

Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE)

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The Global Energy and Water Cycle Exchanges Project (GEWEX) is an integrated program of research, observations, and science activities that focuses on the **atmospheric, terrestrial, radiative, hydrological, coupled processes, and interactions** that determine the global and regional hydrological cycle, radiation and energy transitions, and their involvement in climate change.

GEWEX Science Questions potentially addressed by LIAISE & HILIAISE:

- 1) **Observations and Predictions of Precipitation**: How can we better understand and predict precipitation variability and changes?
- 2) **Global Water Resource Systems**: How do changes in land surface and hydrology influence past and future changes in water availability and security?
- 3) **Changes in Extremes**: How does a warming world affect climate extremes, esp. droughts, floods, and heat waves, and how do land area processes, in particular, contribute?
- 4) **Water and Energy Cycles and Processes**: How can understanding of the effects and uncertainties of water and energy exchanges in the current and changing climate be improved and conveyed?

Context

- Climate projections from the CMIP5 predict that the Mediterranean region will be a climate change “hot-spot” during 21st century, **BUT** semi-arid regions are hot-spots for biases in model variables
- Mediterranean basin has highly heterogeneous land cover - driven by the limited availability of soil moisture and the nature of precipitation, **BUT land surface models** lack the ability to capture such heterogeneity within semi-arid environments
- Surface flux heterogeneity results not only from atmospheric forcing and land cover, but also from soil moisture gradients arising from strongly contrasting surface runoff processes
- Semi-arid regions where the coupling between soil moisture and precipitation is potentially at its greatest
- Irrigation is also known to significantly impact local planetary boundary layer (PBL) growth, meso scale meteorology, potentially precip...
- Water resources are limited, depend to a certain extent on water natural *water towers*, reservoir functioning

WCRP Grand Challenges



*WCRP engages the international climate research community in a number of Grand Science Challenges through community organized workshops, conferences strategic planning on: **Water for food-baskets of the world***

Motivation :

Understand the interactions between water management and climate variability and change.

Improve our modelling capabilities of human water management.

Regional re-analysis which include the evolution of water usage and land use ... thus reproduce the real water cycle.

Methodology :

Downscaling with convection permitting models.

Re-visit the last 50 years over a region with a large expansion of irrigated crops.

Expected outcome of the GC :

- Progress in land surface modeling with the explicit representation of water management.
- Enhance our knowledge of surface atmosphere interactions in managed environments.
- Build the capability to predict the “real system” at least at the regional scale for weather forecasting as well as climate research.
- Develop our capabilities to predict the water and nutrient fluxes to the oceans.
- Make climate sciences more relevant to hydrological and agronomic sciences in terms of processes and scales considered.

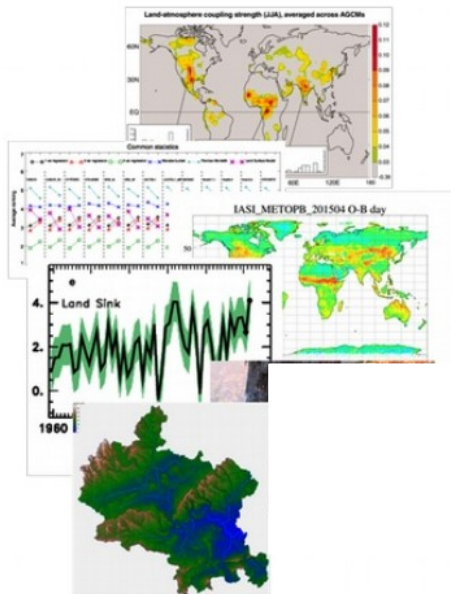
Objectives of HLIAISE :

The overall objective of HLIAISE is to better understand and model the **human imprint on the semi-arid energy and water cycle** over a region which has significant anthropization.

Three components :

Science

Questions



Observational

Capabilities



Community

Experiments



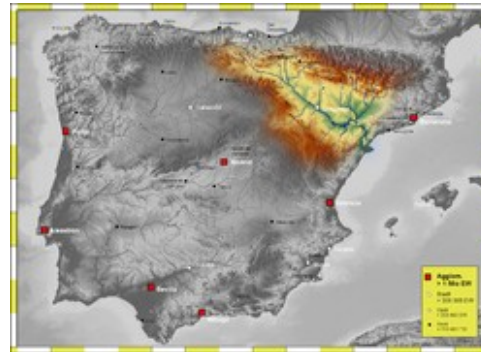
Science Questions

- 1) How does the **anthropization** (LULCC, irrigation...) impact the boundary layer development, mesoscale circulations and potentially precipitation recycling over this region via **feed-backs** with the atmosphere?
- 2) What are the **key natural semi-arid processes** and how does their spatial **heterogeneity** impact the planetary boundary layer growth and structure?
- 3) What is the **sustainability** of ground water and surface reservoirs in the face of expanding agricultural and farming activities, especially in light of projected **future warming and drying** over this region?



Field Campaign

Observational campaign will bring together [ground-based](#) and [airborne](#) measurements with [modeling studies](#) including data [assimilation of remotely sensed data](#)

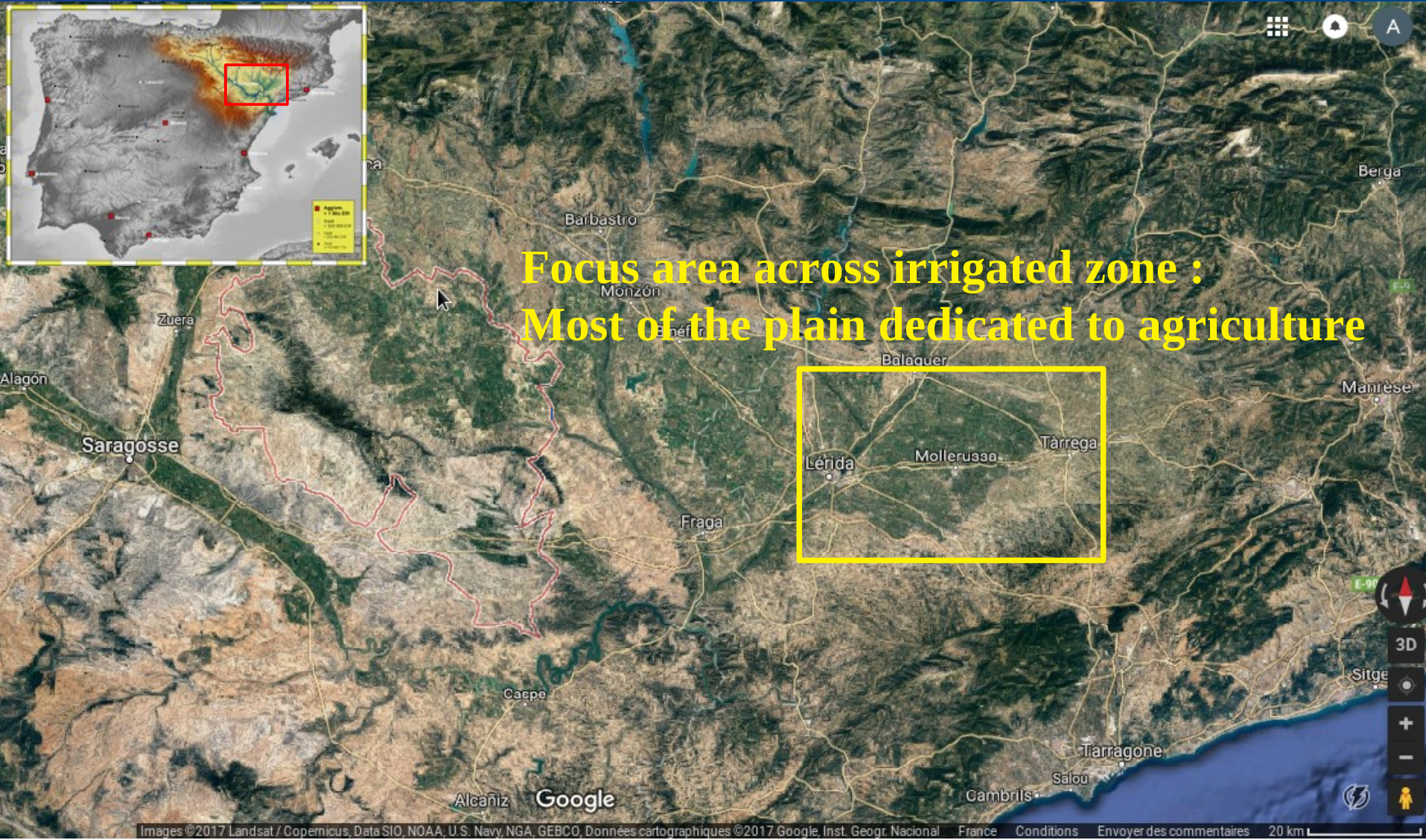


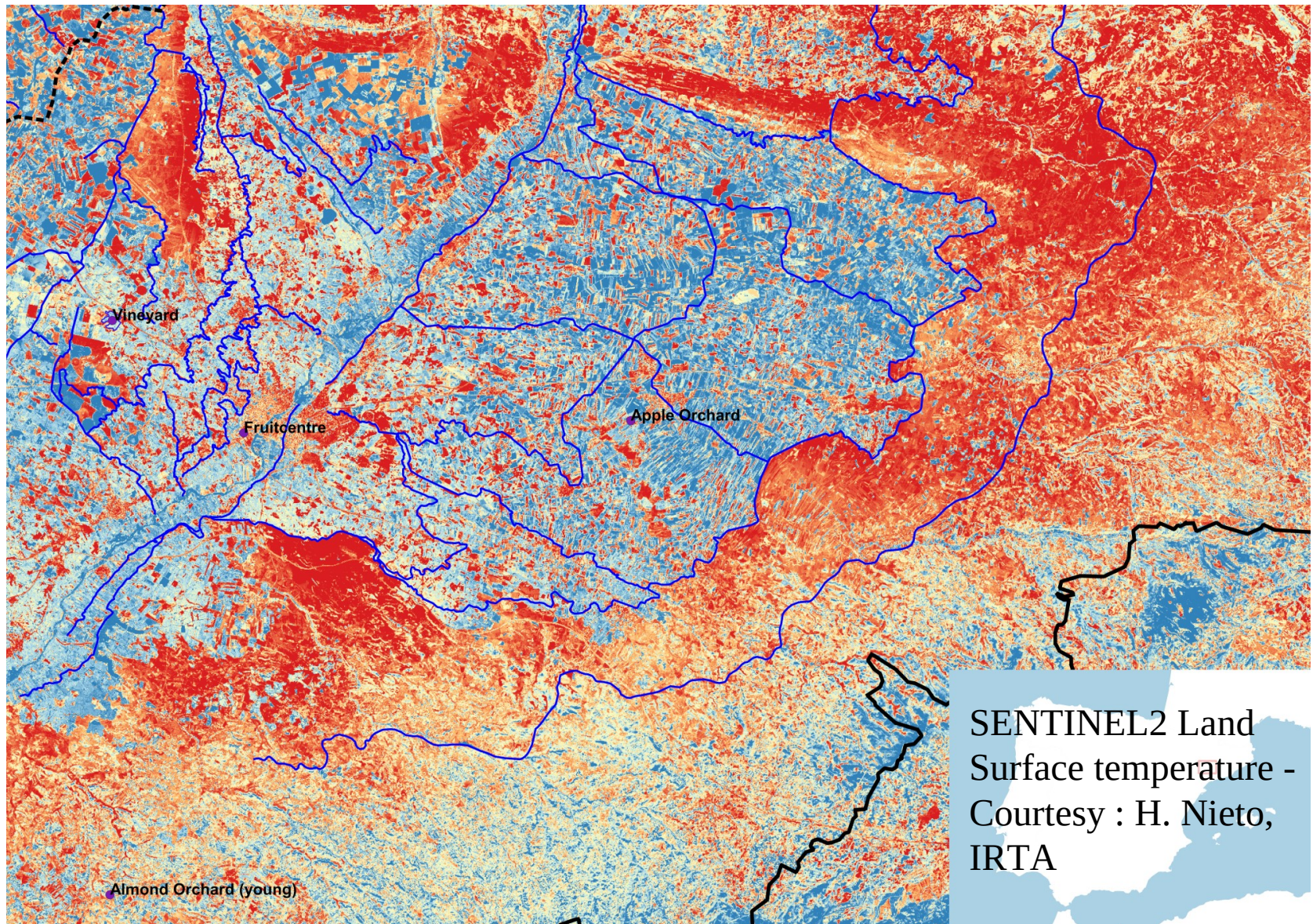
Ebro
basin

Surface-based deployment:

- (i) obtain continuous monitoring of physical processes and their evolution
- (ii) to provide complete and multidisciplinary data-sets for numerical modeling evaluation as well as satellite product validation.

It will be implemented through the enhancement of existing measurements sites from [Spanish research groups](#), the Spanish State Meteorological Agency ([AEMET](#)) and the Meteorological Service of Catalonia ([SMC](#)), the [Hydrographic Confederation of the Ebro](#), and [private companies](#) involved in irrigation monitoring such as Isardsat and Lab-Ferrer... other potential partners (Germany, Morocco...)





Experimental setup

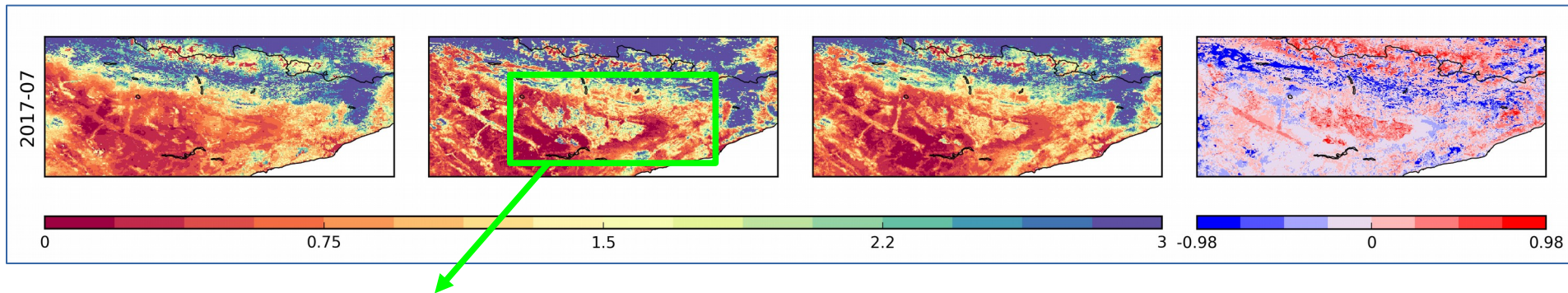
Model	Domaine	Atm. Forcing	DA Method	Assimilated Obs.	Observation Operator	Control Variables	Additional Option
ISBA Multi-layer soil model CO ₂ -responsive version (Interactive veg.)	Adour-Garonne & Ebro basins 2017	IFS downscaled to 1km x 1km	SEKF	LAI (GEOV1-300m)	Second layer of soil (1-4cm) LAI	Layers of soil 2 to 8 (1-100cm) LAI	N/A

Open-loop

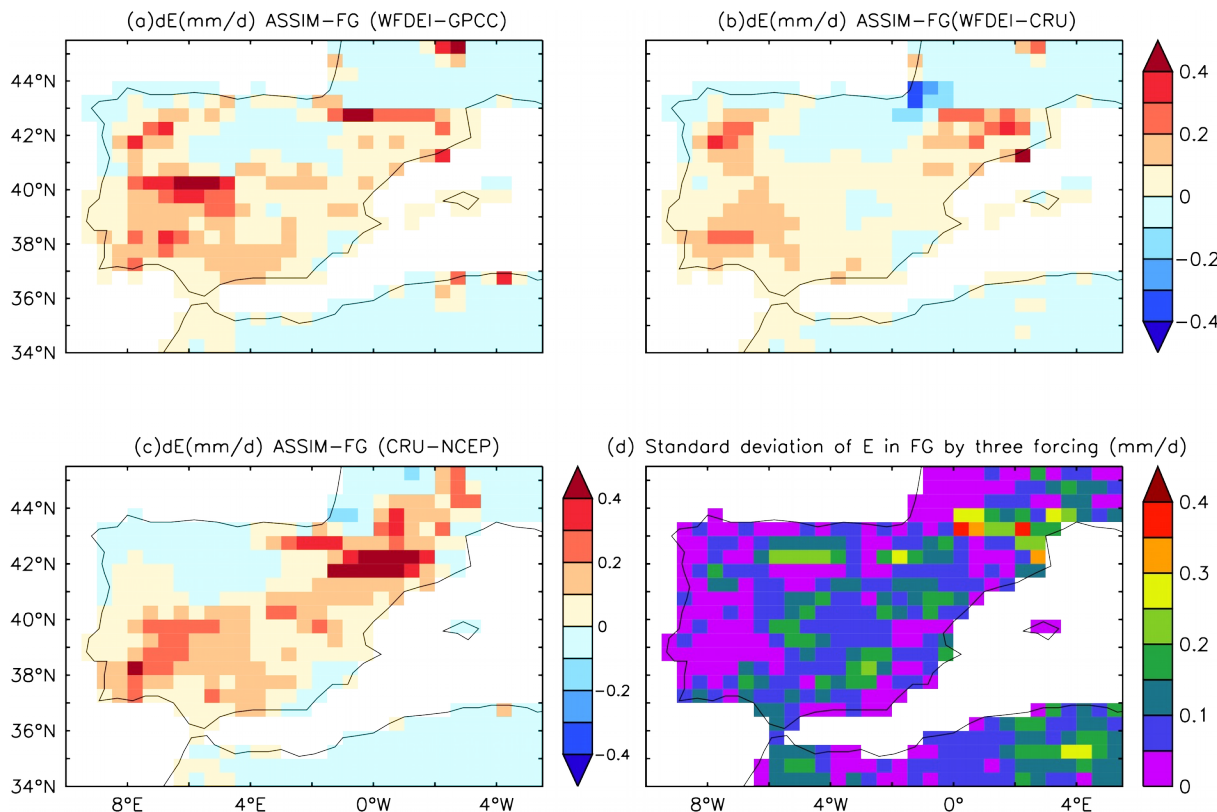
Obs

Analysis

Analysis-Open loop



- LAI Obs. (300m aggregated to 1km highlights areas with high LAI)
- Almost a perfect match with irrigated land presented on the left
- While the open-loop does not reflect these areas (no irrigation in SURFEX, yet [!]), this specific pattern is visible in analysis (i.e. after data assimilation)



- Assimilating observed river discharge allows to correct the water divergence over the continents.
- ORCHIDEE forced by classical forcing data.
- 27 stations from the GRDC database can be used on the peninsula.

The assimilation increases evaporation in areas known for intense agriculture.

The correction in E is larger than the variance of E estimates for all 3 forcing.

F. Wang, et al. 2018

Field Campaign : Last Campaign of HyMeX → Ebro Basin, NE Spain

Measurement strategy :

Lower Atmospheric (3-4 km)

- Take observations within and outside of irrigated zone (UHF wind profilers, radiosounding releases and tethered balloons at 2 locations)...how is PBL conditioned over each of the regions and how does vapor and heat interact with non-irrigated atmosphere
- fluxes from aircraft (V, q, T) at multiple levels to sample convective PBL heterogeneities

Surface

- 6 (or 7) SEB stations (surface flux, soil T and moisture profiles), each over a representative land cover :
 - 1) Rain-fed fruit trees
 - 2) Irrigated crops (alfalfa)
 - 3) Natural grass+bare soil
 - 4) Mixed holm oak/pine forest
 - 5) Irrigated fruit trees
- Lake/reservoir (water stored/used for irrigation)
- Remote sensing products (irrigated surface, LST, superficial soil moisture)
- Aircraft measured LST and superficial soil moisture...how well do these measurements compare to satellite derived products ?

Field Campaign : Last Campaign of HyMeX → Ebro Basin, NE Spain

IOP : April-October, 2020 → surface flux stations, sfc satellite products, operational NWP (AROME from Météo-France and WRF from SMC), lysemeters, river discharge...

SOP (summer/mid-July 2020...~15d)

SAFIRE : ATR42

- 5 flights (days)...max 5h
- 4-5 flight levels (up to 4 km), ~30km transect
- Turbulent fluxes of heat, moisture, momentum...
- Onboard instruments : GLORI (surface soil moisture), LST

Surface Energy Budget (SEB) sites

- Turbulent fluxes of heat, moisture, conduction, radiation, LST (3 from CNRM, 1 each from UKMO, UIB, IRTA, SCM)
- Soil moisture and T at 4 (5) levels, Soil and vegetation properties
- 2 lysemeters
- 2 SEB sites with 50m towers (UKMO & Météo-France)

Lower Atmosphere

- 2 Tethered balloons : 10d (CNRM & UIB)
- Radiosoundings : 2 sites, up to 3-4 km, (6/d) for part of SOP (10/15d)
- 2 Wind profilers (UHF)
- Meteo obs and radar from SMC

Results/Outcome : Scientific, Social, Economic impact

- A **comprehensive database** : surface-based and aircraft measurements of surface and hydrological fluxes and states, and properties of the PBL - **MISTRALS/HyMeX database**
- Better representation of **semi-arid surface processes** : LST, Evap (soil & veg), sfc hydrology... **hydrological monitoring, weather forecasting and climate studies**

Improved understanding and representation of **anthropogenic processes** in LSMs used for **hydrological monitoring, weather forecasting and climate studies**

- Improved anthropization - for **water resource** impact studies under **future climate change**-communicated to water management services within the Ebro basin.

GEWEX Community Experiments

A true GEWEX cross-cutting campaign



- Benchmarking: PLUMBER 2
- Land/atmos coupling: DICE 2
- MDF: Soil moisture assimilation?



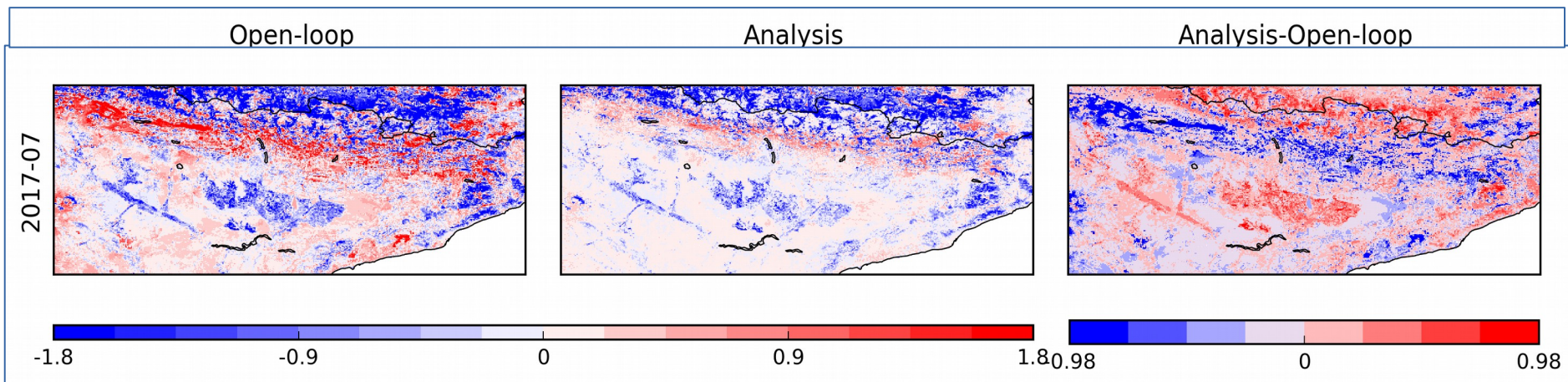
- Regional hydrological study of basin:
 - River discharge evaluation
 - Human interactions
 - Reservoirs
 - Irrigation
 - Extractions



- Evaluation of LST from various satellites

Extra.....

Maps of biases: LAI open-loop vs. Obs., LAI analysis vs. Obs., map of differences



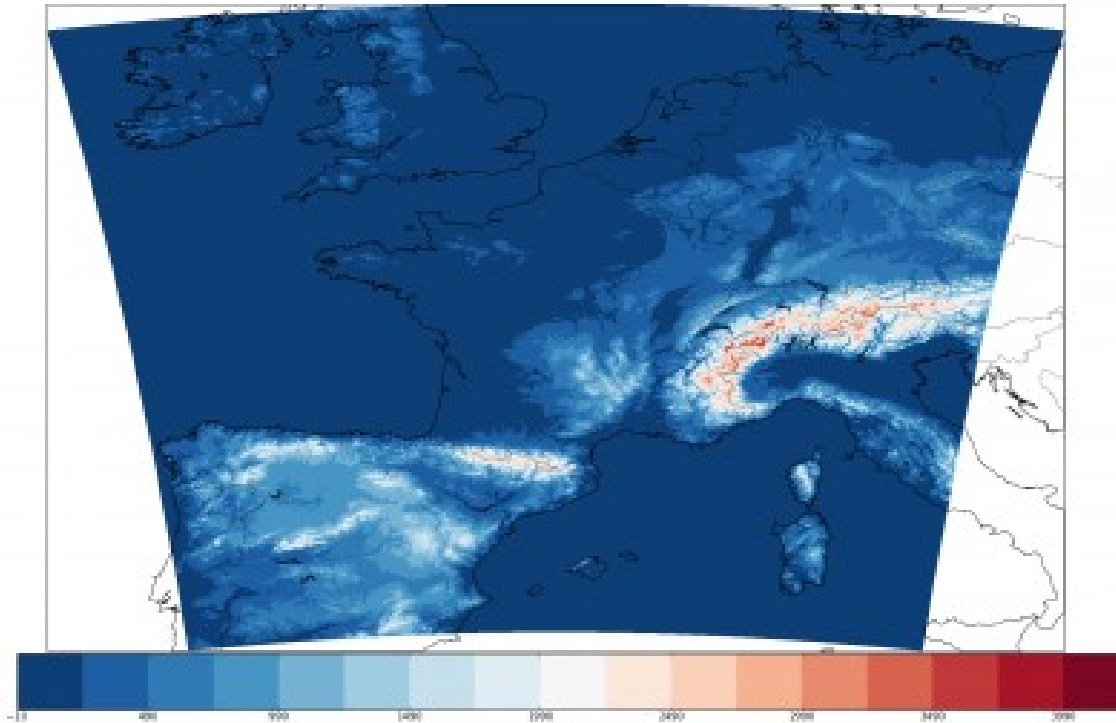
- Analysis leads to a bias reduction, almost everywhere, including in the irrigated areas
- Analysis artificially integrates a missing process
- Modelling of irrigation is ongoing within SURFEX

Objectives

The overall objective of HILIAISE is to better understand and model the **human imprint on the semi-arid energy and water cycle** over a region which has significant anthropization.

To meet this, need to understand the **limitations of models to represent** all aspects of the terrestrial water cycle in a semi-arid environment on the Iberian peninsula ;

- i) The influence of **land/atmosphere interactions** on local initiation of precipitation and the PBL
- ii) the influence of **heterogeneity** in land cover on surface fluxes of momentum, heat, moisture and carbon
- iii) the relationship between **soil moisture and both bare-soil evaporation and transpiration** under semi-arid conditions
- iv) the interactions between **soil moisture and groundwater** and its influence on other aspects of the water cycle
- v) **runoff generation** and its impact on stream flow within hydrological basins
- vi) understanding the **impact of water management and human influences** in the water cycle



AROME operational domain (1.3 km res.)
Fcsts : 8x per day