Conclusion. The empirical evidence shows that the snowfall over the Pyrenees from January to June of 2013 was a rare weather event. Despite five winters in the last decade clearly exceeding the long-term average (above the 75th percentile), we have not been able to find a link between the recent increase in greater-than-normal snowfall seasons and anthropogenic forcing of climate in our model simulations. On the contrary, simulating precipitation and snow cover in the Pyrenees with and without the influence of anthropogenic greenhouse gas emissions shows a decrease in the occurrence probability of the event, although the result is not statistically significant for rare phenomena. In this assessment we find no evidence of a significant influence of anthropogenic emissions on this event.

22. A VIOLENT MIDLATITUDE STORM IN NORTHERN GERMANY AND DENMARK, 28 OCTOBER 2013

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A strong storm on 28 October 2013 over northern Germany and southern Denmark fits a slight increase in storminess during recent decades. However, the increase constitutes part of multidecadal variability.

Introduction. In late October 2013, a strong cyclone moved across northern Europe causing massive damages and interruptions. In Germany, the storm was named "Christian", in Denmark, "Allan".

The impact of the storm was considerable. At least 15 people perished, a large number of trees were blown down, power supply broke down, train connections were interrupted, streets were impassable, and the Øresund Bridge between Denmark and Sweden had to be closed (Haeseler et al. 2013).

Synoptic analysis. The cyclone formed off the coast of Newfoundland, favored by large temperature differences between cold air behind a previous storm there and warm air related to the remnants of a former tropical storm. At 18 UTC on Sunday, 27 October, the storm was located southwest of Ireland; then, it crossed the southern part of the United Kingdom, moved across the North Sea, and made landfall in northern Denmark. In northern Germany, the first storm gusts were observed at about 1100 UTC. The storm moved on northeastward across southern Sweden and Finland towards Russia, where it weakened considerably on 29 October.

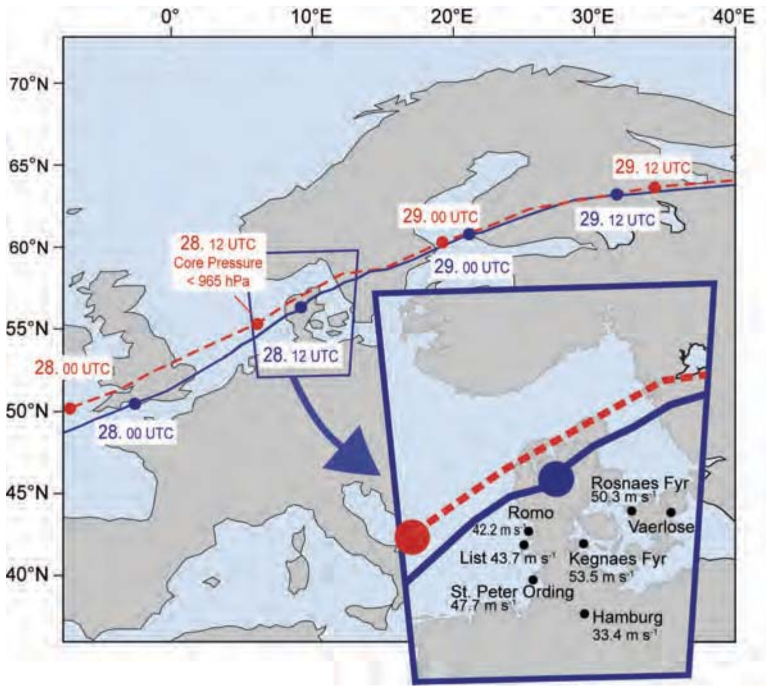

Fig. 22.1. Track of the Christian/Allan storm according to an analysis by Deutscher Wetterdienst [(German National Meteorological Service (red, dashed)] and to the reconstruction in CoastDat (blue, continuous).The box, showing the mentioned stations with measured peak gusts, marks the area for the storm statistics.

In Germany, peak wind speeds ranking 11 (28.5–32.6 m s^{-1}) and 12 (≥ 32.7 m s^{-1}) on the Beaufort scale (Bft) were observed at many stations along the North and Baltic Seas coasts as well as further inland, with a maximum of 47.7 m s^{-1} at St Peter Ording, a location facing the North Sea. Even 10-minute sustained winds reached Bft 12, which is a rare event. Very high wind speeds were also observed in Denmark, even far away from the North Sea. The maximum 10-minute sustained wind was observed at Røsnæs Fyr (39.5 m s^{-1}), on a peninsula in the Great Belt, and the strongest gust was observed at Kegnæs Fyr (53.5 m s^{-1}) in the Flensburg Firth. Both are the highest wind speeds that have ever been recorded in Denmark. Station locations as well as the analyzed track are shown in Fig. 22.1.

Climatological assessment: Local observations. Storms can be ranked by many factors, including by maximum sustained wind or by strongest gust. Of course, such rankings depend on the homogeneity of the data. This not only has to take into account local effects, such as changes in the surroundings of the meteorological station (for example, trees growing over time or new buildings, c.f. Lindenberg et al. 2012) and modifications in instrumentation or the definition of "sustained wind speed", but also inhomogeneities that relate to the violent wind as such cases where the anemometers were blown away. The series by Hamburg airport, starting in the mid-1930s, seems to be less affected by inhomogeneities. Therefore, observations from this station are useful for assessing the Christian/Allan event. Here, we find a peak gust of 33.4 m s^{-1}, which makes it the eighth strongest since 1951 compared to the maximum value of 39.1 m s^{-1} in January 1990 (Haeseler et al. 2013).

The 2013 event's impact can be regarded as highly unusual, but there have been stronger events before. While the storm reached the highest wind speed ever recorded in Denmark, its peak gust ranks among the top five of the previous 30 years at German weather stations (altitude below 600 m). However, what makes the storm a rare event is the timing. In Germany and Denmark, hurricane force winds in October are very unusual.

Climatological assessment: Reanalysis. When assessing whether an event or its statistics are outside the range of normal, a long homogeneous reference is needed, i.e., historical observations covering several decades. This is often not available for wind speeds. Ways to overcome this limitation are to use either more robust proxies, such as geostrophic winds calculated from pressure differences (Alexandersson et al. 1998), or to dynamically downscale reanalyses, that are as homogeneous as possible in terms of large-scale patterns (c.f. Feser et al. 2001). The CoastDat dataset describes storms in the region of the northeast Atlantic and northern Europe, obtained by downscaling NCEP/NCAR Reanalysis 1 with the large-scale constrained regional atmospheric model COSMO-CLM (Geyer 2014). It, thus, constitutes a near-real-time homogeneous dataset, beginning in the late 1950s (Weisse et al. 2005). The dataset is of limited accuracy, but the error characteristics are homogeneous.

In this simulation, the storm of 28 October 2013 compares favorably with the operational analyses. It is associated with a maximum (instantaneous) wind speed of 26.7 m s^{-1}, derived for grid boxes of about 50 × 50 km^2. The homogeneous dataset allows for the analysis of changes in storm frequency and intensity over time.

Considering strong winter storms, defined by a minimum core pressure of 970 hPa or less, we find 74 events since 1948 that have passed over a region covering northern Germany, Denmark, and the Skagerrak/Kattegat region (52°–60°N, 6°–13°E). Of these, 52 are weaker than Christian/Allen in terms of maximum wind speeds, and 22 are stronger in the downscaled reanalysis. We conclude that the Christian/Allan storm of 28 October 2013 was, indeed, a very strong and unusual one. Storms of this strength have crossed the region of interest about once every one or two years, however, rarely in October. Interestingly, a few weeks later (5–7 December 2013) another storm, named "Xaver" in Germany (Deutschländer et al. 2013) and "Bodil" in Denmark, passed over the region. It was stronger in parts of Denmark and in the Baltic Sea area. Its storm field was more extended and slower, so it caused severe storm surges in the North Sea and the Kattegat region.

Another question is, "Have such storms clustered in recent years?" An answer to this question is provided by Fig. 22.2, which displays the number of storms weaker or stronger than Christian/Allen for all years from 1948 to 2013 in the CoastDat dataset. We note that a strong storm event occasionally is followed by another one a few days or even weeks later, as the general circulation may still be favorable for storm development. This was recently shown by Pinto et al. (2013).

Figure 22.2 describes not a clear change, but rather a slight tendency towards more intense storms in the last decades. This is in accordance with the

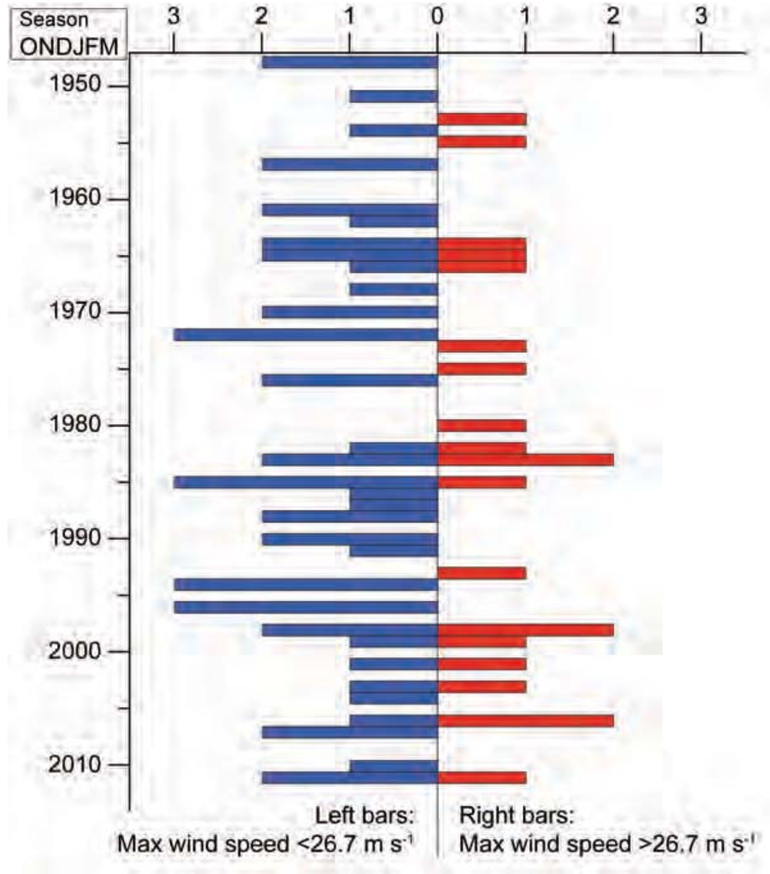

Fig. 22.2. Number of heavy storms (with minimum pressure ≤970 hPa) crossing the Jutland area during winter (ONDJFM) seasons according to the CoastDat data set (using 50 km × 50 km grid boxes). Left: Storms with maximum wind speeds smaller than Christian/Allan (26.7 m s^{-1}); right: storms with larger maximum wind speeds.

latest IPCC Fifth Assessment Report (Stocker et al. 2014), which states that it is "virtually certain" that the frequency and intensity of storms over the North Atlantic have increased since the 1970s. An eastward extension of the North Atlantic storm track towards Europe may have contributed to higher intense storm counts. An increase in storm numbers over the last decades is consistent with trends found in other reanalyses (e.g., Feser et al. 2014), while studies of long-term proxy data, in particular geostrophic winds (Alexandersson et al. 1998; Matulla et al. 2007; Schmidt and von Storch 1993) and storm surge records (e.g., Dangendorf et al. 2014), describe the trend as part of multidecadal variability. Since the 1880s, a decrease in storm numbers over the North Atlantic and western Europe was found until the mid-1960s, followed by an increase until the mid-1990s (Alexandersson et al. 1998, 2000). These decadal trends are also reflected in the number of low pressure systems (≤950 hPa) over the North Atlantic (Franke 2009). They peaked during the 1990s and reached the highest number since the first records in 1956/57 between November 2013 and March 2014. Ensembles of regional climate change scenarios, as available from Norddeutscher Klimaatlas (http://www.norddeutscher-klimaatlas.de), do not envisage a well-defined change, as some of the scenarios point towards higher maximum wind speeds and others to smaller. It should be emphasized that extreme wind statistics differ from extreme temperature and precipitation statistics in this respect.

Conclusions. When analyzing the Christian/Allan storm, we used an approach similar to van Oldenborgh et al. (2012), who examined both limited recorded data as well as model output. Within the framework of classical detection of climate change and attribution of plausible cases (Hasselmann 1979), there is no robust evidence for supporting claims that the intensity of the Christian/Allen storm would be beyond historical occurrences and that the recent clustering of storms should be related to the recently elevated greenhouse gas levels. Studies (e.g., Stocker et al. 2014) have demonstrated that a trend beyond the range of natural variations and possible drivers cannot be detected at this time. Instead, we explore if the considered event is outside the range of normal storms and if such storms cluster in recent times. Doing this as a formal hypothesis test is difficult given the multidecadal variability, as is demonstrated by proxy reconstructions (Alexandersson et al. 1998; Matulla et al. 2007; Schmidt and von Storch 1993). Thus, instead of falsely suggesting statistical rigor, we prefer to only demonstrate that such events took place throughout the documented past, albeit rarely so. For the time being, the simplest answer—the 2013 event is a realization that cannot be distinguished from those drawn out of a climate undisturbed by anthropogenic influence—cannot be rejected. However, ongoing monitoring may reveal more storms at a later time, which may then possibly be explained only by assuming an external forcing.