Monitoring and Forecasting the Impact of the 2018 Summer Heatwave on Vegetation

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3 ECMWF, Reading, UK

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Study the vegetation and terrestrial water cycles

- **Current fleet of Earth Satellite missions holds an unprecedent potential to quantify Land Surface Variables (LSVs)** *[Lettenmaier et al., 2015]*

➔ Spatial and temporal gaps & Cannot observe all key LSVs (e.g. RZSM)

- **Land Surface Models (LSMs)** provide LSV estimates at all time/location

- 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

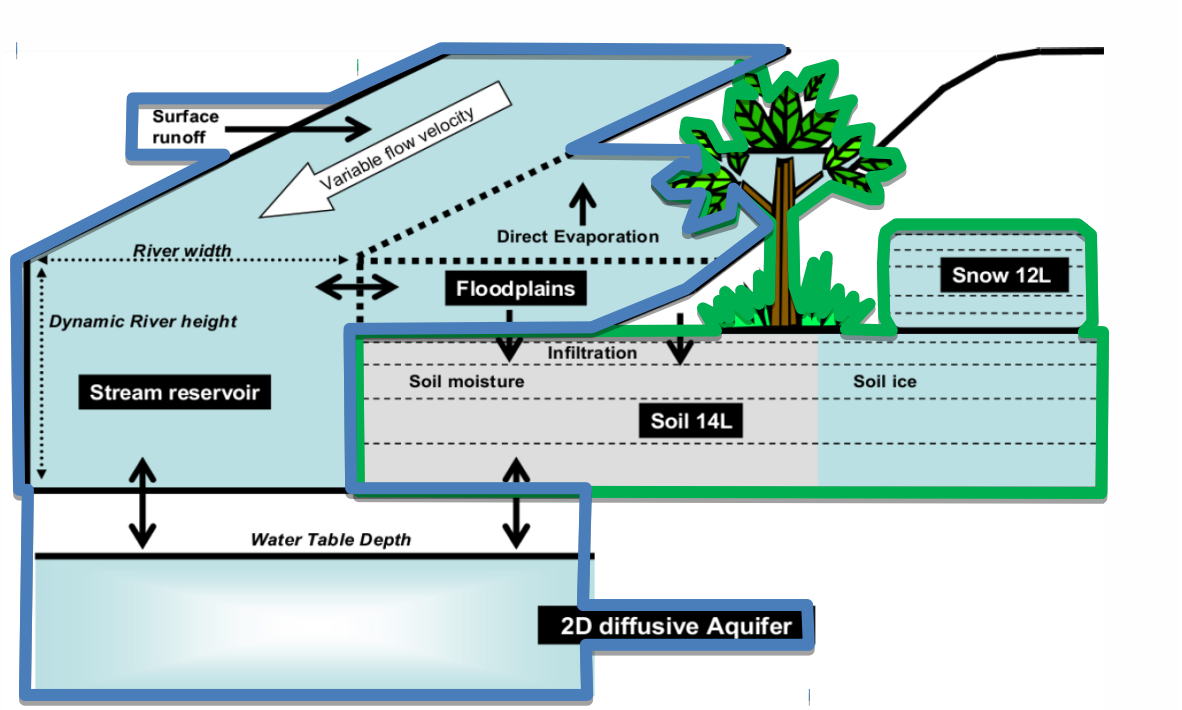
Study the vegetation and terrestrial water cycles

LDAS-Monde: Global capacity offline integration of satellite observations into a land surface model fully coupled to hydrology

LDAS-Monde involves:

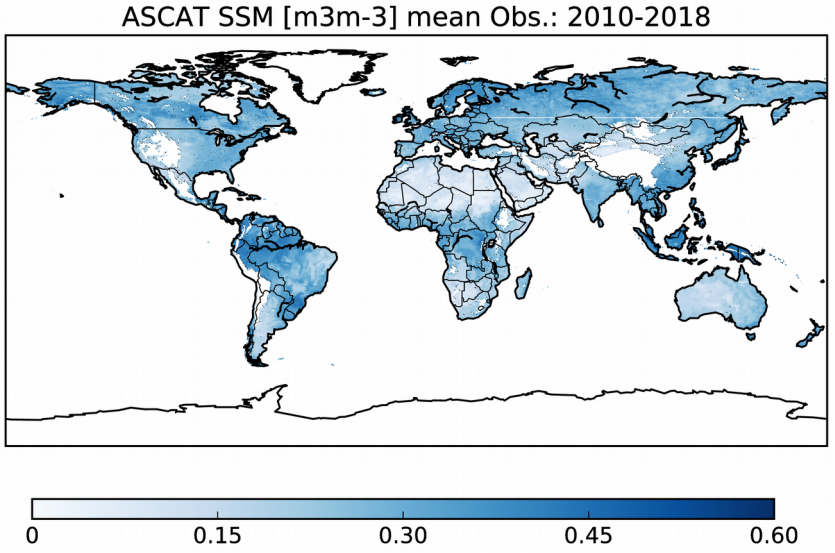
- Land surface model: **ISBA** (Interaction Sol-Biosphere-Atmosphere)
- River routing system: **CTRIP** (CNRM version of Total Runoff Integrating Pathways)
- Data assimilation routines (SEKF, EnSRF, PF)

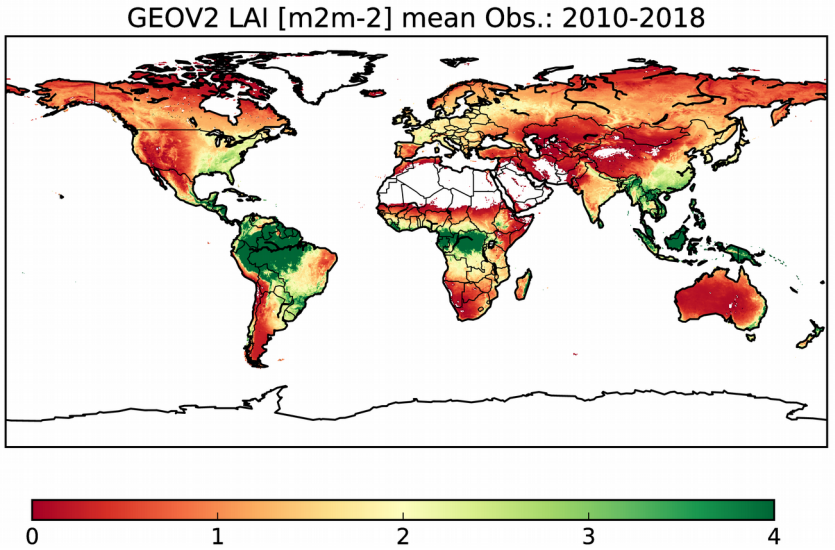
LDAS-Monde is freely available through the SURFEX platform



LDAS-Monde experimental set up

Model	Domain	Atm. Forcing	DA Method	Assimilated Obs.	Observation Operator	Control Variables	Additional Option
ISBA Multi-layer soil model CO_2-responsive version (Interactive vegetation)	**Global** **(2010 – 2018)**	**ERA-5** **Res.: 0.25°x0.25°**	**SEKF**	**SSM** (CGLS SWI + cdf matching) **LAI** (CGLS)	**Second layer of soil (1-4cm)** **LAI**	**Layers of soil 2 to 8 (1-100cm)** **LAI**	**Coupling with CTRIP (0.5°)**





- Control variables (CVs) are directly updated thanks to their sensitivity to the observed variables *[expressed by the SEKF Jacobians]*
- Other variables are indirectly modified through biophysical processes and feedbacks in the model by CVs' updates

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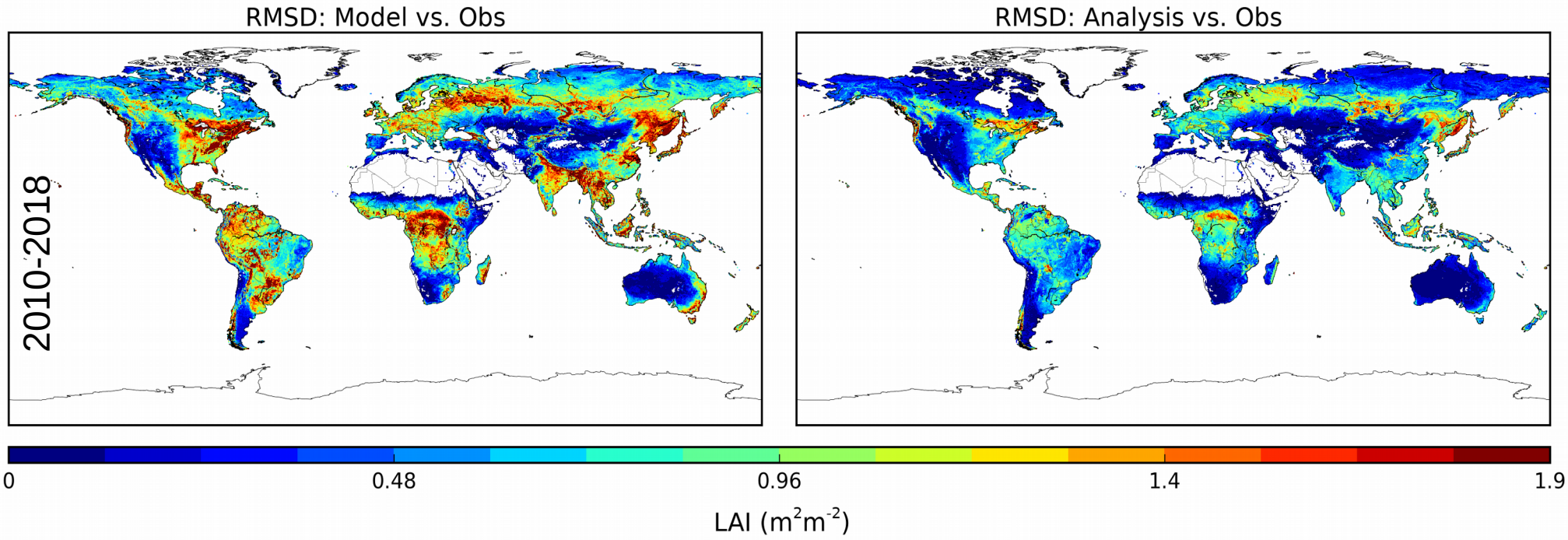
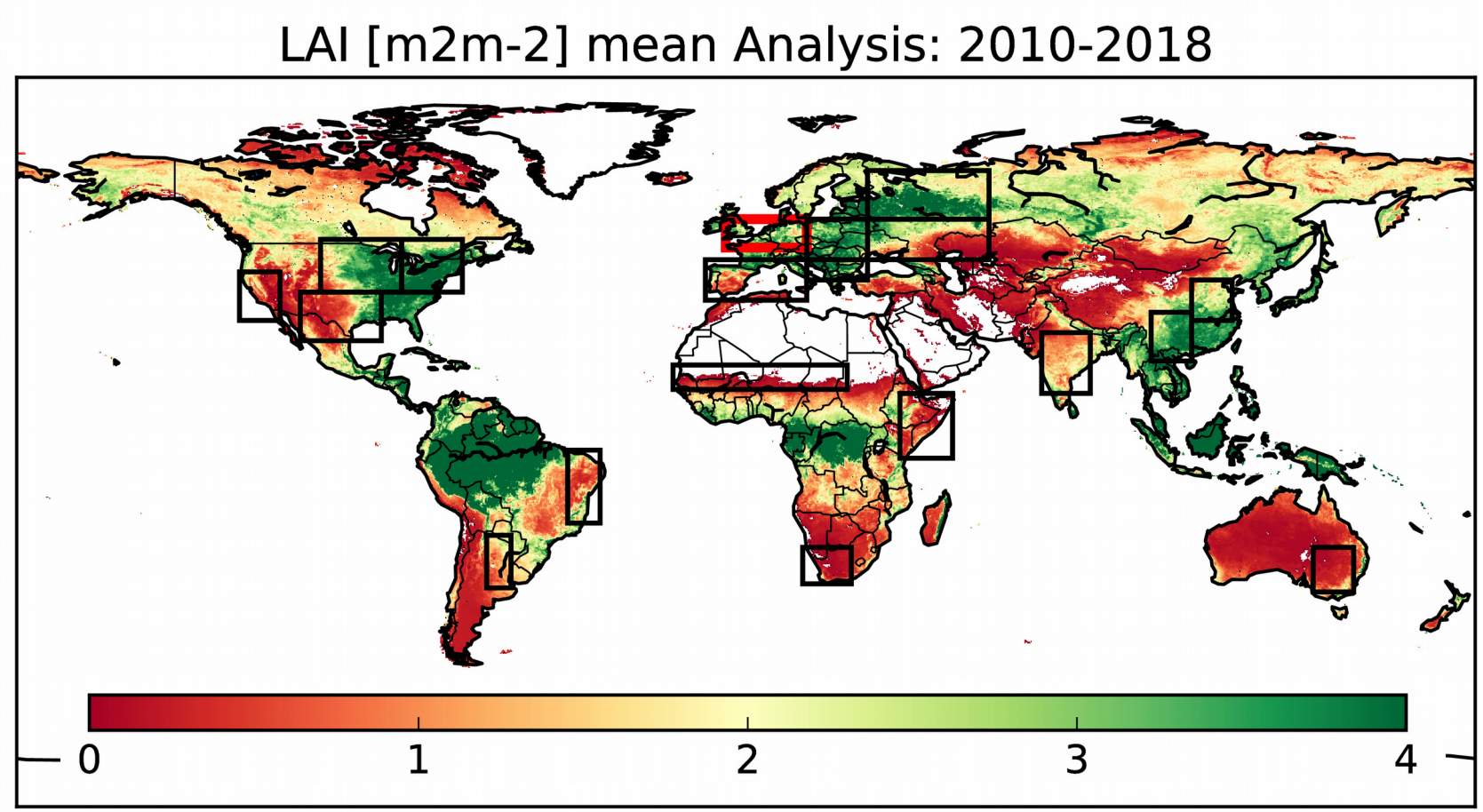
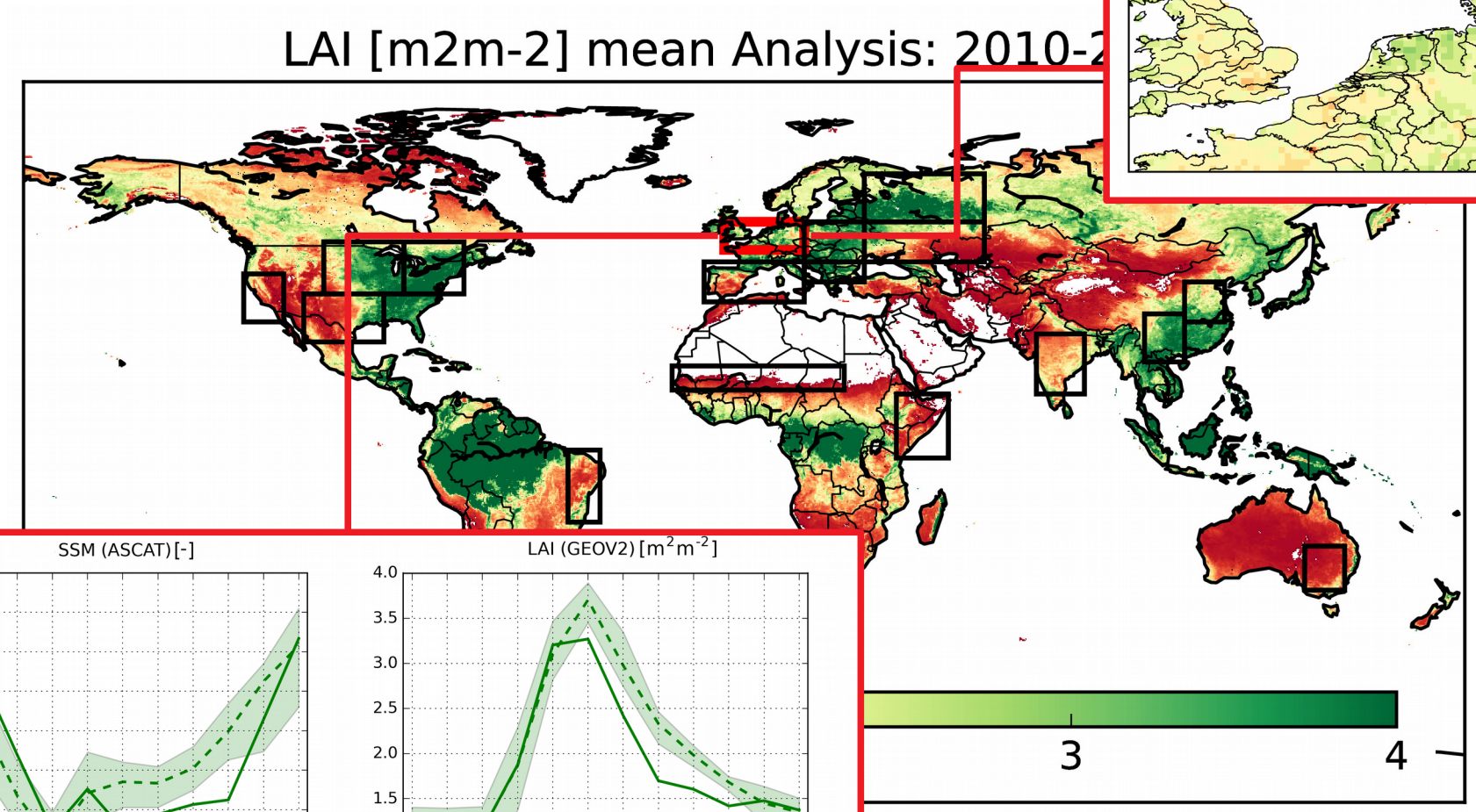


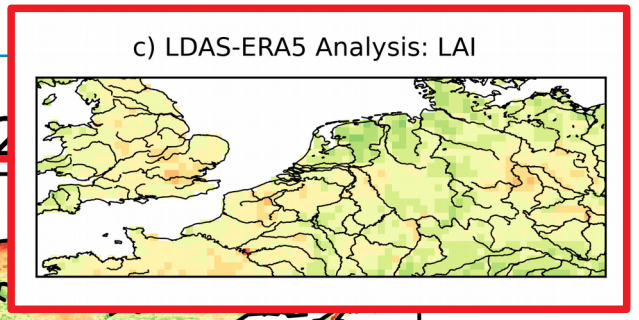
LDAS-Monde goes global

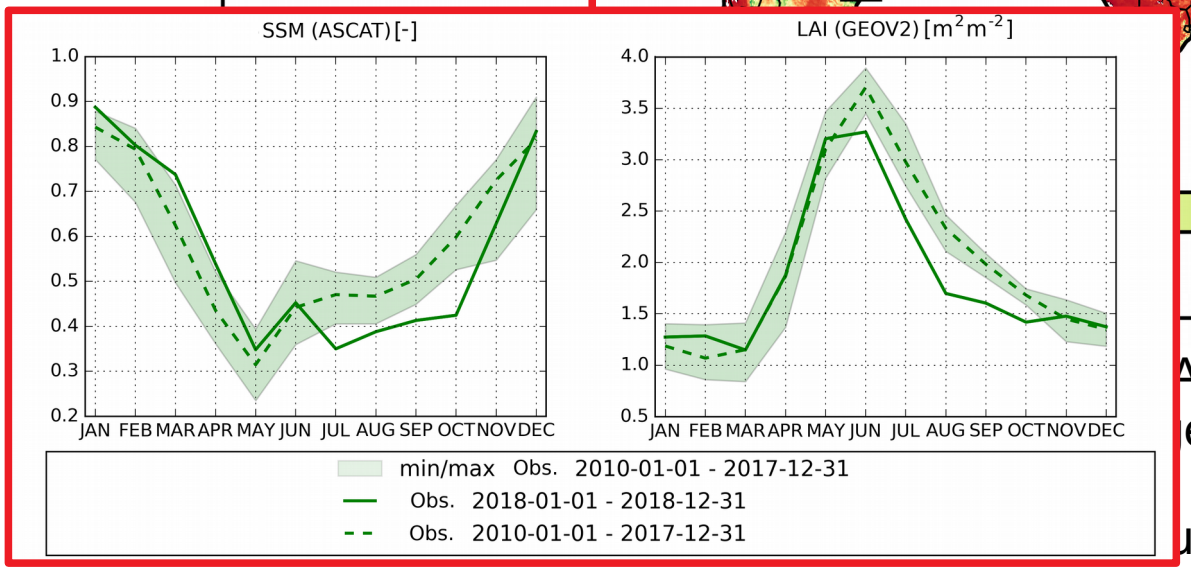


- **ECMWF newsletter#157 (autumn 2018):** Apr.-Aug. near-surface air temperature anomaly in Europe (w.r.t. 1981–2010) much larger in 2018 than in any previous year since 1979
- **NOAA:** Summer 2018 was Europe's warmest summer since continental records began in 1910

LDAS-Monde goes global







Aug. near-surface air temperature
er in 2018 than in any previous year

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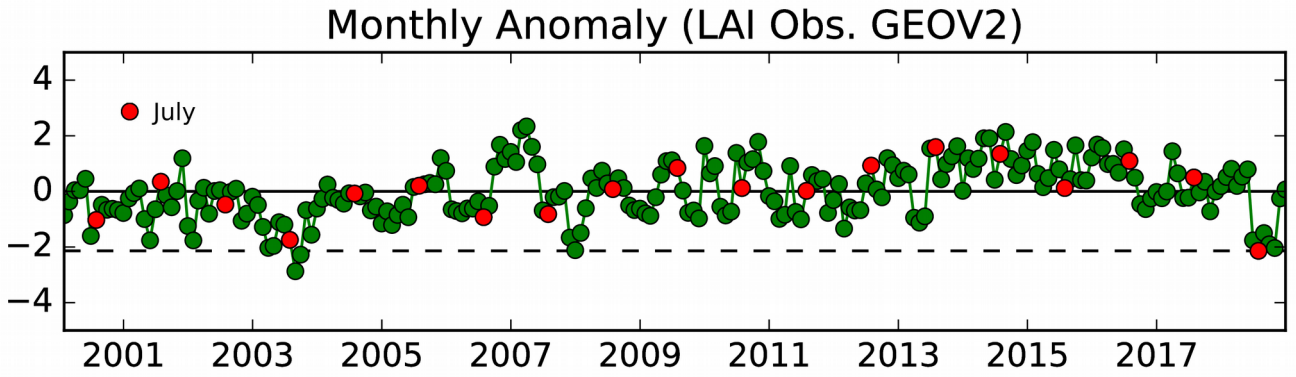
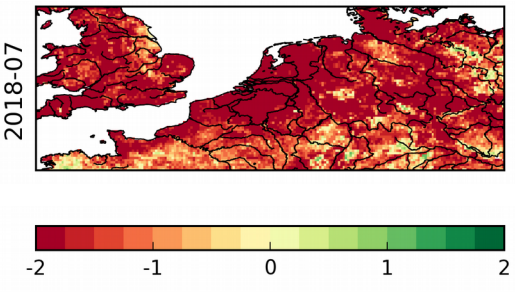
Impact of the Summer 2018 heatwave on LSVs

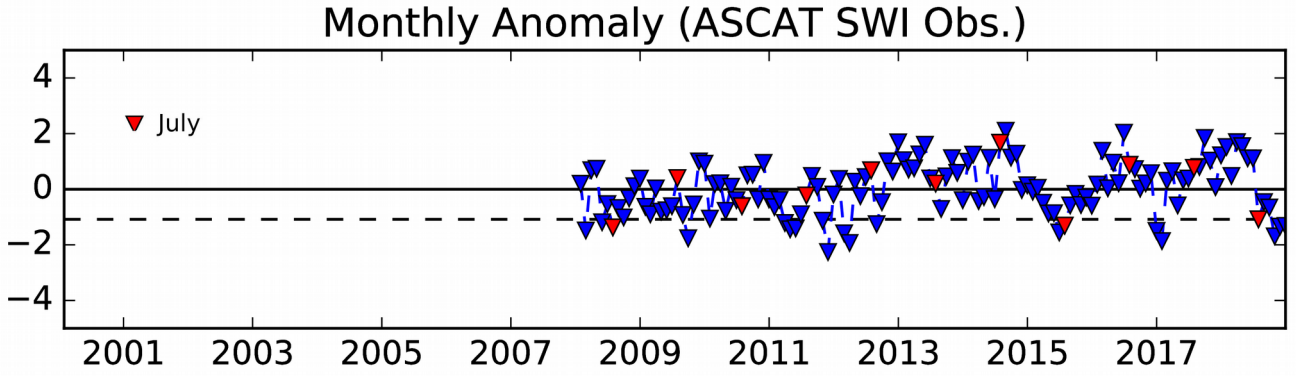
The Earth Observations point of view: *CGLS GEOV2 and SWI*
Monthly anomaly (scaled by stdv)

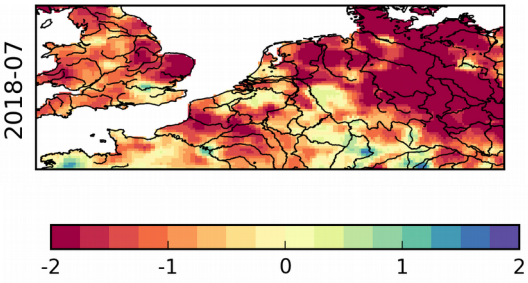
a)





b)

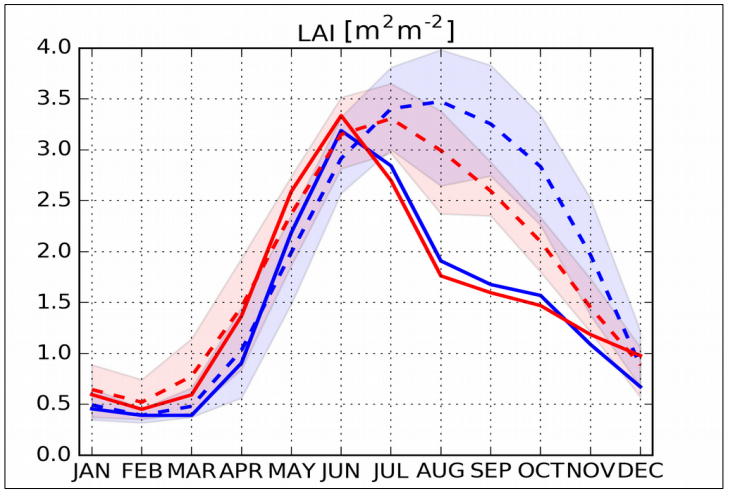


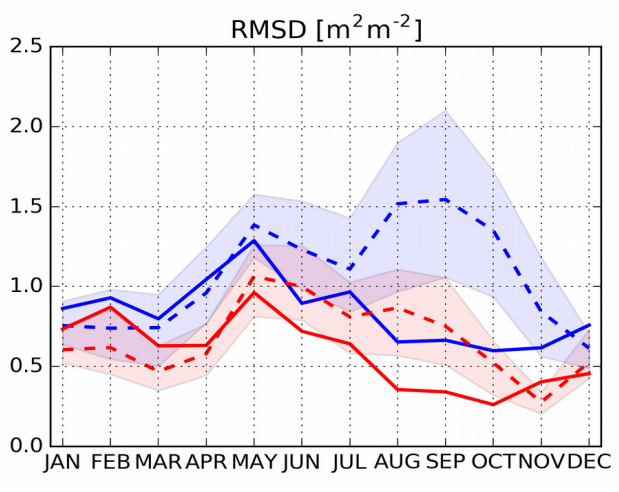


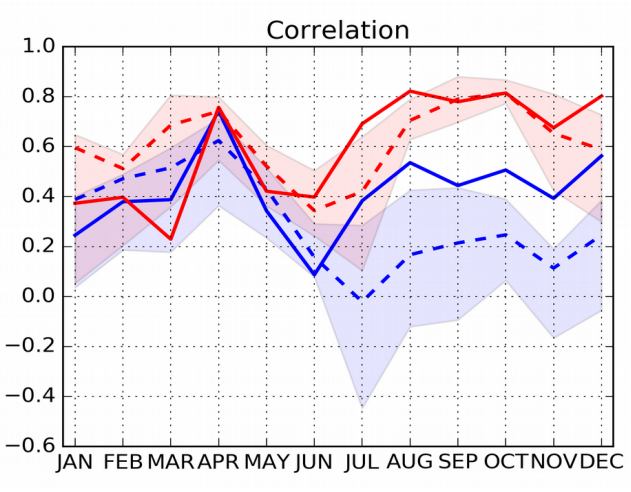
Impact of the Summer 2018 heatwave on LSVs

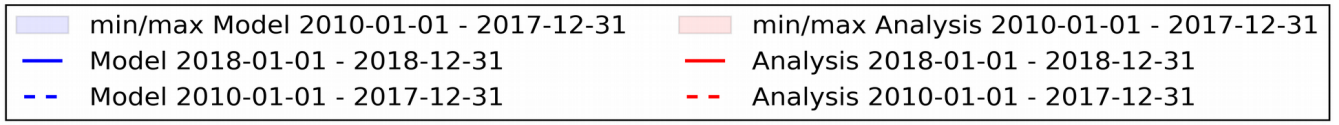
LDAS-Monde : Leaf Area Index

- Seasonal cycles, RMSD and Correlations values (Model, Analysis)









- Seasonal cycles:

➔ 2018 quite different from 2010-2017

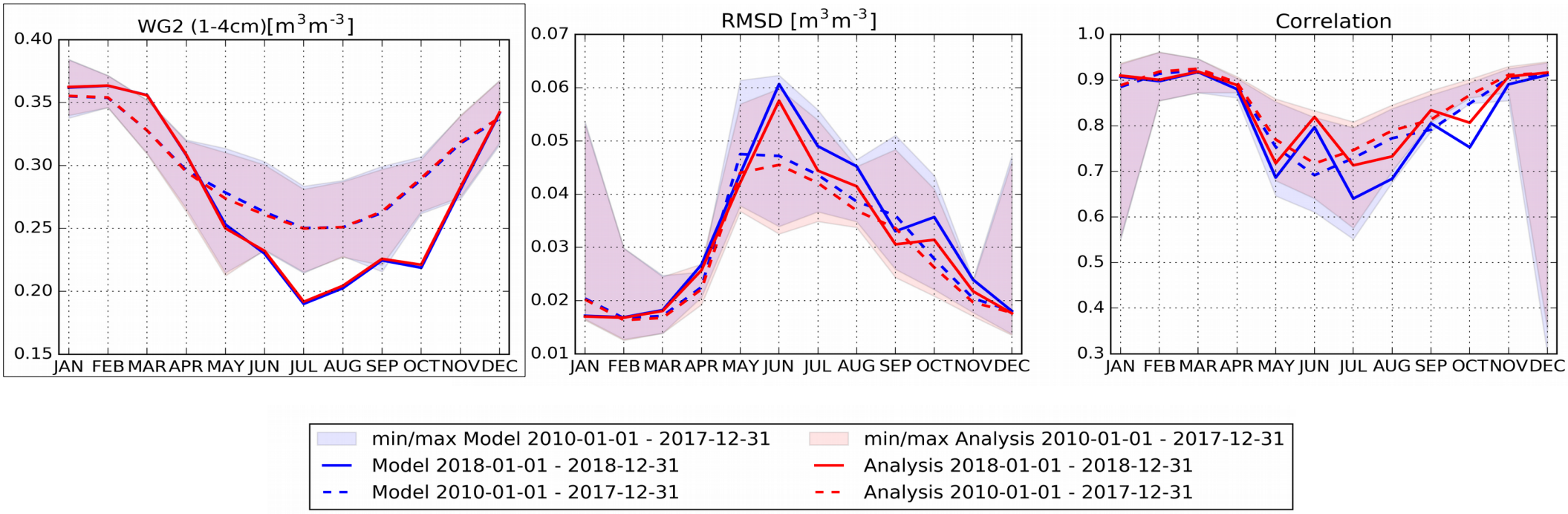
➔ smaller differences between Model and Analysis for 2018 than for 2010-2017 (True for RMSD and R values as well)

- Analysis improvements over Model simulation

Impact of the Summer 2018 heatwave on LSVs

LDAS-Monde : surface soil moisture

- Seasonal cycles, RMSD and Correlations values (Model, Analysis)



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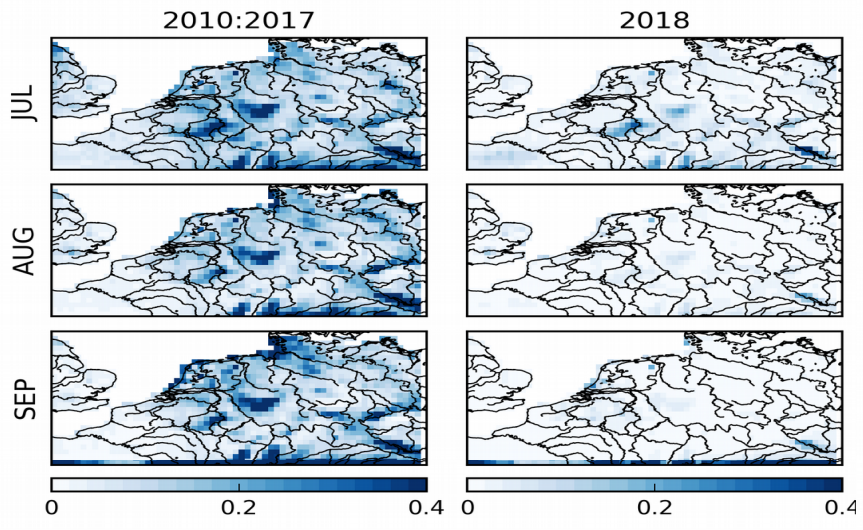
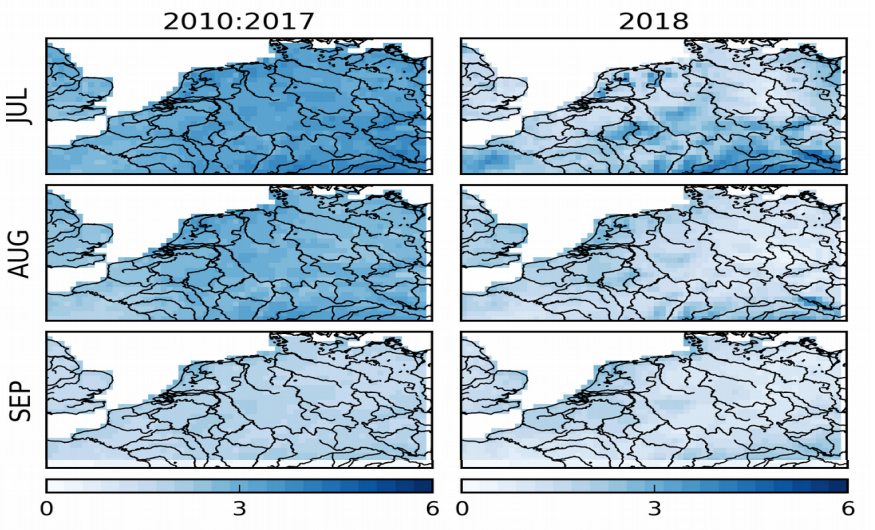
Impact of the Summer 2018 heatwave on LSVs

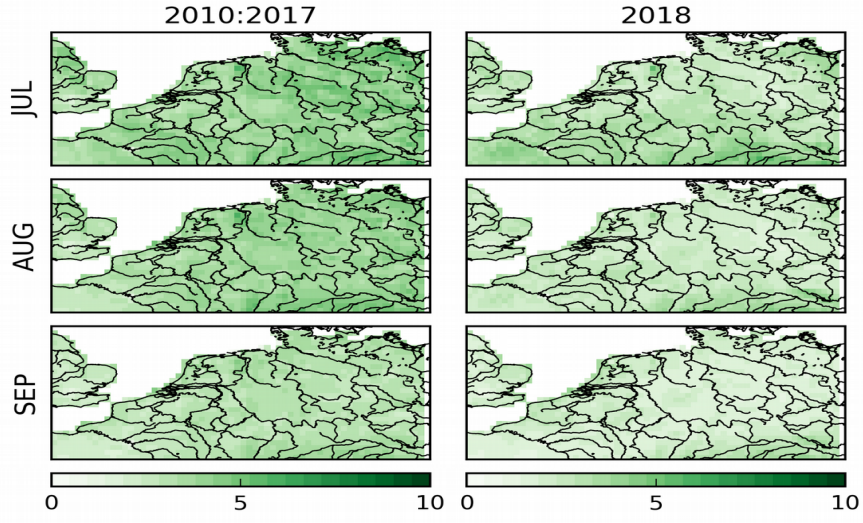
Drainage ($kg.m^{-2}.d^{-1}$)



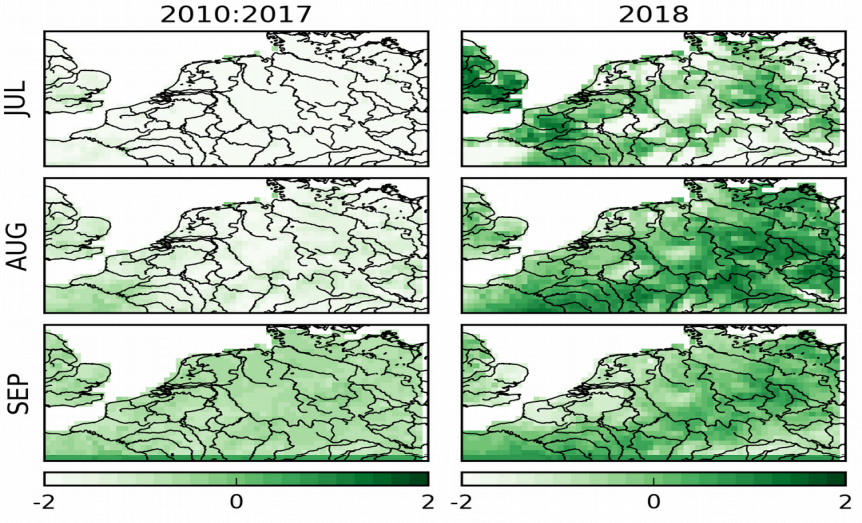
EVAP. ($kg.m^{-2}.d^{-1}$)



RC_ECO ($g(C).m^{-2}.d^{-1}$)



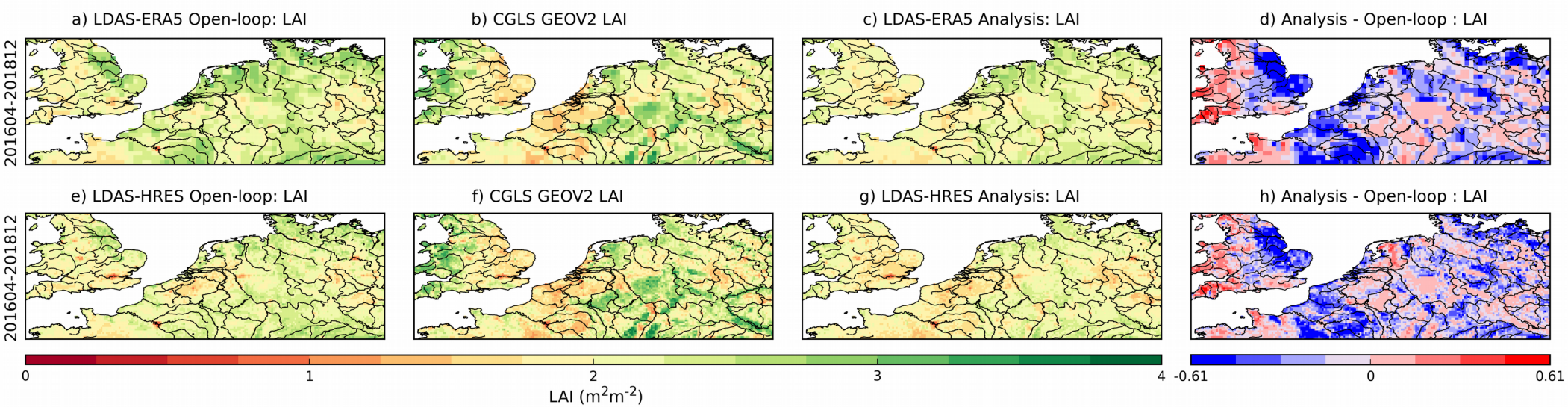
NEE ($g(C).m^{-2}.d^{-1}$)



Impact of the Summer 2018 heatwave on LSVs

Such an extreme event needs more attention!
Implement a flexible focus of attention and spatial resolution over this area:

- Using ECMWF high resolution operational IFS (LDAS-HRES, from 04/2016 onwards, 0.10°x0.10° spatial resolution), to complement the use of ERA5 (LDAS-ERA5, from 1979 onwards, 0.25°x0.25°)



➔ Despite the spatial resolution, ERA5 production cycle (IFS Cycle 41r2) is still close to that of the HRES (IFS Cycle 41r2 to 43r3 from 2016 and 45r1 from June 2018)

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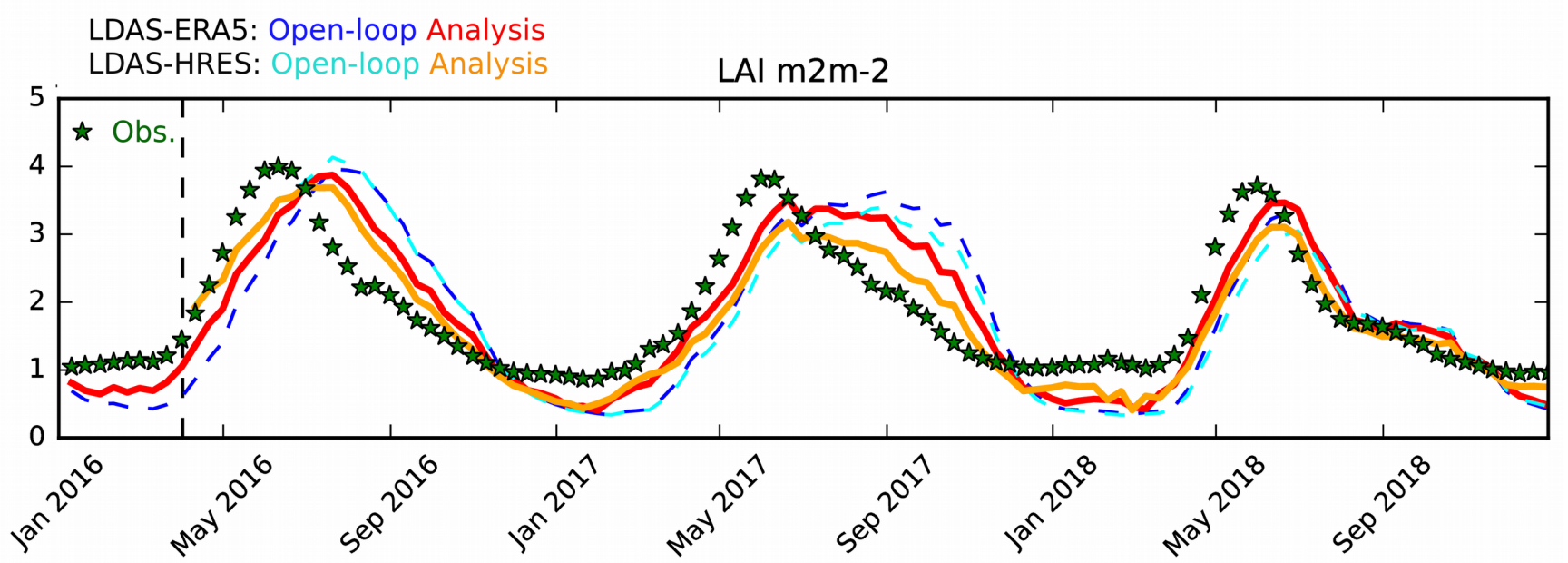

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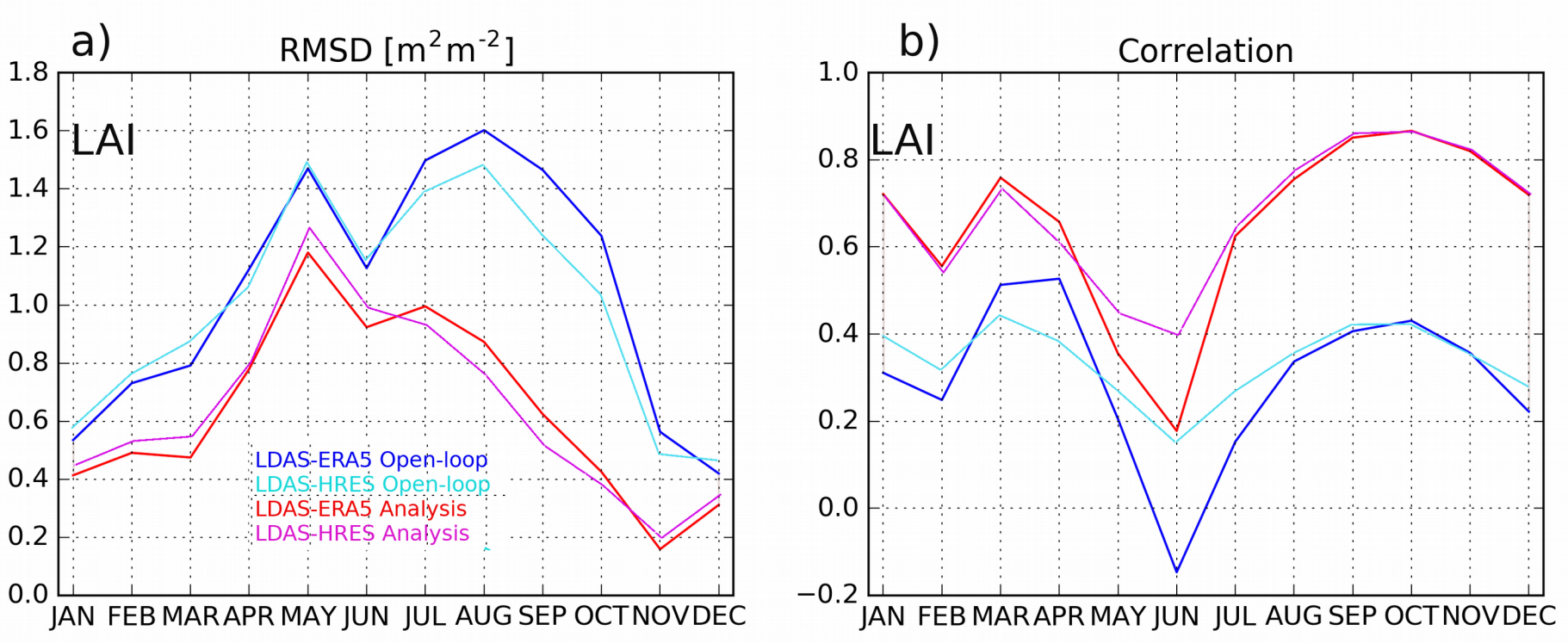
Impact of the Summer 2018 heatwave on LSVs

LDAS-ERA5, LDAS-HRES

- 4 experiments: 2 analyses and their 2 openloops
- Seasonal scores over April 2016 to October 2018 : each experiments vs. LAI obs.



- ERA5 (blue) and HRES (cyan) driven open loop are comparable, HRES being better
- Analysis (red and pink) add skill to both which is indication of healthy behaviour

Impact of the Summer 2018 heatwave on LSVs

LDAS-ERA5, LDAS-HRES

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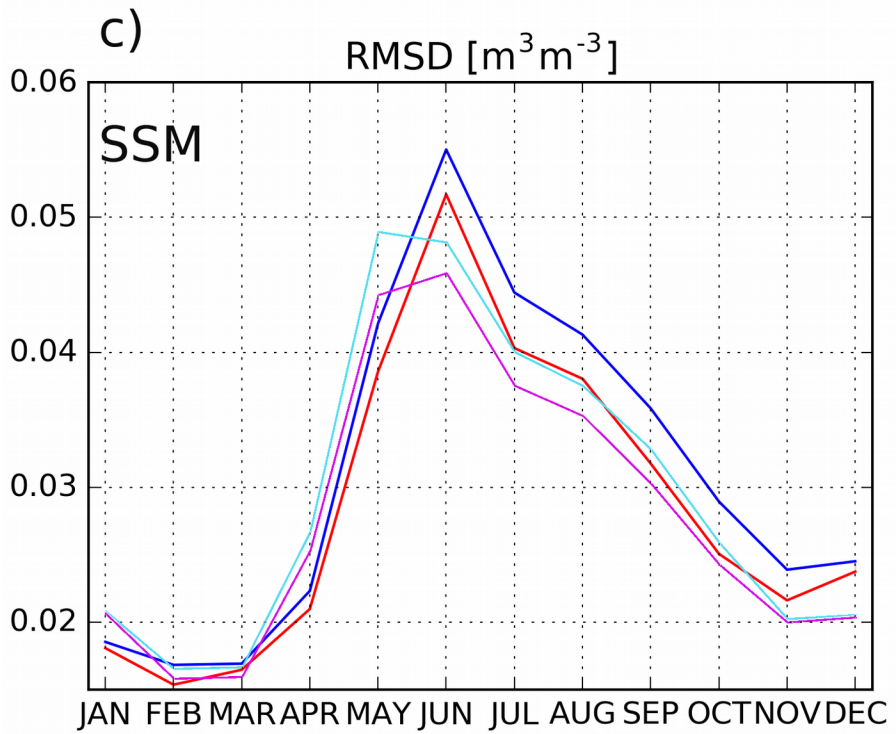

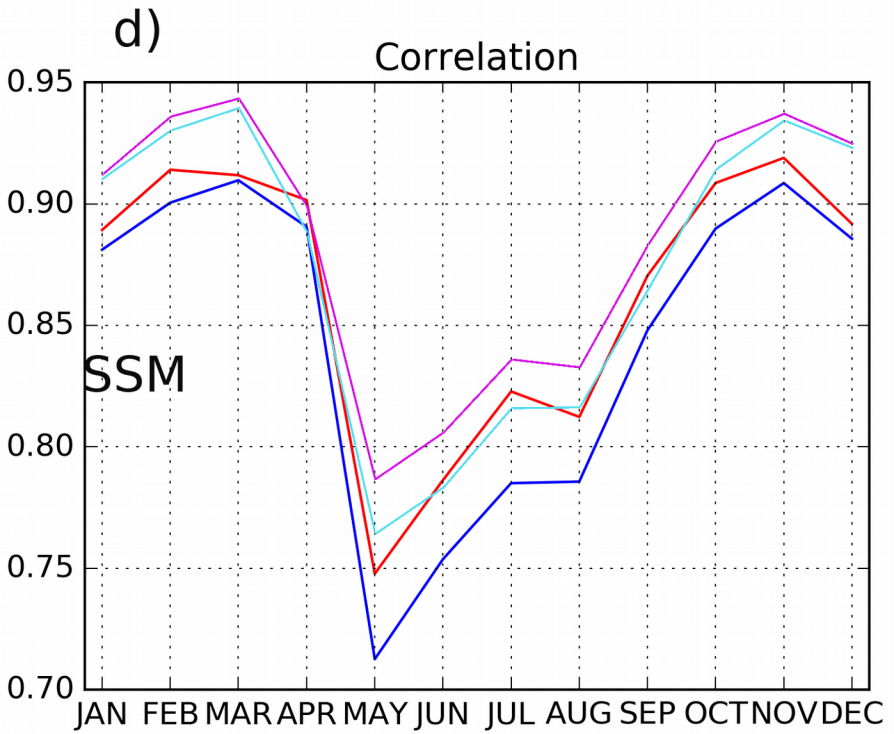

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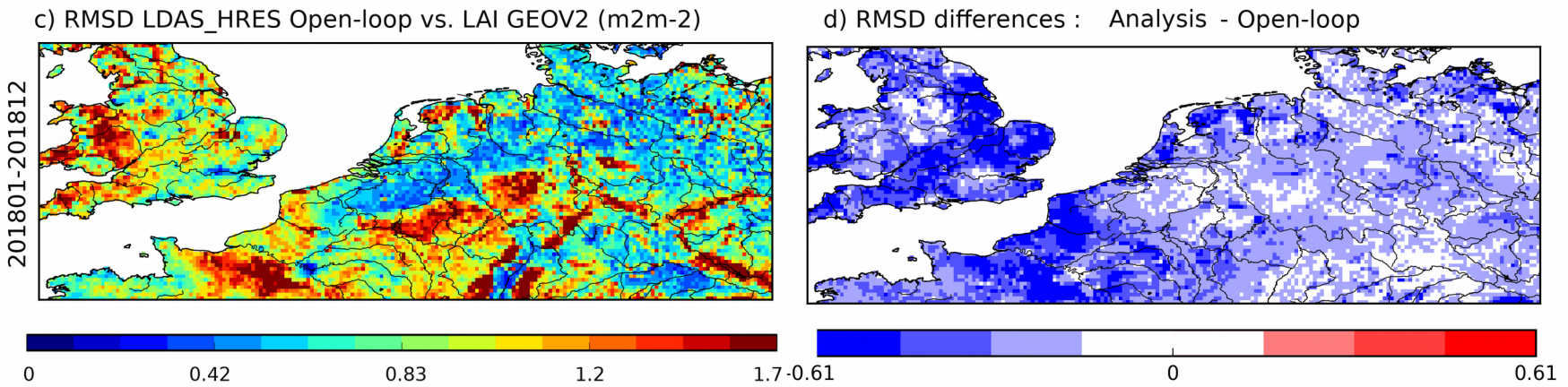
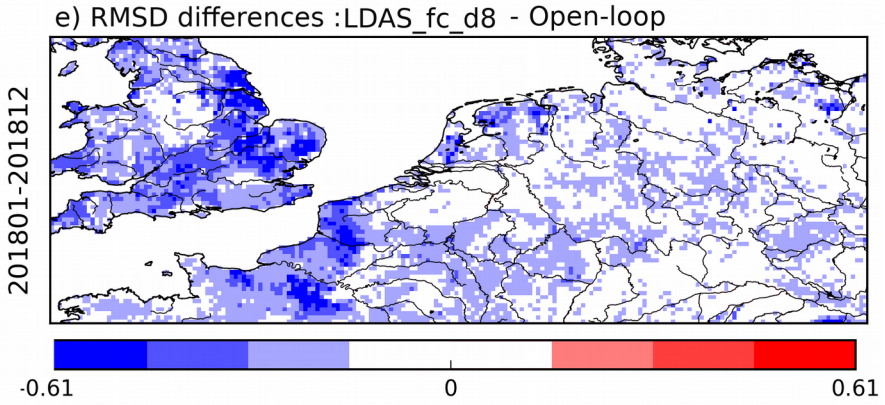
Impact of the Summer 2018 heatwave on LSVs

From monitoring to forecasting :

- LAI forecast up to 8-days ahead (initialised by LDAS-Monde) vs. Openloop



82 % of the domain presents lower RMSD values



49 % of the domain presents lower RMSD values

➔Forecast experiment with up to 8-day lead time, initialised by EKF, better than an open-loop

➔Forecast of LSVs is also a matter of initial conditions

Impact of the Summer 2018 heatwave on LSVs

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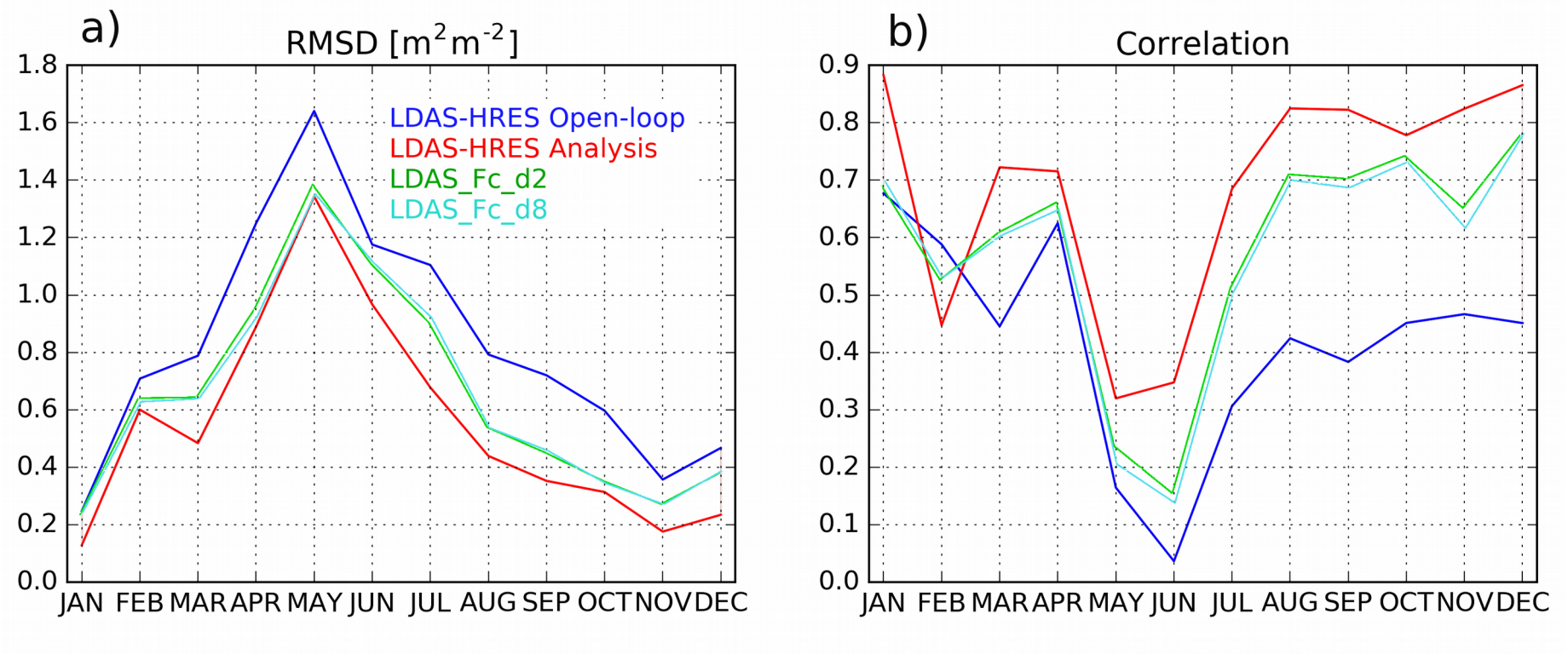

➔ Forecast experiment with up to 8-day lead time, initialised by EKF, better than an open-loop

Conclusions

LDAS-Monde forced by either ERA5 or HRES captures well the impact of the summer 2018 heatwave on LSVs

- LDAS-ERA5 and LDAS-HRES open loop are comparable, HRES being better
- Analysis add skill to both which is indication of healthy behaviour

- Forecast initialised by analysis is of better quality than the model (> 10-d ahead for LAI)

Combining LSM, satellite EOs and ECMWF atmospheric forcing through LDAS-Monde

➔Great potential to monitor and forecast the impact of extreme weather on LSVs

Global long term LDAS-ERA5

➔Provides a model climate as reference for anomalies of LSVs

➔Significant anomalies trigger more detailed monitoring and forecasting activities for a region of interest using **LDAS-HRES** (use of ECMWF ENS forecast under study)

LDAS-AROME (offine, 2.5 km x 2.5 km spatial resolution) under study

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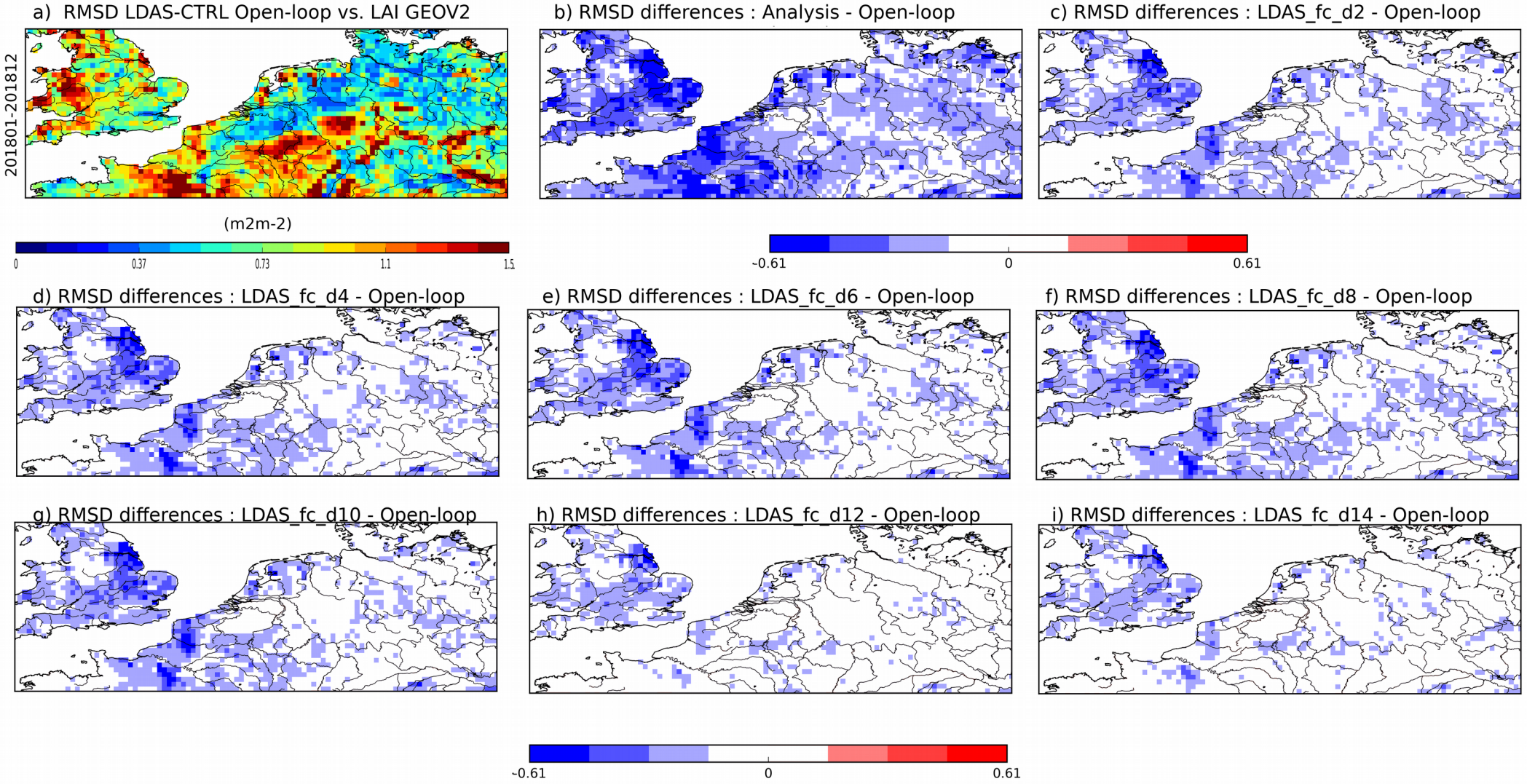
Impact of the Summer 2018 heatwave on LSVs

From monitoring to forecasting : IFS Ensemble control member (CTRL ~0.20°x0.20°)

- LAI forecast from 2 to 14-days ahead initialised by LDAS-Monde vs. Openloop

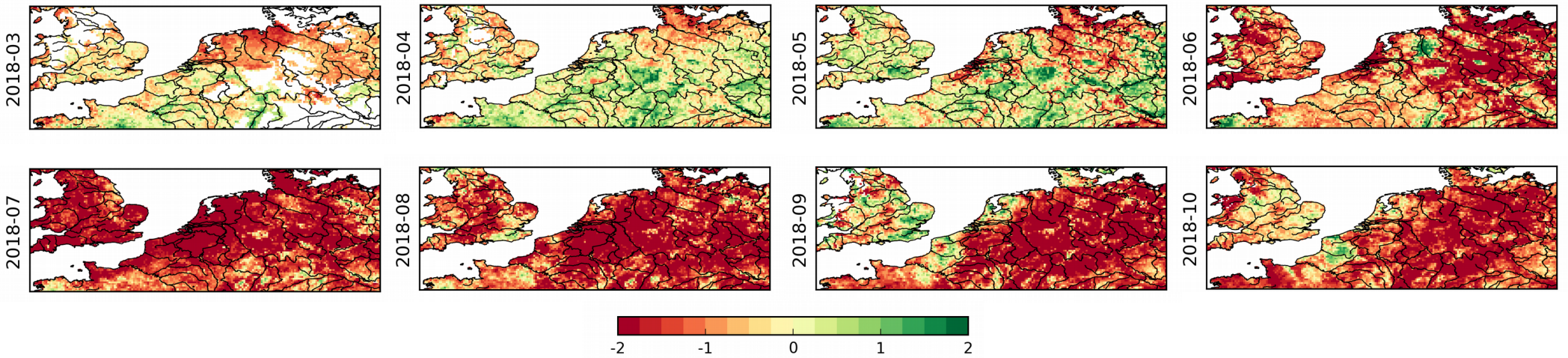


➔ 2-day forecast experiment (and even 14-day) initialised by EKF better than an open-loop

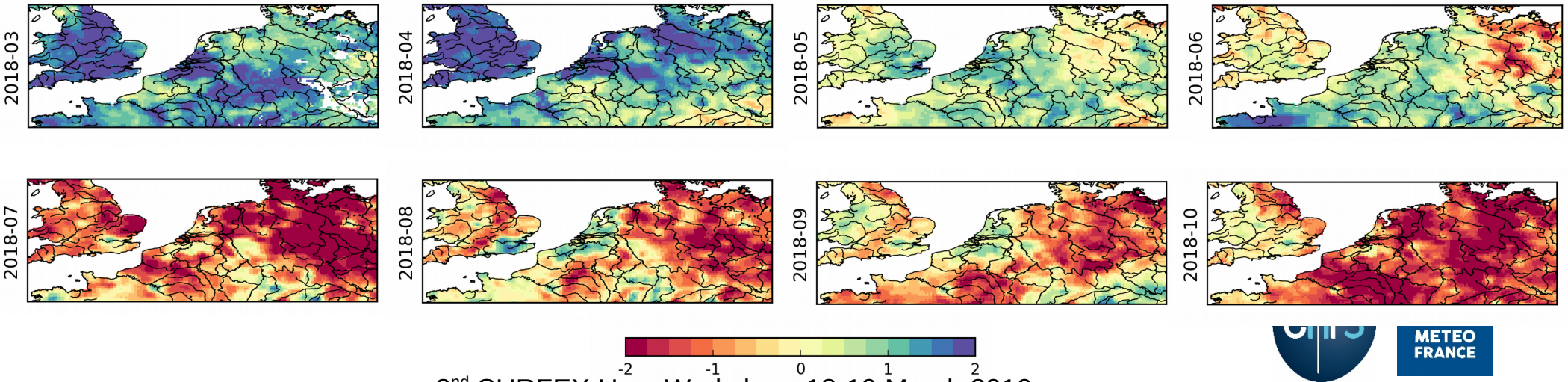
Impact of the Summer 2018 heatwave on LSVs

The Earth Observations point of view : *CGLS GEOV2 and SWI*

- Monthly anomaly (scaled by stdv) over 2000-2018 (LAI)



- Monthly anomaly (scaled by stdv) over 2008-2019 (SWI)



Details on ISBA land surface model

ISBA solves the energy and water budgets at the surface level and describes the exchanges between the land surface and the atmosphere (on a sub-hourly basis)

- ISBA-A-gs (CO_2-responsive version) simulates the diurnal cycle of water and carbon fluxes, plant growth and key vegetation variables
- Phenology driven by photosynthesis

➔ *LAI is very flexible and can be updated when observations are available*

- ISBA-Dif multilayer soil diffusion scheme (14 layers, 12 m)
- ISBA land surface model needs:
  - Parameters for the vegetation and soil texture

    Derived from the ECOCLIMAP landcover database*
  - Atmospheric forcing

    Longwave & shortwave radiation, 2-metre air temperature & humidity, precipitations (liquid and solid, surface pressure and near surface wind speed)

    ** 1km spatial resolution, ECOCLIMAP-SG already available, 300m resolution*