Generating Global CH_4 NASA GEOS Product by Assimilating TROPOMI

Nikolay Balasov (1, 2) Brad Weir (1, 3) Lesley Ott (1), Sourish Basu (1,2)

(1) Global Modeling and Assimilation Office, NASA Goddard Space Flight Center, Greenbelt, MD
(2) Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD
(3) Morgan State University, Baltimore, MD

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Motivation

- Methane (CH4), a potent greenhouse gas, after a period of minimal growth (1999-2006) has shown a renewed steady growth from about 2006 (Figure 1).
- The cause for this steady growth is not fully understood, but an evidence of decreasing $\delta^{13}CH_4$ points to microbial sources (agriculture-waste emission sector and wetlands) as a potential culprit.
- Further global investigation is required to better understand the mentioned CH_4 increases.

Time series of global CH_4 and $\delta^{13}CH_4$

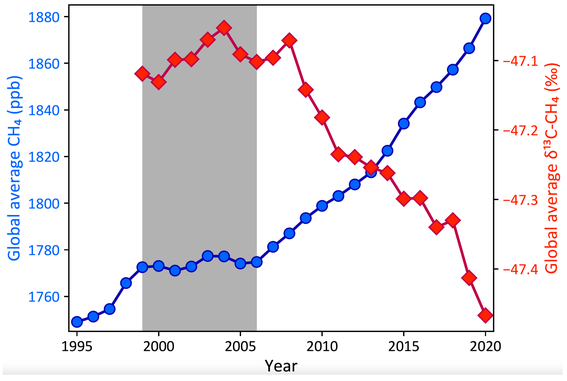


Figure 1. Global average CH_4 (blue circles, left axis) and $\delta^{13}CH_4$ (red diamonds, right axis) from NOAA marine boundary layer (MBL) and other background sampling sites (Basu et al., 2022).

Reference: Basu, S., Lan, X., Dlugokencky, E., Michel, S., Schwietzke, S., Miller, J.B., Bruhwiler, L., Oh, Y., Tans, P.P., Apadula, F. and Gatti, L.V., 2022. Estimating emissions of methane consistent with atmospheric measurements of methane and $\delta^{13}C$ of methane. *Atmospheric Chemistry and Physics*, *22*(23), pp.15351-15377.

Objectives

- To create a reliable, easy to use, global atmospheric CH_4 product that could contribute to assessment of emissions processes.
- Potential applications of this approach include support for interpretation of high-resolution point source detection approaches, climate and greenhouse gas reanalyses, and boundary conditions for regional modeling approaches.

Methods

- NASA Goddard Earth Observing System (GEOS) based global CH_4 simulation is constrained by atmospheric transport from the Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) and retrieved CH_4 from the TROPOspheric Monitoring Instrument (TROPOMI).
- This product uses the Constituent Data Assimilation System (CoDAS) capability of GEOS, which assimilates constituent observations, both point samples and column averages.

Major CH_4 emissions driving the simulation

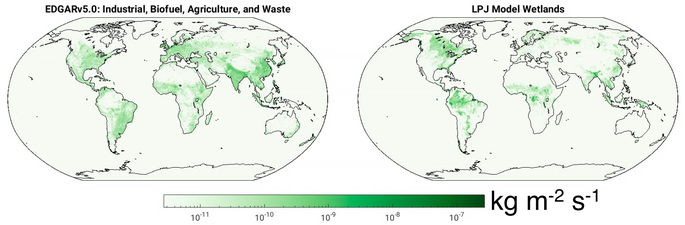


Figure 2. (Left side) June 2018 CH_4 emissions from EDGAR v5.0 and (Right side) early June 2018 CH_4 emissions from Lund-Potsdam-Jena (LPJ) wetlands model.

TROPOMI CH_4 column-average dry mole fractions (XCH_4) used for assimilation

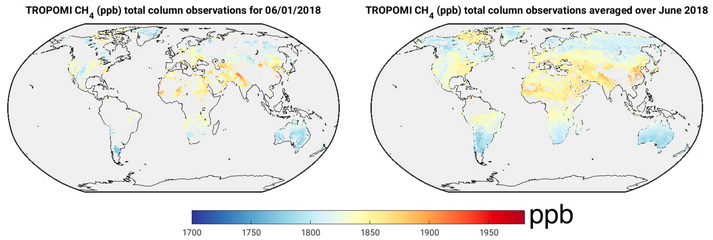
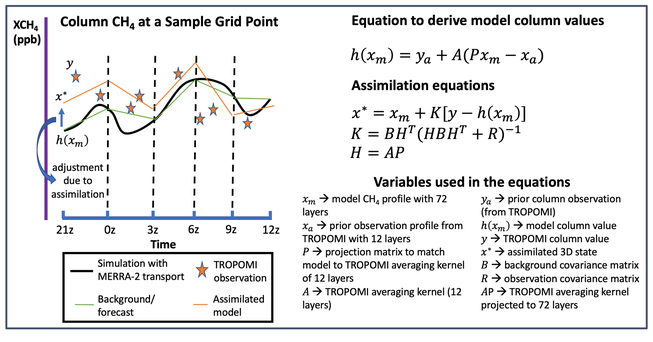


Figure 3. (Left side) TROPOMI XCH_4 observations for a single day (06/01/2018) and (Right side) TROPOMI XCH_4 observations for a month of June 2018.

Approach to assimilate TROPOMI into GEOS with CoDAS



Preliminary Results

- We perform assimilation and compare it to CH_4 column-average observations from TCCON.
- Initial comparisons show that TROPOMI significantly improves our initial CH_4 simulation.
- Further comparisons are needed as still our biases are significant.

TCCON sites

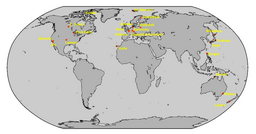


Figure 4. Total Carbon Column Observation Network (TCCON) is a network of ground-based Fourier Transform Spectrometers recording direct solar spectra in the near-infrared spectral region providing accurate and precise column-averaged abundances of CH_4.

GEOS simulation vs. TCCON and Assimilation

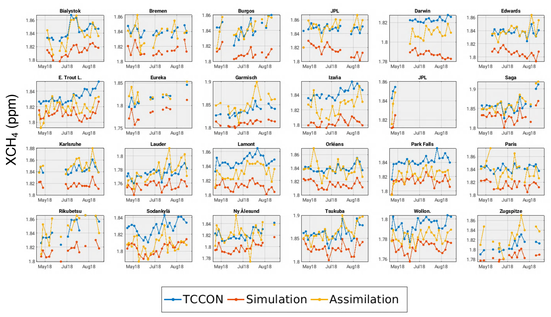


Figure 5. Comparisons of weekly-smoothed XCH_4 from TCCON, GEOS simulation, and corresponding assimilation indicate on average large improvements after TROPOMI observations are assimilated.

GEOS assimilation minus TCCON (in ppb)

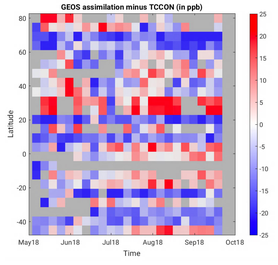


Figure 6. Time series of differences between assimilated weekly-smoothed XCH_4 and TCCON shown as a function of latitude.

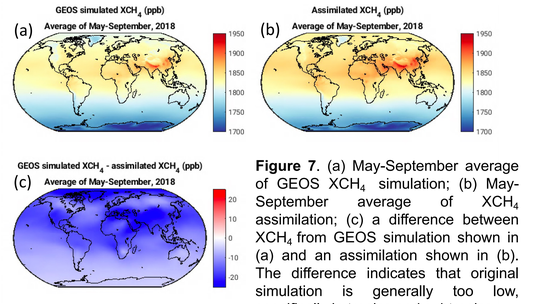


Figure 7. (a) May-September average of GEOS XCH_4 simulation; (b) May-September average of XCH_4 assimilation; (c) a difference between XCH_4 from GEOS simulation shown in (a) and an assimilation shown in (b). The difference indicates that original simulation is generally too low, specifically in tropics and subtropics.

Future work

- Next steps would include updated CH_4 emissions and improved oxidation rates.
- Then tagged tracers could be used to identify specific areas where emissions are likely incorrect.

GODDARD EARTH SCIENCES

E-mail: nikolay.v.balashov@nasa.gov | *Web:* gmao.gsfc.nasa.gov

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