LOOKING FOR TRIGGER

INTERVIEW: SINA LÖSCHKE

History teaches us: the Earth's climate can suddenly 'tip', causing it to grow far cooler or far warmer in just a short time. The REKLIM climate experts Achim Brauer and Ralf Tiedemann are currently investigating the likelihood of an abrupt climate change, and what set off such changes in the past. A discussion about new findings that cast an uncertain light on our future.

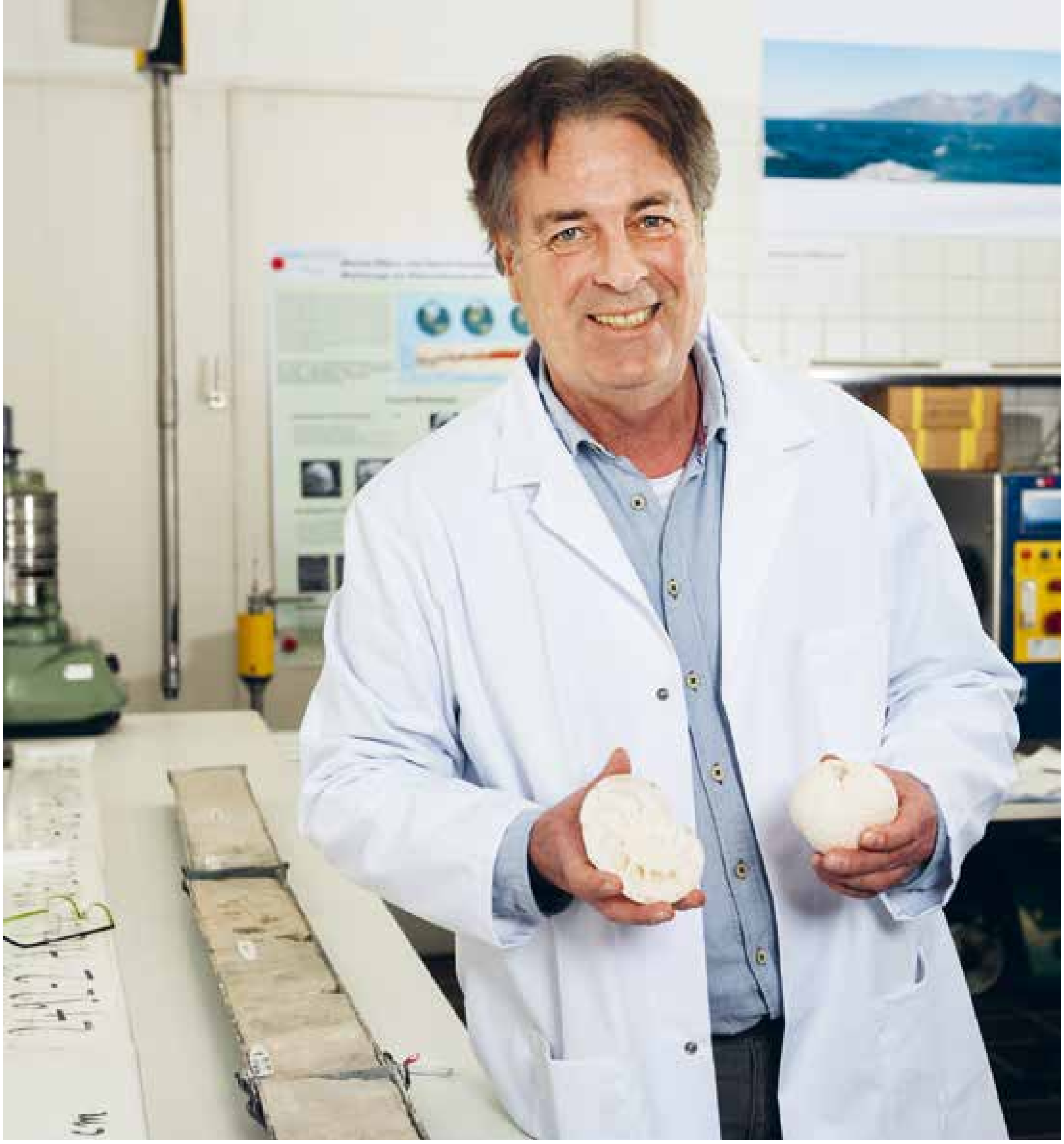
Mr Tiedemann, Mr Brauer: Earth's climate history holds its fair share of surprises: there were more than twenty sudden, dramatic warming phases in the last glacial period alone. How quickly did the climate change back then, and are we currently experiencing a similarly rapid change?

Ralf Tiedemann: It's difficult to compare current developments with the climate variations back then, because the abrupt climate changes 10,000 to 50,000 years ago took place in just a few decades. For example, we know, thanks to climate data gleaned from ice cores, that during these phases the atmospheric temperature over Greenland rose by 8 to 10 degrees Celsius in only one to three decades, and in some cases in just a handful of years. Temperatures over Europe rose by 4 to 5 degrees Celsius. Once the respective phases were over, it took several centuries before the atmosphere cooled back down to normal levels for glacial periods.

Achim Brauer: Needless to say, we're not currently observing any temperature changes on that scale. Over the past 120 years, the Earth has grown one degree warmer. That being said, the warming trend isn't the same everywhere: the Arctic, for example, is warming twice as quickly as the rest of the world. And we can see similar regional differences in the climate data from the past. Even if we're not currently witnessing a temperature rise in Greenland to match the abrupt changes of the distant past, our climate history indicates that the manmade, gradual global warming makes sudden climate changes more likely.

That's a fairly troubling statement; what made you come to that conclusion?

Achim Brauer: What we know about the past climate is based on ice cores from Greenland, and from sediment cores that we collected in various ocean regions and in lakes throughout Europe. We also investigated the growth rings from fossilised trees. These climate archives allow us, for example, to reconstruct past temperature levels



PROF RALF TIEDEMANN

is a geologist at the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, and has specialised in reconstructing climate history with the aid of ice cores and sediment cores from the oceans. What he finds exciting about REKLIM is that the initiative "has brought together leading researchers who work in various regions throughout the Northern Hemisphere, which has made it possible for the first time to comprehensively compare climate data from Greenland, Europe, the Atlantic and the North Pacific."

and precipitation conditions. According to the data, sudden climate changes especially took place during the transitional phases between glacial and interglacial periods. These always came about when changes in orbital parameters caused the amount of sunlight reaching Earth to rise or fall. This gradually produced widespread effects that destabilised the climate system and increased the probability of abrupt changes.
Ralf Tiedemann: Thanks to massive emissions of carbon dioxide and other greenhouse gases, we human beings have artificially initiated such a transitional phase. The climate is growing warmer and warmer, making it less stable and more susceptible to abrupt climate changes.

What factors set off these changes in the past?
Ralf Tiedemann: There wasn't usually just one cause, but an entire cascade of causes.
Achim Brauer: In the context of REKLIM, we've especially investigated the sudden beginning of the cold phase roughly 12,700 years ago. It produced far colder winters in Europe, continued for 1,100 years, and came at the end of the last glacial period, a time when the climate was gradually warming. Who or what set off the cold phase still remains unclear. However, in our studies, we came to the conclusion that the sea ice in the Northern Hemisphere played an important part. Its winter extent, from the Arctic Ocean to the 50th parallel north, that is, roughly at the latitude of Frankfurt am Main, influenced the circulation of air masses over the Northern Hemisphere. That's because, wherever it's covered by sea ice, the water can't effectively pass on its heat to the atmosphere.
Ralf Tiedemann: A second mechanism that may have been important back then was the change in the currents of the North Atlantic, especially the weakening of the North Atlantic Current, also known as the Gulf Stream. Today it transports the majority of the warmth to the northern Atlantic region that accounts for the mild climate in Northern Europe. But back then, the heat transport broke down, which most likely

PROF ACHIM BRAUER

is a geologist at the Helmholtz Centre Potsdam - German Research Centre for Geosciences (GFZ). The basis of his climate reconstructions chiefly consists in continental archives like lake sediments or growth rings. During his work with REKLIM, he has learned "to always bear in mind the influence of the oceans when interpreting continental climate data."

explains why the cold phase continued for so long.

➨ ***That makes it sound like, when it comes to the climate, sea ice can tip the scales?***

Ralf Tiedemann: Yes, and that's true for the weather in Europe, but also and even more so for the ventilation of the North Pacific. In this regard it's important to bear in mind that the Pacific Ocean is home to the world's largest oxygen minimum zones, which are expected to expand in response to climate change. At the moment, a stable layer of low-salinity surface water prevents the circulation of water masses in the North Pacific, and with it, the transport of oxygen-rich water from the surface to the ocean's depths. The only source of oxygen for this massive region is the Sea of Okhotsk – a marginal sea of the North Pacific located between Kamchatka, Japan and the Russian mainland. If sea ice forms there in winter, the salinity of the water masses below the ice rises due to settling brine, which in turn increases their density. The cold and oxygen-rich water masses become heavier, sink, and flow from the Sea of Okhotsk to the North Pacific, where they supply oxygen for water masses at intermediate depths all the way to the Equator.

Achim Brauer: But in the past, this mechanism was the exception and not the rule, as our research for REKLIM has revealed.

Ralf Tiedemann: That's right; if we turn back the clock roughly 6,000 years, we can see that back then, the ventilation of the North Pacific was drastically reduced; no more ice formed in the Sea of Okhotsk. During this phase, the Pacific Ocean literally ran out of oxygen. In the course of modern climate change, we're likely to see this trend repeat itself. Oceanographic readings already show that the oxygen content of the intermediate water is declining, while its temperature is on the rise. We run the risk of a widespread oxygen shortage, which would have grave consequences for organic communities in the North Pacific, and ultimately, for the fishing industry.

Dwindling sea ice in the Arctic, oxygen-poor water in the Pacific, and a weakening Gulf Stream: these contemporary observations are reminiscent of the past climate changes you've investigated. But how exactly does understanding historical climate variations help us deal with today's climate change?

Achim Brauer: First of all, it makes us more aware of the fact that extremely rapid climate changes are a reality; secondly, thanks to our research we now have a much better grasp of which interactions occur when the climate begins to change. For example, will the Earth's surface and the vegetation change? Will we see more erosion, or more extreme weather events? We can use data from the past to arrive at answers to these questions, which gives us a better idea of what changes are to be expected if it comes to abrupt temperature changes in the future.

What could happen in the worst-case scenario; could you give us an example?

Achim Brauer: Northern Germany offers a representative example. We've determined that, during the sudden warming phases roughly 11,000 years ago, the water level in northern Germany's lakes was eight to nine metres lower than today. Many readers may remember the pictures in the newspapers from the extremely dry summer of 2018, when the water levels in the same lakes sank by two to three metres. Yet our climate data indicates that a rapid warming would entail far more drastic water losses; this would very likely be accompanied by dramatic changes to the vegetation.
Ralf Tiedemann: That being said, we should recall that the changes that took place in Europe in the remote past can't be applied to today's Europe one-to-one. But in our studies, we observe systems that were untouched by humankind, and the changes were already massive; today we live in a world that has been significantly influenced by human beings, and one that is far more vulnerable – especially to sudden climate variations.

Let me ask you directly: how likely is a major climate change?

Ralf Tiedemann: Before human beings made lasting changes to the environment, atmospheric carbon dioxide concentrations varied between 180 and 280 parts per million (ppm). This range represented the difference between a cold phase and warm phase, and even small changes in the concentration were enough to set off major temperature changes. Today the level is roughly 410 ppm. In other words, in a very short time we have rapidly increased the concentration of greenhouse gases, and in the process we may very well have exceeded certain thresholds in the climate system; moreover, we still don't know exactly where those limits lie. Accordingly, we can't answer the questions of how and when we exceeded them, either.

Can the research work you're engaged in deliver more certainty?

Achim Brauer: In the course of ten years working with REKLIM, we've truly made significant methodological advances. For example, we can now synchronise the various climate archives from Greenland and Europe, down to a single year. To do so, we use minuscule traces of ash from volcanic eruptions on Iceland, which we can find in all climate archives. They help us precisely date the samples, so that we can compare sediments or ice samples of the same age. In this way, we can explore the state of various climate components at a given point in time. How warm was it back then? What were the ocean currents like, and how did the air masses circulate? These are central questions, which we can now tackle.

Did the initial comparisons yield any unexpected outcomes?

Achim Brauer: It surprised me that the abrupt cool-down 12,700 years ago can be seen in the ice cores from Greenland 170 earlier than in the sediment samples from Europe. That serves to confirm a pattern we continue to see today: climate changes first manifest in the polar regions, and can only be felt in the middle latitudes several decades later. Using our climate data, we can now not only describe the regional differences in past climate changes; we can also trace how quickly the changes spread over the Northern Hemisphere.
Ralf Tiedemann: We discovered an equally revealing pattern when we compared the reconstructed temperature data from the North Pacific and the North Atlantic. The data indicated that climate signals from the North Atlantic near Greenland were transferred to the northern Pacific region: for example, when the overturning of water masses in the North Atlantic intensified, less intermediate water was produced in the North Pacific, and vice versa.
Achim Brauer: We now know that abrupt climate changes affected the entire planet, but not in the same way everywhere; in fact, the changes didn't even happen at the same time. They varied in terms of their amplitudes and characteristics, making them different for every region. Over the next several years, the goal will be to investigate these regional impacts in more detail. ■

IN BRIEF

- **In the past, transitional phases between glacial and interglacial periods were repeatedly characterised by sudden climate changes, during which the Earth rapidly warmed or cooled.**
- **Through the enormous emissions of greenhouse gases, human beings have artificially initiated a new transitional phase. Consequently, the likelihood of the climate suddenly 'tipping' is currently rising.**
- **In this context, Arctic sea ice plays a pivotal role: whenever it dwindled or spread extensively in the past, it produced fundamental changes in the Earth's climate.**