

Towards a State-of-the-Art Greenhouse Gas Data Assimilation/ Flux Inversion Modeling System

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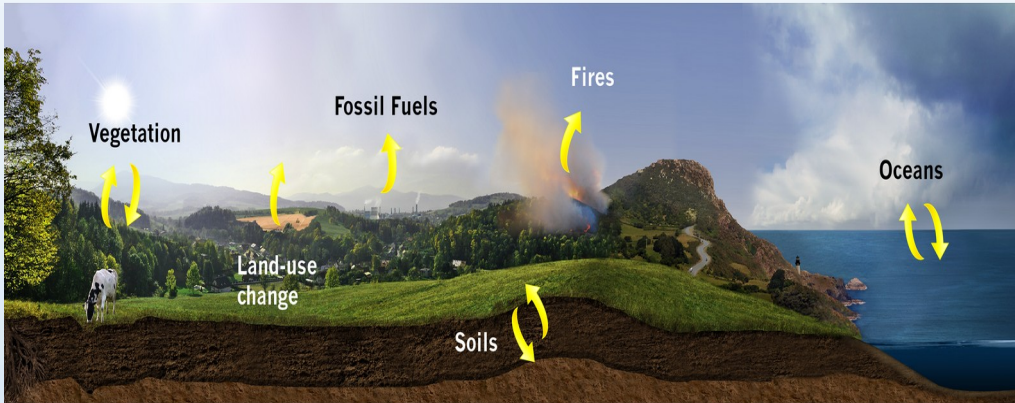
NOAA Global Monitoring Laboratory & Cooperative Institute for Research in the Atmosphere, Colorado State U.



Atmospheric Carbon Data Assimilation/ Flux Inversion

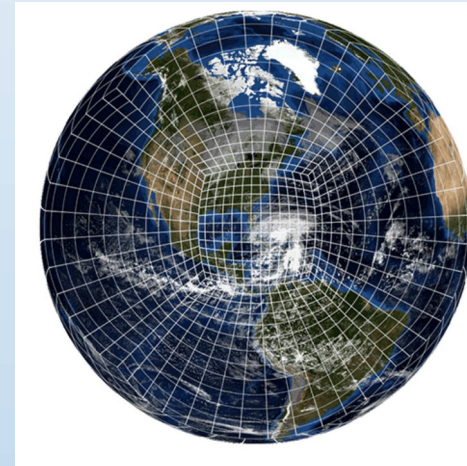
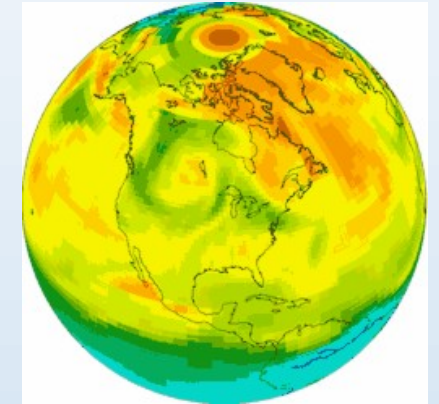
Carbon Flux Models (inventories, wetland models)

Carbon Analyses

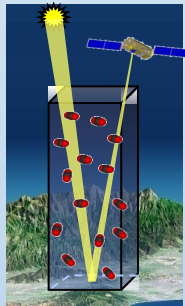


Credit: NASA/Jenny Mottar and Abhishek Chatterjee

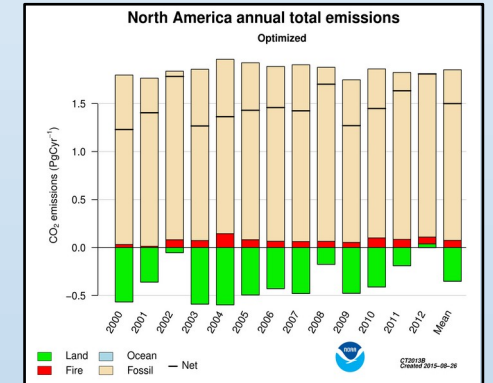
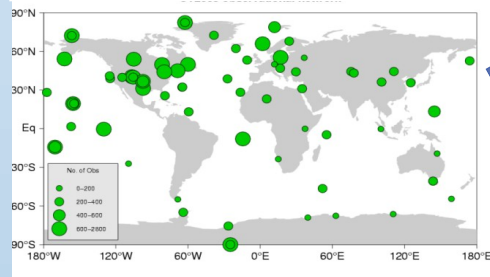
Atmospheric Transport Model+ DA/Inversion Techniques (FV3 Development!)



Remotely- Sensed Column Data



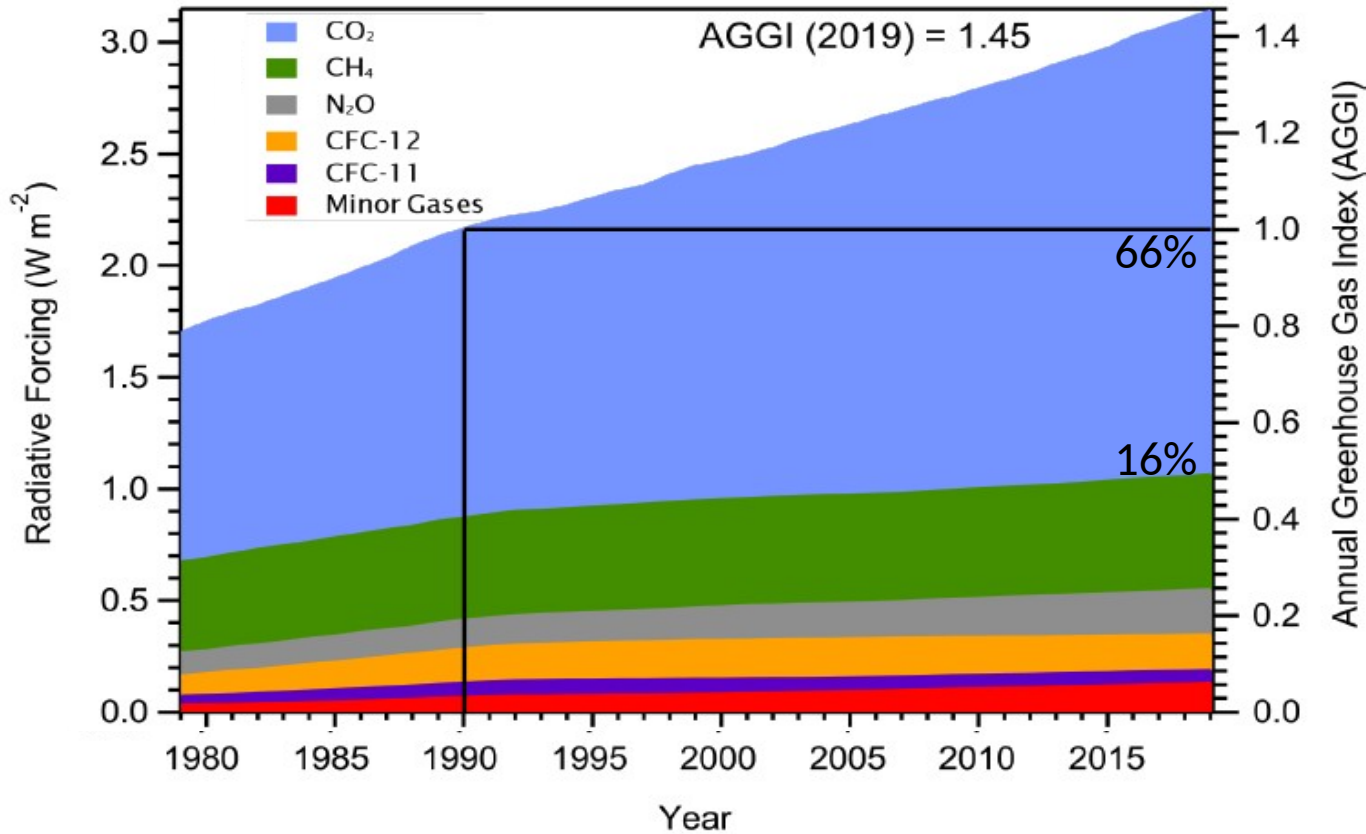
In Situ Surface Network Data



Estimated Fluxes

www.esrl.noaa.gov/gmd/ccgg/carbontracker/
www.esrl.noaa.gov/gmd/ccgg/carbontracker-ch4/

The Role of Anthropogenic Emissions in the Earth's Energy Budget: Radiative Forcing



The CO₂ contribution is rapidly increasing.

The GWP-100 of CH₄ is 28-36, but there is less of it in the atmosphere.

Using Climate-Chemistry Models (IPCC):

$$\Delta T (\text{CO}_2) = 0.75 \text{ (} 0.25 - 1.25 \text{) } ^\circ \text{C}$$

$$\Delta T (\text{CH}_4) = 0.5 \text{ (} 0.25 - 0.8 \text{) } ^\circ \text{C} \text{ **}$$

- Radiative Forcing = human impact on Earth's energy budget since pre-industrial times. Units are Watts/meter². Based on NOAA network measurements.

www.esrl.noaa.gov/gmd/aggi

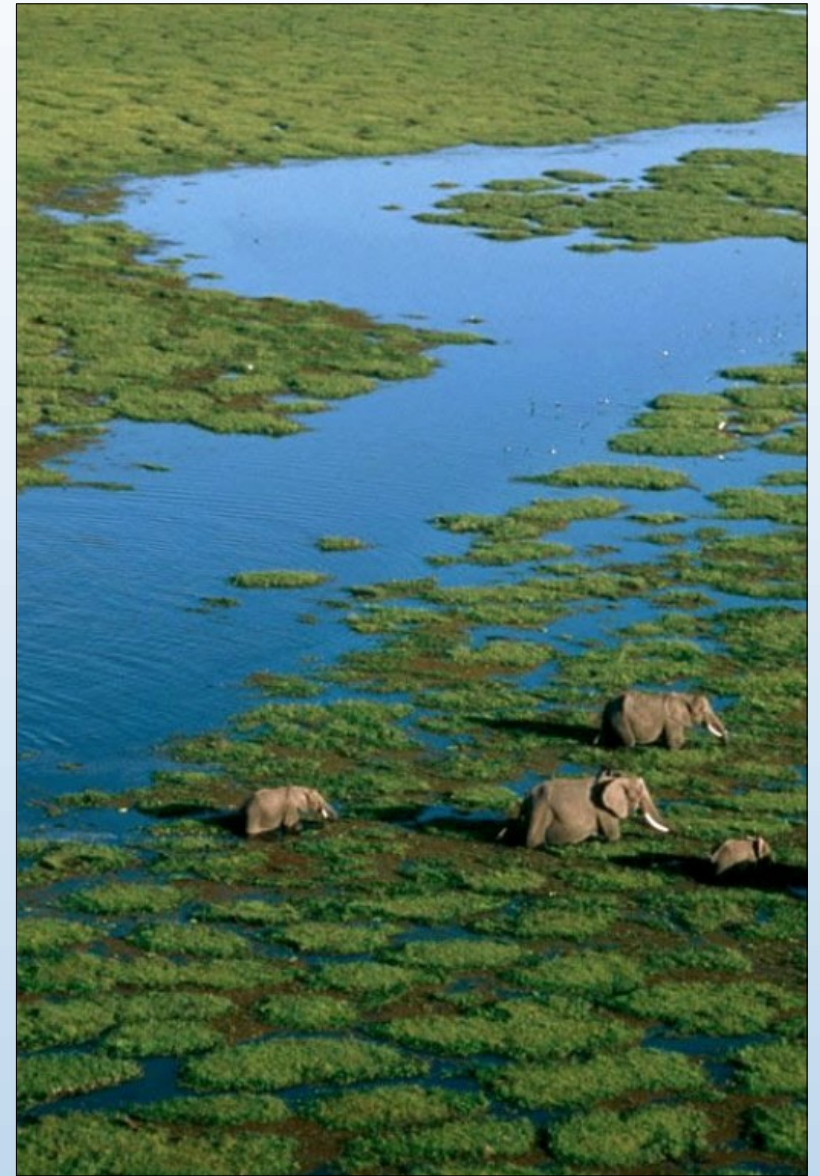
** Includes chemical effects on other radiative forcers. CH₄ has an atmospheric lifetime of ~9-10 yrs.

Carbon-Climate Feedbacks

The amount of carbon in Arctic permafrost soils is ~4x what humans have already emitted since preindustrial times.

Arctic CH₄ emissions could double over this century with accelerating increases next century.

Monitoring observations suggest large emission increases are not happening.....yet.



Are tropical wetlands drying up or expanding?

The Need for MMRV (Measuring, Monitoring, Reporting and Verification) of Emissions

Reduce Anthropogenic Emissions of CH₄ by 30% below 2020 levels by 2030



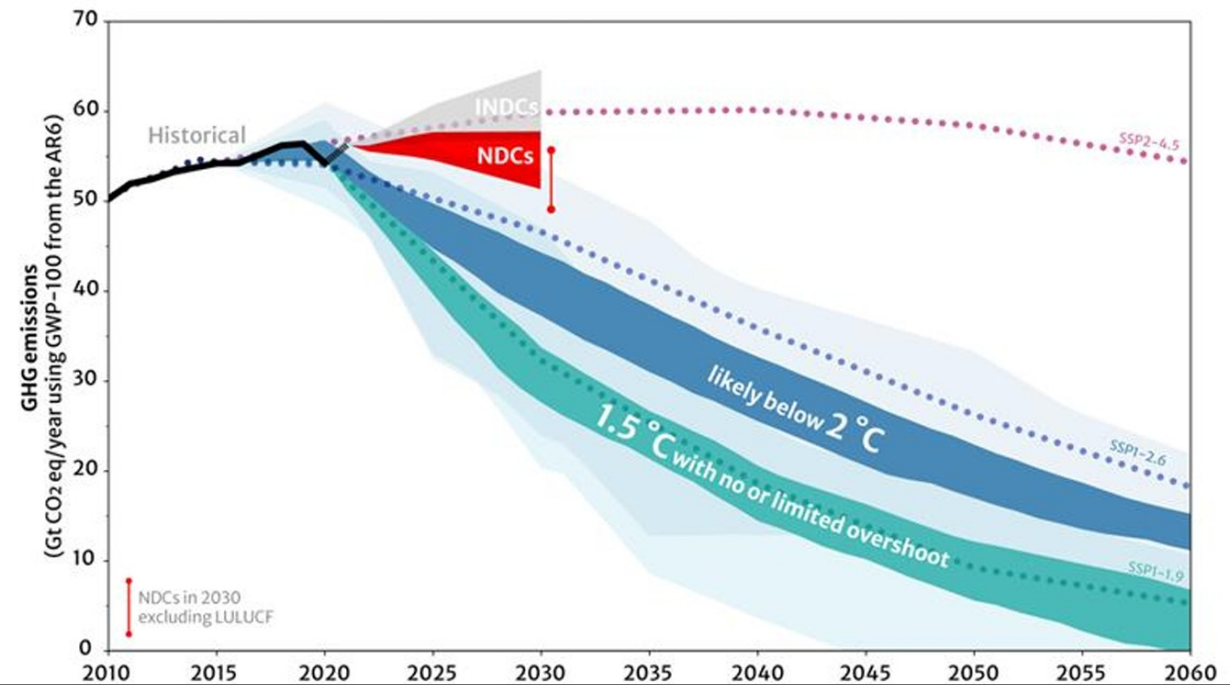
LAUNCH OF THE GLOBAL METHANE PLEDGE

2ND NOVEMBER 2021, GLASGOW

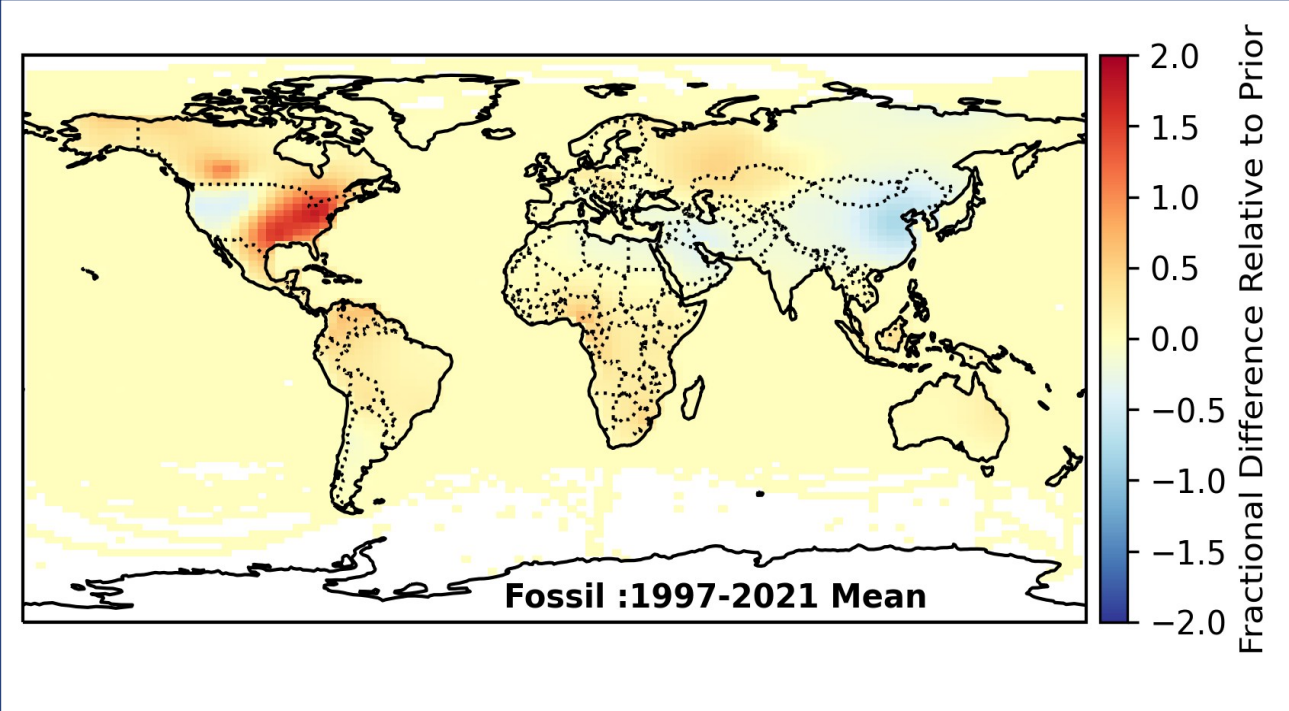
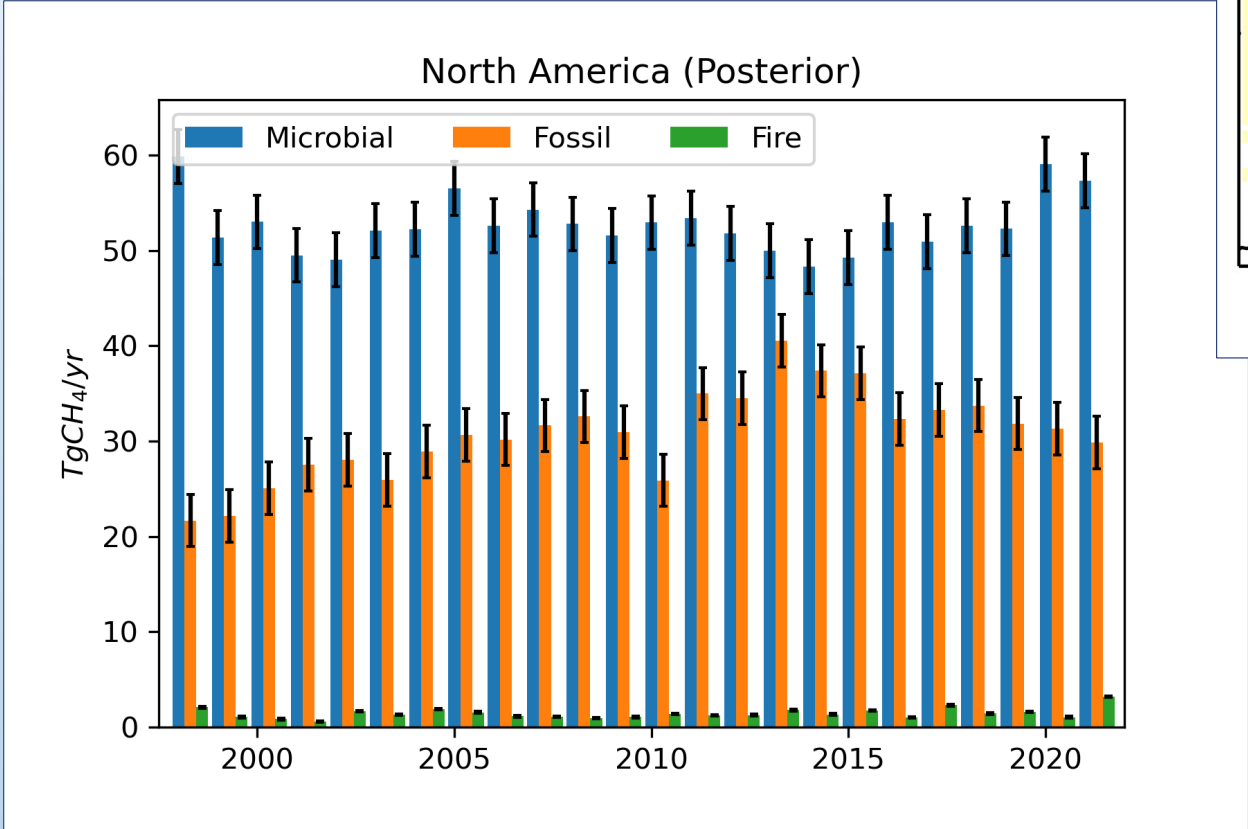
Global Methane Pledge

European Union	United States
Argentina	Finland
Albania	Fiji
Andorra	France
Armenia	Gabon
Barbados	Georgia
Belgium	Germany
Belize	Ghana
Benin	Greece
Bosnia and Herzegovina	Iceland
Brazil	Indonesia
Bulgaria	Israel
Cameroon	Italy
Canada	Japan
Central African Republic	Jordan
Chile	Kazakhstan
Colombia	Kenya
Costa Rica	Kyrgyzstan
Cote D'Ivoire	Laos
Croatia	Libya
Cyprus	Lichtenstein
Dominican Republic	Luxembourg
Democratic Republic of the Congo	Mali
Dominican Republic	Mexico
Dominican Republic	Moldova
Dominican Republic	Montenegro
Dominican Republic	Morocco
Dominican Republic	Nauru
Dominican Republic	Nepal
Dominican Republic	Netherlands
Dominican Republic	New Zealand
Dominican Republic	Nigeria
Dominican Republic	North Macedonia
Dominican Republic	Poland
Dominican Republic	Portugal
Dominican Republic	Republic of Korea
Dominican Republic	Republic of the Congo
Dominican Republic	Rwanda
Dominican Republic	Saudi Arabia
Dominican Republic	Senegal
Dominican Republic	Serbia
Dominican Republic	Singapore
Dominican Republic	Slovenia
Dominican Republic	Spain
Dominican Republic	St. Kitts & Nevis
Dominican Republic	Sudan
Dominican Republic	Sweden
Dominican Republic	Switzerland
Dominican Republic	Togo
Dominican Republic	Tonga
Dominican Republic	Tunisia
Dominican Republic	Ukraine
Dominican Republic	United Arab Emirates
Dominican Republic	United Kingdom
Dominican Republic	Vanuatu
Dominican Republic	Vietnam
Dominican Republic	Zambia

Comparison of scenarios assessed in the Intergovernmental Panel on Climate Change Sixth Assessment Report with projected total and per capita global emissions according to nationally determined contributions



Carbon Tracker-CH₄ :North America

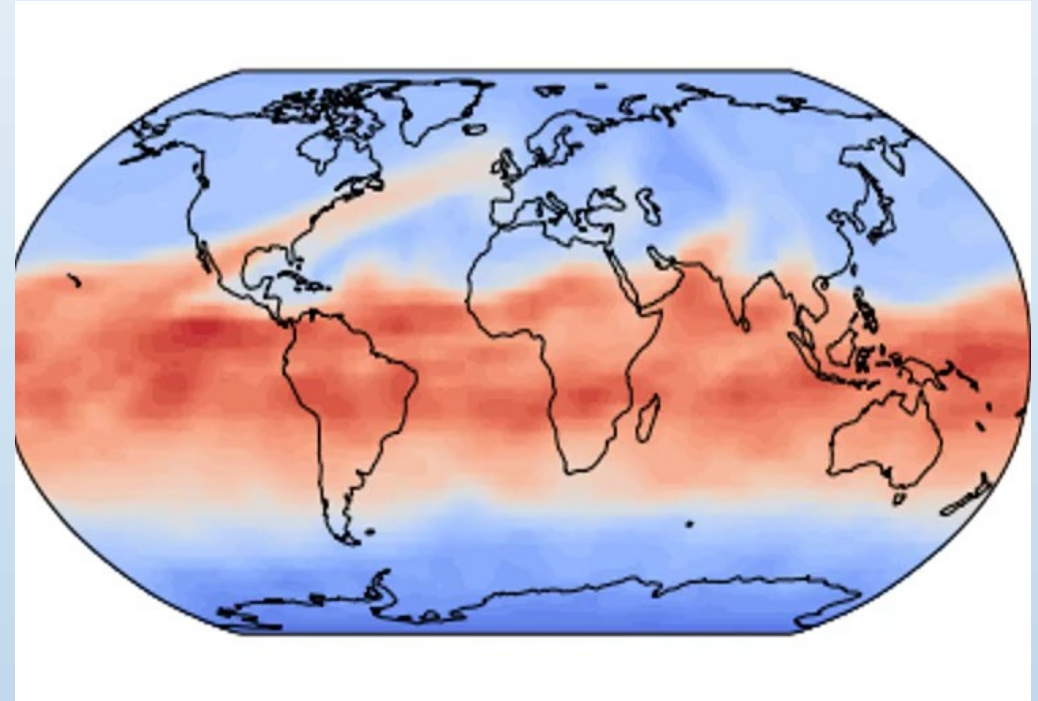


- Microbial emissions are the largest contribution.
- Fossil fuel emissions are revised upwards from priors due to the isotopic constraint.
- Peak fossil fuel emissions occurred between 2010-2015 (note that prior is relatively flat).

Why Should We Consider Using UFS-Chem?

- To better simulate observations, we need higher spatial and temporal resolution than is currently possible in our existing CarbonTrackers. We could resolve emissions at finer spatial scales.
- We are currently dependent on our European colleagues for our global transport model and driving fields.
- Can we use the GEFS reanalysis ensemble to independently estimate model transport error?
- Carbon and moisture exchanges are fundamentally linked - what could we learn from including a detailed treatment of the carbon cycle in the LSM?

Forecast CH₄ 050120



Mass Conservation and Dry Airmass:

We measure dry, not specific mole fractions

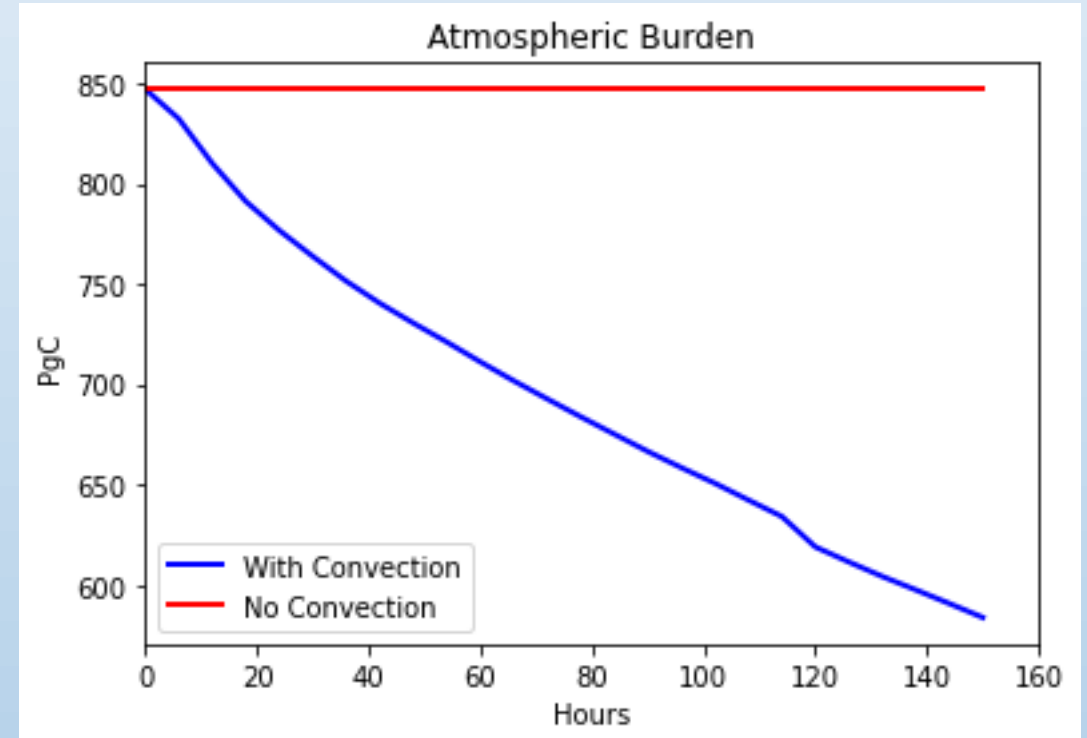
Dry air mass can be calculated using UFS model pressure level thickness, specific humidity and condensates. But formulation of parameterizations affecting moisture variables can adversely impact tracer mixing ratio.

Successive reinitialization of the simulation can introduce analysis shocks that can also lead to non-conservation of tracer mass.

The Experiment:

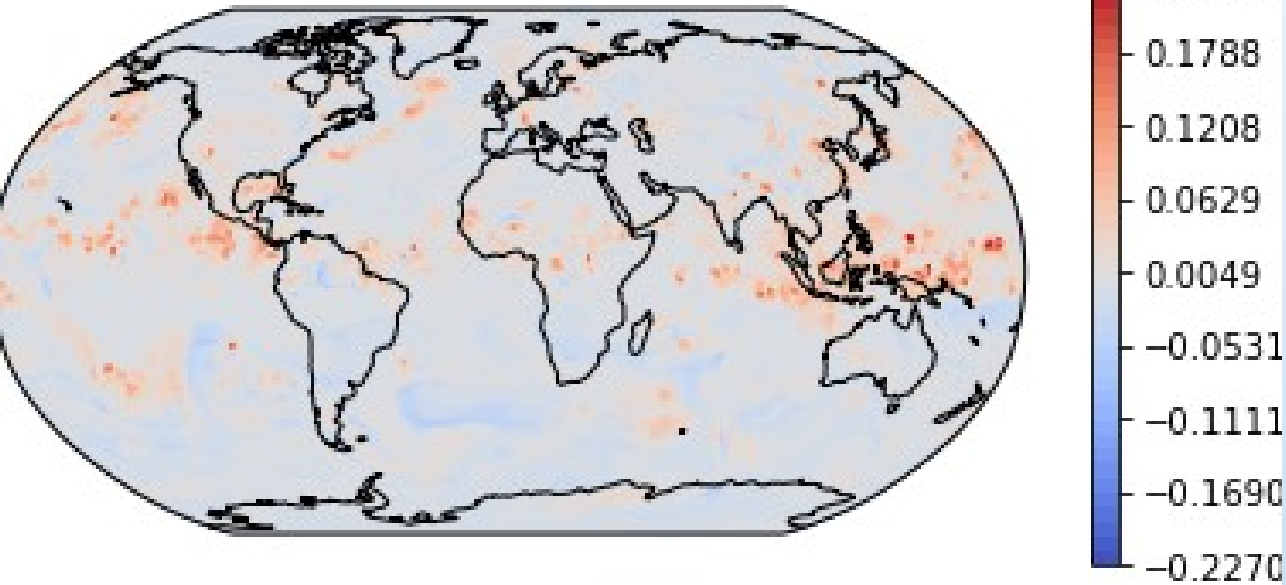
Constant CO₂ field (400 ppm)

No sources/sinks/deposition

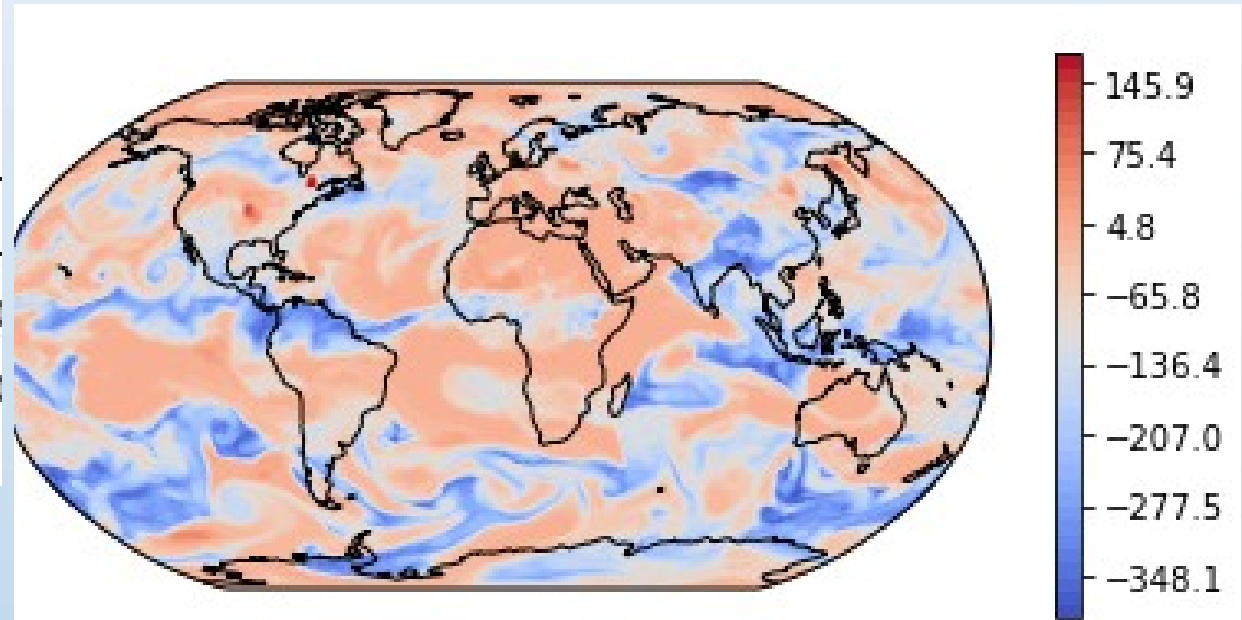


Mass Conservation and Dry Airmass: Tracer Gradients 500hPa, 6 Days

No Convection



Colorbar: Departure from 400 ppm



20160715-20160721

The Experiment:

Constant CO₂ field (400 ppm)

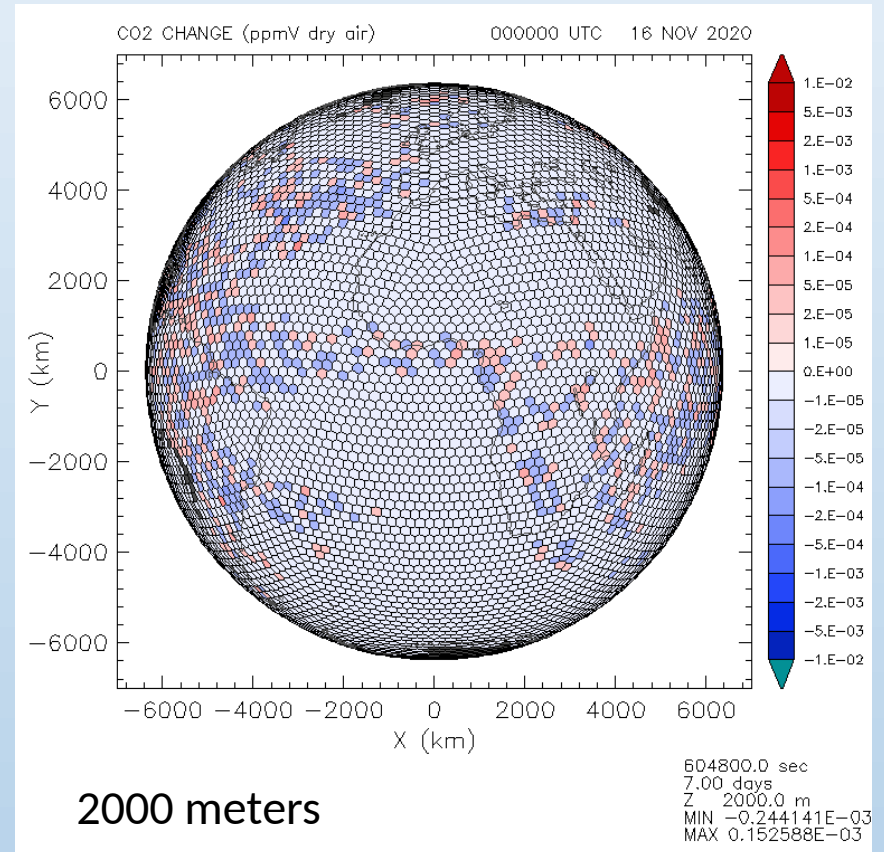
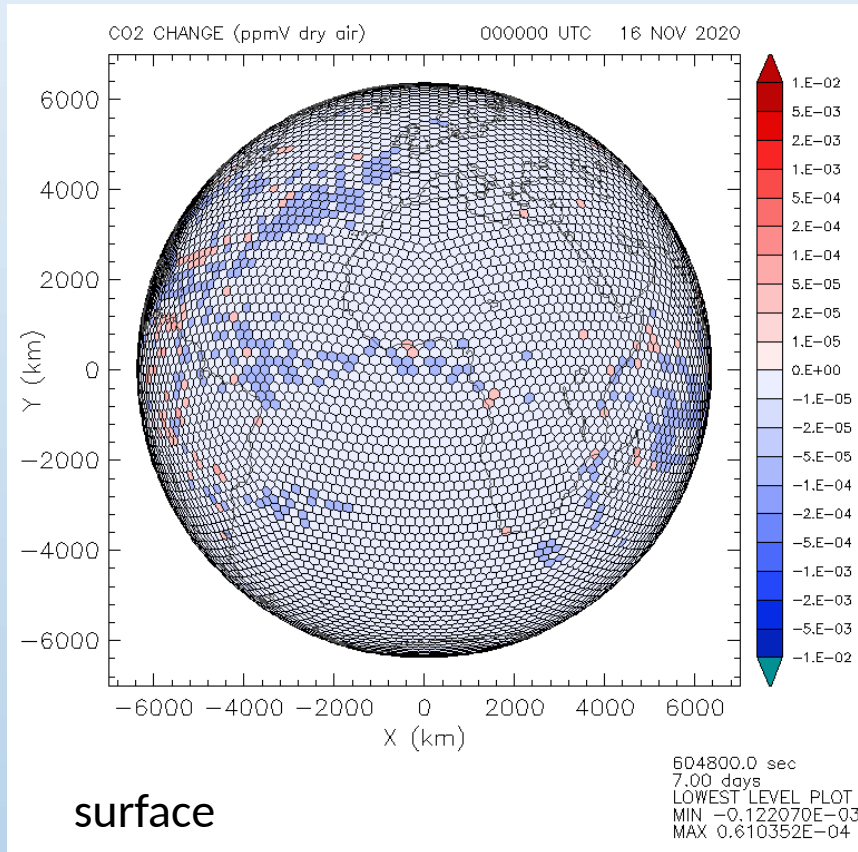
No sources/sinks/deposition

Progress is Possible: The OLAM Model

Total global tracer mass is conserved

A “uniform” tracer field, e.g. 400ppm dry mix ratio, remains well mixed and doesn’t “unmix”

Results from 7 day forecast of full model showing errors $\sim 0.00002\%$



Conclusions

- Conservation of tracer mass and local gradients must be addressed before UFS-Chem can be used for greenhouse gas data assimilation/flux inversion
- Convective parameterizations appear to be the largest source of error in tracer mass conservation.
- It is certain that this problem will exist for other long-lived trace species and is likely to exist for shorter-lived trace species
- It is possible to fix these problems, but will likely require accurate tracking of the water budget.
- Fixing the problems could potentially lead to better predictions.