The First Northern Hemisphere High-Resolution Holocene Methane Record Reveals a Centennial Variability

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Abstract

We present the first Northern Hemisphere high-resolution Holocene methane (CH4) record obtained from the Renland Ice Cap (ReCAP) – 71.3N 26.6W 2300 m a.s.l. in 2015. The total length of the core is 584 m containing 532 m of the Holocene ice without brittle ice zone thus allowing to obtain an uninterrupted CH4 record over the Holocene. An ice core analytical technique developed in 2010 – continuous flow analysis (CFA) provides a unique opportunity of revealing high-resolution greenhouse gas record of the past. Considering a mean annual layer thickness the depth resolution translates to a nominal temporal resolution of 35 data points 100 yr-1 over the Meghalayan (back to 4.2 ka BP) Holocene section. Note that due to the average residence time of CH4 in the atmosphere and the gas age distribution width in the firn, the maximum temporal effective resolution is lower by a factor of 10. The pattern of the centennial scale variability seen in the ReCAP CH4 record is coherent with the earlier published Southern Hemisphere record based on the West Antarctic Ice Divide (WAIS) CH4 record. The wavelet coherence analysis identifies a high correlation on the long- and midterm variability (600-700, 200-500 yr periodicity) as expected; the Meghalayan Holocene section reveals a common variability down to 70 yr. Inter-laboratory offsets of the absolute CH4 values are likely constant as the entire cores were running over continuing measurement campaigns. The elevated ReCAP CH4 level due to the local dust presence is disproved for at least the Last Glacial section. Gas trapping uncertainties should not matter on a decadal scale besides probable layered bubble trapping. Melt layers are untraceable prior to 2 ka BP due to the annual layers thinning. The analysis was performed on the ReCAP record cleaned from the possible melting- and the CFA technique-related spikes. This study leads, however, to a more detailed evaluation of the interpolar difference in the future work as the absolute value remains unresolved though we are confident that there were no big variations. We argue that the centennial variability in the CH4 is explained by the intertropical convergence zone global teleconnection and its influence on the monsoon activity and thus the CH4 production by tropical wetlands. The duration of the periods in CH4 concentration evolves through the time, which could potentially suggest a change in the atmospheric residence time of CH4.

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Data and methods

- continuous flow analysis (CFA)
- calibration to discrete CH_4 data
- preliminary RECAP timescale
- CH_4 synchronization
- wavelet transformation
- wavelet coherence

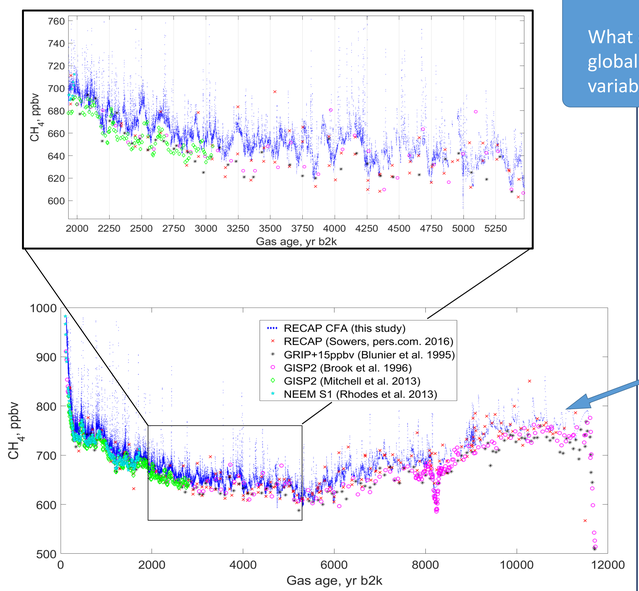


Fig. 1. *Holocene CH_4 ice core records on its gas timescales translated to yr b2k (years before 2000 AD).*

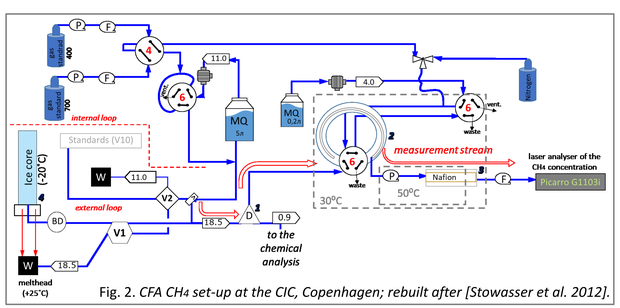


Fig. 2. *CFA CH_4 set-up at the CIC, Copenhagen; rebuilt after [Stowasser et al. 2012].*

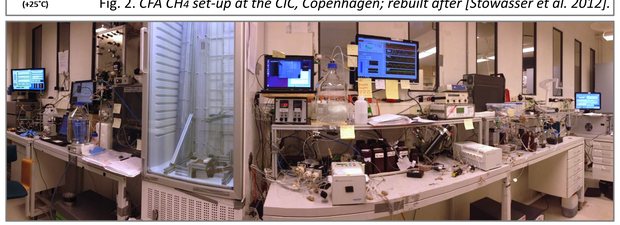


Fig. 3. *A panorama of the CFA set-up at the CIC, Copenhagen.*

Introduction

Previously obtained CH_4 Holocene records (Fig. 1) include predominantly the discrete data, the continuous datasets are patchy. Thus the variability of the CH_4 signal on submillennial timescales was not traced. The centennial scale CH_4 variability was only revealed during the interstadials of the Last Glacial Period [Rhodes et al. 2017].

Question

What caused the centennial scale global methane concentration variability during the Holocene?

Summary

The first Northern Hemisphere continuous flow analysis (CFA) methane (CH_4) record covering the entire Holocene is obtained from the RECAP ice core (Eastern Greenland). The record reveals centennial scale variability (600-700, 200-500 yr); the late Holocene section reveals a periodicity scaled down to 70 yr.
The centennial scale CH_4 variability is coherent with the earlier published Southern Hemisphere record based on the WAIS Divide (West Antarctica) CH_4 record.
The origin is debatable, we hypothesize the link to the tropical monsoon activity.

Results and discussion

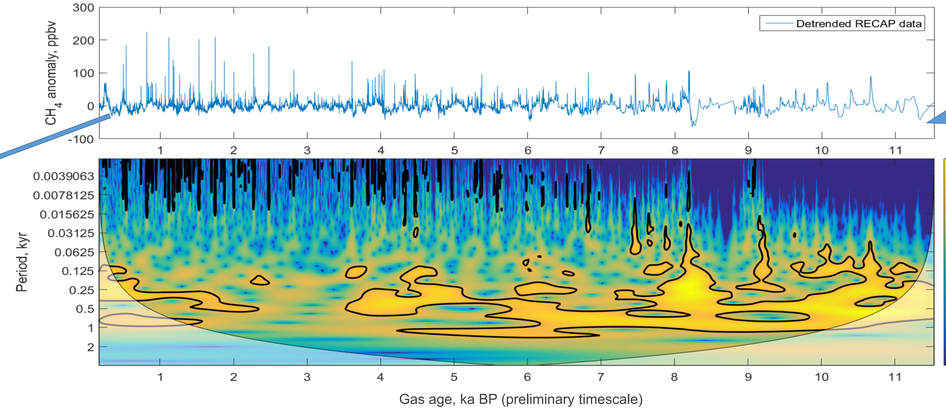


Fig. 4. *The detrended RECAP CH_4 record (upper panel) and its wavelet transform in time domain (lower panel).*

We emphasize the first high-resolution record as this record was obtained using the continuous flow analysis with a resulting average effective resolution 3.5 data points per 100 yr.

The wavelet transform [Grinsted et al., 2004] identifies a significant variability 125-1000 yr throughout the mid and early Holocene. A short-term variability is more prevailing in the late Holocene (Fig. 4).

The wavelet coherence analysis identified a high correlation on the long- and midterm variability (600-700, 200-500yr periodicity); the late Holocene section revealed a common variability down to 70 yr (Fig.5).

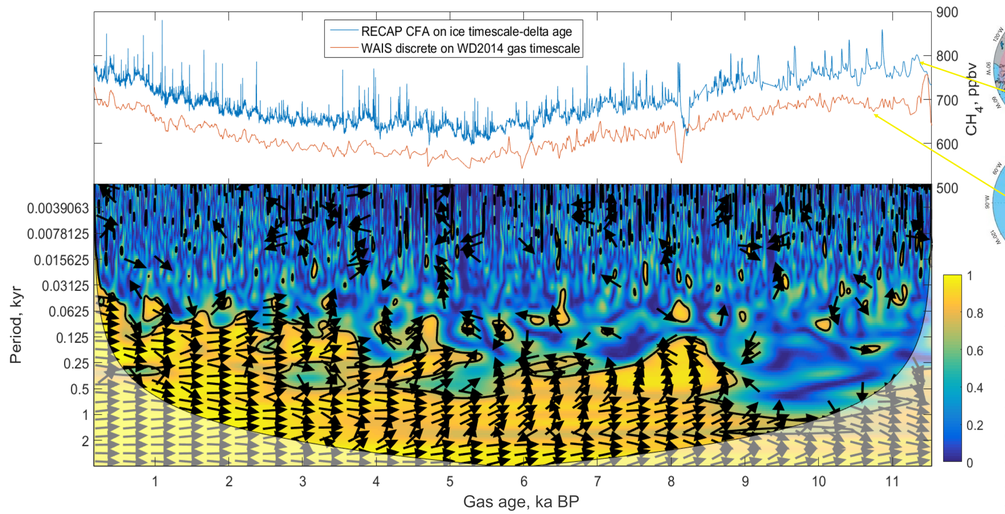
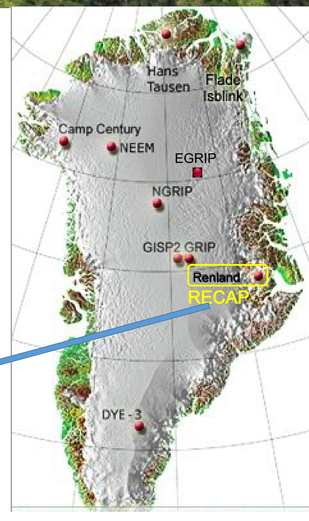


Fig. 5. *RECAP and WAIS Divide CH_4 records on its gas timescales (upper panel); wavelet coherence of the two CH_4 records.*

A centennial-scale variability was traceable in the RECAP CH_4 record and its pattern turned out to be coherent with the earlier published Southern Hemisphere record based on the West Antarctic Ice Divide (WAIS) CH_4 record [Mitchell et al., 2013; WAIS com.memb., 2013].

The phase relationship is not direct throughout the Holocene, which might be related to the RECAP gas timescale.

We argue that the centennial variability in the CH_4 is explained by the intertropical convergence zone global teleconnection and its influence on the monsoon activity and thus the CH_4 emissions by the tropical wetlands [e.g. Bernal et al. 2016; Wen et al. 2016; Yang et al. 2017].



Conclusions and perspectives

- The first Northern Hemisphere CFA CH_4 Holocene record is obtained.
- It demonstrates the centennial scale variability.
- This variability is coherent with Antarctic Holocene CH_4 record.
- We hypothesized the link to the tropical monsoon activity, its centennial variability in Holocene and the correspondent tropical wetlands methane emissions.
- Is there a possibility for the interpolar difference calculation?
- How to deal with the Holocene timescales of the ice core gas records and stable isotopic speleothem records in order to trace the phase relationship between the high-latitude CH_4 concentration and tropical methane production?

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