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Weather Conditions in Northern Europe in the Exceptionally Cold Spring Season of the Famine Year 1867

Juha Jantunen[1] *and Kimmo Ruosteenoja*[2]

[1] SMHI – Finland, Turku, Finland
[2] Department of Meteorology, University of Helsinki, Finland

(Corresponding author: Kimmo Ruosteenoja, Department of Meteorology, P.O. Box 4, 00014 University of Helsinki, Finland)

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Abstract

In 1867, the mean May temperature over large areas of Northern Europe was so low that anomalies of that magnitude can be expected to occur only a few times in a millennium. Cold weather conditions continued for the first half of June. On the basis of the available observational data, we reconstructed the temperature anomaly and surface pressure patterns over Europe for both months, and compared these with the distributions of other meteorological parameters. The daily synoptic situations in Northern Europe were also analyzed.

The extreme coldness of May was caused by a quasi-stationary flow pattern with high surface pressure over the Norwegian Sea and a depression over Northern Russia, bringing cold air into Northern Europe from the north and north-east. An anomalously extensive ice cover in the Arctic Ocean also contributed to the coldness. The northerly stream was sporadically strengthened by transient cyclones that travelled over Southern Scandinavia, the Baltic area or Central Russia to the east and north. The associated cold surges produced below-zero day-time temperatures at 60ºN even in mid-May.

In the first half of June, several cyclones passed over Central Scandinavia, filling over Finland and Northern Russia. The cold air stream continued to prevail, especially in Northern Scandinavia. An abrupt change in the weather type occurred around 20 June, when a warm easterly airstream spread into Northern Europe, and temperatures rose suddenly by about ten degrees.

Key words: Spring 1867, famine year, northern Europe

1. Introduction

In the year 1867, the spring season in Northern Europe was exceptionally cold. The vegetational period remained short and the temperature sum low, and a severe crop failure resulted. In the following year, about 8% of the population of Finland perished. In addition to hunger, this high mortality was caused by typhoid fever and other infectious diseases that afflicted the country at the same time (*Turpeinen*, 1986).

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Owing to the coldness of the spring, the break-up of ice occurred very late that year. For example, on Lake Näsijärvi (62ºN, 24ºE), the ice did not break up until 17 June (*Simojoki*, 1940); this is the only occasion during the observational period 1836–2000 when the break-up has taken place in June, the date being about 1.2 months later than the climatological average.

The mean temperature of the entire spring and summer season was substantially below normal, but especially severe was the coldness in May. Figure 1 shows the frequency distribution of the mean temperature for May in Helsinki, Finland. The mean temperature of May 1867, 1.8ºC, is so anomalous that it would certainly be regarded as an observational error were it not for the presence of anomalies of similar magnitude at nearby stations (section 3) and the exceptionally late break-up of ice mentioned above. In the relatively cool period 1861–1920, the mean temperature of May in Helsinki was +7.8ºC, the standard deviation being 2.1ºC. Assuming that the distribution of the mean temperatures is Gaussian with these parameters, the probability of the occurrence of a May mean temperature below 1.8ºC is about 0.002.

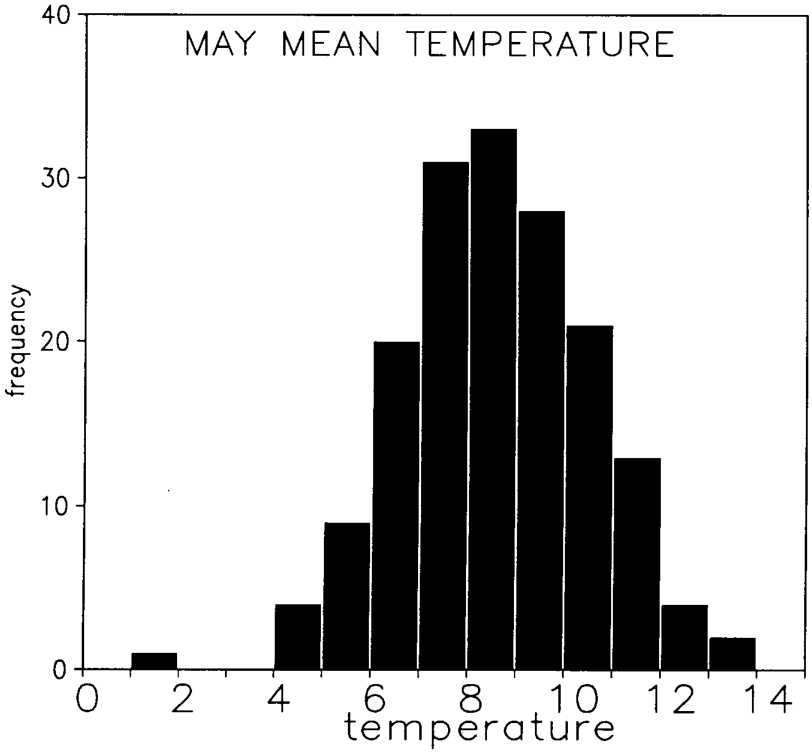

Fig. 1. The frequency histogram of the mean May temperature in Helsinki (60ºN, 25ºE) in the years 1829–1994, with a class interval of 1ºC. May 1867 is the only case in the class 1.0 … 1.9ºC, while the two subsequent higher classes are empty.

Cold weather conditions continued during the first half of June, but the mean temperature of that month was not particularly low, since the last third of the month was warm.

The purpose of the present paper is to investigate which kind of atmospheric conditions caused the extreme coldness of May and early June in Northern Europe. On the basis of the observational data available, we analyzed both the monthly means and the daily patterns of various meteorological variables. Despite the sparsity of the data, the weather type associated with the coldness could be reconstructed fairly well. The late Professor Jehuda Neumann had planned a similar study for his article series "Great historical events that were significantly affected by the weather", but he was not able to undertake the work during his lifetime.

As far as we know, there are no previous studies dealing with the springtime synoptic conditions of 1867. The severe crop failure experienced in the years 1695–96 has received attention by meteorologists, however. As in 1867, the spring came very late in these years, and the summer was cool and rainy (*Neumann and Lindgrén*, 1979). *Chernavskaya* (1996) sought information from chronicles and diaries about weather events occurring in Russia at that time, and made an effort to reconstruct the prevailing circulation patterns on the basis of analogous weather types in the period of instrumental observations.

In what follows, we first briefly describe the observational data employed in the study. The monthly mean conditions in May and June are then presented, especially the relation between the temperature anomaly and the surface pressure fields. Finally we study the daily variations in the weather conditions and discuss the factors that may have caused the anomalous circulation type.

2. Observational data

In the 1860's, the meteorological observational network in Europe was still fairly sparse. We were able to analyze monthly mean temperature anomalies reliably; unfortunately, surface pressure observations are scarce over large areas, especially over South-Eastern Europe. Despite this, the daily synoptic surface pressure maps could be analyzed, at least over Northern Europe, for almost every day. Some examples are given in section 4.

In Finland, regular meteorological observations have been made since the year 1829. Unfortunately, daily observations have only been published from 1873 onwards, and for 1867 only monthly means were obtainable. In neighbouring countries, especially in Scandinavia, much more observations are available (observations have been obtained from the published meteorological year-books). In this study, daily observations from 11 Swedish and 7 Norwegian stations are utilized. Regarding the Russian Empire as it existed at that time, we used daily observations from 7 stations, 3 of which are now located in the Baltic countries. The quality of Russian observations of the period has been questioned. For example, *Exner et al.* (1944) did not include any Russian observations before the year 1881 in their catalogue, since the homogeneity of these observations could not be assured. In our analyses, however, the Russian observations in most cases fitted in well with the general pattern, and we found no reason to reject them. The most important problem concerns the elevation of the station, which was not always known with adequate accuracy. Additionally, we employed the daily temperature values from Berlin, Germany.

In addition to the above daily observations, we utilized the monthly mean temperature, surface pressure and precipitation data from various stations elsewhere in Europe (*Exner et al.*, 1944; *Wild*, 1881, 1887; *Hann*, 1887). In the maps to be presented, the data points used in each analysis are shown.

The original temperature observations given in various units were converted into degrees centigrade (ºC). Because we wanted to compare the conditions in 1867 with the climate which prevailed at that time, we employed the climatology for the period 1861–1920 (in Russia, 1861–1915) in calculating the temperature anomalies. At several stations, monthly mean temperatures were not available for the entire period; the values for missing years were then derived from the observations of nearby stations. This procedure produces some inaccuracy in the temperature anomalies, typically of the order of a few tenths of ºC. However, this inaccuracy is small when compared with the actual anomalies, especially in May, when the anomalies were strongest. There was no need to reduce the temperatures to sea level, since in this study the focus is on the anomalies, not on the precise values of the temperature. In addition, the use of anomalies makes the results less sensitive to possible inhomogeneity in the time series caused by station relocations and changes of instrumentation, for instance (see, e.g., *Heino*, 1994).

The values of surface pressure were converted into SI units, temperature (to 0ºC) and gravity (45ºN) corrections were applied, and the pressure data were reduced to sea level. For some Russian lighthouse stations the actual elevation of the barometer was not given, and consequently these pressure observations could not be used. In addition, there are a few stations for which the information about the elevation given in various sources is contradictory. We then chose the value that we found most reliable.

Several stations also reported wind direction and speed, cloudiness and amount of precipitation. At that time the wind speed could not be measured quantitatively but was given on a qualitative scale, the number of classes varying from one country to another. Precipitation measurements are, as is generally known, notoriously susceptible to errors from several sources.

On the basis of the observational data, we constructed monthly mean temperature anomaly and sea-level pressure analyses for May and June 1867. We also studied the distribution of wind direction, precipitation and cloudiness at several stations. In addition, we constructed time series of daily mean temperature for some stations and analyzed the daily synoptic pressure fields in Northern Europe.

3. Monthly mean temperature anomalies and circulation patterns

The geographical distributions of monthly mean temperature anomalies in May and June 1867 are shown in Fig. 2. In May, the area of strongest negative temperature anomaly, more than 6ºC, ranges from Estonia and Southern Finland to Northwestern

Russia. A single station (Ustsyssolsk) located still further east (62ºN, 51ºE) showed an even stronger anomaly of –7.6ºC, but this figure is suspicious, since at surrounding stations the anomaly was distinctly smaller. This station was not included in the analysis. A substantial negative temperature anomaly covers the entire area of Northeastern Europe, whereas over large areas of Western and Southern Europe temperature conditions were quite normal. In the Mediterranean countries the month was even somewhat warmer than normal.

In June (Fig. 2b), there were also substantial negative temperature anomalies in Northern Europe, albeit smaller than in May. Compared with the climatology, the month was coldest in Northern Scandinavia and over the Baltic Sea. The latter area was evidently chilled by the late break-up of sea ice and the low temperature of the sea water, caused by the coldness of the preceding months. In Western Europe temperatures were nearly normal, and in the eastern part of European Russia the month was relatively warm.

It is interesting to compare the observed temperature anomalies with the circulation patterns. The distributions of monthly mean sea level pressure are given in Fig. 3. In May, there was a high pressure area over the Norwegian Sea and a depression in northern Russia. Apart from Scandinavia, however, the pressure data are sparse, and therefore the location of these pressure centres can only be estimated approximately. There are large areas of South-Eastern Europe where pressure observations are lacking totally, and it was hard to draw any isobars there.

Additional information about the position of the isobars can be obtained by studying the distribution of the wind directions; examples are given in Fig. 4. For instance, the location of the depression in Northern Russia was found on the basis of the most frequent wind directions at Kem (north-east, see Fig. 4b), Moscow (west and north-west, Fig. 4c) and Jekaterinburg (west and south-west, Fig. 4d).

The mean surface pressure distribution in May 1867 (Fig. 3a) definitely shows that arctic air streamed down from the Arctic Ocean into northern Europe. Over Southern Finland and the Baltic area the flow is diffluent, the eastern branch of the flow turning cyclonically into Russia and the western one anticyclonically into Southern Scandinavia. In Northern Europe northerly winds were much more common than they usually are, in agreement with the pressure pattern. For example, at Uppsala in Central Sweden as much as 60% of the observed winds in May 1867 blew from between NW and NE, the corresponding climatological figure for that period being 39% (Fig. 4a).

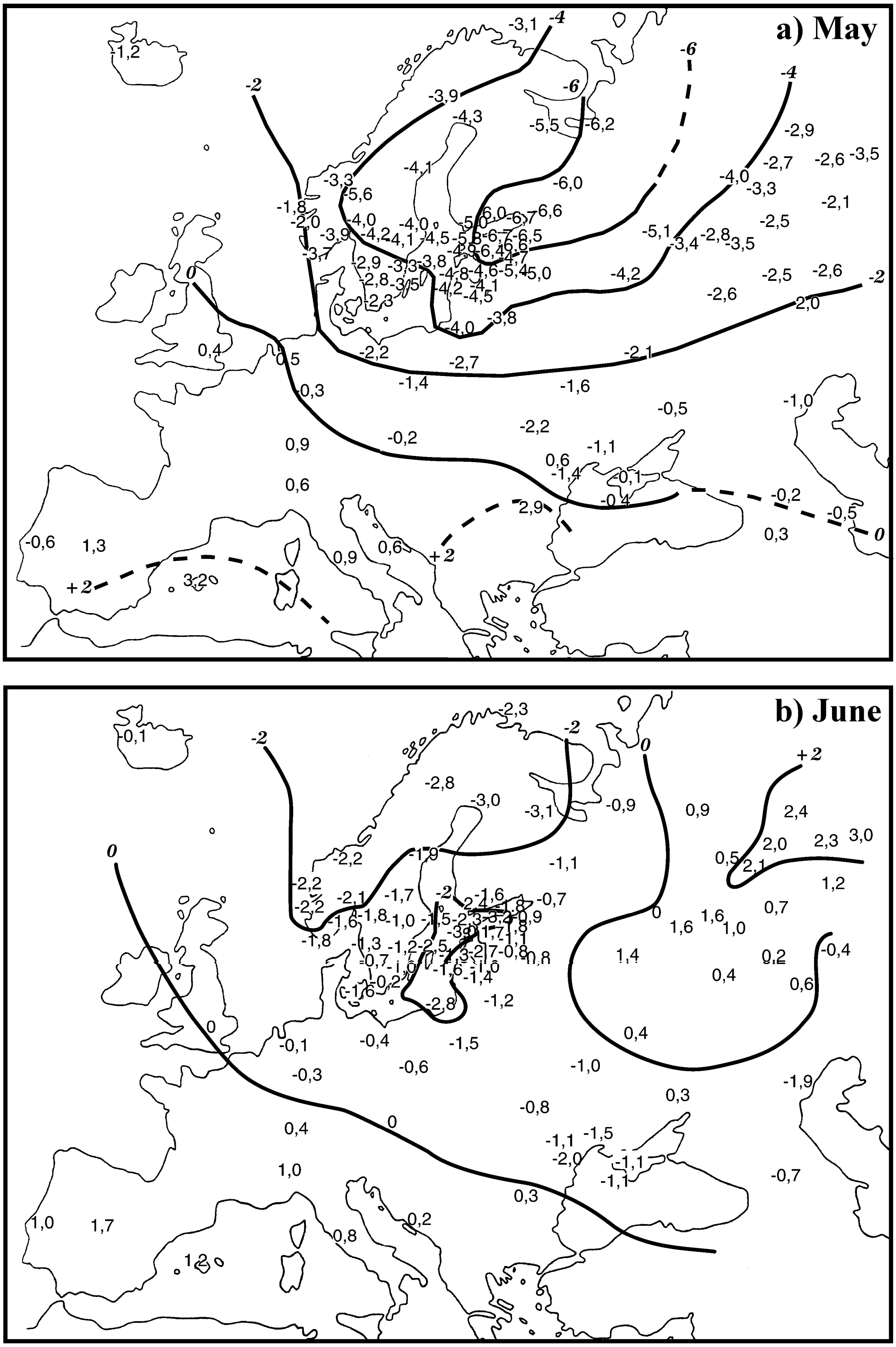

Fig. 2. Deviation of the monthly mean temperature of a) May and b) June 1867 from the climatological mean (1861–1920; in Russia 1861–1915). The contour interval is 2°C. In areas where the analysis is doubtful isotherms are indicated with a dashed line. The numbers indicate the temperature anomalies at the stations used in the analysis.

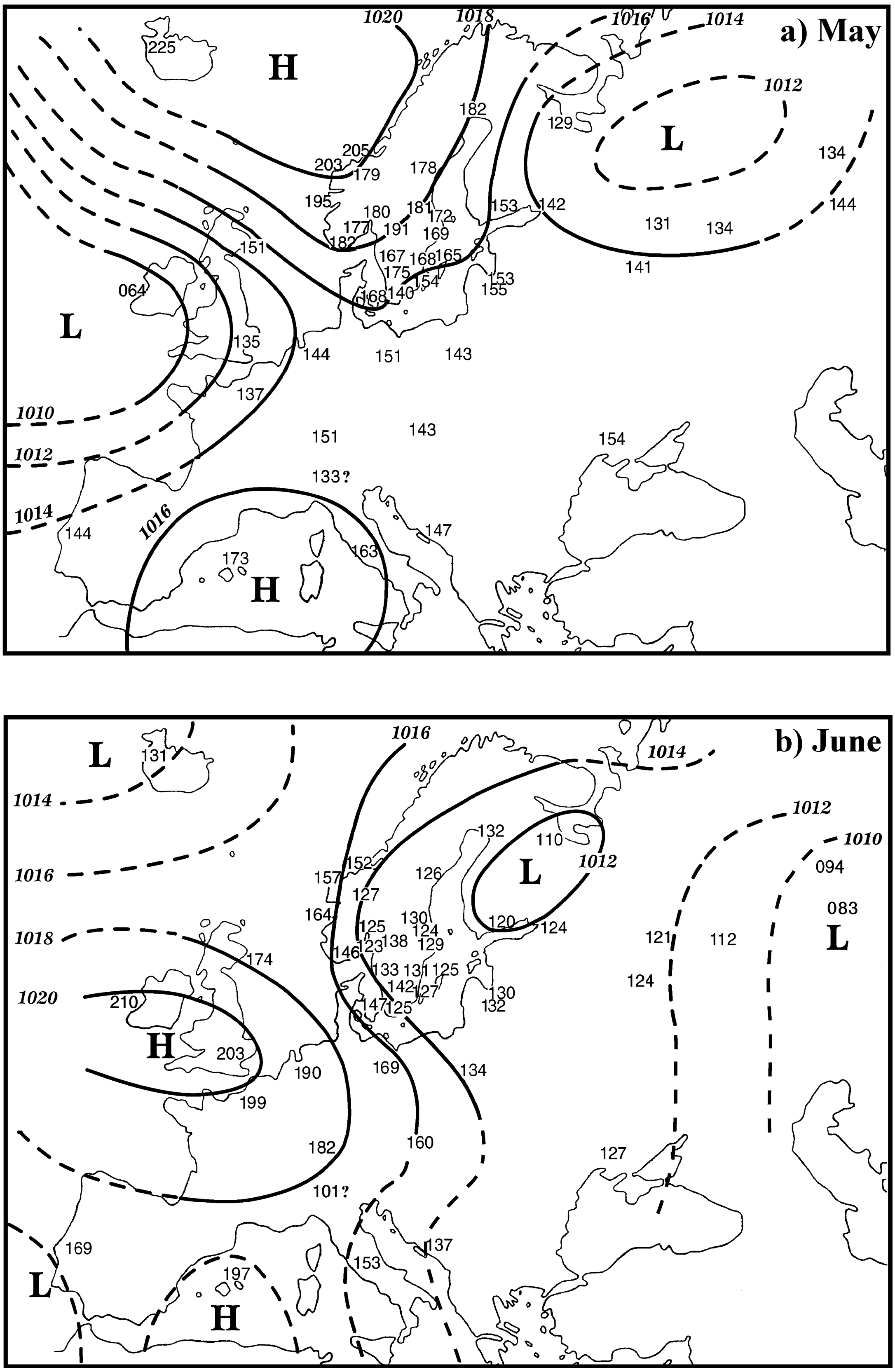

Fig. 3. The distribution of sea level pressure in a) May and b) June 1867. The interval of the isobars is 2 hPa. In areas where the analysis is very doubtful isobars are drawn with a dashed line. In the eastern part of European Russia, this is due to uncertainty about the elevation of some stations. Numbers show the locations of the monthly mean pressure data (p – 1000 hPa in units of 0.1 hPa).

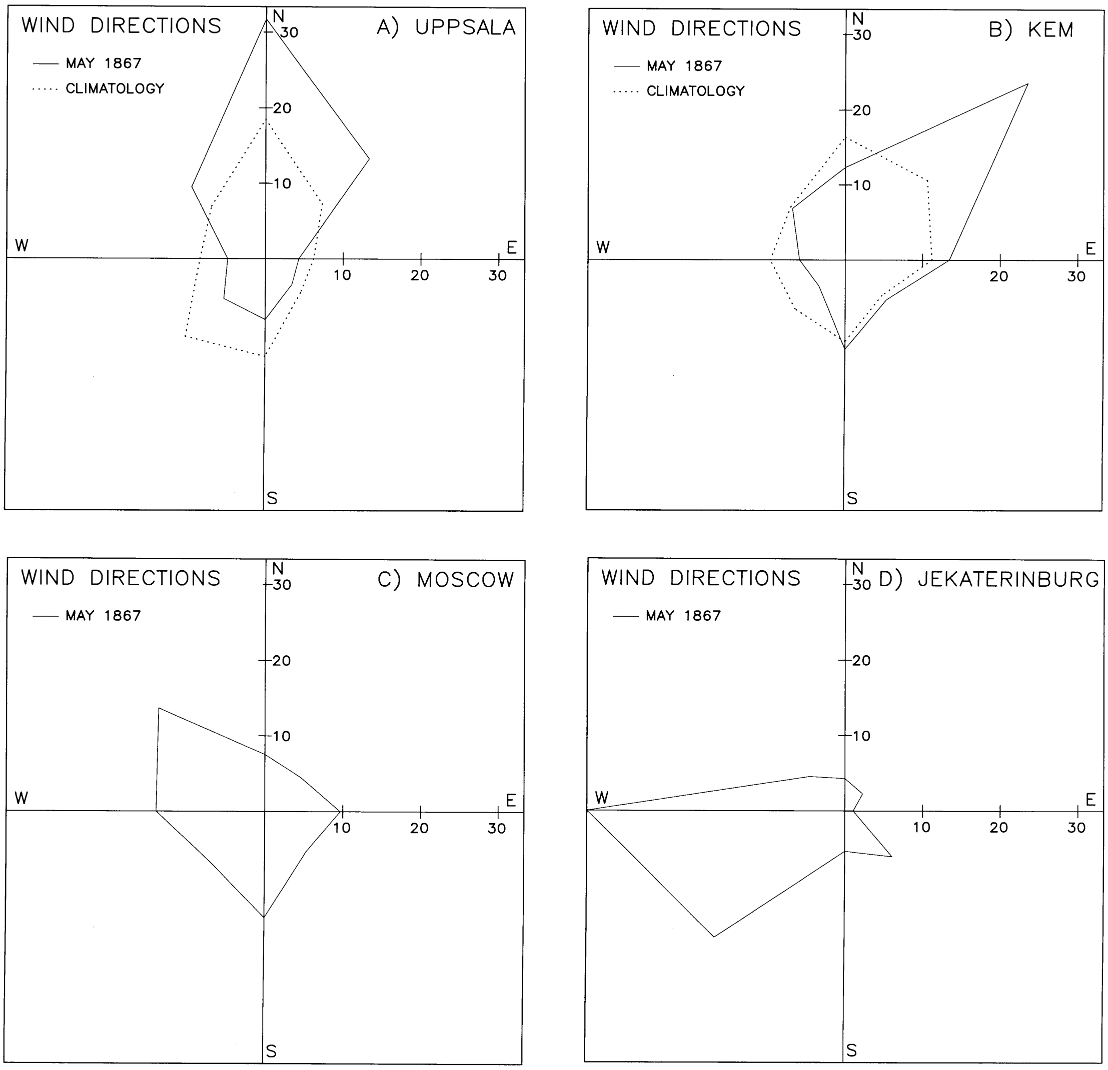

Fig. 4. Distribution of the wind direction at a) Uppsala (60°N, 18°E), b) Kem (65°N, 35°E), c) Moscow (56°N, 38°E) and d) Jekaterinburg (57°N, 61°E) in May 1867 (solid line). In panels a and b the climatological distribution (*Rykatschew*, 1878, 1880; dotted line) is also given. Depicted is the percentage of winds from each of the eight directions (N, NE, E, …, NW).

The averaged pressure distribution and the location of the associated northerly air flow are in excellent agreement with the temperature anomaly (Fig. 2a). The relatively coldest air lies in the area of the strongest diffluence of the northern mean flow. At Kem on the coast of the White Sea, the prevailing wind direction was north-easterly (Fig. 4b). This indicates that the extremely cold air masses reaching Southern Finland chiefly originated from the ice-covered areas surrounding Novaya Zemlya, not from the partially ice-free Barents Sea. In Western Siberia, cold air advection from these ice-covered seas is a common phenomenon, and there the climatological mean spring-time temperatures are indeed much lower than at corresponding latitudes in Northern Europe (*Solantie*, 1987).

The coldness of the northerly and northeasterly airstreams was further intensified by the unusually southerly location of the ice edge in the Arctic Ocean. *Vinje* (2000;

Figs. 1–3) showed that in the years 1866 and 1867 the spring-time ice cover in the sector 10ºE – 70ºE was the most extensive during his entire research period 1864–1998. In fact, large positive ice-cover anomalies have likewise occurred earlier during the Little Ice Age, e.g., during the period 1800–1830 (Vinje, personal communication), but generally these events did not coincide with such an exceptionally permanent northerly flow type as in 1867.

Over the Scandinavian peninsula, the air in the cold anticyclonic flow evidently tends to subside, and the associated adiabatic warming and radiative heating of the surface raise the temperature. This explains why the temperature anomaly weakens downstream toward the west. Moreover, before entering Western Scandinavia, the mean air flow passes over large ice-free sea areas. The northerly mean flow does not reach Central Europe, and the temperature anomaly weakens to the south accordingly.

In June 1867, an extensive low pressure area covered Eastern and Northeastern Europe (Fig. 3b). The distribution of wind directions was generally closer to the climatological state than that in May. However, the large frequency of northerly winds at Skudesnes on the Norwegian coast (59ºN, 5ºE) and the northwesterly winds at Bremen in Northwestern Germany (53ºN, 9ºE) fit well with the pressure distribution. In Moscow (56ºN, 38ºE), the most frequent wind directions were north and north-west, which supports the idea of the Northeast-European low having two centres.

As in May, the monthly mean temperature anomaly (Fig. 2b) and surface pressure patterns agree well. The relatively coldest area, Northern Scandinavia, is in the region of northeasterly mean flow from the Arctic Ocean, where the ice cover was anomalously extensive (see discussion above). This cold airstream extends southward on the western side of the depression; in the temperature anomaly field this is seen as a cold tongue over the eastern part of Central Europe. On the northern side of the Russian low, the easterly airflows produce positive temperature anomalies in the Urals area; in Jekaterinburg, in 2/3 of the cases where nonzero wind speed was reported, the wind direction was between NE and SE.

Analyzing the monthly precipitation sums is a much more difficult task than constructing the distributions of temperature and surface pressure, since precipitation is a smaller-scale phenomenon and the quality of the precipitation measurements is questionable. Therefore no illustration is given, and only the main features are briefly discussed. In May, the monthly precipitation sum in Scandinavia was mainly less than 30 mm, except for the southernmost part and the Norwegian coast. North of 65ºN, the reported monthly precipitation was even lower than 10 mm, but this may be related to difficulties in measuring precipitation that mainly occurred as snow. The dryness of Northern Europe is in agreement with the occurrence of the cold northern mean flow curving anticyclonically over the Scandinavian peninsula. In a zone extending from Central Europe to central Russia, rainier conditions prevailed, the monthly precipitation being generally ~60–100 mm. The anticyclonic Western Mediterranean area was almost rainless.

In June, Central Scandinavia and large areas of Russia received moderately strong precipitation. Russia was under the influence of a quasi-stationary depression (Fig. 3b), while several transient cyclones passed over the Scandinavian peninsula in the first half of the month. The areas surrounding the Baltic and the White Sea were fairly dry. This may be partly due to reduced convective activity near the coasts of these anomalously cold sea areas.

All results based on the precipitation analyses must, of course, be considered as tentative owing to the sparsity and inhomogeneity of the data.

As far as cloudiness is concerned, one must be extremely cautious in drawing any conclusions from unverifiable observations based on subjective evaluation of the cloud cover (*Heino*, 1994). This especially holds for the Russian Empire, where there were great differences in the reported mean cloudiness even at stations situated close to one another. In Central and Northern Sweden, May 1867 seems to have been cloudier than average; in Stockholm and Haaparanta (Haparanda) the monthly mean cloudiness exceeded the climatological value (*Birkeland and Föyn*, 1932) by about 5, in Falun by 14 percentage units. In June the mean cloudiness likewise exceeded the climatological values slightly, by 5–7 percentage units, in spite of the fairly clear warm period at the end of the month. Above-mean cloudiness tends to reduce insolation and lower day-time temperatures.

There are two additional factors that strengthened the coldness, especially in May. The first is the positive feedback associated with the snow cover. Because of the coldness of the spring, the snow cover presumably melted unusually late (no quantitative snow measurements are available); the heat consumed by melting and the high albedo of the snow tended to reduce day-time temperatures. Probably, however, the influence of the snow on the surface albedo was fairly small, since a major part of Finland was covered by coniferous forest; the influence was strongest in Southern Finland where the proportion of open and bush-covered terrain was greatest. Secondly, a substantial fraction of the precipitation was received in the solid phase, which prevented the temperature from rising higher than a few degrees on several occasions. For example, in St. Petersburg 9 days with snowfall were reported in May 1867, the corresponding average figure for the years 1836–1882 being 2.0 (*Wild*, 1887).

4. Daily variations

Merely studying the monthly means does not give a comprehensive picture of the meteorological conditions for a month, since several interesting features in daily patterns are then smoothed out. This section deals with the daily variation of the weather.

The time series of daily mean temperatures (Fig. 5) demonstrate the coldness of May and early June in Northern Europe. At Haparanda, for example, the daily means did not exceed 0ºC until 18 May. In Stockholm there were a few warmer days (7 and 30–31 May; 7–8 June), but at other stations the temperature anomaly was almost uniformly negative. Substantial warming occurred around 20 June, except at Kem, which was chilled by the easterly flow from the White Sea.

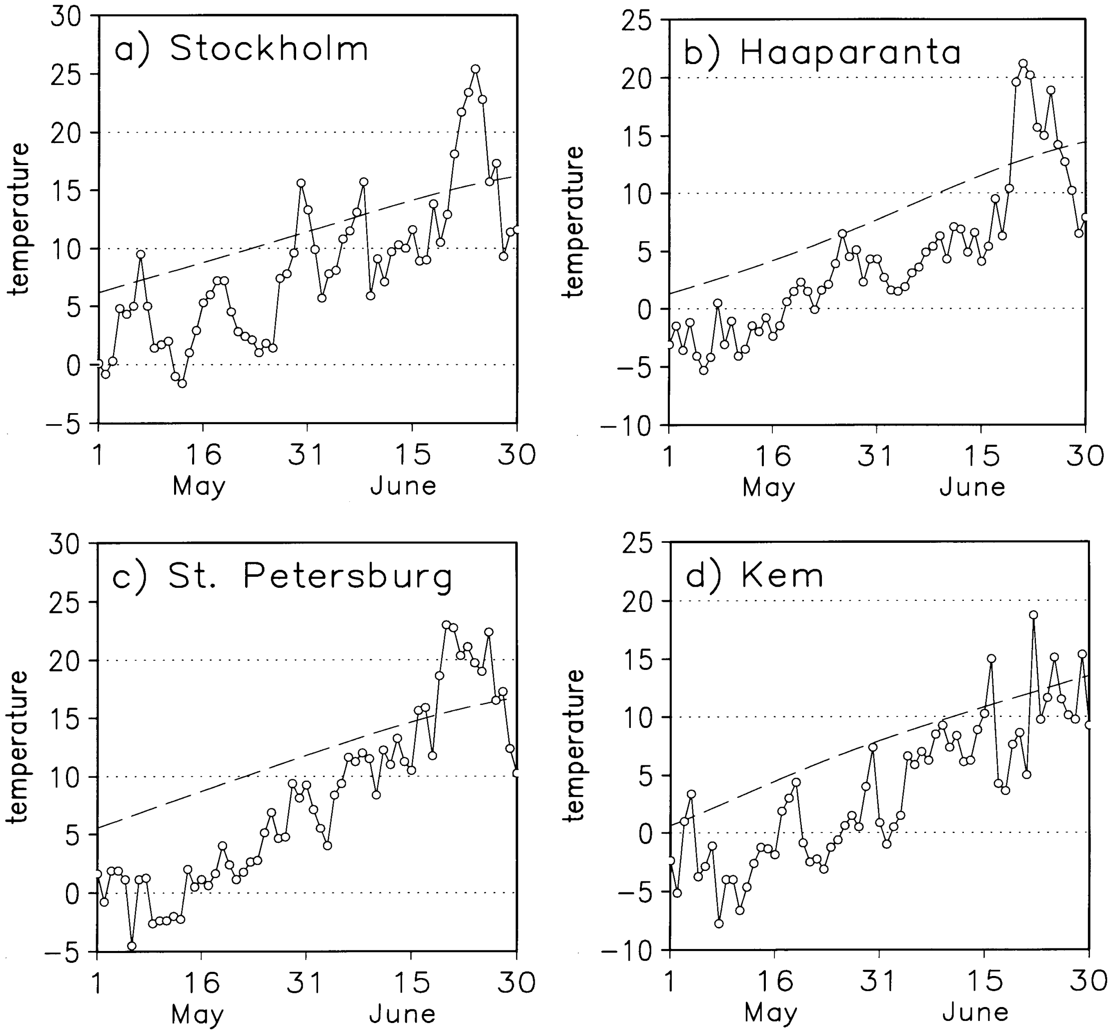

Fig. 5. Daily mean temperatures in a) Stockholm (59°N, 18°E), b) Haaparanta (Haparanda) (66°N, 24°E), c) St. Petersburg (60°N, 30°E) and d) Kem (65°N, 35°E) in May–June 1867 (open circles). The dashed curves show the climatological mean temperatures on each calendar day; these averages have been obtained by fitting a six-component Fourier series to the annual course of the climatological monthly mean temperatures.

In central Europe the cold anomaly in the monthly mean temperature was much weaker than in Scandinavia, but temperature variations were strong. In Berlin, for example, the daily mean temperature for 8 May was +17ºC, for 24 May as low as +3ºC, and for 31 May very high again, +24ºC (not shown). Farther north the variations were weaker, especially so in St. Petersburg and Haparanda. At Kem the temperature conditions depend strongly on whether the wind is blowing from the land or from the sea.

At the beginning of May, there was a high pressure area over Northern Scandinavia and a depression in Central Europe, the associated easterly flow bringing in cold air, especially into Northern Scandinavia. During the next few days the flow became northwesterly. On 7–8 May, a strong cyclone travelled over Central Scandinavia and

Southern Finland into Russia, temporarily bringing warmer air into Southern Scandinavia and the Baltic provinces. This cyclone was followed by an exceptionally cold northerly airstream lasting about a week. On some days, even the day-time temperature remained below 0ºC as far south as Central Sweden and St. Petersburg (Fig. 6a).

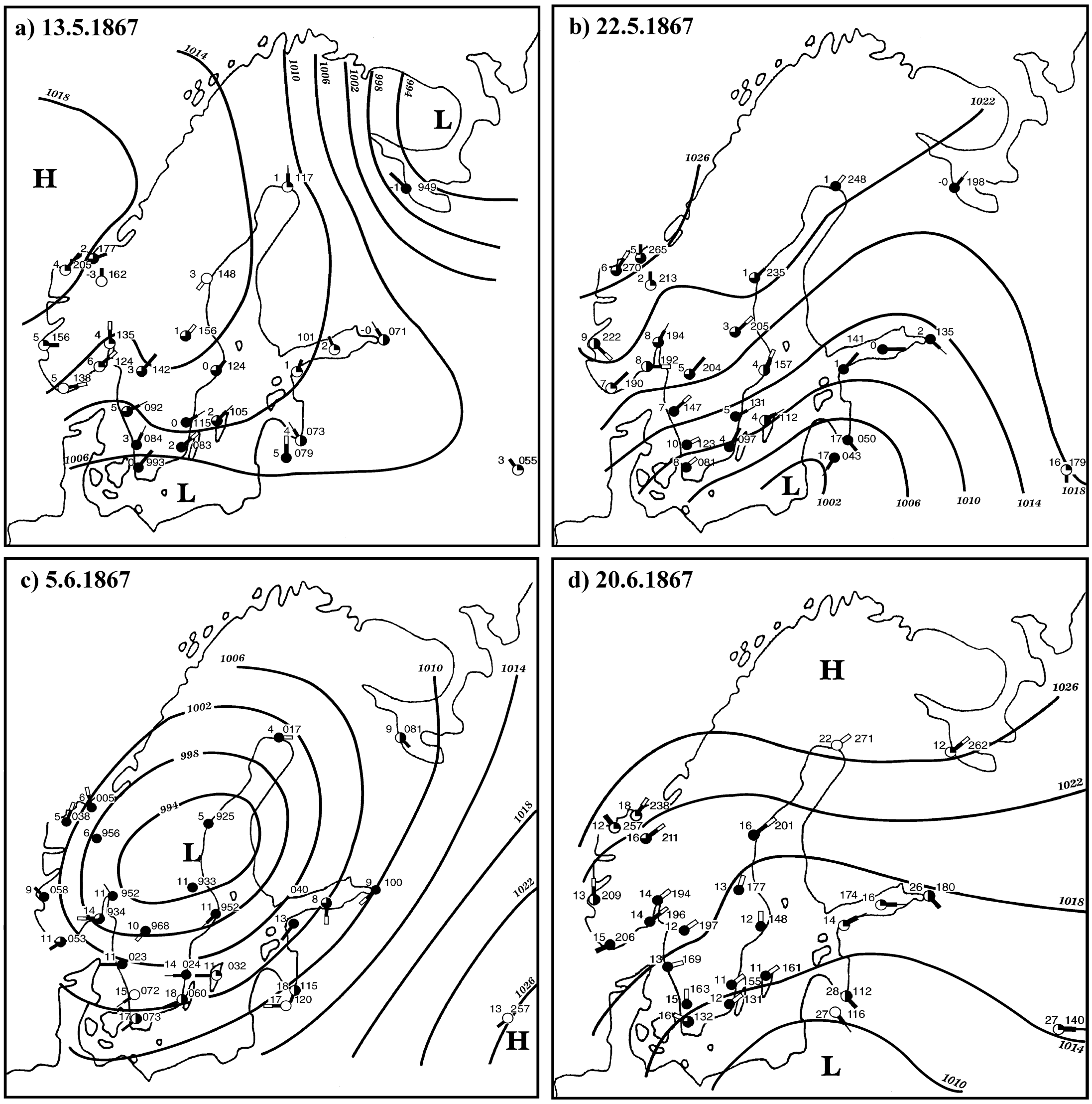

Fig. 6. The synoptic situation in Northern Europe on the afternoon of a) 13 May, b) 22 May, c) 5 June and d) 20 June 1867. Contours show the isolines of surface pressure reduced to sea level, with an interval of 4 hPa. Temperature, reduced air pressure, cloudiness and wind direction are plotted at the location of the observation stations in a way similar to conventional synoptic maps. The wind arrow indicates the subjectively-evaluated observed wind speed: no arrow – calm; short thin arrow – almost calm; short open – very weak wind; short thick – weak wind; thick + thin arrow – moderate wind; thick + open arrow – strong wind; long thick arrow – very strong wind. Note that the wind speeds at the various stations are not quite commensurable. The reduced air pressures at Lund (Southern Sweden) and Dovre (the inland station in southern Norway) do not completely agree with the analysis, which may be due to inaccurate information about the station elevation.

After a minor warming associated with an anticyclone extending from the south into Southern Finland, a new cold period began on 20–21 May when a strong cyclone moved from central Russia to the White Sea. After that, several depressions moved north-eastwards from Central Europe, and a cold northeasterly flow prevailed in Northern Europe (Fig. 6b). On 23–25 May the cold air mass even reached Northern Germany. On 27 May a high pressure area formed on the eastern coast of the Baltic Sea, and a warmer south-westerly airstream spread into Southern Scandinavia.

In the first half of June, several depressions moved from the west into Scandinavia, bringing in cool maritime air (Fig. 6c). Some of these cyclones filled over Finland, others continued into Russia, followed by cold outbreaks. A dramatic change in weather conditions occurred around 20 June, when an anticyclone developed in Northern Scandinavia and a cyclone over Central Europe (Fig. 6d). This allowed warm air to spread into Northern Europe from the east, and temperatures rose suddenly by about ten degrees. This warm period lasted about one week, after which a cyclone formed over Northern Scandinavia, and a cool northwesterly flow followed.

The spring-time flow pattern elucidated here is quite different from that which *Chernavskaya* (1996) suggested to have prevailed in 1695. For example, in that work the main storm track was found to extend from the Black Sea north and north-eastwards into Central Russia. In the present work, by contrast, we found that the cyclonic activity in 1867 was strong south of the Baltic Sea (in May) and over Scandinavia (in June). Of course, there is no reason why the flow configurations in these two cold years should have been similar.

5. Summary and discussion

In 1867 the spring in northern Europe was extraordinarily late. In Helsinki, for example, the mean temperature for May was so low that the estimated statistical probability for such coldness is about 1/500. Our analysis indicates that deviations of nearly the same amplitude occurred at a large number of nearby stations. The distribution of the temperature anomaly and the analyzed monthly mean flow pattern are in good agreement. The principal reason for the coldness was a prevailing northerly to north-easterly air stream between the stationary high over the Norwegian Sea and a depression in the monthly mean pressure field over Northern Russia. Several transient cyclones sporadically strengthened the northerly air flow. The anomalously southerly ice edge in the Arctic Ocean also contributed to the coldness.

Cold weather continued into early June, but an abrupt warming on about 20 June caused the mean temperature of that month to be less extreme than in May. In the first half of June, several cyclones travelled over Central Scandinavia from the west, bringing polar maritime air into Northern Europe. In addition, the coldness of the Baltic Sea lowered the temperature, especially in coastal areas.

All the analyses presented are based on the original data, and no attempt has been made to eliminate inhomogeneities caused by exposure of instruments, station relocations etc. (*Heino*, 1994). The spring season of 1867 was, in any case, so extreme that such corrections would not alter the results significantly. Moreover, the observations were compared with the climatological normal values for that period, further reducing the inhomogeneity problem.

A simultaneous examination of the monthly mean pressure and temperature fields reveals that in May 1867 there was evidently a stationary upper-air trough over North-western Russia. Moreover, if the anomalies of the surface temperature are representative of the free atmosphere, then the baroclinicity and tropospheric westerlies would have been stronger than usual for that season in a zone extending from Central Europe to Russia. The strong variability of temperatures in Central Europe and the fairly abundant precipitation in Central Europe and Russia are consistent with the idea of such a baroclinic jet stream.

In 1867, there was a minimum in the sunspot activity cycle, and *Hamilton and Garcia* (1984) have suggested, on the basis of solar semi-diurnal tidal data, that during this minimum the incident solar ultraviolet radiation would have been abnormally weak. On the other hand, in that year the land-area mean temperature in the Northern Hemisphere was only ~0.1ºC lower than the average for the second half of the 19th century (*IPCC*, 1990, p. 206). The coldness of May and early June is thus explained primarily by an unusually permanent anomaly in planetary waves, which steered cold air masses into Northern Europe. Such extratropical flow anomalies are mainly maintained by the heat and momentum fluxes in high-frequency transient eddies (see *Holopainen et al.*, 1988, and references given in that paper). On the other hand, the track of these eddies is determined by the position of stationary waves. Thus the persistent cold anomaly is likely to have been principally caused by internal atmospheric dynamics. Of course, one cannot rule out the possibility that some external forcing, e.g. such as induced by variations in solar radiation or a large-scale ocean surface temperature anomaly, may have contributed to the flow anomaly to some extent. The sea-ice anomaly north of Scandinavia, albeit effective in chilling the prevailing northerly air flow, was evidently too small-scale to be the fundamental cause of the flow pattern.

In the future, it will be possible to make multi-centennial climate simulations with high-resolution general circulation models. It might be interesting to search the model output for anomalies resembling those which occurred in spring 1867, and to analyze the physical factors behind the flow pattern.

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