Ozone highs and associated flow features in the first half of the twentieth century in different data sets

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Abstract
In order to better understand weather extremes, their relation to the large-scale climate variability, and their possible changes over time, observation-based atmospheric data sets are required that reach back in time as far as possible and that provide information on the 3-dimensional structure of the atmosphere. A number of new such data sets have been published in recent years, including historical observations, reanalyses, and reconstructions, some of which reach back into the nineteenth century. However, their usefulness for studying weather extremes remains to be shown. Here we compare some of these historical data sets in the first half of the twentieth century, focusing on one specific type of extreme, namely “ozone highs”. Using historical total ozone observations as a starting point, we assess dynamical links between total ozone, the flow near the tropopause, and tropospheric circulation in the “Twentieth Century Reanalysis” (20CR), historical radiosonde and aircraft observations, and hand drawn historical maps. Selected cases are presented for two regions (Europe and China). Ozone highs over Europe in the 1920s to 1950s were qualitatively well reproduced in 20CR and could mostly be interpreted in the context of cut-off lows. Some of these coincided with a blocking high over the North Atlantic or with vigorous cold-air outbreaks. One of these cases is analysed in more detail. Ozone highs over China in the 1930s may have been related to changes in the jet stream and the subtropical tropopause, but they were not always well reproduced in 20CR. The results demonstrate that, in many of the cases, the available data allow a dynamical interpretation. This confirms the potential of the available data and techniques to extend the length of atmospheric data sets suitable for studying extremes.

1 Introduction

Weather extremes are rare by definition and hence long data sets reaching back in time as far as possible are needed for analyzing their occurrence, their relation to the large-scale circulation and climate variability, and their possible changes over time. At the same time, dynamical interpretations of extremes require detailed knowledge of the vertical structure of the atmosphere (i.e., upper-level flow features such as blocking or jet streams). Therefore, until recently, the time frame available for such studies was limited to the last 50–60 years, i.e., the periods of ERA-40 (UPPALA et al., 2005) or NCEP/NCAR (KISTLER et al., 2001) reanalysis data.

During the last few years major attempts have been undertaken to extend observation-based upper-air data products back in time. In addition to compilations of upper-air (STICKLER et al., 2010) and total ozone (BRÖNNIMANN et al., 2003b) observations, a new reanalysis has been produced. The “Twentieth Century Reanalysis” (20CR, COMPO et al., 2011), which is constrained only at the surface, provides 6-hourly 3-dimensional global data back to 1871 using an ensemble assimilation approach (WHITAKER and HAMIL, 2002). The data set might be useful for studying extremes, but it has not yet been assessed. In this paper we analyse one specific aspect in these data sets, namely the variability and extremes in total ozone in the first half of the twentieth century. This is of interest as total ozone variations are associated with specific flow features that themselves may be relevant for extreme weather. The depiction of another type of extremes in 20CR, namely midlatitude storms, is addressed in another paper in this issue (BRÖNNIMANN et al., 2012).

In 1926, DOBSON and HARRISON (1926) found that total ozone is closely correlated with the altitude of the tropopause (see Figure 1). This being the era before radiosondes, they hoped that total ozone could provide useful upper-air information on an operational basis for weather forecasting (for a history of ozone research see MÜLLER, 2009). While Dobson’s dream finally came true decades later, when satellite ozone data were assimilated into operational analyses to improve weather forecasts, we now use the total ozone data measured by Dobson and many others during these early years for analyzing atmospheric dynamics in historical times. Hence, we are using the total ozone observations for the very purpose they were made for. After describing the data sets (Section 2), we first compare the historical total ozone observations with total ozone and upper-level geopotential height (GPH) from 20CR (Section 3). Then we se-