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An Analysis of the "Great Gale of October 1881" using the Twentieth Century Reanalysis

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Abstract

This paper examines the historically recorded storm of 14 October 1881, the "Great Gale of October 1881", over Great Britain. We analyse the storm in the "Twentieth Century Reanalysis" Version 2c (20CRv2c) and in historical weather charts printed in the *Quarterly Journal of the Royal Meteorological Society*. The focus is on the temporal evolution of sea-level pressure over the Atlantic from 9 to 14 October. We find a generally good agreement between the hand-analysed charts and the ensemble mean of 20CRv2c. The development and track of several individual depressions during this six-day period is well reproduced in 20CRv2c. However, regionally some differences are found between the two data sources.

1. Introduction

Extreme weather events have severe socioeconomic and ecological consequences. It is therefore of great importance to foresee and understand such events. This requires both statistical analyses and individual case studies of many events. However, extreme weather events are, by definition, rare. The availability of historical climate data is therefore often the limiting factor. In the last few years, starting with the "Twentieth Century Reanalysis" (20CR, Compo et al., 2011), new reanalysis data sets have become available. They enable studying weather events back to the 19th century by quantitative means, despite little observed data (Brönnimann et al., 2012). Today several such reanalysis data sets are available and allow studying historical weather events in great detail. In this contribution we analyse a specific extreme event in a historical reanalysis.

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Our objective is to examine the quality of version 2c of 20CR (termed 20CRv2c hereafter) for studying extreme weather events. This is necessary particularly for the early decades of the data set, when the amount of data assimilated was still limited. Assessing the quality of 20CRv2c is the first step towards further studies, including dynamical downscaling of events. Previous work based on version 2 of 20CR has shown that storms in Europe are mostly well depicted, though they often underestimate the magnitude of the events (Brönnimann et al., 2013).

In this paper we analyse the "Great Gale of October 1881", a deep depression that formed over Nova Scotia and hit the English and Scottish East Coast with winds of up to 117 km h^{-1} (Peggs, 1882). The storm cost many lives, particularly in the village of Eyemouth (Fig. 1) and caused severe destruction in the affected areas. Forests were levelled to the ground, houses destroyed or unroofed, stone structures moved, and chimneys blown down (Harding, 1882).

Lamb and Frydendahl (1991) and Symons (1882) studied the event in detail and showed that the depression over the North Sea that caused the storm was exceptionally strong, reaching minimum values of 955 hPa. Additional historical weather maps (Peggs, 1882) show the centre of the storm moving across the Atlantic towards the British Isles, manifesting itself as a deep depression over north-east England on 14 October 1881. These precise descriptions enable a graphical comparison of 20CRv2c generated plots with the historical weather maps, to show differences and consistencies between the two.

Here we examine if the pressure levels over north-east England on 14 October 1881 in 20CRv2c match with the weather maps and descriptions of Lamb and Frydendahl (1991) and those published in contemporary articles (Symons, 1882; Peggs, 1882; see also Ernst et al., 2017, and Villiger et al., 2017, in this volume for analyses of other Western European storms). We further analyse the development over the preceding five days. This paper is structured as follows. In Section 2 we present the Data and Methods. Results and Discussion follow in Sections 3 and 4. Final conclusions are drawn in Section 5.

Figure 1. Memorial near Eyemouth, Scotland, showing distraught wives and children of the 129 fishermen who perished at sea. Many fishermen drowned just outside the harbour, within sight of their families. Photo: Kim Traynor, 2011.

2. Data and Methods

The basis of our work is the Version 2c of the "Twentieth Century Reanalysis" (20CRv2c). This is a global, retrospective three-dimensional analysis of the atmosphere covering the period since 1851. This reanalysis uses an Ensemble Kalmann Filter data assimilation system to assimilate surface and sea-level pressure into a weather prediction model which uses monthly observed sea-surface temperatures and sea ice as boundary conditions (Compo et al. 2011; a description of all data sets used in this book is given in the introductory chapter, see Brönnimann, 2017). The surface pressure data are from the International Surface Pressure Databank (Cram et al., 2015). For the case of 14 October 1881, 12 UTC, the assimilated data are shown in Figure 2. While coverage is relatively poor compared to present, several ships on the Atlantic Ocean reported measurements. Sea-surface temperatures are from the sparse input version of the Simple Ocean Data Assimilation (SODAsi, Giese et al., 2016), complemented with COBE sea-surface temperature data at high latitudes (>60°) (Hirahara et al., 2014). 20CRv2c is an ensemble product, consisting of 56 members.

We used the ensemble mean of 20CRv2c and extracted sea-level pressure for the period 9-14 October 1881. These data were compared with weather maps published in an article by Wallace Peggs on the structural damage caused by the "Great Gale" (Peggs, 1882). The maps show sea-level pressure over England and the North Atlantic for 9-14 October 1881 at 12:00. A second article produced a sea-level pressure map of England for 14 October 1881 at 09:00 (Symons, 1882). Generally, the maps are of good quality, with arrows and dots showing the point of observation for each measurement. The time of measurement and the precision of the measuring instruments, however, are questionable, since the data were collected by vessels at sea. We coloured the plots manually for better comparison.

For comparison, the isobar spacing for 20CRv2c was chosen such as to match the unit of the historical publication, which is inches of mercury (inHg), but all values are reported in hPa. At 0° Celsius 1 inch of mercury equals to 33.86389 hPa.

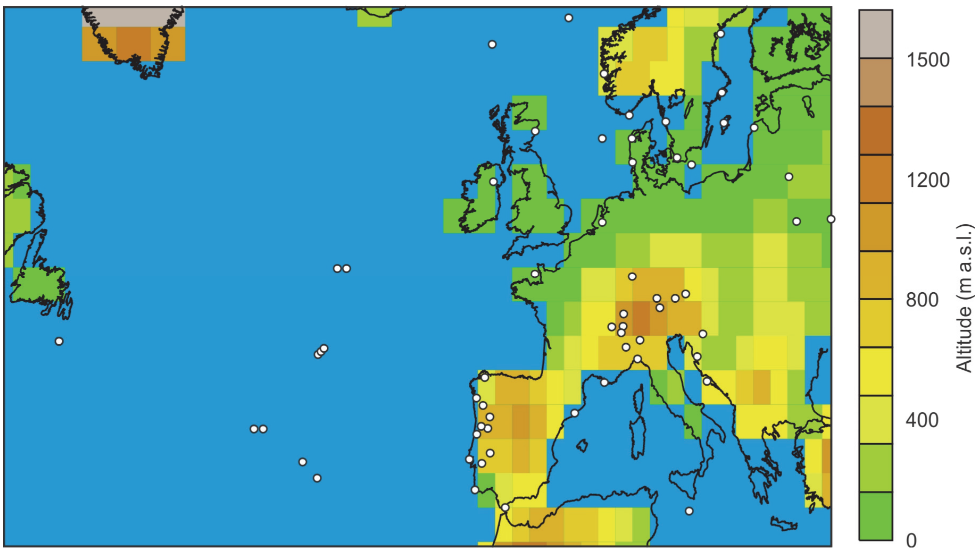

Figure 2. Topography and location of assimilated surface pressure data in 20CRv2c for the analysis of 14 October 1881, 12 UTC.

Another source is the already mentioned book “Historic Storms of the North Sea, British Isles and Northwest Europe” (Lamb and Frydendahl, 1991). It contains a short paragraph discussing the storm of 14 October 1881 and a detailed surface level pressure map. Additionally, it provides an opportunity to compare the “Great Gale” with other storms and information on how storms develop and how they might be predicted.

3. Results

3.1. Sea-level pressure over the Atlantic Ocean from 9 to 14 October 1881

In the following Section 20CRv2c is compared with the maps in Peggs (1882) for 9-14 October, 12 UTC (Fig. 3 and 4). Roman numerals refer to the different storms on the maps.

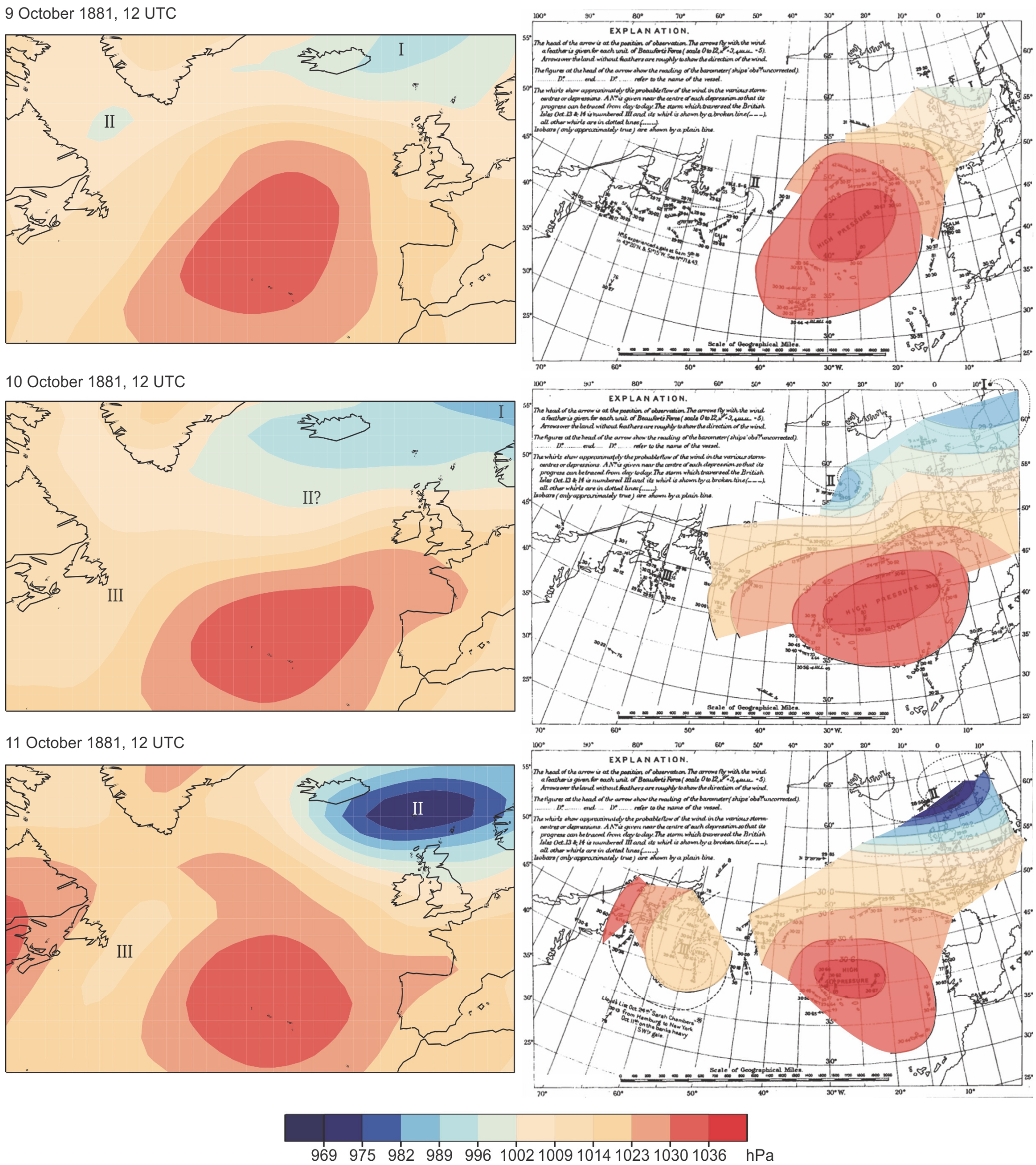

Figure 3. Sea-level pressure on 9-11 October, 12 UTC in (left) 20CRv2c and (right) Peggs (1882).

Figure 3 (top) depicts the situation on 9 October. The historical weather map shows a strong Azores High, ranging from 1022 hPa to 1043 hPa. Northwest of the British Isles, in the North Sea, a weak low-pressure area (I) with values of 1002 hPa was forming. Over the western Atlantic, east of Newfoundland in Canada, a storm (II) was brewing. However, its values are barely distinguishable from the mean sea-level pressure of 1013 hPa. 20CRv2c shows the strong Azores High reaching 1036 hPa, as well as the Icelandic Low (988 hPa).

One day later, on 10 October, the historical weather map again shows the Azores High, which had moved eastward towards the European mainland, with a maximum value of 1036 hPa. The depression (I) in the North Sea had moved to the north-east and lay over central Norway. The storm that had formed over the western Atlantic (II) had nearly fully traversed it by 10 October and was approaching the British Isles with low values of 990 hPa.

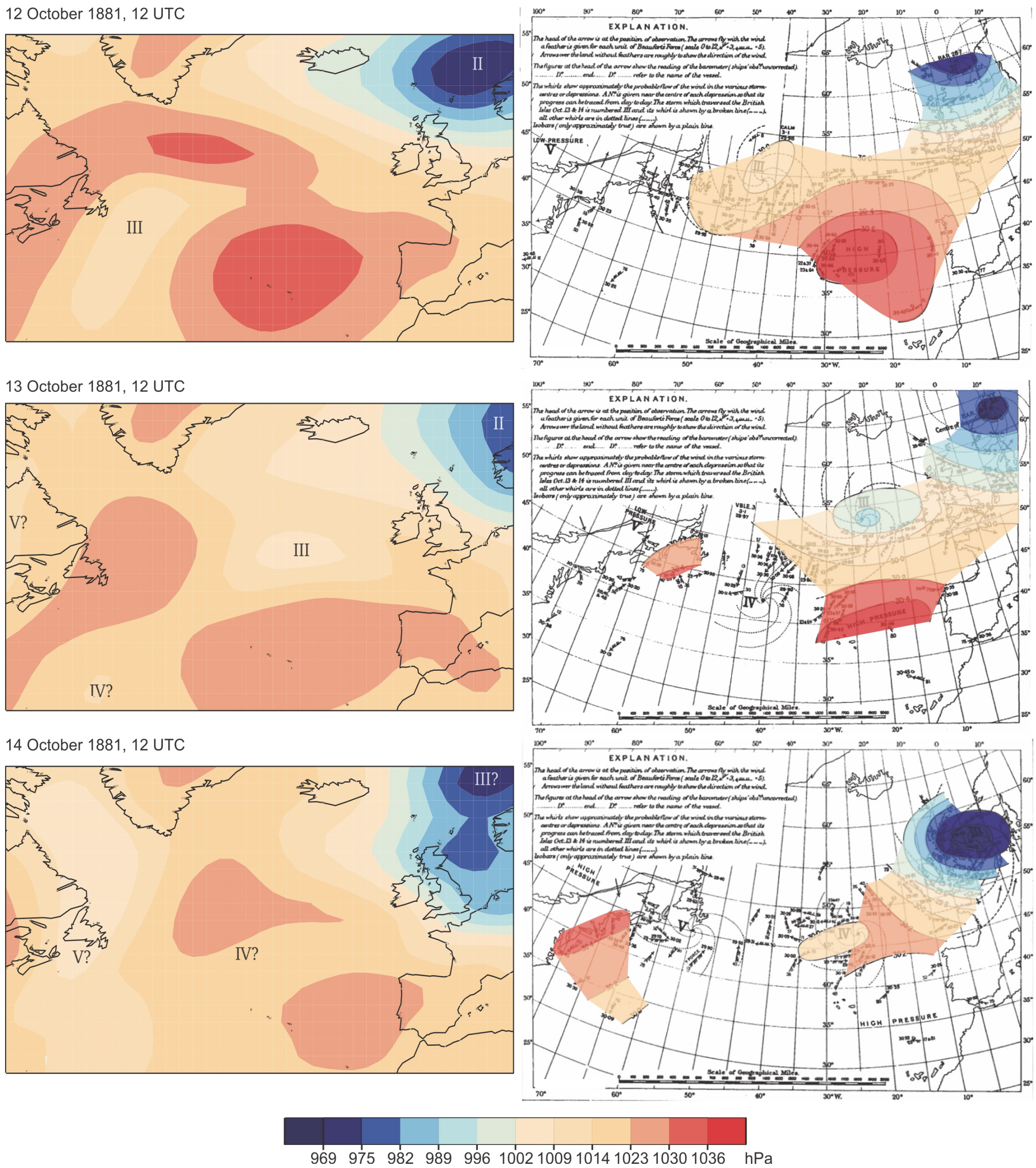

Figure 4. Sea-level pressure on 12-14 October, 12 UTC in (left) 20CRv2c and (right) Peggs (1882).

Simultaneously, a new storm (III), the future “Great Gale”, was forming south-west of Nova Scotia. 20CRv2c shows the movement of both the Azores High and the Icelandic Low, with the latter being further north and less pronounced than on the historical weather map.

On 11 October (Fig. 3, bottom), the Azores High, whilst still similarly strong, had moved towards the Azores. The depression (II) had settled down over Scotland, with very low pressure values of 969 hPa on the historical maps. The storm (III) exhibited values of 1010 hPa and was slowly moving away from North America towards Europe.

In 20CRv2c the storm (II) is clearly visible, with the same location and pressure values as on the historical weather maps. The storm (III) is depicted off the coast of Canada, where, additionally, a new high-pressure area had formed.

Figure 4 (top) depicts the situation on 12 October. The historical weather maps show an unchanged Azores High. The depression (II) had moved further towards Norway, with pressure values still around 990 hPa. The storm (III) had moved in a north-east direction, across the Atlantic, with a pressure of 1015 hPa.

In 20CRv2c the Azores High is still at the same location as on 11 October, but had joined the high-pressure area off the Canadian coast. The depression (II) stretched from Iceland over the British Isles up to Norway, with the centre lying over the Norwegian coast. The storm (III) had not changed its position.

On 13 October, the Azores High in the historical weather maps has weakened slightly, with values of 1036 hPa. The storm (II) had moved further north and exhibits pressure values of 975 hPa. The storm (III) was moving towards the British Isles at high speed and was amplified by the warm air from the Azores High. Its pressure value was around 996 hPa. A further depression (IV) was forming over the western Atlantic. The storm (V) was moving over the east coast of Canada in a north-eastern direction.

It is evident from the 20CRv2c data that the Azores High was weakening continuously. The low-pressure area (III) over the Atlantic had moved towards the north-east and now lay off the British Isles. It is, however, weaker in 20CRv2c than on the historical weather maps. The storm (II) off the Norwegian coast had moved further north, but still reaches the eastern coast of England.

Figure 4 (bottom) shows the situation on 14 October. On the historical weather map a weakened Azores High is visible. The centre of the storm (III) had reached the British Isles with extreme values of below 969 hPa. The low-pressure areas (IV & V) can be seen on the weather maps, but they have not changed much.

In 20CRv2c the weakened Azores High appears. The low-pressure area (III), with pressure values of about 970 hPa, lay over the British Isles and had connected to the low-pressure area (II). However, the centre of the low-pressure area was further north and not as pronounced as on the historical weather maps. The low-pressure area (V) had formed off the Canadian coast.

3.2. Pressure levels over the British Isles on 14 October 1881

In the following section 20CRv2c is compared to the historical weather map of the British Isles on the day of the storm, 14 October 1881 at 09:00, from Symons (1882) as well as with a map from Lamb and Frydendahl (1991).

On the historical weather map (Fig. 5, right) the isobars display a typical North-South Gradient. Extremely low pressure values appear over the British Isles with 958 hPa over Berwickshire. Over Northern England and Scotland an exceptionally strong pressure gradient is visible.

In 20CRv2c the isobars display a Southwest-Northeast gradient. The pressure gradient is very strong here as well, however, the lowest values only reach 979 hPa. It is also visible, that the low-pressure area greatly increased in size from 06:00 to 12:00.

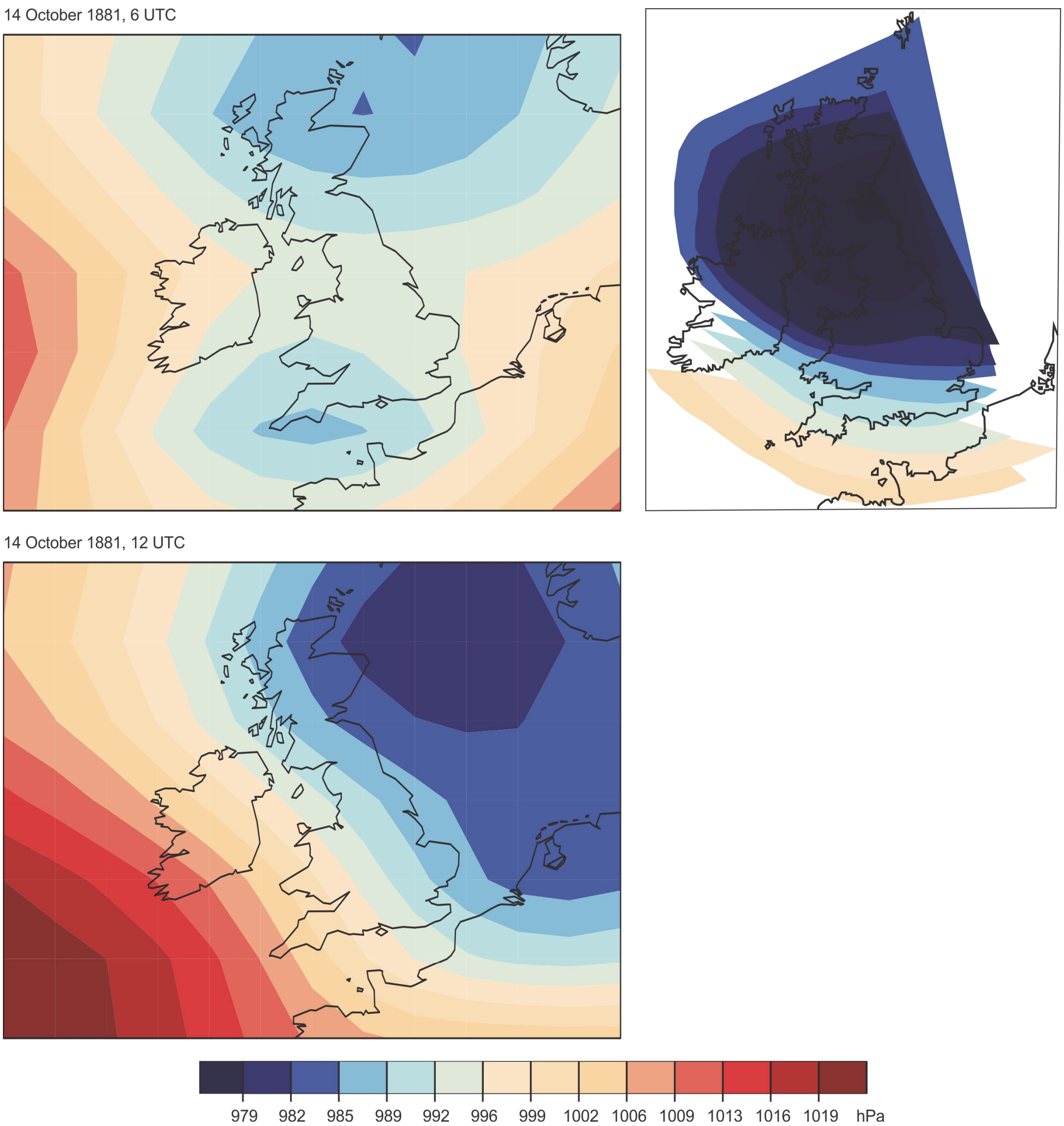

Figure 5. Sea-level pressure on 14 October, 6 and 12 UTC in (left) 20CRv2c and (right) at 9:00 from Symons (1882).

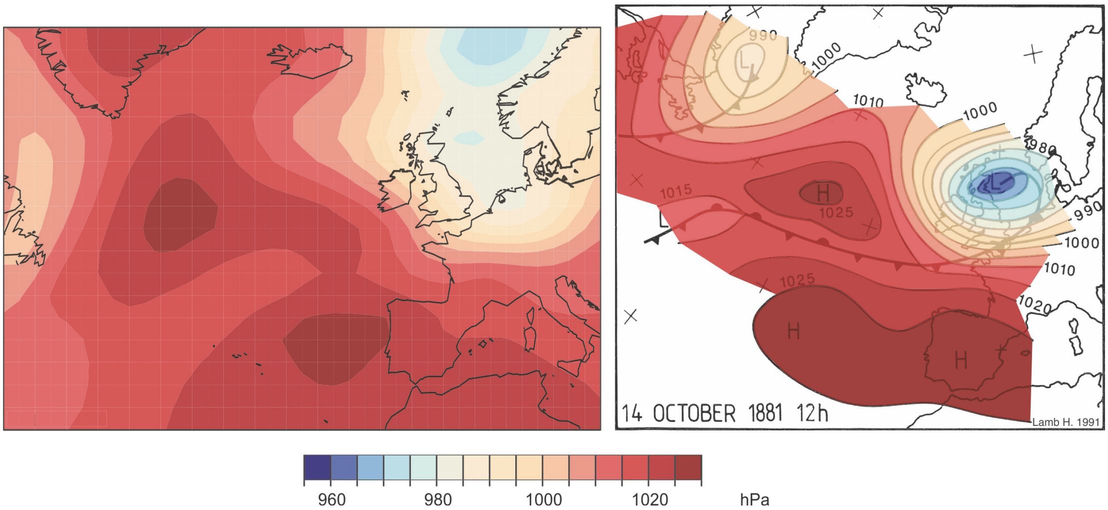

Figure 6. Sea-level pressure on 14 October, 12 UTC in (left) 20CRv2c and (right) Lamb and Frydendahl (1991).

On the map of Lamb and Frydendahl (1991) of 14 October at 12:00 (Fig. 6), a strong depression is discernible, with low values of 960 hPa. The depression lay over Berwickshire in south-eastern Scotland, causing exceptionally high pressure gradients over the British Isles. A second, much weaker depression, with low values of 990 hPa, lay between Greenland and Labrador. The Azores High ranged from the central Atlantic to the Iberian Peninsula and reached maximum values of 1025 hPa. Another high-pressure area, also reaching values of 1025 hPa, lay west of Iceland.

The 20CRv2c data of 14 October 1881 at 12:00 show that a low-pressure area, with pressure values of 980 hPa, lay over Norway. A further low-pressure area, with similar pressure gradients, lay east of Scotland. The Azores-High was west of Portugal, and another high-pressure area was situated in the centre of the northern Atlantic. A weak low-pressure area, with pressure values of 1000 hPa, is visible over Newfoundland.

4. Discussion

Through the comparison of the historical sources in the *Quarterly Journal of the Royal Meteorological Society* and the maps from Lamb and Frydendahl (1991) with the 20CRv2c generated maps, statements on the accuracy of 20CRv2c concerning its depiction of the “Great Gale of October 1881” can be made.

20CRv2c depicts the weather map of the northern Atlantic with a very high accuracy of both pressure levels and isobars. On 10 October, for example, one can find a very similar pressure gradient between the Azores High and the Icelandic Low in the historical maps and 20CRv2c. Especially the studied storm (III) and its route over the Atlantic to the British Isles are very consistent. The storm over Norway is also shown in both maps, but the extent of the depression of the “Great Gale of October 1881” on 13 and 14 October is not adequately depicted.

On closer inspection of the meteorological situation over the British Isles, however, some deviations can be observed. The different direction of the pressure gradients over Great Britain as well as the presence of a much stronger depression in 20CRv2c raise questions. The maps of the Atlantic (Figs. 3 and 4) and of Lamb and Frydendahl (Fig. 6) are, however, of high consistency. The circumstance that 20CRv2c inadequately depicts the low-pressure values of the “Great Gale of October 1881” accords with previous research (Brönnimann et al., 2013).

5. Conclusions

The data from 20CRv2c capture the main features of the “Great Gale of 1881” as depicted and described by contemporary authors as well as by Lamb and Frydendahl (1991). The general weather situation is well represented, as is the development over the preceding days. Secondary low-pressure systems could be identified and matched in the different sources. However, with increasing resolution, the reanalysis becomes less accurate differences to the historical weather maps appear. The map for the British Isles show larger deviations, but the resolution is beyond what can be expected to be captured in a 2° x 2° reanalysis.

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