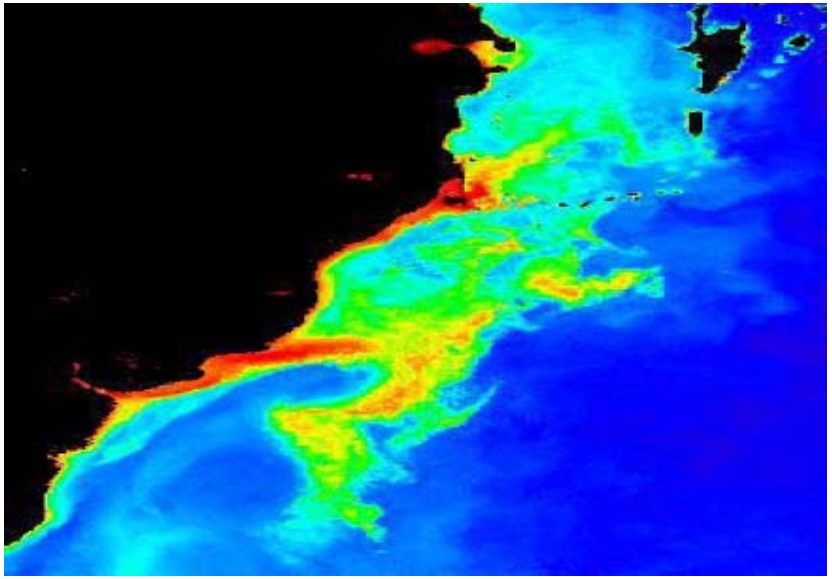
Week 7

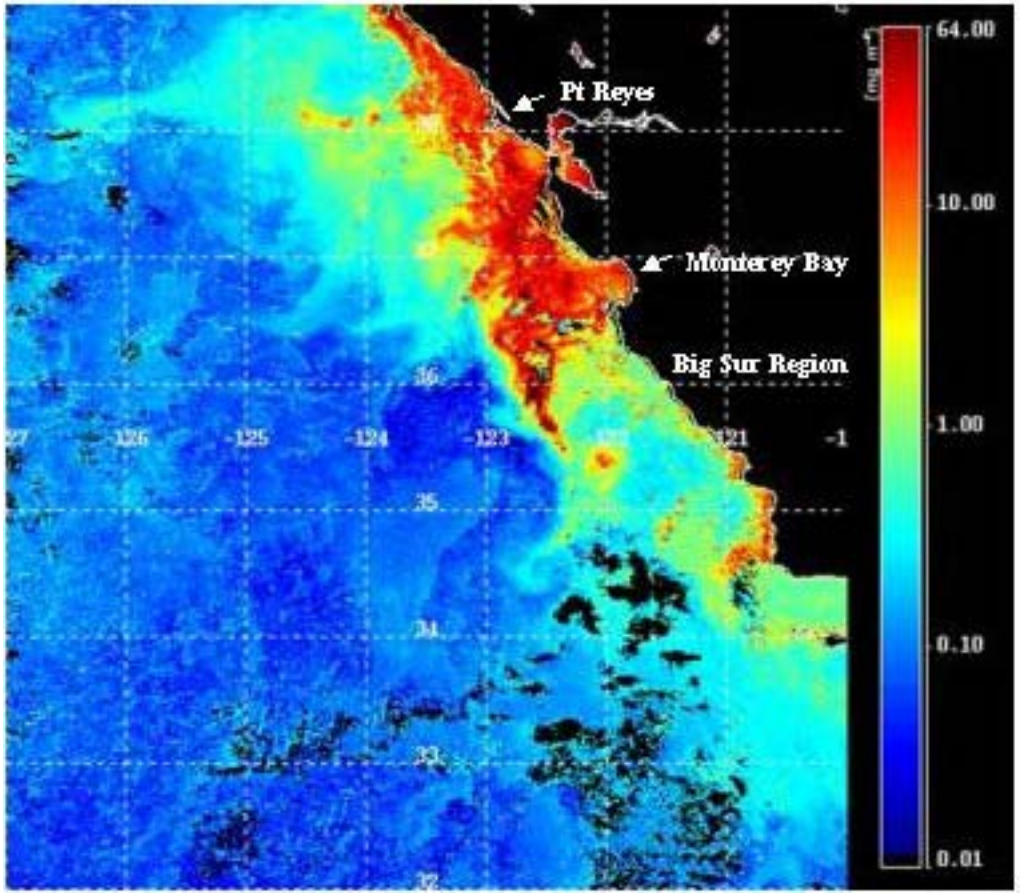
Continental Margin Exchanges

Why worrying about continental margins?

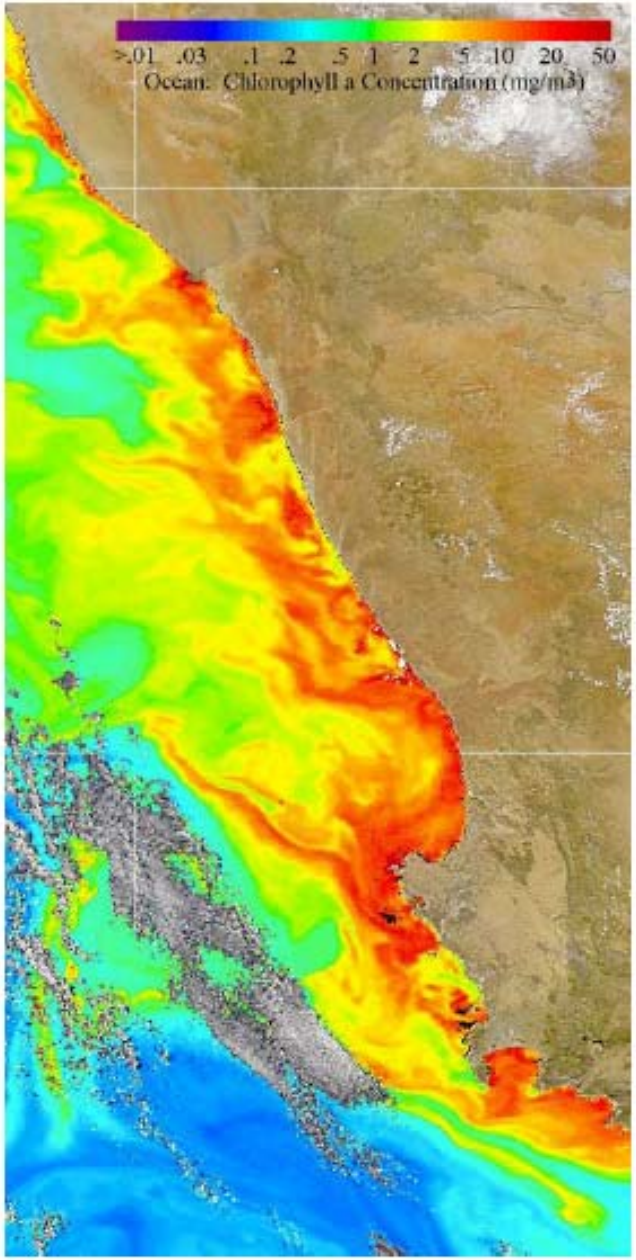
- They occupy 7% of the ocean surface (defined as regions where the water column is 200m or shallower) and 0.5% of the ocean volume
- ~80-90% of new production, 14% of total production and ~50% of denitrification takes place in the ocean margins
- They contain ~ 80% of the organic carbon from oceanic and land processes and 50% of global carbonate deposition



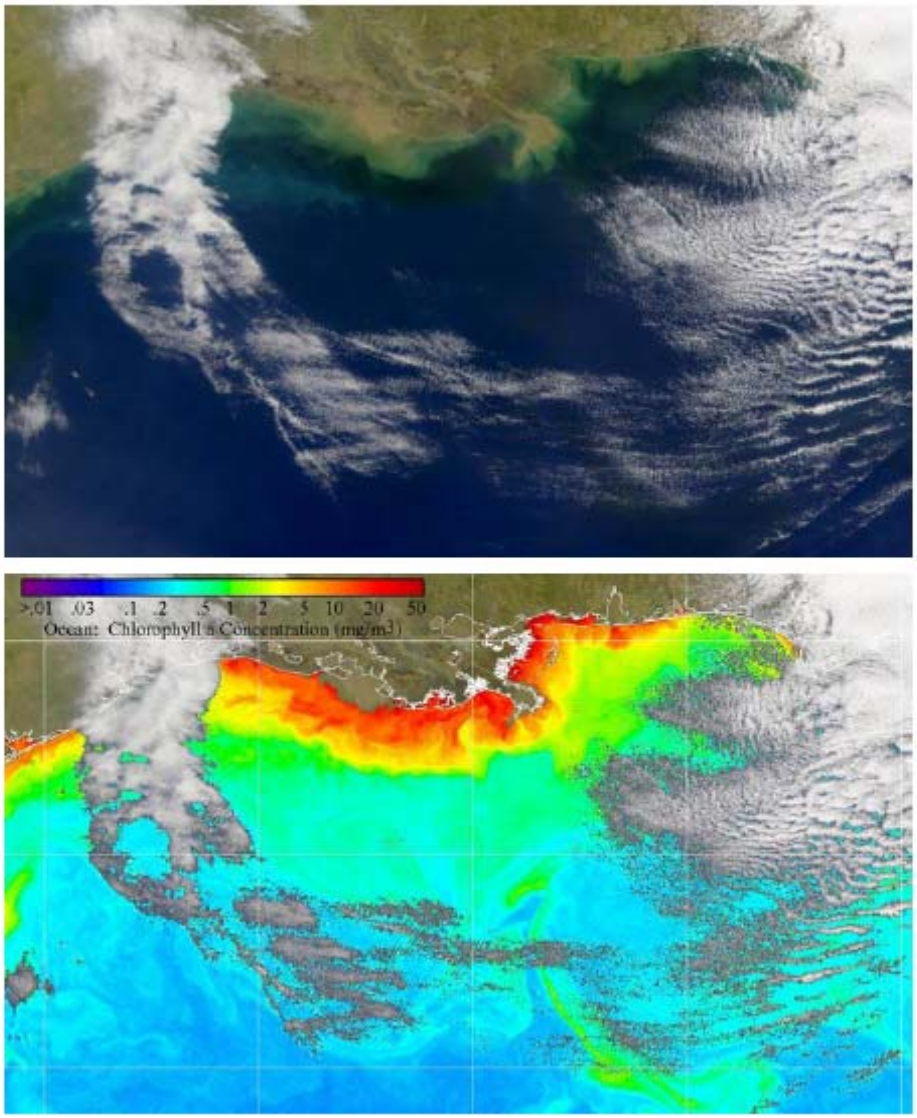
Amazon River



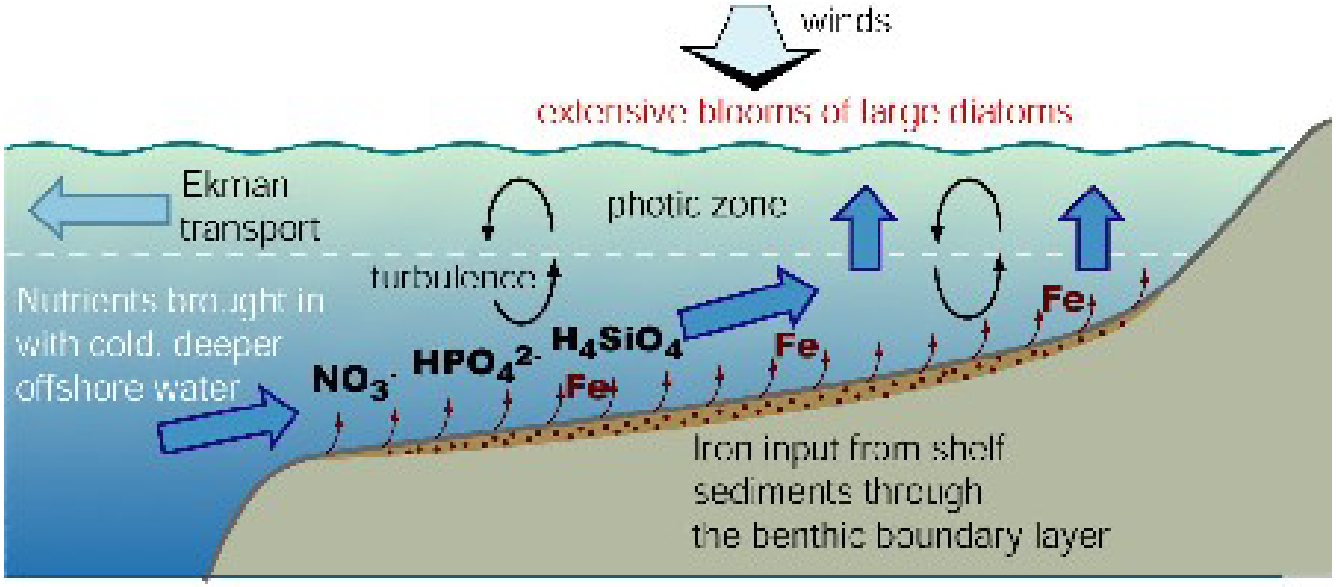
California coast

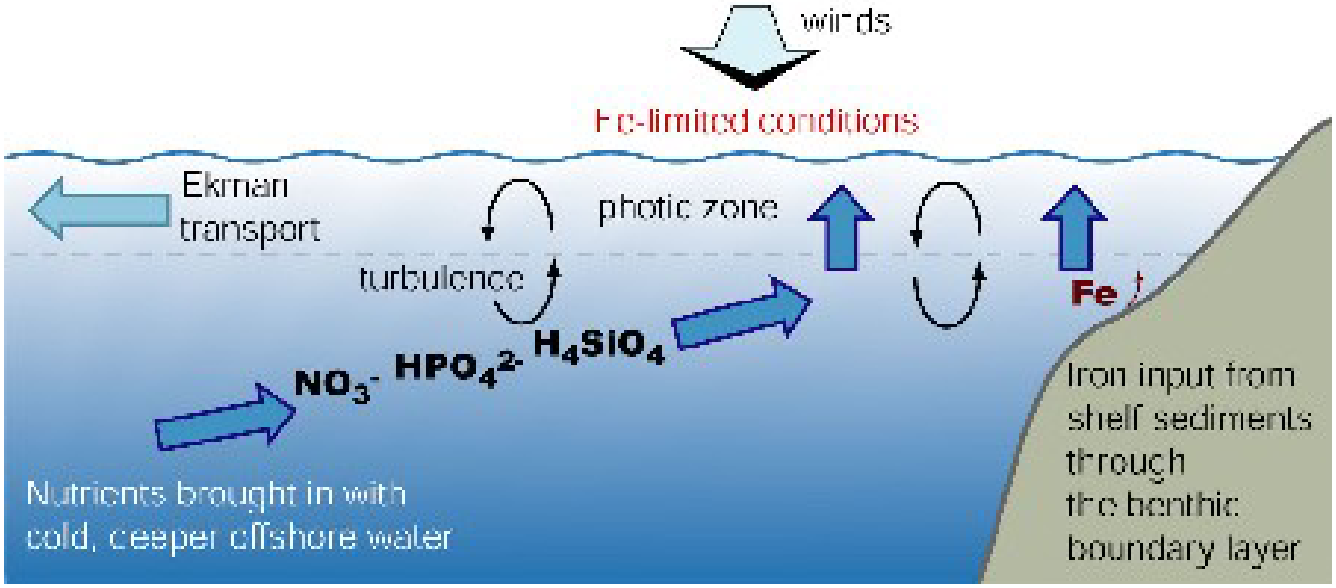


Upwelling zone off the west coast of South Africa (Feb. 21, 2000)



The Gulf of Mexico region for February 25, 1999.


winds
extensive blooms of large diatoms
Ekman transport
photic zone
turbulence
Nutrients brought in with cold, deeper offshore water
NO_3^-
HPO_4^{2-}
H_4SiO_4
Fe
Fe
Fe
Iron input from shelf sediments through the benthic boundary layer


winds
Fe-limited conditions
Ekman transport
photic zone
turbulence
NO_3^-
HPO_4^{2-}
H_4SiO_4
Fe
Nutrients brought in with cold, deeper offshore water
Iron input from shelf sediments through the benthic boundary layer

Carbon fluxes in continental margins

- open question:

  How quickly anthropogenic CO_2 is absorbed by the ocean?
- Why is it difficult to assess?

  The difference between uptake and release of CO^2 at the sea surface is small (~2Pg C yr^{-1}, Pg=10^{15}g vs ~90Pg C yr^{-1} in uptake/release)
- Ocean margins are active sites where physical and biological processes transform, transport or bury carbon

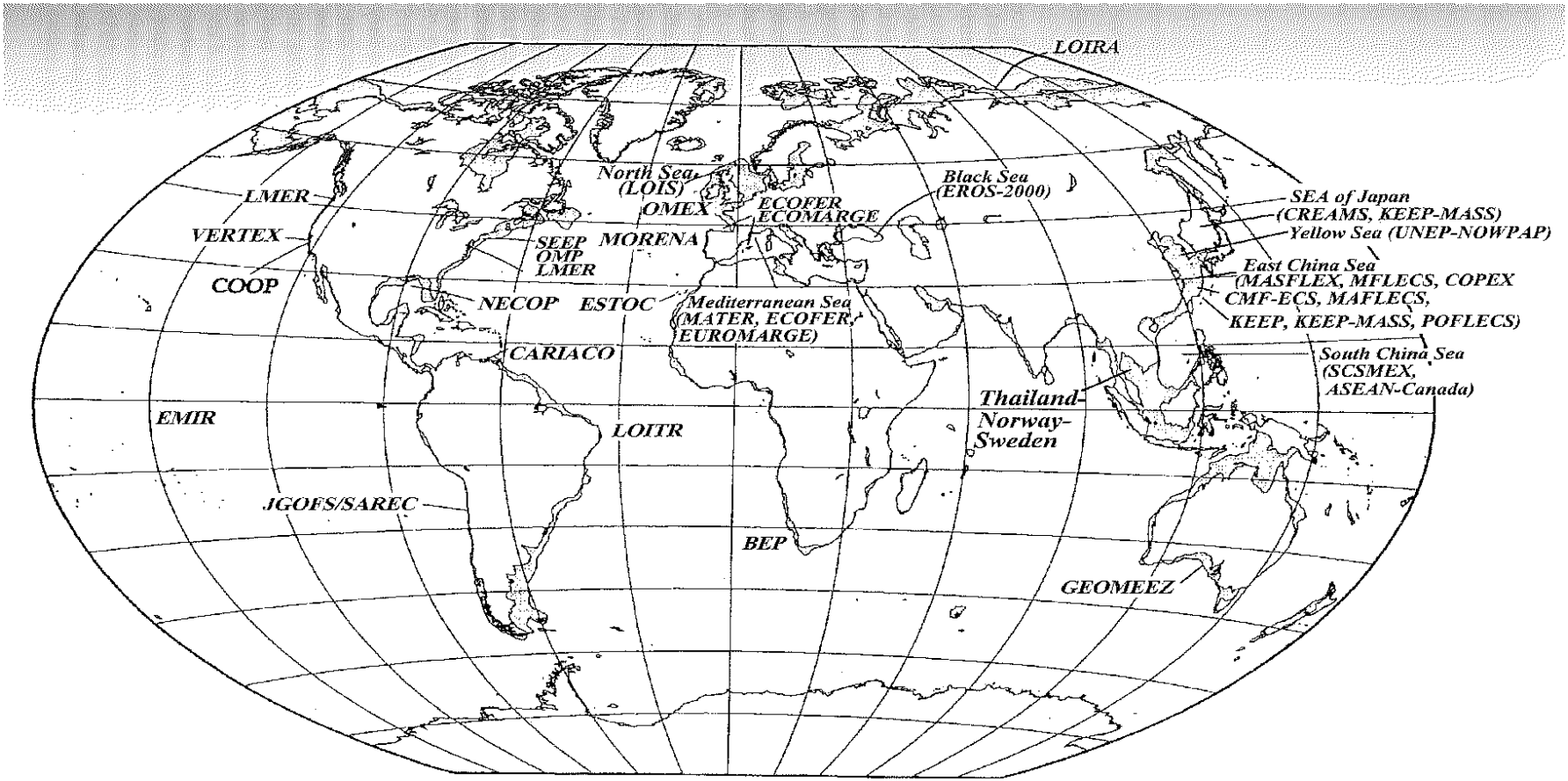
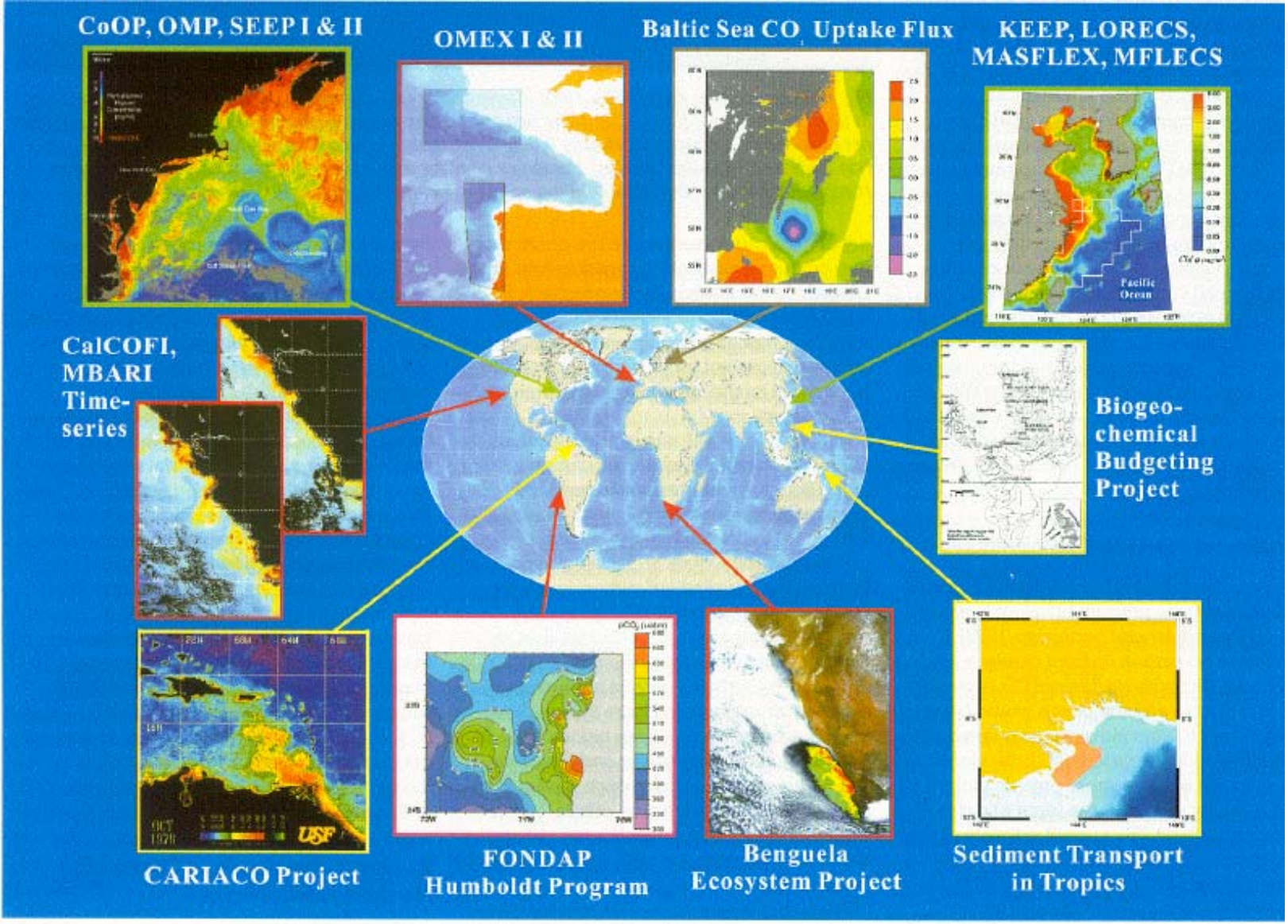


Fig. 3.1. Map of continental margins. Stippled areas represent the continental shelves with depths less than 200 m. Selected programs for continental margin studies, both completed and ongoing, are shown. The acronyms are as follows: *BEP* (Benguela Ecology Programme); *CARIACO* (Carbon Retention In a Colored Ocean); *CMF-ECS* (Continental Margin Flux-East China Sea); *COPEX* (The Coastal Ocean Processes Experiment of the East China Sea); *COOP* (Coastal Ocean Processes); *CREAMS* (The Circulation Research Experiment in Asian Marginal Sea); *ECOFER* (Ecosysteme du canyon du cap Ferret program); *ECOMARGE* (Ecosystems de Marge); *EMIR* (Exportation de Carbon sur une Marge Insulaire Recifale); *EROS-2000* (European River-Ocean System); *ESTOC* (European Station for Time-Series on the Ocean, Canary Islands); *GEOMEEZ* (Marine Geolological and Oceanographic computer model for Management of Australia's EEZ); *JGOFS/SAREC* (Eastern Boundary Current Programme); *KEEP* (Kuroshio Edge Exchange Processes); *KEEP-MASS* (Kuroshio Edge Exchange Processes-Marginal Seas Studies); *LMER* (Land Margin Ecosystem Research); *LOIRA* (Land/Ocean Interactions in the Russian Arctic); *LOISE* (Land Ocean Interaction Study); *LOITRO* (Land-Ocean Interaction in Tropical Regions); *MAFLECS* (Marginal Flux in the East China Sea); *MASFLEX* (The Marginal Sea Flux Experiment); *MATER* (Mass Transfer and Ecosystem Response); *MFLECS* (The Margin Flux in the East China Sea Program); *MORENA* (Multidisciplinary Oceanographic Research in the Eastern Boundary of the North Atlantic); *NECOP* (Nutrient Enhanced Coastal Ocean Productivity); *OMEX* (The Ocean Margin Exchange); *OMP* (US Ocean Margins Programme); *POFLECS* (The Key Processes of Ocean Fluxes in the East China Sea); *SEEP* (Shelf Edge Exchange Processes); *UNEP-NOWPAP* (The United Nations Environment Program – Northern Western Pacific Area Protection); *VERTEX* (Vertical Transport and Exchange)



Liu et al., 2000 EOS

Fig. 1. Examples of continental margin biogeochemical studies in recent years. The margins are classified into five types: Western boundary current systems (indicated by arrows in green), eastern boundary current systems (red), marginal seas (brown), tropical coasts (yellow), and polar margins. For each area, the type of image is explained. Clockwise, starting from upper left-hand corner: 1. Mid-Atlantic Bight: CZCS pigment image; 2. Bay of Biscay & Iberian Coast: bathymetry; 3. Baltic Sea: distribution of CO_2 uptake [Thomas and Schneider, 1999]; 4. East China Sea: chlorophyll distribution in summer with CZCS image as the background; 5. Lingayen Gulf, Philippines: a study site (courtesy of LOICZ Newsletter); 6. Gulf of Papua: bathymetry with mud patch of the Fly Delta [Harris et al., 1993]; 7. West coast of South Africa: SeaWiFS image; 8. Chilean coast at 23°S: PCO_2 map for July 1997 [N. Lefevre et al., pers. comm., 2000]; 9. Cariaco Basin area: CZCS image; 10. California current system: SeaWiFS images during strong and weak upwelling conditions.

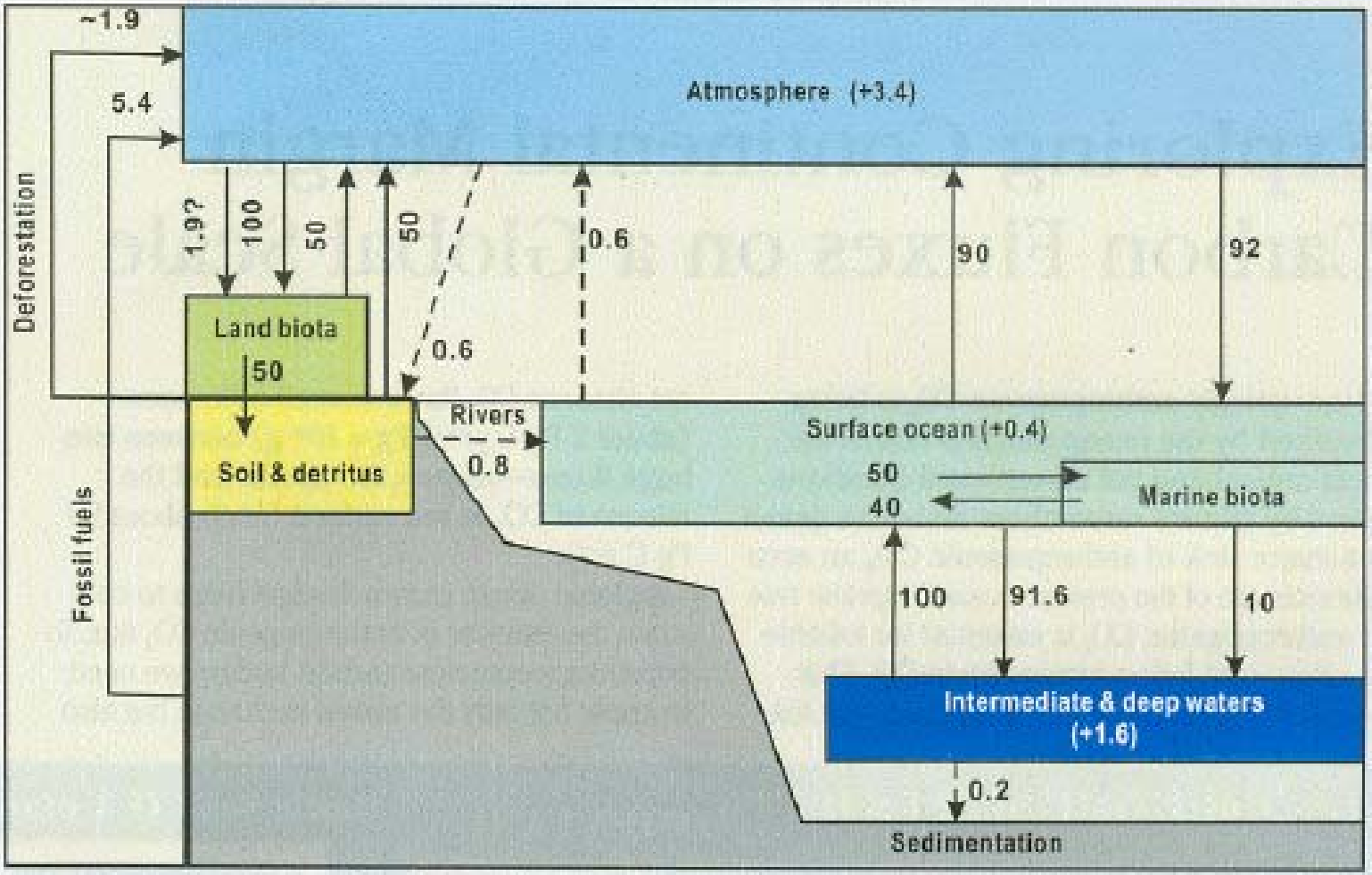


Fig. 2. Global carbon cycle 1980–1989 [Siegenthaler and Sarmiento, 1993]. The carbon fluxes are in units of Pg C yr^{-1} (10^{15} g C yr^{-1}). The oceanic uptake of anthropogenic CO_2 is 2 Pg C yr^{-1}, but the net air-to-sea CO_2 transfer is offset by 0.6 Pg C yr^{-1}, which represents outgassing of the riverine carbon (indicated by dashed arrows). However, if all of the remobilized riverine carbon is outgassed in continental margins, then there will be no offset for the CO_2 flux in the interior ocean.

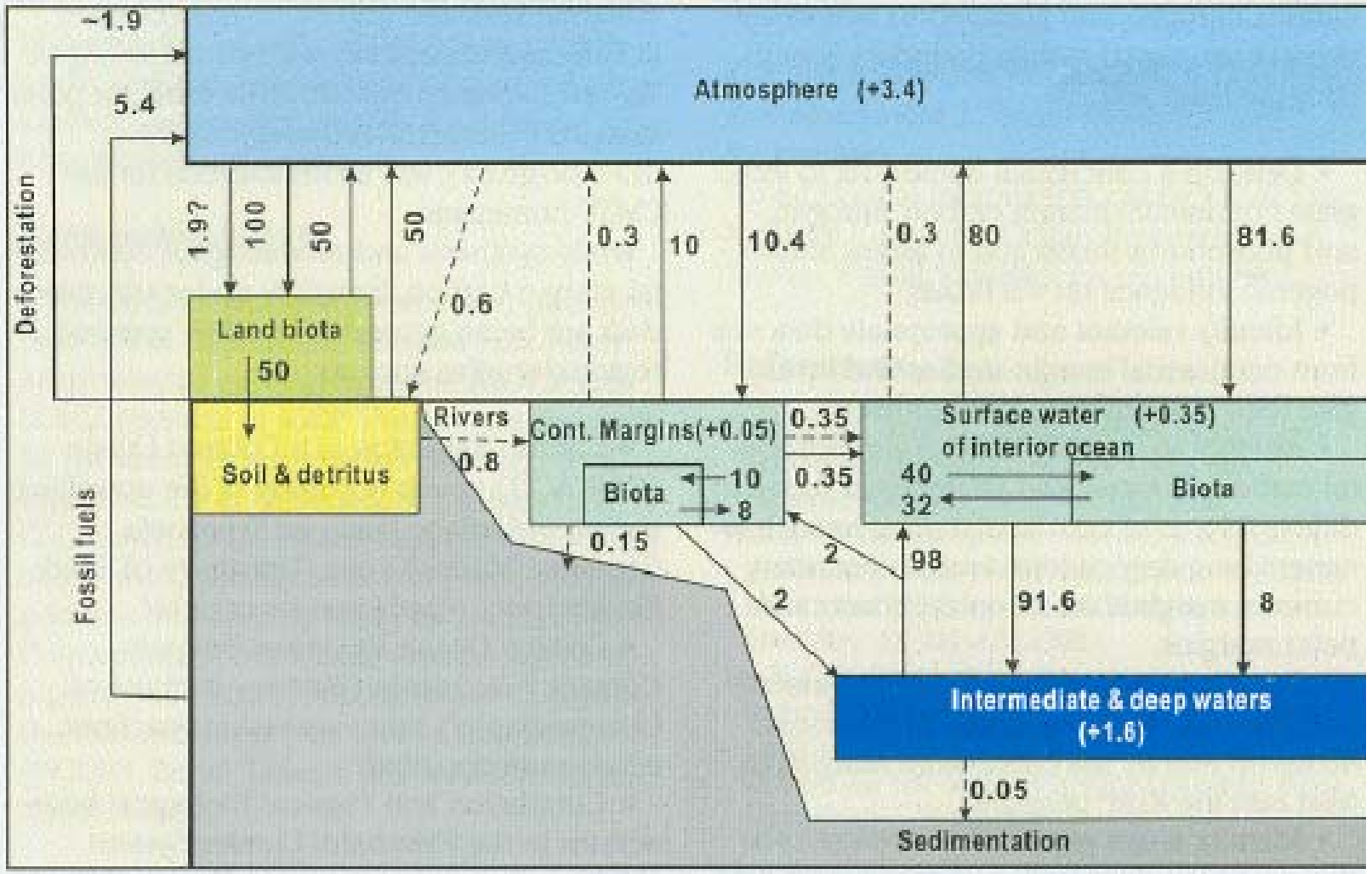


Fig. 3. A modified global carbon cycle with consideration of continental margin carbon fluxes. The net exchanges between the ocean and other reservoirs remain the same as those in Figure 2. It is assumed that continental margins are a net CO_2 sink (0.1 Pg C yr^{-1}), and the shelf export accounts for 20% of the oceanic biological pump, which is compensated by upwelling of dissolved inorganic carbon of the same strength, and about half of the total riverine carbon flux gets exported from the shelf. (See text for details.)

- Each margin needs to the addressed to establish the contribution to the C, N and P budgets.
- Although coastal upwelling simulates primary productivity, the high partial pressure of CO_2 in the upwelled waters may (and often does) offset the CO_2 consumption resulting in a net release

Which factors have to be accounted for?

- Shelf width, depth, shape
- Long-shore vs cross-shelf scales: for large long-shore transport the retention of material on the shelf is favored
- River input: large rivers discharge beyond the shelf break, while small rivers on the shelf affecting the local buoyancy
- winds and orientation of the coast: upwelling / downwelling cycles, eddies…
- heat balance and fluxes: affect stratification
- retention time: whether is less or greater than 1 month impact the balance between ‘recycling’ or ‘export’

River dominated recycling systems (JGOFS 1997)

- biologically mediated; tidal and geostrophic circulation; benthic bioturbation
- broad shelves (>50km); forcing and responses on seasonal time scales
- Long water exchange time (> 1 month)
- East China Sea, North Sea, Baltic Sea, Sea of Japan, South China Sea, NW Atlantic, Great Barrier Reef, Barents Sea, Sea of Okhotsk

Ocean dominated, export systems

- Physically forced: Ekman shelf-edge upwelling, boundary currents, can be forced by river input
- Narrow shelves (<50km)
- Episodic response to forcings
- Short water exchange time (<1month)
- Western Boundary currents of the Americas and Africa, Amazon, Mackenzie and Mississippi river systems

Results from 2000 synthesis (EOS paper)

- The continental margin as a whole are a weak CO2 sink (0.1 $PgCyr^{-1}$)
- The storage of anthropogenic CO2 in margins (~0.05$PgCyr^{-1}$) is proportional to their seawater volume
- Three quarters of carbon burial occurs in margins (0.15 $PgCyr^{-1}$)
- Half of the carbon that can be remobilized from the river run-off is released to the atmosphere from margins (0.3 $PgCyr^{-1}$)
- The export of shelf primary production accounts for 20% of the biological pump (2$PgCyr^{-1}$ from margins to deep waters), which is compensated by upwelling of dissolved inorganic carbon