Satellite data and ISBA: Assimilation

Jean-Christophe Calvet

with contributions from Clément Albergel, Alina Barbu, Hélène Dewaele, Delphine Leroux, Marie Parrens

A TRIBUTE TO JOEL NOILHAN, Toulouse, 22 March 2019

Why land data assimilation?

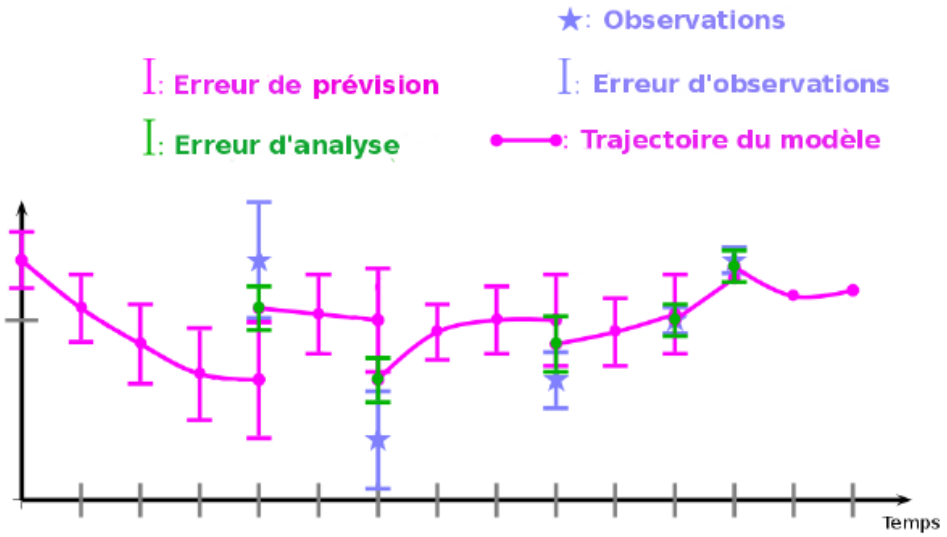
- **Land surface models are not perfect !**
  - **Lack of knowledge: assumptions / simplifications**
  - **Uncertainties in forcings (e.g. atmospheric variables)**
  - **Uncertainties in model parameter values**
  - **Uncertainties in initial conditions**
- **Integrating observations into models can enhance realism of simulations**
- **Current values of key land surface variables can impact future surface states**
  - **Root-zone soil moisture**
  - **Vegetation leaf biomass**
- **Analyzing these variables is needed to forecast land surface variables**
  - **Satellite remote sensing can be used**

Why land data assimilation?

Sequential assimilation

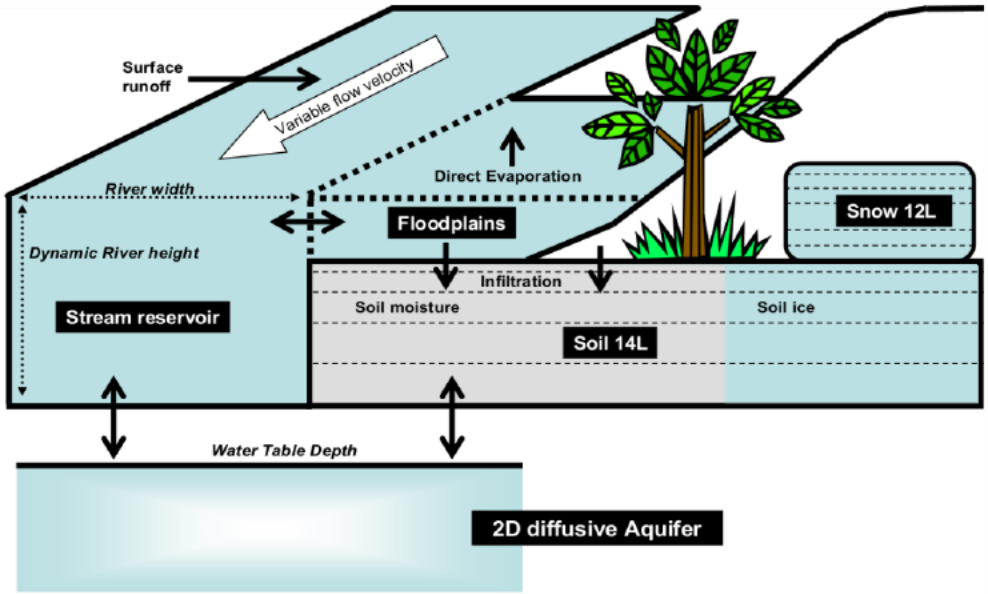
- **Model trajectory is driven by observations**
  e.g. Kalman Filtering approach

- **More suited to monitoring applications than model calibration**
  - **permits a better monitoring of unusual / extreme / poorly modeled events**
  - all kinds of errors can be accounted for
  - near real-time operation is possible
  - key parameters can be efficiently tuned by minimizing analysis increments



LDAS-Monde: a European global LDAS

- Integration of satellite observations into the ISBA model
- Fully coupled to hydrology within SURFEX



- ISBA: 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)

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

ISBA to CTRIP:

runoff, drainage, groundwater and floodplain recharges

CTRIP to ISBA:

water table depth/rise, floodplain fraction, flood potential infiltration

LDAS-Monde: a European global LDAS

- **Sequential assimilation of vegetation products**

  Thanks to flexible LAI simulated by the ISBA model

  Photosynthesis-driven phenology, no GDD phenology sub-model

- **Joint assimilation of LAI and surface soil moisture**

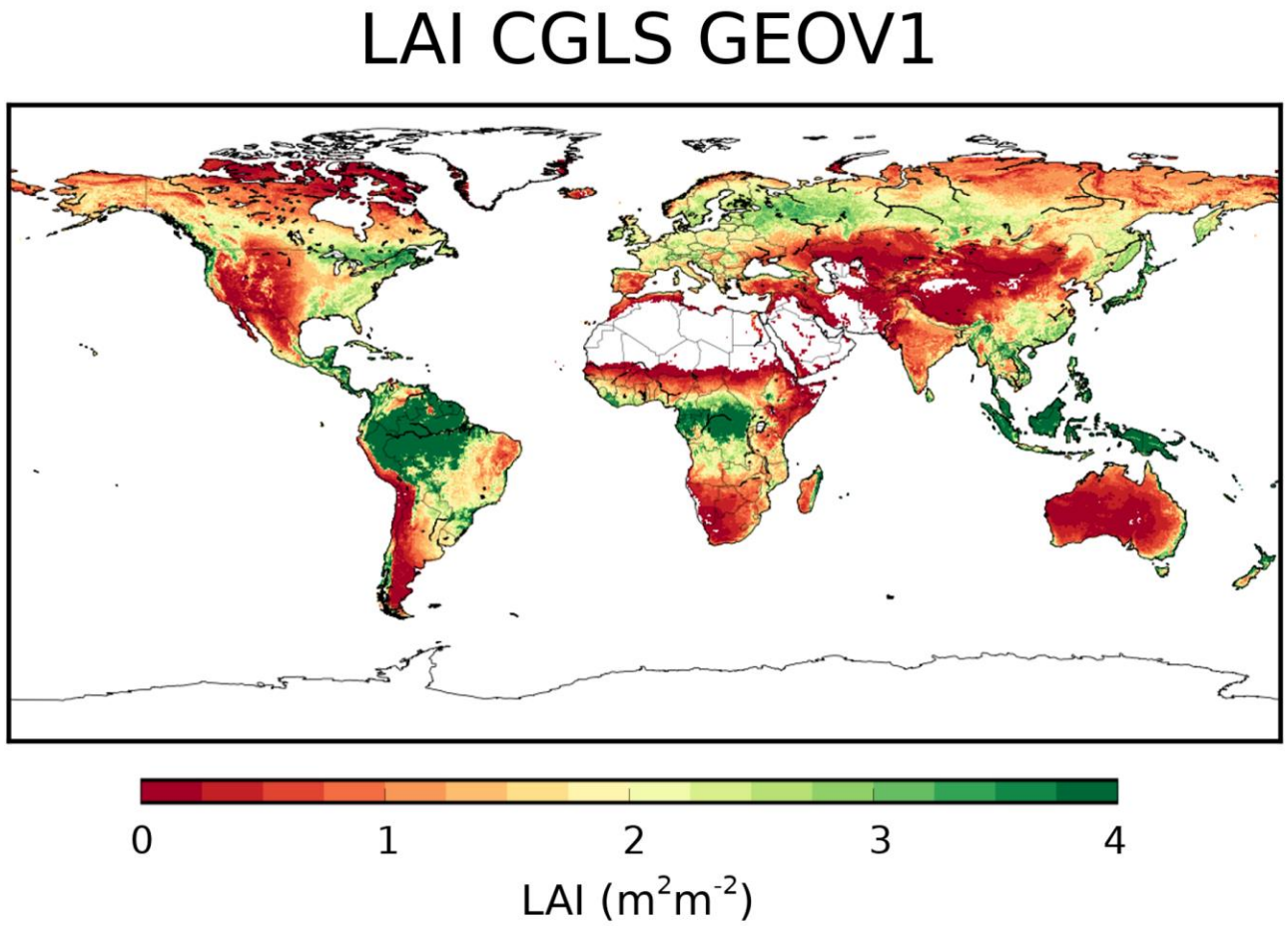
  http://land.copernicus.eu/global

- **Disaggregation of satellite-derived LAI (Munier et al. Remote Sensing 2018)**

  Kalman filter based on SURFEX static proxy
  (ECOCLIMAP, **Faroux et al. GMD 2013**)

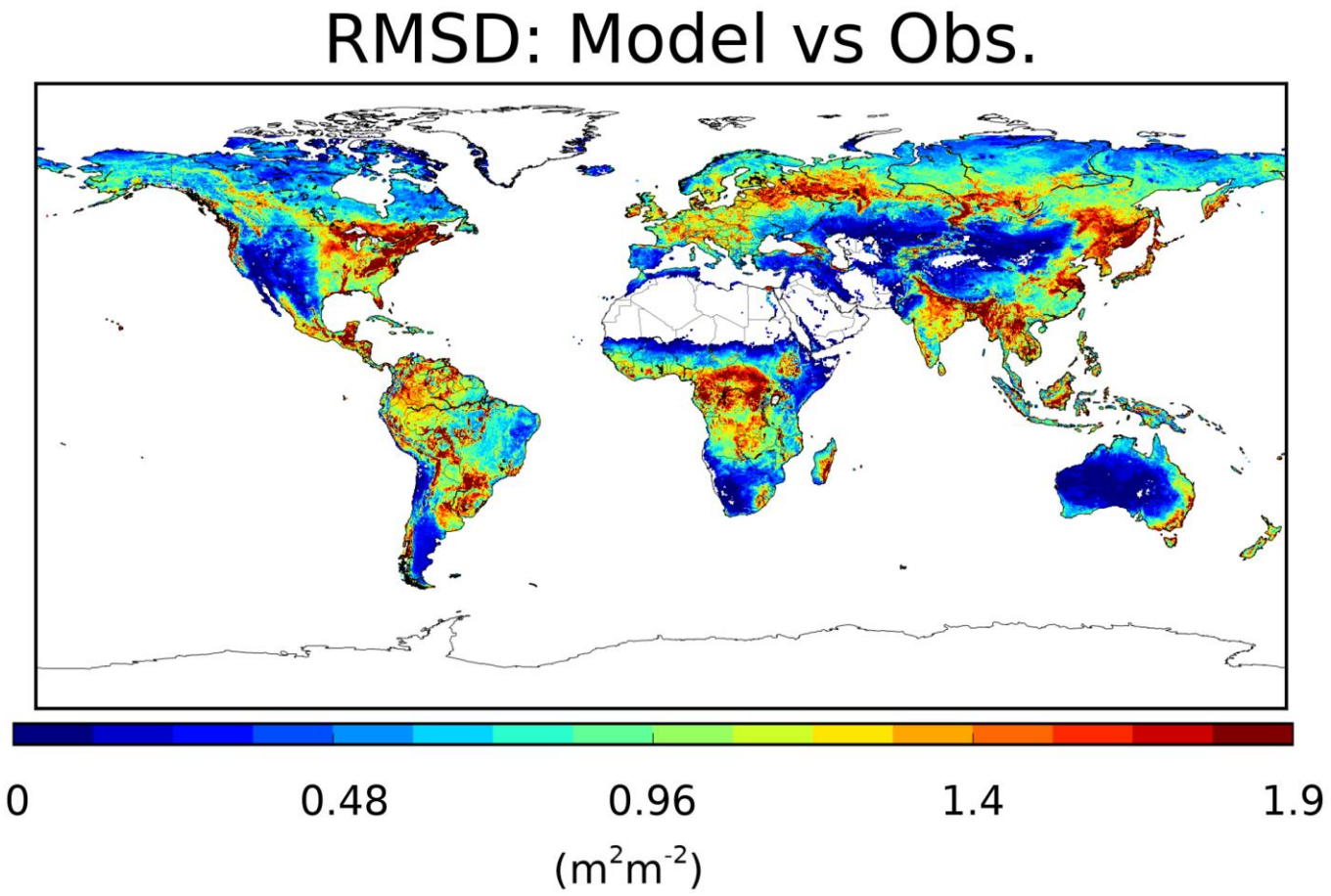
LDAS-Monde: a European global LDAS

- **Leaf Area Index (2010-2018): observations**



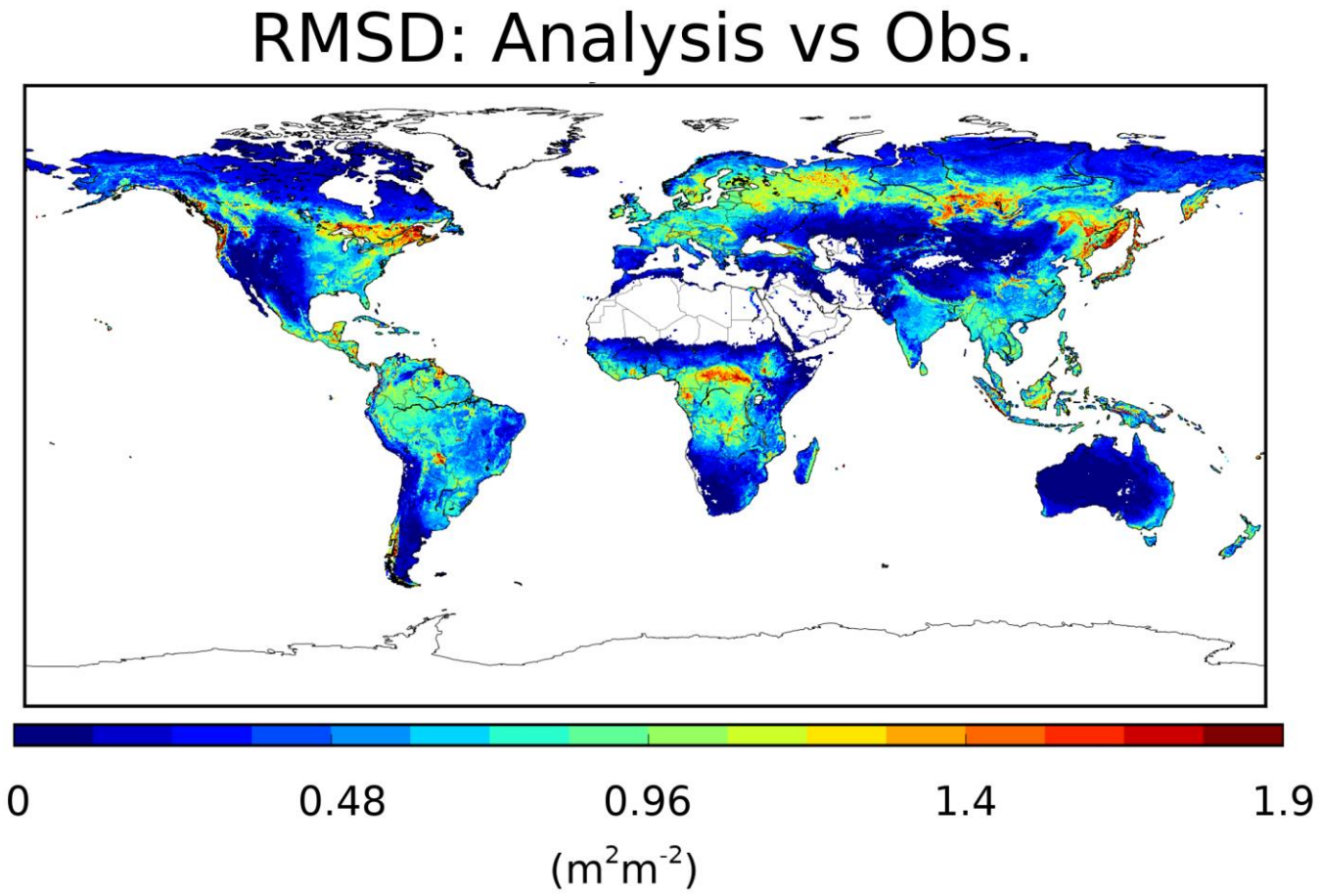
LDAS-Monde: a European global LDAS

- **Leaf Area Index (2010-2018): simulations vs. observations**



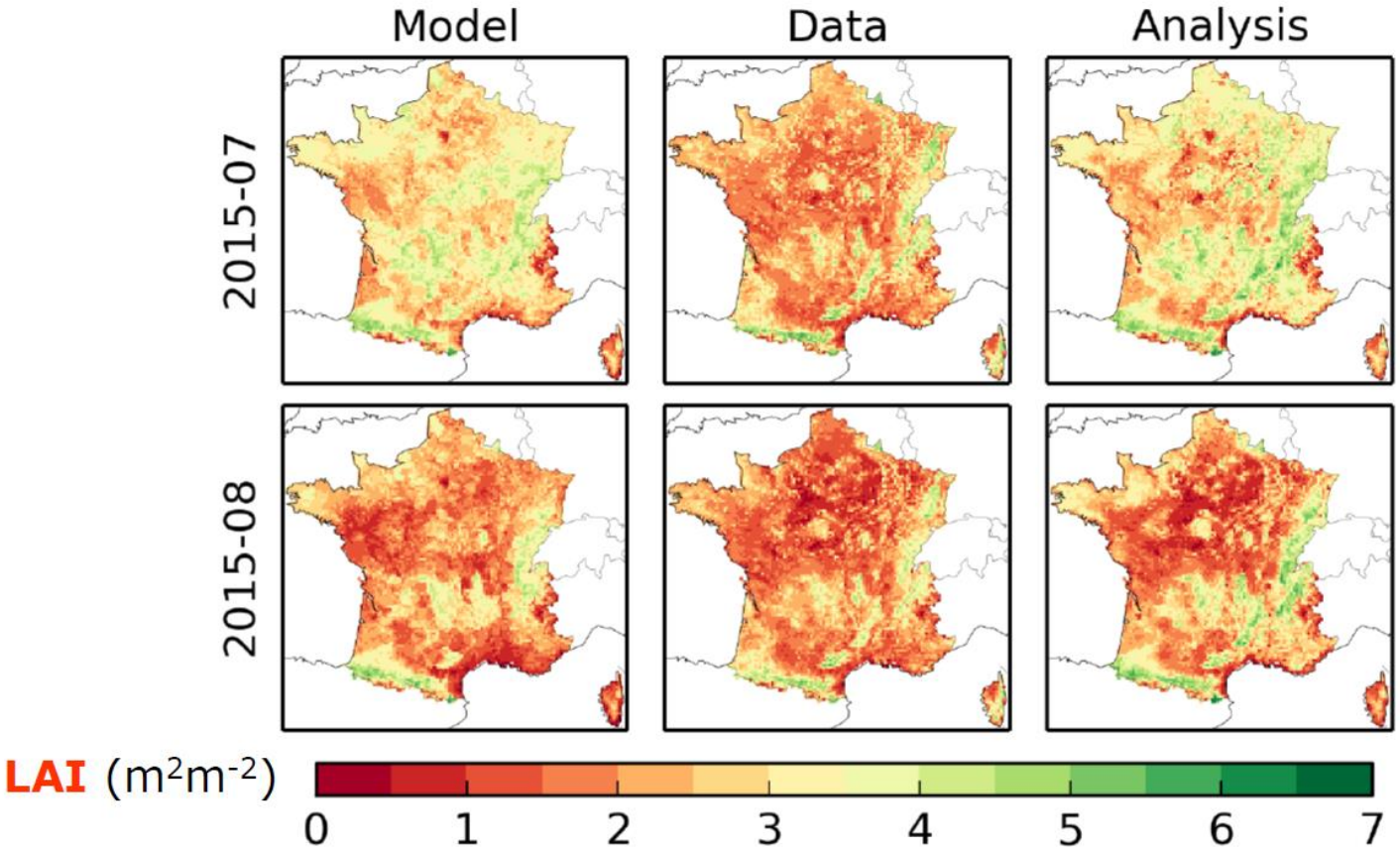
LDAS-Monde: a European global LDAS

- **Leaf Area Index (2010-2018): analysis vs. observations**



LDAS-Monde: a European global LDAS

- **Incorporation of geographic information into land surface models**
- Example: France



LDAS-Monde: a long heritage of research

- **1989-1993: assimilation of T2m, HU2m in NWP models**
- **1995-2005: soil moisture field campaigns (MUREX, SMOSREX)**
- **1998: ISBA-A-gs (Calvet, Noilhan, et al. 1998)**
- **2004-2017: PhD theses on data assimilation**
  - 2007: Joaquin Munoz-Sabater
  - 2010: Clément Albergel
  - 2014: Marie Parrens
  - 2017: Hélène Dewaele
- **2001-2017: European projects developing data assimilation**
  - 2001-2004: FP5-ELDAS
  - 2004-2007: FP6-GEOLAND
  - 2008-2012: FP7-GEOLAND2
  - 2012-2016: FP7-IMAGINES
  - 2014-2017: FP7-eartH2Observe
- **2013-2019: used for the validation of the Copernicus Global Land service**

Assimilation of T2m, HU2m in NWP models

Analysis of Soil Moisture from Near-Surface Parameters: A Feasibility Study

JEAN-FRANÇOIS MAHFOUF

Météo-France/CNRM, Toulouse Cedex, France

(Manuscript received 6 September 1990, in final form 20 March 1991)

(J. Applied Meteorology, 1991)

- Principles still in operations today
- Contributed to initiate research on the assimilation of land satellite remotely sensed observations

Acknowledgments. The author wishes to thank P. Bougeault and J. F. Geleyn for useful suggestions concerning the design of this study. Thanks are also due to J. Noilhan and to O. Talagrand for their help and encouragement. The current study was supported by grants from Institut National des Sciences de l'Univers.

MUREX soil moisture field campaign

Retrieving the Root-Zone Soil Moisture from Surface Soil Moisture or Temperature Estimates: A Feasibility Study Based on Field Measurements

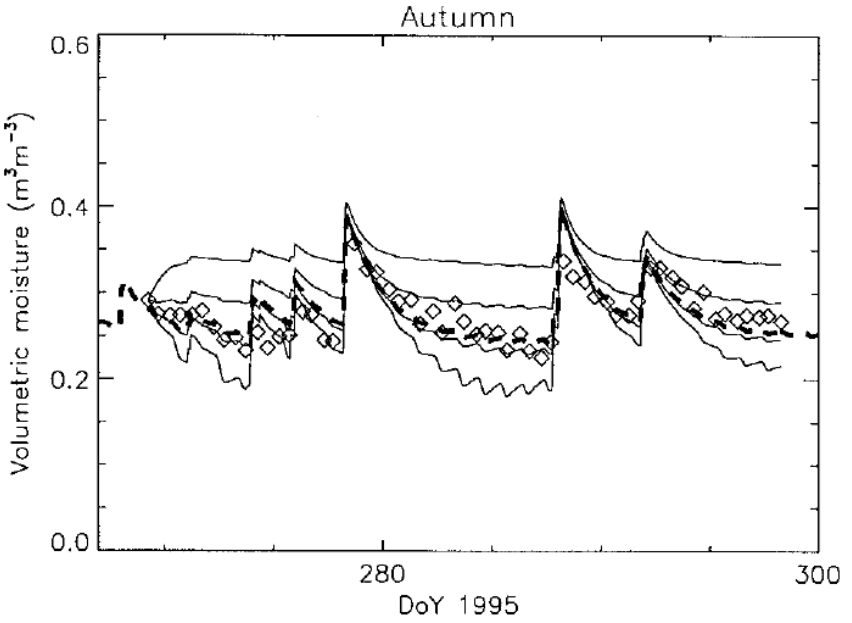
J.-C. CALVET, J. NOILHAN, AND P. BESSEMOULIN

Météo-France/CNRM, Toulouse, France

(Manuscript received 19 March 1997, in final form 31 July 1997)

(J. Applied Meteorology, 1998)

- « Four or five estimations of the surface soil moisture at low temporal resolution (one every 4 days for example) are enough to retrieve the total soil water content by inverting ISBA »
- Was a key argument to initiate the ESA SMOS satellite programme (launched in 2009)



MUREX soil moisture field campaign

From Near-Surface to Root-Zone Soil Moisture Using Year-Round Data

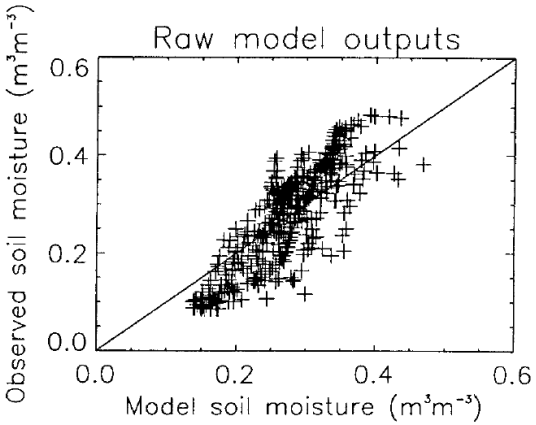
JEAN-CHRISTOPHE CALVET AND JOËL NOILHAN

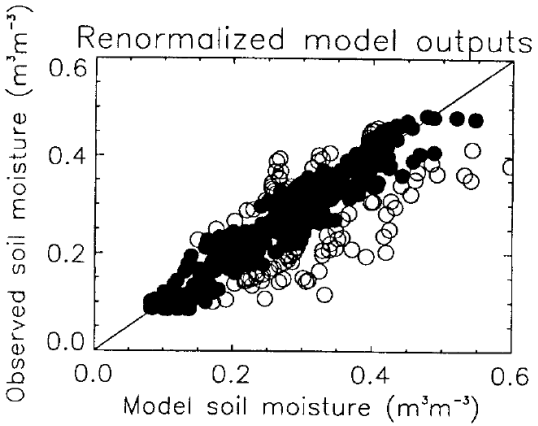
Météo-France/CNRM, Toulouse, France

(Manuscript received 9 August 1999, in final form 15 May 2000)

(J. Hydrometeorology, 2000)

- « Renormalization method »
  to cope for model parameter errors
- A precursor of the use of CDF-matching





ISBA-A-gs

An interactive vegetation SVAT model tested against data from six contrasting sites

Jean-Christophe Calvet[a,*], Joël Noilhan[a], Jean-Louis Roujean[a], Pierre Bessemoulin[a], Maurice Cabelguenne[b], Albert Olioso[c], Jean-Pierre Wigneron[c]

[a] *Météo-France/CNRM, 42 Av. Coriolis, F-31057 Toulouse Cedex 1, France*
[b] *INRA/Agronomie, BP27 Auzeville, F-31326 Castanet Tolosan, France*
[c] *INRA/Bioclimatologie, Agroparc, F-84914 Avignon Cedex 9, France*

Received 19 December 1997; received in revised form 2 May 1998; accepted 22 May 1998

(Agric. Forest Meteorol., 1998)

- **WMO NORBERT-GERBIER-MUMM award 2000**
- **Photosynthesis-driven phenology**
- **Flexible LAI**
- **Sequential assimilation of vegetation products is possible**

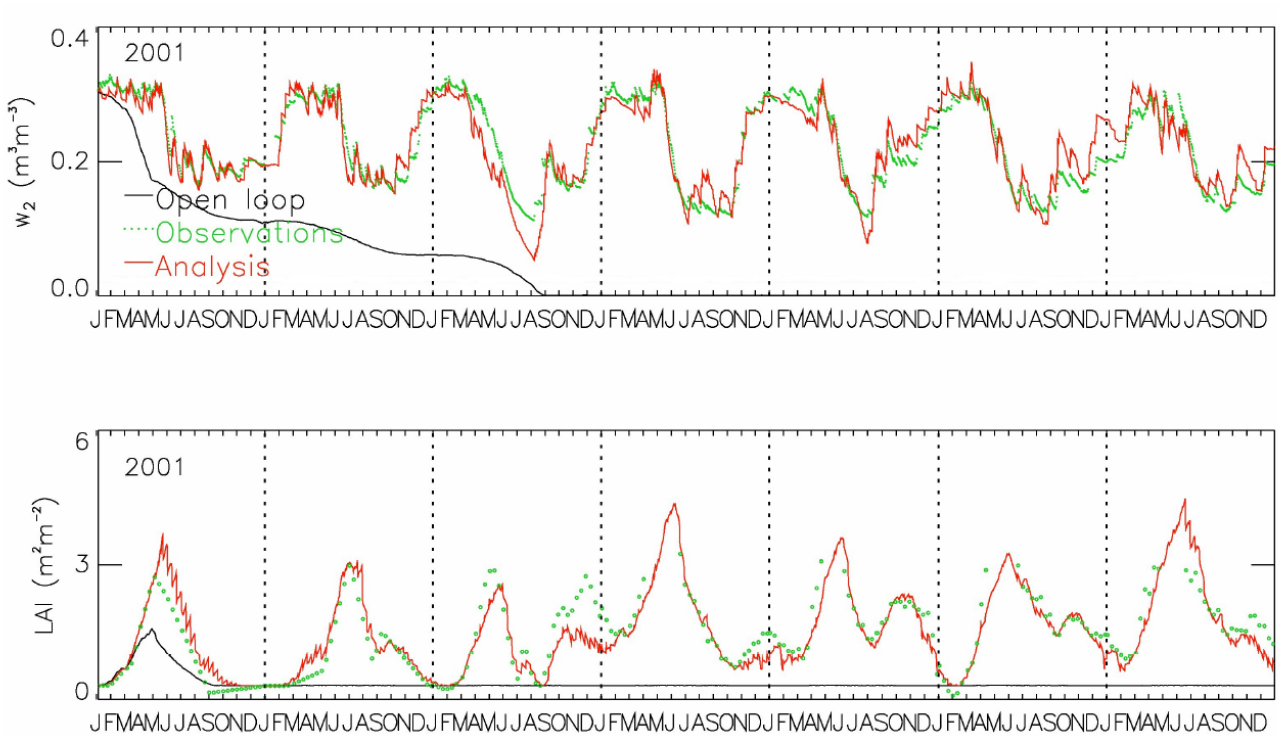
SMOSREX soil moisture field campaign

Monitoring of water and carbon fluxes using a land data assimilation system: a case study for southwestern France

C. Albergel[1], J.-C. Calvet[1], J.-F. Mahfouf[1], C. Rüdiger[1,*], A. L. Barbu[1], S. Lafont[1], J.-L. Roujean[1], J. P. Walker[2,*], M. Crapeau[3,**], and J.-P. Wigneron[3]

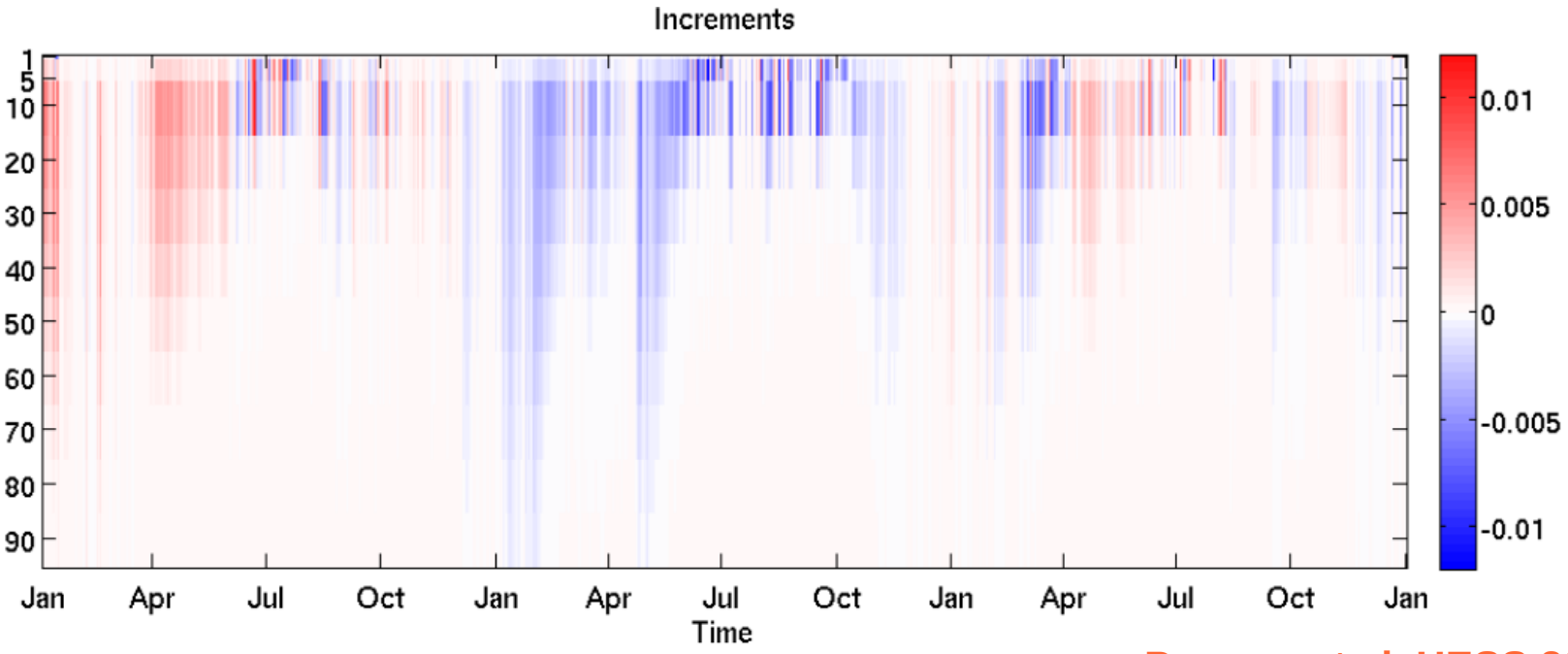
(Hydrol. Earth Syst. Sci., 2010)

- Joint soil moisture and vegetation analysis



SMOSREX soil moisture field campaign

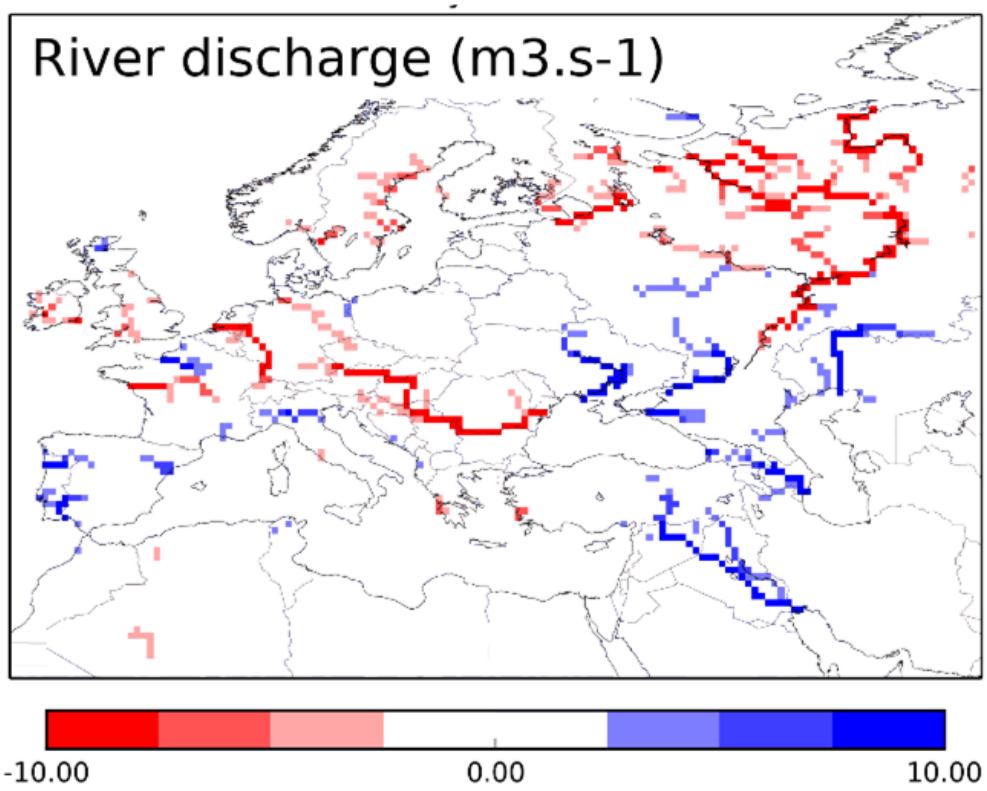
- **From a single root-zone soil moisture layer to multiple soil layers**
  - **Decoupling between surface and deep soil moisture in dry conditions**



Parrens et al. HESS 2014

Validation: hydrology

- **Example: Impact of vegetation and soil moisture analysis on river discharge**

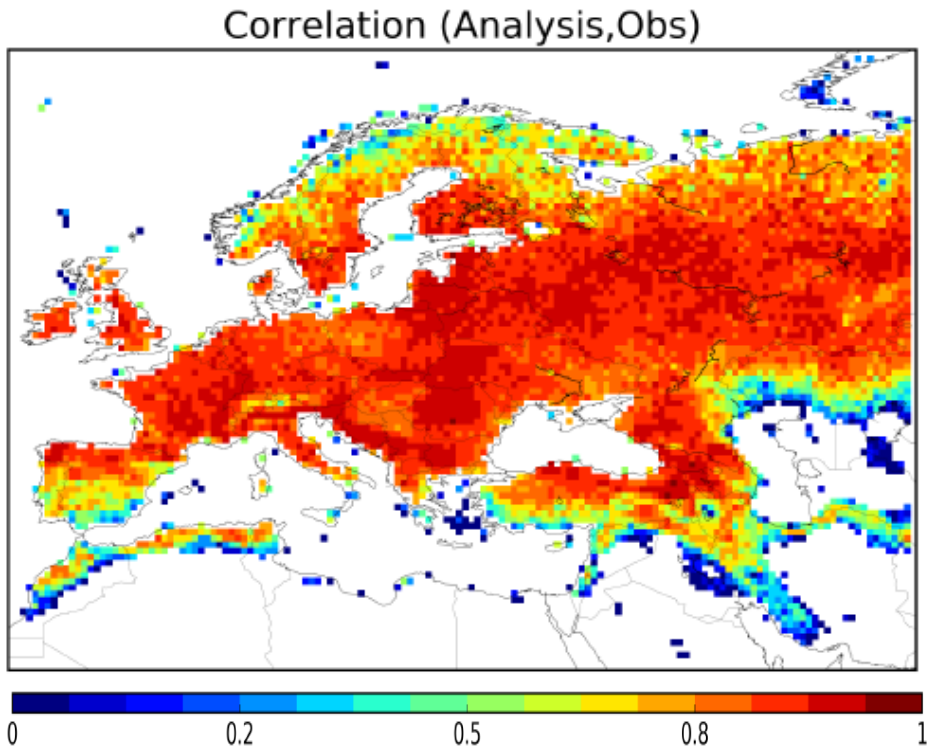


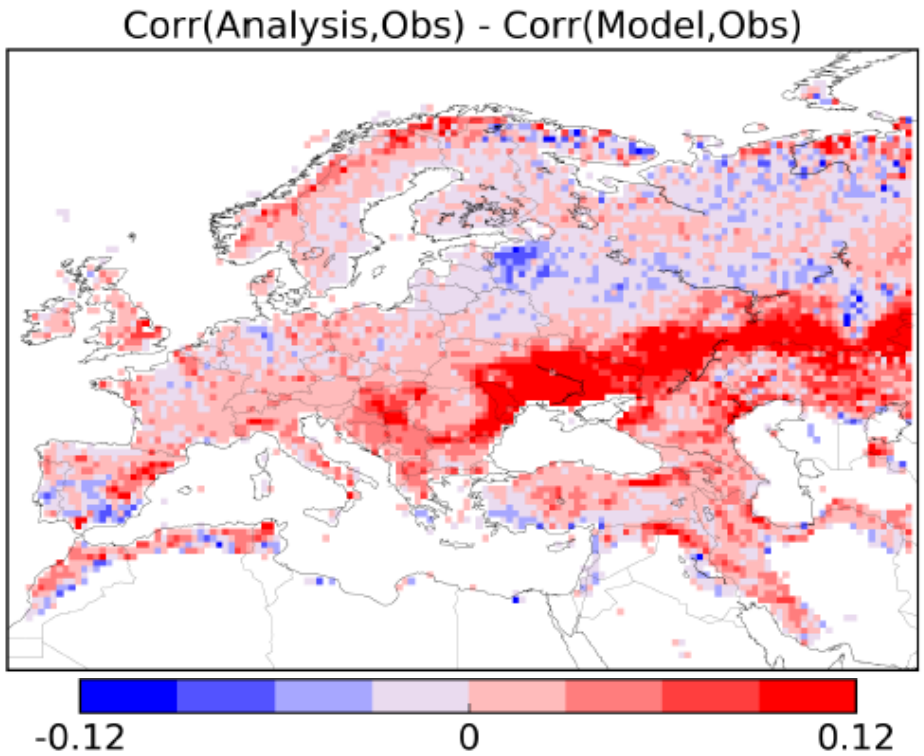
Mean analysis impact on river discharge over the 2000-2012 period

Albergel et al. GMD 2017

Validation: natural CO_2 fluxes

- **Example: GPP vs. GOME-2 SIF product (2007-2015)**

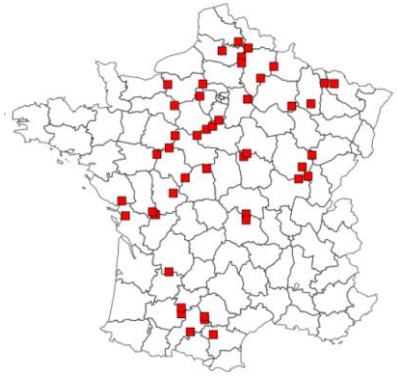


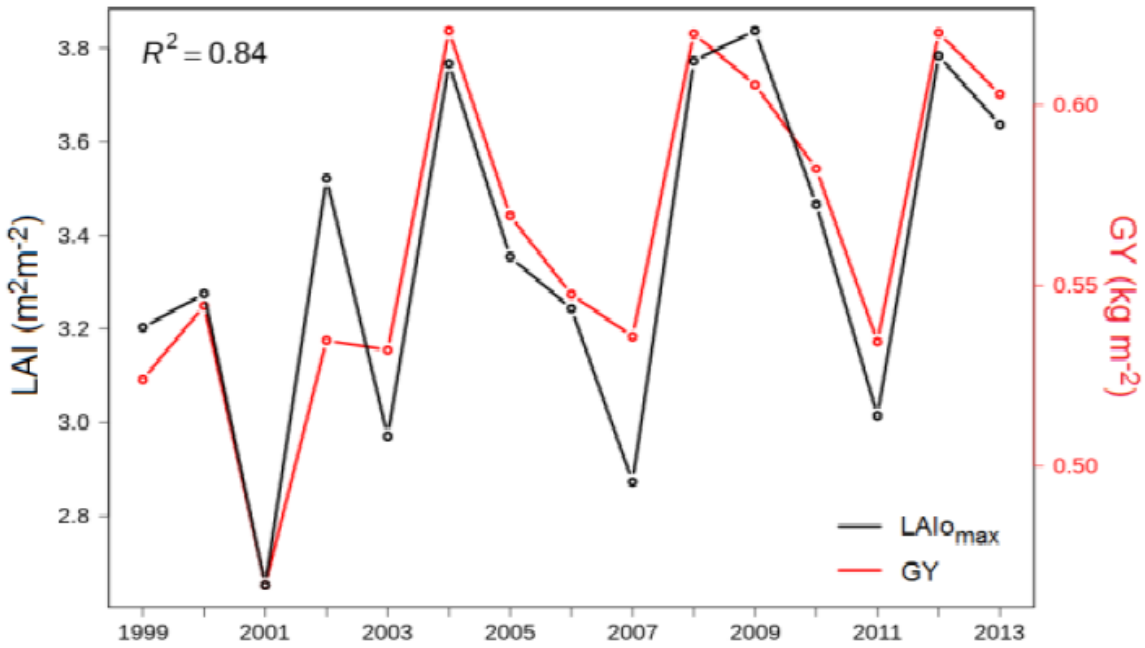


Leroux et al. Remote Sensing 2018

Validation: crop yields

- **Example: wheat yields in France (1999-2013)**
- Disaggregated Copernicus GLS LAI correlates with wheat yields

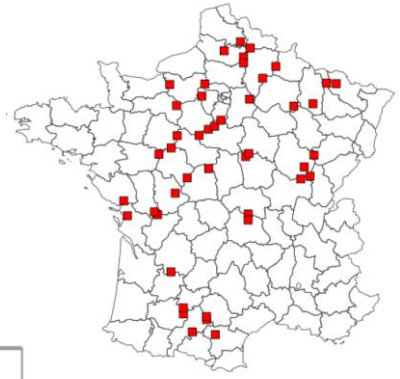




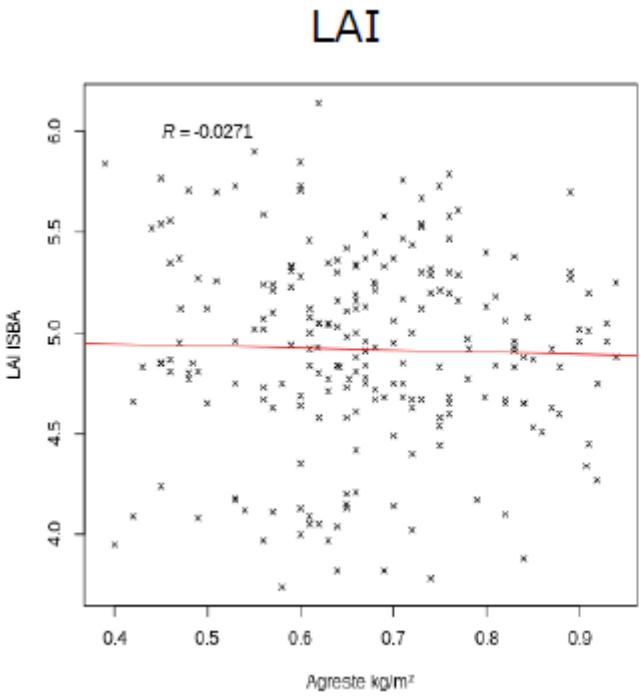
Dewaele et al. HESS 2017

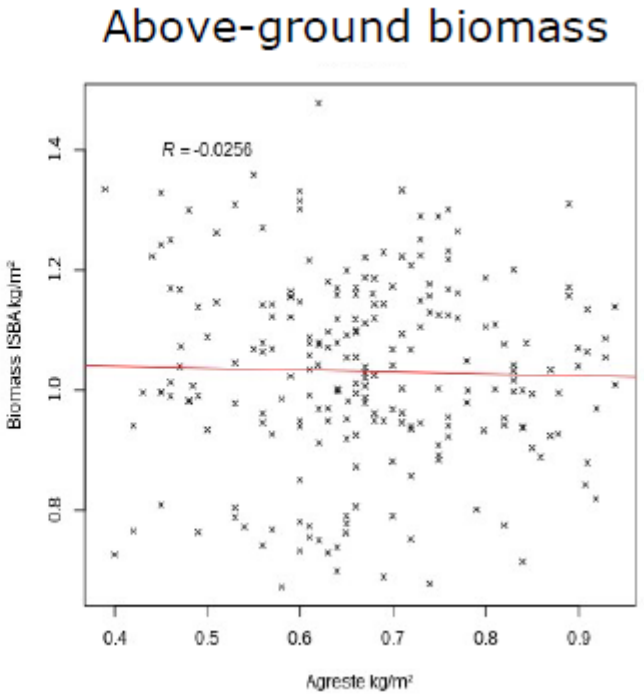
Validation: crop yields

- **Example: wheat yields in France (1999-2013)**



ISBA MODEL WITHOUT ASSIMILATION

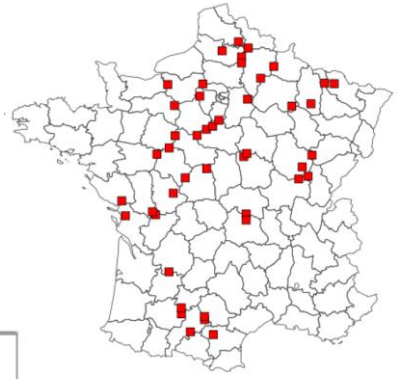




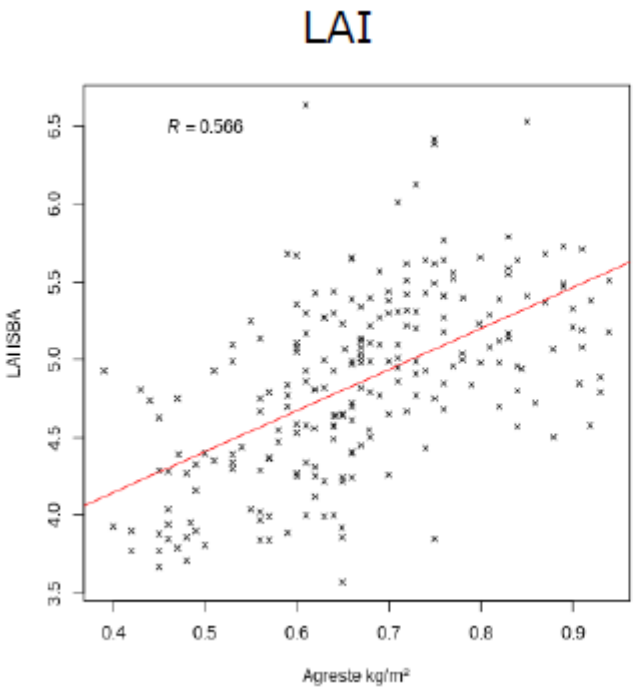
Dewaele et al. PhD 2017

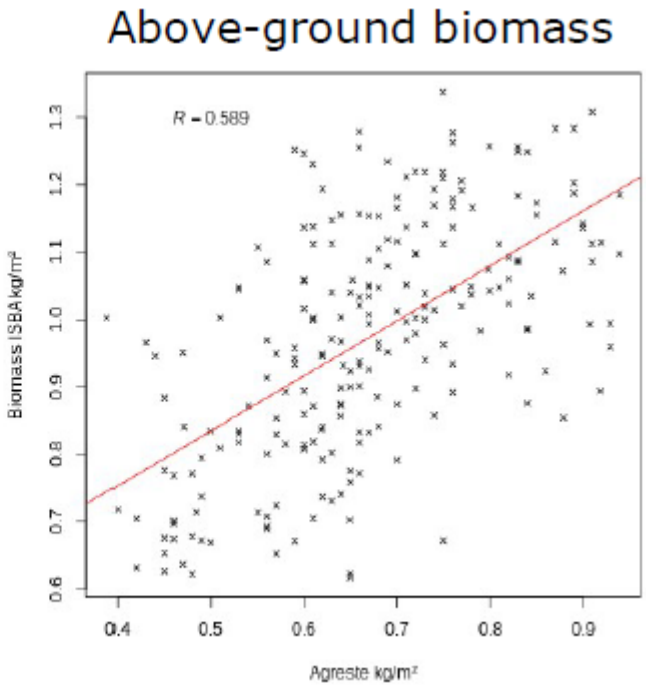
Validation: crop yields

- **Example: wheat yields in France (1999-2013)**



ISBA MODEL WITH ASSIMILATION

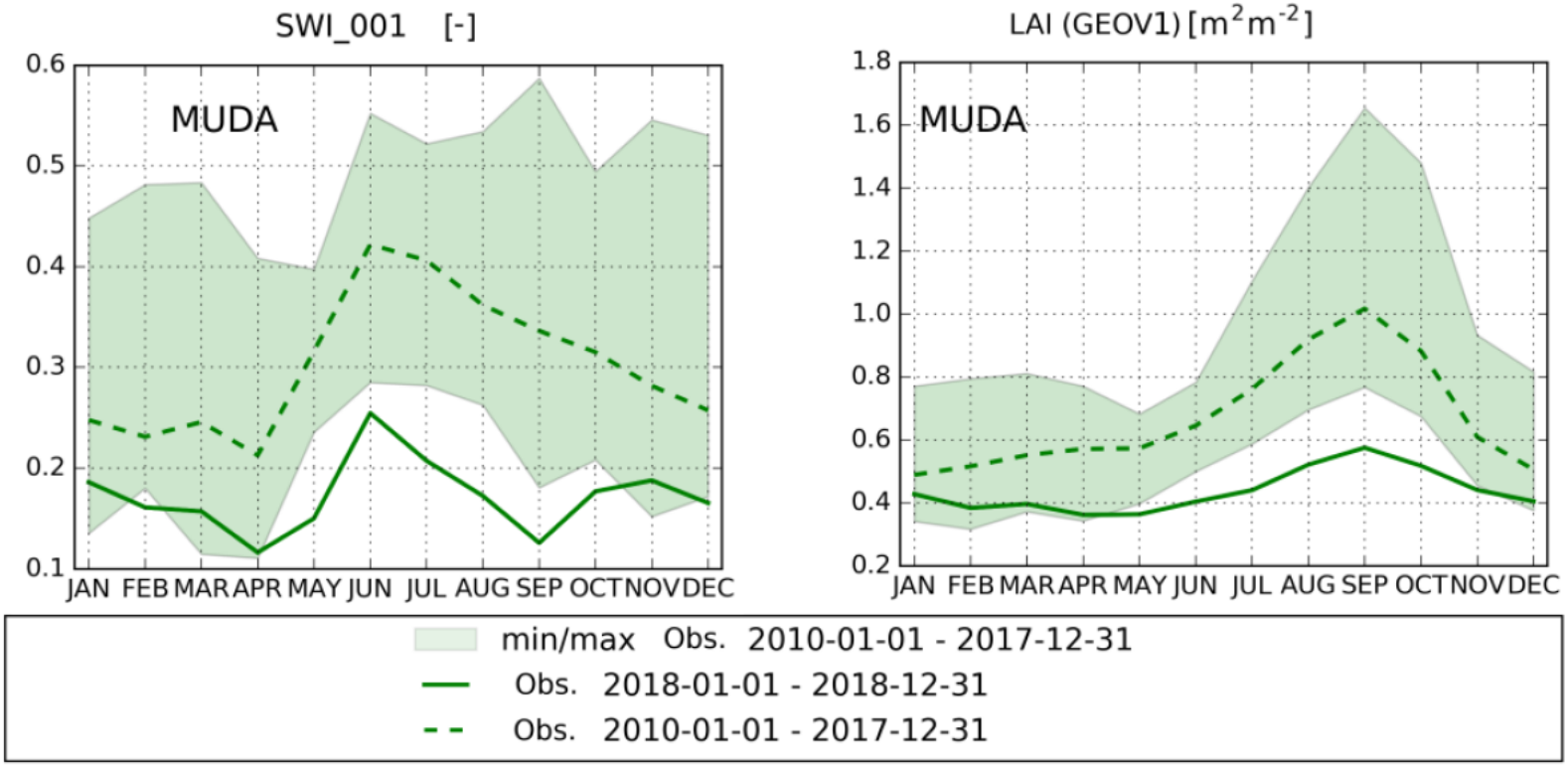




Dewaele et al. PhD 2017

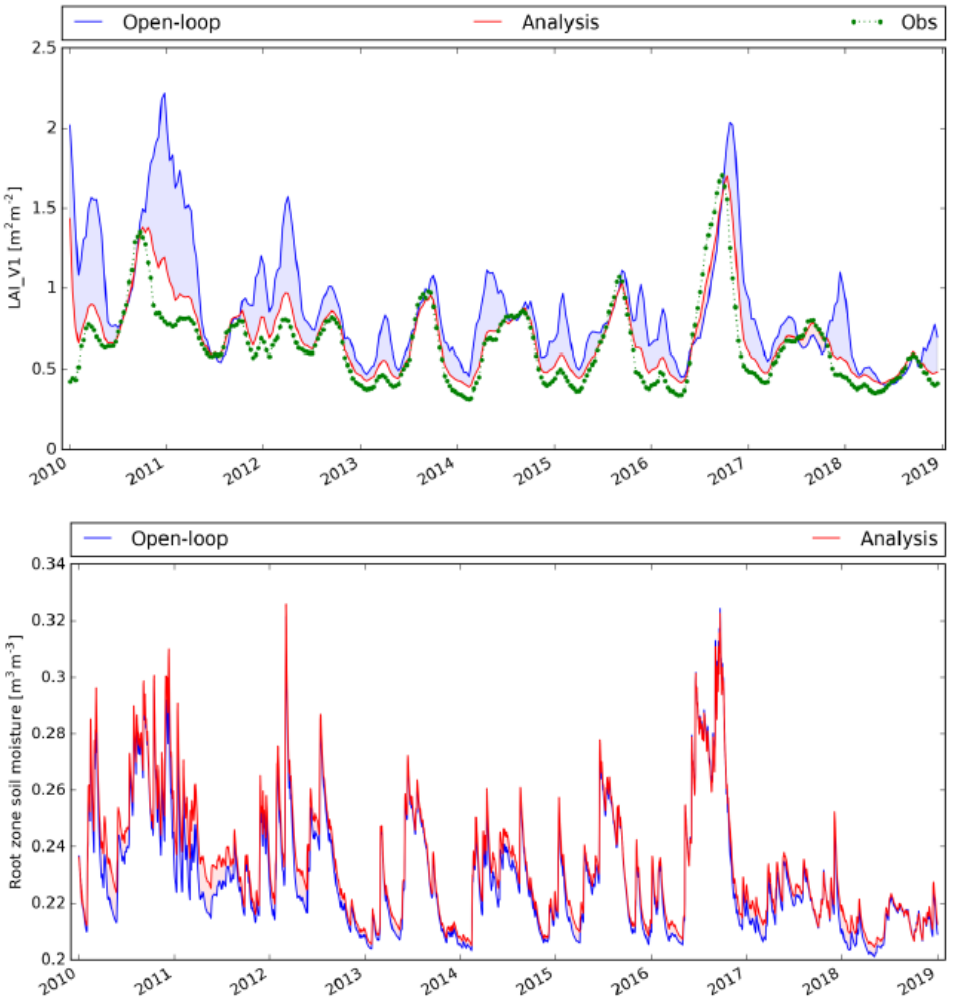
Applications: monitoring severe conditions

- **2018 drought in Australia (Murray-darling basin)**



Applications: monitoring severe conditions

- **2018 drought in Australia (Murray-darling basin)**



LDAS-Monde now

- Global (« LDAS-Monde »): see papers on

https://www.umr-cnrm.fr/spip.php?article1022

- Global atmospheric forcings: ERA5 (25km), HRES (9km)

- Land satellite products assimilated by LDAS-Monde (active monitoring)
  - LAI (Copernicus Global Land Service)
  - SSM (Copernicus Global Land Service)

- Monitoring of many other land variables (passive monitoring)
  - Surface temperature
  - Surface albedo, FAPAR
  - Surface fluxes: evapotranspiration, heat, carbon dioxide
  - Root-zone soil moisture
  - River discharge, inundation plains

- Initialisation of **forecasts** of land variables

LDAS-Monde in the near future

- **Prospects**
  - **High spatial resolution : ~1km on areas of interest**
  - **Observation operators: sigma0 at C-band, surface albedo**
  - **Assimilation of snow cover extent**
  - **Modeling: multiple energy budgets, irrigation**
- **Towards applications**
  - **Reanalyses of land essential climate variables**
  - **Water resource / drought / vegetation monitoring**
  - **Detection of severe conditions over land**