Using a Data-assimilative Ocean Biogeochemistry Model (ECCO-Darwin) as a Novel Framework for Evaluating Carbon Mitigation Strategies, Outreach, and Policy

Abstract: SI14C-1553

Jet Propulsion Laboratory
California Institute of Technology

D. Carroll[1,2], D. Menemenlis[2], T. Van der Stocken[2], J. O. Niles[3], K. C. Cavanaugh[4], J. F. Adkins[5]

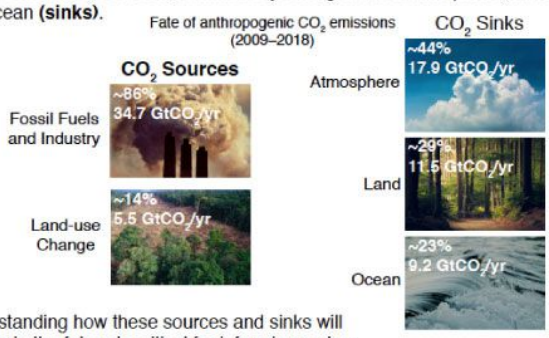
[1]Moss Landing Marine Laboratories, San José State University, [2]Jet Propulsion Laboratory, [3]The Carbon Institute, [4]University of California Los Angeles, [5]California Institute of Technology

dcarroll@mlml.calstate.edu

Model Output Available @ https://data.nas.nasa.gov/ecco

1. The Global Carbon Budget

The global carbon budget[1] determines the input of CO_2 by emissions from human activities **(sources)**, balanced by storage in the atmosphere, land, and ocean **(sinks)**.



Understanding how these sources and sinks will change in the future is critical for informing carbon mitigation strategies, policy, and public awareness.

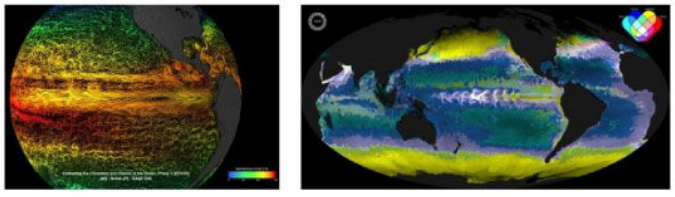
2. What is ECCO-Darwin?

ECCO-Darwin is a new global ocean biogeochemistry model that 1) assimilates observations, 2) has highly-realistic ocean ecology, and 3) provides improved estimates of the ocean CO_2 sink from 1992 to near-present.

ECCO-Darwin leverages interdisciplinary results from two well-established projects[2,3,4]:

Model Physics:
Estimating the Climate and Circulation of the Ocean (ECCO) Consortium

Model Ecosystem and Chemistry:
MIT Darwin Project



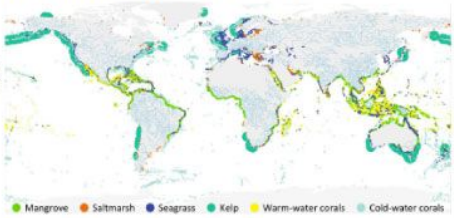
[LEFT] Snapshot of sea-surface temperature from the ECCO ocean state estimate. **[RIGHT]** The Darwin Project ecosystem model (35 phytoplankton species) driven by ECCO ocean circulation fields. This realistic, "survival of the fittest" ocean ecology is the basis of ECCO-Darwin, which uses a simplified ecosystem based on the most successful species in the above simulation.

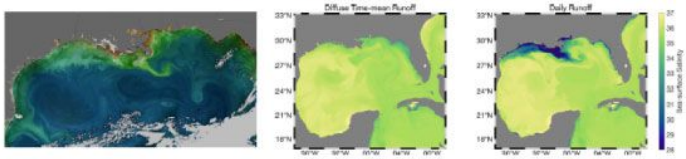
We are using ECCO-Darwin to: quantify the impact of terrestrial runoff and blue carbon on the ocean CO_2 sink, test various ocean carbon mitigation strategies at regional and global scales, and attribute long-term changes in the ocean CO_2 sink to their respective physical, chemical, and biological drivers.

3. Terrestrial Runoff and Blue Carbon

[RIGHT] Global distribution of major rivers and coastal ecosystems. Despite recognition of the importance of these systems in ocean CO_2 sequestration, their contribution to the coastal and open-ocean carbon cycle has not been previously been included in a global-ocean biogeochemistry model.

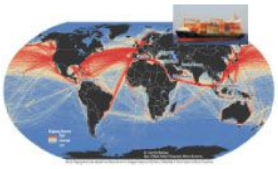
We are actively working towards representing realistic terrestrial runoff and blue carbon in ECCO-Darwin.





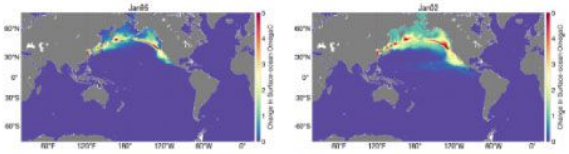
[LEFT] Gulf of Mexico image created from remote-sensing reflectance measurements taken from the NASA Visible Infrared Imaging Radiometer Suite (VIIRS). **[RIGHT]** Modeled sea-surface salinity downstream of the Mississippi with 1) climatological runoff and 2) daily localized runoff. Note similarity of river plume patterns in left panel with our improved simulation.

4. Geoengineering Applications



[RIGHT] In this century, humanity may need to find suitable reservoirs for storing trillions of tons of CO_2 emitted from fossil fuel combustion. Recent work[5] suggests that artificially increasing ocean alkalinity would allow for copious sequestration of atmospheric CO_2.

Given the frequency of ocean shipping and container transport, and that container ships are often traveling with excess capacity (~5–50% empty containers), we are working with the Adkins lab at Caltech to explore the mechanics, kinetics, logistics, and global-ocean impacts of reacting CO_2 and limestone along shipping lanes to alkalize the ocean and sequester anthropogenic CO_2.



[ABOVE] Using ECCO-Darwin to simulate geoengineered ocean alkalization along a shipping track from Los Angeles to Shanghai. Model results show the change in calcium carbonate saturation state (omegaC) for three and ten years of continuous input.

5. Ongoing ECCO-Darwin Development

- Realistic ocean acidification
- Daily terrestrial runoff
- Coastal blue carbon fluxes
- Under-ice biology
- Vertically-migrating zooplankton
- Global uncertainty analysis

[ABOVE] We are actively improving ECCO-Darwin's representation of land-to-ocean carbon fluxes at coastal, open-ocean, and global scales.

References: [1]Friedlingstein et al. 2019, [2]Forget et al. 2015, [3]Follows and Dutkiewicz, 2011, [4]Brix et al. 2015, [5]Renforth and Henderson, 2017