Data Assimilation for Continuous Assessment of Severe Conditions Over Terrestrial Surfaces

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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 (LSVs)**
  [Lettenmaier et al., 2015, Balsamo et al., 2018]

→ Spatial and temporal gaps & cannot observe all key LSVs (e.g. RZSM)

- **Land Surface Models (LSMs)** provide LSV estimates at all time/location

→ LSMs have uncertainties

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

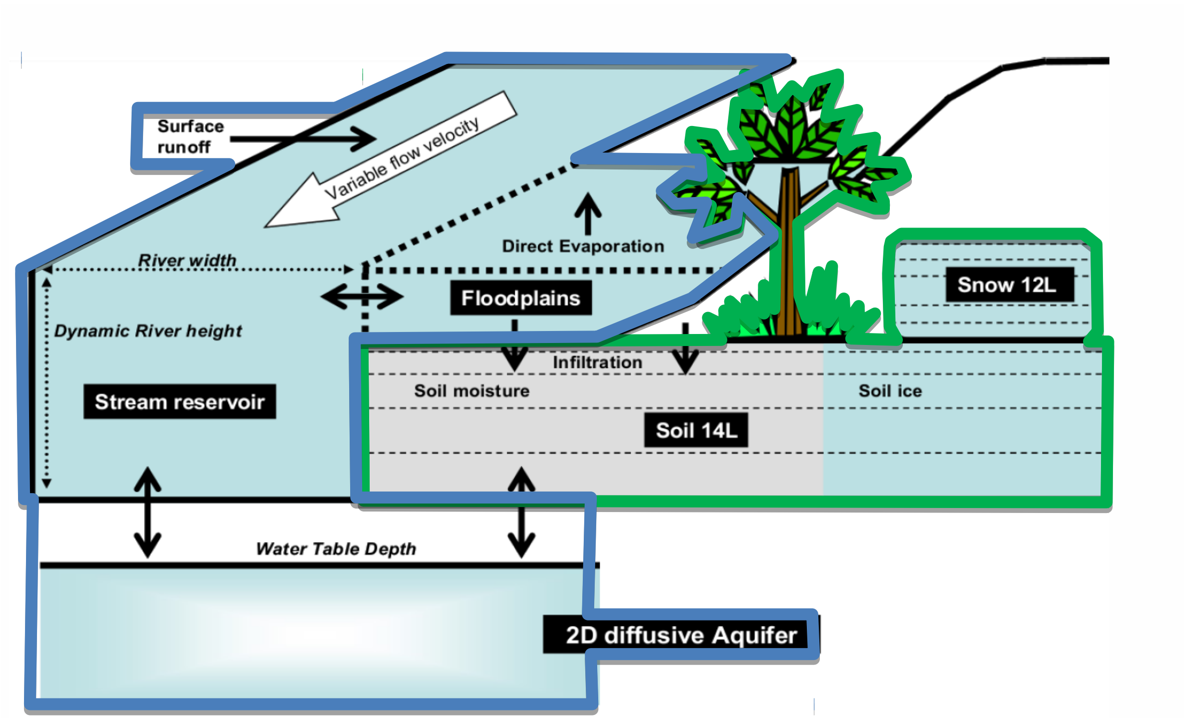
→ **Data assimilation**
Spatially and temporally integrates the observed information into LSMs in a consistent way to unobserved locations, time steps and variables

Study the vegetation and terrestrial water cycles

LDAS-Monde: global capacity offline integration of satellite observations into a land surface model fully coupled to hydrology

LDAS-Monde involves

- **Land surface model: ISBA-A-gs**
- **River routing system: CTRIP** (CNRM-Total Runoff Integrating Pathways, now 1/12°)
- **Data assimilation routines** (SEKF, EnSRF, PF)
- **Satellite derived observations** (SSM, LAI)



ISBA Land Surface Model

ISBA solves the energy and water budgets at the surface level and describes the exchanges between the land surface and the atmosphere (on a sub-hourly basis)

- ISBA-A-gs (CO_2-responsive version) simulates the diurnal cycle of water and carbon fluxes, plant growth and key vegetation variables
- Phenology driven by photosynthesis

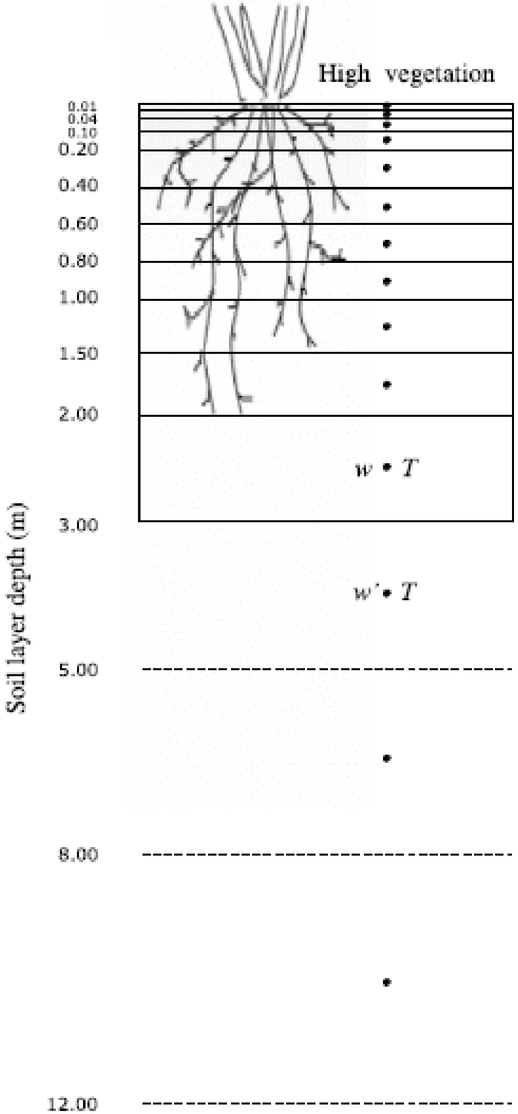
➔ *LAI is very flexible and can be updated when observations are available*

- ISBA-Dif multilayer soil diffusion scheme (14 layers, 12 m)

- ISBA land surface model needs:
  - Parameters for the vegetation and soil texture

    Derived from the ECOCLIMAP-II landcover database*
  - Atmospheric forcing

    Longwave & shortwave radiation, 2-metre air temperature & humidity, precipitations (liquid and solid), surface pressure and near surface wind speed



** 1km spatial resolution, ECOCLIMAP-SG already available, 300m resolution*

https://www.umr-cnrm.fr/spip.php?article146

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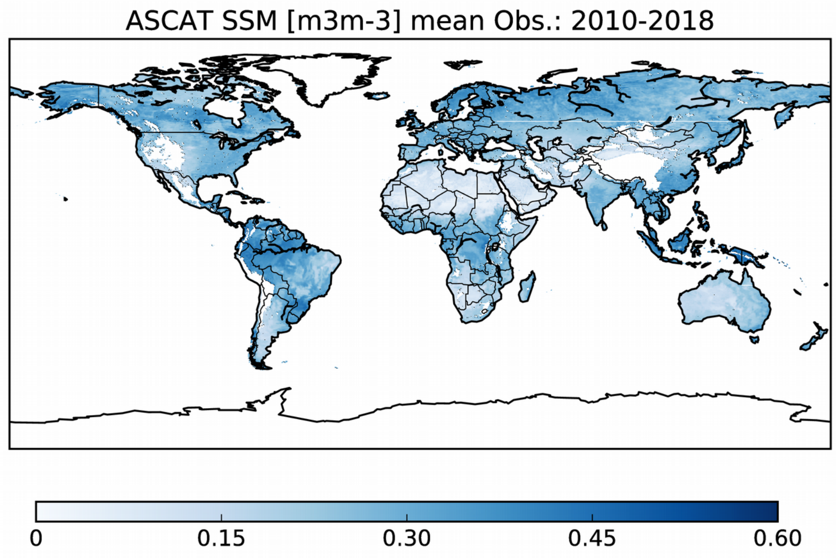
LDAS-Monde successfully validated at regional/continental scale

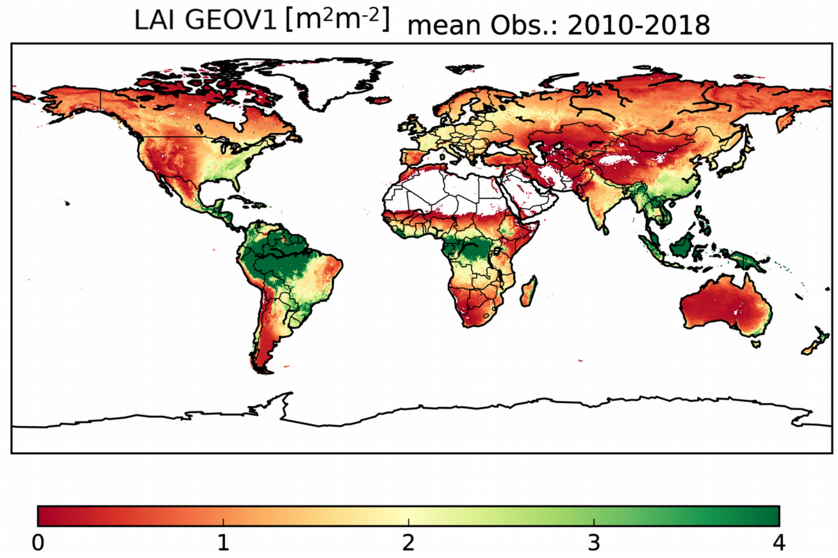
- Agricultural statistics (e.g. Dewaele et al., 2018, HESS)
- River discharge (e.g. Albergel et al., 2017, GMD, 2018, RS)
- In situ measurements of soil moisture (e.g. Albergel et al., 2018, *RS*)
- Evapotranspiration from GLEAM, Fluxnet2015 (e.g. Albergel et al., 2018, *RS*)
- Gross Primary Production from FLUXCOM (e.g. Tall et al., 2019, *RS*)
- Sun-Induced Fluorescence (vs. GPP, e.g. Leroux et al., 2018, *RS*, Tall et al., 2019, *RS*)

[*LDAS EnSRF: Bonan et al HESSD]

LDAS-Monde goes global

Model	Domain	Atm. Forcing	DA Method	Assimilated Obs.	Observation Operator	Control Variables	Additional Option
ISBA Multi-layer soil model CO_2-responsive version (Interactive vegetation)	**Global (2010 – 2018)**	**ERA-5 Res.: 0.25°x0.25° (LDAS-ERA5)**	**SEKF**	**SSM** (CGLS ASCAT SWI* + cdf matching) **LAI** (CGLS GEOV1*)	**Second layer of soil (1-4cm)** **LAI**	**Layers of soil 2 to 8 (1-100cm)** **LAI**	**Coupling with CTRIP (0.5°)**





- Control variables (CVs) are directly updated thanks to their sensitivity to the observed variables
- Other variables are indirectly modified through biophysical processes and feedbacks in the model

*https://land.copernicus.eu/global/

LDAS-Monde goes global

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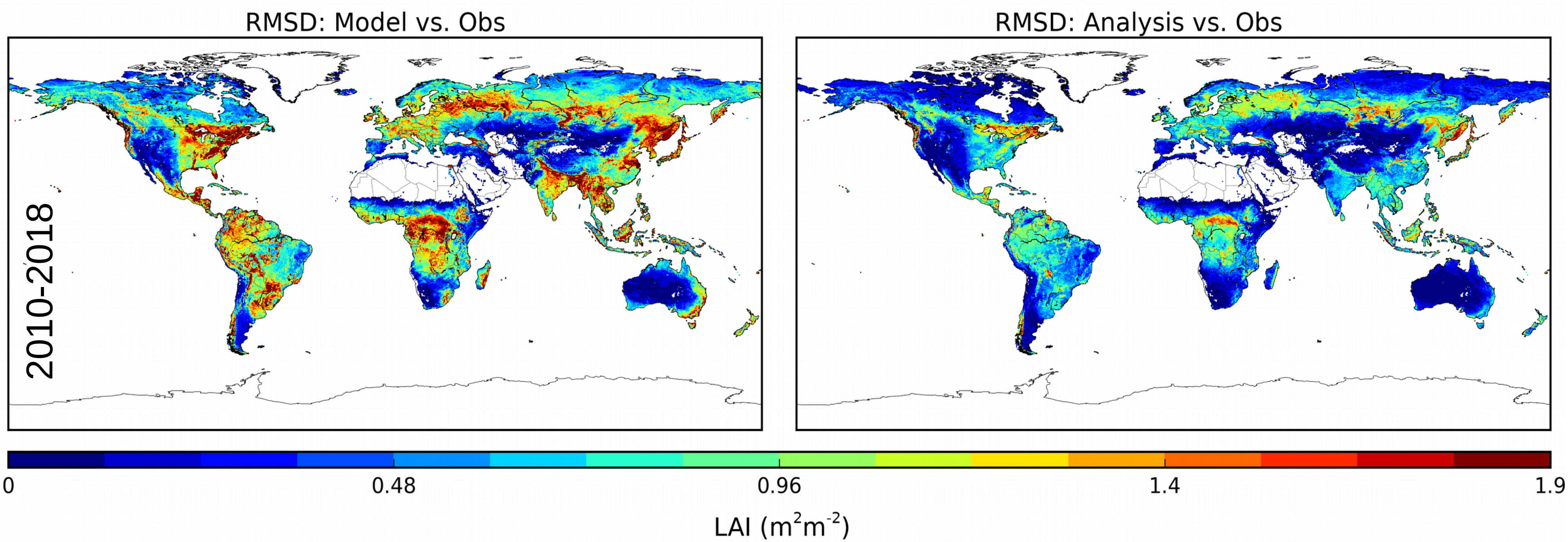
2 LDAS-ERA5 experiments : Model/Open-loop (no assimilation) and Analysis (assimilation)

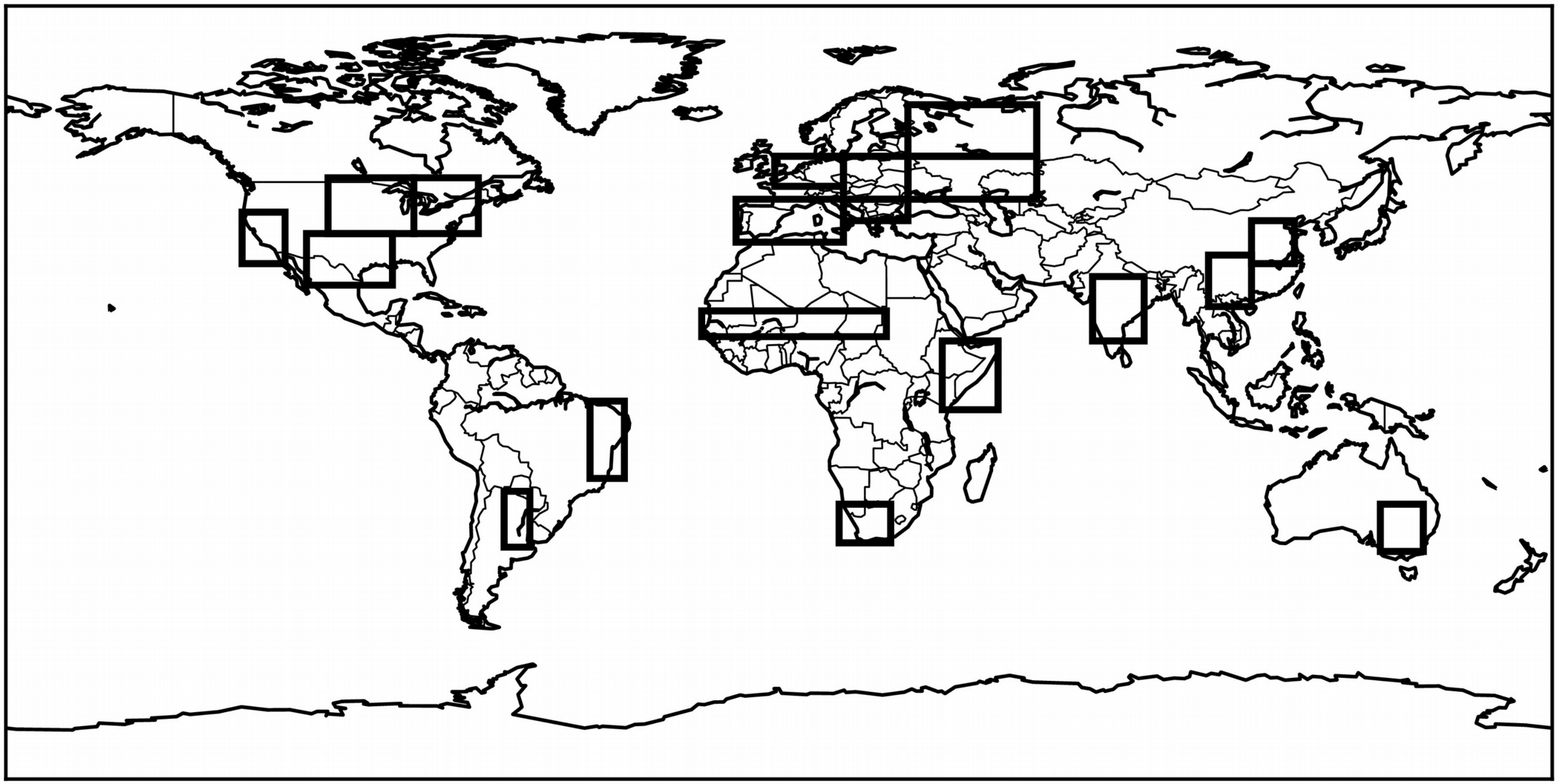


*https://land.copernicus.eu/global/

More evaluation :
https://www.hydrol-earth-syst-sci-discuss.net/hess-2019-534/

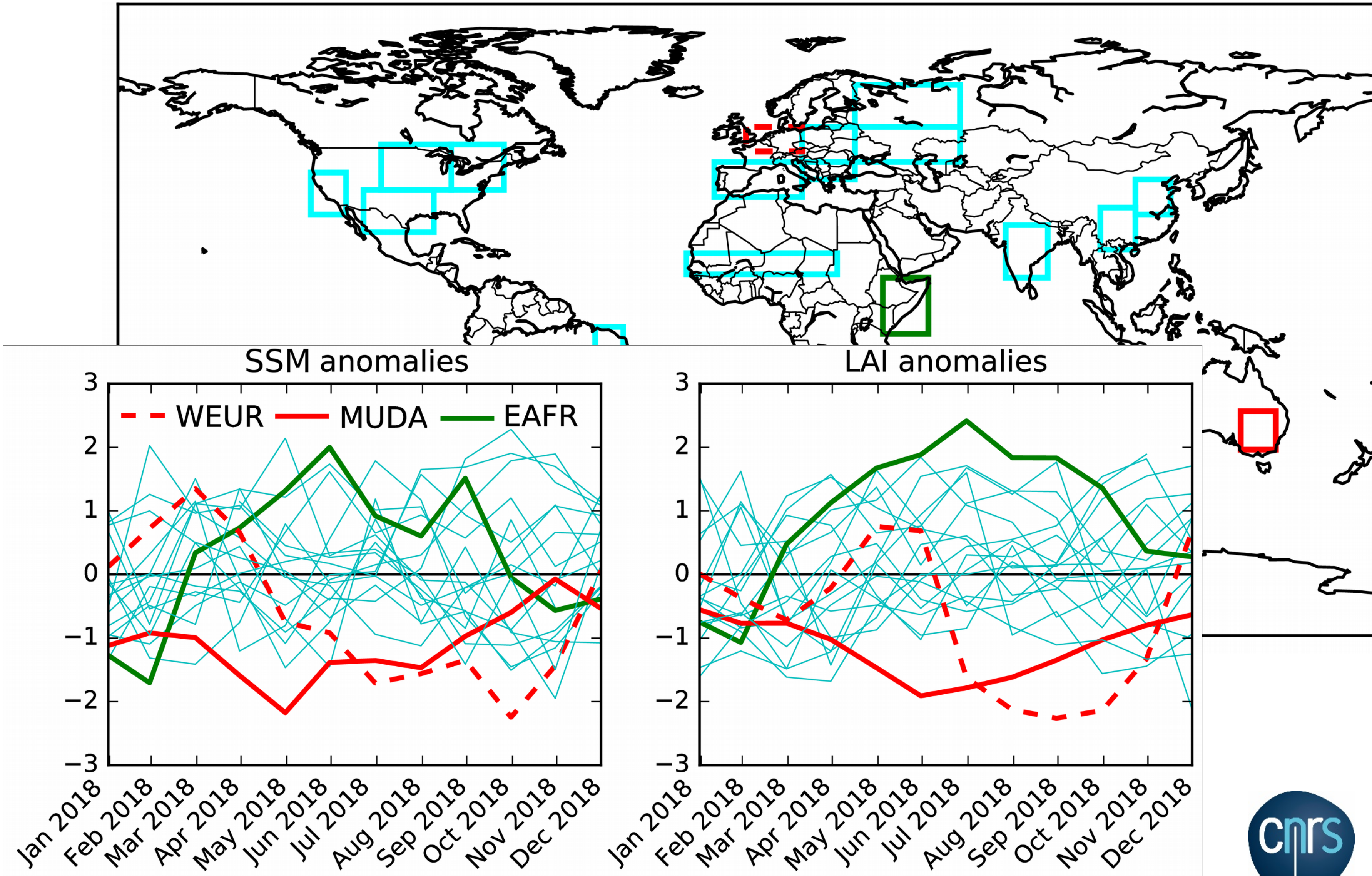
LDAS-Monde goes global

Selection of 19 regions known for being potential hot spots for droughts and heat waves



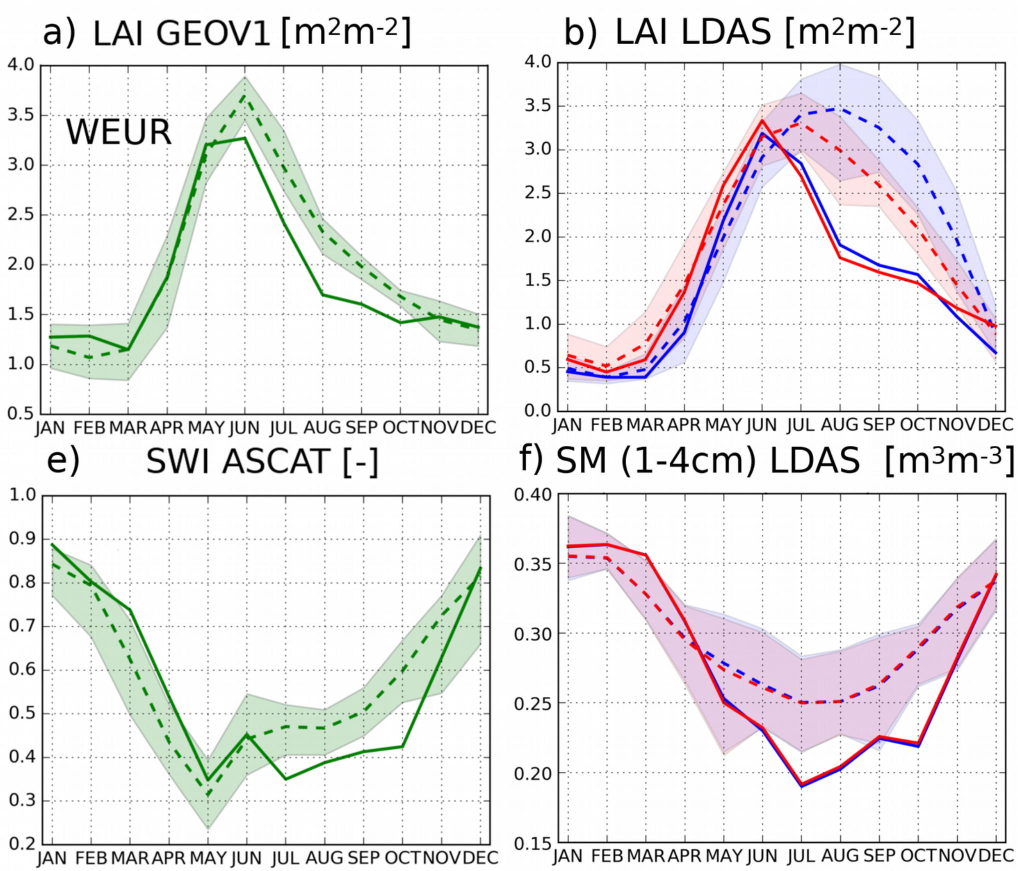
LDAS-Monde goes global

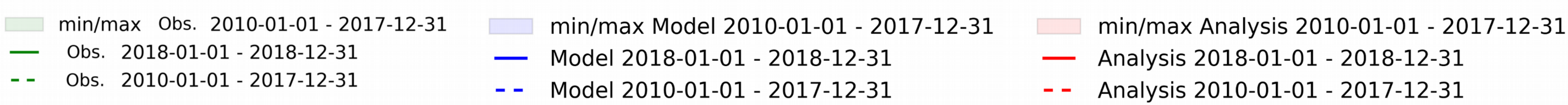
Monthly anomalies for 2018 with respect to 2010-2018



Impact of the 2018 heatwave on LSVs : WEUR

LDAS-Monde : Leaf Area Index (top) and soil Moisture (bottom)





Seasonal cycles:

- Obs., Model, Analysis : 2018 quite different from 2010-2017
- smaller differences between Model and Analysis for 2018 than for 2010-2017

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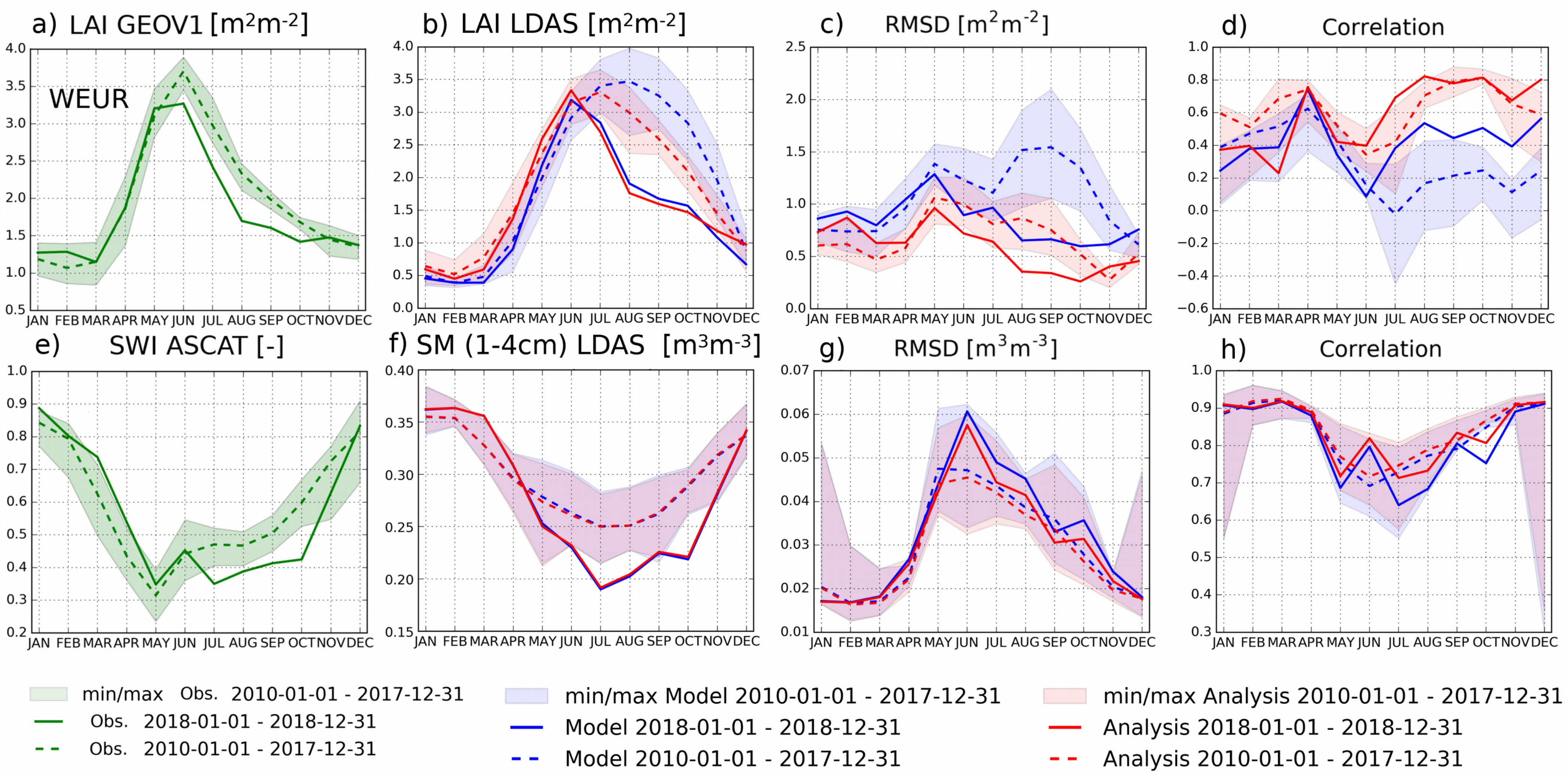
Analysis improvements over Model simulation



Impact of the 2018 heatwave on LSVs : MUDA

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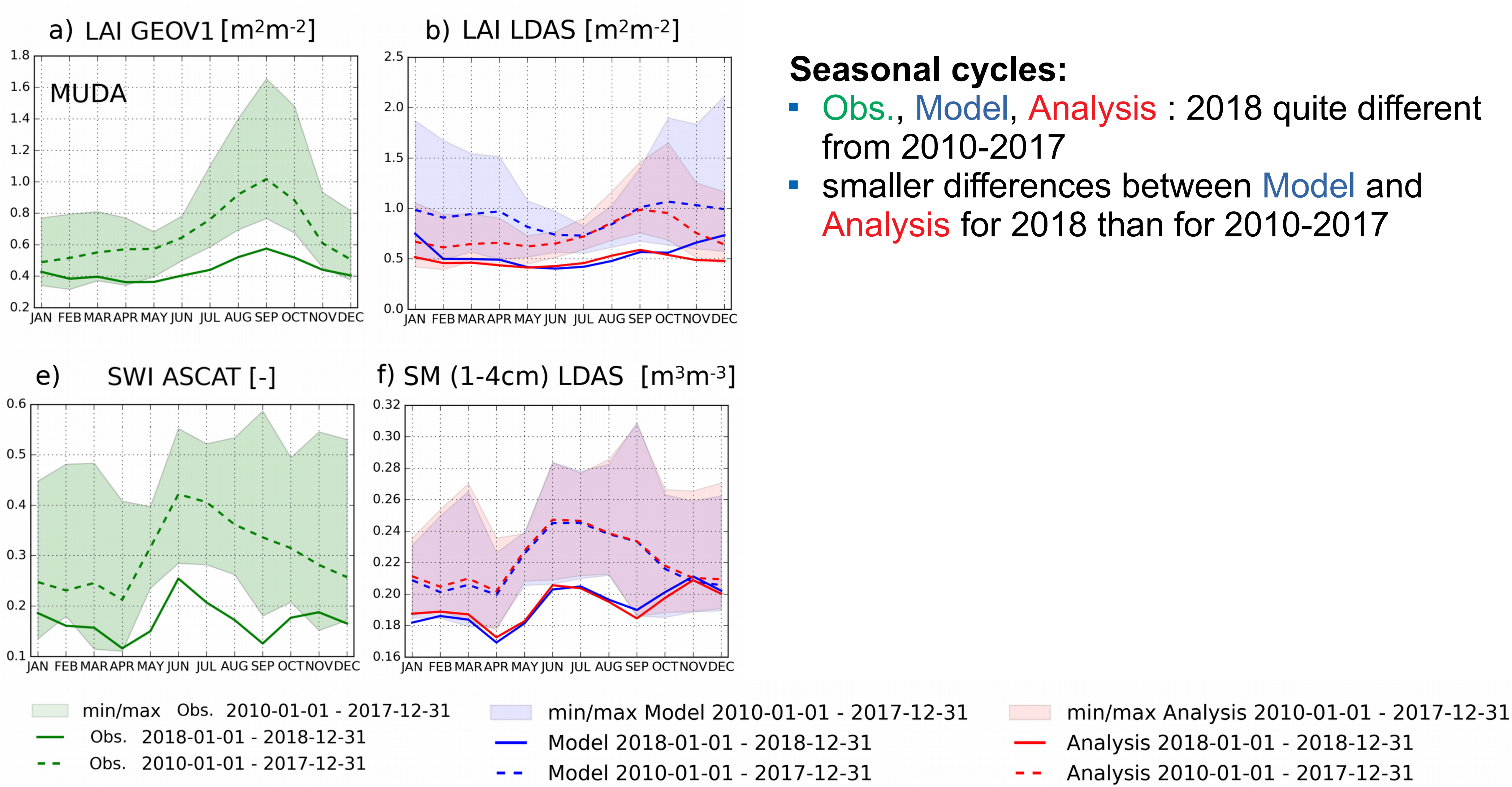

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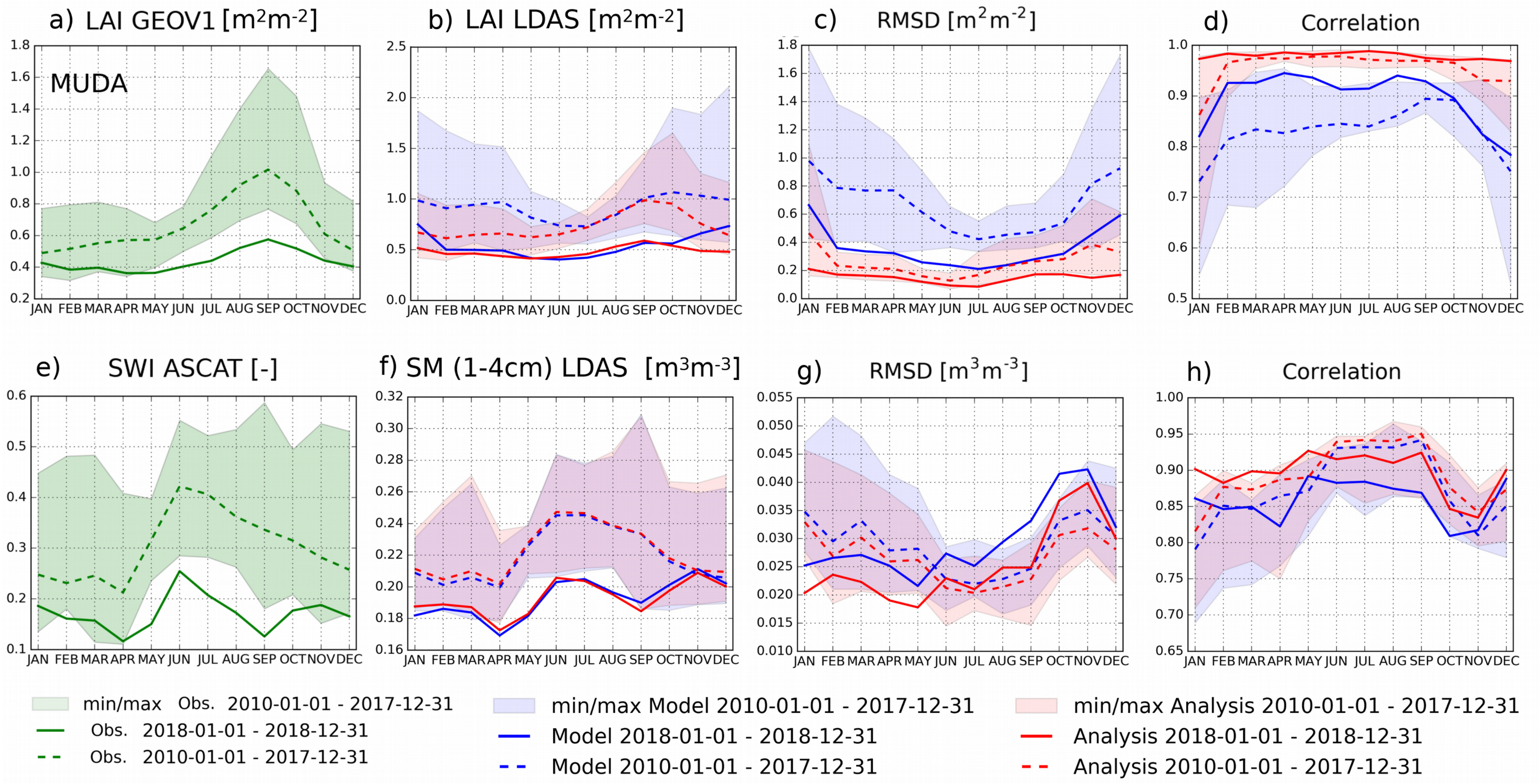
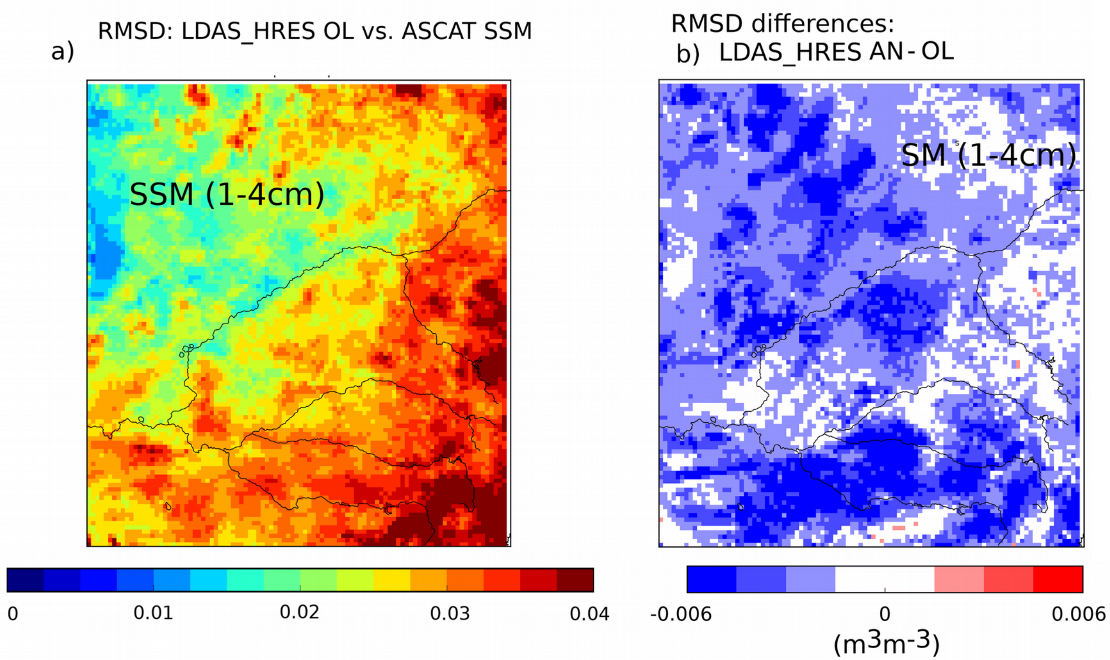


Impact of the 2018 heatwave on LSVs : MUDA

Such an extreme event needs more attention!

- Using ECMWF high resolution operational analysis to force LDAS-Monde (LDAS-HRES, 0.10°x0.10°) and complement the use of ERA5 (LDAS-ERA5, 0.25°x0.25°)



- SSM: strong positive impact from the analysis

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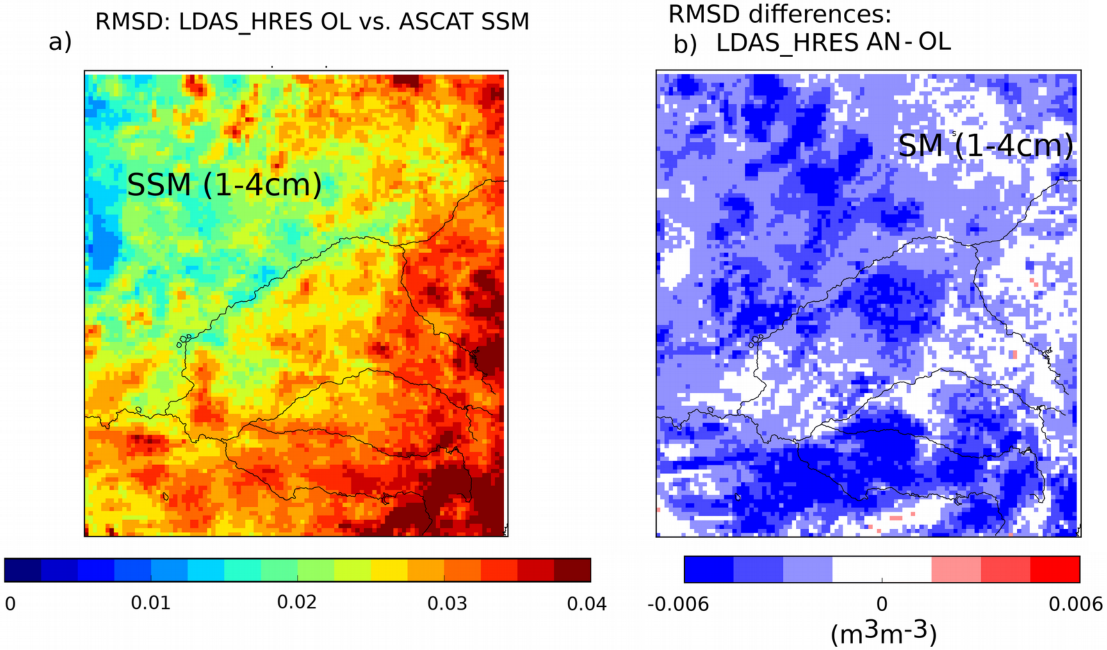
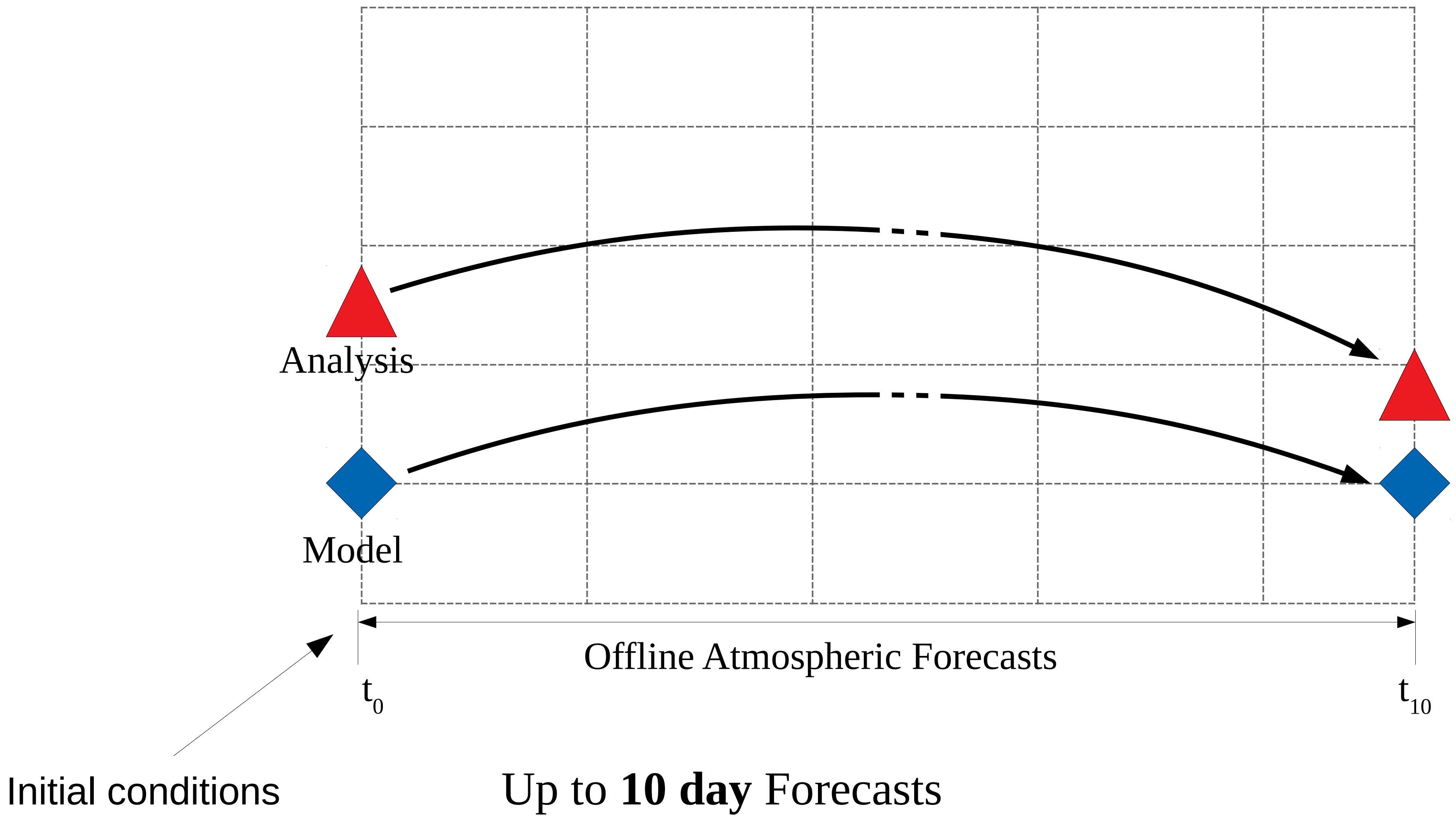
- 10-day forecast : assess the impact of the initial conditions on the LSVs Fc



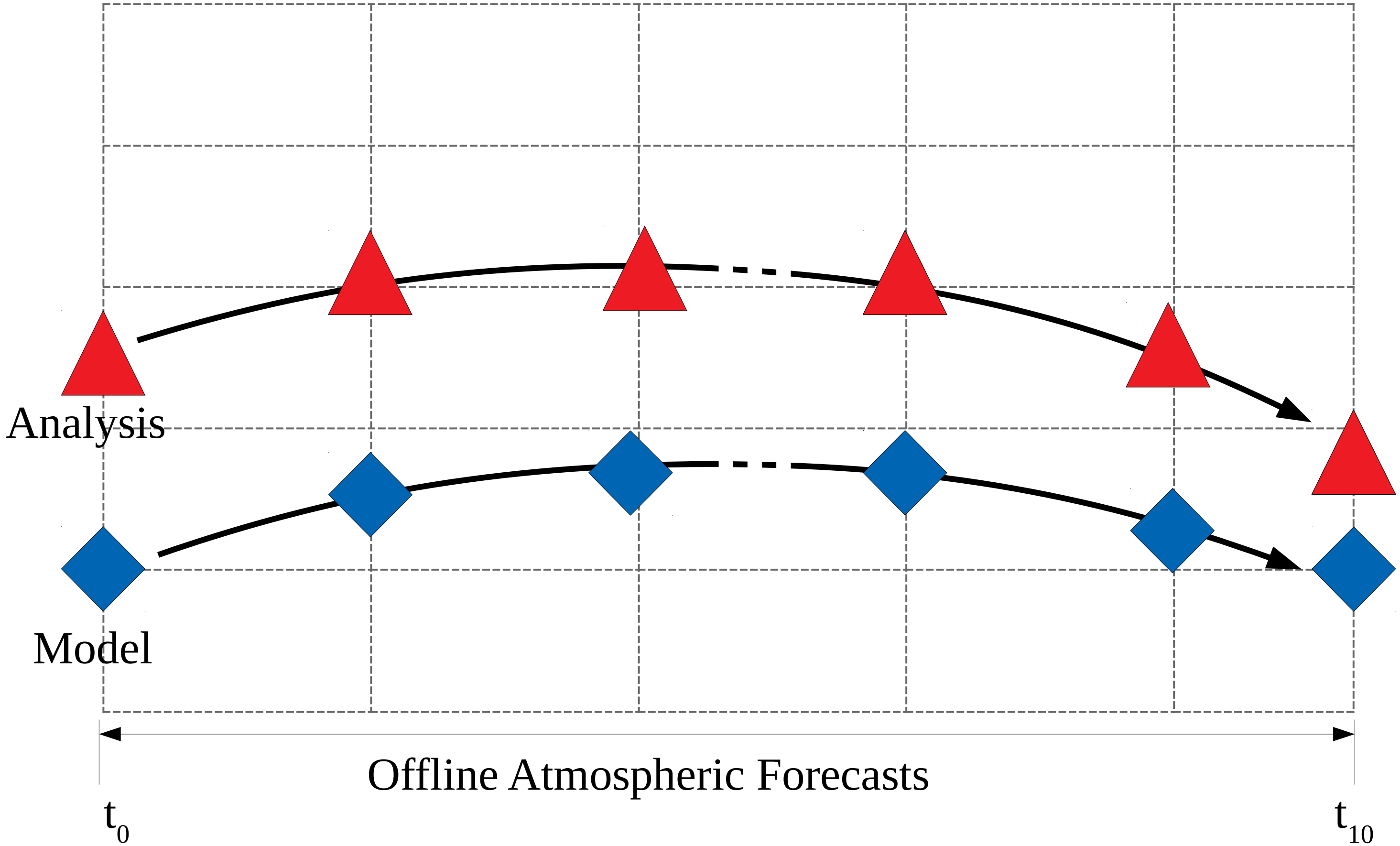
- SSM: strong positive impact from the analysis

LDAS-Monde Forecast Implementation



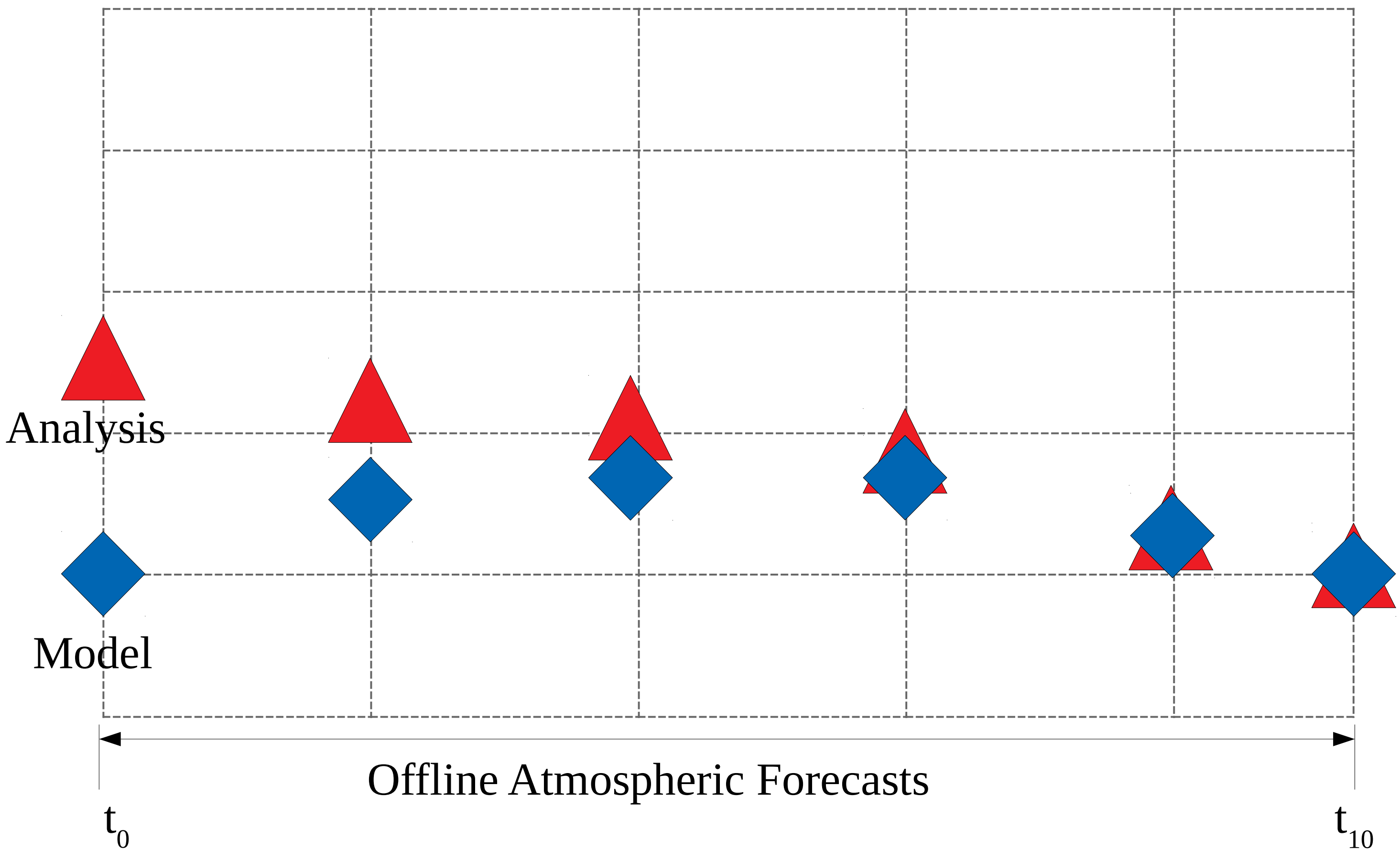
Up to **10 day** Forecasts

LDAS-Monde Forecast Implementation



Up to **10 day** Forecasts
Strong impact from the initial conditions

LDAS-Monde Forecast Implementation



Up to **10 day** Forecasts
Small impact from the initial conidtions, model goes back quickly to its climatology

Impact of the 2018 heatwave on LSVs : MUDA

Such an extreme event needs more attention!

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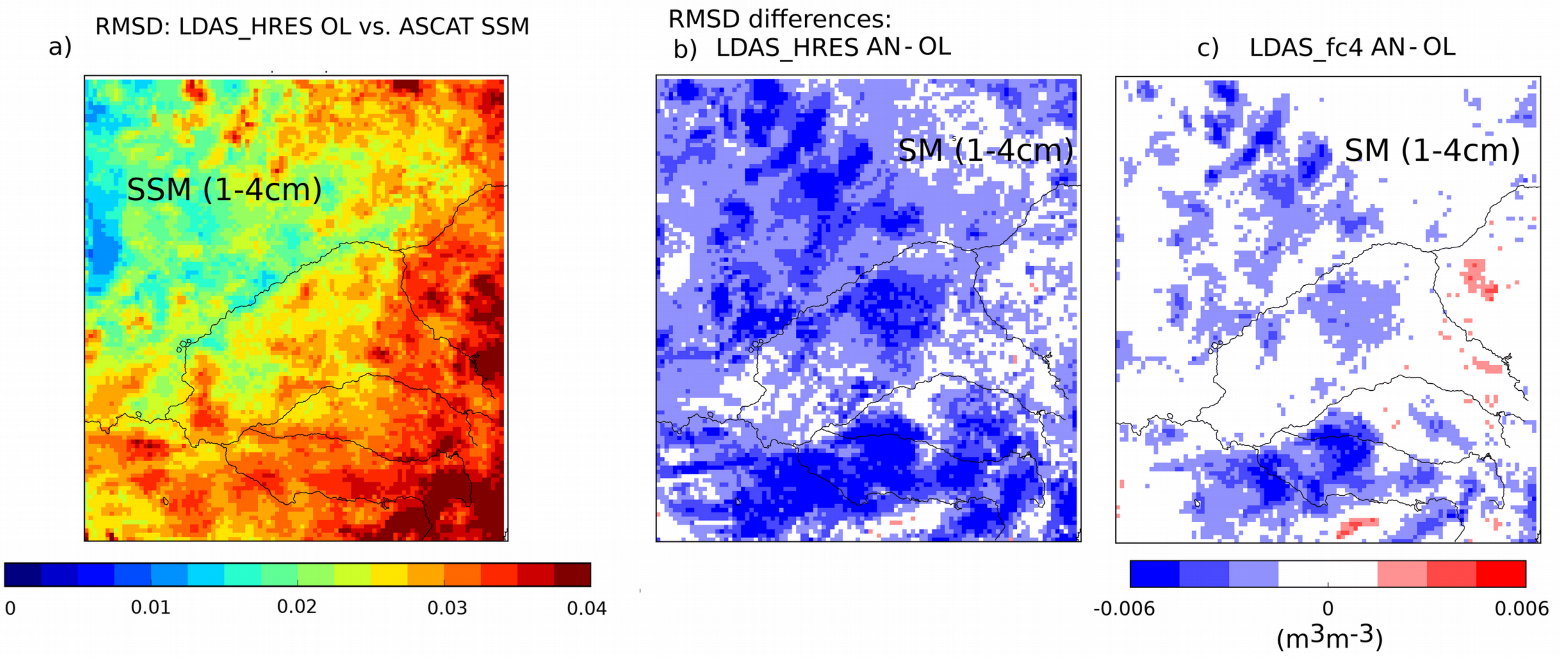

- SSM: strong positive impact from the analysis, impact of initialisation seems to vanish quickly

Impact of the 2018 heatwave on LSVs : MUDA

Such an extreme event needs more attention!

- Using ECMWF high resolution operational analysis to force LDAS-Monde (LDAS-HRES, 0.10°x0.10°) and complement the use of ERA5 (LDAS-ERA5, 0.25°x0.25°)
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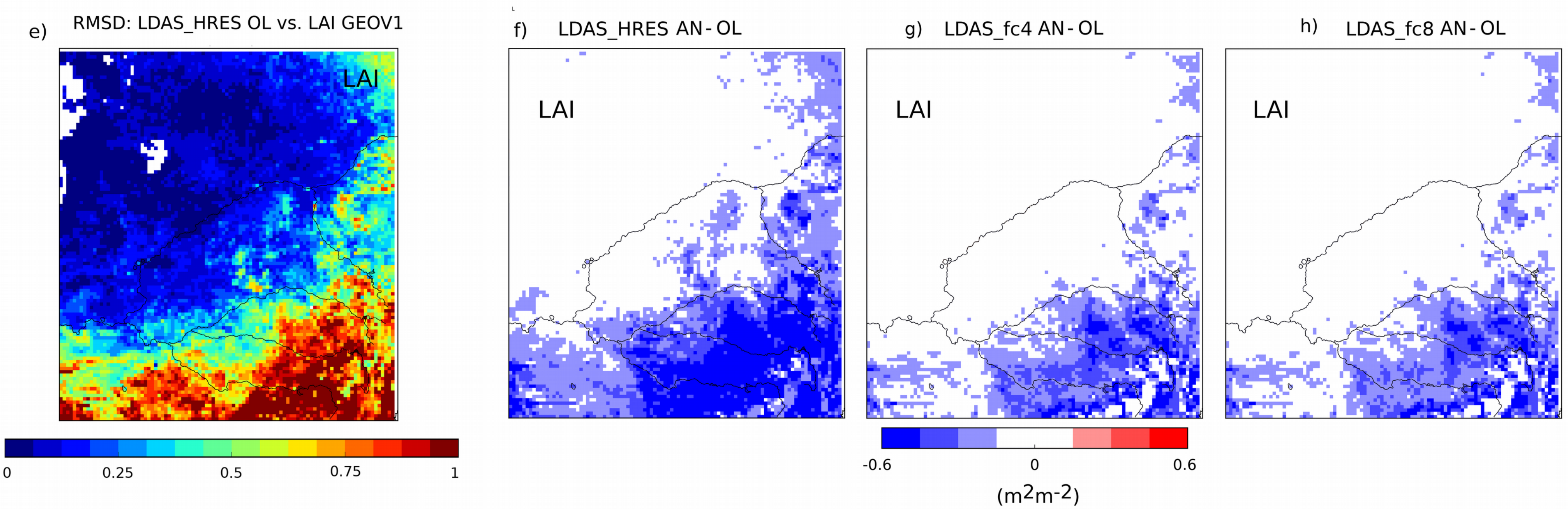
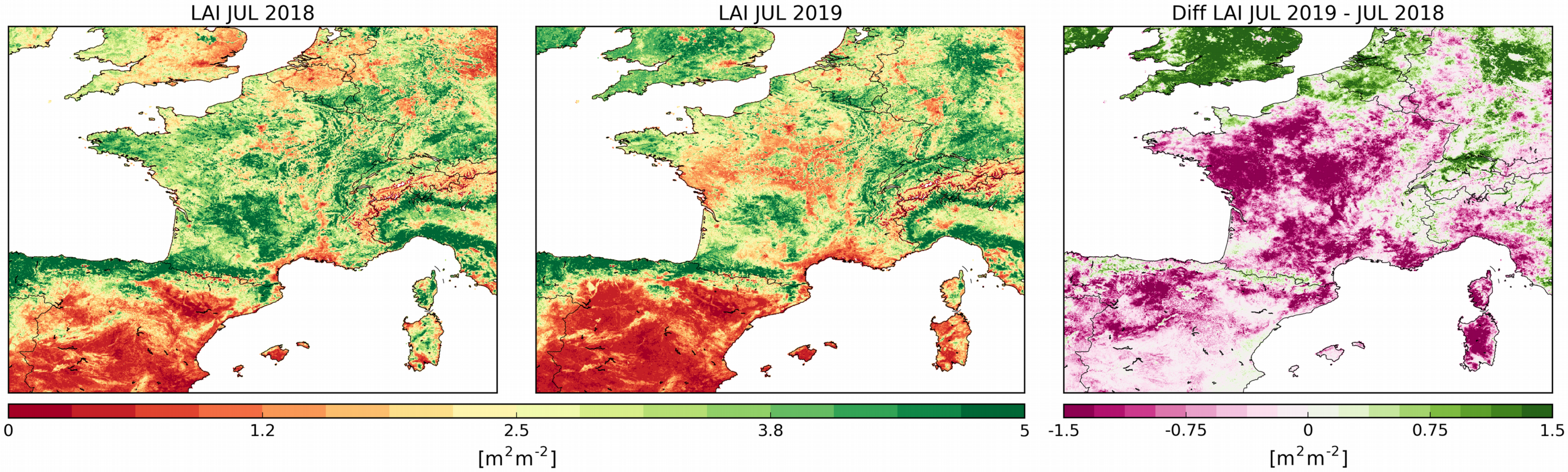


- LAI: strong positive impact from the analysis, strong positive impact from the initialisation

Towards ‘*higher*’ spatial resolution

- **LDAS-Monde** forced by **AROME** atmospheric fields from Météo-France at 2.5km x 2.5km spatial resolution (aggregated from 1.3km x 1.3km spatial resolution), assimilation of LAI300 CGLS

➔ Impact of the July 2019 heatwave



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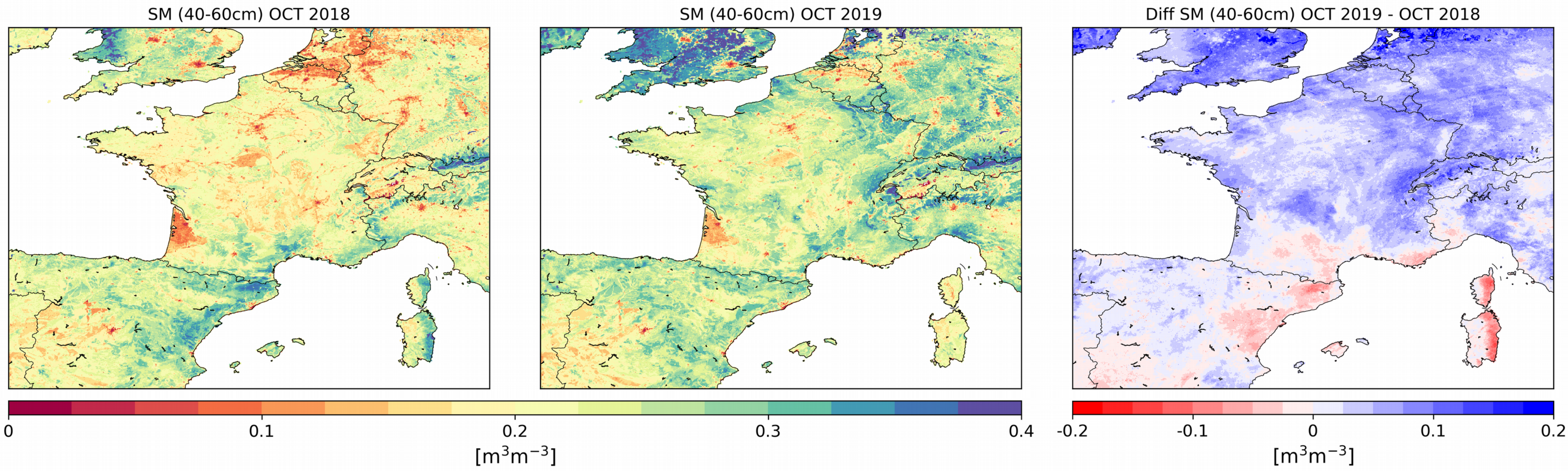
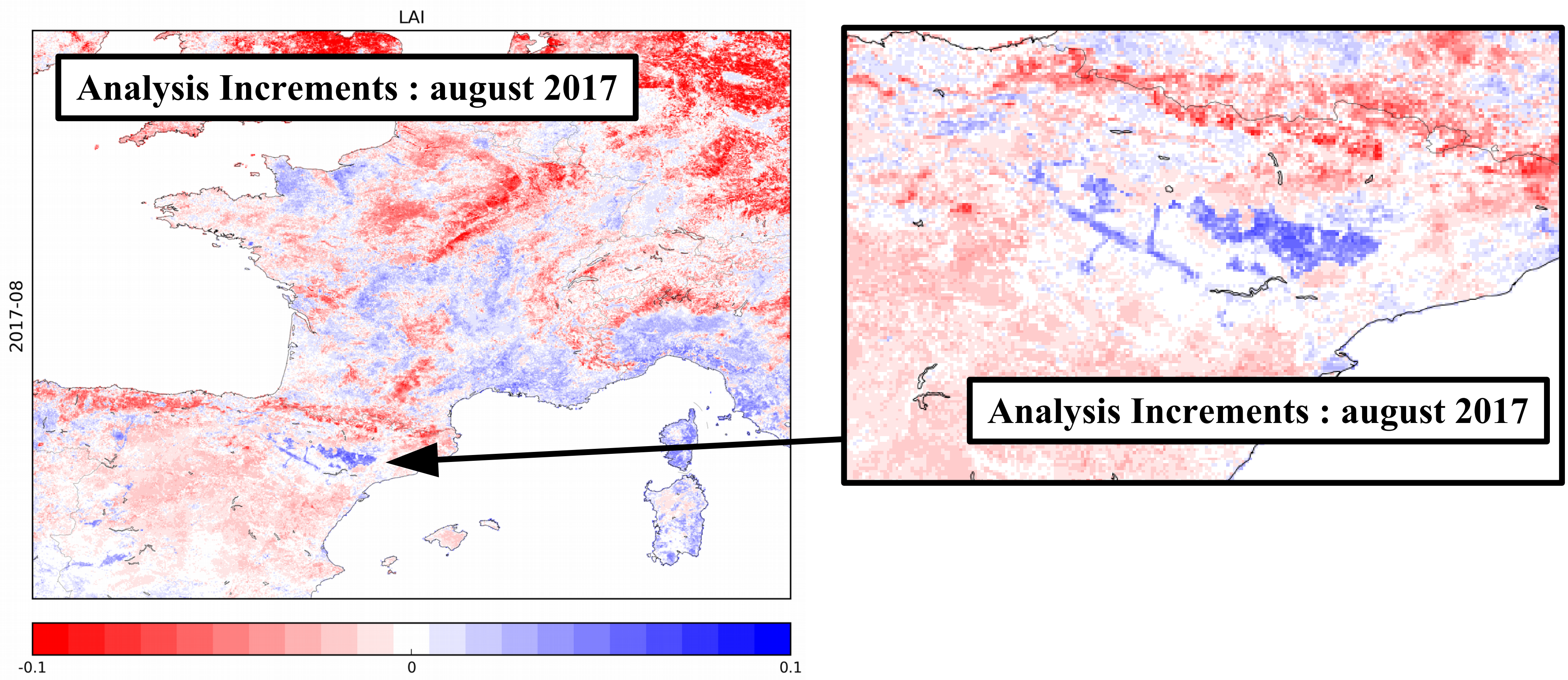


LDAS-Monde : DA specific patterns



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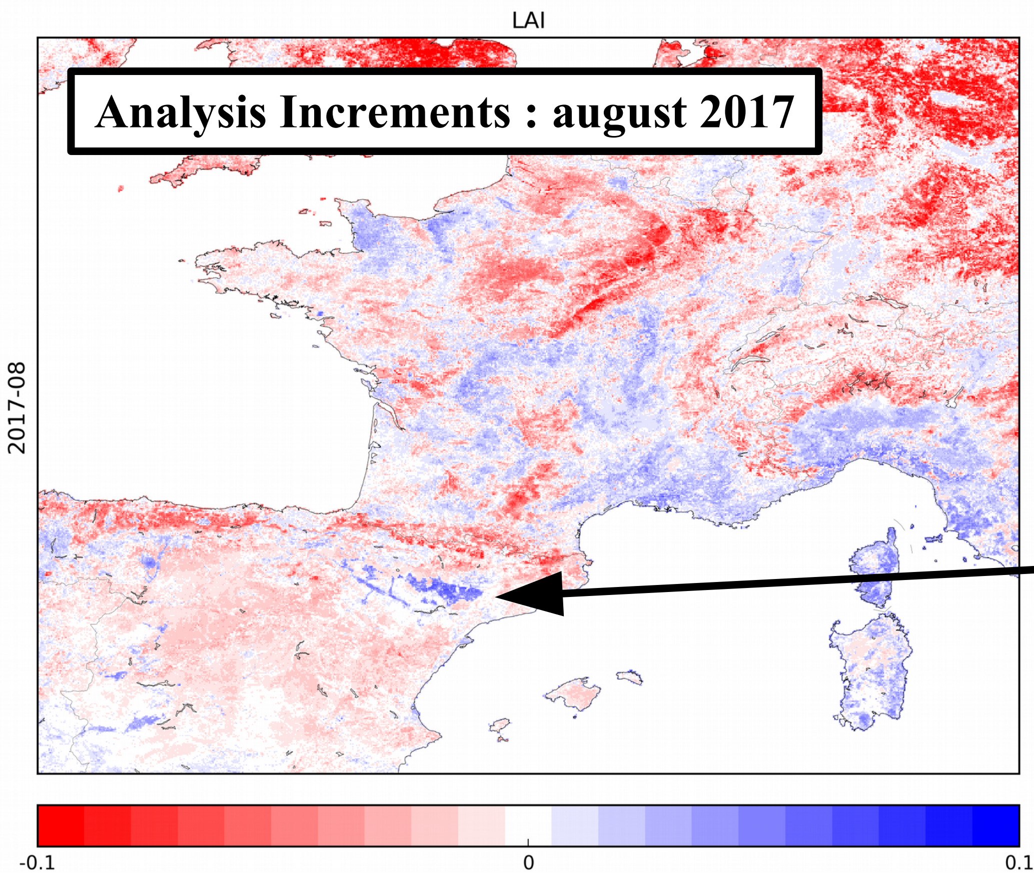
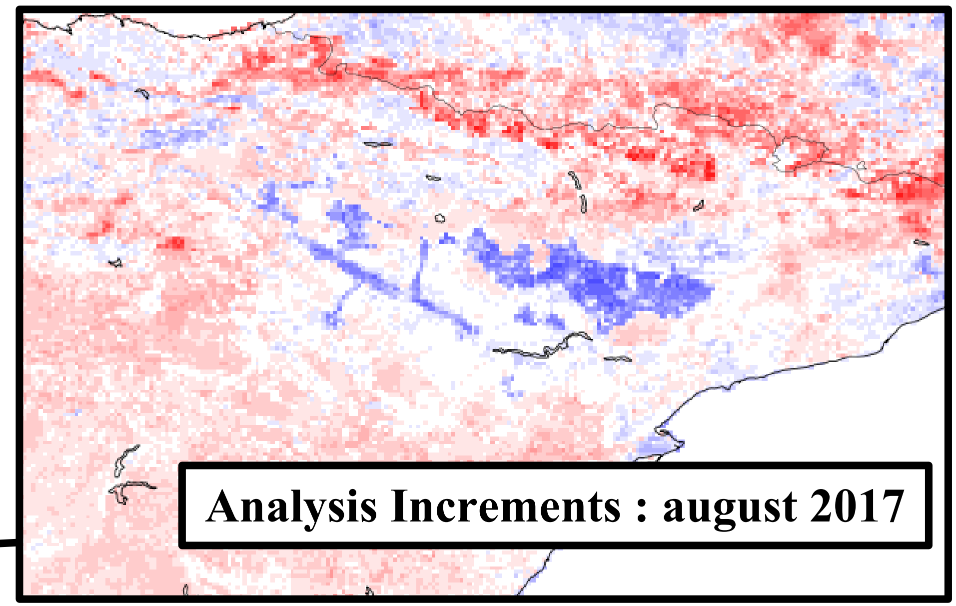
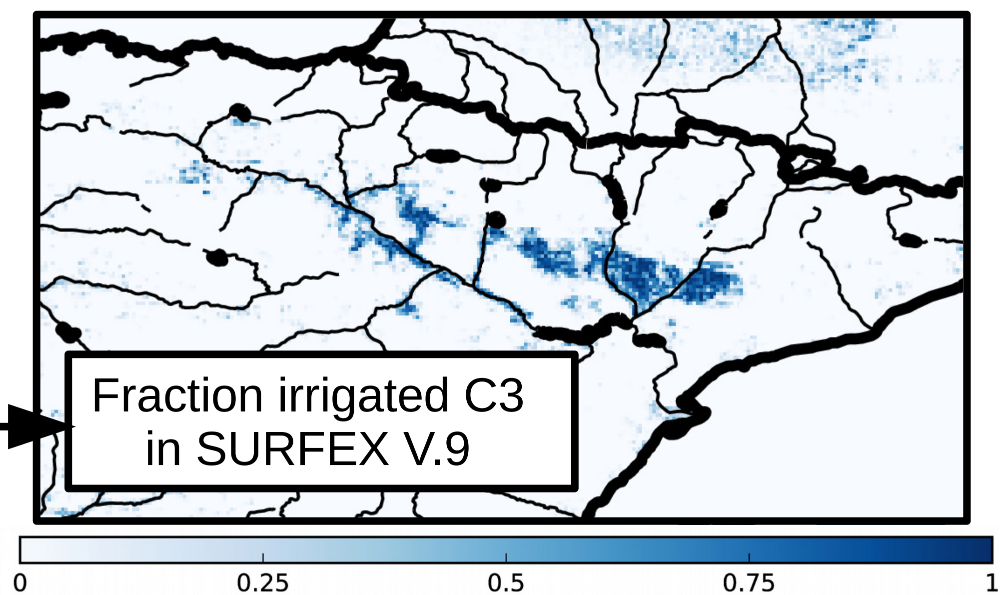


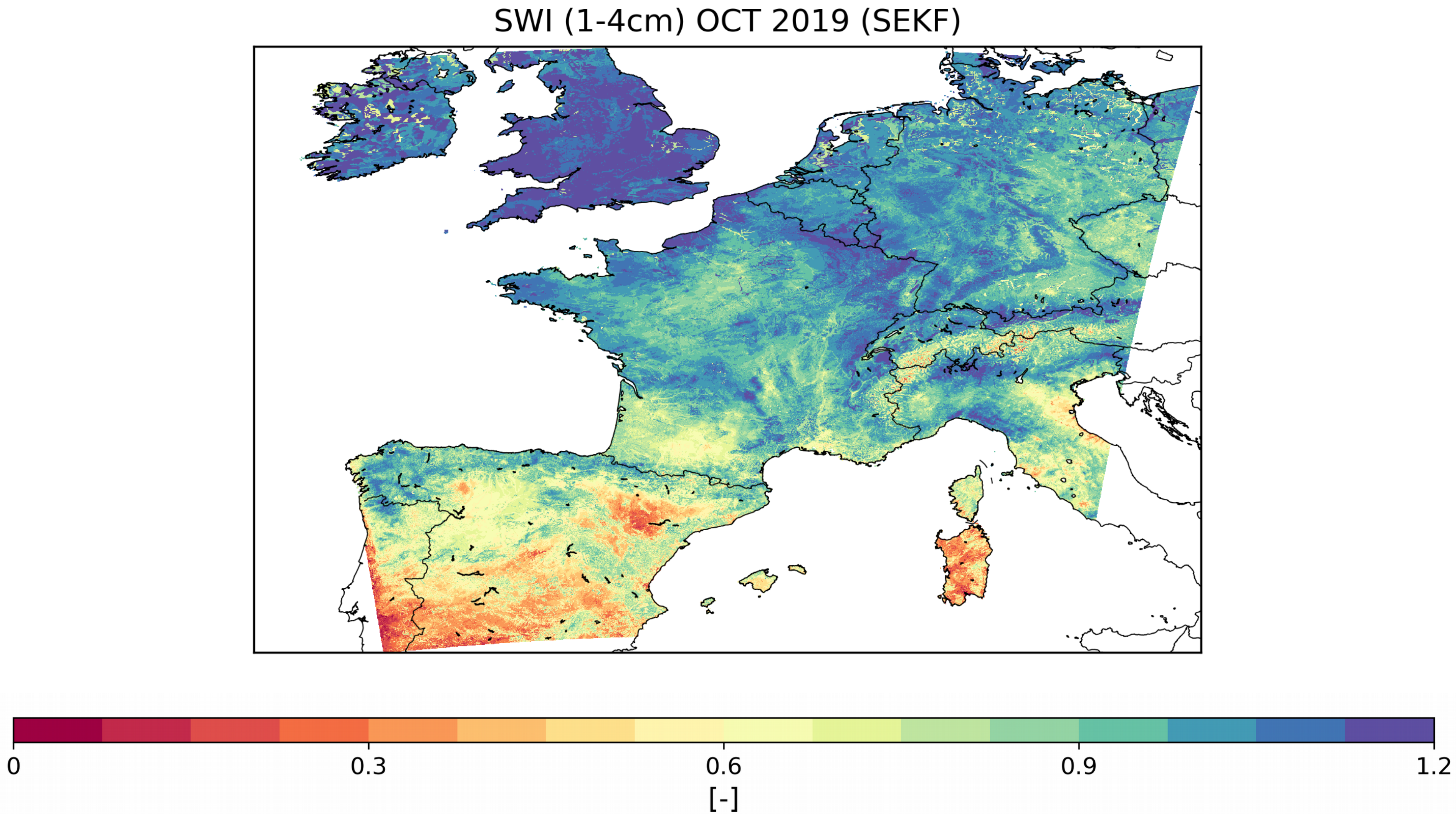


- **Data assimilation compensates for missing process: irrigation** (available from SURFEX V.9)

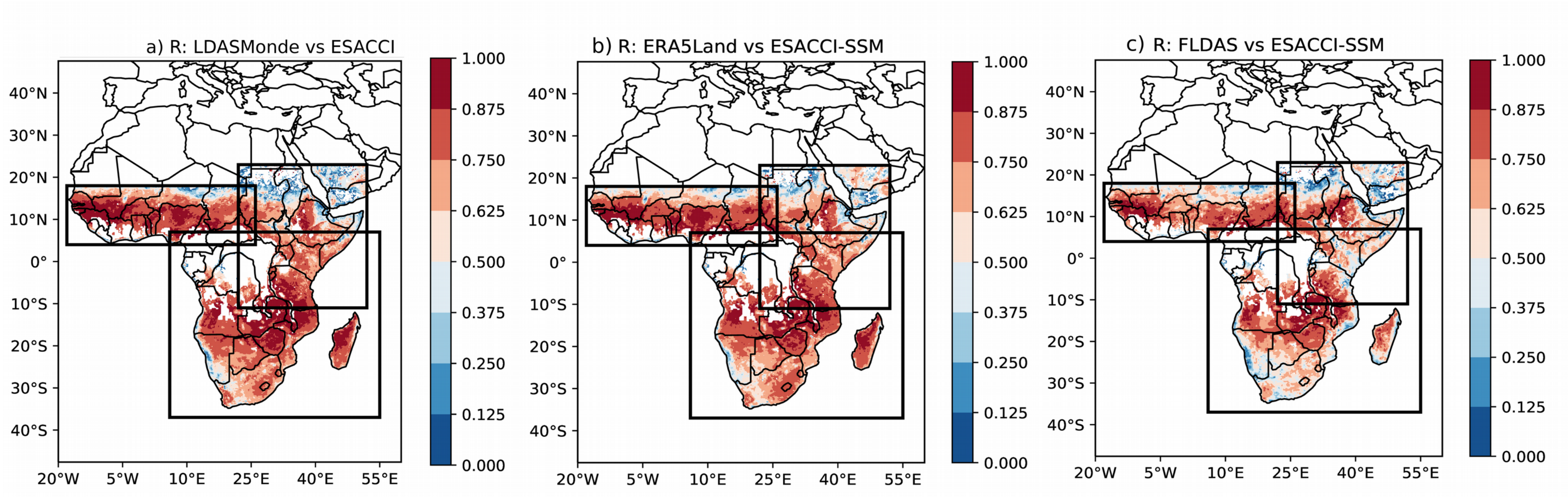


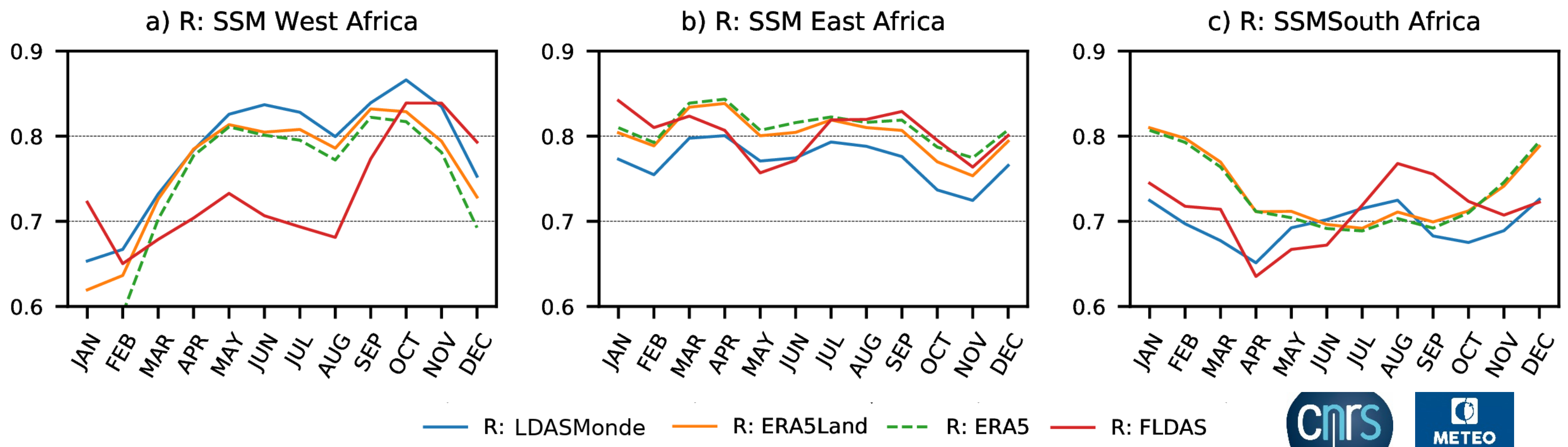
Towards ‘*higher*’ spatial resolution

- **LDAS-Monde** forced by **AROME** atmospheric fields from Météo-France at 1km x 1km spatial resolution from summer 2019, assimilation of LAI300 CGLS



Evaluation vs ESA-CCI v4.5 Combined product (2017-2018, 10kmx10km)





PhD of Moustapha Tall, LPAO/CNRM

Conclusions & Prospects (1/2)

LDAS-Monde: combining LSM, satellite EOs and atmospheric forcing

➔ Great potential to monitor and forecast the impact of extreme weather on LSVs

LDAS-Monde provides a climatology as reference for anomalies of LSVs

➔ Significant anomalies trigger more detailed monitoring and forecasting activities at higher spatial resolution

LDAS-Monde ready for use in various applications

➔ Reanalyses of land ECVs
➔ Water resource / drought / vegetation monitoring
➔ Detection of severe conditions over land and initialisation of LSVs forecast

Collaborations with different national meteorological services, research institutes, service providers

➔ ANAM (Burkina-Faso), BoM (Australia), CESBIO, Delft Uni., Monash Uni. Agro-meteorological department of Météo-France

Conclusions & Prospects (2/2)

LAI DA can improve RZSM but LAI is available every 10-day at best
→ VOD available daily (X-, C-, L- Band) could be used as a surrogate of LAI (?) *

Sigma0 contains information on both SSM and vegetation
→ Assimilation of level1 data**
→ AI in support of data assimilation (observation operators)

Impact of the initial conditions on LSVs forecast up to 15-d ahead
→ Use the control member of ECMWF ensemble as atm. forcing*

Higher spatial resolution
→~1km atm. forcing over AROME domain, <1km satellite observations

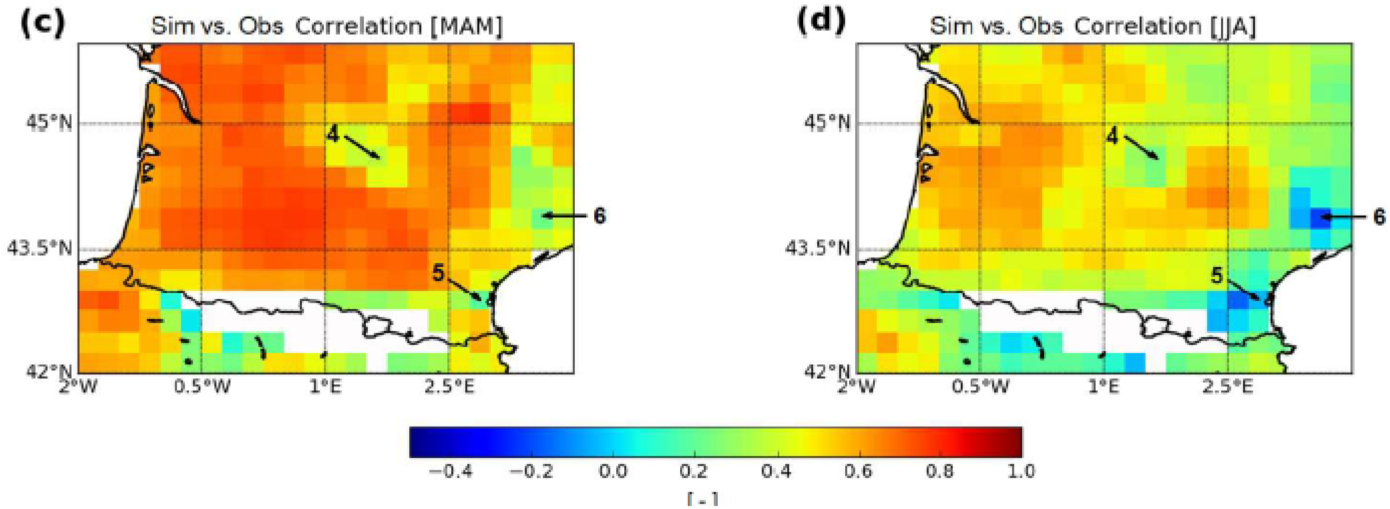
Assimilation of snow data
→IMS, ESA CCI+ snow cover

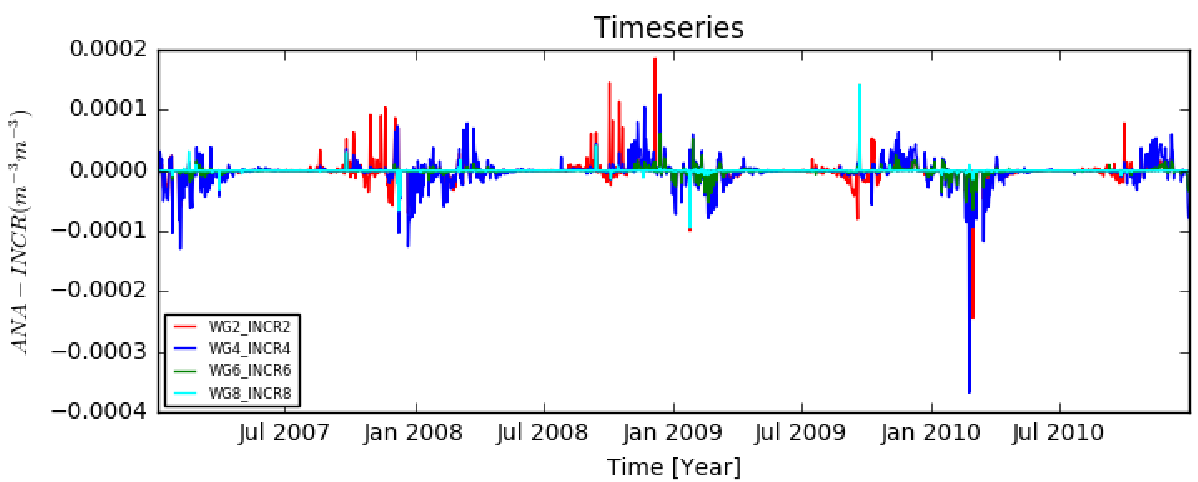
Open LDAS-Monde freely available:
https://opensource.umr-cnrm.fr/projects/openldasmonde
contact: clement.albergel@meteo.fr @Calbergel

* : PhD of Anthony Mucia, CNRM (MOPGA)
**: PhD of Daniel Shamambo, CNRM

Assimilating new types of observations

ASCAT derived SSM is obtained from radar backscatter measurements :
Assimilating radar backscatter instead of SSM using the Water Cloud Model fed by modelled SSM and LAI

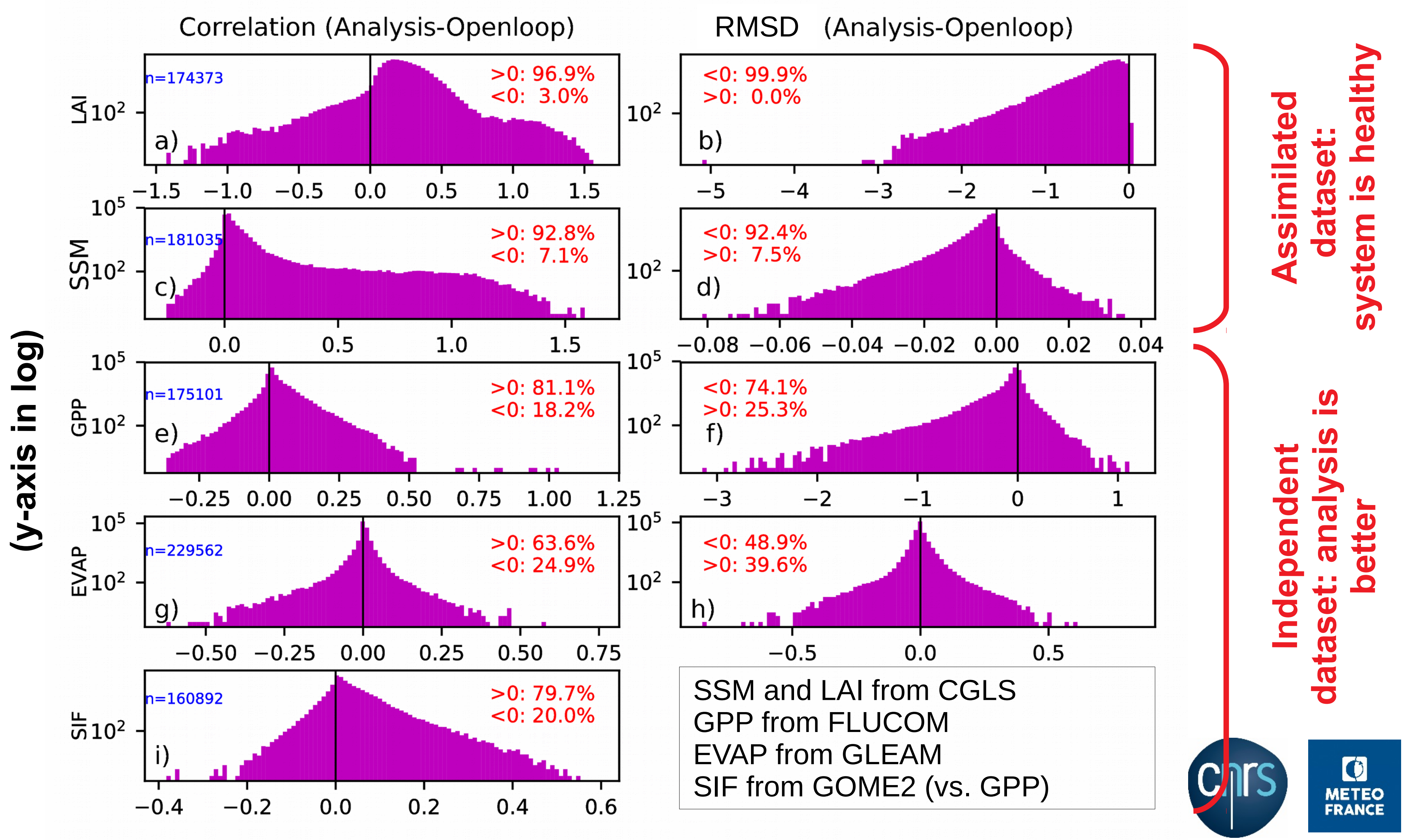




PhD of Daniel Shamambo, CNRM

LDAS-Monde global evaluation (in a nutshell!)

Histograms of score differences: Analysis – Openloop (Correlation, RMSD)

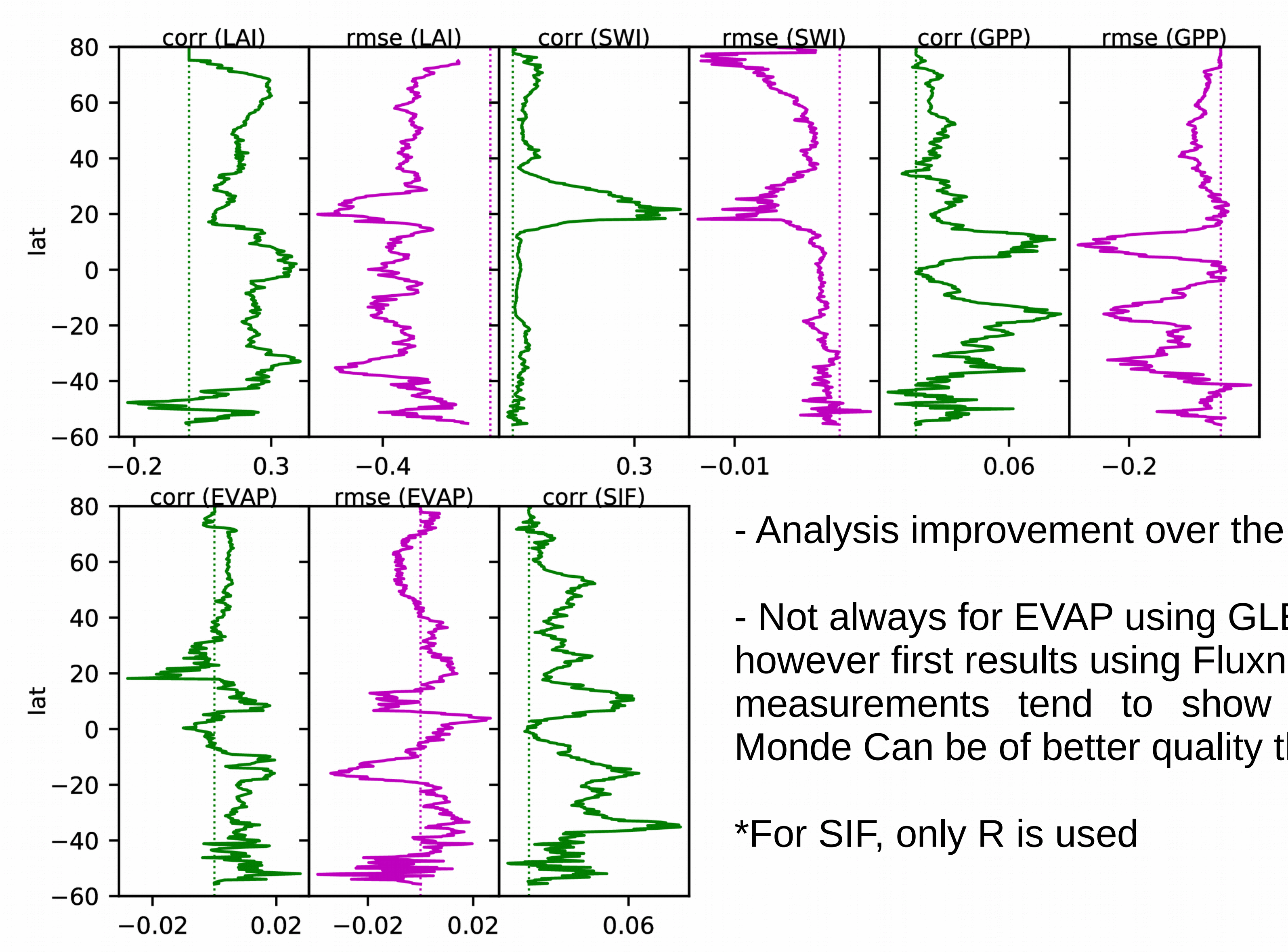


SSM and LAI from CGLS
GPP from FLUCOM
EVAP from GLEAM
SIF from GOME2 (vs. GPP)

Study the vegetation and terrestrial water cycles

Latitudinal plots of score differences: Analysis – Model (Correlation, RMSE)*

- **!! DASHED LINE IS THE 0 VALUE !!**



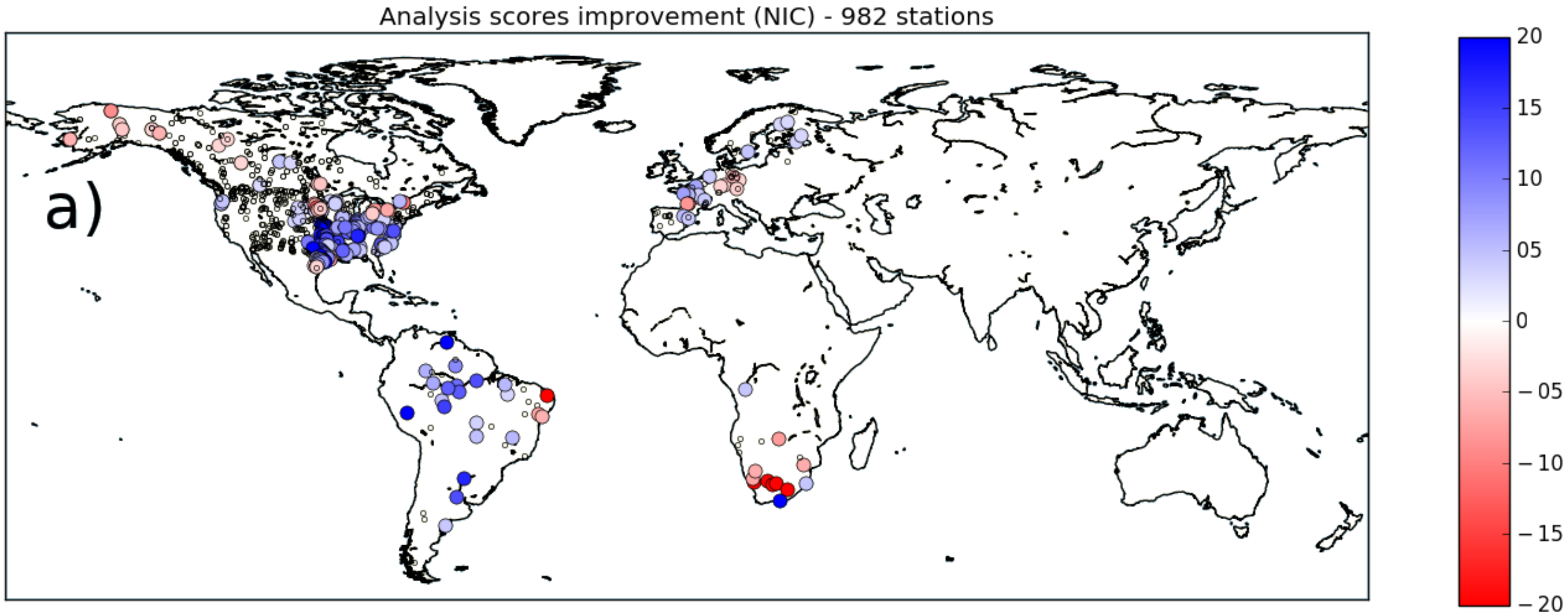
- Analysis improvement over the model run

- Not always for EVAP using GLEAM dataset however first results using Fluxnet2015 insitu measurements tend to show that LDAS-Monde Can be of better quality than GLEAM

*For SIF, only R is used

Evaluation against river discharge

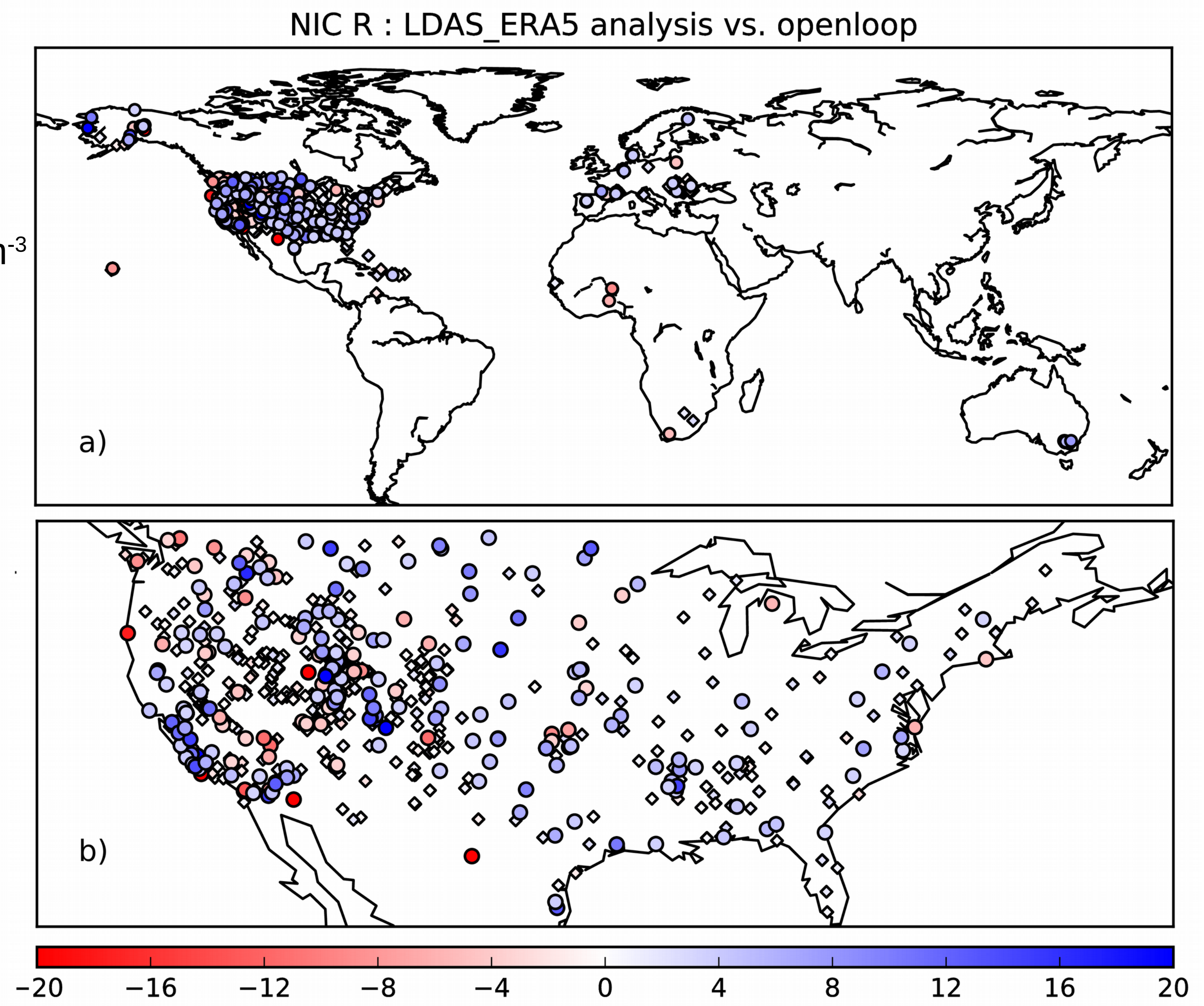
- River discharge from 982 stations
- **NSE** values are computed for each stations *(monthly values scaled to the drainage area)*
- **N**ormalised **I**nformation **C**ontribution used to quantify improvment/degradation



N stations >2-yr of data Analysis impact > |3 %|	
254 (26 %)	
Impact is >+3 %	Impact is < -3 %
189 (74 %)	65 (26 %)

Evaluation against in situ SSM

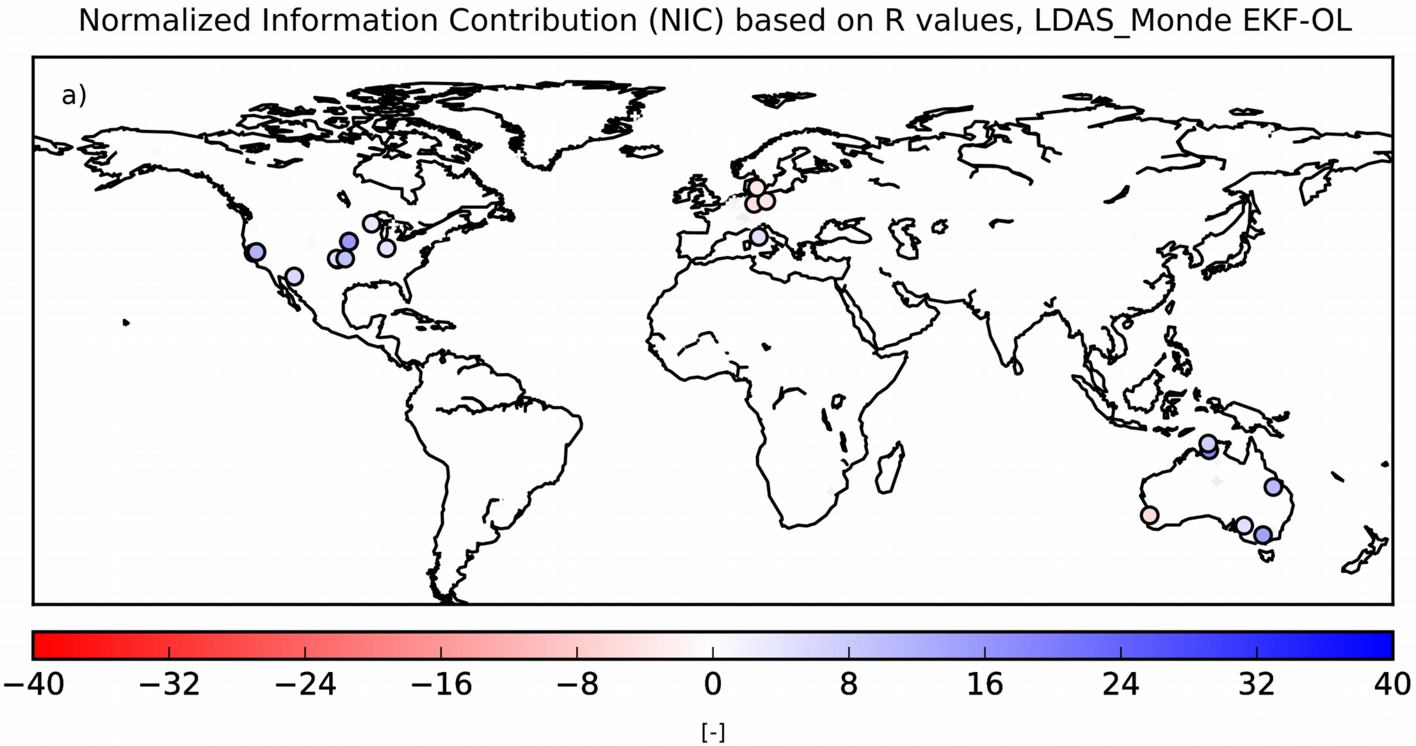
> 900 stations
Score for the analysis
R : 0.68
UbRMSD : 0.058 $m^{-3} \cdot m^{-3}$
Bias: 0.078 $m^{-3} \cdot m^{-3}$



Evaluation against Fluxnet2015 (evap)

- Evapotranspiration from 85 stations (2010-2015), NIC on R values

Score for the analysis
R : 0.73
UbRMSD : 29.60 $w.m^{-2}$
Bias: 4.64 $w.m^{-2}$



N stations >2-yr of data Analysis impact > |3 %|	
25 stations	
Impact is >+3 %	Impact is < -3 %
20 stations	5 stations

remote sensing

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Data Assimilation of Satellite-Based Observations into Land Surface Models

https://www.mdpi.com/journal/remotesensing/special_issues/LSM

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