Monitoring Global Tropospheric OH Concentrations using Satellite Observations of Atmospheric Methane

Yuzhong Zhang[1,2] (yuzhongzhang@seas.harvard.edu), Daniel J. Jacob[1], Joannes D. Maasakkers[1], Melissa P. Sulprizio[1], Jianxiong Sheng[1], Ritesh Gautam[2], Daniel Zavala-Araiza[2], John Worden[3]

[1]School of Engineering and Applied Sciences, Harvard University
[2]Environmental Defense Fund
[3]Jet Propulsion Laboratory, California Institute of Technology

Key Findings

- Satellite observations of atmospheric methane is a promising proxy to monitor the global OH concentration and its trend.
- Combining shortwave infrared (SWIR) and thermal infrared (TIR) measurements improves the ability to separate constraints on OH from those on emissions.

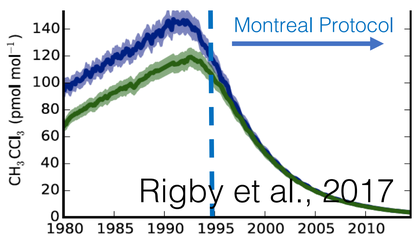
Motivation

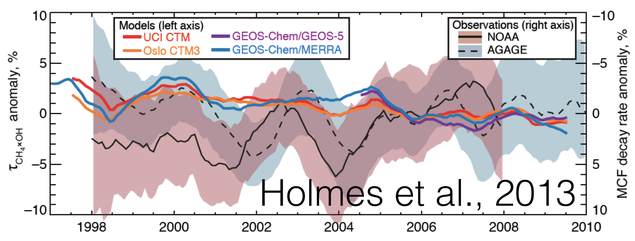
➢ **Monitoring global OH has relied on the methyl chloroform (MCF) proxy**

Mass balance for MCF

$$\frac{dm}{dt} = k[\mathrm{OH}]m + \text{minor terms}$$

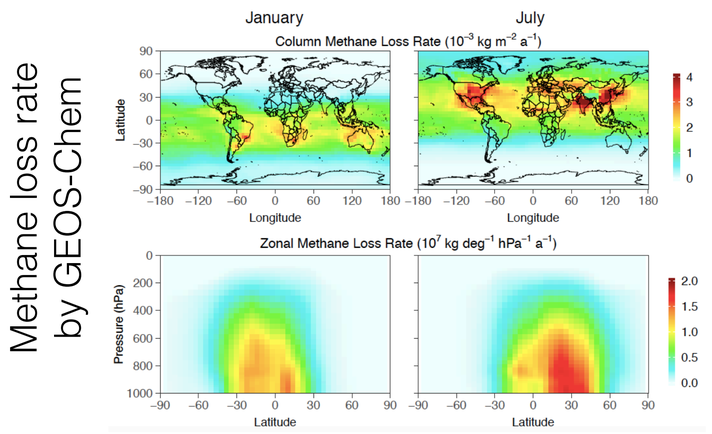
- Large and growing error
- Highly uncertain OH trend

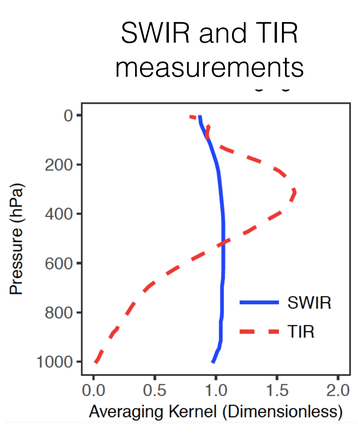




➢ **Potential replacement: satellite methane observations**

- Signature of OH+methane should be observable by satellite
- Distinct signatures of methane emissions and sink
- Expanding observing power of satellite (improved coverage, resolution, precision)

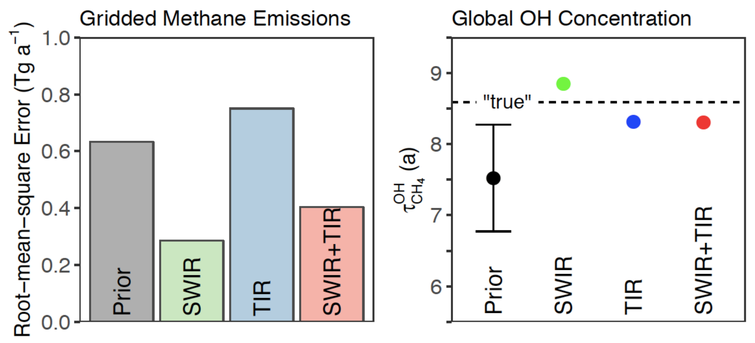




Joint Optimization of Emissions and OH

Global OH expressed as $\tau_{\mathrm{CH_4}}^{\mathrm{OH}} = \frac{\int_{troposphere} n_a \, dv}{\int_{troposphere} k(T)[\mathrm{OH}] n_a \, dv}$

Gridded emission rates and global OH are jointly retrieved and evaluated against the "truth".



SWIR and SWIR+TIR improve the estimation of emission rates

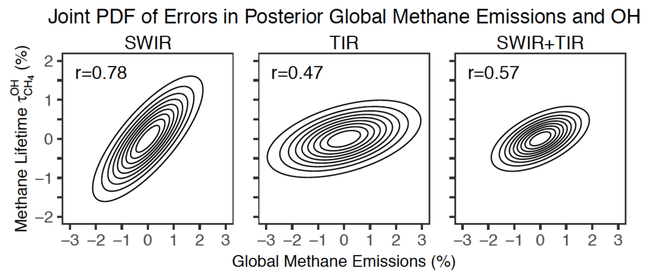
All three systems improve global OH estimation

Can We Separate OH from Emissions?

➢ **Aliasing effect?** $\frac{d\, m_{\mathrm{CH_4}}}{dt} = \sum_i E_i - k[\mathrm{OH}]m_{\mathrm{CH_4}} - \text{minor losses}$

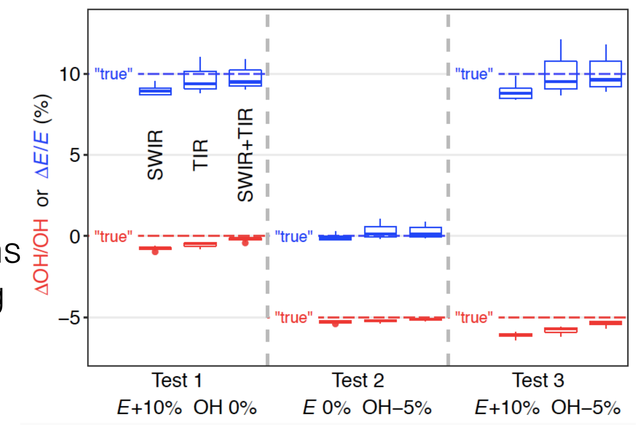
➢ **Analysis of posterior error covariance matrix**

Error correlation is highest for SWIR. Combining SWIR and TIR gives the best constraint although its error correlation is bigger than TIR's.



➢ **Ability to retrieve perturbations to emissions and/or OH**

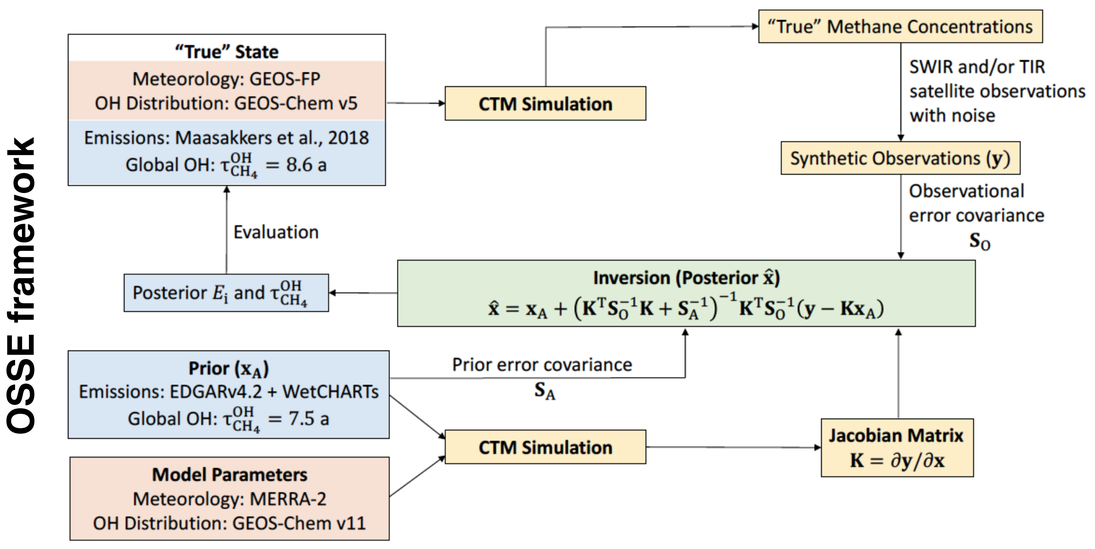
- Able to separate changes in emissions and OH
- SWIR+TIR achieves the best performance
- Errors in prior OH distributions have little impact in detecting changes in global OH



Observing System Simulation Experiment (OSSE)

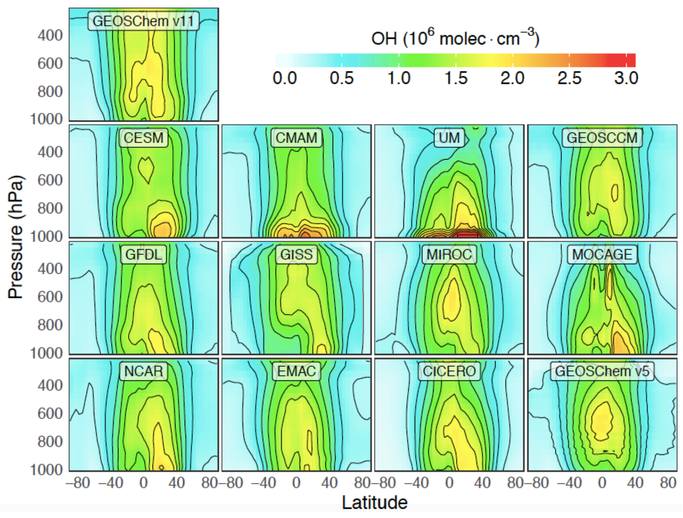
OSSE provides a controlled environment to

- Assess potential of next-generation satellite for monitoring OH
  SWIR: TROPOMI & TIR: CrIS
- Evaluate ability to separately retrieve emissions and OH
- Understand the effect of errors in model parameters:
  OH distributions, meteorological fields

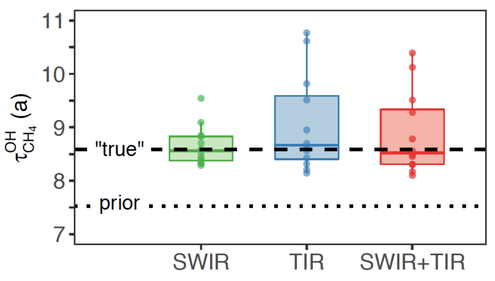


Impact of Errors in Prior OH Distributions

Different OH distributions from ACCMIP and GEOS-Chem



Error in OH dist. can cause 3-7% error in global OH, but may not have large impact on the OH trend. We may improve by optimizing OH distribution in inversion.



Acknowledgement

This work was funded by the Interdisciplinary Science (IDS) program of the NASA Earth Science Division. Y. Zhang was partially funded by the Kravis Scientific Research Fund at Environmental Defense Fund.