



The 1945-1949 Droughts in Switzerland

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Abstract

This paper studies the representation of a drought period that affected Central Europe from 1945 to 1949 in the “Twentieth Century Reanalysis” (20CR). We analysed temperature and precipitation fields in 20CR and compared them to other data products. From the monthly precipitation rate at a 20CR grid point in the Swiss Plateau, the Standardised Precipitation Index over six months (SPI6) was calculated and compared with the corresponding index calculated from station data. For additional analyses, 20CR soil moisture, run off, and evaporation data were used. 20CR well reproduces the temperature and precipitation anomalies over Central Europe during this period, although during 1947, the precipitation anomaly is shifted to the east as compared to observations. With respect to the SPI6 index, the agreement between 20CR and station data is good except again for 1947 (conversely, drought was overestimated in 20CR for 1945 and 1949). Low SPI values in 20CR are accompanied by negative soil moisture anomalies and a negative water balance. Thus, apart from the shift in the spatial drought pattern in 1947, the drought is depicted in a realistic way in 20CR.

1. Introduction

Central Europe is a region regularly but not permanently affected by droughts. Over the last 150 years there have been several drought years or even drought periods (sequences of drought years). Studying these historical events might help to better understand drought mechanisms. However, until recently this was only possible based on surface variables such as precipitation or air temperature or drought indices derived therefrom. With the new Twentieth Century Reanalysis (20CR, Compo et al., 2011), the study of historical drought events can now be supplemented with an analysis of atmospheric circulation. In this paper we

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study one particular, prolonged drought period and analyse how it is represented in the Twentieth Century Reanalysis (20CR) data set.

The drought chosen is that of the mid-1940s to early 1950s (Sutton and Hodson, 2005) that affected central-western Europe. Switzerland was particularly strongly affected in 1947 (see Grütter et al., this issue, for an analysis of the heatwave that accompanied this event). A near-complete loss of agricultural production was recorded (Schorer, 1992). In Germany, the 1947 heatwave and droughts affected transportation, energy production as well as the forests through pests and fires (Baumgartner, 1950). Fear of an ongoing desertification (in German “Versteppung”) of central Europe was widespread.

The 1945-1949 drought years in Switzerland have been studied with respect to drought characterisation and impacts (Schorer, 1992; Pfister, 1999; Pfister and Rutishauser, 2000; Calanca, 2007), but not with respect to meteorological conditions. Griesser (2008) analysed reconstructed upper-level fields for drought conditions since 1880. He noted that the drought summer of 1947 was preceded in spring by negative precipitation anomalies centred over France and stretching into Scandinavia. In early summer, the negative anomaly covered all of Europe, and was accompanied by above normal temperatures. The sea-level pressure field showed a strong positive anomaly over Scandinavia during winter which in spring was replaced by a weaker but broader high pressure anomaly over Central Europe, shifting to north-western Europe in late summer. With respect to the underlying causes, it has been suggested that the Atlantic Ocean contributed to forcing the drought conditions by changing atmospheric circulation patterns (Sutton and Hodson, 2005). 20CR could help to disentangle the mechanisms responsible for the drought, but first it needs to be shown whether or not the droughts are depicted at all. In this paper we focus on Switzerland where the drought was particularly severe and good observational data are available.

The paper is organized as follows. The data and analysis methods used are described in Section 2. Section 3 then presents the results, followed by a discussion in Section 4. Conclusions are drawn in Section 5.

2. Data and Methods

2.1. Data sets

In this paper we use version 2 of the Twentieth Century Reanalysis (20CR, Compo et al., 2011). 20CR is a reanalysis covering the period from 1871 to 2010 that is based on the assimilation of surface pressure and sea level pressure. Additionally, monthly sea surface temperature and sea ice (Rayner et al., 2003) was used as model boundary conditions. The assimilation was performed with a variant of the Ensemble Kalman Filter, with background fields generated by the NCEP/CFS model (Saha et al., 2010). 20CR is an ensemble product with 56 equally likely members. In this study we focus on the ensemble mean. The variables consulted in this study encompass air temperature, precipitation rate, potential evaporation, run off, soil moisture (0-100 cm), and latent heat flux.

The locations of observations that were assimilated for a specific day in the analysed period are shown in Figure 2, together with the orography and the land sea mask of 20CR. Note that orography is only crudely depicted in 20CR, which needs to be considered in a

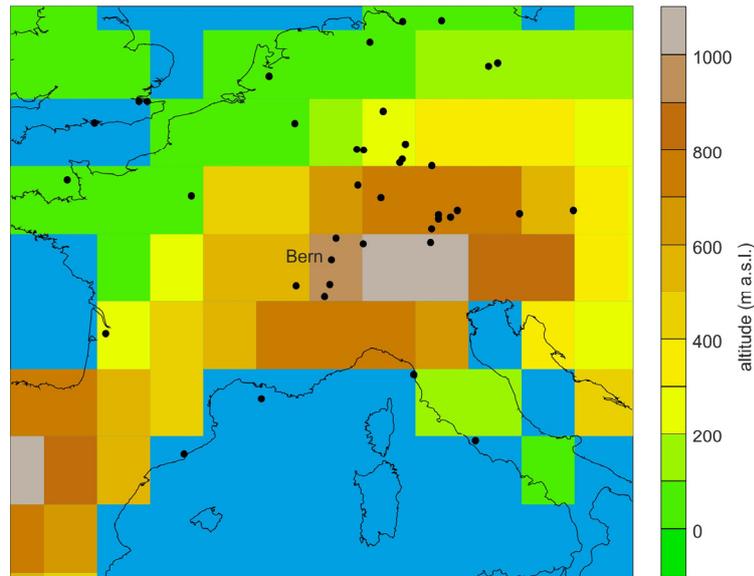


Figure 1. Map showing the surface and sea-level pressure measurements assimilated into 20CR on 29 July 1947, 12 UTC. Colours indicate the orography in 20CR and the land-sea mask as depicted in the Gaussian grid (192x94 cells).

station-by-station comparison. For some of the analyses we select the grid point at 7.50° E and 46.67° N, which approximately corresponds to the Swiss Plateau (see Fig. 1, label “Bern”), and compare this grid point to observations from MeteoSwiss from the station of Bern (Fig. 1). Note that in August 2006, the latter station was moved several kilometres northward to Zollikofen and therefore the earlier part of the record was adjusted to the Zollikofen location. Also, it should be noted that in 20CR, the grid point elevation is at 958 m a.s.l. rather than 552 m a.s.l.

In addition to 20CR and Swiss station data, we use further gridded climate data sets in order to better assess the results from 20CR. Specifically, we use temperature and precipitation from the CRU TS3.1 data set (Harris et al., 2013), which provides monthly data on a $0.5^{\circ} \times 0.5^{\circ}$ grid based on station observations. Unless otherwise noted, anomalies in this paper as expressed relative to the 1981-2010 climatology (1981-2009 for CRU TS3.1, which ends in 2009).

2.2. Drought indices and variables studied

The primary element of a drought is a precipitation deficit (Lloyd-Hughes and Saunders, 2002), which leads to a negative deviation of the water balance compared to the climatological mean. Although for agricultural definitions, soil moisture is crucial (Dracup et al., 1980), we focus here on a pure meteorological definition of drought, the Standardised Precipitation Index over six months (SPI6). The SPI is calculated based on monthly data and measures the standardised deficit of average precipitation data over a period of several months (McKee et al., 1993; Guttman, 1998). Here we choose the time span as 6 months to cover the vegetation period (hence the SPI6). The SPI6 compares the precipitation for the 6 months of a specific year to all recorded 6-month periods. After standardisation based on the probability distribution of long-term monthly precipitation data, cumulative probabilities are calculated for the observed precipitation sums of each time step, from which the SPI is then derived. Drought intensity is defined according to McKee et al. (1993), summarized in Tab. 1.

Table 1: Definition of drought intensities (McKee et al., 1993)

SPI Values	Drought Category
0 to -0.99	mild drought
-1.00 to -1.49	moderate drought
-1.50 to -1.99	severe drought
≤ -2.00	extreme drought

The SPI analyses are complemented by analyses of the water balance. 20CR provides precipitation (P), runoff (R), soil moisture (0-100 cm), latent heat flux from which we derived evaporation E , and potential evaporation E_{pot} . As a diagnostic of the water balance, we calculated $P-R-E$ and $P-R-E_{pot}$. Note that sub-grid scale spatial variability in these variables may be large (see Seneviratne et al., 2010, for a review).

In literature there is wide consensus that there was an increased frequency of drought seasons in Switzerland in the late 1940s and early 1950s (see Schorer, 1992; Pfister, 1999; Pfister and Rutishauser, 2000; Calanca, 2007). However, since the authors use different definitions of droughts they do not all come to the same results regarding drought years and lengths of drought periods. This paper examines the years 1945, 1947 and 1949 as they fulfil the criteria for droughts set by McKee et al. (1993).

3. Results

3.1. Precipitation and temperature fields

The comparison of temperature anomalies in 20CR with CRU TS3.1 for the three drought summers 1945, 1947, and 1949 (Fig. 2) shows an overall good agreement (see also Grütter et al., this issue). For 1945, 20CR produces a temperature anomaly maximum over the Iberian Peninsula, which is stronger than observed. Conversely, in 1947 maximum temperature anomalies over France are underestimated. For precipitation (Fig. 3) the agreement is also good, but some of the spatial details differ. Most notably, in 1947, 20CR has the maximum negative precipitation anomaly over Austria, with only weak negative anomalies over Switzerland and positive anomalies over the British Isles whereas according to CRU TS3.1, Switzerland was in the centre of the negative precipitation anomaly and the British Isles also had below normal precipitation. For the summers of 1945 and 1949 a negative precipitation anomaly is found for the Swiss Plateau in both data sets.

3.2. Standardized precipitation index

The SPI6 calculation with 20CR data shows a negative peak for each of the three drought years (1945, 1947 and 1949; see Fig. 4). All three drought events show similar minimum SPI6 values. The three peaks are all between -2.2 and -2.6; values are displayed in Table 2. According to the drought intensity definition table (Tab. 1) all three years can be described as extreme droughts. The lowest SPI6 value occurred in 1945 with a minimum SPI6 of -2.6 in August 1945, the longest drought period was in 1949 over a time span of 14 months.

This SPI6 series calculated with data from Bern/Zollikofen shows, similar to the 20CR series, three negative SPI6 peaks for the three drought events (Fig. 4). Compared to the results

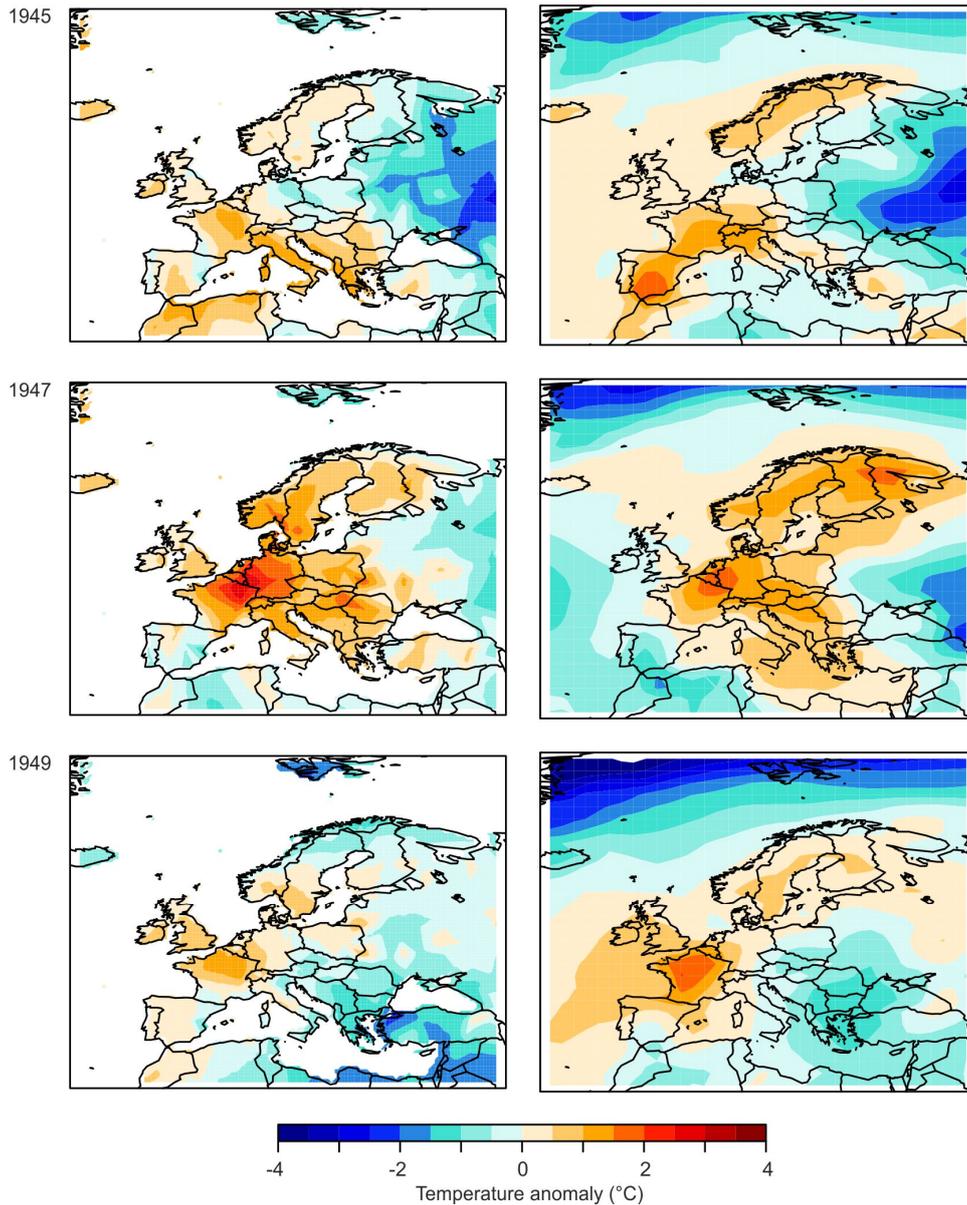


Figure 2. Anomalies of 2 m temperature in April to September of 1945 (top), 1947 (middle), and 1949 (bottom) for 20CR data (left) and CRU TS3.1 (right). Anomalies are with respect to 1981-2010 (1981-2009 for CRU).

obtained from 20CR, this series shows larger differences between the peaks. It shows one extreme drought in 1947, a severe drought in 1949 and a moderate drought in 1945. The most negative SPI6 value occurred in October 1947 with -2.67. This is also the longest drought period – during this event the SPI6 is negative for 17 consecutive months.

The duration of the drought period in 1947 in the 20CR data is considerably shorter than in the data of the Bern/Zollikofen station. The drought periods in the two other years are for both data sets roughly of equal length. Another difference between the two series is a temporal shift in the drought peak. In 1945, the peak in SPI6 from 20CR occurs in August, SPI6 from station data peaks in July. For 1947, SPI6 from 20CR peaks in January whereas SPI6 from Bern/Zollikofen peaks in October. In 1949, the peak occurs in April in 20CR data but in February in data from Bern/Zollikofen. The SPI6 series calculated with 20CR data has a larger variability than the SPI6 calculated with station data.

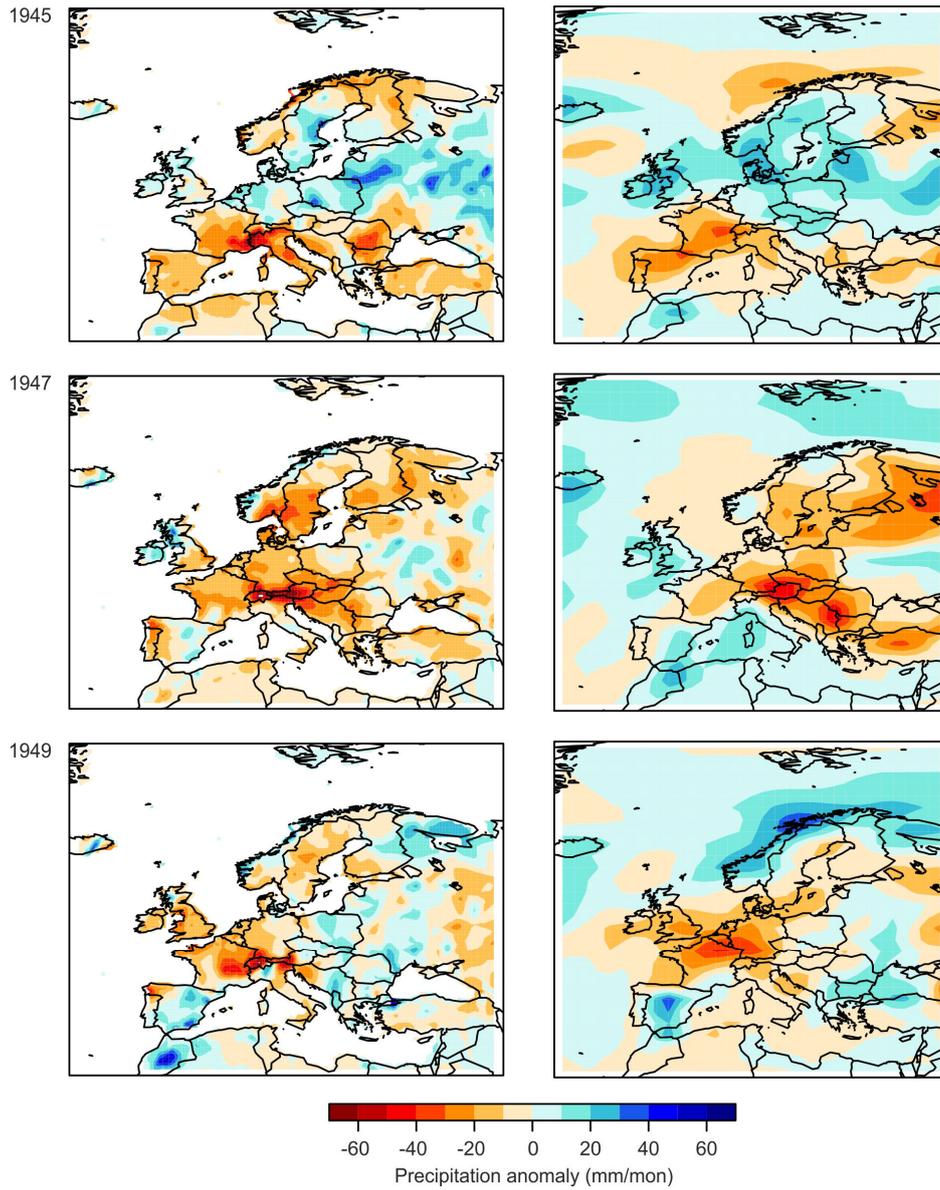


Figure 3. Anomalies of precipitation in April to September of 1945 (top), 1947 (middle), and 1949 (bottom) for 20CR data (left) and CRU TS3.1 (right). Anomalies are with respect to 1981-2010 (1981-2009 for CRU TS3.1).

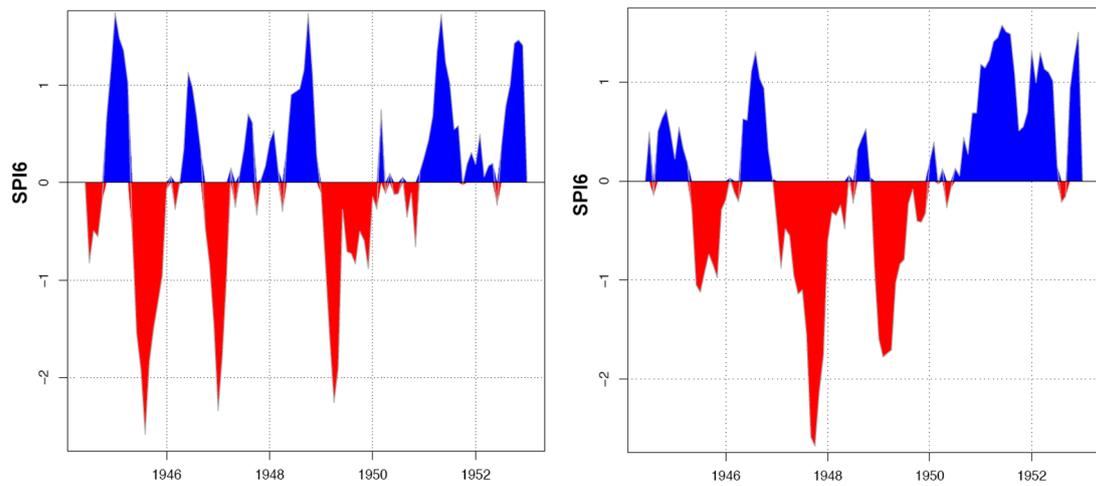


Figure 4. Time series of the SPI6 index (with respect to 1961-1990) at Bern/Zolllikofen in 20CR (left) and in observations (right).

Table 2: Results from the SPI6 calculations. Displayed are the minimum SPI6 values, time of the peak and the duration of the drought period. Additionally results from Pfister and Rutishauser (2000) are displayed.

Year	20CR SPI6 Series		Bern/Zollikofen SPI6 Series		Pfister and Rutishauser (2000)
	Min. SPI6	Duration	Min. SPI6	Duration	Duration
1945	-2.6, Aug	9 months	-1.13, Jul	9 months	Jun 45 – Sep 45
		May 45 – Jan 46		May 45 – Jan 46	
1947	-2.3, Jan	6 months	-2.67, Oct	17 months	May 47 – Sep 47
		Oct 46 – Mar 47		Jan 47 – May 48	
1949	-2.2, Apr	14 months	-1.78, Feb	13 months	Jul 49 – Sep 49
		Jan 49 – Feb 50		Dec 48 – Dec 49	

The drought period in 1947 is not well reproduced in 20CR for the chosen location. The minimum SPI6 value does not differ much from the SPI6 calculated with station data from Bern/Zollikofen, but the duration in 20CR is underestimated. According to station data the duration of the drought period was 17 months, whereas in 20CR only 6 months are considered drought months. Note, however, that Pfister and Rutishauser (2000) also show a shorter drought period.

3.3. The water balance

With respect to the water balance, soil moisture in 20CR shows negative peaks representing drought years, but they do not coincide with the 1945, 1947 and 1949 drought summers (Fig. 5 top). Lowest soil moisture values were found in summer 1945, fall 1946, and fall 1949, while minimum values in fall 1947 reached only 500 kg/m^3 , which is a typical fall value at this location. Unfortunately, there are no observations of soil moisture. If real, the minimum in fall 1946 may have been the start into the extreme drought season of 1947. In 20CR, however, the soil moisture deficit was replenished rather quickly in February and March 1947 and the summer proceeded normally. Note also that minima in 20CR soil moisture do not always concur with 20CR SPI6 peaks. In the winter 1946/47, the negative peak of soil moisture occurs in November 1946, whereas the peak in SPI6 is in January 1947. In 1949 the peak in the SPI6 series occurs in April, the peak in the soil moisture series in October.

The water balance is approximately closed (Fig. 5 bottom), *i.e.* the change in soil moisture from month to month is equivalent to precipitation minus run-off minus the estimated evaporation ($P-R-E$). Evapotranspiration may vary in space, and sub-grid scale areas with higher evapotranspiration may suffer more from drought. We therefore also calculated $P-R-E_{pot}$ (shaded area in Fig. 5, bottom), indicating the potential for much stronger drought conditions particularly in summer. Again, the summer of 1947 comes out as an average summer, not only in terms of soil moisture, but also in $P-R-E$ and $P-R-E_{pot}$.

4. Discussion

The negative precipitation anomalies in 20CR on the Swiss Plateau in the summers of 1945 and 1949 (Fig. 3) are consistent with gridded station data and the literature (Pfister and Rutishauser, 2000; Calanca, 2007). The dry period in 20CR in the winter 1946/1947 is also consistent with descriptions in the literature (Pfister, 1999). However, precipitation over the Swiss Plateau in the summer of 1947 is overestimated considerably.

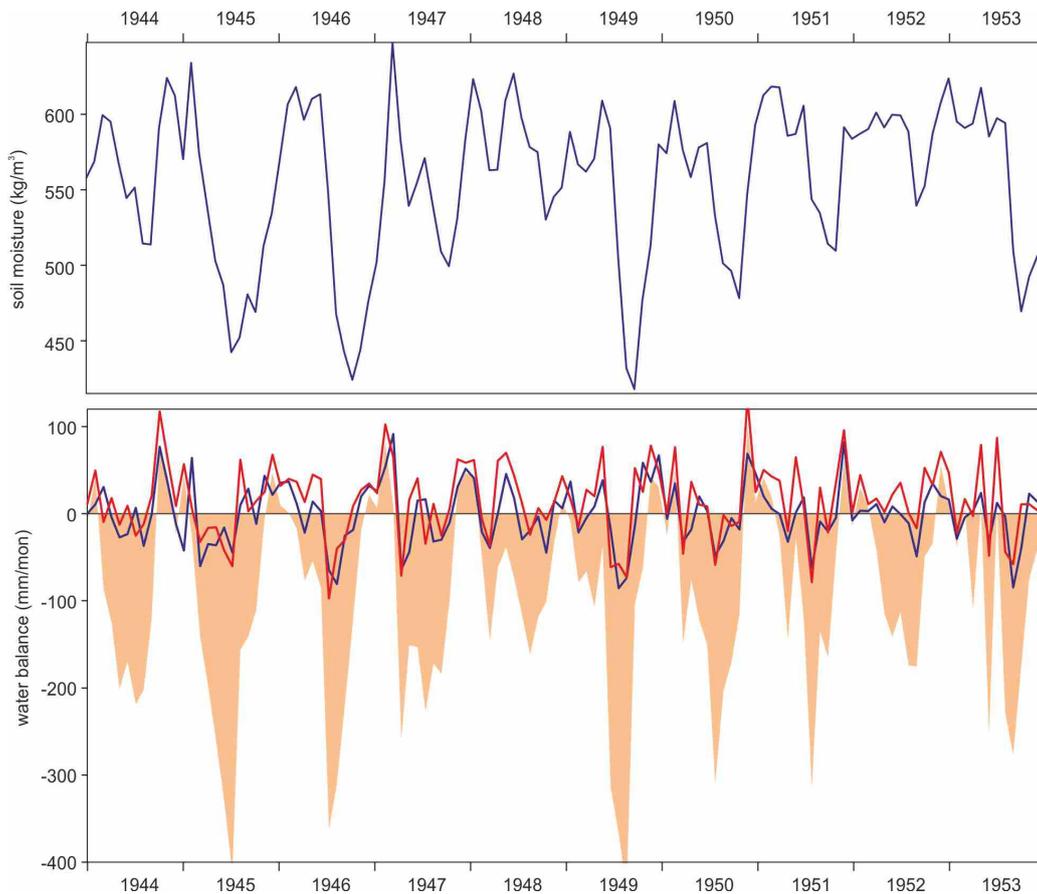


Figure 5. (top) Monthly values of soil moisture in 20CR from 1944 to 1953. (bottom) Month-to-month change in soil moisture (blue), $P-R-E$ (red), and $P-R-E_{pot}$ (shaded) in 20CR from 1944 to 1953.

The severe drought in 1947 and the two less severe droughts in 1945 and 1949 in the SPI6 series for Bern/Zollikofen are consistent with descriptions in the literature (Pfister, 1999). The drought 1947 is said to have been a “catastrophic event” and the most severe drought in the observed record (Pfister, 1999; Calanca, 2007; Pfister and Rutishauser, 2000). Nevertheless, there are differences between the station-based SPI6 index and the literature concerning the duration of the drought period. Pfister and Rutishauser (2000) describe the drought duration as five months (Tab. 2), which is based on damages in agricultural production. On the grounds of the agricultural definition of drought, no statements can be made about drought periods in winter months (which are found, *e.g.*, from SPI6 in 20CR).

The two drought events 1945 and 1949 are also visible in the 20CR data set in terms of SPI6 as well as in soil moisture and the water balance. This holds particularly for the duration of the drought period. The 1947 drought, however, is not depicted at all as 20CR produces a winter drought whereas the observed drought was in summer. In summer and autumn 1947, the station Bern/Zollikofen exhibits a period of a very severe drought, lasting until the first months of 1948. This is consistent with the literature (Pfister, 1999; Pfister and Rutishauser, 2000; Calanca, 2007). The reason for the failure of 20CR in this case lies in the 20CR precipitation pattern, which shows a spatial offset (*i.e.* the area with a strong precipitation deficit in 20CR only covers Western-central Europe, not Switzerland).

Furthermore, when analysing the SPI6 minimum values in all three drought years, station data and 20CR data do not always coincide. This is not surprising as precipitation varies locally, specifically in complex topography, which is only crudely depicted in 20CR. For 1945

and 1949, 20CR shows more extreme SPI6 values than Bern/Zollikofen, but the opposite is the case for 1947. It appears that 20CR is able to detect the three drought periods, but not the intensities.

As discussed above, the modelled soil moisture series shows three droughts. In periods where precipitation is overestimated, also soil moisture might be overestimated. However, no measured soil moisture data is available for verification

5. Conclusions

The 1945-1949 drought years in Switzerland were studied in observation-based data and in the Twentieth Century Reanalysis data set (20CR). While a good agreement for temperature fields was found, precipitation is somewhat less well depicted when comparing single locations. Specifically, the very dry summer of 1947 was not dry - in Switzerland - in 20CR, although a strong precipitation deficit is produced northeast of the study region.

With respect to drought indices, the SPI6 series from observations depict three drought periods that are well known from other studies, although duration and intensity differ somewhat from descriptions in the literature. In 20CR, two of the periods are also well captured, but (again) not 1947, when 20CR produces a winter drought. Soil moisture in 20CR also shows three drought periods (including the winter drought of 1947), consistent with SPI6, but the summer drought of 1947 is not depicted.

Overall, the analysis shows that 20CR data is able to detect and reproduce the structure of the three drought periods. However, it does not represent some of the drought periods accurately enough (duration, intensity). Specifically, local (grid-point) comparisons may turn out unfavourably.

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