Global Methane Cycle in the NOAA GFDL Earth System Modeling Framework

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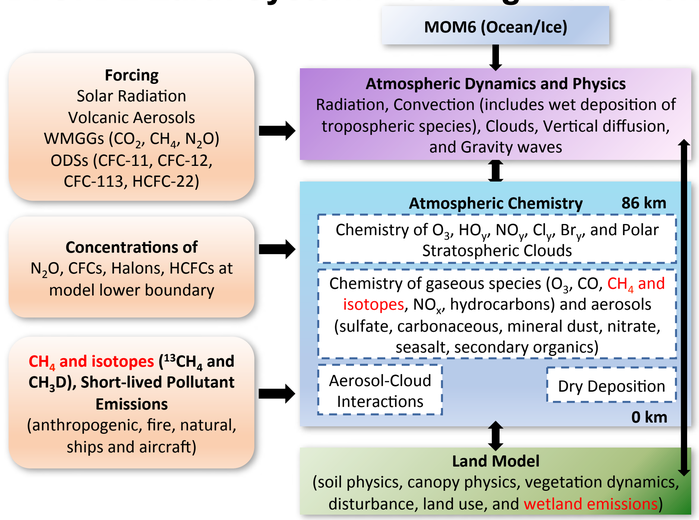
Motivation

- Methane (CH_4) is a potent greenhouse gas and a precursor of ground-level ozone pollution. Its concentration in the atmosphere has increased from 650 to 1800 ppb since the beginning of the industrial revolution. The cycling of methane in the atmosphere is rapid (residence time ~ 12 years) and complex as it involves several biological, geological and industrial sources as well as photochemical and microbiological sinks. Despite extensive research, we still have an incomplete understanding of the processes responsible for the changes in atmospheric methane.

Objective

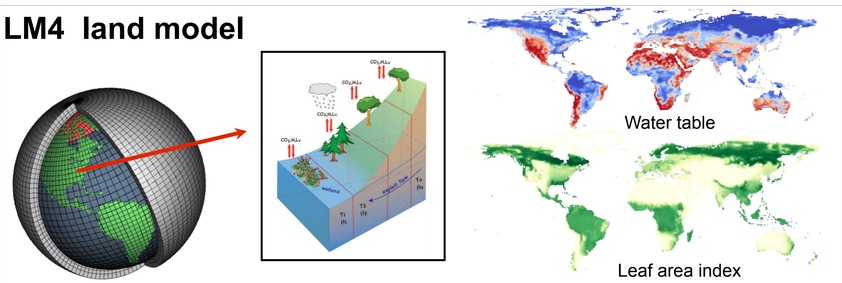
- **To quantify the contribution of individual sources and sinks to past and future atmospheric methane trends and variability through global comprehensive Earth System Modeling**
  - First, we leverage observations to quantify individual sources of methane either directly (e.g., ^{13}C isotopes for fossil fuel, biomass, and microbial sources) or indirectly (e.g., ethane/methane ratio for fossil fuel, NH_3/N_2O for agriculture).
  - Second, we will characterize the drivers of variability of the atmospheric methane sink using observations of methylchloroform for OH concentration.

NOAA GFDL Earth System Modeling Framework



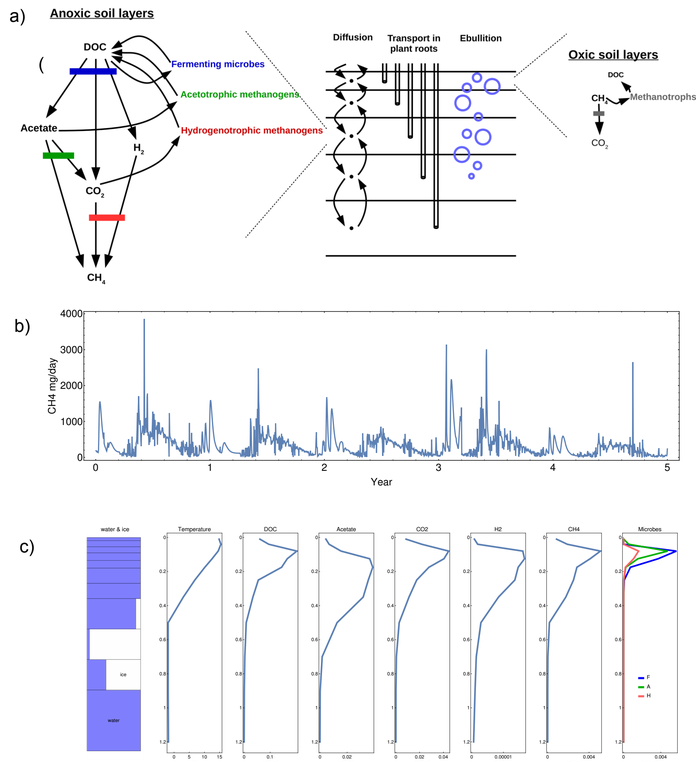
Comprehensive Bottom-Up Earth System Model includes an explicit representation of methane sources (e.g., energy use & wetlands), accounts for key drivers of sink variability, and allows the characterization of the full impact of methane on past and future climate (direct, indirect and feedbacks)

LM4 land model



New GFDL land model LM4 predicts a suit of hydrological and ecological variables as well as the state of vegetation/soil carbon and fluxes of CO_2 between land and atmosphere. We are evaluating the new global CH4 wetland emissions and prognostic wetland area capabilities.

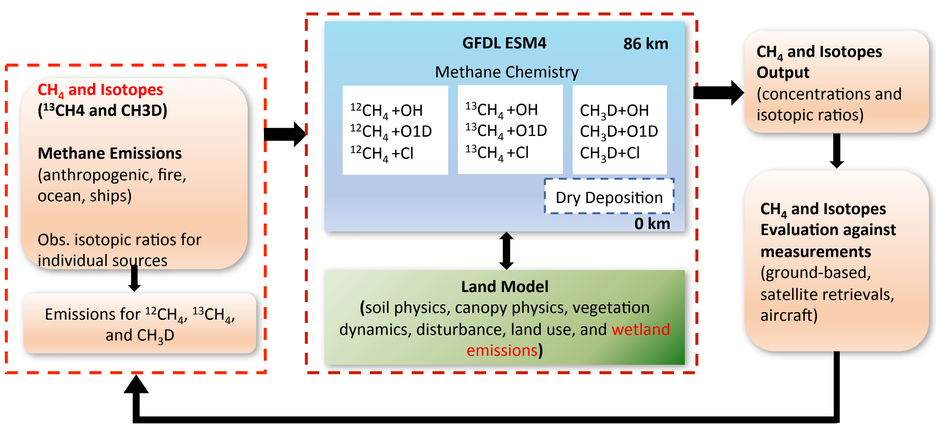
New GFDL prognostic methane model with explicit treatment of four functional microbe groups



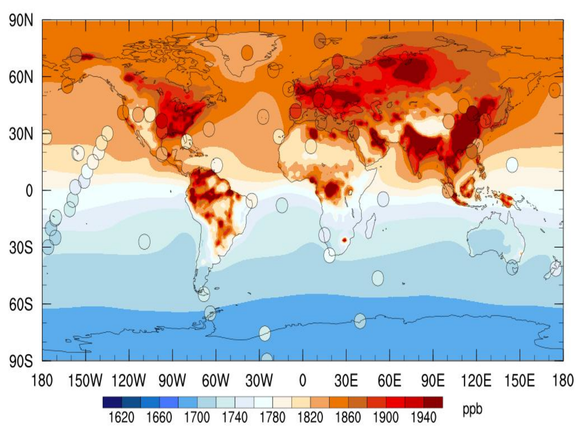
a) Schematic diagram: network of microbes produce methane in anoxic soil layers; physical processes of gas transport; methane oxidation in oxic soil layers.
b) Example 5-year model run and soil surface methane emissions. Southern Canada (Mer Bleue) location.
c) Examples of soil profiles to 1.2 m depth. Soil is saturated with water. Wetland microbes consume Dissolved Organic Carbon (DOC) and produce CO_2 and methane (CH_4) via intermediate products Acetate and H2. Northern Canada (Hudson Bay) location, August.

Work in Progress for Atmospheric Chemistry – Land Components

- Improve emissions inventory using gridded isotopic source signatures
- Finalize and evaluate global model of microbial methane emissions and consumption
- Couple wetland emissions with the Atmospheric Chemistry and Climate Components



Comparison of Modeled Surface CH_4 concentrations with Observations



GFDL-AM4 simulation with optimized global total emissions from CMIP6 (Coupled Model Intercomparison Project) inventory. The plot shows modeled climatological mean surface methane concentrations overlaid with observations from the NOAA Global Monitoring Division for the 1983-2014 time period.