HUMID

Using remote sensing data and land-surface models to understand and monitor drought in Iberia within the HUMID project

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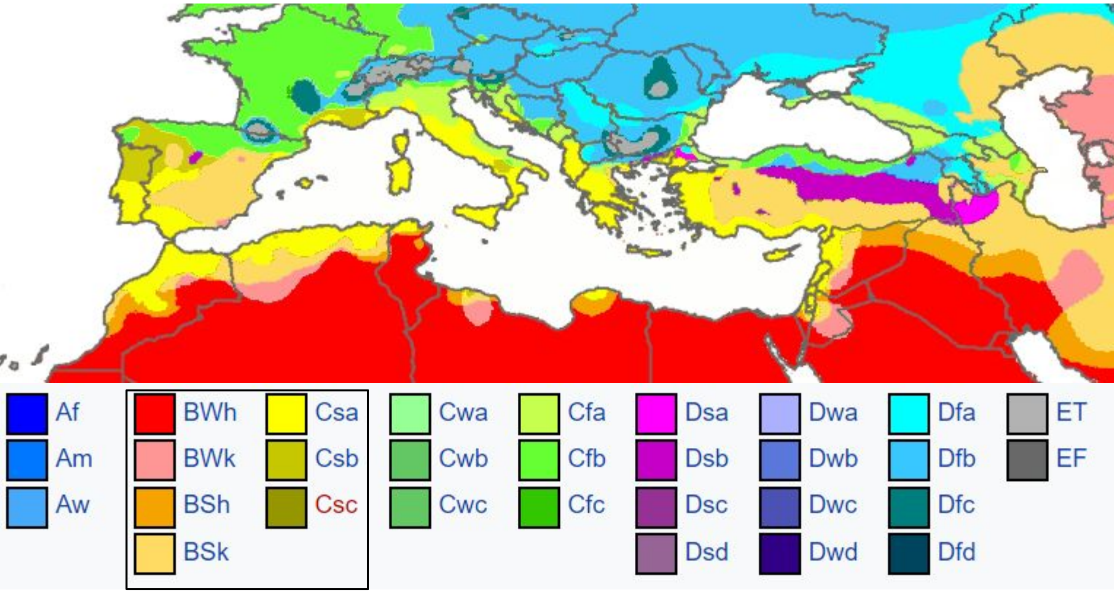
ESA MED 2018, ESRIN, Ispra, Italy.

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES

The Mediterranean

Köppen Climate Classifcation



Two landscapes of the Ebro basin.

Aridity and **semi-aridity** in the **Mediterranean**

- BWh, BWk: deserts.
- BSh, BSk: semi-arid climates.
- CSa, CSb, Csc: semi-arid during the dry season.

The Mediterranean is variable in time and space.

- High contrast between wet areas (relief, North, etc.) and dry areas.
- Mesoscale systems.
- High interannual variability.
- Prone to extremes.

Climate change will expand semi-arid areas and seasons.

The role of soil moisture in semi-arid environments

Semi-arid environments are soil-moisture limited (at least during some seasons).

Land-atmosphere coupling

- Soil moisture heavily influences fluxes to the atmosphere.
- Complex interaction with vegetation.
  - Soil moisture availability influences plant development.
  - Plant development influences soil moisture depletion.
- It has an impact on albedo.
- …

Complex dynamics: Very variable transition from wet to dry and reverse (spring and autumn).

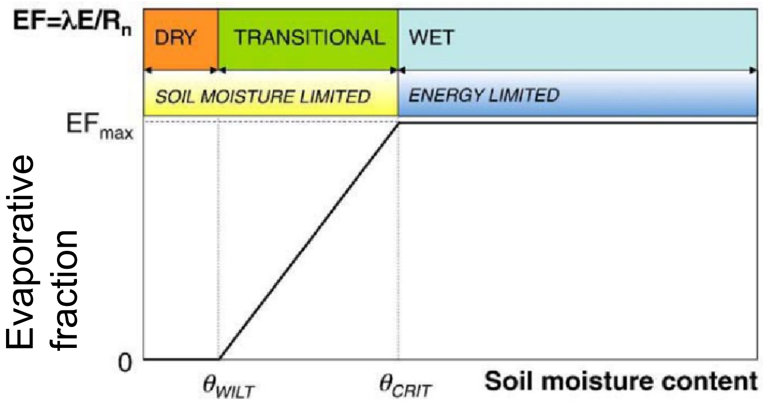


Fig. 5. Definition of soil moisture regimes and corresponding evapotranspiration regimes according to framework described in Section 4.1. *EF* denotes the evaporative fraction, and EF_{max} its maximal value.

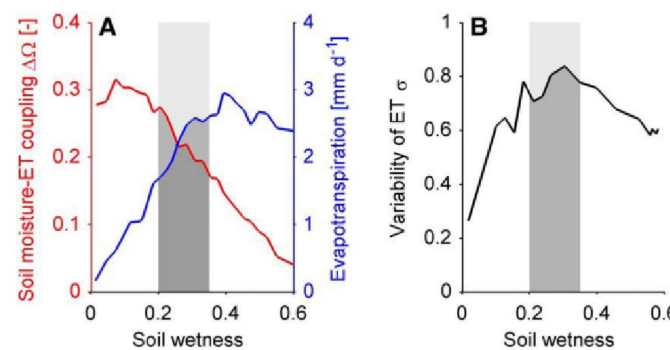


Fig. 6. Dependence on soil wetness of coupling of soil moisture and evapotranspiration estimated with $\Delta\Omega$ diagnostic (left) and standard deviation of evapotranspiration (right) in GLACE simulations (computed from 224 aggregated 6-day totals, corresponding to 16 ensemble members times 14 intervals over analysed JJA period). See Appendix B.1 and Eq. (18) for more details on the $\Delta\Omega$ diagnostic. [Figures adapted from Koster et al., 2004a (left) and Guo et al., 2006a (right)].

Seneviratne et al. 2010.

Soil moisture is critical in order to study the continental water cycle in semi-arid regions.

The Mediterranean

Soil moisture and hydrology

- Impacts on runoff generation
  - Dune vs Horton runoff.
  - Formation of crusts on very dry soils.
  - The presence, or not, of vegetation, which depends on soil moisture, also influences runoff.
- Interaction with groundwater
  - Bi-directional exchanges of water between the vadoze zone and underground water.
  - Mediterranean vegetation depends on this during the dry season! It influences ET.
  - The role of underground water is crucial in the Mediterranean, but it is poorly simulated, if it is simulated.

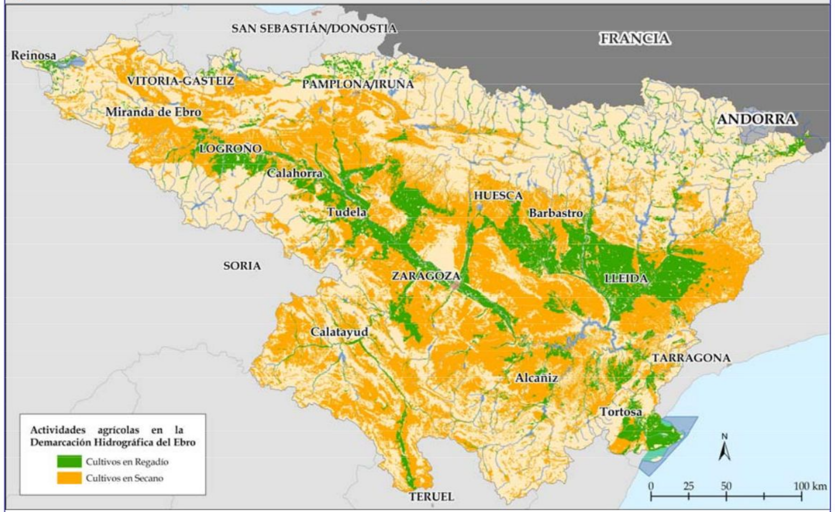
Water management

- Runoff is often generated in the relief (Pyrenees, Atlas, etc.).
- Agriculture happens in the plains (high ETP)..

Complex water management systems!

- Impacts in the atmosphere.
- Impacts downstream.
- How does all this affect drought?

Figura 51. Tipos de cultivos en la Demarcación Hidrográfica del Ebro



Fuente: CORINE

The HUMID project

Drought diagnosis is a fundamental issue for hydrological management in Spain, where recurrent water scarcity periods are the norm.

Managers have **drought monitoring systems** tailored to their needs (i.e. dam levels in Spain).

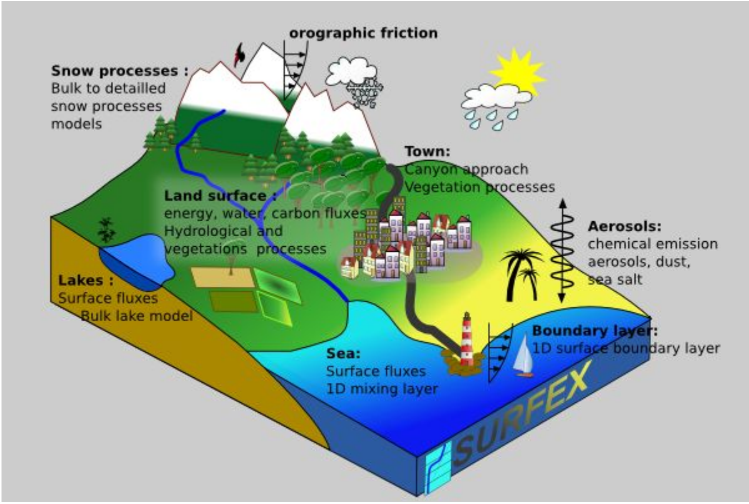
A **wider view on drought** could benefit other kinds of users (forestry, rainfed agriculture, etc.)

In the Mediterranean, the **dynamic** aspect of drought is crucial (propagation through the system, soil moisture state, etc.).

Humans are part of the system, we should take this into account.

HUMID: *Can we better understand the processes that lead to different types of drought, their connections and their dynamics?*

Can we provide useful information to stakeholders using LSMs and remote sensing data?



Main objectives of the HUMID project

1. **Understanding Iberian drought processes** by means of a **systemic and dynamic** perspective (including drought propagation).

2. **Understand the strengths and weaknesses of LSMs for drought studies.**

3. **Improve SASER** (LSM based model) with the aim to simulate anthropic effects.

4. **Better understand the utility of satellite data for drought studies**, with emphasis on soil moisture.

5. **Interact with stakeholders** in order to learn their needs, tailor our work to their needs and inform them about last generation model and satellite products.

Scientific and technical aspects.

Applied component

Financed by: Spanish National plan (2017), Spanish Ministry of Science, Universities and Innovation. **Budget**: 111.078,00 EUR. **Length**: 3 years (2018 - 2020).

Kick-Off meeting was held in July 2018.

Drought in the Mediterranean

The ratio of water that is managed in the Mediterranean is high.

When drought hits, it stresses systems that are often close to stress in normal conditions.

Climate change:

- Increased **ETP**!
- Decreased **mean precipitation** is expected.
- Decreased number of **precipitation days** and **increased intense precipitation**.

HUMID wants to contribute to the discussion of drought monitoring in a Mediterranean context.

How do we measure drought in the Mediterranean?

- Precipitation alone is not enough (SPI).
- Root zone soil moisture seems very important (SSMI).
- Evapotranspiration deficit seems interesting in semi-arid areas (SEDI, SMDI).
- Dam levels:
- Underground water.
  - Important even if not used for irrigation.

This is an ongoing discussion.

There is no single good definition of drought!

Stakeholders must participate in the process.

Simulation of soil moisture drought in Spain

Offline LSM simulations are performed in Spain.

Forcing datasets

- Local products
  - SAFRAN (5 km).
  - SAFRAN (30 km)
- Global products
  - eartH2Observe (25 km)
  - eartH2Observe + MSWEP (25 km).

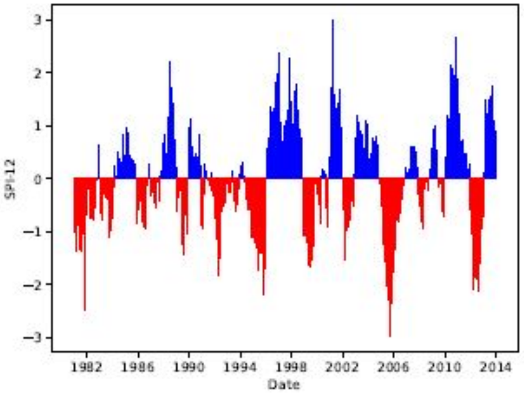
Land-Surface models

- SURFEX (5 km)
  - Force-restore (3L) and diffusion (DIF)
- LEAFHYDRO (2.5) km
  - Simulates underground water processes.

Quintana-Seguí et al. (2019), “The utility of land-surface model simulations to provide drought information in a water management context using global and local forcing datasets.”, WaRM (accepted)

Drought analysis

Drought is studied by means of standardized indices of **precipitation** (SPI-n) and **soil moisture** (SSMI-1).



Drought propagation to soil moisture (memory)

We find the accumulation *n* that maximizes the correlation between SPI-n and SSMI-1 or SSI-1.

Comparison of simulated soil moisture drought

The table shows the RMSD and correlation between the **SSMI** calculated by all forcing-model combinations.

Root zone

RMSD	E2O-DIF	E2O-LHD	MSW-DIF	MSW-LHD	SLR-DIF	SFR-DIF	SFR-LHD	SFR-3L
E2O-DIF		0,54	0,49	0,66	0,57	0,61	0,73	0,68
E2O-LHD			0,67	0,52	0,71	0,74	0,61	0,7
MSW-DIF				0,54	0,42	0,48	0,64	0,58
MSW-LHD					0,61	0,65	0,47	0,6
SLR-DIF						0,28	0,56	0,47
SFR-DIF							0,55	0,42
SFR-LHD								0,46
SFR-3L								

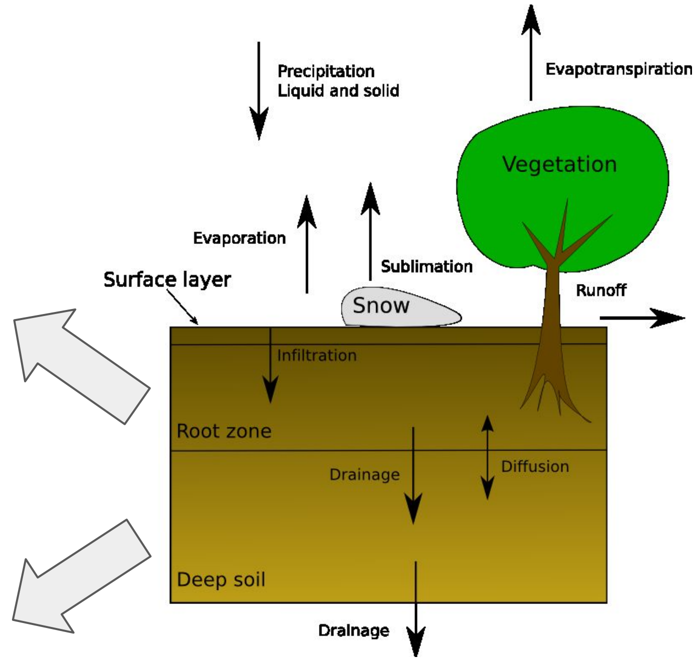
r	E2O-DIF	E2O-LHD	MSW-DIF	MSW-LHD	SLR-DIF	SFR-DIF	SFR-LHD	SFR-3L
E2O-DIF		0,85	0,88	0,77	0,83	0,8	0,72	0,76
E2O-LHD			0,76	0,86	0,73	0,71	0,8	0,74
MSW-DIF				0,85	0,91	0,88	0,78	0,82
MSW-LHD					0,8	0,78	0,88	0,81
SLR-DIF						0,96	0,83	0,88
SFR-DIF							0,84	0,9
SFR-LHD								0,89
SFR-3L								

Deep soil

RMSD	E2O-DIF	E2O-LHD	MSW-DIF	MSW-LHD	SLR-DIF	SFR-DIF	SFR-LHD	SFR-3L
E2O-DIF		0,69	0,54	0,83	0,65	0,7	0,89	0,96
E2O-LHD			0,75	0,53	0,76	0,79	0,63	0,73
MSW-DIF				0,69	0,45	0,53	0,78	0,87
MSW-LHD					0,71	0,73	0,48	0,63
SLR-DIF						0,31	0,68	0,77
SFR-DIF							0,65	0,74
SFR-LHD								0,5
SFR-3L								

r	E2O-DIF	E2O-LHD	MSW-DIF	MSW-LHD	SLR-DIF	SFR-DIF	SFR-LHD	SFR-3L
E2O-DIF		0,75	0,85	0,63	0,78	0,74	0,58	0,51
E2O-LHD			0,7	0,85	0,69	0,67	0,79	0,72
MSW-DIF				0,74	0,89	0,85	0,68	0,6
MSW-LHD					0,74	0,72	0,88	0,79
SLR-DIF						0,95	0,76	0,68
SFR-DIF							0,78	0,71
SFR-LHD								0,87
SFR-3L								

Green is better performance than red.



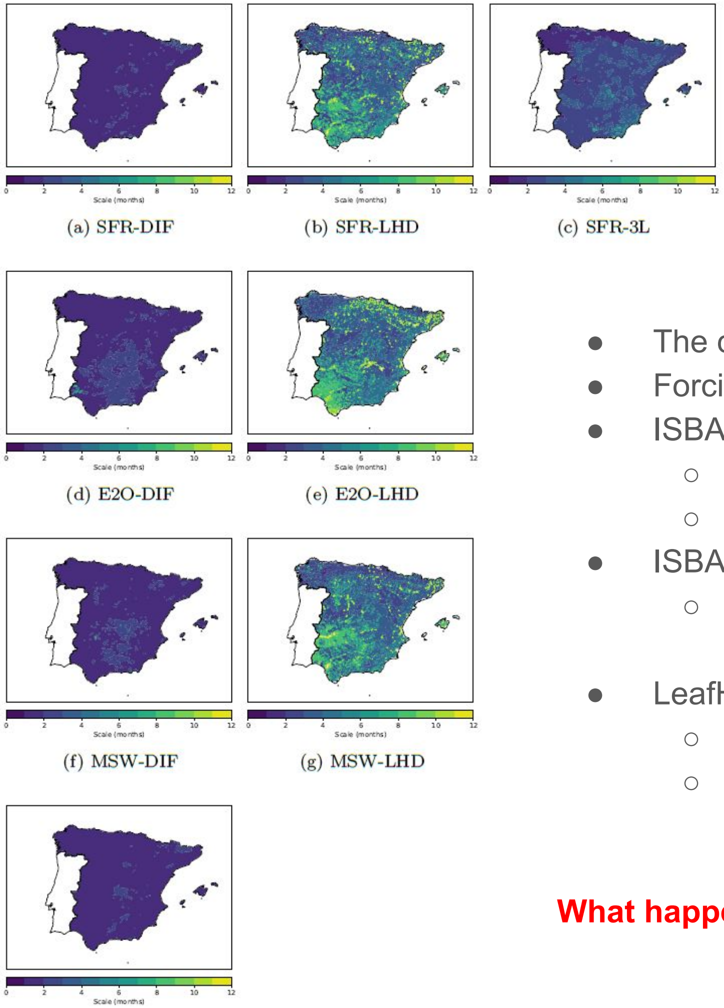
Truth is unknown (no observations) → All simulations are compared between them..

- <u>Large uncertainty in drought status.</u>
- Larger differences for deeper soil than for root zone, as expected.
- In root zone, SSMI RMSD is almost always larger than 0.5 (half std).
  - Drought category could easily change.
- Model structure has large impact on SSMI.

Quintana-Seguí et al. WaRM (accepted 2018)

Simulation of root zone soil moisture memory

Scale n_x which maximizes the correlation between SPI-n and SSMI.



(a) SFR-DIF (b) SFR-LHD (c) SFR-3L (d) E2O-DIF (e) E2O-LHD (f) MSW-DIF (g) MSW-LHD (h) SLR-DIF

- Propagation to **root zone** soil moisture..
- Truth is unknown (no observations).
- All forcing-model combinations are presented.

- The dynamics are determined by the **model structure**.
- Forcing can modify n_x by one month.
- ISBA-DIF
  - Maps are very homogenous.
  - Soil moisture is very reactive to precipitation (1-4 months).
- ISBA-3L
  - Similar to DIF, but less reactive and with different spatial patterns.
- LeafHydro (LHD).
  - It simulates underground water processes.
  - Underground water adds memory to the system. n_x up to 12 months!!

What happens in the real system?

Remote sensing and LSMs

- LSMs do not agree in the soil moisture drought status and soil moisture drought memory.
- Observations are scarce.

Remote sensing to the rescue!

L-band soil moisture remote sensing

- Good spatial coverage.
- Low resolution (30-40 km).
- Good temporal coverage (2-3 days).
- Surface soil moisture only (0-5 cm).

Land-Surface models to the rescue!

Using LSMs and Remote Sensing together.

1. Comparison (Escorihuela and Quintana-Seguí 2016).
2. Hydrological model calibration using RS data (López López et al., 2017).
3. Empirical RS methods can be calibrated using models, when in-situ data is not available.
4. Data assimilation within LDAS (LDAS-Monde, NLDAS, etc.).

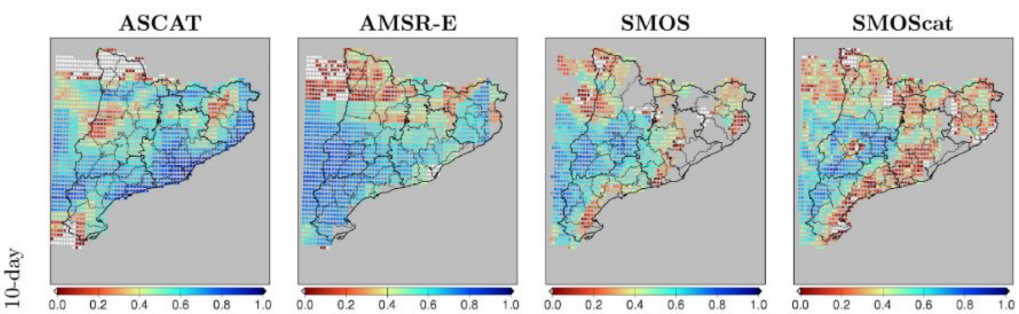


Fig. 4. Correlations of ASCAT, AMSR-E, SMOS and SMOScat with ISBA1 using ZV without any smoothing (first row) and using a 10-day moving average window (second row).

Temporal correlation of normalized soil moisture (Escorihuela and Quintana-seguí et al 2016).

High resolution soil moisture

L-band data is very coarse.

But we can increase its resolution using other remote sensing products.

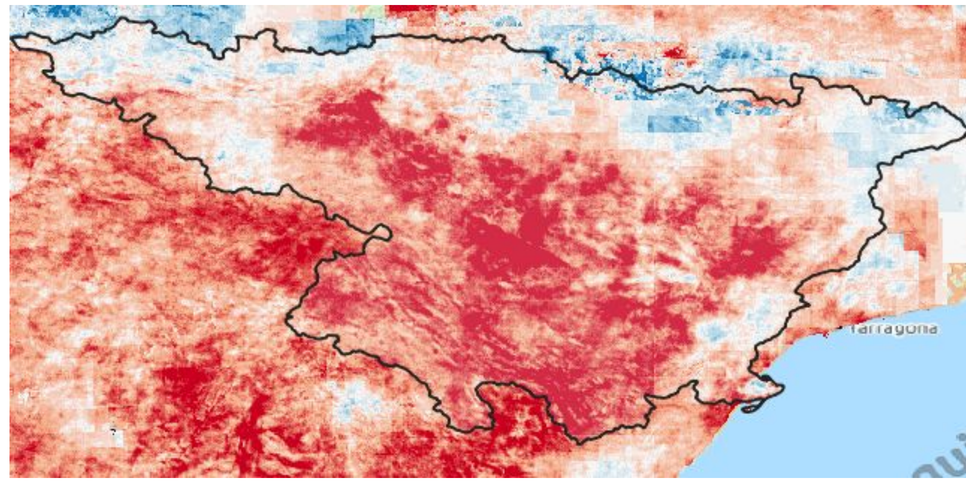
- We can go to 1-km scale resolutions.
- Typical resolution LSMs.
- Minimum resolution for drought and water management.

For example, DISPATCH uses MODIS LST and NDVI.

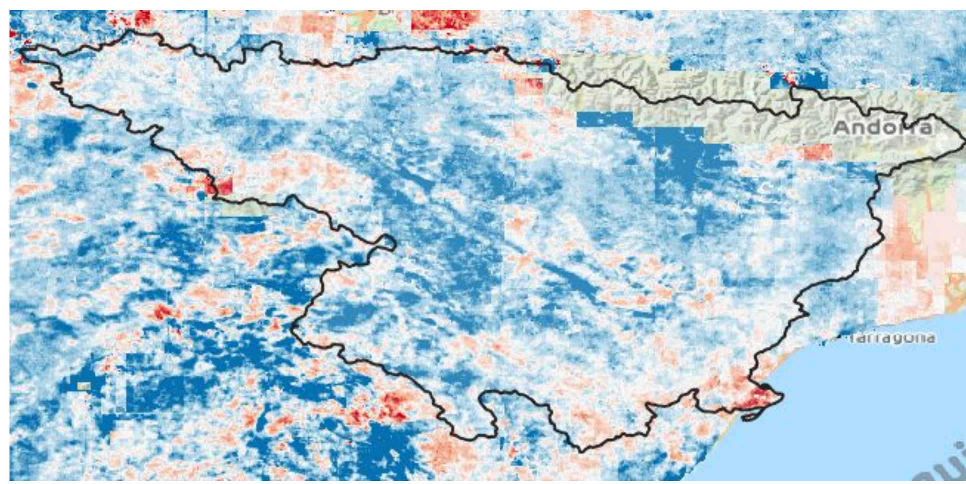
- Downscaled SSM produced by **isardSAT** using DISPATCH.
- Already 10 years of data! :-)

These products are very useful for drought monitoring.

SSM anomaly (November 2017)



SSM anomaly (April 2018)



Humans are part of the continental water cycle

Irrigation, dams, canals, groundwater pumping ...

- Increased evapotranspiration
- Decreased streamflow and modified regime.
- Human activities are difficult to model.
- **Remote sensing sees the real water cycle.**
- Drought, human induced drought, water scarcity, ...

We are currently working on:

1. The introduction of dams in our model (in collaboration with Luis Garrote (UPM) and Florence Habets (CNRS).
2. The quantification of irrigation (J. Dari PhD thesis, in collaboration with IRPI-CNR and U. Perugia).

A. F. Van Loon et al.: Drought in a human-modified world

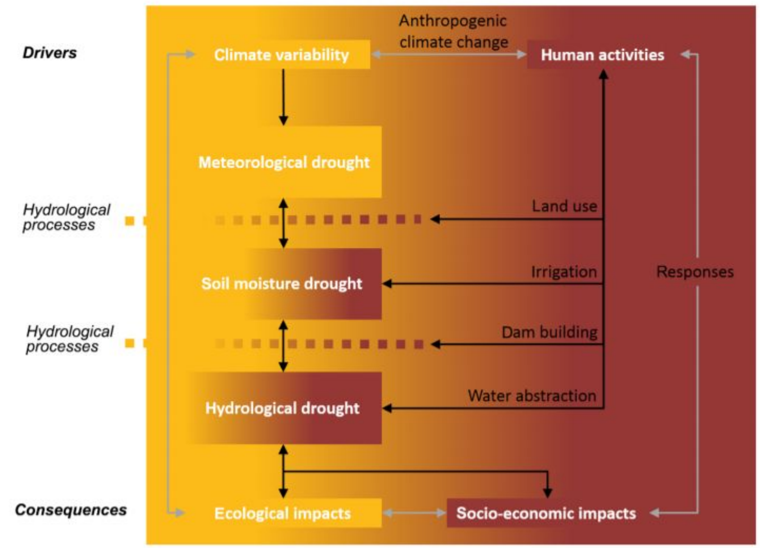
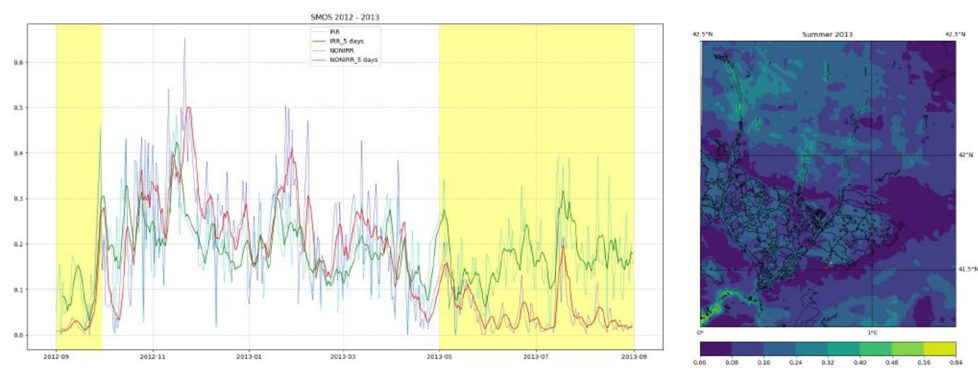


Figure 2. Drought propagation including natural and human drivers and feedbacks; black arrows indicate direct influences and grey arrows indicate feedbacks (modified from Van Loon et al., 2016).



Dispatch downscaled SMOS at two nearby sites (isardSAT data), one irrigated, the other rainfed.

Beyond soil moisture

Soil moisture is very important, but remote sensing can provide other very useful datasets.

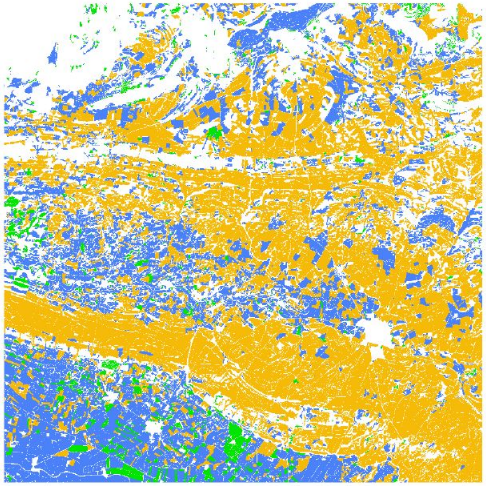
- Total evaporation and its components.
- Vegetation (LAI, NDVI, etc.)
- Water levels.
- Irrigation mapping.
- ...

Qi Gao (PhD isardSAT, CESBIO and OE-URL) has worked on

1. Soil moisture mapping with Sentinel 1, 2.
2. Irrigation mapping with Sentinel Sentinel 1.
3. Dam level altimetry (Sentinel 3) applied to hydrology.

These data can be used to calibrate, improve or assimilate in models, or can be used together with model data, such as in the European Drought Observatory.

Irrigation mapping in Urgell (Catalonia)



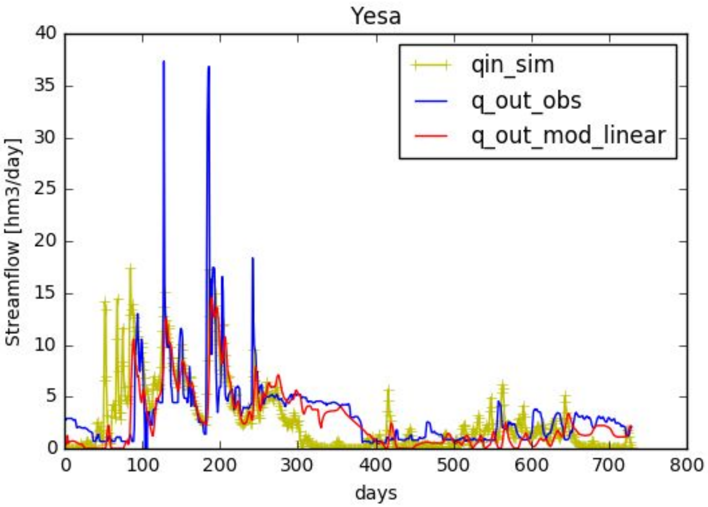
- Nonirrigated fields
- Irrigated trees
- Irrigated crops

The validation is done with the database from SIGPAC over the whole study area (26,434 fields).

Overall accuracy = 81,08%
nonirrigated accuracy = 83,27%
irrigated trees accuracy = 73,49%
irrigated crops accuracy = 77,53%

Good maps of irrigated areas (not areas equipped for irrigation) are important for hydrological modeling.

Dam altimetry and dam simulation



Altimetry can be used to deduce dam levels, which can force a dam model.

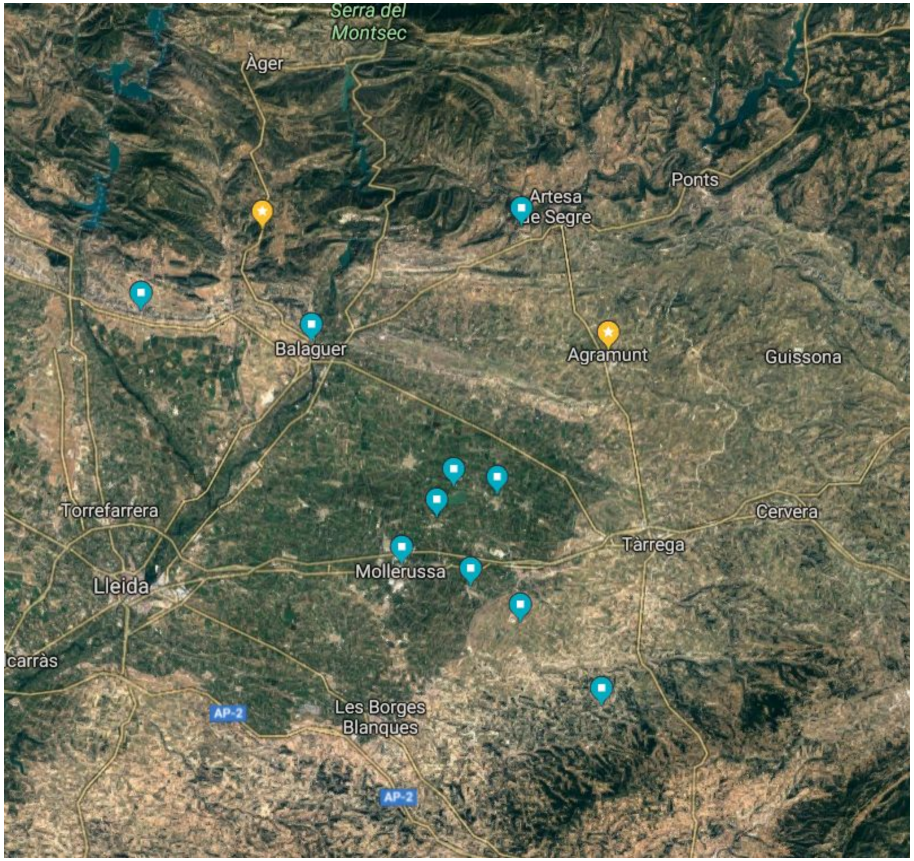
The LIAISE campaign

HUMID is a contributor to the LIAISE campaign.

LIAISE wil study:

- Role of land-surface heterogeneity on surface fluxes and land-atmosphere coupling.
- Impact of irrigation in a semi-arid area.
- LSM capacity to simulate dry-down events.
- Impacts on atmosphere.
- Impacts on hydrology and drought.

This is also an opportunity to test remote sensing based products of soil moisture, evapotranspiration, irrigation mapping, irrigation estimation, etc.



LIAISE study area (Google Maps).

Conclusions

In the Mediterranean:

- High variability of the continental water cycle, which makes management difficult.
- Uneven spatial distribution of water resources and water consumption, which leads to large infraestructures (Spain, Morocco, etc.).
- Limited water resources, which lead to a high ratio of management of the available resource.
- Drought is thus a hazard with high impacts.
- Drought monitoring and alert systems need to improve.
- Remote sensing and land-surface modeling, together, can contribute to improve drought monitoring.

Land-Surface models

- Physically simulate the whole system.
- Provide non observed variables.
- Lack human processes.

Remote sensing

- Sense the real water cycle.
- But only has access to part of the system.

There are many ways to put them to work together.

HUMID is a young project:

- Improve drought monitoring in Iberia.
- Improve our capacity to take human processes into account.

LIAISE is a great opportunity to gather data to improve models and remote sensing products.

HUMID

Thank You!

You may contact me at pquintana@obsebre.es

The HUMID project

- **H**ydrological **U**nderstanding and **M**odelling of **I**berian **D**rought.
- **Financed by:** Spanish National plan (2017), Spanish Ministry of Science, Universities and Innovation..
- **Budget**: 111.078,00 EUR.
- **Length**: 3 years (2018 - 2020).

Scientific team

- Pere Quintana Seguí (OE) - PI
- Luis Garrote (UPM)

Collaborators

- Barella Ortiz, Anaïs (OE)
- Boone, Aaron (CNRS)
- Escorihuela, María José (isardSAT)
- Gao, Qi (isardSAT)
- Habets, Florence (CNRS)
- Polcher, Jan (CNRS)
- Solé, Germán (OE)
- Tramblay, Yves (IRD)
- Werner, Micha (UNESCO-IHE)

Contracts

- 1.5 years of post-doc.
- 1 PhD thesis.

Drought quantification

Negative anomaly of the relevant quantity over a long time period.

Meteorological drought

- Lower P
- Higher ETP

Agronomical / SM drought

- Lower SM
- Water stressed vegetation.

Hydrological drought

- Lower flows.
- Lower dam levels.
- Lower piezometric levels.

All these drought types are not independent.

- **Do we understand well their relationships?**
- **Do we study them as a whole?**

How do we define what "low" means

- Variability of the variable.
    - Is it really a drought when in Scotland it rains 50% of the mean on a given trimester?
- Depending on its (sectorial) impacts

What is the relevant time period?

- A given month or season?
- The last *n* months?

How do we monitor the situation?

- In-situ measurements (i.e. dam levels).
- Model (reanalysis)
- Remote sensing (SM, NDVI)
- A combination of all of them?

Drought, water shortage and water scarcity

- What do we really want to study?

Anthropic feedback

- The system is heavily influenced by humans, so there is a two-way feedback.

Tasks

1. Management and international coordination.
2. Relationship with stakeholders.
3. Development of a transversal methodology to study drought and its propagation using modeling and satellite data.
4. Generation of the project’s database.
    a. **Including extending SAFRAN to Portugal and to 2017.**
5. Observation of drought using satellite data.
    a. **Satellites observe the real system, including human impacts, such as irrigation!**
6. Improvement of the SASER model, inclusion of dams.
    a. **Dams and irrigation are affecting hydrological drought processes.**
    b. **We need to understand and quantify their impacts.**
7. Evaluation of drought in HUMID generated data.
8. Synthesis
9. Outreach

Drought indices and general project methodology

The main aims of the project would be:

- Complete the methodology in development that allows to quantify drought and its propagation.
  - Using models and satellite, separately and together.
- Using indices that make sense in the Mediterranean area (semi-arid).
- Understanding the impact of dams.
- Think how this could be applied in a Drought Information Portal.

- Drought propagation
  - Quintana-Seguí et al. (2018) - in review.
  - Barella-Ortiz et al. (2019) - in prep.
  - Take ETP and vegetation into account.
  - Can we do the same with remote-sensing only data?
- Mediterranean drought indices
  - HyMeX DWR - MISTRALS - MedECC
- Anthropic drought
  - Dams
  - *irrigation*
- Prototype for stakeholders
  - Concept of drought information portal.
    1. Show how it could be built.
    2. Next project: operational product.

International coordination

- HyMeX Drought and Water Resources Science Team.
    - LIAISE: Campanya para estudiar el impacto antrópico en la capa límite atmosférica y el ciclo hidrológico en zonas semiáridas.
- MISTRALS-IMPACTCC
    - Habrá un *workshop* sobre sequía este otoño en Montpellier, co-organizado con HyMeX DWR.
    - Interés en índices de sequía adaptados a la realidad mediterránea.
- GEWEX GLASS y GHP
    - HUMID is a child of the “Including water management in large scale models” workshop.
        - Polcher, J. et al., 2016. A New GHP/GLASS Crosscutting Project: Human Regulation of the Water Cycle (HRWC). GEWEX News, 26(November), pp.4–6.
- H2020 REC and ACCWA
- PhD thesis of Jacopo Dari
    - Tesis con el IRPI-CNR y U. Perugia.
    - Teledetección de la irrigación (Luca Brocca)
    - CNRM-GAME (Albergel, Boone, …)
    - CESBIO

SAFRAN Meteorological forcing dataset

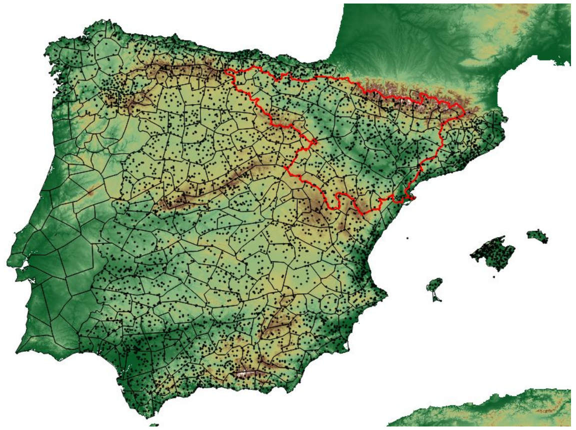
We developed a meteorological forcing dataset.

- Gridded dataset of all necessary screen-level atmospheric variables.

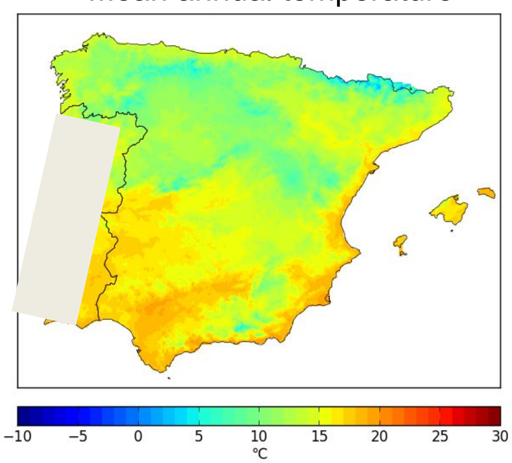
Our product is based on the **SAFRAN** meteorological analysis system (Météo-France)

  - Variables: P, T, W, RH, C.
  - Optimal interpolation method.
- Modelled downward VIS and IR radiation.
- Input:
  - 6h observed data, 24h for P (AEMET).
  - First guess (ERA-Interim).
- Output:
  - 1h time step,
  - 5 km resolution.
- Current dataset:
  - Mainland Spain and Balearic Islands (Portugal to be included next year)
  - 1979/80-2013/14 (soon to be extended to 2017).

SAFRAN zones and meteorological stations.



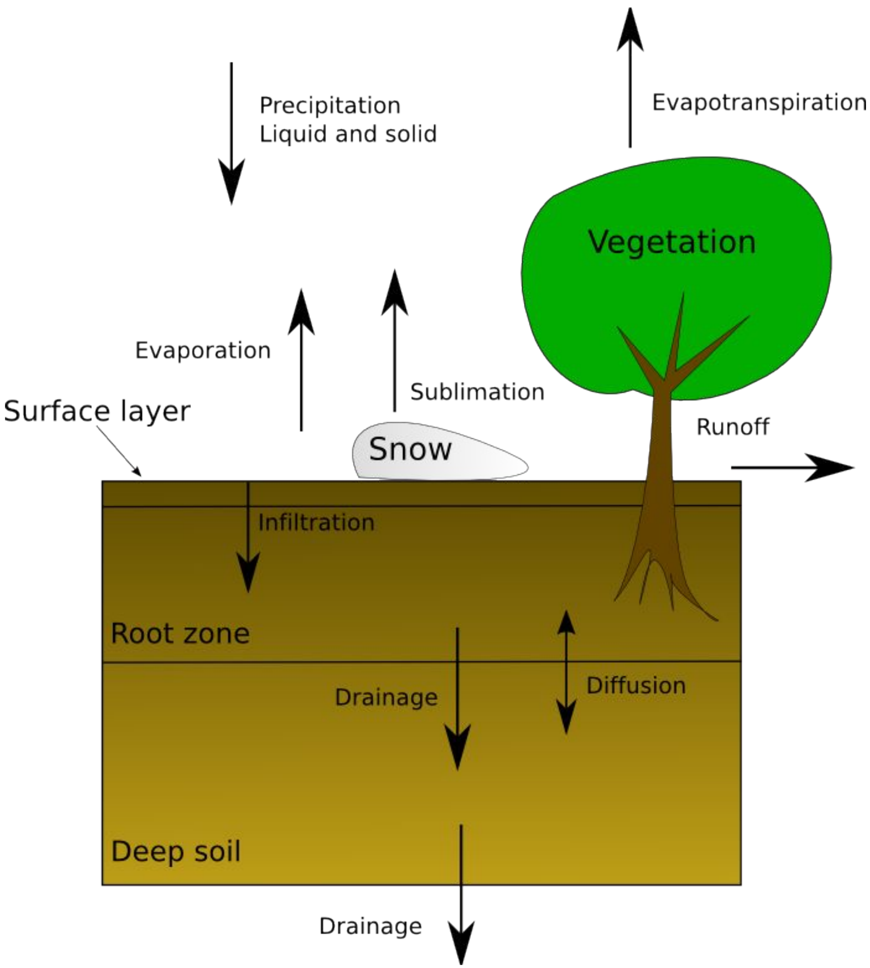
Mean annual temperature



The dataset is available for download at the HyMeX database

http://dx.doi.org/10.14768/MISTRALS-HYMEX.1388

SURFEX land-surface modelling platform



Structure of ISBA-3L

- Developed at Météo-France.
- Used in meteorological and climatological models (not only in MF).
- It has schemes for natural surfaces, cities, lakes, etc.
- ISBA is the scheme for natural surfaces.

ISBA is the central part of our hydrological modeling approach within SASER

- It describes the vertical processes in the soil column and the vegetation and generates the outflows that will allow us to simulate the river-flow.
- Modular:
  - ISBA-3L, simple three layered description of the soil using a force restore approach.
  - ISBA-DIF, explicit multi-layer approach.
  - ISBA-A-gs, interactive vegetation.
- We run it on a 5 km grid for the whole Iberian Peninsula and the Balearic Islands.
- Limitations:
  - No horizontal transfers of water.
  - No routing.
  - No underground water.

Water balance

SURFEX, when forced by SAFRAN, allows us to simulate the water balance.

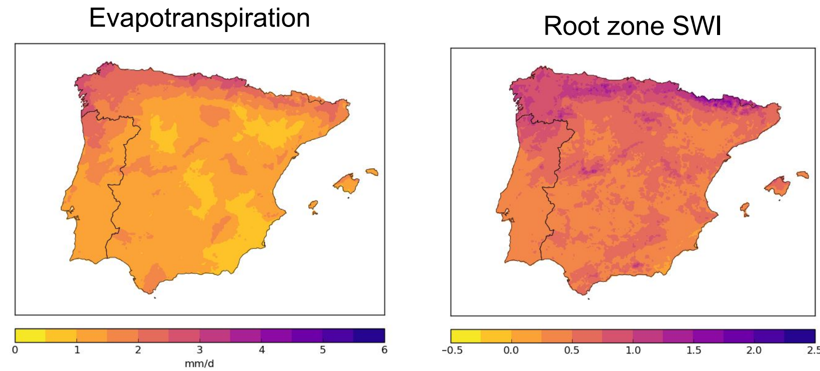
- **Water fluxes**: Evapotranspiration, runoff, and drainage.
- **Water Stocks**: Soil wetness, snow, interception.
- **Energy fluxes**: sensible and latent heat fluxes to the atmosphere.
- **Energy stocks**: energy in the vegetation, the soil, the snow, ...

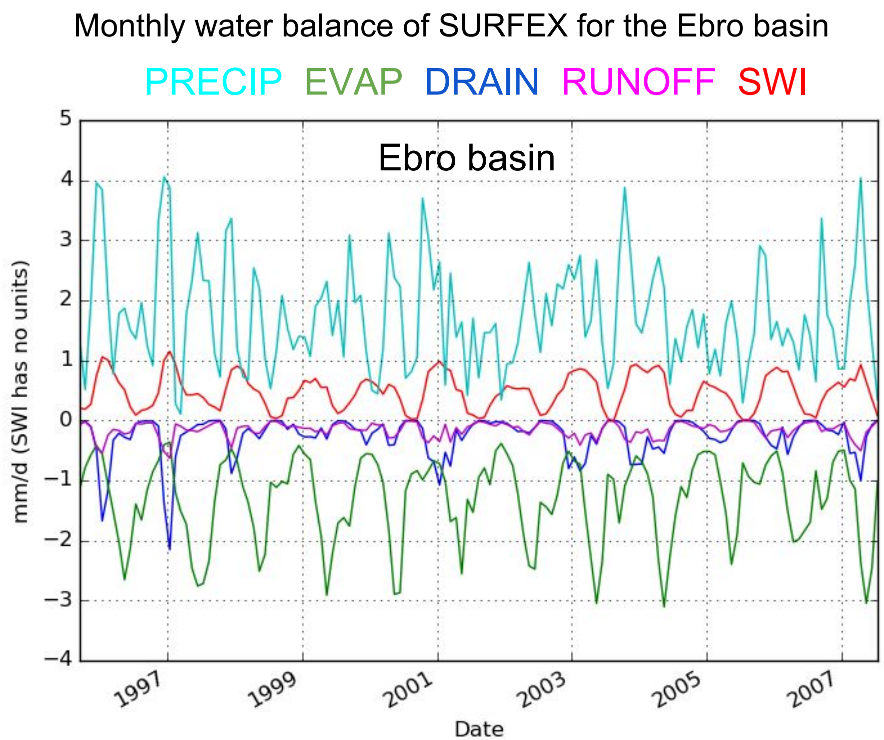
Current resolution: 5 km.

Important limitation: no lateral flows.

Further possibilities:

- Data assimilation (in-situ, remote sensing).
- Land-use change.
- Irrigation.





Streamflow

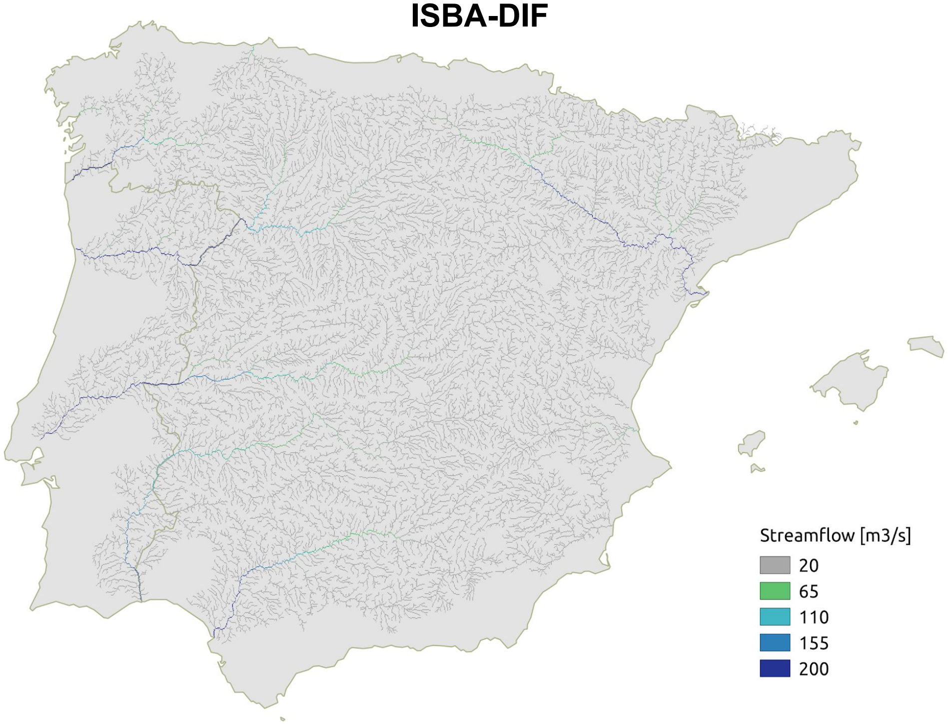
SURFEX does not simulate river flow. Thus, we need to transport SURFEX's runoff and drainage to the river (currently we do not simulate underground water processes) and then compute the river flow.

We chose **Eau-dyssée** (CNRS, France) to perform this task. It is a framework for hydrological modeling that allows to easily couple different models.

- **IMPOSED**: provide water balance (SURFEX).
- **ISO**: routes runoff to the river network using isochronal zones.
- **RAPID**: routing scheme
  - Muskingum type model.
  - Flow estimation at any river network point.
  - Parallel computation.
  - **Inclusion of anthropic effects (dams)**
- **RCB**: simulates dam management.
- It has other modules we don't currently use for underground water, etc.

Following the same approach as David et al,. 2011 and Habets et al. 2014.

SASER's mean annual streamflow (1979 to 2013) using ISBA-DIF



Hydrography:

Hydrosheds (drainage direction, flow accumulation).

- It is a fine product, but not perfect.

SASER

- We call **SASER** the whole SAFRAN-SURFEX-Eaudyssée-RAPID modeling suite.

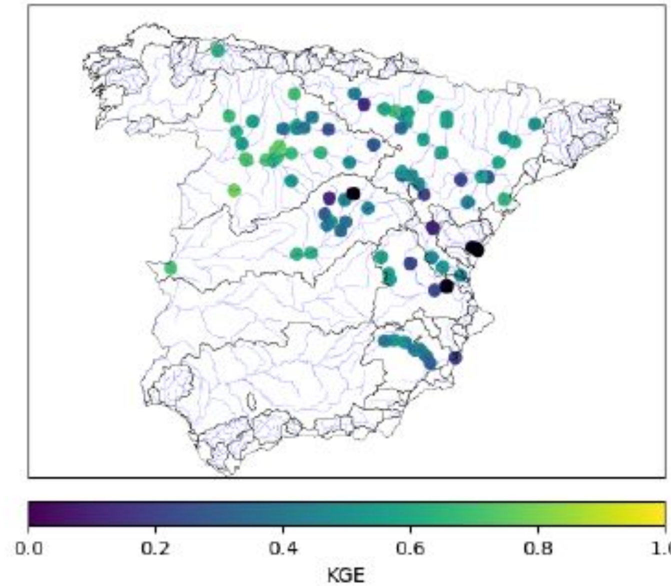
Streamflow

KGE using OBS as reference (natural basins)

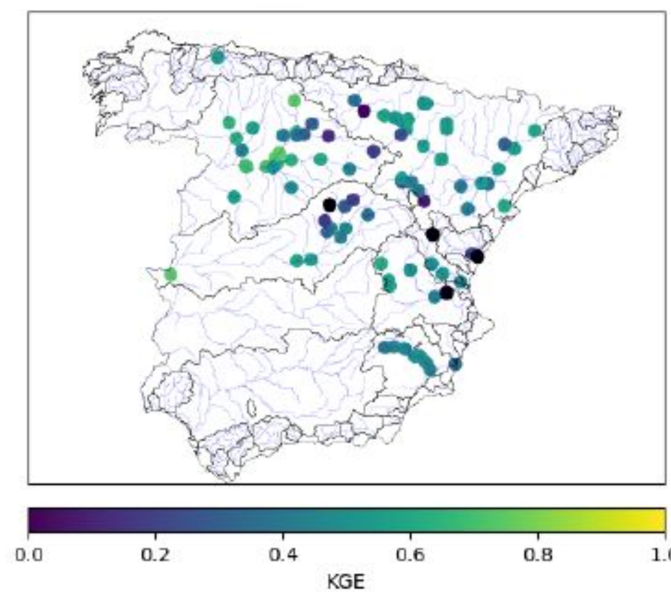
Code	E2O-DIF	MSW-DIF	MSW-LHD	SFR-3L	SFR-DIF	SFR-LHD	SLR-DIF	SMP-SMP
1359	-0,06	0,45	0,43	0,58	0,50	0,42	0,41	0,61
2029	0,18	0,89	-0,19	0,34	0,73	-0,20	0,69	0,75
2030	-0,29	0,12	0,24	0,44	0,26	0,31	0,13	0,76
2031	-0,12	0,21	0,16	0,57	0,39	0,24	0,30	0,75
2036	0,07	0,47	-1,28	0,64	0,68	-1,23	0,57	0,68
2042	0,33	0,65	0,35	0,34	0,70	0,26	0,74	0,74
2043	0,26	0,72	0,09	0,35	0,83	0,08	0,87	0,76
2074	0,1	0,54	0,41	0,57	0,78	0,47	0,74	0,81
2087	0,55	0,54	-0,26	0,57	0,73	-0,17	0,57	0,71
2097	0,29	0,72	0,09	0,32	0,81	0,08	0,84	0,76
3005	0,02	0,09	0,05	0,51	0,57	0,21	0,43	0,75
3169	0,6	0,52	-1,02	0,66	0,55	-0,99	0,57	0,77
8091	-0,02	0,07	0,19	0,61	0,65	0,1	0,5	0,63
9002	0,04	0,82	-0,18	0,76	0,85	0,02	0,84	0,6
9003	-0,06	0,35	0,15	0,5	0,87	-0,02	0,76	0,65
9004	-0,13	0,44	0,36	0,68	0,52	0,38	0,63	0,86
9065	-0,13	0,45	0,36	0,75	0,63	0,44	0,59	0,71
9120	-0,04	0,67	0,04	0,56	0,69	0,29	0,68	0,79

- Validation of monthly flows.
- Comparison to naturalized flows.
  - Our models do not simulate management.
  - SIMPA hydrological model is used as reference.

KGE using SIMPA as reference

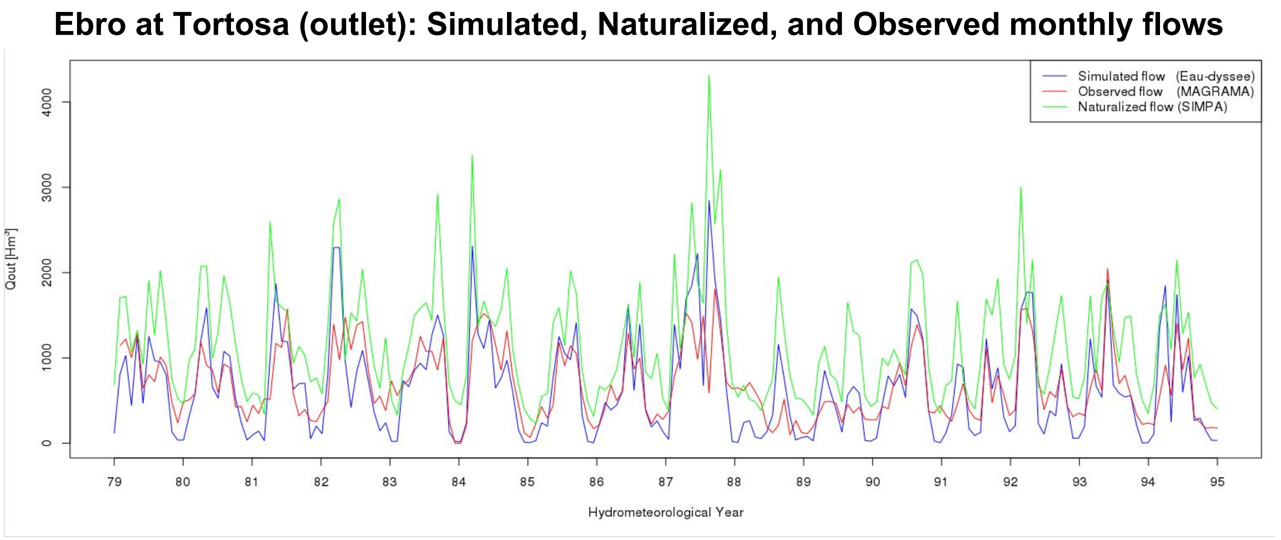


(c) SFR-DIF

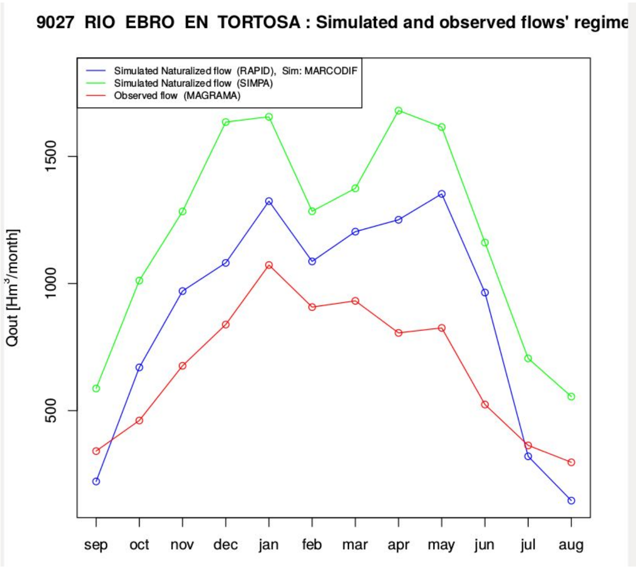


(d) SLR-DIF

SASER's River flow



- **No calibrations or optimizations were applied at all.**
  - Most parameters depend on the physiography.
  - Those that are calibrated, use default values.
- **Current status**
  - Natural flows (no human processes).
  - Peak and mean flow lower than SIMPA's.
  - Low flows are not sustained.
- **Proposed improvements (short term)**
  - Increased resolution:
    - increased relief, increased SAFRAN precipitation.
    - Higher resolution on relief and lower in the plains?
  - Inclusion of linear reservoir to dampen drainage in order to conceptually simulate underground processes.
  - Dams (at least in forced mode [using observations to force the levels], not including irrigation in a first stage).
- **Things to look at (longer term)**
  - Snow: impact on evaporation and snow-melt.
  - Evapotranspiration in semi-arid areas.



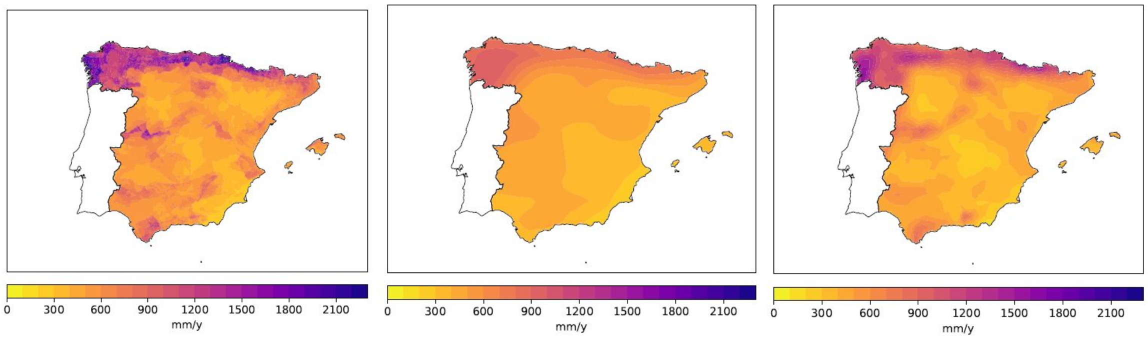
How do Land-surface models reproduce drought and its propagation in Spain?

“On the utility of land-surface model simulations to provide drought information in a water management context using global and local forcing datasets”

- Quintana-Seguí et al (2018), Water Resources Management (in review).

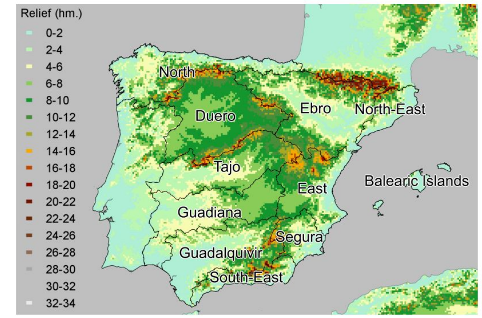
Datasets and models

Mean annual precipitation (mm)

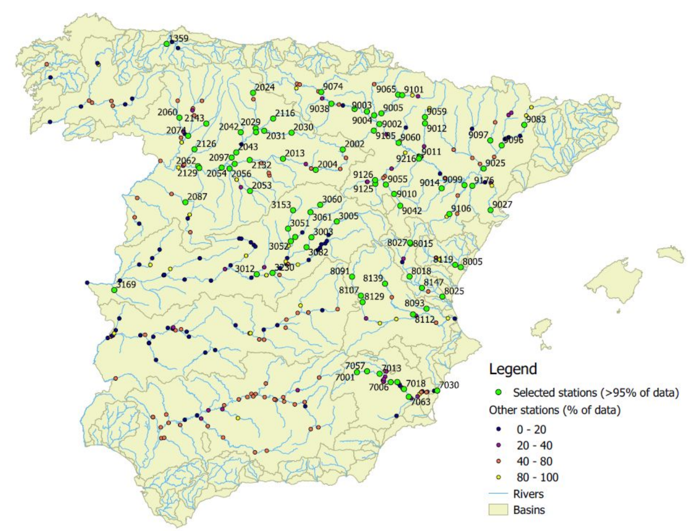


SAFRAN (5 km) eartH2Observe (0.25°) MSWEP (0.25°)

Relief and main river basins



River gauging network



Observations

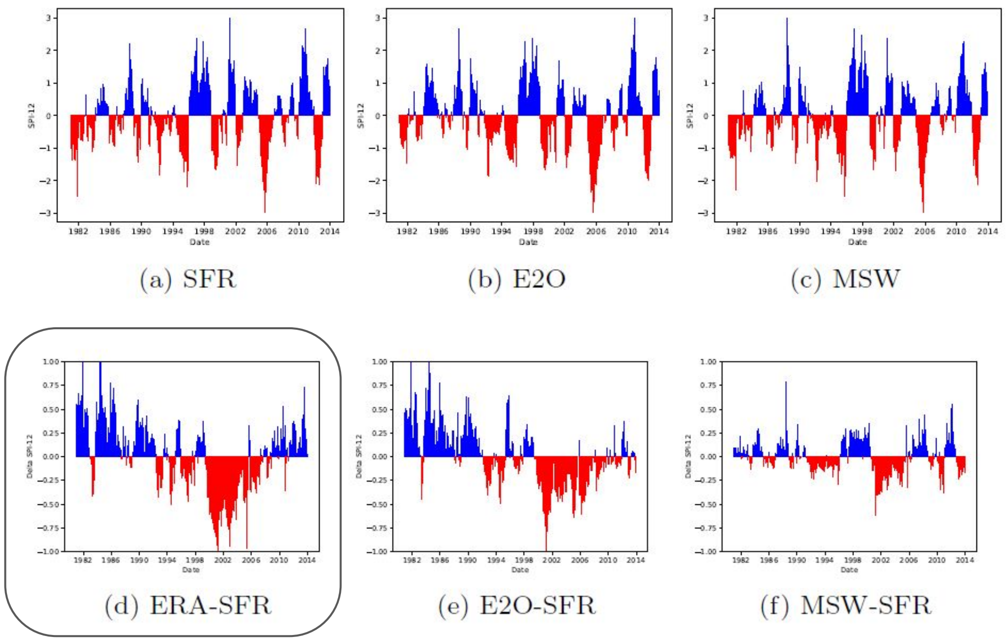
- Observed streamflows from the MAPAMA database.

Reference naturalized flows

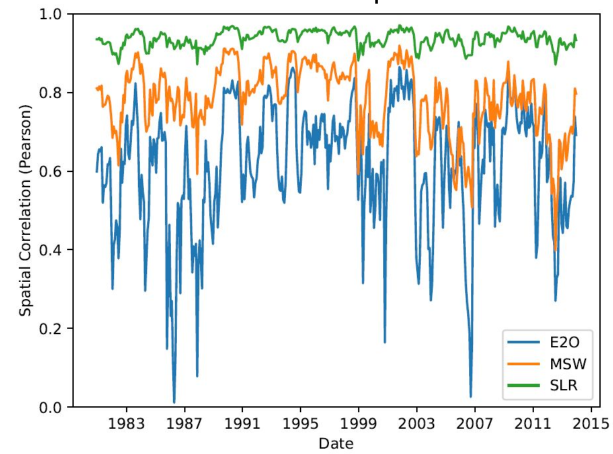
- SIMPA monthly hydrological model (developed by GEWEX and distributed by MAPAMA).

Meteorological drought

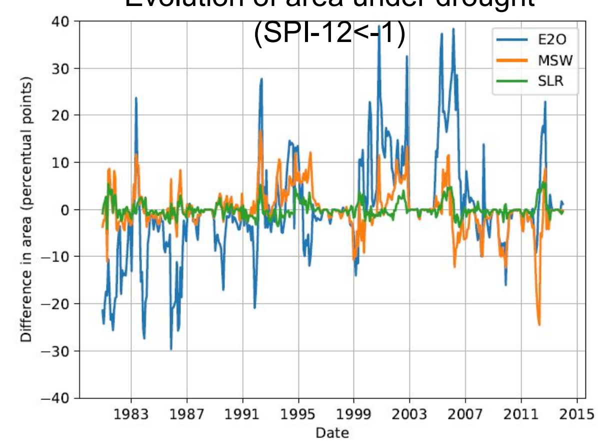
Aggregated time series



Time evolution of the spatial correlation



Evolution of area under drought (SPI-12<-1)

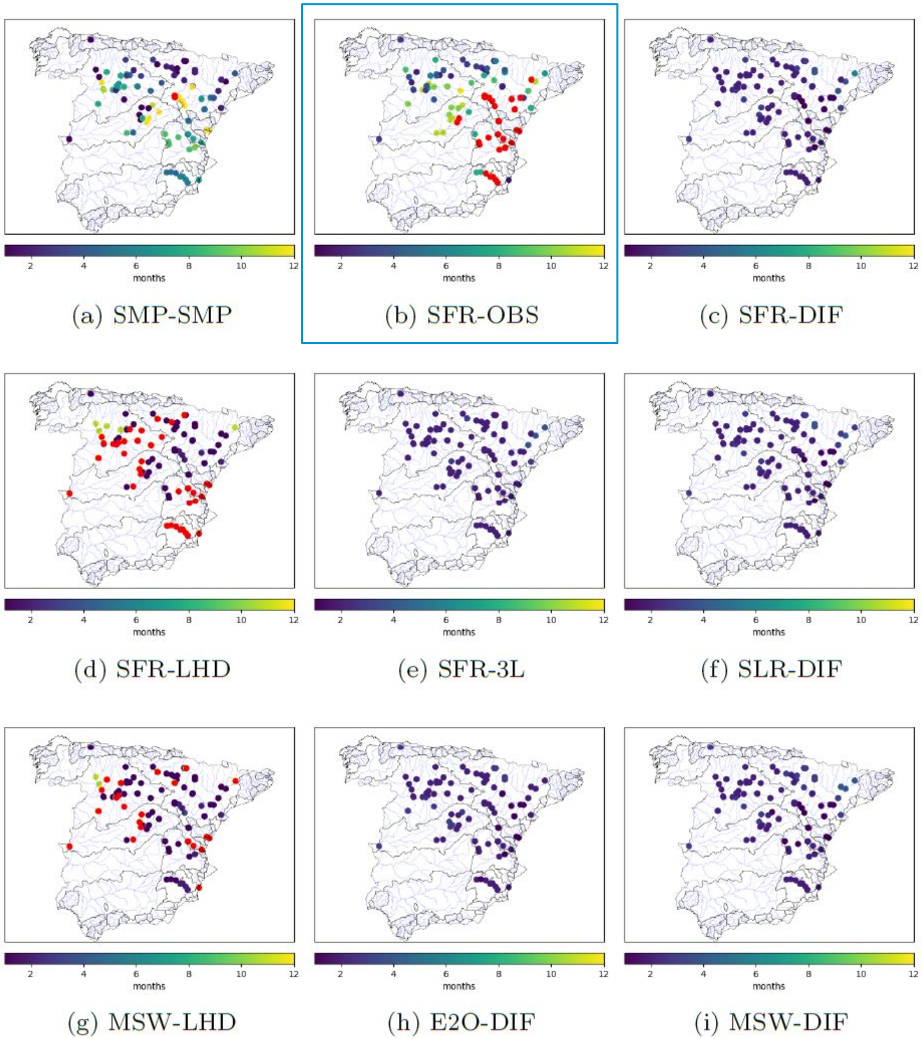


- Similar drought periods in all datasets, but notable differences in severity and duration.
- E2O inherits an spurious trend that comes from ERA-Interim.
- MSWEP is a much better product than E2O.
    - Better reliability.
    - Better robustness.

Drought propagation to streamflow

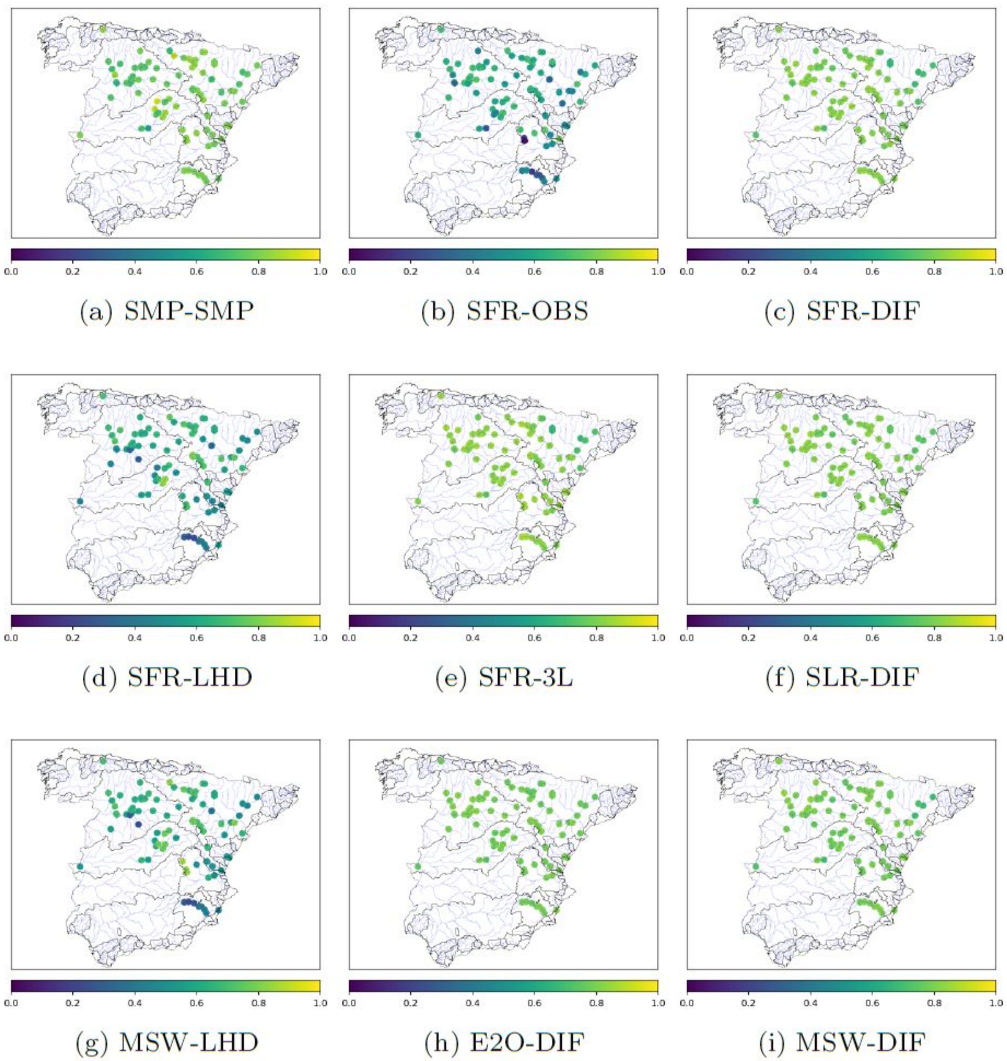
- OBS: n_x is very high in many basins due to water management.
- SMP (hydrological model without management): n_x is much lower than OBS, but it is not always perfect (tested on some natural basins).
- ISBA (DIF and 3L): very dynamic, very homogenous. Unrealistic.
- LEAFHYDRO: very different to SMP or to OBS, very high n_x on many basins.

Scale n_x which maximizes the correlation between SPI-n and SSI-1.



Drought propagation to streamflow

Correlation between SPI-n_x and SSI-1.



- SFR-OBS: n_x is around 0.5 and 0.7, showing that precip. is the main driver of streamflow variability (these data include water management!).
- SMP (reference hydrological model) presents higher correlations between precip and streamflow, which is intuitive. Better than LSMs in near naturals basins, but far from perfect.
- ISBA DIF-3L: the response is too correlated to precipitation.
- LEAFHYDRO: Correlations are too low (too large influence of underground water).

Conclusions and perspectives

- Model structure uncertainty remains an important issue in current generation large scale hydrological simulations based on land-surface models.
- This is true for both SSMI and SSI.
- The differences between simulated SSMI and SSI are large and the scales of propagation of drought to both soil moisture and streamflow are very dependent on model structure.
- Forcing datasets have an impact on the uncertainty of the results, but, in general, this is not as large as the uncertainty due to model formulation.
- MSWEP, which includes satellite precipitation data, represents a large improvement compared with E2O.

Perspectives

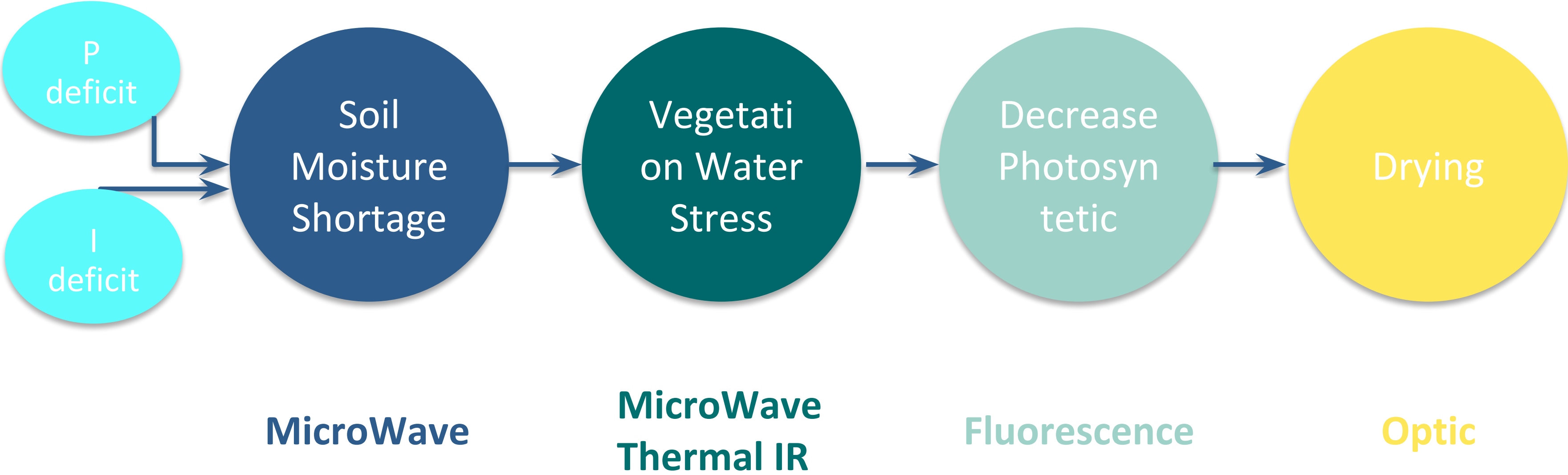
- Study the results by season.
- Analyze the role of evapotranspiration and vegetation dynamics.
- Physical analysis of the processes in play.
- Inclusion of anthropic processes.

This work will be continued in the HUMID (Hydrological Modeling and Understanding of Iberian Drought) project.

Remote sensing of drought

Remote Sensing can provide comprehensive view on the **soil and vegetation conditions** and thus help in irrigation management

Agricultural Drought - dynamics and monitoring

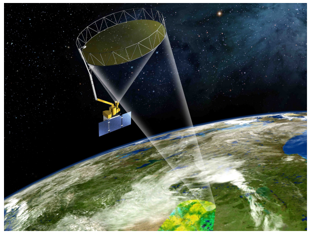


Remote sensing can help us access the real system, including human impacts!

SMOS

November 2 2009

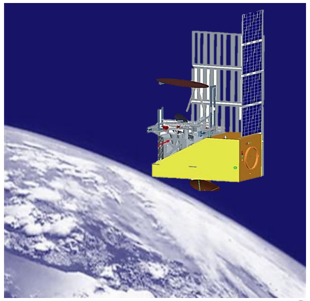
2019



SMAP

January 31 2015

2020

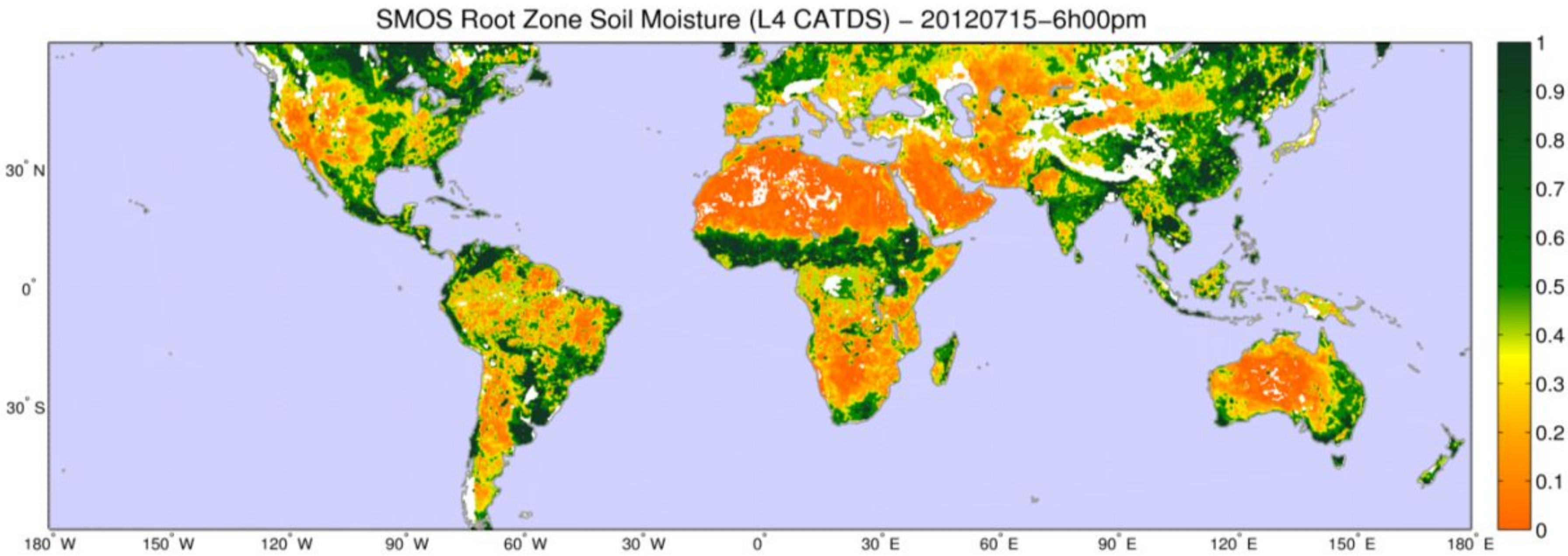


WCOM

before 2020

2025

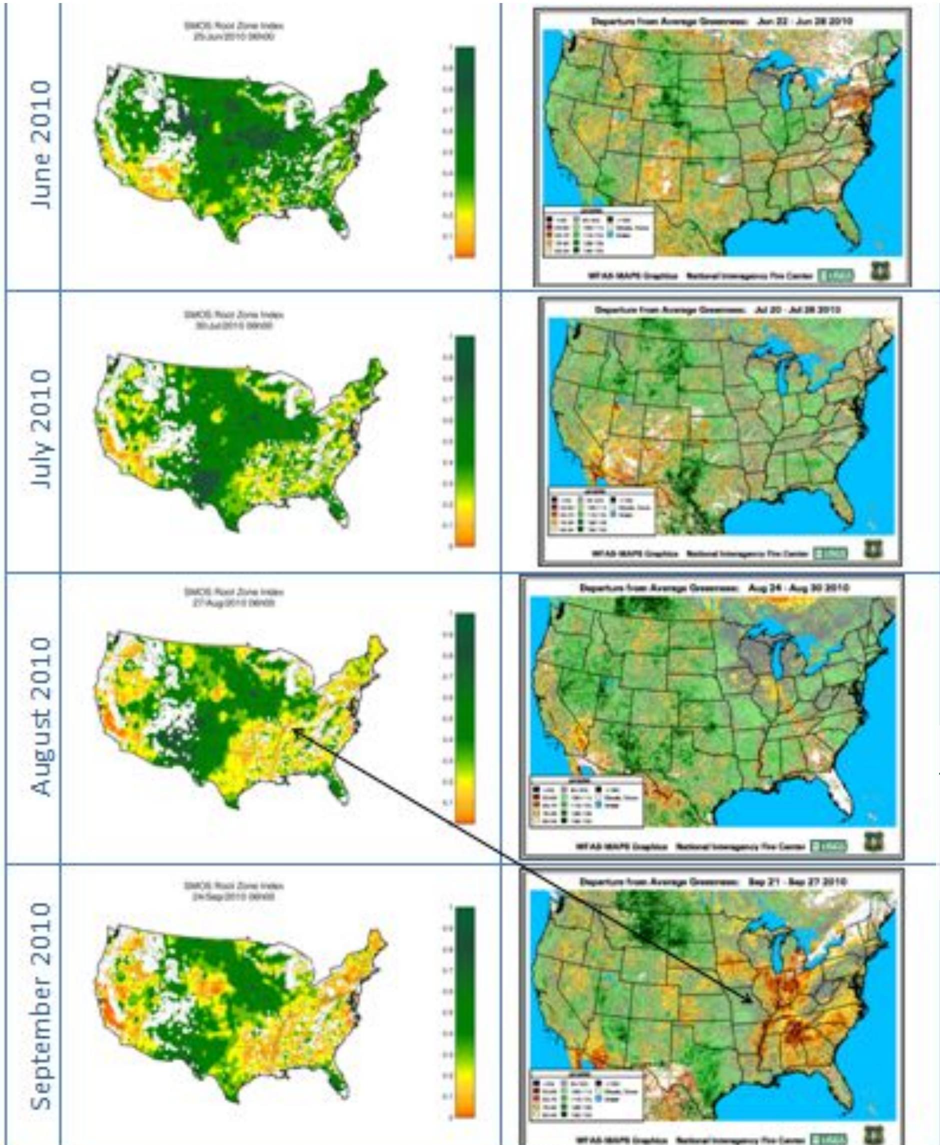
Root Zone Soil Moisture Drought



A. *Albitar et al. Global drought index from SMOS Soil Moisture, IGARSS 2013*

Root Zone Soil Moisture Drought

SMOS Drought Index AVHRR NDVI



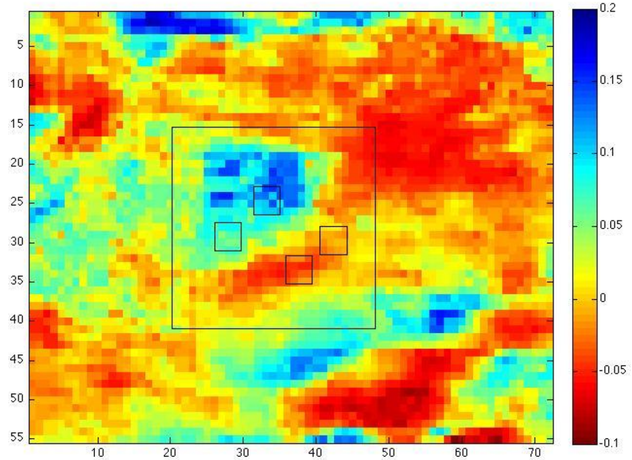
A. *Albitar et al. Global drought index from SMOS Soil Moisture, IGARSS 2013*

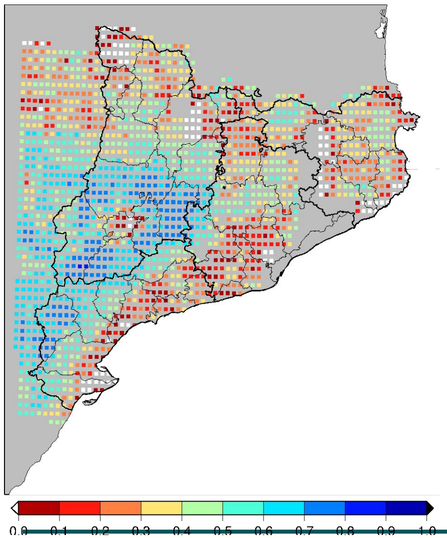
Downscaling to higher resolution

NSSM

L-band Passive MW SMOS/SMAP/WCOM
(40 km, 2/3 d)
+
Medium Resolution O/T S3/MODIS
(1 km, 1 d)

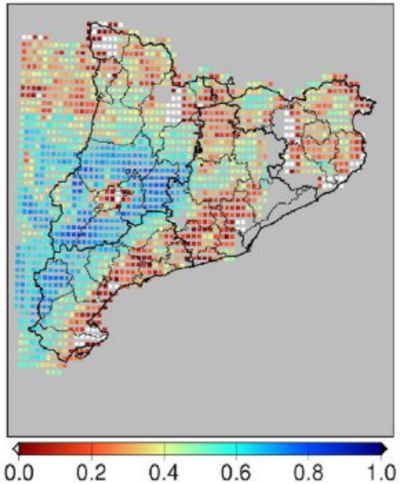
NSSM (1 km, 2/3 d)



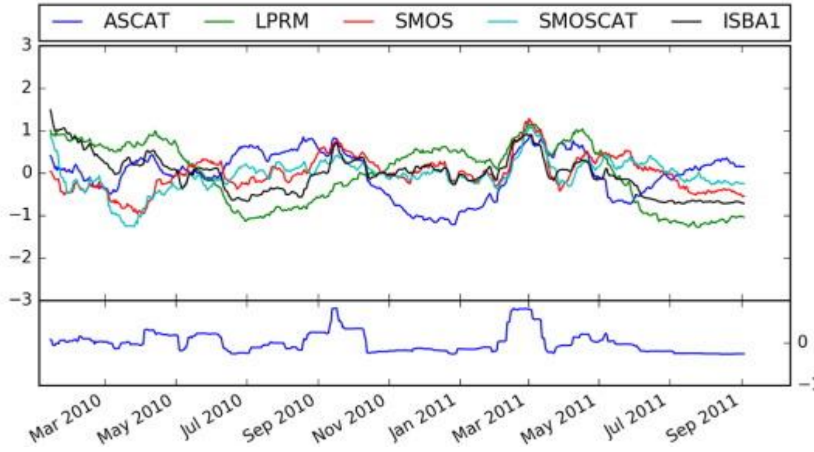


Comparison of LSM and satellite soil moisture

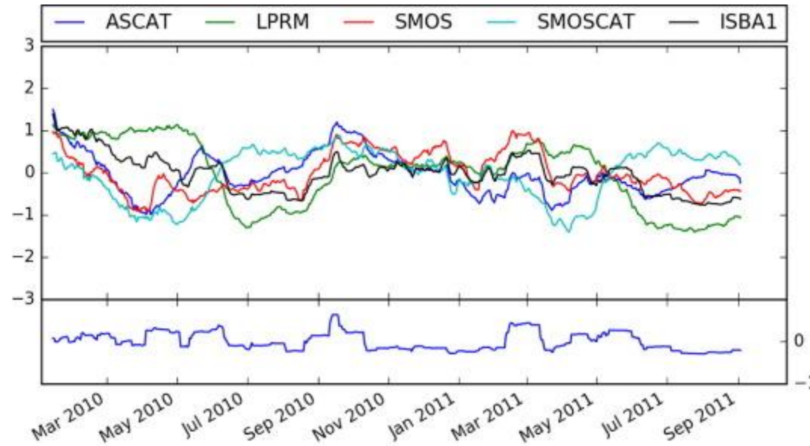
- We have compared the simulated (E&QS 2016) surface soil moisture with remotely sensed datasets.
- These comparisons allow us to learn about the behaviour of the different products, finding their strengths and weaknesses.
- SMOScat data suggests that we can quantify irrigation!



Time correlation between SMOScat's and SURFEX's surface soil moisture in Catalonia.



Temporal series of soil moisture z-values over a **dryland pixel** (Baix Ebre) using a 30-days window average.



Temporal series of ASCAT, AMSR-E, SMOS, SMOScat and SURFEX zvalues over an **irrigated pixel** in Urgell using a 30-days window average.

Escorihuela and Quintana-Seguí, Comparison of remote sensing and simulated soil moisture datasets in Mediterranean landscapes, Remote Sensing of Environment, Volume 180, 2016, 99–114, http://dx.doi.org/10.1016/j.rse.2016.02.046

isardSAT's SM data for HUMID

Remote Sensed Soil Moisture operationally produced at 1km. Long term dataset 2010 – 2018.

-> soon Soil Moisture anomalies

Introduction of meteorological data for algorithm improvement and to increase temporal resolution

Efforts concentrated in estimations of soil moisture at the field scale (100 m) in synergy with SAR from S1

Several approaches tested but not yet a fully satisfactory solution over agricultural fields

Current ongoing work to synthetize previous works.

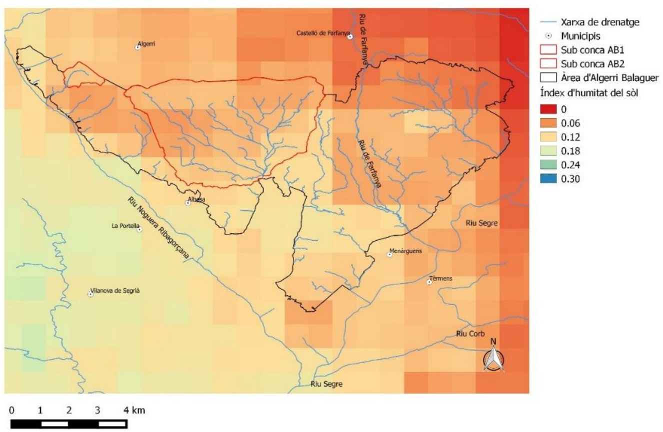
HUMID

Seeing the real system with remote sensing

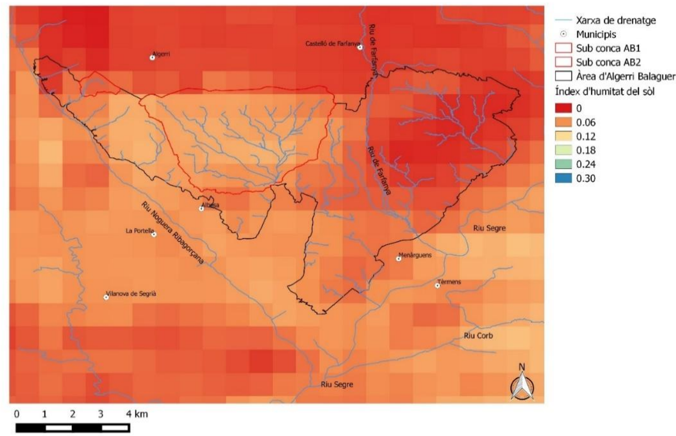
March 14, 2017

July 23, 2017

Humitat del sòl 14 de març del 2017

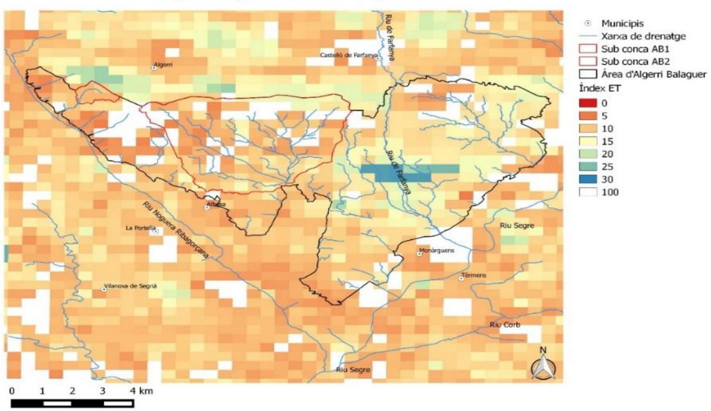


Humitat del sòl 23 del juliol de 2017

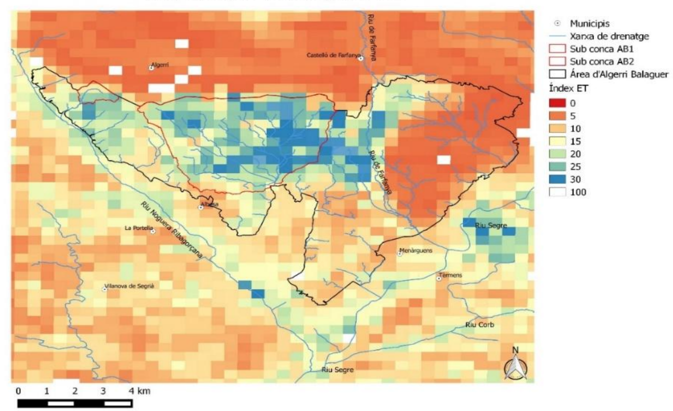


Soil Moisture 1 km

Evapotranspiració 14 de març 2017



Evapotranspiració 23 de juliol 2017



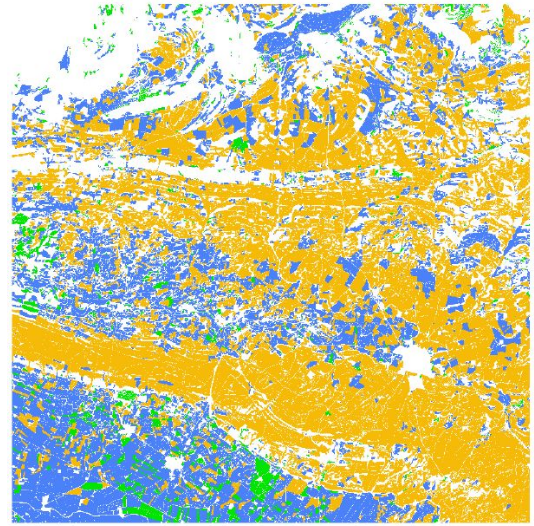
MODIS ET

Remote sensing data detects irrigation in summer.

Qi Gao's PhD thesis

1. Directed by M. Zribi (CESBIO), MJ Escorihuela (isardSAT) and P. Quintana Seguí (OE).
2. Remote sensing of water resources.

Irrigation mapping



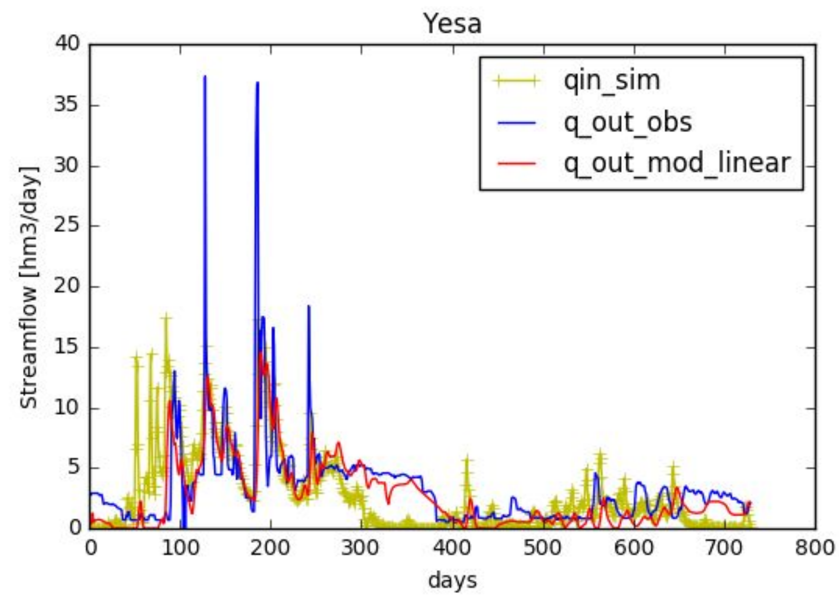
- Nonirrigated fields
- Irrigated trees
- Irrigated crops

The validation is done with the database from SIGPAC over the whole study area (26,434 fields).

Overall accuracy = 81,08%
nonirrigated accuracy = 83,27%
irrigated trees accuracy = 73,49%
irrigated crops accuracy = 77,53%

High resolution soil moisture.

Dam altimetry and dam simulation



Human induced drought

A. F. Van Loon et al.: Drought in a human-modified world

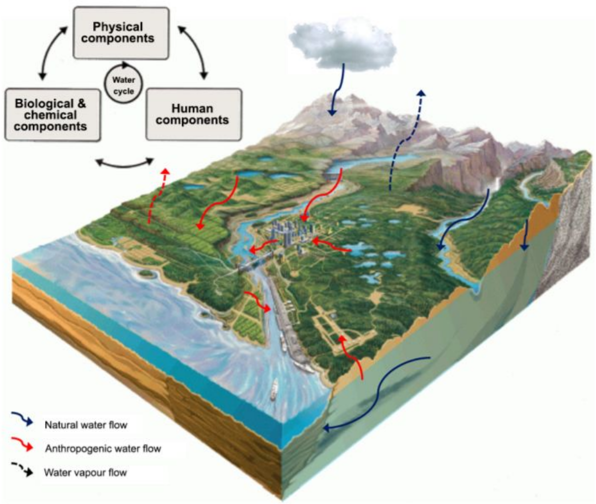


Figure 1. The water system linking physical, biological, and human components through natural and anthropogenic water flows (adapted from Winter et al., 1998; Vörösmarty et al., 2004; copyright: AGU).

A. F. Van Loon et al.: Drought in a human-modified world

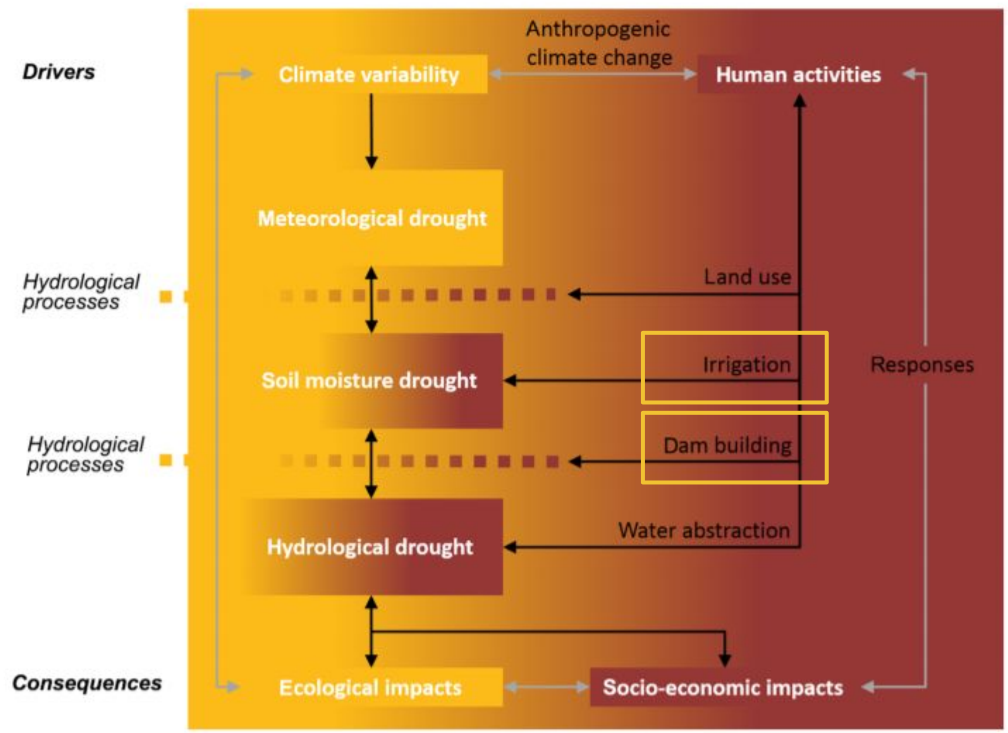
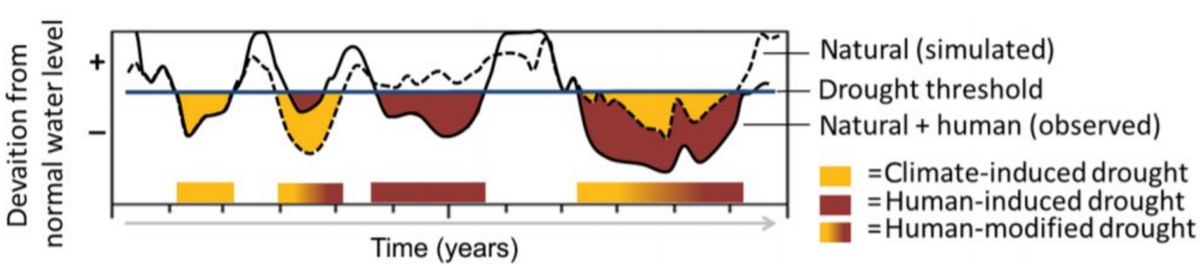


Figure 2. Drought propagation including natural and human drivers and feedbacks; black arrows indicate direct influences and grey arrows indicate feedbacks (modified from Van Loon et al., 2016).



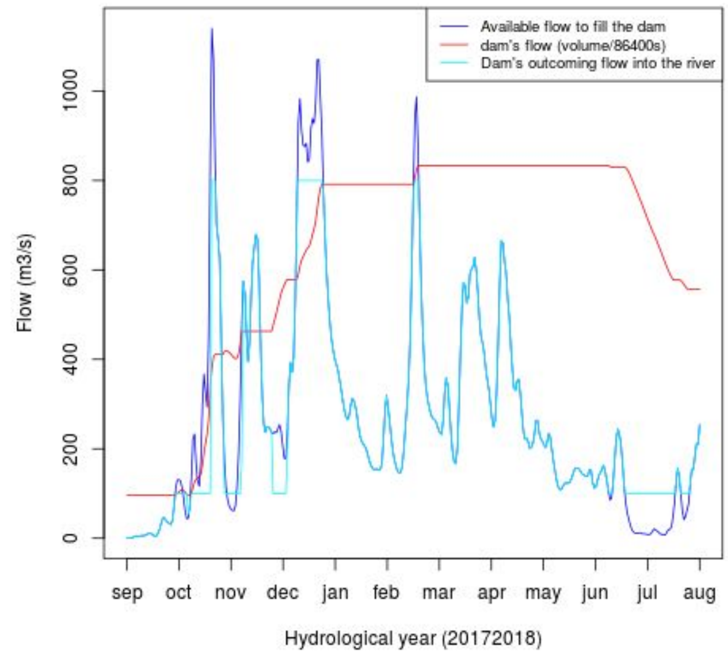
What is the human impact on droughts?

Inclusion of dams in SASER

Eau-Dyssée's RCB (Retenue Collinaire Barrage) module simulates the management of a given number of dams located along the watercourse or in its upstream section (hillside retention).

1. Remove from the current volume the evaporation loss.
2. Compute the dam's water input:
   a. Estimate the target volume.
   b. Obtain the difference between current and target volumes.
3. The dam is filled until the target volume is assessed.
   a. First, the water input from the river network is considered.
   b. Second, external pumping is considered.
4. Compute the dam's water output. Priority order:
   a. To sustain minimum volume.
   b. To sustain low flow.
   c. To sustain minimum pumping.
   d. To reduce flood peak.

Preliminary result: flow at the Mequinenza dam using ISBA-DIF



- The relaxation to the target volume should be slower.
  - $V_{flowout} = (V - V_{target}) / \tau$
- Otherwise the dam is often transparent!
- Qi Gao is experimenting with satellite target volumes.

Modelling irrigation (Jacopo Dari’s PhD)

Title: Anthropogenic impact on the hydrological cycle.

- 9 months at EO (3 months * 3 years)

PhD advisors in Italy

- Luca Brocca (IRPI-CNR)
- Renato Morbidelli

PhD advisor in Spain

- Pere Quintana-Seguí (OE)

The thesis does not come from the HUMID project but it will certainly improve its scope by introducing the irrigation topic.

Collaboration: Simulation of the impact of irrigation using remote sensing data.

- Simulate irrigation with SURFEX.
- Use remote sensing irrigation data (Luca Brocca’s method).
    - Applied to SMOScat data and other products.
- Analyse hydrological impact.
- Can we connect dams and irrigation?
    - Will he have advanced enough with our implementation of dams?
    - F. Habets says it is possible with her code.

Sites:

- Ebro basin (LIAISE).
    - LDAS-Monde
    - SASER
- Tiber basin.
    - ERA-5 (?)
    - SURFEX
    - Eaudyssee-RAPID (?)

PhD Opportunity

The project has the right to present a candidate to the FPI (*Formación Personal Investigador*) call.

- 4 years (max.).
- 20.500 EUR/y for the contract.
- 6250 EUR/y for travel.
- + travel within the ACCWA project.

The call just openned.

DEADLINE: 29/10/2018.

Title of the topic	**Large scale hydrological simulation: anthropic processes and drought in Iberia.**
Host institution	**Observatori de l'Ebre - Ramon Llull University.** *Roquetes (Tarragona Province), Spain.* The student may spend some time at Polytechnic University of Madrid and in foreign research centers.
Advisors	Dr. Pere Quintana-Seguí (Observatori de l'Ebre-URL) Dr. Luis Garrote (Polytechnic University of Madrid)
Financial Framework	*Ayudas para contratos predoctorales para la formación de doctores 2018. Programa Estatal de Promoción del Talento y su Empleabilidad en I+D+i. Subprograma Estatal de Formación.* Spanish Ministry of Science. ● **The call is expected to open in early September and close in October 2018.** ● The position is for 3 years (maximum of 4 years). ● Annual gross salary: **16.420 €**. ● The funding also includes money for visiting other research centers. ● The funds are linked to the **HUMID project**. Furthermore, the student may travel abroad (Morocco or Niger) using funds tied to the **ACCWA project** (Marie Skłodowska-Curie Research And Innovation Staff Exchange, 2018). ● These funds include a generous travel allowance (which is added to the monthly salary) for the student for every month spent abroad.

Conclusions

1. Drought is a very important topic in the Mediterranean.
    a. But it is still not well understood.
2. LSMs are great tools to study drought.
    a. But there are still large differences between models in terms of drought propagation and soil moisture drought simulation.
3. The humans are part of the system.
    a. We need to take this fact into account.
4. Remote sensing sees the real system
    a. But it has important limitations.
5. The HUMID aims at tackling these issues.
6. Irrigation wasn’t included in HUMID, but JD’s PhD and the collaboration with all of you all is an opportunity to include this very important topic on the project’s framework.