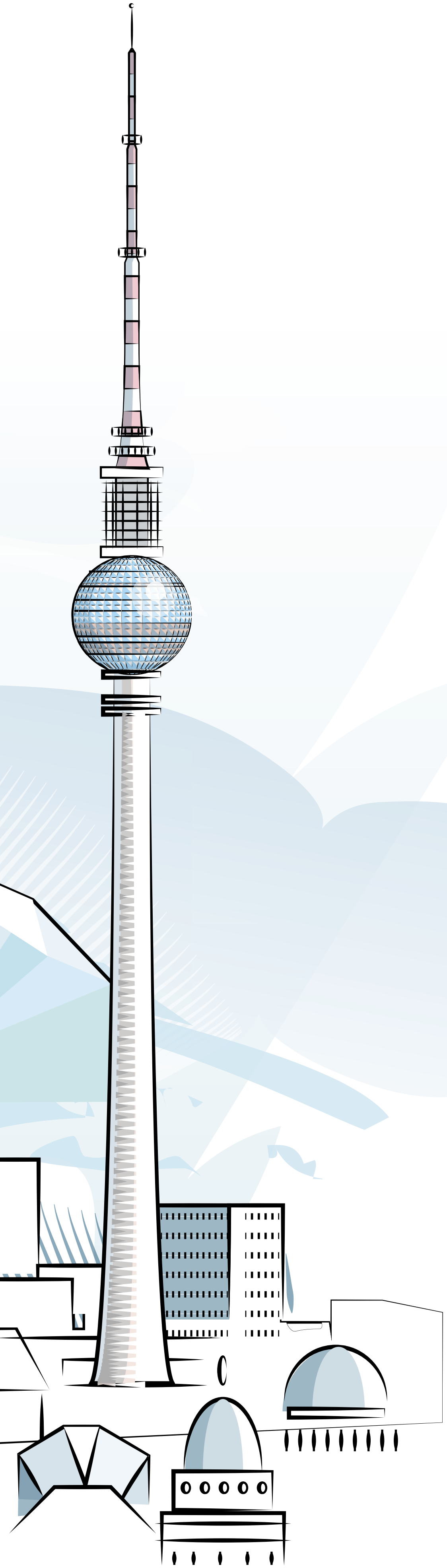
A FATEFUL LINK

Berlin is closer to the Arctic Circle than it is to Barcelona. As such, it's hardly surprising that the Arctic significantly influences the climate in Central Europe. REKLIM researchers have now shown how the retreating Arctic sea ice is changing the weather in Germany.

TEXT: TIM SCHRÖDER



“Today, we’re essentially dealing with a new Arctic,” says Prof Klaus Dethloff, an atmospheric physicist at the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI) in Potsdam. What he’s referring to is the fact that the face of the Arctic is slowly but indisputably changing: for example, Arctic sea ice is now much thinner, younger and more mobile than it was just 40 years ago, making it especially sensitive. The ice cover is now more likely to break up in response to wind and waves, begins melting earlier in the year, and begins reforming much later in the autumn or winter. “It goes without saying that this dwindling is also influenced by anthropogenic climate change,” says Dethloff. “But when it comes to the processes between the atmosphere, ice and ocean that produce sea-ice retreat, we still don’t understand them in detail – for example, the ice mass is actually declining faster than predicted by our climate models.”

The Arctic under a magnifying glass

Klaus Dethloff and his colleague in Potsdam, Dr Annette Rinke, are pioneers. As far back as the early 1990s, they developed initial computer models in an attempt to better understand the fate of the Arctic. And today, they continue to look at the Arctic region ‘under a magnifying glass’. To be more precise, they are developing regional climate models that can depict processes from the Arctic Circle to the North Pole at a resolution of just 10-20 kilometres. Consequently, their regional models are much more precise than global models, which don’t offer sufficient resolution to analyse the North Pole region in detail.

The better scientists understand the role of Arctic sea ice in the Earth’s climate system, the clearer it becomes: the extent and thickness of the ice have a major influence on meteorological processes in Central Europe – in winter and summer alike.

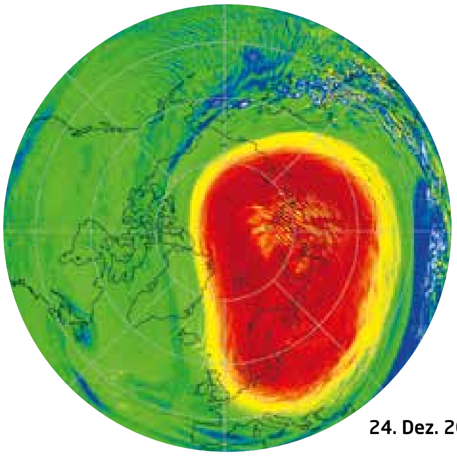
A 'regional Arctic model': it sounds like peering through a narrow window into an extreme region that is of little interest to us here in Germany. But that impression is misleading; in terms of the climate, the Arctic and Europe are closely linked. Accordingly, the research being pursued in Potsdam, and as part of the REKLIM network, is extremely relevant for everyone living in Europe.

"It's now broadly accepted that the processes and changes at work in the north have a major impact on the climate in Europe," says Klaus Dethloff. "It would appear that this was also the cause of the prolonged, stable and in some cases extreme weather conditions that we've seen in the past several years" – e.g. cold snaps in Central Europe, and extreme winter storms in the USA, are now more frequent than in the past. Clearly, the middle latitudes and the Arctic are engaged in a fateful long-distance relationship.

The weather seesaw between north and south

Europe's weather and climate are shaped by major air currents and the interactions of high-pressure and low-pressure cells. One motor that substantially contributes to weather anomalies is the jet stream, which is linked to the polar front. This rapid air current whips across the Northern Hemisphere from west to east, between the 40th and 60th parallels. On the one hand, the jet stream plays a major part in Europe's 'weather kitchen' by pushing high-pressure and low-pressure cells back and forth; on the other, especially in winter it can keep warm air masses from the south separated from frigid polar air from the north, like a force field. "But for several years now, what we've seen more and more frequently is that in winter, warm air from the south is penetrating deep into the Arctic," says Annette Rinke. "When that happens, the temperatures at AWIPEV, our German-French research station on Spitsbergen, actually rise above zero." The jet stream, it would seem, is now taking breaks from time to time, during which it can no longer serve as a barrier. These

HOW THE POLAR VORTEX COLLAPSED IN WINTER 2018/19



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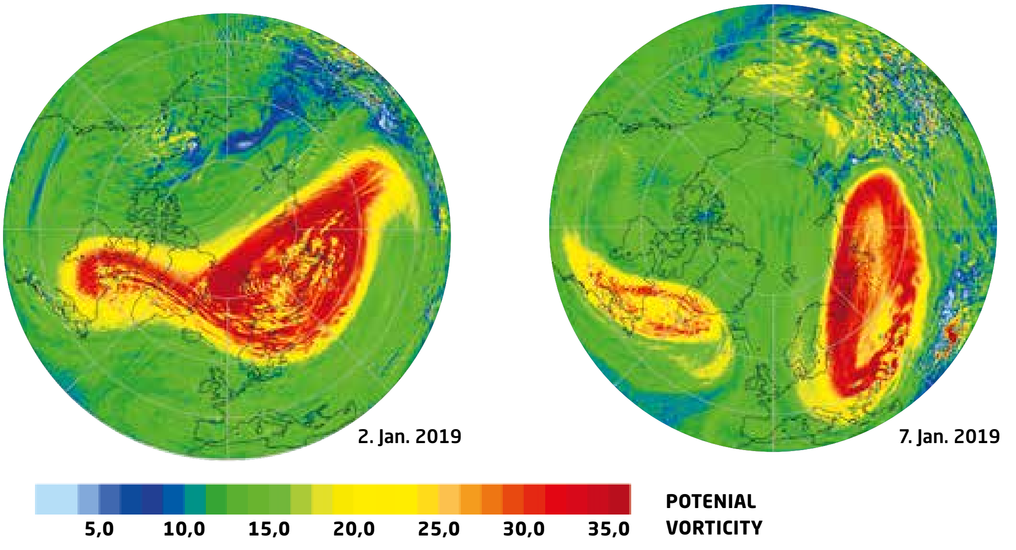
THE STRATOSPHERIC POLAR VORTEX (1)

When the air over the Arctic grows much colder in the autumn and winter, a low-pressure cell is formed roughly eight to ten kilometres above the surface. Referred to as the stratospheric polar vortex, it can reach up to 50 kilometres high. Normally, its air masses are held together by a strong westerly wind, which acts like a force field, preventing warm air from the middle latitudes from reaching the Arctic. Yet this barrier can fail when planetary waves from the troposphere rise and penetrate the vortex like wedges. This produces a sudden warming in the stratosphere – with dramatic effects on the intensity and course of the polar front jet stream in the troposphere below.

THE POLAR FRONT JET STREAM (2)

The polar front jet stream (or simply jet stream) refers to several bands of powerful wind (left) that blow between the 40th and 60th parallels, at an altitude of eight to ten kilometres. The wind can reach speeds of up to 500 kilometres per hour and is powered by the temperature difference between the tropics and the Arctic. If the difference is great, the wind blows at high speeds straight course parallel to the Equator; if the difference declines, e.g. due to sea-ice retreat, the wind slows and meanders about the Northern Hemisphere (right).



COLLAPSING VORTEX

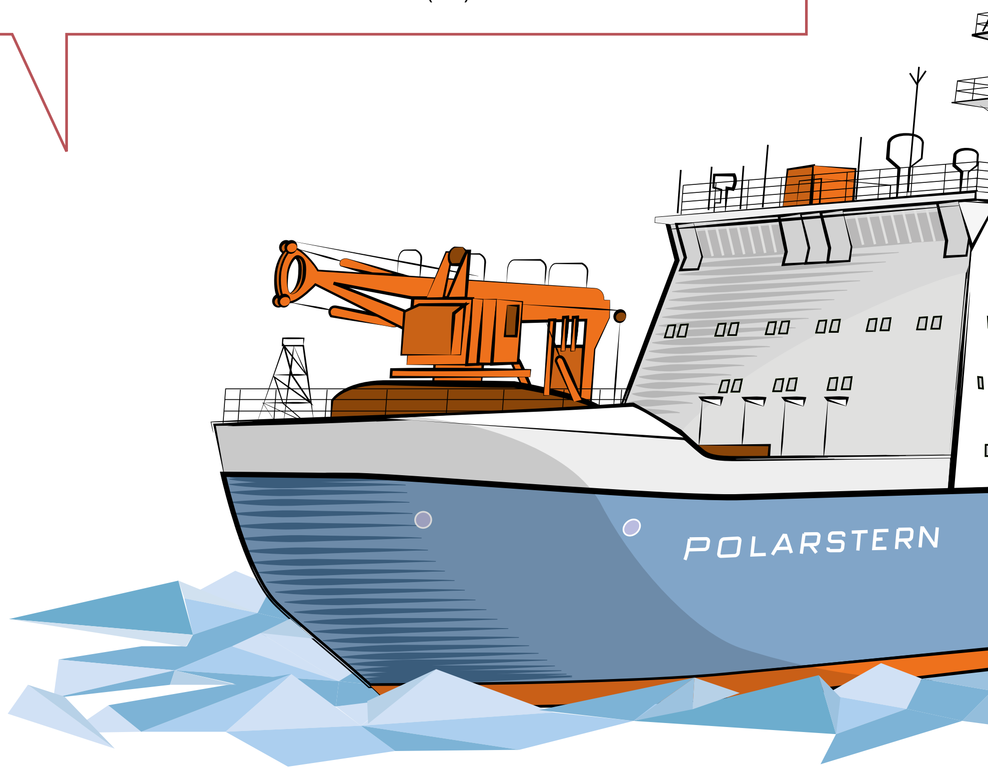
In winter 2018 / 2019 meteorologists bore witness as the stratospheric polar vortex over the Arctic collapsed in a matter of days. These three figures show the vortex strength in the low-pressure cell at an elevation of 30 to 35 kilometres. On 24 December 2018 (left) the vortex was still an intact system over the eastern Arctic. Nine days later, on 2 January 2019, it had already become elongated (middle), and was subsequently disrupted (right). This event in the stratosphere produced e.g. an unusual cold snap in North America.

weak phases are set off by a complex chain reaction in the troposphere, the lowest level of the atmosphere, and in the stratosphere above it. AWI modeller Dr Ralf Jaiser has discovered that, in layman's terms, the following happens: in winter, the intensity and resilience of the jet stream in the troposphere depend in part on the stability of a second major vortex. At the end of the summer, this polar vortex forms directly above the Arctic, albeit one level higher, in the stratosphere. When the vortex spins at full power, the jet stream below it often also reaches top speed. But if the vortex dissipates, the jet stream basically runs out of steam. But what could jeopardise the polar vortex?
One potential threat stems from planetary waves: large-scale wavelike movements in the troposphere that move about the globe with the westerly winds. When these air currents encounter an obstacle, e.g. a mountain range, they shift upward, pushing the air masses above the obstacle upward. As a result, the effect of the rising wave can reach the stratosphere, where it can weaken or even disrupt the polar vortex. When this happens, the jet stream below it falters and begins wandering about the Northern Hemisphere. While the jet stream meanders, in some places warm air masses can make their way to the Arctic, while elsewhere cold polar air pushes far to the south.

LOOKING AHEAD

We're currently working on a high-resolution Earth system model that takes into account not only the atmosphere, ice and ocean, but also chemical processes, vegetation and permafrost dynamics. In this way, we hope to be able to make more definitive statements on the variability of, and changes in, the Arctic's climate.

ANNETTE RINKE
Climate modeller, Alfred Wegener Institute,
Helmholtz Centre for Polar and Marine Research (AWI)

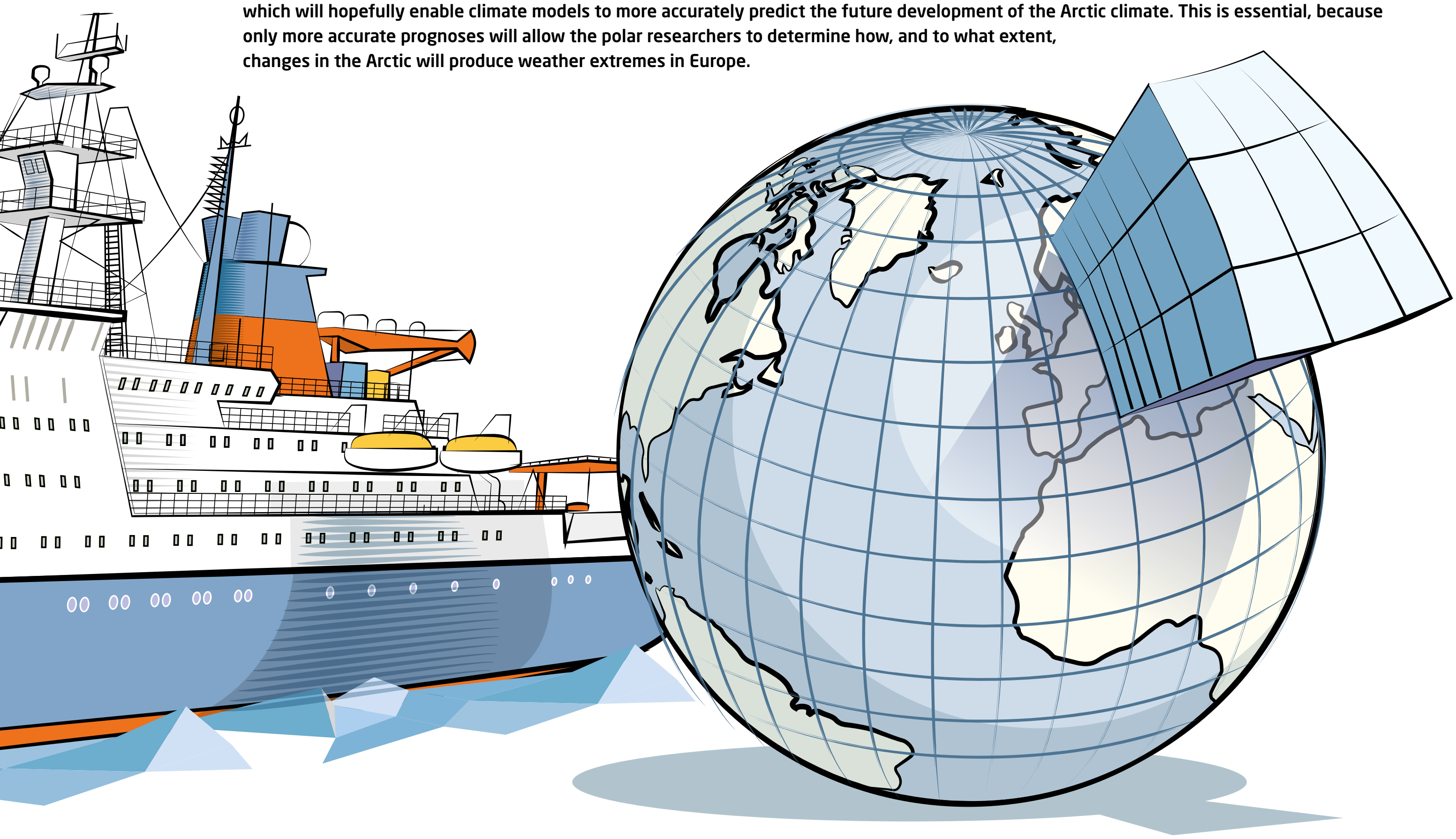


Using details from the Arctic to better grasp the world as a whole

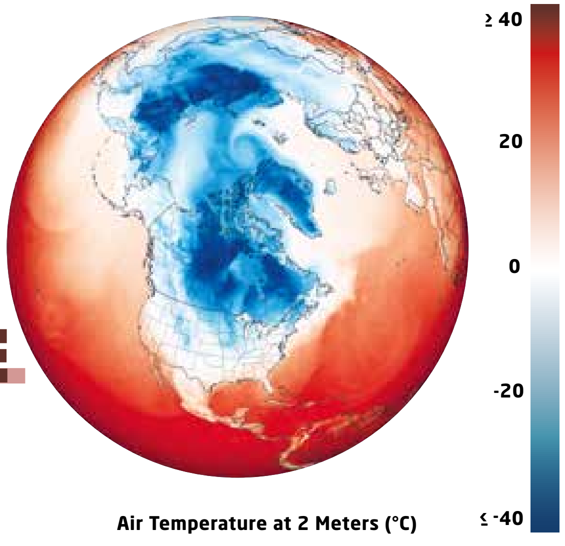
For many years, researchers were at a loss to explain these complex changes. But thanks to experiments involving several interconnected models, they're now beginning to decipher the causal relations. For example, Annette Rinke and her colleagues have used a regional Arctic model to demonstrate the importance of changes in the Barents Sea and Kara Sea to the north of Norway and Siberia. Because the waters are now warmer there, they freeze over more slowly in the late autumn. As a result, the ocean can release more heat and moisture in October and November than in the past, creating a dome of warmth over the region. In turn, Ralf Jaiser and his colleagues integrated these changes in a global climate model, which they used to simulate the large-scale consequences. Their findings indicate that the dome of warm air over the ocean, together with the additional moisture, is producing more snowfall in Siberia. In turn, warmth and snow tend to reinforce the high-pressure cells between Scandinavia and Siberia. As a result, the jet stream deviates to the south, or in some cases to the north. In addition, the high-pressure cells are obstacles for planetary waves. Like in a half-pipe, the air packets from the west shoot upwards, retaining sufficient momentum to disrupt the polar vortex in the stratosphere – and pull the plug on the jet stream one level below it.
The effects of this chain reaction can be felt throughout the Northern Hemisphere: between Greenland and Scandinavia, warm air pushes into the Arctic, while people living in Europe and Asia face weeks of frigid temperatures. In addition, the westerly winds over the Atlantic, which are so important for Europe, grow weaker, and the weather conditions in Europe stagnate.
"As this example shows, our regional and global climate models can help us understand the feedback processes between the atmosphere and the sea ice / ocean system, to identify connections between the Arctic

AN UNPARALLELED OPPORTUNITY

Researchers participating in the Arctic expedition MOSAiC – during which, from September 2019, the German research icebreaker RV Polarstern will spend an entire year drifting through the Arctic Ocean with the sea ice – hope to gain deeper insights into the interplay between the sea ice and atmosphere. More information on: www.mosaic-expedition.org. While on board, they will gather a wealth of new ice and atmospheric data, which will hopefully enable climate models to more accurately predict the future development of the Arctic climate. This is essential, because only more accurate prognoses will allow the polar researchers to determine how, and to what extent, changes in the Arctic will produce weather extremes in Europe.



JANUARY 2019: RECORD LOW TEMPERATURE IN NORTH AMERICA



Air Temperature at 2 Meters (°C)

POLAR AIR OVER THE MIDWEST

This graphic shows how, on 29 January 2019, polar air masses from the Arctic penetrated deep into the American Midwest, causing temperatures in the regions affected to plummet to minus 30 degrees Celsius or lower. The stratospheric polar vortex over the Arctic had collapsed roughly three weeks earlier. In response, the jet stream began faltering, sweeping over North America on a winding course – and this gap in the wind barrier allowed air masses from the Arctic to flow southwards.

region and Central Europe and, in the long term, to refine weather forecasts," says Annette Rinke.

Using real-world data to refine climate models

That being said, the results of the Potsdam-based researchers' models don't yet correspond 100% to the reality, which is why it's important to supply them with real-world observational data, helping them come as close as possible. Unfortunately, data is only available from comparatively few sites in the Arctic. For example, in the late 1990s the experts in Potsdam collaborated with a team of Russian researchers who drifted through the Arctic on a large ice floe every winter, so as to take on-site readings on the atmosphere, ice and ocean. This data, too, was added to the regional Arctic model. "The more field data we have, the better we can describe the physical processes at work in the Arctic – and make our models more accurate, bit by bit," says Annette Rinke.

In order to perfect their models, the AWI researchers also plan to integrate data that will be gathered in the course of the largest international expedition to the Central Arctic to date – the MOSAiC project. In September 2019, the German research icebreaker RV Polarstern will allow itself to become trapped in the ice of the East Siberian Sea, and subsequently drift through the Arctic Ocean for an entire year. During that time, several hundred experts from 17 countries will take measurements of the ocean, ice and atmosphere, using the opportunity to gather unprecedented data. "We hope this will help us more accurately simulate processes at work between the ocean and atmosphere in the Arctic; and to clarify when and why it is home to more ice, or less ice," says Annette Rinke. "Because this will have a decisive influence on how the climate and weather in Europe develop over the decades to come."

The latest findings from the Arctic confirm the core message of the Fridays for Future demonstrations. Climate change poses a threat to the future of all humankind.
The only solution: immediately reducing global carbon dioxide emissions.

IN BRIEF

- Due to the loss of Arctic sea ice, the ocean is releasing more heat and moisture into the atmosphere. As a result, the air currents between the Arctic and the middle latitudes are changing – and so is the climate in Europe.
- To better predict future changes in the Arctic, regional climate models have been developed. They can depict processes and interactions between the ocean, ice and atmosphere in greater detail than global climate models.
- The sea-ice retreat can produce wide-scale temperature and atmospheric-pressure changes. In Europe, but also in Asia and North America, winter cold snaps can become more frequent, while temperatures can rise in the Arctic.

OPTIMISING SEASONAL FORECASTS

Regional models like the AWI's Arctic model can help us improve global climate projections. These optimisations can in turn benefit institutes like the German Meteorological Service (DWD), which has offered a seasonal forecast (available on a web portal) as an operational climate service since 2016. In the following, DWD meteorologist Dr Barbara Früh tells us what it's all about.

➨ ***Researchers at the Alfred Wegener Institute are working to determine how climate changes in the Arctic are connected to the weather and climate in Central Europe. To do so, they employ regional climate models, which can depict the Arctic at higher resolutions than global models. How can these more detailed models help you in your work?***

Barbara Früh: A more precise spatial resolution can help us understand the physical processes at work in the Arctic, and ice dynamics in detail. And the insights we gain into these mechanisms can in turn be used to refine global climate models. Unfortunately, there are certain physical processes that global climate models don't reflect in detail for the Arctic. But by taking a closer look at these natural processes, we can gain a better grasp of them, and enrich the global models with improved statistical descriptions of them; we refer to this as parameterisation.

➨ ***And how does the DWD profit from this fundamental improvement to global climate models? After all, they have to make forecasts for a comparatively small region, namely Germany or Central Europe.***

Having access to improved global models naturally also means that we can better judge the situation in our home region. Since 2016 the DWD, working together with Universität Hamburg and the Max Planck Institute for Meteorology, has been preparing seasonal forecasts that are available on a web portal. Open to the public, it offers projections of how the weather will most likely develop over the next few months. Moreover, users are explicitly encouraged to use the 'feedback' button and rate the portal's performance. The computational climate model behind the seasonal forecasts produces a number of realistic prognoses, which, taken together, allow conclusions to be drawn on how likely it is that the next three months will be drier or wetter, warmer or cooler than the long-term average values. The seasonal forecasts represent an on-going, operative service provided by the DWD, in the course of which we continually improve the specially tailored climate model. In short: the better the underlying global model is, the more accurate future seasonal forecasts will be.

➨ ***So does that mean you don't directly use your findings from the Arctic?***

That's right. Although we know that the Arctic and Europe are linked by what are known as teleconnections, we need the global model in order to take into account all of the influencing factors that shape the weather in Central Europe – like changes in high-pressure and low-pressure cells over the Atlantic. Nevertheless, what we learn from models like the regional Arctic model is extremely important in terms of understanding the climate context as a whole.

➨ ***In other words, you could say that the Arctic is implicitly reflected in your seasonal forecast model. What exactly does the model do?***

In order to make prognoses on a seasonal trend, the interplay of various components in the climate system is taken into account: the current state of the stratosphere, the 'second storey' of the atmosphere, and the state of the soil, the ocean and even the sea ice have a much greater influence on weather development than they do in a weather forecast. Accordingly, the latest readings on all of these aspects are fed into the climate model, making the starting point for the prognosis as accurate as possible. Then the model calculates a set, or what we call an ensemble, of possible seasonal developments. In other words, the model is used to generate several possible forecasts, all of which take into account uncertainties in the Earth observation data, and in the climate model. ■

BARBARA FRÜH

For more than ten years, Barbara Früh has headed the 'Climate Forecasts and Climate Projections' division at the German Meteorological Service (DWD). You can access the DWD's seasonal forecast portal at dwd.de/jahreszeitenvorhersage.