Monthly probabilistic drought forecasting using the ECMWF Ensemble system

Christophe Lavaysse(1)
J. Vogt(1), F. Pappenberger(2) and P. Barbosa(1)

(1) European Commission (JRC-IES), Ispra Italy
(2) ECMWF, Reading, UK

WWOSC, Montréal, QC, Canada
"To provide to policy and decision makers science advice with independent, evidence-based scientific and technical support."

**EDO (Europe)**
http://edo.jrc.ec.europa.eu/edov2

**ADO (Africa)**
http://edo.jrc.ec.europa.eu/ado
Several definitions and forecast products:

1. Meteorological droughts: based on precipitation
   - Standardized Precipitation Index (SPI), drought spells

2. Hydrological droughts:
   - Palmer Drought severity Index (PDSI), Standardized runoff Index (SRI)

3. Agronomical droughts:
   - Soil moisture anomalies (SMA), Vegetation index

complexity so uncertainties

Objective of this study:
Forecasting the meteorological droughts
- quantify the predictability of these events
- produce an early warning system (1 month LT, SPI1)
Data and methods

Identified adapted products for drought timescales → Ensemble products

**ENS**
- Forecast: 51 members
- Hindcast: 5 members
- Years of hind.: 20 years
- 1/week
- Model "up-to-date"
- 1*1 resolution

**SEAS or S4**
- Forecast: 51 members
- Hindcast: 15 members
- Years of hind.: limited to 20 years
- 1/month
- Coarser resol.
- 1*1 resolution

Also used: → the unperturbed members (CNTRL)
### Standard Precipitation Index (SPI)

#### Methodology

1. Ranked accumulated precipitation from the hindcast
2. Fitting a gamma distribution
3. Transformation to a normal distribution

<table>
<thead>
<tr>
<th>SPI values</th>
<th>Conditions</th>
<th>SPI values</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1 to -1.5</td>
<td>moderately dry</td>
<td>2</td>
<td>extremely wet</td>
</tr>
<tr>
<td>-1.5 to -2</td>
<td>severely dry</td>
<td>1.5 to 2</td>
<td>severely wet</td>
</tr>
<tr>
<td>≤ -2</td>
<td>extremely dry</td>
<td>1 to 1.5</td>
<td>moderately wet</td>
</tr>
</tbody>
</table>
Standard Precipitation Index (SPI)

☑️ Flexible
  • accumulation period
  • size of domain

☑️ Interests
  • bias corrected
  • relative to the antecedent precipitation
  • adapted to compare precipitation from different products / regions

☑️ recommended by WMO

Period of forecasts: Nov. 2012 - Nov. 2013
Standard Precipitation Index (SPI)

Climatology of the SPI in Europe

Droughts observed during the period [1992-2012]

<table>
<thead>
<tr>
<th>SPI &lt; -1</th>
<th>SPI &lt; -1.5</th>
<th>SPI &lt; -2</th>
</tr>
</thead>
</table>

⚠️ for SPI < -2, database too short
Ensemble scores

General evaluation of the SPI (median)

- better score for ENS than SEAS
- sensible to small variations of SPI
- strong dependency upon the meteorological situation
  → large temporal variability
Ensemble scores

Distribution of the individual members for the extreme SPI

SPI observed
Drought
Floods

SPI forecasted
Drought
Floods
Ensemble scores

Distribution of the members

Distribution of ranked members

Mean and spread of members

SPI observed < -1.5
SPI observed > 1.5

Mean SPI forecasted
SD SPI forecasted
Forecast a drought:

**Obs** = 'binary'

**Pred** = 'probability'

ROC score

- very sensible to the number of members and events
- slightly improvement of the ENS
Forecast a drought: Reliability diagrams

- comparable results
- artificial improvement with diff thresholds
- no significant signal for SPI < -2

- Significant reliability for SPI < -1 and -1.5
- No information about the missed events.
- Brier better for SPI: 0.14
  reliability > resolution
- Mean $= 0.71$
- Spatial variability of about 10% of the ROC
- Larger variability depending upon the weather conditions

$\rightarrow$ No significant seasonal variation of the ENS performance
Developing a warning system

Provide to stakeholders a clear and robust information for a warning system
Obs and pred = 'binary'

➔ Identification of products:
  • individual values (quantiles, median)
  • integrative (mean)
  • probabilistic (percentage of the members)
  • deviations / differences between members
    • consistency of the members
    • provide an assessment of the uncertainty

➔ Definition of thresholds (same nb. of events / obs.)

What is the accuracy of a drought warning?
Is there an index better than the others?
Evaluation of the index

• 1/3 of droughts detected one month in advance
• ± 7% following the method used
• Larger variability of SEAS using these criteria
Evaluation of the index

- More adapted for extreme values (Stephanson et al. 2008)
- larger variability between methods
- Behaviour of the driest members more related to the droughts observed

### Methods

**Extreme Dependency Score**

- Q13
- Q23
- MED
- Q77
- Q88
- SpL
- Spl
- SpD
- SpF
- Mean
Evaluation of the index

Using the percentage of members

- Opposite POD / PC evolutions
- Optimum ETS around 30% of members
- Similar results with SEAS
Evaluation of the index

Uncertainty based on the SPI values/distribution?

- SPI lower for misses in rel. to correct neg.
- No distinction for hits and false alarms
### Evaluation of the index

#### Uncertainty based on the spread of the members:

<table>
<thead>
<tr>
<th>Drought observed</th>
<th>Drought yes</th>
<th>Drought no</th>
</tr>
</thead>
<tbody>
<tr>
<td>yes</td>
<td>2.31 ± 0.4</td>
<td>2.37 ± 0.4</td>
</tr>
<tr>
<td>no</td>
<td>1.99 ± 0.4</td>
<td>1.88 ± 0.3</td>
</tr>
</tbody>
</table>

- No significant differences
- Difficult to assess the uncertainties
Conclusions/Perspectives

✓ 1/3 droughts correctly detected
✓ 10% of variation following the method used but main errors from the model
✓ ENS slightly better than SEAS
✓ No clear indicators to provide the uncertainties
→ sensitivity to the horizontal resolution (ongoing)

Next step:

• droughts prediction using predictors (WT, large scale components over Europe and Africa)
  → improvement of the warning system ?
• Dry spells (short term drought events using 10d accumulation periods)
  → especially important over region with low resilience