Sequential assimilation of satellite-derived vegetation and soil moisture products:

LDAS-Monde over the Euro-Mediterranean area

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

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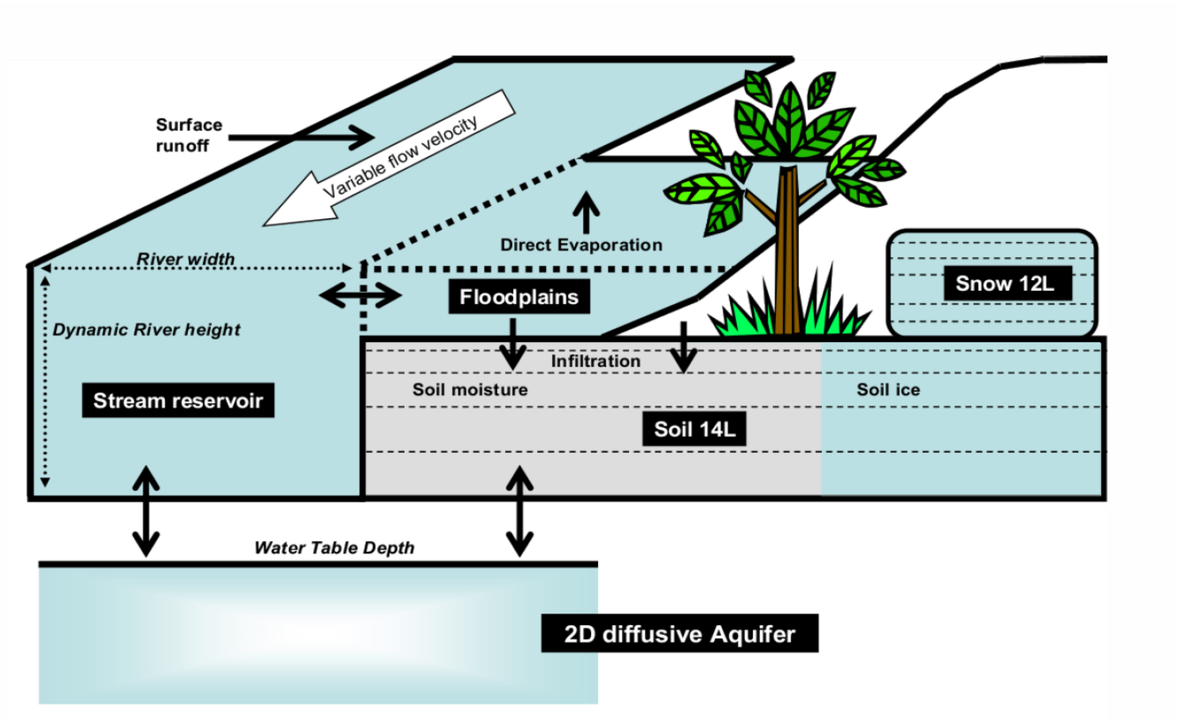
Study the vegetation and terrestrial water cycles

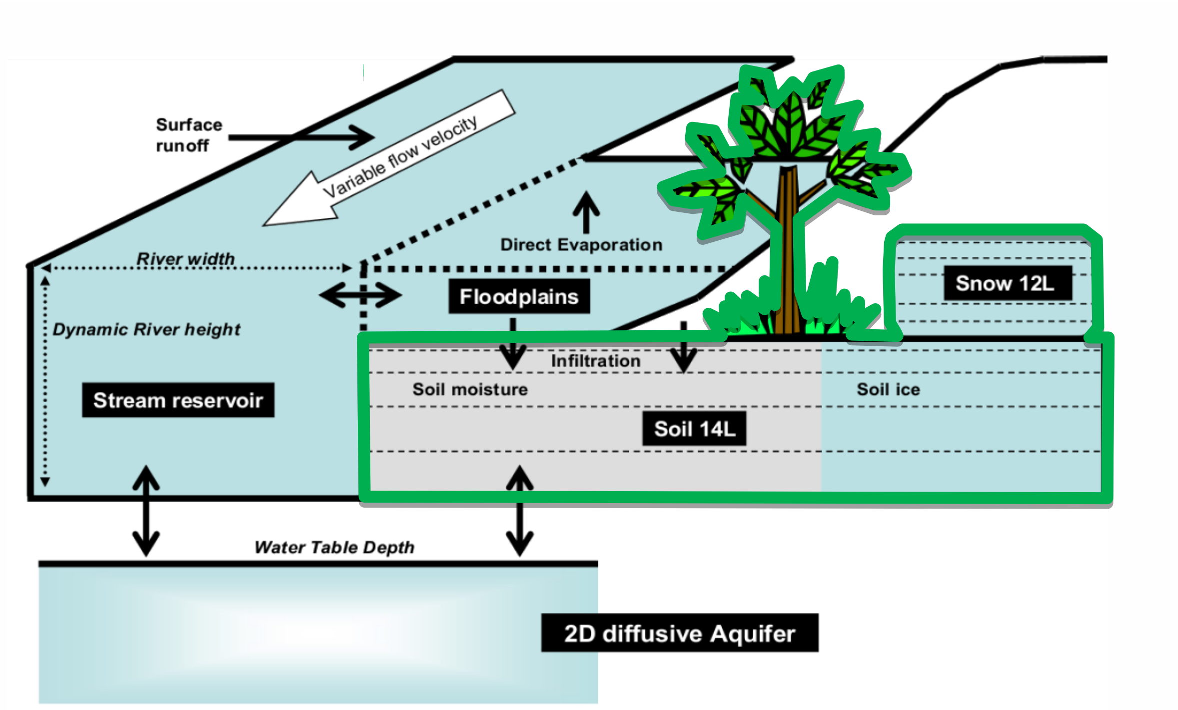
- **LDAS-Monde : Integration of satellite observations into SURFEX, fully coupled to hydrology**



Study the vegetation and terrestrial water cycles

- **LDAS-Monde : Integration of satellite observations into SURFEX, fully coupled to hydrology**
  - ISBA-A-gs : simulates the diurnal cycle of water and carbon fluxes, plant growth and key vegetation variables on a daily basis
  - Multi-layer, CO_2-responsive version

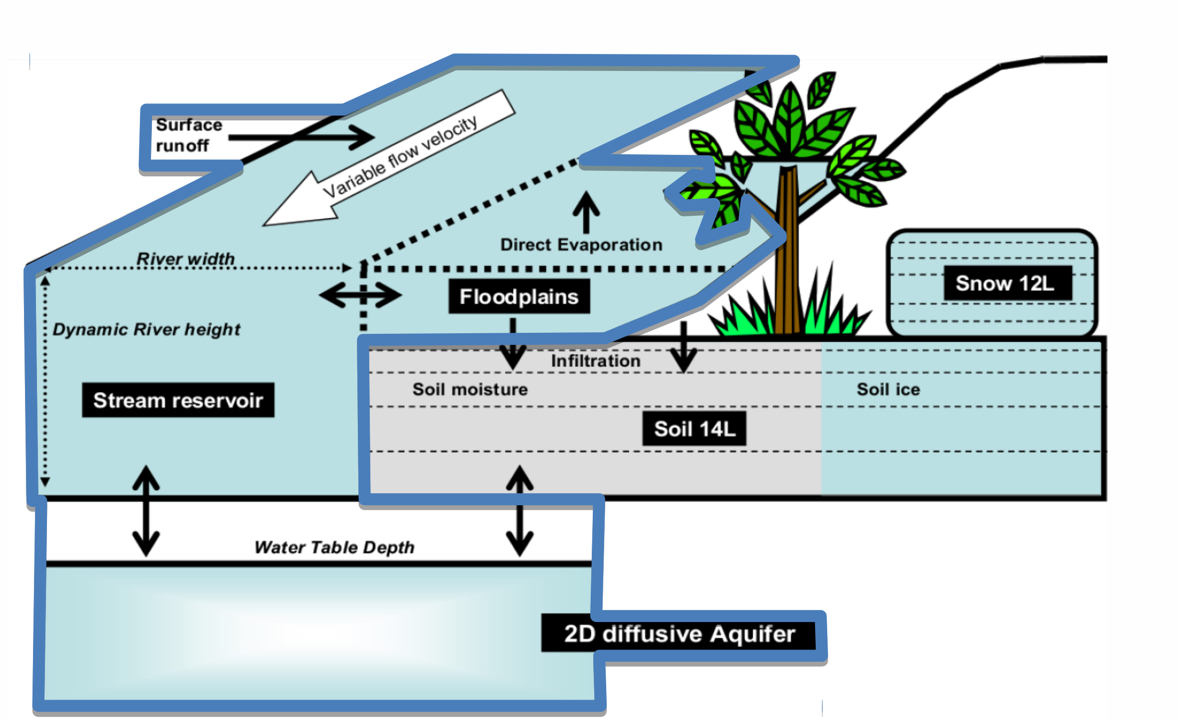
(Calvet et al., 1998, 2007, Gibelin et al., 2006)



Study the vegetation and terrestrial water cycles

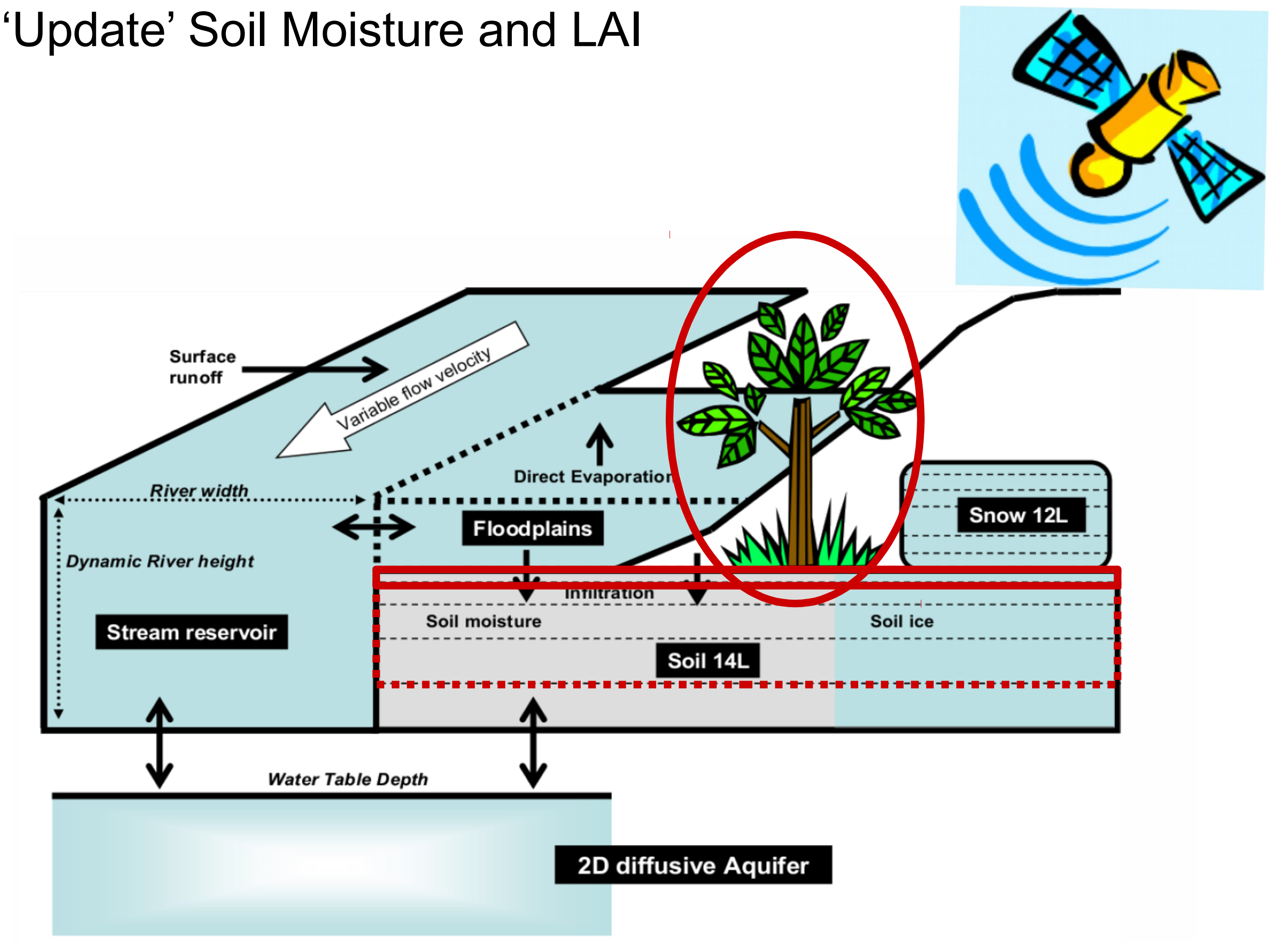
- **LDAS-Monde : Integration of satellite observations into SURFEX, fully coupled to hydrology**
  - CTRIP : TRIP based river routing system with CNRM developments for global hydrological applications

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



Study the vegetation and terrestrial water cycles

- **LDAS-Monde : Integration of satellite observations into SURFEX, fully coupled to hydrology**
  - 'Update' Soil Moisture and LAI



Study the vegetation and terrestrial water cycles

- **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 Multi-layer soil model CO_2-responsive version (Interactive veg.)	**Europe and the Mediterranean basin (0.5°)**	**Earth2Observe/ WFDEI** (Schellekens et al., 2017)	**SEKF**	**SSM** **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

Study the vegetation and terrestrial water cycles

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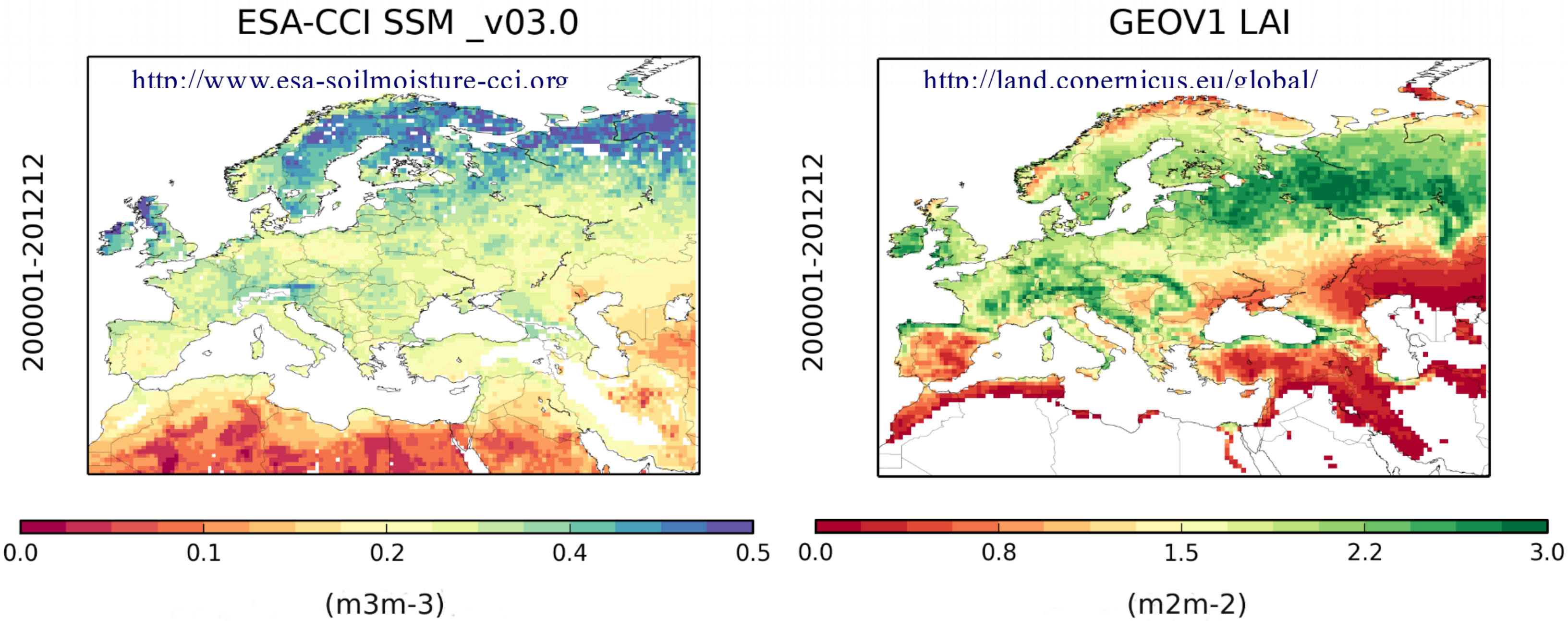

Study the vegetation and terrestrial water cycles

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

➔ Model sensitivity to the observations (24h assimilation window)

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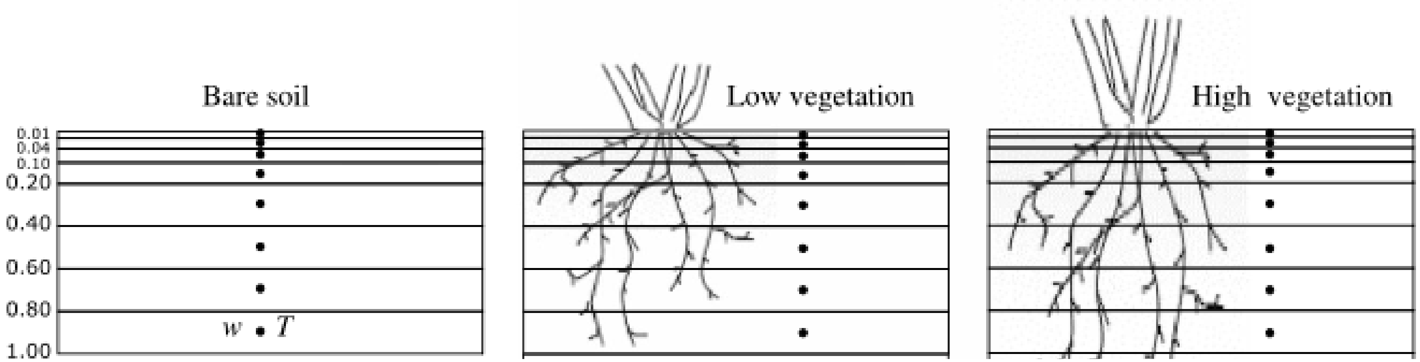

Adapted from Decharme et al., 2013, only the first 8 layers of soil (over 14) are represented

Study the vegetation and terrestrial water cycles

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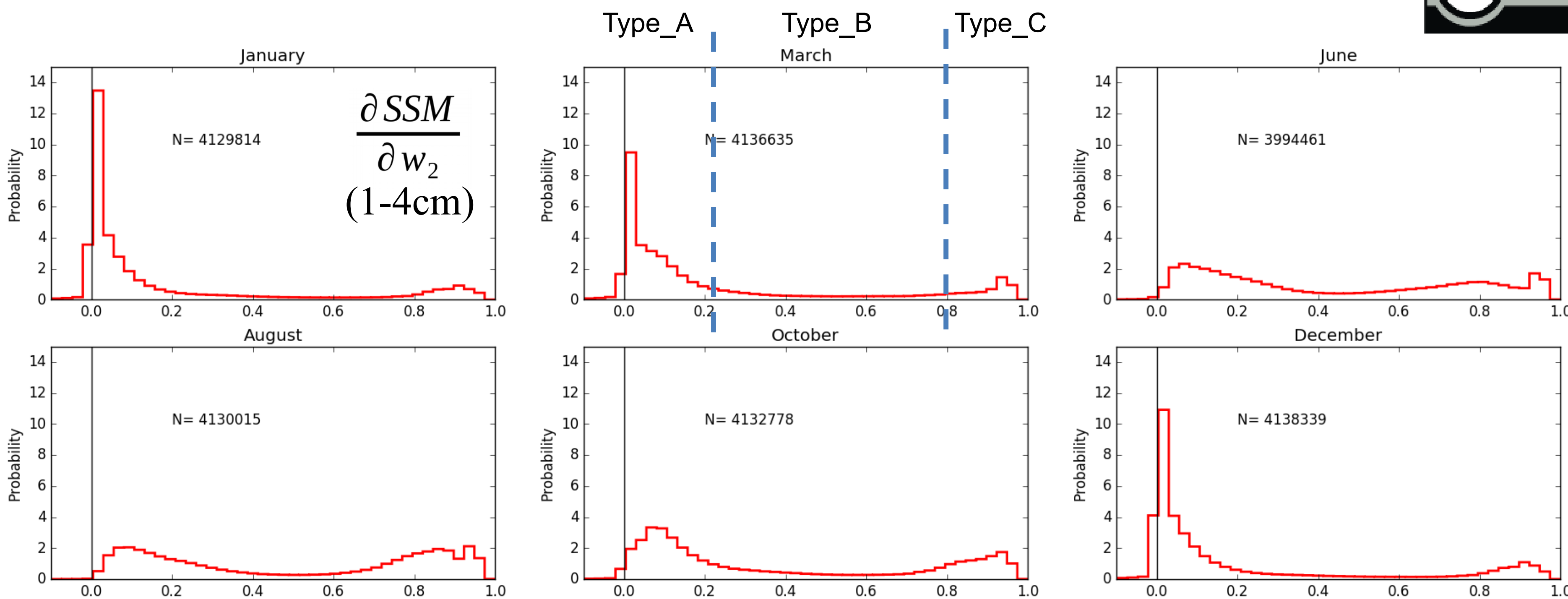
Median	-0.0010	**0.1719**	**0.1543**	**0.0694**	0.0275	0.0043	0.0006	0.0001
	$\frac{\partial LAI}{\partial LAI}$	$\frac{\partial LAI}{\partial w_2}$	$\frac{\partial LAI}{\partial w_3}$	$\frac{\partial LAI}{\partial w_4}$	$\frac{\partial LAI}{\partial w_5}$	$\frac{\partial LAI}{\partial w_6}$	$\frac{\partial LAI}{\partial w_7}$	$\frac{\partial LAI}{\partial w_8}$
Median	0.2220	0.0006	0.0015	**0.0032**	**0.0068**	**0.0038**	0.0011	0.0006

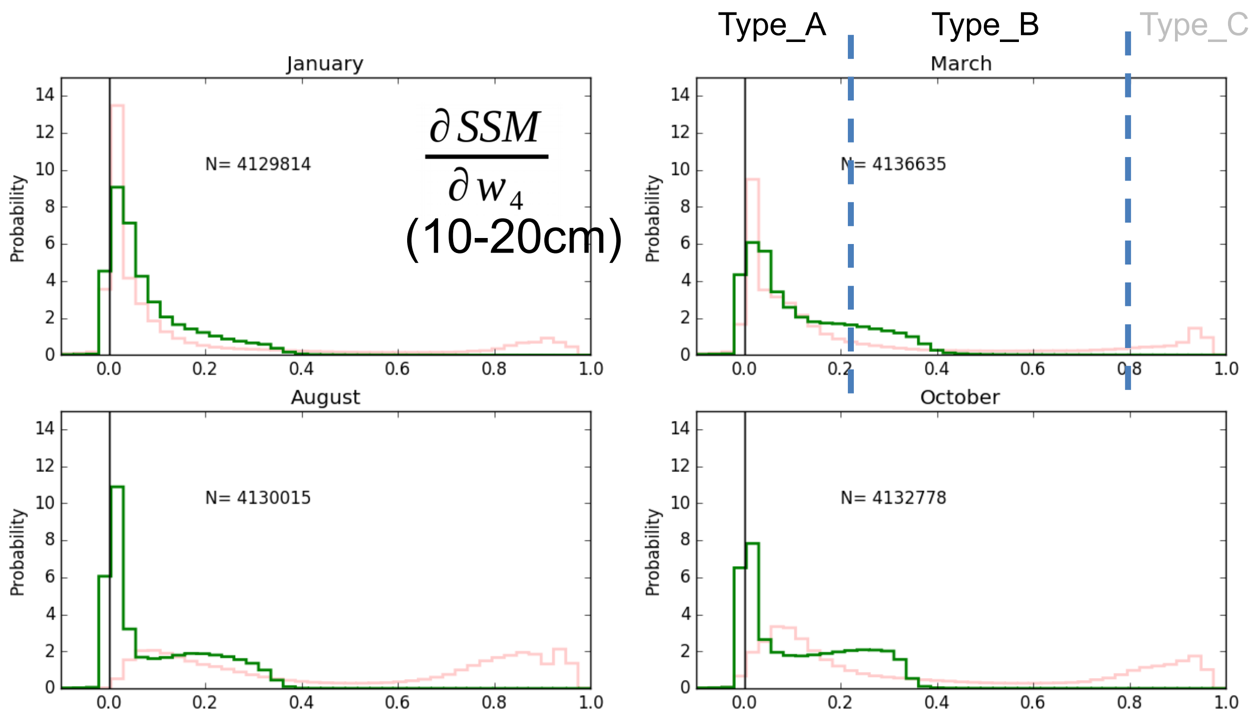
- Assimilation of SSM
  ➔ *LDAS will be more effective in modifying SM from the first layers of soil as **model sensitivity to SSM decreases with depth***
- Assimilation of LAI
  ➔ *LDAS will be more effective **in modifying SM from layers where most of the roots are present** ($w_{4\text{-}6}$, 10-60cm)*

Study the vegetation and terrestrial water cycles



- **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 vegetation and terrestrial water cycles



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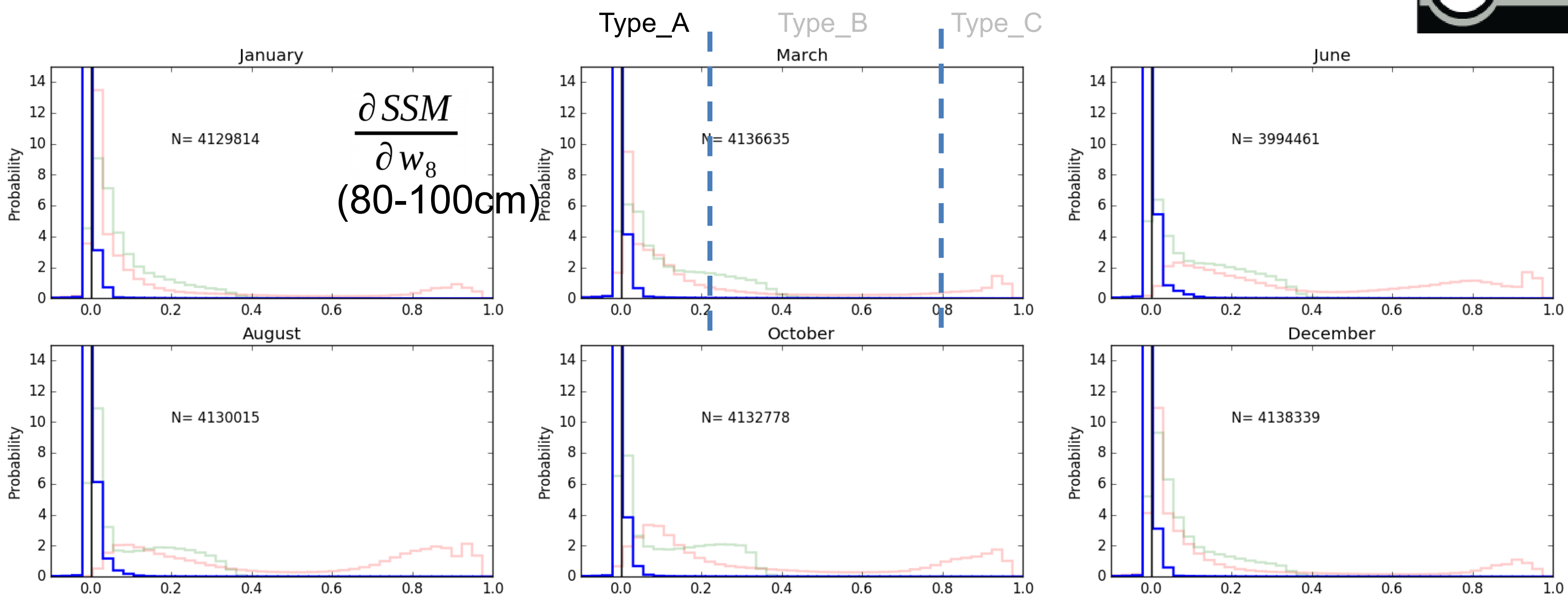

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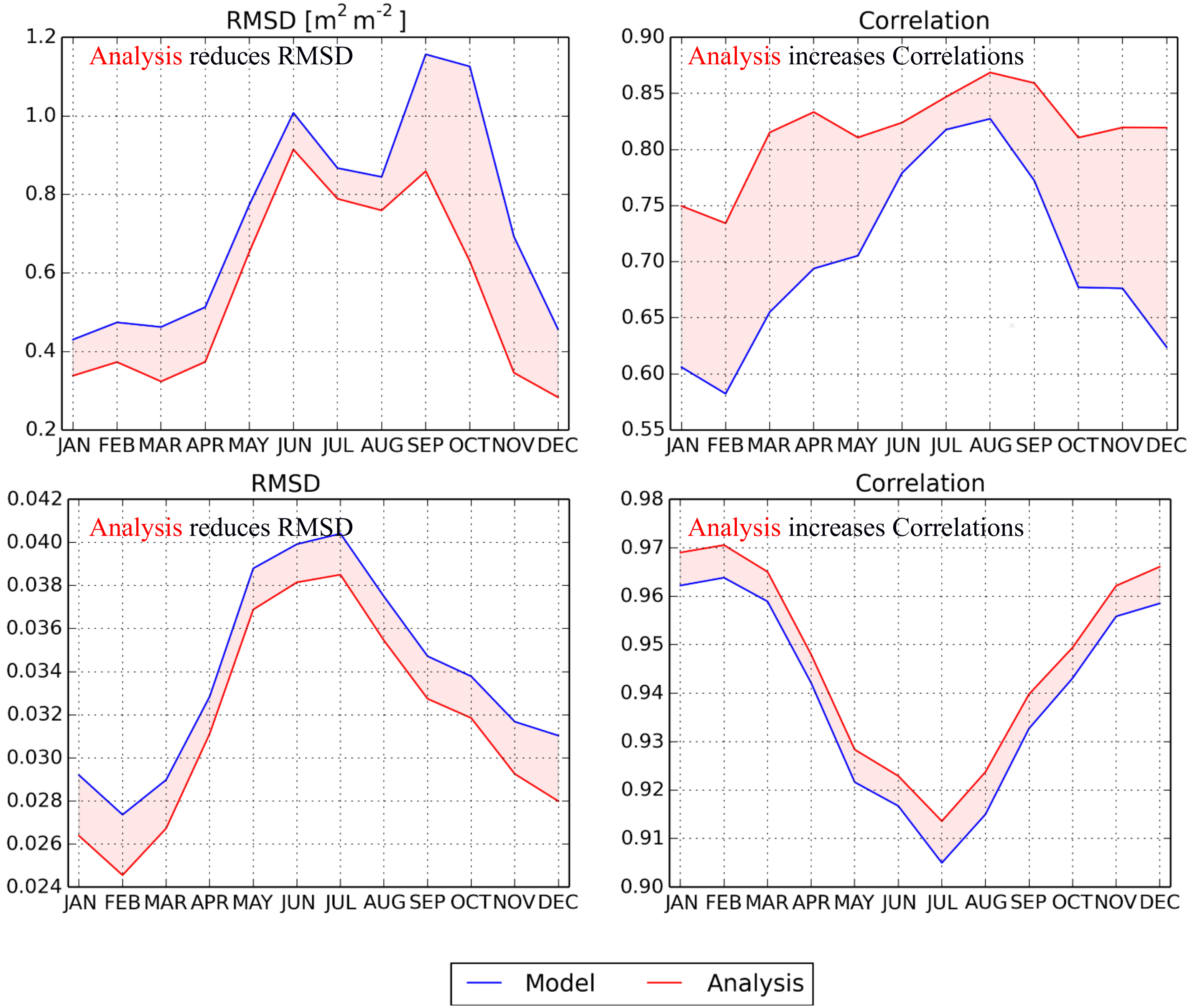
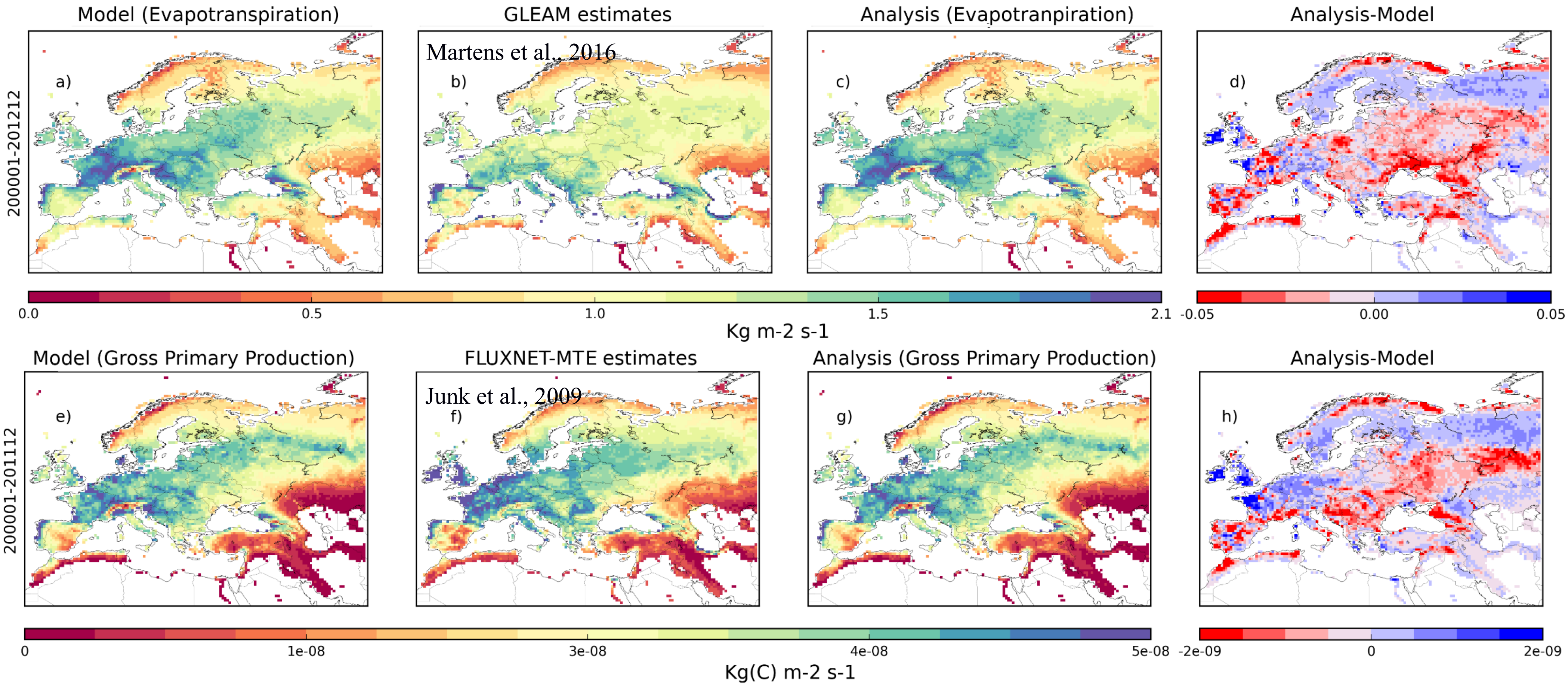
Study the vegetation and terrestrial water cycles

- LDAS-Monde analysis impact on LAI (top) & SSM (bottom), 2000-2012



Study the vegetation and terrestrial water cycles

- LDAS-Monde analysis impact: Evapotranspiration (top) and Gross Primary Production (bottom)



Study the vegetation and terrestrial water cycles

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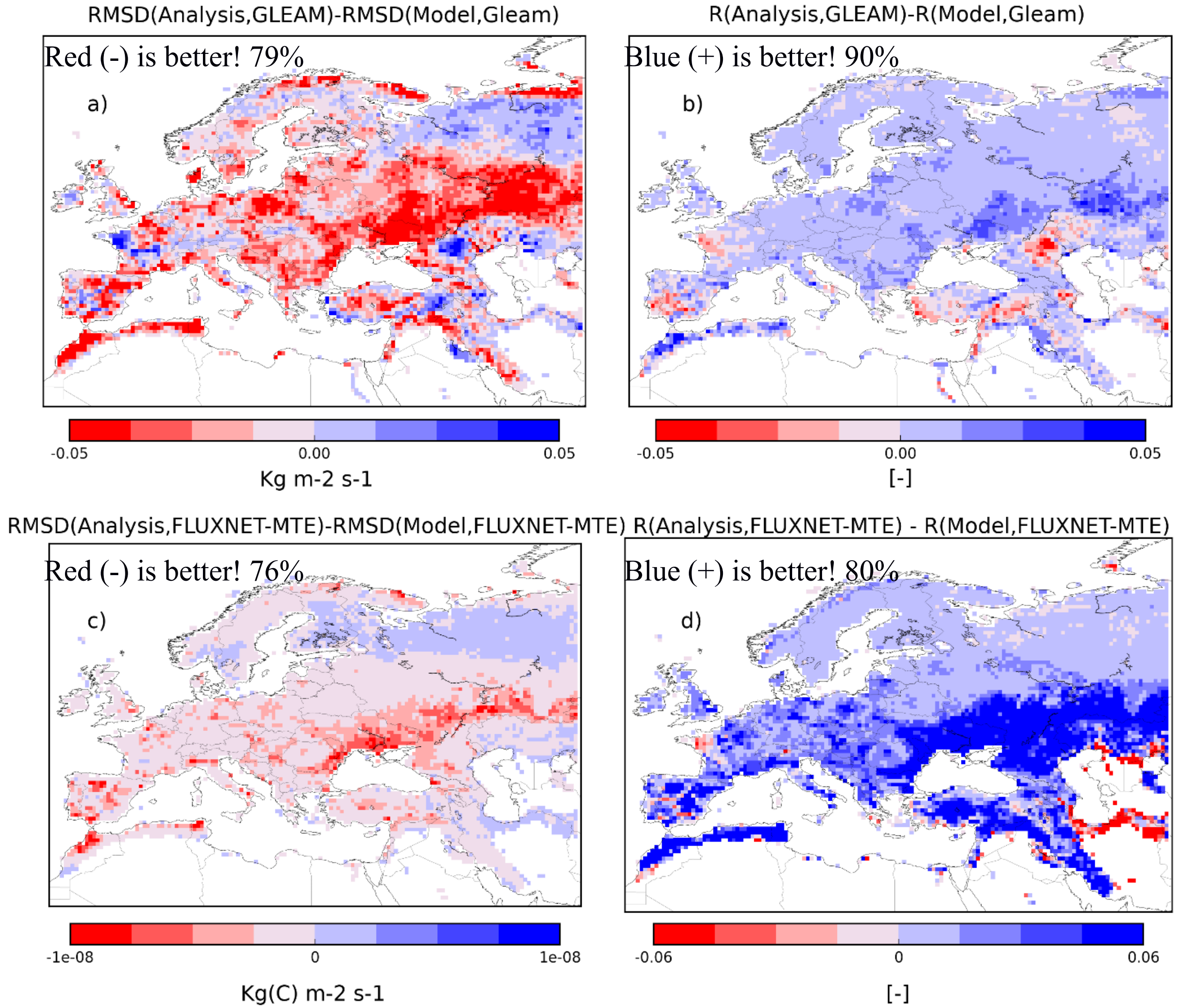
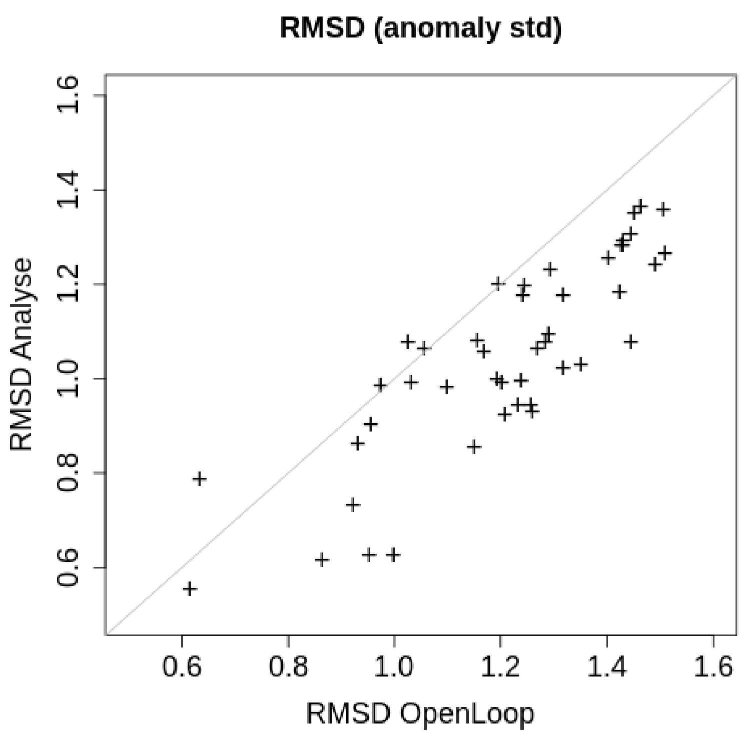
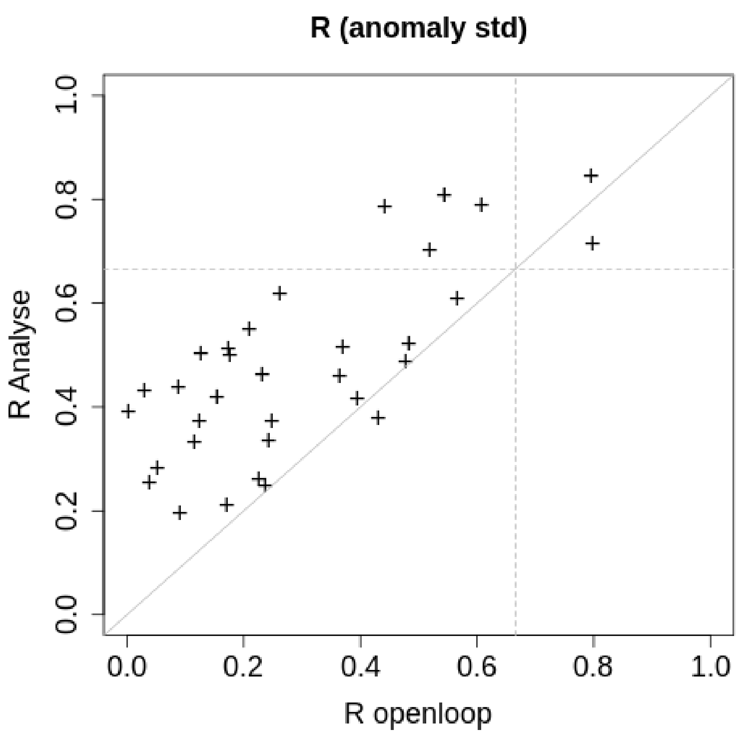


Study the vegetation and terrestrial water cycles

- 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





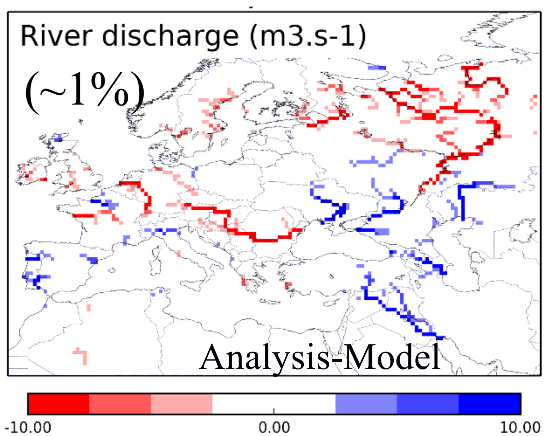
➔ Analysed Biomass shows better R and RMSD than that of the open-loop

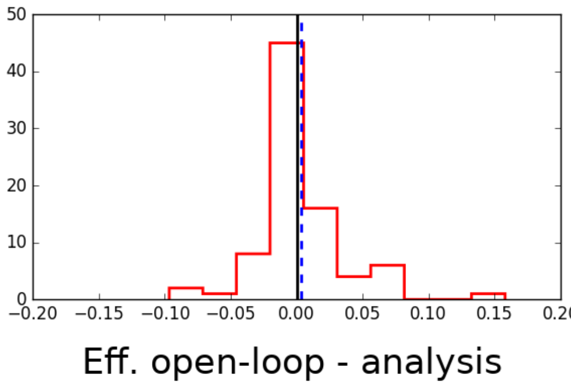
Study the vegetation and terrestrial water cycles

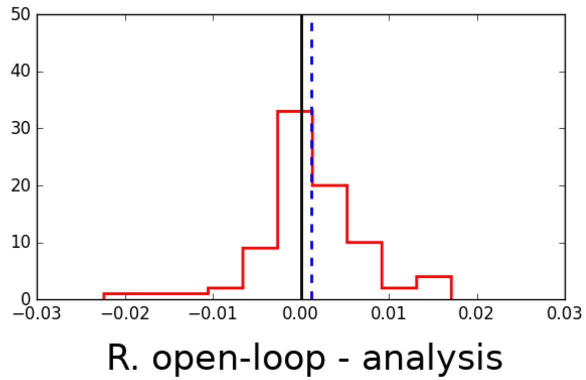
- Evaluation of non-direct analysis impact 2000-2010: River discharge (Q)

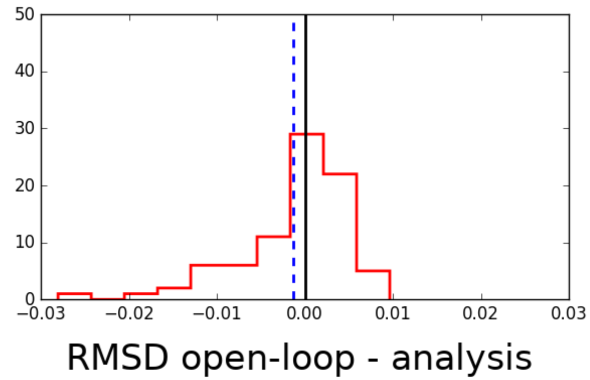
Q is scale to the drainage area, sub-basin > 10000km², 4-yr of data

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









→ Neutral to positive impact

Conclusions and perspectives

- **LDAS-Monde:** Integration of satellite observations into SURFEX, fully coupled to hydrology
- Only system able to sequentially assimilate vegetation products such as LAI together with SSM observations

➔ **Positive impact** on Evapotranspiration, Gross Primary Production and above ground Biomass, **neutral to positive** on river discharge

- **Issues :**
  - Assimilation of LAI is more beneficial than assimilation of SSM (CDF matching)
  - LAI can be used to analyze RZSM but sampling time (10 days) is affected by clouds
- **Solutions :**
  - Use vegetation information in ASCAT σ_0 (not affected by clouds)
  - Observation operator of ASCAT σ_0 using a multi-layer soil model

  ➔ **PhD work starting at CNRM in 2017 (looking for candidates !)**

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