ENSO and the fate of coastal production in the California Current System from 1979 to 2015

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① What, Why and How?

- The California Current System (CalCS) is a **highly productive ecosystem** that supports fisheries of **immense economic values**[1,2,3].
- The CalCS is strongly affected by **El Niño - Southern Oscillation (ENSO)**[4], the strongest mode of climate variability on interannual time scales[5].
- **Comprehensive work on long records** that capture the complex coastal dynamics and assess the CalCS response to ENSO (facilitated through numerical modeling) is still lacking.

Research Objectives:

What is the mean response of the CalCS coastal biogeochemistry to ENSO?

How do these changes affect the cross-shore exchange of carbon and nutrients that support offshore ecosystems?

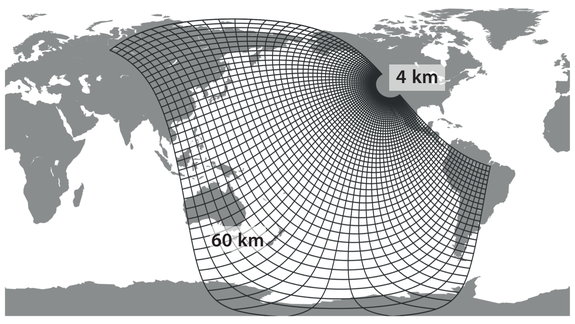

Figure 1: Regional Oceanic Modeling System (ROMS) setup that particularly facilitates the assessment of coastal CalCS dynamics (high resolution), while still capturing the tropical Pacific where ENSO events are triggered.

② Model Mean State: High Coastal Production

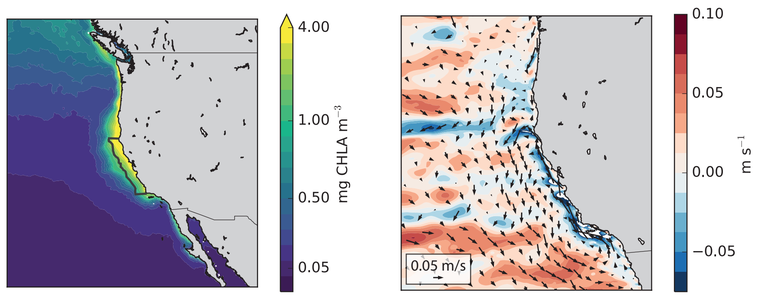

Figure 2: Annual mean euphotic layer chlorophyll-a concentrations (**left**) and zonal circulation (**right**) in the CalCS with red indicating eastward and blue westward circulation. In the circulation plot, arrows depict annual mean euphotic layer circulation. The highlighted region (**left**) along the central California coast indicates the region that was used to compute the nutrient and carbon budgets (Figure 3) and the corresponding sensitivities to interannual variability (Figure 4, Figure 5).

- High euphotic layer nutrient concentrations supplied through coastal upwelling **facilitate high coastal productivity** (Figure 2, left).
- Circulation patterns **redistribute organic matter and nutrients** (Figure 2, Figure 3) and serve as a conduit from coastal to offshore regions.

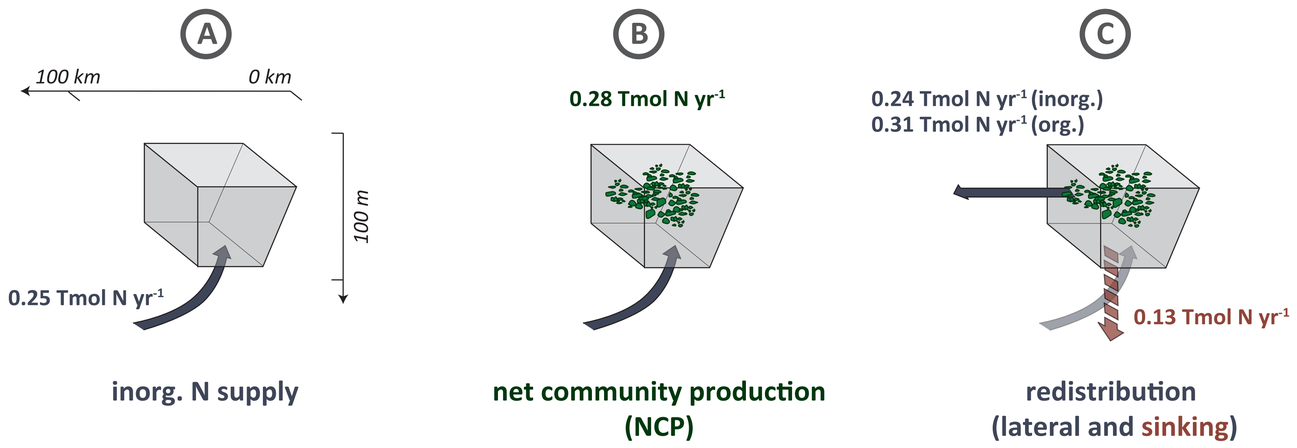

Figure 3: Annual mean coastal biogeochemistry in the central CalCS (region highlighted in Figure 2). Processes depicted are (**A**) inorganic nutrient supply through upwelling, (**B**) organic matter production in the euphotic zone and (**C**) redistribution of both organic and inorganic matter.

③ Interannual Variability in the Pacific: El Niño - Southern Oscillation (ENSO)

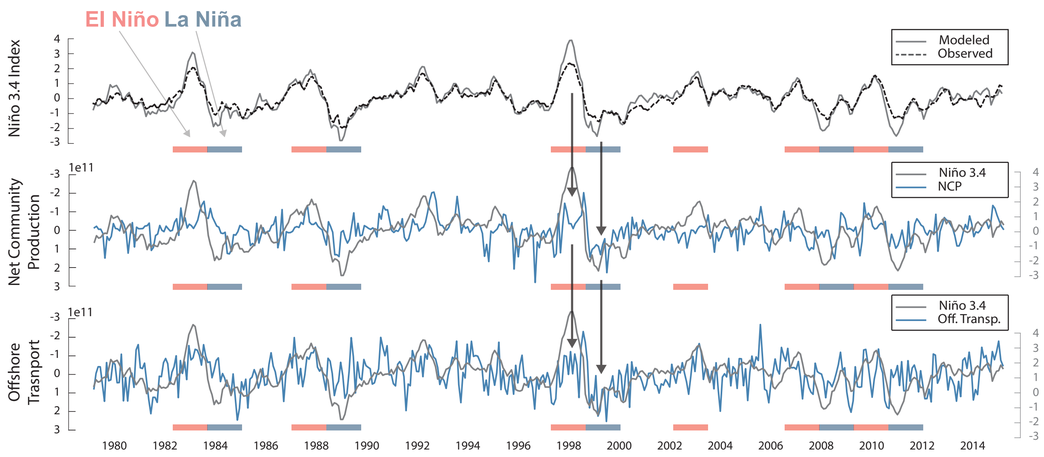

Figure 4: Interannual variability of tropical Pacific sea surface temperatures (**top**, in °C), CalCS coastal NCP (**middle**, in mol) and CalCS offshore transport of organic carbon across 100 km (**bottom**, in mol). The latter panels have an inverted vertical axis to better illustrate the correspondence of biogeochemical fluxes (blue) and the Niño 3.4 index (grey). Colored bars exemplary depict periods of El Niño (red) and La Liña (blue) events.

- The tropical Pacific is known to show substantial interannual variability (**ENSO**)
- The changes translate into **changes in the coastal biogeochemistry** in the CalCS
- During El Niño, both NCP and offshore transport of organic carbon in the central CalCS are **substantially reduced** (inverted axis!)

④ Coastal CalCS Response to ENSO

Taking all the months that that experience tropical ENSO perturbations of ± 1 standard deviation from the Niño 3.4 mean (Figure 4, top) to build El Niño (red) and La Niña (blue) composites, we find that:

- During El Niño events, nutrient supply through upwelling, euphotic layer production and redistribution of organic matter are **substantially reduced.**
- Vice versa, during La Niña, these biogeochemical pathways are **intensified**.

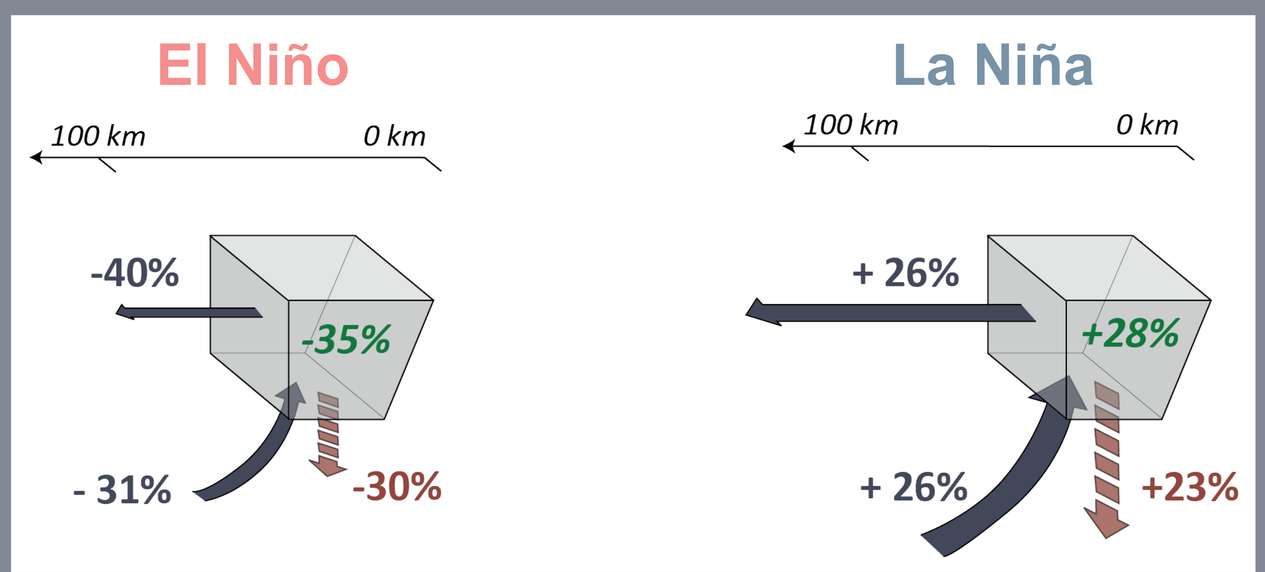

Figure 5: Composite mean response of the coastal ecosystem along central California to ENSO. El Niño events (**left**) cause a substantial weakening of all investigated biogeochemical pathways including upwelling of inorganic nitrogen, euphotic layer production, vertical export of particulate organic matter and offshore transport of organic carbon on the order of around ~30-40% with respect to the mean fluxes (see Figure 3). La Niña events on the other hand (**right**) cause an intensification of these pathways in the same order of magnitude.

⑤ Beyond the coastal margin: Implications for offshore ecosystems

The influence of ENSO does not only affect the central California coastal ecosystem, but does **reach far offshore** through the associated offshore transport mechanisms.

- **Strong anomalies** of both nutrients and organic matter are found during ENSO events (Figure 5, Figure 6) along the central California coast.
- These **anomalies are transported offshore** in a Rossby-Wave like fashion.
- This process potentially **affects offshore ecosystems** by changing both their inorganic nutrient and organic matter supply.

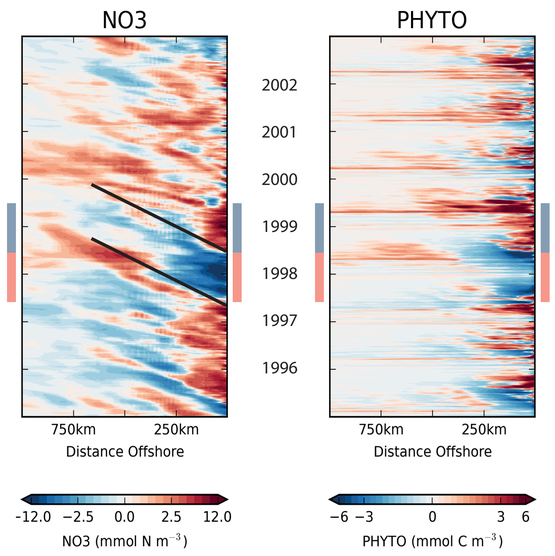

Figure 6: Hovmöller diagrams of nitrate and phytoplankton concentration anomalies from 1995 to 2003. Vertical bars mark periods of strong El Niño (red) and La Niña (blue) perturbations. The slanted black line indicates Rossby-Wave like offshore transport.

Conclusions:

- ENSO changes the biogeochemical cycling of elements along the U.S. West Coast.
- **During El Niño events, nutrient supply through upwelling, organic matter production, vertical export and offshore transport of organic matter decrease by about 30-40%. Vice versa, during La Niña events, these processes intensify.**
- These findings have potential **repercussions for offshore ecosystems** that have yet to be quantified.

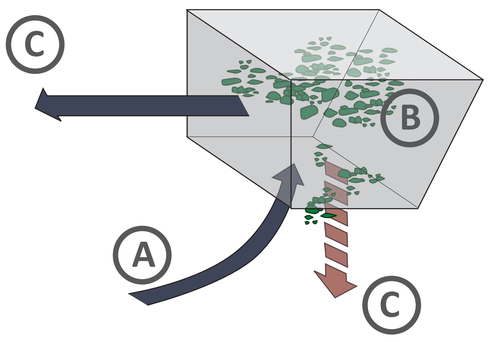

Figure 7: ENSO and the fate of biogeochemical matter in the coastal CalCS. El Niño events weaken the depicted pathways (A-C), whereas La Niña events intensify the turnover.

References:

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