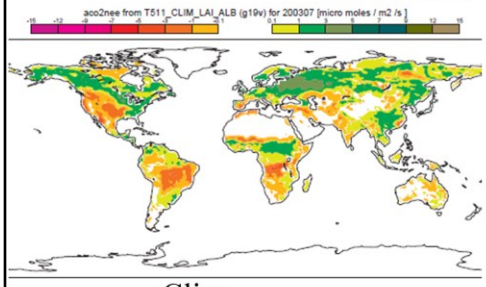
Net Ecosystem Exchange



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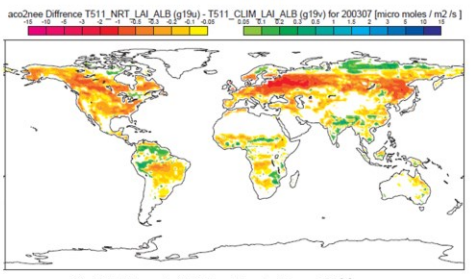
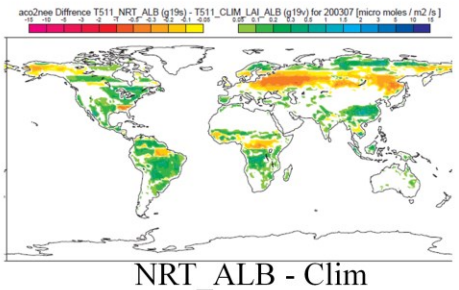
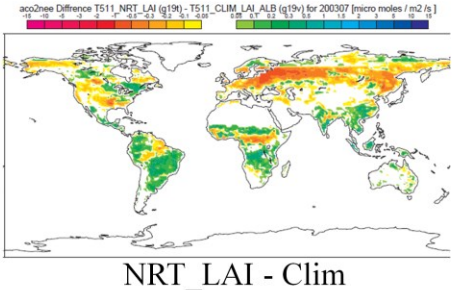


NRT_ALB_LAI - Clim



NRT_ALB - Clim



NRT_LAI - Clim