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# GPCC Drought Index – a new, combined, and gridded global drought index

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## Abstract

The Global Precipitation Climatology Centre Drought Index (GPCC-DI) provides estimations of precipitation anomalies with respect to long term statistics. It is a combination of the Standardized Precipitation Index with adaptations from Deutscher Wetterdienst (SPI-DWD) and the Standardized Precipitation Evapotranspiration Index (SPEI). Precipitation data were taken from the Global Precipitation Climatology Centre (GPCC) and temperature data from NOAA's Climate Prediction Center (CPC). The GPCC-DI is available with several averaging periods of 1, 3, 6, 9, 12, 24 and 48 months for different applications. Since spring 2013, the GPCC-DI is calculated operationally and available back to January 2013. Typically it is released at the 10th day of the following month, depending on the availability of the input data. It is calculated on a regular grid with 1°spatial resolution. All averaging periods are integrated into one netCDF-file for each month. This dataset can be referenced by the DOI: 10.5676/DWD\_GPCC/DI\_M\_100 and is available free of charge from the GPCC website [ftp://ftp.dwd.de/pub/data/gpcc/html/gpcc\\_di\\_doi\\_download.html](ftp://ftp.dwd.de/pub/data/gpcc/html/gpcc_di_doi_download.html).

## 1 Introduction

Drought indices are a measure of anomalies of available water with respect to long term statistics. They can be based on station as well as on grid data like precipitation, temperature, wind speed, radiation, evaporation but also non-meteorological data like soil type, soil moisture or ground water level. It is common to classify three main conditions: drought, normal and wet. Drought conditions are refined to moderate, severe and extreme drought (Palmer, 1965).

Drought indices allow to distinguish easily between the different conditions. They provide information on the onset and end, their length and severity of droughts.

There are several types and definitions of droughts. Usually, droughts are defined as a shortage of available water (Heim, 2002; Wilhite and Glantz, 1985). The differ-

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ences between aridity and drought have to be kept in mind. For example, droughts are categorized as meteorological, agricultural or hydrological droughts, with a variety of definitions (Anderson et al., 2010; Heim, 2002; McKee et al., 1993; Wilhite and Glantz, 1985) for each category. They can also differ in the time span of the water deficit.

- 5 A precipitation deficit of one or two consecutive months has usually an impact on the agricultural yield whereas longer lasting deficits have an impact on ground water levels and river runoffs (e.g. Sustek and Vido, 2013).

## 2 Some existing drought indices

Depending on the available data and the target application specific drought indices were developed. Some of the most common are discussed in this section. A thorough review of drought indices is given in Heim (2002).

One frequently utilized drought index is the Palmer Drought Severity Index (PDSI, Palmer, 1965). It is based on several empirical relationships. The PDSI uses precipitation, evapotranspiration, soil water recharge, runoff, water loss from soil and an empirical weighting factor (Lloyd-Hughes and Saunders, 2002). Also the soil water storage capacity is needed. The evapotranspiration can be measured or calculated using several parameterizations. A strength of the PDSI lies in its high level of standardization. On the other hand it is build on empirical relationships and comes with a high demand on input data that can be hardly addressed on the global scale (Lloyd-Hughes and Saunders, 2002).

Another drought index is the Reconnaissance Drought Index (RDI, Tsakiris and Vangelis, 2005). It is based on the ratio of precipitation and potential evapotranspiration (PET). Again, the potential evapotranspiration can be calculated applying several parameterizations or measured (see Sect. 5). It is possible to standardize the RDI. However, the RDI is not defined, if the PET is zero.

The Standardized Precipitation Index (SPI) was developed by McKee et al. (1993). It is based on the anomaly of (monthly) precipitation divided by the standard deviation

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of precipitation for this time span (e.g. one month). Only precipitation data are needed, which is a big advantage. On the other hand, if the temperature changes due to climate change, the SPI has not the ability to take the increased evapotranspiration into account. This leads also to misleading values in arid areas (Lloyd-Hughes and Saunders, 2002). An adjustment of the SPI by DWD, called SPI-DWD, fixed this problem (Pietzsch and Bissolli, 2011). Nevertheless, the usage of the SPI was recommended by WMO (WMO, 2009). A user guide of the SPI is also given in WMO (2012).

A recently developed drought index is the Standardized Precipitation Evapotranspiration Index (SPEI, Vicente-Serrano et al., 2009). It is based on the difference between precipitation and PET. As for RDI and PDSI, the calculation or measurement of the PET is the main challenge. The calculation of the SPEI is similar to the calculation of the SPI. As an alternative to the SPI, the SPEI was suggested by WMO (WMO, 2009).

### 3 Some existing drought index data sets and monitoring tools

There are a number of regional and global drought index data sets and monitoring tools. They differ in target region, input data, processing of input data (like regridding), utilized drought index, timeliness and scope of provided information and data (e.g., figures, bulletins or data files). Some of them are briefly described below, but it is not a comprehensive review!

For instance, the “Drought Management Centre for Southeastern Europe” (DMC-SEE) provides figures and bulletins based on SPI for Southeastern Europe ([http://www.dmcsee.org/en/drought\\_monitor/](http://www.dmcsee.org/en/drought_monitor/), last access: 9 December 2013). Precipitation data are taken from the GPCC and downscaled to a higher resolution of  $0.01^\circ$ . The data are available back to 1986.

Another European drought data set is produced by the “Pilot Regional Climate Centre on Climate Monitoring” (RCC-CM) for the WMO-region RA VI (Europe and the Middle East). Maps and gridded data of the SPI-DWD (Pietzsch and Bissolli, 2011) are

provided with 1° spatial resolution. Precipitation products of the GPCP were utilized (Pietzsch and Bissolli, 2011).

The European Drought Observatory (<http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1000>, last access: 26 March 2014) provides drought related information based on precipitation, temperature, soil moisture and vegetation response data for Europe. The analyses can be visualized as maps and time series for user chosen locations. The time series can also be downloaded as text files, whereas the maps can only be downloaded as graphs. A comparison of several indicators is also possible at this website.

On the other hand, the North American Drought Monitor (Lawrimore et al., 2002, <http://www.ncdc.noaa.gov/temp-and-precip/drought/nadm/index.php>, last access: 26 March 2014) provide information on droughts for Mexico, USA and Canada based on SPI, PDSI and precipitation anomalies. Data can be downloaded as text files including station related data or maps.

The US Drought Monitor provides drought information for the USA (Svoboda et al., 2002, <http://droughtmonitor.unl.edu/Home.aspx>, last access: 9 December 2013). It is based on meteorological observations as well as reports from observers.

The “SPEI Global Drought Monitor” provides global maps and gridded data of the SPEI with 0.5° spatial resolution (<http://sac.csic.es/spei/>, last access: 5 March 2014). There is a monitoring tool based on precipitation data from the GPCP and temperature data from the NOAA NCEP CPC GHCN\_CAMS gridded dataset (Fan and van den Dool, 2008). The estimation of the PET is based on the parameterization from Thornthwaite (1948). Additionally, an improved version for climatological applications is provided from 1901 to 2011 based on the version 3.2 of the CRU dataset (Jones and Harris, 2013) with an enhanced estimation of the PET.

One global drought monitor based on SPI is provided by the International Research Institute for Climate and Society (<http://iridl.ldeo.columbia.edu/SOURCES/.IRI/.Analyses/.SPI/SOURCES/.IRI/.Analyses/.SPI/>, last access: 25 March 2014). The spatial resolution is 2.5°. Several precipitation data sets are used as input data.

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## 4 Used data

The GPCC-DI is based on gridded precipitation data and gridded monthly mean temperatures. Because of the necessary high timeliness only a limited number of data sets are currently available in such a timely fashion.

5 The “First Guess Product” of the GPCC (Ziese et al., 2011, doi: 10.5676/DWD\_GPCC/FG\_M\_100) is available three to five days after the end of each month and used as precipitation input data. It is based on monthly totals calculated from SYNOP-reports, interpolated to a regular grid using a modified SPHEREMAP scheme (Willmott et al., 1985) and a background climatology. A detailed  
10 description of the data set, data base and interpolation is given in Becker et al. (2013).

On the other hand monthly mean temperatures were applied from the NOAA NCEP CPC GHCN\_CAMS gridded data set (Fan and van den Dool, 2008), where the temperature data are taken from GHCN version 2 (Peterson and Vose, 1997) and CAMS (Ropelewski et al., 1984). Due to the higher timeliness of the CAMS data set, CAMS is  
15 more important for the drought index calculation. The station data are interpolated by means of a Cressman based objective analysis scheme and a background climatology. The temperature data are delivered originally with 0.5° spatial resolution (see Fig. 1). To match the GPCC grid the data are regridded to 1° spatial resolution taking land portion and area-average into account (see Fig. 2).

## 20 5 How to calculate the GPCC-DI

The calculation of the GPCC-DI is based on the above mentioned gridded data sets. We decided to use gridded data as input data and not station data, because both data sets have spent a lot of efforts to reach a high quality level. Also, we think an interpolation of station based drought indices is more error-prone than the calculation based  
25 on gridded data. Additionally, station data suffers from gaps in time series, relocation, opening and closing of stations.

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The calculation of the GPCC-DI takes place in two steps. First, the SPI-DWD and SPEI are calculated independently on the grids where possible. Afterwards, the GPCC-DI is computed using the mean of both indices for each grid cell, where both indices are valid. For the other grid cells the index that is still possible to be calculated is taken.

Although the DWD-adaptation of the SPI (Pietzsch and Bissolli, 2011) was taken into account, the SPI-DWD cannot be computed in very arid regions. This is because the applied gamma distribution to describe the distribution of the precipitation amounts has not a shape with a maximum above zero, which is necessary to calculate the SPI (see also Wu et al., 2007). Examples of the SPI-DWD with averaging intervals of one, three and six months are depicted in Figs. 3, 4 and 5. Green indicates precipitation around normal and blue precipitation above normal. Droughts occur in red areas, where precipitation is below normal. Grids without data are white. These areas are the oceans, Antarctica as well as areas where the SPI-DWD cannot be calculated due to the above mentioned limitations of the applied gamma function (see also Sect. 5.1).

The PET is computed according to the algorithm from Thornthwaite (1948). This algorithm fails in areas where the mean temperature is near or below 0 °C (see Fig. 6 and Figs. 1 and 2). Even if other parameterizations for the computation of the PET exist, they need more input data than temperature and astronomical data. To our knowledge, no data sets exist that provide for example wind speed, radiation or humidity (dew point) with the high timeliness, global coverage and spatial resolution like the applied temperature data set. Also existing PET data sets are not applicable, because they are provided as figures or files unemployable for further automated usage (e.g. <http://earlywarning.usgs.gov/fews/global/index.php>, last access: 9 December 2013).

To estimate the SPEI, the above described PET data and precipitation data are utilized. In areas, where the PET cannot be computed, the calculation of the SPEI is also impossible. This occurs north of roughly 30° N and south of about 50° S. Examples of computed SPEI are shown in Figs. 7, 8 and 9 for one, three and six months averaging intervals. The color scale is the same as for the SPI (see Fig. 3).

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As mentioned above, the gridwise combination of SPI-DWD and SPEI yields the GPCC-DI. Examples of the GPCC-DI with averaging periods of 1, 3 and 6 months are shown in Figs. 10, 11 and 12. The combination is possible due to the comparable indicating of both indices (see for example Figs. 3, 7 and 10). A nearly global coverage is possible by the combination of both drought indices. Otherwise the one which can be computed is applied. Only cold arid areas cannot be covered with this approach (e.g. Tibet).

### 5.1 How to calculate the parameters for the SPI-DWD and SPEI

To estimate the parameters of the distribution function of the SPI-DWD and SPEI, data from the reference period 1961 to 1990 were used. Temperature data were taken from the above mentioned temperature data set, regrided to the GPCC grid with 1° spatial resolution. Due to its higher data coverage and the more rigorous quality control applied, the Full Data Reanalysis Version 6 with 1° spatial resolution was utilized for the precipitation parameterization (Schneider et al., 2011, doi: 10.5676/DWD\_GPCC/FD\_M\_V6\_100). The parameters for precipitation and PET were calculated for each grid box and averaging intervall seperately.

Depending on the parameters of the gamma distribution used, the distribution has a maximum at zero or above zero. Parameter sets leading to a maximum of the distribution at zero are not applicable to compute SPI-DWD values. This occurs in areas with monthly mean precipitation at about zero millimeters. Due to the averaging of several months for the longer averaging periods, the mean precipitation total for this period can result in a maximum of the distribution above zero, even if some months of this period have monthly totals of zero millimeter. Therefore, the SPI-DWD could be calculated for some grid cells only for the longer sampling intervals, for instance in arid regions in India, China, Mongolia, Southern and Central Africa or Southern and Central America (see Figs. 3, 4 and 5).



## 6 How to interpret the index

The provided drought index is a standardized precipitation anomaly. The value of the index corresponds with the  $\sigma$ -value of a standardized normal distribution and can be interpreted as the SPI (see Table 1, Lloyd-Hughes and Saunders, 2002). Negative values correspond with precipitation totals less than normal – drought – whereas positive values conform with precipitation totals wetter than normal. Values between  $-1$  and  $1$  match to the  $1\sigma$ -environment and are defined as normal conditions or mild drought/wet.

## 7 Access to the GPCC-DI

The GPCC-DI can be downloaded as netCDF-files (net, 2014) from the DOI-referenced website [ftp://ftp.dwd.de/pub/data/gpcc/html/gpcc\\_di\\_doi\\_download.html](ftp://ftp.dwd.de/pub/data/gpcc/html/gpcc_di_doi_download.html). No registration is required to download the data.

The file for each month contains seven sets of GPCC-DI data for the different averaging intervals. These averaging intervals are 1, 3, 6, 9, 12, 24 and 48 months. The GPCC-DI is provided at a regular global grid ( $-180^\circ$  to  $180^\circ$  longitude and  $-90^\circ$  to  $90^\circ$  latitude) with  $1^\circ$  latitude by longitude grid size. This grid has no projection! One zipped netCDF-file has about 235 KB.

netCDF is a standardized, self describing binary file formate (net, 2014). In the header of each netCDF-file the coordinates of each grid cell and missing values are encoded. We reference the coordinates to the center of each grid cell. The missing value is  $-99\,999.99$ , but can be visualized with other values by visualizing software. Suitable software to analyse and convert netCDF-files is listed at the GPCC-DI website [ftp://ftp.dwd.de/pub/data/gpcc/html/gpcc\\_di\\_doi\\_download.html](ftp://ftp.dwd.de/pub/data/gpcc/html/gpcc_di_doi_download.html). Table 2 summarizes the applied grid and Table 3 the variables in the netCDF-file. The release of the DOI references implies that ISO 19115 compliant metadata are provided under web addresses constructed from the DOI proceeded by <http://data.datacite.org>. In addition, this product will also be included in the data set catalogue of the Climate Data Cen-

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tre (CDC) of Deutscher Wetterdienst (DWD), which disseminates ISO 19139 compliant metadata on its data sets through the Geo-Network software application.

The data set is regularly updated at the tenth day of each month. It can be delayed, if input data are not available in time. In this case, it will be delivered upon availability of the missing data.

## 8 Conclusions

The Global Precipitation Climatology Centre Drought Index (GPCC-DI) is a new gridded drought index with nearly global coverage. It is a combination of the SPI-DWD and SPEI and based on precipitation analyses from the Global Precipitation Climatology Centre (GPCC) and temperature data from the NOAA NCEP CPC. The spatial resolution is 1° latitude by longitude. Seven averaging intervals are provided: 1, 3, 6, 9, 12, 24 and 48 months to cover several applications from meteorological droughts to hydrological droughts. All averaging intervals are summarized to one downloadable netCDF-file ([ftp://ftp.dwd.de/pub/data/gpcc/html/gpcc\\_di\\_doi\\_download.html](ftp://ftp.dwd.de/pub/data/gpcc/html/gpcc_di_doi_download.html)). The download is free of charge and no registration is required. Due to limitations in the validity range of the underlying drought indices, the GPCC-DI cannot be provided for cold arid areas like the Southern Andes and the Himalayan, so in areas where it would not be of use anyway given the hostile conditions there.

The GPCC-DI is available back to January 2013. If the input data are available, the data set is updated regularly at the tenth of each month. It should only be used for monitoring purposes because the input data are not homogenized. Therefore we don't recalculate the data set for earlier years.

*Acknowledgements.* First of all we are most appreciative to the data suppliers who are to the largest extent the worldwide spread National Meteorological and/or Hydrological Services, but also other institutes. These data contributions have put GPCC into the position to provide the underlying global precipitation analyses applied for the described data set, and we are look-

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ing forward to their further contributions, which are crucial in order to maintain and enhance GPCP's level of products in terms of scope and quality.

We would like to thank also NOAA NCEP CPC for providing the NOAA NCEP CPC GHCN\_CAMS gridded data set and their permission to use these data.

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- Ziese, M., Becker, A., Finger, P., Meyer-Christoffer, A., Rudolf, B., and Schneider, U.: GPCC First Guess Product at 1.0°: Near Real-Time First Guess monthly Land-Surface Precipitation from Rain-Gauges based on SYNOP Data, doi:10.5676/DWD\_GPCC/FG\_M\_100, available at: [ftp://ftp.dwd.de/pub/data/gpcc/html/gpcc\\_firstguess\\_doi\\_download.html](ftp://ftp.dwd.de/pub/data/gpcc/html/gpcc_firstguess_doi_download.html) (last access: 20 March 2014), 2011. 248
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GPCC-DI value	Category
2.00 or more	extremely wet
1.50 to 1.99	severly wet
1.00 to 1.49	moderately wet
0.00 to 0.99	mildly wet
−0.99 to 0.00	mild drought
−1.00 to −1.49	moderate drought
−1.50 to −1.99	serve drought
−2.00 or less	extreme drought

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property	value
gridtype	lonlat
gridsize	64 800
xname	lon
xlongname	longitude
xunits	degrees east
yname	lat
ylongname	latitude
yunits	degrees north
xsize	360
ysize	180
xfirst	−179.50
xinc	1.0
yfirst	−89.50
yinc	1.0

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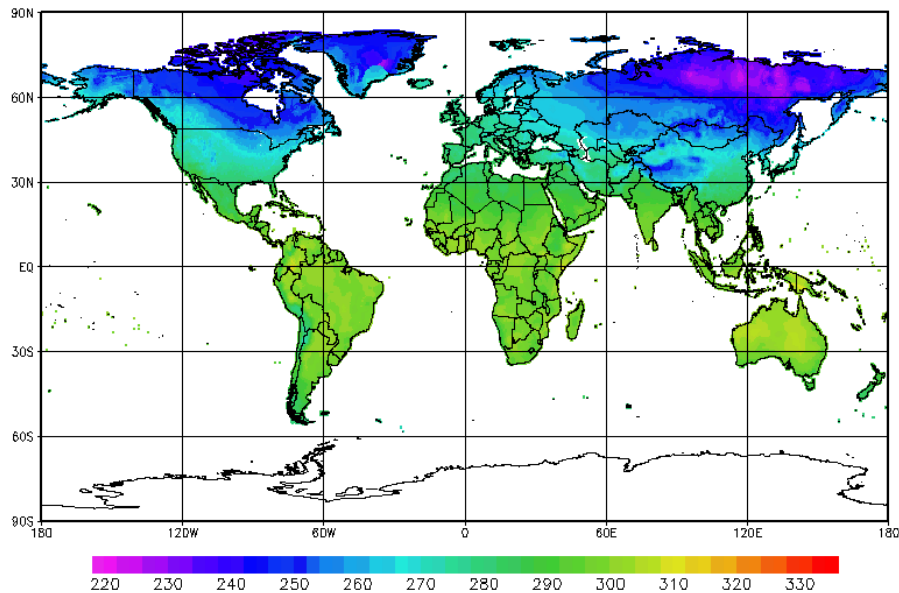
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**Table 3.** Description of the used variables in the netCDF-files.

name	description
di_01	Global Precipitation Climatology Centre Drought Index version 1 averaging time 1 month
di_03	Global Precipitation Climatology Centre Drought Index version 1 averaging time 3 months
di_06	Global Precipitation Climatology Centre Drought Index version 1 averaging time 6 months
di_09	Global Precipitation Climatology Centre Drought Index version 1 averaging time 9 months
di_12	Global Precipitation Climatology Centre Drought Index version 1 averaging time 12 months
di_24	Global Precipitation Climatology Centre Drought Index version 1 averaging time 24 months
di_48	Global Precipitation Climatology Centre Drought Index version 1 averaging time 48 months





**Fig. 1.** Monthly mean temperature in Kelvin for January 2014 from the NOAA NCEP CPC GHCN\_CAMS gridded data set with the original 0.5° spatial resolution.

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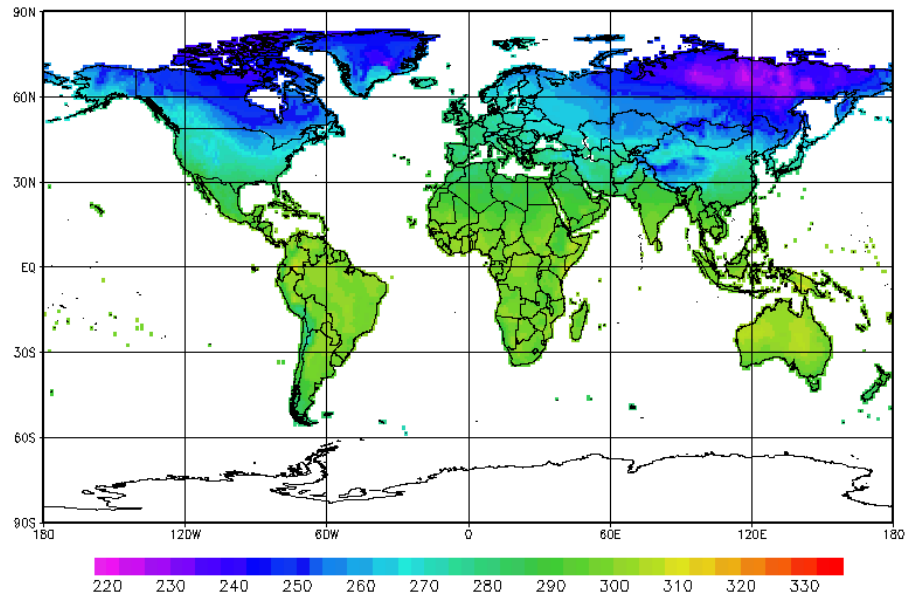
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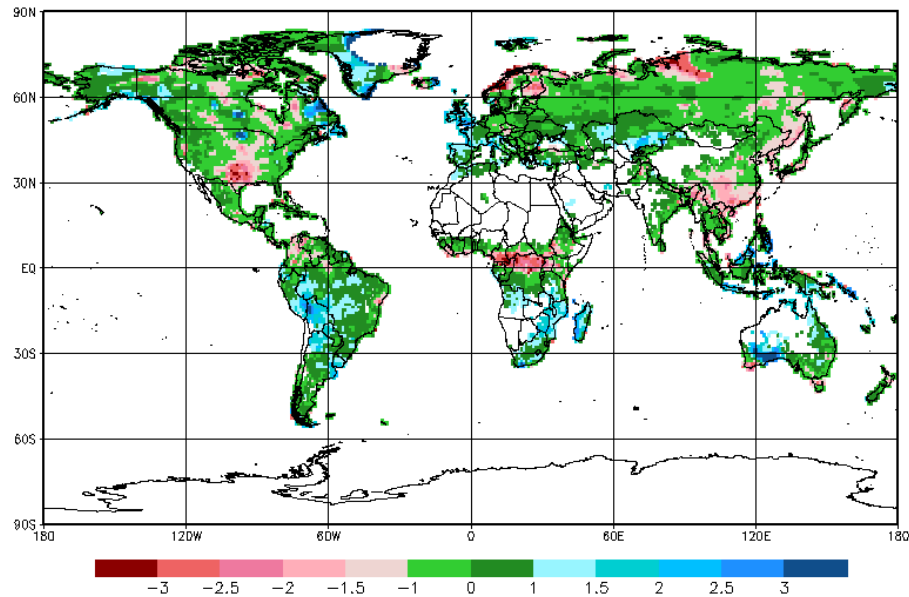
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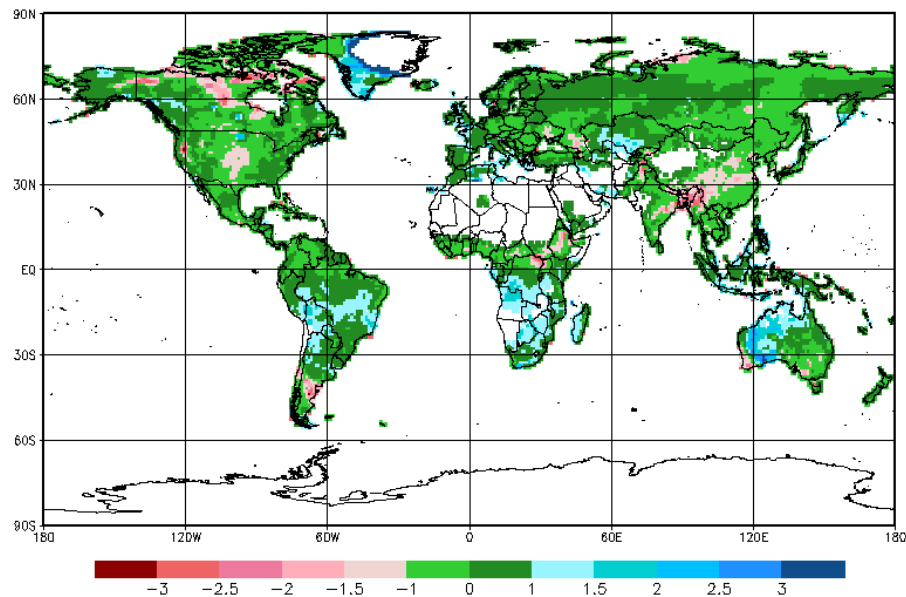
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**Fig. 2.** Monthly mean temperature in Kelvin as in Fig. 1, but regridded to the GPCC grid with 1.0° spatial resolution.

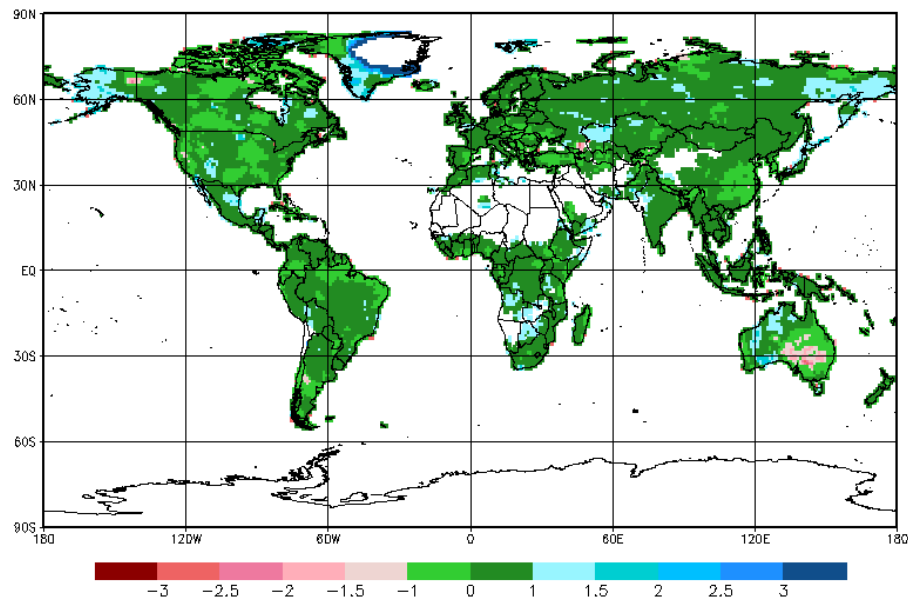


**Fig. 3.** SPI-DWD for January 2014 with one month averaging interval. Green means normal precipitation, blue wetter than normal and red drier than normal (drought). Grid cells without data are white.

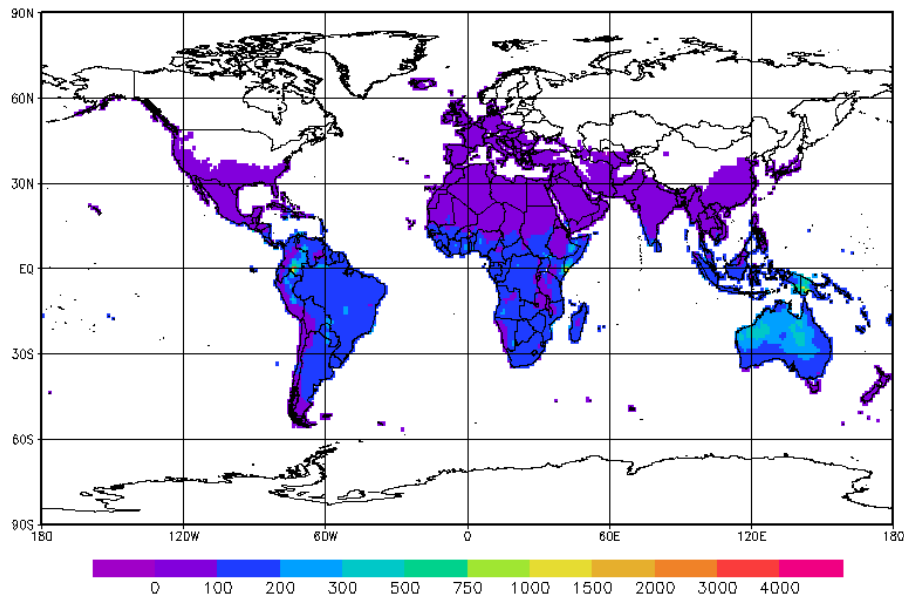
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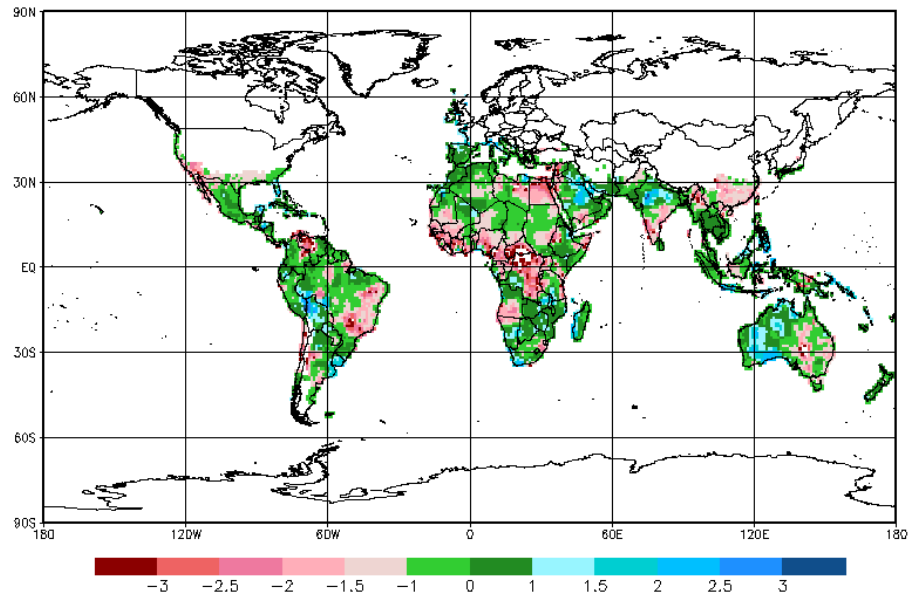
**Fig. 4.** SPI-DWD for January 2014 with three months averaging interval. Colors are the same as in Fig. 3.

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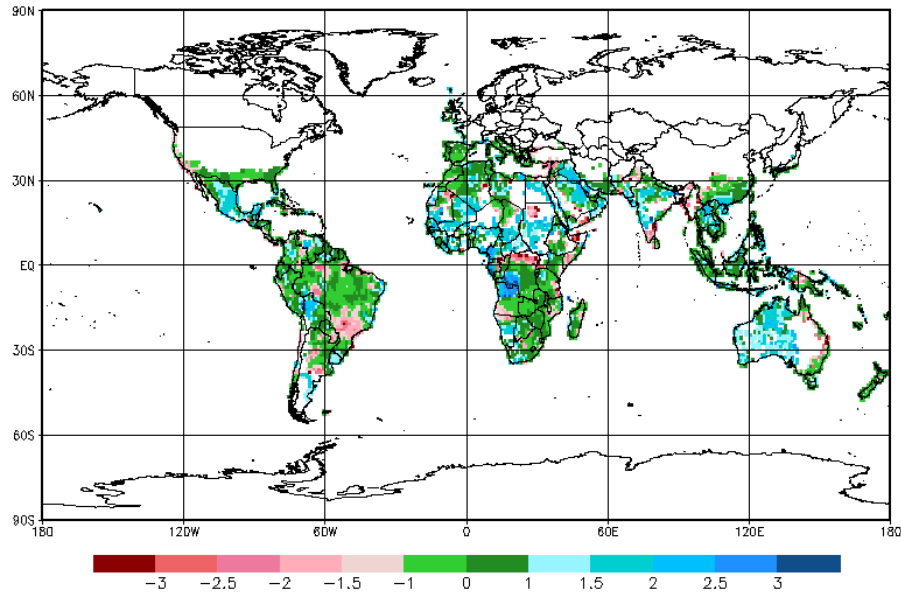
**Fig. 5.** SPI-DWD for January 2014 with six months averaging interval. Colors are the same as in Fig. 3.

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**Fig. 6.** PET calculated according to Thornthwaite (1948) for January 2014.

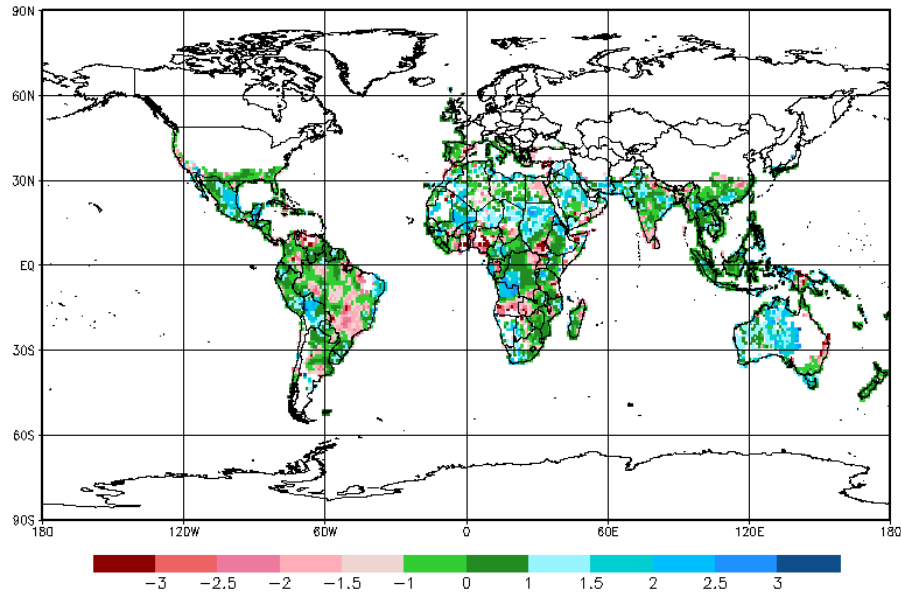
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**Fig. 7.** SPEI with one month averaging interval for January 2014. The color scale is the same as in Fig. 3.

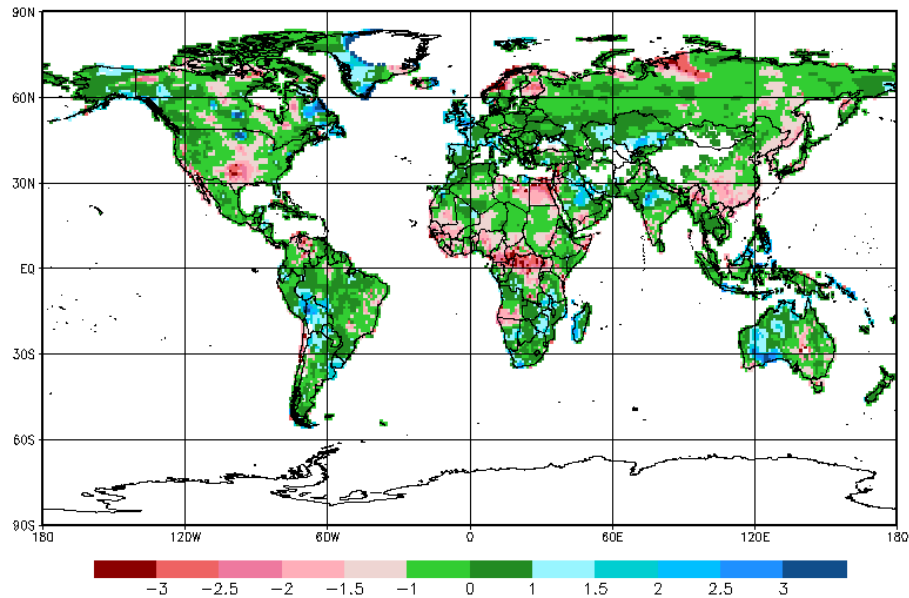
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**Fig. 8.** SPEI with three months averaging interval for January 2014. The color scale is the same as in Fig. 3.

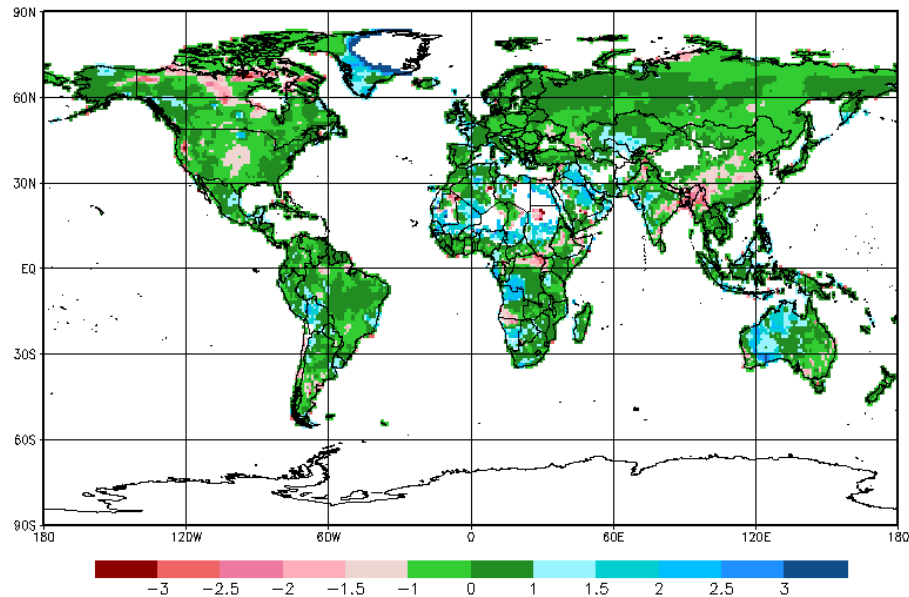


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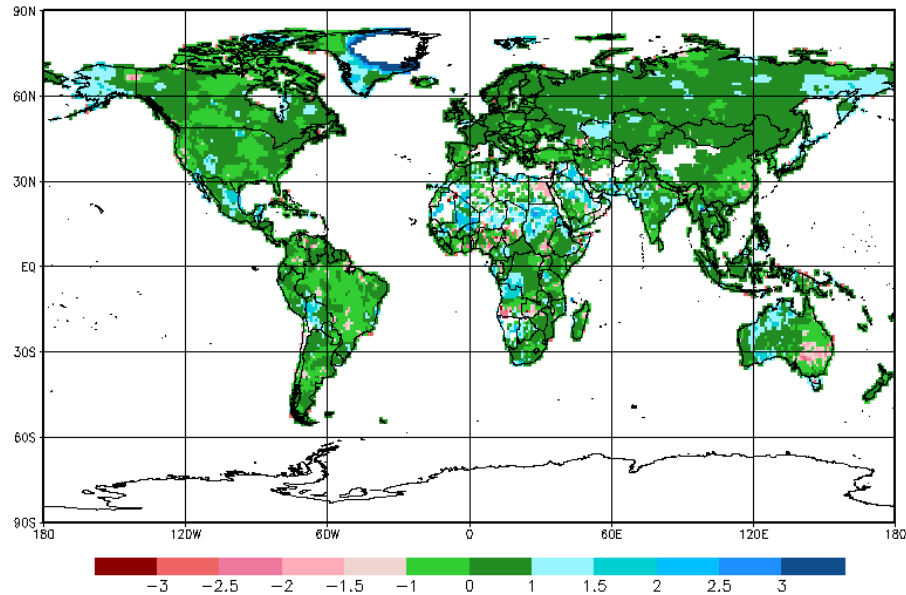
**Fig. 9.** SPEI with six months averaging interval for January 2014. The color scale is the same as in Fig. 3.

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**Fig. 10.** GPCC-DI with one month averaging interval for January 2014. The color scale is the same as in Fig. 3.

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**Fig. 11.** GPCC-DI with three months averaging interval for January 2014. The color scale is the same as in Fig. 3.

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**Fig. 12.** GPCC-DI with six months averaging interval for January 2014. The color scale is the same as in Fig. 3.