Cold Season Emissions Dominate the Arctic Tundra Methane Budget on the North Slope of Alaska

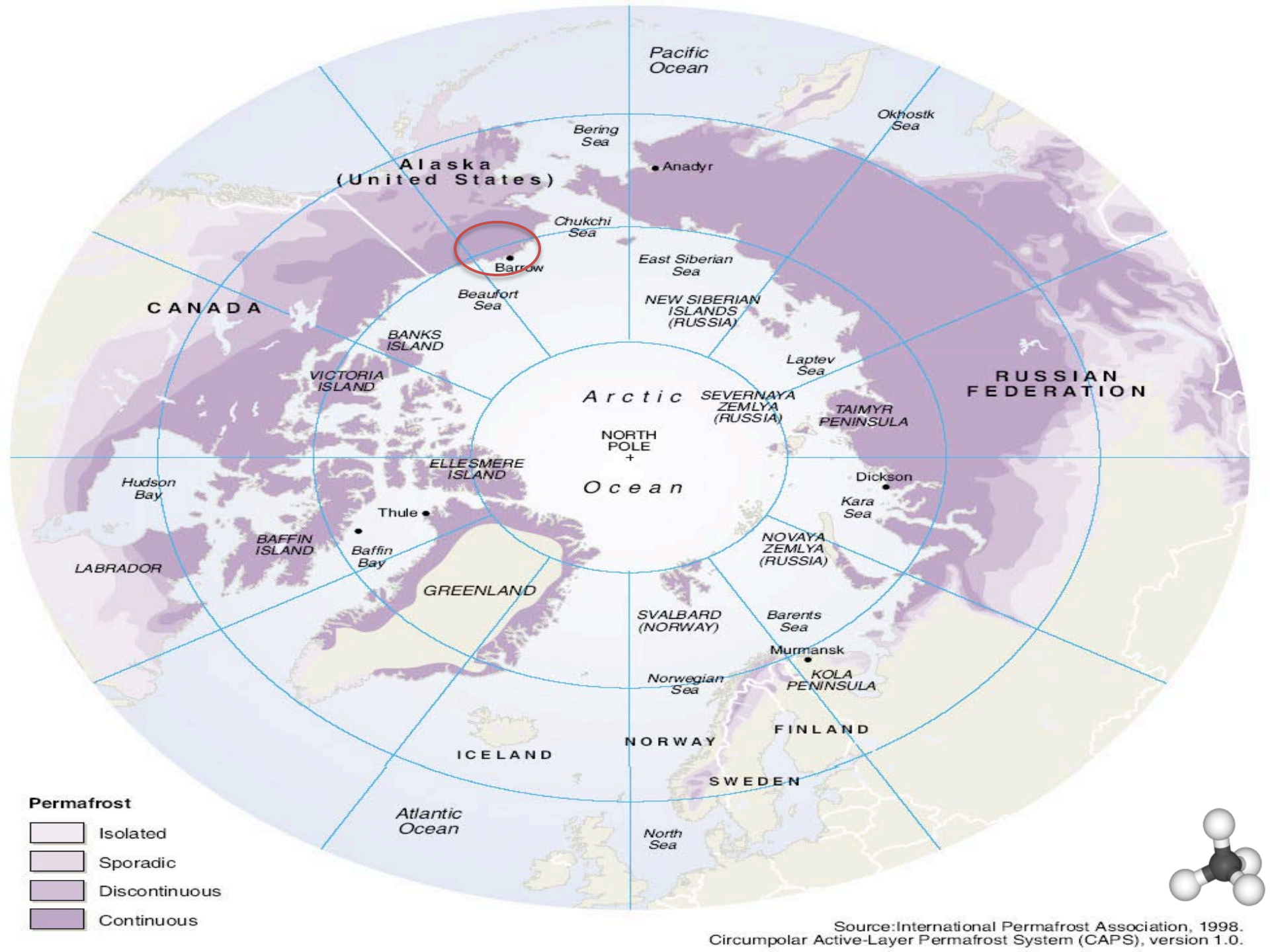
Walter Oechel (SDSU, Open U),

Donatella Zona, Beniamino Gioli, Róisín Commane, Jakob Lindaas, Steven C. Wofsy, Charles E. Miller, Steven J. Dinardo, Sigrid Dengel, Colm Sweeney, Anna Karion, Rachel Y.-W. Chang, John M. Henderson, Jordan P. Goodrich, Anna Liljedahl, Jennifer D. Watts, John S. Kimball,

David A. Lipson and the NASA CARVE Science Team

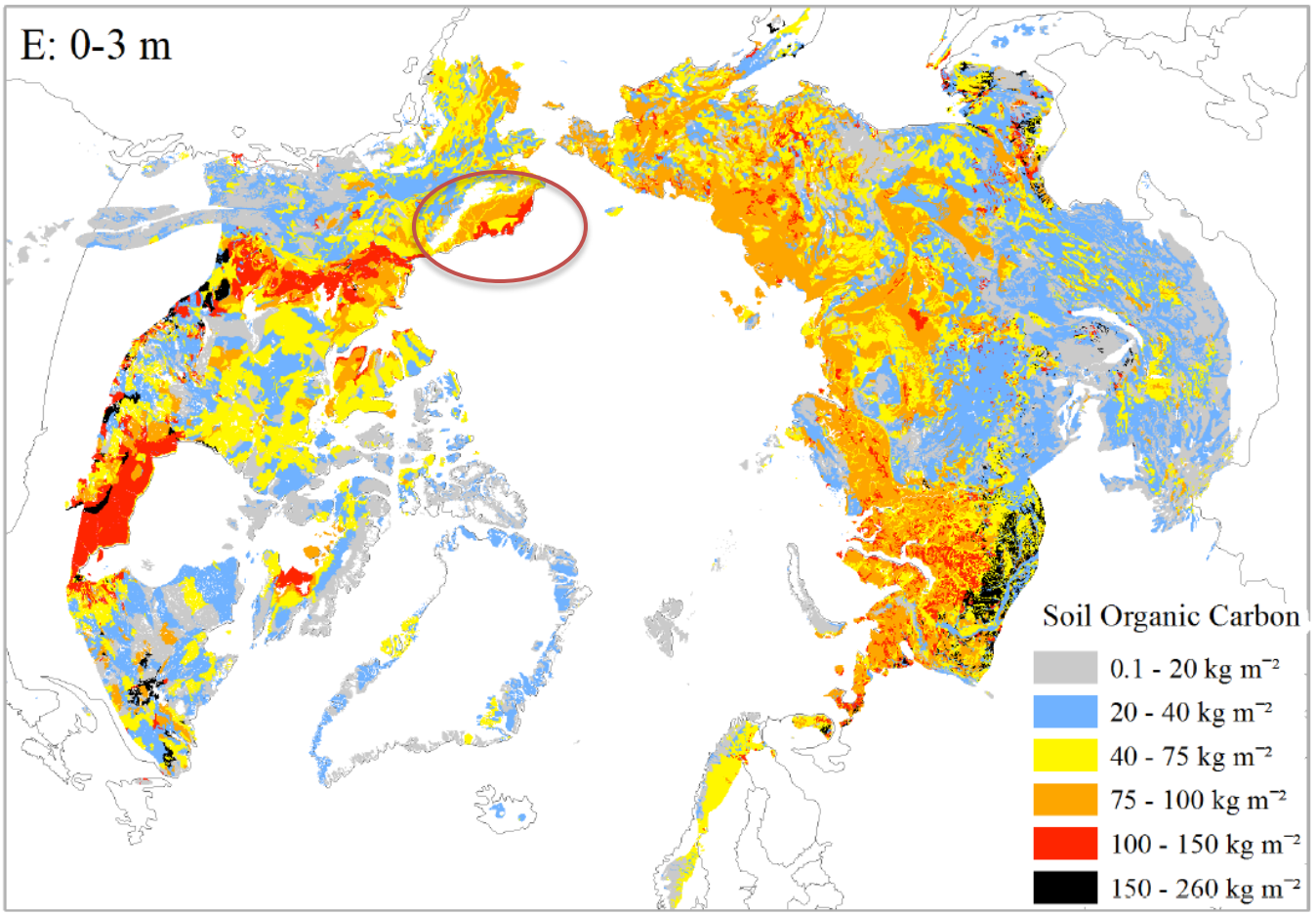
SAN DIEGO STATE UNIVERSITY

NOAA GMD Conference
Boulder, CO
May 17, 2016



Source:International Permafrost Association, 1998.
Circumpolar Active-Layer Permafrost System (CAPS), version 1.0.

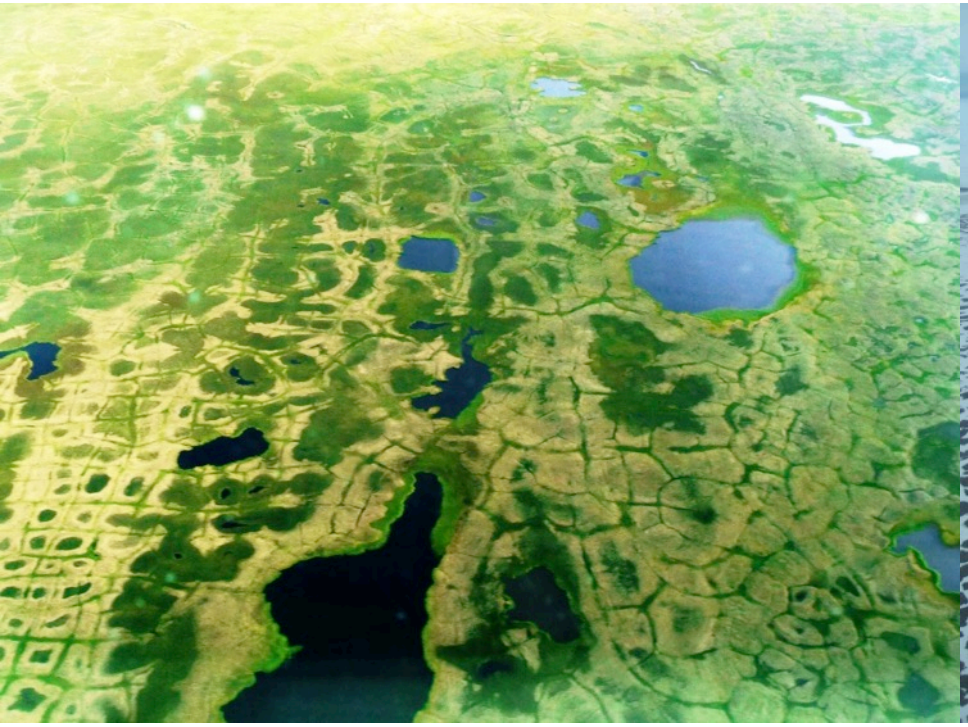
Permafrost soil C



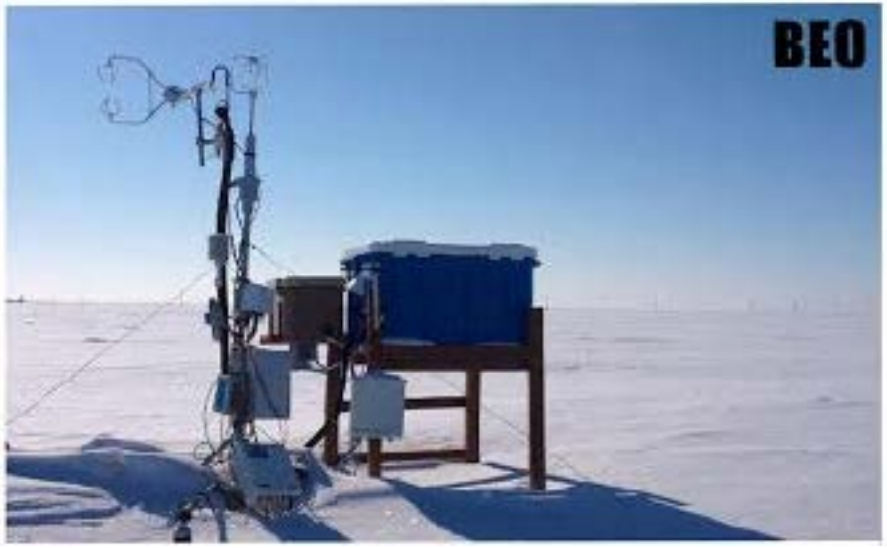
Hugelius et al. Biogeosciences 2014

Objectives

- **Refine rates, patterns, and controls on trace gas fluxes in the Arctic**
  - **Better define the seasonal pattern on trace gas fluxes in the Arctic**
  - **Better define the spatial heterogeneity of fluxes in the Arctic**
  - **Better predict future greenhouse gas feedbacks**
    - **Integrate observations, experiments, and modeling**



Primary towers in Barrow



CO_2 and CH_4 fluxes in the Arctic, Alaska

Different approaches

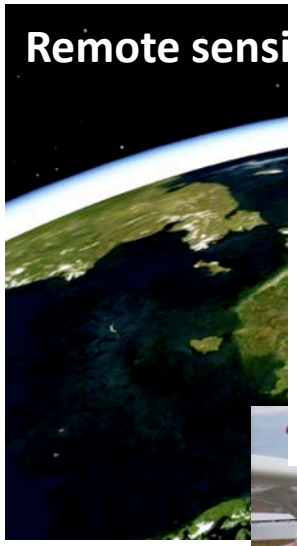
Decades

Years

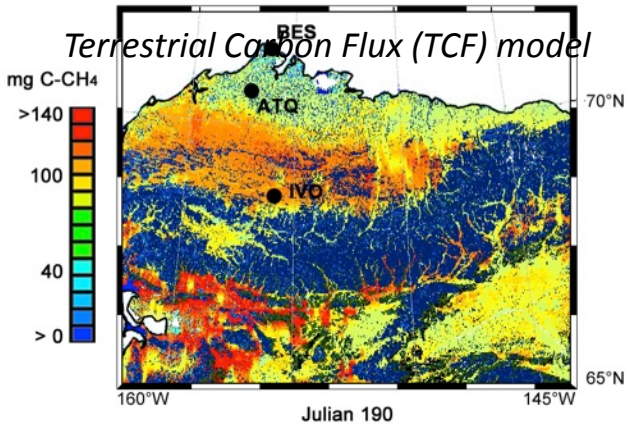
Seasons

Days

Remote sensi



Terrestrial Carbon Flux (TCF) model



Following From: Watts, Kimball, Zona, Oechel, et al. 2014 Biogeosciences

Eddy-covariance towers
GMD Barrow

Aircraft

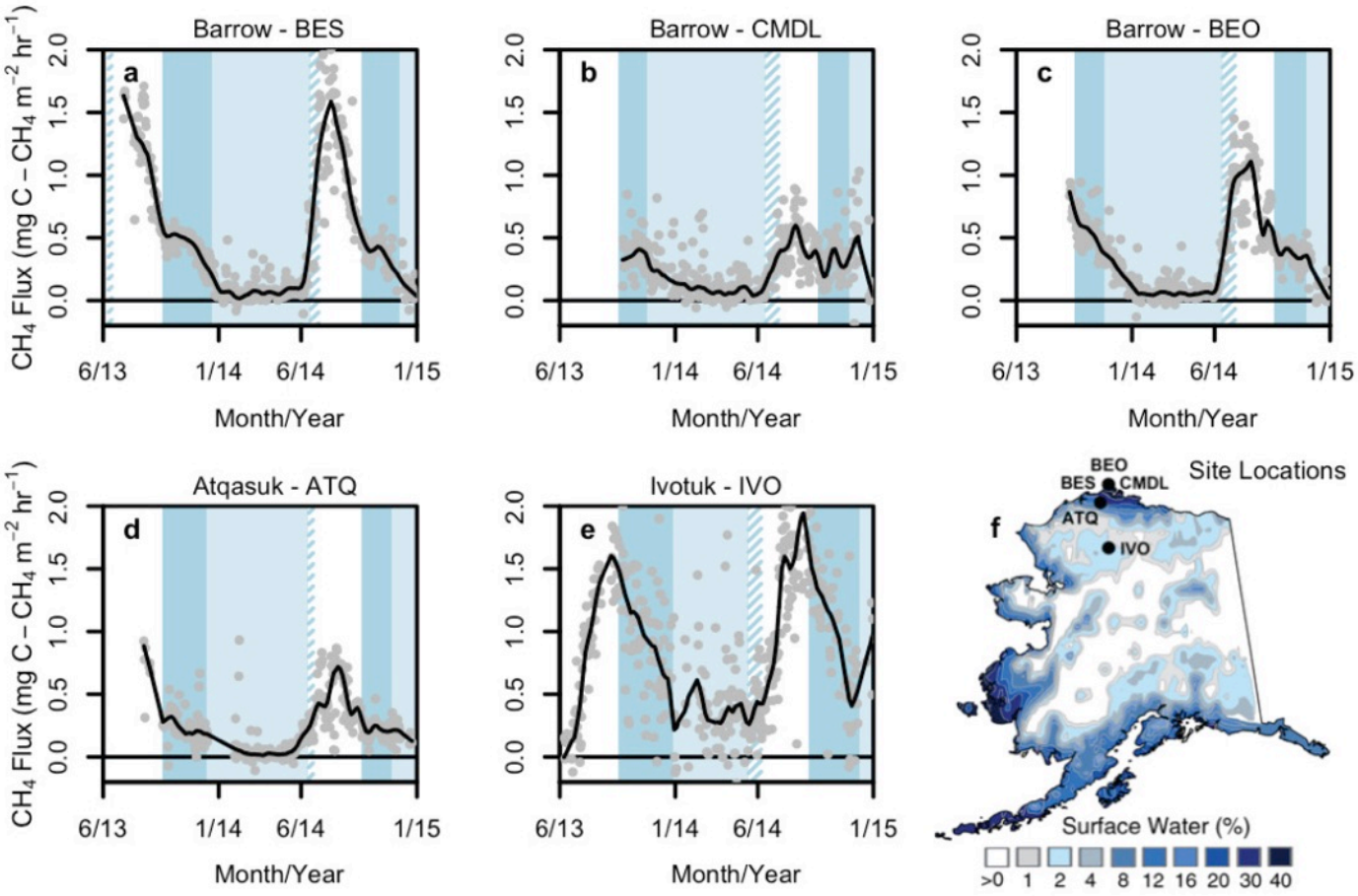
Chambers

Plot scale : 1

Ecosystem scale : 10^3

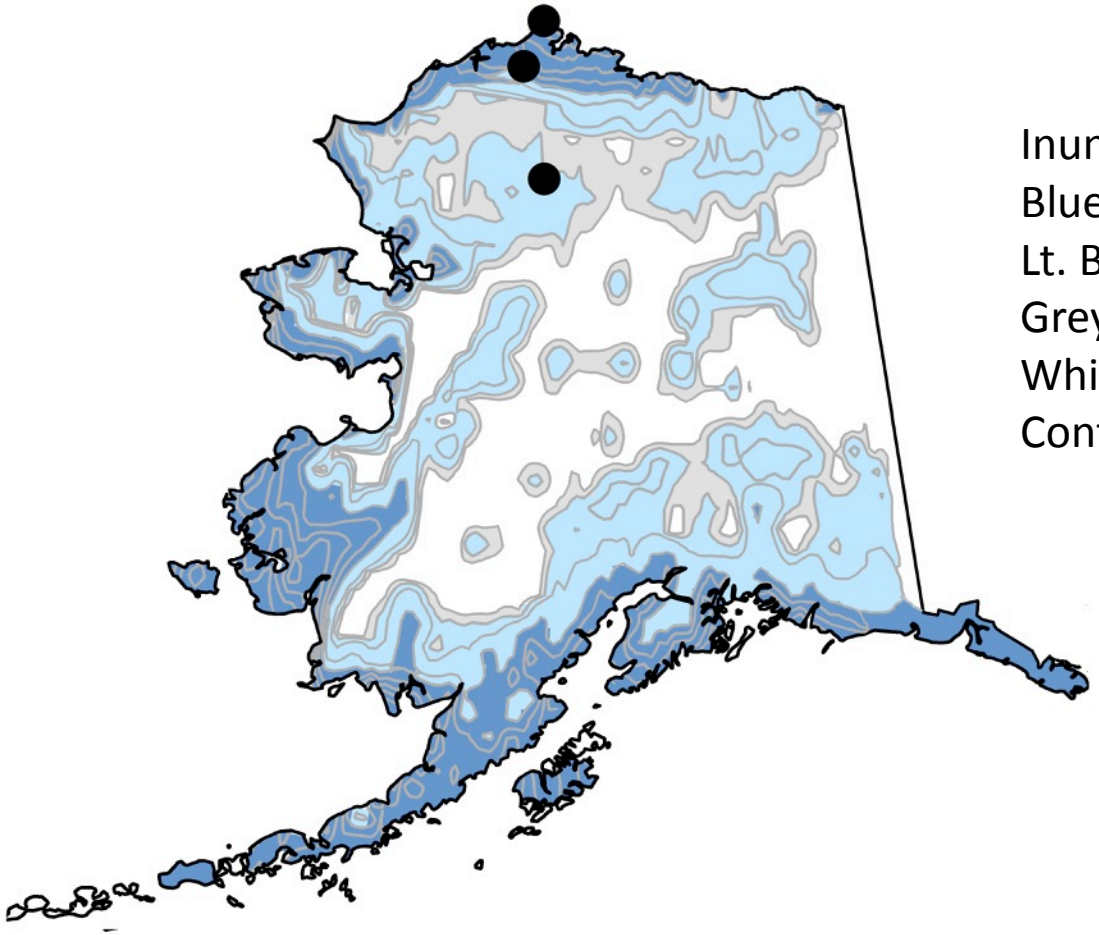
Regional scale : 10^6

Annual CH_4 fluxes North Slope Alaska 2013-2014



Zona et al. PNAS 2016

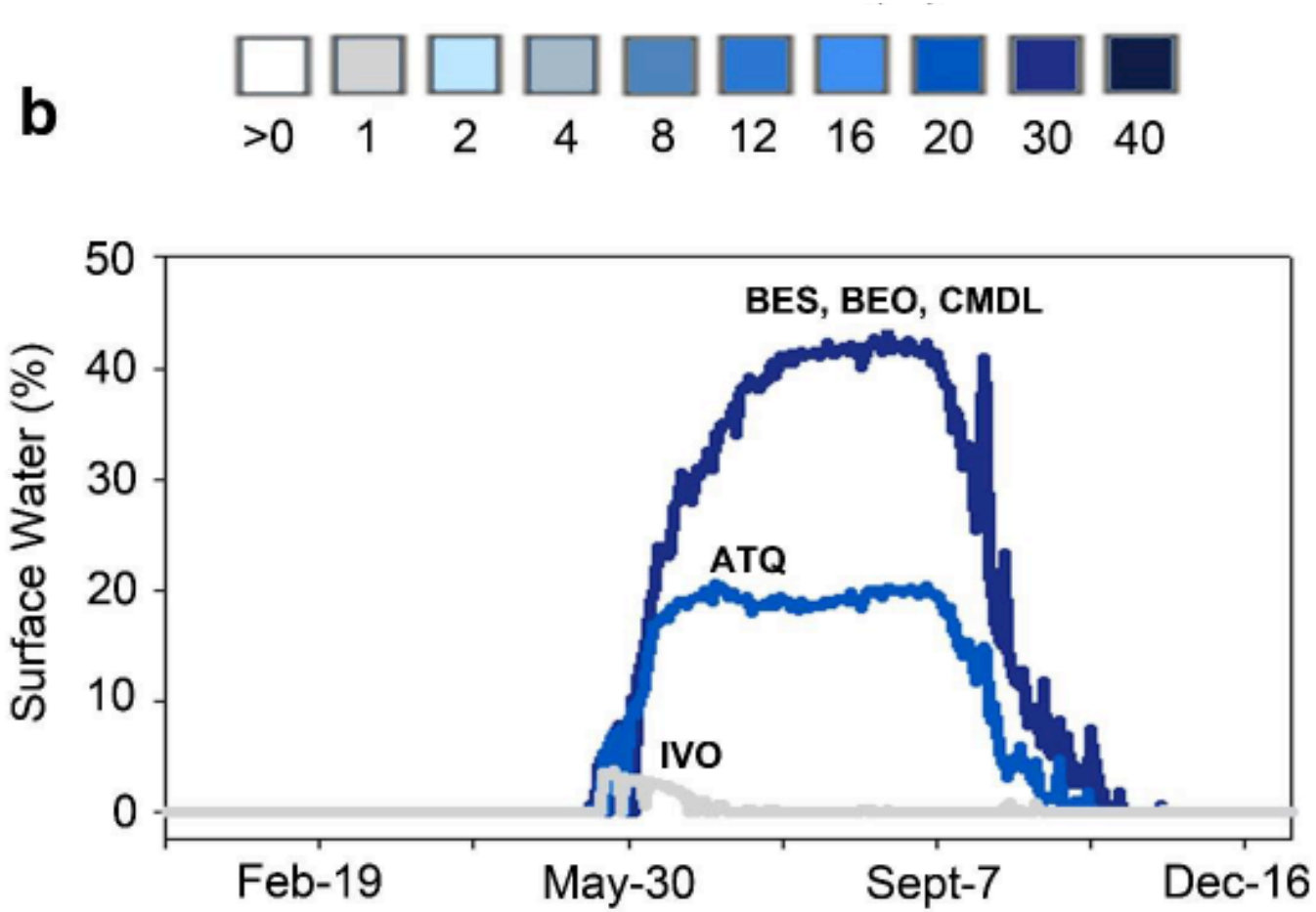
2013 Inundation from AMSR-E



Inundation:
Blue >10%
Lt. Blue 2-5%
Grey 1-2%
White <1%
Contour Intervals 5%

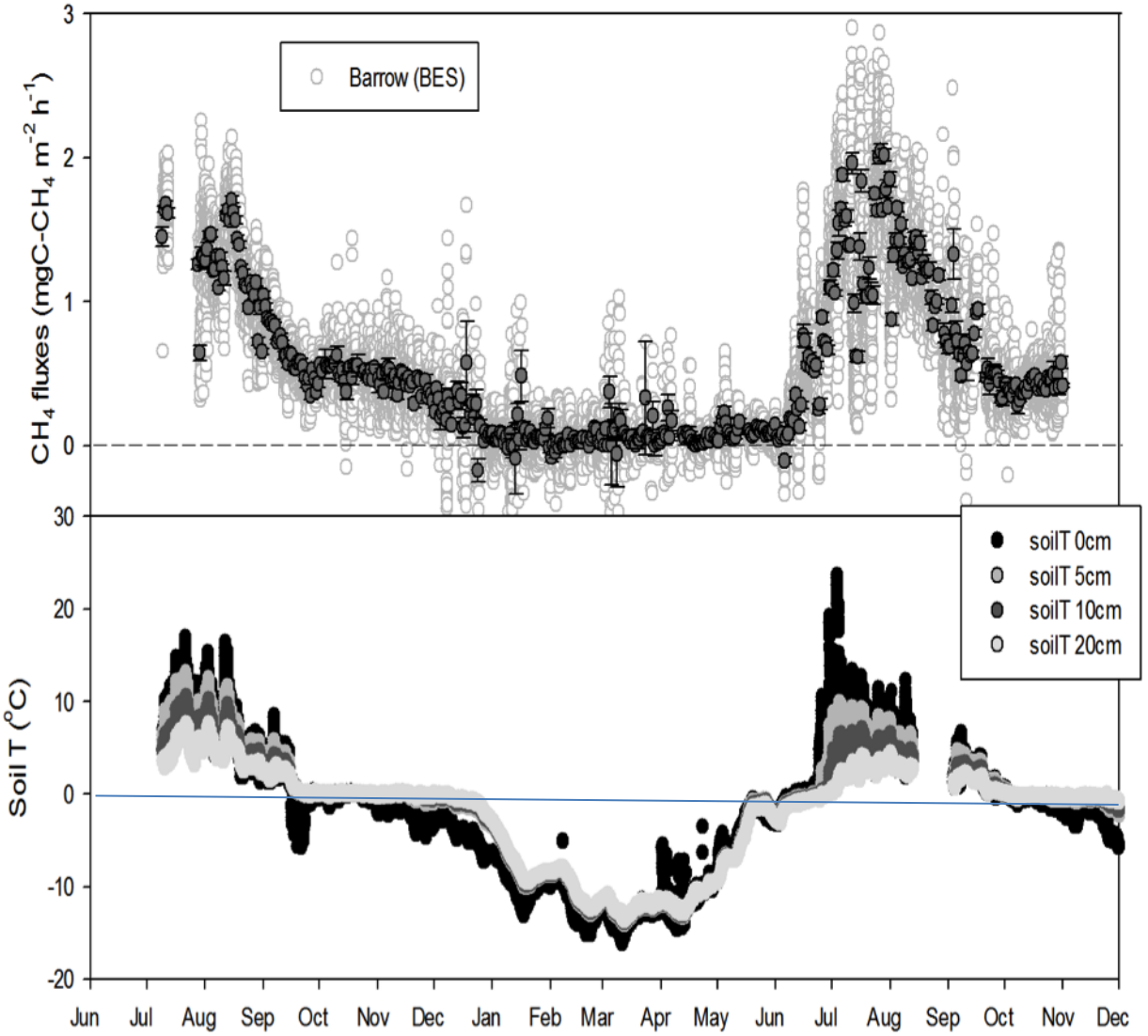
Du, Kimball, et al. 2014
Watt et al. 2012

2013 Inundation for study regions from AMSR-E



Zona et al. PNAS 2016
Du, Kimball, et al. 2014
Watt et al. 2012

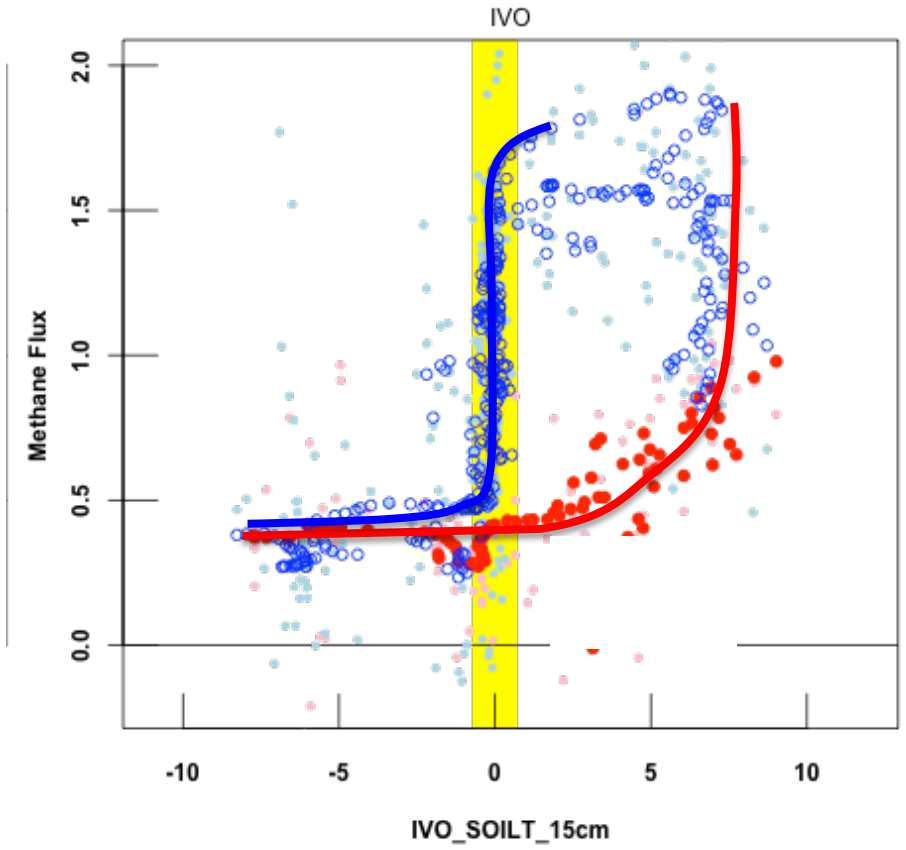
Barrow BES Half hour data + daily average flux



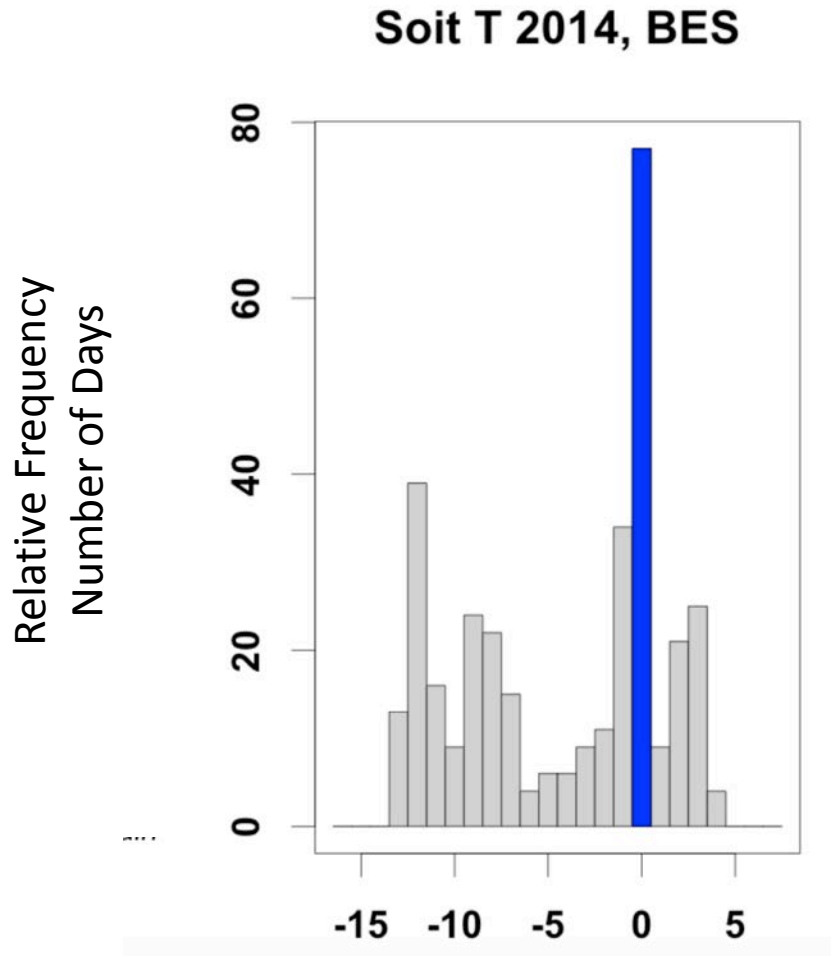
- No consistent diurnal pattern
- Unfrozen "zero curtain" soil layer linked to large fall CH_4 emissions

Zona et al., PNAS 2016

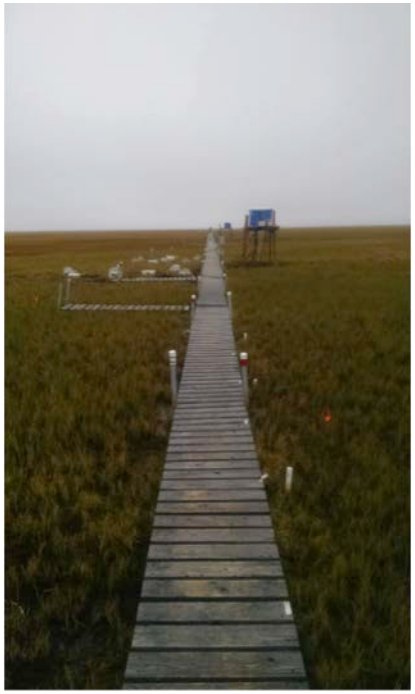
Ivotuk

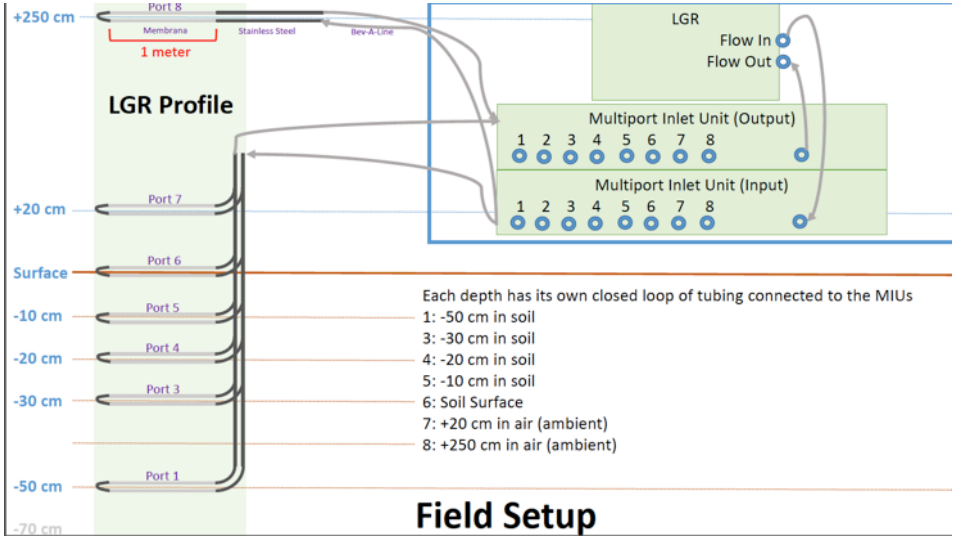


Soil Temperature Distributions



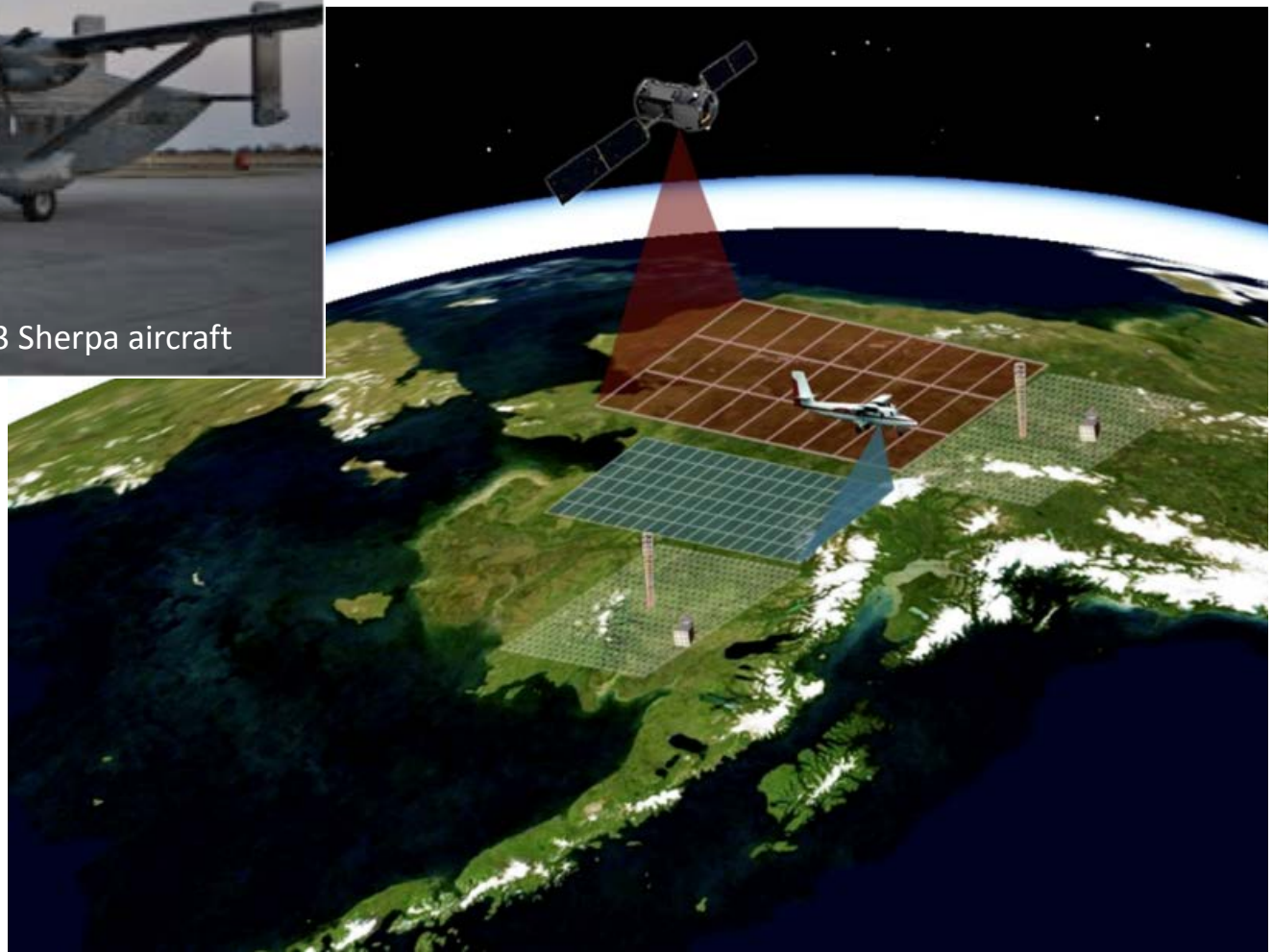
CO_2, CH_4, Radon, Diffusivity and Flux System



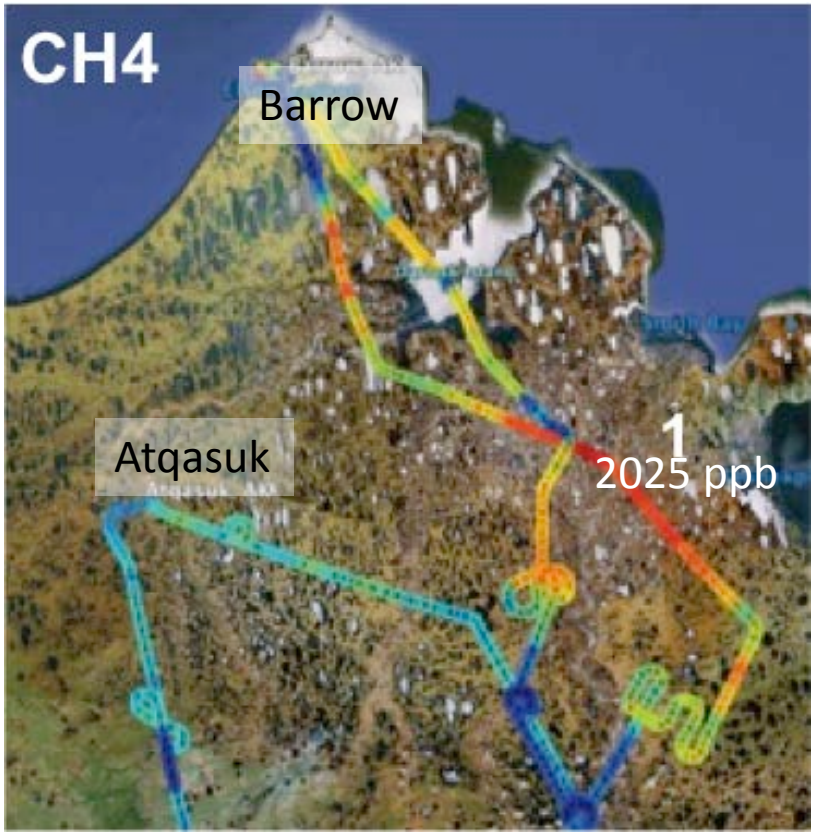


NASA CARVE
Aircraft Concentrations and Remote Sensing

NASA CARVE C-23 Sherpa aircraft

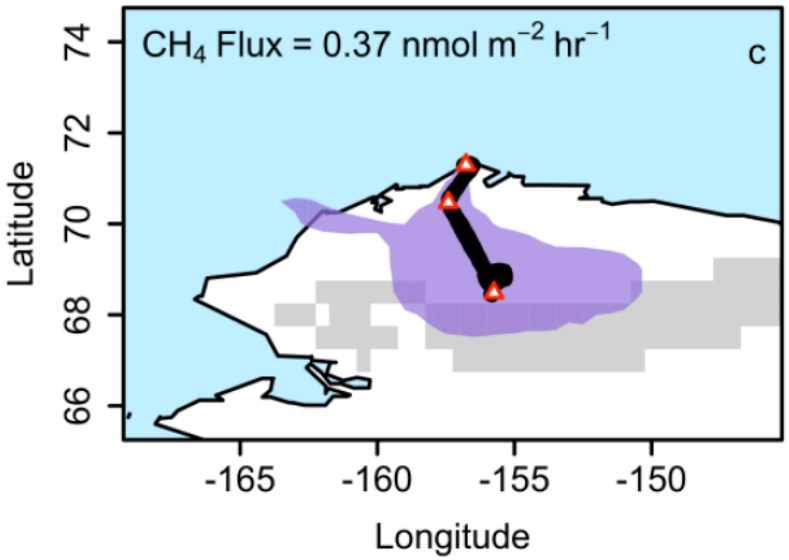


NASA CARVE Aircraft CH_4 Concentrations

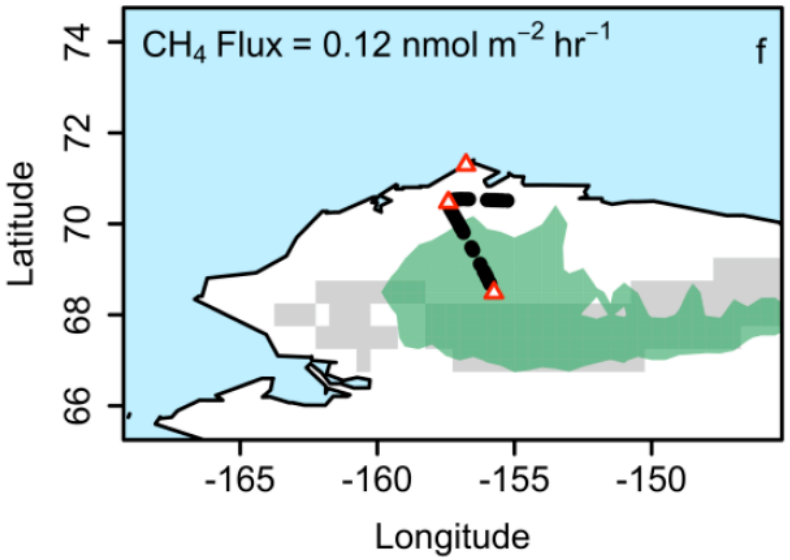


Footprint WRF STILT (Stochastic Time-Inverted Lagrangian Transport) Modeling

September 6, 2014

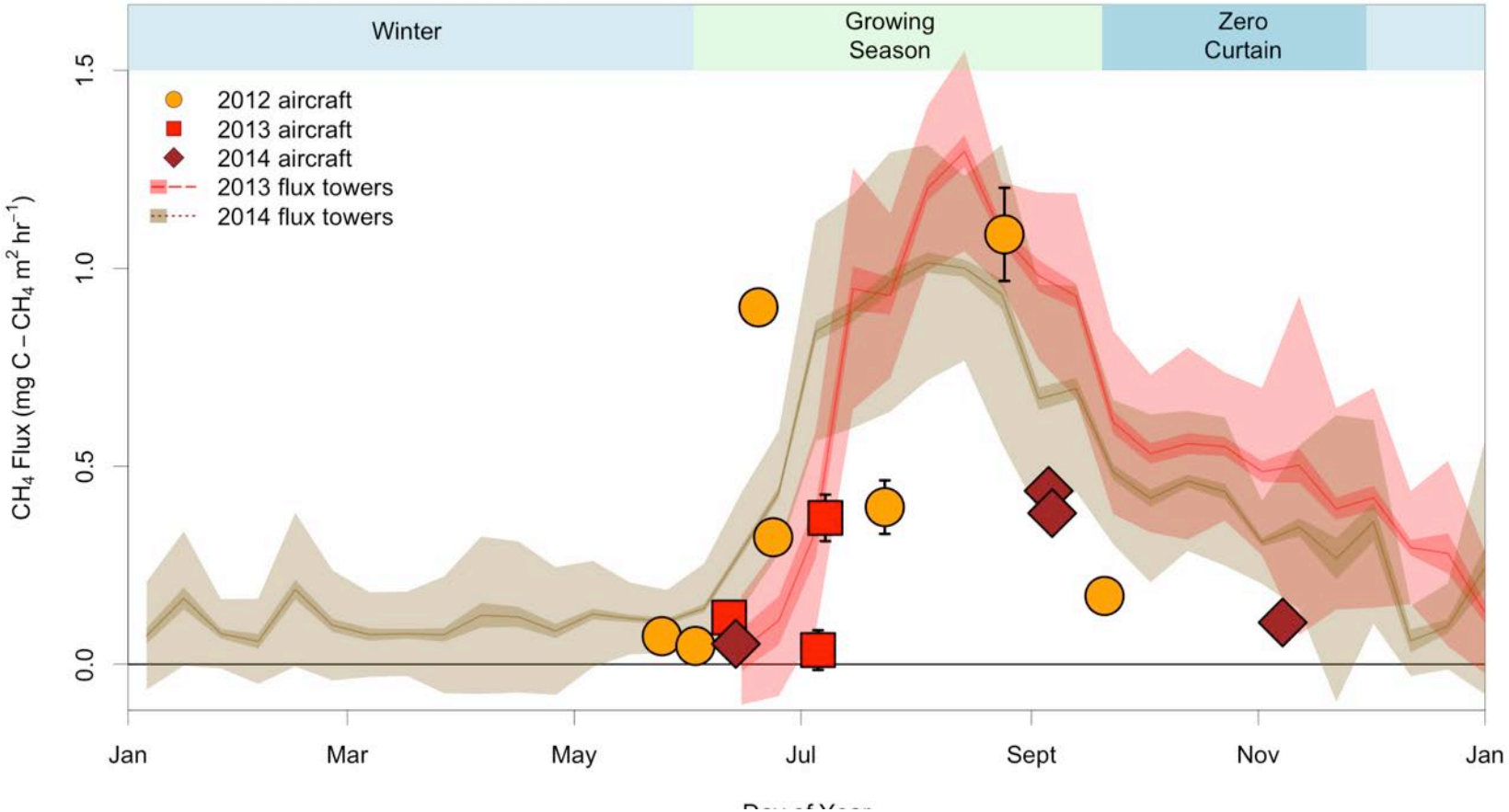


November 7, 2014



Zona et al. PNAS 2016

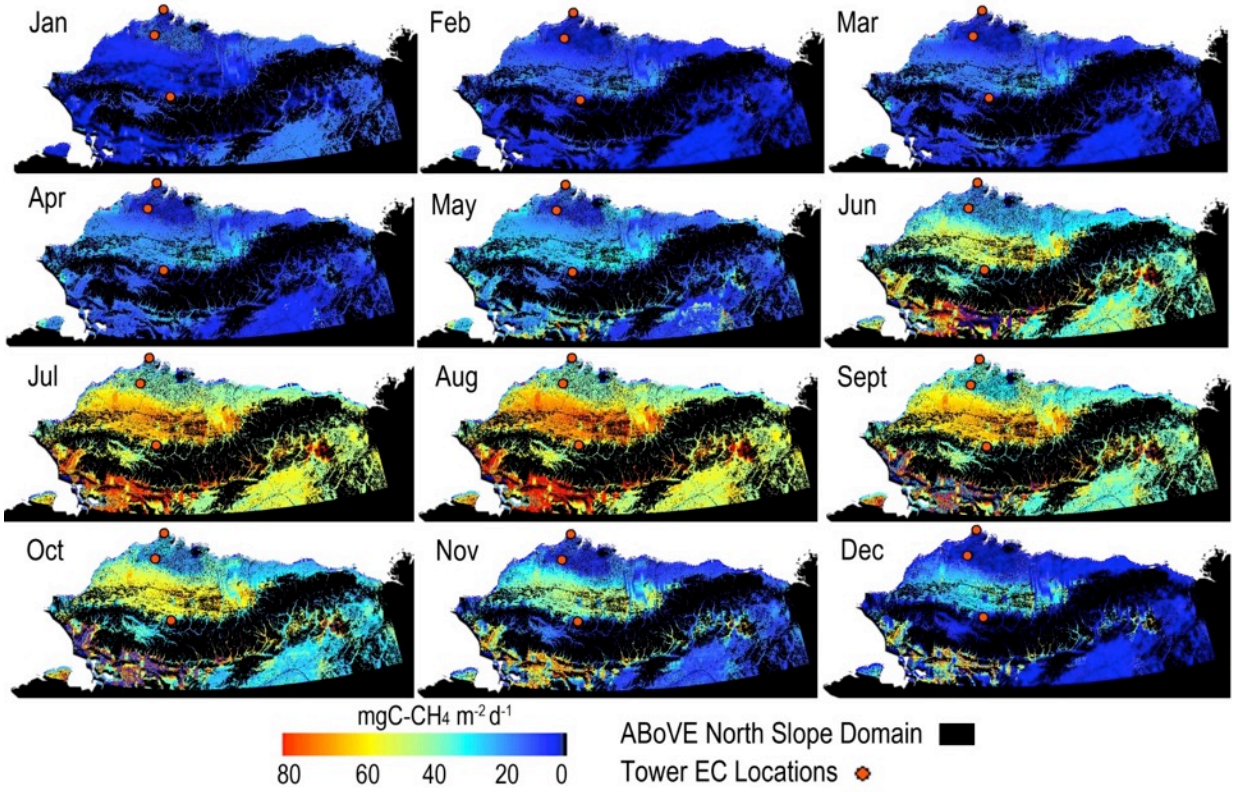
North Slope Alaska Fluxes Aircraft vs. Tower



Zona et al., PNAS 2016

Terrestrial Carbon Flux (TCF) model simulations of daily methane (CH_4)

using SMAP, MODIS, MERRA Climate data



Watts et al. in prep.

Methods: Watts et al. 2013.

Conclusions

- The cold period is a critical contributor to annual CH_4 fluxes in the Arctic.
  - Based on rates presented here, annual Arctic CH_4 emissions are ~27 Tg which ~50% occur in the cold season.

- Past models and atmospheric inversions have often been in error by assuming near zero CH_4 fluxes the cold period.

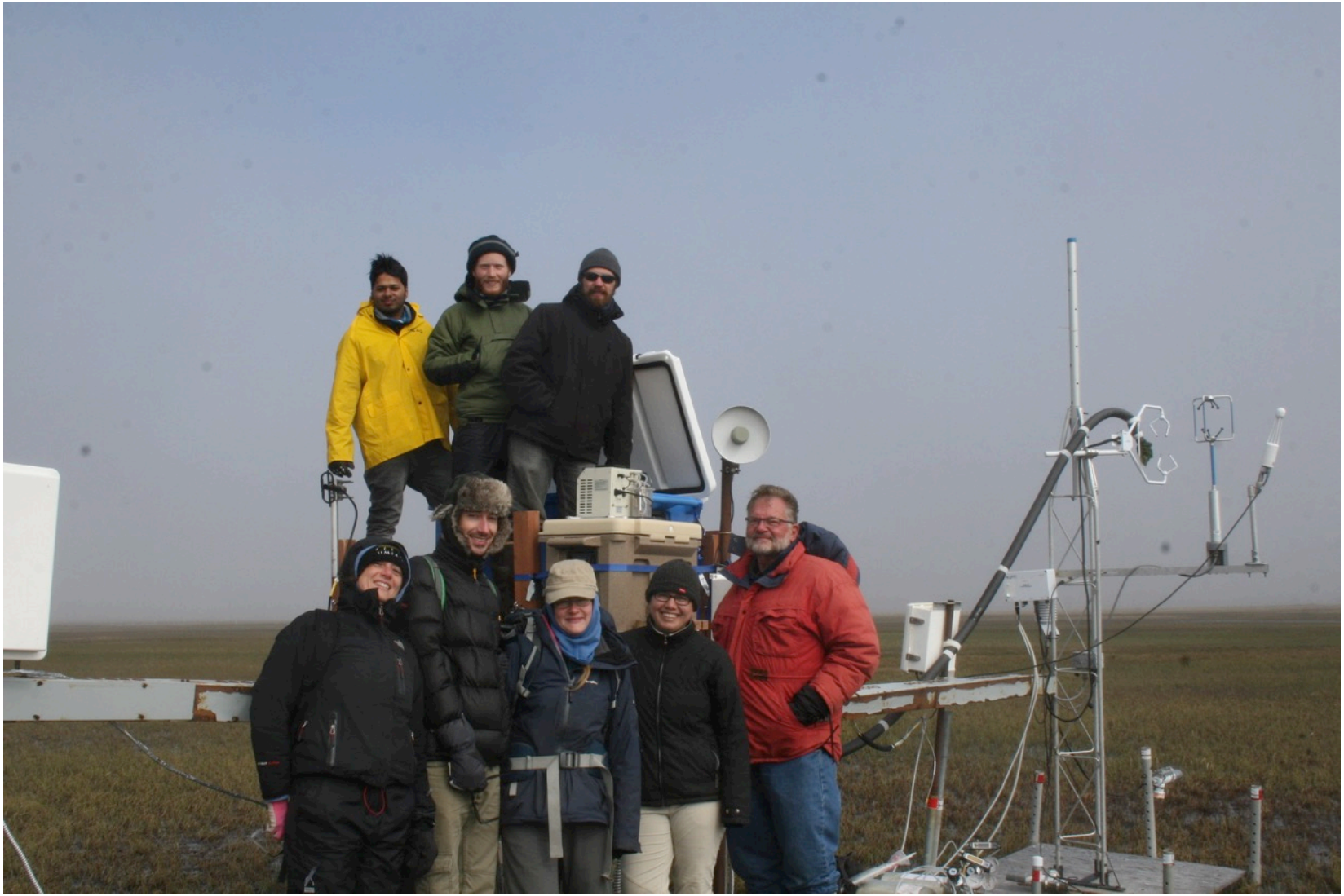
- Fall "zero curtain" CH_4 fluxes can be substantial compared to summer fluxes
  - Methanogenesis continues in the saturated unfrozen layer.
  - Methanotropy, on the other hand, is suppressed by fall freezing.

- The relative impact of zero curtain emissions on annual fluxes is greatest in dry sites where methanotropy is highest in the summer. So, drier sites may be significant methane emitters.

- Extension of the zero curtain under future climate conditions could have significant impacts on annual emissions.

- Long-term measurements and high resolution models can set the baseline against which change in CH_4 fluxes can be detected.

Thanks to the GCRG SDSU team, collaborators, and funders



GMD "Supporting the CMDL tower since 1997"

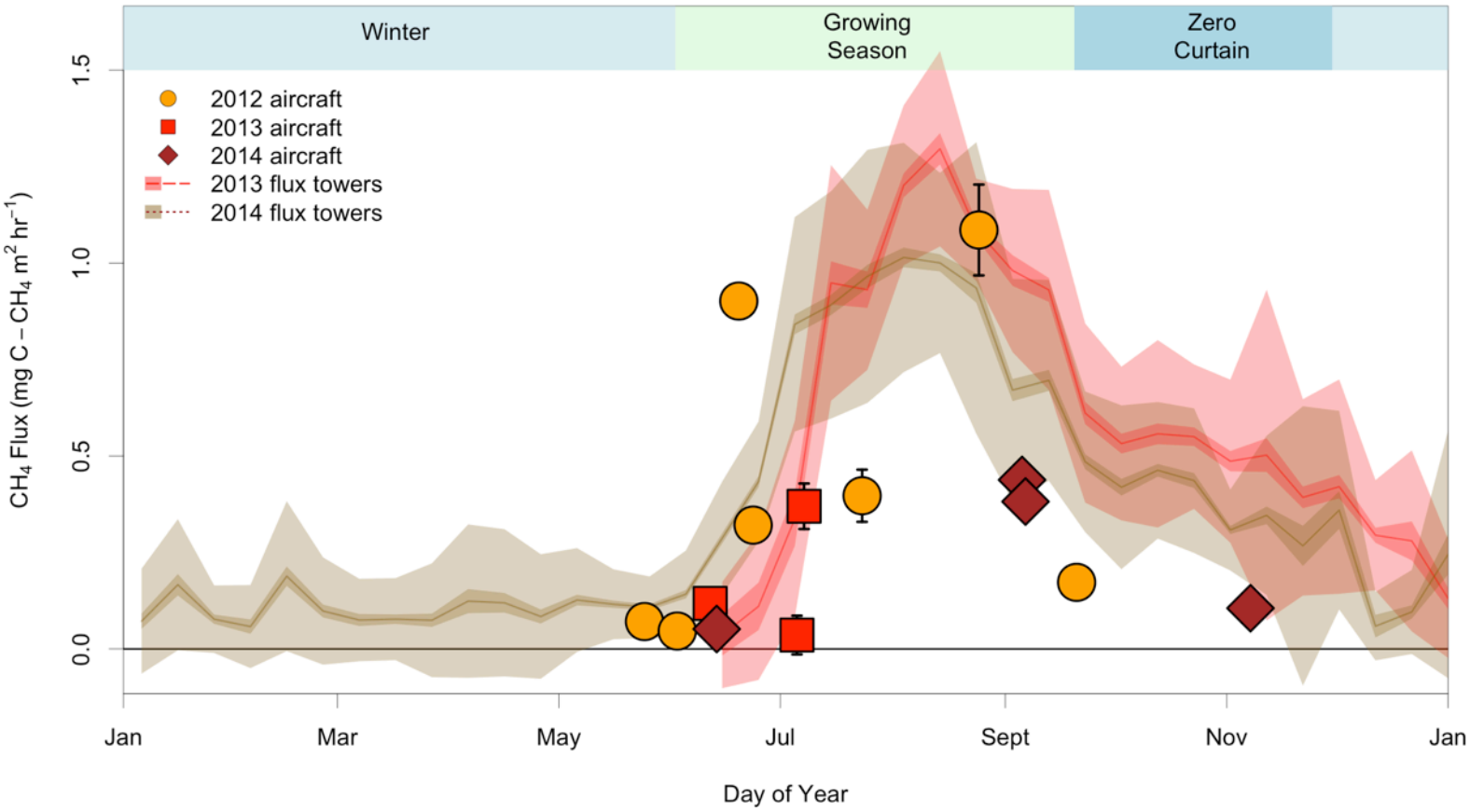
NOAA EPP SDSU Interns

- SDSU is a Hispanic serving institution.
- We submitted to the **NOAA EPP (NOAA Education Partnership Program)/MSI** with the NOAA-Cooperative remote Sensing Science and Technology Center **(NOAA-CREST)**
- If successful, the goal is is to engage more students into stem disciplines including URM.

Midnight over the Arctic Ocean

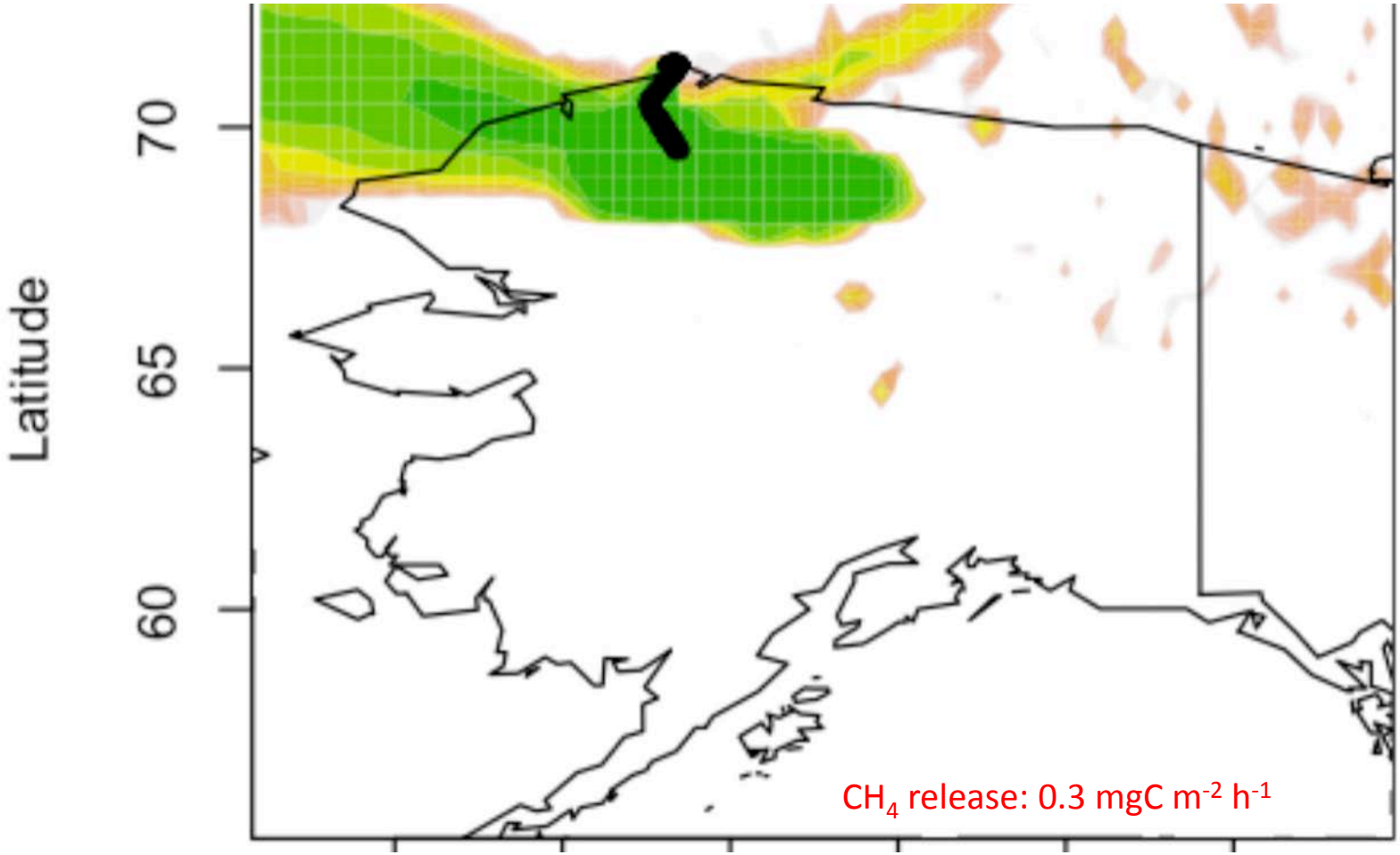
Thank you
Questions?

North Slope Alaska Fluxes Aircraft vs. Tower



Zona et al., in Review

Footprint WRF STILT (Stochastic Time-Inverted Lagrangian Transport) Modeling



Zona et al., PNAS 2016

Conclusions

- The cold period is a critical contributor to annual CH_4 fluxes in the Arctic.
  - Based on rates presented here, annual Arctic CH_4 emissions are ~27 Tg which 11 Tg occur in the cold season.

- Models and atmospheric inversions have often been in error by assuming near zero CH_4 fluxes the cold period.

- Fall "zero curtain" CH_4 fluxes can be substantial compared to summer fluxes
  - Methanogenesis continues in the saturated unfrozen layer.
  - Methanotropy, on the other hand, is suppressed by fall freezing.

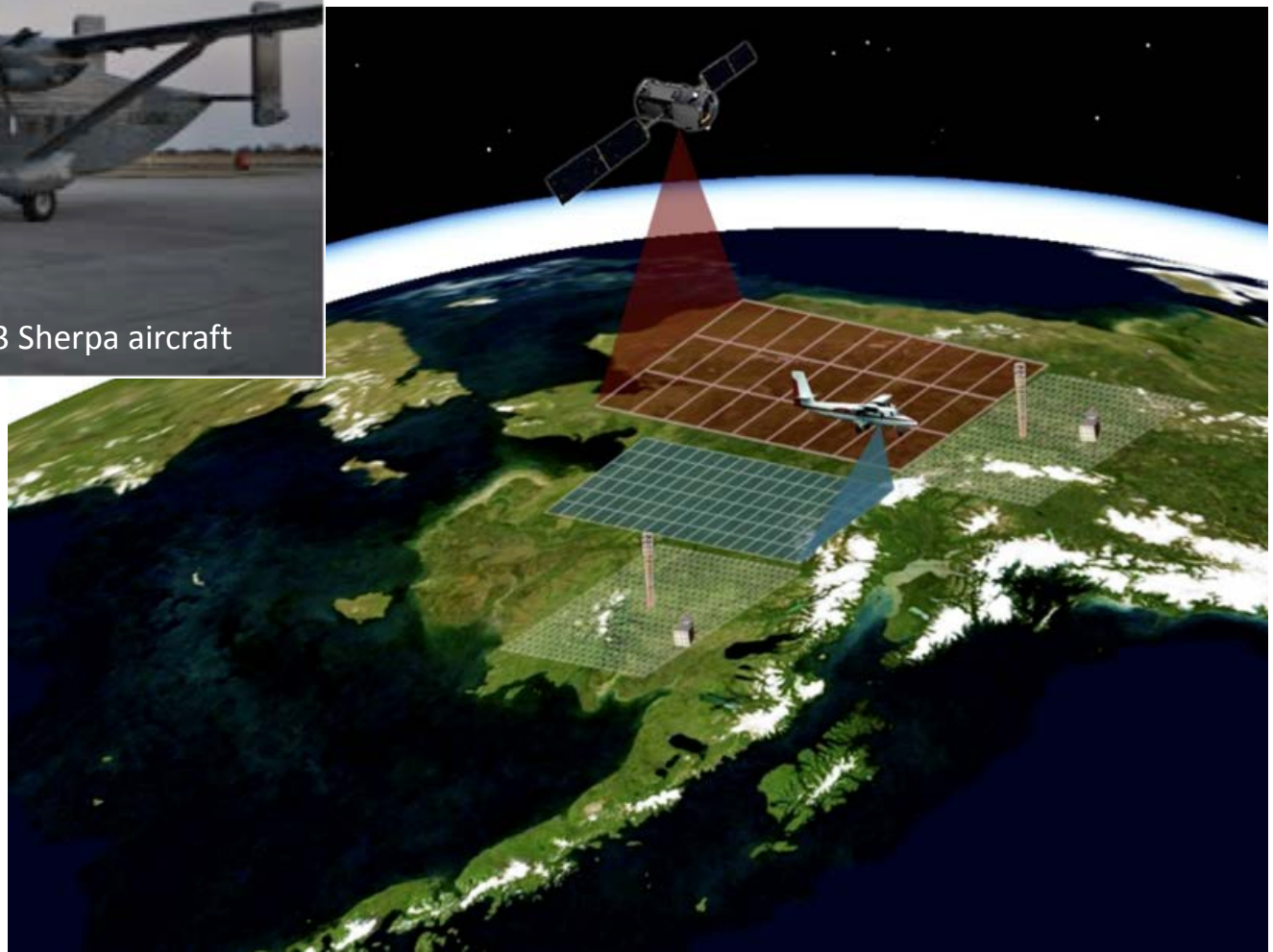
- The relative impact of zero curtain emissions on annual fluxes is greatest in dry sites where methanotropy is highest in the summer. So, drier sites may be significant methane emitters.

- Extension of the zero curtain under future climate conditions could have significant impacts on annual emissions.

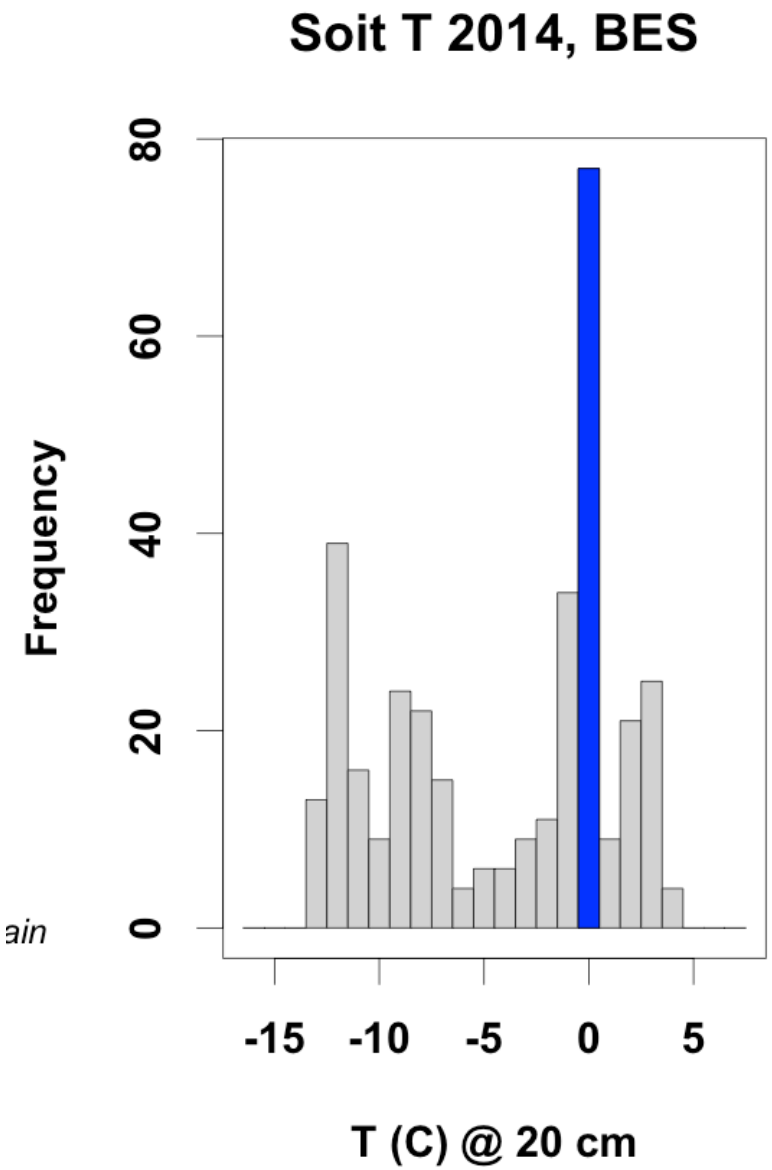
- Long-term measurements and high resolution models can set the baseline against which change in CH_4 fluxes can be detected.

NASA CARVE
Aircraft Concentrations and Remote Sensing

NASA CARVE C-23 Sherpa aircraft

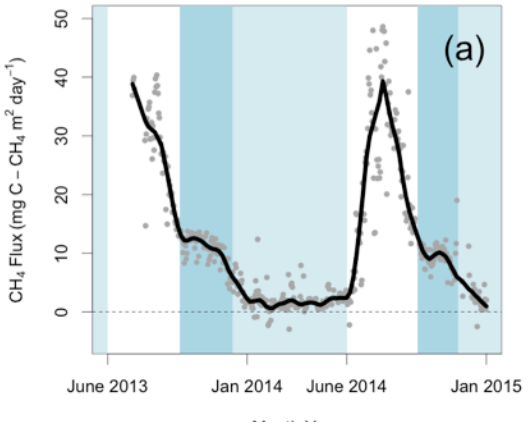


Soil Temperature Distributions

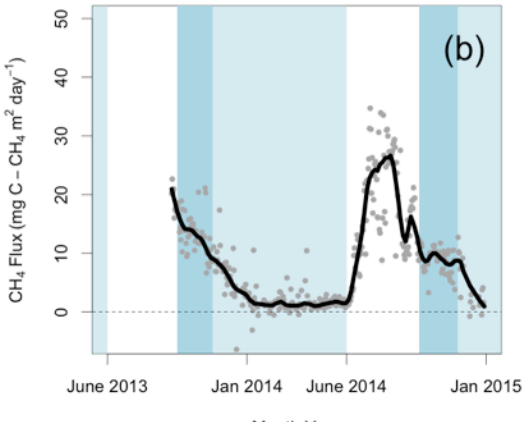


Annual CH_4 fluxes North Slope Alaska 2013-2014

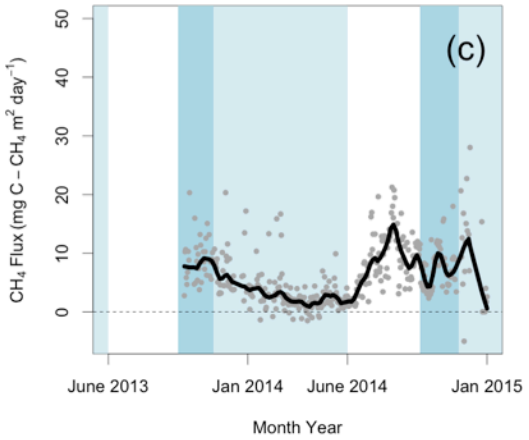
Barrow BES



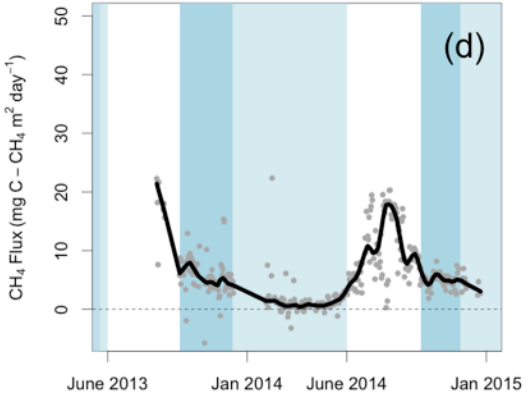
Barrow BEO



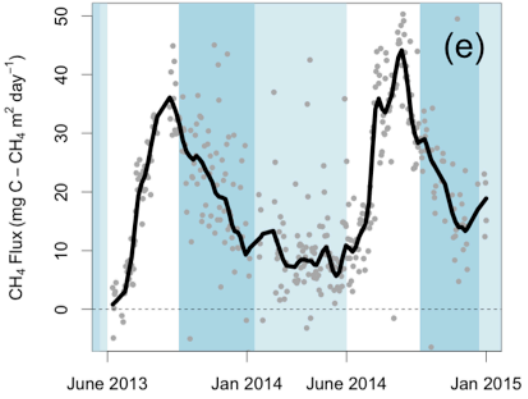
Barrow CMDL

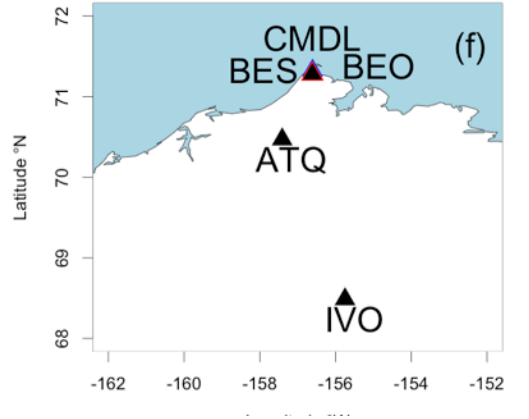


Atqasuk- ATQ



Ivotuk-IVO

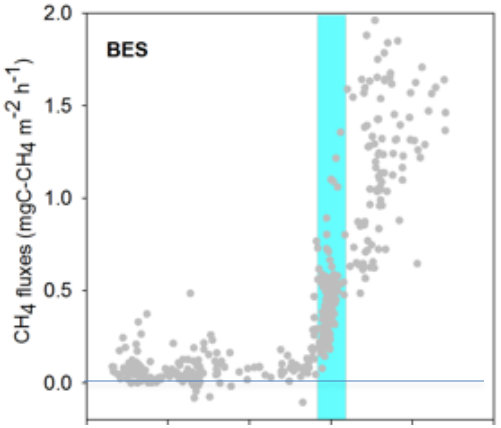




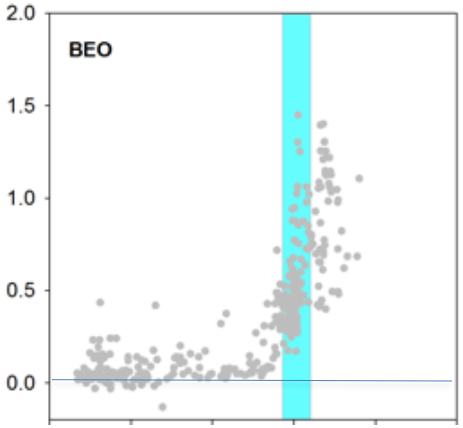
Zona et al., PNAS 2016

CH_4 Emissions vs Active Layer Temperature

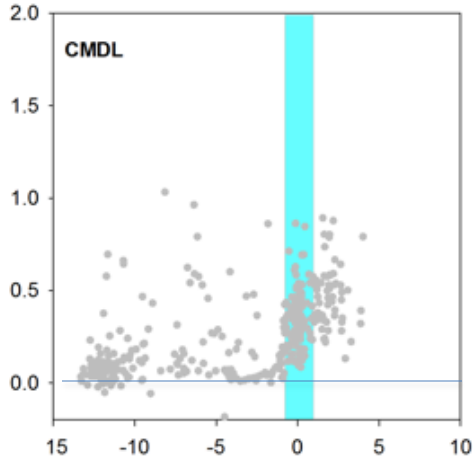
Barrow BES



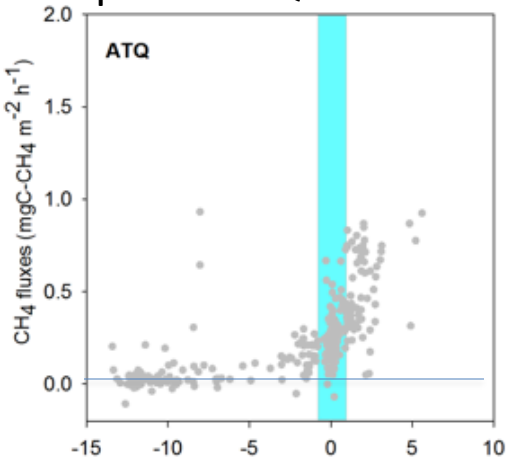
Barrow BEO



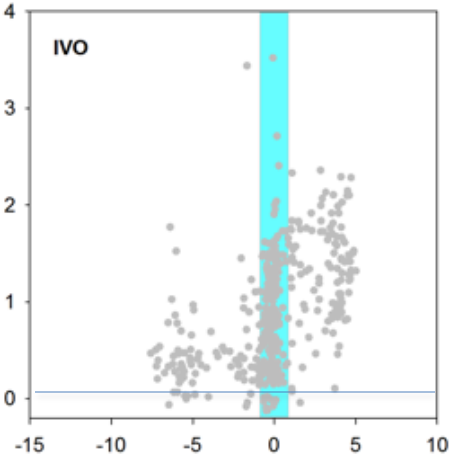
Barrow CMDL



Atqasuk- ATQ



Ivotuk-IVO

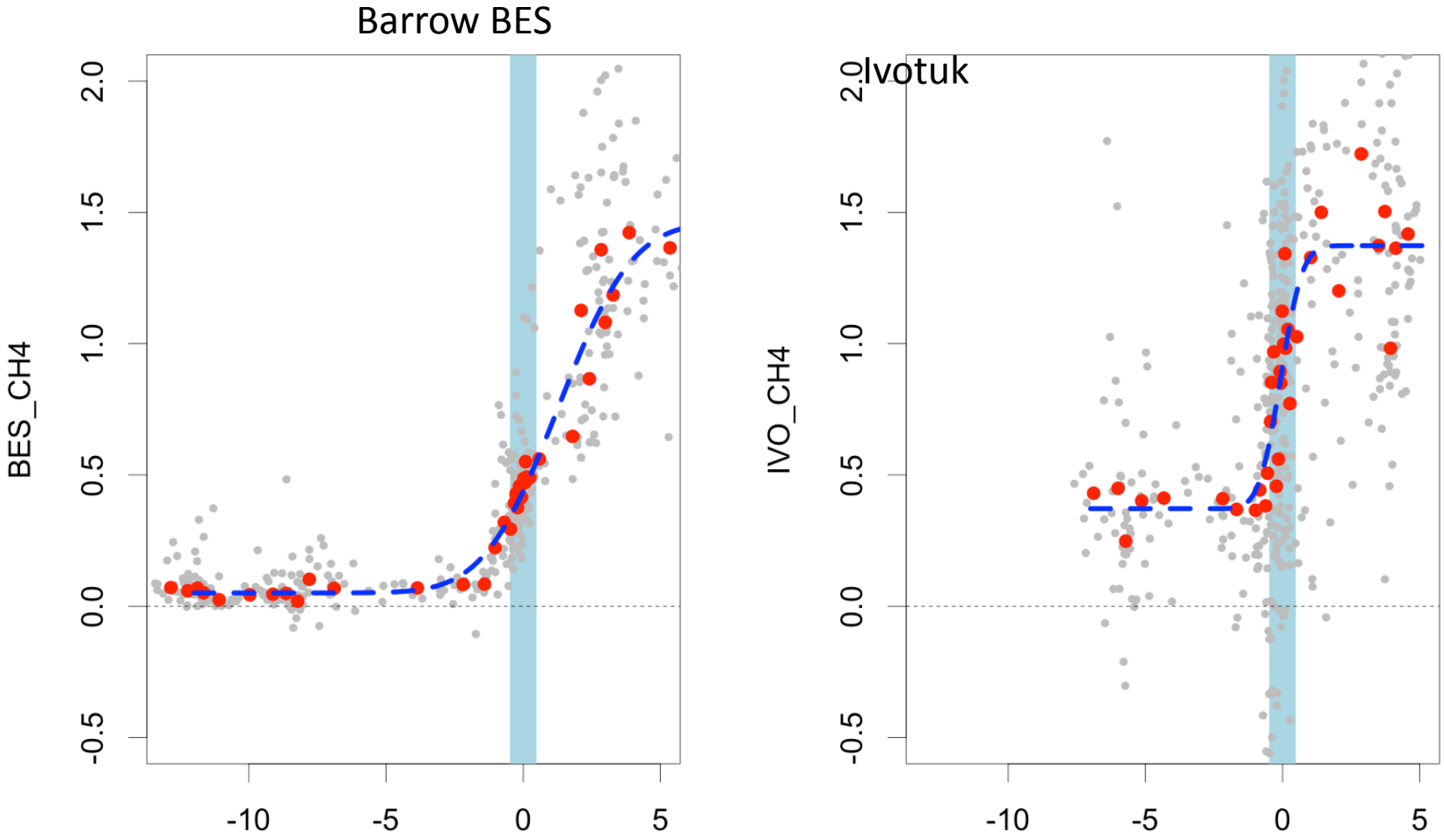


Active Layer Temperature °C (-20 cm or -30cm)

Zona et al., in prep.

CH4 Flux vs Soil Temp

mg C-CH_4 m^{-2} h^{-1}



CARVE Aircraft CH_4 Concentrations