The sensitivity of drought variability to index and data selection

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• Can a meteorological drought index sufficiently represent agricultural/soil moisture drought for drought identification?

• What is the sensitivity of the drought index to the choice of input data?
How can we measure drought?

The different definitions of drought make it challenging to measure it

• Indices simplify the complex mechanisms of droughts and convey them as a single numeric values
  • More than 150 drought indices were developed encompassing meteorological and hydrological parameters (Zargar et al., 2011)

• Direct drought metrics measure drought effected parameters
  • Stationary soil moisture measurements are sparse and don’t cover long time periods
  • Stream flow, gross primary production (GPP)

➢ This study: Two drought indices (SPI and PDSI) and modelled and satellite observed soil moisture (GLDAS and GRACE)
Standardized Precipitation Index (SPI)

- **SPI** (McKee et al., 1993) specifies drought time scales for, typically 3 to 48 months, by simply comparing precipitation with its multiyear average.
- A long-term precipitation record is fitted to a probability distribution from which a normal density distribution is derived.

![SPI Distribution](image)

Palmer Drought Severity Index (PDSI)

- **PDSI** (Palmer, 1965) measures the departure (d) of moisture balance from normal conditions, taking rainfall, evapotranspiration, runoff and water loss into account.

\[
P = \alpha_i \cdot PE + \beta_i \cdot PR + \gamma_i \cdot PRO - \delta_i \cdot PL
\]

- Penmen-Monteith method requires multiple datasets and various assumptions:
  - Min/max/mean temperature
  - Precipitation
  - Available water content
  - Wind speed
  - Specific humidity
  - Downward shortwave solar radiation
  - Latitude, elevation, albedo
Overlap of PDSI and SPI

- 1948-2013
- SPI3, SPI6 and SPI12 overlap with PDSI
- SPI set as “truth”
- How much of the time the SPI is below the 10th percentile is represented in the PDSI?
  - PDSI has a memory of about 12 months
- Onset and cessation can vary

- GPCC precipitation
- NCEP temp, humidity, radiation, wind speed

Schematic:

- PDSIpm & SPI3
- PDSIpm & SPI6
- PDSIpm & SPI12

PDSI

10th percentile
• Dataset used can decide between drought and non-drought conditions

• Highest variations in regions with less observations (EAF, EAS, AMZ)
GLDAS

• **CLMv1** 10 soil layer depths up to 3.4m
• **NOAHv1/v2** 4 soil layer depths up to 2m
• Anomalies of average layer soil moisture
• estimate terrestrial water and energy storage
• v1 forcings: NCEP’s GDAS, disaggregated CMAP, and AFWA radiation datasets
• v2 forcings: The Princeton Global Meteorological Forcing Dataset
Correlation of drought indices with GLDAS soil moisture levels

GLDAS NOAHv2

- SPI3 best co-variability
  - SPI uses GPCC precipitation
  - 1948-2013
- PDSI uses GPCC precipitation, NCEP temperature, solar radiation, wind speed and specific humidity

GLDAS NOAHv2 0-10cm

- SPI3 best co-variability
- PDSI uses GPCC precipitation, NCEP temperature, solar radiation, wind speed and specific humidity

GLDAS NOAHv2 10-40cm

- SPI6 best co-variability
- PDSI uses GPCC precipitation, NCEP temperature, solar radiation, wind speed and specific humidity

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Correlation of SPI indices with GLDAS soil moisture levels:

- SPI3: 0-10 cm
- SPI6: 10-40 cm
- SPI12: 0-10 cm
- SPI12: 10-40 cm

PDSI uses GPCC precipitation, NCEP temperature, solar radiation, wind speed and specific humidity.
High correlations of DIs in the subtropics

- Inclusion of ET is not crucial to identify agricultural drought in the mid latitudes
- Variations in soil moisture in the subtropics is mainly driven by precipitation
Correlation of SPI1 with GLDAS soil moisture levels

- SPI1 uses GPCC precipitation
- GLDAS NOAHv2
  - 0-10cm
  - 10-40cm

Correlation SPI1gpcc and NOAHv2 0-0.1m

Correlation SPI1gpcc and NOAHv2 0.1-0.4m

Stipples are $R^2 \geq 50\%$.
Inclusion of evapotranspiration vs choice of dataset for 0-10cm soil moisture

Temperature data:
- UDel
- CRUTS
- NCEP

Precipitation data:
- UDel
- CRUTS
- GPCC

➢ Choice of data in most regions more important than ET (MED, EAF, WNA, AMZ)
• SPI identifies droughts in low to mid latitudes (15°-40°N/S) as well as the PDSI identifies droughts.

• Using longer time scales for calculating precipitation anomalies (> 6 months) identifies droughts as well as soil moisture estimates, which include evapotranspiration

• Attention is required when selecting datasets for computing drought indices, depending on the region of interest
Thank you very much for your attention!

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GRACE JPL

• monthly anomalies of liquid water equivalent thickness (lwe)
• derived from temporal gravity field variations measured by the GRACE satellite, based on the RL05 spherical harmonics
• Unlimited depth

GLDAS

• CLMv1 10 soil layer depths up to 3.4m
• NOAHv1/v2 4 soil layer depths up to 2m
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• v1 forcings: NCEP’s GDAS, disaggregated CMAP, and AFWA radiation datasets
• v2 forcings: The Princeton Global Meteorological Forcing Dataset
• Weak correlations in dry and high altitude/latitude regions

• Higher correlations in the low to mid latitudes (~15 - 40°S, ~30 - 55°N)

• PDSI does not perform much better than SPI9/12 showing that the SPI captures deeper soil moisture as well
References


## Utilized data

<table>
<thead>
<tr>
<th>Data</th>
<th>Years available</th>
<th>Variables used</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERA Interim</td>
<td>1979-2016</td>
<td>Wind speed, spec. humidity, dw sw solar radiation, max/min temperature</td>
</tr>
<tr>
<td>NCEP reanalysis II</td>
<td>1948-2016</td>
<td>As above, but mean temperature, precipitation</td>
</tr>
<tr>
<td>GPCP</td>
<td>1979-2016</td>
<td>Precipitation</td>
</tr>
<tr>
<td>GPCC</td>
<td>1900-2013</td>
<td>Precipitation</td>
</tr>
<tr>
<td>AWC</td>
<td>constant</td>
<td>Available water content</td>
</tr>
<tr>
<td>GRACE JPL</td>
<td>2002-2016</td>
<td>monthly anomalies of liquid water equivalent thickness</td>
</tr>
<tr>
<td>GLDAS CLM/NOAH</td>
<td>1979-2016</td>
<td>Average layer soil moisture</td>
</tr>
<tr>
<td>CRU TS v.4.01</td>
<td>1901-2016</td>
<td>Precipitation, min/max temperature</td>
</tr>
<tr>
<td>scPDSI</td>
<td>1850-2014</td>
<td>scPDSI (Dai et al., 2011)</td>
</tr>
<tr>
<td>CMAP</td>
<td>1979-2017</td>
<td>precipitation</td>
</tr>
</tbody>
</table>

→ Regridded to 2.5° x 2.5°
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Level of uncertainty in measuring drought
- Depends on datasets used
- PDSI and SPI are well correlated (1948-2013)
What is a drought?

- Drought research differentiates between drought **types** and **characteristics**


Ukkola et al. 2017 (modified)
**Palmer Drought Severity Index (PDSI)**

**Self-calibration method (scPDSI)** (Dai 2011, Wells & Hayes 2004)
- PDSI model uses constant parameter for local climate
- Local distribution of PDSI values is sometimes skewed → rescaling
- Calibrated parameter very similar to original
- Calibration can exaggerate or diminish the trend