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

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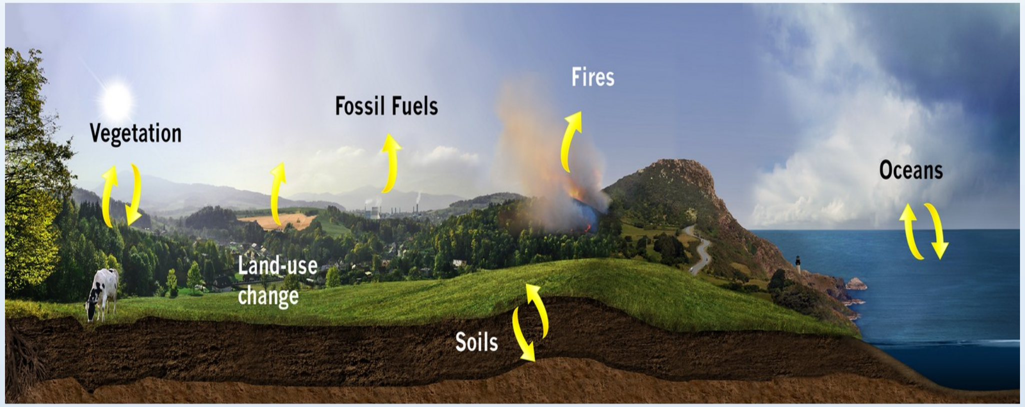
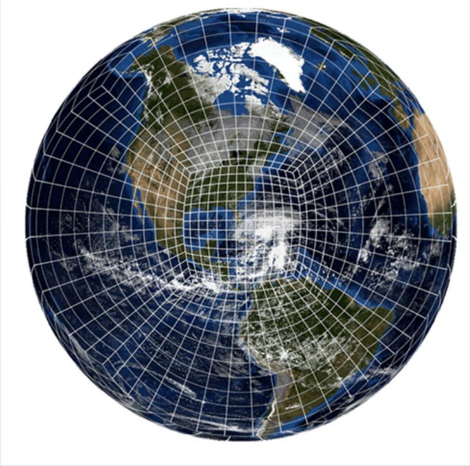
Atmospheric Carbon Data Assimilation/ Flux Inversion

Carbon Flux Models (inventories , wetland models)

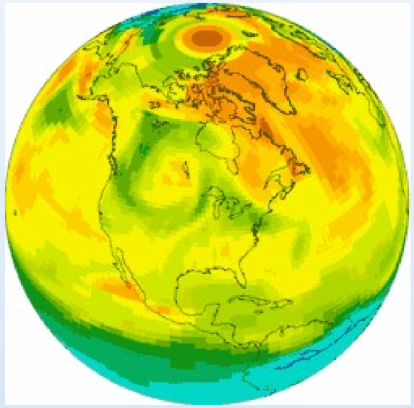


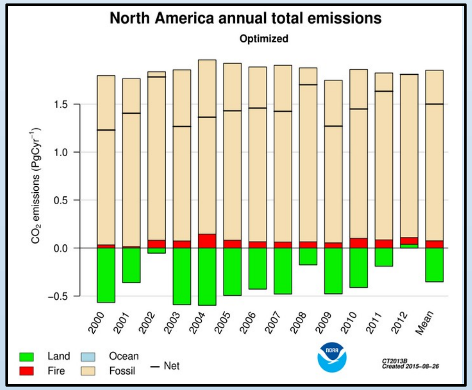
Credit: NASA/Jenny Mottar and Abhishek Chatterjee

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



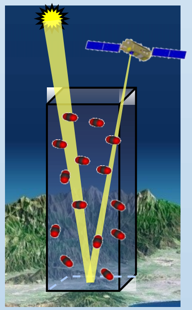
Carbon Analyses





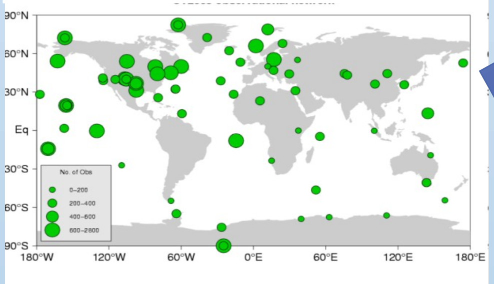
Estimated Fluxes

Remotely- Sensed Column Data



Profiles from aircraft

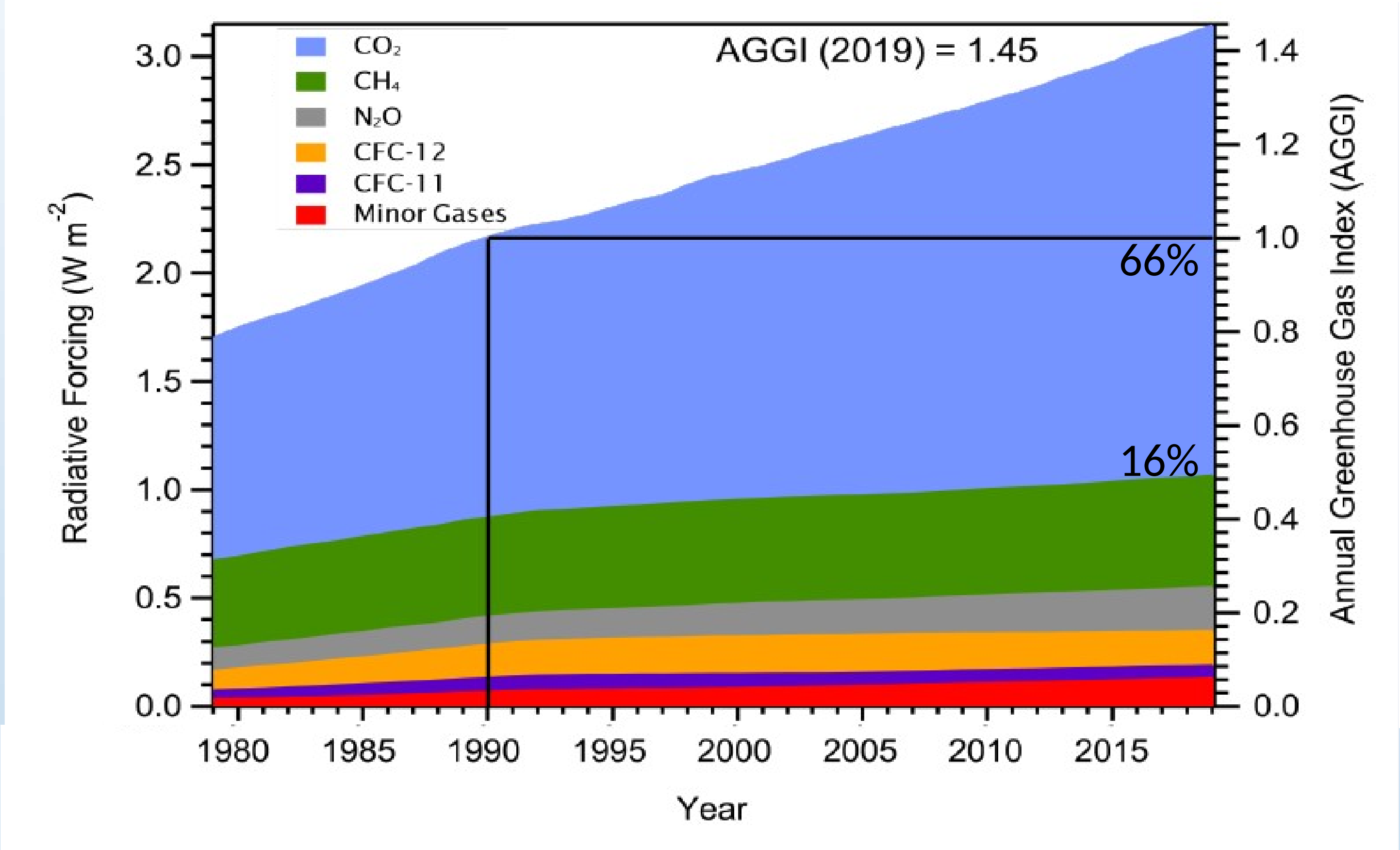
In Situ Surface Network Data



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



- *Radiative Forcing = human impact on Earth's energy budget since pre-industrial times. Units are Watts/meter^2. Based on NOAA network measurements.*

www.esrl.noaa.gov/gmd/aggi

The CO_2 contribution is rapidly increasing.

The GWP-100 of CH_4 is 28-36, but there is less of it in the atmosphere.

Using Climate-Chemistry Models (IPCC):

ΔT (CO_2) = 0.75 (0.25 – 1.25) ˚C

ΔT (CH_4) = 0.5 (0.25 – 0.8) ˚C **

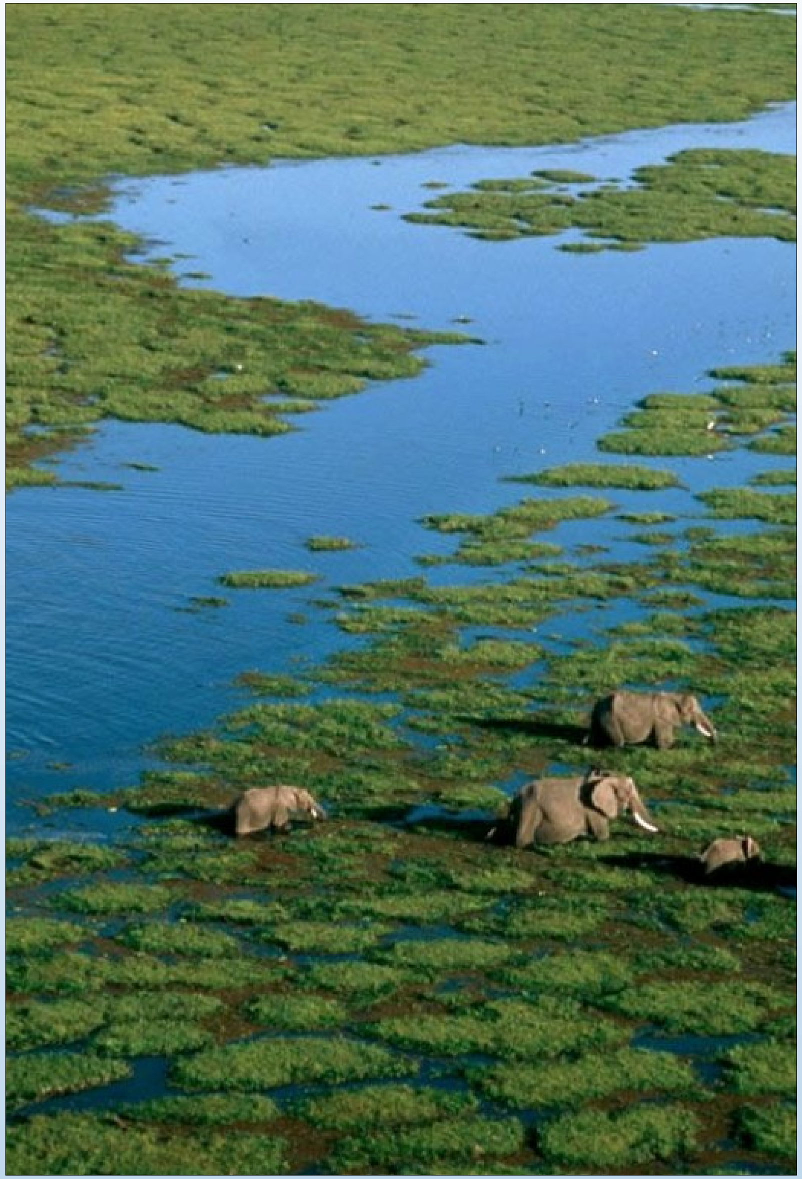
****Includes chemical effects on other radiative forcers. CH_4 has an atmospheric lifetime of ~9-10 yrs.**

Carbon-Climate Feedbacks

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

Arctic CH_4 emissions could double over this century with accelerating increases next century.

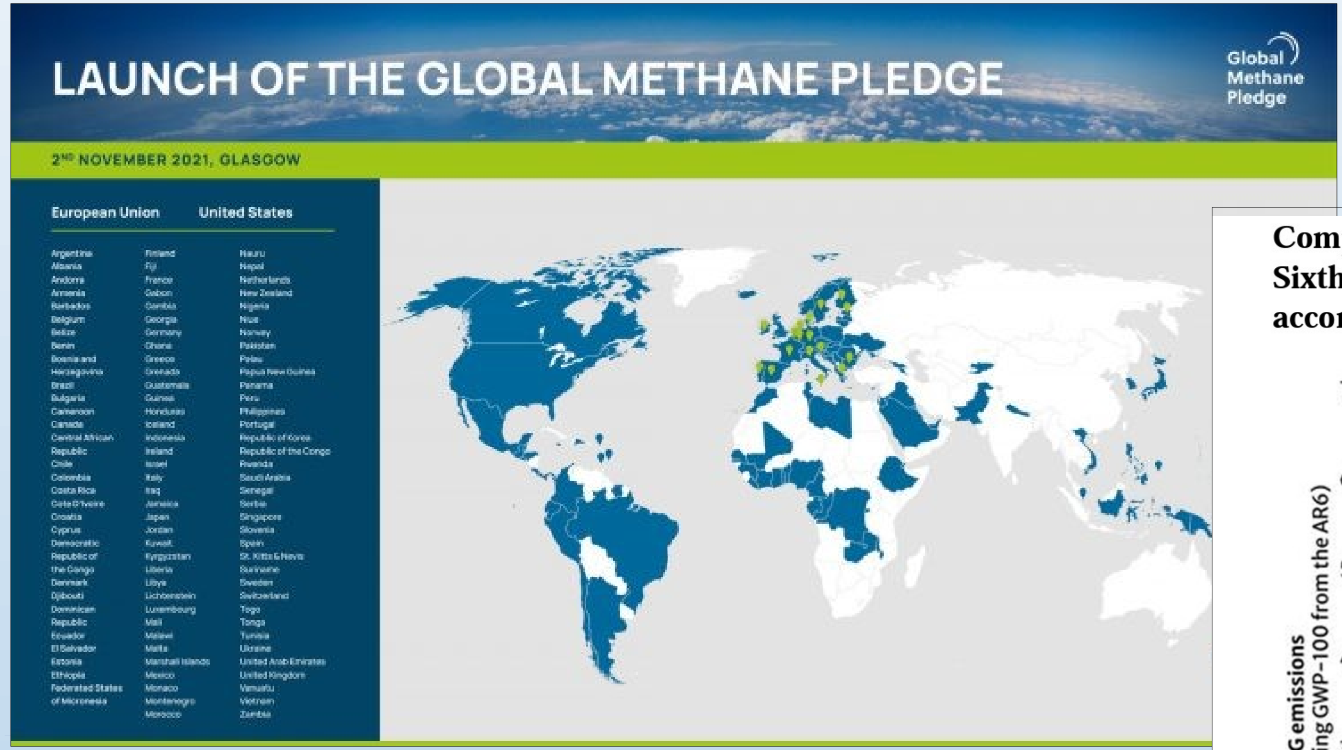
Monitoring observations suggest large emission increases are not happening……yet.

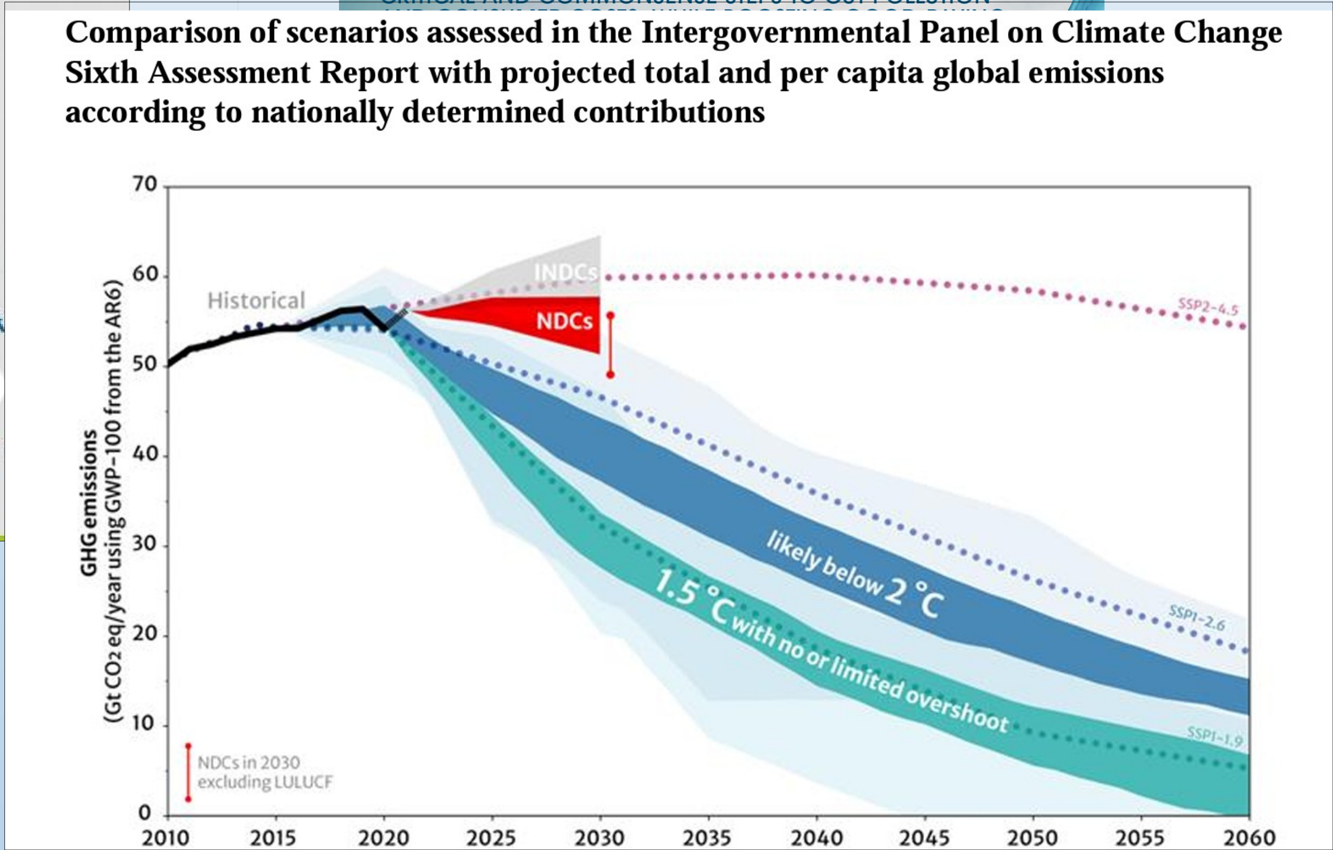


Are tropical wetlands drying up or expanding?

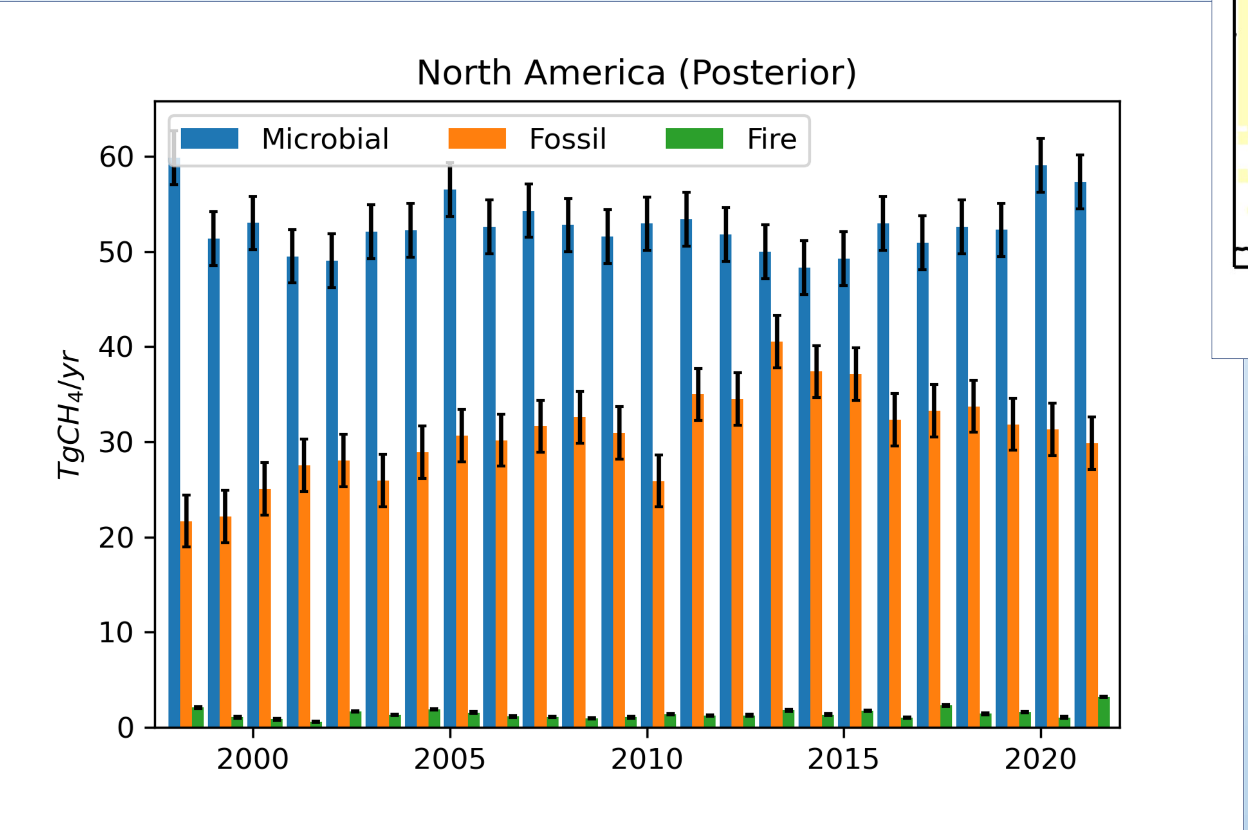
The Need for MMRV (Measuring, Monitoring, Reporting and Verification) of Emissions

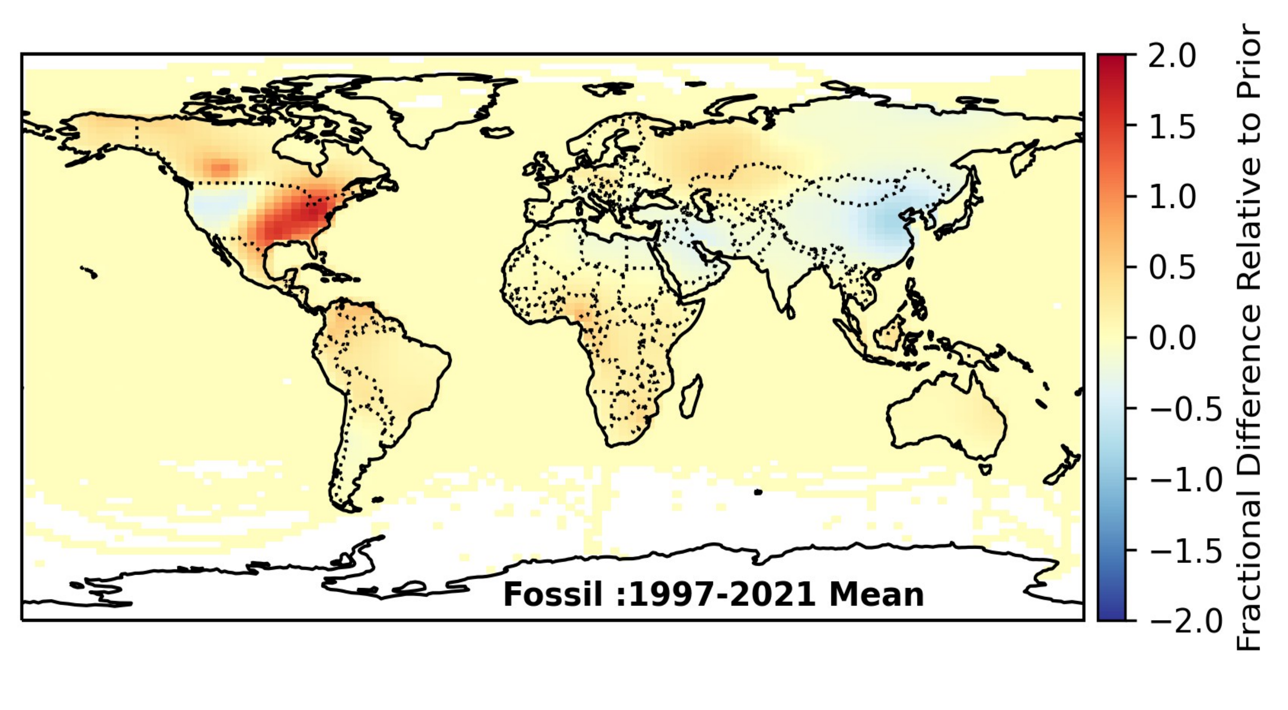
Reduce Anthropogenic Emissions of CH_4 by 30% below 2020 levels by 2030





Carbon Tracker-CH_4 :North America



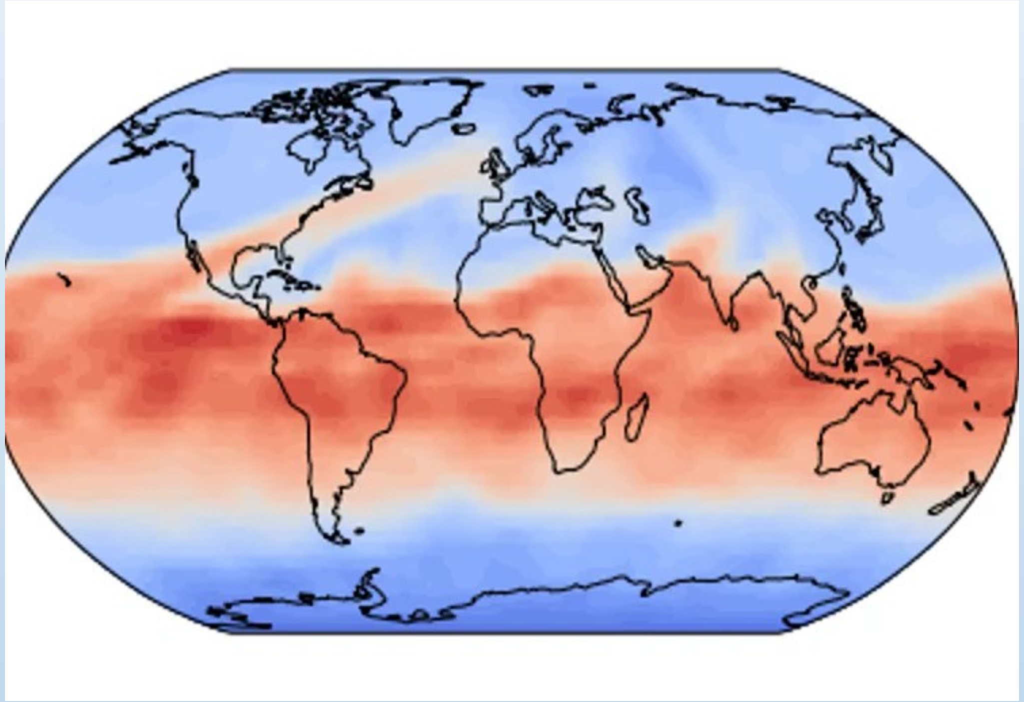


- **Microbial emissions are the largest contribution.**
- **Fossil fuel emissions are revised upwards from priors due to the isotopic constraint.**
- **Peak fossil fuel emissions occurred between 2010-2015 (note that prior is relatively flat).**

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 CH_4 050120



Mass Conservation and Dry Airmass:

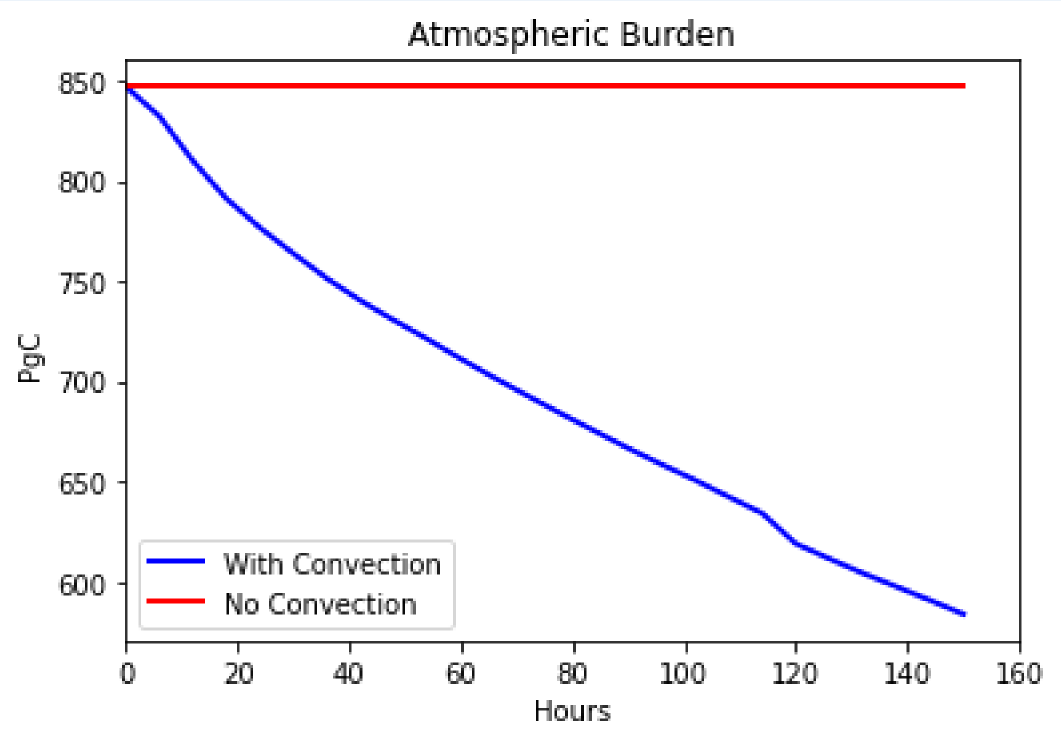
We measure dry, not specific mole fractions

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.

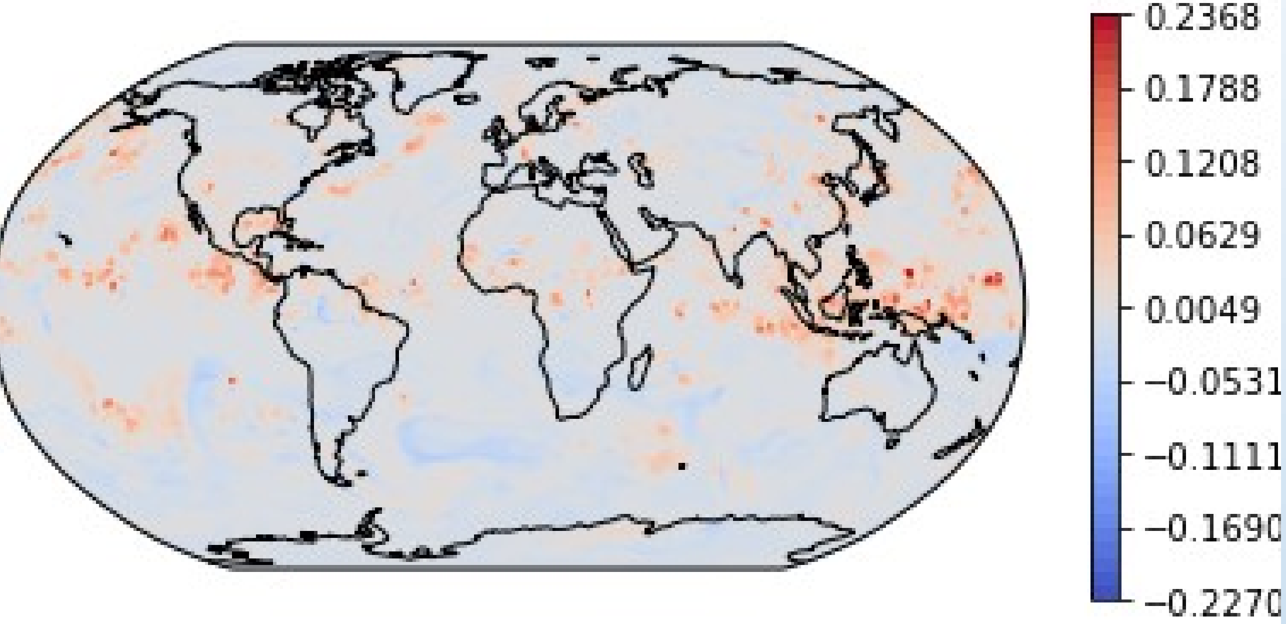
The Experiment:

Constant CO_2 field (400 ppm)
No sources/sinks/deposition

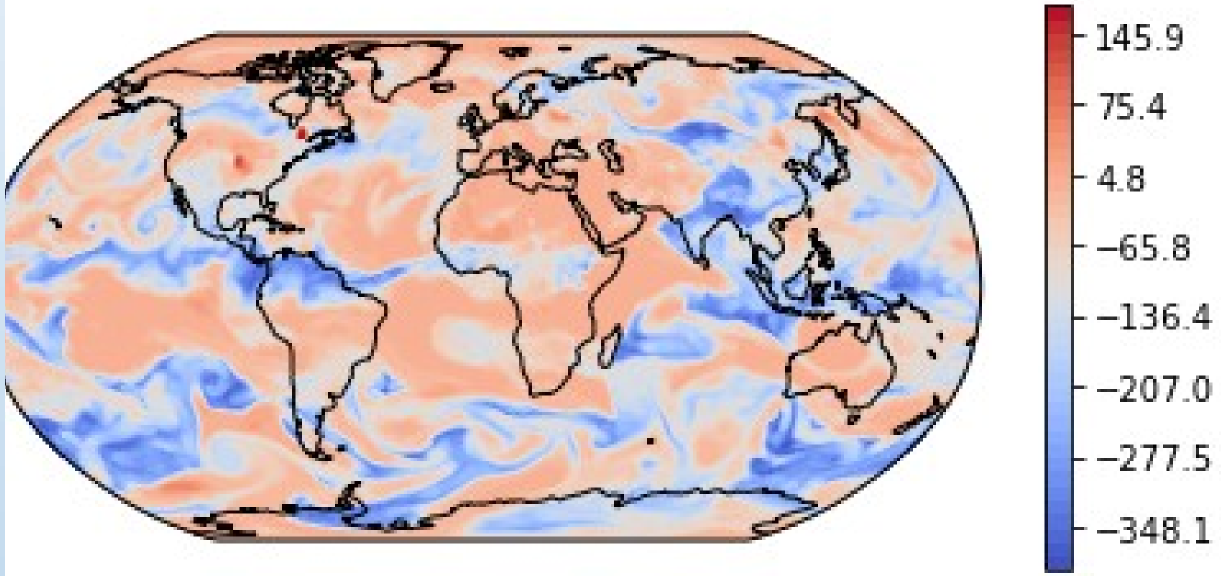


Mass Conservation and Dry Airmass: Tracer Gradients 500hPa, 6 Days

No Convection



Colorbar: Departure from 400 ppm



20160715-20160721

The Experiment:

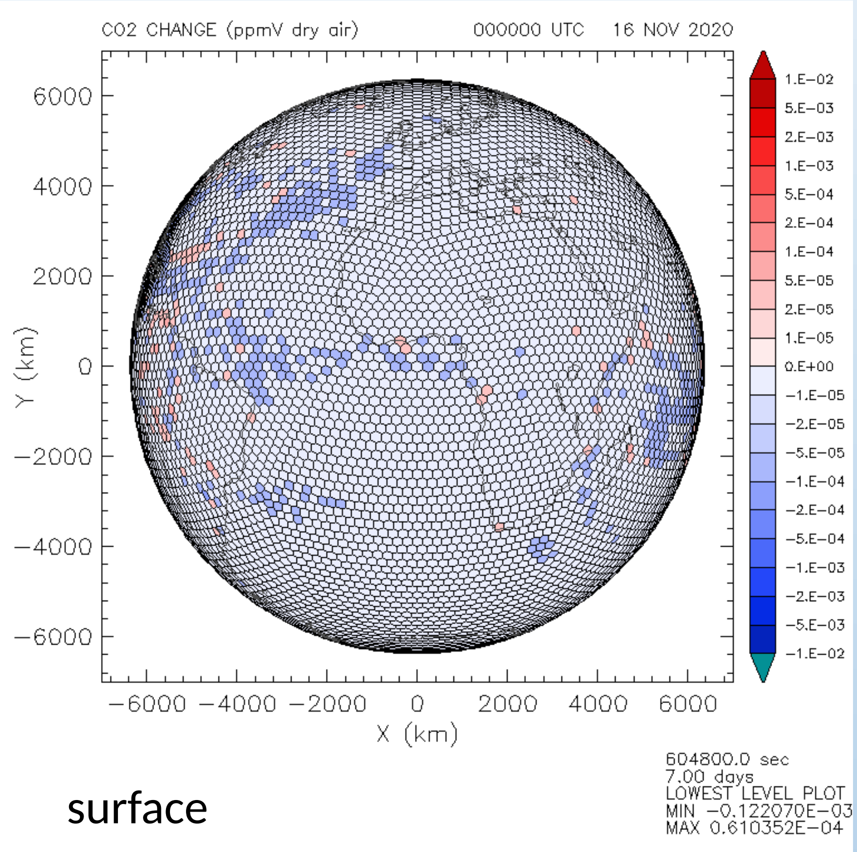
Constant CO_2 field (400 ppm)
No sources/sinks/deposition

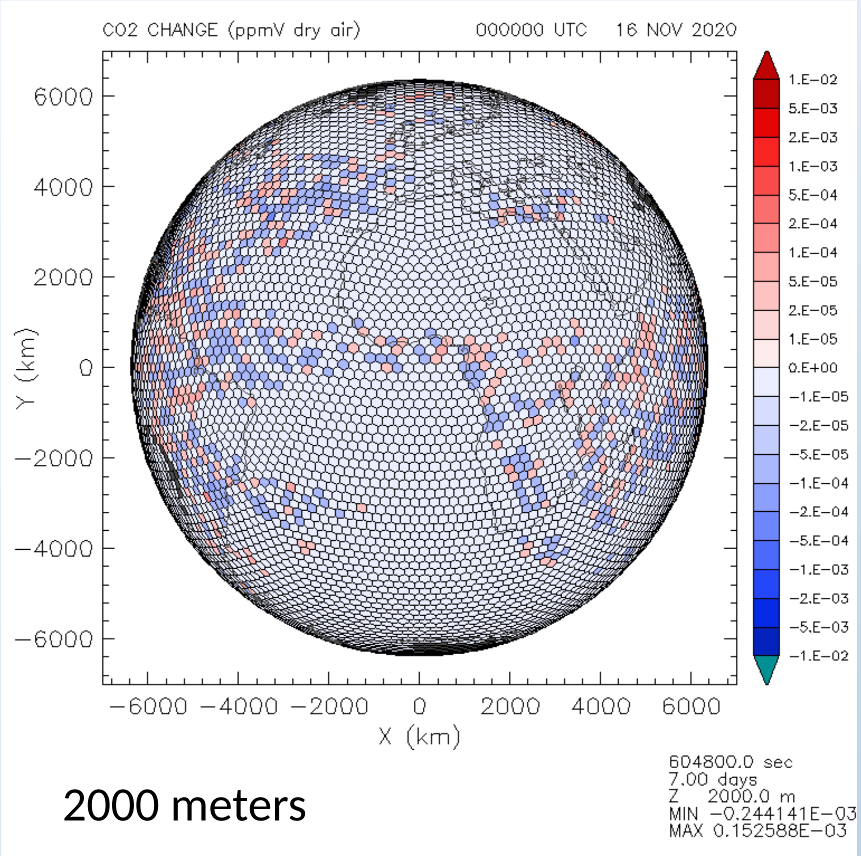
Progress is Possible: The OLAM Model

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 ~ 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 like require accurate tracking of the water budget.
- Fixing the problems could potentially lead to better predictions.