Deutscher Wetterdienst
Wetter und Klima aus einer Hand

DWD

19

Yearbook 2019

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 of Transport and Digital Infrastructure (BMVI), 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).

below

On their way to the lift of the radar tower: the technician team, Melanie Eickmeier, Serguei Laskovitch and Ladislav Hart, with the equipment they need for servicing the radar devices.

Facts and figures about Memmingen radar tower

Construction time
August 2009 – April 2010

Construction costs
approx. 1.5 million euros

Operational since
3 April 2013

Tower height AGL (without radome)
55 m

Tower height (above ground level including radome)
60.20 m

Foundation diameter
14 m

Diameter of the tower's shaft
5.20 m

Diameter of the radar's operating room
9.90 m

Diameter of radome
6 m

Number of steps
313

Photo series in the Yearbook 2019

The special photo series in the DWD Yearbook 2019 is dedicated to the Deutscher Wetterdienst's radar network. The photos at the beginning of each chapter were taken at and in the DWD radar tower near Memmingen during maintenance work for which the radar had to be taken out of operation. Such inspections and maintenance operations are planned long in advance, but still entail close coordination right up to the last minute between the Forecasting and Advisory Centre at DWD headquarters in Offenbach and the DWD's technical team in order to assess the current weather situation. This is necessary to check whether it is possible to do without the radar's measurements for a short period or whether maintenance has to be postponed.

Table of contents

Foreword

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

Dear readers,

For the first time since the beginning of systematic and nationwide weather recordings, maximum temperatures of more than 40 °C were measured on three consecutive days in 2019. At an average temperature of 10.3 °C, the year 2019, together with 2014, was the second warmest year ever in Germany. Nine of the ten warmest years in Germany occurred during the last 20 years. With these facts illustrating the sometimes remarkable weather events last year, I welcome you to the Yearbook 2019 of the Deutscher Wetterdienst. In the chapter 'Weather and Climate', you can read detailed information and analysis of the meteorological and climatological events in the course of 2019. We also included an overview of how the weather affected the agricultural sector, which was hit especially hard by the high temperatures, as well as a report on the strong snowfall in the Bavarian Alps at the beginning of the year – a contrast which couldn't be any greater.

An important milestone in 2019 was the release by our ministry of the DWD's new strategy for the period from 2020 to 2030. In ten strategic development lines, this document describes how the DWD can fulfil the requirements of its customers in an era of climate change and how we can also use the increasing digital–isation for the benefit of all. In addition to opportunities such as crowdsourcing or using weather information provided by vehicles, the DWD's radar network plays an important role in the acquisition of data. This is why the special photo series of this yearbook as well as the enclosed poster is dedicated to our radar network, one of the most important instruments for weather forecasting and warning management. The DWD in its role as national meteorological service operates the only radar network in Germany. The latest generation of radar devices, in use at the DWD since 2015, is not only capable of registering where and how much precipitation occurs, but its data also show whether it is rain, hail or snow. This makes the weather radar a crucial tool especially for forecasting the weather up to around two hours ahead, the so-called nowcasting. Small-scale thunderstorm cells can emerge within a matter of minutes and lead to heavy precipitation. This phenomenon occurs mainly in the summer and can only be detected extensively by weather radar. In addition to the 18 existing sites, the DWD aims to install radar stations in four more locations, thus improving the radar network's coverage even further.

Other development lines of the strategy deal with issues such as enhancing our climate and environmental services, intensifying national and international co-operation as well as implementing and updating the release policy for our data. In order to cope with the increasing data volume, we need innovative solutions for the release of data. One of the current priorities of the DWD's research is seamless prediction at all timescales and our forecasting system ICON plays a central role in this.

In my role as honorary president of the World Meteorological Organisation, it is a matter of particular concern for me to secure the continuation of the free global exchange of meteorological data. This is the only way to ensure that countries especially affected by climate change are enabled to set up appropriate weather and climate services. In order to achieve this, the DWD engages with partners in several projects. I am therefore very pleased that Patricia Espinosa Cantellano, Executive Secretary of the United Nations Framework Convention on Climate Change (UNFCCC) in Bonn, was available for an interview with us. Among other subjects, she reports on the Paris Agreement and on the importance of climate conferences, in order to ensure that climate change is addressed by the whole of society.

Dear readers, as you can see, Germany's national meteorological service once more has a great deal of interesting news for you – I hope you enjoy going through our Yearbook 2019.

Yours sincerely,

Gerhard Adrian

Prelude

right

Memmingen's radar tower, which is over 60 m high, rising above the trees. The frequency of checks is once every three months. A major servicing is carried out at nine-month intervals and includes a very detailed inspection and overhaul of all parts of the radar system.

01

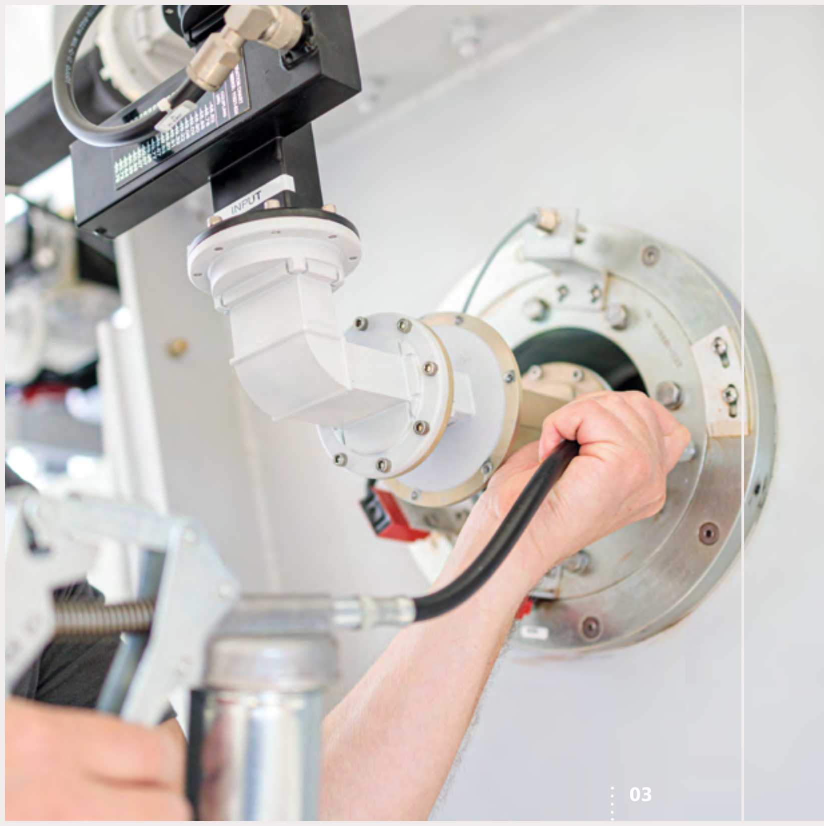
The one and only German radar network

Will I need an umbrella today? We usually just take a look at the rain radar of a weather app. But where does the rain radar get its data from?

As the national meteorological service, the Deutscher Wetterdienst (DWD) operates Germany's only weather radar network. Together with the radar networks operated by other national meteorological services in Europe, it forms the European Weather Radar Network. Of course, neither rain nor weather in general respects national borders. The weather radar is the only measuring method that can record precipitation over a wide area and in three dimensions.

The latest generation of radar devices, in use at the DWD since 2015, is not only capable of registering where and how much precipitation occurs, but its data also show whether it is rain, hail or snow. What is more, the radar devices supply information about the wind field. A total of 17 radar systems are up and running in Germany. The DWD also operates a research and quality control radar at its Hohenpeissenberg Meteorological Observatory (MOHp).

02



03

01

"Radar is off". In consultation with the Forecasting and Advisory Centre in Offenbach, Serguei Laskovitch turns off the radar signal of Memmingen radar tower. Servicing operations on the radome are only possible when the radar system is switched off.

02+03

The gears must be lubricated regularly to ensure the antenna continues to move smoothly and at a low wear rate. Lubrication takes place automatically as the antenna rotates around the horizontal axis (azimuth angle) whereas elevation movements require manual lubrication every nine months.

How it works

A weather radar consists of an antenna unit, a radome to protect against weather, a transmitter, a receiver, signal and data-processing units and a radar computer. A local network controls and monitors components and records data.

The constantly rotating antenna emits both vertically and horizontally polarised electromagnetic waves. The specialist term for this is 'dual polarisation'. These waves are reflected by raindrops, snowflakes or hailstones, each of which produces different radar echoes. The distance can be determined from the travel time of the received signal, and the echo strength, which is referred to as reflectivity, provides information about the amount of precipitation. The type of precipitation can be derived from the differences in the backscattering of the vertical and horizontal waves.

Another advantage of the weather radar systems is that the so-called Doppler effect can be used to obtain information about the wind. The Doppler effect is a well-known everyday phenomenon: the siren of an ambulance driving towards us sounds higher than it does when it is driving away from us. This is exactly how radar velocity measurements work when the wind blows precipitation particles towards or away from the station. In this way, wind speed can be calculated relative to the station.

Every five minutes, the weather radar supplies a scan of the latest measured precipitation echoes for evaluation. Scanning begins with a so-called precipitation scan, which records precipitation near the surface up to a distance of 150 km around the radar site. The entire height of the atmosphere is then scanned at ten different oblique angles (referred to as elevation angles) up to a distance of 180 kilometres to collect information about the vertical extent of the precipitation fields.

However, the radar beams are not only reflected by precipitation, but by objects, such as buildings, ships, aircraft or wind turbines as well. This means that the precipitation behind a building blocking the radar beams cannot be measured. If a stationary object blocks the beam, it is usually possible to filter out the unwanted signal. However, this is less likely to work with moving objects such as the blades of a wind turbine. Depending on the filter method used, this may leave 'gaps' or strong interference echoes in the data. Echoes produced by wind turbines can even interfere with radar signals up to a distance of 300 kilometres.

The way it is used

The weather radar is indispensable especially for forecasting the weather up to around two hours ahead, the so-called nowcasting. Small-scale thunderstorm cells can arise within a matter of minutes and lead to heavy precipitation. This phenomenon occurs mainly in the summer and can only be detected extensively by weather radar. The images from all radar sites are combined to form a composite image, which is then enriched with radar data obtained internationally by the DWD from other sources in Europe. This is how it is possible to obtain on-the-spot accurate severe weather warnings of extreme precipitation events. Wind measurements based on the Doppler effect can also be used to identify tornadoes.

Because radar data are so important, the DWD has developed the KONRAD online warning system (abbreviated from the German ‚**KON**vektionsentwicklung in **RAD**arprodukten‘, i. e. development of convection in radar products). This system is specially tailored to the needs of fire brigades and other emergency services and shows in simple and understandable symbols where, for example, hailstones will fall. The FeWIS weather information system for disaster management is based on KONRAD. Fire brigades, disaster response units, police and other emergency services use it, for example, to prepare for severe weather events. The RADOLAN ('**RAD**ar-**O**n**L**ine-**AN**eichung', i. e. radar online adjustment) procedure combines radar data with point-related precipitation measurements from surface stations. This enables localised precipitation to be determined with great precision and warning centres to recognise very early where there is a risk of flooding.

The amendment of the DWD Act in 2017 now requires the DWD to make the radar data it obtains from its unique radar network available as open data free of charge. This means that any other providers of meteorological services can use the data of the DWD rain radars in their weather apps, for example.


01


02

How it was and how it will be

The former GDR's meteorological service put the first weather radar into operation in Leipzig in 1967. Work on the development of a nationwide radar network in the Federal Republic of Germany was stepped up after the devastating hailstorm in Munich in 1984. The DWD's radar network has covered almost all of the German territory since 2001, with all stations fitted with the latest technology since 2015. The DWD currently plans to improve the radar network's coverage even further by setting up four additional radar sites. This concerns the metropolitan regions of Bremen, Leipzig, Nuremberg and the Upper Rhine valley.

Photo series in the Yearbook 2019

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01+02
When lubricating manually, it is necessary to rotate the antenna continuously by hand so that the grease reaches all relevant parts of the gear. Due to the weight of the antenna and its components, Melanie Eickmeier and Serguei Laskovitch push it together.

03
All done: the radar team at the antenna's pedestal in the radar's radome. Serguei Laskovitch and Ladislav Hart came to the radar site to carry out the nine-month servicing. Melanie Eickmeier is responsible for the professional and technical coordination of remote sensing systems.


03

14

Weather and climate in 2019

right

Working in a small space: using the network analyser, the technician team checks the attenuation of the TR limiter, a component designed to protect the receiver from the very high-power transmission pulses. As this limiter ages very quickly and precise information is required for the entire range of transmission and reception channels, the attenuation of all components needs to be checked regularly and, if necessary, adjusted in the calibration data sheet of the radar system.

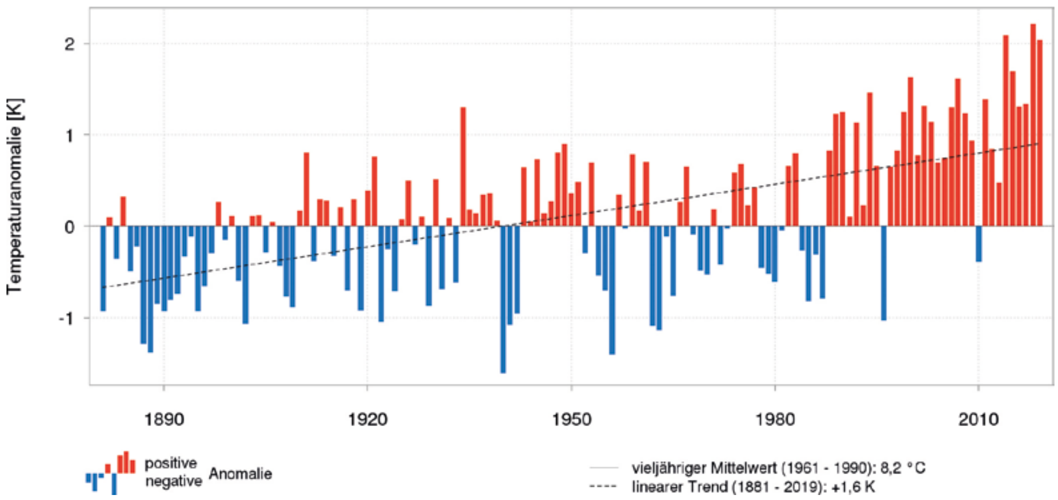
Nine of the ten warmest years were in the last 20 years; 2019 in second place

With an average temperature of 10.3 °C, the years 2019 and 2014 together rank as second warmest years in Germany since regular records began in 1881.

The linear trend over the period 1881 to 2019 is +1.6 Kelvin [K]. Nine of the ten warmest ever years in Germany were in the last 20 years. Temperatures were only below average in two of the last 32 years (in relation to the internationally valid reference period 1961–1990). The federal states of Berlin, Brandenburg, Mecklenburg-Western Pomerania and Saxony all experienced the warmest year ever. In Saxony-Anhalt, the years 2019 and 2018 were both in first place.

Figure 1

Temperaturanomalie
Deutschland Jahr, 1881 – 2019, Referenzzeitraum 1961 – 1990



Temperatures during the year

At an annual average temperature of 10.3 °C, the year 2019 comes second in the ranking of warmest years, together with 2014 right behind the record-breaking year of 2018.[1] Compared to the long-term average for the reference period 1961–1990, this was a positive deviation of +2.0 K. All months from January to April showed positive temperature anomalies. Only May (1.1 K) was cooler than the long-term average and thus ended the series of 13 warmer-than-normal months. June 2019 brought a new monthly record. Temperatures were again above average in all the months after June 2019. The first summer days (days with maximum temperatures above 25 °C) were observed as early as the last ten days of April. October also brought many summer days. Across the country as a whole, there was an average of 52 summer days in 2019 (Figure 2). Very high temperatures, in many cases over 30 °C, were measured in the last ten days of June and July. Overall, Germany recorded 17 hot days (days with maximum temperatures above 30 °C) distributed all over the country (Figure 3). What was very unusual was that many measuring stations in western parts of Germany recorded temperatures of over 40 °C on three consecutive days (24–26 July 2019), with a new German temperature record (42.6 °C) set in Lingen on 25 July.

Long-term temperature development up to 2019

The linear trend over the period 1881–2019 is +1.6 K (Figure 1). Nine of the ten warmest years in Germany were in the last 20 years. Temperatures were only below average in two (1996 and 2010) of the last 32 years (in relation to the period 1961–1990).

The trend line in Figure 1 illustrates the long-term development, but does not provide a physical interpretation of climate trends. All the years since 2014 have been significantly above the linear trend line.

[1] For ranking, the DWD uses a temperature scale with one decimal place. Accordingly, the years 2014 and 2019, both recorded with a nationwide average temperature of 10.3 °C, were assessed as equally warm, which puts them jointly in second place of the ranking.

Figure 2

Sommertage
Deutschland Jahr, 1851 – 2019

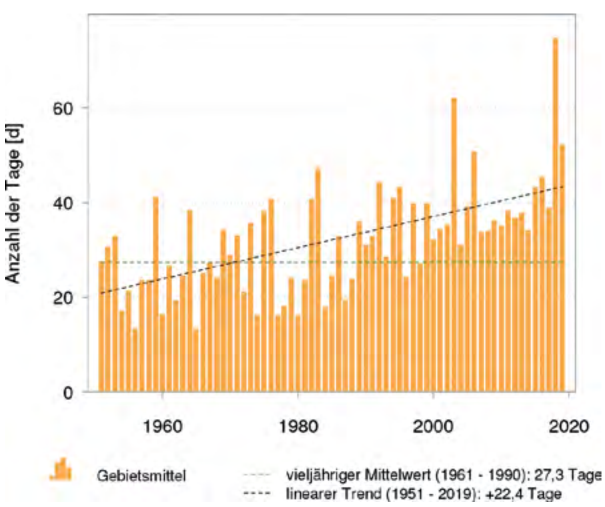
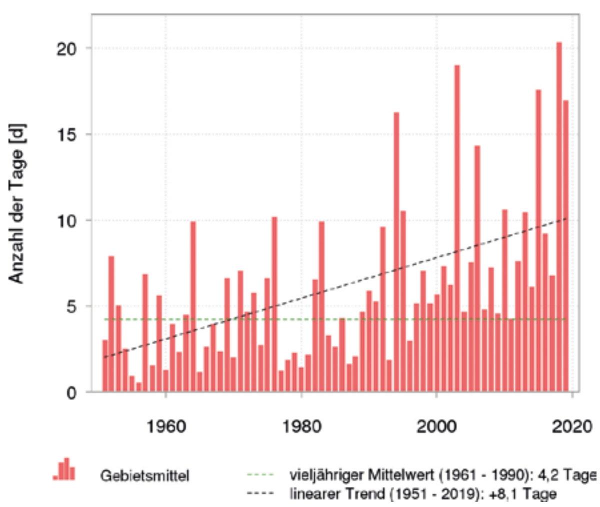


Figure 3

Heiße Tage
Deutschland Jahr, 1851 – 2019



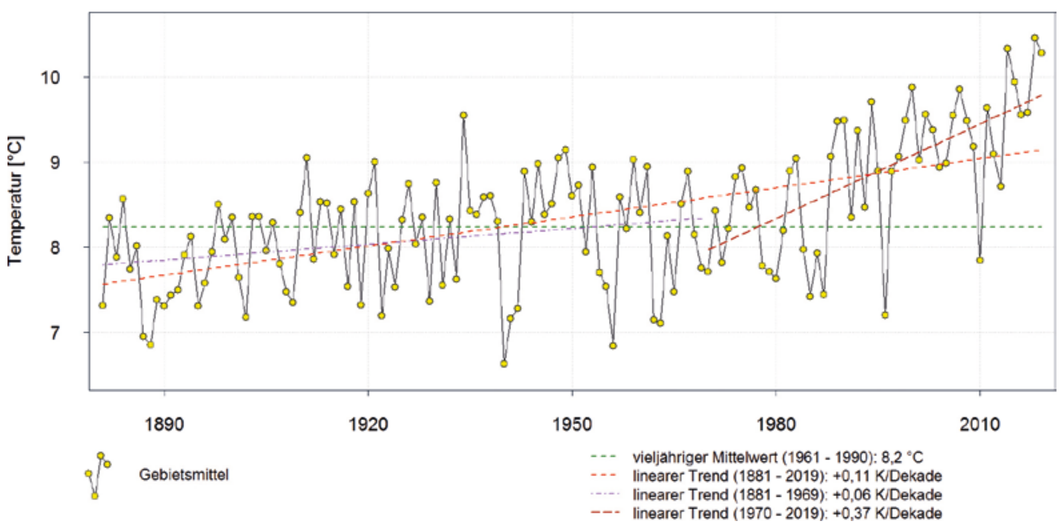
A more detailed look at the data shows that temperatures have been rising more steeply in recent decades.

This is illustrated by the trend calculation shown in Figure 4: the trend to warming in recent decades is shown by contrasting the trend over the last 50 years (1970–2019) with the separately calculated trend over the previous period (1881–1969), both included in the graphic. The rate of warming for the period 1970–2019 is 0.37 K per decade; the rate for the period 1881–1969 was just 0.06 K per decade. The rate over the entire period (1881–2019) is 0.11 K per decade.

The sharp rise in temperature in recent decades is also apparent from an analysis of 10-year averaging periods (Figure 5). According to a general definition, the current decade continues through to the end of 2020. In contrast to this definition, Figure 5 shows a comparison of 10-year periods, each of which is offset by one year due to current data availability. The nationwide average temperature in Germany for the period 2010–2019 was 9.5 °C. The average in the first decade of the data series (1881–1890) was 7.6 °C.

Figure 4

Temperatur
Deutschland Jahr, 1881 – 2019



Calculation methods and data basis

The DWD usually evaluates temperature rises in Germany as from 1881, the year in which systematic and nationwide weather records first began to be made. The calculation method on which this evaluation (i. e. the calculation of the nationwide average temperature) is based is designed to minimise the influence of changes in the measuring network.

The dependence of temperature on altitude is taken into account when calculating the area averages for temperature in Germany. This ensures that the distribution of stations over different altitudes does not have any systematic impact on the calculated decadal area averages. This method does not simply average the individual measurements made at different stations, it first derives a regularly spaced temperature grid (resolution 1 km x 1 km), which is then used to determine the average temperature for Germany.

The manually read mercury thermometers of the past have now largely been replaced by electronic means of measuring temperatures. The DWD operates several climate reference stations spread around Germany. One of the functions of these stations is to evaluate the comparability of past and current measuring sensors. In particular, climate reference stations continued for many years to use both traditional mercury thermometers (with manual readings) and current electronic temperature sensors in parallel. Comparisons of these parallel measurements show that the changeover to automatic measuring has not resulted in any systematic changes in the measurements.

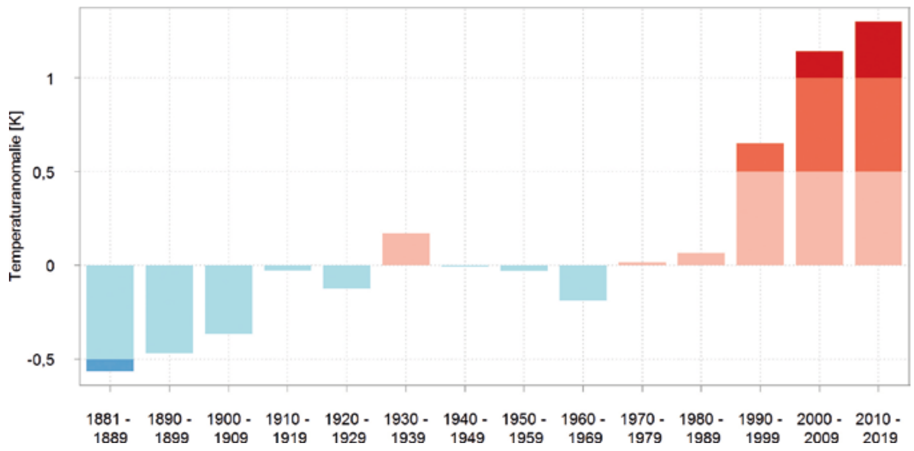
Station sites are selected carefully to ensure that they are distributed evenly across the various natural regions and altitudes within Germany. It is often difficult to make observations at the same station sites over long periods, for example, when the conditions for representative measurements are no longer guaranteed. In recent years, more and more stations have therefore been relocated to urban peripheries or the surrounding countryside as their previous sites in inner cities (such as in Freiburg, Karlsruhe or Kassel) have become increasingly built up and unsuitable.

The fact that the Germany-wide temperature trend is not due to methodological effects, such as the so-called urban heat island effect, is also apparent from the similar trends observed at unaffected rural stations continuously located at the same site.

www.dwd.de/zeitreihen

Figure 5

Temperaturanomalie der 10-Jahresperioden
Deutschland, Referenzzeitraum 1961 – 1990

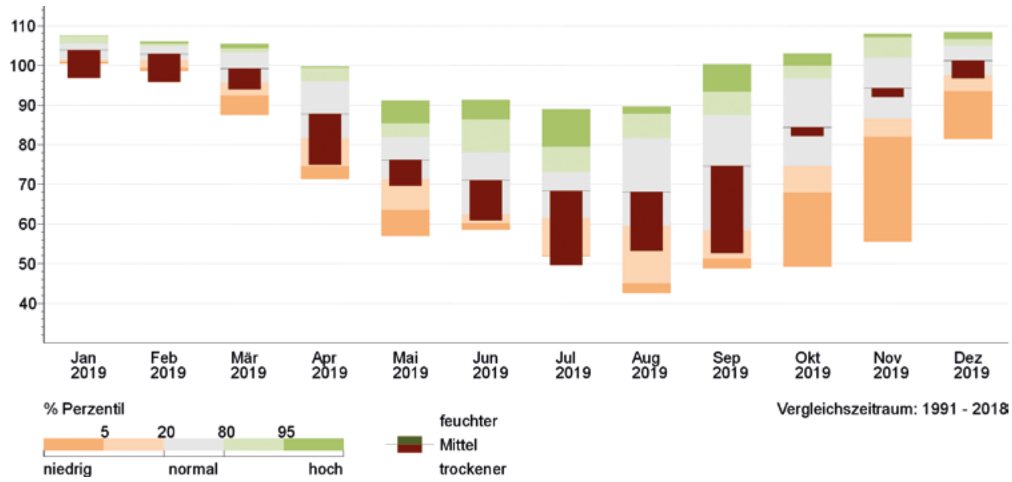


The second drought year in a row – 2019 from an agrometeorological perspective

The year 2018 may have been a record year in terms of heat and dryness, but 2019 is not far behind. Total rainfall over 2019 as a whole was close to the long-term average. However, the massive precipitation deficit from 2018 still had an impact, and the year 2019 consequently got off to a worse start than the previous year.

The soils were already completely dry at the start of the 2019 growing season and, in addition, the summer was again drier and warmer than usual, albeit wetter than in 2018. The soil moisture consequently deteriorated further in the course of the year. The observed drought damage to forests in particular resulted from the extreme drying out of deeper soil layers due to the unusually dry previous year and the below-average recharging of groundwater reserves in the winter of 2018/19.

Klimatologische Einordnung der Monatsmittelwerte der Bodenfeuchte (Gras, sandiger Lehm) in % nFK, Deutschland



Dry soils despite a largely wet winter

Precipitation in the above-averagely wet months of December 2018 and January 2019 was not sufficient to compensate for the deficit in soil moisture over the previous ten dry months. The 0–60 cm layer remained far too dry, in particular in the north-east, where the plant-available water capacity (AWC) was between 15 to 35 % below the long-term average. With persistent dry and mild weather in February, the drop in soil moisture in February was unusually sharp for the time of year. On average over the whole of Germany, the winter months from December 2018 to February 2019 were drier in terms of soil moisture than all winter months of the comparative period 1991–2018!

left
Monthly mean soil moisture in Germany in 2019

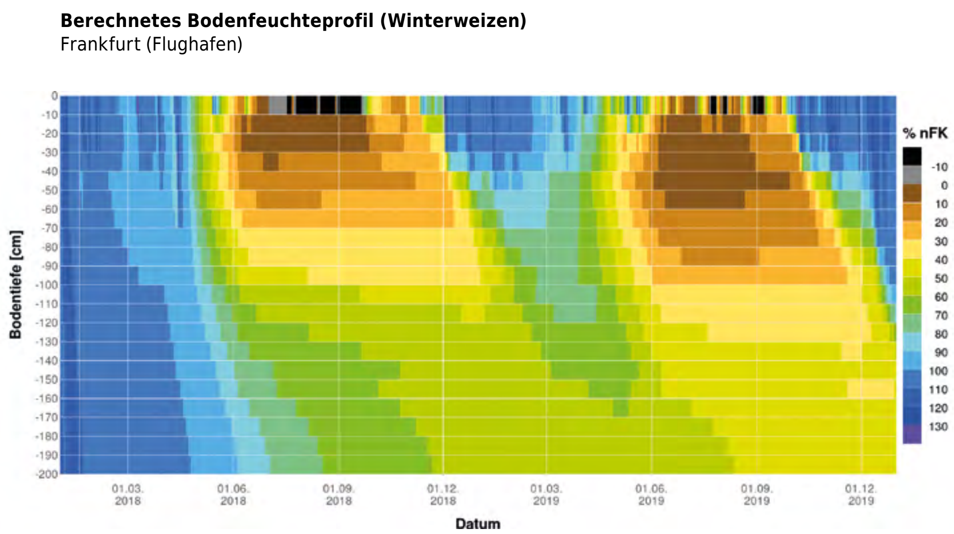
right
2 m soil moisture in Frankfurt (Main) in 2018 and 2019

Spring: soils similarly dry as in 2018

The wet first half of March temporarily eased the soil moisture situation. In the milder weather, the vegetation was now almost a week ahead of the long-term average.

Occasional spells of cold weather meant that April was not quite as warm over the whole of Germany as it was in 2018; but it was even drier. Large differences between daytime temperatures and frosts at night resulted in local damage to fruit blossoms and contributed to physiological bud wilt in rapeseed. In the second half of the month, still weakly rooted summer crops suffered from drought stress especially at dry locations.

A run of 13 above-averagely warm months in a row was followed in May by cooler-than-normal temperatures, which delayed the development of warmth-dependent maize and sugar beet, in particular. Night frost caused damage in some places. The dry situation was relieved for farmers by copious precipitation in southern and central Germany, which temporarily replenished the upper soil layers with water. Nonetheless, soils remained drier than usual through much of Germany.



Plant-available water capacity

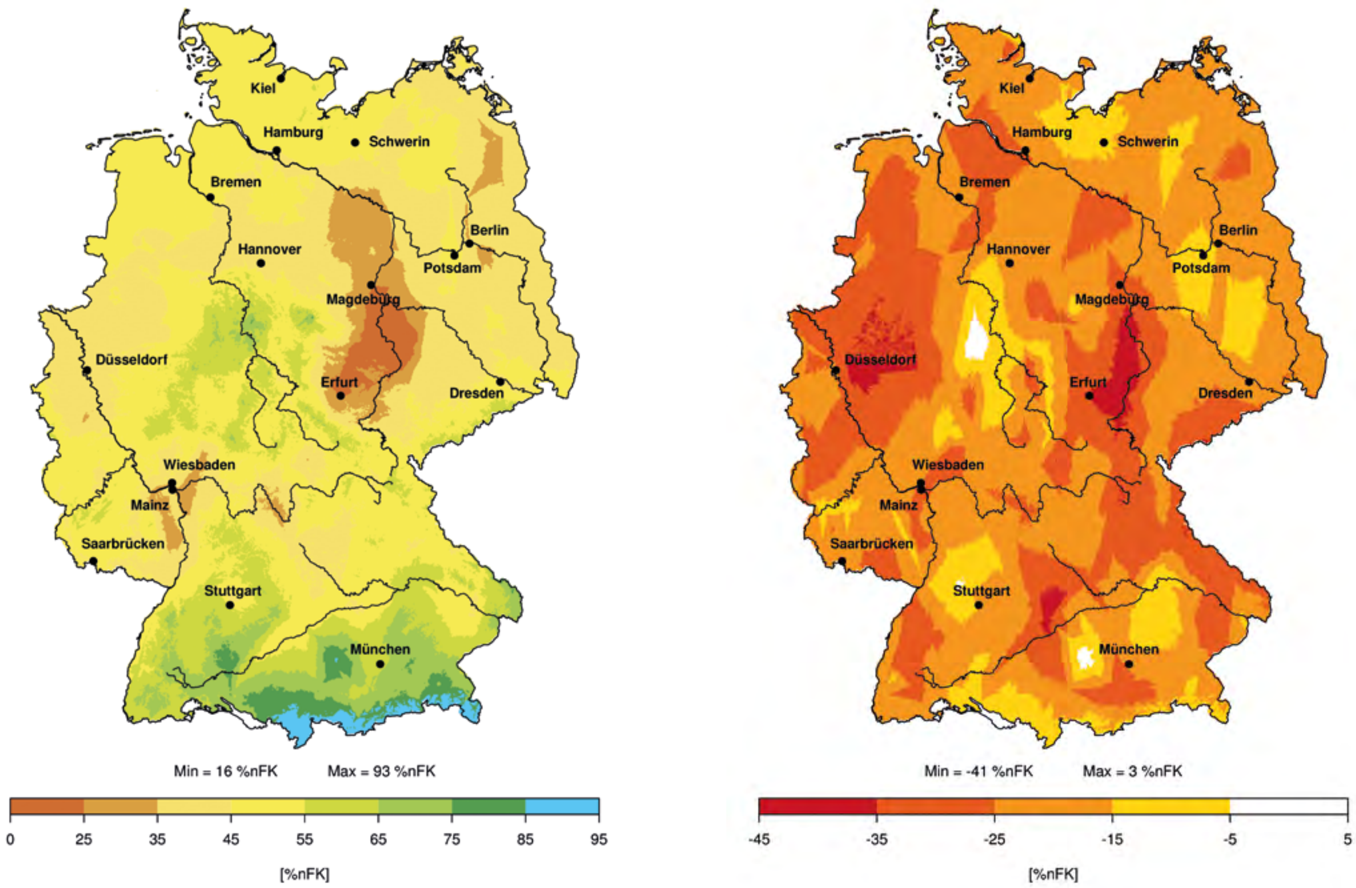
The field capacity (FC) is the amount of water which water-logged soil can retain against the force of gravity. This threshold is usually reached two to three days after complete water saturation when the excess water has drained away. As plants are not able to take up all the water in the ground, the available water capacity (AWC) is used as the measure of water available for plants. The Deutscher Wetterdienst usually calculates the plant-available water capacity for the top 60 cm of soil. Accordingly, the information in the text refers to the top 0–60 cm layer of soil.

Summer: lack of precipitation with periods of extreme heat

The weather in the summer of 2019 was again drier than usual. Plant life also came under stress due to exceptional heatwaves at the end of June and July. Fruit and vines in particular suffered from sunburn. The combination of low amounts of precipitation and higher potential evaporation exacerbated the critical dryness throughout much of Germany.

Soil moisture in Germany in July 2019 was lower than in all years of the comparative period 1991–2018 and thus also below the value for 2018. This mainly resulted from the drier conditions at the beginning of the year. Apart from the particularly dry regions stretching from North Rhine-Westphalia to eastern Germany, the sparse precipitation was in many cases sufficient to wet the soil surfaces temporarily. Supply of water to agricultural crops was thus maintained to a reasonable level and harvest losses were limited.

Soil moisture improved slightly in August and prevented further drought damage to crops such as maize and sugar beet, which still need water at that time of the year. A heatwave put plants under stress again towards the end of the month.



left
Absolute soil moisture in the very dry month of July 2019

right
Absolute soil moisture and anomalies in the very dry month of July 2019

Significant improvement in soil moisture in autumn

The first three weeks of September continued to be dry. This again made it difficult to sow rapeseed, which emerged sparsely depending on the availability of water. However, the weather then changed with extensive and abundant precipitation across Germany from late September through to mid-October. Soil moisture began rising significantly everywhere and developed in a significantly different way than in 2018.

Groundwater reserves recharged considerably in the weeks that followed and through to the end of the year while precipitation levels remained around average. From October to December, soil moisture levels in the upper 60 cm were therefore slightly below-average almost everywhere in Germany – apart from some positive and negative deviations in the west and in the south and east, respectively. However, deeper layers of soil were still far too dry in almost all regions.

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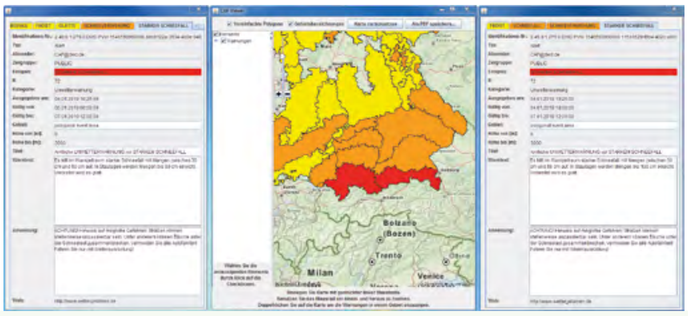

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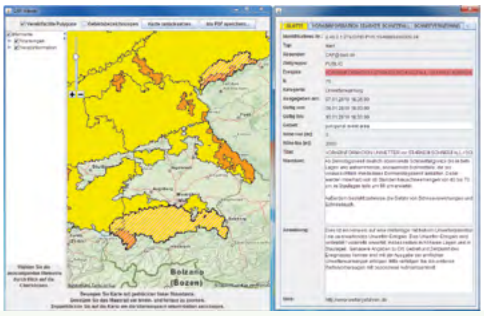


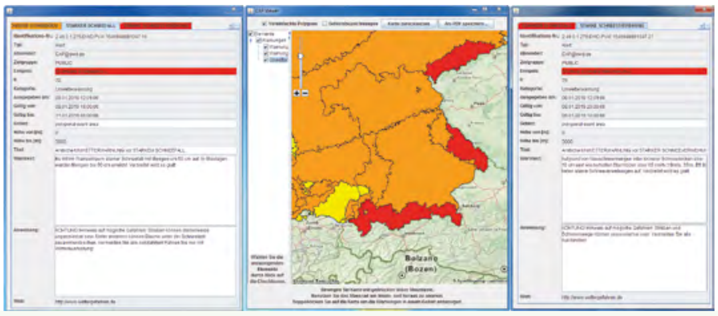
01
Weather warning situation on 04.01.2019, at midday, for the western edge of the Alps (left) and the area from Werdenfelser Land to Berchtesgadener Land including warning polygons (centre): warnings in place for snowfall, heavy snowfall and snowdrifts (severe weather warnings are marked in red)

02
Weather warning situation on 07.01.2019, in the evening, including warning polygons: severe weather watch in place for heavy snowfall/snowdrifts

Heavy snowfall in January: rapid increase in snow depth in short period of time

Heavy snow fell repeatedly and persistently from early through to mid-January in the Bavarian Alpine region and parts of the Bavarian Alpine Foreland. In three phases within little more than a week, more than one metre of fresh snow accumulated in places, including at lower altitudes, along the northern edge of the Alps and their outer reaches up to the southern city limits of Munich (some stations there still reported snow depths of up to almost half a metre). Milder temperatures and persistent rain in-between resulted in banks bursting and small-scale regional flooding.

03



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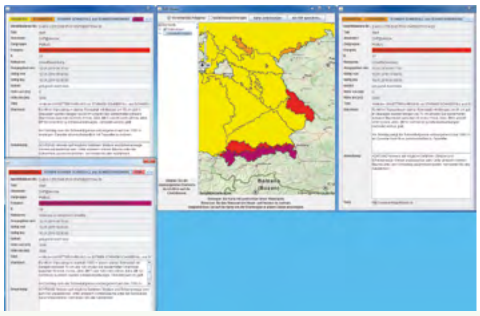


03
Weather warning situation on 08.01.2019, at midday, with severe weather warnings (red) in place for heavy snowfall (left) and heavy snowdrifts (right).

04
Weather warning situation on 12.01.2019, in the morning, including warning polygons: severe/extremely severe weather warnings in place for heavy snowfall and snowdrifts (red, left top and right) and extremely heavy snowfall and snowdrifts (purple, left bottom)

The rapid rise in snow depths within a relatively short span of time during the winter had disastrous consequences for infrastructure in some Alpine districts and quickly led to an increased danger of avalanches. The authorities declared a state of emergency in parts of Berchtesgadener Land, the districts of Traunstein and Bad Tölz-Wolfratshausen and, later, also in the districts of Garmisch-Partenkirchen, Miesbach and Rosenheim. The disaster response services were working around the clock. The Bundeswehr took care of people who were trapped, helped clear the masses of snow from the roofs and organised the transport of emergency responders. Many schools in the affected districts remained closed. Public life was massively affected in all these areas. Several people lost their lives in avalanches and accidents. Climate projections show that winter precipitation will be more intense in the future.

The influence of climate change on heavy and continuous snowfall

Analyses performed by the DWD show that a weather situation such as in January 2019, with its influx of cold and humid air from northerly directions, will probably occur more frequently in the future. Climate projections also show that winter precipitation will probably become more intense[1]. As global mean temperatures continue to rise[2], precipitation may be expected to fall more frequently as rain rather than snow. Nonetheless, heavy snowfall may still occur at higher altitudes in particular. An accumulation of the currently observed combination of heavy and continuous snowfall alternating with thaw and persistent rain is also conceivable.

Weather situation

Sustained and continuously recurring westerly weather patterns dominated much of central Europe in the first half of January 2019. A large high ('Angela') settled over western Europe and the nearby Atlantic Ocean while, on its northern and eastern flanks, a series of low-pressure areas ('Zeetje', 'André', 'Benjamin') came in from across the North Atlantic, moving either to Scandinavia or eastern Europe. While the general weather situation changed in the middle of the month – the core of the high-pressure system moved to the Azores area – the basic pattern remained the same through to the end of January. Throughout the whole month, average air pressure to the west of the British Isles was as high as 14 hPa above the January average for the years 1961–1990. At the same time, air pressure levels in the area between the Baltic States and Romania were up to 10 hPa lower than the climatological average for January. Between the high in the west and the lows in the north and east, a north-westerly, partly northerly and at times also westerly current sent predominantly polar sea air to central Europe and Bavaria, interrupted by short spells of mild Atlantic air. The weather finally calmed with the inflow of cooler and drier air masses from the north-east on 14 and 15 January.

[1+2] Sources see page 71

01

02

First phase: 4–7 January

Abundant fresh snow fell up to 7 January, especially in the south of Bavaria. While it was mostly a little too mild for snow to the north of and on the Danube itself, total snow depths at 06 UTC (07:00 CET) on this Monday morning were between 15 and 30 cm in many places in the Alpine Foreland and in places even deeper than 40 cm in the southern parts of the Foreland (e. g. 45 cm in Egling/Isar-Attenham [709 m] and 50 cm in Aitrang [747 m] and Nesselwang [880 m]).

Second phase: 8–11 January

Some stations along the edge of the Alps and in the Bavarian Forest again reported more than 30 cm of fresh snow in 24 hours (e. g. 40 cm at 941 m in Oberstdorf-Birgsau) as early as 8 to 9 January. The largest 24-hour increase in fresh snow during this phase was recorded from 9 to 10 January, however. Along the Alps, in particular, another 15 to 30 cm of snow fell, in some windward areas even more than half a metre (e. g. 74 cm at 746 m in Ruhpolding-Seehaus). As a result, some places in the Alps and the southern parts of the Alpine Foreland registered total snow depths of up to 1 m of fresh snow within 48 hours. Accordingly, the total snow depth on 10 January was between 25 and 75 cm in most cases, 100 to 250 cm in places above around 1,000 m a.s.l. and 325 cm on the Zugspitze.

Between 10 and 11 January, another half-metre of fresh snow fell locally in the Chiemgau and Berchtesgaden Alps (e. g. 52 cm at 518 m in Kiefersfelden-Gach) whereas the other parts in the southern Alpine Foreland mostly received between 15 and 30 cm. Impressive total snow depths were reported on the morning of 11 January, such as 210 cm at Ruhpolding-Seehaus (746 m), 150 cm at Reit im Winkl (685 m), 101 cm at Immenstadt-Reute (960 m) and 81 cm at Holzkirchen (685 m). Almost 30 cm even fell in some parts of Munich.

Third phase: 12–15 January

A mild thaw resulted in a collapse of snow cover at lower altitudes as early as 12 January. Precipitation fell here as rain while the middle and higher regions of the Alps received another 15 to 30 cm of fresh snow up to the morning of 13 January (e. g. 29 cm at 1088 m in Ramsau-Schwarzeck/Schmuck). Temperatures on 13, 14 and 15 January were also mostly slightly above freezing and, in the Alpine Foreland, even the nights of 13 and 14 January remained largely frost-free. Some fresh snow only fell here again in the night of 15 January while a further 15 to 30 cm of snow, in places even more, fell at altitudes higher than 800 to 1,000 m above sea level. For instance, Mittenwald-Buckelwiesen (981 m) received 35 cm of fresh snow within 24 hours on 15 January.

03

04

01-04

Deceptive idylls and snow in abundance: snowy landscapes, roofs laden with snow or drifts of snow as tall as a man so that in some houses the windows on the ground floor could no longer be opened. Photos taken by DWD colleague Torsten Wendt in the Chiemgau area, near Kufstein and in the vicinity of Rottach-Egern

Warning management

For its weather forecasts and warning management, the DWD not only relies on its own ICON forecast model but also uses the forecasts produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) and various ensemble forecasts. Fresh snow accumulations were forecast extremely well in all three phases.

Following initial indications in the severe weather warning report for Bavaria, severe weather warnings of heavy snowfall from the late morning of 4 January were issued for the Alpine districts. In compliance with the Bavarian ordinance on official announcements in the event of disasters, these warnings were also broadcast on radio and television.

On 7 January, the DWD again published a severe weather watch for the second phase, upgrading it to a severe weather warning the following day. Warnings of heavy snowfall with fresh snow of up to 90 cm as well as snowdrifts were issued for the period up to 11 January.

The warning history for the third phase was similar: a severe weather watch was initially issued on 11 January indicating that heavy snowfall and snowdrifts were expected on 12 January. Again, this preliminary alert was stepped up to an official warning of extremely severe weather on the same day for locations above 1,000 m. Accumulations of between 70 and 100 cm of fresh snow were projected.

Situation in Europe

Outside of Germany, Austria was most strongly affected by heavy snowfalls, although the northern edges of mountains in southern Poland, the Czech Republic and Slovakia were also hit. Up to over 3 m of fresh snow fell within 10 days in Austria. Buildings had to withstand heavy loads of snow. Several major avalanches occurred some of which led to fatalities, and the highest avalanche warning level was issued in some places. Several places were cut off from the outside world and many left without power.

Snowfall lessened towards the west (eastern France, Switzerland) with the increasing influence of high pressure, although there was still 50 cm of snow at altitudes of 1,200 m and higher in the Vosges mountains. In addition, several areas of low pressure over the eastern Mediterranean combined with incoming cold air brought some abundant snowfall to parts of south-eastern Europe (southern Italy, Balkans, Greece), Turkey and even the Middle East. In contrast, foehn winds on the southern slopes of the Alps kept northern Italy dry, which caused several unseasonal and large forest fires.

Exceptional heatwave

Germany experienced an extraordinary heatwave from 24 to 26 July 2019: over three consecutive days, and for the first time since systematic weather records began to be made, maximum temperatures in the west of the country rose above 40 °C.

Records were broken at several measuring stations with an all-time record of 42.6 °C registered at Lingen station in the Emsland on 25 July 2019. Many places in other western European countries also registered new station records, and new national records were set in the Netherlands, Belgium and Luxembourg.

The July heatwave, like the one experienced at the end of June 2019, started with a so-called omega weather pattern. Large parts of Europe were again subject to the influence of high pressure while pronounced areas of low pressure resided over the North Atlantic and western Russia. Unlike the situation at the end of June, this time the influence of high pressure reached much further to the north, right up to large parts of Scandinavia. On the western edge of the high-pressure area, very warm air was carried from North Africa across Spain and western Central Europe to Scandinavia.

Table

Stations in the joint Bundeswehr/DWD measuring network with maximum temperatures of at least 40.0 °C on 25 July 2019. All these values were also local records for each of the stations.

Record temperatures in Germany

The previous temperature record in Germany of 40.3 °C, which was measured on 5 July and 7 August 2015 in Kitzingen in the Mainfranken area (Bavaria), was broken for the first time on 24 July 2019. On that day, Geilenkirchen, one of the Bundeswehr-owned stations in the joint Bundeswehr/DWD network, reported a record-breaking temperature of 40.5 °C – a record destined to be beaten within just 24 hours. The heatwave peaked in large parts of Germany on 25 July when as many as 14 measuring stations reported temperatures surpassing the former Kitzingen record. New local station records were also set across much of the west and middle of Germany.

Lingen in the Emsland reported the highest temperature of all, setting the new record at 42.6 °C. Three other stations recorded temperatures above 41 °C. On 25 July, as many as 25 stations in the joint Bundeswehr/DWD network reported maximum temperatures of 40 °C or higher. Daily maxima of less than 35 °C mostly occurred at stations immediately near the Alps, north of Berlin and near the coast. Due to on-shore winds, some stations along the Baltic coast registered temperatures below 25 °C, which meant no summer day that day for them.

Nightly lows were also very high. On 25 July, altogether 91 stations reported a tropical night (temperature not below 20 °C); at 6 of these stations the night-time temperatures even remained above 25.0 °C. Apart from the Weinbiet, where a top minimum temperature of 26.2 °C was measured, stations in the western low mountain ranges in particular, including the Hoherodskopf in the Vogelsberg, the Kleiner Feldberg in the Taunus and the Kahler Asten in the Rothaargebirge, reported minimum temperatures of over 25 °C. On 26 July, as many as 117 DWD stations reported a tropical night, with 7 of these stations measuring a minimum temperature of 25.0 °C; at 26.1 °C, temperatures were highest in Hümmerich (Rhein-Westerwald). Even though by then the heatwave was already past its peak, a maximum temperature of 40.4 °C was once more reached on 26 July (Tönisvorst, Lower Rhine). At 30 to 34 °C, maximum temperatures between the Emsland and the Ore Mountains on 27 July were significantly lower.

Station	°C
Lingen	42.6
Tönisvorst	41.2
Duisburg-Baerl	41.2
Köln-Stammheim	41.1
Bonn-Roleber	40.9
Kleve	40.9
Düsseldorf	40.7
Trier-Petrisberg	40.6
Geilenkirchen	40.6
Nörvenich	40.6
Weilerswist-Lommersum	40.6
Waltrop-Abdinghof	40.5
Andernach	40.4

Station	°C
Bad Neuenahr-Ahrweiler	40.4
Köln/Bonn	40.3
Wuppertal-Buchenhofen	40.2
Neunkirchen-Wellesweiler	40.2
Frankfurt/Main Westend	40.2
Bad Nauheim	40.1
Frankfurt/Main Flughafen (Airport)	40.1
Kahl am Main	40.0
Münster/Osnabrück	40.0
Essen-Bredeney	40.0
Schaafheim-Schlierbach	40.0
Mannheim	40.0

Record-breaking temperatures also in other western European countries

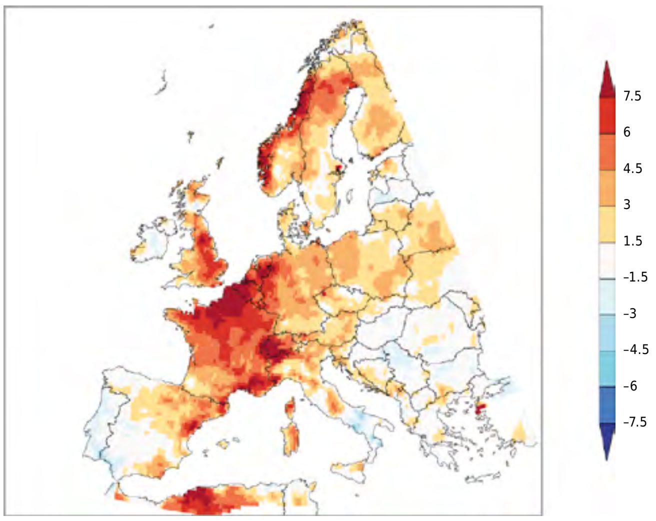
New national heat records were also established in the United Kingdom, the Netherlands, Belgium and Luxembourg, with new all-time records of 38.7 °C at Cambridge Botanic Garden in the UK, 40.7 °C at Gilze-Rijen in the Netherlands, 40.8 °C at Steinsel in Luxembourg and as much as 41.8 °C at Begijnendijk in Belgium. Belgium and the Netherlands had never before seen temperatures of over 40 °C. France equally reported numerous station records, such as 42.6 °C in Paris-Montsouri, and high maximum temperatures exceeding 40 °C extended to the north of the country.

The high-pressure area extended over such a wide area as to produce new records as far north as Scandinavia. For instance, temperatures at Helsinki Kaisaniemi station, in operation since 1844, rose to 33.2 °C on 28 July, thereby breaking the previous record of 31.6 °C set in July 1945. Maximum temperatures measured in Sweden exceeded 32 °C; in Norway, they went over 34 °C. Preliminary analyses by the Royal Netherlands Meteorological Institute (KNMI) based on the E-OBS data set illustrate the exceptional situation at the end of July 2019.

Climatological assessment

Temperatures of 40 °C or higher have been extremely rare in Germany in the past and have mostly been restricted to particular regions. The first record of ≥ 40 °C (record temperature of 40.2 °C in Gärmersdorf on 27 July 1983) had only been reached at two other stations (Karlsruhe and Freiburg) in August 2003 and exceeded by 0.1 °C on 5 July and 7 August 2015 in Kitzingen. What makes the heatwave of late July 2019 so unusual is that temperatures of ≥ 40 °C occurred over such a wide area (from the Rhine-Main area across the Lower Rhine through to the Emsland), that six stations registered temperatures by 0.6 degrees or more above previous records and that temperatures rose to ≥ 40 °C on three consecutive days.

Nationwide, temperatures in July 2019 deviated by 2 degrees from the international standard reference period 1961–1990 and by 0.9 degrees from the reference period 1981–2010. While June 2019 was on average the warmest June ever in Germany, July 2019 is not among the warmest July months since records began, even despite the heatwave and the record-breaking temperatures measured in the last third of the month. What is striking, however, is the same frequent occurrence of heatwaves within a short period of time as has been observed in the summers over the last two to three decades. These developments also largely correspond to climate projections indicating an increase in the frequency and intensity of heatwaves in the decades ahead. The extreme record-breaking temperatures measured during the most recent heatwaves also fit very well into this picture.



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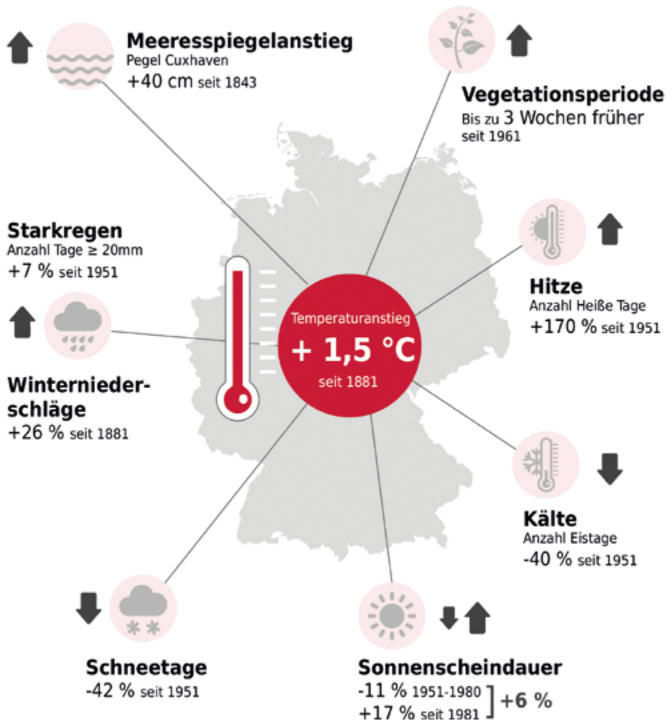
The dark red areas in this diagram show how much hotter it was on the hottest day in the summer of 2019 compared to the average hottest day of the year in the period 1981–2010. The highest deviations occurred in a clearly visible band stretching along the French North Sea coast across the Netherlands and Belgium into the Emsland.



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Since 1881, the temperature in Germany has risen by 1.5 °C. However, climate change is also visible and perceptible in other parameters.

Germany in the midst of climate change

The 2019 Monitoring Report on the German Strategy for Adaptation to Climate Change was presented in Berlin at the end of November at the invitation of the Federal Press Conference.

The Federal Minister of the Environment, Nature Conservation and Nuclear Safety, Svenja Schulze, Dr Maike Schaefer, Mayor of Bremen and Senator for Climate Protection, Environment, Mobility, Urban Development and Housing, Maria Krautzberger, President of the German Environment Agency (UBA), and Tobias Fuchs, Head of Climate and Environment at the DWD, together presented the key findings.

The introductory climate chapter of the Monitoring Report provides an overview of the climate changes observed in Germany since the end of the 19th century. It describes the mean changes in climate and looks at changes in extreme events, such as heat waves, heavy precipitation events or droughts. The DWD not only provided extensive data material for this chapter, it also supplied the data on how the climate is expected to change in the future. Mitigation and adaptation measures are based in part on these data.

“The observations made by the Deutscher Wetterdienst are unequivocal. Temperatures are rising very quickly. More heatwaves pose a threat to our health. We must all expect much more serious damage from heavy rain. Climate change has taken hold in Germany,” concluded Tobias Fuchs in his statement to the press conference.

Weather in Germany 2019

	Average temperature in °C	Highest temperature in °C	Lowest temperature in °C
January	**0.6 (–0.5)**	**11.0** on the 27th in Rheinfelden	**–22.4** on the 3rd on the Zugspitze
February	**4.0 (0.4)**	**21.7** on the 27th in Saarbrücken-Burbach	**–18.6** on the 3rd on the Zugspitze
March	**6.6 (3.5)**	**22.0** on the 22nd in Walltrop-Abdinghof	**–18.5** on the 11th on the Zugspitze
April	**9.6 (7.4)**	**28.1** on the 24th in Kitzingen and Munich-City	**–13.5** on the 28th on the Zugspitze
May	**11.0 (12.1)**	**27.6** on the 19th in Lingen	**–16.0** on the 5th on the Zugspitze
June	**19.8 (15.4)**	**39.6** on the 30th in Bernburg/Saale (Nord)	**–1.7** on the 1st on the Zugspitze
July	**18.9 (16.9)**	**42.6** on the 25th in Lingen	**–6.6** on the 10th on the Zugspitze
August	**19.1 (16.5)**	**35.6** on the 28th in Bernburg/Saale (Nord)	**–5.7** on the 14th on the Zugspitze
September	**14.1 (13.3)**	**33.8** on the 1st in Coschen	**–5.3** on the 3rd, 6th and 9th on the Zugspitze
October	**10.8 (9)**	**27.7** on the 13th and 14th in Ohlsbach and Müllheim, respectively	**–10.8** on the 3rd on the Zugspitze
November	**5.2 (4)**	**20.1** on the 2nd in Ohlsbach	**–15.4** on the 13th on the Zugspitze
December	**3.8 (0.8)**	**20.2** on the 20th in Piding	**–16.5** on the 10th on the Zugspitze
Winter 2018/19	**2.8 (0.2)**	**21.7** on 27 February in Saarbrücken-Burbach	**–22.4** on 3 January on the Zugspitze
Spring	**9.1 (7.7)**	**28.1** on 24 April in Kitzingen and Munich-City	**–18.5** on 11 March on the Zugspitze
Summer	**19.2 (16.3)**	**42.6** on 25 July in Lingen	**–6.6** on 10 July on the Zugspitze
Autumn	**10.0 (8.8)**	**33.8** on 1 September in Coschen	**–15.4** on 13 November on the Zugspitze
Year	**10.3 (8.2)**	**42.6** on 25 July in Lingen	**–22.4** on 3 January on the Zugspitze

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
81.8 (60.8)	44.0 (43.6)	Extreme continuous snowfalls in the Alps at the beginning of the month
29.9 (49.4)	128.9 (71.5)	Sunniest February since measurements began in 1951; very dry
74.7 (56.5)	113.2 (111.2)	Very mild during the first half of the month; passage of several deep lows ('Bennet', 'Eberhard')
29.4 (58.2)	227.9 (153.7)	13th month in succession with a positive temperature anomaly
78.6 (71.1)	179.6 (201.6)	First month for a while that was colder than the long-term average for the period 1961–1990
55.6 (84.6)	308.1 (203.3)	Warmest June on record since measurements began in 1881; first extreme heatwave at the end of the month
56.0 (77.6)	232.4 (210.7)	Period of several days of intense heat towards the end of the month with a new temperature record set for Germany; three consecutive days with temperatures above 40 °C
63.0 (77.2)	226.9 (199.5)	Changeable weather at the beginning of the month; then a late summer heatwave during the last third of the month
64.5 (61.1)	162.8 (149.6)	End of the period of very dry summer months thanks to precipitation during the last third of the month
83.8 (55.8)	107.6 (108.5)	Summer days at many stations in the middle of the month; clear surplus of precipitation at the end of the month
58.9 (66.3)	43.8 (52.8)	Calm autumn month with much fog and low stratus cloud cover
58.8 (70.2)	59.0 (38.0)	Very mild month with hardly any wintry periods
215.8 (180.7)	198.1 (152.9)	Very changeable winter, but mild with much sunshine and rain; enormous amounts of snow in some parts of mountainous areas
182.7 (185.9)	520.7 (466.6)	Very mild during the first two spring months, March and April, followed by a cool May
174.6 (239.4)	767.4 (613.5)	Two extreme heatwaves at the end of June and July with many new temperature records set
207.2 (183.3)	314.3 (310.9)	Milder-than-normal autumn, but with an excess of precipitation, most of which fell in October
735.0 (788.9)	1,834.2 (1,544.0)	Second warmest year, together with 2014, since measurements began in 1881; fifth sunniest year since measurements began in 1951

The year in review

right

Power slip ring brushes for transmitting the power to the antenna: due to the antenna's rotating movement, signal lines and power supplies need to be connected using a slip ring.

left
The WMO's new team of President and Vice-Presidents (left to right): Dr Albert Martis, Prof. Celeste Saulo, Prof. Dr Gerhard Adrian and Dr Agnes Kijazi after their successful election

World Meteorological Organization (WMO): Reform and German presidency

The Eighteenth World Meteorological Congress held in Geneva from 3 to 14 June 2019 was dominated by the discussions about the organisation's ongoing reform. For the first time since the WMO was founded, this specialised agency of the United Nations is led by a German president: with a large majority, the Congress elected Prof. Dr Gerhard Adrian, President of the DWD, to this honorary office. Three Vice-Presidents, also elected by the Congress, are at his side for the next four years: Prof. Celeste Saulo (Argentina), Dr Albert Martis (Curaçao and Sint Maarten) and Dr Agnes Kijazi (Tanzania). Petteri Taalas was re-appointed as Secretary-General and has thus embarked on his second and last term in office.

The Congress took groundbreaking decisions that will shape the WMO's future work. Among other things, the Strategic Plan for 2020–2023 was adopted, which, recalling the 2030 Agenda for Sustainable Development, the Paris Agreement and the Sendai Framework for Disaster Risk Reduction, defines five long-term goals covering service provision, Earth system observations and predictions, research, capacity development and the realignment of WMO structures. These goals form the basis for establishing the budget and are backed up with success indicators.

The adoption of the proposed WMO reform, which, among others, was strongly supported by Germany, represented a further milestone for the organisation. The existing governance structures had proved to be too inflexible and were no longer suited to respond adequately to new developments. Instead of the former eight Technical Commissions, there will be only two in the future, the Infrastructure Commission for observation, infrastructure and information systems and the Services Commission for the WMO's entire range of services and applications. Overarching co-ordination and implementation of research will from now on be the responsibility of a Research Board. Other important elements of the reform include the greater involvement of the Regional Associations in the work of the Technical Commissions and the switch to a two-year meeting cycle in order to be able to implement changes more rapidly. In future, extraordinary, shorter Congress meetings will be convened in-between the regular quadrennial sessions of Congress. The two Technical Commissions, the Research Board and the Regional Associations will meet every two years shortly after the Congress.

The Geneva Declaration – 2019: Building Community for Weather, Climate and Water Actions, successfully adopted by the WMO Members, calls for strengthening the co-operation between the public, private and academic sectors and constitutes a clear commitment in favour of the free exchange of meteorological data. The Congress also adopted a two per cent increase in the WMO's regular budget to around 271 million Swiss francs for the period 2020 to 2023. Under the new contribution scale, Germany will contribute a smaller percentage so that, even despite the budget increase, its contributions to the WMO will be slightly smaller than before.

https://public.wmo.int/en

Is climate change responsible for more extreme weather events?

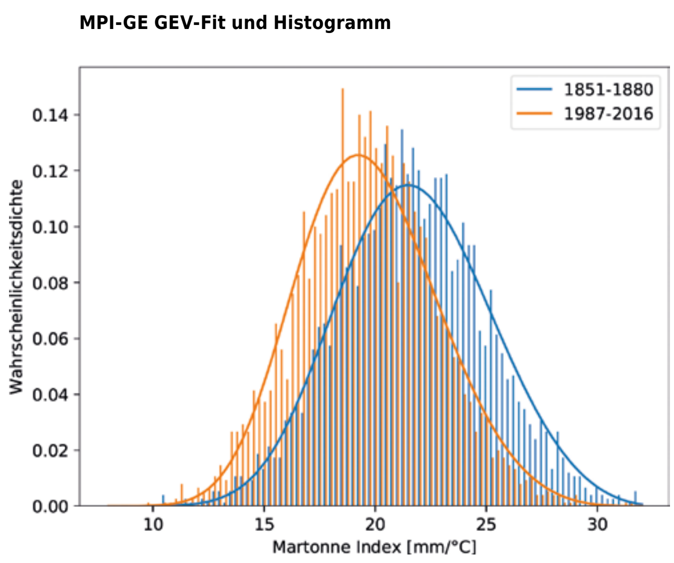
This question is being addressed by the still very new science of extreme event attribution, a discipline examining whether and to what extent human-induced climate change plays a role in the magnitude and likelihood of extreme weather events.

In summer 2019, the Deutscher Wetterdienst took part for the first time in such a study, which saw a group of researchers, in collaboration with the World Weather Attribution (WWA) partnership, examine the heatwave that hit Europe in late July 2019. The team consisted of scientists from the French Institut Pierre Simon Laplace (IPSL) and the national meteorological services of the Netherlands (KNMI), France (MétéoFrance) and the United Kingdom (Met Office) as well as from the Environmental Change Institute/ University of Oxford, the ITC Faculty of Geo-Information Science and Earth Observation/ University of Twente in the Netherlands, the Dutch Climate Centre of Red Cross and Red Crescent Societies and, last but not least, the DWD.

The study concluded that, without climate change, the return period for such a heatwave would have been at least three times higher in Germany. In other words: such an event would occur three times less frequently. For France and the Netherlands, the study found that, without human influence on climate, such a heatwave would have been much less likely (at least by a factor of ten). Without climate change, the maximum temperatures in all the countries examined in the study would have been between 1.5 and 3 degrees Celsius below the values measured in July 2019.

The DWD will carry out more work on this topic in the coming years, including special climate simulations that form an essential basis for attribution research.

www.dwd.de/attribution



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Change in drought index probability according to De Martonne (see explanation on the right) for North-East Germany: the graph shows a marked increase in the probability of smaller De Martonne values for the current climate compared to the pre-industrial climate. This means that the meteorological droughts are more pronounced.

Martonne Index: De Martonne's Aridity Index describes the ratio of total precipitation to temperatures averaged over time. If the ratio decreases, this is an indicator of meteorological droughts.

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The DWD is currently setting up an integrated greenhouse gas monitoring system. This system, called ITMS after its German name 'Integriertes Treibhausgas-Monitoringsystem', provides additional information about sources and sinks of greenhouse gases.

Integrated system for the monitoring of greenhouse gases

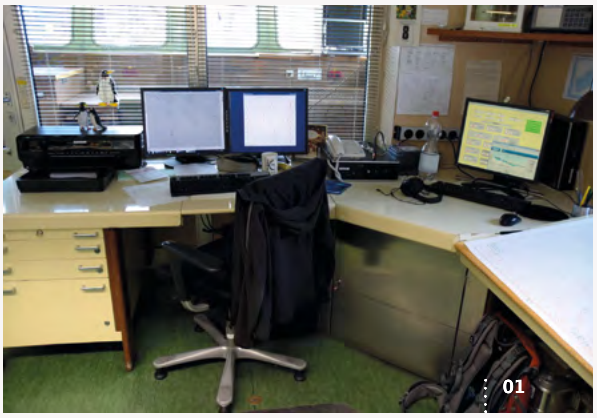
The Paris Agreement and the United Nations Framework Convention on Climate Change (UNFCCC) oblige the Parties to report on their greenhouse gas emissions and to document the progress they make in reducing emissions. In Germany, the so-called standardised national inventory report falls under the responsibility of the Federal Environment Agency (UBA).

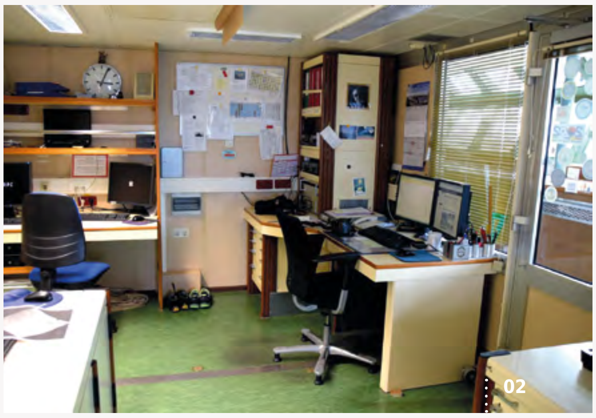
For several years now, the DWD's Meteorological Observatory Hohenpeissenberg (MOHp) has been responsible for setting up and operating the atmospheric monitoring network underpinning the Integrated Carbon Observation System (ICOS). ICOS was launched in 2015 by the European Commission as a pan-European environmental research infrastructure consisting of three observation domains: Atmosphere, Ecosystems and Oceans. Its aim is to carry out long-term observations of the greenhouse gases carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in Europe and to make the results available to all interested users. Currently, the MOHp carries out such measurements at eight towers distributed over the whole of Germany.

So far, Germany's inventory reports did not include any atmospheric concentration measurements such as those recorded by ICOS measuring instruments or via satellites. An integrated system for the monitoring of greenhouse gases, ITMS after its German name 'Integriertes Treibhausgas-Monitoringsystem', will make it possible to deliver valuable additional information, validate the accuracy of existing emission information and reduce uncertainties while increasing the reliability of statements. Thanks to weather models, information on atmospheric transport can be included in the analysis of measurement series and thus allow conclusions regarding sources and sinks of greenhouse gases.

The DWD is currently building the ITMS greenhouse gas monitoring system to operate based on the DWD's numerical weather forecast model ICON. This will enable the combined use of all available ground- and satellite-based measurements. In parallel with setting up the operational ITMS, the DWD is carrying out a range of accompanying research activities in collaboration with partners at German universities and research institutions. In this context, the DWD uses the European Copernicus Services and is connected at a global level with the ongoing activities in other countries through the Integrated Global Greenhouse Gas Information System (IG3IS) of the World Meteorological Organization (WMO).

www.dwd.de/icos





01
The DWD's ship weather station aboard the POLARSTERN: the ***meteorologist's*** *desk*

02
The DWD's ship weather station aboard the POLARSTERN: the ***weather technician's*** *desk*

MOSAiC expedition with DWD shipboard weather station

The German research ship POLARSTERN never leaves port without 'it' – one of the 'shipboard weather stations' that the DWD runs aboard ships, equipped with staff. And so it was the case on 20 September, when the POLARSTERN set sail from Tromsø in Norway to its year-round MOSAiC expedition in the Arctic. Also on board the ship: a meteorologist and a weather technician of the DWD.

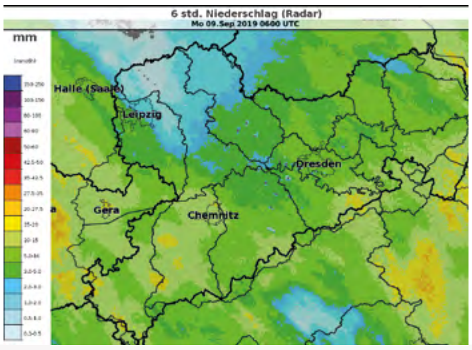
"As a long-standing partner of the Alfred Wegener Institute, we are delighted to support this unique expedition from the meteorological side by seconding our experienced colleagues on board the ship," says Prof. Dr Gerhard Adrian, President of the DWD and President of the World Meteorological Organization (WMO). "The expedition will promote climate research around the world by contributing valuable insights into physical processes in the Arctic, which are becoming all the more important in the ongoing climate change."

The POLARSTERN has been equipped with the DWD weather station since its launch in 1982. A total of four meteorologists and three weather technicians take turns during the six legs of the 12-month MOSAiC expedition. The meteorologists' tasks include providing the captain, the cruise leader and the helicopter crew with meteorological advice and weather forecasts to ensure that the research activities can be carried out safely and efficiently. The weather technicians are generally responsible for the station's meteorological sensors and the daily radiosonde launches; they also assist the meteorologists on board with the processing and preparation of meteorological data.

The research ship drifts with the ice in an area where data for weather forecasts are scarce. Numerical forecast data for the meteorological briefings on board reach the ship only via the polar-orbiting communication satellites with their low bandwidth data connections. Powerful geostationary satellites are not available in the high latitudes where the POLARSTERN is operating. With its own antenna, the shipboard weather station also receives images in near real-time from the meteorological satellites in the polar orbit. Moreover, the data obtained from on-board radiosonde flights are indispensable for the weather forecasts. In the mornings, short briefings are held with the captain, the cruise leader and the helicopter crew in order to help them plan their day of scientific operations. The DWD supports the whole operation with its weather forecasts. Thanks to many colleagues back home at the DWD in Germany, who provide the shipboard weather team with additional data, weather forecasts are produced on board all day round, especially for aviation purposes.

www.dwd.de/mosaic
www.mosaic-expedition.org
follow.mosaic-expedition.org

01



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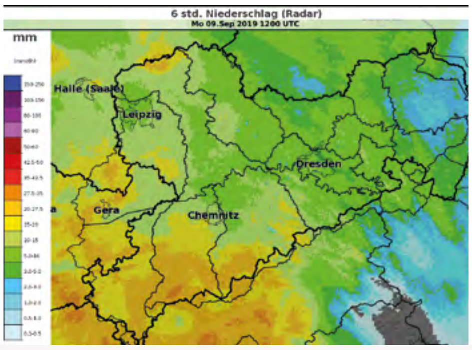

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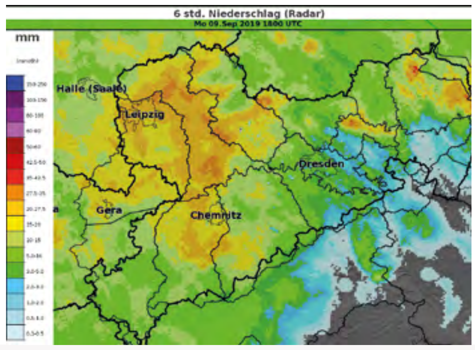


01-04

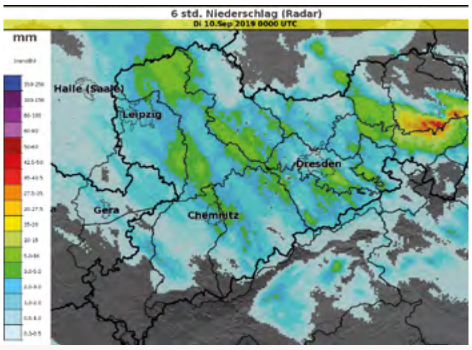
Graphics 01 to 04 show the 6-hour precipitation totals for the federal state of Saxony starting on 09.09.2019, 06:00 UTC. Saxony's catchment areas are highlighted. The precipitation figures result from calculations based on data from the DWD's radar network.

Flood control centres: collaboration through tailor-made forecasts

Who does not remember the disastrous inundations along the rivers Elbe, Oder and Danube in 2002, 2010 and 2013? The huge floods caused many deaths and enormous damage to property totalling to billions of euros in central Europe. Torrential rain is often triggered by certain weather situations that last for several weeks. A well-known example associated with abundant rainfall is the weather pattern referred to as 'Vb weather situation'.

In order to obtain forecasts of inflows and water levels, hydrologists use the observations and forecasts of the Deutscher Wetterdienst as input data. In the event of a flood, it is essential to know height and length of the flood peak in order to plan further measures, especially those to be taken by disaster control organisations. The hydrological runoff models use the data from the DWD's numerical weather prediction models ICON and COSMO-D2. The DWD also supplies German authorities with precipitation data from its weather stations and its radar network. Nationwide quantitative precipitation data with high spatial and temporal resolution for Germany are provided by RADOLAN, the DWD's radar data system. Furthermore, the hydrologists receive the complete set of data via the DWD's Water Management and Weather Information System (WaWIS). In addition to all this, DWD meteorologists assist the hydrologists with advice and guidance and elaborate long-term trend forecasts or specific forecasts for the individual catchment areas.

04



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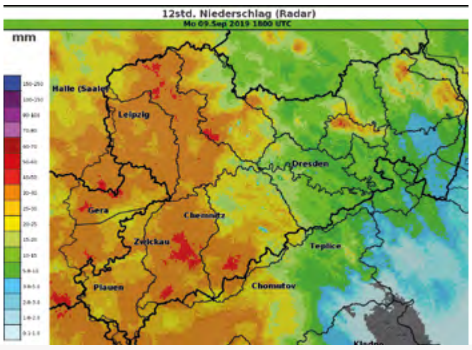


05

Graphic 05 shows the 12-hour precipitation totals for the federal state of Saxony (calculated on 09.09.2019, 18:00 UTC). Saxony's catchment areas are again especially highlighted. The precipitation figures result from calculations based on data from the DWD's radar network.

In Germany, flood control falls under the responsibility of the federal states. For this reason, the DWD offers individual tailor-made forecasts to the flood control centres of each federal state. For the central German region, which comprises the free states of Saxony and Thuringia and the federal state of Saxony-Anhalt, these forecasts are issued by the DWD's Regional Weather Advisory Office (RWB) in Leipzig. Special probabilistic forecasts are available for some specific catchment areas, for example the river basins of the Saale and the Elbe. These forecasts contain detailed probabilities for the moment in time when certain precipitation thresholds are expected to be exceeded. This enables a better estimation of any uncertainties in the forecasting of rainfall amounts. In the context of Saxony, it must be borne in mind that large parts of the Elbe and Neisse river basins are situated in the Czech Republic and Poland. Therefore, when generating the forecast, the meteorologist must also take account of the weather conditions and the evolution of the precipitation situation in the neighbouring countries.

Apart from the flood control centres in central Germany, the DWD's Leipzig Advisory Office also co-operates with the Saxon dam administration. In order to prevent flooding, it is sometimes necessary to discharge water from the reservoirs. A key factor triggering this step is the DWD forecasts predicting extreme precipitation with more than 100 litres in 24 hours.

left
Imminent warning of fine dust: view from Mount Schnarrenberg over the vineyards into the haze-covered valley basin of Stuttgart

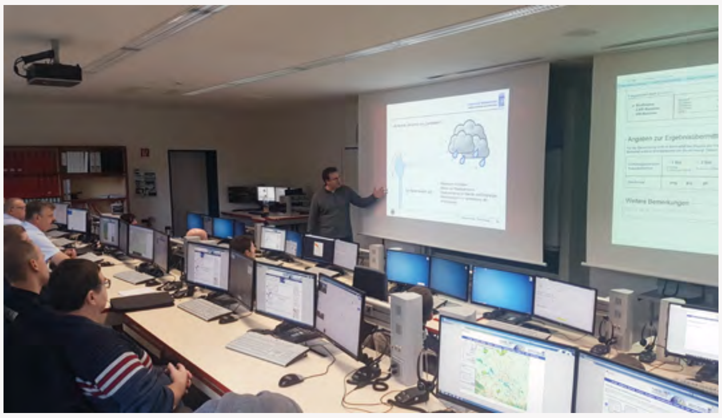
Air quality control: forecasting the atmosphere's capacity for exchange

Warm air on top, cold air underneath, and in-between a layer of inversion blocking all vertical exchange – these are, in brief, the characteristics of a specific weather situation referred to as inversion, which is particularly dreaded in large conurbations. Underneath the inversion layer, pollutants are trapped and accumulate in the air without any chance to 'escape' into the upper layers of the atmosphere. The result: increased fine particle concentrations, which depend on the two key parameters emissions and capacity of the atmosphere to clean itself.

As early as some ten years ago, the increasingly pressing problem of fine particle pollution led to the Deutscher Wetterdienst being asked to develop inversion forecasts for the Stuttgart region. Precise forecasting of such inversion situations with reduced atmospheric exchange had already been a challenging task for the meteorologists during the smog-laden winters of the 1980s. The issue became highly relevant again with the new focus on fine particle pollution. It became quickly clear that standardised inversion warnings are of no use in the case of Stuttgart. The reason: over the valley basin of Stuttgart, fine particles begin to accumulate in the air at atmospheric exchange conditions that are much less impaired than the levels specified in the World Meteorological Organization's (WMO) definition of inversion. Under such conditions, pollutant concentrations over Stuttgart increase strongly, sometimes rising above the EU threshold of a daily average of 50 µg per cubic metre. This fact needed to be taken into account when a forecast model adapted to Stuttgart's valley basin situation was to be developed.

Guided by the DWD's Regional Weather Advisory Office (RWB) in Stuttgart, guest scientists and interns from the universities of Tübingen, Potsdam and Hamburg developed a detailed, well-refined forecast matrix tailored to Stuttgart's specific emission profile and to the city's geographic position in a valley basin. The matrix divides the atmosphere's capacity for exchange into three categories: not impaired, impaired and strongly impaired. If the forecast predicts two consecutive days of strongly impaired exchange, the city of Stuttgart issues a 'fine dust alert'. As soon as the forecast predicts better dispersion conditions on two consecutive days, the alert is cancelled. The crucial factors in this decision are previous concentration figures, forecasts for no rain, existing inversion as well as wind direction and wind speed. All these factors are monitored against six different criteria.

The city of Stuttgart introduced the fine dust alert system in January 2016. During the winter of 2016/17, which was characterised by many high pressure systems, it was possible, thanks to the DWD forecasts, to issue immission forecasts with a success rate of more than 90 per cent, while the false alarm rate remained low at less than 20 per cent. The prognostic air quality approach taken by the DWD has made its atmospheric exchange forecasts one of the most innovative air quality control tools in Europe. This is because measures and appeals are not triggered by the exceeding of thresholds, but they already become effective as soon as unfavourable conditions are predicted. Such cases, for example, lead to appeals being issued asking people to use public transport instead of their cars and to a ban on the use of auxiliary heating systems. The procedure serves as a model for other metropolitan areas experiencing air quality problems and has been applied in Leipzig since January 2020 based on a forecast matrix adapted to local conditions.



top
FeWIS introduction seminar at the fire brigade training centre in Eisenhüttenstadt

Close contact with the customers: training courses and seminars

The customer service teams at the DWD's branch and regional offices are in close contact with the users and customers of weather data, forecasts and warnings of the DWD. As set out in the Deutscher Wetterdienst Act, the DWD is responsible for supporting the Federation, the federal states and the local governments in the performance of their duties with regard to disaster, civil and environmental protection, especially in cases of extreme weather and climate events with a high potential to cause damage. To this end, the DWD offers special customer information systems, such as FeWIS, the weather information system for disaster management, and SWIS, Germany's road weather information system. The two systems are currently used by around 4,000 users in public authorities and disaster management organisations. In addition, the DWD's weather warning app 'WarnWetter' has become very well established as a mobile information system for this group of customers as well as for the general public. Five years after its introduction, the WarnWetter app already has over one million regularly active users.

Requirements, special wishes and criticism as well as positive response from the customers reach the DWD through digital channels. Very often, they are also communicated during the seminars held by the customer service units. It is essential to explain the contents to the professional users whose job it is to take important decisions.

This is why in 2019 the DWD delivered more than 80 introductory or further training courses on the use of the DWD systems to over 1,000 participants from customers performing public tasks. Among others, the seminars were held at fire brigade training and operations control centres, at different public authorities as well as at the DWD itself. The contents of these seminars are designed to train the users under near-practical conditions on how to make better use of the systems. Users are also given a basic understanding of meteorological concepts to help them within their day-to-day work. FeWIS users, for example, can thus draw up better plans for deploying the personnel and the resources needed to prevent or minimise damage in advance of approaching or ongoing severe weather situations. Winter road services can improve the co-ordination of gritters and snow-ploughs and protect the environment through intelligent use of gritting material.

User conferences on the FeWIS/SWIS information systems, trade fairs such as FLORIAN, Germany's trade fair for fire brigades, civil protection and disaster control, and various open days have also contributed to a better understanding of customer requirements and will continue to do so in the future. It has been shown many times that personal contact is indispensable for optimum co-operation, especially in extraordinary situations, such as the forest fires in the summer or the massive snowfalls in the Alpine region in January 2019. The findings resulting from these contacts are very valuable and are gathered and evaluated at the DWD and then implemented in new or improved applications.

In the future, digitisation will shift the emphases in the communication with customers. Already now, the support teams for the WarnWetter app, the DWD's spatial data services and the OpenData products offered are providing the users with daily support. The growing demand for seminars and explanations regarding DWD services will be met increasingly by new e-learning tools. But despite all these innovations, one thing will remain the same: the DWD will always be in close contact with its customers.

Regional airports – how the DWD ensures the quality of meteorological reports

The DWD is tasked with providing information and services to ensure the safety of aviation. Pursuant to the German Civil Aviation Act (LuftVG) and international rules and regulations (ICAO, WMO, EU), the DWD, in its role as certified and sole meteorological service provider designated for Germany, renders aeronautical meteorological operations services at international and regional airports. This includes weather observation and weather reporting services.

The meteorological data and reports resulting from the weather observations include information on surface wind, visibility, runway visual range, weather phenomena, cloud cover, air temperature, humidity and atmospheric pressure. They inform pilots, air navigation services and other users about the weather conditions at the relevant airports and thus primarily ensure the safety of aircraft during take-off and landing.

At international airports, such as Frankfurt or Munich, the DWD uses its own dedicated observation devices, whereas the 23 regional airports in Germany are equipped with meteorological instruments procured and operated by the aerodromes' operators. The technical responsibility, however, remains with the DWD.

The DWD fulfils this responsibility by regularly checking the aeronautical meteorological equipment – consisting of the Automated Weather Observing Systems (AWOS) – and the associated sensors installed at the regional airports. If new technology is to be introduced, all instruments are tested by the DWD at its site in Hamburg-Sasel as well as in the field. Once the instruments have successfully passed the tests, type certifications are issued and the instruments are permitted to be used at regional airports. In 2019, new sensors for measuring background luminance, air temperature, humidity and visibility were accepted in this way. The DWD also has to approve any individual system/sensor configurations installed at a regional airport and endorse their operational use. In 2019, this was necessary for system changes at eleven regional airports.

The DWD has laid down the system requirements, inter alia, in a manual, which serves as a detailed implementation guidance for regional airports and manufacturers of aeronautical meteorological installations and sensors. The regulations were developed at the DWD and already contain specifications for the launch and operational service of the next AWOS generation. The new AWOS instruments will allow regional airports to establish, for the first time, a fully automated weather reporting service at the scheduled times of operational air traffic. Only information about convective weather phenomena needs to be added manually, if applicable.

left

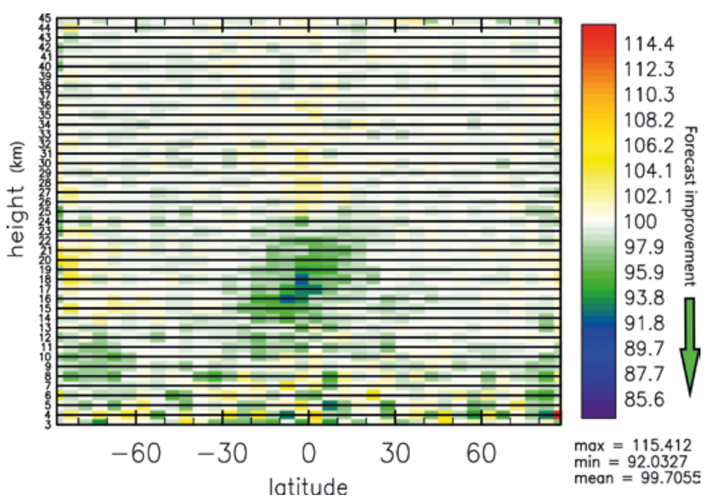
Regional airports in Germany where the DWD has the technical responsibility for the meteorological instruments.

Use of lidar-measured wind data from Aeolus at the DWD

All types of conventional as well as satellite-based observations of atmospheric parameters, such as wind, temperature, humidity or pressure, are used in numerical weather prediction to define the forecasts' initial state. In this process, wind observations play a key role. Unfortunately, full coverage of three-dimensional wind data is only available from radiosonde flights, wind profile measurements and aircraft-based observations over land. Wind observations are sparse, however, over large parts of the Earth, especially over the world's oceans, the polar regions and the tropics.

On 22 August 2018, after nearly 20 years of development and assembling, the European Space Agency (ESA) successfully launched its fifth Earth Explorer Mission into space, placing the Earth observation satellite Aeolus into its polar orbit at 320 km altitude. Aeolus is the first-ever satellite that is able to measure global, three-dimensional wind profiles from the near-surface layer up to 30 km altitude while achieving a horizontal resolution of around 80 km and an accuracy of 1 m/s to 2 m/s. The measurement instrument, a so-called lidar, consists of a high-power laser and a telescope emitting short light impulses in the near infrared spectral range. From the round-trip times of the light signals reflected by the atmosphere and their Doppler shift, it is possible to derive information on the airflow in different layers of the atmosphere.

German Aeolus activities are grouped together under the initiative Experimental Validation and Assimilation of Aeolus observation (EVVA), with the participation of the German Aerospace Center (DLR), Munich and Leipzig universities and the DWD. Extensive validation checks run against the DWD's four wind profilers as well as long test series confirm the high quality of the data obtained with the wind lidar aboard the Aeolus satellite. Using Aeolus wind measurements also improves the exploitation of atmospheric data obtained through radio occultation. These improvements in quality even benefit the later stages of the forecast process across all forecast areas. For this reason, it is envisaged to use Aeolus wind measurements in operational data assimilation.



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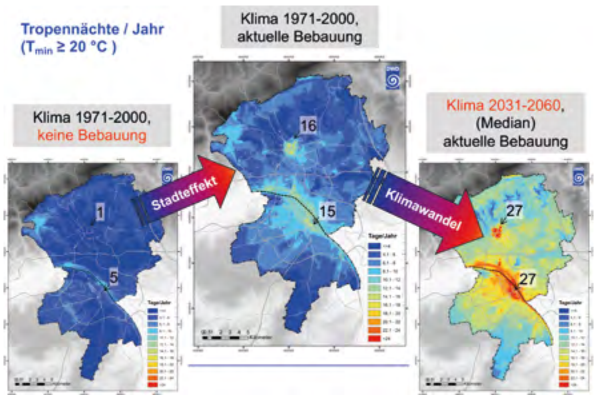
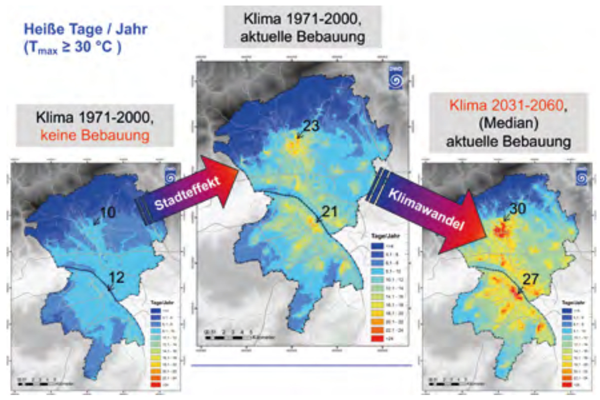
The graphic illustrates the outcome of a comparison of two experiments, one carried out with and the other one without Aeolus wind data. The blue and green areas in the graphic (tropics, polar latitudes, southern hemisphere) indicate where, in the analysis, the wind data provided by the Aeolus satellite improve the usage of radio occultations.





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Average number of ***tropical nights*** *per year in the cities of Wiesbaden and Mainz (grid spacing 100 m) and their increase due to built-up cover (heat island) and climate change. The values given are typical for inner cities (Wiesbaden in the north and Mainz in the south).*

right
Average number of ***hot days*** *per year in the cities of Wiesbaden and Mainz (grid spacing 100 m) and their increase due to built-up cover (heat island) and climate change. The values given are typical for inner cities (Wiesbaden in the north and Mainz in the south).*

Urban air is heating up

City dwellers know this from experience: in the late evening after a hot summer's day, temperatures in the green outskirts will have cooled down significantly, but when you open the windows in the city, there is still hot air coming into your apartment. The heat makes it almost impossible to get a good night of refreshing sleep.

Due to climate change and the associated warmer temperatures, this problem will get worse in the future. For this reason, cities are called upon to take more account of the climate in future town planning. In order to support local authorities to deal with this issue, the Hessian Agency for Nature Conservation, Environment and Geology (HLNUG) launched the urban climate project KLIMPRAX-Stadtklima for the cities of Wiesbaden/Mainz. KLIMPRAX is an abbreviation from the German project title "KLIMawandel in der PRAXis – Stadtklima in der kommunalen Praxis", Climate change in practice – Urban climate in municipal practice. The project was led by the HLNUG's Centre on Climate Change and Adaptation.

The DWD's part in the project was to supply the basic meteorological data. In order to do this, the DWD carried out studies of the current and the future climate in these two cities, using the DWD's urban climate model MUKLIMO_3 and an ensemble of 17 regional climate projections. The studies compared the heat island effect resulting from the building density with the impacts of the climate change to be expected until the middle of the century (2031–2060). In this way, it was possible for both cities to identify areas that are already especially affected or will be in the future. In addition, the model results showed the areas where fresh air is generated and its trajectories. This is relevant because the provision of fresh air is an important factor in urban and regional planning.

As well as providing a detailed report, the DWD presented the results of its studies to the project partners in a one-day closing event at the end of August 2019. The project enabled an important insight: translating meteorological information into categories and charts relevant for the planning process represents an essential step and requires thorough interdisciplinary exchanges. As a result, the authorities responsible for environmental matters in both cities have integrated the DWD data into their own GIS and, by their own account, have been using them regularly.

www.dwd.de/stadtklima

DWD and DLR conducting joint research

At the end of 2018, the Deutscher Wetterdienst (DWD) and the Institute of Atmospheric Physics of the German Aerospace Center (DLR-IPA) concluded a fundamental co-operation agreement aimed at conducting excellent joint research, producing joint publications, strengthening the international standing of both organisations and enabling the transfer of the acquired findings into operational applications.

The co-operation will focus on fundamental and user-oriented developments in areas such as weather forecasting (for example for aviation and general warning services) and climate research. This also includes creating the work environment and adjusting it in a way that is conducive to joint research. The chosen research and development topics take into account the partners' strategic and especially the scientific objectives and are consistent with their statutory mandates. By signing the research agreement, both partners agree in principle to conduct their research and development activities within the DWD's environment in order to enable a successful transfer into operations and follow-up at the DWD.

In the meantime, work has already started on the first concrete projects focussing on the collaboration's main topics:

- Volcanic ash: development of a method to derive volcanic ash concentrations from satellite observations
- Detection of ice clouds: filtering of ice clouds in order to improve the identification of volcanic ash
- Turbulence: definition of appropriate cases of turbulence in order to evaluate and improve turbulence forecasting
- Ice crystal icing (including ice accretion): development of icing forecasts for aviation

01 + 02
Radar tower Memmingen:
More gear parts to grease (photo 01). Ladislav Hart also checks the slip ring brushes to verify whether there is still enough contact material and whether all the slip ring brushes are in the correct position (photo 02).


01


02

Development co-operation activities at the DWD

Intensified co-operation with GIZ

For several years now, there have been good contacts, for instance through joint projects, between the DWD and Germany's agency for international co-operation, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). Both sides regard the co-operation as very fruitful. Development co-operation being a strategic goal of the DWD, activities in this area are being enhanced by intensified, systematic collaboration with the GIZ.

Strengthening agricultural meteorology in Madagascar

Since 2017, DWD and GIZ have been collaborating with other stakeholders in a joint project entitled Adaptation of agricultural value chains to climate change (PrAda) in Madagascar. The key partner in the work package in which the DWD is involved is the country's national meteorological service, Direction Générale de la Météorologie (DGM). The co-operation between DWD, GIZ and DGM aims at enabling the latter to independently use and further develop the DWD's agrometeorological model AMBAV Global for Madagascar. To this end, a distance training course was held in 2019 for selected DGM staff members, followed by an intensive attendance course in Germany in the first half of July.

In connection with the latter, a six-member Malagasy delegation came to Offenbach for a meeting with DWD and GIZ representatives. Besides scientific/technical staff members, the delegation also included Mr Lantonirina Ramaroson, Director-General for Agriculture at the Ministry of Agriculture of Madagascar, and Ms Nirivololona Raholijao, Director-General of the DGM. During the visit, a short ceremony was held to seal the Memorandum of Understanding on mutual co-operation signed shortly before the occasion. The agreement forms the basis for the medium-term collaboration that the DWD and the DGM intend to continue beyond the end of the PrAda project.

WMO: Alliance for Hydromet Development and Country Support Initiative

The Alliance for Hydromet Development is an initiative that unites representatives from various development, humanitarian and climate finance institutions, all committed to scale up the national meteorological and hydrological services' capacities in order to upgrade their observational systems and data exchange procedures to comply with WMO standards. The aim is to take sustainable measures that enable the national meteorological services in developing countries to produce high-quality weather forecasts, early warning systems as well as hydrological and climate services. The actions planned by the Alliance are guided by the principles set out in various United Nations agreements, including the Sustainable Development Goals under the 2030 Agenda for Sustainable Development, the Paris Agreement on Climate Change and the Sendai Framework for Disaster Risk Reduction 2015–2030. The creation of the Alliance was decided by the WMO Congress in summer 2019; it was then launched at the COP25 climate conference on 10 December 2019.

In addition, the DWD supports the so-called Country Support Initiative (CSI), aimed to help developing countries and development partners by offering advice on developing, implementing and evaluating hydrometeorological projects. The Alliance for Hydromet Development also makes use of the Country Support Initiative, which provides the technical expertise and knowledge from the WMO institutional network for development and climate finance.

European Centre for Medium-Range Weather Forecasts: 40 years of medium-range forecasts

The European Centre for Medium-Range Weather Forecasts (ECMWF) has been producing operational medium-range weather forecasts for 40 years: its first medium-range forecast was published on 1 August 1979. Since then, the ECMWF, an intergovernmental organisation, has continuously improved and refined its forecasts, which currently provide an outlook for the next ten days. As in previous years, the DWD invited ECMWF's management to an exchange of ideas, which took place at the Meteorological Observatory in Hohenpeissenberg in October 2019.

The year 2019 saw some important milestones for the ECWMF's future: the first group of staff members, around 20, were relocated to Italy, where the new computing centre is being built. After some unforeseen delays, the centre is now due to be completed in mid-2020. The contract negotiations for the delivery of the new high-performance computer have been concluded. Beginning in 2020 and over a period of five years, the ECMWF will gradually introduce a free and open data policy.

www.ecmwf.int

01+02
Radar tower Memmingen:
Getting ready before climbing up to the top platform of the radar tower. The use of personal protective equipment is mandatory on the top platform, which has no guard rails because these would interfere with the radar signal. The shell of the radome and the seams on it must be checked regularly for any damage and, if found necessary, repaired by a contractor.

Network of European meteorological services (EUMETNET): next programme phase

EUMETNET is a consortium of European national meteorological services founded as a framework to carry out joint projects and programmes for all its members. It is based on the principle of 'one for all', meaning that one member or a group of members performs a service benefiting all partners. The beginning of 2019 saw the start of EUMETNET's new five-year programme phase. As in previous years, the DWD will continue to lead the EUMETNET Automated Shipboard Aerological Programme, E-ASAP, charged with the co-ordination of radiosonde ascents from merchant ships. The DWD also contributes as a partner to EUMETNET's Observations Programme Management as well as to the consortium co-ordinating the Operational Programme for the Exchange of Weather Radar Information (OPERA).

www.eumetnet.eu


01


02

EUMETSAT: next generation of meteorological satellite systems

Efforts to develop the next generation of geostationary and polar-orbiting satellites are progressing well. These new meteorological satellites, which will benefit from enhanced observation technology and carry innovative instruments, are scheduled to be launched from 2021. The DWD expects them to provide valuable information for a substantial improvement in weather forecasting, such as better detection and prediction of fog as well as early detection and better forecasts of thunderstorm cells, and hence of weather events with the potential of causing serious damage. New additional findings about the distribution of water and ice as well as atmospheric trace gases will be used in both numerical weather forecasting and climatology.

The focus of EUMETSAT's so-called mandatory programmes is on the continuation and extension of long-term satellite observation series and thus their usability for climate and climate change monitoring. Regarding Copernicus, the European Union's Earth observation programme, EUMETSAT has proven itself as a strong partner for the establishment and operation of the observation infrastructure. It is expected that the continuation of this role will lead to an increasing number of tasks. One of them will be the operation of a satellite-based observation capability contributing to an integrated greenhouse gas monitoring system, which the DWD, together with other partners, is currently establishing for Germany.

www.eumetsat.int

European Union: Copernicus and DWD

In the past years, the DWD has successfully participated in several invitations to tender, increasingly establishing itself as a trustworthy partner of the Copernicus programme. In addition to the validation of products to monitor atmospheric composition or contributions to the European Flood Alert System (EFAS), the DWD's activities mainly focus on services for monitoring climate change. These include the derivation of climate variables (referred to as essential climate variables or ECV) from satellite data, the provision of seasonal forecasts as well as contributions to climate assessment summaries. The DWD was thus able to increase its visibility in Europe, showcase its competencies and position itself favourably for Copernicus 2.0, the next phase of the programme.

www.d-copernicus.de

Bilateral co-operation

As part of its international exchanges, the DWD regularly hosts meetings with other meteorological services and international organisations. In 2019, bilateral as well as trilateral talks took place with the national meteorological services of the United Kingdom, France, Switzerland, Austria, the Netherlands, Poland and the Czech Republic. At the beginning of September 2019, the DWD received a delegation from South Korea. During the WMO Congress in June 2019, meetings were held with representatives of the Chinese, Japanese and South African meteorological services. Most of the bilateral meetings took place at director level. In addition, some experts from other meteorological services visited the DWD to gain information about its tasks and activities.

Brief and concise infos from the new social media studio

On social media, especially Facebook, Twitter and Instagram, the use of moving picture information is growing steadily. Users expect from the DWD simple, easy-to-understand videos with information about weather and climate. Online media organisations also have an increasing demand for interviews at short notice, for example over Skype.

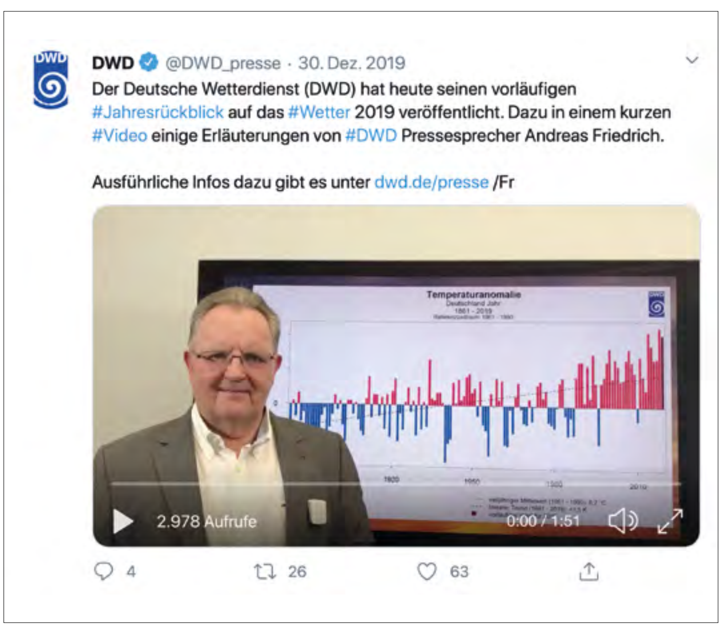
In order to meet these requirements, the DWD's staff division Press and Public Relations has set up a special social media studio. Equipped with a large HD monitor, two computers for graphics and animations, two studio lights, a stand and a special, wireless microphone, the studio can be used for Skype interviews or for the production of social media videos within a short lead-time. An iPhone and an iPad serve as filming and recording devices. This set-up allows for Skype sessions to be held via WiFi, for example with bild.de, as well as the production of videos without any postprocessing. Weather information from and for everywhere in the world can be displayed using the TriVis visualisation system. In extraordinary weather or climate situations, the new studio with its equipment enables the press team to provide important information in a brief and concise form.

An example, the annual review for the meteorological year of 2019, can be found on our Twitter page.

https://twitter.com/DWD_presse/status/1211672032951320577?s=20

www.dwd.de/presse

below
DWD Press Officer Andreas Friedrich in the new social media studio producing a short annual review clip for 2019.



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The DWD's new hail sensor used in the observation network, especially at airports.

Prize for innovative partnership

On 19 February 2019, the Deutscher Wetterdienst (DWD) received the award 'Innovation creates advantage' (in German: Innovation schafft Vorsprung), which is conferred by the Association for Supply Chain Management, Procurement and Logistics (BME) to honour outstanding achievements of public-sector contracting authorities. This prize, which awards vouchers for consulting services worth up to 10,000 euros, was presented to the DWD at the Public Contractors' Day by Christian Hirte, Parliamentary State Secretary at the Federal Ministry for Economic Affairs and Energy (BMWi), and Dr Silvius Grobosch, CEO of BME.

The DWD had applied for this award proposing a task carried out as part of a long-term project aimed at automating weather observations at airports. One of the challenges of this project is the implementation of a new sensor concept. The results of a market survey showed that all currently available sensors and detectors for identifying hail operate based on a closed impact surface not allowing for a differentiation between hail and heavy rain. This is why the DWD wanted to modify the impact surface in such a way that the impact of a hailstone on the detector's surface would prompt a significantly stronger impulse than that of a raindrop. In addition, a cost-effectiveness analysis revealed that developing a hail sensor tailored to the DWD's needs was the most economical option.

The DWD was the first institution in Germany to resort, for this technically and legally complex development project, to the new concept of 'innovation partnership', which is based on the principle of having new innovative services developed that are not yet available on the market and purchasing the resulting products. It has become clear in the process that such an innovation partnership is not just a tendering procedure, but also a collaborative project between the public sector and innovative companies requiring active contributions from both sides in order to succeed. This flagship project also contributed to an increased acceptance by the specialist departments and units within the DWD. As a result, more innovation partnerships are being considered, for example in order to develop a detector for freezing rain.

Next milestone for the new building in Potsdam: topping-out ceremony

At the beginning of April, clear blue sky and spring like temperatures of 21 °C greeted the many guests on the construction site at Michendorfer Chaussee 23 in Potsdam. The Brandenburg State Office for Estate Management and Construction (BLB) had invited to the topping-out ceremony for the new building of the DWD's Potsdam branch. After the laying of the foundations in October 2018, this event constituted another important milestone.

In his speech, Norbert John, technical director of BLB, praised the excellent work of the construction workers and the fact that the timeframe had been respected. The financial situation, however, is more difficult. Due to the continuing construction boom and the large demand for building services, the estimated construction costs of 37 million euros might increase even further. In his welcoming address, DWD President Prof. Dr Gerhard Adrian underlined the importance of the DWD's third-largest site.

After the foreman of the builders read out the traditional address and, as it is the custom, a few glasses were smashed, the ceremonial topping crown was raised. Architect Henning von Wedemeyer led a tour of the building and explained his creative concept. Exposed concrete and elements of wooden cladding at the front of the building are combined with wide windows and light shafts. In this way, the ensemble comprising altogether six buildings fits harmoniously into the wooded surroundings. A three-storey office block is linked via the weather boulevard to the service and logistics building and the computing centre. Added to this complex are an antenna tower, several garages and a building containing technical equipment. The antenna tower will reach a height of 25 m and is situated within the protected buffer zone of the World Heritage-listed Berlin-Potsdam landscape. For this reason, the tower's colour and front will need to be adjusted to the surrounding historic landscape.

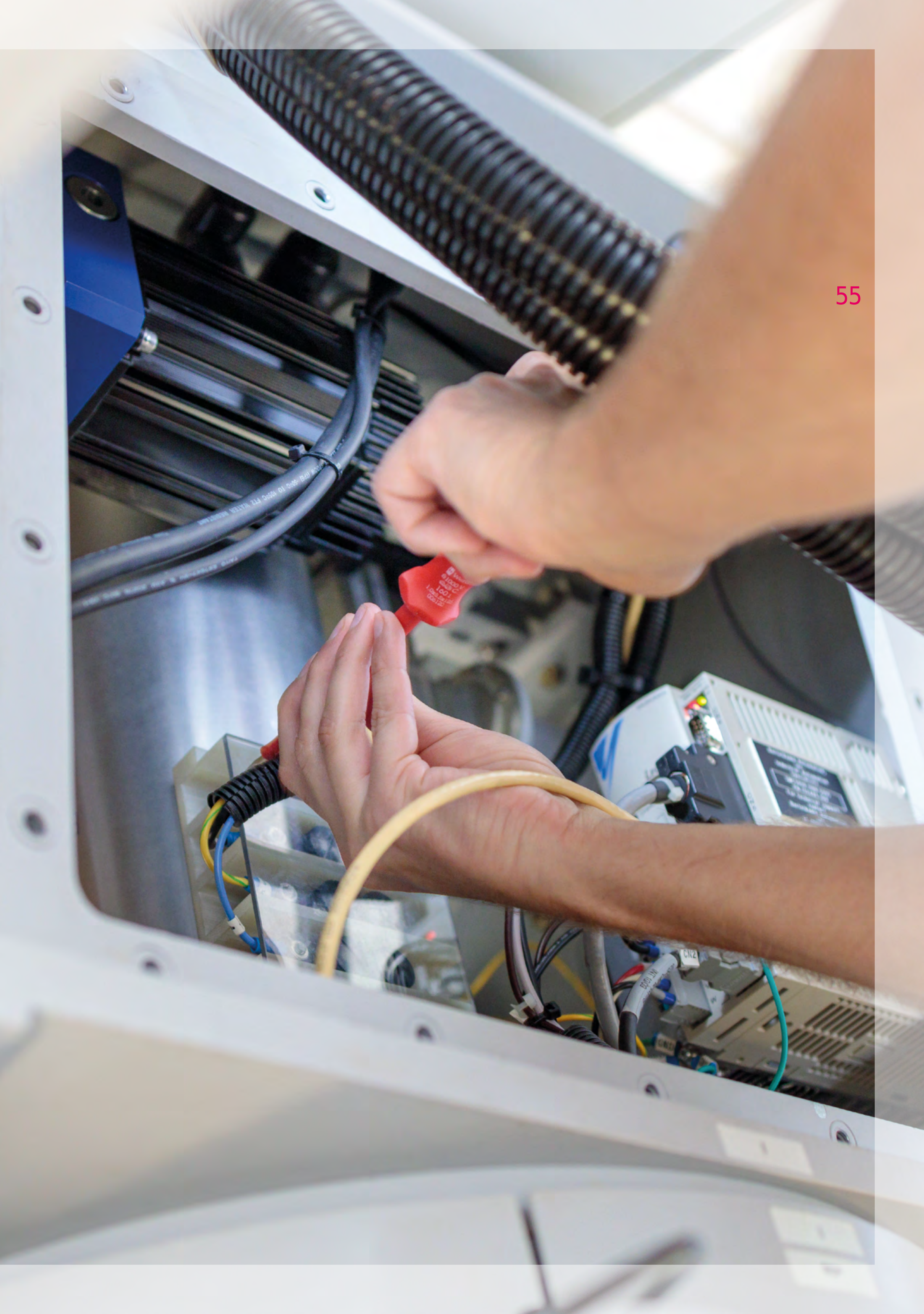
The structural acceptance is scheduled for the summer of 2021, followed by the installation and testing of the technical equipment of the building. In 2022, about 200 employees, who are temporarily housed at sites in Stahnsdorf and Drewitz, will move back into their 'old' place of work.

left

Topping-out ceremony at the construction site of the new building for the DWD's Potsdam Branch Office in wonderful sunshine at the beginning of April. The topping-out crown hovers above the 'weather boulevard', the hall area at ground floor level that will link all the parts of the building with one another and with the outdoor area.

Interview

right
The first thing to do in order to reach the slip ring brushes is loosen the protective cover.



‘What we need now are results’

Interview with Patricia Espinosa Cantellano, Executive Secretary of the United Nations Framework Convention on Climate Change (UNFCCC) in Bonn since May 2016

DWD:
When and how did you first become interested in weather and climate?

Patricia Espinosa Cantellano:
I’ve been a career diplomat since 1981, ambassador to four countries and foreign minister in my home country, Mexico. Those positions all came with a dossier that included environmental issues. When I look back, I see over and over how fortunate I was throughout to be engaged in the global challenge to address climate change and its consequences.

DWD:
The United Nations Framework Convention on Climate Change has been in force for 25 years. What progress do you think has been made in the protection of our climate system?

Patricia Espinosa Cantellano:
The last 25 years have seen a mix of challenges and opportunities – a few disappointments matched by some incredible successes. In 25 years, we’ve gone from the Convention, to the Kyoto Protocol to the Paris Agreement – that’s a remarkable journey in and of itself – and just over a year ago, nations agreed on a set of guidelines designed to maximize the impact of the Paris Agreement.

Yet while we’ve made enormous progress in 25 years, the world is still running behind climate change. The urgency to address climate change has never been greater. But because of the work begun 25 years ago, we have the tools to address this existential threat. We have the Paris Agreement, and we have the guidelines to make it fully operational. They provide national governments and other stakeholders the tools to put in place national climate plans to accelerate their climate actions in accordance with their national circumstances. What we need now are results.

left
Patricia Espinosa Cantellano, Executive Secretary of the United Nations Framework Convention on Climate Change

DWD:
When you think back to the various climate change conferences which you led or in which you participated, what was your biggest disappointment, what your biggest pleasure?

Patricia Espinosa Cantellano:
Those involved in or following the climate change negotiating process identify me closely with my role as President of COP 16. I am deeply proud of having led the efforts which ultimately resulted in the adoption of the Cancun Agreements. The process was in a fragile place at that time and picking up the pieces from Copenhagen helped the international community to pave the way towards the Paris Agreement.

As Executive Secretary of the UNFCCC, my biggest pleasure was when countries put in place the largest part of the Paris Agreement's fine print at COP 24 in 2018. This will guide the implementation efforts of the 189 Parties that have ratified the agreement. That was a huge moment of joy, especially because it was a moment where we saw the world coming together to address the biggest challenge of our generation.

DWD:
What needs to be done to actually implement the Paris Agreement?

Patricia Espinosa Cantellano:
2020 represents our last best chance to unlock the potential of the Paris Agreement and achieve three primary climate goals:

1. Limit global temperatures to 1.5 degrees by the end of the century.
2. Achieve climate neutrality by 2050.
3. Reduce emissions 45 per cent by 2030.

The Paris Agreement is the world's framework for achieving these goals. While we have the tools under the Paris Agreement to address the climate emergency, we are not yet seeing the required political will to act with a sense of urgency. It really is an existential threat and we already know that some of the consequences of climate change are irreversible. Unfinished work from COP 25 – including agreement on market- and non-market based tools to help countries reduce emissions in a cost-effective way – and ambition levels remain significantly inadequate to meet climate goals.

We didn't get the results we were hoping for in Madrid. Now we must redouble our efforts.

We need to respond to the call from societies around the world, especially from the youth. It is crucial that countries come forward with more ambitious commitments and determination to implement them.

Negotiations will continue at COP 26. In addition to completing the guidelines to make the Paris Agreement fully operational, 2020 is the first opportunity for countries to submit more ambitious climate action plans, which are officially called nationally determined contributions (NDCs). It also marks the beginning of the Secretary-General's global call for a Decade of Action to deliver the Sustainable Development Goals (SDGs), which include climate action, poverty and inequality, and gender equity.

DWD:
Do politicians and scientists communicate climate change issues adequately?

Patricia Espinosa Cantellano:
The science around climate change can seem overwhelming at times. Thousands of scientists from around the world have spent years – often decades – analyzing the information that society needs in order to make sound decisions about how to respond to climate change.

We are indebted to them – without their work, we wouldn't have the UNFCCC, the Kyoto Protocol or the Paris Agreement. And while the information they provide is complex, their message is essentially a very simple one: we are poisoning our land, sea, and air and we must change course as rapidly as possible. Why? Because we're almost out of time to be able to make that difference. With respect to climate change, we must reduce our emissions and achieve the Paris Agreement goal of limiting global temperatures to 2 °C , while working towards 1.5 °C by the end of the century.

While many politicians and scientists – for example those of the Intergovernmental Panel on Climate Change, the body tasked with assessing climate change science – communicate to the public very well about climate change, not everybody does. We need to speak to people in plain language. It must go beyond statistics, beyond legislation, beyond the policy, and look to how this affects people on a daily basis. What does it mean for their jobs? What does it mean for their homes? Their children? And while we need to talk about the *negative* impacts of climate change, I feel we could do a better job communicating the *benefits* of addressing climate change. For example, the economic opportunities associated with it; the health benefits; the way it will have a positive impact on almost every single other major challenge humanity faces.

Can politicians and scientists do a better job of conveying the climate change challenge? We can *all* do a better job.

DWD:
What do you think of the many young people who, supported by parents, business owners and scientists, take to the streets every week to protest in favour of climate protection?

Patricia Espinosa Cantellano:
Young people are taking up the mantle of this responsibility, providing both a moral voice and a strong reminder that deep transformative actions need to be taken immediately in order to avoid compromising their opportunities. Youth have made it clear that they perceive climate change as a threat to their future and that their calls should not be ignored. They shouldn't be – and they certainly won't be – ignored by our process. Their voices, their solutions and their creativity are badly needed.

DWD:
Given the many trouble spots in the world, why should young people have an interest at all in engaging in or standing up for weather and climate?

Patricia Espinosa Cantellano:
From natural disasters to human-made disasters, humanity has overcome many daunting challenges. People have demonstrated a huge capacity to adapt and to develop solutions that were unthinkable. Just think of penicillin or the printing press. Humans are characterised by ingenuity and creativity, particularly from the youth. Given that climate action is about the quality of their future, it is only natural that young people are taking such a strong interest in the climate emergency. The creativity that youth bring to the table can be incredibly valuable. For example, Boyan Slat and his invention to clean up the oceans, or Anna Luisa Beserra who invented a solar-powered device to make safe drinking water. There are many more examples and the UN has honoured many of them, not least through the Young Champions of the Earth awards.

DWD:
What do you think is the greatest challenge facing humanity?

Patricia Espinosa Cantellano:
Concerning climate change, we have almost reached the point of no return. More and more studies clearly point to increasing climate change effects, and more and more studies point to the fact that we are close to running out of time. In the face of clear climate science, we cannot continue to release greenhouse gases into our atmosphere, watch how they wrap themselves around our planet like a blanket and expect nothing to go wrong. We stand at the dawn of a new decade: one that will determine the fate of humanity in our fight against climate change. The deep economic transformation needed to address climate change and to make the future safer, can no longer be delayed or attempted half-heartedly. It needs to be completed cooperatively.

DWD:
Finally, a very different question: In fulfilment of your numerous functions, you have been staying in many different places around the globe for nearly 40 years. Is there a place in the world where you personally feel at home? Where would that be and why?

Patricia Espinosa Cantellano:
You may have heard that Mexicans are very fond of their country, their culture, their traditions, their food… and that applies to me. I would also add that for me home relates to family, and my family is there.

At the same time, as you say, I have had the privilege of living in different places around the world. It has been a fascinating journey that has allowed me to discover new places, new people, new friends, music, food, etc. There is always something special and something to learn.

However, I am particularly attached to Germany. I attended the German school in Mexico and therefore, since I was a child, I have a strong connection to this country, professionally and personally. I have friends and even a German family with whom I lived for a year – a long, long time ago! Germany also feels like home and I feel privileged to be able to spend these years here.

DWD:
Thank you very much for the interview!

Note
This interview was held at the beginning of 2020 before the coronavirus pandemic broke out.

www.unfccc.int

Finale

right

All systems back in operating mode: in the radar tower's operating room, Melanie Eickmeier and Ladislav Hart check the radar's transmission pulse using a USB power meter. If the transmission pulse does not meet the requirements, it has to be adapted accordingly.

Annual productivity and performance figures

Approx. 90,000 forecasts and approx. 185,000 weather and severe weather warnings (heat and UV warnings not counted)

Over 14,000 advisory statements on weather and climate as well as expert reports for public authorities, disaster control units and other customers

Approx. 460,000 forecasts and warnings for aviation

Approx. 34,000 telephone briefings for aviation

Provision of self-briefing systems for civil aviation, aerodromes & airports and air services providers (approx. 380 million requests)

Approx. 200,000 reports, warnings and advisory services for maritime shipping, coastal protection and offshore projects

Provision of over 23,000 products for climate monitoring

DWD sites throughout Germany

Headquarters in Offenbach am Main

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

5 regional offices providing consultancy services in the field of climate and environment

5 MET advisory centres

3 agrometeorological advisory centres

182 main weather stations, of which

4 are manned around the clock and **1** is manned part time

161 are fully automated

16 are aeronautical meteorological stations at international airports

1,735 secondary weather and precipitation stations, of which

834 are online stations reporting every half-hour

1,082 phenological observation sites

2 staffed main weather stations aboard research ships

66 automated shipboard weather stations

472 weather reporting stations aboard merchant ships

5 moored buoys in the North and Baltic Seas

4 automated shipboard aerological stations

18 weather radar sites in Germany

2 meteorological observatories

10 upper-air stations with approx. 7,000 radiosonde launches per year

48 stations where radioactivity is measured

3 mobile measuring units

7 automatic greenhouse gas measuring stations at high towers

Figures relating to the DWD's budget

The DWD total budget amounted to:

2019	2018	2017
around 370 million euros	around 343 million euros	around 369 million euros

Every citizen of Germany thus paid[1]:

2019	2018	2017
4.12 euros	3.82 euros	4.01 euros

In 2019, the DWD's expenditure was distributed as follows:

Appropriations/Subsidies (external funds not included):	Investments:	Expenditure on material:	Personnel:
171.5 million euros	33.3 million euros	45.5 million euros	119.6 million euros

In 2019, appropriations and subsidies went to the following organisations (external funds included):

EUMETSAT:	ESA:	ECMWF:	EUMETNET, WMO, others:
107.6 million euros	47.2 million euros	10.3 million euros	17.6 million euros

[1] According to estimates by the Federal Statistical Office: 83.2 million inhabitants at the end of 2019

Figures relating to the DWD's staff

Number of established posts:

2019	2018	2017
2,171.0	2,178.5	2,197

Number of staff members[2]:

2019		2018		2017	
2,216		2,248		2,296	
Men	Women	Men	Women	Men	Women
1,384	832	1,412	836	1,442	854

[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 routaine

Registration of 1,300 new heavy rain events in Germany

(since 2001, the DWD has registered over 22,000 heavy rain events)

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 close to 121,000 stations around the globe.

177 scientific publications, of which 146 were published in international, peer-reviewed specialist journals

The DWD's Marine Meteorological Office in Hamburg holds around 37,000 meteorological logbooks from the years between 1826 and 1940; by now, more than half of these journals have been digitised for climate research purposes.

- The journals contain an estimated 23 million meteorological observations from the world's oceans.
- Climate time series could thus be extended by up to 60 years.
- For comparison: The DWD currently receives around 2.2 million observation data sets per year from ships alone.

Participation in close to 50 large national and international climate and weather research projects

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Slightly more than three quarters of the data processed for the DWD’s global weather forecasting system ICON come from meteorological satellites.

Approx. 7.5 terabytes of archived weather and climate data (station data as well as gridded and reanalysis data) are made available for free access by the general public, public authorities, industry and research community (https://opendata.dwd.de/).

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

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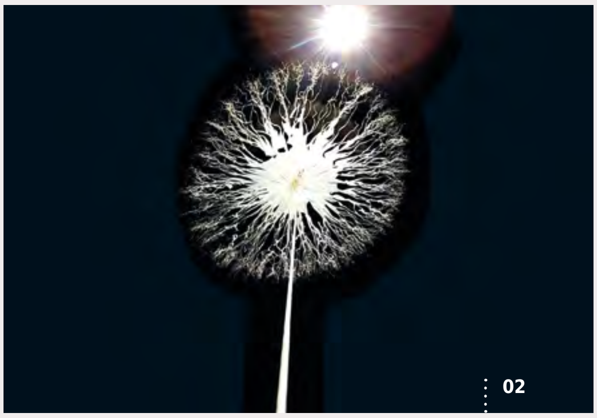
The DWD’s National Meteorological Library holds more than 190,000 media units.

Approx. 1,400 birthday weather charts were issued to visitors of the Federal Government’s open day in Berlin last August.



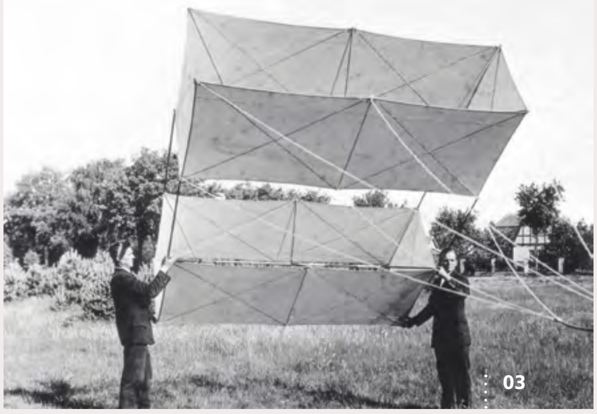
01
Replica of the Lindenberg box kite, exhibited at Lindenberg Weather Museum

02
Weather balloon bursting at 31.4 km altitude, photographed in spring 2014

Last but not least:

9750 metres is still the unbroken high altitude world record for a weather kite

Meteorological history was written on 1 August 1919, the day on which scientists and technicians at the Royal Prussian Aeronautical Observatory in Lindenberg (now in the Oder-Spree district) succeeded in sending a train of eight box kites up to an altitude of 9750 metres to measure air temperature, air humidity and air pressure. An unbroken world record for kites. The Deutscher Wetterdienst (DWD) recalled this unique achievement 100 years later at the same location, its Meteorological Observatory in Lindenberg, the Richard Assmann Observatory (MOL-RAO).



03
Preparing a box kite for launch

04
Kite above the winch house at Lindenberg

Exploring higher air layers with kites and tethered balloons

Today's radiosondes can ascend as high as 35 kilometres and transmit meteorological information for weather forecasting and climate research in real time. Data on the Earth's atmosphere, which can be used to determine meteorological values, additionally come from many meteorological satellites at intervals of sometimes less than ten minutes. 100 years ago, prior to radio transmissions, it was only possible to collect data on the upper air with the help of kites and tethered balloons. The early days, at the beginning of the 20th century, when altitudes of between 2,700 and 4,000 metres were being reached, were modest compared to today. Scientists at the Aeronautical Observatory founded by Richard Assmann in 1905 concentrated on the vertical profiling of the atmosphere in particular.

The scientists used so-called meteorographs. The signals of the sensors for pressure, temperature and humidity were transferred to a clockwork-driven recording drum. The balloon or kite was attached to a steel cable moved by a winch in the so-called winch house. The cable winch was used to release balloons and kites up and pull them down again. The data captured by the meteorograph were evaluated by the scientists as soon as the instruments were back on the ground. Between 1905 and 1931, more than 21,000 ascents, or an average of around two every day, were performed in Lindenberg; over two thirds of these ascents were with kites and the rest with tethered balloons. Kite ascent technology made huge steps forward and was perfected over the course of several decades at the Lindenberg Observatory.

The world record ascent on 1 August 1919 was made with a train of eight box kites. The top kite carried the meteorographs while the other seven were needed to lift the weight of around 15 kilometres of steel cable. When the scientists came to evaluate the data, they found that the barometer spring had hit the edge of the barometer box at an altitude of 9190 metres and was unable to register the further ascent of the train. The maximum altitude actually reached was therefore derived from the temperature values recorded.

Four weather balloon ascents up to 35 kilometres altitude every day

Four radiosondes with weather balloons are now launched at the MOL-RAO every day to supply data about air pressure, air humidity and wind at altitudes of up to 35 kilometres. Within the framework of the WMO, the observatory has also taken on the task of ensuring the global quality of the international radiosounding network. Measurements are also made of these variables as well as additional cloud and radiation parameters with so-called ground-based remote sounding techniques. These techniques use propagated radio, light and sound waves to explore the atmosphere. Information is continuously available with a time resolution of between a few minutes and around one hour. This facilitates detailed study of atmospheric processes. The measurement data obtained in Lindenberg are used for current weather forecasting and the further development of weather prediction and climate models as well as for the validation of satellite measurements and for climate monitoring.

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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

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Imprint

Editor
Deutscher Wetterdienst

Concept and editing
Gertrud Nöth
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Press and Public Relations

Translation
Gabriele Engel
DWD

Layout
Simone Leonhardt, Frankfurt am Main

Printing
Printed by the Federal Ministry of Transport and Digital Infrastructure (BMVI)

This yearbook is published as part of the DWD's public relations activities. It is distributed free of charge.

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Page 25

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Photos and graphics

Source	Page
Bernd Lammel, Bild-Kraftwerk	Titel, 4, 7, 9, 10, 11, 12, 13, 15, 35, 47, 49, 55, 61
Deutscher Wetterdienst	16, 17, 18, 19, 20, 21, 23, 24, 25, 31, 37, 38, 40, 41, 42, 44, 45, 46, 51, 68 (left), back of poster
Torsten Wendt, DWD	26, 27
KNMI/E-OBS	30
World Meteorological Organization (WMO)	36
Julia Fruntke, DWD	39
Mathias Rudolph, DWD	43
Eckhard Lanzinger, DWD	52
Sabine Neumann, DWD	53
United Nations Framework Convention on Climate Change (UNFCCC)	57
DWD/MOL-RAO	68 (right), 69
Flughafen Hannover-Langenhagen GmbH	Front of poster (Hannover)
Rüdiger Manig, DWD	Front of poster (Neuhaus)
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Cover

Serguei Laskovitch moves the 4 m antenna into a position allowing our technicians to reach the components in need of checks and maintenance.

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ISSN 2629-2084

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audit berufundfamilie