Monitoring and Forecasting the Impact of the 2018 Summer Heatwave on Vegetation using LDAS-Monde

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Overview

This study aims to assess the potential of the LDAS-Monde platform, a land data assimilation system developed by Météo-France, to monitor the impact on vegetation state of the 2018 summer heatwave over Western Europe. The LDAS-Monde is forced by ECMWF's (i) ERA5 reanalysis, and (ii) the Integrated Forecasting System High Resolution operational analysis (IFS-HRES), used in conjunction with the assimilation of Copernicus Global Land Service (CGLS) satellite-derived products, namely the Surface Soil Moisture (SSM) and the Leaf Area Index (LAI).

The study of long time series of satellite derived CGLS LAI (2000-2018) and SSM (2008-2018) highlights marked negative anomalies for July 2018 affecting large areas of northwestern Europe and reflects the impact of the heatwave. Such large anomalies spreading over a large part of the domain of interest have never been observed in the LAI product over this 19-yr period.

LDAS-Monde land surface reanalyses were produced at spatial resolutions of 0.25° × 0.25° (January 2010 to December 2018) at global scale. Within the area of interest, a 0.10° × 0.10° spatial resolution experiment has also been produced (April 2016 to December 2018). Both configurations of LDAS-Monde forced by either ERA5 or HRES capture well the vegetation state in general and for this specific event, with HRES configuration exhibiting better monitoring skills than ERA5 configuration. The consistency of ERA5 and IFS HRES driven simulations over the common period (April 2016 to December 2018) allowed to disentangle and appreciate the origin of improvements observed between the ERA5 and HRES.

If the improvement from LDAS-Monde analysis on control variables (soil moisture from layers 2 to 8 of the model representing the first meter of soil and LAI) from the assimilation of SSM and LAI was expected, other model variables benefit from the assimilation through biophysical processes and feedback in the model. Finally, we also found added value of initializing 8-day land surface HRES driven forecasts from LDAS-Monde analysis when compared with model-only initial conditions. Accurate initial conditions is key for forecasting the Land Surface Variables.

LDAS-Monde

An offline global capacity integration of satellite derived Surface Soil Moisture and Leaf Areas Index in the SURFEX modeling platform of Météo-France, it includes:

- The **ISBA Land Surface Model** (LSM) that solves the energy and water budgets at the surface level and describes the exchanges between the land surface and the atmosphere. We use the **CO_2-responsive version** of ISBA that simulates the diurnal cycle of water and carbon fluxes, plant growth and key vegetation variables. Transfers of water and heat through the soil rely on a **multilayer diffusion scheme**.
- **CTRIP river routing system**: coupled daily with ISBA to simulate streamflows of the main rivers.
- Data assimilation schemes like the **Simplified Extended Kalman Filter**, SEKF (EnSRF also available, PF under development)

LDAS-Monde reanalysis involves several data-set:

- Atmospheric forcing like ECMWF **ERA-5 atmospheric reanalyses** to force ISBA
- **Surface Soil Moisture** observations (SSM): we use the Copernicus Global Land Service (CGLS) Soil Water Index
- **Leaf Area Index** observations (LAI): we use the CGLS LAI product, Observations are available on a 10-d basis.

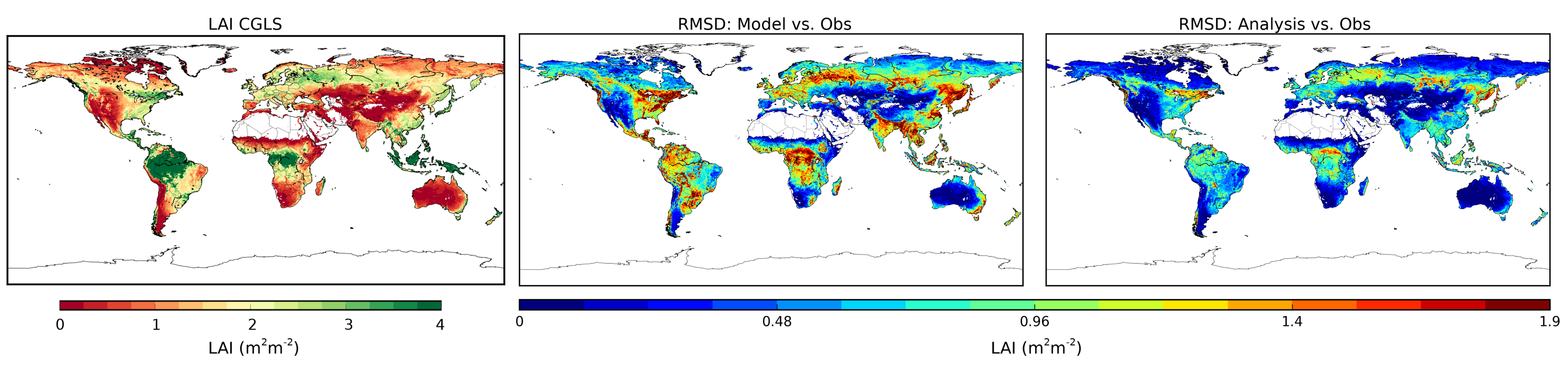


Figure 1: Mean observed LAI (left), RMSD for LDAS-Monde open-loop (middle) and analysis (right) over 2010-2018 at 0.25°x0.25° spatial Resolution. LDAS-Monde is forced by ERA5 (LDAS-ERA5).

Summer 2018 heatwave in Europe

ECMWF newsletter#157 (autumn 2018): April to August 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.

The Earth Observations point of view : CGLS LAI and SWI, strong impact of the heatwave

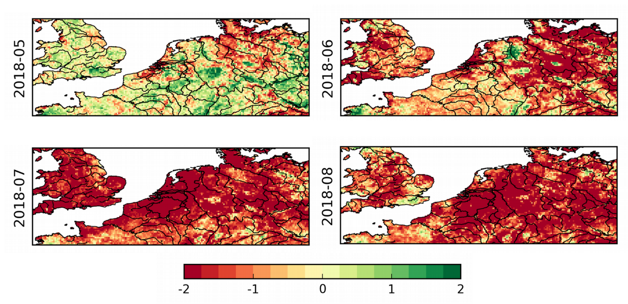


Figure 2: LAI monthly anomalies (scaled by stdev) over 2000-2018 for May to August 2018

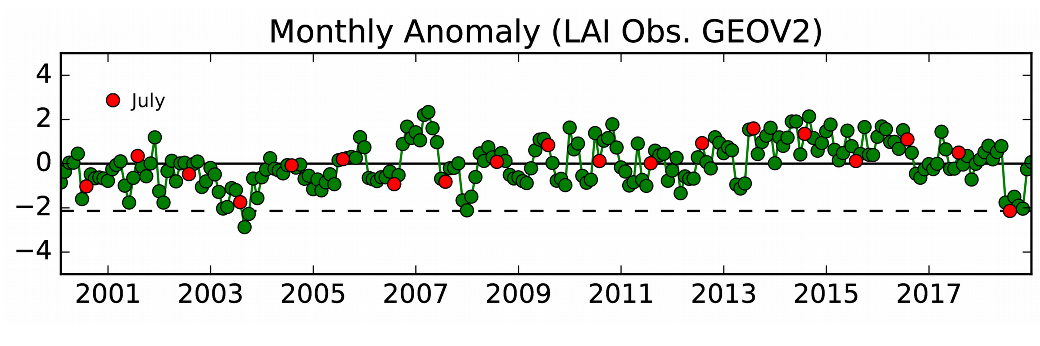


Figure 3: Monthly Anomaly time-series (scaled by the standard deviation) of satellite derived GEOV2 Leaf Area Index over 2000–2018. Months of July are highlighted in red, straight dashed lines represent values for July 2018.

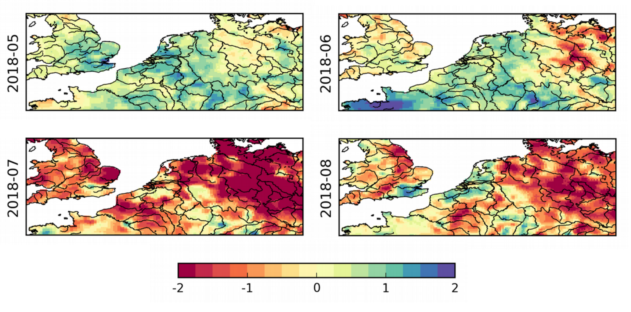


Figure 4: SWI monthly anomalies (scaled by stdev) over 2008-2018 for May to August 2018

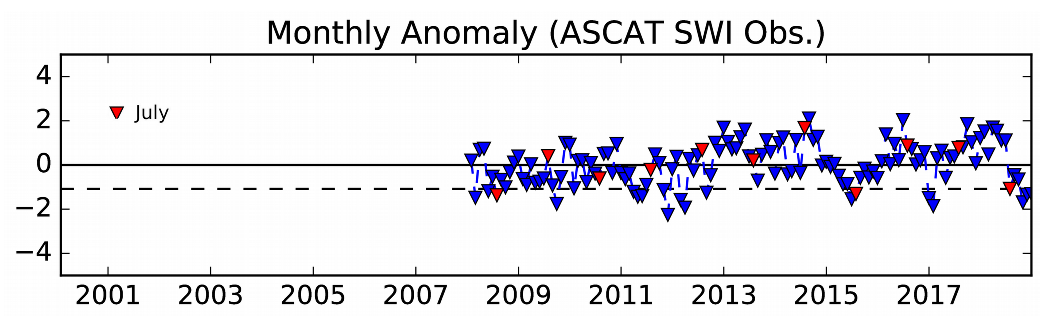


Figure 5: Monthly Anomaly time-series (scaled by the standard deviation) of satellite derived ASCAT SWI over 2008–2018. Months of July are highlighted in red, straight dashed lines represent values for July 2018.

The study of long time series of satellite derived CGLS LAI (2000-2018) and SSM (2008-2018) highlights marked negative anomalies for July 2018 affecting large areas of northwestern Europe and reflects the impact of the heatwave. Such large anomalies spreading over a large part of the domain of interest have never been observed in July for the LAI product over this 19-yr period.

LDAS-Monde forced by ERA5 (LDAS-ERA5) could lead to large scale long term reanalysis of the Land Surface Variables: useful to monitor the impact of extreme events...

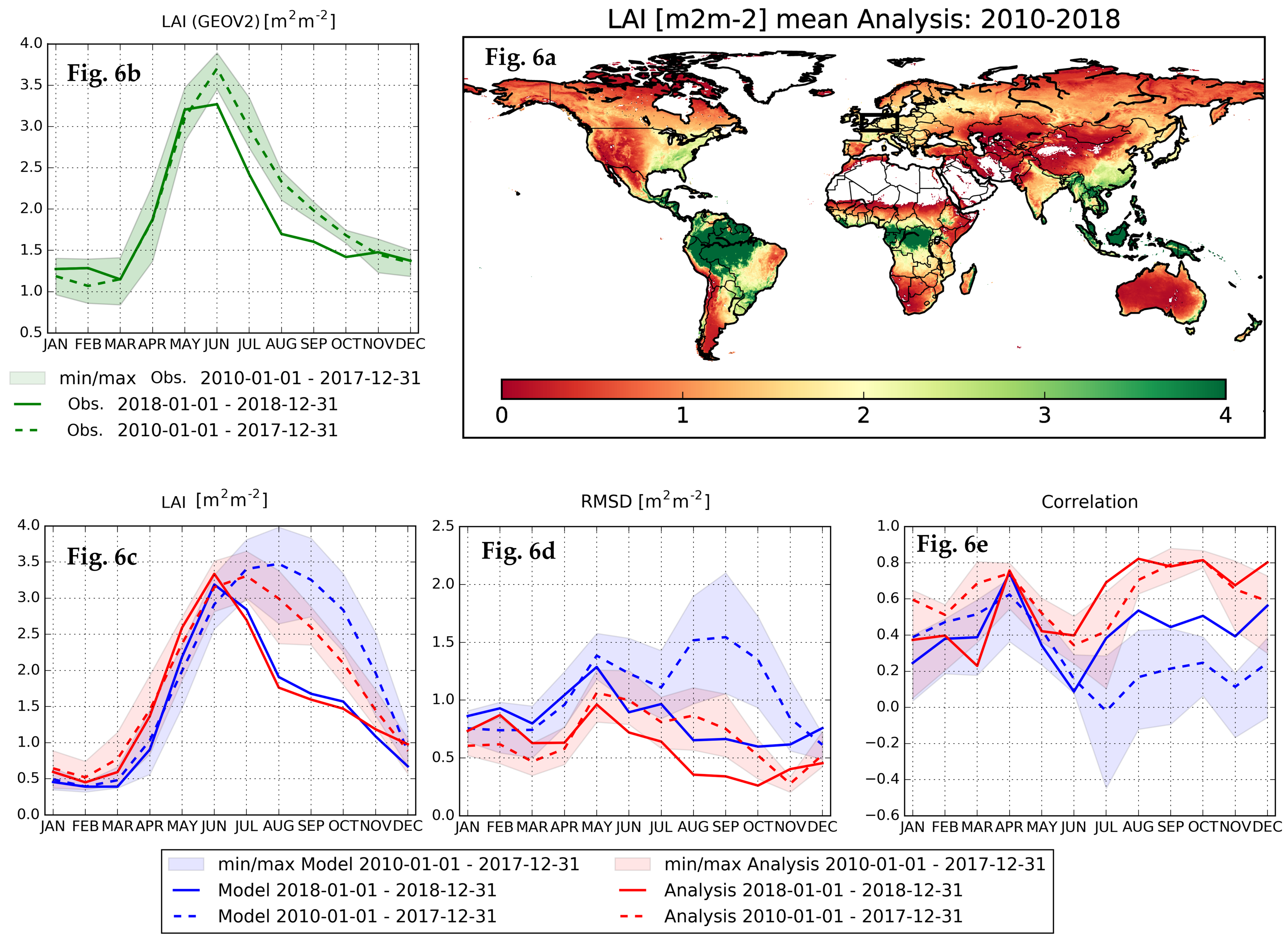


Figure 6: a) Global reanalysis of LAI from LDAS-Monde averaged over 2010-2018 (0.25°x0.25°). **b)** Satellite derived LAI seasonal cycle averaged over 2010-2017 (dashed line) and for the year 2018 and the domain presented in figure 2. **c)** Same as b) for LAI from LDAS-Monde open-loop, i.e. no assimilation, (in blue) and LDAS-Monde analysis (in red). **d)** Seasonal RMSD values between LAI from the model (in blue), the analysis (in red) and the observations for 2010-2017 (dashed line) and 2018 (solid line). **e)** Same as d) for correlations values.

...LDAS-Monde can also be forced by higher spatial resolution atmospheric forcing like ECMWF IFS-HRES (LDAS-HRES)

Using HRES leads to 0.10°x0.10° spatial resolution reanalysis of the LSVs (available from 04/2016)

Neither the open-loop nor the analysis capture the maximum LAI peak well, analysis efficiently corrects for the open-loop delay during the senescence phase.

Good agreement between the analyzed LAI and the observed annual cycle, particularly for 2018 during the vegetation senescence phase.

LDAS-ERA5 and LDAS-HRES open-loops are quite comparable, LDAS-HRES open-loop being slightly better than LDAS-ERA5 open-loop in representing LAI (figure 8).

The analyses add skill to both open-loops which indicates the healthy behavior from the land data assimilation system.

Figure 8: a) RMSD and **b)** correlation values between LAI from the model forced by either ERA5 or HRES, the analysis forced by either ERA5 or HRES observed LAI estimates from April 2016 to October 2018.

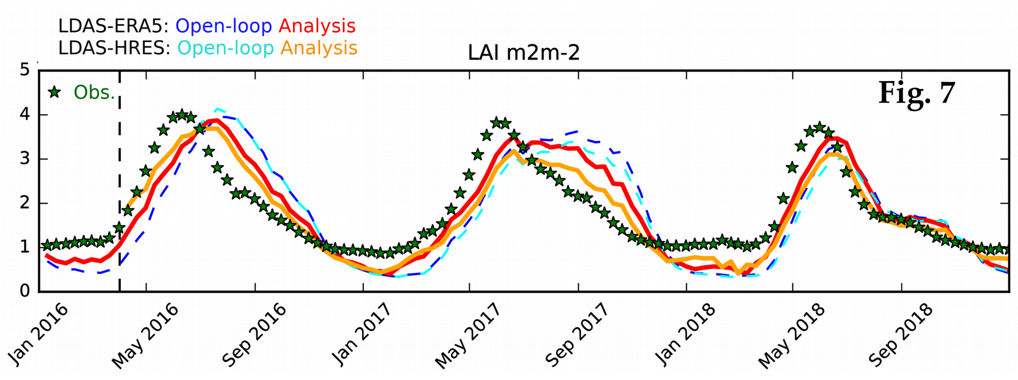
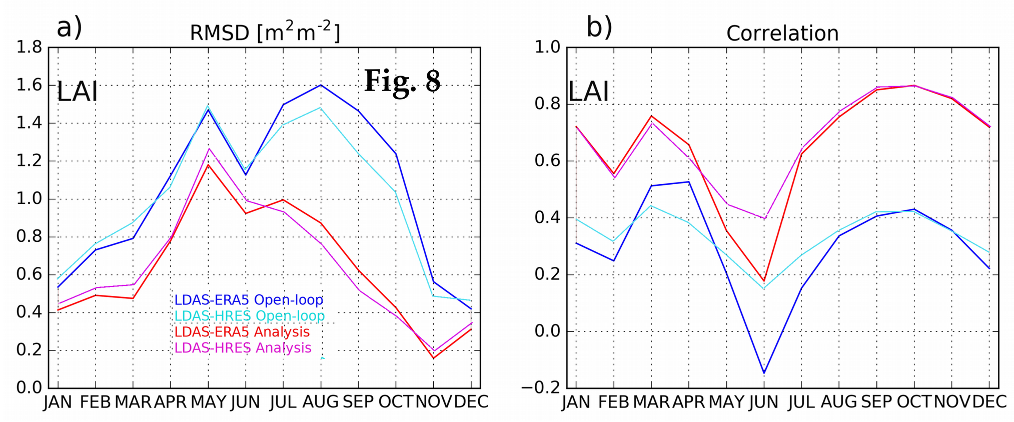


Figure 7: Observed CGLS GEOV2 Leaf Area Index (LAI) as well as LDAS-Monde LAI time-series forced by either ERA5 or HRES.



LDAS-Monde analysis provides better initial conditions to forecast LSVs that its model counterpart

Another added value of using IFS-HRES consists in its forecast capacity. Forecast of LAI initialized by LDAS-Monde analysis with a leading time up to 8-days has better skills than (i) a forecast initialized by the open-loop and (ii) the openloop itself.

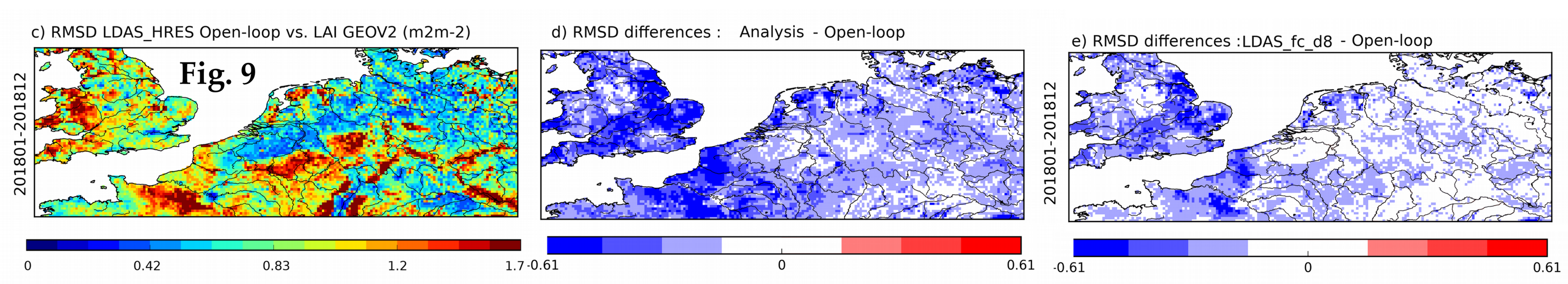


Figure 9: c) RMSD values between the open-loop (ran for 2018, only) and the observed LAI. **d)** RMSD differences between the open-loop (analysis) and the observed LAI (blue indicates that the analysis is better: 82%). **e)** Same as d) between the open-loop and an 8-day forecast initialized by the analysis (blue indicates that the forecast is better: 49%)

This study has investigated the capability of LDAS-Monde offline land data assimilation system to represent the impact of the summer 2018 heatwave on vegetation. Satellite derived leaf area index and surface soil moisture were assimilated in LDAS-Monde forced by either ERA5 reanalyses (0.25° × 0.25° spatial resolution) or IFS HRES operational product (0.10° × 0.10° spatial resolution) from ECMWF. Both analysis experiments were able to represent the impact of the heatwave on vegetation well with an advantage to the IFS HRES configuration.

The possibility of forecasting LSVs was tested and it was shown that a forecast of LAI from analyzed initial conditions has more skill than an open-loop (with a persistence of at least 8 days). Combining ERA5 atmospheric re-analysis, HRES analysis and its forecast within LDAS-Monde is highly relevant to foster research for land applications at various timescales from daily to annual.

Further reading: Albergel, C.; Dutra, E.; Bonan, B.; Zheng, Y.; Munier, S.; Balsamo, G.; de Rosnay, P.; Munoz-Sabater, J.; Calvet, J. Monitoring and Forecasting the Impact of the 2018 Summer Heatwave on Vegetation. Remote Sens. 2019, 11(5), 520; doi: 10.3390/rs11050520

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