Assimilation of Satellite Data for Monitoring and Forecasting Agricultural Drought and Water Resources

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Why?

- **Droughts:** The single most detrimental and expensive natural risk

How?

- **Observations** (in situ, remote sensing)
  - Ability to monitor
- **Land Surface Models (LSMs)**
  - Ability to monitor and forecast!
- **Combination of the two:** Data Assimilation (analyses)
  - Better initial state for forecasting surface variables
Research Questions

• Can LDAS-Monde go from a monitoring mode to a forecast mode?

• Can LDAS-Monde represent agricultural droughts?
Methods : LDAS Setup

Model only Configuration (Open-Loop/OL)
Methods : LDAS Setup

Analysis Configuration (SEKF)

Atmospheric Forcing
Initial Conditions

SURFEX\textsuperscript{[2,3]}
ISBA LSM
CO\textsubscript{2} Responsive
Multi Layer

LDAS Monde\textsuperscript{[4,5]}
SEKF Assimilation

Satellite Observations
LAI & SSM

Analysis (SEKF) outputs
LAI, SSM, ET...
Methods : LDAS Setup

Forecast Configuration

Atmospheric Forcing : 14-day Forecast

Initial conditions : Model (OL) outputs

OR

Initial conditions : Analysis (SEKF) outputs

SURFEX\textsuperscript{[2,3]}

ISBA LSM

CO\textsubscript{2} Responsive Multi Layer

OL Init

14 day FC

LAI, SSM, ET...

SEKF Init

14 day FC

LAI, SSM, ET...

Does the initialization have an impact on the quality of forecasted surface variables?
### Experiment Configuration and Evaluation

- **Domain**: CONUS
- **Period**: 2017-2018
- **Evaluation**:
  - CGLS SSM - Assimilated
  - CGLS LAI - Assimilated
  - ALEXI Evapotranspiration (ET)

#### Metrics:

- **NIC**:
  \[
  NIC_R = \frac{R_{(FCx EKF)} - R_{(FCx OL)}}{1 - R_{(FCx OL)}} \times 100
  \]

- **NIC RMSD**:
  \[
  NIC_{RMSD} = \frac{RMSD_{(FCx EKF)} - RMSD_{(FCx OL)}}{RMSD_{(FCx OL)}} \times 100
  \]
Evaluation against CGLS SSM

- Assimilation has positive impact on Correlation and RMSD
  - This impact doesn’t persist

**Figure 1.** Spatial patterns of persistence of SEKF impact on simulated SSM as compared to CGLS SSM as forecast lead time increases. Upper row of maps show NICR values at FC2, FC8, and FC14. Bottom row of maps are NICRMSD values at the same forecast lead times. Note that red color for correlation is improvement from assimilation, whereas blue is improvement for RMSD.
Evaluation against CGLS SSM

- At early forecast days, correlation shows an improvement from the assimilation
- Improvement persists until ~FC5, then both initializations result in similar values

**Figure 2.** Temporal evolution of SSM correlation (solid lines) and RMSD (dashed lines) averaged over the domain. OL initializations are in blue, SEKF initializations are in red.
Evaluation against CGLS LAI

- Assimilation has overall positive impact on R and RMSD
  - Impact persists far longer than with SSM
  - Patches of negative impacts are being investigated

Figure 3. Spatial patterns of persistence of SEKF impact on simulated LAI as compared to CGLS LAI as forecast lead time increases. Upper row of maps show NICR values at FC2, FC8, and FC14. Bottom row of maps are NICRMSD values at the same forecast lead times. Note that red color for correlation is improvement from assimilation, whereas blue is improvement for RMSD.
Evaluation against CGLS LAI

- SEKF initializations are better than OL initializations at ALL forecast lengths
- Drop in R, rise in RMSD explained by LAI observations every 10 days

Figure 4. Temporal evolution of LAI correlation (solid lines) and RMSD (dashed lines) averaged over the domain. OL initializations are in blue, SEKF initializations are in red.
Evaluation against ALEXI ET

- Strongest impact is in the center “Great Plains” corridor of the U.S.
  - Area of large agricultural importance

Figure 5. Spatial patterns of persistence of SEKF impact on simulated ET as compared to ALEXI ET as forecast lead time increases. Upper row of maps show NICR values at FC2, FC8, and FC14. Bottom row of maps are NICRMSD values at the same forecast lead times. Note that red color for correlation is improvement from assimilation, whereas blue is improvement for RMSD.
Evaluation against ALEXI ET

- SEKF initializations are better than OL initializations at ALL forecast lengths
- Persistence of correlation throughout the forecast period

Figure 6. Temporal evolution of ET correlation (solid lines) and RMSD (dashed lines) averaged over the domain. OL initializations are in blue, SEKF initializations are in red.
Research Questions

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Links to Agriculture

- Inter-annual variability and drought events are well captured

<table>
<thead>
<tr>
<th>Correlation to Yield Anomalies (R)</th>
<th></th>
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<tbody>
<tr>
<td>Observations</td>
<td>0.92</td>
</tr>
<tr>
<td>SEKF (Data Assimilation)</td>
<td>0.88</td>
</tr>
<tr>
<td>OL (No Assimilation)</td>
<td>0.80</td>
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</tbody>
</table>

**Figure 7.** Annual average LAI anomalies of observations (black stars), OL (blue line), and SEKF (red lines) estimates, compared to reported corn yield anomalies over Nebraska (green dots).
Research Questions

Can LDAS-Monde go from a monitoring mode to a forecast mode?

Can LDAS-Monde represent agricultural droughts?
Next Steps

  - Impact of each observation on the analysis (SSM and/or LAI)
  - LAI observations - optical products available every 10 days
    - Incompatible with clouds
    - Assimilate Vegetation Optical Depth (VOD) – microwave derived, available daily, as proxy of LAI
  - Analysis of extreme events

- Create an forecast alert system for agricultural droughts in LDAS-Monde
Thank you!

If you have any questions, please do not hesitate to ask them in the chat

Citations:
1 WMO 2017