ENSO effects on the terrestrial carbon cycle on Tropics

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Outlines

- Introduction and motivations
- Model and data
- Model evaluations (by ILAMB)
- Results and discussions
- Conclusions

Introduction and motivations

The sea surface temperature (SST) in the central and eastern tropical Pacific Ocean irregularly departs from its expected value with warm and cold phases that are known as El Niño and La Niña respectively, together called the El Niño Southern Oscillation (ENSO).

- Important climate phenomenon and from the interactions between atmosphere and ocean in the tropical Pacific Ocean
- Modifications and changes of global weather pattern and climate regime
- Strong impacts on carbon cycle variations locally and globally

But Large uncertainties of ENSO impacts on terrestrial ecosystem and its responses to ENSO induced extremes

Surface CO_2 flux IAV

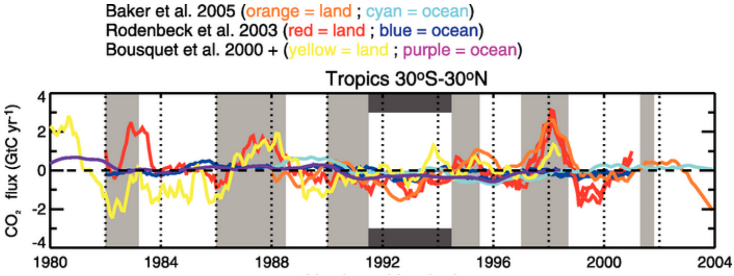


Figure: The interannual variability (IAV) of CO_2 fluxes (from IPCC Assessment Report 4)

- *the flux IAV at land is dominant and much larger than that at ocean*
- *the high positive/negative anomaly generally coincides with El Niño and La Niña events*

Observed CO_2 growth rate IAV

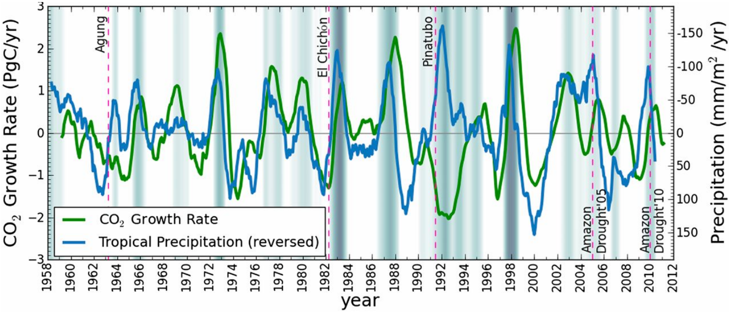


Figure: The IAV of CO_2 growth rate derived from observations in Mauna Loa. Courtesy of Wang et al. 2013 (PNAS)

Large positive CO_2 growth rates usually happened in El Niño events while negative growth rates were generally associated with La Niña events

Objectives

- **CO_2 responses to ENSO events**
- **Carbon sensitivity to ENSO events**

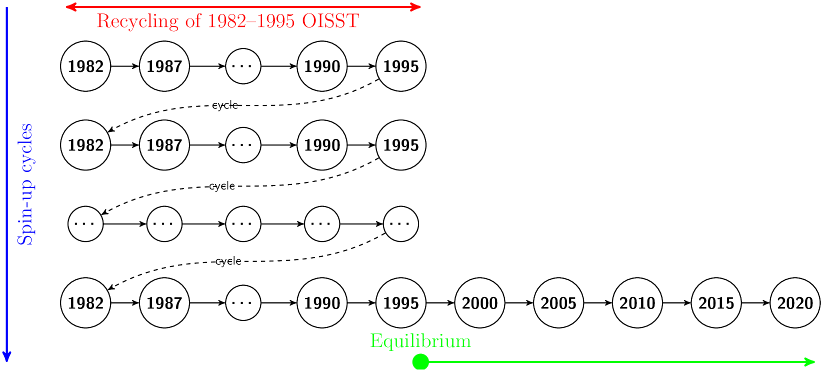
Model and data

- Energy Exascale Earth System Model version 0.3
- International Land Model Benchmarking version 2
- Data
    - NOAA surface flasks
    - NOAA CarbonTracker 2017

E3SM v0.3

- 1-degree (ne30np4) F-compset configuration:
  - active atmosphere model with spectral element dynamic core (CAM5-SE)
  - active land model with the biogeochemical model turned on
  - active CO_2 transport model with prognostic and prescribed CO_2 flux from the land model and data file respectively.
  - data ocean (DOCN)
  - thermodynamic sea ice (CICE)
- Data ocean reads NOAA Optimum Interpolation (OI) version 2 daily sea surface temperature (SST)
- Ice fractions are also provided by the OISST v2 product
- Future SST projections come from 9-month seasonal forecasts of the NOAA Climate Forecast System (CFSv2)
- Beyond CFS seasonal forecast period, SSTs and ice fractions are estimated from historical OISSTv2 data till 2020

Model spin-ups



We recycled OISST data from 1982 to 1995 to force the E3SM for **420** model years. Then we turned on the CO_2 transport model to let CO_2 disperse with wind for another **420** model years.

Experiments

We conducted multiple transitional simulations from year 1996 to 2020.

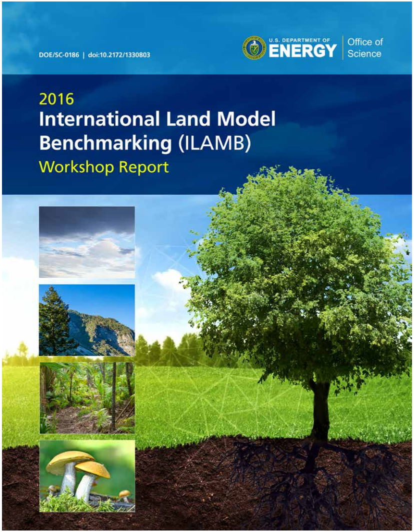
- **CTL**: Transitional runs forced by daily SST data from NOAA OISST v2 (six ensembles from different spin-up years)
- **NOVARGBL**: Same as CTL, except using a climatology daily SST averaged from 1982-2016
- **NOVARATL**: Same as CTL, except SSTs over the Atlantic Ocean from the above climatology daily SST

In this study, we only analyzed one of the members from CTL.

International land model benchmarking (ILAMB) v2

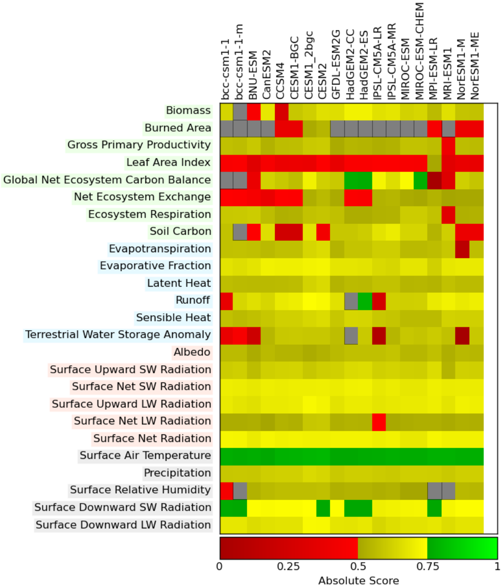
We used ILAMB to evaluate model overall performance.

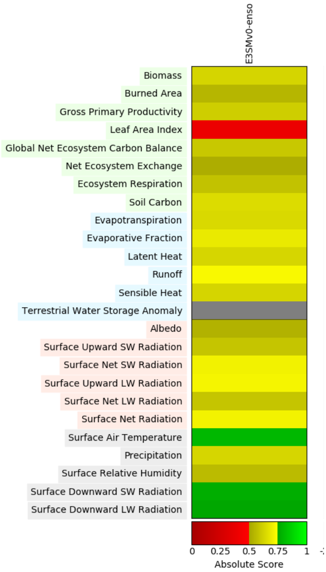
- comprehensive and systematic benchmarking system in evaluating performance of multiple land model
- written in python with strong flexibility and portability
- intuitive and hierarchical illustrations of analytic results using web pages



- ILAMB code repo: `https://bitbucket.org/ncollier/ilamb`
- Tutorial in AOGS on Thursday

Overall model performance





The CMIP5 results from `http://ilamb.ornl.gov/CMIP5/`

Cooperative Air Sampling Network

The NOAA's ESRL Carbon Cycle Greenhouse Gases (CCGG) Cooperative Air Sampling Network conducts regular discrete samples from its baseline observations, cooperative fix sites, and ships. It includes CO_2 observations from surface flasks at more than 95 sites all over the global.

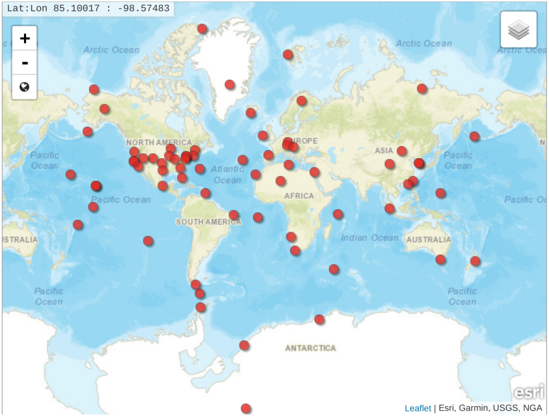


Figure: Map of the surface flask sites

Latitudinal variations of CO_2 seasonal amplitude and IAV

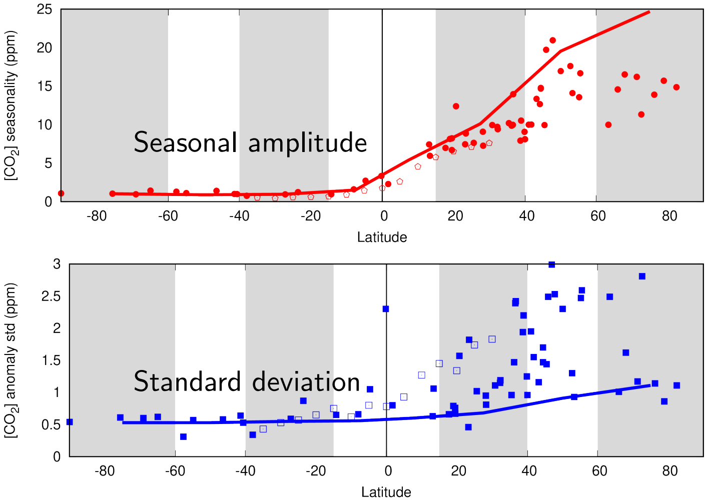


Figure: Seasonality and IAV of CO_2 concentrations from NOAA GMD Flask data and model outputs

Modeled and CarbonTracker CO_2 flux IAV

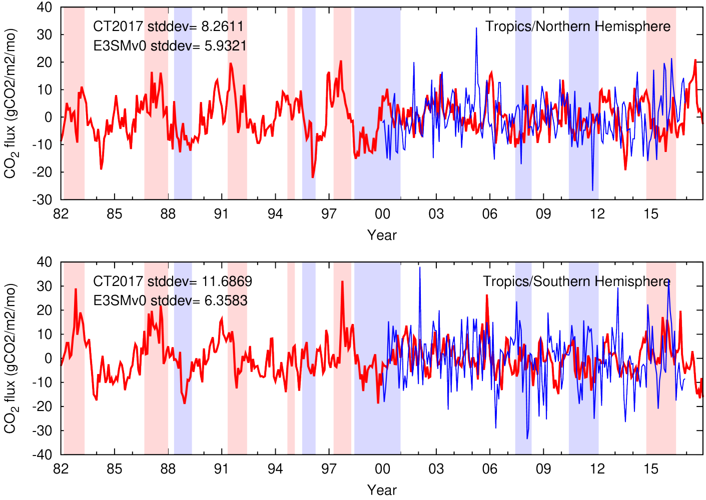


Figure: Modeled (red) and CT2016 (blue) interannual variability of CO_2 surface flux. Shaded red and blue areas show El Niño and La Niña years respectively

Modeled and observed CO_2 concentration IAV

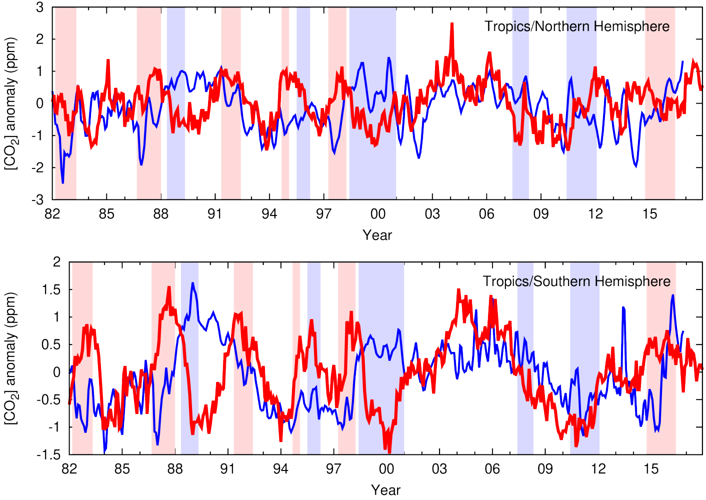


Figure: Modeled (red) and observed (blue) CO_2 concentrations anomalies. Shaded red and blue areas show El Niño and La Niña years respectively

Modeled and observed CO_2 growth rate IAV

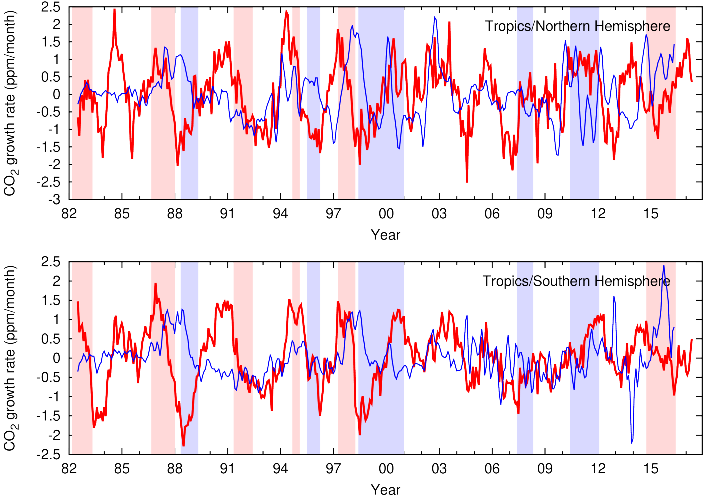


Figure: Modeled (red) and observed (blue) CO_2 growth rate anomalies. Shaded red and blue areas show El Niño and La Niña years respectively

CO_2 vs. Precipitation

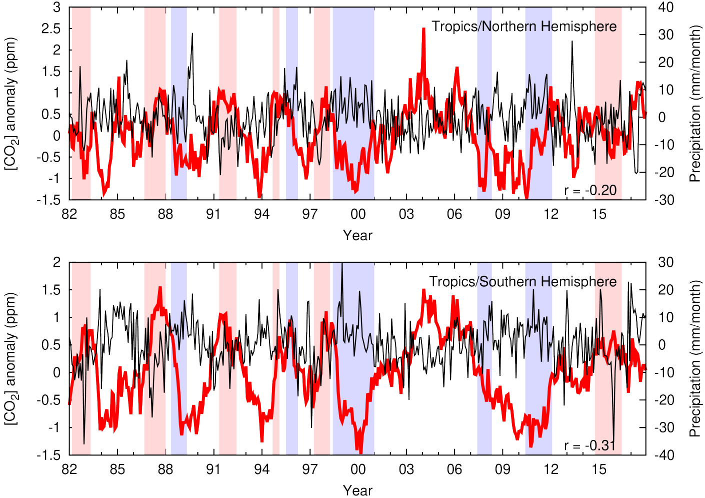


Figure: Modeled (red) CO_2 concentration and precipitation (black) anomalies. Shaded red and blue areas show El Niño and La Niña years respectively

CO_2 vs. Temperature

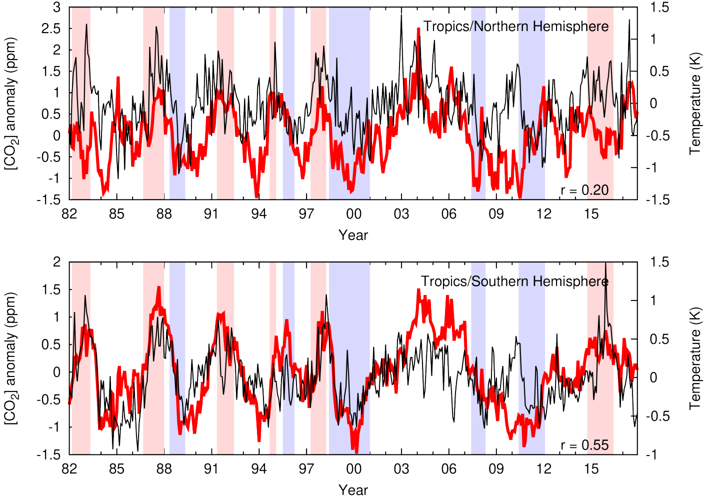


Figure: Modeled (red) CO_2 concentration and temperature (black) anomalies. Shaded red and blue areas show El Niño and La Niña years respectively

CO_2 seasonality change

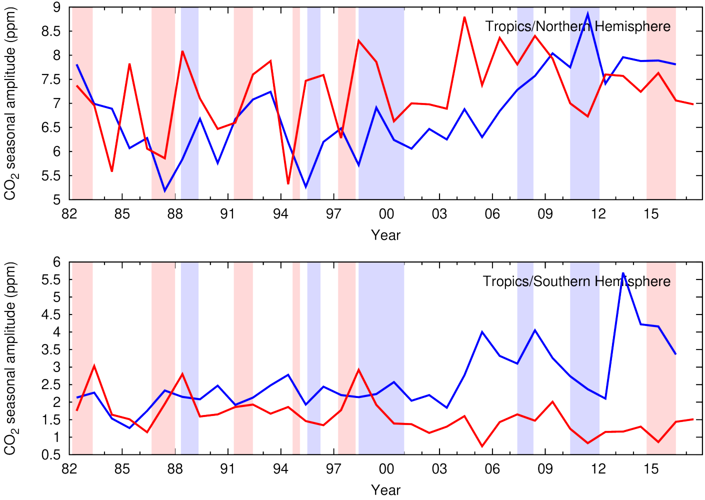


Figure: Modeled (red) and observed (blue) CO_2 annual amplitudes. Shaded red and blue areas show El Niño and La Niña years respectively

Conclusions

- Less CO_2 IAV and higher seasonal amplitudes compared with observations, especially in northern high latitude areas
- Less CO_2 flux IAV on tropics compared with CT2017 data
- Too sensitive to the climate variability caused by ENSO events
- The seasonal amplitude on the tropics of northern hemisphere increased with time

Acknowledgment

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Questions?