Deutscher Wetterdienst
Wetter und Klima aus einer Hand

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Yearbook 2021
of the Deutscher Wetterdienst

The Reference for Meteorology is the Deutscher Wetterdienst

Virtually everyone is interested in the weather and virtually every area of our lives is affected by weather and climate. As the reference for meteorology in Germany, the Deutscher Wetterdienst (DWD) is the prime point of contact for all questions related to these areas. The range of duties is many and varied. The DWD records, analyses and monitors the physical and chemical processes in our atmosphere. It holds information on all types of meteorological events, offers a diverse range of services both for the general public and for special user groups and operates the national climate archive.

In its role as a national meteorological service, the DWD is also a provider of scientific and technical services and a competent and reliable partner for public and private partners in the field of meteorology and climatology. Its customers' increasing demands on quality not only oblige the DWD to supply high-quality products and services, but also are a continuous incentive to improve product quality, customer orientation and economic efficiency.

The DWD, which was founded in 1952, is, as the national meteorological service of the Federal Republic of Germany, responsible for providing services for the protection of life and property in the form of weather and climate information. This is its core task. Established as an executive agency of the Federal Ministry for Digital and Transport (BMDV), the DWD provides meteorological information to ensure the safety of aviation and maritime shipping, traffic routes and vital infrastructures, in particular those needed for energy supply and communication systems. It also issues warnings of meteorological events that could become a danger to public safety and order and have a high potential to cause damage. The DWD, however, also has other important tasks, such as serving the needs of the Federation, the Länder, the local governments and institutions of justice; monitoring the climate; analysing and projecting climate change and climate change impacts; providing climate and environment consultancy services; and ensuring the fulfilment of the international commitments entered into by the Federal Republic of Germany. The DWD thus co-ordinates the meteorological interests of Germany on a national level in close agreement with the Federal Government and represents the Government in intergovernmental and international organisations such as, for example, the World Meteorological Organization (WMO). These duties are embodied in the Deutscher Wetterdienst Act of 10 September 1998 (Federal Law Gazette I, p. 2871), last amended by Article 1 of the Act of 17 July 2017 (Federal Law Gazette I, p. 2642).

Photo series in the Yearbook 2021

The photos this year are dedicated to Alpine climatology. We would like to express our particular gratitude to Berchtesgaden National Park and Zugspitze Environmental Research Station for providing us with pictures. Thank you also to all DWD colleagues who supplied us with extensive photo material. Last but not least, we sincerely thank Josef Klenner, President of the German Alpine Club (DAV), for his interview with us.

below
DWD measuring station at Lake Funtensee (valley station at 1,604 m a.s.l.) in the Berchtesgaden National Park in winter. At this self-contained station, measurements of air temperature and air humidity have been taken without interruption since 1998. If possible, maintenance of the station and retrieval of the data records takes place on a quarterly basis. In future, it is planned to retrieve the records of this station by radio (satellite) in co-operation with the DAV.

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Foreword

Dear readers,

None of us will ever forget what happened in July 2021: devastating floods of un-precedented magnitude cost the lives of more than 180 people in the federal states of Rhineland-Palatinate and North Rhine-Westphalia and caused damage totalling double-digit billions of euros.

At times of man-made climate change, it has to be expected that the likelihood of such rainfall events occurring will increase in the future. This is the result of a study carried out shortly after the flood disaster by an international team of scientists led by the Deutscher Wetterdienst. The so-called attribution study examines the relation between individual weather events and climate change.

The study is presented in the ‘Weather and climate 2021’ section of this yearbook, as well as a climatological assessment of the extreme weather event. The yearbook also gives an overview of the temporal evolution of low ‘Bernd’ and a chronology of the warnings issued by the DWD. On the Saturday preceding the flash flood, the DWD had already announced ‘significant precipitation’. The warnings became more precise every day and the warning level was upgraded successively; one day before the disaster, the DWD even triggered the dissemination of the warnings via the federal warning system MoWaS. A detailed description is provided of all the channels through which we published our warnings. Although we are certain of the good excellence and targetedness of the warnings issued for this event, we see potential for improving the forecasts, espe-cially those for severe weather events such as ‘Bernd’, and the efficiency of our warning management even further. In this context, we are co-operating closely with both the federal state governments and disaster management institutions in order to identify needs for improvement and to define and implement any measures to achieve this.

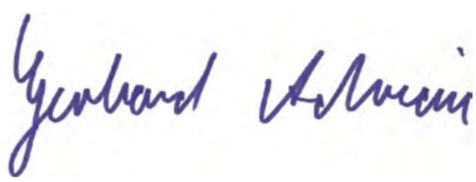
top
Prof. Dr Gerhard Adrian, President of the Deutscher Wetterdienst

The focus topic of this yearbook and the related photo series is Alpine climatology. The DWD has established a know-how centre for Alpine climatology at the Munich Branch Office. From there, we study the climate of the high mountains together with other partners, such as Berchtesgaden National Park. In this sensitive region of the Alps, the impacts of climate change are particularly visible, for example in the form of melting glaciers or an increasing number of rockfalls. I am therefore very happy that Josef Klenner, President of the German Alpine Club (DAV), has given us the opportunity for an interview. In it, he explains, among other things, which measures the DAV is planning to take in order to tackle the challenges of climate change.

Although the coronavirus pandemic continues to impose many restrictions on us, we have achieved a number of milestones. For instance, with the implementation of ICON-D2 and the ensemble system ICON-D2-EPS last year, we completed the model chain of our ICON weather forecasting system. The new DWD soil moisture viewer was introduced and, together with our partners, we launched the DAS core service Climate and Water. Last but not least, the redesigned version of the FeWIS information system for disaster management went online. In disaster situations, especially FeWIS is of great importance for the emergency response teams.

I am inviting you, dear reader, to read about these and many other topics in our yearbook, hoping that you will enjoy the new insights into the world of weather and climate.

Yours sincerely,



Gerhard Adrian

Prelude

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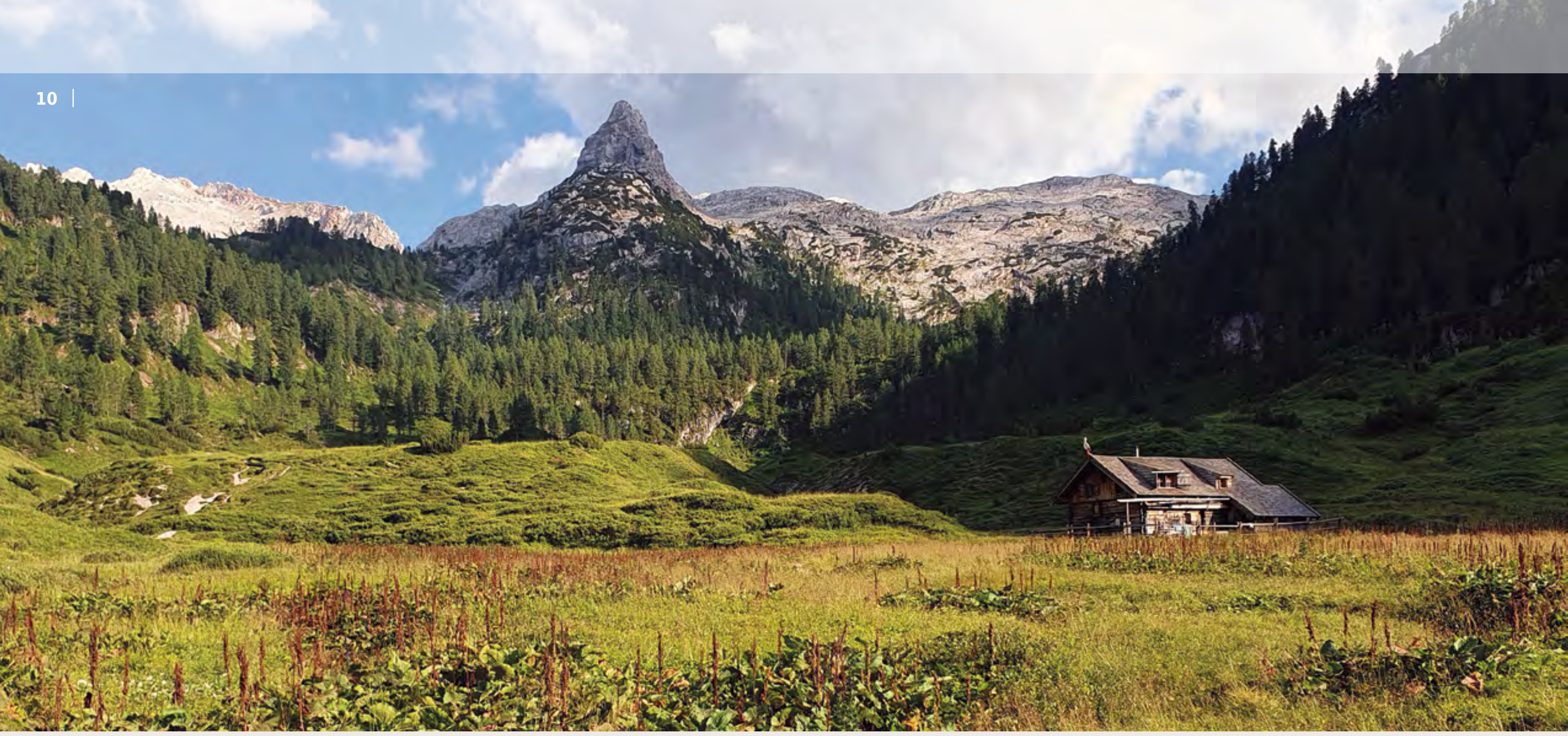
Oliver Nitsche (DWD) preparing the maintenance work at the DWD station at Lake Grünsee in the Berchtesgaden National Park.



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View onto the mountain hut of Funtensee-Enzianbrenn in the Berchtesgaden National Park; the Steinernes Meer can be seen in the background.

The Alps – a unique ecosystem

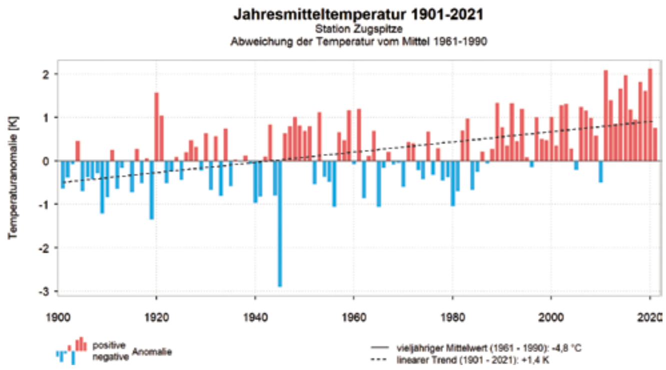
The Deutscher Wetterdienst has established a know-how centre for Alpine climatology as part of the Regional Climate Office at its branch office in Munich. The aim of this centre is to carry out scientific research into Alpine-specific issues, pool meteorological and climatological knowledge regarding the Alpine region at the DWD and thus be able to provide expert advice and consultancy for the Alpine region at the existing multi-year climate scale. Data from various weather and climate observation sites in the area have been available for over 100 years. This treasure trove of data records, many of which still need to be digitised, can be used to understand climate changes in the Alpine and Pre-Alpine regions. The rise in temperatures, in particular, affects all seasons and is higher in the Alpine region than the global mean.

Unique ecosystem

With their central position in Europe, the Alps are one of the most valuable drinking water reservoirs for Europe. Via rivers and streams and throughout the whole year, glaciers and sources not only supply many regions with drinking water but also feed important waterways, such as the Rhine, Danube and Rhône. The Alps are one of Europe's largest coherent natural regions and offer a habitat for numerous plants and animals, some of which, such as gentian and edelweiss, can only be found there. In addition to this, there are around 70 million people of great cultural diversity living and working in the Alpine region.* The Alps are a unique ecosystem – as well as an inhabited environment, an economic region and a destination for recreation – and have as such been under the special protection of the Alpine Convention since 1991. Signatories to this convention are the eight Alpine countries (Austria, Germany, France, Italy, Liechtenstein, Monaco, Slovenia, Switzerland) and the European Union. The convention's objective is the preservation and sustainable development of the Alps.

The Alpine ecosystem is faced with a large variety of problems, for instance, pollutant concentrations in the air increase with traffic; there is a risk of 'overtourism'; and population development statistics show large growth in certain areas whereas other regions in the Alps experience severe depopulation. On top of this is climate change, the effects of which are visible due to obvious changes in the Alpine life. Depending on the altitude, there is less snow, and the ski resorts move higher up or to areas where the ski slopes are operated almost exclusively with artificial snow. Several fauna and flora react by migrating to other regions or changing vegetation patterns. Melting permafrost poses a threat to operating mountain huts and can lead to more frequent mudslides as the rocks become increasingly porous. As a result, many roads, hiking paths and climbing routes are changing or will change in the future.

* Sources see page 83



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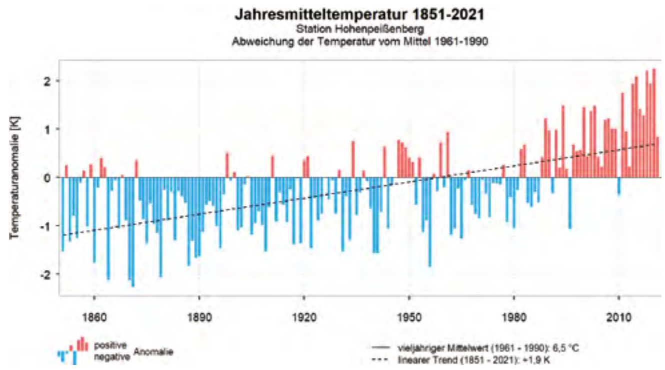

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Mean annual temperatures on the Zugspitze relative to the international standard reference period 1961–1990: since the beginning of systematic weather recordings at Zugspitze station in 1901, the mean annual temperature there has risen by 1.4 degrees.

02
Mean annual temperatures at Hohenpeissenberg Meteorological Observatory relative to the international standard reference period 1961–1990: since 1851, the mean annual temperature at the station has risen by nearly two degrees.

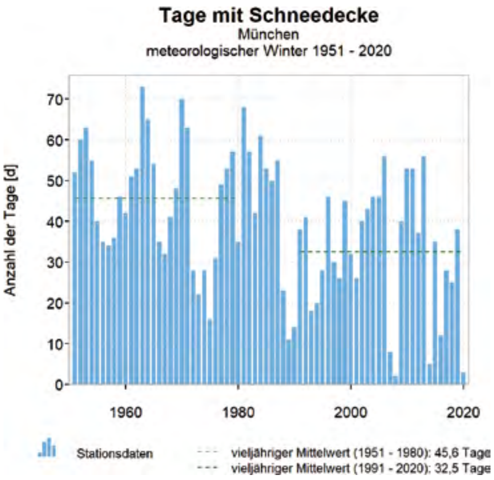
Studying and analysing the climate and climate change, pooling knowledge and obtaining a scientific basis to underpin consultancy and decision-making – this is what the scientific work of the DWD's know-how centre for Alpine climatology is about. To achieve this, the centre collaborates with numerous partners.

Virtual Alpine Observatory

With its ratification during the 1990s, the Alpine Convention was the first international agreement in the world to consider a mountain region as a geographical unit across national borders. The Convention entered into force in 1995. Its goals include the preservation of regional cultural identities, heritage and traditions in the Alps for future generations. The Alpine Convention regularly holds Alpine Conferences and the topics climate change, climate neutrality and climate resilience play a key role.

One element of the Alpine Convention is the Virtual Alpine Observatory (VAO), with the DWD involved as a partner. The VAO satisfies the Article of the Alpine Convention with which the Contracting Parties have committed themselves to close co-operation on research activities and systematic observations. The VAO thrives on the networking and consistent exchange between the partners. For instance, a VAO Symposium is held on a regular basis to share know-how and experience and to intensify networking. By acting as a platform, the VAO brings together already existing structures, for example observatories, data centres, authorities and interdisciplinary scientists. The DWD participates via its Hohenpeissenberg Meteorological Observatory (MOHp) and the know-how centre for Alpine climatology in Munich.

The first initiative for the Alpine Convention mainly came from the International Commission for the Protection of the Alps (CIPRA), a non-governmental umbrella organisation with more than 100 member associations in the Alpine region. CIPRA had demanded an Alpine Convention since its founding in 1952 (the same year that the DWD was founded) and had then also seen through its creation and implementation. Today, CIPRA still participates in the Alpine Convention's committees as an official observer. Preservation and sustainable development of the Alps have thus been on the agenda of various organisations and bodies for 70 years.



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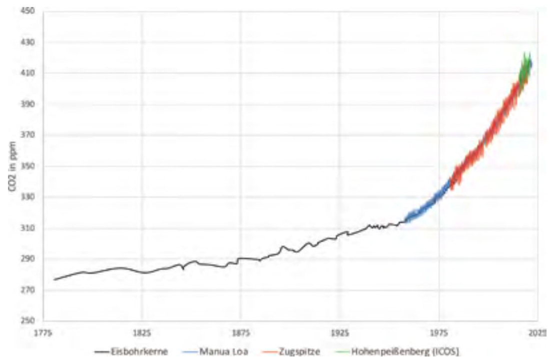

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Changes in the climate of the Alpine Foreland: the average number of days with continuous snow cover in Munich during the meteorological winter (December, January and February) has decreased considerably from 45.6 days in the period 1951–1980 to 32 days in the period 1991–2020.

02
Development of long-lived greenhouse gases such as CO_2: the curve shows a clear upward trend. These gases are distributed very evenly around the world and thus act everywhere as a driving force for climate change.

Berchtesgaden National Park

The DWD has been in close contact and co-operation with Berchtesgaden National Park, Germany's only Alpine national park, since 1984. The park, due to its vertical structure, features a range of different ecosystems. Results from research work in the respective fields can be transferred to other regions with similar conditions and may also be relevant to many other areas of life, such as ecology, forestry, tourism, protection of the environment and nature, water resources management and civil protection. The long-term and continuous recording and archiving of climate data in combination with altitude, exposure, type and structure of stand and soil conditions are therefore of major importance for both research and documentation of climate change.

The Deutscher Wetterdienst, in its role as national meteorological service of the Federal Republic of Germany and in fulfilment of its statutory functions in the field of meteorology and climatology, operates several climate stations within the area of the national park. The administrative authority of the park operates a climate network of its own for long-term observations of the environment pursuant to the Ordinance on the Alpine Park and National Park Berchtesgaden (BayNatBGLV). Both project partners are currently engaged in opening up the existing treasure trove of historic climate data by digitising the manual records and making them available in a database in a homogeneous format.

Berchtesgaden National Park falls within the remit of the Bavarian State Ministry of the Environment and Consumer Protection (StMUV). There exists an intensive partnership between the StMUV and the DWD for collaboration on a wide range of specialist areas and with subordinate authorities of the StMUV. One example to mention is the co-operation with the Bavarian Environment Agency, which incorporates, among other things, the Flood Information Centre and the Avalanche Warning Centre. Co-operation is very close and beneficial in these contexts, especially with regard to weather forecasting and warning of severe weather, since the common task is to warn and protect the population against weather-related damage.

top
DWD station on Mount Glunkerer in the Berchtesgaden National Park at 1,712 m. At this station, which is self-contained, measurements of air temperature and air humidity have been taken since 1998. Maintenance and data retrieval are carried out together with the work at the station Funtensee-Tal.

Long-lived greenhouse gases, such as CO_2, are distributed very evenly around the world and thus act everywhere as a driving force for climate change.

Other meteorological services

In the field of weather and climate in the Alps, the DWD also co-operates with other national meteorological services, for example Austria's Zentralanstalt für Meteorologie und Geodynamik (ZAMG) and the Swiss Federal Office for Meteorology and Climatology MeteoSwiss. Here, in addition to the well-established D-A-CH meetings between Germany, Austria and Switzerland at different levels, a fruitful co-operation on climate issues has developed in recent years, which has already led to the publication of several joint reports. In addition, work is under way on a joint Alpine Climate Bulletin, which is to be published for the first time this year and will complement the national climate reports.

Environmental research station on the Zugspitze

The Global Atmosphere Watch (GAW) programme of the World Meteorological Organization (WMO) consists of a co-ordinated global network of measurement stations for observing chemical and physical changes in the atmosphere. Together with the German Federal Environment Agency (UBA), the DWD, represented by its Hohenpeissenberg Meteorological Observatory (MOHp), operates one of 31 GAW Global stations around the world. The German station comprises two measuring platforms, one at Hohenpeissenberg and the other one on the Zugspitze. The Zugspitze measurement station provides ideal conditions for broadly-based, long-term observation and research of the lower free troposphere with a particular focus on atmospheric greenhouse gases, chemically reactive gases and aerosols, as well as on the global long-range transport of environmental pollutants.

Increasing attention is also being paid to short-lived climate drivers, such as ozone, aerosol, water vapour and clouds. They are further examined in studies carried out by the European Research infrastructure ACTRIS (Aerosol, Clouds and Trace gases Research InfraStructure) on the Zugspitze, at Hohenpeissenberg and in station networks spanning the Alps at different altitudes. The main interest is in understanding the processes and feed-back mechanisms that are behind the adaptation of regional systems, such as ecology and hydrology, to climate change and what impact changes in evaporation, emission and albedo have on the climate.

The photos this year are dedicated to Alpine climatology. We would like to express our particular gratitude to Berchtesgaden National Park and Zugspitze Environmental Research Station for providing us with pictures. Thank you also to all DWD colleagues who supplied us with extensive photo material. Last but not least, we sincerely thank Josef Klenner, President of the German Alpine Club (DAV), for his interview with us.

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Weather and climate in 2021

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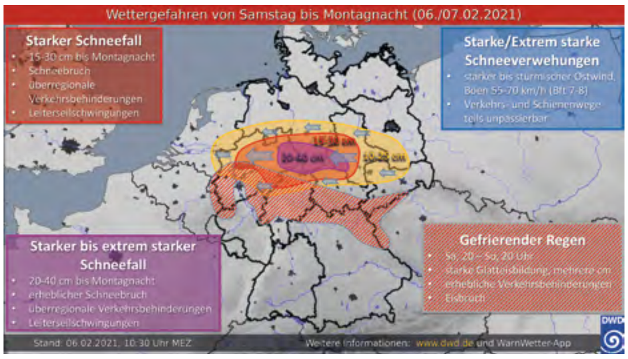
Solar panel of the automatic climate station in the karst plateau Steinernes Meer, Berchtesgaden National Park



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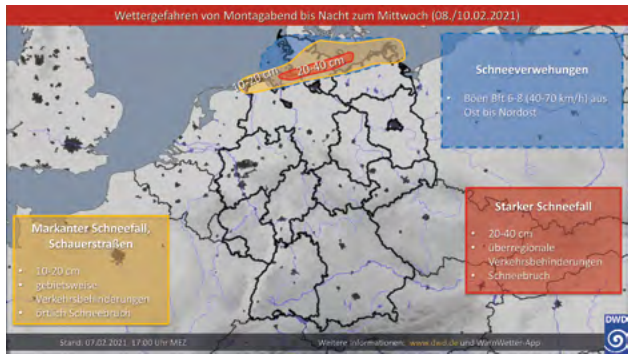

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Weather hazard map for the period 6–7 February 2021

02
Warnings of moderate and severe frost for the period 9–10 February 2021

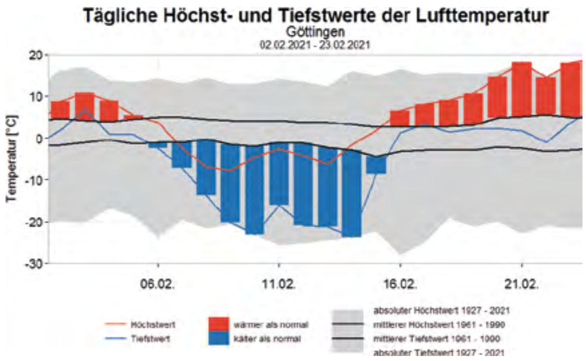
February 2021: A month of extremes

During the first half of February, Germany was under the influence of cold polar air masses, which produced a spell of intense cold weather and brought copious amounts of snow, particularly in the middle of the country. In the second half of the month, the cold air masses were pushed back by arriving subtropical air. Among other things, this led to a period of six successive days with temperatures of 20 °C or higher during the last week of February. The month not only saw many new station records for both daily minimum and daily maximum temperatures, it also registered the highest-ever temperature difference within a week since meteorological records began.

Weather development leading up to a record temperature difference

A sharp air mass boundary formed over Germany from the end of January, with mild to spring-like warm temperatures in the southern part of the country and, at first, moderately cold air in the north. This difference in temperatures increased over the following two weeks as the air mass boundary moved southwards and cold continental air of polar origin was pushed underneath the warm air moving in from the south. From 6 February, the temperatures remained below freezing north of a line stretching from the mouth of the river Ems via the Weser Uplands and Harz mountains to the Oberlausitz region, whereas southern Germany still saw daily maxima of up to 14 °C. As the air mass boundary continued its move, severe continuous frost developed during the following days notably in some places in central Germany with daily maximum temperatures of less than –10 °C between the 9^{th} and the 14^{th}. At the same time, temperatures above zero continued to prevail in the extreme south-west, the Lake Constance region and the Alpine Foreland.

From the 9^{th}, daily minima of ≤ 20 °C occurred more and more frequently in central parts of Germany in a band covering eastern North Rhine-Westphalia, southern Lower Saxony, northern Hesse, Thuringia, Saxony and the southern parts of Brandenburg and Saxony-Anhalt. From the 11^{th}, this band extended to include parts of Bavaria and Baden-Württemberg. During this period, many observing stations of the Deutscher Wetterdienst in these areas registered new monthly records for minimum temperatures.



03

03
Daily maximum and minimum air temperatures at Göttingen station from 2 to 23 February 2021

In recent years, there have been other cold polar air events of similar extent, for instance in central Germany during the first half of February 2012 and over southern Germany in January 2017. During the latest cold air event this year, the minimum temperatures remained below –20 °C on seven consecutive days (9–15 February) at many stations (> 500 m a.s.l.) in an area covering Thuringia, northern Hesse, the southern part of Lower Saxony and western parts of North Rhine-Westphalia. In the winters of 1956, 1963 and 1942, the temperatures remained below this threshold on 20 (8–27 February 1956) and 17 (9–25 January 1963 and 12–28 January 1942) consecutive days, respectively.

As the air mass boundary continued to move southwards, the warm, humid subtropical air rose above the cold air mass. This caused intense snowfalls over central Germany from 7 February, and from the 11th also over southern Germany. In an area from south-eastern Saxony-Anhalt and eastern Thuringia to northern Hesse, many lowland stations (< 350 m a.s.l.) with long-term observation series measured new records for total snow depth, both for February and, in some cases, even for the whole year, with return periods of more than 50 years. At altitudes above 350 m a.s.l., no new records were set.

Towards the middle of the month, a warm front cleared away the cold air almost completely from Germany. The frontal passage was associated with snow showers and later also with rain, which led to icy roads and freezing grounds. A south-westerly flow set in, bringing very warm subtropical air to Germany, which was warmed even further on account of the usual seasonal increase in solar radiation. Within a matter of a few days, the temperatures went up considerably, with differences of more than 40 degrees between minimum temperatures during the very cold spell and maximum temperatures during the very warm phase.

In February 2021, a new record was set at Göttingen station with the highest temperature difference ever measured at a station within one week. Within seven days, the temperature there rose from –23.8 °C (minimum temperature on 14.2.2021) to 18.1 °C (maximum temperature on 21.2.2021), which equates to a difference of 41.9 degrees. During the same period, seven other DWD stations registered temperature differences of 40 °degrees or more within one week.

Previous to this, the highest temperature difference within a week was registered at Jena (station Sternwarte) in the week from 20 to 25 May 1880, with a minimum temperature of –5.1 °C on the 20th and a maximum temperature of 36 °C on the 27th. This equates to a temperature difference of 41.1°degrees. The largest temperature increase of 39 °C within a week in winter was recorded in Titisee-Neustadt, where, on 25.01.2000, a minimum temperature of –27.3 °C was measured compared to a maximum temperature of 12.3 °C seven days later on 1 February. Such a change in the weather is very extreme and very rare.

top left and right
The Saharan dust shows particularly well against the white snow.

The south-westerly flow continued during the month and the temperatures at several stations soon exceeded the threshold of 20° C. In the period from 20 to 25 February, a maximum temperature of ≥ 20 °C was measured in Germany on six consecutive days. This has never occurred before in a winter month (December, January and February). Before, this temperature threshold had only been exceeded on a maximum of three consecutive days (observed on 26–28.2.2019, 23–25.2.1990, 15–17.12.1989 and 13–15.2.1958).

When, on 22 February, a subtropical airmass carried massive amounts of Saharan dust into the air over Germany, this affected the maximum temperatures in the low mountain ranges in central Germany due to reduced solar radiation and growing cloud cover.

The warm air also reached the federal states in the east, bringing temperatures of above 20 °C for the first time ever in a February to Brandenburg on the 25th. The thermometers in Cottbus and Klettwitz climbed to 20.6 °C and 20.1 °C, respectively. This particular weather situation ended with the passage of a cold front on 26.2.2021.

Climatological assessment

All in all, despite the intense cold period during the first half of the month, February 2021 was warmer than the long-term average for February over both the reference period 1961–1990 (+1.3 degrees) and the new climate normal period 1991–2020 (+0.2 degrees). In the 140 years of measurements by the DWD, cold periods such as this one have occurred time and again, for example in 1929, 1956 and 1986, but there is currently no reliable evidence that such events happen more or less often due to global warming, However, it is to be expected that, just like intense heatwaves in the summer months, warm winter periods such as the one experienced at the end of February 2021 will become more frequent in the future.

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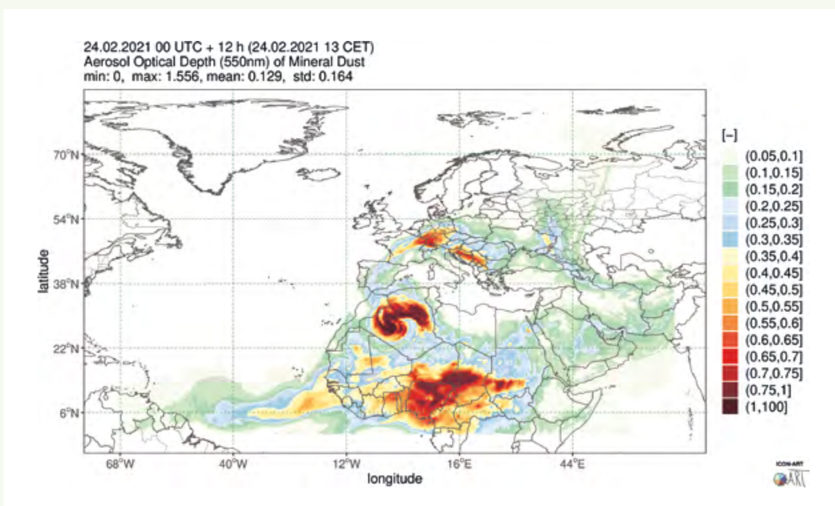
Spread of the Saharan dust cloud expected for 24 February 2021



Low-pressure system ‘Bernd’: Climate change made the devastating heavy rainfalls that flooded western Europe more likely

In mid-July 2021, low-pressure system ‘Bernd’ brought regionally extremely pronounced heavy rainfalls in Germany and in neighbouring countries. These rainfalls led to catastrophic flooding particularly in Rhineland-Palatinate and North Rhine-Westphalia, causing the death of more than 180 people and an unprecedented amount of damage.

Meteorological situation and further development

In the days from 12 to 15 July 2021, the meteorological situation over central Europe was predominantly characterised by low air pressure. In conjunction with a slow-moving upper-level low approaching from France, the stratification of the troposphere became increasingly unstable. Warm and very humid air arrived from the Mediterranean and moved in a rotary motion around the surface low ‘Bernd’ into Germany. Recurring or persistent heavy rain fell in the western low mountain ranges Sauerland, Bergisches Land and Eifel, at first over smaller, but later also over large areas. In the days that followed, high-pressure area ‘Dana’ pushed low ‘Bernd’ towards south-eastern Europe. This led to further, in parts persistent heavy rainfall in the eastern Ore Mountains and the Lausitz region as well as in the Berchtesgadener Land.

The first areas to be affected from the 12th were Baden-Württemberg (up to more than 50 l/m² in 24 hours) as well as parts of Hesse, Rhineland-Palatinate, Saarland and North Rhine-Westphalia (up to more than 20 l/m² in 24 hours). As the situation progressed, the core of low ‘Bernd’ slowly continued its path from south-western Europe to Germany.

On 13 July, the precipitation activities were centred over central Germany (Figure 1). According to radar measurements, the Marienberg region in the Ore Mountains, for example, received amounts of up to 87 l/m² within 2 hours, Selbitz in the Hof region (Upper Franconia) 43 l/m² within only 30 minutes, and Mühle-Lodersleben station in Querfurt (Saale district) 66 l/m² within no more than 2 hours. The northern parts of Hesse (Waldeck-Frankenberg district) as well as the Ruhr basin and the southern parts of Westphalia were also severely affected. The cities of Solingen and Hagen as well as Wuppertal suffered severe flooding. One of the stations of the North Rhine-Westphalian State Agency for Nature, Environment and Consumer Protection (LANUV) in Hagen registered amounts of over 241 l/m² within no more than 22 hours.

Figure 1
Precipitation analysis based on RADOLAN for the duration levels 24 h and 72 h until 15.7., 5:50 UTC (7:50 CEST).

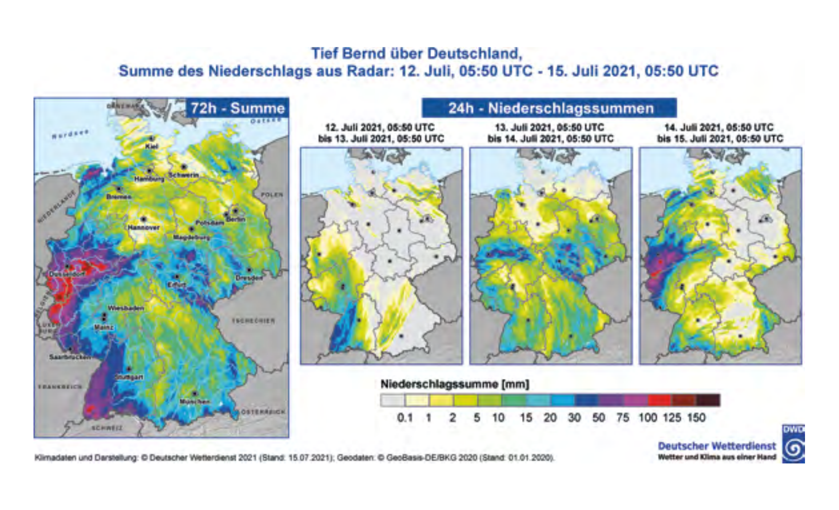


Figure 1

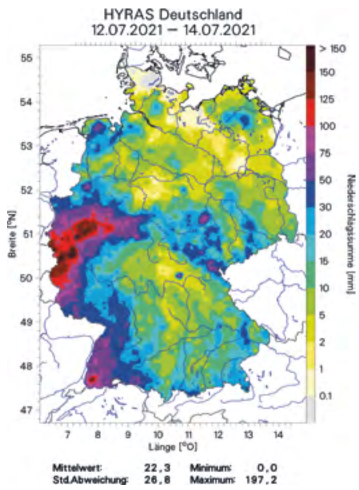


Figure 2a

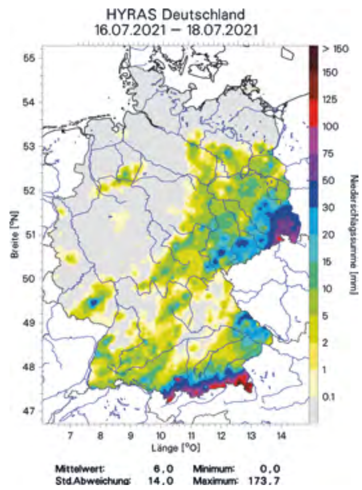


Figure 2b

Figures 2a and 2b
Precipitation analysis based on hydrometeorological grid data (HYRAS) for the duration level 72 h until 15.7., 8:00 CEST (left) and 19.7., 8:00 CEST (right)

Heavy persistent rain then fell from 14.7. until the morning hours of 15.7. and was intensified locally by recurring rain showers. The precipitation activity was centred over an area stretching from Dortmund via Cologne, Euskirchen, Gerolstein and Bitburg as far as Trier (Figures 2a and 2b). Amounts of more than 100 l/m² within 24 hours were measured over widespread parts of the area, with some areas receiving even more than 150 l/m² within 24 hours.

This large-scale and persistent heavy rain event affected the catchment areas of numerous rivers, including Ahr, Erft, Kyll, Prüm, Eifel-Rur, Sieg and Swist. The water gathered and was channelled in some places in narrow river valleys. The enormous amounts of rain, even more so because of the orographic conditions and fully saturated grounds, led to an exponential increase in damage. Particularly affected by this situation was the Ahr Valley, where a high number of casualties and enormous damage to property occurred within a short time. The district of Ahrweiler alone reported the death of at least 110 people. Many houses in Bad Neuenahr-Ahrweiler, Sinzig and Schuld were completely destroyed and there was devastating damage to infrastructure. All rail bridges in the Ahr Valley were destroyed, roads and rail tracks washed away. The electricity and water supplies collapsed, as well as the communication lines. Several localities in the district of Euskirchen had to be evacuated as the dam of the Steinbachtal reservoir was at risk of breaking.

Cities and localities along the rivers Erft, Swist und Eifel-Rur were also affected heavily. After the copious and persistent heavy rainfalls, the cities of Cologne, Leverkusen and Düsseldorf as well as the areas along the Westphalian Ruhr also saw personal injury and numerous roads and cellars were flooded. Several river-near residential areas had to be evacuated.

As low 'Bernd' moved away towards south-eastern Europe, the eastern parts of Saxony and southern Bavaria were once more affected by persistent or recurring heavy rainfall from 15 to 19 July (Figure 2b). Again, the orography worsened the effects of the rainfall even more due to blockages. In Saxony, this led to torrential flooding in some upper stretches of rivers and narrow valleys; the rivers Sebnitz, Polenz, Wesnitz and Lusatian Neiße temporarily had very high water levels. In southern Bavaria, in particular in the Berchtesgadener Land region, heavy rain episodes of short duration (duration level D = 1 to 3 hours) caused the water levels in mountain streams to rise rapidly, which resulted in minor flash floods and mudslides that brought serious damage in places.

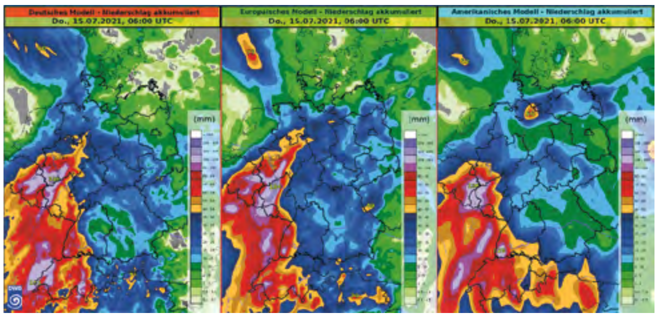


Figure 3

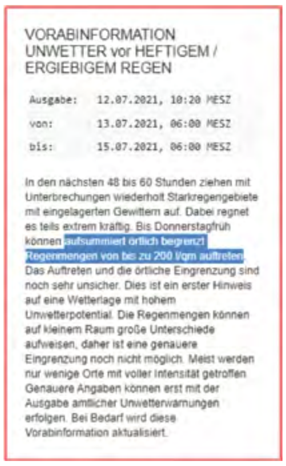
Figure 3
Illustration of the concordance of the precipitation totals forecast by the different numerical models on 12.7., 2 a.m., for the period 12–15 July (left) compared with the radar-measured 72 h precipitation total, last update: 15.7., 7.50 a.m. (right, slightly shifted map section).

Chronology of the weather forecasts and warnings, in particular for the federal states of Rhineland-Palatinate and North Rhine-Westphalia

The warning management system of the Deutscher Wetterdienst consists of several warning levels, starting with the publication of early warning notices. These are followed by more specific advance weather watches and the actual warnings issued closer to the expected event. The weather situation is monitored around the clock and the warning status updated continuously according to the demands of the situation.

The first indications of extreme rainfall were already visible in the numerical weather predictions on Sunday (11.7.). On Monday, the different prediction models showed an unusually strong agreement in terms of the predicted precipitation, so that the area that would be affected could be determined already at that stage with quite high probability. Subsequent model runs increased the certainty of this, with the result that warnings of extremely severe weather were published very early (Figure 3).

The routine ‘Weekly weather hazard forecast’ of Saturday, 10 July 2021, had already announced ‘significant precipitation’ for the region in question. The forecast became more precise on the morning of Sunday, 11 July, 11 a.m.: ‘On Wednesday, increased risk of severe weather over a band stretching from Saarland and Eifel to North Rhine-Westphalia due to heavy persistent rain with rainfall totals in places significantly above 100 l/m² within 24 hours.’ This early warning notice was extended on Monday, 12 July, 10:20 a.m., and a so-called ‘Severe weather watch’ was issued. In the evening, the latter was complemented by the first concrete ‘Warning of severe weather’, which was upgraded on Tuesday, 13.7., 9:40 a.m., to a ‘Warning of extremely severe weather’. The first ‘Official information about a dangerous situation’, which the DWD disseminated via the modular warning system MoWaS of the Federal Office of Civil Protection and Disaster Assistance (BBK), was issued on the same day at 11:36 a.m. and updated on the next day, 14.7., at 9:08 a.m. Earlier on, at 7:40 a.m., the DWD had disseminated the upgraded warning of extremely severe weather via its own warning system (Figure 4).


VORABINFORMATION
UNWETTER vor HEFTIGEM /
ERGIEBIGEM REGEN

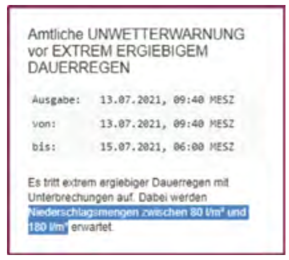
Ausgabe: 12.07.2021, 10:20 MESZ
von: 13.07.2021, 06:00 MESZ
bis: 15.07.2021, 06:00 MESZ

In den nächsten 48 bis 60 Stunden ziehen mit Unterbrechungen wiederholt Starkregengebiete mit eingelagerten Gewittern auf. Dabei regnet es teils extrem kräftig. Bis Donnerstagfrüh können aufsummiert örtlich begrenzt Regenmengen von bis zu 200 l/qm auftreten. Das Auftreten und die örtliche Eingrenzung sind noch sehr unsicher. Dies ist ein erster Hinweis auf eine Wetterlage mit hohem Unwetterpotential. Die Regenmengen können auf kleinem Raum große Unterschiede aufweisen, daher ist eine genauere Eingrenzung noch nicht möglich. Meist werden nur wenige Orte mit voller Intensität getroffen. Genauere Angaben können erst mit der Ausgabe amtlicher Unwetterwarnungen erfolgen. Bei Bedarf wird diese Vorabinformation aktualisiert.


Amtliche UNWETTERWARNUNG
vor ERGIEBIGEM DAUERREGEN

Ausgabe: 12.07.2021, 17:55 MESZ
von: 13.07.2021, 06:00 MESZ
bis: 15.07.2021, 06:00 MESZ

Es tritt ergiebiger Dauerregen mit Unterbrechungen auf. Dabei werden Niederschlagsmengen zwischen 60 l/m² und 90 l/m² erwartet. Im Warnzeitraum ziehen mehrere, teils gewittrige Starkregengebiete hinweg, die Regenmengen zwischen 30 und 60 l/qm innerhalb weniger Stunden oder bis 30 l/qm in kurzer Zeit bringen können. Akkumuliert sind bis Donnerstagfrüh strichweise deutlich höhere Regenmengen zwischen 100 und 150 l/qm möglich. Daher ist gebietsweise mit einer Hochstufung der Warnung zu rechnen.


Amtliche UNWETTERWARNUNG
vor EXTREM ERGIEBIGEM
DAUERREGEN

Ausgabe: 13.07.2021, 09:40 MESZ
von: 13.07.2021, 09:40 MESZ
bis: 15.07.2021, 06:00 MESZ

Es tritt extrem ergiebiger Dauerregen mit Unterbrechungen auf. Dabei werden Niederschlagsmengen zwischen 80 l/m² und 180 l/m² erwartet.

11 July, 11 a.m.
Weekly weather hazard forecast

12 July, 10.20 a.m.
Severe weather watch

12 July, 5:55 p.m.
Severe weather warning

13 July, 09:40 a.m.
Warning of extremely severe weather

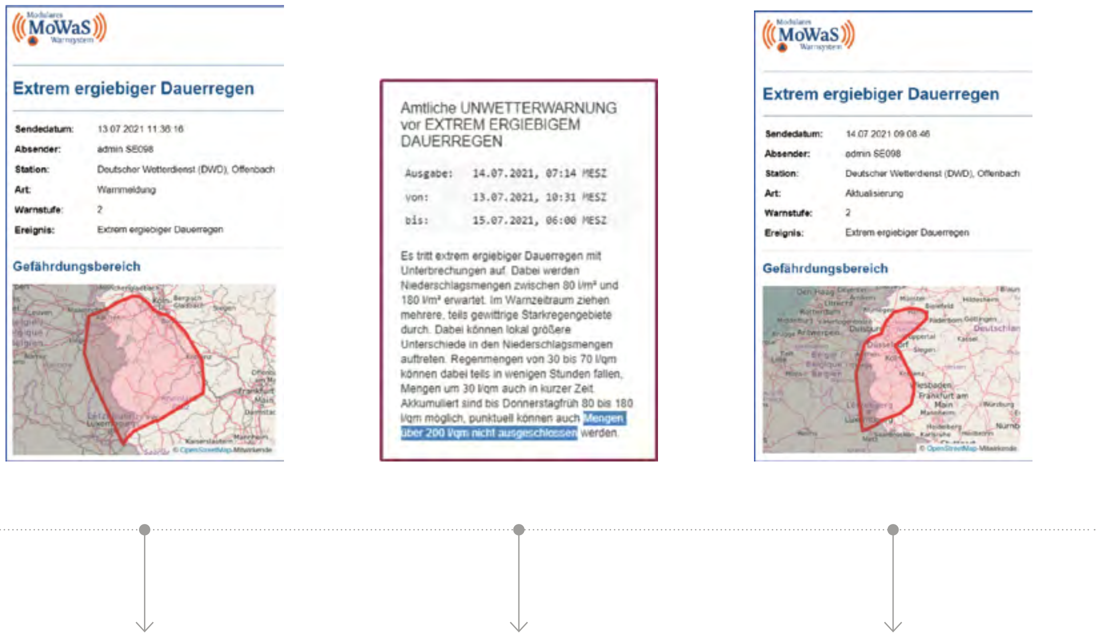
Figure 4

How were the warnings and information distributed?

The following enumeration gives an overview of the data and products and the distribution channels used by the key actors, shedding light on some particular details regarding this event.

Distribution channels and data portals

- The DWD distributes warning information directly through a multitude of channels and distribution lists for e-mail, mobile text messaging and fax. According to respective administrative agreements, these channels are also used to transmit information directly to the responsible disaster management bodies, such as the situation centre of the North Rhine-Westphalian Ministry of the Interior (MIK), the control centres of the federal states and the regional governments. In the federal state of Rhineland-Palatinate, the information is transmitted to the responsible divisions, offices, etc. at the district administrations (19) and municipal authorities (9) and to all integrated control centres and professional fire brigades.
- Data portals, such as the Open Data platform of the DWD, offer data for free access and download by the public. A selected range of data sets, such as radar precipitation data or the latest warnings, are also available as web services for direct integration into websites or situation assessment systems. One example is the Web Map Service through which, from 12 to 15 July, around 28 million image tiles were issued for the precipitation radar.



13 July, 11:36 a.m.
MoWaS warning

14 July, 07:40 a.m.
Upgraded warning of extremely severe weather

14 July, 09:08 a.m.
Updated MoWaS warning

Figure 4
Timeline of selected warning messages issued by the DWD in advance and during the further course of the event.

Figure 5
Warning situation on 14.7. as shown in the DWD WarnWetter app. The concordance between the warning areas, precipitation radar and reports from users is well visible.

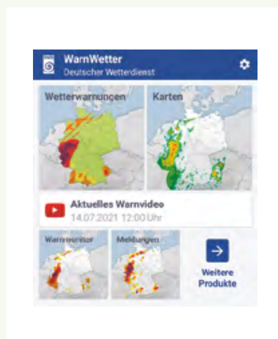


Figure 5

- Observation and numerical prediction data of the DWD are supplied routinely by SFTP retrieval to the responsible agencies of the federal states, water authorities, the European Flood Awareness System (EFAS) and other meteorological service providers to be used as input data for application processes.
- In the period from 12 to 15 July 2021, the DWD WarnWetter app sent out a total of approximately 53 million push messages to its around 8 million subscribers of warning services. DWD WarnWetter also includes a specific natural hazard component (distribution of flood warnings, water level and storm surge information as well as avalanche forecasts) with around 150,000 users subscribed to the push services for flood warnings. During the said period, around 0,5 million push warnings were sent out to this group of users (Figure 5).

Modulares MoWaS Warnsystem

Extrem ergiebiger Dauerregen

Sendedatum:	13.07.2021 11:36:16
Absender:	admin SE098
Station:	Deutscher Wetterdienst (DWD), Offenbach
Art:	Warnmeldung
Warnstufe:	2
Ereignis:	Extrem ergiebiger Dauerregen

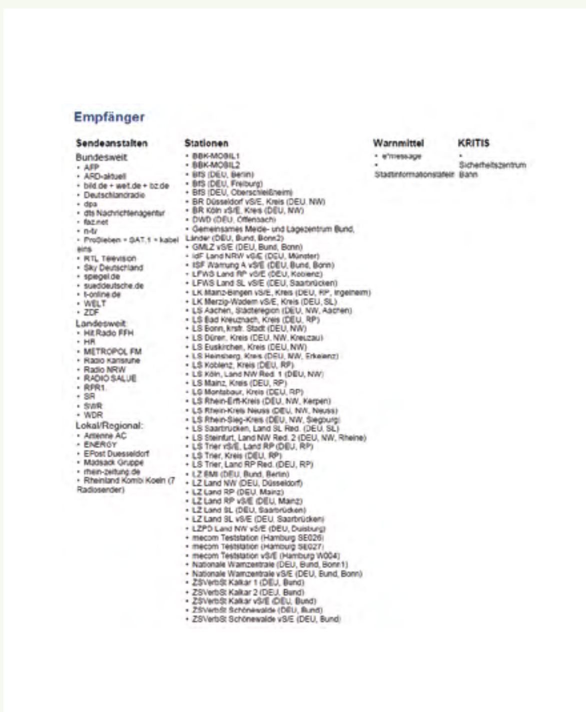
Gefährdungsbereich

Figure 6a

Figures 6a und 6b
Emergency message issued by the DWD for distribution via MoWas and the list of recipients.

- In monitored processes, key warning multipliers such as highly used apps (NINA, KATWARN) receive the DWD's latest warnings to the second via SFTP in the CAP format (Common Alert Protocol). The app operators then redistribute these warnings seamlessly and without any delay to the users connected. Some of the recipients apply filters so that only warnings exceeding the severe weather threshold (DWD warning level 3) are displayed in their media.

- The DWD is linked to MoWaS, the modular warning system of the Federal Office of Civil Protection and Disaster Assistance (BBK), via a full MoWaS communication station. In the event of potentially very dangerous, extremely severe weather, a separate message is co-ordinated centrally and sent out in addition to the DWD's usual warnings. The official emergency messages and announcements are directed to all crisis management units, situation centres and media in the affected area. The legal basis for this procedure is established by the right of the Federal Government and the governments of the federal states to make official public announcements. In the situation prevailing in July 2021, MoWaS began to be used on 13.7. at 11:36 a.m. as an additional channel for distributing an 'official emergency message', which was directed to all affiliated operations control centres in the affected area, regional public media broadcast companies (such as SWR and WDR) and national media agencies (such as AFP and dpa), etc. If a warning is sent out as an 'official emergency message', all recipients are obliged to broadcast the message within ten minutes of receipt and without any change to the content (Figures 6a and 6b).



Empfänger

Sendeanstalten

Bundesweit
- AFP
- ARD-aktuell
- bild.de + welt.de + bz.de
- Deutschlandradio
- dpa
- dts Nachrichtenagentur
- faz.net
- n-tv
- ProSieben + SAT.1 + kabel eins
- RTL Television
- Sky Deutschland
- spiegel.de
- sueddeutsche.de
- t-online.de
- WELT
- ZDF

Landesweit
- Hit Radio FFH
- HR
- METROPOL FM
- Radio Karlsruhe
- Radio NRW
- RADIO SALUE
- RPR1
- SR
- SWR
- WDR

Lokal/Regional:
- Antenne AC
- ENERGY
- EPost Duesseldorf
- Madsack Gruppe
- rhein-zeitung.de
- Rheinland Kombi Koeln (7 Radiosender)

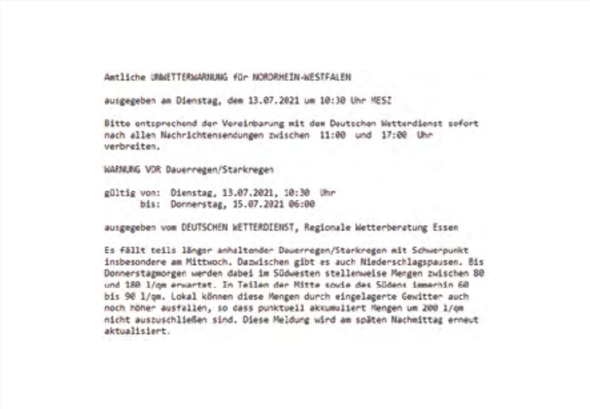
Stationen
- BBK-MOBIL1
- BBK-MOBIL2
- BfS (DEU, Berlin)
- BfS (DEU, Freiburg)
- BfS (DEU, Oberschleißheim)
- BR Düsseldorf vS/E, Kreis (DEU, NW)
- BR Köln vS/E, Kreis (DEU, NW)
- DWD (DEU, Offenbach)
- Gemeinsames Melde- und Lagezentrum Bund, Länder (DEU, Bund, Bonn2)
- GMLZ vS/E (DEU, Bund, Bonn)
- IdF Land NRW vS/E (DEU, Münster)
- ISF Warnung A vS/E (DEU, Bund, Bonn)
- LFWS Land RP vS/E (DEU, Koblenz)
- LFWS Land SL vS/E (DEU, Saarbrücken)
- LK Mainz-Bingen vS/E, Kreis (DEU, RP, Ingelheim)
- LK Merzig-Wadern vS/E, Kreis (DEU, SL)
- LS Aachen, Städteregion (DEU, NW, Aachen)
- LS Bad Kreuznach, Kreis (DEU, RP)
- LS Bonn, krsfr. Stadt (DEU, NW)
- LS Düren, Kreis (DEU, NW, Kreuzau)
- LS Euskirchen, Kreis (DEU, NW)
- LS Heinsberg, Kreis (DEU, NW, Erkelenz)
- LS Koblenz, Kreis (DEU, RP)
- LS Köln, Land NW Red. 1 (DEU, NW)
- LS Mainz, Kreis (DEU, RP)
- LS Montabaur, Kreis (DEU, RP)
- LS Rhein-Erft-Kreis (DEU, NW, Kerpen)
- LS Rhein-Kreis Neuss (DEU, NW, Neuss)
- LS Rhein-Sieg-Kreis (DEU, NW, Siegburg)
- LS Saarbrücken, Land SL Red. (DEU, SL)
- LS Steinfurt, Land NW Red. 2 (DEU, NW, Rheine)
- LS Trier vS/E, Land RP (DEU, RP)
- LS Trier, Kreis (DEU, RP)
- LS Trier, Land RP Red. (DEU, RP)
- LZ BMI (DEU, Bund, Berlin)
- LZ Land NW (DEU, Düsseldorf)
- LZ Land RP (DEU, Mainz)
- LZ Land RP vS/E (DEU, Mainz)
- LZ Land SL (DEU, Saarbrücken)
- LZ Land SL vS/E (DEU, Saarbrücken)
- LZPD Land NW vS/E (DEU, Duisburg)
- mecom Teststation (Hamburg SE026)
- mecom Teststation (Hamburg SE027)
- mecom Teststation vS/E (Hamburg W004)
- Nationale Warnzentrale (DEU, Bund, Bonn1)
- Nationale Warnzentrale vS/E (DEU, Bund, Bonn)
- ZSVerbSt Kalkar 1 (DEU, Bund)
- ZSVerbSt Kalkar 2 (DEU, Bund)
- ZSVerbSt Kalkar vS/E (DEU, Bund)
- ZSVerbSt Schönewalde (DEU, Bund)
- ZSVerbSt Schönewalde vS/E (DEU, Bund)

Warnmittel
- e*message
- Stadtinformationstafeln

KRITIS
- Sicherheitszentrum Bahn

Figure 6b

Figure 7
Example of a media report issued by Essen Regional Weather Advisory Office (in this case here on 13.7., 10 a.m.).



Amtliche UNWETTERWARNUNG für NORDRHEIN-WESTFALEN

ausgegeben am Dienstag, dem 13.07.2021 um 10:30 Uhr MESZ

Bitte entsprechend der Vereinbarung mit dem Deutschen Wetterdienst sofort nach allen Nachrichtensendungen zwischen 11:00 und 17:00 Uhr verbreiten.

WARNUNG VOR Dauerregen/Starkregen

gültig von: Dienstag, 13.07.2021, 10:30 Uhr
bis: Donnerstag, 15.07.2021 06:00

ausgegeben vom DEUTSCHEN WETTERDIENST, Regionale Wetterberatung Essen

Es fällt teils länger anhaltender Dauerregen/Starkregen mit Schwerpunkt insbesondere am Mittwoch. Dazwischen gibt es auch Niederschlagspausen. Bis Donnerstagmorgen werden dabei im Südwesten stellenweise Mengen zwischen 80 und 180 l/qm erwartet. In Teilen der Mitte sowie des Südens immerhin 60 bis 90 l/qm. Lokal können diese Mengen durch eingelagerte Gewitter auch noch höher ausfallen, so dass punktuell akkumuliert Mengen um 200 l/qm nicht auszuschließen sind. Diese Meldung wird am späten Nachmittag erneut aktualisiert.

Figure 7

- For additional information, special reports are compiled to provide a detailed assessment of the expected situation using several different prediction models. Accordingly, the flood forecasting centres in North Rhine-Westphalia, Rhineland-Palatinate, Saarland and Hesse as well as all water authorities in North Rhine-Westphalia not only received the supraregional reports from the Weather Forecasting and Advisory Centre (VBZ) at the DWD headquarters in Offenbach. They were also provided by the DWD's branch office in Essen with daily updated reports, which, from Monday, 12 July, contained clear indications for extremely copious heavy rain, 'in places with totals of up to 200 l in 48 h'.
- The branch offices of the DWD in particular provide close support to the various actors at the coalface of disaster management, who can contact the DWD any time through a 24/7 disaster hotline. In the period from 12 to 15 July, the DWD's branch office in Essen, which is responsible for both federal states North Rhine-Westphalia and Rhineland-Palatinate, answered more than 150 individual consultation calls from fire brigades, situation centres, operations control centres, media and water authorities to help them assess the situation. In some federal states, the DWD has concluded targeted agreements with the media (North Rhine-Westphalia) or there exist special regulations (Bavaria) stipulating the immediate dissemination of emergency messages on the broadcasting channels. The necessary specialised products are made available by the DWD branch offices on a routine basis. On 13.7., 6:00 a.m., for example, the Essen branch office provided the WDR broadcasting centre with a report for the media about the situation. This initial report was read out after the main news programmes between 6:30 and 12:30 a.m.; after that the DWD continuously supplied an update every 4 to 6 hours (Figure 7).

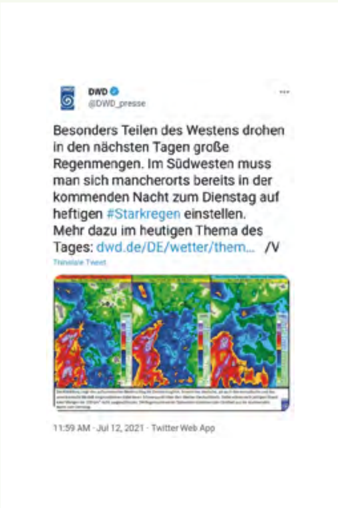


Figure 8a

Figure 8b

Figures 8a, 8b und 8c
Coverage of forecasts and warnings distributed via the DWD's Internet and social media channels: Twitter message of 12 July announcing extreme amounts of rain (Figure 8a), warning situation on 13 July as shown by the interactive warning map on the DWD website (Figure 8b) and severe weather clip posted on YouTube on 12 July (Figure 8c).

- In addition, the Weather Forecasting and Advisory Centre of the DWD collaborates closely with the Joint Information and Situation Centre of the German Federation and the federal states (GMLZ). If necessary, daily conference calls are organised to discuss the situation and provide individual advice. In the situation prevailing in July 2021, the first event-related communication took place on 11.7.. The first extensive consultation regarding the expected developments was held on 12.7.. During the discussions, it was mentioned explicitly that amounts of more than 100 l/m² within 24 hours were expected.
- All warnings were published simultaneously on the DWD website. During the week from 12 to 18 July 2021, the DWD counted 64 million accesses to the warnings published at www.dwd.de.
- The DWD Press Office, together with the media meteorologists of the DWD Weather Forecasting and Advisory Centre, was in direct contact with the national media and supplied these as well as the social media channels of the DWD with information. In the event of imminent severe weather, the DWD additionally publishes so-called 'severe weather clips' to inform the population about the risks. The clips are made available on YouTube and are disseminated through the WarnWetter app. All the different formats were also used in July to inform extensively about the upcoming severe weather situation (Figures 8a, b, c).

Figure 8c

Figure 9a

Figure 9b

Figures 9a und 9b
Examples of the situation overview in the FeWIS disaster management portal as in the event of an extremely severe warning situation (left) and of the product portfolio available in the WaWIS water management and weather information system (right).

Specialised portals

- With the FeWIS weather information system for fire brigades, the DWD offers a central and extensive online information portal for disaster management. Across Germany, there are over 2,500 access points for actors in disaster management, in particular staff at the operations control centres, fire brigades, technical relief units (THW) and situation centres. The system presents a general situation overview (warning situation, precipitation radar, reports from users) as well as the latest details about the weather situation, such as actual values measured at stations and precipitation totals. As part of its natural hazard approach, FeWIS also incorporates complementary information, such as flood and water level data. During the period from 12 to 15 July, FeWIS recorded as many as 55 million page views.
- By operating the WaWIS water management and weather information system, the DWD additionally provides registered users in the field of flood forecasting and disaster management with specialised meteorological information. The focus is on visualising a wide range of meteorological observation data and forecast products, in particular for precipitation. This includes, among other things:
  - static image files of hourly weather observations
  - hourly precipitation data of the last 72 hours
  - 5-minutely analysis of precipitation data obtained by area-covering radar measurements
  - quantitative analyses of radar data
  - 5-minutely radar-based precipitation forecasts for the next two hours
  - precipitation forecasts from various prediction models (both deterministic or probabilistic numerical predictions based on up to 40 different ensemble members in the DWD model chain [Figures 9a, b]).

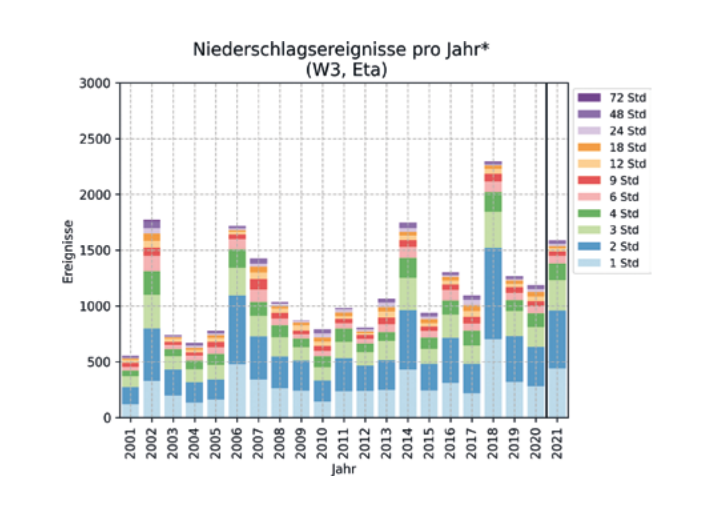


Figure 10

Climatological assessment

2021 was the year with the second-highest number of single precipitation events in the last 21 years (Figure 10). The weeks before the July event were already marked by severe weather, which had resulted in locally very heavy rainfall and flash floods in some places. In Germany, both the most and the severest heavy rain events usually occur in the period between May and September. In principle, heavy rain events can occur anywhere in Germany. However, there is a tendency for extreme events of increasing duration to happen more frequently in lower mountain ranges and in higher alpine regions.

Particularly over the last few decades, an increase in temperatures has been observed around the world and in Germany, which can only be explained by the rise in atmospheric greenhouse gas concentrations. The question therefore arises as to what effect this climate change has regionally on the frequency and intensity of such intense heavy rainfall events.

Analyses conducted over the past 70 years using daily observation data show that the intensity and frequency of days with heavy precipitation (defined as days with precipitation totals >20 l/m² per day) have increased slightly. The change signals are strongest for the winter, whereas there is still no clear picture for the summer. This is probably caused by two opposing effects: the number of days with precipitation is decreasing while the intensity of precipitation on the remaining days is increasing. According to climate projections, this trend is expected to continue.

Figure 10
Annual number of radar-detected heavy rain events since 2001 as resulting from climatologically processed radar data. The threshold used is warning level 3 (severe weather) for persistent/heavy rain. The figures for 2021 are based on archived real-time data until 19.7., 5:50 UTC (7:50 CEST).

In the first place, single extreme events generally do not constitute direct evidence of climate change. Only long-term observations can show whether the frequency of certain events has increased or not. In the case of extreme events that occur rarely, it is particularly important to look at a very long period of time. There is no easy or even universal answer to the question of whether climate change has increased the severity of a certain weather event. Although attribution research has already made it possible to show for selected events of extreme weather (for example heatwaves) that climate change has increased their probability of occurrence, extensive investigations are still necessary depending on the individual case. A recently published global study on daily maximum precipitation shows that anthropogenic climate change has contributed, at least to some degree, to the increased intensity of heavy rain events, for example in central Europe.

Attribution study: Heavy rainfalls which led to severe flooding in western Europe made more likely by climate change

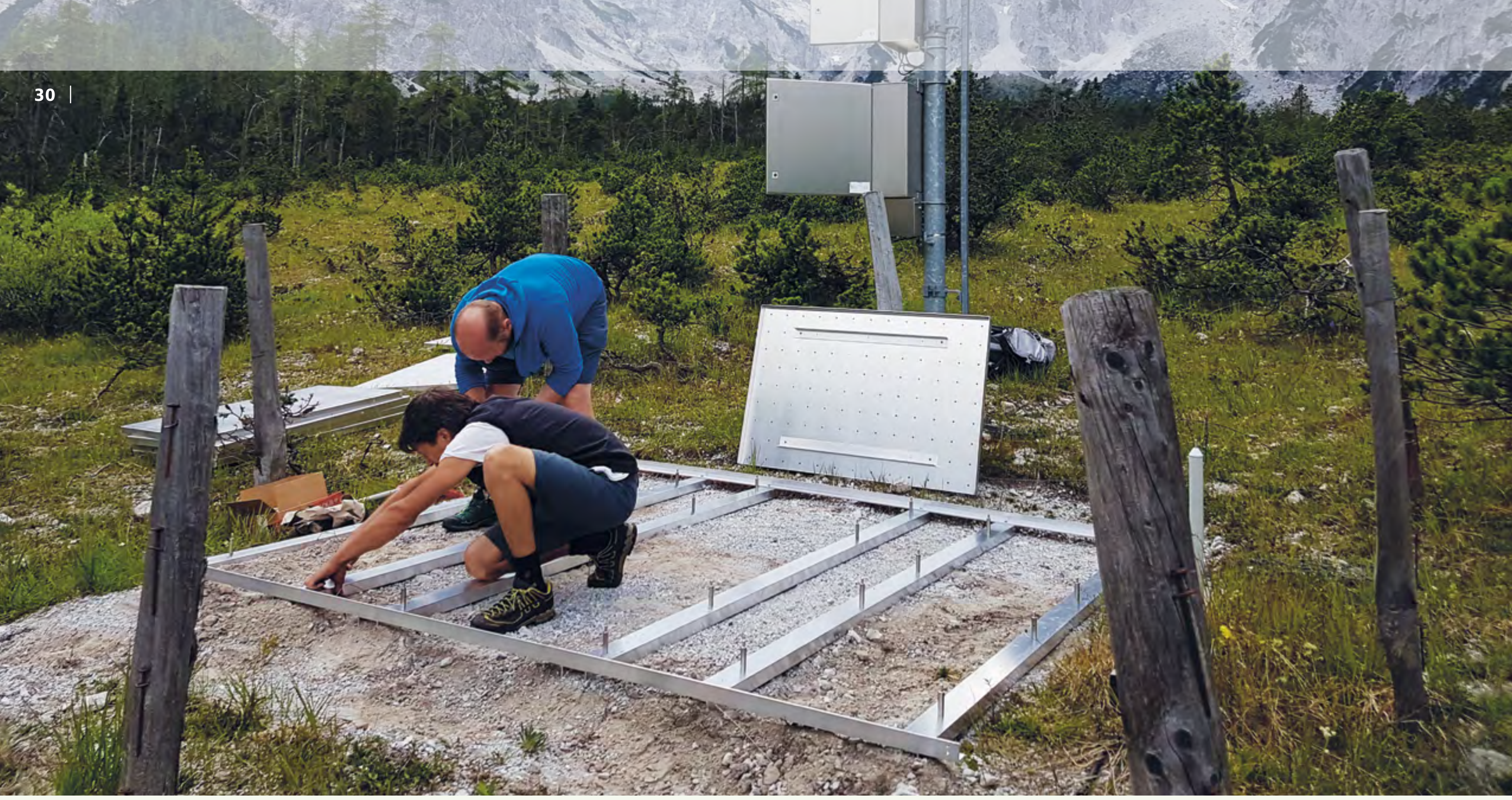
Following the flood disaster of July 2021, an attribution study examining the events was conducted as part of the World Weather Attribution initiative. The study with 39 participating scientists from universities and the national meteorological and hydrological authorities in Belgium, France, Germany, Luxembourg, the Netherlands, Switzerland, the United States and the United Kingdom was co-ordinated by the DWD.

The scientists' attention was not on the water levels of the rivers, but on the amounts of rain that had fallen. Ad-hoc studies such as this one adhere to a peer-reviewed protocol for analysing weather observations and computer simulations.

The scientists examined the influence of climate change on similar rain events in western Europe, more precisely in an area stretching from the Netherlands to north of the Alps and from Belgium to Thuringia in Germany. It was found that, under current climate conditions, such an event can be expected to occur at a given location in this large area every 400 years. This also means that such events can also occur more often than once in 400 years within the greater region of western Europe.

Climate change has increased the intensity of the maximum 1-day precipitation event in the summer season in this large area by about 3 to 19 per cent compared to a global, pre-industrial climate around 1850. Compared to the pre-industrial level, the likelihood of such an event occurring today in the larger area has increased by a factor of 1.2 to 9.

The results underpin the statement of the latest report published by the Intergovernmental Panel on Climate Change (IPCC), according to which there is no doubt that global warming is man-made and that the resulting climate change is the main cause of the increase in extreme weather events. According to the IPCC report, heavy rain events and flooding will occur more frequently in western and central Europe due to the increasing temperatures.



top
Installation of a snow scale at the automatic climate station Brunftbergtiefe, Berchtesgaden National Park

WMO recommends two periods of reference

As recommended by the World Meteorological Organization (WMO), it is common practice to use 30-year period averages for recording the climate and climate change. The aim is to exclude the influence of natural variability in statistical climate analyses.

In the past, the period from 1961 to 1990 was often used for this purpose. However, many applications require a statistical description of the current climate, for which reason the climate normal period 1981–2010 has been used lately as standard baseline. The climate conditions observed in a more recent period correspond to the climate people have 'actually experienced'. Since the beginning of 2021, the baseline period for current climatological assessments has been changed to 1991–2020.

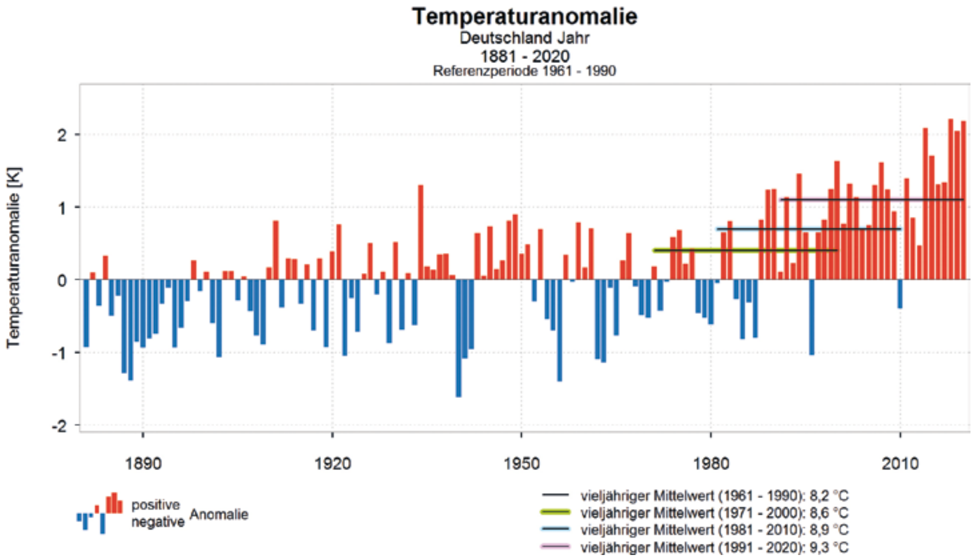


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Illustration of the differences between the reference periods on the example of average temperature for Germany

In general, climate reference periods are intended as a tool to benchmark current weather conditions against the most recent state of the climate in a given region as well as against the long-term climate development in the same region. In a stable climate, both purposes can be satisfied by the same reference period. However, if climate elements such as air temperature show a clear and consistent trend due to anthropogenic climate change, an update frequency of thirty years is no longer sufficient to obtain a correct description of the current state of the climate. The 1991–2020 averaging period is much better suited than the period 1961–1990 to classifying a current month. On the other hand, it is also appropriate to use a fixed standard period that reflects the mean state of the climate in the studied period as a reference for the evaluation of long-term climate developments. In order to ensure an internationally uniform approach to this matter, the WMO has revised its corresponding recommendations accordingly (WMO 2014, 2017)*.

Recommendation of the WMO

Given that one climate reference period alone no longer satisfies all the requirements, the WMO recommends using two base periods:

- The period 1961–1990 is retained as the standard reference period for long-term climate change assessments since this period is only partially affected by the accelerating global warming we are observing today.
- From now on, the climate normal periods required for climate monitoring other than long-term climate change assessments, for example the publication of monthly, seasonal or annual maps of anomalies, and as a basis for climate prediction will be updated every ten years.

The WMO also points out that the definition and use of climate normals must be documented and communicated clearly and accurately in order to avoid misinterpretations.

Implementation by the DWD

In line with this recommendation, the DWD continues to use the period 1961–1990 as the standard reference for assessments of long-term climate change. In addition, the latest climate normal period, currently 1991–2020, is used in the context of short-term climate monitoring.

* Source see page 83

Weather in Germany 2021

	Average temperature in °C	Highest temperature in °C	Lowest temperature in °C
January	0.6 (–0.5)	15.6 on the 22nd in Emmendingen-Mundingen	-21.0 on the 16th on the Zugspitze
February	1.7 (0.4)	22.0 on the 25th in Ohlsbach	-26.7 on the 10th in Mühlhausen-Görmar
March	4.8 (3.5)	27.2 on the 31st in Rheinau-Memprechtshofen	-20.9 on the 20th on the Zugspitze
April	6.0 (7.4)	25.9 on the 1st in Müllheim	-21.9 on the 6th on the Zugspitze
May	10.7 (12.1)	31.3 on the 9th in Waghäusel-Kirrlach	-13.9 on the 8th on the Zugspitze
June	19.0 (15.4)	36.6 on the 19th at Berlin-Tempelhof and in Baruth	-3.2 on the 30th on the Zugspitze
July	18.4 (16.9)	32.8 on the 6th in Rosenheim	-2.9 on the 1st on the Zugspitze
August	16.4 (16.5)	33.2 on the 15th in Regensburg	-4.1 on the 29th on the Zugspitze
September	15.2 (13.3)	30.0 on the 9th in Huy-Pabstorf	-6.6 on the 30th on the Zugspitze
October	9.6 (9.0)	27.5 on the 13th and 14th in Munich (city)	-13.0 on the 14th on the Zugspitze
November	4.9 (4.0)	17.5 on the 11th in Mittenwald-Buckelwiesen	-19.6 on the 29th on the Zugspitze
December	2.6 (0.8)	16.6 on the 23rd in Müllheim	-19.2 on the 22nd in Oberstdorf
Winter 2020/21	1.8 (0.2)	22.0 on 25 February in Ohlsbach	-26.7 on 10 February in Mühlhausen-Görmar
Spring	7.2 (7.7)	31.3 on 9 May in Waghäusel-Kirrlach	-21.9 on 6 April on the Zugspitze
Summer	17.9 (16.3)	36.6 on 19 June at Berlin-Tempelhof and in Baruth	-4.1 on 29 August on the Zugspitze
Autumn	9.9 (8.8)	30.0 on 9 September in Huy-Pabstorf	-19.6 on 29 November on the Zugspitze
Year	9.2 (8.2)	36.6 on 19 June at Berlin-Tempelhof and in Baruth	-26.7 on 10 February in Mühlhausen-Görmar

The figures in parenthesis indicate the long-term mean values according to the internationally agreed 1961 to 1990 reference period.

Precipitation in l/m²	Sunshine duration in hours	Memorable facts
80.2 (60.8)	30.0 (43.6)	Very dull and wet start of the year
48.9 (49.4)	107.3 (71.5)	Very low temperatures during the first half of the month; extreme temperature increase towards the end of the month; highest ever difference between minimum and maximum temperatures within 7 days (Göttingen: 41.9 K)
46.0 (56.5)	146.7 (111.2)	Once more winter conditions in the low mountain ranges in the middle of the month; first summer days at the end of the month
34.7 (58.2)	183.5 (153.7)	Very dry April; much cooler
94.9 (71.1)	168.4 (201.6)	Second cooler-than-normal month in succession; very wet
95.4 (84.6)	257.2 (203.3)	First and only extreme heatwave of the year from the middle of the month
107.2 (77.6)	198.6 (210.7)	Extreme amounts of precipitation in the middle of the month caused devastating flooding in Rhineland-Palatinate, North Rhine-Westphalia and Bavaria
102.5 (77.2)	156.7 (199.5)	Very wet and dull last summer month, with slightly cooler than normal temperatures
35.3 (61.1)	174.3 (149.6)	Once more summer-like temperatures, much sunshine and very dry from the middle of the month; tornado in Kiel towards the end of the month
44.8 (55.8)	128.0 (108.5)	Unusually high daily minimum temperatures on 20 October; storm 'Hendrick' on 21 October
49.7 (66.3)	42.7 (52.8)	Very dry with high amounts of precipitation in eastern Germany only at the beginning of the month
61.4 (70.2)	37.9 (38.0)	Thaw in the low mountain ranges and in the Alps over Christmas; extremely mild temperatures at the turn of the year
186.6 (180.7)	172.0 (152.9)	Significantly more days with snow cover than in preceding years, especially at the beginning of the year and during the first half of February
175.6 (185.9)	498.6 (466.6)	Unusually cool spring; the first summer day of the year in March and the first hot day of the year in May
305.1 (239.4)	612.5 (613.5)	Very mixed weather; very warm at the start and cool at the end; high amounts of precipitation with extreme flooding in July
129.9 (183.3)	345.0 (310.9)	Very dry; the last hot day of the year in September
801.1 (788.9)	1.631.2 (1.544.0)	Mean annual temperature not quite as high as in the preceding years

The year in review

right
Oliver Nitsche (left, DWD) and Peter Köhler (right, DWD, retired) checking the station Funtensee-Tal in autumn; the mountain hut Kärlingerhaus can be seen in the background.

ICON – complete and unified modelling framework

It was in January 2015 that the DWD first introduced the global weather forecasting system ICON[1], jointly developed with the Max Planck Institute for Meteorology (MPI-M). Now, six years later, the last component of the full model chain, the module ICON-D2/ ICON-D2-EPS, has been put into operation. With this transition to ICON-D2, the DWD's operational numerical weather prediction system is now entirely based on the unified ICON modelling framework. The ICON 'family' for deterministic weather prediction at the DWD includes the global model ICON, the higher-resolution ICON-EU nest for Europe (which is tightly coupled with ICON by two-way interaction) and the convection-resolving ICON-D2. In the field of probabilistic weather prediction, the DWD has the ensemble predictions of ICON-EPS/ICON-EU-EPS and ICON-D2-EPS at its disposal.

The name ICON (ICOsahedral Nonhydrostatic modelling framework) basically derives from its icosahedral grid made up of adjacent triangles. The ICON grid has two particular advantages: the model provides nearly homogeneous global coverage and makes efficient use of modern parallel computer architectures. Compared with its predecessors, ICON benefits from a number of improvements in the representation of physical processes in the atmosphere and on the Earth's surface. This allows significantly more precise medium- and long-term weather forecasts and much better detection and forecasting of small-scale, local weather developments. Since the introduction of ICON, the quality of the DWD's global forecasting system has improved significantly and reached an internationally leading position especially in the short range. In early 2021, the project ICON-Seamless was started with a view to extending the application range of ICON to climate prediction scales.

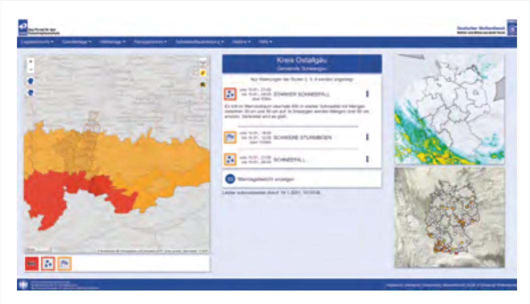
At the global and European level, ICON and ICON-EPS forecasts are initialised by combined and so-called 'ensemble variational' data assimilation (EnVAR[2] and LETKF[3]). For several years now, the DWD has been using the KENDA system to determine the initial state of forecasts from the high-resolution regional forecasting model – and is now applying the same method for ICON. KENDA[4] stands for 'Kilometre-scale ENsemble Data Assimilation' and is based on the Kalman Filter method (4D-LETKF). It allows to determine, at the same time and with consistency, the initial conditions for deterministic as well as probabilistic predictions. In addition, the system also uses the data from upper-air soundings (both ascents and descents), aircraft measurements, wind profiler and surface station data as well as 3D radar precipitation data.

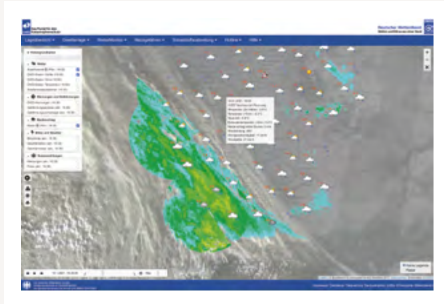
[1-4] Sources see page 83

Facts and figures about ICON

	Mean grid spacing	Layers	Geographical coverage
ICON	13 kilometres	90 layers up to a height of 74 km	Globe
ICON-EPS	40 kilometres	90 layers up to a height of 74 km	Globe
ICON-EU	6.5 kilometres	60 layers up to a height of around 23 km	Europe, including the European part of Russia, parts of the North Atlantic
ICON-EU-EPS	20 kilometres	60 layers up to a height of around 23 km	Europe, including the European part of Russia, parts of the North Atlantic
ICON-D2, ICON-D2-EPS	2.1 kilometres	65 layers up to a height of around 23 km	Germany and the eastern part of the British Isles, parts of France, the whole mountain range of the Alps, large parts of the North Sea

Oliver Nitsche maintaining and repairing the solar panel of the DWD measuring station Funtensee-Tal





top left
Central situation overview: presentation of different meteorological risk situations at a glance and quick access to the monitors

top right
Monitor for the dynamic visualisation of various meteorological data sets depending on the risk situation and customer needs

Revamped design for FeWIS

The FeWIS information system for disaster management is a centralised tool provided by the DWD for operations control centres, fire brigades and situation centres. In the event of severe weather, it supplies more than 2,500 units connected to it with vital information reports on the latest situation. At the start of 2021, the DWD has launched a completely revamped version of its portal for disaster management, offering a whole range of new features.

Revision of the portal for disaster management

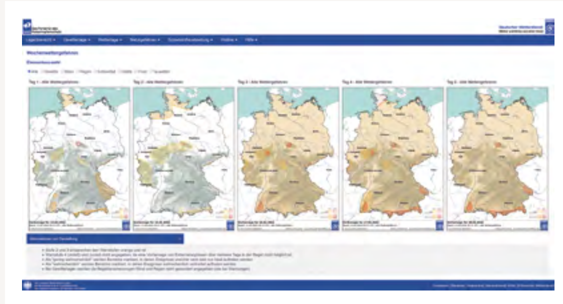
Through FeWIS, the DWD has been providing weather information tailored to the needs of disaster management for more than 18 years. In line with the technical standards at the time, FeWIS was started as an interactive web portal built on the well-known Adobe Flash technology. With the discontinuation of the support for Adobe Flash Player at the end of 2020, a complete revision of the portal had become necessary. Work to prepare the change, i.e. development of prototypes, beta-testing, etc., had already been under way over the past few years.

This revision of FeWIS also created multiple opportunities for developing the portal further also beyond purely technical aspects. For instance, the new version of FeWIS has a responsive design for seamless use on mobile devices. In addition, a large number of new data sets were added, for instance, data for the central thunderstorm monitor, which is activated during hazardous convective conditions in the summer. Now, the disaster management bodies also have direct access to the weather information reported by users through the DWD WarnWetter app. This gives them a better overview of the situation on the ground and, in particular, of the meteorological conditions there and the damage caused.

As the meteorological information in the new FeWIS version is mostly made available through standardised geo-web services, it can be integrated directly into the situation assessment systems operated by the control centres or even be processed further, if necessary.

Facts and figures about FeWIS

- Over 2,500 registered access points in the disaster management sector
- Over 100,000 individual access codes for DWD WarnWetter
- Over 20 million page views per day during severe weather situations



top left
Weather situation in winter in responsive design: reports from users in the DWD WarnWetter app provide the relief units with news details about the impacts being suffered on the ground.

top right
Weekly weather hazard forecast: overview of risk situations in the next five days for situation centres

top
Monitoring of natural risk situations: other information about weather-related risk situations are available directly in FeWIS.

Direct access to information on other natural hazards

For situation and operations control centres, it is crucially important that they can combine all information available about the situation as quickly as possible. As part of its natural hazard approach, FeWIS already incorporates weather-related emergency information. The information on offer has been expanded recently to allow direct access to water levels and flood information.

The latest addition are graphical representations showing an overview of expected weather hazards in Germany for the next five days. In the past, this situation overview was available to the Joint Information and Situation Centre of the German Federation and the federal states (GMLZ) as well as to the Deutsche Bahn company situation centre. Now, all FeWis users have access to it.

FeWIS and DWD WarnWetter app

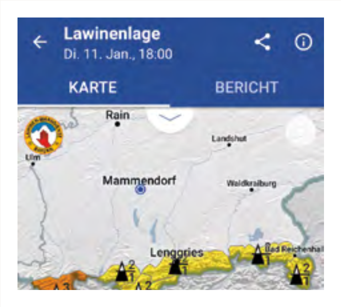
FeWIS is a tool for mainly stationary use by the staff of disaster relief units, operations control centres and fire brigades for the co-ordination of rescue operations and the targeted planning of resources. In addition, the full version of the DWD WarnWetter app is often used to obtain a rapid assessment of the situation on the ground and ensure the safety of relief units. The full version of the app is free of charge for members of disaster management services while other users have to pay for its use. As part of its mandate in the field of disaster, civil and environmental protection, the DWD has already authorised more than 100,000 registered users to access the full version of the app.

It was also possible to integrate the latest developments relating to the central thunderstorm monitor in FeWIS into DWD WarnWetter so that both systems, FeWIS and the app, now use the same data base, and thus provide the disaster management sector with an optimal range of information.

Close collaboration: Bavarian Avalanche Warning Service and DWD

For more than half a century, the Bavarian Avalanche Warning Service (Lawinenwarndienst Bayern, LWD) has played an important role in avalanche prevention in the Bavarian Alps. The focus is not only on the safety of winter tourism and winter sports, but also on the protection of people living in the Alps and the region's infrastructure.

The key element in fulfilling these tasks is to assess the current snow situation for avalanche risks and, in particular, its evolution over the next days. This illustrates the close link to the weather and therefore to the Deutscher Wetterdienst. Without precise predictions of temperature, type and intensity of precipitation, snow level, cloud cover, incoming radiation, wind direction and wind speed, it would not be possible to forecast the evolution of the avalanche situation with the existing high standards of quality.



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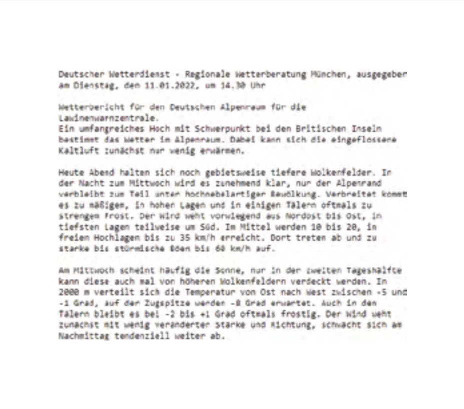
Example of an avalanche warning in the DWD WarnWetter app

below
Oliver Nitsche and Peter Köhler discussing and planning their maintenance work in the area of Lake Funtensee in the Berchtesgaden National Park; the mountain hut Kärlingerhaus can be seen in the background.

For many years, there has been close collaboration between the DWD, represented by its Regional Weather Advisory Office (RWB) in Munich, and the Bavarian Avalanche Warning Service. The services on offer include the transmission of a comprehensive range of daily forecast products during the winter period:

- Nine different high-resolution forecasts for key weather parameters at various altitudes and subdivided by regions for the area stretching from the Allgäu Alps to the Berchtesgaden Alps
- Graphical displays of model predictions of geopotential height and temperature at 850 hPa (Figure 1) with precipitation amounts accumulated over 3 hours (Figure 2)
- Since 2018: 12- and 24-hourly deterministic and probabilistic point and time forecasts (MOSMIX-SNOW) of new snow for LWD measuring stations
- Daily weather reports for the Bavarian Alps for the next 24 hours (also in the summer) (Figure 3)
- Telephone meetings between DWD and LWD in winter, if necessary.



Deutscher Wetterdienst - Regionale Wetterberatung München, ausgegeben am Dienstag, den 11.01.2022, um 14.30 Uhr

Wetterbericht für den Deutschen Alpenraum für die Lawinenwarnzentrale.
Ein umfangreiches Hoch mit Schwerpunkt bei den Britischen Inseln bestimmt das Wetter im Alpenraum. Dabei kann sich die eingeflossene Kaltluft zunächst nur wenig erwärmen.

Heute Abend halten sich noch gebietsweise tiefere Wolkenfelder. In der Nacht zum Mittwoch wird es zunehmend klar, nur der Alpenrand verbleibt zum Teil unter hochnebelartiger Bewölkung. Verbreitet kommt es zu mäßigem, in hohen Lagen und in einigen Tälern oftmals zu strengem Frost. Der Wind weht vorwiegend aus Nordost bis Ost, in tiefsten Lagen teilweise um Süd. Im Mittel werden 10 bis 20, in freien Hochlagen bis zu 35 km/h erreicht. Dort treten ab und zu starke bis stürmische Böen bis 60 km/h auf.

Am Mittwoch scheint häufig die Sonne, nur in der zweiten Tageshälfte kann diese auch mal von höheren Wolkenfeldern verdeckt werden. In 2000 m verteilt sich die Temperatur von Ost nach West zwischen -5 und -1 Grad, auf der Zugspitze werden -8 Grad erwartet. Auch in den Tälern bleibt es bei -2 bis +1 Grad oftmals frostig. Der Wind weht zunächst mit wenig veränderter Stärke und Richtung, schwächt sich am Nachmittag tendenziell weiter ab.

Figure 3

Figure 3
Example of a daily 24 h weather forecast for the Bavarian Alps (also in summer)

Figures 1 and 2
Graphical presentation of model predictions of geopotential height and temperature at 850 hPa (Figure 1) with precipitation amounts accumulated over 3 hours (Figure 2)

As part of this co-operation, the LWD makes the measurement data from 17 of its stations available to the DWD. These data are highly important for the work of the meteorologists at the DWD as they help to assess the snow situation and its further evolution. The data from the LWD stations are directly available in the DWD's meteorological workstation NinJo.

The data and forecasts of the Bavarian Avalanche Warning Service can be accessed on the LWD website at www.lawinenwarndienst-bayern.de/. In addition to this, the latest avalanche situation reports as well as weather reports for the Bavarian Alps are also made available in the DWD WarnWetter app as part of the natural hazard approach (distribution of flood warnings, water level and storm surge information as well as avalanche forecasts).

Figure 1

Figure 2

DAS core service Climate and Water

The consequences of climate change affect many areas of business and politics. Extreme events, such as heatwaves, droughts, heavy precipitation, etc., set in motion chains of effects which ultimately concern aspects of protecting and safeguarding life and property. The Federal Government is addressing this issue as part of the implementation of the German Strategy for Adaptation to Climate Change (DAS), adopted in December 2008 and updated in 2021 by the Climate Impact and Risk Assessment study for Germany (KWRA).

In order to adapt, for example, the transport system or many of the other DAS action fields to the impacts of climate change and to extreme weather events, there is a continuous need for up-to-date and reliable basic data and information on climatological, oceanographic and hydrological parameters of the past, the present and the future as well as for operational services derived from these. In order to fulfil this task requirement, the Federal Ministry for Digital and Transport (BMDV) set up the DAS core service Climate and Water on 20 November 2020. In this context, the DWD, the Federal Institute of Hydrology (BfG), the Federal Maritime and Hydrographic Agency (BSH) and the Federal Institute for Waterway Engineering and Research (BAW) – all higher federal authorities under the remit of the BMDV – have been given new permanent tasks in support of the German DAS Adaptation Strategy.

With the DAS core service Climate and Water, an operational climate service has been established for specialised consultancy and advice on these topics and for the exchange of data required for climate change adaptation in Germany. The goal is the continuous provision of latest quality-assured data, analyses and consultancy services on climate change in Germany. The DAS Climate and Water service supplies users from the transport sector and from other branches, such as water management, the energy sector, the building industry as well as coastal, marine and civil protection, with uniform and coherent information. With the help of these data, it is possible to evaluate the effects of climate change, develop adaptation options and thus, among other things, create a basis for ensuring a climate-resilient and sustainably usable infrastructure. The information chain in the DAS Water and Climate service will be refined further, from the basic data to climate events and from impact modelling through to the products offered.

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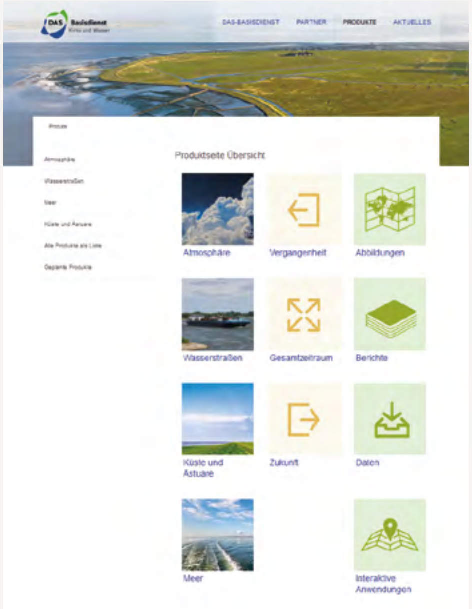
Ice formation after flooding



On the website of the DAS core service Water and Climate at www.das-basisdienst.de, the users will find numerous products which the four participating authorities provide in the context of climate change adaptation. The website also offers background information about the service, links to further information and the contact details of the advisory teams at the authorities involved. The product range of the DAS Water and Climate service (as available on the website) will be expanded to include more products from the participating authorities. A newsletter is being prepared with the aim of informing regularly about new developments. Ongoing exchange with users is of key importance in order to take requests or suggestions into account when developing new products.

Contact: das-basisdienst@dwd.de

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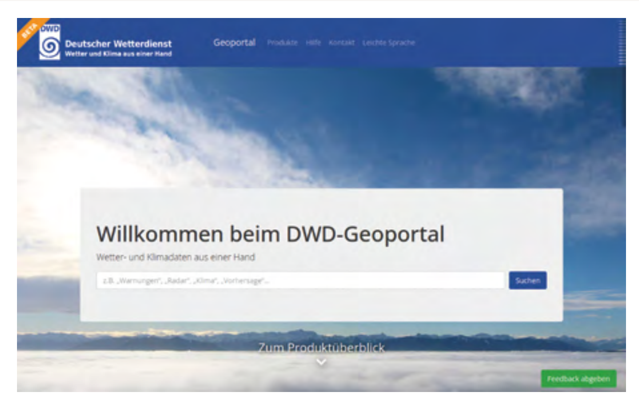
Oliver Nitsche and Peter Köhler starting a comparative measurement at Trischübel station, operated by the Berchtesgaden National Park at 1.762 m.

top
Product categories available on the website of the DAS core service



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The DWD Geoportal welcomes its users, offering a search line as central element of the start page. Scrolling down gives access to the various products, sorted along a timeline from archived data through to predictions. Sending feedback to the DWD is possible using the button in the bottom right corner of the page.

DWD Geoportal – Optimisation of the DWD's open data portal under way

Open data plays an increasingly important role in the field of weather and climate. In accordance with its statutory mandate, the Deutscher Wetterdienst provides the public with weather and climate data free of charge and for free use. Access to open data of the DWD has been possible at opendata.dwd.de since 2017. This file server with a simple tree directory structure was supplemented with the DWD's public web pages and several other portals. The DWD has now established a new DWD Geoportal with the aim of offering a central and state-of-the-art public entry point to the entire range of open data products provided by the DWD.

The DWD Geoportal was launched in November 2021 with a public test phase at dwd-geoportal.de. Through this portal, users can explore the DWD's range of open data products and filter their searches freely according to specialist parameters. The product pages provide information, metadata, download options and interactive previews. The new portal gives users as well as customer service and specialist divisions at the DWD an optimised overview of the existing open data and allows refined searches and use according to specific needs or better support, respectively.

During the ongoing public test phase, user feedback is collected and analysed continuously with a particular focus on clarity of presentation, intuitive handling, scope of functions and availability of product pages. New products are added continuously to include the content of the open data file server at opendata.dwd.de. The product overview additionally includes links to the other open data resources of the Deutscher Wetterdienst, such as the DWD GeoServer at maps.dwd.de, the Climate Data Center at cdc.dwd.de/portal, the DWD's public website dwd.de and the WIS Portal of the DWD at gisc.dwd.de. In future, the DWD Geoportal will combine all these services to offer a comprehensive catalogue of the open data of the DWD.

Figure 1

Figure 1
The search results page lists the corresponding products in tile form. The menu on the left side offers a range of filters for further refinement of the search.

Figure 2

Figure 2
The product pages provide further information as well as access to the download of data and products. Interactive previews are available for many products.

Oliver Nitsche checking the comparative measurement at the Berchtesgaden National Park station Trischübel (1,762 m).

Study of the Strategic Alliance of Public Authorities for Adaptation to Climate Change: Changes in precipitation affect relief operations and urban environments

Findings on the frequency and intensity of extreme precipitation events are of essential importance for civil protection and disaster risk management as well as for urban and spatial planning in Germany, especially against the backdrop of advancing climate change. Together with the partners of the Strategic Alliance of Public Authorities for Adaptation to Climate Change, the Deutscher Wetterdienst (DWD) has successfully concluded a project on the ‘Classification of extreme meteorological events for the prevention of risks associated with heavy rain for the purposes of civil protection and urban development (KlamEx)’.

Besides the DWD, the Strategic Alliance also comprises the Federal Office for Civil Protection and Disaster (BBK), the Federal Agency for Technical Relief (THW), the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) and the Federal Environment Agency (UBA). The results of the KlamEx study were presented at a press conference held at the DWD headquarters in August 2021. This was the first press conference at the DWD to be held in hybrid mode and thus enabled media representatives from all over Germany to take part virtually.

Heavy rainfall is increasingly becoming a challenge

Using the DWD’s radar data-based precipitation climatology RADKLIM as a basis, there now exists a catalogue of extreme rainfall events in Germany since 2001. Besides meteorological information on the events and the places where they occurred, this data collection also contains the geographical and demographic details that mainly determine the potential impact of a weather event. It also includes fire brigade incident statistics. An analysis of the frequency of events made it possible to identify regional distribution patterns and hotspots of heavy and persistent rainfall events over the past 20 years (Figure 1).

Figure 1
Spatial distribution of heavy and persistent rainfall events in the years 2001 to 2020 during which the DWD’s severe weather warning level 3 was exceeded. Left: Short, typically local convective rainfall events with duration levels up to 9 hours. Right: Persistent, typically large-scale rainfall events with duration levels of more than 12 hours. According to the new catalogue of events, the characteristic duration level is defined as the phase of an event during which, when considered together, the precipitation intensity and the area affected reach maximum figures.

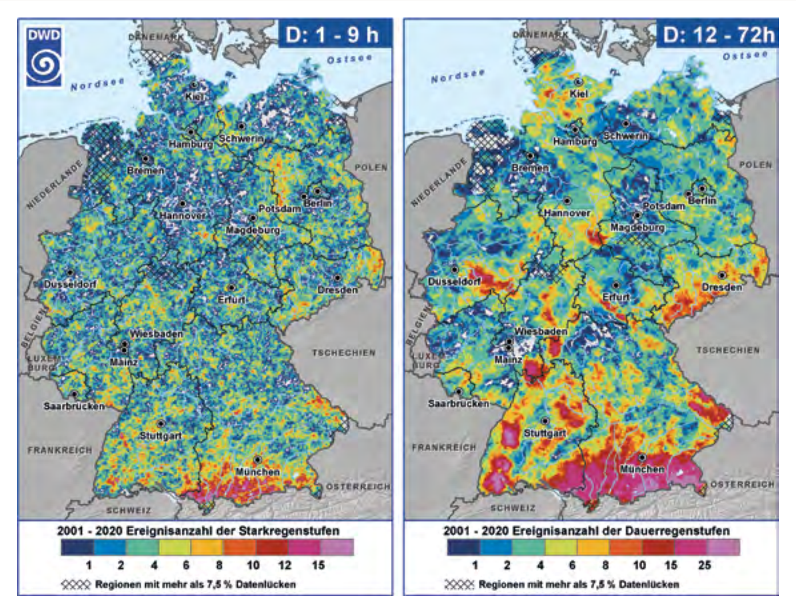

Figure 1

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Berchtesgaden National Park station on the ridge of the Watzmann massif: the station is situated at 2,650 m and difficult to access.

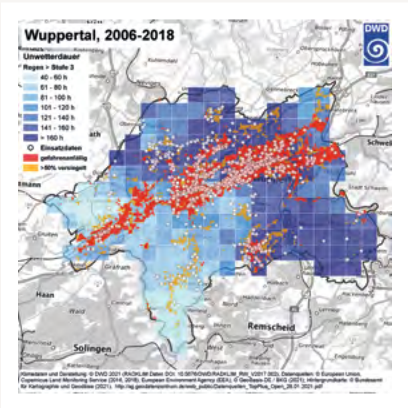
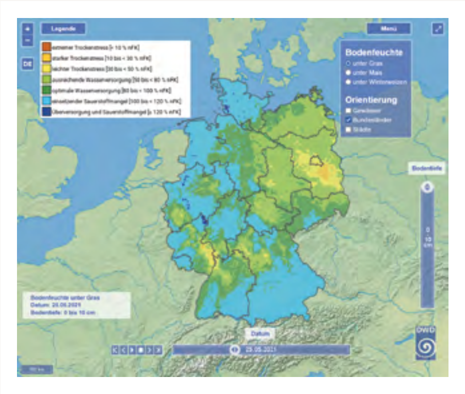


Figure 2

Figure 2
Analysis of the interrelation between geographical and demographic details of the urban area, the precipitation climatology and the fire and rescue incident statistics of the city of Wuppertal.

KlamEx has shown that even though heavy rain occurs all over Germany, the actual danger is crucially dependent on local conditions. Not every event over an inhabited area causes damage and requires relief operations. The local topography and degree of urbanisation have been identified as the key factors that determine the location of incidents requiring rescue operations. For instance, incidents attended by fire services occur significantly more often in hollows and densely populated places with high levels of soil sealing (Figure 2). The results furthermore show that, in the light of the temperature rise expected to occur due to climate change, short events of extremely heavy rain are increasing significantly in geographical extent and are also becoming slightly more intense. As a consequence of this, there is an increase in the potential impact from the events.

Conclusion: Heavy rainfall is increasingly becoming a challenge for civil protection and disaster risk management as well as for urban and spatial planning. Investment in climate change mitigation and adaptation is required now, in particular in the climate-compatible and water-sensitive redesign of cities, in order to achieve better protection against the catastrophic consequences of future extreme events.



left
Screenshot of the soil moisture application showing the main components of the viewer: menu, legend, sliding bars for selecting the date and soil depth

right
The soil moisture viewer allows for zooming in and out on areas. The figure shows the soil moisture situation under grass in the Berlin area on 25 May 2021.

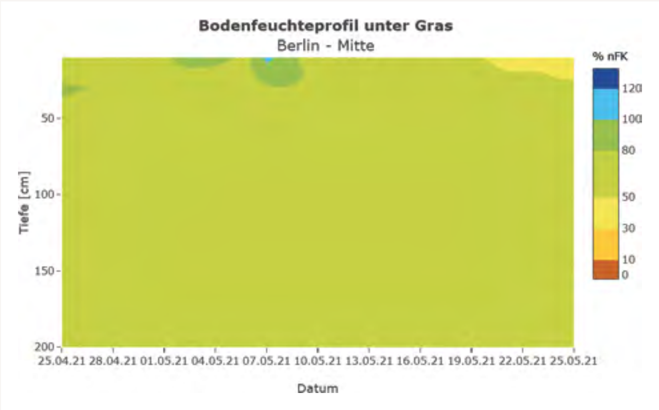
Soil moisture viewer: Online monitoring tool for soil moisture in Germany

The soil moisture viewer offered by the Deutscher Wetterdienst (DWD) is a new tool to support work processes in agriculture and forestry. The amount of moisture contained in the soil and available for plant growth has an essential influence on work processes and yields in agriculture and forestry as well in gardening. If the soil is too dry, frequent irrigation is required, whereas waterlogged fields make machine working more difficult.

Droughts regularly lead to massive reductions in harvest yields. Dried out forest soils can cause trees to die or aggravate the risk of forest fires. For this reason, the Deutscher Wetterdienst (DWD), as the German national meteorological service, has launched its new online soil moisture viewer to provide everyone concerned or interested from now on free of charge with all the information available about soil moisture in Germany. The new web portal at www.dwd.de/bodenfeuchteviewer enables a quick and easy search for detailed facts about soil moisture and drought situations in Germany.

The content of the soil moisture viewer is updated daily by the DWD. Users can gain an overview of the situation in Germany, but can also zoom in on individual regions or locations with a resolution of up to 1 km. In addition to map views showing precipitation analyses or current soil water levels, the portal also allows for the retrieval of detailed information about soil moisture. For instance, it is possible to view the temporal evolution of the soil moisture at different soil depths during the past year or to retrieve the soil moisture profile up to a depth of 200 cm over the past month.

top
Berchtesgaden National Park station Trischübel at 1,762 m; one of the DWD's mechanical wind measurement devices can be seen on the right.



top
Soil moisture profile under grass up to a depth of 2 m at Berlin four weeks back from the selected date (here: 25.4.–25.5.2021).

Depending on the crops, the demands for plant-available water in the soil at a certain time can vary greatly. Maize, for example, is sown much later than winter wheat and therefore still takes up a lot of water from the soil later in the season after the harvesting of winter grain. For this reason, the user can choose between different agricultural crops, namely grass, maize and winter wheat.

At a glance: key information contained in the new soil moisture viewer

- Temporal evolution of soil moisture (up to one year back via a sliding time bar)
- Evolution of soil moisture at depths of up to 200 cm
- Soil moisture underneath different agricultural crops
- Soil moisture profile for a chosen location (30 days back from the set date)
- Soil moisture analyses
- Soil water level
- Precipitation analyses
- Report on the current soil moisture situation
- Links to DWD web pages with information about soil moisture, aridity and drought

De-icing of instruments at mountain stations

Throughout Germany, the DWD operates 180 main weather stations for surface observation. In the winter months, the operation of the high-precision measuring instruments poses a particular challenge at a dozen of these stations. During that time, stations located at higher altitudes such as in the low mountain ranges and in the Alps are regularly exposed to conditions that typically lead to freezing fog deposits, namely high air humidity and below-freezing temperatures. Under adverse conditions, this is aggravated by the wind blowing the heat away from the instruments. This wind chill effect particularly acts on the optical and acoustic devices, the surfaces of which must be snow- and ice-free for measuring. Out of the ten meteorological parameters recorded as a standard, this particularly affects the measurement of duration and type of precipitation, visibility and snow depth.

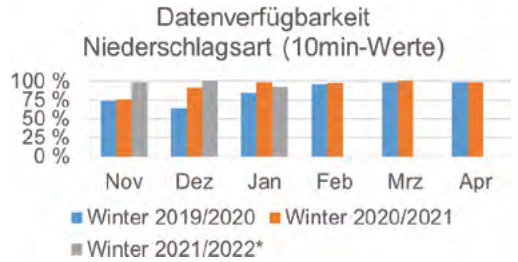
Due to the limited number of devices needed for this purpose, the small market for meteorological instruments with its very special and anyway sparse range of business has no instruments on offer that could meet such requirements. In July 2019, the DWD therefore set up the task force ‘De-icing mountain stations’ with the aim of increasing the availability of data from mountain stations. A team composed of representatives from all business areas of the DWD, who worked in collaboration and exchanged experiences with colleagues of the Austrian meteorological service ZAMG, developed approaches to technical solutions and tested their effectiveness. And what place would be better suited for such testing than the Zugspitze? Winter conditions prevail there for up to eleven months of the year. In addition, a committed team of DWD staff, who, as part of the atmospheric research activities of the DWD’s Hohenpeissenberg Meteorological Observatory, perform special tasks at the Schneefernerhaus environmental research station, could continuously provide valuable feedback.

Once some significant progress had been made with supplementary heating and modified surfaces in the measuring systems for visibility and duration and type of precipitation on the Zugspitze, the instruments at Brocken station were adapted accordingly for the winter season 2020/21. It was a positive surprise that the three measuring instruments showed the same or even better behaviour than their counterparts on the Zugspitze – despite the fact that ice deposits on the Brocken generally tend to be much thicker.

Parameter

1	Atmospheric pressure
2	Relative humidity
3	Air temperature
4	Duration of precipitation
5	Amount of precipitation
6	Type of precipitation
7	Snow depth
8	Visibility
9	Wind speed and direction
10	Height of cloud base

below
At Brocken weather station, for example, measurements for precipitation type were lacking during two months in the winters of 2019/20 and 2020/21; accordingly, only 75 per cent of the usual amount of data could be made available to the customers. Once optimisation of the sensors had taken place, data availability improved significantly.



*Stand 01.02.2022

top left
Weather station on the Zugspitze, Germany's highest mountain.

top right
DWD technicians Holger Heine (at the back) and Stefan Lünser (at the front) doing the routine maintenance at Brocken weather station.

At the same time, comprehensive trials were carried out in order to improve the instruments measuring snow depth at the stations on the Feldberg (Black Forest), Fichtelberg, Grosser Arber and at the Hohenpeissenberg Meteorological Observatory. Even in adverse conditions, the laser beam now finds its way to the measuring board through a heated pipe – without an ice block obstructing the view. Since autumn 2021, snow depth measurements on the Brocken have been automated. During winter 2021/22, this required regular checks by the technicians in order to optimise the instruments in operation. Carrying out snow depth measurements while ensuring high levels of quality is as arduous as walking through wintry snowdrifts on the highest mountain in northern Germany.

After good results in terms of data availability (93 to 97 per cent in the months from October to December), it was discovered in January 2022 that the steel support structures of the instruments on the Brocken also require further optimisation against the ice deposits. The measuring device had disappeared for several days underneath a 50 cm thick coating of ice. Since 2019, data availability at all four stations mentioned above has been successfully increased to 95 per cent. Within the framework of the continuous improvement process, the knowledge gained during this optimisation will continue to bear fruit in future, for example for the next instrument upgrade, and be expanded even further.

Figure 1

Figure 2

Figure 1
Snow depth measurements in adverse circumstances: the laser finds its way to the measuring board through a heated pipe.

Figure 2
DWD technician Holger Heine during servicing at Brocken weather station

left
Inside view of a drift buoy like the ones deployed by the frigate BAYERN

right
Delivery of the drift buoys to the frigate BAYERN

New drift buoys added to the marine meteorological network

On August 2021, the frigate BAYERN of the Germany Navy departed from Wilhelmshaven for the Indo-Pacific region, carrying 15 new drift buoys for measuring meteorological and oceanographic parameters. The buoys were to be deployed there in the area between the Horn of Africa and Australia in order to reinforce the measurement network, which had been – and to some extent still is – severely impaired by the absence of ships during the COVID-19 pandemic. The first buoy was released into the water as planned on 14 September 2021, when the frigate was crossing the latitude of 14°N.

The DWD as well as the German Navy operate so-called port meteorological offices, with responsibility for the collection of meteorological data at sea and a long-standing close collaboration between both sides. When the Navy informed the DWD about the frigate's forthcoming voyage, this was the start of discussing possibilities for further improvement to meteorological data collection at sea. Similar to the surface observation network co-ordinated internationally by the members of the World Meteorological Organisation (WMO), there is also a globally co-ordinated network for buoy measurements. The responsibility for it lies with the WMO's Data Buoy Cooperation Panel (DBCP) and the Intergovernmental Oceanographic Commission of UNESCO (IOC). Due to the COVID-19 pandemic, data coverage in the frigate's destination in the Indo-Pacific has become particularly scarce as the capacity of ships was not sufficient to ensure maintenance of the buoy network.

The buoys are autonomous devices with a service life of a good two and a half years; they measure parameters such as air pressure, sea surface temperatures, currents (derived from their positions over time) and sometimes also waves. The data are transmitted automatically via satellite, allowing for them to be fed into the WMO's Global Telecommunication System (GTS) for the global exchange of meteorological data.

German atmospheric research is being significantly expanded

The Deutscher Wetterdienst (DWD) is one of eleven institutions in Germany that are participating in the new infrastructure for research into fine particulate matter, clouds and trace gases. This is Germany's contribution to the ACTRIS research infrastructure of the European Union and, through it, to improved forecasts of air quality, weather and climate. The setting up of the ACTRIS-D infrastructure over the next eight years is supported by the Federal Ministry of Education and Research (BMBF) with a funding amount of 86 million euros in total. ACTRIS-D unites players from all areas of atmospheric research in Germany, including university and non-university research institutions and public authorities, one of which is the DWD. The responsibility for co-ordinating the German contribution to the European research infrastructure lies with the Leibniz Institute for Tropospheric Research (TROPOS) in Leipzig.

Focus on short-lived atmospheric constituents

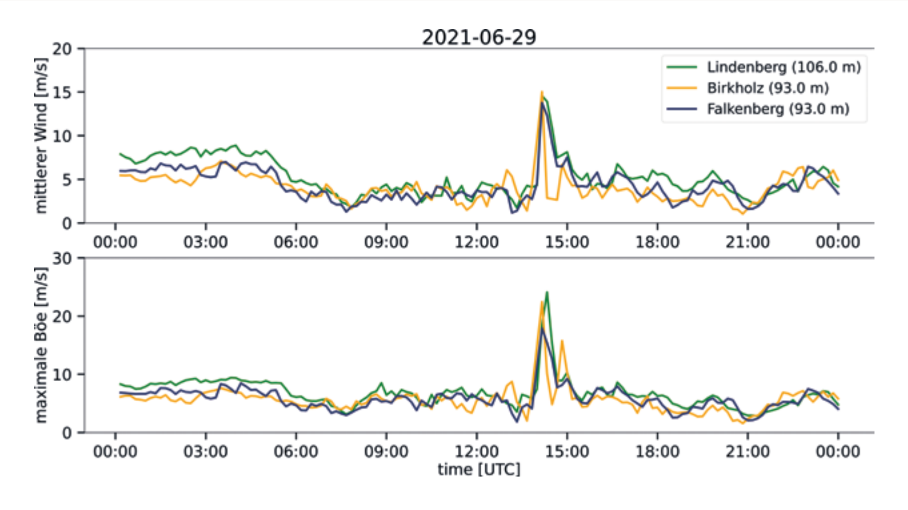
The new research infrastructure will provide data about the short-lived atmospheric constituents from the Earth's surface up to the stratosphere. It will help to reduce uncertainties in predictions of the future climate, enhance the knowledge of climate feedback mechanisms and assess measures to improve air quality as well as their impacts on health and ecosystems.

Involvement of DWD

The acronym ACTRIS stands for Aerosol, Clouds and Trace Gases Research Infrastructure, an international research programme for the study of these three atmospheric constituents in their capacity as so-called 'short lived climate forcers' (SLCF). In addition to satellite data, each of these themes is addressed using in-situ observations as well as ground-based remote sensing data.
This has led to altogether six fields of work, around which central facilities, so-called Topical Centres, are organized that provide standardised quality management processes and foster the advancement of new techniques. Their aim is to ensure comparable measurements in Europe, availability of data and state-of-the-art measurement techniques.

In Germany, the contributions (Units) to the six Topical Centres are provided by renowned scientific institutions. One of these is the Hohenpeissenberg Meteorological Observatory (MOHp) of the DWD with Units in the Topical Centres for Aerosol Remote Sensing and for Reactive Trace Gases In Situ. In addition, both the MOHp and the DWD's other research institute, the Lindenberg Meteorological Observatory – Richard Assmann Observatory (MOL-RAO), also act as observation stations for aerosol (in-situ and remote sensing), reactive trace gases (MOHp) and clouds (MOL-RAO). The ACTRIS tasks thus constitute a further permanent addition to the observatories' wide-ranging observation programmes.

below
The two meteorological observatories of the DWD on Mount Hoher Peissenberg (right) and in Lindenberg (left) are part of the network of the European Research Infrastructure ACTRIS.



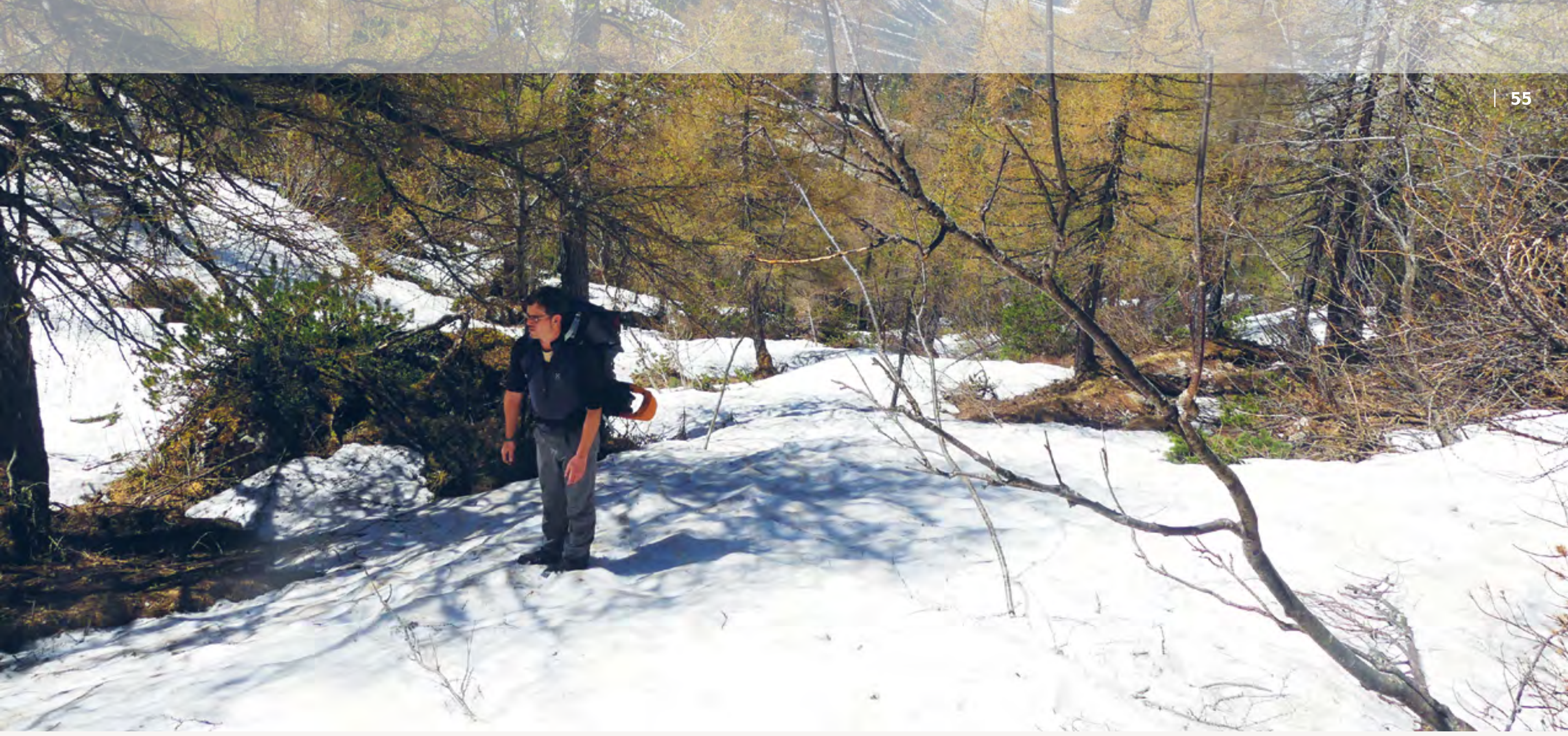
top
Time series of Doppler-Lidar wind measurements at a height of around 90 m. The measurements were taken on 29 June 2021 at the three sites of Falkenberg (blue), Birkholz (yellow) and Lindenberg (green), all located at a distance of around 5 km from each other. The curves show a sharp increase in the mean wind speed (top) and maximum gusts (bottom) during the cold pool event 'Jogi' at around 14 UTC.

Tracking small-scale weather events

The weather is warm and sunny, then suddenly a thunderstorm strikes, the air cools down considerably and strong gusts of wind occur. But a few minutes later, the whole thing is over and the sun is shining again, with hardly any wind blowing. Most of the time, such an event affects only a very small area, yet it can still cause major damage. Current surface measurement systems are not yet able to detect this type of weather events. In order to explore such phenomena and improve the forecasting of them, a major measurement campaign took place at the Meteorological Observatory Lindenberg – Richard Assmann Observatory (MOL-RAO) between May and the end of August 2021. It was carried out by the DWD and several other partners following an initiative of the Hans Ertel Centre for Weather Research (HErZ). The campaign had originally been scheduled for 2020, but was postponed by a year due to the coronavirus pandemic.

A particular feature of this campaign, which is known as FESSTVaL (**F**ield **E**xperiment on **S**ubmesoscale **S**patio-**T**emporal **Va**riability in **L**indenberg), was the high density of the near-surface measurements, with around 80 stations for air temperature and air pressure, 20 small weather stations, 10 Doppler lidar systems for measuring wind profiles and turbulence variables up to an altitude of several kilometres, as well as several remote-controlled small aeroplanes and drones. In addition, a citizen measurement network was set up specifically for this campaign, with data collected by around 70 self-designed weather stations, all assembled out of components 3D-printed at the Freie Universität Berlin (FU). The stations were put together, set up and maintained by committed citizens in the area around the observatory.

The measurements to record the physical processes took place at high density within a radius of 20 km around the MOL-RAO; the distances between the individual measuring sites varied from ten metres to several kilometres. In the context of convection and thunderstorms, the scientists' main focus of attention was on the structures prevailing in the atmospheric boundary layer up to 1–2 km as well as on cold pools and wind gusts. The findings from the campaign will, among other things, help to improve the representation of such small-scale processes in numerical prediction models.



top
Climb to DWD measurement stations across a snow field: Oliver Nitsche carries his snowshoes with him, which he will need for reaching the stations at higher altitudes.

right
The eight ‘streamline’ Doppler-Lidar systems used for FESSTVal on the Falkenberg boundary layer field

So far, the following conclusions were drawn from the campaign: it was possible to observe phenomena and record extensive data sets related to all thematic areas (cold pools, wind gusts, convective structures). A central goal was to identify the same events in the different data sets and thus be able to provide comprehensive descriptions from different viewpoints. The first data were used for model calculations with the DWD weather forecasting system ICON even while the campaign was still ongoing. The FESSTVaL campaign was complemented by online lectures on the campaign’s key topics and the newly deployed measurement techniques. The lectures were held every Monday and received a great response from the scientific community, both nationally and internationally. The scientific analysis of the data is still ongoing.

Further information about the campaign is available at www.hans-ertel-zentrum.de and https://fesstval.de.

In addition to the DWD, the following partners took part in FESSTVaL:

- Max Planck Institutes for Meteorology (MPI-M) in Hamburg and for Human Development (MPIB) in Berlin
- Universities of Berlin (FU, TU), Bonn, Frankfurt am Main, Hamburg, Hamburg-Harburg (TU), Cologne and Tübingen
- Campus Alpin of the Karlsruhe Institute of Technology (KIT)
- German Aerospace Center (DLR), Oberpfaffenhofen
- Helmholtz Centre for Environmental Research (UFZ) in Leipzig
- Wageningen University (Netherlands)
- Finnish Meteorological Institute (FMI) in Helsinki (Finland)
- Companies METEK GmbH (Elmshorn, Germany) and LRTech Inc. (Canada)

World Meteorological Organization (WMO)

The objective of the WMO's reform started in 2019 was to take decisions more quickly. This has now been implemented for the first time: decisions that had been prepared over the past two years could be discussed as early as at the Extraordinary Congress in October 2021. At this session, which was directed by DWD and WMO President Prof. Dr Gerhard Adrian and which was the first to be held virtually, it was even possible to already adopt three major WMO initiatives, all interconnected with each other: the Global Basic Observation Network (GBON), which will define new standards for surface-based climate and weather observation; the WMO Unified Data Policy for the international exchange of Earth system data; and the closely related Systematic Observations Financing Facility (SOFF), which aims to reduce capacity deficits with regard to weather observation in developing countries.

The data policy resolution relates to one of the WMO's core tasks and therefore has been one of the most important projects for decades. It is intended to ensure, expand and further enhance the free and unrestricted exchange of Earth system data. GBON forms part of the new WMO data policy and mainly aims to improve both the temporal and spatial resolution of surface-based observations. SOFF's part is to support implementation of the policy as well as the monitoring of it by providing financial and, above all, sustainable assistance. At first, this will benefit only the least developed countries.

below
Conversion work at the former DWD station in St. Bartholomä on Lake Königsee. In the meantime, this station has been relocated from the marsh area to the information point of Berchtesgaden National Park in St. Bartholomä (616 m) for nature conservation reasons.

right
From left to right: Viktor Haase (Head of Sustainable Development, Climate Change and Green Finance at the Ministry for Environment of North Rhine-Westphalia), Dr Daniel Gellens (President of ECMWF Council), Dr Florence Rabier (Director-General of ECMWF), Prof. Dr Gerhard Adrian (DWD and WMO President), Dr Ursula Sautter (Lady Mayoress of the city of Bonn)

European Centre for Medium-Range Weather Forecasts (ECMWF)

At its meeting in December 2020, the ECMWF Council chose Bonn as its third location in addition to Reading and Bologna. The focus of the ECMWF's work in Bonn is on the tasks assumed by the Centre under the Copernicus Earth observation programme of the European Union (EU), the Destination Earth initiative and other EU-funded projects.

Whilst the ECMWF headquarters remain in the UK, the first ECMWF staff members started their work in Bonn in August 2021, accommodated in temporary offices at the premises of the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV). A new and permanent ECMWF building will be constructed in Bonn's international quarter and is scheduled to become available by the end of 2026. The new facility in Germany's former capital city will provide the ECMWF with a very favourable location for close collaboration with scientific institutions in the surrounding region and anywhere else in Germany. The ECMWF will in particular collaborate with the Center for Earth System Observations and Computational analysis (CESOC), which incorporates the research activities conducted at the Universities of Bonn and Cologne and at the Forschungszentrum Jülich.

The formal opening of the ECMWF's new, albeit interim, offices in Bonn took place on 13 September 2021 in the presence of high representatives of the ECMWF, the Federal Ministry for Digital and Transport (BMDV) and the DWD. The ECMWF's new data centre in Bologna, Italy, was formally opened a day later on 14 September 2021.

On 22 July 2021, the ECMWF and the European Commission signed an agreement to continue the services run by the ECMWF on behalf of the Copernicus Earth observation programme. Accordingly, the ECMWF will continue operating the Copernicus Climate Change Service (C3S) and the Atmosphere Monitoring Service (CAMS) for another seven years. At the end of last year, the ECMWF Council also decided to take part in the EU's Destination Earth programme.

An important activity of the ECMWF in the context of Copernicus is the Copernicus Emergency Management Service (CEMS). In 2021, a contract was signed agreeing that the ECMWF, as a 24/7 operational centre for flood forecasting, will continue to be responsible for the provision of hydrological probabilistic forecasts for a further six years until 2027. The European Flood Awareness System (EFAS) and its global counterpart GloFAS form the core of the flood information services of the early warning and monitoring component of CEMS.

At the beginning of 2021, the ECMWF started implementing its Strategy 2021–2030. Basic elements of the strategy include the increasing use of cloud technologies, the continuing move to open data and the provision of increasingly better predictions (for example ensemble predictions at a resolution of three to four kilometres).

The annual bilateral talks between ECMWF and DWD took place as a video conference on 12 November 2021. The topics covered a wide range from the flood disaster in western Germany in the summer of 2021 through to EU activities and concrete ECMWF-DWD collaboration projects.

European Union

The participation of the key partners ECMWF, EUMETSAT and ESA in the implementation of the Copernicus programme was also decided for the second programme phase until 2027. In this context, the DWD will continue to provide significant contractual contributions for both the Climate Change and the Atmosphere Monitoring services (C3S and CAMS) as well as for the early flood warning component of the Emergency Management Service (CEMS).

A new and – in the view of the DWD – outstanding programme is the Destination Earth initiative, which is aimed to create a highly accurate digital model of the Earth in order to better investigate the impacts of climate change and extreme weather events. The negotiations with the key partners were difficult as the status of Switzerland and Great Britain regarding contracts for EU-funded projects still remains unclear. However, it has finally been possible to secure the indispensable participation of ECMWF, EUMETSAT and ESA as key partners for implementing the Destination Earth initiative.

Bilateral co-operation

The DWD is part of an excellent network and closely co-operates with other national meteorological services, in particular those in Europe. The main focus here is on the exchange of information about the latest developments within the services and on the partners' strategic and political views regarding the work of international organisations. After cancellation of all meetings in 2020 due to the COVID19 pandemic, these valuable negotiations could be resumed in 2021.

For many years, great significance has been attached to the exchange between the three large partners Météo-France, UK Met Office and DWD. The talks usually cover topics such as high-performance computers, Destination Earth, use of artificial intelligence in the meteorological community and the possibilities of the European Weather Cloud. Another important topic in 2021 was the question of how the national meteorological services can ensure the delivery of their operational services in times of a pandemic.

Besides the triennial exchange with the South Korean National Meteorological Service KMA, which was held virtually in 2021, it was possible again to hold the annual trilateral D-A-CH meeting at directors' level with MeteoSwiss and the Austrian meteorological service ZAMG as well as the bilateral meeting with MeteoSwiss alone. The D-A-CH meeting mainly dealt with the work of international organisations with a special focus on Destination Earth and the influence of the European Union on the future of ECMWF, EUMETSAT and EUMETNET. The meeting also confirmed the parties' mutual interest in continuing their close co-operation in the field of numerical weather prediction. Plans were made for collaborating on improvements to existing warning chains (in the aftermath of the severe weather events in summer 2021) and the modernisation of the warning systems. The bilateral meeting with MeteoSwiss focussed on the close collaboration between the two services, for example in the field of aviation, but also in the context of the further development of the ICON model and the progress made with the DWD's **S**eamless **IN**tegrated **FO**re-casti**N**g s**Y**stem SINFONY.

top left
DWD measuring station in the Funtensee Valley in autumn with the Kärlingerhaus hut in the background

top right
Detail view of the sign at the DWD's measuring station Funtensee-Tal, informing about the climate measurements taken there

Schedule for the launch of satellites for mandatory programmes:

Programmes	Scheduled launch
MTG (Meteosat Third Generation)	MTG-I 1: Q4 2022 MTG-S 1: Q1 2024
EPS-SG (EUMETSAT-Polar System Second Generation)	Metop-SG A1: Q1 2024 Metop-SG B1: Q1 2025

EUMETSAT

The development of the next generation of meteorological satellites for mandatory programmes in geostationary and polar orbits is nearing its end (see launch schedule). Generally, the development of 'big data services' based on innovative cloud technology receives a great deal of attention and is encouraged by considerable investments. One example is the operational launch of the European Weather Cloud (EWC), which was agreed and scheduled to be completed by mid-2022.

After six months of evaluation, the provision of purchased radio occultation data will enter into operational service. This decision was taken after intensive discussion of technical and data policy aspects with the aim of preserving the WMO principle of free international exchange of data by means of suitable licensing models.

An era ended at the same time as the 99th meeting of the EUMETSAT Council: EUMETSAT's first polar-orbiting satellite Metop-A was successfully taken out of service. According to international standards, a complex series of manoeuvres is required for space debris mitigation. This manoeuvre, known as deorbiting, ensures that the satellite descends in a controlled manner over a period of around 19 years until it disintegrates upon re-entering the Earth's atmosphere. Nearly half of the total amount of fuel needed to power a polar-orbiting satellite for its expected lifetime of 15 years is required for this procedure. As part of the manoeuvre, the satellite performed a 'backflip', which allowed the instruments to look into deep space and gather a set of data that may later allow for a valuable correction of the usual atmosphere observations.

Development co-operation activities at the DWD

The goals of the PrAda project 'Adaptation of agricultural value chains to climate change in Madagascar', jointly led with the Gesellschaft für Internationale Zusammenarbeit (GIZ), were achieved by the end of 2020/beginning of 2021. The overarching objective of this project was to improve the accuracy of the climate services for the agricultural sector in Madagascar. The DWD's key partner on the ground was the country's national meteorological service, Direction Générale de la Météorologie (DGM). Completing the work packages and achieving the project results were of great scientific interest to both the Madagascan meteorological service and the DWD. A particular success was the integration of the DWD's agrometeorological model AMBAV_global into the DGM's working procedures. In future, the DGM in Madagascar will be able to use the model independently and possibly develop it further. At the beginning of 2021, a comprehensive article and a fact sheet containing the most important information about the project were published in the WMO newsletter MeteoWorld.

In February 2021, the DWD presented the Honorary Consul of the Republic of Cameroon of Hamburg with a set of historical weather data digitised at the DWD. The data, together with descriptive documents, were then forwarded by diplomatic pouch via the Cameroon Embassy in Berlin to the President of Cameroon's national meteorological service.

After the Systematic Observations Financing Facility (SOFF) had been adopted at the Extraordinary WMO Congress, the WMO, the United Nations Development Programme (UNDP) and the United Nations Environment Programme (UNEP) signed an agreement with which they jointly established SOFF as a United Nations Multi Partner Trust Fund (UNMPTF). SOFF UNMPTF aims to collect funds from various bi- and multilateral public and private sources in order to build up and operate a sustained network and infrastructure for meteorological observation in developing countries.

Furthermore, the DWD is involved in the project 'Water Security in Africa – WASA', which is funded by the Federal Ministry of Education and Research (BMBF) and led by the Karlsruhe Institute of Technology (KIT). Another activity with contributions by the DWD is the project 'Co-design of a hydrometeorological information system for sustainable water resources management in southern Africa' (CO-HYDIM-SA). The project aims to improve fresh and wastewater services in Africa and is part of the BMBF strategy 'Research for Sustainability – FONA".

Network of European Meteorological Services (EUMETNET)

By adopting a common, co-ordinated strategy up to 2025, the European meteorological services have agreed to work together as a co-operative and complementary network. Their goal is to provide society with scientifically sound, high-quality and innovative data, information, products and services regarding weather, water and climate.

The strategy was signed by the meteorological services united in EUMETNET in May 2021 with a view to engage in further projects. These include, for example, the setting up a regional data management network, which, based on cloud infrastructures, will allow for an optimised exchange of data. The work will be done in accordance with the requirements of the WMO's data policy. In addition, there are plans to set up a technical environment for ensuring free and open sharing of high-quality meteorological data sets as required by the Open Data Directive of the European Union.

Transformation to open access publishing in Germany and how this is implemented at the DWD library

As digitalisation progresses, more and more new fields of action emerge in the context of open science, which all share one major aim: the promotion of free access to scientific research processes and easy re-use of scientific findings.

The worldwide initiative for the transformation of scientific publishing plays an important role in the movement towards open access as it aims to facilitate the free and unrestricted use of scientific publications and all the findings they contain.

By signing the 'Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities', the DWD committed itself already in 2016 to actively support open access publishing. Pursuant to this commitment, the German National Meteorological Library at the DWD, like many of its counterparts, participates in open access initiatives such as the 'Publish and Read' agreement of the Alliance of Science Organisations in Germany. So far, such deals have been agreed with two large commercial publishing houses, namely Wiley and Springer. They not only include agreements on the use of the publishers' extensive portfolios of journals but also offer a simplified process for the participating institutions to engage in open access publishing.

The library of the DWD, which is the largest specialist libraries for meteorology in Germany, not only encourages open access publishing at the DWD but also supports the scientists in all branches of the DWD during the entire publication process. Among other things, this includes the DWD's subscription for accessing the citation database Scopus and the provision of advice and support to users about how to handle literature databases specific to a certain task. The library also conducts individual bibliometric analyses that are required in connection with surveys and project proposals for third party research projects, and manages the entire publication budget of the DWD.

Another topic that is becoming increasingly important in the context of open science is the structured management of research data, the aims of which include offering easy and standardised access to referenced research data while taking account of the so-called FAIR principles. In future, the DWD will attach increasing importance to the question and optimise and expand the existing infrastructure and all related processes. The National Meteorological Library sees new areas of work in this context and will contribute to them in a supporting and co-ordinating role.

top
Deposition collectors for measuring organic air pollutants at the Schneefernerhaus environmental research station

Introduction of an environmental management system

Germany aims to be fully climate neutral by 2045. To achieve this, the Federal Administration must lead by example, which is why the Federal Government has started a restructuring programme to reach its climate neutrality by 2030. Besides the Federal Railway Authority (EBA) and the Federal Agency for Administrative Services (BAV), the Deutscher Wetterdienst is one of the first authorities under the Federal Ministry for Digital and Transport (BMDV) to have committed itself to implementing an environmental management system according to the European Eco-Management and Audit Scheme (EMAS). The aim is to obtain the corresponding certification by March 2023.

EMAS is the world's most demanding environmental management system. This instrument developed by the EU helps organisations in finding intelligent ways to save resources and contribute effectively to environmental protection, to reduce costs and to assume social responsibility for their actions. EMAS ensures that all environmental aspects from energy consumption to waste management and emissions are dealt with in a legally safe and transparent manner. The continuous improvement process started by an organisation will ultimately lead to an improvement of its energy efficiency and thus to a reduction in the carbon footprint.

In order to prepare for the certification and deal with other environmental aspects in a forward-looking manner, two new bodies were formed at the DWD: the 'Environment Team', which acts as a working group for environmental issues, and the 'Environment Board' as the steering and decision-taking body. When these bodies were established, an important condition was that they include members from all branches of the DWD in order to cover the whole range of topics concerned by the introduction of the environmental management system. One of the first tasks of the bodies' joint work was the definition of the guidelines for the DWD's future Environment Policy. The resulting rules stipulate that environmental protection and sustainability be a key foundation for action in the DWD's various fields of activity. Their approval by the Executive Board of the DWD marked the next significant step towards the future and set a clear signal in favour of climate and environment protection.

top left
Measurement instruments on the platform of the DWD's weather station on the Zugspitze

top right
Profile and snow sampling at the measuring field on the Zugspitz Plateau

Leadership and management development – an important building block for tomorrow's success

As the cycles of technological and technical innovation, structural changes and digitalisation are getting shorter and shorter, both staff and management are faced with challenging demands. The DWD addresses the concerns and needs of managers individually by using instruments for targeted human resources development.

With its various facets, the DWD Mentoring Programme for managers and junior managers aims to support interested employees with management potential in their development for a leadership position. The mentoring programme runs for twelve months and includes exchanges between the mentee and the mentor as well as an accompanying guidance programme. Furthermore, a Cross Mentoring Programme for Women, run in co-operation with the DWD's Equal Opportunities Officer, has been offered on a regular basis since 2018 to women in first-line positions of the higher intermediate or the higher civil service. In this programme, the mentoring pairs are formed between participants from public authorities and companies in the region.

Staff members in leadership positions in the higher intermediate or the higher civil service are facing challenging demands, especially when they take on leadership functions for the first time. To address these challenges, a dedicated seminar cycle 'Management in compact' has been set up. This 10-day seminar covers the key knowledge and skills needed for line management as well as for the management of an organisational unit.

Another element of the DWD's management culture is the Leadership and Management Conference, known as FÜKO, which was initiated in 2007 and now takes place every two years. Due to the pandemic, the 2021 conference was held entirely virtually, transmitted from a studio in Offenbach to the DWD's leaders anywhere in Germany. A key part of the conference is generally dedicated to discussing the DWD Strategy and the DWD's mission and vision. Other equally important topics are the latest trends and the challenges faced by the DWD, such as new working practices, digital transformation and innovation.

The foundation of all management development instruments consists in a common understanding of leadership and management with a clear role and requirements profile. To achieve this, the leadership competence model was revised last year and adapted to new requirements to reflect a contemporary understanding of leadership and management. The new concept not only includes traditional line management skills but also approaches to co-operative and goal-oriented management as well as competence characteristics such as agility, flexibility, digital competence and innovation capability.

All these instruments help to put line management at the heart of leadership and management development. Good leadership and management development is of great importance to enable both the staff members and the DWD as a whole to succeed in the upcoming transformation of the world or work.

Interview

right
Maintenance work at the automatic climate station next to the Watzmannhaus hut, Berchtesgaden National Park

“We want to set an example”

At its Annual General Meeting in October 2021, the German Alpine Club (DAV) decided to be climate neutral by 2030. In the following interview, DAV President Josef Klenner explains, among other things, how the DAV intends to achieve this goal.

DWD:
Preservation of the Alps is the DAV’s top priority. The club finds itself in a balancing act between protecting nature, in particular in the Alps, on the one hand and promoting mountain sports on the other. At the same time, there are many economic interests to consider in connection with the Alps, such as tourism. How do you manage to reconcile these conflicting topics with one another?

Josef Klenner:
Of course, this is always a difficult venture, but it should not lead us to trying to please everybody. In certain areas of the Alps, protecting the natural environment clearly overrides exploiting it. For example, protected areas of tranquillity as well as Natura 2000 areas should remain untouched by plans to expand tourism infrastructures. This is our position which we advocate unambiguously – and which we also communicate to our members. The same applies to our expectation that mountaineers behave in a way respectful to nature. What this means is at the heart of our training courses in the various areas, whether for summer or winter activities.

DWD:
The German Alpine Club has around 1.4 million members. What are the chances that all these people will share your commitment, embark on climate protection and even become passionate about it?

Josef Klenner:
This is the greatest challenge which not only the German Alpine Club but also society as a whole has to deal with today. Climate change has advanced so much that it is clearly visible. And it will continue to proceed unless active measures are taken. We as the DAV do act in a very concrete way: at our general meeting, we discussed a climate protection programme and almost ninety per cent of the section chairs supported its adoption. It means that we want to take action now. Our goal is clearly defined: we as the DAV want to be climate neutral by 2030. Accordingly, concrete CO_2 reduction measures were adopted at the general meeting – especially regarding mobility, infrastructure and the supply of food and drink. For this, we are making money available, which we raise from our own resources by means of an internal CO_2 price. This is a novelty in the German association landscape and constitutes a unique approach so far. So, what we do goes beyond the stage of simply demanding action. We are prepared to do something ourselves. Adopting the programme in October 2021 was a landmark decision. With it, we want to set an example, motivate everyone around us to strive for maximum success – not only internally in our own organisation but also beyond it, with the aim of igniting a spark in people.

left

Josef Klenner, President of the German Alpine Club

DWD:
Have you already received any feedback on this?

Josef Klenner:
We received remarkable interest from the media, as the approach we have chosen follows a completely new path. Our members' response is mostly positive. Of course, there has also been some criticism, but not of the sort that doubts or denies climate change. In summary, the critical voices reason that a single individual, after all, cannot achieve so much, given the fact that Germany is responsible for “only” two per cent of global total emissions. Of course, if we apportion this to the DAV and its 1.4 million members, which is around one eightieth of the German population, and from there to the individual members of our association, the resulting figures are marginal. But I believe that this is not how one should approach the problem. What needs to be done is simply to get started, and this has been our guiding principle for two years now. This strategic direction was already adopted in 2019 when the DAV celebrated its 150^{th} anniversary; we have now filled it with contents and will make sure for it to be implemented.

DWD:
You reach many people at different levels. Do you see any encouraging signs that people are really serious about taking action against climate change, action that may possibly affect them at very personal level?

Josef Klenner:
We have drawn up a list of measures covering a range of different topics. A large part deals with mobility. People who participate in club life or go to the mountains usually use their own car. But as we all know, transport is one of the highest contributors to CO_2 emissions. This is why we are developing strategies to offer many of these activities in a way that allows better use of public transport. Another part concerns climbing gyms and mountain huts operated by the DAV and its various sections. The question here is how to optimise operations, save energy and reduce emissions, and this not only regarding the use of the facilities but also with respect to investments. It is about solar photovoltaic and wind power systems, about best possible insulation, but also about the discussion around how much luxury is actually needed in a mountain hut. The DAV has a support system in place for this. The federal DAV association assumes part of the financial burden, especially in relation to construction and renovation work. The main burden, however, rests with the individual sections of the DAV who are the owners of the huts and climbing gyms.

DWD:
As an Alpine association you are very close to the situation in the Alps and can recognize changes, including those caused by climate change. What is the future of the DAV huts in the high mountains?

Josef Klenner:
Climate change is particularly evident in the mountains, at higher altitudes and in the glacier areas, and this has been the case for many years – but increasingly more so over the past five to ten years. We are witnessing a massive retreat of glaciers, an increased risk of rockfalls, and certain tour paths are no longer accessible. Another issue that affects the operation of huts enormously is the issue of water availability. Severe weather causes tremendous damage, to the huts and to the roads and paths. These are no short-term weather events but signs of climate change. There is a very striking example: six years ago, we had to shut a hut at 2,885 m altitude in the Ötztal Alps. Melting permafrost has led to cracks appearing in the walls and we can no longer open the hut because of the risk of collapse. We have not yet found a solution to this problem.

DWD:
You offer a great deal of information, for example exhibitions or workshops on climate change. How has this offer been received so far and do you see any changes in the way the Alps are now 'exploited'?

Josef Klenner:
The situation we are in is somewhat ambivalent. Of course, most of the inquiries reaching us are about the desire of many members to spend their holidays in the mountains, to hike or climb, to ascend the mountains. But we also see a slow increase in the number of other inquires with questions that relate to the protection of nature, of the Alps, or to the development of tourism – the new German word in this context is 'overtourism'. This shows us that our members are beginning to engage with these issues. Still, as far as climate protection measures are concerned, we are not yet able to report much on developments because we have only just started.

However, we must also realize that personal concerns about climate change in the Alps decrease with the distance from the mountains. The problem is not so much with the huts, as we have already done a great deal to reduce their CO_2 emissions. One example I am thinking of is that we started to use solar power at a very early stage. A large majority of the DAV huts in the high mountains are fitted with a photovoltaic installation for electricity generation. Our members will see from the mobility concepts that, in future, travel to and from places may only be possible by train or by group or shared rides. But as I said before, we have only just started.

It is also important to me – which is a known fact – that the DAV's position concerning these issues is consolidated and advocated. A prime example is the Riedberger Horn area. In the more than five years of discussions about this development project, the DAV clearly objected to the construction of new ski lifts and ski pistes because of the resulting interference with special conservation areas and counter-running of the 'Alpenplan' protection scheme adopted by the Bavarian state government several decades ago. There are other projects in the Alps, such as the current development plan for the Grünten im Allgäu area. Our concern there, as anywhere else, is not so much about preventing or criticising. Instead, we are committed to design projects in a way that achieves better harmony with nature.

DWD:
Let us talk about climate communication: sometimes scientists find it difficult to communicate content in a comprehensible way. What could scientists learn from the DAV for their communication, taking the motto 'We love the mountains, we protect nature' as an example.

Josef Klenner:
Citing the leitmotif alone is certainly not sufficient. We regularly communicate with our members via the association magazine Panorama, where we take up climate topics that are relevant to us. Following our decision of last October to be climate neutral by 2030, we will expand and intensify our efforts in this respect even more. We are currently setting up an information platform on our website, through which members can actively communicate and interact with one another. Climate change and the fight against it will become part of our training programmes for volunteers and for specialised trainers and instructors. Including this as a standard component into our training activities will have a huge multiplying effect. And, of course, we will continue to offer and organise even more information events and exhibitions.

DWD:
Regarding preservation of the Alps, how do you co-operate with partners, including activities across the borders?

Josef Klenner:
The co-operation with international partners, especially our direct neighbours, works very well. This is particularly true for the Austrian Alpine Club (ÖAV), with whom we share a common history as we were joined in one single club from 1874 until shortly after the end of the Second World War. We work closely together on all key issues regarding our huts and paths in Austria or in South Tyrol.

There is also good collaboration with the organisations and contact persons in the other Alpine countries, at the European level and also with the International Federation. We exchange information with them promptly and co-ordinate measures. But one must understand and recognize that the larger the geographical dimensions the more difficult is the co-ordination process.

Facts and figures about the German Alpine Club[1]

- Founded on 9 May 1869
- 1,402,067 members (as of 31.12.2021)
- 356 regional clubs referred to as ‘sections’ all over Germany, plus two foundations
- 323 publicly accessible mountain huts and refuges in the Alps and German low mountain ranges, with
  - around 20,000 sleeping places
  - around 2 million day visitors per year
  - around 890,000 overnight stays per year
- 30,000 km of paths and climbing routes (50,000 km together with the Austrian Alpine Club, ÖAV)
- 220 climbing centres with a total of 200,000 m² of climbing surface (including bouldering walls)
- Around 22,500 volunteer DAV-trained tour guides and instructors for all types of mountain sports as well as child, youth and family services
- Around 30.35 million euros per year of economic value added by volunteer work

[1] Status: 31 December 2021

DWD:
Speaking of international co-operation, the DAV also organizes international travels, trekking tours in the Himalayas and similar activities. What happens here with respect to climate change?

Josef Klenner:
With the DAV Summit Club, the DAV has a subsidiary that operates as a tour agency. The DAV’s resolution to be climate neutral by 2030 also applies to the DAV Summit Club. This is part of our consistent approach to climate change and to what we can do to tackle it. The DAV Summit Club has already begun to change destinations, identify new ones, develop climate-friendly travel options, review the choice of partners and initiate further measures so that we can jointly achieve the goal by 2030.

DWD:
How important are weather forecasts for you and how much do you rely on them?

Josef Klenner:
For mountaineers, reliable weather forecasts are of vital importance because, without them, modern risk management in the mountains is impossible. In the mountains, weather information is an important element when deciding on the course of the day. This is certainly different in the city. Of course, weather forecasts also play a role there, but I don’t think they are as essential as they are in the mountains. If I am cycling in the city and get wet, this does not automatically put me at risk, as it might be the case in the mountains.

DWD:
Let me conclude with a very personal question: what has been your most important ‘summit experience’ so far?

Josef Klenner:
In the course of my life, I have undertaken numerous mountain tours and have experienced very beautiful and eventful moments. However, some tours in recent years have stood out, tours during which I was confronted with the destruction of nature. This summer, in particular, a tour in the Stubai Alps showed me once again the urgency of the situation. Another example is a very unspectacular tour I undertook to the Riedberger Horn. My impressions during these tours have considerably spurred on my work in favour of climate protection.

DWD:
Thank you very much for the interview and the insights you have shared with us.

Finale

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Automatic climate station of the Bavarian Avalanche Warning Service in the Kühroint pasture of the Berchtesgaden National Park

Annual productivity and performance figures

Around **90,000** forecasts and **220,000** weather and severe weather warnings

8,760 automated road weather forecasts for winter maintenance services with some 200 million page views on the SWIS winter services portal

Around **1.3 billion** page views on the FeWIS disaster management portal; provision of more than **30** terabytes of data for disaster situation assessment

Distribution of around **1.96 billion** push messages (warnings) through the DWD WarnWetter app for weather warnings

About **1.3 million** weather observations transmitted by users to the forecasting service through the DWD WarnWetter app

Around **560,000** forecasts and warnings for aviation

Around **27,000** telephone briefings for aviation

Provision of self-briefing systems for civil aviation, aerodromes/airports and air services providers (some **360 million** page views)

Around **240,000** reports, warnings and advisory services for maritime shipping, coastal protection and offshore projects

Provision of some **500** expert reports on weather and climate for public authorities, disaster control units and other customers

Provision of over **23,000** products for climate monitoring

DWD sites throughout Germany

Headquarters in Offenbach am Main

6 main branch offices (Hamburg, Potsdam, Leipzig, Essen, Stuttgart, Munich), partly with more than 100 staff members

5 regional climate and environment consultancy offices

1 Aeronautical Meteorological Centre (Frankfurt) and

4 Aeronautical Meteorological (MET) Advisory Centres

2 meteorological observatories

3 agrometeorological advisory offices

180 main weather observation sites

165 fully automatic weather stations **15** staffed aeronautical meteorological stations at international airports

Aeronautical meteorological observation at **26** regional airports

1.734 secondary weather and precipitation stations, of which **836** are online stations reporting every half-hour

1.065 phenological observation sites

About **1.900** road weather stations in partner networks with automatic quality assurance every 15 minutes

2 staffed main weather stations aboard research ships

125 shipborne automatic weather stations

391 hips at sea participating in the WMO Voluntary Observing Ships (VOS) programme

5 moored buoys in the North and Baltic Seas

10 automated shipboard aerological stations

18 weather radar sites in Germany

10 upper-air stations with some 7,500 radiosonde launches per year

48 stations where radioactivity is measured

Mobile measuring unit at **3** sites

9 automatic greenhouse gas measuring stations at high towers

1 special air mission unit for radioactivity and volcanic ash measurements

Figures relating to the DWD's budget

DWD costs each citizen 4.46 euros per year

The DWD's budget in 2021 amounted to close to 388 million euros, which was over 9 million euros more than in the previous year. The actual requirement for public funds, however, was much lower than that due to the fact that 4.3 per cent of the overall budget were indirectly covered by revenues. Compared to the previous year, the DWD's requirement for public funds increased by around 13.8 million euros in 2021. This means that every citizen in Germany [number of inhabitants at the end of September 2021: 83.222 million; source: Federal Statistical Office] had to pay 4.46 euros for public or statutory tasks such as weather forecasting, severe weather warnings and climate monitoring. The main reasons for the increased requirement for public funds was the higher amount of subsidies for international organisations (overall around 14.1 million euros more shared between ESA (about 12.7 million more) and EUMETSAT (about 1.4 million more). At the same time, the DWD's revenues, which are not ascribed to the DWD but to the federal budget, dropped by another 4.4 million euros.

The DWD total budget amounted to:

2021	2020	2019	2018
around 388 million euros	around 379 million euros	around 370 million euros	around 343 million euros

Every citizen of Germany thus paid[1]:

2021	2020	2019	2018
4.46 €	4.30 €	4.12 €	3.82 €

In 2021, the DWD's expenditure was distributed as follows:

Appropriations/Subsidies (external funds not included):	Investments:	Expenditure on material:	Personnel:
168.857 million €	48.732 million €	48.227 million €	122.180 million €

In 2021, appropriations and subsidies went to the following organisations (external funds included):

EUMETSAT:	ESA:	ECMWF:	EUMETNET, WMO, others:
95.346 million €	55.854 million €	10.969 million €	17.470 million €

[1] According to estimates by the Federal Statistical Office: 83.222442 million inhabitants at the end of September 2021

Figures relating to the DWD's staff

Number of established posts:

2021	2020	2019	2018
2,143.0	2,156.5	2,171.0	2,178.5

Number of staff members[2]:

	2021		2020		2019		2018
Total	2,157		2,187		2,216		2,248
Men:	1,339	Men:	1,363	Men:	1,384	Men:	1,412
Women:	818	Women:	824	Women:	832	Women:	836

[2] The difference between the number of established posts and the total number of staff members is partly due to temporary or part-time employment.

… and some more facts from the DWD's daily routine

For the first time, more than **1 million weather observations at sea** were pooled by the Voluntary Observing Ships (VOS) programme of the World Meteorological Organization (WMO) and distributed as part of the global exchange of meteorological data coordinated by the WMO. This increase results from the growing number of Shipborne European Common Automatic Weather Stations (EUCAWS), which the DWD is currently installing aboard marine vessels.

On Mount Hoher Peissenberg, temperature measurements have taken place since 1781. According to findings by the DWD's Hohenpeissenberg Meteorological Observatory, **summer days** (> 25 °C) occur **six times** more often today than in earlier times. **Cold days** (< 10 °C) occur **three times less often**.

The weather patterns in February 2021 saw around **168,000 tonnes of Saharan sand** deposit over Germany. When looking at the larger area of Europe, North Africa and the North Atlantic, the figure was even some **14 million tonnes**.

Participation in some 50 large national and international climate and weather research projects

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169 scientific publications, of which 150 were published in international, peer-reviewed specialist journals

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Registration of 1,300 new heavy rain events in Germany (since 2001, the DWD has registered over 22,500 heavy rain events)

Provision of around 7.5 terabytes of archived weather and climate data (station data as well as gridded and reanalysis data), all freely available to the general public, public authorities, industry and research community (https://opendata.dwd.de/)

Around 500 terabytes of archived, freely available meteorological satellite data and satellite-based climate data

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Number of recorded satellite overflights: over 20,000

As the host of the Global Precipitation Climatology Centre, the DWD maintains and continuously extends the world's largest database of direct precipitation measurements from currently over 123,000 stations around the globe.

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The flying telescope

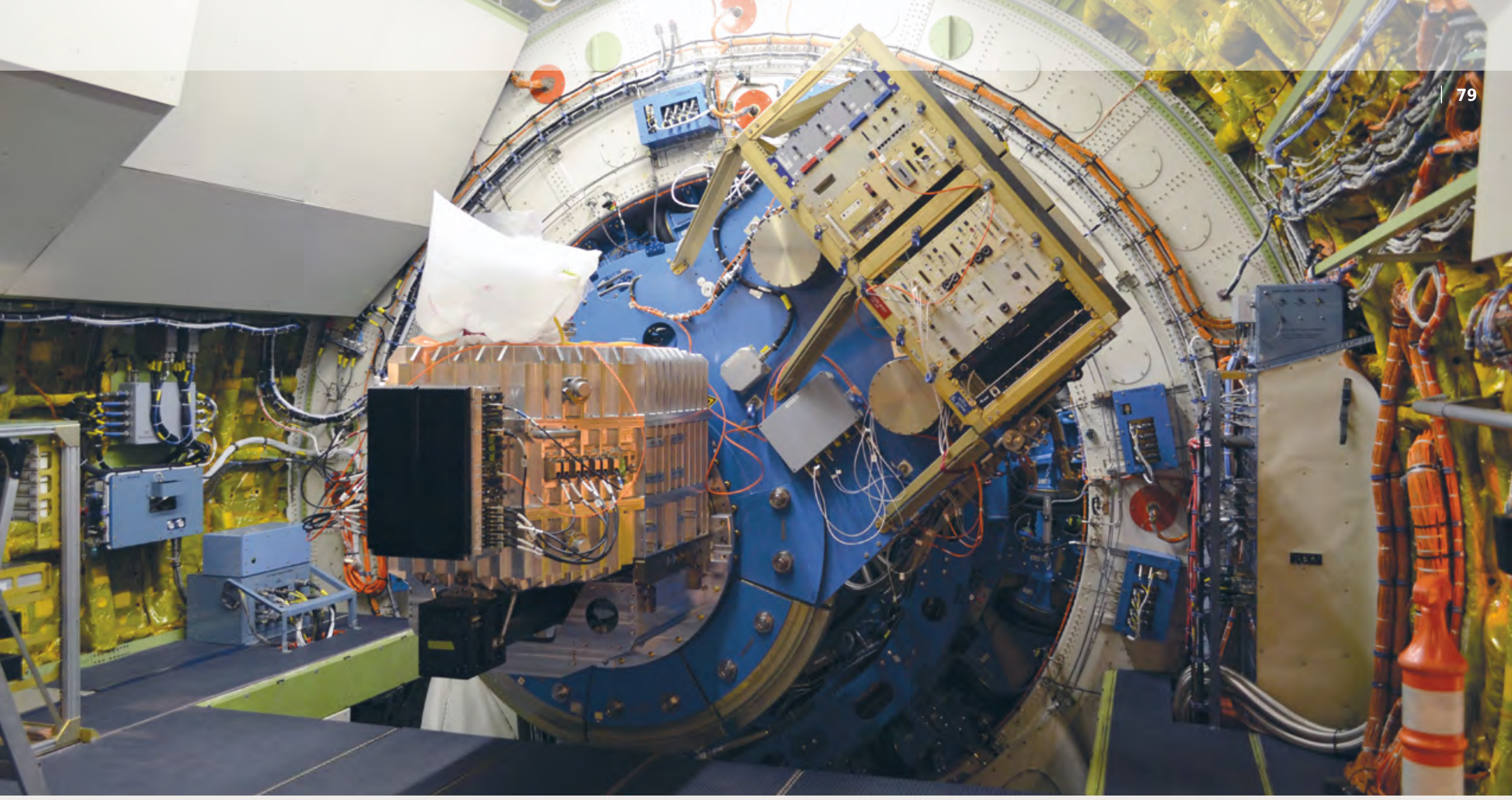
Last but not least:

Aeronautical meteorological consultancy for the flying telescope SOFIA

The acronym SOFIA stands for **S**tratospheric **O**bservatory **f**or **I**nfrared **A**stronomy and refers to a joint German-US space science project of the National Aeronautics and Space Administration (NASA) and the German Aerospace Centre (DLR). In February and March 2021, a modified Boeing 747SP took off around 20 times from Cologne/Bonn Airport for project missions. The DWD's Aeronautical Meteorological Centre at Frankfurt Airport supported these flights of SOFIA by providing weather forecasts and aeronautical meteorological briefings.

The jumbo jet is equipped with a 17-tonne telescope. The hatchway in the aircraft's fuselage behind the wing, large enough for a passenger car to fit through, is opened and remains open all through the 8-hour night flights at 11 to 14 km altitude – something a 'normal' aircraft should avoid at all costs. But this is how the Boeing aircraft transforms into a flying telescope. At an outside temperature of –40 °C to –65 °C in the stratosphere and a very low atmospheric pressure, the infrared telescope observes exoplanets, the emergence of new stars, the Milky Way as well as planets, moons, asteroids and comets of our solar system.

In fact, the research project could already prove the existence of water molecules on the moon, developed a more accurate method of determining the age of star-forming regions and measured the inside of the Milky Way. None of this would have been possible with a telescope based on the ground because the infrared radiation from space is partly absorbed by water vapour in the lower layer of the atmosphere (the troposphere). For the safety and successful completion of the missions, detailed and accurate planning is required.



top
View into the inside of the modified Boeing 747 with the remote infrared spectrometer

In winter conditions, the huge hatchway in the fuselage makes de-icing of the aircraft impossible, with the consequence that the aircraft cannot take off in snow or freezing-rain.

In addition, wind conditions with strong side or tail-wind components, thunderstorms and even dense fog often prevent the flights. Good conditions are not only required around Cologne/Bonn airport, but also along the route at chosen alternate aerodromes and significant points where the aircraft could fly to in an emergency. For this reason, the DWD provided point forecasts for a range of airports in Germany.

There is a high risk of dangerous aircraft icing especially during the climb and descent phases of a flight, mostly in compact clouds at temperatures between –5 °C and –20 °C. Turbulence, such as in frontal zones, can occur in all flight phases and require minute analysis and forecasting of the wind situation along the entire route. Even in winter, very high towering cumulonimbus clouds with thunderstorms may form along routes towards southern directions or towards the Atlantic. In the area around these hazardous weather zones, which may be hidden by surrounding clouds, lightning, hail, icing and extreme turbulence can occur. It is therefore very important for the crew to avoid such areas by flying around or, if possible, high above them. If possible, there should be no cirrus clouds (ice clouds in the upper level of the troposphere, but very rare in the stratosphere above the tropopause) above the aircraft while the telescope is in operation. When planning a flight, forecasts are therefore needed that indicate the altitude of the tropopause and whether it can be reached by the aircraft.

For producing the forecasts of the required meteorological parameters, the aeronautical meteorologists of the DWD used a series of different model predictions, compared and analysed them and then prepared up-to-date briefing documents for the crew. Before take-off, online briefings were held for the crew in English to explain the current weather situation and any particular conditions. Providing meteorological support for these missions was a very challenging, but also exciting and unique experience for the colleagues at Frankfurt Aeronautical Meteorological Centre.

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Contact, publishing details and source references

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Oliver Nitsche checking the DWD measuring station in the Funtensee Valley in summer 2020; the Kärlingerhaus hut can be seen in the background.

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Telephone +49 18 02 91 39 13

When calling the weather hotline you will automatically be connected with the closest DWD Branch Office.

[1] Availability and costs depending on foreign telephone provider

Further telephone- and service numbers
www.dwd.de/kontakt

Important links

Climate information
www.dwd.de/klima

Current weather
www.dwd.de/wetter

App for weather warnings
www.dwd.de/app

Information for journalists
www.dwd.de/presse

Newsletters
www.dwd.de/newsletter

Publications
www.dwd.de/bibliothek

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www.twitter.com/dwd_presse

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www.instagram.com/deutscherwetterdienst

www.pinterest.de/deutscherwetterdienst

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Cover
DWD measuring station in the middle of a butterbur field on the banks of Lake Grünsee in the Berchtesgaden National Park at 1,527 m. At this self-contained station, measurements of air temperature and air humidity have been taken without interruption since 2008. Oliver Nitsche of the DWD's mobile measuring unit visits the station twice a year for maintenance and to retrieve the data records – data that are a real treasure trove of value for studies into the Alpine climate. The retrieving job still needs to be done manually. In winter, the station cannot be accessed.

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