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

Alberge C.\textsuperscript{1}, E. Dutra\textsuperscript{2}, B. Bonan\textsuperscript{1}, Y. Zheng\textsuperscript{1}, S. Munier\textsuperscript{1}, G. Balsamo\textsuperscript{3}, P. de Rosnay\textsuperscript{3}, J. Muñoz-Sabater\textsuperscript{3} and J.-C. Calvet\textsuperscript{1}

\textsuperscript{1} CNRM - Université de Toulouse, Météo-France, CNRS, Toulouse, France
\textsuperscript{2} Instituto Dom Luiz, IDL, Faculty of Sciences, University of Lisbon, Portugal
\textsuperscript{3} ECMWF, Reading, UK

2nd SURFEX User Workshop in Toulouse, Fr, 18-19 March 2019
Study the vegetation and terrestrial water cycles

- Current fleet of Earth Satellite missions holds an unprecedented potential to quantify Land Surface Variables (LSVs) \cite{Lettenmaier2015}
  - 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 \cite{Reichle2007}
  
  - **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

<table>
<thead>
<tr>
<th>Model</th>
<th>Domain</th>
<th>Atm. Forcing</th>
<th>DA Method</th>
<th>Assimilated Obs.</th>
<th>Observation Operator</th>
<th>Control Variables</th>
<th>Additional Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISBA</td>
<td>Global (2010 – 2018)</td>
<td>ERA-5 Res.: 0.25°x0.25°</td>
<td>SEKF</td>
<td>SSM (CGLS SWI + cdf matching)</td>
<td>Second layer of soil (1-4cm)</td>
<td>Layers of soil 2 to 8 (1-100cm)</td>
<td>Coupling with CTRIP (0.5°)</td>
</tr>
</tbody>
</table>

- 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
LDAS-Monde experimental set up

<table>
<thead>
<tr>
<th>Model</th>
<th>Domain</th>
<th>Atm. Forcing</th>
<th>DA Method</th>
<th>Assimilated Obs.</th>
<th>Observation Operator</th>
<th>Control Variables</th>
<th>Additional Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISBA</td>
<td>Global (2010 – 2018)</td>
<td>ERA-5 Res.: 0.25°x0.25°</td>
<td>SEKF</td>
<td>SSM (CGLS SWI + cdf matching)</td>
<td>Second layer of soil (1-4cm)</td>
<td>Layers of soil 2 to 8 (1-100cm)</td>
<td>Coupling with CTRIP (0.5°)</td>
</tr>
<tr>
<td>Multi-layer soil model CO₂-responsive version (Interactive vegetation)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RMSD: Model vs. Obs

RMSD: Analysis vs. Obs

2010-2018

LAI (m²/m²)
LDAS-Monde goes global

- NOAA: Summer 2018 was Europe's warmest summer since continental records began in 1910
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

2nd SURFEX User Workshop, 18-19 March 2019
The Earth Observations point of view: **CGLS GEOV2 and SWI**
Monthly anomaly (scaled by stdv)

**Impact of the Summer 2018 heatwave on LSVs**
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)

Seasonal cycles:
- 2018 quite different from 2010-2017
- Analysis improvements over Model simulation
Impact of the Summer 2018 heatwave on LSVs

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

<table>
<thead>
<tr>
<th></th>
<th>2010:2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>JUL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>2010:2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>JUL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>2010:2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>JUL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>2010:2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>JUL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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)
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)
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 experiment 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**
- 4 experiments: 2 analyses and their 2 openloops
- Seasonal scores over April 2016 to October 2018: each experiments vs. SSM 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

2\textsuperscript{nd} SURFEX User Workshop, 18-19 March 2019
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

- 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

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

➔ 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** (offline, 2.5 km x 2.5 km spatial resolution) under study


2nd SURFEX User Workshop, 18-19 March 2019
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)

2nd SURFEX User Workshop, 18-19 March 2019
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