HUMID

Drought indexes (ETDI / SMDI) derived from global ET(MOD16A2) and SM (SMOS 1km) remote sensing data for drought assessment

Pere Quintana-Seguí and Jaime Gaona
Observatori de l'Ebre (Universitat Ramon Llull - CSIC)

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I – DROUGHT and its relevance

Climate variability determines natural periods of low rainfall /+ high temperature (T) which reduce the availability of water along the water cycle (e.g. soil moisture).

"DROUGHT"

This is a complex phenomenon interacting with biosphere (& humans) that requires conducting interdiciplinary research from basic science to policy making, especially on the following aspects:

1. Drought processes: **with special attention to the study of drivers, onset, propagation, mitigation and interaction of processes. This is the focus of our study.**

2. Impacts: **The periods of drought at atmospheric and/or terrestrial level can have great ecological and socio-economic impact, particularly in semi-arid regions.**

3. Human pressure: **high demand of water supply and low offer can cause periods of water scarcity in addition to the natural drought events that must be managed.**

4. Climate change: **this severe human impact causes destabilisation of the system, alters mechanisms of drought and adds the complexity of studying transient states.**

II – Goals

1. Understand drought **processes in the Iberian Peninsula, integrating hydrological and meteorological knowledge.**
   - **Drought propagation in LSMs,** Quintana-Seguí et al. (2018)
   - **Drought propagation in RCMs,** Barella-Ortiz et al. (2019, HESS)

2. Use remote sensing (RS) data to calculate drought indexes.
   - **SMOS 1km (DisPATCh),** Merlin et al. , 2013, RSE, Escorihuela et al., 2012, IEEE.
   - **MOD16A2 ET**, Mu et al., 2011, RSE.

3. Evaluate the SMDI / ETDI indexes to characterize drought

   Analysis of the spatio-temporal patterns, lags, and interaction between indices.

4. Discuss the potential of combining RS products with LSM modelling

   Drought indexes from the RS data compared to the calculated ones using land-surface model (LSM) SURFEX to assess, monitor and manage Iberian droughts.

   - **SURFEX,** Mason et al. 2013, GMD.

III – Drought indexes: ETDI and SMDI

SMDI / ETDI drought indexes provide insight on drought propagation beyond rain and temperature anomalies. They can be calculated from RS and LSM data.

ETDI

The Evapotranspiration (ET) Deficit Index is an indicator describing evolution of the water stress (WS) based on the short-term anomalies of the evaporative déficit

- **The index starting from 0, indicates WS anomalies, from dry (–) to wet (+) values**
- **MOD16A2 ET can provide the ET/PET values to calculate water stress**

$$WS = \frac{PET - AET}{PET} \rightarrow \begin{cases} WSA_{i,j} = \frac{MWS_j - WS_{i,j}}{MWS_j - \min WS_j} \times 100, & \text{if } WS_{i,j} = MWS_j \\ WSA_{i,j} = \frac{MWS_j - WS_{i,j}}{\max WS_j - MWS_j} \times 100, & \text{if } WS_{i,j} > MWS_j \end{cases} \rightarrow ETDI_j = 0.5 ETDI_{j-1} + \frac{WSA_j}{50}$$

(Narasimhan & Srinivasan, 2005)

SMDI

The Soil Moisture (SM) Deficit Index is an indicator devoted to describe the onset, duration and magnitude of soil drought based on the short-term anomalies of SM.

- **The index starting from 0, indicates SM anomalies, from dry (–) to wet (+) values**
- **SMOS 1km/SURFEX can provide the upper soil moisture data to calculate it**
- **Multiple depths of SMDI are not feasible with SMOS, but posible with SURFEX**

Soil water (SW) $\rightarrow$

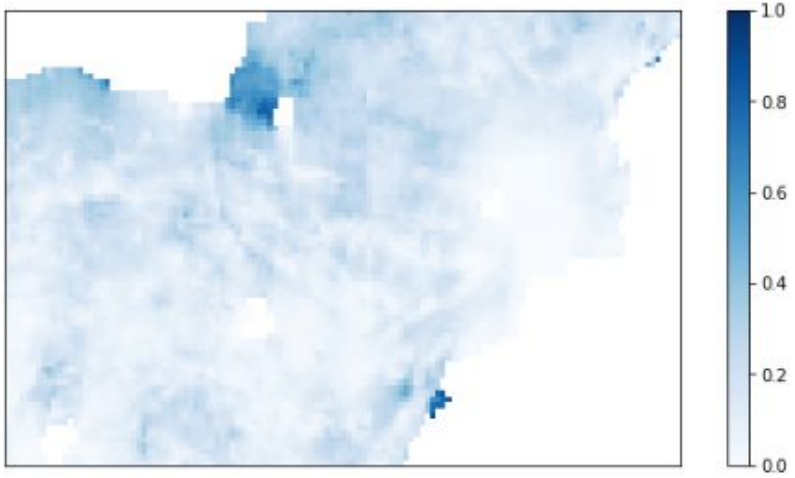
$$\begin{cases} SD_{i,j} = \frac{SW_{i,j} - MSW_j}{MSW_j - \min SW_j} \times 100, & \text{if } SW_{i,j} = MSW_j \\ SD_{i,j} = \frac{SW_{i,j} - MSW_j}{\max SW_j - MSW_j} \times 100, & \text{if } SW_{i,j} > MSW_j \end{cases} \rightarrow SMDI_j = 0.5 SMDI_{j-1} + \frac{SD_j}{50}$$

(Narasimhan & Srinivasan, 2005)

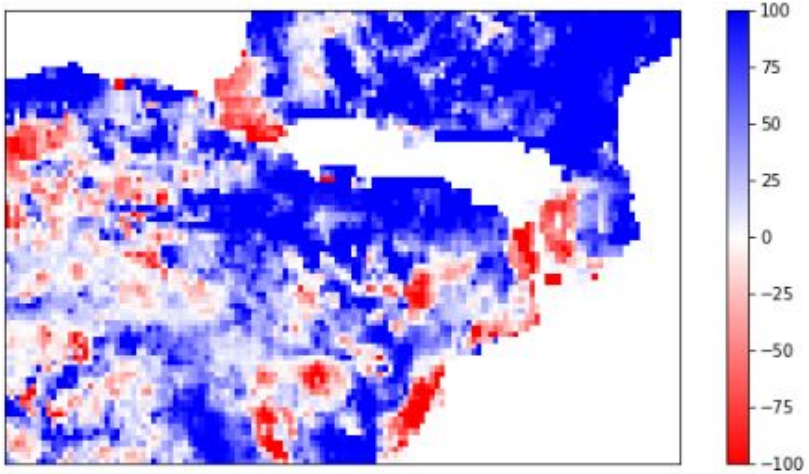
IV – Process to generate drought indexes from RS data

Soil Moisture data (SMOS 1km)

Soil Moisture (SM) (0: Dry / 1: Wet)

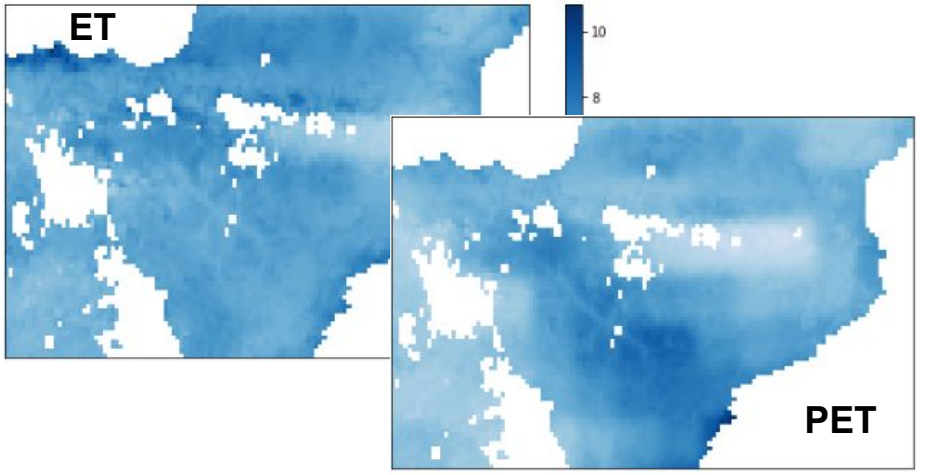


SM deficit (-100: Dry / 100: Wet)

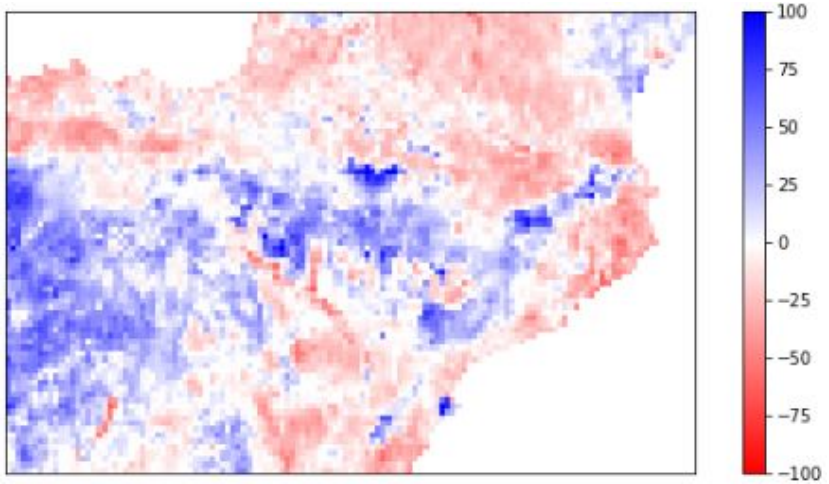


Evapotranspiration data (MOD16A2ET)

Evapotranspiration



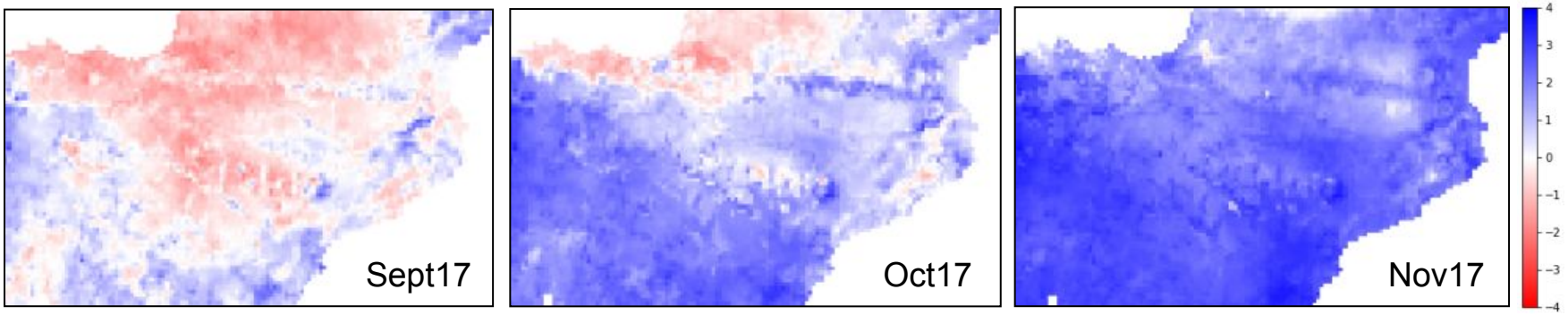
Water Stress anomaly (-100: no ET /100: full PET)



V – SMDI and ETDI description of processes at ≠ levels

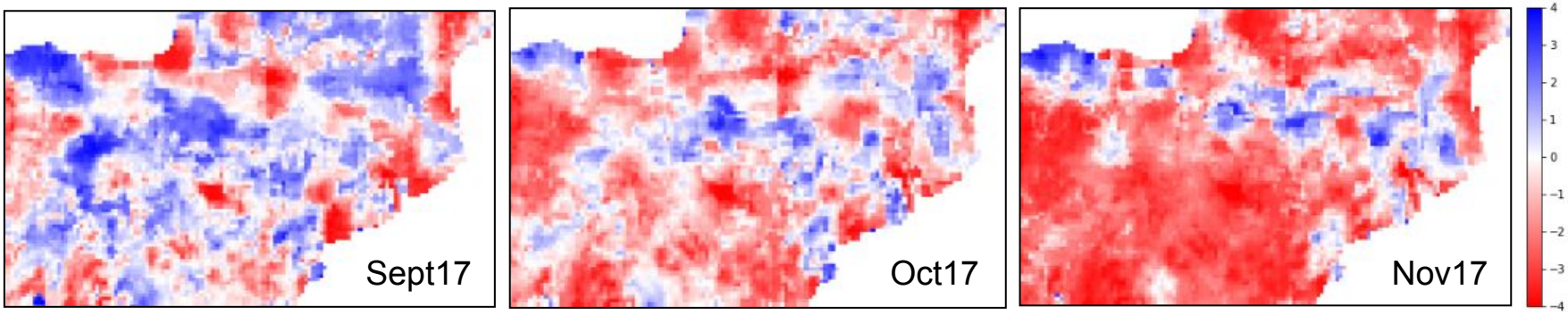
ETDI (MOD16A2 ET)

ETDI informs about the evolution of the water stress ratio anomalies (PET-ET/PET) (atmosphere level)



SMDI (SMOS 1km)

SMDI describes the evolution of soil moisture anomalies in the upper layer of soil (litosphere level)

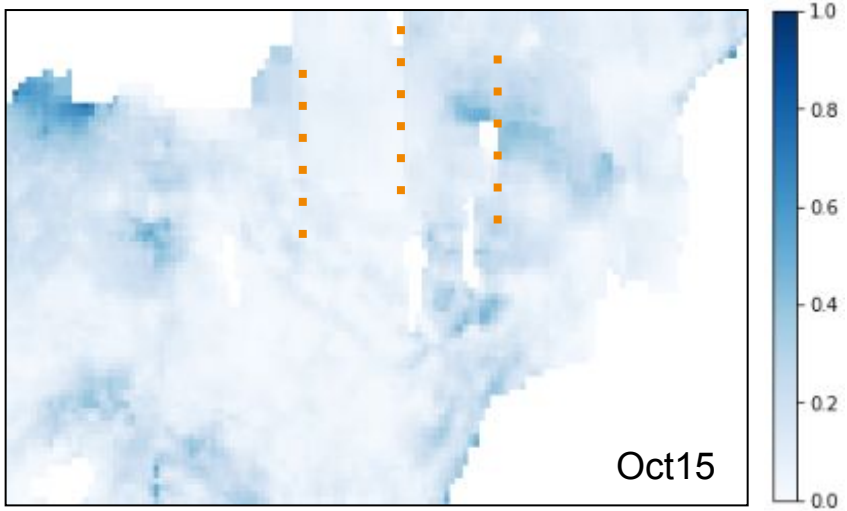


Preliminary issues observed during the evaluation of results:

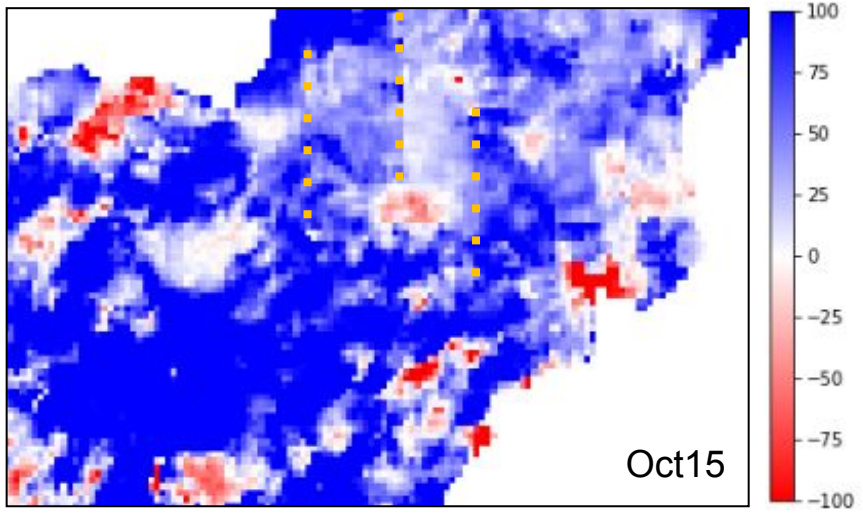
- **Discontinuities due to data gaps, suitability of filling methods to give proper continuous estimates**
- **Artifacts of resolution inherited from the generation of the RS data products**
- **Spatio-temporal variability ('patchiness') depending on the type of sensor? (e.g. too smooth ET?)**

VI – Issues processing RS data: Artifacts of resolution

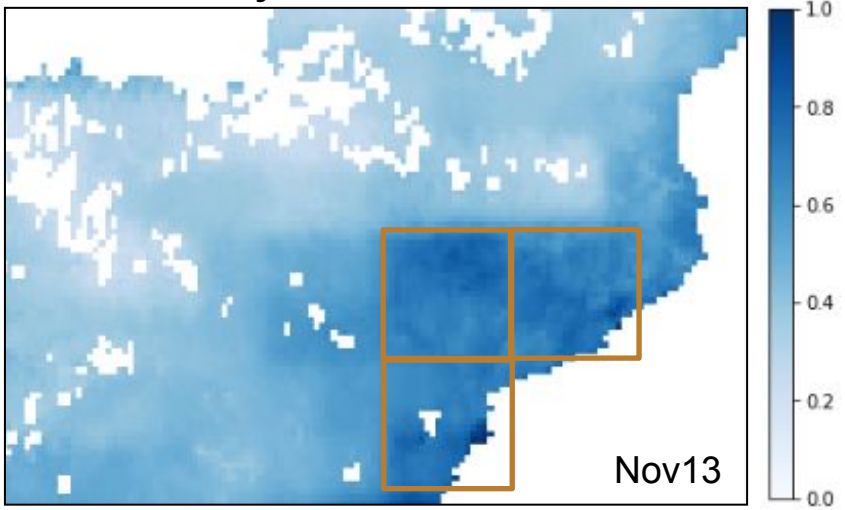
SM at monthly scale



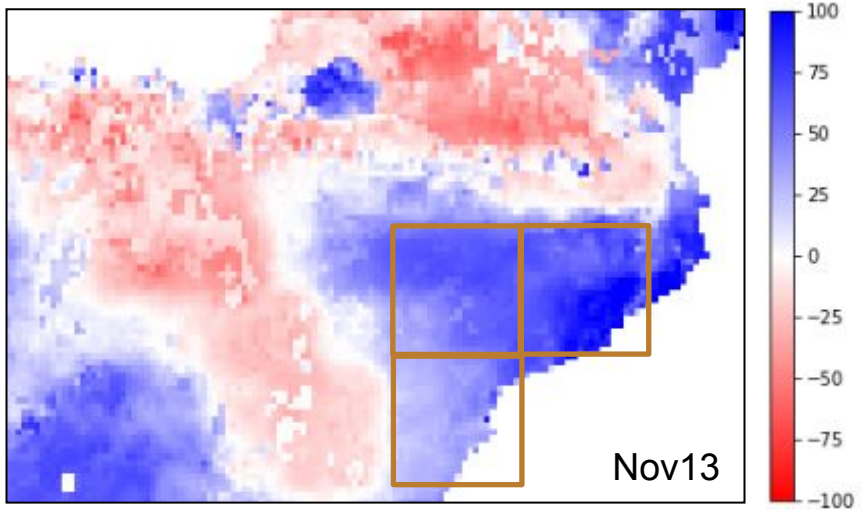
SD inherits pixelation of SM images



PET at monthly scale



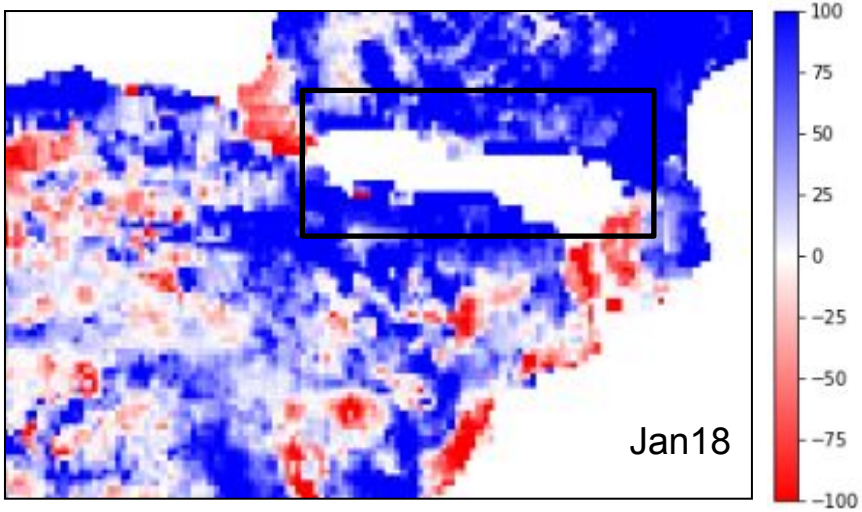
WS shows less subtle pixels inherited from PET



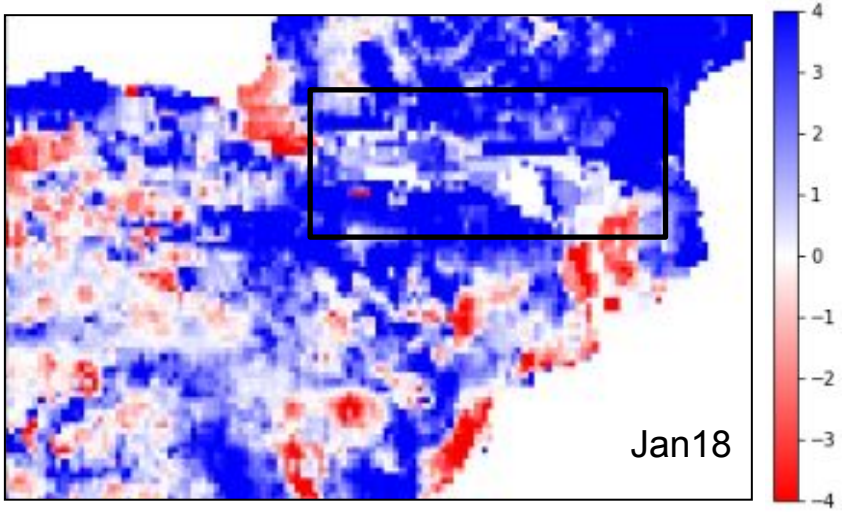
Resolution effects propagate from input data to indexes with +/- impact

VI – Issues processing RS data: Discontinuities

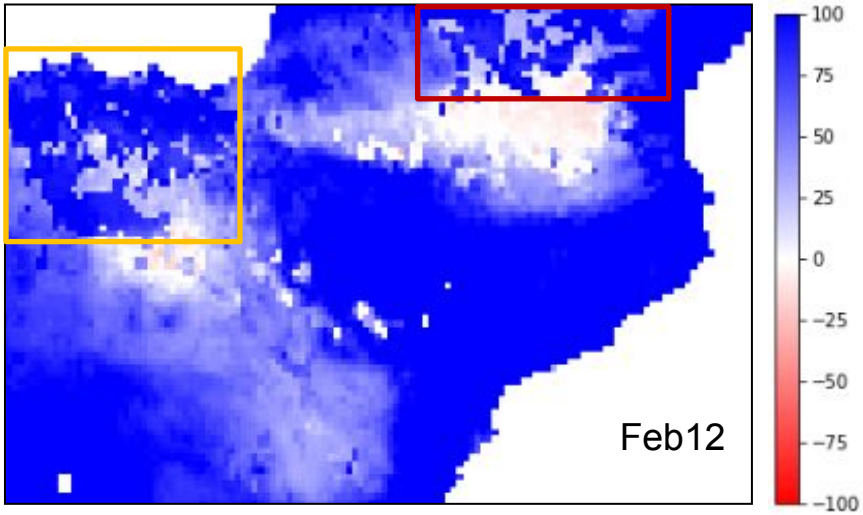
Soil deficit (SD) monthly



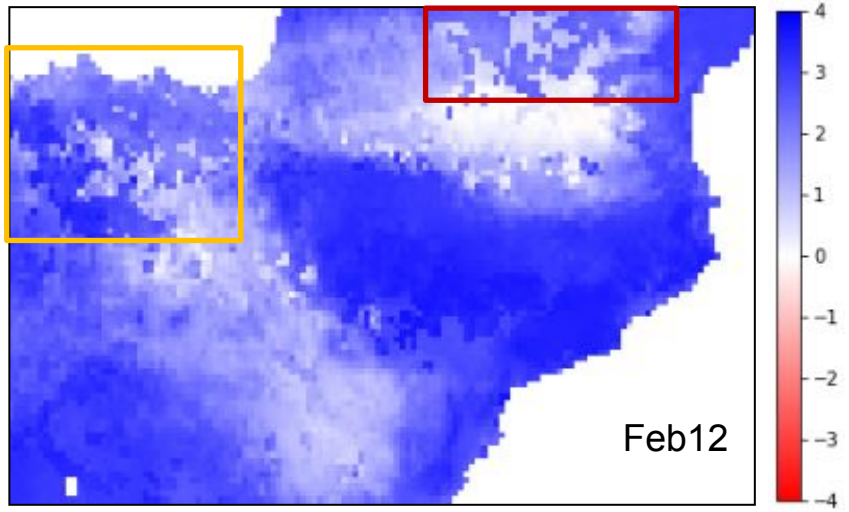
SD refilling may cause discontinuities in SMDI



Water Stress (WS) monthly



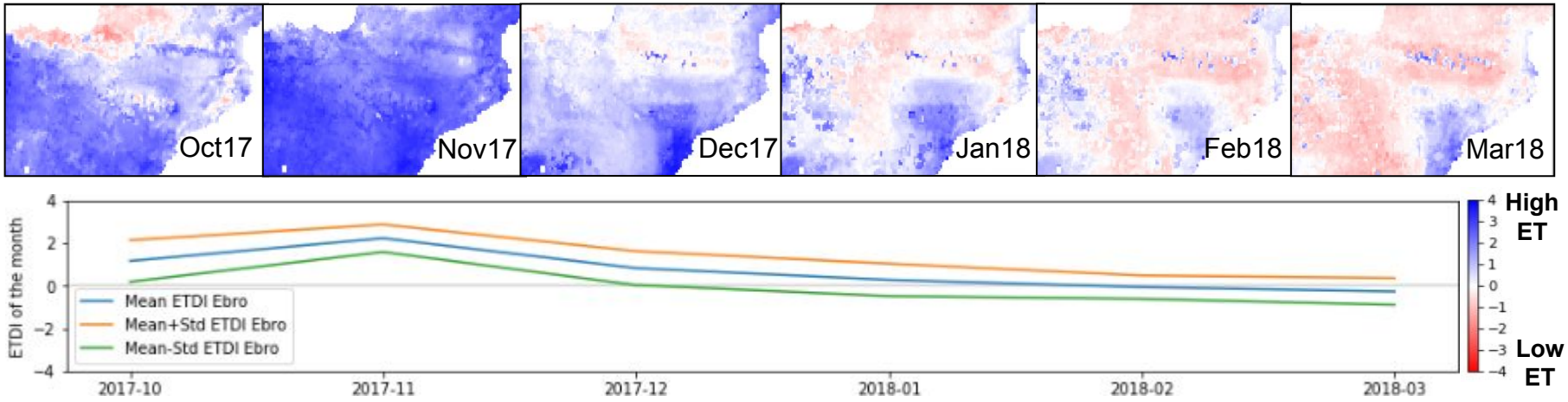
ETDI impacted by discontinuities of WS



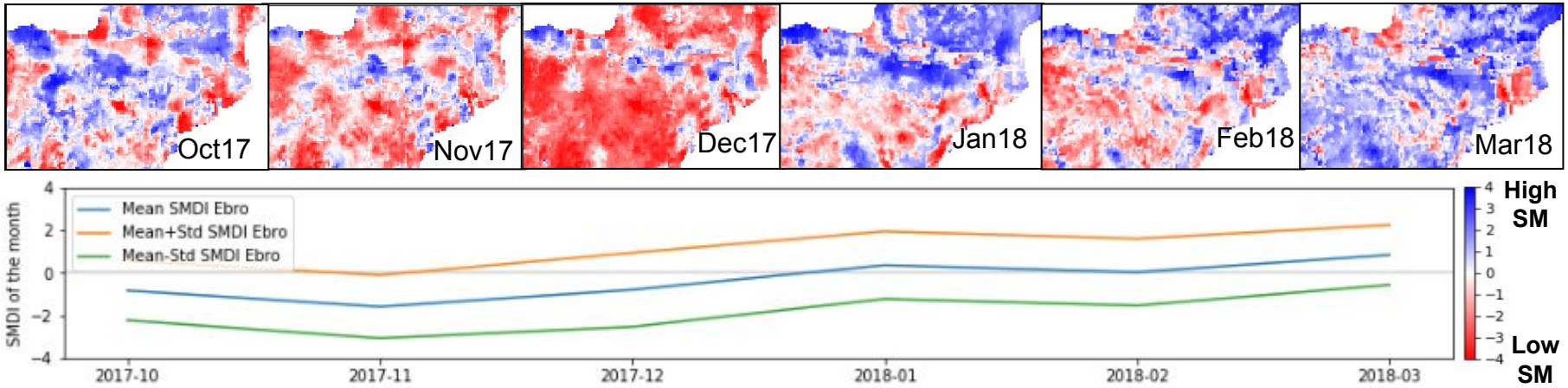
Applying spatial interpolation apart from temporal may reduce issues

VII – Drought analysis: SM-ET a synchronic opposition…

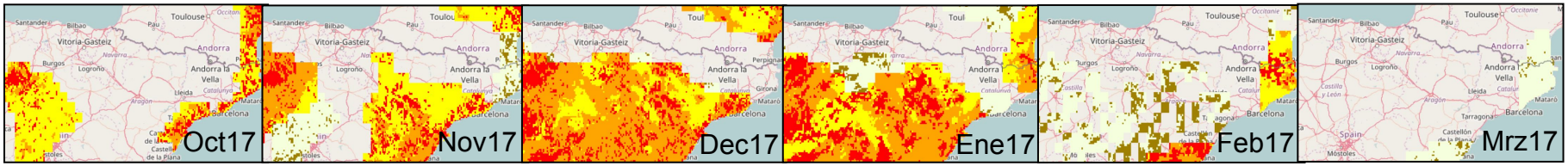
Evapotranspiration Deficit Index (ETDI) **ETDI monthly**



Soil Moisture Deficit Index (SMDI) **SMDI monthly**

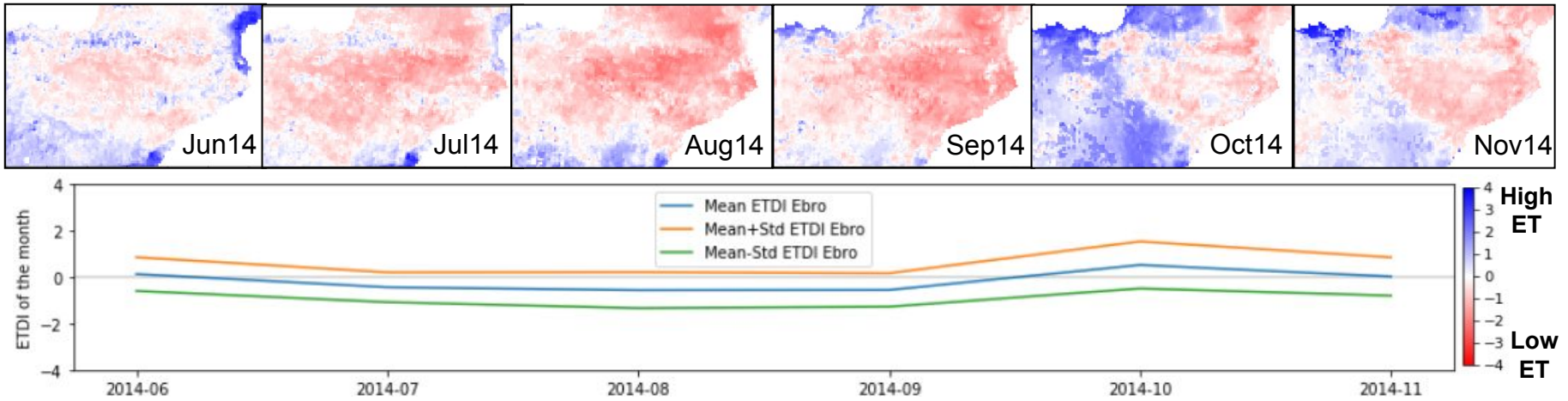


EDO's Combined Drought Indicator (CDI):

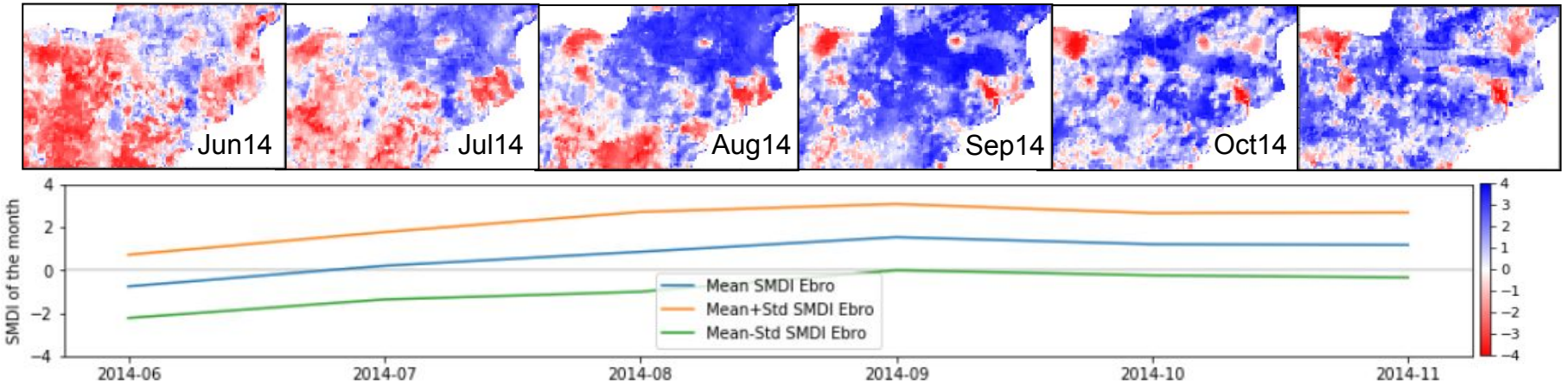


VII – Drought analysis (II): …not always synchronic

Evapotranspiration Deficit Index (ETDI) **ETDI monthly**



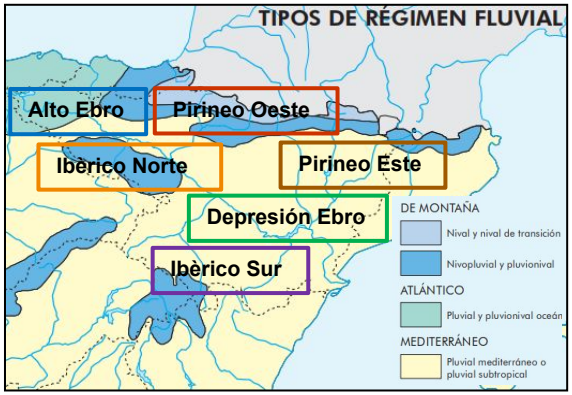
Soil Moisture Deficit Index (SMDI) **SMDI monthly**

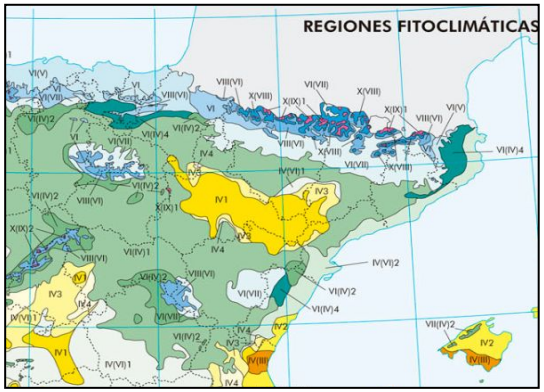


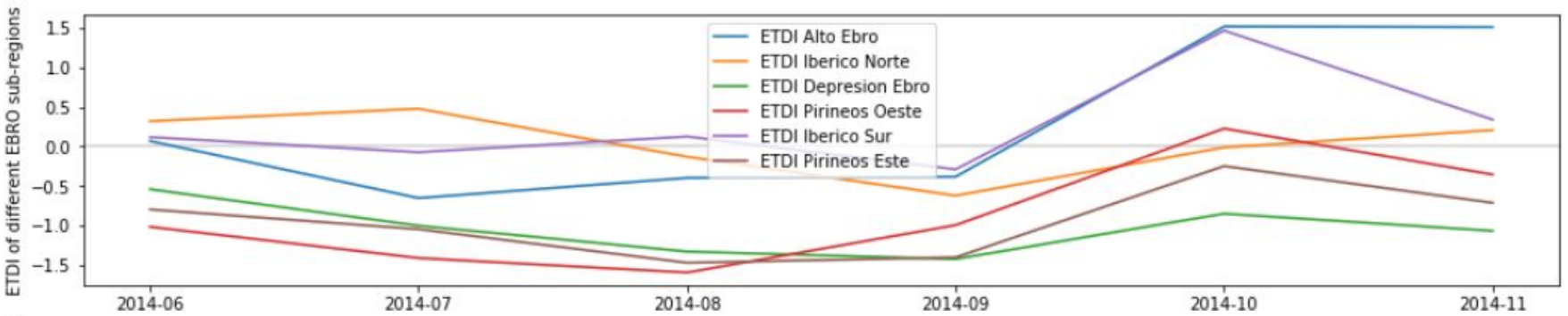
EDO's Combined Drought Indicator (CDI):

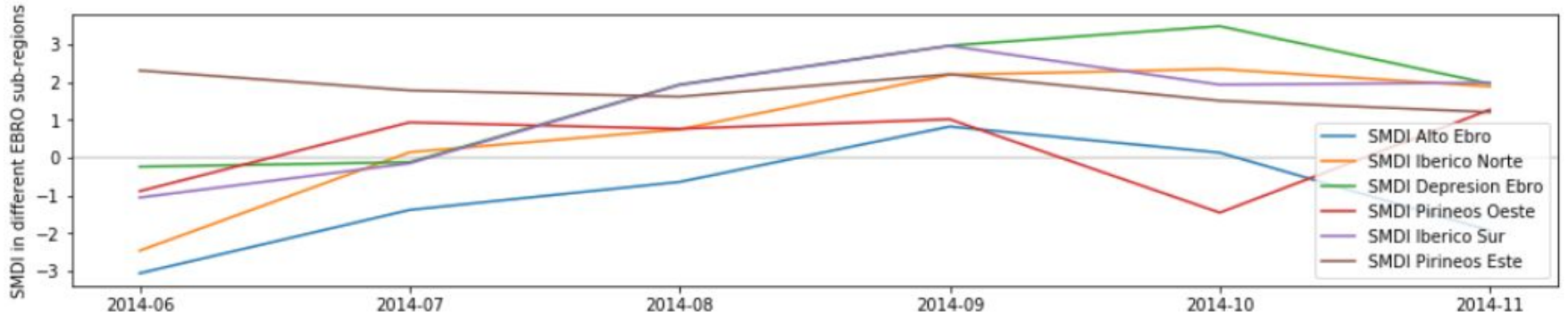
VIII - Regional characteristics relevant for drought

- **Regions with different synoptic weather patterns: Atlantic/Continental/Mediterranean**
- **Drought generation associated to these climatic patterns and biogeographical ones**
- **Physical regionalization for drought analysis suitable for stakeholders?**









IX - SMDI/ETDI prospective results enable analyzing:

1. The complementarity of evapotranspiration and soil moisture drought indexes. **Combined, they are very informative, especially about correlations / lags**

2. The spatio-temporal patterns of drought affecting EBRO basin
   based on the regional prevalence of synoptic/bioclimatic settings in certain areas.

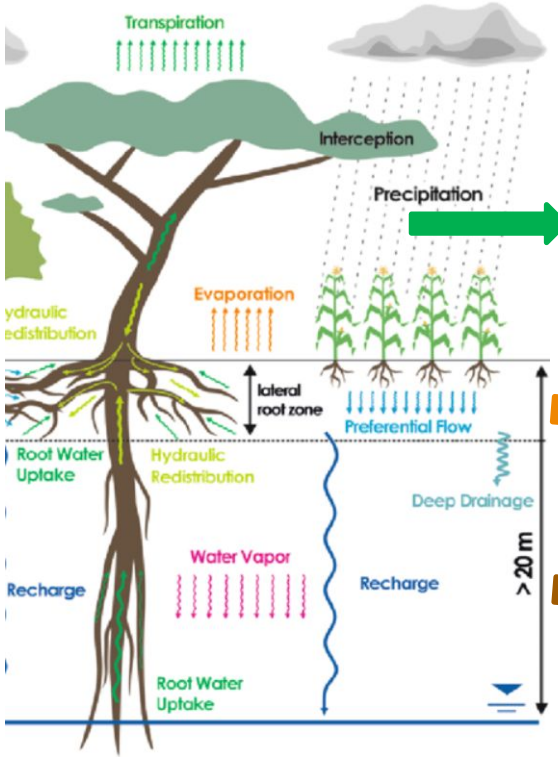
3. The potential of RS data for calculating drought indexes
   e.g. its comparability to LSM results and its potential of integration with simulations

4. The driving role of vegetation on the evolution of ETDI / SMDI indexes
   taking advantage of the wide range of bioclimatic conditions in the EBRO basin

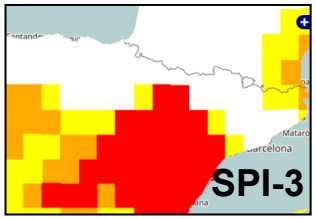
X - Complementarity of drought indicators

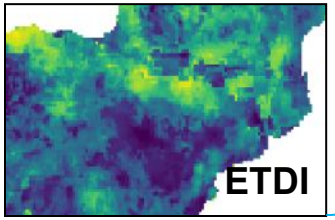
- **Drought indexes (e.g SPI) based on climatic var. (or combination) anticipate drought**
- **Integrating vegetation in indexes can add relevant info to the significance of drought**
- **Soil characteristics can reveal the influence of water storage in drought resilience**
- **The role of deep water storage in drought in semi-arid climates remains underevaluated**

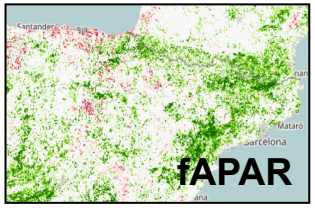
Illustration of the Critical zone:
M. Beyer & F. Holst

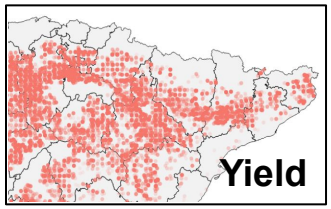


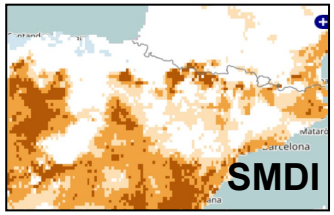
Groundwater (aquifers)







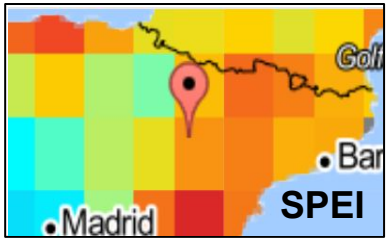




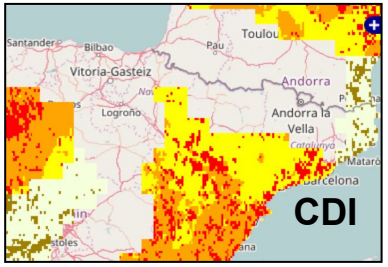
Deep SM storage?

GW storage?

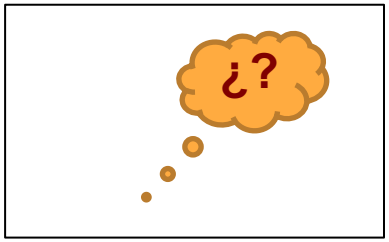
Combined indexes



Multilevel combined indexes



Water cycle integrated indexes



Questions?