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

Albergel C.\textsuperscript{1}, Munier S.\textsuperscript{1}, Leroux D.\textsuperscript{1} and Calvet J.-C.\textsuperscript{1}

With help from many others!

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

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
<table>
<thead>
<tr>
<th>Model</th>
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LAI (m²m⁻²)

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Study the vegetation and terrestrial water cycles

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Legend:

- **LAI (m²/m²)**
- **Analysis-Model**
- **FRANCE**

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Study the vegetation and terrestrial water cycles

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**LAI (m²/m²)**

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**Legend:**
- **Model**
- **Obs**
- **Analysis**

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Study the vegetation and terrestrial water cycles

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![Map of Spain showing LAI (m$^2$m$^{-2}$)](image)
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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**Maps:**

- **ASCAT SWI:** (C-band microwave sensor, 0.1°) (seasonal bias correction)
- **LAI GEOV1:** (SPOT-VGT / PROBA-V, 1km)

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

[Link to Copernicus:](http://land.copernicus.eu/global/)
**LDAS-Monde assessment over North America**

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

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assimilated SSM &amp; LAI (analysis has to be closer to them than the open-loop !)</td>
<td><a href="https://land.copernicus.eu/">https://land.copernicus.eu/</a></td>
</tr>
<tr>
<td>In situ measurements of soil moisture from USCRN network</td>
<td><a href="https://www.ncdc.noaa.gov/crn">https://www.ncdc.noaa.gov/crn</a></td>
</tr>
<tr>
<td>River discharge from USGS</td>
<td><a href="https://waterdata.usgs.gov/nwis">https://waterdata.usgs.gov/nwis</a></td>
</tr>
<tr>
<td>Evapotranspiration from the GLEAM project</td>
<td><a href="http://www.gleam.eu">http://www.gleam.eu</a></td>
</tr>
<tr>
<td>Gross Primary Production from the FLUXCOM project</td>
<td><a href="http://www.fluxcom.org">http://www.fluxcom.org</a></td>
</tr>
</tbody>
</table>
LDAS-Monde assessment over North America

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

- Open-loop Analysis

- RMSD [m$^3$ m$^{-3}$]

- Correlation
LDAS-Monde assessment over North America

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

![Maps and graphs showing LAI values and analysis over North America](image-url)
LDAS-Monde assessment over North America

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

<table>
<thead>
<tr>
<th>Correlations</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>N stations (significant Correlations values)</td>
<td>108</td>
</tr>
<tr>
<td>% stations R(Analysis) &gt;= R(Open-loop)</td>
<td>74%</td>
</tr>
</tbody>
</table>

**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*)

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<th>NEE</th>
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<tbody>
<tr>
<td>N stations (significant R values)</td>
<td>44</td>
<td>44</td>
<td>40</td>
</tr>
<tr>
<td>N stations (%) R(Analysis) &gt; R(Open-loop)</td>
<td>30 (68%)</td>
<td>32 (72%)</td>
<td>31 (77%)</td>
</tr>
<tr>
<td>N stations (%) RMSD(Analysis) &lt; RMSD(Open-loop)</td>
<td>32 (72%)</td>
<td>33 (75%)</td>
<td>29 (72%)</td>
</tr>
</tbody>
</table>

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

Blue : R(analysis) is better than R(open-loop)
Study the terrestrial water cycle using SODA LDAS-Monde assessment over North America

- River discharge from USGS
- **NSE** values are computed for each stations *(monthly values scaled to the drainage area)*
- **Normalized Information Contribution** used to quantify improvement/degradation

<table>
<thead>
<tr>
<th>N stations</th>
<th>&gt;4-yr of data</th>
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<tbody>
<tr>
<td>3155</td>
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| Analysis impact > |3%| |
|-------------------|---|
| 503 (16%)         |   |

<table>
<thead>
<tr>
<th>Impact is</th>
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<tbody>
<tr>
<td>+3 %</td>
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<tr>
<td>-3 %</td>
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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)

Maps showing open-loop and analysis results for North America, with graphs depicting RMSD and correlation over different months.
Gross Primary Production from the FLUXCOM project (Jung et al., 2017)
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**

Averaged LAI over North America

Initial conditions from analysis (USA 01/2007 to 04/2016)
LDAS-Monde over France

Analysis – Model (2017)

LAI (m$^2$m$^{-2}$)

<table>
<thead>
<tr>
<th>Year</th>
<th>Model</th>
<th>Obs</th>
<th>Analysis</th>
<th>Analysis-Model</th>
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<tr>
<td>2017-07</td>
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<td>2017-08</td>
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<td>2017-09</td>
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<th>Month</th>
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<th>DRAINC</th>
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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

  - 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 and water resources (funding? MF/ED/MOPGA)
LDAS recent publications:


Contact : clement.albergel@meteo.fr
Study the terrestrial water cycle using SODA LDAS-Monde processing chain

prepareForcing.py
Ajuste le domaine
Fichiers journaliers

e.g. SAFRAN,
ERA-Interim

ldasPre.py
Prépare les observations
(e.g. CDF matching SSM)

Assimilation

IdasPost.py
Visualisation & Statistiques

SURFEX
Conditions initiales et forçage

Observations

Analyses
Study the terrestrial water cycle using SODA LDAS-Monde processing chain

- Monthly files (year 1 for spinup)
- Daily files (open-loop and analysis)

Open-loop outputs

Remotely sensed Observations

Analysis Outputs

**Hendrix**

1. Run pgd_prep
2. Run PrepareForcing
3. Run job_spinup
4. Run LdasPre
5. Run LdasPost
6. Run LdasPost

**Beaufix**

1. Run pgd_prep
2. Run job_spinup
3. Run Open-Loop
4. Run Analysis

**Steps:**
- Run pgd_prep
- Run PrepareForcing
- Run job_spinup
- Run Open-Loop
- Run Analysis
- Run LdasPre
- Run LdasPost

**Commands:**
- Run pgd_prep
- Run PrepareForcing
- Run job_spinup
- Run Open-Loop
- Run Analysis
- Run LdasPre
- Run LdasPost

**Variables:**
- PGD, PGD_fractown, PREP, TRIP_PREP