Drought Indices

PDSI (Palmer, 1965) is based on a soil moisture/water balance model. Input: precipitation and temperature (monthly or weekly); available soil water content (1 parameter, based on soil-texture-based water holding capacity global data developed by Webb et al. (1993, Global Biogeochem. Cycles 7, 97–108);

Z-index is the key component of PDSI calculations. It describes a water balance value (monthly or weekly);

Relative Drought Indices

Self-calibrated indices (classical versions of indices) are applied on the same series that are used to calibrate them

⇒ the PDSIs of indices are about the same for each input series (Z^+ / 98th percentile = \pm 0.400 – 4.000) ⇒ 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 indices (rPDSI, rZ): in the first step, indices are calibrated using a "learning" series (reference station or reference period). Then the model is applied to a series, which is generally different from the learning 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; test series = future climate series)

Experiment

PDSI model is applied to monthly TEMP + PREC series simulated by 7 GCMs GCMs (SRES-A2 runs; IPCC-TAR database): CSIRO, CGCM2, ECHAM4/OPYC3, GFDL-R30, HadCM3, CCSR/NIES, NCAR-PCM

area: 66.5S,66.5N

calibration period: 1991-2020

future periods: 2031-2060, 2070-2099

spin-up: 5 years are dismissed from the analysis


Summary

Relative Drought Indices (PDSI and Z-index) and results from 7 GCMs were used in assessing drought impacts of future climate changes. Considering the differences between projections made by individual GCMs (Fig.1), the stress was put on uncertainty, which is shown together with the median values in the maps (Figs.2-4).

∆TEMP (Fig.2-left): Temperature is projected to increase over the whole globe and in all seasons; more over continents and most significantly in northern regions in winter. Good inter-GCM fit is found, except for (i) the northern regions (in winter most apparent inter-GCM uncertainty, spring and autumn), (ii) Amazonia, (iii) southeastern USA, (iv) Central America.

∆PREC (Fig.2-right): much higher (compared to ∆TEMP) inter-GCM uncertainty, though a good inter-GCM fit is found in some regions for some seasons (example: • spring (MAM): increase in North America, Central-N+NE Europe and Central Asia; decrease in Mediterranean and Middle East; • summer: decrease in NW USA, inland South Africa, Turkey, and parts of Middle East; increase in Central and NE India; • autumn: increase of PREC north of 50-55 N over continents and NW India; decrease in SW Australia; • winter: increase of PREC in E. Africa and over large areas of N.America, Europe and Asia; decrease in NW Mexico)

PDSI changes (Fig.3-top panel): decreased values of rPDSI over most regions of the globe indicate increased risk of drought. Most significant increase of the drought risk (great decrease of rPDSI together with low inter-model uncertainty) is projected for central USA, central-south Canada, Mexico, most of Brazil, south and equatorial (west of 35E) Africa, south Australia, Mediterranean + Middle East, Japan. Many of these regions belong to important agricultural regions.

Z-index shows changes in water balance in individual seasons. For example: • of the four seasons, summer shows the largest area exhibiting a significant increase of drought stress: nearly whole USA, Europe (except for the North of 55° latitude) and Brazil will become drier; • the greatest increase in drought risk in Mediterranean and Mexico will occur in spring; • in some regions (central USA, NW of Great Lakes, parts of Brazil, west-equatorial and interior-south Africa, Turkey, coastal area along the Biskai gulf, Balkan peninsula), the drying will occur in all seasons.

Not surprisingly, uncertainty for 2031-60 (Fig.4) is larger than for 2070-99 (Fig.3). However, the regions where the good inter-GCM fit is found for 2070-99 exhibit similar pattern of change even for 2031-60.

!!! What is now extreme drought may become normal !!!
Combining information from 7 GCMs

**Motivation:** To show the multi-model mean/median + uncertainty in a single map

**Step 1:** results obtained with each of 7 GCMs are re-gridded into 1x1º resolution

**Step 2:** median (med(X)) and std (std(X)) from the 7 values in each grid box are derived

**Map:** the median is represented by a colour, the shape of the symbol represents the value of uncertainty factor Q:

\[ Q = \frac{std(X)}{med(X)} \]

**Interpreting the uncertainty:**
- squares and circles \( std(X) < 0.5 \times med(X) \) indicate that med(X) differs from 0 at significance level higher than 95% (roughly)
- 4-point stars indicate high uncertainty \( std(X) > med(X) \)
- the greater is the proportion of grey (over sea) or black (over land) colour, the lower is the significance, with which the median value differs from zero

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**Fig. 2** Climate change scenario (2070-2099) wrt (1991-2020) based on 7 GCMs

**Fig. 3** Relative drought indices in 2070-2099 (calibration period = 1991-2020) based on 7 GCMs.

- rPDSI: annual means; rZ: seasonal means

**Fig. 4** Relative drought indices in 2031-60 - calibration period = 1991-2020; based on 7 GCMs -
- rPDSI: annual means; rZ: seasonal means