

# 2020



## Yearbook 2020

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).



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### Photo series in the Yearbook 2020

The photos in this Yearbook are dedicated to the MOSAiC expedition. The German research icebreaker FS Polarstern (01) is equipped with a shipboard weather station - owned and staffed by the DWD. The weather station team of the DWD accompanied the expedition during the whole journey. Due to the coronavirus pandemic, DWD weather technician Christian Rohleder (02) stayed several months on board of the ship during leg three of the expedition, spending some of his time to capture very special moments with his photographer's eye. His team partner was meteorologist Robert Hausen (03) from the DWD's Weather Forecasting and Advisory Centre in Offenbach. Without weather forecasts, it would not have been possible to venture on outdoor missions, neither on foot nor by helicopter.



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# Foreword

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

Dear readers,

With an annual mean temperature of 10.4 °C, 2020, behind 2018, is the second-warmest year in Germany since records began. In some European countries, the past year even was the warmest year ever recorded. According to analyses carried out by the World Meteorological Organization (WMO) on the basis of five international data sets, 2020 was also globally one of the two warmest years since the middle of the 19<sup>th</sup> century. Climate change is continuing – despite the coronavirus pandemic.

In our latitudes, the changes in the climate mainly manifest themselves in higher temperatures or the increase in heavy rain. In the Arctic, the changes are even more noticeable. The sea ice expansion in the Arctic was at its second-lowest level since records began, the lowest expansions being observed in July and October. It was the objective of the MOSAIC expedition of the Alfred Wegener Institute (AWI), Helmholtz Centre for Polar and Marine Research, to gain a better understanding of the complex climate processes in the Arctic and their impact on our weather. The Deutscher Wetterdienst (DWD) provided meteorological support to ensure the safety of this unique research expedition. For this reason, I am especially pleased that Prof. Dr Antje Boetius, the AWI's

director, agreed to an extensive interview and allowed us some insights into previously unknown details of the AWI's work and the expedition. In addition to this yearbook's photo series, which is dedicated to the expedition, you will read in the first chapter about weather forecasting in the polar regions and the challenges this involves.

It will come as no surprise that our work during the past year was heavily influenced by the coronavirus pandemic. What was most needed was flexibility in all areas and on all levels. Thanks to the high degree of digitalisation of our work environment, the DWD has coped very well with the pandemic. Among other things, we benefitted from a service agreement concluded in 2019, which allowed us to quickly offer mobile working opportunities for a large number of our employees. We also found creative solutions, when during the first lockdown in March 2020, the amount of weather data provided by aircraft fell sharply. Alternative data sources were sought, quickly identified and integrated into operations, so that the DWD's weather forecasts and warning management could continue to be delivered with the customary high quality. Despite the pandemic, we were



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able to introduce innovations, such as launching the new health app, switching over the data acquisition systems at our secondary weather stations to mobile transmission technology, and expanding the DWD's WarnWetter app. Since July 2020, users have been able via the app to report their own weather observations to the DWD. After an initial plausibility check, these data are available to meteorologists for the generation of weather warnings as well as for other purposes. In the autumn, we put into operation our new high-performance computer. This upgrade brings another marked acceleration in weather forecasting and, thanks to the warm water-cooling system, is providing further energy savings.

In December, the Council of the European Centre for Medium-Range Weather Forecasts (ECMWF) accepted the convincing application put forward by our ministry and selected Bonn as its third location. After the UK's exit from the European Union, the new site in Bonn will be used to combine EU-funded activities. Among those are ECMWF's Copernicus services, for which the DWD coordinates and delivers important contributions from Germany. The DWD is therefore looking forward very much to continuing our cooperation with the ECMWF.

As you can see, there are plenty of exciting developments at the DWD and I hope that our yearbook 2020 will provide you, dear readers, with an interesting read.

Yours sincerely,

A handwritten signature in blue ink that reads "Gerhard Adrian". The signature is written in a cursive, flowing style.

Gerhard Adrian

**01** Drifting through the North Polar Sea aboard the RV Polarstern frozen into an Arctic ice floe and collecting a wealth of data for a better understanding of the climate processes in the Arctic and their influence on the weather - this was one the aims of MOSAiC, the largest polar expedition ever. From mid-March, after months

of darkness, polar daylight came back for the team aboard the Polarstern, which always included a DWD tandem consisting of a weather technician and a meteorologist. But not all days brought glorious sunshine, the clouds on the horizon announce the arrival of the next storm.



# Prelude





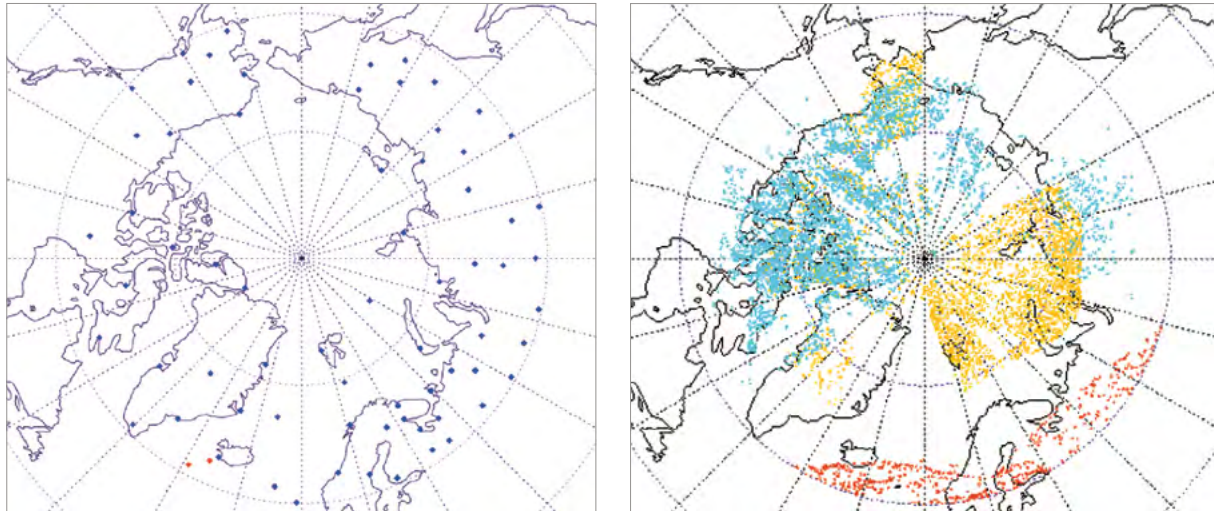
**01** Broken ice ahead of the Polarstern on her way to Spitzbergen, where the team was to be exchanged and supplies refilled in mid-May. Next to the ship's railing: some of the weather station's instruments.

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## The shipboard weather station – a crucial role for the expedition

**A**fter an expedition lasting 389 days, the German research icebreaker Polarstern returned to her homeport of Bremerhaven on 12 October 2020. During each of these 389 days, the Deutscher Wetterdienst (DWD) gave meteorological assistance to the whole expedition and ensured its safety via the DWD weather station on board.

This cruise was an exceptional event – even despite the fact that the Polarstern has made all her journeys since her launch in 1982 with DWD meteorologists on board to operate the weather station and that the DWD therefore has decades of experience. It goes without saying that the DWD's preparations for the expedition began well ahead of its start in Tromsø, Norway, on 20 September 2019. The DWD will continue benefitting from the newly gained experience and meteorological data far beyond the end of the expedition's journey.



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02 Two-hour data coverage by stations with radiosonde ascents (left) and by wind observations derived from satellites (right) for the Arctic (north of 60° N)

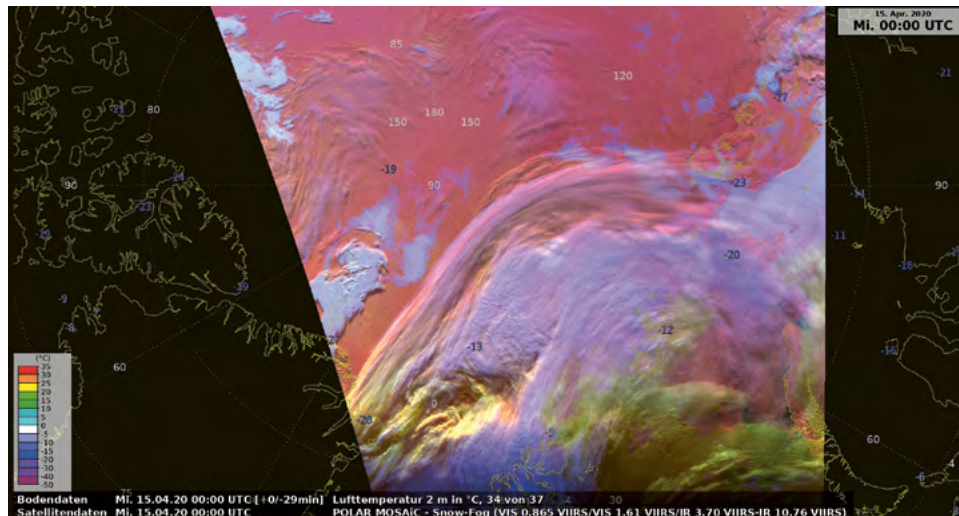
### Better understanding of processes

The advancing global climate change causes ever faster variations in the climate system of the Earth's polar regions, with serious consequences for weather and climate in the polar and mid-latitudes. This is the reason why, from mid-2017 until mid-2019, the World Meteorological Organization (WMO) had declared the 'Year of Polar Prediction (YOPP)', which was now followed on by the largest polar expedition of the previous decades, called MOSAiC (Multidisciplinary drifting Observatory for the Study of Arctic Climate). While YOPP's purpose was, among other things, to examine the influence of existing observing systems on the analysis and forecast quality of global and regional weather forecasting models (Figure 02), MOSAiC aimed at researching the complex, still insufficiently understood climate processes in the central Arctic, improving the representation of these processes in global climate models, and thus contributing to more reliable climate predictions. In order to achieve this, the Polarstern, frozen into an ice floe, drifted across the Arctic Ocean for a year and collected a unique treasure of observation data.

### Combining of data sources

For two reasons, one of the greatest challenges for the meteorological briefing on board was the intended drift route: firstly, when a ship is located north of 75° N, only a limited volume of the data required for the weather forecast can be transmitted to the weather station on board. Secondly, there are very few conventional weather stations, buoys or radiosonde launches in these polar regions; however, these data are needed as a basis for the weather forecast. This means that the satellite data, which are abundantly available for these latitudes, are of even greater importance. The meteorologists on board continuously carry out weather observations and radiosonde ascents. The ship is also specifically equipped with an antenna, which allows for data of polar-orbiting weather satellites to be received in near-real time for direct handling and processing. These data are used to derive information on cloud properties and surface tempera-

tures, among others. However, a lot more is required in order to produce a precise weather forecast for these latitudes, and all the more so as this forecast will determine the scientists' missions on the ice floe or the flights of the ship's helicopters. Only when the ship's own data sources (weather observations, radiosonde launches, satellite images) were combined with the location-specific forecasts of the DWD weather prediction system ICON and the processed data from polar-orbiting satellites was the DWD team able to produce specific forecasts for each mission. For this to happen, parts of the data parcel, freshly configured every day up to a volume of about 50 Mbit, had to travel over a very long distance before it reached the Polarstern.



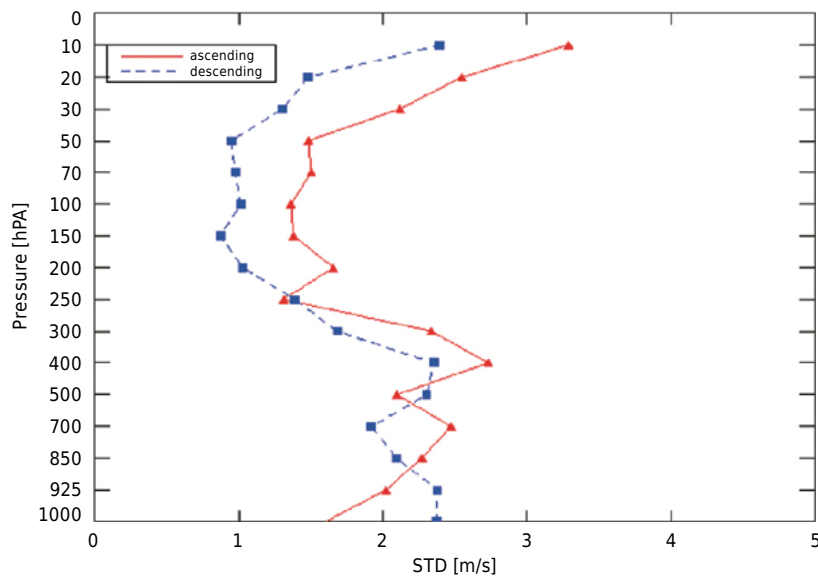
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Offenbach prepared not only data from Metop, EUMETSAT's polar-orbiting satellite, but also raw data originating from the two US-American weather satellites NOAA 20 and Suomi NPP. The satellites' images were first transmitted to EUMETSAT in Darmstadt and then via a communication satellite to the DWD in Offenbach. Having received the raw data, the DWD prepared them for the meteorological workstation application Ninjo and transmission to the Marine Meteorological Office in Hamburg, where all shipboard weather missions are coordinated. Further information added, the data sets were then sent to the Alfred Wegener Institute (AWI) in Bremerhaven and forwarded from there via satellite to the weather station on the Polarstern.

NOAA 20 and Soumi NPP take about 100 minutes to orbit the Earth via the poles. They produce images of the Earth in 22 spectral bands of the visible and infrared spectrum, making these available at almost hourly intervals. The user can combine several spectral bands and produce so-called colour composite images in order to identify ice or clouds, for example. All these products are additionally combined with data from the continuous observation of weather parameters on board, such as wind or temperature. The results also take account of the information gained with radiosonde ascents, which are usually carried out four times per day from the Polarstern. Before these procedures became operational, all of them were extensively and thoroughly tested in the run-up to the expedition.

01 The false colour image of Wednesday, 15 April 2020, shows ice on land and at sea in red whereas low clouds or fog, for example, are represented in bluish colours. On the left, Greenland can be seen,

Spitsbergen is further to the right; the islands top right are part of Franz Josef Land. At the time of the image, the Polarstern is situated somewhere near the number '-13' appearing in the lower middle part of the image.



**02** Mean 3-hour wind speed forecast error (m/sec) of Polarstern radiosonde ascents (red) and descents (blue) averaged over October 2019

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### Data from ascents and descents of radiosondes

Analyses carried out by several global meteorological centres show that, for the Arctic region, the influence of conventional observations on the forecast quality of meteorological models is as strong as or even stronger than the influence of satellite observations. This is not the case for other global regions and is mainly due to the fact that the exploitation of radiances measured by satellites over areas covered by snow and ice is still relatively difficult. For this reason, only a small part of the data can be used. Studies with the ICON global model in use at the DWD have shown that especially wind data derived from satellite images have a large positive impact on the quality of the forecast for high- and mid-latitudes, similar to that of radiosonde measurements. In

addition to observations taken in situ, for the first time not only the radiosonde ascents were used, but also the descent data, emitted by the falling sondes after the bursting of the weather balloon. It was found that the quality of the descent data was comparable to that of the measurements taken during the ascent (Figure 02). Work to analyse and exploit the expedition's extensive data treasure especially for numerical weather prediction and climate research is still ongoing at the DWD.

### A crucial role

The DWD played a crucial role for the MOSAiC expedition. Altogether five DWD tandems, each of them consisting of a weather technician and a meteorologist, ensured that the expedition leader and the scientists on board could plan and carry out their research missions. Thanks to the work of many colleagues in the background, the additional challenge posed by the pandemic could also be overcome.

In addition, the DWD used weather information gained in the expedition for the training of future meteorologists. One DWD group cooperated closely with students from the South African Weather Service and the Russian State Hydrometeorological University on subjects directly linked to the expedition, such as weather analysis or aeronautical meteorological forecasting for the Arctic. Related reports were published on EUMETSAT's science blog.

This yearbook's photo series is dedicated to the expedition. Due to the coronavirus pandemic, the DWD weather technician Christian Rohleder stayed several months on board of the ship during leg three of the journey, spending some of his time to record special moments with his camera. The DWD's shipboard weather station is one element of a large range of marine meteorological services, some of which are being offered by the DWD on a global level. These services are pictured on the front page of the poster enclosed with the yearbook.

# Weather and climate in 2020

**01** Finally arrived: the team of leg 3 reached the Polarstern at the end of February 2020 - three weeks later than planned. In the DWD's weather station office, meteorologist Julia Wenzel hands over operations to her colleague Robert Hausen from the DWD in Offenbach. Also on board: a camera team from the German film and television company UFA in Potsdam, who accompanied and documented the expedition during the whole journey.





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**01** View down to the Polarstern during a helicopter flight in mid-March: the large, free area to her right was the 'Logistic Area', which served as a parking space for the vehicle fleet. Here, the material was stored, at least temporarily, which didn't have to be loaded back on board every day, such as the snowmobiles.

## Second-warmest year ever, third year in a row with a dry spring

**2020** was the second-warmest year in Germany since the beginning of systematic weather recordings. The last decade saw a large number of very warm years and was on the whole 2 °C warmer than the first thirty years of the evaluation period (since 1881). 2020 is the third year in a row in Germany with a significant spring drought.

### Nationwide temperature

With an annual mean temperature of 10.4 °C, 2020 was the second-warmest year in Germany since 1881, narrowly behind 2018, the warmest year so far with 10.5 °C, and closely followed by 2019 and 2014, with 10.3 °C each. Compared to the reference period 1961–1990, the year was 2.2 °C too warm. Including 2020, nine of the ten warmest years in Germany were recorded in the 21<sup>st</sup> century. 2014 was the first year with an annual mean temperature above 10 °C; since then, such a high average has been recorded four times in total.

Apart from May, all the months and seasons of 2020 were warmer than the long-term monthly and seasonal averages of the reference period 1961–1990. The following months were significantly warmer than normal: January (+4 K), February (+4.9 K), April (+3 K) and August (+3.4 K). The winter 2019/20 was the second-warmest winter since 1881 and 3.9 K warmer than the long-term winter average 1961–1990. After the colder-than-average temperatures in May, December 2020 concluded another series of seven months with temperatures warmer than normal (1961–1990).

**Record temperatures in the federal states**

Federal state	Annual mean temperatur (in °C)	Ranking	Same as in
Baden-Württemberg	10.2	2	-
Bavaria	9.5	3	2019
Hesse	10.4	2	-
Mecklenburg-Western Pomerania	10.4	2	-
Lower Saxony/Hamburg/Bremen	10.9	1	-
North Rhine-Westphalia	11.1	1	-
Rhineland-Palatinate/Saarland	11	1	-
Schleswig-Holstein	10.5	1	2014
Saxony	10.3	2	2018
Saxony-Anhalt	11	1	-
Thuringia	9.9	1	2018

A look at the climatological indicators ‘frost days’ (number of days with minimum temperature below 0 °C) and ‘ice days’ (number of days with temperatures continuously below 0 °C) reveals very low rankings for 2020. Due to the very mild winter 2019/20 and December 2020, the year ended with the seventh lowest number of frost days and the lowest number of ice days (3.7 averaged over the whole of Germany) since 1951. With regard to the indicators ‘summer days’ (number of days with a maximum temperature of at least 25 °C) and ‘hot days’ (number of days with a maximum temperature of at least 30 °C), the positioning of 2020 (ranks 6 and 7, respectively) is less pronounced, since the positive temperature anomalies were spread over all seasons.

**Temperatures in the federal states**

Several federal states, especially in the north and west, saw their warmest ever year or reached equally high temperatures as in previous year. Only Bavaria recorded 2020 as its third-warmest year with 9.5 °C.

**Long-term temperature trend in Germany**

Since the 1970s, every decade in Germany has been warmer than the previous one. The years 2011–2020 were 2 K warmer than the first thirty years (1881–1910) of the evaluation period, which makes them the warmest decade since records began in 1881. In line with global temperature data sets, Germany has also seen an accelerated increase of temperature averages since about 1970. Calculating the trend of the temperature evolution for the period 1971–2020 results in a temperature increase of 0.38 K per decade, whereas during the period 1881–1970, temperatures only increased by 0.06 K per decade. The temperature increase for the whole observation period 1881–2020 amounts to 0.12 K per decade.

**Precipitation**

In 2020, areal precipitations were 84 l/m<sup>2</sup> below the average 1961–1990, which is equivalent to an annual deficit of 10.7 percent. In contrast to this, February was the second-wettest month since 1881, but its far-above-average precipitations were an important contribution to replenishing the reserves depleted in 2019. Apart from the winter 2019/20, all seasons were too dry.

**Sunshine hours**

2020 was the fourth-sunniest year in Germany, with a nationwide average of 1986 sunshine hours, 22.8 percent above the long-term average of 1961–1990. April 2020 was the sunniest April and the months March, April and May the sunniest spring since 1951.

## Global temperatures

According to analyses carried out by the World Meteorological Organization (WMO), 2020 was also globally one of the two warmest years since the middle of the 19<sup>th</sup> century. The WMO used data from the Copernicus Climate Change Service (C3S), Japan Meteorological Agency (JMA), Met Office (UK), NASA's Goddard Institute for Space Studies (NASA GISS) and the National Oceanographic and Atmospheric Administration (NOAA). Compared to pre-industrial levels (1850-1900), the global average temperature in 2020 has risen by about 1.2 °C. The six warmest years ever have all occurred since 2015.

2020 was such a warm year despite a La Niña event. This is what makes this year's global temperature evolution so unusual. Commonly, record-breaking years are El Niño years, such as 2016, the warmest year ever. La Niña events usually have a cooling effect on global temperatures. Since the 1980s, every decade has been warmer than the previous one, and 2020 marks the end of the warmest decade (2011-2020) since records began.

Several European meteorological services declared 2020 the warmest year in their respective country:

- Finland: warmest year since records began
- Sweden: warmest year since 1860
- Estonia: warmest year since 1866
- France: warmest year since 1900
- Netherlands: warmest year since 1901
- Switzerland: warmest year (together with 2018)

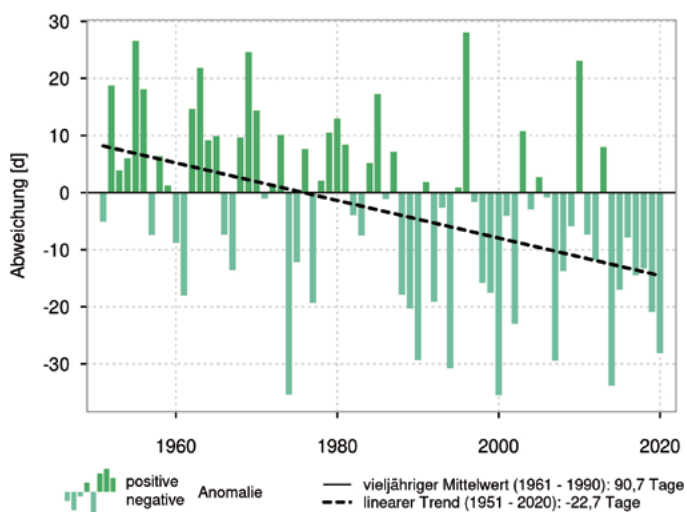
**01-04** Temperature-related indicator days 1951-2020: frost days (Fig. 01), ice days (Fig. 02), summer days (Fig. 03), hot days (Fig. 04)

\* Sources see page 75

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### Anomalie der Anzahl der Frosttage

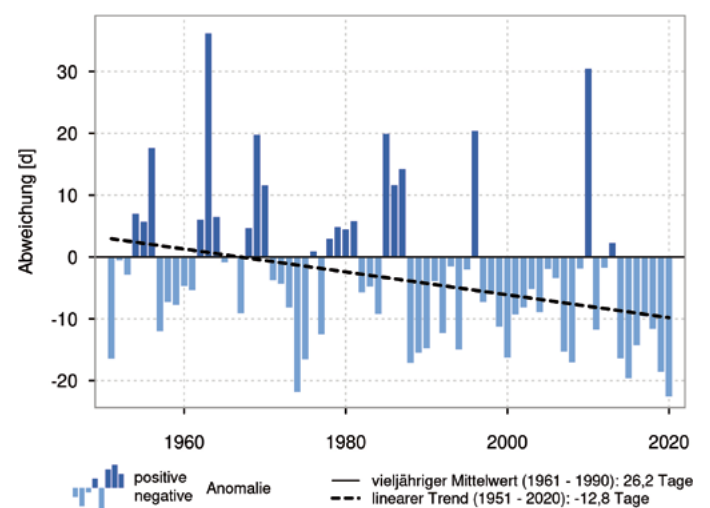
Deutschland Jahr, 1951 - 2020, Referenzzeitraum 1961 - 1990



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### Anomalie der Anzahl der Eistage

Deutschland Jahr, 1951 - 2020, Referenzzeitraum 1961 - 1990



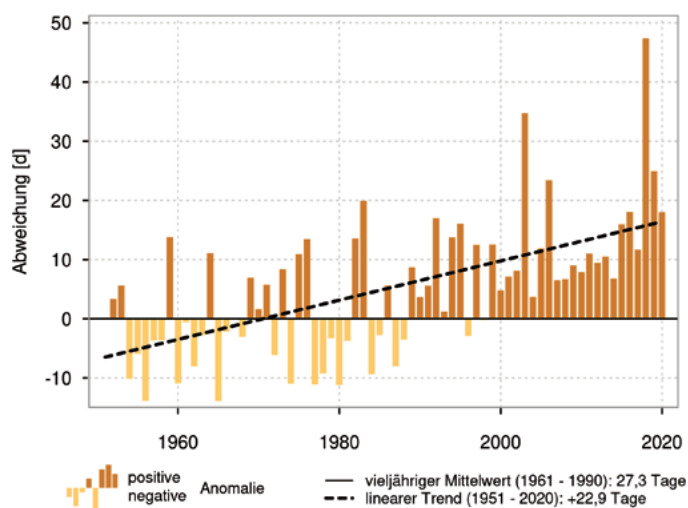
### Important global extreme events in 2020

- Record temperatures in the Arctic (for example a new Arctic temperature record of 38 °C measured on 20 June 2020 in Verkhoyansk, Siberia). According to an attribution study carried out with the participation of the DWD, climate change made the Siberian heatwave in the first half of 2020 600 times more likely and caused the maximum temperatures to increase by 1-2 K compared to the situation without climate change. Along with record temperatures in the Arctic, there were also extensive forest and bush fires.
- Forest fires in California in the summer of 2020, caused by very dry and hot conditions.
- During the heat waves up to March 2020, eastern Australia saw many strong bush fires. More extensive fires occurred in the autumn.
- In 2020, more than 80 % of ocean surfaces were subject to at least one marine heatwave. A larger part of the oceans was affected by marine heatwaves classified as 'strong' (43 %) rather than 'moderate' (28 %). In 2019, records showed the largest ocean heat content since measurements began. The rate of warming in the last ten years exceeded the long-term average. This is due to the increasing thermal absorption caused by changes in the atmospheric radiative forcing.
- The sea ice expansion in the Arctic was at its second-lowest level since records began, the lowest expansions being observed in July and October. The Antarctic sea ice expansion was close to the long-term average.
- 30 hurricanes in the Atlantic in 2020 constitute a new record, replacing the previous record of 28 in 2005. The main reason for this was the warm sea water in the Caribbean – for a hurricane to develop, the sea surface temperature must be at least 26.5 °C.
- In 2020, extreme precipitation events and extensive flooding were recorded in many areas of Africa and Asia. Large parts of the Sahel zone, the Horn of Africa, the Indian subcontinent and neighbouring areas, China, Korea, Japan and parts of South East Asia were affected by strong rainfalls and flooding. Vast parts of South America suffered from severe drought, with northern Argentina, Paraguay and western border regions of Brazil being hit hardest.

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#### Anomalie der Anzahl der Sommertage

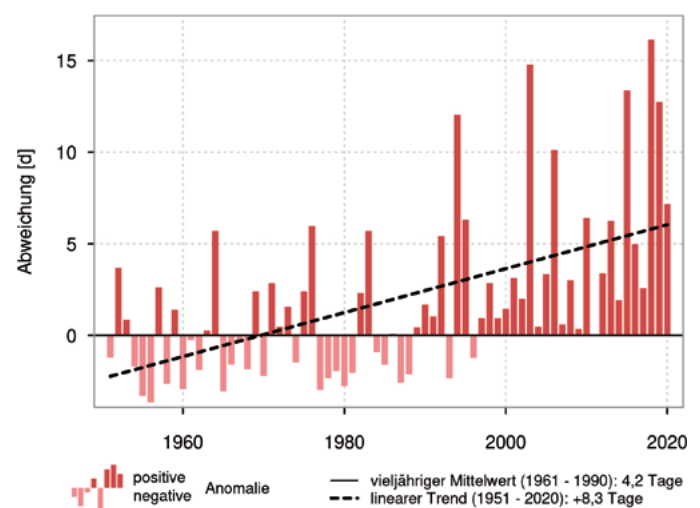
Deutschland Jahr, 1951 - 2020, Referenzzeitraum 1961 - 1990



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#### Anomalie der Anzahl der Heißen Tage

Deutschland Jahr, 1951 - 2020, Referenzzeitraum 1961 - 1990



## Agriculture and forestry: noticeable increase in dry springs

The previous three years saw extended dry periods already during springtime, causing harm to agriculture. However, this tendency for springs with markedly dry conditions has been observed for some time.

### Characteristic cool shower weather in April has become rare

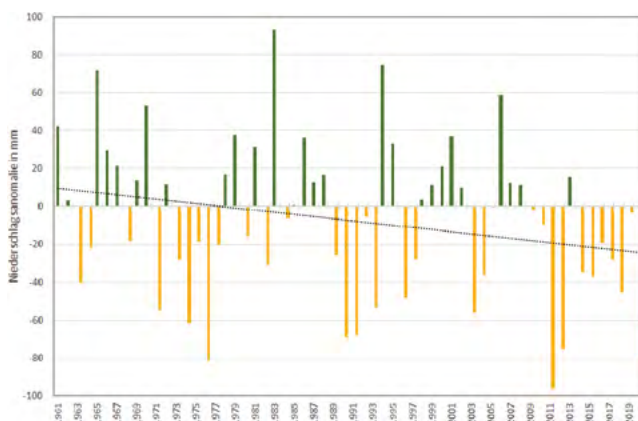
The recent April months brought a lot of sunshine and some early summer warmth, but very little of the cool showers that are characteristic of this month. As early as in the 1990s, there were clear trends towards higher temperatures and less precipitation. However, the series of exceptional Aprils started in 2007: the April of that year was by far the driest and sunniest since records began, with only the April of 1893 being

similarly dry. The temperature record of 2007 was already broken in 2009, and surpassed again in 2018. A new April record for sunshine was set in 2020. It is also very unusual that almost all Aprils since 2007 were warmer and drier than the average of the international standard reference period 1961-1990.

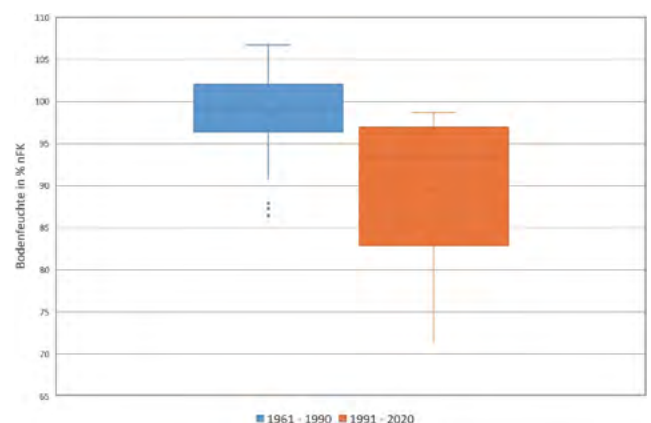
**01** Over the last decades, the nationwide average for spring precipitation (March to May) has decreased significantly, with below-average levels in almost every year since 2009 (compared with the 1961-1990 reference period).

**02** At an Available water capacity (AWC) of 89.5 % (% nFK), the Germany-wide average spring soil moisture for 1991-2020 was clearly below the value of 98.5 % for 1961-1990. In addition, the variance between the individual years has increased over the period 1991-2020.

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## Springs becoming drier

The past decades show a clear trend towards more sunshine and warmth, not only in April, but during the whole of the meteorological spring (which also includes March and May). The result is increased evaporation, both from the plants as well as directly from the soil. Together with a marked reduction in precipitation (Figure 01), this is the cause for the soils drying out more. A comparison of the average soil moisture between 1961–1990 and 1991–2020 (Figure 02) shows that in the previous decades, soils in spring have become much drier on average.

### Consequences for agriculture and forestry

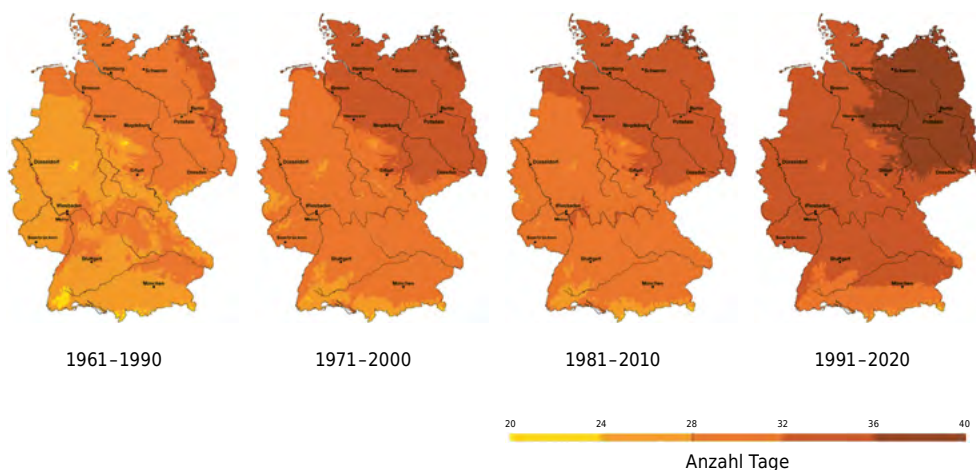
If the soil dries out faster in the spring, heavy agricultural machinery can be used sooner, without causing any harmful soil compaction. For crops to be sown in spring, such as summer cereals, maize or sugar beet, earlier sowing dates are desirable, since the advancing of the season brings an increased risk of the top soil layers drying out to such an extent that the young plants suffer from drought stress or even desiccate. However, maize and sugar beet in particular are very susceptible to late frosts, and the advantage of early sowings must thus be balanced against the risk of late frost damage. If a spring drought persists as it was the case in recent years, even winter cereals with longer roots reaching further down into the soil do suffer from drought stress. In addition, if the top soil is dry, the nutrients applied in spring cannot or can only partly reach the roots of the plants. The consequences are thin and low plant growth and a likely loss of yields.

In forestry, the harm caused by extended dry periods in the spring depends on the situation in previous and subsequent seasons. The forest would cope well with one dry spring alone, because the trees can access water from deeper soil layers. However, as the ground water reserves under the forests were not replenished in the previous three years, this led to drought damage.

**03** When comparing the different 30-year reference periods with one another, the number of dry days in Germany has increased significantly.

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### Tage ohne Niederschlag zwischen 15.03. und 15.05.



## Series of dry years continues – 2020 from an agro-meteorological perspective

For a third year in a row, the drought poses a big challenge for farmers. However, in contrast to the previous year, the upper soil layers down to 60 cm depth were often well watered, at least at the beginning of the growing season.

**01** Monthly averages and climatological assessment of soil moisture (0–60 cm, under grass cover, sandy clay) from January 2020 to December 2020 in percent of available water capacity

### A wet ending of the winter 2019/20

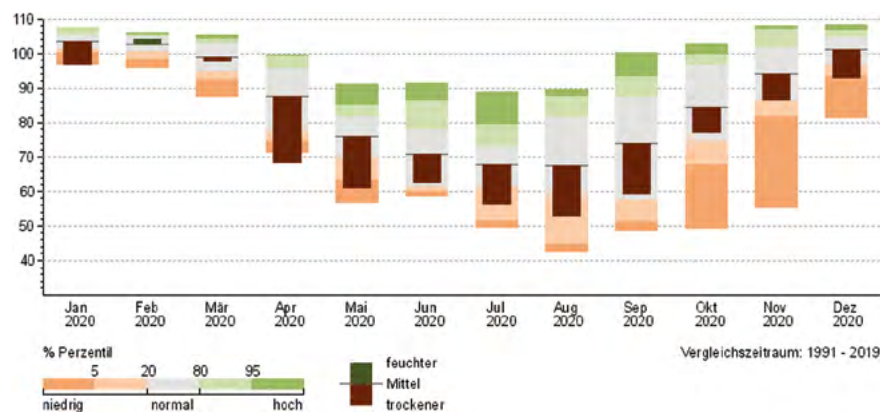
Precipitation amounts below their long-term averages in December 2019 and January 2020 were followed by the second-wettest February since records began. February also was the only month in 2020 with monthly soil moisture means (0–60 cm) exceeding the long-term averages (Figure 01). While the soil moisture reached more than 100 percent of available water capacity (AWC) in many parts of the western federal states, in Saxony-Anhalt, Brandenburg, Saxony and Thuringia it often was below 100 percent. Like in the two previous years, lower soil layers down to 2 m depth could again not be replenished everywhere (Figure 02). Temperatures far above the long-term averages cut short the plants' winter dormancy, and permanent pastures and some of the winter crops kept growing.

### Once again reversal towards drought in spring

After an unsettled start, the period from mid-March until the end of April brought very dry and sometimes very warm weather with abundant sunshine and occasional wind. The upper soil layers (0–30 cm) became very dry, whereas the lower layers (30–60 cm) still retained plenty of moisture. Nonetheless, in April, the average monthly soil moisture in Germany at a depth of 0–60 cm only amounted to 68 percent AWC, the lowest figure ever recorded in the reference period since 1991 (Figure 01). The consequence was drought stress for winter cereals and delayed growth of summer crops. On the positive side, there was very little threat of fungal diseases. An unsettled May led to a weakening of the drought, although soil moistures, in particular in the western half and in the middle of Germany, remained well below the long-term averages. Repeated cold snaps in April and May slowed down plant development. They not only brought frost damage to orchards and vineyards in some regions, but also caused exceptionally heavy damage to flowering winter barley.

01

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



**Summer 2020: mixed but nonetheless often too dry**

On the whole, summer 2020 was less extreme than the two previous ones. Nonetheless, already at the beginning of the summer, the soil moisture was well below its long-term average almost everywhere in Germany. During an unsettled and moderately warm June, the drought lessened slightly, but soon after, in July, the situation worsened again. In some regions, a heatwave in August led to sunburn damage to fruit and wine grapes. Around the middle of the month, heavy thunderstorms caused local damage. Extensive precipitation followed at the end of the month, which improved the conditions for the sowing of rape seed, and, in some parts of the country, even benefitted maize and sugar beet. Averaged over the area, the precipitation in summer was only slightly below the mean, thus preventing substantial crop losses in many places, although there were big differences even within small areas.

**Summery start to the autumn**

In September, the soil moisture situation worsened again due to dry and very warm weather. In the middle of the country in particular, the top soil layers down to 30 cm depth were very dry, with an AWC below 10 percent in many places. The dry conditions locally posed a danger to the water supply for rape seed and winter cereal crops, which had just emerged. Sugar beet and maize, too, were affected by drought stress. Only the changeable weather in October brought a lasting end to the dryness of the top soil. Thereafter, a very dry and mild November prevented the moisture from spreading to deeper layers.

December started rather changeable, with the last third of the month being wetter than average. This resulted in the soil moisture at the end of the year being below the long-term averages, but still above the levels of the two previous years (Figure 03).

**Available water capacity (AWC)**

‘Field capacity’ (FC) is defined as the quantity of water which a saturated soil is able to hold against gravity. It is usually reached about 2-3 days after the soil has been completely saturated, when excess water has drained away. Given that

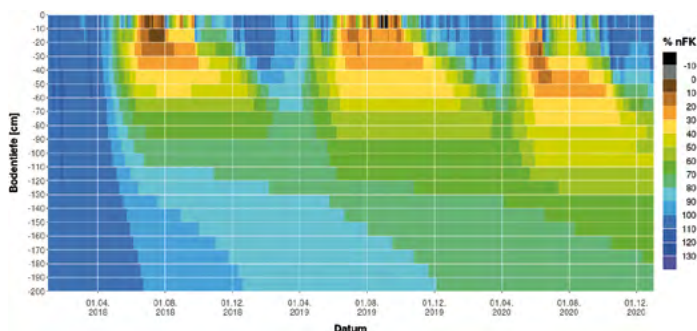
plants are not able to make use of all the water in the soil, the term ‘available water capacity’ (AWC) is used to measure the amount of water plants can use. This parameter is calculated by the DWD for the upper 60 cm of the soil, unless stated otherwise.

**02** Soil moisture profile (2 m) for winter wheat in per cent of available water capacity (% nFK) for Erfurt/Weimar airport (real soil on the ground) from 01.01.2018 to 31.12.2020

**03** Evolution of soil moisture (% nFK, under grass cover, sandy clay) in Germany in 2020 compared with the years 2018 and 2019 and with the long-term average for 1981-2010

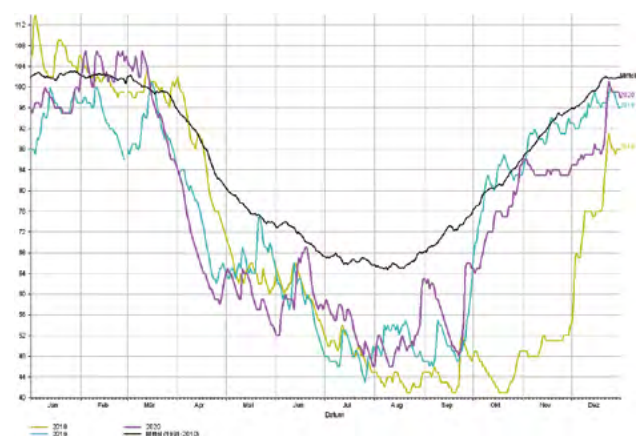
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**Berechnetes Bodenfeuchteprofil (Winterweizen)**  
Erfurt-Weimar (Flughafen)



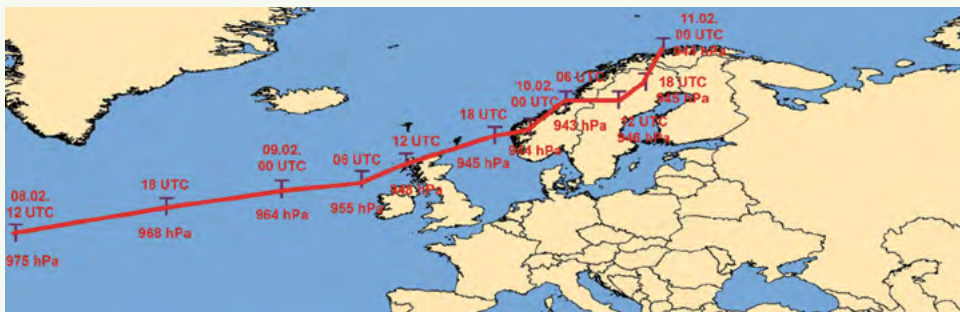
03

**Bodenfeuchte 0-60 cm unter Gras bei sandigem Lehm in % nFK, Mittel für Deutschland**  
Auswertung vom 01.01. bis 31.12. in den Jahren 1981 - 2020



## SABINE: extreme storm situation announced days before the event

On 9 and 10 February 2020, deep low SABINE (called CIARA in western Europe and ELSA in Norway) brought gale-force gusts up to hurricane-strength (12 Bft) to all parts of Germany.



01 Track of deep low SABINE between 8 and 11 February 2020

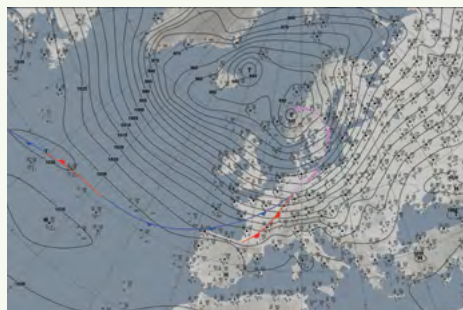
01

The strongest gust of 49.1 m/sec or 177 km/h was recorded on the Feldberg in the Black Forest on 10 February. The core of the deep low moved from the Atlantic over Scotland to Norway, with a core pressure of sometimes below 945 hPa. The air pressure in northern and southern Europe differed by about 80 hPa, generating a storm field that covered large parts of western, central and northern Europe. The storm expanded from the North Sea towards the Alps. In Germany, it was accompanied by showers and thunderstorms, some of which heavy. Between 10 and 12 February, there were several, occasionally strong storm surges at the North Sea.

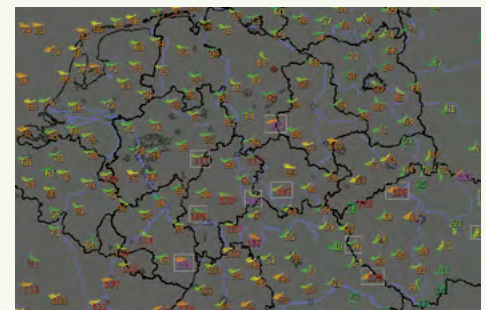
The extreme storm situation had been announced days before. Outdoor activities and travel were discouraged during this time and, as a precaution, sport and music events were cancelled. On 9 and 10 February, railway services in Germany were suspended for some of the time. Flights and ferry journeys were cancelled. On 10 February, many schools and nurseries remained closed. In the affected countries, the storm uprooted trees and caused roof damage. There was flooding on the British Isles and some regions, including in Germany, suffered power outages.

02 Surface analysis chart of 10 February 2020 at 00 UTC: the core of deep low SABINE was situated off the Norwegian west coast.

03 Maximum gust speeds over the last 3 hours on the 10<sup>th</sup> of February, 03 UTC



02



03

**Weather situation**

On Sunday, 9 February 2020, a large area of low pressure resided over the North Atlantic. On its southern edge, a strong secondary low had developed, which intensified and moved over Scotland towards Norway. At that point, it was named SABINE. At times, its core pressure was below 945 hPa, reaching a minimum of 943 hPa at the north-western coast of Norway. The air pressure in northern and southern Europe differed by about 80 hPa, which led to a storm situation over western, central and northern Europe, lasting several days. In Germany, the first heavy storm-force gusts (10 Bft) arrived on Sunday, 9 February, at midday. Over the course of the afternoon and night and the following day (10 February), the storm field expanded towards the Alps, with the cold front of deep low SABINE crossing Germany from north-west to south-east during Sunday evening and Monday morning. The strongest gusts were expected near this cold front. The storm continued for a few more days, although the wind strength decreased slightly. On 11 February, some stations however recorded even stronger peak gusts than on the previous days.

Between 10 and 12 February, the persistently strong westerly winds also caused several, occasionally heavy storm surges at the North Sea, for example in Hamburg. There was short but intense precipitation near SABINE's cold front, as well as a few heavy showers behind it. All in all, SABINE brought daily precipitation totals of up to 40 mm.

**Warning management**

As early as Friday, 7 February 2020, the DWD issued a severe weather watch. For several days, models and probabilistic forecast methods had indicated a severe storm event. Accordingly, a severe weather watch was published – at first for the north-west and in the afternoon for large parts of the country.

The IFS forecast model of the European Centre for Medium-Range Weather Forecasts (ECMWF) very consistently simulated storm-force to violent storm-force gusts for almost the whole of Germany on Sunday evening and Sunday night as well as hurricane-force gusts for some areas even at lower altitudes. Despite similar pressure gradients over Germany, the gust strength predicted by the DWD model ICON was about 1-2 Bft lower. The peak of the storm was predicted to coincide with the passage of the cold front beginning in the night of Sunday to Monday, 10 February, when the upper-air winds (at 925 hPa up to more than 110 km/h, at

850 hPa up to more than 140 km/h) could mix with lower air masses.

On Saturday evening, 8 February, the first severe weather warnings were issued for regions affected by violent storm- and hurricane-force gusts, such as the North Sea and neighbouring areas as well as the mountain ranges. In addition, a long-term basic warning of significant weather (in force until Tuesday, 11 February) for gale-force gusts was published. Warnings of violent storm-gusts and occasional hurricane-force gusts were added during the morning of Sunday, 9 February, at around 9 am for the north-west and at around 11 am for regions up to the middle of Germany, Saxony and the Palatinate region. In the afternoon, warnings were also issued for the south, and the severe weather watch was extended to the north-east, as there were indications that the cold front would produce severe weather conditions in these regions, too. The passage of the cold front on Sunday evening gave rise to first warnings of thunderstorms for the north-west. These measures were based on the premise that thunderstorms should be treated as isolated severe weather events (gusts of 11-12 Bft) requiring separate warnings. The warning for the coast expired in the early hours of Monday. After the passage of the cold front, the severe weather warnings were lifted for the respective areas.

04 Warning map for wind, issued Friday early evening

05 Warning map for wind/gale-force wind, issued Saturday evening

04



05



### Climatological assessment

Already in the first half of January 2020, there were several very strong low-pressure systems over the north-eastern Atlantic with core pressures temporarily below 950 hPa. On 7 February 2020, another such low (RUTH) was located over the Irminger Sea (between Greenland and Iceland). At times, its core pressure decreased to around 935 hPa. RUTH was considered a steering low, which guided SABINE along its southern edge towards Europe.

The North Atlantic Oscillation (NAO) plays a crucial role in the evolution of storms over the North Atlantic and Europe. If the westerlies are strengthened by a very strong low over Iceland and a distinct Azores high (strongly positive NAO index), there is a higher probability of storms over Europe. According to Feser and Tinz (2018)\*, over the last 100 years, the NAO index has shown strong fluctuations on time scales ranging from years to several decades. They state in their conclusion that “storms over the North Atlantic and northern Europe exhibit a high decadal variability as well as large annual fluctuations. For the last 100 years and beyond, however, no steady long-term trend can be identified.”

### Impacts in other European countries

Other European countries in western, central and northern Europe have also been severely affected by deep low SABINE. In many places, peak gusts of more than 90 km/h were recorded, corresponding to force 10 and above on the Beaufort scale. The highest wind speed of 219 km/h was measured at CAP Corse, France, the strongest wind gust of 202 km/h at Güttschob Andermatt, Switzerland, and Cairngorm Summit, United Kingdom.

\* Source see page 75

### Weather adoption scheme ‘Adopt-a-Vortex’

In 1954, a student at the Institute for Meteorology of the Freie Universität Berlin, Dr Karla Wege, later a forecaster at the German television station ZDF, suggested also giving names to pressure systems in central Europe. From then on, low-pressure systems have been given female names and high-pressure areas male names, in alphabetical order, to provide a clearer overview of weather systems on weather maps. Since the turn of the millennium, an annually

changing system was introduced, with highs and lows alternately receiving female and male names. Eventually, the weather adoption scheme ‘Adopt-a-Vortex’ was launched in November 2002. Since then, citizens can contribute to creating alphabetical lists while, at the same time, any income thus generated supports students observing the weather at weather station 10381 in Berlin-Dahlem.

All information on the Adopt-a-Vortex scheme can be found at [www.met.fu-berlin.de/adopt-a-vortex/](http://www.met.fu-berlin.de/adopt-a-vortex/).

01 Warning situation for wind, issued Sunday midday

02+03 Warning map for wind (Fig. 02) and thunderstorms (Fig. 03), issued Sunday evening

01



02



03





04

04 During the whole time the Polarstern was frozen to the floe, there was only one polar bear that came straying. But this was a rather curious one, checking out the instruments in the Logistic Area and wandering around in Met City. This photo of the bear looking back before leaving was taken at the end of May when the Polarstern was already on her way to Spitsbergen.

## New record holder for maximum temperature in Germany

The Deutscher Wetterdienst (DWD) annulled the German temperature record of 42.6 degrees Celsius (°C) measured in Lingen in the Emsland on 25 July 2019. Now, the DWD weather stations Duisburg-Baerl and Tönisvorst are the new joint record holders with 41.2 °C on 25 July 2019. Recent assessments of measurements taken in parallel to those from Lingen station showed that in some weather situations, there can be noticeably increased temperatures in a very small part of the Lingen observation area, especially in the early afternoon.

Since early June 2020, the DWD has no longer published data from the Lingen weather station. For half a year, the station's temperature measurements were thoroughly monitored and parallel measurements carried out. The results of these investigations were used as a basis for a re-examination of older measurements. They were unambiguous: since 2017, temperature measurements carried out on the observation area repeatedly produced results not representative for the region. This also was the case on 25 July 2019. The German temperature record of 42.6 °C, measured in Lingen, must therefore be removed from the DWD's climate archive. The high temperatures recorded there in the previous years are caused by strong growth of the vege-

tation directly to the east of the station. With north-easterly to south-easterly winds, it frequently inhibited the air exchange. This had led to a decoupling of the local temperatures at the station's observation area from the wider temperature trend, especially in weather situations with little wind, but strong radiation. The DWD has been looking for a new location of the Lingen station for several years and is already planning to open a new station in Lingen-Baccum in spring 2021. Until then, the DWD will publish no more measurements from Lingen and will also remove all the data provided by this station since 1 January 2017 from its freely accessible resources.

## Weather in Germany 2020

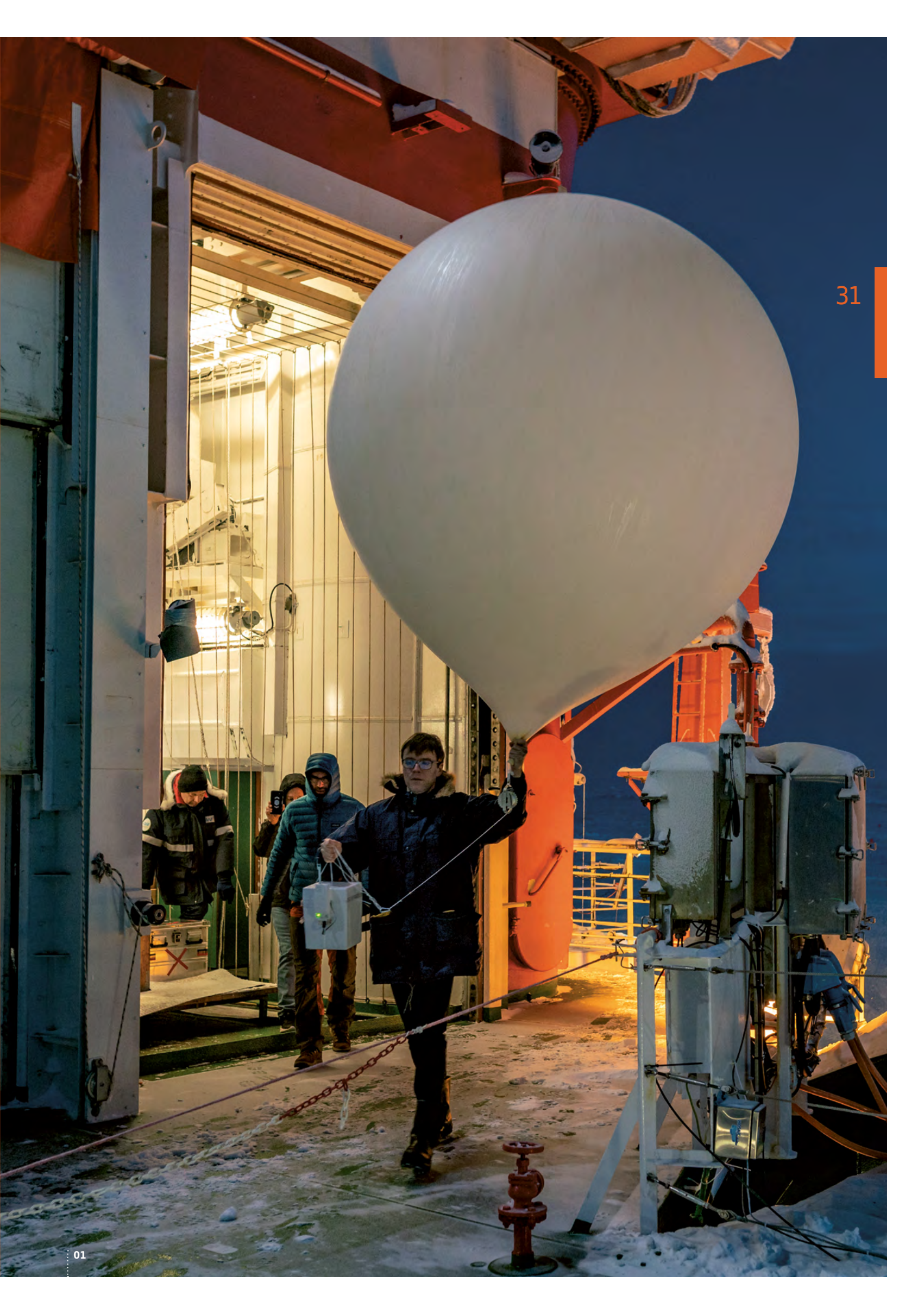
	Average temperature in °C	Highest temperature in °C	Lowest temperature in °C
<b>January</b>	3.5 (-0.5)	16.2 on the 31 <sup>st</sup> in Andernach	-18.9 on the 19 <sup>th</sup> on the Zugspitze
<b>February</b>	5.3 (0.4)	21.5 on the 16 <sup>th</sup> in Müllheim	-18.6 on the 5 <sup>th</sup> on the Zugspitze
<b>March</b>	5.3 (3.5)	22.3 on the 12 <sup>th</sup> in Garmisch-Partenkirchen	-18.3 on the 26 <sup>th</sup> on the Zugspitze
<b>April</b>	10.4 (7.4)	26.5 on the 17 <sup>th</sup> in Waghäusel-Kirrlach	-15.1 on the 14 <sup>th</sup> on the Zugspitze
<b>May</b>	11.9 (12.1)	29.0 on the 22 <sup>nd</sup> in Kleve	-11.7 on the 3 <sup>rd</sup> on the Zugspitze
<b>June</b>	16.9 (15.4)	34.0 on the 13 <sup>th</sup> in Coschen and Lindenberg	-5.9 on the 8 <sup>th</sup> on the Zugspitze
<b>July</b>	17.7 (16.9)	38.5 on the 31 <sup>st</sup> in Rheinfelden	-6.6 on the 7 <sup>th</sup> on the Zugspitze
<b>August</b>	20.0 (16.5)	38.6 on the 9 <sup>th</sup> in Trier-Petrisberg	-3.7 on the 4 <sup>th</sup> on the Zugspitze
<b>September</b>	14.8 (13.3)	34.8 on the 15 <sup>th</sup> in Trier-Petrisberg	-10.9 on the 26 <sup>th</sup> on the Zugspitze
<b>October</b>	10.2 (9.0)	24.6 on the 13 <sup>th</sup> and 14 <sup>th</sup> in Kiefersfelden-Gach	-12.4 on the 13 <sup>th</sup> on the Zugspitze
<b>November</b>	6.2 (4.0)	24.0 on the 2 <sup>nd</sup> in Bad Dürkheim	-16.1 on the 20 <sup>th</sup> on the Zugspitze
<b>December</b>	3.8 (0.8)	20.2 on the 20 <sup>th</sup> in Piding	-19.6 on the 26 <sup>th</sup> on the Zugspitze
<b>Winter 2019/20</b>	4.2 (0.2)	21.5 on the 16 <sup>th</sup> of February in Müllheim	-18.9 on the 19 <sup>th</sup> of January on the Zugspitze
<b>Frühling</b>	9.2 (7.7)	29.0 on the 22 <sup>nd</sup> of May in Kleve	-18.3 on the 26 <sup>th</sup> of March on the Zugspitze
<b>Sommer</b>	18.2 (16.3)	38.6 on the 9 <sup>th</sup> of August in Trier-Petrisberg	-6.6 on the 7 <sup>th</sup> of July on the Zugspitze
<b>Autumn</b>	10.4 (8.8)	34.8 on the 15 <sup>th</sup> of September in Trier-Petrisberg	-16.1 on the 20 <sup>th</sup> of November on the Zugspitze
<b>Jahr</b>	10.4 (8.2)	38.6 on the 9 <sup>th</sup> of August in Trier-Petrisberg	-19.6 on the 26 <sup>th</sup> of December 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/m <sup>2</sup>	Sunshine duration in hours	Memorable facts
40.5 (60.8)	59.2 (43.6)	Very mild month in which winter failed to make any appearance in most areas
124.1 (49.4)	64.0 (71.5)	Second-warmest and second-wettest February since observations began
50.9 (56.5)	175.8 (111.2)	Mild, with much precipitation at the beginning; then, around the middle of the month, change to high pressure conditions, with much sunshine but a cold north-easterly flow of air
16.3 (58.2)	292.4 (153.7)	Sunniest April ever and extremely dry
38.4 (71.1)	240.5 (201.6)	First month for a while that was colder than the 1961–1990 average
90.9 (84.6)	214.7 (203.3)	Typical central European summer weather, very changeable with much rain but also very sunny spells of weather
51.8 (77.6)	232.9 (210.7)	Very pleasant summer month; no particular heatwave
85.5 (77.2)	221.6 (199.5)	Pronounced heatwave from the very beginning of the month; second-warmest August ever
50.0 (61.1)	207.1 (149.6)	Sixth month in a row with more than 200 hours of sunshine
78.4 (55.8)	67.5 (108.5)	First month for a while with above-average precipitation
20.7 (66.3)	85.7 (52.8)	Very dry and sunny autumn month
58.8 (70.2)	59.0 (38.0)	Very mild phase at the beginning, then winter conditions from the middle of the month, in mountainous areas especially after Christmas
222.1 (180.7)	182.1 (152.9)	Second-warmest winter since measurements began (behind 2006/07)
105.6 (185.9)	708.7 (466.6)	Very dry season with a new record for plenty of sunshine
228.2 (239.4)	669.3 (613.5)	Very changeable summer, with high summer temperatures not arriving until August
149.0 (183.3)	360.3 (310.9)	Third-warmest autumn since 1881, with no major storm events or persistent spells of winter
704.9 (788.9)	1,896.0 (1,544.0)	Second-warmest year (behind 2018); very dry, especially during the growing season; much sunshine throughout the whole year

# The year in review

**01** : Voyage into the atmosphere:  
: depending on the research  
activities on the plan, up to eight radiosondes per day were sent from the Polarstern to explore the atmosphere. Their launch was one of the jobs of the DWD weather technician aboard. On the way up into the atmosphere, most of the time up to a height of 30 km at least, the radiosondes' instruments collect real-time data about the meteorological conditions. These data are indispensable for weather forecasting aboard the Polarstern.



## Weather forecasting during the coronavirus pandemic

During take-off and landing, many aircraft all over the world measure air pressure, air temperature and wind, with a few also recording the air humidity. These meteorological data are then transmitted to the national meteorological services, including the Deutscher Wetterdienst (DWD). The data are available almost in real time and represent so-called vertical profiles of the atmosphere, which are used for weather forecasting, and hence also to produce warnings. Due to the lockdown in Germany from mid-March 2020, almost all aircraft were grounded. The number of weather observations from aircraft over central Europe fell rapidly from about 350,000 per day to sometimes less than 50,000. As none of the aircraft recording air humidity could take off, the number of those measurements was reduced to zero. The shortfall of aircraft measurements amounted to about 80 per cent.

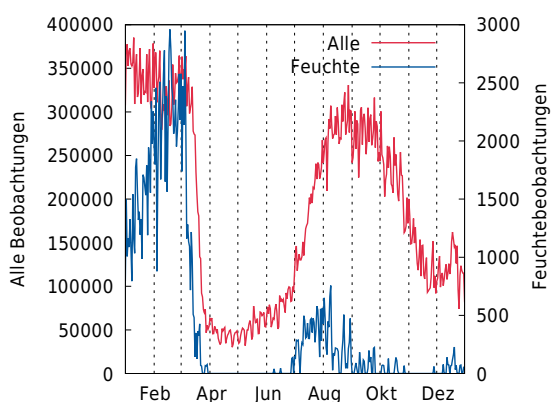
In order to compensate for at least some of the missing data, the DWD immediately introduced additional launches of radiosondes at four of its altogether ten upper-air stations in Germany. From mid-April, a special procedure allowed for information on air humidity to be derived using the Global Navigation Satellite System **GNSS** and integrated into the global weather forecasting system of the DWD. Further data sources were added from mid-May and from June: whereas up to that time, the **radiosonde ascents** only delivered information up to the bursting of the weather balloon at a height of about 30 kilometres, it has now become possible to also use **information emitted during the radiosondes' descents**. In addition, wind measurements from the European research satellite **Aeolus** could be fed into the DWD's weather forecasting models. **Aeolus** provides precise wind data from those parts of the atmosphere which are crucial for the formation of weather in Europe. During each orbit, the satellite produces a new band of data around the Earth about 80 kilometres wide and 30 kilometres high. The Aeolus data could

thus fill some gaps in the global meteorological observing system. Further substantial improvements have been achieved since mid-2020 by using **3D-RADAR** volume measurements (radial winds and reflectivities) in the DWD's regional numerical weather prediction system.

On the whole, meteorological measurements from aircraft have a very positive impact on the quality of numerical weather predictions. Sensitivity studies carried out at the European Centre for Medium-Range Weather Forecasts (ECMWF) have shown that, if none of the global observations from aircraft are taken into account, the forecast quality diminishes by up to 15 per cent. Thanks to the above-mentioned extensive measures, taken in order to compensate for the loss of the aircraft measurements, no significant deterioration of the forecast quality was observed over Europe.

01

Gesamtzahl in Mitteleuropa



**01** In March 2020, the number of weather observations from aircraft over central Europe fell from about 350,000 per day to sometimes less than 50,000. It only began to rise again significantly at the beginning of the summer holidays, but dropped once more from October/November.

**02** 'Miss Piggy' in operation: 'Miss Piggy', as the tethered balloon is called, can take measurements over several hours up to a height of 1,600 m and thus collect important data about the lower atmosphere.



## Coronavirus lockdown, nitrogen oxides and ozone

As the coronavirus lockdown in March and April 2020 led to a reduction in traffic, there was an expectation that nitrogen oxide concentrations in cities would diminish. However, such an improvement of the air quality due to the lockdown could only be detected when meteorological influences were excluded. An analysis, carried out jointly by the Deutscher Wetterdienst (DWD) and the Federal Environment Agency (UBA) on data from all air monitoring sites in Germany, has shown a reduction in nitrogen oxides (NO<sub>x</sub>) by about 30 per cent in a total of 48 German cities with more than 100,000 inhabitants.

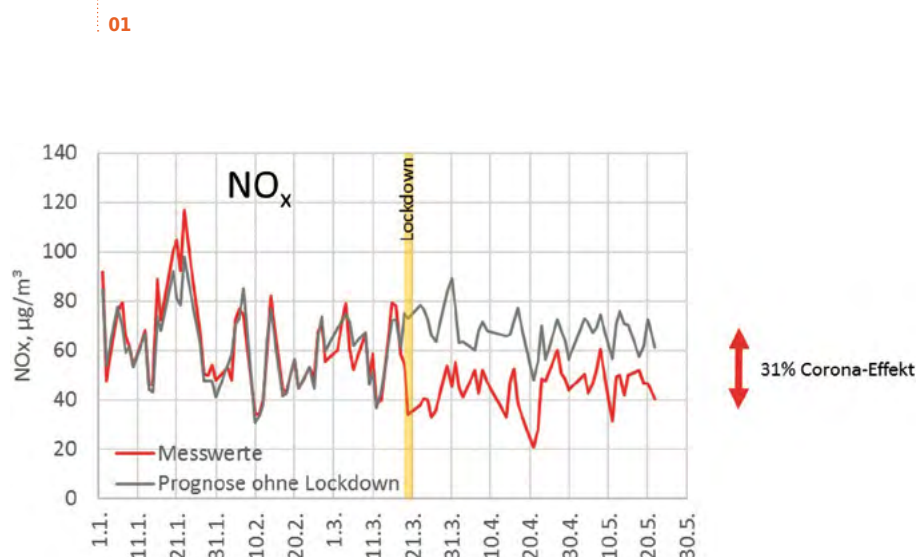
### Traffic emissions and meteorological conditions

Nitrogen oxide concentrations mainly depend on traffic emissions, but also on the prevailing meteorological conditions, as these have an impact on the 'removal' of the pollutants. In February and March 2020, unusually high wind speeds were observed, causing a strong dilution of the nitrogen oxides in the cities and thus resulting in unusually low concentrations. From mid-March, the winds slowed down. This would usually have led to an increase in nitrogen oxides, but it coincided with the first lockdown, which caused a reduction of the emissions. All in all, the 4-week average of NO<sub>2</sub> concentrations in different regions of Germany only fluctuated between minus 12 and plus 4 per cent. The evolution of the concentrations alone does not show a clear effect of the coronavirus pandemic. The reduction caused by the lockdown can only be seen by excluding the meteorological influences masking the reduction. Apart from wind, temperature is the biggest factor influencing nitrogen oxide concentrations and thus the air quality.

### Reduction in nitrogen oxides by about 30 per cent

The joint analysis compared 5-year time series (2015–2020) with the first two 4-week periods of the coronavirus lockdown (23.03.–19.04.2020 and 20.04.–17.05.2020): during the first four weeks of lockdown, NO<sub>x</sub> concentrations decreased by 31 ± 8 per cent and NO<sub>2</sub> concentrations by 22 ± 6 per cent. Due to traffic picking up again, the decrease in the second lockdown period was smaller.

**01** Reduced nitrogen oxide levels during the lockdown in spring 2020 once the meteorological influences, which were "masking" the reduction, had been excluded.



## Ozone

Ozone is an important trace gas in the Earth's atmosphere. About 90 per cent of ozone is found in the stratospheric ozone layer at a height of 10–50 kilometres. By blocking almost all hard and dangerous radiation coming from the sun, this layer acts like a natural pair of sunglasses and protects life at the Earth's surface.

Sufficient ozone in the stratosphere is absolutely essential for life on Earth.

The remaining 10 per cent of ozone is found in the troposphere, a layer reaching from the ground up to a height of 10 kilometres, where the ozone is an important greenhouse gas. Acting as a strong oxidizing agent, it can, in higher concentrations, cause irritation and damage to the respiratory tract in humans and animals, as well as damage and loss of yields in plants.

In an ideal situation, there would be a lot of ozone in the stratosphere and only a little in the troposphere. However, human activities over the previous hundred years have led to a global decrease in

stratospheric ozone and an increase in tropospheric ozone. The global ban on chlorofluorocarbons (CFCs), implemented with the Montreal Protocol in 1987, has initiated a slow recovery of the stratospheric ozone layer since about 2000, but it will take another 50–100 years to be completed. With regard to tropospheric ozone, concentrations in the west went up steeply until the 1990s, when the increase was stopped almost completely by denitrifying power plants and introducing catalytic converters. However, nitrogen oxide emissions, for example from older diesel vehicles, continue to pose a problem.

## Impact on tropospheric ozone in the northern hemisphere

Ozone in the troposphere is mainly generated photochemically from nitrogen oxides, hydrocarbons and sunlight. This means that the substantial emissions reductions caused by the global coronavirus lockdowns should lead to less ozone in the relatively clean air of the free troposphere.

This expected reduction in ozone could be demonstrated in a scientific study led by the DWD. Measurements, taken at 45 global stations with radiosondes, infrared spectrometers and lidars, show that in spring and summer 2020, due to the coronavirus lockdowns, ozone concentrations in the free troposphere over the northern hemisphere fell on average by seven per cent compared with previous years.\* Many stations haven't measured such low tropospheric ozone concentrations for as many as 20 years. At Hohenpeissenberg, for example, this hasn't been the case since 1976.

The emissions reductions due to the coronavirus pandemic have constituted a huge unplanned experiment at a global scale, offering a further contribution to a better scientific understanding of chemical processes in the troposphere. Comparisons between simulations with chemical models of the atmosphere and observations provide valuable insights into the exact repercussions of the coronavirus lockdowns, for instance the impact of the massive reductions in air traffic emissions throughout the entire year of 2020. Improved simulations will also support the planning and evaluation of future measures aimed at emissions reduction.

The complexity of the problem becomes clear when looking, among other things, at densely populated areas with heavy air pollution, where, despite the large reductions in local emissions, the lockdowns caused an increase in near-surface ozone.

The reason for this is that, in polluted air next to emission sources, nitrogen oxides destroy ozone, and a reduction in nitrogen oxide emissions therefore leads to more ozone. In contrast, in air far away from any emission sources such as in the free troposphere, less nitrogen oxides lead to less ozone – as has now been observed at 45 stations in the northern hemisphere.

\* Source see page 75

## Together through the pandemic

In early 2020, Germany watched the news from China and from European countries, such as Italy and Spain, where the new coronavirus spread rapidly. The DWD's Board of Directors responded quickly to these new developments. As early as late February, a pandemic response team started its work in order to support the board. Its task consisted in carefully monitoring the constantly evolving situation and preparing precautionary measures to protect the workforce. The team included staff from many different departments, such as estate and facilities management, human resources, information technology, administration, communication, health and safety, health services and crisis management. The quick establishment of this team enabled the DWD to cope successfully with the pandemic, since the dynamics of the crisis made it necessary, especially in the first few months, for the situation to be reassessed almost every day and decisions to be taken without delay.

Among the issues to be discussed daily were, for example, hygiene measures, quarantine rules, technical equipment and possibilities for working at home. In addition, the team drew up emergency lists and identified critical areas requiring special protective measures, such as the Weather Forecasting and Advisory Centre and the German Meteorological Computing Centre. The response team attached great importance to good communication with the workforce. This led to the establishment of a telephone and an e-mail hotline and the publication of a daily updated SARS-Cov-2 news ticker on the DWD's intranet.

The DWD benefitted especially from an agreement on new rules for mobile working, which had been reached by the board and the staff representatives about a year prior to the crisis and which were extended fairly quickly. This meant that early on, a large part of the staff was able to work from home. Due to this and many precautionary measures such as effective hygiene standards, a high degree of protection was established at the DWD already in the early days of the pandemic.

From late summer, infection figures increased substantially. With sites all over Germany, it was a challenge for the DWD to respond to the regionally varying developments and the differing rules in the federal states. However, these difficulties have so far been handled well, thanks to sound judgements and a coordinated approach. In this context, the close cooperation between the branch leaders on the one hand and the Executive Board and the pandemic response team on the other hand has proved to be very beneficial. In 2020, the DWD saw only a few cases of coronavirus infection among its staff; the processes introduced for mobile and digital working have been functioning well. At all times, the DWD was in a position to fulfil its statutory obligations. Services regarding weather and climate were made available reliably, at all times and with the usual quality.

**01** Shortly before the end of the polar night: the UFA film team installed a camera next to the runway, which had been built on the ice floe and was already affected by a crack.





02

## New high-performance computer for the DWD

In September 2020, the DWD's entire forecast production was successfully migrated to a new high-performance computer (HPC). Preparations for this project had already begun in 2017, when the technical requirements had been identified and the necessary funds applied for. At the end of 2018, the search began for a successor to the Cray system in use since 2013, and a Europe-wide invitation to tender was published. In mid-2019, a contract was concluded with the Japanese company NEC for the provision of a computer system, which, in its final phase, would be six times faster than the old one.

The performance of the new HPC system is based on specific vector processors which allow for the mathematical computations of the weather forecasting models to be carried out faster and more efficiently. Regarding the cooling of the computer, the DWD, for the first time, chose a system using warm-water technology. In order to prevent overheating, each processor is flushed with water about 40 °C warm. This relatively high cooling temperature makes it possible to cool the system using ambient air all year round, without relying on cooling machines, thus saving a lot of energy and providing more environmentally friendly weather forecasts.

02 Brigadier General Peter Webert, commander of the Bundeswehr Geoinformation Centre and head of the Bundeswehr Geoinfor-

mation Service (left), and Prof. Dr Gerhard Adrian, President of the DWD and WMO (right), launched the new HPC in autumn.

For the first time, the new HPC allows the DWD to protect its services against large-scale damage, since the two components of the dual system are located at a distance of 70 km from each other. One system is hosted by the German Meteorological Computing Centre at the DWD headquarters in Offenbach while the other one is situated in Ludwigshafen am Rhein. A high-speed data link between the two computing centres ensures that all forecast products can be generated at both sites and delivered to the customers in a timely manner.

The additional computing power will be used to further extend the DWD's weather forecasting system for the very short range and to increase the models' spatial and temporal resolution. The new system will also be used by the Bundeswehr Geoinformation Centre (ZgeoBw), with which the DWD has been closely cooperating on the provision of meteorological services since 2004. Until 2024, the DWD and the ZgeoBw will together invest more than 60 million euros in the common meteorological IT infrastructure.

03 The new HPC's warm-water cooling system

04 Dual system: the German Meteorological Computing Centre's HPC backup components in Ludwigshafen

03



04



## Interactive WarnWetter app: citizens report weather events

Since the end of July 2020, users of the full version of the DWD's WarnWetter app for weather warnings can send their own observations of weather events and the impacts of these events directly to the DWD. In this way, the DWD has created a new channel for weather data and launched one of the most popular crowd sourcing projects in Germany. Very soon after the new function had been released on 2 August, the DWD received more than 26,000 reports within 24 hours. After reaching very high figures initially, the number of reports has stabilised at a high level of about 2,000 per day. If weather conditions are critical, many more reports are being received.

### Consideration of these reports for targeted warning management

The contributions of citizens represent an extremely valuable addition to the network of observing stations. For the first time, they not only allow for the recording of meteorological phenomena which are difficult to measure, such as hail or snow depths, but also the systematic capture of local weather effects. The report forms to be sent by WarnWetter app users contain a standardised selection of weather phenomena and their manifestations. It is also possible to transmit additional parameters, comments and even images.

After an automatic plausibility check, the reports are directly displayed for all WarnWetter users. Meteorologists at the DWD's Weather Forecasting Centre have direct access to this information and can thus take them into account when generating targeted warnings. In order to enable disaster management control centres to better assess the situation on the ground, the reports are made available via the FeWIS portal. In addition, the DWD is currently examining a wide range of applications for these data, for instance their assimilation for numerical and short-range weather prediction, as well as using them for improved consultation procedures, verification purposes and the preparation of expert assessments.

### Compliance with data protection

In order to ensure the data's quality and enable further analysis, the DWD stores all the data it obtains in a permanent archive. When developing this facility, the DWD ensured that the data collection and storage complied with data protection rules and that the framework for using the new data was legally sound. It implemented a concept according to which the DWD does not store personal data, but is entitled to make full use of the reported observations.

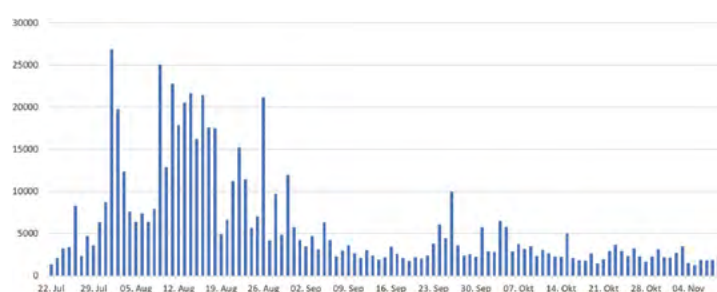
When cooperating with other European meteorological services, the DWD endeavours to ensure a standardised quality control system and an exchange of reports in real time – after all, the weather does not stop at national borders. One of the main topics in going forward will be the sustainable activation of users and the targeted integration of special observers (so-called 'trusted spotters') under the umbrella of citizen science. Thanks to a closer involvement of the citizens, the population has become much more aware of dangerous weather events.

### Some key figures

- 750,000 user messages in 2020
- Approx. 70,000 images
- Peaks of 26,000 reports per day
- User reports distributed via the WarnWetter app and, for disaster management, via FeWIS (accessed approx. 300 million times per year)

**01** User reports per day during the first four months with a peak value of 26,000 reports in 24 hours during severe weather situations

01





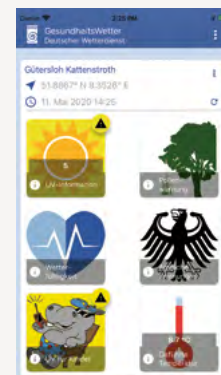
02

02 Delayed by three days because of adverse weather: at the end of April, some members of the team were picked up from the Polarstern by aircraft because they couldn't

stay longer for personal reasons. This would not have been possible without reliable meteorological briefings for this flight. The aircraft had started in Greenland and also returned there.

03 Overview page of the GesundheitsWetter app

03



## New app GesundheitsWetter warns of weather dangerous to health

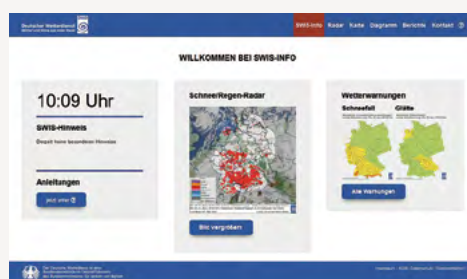
Millions of people in Germany suffer from pollen allergies or from negative effects of certain weather situations, or need to protect themselves from sunburn or heat during work and leisure time. The weather not only poses a danger or disturbance to the health of many people, it also has a negative impact on the German economy as a whole, for example due to employees taking more sick days.

At the end of May 2020, the Deutscher Wetterdienst (DWD) launched a new app, GesundheitsWetter, to provide daily updated information about possible weather effects on people or warnings of health risks such as dangerous heat. The app enables citizens to prepare themselves in good time, so that they can cope with weather situations having a particular effect on them. Users can customise the information they receive, pre-setting their individual level of impairment, for a one-off payment of 0.99 euro. The app can be found in the app stores of Apple and Google by searching for its name GesundheitsWetter.

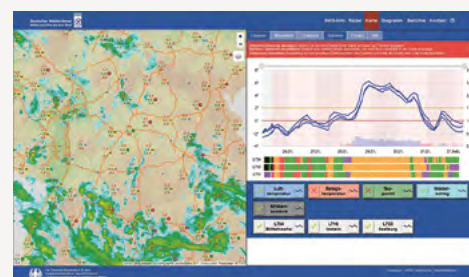
Functions provided by the DWD GesundheitsWetter app include:

- Official UV warnings, UV index and UV warnings for children
- Official heat warnings
- Forecast of the perceived temperature
- Pollen forecast and derived risk index
- Forecast of the weather sensitivity for common adverse health effects, asthmatic conditions, cardiovascular disorders and rheumatoid diseases
- Freely configurable warning elements and warning levels
- Configurable alert functions (push notifications) for freely selectable favourite locations

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## SWIS – DWD’s road weather information system now available in a new format

Since mid-October 2020, a new portal for winter maintenance services called SWIS-Info has been made available to the federal states’ motorway and road maintenance authorities and the Autobahn GmbH, as well as to private customers (subject to a fee). This new portal provides a user-friendly summary of all relevant weather data, especially those required for the planning and coordination of winter maintenance services. In addition to official warnings, the system also includes other information, such as snow/rain radar images and films, weather station data and weather reports (Figure 01).

As a special feature, SWIS-Info presents the measurements of more than 1,500 road weather stations as well as the forecasts for their locations. The road weather stations are operated by the road administrations of the federal states, with a pro-rata contribution of the Autobahn GmbH from 2021 onwards. The DWD is therefore not in charge of the measurements, it however provides support to the data producers, based on its extensive experience in the field of measuring and information technology.

Due to external influences, temperature measurements of road surfaces are somewhat prone to error. For this reason, 2018 saw the introduction of a fully-automated quality control system that verifies the measurements of the more than 1,500 road weather stations, taken every 15 minutes all over Germany. Any anomalies are flagged in SWIS-Info. A map (Figure 02) enables the user to select certain road weather stations and, with an hourly resolution and in form of a graphic, to visualise the evolution of the temperature, dew point, road surface temperature, type and amount of precipitation as well as the state of the road, currently up to the seventh subsequent day.

### Forecasting method

In a thorough update of the forecasting method, the forecast period and the temporal resolution were substantially increased and a more detailed description of the road surface state added. The energy balance model (EBM) used up to now to produce the forecast had been developed at the beginning of the 1990s. It had become technologically obsolete and was therefore replaced with a new open-source model. The new model, called **Model of the Environment and Temperature of Roads (METRo)**, calculates the specific parameters required for the road weather forecasts. Based on a statistical approach, another new set of forecast data combines quality-assured historical and current measurements from the road weather stations with various weather models. The resulting data set is then fed into the METRo system.

01 Start page of SWIS-Info

02 Map with radar image and road weather data (left) and graphic showing road weather measurements and forecasts for the next seven days (right)

### User training

Due to the coronavirus pandemic and the relatively short time available for the development of the new portal, it was not possible to arrange presentations for the customers or individual training sessions on the system’s new features. For this reason, a virtual advent calendar was added to the new portal in December for the start of the winter. On every working day, a tutorial lasting about six minutes presented technical explanations regarding the contents of SWIS-Info as well as a little story, featuring the characters Melti, a snowman, and Rudi, a reindeer, who entered into a dialogue with the DWD’s presenter. This format, which is slightly unusual for a scientific institution such as the DWD, was met with a very positive response by the customers.

## Climate predictions for the coming ten years

Decadal climate predictions cover the period of the next ten years, crucial for the economy, politics and society, and fill the gap between climate predictions for the coming months and long-term climate projections until 2100. The predictability for longer time horizons is based on components of the climate system responding slowly to changes in the atmosphere, such as oceans and land surfaces.

**03** Basic ensemble mean prediction for temperatures in Germany for 2020 and 2025–2029

**04** Basic probability prediction for precipitation in southern Germany for different time periods

**05** Expert ensemble mean prediction for temperature and precipitation in Europe in 2020

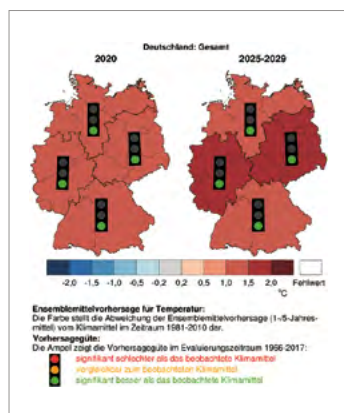
In order to assess the quality of climate predictions, scientists calculate predictions for time periods in the past and compare these with observations. It is then assumed that the quality of the climate predictions for the next ten years will be of similar quality. However, as the model cannot represent all processes perfectly, a prediction's quality is dependent on which climate elements, which regions and which time periods are being considered. In order to estimate the error in the observations used to initialise the predictions, the scientists calculate ten climate predictions based on different initial data and look at the mean and the spread of the forecast ensemble.

As part of the MiKlip (**M**ittelfristige **K**lima-**p**rognose) medium-range climate prediction programme funded by the Federal Ministry of Education and Research (BMBF), a decadal climate prediction system was developed between 2011 and 2020. This system has been used by the DWD since 2020 to produce climate predictions for the next ten years. The results are published on the web page [www.dwd.de/climatepredictions](http://www.dwd.de/climatepredictions).

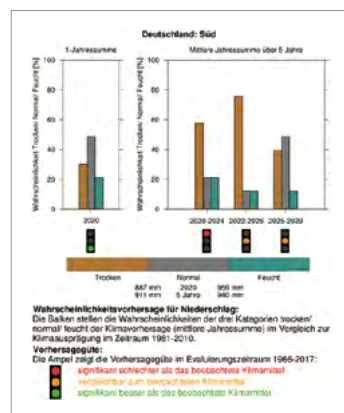
Basic climate predictions contain maps, time series and tables for German regions. Their quality is displayed as a traffic light. The climate prediction for 2020 published in March 2020, for example, forecasted temperatures 1–1.5 degree Celsius above those in the reference period 1981–2020 for the whole of Germany. For the period 2025–2029, even higher temperatures were predicted.<sup>1</sup> Another example shows a probability of more than 50 and up to 70 per cent of drier periods occurring in 2020–2024 and 2022–2026 in southern Germany, the skill of this forecast however being lower. Expert climate predictions provide more detailed descriptions for Germany, Europe and the whole world. One of these predictions, also published in March 2020, forecasted temperatures more than 2 degrees Celsius above those in the reference period for south-east Europe in 2020. More precipitation is expected in western Norway and southern Italy, and less precipitation in central France and southern Ukraine. The forecast skill is represented with three dot sizes. The web page is gradually expanded by adding climate predictions for the coming weeks and seasons. All in all, decadal climate predictions form another milestone supporting society's adaptation to climate change.

<sup>1</sup> The actual annual mean temperature in Germany in 2020 was 10.4 degrees Celsius. This exceeds the average for the reference period 1981–2010 by +1.5 degrees.

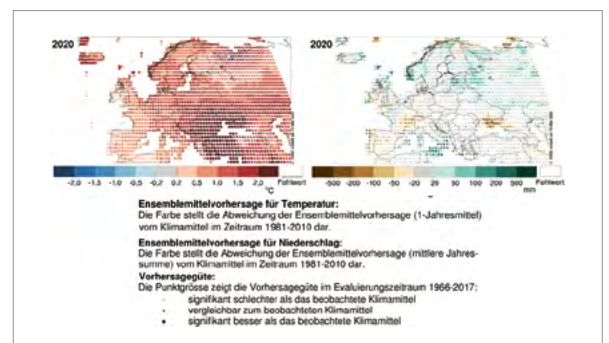
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## Berchtesgaden National Park – cooperation with a unique reference area

The Berchtesgaden National Park and the Deutscher Wetterdienst (DWD) are intensifying their long-standing cooperation. Research carried out in the only national park in the German Alps focusses, among others, on the effects of ongoing climate change on small-scale, ecologically diverse habitats. Since the effects of climate change are more extreme and visible earlier in mountainous regions, the Alps are an area of particular concern. The Berchtesgaden National Park, which has an explicit mandate to carry out research, extends over areas with altitudes ranging from 600 m to 2,700 m above sea level and covers a variety of habitats. It therefore represents a unique reference area, where the effects of climate change can be studied in great detail. The results can be applied to similar areas in other regions and are very valuable for many areas of life, such as ecology, forestry, tourism, water management and the protection of the population, environment and nature.

### Collecting and archiving of historical measurement data

The DWD is currently providing support to the national park with the collecting and archiving of historical measurement data. Quality assurance and the comparability of these measurement data are of crucial importance in order to ensure an even more nuanced assessment of the evolution of the national park's long-term local climate. To achieve this, the DWD, among other measures, digitises old measurement strips from the national park in its know-how centre for alpine climatology in Munich, and examines and homogenises data sets from the national park and from its own stations. In the future, the cooperation between the DWD and the alpine national park will focus even more on the areas of climate change, monitoring of the environment and data management. New research objectives and activities will thus be agreed and tackled together.

**02** Flying sensor EM Bird: hanging down from a helicopter and towed by it through the air over long distances, this sensor measures the ice thickness ten times per second, thus collecting plenty of values for the scientists.

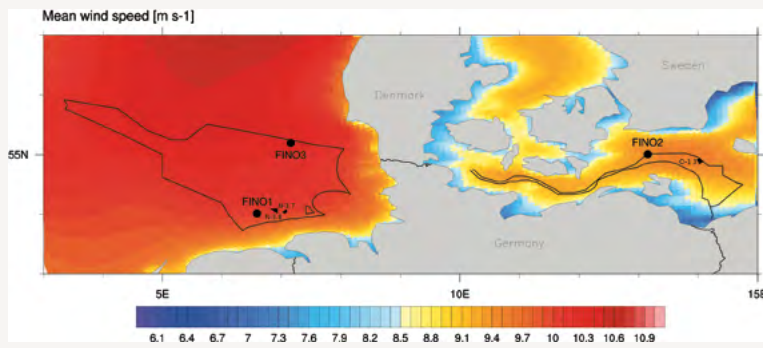
According to the cooperation agreement, the DWD currently operates a total of eight stations in the national park via its mobile measuring unit. The measurements from these stations complement those obtained from the stations operated by the national park and the avalanche warning service. Some of the stations have been providing data for more than 20 years. Since 2017, they have been producing measurements, with a temporal resolution of ten minutes, of the air temperature (mean temperature and, since this year, also 10-minute minima and maxima) and air humidity. The stations must be serviced regularly and the data downloaded, because the latter are not (yet) transmitted automatically. Some of the stations, among those the DWD stations at the two lakes, Funtensee and Grünsee, are accessible only by foot. Heavier components, if required, must be delivered by helicopter. In the winter, these stations, depending on the snow conditions, can only be reached on snowshoes. If there is a high risk of avalanches, access is impossible.

**01** Measurement stations in the Berchtesgaden National Park: the red dots show the measuring sites of the DWD, white dots those of the National Park

**01**







01

01 Long-term means of wind speed in m/s from COSMO-REA6 on model layer 37 (116 m) for the period 1995–2018. The borders of the German EEZ in the North and Baltic Seas are represented by black lines. The areas for tender in 2021 are shown as black filled areas, the FINO masts are represented by black dots.\*

\* Source see page 75

## Offshore wind farms supported with DWD weather data

An essential component of the shift towards green energy in Germany is the establishment of offshore wind farms in the waters of the exclusive economic zone (EEZ). So far, it was mainly up to the operators of the farms to select their location, design and performance. These parameters were taken into account in the farms' planning process, which had to be reviewed by the responsible regulatory body, the Federal Maritime and Hydrographic Authority (BSH).

With the entry into force of the Offshore Wind Energy Act (WindSeeG), the state's planning powers have now been extended considerably. In the first step of a multi-level procedure, the BSH checks whether an area is suitable for the establishment of wind farms by examining site, marine environment as well as wind and ocean conditions (preliminary inspection). This is followed by a public invitation to tender to find the most suitable operator. A decisive factor in the decision on who to award the contract is the level of state subsidies requested.

The first round of invitations to tender based on the WindSeeG was launched in March 2021, with two areas in the North Sea (designated N-3.7 and N-3.8, both situated about 30–40 km north of the East Frisian Islands) and an area in the Baltic Sea (designated O-1.3, about 40 km north-east of the island of Rügen) (Figure 01). For the bidders to be able to calculate the expected yields, it is essential that they are provided with precise information on the wind conditions. For this purpose, the Deutscher Wetterdienst (DWD) coordinates the selection and compilation of appropriate data and reports. These mainly contain the measurements of vertical wind profiles right above the areas or in their immediate vicinity as well as evaluations of so-called reanalyses.



02

## Actual measurements + reanalyses = high quality of data

The DWD started its work on the three eligible areas by looking at measurement series taken over many years at the research platforms FINO1 (North Sea) and FINO2 (Baltic Sea). Wind speed and wind direction data for heights between 30 m and 100 m were standardised and subjected to consistent quality checks ([www.dwd.de/fino-wind](http://www.dwd.de/fino-wind)). Since FINO1 and FINO2 are situated at some distance of the three areas, the BSH also commissioned a year of measurements of the vertical wind profile for the two areas in the North Sea to be carried out in accordance with industrial standards. For the area O-1.3, the DWD could draw on several years of measurements taken at the mast of an

energy provider in the Arkona Basin. In addition, the DWD used two operational atmospheric reanalyses for all three areas. The results were as follows: in all three cases, the average wind speed at the hub height of current wind farms consistently amounts to about 10 m/s. A comparison shows very good agreement between the measurements taken at FINO1 and FINO2 and the reanalyses. The frequency distribution coefficients are closely matching, demonstrating the high quality achieved today by these data sets. The final report on the wind conditions over all three areas has been added to the data parcel to be provided to the bidders participating in the tender.

All the data and reports used in the project are available to the public. This hasn't always been common practice. In the past, offshore measurements were often not accessible. The data from the preliminary inspection can, for example, also be used for climate monitoring or model validation.

### Reanalysis

Every day, millions of observations are assimilated using numerical weather prediction models. The resulting analyses are three-dimensional, consistent descriptions of the state of the atmosphere. In this way, analyses combine the advantages of models with those of observed data. Every operational model is continuously improved over a period of several years. For this reason, long time series of operational analyses are often

not consistent over a longer period. Reanalyses are analyses of years to decades in the past, but are run with a single updated version of model. The new calculation also makes use of all observations that have become available in the meantime. For the application presented here, the DWD uses the COSMO-REA6 reanalysis, developed in cooperation with the university of Bonn, and the ERA5 reanalysis of the European Centre for Medium-Range Weather Forecasts (ECMWF).

**02** Clearing up: shortly before the Polarstern left the floe for Spitsbergen, the team had to collect their material and transport it to the ship by helicopter. Many of the measuring sites could no longer be reached on foot due to the breaking ice.

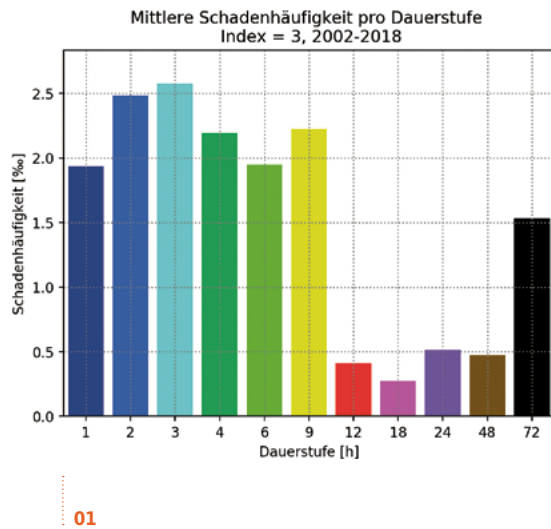
**03+04** Towed sensor platform  
Helipod in operation: this sensor platform is like a mini observatory. Similar to the EM Bird, it is towed by the flying helicopter while taking measurements over the ice floe, for example of the greenhouse gas methane.



03



04



01 Mean frequency of loss events due to heavy rain for all 11 duration levels over the entire period 2002-2018

## Cooperation with the German Insurance Association

Climate researchers assume that, with climate change unfolding, the number and severity of extreme climate events will increase. However, how does this increasing danger translate into an actual risk? In a four-year project focussing on the weather extreme 'heavy rain', the Deutscher Wetterdienst (DWD) and the German Insurance Association (GDV) examined the complex interrelation between heavy rain and insured losses.

In order to identify any possible links at all, the first step consists in an adequate preparation of the existing information on such events and on insured losses for further analysis. This required both extensive expertise of the underlying raw data and knowledge regarding their robustness. For the heavy rain project, the DWD has completely reorganised and re-processed the radar-based precipitation monitoring data collected since 2001. The GDV, for its part, contributed the information on nationwide loss declarations in a format enabling comparisons and ensuring the greatest possible homogeneity, which, for the first time ever, allowed for nationwide data blending. This enabled the DWD to gain a thorough understanding of the repercussions and the potential risks of heavy rain as a natural disaster event.

It is now possible to demonstrate, for example, that heavy rain will cause particularly serious damage if it is intense, concentrates over a small area and lasts only a relatively short time (up to three hours). The DWD and GDV have agreed a long-term cooperation in order to work in a very similar way on other natural dangers, too, and to gain a better understanding of the repercussions of, for example, hail. Among the measures considered is the nationwide mapping of natural risks, including the quantification and evaluation of their fiscal implications. The principle of free data exchange will be continued, as well as the pre-processing of the data that allows for the blending with other data sets. In principle, it will also be possible to extend the agreement to all other weather phenomena, if there are appropriate data available on the corresponding insured losses.

On a strategic level, the agreed cooperation will provide the DWD with strong arguments for upgrading its analyses of the spatial distribution of the risks caused by weather extremes. This analysis of the current landscape of risks will also constitute an important element in climate modelling, since, if there is a change in weather-related risks, this will also affect the risks landscape in general. In this way, the DWD is reinforcing its expertise in the areas of climate and environmental consultancy services, particularly with regard to the prevention of and the adaptation to natural hazards, which are expected to occur more frequently because of climate change.

**02** Approaching measurement aircraft: unmanned measurement aircraft provided the direct measurements with which it was possible to verify the values derived from indirect lidar measurements.



**02**

## Monitoring thunderstorms and wind gusts

**Y**ou receive a short-term warning of thunderstorms with heavy rain and strong wind gusts on your smart phone; soon after, it is pouring with rain and the trees are bending in the wind – but five kilometres away, there is not a single drop of rain. Who hasn't seen a situation like this? In order to monitor such weather events, which often extend over only a few kilometres and usually only last a short time, the Deutscher Wetterdienst (DWD), together with some partners, has been carrying out a field experiment at its Lindenberg Meteorological Observatory – Richard Assmann Observatory (MOL-RAO) in Brandenburg.

Cumulus clouds, rain showers, thunderstorms and wind gusts represent a particular challenge to weather forecasting. Forecasting models are not in a position to simulate explicitly such small-scale and short-lived phenomena. In the summer of 2020, scientists carried out investigations of the wind in order to better understand such processes in the atmosphere. Using so-called Doppler lidar instruments, which work with laser beams, they examined wind patterns, wind gusts and convective turbulent structures up to a height of several hundred metres above ground level. These measurements were taken at the Lindenberg Observatory and at the associated boundary layer field site in neighbouring Falkenberg. In addition, unmanned measurement aircraft were deployed over a period of four weeks in July in order to take direct measurements for the verification of values resulting from indirect lidar measurements.

### Objective: improvement of the warning management

Thanks to the reduction in air traffic caused by the coronavirus pandemic and to the fact that the new Berlin airport BER had not been opened yet, the measurement aircraft obtained permission from the DFS Deutsche Flugsicherung GmbH, Germany's national air navigation service provider, to extend the measurements up to a height of several kilometres. However, most of the measurements were taken in the lower parts of the atmosphere up to 500 metres. The measurement aircraft can capture the variability of wind and temperature as well as of the air's water vapour content with a very high resolution. The sensors record more than one hundred measurement signals per second, which translates into a spatial resolution in the range of decimetres. The aim of these measurements was not only to gain a better understanding of convection, wind gusts and thunderstorms. The scientists also wanted to identify the optimal measuring strategy for the continuous routine operations of the observatory's lidar instruments. It might be possible in a few years to produce better short-term forecasts of the formation of cumulus clouds and the occurrence of thunderstorms and wind gusts, and thus to provide the population and various economic sectors, such as air traffic, energy or construction, with earlier and more localised warnings.

### Smaller experiment due to the coronavirus pandemic

The field experiment was called FESST@MOL (Field Experiment on Submesoscale Structures @ Meteorological Observatory Lindenberg). It was conducted with the participation of the KIT-Campus Alpin of the Karlsruhe Institute of Technology (Garmisch-Partenkirchen), the Institute of Atmospheric Physics at the German Aerospace Center – DLR (Oberpfaffenhofen) and the Center for Applied Geosciences of the Eberhard Karls University (Tübingen). FESST@MOL was a reduced version of the larger Lindenberg Field Experiment on Submesoscale Spatio-Temporal Variability (FESSTVaL), which had been scheduled to be carried out at the MOL-RAO in 2020. The plan had been for scientists from the universities of Hamburg, Cologne, Bonn, Frankfurt am Main and Berlin, all cooperating with the DWD at the Hans Ertel Centre for Weather Research (HErZ), and the above-mentioned partners to work together. The objective of the experiment was to gain a better understanding of the above-mentioned processes by collecting and examining a wide range of observations, including those from a network of more than 100 ground stations and a local weather radar. However, this larger experiment had to be postponed by a year because of the coronavirus pandemic.



01

01 Outdoor mission on the floe: caution and imagination were needed when the scientists went on their missions to the research stations. Without exception, outdoor missions were only possible when the weather conditions allowed it.

## World Meteorological Organization (WMO)

The implementation of the WMO reform, agreed by its Congress in 2019, has been continued. Due to the global COVID-19 pandemic, the two new technical commissions and their subgroups (standing committees and study groups) had to set themselves up virtually. More than 130 German experts were nominated and many of them appointed to the working groups of the two technical commissions.

The first meetings of the newly established Technical Coordination Committee and the Policy Advisory Committee were also held by videoconference, with the latter being chaired by Prof. Dr Gerhard Adrian. The main objective of this new committee is to prepare decisions for the Executive Council (EC) and the WMO Congress and ensure good coordination between all bodies and with the regions.

For the first time ever, the meetings of the EC and of the Finance Committee were held by videoconference. At times, up to 300 advisors from the 37 members were taking part in the EC. The discussions centred on the financial situation of the WMO, which has been negatively affected by delayed payments of membership contributions. It was also decided that the extraordinary session of the Congress in 2021 should mainly focus on the reform, data policy and hydrology. In addition, a task force was created, which will review the concept and the working methods of the Regional Associations, with the aim of improving their integration into the new WMO structures.

In November, the Infrastructure Commission met for the first time and, among other subjects, debated the future-orientated Global Basic Observing Network (GBON) and the resulting new requirements to be met by the observing systems. During a one-day meeting of the Regional Association for Europe (RA VI), its regional structure was adapted to the new WMO structure and a debate took place on the priorities for the coming years.

More than 1,200 people participated in the global data conference in November, which was held as an entirely virtual event. The objective of this conference consisted in formulating the requirements of the WMO data policy, which is currently under review.



02

**02** DroneVille, the site where the drones for atmospheric measurements were launched. Heavy movements in the ice caused the initially continuous floe to break into pieces. In constant danger: the power cables (in the foreground).

## European Centre for Medium-Range Weather Forecasts

The European Centre for Medium-Range Weather Forecasts (ECMWF) signed a four-year contract with the company Atos SE for the provision of a new supercomputer, worth more than 80 million euros. The decision was taken after conducting an international invitation to tender, during which the bidders were assessed according to a range of criteria, such as promised performance, implementation plan, flexibility and risks, quality of the technical solution, environmental impact, quality of the delivery, support of services and price. Compared with the current high-performance computing system at ECMWF, the sustained performance of the new system will be increased by a factor of five.

On 9 December, the ECMWF Council chose Bonn as its third location (in addition to Reading and Bologna). The new site in Bonn's international district will be completed in 2026. While the headquarters of ECMWF will remain in Great Britain, the first staff members are due to commence work at a temporary site in Germany's former capital city as early as in the summer of 2021; their relocation to the permanent site is scheduled for the end of 2026. The ECMWF's new site will be used to combine EU-funded activities, which, after the UK's exit from the European Union (EU), can no longer be carried out in Reading.

In addition, work was carried out at ECMWF in 2020 to prepare the delegation agreement for the next phase of Copernicus. Since the negotiations on the next Multiannual Financial Framework (MFF) of the EU had not been completed, the financing of the agreement was somewhat uncertain, especially for 2021, the transition year to the next phase.

Apart from working on the Copernicus services last year, ECMWF was also continuously involved in the Destination Earth project. This initiative of the European Commission aims at developing a very high precision digital model of the Earth. Germany supports this activity, with EUMETSAT and ESA also participating in the initiative.

On 1 December 2020, Estonia officially became a party to the ECWTF Convention, joining the other 22 member states.

## Network of European meteorological services: EIG EUMETNET

The European Interest Grouping EIG EUMETNET has paved the way for a closer cooperation on the exchange of new data sources via promising cloud infrastructures. In order to fulfil the requirements of all members, a series of virtual workshops at director level was initiated, with the results of these workshops contributing to the concept of a regional Federated Data Coordination Mechanism. In this process, national requirements need to be taken into consideration, as well as synergies with comparable WMO concepts (WMO Information System, WIS) or with the European Weather Cloud, developed jointly by EUMETSAT and ECMWF.

EUMETNET has been working on a new presentation of the severe weather warning system Metealarm ([www.meteoalarm.eu](http://www.meteoalarm.eu)). The DWD was involved in the implementation of its prototype. Launched in 2007, this system has published warnings of possible extreme weather events in Europe, such as heavy rain with the risk of flooding, severe thunderstorms, gale-force gusts, heat waves, forest fires, fog, snow, extreme cold, snow storms, avalanches or severe flooding. The severe weather warnings distributed by Metealarm are provided by the European meteorological services and their partners.

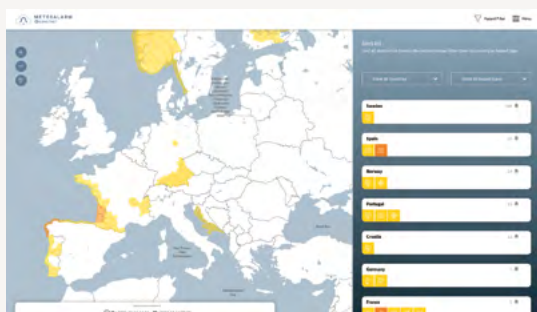
## Development cooperation at the DWD

At the 72<sup>nd</sup> session of the WMO Executive Council in the summer, a decision was taken regarding the further development of the Sustainable Observation Financing Facility (SOFF) initiative. The objective is to launch this facility officially at the World Climate Conference COP 26 in Glasgow in November 2021. SOFF aims to provide the financial tools to close the gaps in the global observing network. With the support of, for example, international development banks, SOFF is meant to enable developing countries to contribute to the Global Basic Observation Network (GBON). At the occasion of the meeting of the WMO Executive Council, the directors of ECMWF, EUMETSAT, EUMETNET and WMO issued a joint statement, declaring their support for SOFF. The DWD was involved in developing the concept for SOFF.

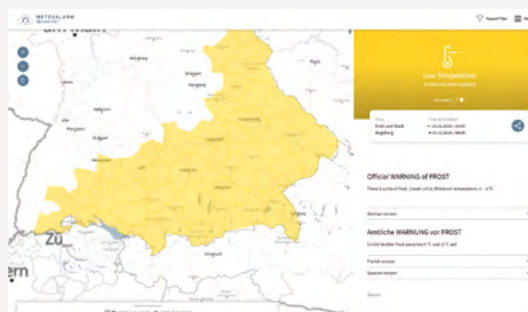
In February, the final meeting of the International Climate Initiative - Enhancing Climate Services for Infrastructure (IKI-CSI) was held in Bonn, together with Germany's agency for international cooperation, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). The DWD's involvement in the second phase of the project (until early 2022) will be quite small, with the DWD not providing any project staff.

From April 2020 until February 2021, a holder of a scholarship of the Alexander von Humboldt Foundation from the Meteorological Service Department Zimbabwe (MSD) did an internship at the DWD's Regional Climate Office in Potsdam. His work was mainly focused on an "Analysis of the results of regional climate models over southern Africa with a focus on climate extremes and on Zimbabwe".

- 01** Map representation in the new Metealarm application, version 2.0 (prototype)
- 02** View of official weather warning in Metealarm 2.0



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## Bilateral cooperation

The DWD regularly hosts meetings with other meteorological services and international organisations. The Informal Conference of Directors of Meteorological Services in Western Europe (ICWED) initiated a revision of the strategy of the European meteorological services, adopted in May 2016, with a view of updating it for the period until 2030. Prof. Dr Gerhard Arian has been actively participating and representing the DWD in this work.

In 2020, the COVID-19 pandemic caused talks with other meteorological services at director level to be either held as a virtual event or postponed indefinitely. However, it was possible to continue the exchange of views with experts from other meteorological services regarding specialist tasks and activities at a virtual level.

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## European Union

### Copernicus

The DWD continued the highly reliable delivery of its contributions to the Copernicus services in the areas of atmosphere, climate change monitoring and emergency management (as part of the Flood Awareness System). 2020 was marked by the transition from the first programme phase, financed under the Multiannual Financial Framework 2014–2020 of the European Union (EU), to the next phase, Copernicus 2.0. Preparations for the new phase have almost been completed and the official agreements between the EU and key partners such as ECMWF, EUMETSAT and ESA are expected to be concluded shortly.

### Open Data Directive

The European Union continues to aim for the provision of existing data that have been produced with public funds to be open and free of charge. The Public Sector Information Directive (PSI) has been revised and renamed Open Data Directive and is scheduled to be adopted in 2021. Work is currently underway to identify so-called High-Value Datasets, with one category, 'Meteorology', already defined. 2021 should also see a comprehensive classification of meteorological and climatological data as high-value datasets.

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## EUMETSAT

### Missions

Sentinel-6 satellite Michael Freilich (Jason-CS) was successfully launched on 21 November. It will mainly provide high-resolution sea-level measurements and vertical temperature profiles of the troposphere and stratosphere.

In November 2020, DWD and WMO President Prof. Dr Gerhard Adrian inaugurated a workshop, where scientists could exchange their knowledge and experience regarding data provided by a new wind lidar on the Aeolus satellite. Studies carried out at ECMWF as well as at the DWD have confirmed the expected positive impact of these data on the forecast quality. Work is progressing on the technical and scientific considerations for the Aeolus follow-on mission, with the objective of implementing this technology for operational services.

### Data services

Substantial progress has been made in the development of new data accessing services based on cloud technology. These services are expected to become fully operational in the first quarter of 2021. The work is closely linked to the development of the European Weather Cloud, a cooperation between ECMWF and EUMETSAT.

01



01 Nirivololona Raholijao (left) and Prof. Dr Gerhard Adrian after signing the Memorandum of Understanding at the DWD headquarters in summer 2019

## Strengthening agrometeorology in Madagascar

Due to its geographical location and the dependence of its population on natural resources, Madagascar is very vulnerable to the impacts of climate change. These impacts mainly affect the agricultural sector, which both represents an important component of the island's economy and provides for the livelihood of a very large part of the population. In 2020, three out of four Madagascans lived below the poverty line.

Since 2017, the DWD and Germany's agency for international cooperation, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), have been collaborating with local stakeholders in a project entitled 'Adaptation of agricultural value chains to climate change' (PrAda) in Madagascar. The overarching objective of this project is to improve the precision of the climate services for the agricultural sector in Madagascar. The DWD's key partner on the ground is the country's national meteorological service, Direction Générale de la Météorologie (DGM). The project is aimed at supporting the DGM in the implementation and independent application of the agrometeorological model AMBAV\_global.

In 2020, the DWD's activities focussed on improving the agricultural crop calendar in Madagascar by means of AMBAV\_global and the seasonal predictions produced by the German Climate Forecast System (GCFS). AMBAV\_global is an agrometeorological model developed by the DWD in order to determine two key parameters: the actual evaporation in plants and soils (evapotranspiration) and the soil moisture in the root layer of agricultural land. Both parameters are of great value to those working in the agricultural sector in order to reduce the weather-induced risk of crop losses, optimise the use of resources and deal with the increasing climate variability and climate change. Madagascar is the first developing country to make use of AMBAV\_global.

The project objectives were achieved at the end of December 2020, after an extension of the cooperation between DWD, GIZ and DGM due to the coronavirus pandemic. Completing the work packages and achieving the project results were of great scientific interest to both the Madagascan meteorological service and the DWD. A particular success was the integration of the DWD's model AMBAV\_global into the DGM's working procedures. In the future, the DGM in Madagascar will be able to use the model independently and might also be able to develop it further.

As agreed in the Memorandum of Understanding signed by both meteorological services in 2019, DWD and DGM will continue their close technical collaboration on the development of agrometeorological and agricultural consultancy services for applications in Madagascar.

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**02** Conversion of a MODES III system at the secondary weather station (Wst III) in Helmstedt-Emmerstedt (view into the open switch cabinet)

**03** Conversion complete: Rosenheim secondary weather station after converting the MODES III system on 11.09.2019

## From AMDA III to MODES III in record time

In addition to the DWD's main ground-based observing network, there are also more than 1,700 secondary weather stations distributed all over Germany, which are maintained by unpaid volunteers. Every 30 minutes, more than half of these stations transmit meteorological data to the DWD's German Meteorological Computing Centre in Offenbach. This is possible via the Automatic Meteorological Data Acquisition System (AMDA), which transmits data using the Internet according to a standardised procedure. While the measuring instruments have a service life of generally about ten years, the AMDA systems must be renewed every 15 years. The systems are usually replaced during the regular scheduled maintenance sessions at the stations, which means that the renewal can take place step by step. At the same time, new measuring instruments are installed during these inspections. Since 2016, the AMDA systems have been replaced with the new Modular Data Acquisition System (MODES).

However, the Deutsche Telekom had announced in 2017 that the ISDN transmission service would be discontinued by mid-2020, so that until then, all AMDA had to be replaced with the new Modular Data Acquisition System (MODES). Up to this point in time, 300 stations had already been converted to MODES, but were still using ISDN. This meant that these stations had to be switched quickly to a mobile network connection and that the remaining more than 500 stations had to be converted at a much faster pace; otherwise, the deactivation of the ISDN connections would have led to too many stations no longer transmitting weather data. In parallel to the installation of MODES, new precipitation and air humidity sensors were added. Close cooperation of all participants at the DWD at all stages, from the purchasing to the quality control of the data, allowed for a considerable tightening of the schedule. At the stations, DWD technicians and their colleagues from the internal data validation were often working in parallel. During 2020, this was made even more difficult by the coronavirus pandemic. Nonetheless, the changeover was completed successfully by 30 September 2020, the day when the Deutsche Telekom shut down the ISDN lines. Since then, meteorological data from the DWD's secondary weather stations are automatically transmitted to Offenbach via much faster mobile connections.

### Measuring programme of the automated secondary weather stations, called Wst III:

- Air temperature (at 5 cm and 2 m above ground)
- Soil temperature
- Air humidity
- Precipitation totals

Selected stations also measure:

- Sunshine duration
- Wind direction
- Wind speed
- Snow depth (total snow and fresh snow)
- Degree of snow coverage (conventional)
- Snow water equivalent (conventional)

## Increasing digitisation of the training centre

For all DWD employees, digital ways of working and organising as well as modern knowledge and communication strategies are of paramount importance. This is also the case for the DWD's training centre at the campus of the DFS Deutsche Flugsicherung GmbH in Langen. Several significant steps were taken in 2020 in order to achieve this strategic objective.

For example, several modules of the career training were taught as distance learning courses. The students followed the live teaching sessions via the conference and presentation tool Webex, which had been purchased specifically for the training centre. Webex offers many different ways for tutors and students to communicate with each other. Training materials were exchanged mainly via the ILIAS platform of the Federal University of Applied Administrative Sciences. For international training courses, the chosen tool was Moodle. In the future, it is planned to integrate distance teaching and electronic learning into the DWD's further education programme and the training centre's curriculum.

two rooms. At the end of June 2020, this technology was used successfully for the first time during two training courses for aeronautical meteorological observers at regional airports. After the pandemic, it will help saving travel costs, reaching larger audiences and generally improving flexibility.

For civil service career training at higher intermediate level, laptops were purchased and lent out to all students. This was especially useful for the periods when the students were not participating in residential courses at the training centre. It also meant that they could access the DWD network from outside. In addition, the tutors were issued with special tablets, enabling them to use the many different functions provided by the smart boards in the class rooms also during their online lessons.

**01** The measuring field at Met City with its various measurement systems. In the left half of the picture, the installations for snow depth measurements can be seen, the radiation measurement devices are in the foreground.

The newly purchased conference equipment, such as mobile cameras, screens and microphones, allow for the face-to-face teaching to be transmitted to different rooms or even to locations outside the training centre. During the coronavirus pandemic, the number of participants in a class room was restricted to twelve, which meant that some training sessions had to be held in



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## Decision by the Federal Court of Justice ends dispute over the DWD's WarnWetter app

With the decision of the Federal Court of Justice (BGH) from 12 March 2020 regarding the WarnWetter app, the long and eventful legal dispute, which had already begun in 2015, reached its peak.

In July 2015, the DWD had released the first free-of-charge version of its WarnWetter app for weather warnings. The app's objective was to protect the citizens from severe weather impacts and to enable them to protect themselves better, and to do this reliably, professionally and in an up-to-date way. From the beginning, the app attracted a lot of interest. The association of private meteorological service providers lodged an appeal against the free app, initially using a fast-track procedure, which was however not successful.

Thereafter, two private providers of meteorological services sought an injunction against the DWD to discontinue the free WarnWetter app. They essentially claimed that the DWD violated competition law by providing, in addition to official warnings, general weather information to the public free of charge. While the DWD won its case at higher regional court level, the BGH Senate in charge of competition law, with its decision from 12 March 2020, confirmed the legal position of the private meteorological service providers and decreed that the DWD was not entitled to make certain meteorological content of its WarnWetter app freely available to the public. After the decision of the BGH, the parties agreed to no longer pursue the concurrent proceedings.

For this reason, the DWD has, in addition to the free version of the WarnWetter app, also been offering a chargeable version for quite some time. The chargeable version offers some additional meteorological information, called context information, which the DWD considers of great importance for a meaningful use of the app and the optimal fulfilment of the DWD's statutory warning mandate. With both app versions, the DWD continues to reach many people and thus contributes to protecting them against severe weather impacts.

The DWD also sees the court's decision as an opportunity to further strengthen its position towards the competition. Accordingly, the DWD fully acknowledges the opinion issued by the BGH in the court's decision as well as the resulting repercussions and will take them into account in the continued development of its data delivery strategy.

02 Beautiful frost flowers often formed over refrozen cracks in the floe; they were best admired or photographed by lying on the ground.



01 Research at its extremes: in the surroundings of the Polarstern, a network of satellite-like sensing sites had been set up, each dedicated to a specific research topic and to carrying out related measurements. The photo shows Ocean City, recognizable by the blue tent put up to cover the instruments for measuring the upper water column. The instruments were winched into the water through a hole in the floe.

The orange-coloured tents are part of Balloon Town, with the larger tent on the left deployed as base for 'Miss Piggy', the tethered weather balloon. Miss Piggy can take measurements up to a height of around 1,600 m and this during several hours.

# Interview



## “I am learning all the time”

Prof. Dr Antje Boetius is the director of the Alfred Wegener Institute (AWI), Helmholtz Centre for Polar and Marine Research.

**A**WI and DWD have been closely cooperating for several decades. By operating the staffed weather stations on board of the research ships Polarstern and Meteor and by offering remote consultations from the Marine Meteorological Office in Hamburg, the DWD provides meteorological support to ensure the safety of research trips undertaken by the AWI as well as of the Neumayer research station in the Antarctic.

### **DWD:**

In addition to carrying out research on coastal areas and oceans in temperate latitudes, a particular emphasis of the AWI's work is put on both the Arctic and the Antarctic. Which aspects of these regions capture your interest as a trained biologist, given that, for many people in Europe, they are rather alien and remote?

### **Antje Boetius:**

Initially, I have been fascinated by the same things as many other people who have had the opportunity to travel to these frozen white landscapes. These are strange regions, but they are exceptionally beautiful. Only once you are there, can you understand that there are so many different kinds of white, and that ice and snow can look so differently. As someone specialising on the Earth system, I find it fascinating to understand the importance of these white shields for life on Earth – they reflect sunlight and thus prevent overheating. They stabilize the climate and therefore create the conditions for us humans in the Holocene to be able to develop civilisations in the first place. As a biologist, I especially like the diversity of life inherent to these regions. There is so much still to discover, such incredibly fascinating underwater landscapes, as well as the many different marine mammals. But even the smallest life form in the ice is astonishingly adaptable. You see, it is a subject I could passionately talk about all day ...

### **DWD:**

MOSAIC, led by the AWI, has been the largest ever expedition to the Arctic, carried out in cooperation with many national and international partners. What are the most important findings you have gained so far from this expedition?

### **Antje Boetius:**

More than 300 scientists participated in the MOSAIC expedition. They managed to collect a great treasure of data from a region that, for the first time, was surveyed from a research icebreaker over a complete Arctic winter. The MOSAIC team, which included staff from the DWD, could take synchronous recordings of hundreds of parameters from 30 km above to 4.5 km below the ice. These data enable us to improve the representation in climate models of the manifold interactions between the atmosphere, ocean and sea ice in the climate system. At the same time, the researchers were confronted during the expedition with enormously dynamic and sometimes alarming processes. In the early summers and summers of 2019 and 2020, the ice retreated faster than ever. The extent of the sea ice in the summer has now reduced to slightly more than half of the size it had 30 years ago, when I was working on my PhD. Its thickness has about halved over this time. The temperatures measured during the winter by the MOSAIC expedition exceeded the temperatures measured by Nansen and his team of the Fram expedition 125 years ago almost consistently by approximately 10 degrees Celsius. All this illustrates the speed of the change which affects the Arctic and its climate as a result of human-made global warming. If MOSAIC data now contribute to improving climate models, we will also be able to produce much better predictions of the remote effects of these Arctic changes on our latitudes.



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**DWD:**

What kind of feedback did you receive about the expedition? From politicians, the public and the participants?

**Antje Boetius:**

The MOSAiC mission was accompanied during the whole time by our media team, our excellent photographer Esther Horvath and an UFA film team. Despite the strenuous conditions, all the scientists and many crew members on board were willing to blog, to be interviewed, to answer questions from students and to give many talks after their return. This has really helped us to receive extensive coverage and has given us great pleasure. All the teams could feel that the public supported them in their big challenge. Nonetheless, they were also very stressed by the pandemic; the exchanges didn't work as planned and many team members were away from home for much longer than scheduled and worried about their families. It was wonderful to see the support of the international polar research community and of Ms Karliczek, the Federal Minister of Education and Research, who took a great interest in the mission and showed a lot of commitment, as it was also the case for the whole city of Bremerhaven. I will never forget the welcome given to the ship on her return.

For me, too, the enormous interest shown in the mission has mattered a lot. The chance to carry out such thorough research into the North Pole and the Arctic climate and ecosystem, and to do this during the up-to-now virtually unexplored polar night and over a full annual cycle, has represented a unique opportunity for the participants from all over the world, and especially for young scientists. Thanks to the expedition, all of us including the public gained access, for the first time, to a crucial region of the global climate system, which so far had been considered as inaccessible, unknown and remote. Suddenly, the North Pole and the Polarstern with her crew entered everybody's living room. Reports of several pages were published on all continents, a conference was held with the astronauts on the ISS, our Federal President and his wife sent greetings, and many thoughts were shared by friends and families. We were moved by all the letters sent by children and adults, containing job applications, questions and praise. Sometimes I was also touched by a little bit of nostalgia, as we sensed that some of the observations and pictures bear witness to a landscape that might disappear if we don't manage to halt climate change.

**01** Prof. Dr Antje Boetius,  
Director of the Alfred  
Wegener Institute (AWI),  
Helmholtz Centre for Polar  
and Marine Research

**DWD:**

You called the data collected during the one-year-long expedition a "present to all humankind", so that the new knowledge enables good decisions. What will now happen to these huge amounts of data, and which decisions do you consider necessary?

**Antje Boetius:**

The team returned at the end of October; since then, the samples have been distributed and the data sets downloaded. At the moment, work is carried out to complete the central data management and draw up a strategy with the international partners for the second round of publications and communications. Unfortunately, meetings in person and workshops are still not possible due to the pandemic, but Markus Rex, the coordinator, and the MOSAiC teams are working on the data evaluations. Some studies on the atmosphere and ice are already in the pipeline, but other analyses, in particular the lengthy biological investigations, will keep the team busy for a long time. There are also many interdisciplinary links, such as the effects of certain weather situations and ice dynamics on the exchange of gases, on life in the sea or on other regions of the world. In these cases, it is always slightly more complex to bring together different data sets. The big challenge is improving the modelling of the atmosphere, ice and ocean, as well as their remote effects. In order to achieve this, many data sets must be evaluated and integrated into a structure.

With regard to “good decisions”, it is most important to understand what has to happen in order to prevent the widespread melting of sea ice.

This quickly leads to a direct link to the CO<sub>2</sub> emissions of humankind, but also to the issue of other greenhouse gases such as methane.

Given the Arctic heatwaves we have observed and the extremely fast melting of the ice in many regions, an immediate recommendation would be not to lose any more time and, without delay, replace fossil fuels with renewable and climate neutral energies. We often think in ways which are too linear, whereas nature teaches us that there are interactions on a small scale that often go unnoticed. However, when scaled up to a global level, they accelerate climate change. The MOSAiC observations show us that we must be more ambitious with regard to protecting the climate.

**DWD:**

Will there ever be another such expedition?

**Antje Boetius:**

MOSAiC has been a unique Arctic expedition, which will remain unrivalled. For financial reasons alone, we will not be able to repeat what we achieved in 2019/20 together with our international partners and overcoming enormous logistic challenges. However, I really hope that a second international phase, called Terrestrial MOSAiC or T-MOSAiC, focussing on a panarctic study of permafrost soils, will still go ahead. On the whole, I think it is important to organise international observation campaigns for the climate, nature and environment frequently – not only do you learn more together and are able to combine many more measurement techniques, but it is also vital to practice a culture of international learning, understanding and acting together.

**DWD:**

Let’s talk about climate change: both AWI and DWD observe and study human-made climate change. Where do you see similarities, and where differences?

**Antje Boetius:**

We cooperate a lot in the polar regions and on the oceans, with an excellent distribution of tasks. In general, Helmholtz centres work differently than departmental research institutes. However, when trying to understand climate change, it is important for both types of organisations to combine direct observations, to improve predictions using techniques such as climate calculations and, finally, share their knowledge with society.

**DWD:**

Many young people are committed to the protection of the environment and the climate. What would be your most important message to them?

**Antje Boetius:**

The campaign Fridays for Future has reached a large global audience and has increased the awareness of climate change and of the transformations necessary in our society. The movement has achieved a lot, because its approach to the subject is not only emotional and emphatic, but also relies on a wide and mostly enormously well-informed scientific knowledge by its members. My message would be the following: “Keep up the good work and continue fighting for the future” – because I know from many supporters how difficult it is to remain confident and united, and to acknowledge the progress which has been achieved.

**DWD:**

Scientists often struggle to explain complex issues in an understandable and transparent way. One of the key topics of your work is scientific communication. Which concrete steps can be taken by scientists in order to communicate their findings and to initiate urgently needed changes, for example with regard to climate change?

**Antje Boetius:**

We scientists have a fairly clear mandate: research, education and transfer. Each of these three pillars of science implies communicating with society. As part of our responsibilities towards society, we must also talk about risks. This includes uncomfortable truths such as our generation's responsibility to halt global warming in order not to destroy the basis of life for future generations. However, we scientists are also aware that, when we engage in the public debate, what is expected from us is often a lot more than just the factual results of our research: they must be put into context. We polar researchers are bombarded with questions regarding ethics, economics, social justice, emotions and attitudes, and we have to explain that the object of our research is changing very quickly. We must succeed in thinking at large, listening and, at the same time, distinguishing when we speak in our role as a scientist based on our own research, and when we combine results, information and assessments as a thinking human being and responsible citizen.

**DWD:**

In 2019, you received the Federal Cross of Merit for your contributions to ocean research, among others. The Federal President admonished his listeners with the words "confidence in the future: transcending boundaries". In your opinion, which are the boundaries the scientists should transcend?

**Antje Boetius:**

It is crucial for me to transcend the boundaries of my own specialisation and my still very limited knowledge. I am learning all the time. As a researcher, I am curious to understand the Earth and the relationship between humans and nature to the fullest extent. Our scientific knowledge certainly contributes to raising awareness in society and issuing warnings, but also to finding solutions. However, many questions regarding climate change and the shaping of the future are profoundly linked to economics, ethics and philosophy, to the question "how could we end up in this situation and how can we quickly get out of it". In my response, I try to absorb knowledge from all available sources in order to be able to make sense of what I observe, and in order not to lose hope.

**DWD:**

Which key tasks do you foresee for the AWI in the next couple of years?

**Antje Boetius:**

Together with the other Helmholtz centres of the Earth and Environment facility, we have just started a new research programme, called 'Changing Earth – Sustaining our Future'. Climate change, species extinction, environmental pollution and natural hazards are among the largest challenges of our times. We want to explore the functions of the Earth and the natural foundations of life based on a systemic approach ranging from land surfaces via oceans to the most remote polar regions.

Together with a thorough knowledge of the Earth system, innovative technologies, strategic approaches and recommendations for political action, we hope to be able to support a path towards a sustainable future, and we certainly do this in cooperation with many partners such as the DWD.

**DWD:**

We would like to end with a personal question: if you met Alfred Wegener today, which question would you ask him first, and why?

**Antje Boetius:**

I have got two questions I would like to ask Alfred Wegener. One is rather cheerful and the other quite sad:

Dear Alfred Wegener: what did it feel like to find the puzzle pieces of one of the greatest scientific discoveries of all times and to fit them together to a coherent picture: that the continents, the ground on which we stand, are drifting, that the Earth is tectonically active and nothing ever remains the same. This certainly was an incredible eureka moment, wasn't it?

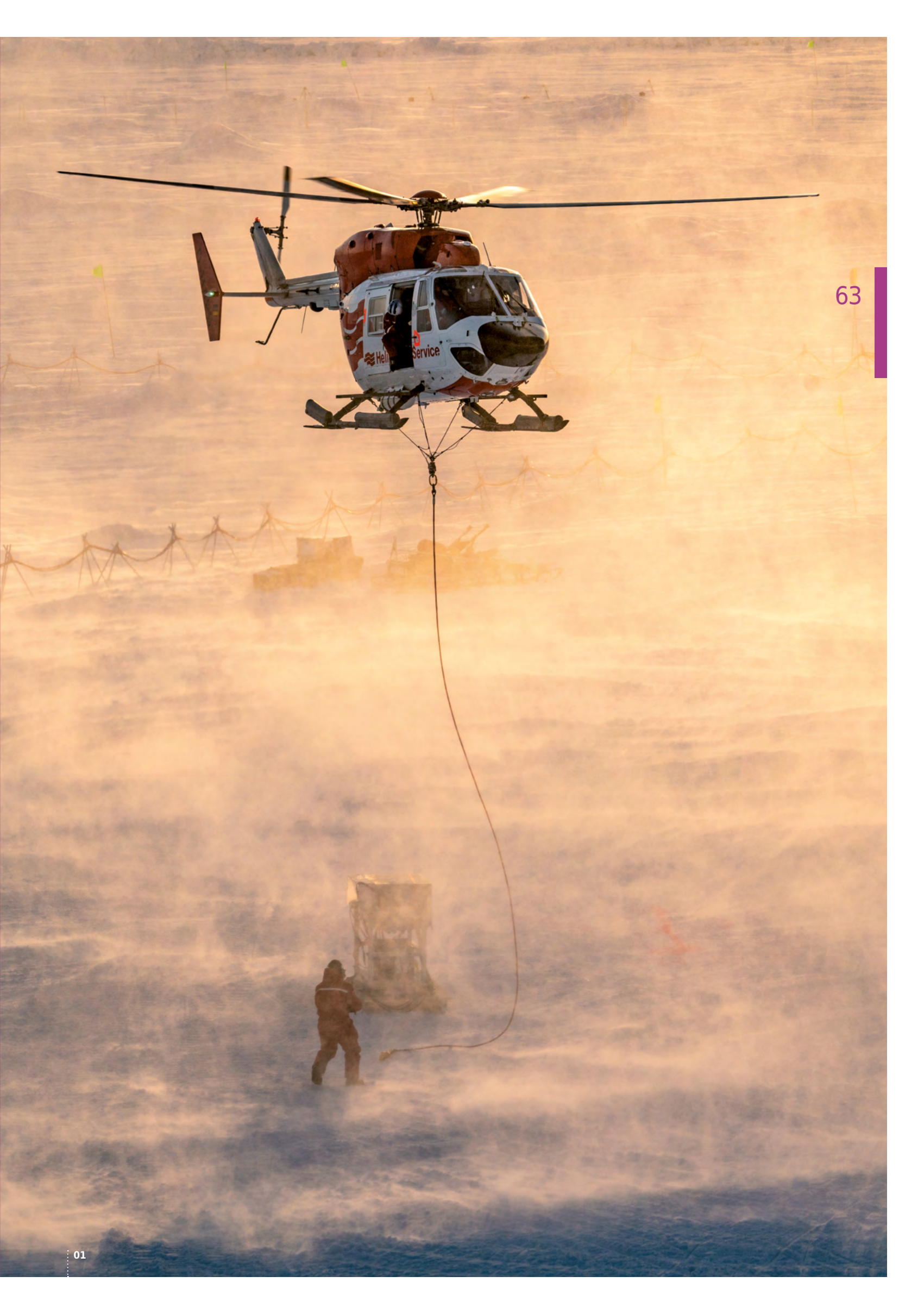
Dear Alfred Wegener: you wrote "Whatever happens, the cause [the expedition] must not be affected! It is our sanctum; it binds us together; it must be driven forward under all circumstances, even with the greatest sacrifices." What was it exactly which motivated you so strongly during your expedition to Greenland, that you risked the lives of the members of your expedition and your own life?

**DWD:**

Ms Boetius, many thanks for this comprehensive and fascinating interview!

# Finale

**01** : Helicopters in operation: the ship's  
: helicopters could take off for their  
missions only when decent weather allowed  
it and after the DWD meteorologist  
aboard had briefed the teams about the  
meteorological conditions expected for  
the flight. Such missions included, among  
other things, measurement flights into  
the wider surroundings of the Polarstern,  
for example to measure ice thickness.  
When the ice floe where the Polarstern  
was moored began to break away more  
and more, some of the measuring sites  
could no longer be reached on foot or by  
snowmobile, so the helicopters had to  
'rescue' the sensors.



## Annual productivity and performance figures

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Approx. **90,000** forecasts and **164,000** weather and severe weather warnings

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

---

Approx. **470,000** forecasts and warnings for aviation

---

Approx. **24,000** telephone briefings for aviation

---

Provision of self-briefing systems for civil aviation, aerodromes/airports and air services providers

(approx. **370 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** main 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

**1** Aeronautical Meteorological Centre (Frankfurt) and

**4** MET Advisory Centres

**3** agrometeorological advisory centres

**181** main weather stations (staffed and automatic) and aeronautical meteorological stations

Aeronautical meteorological observation at **23** regional airports

**1,737** secondary weather and precipitation stations, of which **836** are online stations reporting every half-hour

**1.098** phenological observation sites

**2** staffed main weather stations aboard research ships

**101** automated shipboard weather stations

**448** ships at sea participating in the WMO Voluntary Observing Ships (VOS) programme

**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

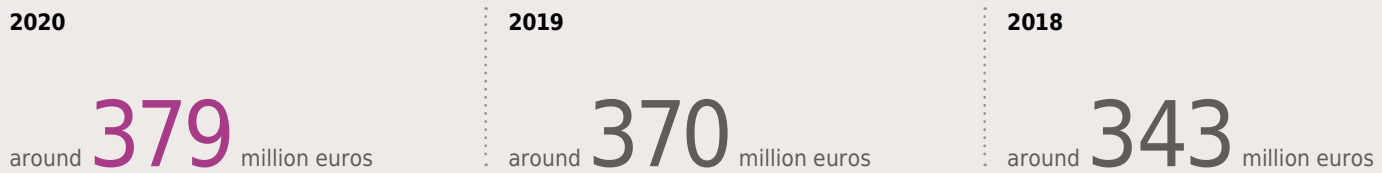
**48** stations where radioactivity is measured

**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:



### Every citizen of Germany thus paid<sup>1</sup>:



### In 2020, the DWD's expenditure was distributed as follows:



### In 2020, appropriations and subsidies went to the following organisations (external funds included)



<sup>1</sup> According to estimates by the Federal Statistical Office: 83.2 million inhabitants at the end of September 2020

## Figures relating to the DWD's staff

### Number of established posts:

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

### Number of staff members<sup>2</sup>:

2020		2019		2018	
Men	Women	Men	Women	Men	Women
2,187		2,216		2,248	
1,363	824	1,384	832	1,412	836

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

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

---

Following on from its predecessor GME, the DWD's current weather prediction system **ICON** computes

the forecasts based on a **triangular grid spanning** the entire **globe**. At a mesh width

of 13 km, the total **number of triangles** amounts to **2,949,120**.

With ICON defining 90 atmosphere levels from 0 to 75 km of altitude, there are 2,949,120 x 90, in other words

**265 million**, **grid points** representing the Earth's atmosphere.

---

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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Number of recorded **satellite overflights**: over **20,000**

---

**172** scientific publications, of which **157** were published in  
**international**, peer-reviewed **specialist journals**

---

Participation in about **50** large **national** and **international** climate and  
weather research **projects**

---

As the host of the Global Precipitation Climatology Centre, the DWD maintains and continuously extends

the **world's largest database** of direct **precipitation measurements**

from currently over **123,000** stations around the globe.

---

Registration of more than **1,300** new **heavy rain events** in Germany (Since 2001,  
the DWD has registered over 22,500 heavy rain events.)

Last but not least:

## DWD's observation network for monitoring atmospheric greenhouse gases now complete

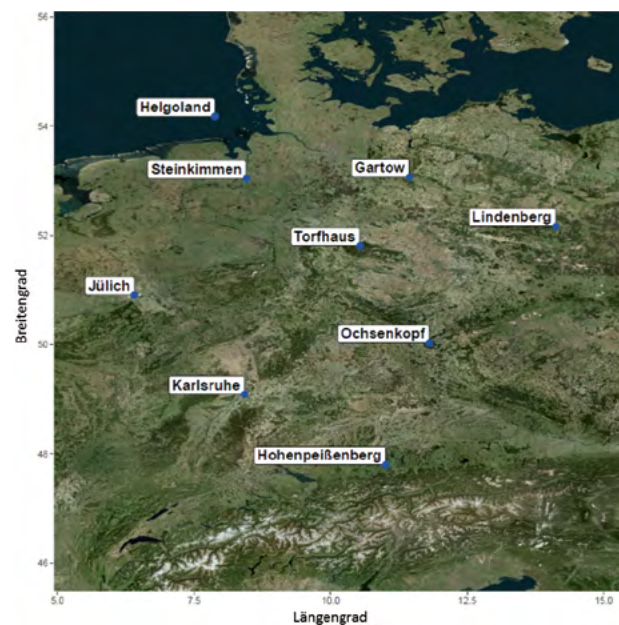
Since the beginning of August 2020, the observation network for monitoring atmospheric greenhouse gases set up by the DWD as part of the German contribution to the Integrated Carbon Observation System (ICOS) has been fully operational. ICOS is a European research infrastructure for the observation of greenhouse gases and their exchange in the atmosphere, in ecosystems and in oceans. The ninth station of the German atmosphere monitoring network and the last one to become operational is located on the island of Helgoland.

Once the extensive ICOS network has been completed, it will comprise about 140 stations all over Europe. The DWD operates the German atmosphere monitoring network from its Hohenpeissenberg Meteorological Observatory (MOHp) and, together with other partners, is setting up an integrated system for monitoring greenhouse gases for Germany (ITMS after its German name 'Integriertes Treibhausgas-Monitoring-system'). The creation of the German part of ICOS was funded by the Federal Ministry of Education and Research (BMBF), while routine operations of the network are financed by the Federal Ministry of Transport and Digital Infrastructure (BMVI) and the participating institutions' own resources.

01 The DWD's atmospheric observation network for ICOS

01

### Deutsches ICOS Atmosphärennetzwerk





02

02 Working at dizzying heights: DWD staff members are mounting the cantilever with wind sensor and suction filter to the mast of Helgoland station.

### Monitoring of climate gases in various European regions

The ICOS Research Infrastructure was established in 2015 by the European Commission as a Europe-wide infrastructure for environmental research. It is aimed at conducting long-term observations of the greenhouse gases carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) in Europe, with the observations being made available to all interested users. The overarching objective is to gain a better understanding of the greenhouse gas fluxes and in particular of the carbon cycle. ICOS consists of three observation networks dedicated to the atmosphere, ecosystems and oceans. In Germany, the DWD's MOHp is responsible for the establishment and operation of the atmosphere network.

The ICOS measuring sensors are located on nine towers distributed all over the country. The ninth station on Helgoland is installed at the transmission mast of the Deutsche Funkturm GmbH, with sensors at a height of 60 m and 100 m above ground. The measurements are fully automated and transmitted to a central server collecting the data from all DWD ICOS stations.

Together with data from aircraft, satellites and other sources, the ICOS data are fed into the ITMS in order to allow the users to determine carbon emissions and carbon sinks in Europe. ITMS thus provides the basis for monitoring the implementation of measures decided at European level and aimed at reducing greenhouse gas emissions.

The first results are expected in 2022. A key feature of the new system is the use of all available observation data as well as of the meteorological prediction model ICON, with the latter allowing a description of the transport of greenhouse gases and, based on gas concentration data, the drawing of conclusions regarding emissions. Results from the ITMS will make it possible to better understand the future evolution of climate change and to draw up predictions as well as effective mitigation measures. The ICOS towers also provide a secondary benefit: the meteorological data collected between Helgoland and Hohenpeissenberg contribute to produce better forecasts for wind at the hub height of windfarms – forecasts that the DWD makes available to energy companies.

## Contact, publishing details and source references

**01** Even if the major part of the floe was still fine, movements in the ice were observed daily with great concern from mid-March. Heavy material such as the PistenBulli were always loaded back aboard the ship to not lose it in case of major ice breaks. This was only possible once the helicopter had returned from its missions and was parked in the hangar so that the helicopter deck was free for the PistenBulli.





## Contact

### Deutscher Wetterdienst (DWD)

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63067 Offenbach am Main  
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Telephone +49 69 8 06 20  
Fax +49 69 80 62 44 84  
[www.dwd.de](http://www.dwd.de)  
[info@dwd.de](mailto:info@dwd.de)

### Wetterdiensthotline<sup>1</sup>

Telephone +49 18 02 91 39 13

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

<sup>1</sup> Availability and costs depending on foreign telephone provider

### Further telephone- and service numbers

[www.dwd.de/kontakt](http://www.dwd.de/kontakt)

## Important links

### Climate information

[www.dwd.de/klima](http://www.dwd.de/klima)

### Current weather

[www.dwd.de/wetter](http://www.dwd.de/wetter)

### App for weather warnings

[www.dwd.de/app](http://www.dwd.de/app)

### Information for journalists

[www.dwd.de/presse](http://www.dwd.de/presse)

### Newsletters

[www.dwd.de/newsletter](http://www.dwd.de/newsletter)

### Publications

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[www.pinterest.de/deutscherwetterdienst](http://www.pinterest.de/deutscherwetterdienst)

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## Sources

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## Photos and graphics

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### Source

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Christian Rohleder, DWD

Cover, 4, 8/9, 10, 15, 16, 27, 31, 33, 36, 39 (top), 43, 44 (below), 45, 48, 49, 54, 55, 56/57, 63, 72/73, front of poster (1)

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Bernd Lammel, Bild-Kraftwerk

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Deutscher Wetterdienst

11, 13, 18, 19, 20, 21, 22, 23, 24, 25, 26, 32, 34, 37 (below), 38, 39 (in the middle), 40, 41, 44 (top), 46, 50, 70, 71, front of poster (5), back of poster

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Maria Carvalho, DWD

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DWD/Nationalpark

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Frank Rückert, DWD

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Stefan Lünser, DWD

53 (left)

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Wolfgang Große, DWD

53 (right)

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Esther Horvath, AWI

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Frank Kahl, DWD

Front of poster (2)

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Horst von Bargaen

Front of poster (1)

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**Cover** : 23 March 2020, at the  
Polarstern's position at  
15.8° E and 86.2° N, air temperature  
-27 °C. New cracks kept opening up  
in the floe where the RV Polarstern  
had moored to drift through the North  
Polar Sea. If the temperature is very  
low, sea smoke develops very quickly  
out of freshly opened cracks, as can  
be seen here near the sensors of Met  
City, one of the remote sensing sites  
deployed like satellites around the  
research ship.



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