Backstory

Challenges and opportunities in the global methane cycle

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To control the atmospheric methane concentration for Paris Agreement and Global Methane Pledge, it is urgent to elucidate global methane budget, in the context of dangerous high growth rate of atmospheric methane concentration in the past three years (2020–2022). Interdisciplinary research can definitely help answer the open questions about methane budget, as some examples shown in this Special Issue on "Methane emissions, sinks, and mitigation".

Methane alone is responsible for about 15–35% of warming and understanding the sources and sinks of methane is essential for effective climate change mitigation. "Methane budgets" are the comprehensive assessments of methane emissions and sinks in various systems, such as natural gas and oil consumption, agriculture, and wetlands — these budgets enable us to identify the major sources and sinks of methane which, in turn, are crucial for developing effective mitigation strategies and effectively tackle climate change.

Recent research has made significant progress in improving our understanding of methane budgets. Advances in remote sensing technologies have enabled the accurate quantification of methane emissions from super emitters or large areas, such as oil and gas ultra-emitters,[1] urban areas, agricultural lands, and wetlands.[2] Alongside this, the development of sophisticated models and improved measurement techniques have enabled the identification of previously unknown sources and sinks of methane. Despite these advances, there are still several challenges in this field.

Professor Shushi Peng's work is aimed at addressing the challenges remaining in methane budgets research. Leading *iScience's* ongoing Special Issue on "Methane emissions, sinks, and mitigation" (https://www.sciencedirect.com/journal/iscience/special-issue/1004N86KKJZ), Prof. Peng is bringing interdisciplinary research and researchers together to answer the questions that are still open. In this backstory we discuss the current state of methane budgets research, as well as the most exciting challenges and opportunities in this field.

First impressions

What originally interested you in the field of methane budget? Did you train in this area or are your research interests naturally aligned with the developing field?

The curve of observed atmospheric methane concentration since 1984 interested me, and when I started my postdoc working on modeling permafrost thawing and methane emissions from wetlands and permafrost, I became interested in the field of methane budget. Many hypotheses have been proposed to explain the inter- and decadal-variability of atmospheric methane growth rate (i.e., fast increase in the 1980s and 1990s, no increase between 1999 and 2006, then increase again after 2007 and acceleration after 2014), but no consensus has been reached yet. The community of methane sources and sinks has grown rapidly since I focused on the modeling of wetland methane emissions, and plenty of achievements have been made for global and regional methane budgets.[3] My research interests then expanded to methane budget (sources and sinks for atmospheric methane) from only wetland methane emissions.[4]

Motivation

What are the most important and most exciting questions in the field currently, and why do they matter? What do you think are the biggest challenges that the field is facing?

The most important and interesting question, I think, is to explain the mechanisms of variation in growth rate of atmospheric methane over the past four decades. Understanding this will affect how well we predict

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future warming involving methane–climate feedback. The growth rate depends on anthropogenic and natural emissions, as well as atmospheric methane sinks (hydroxyl radical, chlorine, and soil uptake). The biggest challenges are the large uncertainties that exist in both anthropogenic and natural emissions and sinks, i.e., large differences in estimates of methane emissions and sinks between different inventories, models, and atmospheric inversions.[3] It is still a challenge to disentangle the contributions of each methane source and sink on the variation of the methane's growth rate.

Interdisciplinary methods

What role does interdisciplinarity play in the context of methane budget? Does this interdisciplinarity create any barriers for entering this field?

The Global Carbon Project releases a report of the global methane budget regularly (every two or three years). If you look at the author list of the Global Methane Budget,[3] it is impossible to have methane budget research without interdisciplinarity. The budget involves experts on atmospheric methane observations from stations and satellites, anthropogenic methane emissions from the socioeconomic angle (e.g., two accepted papers in this special issue[5,6]), and satellite/airborne observations, natural emissions from land surface modeling groups and observations for wetlands, termites and permafrost,[1,7] atmospheric chemistry for sinks, soil microbial uptake, and atmospheric inversions.[8] Modeling methane-climate feedback in an earth system model is also a large interdisciplinary community making efforts to predict future methane budget. Of course, this complex interdisciplinarity can create barriers for communication between different disciplines, e.g., different focus, terminology, and methodology, even between observations and modeling groups. But in-depth communications and collaborations can help us move forward to better understand methane budgets and climate change.

> ''It is impossible to have methane budget without interdisciplinarity.''

What are other disciplines that should look to this field with interest? Which new communities do you see forming in the future around the topics the field is interested in?

Recently, I became interested in how paleo-studies on ice-core methane may help researchers to understand climate change and methane budgets on long timescales, as well as the linkage between abrupt change in climate and paleo-atmospheric methane concentration. Isotopes of methane, and methane clumped isotopologue, could help us disentangle methane sources and sinks. In addition, microbiologists advanced the knowledge of the mechanisms of methane production and oxidation in wetlands and lakes. Now, I am interested in ice-core methane and paleoclimatic change, and my research will try to link past and future methane-climate feedback.

Future

What's next? What breakthroughs do you imagine or hope to see in upcoming years?

In the next few years, more and more satellites will be launched to monitor, report, and verify methane emissions. I hope this will help constrain anthropogenic methane emissions, then there will be less freedom to attribute growth rate of atmospheric methane to natural emissions and sinks. I can imagine that isotopes of methane will play a role in helping to understand methane sources and sinks. I also have confidence in the earth system modeling community to highlight the role of methane–climate feedbacks in the next Coupled Model Intercomparison Project (CMIP). In the upcoming years, I really hope to know whether the feedback of wetland methane emissions on climate is positive. If so, it would be important to know whether the positive feedback has already started, or when it will start and with what magnitude at the end of this century.

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