Improving the monitoring of vegetation and droughts by the ISBA land surface model through the integration of satellite data

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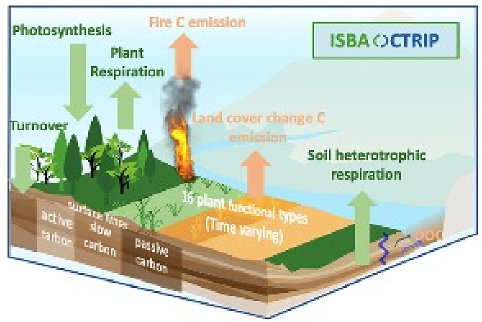
The SURFEX modelling platform

CARBON CYCLE



Delire et al. 2020

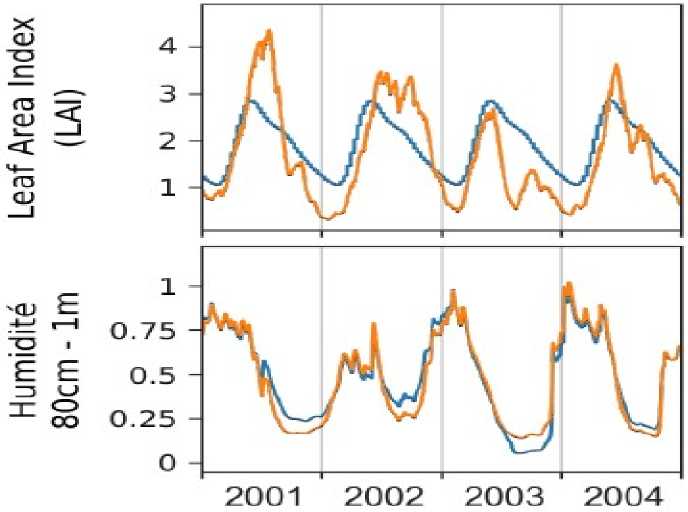
WATER CYCLE

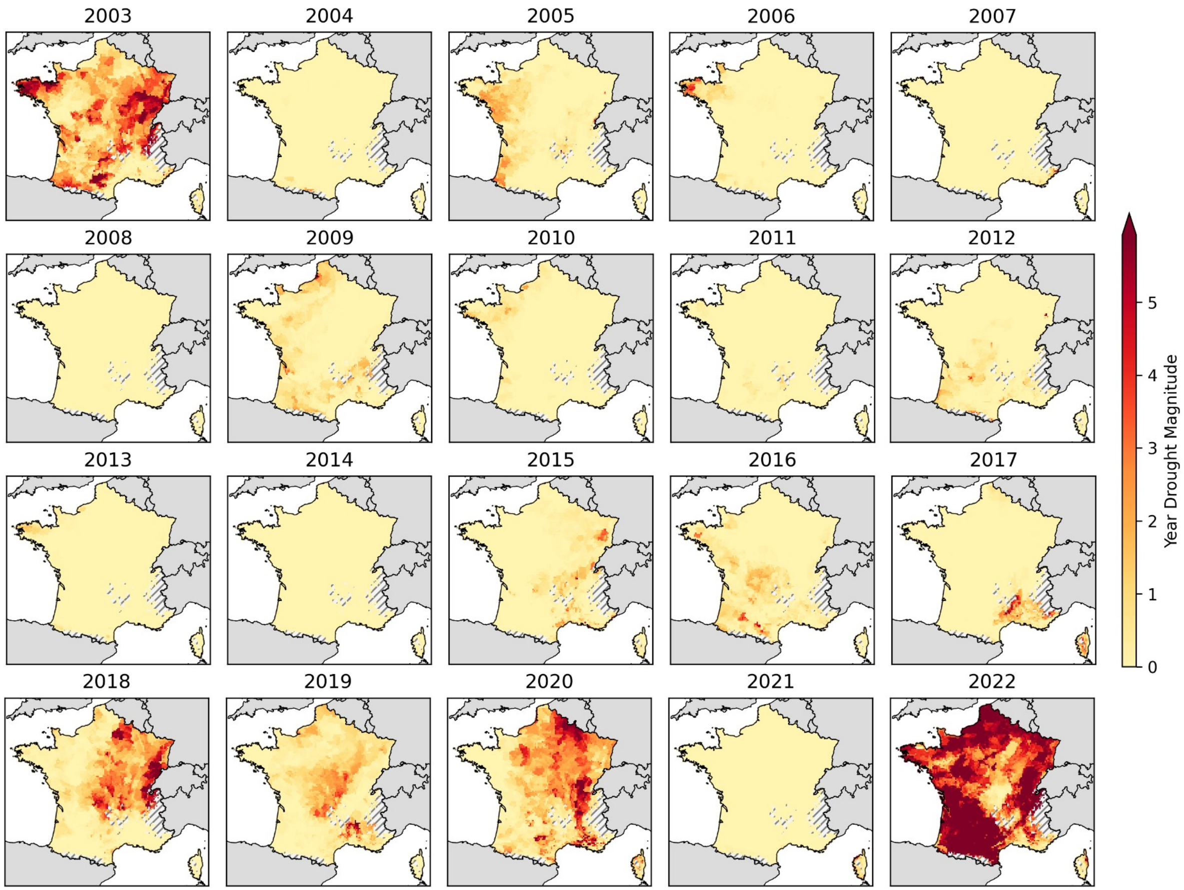
Decharme et al. 2019

ISBA	Soil	Force restore : 2 temperature, 2 or 3 layers for water, icing Diffusion : multilayer (temperature, water, icing)
	Vegetation	Noilhan et Planton 89 (~Jarvis) A-gs (photosynthesis and CO2 fluxes) A-gs and interactive vegetation Slow carbon processes (wood and roots)
	Hydrology	No subgrid process Subgrid surface runoff Subgrid drainage Flooding and coupling with TRIP
	Snow	1 layer, albedo, density variable (ARP/Climat, Douville 95) 1 layer, albedo, density variable (ARP/ALD, Bazile) Multilayer (3, or...) albedo, density, liquid water content (Boone and Etchevers 2000)

Drought monitoring using the ISBA land model

- **Yearly drought magnitude over France (2003-2022)**
  - **Deciduous broadleaf trees**
    - simulated
      soil moisture
      between 0.8 and 1 m
- **Interactive LAI is key**
  - **Can we improve LAI / SM simulations?**

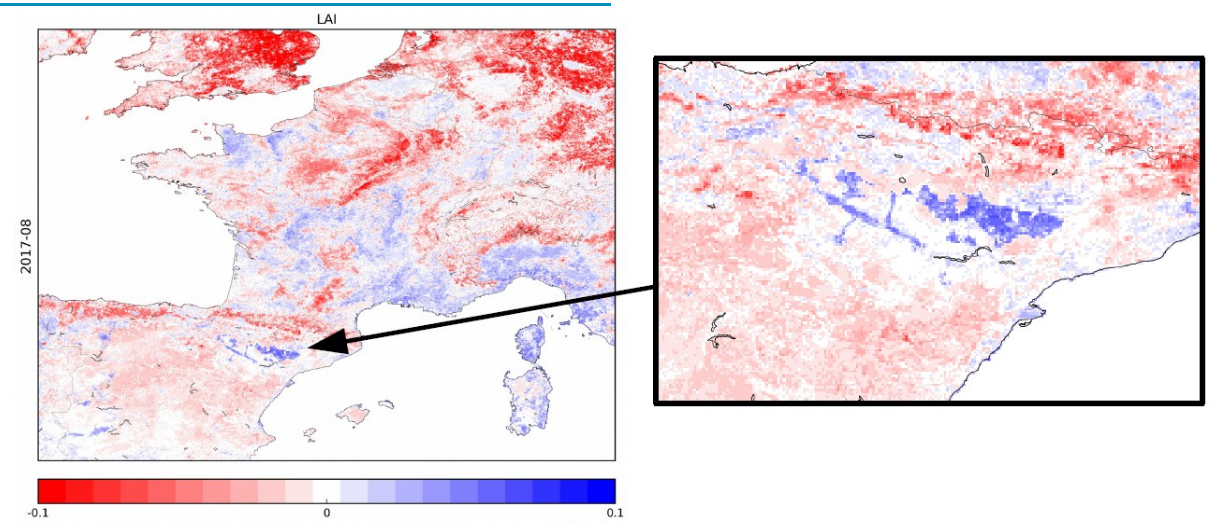




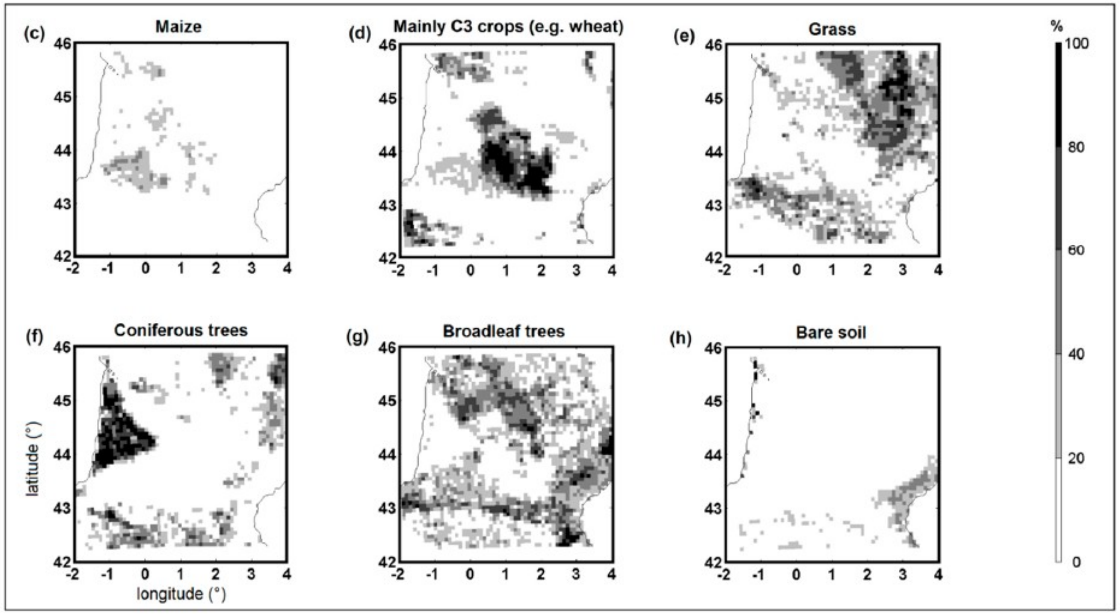
Barthelemy et al. 2024

Integration of geographical information in SURFEX

- **Offline sequential assimilation of satellite-derived LAI**
  - **LDAS-Monde**
    - e.g. LAI increments highlighting irrigated areas in Spain (August 2017)



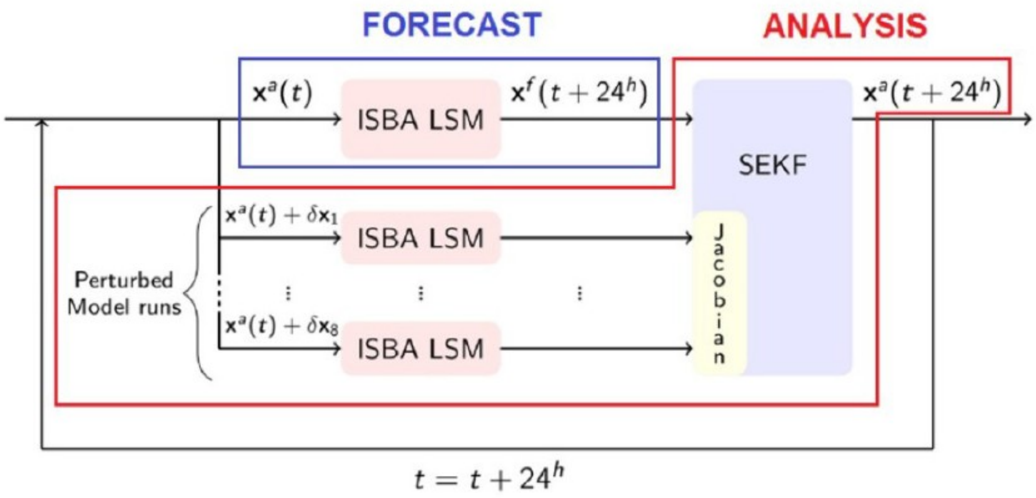
- **Land cover and model parameter mapping**
  - **ECOCLIMAP**
    - e.g. surface types in southwestern France
    - ECOCLIMAP-SG includes ESA-CCI LC



Land data assimilation in SURFEX

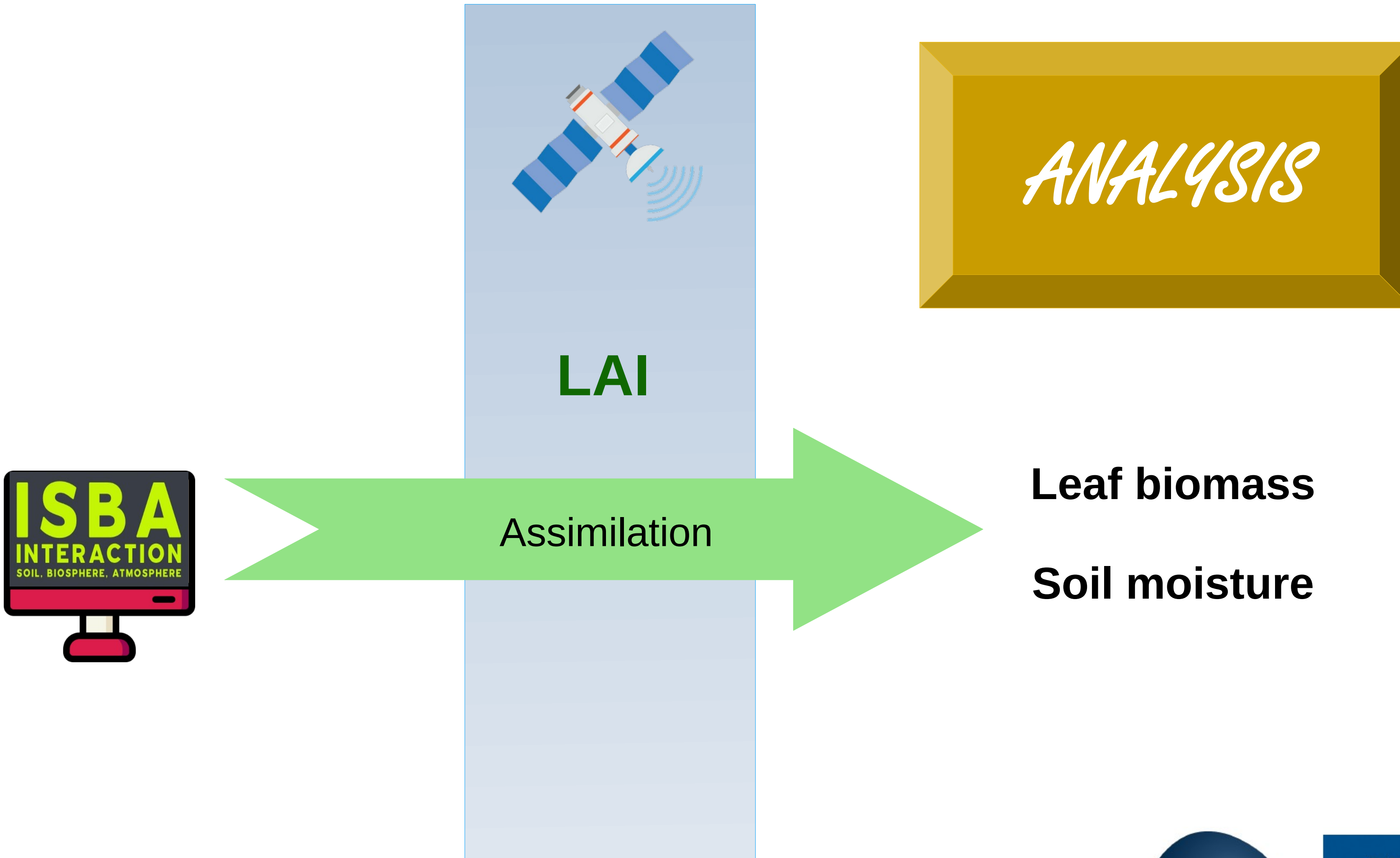
- **LDAS-Monde**
  - Integration of satellite observations into the ISBA land surface model
  - Offline sequential assimilation of LAI
    - Flexible LAI thanks to photosynthesis-driven phenology
    - Root-zone soil moisture can be analysed assimilating LAI
    - Joint LAI and SM assimilation is possible
  - Sequential assimilation of Snow Water Equivalent (SWE)

$$x^a = x^f + \mathbf{K}\left(y^o - \mathbf{H}(x^f)\right)$$



Land data assimilation in SURFEX

- **LDAS-Monde: standard assimilation of LAI**



Land data assimilation in SURFEX

- **LDAS-Monde**
  - Extended Kalman filter

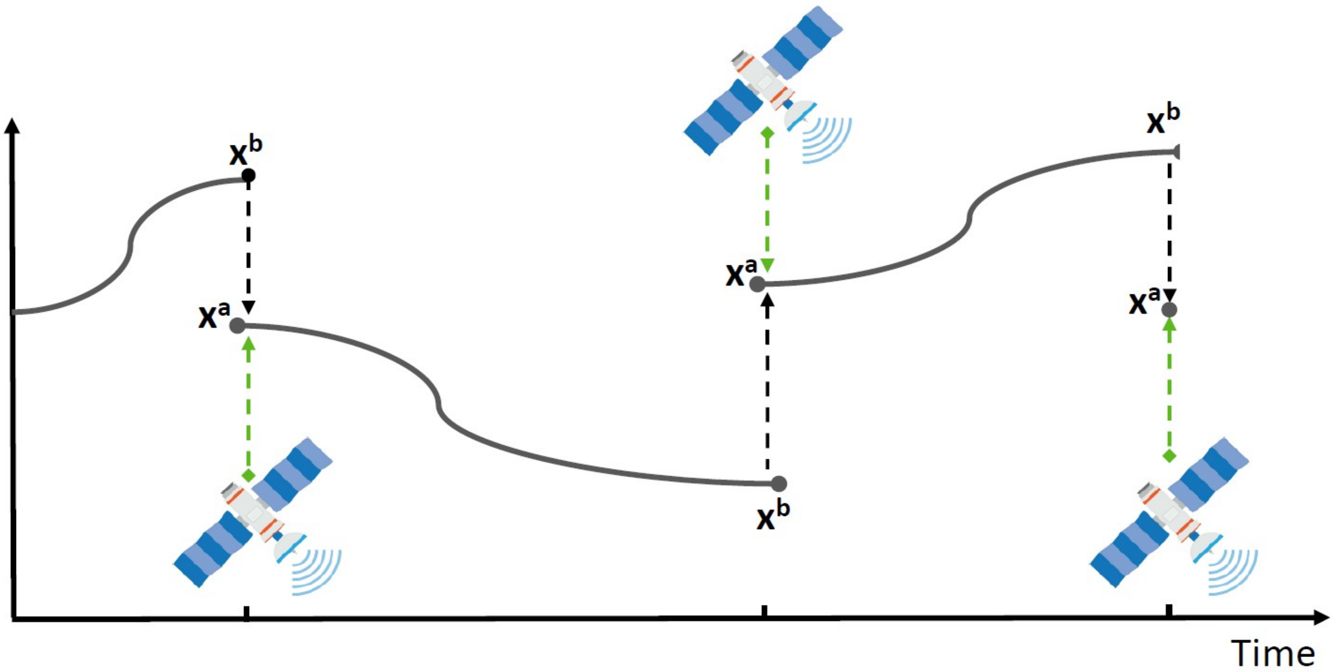
$$\underbrace{x^a}_{\text{Analysis}} = \underbrace{x^b}_{\text{background}} + \overbrace{K}^{\text{Kalman gain}}(\underbrace{y^o}_{\text{Observation vector}} - \overbrace{H}^{\text{Observation Operator}}(x^b))$$

- $\mathcal{x}$ = analysed model state variables (soil moisture, leaf biomass)
- $\mathcal{y}$ = observations (LAI, *microwave Tb, microwave sigma0, SIF*, …)
- $\mathcal{H}$ = observations operator (neural networks (NN) for *Tb, sigma0, SIF*)

Land data assimilation in SURFEX

- **LDAS-Monde: sequential data assimilation**

$$\underbrace{x^a}_{\text{Analysis}} = \underbrace{x^b}_{\text{background}} + \overbrace{K}^{\text{Kalman gain}}(\underbrace{y^o}_{\text{Observation vector}} - \overbrace{H}^{\text{Observation Operator}}(x^b))$$



Land data assimilation in SURFEX

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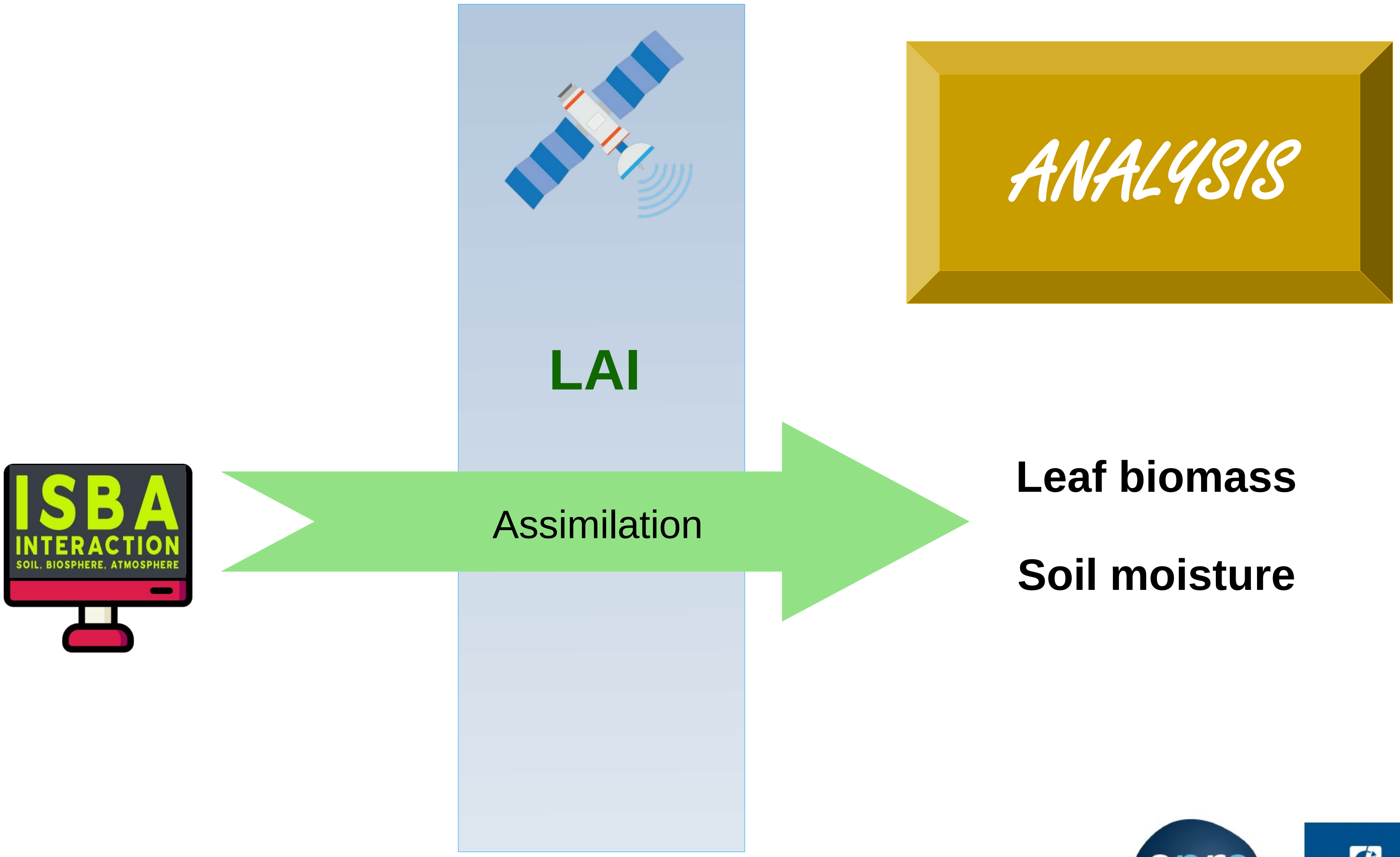
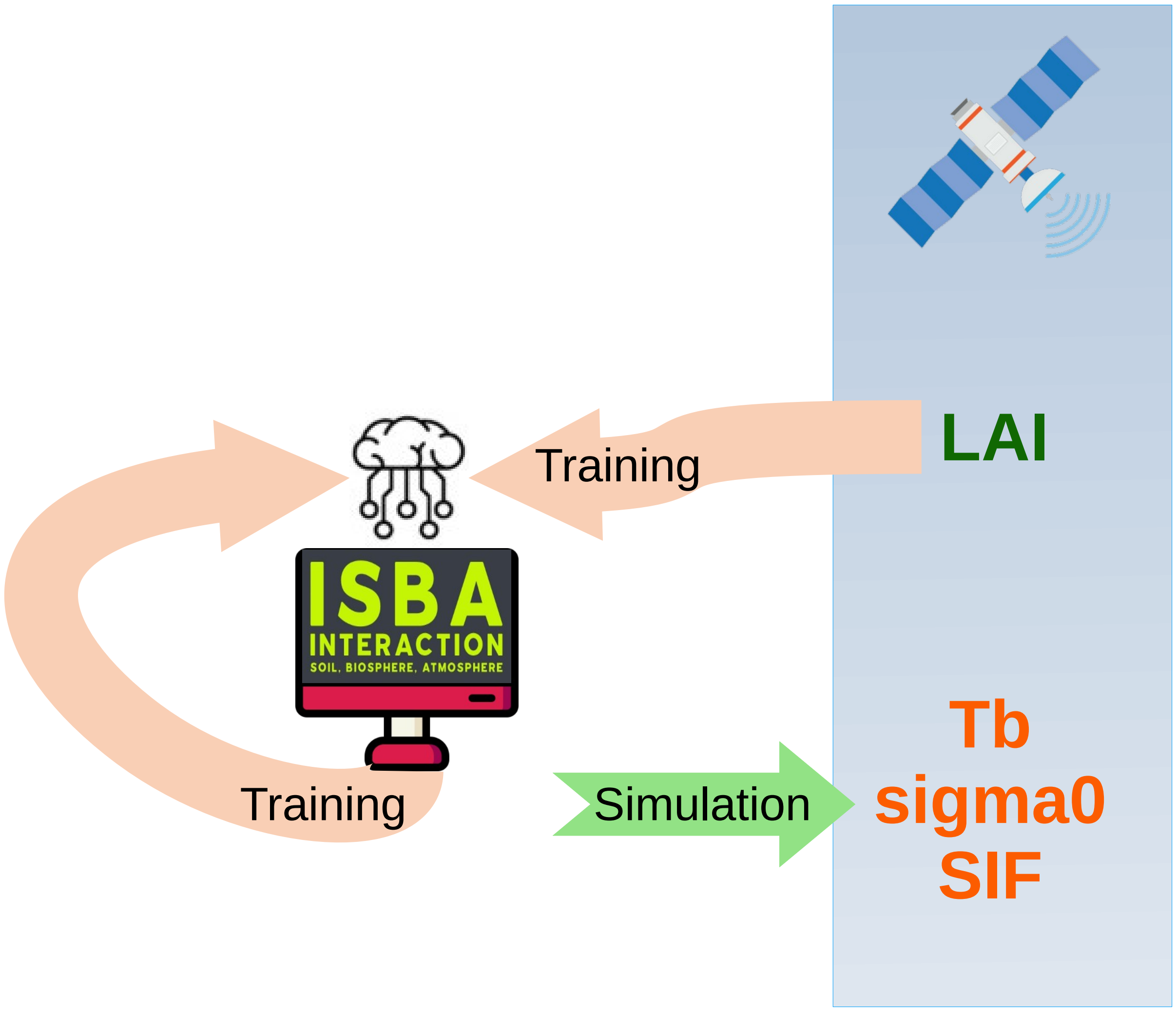


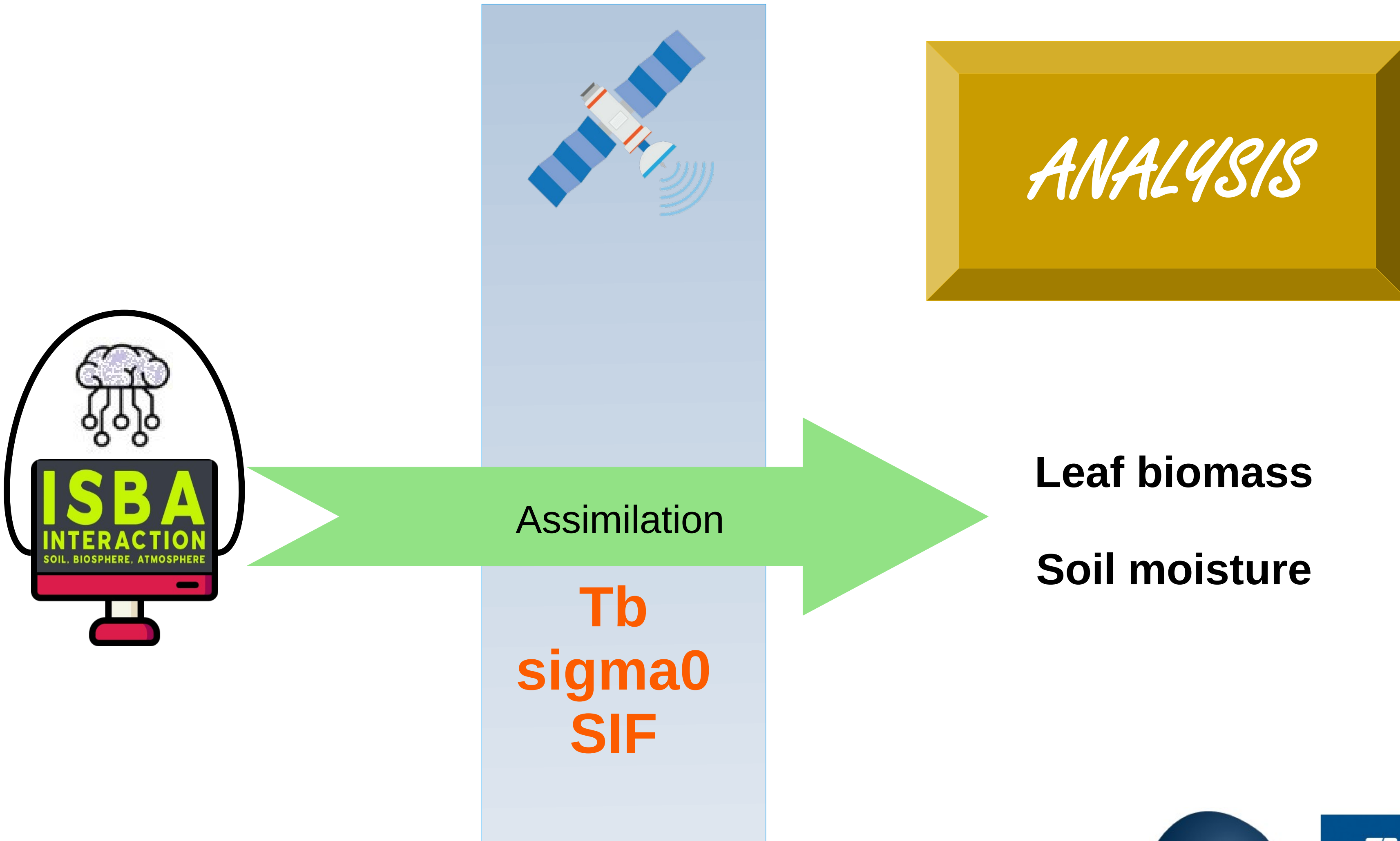
Land data assimilation in SURFEX

- **LDAS-Monde: NN forward operator training**



Land data assimilation in SURFEX

- **LDAS-Monde: assimilation of new variables**

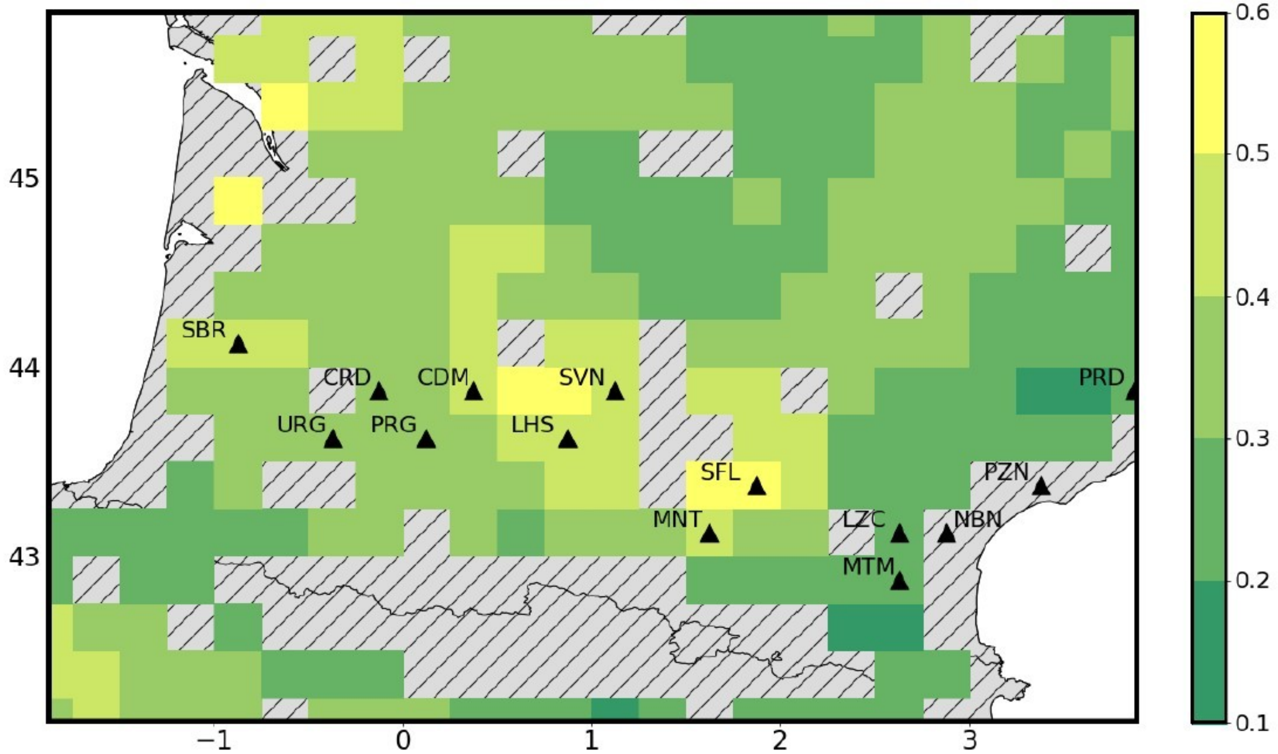


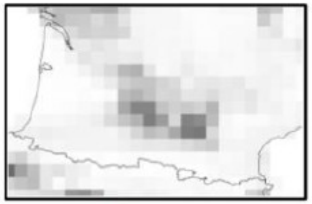
Land data assimilation in SURFEX

EUMETSAT H SAF
SUPPORT TO OPERATIONAL HYDROLOGY AND WATER MANAGEMENT

- **LDAS-Monde: assimilation of ASCAT sigma0 in southwestern France**

σ_0 RMSE map (dB)
Test set





C3 crops

Good performance of the NNs

Higher RMSEs in agricultural areas

ASCAT σ_0 observation error ≈ 0.33dB

Corchia et al. 2023

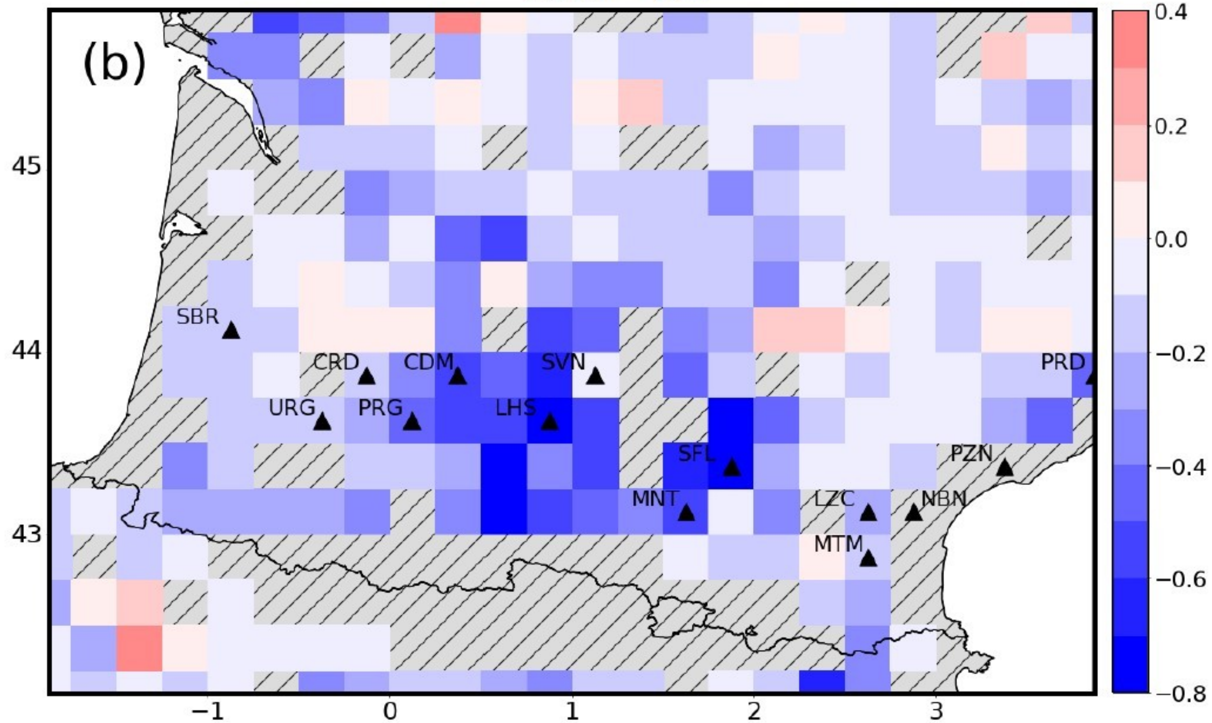
cnrs

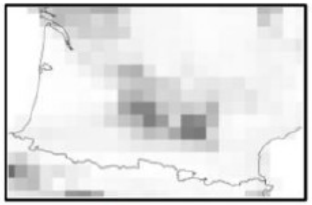
METEO FRANCE

Land data assimilation in SURFEX

- **LDAS-Monde: assimilation of ASCAT sigma0 in southwestern France**

LAI RMSE difference map ($m^2.m^{-2}$)
SEKF - OL





C3 crops

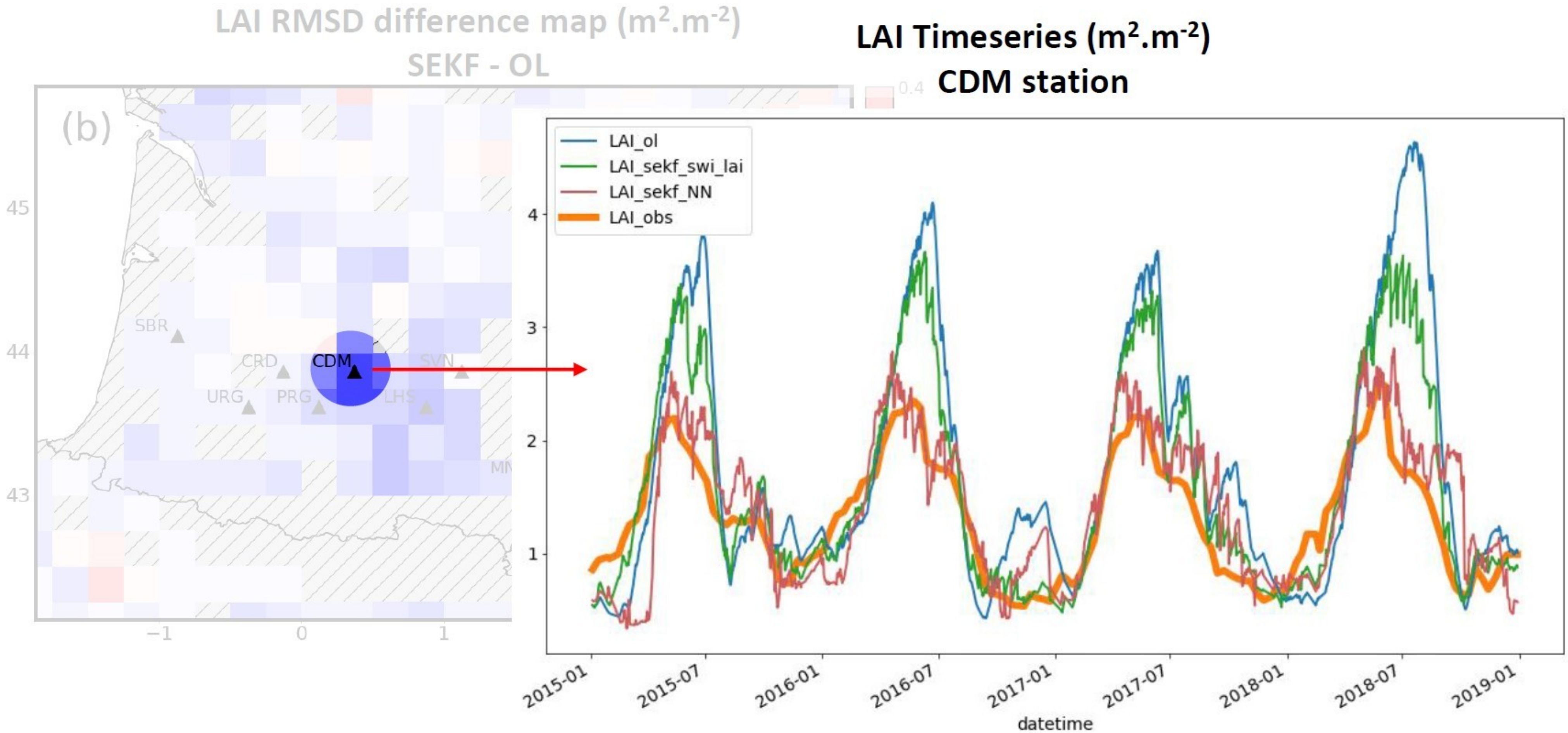
Improvement of LAI RMSE in most grid-cells

Stronger improvement in agricultural areas

Corchia et al. 2023

Land data assimilation in SURFEX

- **LDAS-Monde: assimilation of ASCAT sigma0 in southwestern France**

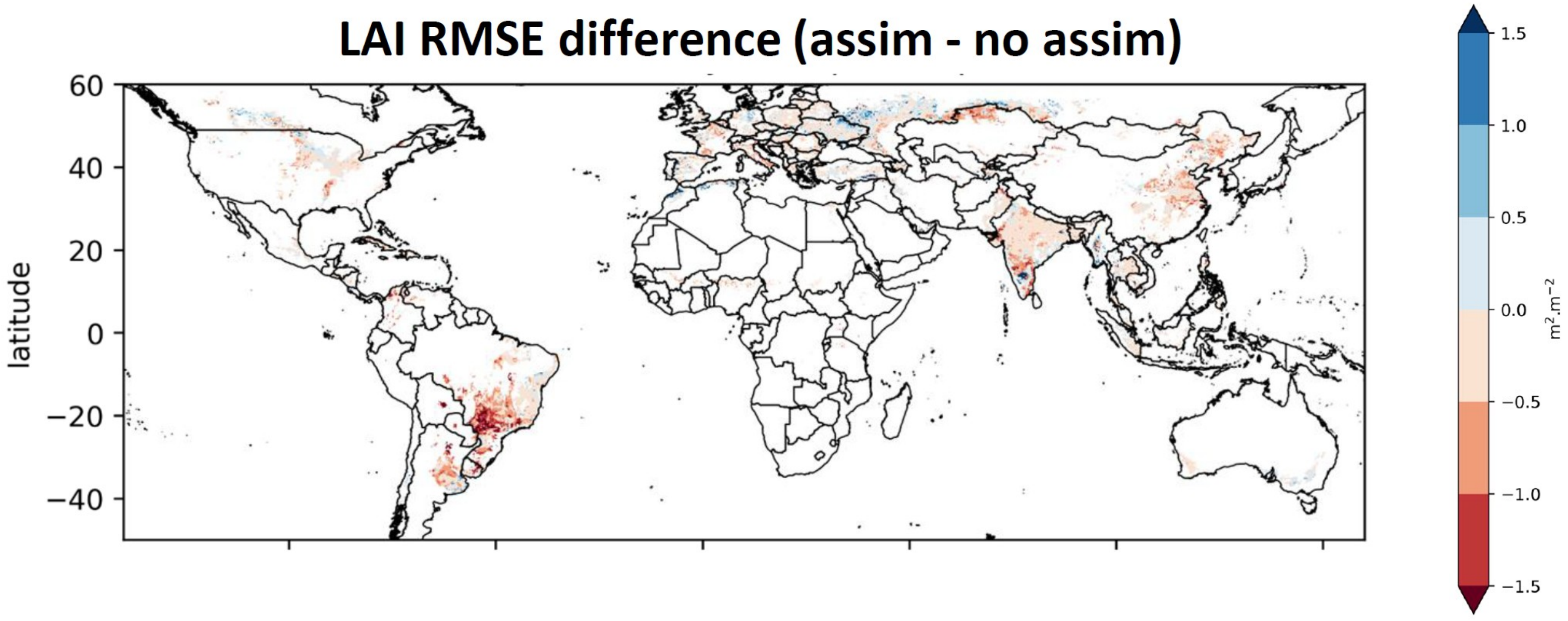


Corchia et al. 2023

Land data assimilation in SURFEX

- **LDAS-Monde: assimilation of ASCAT sigma0 at a global scale over croplands**

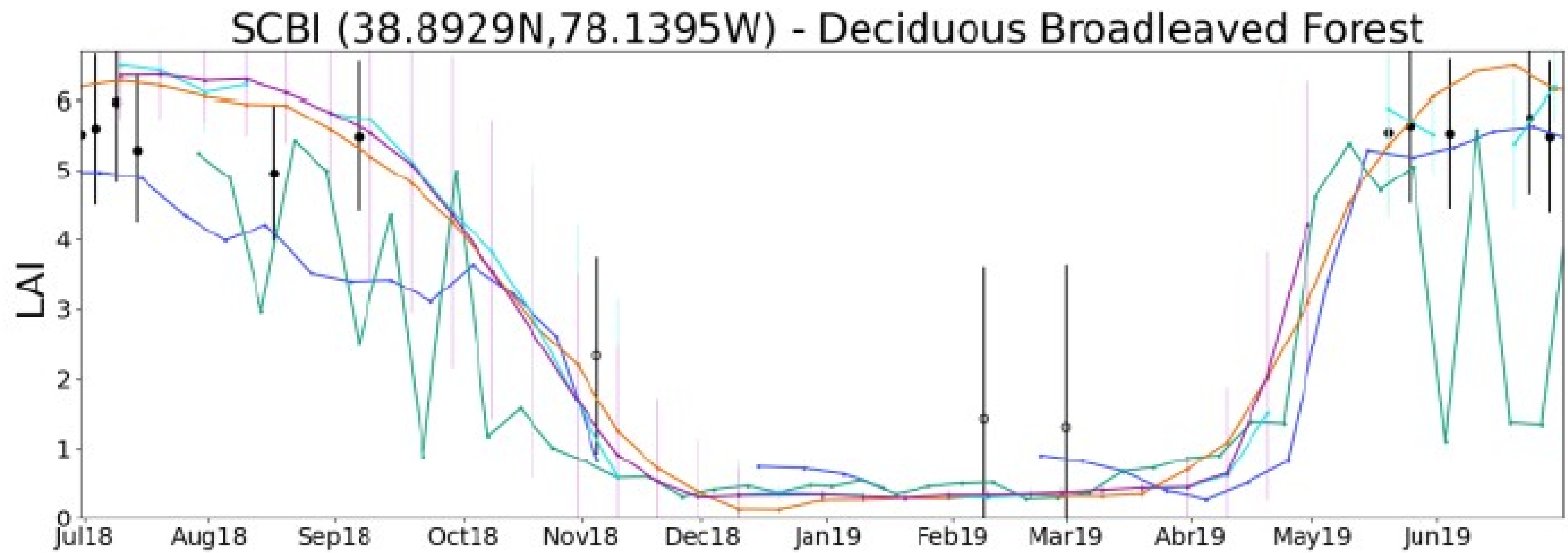
  - **LAI simulation is improved :-)**



Corchia et al. 2024

CLMS true LAI has best temporal consistency

➔ **CLMS comparison with VIIRS and LSASAF_VEGA**



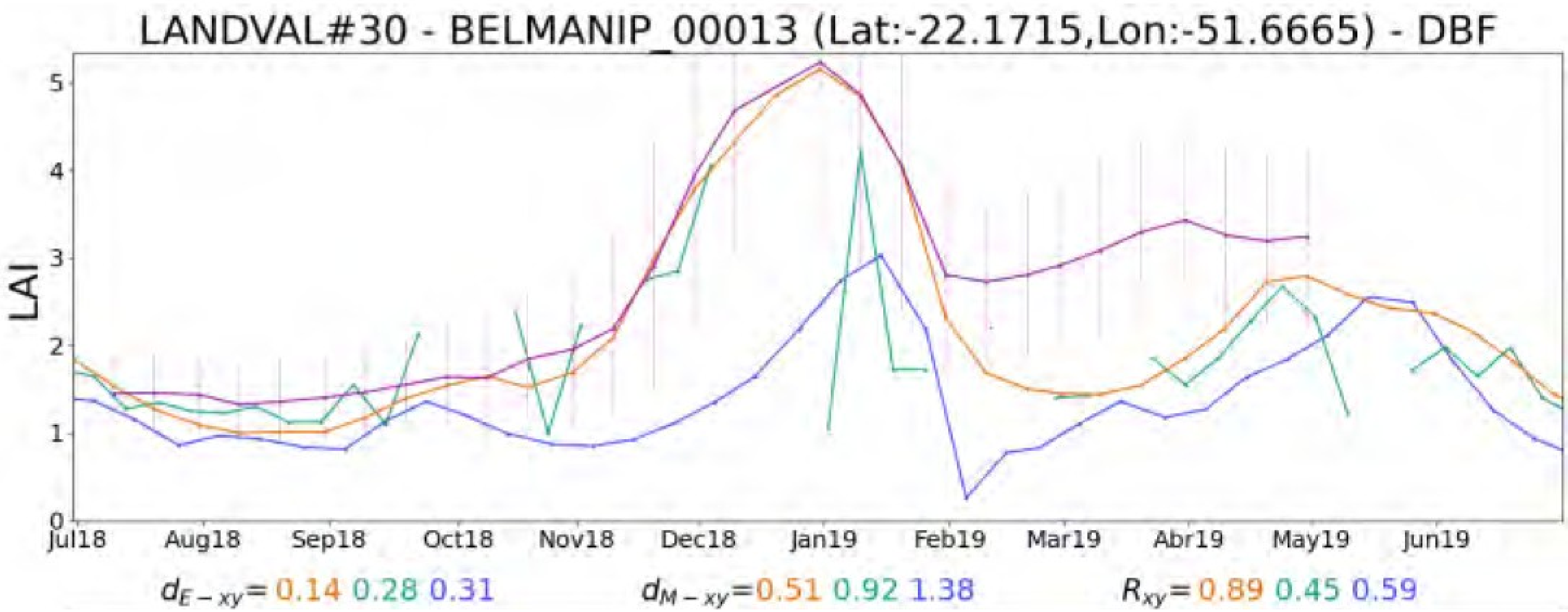
CGLS OLCI V1 (RT6) - CGLS OLCI V1 (RT0) - CGLS PBV 300m V1

VNP15A2H C1- EPS VEGA

GBOV (in situ)

CLMS true LAI has best temporal consistency

➔ **CLMS comparison with VIIRS and LSASAF_VEGA**



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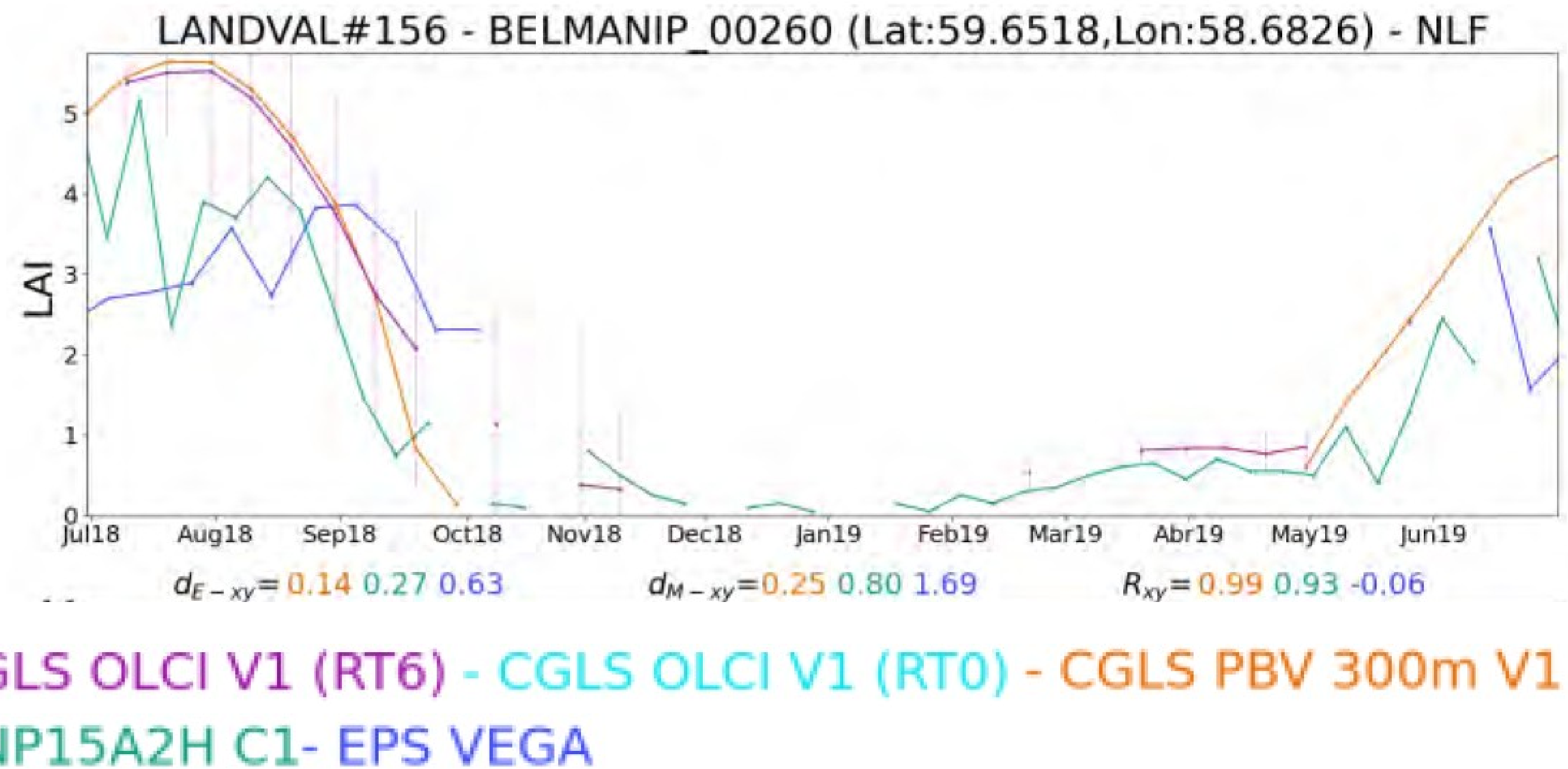
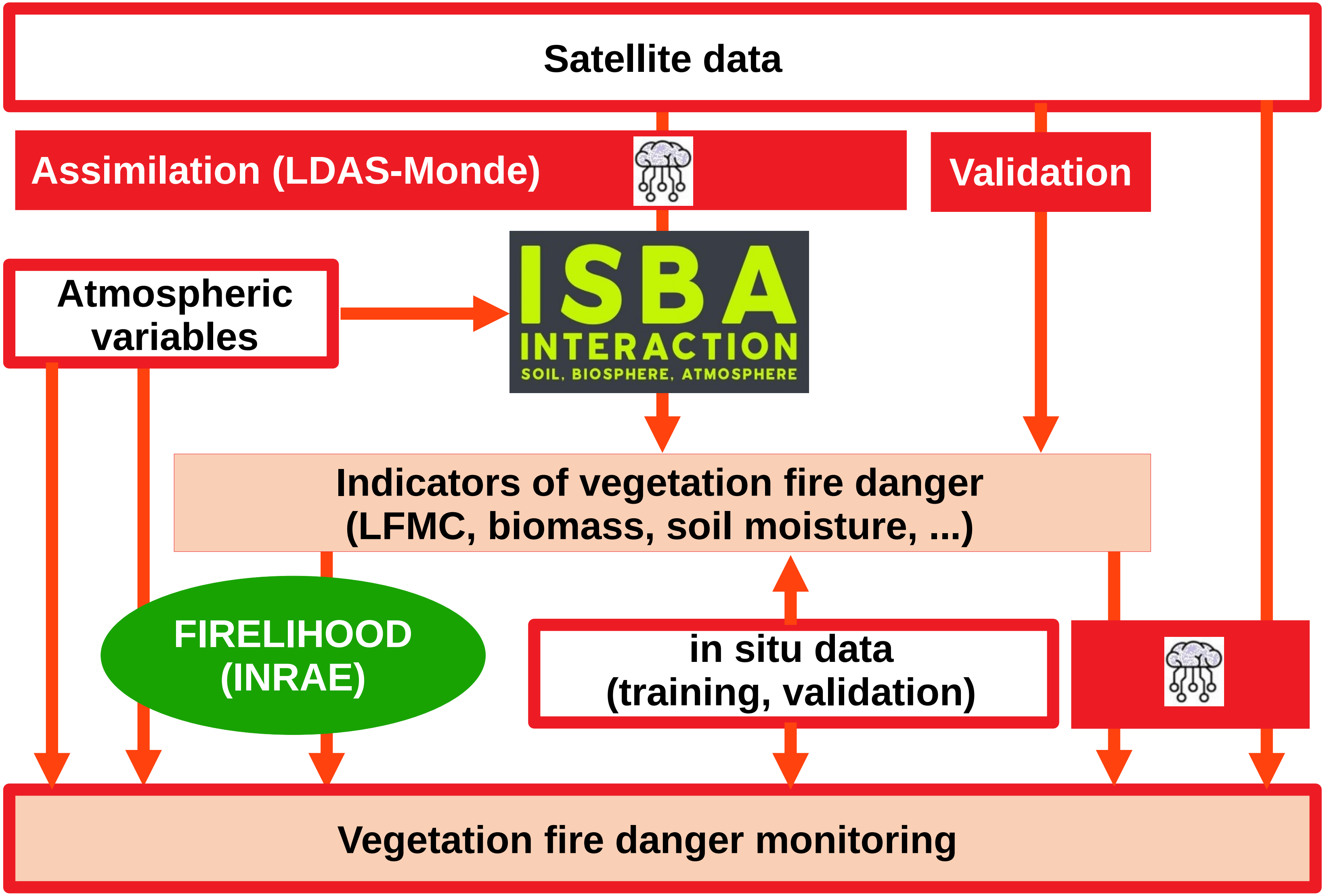


LDAS-Monde and fire danger monitoring



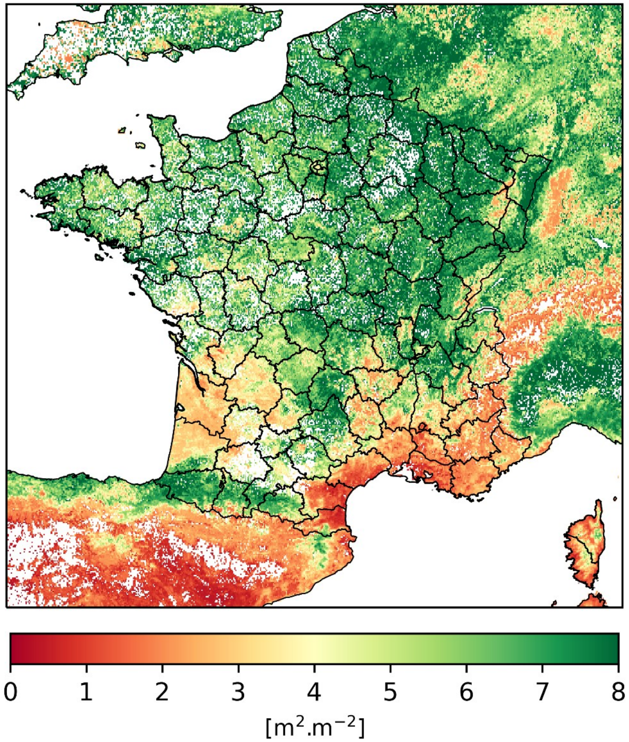
Co-funded by the European Union

LDAS-Monde and fire danger monitoring

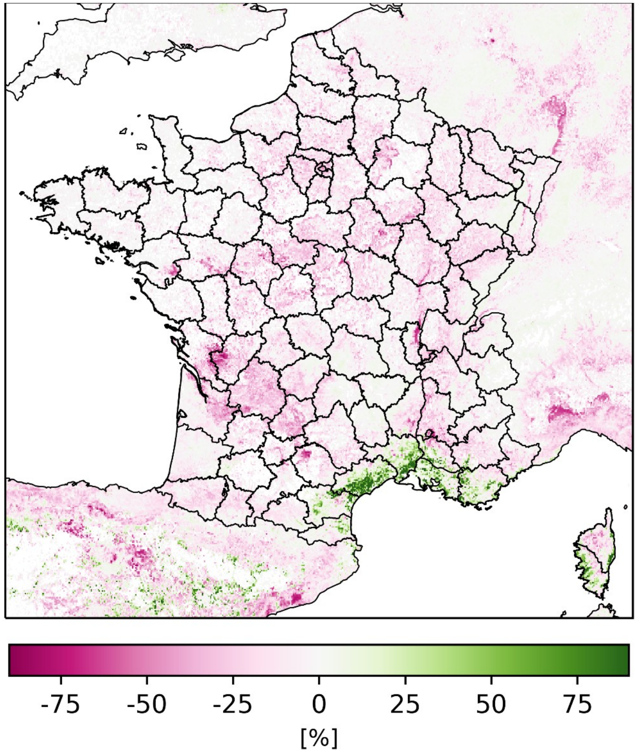
- **LDAS-Monde demonstrator**

  - Western Europe real-time automatic demonstrator
    - AROME NWP atmospheric variables interpolated on a ~2.5km grid
    - Assimilation of CLMS true LAI (RT1)

Forest LAI analysis 9 Sept. 2024



Analysis minus open-loop 9 Sept. 2024



LDAS-Monde and fire danger monitoring

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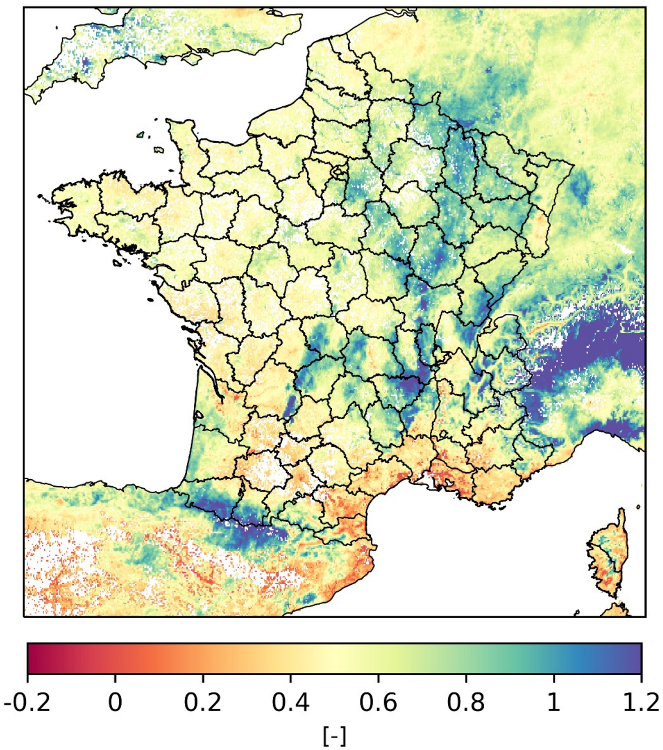
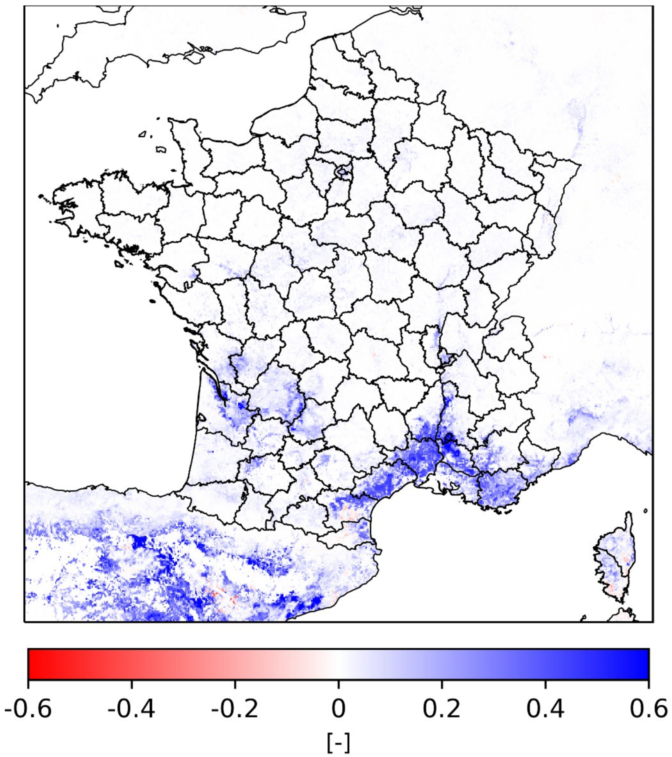
Forest SWI 0.8-1m analysis 9 Sept. 2024



Analysis minus open-loop 9 Sept. 2024 s



Conclusion

ISBA

➔ LAI, biomass, soil moisture, soil temperature, ...
➔ NN observation operator layer being implemented
- New variables can be simulated in a robust way from pre-existing variables
- New observations are assimilated (microwave data, SIF, ...)

Satellite data

➔ LAI: true LAI with good temporal consistency and timeliness is needed
- CLMS RT1 LAI is a good candidate but only one observation every 10 days
- More LAI observations are needed
  - Align **EUMETSAT LSASAF** LAI to CLMS
  - Assimilate LAI-sensitive microwave data (ASCAT, SCA, S1, …)

➔ ASCAT: sigma0_40° from **EUMETSAT HSAF**, multi-angular info (slope) is useful too

Vegetation fire danger monitoring

➔ LDAS within SURFEX forced by AROME (western Europe), ARPEGE (world)

Monitoring of vegetation and droughts

- Thank you for your attention :-)

- Contact: jean-christophe.calvet@meteo.fr