COLD WAVES: METEOROLOGICAL CHARACTERISTICS
AND BIOMETEOROLOGICAL INFLUENCES
(Case Study: Romania, 29th January – 3rd February 2012)

Nicoleta Ionac¹, Vlad Năftănăilă², Monica Matei³

Key words: cold waves, air-temperature, wind-speed, synoptic conditions, Romania.

Abstract. Some definitions describe cold waves as periods of marked cooling of air over large territories, which generate the human physiological stress due to overheating. For this reason, cold waves can be deadly and they rank among the world’s top natural disasters. European countries have already experienced a most severe cold wave in 2012 (January 27 – February 11) and it is expected that, in the years to come, the frequency and intensity of cold waves should increase. That is why, case studies may be very important in analyzing past evolutions and future trends. This paperworks debates on the synoptic conditions that generated the cold wave affecting Romania’s territory on January 29 – February 3, 2012. Moreover, it presents the distribution and evolution of air-temperatures and wind-speeds aloft and at the ground level, which significantly contributed not only to the discomfort people felt during the cold wave, but also to the death of an important number of vulnerable individuals.

Definitions
There is no standard definition of a cold wave, but according to the World Meteorological Organization, it may be roughly defined as: a massive invasion of cold air or a marked cooling of air over a large territory (WMO, 1992). In more general terms, a cold wave is a meteorological phenomenon of excessively cold weather, characterized by severe wind-chills that make weather seem much colder than it actually is. From this point of view, it seems that the meteorological key-factor of cold-waves is high winds that greatly increase the cooling power of air in motion and thus significantly reduce effective air-temperatures actually perceived by the unacclimatised human body (Ionac N., Ciulache S., 2008). The National Oceanic and Atmospheric Administration (NOAA) also defines a cold wave as simply a prolonged period of excessively cold weather (NOAA, 2012); in this case, extremely low air-temperatures becoming the only meteorological element of reference. Lately, cold weather and cold

¹Prof. PhD., University of Bucharest, Romania
²PhD. Stud., University of Romania
³PhD. Stud., university of Romania
waves are more frequently defined in association with other winter weather events, such as blizzards or ice storms, since the former ones are more frequently preceded or accompanied by such significant bad-weather winter phenomena.

1. Cold waves: human and economic impacts

So while there is no universally agreed upon definition for what represents a cold wave, there is no doubt that it is a particular weather hazard ranking among the world’s top natural disasters, because of its negative effects on humans and economic activities. For instance, exposure to extreme and rather unexpected cold weather can lead to hypothermia and frostbite, causing tissue damage, organ failure, injury and, ultimately, death to humans and livestock. Cold waves may affect cardiovascular and peripheral diseases, cerebro-vascular diseases and respiratory diseases as well, greatly increasing the mortality risk. Exposure to cold also requires a greater caloric intake, and if a cold wave is accompanied by heavy snowfalls, grazing animals are unable to reach the needed food and may die of starvation. People, especially the poorly-protected (e.g. the elderly, the disabled, children, women, ethnic minorities, those with low incomes and those living alone), also need extra food, and freezing temperatures or persistent snow may seriously prevent them from getting or purchasing foodstuffs (usually at higher costs), especially when roads are blocked. Moreover, demand for electrical power and fuels greatly rises during cold spells and water supplies may become unreliable due to sub-freezing temperatures. Motor vehicles may also fail in cold weather, resulting in the failure of the transportation system. Winter cold waves that are abnormal in some areas which do not customarily reach freezing air-temperatures (such as countries with subtropical climates in Northern Africa), but cause temperatures significantly below the average for the area, are also highly destructive, as plant and animal life, which is not adapted to such rare cold, especially during the early and most vulnerable stages of growth, may be killed, resulting in food shortage for humans.

Over the past few years, severe floods, windstorms, heat-waves and cold-waves have caused dramatic political, social, environmental and health consequences in Europe. In response to these events, ministries of health and other public health authorities from European countries, along with national and international meteorological services and organizations, are focusing increased attention on developing appropriate strategies and measures to prevent health and economic effects from extreme weather and climate events in the future (WHO Europe, 2004). The recent events have also increased interest in whether the intensity and frequency of future extreme weather and climate events could be expected to change as one result of a changing climate. It is predicted that the current increasing instability of the climate system may lead to increased climate variability and, with it, a change in
### Tab. 1 - Summary of the 2012 European Cold Wave Impacts (adapted after Wikipedia, 2012)

<table>
<thead>
<tr>
<th>Country</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netherlands</td>
<td>−18.9 °C (−2.0 °F) in De Bilt, the lowest recorded since 1956. A national low of −22.8 °C in Lelystad = the lowest temperature recorded all over the Netherlands since 1985. A homeless man was frozen to death on February 2.</td>
</tr>
<tr>
<td>Poland</td>
<td>Subzero cold spread over eastern Poland ever since January 30. 103 people froze to death. 107 people died in flames + 550 suffering various degrees of burns. 360 domestic fires during one night (February 11–12).</td>
</tr>
<tr>
<td>Latvia</td>
<td>−34.2°C - Strenči meteorological station (February 5) For several days, not a single meteorological station reported a temperature above −20°C. Some regions experienced a shortage of power supply. Increased number of domestic fires.</td>
</tr>
<tr>
<td>Belarus</td>
<td>Temperatures in the Brahin region dropped to −34.3 °C on February 11/12. 180 people died in domestic fires.</td>
</tr>
<tr>
<td>Russia (European)</td>
<td>Widespread freezing temperatures. 215 people killed by cold in 2012 winter.</td>
</tr>
<tr>
<td>Ukraine</td>
<td>Onset of temperatures lower than −35 °C at the end of January. Snow: 30 cm – end of January, 130 cm – February 1. 100 homeless people died. More than 600 people treated for frostbites and hypothermia. Gas supplies shortage.</td>
</tr>
<tr>
<td>Romania</td>
<td>5 m high snow dump in some regions. 86 people died. The Danube completely frozen over (February 11). Many villages were isolated. Road, railroad, fluvial and air transport failure. Black Sea ports were closed.</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>−30°C in Knezha. 1 m high snow cover in the mountains and 63 cm in Vidin. 16 deaths reported. The wall of the Ivanovo dam in southern Haskovo Province broke, flooding the village of Biser and killing 11 people.</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>−38.1 °C in Kvilda Surava, on February 3, the lowest temperatures in Central Europe.</td>
</tr>
<tr>
<td>Bosnia and Herzegovina</td>
<td>Temperatures dropped to -30°C – the coldest winter in the last 100 years. Snow: 107 cm in Sarajevo. 15 to 50 people killed by frost.</td>
</tr>
<tr>
<td>Croatia</td>
<td>3 people died. Many villages were isolated.</td>
</tr>
<tr>
<td>Serbia</td>
<td>−32°C at Spjeca, on February 9. 20 people died. 50,000 villagers have been trapped by heavy snow and blizzards in mountainous areas. On February 8, electricity consumption broke a record, standing at 162.67 million kWh, so the government mandated a shutdown of all non-essential industries and decorative lightning.</td>
</tr>
<tr>
<td>Cyprus</td>
<td>Snow was reported in Nicosia, on February 29.</td>
</tr>
<tr>
<td>Malta</td>
<td>−2.4 °C in Zebbug, on February 8.</td>
</tr>
<tr>
<td>Corsica</td>
<td>40 cm of snow all over Corsica. 14,000 homes without electricity.</td>
</tr>
<tr>
<td>Italy</td>
<td>−21 °C in the north of the country, on February 7. Snow: 25 cm – Bologna, on February 3. A rare intense snowfall in Rome. Up to 2 m high snow in the Appenines. 54 people died. Up to 120,000 people were left without electricity.</td>
</tr>
</tbody>
</table>

The frequency and intensity of extreme temperatures. Cold waves are expected to continue to affect areas already vulnerable to cold temperature extremes but the vulnerability of European populations to cold waves depends on the geographical location, the capacity to anticipate the risk, the capacity to intervene and resist, and the ability to recover from the impact of the events.

An unprecedented cold wave affected the European Region in the winter of 2012. The intensity and duration of the cold wave was exceptional in some European countries’ meteorological history. The 2012 European cold wave, starting on January 27, and dissipating on February 11, 2012, brought heavy and
persistent snowfalls (especially in the Balkan region) and freezing temperatures (from 4 to 11 February, reaching as low as −39.2 °C in Kuusamo, Finland, on February 2) to much of the European continent and North Africa, turning into one of the most deadliest and costliest weather events. There were 976 fatalities reported and damages mounted up to $ 660 million (Wikipedia, 2012), some of the most important country reports being summarized in Table 1.

If referring only to the previously-mentioned cold wave episode, one cannot but draw the conclusion that cold waves are definitely a complex form of extreme climate event with substantial impacts. In this respect, case studies are beneficial in assessing their future evolution trends. And this paperworks analyzes the cold wave episode that affected Romania, in January - February 2012. In fact, this was a preliminary opening of a greater cold wave that extended later (mid February) over other countries.

2. Synoptic conditions

In fact, the 2012 cold wave in Romania was preceded, on January 25-27, by a strong blizzard, accompanied by heavy snowfalls that built up a snow cover higher than 60 cm in most of the southern and south-eastern parts of the country, the snow cover on the rest of the territory being thicker than 20 cm. The sequence of weather events that followed can obviously be described in terms of synoptical patterns that influenced air-circulation flows over the country’s territory.

On January 29, Romania’s territory lies at the southern periphery (1,035-1,030 hPa) of a powerful anticyclonic nucleus located over the Kola peninsula (1,055 hPa). At the ground level, a NE wave of cold air advances farther to the S. Consequently, the values of the geopotential energy decrease from the SW (528 gpdm) to the NE parts of the country (516 gpdm), indicating that air is very stable,
Cold waves: meteorological characteristics and biometeorological influences

especially in N Moldavia (Fig. 1a). The fact that our country’s territory is maintained in the SW area of influence of a vast anticyclonic field dominating the N and E parts of the European continent, explains the absence of any frontal activity in the region of interest (Fig. 1b). And this, in turn, is the primary cause of a pronounced air stability that dissipates clouds and favour the intense radiative cooling of ground-level air during the night, thus lowering air-temperatures to critical values (Fig. 1c).

Fig. 2 - Synoptic conditions over Europe, on January 30, 2012 (12.00 UTC)

On January 30, the vast field of high air-pressure (1,035 hPa) resulting from the joining of the Scandinavian-Baltic anti-cyclonic nucleus (in N Europe) with the East-Siberian High (in E Europe), extends over more than 2/3 of the country’s territory, excepting its W and SW parts where air-pressure maintains below 1,030 hPa. The anti-cyclonic nucleus lying over the N shore of the Black Sea basin, characterized by a pronounced air-stability (as ground-level geopotential energy decreases to 508-500 gpdm) makes cold ground-level air from NE Europe advance southwards (Fig. 2a). As Romania’s territory is still maintained at the S periphery of the East-Siberian High and the low air-pressure nuclei over the E basin of the Black Sea are still very weak, there is no frontal activity that might significantly change weather (Fig. 2b). Therefore, there are very low temperatures all over the country, especially in its central, S, SE and E parts, for which the National Administration of Meteorology (ANM) issued an orange code forecast of persistent cold for 37 counties (Fig. 2c).

On January 31, the two pre-existent anti-cyclonic nuclei in the N and NE of Europe join together into a single vast anti-cyclonic field, which keeps the Romanian territory under the influence of a high air-pressure area (1,035 – 1,030 hPa) of pronounced stability as geopotential energy values range between 508 and 516 gpdm. However, the air aloft becomes unstable, especially on the S and SE regions of the
country (Fig. 3a). The fact that the high air-pressure area in N and NE Europe extends into a southward ridge, that determines a corresponding withdrawal and weakening of the previous lows, explains the ground-level persistence of high air-stability. And this, in turn, favours no fronts to be formed in the area of reference (Fig. 3b).

On February 1, although Romania’s territory keeps under the influence of the same East-Siberian High, air-pressure values decrease slowly from N (1,035 hPa) to S (1,030 hPa), with the SW parts of the country excepted. The invasion of cold air from N is reflected by the geopotential energy values that sharply increase from the N (496 gpdm) to the S regions (516 gpdm) (Fig. 4a). No fronts have developed yet over Romania’s territory, but a pronounced frontal activity has been initiated in the central parts of the Mediterranean Sea, over Italy.

On February 2, air-pressure values over Romania start increasing to more than 1,030 hPa in the N, NE and E parts and between 1,025-1,030 hPa in the rest of the territory,
Cold waves: meteorological characteristics and biometeorological influences

as the extensive high air-pressure field in the N of Europe gradually dismantles into several smaller air-pressure highs that still dominate over N Moldavia, where the geopotential energy values range still keep pretty low (488-484 gpdm) (Fig. 5a). The complex system of atmospheric fronts in the Mediterranean moves to the E, determining a slight air instability in the SW regions of the country (Fig. 5b) and probably weak western advections along the Mureș river-valley. Air gets more and more unstable in the S and SE parts of the country, where cloudiness increases as the frontal activity over the Balkan region and the SW part of the Black Sea basin gets more intense (Fig. 5c). Under the circumstances, as ground-level air becomes colder, due to the intense radiative cooling processes overnight, a warning code forecast of persistent cold has been issued for all Romania’s territory (yellow code for 5 counties in the W, and orange code for the remaining 37 counties), as for most of Southern and central Europe (Fig. 6).

On February 3, although air-pressure values remain constantly high over Romania’s territory (above 1,035 hPa in the NE, between 1,035 and 1,030 hPa in the N and E, and between 1,030 and 1,025 hPa in the SW), the NE-wards movement of an active low area located over the W part of the Mediterranean Sea, determines the anti-cyclonic nucleus
in N Europe to withdraw more to the N, but still maintaining a nucleus of high air stability in the N of Germany and Poland. The SE parts of the country are, however, affected by increasing unstable air movements (Fig. 7a). The frontal system in E Mediterranean slowly extends to the Black Sea basin and, consequently, the high-pressure air field over Romania becomes less intense (Fig. 7b). The advancement to the NE, of an active low-pressure area located on the central part of the Mediterranean basin, favors gradual invasions of warmer and more unstable air to the SW, central and N regions of the country (fig. 7c).

3. Meteorological characteristics

As air-temperature and wind-speed are the basic elements of weather and climate, the cold wave affecting Romania on January 29 – February 3, 2012, can best be described in terms of air-temperature value distribution and wind field at relevant isobaric levels aloft.

4.1. Air-temperature (°C) distribution over Europe, at the 850 hPa isobaric level, which roughly corresponds to the 1,500 m-high altitude, fully reflects the space and time evolution of the 2012 European cold wave (Fig. 8).

At the beginning, on January 29, as map 8a shows, the -10°C isotherm follows the inner border of the Carpathian Arch, dividing the Romanian territory into two distinct regions: an external region of persistent cold, in the E and S, due to the stagnation of a very cold air-mass (-16...-20°C) over the N shore of the Black Sea, and an internal warmer region, on the central and western parts of the country, with higher air-temperatures (-10°C). The following day (January 30), the central-eastern parts of the country are invaded by very cold air (-15°C) fastly moving to the western shore of the Black Sea, as it cuts off from the southern ridge of the East-Siberian High (Fig. 8b). Next (on January 31), Romania lies under the influence of cold air from the W peripheries of the Siberian High but air-temperatures are slowly increasing all over the country’s territory (Fig. 8c). As a new nucleus of cold air
Cold waves: meteorological characteristics and biometeorological influences

appears over central Europe, on February 1, strong cold air advections affect the country’s E and S regions, opposing to the slight warming of unstable air in the W parts of the country (Fig. 8d). As the anti-cyclonic field over central Europe gets stronger, on February 2, the invasions of cold air become more intense and rapid (Fig. 8e). But finally, on February 3, an important warming of air from SE to NW, determines air-temperatures all over the country grow from -16 to -6°C (Fig. 8f).

Fig. 8. Air-temperature distribution at the 850 hPa isobaric level (12.00 UTC) (Source: www.wetter3.de, 2012)
However, the actual value distribution of air-temperatures at the ground level is highly different from the one at 850 hPa level, and it more clearly reveals the influence of altitude, relief forms and other local factors. For instance, if analyzing air-temperature distribution in Romania, during the interval of reference, interesting findings are revealed. On January 29, subzero temperatures were recorded all over Romania’s territory, except for a narrow low-lying area along its NW border, in the Western Plain, where air-temperatures were positive (at Oradea and Satu Mare). However, although negative, air-temperatures in the W parts of the country do not drop below -5°C, while on the rest of the territory, they range from -4°C to less than -16°C (Fig. 9a). On January 30, temperatures all over the country’s
Fig. 10. Wind-field at 500 hPa isobaric level (12.00 UTC)
(Source: www.wetter3.de, 2012)

territory become negative, dropping to even lower values than the day before, depending on the altitude or location. The lowest air-temperature value was -22°C on the highest top of the Carpathian Mts. (Fig. 9b). On January 31, as cold air accumulates and stagnates on the bottom of low-lying areas, air-temperatures drop
to lower values mainly in plain and depressionary areas, whereas they maintained pretty stable on the hilly and mountainous area. A large cold air invasion from NE is, however, obvious (Fig. 9c). And this is also evident on the following day (February 1), when air-temperatures in N Moldavia drop below -20°C (Fig. 9d). The area with air-temperatures between -10°C and -20°C practically covers all the country’s territory, except for the Western Plain area. On February 2, air-temperatures drop below -10°C in all regions, reaching values lower than -20°C in most low-lying areas, irrespective whether they are in the mountainous or plain regions. In this case, the lowest air-temperature value was obviously recorded in the intramountainous Buzău Depression, lying in the heart of the inner Carpathian Arch (Fig. 9e). On February 3, cold air still persists over most of the country’s central and eastern regions but yet, they do not drop below -20°C except for a northernmost corner of the Moldavian region (Fig. 9f).

4.2. The wind field at 500 hPa isobaric level, roughly corresponding to the 5,500 m high altitude, also reveals significant details regarding the direction of general air-currents (Fig. 10), without ignoring the fact that this is quite opposite to the direction of air-flows at the ground-level.

As a low area of wind convergence is formed at the 500 hPa level, to the N of the Black Sea basin, Romania’s territory is invaded, on January 29, by intense N-S advections of cold air in its N parts, by NW-SE advections in its W and central parts and even by W-E flows in Dobrudja, all of high velocities (Fig. 10a). The N-S cold advections dominate on the W parts of the country, while, in the SE, as the low area of maximum wind convergence aloft gets pretty close, the relative vorticity of winds greatly increase on January 30, making winds blow from ever changing directions (W-E in S Dobrudja, SW-NE in central Dobrudja and NE-SW in N Dobrudja, with increasing wind-speeds (Fig. 10b).

The invasion of cold air from the SE periphery of the Siberian High is more than obvious on January 31, when Romania’s territory is affected by mostly N winds, but for Dobrudja, lying at the W border periphery of a low-pressure area, with high relative vorticity values (Fig. 10c). As, on February 1, an extensive trough is being formed at the 500 hPa level, cold air generally flows from W to E all over the country’s territory (Fig. 10d). Consequently, on February 2, the vast anti-cyclonic field area over NE Europe is blocked by an extensive low-pressure area, making main air-flows change direction to SW-NE, as they get closer to the area of high relative vorticity developed over Poland (Fig. 10e). On February 3, the advection of cold air still keeps its SW-NE direction at the 500 hPa isobaric level and, furthermore, it gets even more intense (Fig. 10f).
5. Biometeorological influences

Generally, air-temperature and wind-speed are the most important elements influencing wintertime human comfort. Several bioclimatic indices combine these factors to establish the level or degree of physiological comfort. One such index used by Romania’s National Administration of Meteorology (ANM) is called the Cooling Index (ro. = Indicele de răcire - IR), expressed in °C, which indicates the air temperature that would actually be perceived by the human body on certain conditions of wind-speed, namely the temperature equivalent to the cooling power of wind. To note that, as wind-speed increases, the overcooling stress increases as well and, consequently, equivalent temperature decreases. It is, however, important to note that factors such as the length of exposure to cold, the type of clothes and the general health of the individual may greatly affect the amount of overcooling stress a person will experience.

Romania’s legislation includes regulations concerning the specific ways of identifying and reporting on biometeo-climatic risks, according to their character and amplitude of manifestation in given geographical, seasonal and meteorological conditions. Such bioclimatic reports are made according to Emergency Order nr. 99, issued by the Romanian Government on June 29, 2000, which identifies the hazardous weather conditions and establishes the measures to be taken in periods with extreme air-temperatures in order to protect the working persons; although the respective forecast addresses to all people alike. Regarding the IR Index, Article 1, paragraph (2) of this order states that extreme temperatures represent outdoor air-temperatures that...(b) drop below –20°C or, correlating with high wind-speeds, they become equivalent to these... Article 2, par. (1) of the same order states that the National Administration of Meteorology (ANM) is obliged to communicate in local mass-media, the conditions on which air-temperatures drop to the limits established in Article 1, par. (2), the value of these equivalent temperatures and the forecast for the following period. In case the respective temperatures exceed the limits above-mentioned in Article 2, par.(1), ANM must repeat its communicates every 6 hours, throughout the whole period these temperatures maintain, but authorities should take protective steps only if such extreme temperatures persist for two consecutive days.

The methodological application norms of the above-mentioned order have been later established in the Government Decision nr. 580 on July 6, 2000, which gives not only the definitions of the weather terms to be reported, but also their equivalent tempartauure values. Therefore, according to Article (2):

\[ a) \] outdoor air-temperature reflects the warming degree of atmosphere air;........

\[ c) \] a strong wind is a wind reaching a speed higher than 10 m/s;.........................

\[ f) \] a low equivalent temperature is the outdoor temperature correlated with wind-speed and expressed by means of the IR Index;..............................
g) extremely low temperatures are the temperatures below -20°C or equivalent temperatures to IR Index below -32°C.

On January 30, all IR values were negative, even in the NW parts of the country, and the area of IR values below -32°C extended over most of the E and SE parts of the country. The lowest IR value (-43°C) was certainly recorded in the depresionary area inside the Carpathian Arch, due to the accumulation and stagnation of cold, heavy air on the bottom of intra-carpathian basins (Fig. 11b). High altitudes also played an important role in cooling the air since a minimum IR record was reached
on the highest top of the Carpathain Mts. (namely -56°C on the 2,544 m-high Moldoveanu Summit). On January 31, the distribution of critical IR values clearly shows the invading direction of cold air from the NE, since all the E and SE parts of the country record IR values below -20°C; the lowest IR value (-42°C) being reached at Jurilovca, in central Dobrudja (Fig. 11c). We should also note that all IR values are negative (below -4°C) over the whole country. On February 1, there appear more isolated areas with IR values lower than -20°C in the mountainous and eastern regions and only a single one area of extreme IR value (below -32°C) at Jurilovca, in Dobrudja, although the rest of the country’s territory is still being dominated by negative IR values (Fig. 11d). On February 2, cold air covers a more extensive area, invading most of the E, S, and SE parts of the country but forming islands of low IR values only on the most low-lying areas of the Romanian Plain, the Dobrudjan Tableland, the intracarpathian Braşov and Buzău Depressions etc. (Fig. 11e). However, the lowest IR value is recorded again on the highest top of the Carpathian Mts. (-57°C). Finally, on February 3, the air gets colder in all the previously-mentioned areas and, moreover, it also starts cooling to critical IR values on the W and NW parts of the country as well (Fig. 11f).

References:
www.noaa.gov.org
www.meteoromania.ro
www.wetter3.de