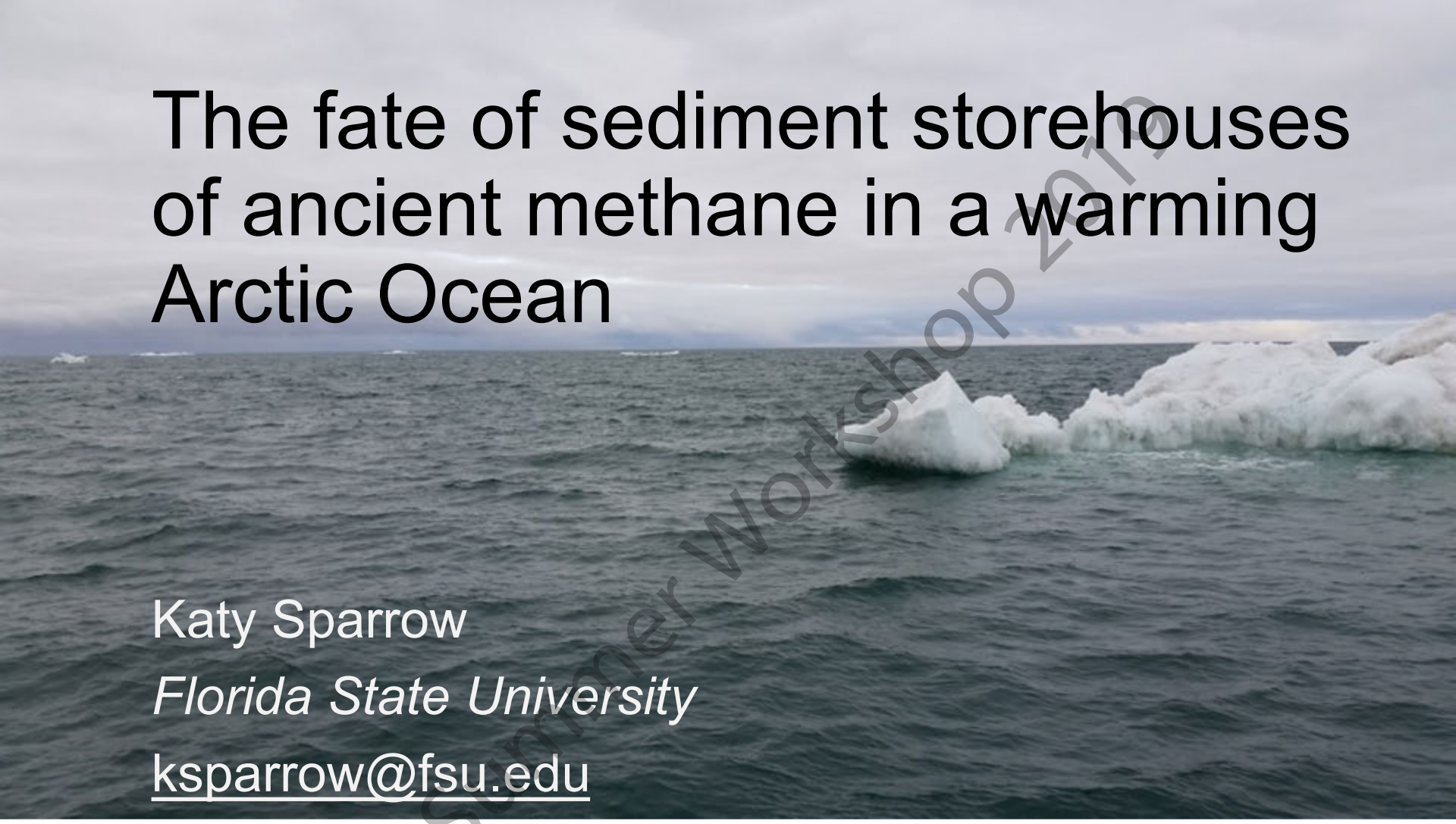
The fate of sediment storehouses of ancient methane in a warming Arctic Ocean



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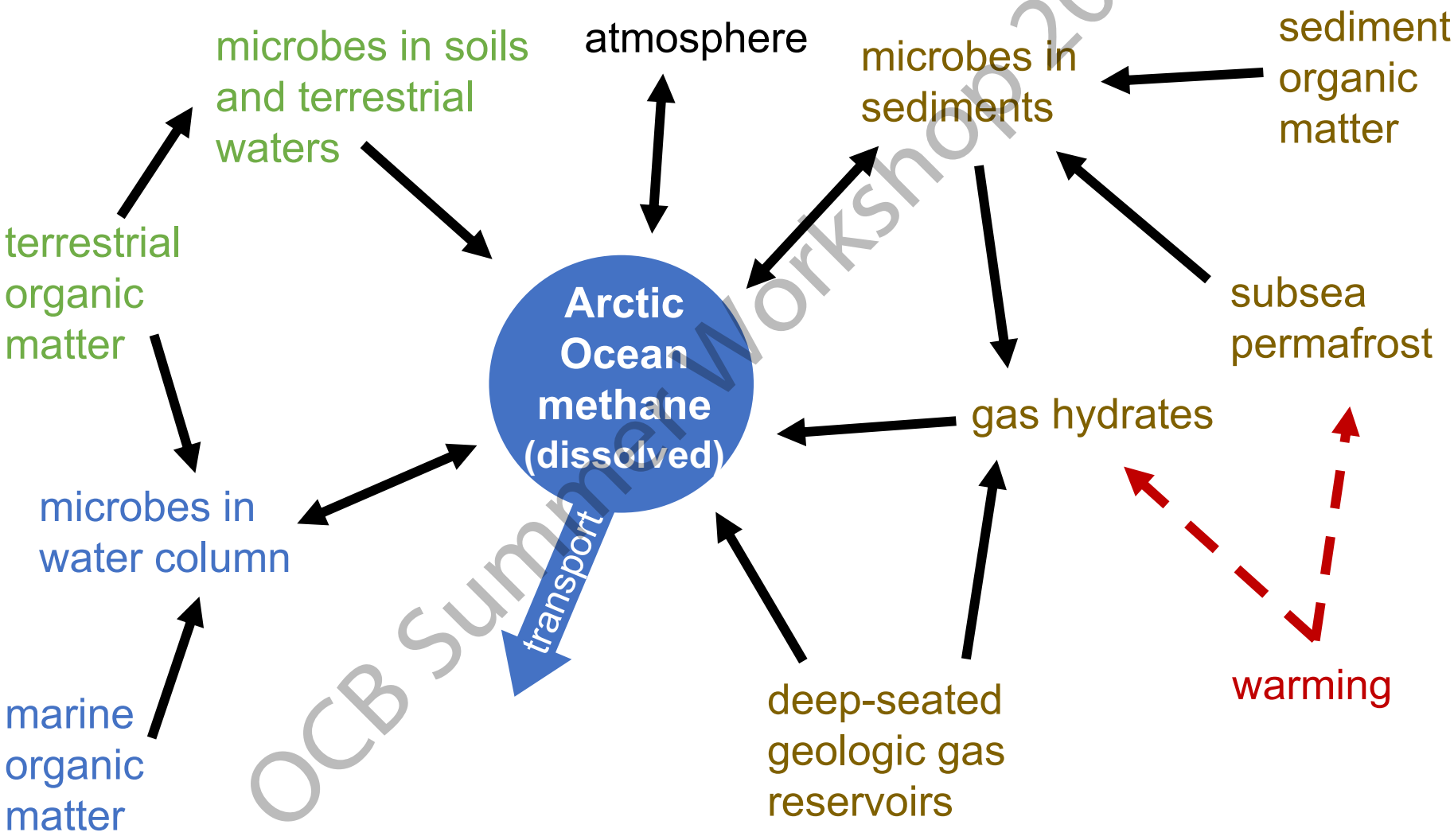
OCB Summer Workshop
June 26, 2019

Outline

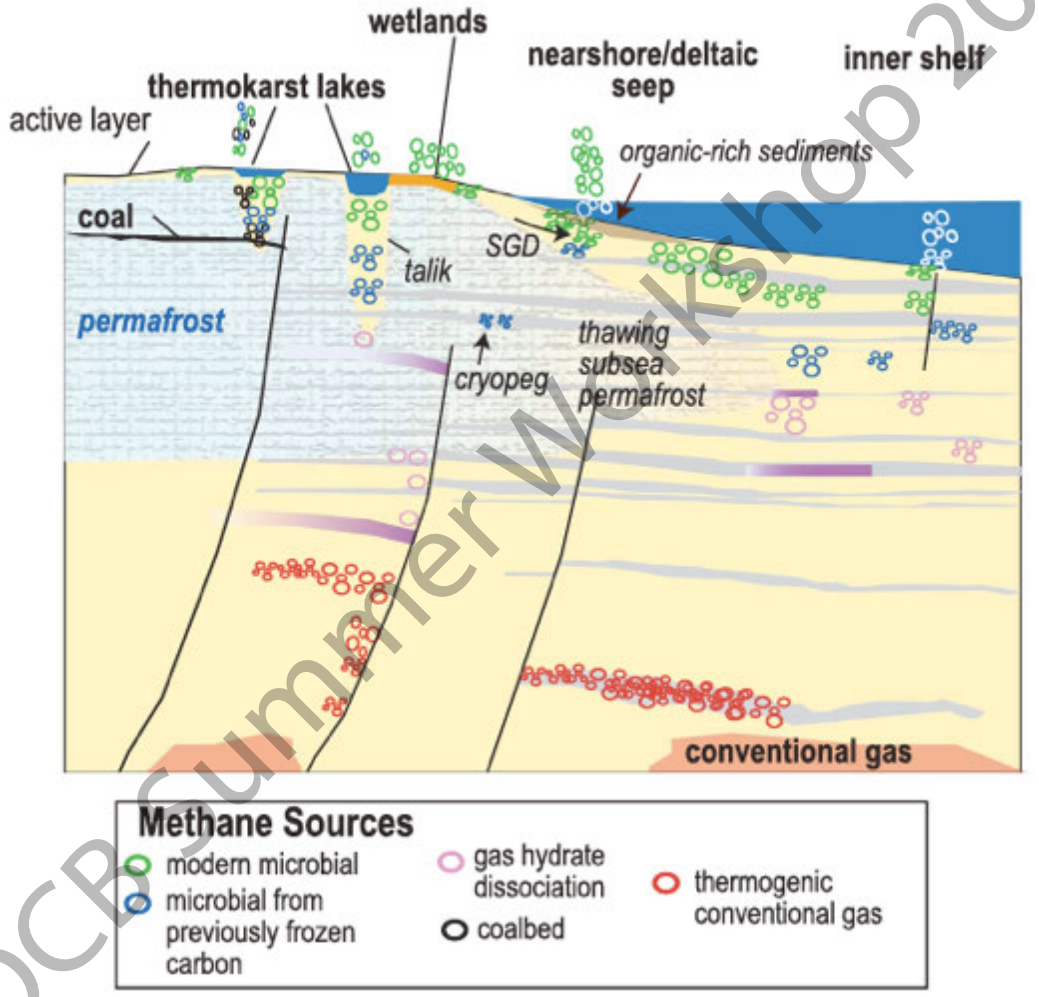
- Introduction
  - -Methane sources and sinks in the Arctic Ocean
  - -Arctic Ocean methane-climate feedback

- State of the science on:
  - -Methane hydrates and subsea permafrost in arctic sediment
  - -Role of microbes in methane production and consumption
  - -Evidence and outlook on the Arctic Ocean methane-climate feedback

Arctic Ocean methane dynamics

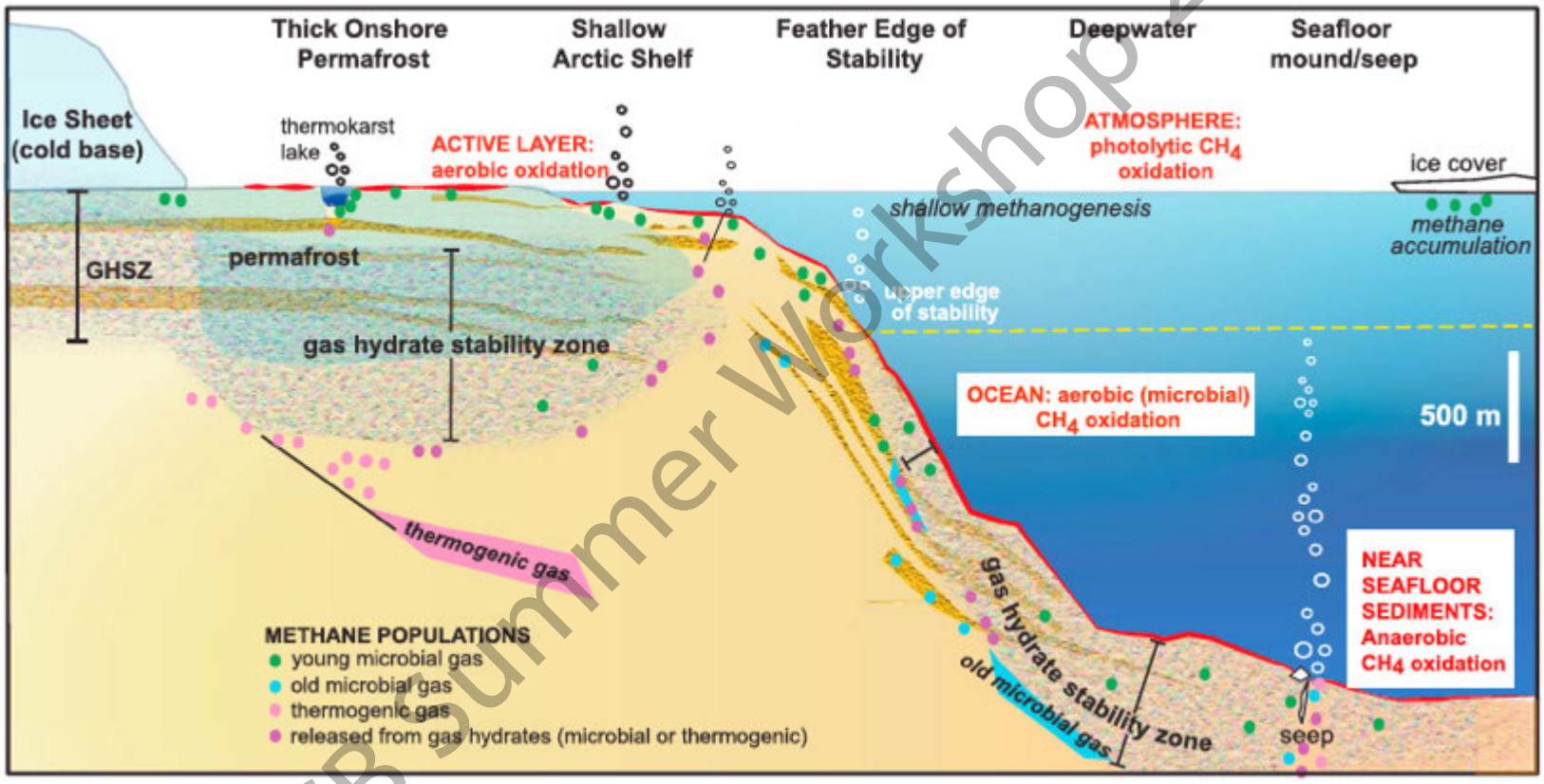


Arctic Ocean methane sources



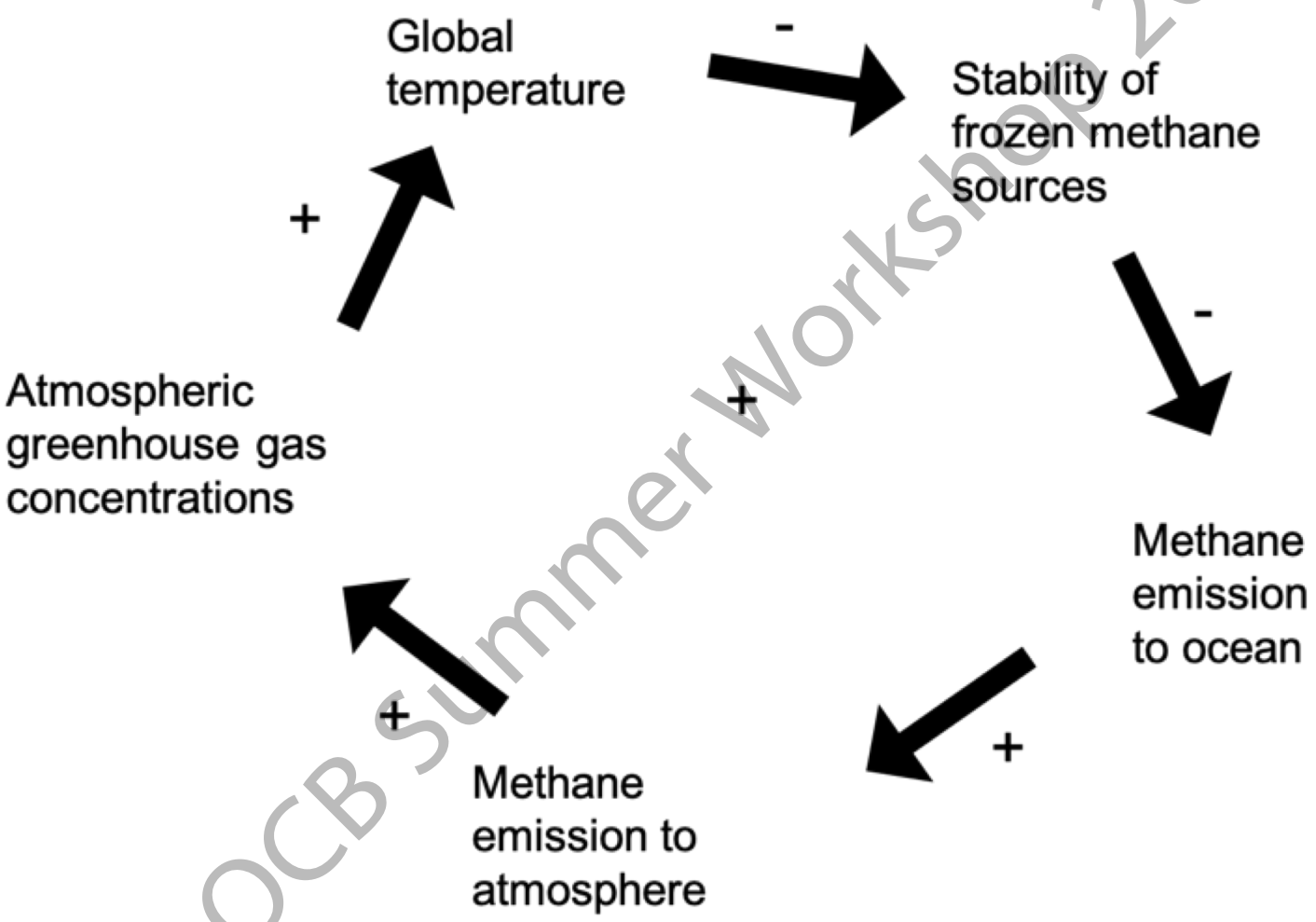
Ruppel and Kessler, 2017

Arctic Ocean methane sinks

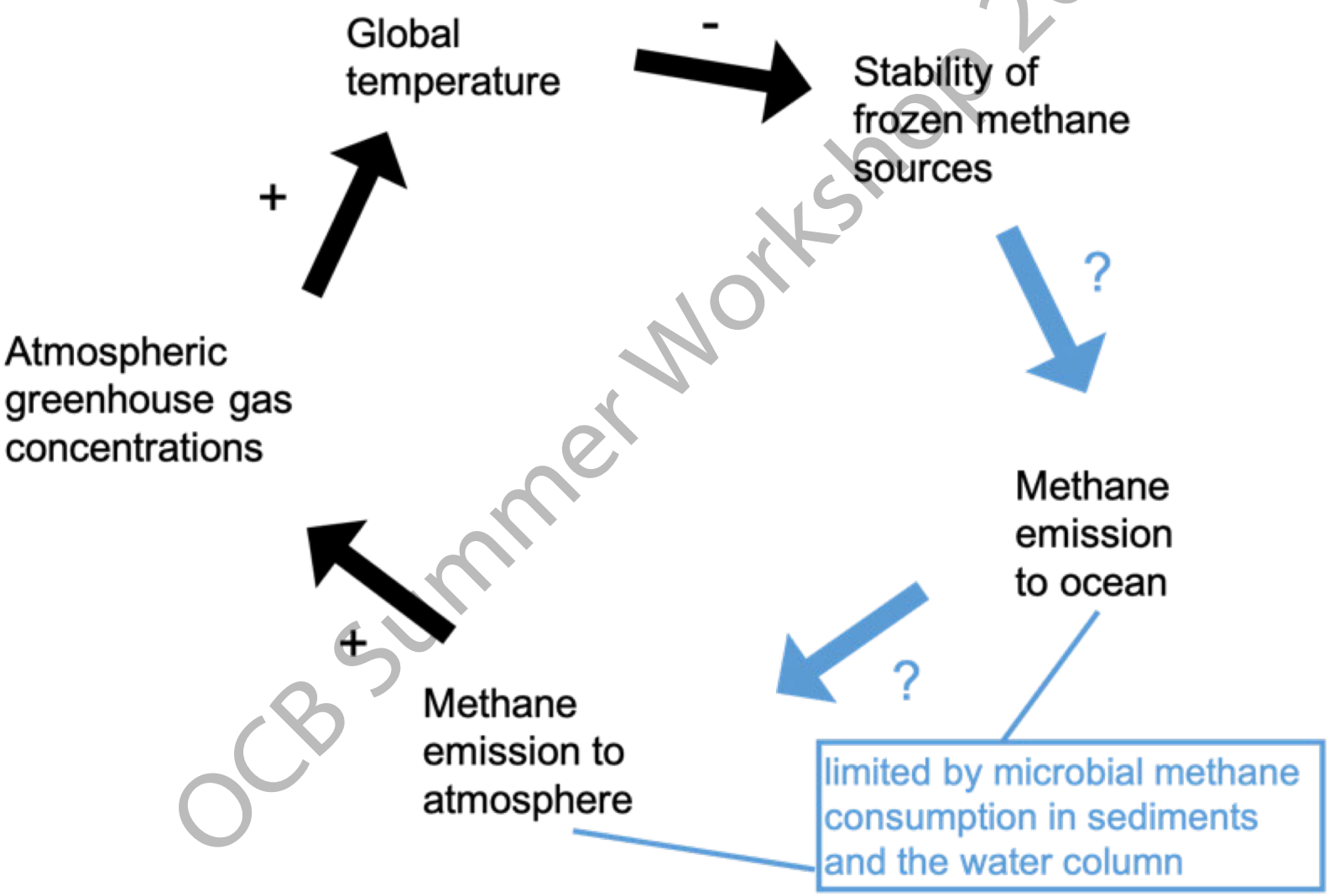


Ruppel and Kessler, 2017

Arctic Ocean methane-climate feedback



Uncertainties in this feedback loop

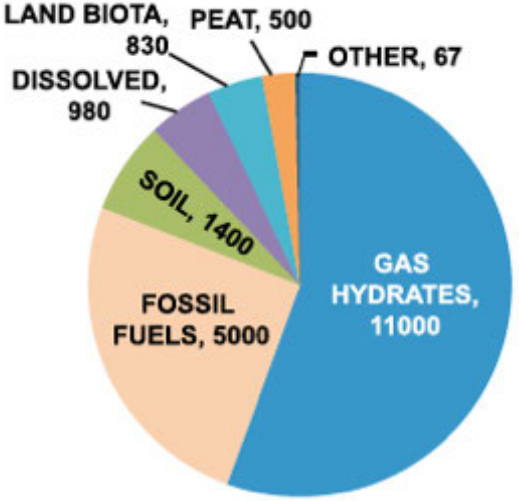


Tempering Arctic Armageddon

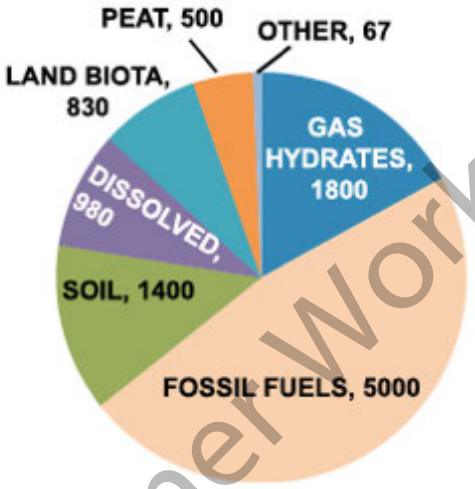
"These findings of CH_4 emissions from the Arctic sea floor add to our understanding of the atmospheric CH_4 budget, but they do not show that Arctic warming has produced a positive feedback in radiative forcing by causing these emissions to increase recently. A newly discovered CH_4 source is not necessarily a changing source, much less a source that is changing in response to Arctic warming."

-Comment by Petrenko et al. (2010) in *Science*

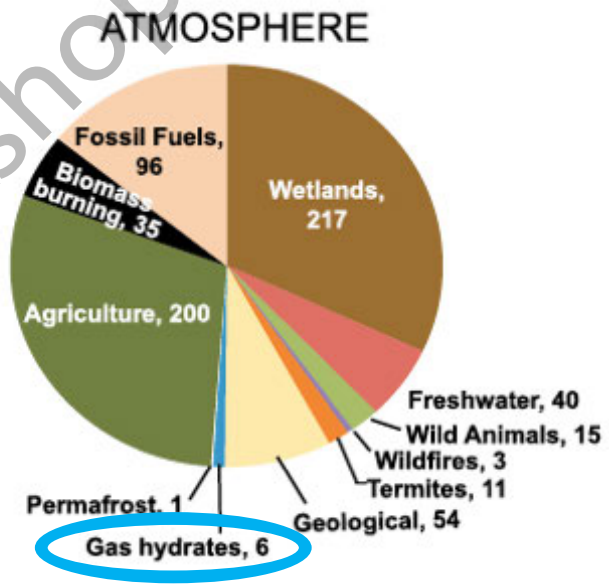
Hydrate reservoir and its role today



Historical estimate (1988)



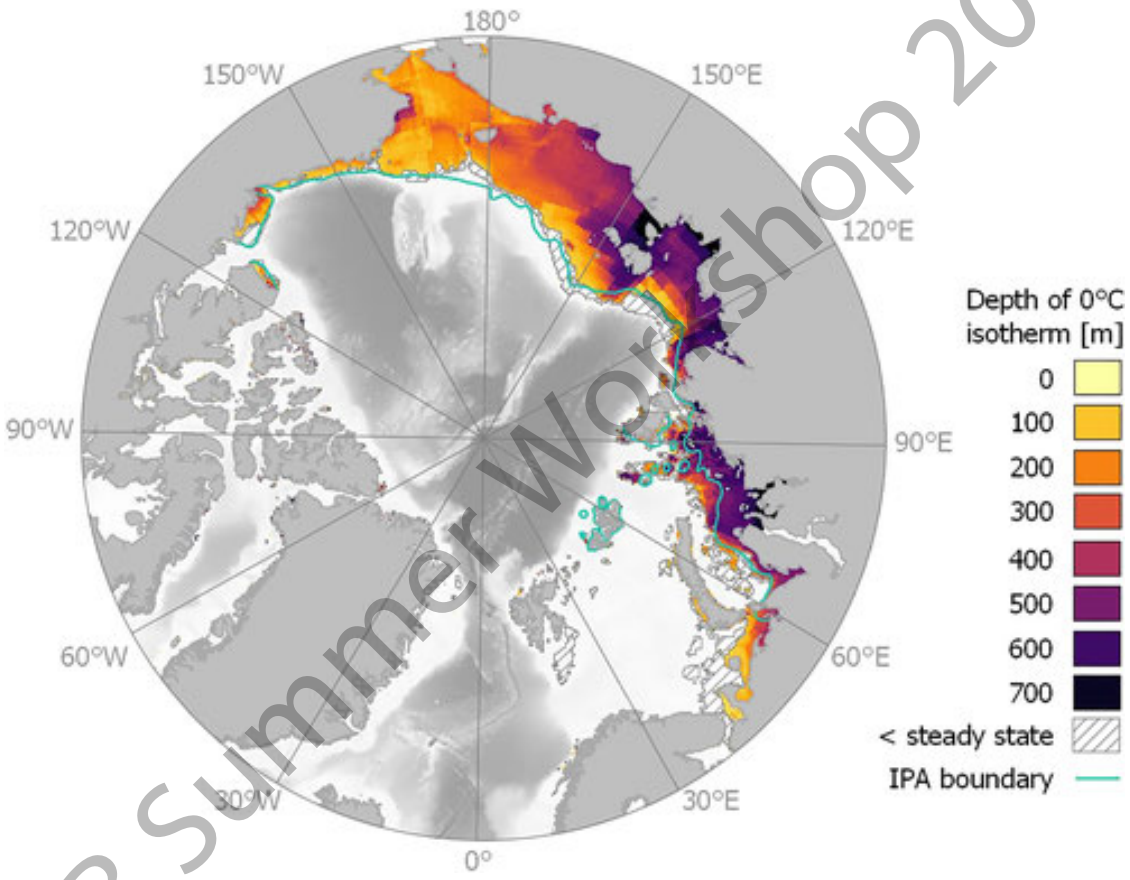
Current estimate (2018)



Nominal methane emissions from hydrates to the atm. relative to other sources

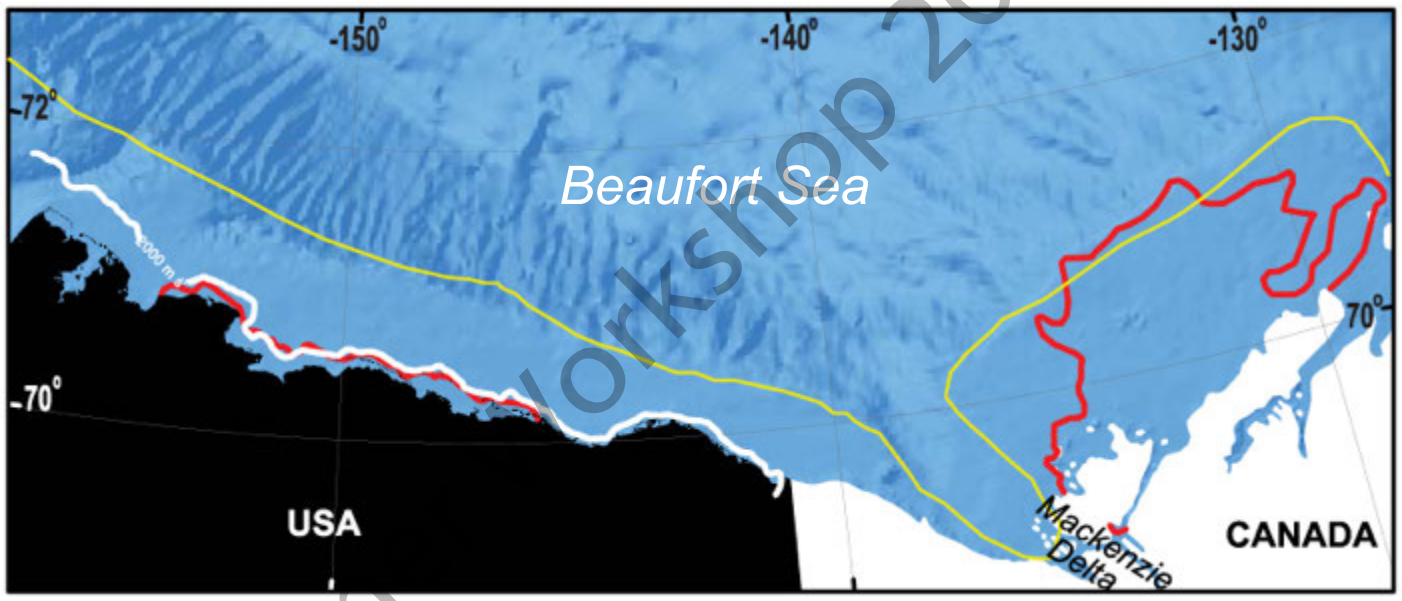
Ruppel and Kessler, 2017: "The interaction of climate change and methane hydrates"

Subsea permafrost has been thermally degrading throughout the Holocene



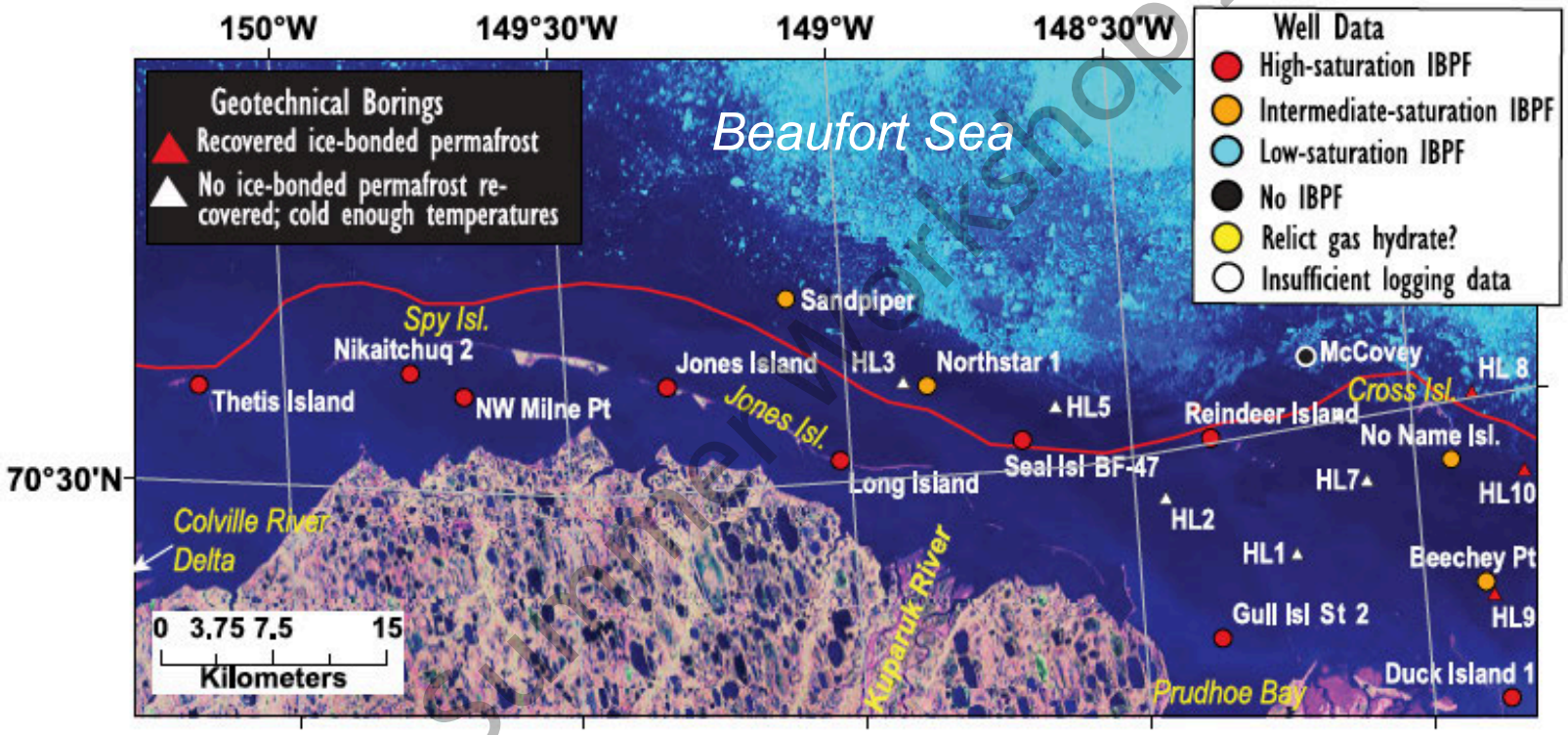
Overduin et al., 2019

Extent of subsea permafrost is *not* to the shelf edge



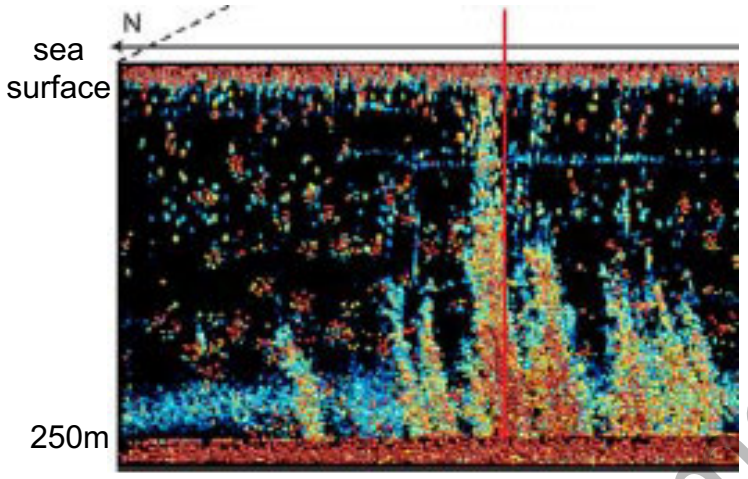
Brothers et al., 2016

Subsea PF is only found in a limited band of this shelf, in waters <25 m deep

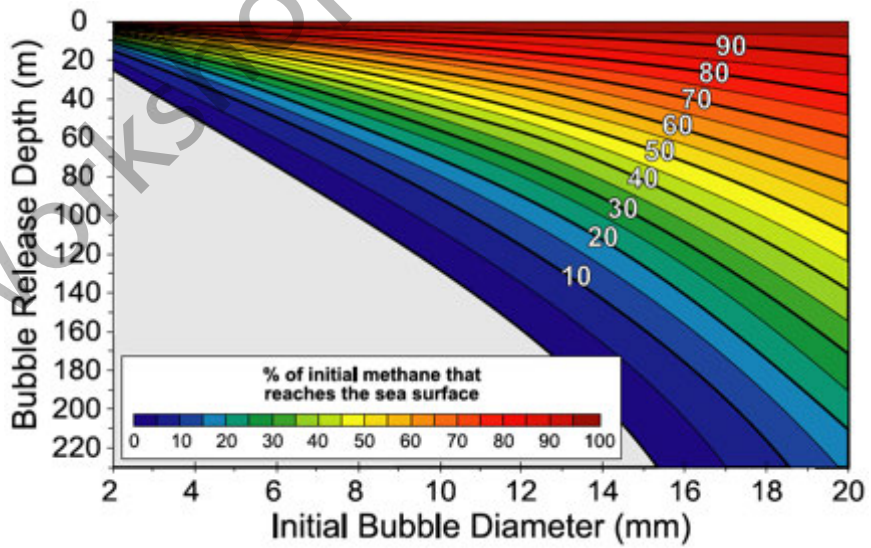


Ruppel et al., 2016

An image of a seep doesn't tell the whole story

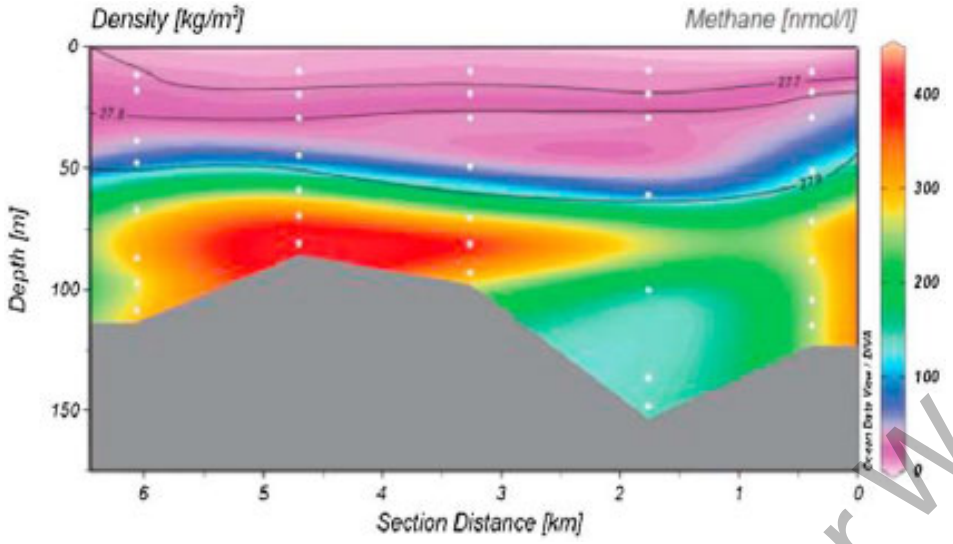


Westbrook et al., 2009

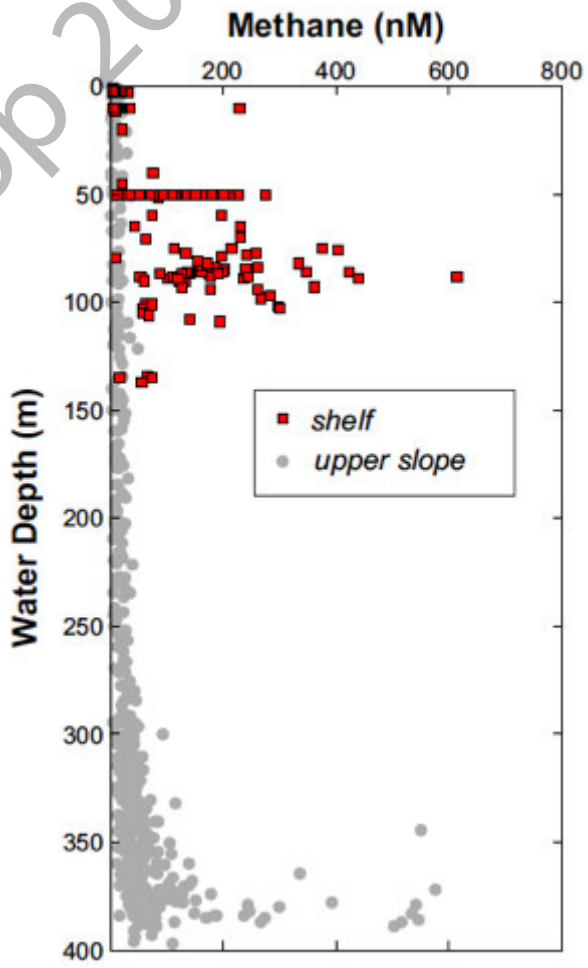


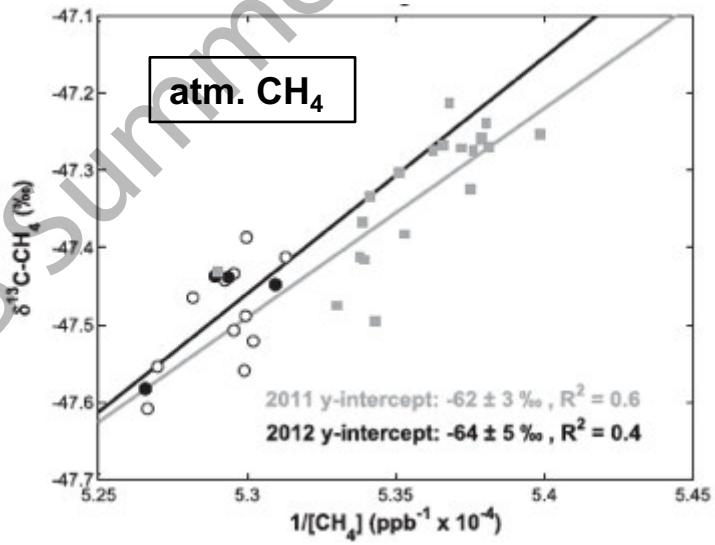
McGinnis et al., 2006

Methane removal processes are strong in 100-150 m deep waters



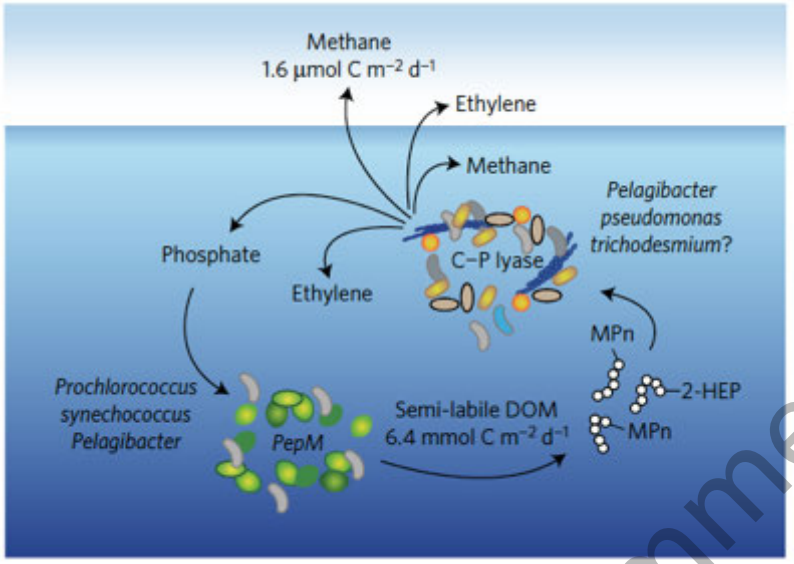
Lund Myhre et al., 2016



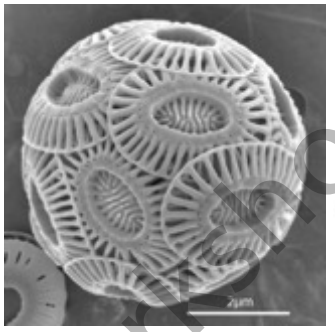


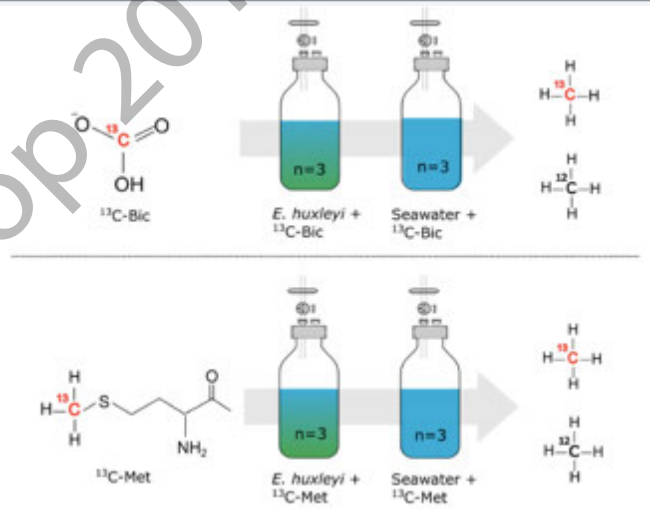
Graves et al., 2015

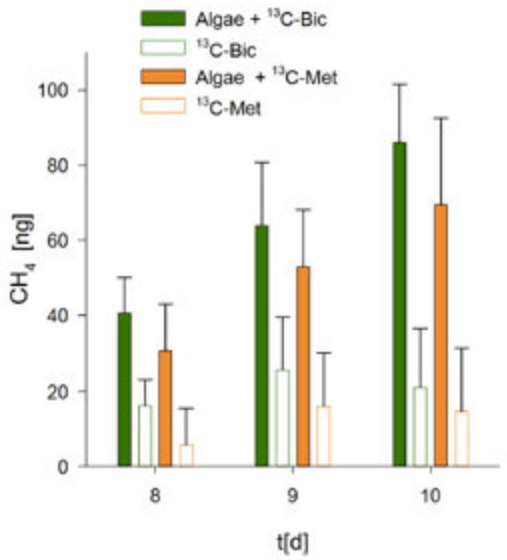
How prevalent is *in situ*-produced methane in shelf waters?



Repeta et al., 2016

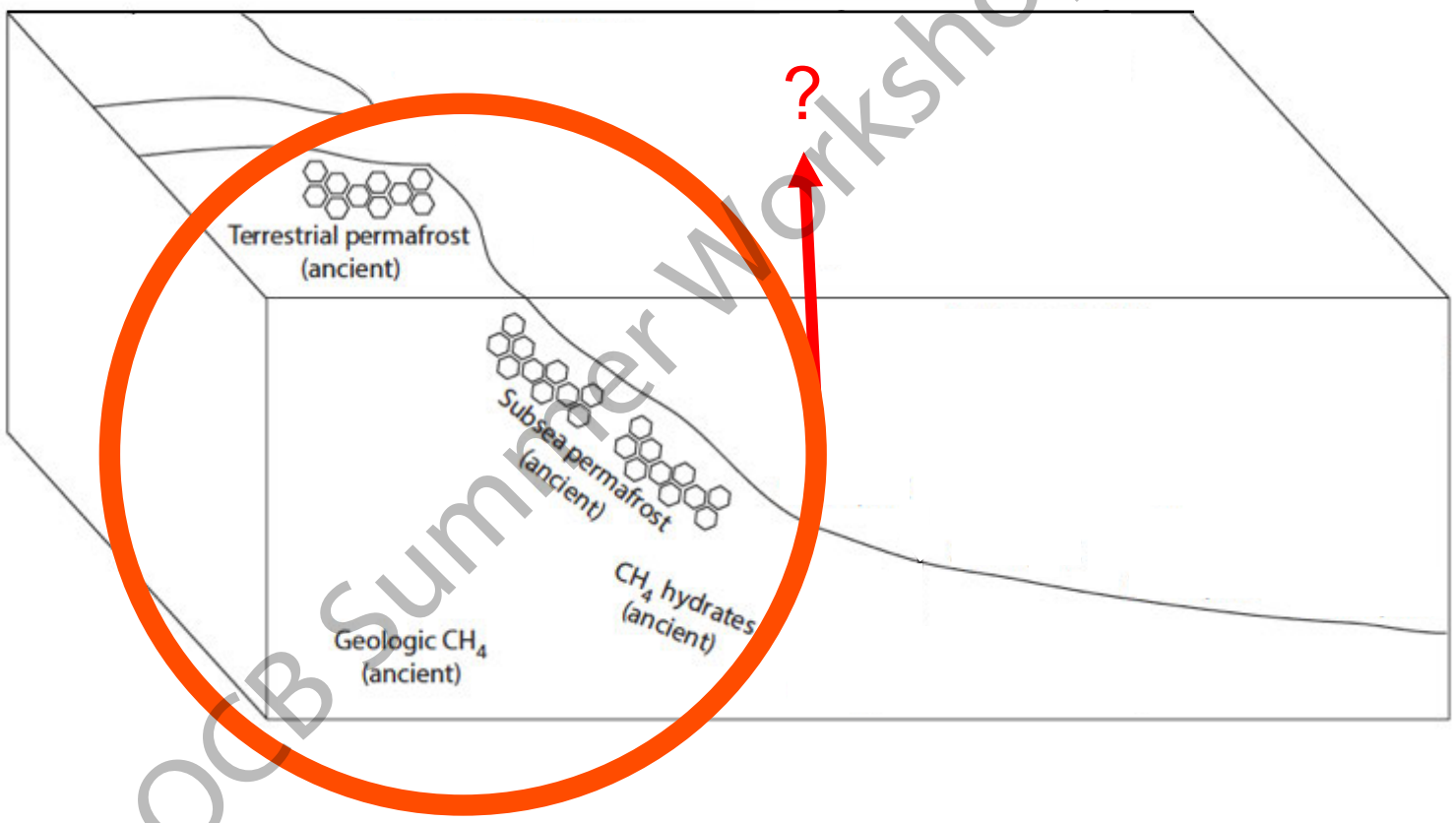




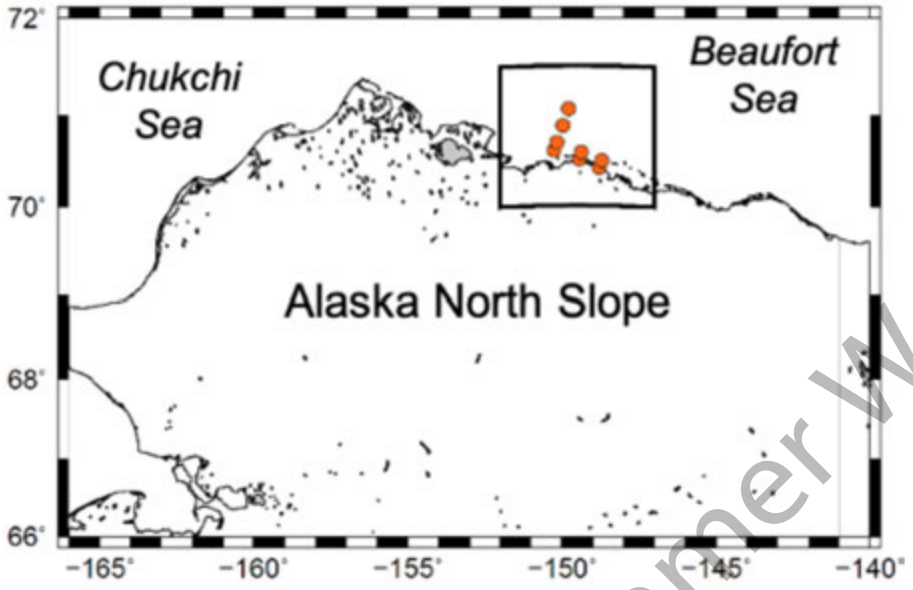


Lenhart et al., 2016

Are ancient sources of methane being emitted from the Arctic Ocean to the atmosphere?

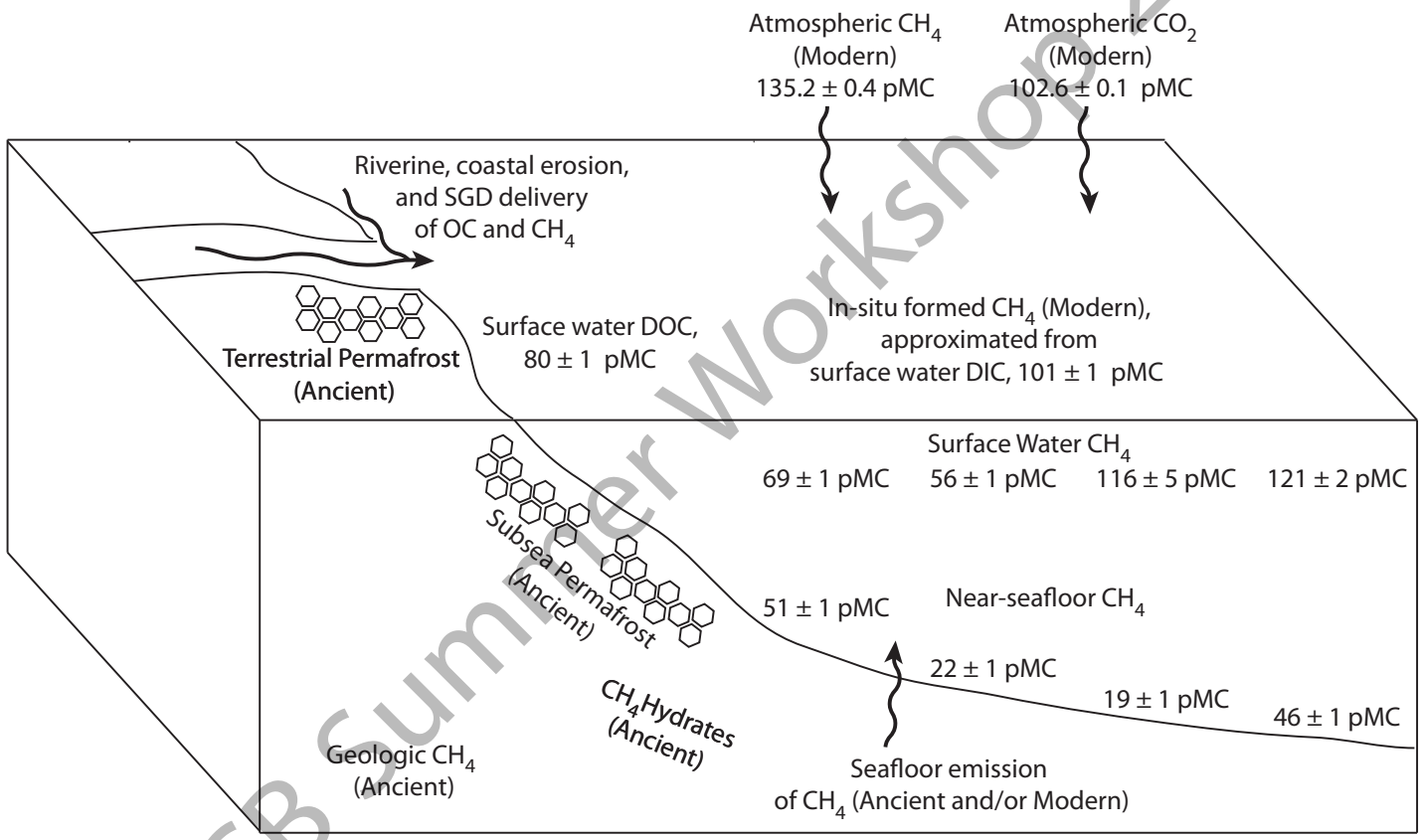


Study area: Alaskan Beaufort Sea



- Cruise in late Aug. – early Sept. 2015
- Water depth of stations ranged from 2 – 40 m
- Natural abundance ^{14}C study

^{14}C was used to fingerprint the sources of dissolved methane

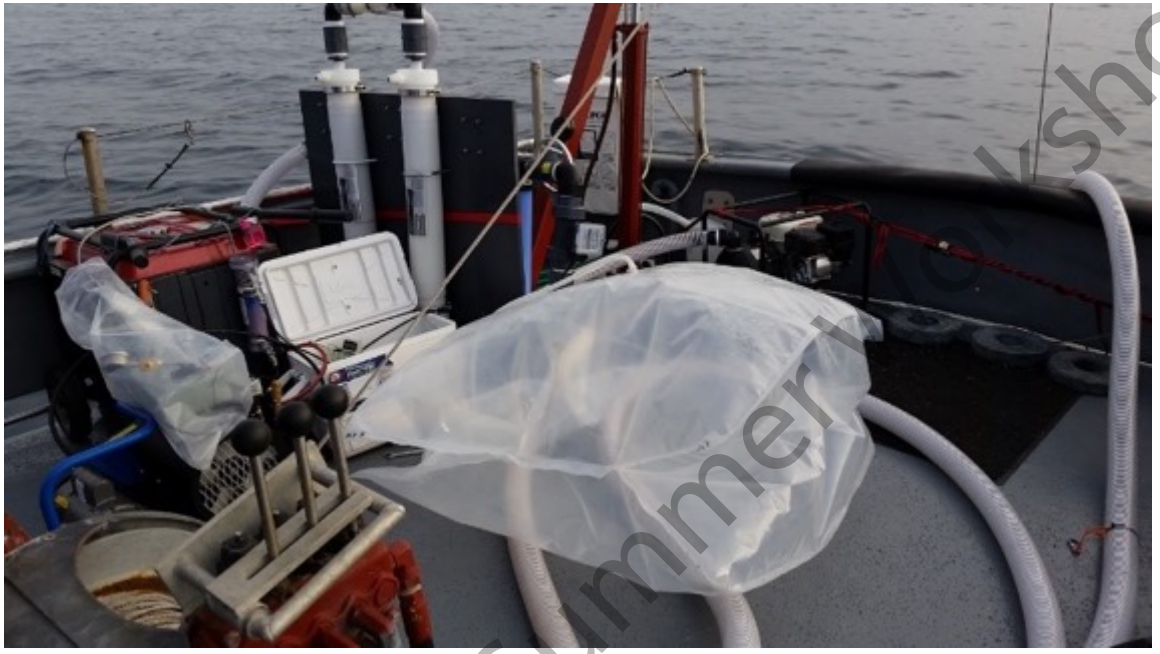


Sparrow et al., 2018

Samples were collected from 30,000 L SW for each ^{14}C-methane sample

Sparrow and Kessler, 2017

300 L of gas was extracted from the water and compressed into a 2 L cylinder



Sparrow and Kessler, 2017

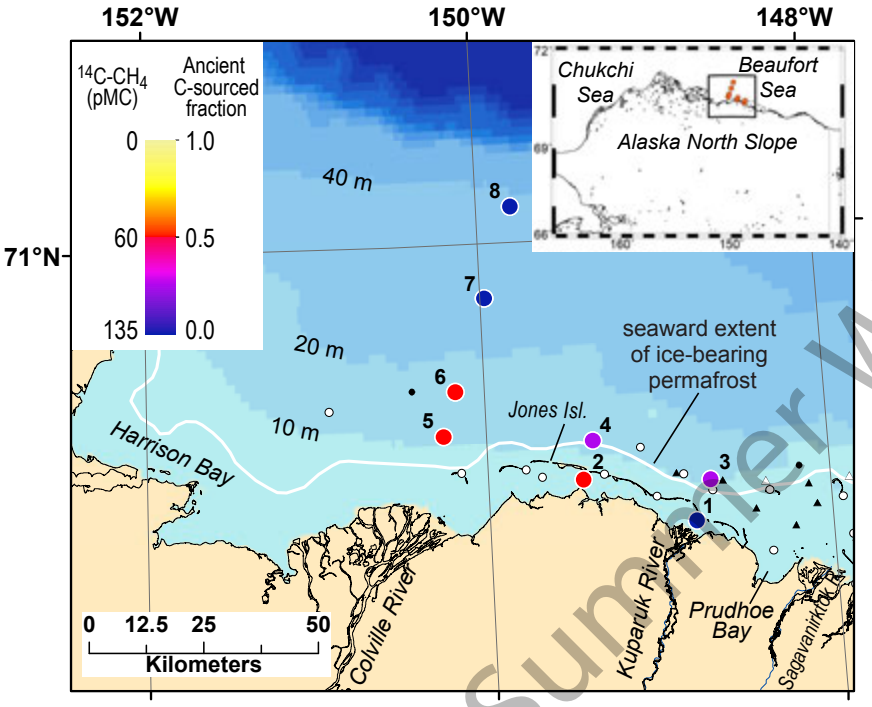
“Decoupling” of surface and deep waters observed within the shallow shelf waters

Table 1. Calculated fractions of ancient and modern C–sourced CH_4 in each sample.

Station	Water depth (m)	Distance offshore (km)	Sample type	Ancient C–sourced CH_4 fraction, f_c	Atmospheric-sourced CH_4 fraction, f_a	In situ produced CH_4 fraction, f_i
1	2	3	Lagoon	0.18 ± 0.06	0.47 ± 0.18	0.35 ± 0.25
2	3	2	Lagoon	0.50 ± 0.04	0.23 ± 0.12	0.27 ± 0.17
3	14	12	Surface	0.26 ± 0.06	0.37 ± 0.18	0.37 ± 0.24
			Near-seafloor	0.60 ± 0.04	0.18 ± 0.10	0.22 ± 0.13
4	15	10	Surface	0.39 ± 0.05	0.29 ± 0.15	0.33 ± 0.20
			Near-seafloor	0.45 ± 0.05	0.25 ± 0.14	0.30 ± 0.18
5	13	18	Surface	0.42 ± 0.05	0.27 ± 0.14	0.31 ± 0.19
			Near-seafloor	0.58 ± 0.04	0.19 ± 0.10	0.23 ± 0.14
6	19	27	Surface	0.53 ± 0.04	0.21 ± 0.12	0.26 ± 0.16
			Near-seafloor	0.83 ± 0.02	0.07 ± 0.04	0.10 ± 0.06
7	28	48	Surface	0.10 ± 0.03	0.72 ± 0.10	0.18 ± 0.13
			Near-seafloor	0.86 ± 0.02	0.06 ± 0.04	0.08 ± 0.05
8	38	69	Surface	0.07 ± 0.03	0.79 ± 0.07	0.14 ± 0.10
			Near-seafloor	0.61 ± 0.03	0.17 ± 0.10	0.22 ± 0.13

Sparrow et al., 2018

Modern sources of methane dominate in surface waters where depth ≥ 30 m



Sparrow et al., 2018

- Ancient sources are contributing to the dissolved methane pool
- Surface water methane in very shallow waters (<20 m) had significant ancient contributions (25-50%)
- In waters ≥30 m, surface water methane had very little ancient contributions (5-10%)
- Study proves existence of the Arctic Ocean methane-climate feedback, however, it remains undetectable in atmospheric methane data

Thanks!

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