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

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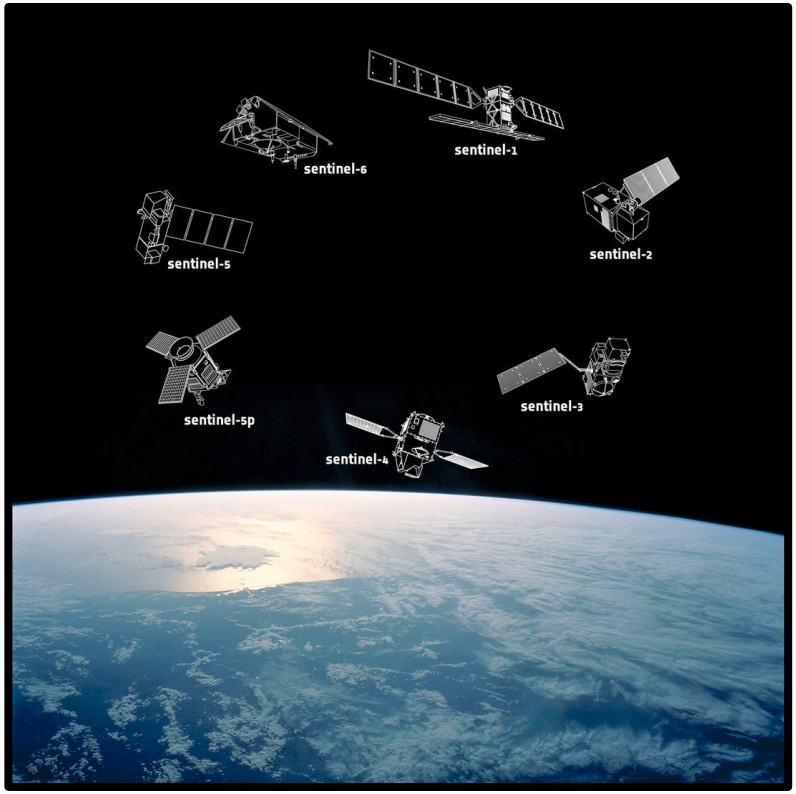
Monitoring and Forecasting

- **Why?**
  - **Droughts:** The single most detrimental and expensive natural risk [1]
- **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 inital state for forecasting surface variables**

http://photos.doniv.org/v/rann/43-design-of-the-rann.jpg.htm



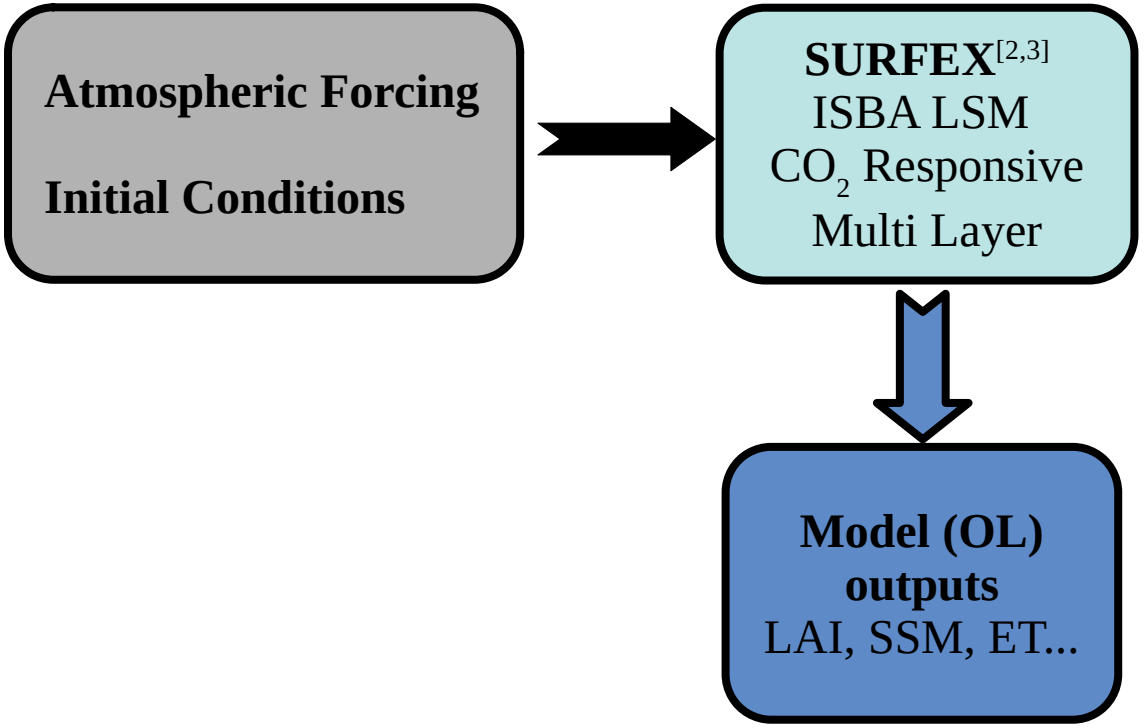
http://www.esa.int/ESA_Multimedia/Images/2014/04/Sentinel_family

Research Questions

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

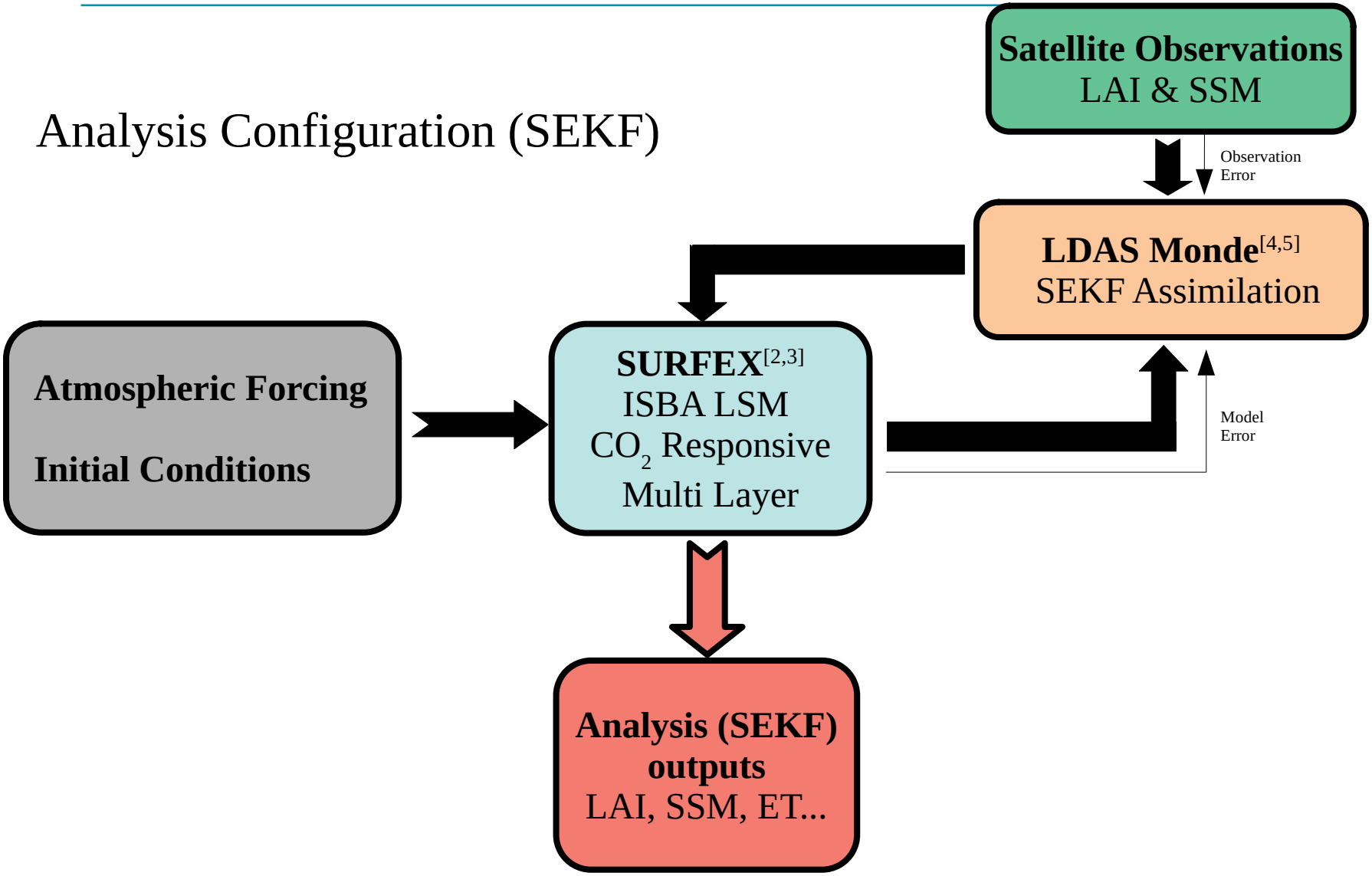
Methods : LDAS Setup

Model only Configuration (Open-Loop/OL)

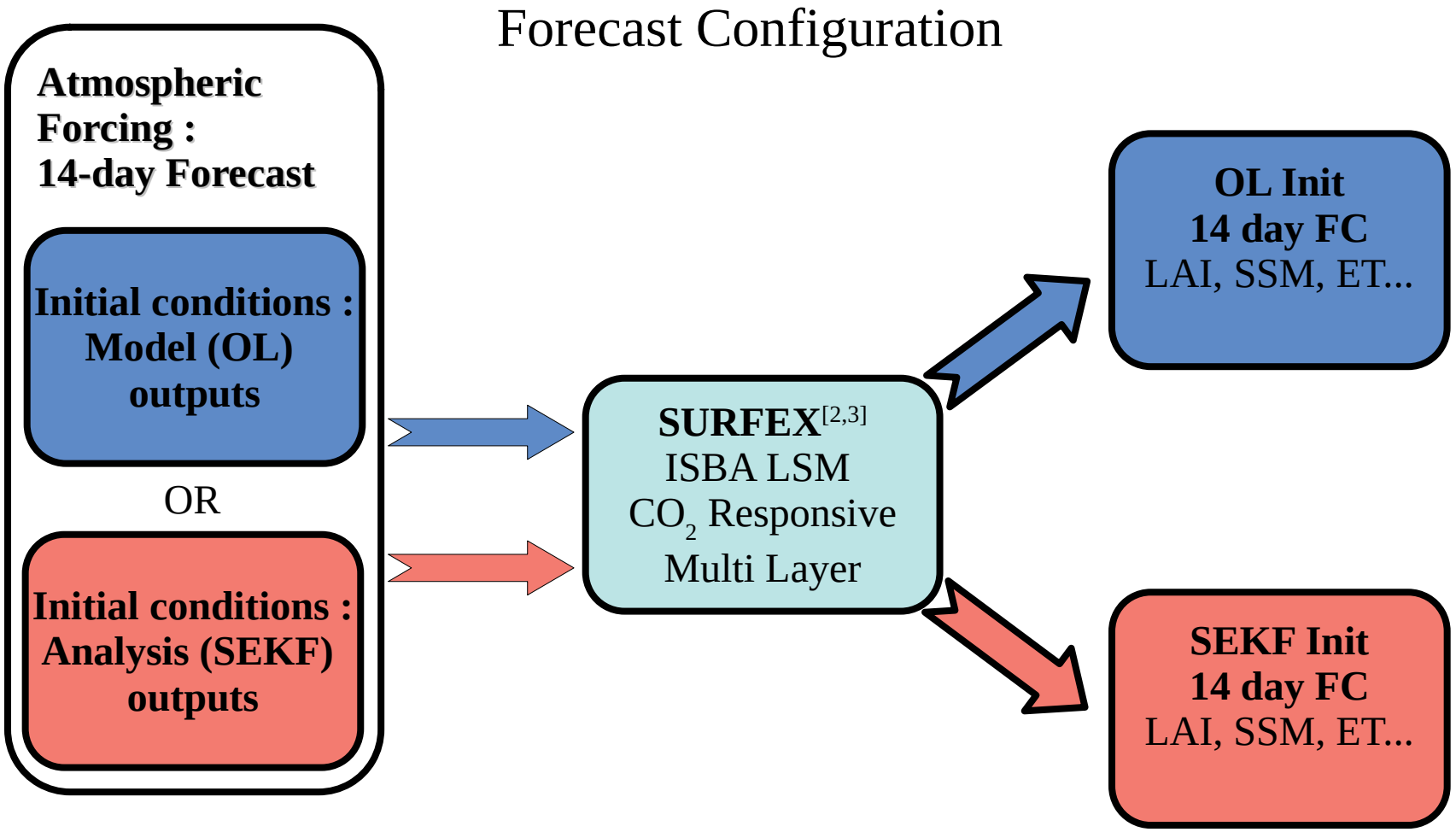


Methods : LDAS Setup

Analysis Configuration (SEKF)

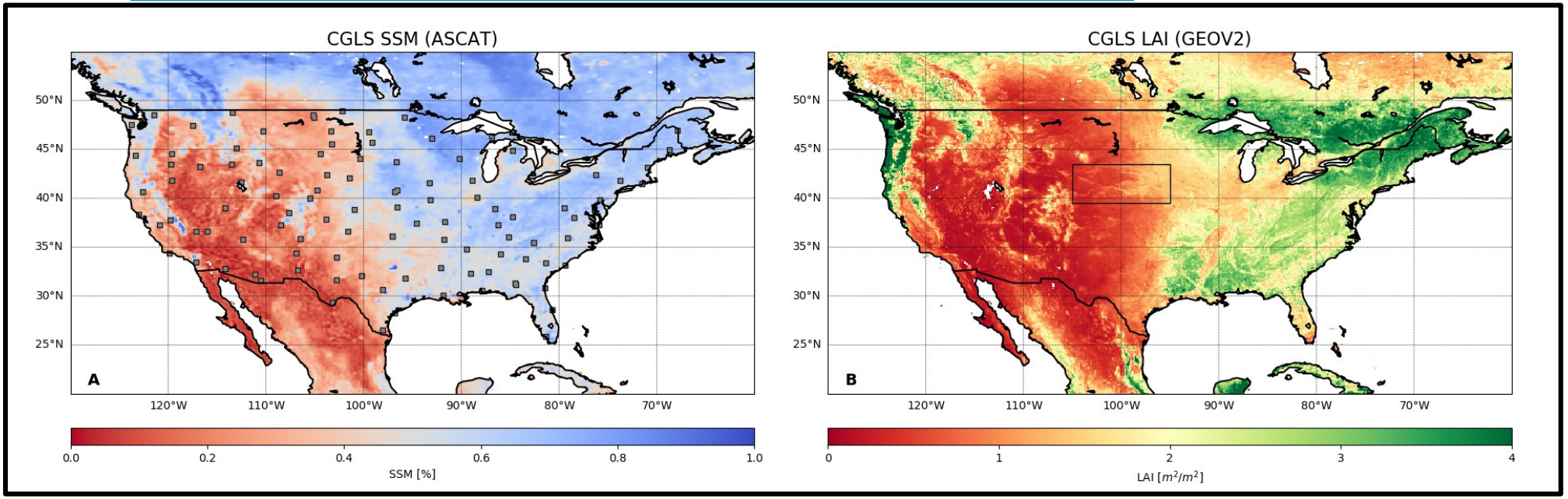


Methods : LDAS Setup



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 - Assimiled
  - CGLS LAI - Assimiled
  - ALEXI Evapotranspiration (ET)

Metrics :

$$NIC_R = \frac{R_{(FCx\,EKF)} - R_{(FCx\,OL)}}{1 - R_{(FCx\,OL)}} \times 100$$

$$NIC_{RMSD} = \frac{RMSD_{(FCx\,EKF)} - RMSD_{(FCx\,OL)}}{RMSD_{(FCx\,OL)}} \times 100$$

Evaluation against CGLS SSM

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

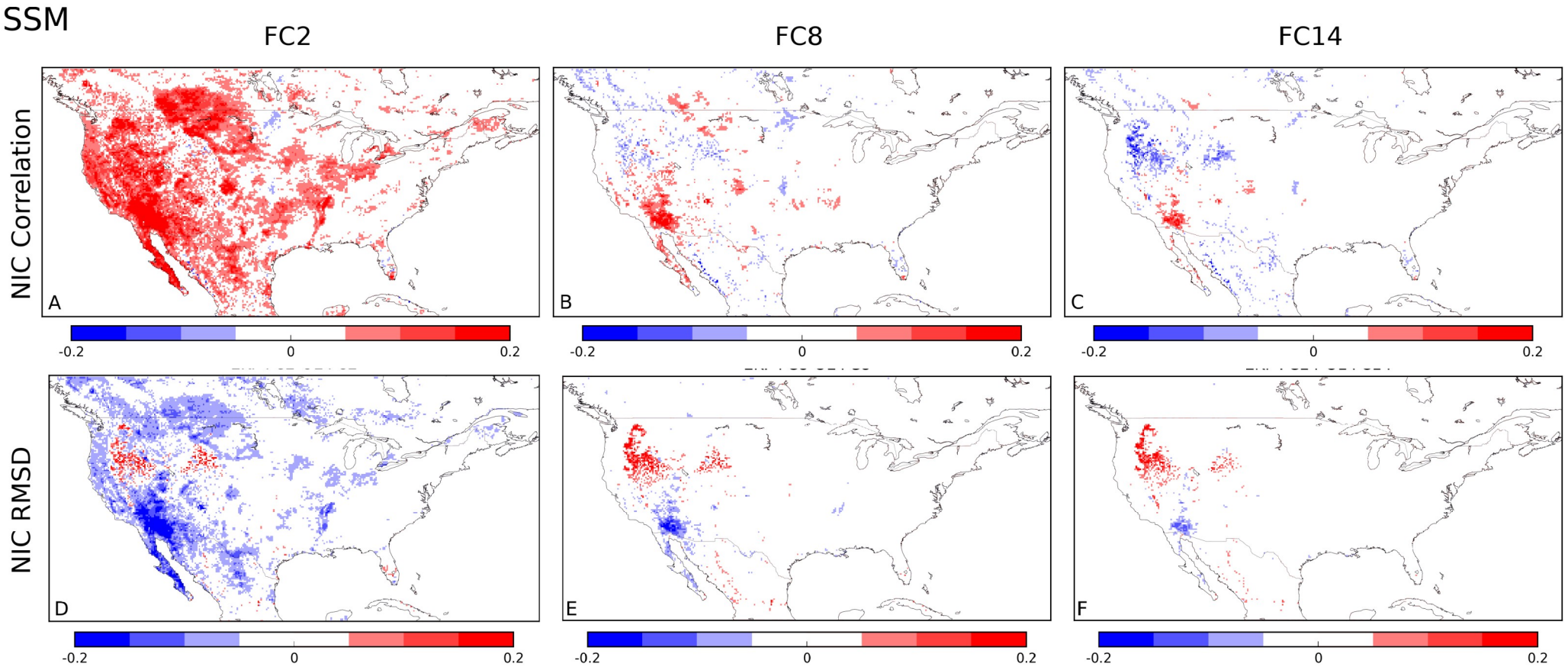


Figure 1. Spatial patterns of persistence of SEKF impact on simulated SSM as compared to CGLS SSM as forecast lead time increases. Upper row of maps show NIC*R* values at FC2, FC8, and FC14. Bottom row of maps are NICRMSD values at the same forecast lead times. Note that red color for correlation is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

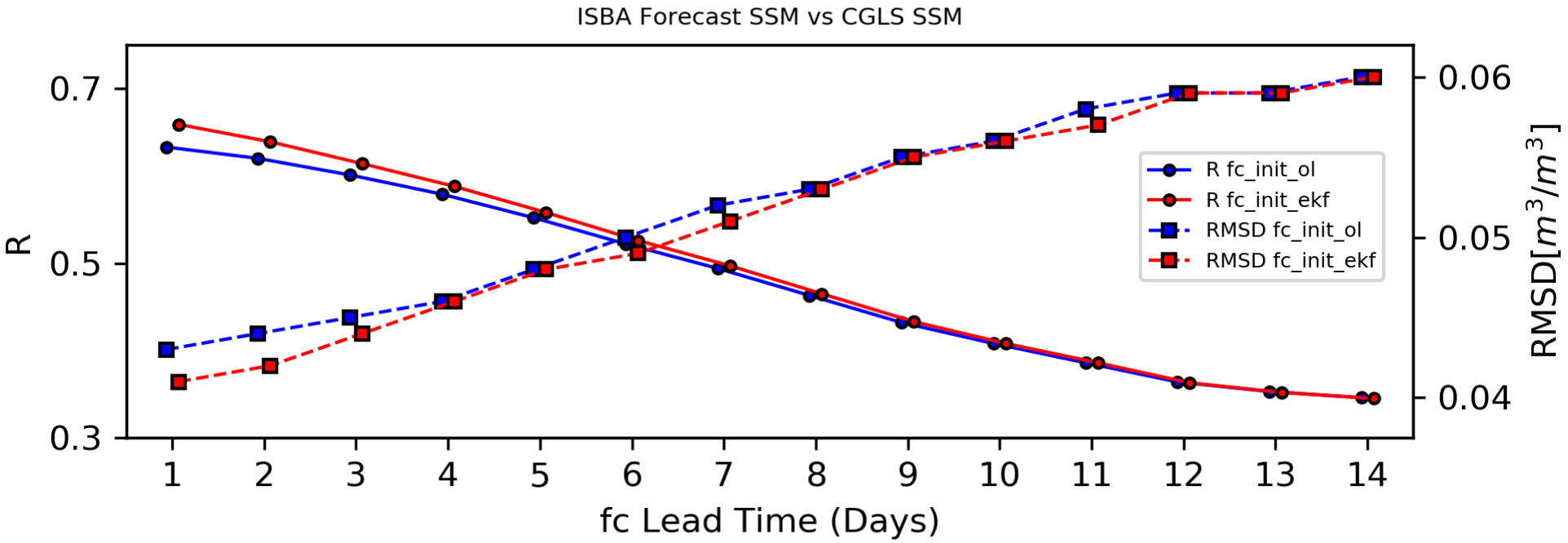


Figure 2. Temporal evolution of SSM correlation (solid lines) and RMSD (dashed lines) averaged over the domain. OL initializations are in blue, SEKF initializations are in red.

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

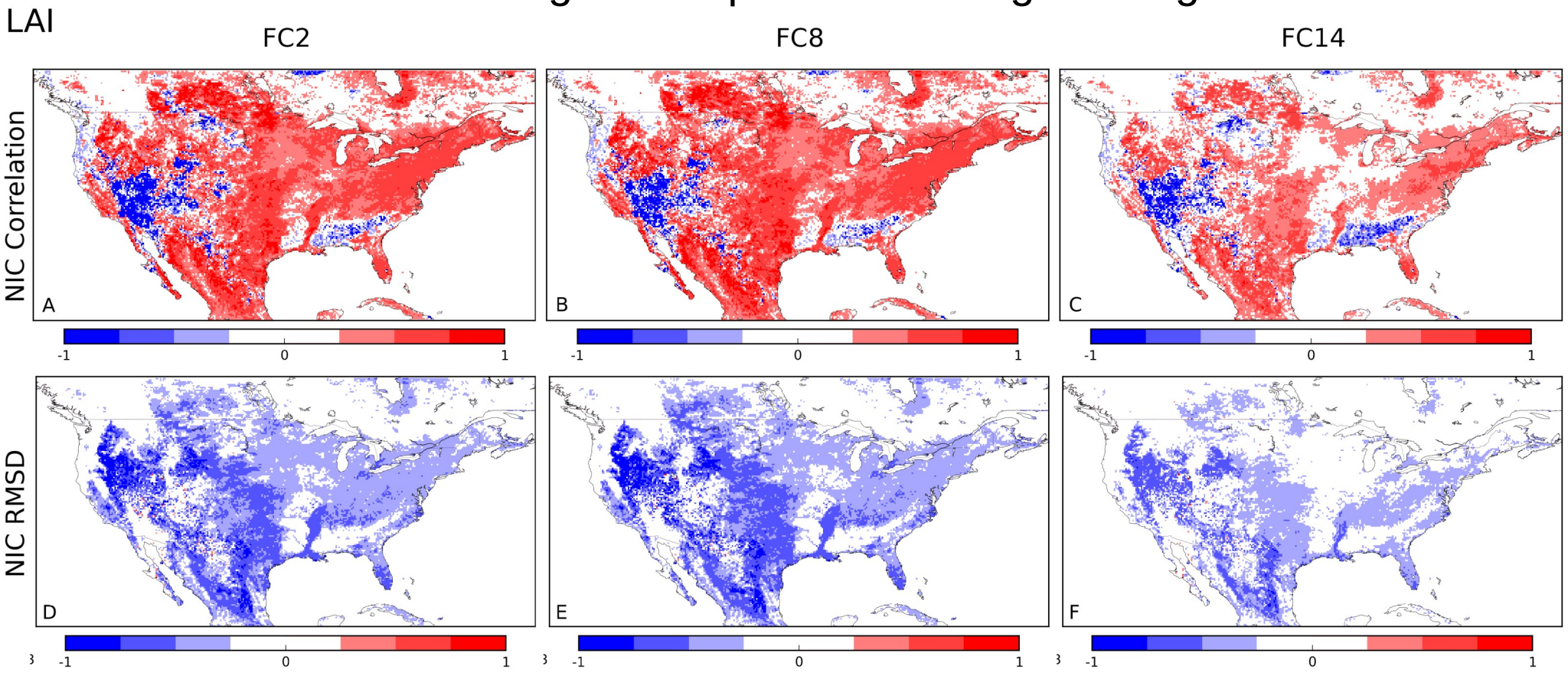


Figure 3. Spatial patterns of persistence of SEKF impact on simulated LAI as compared to CGLS LAI as forecast lead time increases. Upper row of maps show NIC*R* values at FC2, FC8, and FC14. Bottom row of maps are NICRMSD values at the same forecast lead times. Note that red color for correlation is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

Evaluation against CGLS LAI

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

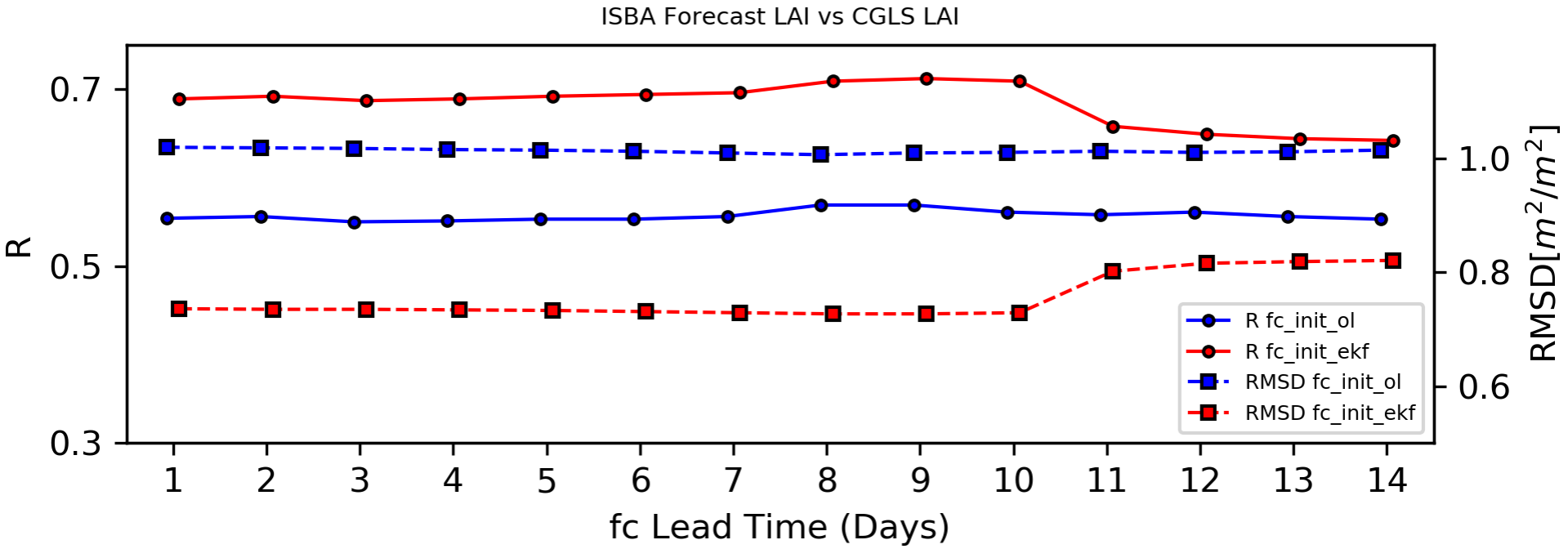


Figure 4. Temporal evolution of LAI correlation (solid lines) and RMSD (dashed lines) averaged over the domain. OL initializations are in blue, SEKF initializations are in red.

Evaluation against ALEXI ET

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

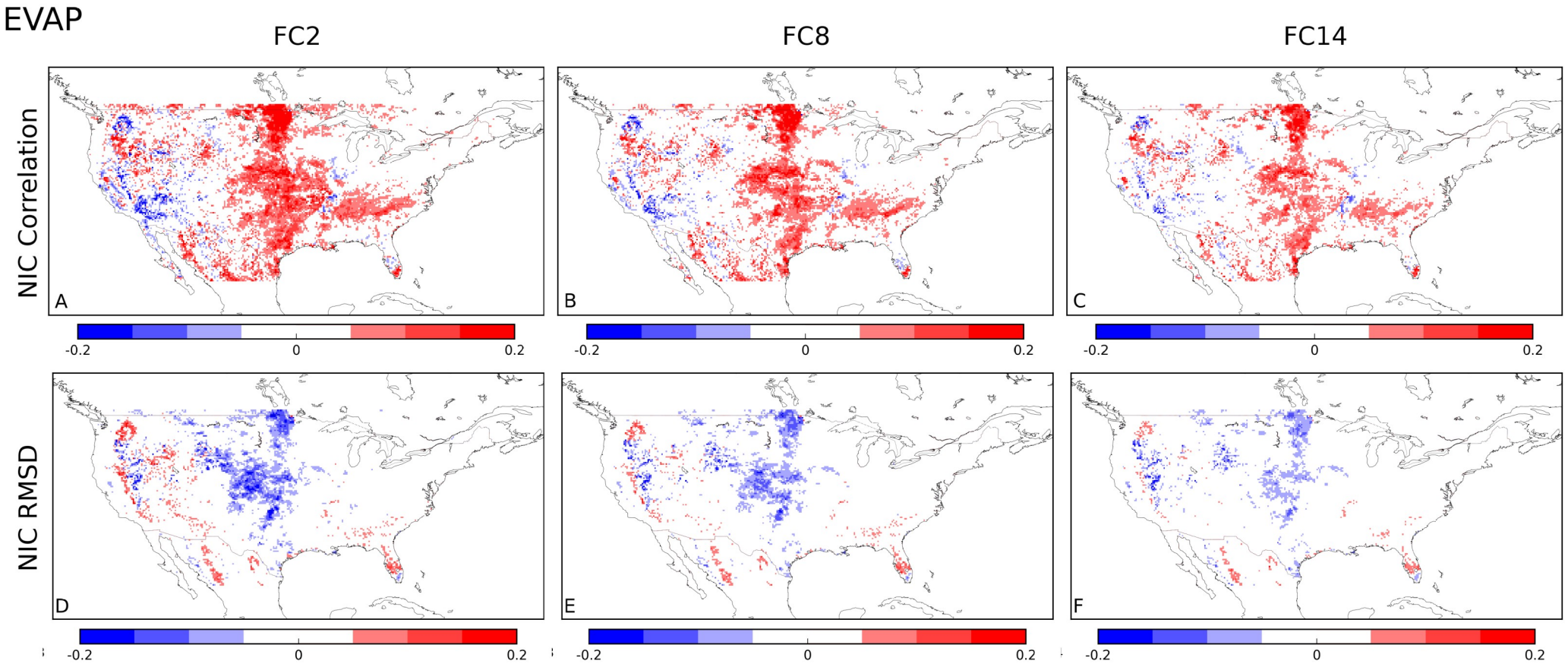


Figure 5. Spatial patterns of persistence of SEKF impact on simulated ET as compared to ALEXI ET as forecast lead time increases. Upper row of maps show NIC*R* values at FC2, FC8, and FC14. Bottom row of maps are NICRMSD values at the same forecast lead times. Note that red color for correlation is improvement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

Evaluation against ALEXI ET

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

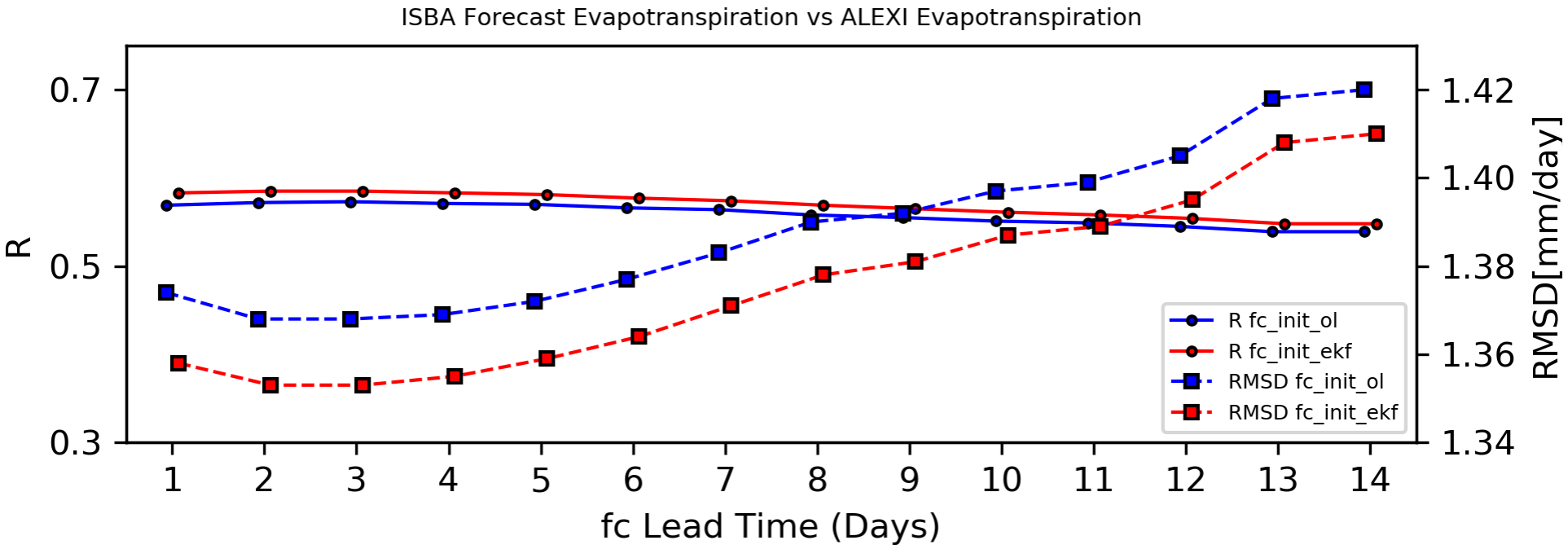


Figure 6. Temporal evolution of ET correlation (solid lines) and RMSD (dashed lines) averaged over the domain. OL initializations are in blue, SEKF initializations are in red.

Research Questions

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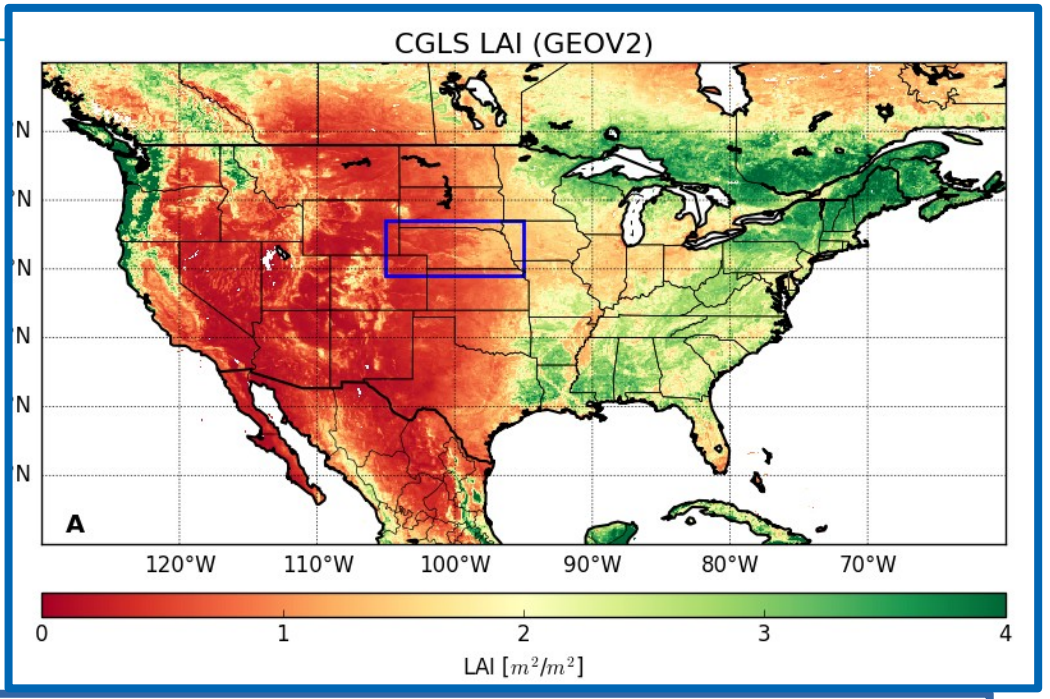
Links to Agriculture

- Inter-annual variability and drought events are well captured

Correlation to Yield Anomalies (R)	
Observations	0.92
SEKF (Data Assmiliation)	0.88
OL (No Assimilation)	0.80



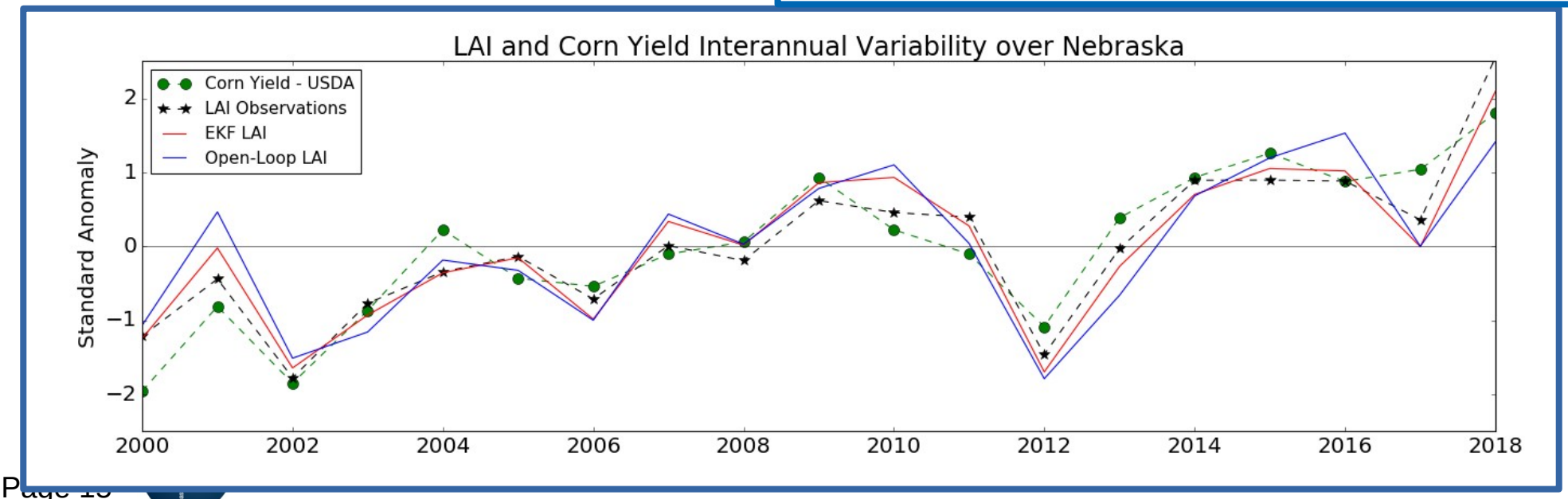


Figure 7. Annual average LAI anomalies of observations (black stars), OL (blue line), and SEKF (red lines) estimates, compared to reported corn yield anomalies over Nebraska (green dots).

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Next Steps

- Long-term simulations over CONUS (2000-2019)
  - 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

[2] Albergel, C., Munier, S., Leroux, D. J., Dewaele, H., Fairbairn, D., Barbu, A. L., ... & Le Moigne, P. (2017). Sequential assimilation of satellite-derived vegetation and soil moisture products using SURFEX_v8. 0: LDAS-Monde assessment over the Euro-Mediterranean area. Geoscientific Model Development, 10(10), 3889.

[3] Masson, V., Le Moigne, P., Martin, E., Faroux, S., Alias, A., Alkama, R., ... & Brousseau, P. (2013). The SURFEXv7. 2 land and ocean surface platform for coupled or offline simulation of e arth surface variables and fluxes. Geoscientific Model Development, 6, 929-960.

[4] Barbu, A. L., Calvet, J. C., Mahfouf, J. F., & Lafont, S. (2014). Integrating ASCAT surface soil moisture and GEOV1 leaf area index into the SURFEX modelling platform: a land data assimilation application over France. Hydrology and Earth System Sciences, 18(1), 173-192.

[5] Fairbairn, D., Barbu, A. L., Napoly, A., Albergel, C., Mahfouf, J. F., & Calvet, J. C. (2017). The effect of satellite-derived surface soil moisture and leaf area index land data assimilation on streamflow simulations over France. Hydrology and Earth System Sciences, 21(4), 2015-2033.