# Application of Drought Indices to Assess Drought Conditions in Changed Climate


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## Introduction

The Standardized Precipitation Index (SPI) and the Palmer Drought Severity Index (PDSI) are two of the most frequently used drought indices for assessing drought conditions. In addition, the Z-index, which is closely related to PDSI but does not account for the persistence, is also used. While the SPI is based solely on precipitation data, the PDSI and Z indices are based on precipitation and temperature data and on the available soil water content. In the original versions of these three indices, a single input weather series is used both to calibrate the models and to construct drought index series, so that the range of the values is approximately the same for all input weather series (self-calibrated indices). To allow for the assessment of the climate change impacts, we made the following modification: the indices are now calibrated using the present climate (= learning) weather series and then applied to the future climate weather series (relative indices).

## Drought Indices

**SPI** = standardized precipitation sum over a given period (**various time-scales**; 1-month and 24-months aggregation is used here). **Gamma distribution** was used to approximate precipitation sums distribution
**input: precipitation** (various time-scales)

**PDSI** (Palmer, 1965) is based on a soil moisture/water balance model
**input:** **- precipitation and temperature** (monthly, weekly)
**- available soil water content** (1 parameter) + latitude
"self-calibrated" index → 2nd / 98th percentiles = -4.00 / +4.00

**Z-index** is the key component of PDSI calculations. It describes the water balance value using the same scale **as the PDSI, but for each month irrespective of the water balance status in preceding periods.**
**input:** **- precipitation** and **temperature (**monthly, weekly**)**
**- available soil water content** (1 parameter) + latitude

## Drought Spells

**Definition:** drought spell is a continuous period with
**SPI:** (SPI ≤ 0) and ($SPI_{min}$ ≤ -1)
**PDSI** and **Z-index:** (PDSI ≤ -1) and ($PDSI_{min}$ ≤ -3)

**The present analysis is based on**
- average value of the indices
- number of months (percentage) within the drought spells

**Other characteristics of drought spells (not used here):**
duration, accumulated intensity [SUM(X), X = drought index], average intensity, maximum intensity

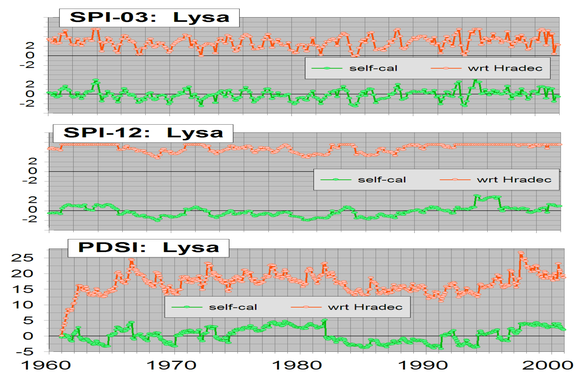
## Introduction of Relative Drought Indices

- ***Self-calibrated SPI, PDSI*** (previous versions of indices) are applied on the same series that are used to calibrate them
  ⇒ the PDFs of indices are about the same for each input series
  Þ **and therefore one can hardly use these indices to study the impact of climate change, or to make a between-station comparison of drought conditions**

- ***Relative SPI, PDSI*** **(present version): indices are calibrated using a "learning" series** (reference station or reference period), which is generally different from the application series

**The relative drought indices allow:**
- **between-station comparison of drought conditions**
  – learning series = reference station
  – test series = other station to be compared with the reference station
- **assessing impact of the climate change on a specific station**
  – learning series = present climate series
  – application series = future climate series

## Self-Calibrated vs. Relative Drought Indices




## Two Approaches (A, B) to Assessing Impact of Changed Climate on the Drought Indices

**Learning series** ( = present climate series) used to calibrate indices:
A) observed surface station series
B) surface variables modelled by GCM

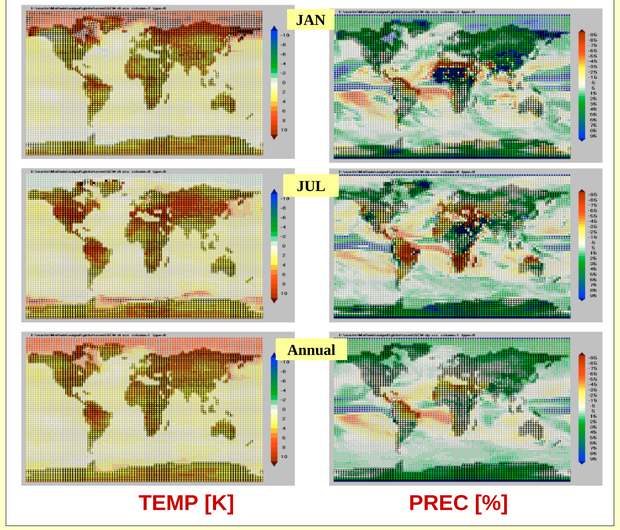
**Application series** (= representing future climate):
A) surface station series modified by climate change scenario
B) surface variables modelled by GCM

**Monthly series are used in both approaches**

(results obtained in approach A are found in www.ufa.cas.cz/dub/impacts/2005-egu-drought.pdf)

## HadCM3 Climate Change Scenario

SRES-A2; scenario = (2060-2099) minus (1961-2000)




## Impact of Climate Change on SPI

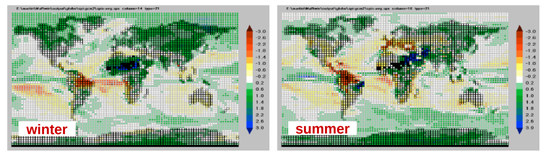
[PREC↘] ⇒ [SPI↘] ⇒ [#(dry months)↗]
[PREC↗] ⇒ [SPI↗] ⇒ [#(dry months)↘]

## Impact of Climate Change on PDSI and Z-index

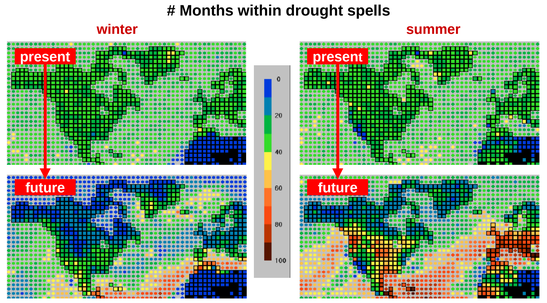
[PREC↘] + [TEMP↗] ⇒ [PDSI↘↘] ⇒ [#(dry months)↗↗]
[PREC↘] + [TEMP↘] ⇒ [PDSI↘OR↗] ⇒ [#(dry months)↗OR↘]
[PREC↗] + [TEMP↗] ⇒ [PDSI↘OR↗] ⇒ [#(dry months)↗OR↘]
[PREC↗] + [TEMP↘] ⇒ [PDSI↗↗] ⇒ [#(dry months)↘↘]

## SPI-01

Average value [(2060-99) w.r.t. (1961-2000)]

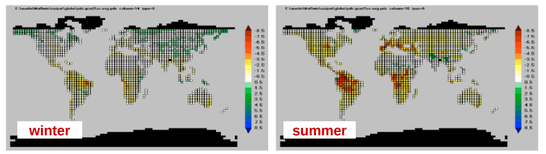



# Months within drought spells

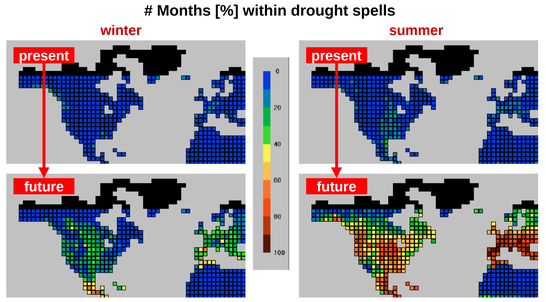



## Z-index

Average value [(2060-99) w.r.t. (1961-2000)]

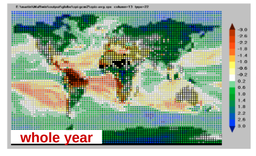



# Months [%] within drought spells

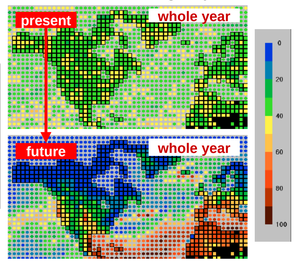



## SPI-12

Average value (2060-99) w.r.t (1961-2000)

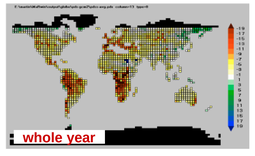



# Months within drought spells

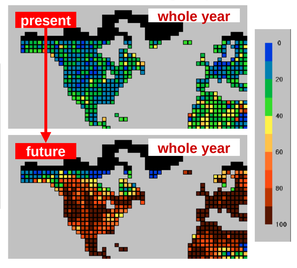



## PDSI

Average Value (2060-99) w.r.t. (1961-2000)




# Months within drought spells




## Conclusions

**Relative drought indices in assessing climate change impacts:**

- **SPI (SPI-01, SPI-12)** changes follow the precipitation changes. **Europe:** ***In winter,*** drought risk will decrease in central and northern Europe and change insignificantly in the Mediterranean region. ***In summer***, drought risk will decrease slightly in northern Europe, but increase substantially in central and southern Europe. **North America:** ***In winter***, drought risk will decrease in northern regions, but no significant change is indicated in the south and along the western and eastern coasts. ***In summer***, drought risk will decrease in the north, but significantly increase in the central and northwestern United States and along the Gulf Coast.
- **PDSI and Z-index** also account for temperature (***thus we consider them more effective in studying climate change impacts***), which is projected to rise in most parts of the world. Therefore, the areas with increased drought stress (under a changed climate) as indicated by PDSI changes are larger than the areas indicated by SPI changes. In contrast to the SPI, drought risk will not decrease anywhere in Europe or North America.

**More details and results** of our drought study were presented during two other conferences:
- http://www.ufa.cas.cz/dub/impacts/2005-egu-drought.pdf (presented in EGU-2005, Vienna)
- http://www.ufa.cas.cz/dub/impacts/2005-ems-drought.pdf (presented in EMS-2005, Utrecht)

**This Poster: http://www.ufa.cas.cz/dub/impacts/2005-agu-drought.pdf**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