# Measuring **methane**

Describing some of the challenges of monitoring methane concentrations in freshwater lakes; **Dr Hilmar Hofmann** discusses the role of littoral zones and spatiotemporal distribution patterns of methane for lake-wide emissions, and his hopes for the applications of his research

**Can you describe the main pathways of methane to the atmosphere?**

In lakes, the main emission pathways of methane from the water body to the atmosphere are: ebullition from anaerobic sediments; diffusive flux across the air-water interface; and plant-mediated fluxes from the littoral sediments. The contribution of each individual pathway to total lake-wide emissions depends on lake characteristics, eg. size, depth, trophic state and plant cover; and lake dynamics, eg. stratification, mixing and transport.

**What is the relative importance of littoral zones as sources of methane?**

Littoral sediments that experience higher water temperatures than profundal (deep) sediments during spring and summer subsequently release more methane into the water column.

Lake littoral zones are highly exposed to surface waves, which trigger the release of methane-rich pore water and enhance the dissolved methane concentration in the littoral water column. Ebullition can be more pronounced in the shallow nearshore zone than in deep water (offshore) and may contribute to higher dissolved methane concentrations in the littoral zone from rising methane bubbles dissolving into the water column.

**How has your research increased understanding of the spatiotemporal distribution of methane in lakes?**

So far, few studies have investigated the spatiotemporal distribution of methane and related emissions on a basin-scale dimension, especially in medium-sized to large lakes. But in particular, these lakes exhibit large offshore directed gradients of dissolved methane with high concentrations in the nearshore, littoral zone and low in the open water. Furthermore, the dissolved methane concentration also varies substantially in the littoral zone. These spatial gradients lead to heterogeneous distribution patterns in the open water dissolved methane concentration and methane flux to the atmosphere.

**Have you faced any challenges working in the dynamic environment of a lake?**

Spatially and temporally resolved lake-wide surveys that account for heterogeneous distribution patterns of methane in lakes are a time-intensive task – the challenge is to sample at a higher spatial resolution than at which spatial heterogeneity is expressed and at a higher temporal resolution as the patterns of these distributions change. This seems to be a vicious cycle, since heterogeneous distribution patterns of methane are especially pronounced in large lakes.

A possible way out of this dilemma involves using 3D hydrodynamic models coupled with water quality models, including methane dynamics. My working group developed and ran such a model for Lake Constance, where the accurate parameterisation of methane needs a lot of care and requires validation with field data. These model simulations seem to be a reliable tool to estimate methane emissions from large lakes.

**Was it important to measure other factors whilst assessing methane concentrations?**

The spatiotemporal distribution of dissolved methane depends on a combination of lake characteristics; catchment properties; external forcing and lake dynamics; or the historic course of the lake (eg. flood events or periods of eutrophication). Thus, a broad knowledge of these factors and processes is required to evaluate distribution patterns and related lake-wide emissions.

**You have also conducted research into the distribution patterns of plankton in lakes. How are these – and indeed the broader lake ecosystem – affected by methane concentrations?**

The concentration level of methane does not directly affect productivity and biodiversity of primary producers (phytoplankton) and their predators (zooplankton), as the availability of nutrients and silicate, in combination with temperature, are the main limiting factors for primary production in freshwater ecosystems. On the other hand, dissolved methane is an important internal pathway of carbon from the sediments back into the water column. Zones with high methane gradients, eg. at oxyclines (the sediment-water interface, between oxic and anoxic water layers), form high productivity and abundance zones of methane-oxidising bacteria. The biomass formed from dissolved methane can be grazed by other organisms and can thus further transfer energy to higher trophic levels of the lake ecosystem.

**Do you see your research being applied on a wider scale?**

My investigations reveal the need for spatially resolved measurements of methane – especially in medium-sized to large lakes – to quantify lake-wide methane emissions, which will help to improve the current estimates of methane fluxes on a global scale.

# A **fresh perspective** on methane

A team from the **University of Konstanz** in Germany is concerned with elucidating the spatial and temporal distribution of methane in freshwater lakes – research that is important for improving methane budgets and expanding our knowledge of climate change owing to the crucial impact of methane on the greenhouse effect

**METHANE IS ONE** of the most important natural gases in biology and climate science. Despite its relatively low atmospheric concentration, it has been estimated to account for around 20 per cent of the greenhouse effect. Methane is a common by-product of biological processes, with large methane sources ranging from termites to water systems. The contribution of these sources to total atmospheric methane varies in both time and space due to a number of complex variables and their interactions. It is this complexity which has limited our knowledge of the contribution of different natural sources to atmospheric methane concentrations. Clearly, as the threat of climate change looms, gaining an understanding of the amount of methane being produced by natural systems is a critical piece of knowledge.

The importance of such a pursuit has not been lost on Dr Hilmar Hofmann from the University of Konstanz. His team is focusing on elucidating the relative contribution of freshwater systems to atmospheric methane concentrations. Although slightly counterintuitive, freshwater systems account for more global methane emissions than oceans: "Recent estimates have suggested that the terrestrial greenhouse gas sink may be smaller than previously believed and that lakes and reservoirs provide around 10 per cent of total methane emissions," Hofmann reveals.

In the MethLake project, Hofmann's group has made several notable contributions to our understanding of methane production and emission in freshwater lakes. Their research – which has mainly focused on Lake Constance on the south German border – has illustrated the importance of the shallow, nearshore area, or littoral zone: "One of the major findings of the MethLake project was that shallow zones are the predominant source of dissolved methane in lakes," explains Hofmann. This enhanced productivity is in part due to the temperature gradient between shallow and deep waters. Methanogenesis is highly dependent on abiotic variables such as temperature – the warmer the water, the more methane produced. In addition, Hofmann points out: "Extended shallow littoral zones in particular heat up faster and stronger than narrow littoral zones," making lake morphometry an important factor for methane production.

While the discovery that littoral zones are the dominant force in methane production is important, these findings represent a broad snapshot of what is actually a complex and constantly changing system. In order to further their research, Hofmann and his team have turned their attention towards elucidating the spatial and temporal variation in dissolved methane concentrations and related emissions from lakes. This research is important because current global methane budgets assume homogenous distributions of methane across lakes, and often throughout time. To improve those budgets, the researchers are striving to heighten the accuracy of their estimations of methane emissions from individual pathways, making them more reflective of true natural variation.

## MEASURING HETEROGENEITY

One of the greatest challenges for Hofmann and his team was constructing a reliable and achievable methodology for sampling methane concentrations in lakes. The researchers once again focused on Lake Constance which was suitable due to its large size and varied characteristics. "The lake consists of several sub-basins and bays, which widely differ in their properties and spatial dimensions," explains Hofmann. The team conducted measurements along transects running from the near shore to deeper parts of the lake – allowing them to calculate methane transport and dynamics between littoral and open lake zones. While the performance of such sampling may at first glance appear simple, the research is extremely time consuming and quite complex. An ample demonstration of this complexity comes from measuring methane concentrations at a sample site. Various devices exist which have different strengths and weaknesses, and for this reason Hofmann and his team chose three measurement methods which they ran simultaneously. The simplest of these is to take water samples at the given site and depth

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and analyse them using gas chromatography with a flame ionisation detector (GC-FID). In conjunction with this laboratory-dependent method, the team also used a state-of-the-art methane probe to provide *in-situ* measurements and a submersible mass spectrometer, developed by colleagues at the Alfred-Wegner Institute in Bremerhaven. In combination, these three methods provided the researchers with a reliable overview of methane concentrations across both time and space.

### BEYOND THE GREENHOUSE EFFECT

Today, methane is often discussed in the context of the greenhouse effect, but its potential impacts – both positive and negative – are far broader. Significant quantities of methane are trapped in lakes across the planet, and methane is a good source of energy – as illustrated by its consumption by bacteria. These two factors have led to discussions about utilising trapped methane as an energy resource. This could have huge social and financial benefits in countries such as Tanzania, which are rich in freshwater stored methane. However, alongside this potential, trapped methane also poses a hazard. When concentrations of methane (along with carbon dioxide) become too high in the water body they can lead to limnic eruptions: "In 1986 such an event occurred in Lake Nyos, Cameroon and killed about 1,700 people overnight," highlights Hofmann. Today Lake Nyos is constantly monitored to prevent any future limnic events.

### SMALLER LAKES, LESS METHANE?

Most recently, the team has been replicating their methodologies in smaller nearby lakes in an attempt to compare the characteristics and methane emissions from lakes of different sizes. "Preliminary results suggest that on an annual timescale, small lakes can emit as much methane as a large lake, despite the size difference," notes Hofmann, an important discovery for estimates of the global methane budget. The group's recent work has confirmed earlier data that identify a surprisingly large variation in methane concentration and emission within very small timescales, ie. daily. This finding, in conjunction with the heterogeneity of methane concentrations between shallow and deep zones, serves to illustrate the dynamic nature of the methane cycle in freshwater lakes.

The work by Hofmann and his team has added significantly to our understanding of methane release, dynamics and emissions in/from freshwater lakes of varying sizes. The results indicate the uncertainty of the current estimates of methane emissions from lakes on a global scale, which assume homogenous methane emissions across lakes, and in many cases also across time. Their studies can be used to improve these global estimates and also empower discussions regarding measures to limit greenhouse effects. With an estimated contribution of 10 per cent to global atmospheric methane – which in turn provides an estimated contribution of 20 per cent to the global greenhouse effect – freshwater lakes should not be ignored in discussions about climate change. On the surface, it may appear that the methane produced, stored and emitted from freshwater lakes is a problem, but the potential for trapped methane to become an energy resource may provide hope for many countries rich in this natural resource. Regardless of the future use of methane, this work is a crucial building block in our understanding of this climate-relevant gas in an age where scientific knowledge is in a race to keep pace with global change.

INTELLIGENCE

## METHLAKE

### THE ROLE OF LITTORAL ZONES AS SOURCE OF METHANE IN LAKES DYNAMICS, DISTRIBUTION PATTERNS AND EMISSIONS

#### OBJECTIVES

Establishing the pivotal role that lake littoral zones play in methane emissions, focusing particularly on the dynamics of methane release from the littoral sediments, exchange of dissolved methane between the littoral zone and the open water body, the spatiotemporal distribution patterns and their implications for estimation of lake-wide methane emissions.

#### PARTNERS/KEY COLLABORATORS

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**DR HILMAR HOFMANN** graduated with an MSc degree in Environmental Engineering at Brandenburg University of Technology Cottbus and conducted his PhD on surface gravity waves and their implications in the nearshore zone of lakes at the Limnological Institute, University of Konstanz. He is now Assistant Professor in the Environmental Physics Group at the University of Konstanz, Germany. His current research interests are focused on a process-orientated understanding of abiotic forcing mechanisms and organismic interactions covering small to large spatial and short to long temporal scales.

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