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Storminess in northern Italy and the Adriatic Sea reaching back to 1760

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ABSTRACT

This study investigates storminess in northern Italy and the northern Adriatic Sea through the examination of several storm proxies. These proxies are based on homogenized daily mean pressure series given at a set of stations (Genoa, Milan, Padua, Turin, and Hvar). The application of widely accepted and well-known methods on pressure series allows for a long-term year-to-year analysis of the intra-seasonal storm variability. As storminess is usually more intense throughout the cold season, our analysis is limited to the October–March period of each year. The following proxies are considered in this study: First, we assess the statistics of geostrophic wind speed. These statistics are derived from two adjacent triangles that are located across the Adriatic Sea (Padua–Hvar–Genoa) and in northern Italy (Genoa–Padua–Turin). Second, we evaluate annual statistics of time series of pressure tendency. Last, intra-seasonal low percentiles of pressure are also made use of. These proxies are used to describe the evolution of the storm climate far back in time, covering in some cases a 260-year long period. The proxies show pronounced interannual and interdecadal variability, but no sustained long-term trend.

1. Introduction

Changes in the storm climate are substantially connected to socio-economic aspects of nations as increasing levels of storminess are related to increasing levels of danger to ecosystems, property, and society. Storms and storm surges represent a permanent threat to, for instance, structures, energy supply facilities, forests and coastal defence systems. Intense precipitation, which can cause soil erosion or significantly harm farming yields, is often associated with storms. Coastal zones are exposed to wind force, surges and waves that can destroy coastal barriers. Quite a number of studies focused on surges in Venice (e.g. Camuffo et al., 2000; Camuffo, 1993; Pirazzoli and Tomasin, 2002). However, many of them are related to local scale events (like surges), whereas we focus on a larger region like Lionello et al. (2003), and Robinson et al. (1973) did. Changes of near-surface winds from wind observations in the Central Mediterranean and Adriatic Sea have been investigated by Tomasin and Pirazzoli (2003) for example.

A robust assessment of changes in the regional storm climate needs to be based on many decades of homogeneous data, which are hardly ever available when regarding direct wind measurements. The homogeneity of data is another main issue (see e.g. Böhm et al., 2001; Aguilar et al., 2003; Auer et al., 2003, 2007) and has to be addressed carefully. Inhomogeneities typically occur when the data are affected by changes in observation practices – such as station-relocations, changes of the gauge or in the environment surrounding the gauge, or others. Particularly, alterations of the surrounding environment strongly affect direct wind recordings. On the other hand, local effects only marginally influence air pressure, which can therefore be measured reliably. Moreover, pressure measurements are based on rather simple physical methods, which ensure a high level of accuracy. Their inhomogeneities (even on a daily base) can, in most cases, be detected and corrected in an almost straightforward way (e.g. Wang et al., 2009). Further, air pressure records are part of the meteorological measurement program since its very beginning and thus reach far back in time.

Bärring and von Storch (2004) investigated pressure series at two stations (one placed in Lund and the other in Stockholm, which are about 500 km away from each other) that reach back to about 1800. They analyzed these time series separately (e.g. by evaluating the number of pressure minima below 980 hPa, or the annual number of 12 h pressure tendencies exceeding a threshold [e.g. 16 hPa]) and compared them afterwards. Bärring and von Storch found quite a reasonable correlation between pressure tendencies and the other storm proxies at each station, as well as a reasonable consistency of the tendencies between the two stations. Moreover, this study clarified that storminess in that region does not exhibit substantial changes since 1800. Schmidt and von Storch (1993) used triplets of stations to derive annual statistics of the geostrophic wind speed. An important point (Kaas et al., 1996) is that strong annual or seasonal wind events are well represented

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by the occurrence of high geostrophic wind speed percentiles. So, high percentiles of the geostrophic wind speed well describe the frequency of strong wind events.

For North-Western Europe a steep increase in storminess from the 1960s into the 1990s has been repeatedly detected (WASA Group, 1998; Alexandersson et al., 2000; Alexander et al., 2005; Weisse et al., 2008). When taking long-term data that cover a century or even longer periods of time into account, it turns out that this steep increase originates from relatively calm storm conditions in the 1960s and ends at relatively high levels of storminess in the 1990s. However, the longer time series reveal that this increase is within the range of natural variability (Trenberth et al., 2007). Based on longer time series of high percentiles and of other storm proxies Alexandersson et al. (1998) inferred that no trend is detectable for North-Western and northern Europe. Weisse et al. (2008) conducted a study that covers a large geographical area across northern Europe in notable regional detail, but for the second half of the 20th century only. They detected the aforementioned roughening of storminess in North-Western Europe as well. Nevertheless, they also showed a reversal of this trend since the middle of the 1990s, which took place in most of the investigated areas. This is in line with e.g. Alexandersson et al. (2000) and Matulla et al. (2008).

One important aim of the WASA project (WASA Group, 1998) was the examination of storm indicators. In the WASA project, the seasonal 95th and 99th percentiles of geostrophic winds, the frequency of geostrophic wind speeds above 25 m/s, the annual frequency of 24-h pressure tendencies exceeding 16 hPa, as well as the annual frequency of pressure observations below 980 hPa (deep lows) were investigated. The WASA Group (1998) found that changes in the mean pressure did not affect the first four indicators, but the fifth. The prior four shared a positive correlation while the last indicator, the number of deep lows, showed still positive, but much smaller correlations. The main reason was found to be large-scale low-frequent variability of air pressure that can alter local pressure distributions to smaller or larger values (more or less deep lows) without having an impact on the storm regime (Bärring and Fortuniak, 2009).

As shown by Schmidt and von Storch (1993), WASA Group (1998), Alexandersson et al. (2000), Alexander et al. (2005), Bärring and von Storch (2004), Weisse et al. (2008), Matulla et al. (2008) pressure based storm proxies form a useful tool to describe the evolution of storminess on long timescales, which is necessary to assess the present and past states of storm climate properly – when direct wind measurements are not available. Presently, studies are underway to examine quantitatively the informational values of proxies. First results on the link of seasonal percentiles of geostrophic wind speed and of ground level wind speed are available from Krueger and von Storch (2011). For the two triangles used in this study, a similar consistency check is carried out (Appendix A).

2. Data

Italy has several meteorological series that reach far back in time. Some of them are among the longest records in the world. The Accademia del Cimento started to record observations from 1654. More widespread observations began in the 18th century in Bologna (1714), Padua (1725), Turin (1756), Milan (1763), Rome (1782) and Palermo (1791).

For this study we use daily long-term time series of air pressure measurements from Italy and Croatia. The Italian stations Genoa, Milan, Padua and Turin have been recovered and digitized a few years ago within the EU-project IMPROVE (Camuffo and Jones, 2002). Consecutively, these series have undergone a homogenization procedure, which includes a temperature correction to 0 °C and a reduction to sea level (Maugeri et al., 2004).

The Genoa series is the shortest among the four records that we focus on. This dataset has been collected at the meteorological observatory of the local university since 1833 (for further details see Dagnino (1978), Flocchini et al. (1983), and Maugeri et al. (2002c)).

The series in Milan sets off in 1763 and continues uninterruptedly up to the present day. The data were collected at Milan Astronomical Observatory. The Milan Astronomical Observatory and the Milan University set up a research program in the early 1990s to restore the pressure record that has been homogenized over the last years (Maugeri et al., 2002a,b).

Pressure measurements in Padua are available on a daily base for the period 1725–1997. The Padua records are the longest pressure records available in Europe. The SLP time series in Padua was produced by Camuffo (2002) and made available digitally (Camuffo and Jones, 2002). Later, this time series was improved, especially for the period 1725–1780, and had some minor corrections that did not exceed 1 hPa for the subsequent period (Camuffo et al., 2006). We use the independently homogenized time series by Maugeri et al. (2004) who corrected some small bias (not exceeding 0.65 hPa), which were present in the original series of Camuffo (2002). We have chosen to use this time series to ensure consistency with the homogenization procedure that was applied to all the time series used in this study.

The Turin chronicles reach back to 1753, but SLP observations at the onset (1753–1787) have not been retrieved yet. Data were recorded at three different stations: Academia delle Scienze (1788–1865), Palazzo Madama (1865–1918) and Collegio Carlo Alberto (1919–1950). The first and second stations are located in the city of Turin (Di Napoli and Mercalli, 2008), the last in Moncalieri, a village about 10 km away from the center of the city. For further information on the Italian time series see Maugeri et al. (2004).

Pressure records from Hvar (1858–2004) in Croatia were retrieved from the European Climate Assessment & Dataset (Klok and Klein Tank, 2008; Klein Tank et al., 2002). This data set is quality checked but not homogenized. We use the Hvar record instead of the Rijeka record as the latter starts not before 1949. The station records of Hvar have gaps of missing data from 10/1918 to 04/1931 and from 09/1943 to 04/1945.

3. Results

We look into time series of several pressure based storm proxies for the stations Genoa, Milan, Turin, Padua and Hvar. These proxies are the seasonal low percentiles in the case of pressure measurements (not shown), as well as high percentiles of pressure tendencies and of geostrophic wind speeds. For a thorough discussion of these proxies see for instance Alexandersson et al. (1998, 2000), WASA Group (1998), Schmidt and von Storch (1993), Bärring and von Storch (2004), Alexander et al. (2005), Bärring and Fortuniak (2009) (see Fig. 1).

Fig. 2 shows the time series of seasonal 95th percentiles of the geostrophic wind speed, which is used as a proxy variable for storminess. We focus on the winter half year (October–March), as this is the season that contains most large-scale storm events (i.e., the so called storm season).

Consider first storminess over northern Italy, i.e., the results for the triangle Genoa–Padua–Turin. Around the 1850s a period of about two decades that exhibits high levels of storminess is visible. Later on, the seasonal 95th percentiles of geostrophic wind speed decrease until 1880 or so, and increase again until the turn from the 19th to the 20th century. In the later 1920s the levels of storminess diminish once more. The latter part of the 20th century is