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A complex ocean-atmosphere-land interaction to predict primary production in the California Current System

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Abstract

Eastern Boundary Upwelling Systems (EBUS), such as the California Current System (CCS), belong to the most productive coastal environments, supporting some of the world's major fisheries. The CCS upwelling and productivity present a seasonal variability with a favorable season during spring and summer, where high biological productivity is largely determined by wind-driven upwelling. As for the other EBUS (e.g., Benguela, Canary and Humboldt), equatorward winds drive coastal upwelling, Ekman pumping, alongshore currents and then productivity. Additionally, coastal currents and significant oceanic mesoscale variability contribute to cross-shore exchange of heat, salt, and biogeochemical tracers between the open and coastal oceans. However, the effects of the observed slackening of the wind (wind drop-off) and of the ocean-atmosphere interactions on regional Net Primary Production (NPP) are not well known.

In recent studies, using regional numerical oceanic and atmospheric simulations, we first show the wind drop-off is mainly driven by the orography and the coastline meandering. We further demonstrate that the wind drop-off has little effect on near-shore phytoplankton productivity, despite a large reduction in upwelling velocity. On a regional scale, it leads to a substantially higher NPP, especially when it occurs over a broad swath, even when the total upwelling rate remains the same. This partial decoupling of NPP from upwelling is effected by alongshore currents and the eddies they generate. When peak winds extend all the way to the coast, alongshore current shear is stronger, and a more energetic eddy field subducts nutrients offshore and out of the photic zone, reducing overall productivity. This causal sequence is supported by satellite remote sensing. Finally, using an interanual coupled simulation over the US West Coast, we show the mechanical coupling between the ocean and the atmosphere (current feedback) drastically dampens the eddy activity by deflecting energy from the oceanic geostrophic currents to the atmosphere, but also induces fine scale spatial structures on the wind itself, inducing a partial re-energization of the ocean, and leading to more realistic eddies characteristics. The subsequent reduction of the EKE reduces the eddy quenching, increasing the nearshore NPP and altering the offshore export of biogeochemical materials. Indeed, the overall phytoplankton production on the shelf increases from 10 to 30% and decreases offshore. We record with this, a change in domination of the type of plankton offshore potentially related to the matters transport. Those complex ocean-atmosphere-land interactions imply that simple wind indices are incomplete predictors of productivity in EBUS. The next step of our research aims to control of the NPP by the submesoscale.