# ERA-5 driven land surface reanalysis : LDAS-Monde applied to the continental US

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# 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

- Through a weighted combination of both, LSVs can be better estimated than by either source of information alone *[Reichle et al., 2007]*

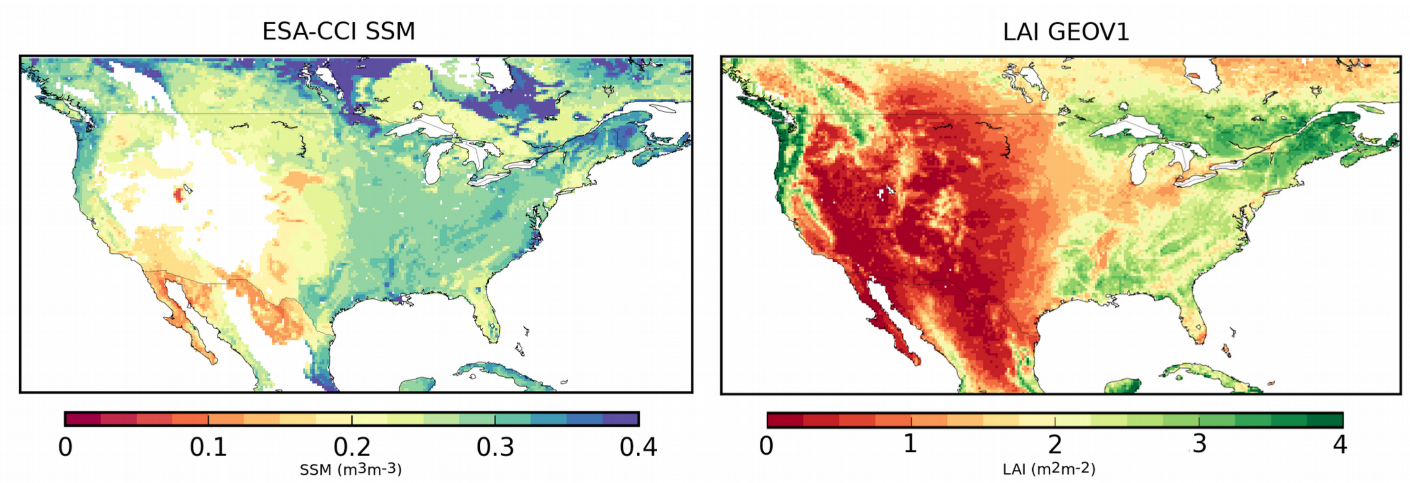
➔ **Data assimilation :** spatially and temporally integrates the observed information into LSMs in a consistent way to unobserved locations, time steps and variables

# Study the vegetation and terrestrial water cycles

## LDAS-Monde (*Albergel et al., 2017, GMD*)

- Global capacity integration of satellite derived observations into SURFEX
- Fully coupled to hydrology
- Offline reanalysis of the LSVs

| Model | Domaine | Atm. Forcing | DA Method | Assimilated Obs. | Observation Operator | Control Variables | Additional Option |
|---|---|---|---|---|---|---|---|
| **ISBA**<br>Multi-layer soil model<br>$CO_2$-responsive version<br>(Interactive veg.) | **CONUS (2010-2016, 0.25°x0.25°)** | **ERA-5 (HersBach, 2016)** | **SEKF** | **SSM**<br>(ESA CCI)<br>**LAI**<br>(GEOV1) | **Second layer of soil (1-4cm)**<br>**LAI** | **Layers of soil 2 to 8 (1-100cm)**<br>**LAI** | **Coupling with CTRIP (0.5°)** |




(ESA CCI SSM)
(seasonal bias correction)
http://www.esa-soilmoisture-cci.org

(SPOT-VGT / PROBA-V, 1km)
http://land.copernicus.eu/global/

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**ERA-5 :** ECMWF latest atmospheric reanalysis, recent 7-yr release (2010-2016)

- Higher spatial and temporal resolution than ERA-Interim

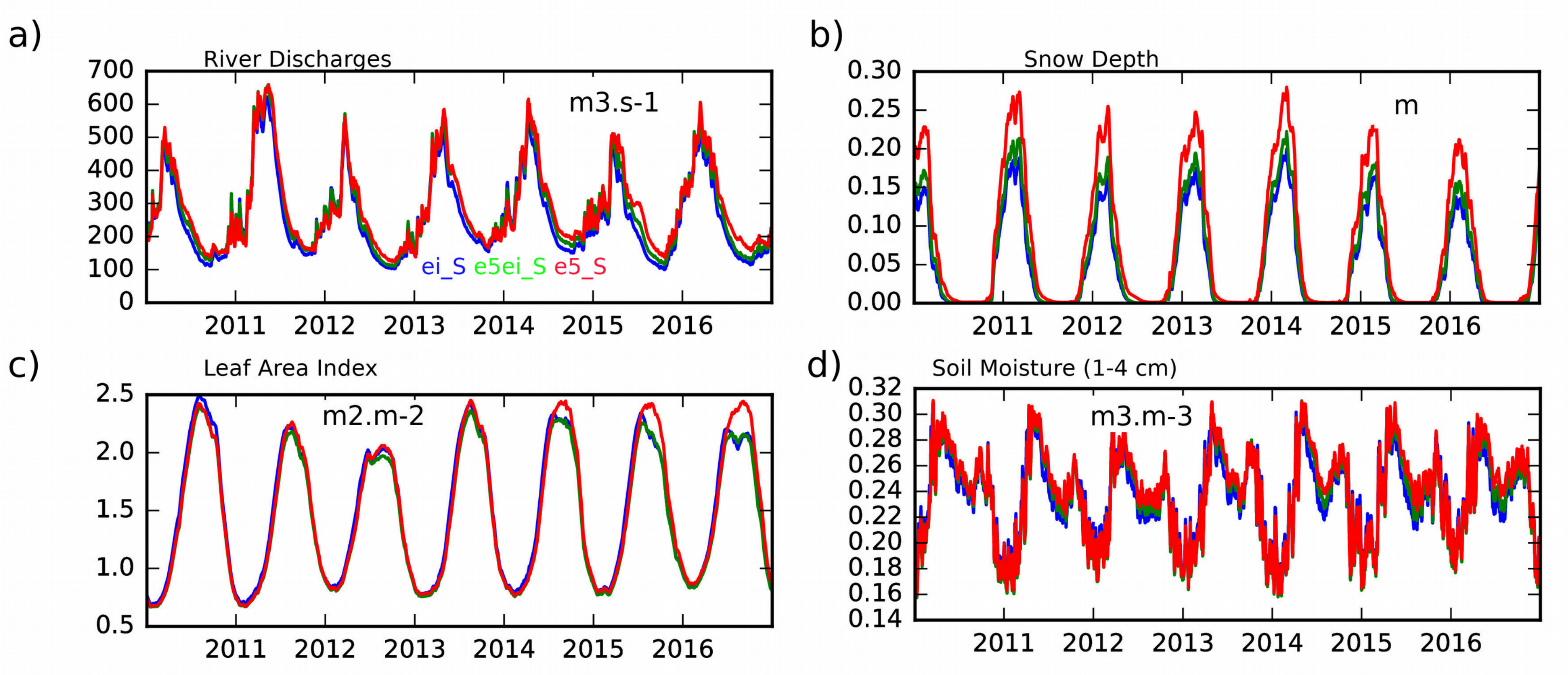
**Objectives :**

- Assess ERA-5 ability to force the ISBA LSM with respect to ERA-Interim
- Assess ERA-5 driven LDAS-Monde reanalysis

# ERA-5 ability to force ISBA LSM

**3 experiments**

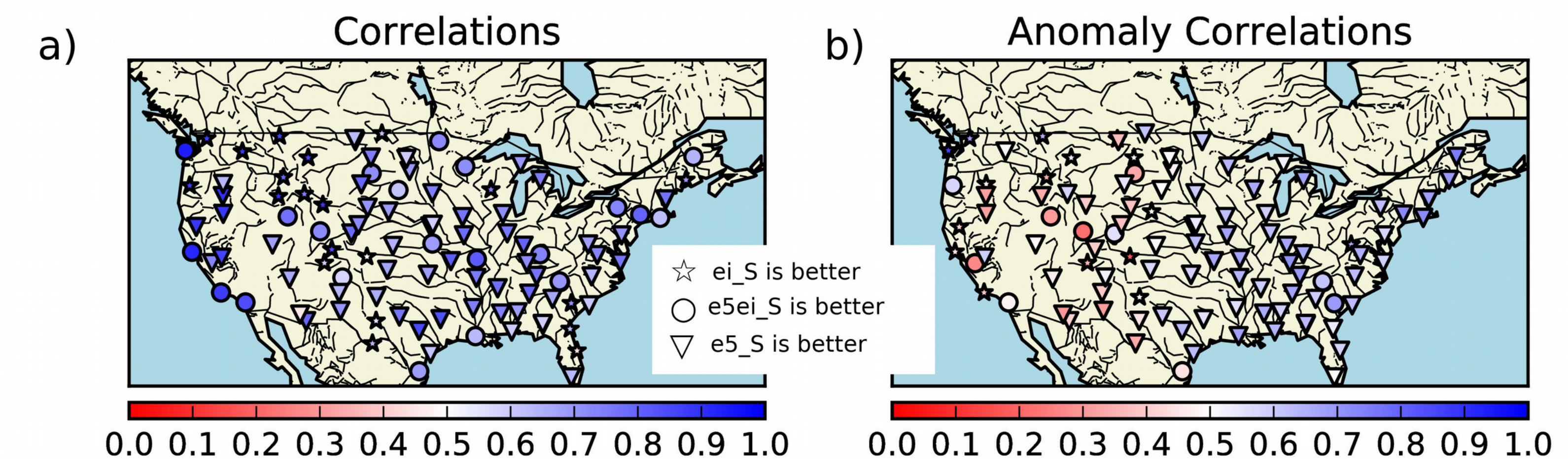
- ERA-Interim (all variables interpolated at 0.5x0.5 spatial resolution) **[ei_S]**
- ERA-5 (all variables at 0.5x0.5) **[e5_S]**
- ERA-5 forcing except Rain/Snow from ERA-Interim (all variables at 0.5x0.5) **[e5ei_S]**



# ERA-5 ability to force ISBA LSM

**Soil moisture** from USCRN network

*(in situ 5cm vs ISBA 4-10cm, April-September 2010-2016, daily data)*




| | Median R* on volumetric time series ( % of stations for which this configuration is the best) | Median R** on anomalies time series ( % of stations for which this configuration is the best) | Median ubRMSD* ($m^3m^{-3}$) ( % of stations for which this configuration is the best) |
|---|---|---|---|
| ei_S | 0.66 (20 %) | 0.53 (15 %) | 0.052 (19 %) |
| e5ei_S | 0.69 (20 %) | 0.54 (11 %) | 0.052 (24 %) |
| e5_S | 0.71 (60 %) | 0.58 (75 %) | 0.050 (57 %) |

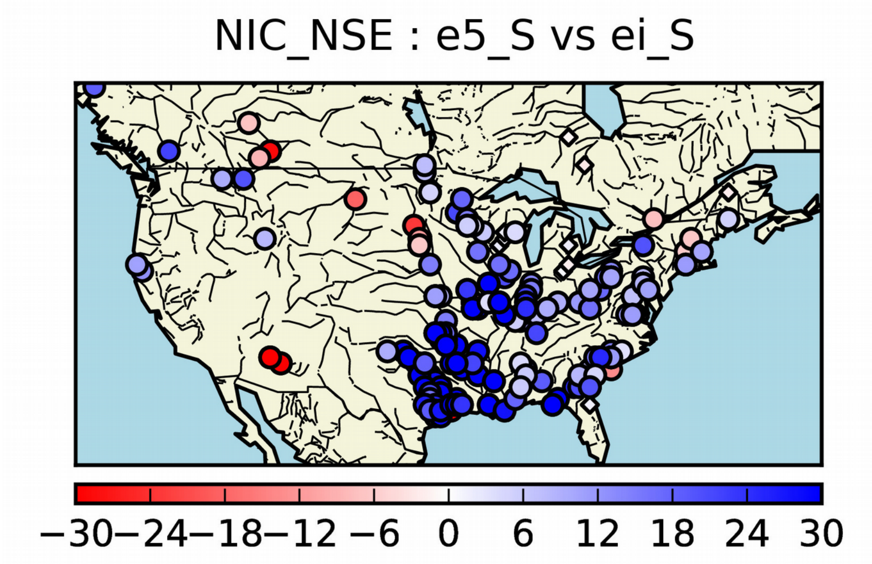
*** only for stations presenting significant R values on volumetric time series (p-value<0.05): 110 stations**
**** only for stations presenting significant R values on anomaly time series (p-value<0.05): 107 stations**

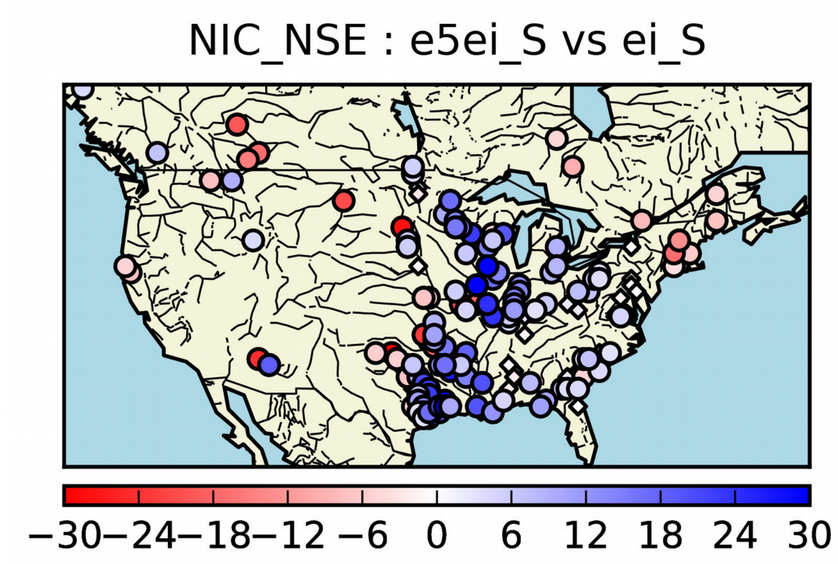
ERA-5 driven simulations perform better !

# ERA-5 ability to force ISBA LSM

## River discharge

- **NSE** values are computed for each Exp. / stations *(daily values scaled to the drainage area)*
- <u>**N**ormalised **I**nformation **C**ontribution</u> used to quantify improvment/degradation (only for NSE > -1)



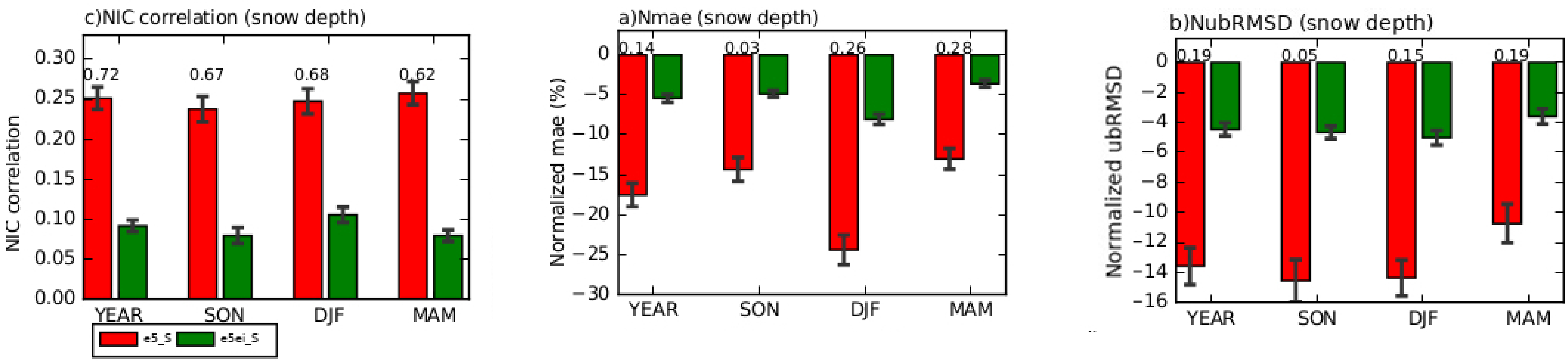

| vs. ei_S | N stations NSE_ei_S >-1 | NIC_NSE > +3 % Blue circles | NIC_NSE < -3 % Red circles | NIC_NSE [-3,+3] Diamonds |
|---|---|---|---|---|
| e5_S | 234 | **185** | 26 | 23 |
| e5ei_S | 234 | **133** | 55 | 53 |
| | | Positive impact | Negative impact | Neutral impact |

ERA-5 driven simulations perform better !

# ERA-5 ability to force ISBA LSM

**Snow depth, ~2000 stations from GHCN**

- MAE, ubRMSD and Correlations are computed for each stations
- **NIC, Normalized** MAE and ubRMSD are used to quantify improvment/degradation



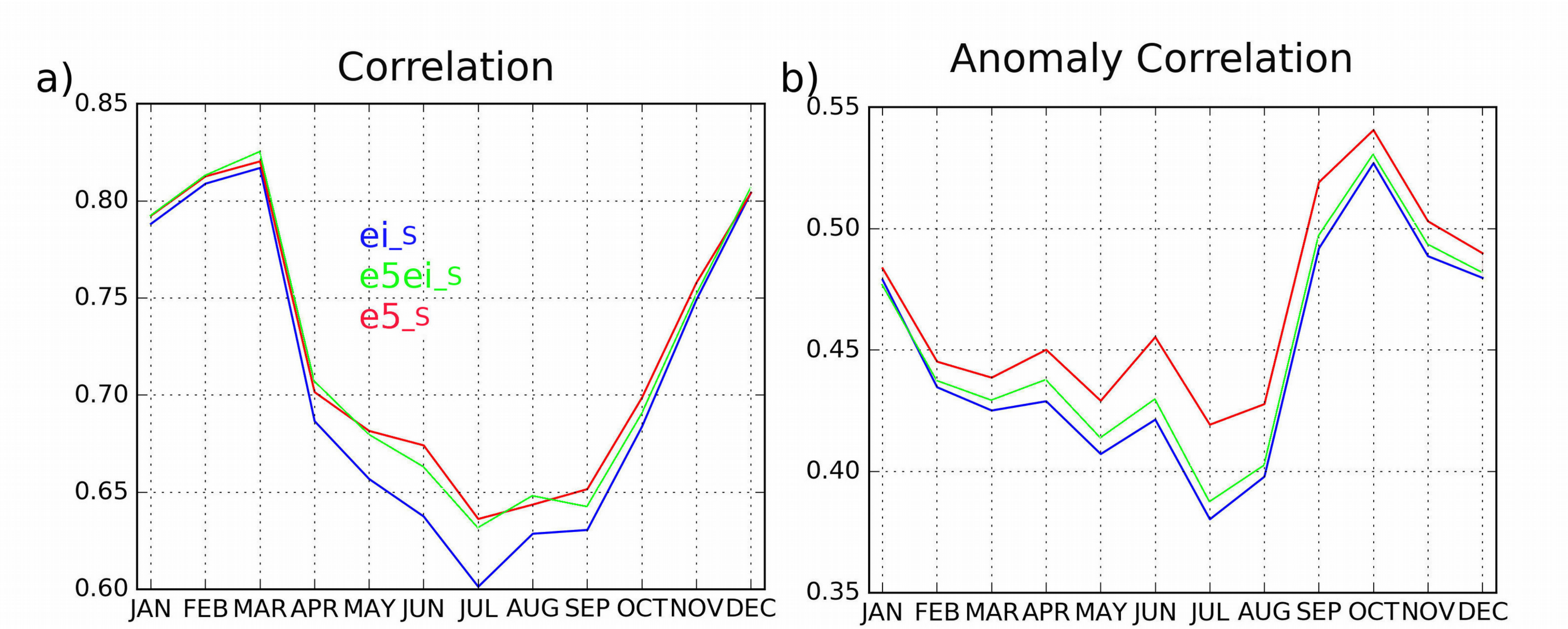

- **e5ei_S :** Some benefits when compared with ei_S in terms of MAE (N MAE ~5%), ubRMSD (N ubRMSD ~4%) and correlation (NIC R of 0.1)
- **e5_S :** Clear improvement in MAE (N MAE ~16%), ubRMSD (N ubRMSD ~14%) and correlation (NIC R of 0.25)

ERA-5 driven simulations perform better !

# ERA-5 ability to force ISBA LSM

**ESA-CCI satellite derived Surface Soil Moisture estimates**

- Correlations on volumetric and anomaly time-series, seasonal scores over 2010-2016



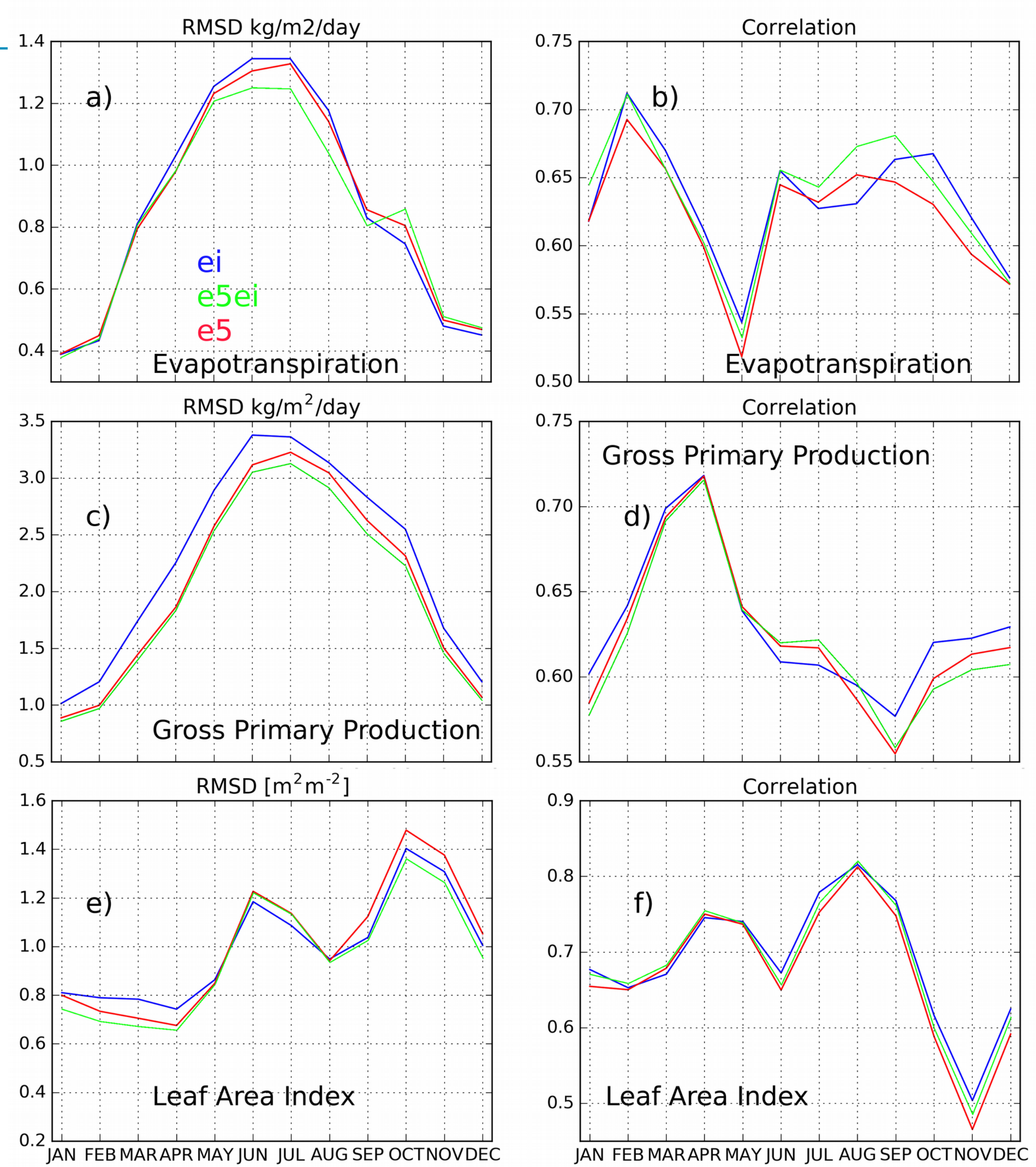

- Mean correlation on volumetric (anomaly) time-series : 0.668 (0.464), 0.682 (0.468), 0.689 (0.490)

ERA-5 driven simulations perform better !

# ERA-5 ability to force ISBA LSM

- **Evapotranspiration estimates (GLEAM, Martens et al., 2017)**
- **Gross Primary Production estimates (FLUXCOM, Jung et al., 2017)**
- **Leaf Area Index (GEOV1, CGLS)**

**ERA-5 driven simulations has a rather neutral impact**



# LDAS-Monde applied over CONUS

## Assess ERA-5 driven LDAS-Monde reanalysis

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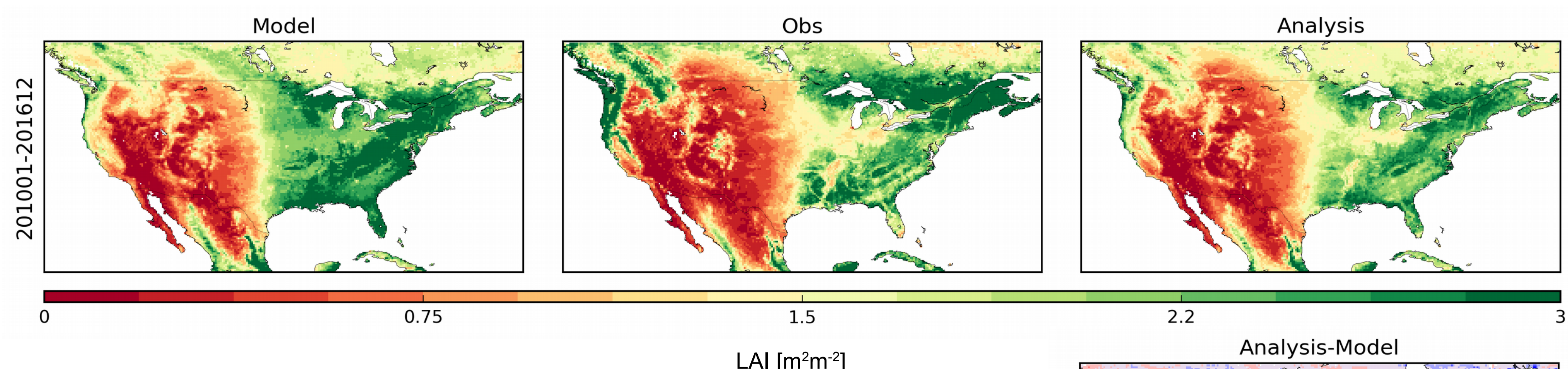


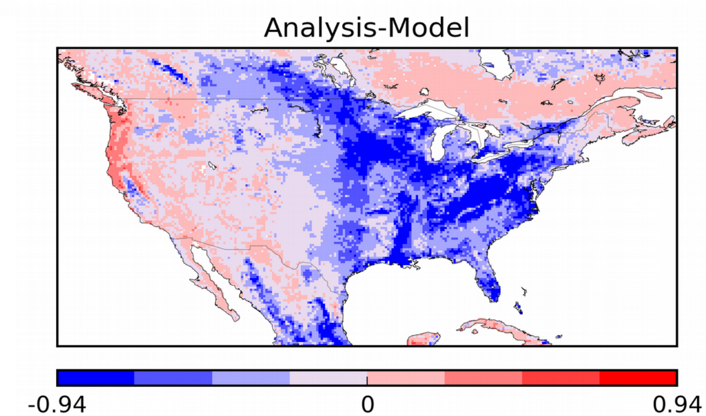


- Model overestimates LAI (e.g. Eastern part) with respect to the observations
- Analysis ‘removes’ LAI in those areas

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- **Evapotranspiration estimates (GLEAM, Martens et al., 2017)**
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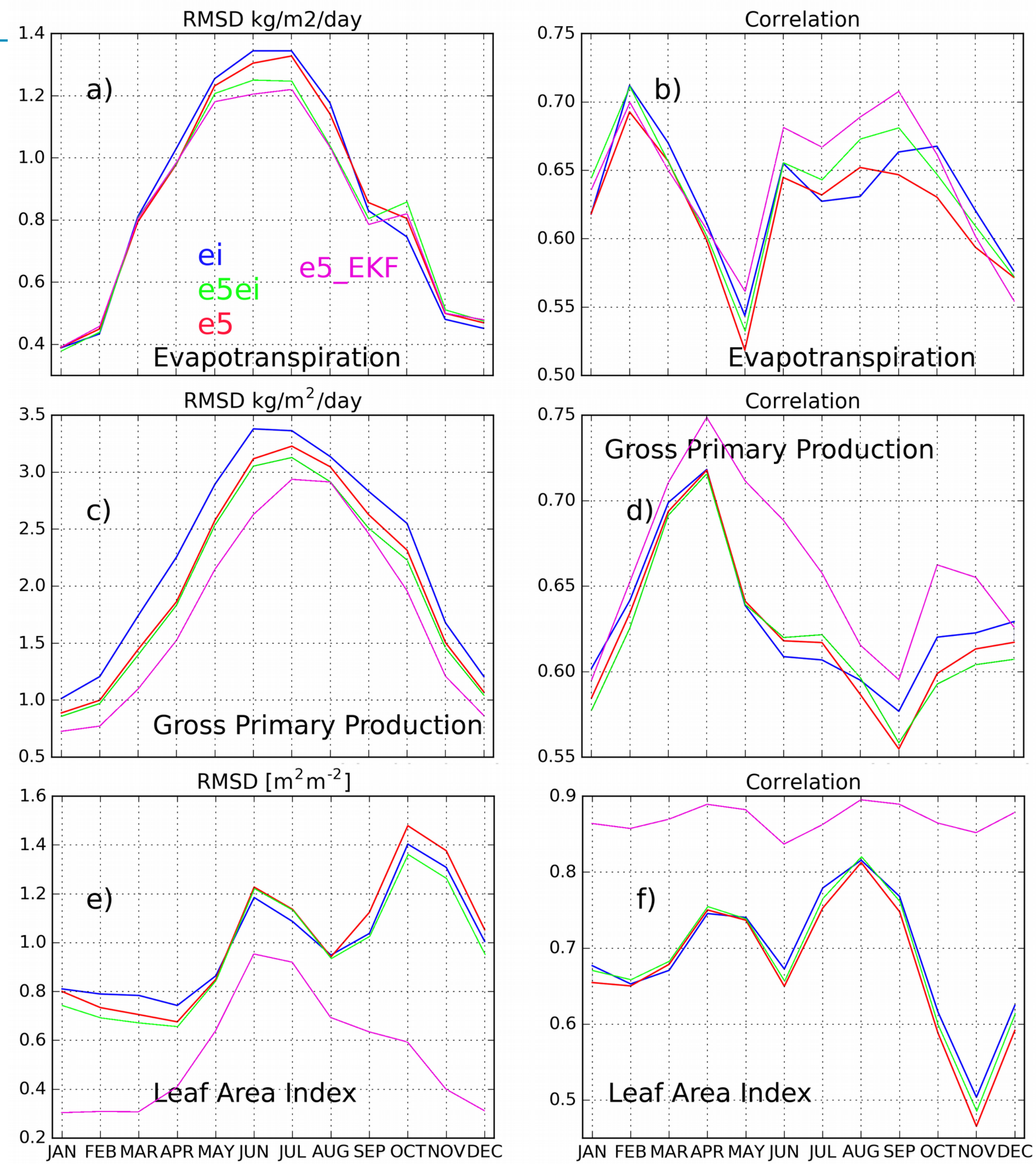
- **Leaf Area Index (GEOV1, CGLS)**

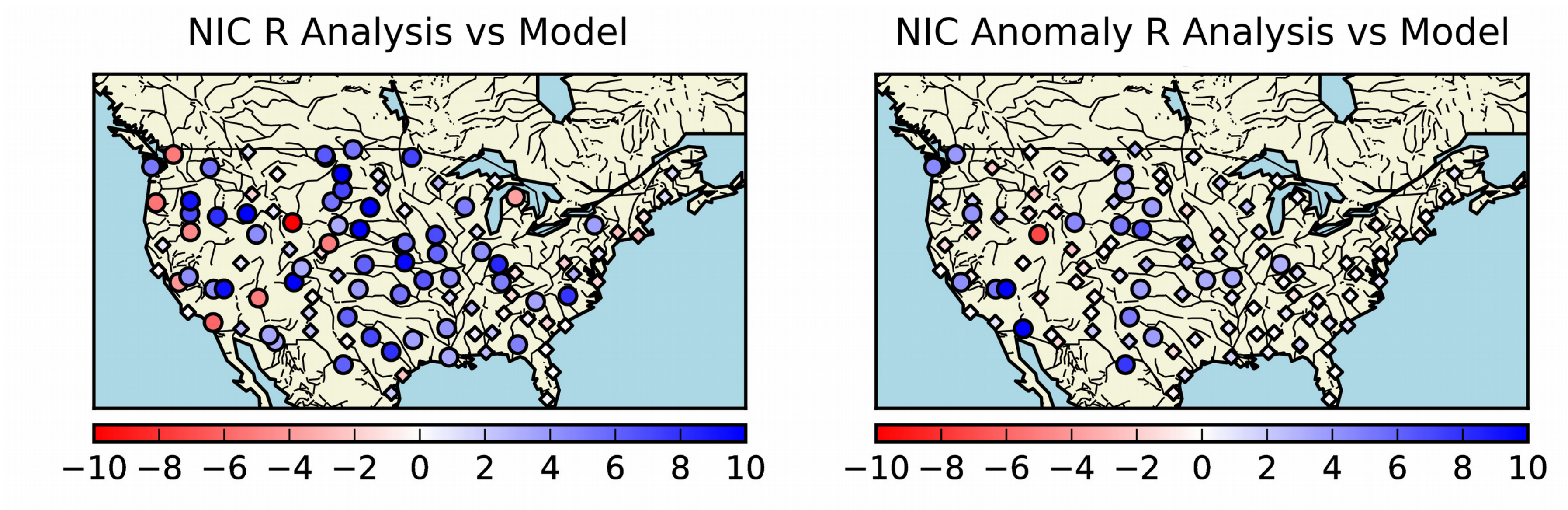
**Clear improvements from ERA-5 driven reanalyses!**



# LDAS-Monde applied over CONUS

**Soil moisture** from USCRN network

*(in situ 5cm vs ISBA 4-10cm, April-September 2010-2016, daily data)*




| 110 stations with significant R (Anomaly R) | **Median R (Anomaly R)** | **Median ubRMSD** | **NIC_R (NIC_ANO_R) > +3 % Red circles** | **NIC_R (NIC_ANO_R) < -3 % Red circles** | **NIC_NSE [-3,+3] Diamonds** |
|---|---|---|---|---|---|
| Model | 0.72 (0.60) | 0.049 | **50** | 9 | 51 |
| Analysis | **0.74** (0.60) | **0.048** | **20** | 1 | 89 |

ERA-5 driven reanalyses bring further improvements !

# LDAS-Monde applied over CONUS

**River discharge**

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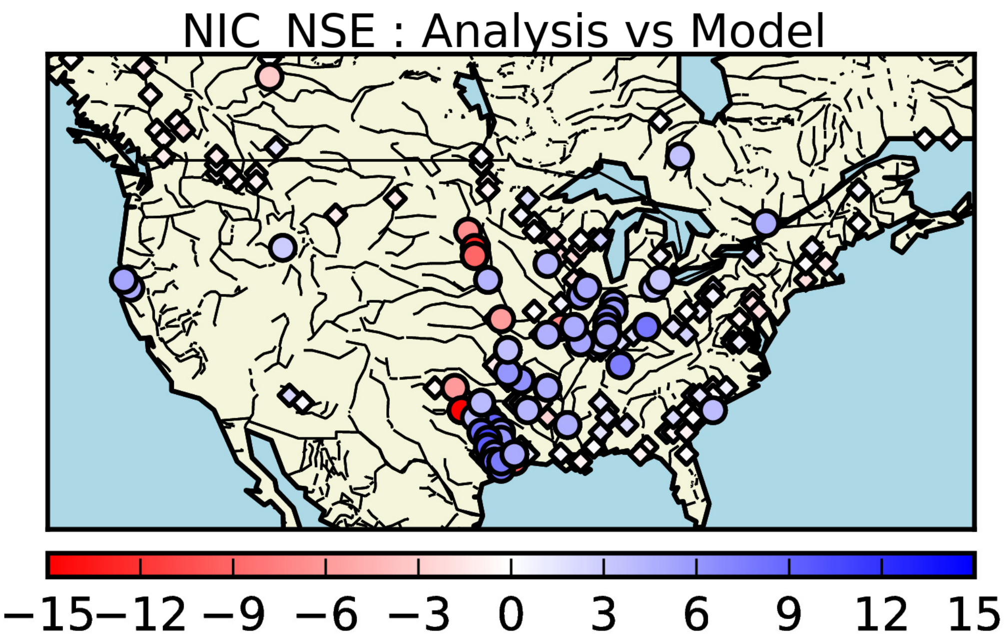
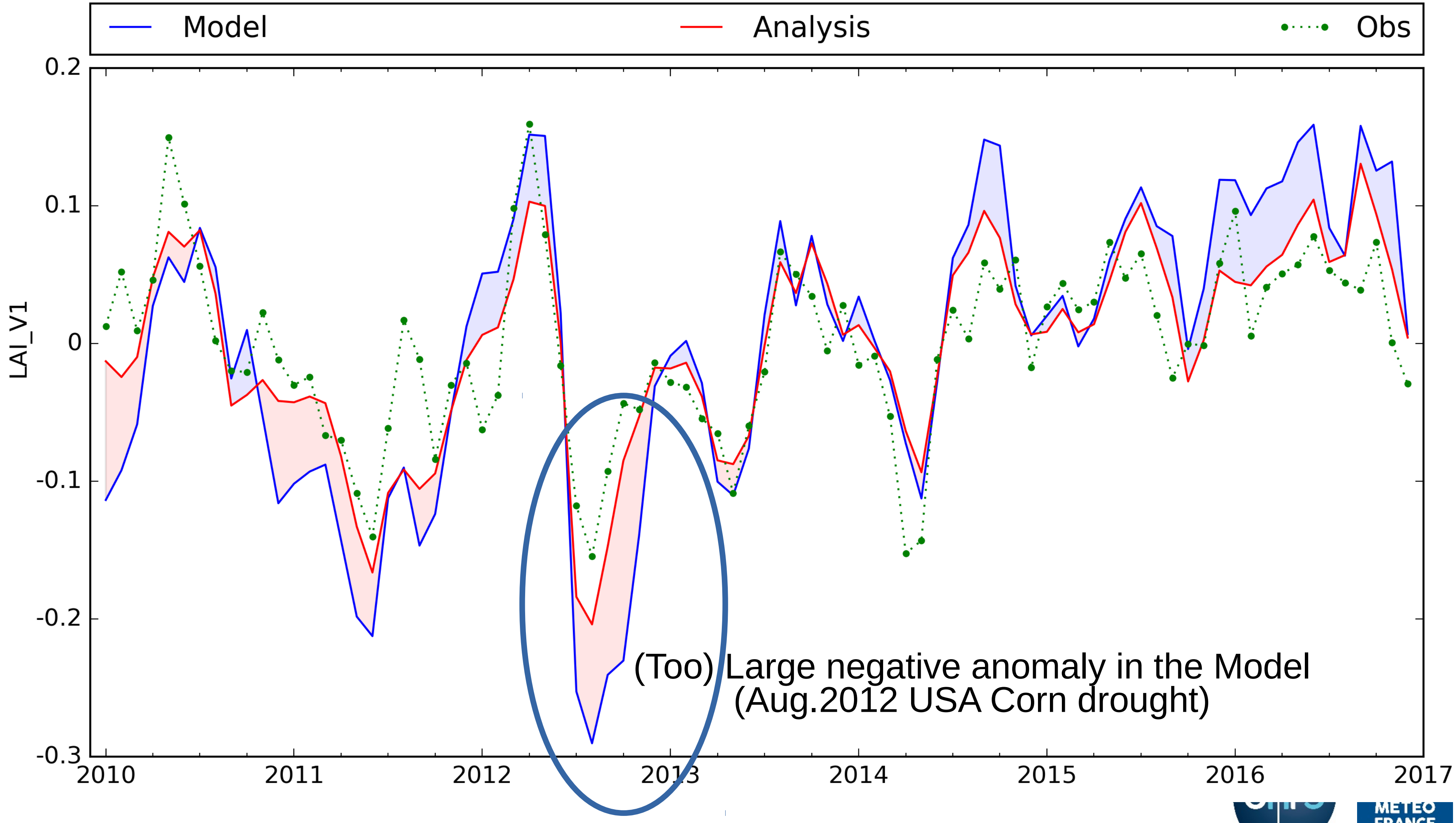



| N stations NSE_Model >-1 | NIC_NSE > +3 % Blue circles | NIC_NSE < -3 % Red circles | NIC_NSE [-3,+3] Diamonds |
|---|---|---|---|
| 266 | **59** | 12 | 95 |

ERA-5 driven reanalysis bring further improvements !

# Monitoring agricultural drought

- **Can LDAS-Monde provides a good monitoring of agricultural drought ?**



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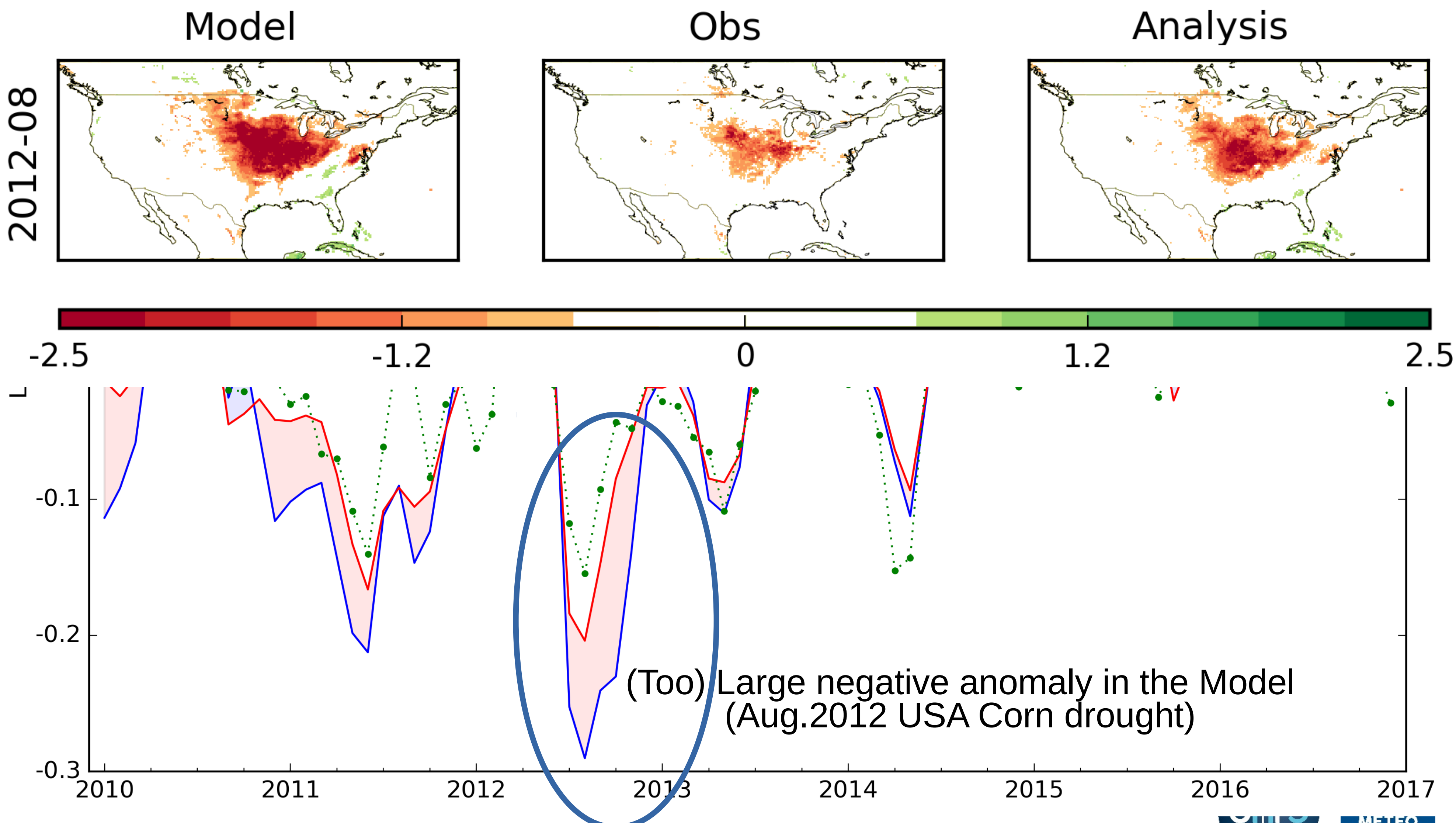
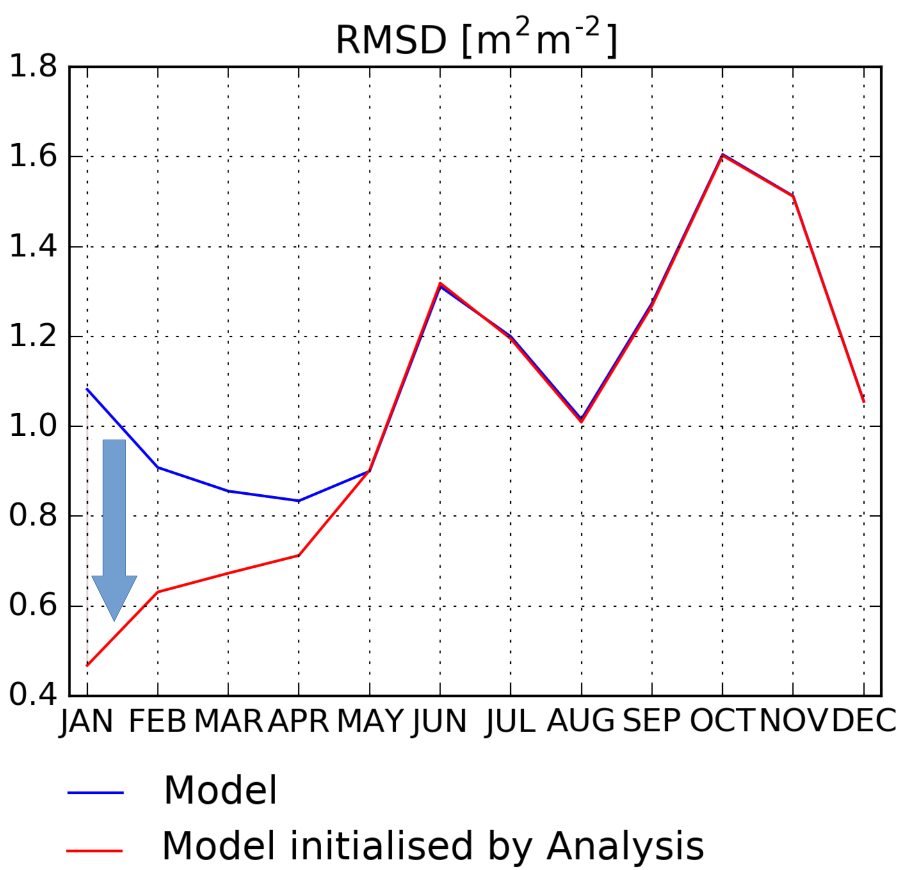
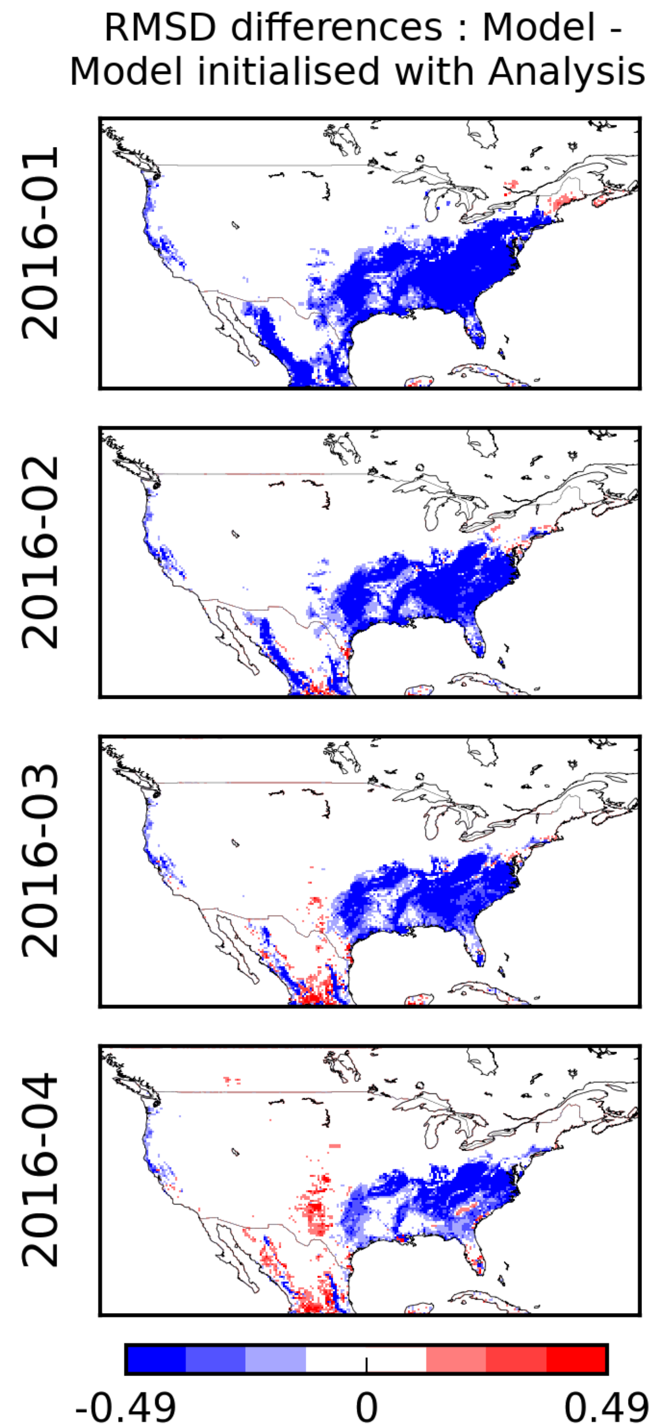


# From monitoring to forecasting

- **Does analysis provide better initial conditions that last in time ?**
  - Use analysis initial conditions at 01/01/2016 to start a 12-month Model run
  - Evaluation against LAI observations over CONUS (2016)

➔ ***Persistence for several weeks / months on LAI***



# ERA-5 driven land surface reanalysis : LDAS-Monde

**ERA-5 driven simulations**

- Significant improvements in the representation of LSVs linked to the terrestrial water cycle
- Smaller impact on LSVs linked to the vegetation cycle
- Better representation of the precipitation in ERA-5, other meteorological forcing also

**LDAS-Monde driven by ERA-5**

*Integration of satellite observations into SURFEX, fully coupled to hydrology*

*Now the only system able to sequentially assimilate vegetation products together with SSM*

- Significant improvements in the representation of LSVs linked to the vegetation cycle !
- Further improvements in the representation of LSVs linked to the terrestrial water cycle !

➔ **Powerful tool to monitor land surface variables, droughts**

➔ **High potential of the analysis for initialising forecasts**

*(Analysis provides better initial conditions than a model run)*

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**LDAS-Monde recent publications :**

***Albergel, C.***, S. Munier, D. J. Leroux, H. Dewaele, D. Fairbairn, A. L. Barbu, E. Gelati, W. Dorigo, S. Faroux, C. Meurey, P. Le Moigne, B. Decharme, J.-F. Mahfouf, J.-C. Calvet : Sequential assimilation of satellite-derived vegetation and soil moisture products using SURFEX_v8.0 : LDAS-Monde assessment over the Euro-Mediterranean area, Geosci. Model Dev., Geosci. Model Dev., 10, 3889–3912, 2017.

Fairbairn, D., Barbu, A. L., Napoly, A., ***Albergel C.***, Mahfouf, J.-F., and Calvet, J.-C. : The effect of satellite-derived surface soil moisture and leaf area index land data assimilation on stramflow simulations over France, Hydrol. Earth Syst. Sci., 21, 2015–2033, 2017.

***Results where Generated using Copernicus Climate Change Service Information 2017***

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