From the Oligotrophic Ocean Gyres to Coastal Upwelling Systems: SIMULATING THE DYNAMIC RANGE OF CHLOROPHYLL CONCENTRATION

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Motivation, Goals and Approach

The measured **concentration of chlorophyll *a* in the surface ocean spans four orders of magnitude**, from ~0.01 mg m^{-3} in the oligotrophic gyres to >10 mg m^{-3} in coastal zones. **Productive areas** with annual mean chlorophyll *a* concentrations >3 mg m^{-3} account for only ~2% of global ocean area yet they contribute disproportionately to marine resources and biogeochemical processes, such as fish catch and oxygen depletion. These areas are **often poorly represented in biogeochemical models**, and when they are, increased spatial resolution only partly alleviates this problem (Stock et al. 2017).

We test the hypothesis that this is **partly because of the very coarse representation of phytoplankton size classes in ecosystem models**, which often include only one or two groups to represent the entirety of ocean phytoplankton communities.

A planktonic ecosystem model with a canonical two size-class phytoplankton structure, the **Carbon, Ocean Biogeochemistry and Lower Trophics (COBALT) model** (Stock *et al.* 2014), was adjusted to include an additional large, chain-forming coastal diatom group to test this hypothesis. The ecosystem model was implemented into a ~7 km horizontal resolution **ROMS model of the California Current System** (CCS).

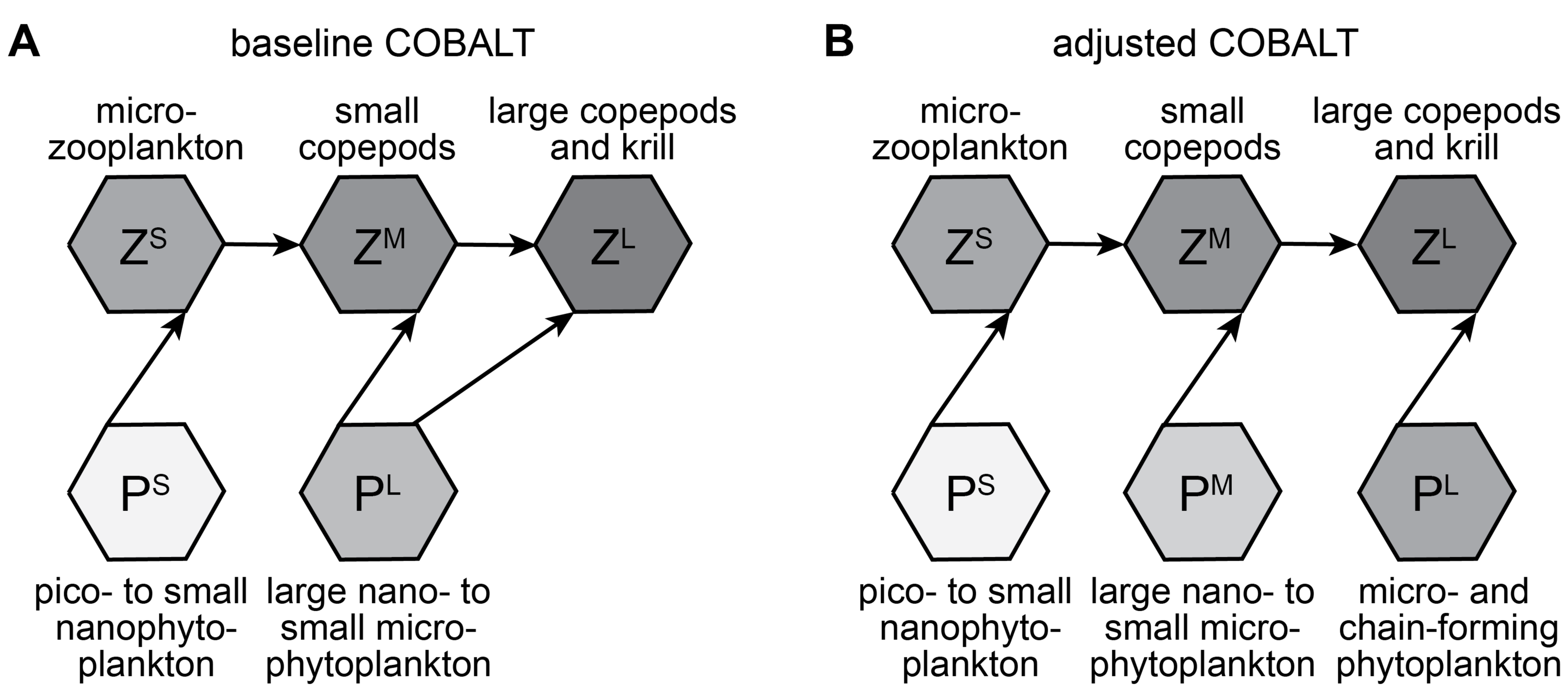

Figure 1. Trophic relationships between the different phytoplankton (P) and zooplankton (Z) size classes in the (A) baseline and (B) adjusted COBALT model configuration, which resolves three phytoplankton size classes (Van Oostende *et al.* 2015). The largest phytoplankton class can only be consumed by the largest zooplankton class, allowing for transient trophic decoupling.

Adjusted COBALT model successfully reproduces the broad range of near-bottom dissolved oxygen (DO) on shallow shelf areas and captures the observed trend of decreasing near-bottom DO with increasing bottom depth along the CCS shelf slopes.

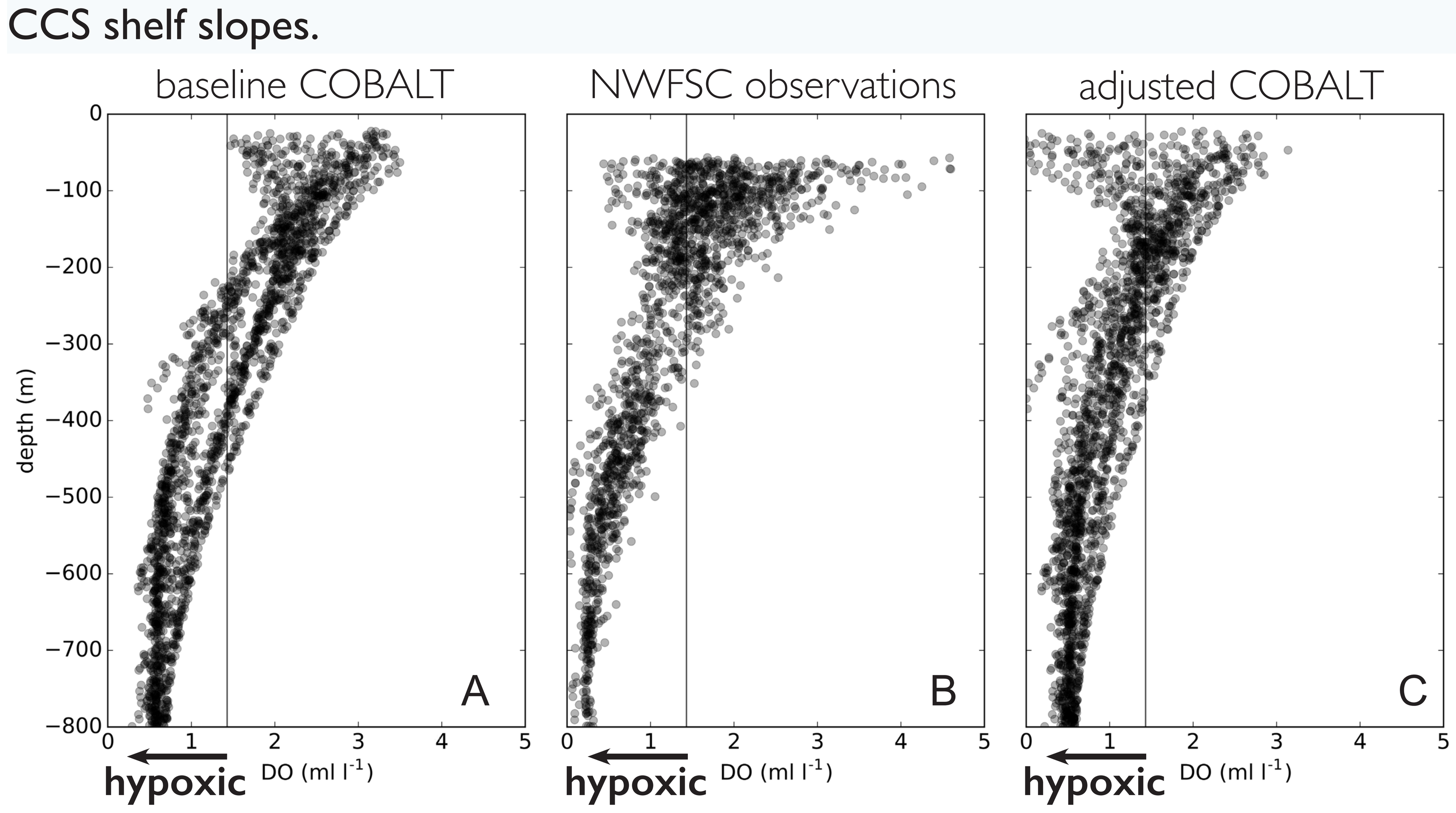

Figure 5. Near-bottom dissolved oxygen (DO) concentration on the California Current System continental shelf. (A) summer (JJA) climatological means from baseline COBALT ROMS model, (B) NOAA Northwest Fisheries Science Center measurements during the months June, July, and August between 2009 and 2015, (C) summer (JJA) climatological means from the adjusted COBALT ROMS model. Vertical line at DO = 1.43 ml l^{-1} denotes hypoxia threshold.

Conclusions & Perspectives

- **Increased spatial resolution only partly remedies simulation of full chlorophyll concentration range.**
- **Addition of a chain-forming, coastal diatom group to the COBALT ecosystem model allows simulation of the full range of chlorophyll concentration and increases maximum chlorophyll concentration by ~2.5 fold in central CCS compared to baseline 2 phyto size class COBALT.**
- **Representation of high chlorophyll and export production improves coastal hypoxia simulation.**
- **Adjusted 3 phyto size class COBALT model will be used to parse the impact of wind-driven upwelling intensity vs. nutrient and O_2 content of source water on coastal hypoxia in CCS.**
- **Impact of the adjusted 3 phyto size class COBALT model will be assessed on timing and magnitude of simulated North Atlantic spring bloom.**

Results

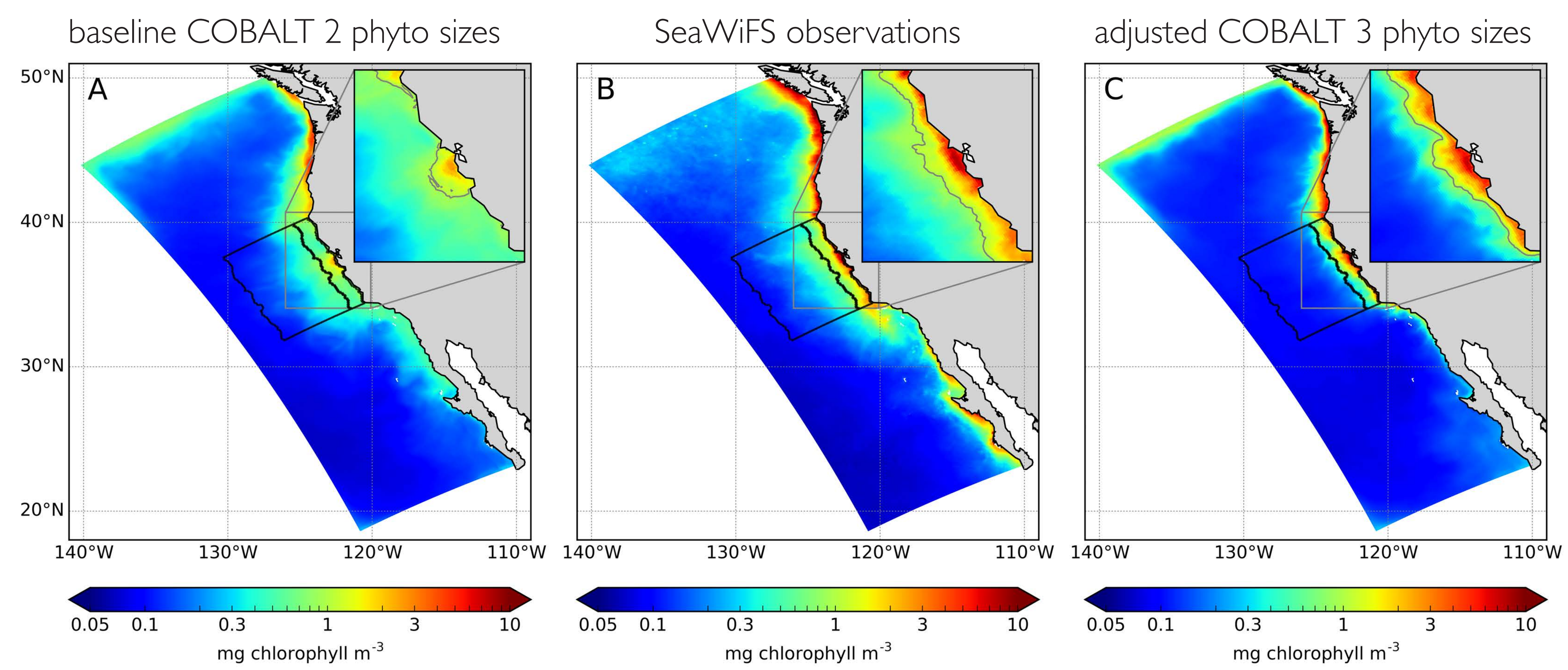

Figure 2. Summer (JJA) climatology (1996-2006) of chlorophyll concentration from (A) 2 phytoplankton size class baseline COBALT model, (B) SeaWiFS observations, and (C) 3 phytoplankton size class COBALT model. The central CCS region, between Point Conception and Cape Mendocino, is outlined in black from the shore to 100 km offshore (coastal region) and to 600 km offshore (coastal to offshore region). The inset details chlorophyll in the coastal zone and the offshore extent of the 1 mg chlorophyll m^{-3} contour (gray contour line).

Broader chlorophyll concentration range in the 3 phyto size class model configuration similar to remote sensing observations

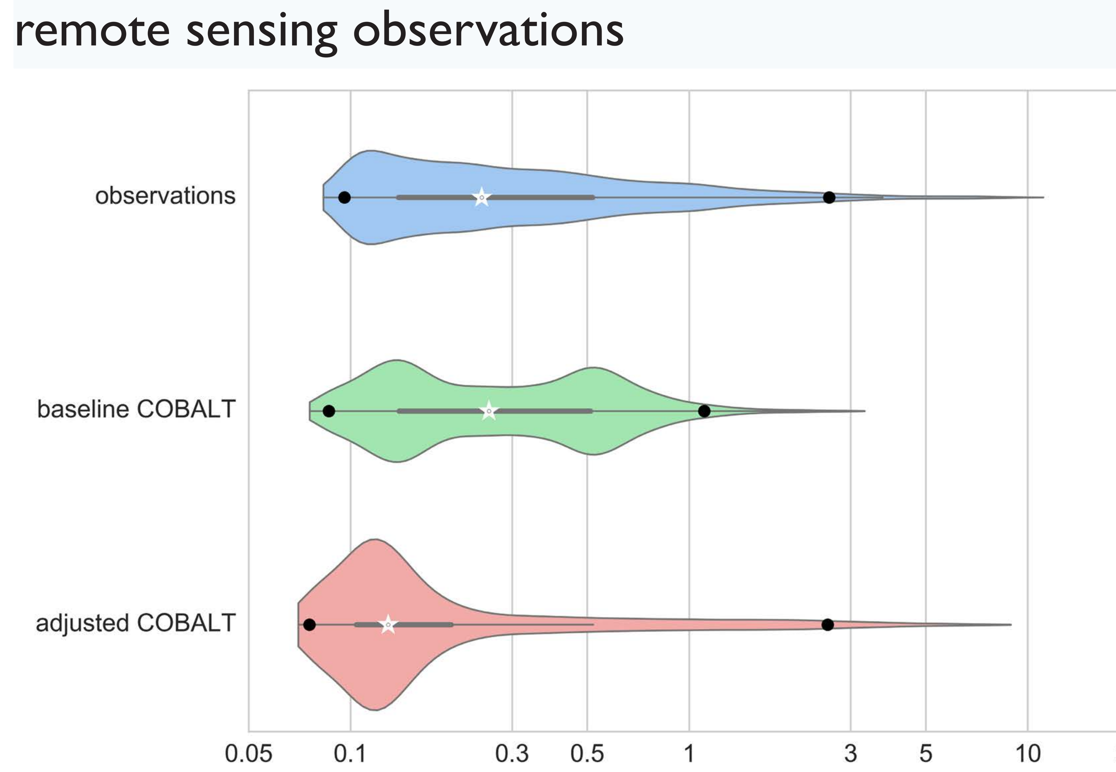

Figure 3. Comparison of chlorophyll concentration range and distribution from (top) SeaWiFS remote sensing observations, (middle) 2 phytoplankton size class, baseline COBALT model and (bottom) 3 phytoplankton size class, adjusted COBALT model outputs. The violin plots show median (white star), interquartile range (black bar) and the 2.5 and 97.5 percentile (black dots) overlaid onto the kernel density estimation of the summer climatological (JJA) chlorophyll concentration in the central CCS region.

Decline of chlorophyll with increasing temperature consistent between the 3 phyto size class model configuration and observations

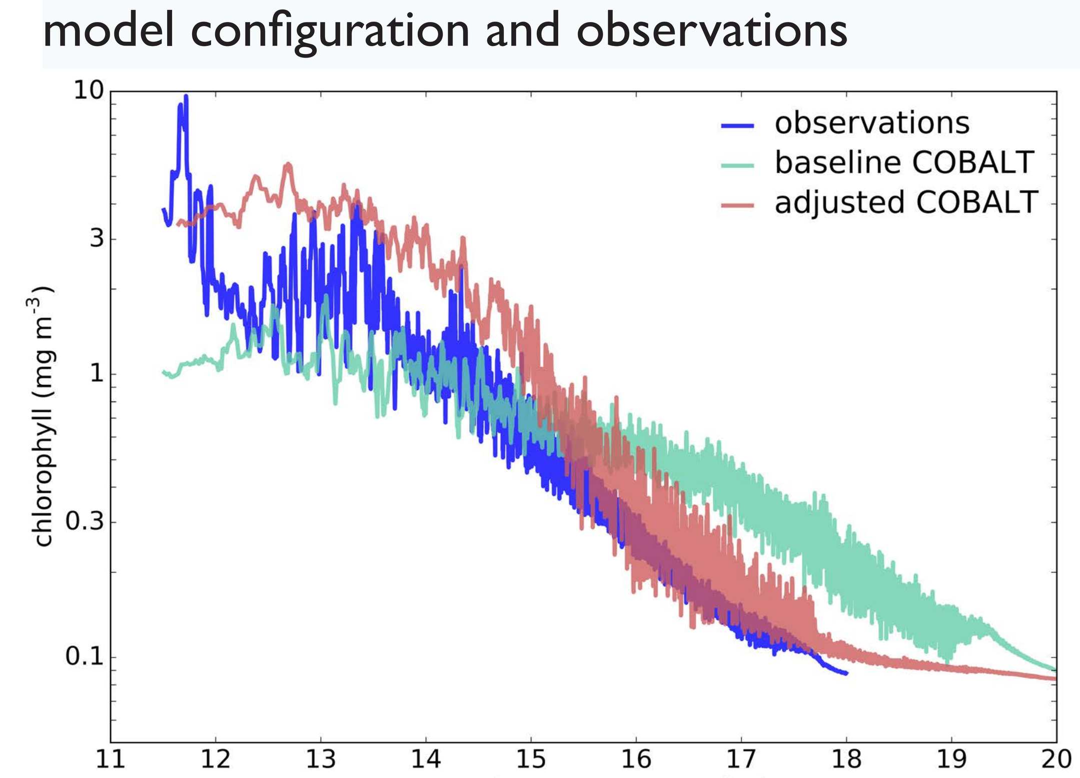

Figure 4. Summer climatology (JJA) of surface chlorophyll concentration versus sea surface temperature from observations (SeaWiFS and NOAA IO.v2, respectively) and model simulations in the central CCS region (running mean of binned temperature over central CCS).

References:
Stock *et al.* (2014) Prog. Ocean. DOI: 10.1016/j.pocean.2013.07.001; Stock *et al.* (2017) PNAS DOI: 10.1073/pnas.1610238114; Van Oostende *et al.* (2015) J. Mar. Sys., DOI: 10.1016/j.jmarsys.2015.01.009; SeaWiFS, Ocean Color Data, NASA Goddard Space Flight Center, Ocean Ecology Laboratory, Ocean Biology Processing Group v2014 processing; Near-bottom dissolved oxygen, NOAA's Northwest Fisheries Science Center, https://www.nwfsc.noaa.gov/data accessed on 12/02/2017.

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