Managing our Planet: State and Fate of the Arctic

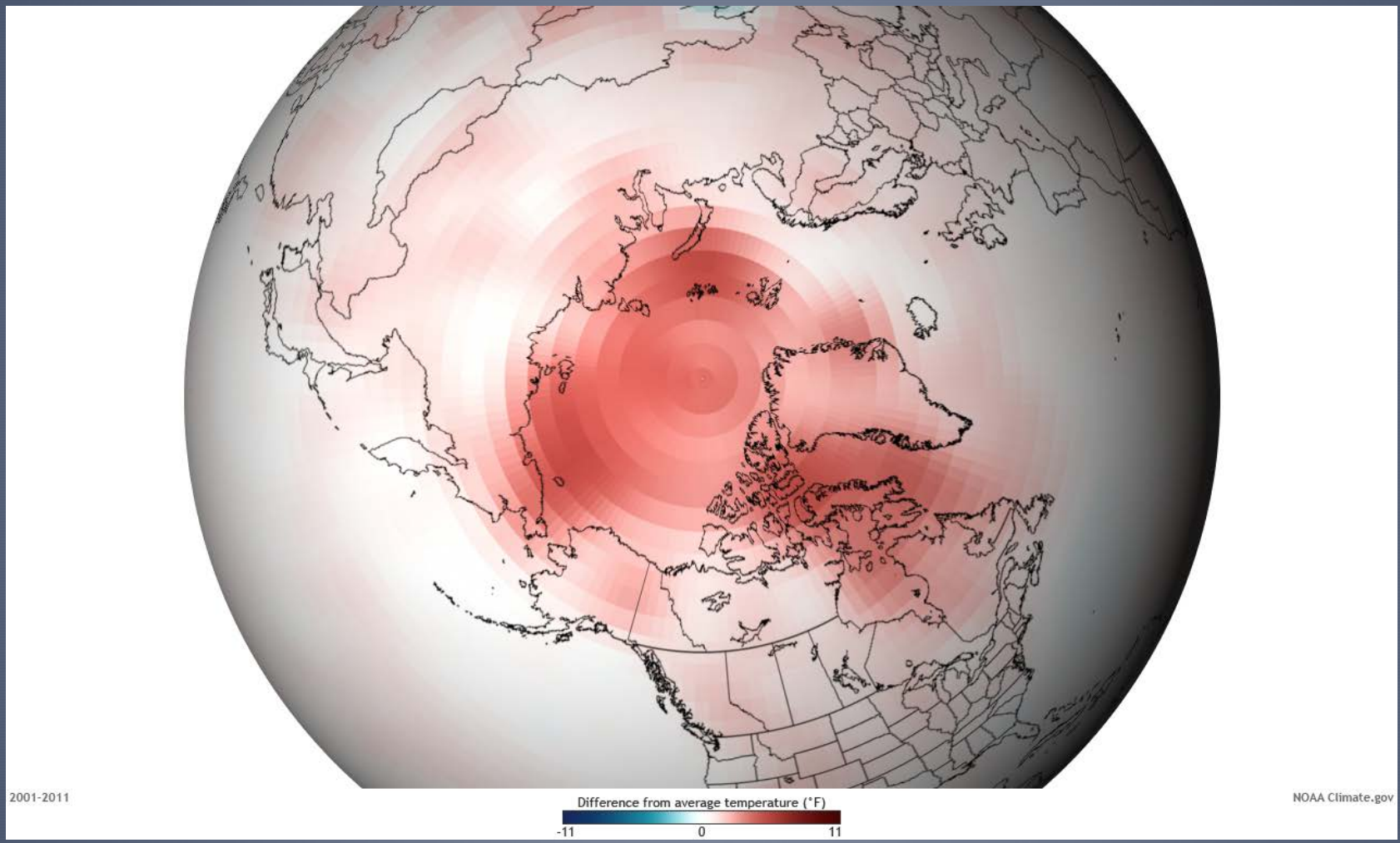
Wilson Center

Miriam C. Jones

U.S. Geological Survey

3/19/2014

Vulnerability of Arctic to climate warming



Temperature anomalies for the Arctic: 2001-2011

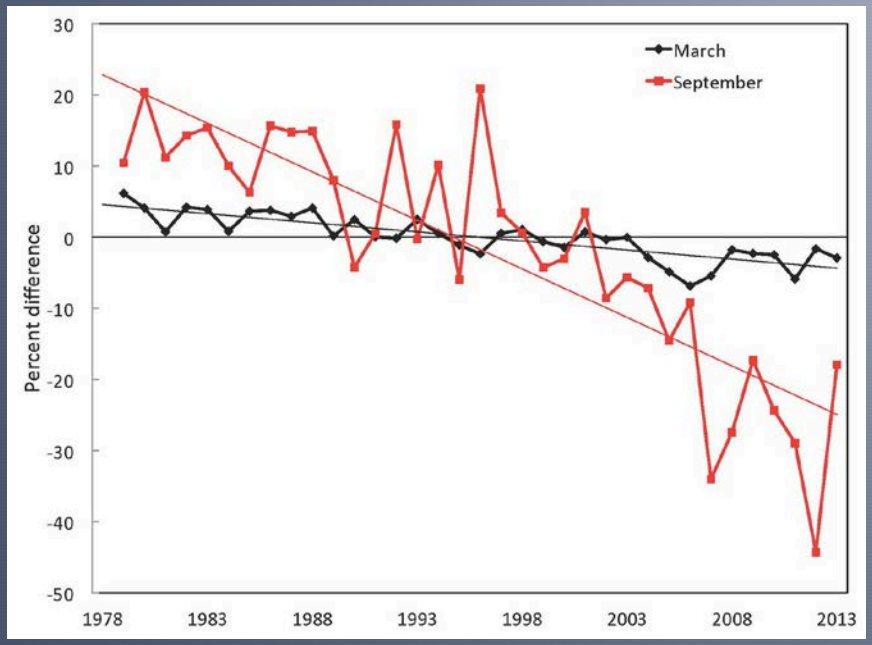
Source: NOAA

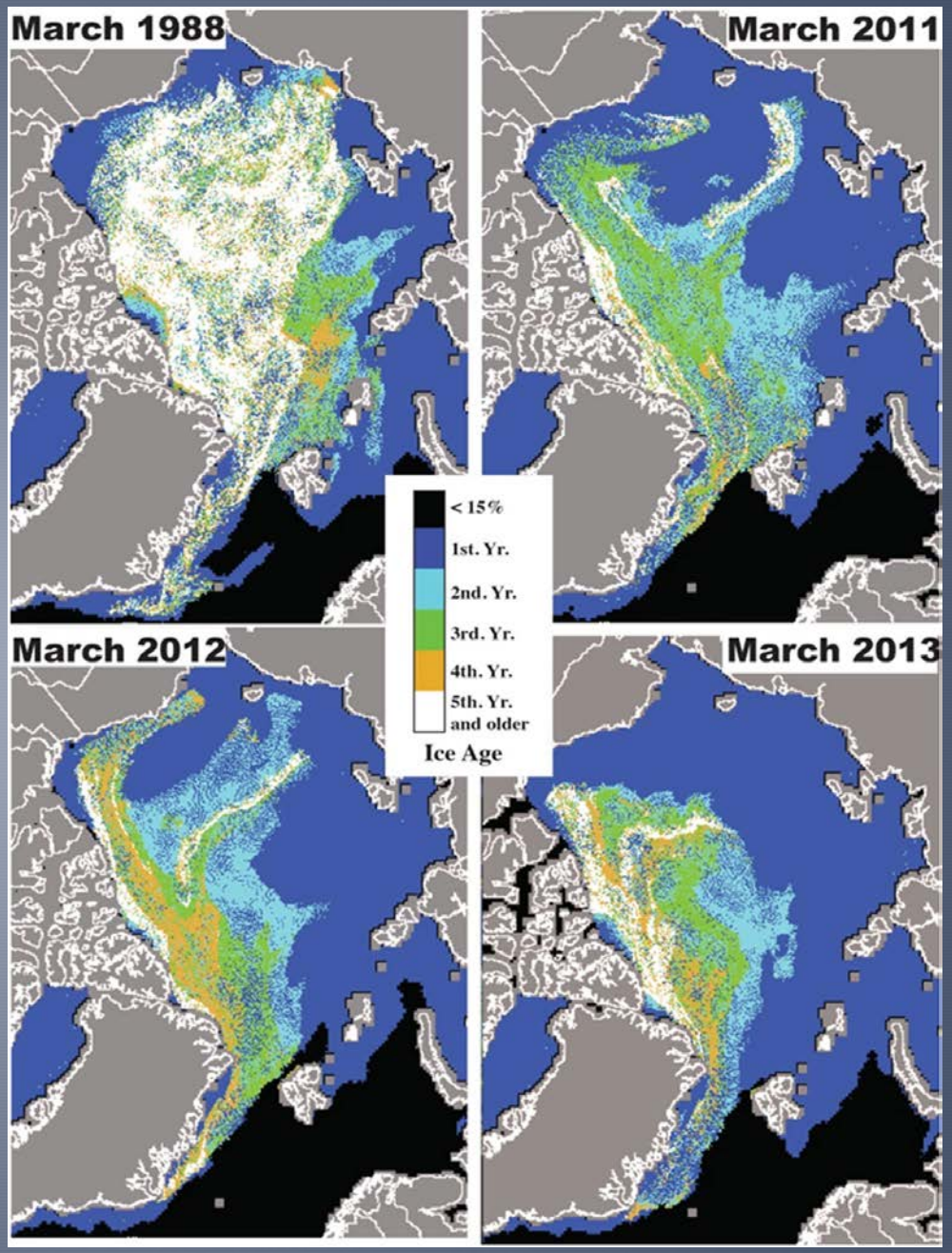
Sea-Ice Trends in the Arctic

Arctic sea ice extent in February 2014 averaged 14.44 million square kilometers (5.58 million square miles).

This is the ***fourth lowest*** February ice extent in the satellite data record, and is 910,000 square kilometers (350,000 square miles) below the 1981 to 2010 average.

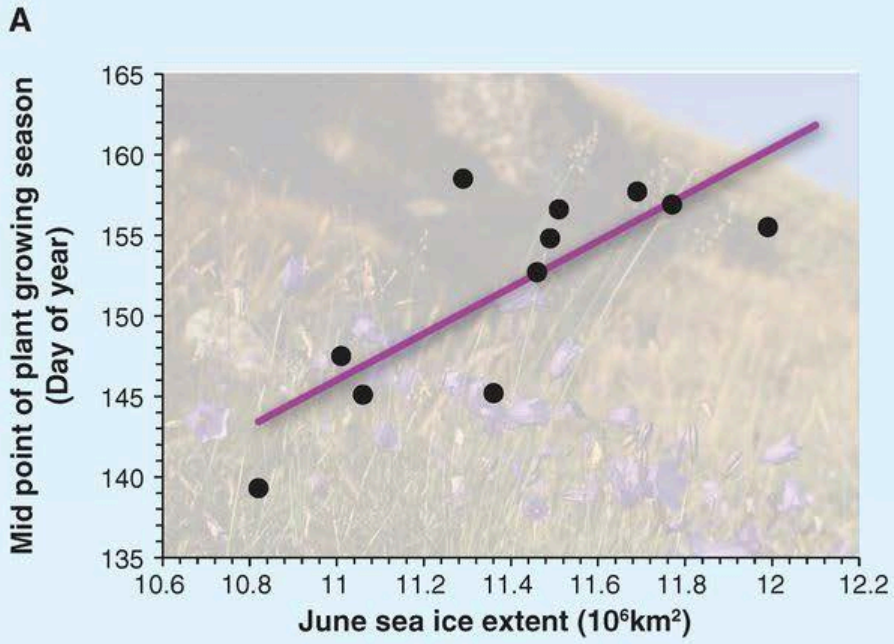
--NSIDC

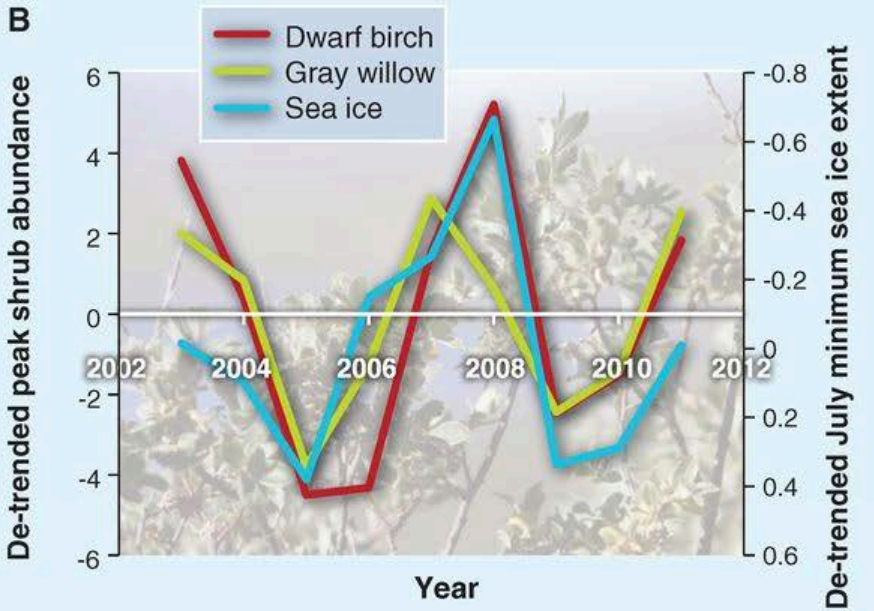




Perovich et al., 2013. "Sea Ice" Arctic Report Card.

Sea ice impacts on vegetation

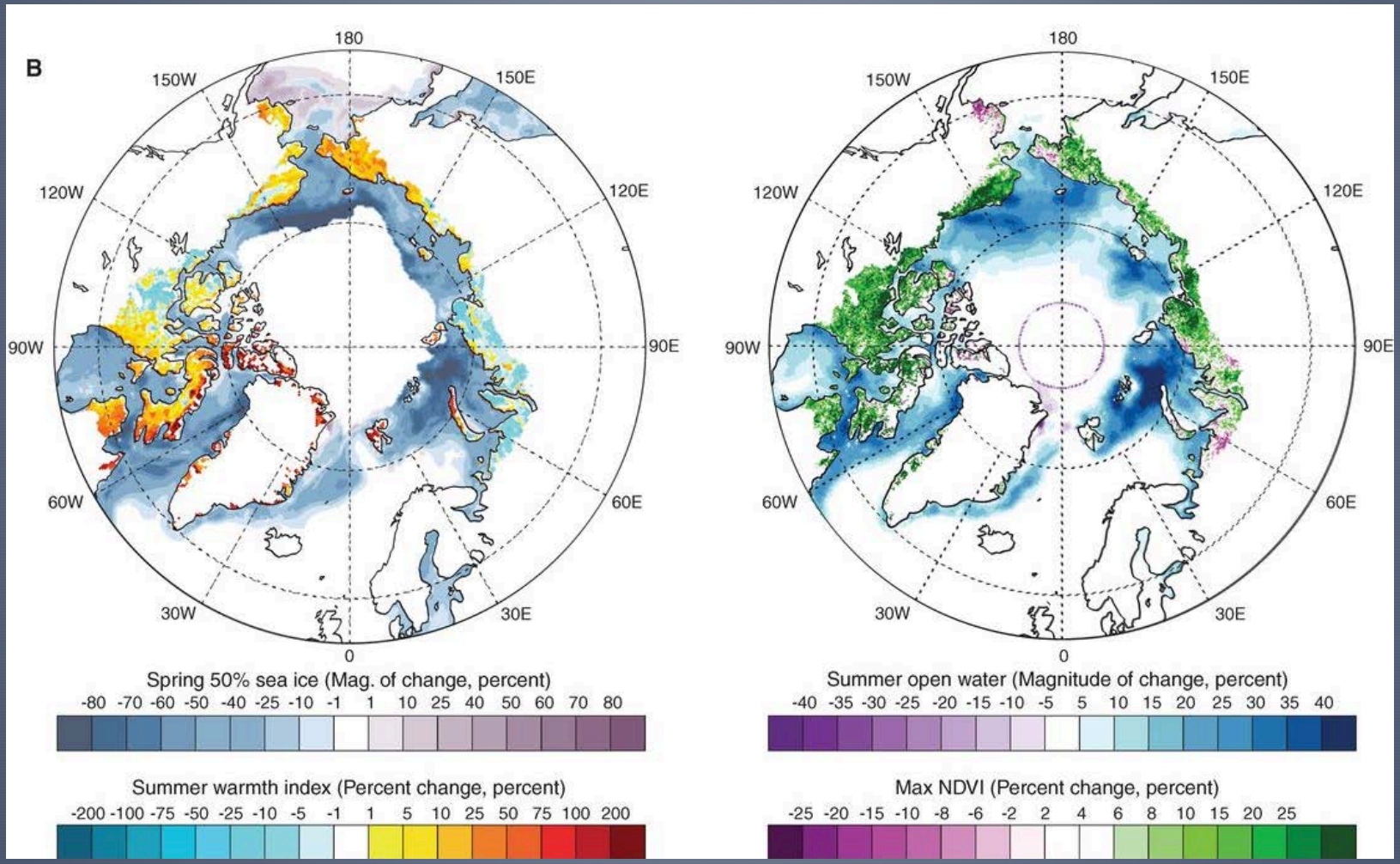




Post et al., 2013. Ecological consequences of Sea-Ice decline. Science

Feedbacks: lower sea ice -> greater open ocean (darker)-> more solar heat absorption (albedo) -> warmer air temperatures -> encroachment of less cold tolerant plants into the Arctic

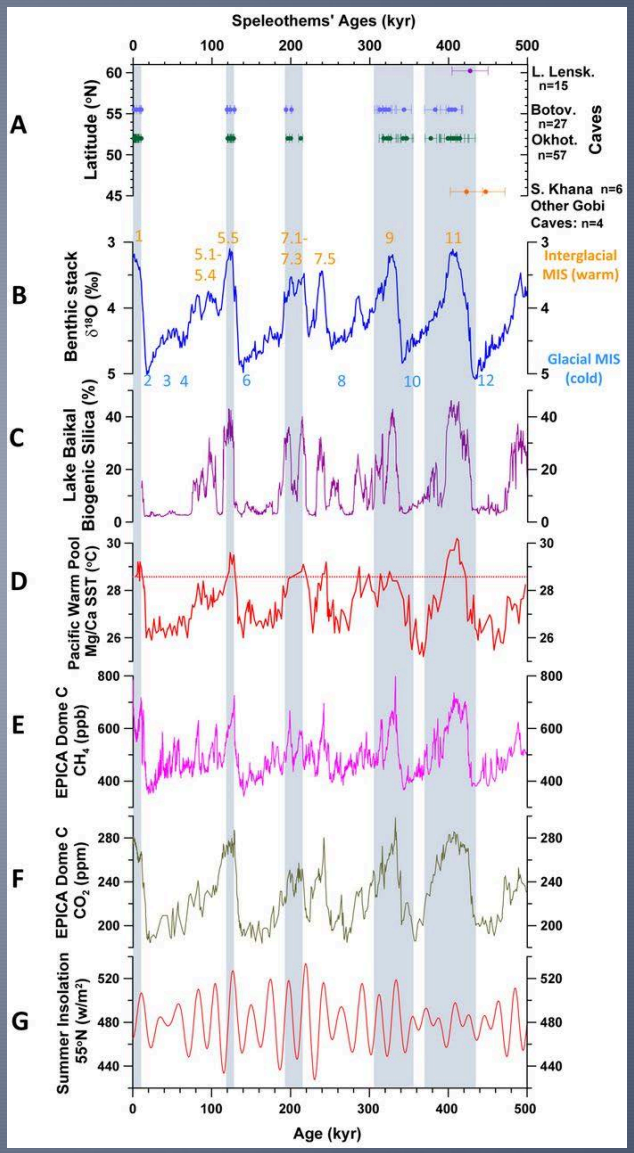
Sea Ice consequences on vegetation production



Post et al., 2013 Science

More aboveground productivity in the Arctic,
but soil carbon
is becoming more vulnerable…

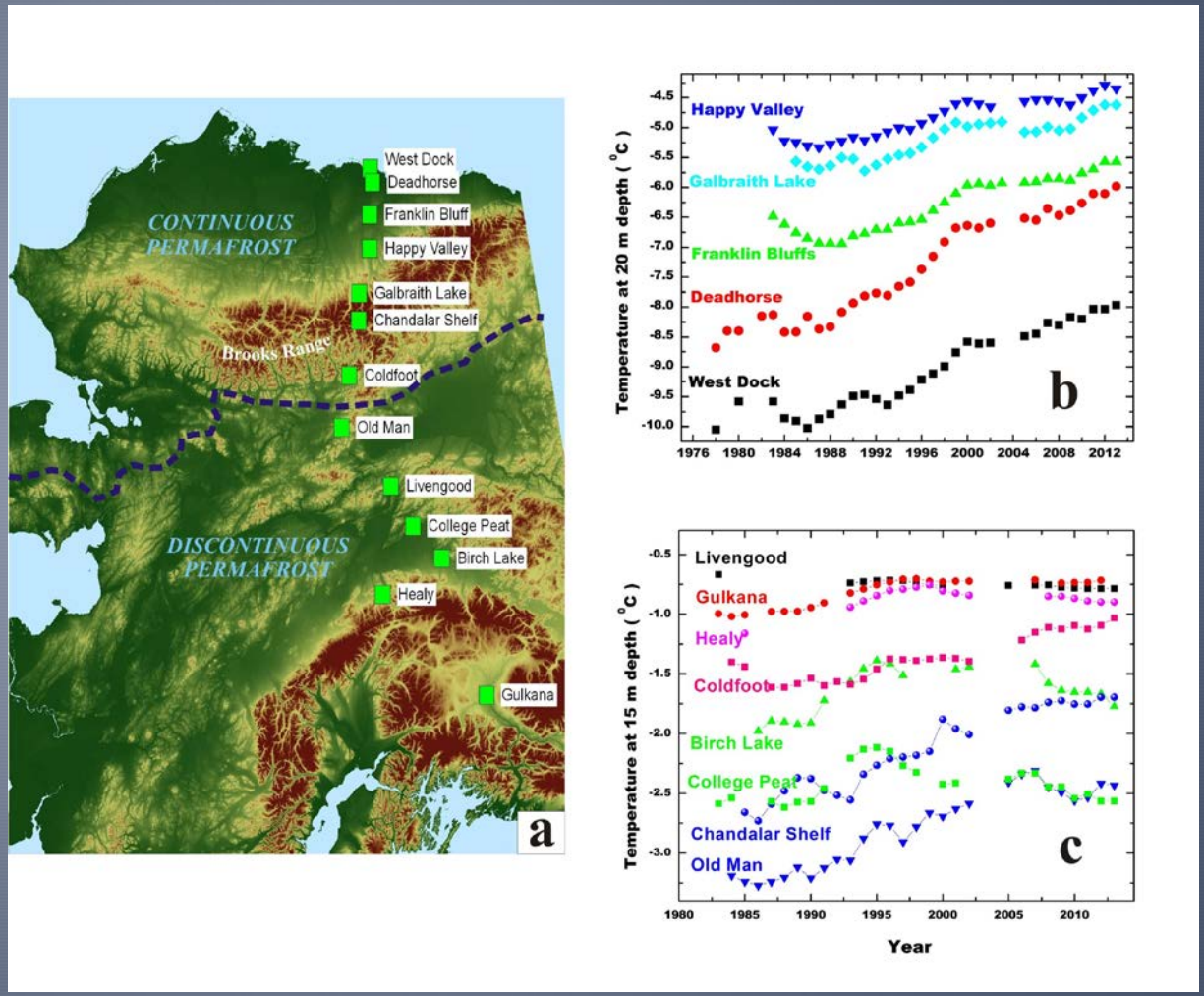
Permafrost extent and vulnerability



1700 Pg of Carbon stored in Permafrost soils (twice the C currently in the atmosphere)

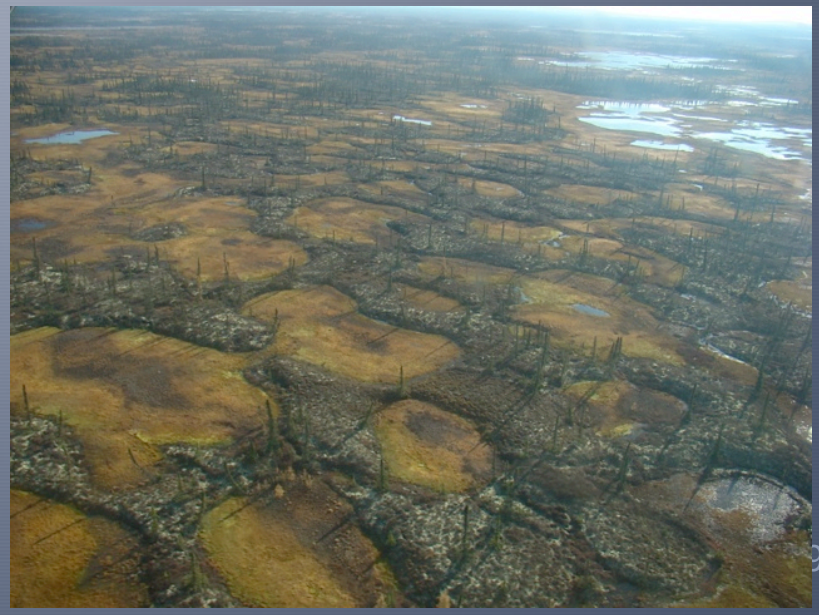
Vaks et al., Feb. 2013 Science

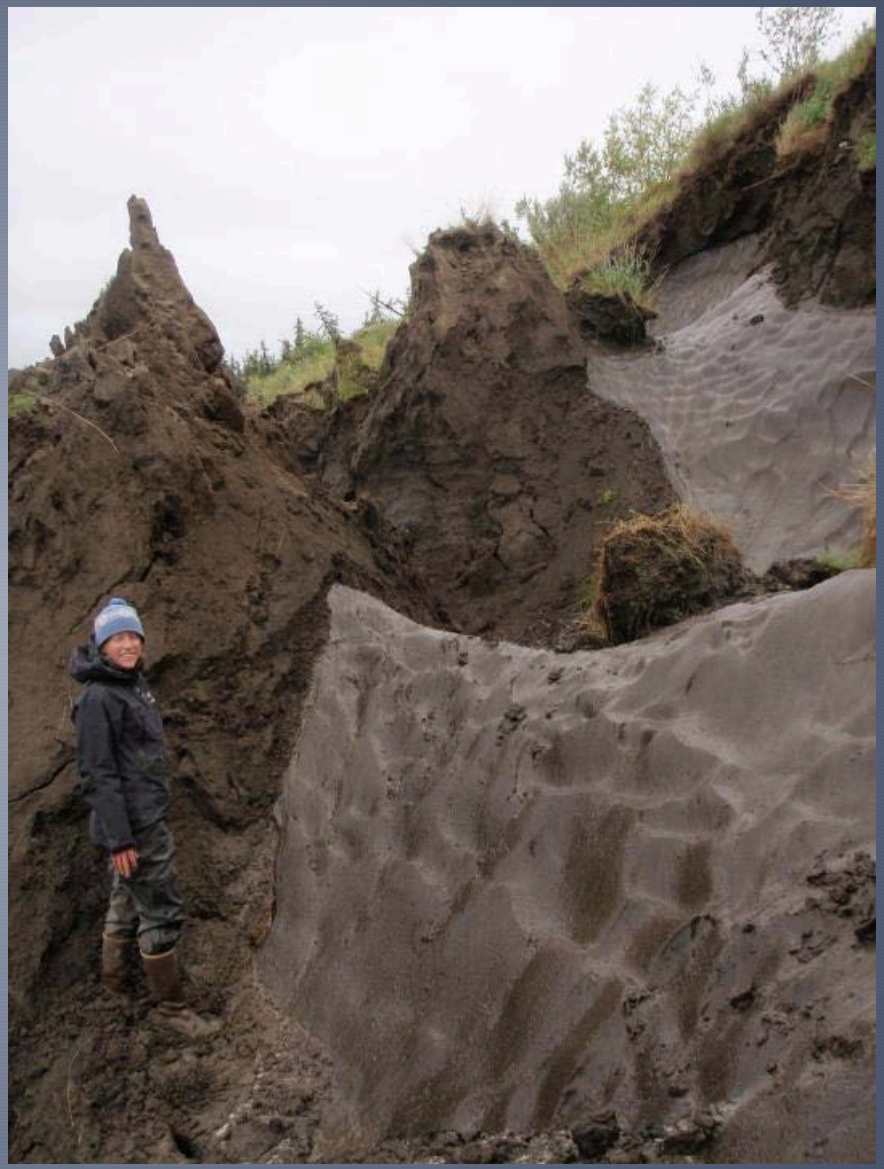
The fate of warming on Permafrost



Romanovsky et al., 2013. “Permafrost.” Arctic Report Card

Impacts of permafrost degradation





National Geographic, Dec. 2012

Science 5 March 2010:
Vol. 327 no. 5970 pp. 1246–1250
DOI: 10.1126/science.1182221

REPORT

Extensive Methane Venting to the Atmosphere from Sediments of the East Siberian Arctic Shelf

Natalia Shakhova[1,2,*,†], Igor Semiletov[1,2,*], Anatoly Salyuk[2], Vladimir Yusupov[2], Denis Kosmach[2], Örjan Gustafsson[3]

How Much Should You Worry About an Arctic Methane Bomb?

Recent warnings that this greenhouse gas could cost us $60 trillion have received widespread publicity. But many scientists are skeptical.

—*By* ***Chris Mooney*** | Thu Aug. 8, 2013 3:00 AM GMT

Arctic Methane Release Due To Climate Change Could Cost Global Economy $60 Trillion, Study Reports

Reuters | Posted: 07/24/2013 9:09 am EDT | Updated: 07/25/2013 6:46 pm EDT

The Telegraph

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Climate change could be accelerated by 'methane time bomb'

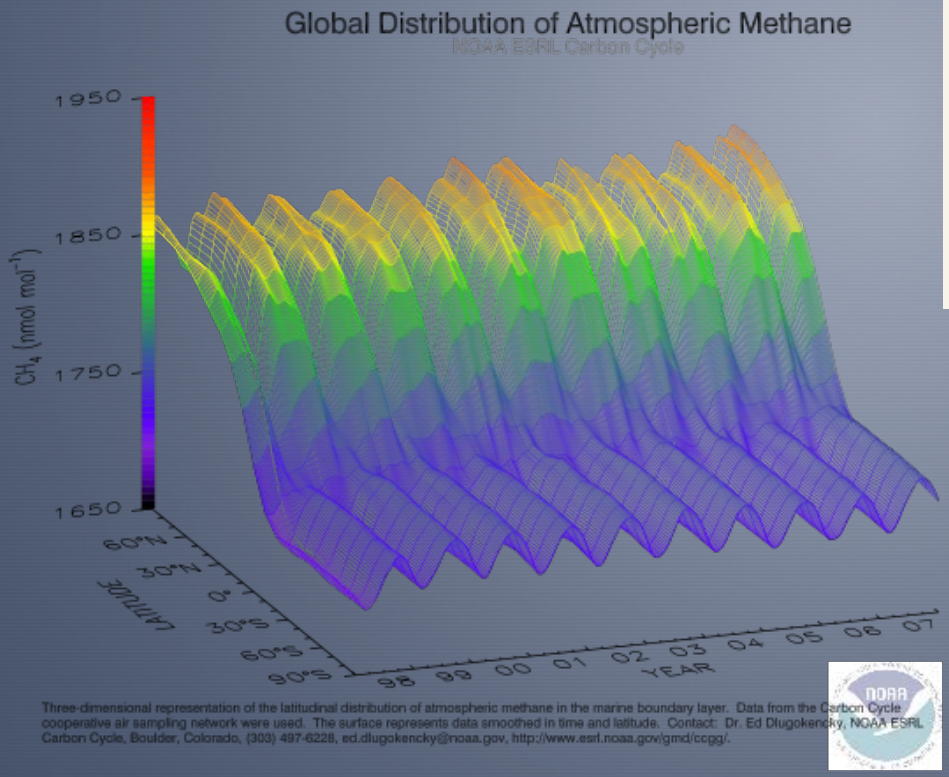
Climate change could be accelerated dramatically by rising levels of methane in the Earth's atmosphere, scientists will warn today.

Global methane sources and distribution

Methane (CH_4) Production:

$$H_3C\text{-}COOH \rightarrow CH_4 + CO_2$$

$$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$$



a

Identified methane sources	Estimates[8]	Range of estimates[2]
Total wetlands	145	92–237
Rice agriculture	60	40–100
Ruminant animals	93	80–115
Termites	20	20–20
Biomass burning	52	23–55
Energy generation	95	75–110
Landfills	50	35–73
Ocean	10	10–15
Hydrates (marine and terrestrial)	5	5–10
Total identified sources	**530**	**500–600**

b

Identified methane sinks	Estimates	Range of estimates
Tropospheric oxidation	507	450–510
Stratospheric loss	40	40–46
Soils	30	10–44
Total identified sinks	**577**	**460–580**
Total sources–sinks	**–47**	**–80 to +140**

Lowe, 2006 Nature

Sinks:

Atmosphere:

$$CH_4 + \cdot OH \rightarrow \cdot CH_3 + H_2O$$

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$$

Soils:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Northern high latitude emissions today

Wetlands north of 45ºN emit 30-106 Tg CH_4 yr^{-1} (McGuire et al., 2009)

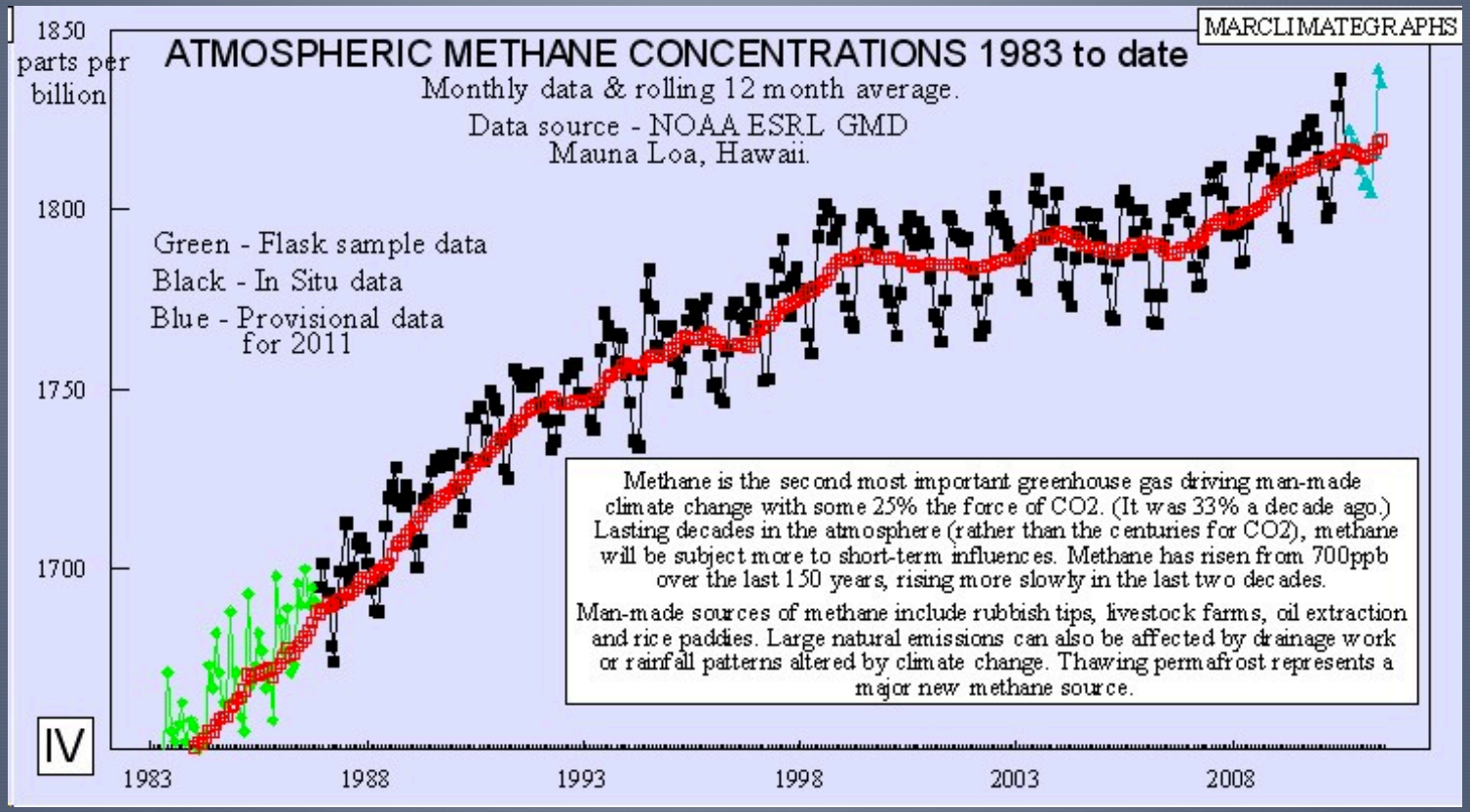
Consumption + emission: 16-65 Tg CH_4 yr^{-1}

Thermokarst lakes: 15-30 Tg CH_4 yr^{-1}

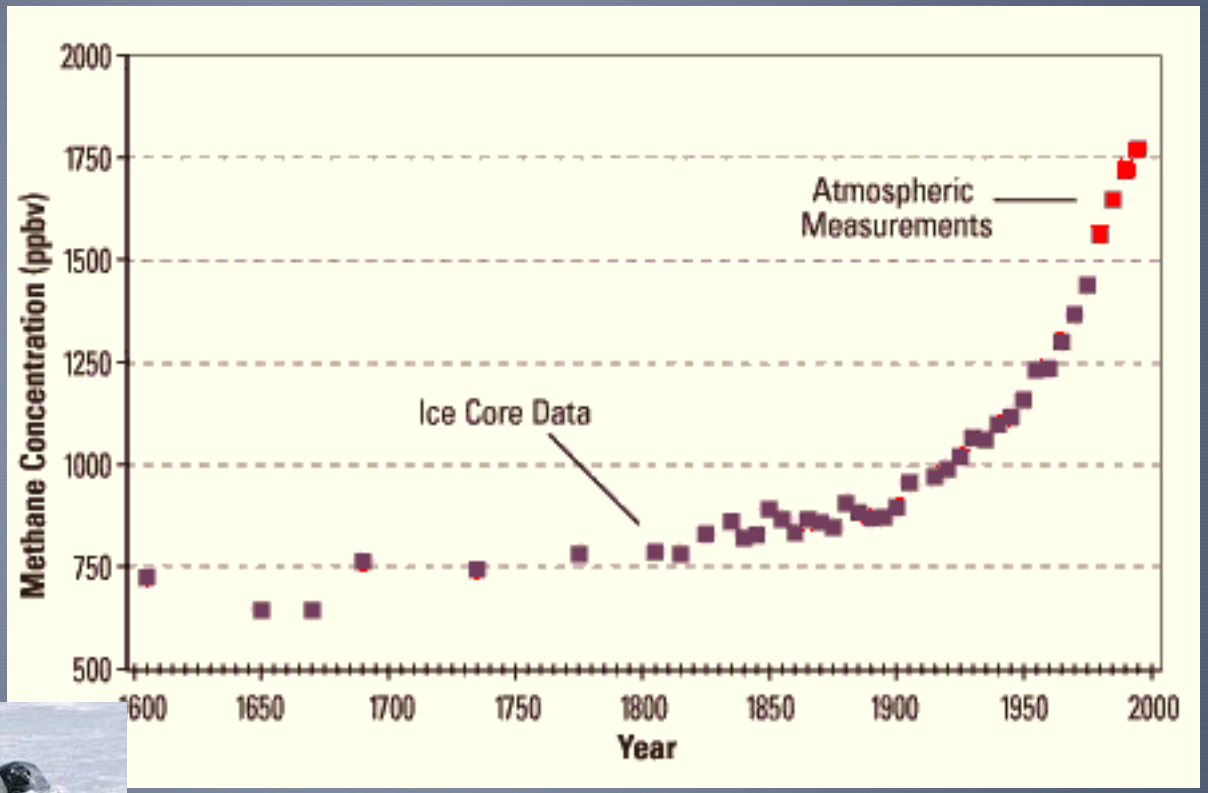
(Walter et al., 2007)

Permafrost gas hydrates: ~5-10 Tg CH_4 yr^{-1}

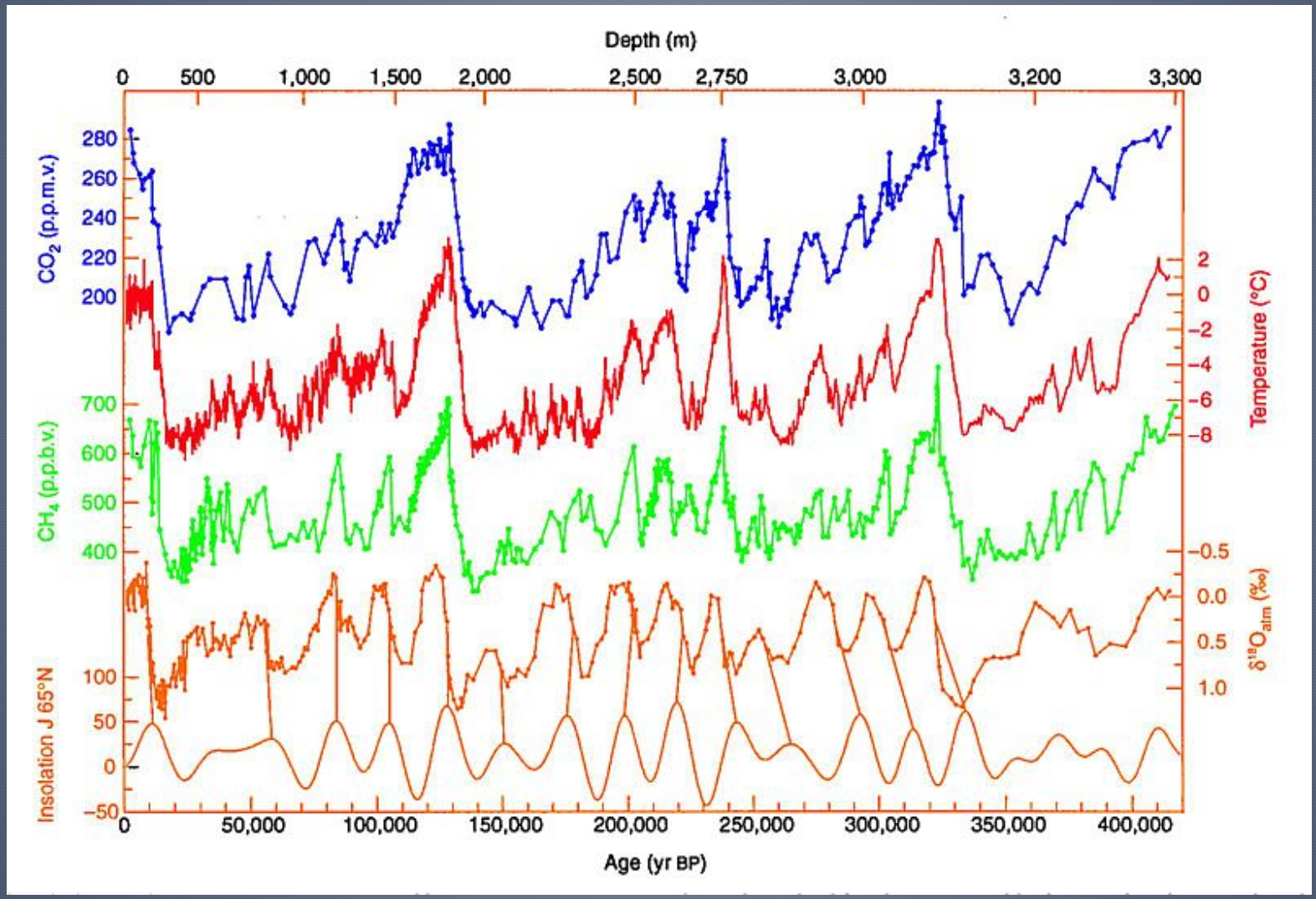
Monthly Methane Concentrations since 1983



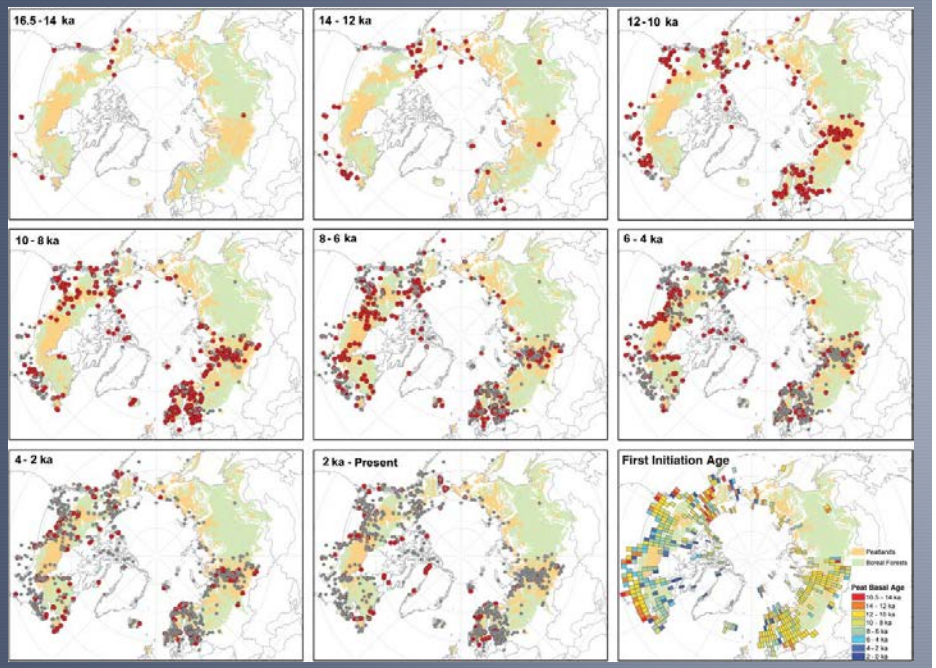
Methane concentrations over the last ~500 years

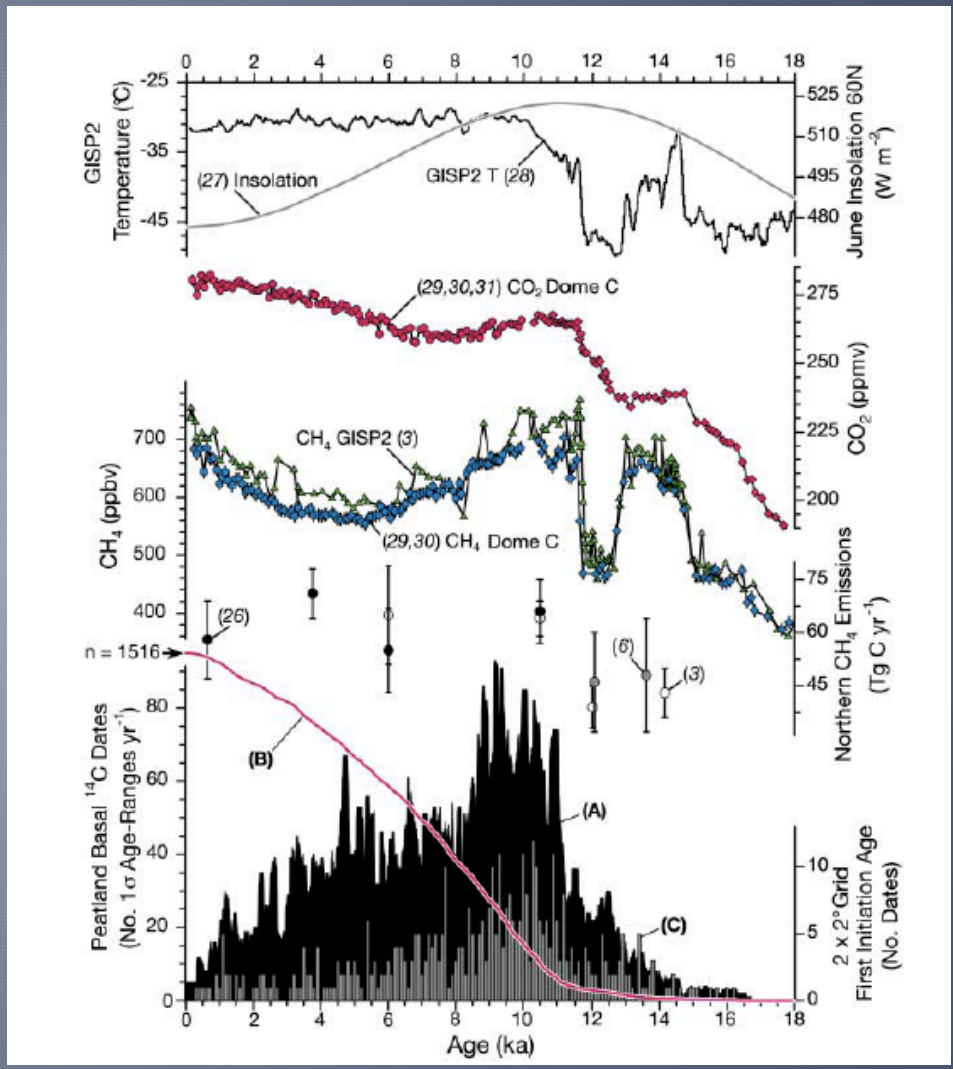


Atmospheric Methane Concentrations from the Vostok, Antarctica Ice Core



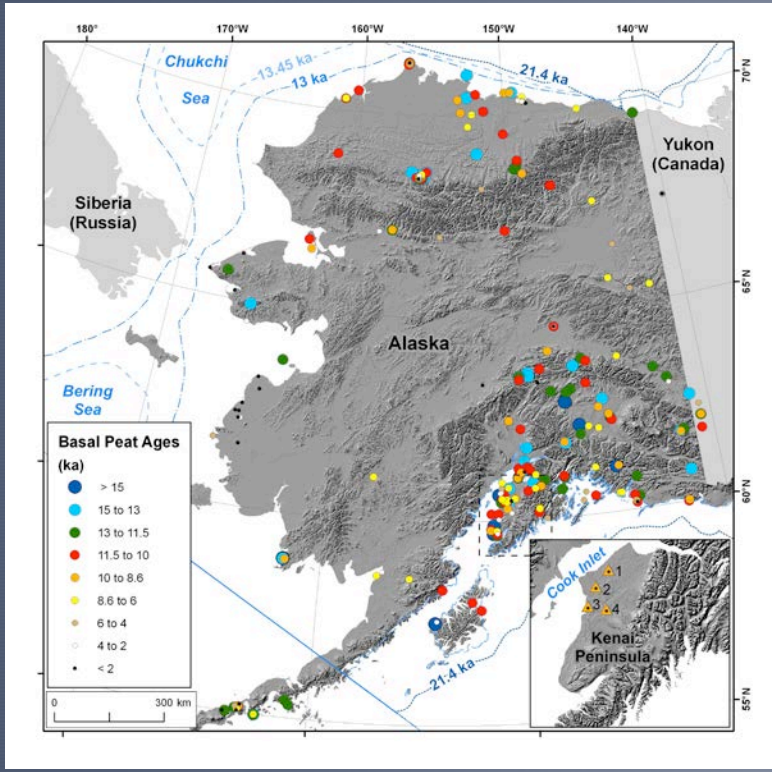
Boreal Peatland Development



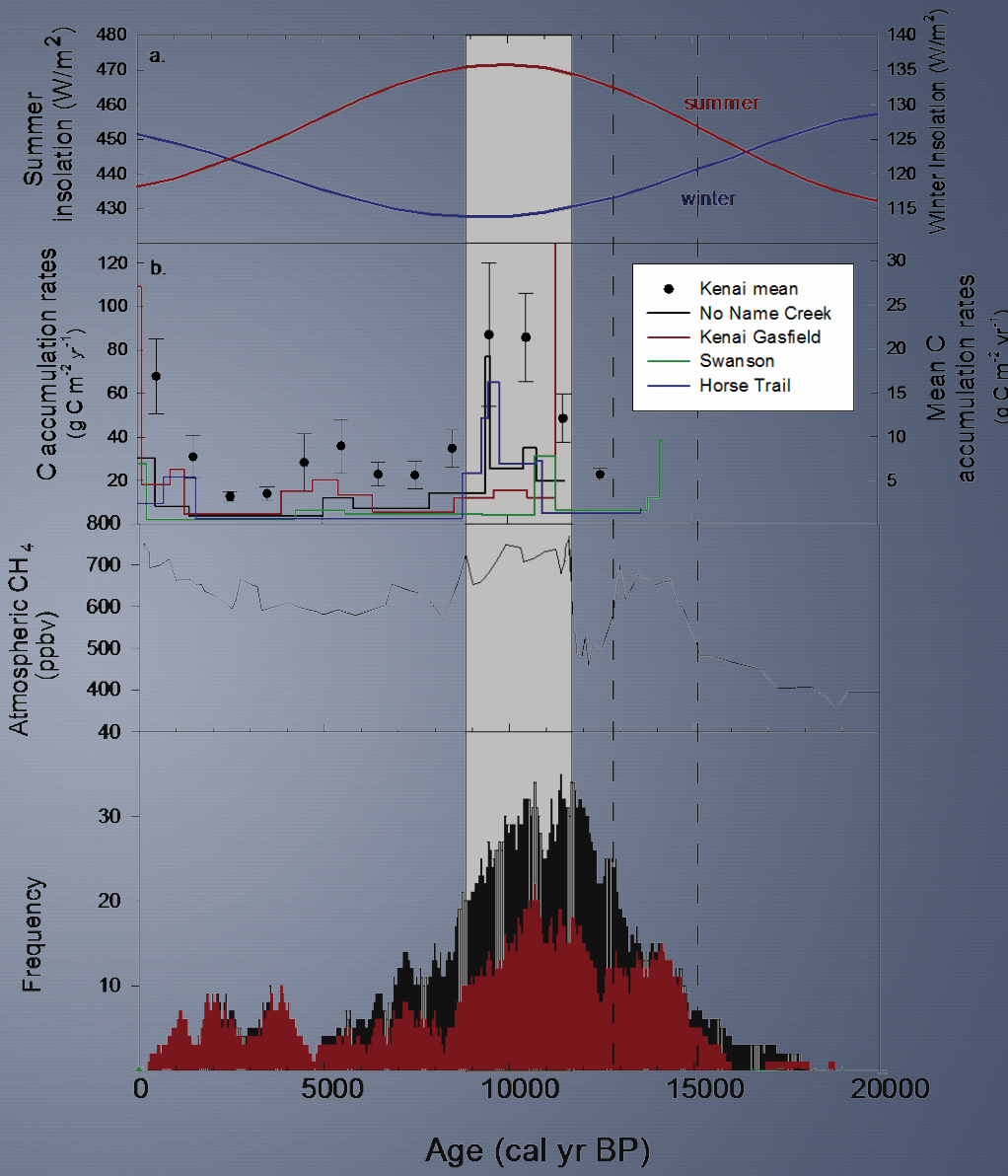


MacDonald et al., 2006 *Science*

Timing and rate of peat accumulation and peatland expansion controlled by climate

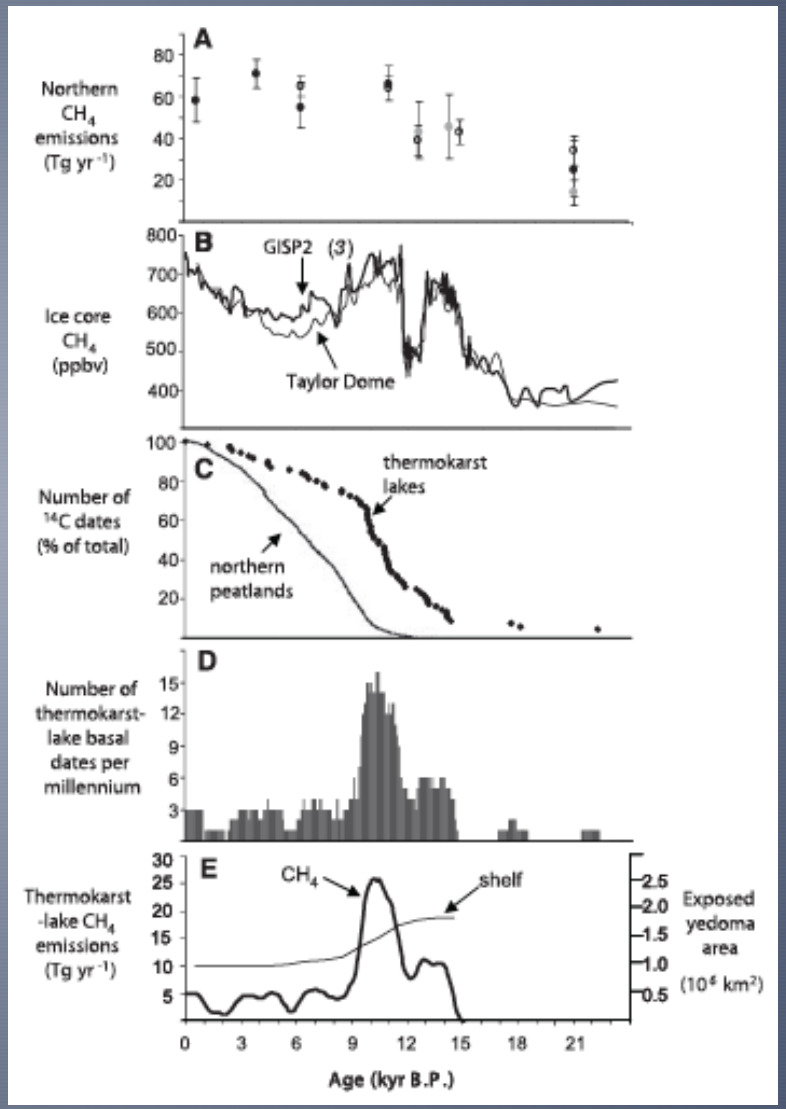


Jones and Yu, 2010, *PNAS*



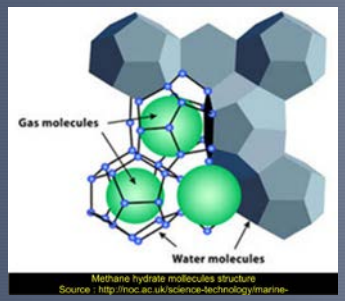
Modified from: Jones and Yu, 2010 *PNAS*

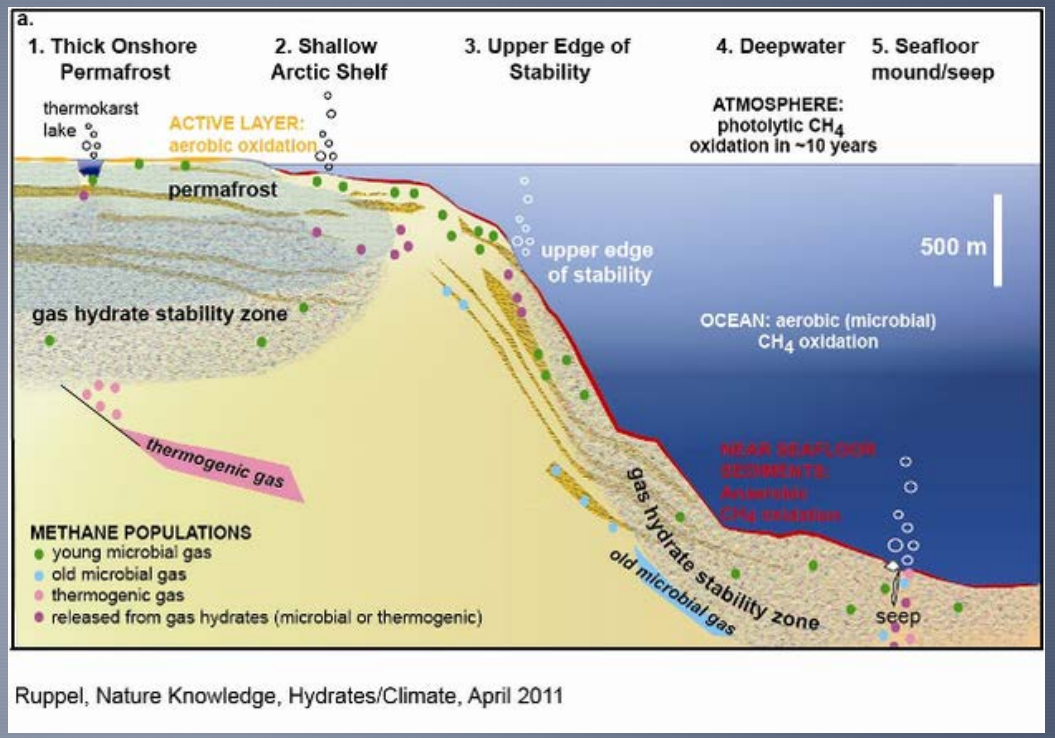
Thermokarst lakes



Walter et al., 2007

Methane hydrates: potential Methane bomb?

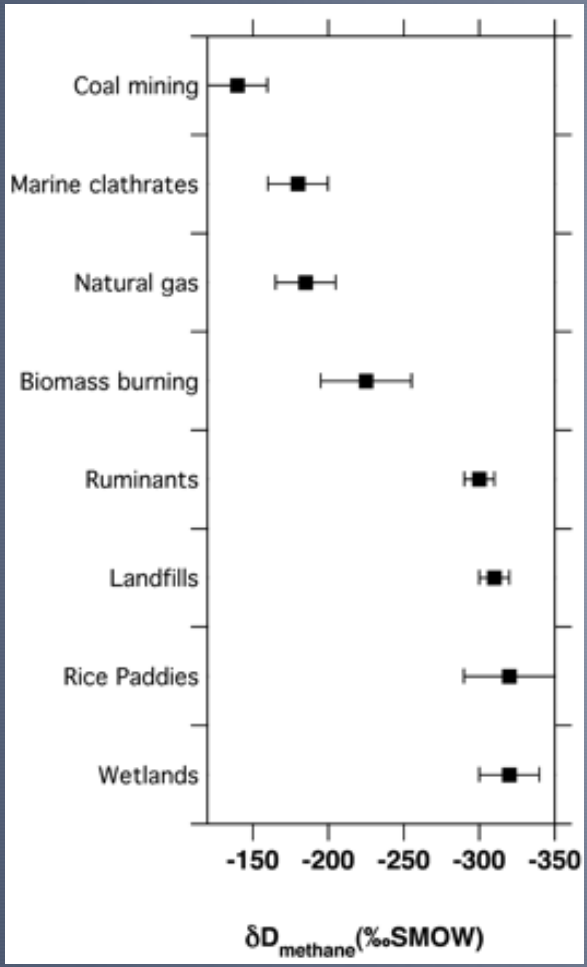




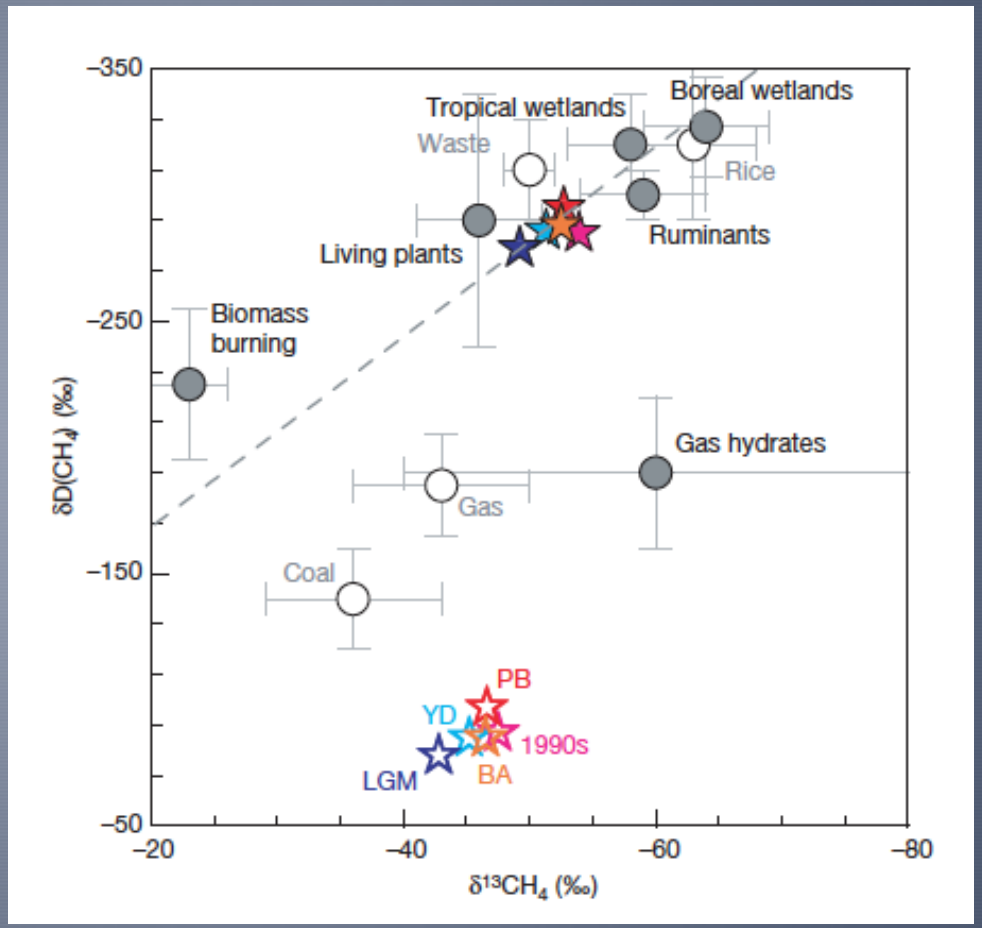
http://woodshole.er.usgs.gov/project-pages/hydrates/

- 99% found offshore in marine sediments, the rest found beneath deep permafrost under the right temperature and pressure
- Form at depth: in permafrost, stable below ~220 m; in marine setting, below ~575 m

Isotopes of Methane Sources

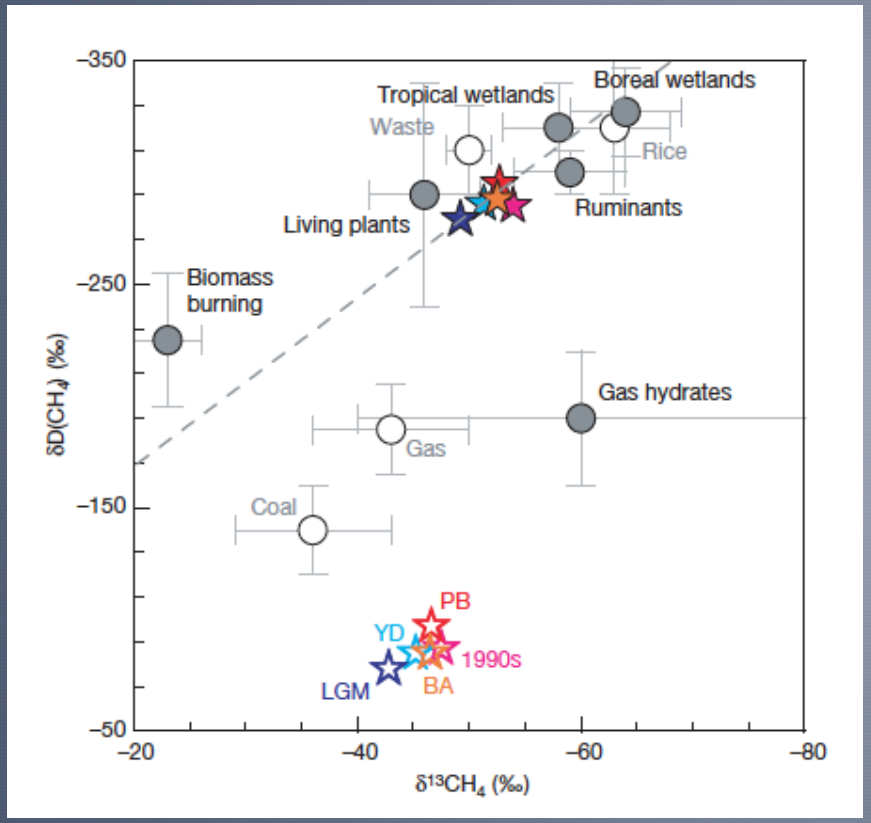


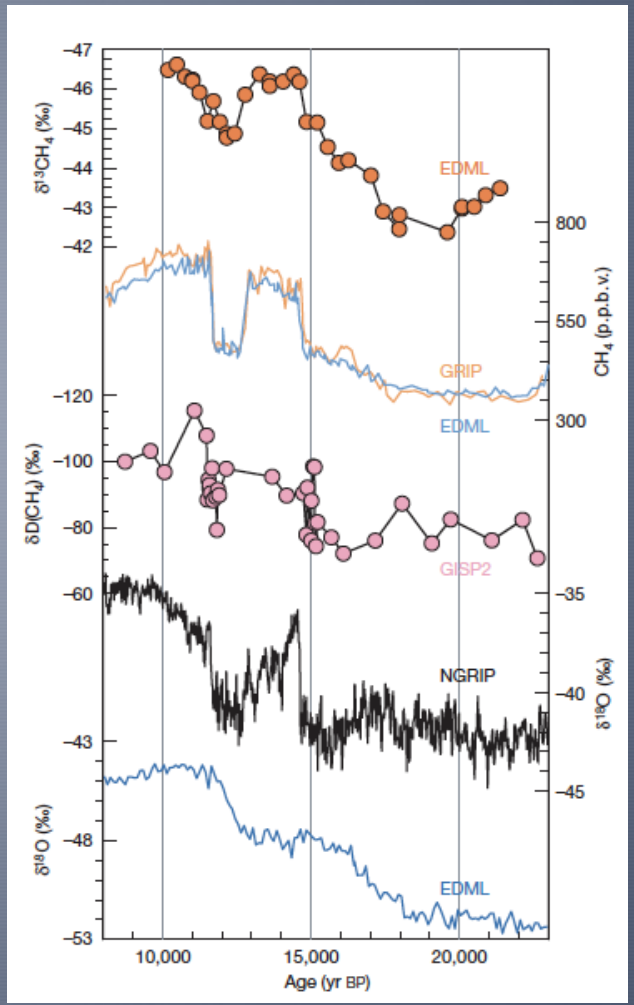
Sowers et al., *Science*, 2006



Fischer et al., *Nature*, 2008

Paleo perspecitve on Methane sources





Conclusions

- Accelerated warming in the Arctic is impacting its ability to store carbon
- Feedbacks: decreasing sea ice, shorter snow cover season-> darker ocean, more heat absorption-> warmer permafrost temperatures->greater release of soil C from thawing permafrost -> dramatic ecosystem change leading to darker plant cover (higher albedo)-> more heat absorption-> less sea ice cover, shorter snow cover-> ETC.
- Release of carbon, however, not necessarily from catastrophic gas hydrate destabilization, but more likely from terrestrial permafrost thaw, amplifying the radiative forcing on the planet.