EUMETSAT H SAF

METEO FRANCE

HSAF SOIL MOISTURE WEEK

Webinars, 4-8/11/2019

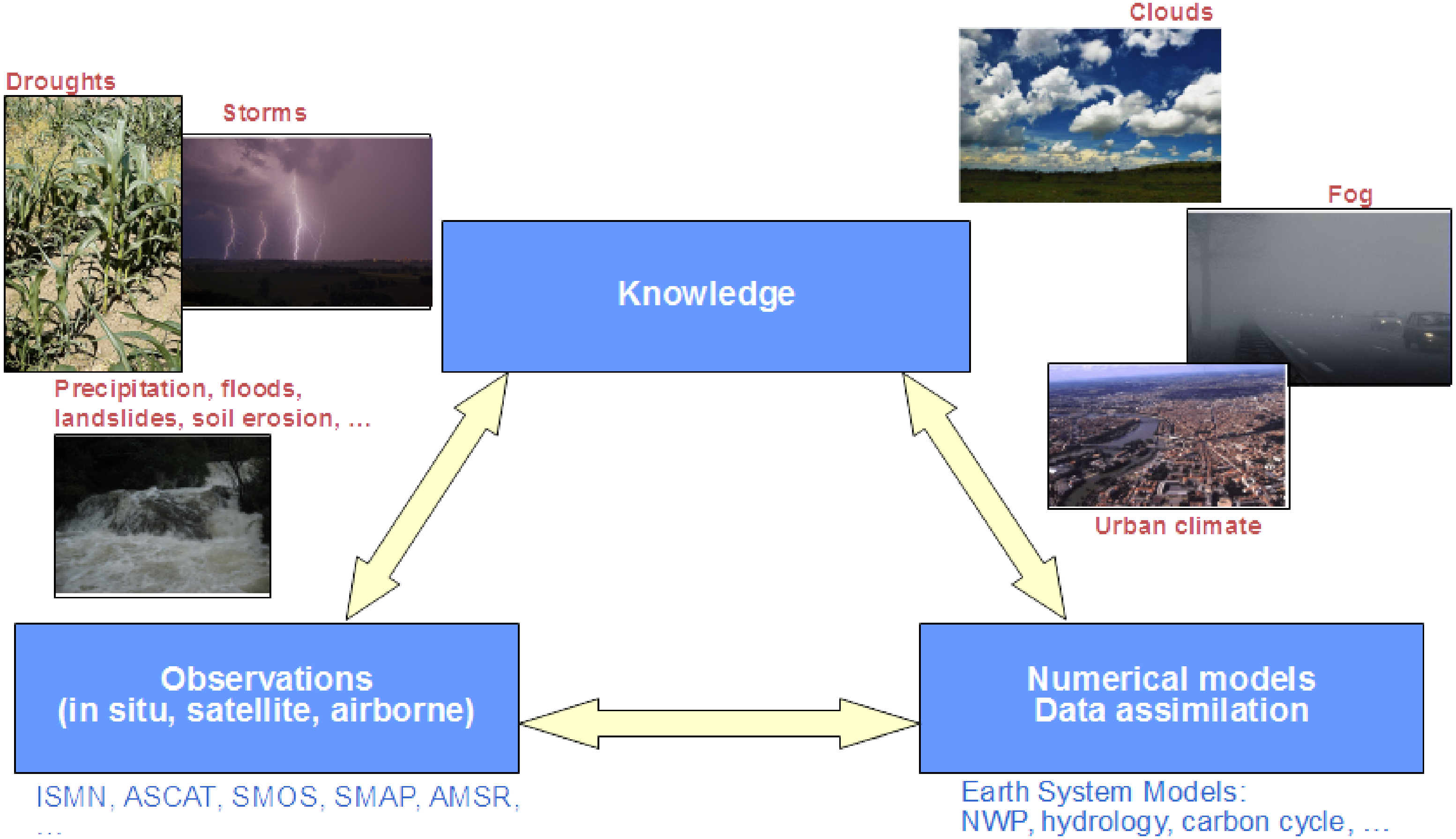
Introduction on soil moisture and how products can be integrated into models

Jean-Christophe Calvet

Meteo-France

Soil moisture: a key variable

Research is needed to better understand, simulate and forecast coupled land-atmosphere processes.



Why focusing on soil moisture?

Soil moisture impacts soil-plant system processes

- Plant water stress
  - $\rightarrow$ photosynthesis and biomass production
- Leaf transpiration, evaporation
  - $\rightarrow$ Latent heat flux (LE)
- Soil hydraulic conductivity
  - $\rightarrow$ Runoff of precipitation water to rivers

Why focusing on soil moisture?

Soil moisture impacts the surface energy budget

- Surface albedo
- Soil thermal conductivity
    - → Ground heat flux (G)
    - → Sensible heat flux (H = Net radiation – LE – G)
    - → Land surface temperature
    - → Air temperature and humidity

Why focusing on soil moisture?

Applications

- Weather forecast, seasonal predictions
  - Soil water storage: up to 300 mm
  - Large memory effect → initialization of models
- Hydrology
  - Simulation of river discharge
  - Flood forecast
  - Estimation of accumulated precipitation (from microwave satellite observations)

Why focusing on soil moisture?

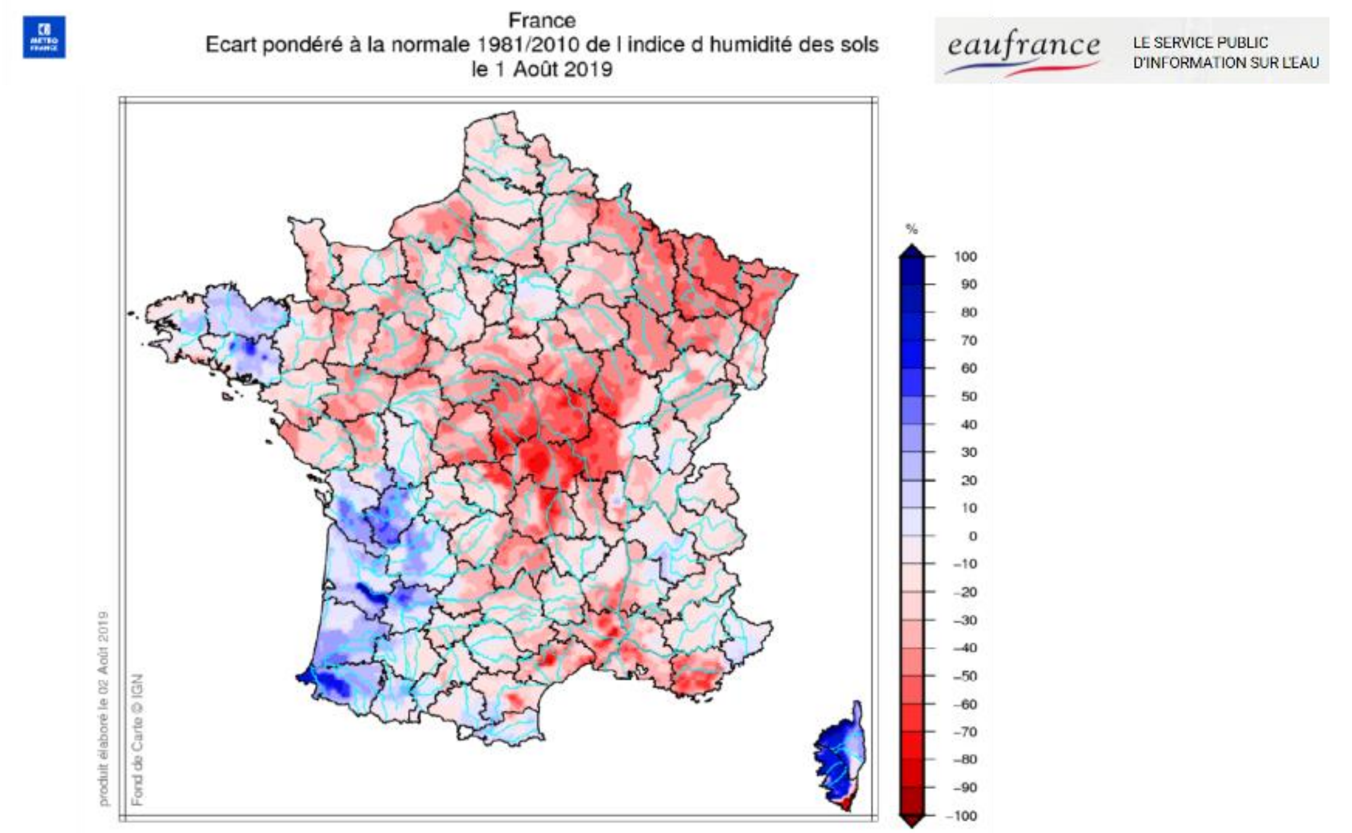
Applications

- Agriculture and forestry
  - Drought and irrigation monitoring
  - Forest fire risk
- Prediction and assessment of geological disasters
  - Landslides
  - Clay shrinkage and swelling (impact on built areas)
  - ...

Why focusing on soil moisture?

Applications: e.g. SIM (Safran-Isba-Modcou)

Écart à la normale de l'indice d'humidité des sols au 1er août 2019

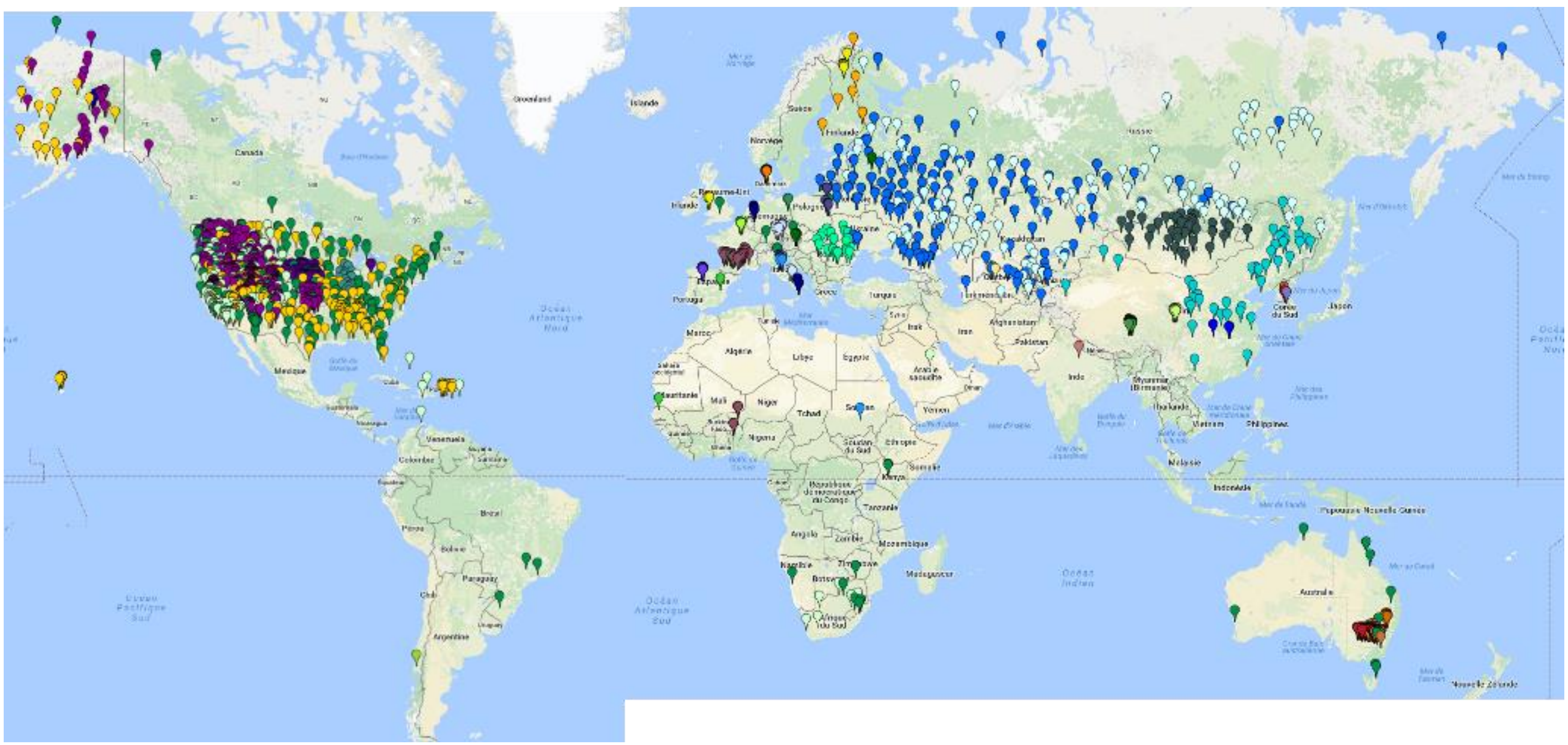


Why measuring soil moisture?

- Monitor droughts
- Validate
  - Model simulations
  - Satellite products
- Assess climate change impacts
  - Long *in situ* time series are needed
  - At several depths
  - Together with soil temperature

Why measuring soil moisture?

International Soil Moisture Network (https://ismn.geo.tuwien.ac.at/en/)



Observations by Meteo-France

Long term research campaings

MUREX (1995-1997)

SMOSREX (2001-2012)

METEOPOLE-FLUX (2012-)

Observations by Meteo-France

SMOSMANIA

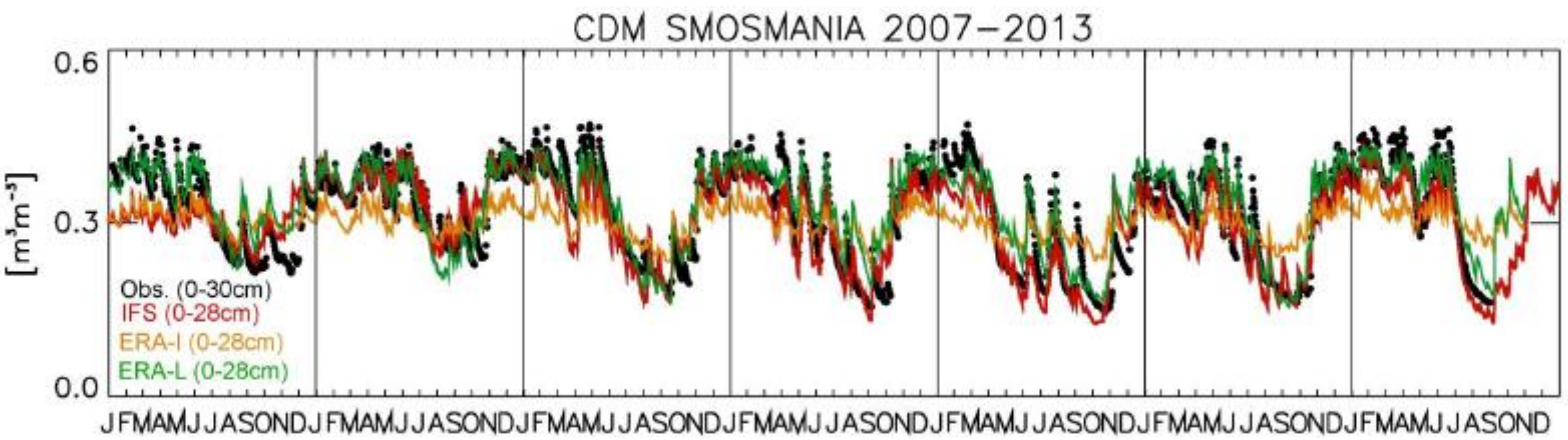
- 21 stations in southern France
  - 4 depths: 5, 10, 20, 30 cm
  - Includes soil temperature
- Since 2007

Sondes Thetaprobe après installation dans l'une des stations SMOSMANIA, à 4 profondeurs (5,10,20,30cm).

Observations by Meteo-France

SMOSMANIA

- Model validation

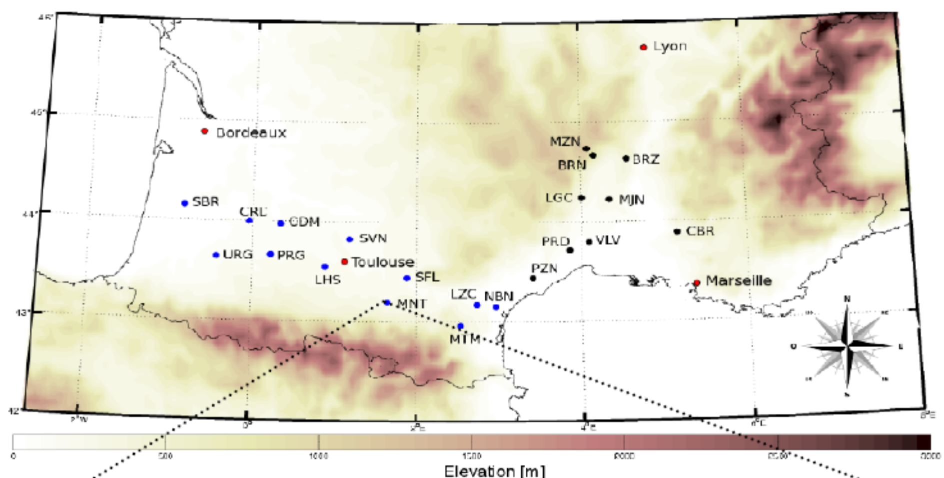


Albergel et al. 2015

Observations by Meteo-France

SMOSMANIA

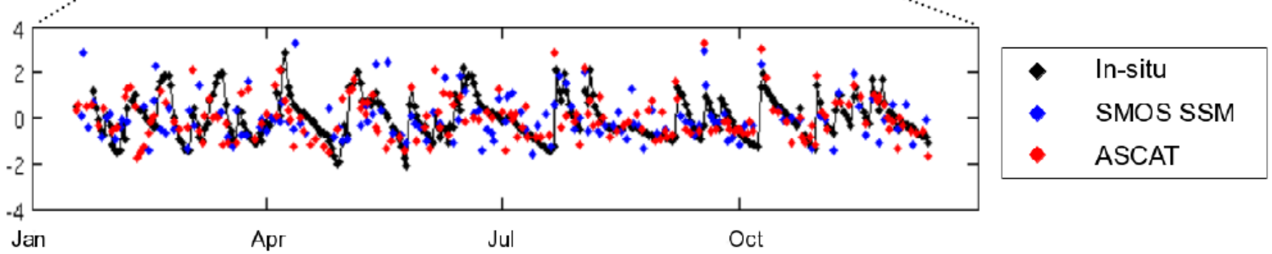
- Validation of satellite products



Anomalies:

$$\Theta = \frac{SSM(i) - \overline{SSM(F)}}{Stdev(SSM(F))}$$

F: 5 week window



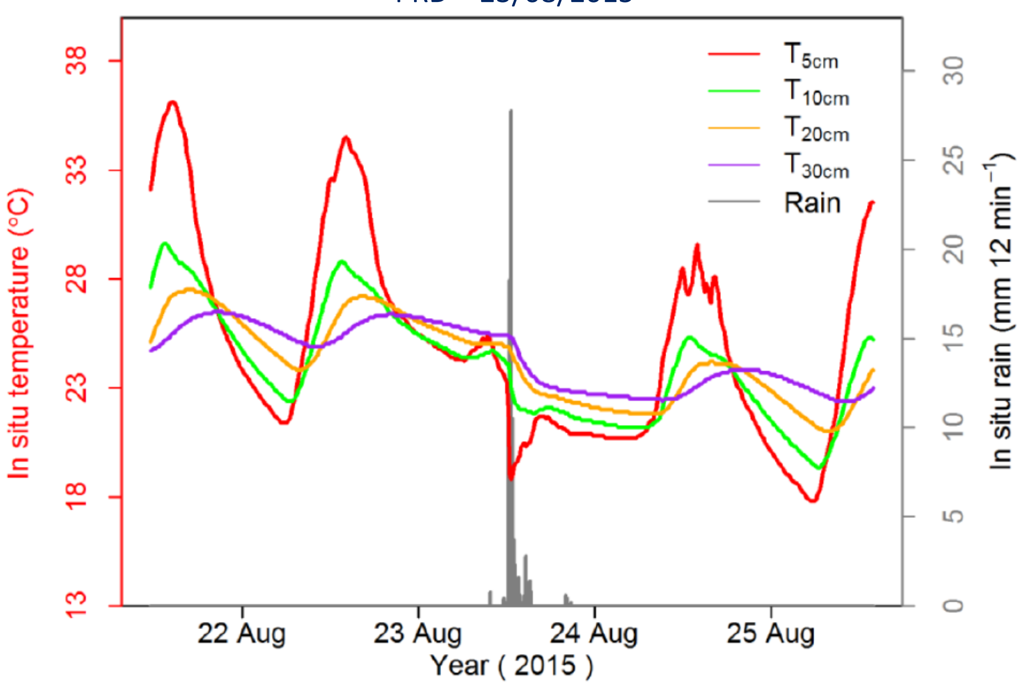
Parrens et al. 2012

Observations by Meteo-France

SMOSMANIA

- Processes: soil-cooling rain

PRD – 23/08/2015



Precipitation-induced sensible heat into the soil

T_{rain} ~ 6 degree C
T_{5cm} ~ 22 degree C

~ 800 W m-2

Zhang et al. 2019

Observations by Meteo-France

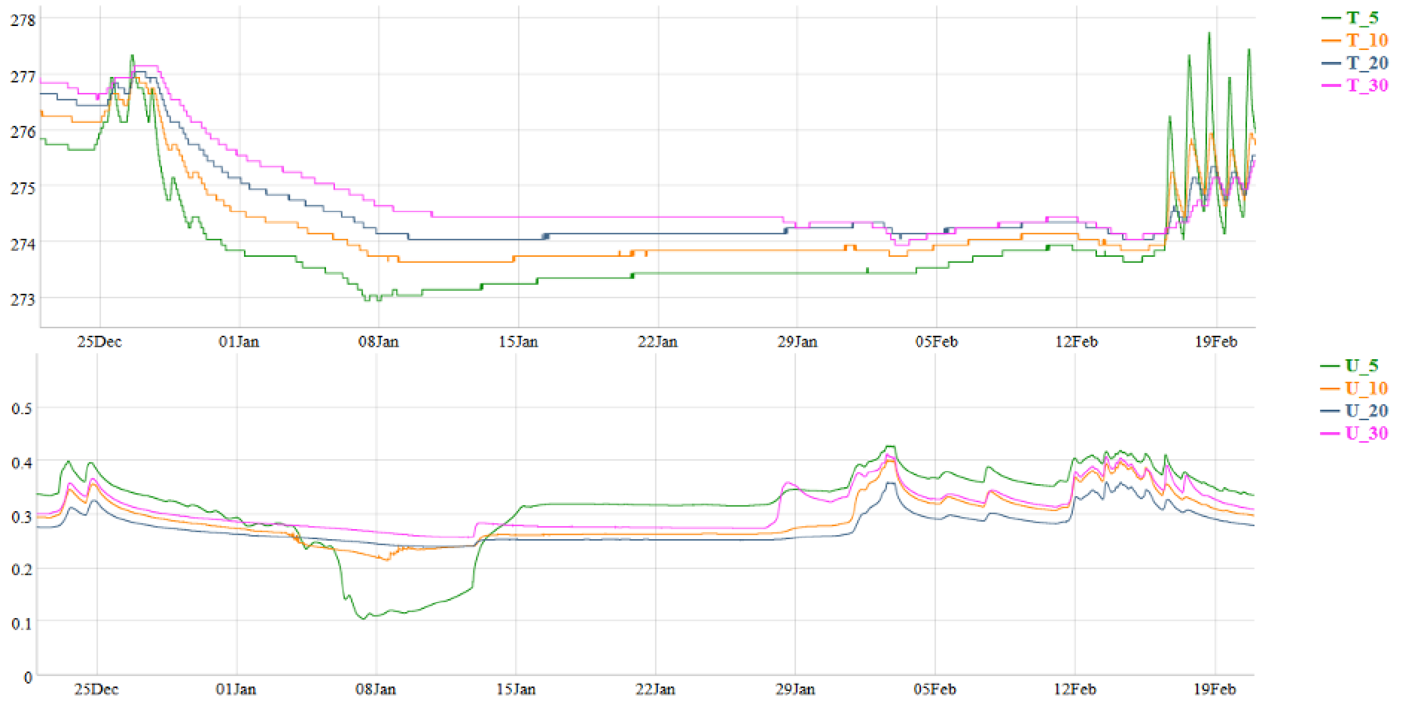
SMOSMANIA

➢ Processes: snow

MZN – 2017

Soil temperature

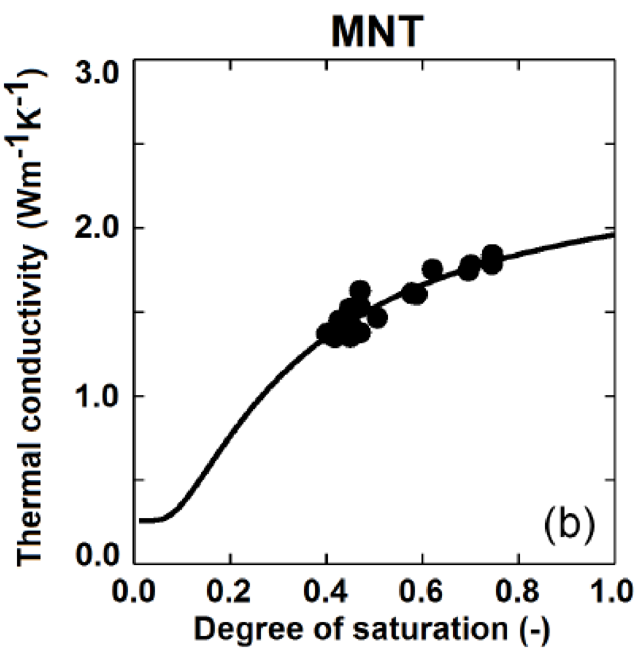
Soil moisture

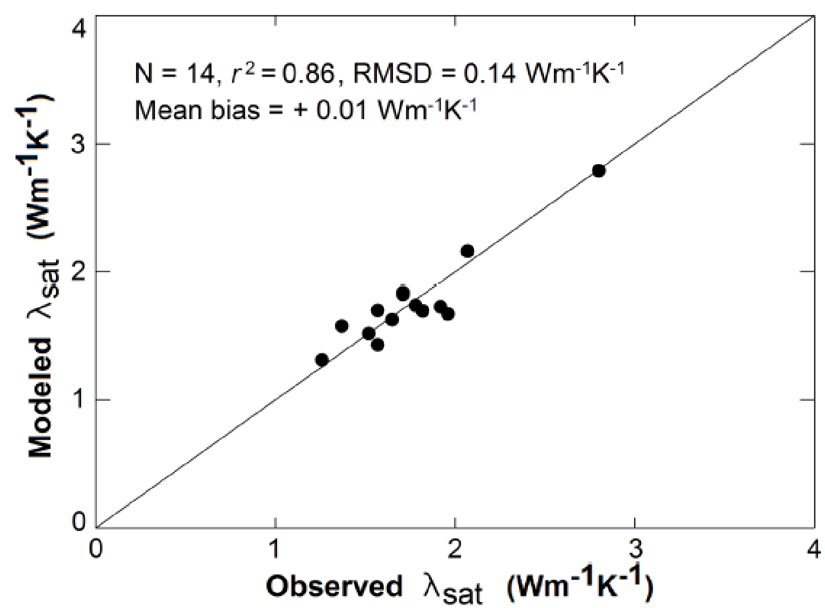


Observations by Meteo-France

SMOSMANIA

➢ Processes: soil thermal conductivity

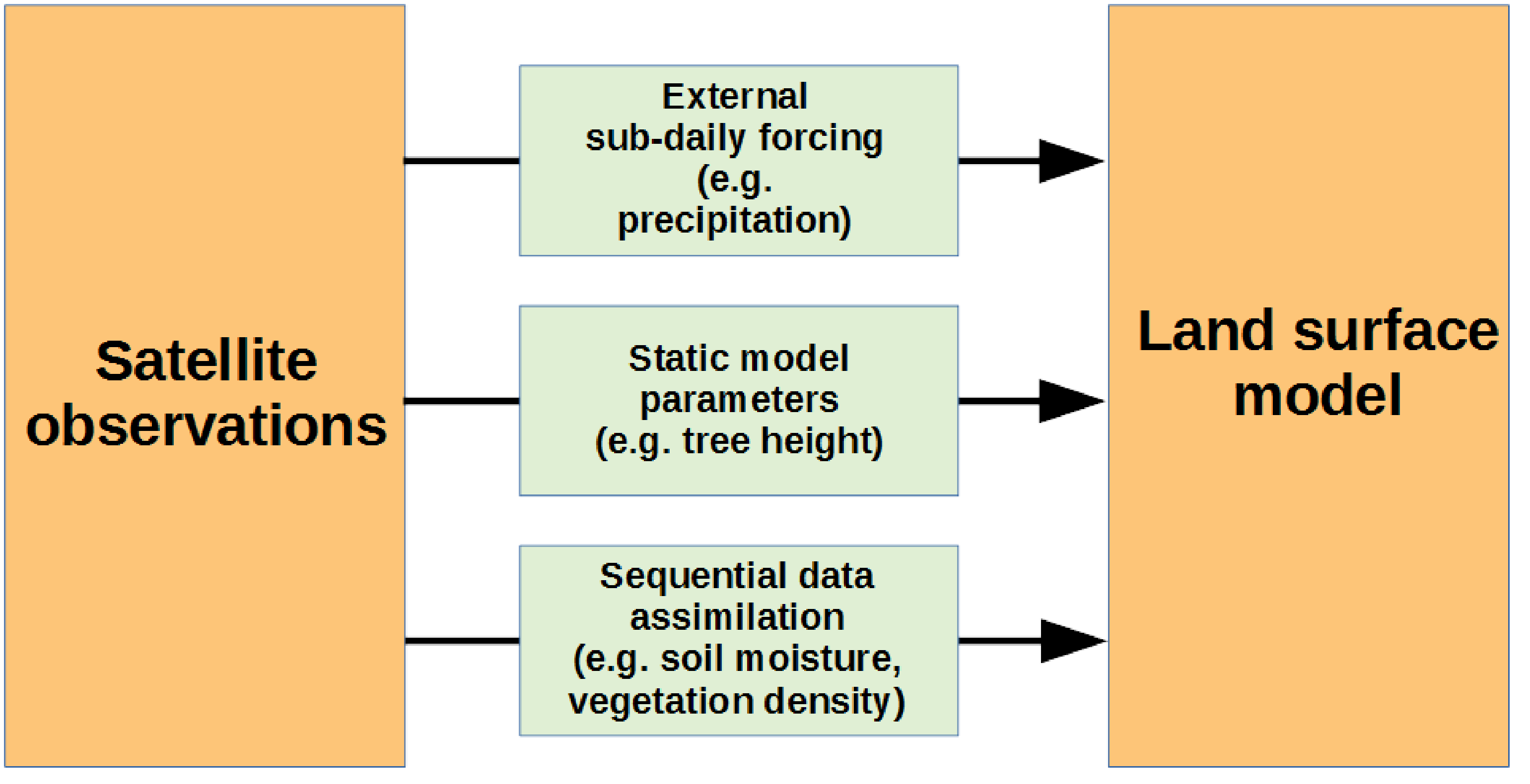




Calvet et al. 2016

Data assimilation

Integration of satellite data into models



Data assimilation

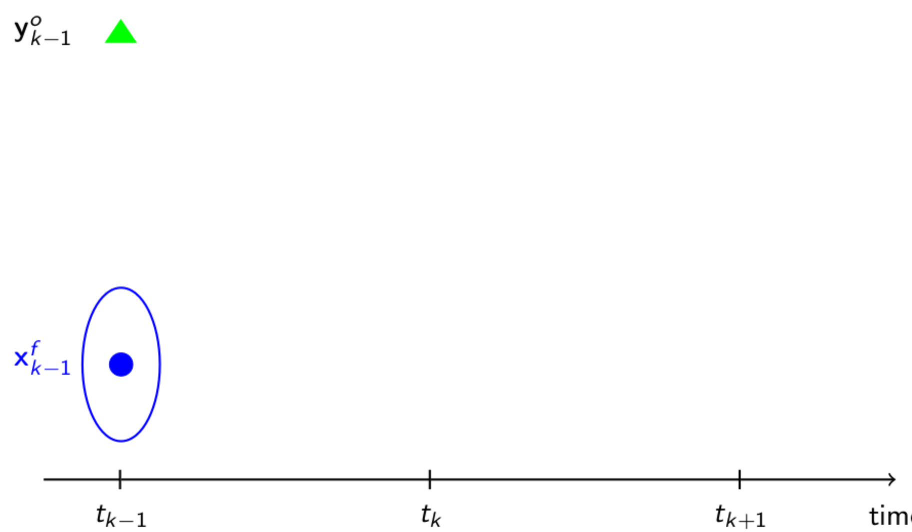
Integration of satellite data into models

- LDAS = "Land Data Assimilation System"
- Through a weighted combination of land surface model simulations and satellite-derived observations land surface variables can be better estimated than by either source of information alone (Reichle et al. 2007)
- Data assimilation can spatially and temporally integrate the observed information into a land surface model

Data assimilation

Sequential data assimilation

- Two-step approach
  - Forecast – predict the state of the system $\mathbf{x}_k^f$ at time t_k from previous time step $\mathbf{x}_{k-1}^a$
  - Analysis – correct the predicted state $\mathbf{x}_k^f$ with observations $\mathbf{y}_k^o$ to give $\mathbf{x}_k^a$



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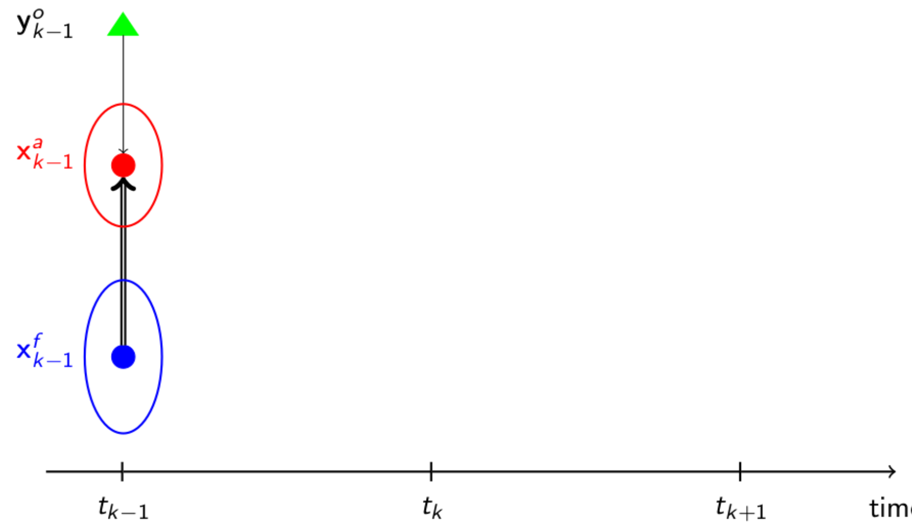

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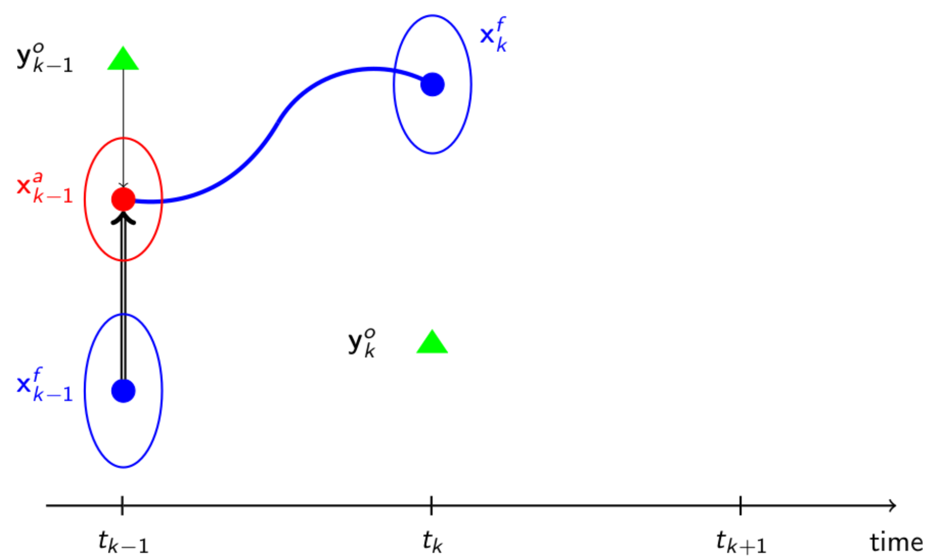

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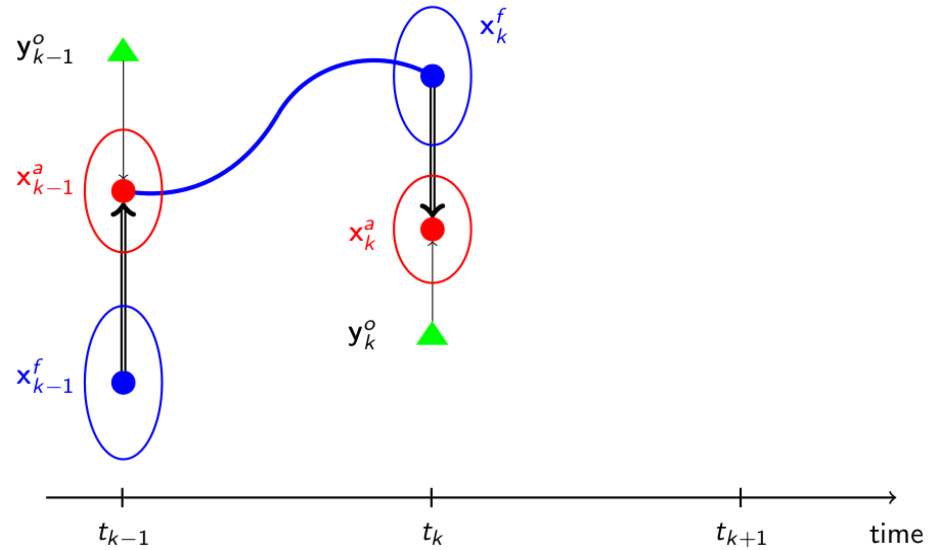

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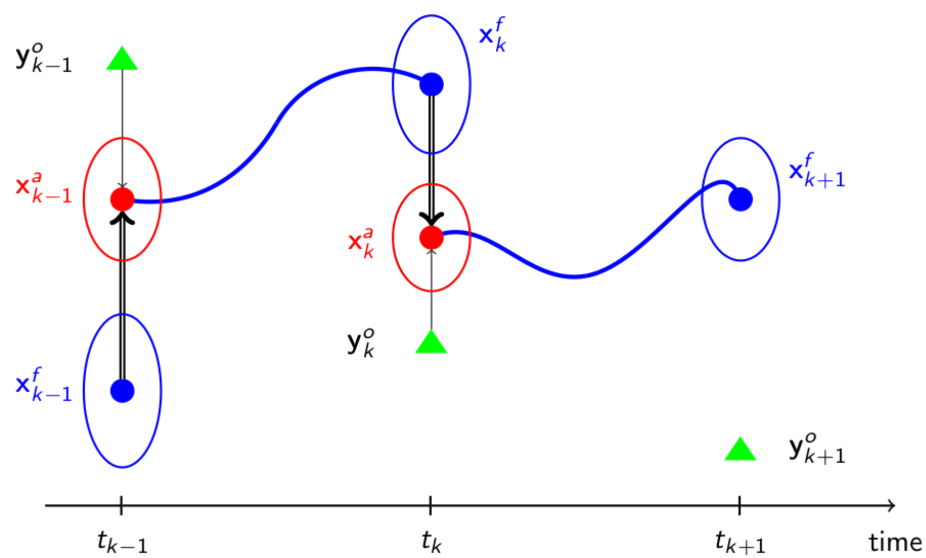

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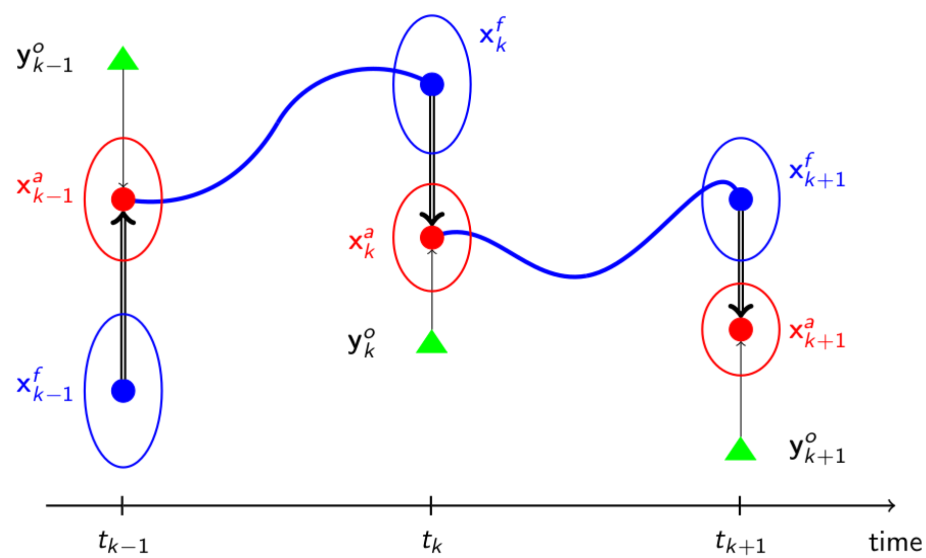

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Data assimilation

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Applications: e.g. LDAS-Monde

- Within the SURFEX modelling platform
  - ISBA land surface model (Calvet et al. 1998, Gibelin et al. 2008)
  - River routing / groundwater (CTRIP) (Decharme et al. 2019)
- Joint sequential assimilation of
  - Surface soil moisture and Leaf Area Index
  - Using a Kalman filter (Barbu et al. 2014, Bonan et al. 2019)
- Global scale: 0.25°x0.25° (Albergel et al. 2019)
- Regional scale: 1 km x 1 km

Data assimilation

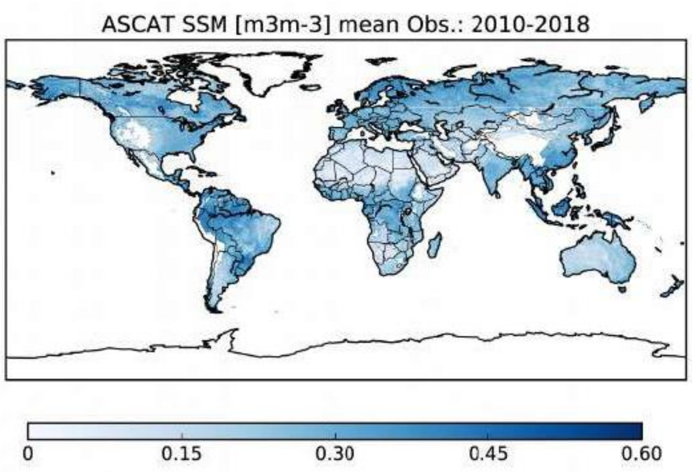
Applications: e.g. LDAS-Monde

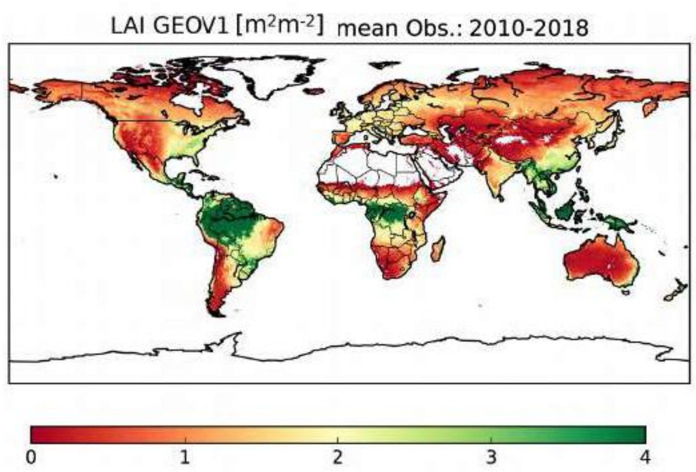
- Observed variables
  - Surface soil moisture (model equivalent 1 cm - 4 cm)
  - Leaf Area Index
- Control variables
  - Soil moisture at 7 depths (down to 1 m)
  - Leaf biomass
  - Updated thanks to their sensitivity to observed variables
    - **Other model variables** are impacted through biological processes and feedbacks in the model

Data assimilation

Applications: e.g. LDAS-Monde

- Example (Albergel et al. 2019)
  - Global analysis 0.25° x 0.25° from 2010 to 2018
  - Atmospheric forcing: ERA5
- Observations

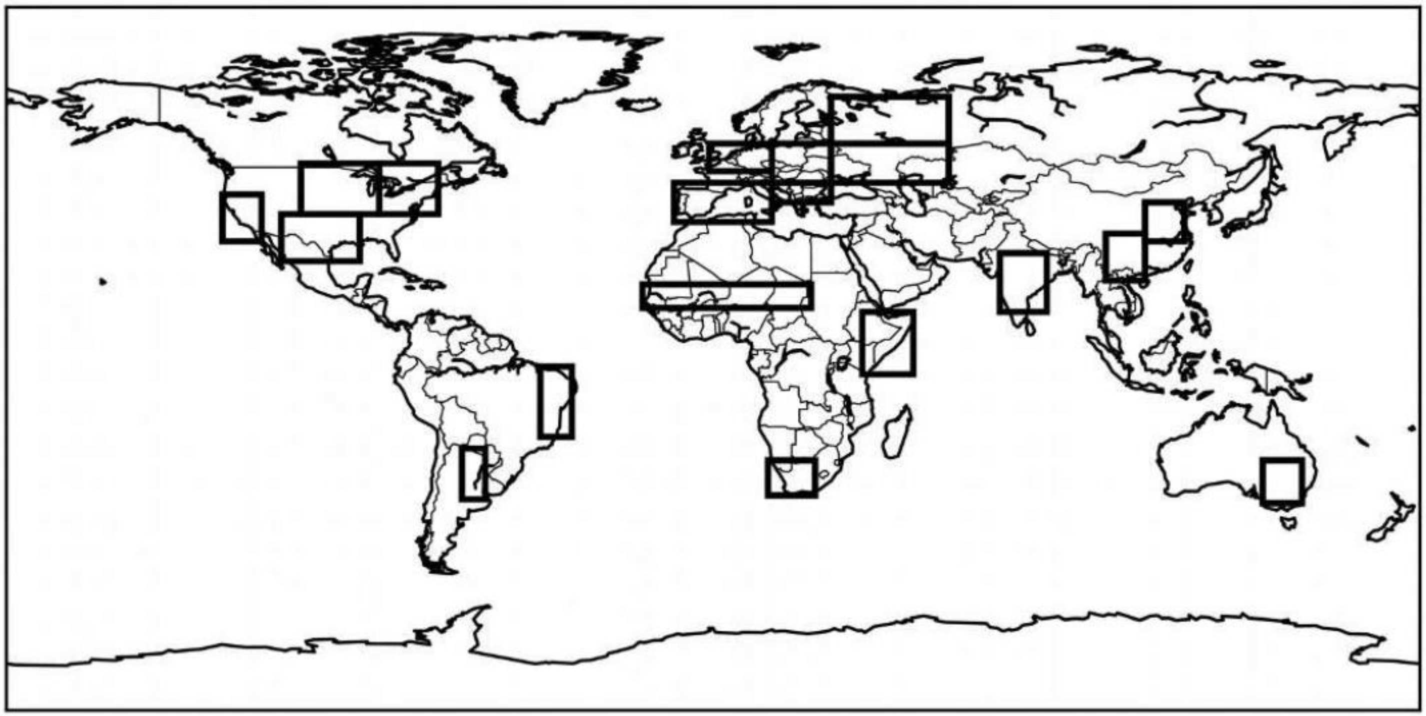




Data assimilation

Applications: e.g. LDAS-Monde

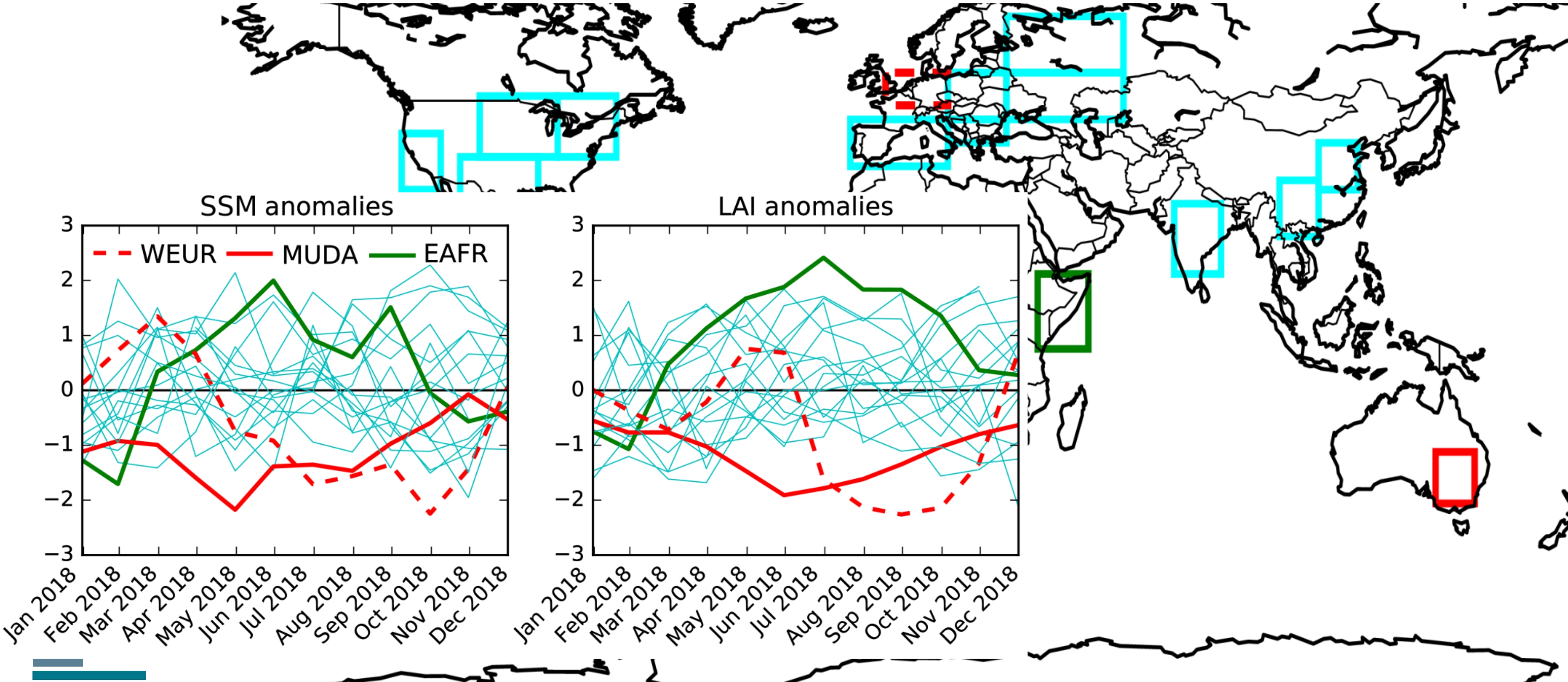
- Selection of 19 regions known for being potential hotspots for droughts and heatwaves



Data assimilation

Applications: e.g. LDAS-Monde

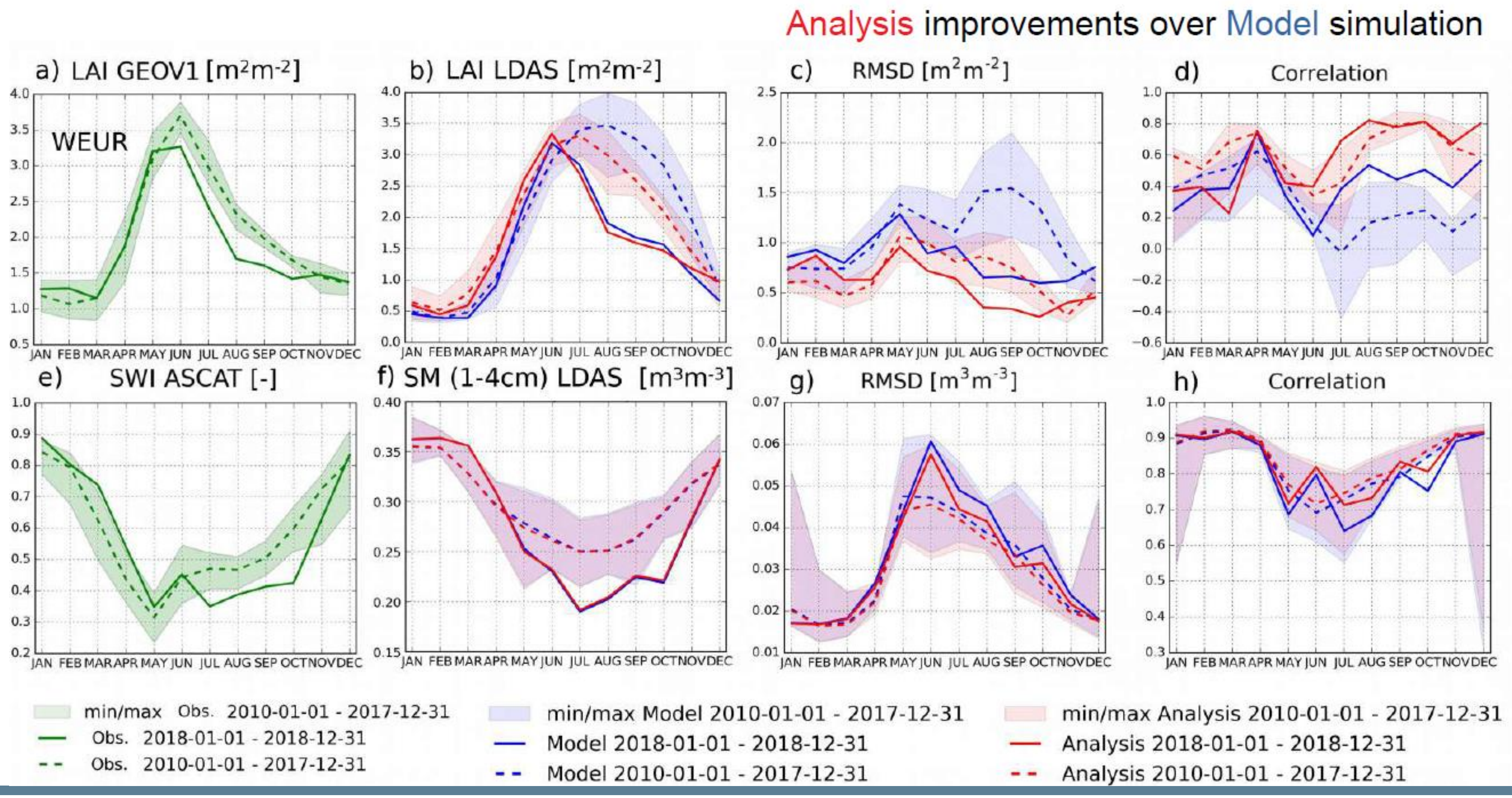
- Monthly anomalies for 2018



Data assimilation

Applications: e.g. LDAS-Monde

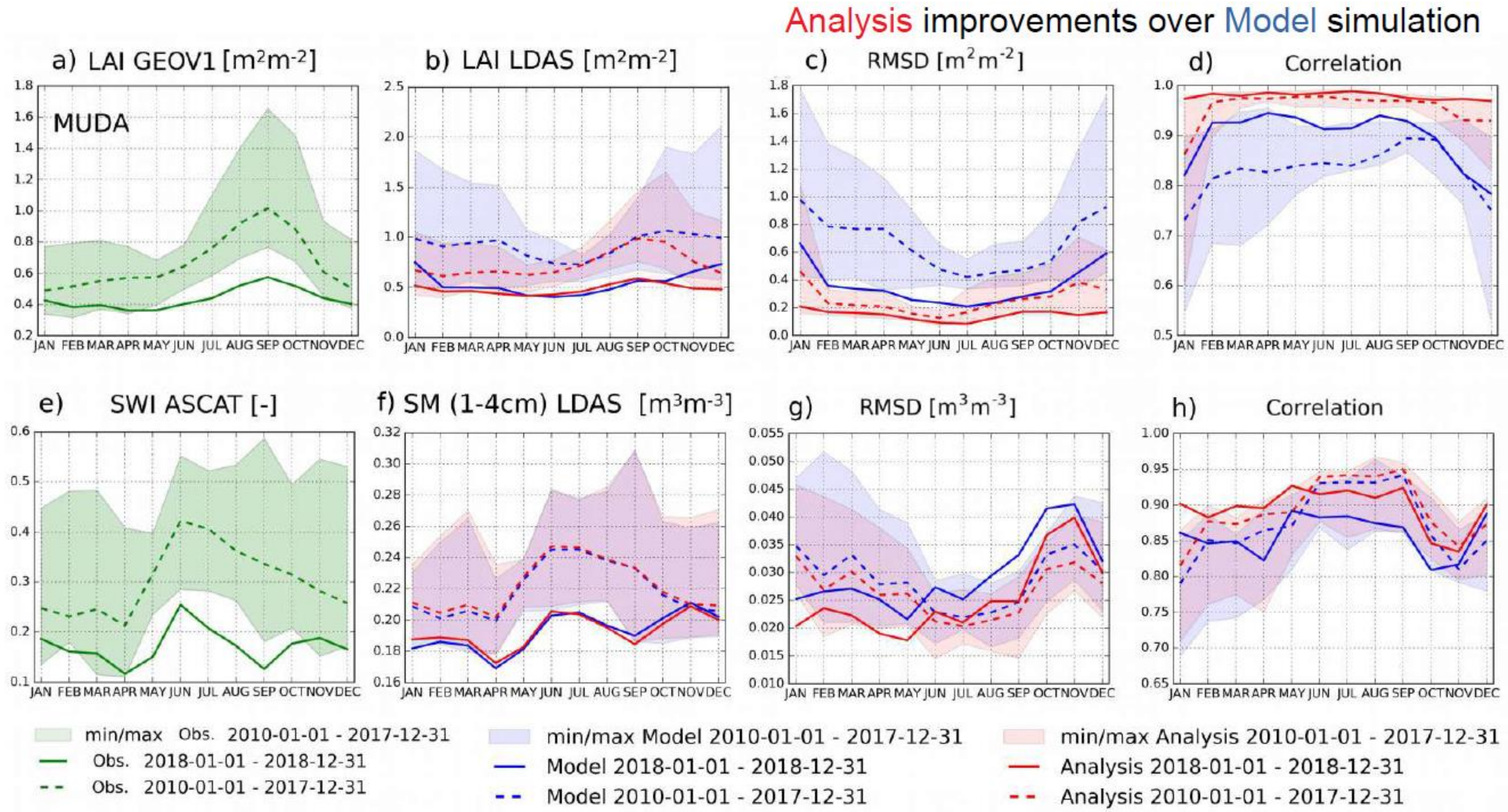
➢ 2018 heatwave: Northwestern Europe



Data assimilation

Applications: e.g. LDAS-Monde

- 2018 heatwave: Murray-Darling basin (Australia)



Soil moisture: recap

Observations

- Global satellite products
  - ASCAT on METOP (EUMETSAT HSAF, Copernicus GLS)
  - SMOS (ESA)
  - SMAP (NASA)
  - Sentinel-1 downscaling (Copernicus GLS)
- Global *in situ* network
  - ISMN (TUWien)

Soil moisture: recap

Modelling

- Land surface models
  - Sub-daily variability
  - Soil moisture / temperature at various depths
  - Vegetation biomass and LAI
  - Water, energy, carbon fluxes
  - Can be forced by ERA5 at a global scale (0.25° x 0.25°)

Soil moisture: recap

Data assimilation

- Sequential assimilation
  - Needed for monitoring applications
  - ISBA model: joint assimilation of SSM and LAI is possible
    - Photosynthesis-driven phenology: flexible LAI
- Applications
  - Drought monitoring
    - Agriculture, forestry
    - Hydrology (coupling to a river routing system is needed)

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Thank you for your attention