Methane Dynamics from Arctic Shelves to Deep Basins

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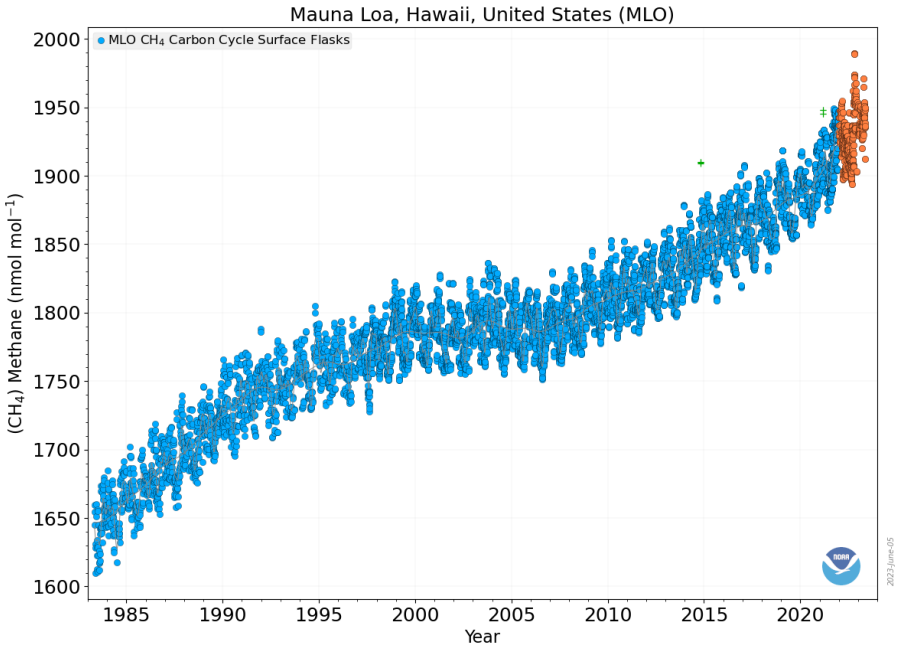
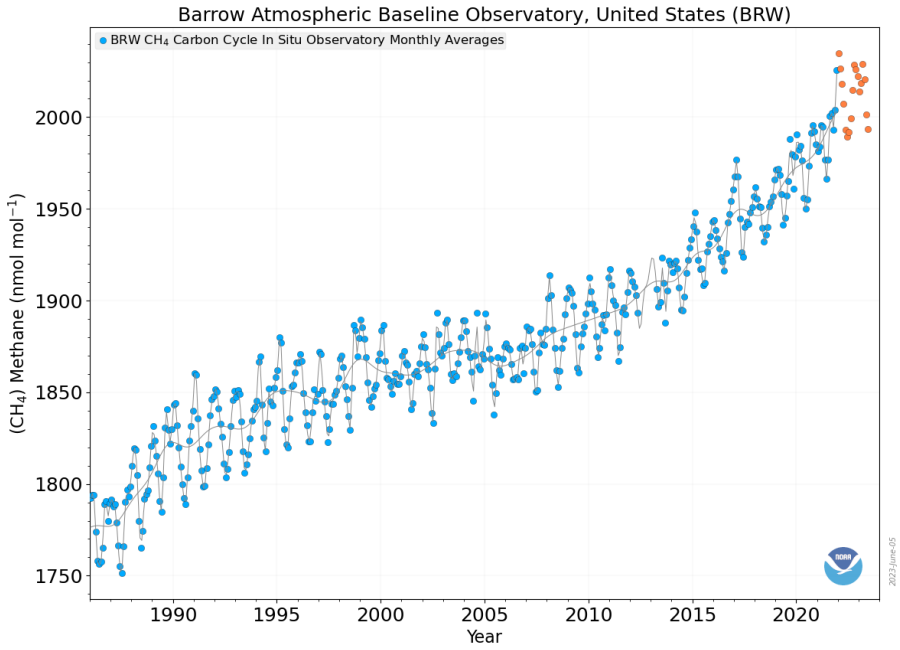
Why are we looking at methane?

It's the **2nd most important gas responsible for the greenhouse effect**
(17% of warming effect is due to methane)

And it's **rising.**

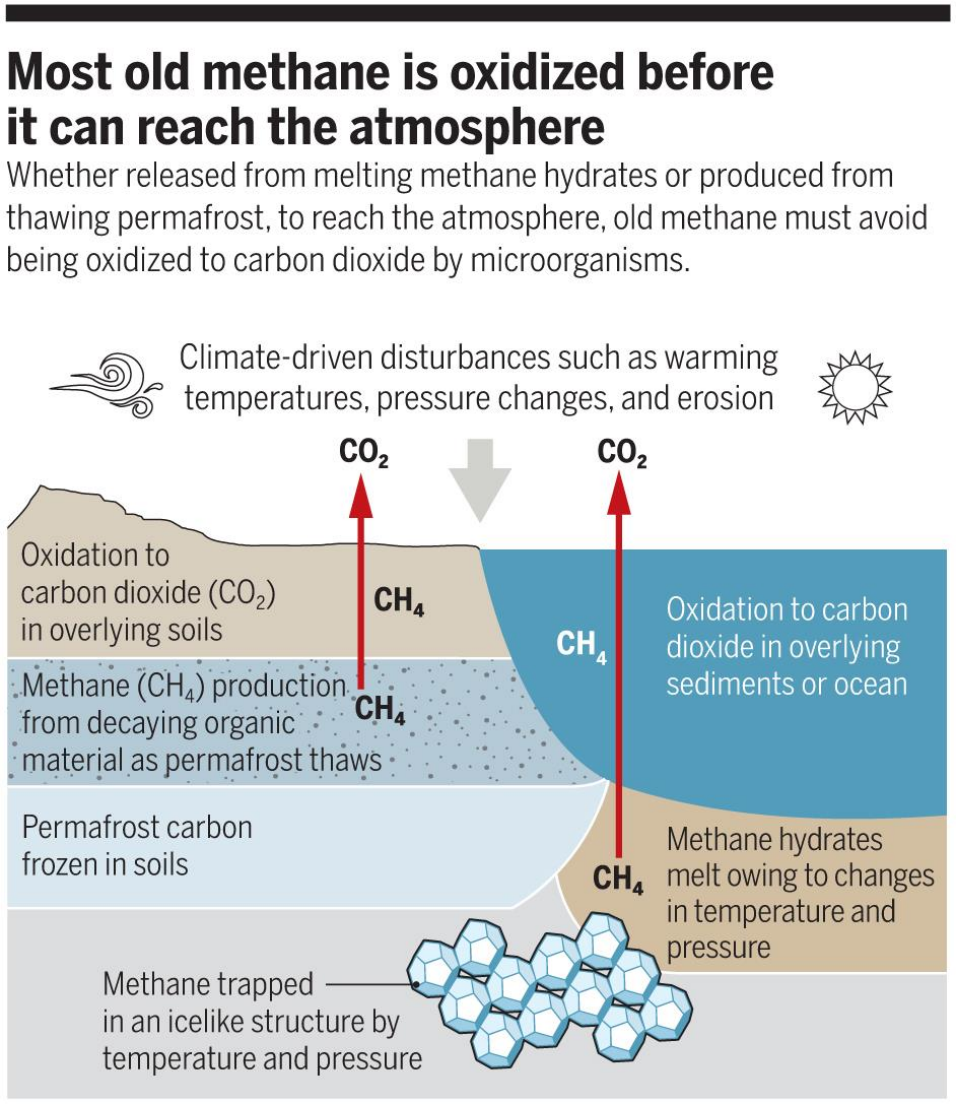




For reference: Pre-industrial revolution concentrations ~700 ppb

Origin of methane in the Ocean

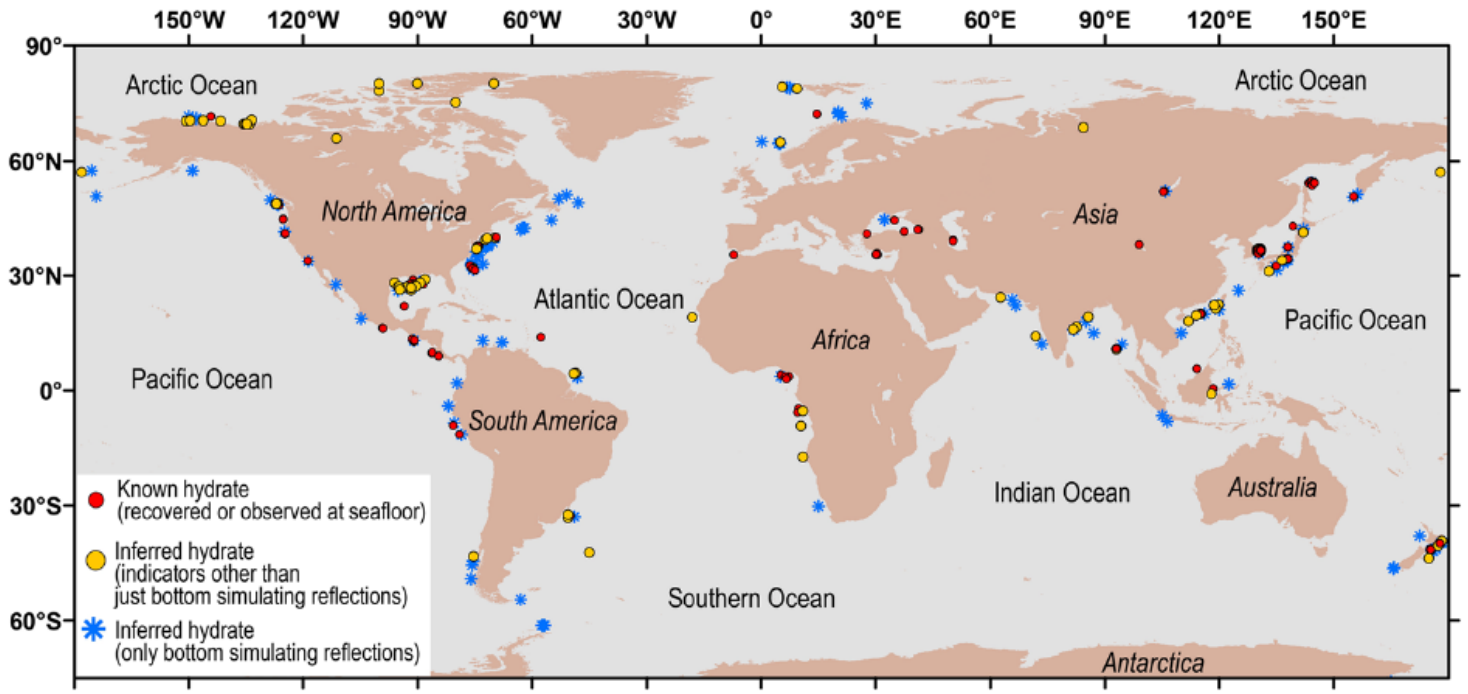
- Methane is issued from **sediments** for the most part
- It is a product of Organic Matter degradation ➔ **Biogenic** methane
- It is a product geological processes (methane associated to oil fields, natural gas)
  - ➔ **Thermogenic** methane (millions of years old)



Dean, 2020, Science

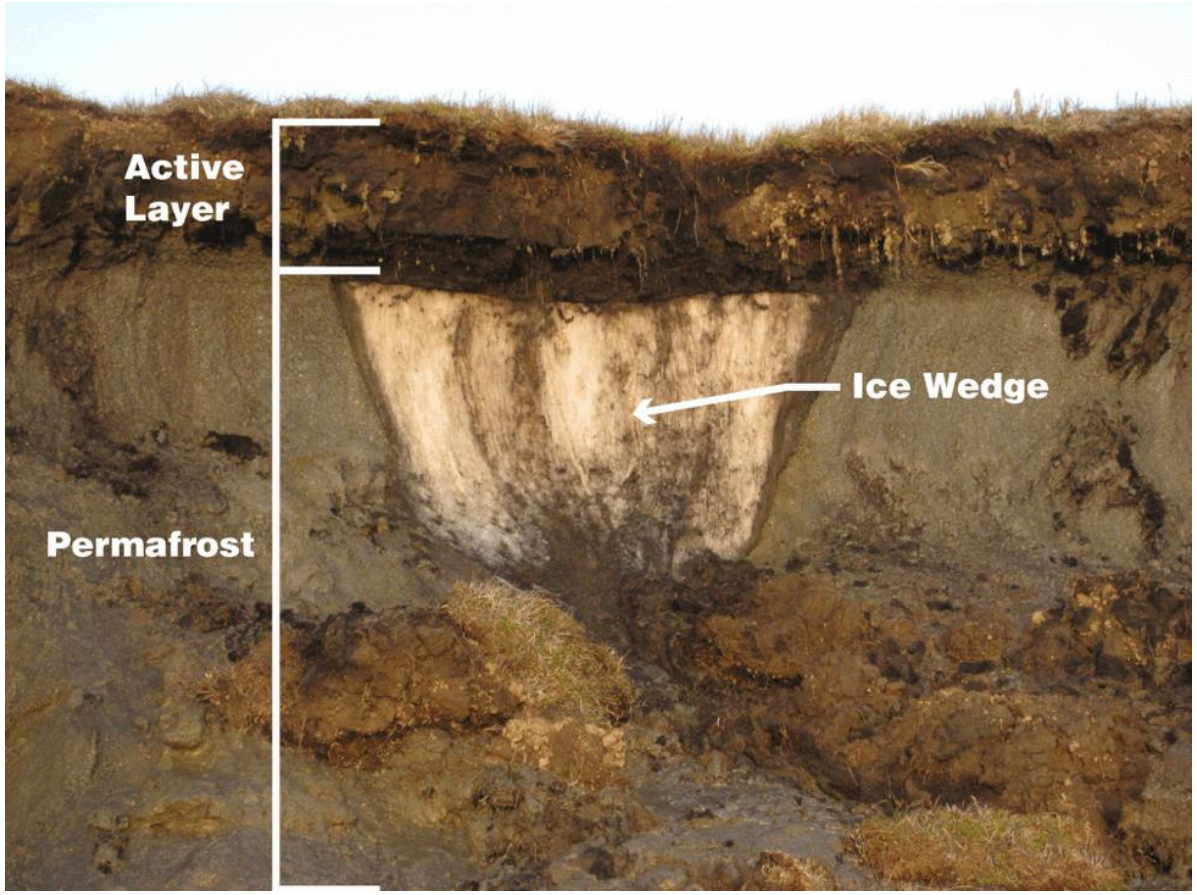
How about Methane in the Arctic?

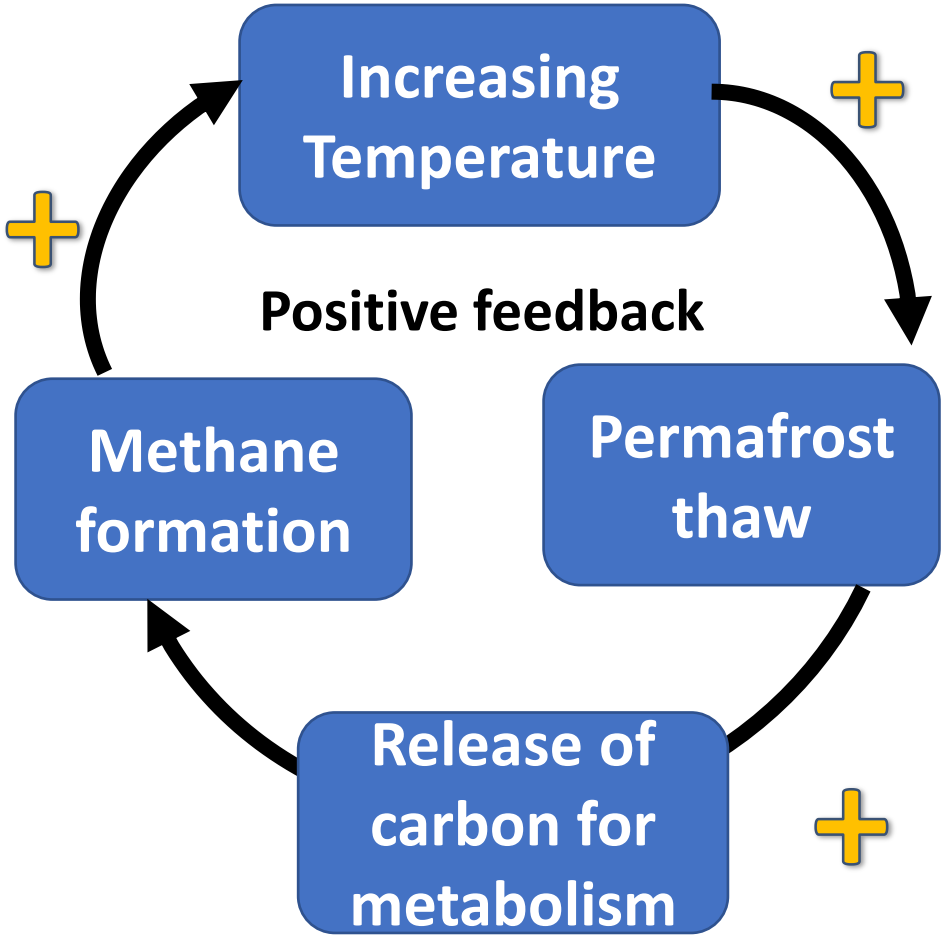
- Arctic Ocean is huge, not very productive, so not prone to lots of methane production in sediments. With the exception of shelves?
- However, temperature and pressure conditions are such that **methane hydrates** can be formed within a few meters of water.



Ruppel and Waite, 2020

The problem: Arctic temps increasing; thawing permafrost from top down

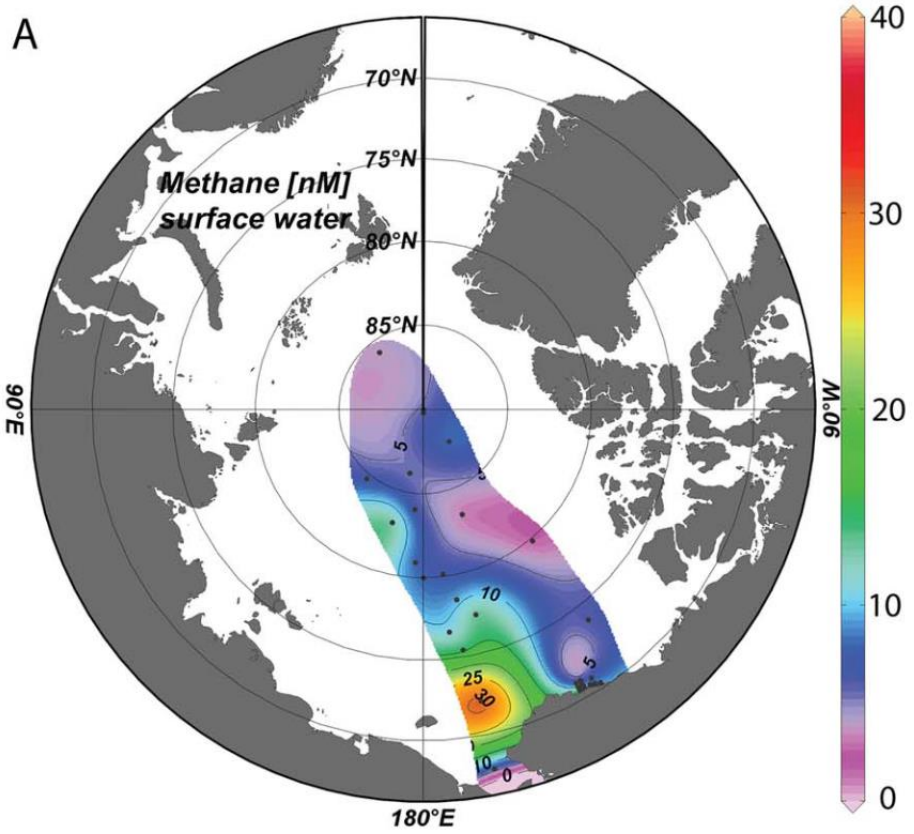


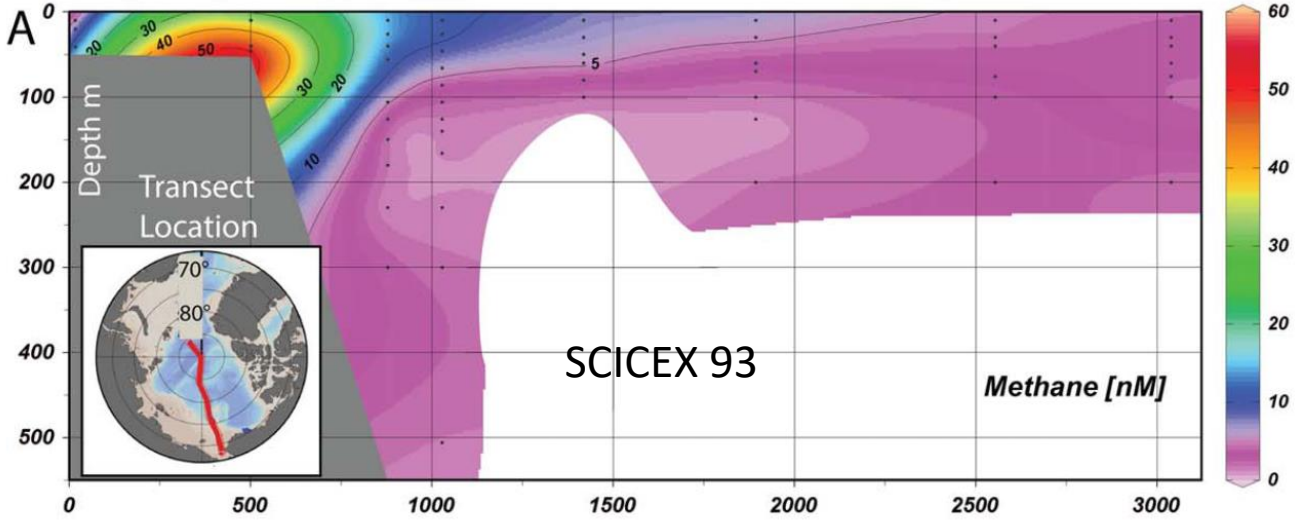


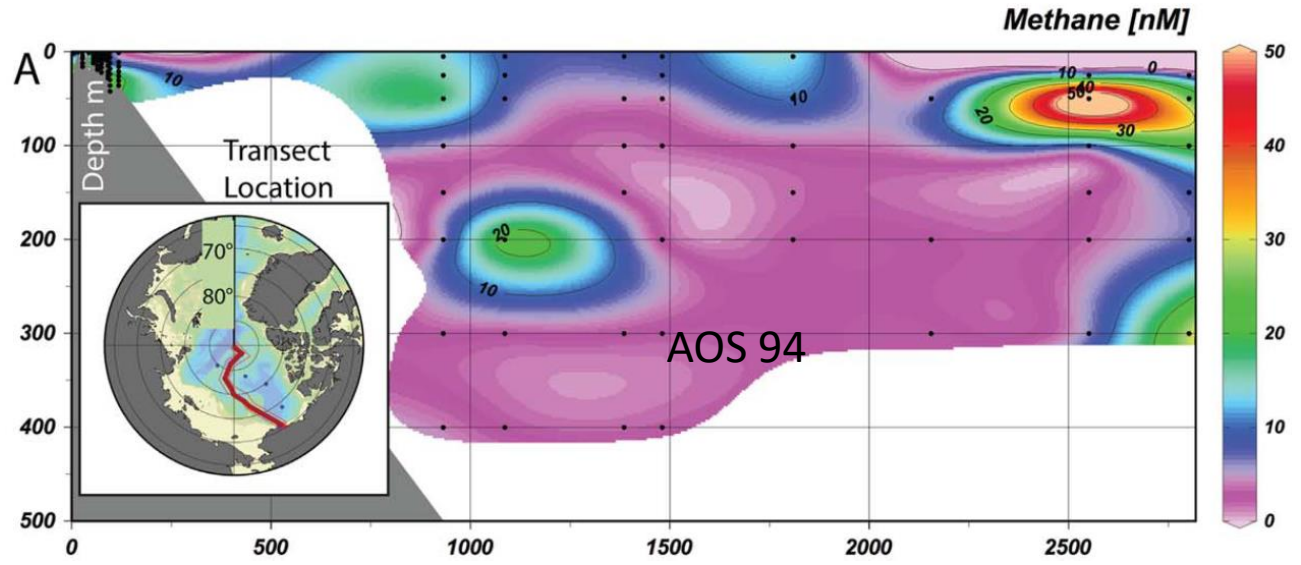
Active layer is getting thicker with warming

➔Does global warming lead to melting gas hydrates and permafrost in underlying sediments?

Latest investigations in the Deep Arctic Basins





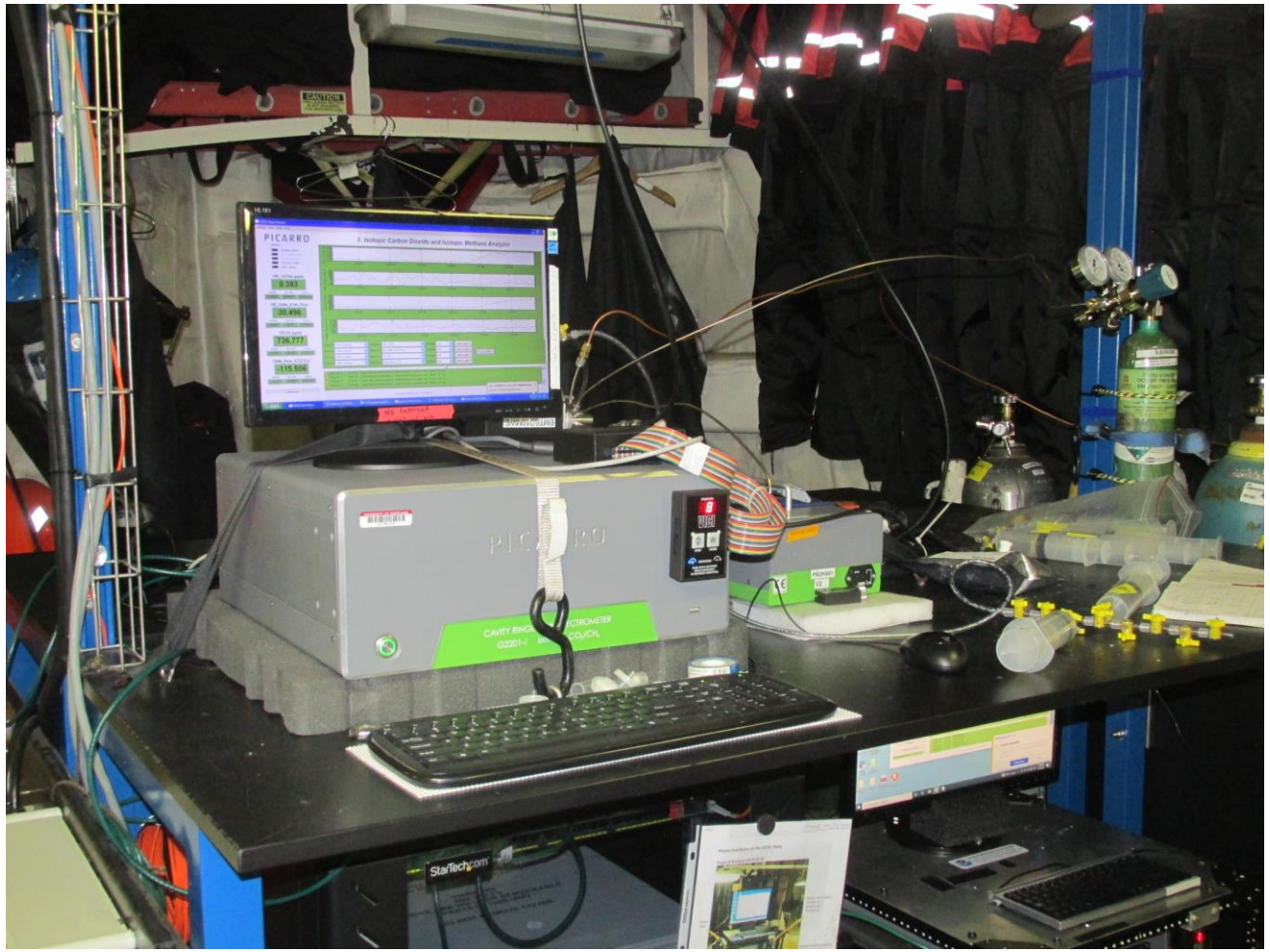


Lorenson et al, 2016, L&O

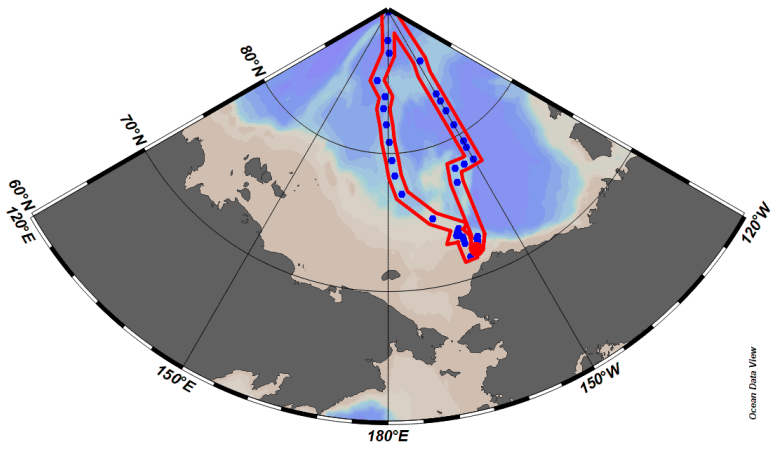
How we measure methane dissolved in water

- Retrieve water from rosette and collect in capped vial
- Inject methane-free headspace gas
- Shake water and headspace gas to reach **equilibrium**
- We analyze the headspace by injecting into instrument (CRDS, Gas chromatograph, etc.)

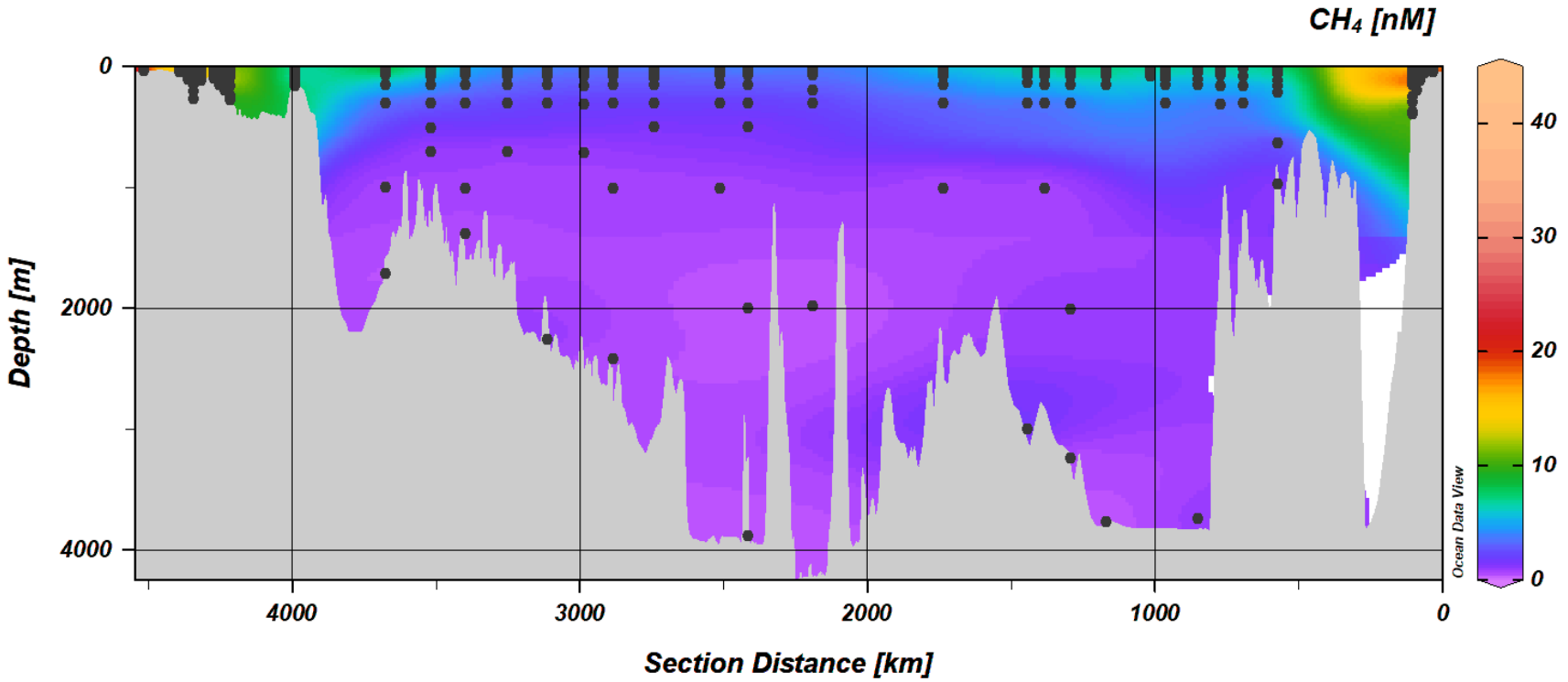
- The equilibrium between headspace and water has been experimentally determined as a function of temperature and salinity.



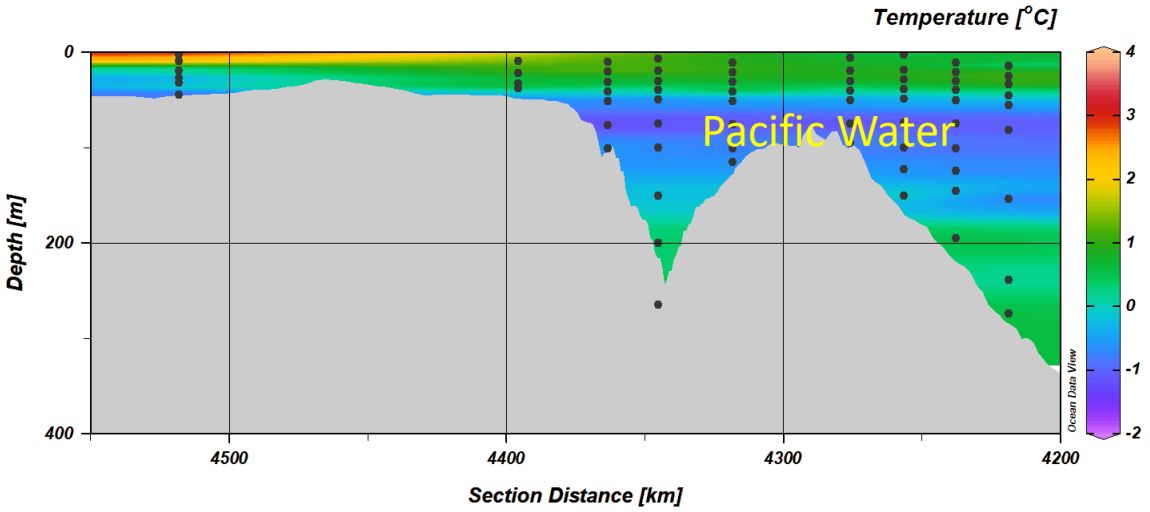
Methane in deep Basins and Alaska Shelf waters in 2022

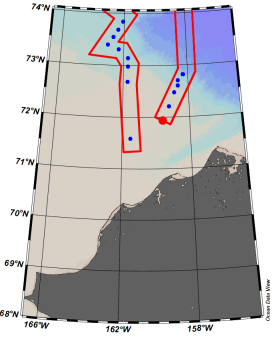


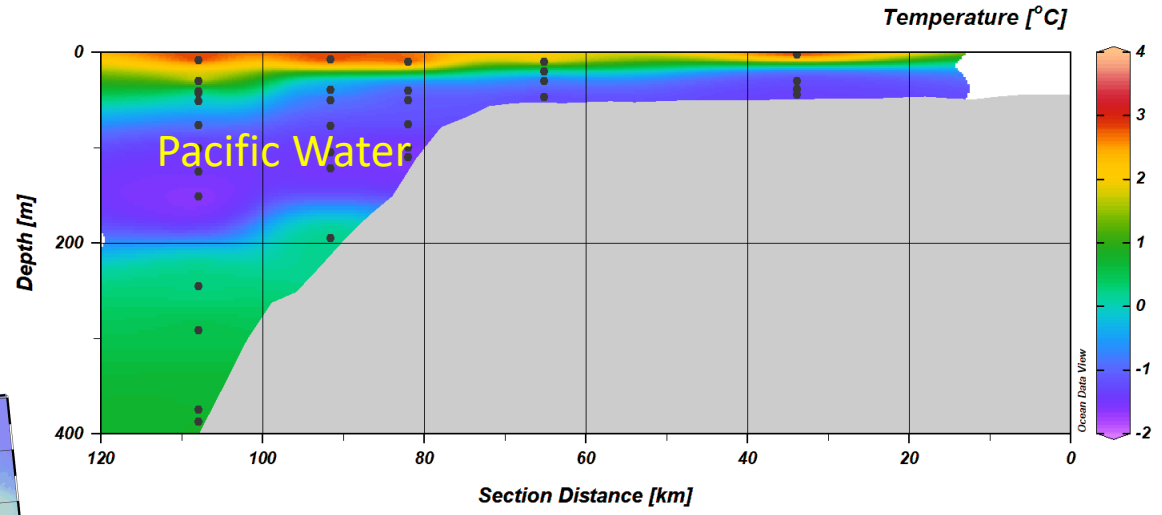
Healy cruise track, Oct – Sep 2022

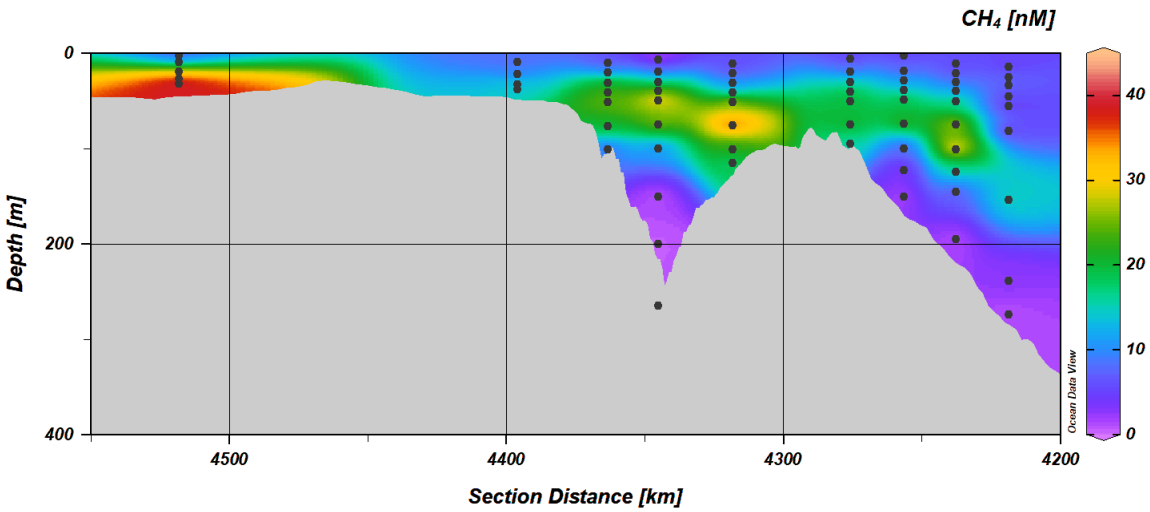


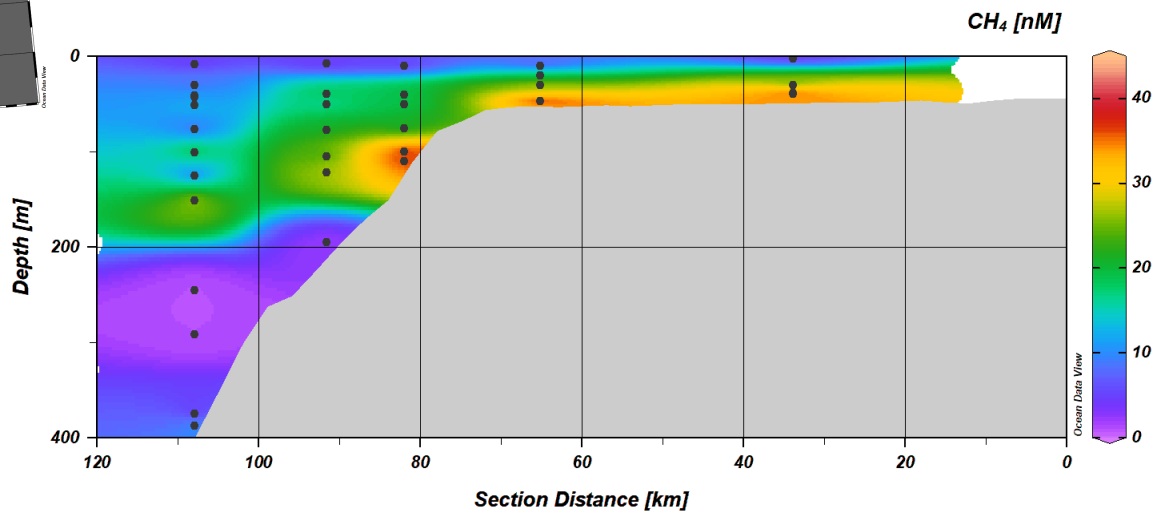
Methane over Alaska Shelf





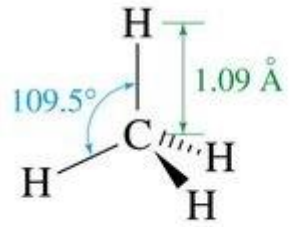


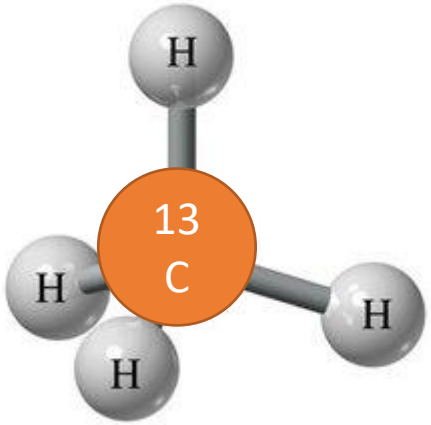


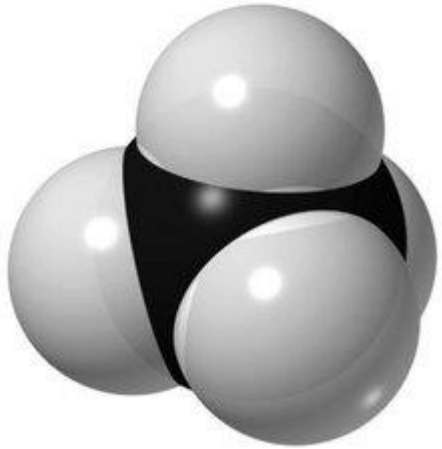


Where does this methane come from?

- We use **stable isotopes** of methane as a tracer





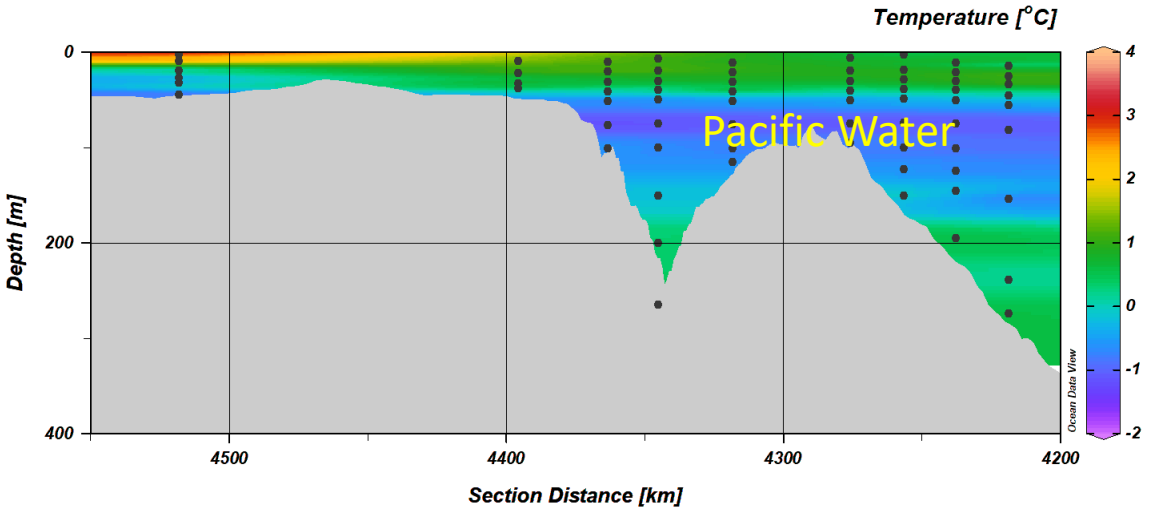


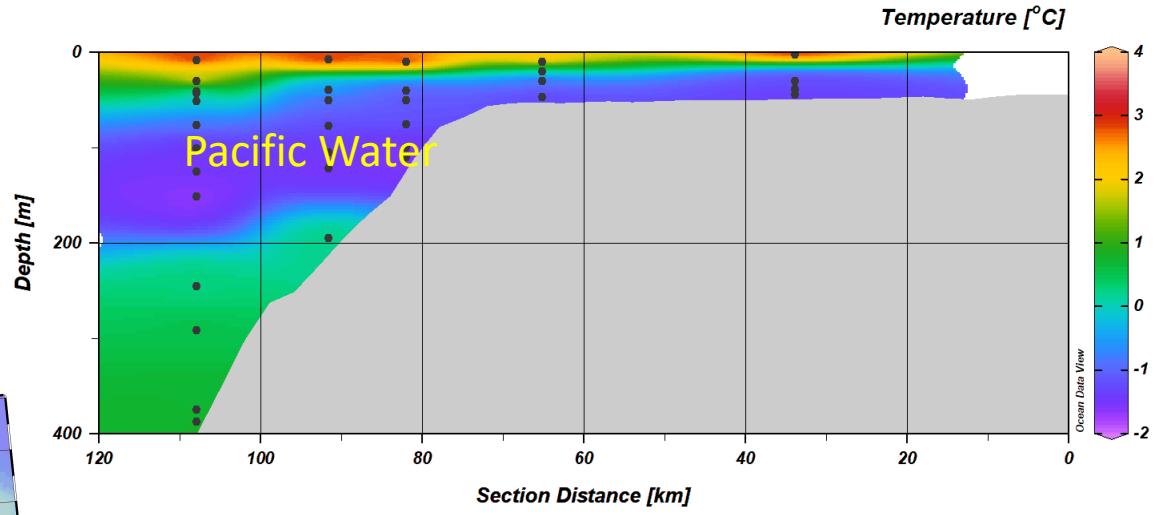
- **Biogenic** methane is isotopically LIGHT ➔ $\delta^{13}C\text{-}CH_4 < -60$ ‰ vs VPDB

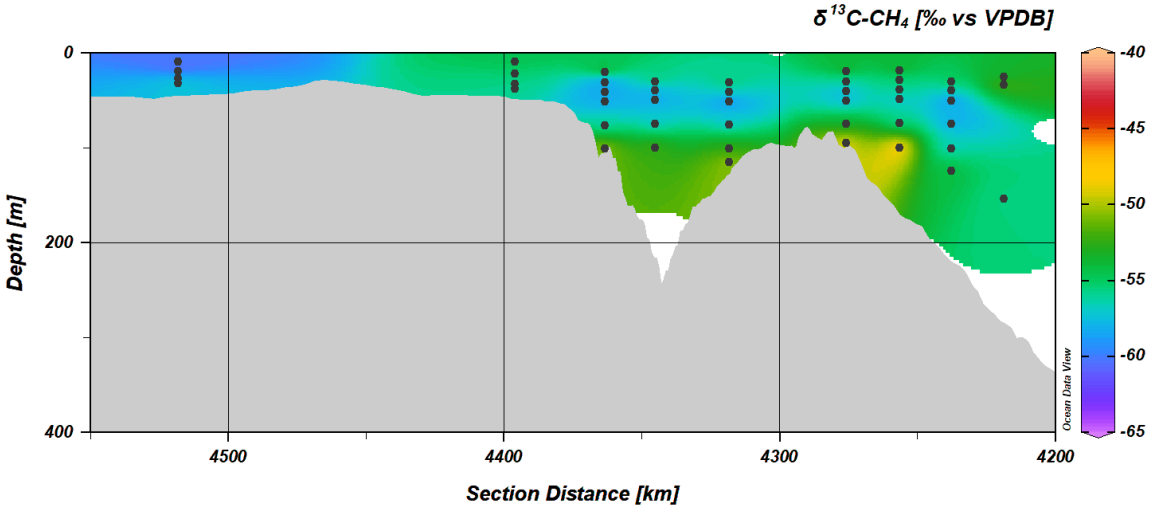
Vs

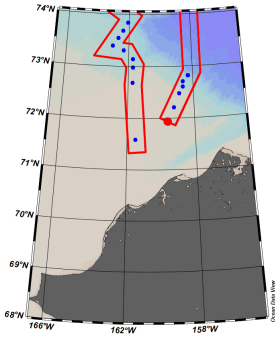
- **Thermogenic** Methane is isotopically HEAVY ➔ $\delta^{13}C\text{-}CH_4 > -45$ ‰ vs VPDB

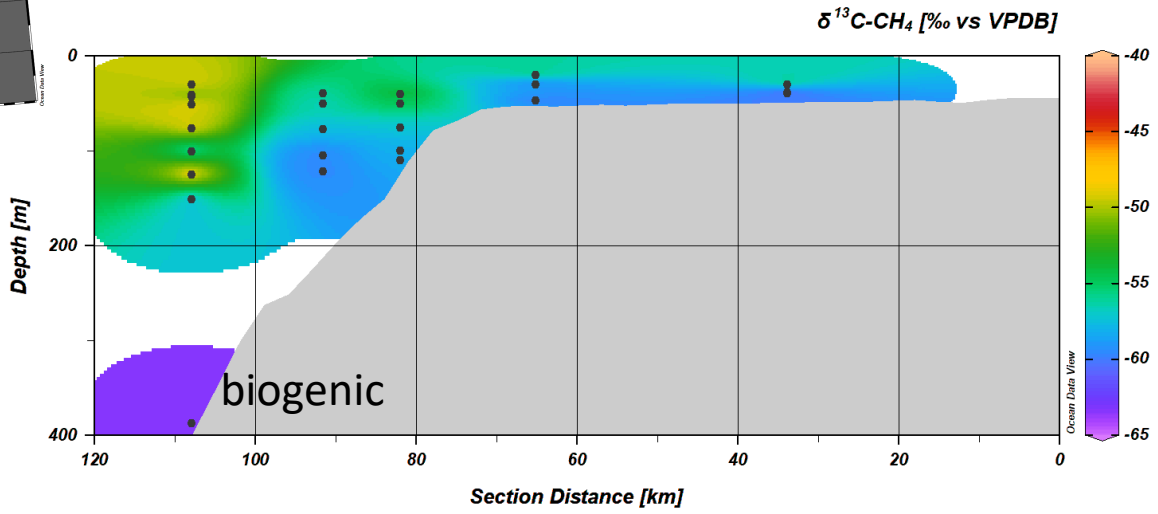
Methane stable isotopic signature



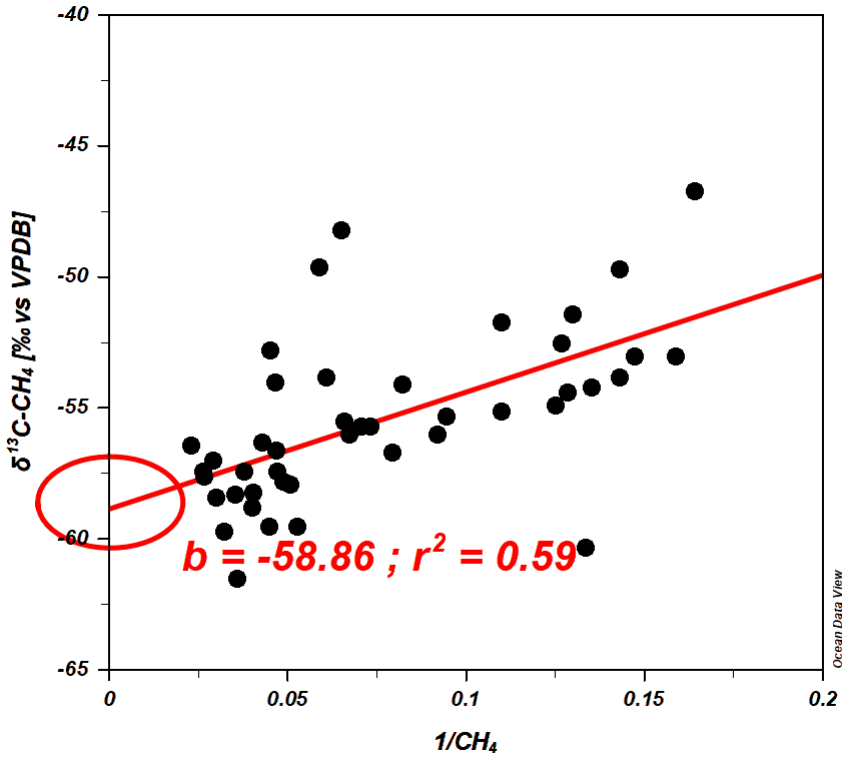


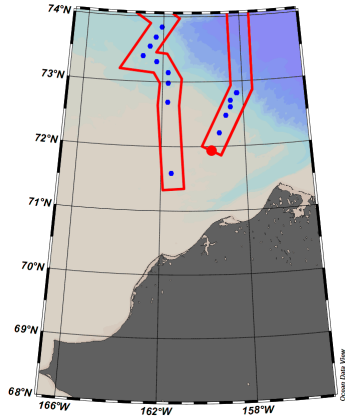


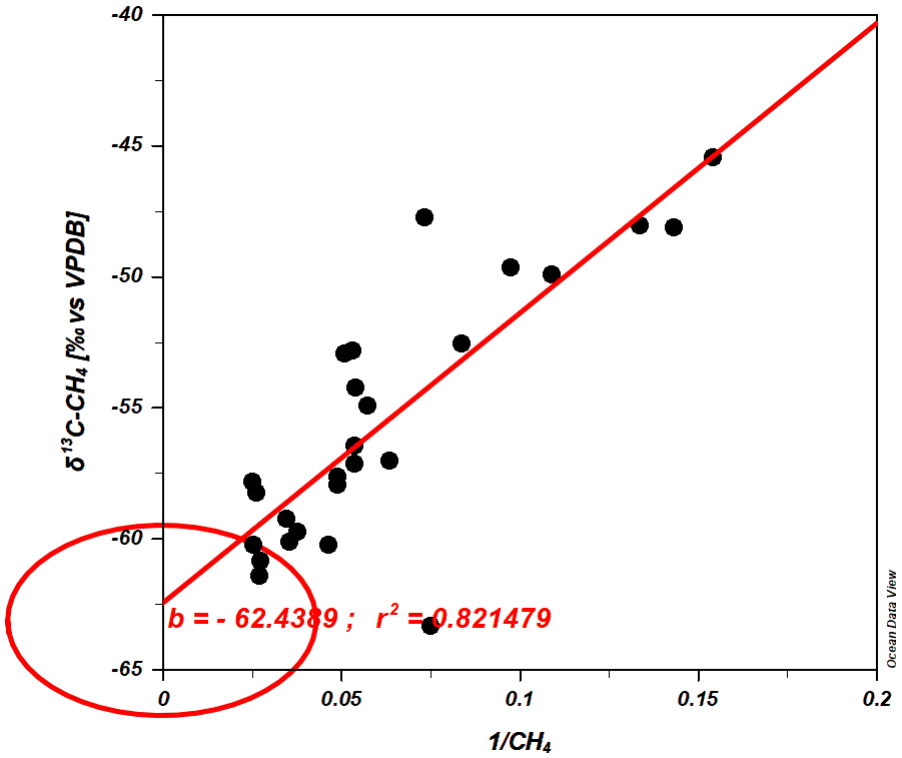




Finding methane end-member using Keeling plots.







- On both transects, the end-member signatures are very similar (~-60 ‰)
- Consistent with a **unique source of methane**
- Consistent with a **biogenic source of methane** : possibly melting methane hydrate, or submarine permafrost, or methane locally produced (methanogenesis) in sediments and diffusing to the water column.

Remaining questions and future work

- Calculate the flux of methane at the air-sea interface.
  - Is the Arctic Ocean a sink or a source for the Atmosphere?
- Assess sources and fate of methane:
  - Can we differentiate methane from hydrates, permafrost, early diagenesis?
  - Can we assess the extent of methane oxidation in sediments and water column?
- **Paper:** Fluxes and transport of methane in the Chukchi and Beaufort Seas. In progress for JGR-Oceans
- Data will be available with the **Artic Data Center**

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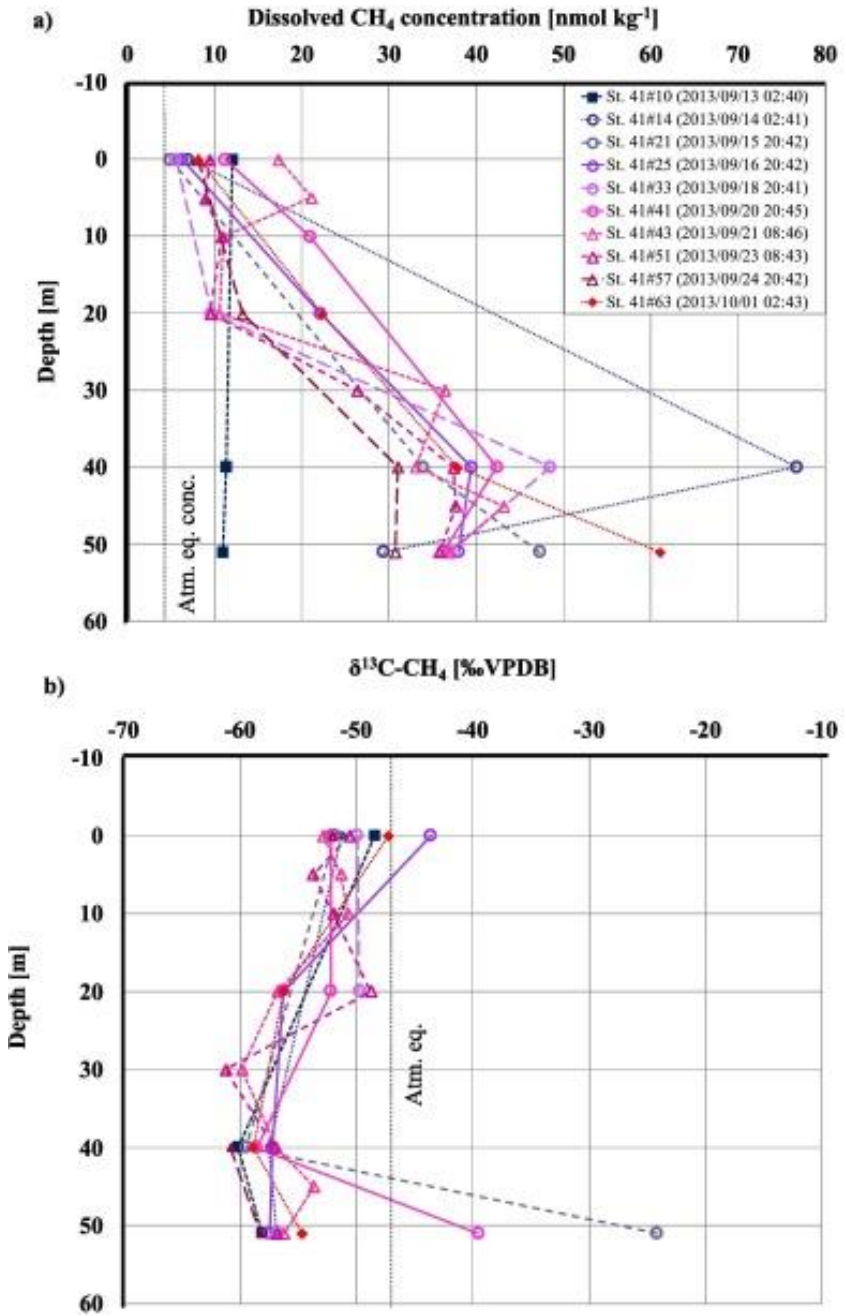
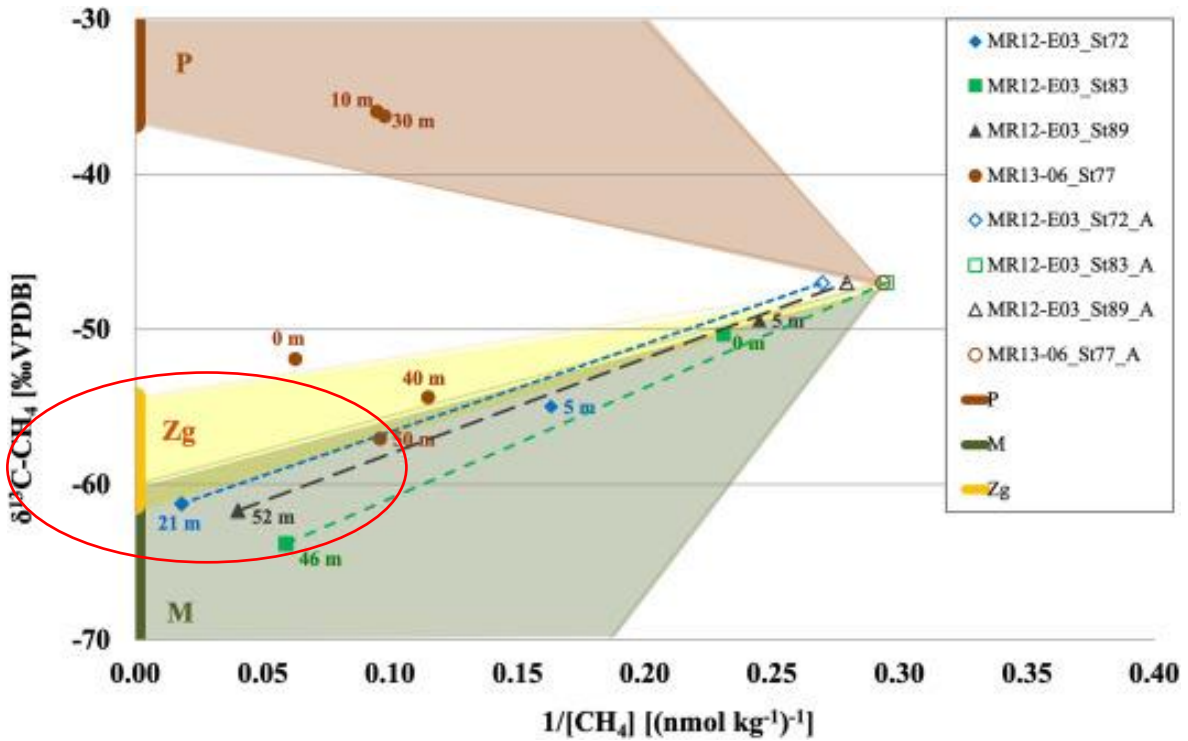
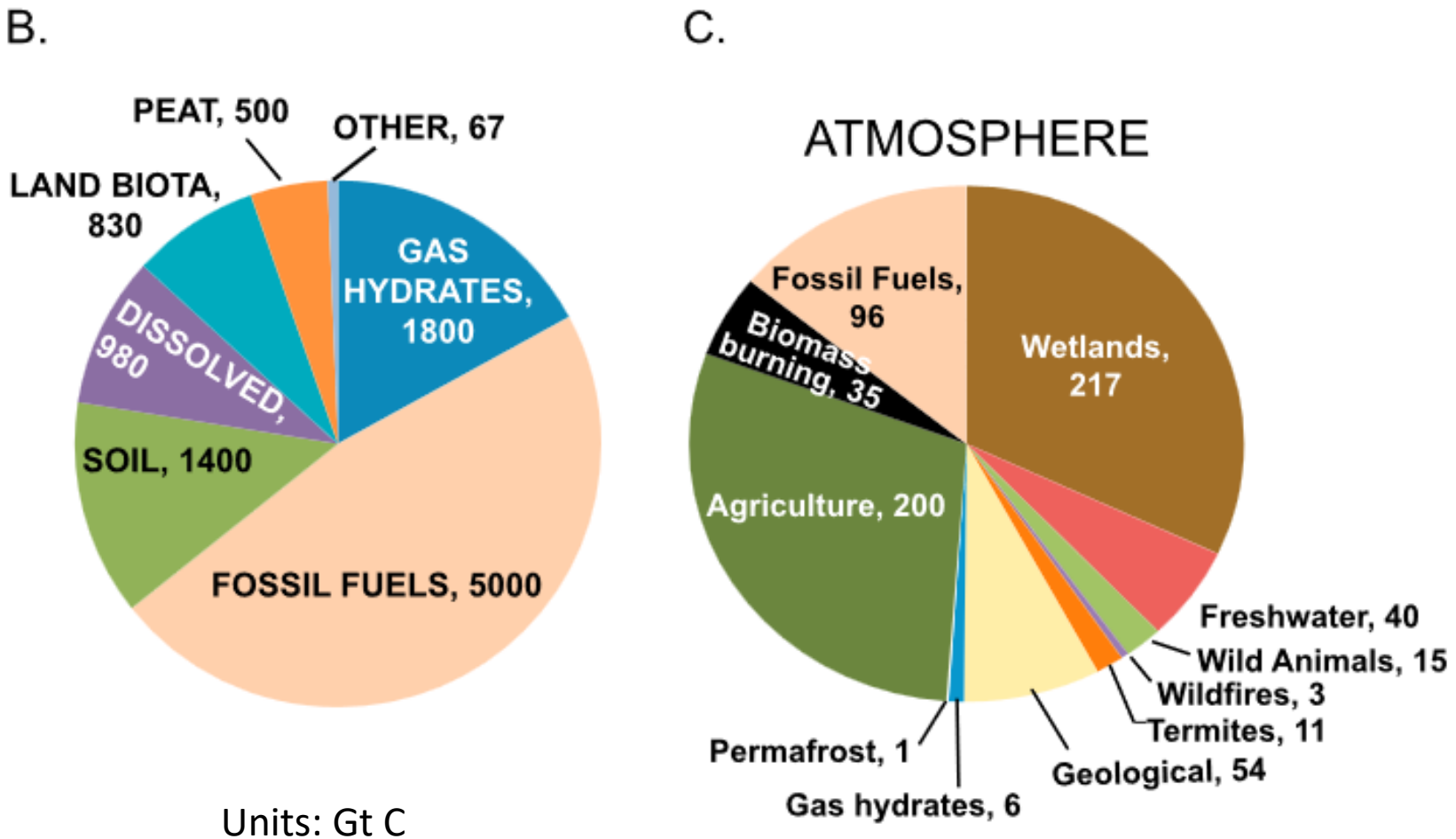
New data from the Chukchi Sea





Kudo et al, 2022, Mar Chem

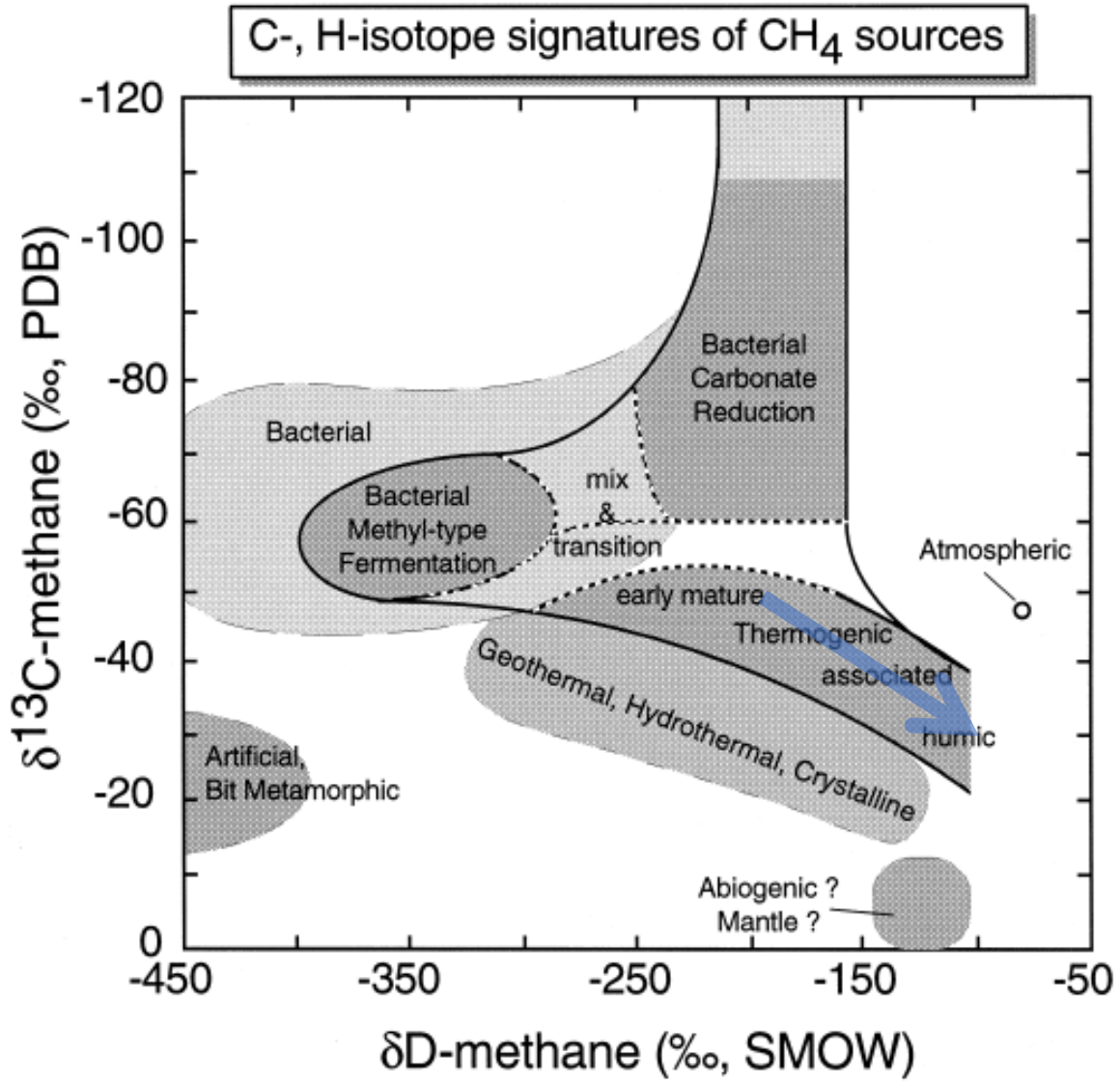
Place of hydrates in global carbon cycle



Units: Gt C

Ruppel and Kessler, 2017, Reviews of Geophysics

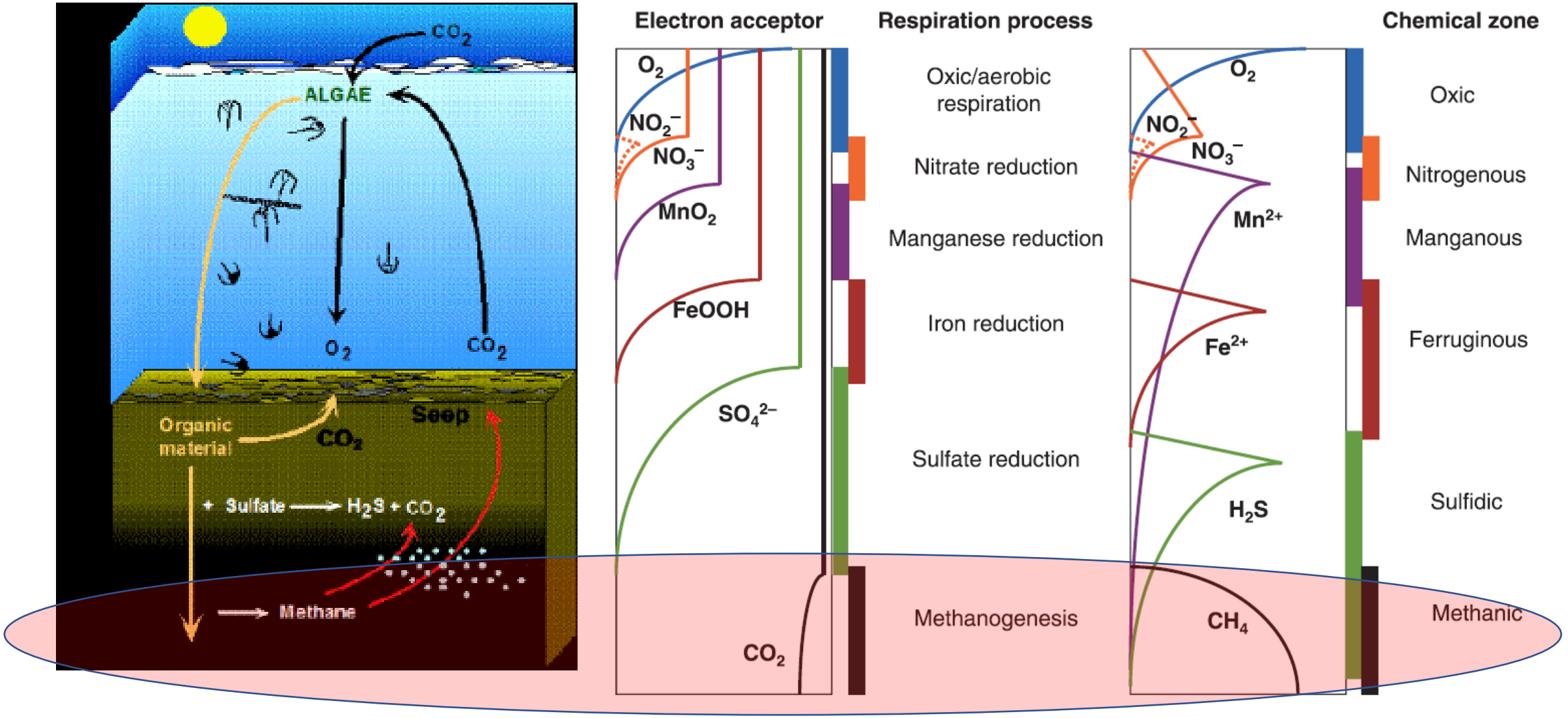
C and H isotope variations of methane in natural environments



thermogenic dD similar to dDorg = -80

from Whiticar, 1999, Chemical Geology

How is methane produced: microbes (methanogens)



Canfield and Thamdrup, 2009