Chemical and biological studies using the OFES

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Biogeochemical Simulation using the OFES

- **Chemical Tracer**
  - Climatological forcing simulation (1950-1997):
    - CFC-11 (3 day snapshot, monthly, annual)

- **Marine Ecosystem**
  - Nitrate, Phytoplankton, Zooplankton, Detritus

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Chemical Tracer Simulation

- $F_c = K(\alpha p_{CFC_{air}} - C_{FC_{sea}})$
  - $F_c$: Air-sea CFC flux
  - $K$: Piston velocity
  - $\alpha$: Solubility of CFC at sea surface
  - $p_{CFC_{air}}$: partial pressure of atmospheric CFCs
  - $C_{FC_{sea}}$: simulated sea surface CFCs

Time history of atmospheric CFC-11 and CFC-12 concentrations (From Walker et al., 2000)
- **Biological Model** *(Oschiles, 2001)*
  - Nitrogen based Nitrate, Phytoplankton, Zooplankton, Detritus (NPZD) pelagic ecosystem model
  
  \[ C(t) = \text{advection} + \text{diffusion} + \text{sms} \ (C) \]
  
  \( C \): Biological tracer
Chemical Tracer Simulation

- Southern Ocean:
  - To investigate the spreading and pathways of AABW (*Sasai et al.*, 2004; 2005)

- North Pacific Ocean:
  - To investigate the ventilation processes
Marine Ecosystem Simulation

- **North Pacific Ocean:**
  - To simulate the seasonal variability and to investigate physical influences on the marine biology (Sasai et al., 2006 submitted)

- **Eastern Tropical Pacific Ocean:**
  - To investigate the response of marine ecosystem to coastal upwelling with the strong wind jets -> OSM2006 Talk!
The eastern Tropical Pacific Ocean is one of the most complex oceanic regimes in terms of the variability of physical processes. Numerous eddies are generated as seasonal winds in the Gulf of Mexico, and trade winds from the Caribbean Sea are funneled through narrow mountains in the Central America. Distinct eddy generation regions off the Central America are the Gulf of Tehuantepec, the Gulf of Papagayo, and the Gulf of Panama. A large cyclonic eddy called the Costa Rica Dome in the thermocline is centered 9N, 90W off the Gulf of Papagayo and is 300 – 500 km in diameter [Crowell, 1958; Fiedler, 2002].
The generated eddies are characterized by the low temperature relative to surrounding waters and also by high chl-a concentration.

Satellite images provide insight on the dynamics phytoplankton pigment distributions associated with eddies due to strong wind jets [Müller-Karger and Fuentes-Yaco, 2000, McClain et al., 2002; Gouzalez-Silvera et al., 2004].

Objectives

- To simulate the seasonal variability of marine biology in the upper ocean using an eddy-resolving (about 10 km) OGCM
- To investigate the response of marine ecosystem to coastal wind jets in the eastern tropical Pacific Ocean
Case-C
The distribution of simulated surface chl-a concentration (ratio of 1.59g chl-a per mol nitrogen) is consistent with the Satellite Image. -> High spatial resolution satellite wind data such as QuikSCAT is necessary to investigate the influence of meso-scale phenomena to the coastal ecosystem.
Comparison with Satellite Images

Simulated surface chl-a distributions are clearly reproduced to Satellite Images. High chl-a concentration regions are shown:
- Gulf of Tehuantepec, Gulf of Papagayo, and Gulf of Panama (March)
- Costa Rica Dome off the Gulf of Papagayo (September)
Seasonal variability of simulated SST, nitrate, and surface chl-a concentrations

High chl-a concentration regions:

- **March**
  - By coastal upwelling due to the strong wind jets, low SST and high nitrate in the Gulf of Tehuantepec, the Gulf of Papagayo, and the Gulf of Panama

- **June**
  - Off the Gulf of Papagayo, the Costa Rica Dome is separated from the coast

- **September**
  - The dome expands to the west as the countercurrent (NECC)

- **December**
  - The dome extends east and west, and thermocline is deepen.

- Shallow thermocline regions: High nitrate waters are lifted to the surface layer.
Off the Gulf of Papagayo, low SST (<25.5°C) and high nitrate (>30 mmol m⁻³) waters by the coastal upwelling are shown in March.

Low SST and high nitrate waters move to the west in June-September.

High Chl-a waters (>1.0 mg m⁻³) are generated associated with the cyclonic eddies and coastal upwelling, which bring high nutrient waters from the subsurface to surface.
Longitude-time sections: (a) SeaWiFS, (b) simulated chl-a concentration

- **March:** Spring bloom occurs along the coast due to the coastal upwelling.
- **June-September:** High chl-a is shown in the Costa Rica Dome along 90W.
Conclusion

- We investigated the response of marine ecosystem to the coastal winds over the eastern Tropical Pacific Ocean.
- Using a global eddy-resolving coupled physical-biological model, it is possible to capture the effects of relevant physical dynamics from coastal to open ocean scale (e.g., Costa Rica Dome).
- High resolution satellite wind data such as QuikSCAT is necessary to investigate the influence of meso-scale phenomena (e.g., coastal upwelling, eddies) to the coastal ecosystem.
- Seasonal variability of surface chl-a is caused by the supply of high nutrient waters from lower to upper layer with the cyclonic eddies and upwelling driven by the coastal wind jets.