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Enhancement of Oceanic Eddy Activity by Fine-Scale Orographic Winds Drives High Productivity, Low Oxygen, and Low pH Conditions in the Santa Barbara Channel

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ABSTRACT

The Santa Barbara Channel is one of the most productive regions of the California Current System. Yet, the physical processes that sustain this high productivity remain unclear. We use a high-resolution physical-biogeochemical model to show that submesoscale eddies generated by islands are energized by orographic effects on the wind, with significant impacts on nutrient, carbon, and oxygen cycles. These eddies are modulated by two co-occurring air-sea-land interactions: transfer of wind energy to ocean currents that intensifies ocean eddies, and a wind-current feedback that tends to dampen them. Here we show that the dampening is overwhelmed by fine scale wind patterns induced by the presence of surrounding capes and islands. The fine-scale winds cause an additional transfer of momentum from the atmosphere to the ocean that energizes submesoscale eddies. This drives upward doming of isopycnals in the center of the channel, allowing a more efficient injection of nutrients to the surface, and triggering intense phytoplankton blooms that nearly double productivity relative to the case without fine-scale winds. The intensification of the doming effect by the wind-curl and submesoscale eddies pumps deep low oxygen, acidic waters to the center of the cyclonic eddies. These eddies are then transported away from the Channel into the California Current, where they impact a wider area along the central coast, with potential ecological consequences. Our study highlights the important role of air-sea-land interactions in modulating coastal processes, and suggests that submesoscale resolving models are required to correctly represent coastal processes and their ecological impacts.