# Dynamic time warping analysis of the evolution of SMOS surface and in-situ soil moisture time series

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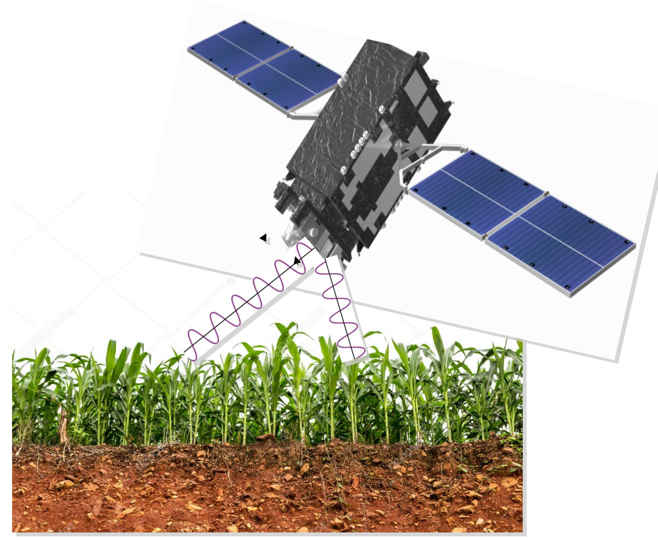
## 1. Introduction

Knowledge about the **temporal variability** of **subsurface soil moisture (SM)** is critical for hydrological and agricultural applications. The largest amount of root's biomass is developed within the 50 - 100 cm **root zone.** Satellite observations are sensitive to surface SM and SM retrievals are available at global coverage. An estimation of local subsurface SM from area-averaged satellite observation is challenging.

**Assumption:** Information about **subsurface SM** is given in **time series** of satellite observations



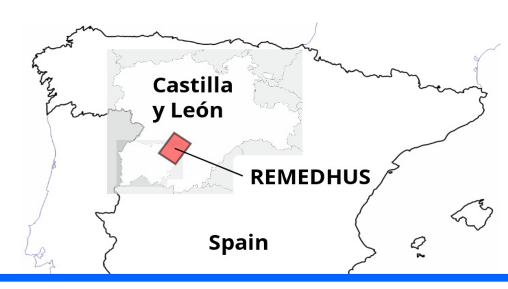
- Surface and subsurface SM are **coupled through SM-related processes**
- The **response time** between subsurface SM and satellite observations is the time span encompassing the **relevant preceding surface events**, which are making up significant contribution to subsurface SM dynamics.
- Subsurface SM estimation can be improved by better knowing the response time and assuming it to be **temporally variable** depending on...
  - Seasonality and local variations (climate, topography, land use, heterogeneity)
  - Intensity and timescale of relevant events (infiltration and runofff, evapotranspiration, root-water uptake)

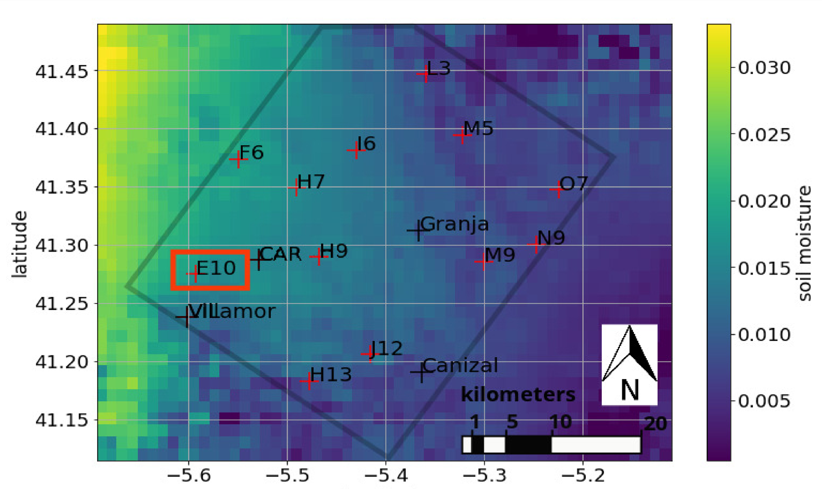
**Objective:** Estimation of the **response time** of subsurface SM to satellite observations

## 2. Data

### In-situ SM observations

Soil Moisture Measurements Station Network of the University of Salamanca (**REMEDHUS**)

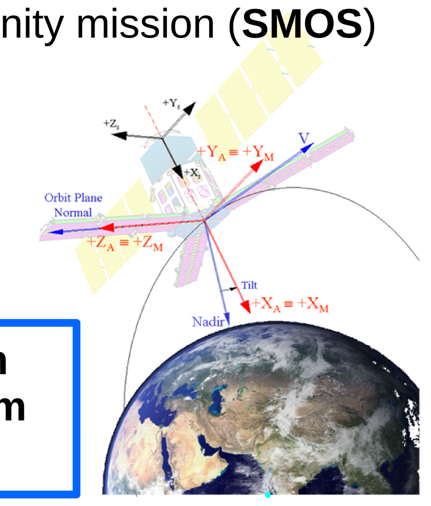


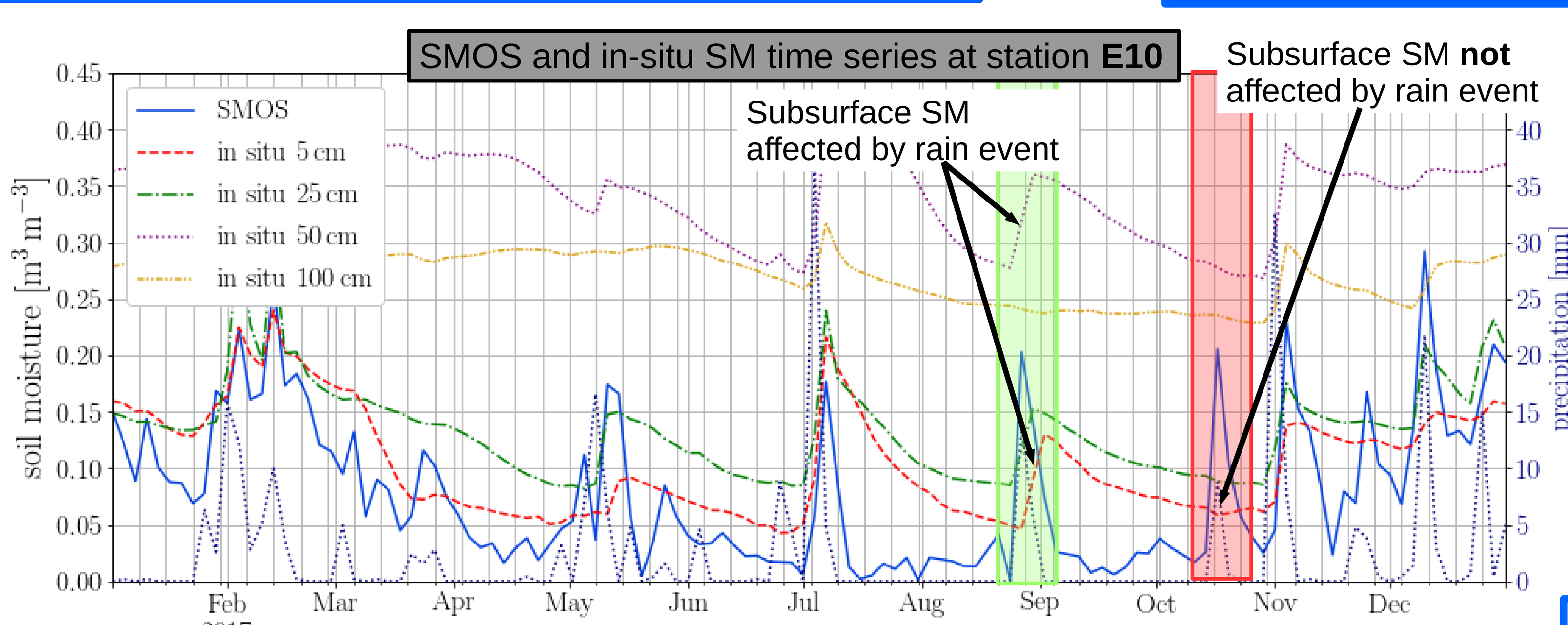

- **Multi-depth** SM observations
- **Homogeneous precipitation** among the network
- **Land use** broadly **stable** (rainfed cereals, vineyard)

### Satellite observations

**Downscaled high-resolution L4 SM product** of the Soil Moisture Ocean Salinity mission (**SMOS**)



- Penetration depth: **top 5 cm**
- Spatial resolution of **1 x 1 km**
- Revisit time of **2-3 days**




SM time series acquired...
- at the root-zone (50 + 100 cm)
- at near-surface (5 + 25 cm)
- from SMOS

...differ in **dynamic range** and **magnitude / frequency of fluctuations** due to...
- intrinsic soil properties
- atmospheric forcing (variable penetration depth of satellite)
- initial SM conditions

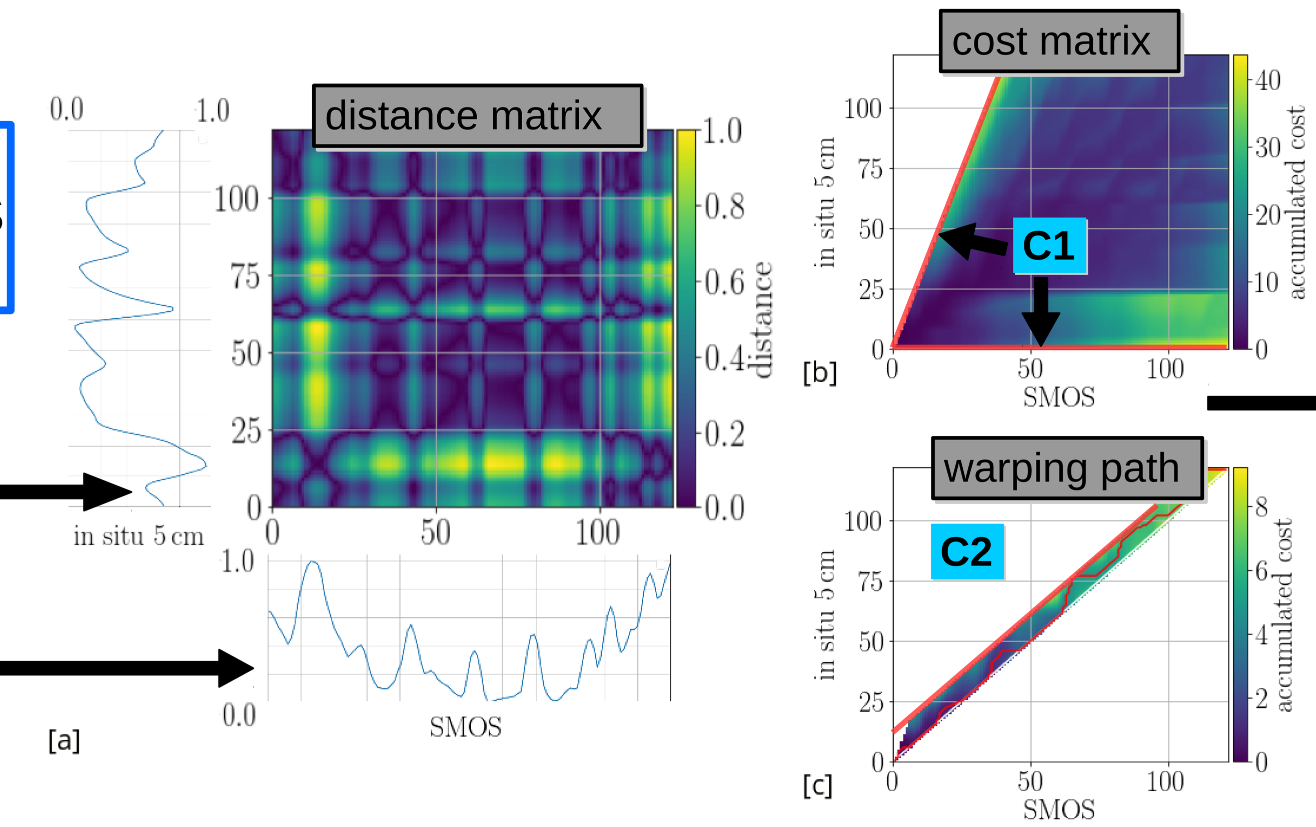
use normalized trend series

## 3. Methods and Results

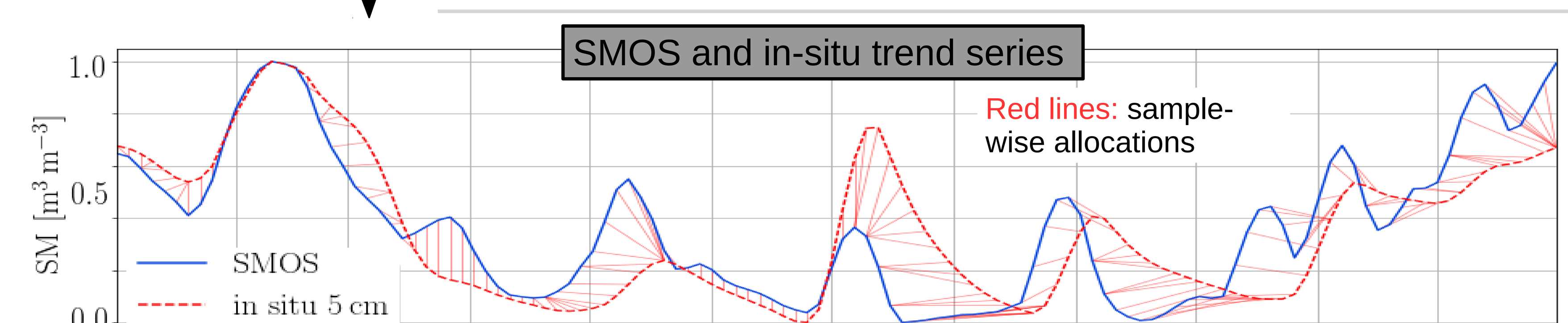
**Idea:** **Estimating the response time** of in-situ to SMOS SM by **quantifying the time lag** between their trend series using **Dynamic Time Warping (DTW)**

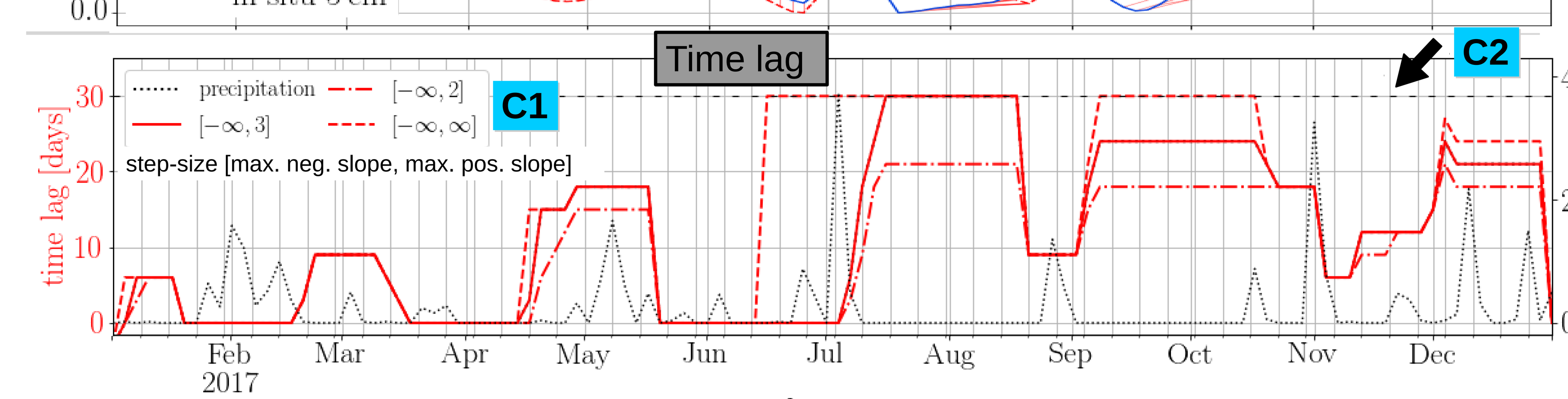
**DTW technique:**

**Input**: in-situ and SMOS **trend series**

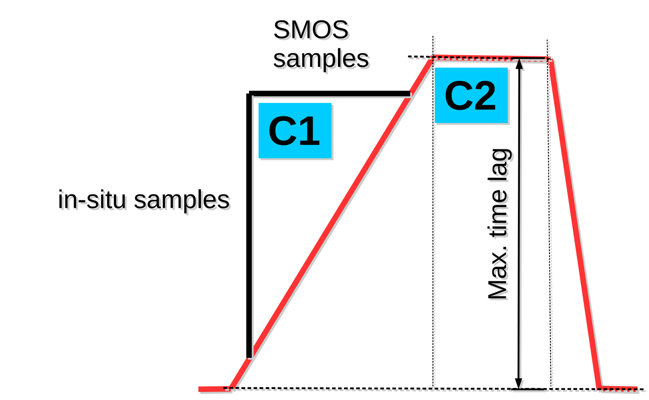



**Output**: time lag




### DTW parameter customization:




**C1** **Step-size condition**
Controls the **rate of accumulation and reduction** of time lag
- **Positive slope:** speed of drying out of the soil
- **Negative slope** accounts for rapid SM increase due to strong wetting fronts

**C2** **Maximum allowed time lag**
avoids the time lag from getting trapped at unreasonably high values

### Preliminary results:

DTW finds the **optimal alignment** between satellite and in-situ SM time series
- Based on the **most significant common features** contained in both SM trend series
- Considering the **relative changes** of the **non-linearly related** observations

The time lag evolution reflects a temporally variable response time, within which subsurface SM is mainly affected by surface processes.

It follows the alternation of short wetting fronts after precipitation events and subsequently lasting drying periods.

## 4. Future proceeding

1. The temporal evolution of the response time can be investigated at specific stations to better understand the relation between **surface processes and subsurface SM** at different timescales.
2. In-situ time series can be compared to satellite observations among **different locations and depth levels** to study **heterogeneity and variability** of the response time within SM networks.
3. The response time obtained at different locations can be **categorically subdivided** with regard to similar land use, soil type and SM seasons to test cases of **characteristic patterns of time lag evolution**.

## References

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Obra Social "la Caixa"