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BONUS briefing

SCIENCE FOR A BETTER FUTURE OF THE BALTIC SEA REGION

BALTIC GAS

Methane emission in the Baltic Sea: gas storage and effects of climate change and eutrophication

BALTIC GAS explores where and why shallow gas occurs in the Baltic seabed. Elevated methane concentrations have been detected in the water column of several basins and indicate a moderate diffuse emission of gas. By a network of seismic transects and sediment cores, combined with reactive transport modelling, the hotspots of methane flux have now been identified and the controls on shallow gas accumulation are widely understood. The natural barriers to methane emission have proven to be robust throughout most of the Baltic Sea under the present climate conditions but continued eutrophication, warming and anoxia will enhance the upward migration of gas.

OVERVIEW

The main objectives of BALTIC GAS are to understand the controls on methane production and degradation in the seabed, to map the distribution of shallow gas, and to predict the future methane balance in the Baltic Sea on the background of climate change and eutrophication. Existing data are compiled and combined with new data obtained during research cruises throughout the Baltic Sea. Due to the recent geological history of the Baltic, methane production is today focussed towards the main deposition areas of organic-rich Holocene mud. When the mud layer thickness exceeds a critical threshold free gas occurs and causes a positive feed-back on the further methane production.

The project is transnational with participants from 12 institutions in 6 countries (Russia, Poland, Denmark, Sweden, Germany, The Netherlands). The project is also interdisciplinary as it combines biogeochemistry and geophysics with GIS-mapping and modelling. The Center for Geomicrobiology, Aarhus University, Denmark, hosts the project.

OUTLINE

Methane formation in the Baltic Sea is sensitive to eutrophication from coastal populations and from river discharge. This has led to the accumulation of free gas in the form of methane bubbles beneath the depth of sulfate penetration. The gas is generally hidden several meters below the sediment surface but in sensitive areas it penetrates up to within a few decimeters of the

surface. This "shallow gas" has now been detected in hundreds of square kilometers of the Baltic seabed. Although the gas is continuously rising up towards the sediment surface, it is in most areas effectively broken down sub-surface when reaching into the sulfate zone. One of the main challenges for BALTIC GAS has been to establish a quantitative and mechanistic understanding of gas accumulation, flux and emission in the seabed. The project has widely succeeded in this objective through data mining, seismo-acoustic mapping, sediment coring and analyses of key biogeochemical parameters, and modelling.

We have discovered a positive feed-back mechanism in the methane cycle triggered by shallow gas. When the Holocene mud layer exceeds a threshold thickness methane concentrations exceed the ambient hydrostatic pressure in the sediment and free gas bubbles form. These ascend up through the sediment column and thereby deplete sulfate and expand the zone where the decay of buried organic matter leads to methane production. This in turn further increases the methane concentration and the evolution of gas. Ultimately, the penetration depth of sulfate, which functions as a barrier to methane emission, becomes shallower and ebullition of gas may occur. Such ebullition is not observed as a widespread phenomenon but it may occur during extreme wind conditions and strong water level variations.

EFFECTS OF GAS ACCUMULATION

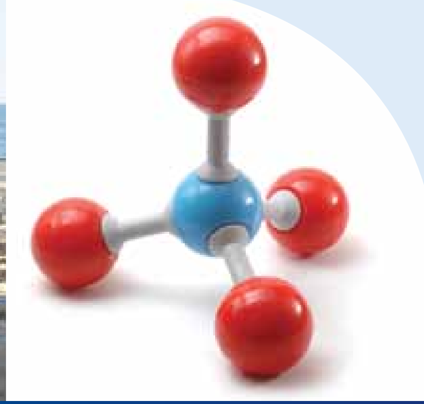
In marginal seas like the Baltic Sea, enhanced eutrophication by nutrients such as nitrate or phosphate leads to increased production of organic matter. Predicted climate change may increase the water temperature and reduce the deep water ventilation, factors which will stimulate anaerobic degradation of organic matter buried in the sediment. As a consequence, more free methane gas (i.e. gas bubbles) will accumulate in the sediment. This may lead to an enhanced emission of methane to the water column and atmosphere where it acts as a very potent greenhouse gas.

Accumulation of shallow gas in the seabed may pose hazards to seabed structures such as wind farms, pipelines, power or communications cables, and off-shore drilling operations by destabilising the sea floor. Enhanced ebullition from hot-spots of shallow gas will also enhance the emission of hydrogen sulphide which is toxic to fish and other marine life and is also highly corrosive.

THE MAJOR FIELD CAMPAIGN

Field campaigns with research ships in different parts of the Baltic Sea have been a main activity of BALTIC GAS. The largest expedition took place with the RV Maria S. Merian in August 2010 and covered the major basins (Arkona Basin, Bornholm Basin, Gotland Basin, Bothnian Bay and Bothnian Sea). During the expedition, subbottom profiling systems were used to map





the thickness and structure of organic-rich deposits and to guide the detailed coring program for biogeochemical analysis. We monitored methane, sulfate, sulfide, iron and other chemical species and performed incubation experiments to measure the production and breakdown of methane. We could demonstrate that the degradation rate of organic matter buried at depth in the seabed continuously decreases with depth in the sediment according to a power law function of its age.

NEXT STEPS

Seismo-acoustic mapping and biogeochemistry

A successful strategy of the BALTIC GAS project has been to integrate seismo-acoustic mapping with geochemical profiling. By scanning the Baltic sea floor with echo sounding equipment, areas with free methane gas has been mapped. Detailed interpretation of the data from the Merian Cruise is now ongoing and geochemical and acoustic data are now being integrated into the BALTIC GAS database.

Model explains development of free methane gas

A transient reactive-transport model has been developed to unravel the methane cycle in the Arkona Basin. Next step is to use the modelling tools to establish basin-scale and regional budgets of methane production and consumption in the Baltic Sea. The ultimate goal is to understand the dynamics of the Baltic Sea methane and use the past record to calibrate the model prediction for the future.

Mapping methane distribution

Different characteristics of methane in the Baltic Sea have been mapped by compiling biogeochemical data obtained during more than ten BALTIC GAS cruises. We now develop algorithms correlating methane fluxes and gas distribution so that GIS-mapping for these key parameters can be extended to major areas of the Baltic Sea.

IN BRIEF

BALTIC GAS
Methane emission in the Baltic Sea: gas storage and effects of climate change and eutrophication

Methane super-saturation has led to the accumulation of free gas in the form of dense bubbles in many areas of the Baltic seabed. A part of the methane escapes into the water column and some may escape into the atmosphere, thereby adding to the emission of greenhouse gas. The Baltic is an ocean margin sea with high accumulation of organic matter and nutrients and with a resulting high methane production. Information on the distribution of methane and free gas in the Baltic Sea has not been available, however, and the role of methane for the carbon cycle was therefore unknown.

KEY RESULTS

- BALTIC GAS has developed a new interdisciplinary approach to map and quantify the occurrence of gas. The project has demonstrated where the hotspots of methane production occur, why methane accumulates to high concentrations, and how the barrier against methane emission is controlled.

- Models of the evolution of shallow gas have now been calibrated against field data and are used to predict the future methane balance in the Baltic Sea under different scenarios of climate change and eutrophication. A critical factor is the accumulation of organic-rich mud in several of the oxygen-depleted basins where methane now penetrates up very close to the sediment surface.

- BALTIC GAS has generated and compiled an extensive database for methane in the Baltic Sea which is the basis for the first GIS maps of methane and gas distribution in any marginal sea.

WHO NEEDS THE INFORMATION

The new maps will be available for environmental authorities to evaluate potential risks coming from the seabed by continued eutrophication and climate change. They will also be available for planners of offshore constructions that depend on long-term seabed stability. The project develops a predictive model of gas accumulation and emission under realistic environmental scenarios which will improve the knowledge base for necessary future policy actions.

PROJECT PARTNERS AND COORDINATOR

BALTIC GAS brings together an interdisciplinary expertise and infrastructure from leading research institutions around the Baltic Sea. The work is conducted at twelve research institutes in six countries, with 25 researchers and PhD students engaged.

Denmark
Center for Geomicrobiology, Department of Bioscience, Aarhus University (Coordinating partner)
Department of Marine Ecology, National Environmental Research Institute (former), Aarhus University
The Geological Survey of Denmark and Greenland, Copenhagen

Germany
The Alfred Wegener Institute for Polar and Marine Research, Bremerhaven
The Leibniz Institute for Baltic Sea Research, Warnemünde
The Max Planck Institute for Marine Microbiology, Bremen
Department of Geosciences, University of Bremen

The Netherlands
The Department of Earth Sciences, Utrecht University

Poland
Institute of Oceanology, Polish Academy of Sciences (IO-PAN)

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