EO based Soil Moisture measurements
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Outline

1. Introduction to drought and Surface Soil Moisture (SSM)
2. Evolution of Soil Moisture-Products
3. State of the art of Surface Soil Moisture datasets
1. Introduction to drought and Surface Soil Moisture (SSM)
No ‘one-size-fits-all’ definition of drought...

*Droughts are prolonged periods of time when an area or region receives shortages in the water supply, whether atmospheric (below-average precipitation), surface water or ground water.*
Introduction

- **Meteorological Drought** – defined based on the degree of dryness compared to an average or “normal” amount as well as the duration of the dry period.

- **Agricultural Drought** – occurs when soil moisture and rainfall are inadequate during the growing season to support healthy crop growth up to maturity. soil-/groundwater deficits

- **Hydrologic Drought** – the concern here is how a deficiency of precipitation influences the hydrologic system. HDs usually occur with a time lag compared to meteorological and agricultural droughts

- **Socio-Economic Drought** – associates the supply and demand of some economic good with elements of meteorological, hydrological, and agricultural drought.
SOIL MOISTURE:

- Water stored in soil within reach of the plants - crucial for biological life
- Definition e.g. \( \theta = \frac{\text{Water Volume} \ (\text{m}^3)}{\text{Total Volume} \ (\text{m}^3)} \)
- a fundamental component of the water cycle
- Crucial for environment and climate system
- Affected by precipitation, temperature, soil characteristics etc.
- Influences hydrological and agricultural processes and plays a key role in drought monitoring and prediction

\[ \text{Was recognized as an } \textbf{Essential Climate Variable} \text{ in 2010} \]
In-Situ Measurement

- Very accurate
- Only representative for very small areas
- Limited network or non-existent

Earth Observation

- Timely, spatially continuous and large-scale observation
- Data derived from multiple sensors: active (e.g. ASCAT, Sentinel-1) and passive (e.g. AMSR-E, SMOS) microwave sensors
- The amount of water in the soil can thus be estimated by measuring the strength of signal
- Advantage of all-weather observations
- Can be automated to a fully automatic degree
2. Evolution of Soil Moisture Products
Surface soil moisture (SSM)

- Surface soil moisture (SSM) - first 5-7 cm of the soil layer are measured
- Top layer crucially important
- used to detect droughts at a very early stage of development.
- SSM information crucial in semi-arid and sub-humid regions
- Suitable EO-variable to assess effects of agricultural droughts - define intensity, duration, severity and spatial extent
Soil Moisture Products

Surface Soil Moisture (SSM)

Soil Water Index (SWI)

Horizons
- 0 (Organic)
- A (Surface)
- B (Subsoil)
- C (Substratum)
- R (Bedrock)

SSM

SWI
Soil Water Index (SWI)

Quantifies moisture conditions at various depths in the soil

→ SWI is the important indicator for water storage monitoring

- Surface soil moisture (SSM): first 5 cm of the soil layer are measured
- Derived Soil Water Index (SWI): first 1 m of the soil layer is modelled
Soil Moisture Products

- Surface Soil Moisture (SSM)
- Soil Water Index (SWI)
- SWI Anomaly (DSWI)
SWI anomaly (DSWI)

- To monitor difference of current SWI to historical conditions microwave data since 1991 were processed to create a
- Historical database since 1991
- Historic data on SSM and SWI can be used to calculate the average condition, which can further be used to quantitatively
- Assess how present Soil moisture level differs from historic “normal” level, expressed by the **SWI anomaly (DSWI)**
- = deviation of the actual SWI from the long-term average SWI.
2018 European Drought
2018 European Drought

Germany
Soil moisture based drought monitoring

- 1 - No drought
- 2 - Dry conditions
- 3 - Moderate dry conditions
- 4 - Very dry conditions
- 5 - Extreme dry conditions
- 6 - Exceptional dry conditions
3. Surface Soil Moisture datasets
Surface Soil Moisture datasets

**ESA Climate Change Initiative (CCI) – global**

- Covers a 40 years period from Nov. 1978 – today
- Anomalies can be clearly identified
- Best available continous soil moisture observation dataset at present
- Has contributed to hundreds of studies worldwide
- Combines advantages of active and passive microwave remote sensing
- Three products: active, passive and combined product
- Global coverage at a temporal resolution of 1-3 days
- Fully automatic and service chain operational
- Broad spatial footprint of 0.25° (25km) homogenize small scale soil moisture variability
- Does not meet the need for small scale soil moisture changes

[https://www.esa-soilmoisture-cci.org](https://www.esa-soilmoisture-cci.org)
Copernicus Surface Soil Moisture – SSM1km

- Spatial resolution 1km
- Sentinel-1 C-SAR
- Daily composite, available from Jan. 2015
- Observation frequency 1.5 - 4 days over Europe
- Relative SSM, in % saturation
- Excellent capability to capture small-scale soil moisture changes
- Limitations

GeoVille

- Spatial resolution (<100m)
- Near real time
- Multi sensor input (SMAP, Sentinel-1, MetOp ASCAT)
- Supporting data: in-situ data for validation
- Observation frequency 1.5 - 4 days over Europe
- Coverage: local/regional/national
- RMSE: < 0.1 Vol.%

https://www.geoville.com/
### SSM datasets - Overview

<table>
<thead>
<tr>
<th></th>
<th>CCI</th>
<th>SMOS</th>
<th>Copernicus</th>
<th>GeoVille</th>
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<tbody>
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<td>Area</td>
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<td>Europe</td>
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<td>Scale</td>
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<td>15 km</td>
<td>1 km</td>
<td>&lt;100 m</td>
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<tr>
<td>revisit</td>
<td>daily</td>
<td>revisit 1 to 3 days</td>
<td>revisit 1.5 to 4 days</td>
<td>revisit 1.5 to 4 days</td>
</tr>
<tr>
<td>Time</td>
<td>since 1978</td>
<td>since 2009</td>
<td>since 2015</td>
<td>since 2015</td>
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<td>Sensors</td>
<td>active/passive Microw.</td>
<td>passive MIRAS L-band</td>
<td>Sentinel-1 C-SAR</td>
<td>multiple sensors</td>
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</table>

- **CCI**: Global, 25 km resolution, daily data since 1978, active/passive microwave.
- **SMOS**: Global, 15 km resolution, revisit 1 to 3 days, since 2009, passive MIRAS L-band.
- **Copernicus**: Europe, 1 km resolution, revisit 1.5 to 4 days, since 2015, Sentinel-1 C-SAR.
- **GeoVille**: Europe / global, <100 m resolution, revisit 1.5 to 4 days, multiple sensors.
Data continuity is fundamental to the development of reliable satellite data records for drought applications.
EO Surface Soil Moisture data

- improves drought predictability
- importance for near-future vegetation anomalies
- sophisticated processing chains
- local, national, regional and global scale
- not corrupted by cloud cover
- high temporal resolution
- long time series...
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