LDAS-Monde sequential assimilation of satellite-derived vegetation and soil moisture products

Albergel C.[1] Munier S.[1], Leroux D.[1] and Calvet J.-C.[1]
With help from many others !

[1]CNRM UMR 3589, Météo-France/CNRS, Toulouse, France

Toulouse – 22 mars 2018

Study the vegetation and terrestrial water cycles

- **Current fleet of Earth Satellite missions holds an unprecedent potential to quantify land surface variables** *[Lettenmaier et al., 2015]*

➔ Spatial and temporal gaps

➔ Cannot observe all key Land Surface Variables (LSVs)

- **Land Surface Models (LSMs) provide LSVs estimates at all time/location based on physical laws**

➔ Both observations and LSMs suffer from uncertainties

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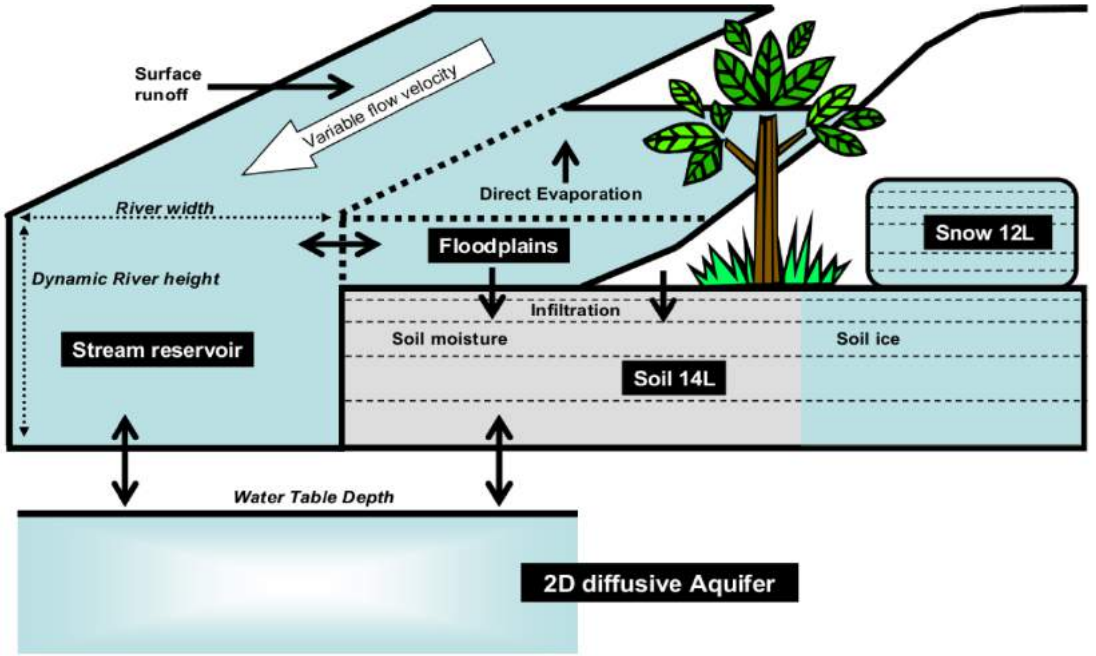
➔ Both observations and LSMs suffer from uncertainties

- Through a weighted combination of both, LSVs can be better estimated than by either source of information alone *[Reichle et al., 2007]*

➔ **Data assimilation :** spatially and temporally integrates the observed information into LSMs in a consistent way to unobserved locations, time steps and variables

Study the vegetation and terrestrial water cycles

LDAS-Monde : Global capacity integration of satellite observations into SURFEX, fully coupled to hydrology

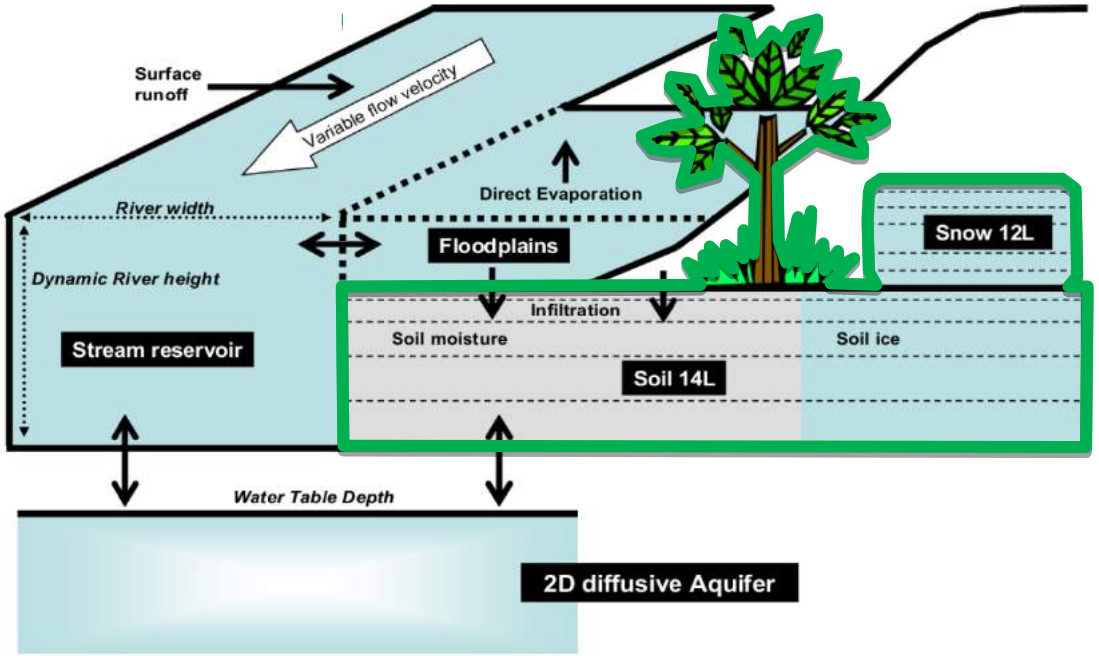


Study the vegetation and terrestrial water cycles

LDAS-Monde : Global capacity 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

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

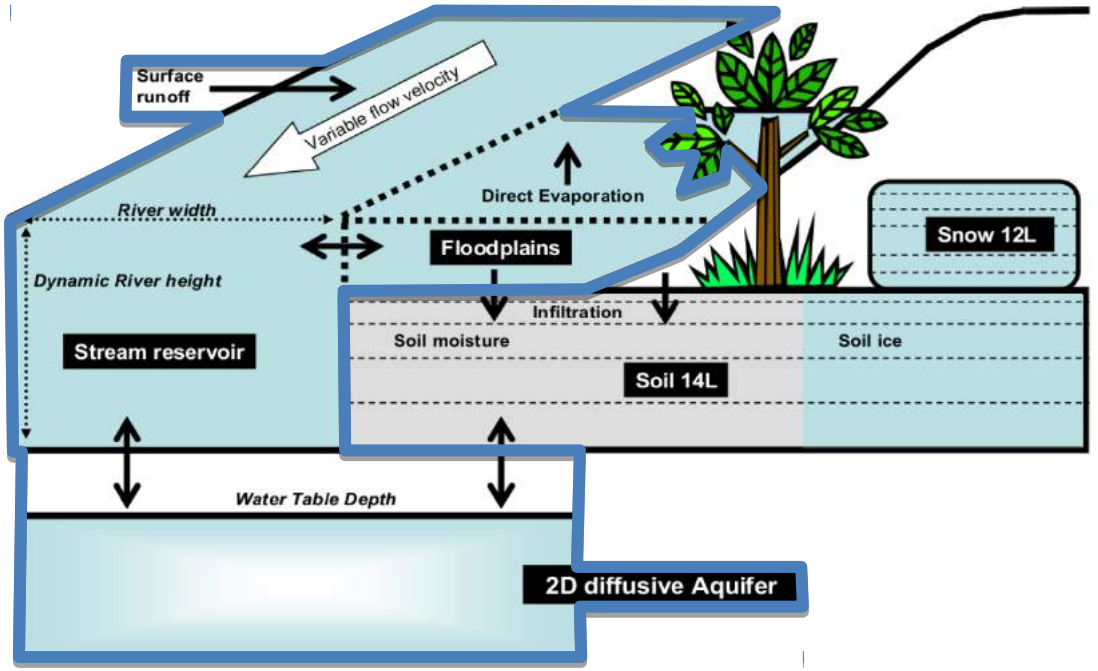


Study the vegetation and terrestrial water cycles

LDAS-Monde : Global capacity 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)



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

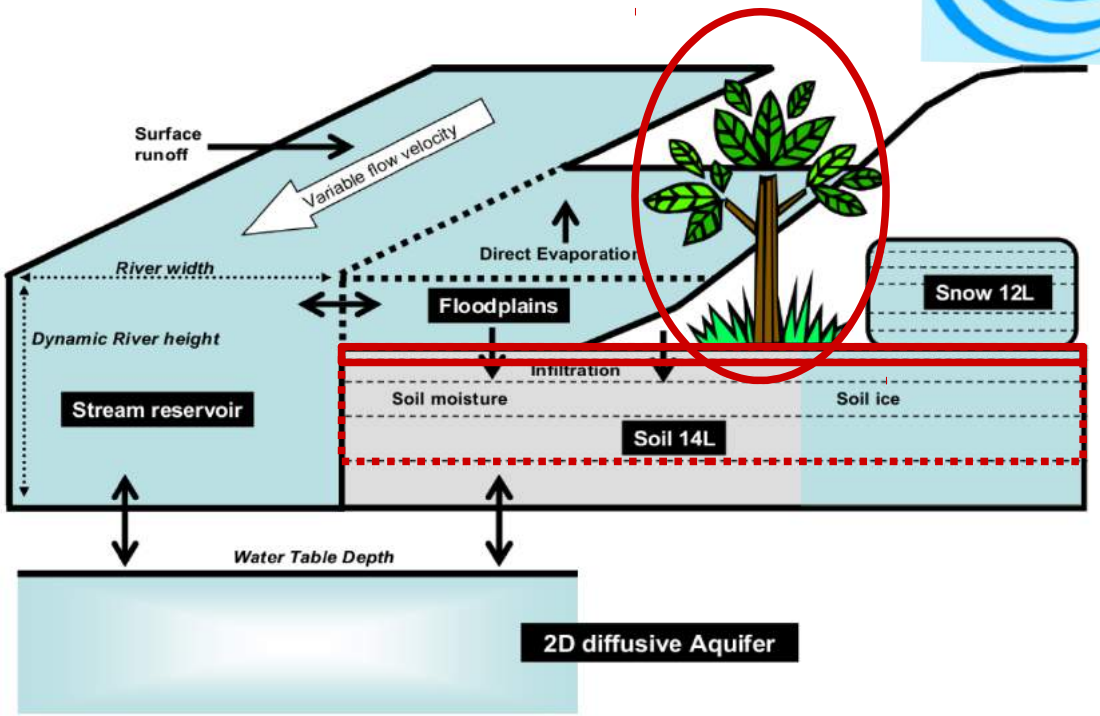
CTRIP to ISBA :
water table depth/rise, floodplain fraction, flood potential infiltration

Study the vegetation and terrestrial water cycles

LDAS-Monde : Global capacity integration of satellite observations into SURFEX, fully coupled to hydrology

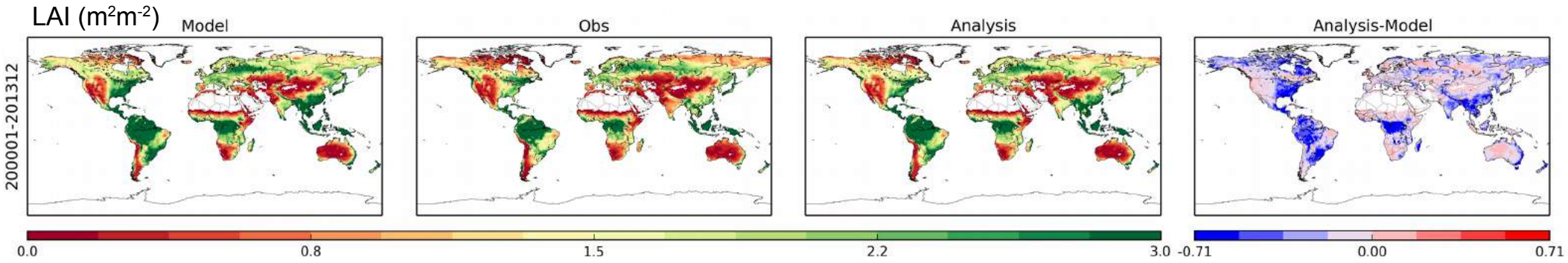
- ‘Update’ Soil Moisture and LAI

SSM
LAI



Study the vegetation and terrestrial water cycles

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.)	**Global (2000-2013, 1°)**	**EartH2Observe project (Schellekens et al., 2017)**	**SEKF**	**SSM** (ESA-CCI, ASCAT) **LAI** (GEOV1)	**Second layer of soil (1-4cm)** **LAI**	**Layers of soil 2 to 8 (1-100cm)** **LAI**	**Coupling with CTRIP (0.5°)**



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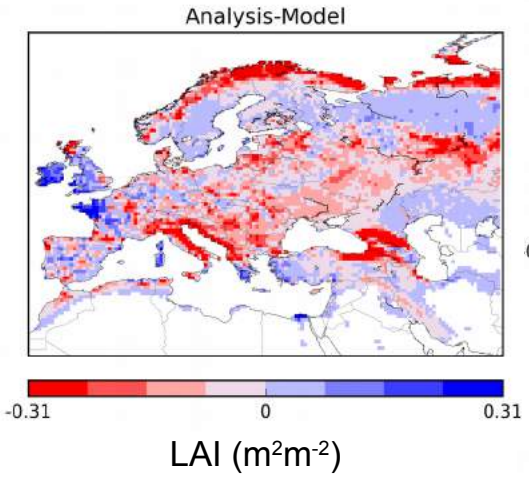

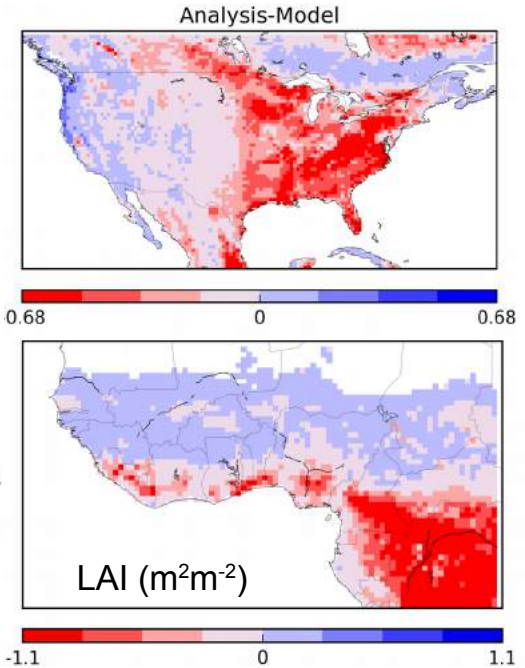

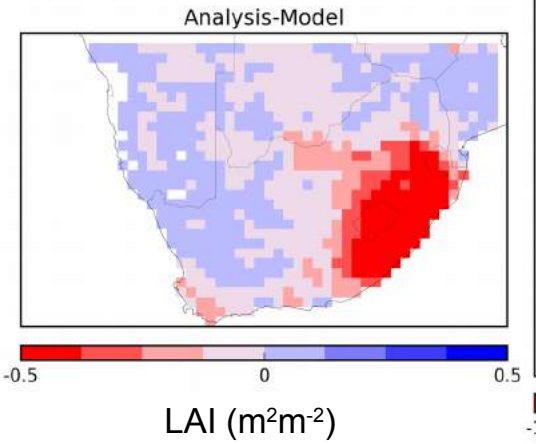

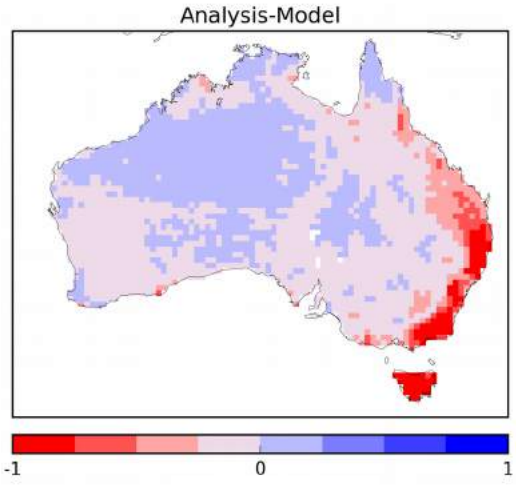

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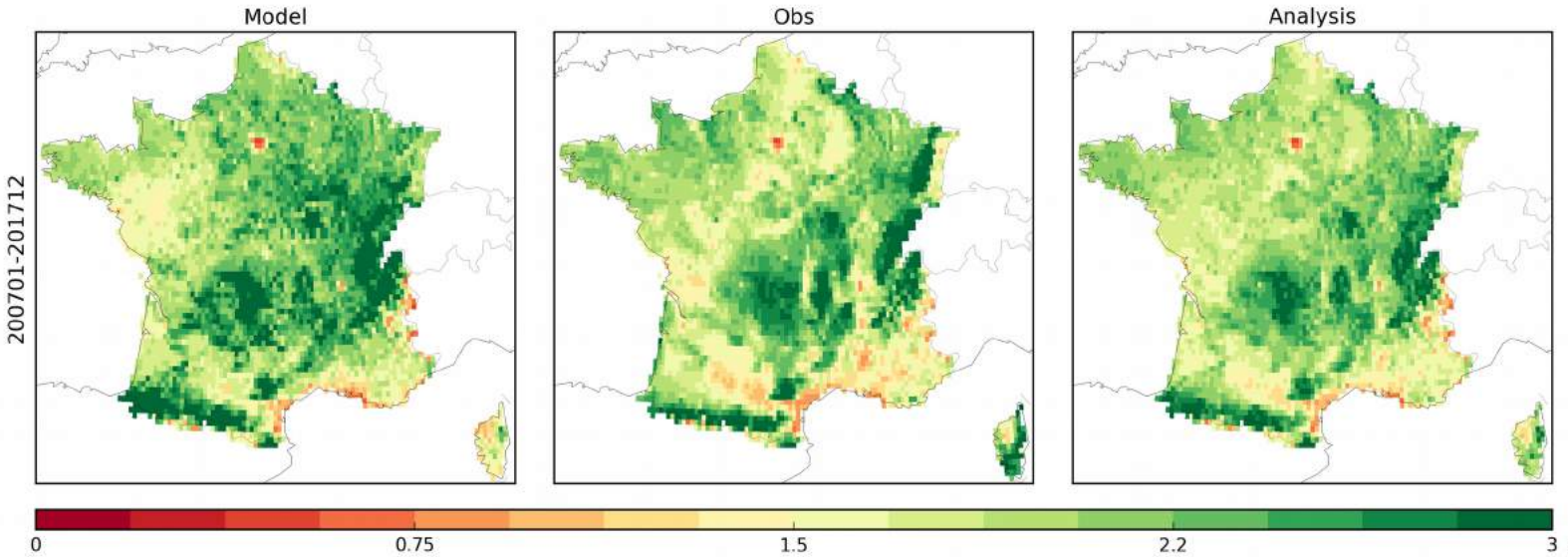
	France (2007-2017, 8kmx8km)	**SAFRAN (Quintena-Segui, et al., 2008)**					**Offline coupling with MODCOU**



Study the vegetation and terrestrial water cycles

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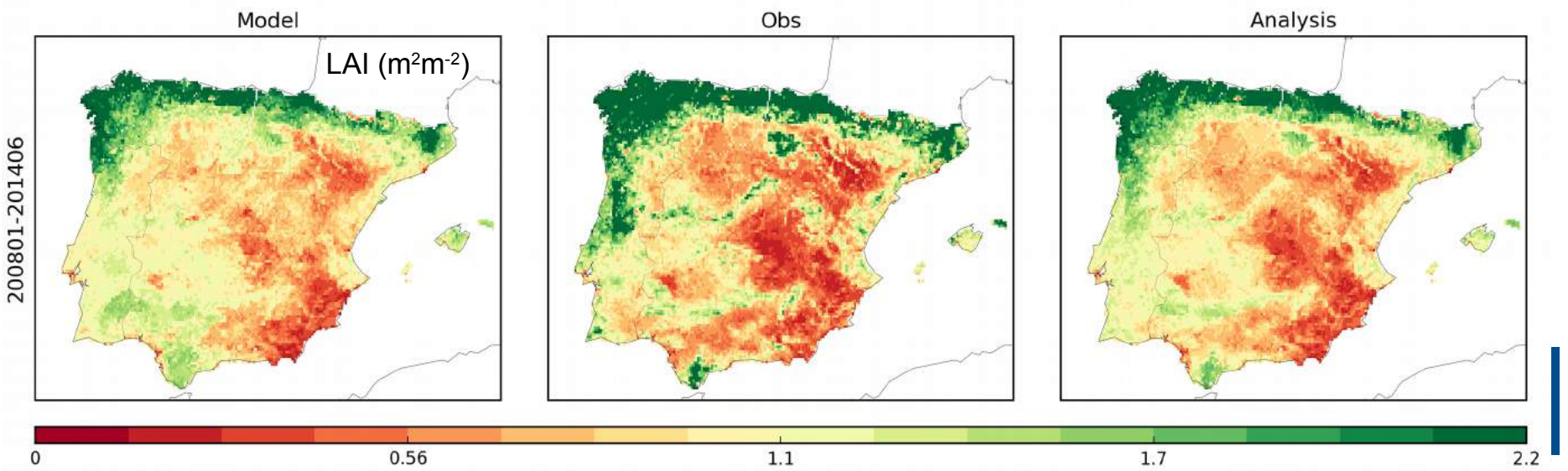
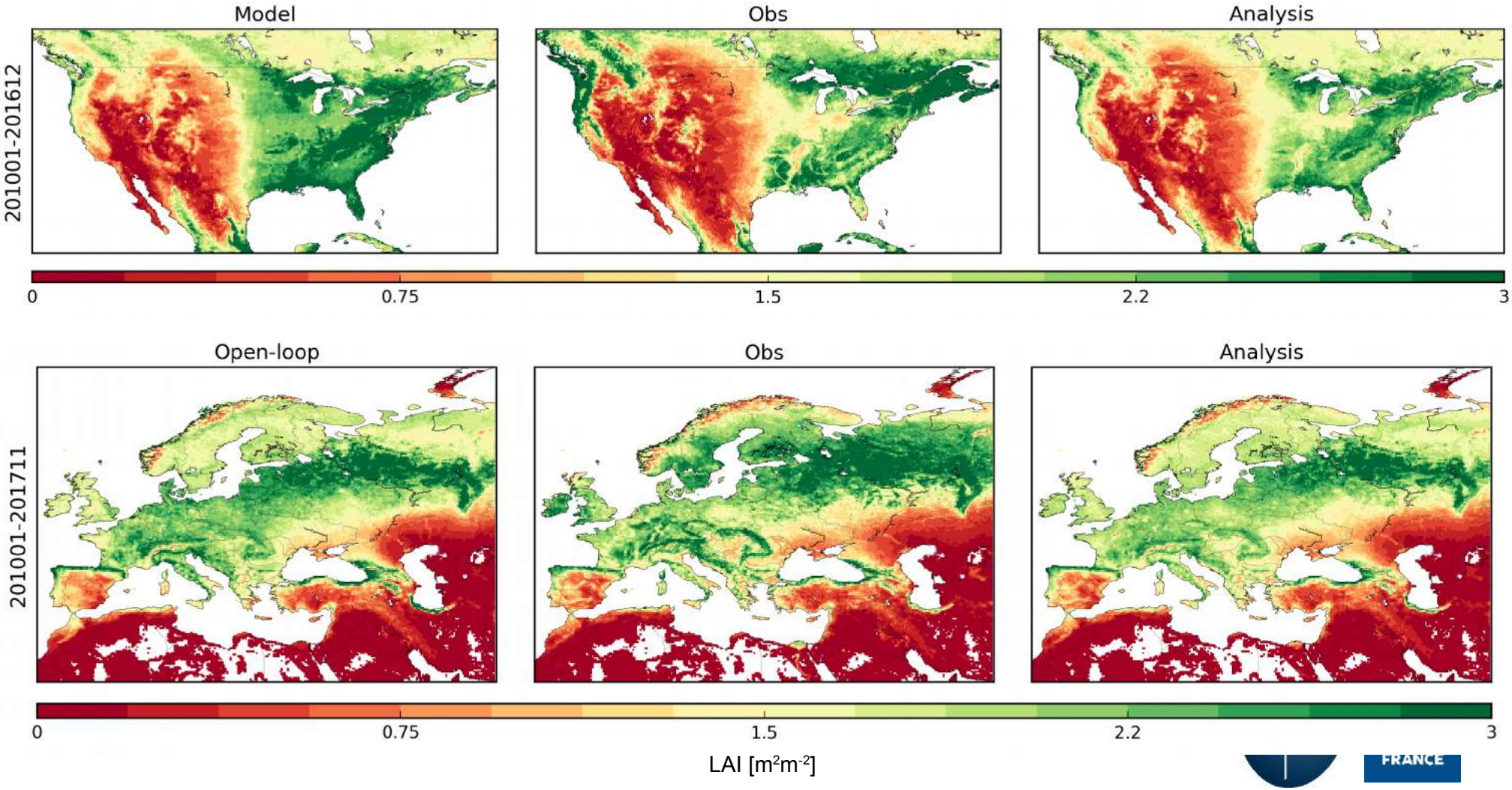
	Spain (2008-07/2014 5kmx5km)	**SAFRAN-Spain (Quintena-Segui, et al., 2017**					**Offline coupling with RAPID**



Study the vegetation and terrestrial water cycles

- First results using ECMWF latest atmospheric re-analysis era-5, **0.25x0.25º**, 2010-2016[17] to force LDAS-Monde : Leaf Area Index



LDAS-Monde assessment over North America

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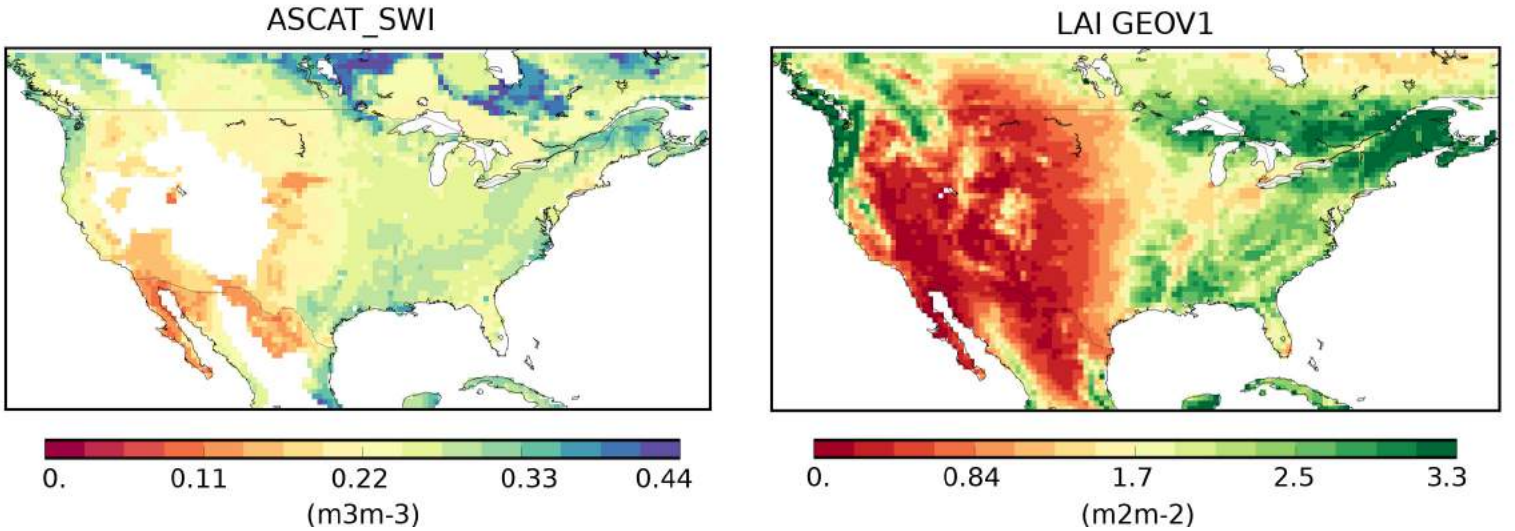


(C-band microwave sensor, 0.1°)
(seasonal bias correction)

(SPOT-VGT / PROBA-V, 1km)

http://land.copernicus.eu/global/

2 experiments over 2007-2016: **open-loop** (i.e. model run), **analysis** (i.e. assimilation)

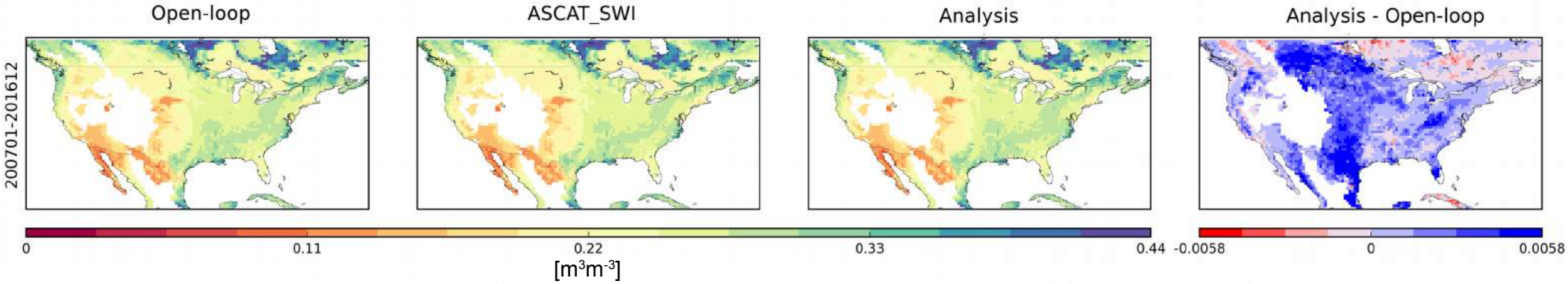
LDAS-Monde assessment over North America

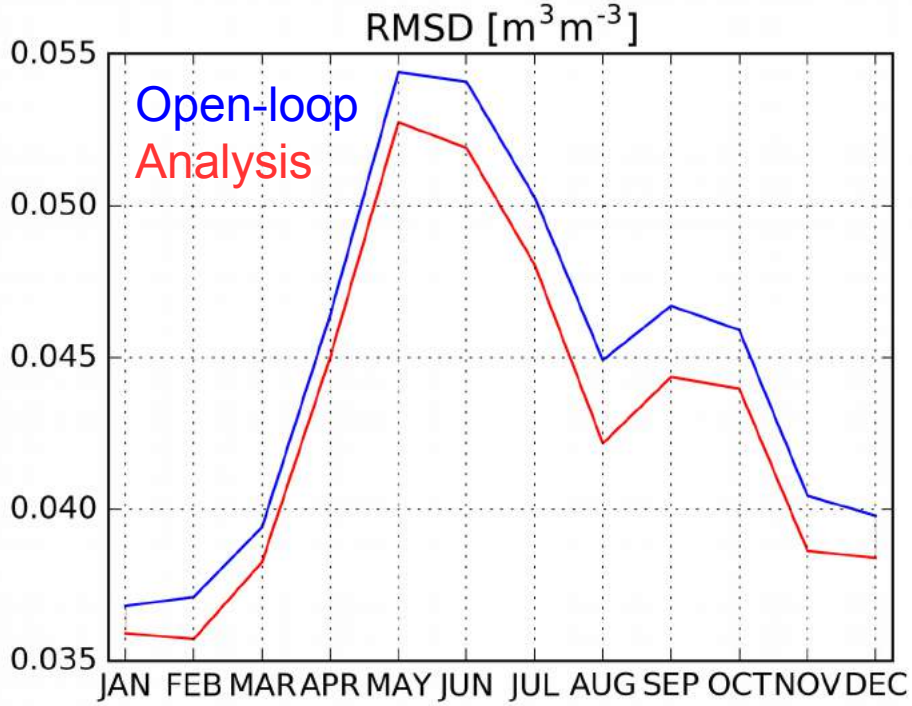
- Analysis Impact is evaluated by comparing performance improvement relative to the open-loop

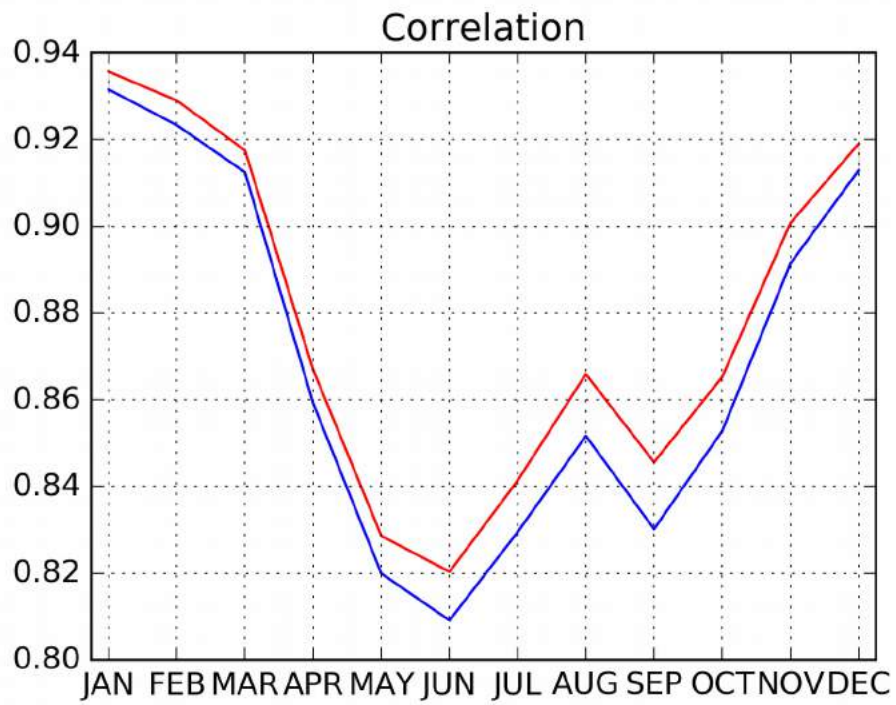
Assimilated SSM & LAI (analysis has to be closer to them than the open-loop !)	https://land.copernicus.eu/
In situ measurements of soil moisture from USCRN network	https://www.ncdc.noaa.gov/crn
River discharge from USGS	https://waterdata.usgs.gov/nwis
FLUXNET measurements : H, LE and NEE	http://fluxnet.fluxdata.org/data/fluxnet2015-dataset/
Evapotranspiration from the GLEAM project	http://www.gleam.eu
Gross Primary Production from the FLUXCOM project	http://www.fluxcom.org

LDAS-Monde assessment over North America

- SSM : Averaged maps and seasonal scores over 2007-2016

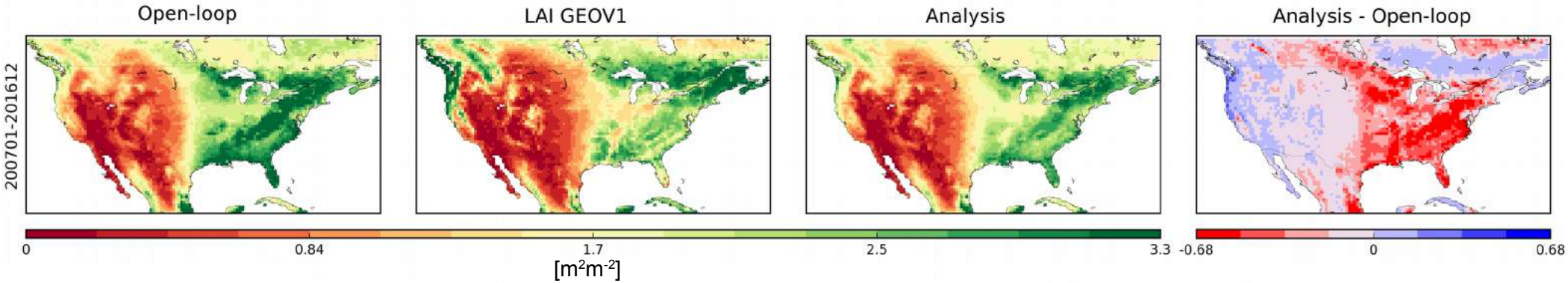


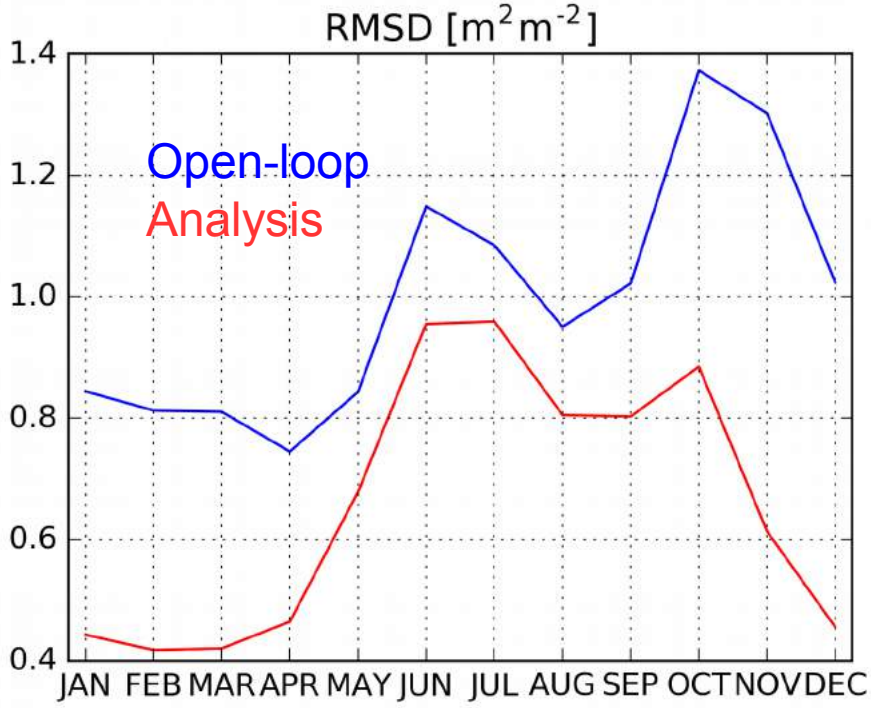


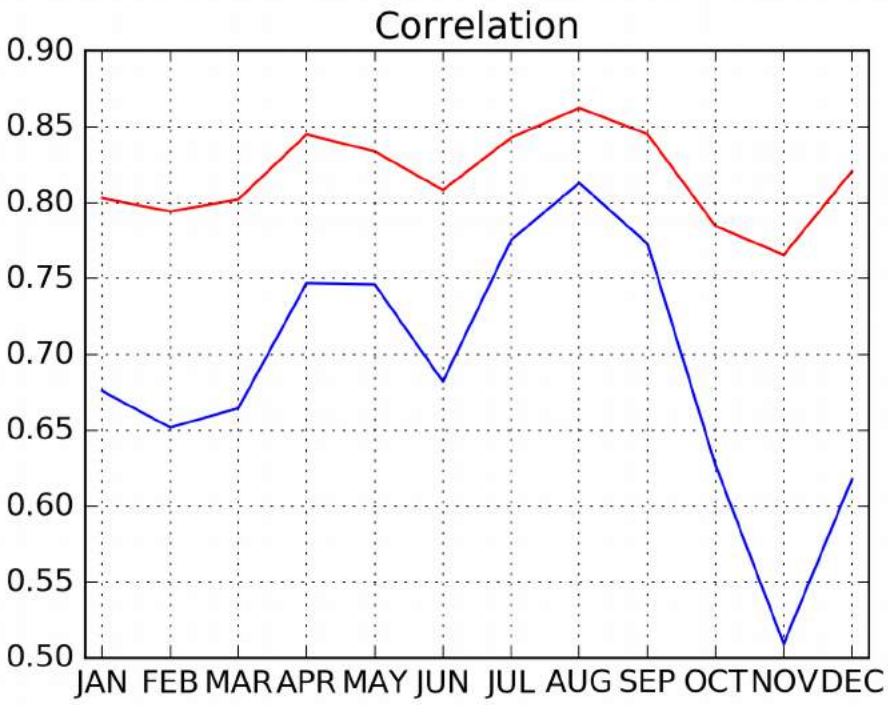


LDAS-Monde assessment over North America

- LAI : Averaged maps and seasonal scores over 2007-2016

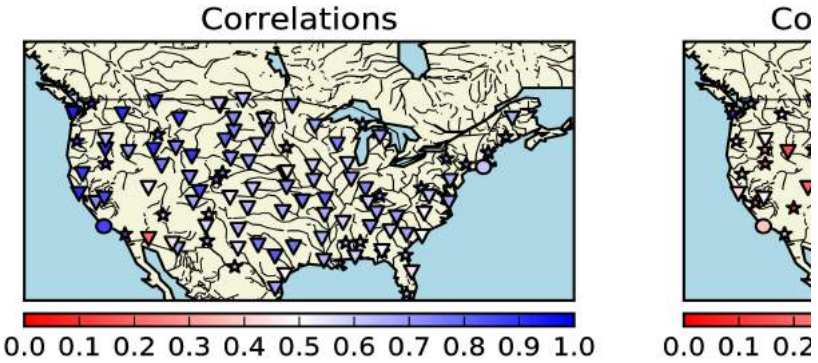






LDAS-Monde assessment over North America

- Soil moisture from USCRN network, 2009-2016 *(April-September, tri-hourly data)*



	Correlations
N stations (significant Correlations values)	108
% stations R(Analysis) >= R(Open-loop)	**74%**

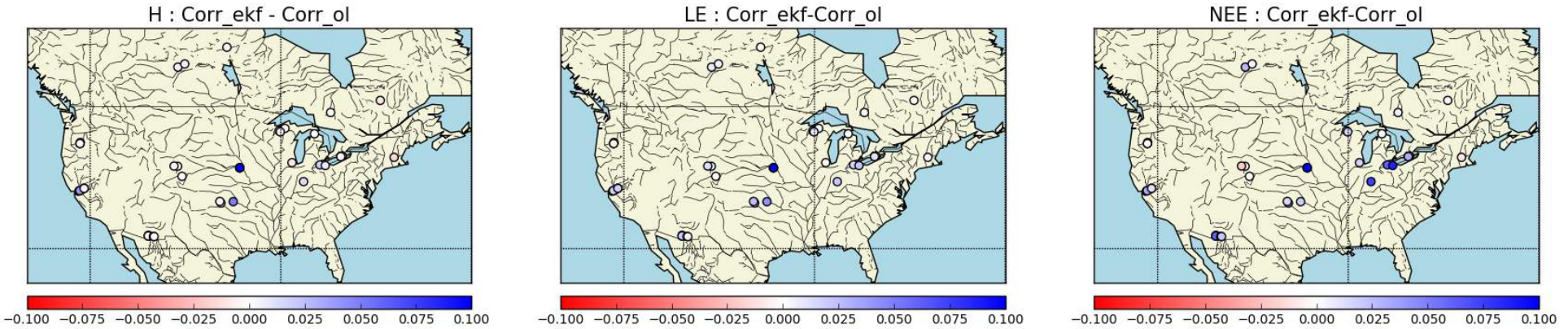
Stars : open-loop provides better Correlations (R)
Circles : no impact at all
Downward-pointing triangles : analysis provide better Correlations (R)

LDAS-Monde assessment over North America

- FLUXNET 2015 data, 2007-2016 *(daily data if at least 2-yr of data)*

	H	LE	NEE
N stations (significant R values)	44	44	40
N stations (%) R(Analysis) > R(Open-loop)	30 (**68%**)	32 (**72%**)	31 (**77%**)
N stations (%) RMSD(Analysis) < RMSD(Open-loop)	32 (**72%**)	33 (**75%**)	29 (**72%**)

Analysis better compare to the FLUXNET stations than the open-loop

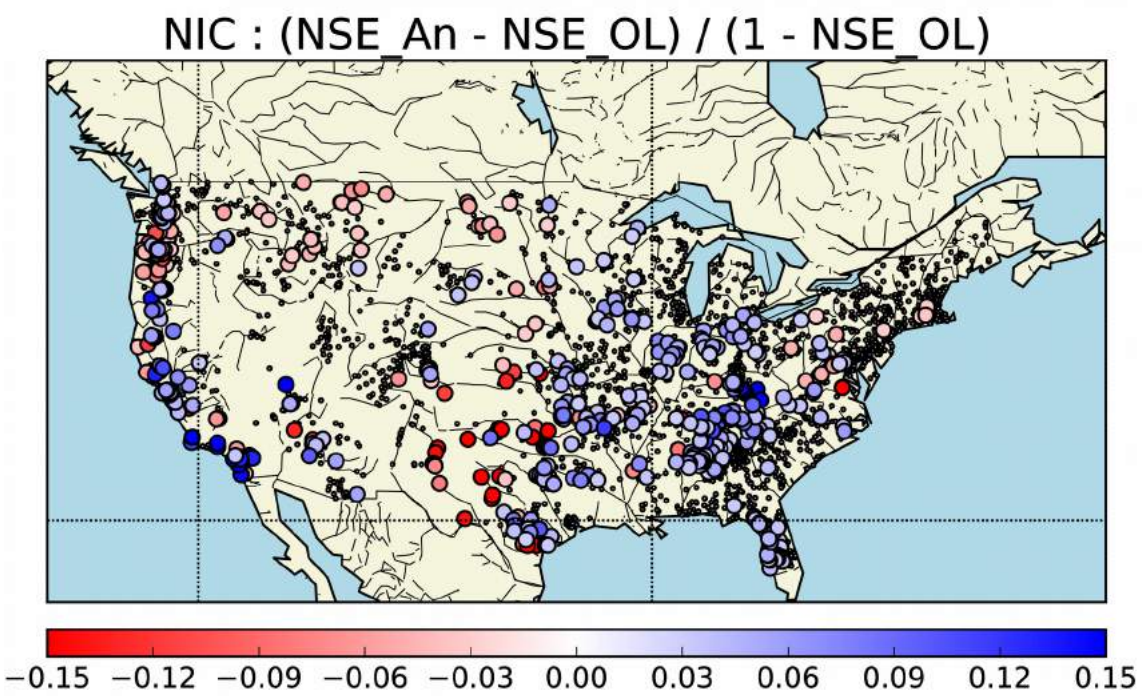


Blue : R(analysis) is better than R(open-loop)

LDAS-Monde assessment over North America

- River discharge from USGS
- **NSE** values are computed for each stations *(monthly values scaled to the drainage area)*
- **N**ormalised **I**nformation **C**ontribution used to quantify improvment/degradation

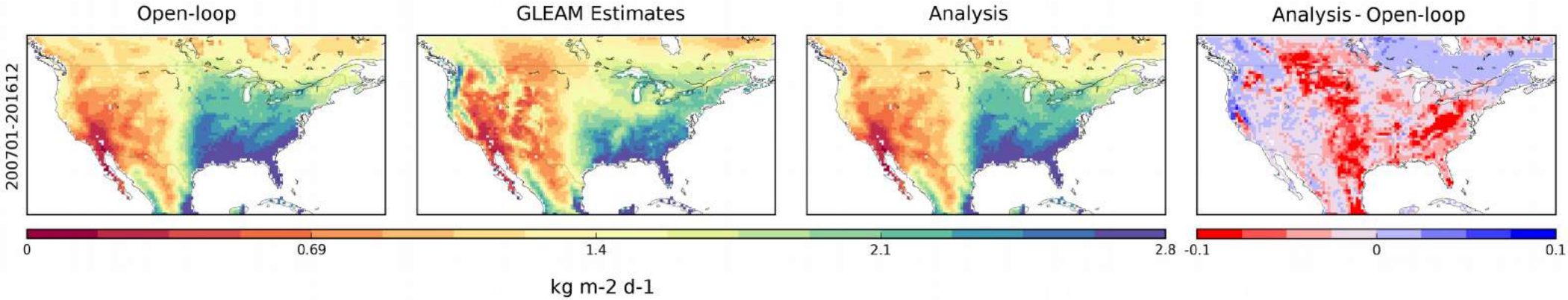
N stations >4-yr of data	
3155	
N stations >4-yr of data Analysis impact > |3 %|	
503 (16 %)	
Impact is +3 %	Impact is -3 %
354 (70 %)	**149 (30 %)**

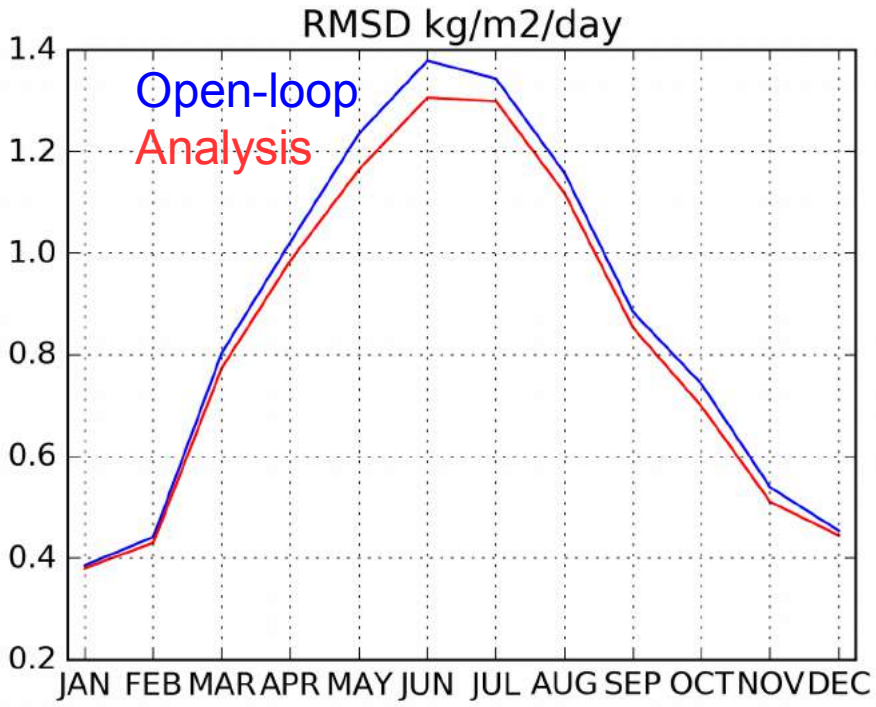


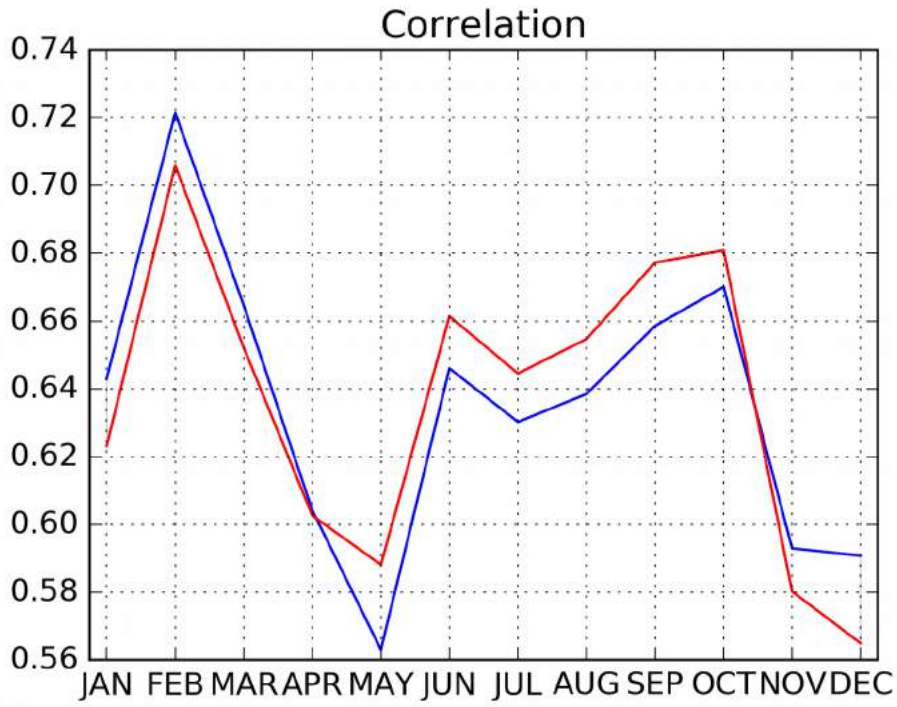
Neutral to positive impact from the analysis on river discharge

LDAS-Monde assessment over North America

- Evapotranspiration from the GLEAM project *(Martens et al., 2017, GMD)*

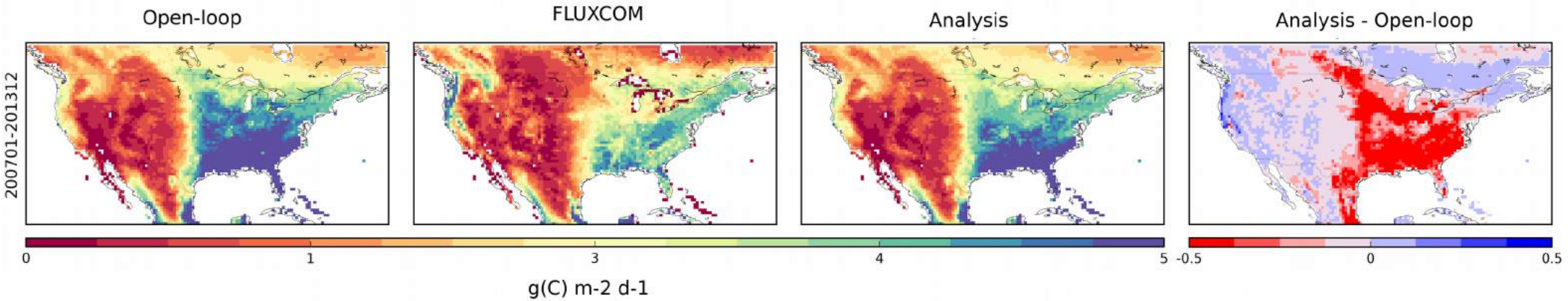


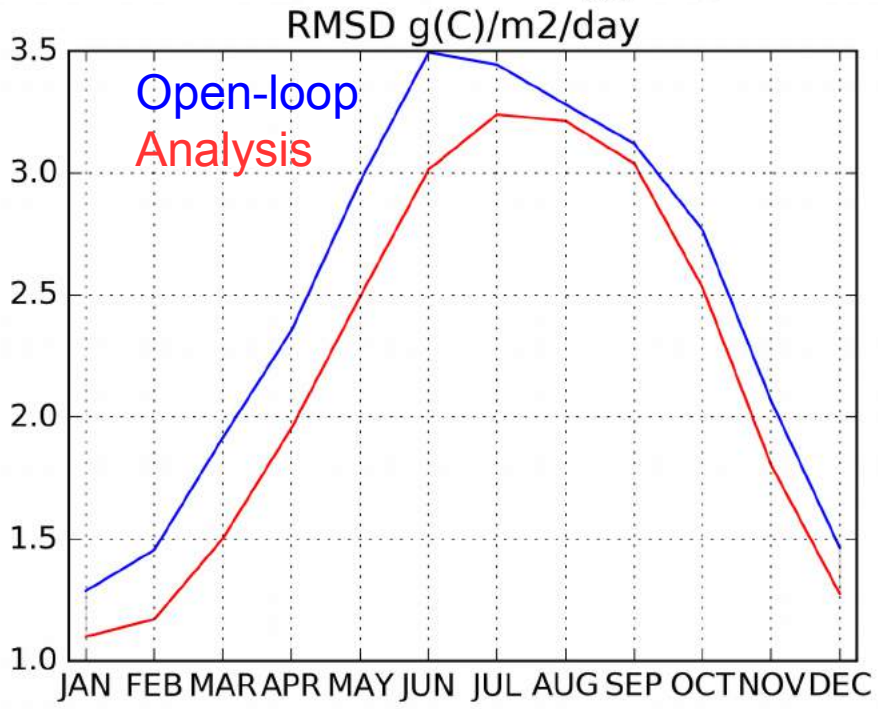


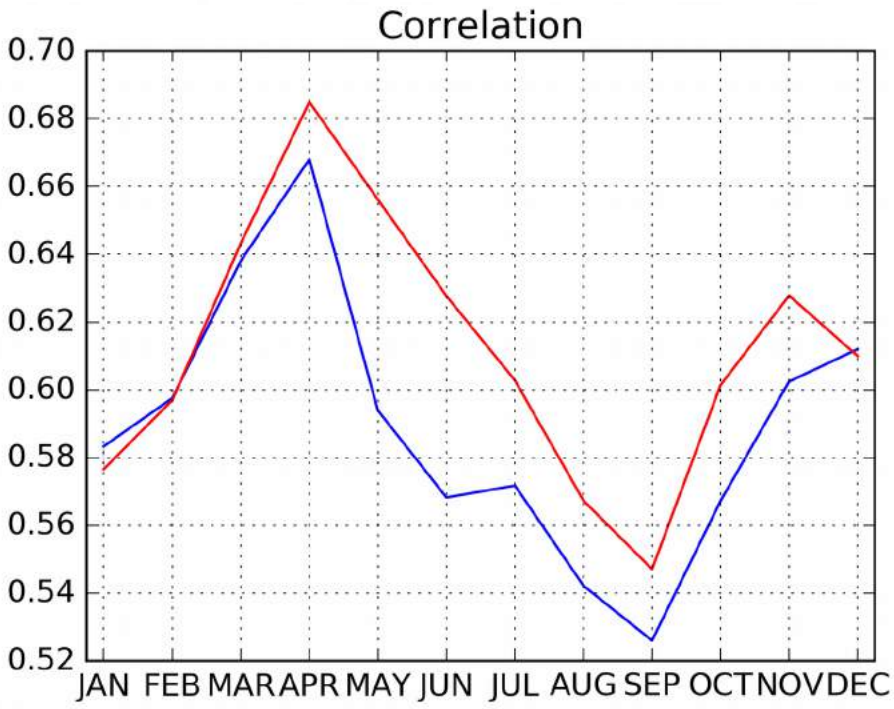


LDAS-Monde assessment over North America

- Gross Primary Production from the FLUXCOM project *(Jung et al., 2017)*



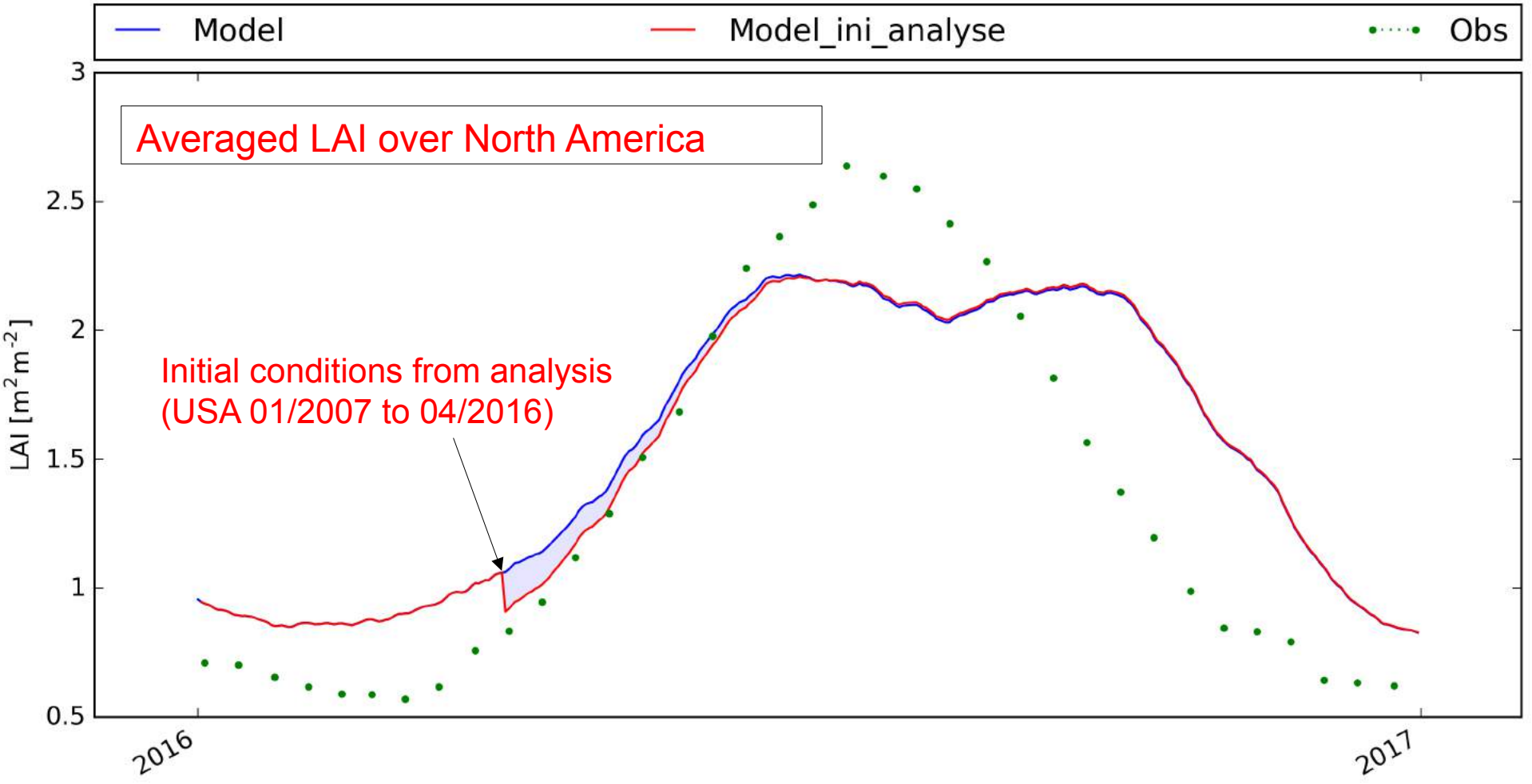




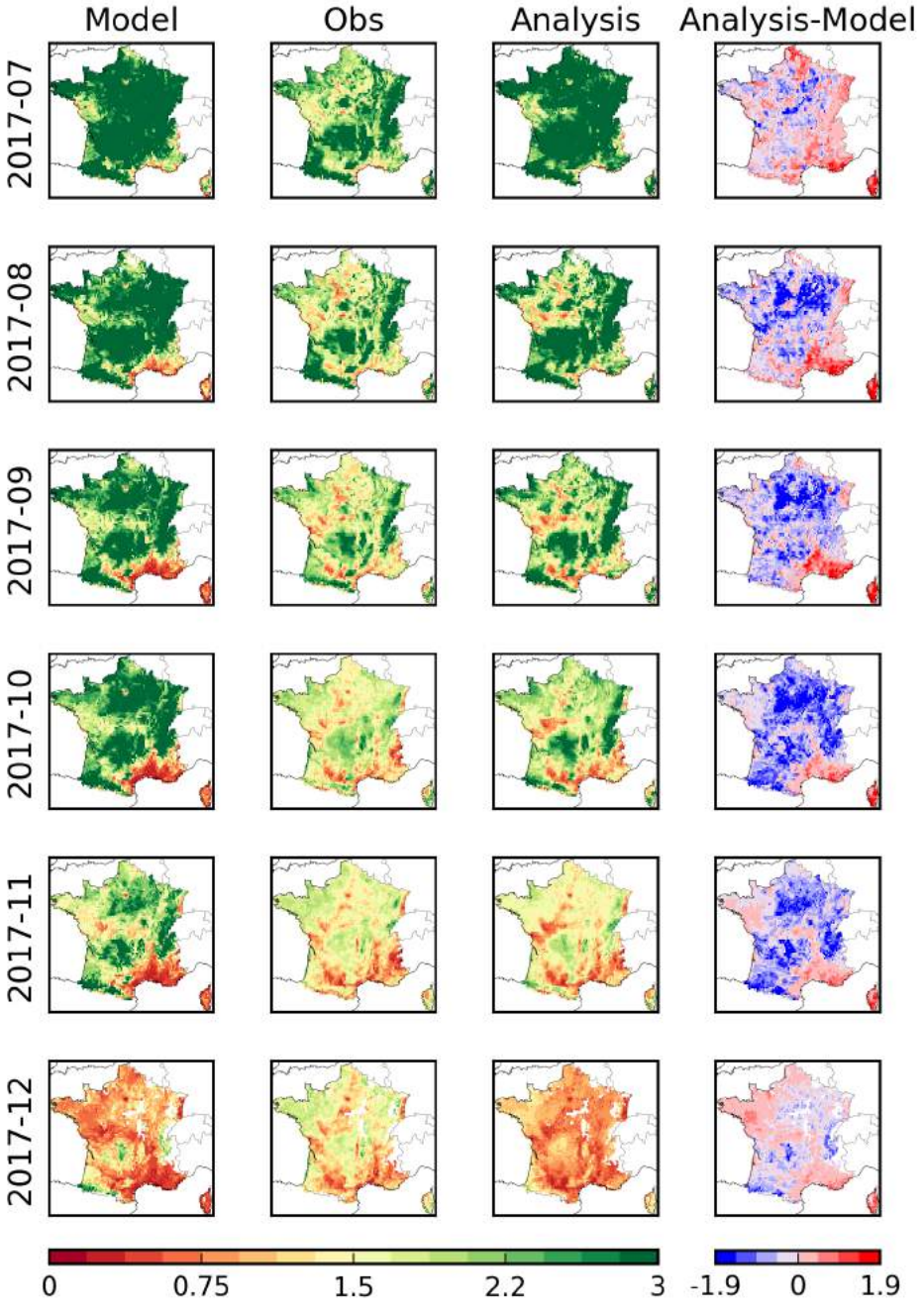
LDAS-Monde assessment over North America

- **Does analysis provide better initial conditions that last in time ?**
  - Use analysis initial conditions at 01/04/2016 to start a 8-month simulation

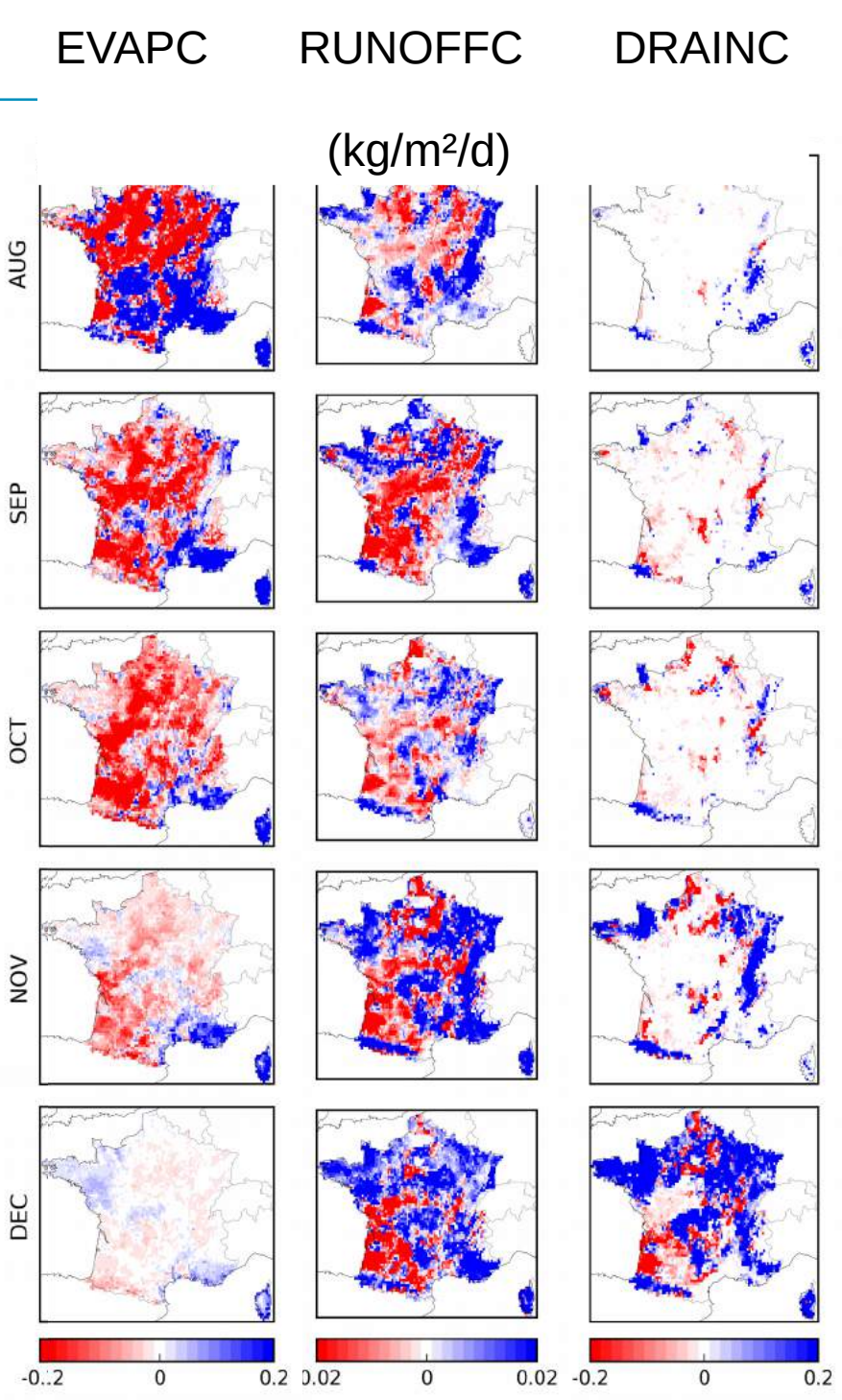
➔ ***Persistence for several weeks / months on LAI***



LDAS-Monde over France



Analysis – Model (2017)

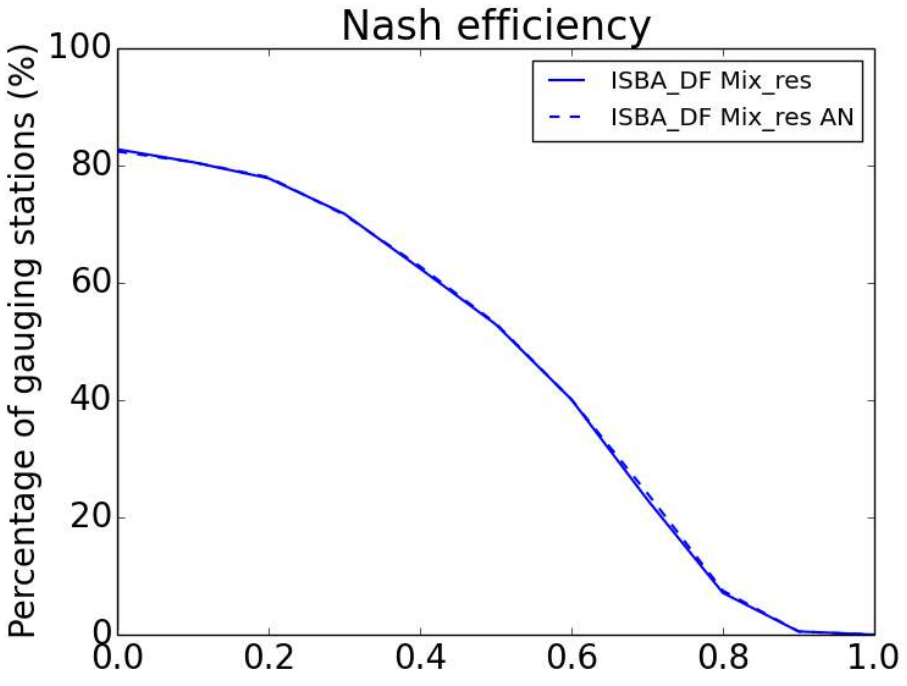


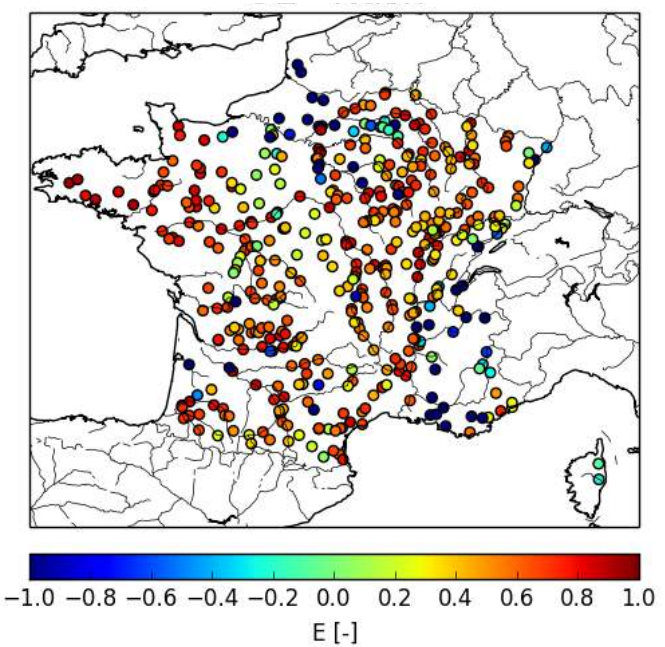
Study the vegetation and terrestrial water cycles

Towards a ‘SIM2-like’ LDAS

- Run SURFEX over 9892 grid points, over 3878 mountainous grid points *(Save RUNOFFC, DRAINC)*

➔ Mix the results of mountains elevation tiles to the original grid France, two different water transfer for mountainous cells and for plain areas outside aquifers simulated by MODCOU (mix_res)





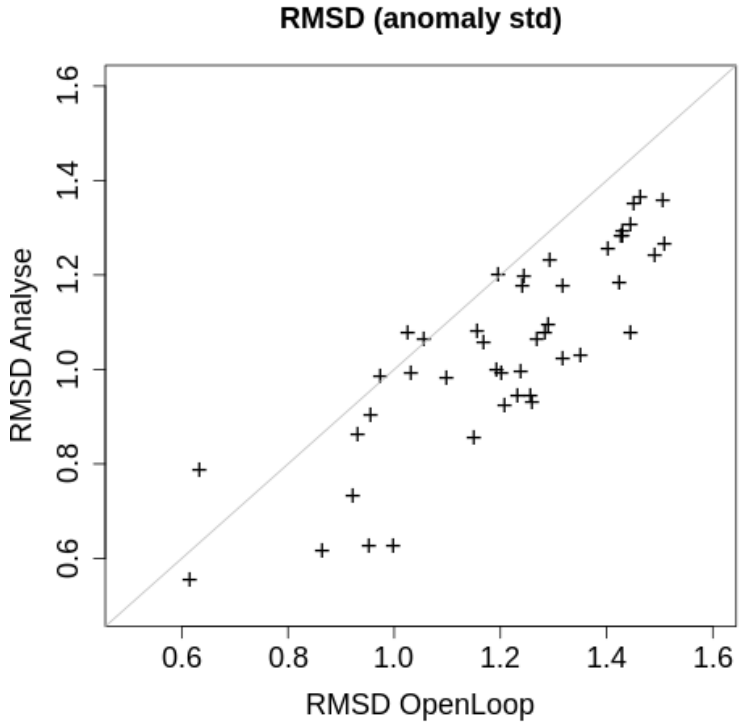
➔ Neutral impact on river discharge / Positive impact on vegetation

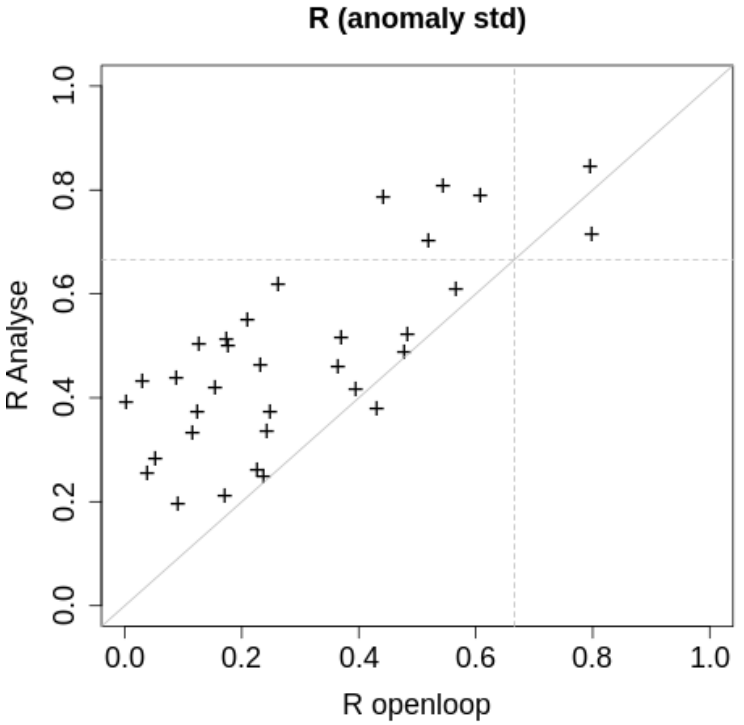
➔ Re-activate this activity (coll. S. Munier CNRM/GMME/SURFACE)

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



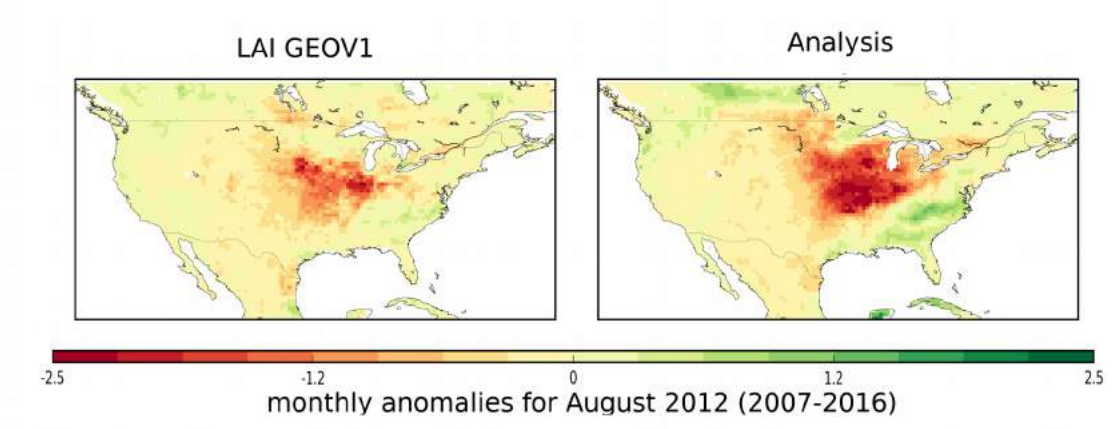


➔ Analysed Biomass shows better R and RMSD than that of the open-loop

LDAS-Monde : Conclusions and perspectives

- Integration of satellite observations into SURFEX, fully coupled to hydrology
- Now the only system able to sequentially assimilate vegetation products together with soil moisture observations
- Positive impact on terrestrial water cycle, vegetation cycle

➔ **Powerful tool to monitor land surface variables, droughts**



Foster link to applications

- **Climate reanalysis**
- **From monitoring to forecasting**

(Analysis provides better initial conditions than a model run)

PhD for 2018 : *Assimilation of satellite data for monitoring and forecasting agricultural drought ans water ressources* (funding ? MF/ED/MOPGA)

Contact : clement.albergel@meteo.fr

LDAS recent publications :

Albergel, C., S. Munier, D. J. Leroux, H. Dewaele, D. Fairbairn, A. L. Barbu, E. Gelati, W. Dorigo, S. Faroux, C. Meurey, P. Le Moigne, B. Decharme, J.-F. Mahfouf, J.-C. Calvet : Sequential assimilation of satellite-derived vegetation and soil moisture products using SURFEX_v8.0 : LDAS-Monde assessment over the Euro-Mediterranean area, Geosci. Model Dev., Geosci. Model Dev., 10, 3889–3912, 2017.

Fairbairn, D., Barbu, A. L., Napoly, A., ***Albergel C.***, Mahfouf, J.-F., and Calvet, J.-C. : The effect of satellite-derived surface soil moisture and leaf area index land data assimilation on stramflow simulations over France, Hydrol. Earth Syst. Sci., 21, 2015–2033, 2017.

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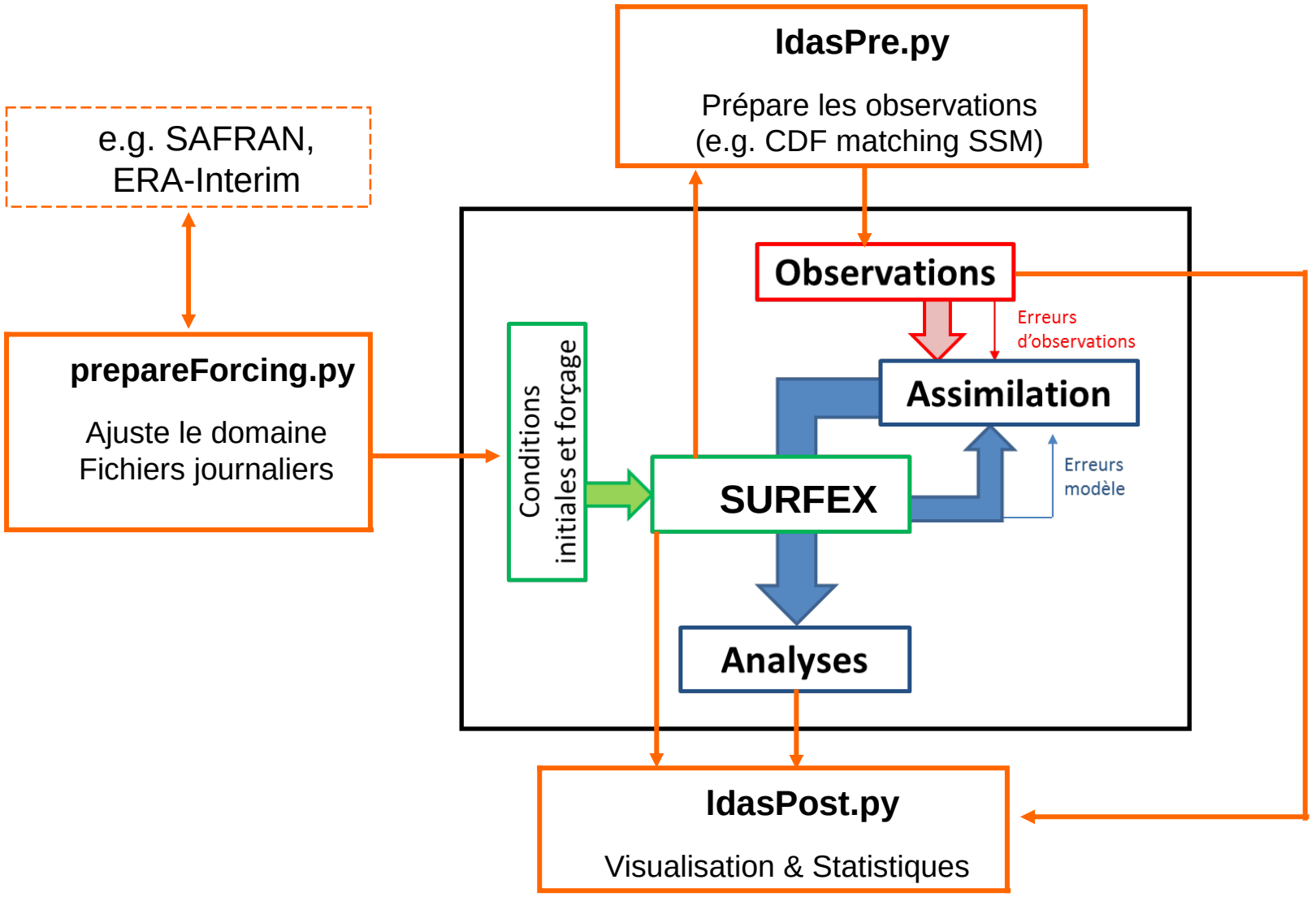
LDAS-Monde processing chain



LDAS-Monde processing chain