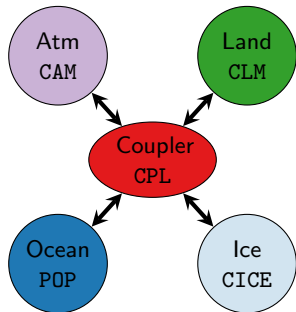
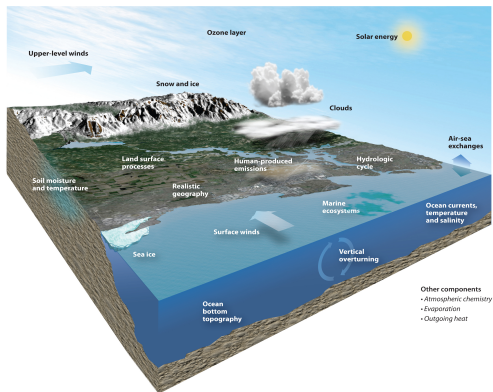


Goals of this talk

Introduce readily available modeling tools.

Prompt discussion about applying these for mission planning, data integration and interpretation.

Community Earth System Model (CESM)

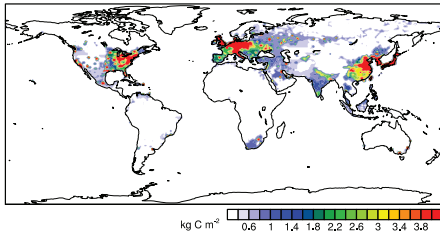


- ▶ Energy and mass conserving;
- ▶ Internal climate variability;
- ▶ External perturbations (i.e. CO₂ emissions);

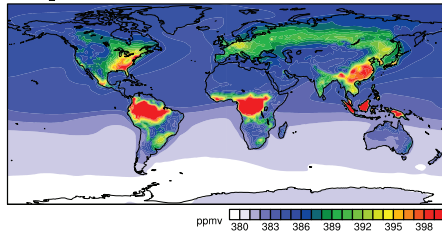
- ▶ Flexible coupling infrastructure.

Prognostic carbon cycle model

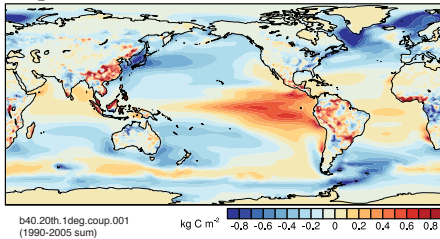
CO₂ emissions



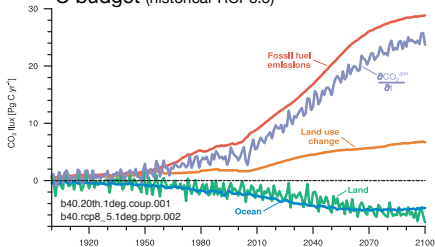
pCO₂ (surface)



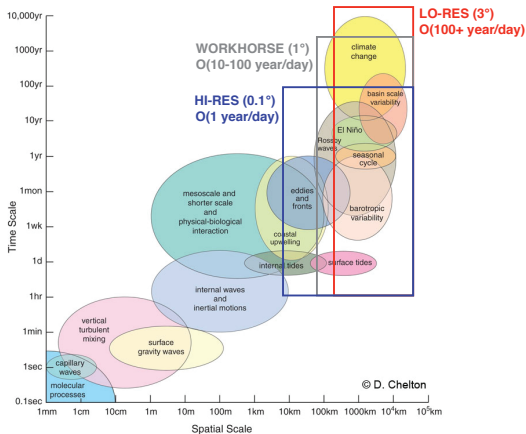
CO₂ flux



C budget (historical-RCP8.5)



CESM Ocean component: three standard resolutions



Workhorse model

Nominal 1° /60 vertical levels;

ETOPO2, smoothed;

Gent-McWilliams mesoscale
w/ diagnostic κ ;

Fox-Kemper et al. submesoscale
mixed-layer restratification;

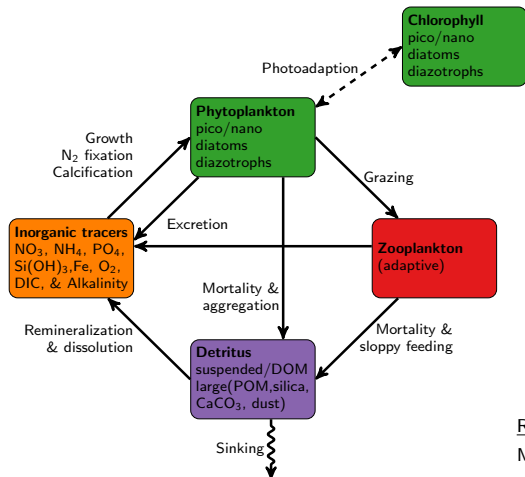
Gravity-driven overflow
parameterization;

Anisotropic horizontal viscosity;

K-profile Parameterization (KPP);

Active ecosystem w/ 4 PFTs,
full C chemistry.

CESM Biogeochemical Elemental Cycling Model (BEC)

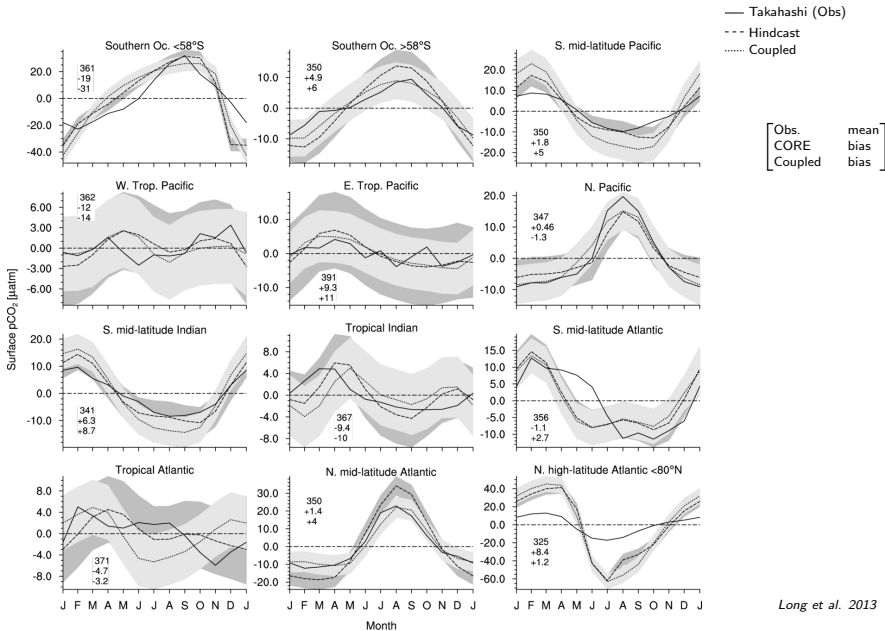


- ▶ 4 Plankton functional types
 - 3 autotrophs, 1 grazer
 - implicit calcifiers
 - explicit N fixers
- ▶ Nutrients: N, P, Si, Fe
- ▶ Fixed C:N:P stoichiometry
- ▶ Variable Fe:C, Si:C, & Chl:C
- ▶ Nonlinear carbon chemistry
- ▶ Atm. deposition: Fe & N
- ▶ Dynamic Fe cycle

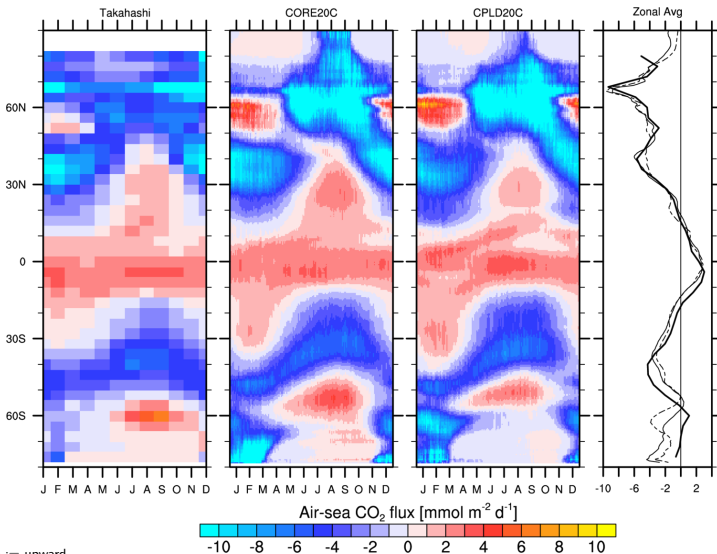
References:

- Moore et al., *Deep Sea Res.*, 2002.
- Moore, Doney, & Lindsay, *GBC*, 2004.
- Moore & Braucher, *Biogeosciences*, 2008.

Seasonal $p\text{CO}_2^{\text{ocn}}$ -cycle fairly well simulated



Zonal mean air-to-sea fluxes

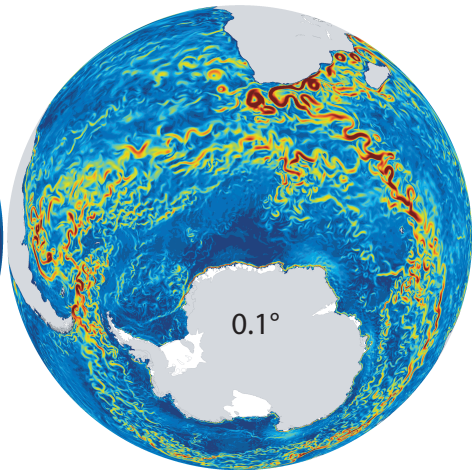
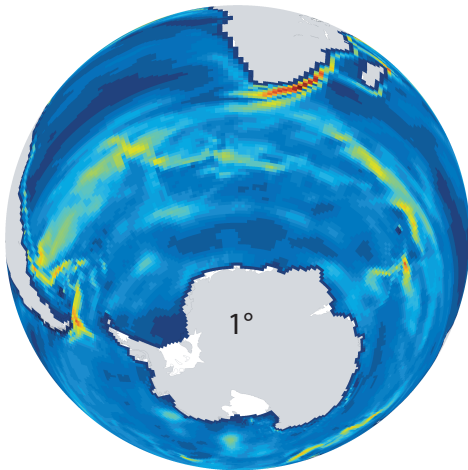


positive := upward

Long et al. 2013

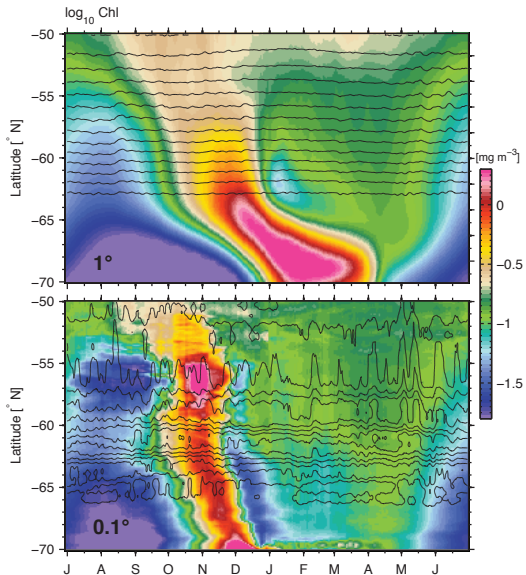
Sluggish versus energetic oceans

Kinetic energy



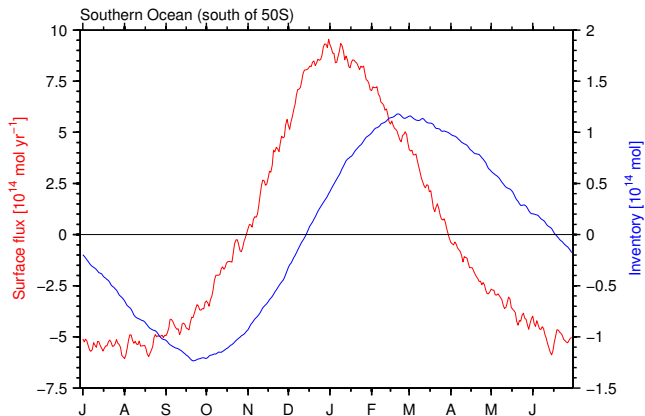
Hi-res/Lo-res differences: surface chlorophyll

Properties along 80°W



Relating atmospheric inventory to fluxes

Surface O₂ fluxes and atmospheric inventory

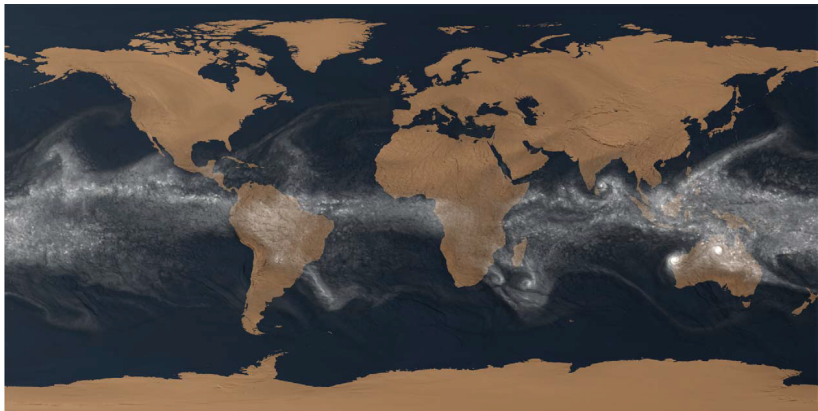


Synoptic scale variability → zonal mean picture

Surface O₂ anomaly

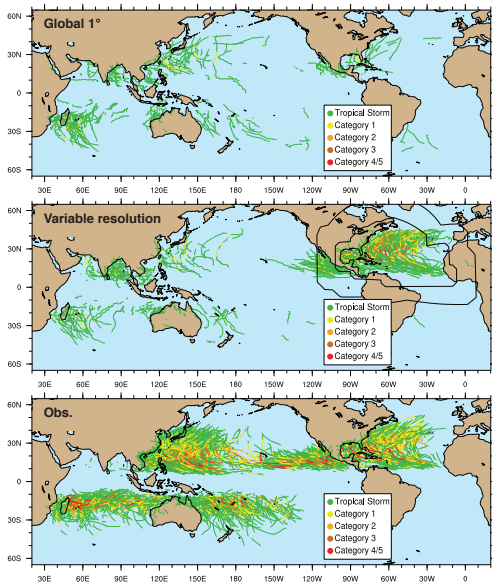
Community atmosphere model (CAM), Spectral Element

Precipitable water snapshot 0.125° CAM-SE

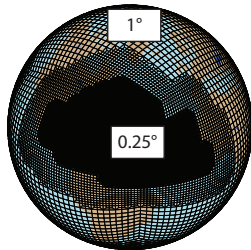
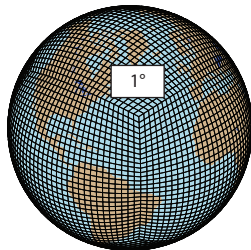


Dennis et al. 2012

CAM-SE native grid refinement capabilities



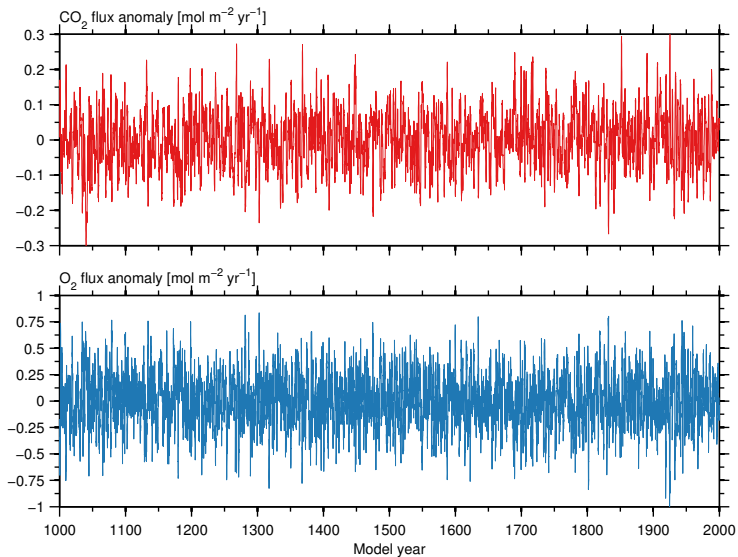
Zarzycki and Jablonowski, 2015



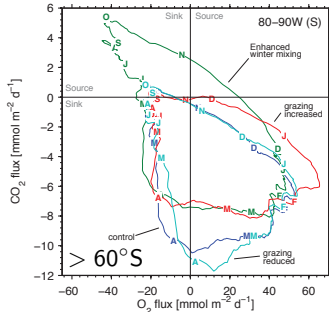
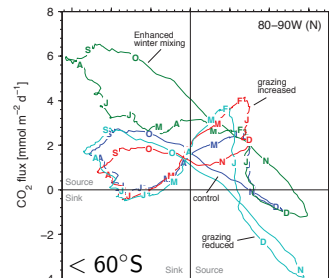
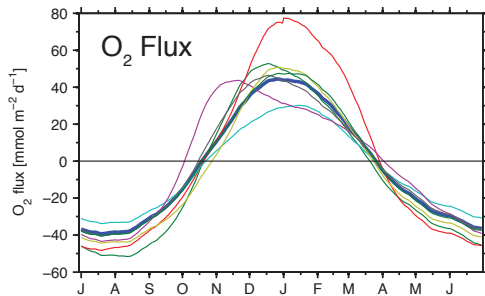
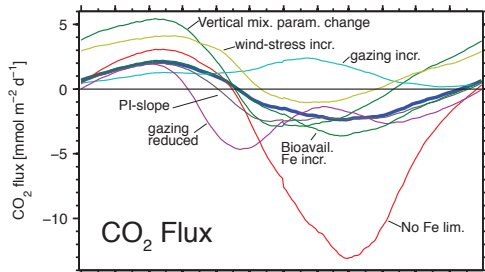
Zarzycki et al. 2015

2016 in context: Quantifying interannual variability

Southern Ocean monthly flux anomalies from CAM5 Control (12-mon running mean)

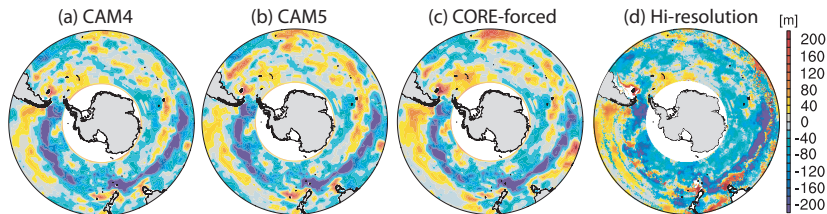


Hypothesis testing: distinct phenological signatures?



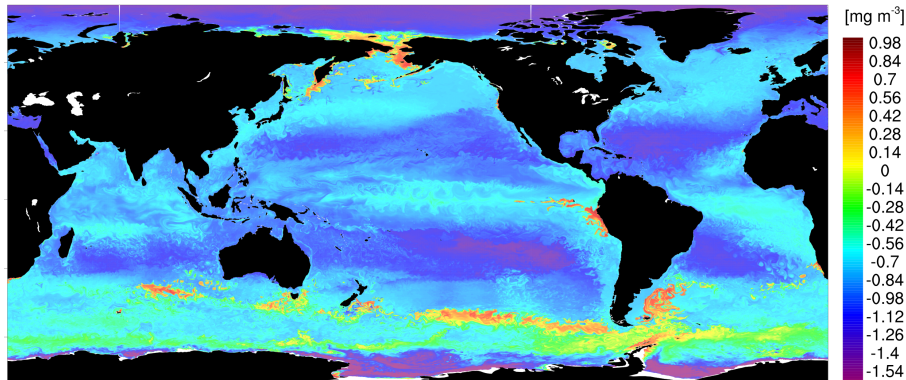
CESM mixed layer depth biases

September mixed layer depth biases



Ecosystem-enabled eddy-resolving integrations

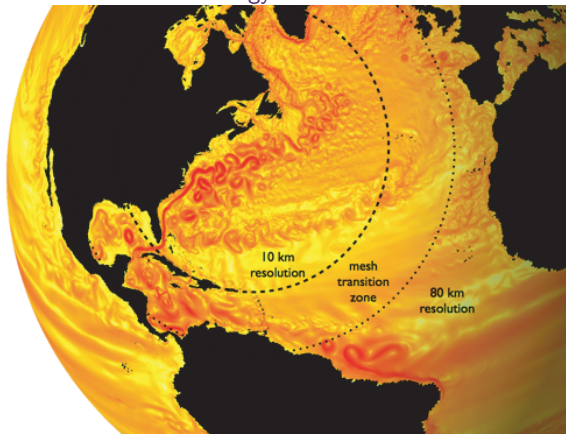
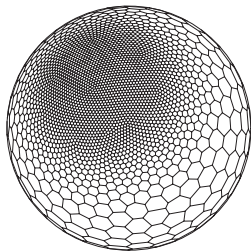
Surface $\log_{10}[\text{chlorophyll}]$ snapshot (daily mean)



MPAS-Ocean

Model for Prediction Across Scales

Surface kinetic energy

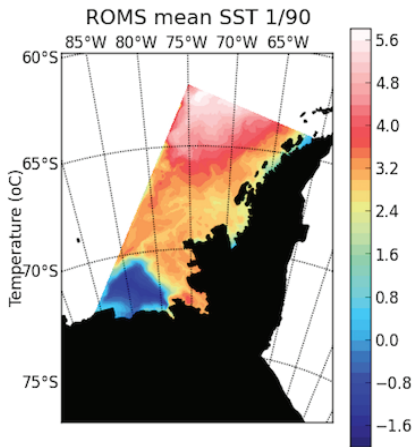


courtesy of T. Ringler

Western Antarctic Peninsula ROMS model

Model in development by Cristina Schultz; collaboration with Scott Doney.

- ▶ ETOPO1 bathymetry
- ▶ 2 km horizontal resolution
- ▶ 40 vertical layers
- ▶ 2 open boundaries



courtesy of C. Schultz