Brönnimann, S., M. Wegmann, R. Wartenburger, and A. Stickler (2013) Arctic Winds in the "Twentieth Century Reanalysis". In: Brönnimann, S. and O. Martius (Eds.) *Weather extremes during the past 140 years*. Geographica Bernensia G89, p. 59-67, DOI: 10.4480/GB2013.G89.07.

Arctic Winds in the "Twentieth Century Reanalysis"

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Abstract

Climate in the European part of the Arctic underwent a rapid warming between the 1910s and the 1930s. Previous studies have addressed the role of atmospheric circulation in this period based on geopotential height fields because observations of upper-level winds in the Arctic are rare. Here we analyse winds over the Arctic and specifically over Spitsbergen in the "Twentieth Century Reanalyses" (20CR). We compare *in situ* upper-air wind measurements performed in 1912 and 1913 in Spitsbergen with six-hourly 20CR data. Furthermore, we compare monthly-to-seasonal 20CR winds at 700 hPa over the European Arctic with statistically reconstructed winds at 3 km altitude. Finally, we analyse long-term trends in Arctic winds in 20CR. The general agreement between observed upper-air winds and 20CR on the day-to-day scale is rather poor, which is not surprising given the paucity of observations in the Arctic at that time that constrain 20CR. In contrast, the seasonally averaged winds (which represent a larger spatial scale) in 20CR compare well with statistically reconstructed winds. The analysis of long term near-surface wind time series in 20CR shows arguably artificial trends from 1871 to around the 1950s over sparsely observed regions, particularly oceanic regions. Densely observed regions such as Europe or the USA show no such trends. This analysis shows that great care needs to be taken when working with 20CR in the Arctic and other sparsely observed regions.

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1. Introduction

The Arctic has warmed rapidly during the past three decades, accompanied by a substantial decrease in sea ice in summer and autumn. The changes in Arctic climate are far more pronounced than the global mean changes; a phenomenon known as Arctic amplification (Holland and Bitz, 2003). A very strong warming occurred also between the 1910s and the 1940s (Polyakov et al., 2003; Overland et al., 2004; Johanessen et al., 2004), specifically in the European Arctic. In previous works (Grant et al., 2009; Brönnimann et al., 2012b) we have analysed this warming in more detail in surface and upper-air temperature measurements and statistically reconstructed geopotential height (GPH) fields (Griesser et al., 2010) and compared the results to the “Twentieth Century Reanalysis” (20CR; Compo et al., 2011). Reasonable agreement was found between observed daily temperature profiles and 20CR from 1 km a.s.l. upward, and very good agreement was found between decadal warming phases and reconstructed atmospheric circulation as imprinted in GPH. However, wind itself was not analysed. For calculating atmospheric heat fluxes from reanalysis data, wind in 20CR needs to be assessed at all time scales that are relevant for heat fluxes.

Here we supplement our previous work by a comparison of observed historical wind profiles from Spitsbergen from the years 1912 and 1913 with corresponding 20CR data. Furthermore, we compare seasonally averaged wind fields in 20CR and statistical reconstructions (Griesser et al., 2010) and analyse long term trends in near-surface winds in 20CR.

The paper is organised as follows. Section 2 introduces the historical observation material and 20CR. In Section 3 we compare observed wind profiles with 20CR during the period 1912 and 1913. In Section 4 we analyse monthly-to-seasonal wind fields in 20CR and statistical reconstructions. Long-term trends in near-surface winds are presented in Section 5. Conclusions are drawn in Section 6.

2. Data

We analyse measurements performed with tethered balloons at Ebeltofthamna between June 1912 and September 1913. The data were originally published by Wegener (1916) and Wegener and Robitzsch (1916a,b). The observations were performed as part of German activities, in 1911-1914, in preparation of envisaged airship exploration of the Arctic (see Lüdecke, 2008, 2009). For the earlier observation period, no wind observations are reported, and the data from the last year (1913/1914) have never been published. In 1914 the observatory ceased operation due to the start of the First World War.

Ebeltofthamna is situated in the Cross Bay in Western Spitsbergen, north of today’s Ny Ålesund (see Fig. 1). It is surrounded by mountains of ca. 500 m altitude. In the period of measurements in Ebeltofthamna, from June 1912 to July 1913, 114 ascents were performed, 99 with balloons and 15 with kites. For this paper, we focus exclusively on the balloon soundings and we only use ascents that reach at least 1000 m, yielding 63 profiles. Also, in the following we do not show the scattered winter soundings but focus on the summers of 1912 and 1913, reducing the number of profiles further to 56.

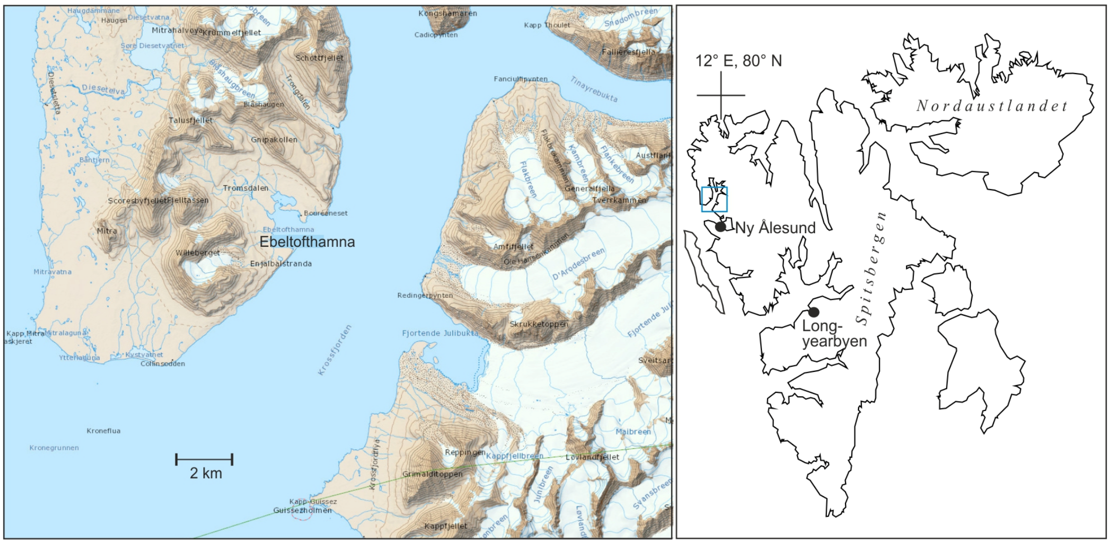

Figure 1. Map of the Cross Bay (Western Spitsbergen) with the location of Ebeltofthamna (left, reproduced with permission of the Norwegian Polar Institute). The right panel shows the Svalbard archipelago.

The data are given in Wegener (1916) and Wegener and Robitzsch (1916a,b) on fixed altitude heights. Although the reported altitudes (steps of 500 m) are almost equivalent to the pressure levels of 20CR (steps every 50 hPa), *u* and *v* wind components were interpolated linearly with pressure to the pressure levels of 20CR. We focus here on the levels up to 600 hPa (only three profiles reached higher up). The historical upper-air data from Spitsbergen are incorporated into the Comprehensive Historical Upper-Air Network (Stickler et al., 2010).

The observations were compared with the "Twentieth Century Reanalysis" version 2, which is a global 3-dimensional atmospheric dataset that reaches back to 1871 (Compo et al., 2011). It is based on an assimilation of only surface or sea-level pressure observations. In addition, monthly sea-surface temperature and sea ice distributions from HadISST (Rayner et al., 2003) were used as boundary conditions for the Global Forecast System atmosphere/land model (NCEP/GFS, Saha et al., 2010), which was run at a spatial resolution of T62 with 28 levels in the vertical. Assimilation was performed using an Ensemble Kalman filter, with 56 ensemble members. Here we use only the ensemble mean. Note that for the time period 1912 to 1913, the pressure data input into 20CR includes one station from Spitsbergen, but no other station within 1000 km.

For analyses on a seasonal time scale, the *in-situ* observations are too sparse. No meaningful seasonal average can be calculated for any level. Therefore, 20CR wind fields are compared with wind fields (*u* and *v* components) at an altitude of 3 km that were statistically reconstructed for the period 1880-1957 (see Griesser et al., 2010; Stickler et al., 2010). The reconstruction was based on a principal component regression approach, calibrated against wind fields from the ERA-40 reanalysis (Uppala et al., 2005). In 1912 and 1913, this reconstruction is solely based on historical surface data from station observations (temperature) and gridded SLP data (Allan and Ansell, 2005). In later periods (such as the 1940s shown later in this paper), upper-air data contribute significantly to the reconstructions.

3. Comparison of wind profiles in 20CR and observations

Figure 2 shows wind profiles from observations and 20CR for the summers of 1912 (left) and 1913 (right). Different profiles are displayed in different colours (but same colours in 20CR and observations), for better comparison. A first inspection shows that the observed wind speeds are smaller than in 20CR, quite often zero. This result might be affected by a sampling bias in that strong wind conditions are not favourable for tethered balloon soundings. In fact, many profiles show a strong increase in wind speed at the top, where the balloon was taken down again. However, also the wind direction does not always agree very well. Below 850 hPa, local topography might be a reason for discrepancies; hence we expect better agreement at or above that level. Although the agreement is better at higher levels, we still find discrepancies. Because of the specific sampling and because measurements also may have errors, the disagreement may not be entirely or even primarily due to problems in 20CR. Note that temperature from the same profiles showed good, though not excellent agreement with 20CR (correlation of ca. 0.5 between anomalies, from a mean annual cycle, of temperature in 20CR and observations at 1 km a.s.l. and higher up, see Brönnimann et al. 2012b).

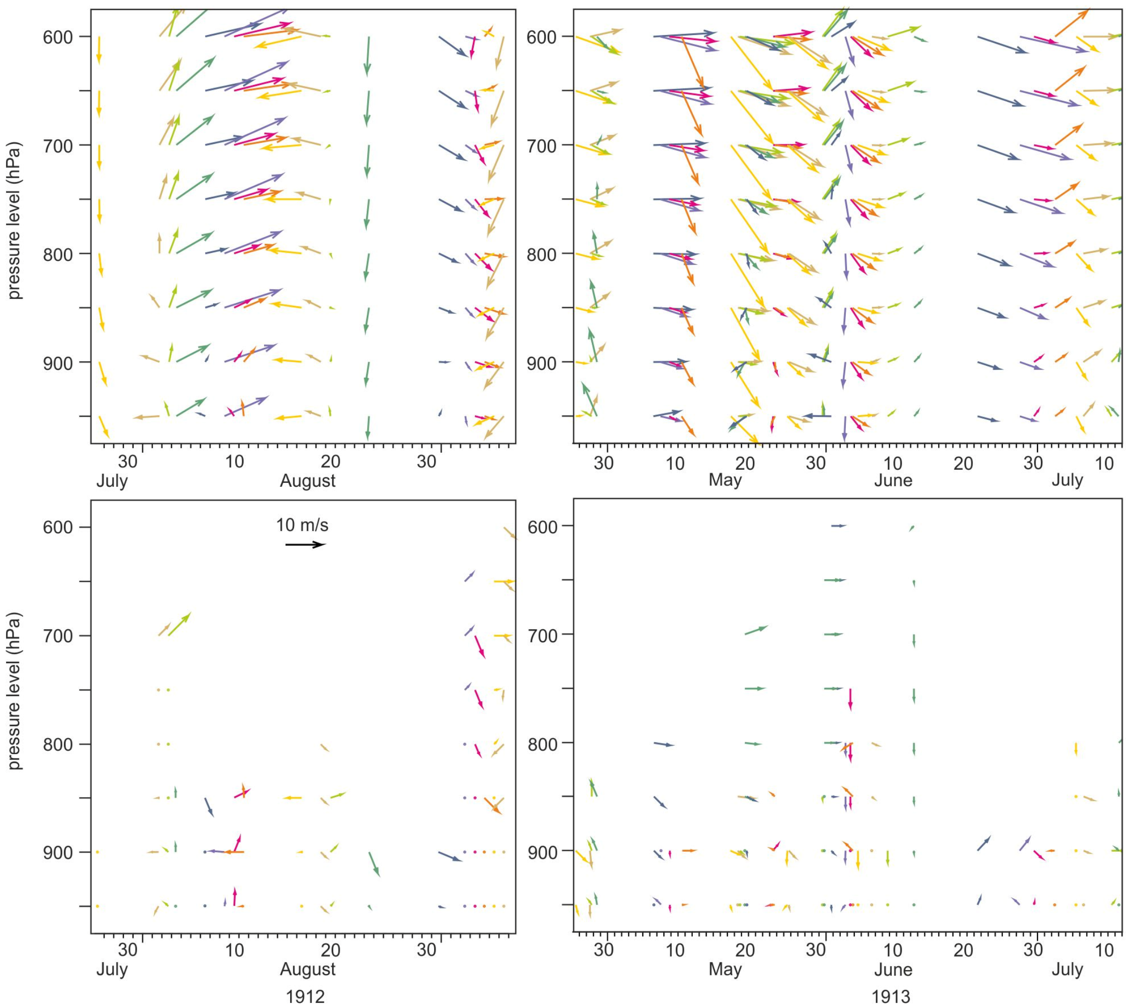

Figure 2. Wind vectors from 20CR (top) and corresponding observations (bottom) for the summers of 1912 (left) and 1913 (right). The observations were interpolated to the pressure levels of 20CR. Dots indicate wind speeds of zero.

4. Comparison of seasonal mean wind fields

Upper-air observations are too sparse to calculate monthly mean or seasonal mean winds. However, wind fields are available from statistical reconstructions for 3 km a.s.l. (Griesser et al., 2010), which we here compare with 20CR at 700 hPa for the observation periods (Fig. 3). For August 1912, both data sets show west-southwesterly winds over Spitsbergen. The agreement over the entire northern North Atlantic and northern Europe is very good. For the second period, May-June 1913, the two data sets show westerly (reconstructions) or northwesterly winds (20CR). The observations would rather indicate northwesterly winds, given the frequent northerlies reported, but the data are too sparse to calculate a mean value. The agreement between 20CR and reconstructions over the North Atlantic is again good, but REC1 shows smaller wind vectors (note that the length of wind vectors gives the magnitude of the averaged vector wind, not the averaged speed).

Similar comparisons were also performed for the winter season, specifically for the very cold winter 1911/1912 and the relatively warm winter 1944/45 (Fig. 4). For both winters, temperature profiles are available from Spitsbergen (discussed in Brönnimann et al., 2012b) showing good agreement between 20CR and observations. For the wind fields, again both data sets agree well. On the monthly-to-seasonal scale, circulation therefore seems well depicted in both data sets, allowing the interpretation of year-to-year variability in winter temperatures in terms of atmospheric circulation. The good agreement between the data sets

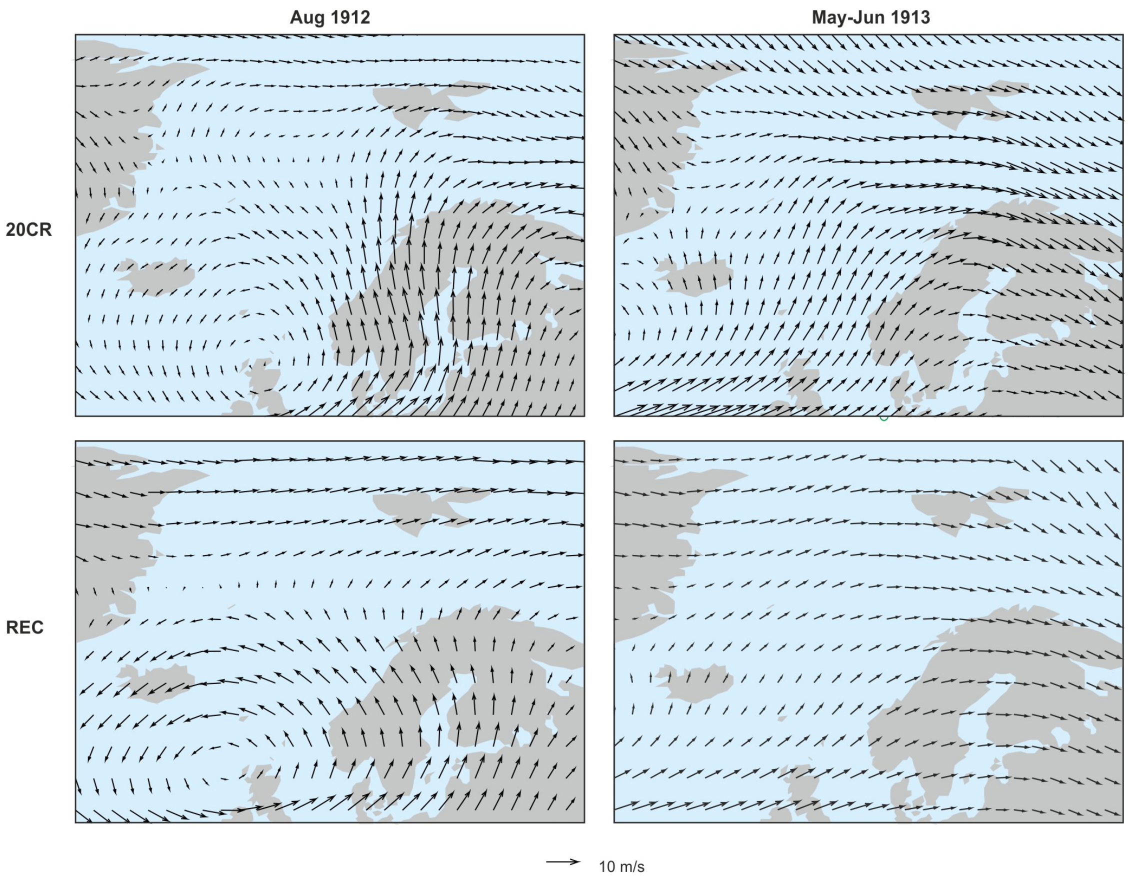

Figure 3. Wind fields for August 1912 (left) and May-June 1913 (right) in 20CR at the 700 hPa level (top) and in statistical reconstructions (REC, bottom) at 3 km a.s.l.

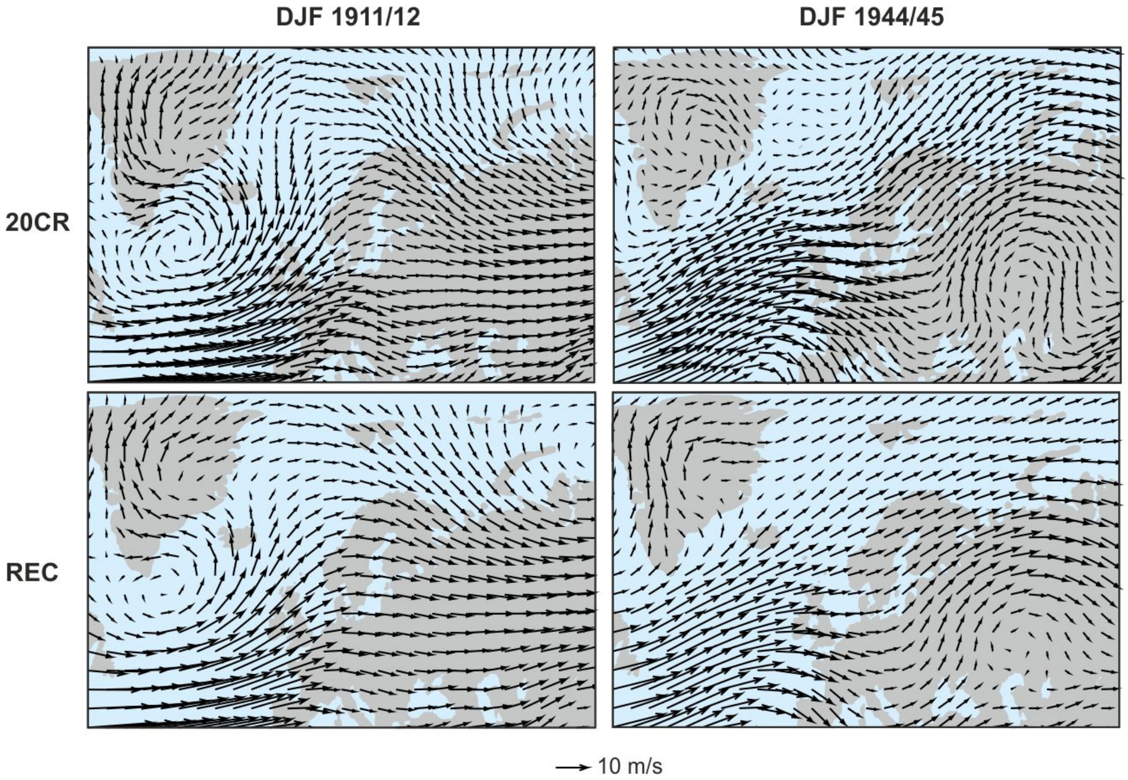

Figure 4. Wind fields for December 1911 to February 1912 (left) and December 1944 to February 1945 (right) in 20CR at the 700 hPa level (top) and in statistical reconstructions (REC, bottom) at 3 km a.s.l.

on this time scale might be related to the spatial scale. Monthly-to-seasonally averaged fields have larger spatial correlation scales than daily fields and large-scale circulation modes become more important. Hence, information from more distant places, where much more information is available, becomes important (see Griesser et al., 2010, for an analysis of typical spatial correlation distances for monthly means).

4. Long-term changes in Arctic winds in 20CR

In order to analyse and quantify the effect of long term trends in circulation on the warming of the Arctic, it would be interesting to calculate fluxes of heat, water vapour, or aerosols into the Arctic based on 20CR winds. For this purpose, not only the seasonally averaged vector wind is important, but also wind speed variations. Therefore, in this section, we analyse ensemble mean wind speed as well as the wind speed of the ensemble mean at the 0.995 sigma level.

We analysed time series of wind speed averages of several regions (shown in Fig. 5 as 20-yr moving averages) as well as hemispheric trend maps over the period 1871-1950 (Fig. 6). The year 1950 was chosen as end period because in previous work (Brönnimann et al., 2012a) we concluded that after 1950, midlatitude storms were better reproduced than before. In fact, the times series shown in Figure 5 confirm this conclusion in that the time series for all regions are almost flat after around 1950. However, depending on the region large changes are observed before 1950. The differences arguably reflect the paucity of observations. For

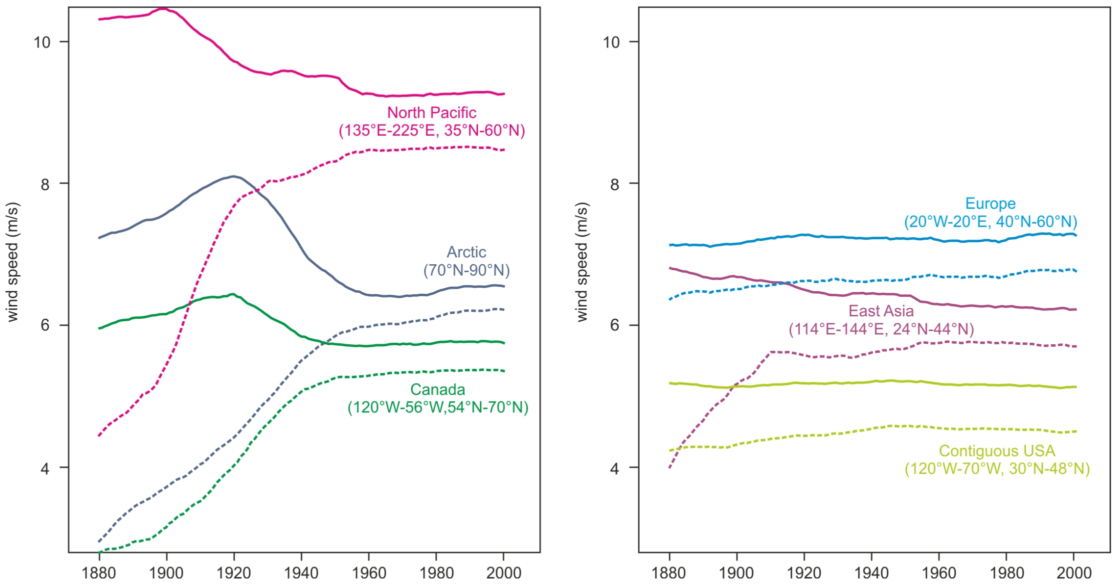

Figure 5. Time series of ensemble mean wind speed (solid) and wind speed of the ensemble mean (dashed) at the 0.995 sigma level from 20CR, averaged for several regions and smoothed with a 20-yr moving average.

the Arctic, northeastern Canada, and the northern North Pacific, all of which are poorly covered with observations, wind speed trend in the ensemble mean amounts approximately to a doubling. In contrast, only small trends are found over the regions that are well covered with observations, *i.e.,* Europe, North America, and (after around 1910) East Asia. The trend map (Fig. 6) further confirms that trends are strongest over the ocean and over land regions that are not well covered with observations. Seasonal trend studies (not shown) reveal that the trend is similar in all seasons.

The trends are largely due to ensemble averaging, however, analysing ensemble mean wind speed rather than the wind speed of the ensemble mean, an increase up to the 1920s and then decrease in Arctic wind speed is found. Strong biases have been found in Arctic near-surface air temperature as well as in tropopause temperature (Brönnimann et al., 2012b). While the former are due to an error in the specification of sea-ice, the latter might be related to a model bias (although on an interannual scale, the strength of the 200 hPa temperature error is correlated with the strength of the temperature error at the Earth's surface). Whether or not there is a relation between the temperature biases and the wind trend remains to be studied. Another possible source of inhomogeneities is changes in the variance inflation factors used in the assimilation procedure. Such changes were undertaken between 1890 and 1891 (globally), 1920 and 1921 (globally), and 1951 and 1952 (only tropics and southern hemisphere). The non-filtered time series (not shown) do not show evidence for step changes around these dates, although the flattening-out of the trends after 1950 occurs in many of the series. Hence, while the causes of the wind biases remain unknown, Figures 5 and 6 make clear that utmost care must be taken when using 20CR for trend analyses in regions with sparse observations such as the Arctic or oceanic regions.

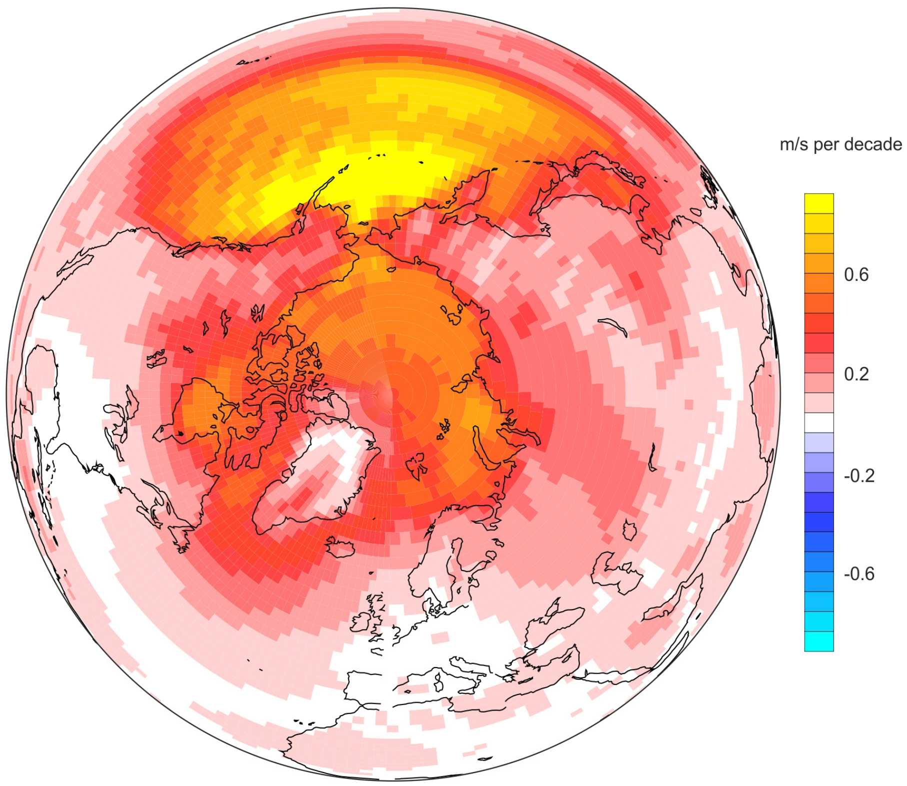

Figure 6. Linear trend (obtained with least-squares regression) of annual mean wind speed of the ensemble mean at the 0.995 sigma level over the northern hemisphere in 20CR from 1871-1950.

5. Conclusions

Winds over the Arctic during the first half of the 20th century were analysed in the "Twentieth Century Reanalysis" (20CR). A comparison with *in-situ* upper-air wind measurements performed in 1912 and 1913 in Spitsbergen revealed a rather poor agreement, which however could also be due to problems in the observations. The agreement was much better on a monthly-to-seasonal time scale, where 20CR was compared to statistically reconstructed winds at 3 km altitude. Large trends were found in near-surface wind speeds over the Arctic and the northern North Pacific in 20CR. The analysis suggests that prior to 1950, wind speeds in 20CR arguably show artificial trends and hence care should be taken when using these data for other purposes than addressing interannual variability.

Acknowledgments

20CR data were obtained courtesy of the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/. Support for the Twentieth Century Reanalysis Project dataset is provided by the U.S. Department of Energy, Office of Science Innovative and Novel Computational Impact on Theory and Experiment (DOE INCITE) program, and Office of Biological and Environmental Research (BER), and by the NOAA Climate Goal. The Project used resources of the National Energy Research Scientific Computing Center and of the National Center for Computational Sciences at Oak Ridge National Laboratory, which are supported by the Office of Science of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231 and Contract No. DE-AC05-00OR22725, respectively. The work was supported by the Swiss National Science Foundation (Project "EVALUATE"), the European project ERA-CLIM, and ERAnet.RUS (Project "ACPCA").

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