Summary of the State of the Carbon Cycle Report-2, Chapter 8: Observations of CO_2 and CH_4.

John B. Miller

john.b.miller@noaa.gov

NOAA Earth System Research Laboratory, Global Monitoring Division

8 Observations of Atmospheric Carbon Dioxide and Methane

Lead Authors

Andrew R. Jacobson, University of Colorado, Boulder, and NOAA Earth System Research Laboratory; John B. Miller, NOAA Earth System Research Laboratory

Contributing Authors

Ashley Ballantyne, University of Montana; Sourish Basu, University of Colorado, Boulder, and NOAA Earth System Research Laboratory; Lori Bruhwiler, NOAA Earth System Research Laboratory; Abhishek Chatterjee, Universities Space Research Association and NASA Global Modeling and Assimilation Office; Scott Denning, Colorado State University; Lesley Ott, NASA Goddard Space Flight Center

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Richard Birdsey (Science Lead), Woods Hole Research Center; Nathaniel A. Brunsell (Review Editor), University of Kansas; James H. Butler (Federal Liasion), NOAA Earth System Research Laboratory

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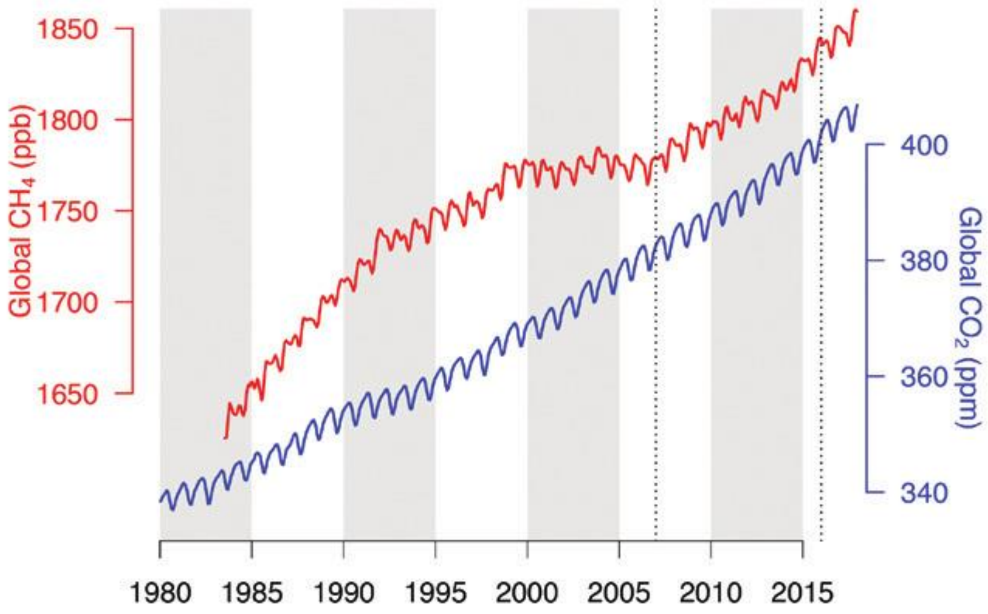
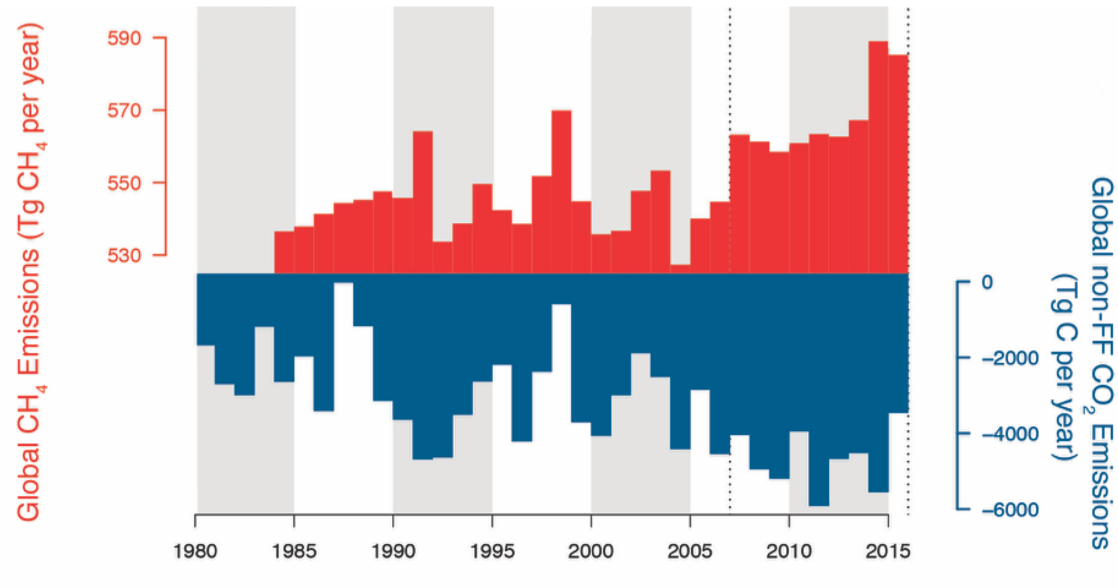
- Report Key Findings
- Trends, future prospects and challenges for measurement and modeling systems

Key Finding 1: Global CO_2 and CH_4 continue to rise



Global sources and Sinks of CO_2 and CH_4 based on growth rates.

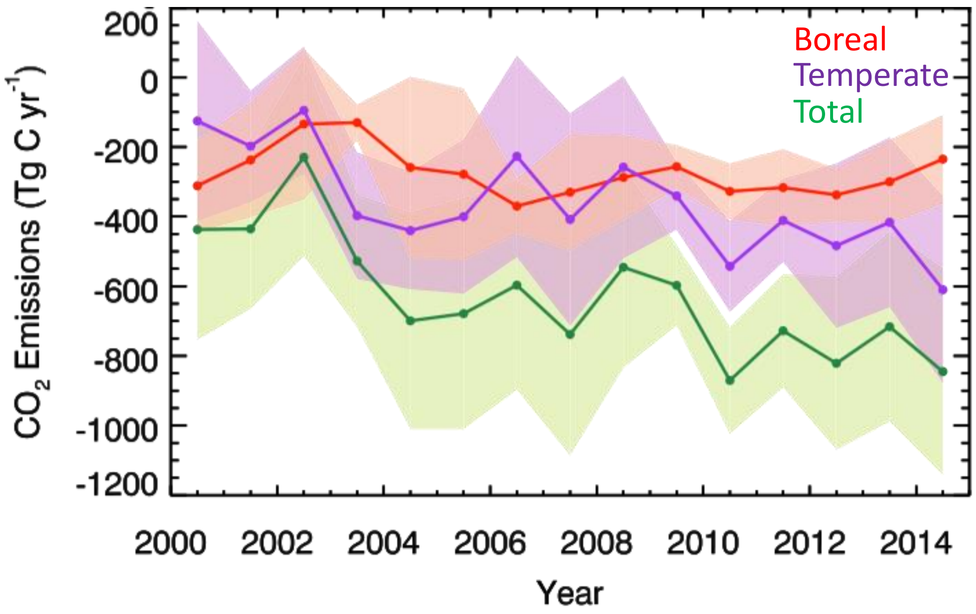


d/dt(CH4) = F_CH4 – [CH4]/τ_{sink}

(assume constant τ_{sink})

d/dt(CO2) = F_Fossil + F_Land + F_ocean

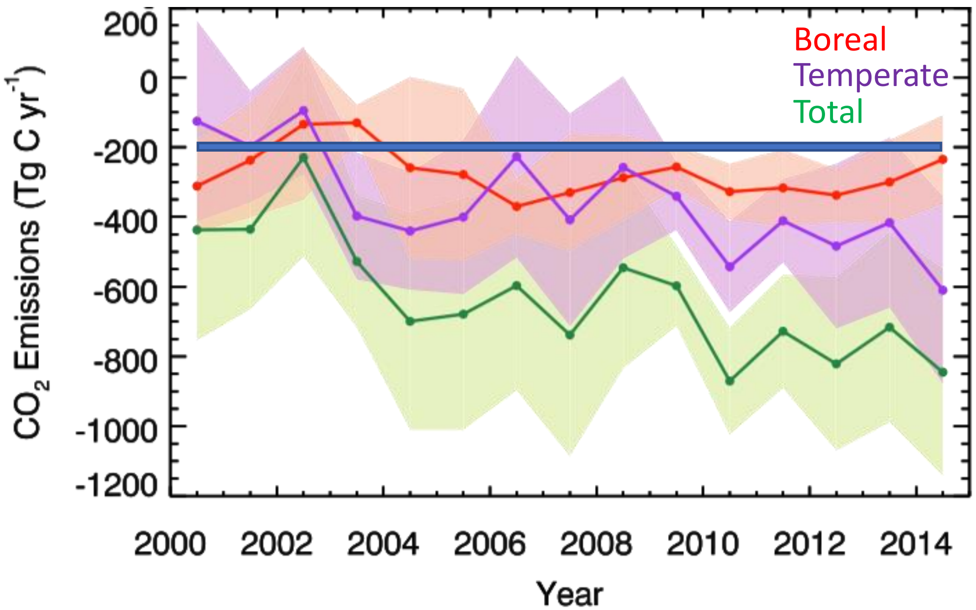
Key Finding 2: Inverse model results show variable CO_2 uptake over North America.



1. Indication of increasing sink for N. American C

→ Net CO_2 flux after accounting for fossil fuel emissions (~1800 TgC/yr) and fires (~100 TgC/yr)
→ Average of four quasi-operational inverse models using similar data input.
→ Better convergence than in previous studies such as RECCAP

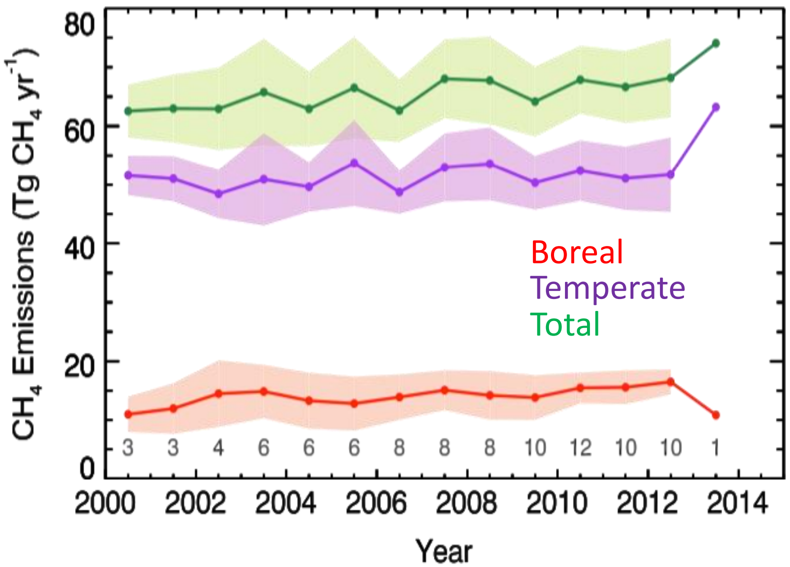
Key Finding 2: Inverse model results show variable CO_2 uptake over North America.



1. Indication of increasing sink for N. American C
2. Temperate (mainly U.S.) sink much more variable in atmospheric data than compared to what EPA reports to UNFCCC (-202 +/- 5 TgC/yr). Also, no discernible trend.
3. Long-term N. American average compares well with bottom-up estimates.

→Net CO_2 flux after accounting for fossil fuel emissions (~1800 TgC/yr) and fires (~100 TgC/yr)
→Average of four quasi-operational inverse models using similar data input.
→Better convergence than in previous studies such as RECCAP

Key Finding 3: Inverse model results show minimal variability in CH_4 emissions.



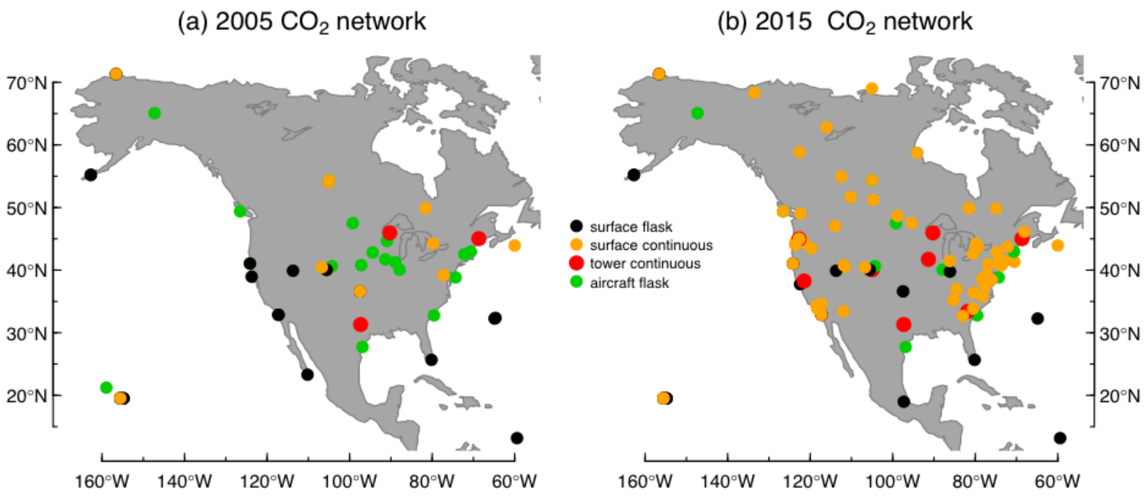
1. No significant trends for either boreal or temperate regions.
2. Temperate totals about twice anthropogenic totals reported by the EPA for the U.S. (not noted in SOCCR-2)

→ Average of global CH_4 inverse models from Global Carbon Project using both in situ and satellite data

Trends, future prospects and challenges for measurement and modeling systems

- Increased density of in situ observations
- Merging remote sensing and in situ observations
- Measurements of tracers related to CO_2 and CH_4
- High resolution national, regional, and urban modeling

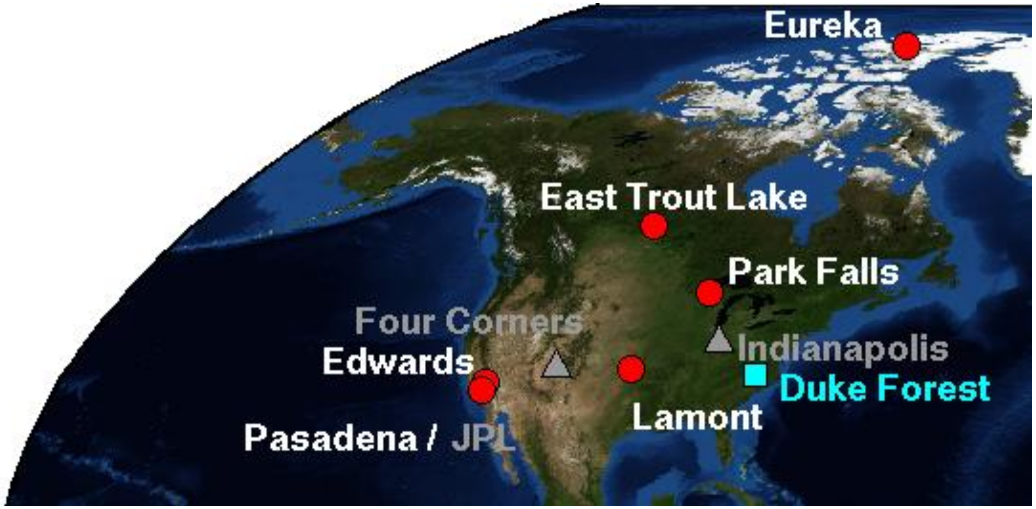
Increased density of in situ observations



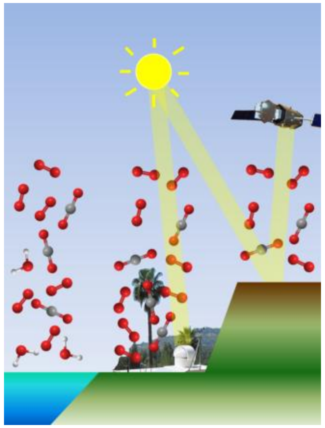
→Commercial aircraft observations (similar to global Japanese program CONTRAIL) would greatly expand measurements.

→If NEON is built out as planned this will add ~25 calibrated CO_2 sites to the existing network.

Also, ground-based remote sensing from TCCON



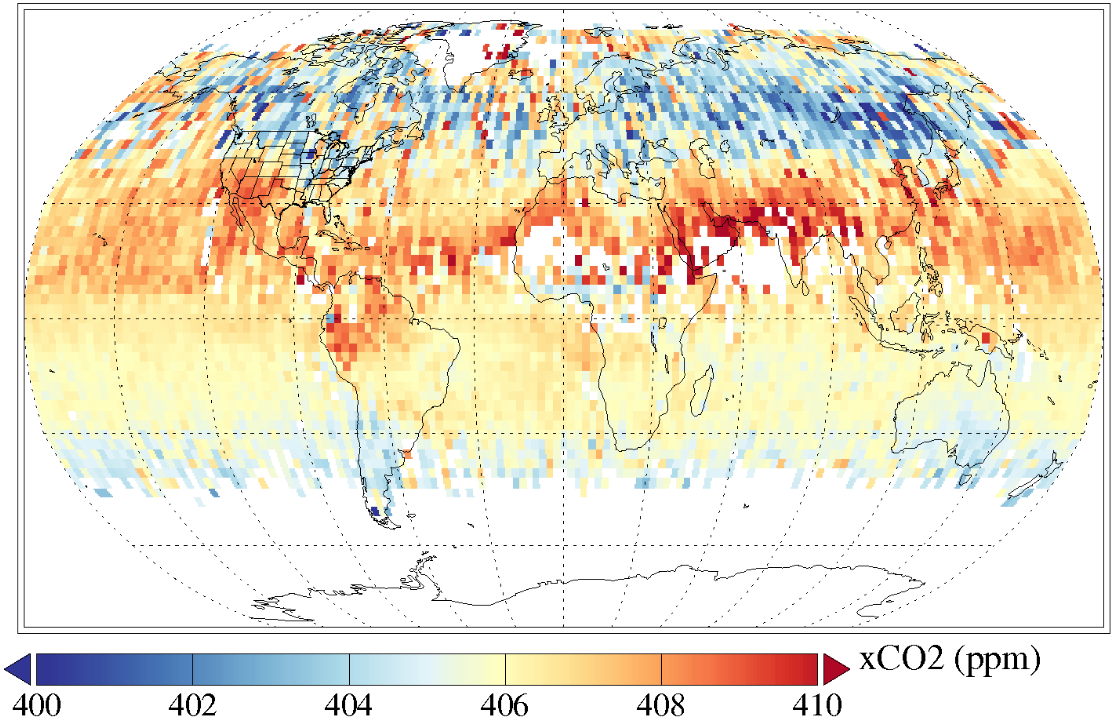
TCCON = Total Carbon Column Observing Network



TCCON is a network of solar tracking Fourier transform infrared spectrometers. (FTIRs)

Satellite remote-sensing

Global amounts of xCO2 in June-July 2018; OCO-2 Lite V9r



- Benefit of relatively dense coverage in space and time.
- Challenge is to link satellite measurements to internationally accepted scales at very high accuracy (TCCON can help with this.)
- OCO-3 and other satellites coming on-line

Trends in measurements and modeling

- Moving towards multi-year regional/national/continental inverse modeling.
  - Nevison et al., 2018 (N_2O)
  - Hu et al. 2019 (CO_2)
  - CH_4 currently limited to shorter/regional studies.
- Sustained, intensive urban studies
  - LA megacity project
  - Indianapolis project (INFLUX)
  - DC/Baltimore area
  - Boston area

Other in situ tracers

- $^{14}CO_2$ (Radiocarbon) – sensitive to just the fossil fuel component of CO_2
- COS, ^{18}O and ^{17}O of CO_2 – can help partition net CO_2 flux into GPP and respiration.
- $^{13}CO_2$ – helps constrain water use efficiency
- $^{13}CH_4$, C_2H_6 – help partition CH_4 sources
- $^{14}CH_4$ – can serve as a warning indicator of old CH_4 release in Arctic.
- Measurements of all* of these exist in N. America.

Improving model representation of transport

- Tracer measurements including SF_6, water vapor isotopes, $^{14}CO_2$ can be used to assess parameterizations including those for convection and PBL height and mixing.
- Additional measurements of the atmosphere using Lidar, radar and rawinsondes should also help improve model performance.
- There is also an ongoing trend towards higher resolution in models used in atmospheric inversion studies.

Summary

- Globally, CO_2 and CH_4 continue to rise.
- The North American sink of CO_2 may be increasing.
- North American emissions of CH_4 appear to be flat.
- Sources/sinks of CH_4 and CO_2 inferred from atmospheric data differ from those reported to UNFCCC by the EPA.