An offline reanalysis of land surface variables with LDAS-Monde forced by a kilometric-scale NWP system

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Abstract

- The need of characterizing the evolution of land surface variables (LSVs) at high temporal and spatial resolutions is increasingly crucial for many applications such as weather prediction, drought monitoring or agricultural practices.
- One key toolbox in this context are Land Data Assimilation Systems (LDASs). By combining satellite observations with outputs from Land Surface Models, they overcome drawbacks of both approaches to monitor accurately LSVs. Most operational LDASs work at spatial resolutions spanning from few kilometres to 0.5°.

Our work

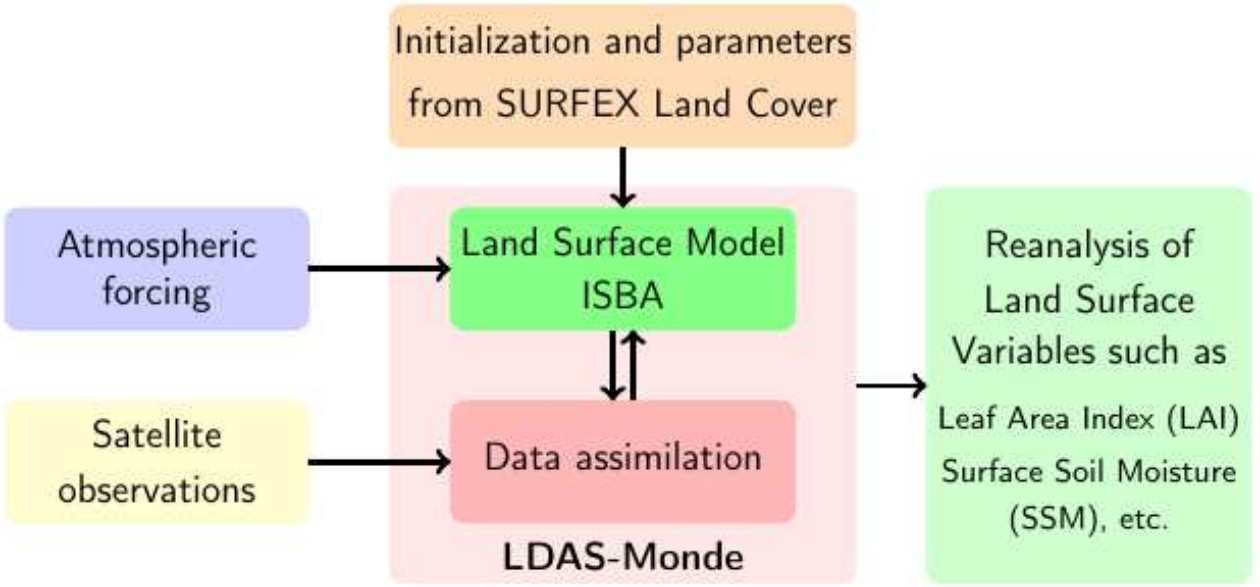
- Set LDAS-Monde, the offline LDAS developed by Météo-France's research centre (CNRM) up to the context of a kilometric spatial resolution. To do so, LDAS-Monde is forced with Météo-France's small scale numerical weather prediction system AROME to produce a reanalysis of LSVs at 1/40° (~ 2.5-km) spatial resolution over a domain centred on France starting from 2017.
- The quality of this approach is assessed by comparing the obtained reanalysis with satellite products of Leaf Area Index (LAI) and Surface Soil Moisture (SSM) from the Copernicus Global Land Service. The ability of our system to monitor the evolution of LSVs under extreme meteorological conditions is also studied.

LDAS-Monde: an overview

LDAS-Monde is a powerful toolbox to monitor land surface variables. It involves:

- The land surface model **ISBA** (Interaction between Soil-Biosphere-Atmosphere) that simulates the evolution of land surface variables,
- **Data assimilation** routines integrating satellite observations to correct directly modelled Leaf Area Index (LAI) and soil moisture for the first metre of soil.

ISBA is initialized using the *Land Cover* (available now at 300-m resolution) included in the **SURFEX** modelling platform (Masson et al., 2013)



LDAS-Monde is the outcome of numerous studies (a full list can be found on LDAS-Monde official website, see last slide).

It has been used at various scales (regional, continental, global) and spatial resolutions (8-km to 0.5°).

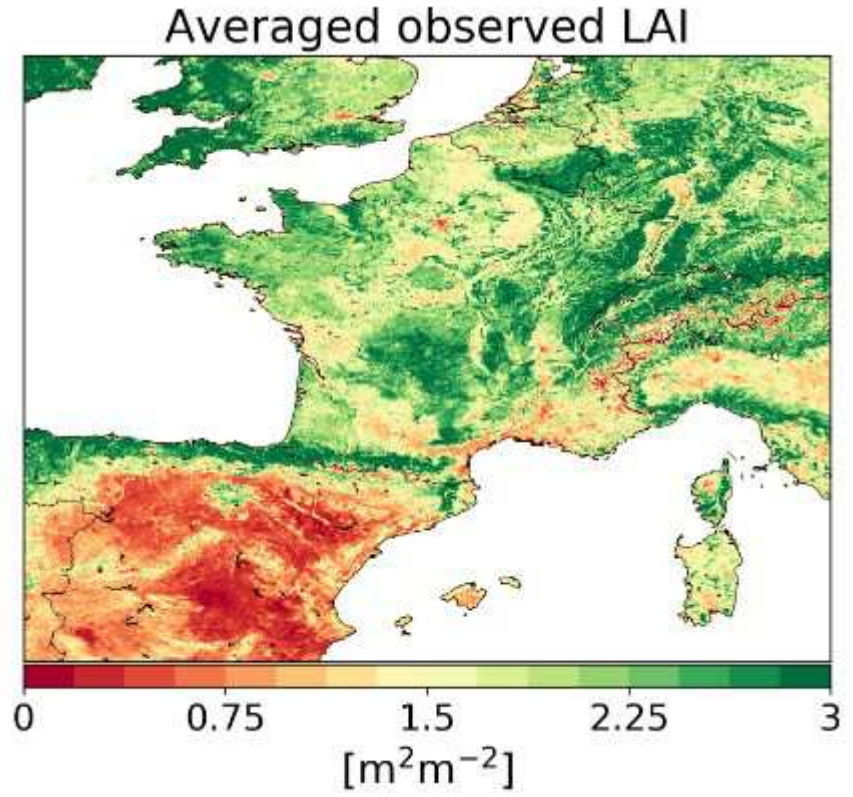
A detailed description of LDAS-Monde can be found in Albergel et al. (2017).

LDAS-Monde forced with AROME NWP forecast

- **Atmospheric forcing**
  - outputs from **AROME atmospheric forecasting system** (Seity et al., 2011)
  - 24h forecast initialised at 00:00 UTC
  - AROME grid: 1.3 km Lambert grid
  - We use the regridded product at **1/40° spatial resolution** from Météo-France's BDAP (Base de Données Analysées et Prévues)

- We assimilate solely the **LAI satellite derived product** from the Copernicus Global Land Service (CGLS), available at 300 m resolution every 10 days (data obtained from PROBA-V sensor)

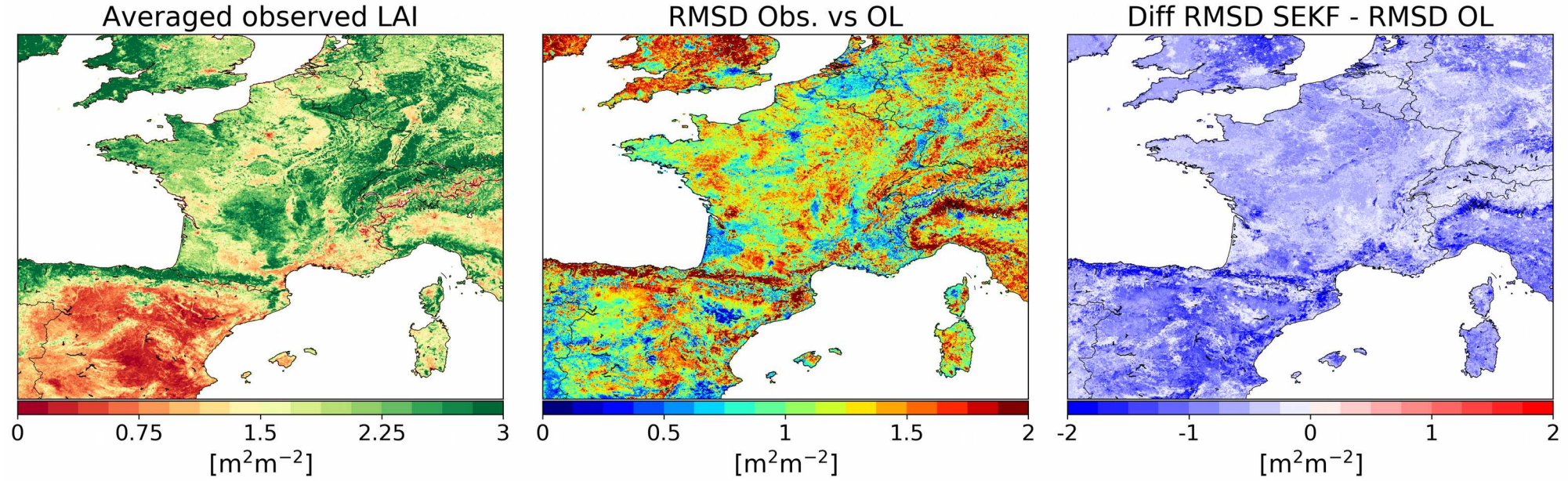
- Time window of the study:
  January 2017 to December 2019.



Observed LAI averaged over Jan. 2017 to Dec. 2019 for the **AROME domain**

Impact of assimilation on LAI reanalysis

We compare the assimilated observations of LAI (Obs.) with modelled LAI (open loop, no assimilation) by computing the Root Mean Square Difference (RMSD, middle panel). The model is not perfect as RMSD can be higher than the averaged observed LAI (left panel).

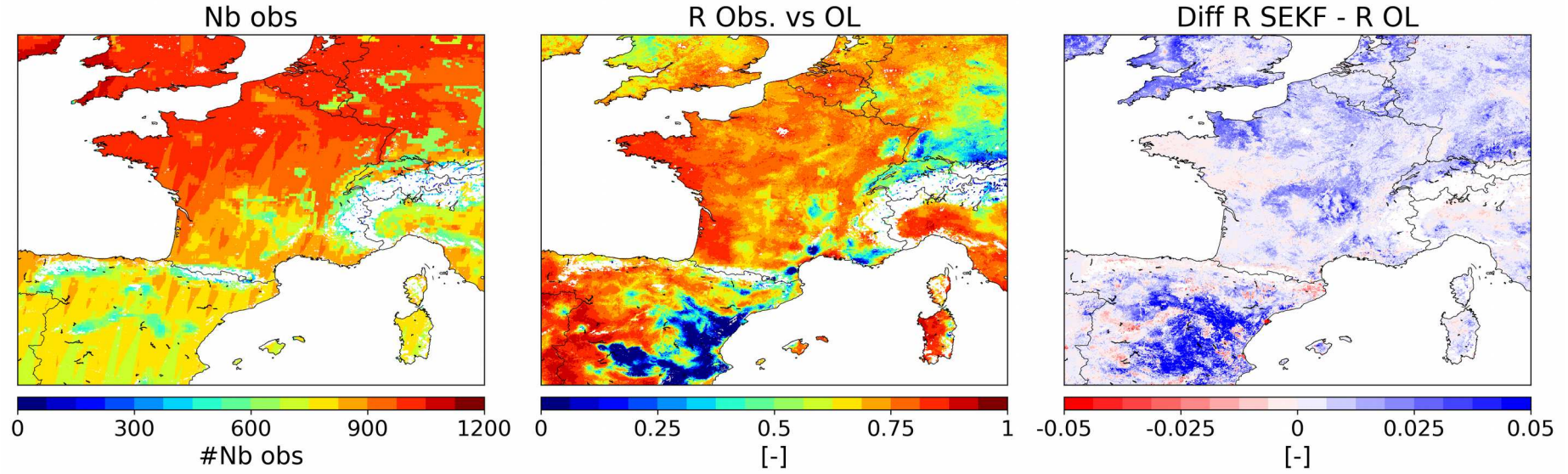


Estimated LAI after assimilation (SEKF*) is closer to observations as expected (reduced RMSD in blue, right panel) and the LAI cycle is improved.

*SEKF: Simplified Extended Kalman Filter is the data assimilation approach used in this study.

Impact of assimilation on surface soil moisture

We compare the modelled soil moisture at 1-4 cm depth with the **Soil Water Index product** from CGLS available at 1-km resolution every day from January 2015 (data obtained from ASCAT and Sentinel 1 C-SAR sensors) by computing correlations (middle panel). In most places, correlations are above 0.75.



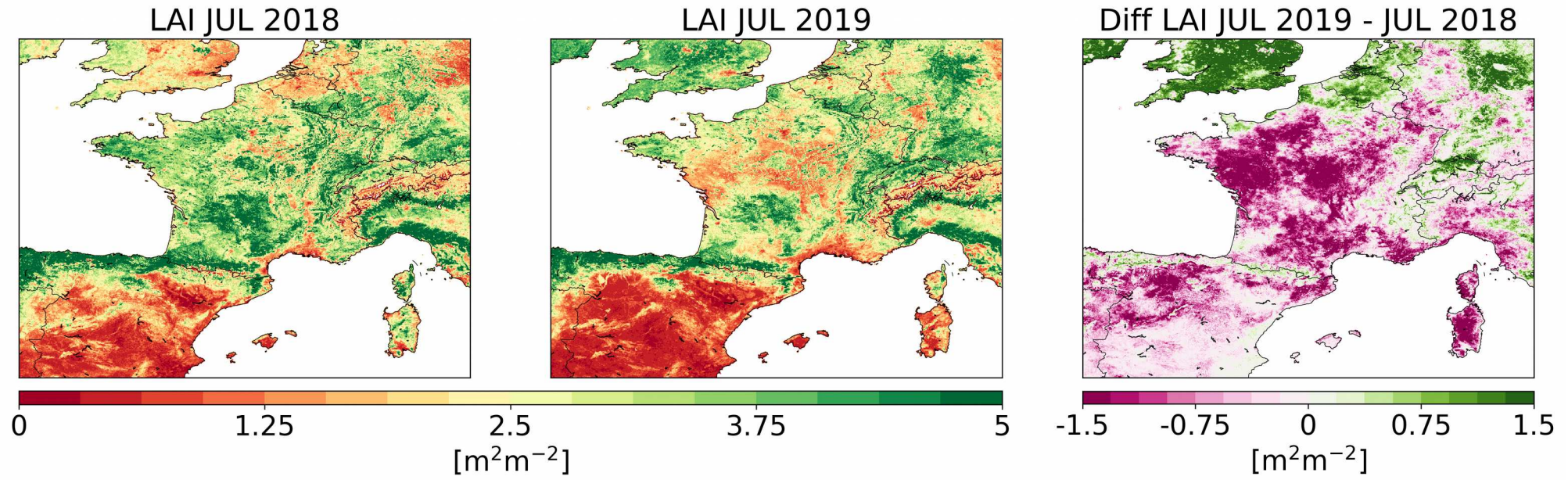
The assimilation of LAI further improves correlations (in blue, right panel) up to 0.05.

Comparison is also carried out with CGLS **Surface Soil Moisture** product available at 1-km resolution from January 2015 (data obtained from Sentinel 1 C-SAR sensor only). Similar trends are noticed (not shown) albeit correlations are reduced around 0.70.

Monitoring LSVs under extreme conditions (1)

Agricultural drought: **Impact of heatwave on LAI reanalysis over France in July 2019, comparison with previous year**

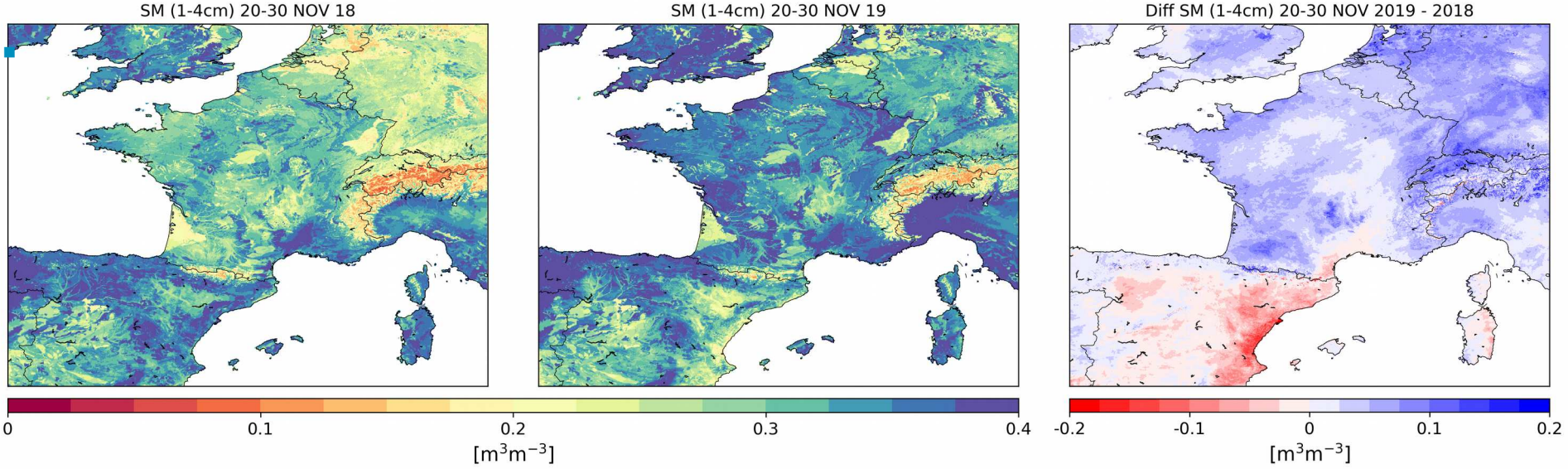
- Reduced LAI over most part of France in July 2019 (in purple, right panel). Large parts of France experience a difference in LAI of 1.5 $m^2.m^{-2}$ compared to previous year.
- LAI bigger in July 2019 compared to 2018 in Southern England, Belgium and Northern Germany (heatwave in 2018 instead).



Monitoring LSVs under extreme conditions (2)

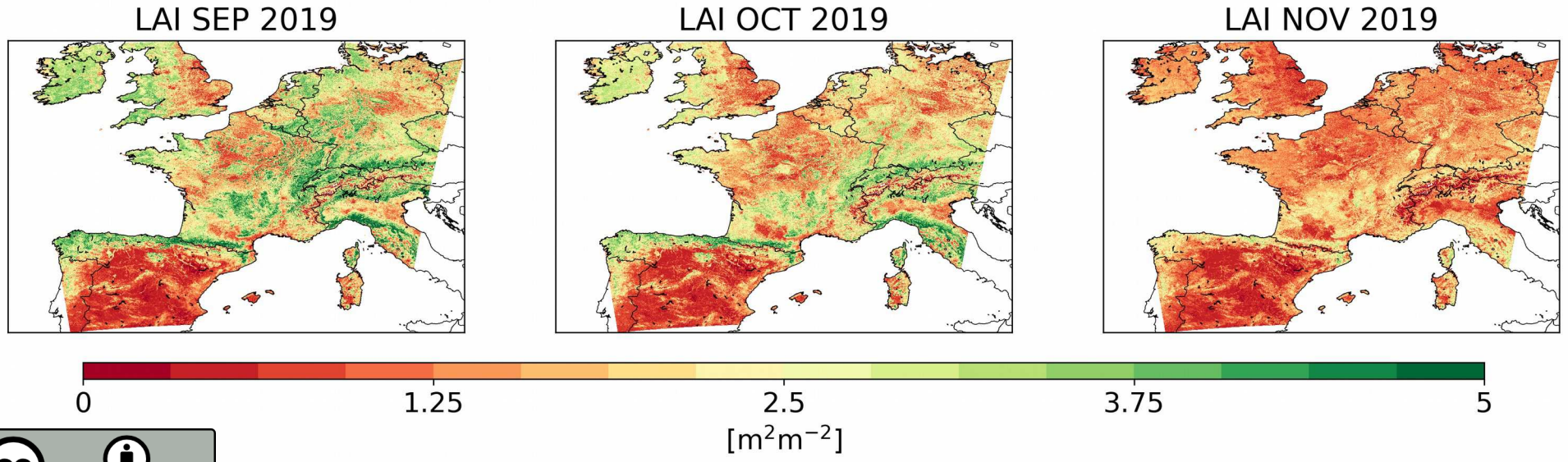
Saturated soil: Impact of heavy rainfalls on SSM reanalysis during the last 10 days of November 2019

- Soil Moisture in 1-4 cm depth higher in 2019 than in 2018 for most places in France, Germany, Italy, … (November 2018 was particularly dry for most parts of France)
- Soil Moisture close to field capacity over Cote d'Azur (France), Piedmont and Liguria (Italy). Flood events occurred in these areas during that period.



Conclusion and Prospects

- **We have a functioning LDAS operating in near-real time over France at 1/40° spatial resolution. Plans are to:**
  - continue the monitoring of LSVs, extend it to other variables such as Evapotranspiration, Gross Primary Production, Runoff, Drainage and extend the time window of the reanalysis (before 2017)
  - assimilate surface soil moisture products in LDAS-Monde forced by AROME (either alone or with LAI) and study their influence on the reanalysis of LSVs
  - working towards LDAS-Monde over France at 1/100° spatial resolution (ongoing work, figure below shows monthly averaged reanalysed LAI over the extended AROME domain at 1/100°)



Data availability and References

Data generated with LDAS-Monde forced by the AROME atmospheric forecasting system are available upon request. For inquiries, please contact:

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LDAS-Monde official webpage:
https://www.umr-cnrm.fr/spip.php?article1022&lang=en

LDAS-Monde is based on an open source code that can be found here:
https://opensource.umr-cnrm.fr/projects/openldasmonde

LDAS-Monde is also available through the SURFEX modelling platform:
https://www.umr-cnrm.fr/surfex/

- References (among others):
  - LDAS-Monde:
    Barbu et al. (2014), https://doi.org/10.5194/hess-18-173-2014
    Albergel et al. (2017), https://doi.org/10.5194/gmd-10-3889-2017
  - SURFEX: Masson et al. (2013), https://doi.org/10.5194/gmd-6-929-2013
  - AROME: Seity et al. (2011), https://doi.org/10.1175/2010MWR3425.1