CESM emission-driven run tutorial

Biogeochemistry working group winter meeting, Feb 26, 2025

Co-chairs: Abby Swann, Gretchen Keppel-Aleks, Kristen Krumhardt

Special thanks to Peter Lawrence, Mike Levy, Nikki Lovenduski, Charlie Koven

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Goals of this tutorial:

- Learn about how to set up an emission-driven CESM run
- Learn about forcing
- Analysis techniques that can be applied to emission-driven runs

Agenda

- 1:30 - ~1:45: Overview of tutorial in the Main Seminar room
- 1:45: Independent work: set up and run a 1 month fully-coupled emission-driven CESM2 run
- [break at 2:30 **in Damon Room**]
- 2:45 - 4:30 Independent work on analysis notebooks
  - Creating emission files
  - Analysis notebooks for ocean
  - Analysis land
  - Atmosphere

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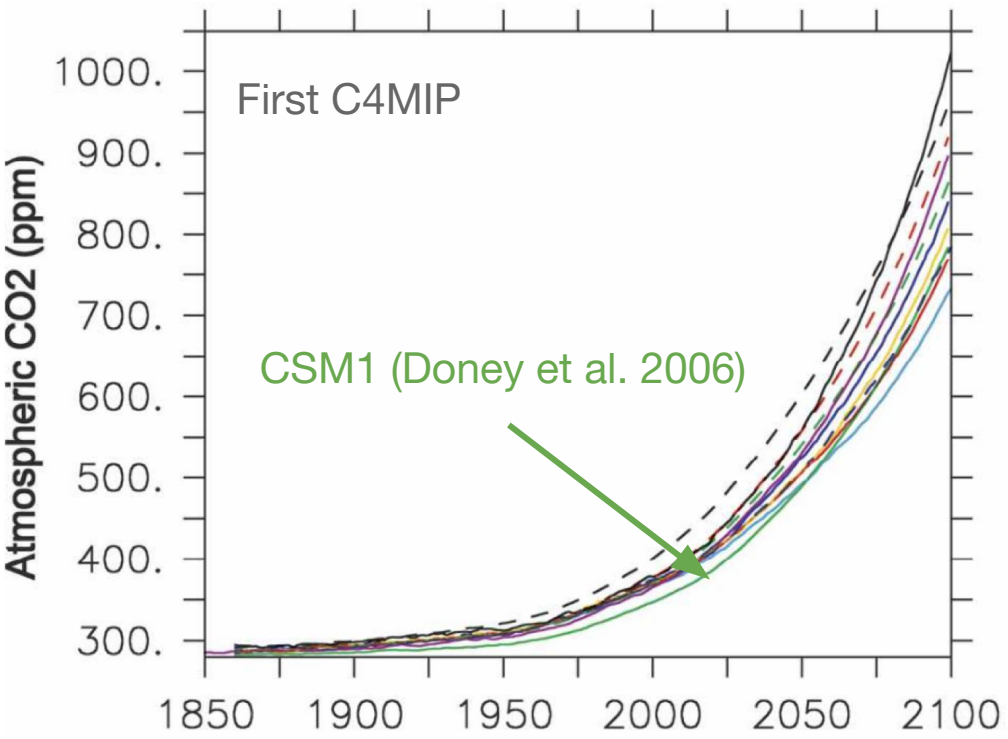
Why are we doing this?

The BGCWG was established in 1998 to create emissions-driven (aka fully coupled carbon cycle) capability - “The Flying Leap”

CESM (and predecessors) have been able to do this since CMIP3!



Friedlingstein et al. 2006

Why are we doing this?

CMIP7 will be (more) emissions-driven!

We want more people to be familiar with running the model in this configuration

https://doi.org/10.5194/egusphere-2024-3874
Preprint. Discussion started: 20 December 2024

EGUsphere
Preprint repository

An evolving Coupled Model Intercomparison Project phase 7 (CMIP7) and Fast Track in support of future climate assessment

John P. Dunne[1], Helene T. Hewitt[2], Julie Arblaster[3], Frédéric Bonou[4], Olivier Boucher[5], Tereza Cavazos[6], Paul J. Durack[7], Birgit Hassler[8], Martin Juckes[9], Tomoki Miyakawa[10], Matt Mizielinski[2], Vaishali Naik[1], Zebedee Nicholls[11], Eleanor O'Rourke[12], Robert Pincus[13], Benjamin M. Sanderson[14], Isla R. Simpson[15], Karl E. Taylor[7]

for the Coupled Model Intercomparison Project (CMIP) is to coordinate community based efforts to
y climate science questions and facilitate delivery of relevant multi-model simulations through shared
benefit of the physical understanding, vulnerability, impacts and adaptations analysis, national and
assessments, and society at large. From its origins as a punctuated phasing of climate model
evaluation, CMIP is now evolving through coordinated and federated planning into a more continuous
ogram. The activity is supported by the design of experimental protocols, an infrastructure that supports
ccess, and the phased delivery or "fast track" of climate information for national and international climate
assessments informing decision making. Key to these CMIP7 efforts are: an expansion of the Diagnostic, Evaluation and
Characterization of Klima (DECK) to include historical, effective radiative forcing, and focus on CO_2-emissions-driven
experiments; sustained support for community MIPs; periodic updating of historical forcings and diagnostics requests; and a
collection of experiments drawn from community MIPs to support research towards the 7th Intergovernmental Panel on

Geosci. Model Dev., 17, 8141–8172, 2024
https://doi.org/10.5194/gmd-17-8141-2024

Geoscientific Model Development
Open Access
EGU

The need for carbon-emissions-driven climate projections in CMIP7

Benjamin M. Sanderson[1], Ben B. B. Booth[2], John Dunne[3], Veronika Eyring[4,5], Rosie A. Fisher[1], Pierre Friedlingstein[6], Matthew J. Gidden[7,20], Tomohiro Hajima[8], Chris D. Jones[2,15], Colin G. Jones[14], Andrew King[9], Charles D. Koven[10], David M. Lawrence[11], Jason Lowe[2], Nadine Mengis[12], Glen P. Peters[1], Joeri Rogelj[7,13], Chris Smith[2,7,14], Abigail C. Snyder[17], Isla R. Simpson[11], Abigail L. S. Swann[16], Claudia Tebaldi[17], Tatiana Ilyina[18,19], Carl-Friedrich Schleussner[20,21], Roland Séférian[22], Bjørn H. Samset[1], Detlef van Vuuren[23], and Sönke Zaehle[24]

NSF NCAR Operated by UCAR

What's unique about emissions-driven mode?

- CO_2 emissions are specified
- CO_2 concentrations are fully prognostic, resulting from the balance of sources and sinks of carbon and atmospheric transport
- CO_2 is traced in the atmosphere and influenced by atmospheric transport - resulting CO_2 field has dimensions of (lat, lon, height, time)
- Land BGC and Ocean BGC are active to produce time varying sinks and sources

Checkout and run 1mo emissions-driven

Clone the Git repository:

git clone https://github.com/NCAR/CESM-emission-driven-run-tutorial.git

The shell script that sets up a HOPE-like emissions-driven run:
set_up_HOPE_historical.sh

- Check out CESM2.1.5 (version used for HOPE runs)
- Create a new historical case (BHIST with adjusted emissions), branching off PI control
- Set up and do a 1-month run

Overview of analysis notebooks

- Can be run on Jupyterhub: **https://jupyterhub.hpc.ucar.edu**
- HOPE output (timeseries files) is located at: /glade/campaign/cesm/community/bgcwg/HOPE
- Jupyter notebooks for land, atmosphere, and ocean components.
- Notebook that shows how to create emission forcing files.
- These are just a starting point, many more notebooks could be added - please let us know your ideas!

Ocean analysis notebooks

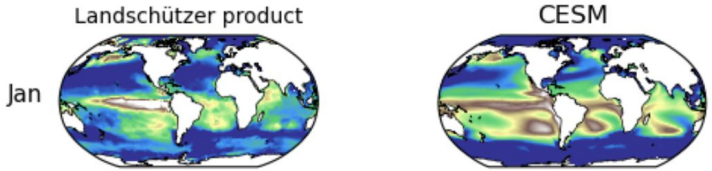
Ocean carbon inventories:

- ocean_carbon_SSP245.ipynb
- Totals up all the carbon in the CESM ocean and makes a table showing inventories for 2015 and 2100

	carbon pool	quantity 2015	quantity 2100	unit
0	Dissolved inorganic carbon	37233.60000	37479.30000	Pg C
1	Refractory dissolved organic carbon	361.57800	362.15700	Pg C
2	Semi-labile dissolved organic carbon	29.42600	30.10500	Pg C
3	Mesozooplankton biomass	0.41400	0.41200	Pg C
4	Microzooplankton biomass	0.23300	0.23300	Pg C
5	Diatom biomass	0.26100	0.25600	Pg C
6	Small phytoplankton biomass	0.19600	0.19600	Pg C
7	Coccolithophore biomass	0.03700	0.03500	Pg C
8	Diazotroph biomass	0.00986	0.00997	Pg C
9	Coccolithophore $CaCO_3$	0.01398	0.01217	Pg C
10	Total carbon in ocean	37625.76000	37872.67000	Pg C

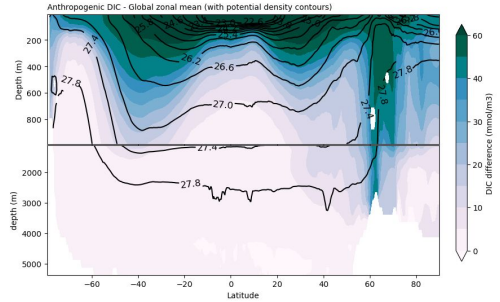
Ocean pCO2, model-observations comparison:

- ocean_monthly_pCO2.ipynb
- Compares monthly climatology of ocean surface pCO2 to observation-based dataset



Zonal means of anthropogenic carbon in the ocean

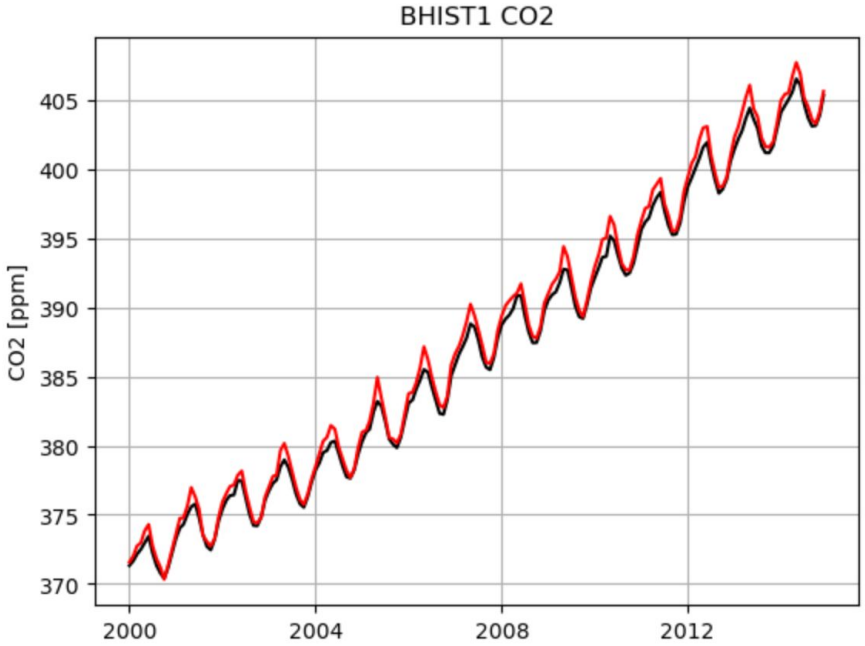
- ocean_anthro_carbon_zonal.ipynb



Atmosphere notebook

Atmospheric CO_2 timeseries:

- atmosphericCO2.ipynb
- Plot, detrend, and calculate a mean annual cycle for CO_2 at a specific pressure level
- Calculate the total column integral (X_{CO2}) observed from space

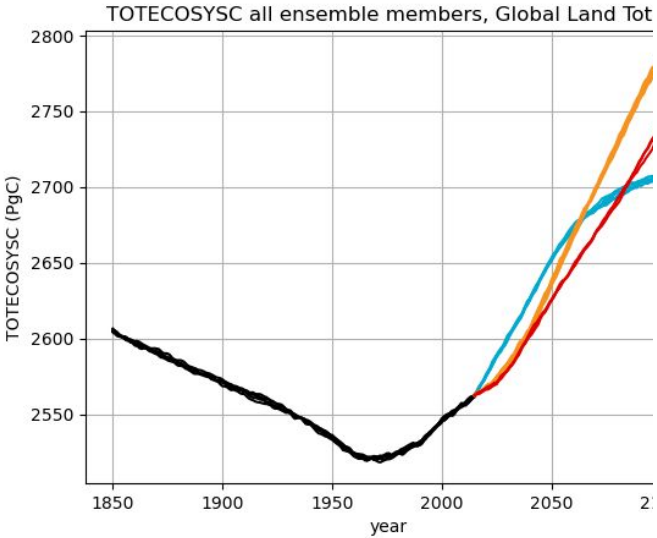


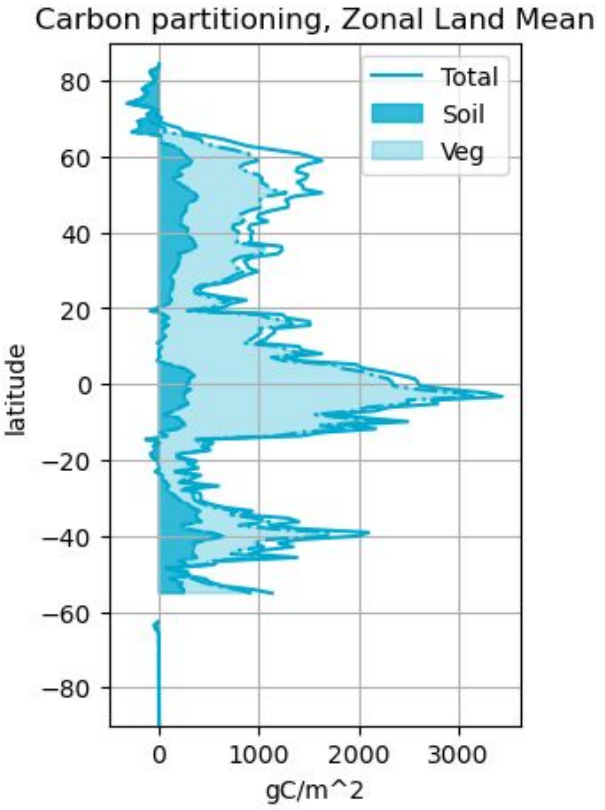
Ideas to expand notebook: multi-site comparisons, comparisons against CO_2 observations, regress hemispheric CO_2 contrast against emissions

Land notebook

Land Carbon:

- land_carbon_analysis.ipynb
- Global maps
- Global mean timeseries
- Regional mean timeseries
- Partitioning between pools
- Partitioning between fluxes



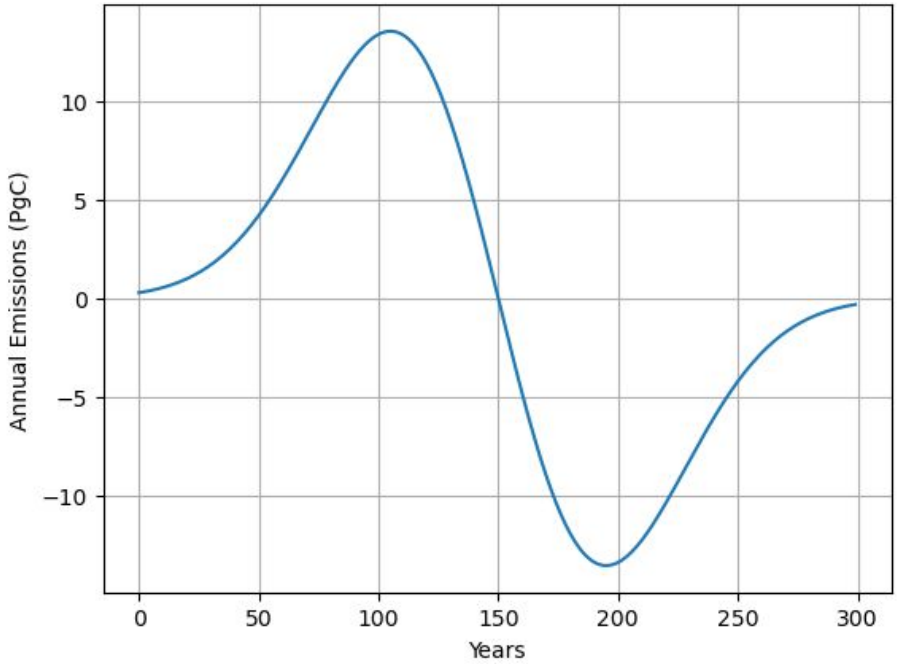


Custom Emissions Files

Make_idealized_edriven_scenario_forcing file.ipynb

It's possible to create your own emissions trajectory files to use in emissions-driven configuration

This notebook makes the emissions trajectory from Koven et al. 2023, but can be modified for making other emissions pathways



Proposed Analysis Ideas

- Effect of fire emissions variability vs. prescribed fire emissions
- CO_2 feedbacks
- Permafrost carbon behavior under low emissions scenarios and across ensemble members

Questions after you leave today?

=> discussCESM forum has a for emissions driven configurations!

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