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THE DESCRIPTION OF IMPORTANT HISTORICAL MOMENTS IN TERMS OF METEOROLOGICAL ASPECTS

COSMINA APETROAIE[1,2], ADRIAN TIMOFTE[1], DIANA-CORINA BOSTAN[1], SORIN BOSTAN[3], MARIUS-MIHAI CAZACU[4,*]

[1]*National Meteorological Administration, Bacău Regional Forecast Center, Timpului Street, No 3, 600234, Bacău, Romania*
[2]*"Alexandru Ioan Cuza" University of Iaşi, Faculty of Geography and Geology, Carol I Blvd., No. 20 A, Iaşi, Romania*
[3]*"Vasile Alecsandri" National College, Vasile Alecsandri Street, No 37, 600011, Bacău, Romania*
[4]*Gheorghe Asachi Technical University of Iaşi, Department of Physics, Bd-ul Dimitrie Mangeron nr. 67, Corp T, Iaşi, 700050, Romania*
[*]*Corresponding author e-mail: cazacumarius@gmail.com*

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APETROAIE COSMINA, TIMOFTE ADRIAN, BOSTAN DIANA-CORINA, BOSTAN SORIN, CAZACU MARIUS-MIHAI

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Abstract. The purpose of this paper is to present the role of meteorology in certain important historical moments both from the last century and from the present one.

To investigate these cases from a meteorological point of view, we used reanalysis data, from some climatological databases, for the events of the last Century and for the events of the 21st Century, we relied on various information that allowed us investigation of the atmosphere, at all levels (synoptic maps at different levels, satellite imaging, backward trajectories, radioactivity data, etc.). Although during the First World War, the investigation of meteorological parameters was limited only to the ground level, in critical moments, the weather forecast decided the fate of some missions carried out on the front during that period. Over time, technology has advanced and the investigation of the atmosphere is carried out on a multitude of levels, using modern investigation technology, with active or passive sensors, located on the ground or on equipment from space.

Forecasts have greater accuracy, and information is easily transmitted to the population and institutions of national interest too. In case of natural or anthropogenic disasters, accurate weather forecasts allow quick decisions to be made for the safety of the population.

More recently, there are stations (national and international) that also monitor aerosol stratification.

The meteorological stations have been modernized and automated, the synoptic maps from the ground and from the altitude are at "one click" away from us. Meteorology has become a field of interest for industry, transport, military and, last but not least, for the safety and security of the general population. In this paper we will show the progress in this field of activity and the implications in people's everyday life.

Keywords: forecasting, synoptic maps, meteorology, environment.

1. Introduction

The National Meteorological Administration celebrated on March the 23rd, 2022, the World Meteorological Day, which marks the entry into effect of the Convention establishing the World Meteorological Organization dated March the 23rd, 1950. Each year, on this day, the World Meteorological Organization (WMO) and its 193 States and Territories celebrate this event by debating on a chosen theme. The name selected for this year's theme was: "Early warnings and actions. Hydrometeorological and climate information for disaster risk reduction". The main focus is to have precise early warnings that would lead to effective early action.

The present general context is characterized by visible climate change, reflected in increasingly numerous extreme weather events. Ocean warming is fuelling the increase of powerful tropical storms, and rising sea and ocean levels are amplifying the impact. Meteorologists and climatologists expect this negative course to continue. And their worrying prediction is founded on fact: greenhouse gas concentrations are at record levels, leading to continuous climate change for decades to come, as well as to the melting of glaciers and to the rising of the sea and ocean levels for hundreds of years into the future. Mitigating climate change is, indeed of great importance. But adapting to climate change should be assigned absolute priority. Early warning systems are a very important method in the direction of adaptation [1, 2]. In this paper we will analyse some important cases in history**,** from the meteorological point of view. There have been many times when human disaster affected environmental and human health too, both in the short and in long term. In the case of Eyjafjallajökull and Grímsvötn volcanoes eruption, the ash plumes were spread over most of Europe, and the air traffic over Europe was disturbed for several days. Whether we are talking about radioactive materials, about smoke due to forest fires or about pollutants carried by strong winds from various (natural or artificial) stationary or mobile sources of pollution, air quality monitoring involves an analysis of meteorological conditions [3, 4].

2. Methods and analysed cases

For this paper, we used Mean Sea Level Pressure and altitude synoptic maps from different sites and ERA5 reanalysis data [5-8], minimum temperature map [9], information about the climatic characterization of some locations [10], satellite imagery [11, 12], data from HYSPLIT that is a complete system for computing simple air parcel trajectories, as well as complex transport,

dispersion, chemical transformation, and deposition simulations. Some examples of the applications include tracking and forecasting the release of radioactive material, wildfire smoke, windblown dust, pollutants from various stationary and mobile emission sources, allergens and volcanic ash [13, 14]. Data related to radioactivity were retrieved from the global environmental monitoring network [15].

3. Case analyses

3.1. 20th Century moments

3.1.1. April 22, 1915- Ypres, Belgium, World War I Chemical Weapons

April the 22nd, 1915 was the day in which the Allied forces on the western front were stupefied at the German choice of means of warfare- they fired more than 150 tons of lethal chlorine gas against two French colonial divisions at Ypres, Belgium [30, 31, 32]. This first major gas attack by the Germans had an absolutely devastating effect upon the Allied line. Previous attempt involving the use of gas at wartime took place in October 1914 when the German forces placed several small tear-gas canisters in shells that were fired at Neuve Chapelle, France. One year later, in January, German fired shells loaded with xylyl bromide at Russian troops at Bolimov, on the eastern front [16, 17, 18]. According to statistics (the last 30 years), in Ypres, the average maximum temperature for the month of April is 15°C, and the average minimum temperature is 6…7°C. The annual precipitation average is close to 70 l/m^2 and the number of days with rain is approximately 10-11 days, and the average relative humidity, for the same area and month, is 80% [10]. On that day, until 12 UTC, light precipitation of about 0.2-0.5 l/m^2 was recorded; in the morning at 06 UTC the relative humidity was quite low [6].

On April the 22nd, 1915, an Anticyclonic Belt dominated most of the continent, except for the northern and the southern part of Europe. Over Belgium, a relatively high-pressure field was present, with values above 1020 mbar, and the wind blew from the northeast sector. In the middle troposphere, a longwave trough was positioned to the north of the analysed area (500 hPa geopotential high value, close to 552 damgp). The stable atmosphere, induced by the presence of the high-pressure field from the ground level, doubled by an intrusion of cold air at the level of 500 hPa facilitated the retention of toxic clouds in the low troposphere. The atmosphere laden with toxic gas was directed to the southwest, as a result of the direction of the wind acting from the northeast sector. Mainly, the Benelux countries, along with France, Great Britain, Denmark, were implicitly in the flow of poisonous gas. Belgium was positioned on the downslope side of the longwave trough. On the ascending side of the valley described, at the contact with the relatively high-pressure field, light rains

were estimated. The cloudiness, the modest surface temperature of about 6 degrees, kept the toxic air in the low atmosphere in the north-western part of Europe. At 850 hPa, the zero-degree isotherm bisected Belgium from northeast to southwest (Fig. 1 left and right) [6]. Germany scheduled its offensive for the night of April the 14th, but the weather conditions were not favorable. Thus, the attack was to take place in the afternoon of April the 22nd, when the southwest wind from that sunny afternoon facilitated the transport of the toxic cloud [33, 34]. These weather conditions contributed to the efficiency of the German attack.

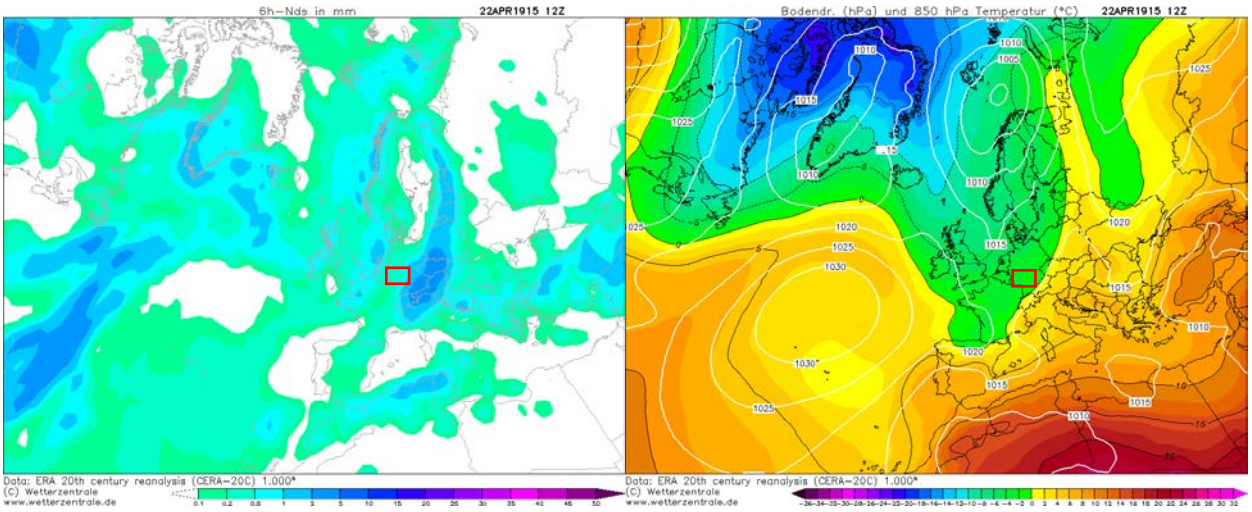


Fig. 1. April 22, 1915 - Ypres, Belgium, amount of precipitation (left) and synoptic situation (right) [6].

3.1.2. November the 03rd, 1944, Japan's Secret WWII Weapon: The Balloon Bombs

During World War II the opponent forces began to experiment with different kinds of military devices. Balloon bombs were some of these ingenious approaches to warfare. These noiseless killers of WWII could silently float across the Pacific Ocean to their marks in North America, while flying with a jet stream [35].

The origin of these military devices- though unknown to most people, was, in fact, an atmospheric experiment by the Axis Power. They used balloons to which measuring instruments were attached, launched them from the Western side of Japan and picked them up on the Eastern side. At about 9144 m, researchers noticed the presence of a strong air flow travelling across the Pacific [36]. Thus, in 1944, the Japanese were the authors of what was regarded by many experts as the first intercontinental weapon system: explosive devices attached to paper balloons that were buoyed across the ocean by a jet stream [34].

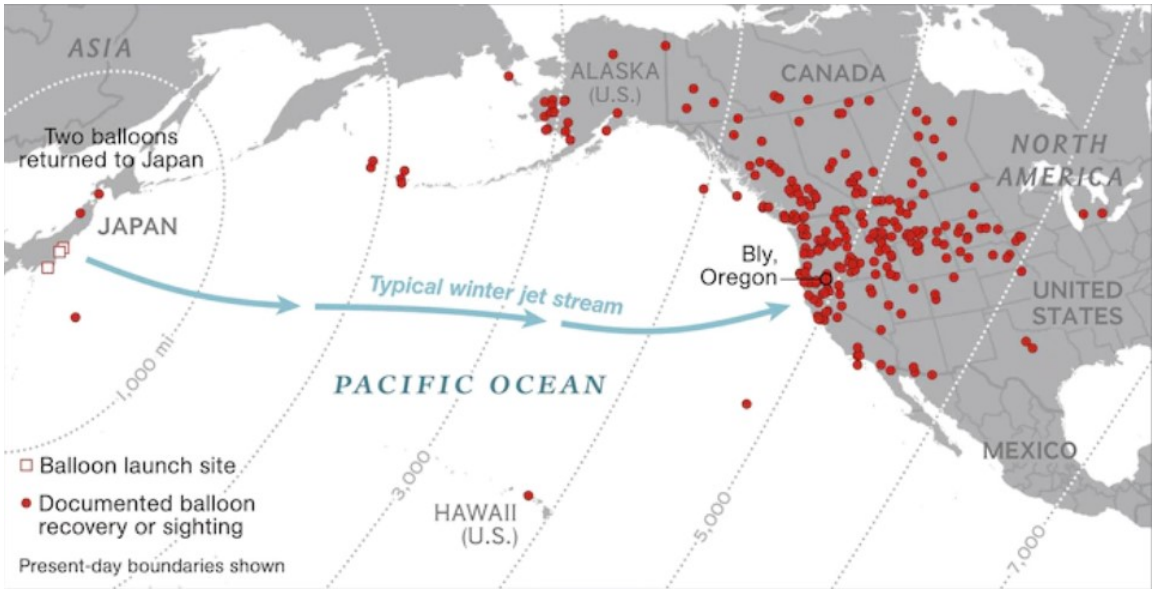


Fig. 2. Balloon bombs launched from Japan. Map by Jerome N. Cookson, National Geographic; Source: Dave Tewksbury, Hamilton College [19].

Jet streams are flat, tubular currents of air, quasi-horizontal, that live in the upper parts of the atmosphere. Jet streams blow from west to east, but the flow often shifts to the north and south. They follow the boundaries between hot and cold air.

Jet streams are the strongest for the northern and southern hemisphere winters because hot and cold air boundaries are most pronounced in winter. Moreover, taking into account the three- cell circulations, the regions with 30 N/S and 50/60 N/S are areas with the most significant temperature changes. Temperature differences and the strength of wind are directly proportional- as the difference in temperature increases between the two locations, the strength of the wind increases.

As a consequence, the regions around 30 N/S and 50/60 N/S are regions where the wind is the strongest in the upper atmosphere. One characteristic of jet streams is that it has variations in height, of six to twelve km, and can reach speeds of more than 125 m/s [20].

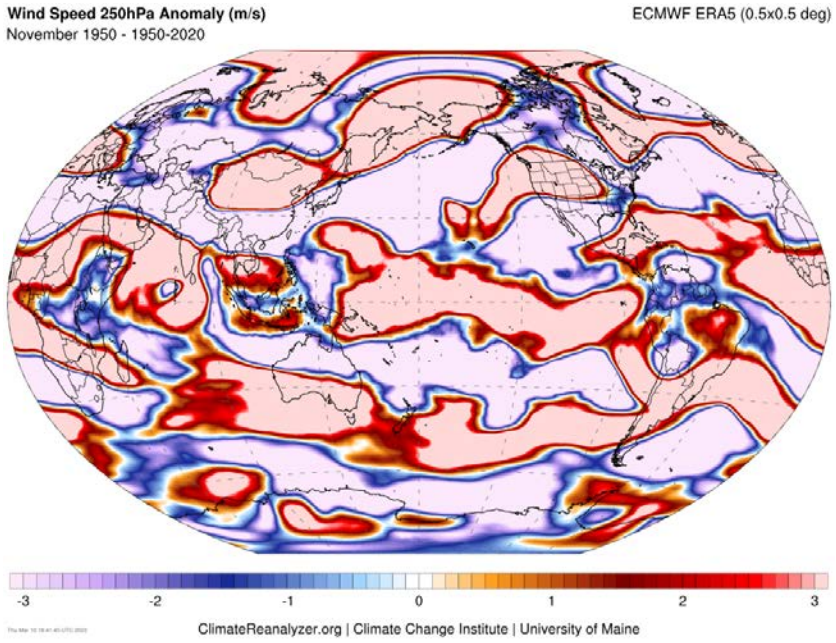


Fig. 3. Wind speed 250 hPa anomaly (m/s), November 1950 to 1950-2020 - positive wind speed anomalies at 250 hPa are marked in red and negative wind speed anomalies are marked in blue [5].

The North Pacific is dominated by the interaction between the North Pacific High and the Aleutian Low. The North Pacific High represents a high-pressure system, semi-permanent, quasi-circular and the Aleutian Low is a low-pressure formation, located in the region of the homonymous Islands. At the end of fall, low pressure systems in the Gulf of Alaska region begin to descend southward, close to the North Pacific High. Following the contact between the two baric centres, an unstable weather results. After each episode of instability, the Pacific High reconstitutes itself, and as November progresses, it moves eastward according with the general circulation in the Northern Hemisphere. The more the Pacific High moves eastward, the more it makes way for low pressure systems to descend to the south [8].

In November 1944, the polar jet was present over the North Pacific (Fig. 3). It favours the rapid movement of air masses from the west (Japan) to the east (west coasts of North America).The presence of the well-defined cyclone in the Aleutian Islands and the Barents Sea prevents the spreading of the masses to the north, instead it favours their movement towards the Western Pacific. In the absence of meridian deviations, air masses could cross the distance between the 2 continents in about 3 days. The main objective of launching these balloons bombs was to set fire to forests and create panic among Americans. This objective was partially hindered due to their launching during the rainy season.

3.1.3. April the 26th, 1986- The Chernobyl nuclear accident

Another case where meteorological context had a major impact was the devastating, tragic event at Chernobyl on April the 26th, 1986.

In the first two decades of April 1986, most of Europe was dominated by a low-pressure field, in which nuclei of Icelandic, Mediterranean and Atlantic origin followed each other. After April the 22nd, the eastern half of the continent is covered from the ridge of the Eastern European High, which becomes strong and stable, with pressure values over 1020 hPa, over extensive areas. As the ridge of the Azores High penetrates the continent, they will cause a weakening of the intensity of the low-pressure field that will remain active only in Western Europe, the British Archipelago and the western half of the Scandinavian Peninsula. This synoptic context was favourable for the transport of air masses from the south-eastern and eastern areas towards the northern countries (Fig. 4).

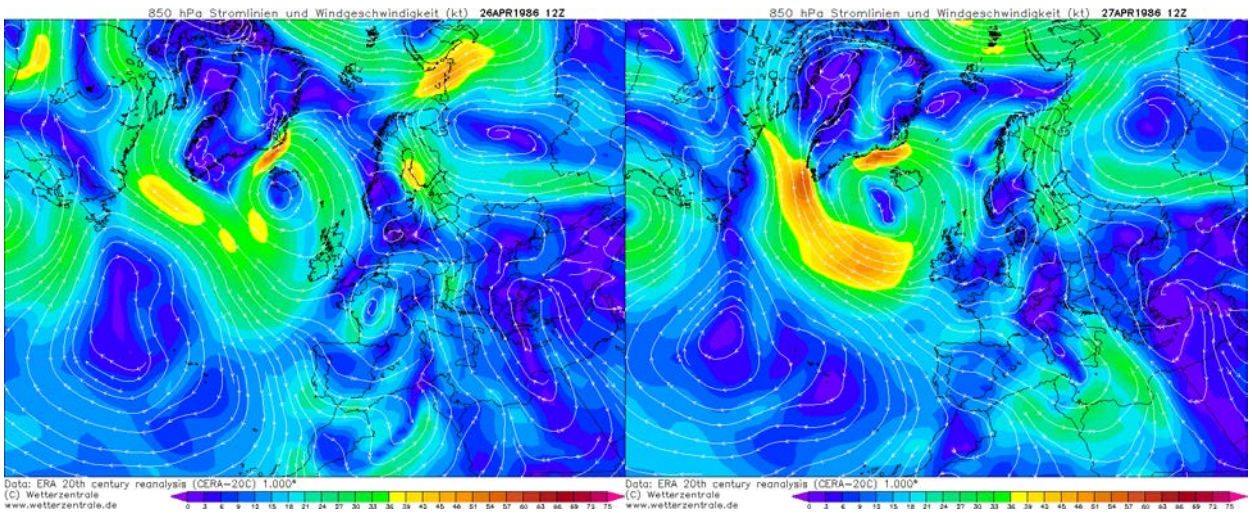


Fig. 4. Streamline at 850 hPa level on April 26 (left) and April 27 (right) 1986 [6].

According to the study by Paatero J. et al., the radioactive plume moved slowly, first to the northwest. Over Lithuania, the plume split in two branches. At altitudes of 750-1000 m, it continued to move towards Sweden and Norway, while at altitudes of 1500-2500 m it turned to the north. The plume reached southwestern Finland on April the 27th at 12 UTC and infiltrated at an altitude of 2000 m. The plume then crossed the territory of Finland to the northeast and back into the Soviet Union. A frontal area north of this route prevented the plumes from reaching northern Finland. This could have caused catastrophic socio-economic problems [21].

Initially, this accident was denied by the Soviet Union, but science revealed the truth by calculating the back trajectories of air particles, according to air flow in the atmosphere. Using this approach, the "source of pollution" was found.

3.2. 21st Century moments

3.2.1. February the 24th, 2022- Russian troops gain control of Chernobyl nuclear power plant

A BBC article dated June 3, elaborated on the present and later events at Chernobyl caused by the Russian occupation of the nuclear power plant on February the 24th. The Russian forces have been in control of the nuclear power plant for five weeks and only withdrew on March the 31st, 2022 [22] (Fig. 5).

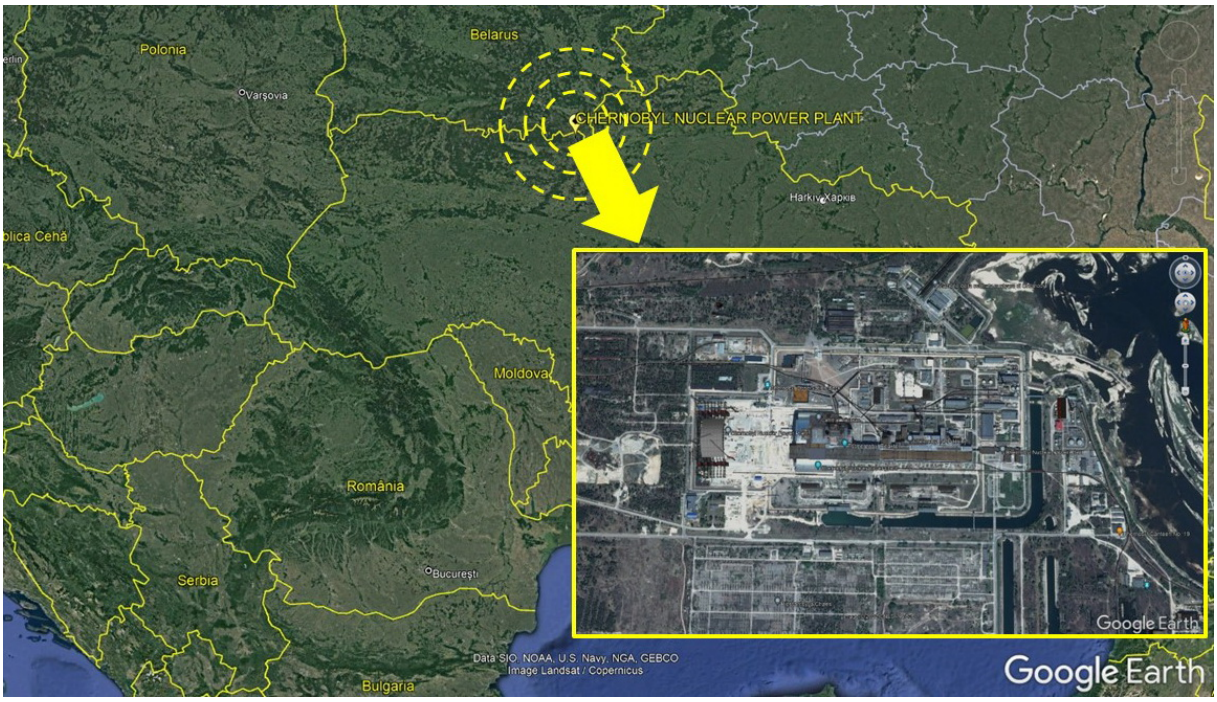


Fig. 5. Location of the Chernobyl Nuclear Power Plant [12].

For that period of time, the uRADMonitor website displayed normal values of the radiation level in Romania. For example, Fig. 7 shows that on February the 28th, 2022, the radiation level in Romania was normal (values between 0.09 and 0.19 μSv/h) [15].

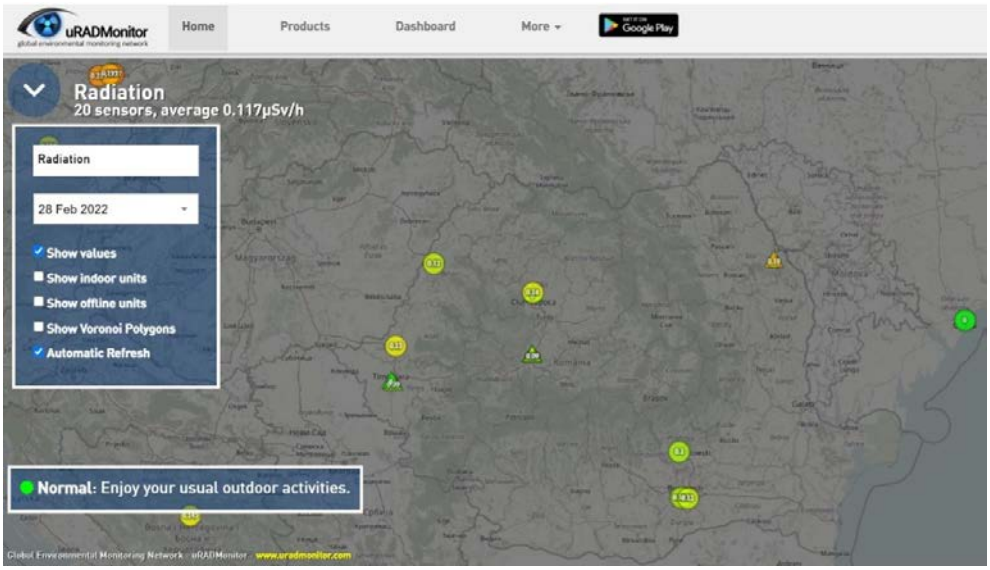


Fig. 6. Radiation map, with existing nuclear sensor, measuring level of radiation in μSv/h [15].

Also, the official websites in Romania, of the authorized institutions, did not announce any exceedances of the radiation level [23].

From a meteorological point of view, on February the 24th, an anticyclonic field dominated most of Europe, except for the north of the continent where a low pressure field (of Icelandic origin) was operating, with two cyclonic cores of 970 mbar, over the Faroe Islands, respectively in the Norwegian Sea and an occluded front with warm character was positioned over the central part of Ukraine. On February the 25th, Romania and Ukraine were in the warm part of a frontal system. The baric configuration and distribution highlighted a trough associated with the depression area in the north of the continent, so that above Romania, at ground level, pressure had values slightly exceeding 1020 mbar, decreasing compared to the previous day when the pressure values had values equal to and greater than 1025 mbar. On February the 26th, a waved front, extended from north to south, from the White Sea, to the central part of Italy, affected Romania and Ukraine. On February the 27th, a high-pressure area with values at the centre of over 1035 mbar, settled in the central-eastern part of Europe.

In this interval, at the level of 500 hPa, the air circulation was predominantly from the northern sector at first, then from the south and southwest. At the level of 850 hPa, air circulation, was predominantly northern, except for the day of February the 25th when it prevailed from the southern sector. The numerical forecast model (GFS) forecasted precipitation over Ukraine every day, between February the 24-27th, 2022, which is why the "radioactive dust" from the exclusion zone had no way of advancing towards the territory of our country, even if the air circulation was from Ukraine, more than half of the interval mentioned above.

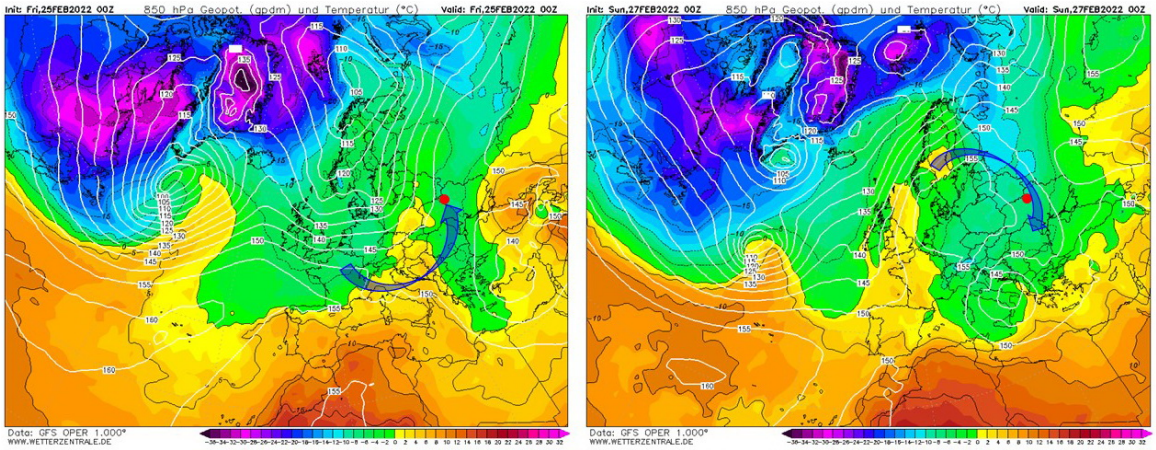


Fig. 7. Synoptic situation at 850 hPa level, on February the 25th 2022, h 00UTC (left) and on February the 27th 2022, h 00UTC (right) [6].

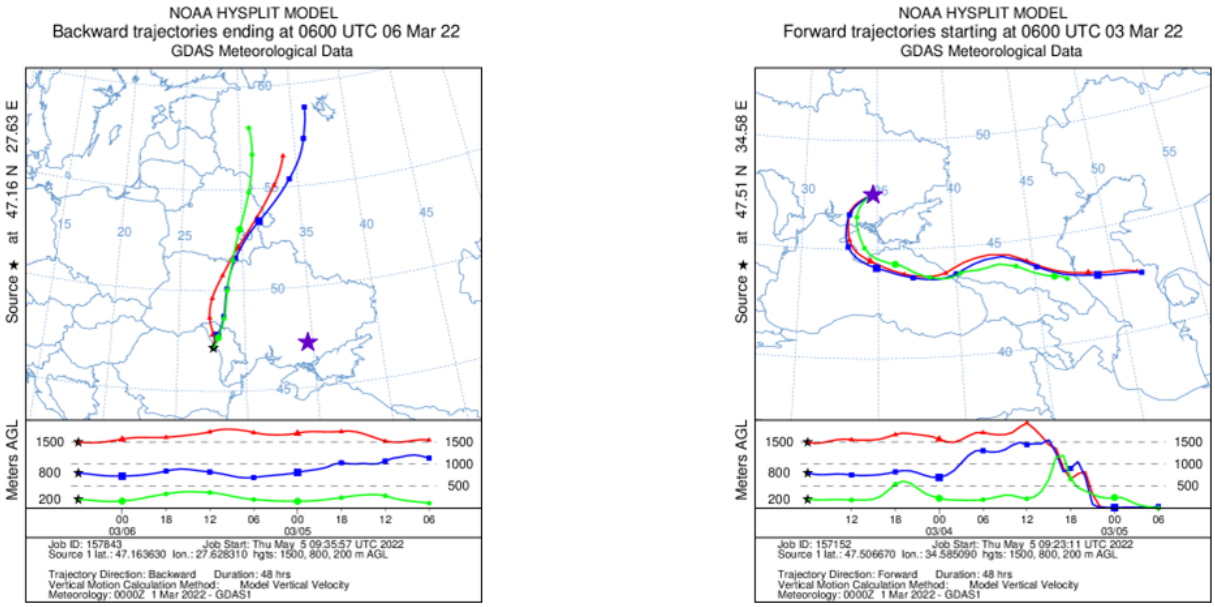


Fig. 8. Backward trajectories ending at February the 25th, 2022 at h06 UTC (left) and backward trajectories ending at February the 27th, 2022 at h06 UTC (right) [13].

Analysing the back trajectories between the 200m-1500m levels on February the 24th and 25th, even though the air circulation was coming from northwest Ukraine, the dust particles were not brought from above the Chernobyl nuclear power plant. On February the 26th and 27th, backtracking indicated a movement of dust particles from Chernobyl. However, no very high values of radioactivity were recorded over Romania. Precipitation during that period probably also played an important role.

3.2.2. March the 03rd, 2022 - The Zaporozhye Power Plant was bombed

On March 04, the media reported how on the night of March the 03rd /04th, 2022, one of the largest nuclear power plants in Ukraine but also in Europe (Zaporozhye) was bombed intensely [24, 25]. Because of the bombings, an administrative building inside the plant caught fire. Even though there were critical moments, the radiation level was normal.

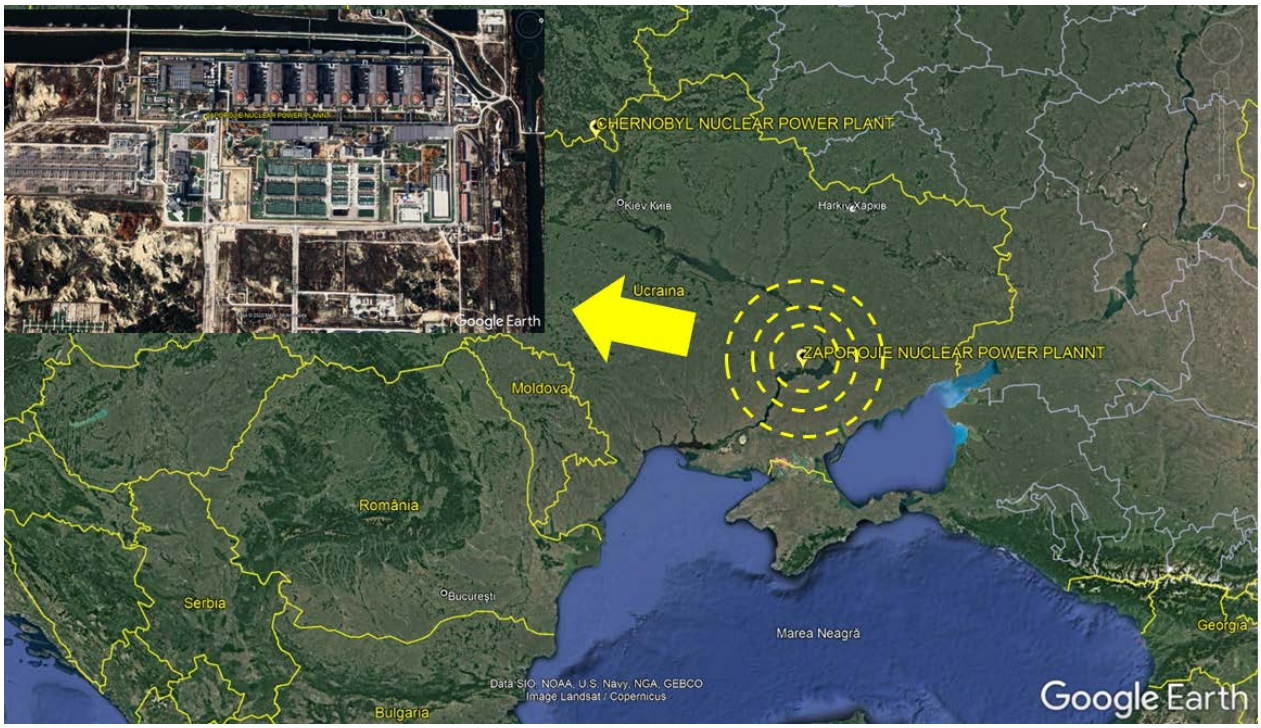


Fig. 9. Location of the Zaporozhye Nuclear Power Plant [12].

Obviously, such a piece of news produced concern among the population. At times like this, the role of science in general and that of meteorology in particular, is of the essence. Obviously, all state institutions of national interest issued press releases, through which the population was informed correctly and in a timely manner.

For example, backward and forward trajectories, from the NOOA HYSPLIT model, did not indicate a real danger, for March the 3rd and 5th, 2022 (Fig. 10).

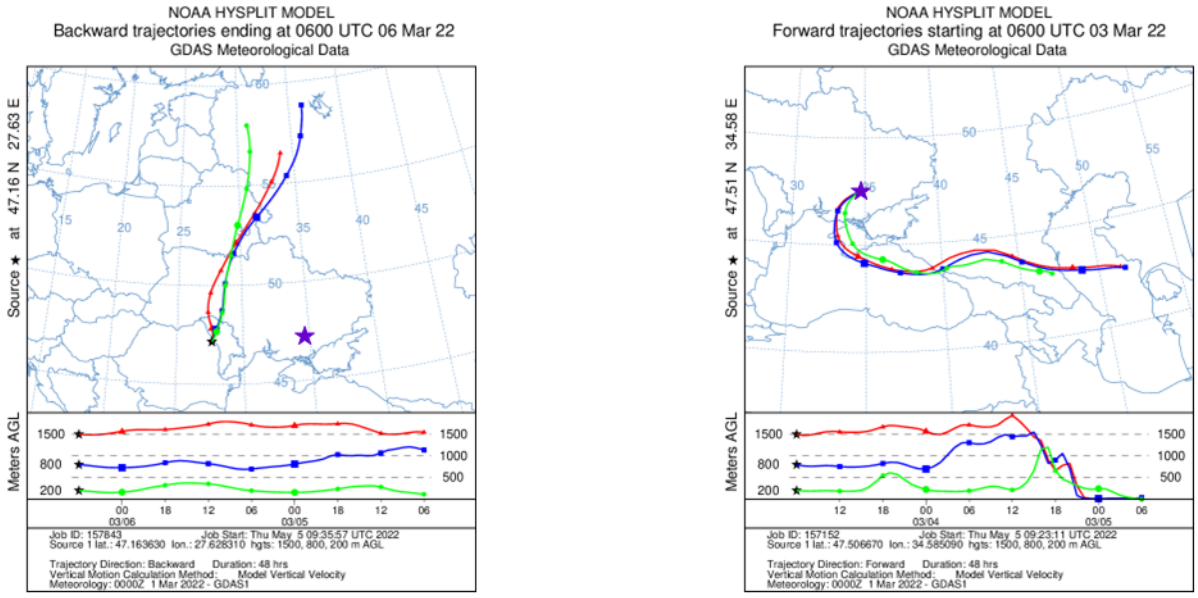


Fig. 10. Backward (left) and forward (right) trajectories, from the NOOA HYSPLIT model; running model for the March the 03rd, 2022 event [13].

From the satellite imagery and level wind analysis, it can be seen that the air circulation on March the 04th, 2022 at 00 UTC was not favourable for air intrusion from the Ukraine nuclear power plant. Due to a blocking circulation at altitude (Fig. 11), at all levels, the wind over Romania was predominantly from the northwest, and above the Zaporozhye nuclear power plant, the circulation was also from the northwest, except for the 500 hPa level where air was pushed from south to north.

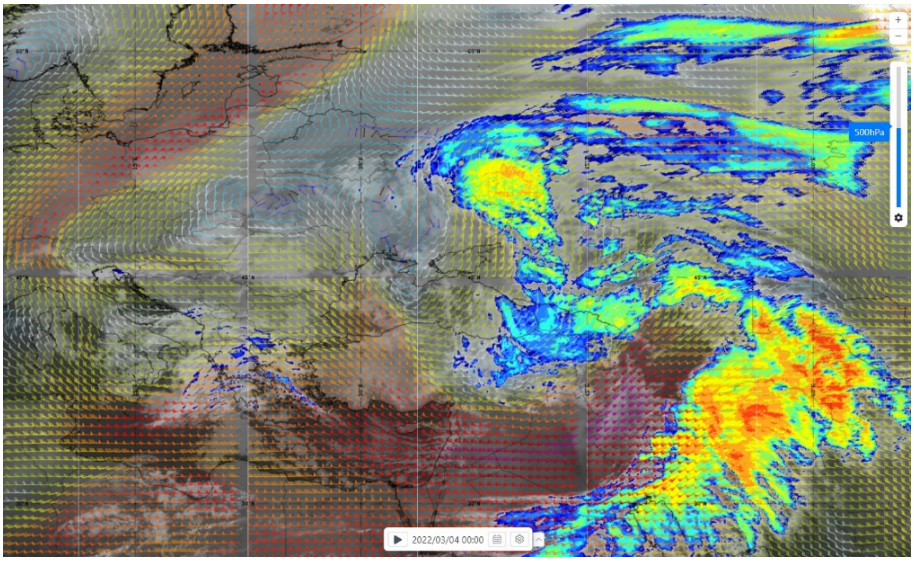


Fig. 11. IR 10.8 and IR 10.8 ENHACED satellite imagery analysis and wind distribution at 500 hPa, on March the 4th, 2022, 00UTC [11].

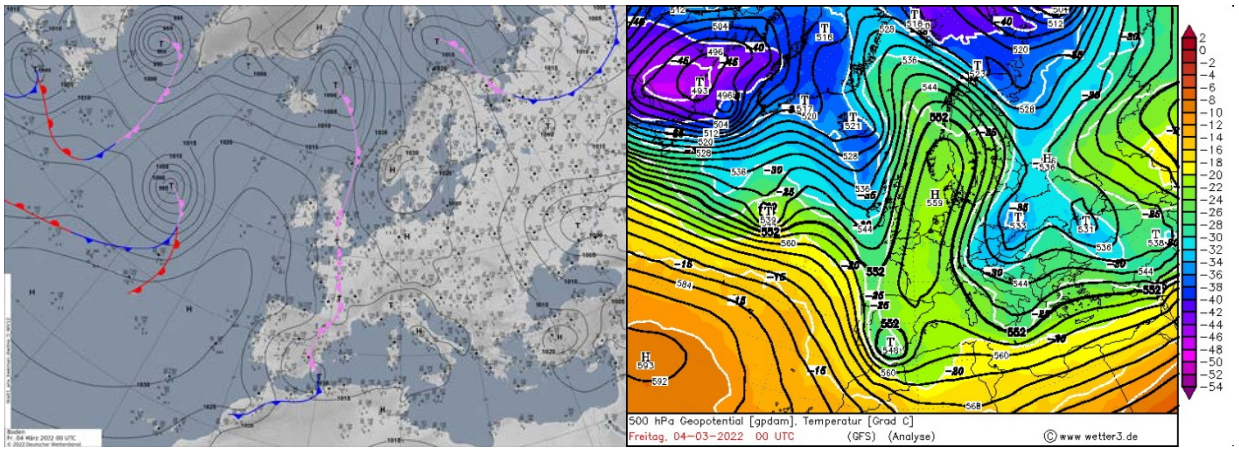


Fig. 12. The synoptic situation on the ground (left) and at the 500 hPa level (right), for March the 4th, 2022, h00UTC [6, 7].

Over most of Europe, an anticyclonic field dominated, with values above 1030 mbar over southern Norway, except for the south and northwest of the continent, where a low-pressure field was present. In the north-western part of the continent, the Icelandic Low was operating, with a 1000 mbar nuclei. In Romania, due to the relatively high-pressure field, the air circulation was from the northern sector. Thus, from the analysis of the data it is clear that at no time was the population affected from a meteorological point of view by the events that took place in Ukraine that night.

3.2.3. March the 09th, 2022- The cold wave invaded northern Ukraine

The cold wave that swept over the northern part of Ukraine was news topic on March the 09th, 2022. Russian soldiers had to endure sub-zero temperatures for several days in a row and were to face several more days where minimum temperatures consistently reached -10 degrees Celsius (Fig. 13). Although weather experts issued an alert about the cold wave that was going to settle in the east and south-east of Europe, the troops were sent north of Kyiv. The first weather warning was issued on February the 25th, 2022 and the first update was made on March the 04th. The validity of this special meteorological bulletin was for the period 07-11 March, 2022 [26-29].

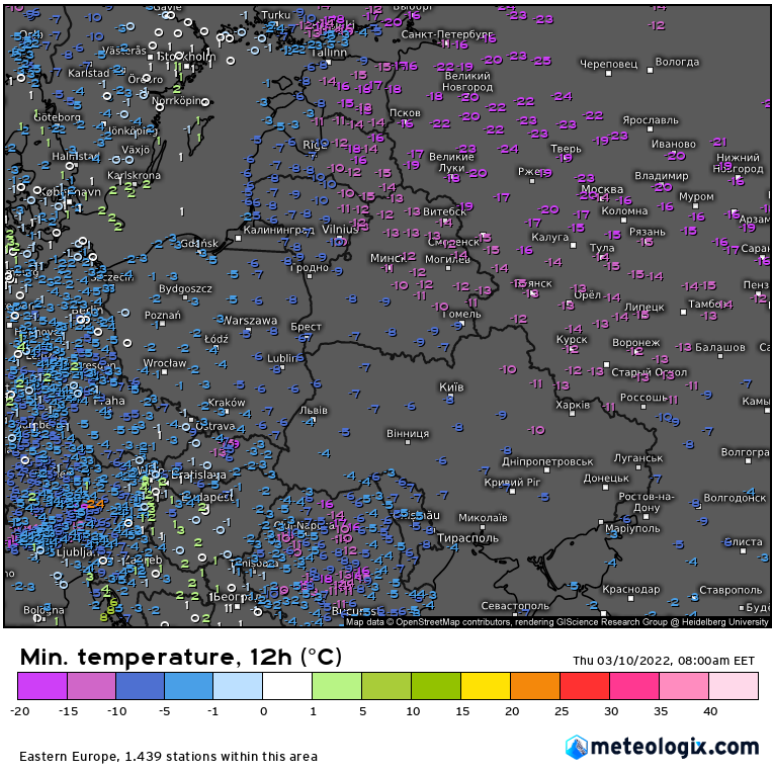


Fig. 13. Minimum temperature for March the 10th, 2022, h08 EET [9].

In the morning of 10th of March 2022, a strong high-pressure field had settled over most of the Europe, with values above 1040 mbar, in the east of Estonia. The winds from the east, combined with the arctic air wave, brought about significantly cold air (Fig. 13 and Fig. 14).

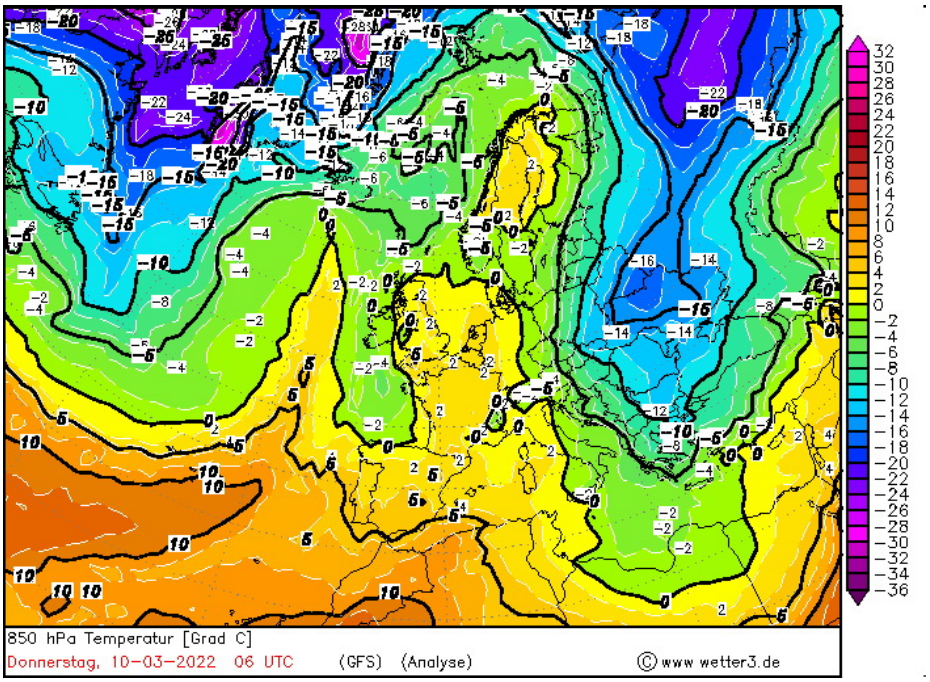


Fig. 14. The synoptic situation on the ground and at the 850 hPa level, for March the 10th, 2022, h06UTC [7].

4. Conclusions

Even though in the early days of meteorology as a science, weather stations were not so frequent, or did not have very high-performance equipment, the whole society was based on rudimentary observations and short-term weather forecasts. Technology has advanced with time and everyone nowadays realizes the importance of a weather forecast. If today any smartphone can provide a 10-day forecast over a certain area in a few seconds, 100 years ago this kind of forecasting process was quite laborious. Over time, the accuracy of forecasts has been improved and the short- and medium-term forecasts are getting better. The efforts of scientists and forecasting meteorologists are rewarded when forecasts are close to reality, and warning messages reach state institutions in time, so that even if we face dangerous meteorological phenomena, we greatly reduce material losses and most importantly, we avoid human life losses. In order to avoid panic and for the sake of accuracy, we strongly advise that official websites be used exclusively and proper credit be given to science.

As we have seen throughout history, both in WWI and WWII, and even today, when "war" should have merely been a theoretical notion evocative of the past, weather forecasting plays a primary role. A weather forecast makes the difference between a precise, meticulously prepared attack and total failure. What if in the First World War, the direction of the wind had been from the south and not from the northern sector? What would the world look like today if the trajectories of balloon bombs from World War II hit their targets? And last but not least, how did the military general feel about the 15,000 Russian soldiers who froze north of Kyiv, although the special weather bulletin contained data about the cold wave from the beginning of March 2022?

Meteorology is a complementary science; without mathematics, physics, informatics and geography, we would not have such accurate weather forecasts today! In times of peace, weather forecasting is very useful to population, aviation, maritime, agriculture, industry and even health. If we were to reflect on that, we may easily conclude that each day of our lives begins under its auspices.

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