Assessment of the observed extreme conditions during late boreal winter 2011/2012

World Meteorological Organization

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- Contributions from NOAA-NCDC and MeteoSwiss
- SYNOP data for daily minimum and maximum temperature and daily snow depth from the Global Telecommunication System (GTS)
-Daily weather charts from the daily publication "Berliner Wetterkarte", Germany
-Mean number of ice days from European Climate Assessment and Dataset (ECA&D)

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Introduction

Congress during its sixteenth session in 2011 welcomed the decision of the Commission for Climatology during its fifteenth session in 2010 for improving WMO Climate System Monitoring including related methodologies and dissemination of monitoring reports for timely information on extreme weather and climate events occurring on large scale and having high socio-economic impacts.

A brochure called "Assessment of the observed extreme conditions during the 2009/2010 boreal winter" was published by WMO in 2010 and is now followed by this supplement to the WMO annual statement on the status of the global climate 2012.

During late January and early February 2012 extreme winter conditions were recorded in Europe and Asia. After a mild December and early January the situation changed abruptly in the second half of January. Extreme low temperatures were recorded in east and central Asia, in Central, Western and Southern Europe. Temperatures dropped to -40°C in north Europe and the northern Russian Federation. These conditions were found to be associated with large-scale atmospheric disturbances connected to the Arctic Oscillation. The cold wave finally started weakening in the first half of February.

It is noteworthy that in contrast to this extreme winter conditions, temperatures recorded in Svalbard were in that time higher than in Milan or Istanbul due to mild air that was carried northwards across the North Atlantic. In addition, the U.S. experienced the warmest February since 2000 and its third smallest winter snow cover footprint in the 46-year satellite record of the Rutgers Global Snow Lab.

Although this cold spell was not the most severe since the last century, it caused many fatalities, economic losses and discomfort to daily life.

The long duration of this cold period, its late onset and the extent of the affected area were exceptional but not unique.

Sudden cooling in late January 2012

After unusually mild weather in December 2011 and early January 2012 almost all over Europe, the weather situation changed abruptly in the second half of January. An incursion of cold polar air, coming from northern Russia at the south flank of an extensive high pressure area brought a sudden cooling to almost the whole Eurasian continent (Fig. 3).

Temperatures had been extremely low from the northern part of East Asia to Central Asia (in and around Mongolia and Kazakhstan, Fig. 1) since mid-January.

Some days later, at the end of January and the beginning of February, the influence of cold air extended to Central, Western and Southern Europe as well as to all over Central Asia, such as Uzbekistan and Tajikistan.

During that cold spell, also some considerable snowfall occurred over various parts of the continent. In the first half of February the cold wave started weakening, first in Asia and in mid-February also in Europe.

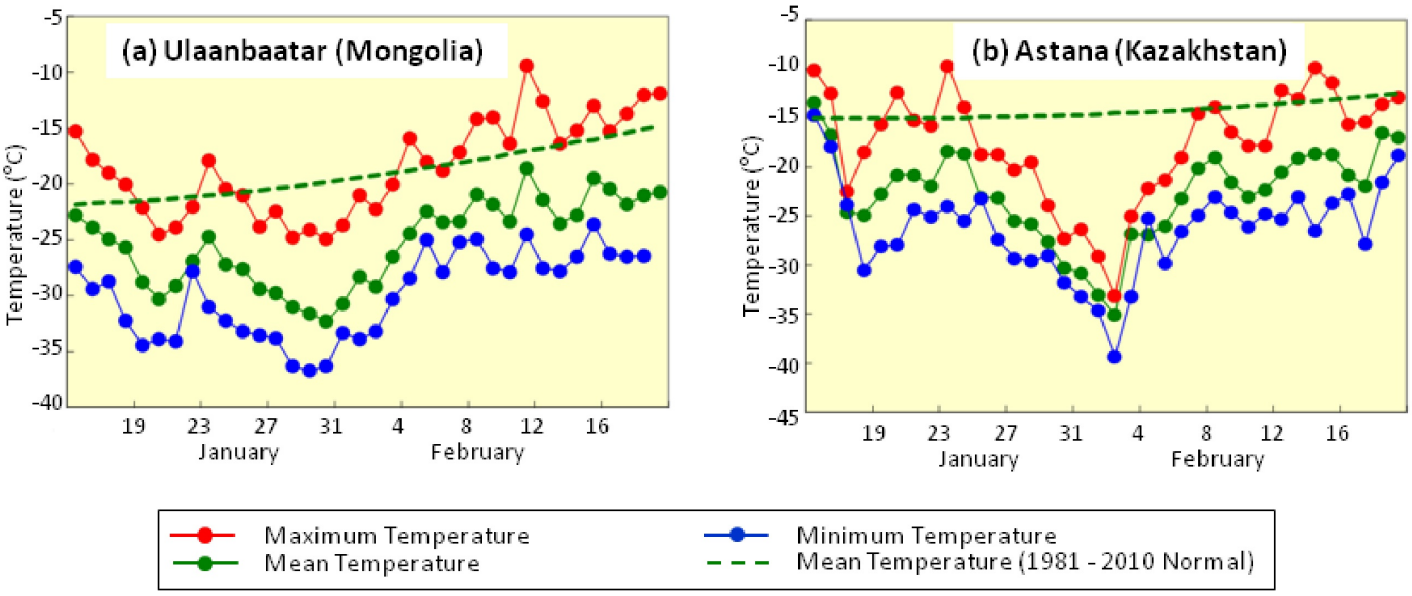


Figure 1: Daily maximum, mean and minimum temperatures at (a) Ulaanbaatar (Mongolia) and (b) Astana (Kazakhstan) from 15 January to 19 February 2012 (Source: JMA, based on SYNOP reports)

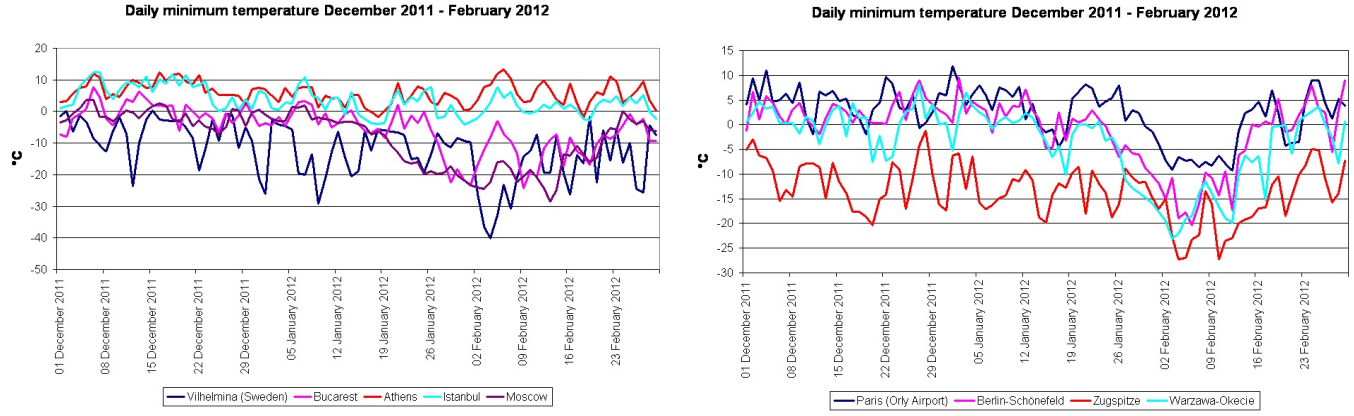


Figure 2: Time series of daily minimum temperatures in the period December to February in Vilhelmina, Bucarest, Athens, Istanbul and Moscow (left) and in Paris, Berlin, Zugspitze and Warszawa (right) (Source: DWD and RHMSS)

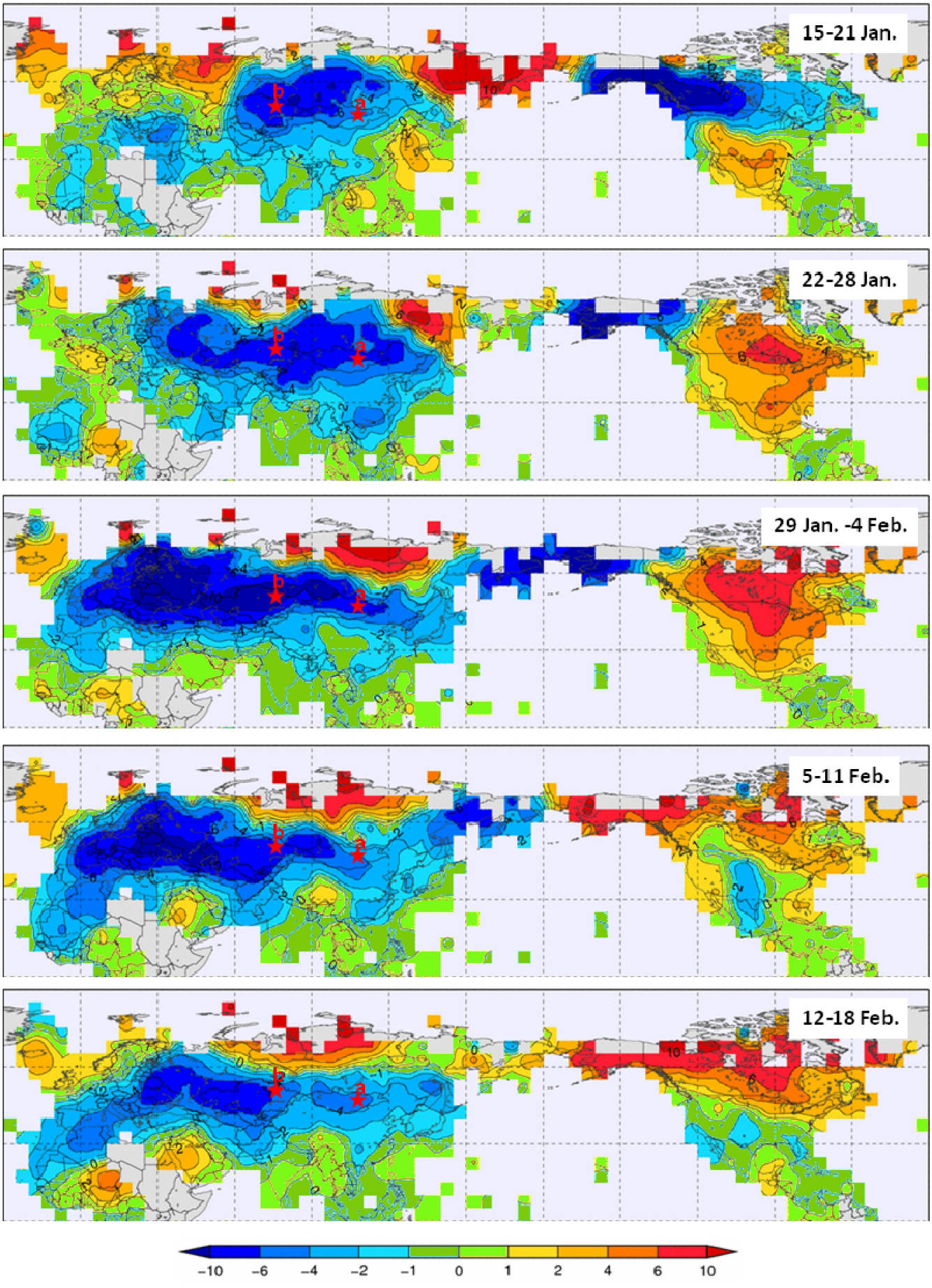


Figure 3: Weekly temperature anomalies in the Northern Hemisphere from 15 January to 18 February 2012 (Unit: °C), (a) Ulaanbaatar (Mongolia), (b) Astana (Kazakhstan), based on SYNOP reports (Source: JMA)

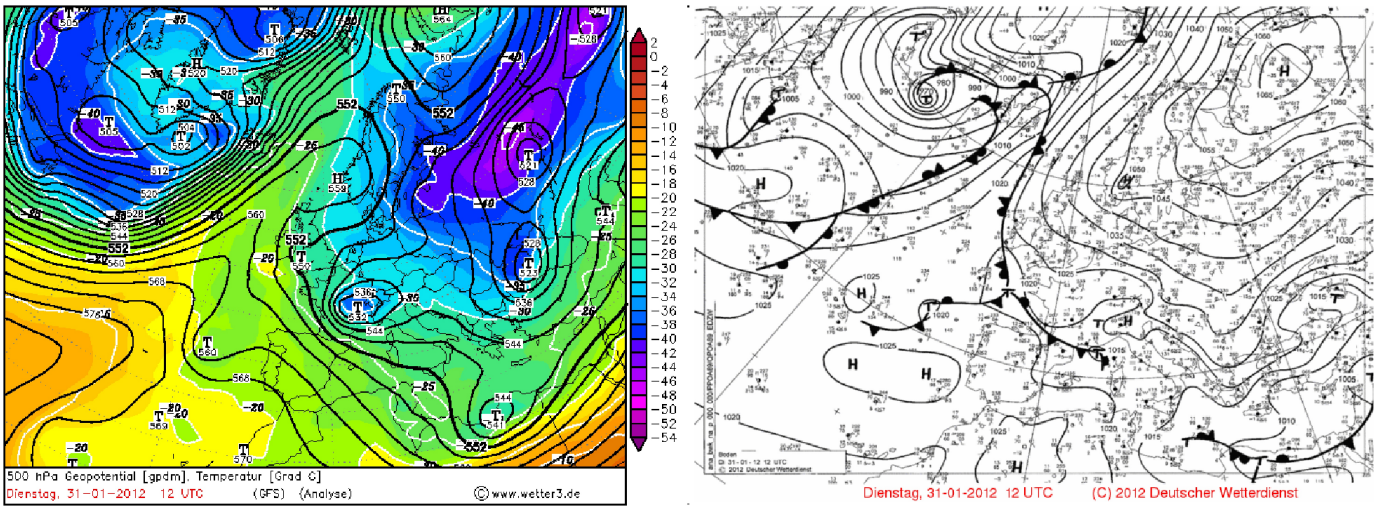


Figure 4: 500 hPa geopotential height and temperature (left) and synoptic weather map of 31 January 2012 (right) (Source: www.wetter3.de)

Extreme low temperature and ongoing frost throughout Europe

In the last few days of January and at the beginning of February 2012, extremely cold continental air from Russia brought ongoing frost to Eastern, Southeastern, Central and large parts of Western Europe. Minimum temperatures in Moscow went down from -3°C on 14 January to -25°C until the beginning of February; more northern, western, southern and southeastern parts of Europe experienced a similar temperature drop some days later (Fig. 2).

The minimum temperature dropped even below the 2% percentile in places, e.g. in Belgrade, Serbia (Fig. 5). Several East European countries (Baltic countries, Belarus, northeastern Poland, Ukraine, northern Moldova, southern European Russian Federation) experienced minimum temperatures of around -30 °C, places in northern Sweden, northern Finland and northern and central Russia below -40 °C (Fig. 6).

In eastern Central Europe, minimum temperatures below -20 °C were measured in many places, in western Central Europe between -10 °C and -20 °C (e.g. Amsterdam -18.7 °C, Zurich -18.1 °C). The cold air extended even to Southern Europe. Minima below -15 °C were recorded in several places around Turin in northern Italy. The Balkan Peninsula had minima mostly below -10 °C, locally below -30 °C in highlands of Romania and Turkey and down to around -24 °C in northern Greece and

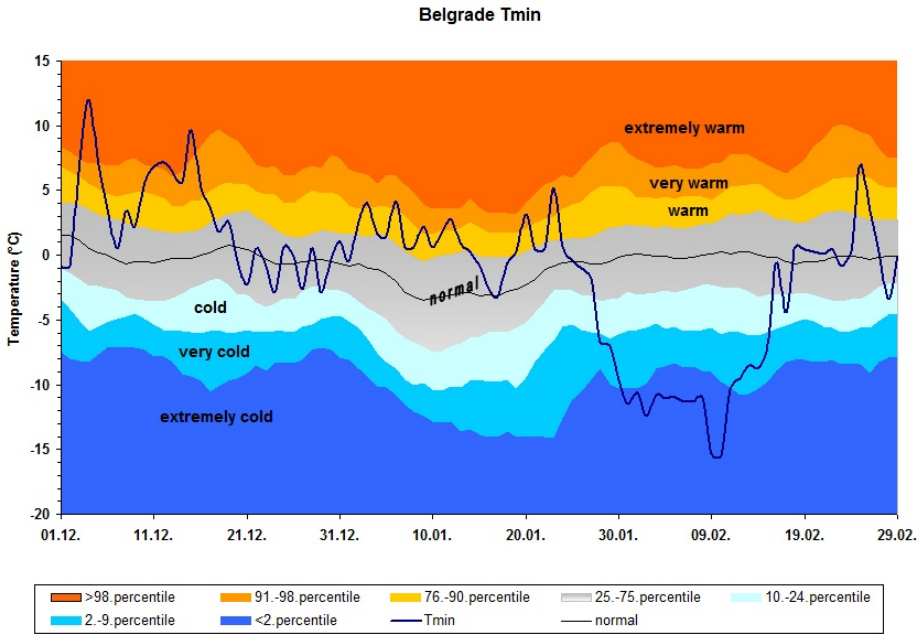


Figure 5: Time series of daily minimum temperature with respect to the 1961-1990 climatological normal values and percentiles for the period 01 December 2011 - 29 February 2012 for the station Belgrade in Serbia (Source: RHMSS)

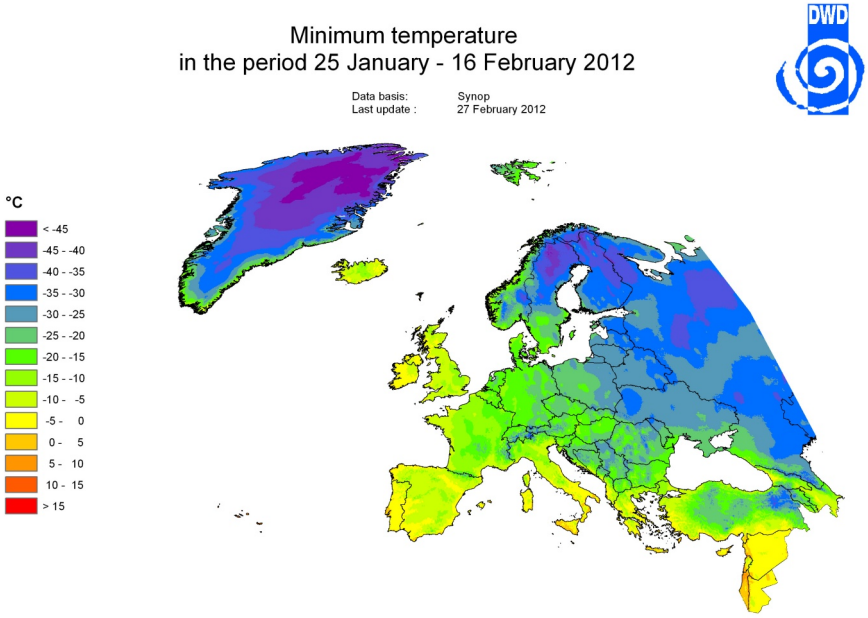


Figure 6: Absolute daily minimum temperature in the period 25 January – 16 February 2012 (Source: DWD)

northern Serbia. Turkey reported -35° C on 3 February 2012 in Erzurum as the lowest temperature in 2012. However, most of these minimum temperatures were not new records. Local records were broken e.g. in Estonia, Bulgaria and Serbia.

The mean minimum temperature during the cold spell was below 0°C almost throughout Europe (Fig. 7 left). In eastern, central and southeastern Europe it was even below -10 °C, in northern Scandinavia and Eastern Europe below -20 °C.

Normally, mean February minimum temperatures are above 0°C in Western and Southern Europe, and climatological normals below -20°C over large areas are only to be found in the highlands of Greenland (Fig. 7 right). The mean minimum temperature of the cold spell in Berlin was lower than the normal mean minimum temperature in Moscow. Maximum temperatures remained below 0 °C (defining ice days) during several successive days almost throughout Europe (Fig. 9 right). This is usual for areas in Northern and Eastern Europe, but not necessarily for western and southern parts where normally not more than 5 ice days (days with a maximum temperature below 0 °C) are recorded on average (Fig. 10).

Prolonged frost occurred even in large parts of Southern Europe and the Middle East. Eastern Central Europe had nearly 20 successive ice days during the cold spell; the February normal is around 10. Likewise, the long frost period over the Balkan Peninsula and around the Black Sea was highly unusual. Parts of the Black Sea were frozen.

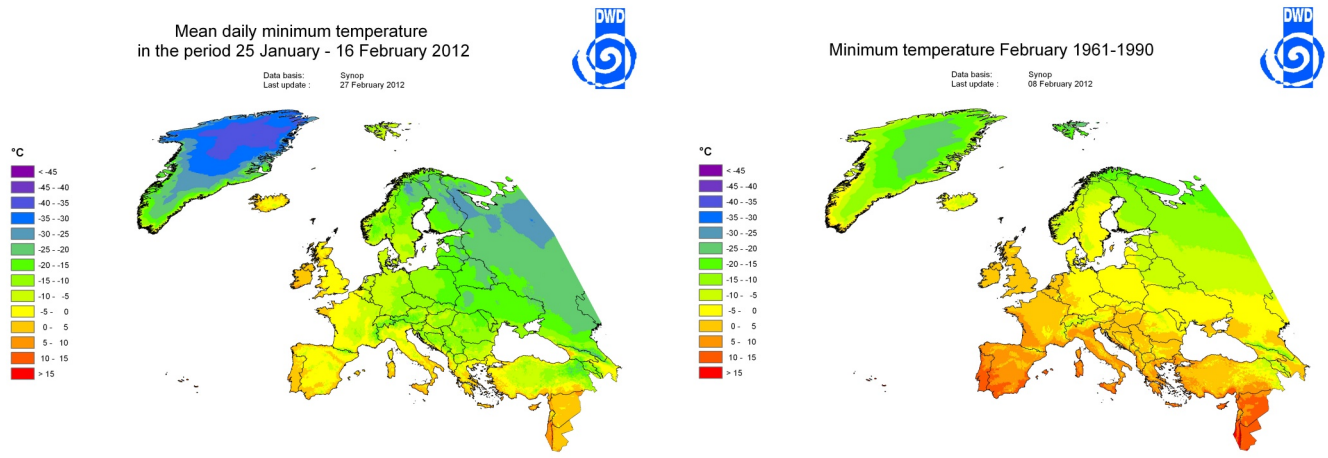


Figure 7: Mean daily minimum temperature during 25 January to 16 February 2012 (left) and in February in the normal period 1961-1990 (right) (Source: DWD)

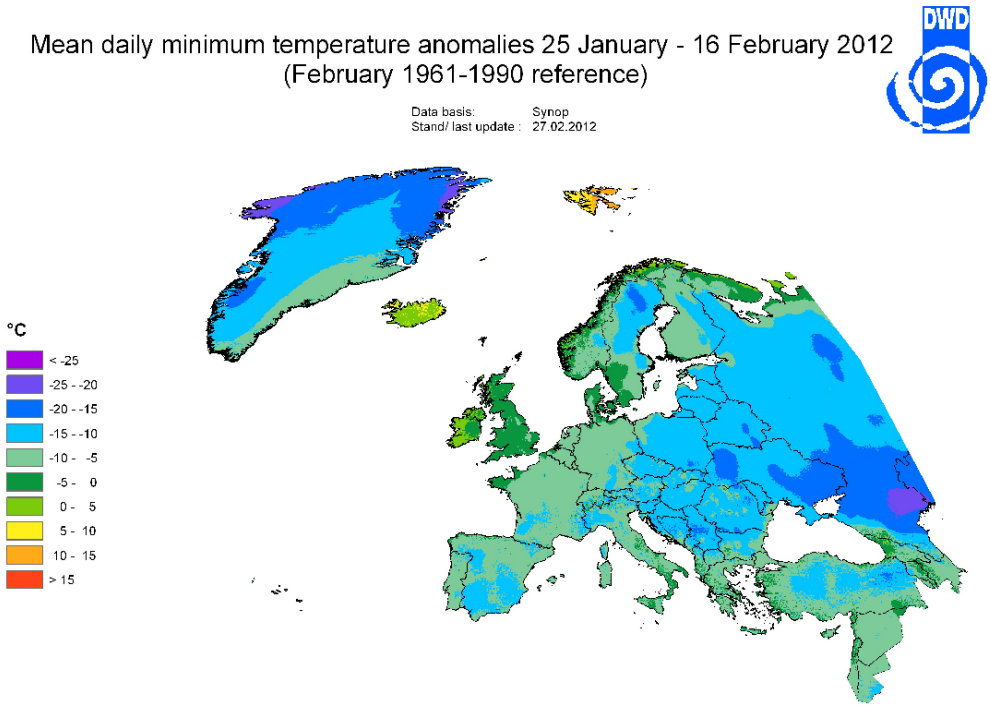


Figure 8: Anomalies of mean daily minimum temperature in the period 25 January – 16 February 2012 (1961-1990 reference) (Source: DWD)

Mild Arctic and North America

In contrast, low pressure systems carried mild air across the North Atlantic northward via Iceland to the Arctic region. The temperatures in Svalbard, far north in the Arctic, reached repeatedly up to 5 °C in that time, being higher than in Milan (Italy) or in Istanbul (Turkey) at the same time. During the cold spell period Svalbard, Iceland, northern and western Ireland as well as several coasts of western and northern Scandinavia and northern Russia recorded above-average temperatures (Fig. 8) due to low pressure influence in these regions. The highest positive anomalies were registered in Svalbard with a temperature around 15° C warmer than normal.

The change in the pressure pattern is well pronounced in the switch of the so-called Arctic Oscillation which reflects the difference in pressure between polar areas and mid-latitude areas. On 22 January, the Arctic Oscillation turned to a distinctively negative mode (Fig. 19), which is connected with cold conditions in Europe and relatively warm conditions in the Arctic.

Warmer-than-average temperatures also dominated the northern and eastern regions of the U.S. in

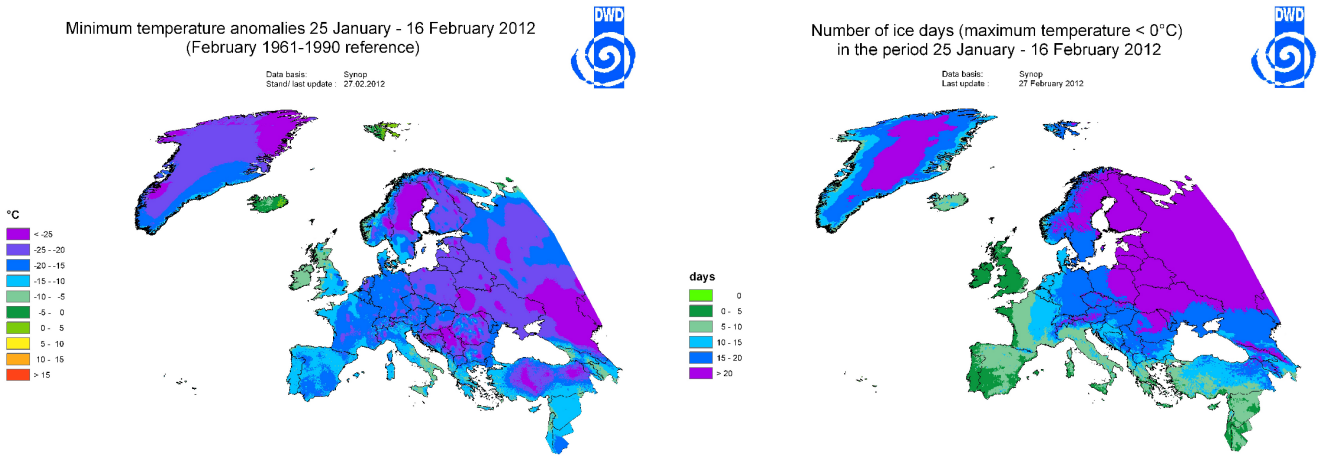


Figure 9: Anomalies of absolute daily minimum temperature during 25 January to 16 February 2012 with respect to 1961-1990 (left) and number of ice days (maximum temperature below 0°C) during 25 January to 16 February 2012 (right) (Source: DWD)

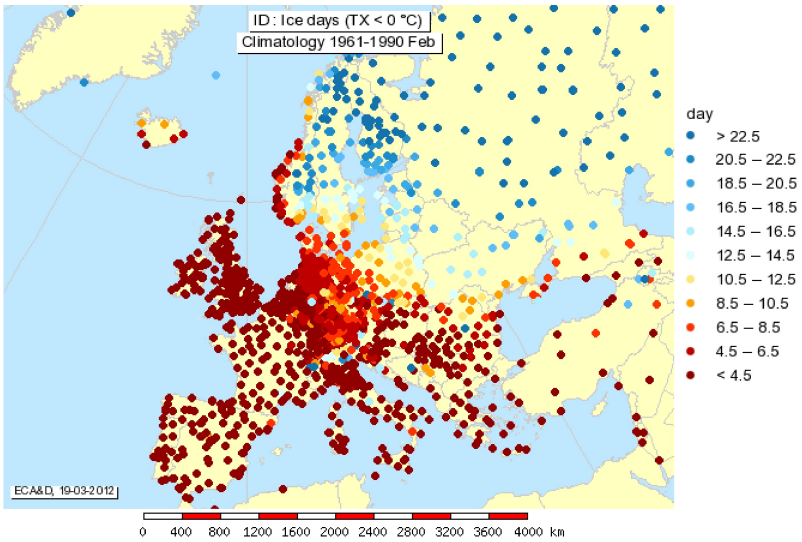


Figure 10: Mean number of ice days (maximum temperature < 0°C) in February (1961-1990 reference) (Source: ECA&D)

December, January and February, leading to the fourth warmest winter on record for the contiguous United States. The winter season was also drier than average, with dry conditions experienced across the West and the Southeast but wetter-than-average conditions in the central and southern Plains and parts of the Ohio Valley.

The average contiguous U.S. temperature during the December-February period was 2.42° C, 2.09° C above the 1901-2000 long-term average - the warmest since 2000.

Warmer-than-average temperatures were widespread; only New Mexico had winter temperatures below its 20th century average.

The warm and dry conditions during the 2011/12 winter season limited snowfall for many locations. According to data from the Rutgers Global Snow Lab, snow cover extent during winter in the contiguous United States was approximately 613,000 square kilometers below the 1981-2010 average — the third smallest winter snow cover footprint in the 46-year satellite record.

For the winter period, NOAA's U.S. Climate Extremes Index, an index that tracks the highest 10 percent and lowest 10 percent of extremes in temperature, precipitation, drought and tropical cyclones, was the ninth highest value in the 102-year period of record, with nearly one-third of the nation experiencing climate extremes as defined by this index. The elevated value was largely driven by extremes in warm daily maximum and minimum temperatures across the Southeast, Upper Midwest, and Ohio Valley.

Alaska had a seasonally-averaged temperature at below average, ranking as the 35th coldest winter in the 94-year record for the State. A warmer-than-average December and February balanced the very cold January temperatures, resulting in a winter temperature nearer the long-term average.

During February, the contiguous United States

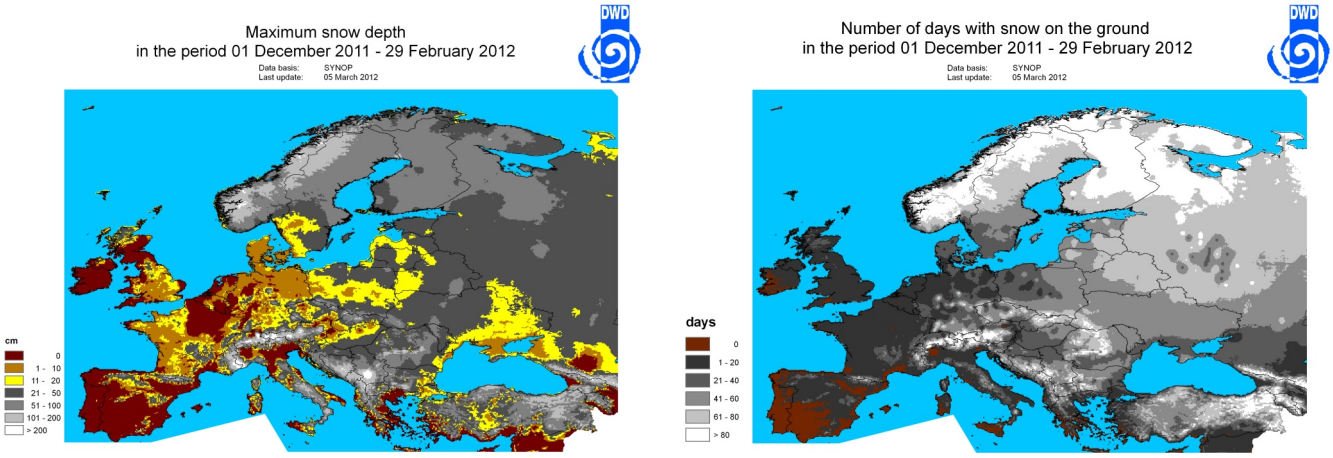


Figure 11: Maximum snow depth (left) and number of days with snow on the ground (right) in the period 01 December - 29 February 2012 (Source: DWD)

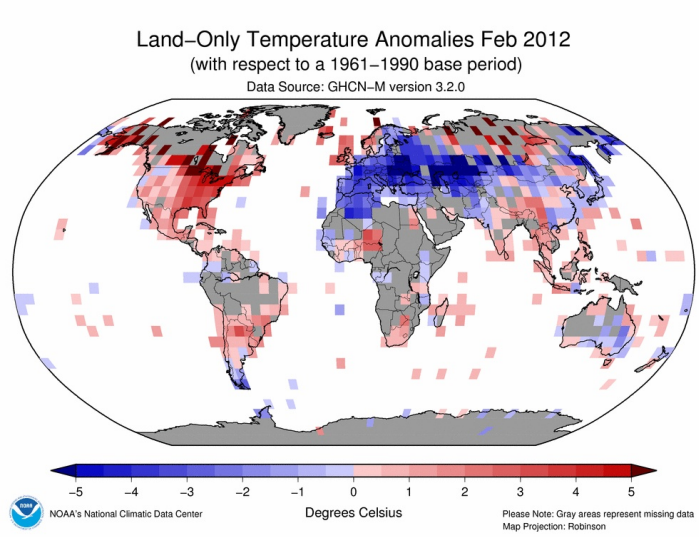


Figure 12: Land-only temperature anomalies for February 2012 with respect to 1961-1990 (Source: NOAA-NCDC)

experienced above-average temperatures with a national average temperature of 3.14° C. This was 1.96° C above the 1901-2000 average, making it the 16th warmest February on record.

According to the U.S. Drought Monitor, as of February 28th, about 39 percent of the contiguous United States was experiencing drought conditions, a slight increase compared to the beginning of the month.

Widespread snowfall

Though high pressure influence prevailed, there were some lows causing widespread snowfall (Fig. 11 left and right). A small low e.g. was responsible for a snow cover of 10-15 cm on the island Rügen in the German Baltic Sea on 3 February 2012. Heavy snow fall was also observed on the windward slopes of the Alps. The highest German mountain Zugspitze (nearly 3,000 m altitude) reported 5 metres of snow on 25 January - the deepest snow cover in 30 years (Fig. 13, left). This snow, however, already came before the cold spell arrived in southern Germany. During the cold spell itself, the snow cover on Zugspitze decreased gradually.

Cold air together with a strong moisture flux from the central Mediterranean Sea caused heavy snowfall over parts of southeastern Europe such as the Balkans, Romania, Bulgaria and Turkey. But also Italy, Spain, and even parts of northern Africa reported snowfall. Italy and the Balkan Peninsula suffered from snowstorms over and near the Adriatic Sea. Snow depths between 10 and 20 cm occurred in southern France, northern Italy and northern Greece, which is not unusual for the Mediterranean region. Even the western Mediterranean islands had snow, e.g. Corsica and Mallorca. Locally the snow depths were very high. Around 2 metres were measured in some places in eastern parts of Italy near Rimini, exceeding the depths in the winters 1929 and 1956. Snow on the Balkan Peninsula was widespread and particularly abundant; deep snow covers of 50-100 cm were reported in many places and over 100 cm in mountain regions of southeastern Europe (Fig. 14). Eastern Turkey received up to 3 metres of snow in valleys in 1000-1500 metres altitude and up to 6 metres in higher mountains.

However, it is remarkable for that event that some areas in Western and Central Europe hardly had any snow or only during a short time, but low temperatures occurred even in those areas. Snow has a high reflectivity for solar radiation (albedo)

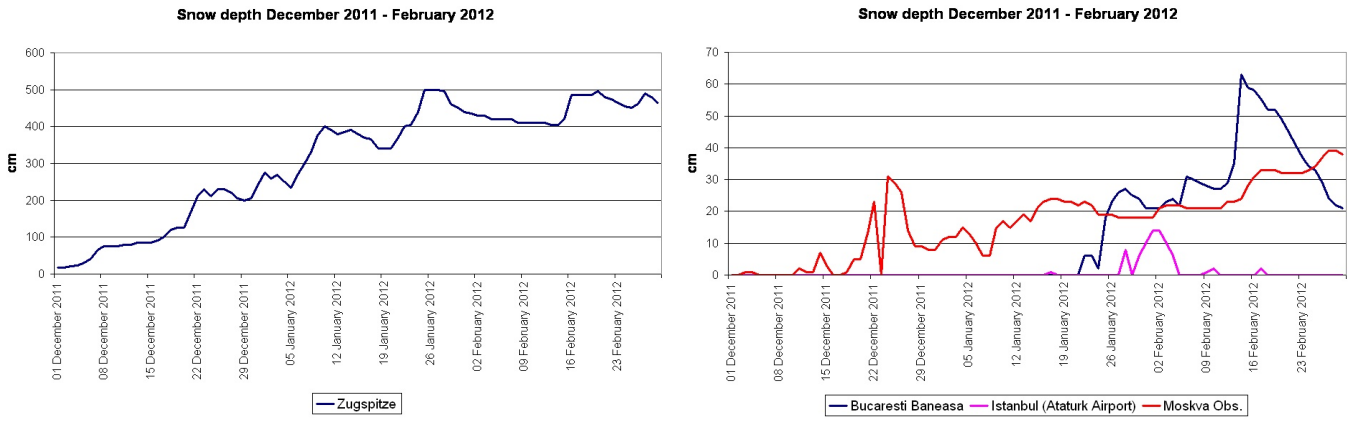


Figure 13: Time series of daily snow depth from December 2011 to February 2012 for Zugspitze (left) and Bucarest, Istanbul and Moskva (right) (Source: DWD)

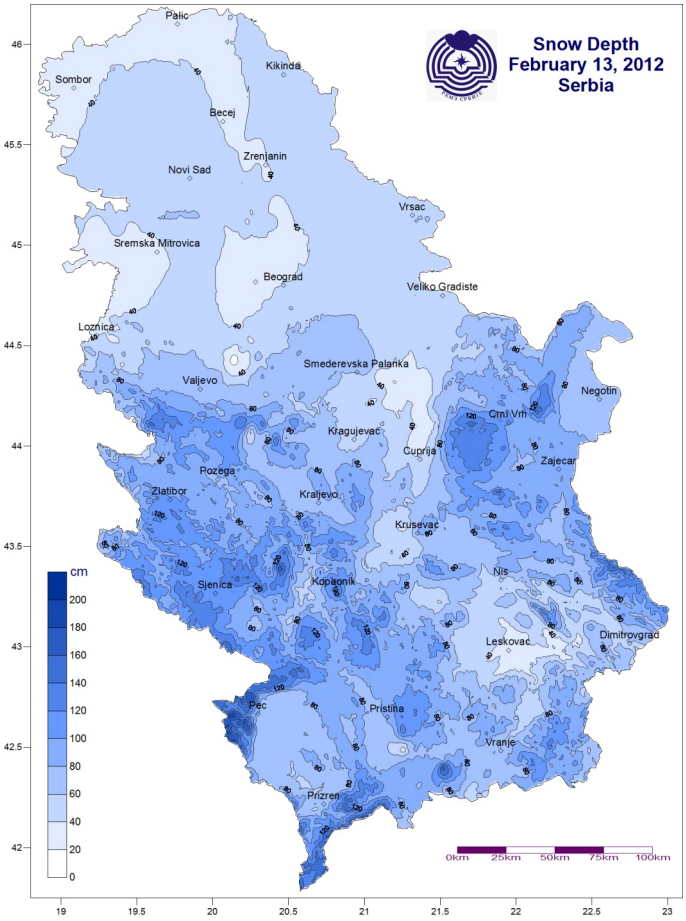


Figure 14: Snow septh on 13 February 2012 in Serbia (Source: RHMSS)

which prevents the earth's surface from warming. The emissivity of terrestrial longwave radiation, too, is very high compared to snowless soils causing a significant cooling at nights. Therefore usually temperatures are lower over snow covered surfaces than on snowless ones.

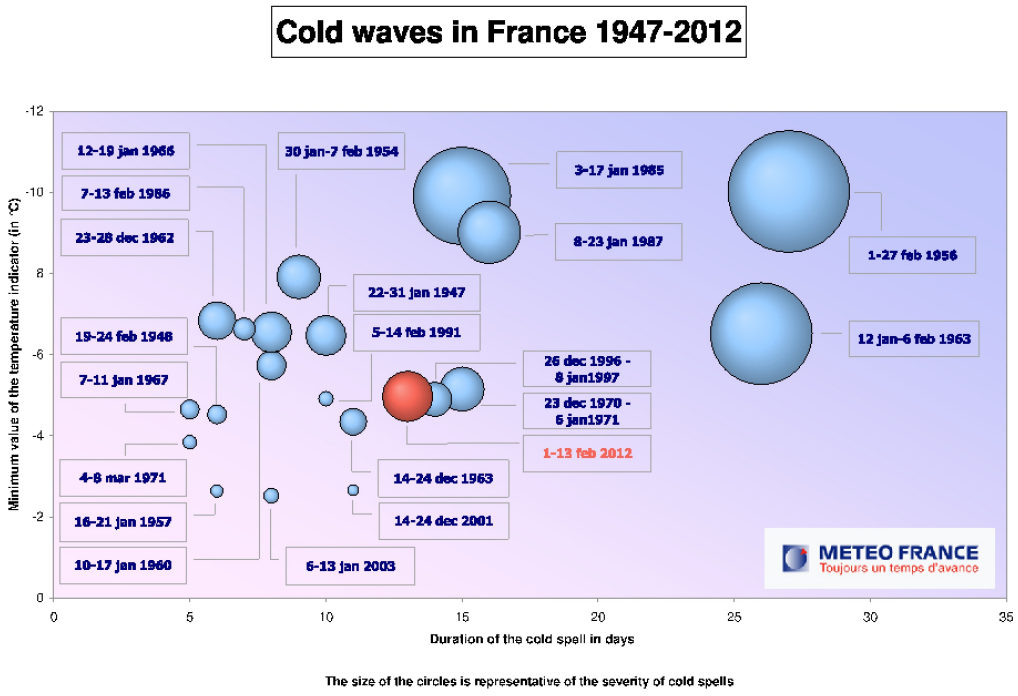
End of the cold spell

On 13 February 2012 the high pressure area over Europe retreated and low pressure systems from the northwest moved over Scandinavia to Western and Central Europe. Temperatures started to exceed 0°C in southern Scandinavia and northern Central Europe. Slight snowfall occurred in these areas, followed by rain with increasing temperatures. The Arctic Oscillation returned to normal values around zero.

The cold spell went on some days longer in Eastern and Southern Europe with still low minima and in the southeast abundant snowfalls. However, until the end of February temperatures returned to the same high level as before the cold spell almost throughout Europe and snow covers were decreasing.

The duration of the cold wave as a whole was about 3 weeks in Europe (25 January – 16 February), but not all of Europe experienced it for the whole time. The main period, when temperatures were extremely low in most of Europe was about 2 weeks (31 January – 13 February).

Figure 15: Cold waves in France 1947-2012. The x-axis shows the duration of the cold spells, the y-axis the highest intensity. The diameter of the circles symbolizes the intensity over the whole of France, which can be interpreted as the severity of the cold waves.



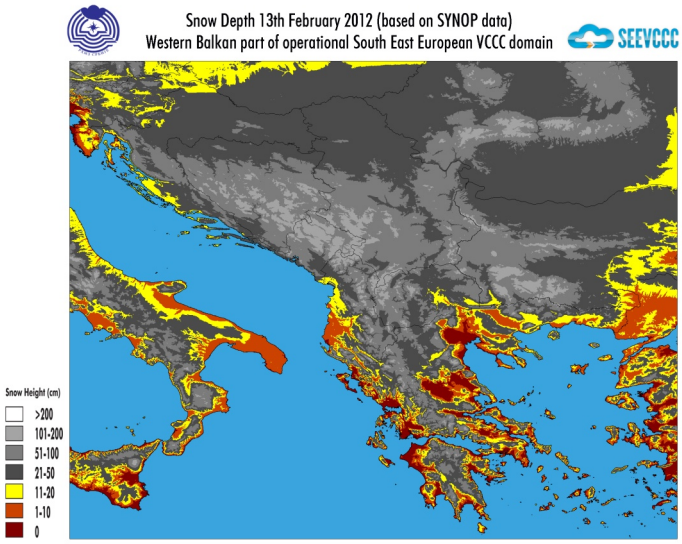


Figure 16: Snow depth on 13 February 2012 for the western Balkan part of the SEEVCCC domain based on SYNOP data (Source: RHMSS/SEEVCCC)

Damage and impacts on daily life

Although this cold spell was not the most severe since the last century, it was nevertheless a very serious one because it caused many fatalities, economical losses and much discomfort to daily life.

Health problems and accidents were the most serious cases. Throughout Europe (particularly in Poland, Russian Federation, Ukraine, Romania, but also in many other countries), many deaths due to freezing were to be mourned, especially among homeless people. Furthermore, medical treatment of frostbite, undercooling and fractures was requested in many cases. Malfunctioning carbon stoves caused numerous cases of carbon monoxide contamination, e.g. in Poland. Avalanches in the Alps caused further fatalities. In Italy, people died because roofs broke down due to heavy snow loads. According to several media reports, altogether more than 600 people died in Europe due to that cold spell.

Traffic was much affected. Numerous accidents occurred due to slippery roads. In Romania, Bulgaria and Montenegro many national roads had to be closed. Buses in Istanbul had to stop service due to high snow loads on the roads. Many flights had to be canceled or airports had to close temporarily, e.g. in the United Kingdom, France, Italy and Turkey (in particular Istanbul). Belated arrivals of trains or even cancellations due to heavy snowfall were reported frequently. Ship traffic also was much affected on some rivers due to freezing, even on larger rivers, e.g. the Odra, Elbe and Danube. Ferries in the Aegean Sea had to be canceled due to stormy winds.

Daily life was affected notably. Many schools were closed for several days due to insufficient heating of the school buildings. In Serbia, the government ordered one week off work to save electricity. Households were cut off from electricity in many parts of Europe due to high snow loads, e.g. in

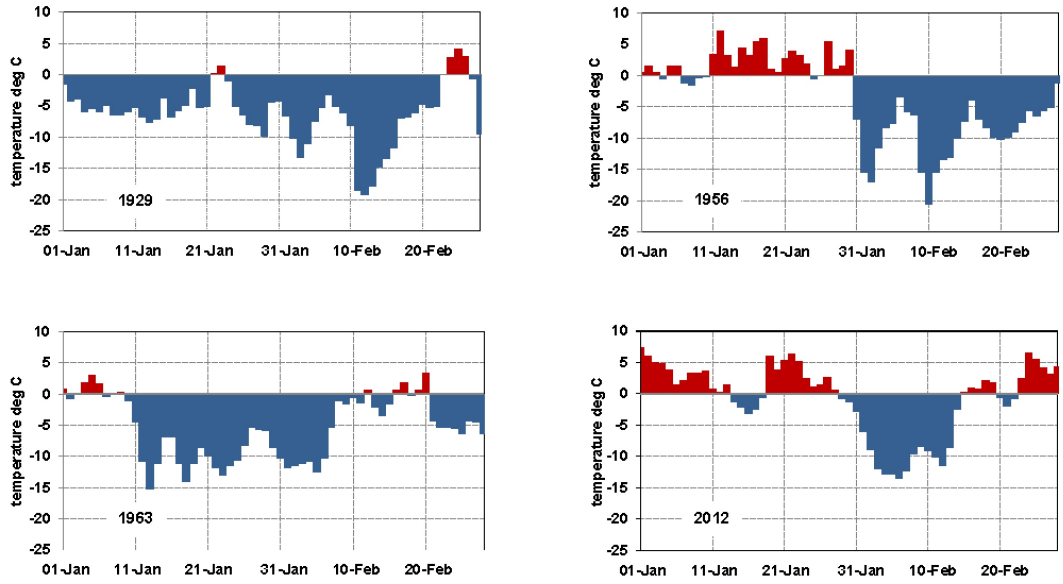


Figure 17: Most extreme cold waves in the 20th century at the station Zurich-Fluntern in Switzerland in comparison to the cold wave in February 2012, displayed by time series of daily mean temperatures in January and February of the corresponding years. (Source: Meteo Swiss)

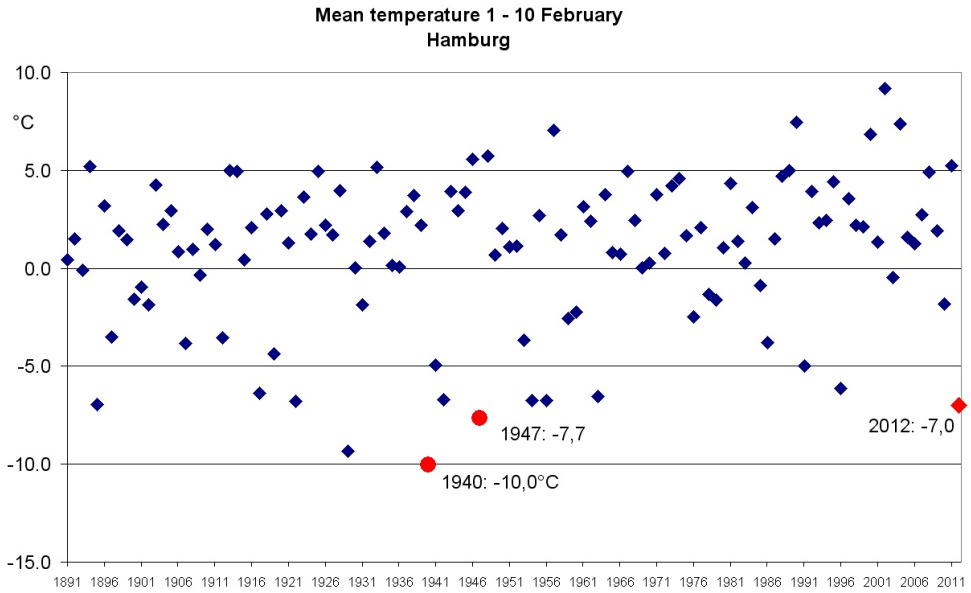


Figure 18: Mean temperature for the 10 day periods 01-10 February of the years 1891-2012 in Hamburg, Germany (Source: DWD)

southeastern France including Corsica Island, and on the Balkan Peninsula. Snow bounded villages in Slovenia, Bosnia and Herzegovina and Serbia were isolated from the outside world; people had to be saved by helicopters or supplied with food.

In some southern parts of Europe (particularly in the Alpine region, on the western Mediterranean islands, in northern Italy and the northern Balkan peninsula), the cold and snowy weather was related also with stronger-than-usual winds, which caused additional discomfort due to a high wind chill. Gusts of more than 125 km/h were measured in valleys in Slovenia, causing damage to agriculture due to wind erosion.

Similar cold spells in the past and future

Since the dramatic arctic sea ice decline during summer 2007, the northern hemisphere was periodically affected by extreme winter outbreaks. The Arctic Oscillation is weakening due to a higher absorption of the ice free ocean and the heat is then released during autumn which is leading to an increased atmospheric pressure and moisture content in the Arctic. A weaker polar vortex is less able to constrain the arctic air masses and leads to severe outbreaks of cold weather and snowfall to certain regions.

It is noteworthy, of course, that there are other factors like ENSO that are influencing the winter weather as well.[1]

With regard to the assessed cold spell in 2012, the long duration, its relatively late onset and the extent of the cold area were exceptional, but not unique. Similar cold spells occurred several times during the past decades. In Western and Central Europe, for instance, severe cold waves occurred in the past in respect to both intensity and duration, e.g. in the 1940s, in February 1929 and 1956, January/February 1963 and the mid-1980s, but also in earlier time (Fig. 15,17-18, 20).

However, such cold waves were rare in recent years. Several places in Europe did not see lower temperatures than in February 2012 for more than 25 years. France did not see such a cold spell since January 1987. Zurich in Switzerland and places in northern Italy were last colder in January 1985; other stations in northern Italy even had their lowest minima since 1956.

Cold waves have become particularly rare since the mid-20th century at least in Switzerland, and since the 1990s also in whole western and central Europe, compared to the previous 100 years. There

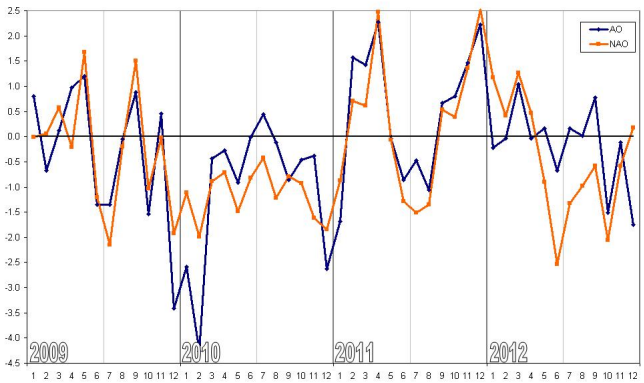


Figure 19: Artic Oscillation Index (blue) and North Atlantic Oscillation Index (orange) from January 2009 to December 2012. (Data source: NCDC)

1 Greene, C.H., and B.C. Monger. 2012. An Arctic wild card in the weather. Oceanography 25(2):7-9, http://dx.doiu.org/10.5670/oceanog.2012.58

were long cold spells with deep snow covers in recent winters too, e.g. in January and December 2010, but the intensity was lower. The cold wave in February 2012 was one of the 10 most intense of such events in Zurich since 1864 and among the 5 most severe in France since 1947. Regarding only the 10-day period 01-10 February, it was the coldest such period in Hamburg (Germany) since 1947. There were also winters in the past with more ice days than this winter in eastern Central Europe, but such a long period of successive ice days was rare in recent time. According to the Free University Berlin there was permanent frost for more than 30 successive days in the very cold winter 1946/47 and throughout the chilly February 1929 in Berlin.

Summing up, cold waves of such intensity, extent and duration have become less frequent in the light of global warming. If global warming goes on in future, a further decrease of frequency of such wintry cold waves will be expected, but in particular with regard to the weaker Polar Vortex they will occur from time to time and we need to be prepared.

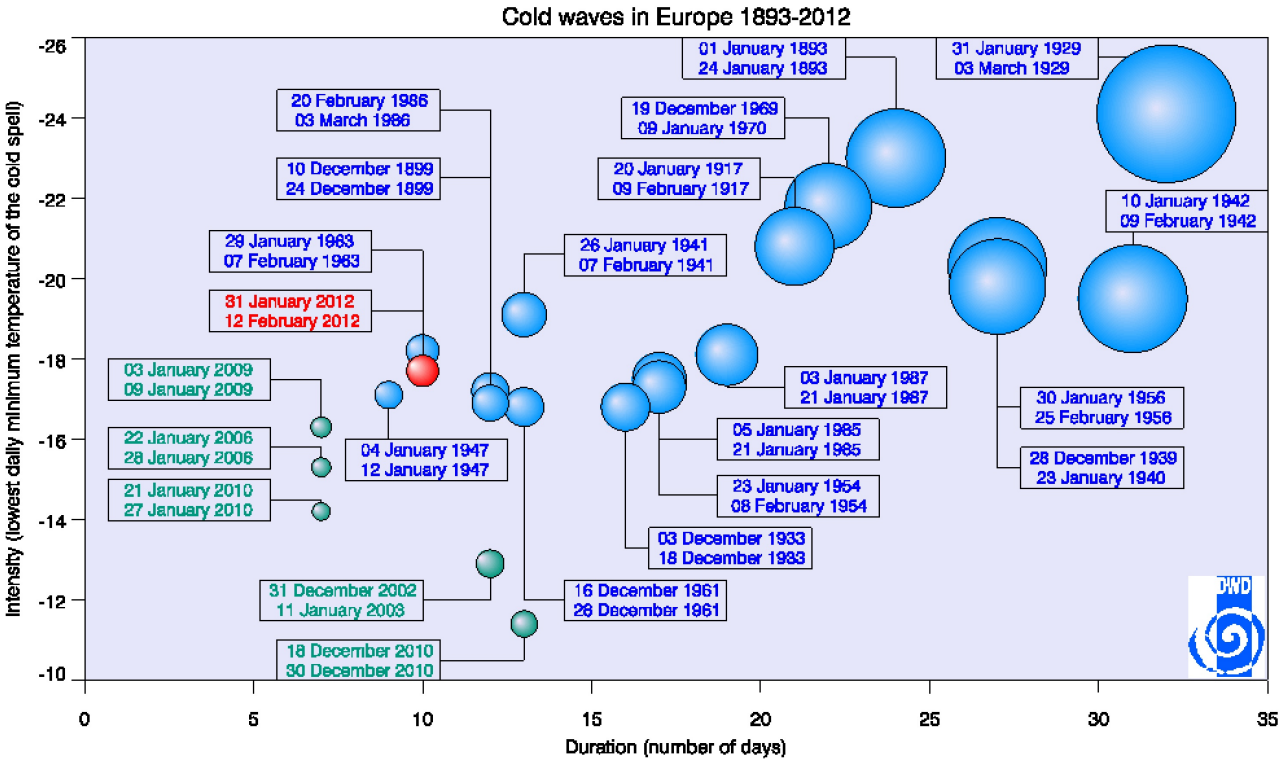


Figure 20: Cold waves in Europe 1893-2012. The x-axis shows the duration of the cold spells, the y-axis the highest intensity. The cold wave 2012 is highlighted in red, the most recent cold waves in the 21st century in green; the others (in blue) represent the most intense cold waves since 1893. The duration is determined by the period when the minimum temperature in Potsdam (eastern Germany, located downstream of the airflow from eastern Europe, time series starts in 1893) is below -10°C (minimum duration 6 days with interruptions up to 5 days). The intensity is the lowest daily anomaly from the 1961-1990 winter normal in Potsdam during that period. The diameter of the circles, which should symbolize the intensity over the whole of Europe is estimated by the product of duration and intensity, assuming that the synoptic conditions for all these cold waves were similar and the cold air spread more or less over Europe. Note that this is only a rough estimate, which is not necessarily true for the whole area throughout Europe.(Source: DWD)

List of abbreviations:

DWD	Deutscher Wetterdienst (German Weather Service)
ECA&D	European Climate Assessment and Dataset
JMA	Japan Meteorological Agency
NOAA-NCDC	NOAA's National Climatic Data Center
RCC	WMO Regional Climate Centre
RHMSS	Republic Hydrometeorological Service of Serbia
SEEVCCC	South East European Virtual Climate Change Center (hosted by RHMSS)

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