Ocean biogeochemistry and climate

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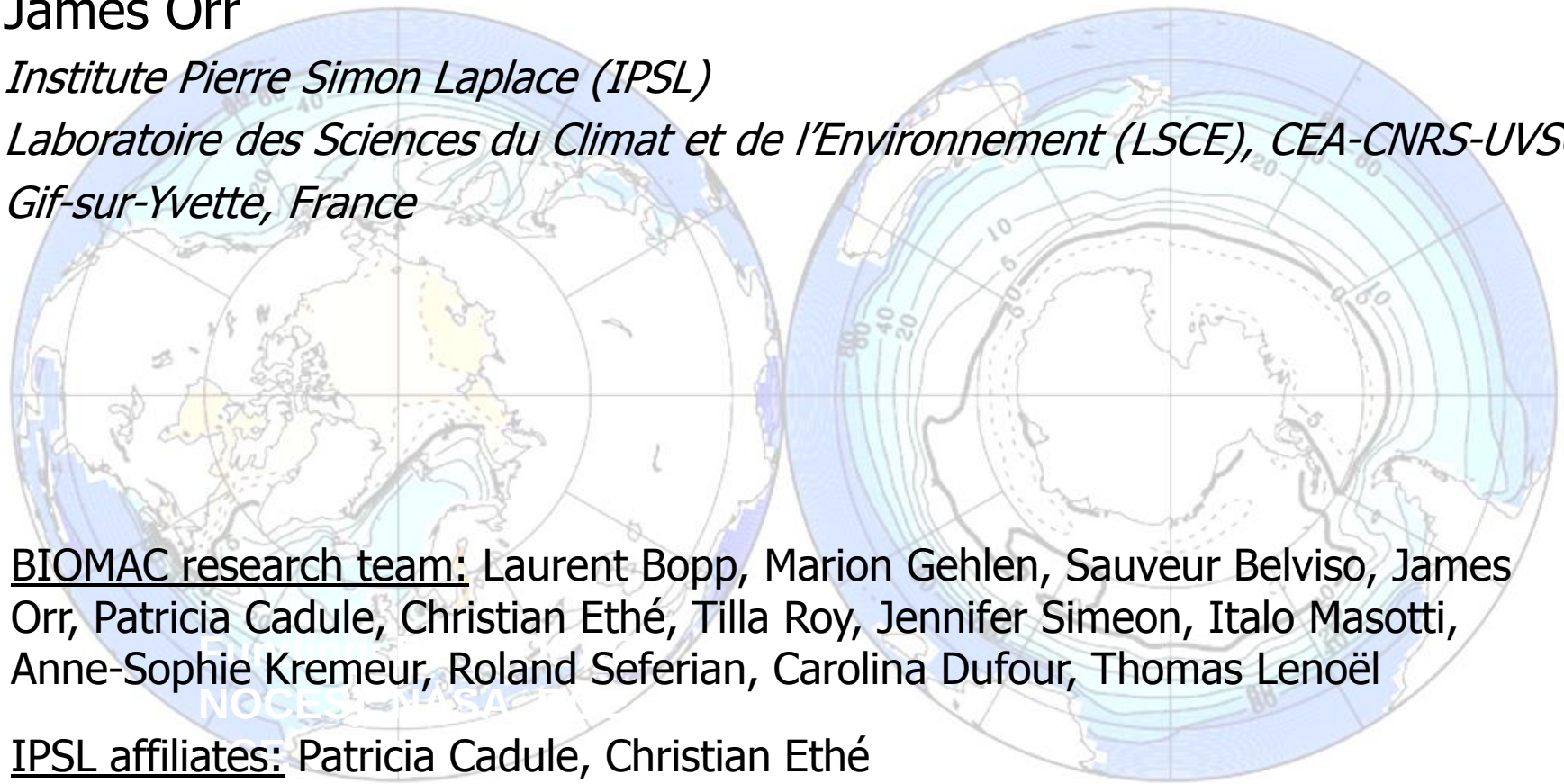


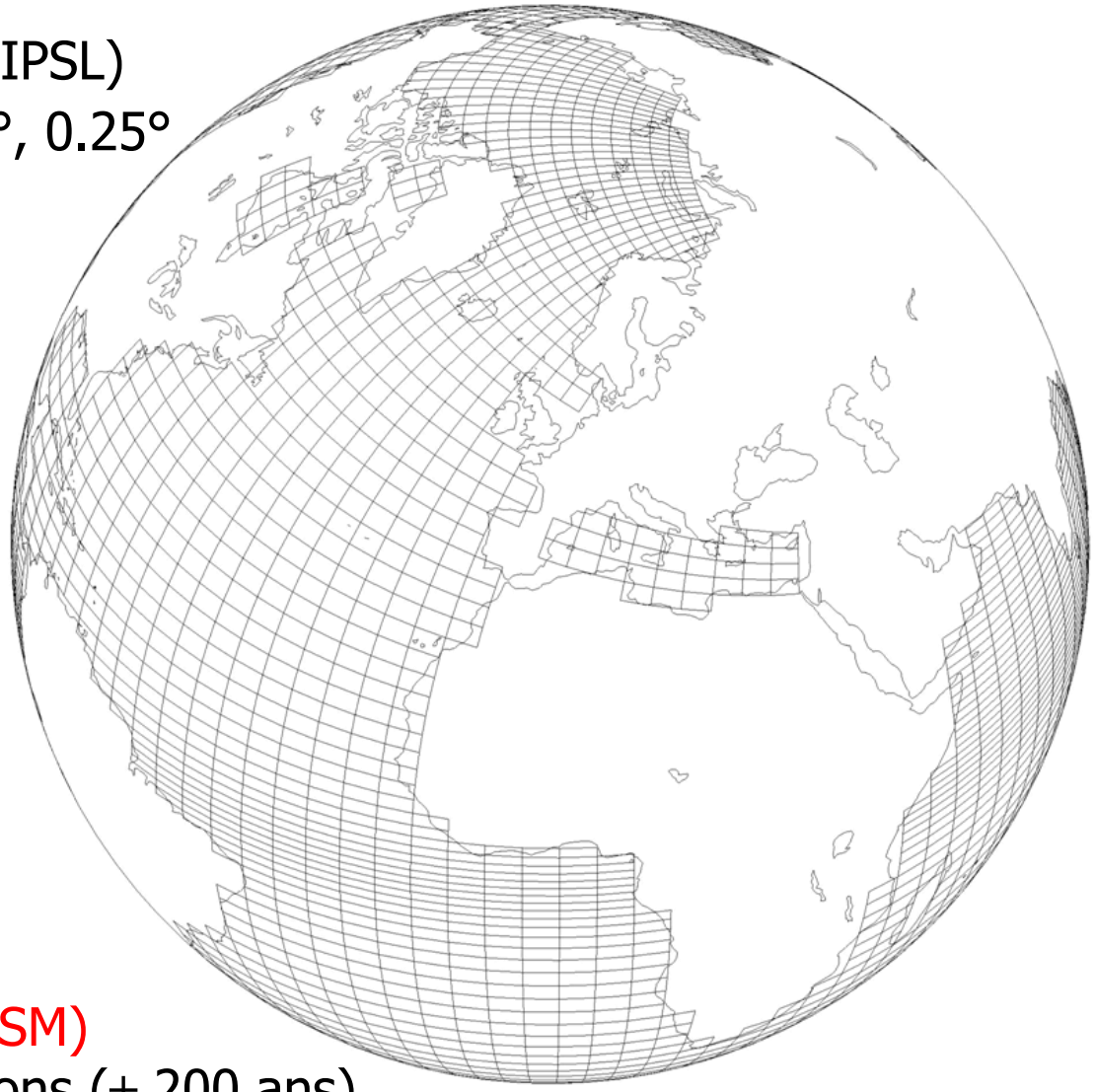
BIOMAC research team: Laurent Bopp, Marion Gehlen, Sauveur Belviso, James Orr, Patricia Cadule, Christian Ethé, Tilla Roy, Jennifer Simeon, Italo Masotti, Anne-Sophie Kremeur, Roland Seferian, Carolina Dufour, Thomas Lenoël

IPSL affiliates: Patricia Cadule, Christian Ethé

NEMO-OPA is ocean circulation component of IPSL-ESM

NEMO-OPA model (LOCEAN-IPSL)

- Global Resolutions: 2°, 0.5°, 0.25°
- Diff. Isopycnal diff. & GM
- TKE turbulent closure
- Ice model - LIM



Forced mode

- LGM
- Preindustrial state
- Industrial perturbation
- Variability
- Future change

Coupled mode (within IPSL ESM)

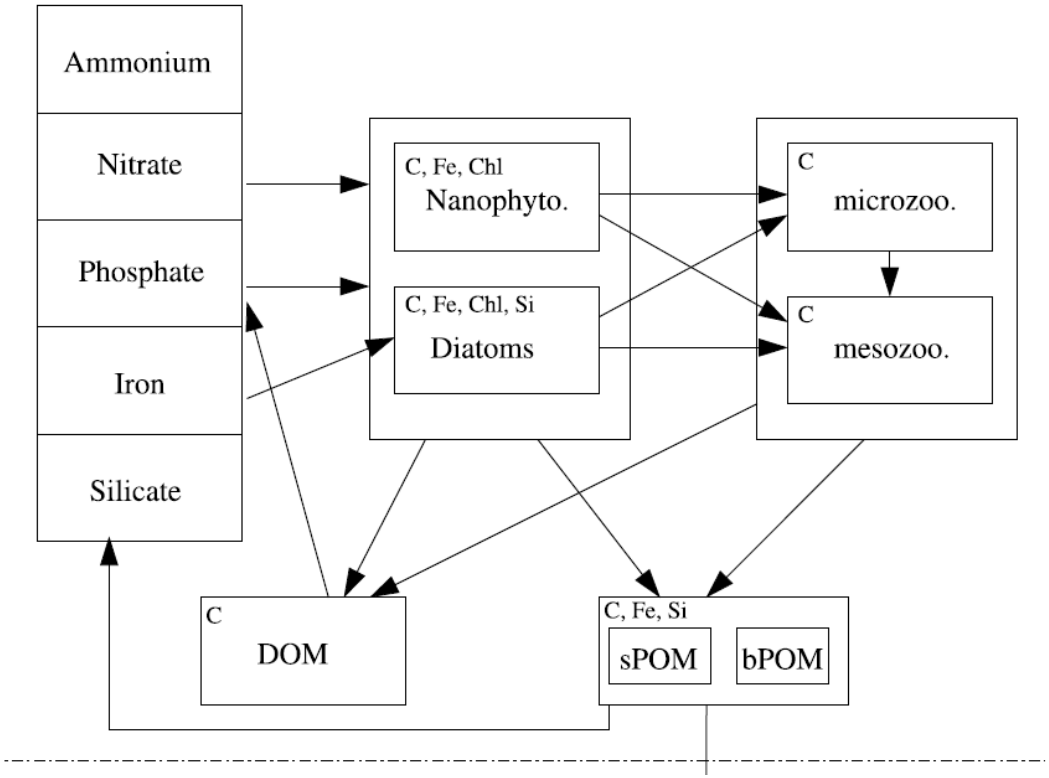
➔ for industrial-era simulations (± 200 ans), IPCC AR5 simulations, etc.

http://www.nemo-ocean.eu

Madec (2008)

PISCES is our *workhorse* ocean biogeochemical model

- 5 nutrients:
  NH_4, NO_3, PO_4, Fe, Si
- Nutrient sources:
  Rivers (all)
  Atmosphere (Fe, Si, P, N)
  Sediment (Fe)
- 2 Phytoplankton, 2 Zooplankton:
  Diatoms / Nano-Pico
  Micro / Meso Zoo
- Constant C:N:P ratios
  Variable Si:Fe:Chl:C ratios
- N-fixation & Denitrification
- Semi-labile DOC; 2 types of organic particles (3 m d^{-1} & 50-200 m d^{-1})
- O_2, DIC, Alkalinity, & Calcite production



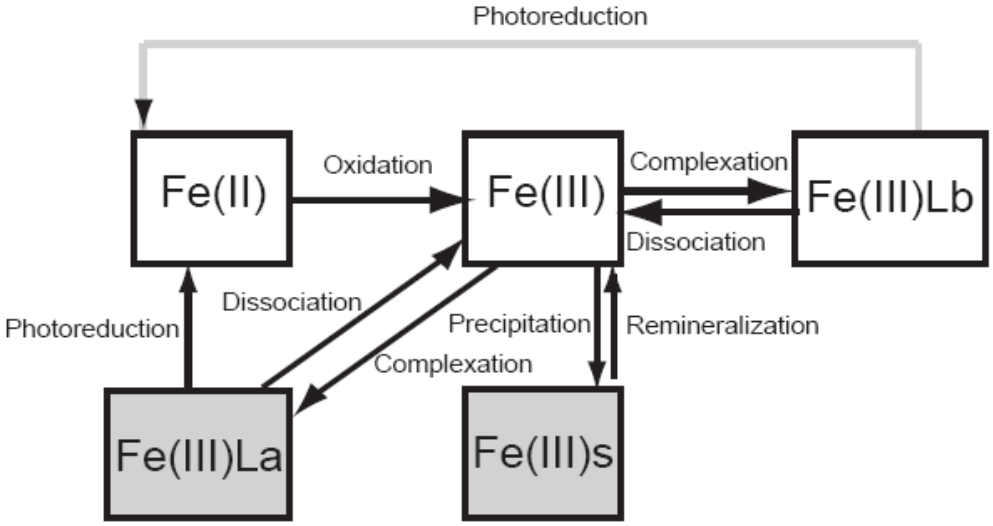
*part of NEMO-TOP

Aumont & Bopp (2006, GBC)

PISCES = Pelagic Interactions Scheme for Carbon and Ecosystem Studies

PISCES also includes non-standard enhancements

- Climate-relevant gases DMS, N_2O, & CH_4 (Bopp et al. 2008, Dutreuil et al. 2009)
- Calcite and Aragonite production (Gangsto et al. 2008)
- Particle dynamics: 2 size classes, size spectrum, or ballast (Gehlen et al. 2007)
- Iron Chemistry (Fe^{2+}, Fe^{3+}, FeL, …) (Tagliabue et al. 2009)



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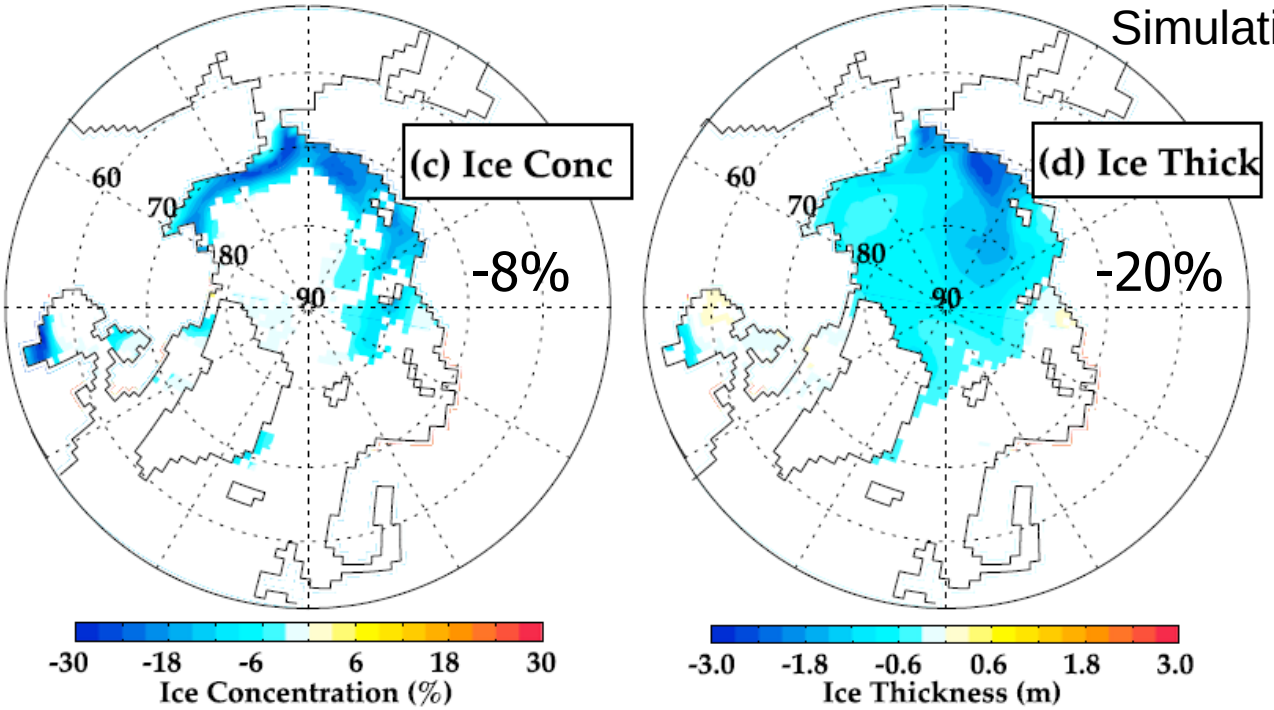
- Calcite and Aragonite production (Gangsto et al. 2008)
- Particle dynamics: 2 size classes vs. size spectrum vs. ballast (Gehlen et al. 2007)
- Iron Chemistry (Fe^{2+}, Fe^{3+}, FeL, …) (Tagliabue et al. 2009)
- Sediment model (from Heinze et al.) (Gehlen et al. 2007)
- Paleoproxies: $\delta^{13}C$, Pa/Th, Nd (Tagliabue et al. 2008, Dutay et al. 2009, Arsouze et al. 2009)
- Adjoint version with optimized parameters (Kane et al. sub)

Biophysical coupling = less sea ice



Simulations (Bio – NoBio)

- Warmer surface
- Colder subsurface
- Less saline
- Less seaice

Now in standard NEMO model (SeaWiFS or simulated Chl)

Tropics - Lengaigne et al. (2007, Climate Dynamics)
High latitudes - Lengaigne et al. (2009, GRL)

LSCE hosts an EU archive of ESMs

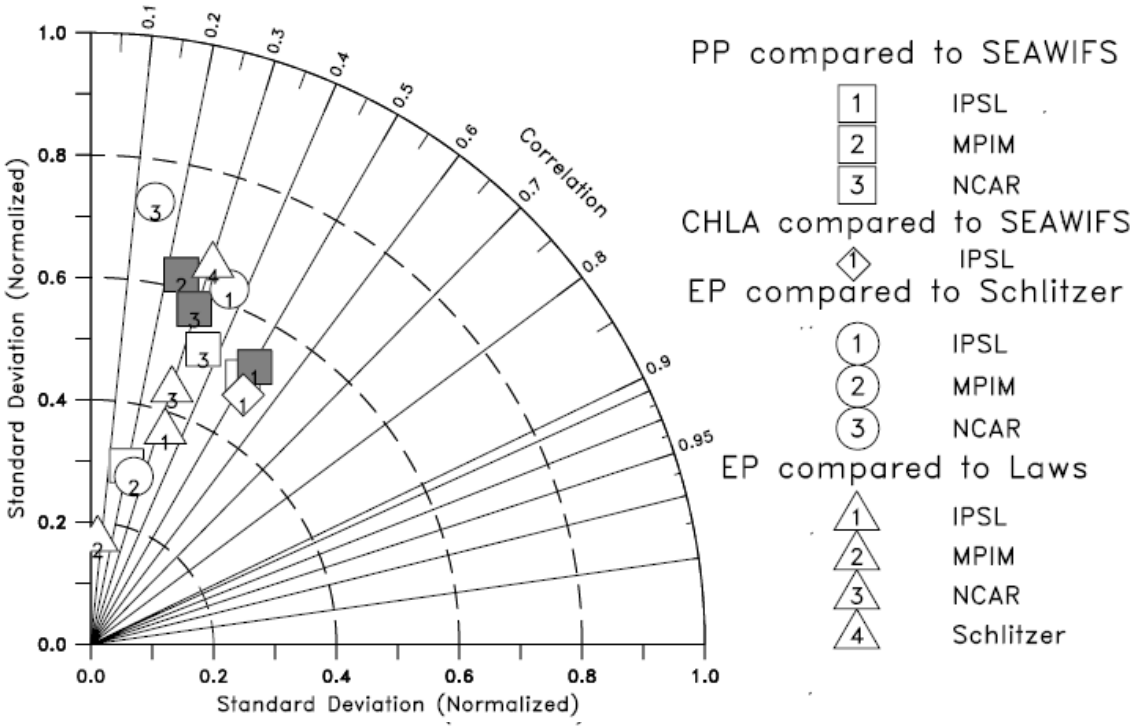
- 6 Earth System models
  - BCCR, Bergen
  - IPSL-CM4-LOOP (LSCE, Paris)
  - COSMOS (MPIM, Hamburg)
  - NCAR CSM1.4 (UNIBE, Bern)
  - NCAR CCSM3 (UNIBE, Bern)
  - UVIC (IFM-GEOMAR, Kiel)

- Standard output (OCMIP-4 guidelines)
  - netCDF files, CF convention (consistent file & variable names)
  - Hydrographic and BGC variables & fluxes (T, S, C_T, A_T, O_2, NO_3^-, …)
  - Annual (1860-2100) & Monthly means (1860-1869, 1980-2009, 2090-2099)

- EU funded activity since 2006 …
  - More models, simulations, variables

- Available on DODS server; precurser for IPCC AR5 (CMIP5)

Archive permits consistent skill assessment across ESMs

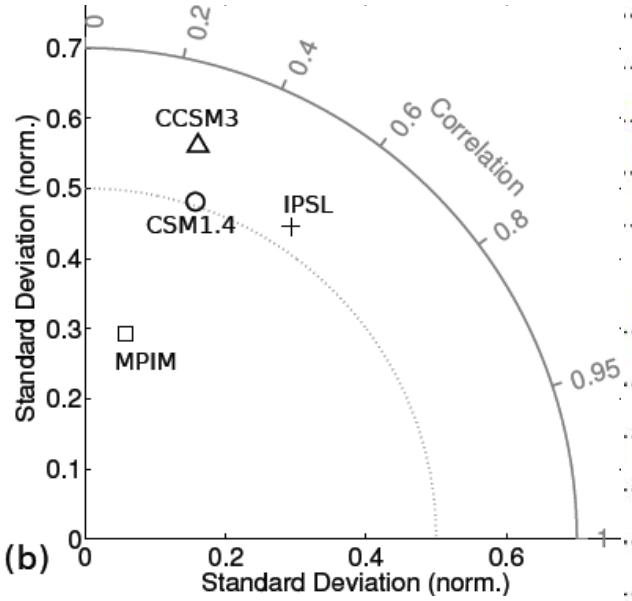


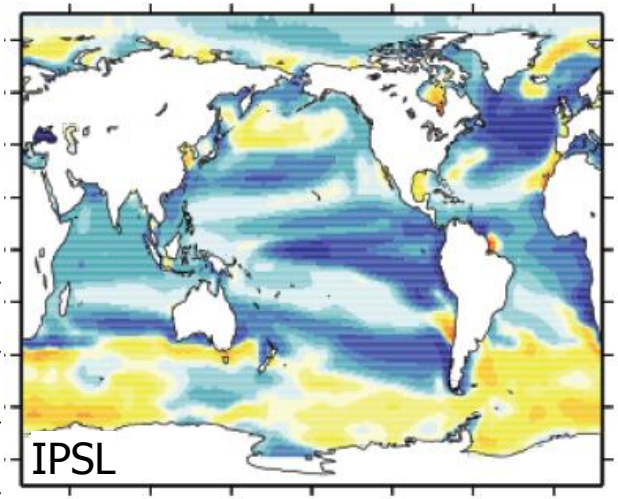
Schneider et al. (2008, Biogeosciences)

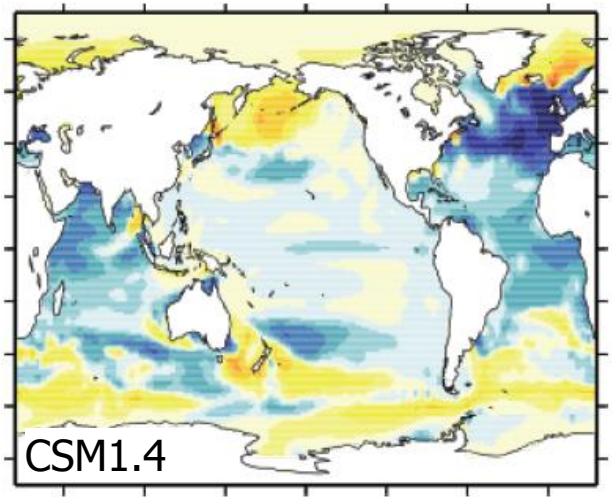
… and allows comparison of future projections

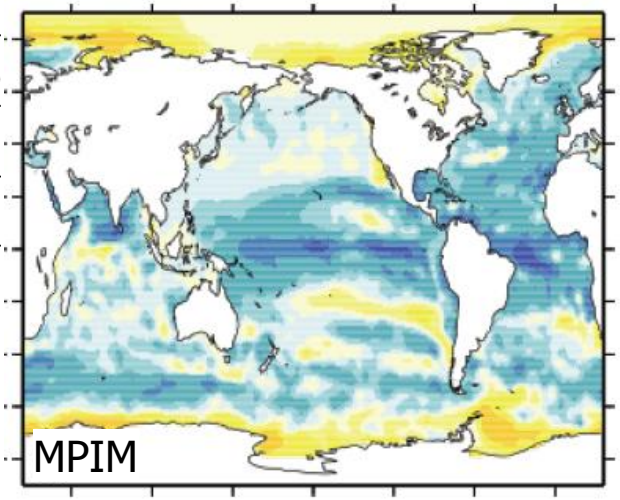
Changes in PP in 2100 (SRES-A2 scenario)

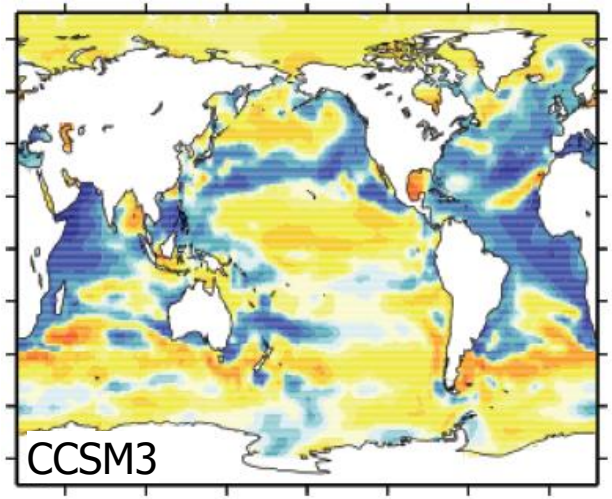
Modern PP vs. SeaWiFS

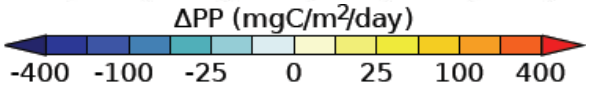








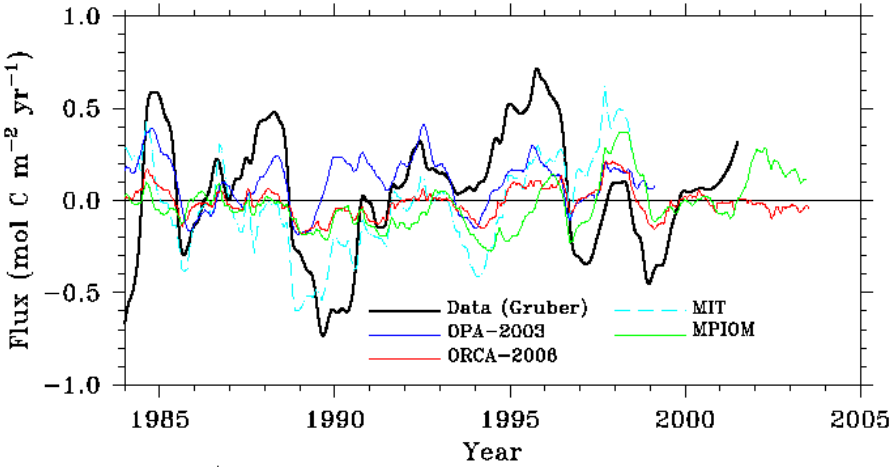


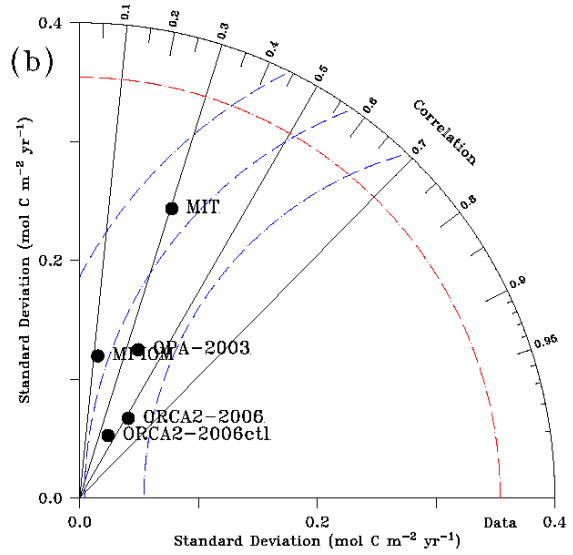


Steinacher et al. (2009, Biogeosciences)

Long interest in ocean carbon cycle, e.g., interannual variability

Raynaud et al., 2006 (Ocean Science, 2, 43-60)

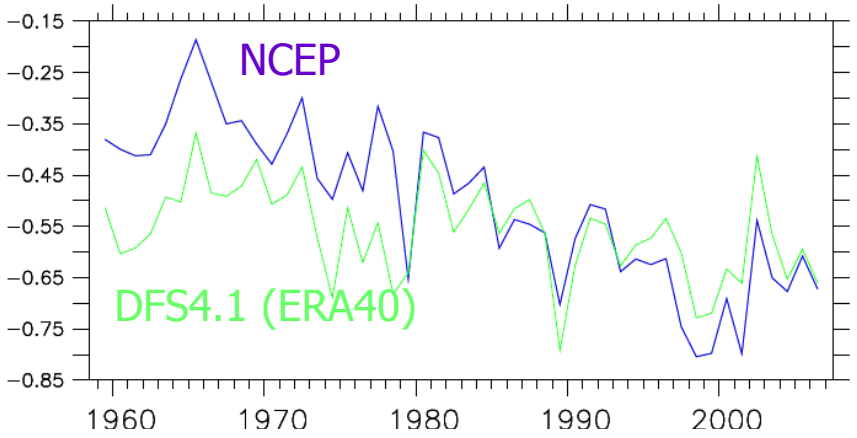




Now studying effects of

- Resolution (2°, 0.5°, 0.25°)
- Forcing (NCEP vs. ERA40)

Natural air-sea CO2 flux (Pg C yr^{-1})



New efforts focused on

- High-resolution regional modeling (Southern Ocean, Mediterranean Sea)
- Optimizing ocean BGC model parameters with assimilation of *in situ* data
- Phytoplankton Physiology: decoupling C:N:P
- “Dead Matter”: DOC lability / age, particles: size spectrum & ballast & remin.
- Higher trophic levels: PISCES & APECOSM (Maury 2008)