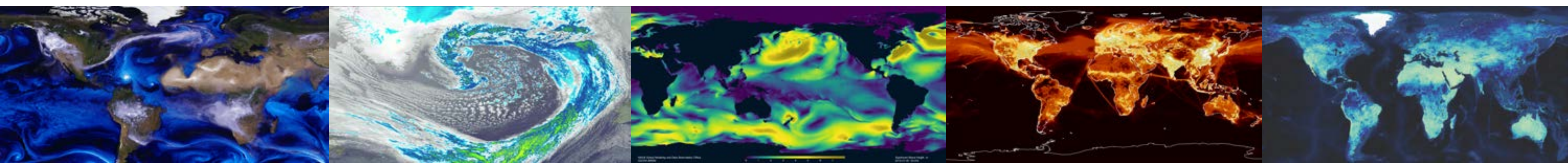
Atmospheric methane in GEOS-5:

development of the methane module in GEOS, current status and planned capabilities



Abhishek Chatterjee, Lesley Ott, Ben Poulter

Z. Zhang, B. Weir, K. Morgan, N. Balashov, S. Basu, S. Kawa and S. Pawson

AMS Annual Meeting **Boston, MA** **January 13, 2020**

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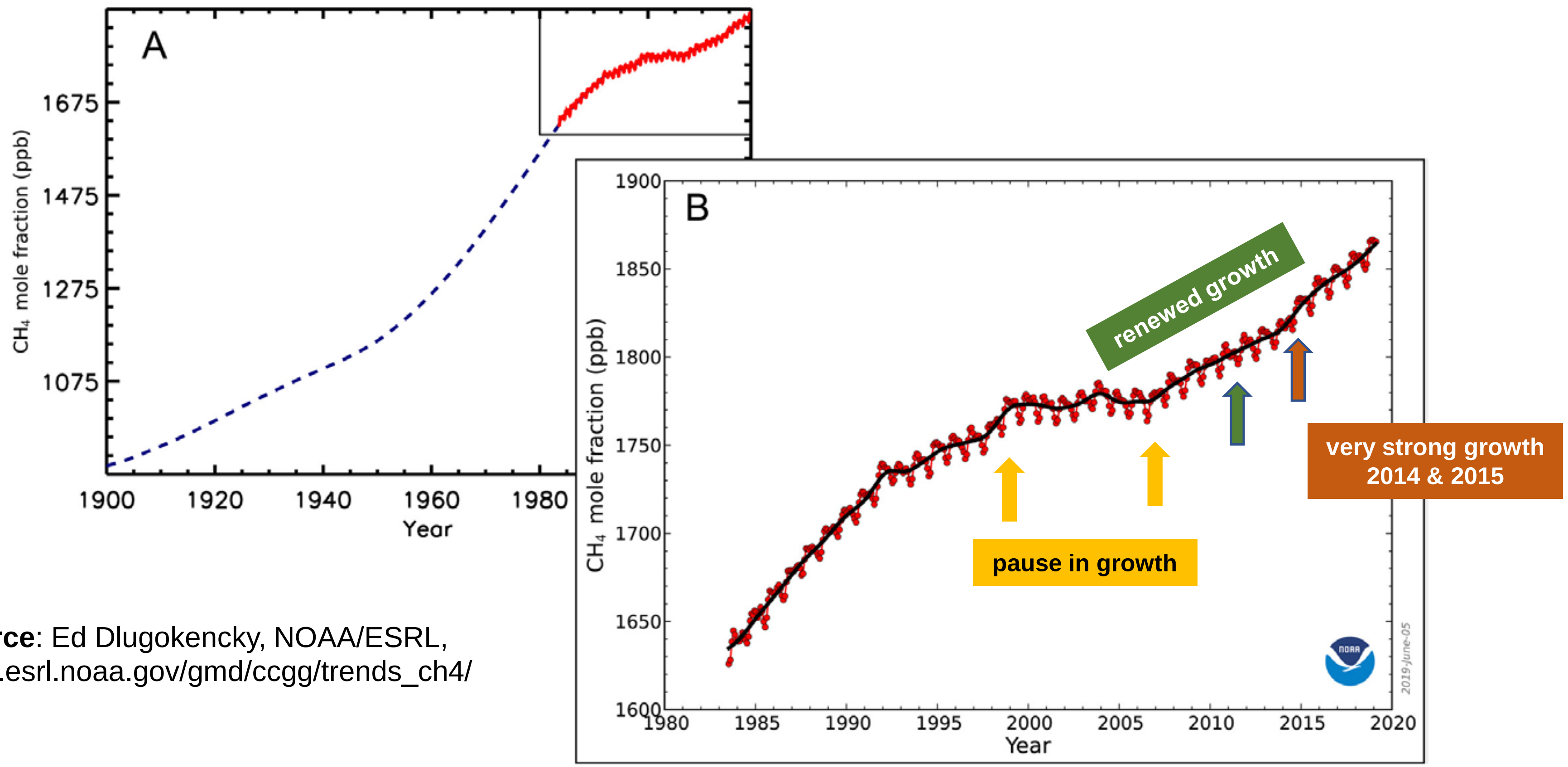
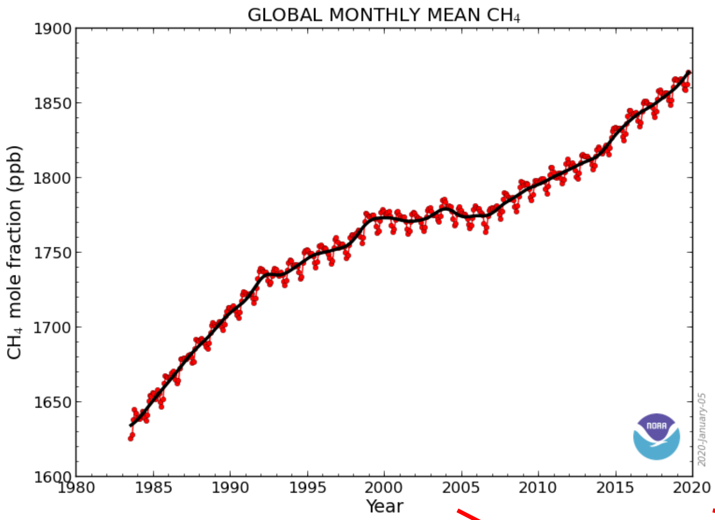
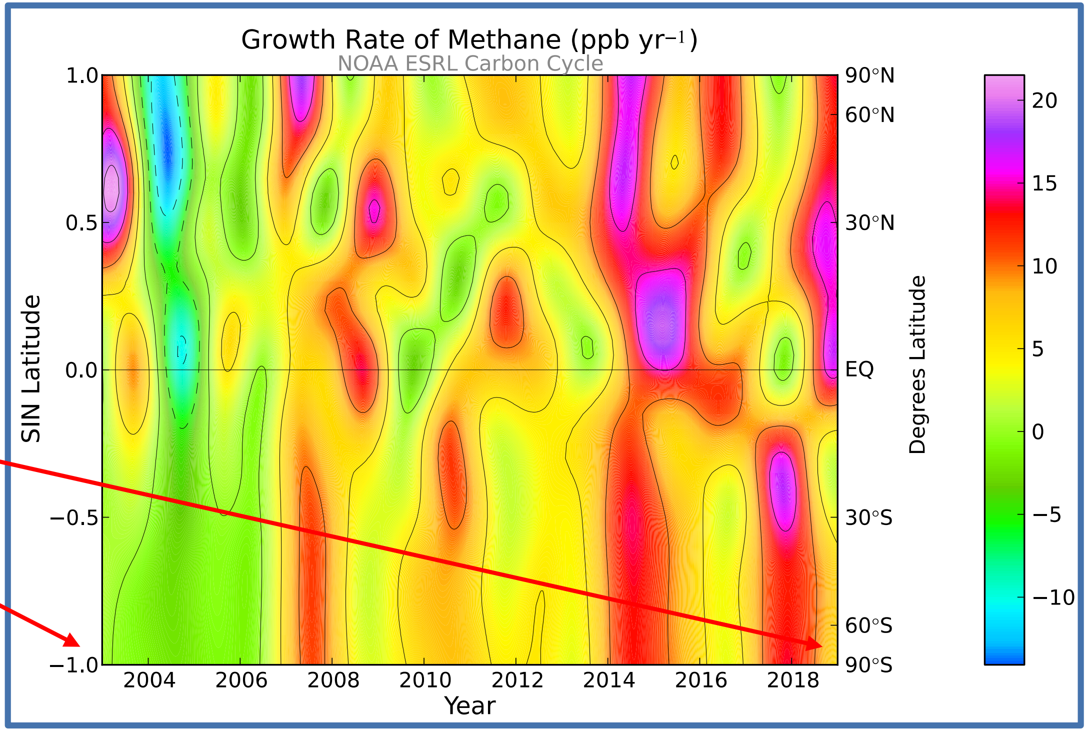
Background



Source: Ed Dlugokencky, NOAA/ESRL,
www.esrl.noaa.gov/gmd/ccgg/trends_ch4/

Background



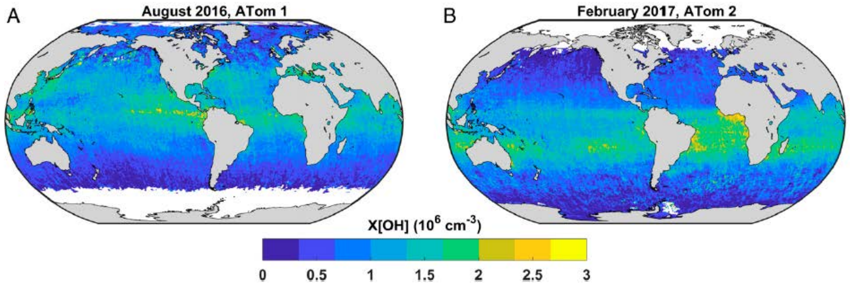


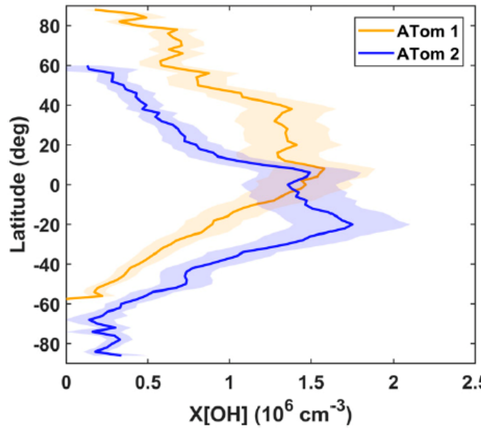
Source: Ed Dlugokencky, Lori Bruhwiler, NOAA/ESRL,

Background

Methane Emission Sources

Methane Removal/Sink

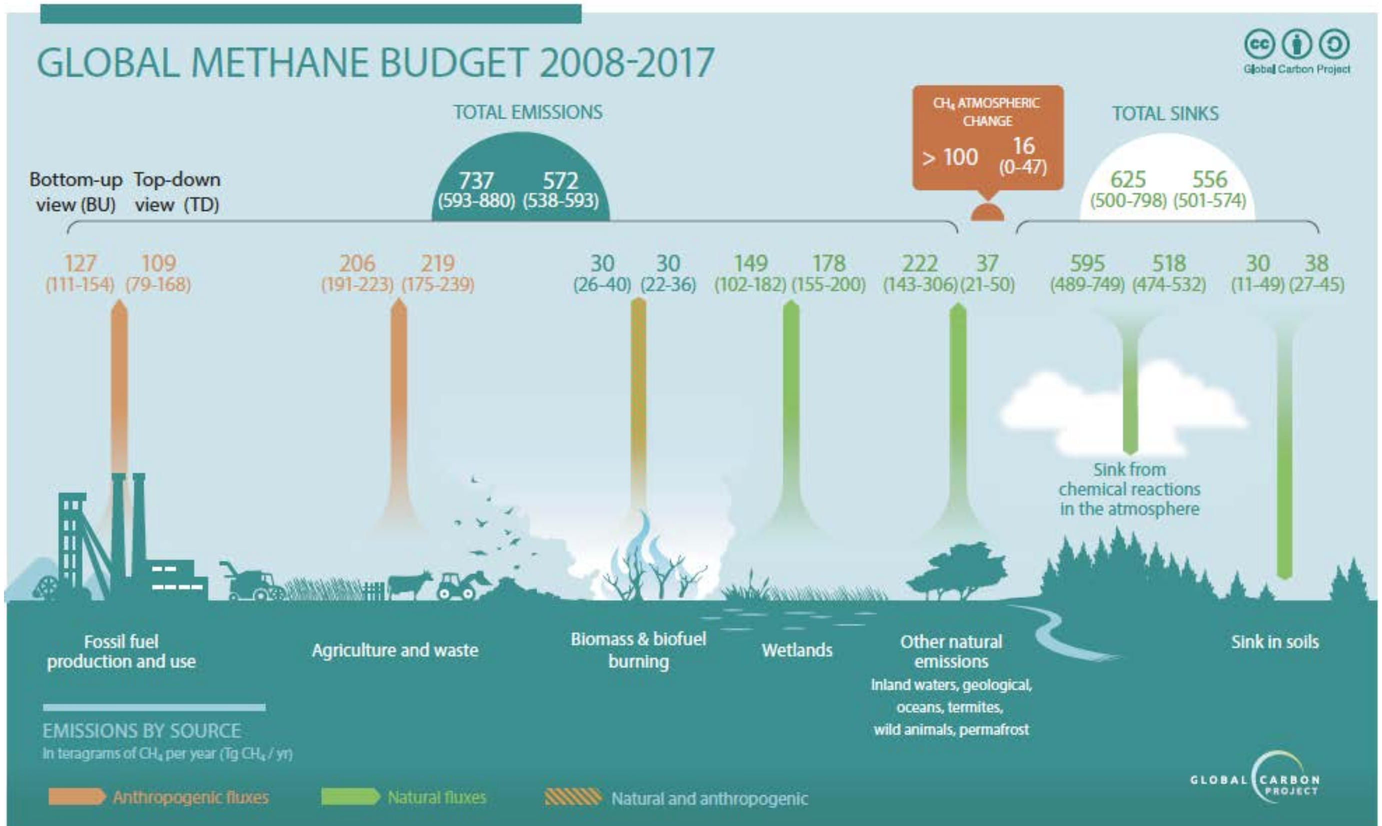




Wolfe et al. 2019
Turner et al. 2017
Rigby et al. 2017

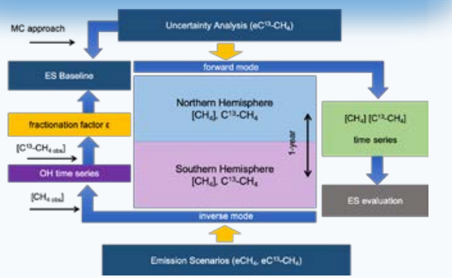
Background

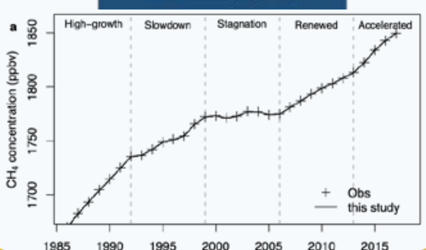
Saunois et al. [2019], ESSD



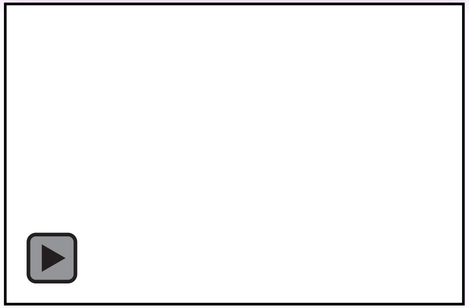
Outline

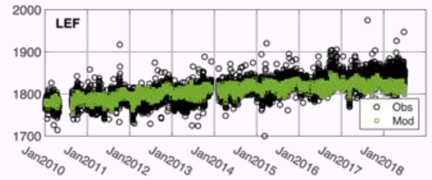
TWO-BOX MODEL





GEOS CH_4 SIMULATIONS





APPLICATIONS

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Recent global atmospheric CH_4 increase

Biomass Burning

ARTICLE

DOI: 10.1038/s41467-017-02246-0 OPEN

Reduced biomass burning emissions reconcile conflicting estimates of the post-2006 atmospheric methane budget

John R. Worden[1], A. Anthony Bloom[1], Sudhanshu Pandey[2,3], Zhe Jiang[1,4], Helen M. Worden[4], Thomas W. Walker[1], Sander Houweling[2,3,5] & Thomas Röckmann[2]

Hydroxyl Radical

PNAS

Role of atmospheric oxidation in recent methane growth

Matthew Rigby[a,1], Stephen A. Montzka[b], Ronald G. Prinn[c], James W. C. White[d], Dickon Young[a], Simon O'Doherty[a], Mark F. Lunt[a], Anita L. Ganesan[e], Alistair J. Manning[f], Peter G. Simmonds[a], Peter K. Salameh[g], Christina M. Harth[g], Jens Mühle[g], Ray F. Weiss[g], Paul J. Fraser[h], L. Paul Steele[h], Paul B. Krummel[h], Archie McCulloch[a], and Sunyoung Park[i]

[a]School of Chemistry, University of Bristol, Bristol BS8 1TS, United Kingdom; [b]Earth System Research Laboratory, National Oceanic and Atmospheric Administration, Boulder, CO 80305; [c]Center for Global Change Science, Massachusetts Institute of Technology, Cambridge, MA 02139; [d]Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO 80309; [e]School of Geographical Sciences, University of Bristol, Bristol BS8 1SS, United Kingdom; [f]Hadley Centre, Met Office, Exeter EX1 3PB, United Kingdom; [g]Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA 92093; [h]Climate Science Centre, Commonwealth Scientific and Industrial Research Organization Oceans and Atmosphere, Aspendale, VIC 3195, Australia; and [i]Department of Oceanography, Kyungpook National University, Daegu 41566, Republic of Korea

PNAS

Ambiguity in the causes for decadal trends in atmospheric methane and hydroxyl

Alexander J. Turner[a,1], Christian Frankenberg[b,c,1], Paul O. Wennberg[b], and Daniel J. Jacob[a]

[a]School of Engineering and Applied Sciences, Harvard University, Cambridge, MA 02138; [b]Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125; and [c]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 21109

Edited by Mark H. Thiemens, University of California, San Diego, La Jolla, CA, and approved December 28, 2016 (received for review September 26, 2016)

PNAS

Atmospheric methane isotopic record favors fossil sources flat in 1980s and 1990s with recent increase

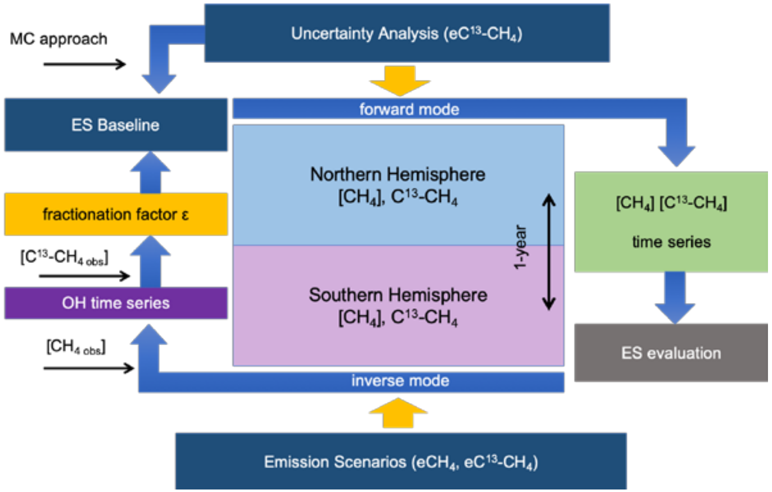
Andrew L. Rice[a,1,2], Christopher L. Butenhoff[a,1], Doaa G. Teama[a], Florian H. Röger[a], M. Aslam K. Khalil[a], and Reinhold A. Rasmussen[b]

[a]Department of Physics, Portland State University, Portland, OR 97207; and [b]Division of Environmental and Biomolecular Systems, Oregon Health & Science University, Portland, OR 97239

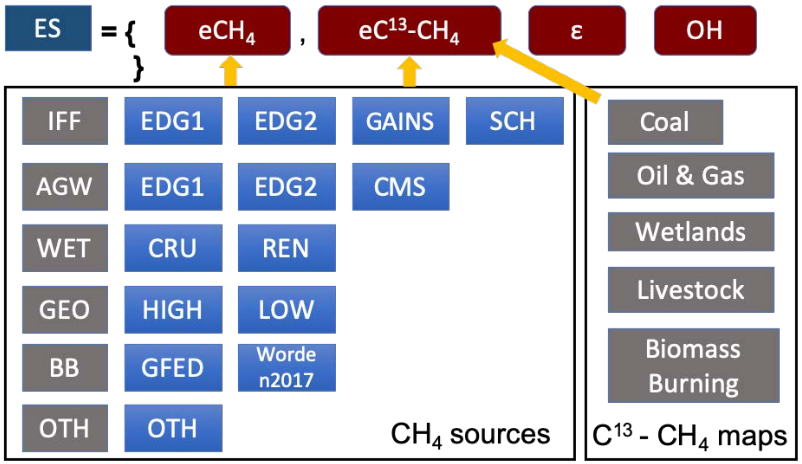
Edited by Mark H. Thiemens, University of California, San Diego, La Jolla, CA, and approved July 26, 2016 (received for review November 19, 2015)

Two-Box model framework and analyses setup

Two-box model framework



Emission scenarios (ES)



- Comprehensive estimates of individual sources to cover all hypotheses (96 emission scenarios)
- Spatial-resolved C^{13}- CH4 signature maps for major sources
- Monte Carlo approach (N=1000) to cover uncertainty in C^{13}- CH4

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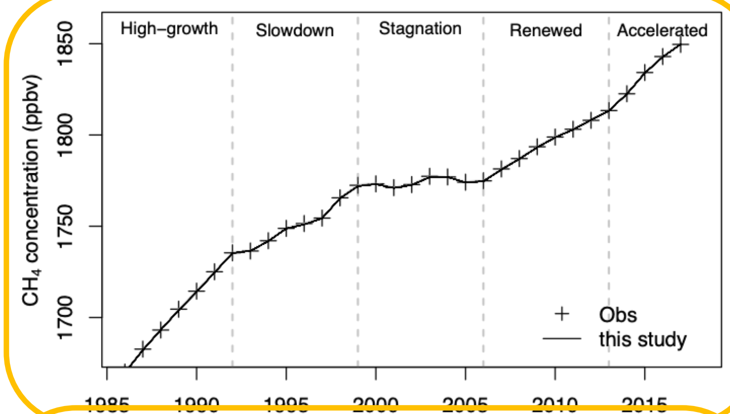
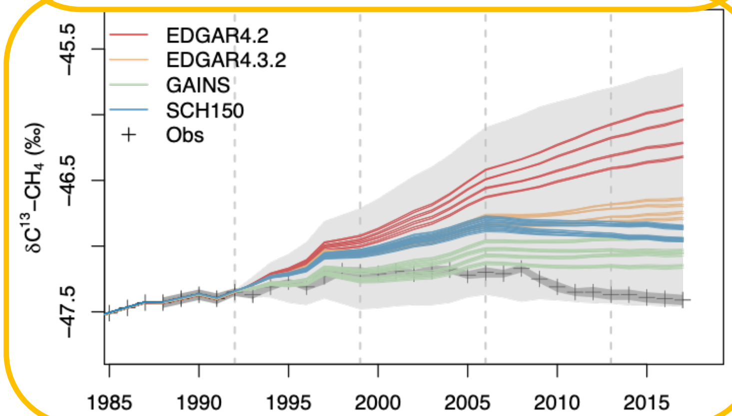
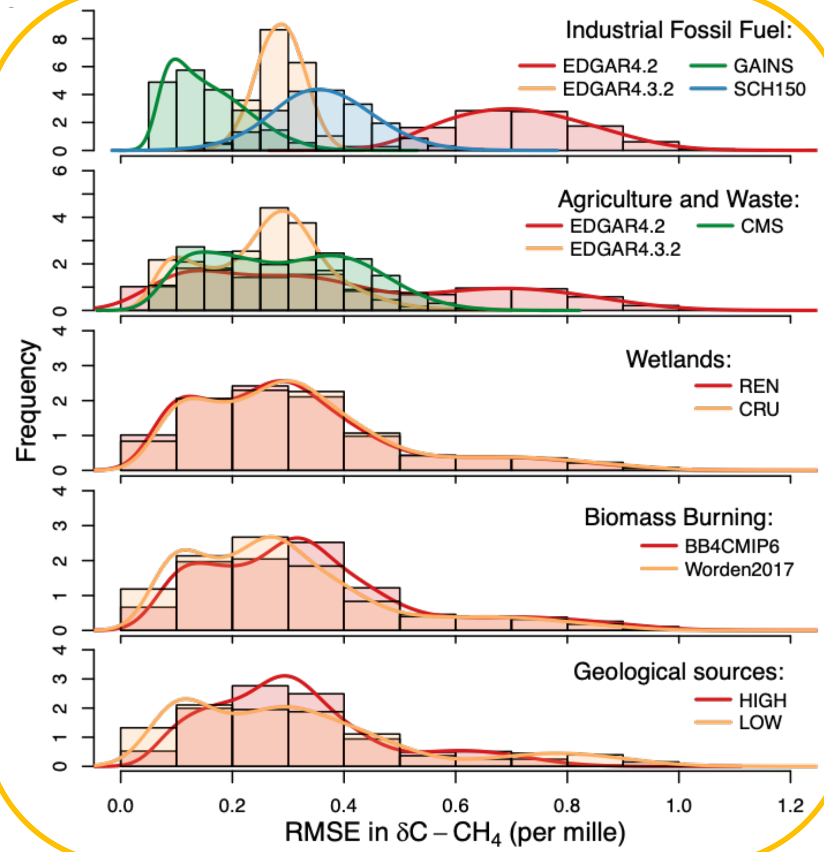
Ability to simulate CH_4 concentrations and $\delta^{13}C\text{-}CH_4$





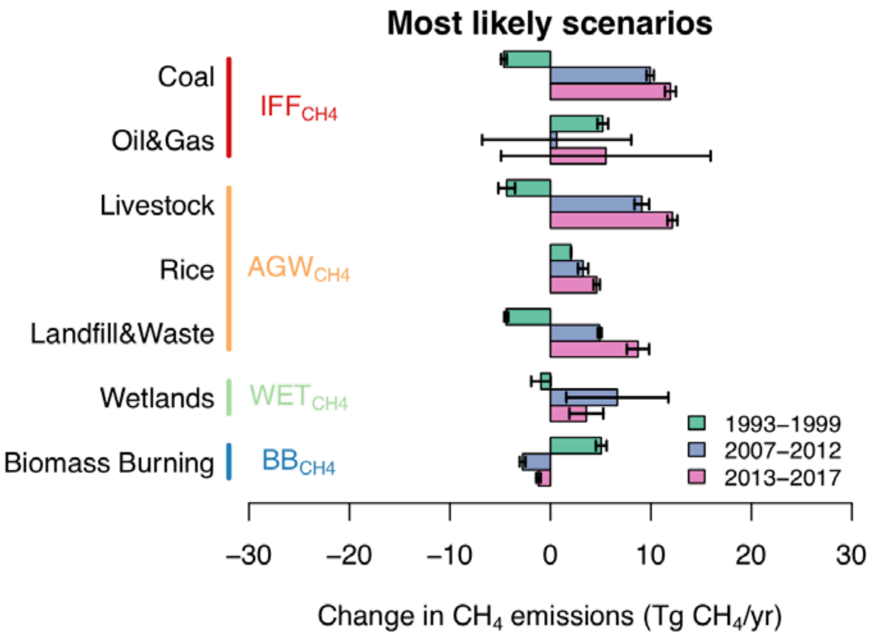


Average CH_4 emissions in the 'most likely' scenarios

- Anthropogenic emissions from Fossil fuel, Agricultural sources (e.g. Livestock, Rice and Waste) are dominating the rise of atmospheric CH_4 between 2013-2017

- Wetlands have relatively minor contribution (< 11%) to the possible increase

- Uncertainty in OH trend and variability remains large enough to play a role in the atmospheric CH_4 rise (though not dominant)

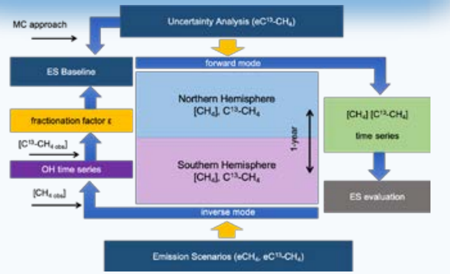


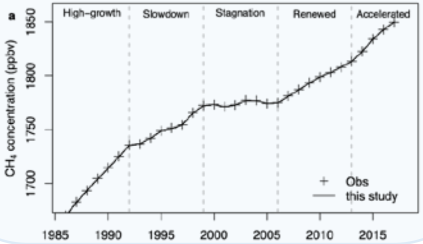
Change relative to 2000-2006 plateau period

Zhang et al. [*in review*]

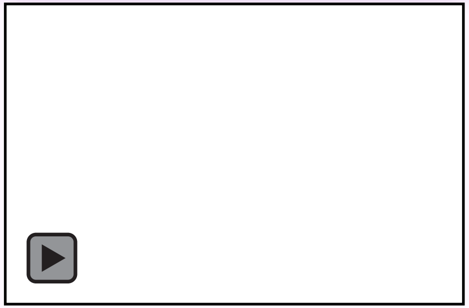
Outline

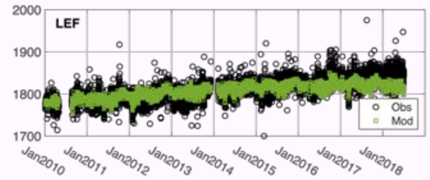
TWO-BOX MODEL





GEOS CH_4 SIMULATIONS





APPLICATIONS

Bottom-up fluxes: tagged tracer specifications

Industrial and Fossil Fuel
EDGAR v4.3.2

Agriculture and waste
EDGAR v4.3.2

Biomass burning & fires
QFED r2.5

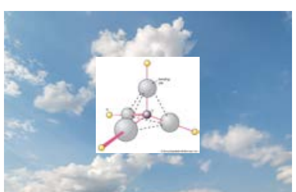
Wetlands
LPJ-*wsl*

Biofuels
EDGAR v4.3.2

Minor Natural
Model for termite emissions + other sources + soil sink from literature

Methane sinks

OH sink from ACCMIP CTMs intercomparison; Chlorine sink and O(1D) taken from literature

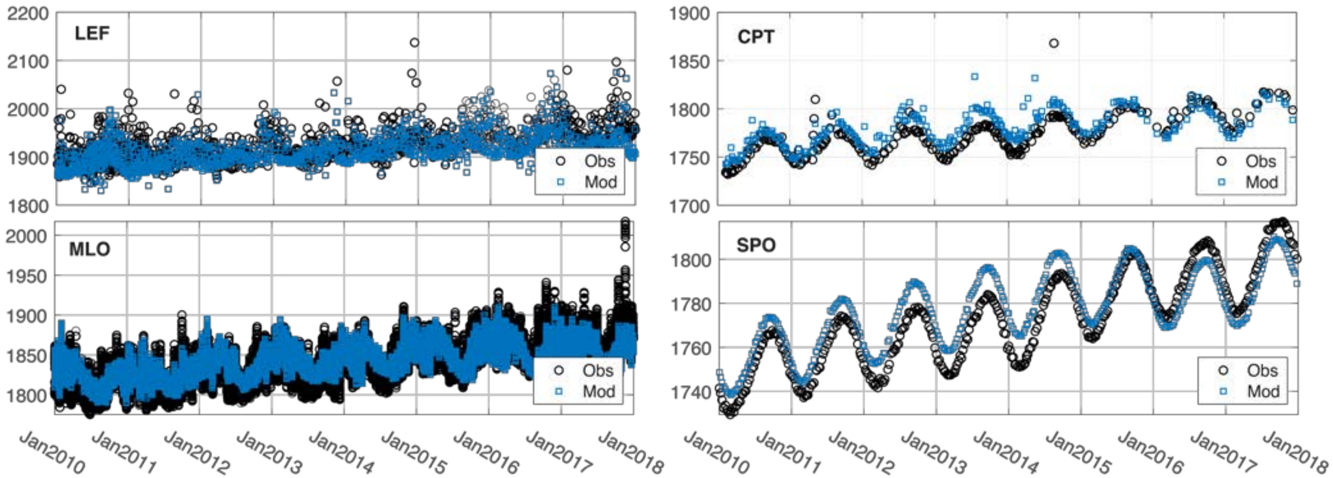


play CH4 Movie

3D fields output

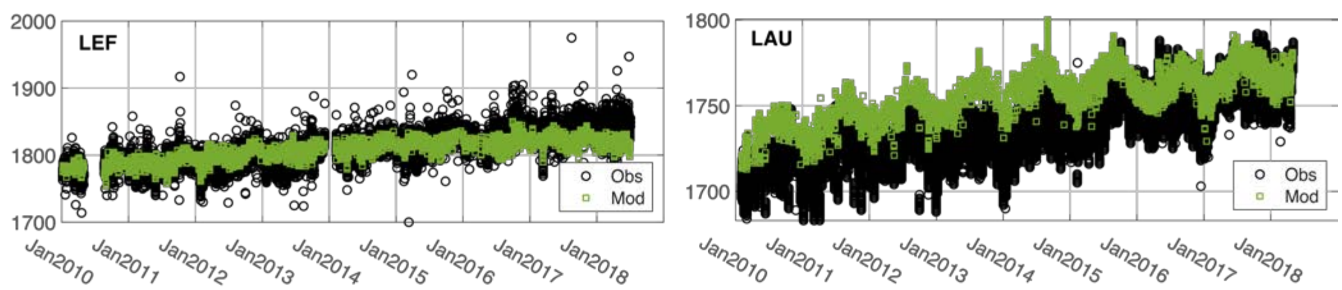
CH4ind CH4agw
CH4bb CH4wetl
CH4bf CH4natl
CH4total

Evaluation of GEOS CH_4 model simulations

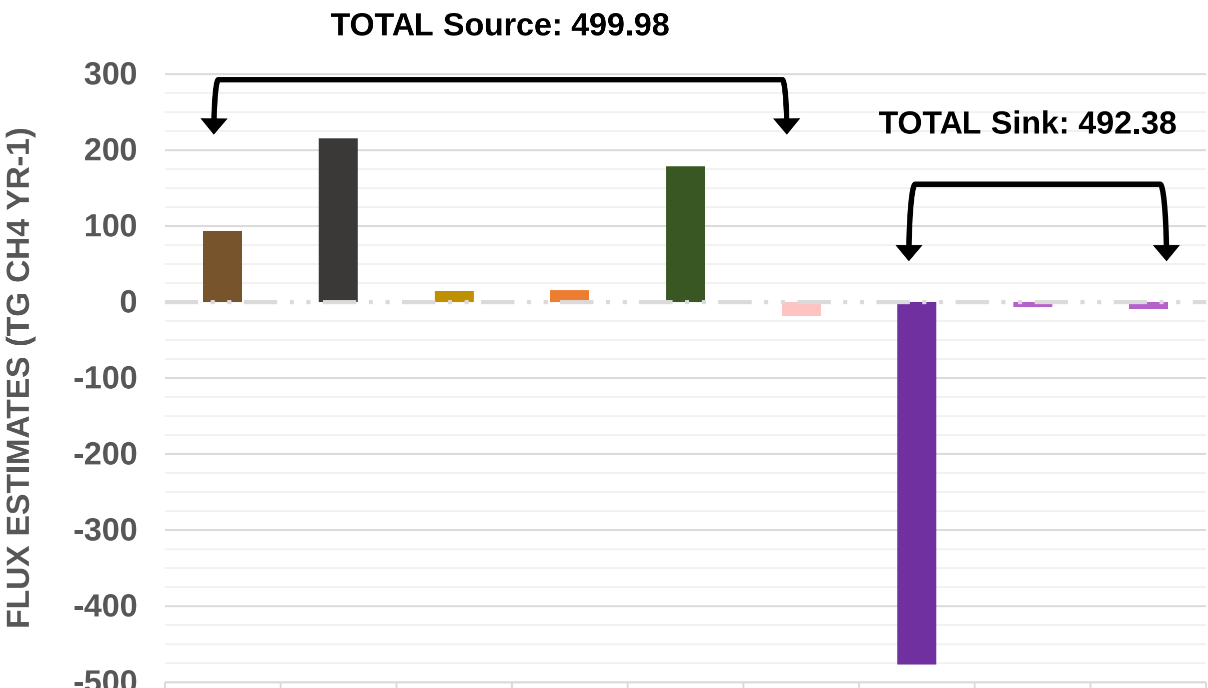


- NOAA SF sites
- overall good agreement, RMSE < 19 ppb (~1%)
- high bias in the southern hemisphere ☞ likely OH bias

- TCCON X_{CH4} data
- overall RMSE <25 ppb



Accounting: bottom-up budget for 2004-2017



	IFF	AGW	BF	BB	WETL	NATL	OH	Cl	O (1D)
Series1	93.960	215.34	14.601	15.121	178.58	-18.22	-476.5	-6.880	-8.949

- Source-sink difference = 7.6 Tg CH_4 yr^{-1}
- Captures post-2007 growth rate reasonably, 6.44 ppb (model sim) vs. 6.86 ppb (NOAA AGR)
- Issues with model spin up, circa 2003-2004

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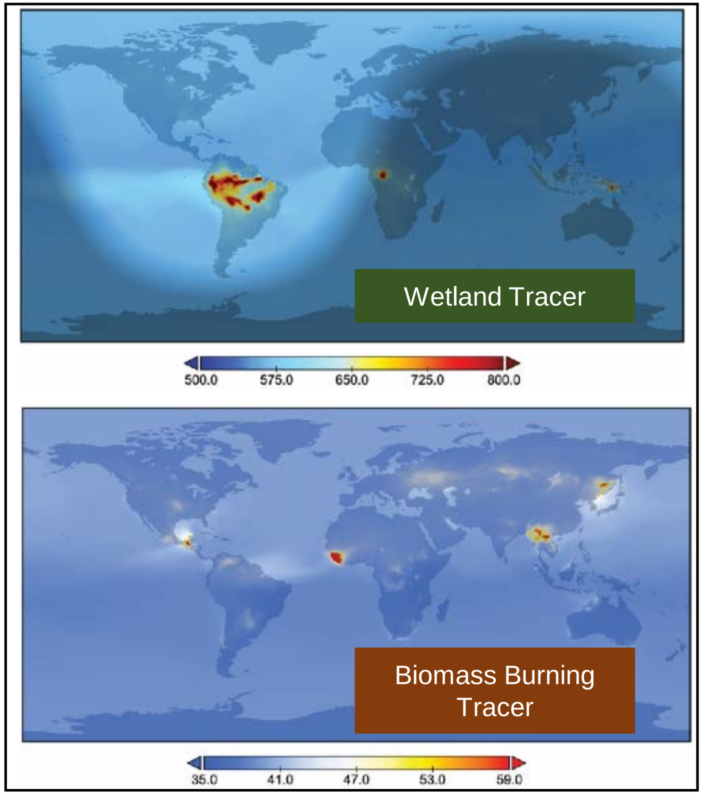
Planned distribution of model simulations

- 3D model fields (total CH_4 & individual CH_4 tracers) will be made available to the community
- Global fields spanning 2007 - 2018
- Nominal 0.5°, 3-hourly time steps
- Evaluation ongoing against aircraft observations, TROPOMI X_{CH4} retrievals



Snapshot of two CH_4 tracers

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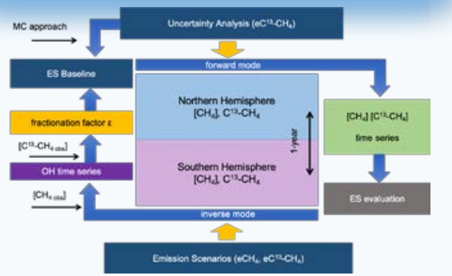
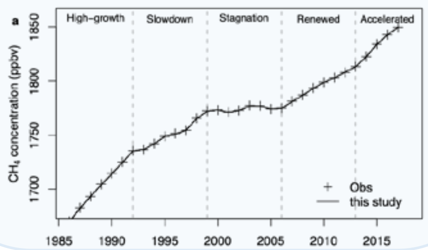
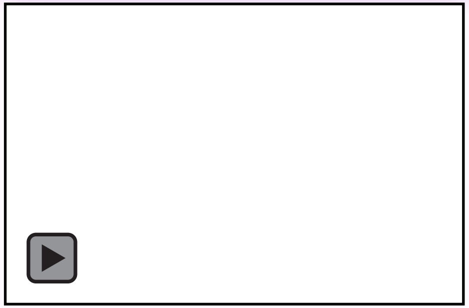
Outline

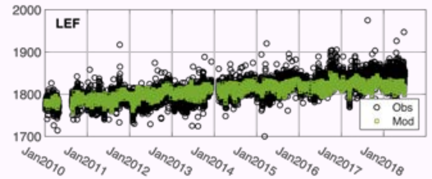
TWO-BOX MODEL





GEOS CH_4 SIMULATIONS





APPLICATIONS

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OSSEs to plan future missions

Nature Run

Assume a set of fluxes and create CH_4 simulation

Synthetic Data

Sample at measurement locations and times, screen for clouds

Add in random errors

Metrics

Use inversion model to assimilate synthetic data and compare estimated fluxes to nature run

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OSSEs to plan future missions

Nature Run

- Community assessment of science priorities
- Assume a set of fluxes and create CO_2, CO and CH_4 simulation
- Simulate multiple process-based flux scenarios

Synthetic Data

- Sample at measurement locations and times, screen for clouds
- Add in random errors | and biases!
- ...or simulate retrievals

Metrics

- Use inversion model to assimilate synthetic data and compare estimated fluxes to nature run
- Evaluate ability to detect process changes

Greater confidence in results, community consensus

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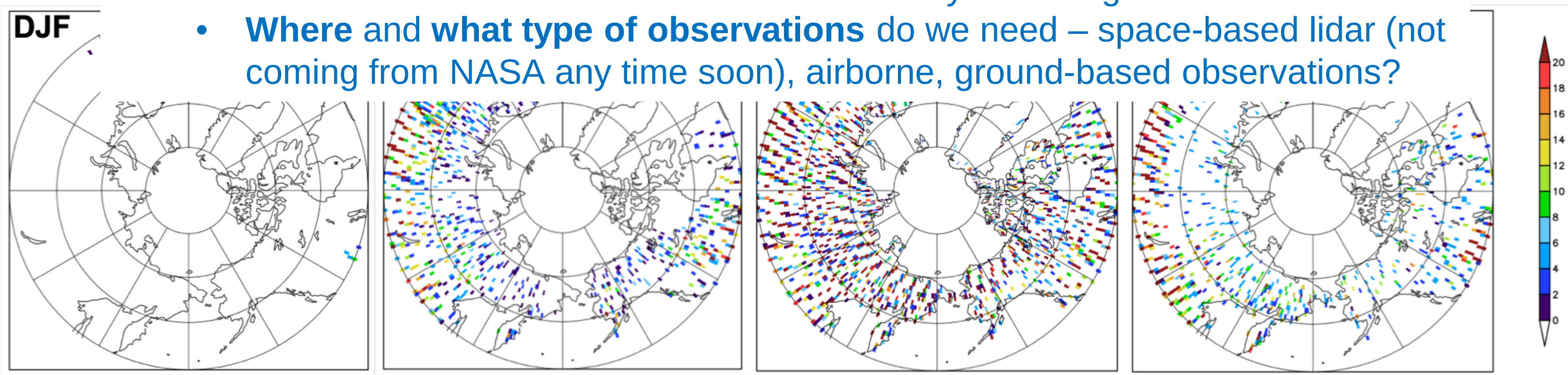
Observing high-latitudes methane emissions

- Current satellites are limited in their ability to observe high latitudes. Need for sunlight means incomplete seasonal coverage (**Example**: GOSAT observation counts)
- Improvement with TROPOMI but not much during the shoulder & winter seasons

Challenge:

- Can we do better with the data we are already collecting?
- **Where** and **what type of observations** do we need – space-based lidar (not coming from NASA any time soon), airborne, ground-based observations?



Summary

- Systematic development of methane simulation capabilities
  - Two-box model to understand the rise of atmospheric CH_4 in recent years, identify source-sink categories critical to simulating atmospheric CH_4 concentrations that match the observed atmospheric growth rate
  - GEOS methane module - unique capability to simultaneously simulate CO_2, CO and CH_4 at unprecedented spatial (~14 km - 2°) and temporal resolutions

- High-resolution GEOS 3D output will be available by Spring-Summer 2020
  - can be used by the larger carbon community for studying trends, IAV, attribution, etc.

- Valuable tool to support various NASA Earth Science programs and goals
  - OSSE activity mandated by HQ
  - GEOS-CF forecasts to support airborne campaigns

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Questions?

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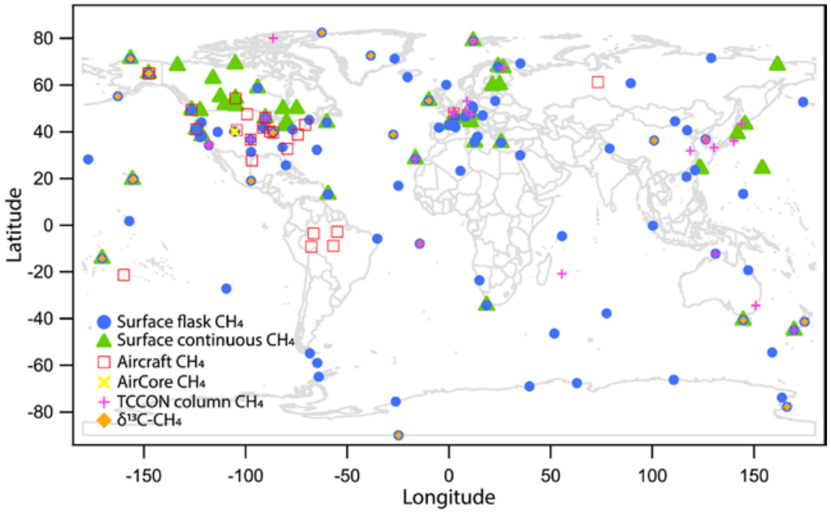
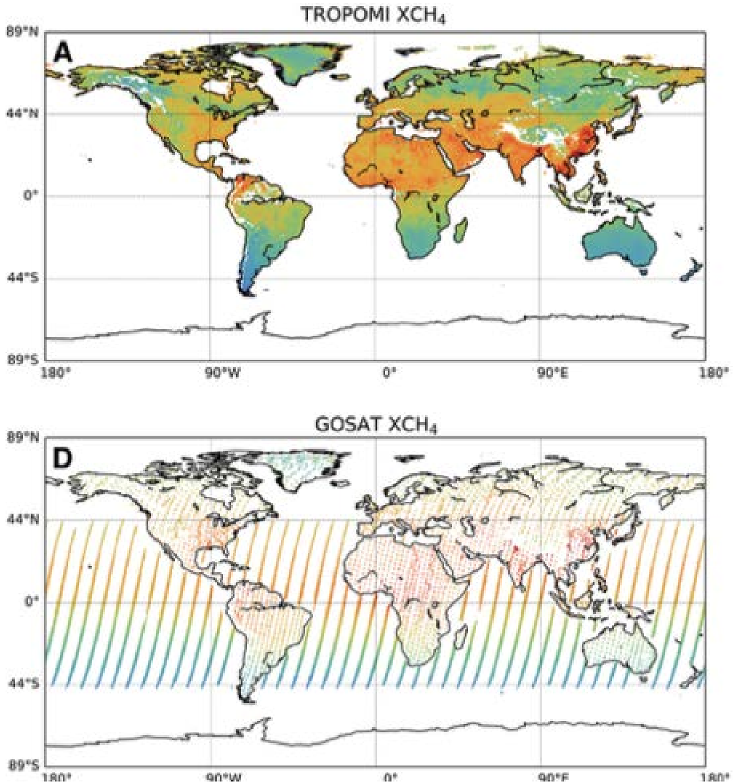
Current CH_4 measurement network





Source: Ganesan et al. [2019], GBC