Arctic Methane: Can the Top-down and Bottom-up Views of its Budget Be Reconciled?

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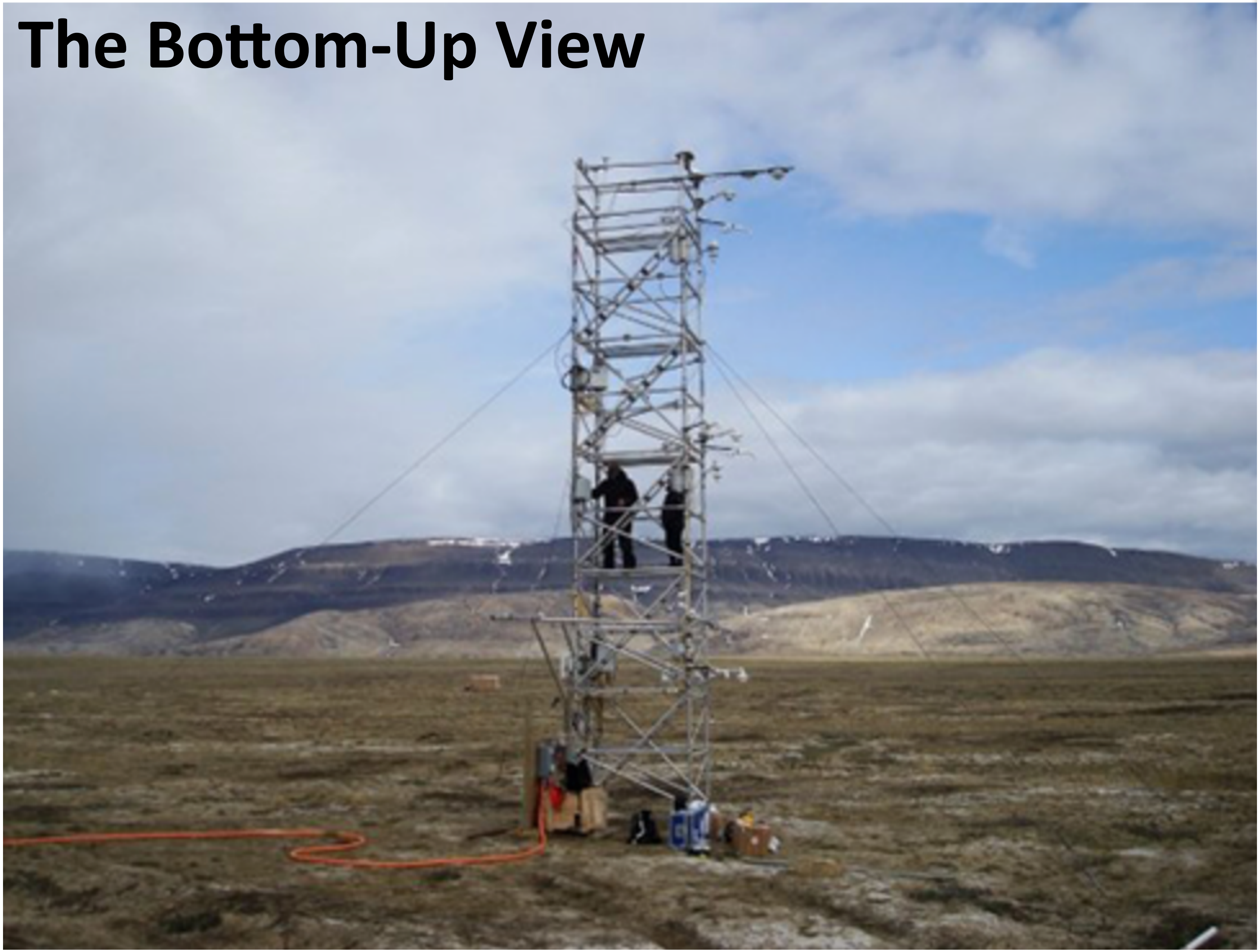
We Need to Understand the Arctic Carbon Budget

- Orbital Forcing and Permafrost Carbon Feedbacks may explain hyperthermal events ~55Mya
- Global T increase of 5 C within a few 1000 years (Today 0.6 C/10yrs!)
- ~3700 PgC in Eocene permafrost (~1700 PgC today) (DeConto et al. Nature 2012)
- Enough carbon could thaw by 2100 to raise atmospheric CO_2 by 100-180 ppm (Harden et al.,2012).

A coryphodon basking in the warm eocene

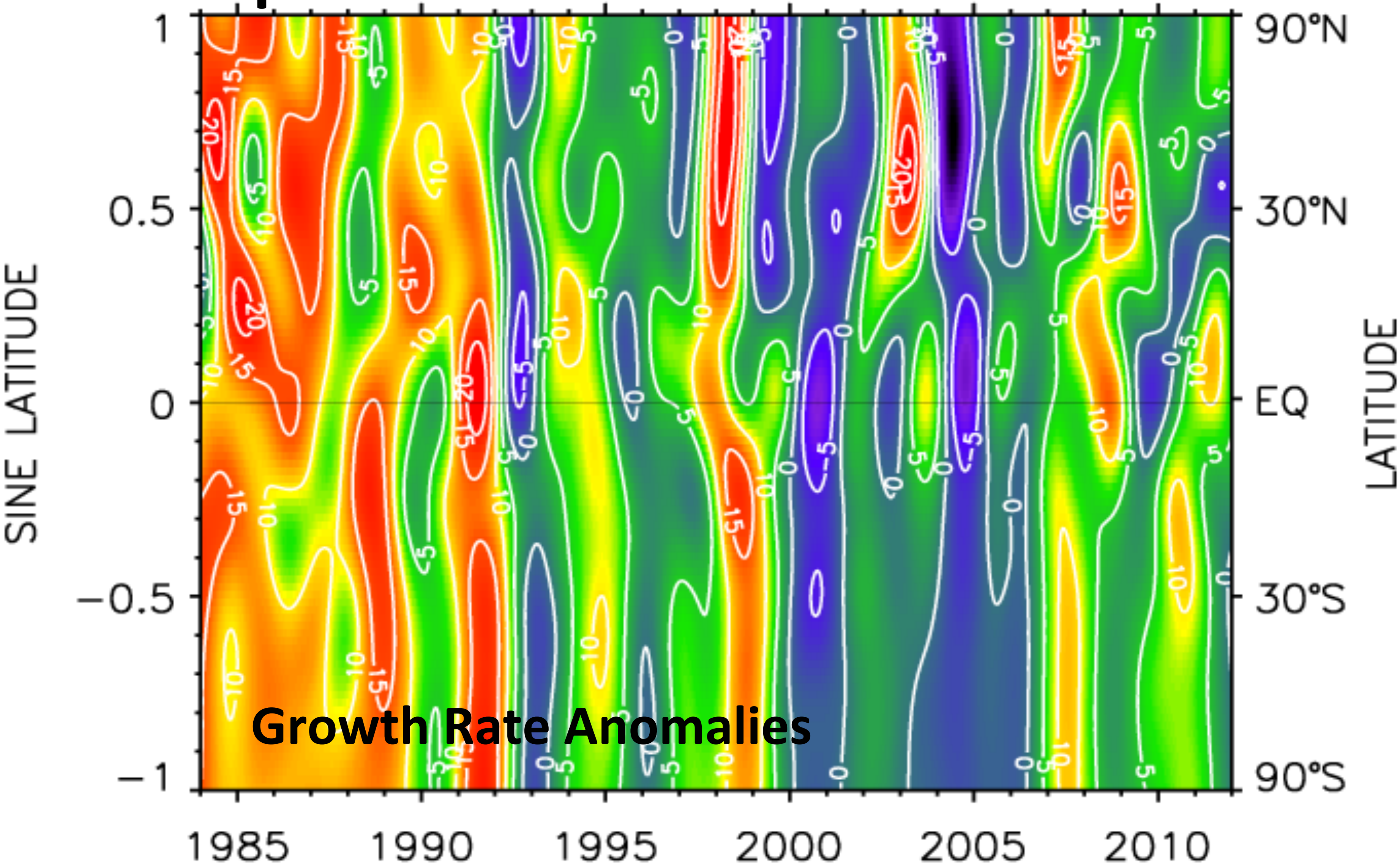
The Bottom-Up View



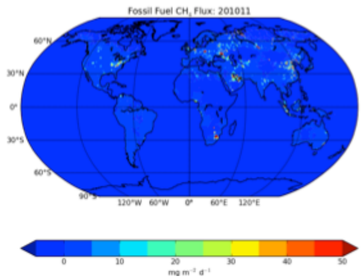
Process	$TgCH_4$/yr	Reference
Arctic Tundra Wetlands	**26 (15 to 68)**	McGuire et al.,,2012
High Northern Lakes (Glacial/Post-Glacial, Thermokarst, Peatland Ponds, Beaver Ponds)	**17 (±10)**	Vik et al., 2014, submitted
“Anomalous Hydrates” in Laptev Sea Sediments	**17**	Shakhova et al., 2013
Autumn “Freeze-out” Emissions	**4**	Mastepanov et al., 2008

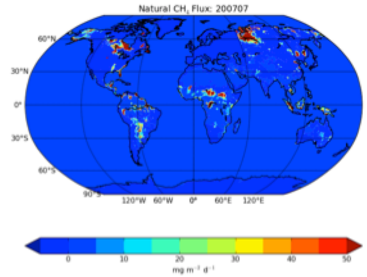
Total Budget of Arctic CH_4: 64 (43 – 99) $TgCH_4$/yr

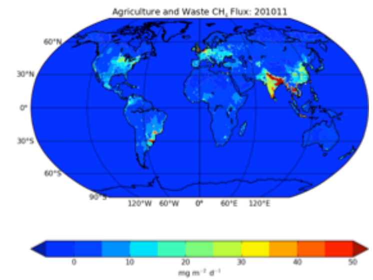
The Top-Down View



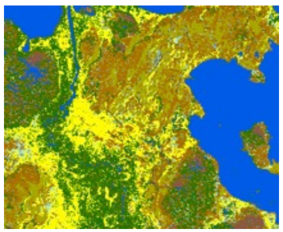
Prior Emission Estimates





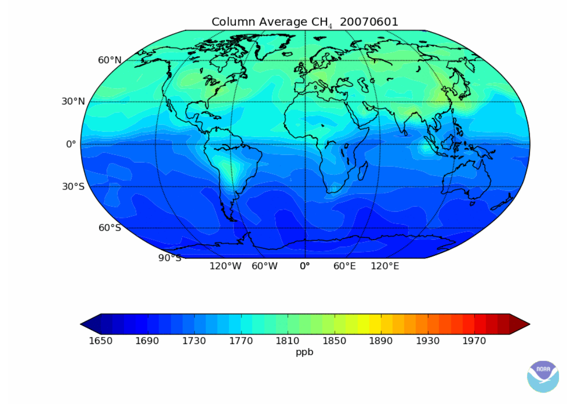


Remotely Sensed Ecological Data

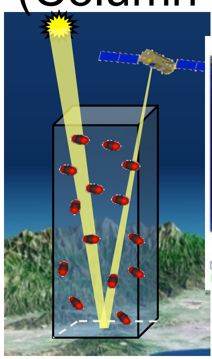


Earth Analyzer - CH_4

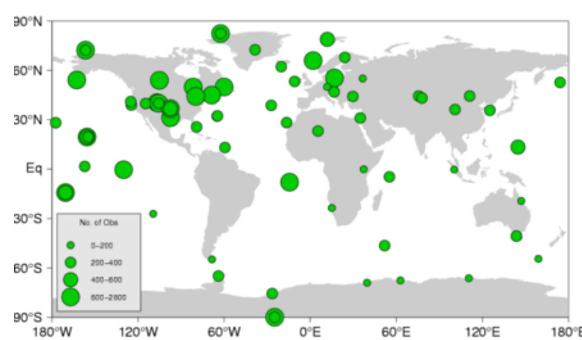
Atmospheric State
(Concentration and Emissions)



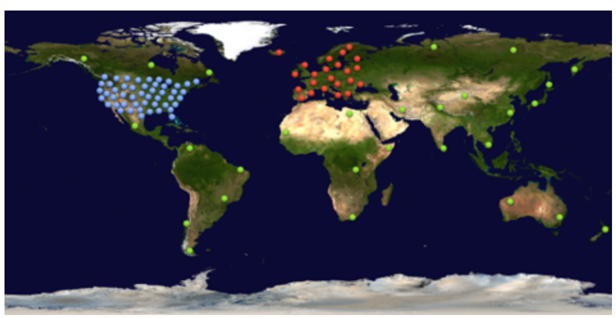
Satellites, TCCON (Column Data)



Current Surface Network



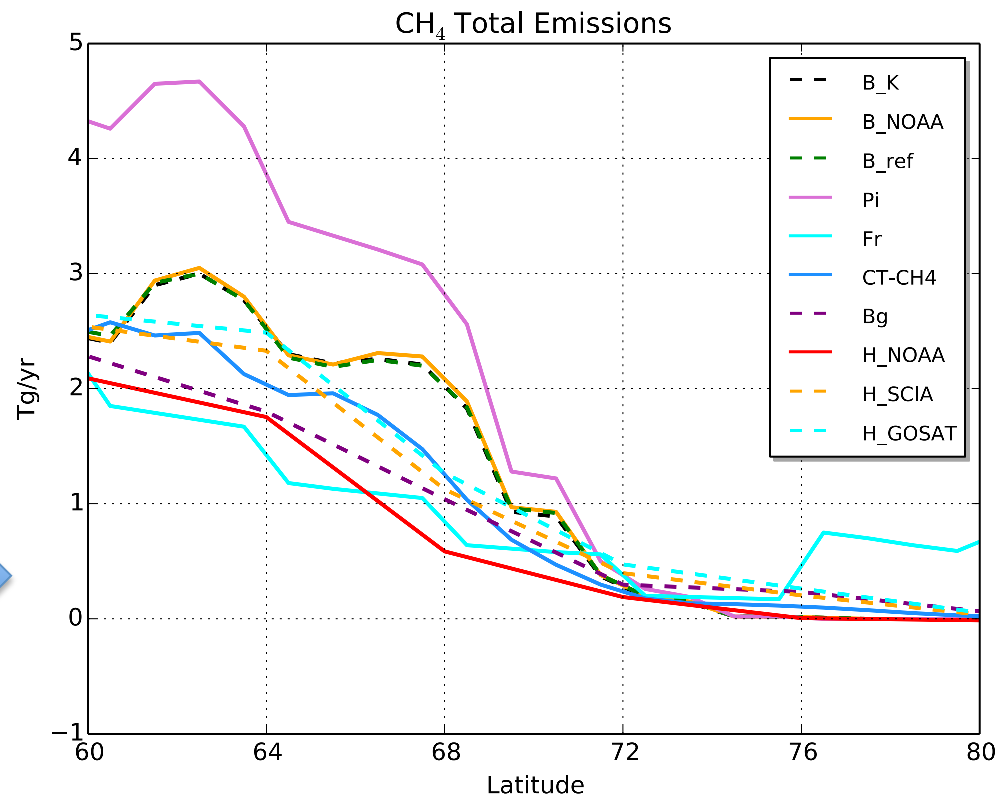
Earth Networks (Planned)



Source	Tg CH_4 yr^{-1}
Wetlands	• **15.5 (11.1-27.4)**
Biomass Burning	• **0.6 (0.4-1.0)**
Anthropogenic	• **9.3 (7.2-10.5)**

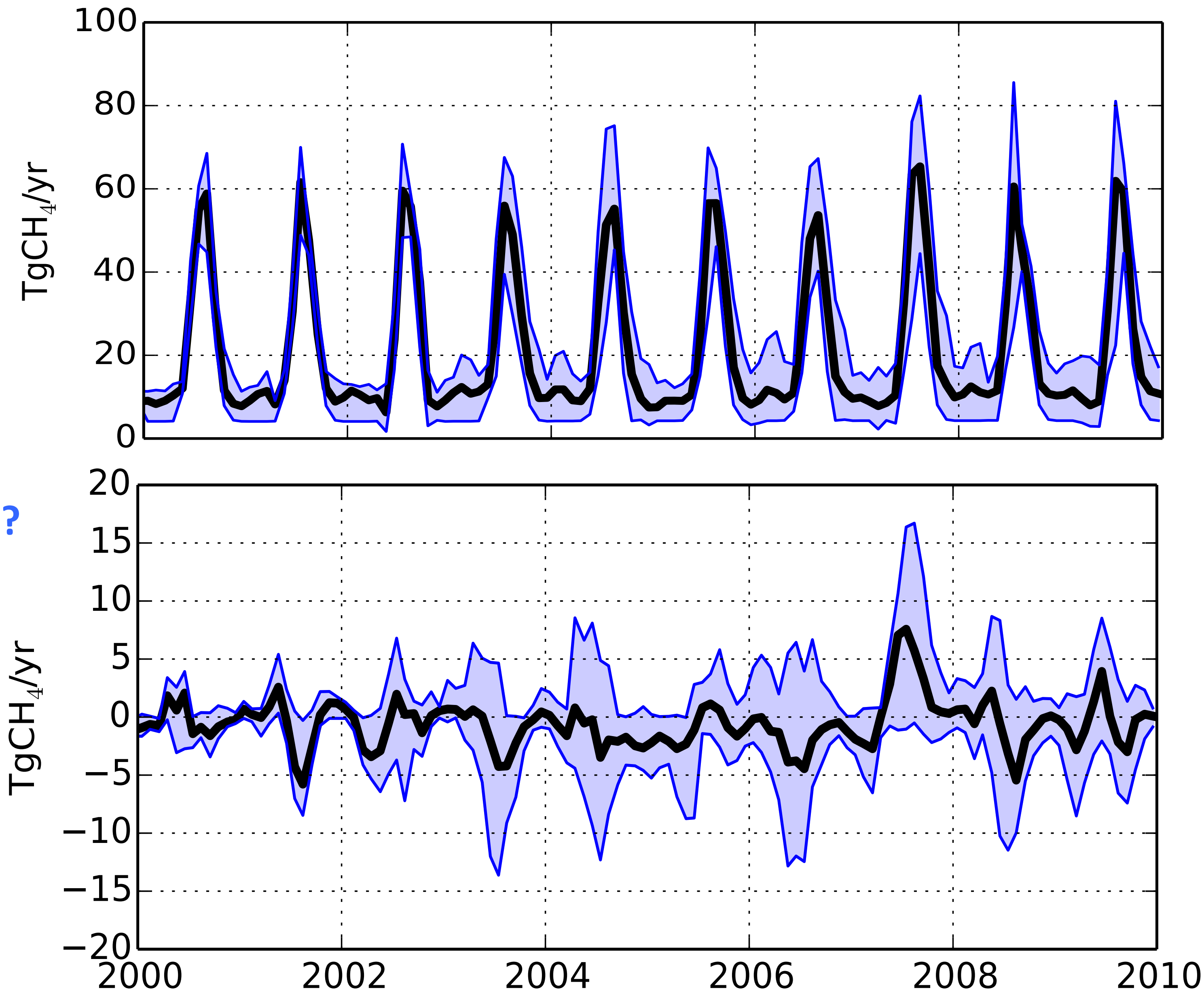
Total Budget of Arctic CH_4: 25 (18 – 29) $TgCH_4$/yr

Atmospheric Inversions



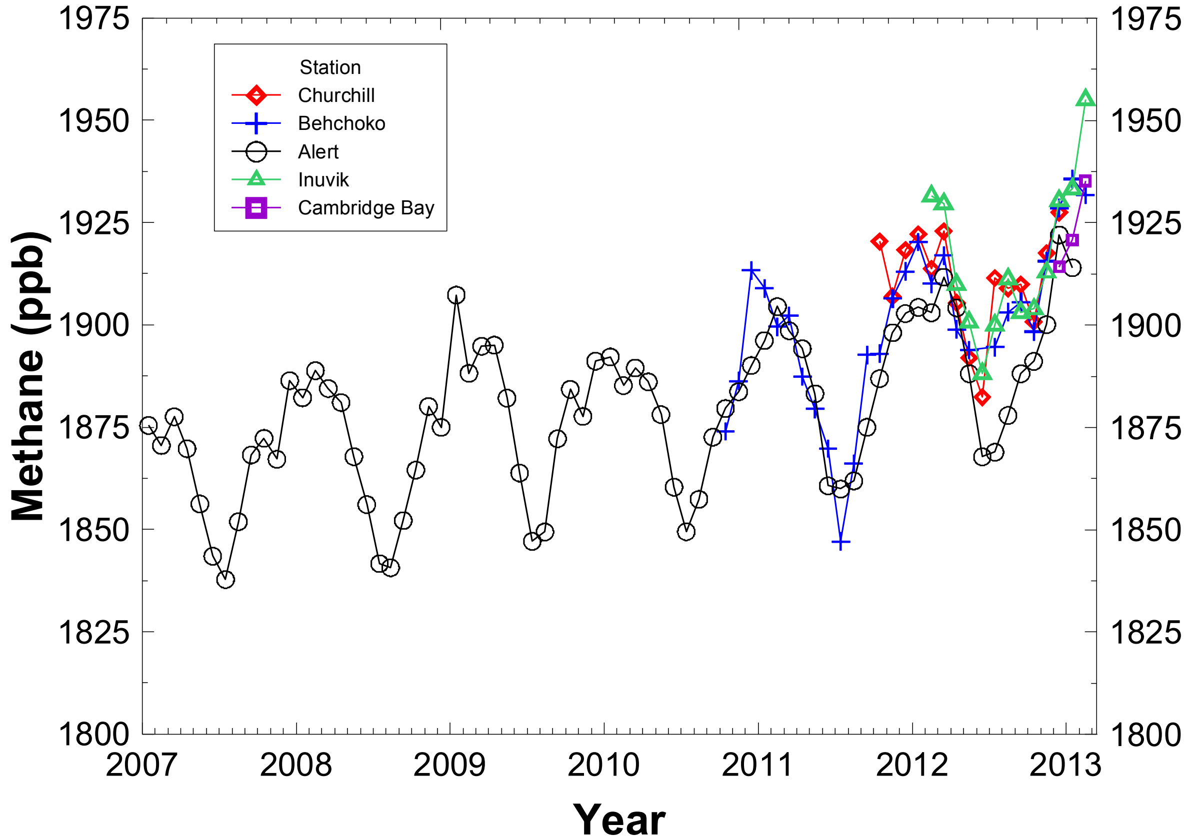
Do Inversions Agree on IAV?

Are There Emission Trends ?



Why Do Top-Down and Bottom-Up Approaches Disagree?

- **Transport Biases in Inversions**
  - **Difficult to Use Continental Sites**
  - **Models may be Biased Towards Stability**



Data from D Worthy, Environment Canada

The \$60 Trillion Paper:

Nature, July 2013

The Scenario: A 50 Gt Reservoir of CH_4 destabilizes!

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Pipes transport oil from rigs on Endicott Island in Alaska.

Vast costs of Arctic change

Methane released by melting permafrost will have global impacts that must be better modelled, say **Gail Whiteman**, **Chris Hope** and **Peter Wadhams**.

Unlike the loss of sea ice, the vulnerability of polar bears and the rising human population, the economic impacts of a warming Arctic are being ignored.

Most economic discussion so far assumes that opening up the region will be beneficial. The Arctic is thought to be home to 30% of the world's undiscovered gas and 13% of its undiscovered oil, and new polar shipping routes would increase regional trade[1,2]. The insurance market Lloyd's of London estimates that investment in the Arctic could reach US\$100 billion within ten years[3].

The costliness of environmental damage from development is recognized by some, such as Lloyd's[3] and the French oil giant Total, and the dangers of Arctic oil spills are the subject of a current panel investigation by the US National Research Council. What is missing from the equation is a worldwide perspective on Arctic change. Economic modelling of the resulting impacts on the world's climate, in particular, has been scant.

We calculate that the costs of a melting Arctic will be huge, because the region is pivotal to the functioning of Earth systems such as oceans and the climate. The release of methane from thawing permafrost beneath the East Siberian Sea, off northern Russia, alone comes with an average global price tag of \$60 trillion in the absence of mitigating action — a figure comparable to the size of the world economy in 2012 (about \$70 trillion). The total cost of Arctic change will be much higher.

Much of the cost will be borne by developing countries, which will face extreme weather, poorer health and lower ▶

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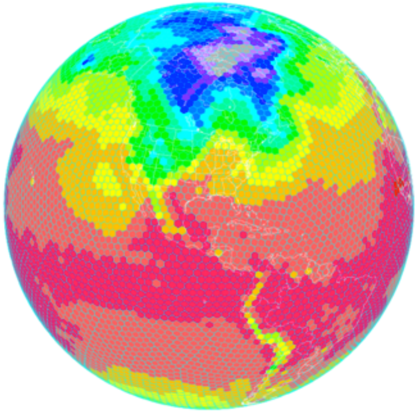
A Possible Way Forward:

1) Increase spatial resolution of atmospheric transport simulations used in inversions.



The FIM-grid

2) Scale-up chamber/flux measurements using progressively lower resolution land surface classification from remote sensing platforms. (NSF MacroSystems Biology Project, Varner, UNH, PI