Towards a satellite driven Land Surface Model using SURFEX Offline Data Assimilation (SODA)

Albergel C., Munier S., Leroux D., Dewaele H., Fairbairn D., Barbu A. L., Mahfouf, J.-F., Faroux S., Le Moigne P., Decharme B. and Calvet J.-C.

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SURFEX USER WORKSHOP

Toulouse Meteopole campus (CIC) February 27 – March 1st 2017

Study the terrestrial water cycle

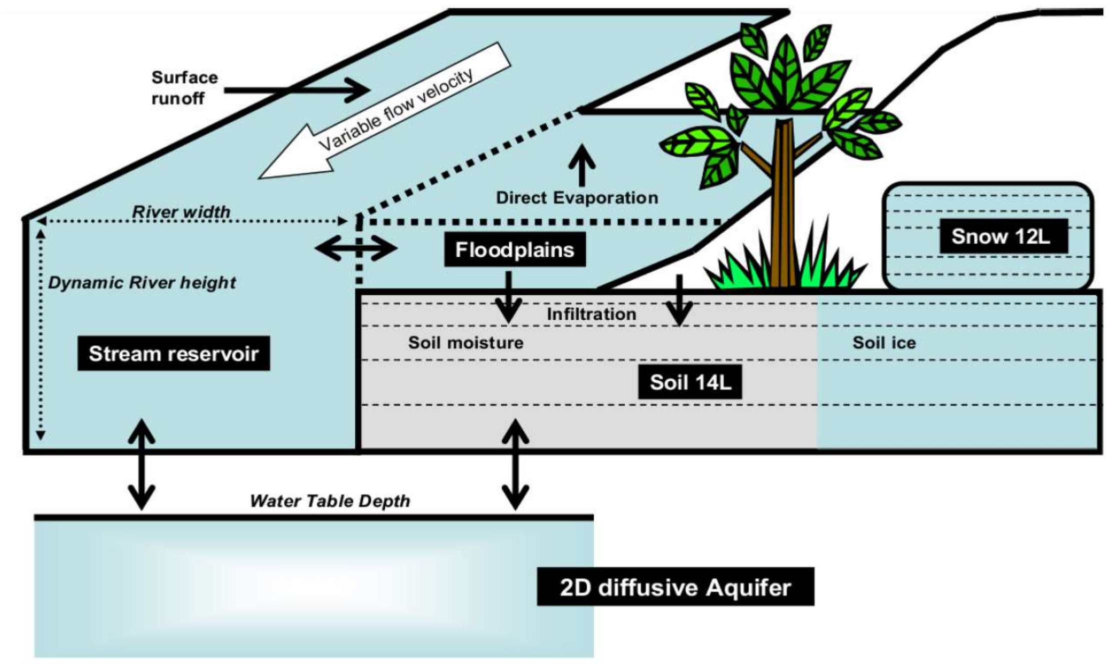
- **Modelling platforms including land surface models (LSMs), forced by gridded atmospheric variables, coupled to river routing models**

(Dirmeyer et al., 2006)

- **LSMs simulated biophysical variables**
  - Fully consistent with surface flux and river discharge simulations
  - Initialized using remotely sensed observations through Land Data Assimilation System

Study the terrestrial water cycle

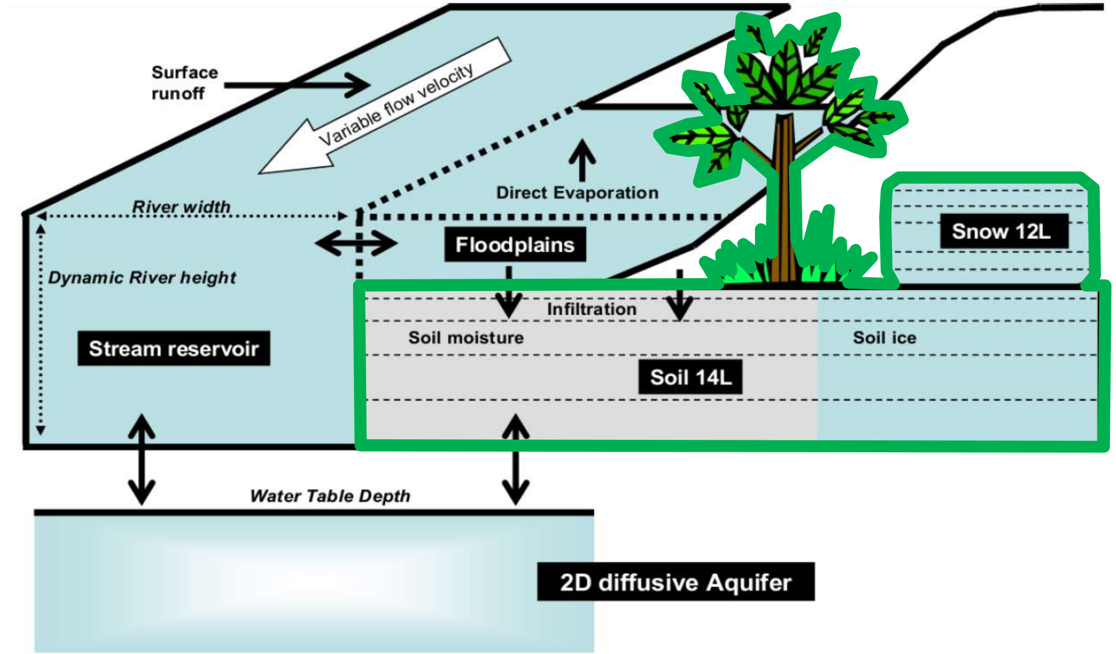
- **SURFEX-CTRIP satellite-driven hydrological system**



Study the terrestrial water cycle

- **SURFEX-CTRIP satellite-driven hydrological system**
  - ISBA-A-gs : simulates the diurnal cycle of water and carbon fluxes, plant growth and key vegetation variables on a daily basis

(Calvet et al., 1998, 2007, Gibelin et al., 2006)

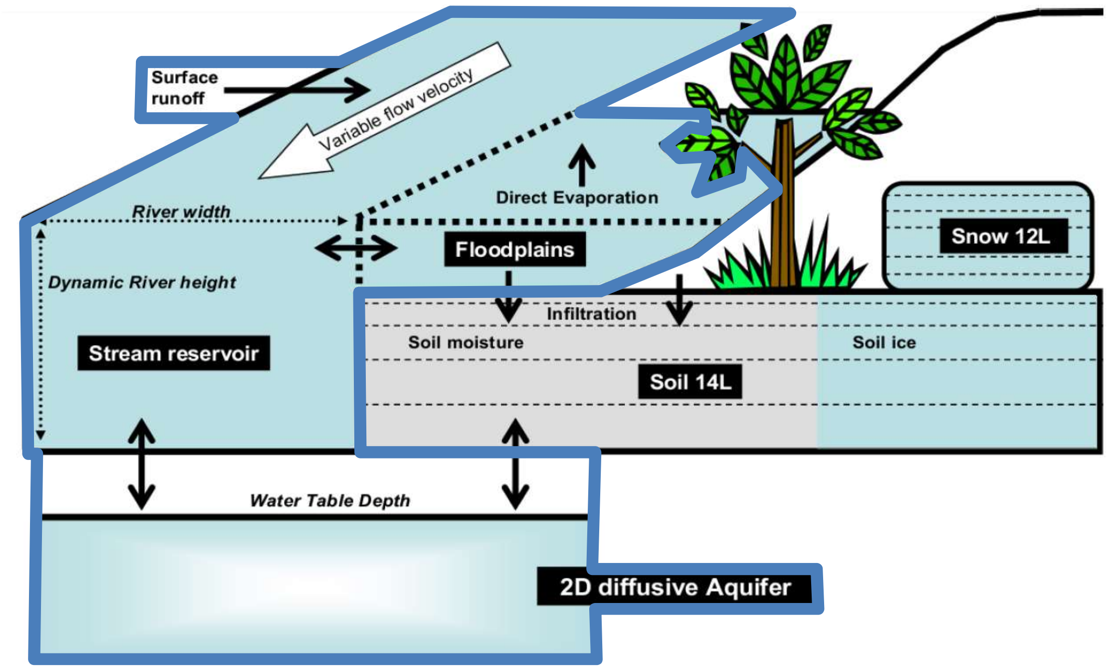


Study the terrestrial water cycle

- **SURFEX-CTRIP satellite-driven hydrological system**
  - CTRIP : TRIP based river routing system with CNRM developments for global hydrological applications

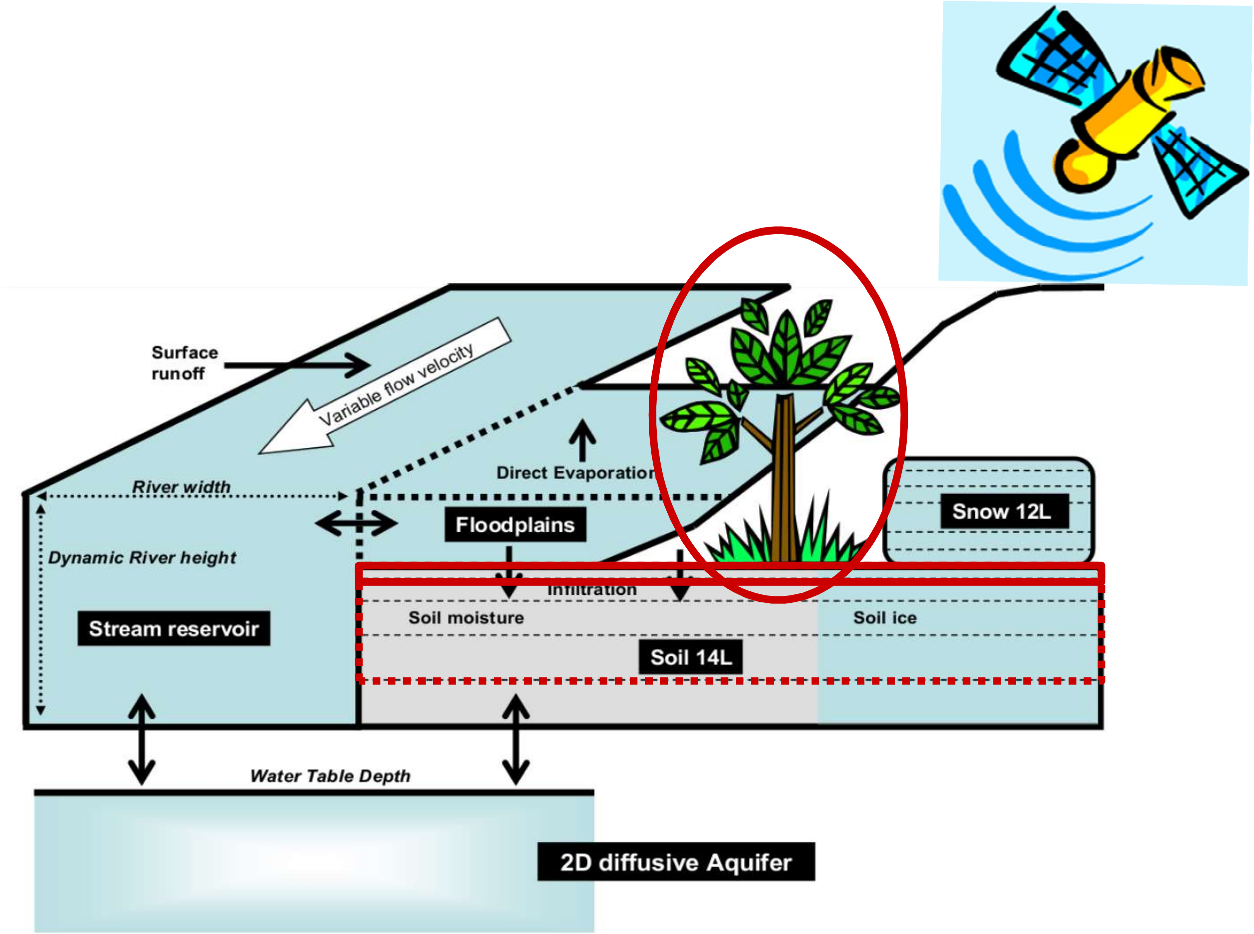
  ➔ variable flow rate, flooding by overflowing rivers, aquifers

(Oki and Sud, 1998, Decharme et al., 2008, 2010)



Study the terrestrial water cycle

- SURFEX-CTRIP **satellite-driven** hydrological system
  Surface Soil Moisture & Leaf Area Index



Study the terrestrial water cycle using SODA

- Open-loop & Analysis experiments over 2000-2012
- Spin-up (20 times 1990 + 1990-1999)

Model	Domaine	Atm. Forcing	DA Method	Assimilated Obs.	Observation Operator	Control Variables	Additional Option
ISBA-DF **CO_2-responsive version** **(Interactive veg.)**	**Europe and the Mediterranean basin (0.5°)**	**Earth2Observe** WRR1 (Schellekens et al., 2017)	**SEKF**	**SSM** **(ESA-CCI)** **LAI**	**Second layer of soil (1-4cm)** **LAI**	**Layers of soil 2 to 8 (1-100cm)** **LAI**	**Coupling with CTRIP (0.5°)**

- ISBA daily coupling with CTRIP

ISBA to CTRIP : runoff, drainage, groundwater and floodplain recharges

CTRIP to ISBA : water table depth/rise, floodplain fraction, flood potential infiltration

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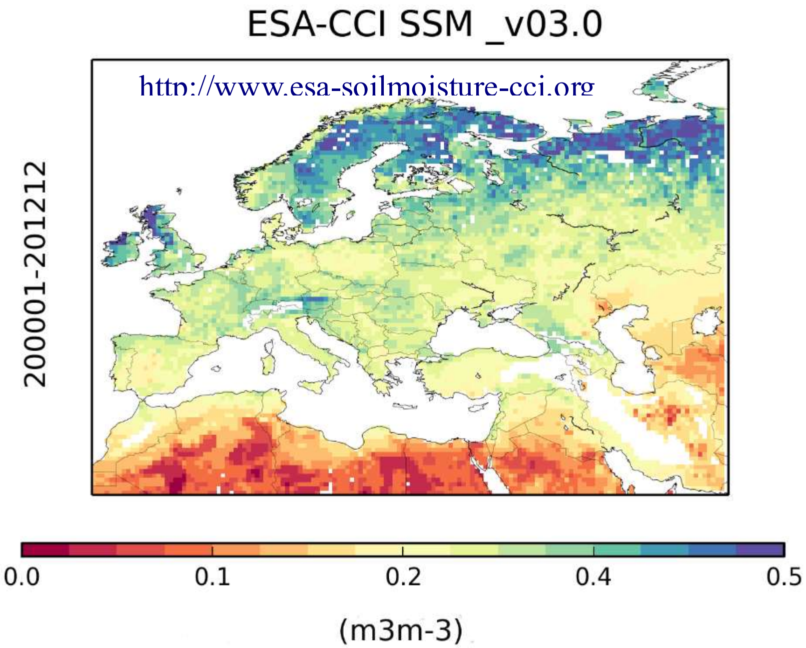

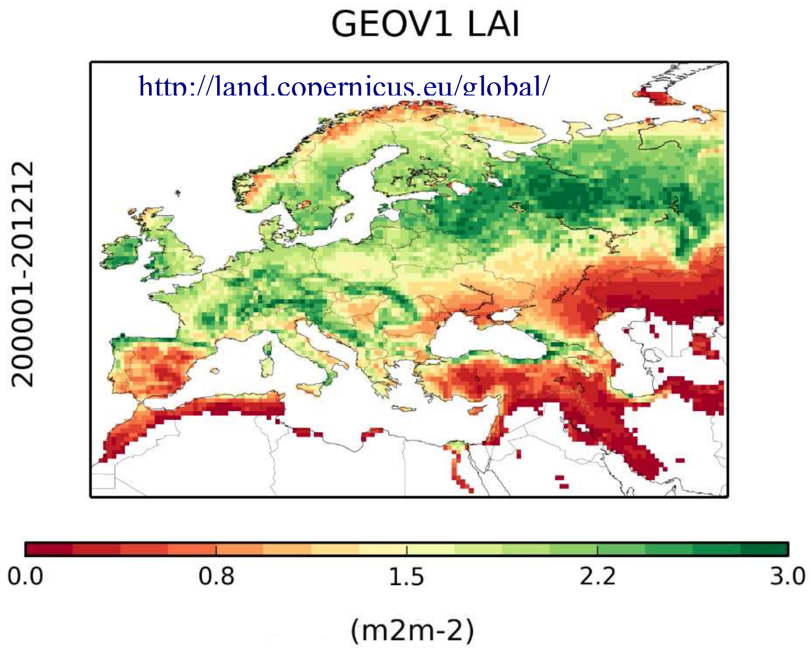

Study the terrestrial water cycle using SODA

- SEKF : uses finite differences in the observation operator Jacobians (H) to relate the observations to the model variables

→ Model sensitivity to the observations over 24h assimilation window

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➔ Model sensitivity to the observations over 24h assimilation window

2000-2012	$\frac{\ }{\partial LAI}$	$\frac{\ }{\partial w_2}$	$\frac{\ }{\partial w_3}$	$\frac{\ }{\partial w_4}$	$\frac{\ }{\partial w_5}$	$\frac{\ }{\partial w_6}$	$\frac{\ }{\partial w_7}$	$\frac{\ }{\partial w_8}$
Median								
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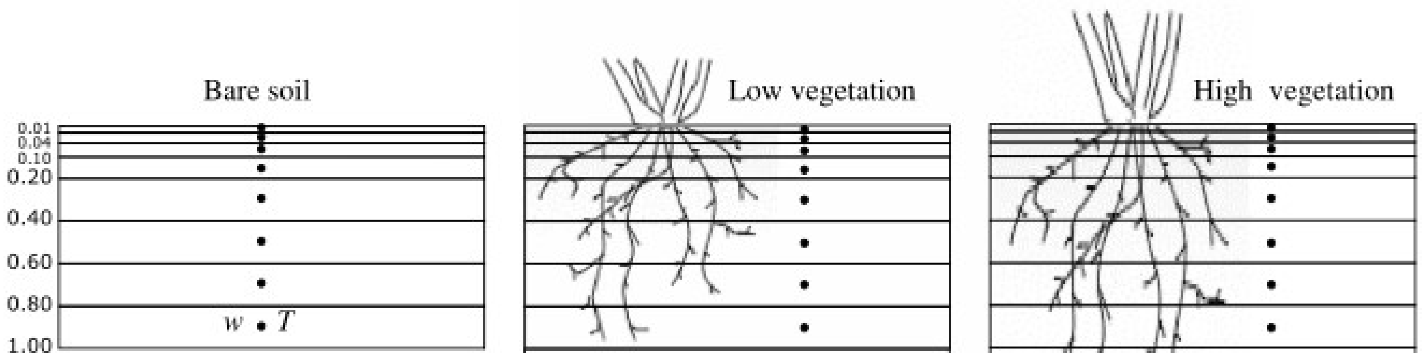

Adapted from Decharme et al., 2013, only the first 8 layers of soil (over 14) are represented

Study the terrestrial water cycle using SODA

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➔ Model sensitivity to the observations over 24h assimilation window

2000-2012	$\frac{\partial SSM}{\partial LAI}$	$\frac{\partial SSM}{\partial w_2}$	$\frac{\partial SSM}{\partial w_3}$	$\frac{\partial SSM}{\partial w_4}$	$\frac{\partial SSM}{\partial w_5}$	$\frac{\partial SSM}{\partial w_6}$	$\frac{\partial SSM}{\partial w_7}$	$\frac{\partial SSM}{\partial w_8}$
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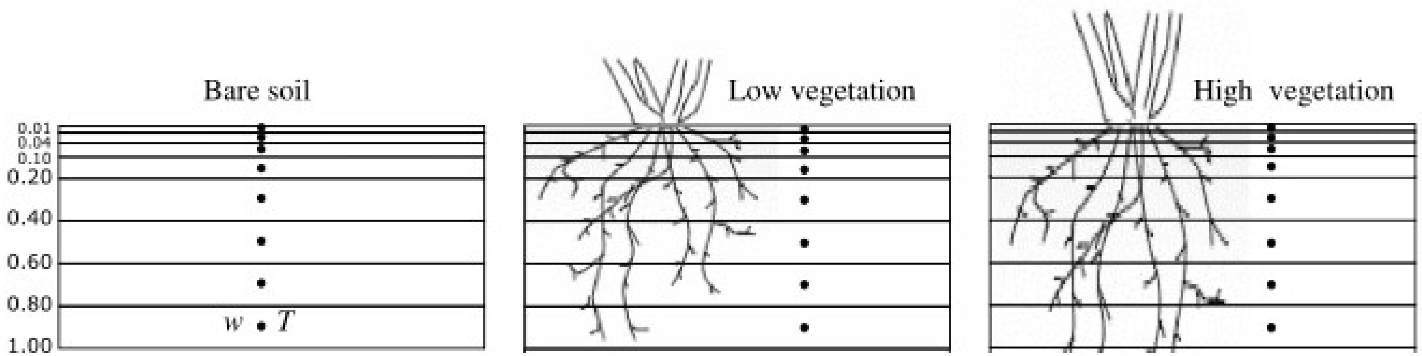

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Median	-0.0010	0.1719	0.1543	0.0694	0.0275	0.0043	0.0006	0.0001
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Median	0.2220	0.0006	0.0015	0.0032	0.0068	0.0038	0.0011	0.0006

- Assimilation of SSM

  → *LDAS will be more effective in modifying SM from the first layers of soil as model sensitivity to SSM decreases with depth*

- Assimilation of LAI

  → *LDAS will be more effective in modifying SM from layers four to six where most of the roots are present*

Study the terrestrial water cycle using SODA

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➔ Model sensitivity to the observations over 24h assimilation window

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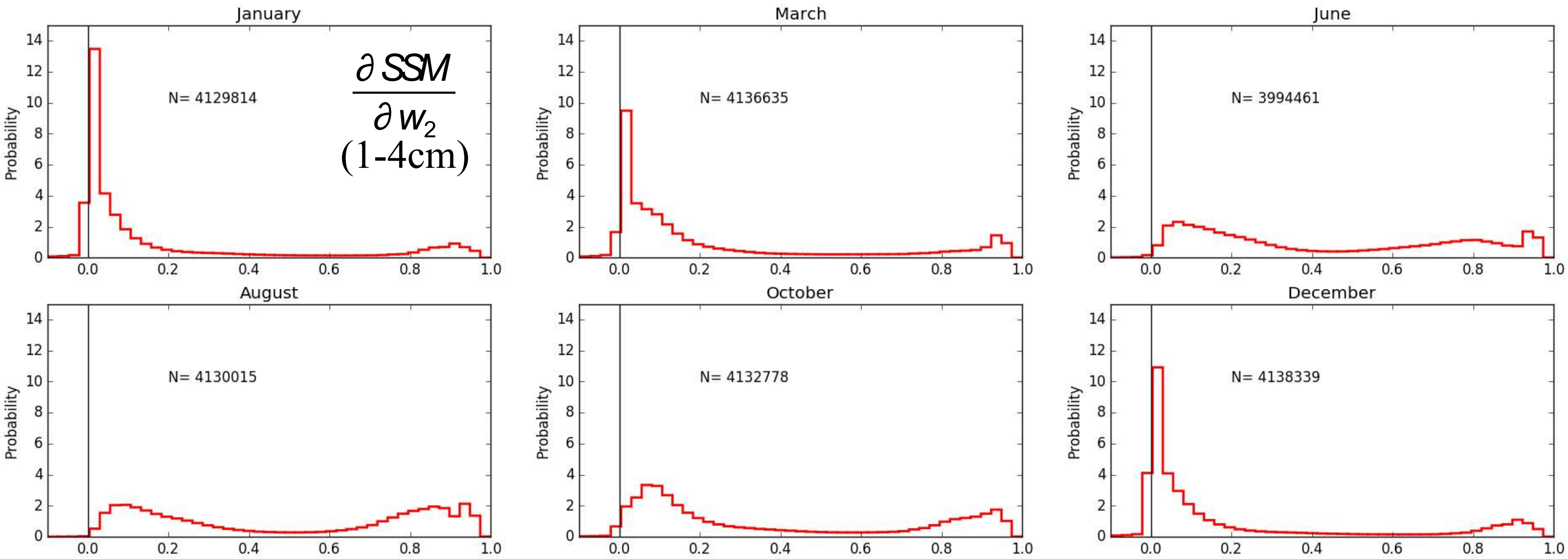
- Sensitivity of LAI to changes in SM weaker than that of SSM

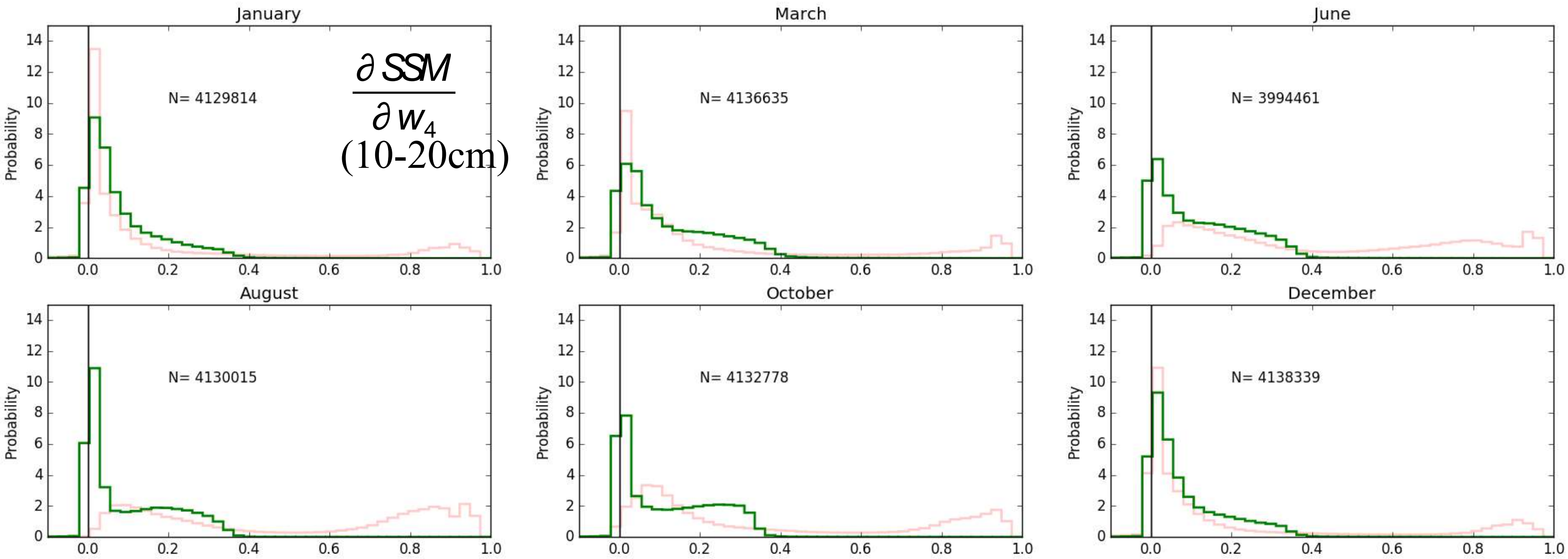
  ➔ *control variables related to SM would be more impacted by the assimilation of SSM than LAI*

Study the terrestrial water cycle using SODA



- **Type_A [~0] :** Model dynamic is almost not sensitive to the observations
- **Type_B [0.2-0.8] :** Final offset is only a fraction of the initial perturbation indicating that the model dynamic is strongly dissipative
- **Type_C [~1] :** Perturbation of the initial state results in a very similar offset at the end of the assimilation window, the model dynamic is close to the identity

Study the terrestrial water cycle using SODA



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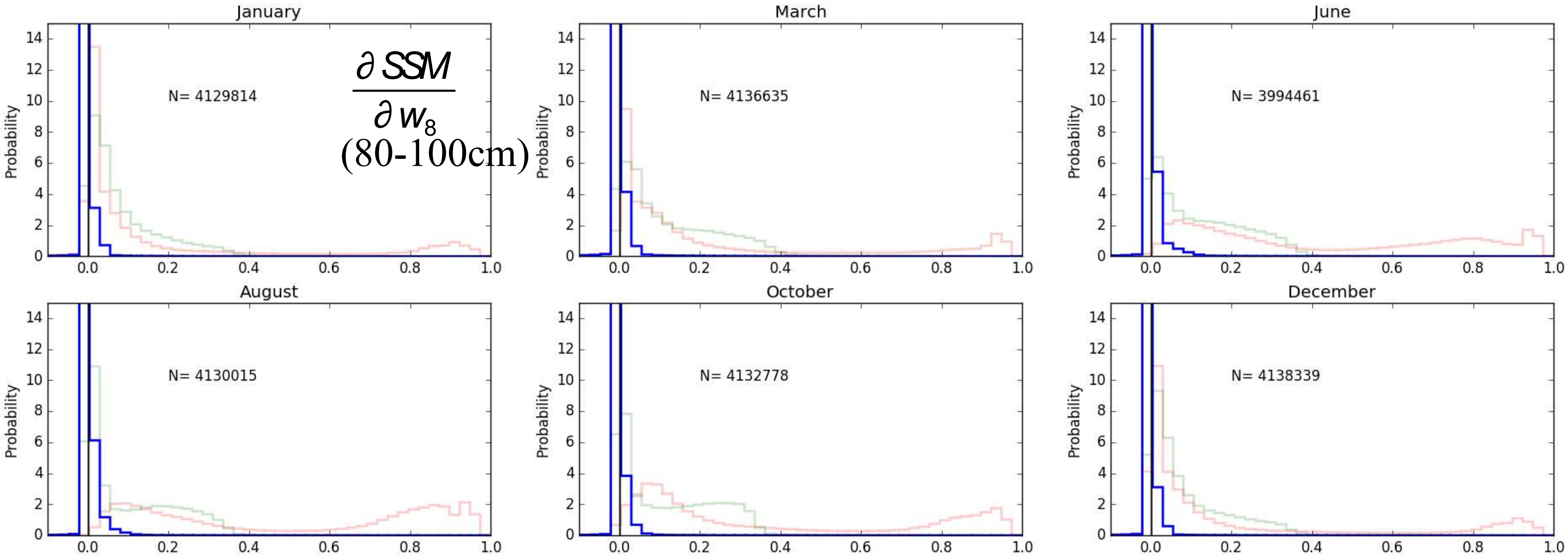

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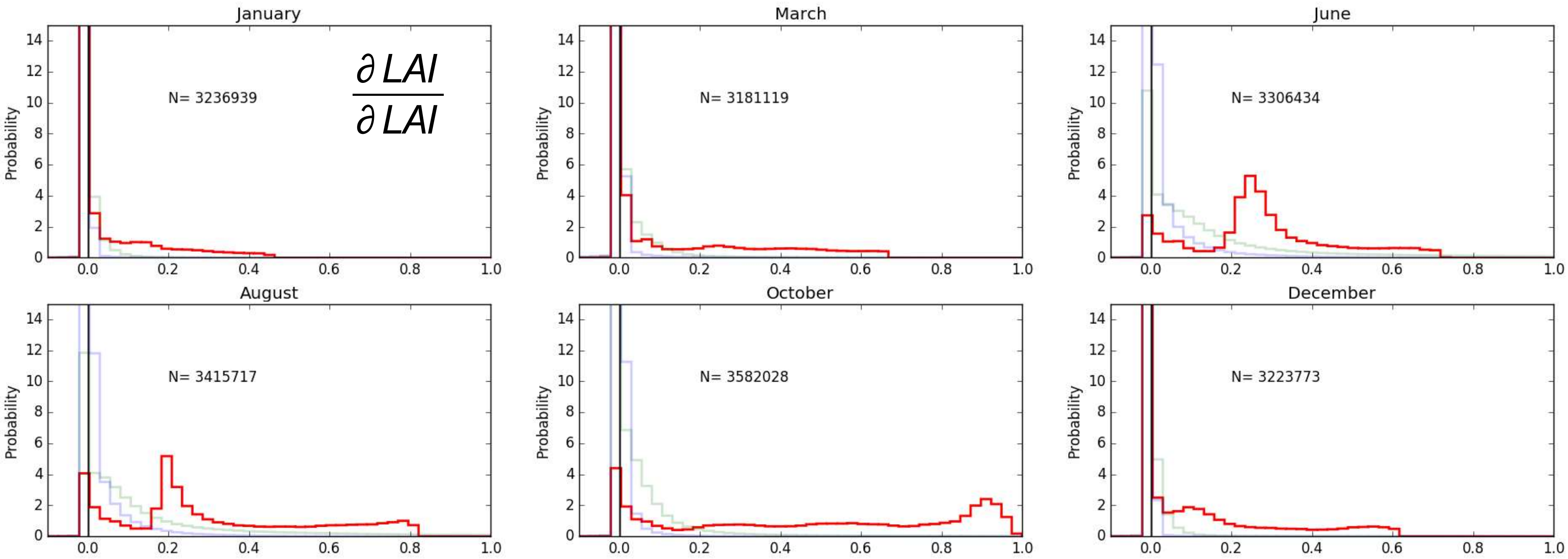

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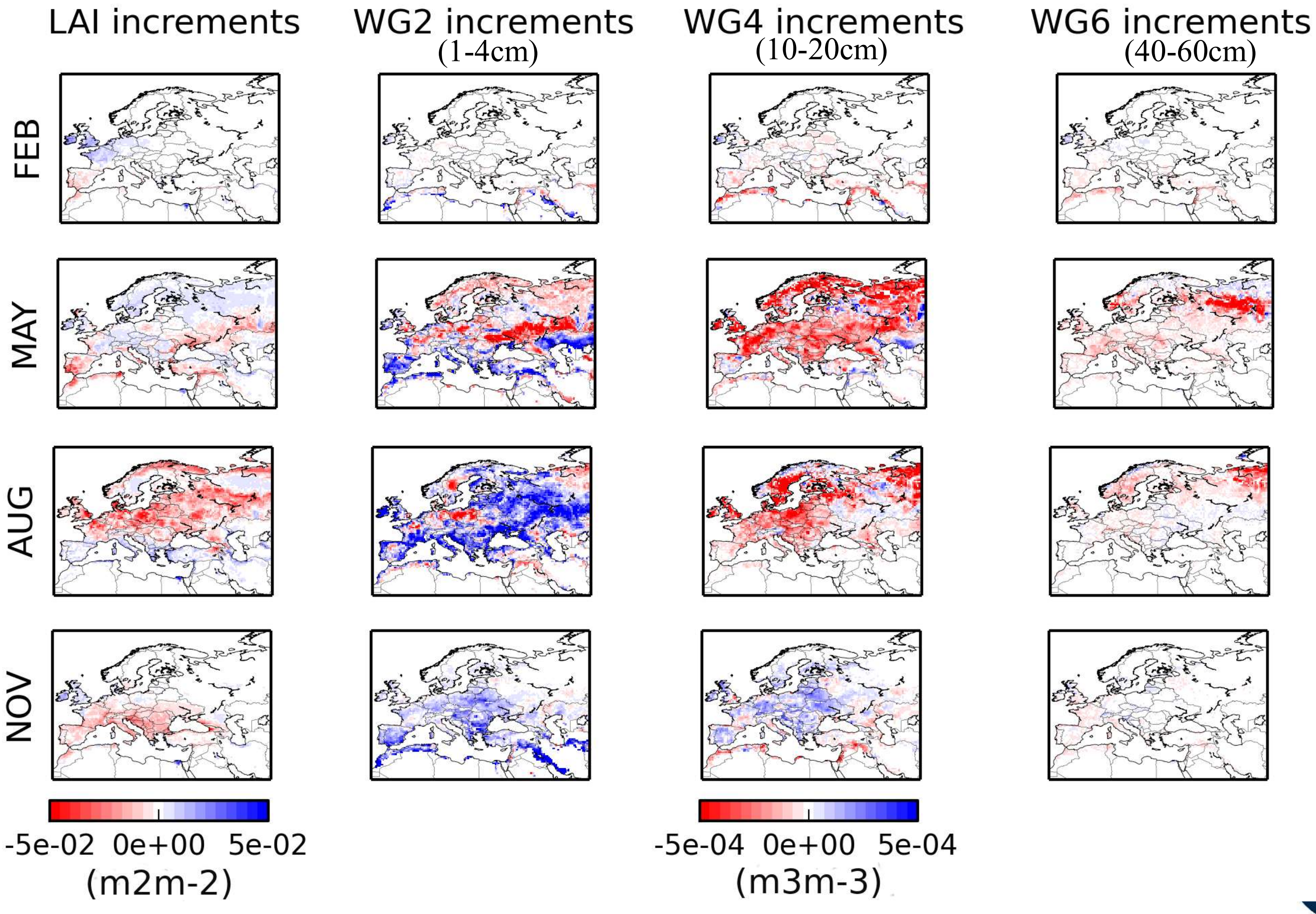
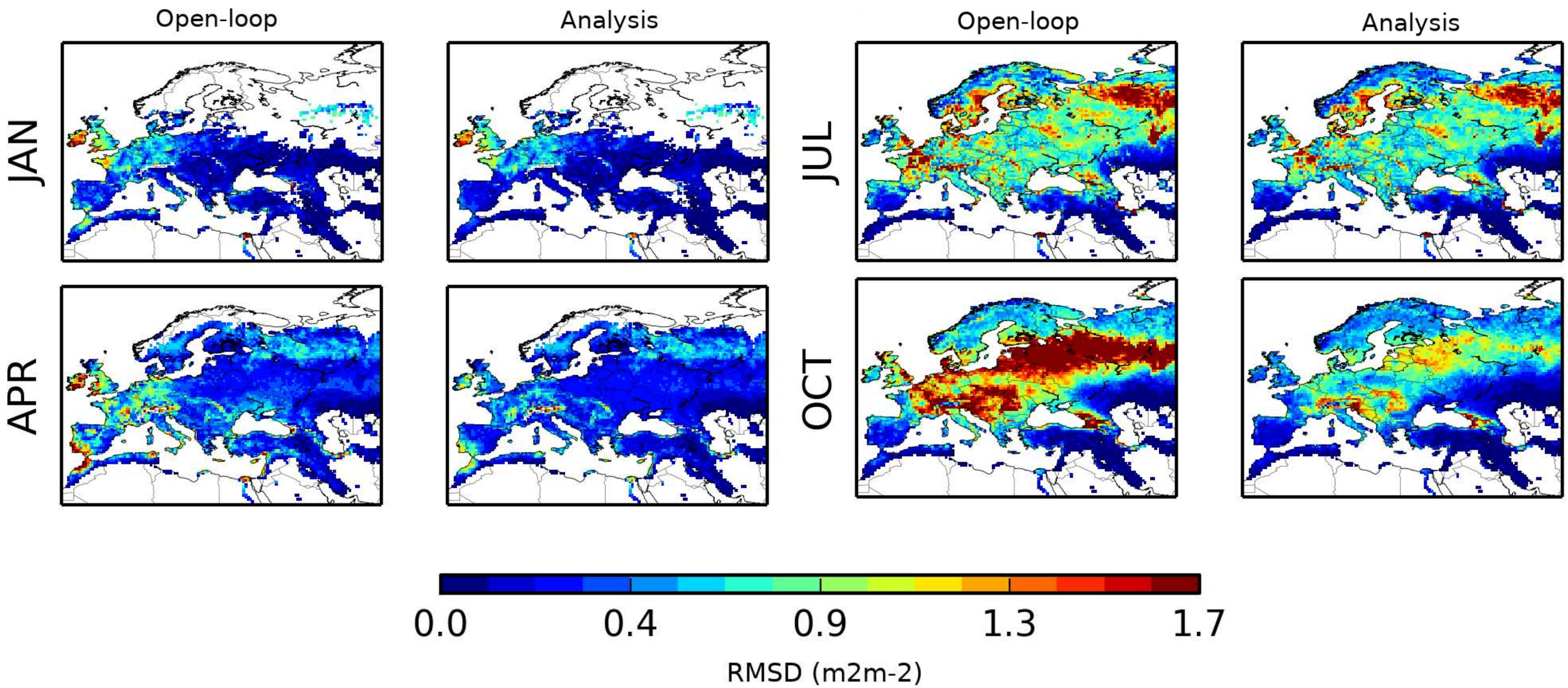
Study the terrestrial water cycle using SODA

- Analysis Increments, 2000-2012



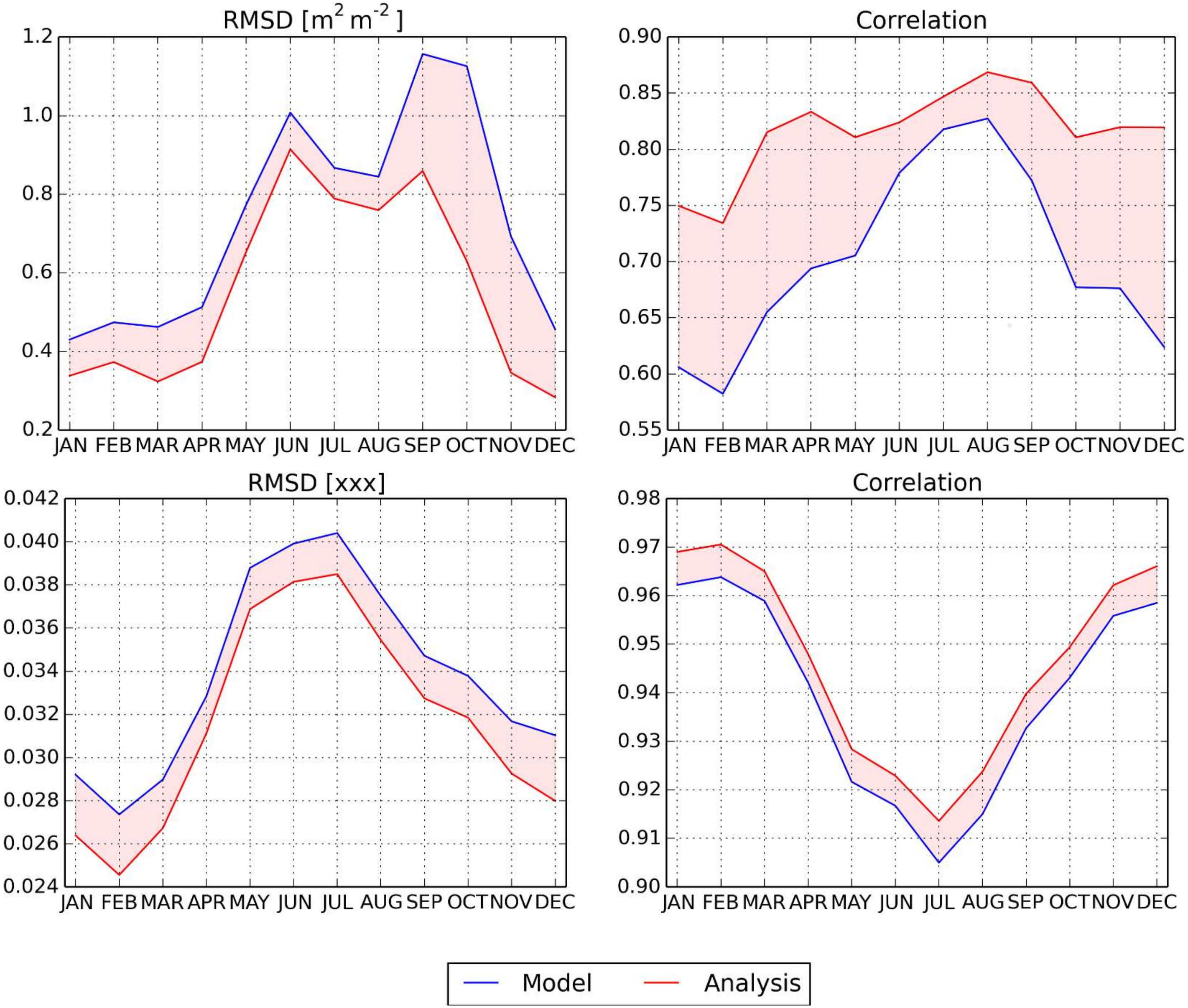
Study the terrestrial water cycle using SODA

- Analysis impact on LAI (RMSD), 2000-2012



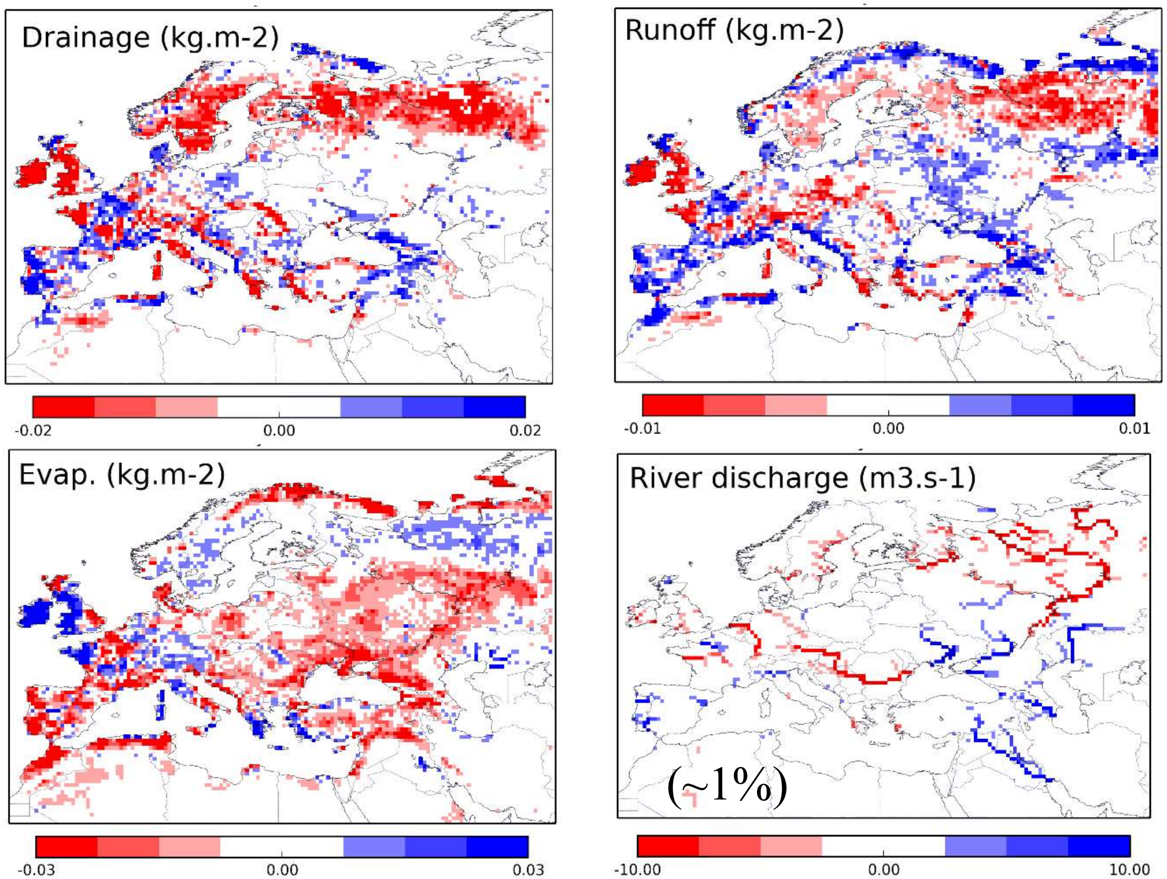
Study the terrestrial water cycle using SODA

- Analysis impact on LAI (top) & SSM (bottom), 2000-2012



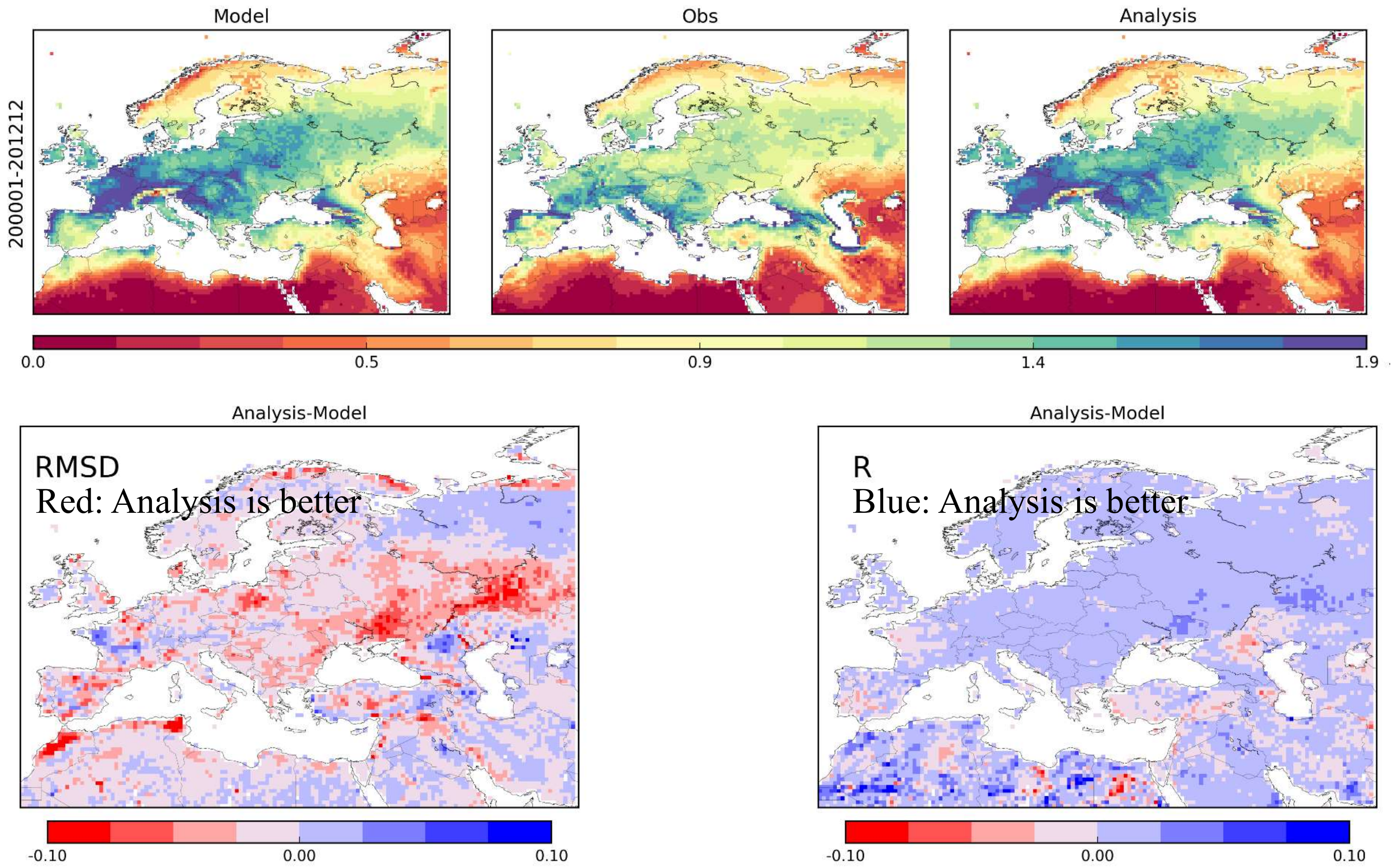
Study the terrestrial water cycle using SODA

- Analysis impact, 'indirectly' impacted variables 2000-2012



Study the terrestrial water cycle using SODA

- Evaluation of analysis impact 2000-2012: evapotranspiration vs. GLEAM dataset (Global Land Evaporation Amsterdam Model, www.gleam.eu)

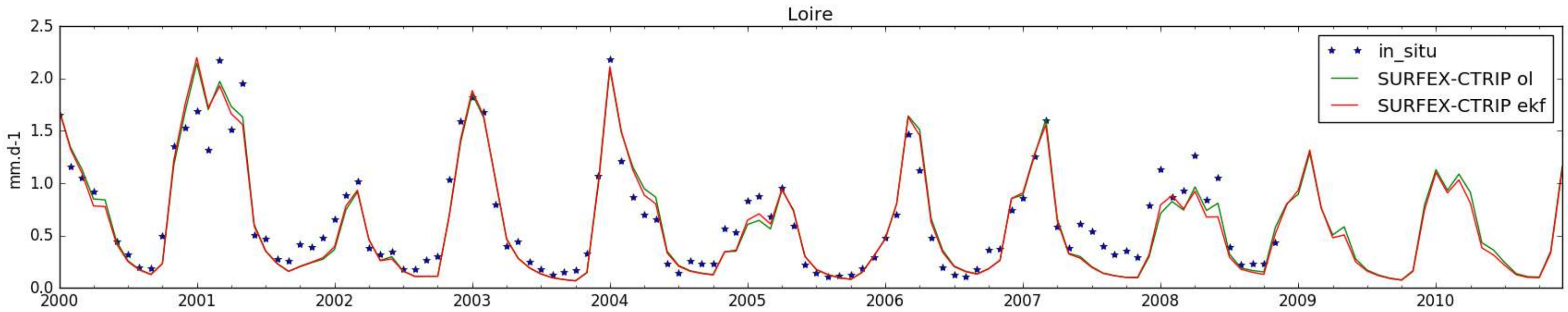


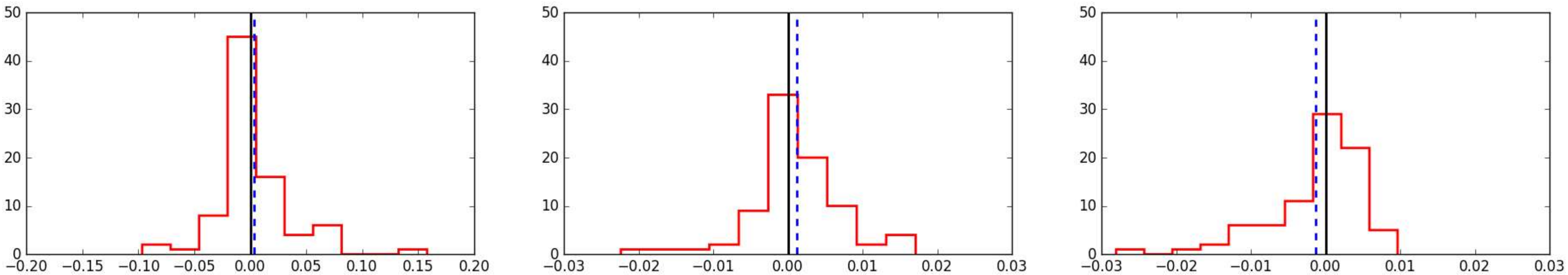
Study the terrestrial water cycle using SODA

- Evaluation of analysis impact 2000-2010: River discharge (Q)

Q is scale to the drainage area, sub-basin > 10000km^2, 4-yr of data

83 stations, 8 with Eff. Increase > 0.05 (3 < 0.05)





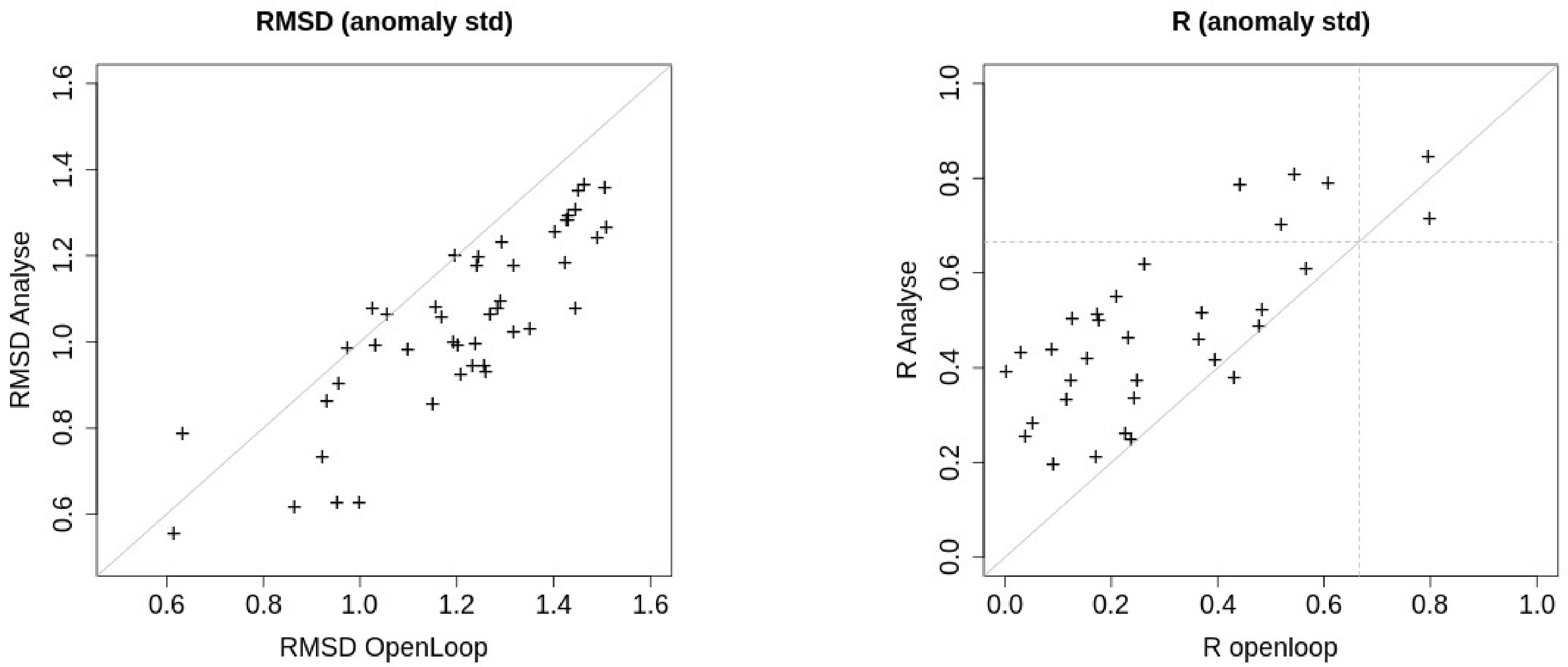
Eff. open-loop - analysis R. open-loop - analysis RMSD open-loop - analysis

➔ Neutral to positive (far of being impressive!)

Study the terrestrial water cycle using SODA

- Evaluation of analysis impact 2000-2010: grain yield over France vs. above-ground biomass 45 sites (Agreste portal, http://agreste.agriculture.gouv.fr)

➔ Inter-annual variability



➔ Analysed Biomass shows better R and RMSD than that of the open-loop

Courtesy H. Dewaele

Study the terrestrial water cycle using SODA

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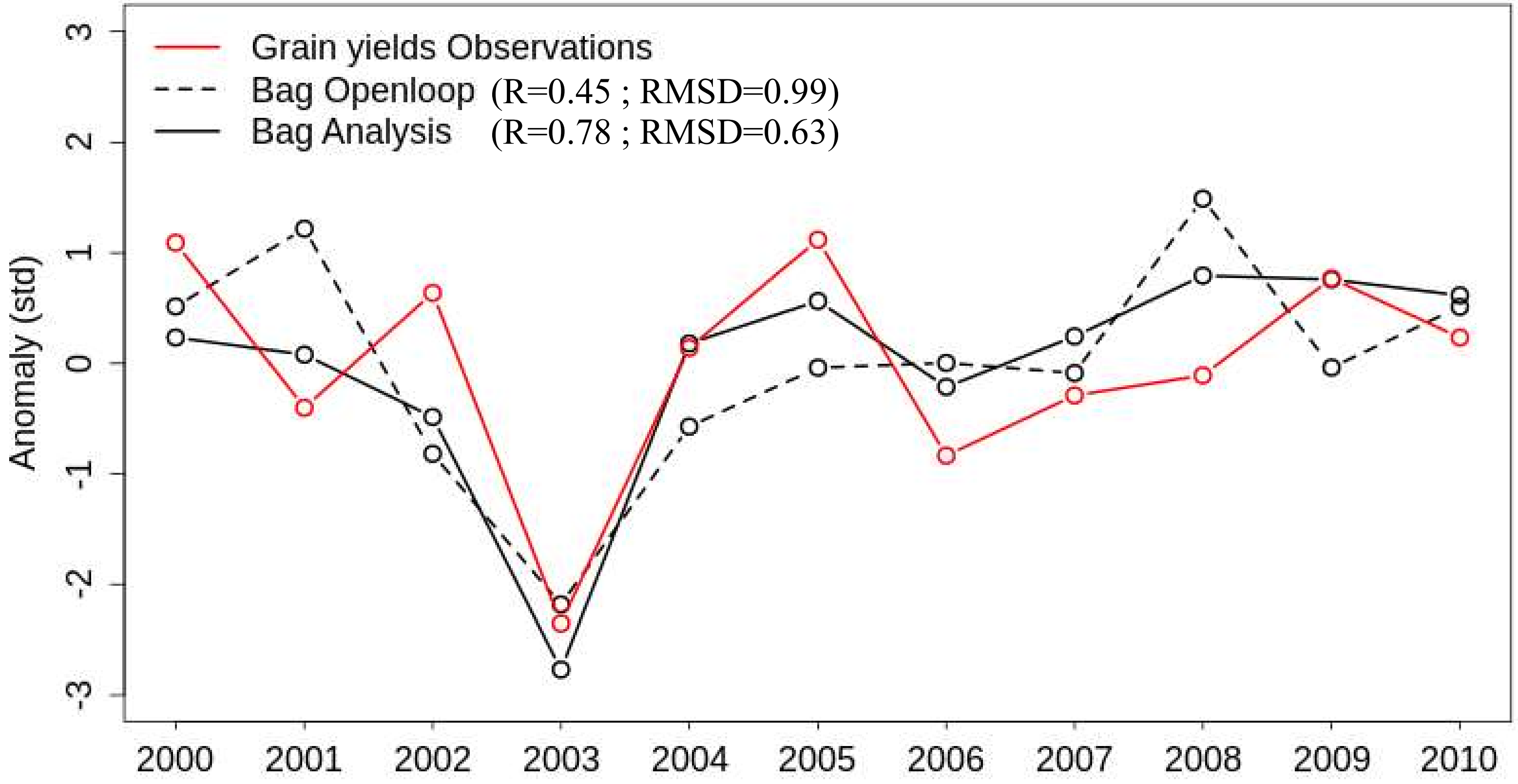

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Study the terrestrial water cycle using SODA

Conclusions :

- SODA implementation offers great perspectives!

(see presentations from Munier S., Calvet J.-C. & Leroux D.)

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* work in progress

** Only if ISBA-DF

*** Only over SAFRAN domain

- Positive impact on biomass, evapotranspiration, neutral to positive on river discharge
- Better use of satellite derived LAI should prove efficient improving e.g. river discharge

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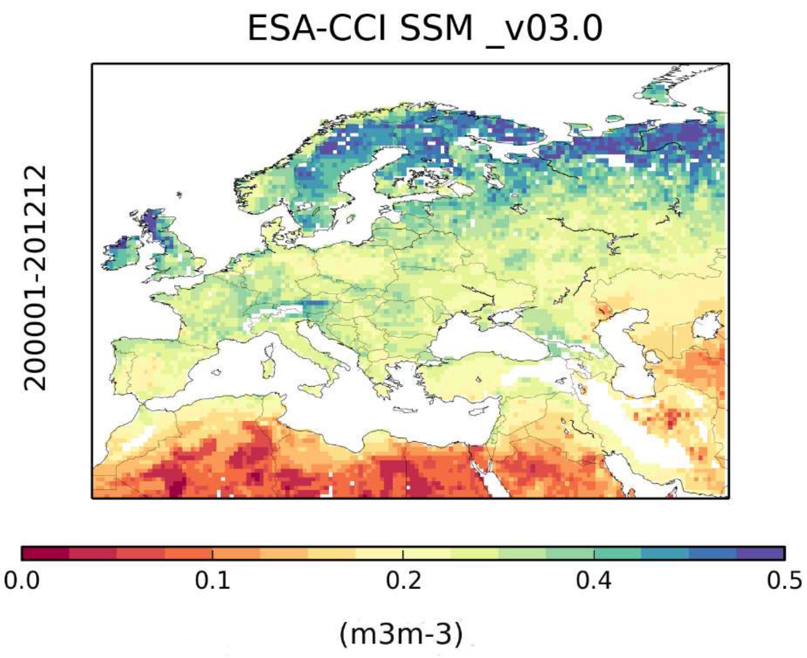
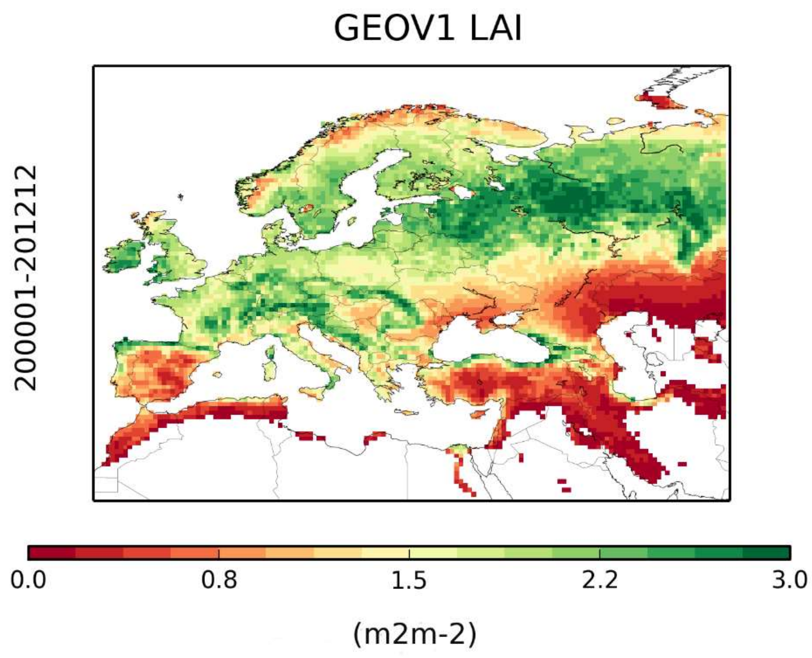
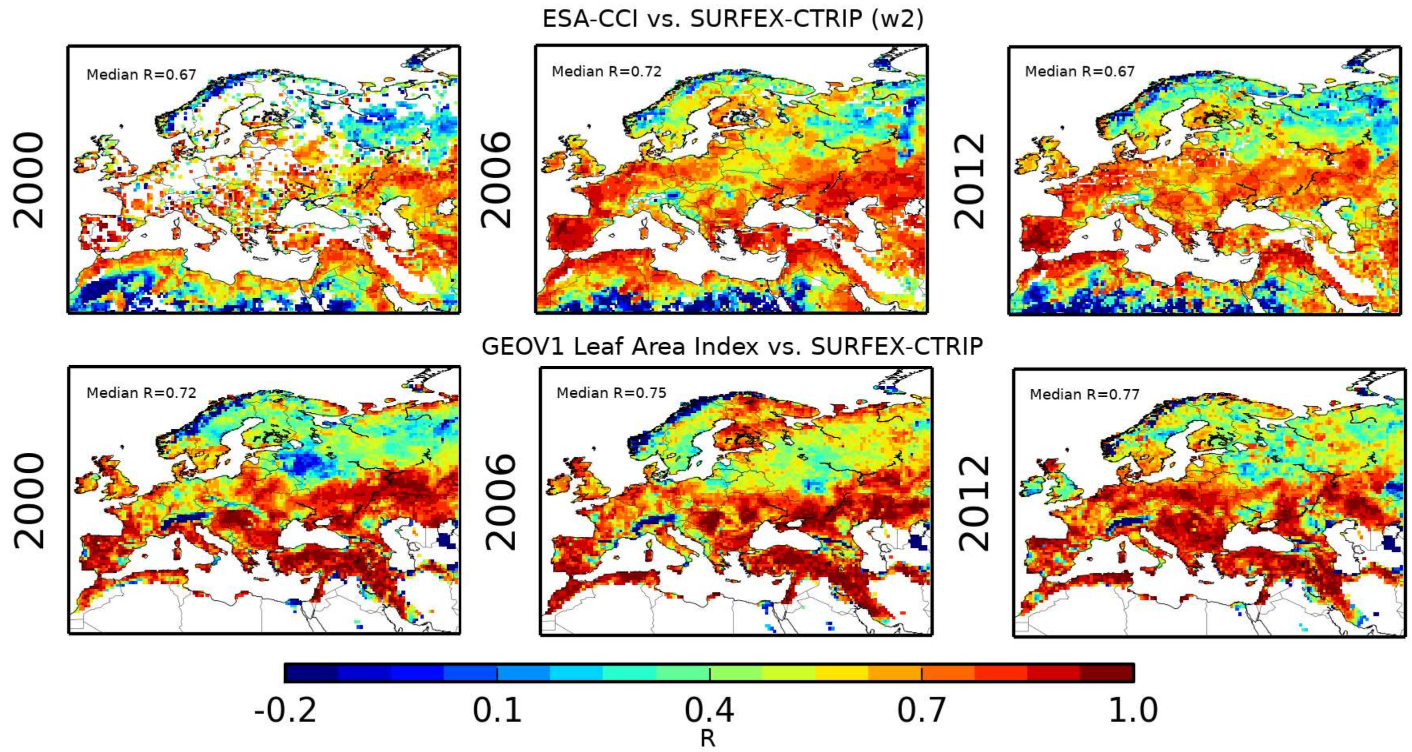




METEO FRANCE

Study the terrestrial water cycle using SODA



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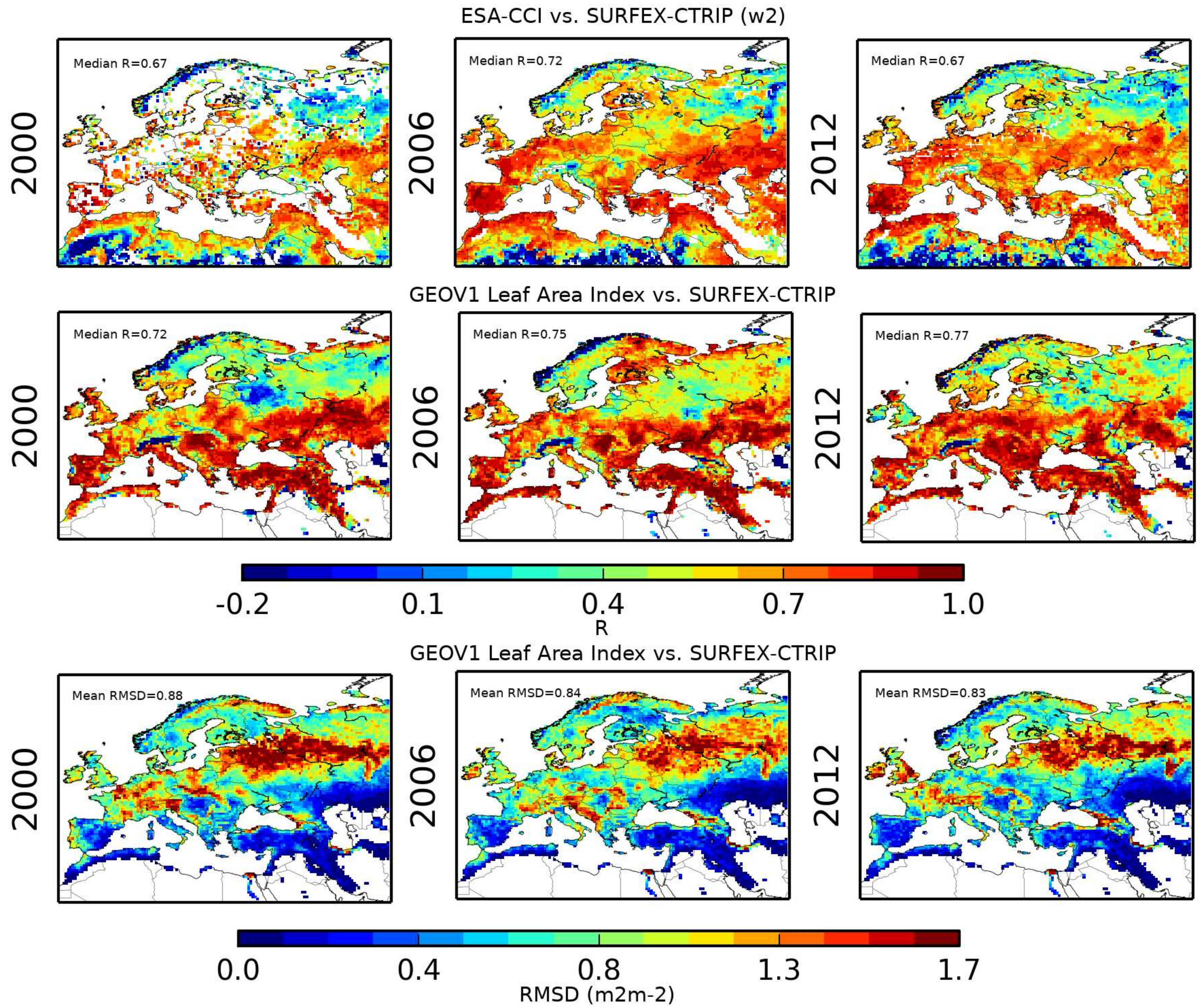

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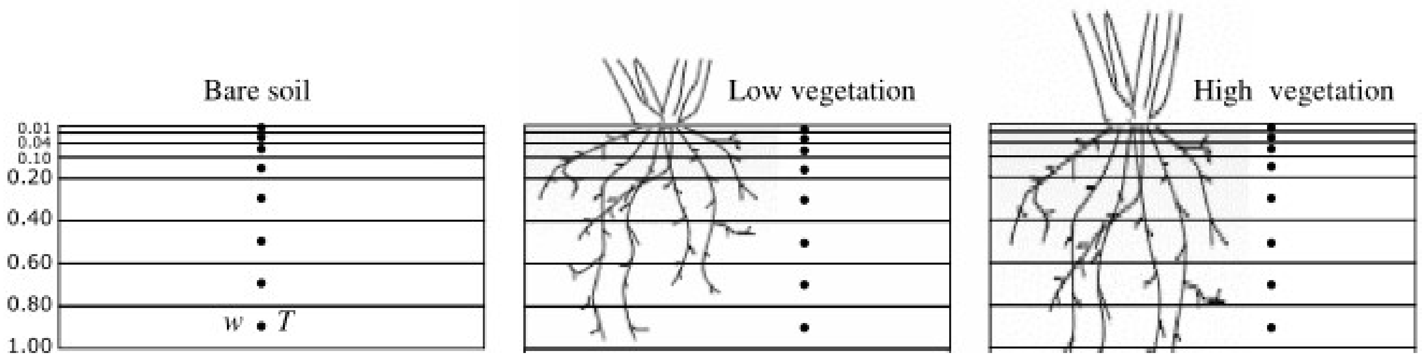

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