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

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[3] ECMWF, Reading, UK

Joint ISWG and LSA-SAF Workshop
IPMA, Lisbon, 26-28 June 2018

Study the vegetation and terrestrial water cycles

- **Current fleet of Earth Satellite missions holds an unprecedent potential to quantify Land Surface Variables (LSVs)** *[Lettenmaier et al., 2015]*

➔ Spatial and temporal gaps / Cannot observe all key LSVs

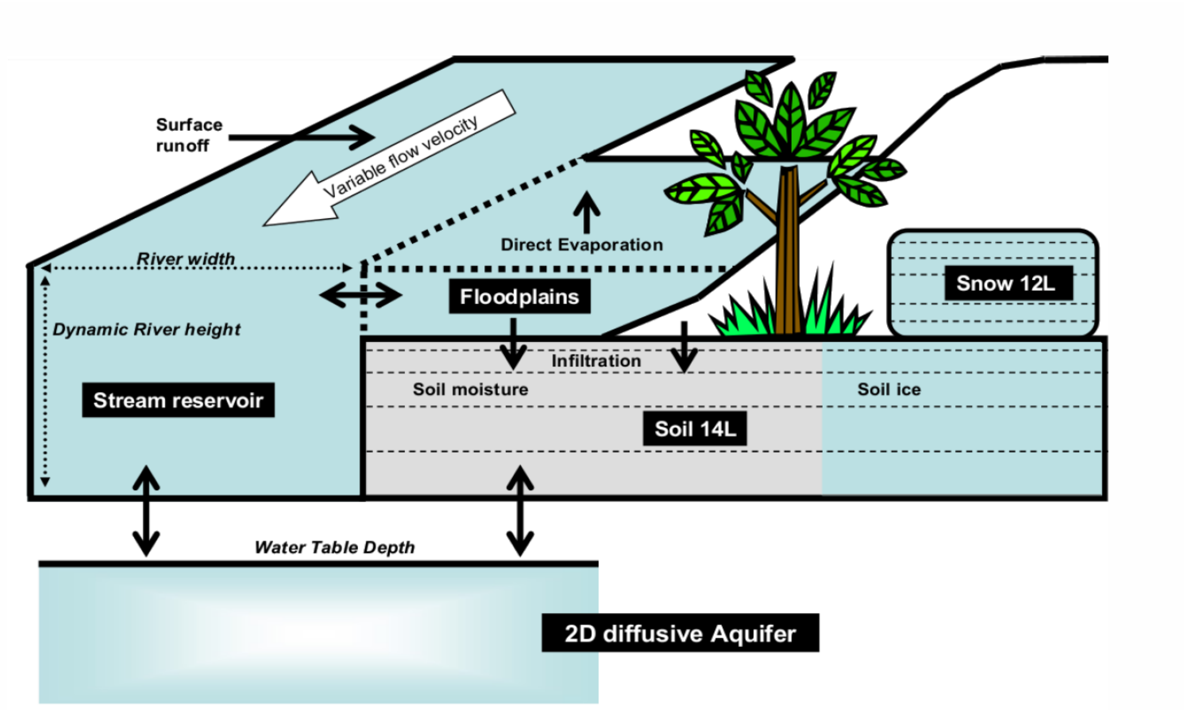
- **Land Surface Models (LSMs)** provide LSVs estimates at all time/location based on physical laws

- 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 (sequential) integration of satellite derived observations into the SURFEX modelling platform



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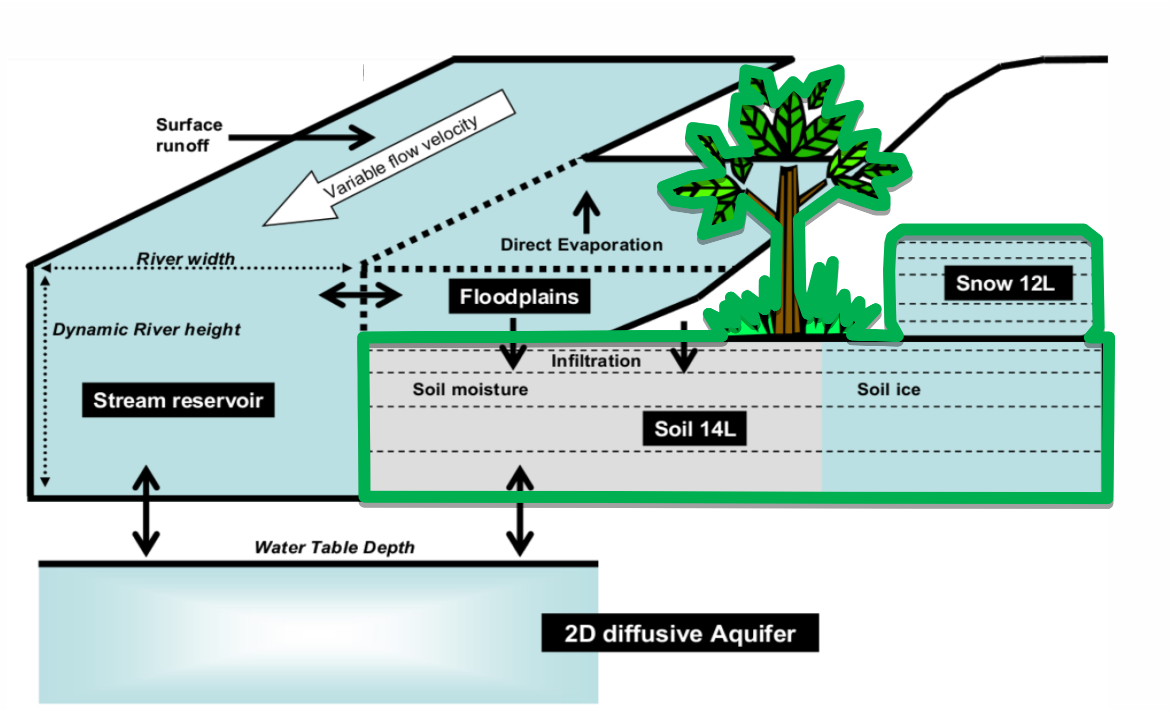
LDAS-Monde : Global capacity (sequential) integration of satellite derived observations into the SURFEX modelling platform

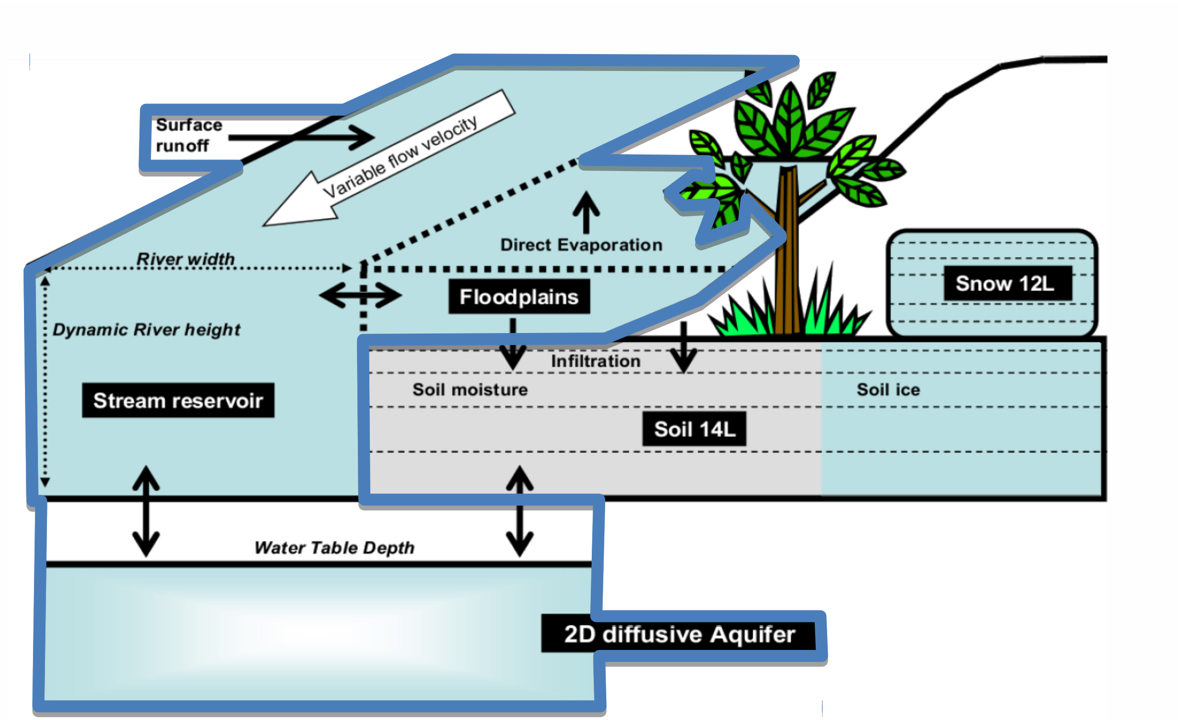
- ISBA-A-gs : simulates the diurnal cycle of water and carbon fluxes, plant growth and key vegetation variables on a daily basis
  [Calvet et al., 1998, 2007, Gibelin et al., 2006]



Study the vegetation and terrestrial water cycles

LDAS-Monde : Global capacity (sequential) integration of satellite derived observations into the SURFEX modelling platform

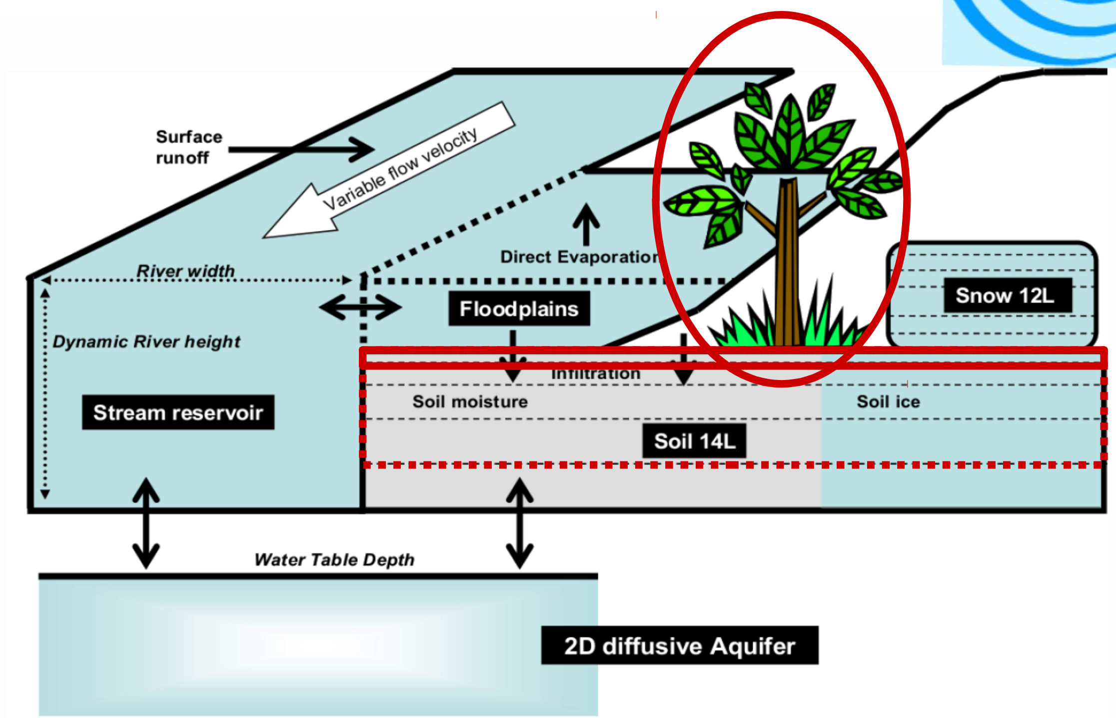
- CTRIP : TRIP based river routing system with CNRM developments for global hydrological applications
  [Oki and Sud, 1998, Decharme et al., 2008, 2010]



Study the vegetation and terrestrial water cycles

LDAS-Monde : Global capacity (sequential) integration of satellite derived observations into the SURFEX modelling platform

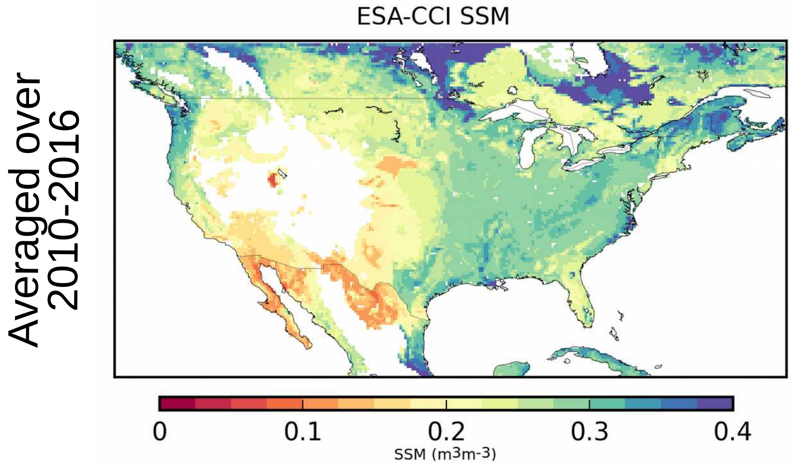
- ‘Update’ Soil Moisture and LAI



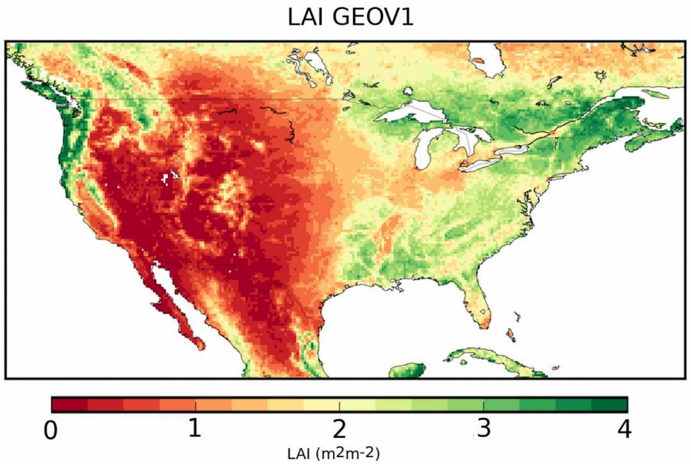
Study the vegetation and terrestrial water cycles

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

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

Study the vegetation and terrestrial water cycles

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

- Offline reanalysis of the LSVs : requires atmospheric forcing dataset

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

- Higher spatial and temporal resolution than ERA-Interim
  https:/ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5

Study the vegetation and terrestrial water cycles

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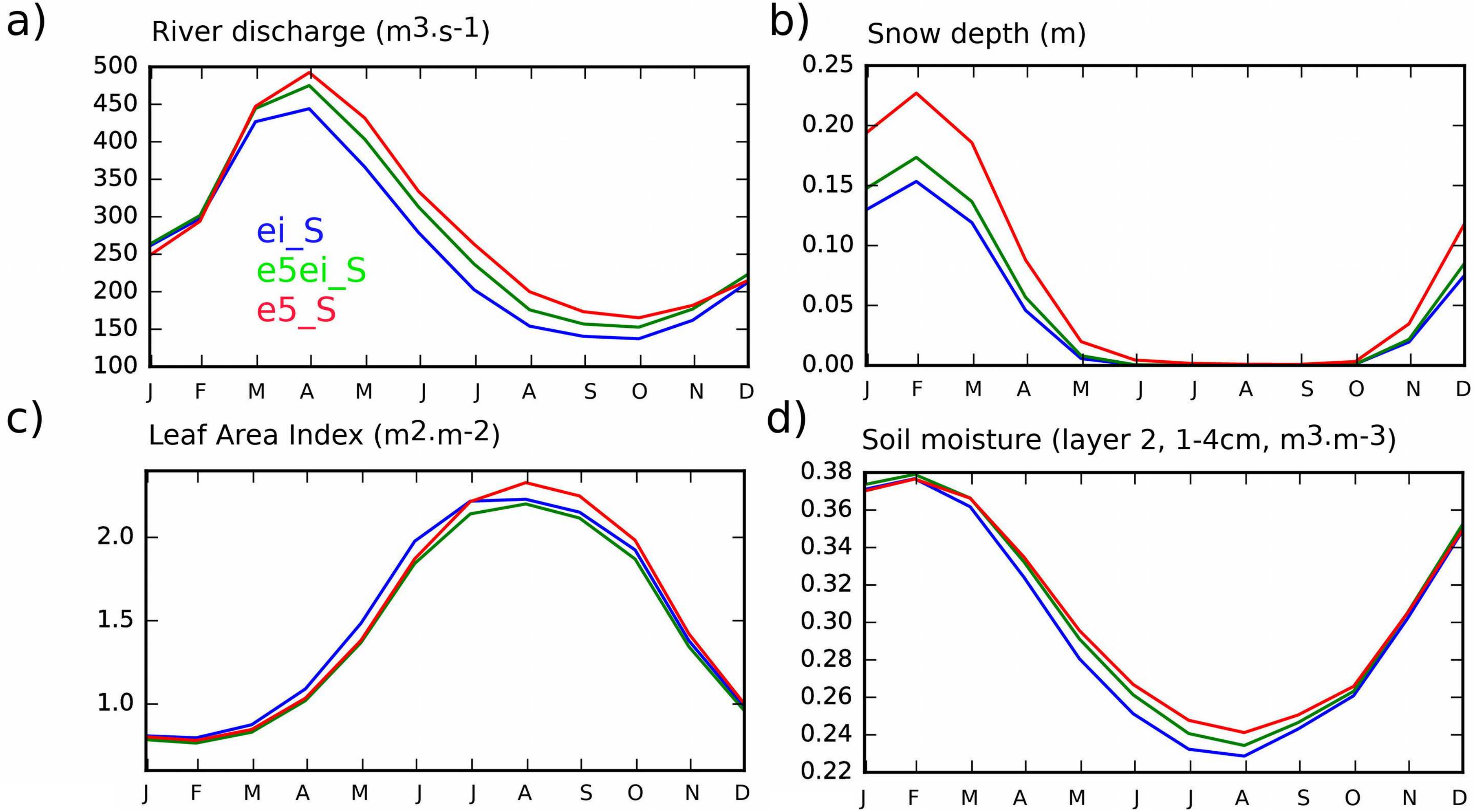
Questions:

- Could ERA-5 enhance the simulation performances w.r.t. ERA-Interim when used to force ISBA ?
- Are ERA-5 driven LDAS-Monde reanalyses better than ERA-5 driven model simulations ?

ERA-5 ability to force ISBA LSM

3 ISBA simulations, 2010-2016, forced by :

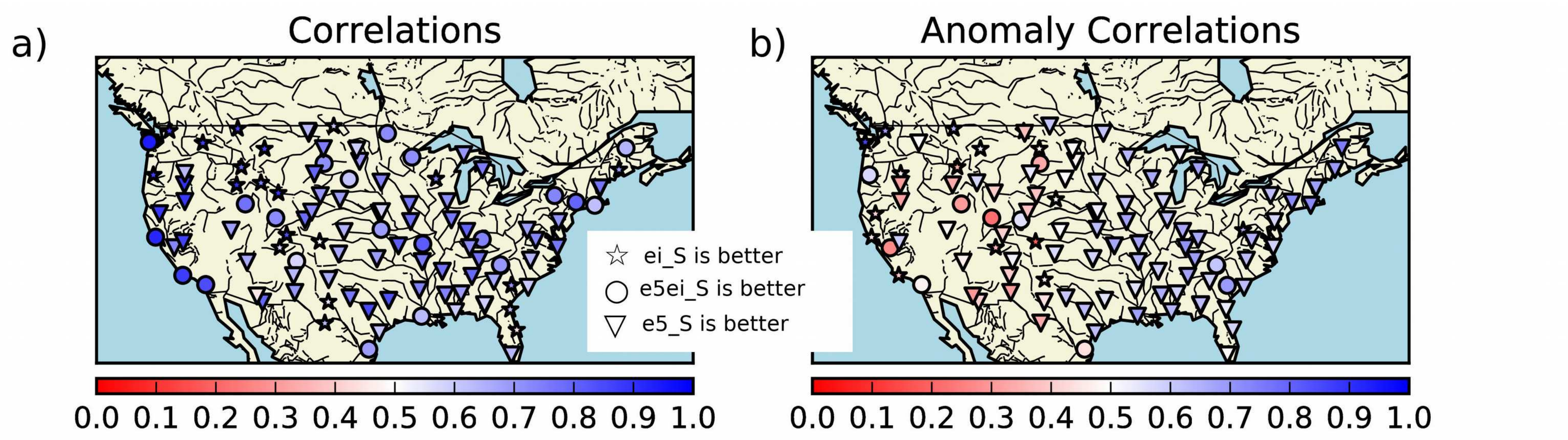
- ERA-Interim (3-hourly time-step, 0.5°x0.5° spatial resolution) **[ei_S]**
- ERA-5 forcing except Rain/Snow from ERA-Interim (hourly, 0.5°x0.5°) **[e5ei_S]**
- ERA-5 (hourly, 0.5°x0.5°) **[e5_S]**



ERA-5 ability to force ISBA LSM

Vs. in situ Soil moisture from USCRN network

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



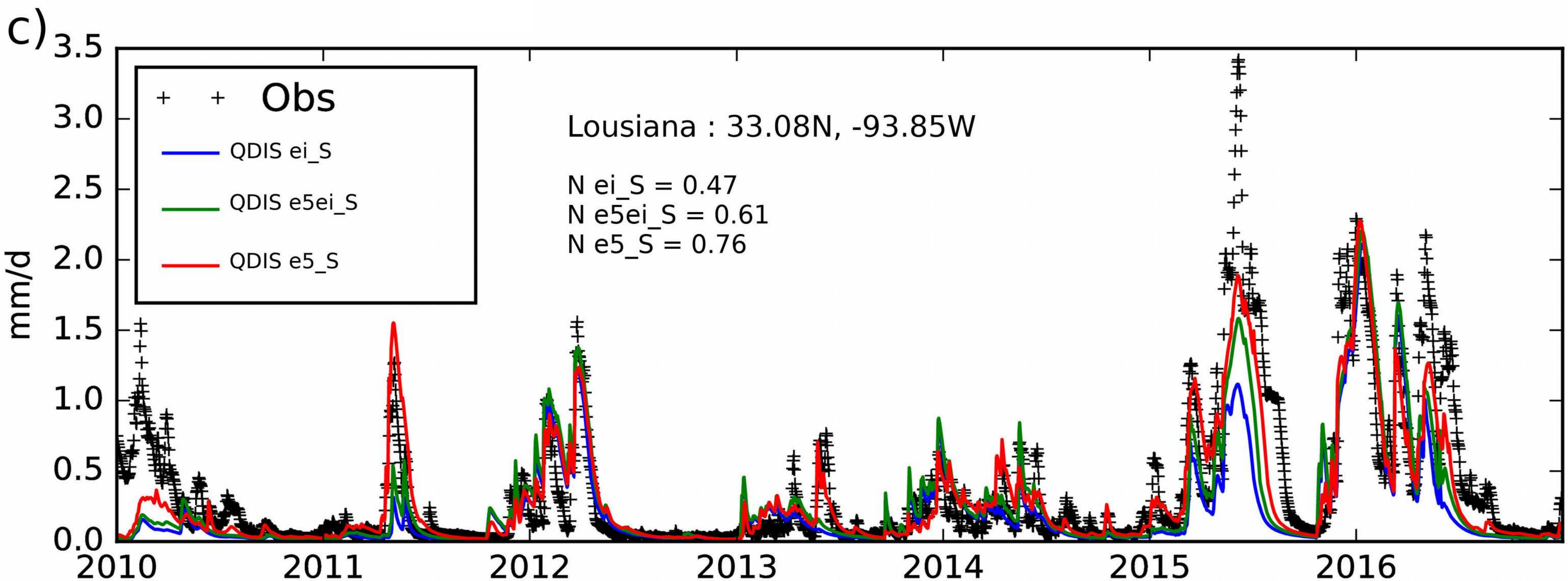
110 (107) stations with significant R (Anomaly R)	**Median R (Anomaly R)**	**Median ubRMSD**
ei_S	0.66 (0.53)	0.052
e5_S	**0.71 (0.58)**	**0.050**
e5ei_S	0.69 (0.54)	0.052

ERA-5 driven simulations perform better !

ERA-5 ability to force ISBA LSM

Vs. River discharge (USGS)

- **NSE** values are computed for each Exp. / stations *(daily values scaled to the drainage area)*



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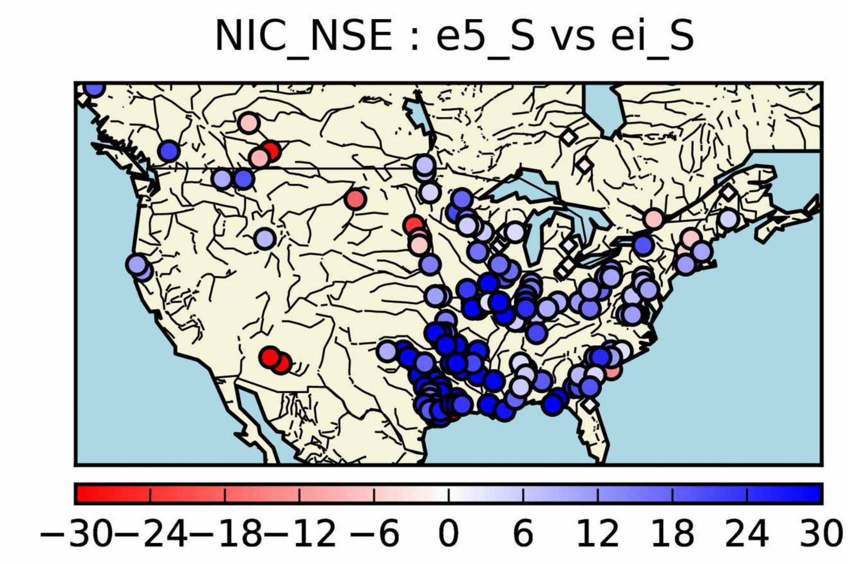

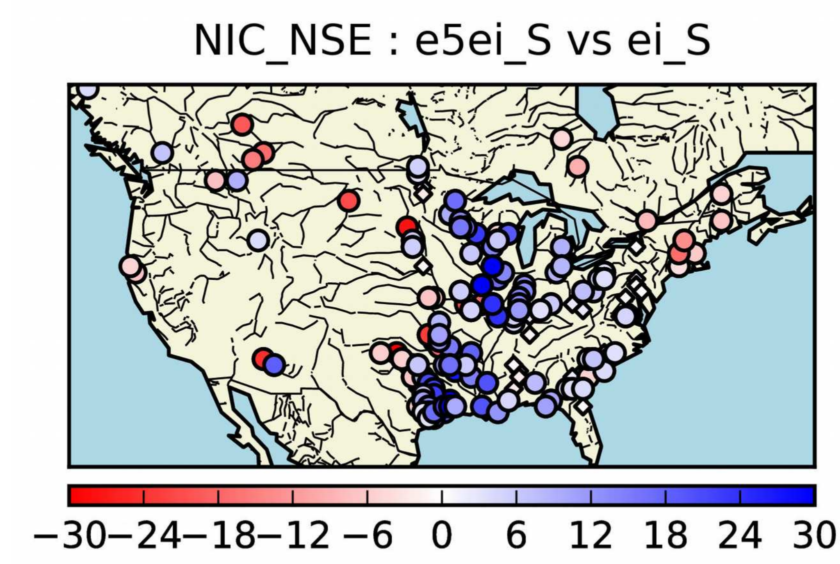

NIC vs. ei_S	N stations NSE_ei_S >-1	NIC_NSE > +3 % Blue circles	NIC_NSE < -3 % Red circles	NIC_NSE [-3,+3] Diamonds
e5_S	234	**80 %**	11 %	9 %
e5ei_S	234	57 %	21 %	22 %
		Positive impact	Negative impact	Neutral impact

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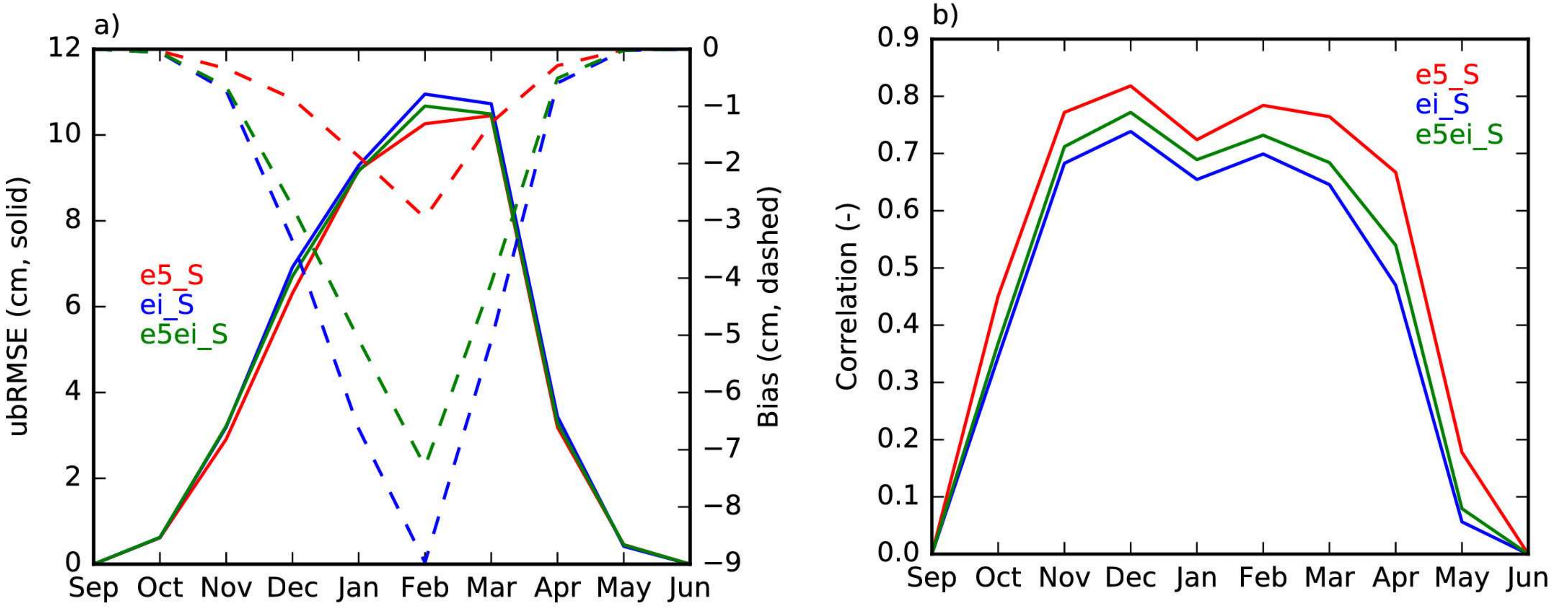
Vs. in situ Snow depth, ~2000 stations from GHCN

- ubRMSD, Bias and Correlations (R) at each stations



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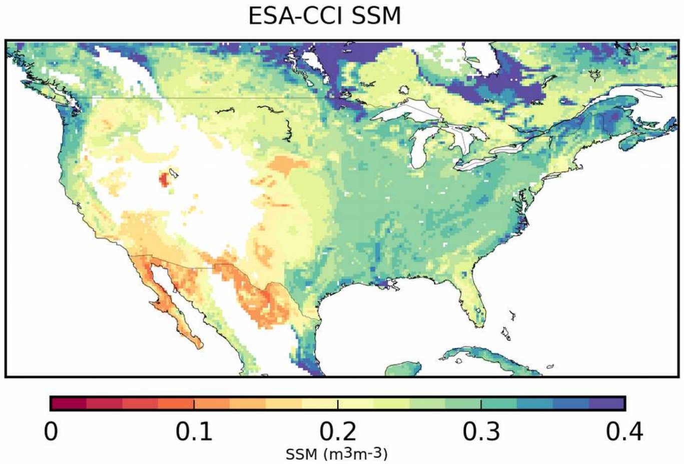
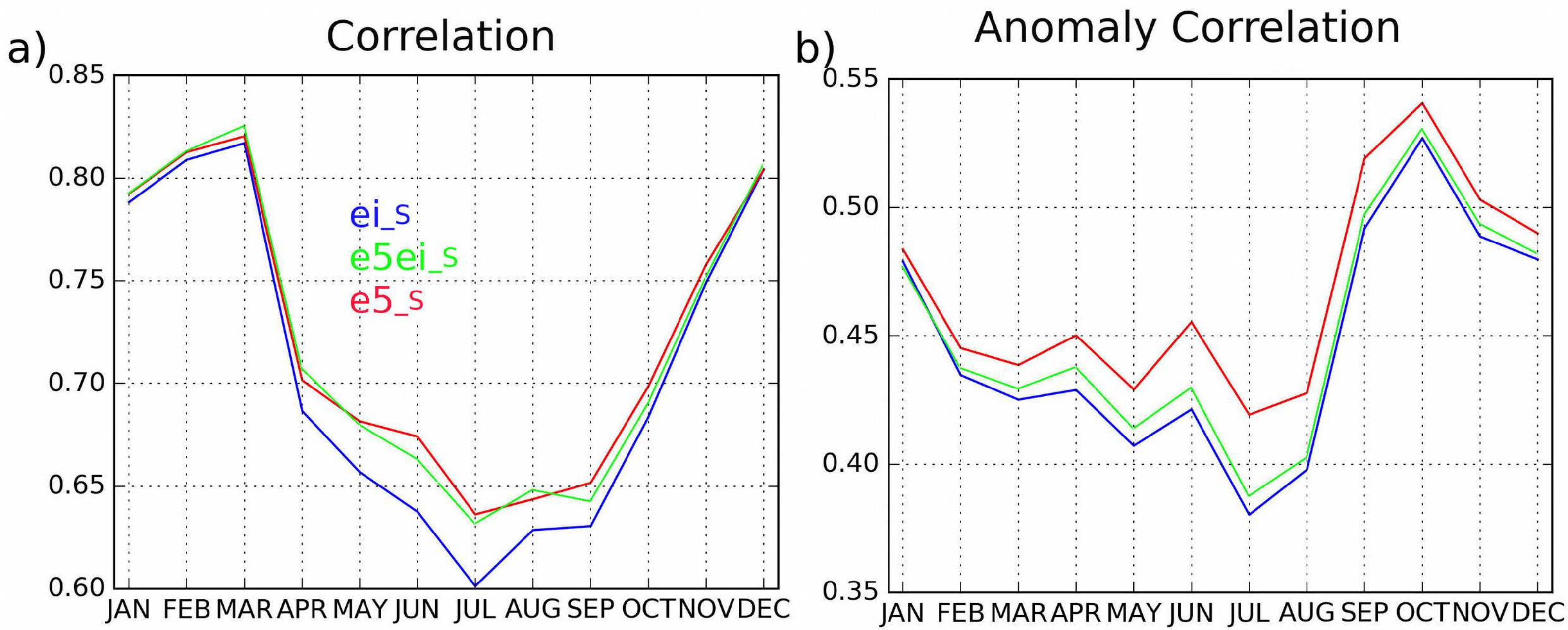
ERA-5 ability to force ISBA LSM



Vs. ESA-CCI satellite derived Surface Soil Moisture

- Correlations on volumetric (a) and anomaly (b) time-series, seasonal scores over 2010-2016 for the whole domain



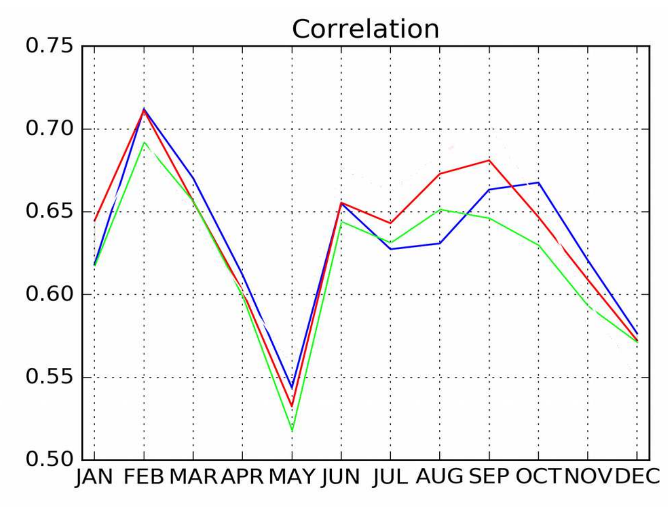
- Mean correlation on volumetric (anomaly) time-series : 0.668 (0.464), 0.682 (0.468), 0.689 (0.490)

ERA-5 driven simulations perform better !

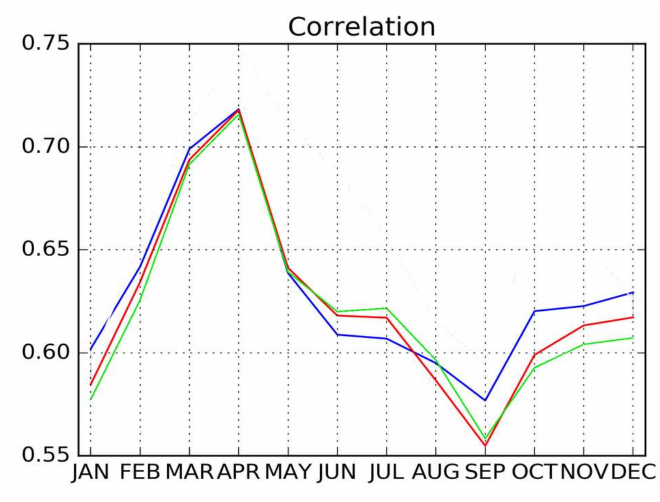
ERA-5 ability to force ISBA LSM

Seasonal scores over 2010-2016 for the whole domain

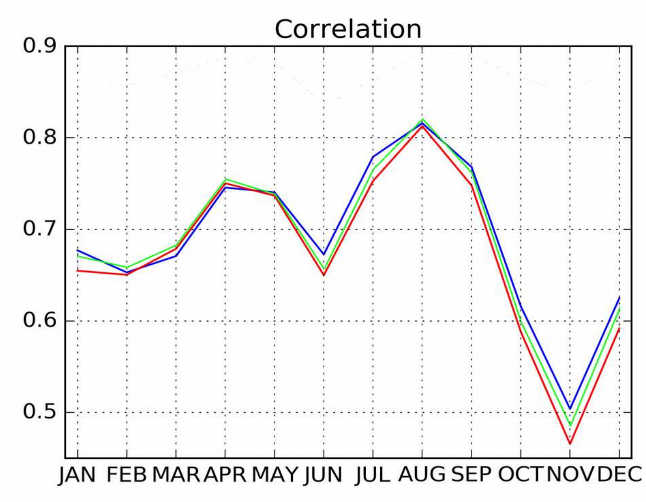
- ei_S, e5ei_S, e5_S, 0.5°x0.5° spatial resolution



Vs. **Evapotranspiration** estimates (GLEAM, Martens et al., 2017)



Vs. **GPP** estimates (FLUXCOM, Jung et al., 2017)



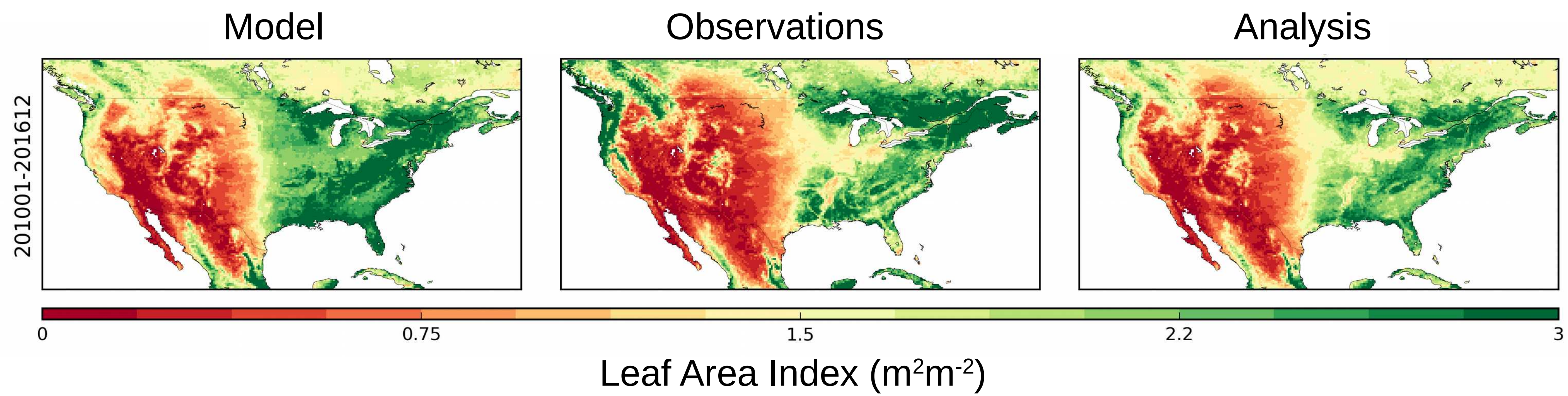
Vs. **LAI** estimates (GEOV1, CGLS)

ERA-5 driven simulations have a rather neutral impact

ERA-5 driven land surface reanalysis : LDAS-Monde

Are ERA-5 driven LDAS-Monde reanalyses better than ERA-5 driven model simulations ?

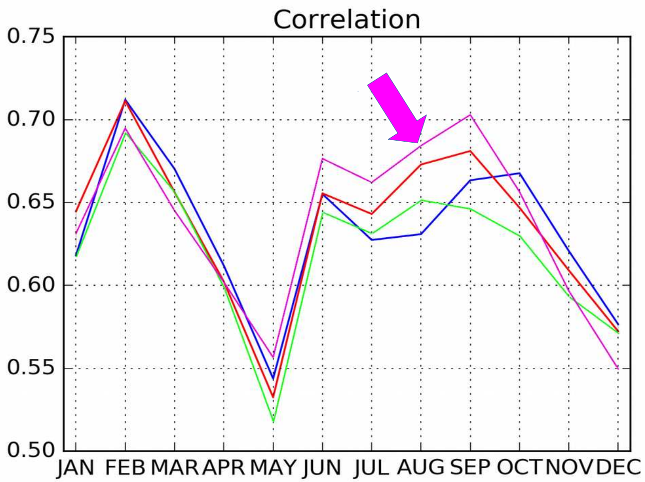
- ERA-5 (hourly, 0.25°x0.25°), assimilation of SSM and LAI : **[Analysis]**
- ERA-5 (hourly, 0.25°x0.25°) : **[Model]** ►*benchmark for the analysis*



ERA-5 driven land surface reanalysis : LDAS-Monde

Seasonal scores over 2010-2016

- ei_S, e5ei_S, e5_S, 0.5°x0.5° spatial resolution
- Analysis, 0.25°x0.25° spatial resolution



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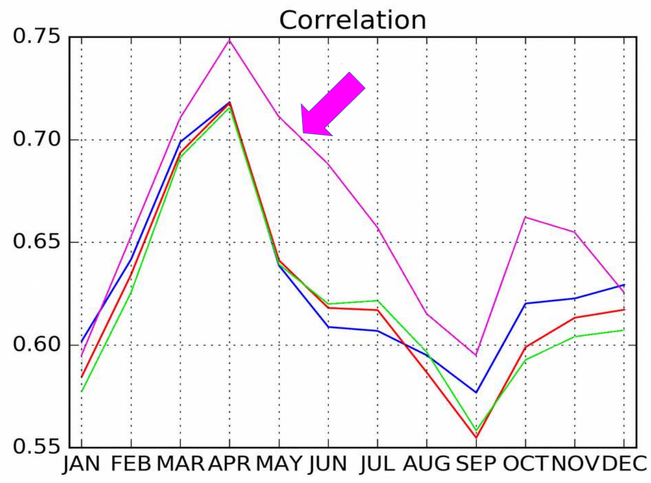

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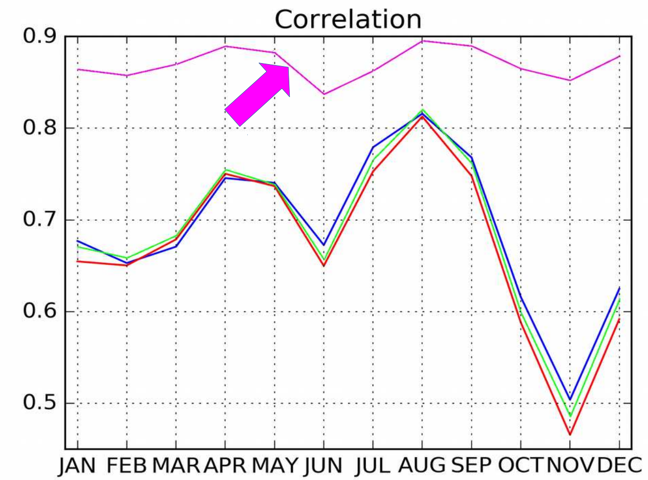


Vs. **LAI** estimates (GEOV1, CGLS)

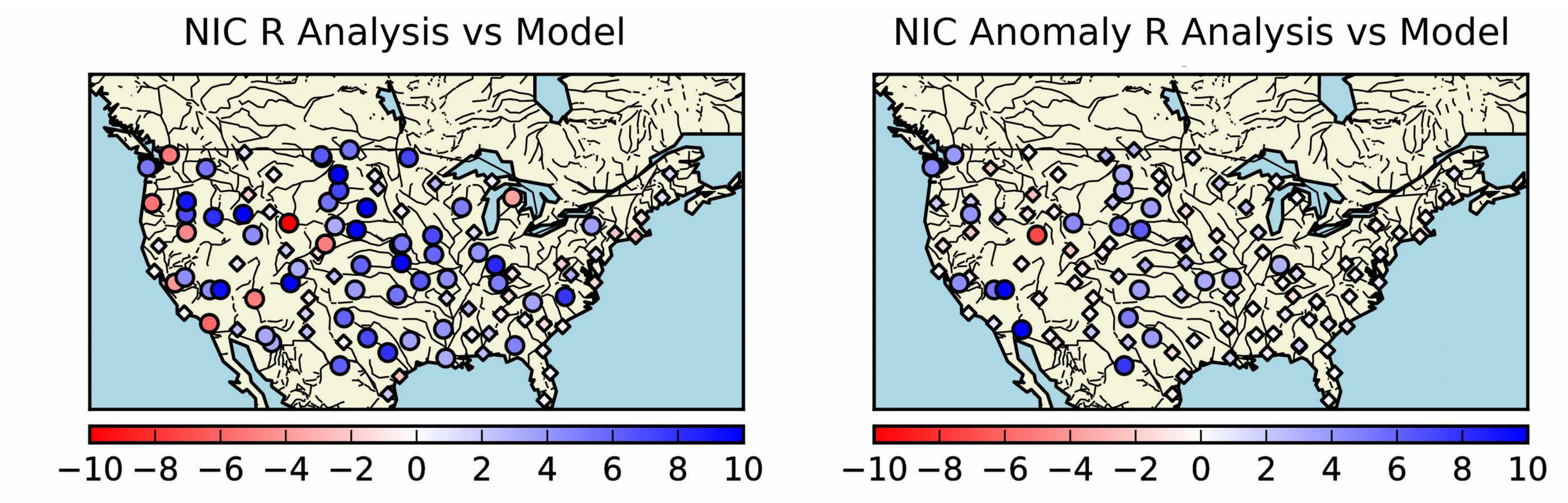
ERA-5 driven simulations have a rather neutral impact

Clear improvements from ERA-5 driven reanalyses!

ERA-5 driven land surface reanalysis : LDAS-Monde

Vs. in situ soil moisture from USCRN network

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



110 (110) stations with significant R (Anomaly R)	**Median R (Anomaly R)**	**Median ubRMSD**	**NIC_R (NIC_ANO_R) > +3 % Blue circles**	**NIC_R (NIC_ANO_R) < -3 % Red circles**	**NIC_NSE [-3,+3] Diamonds**
Model	0.72 (0.60)	0.049	/	/	/
Analysis	**0.74** (0.60)	**0.048**	**46 % (18 %)**	8 % (1 %)	46 % (81 %)
			Positive impact	Negative impact	Neutral impact

ERA-5 driven reanalyses bring further improvements !

ERA-5 driven land surface reanalysis : LDAS-Monde

Vs. River discharge (USGS)

- **NSE** values are computed for each Exp. / stations *(daily values scaled to the drainage area)*
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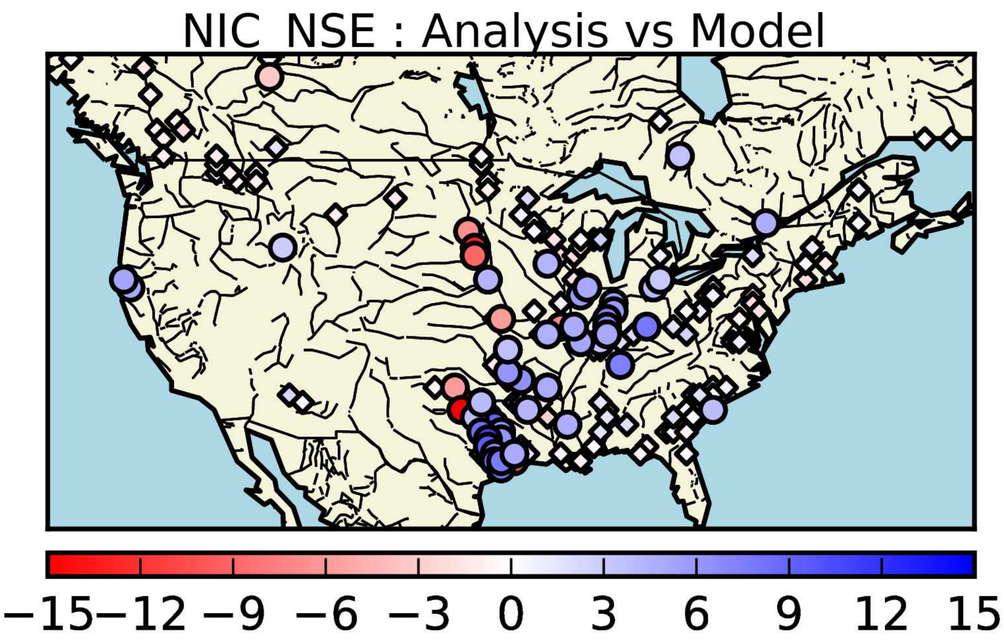
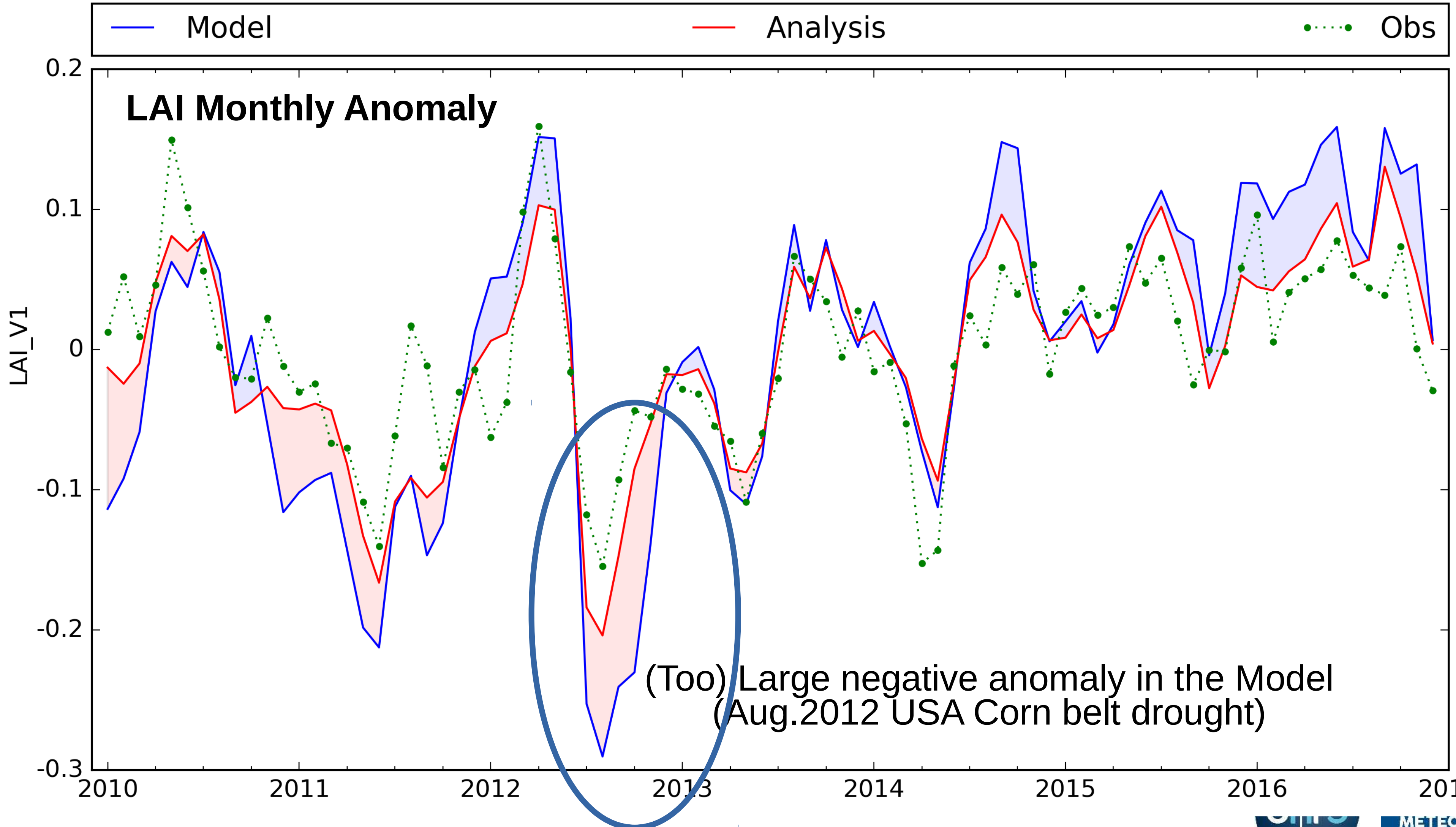


N stations NSE_Model >-1	NIC_NSE > +3 % Blue circles	NIC_NSE < -3 % Red circles	NIC_NSE [-3,+3] Diamonds
258	**22 %**	4 %	74 %
	Positive impact	Negative impact	Neutral impact

ERA-5 driven reanalysis bring further improvements !

Monitoring agricultural drought

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



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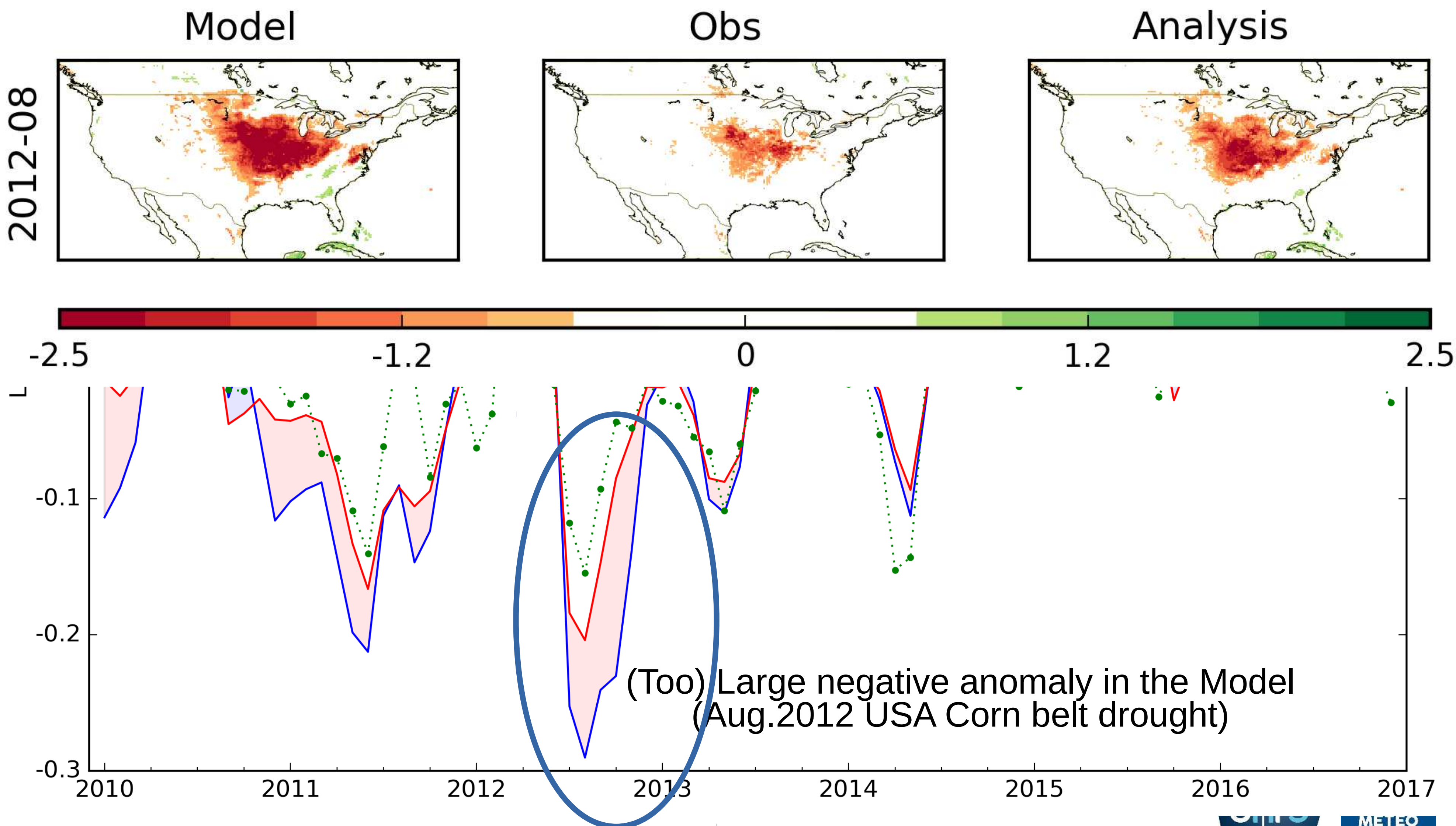
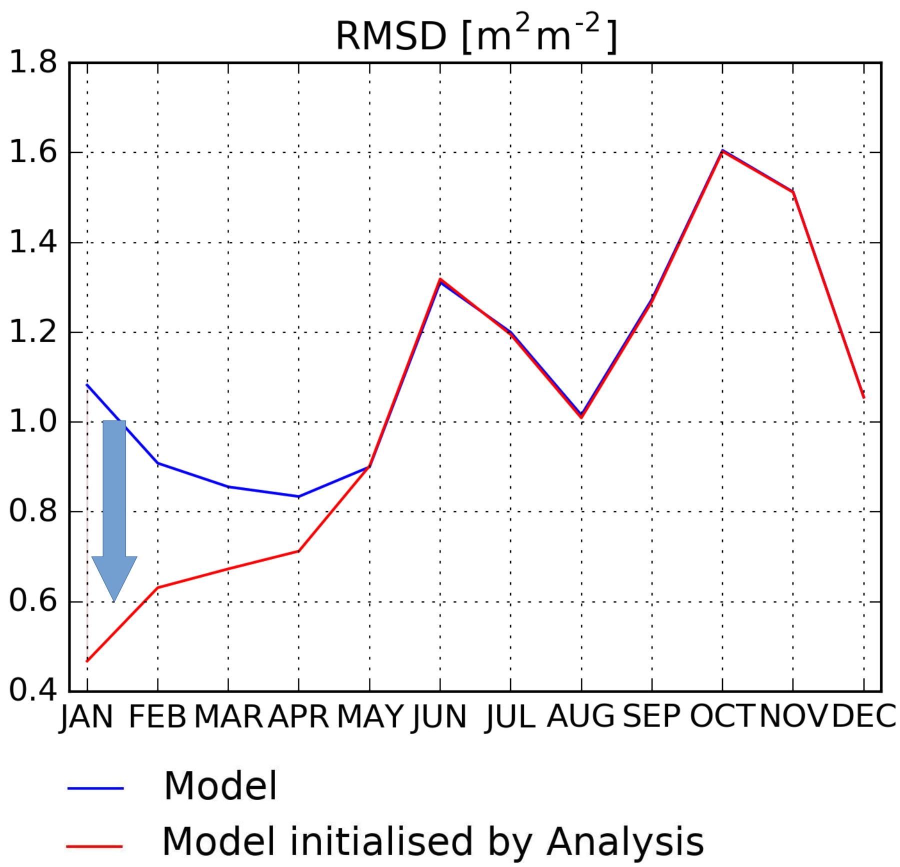
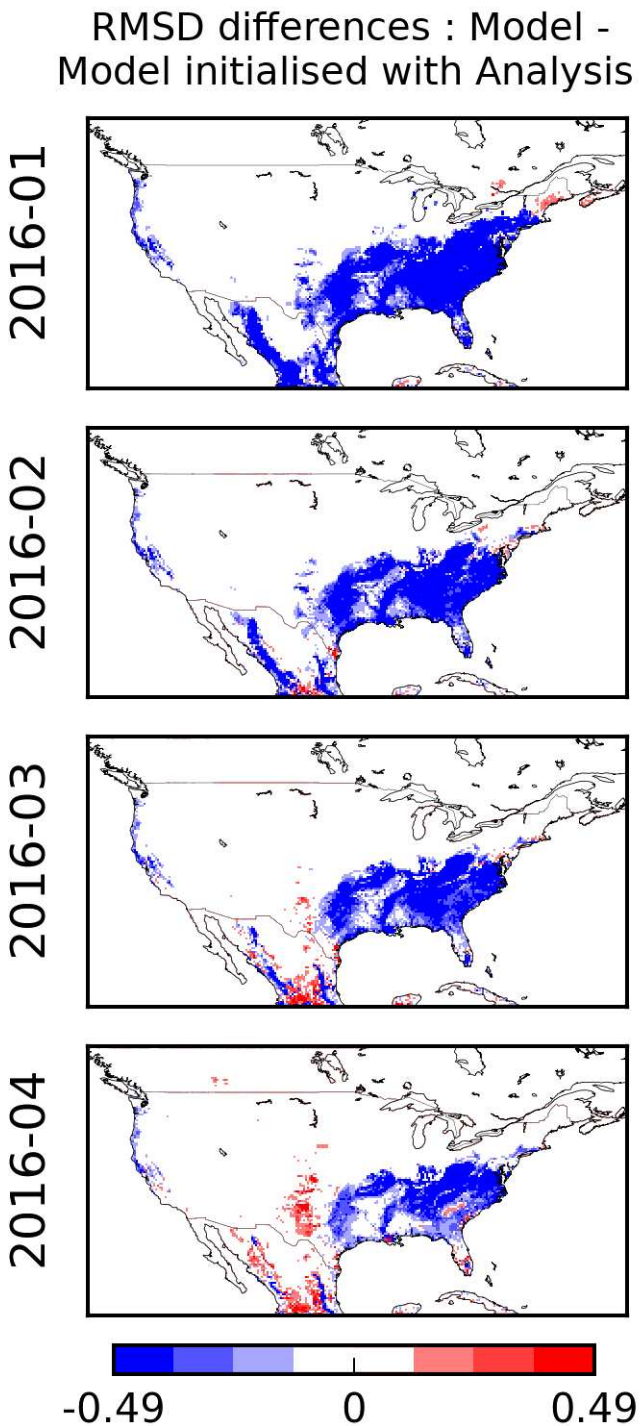


From monitoring to forecasting

- **Could analysis provide better initial conditions than model run ? Does the impact last in time ?**
  - Use analysis initial conditions at 01/01/2016 to start a 12-month Model run
  - Compare with a ‘simple’ model run
  - Evaluation against LAI observations over (2010-2016)

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





ERA-5 driven land surface reanalysis : LDAS-Monde

►*Could ERA-5 enhance the simulation performances w.r.t. ERA-Interim when used to force ISBA ?* **YES**

- 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

(Albergel et al., 2018, HESS)

►*Are ERA-5 driven LDAS-Monde reanalyses better than ERA-5 driven model simulations ?* **YES**

- 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., Dutra, E., Munier, S., Calvet, J.-C., Munoz-Sabater, J., de Rosnay, P., and Balsamo, G.: ERA-5 and ERA-Interim driven ISBA land surface model simulations: Which one performs better?, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2018-117, accepted, 2018.

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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ERA-5 ability to force ISBA LSM

Vs. in situ Soil moisture from USCRN network

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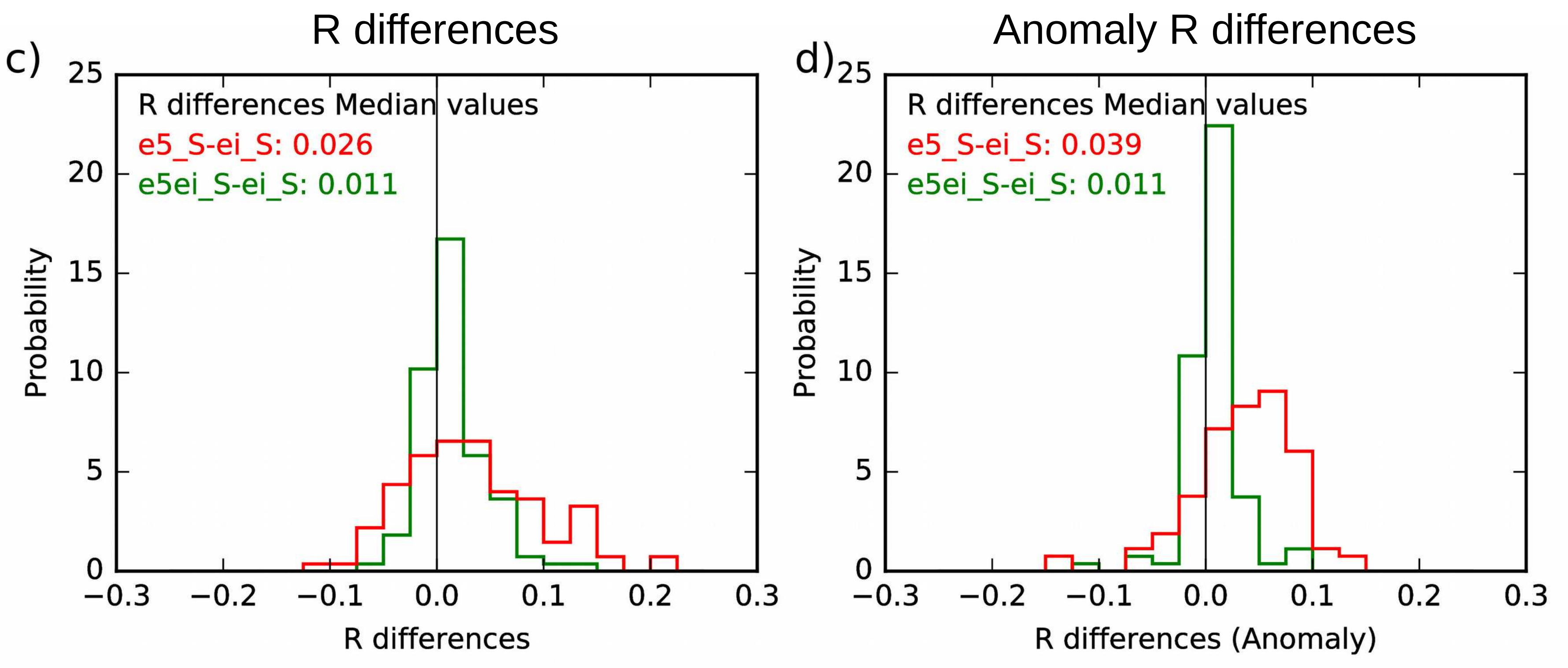

ERA-5 driven simulations perform better !