CALIFORNIA ENERGY COMMISSION

OCEAN PROTECTION COUNCIL

Potential Effects of Offshore Wind Farms on California Upwelling

Grace Chang

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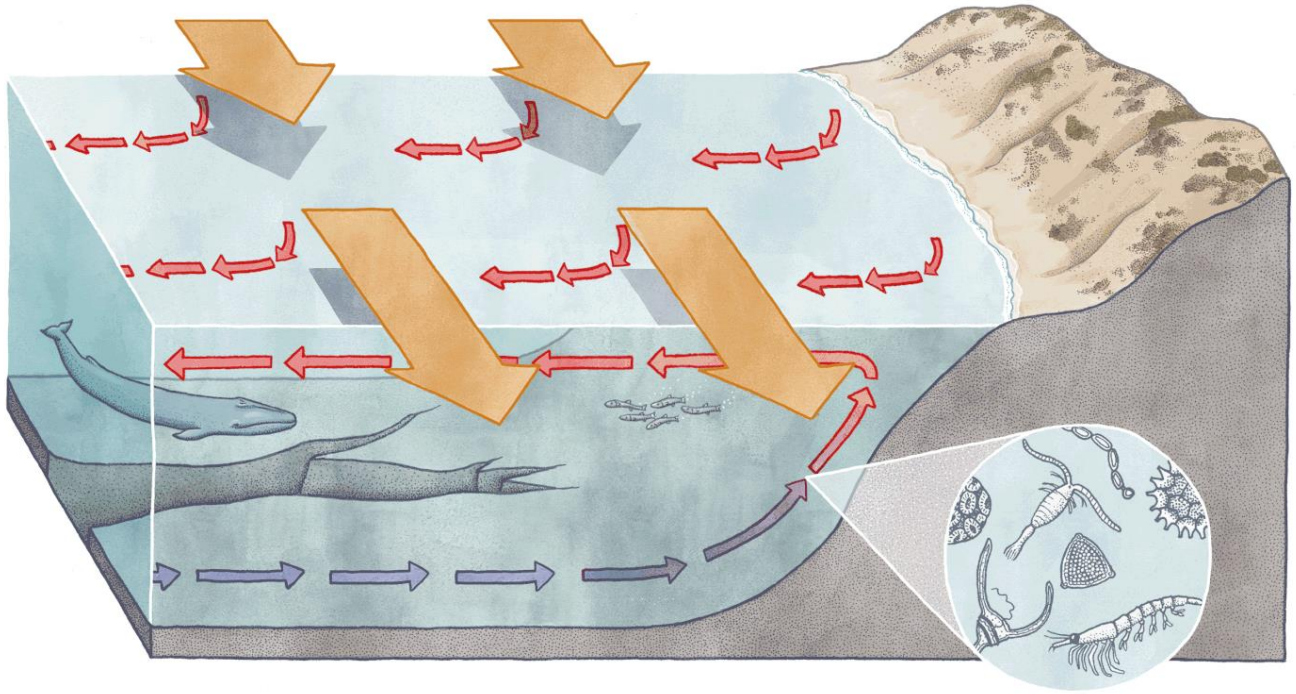
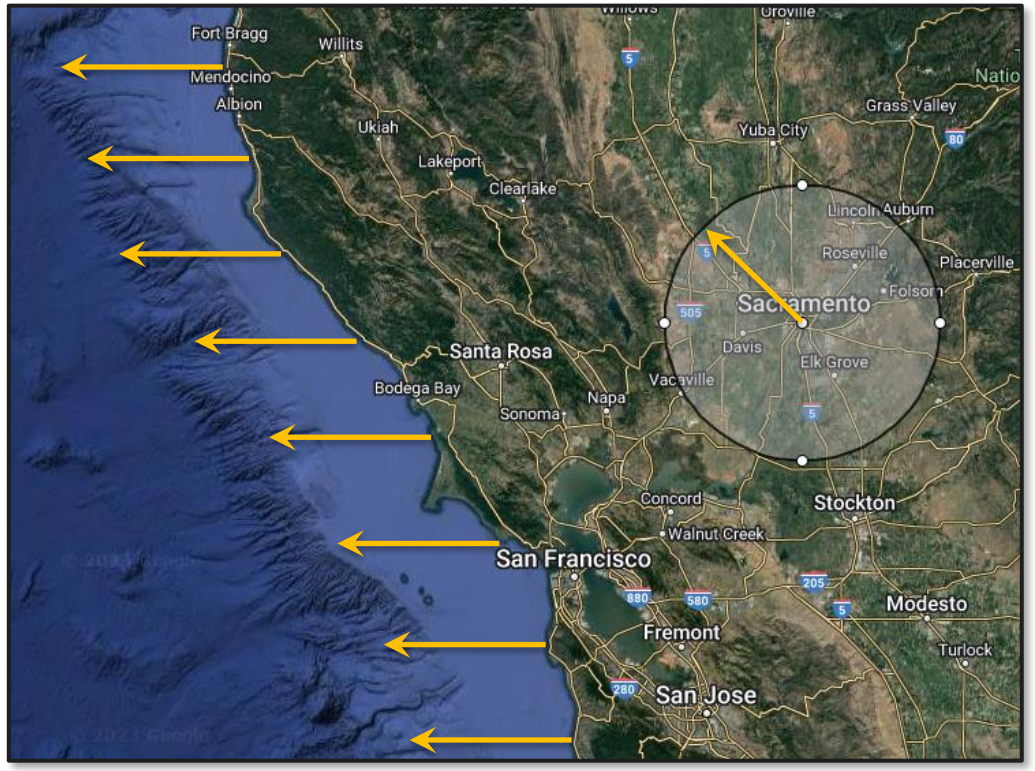
California Upwelling

- **Coastal upwelling**
  - Driven by strong northwesterly winds
  - Generally occurs in a narrow band (~30 mi) along the coast

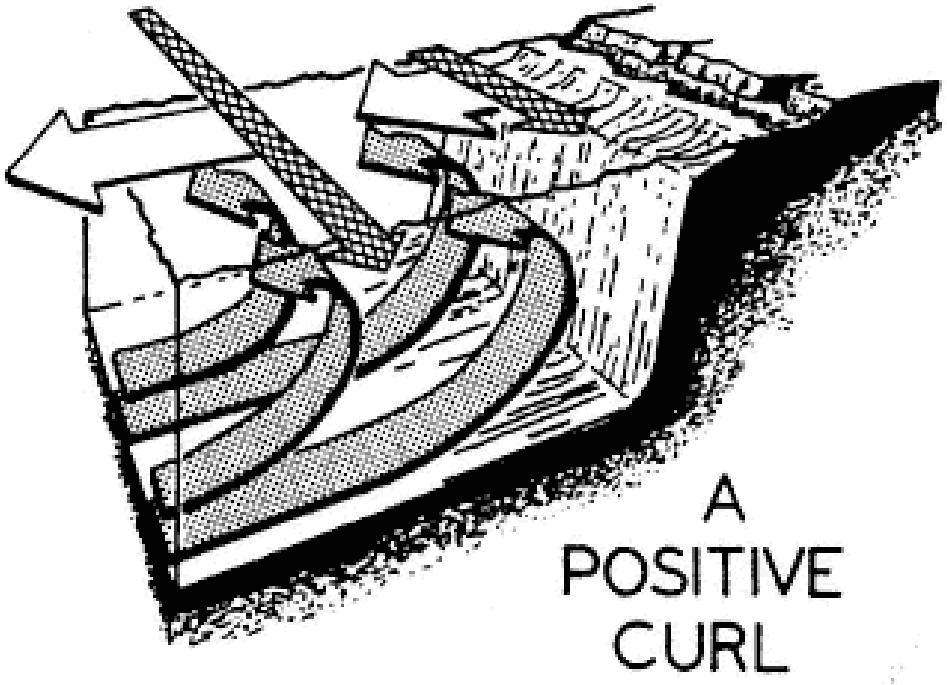


From https://www.alexboersma.com/animation

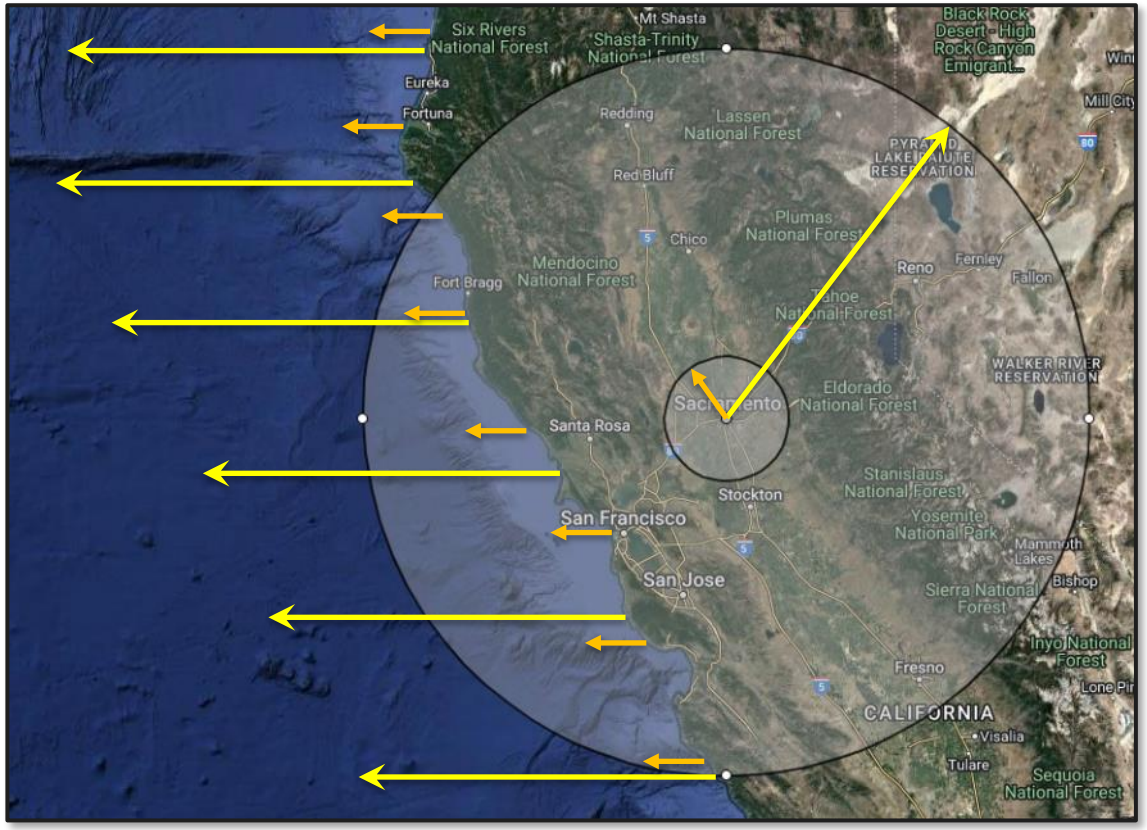


California Upwelling

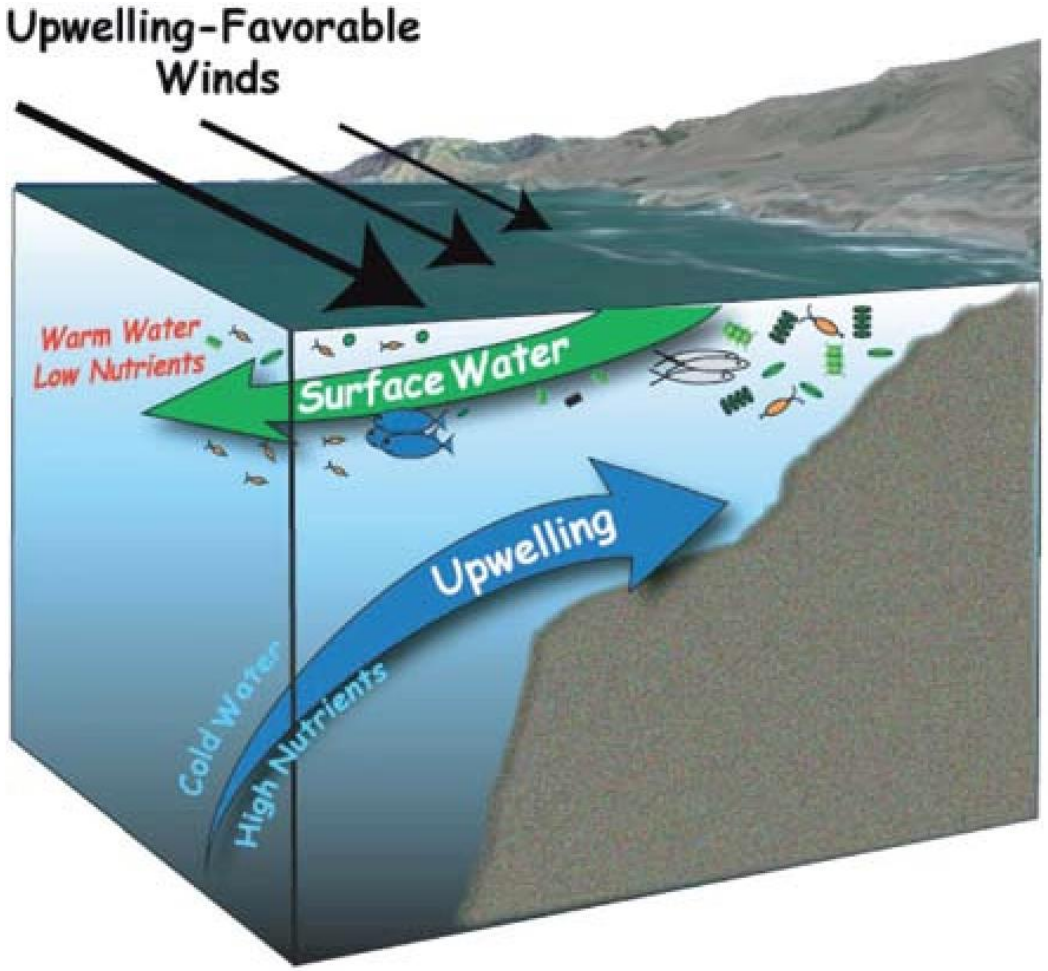
- **Curl-driven upwelling**
  - Driven by cross-shore gradients in wind speed
  - Can extend far offshore (100 – 200 mi)



From https://nap.nationalacademies.org/read/1991/chapter/8

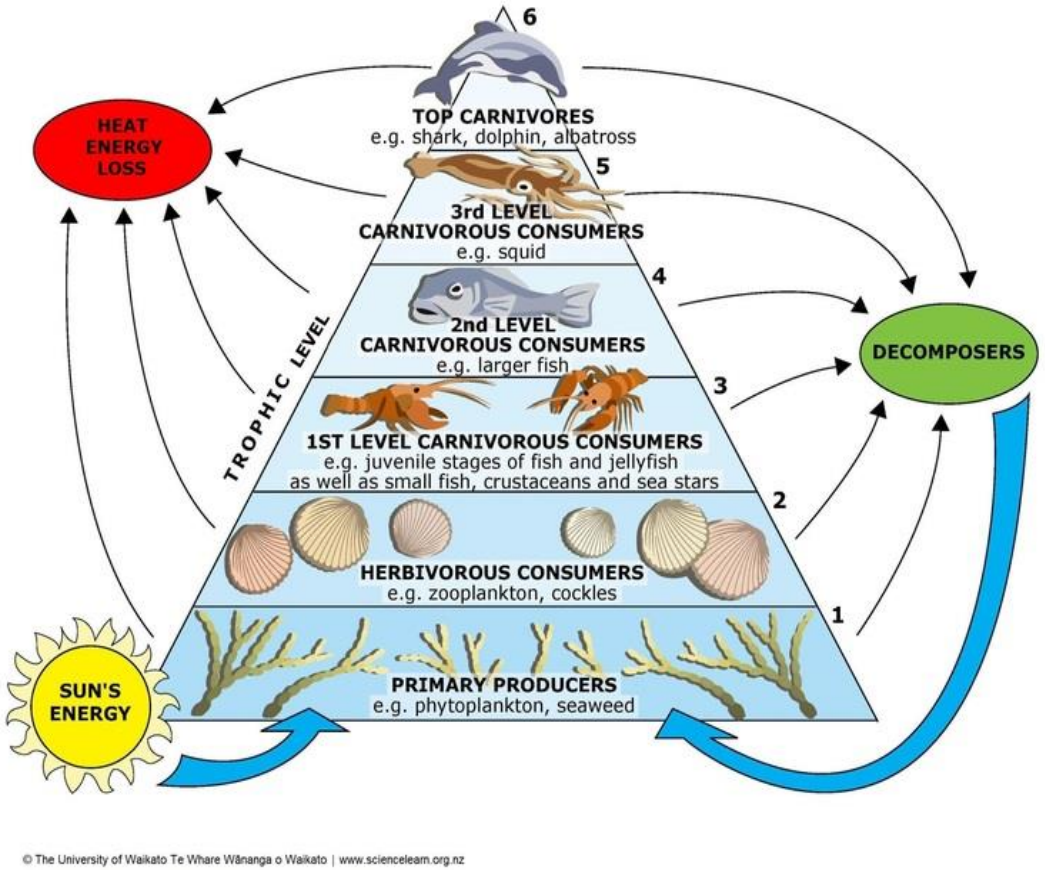


California Upwelling – Why Is It Important?



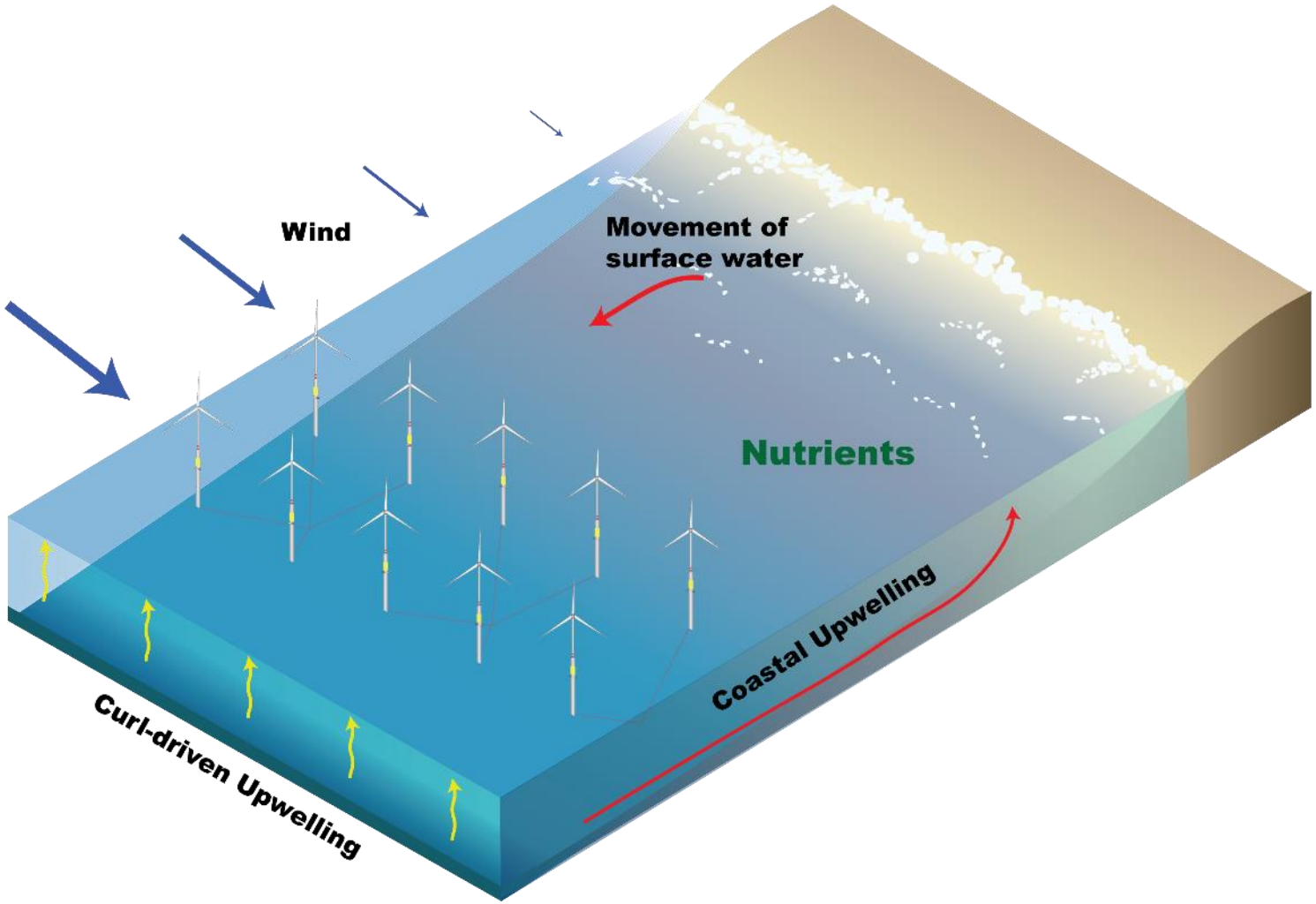
From DOI:10.5670/OCEANOG.2008.04

- **Supports a rich and diverse ecosystem**



From https://www.sciencelearn.org.nz/resources/143-marine-food-webs

Do offshore wind turbine arrays have the potential to affect California upwelling?



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- Additional support provided by the Ocean Protection Council
- Period of performance: 2020 –2023

Project Team Members


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Dr. Lawrence Cheung


Mr. Jesse Roberts


Dr. Chris Chartrand


Dr. Mike Jacox


Dr. Jerome Fiechter

We are a public-private partnership of physical oceanographers and atmospheric scientists working in the realm of marine renewable energy, atmospheric science, and physical-biological interactions in the ocean. We have collaborated on projects on the potential environment effects of marine renewable energy devices, and ecosystem modeling of the California Current System.

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Sandia National Laboratories

NOAA National Oceanic and Atmospheric Administration U.S. Department of Commerce

University of California Santa Cruz

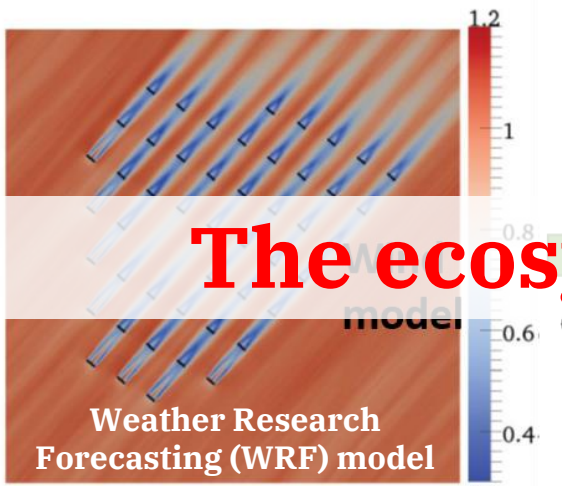
Project Goal and Objectives

Goal

- Determine potential changes in California upwelling due to offshore wind farm development

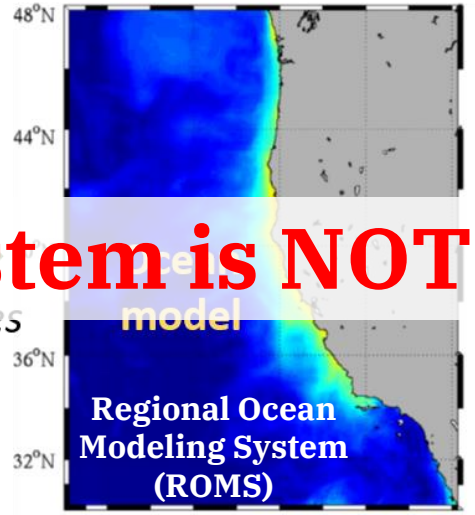
Objectives

- Develop and implement numerical wind and ocean circulation models
  - Baseline (no turbines) and simulated wind farms in the California wind energy areas of interest
- Compute operational upwelling indices



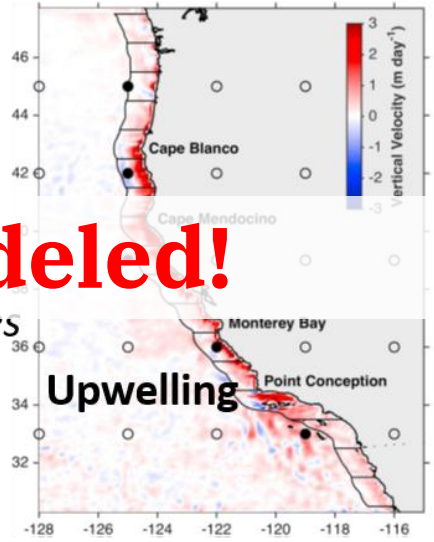
NREL, 2014

drives



Raghukumar et al., 2015 (Integral)

computes

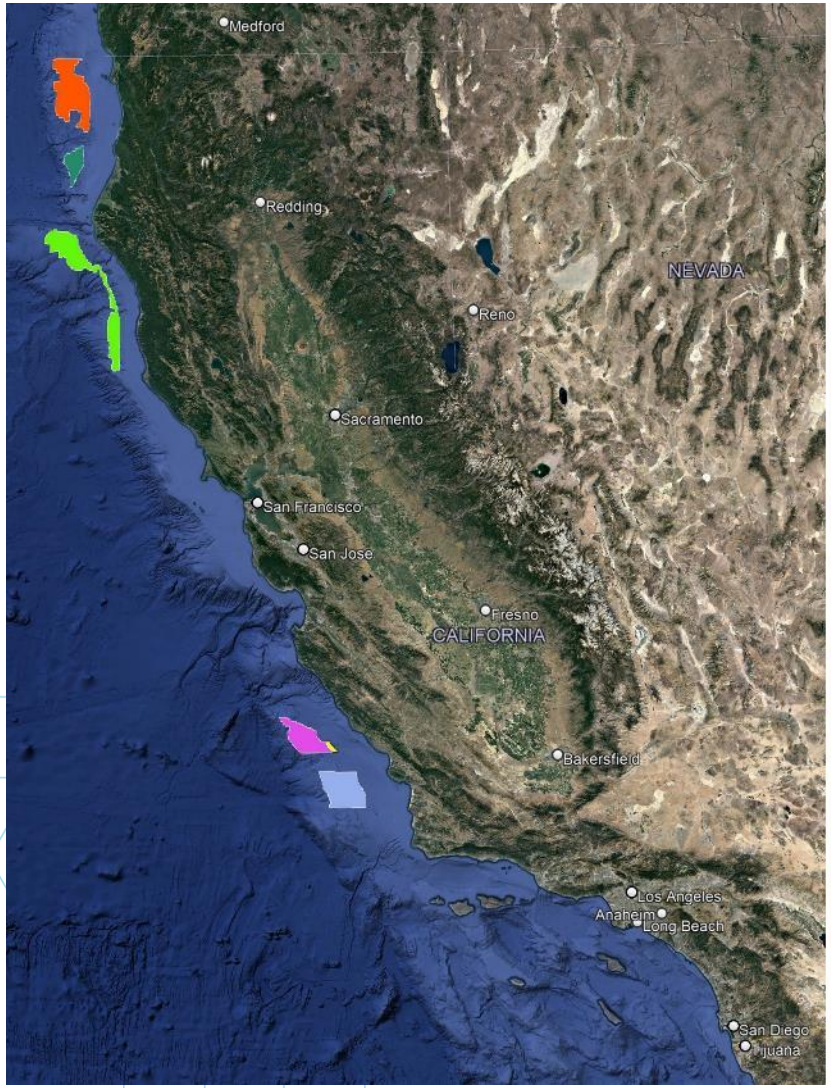


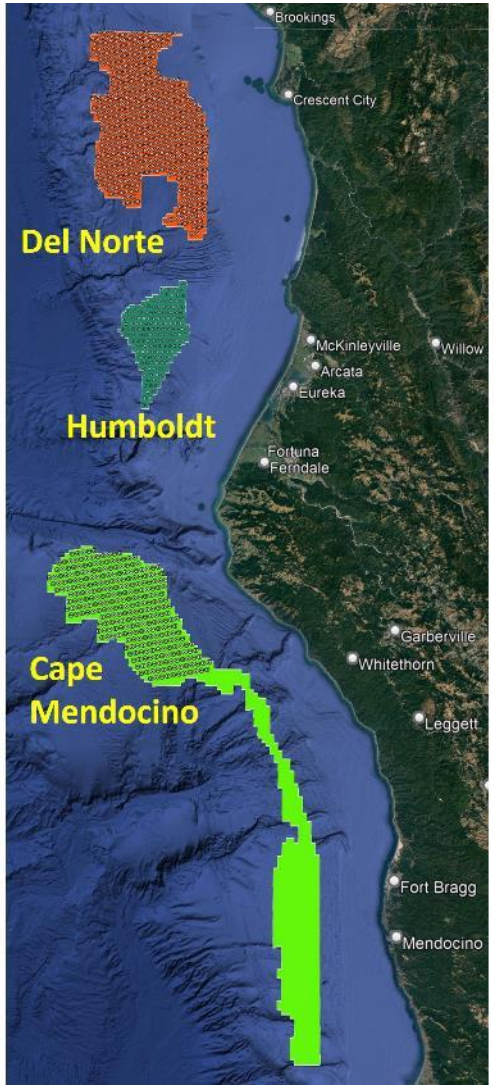
Jacox et al, 2018 (UCSC/NOAA)

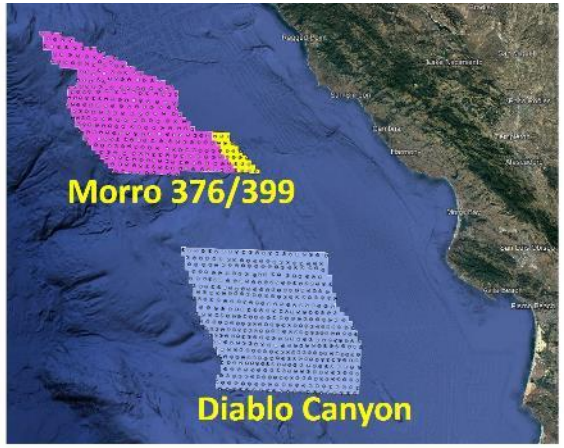
Coastal Upwelling Transport Index (CUTI) and Biologically Effective Upwelling Transport Index (BEUTI)

The ecosystem is NOT modeled!

Simulated Wind Farms

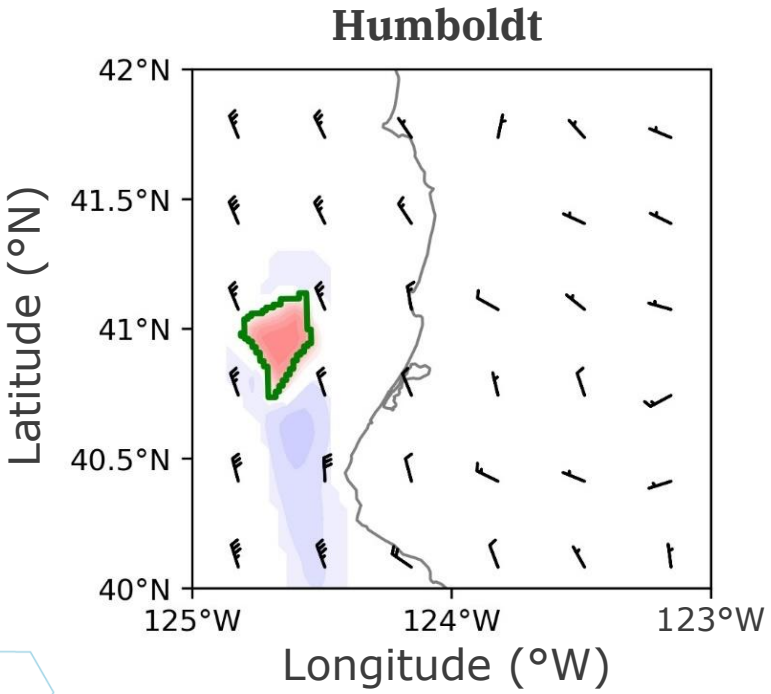


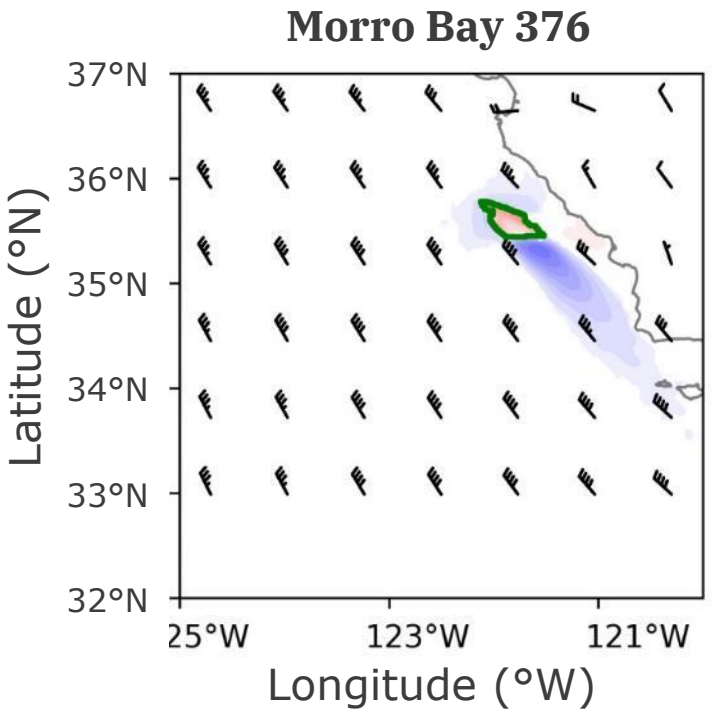


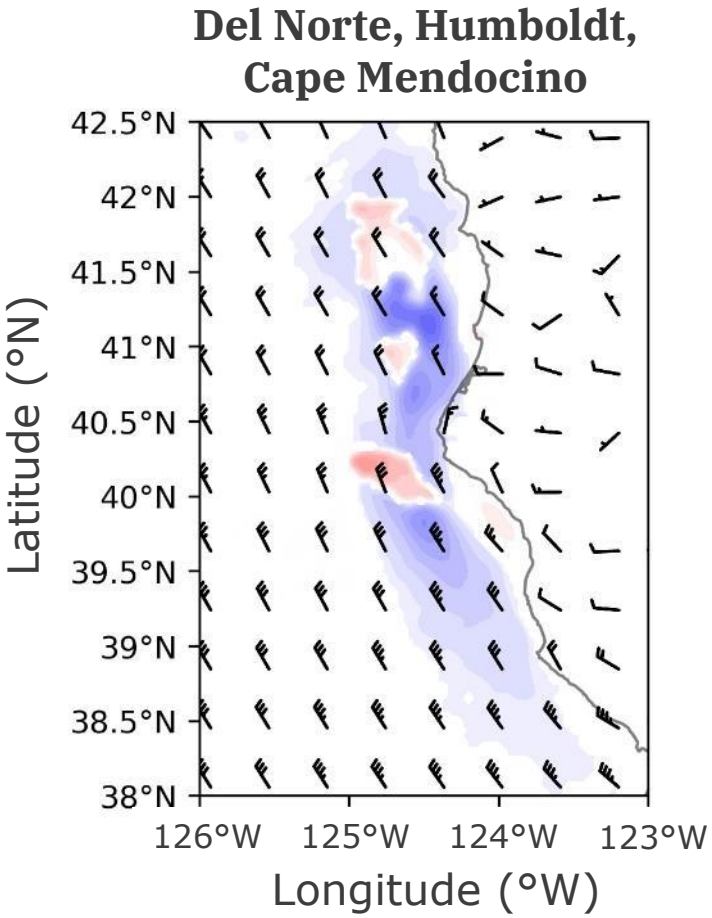


Model Scenarios	
Humboldt/Morro Bay 399/Diablo Canyon	10 MW turbines, 877 turbines = 8.77 GW
Humboldt/Morro Bay 376	10 MW turbines, 470 turbines = 4.7 GW
Del Norte/Humboldt/Cape Mendocino/Morro Bay 376	15 MW turbines, 1343 turbines = 20 GW

Wind Speed Changes – Spring Season

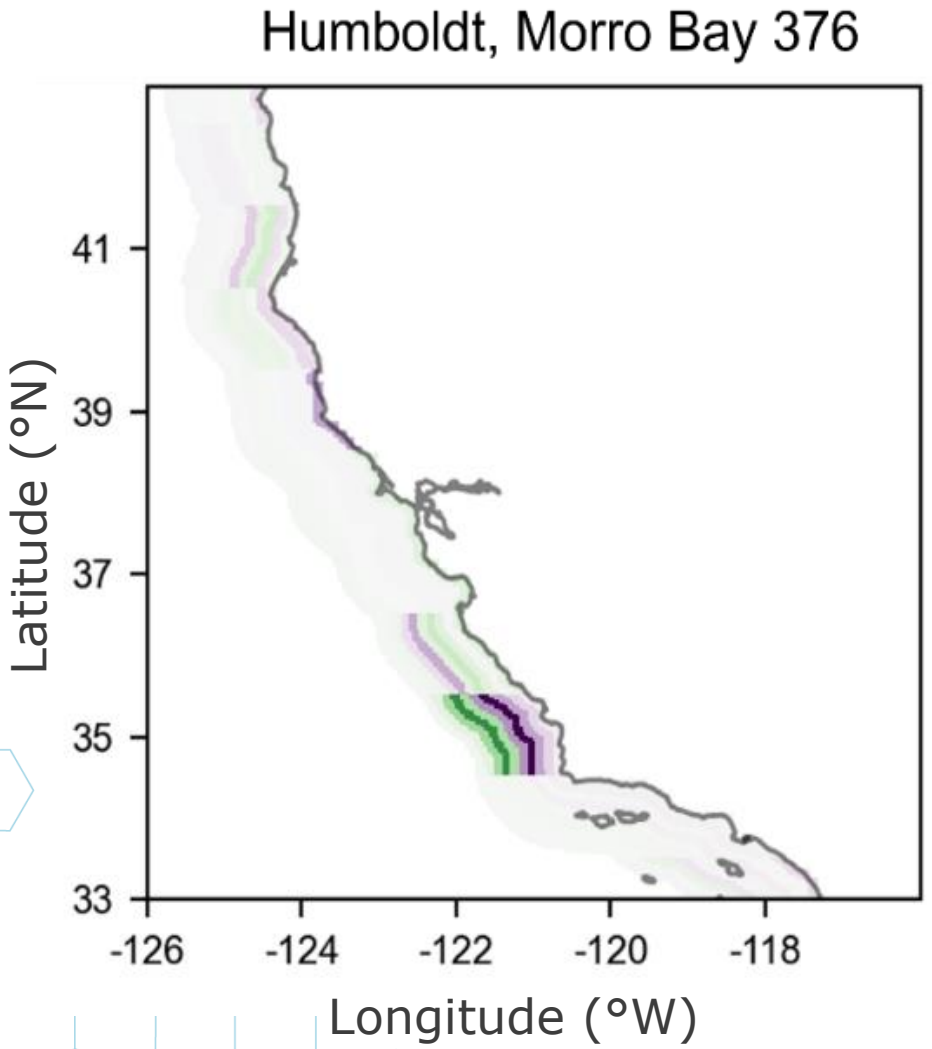


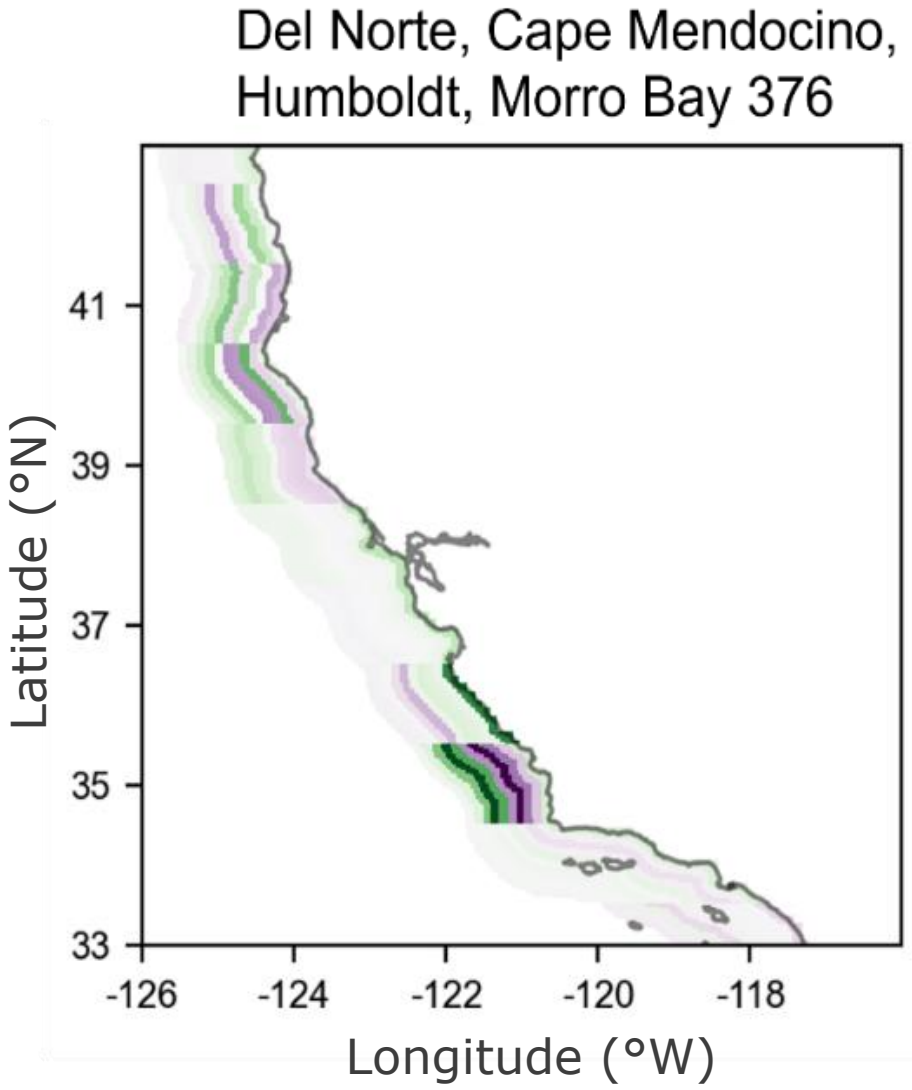




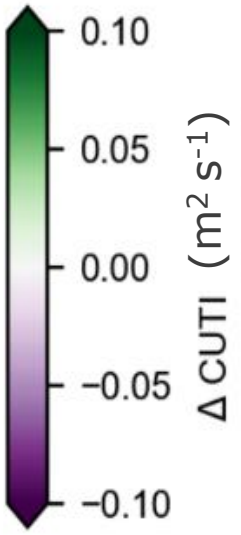
- Reductions in wind speed of 1 – 5%
- Smaller reductions at Humboldt area
- Larger reductions for larger footprints

Upwelling Metrics – CUTI (Upwelling Strength)





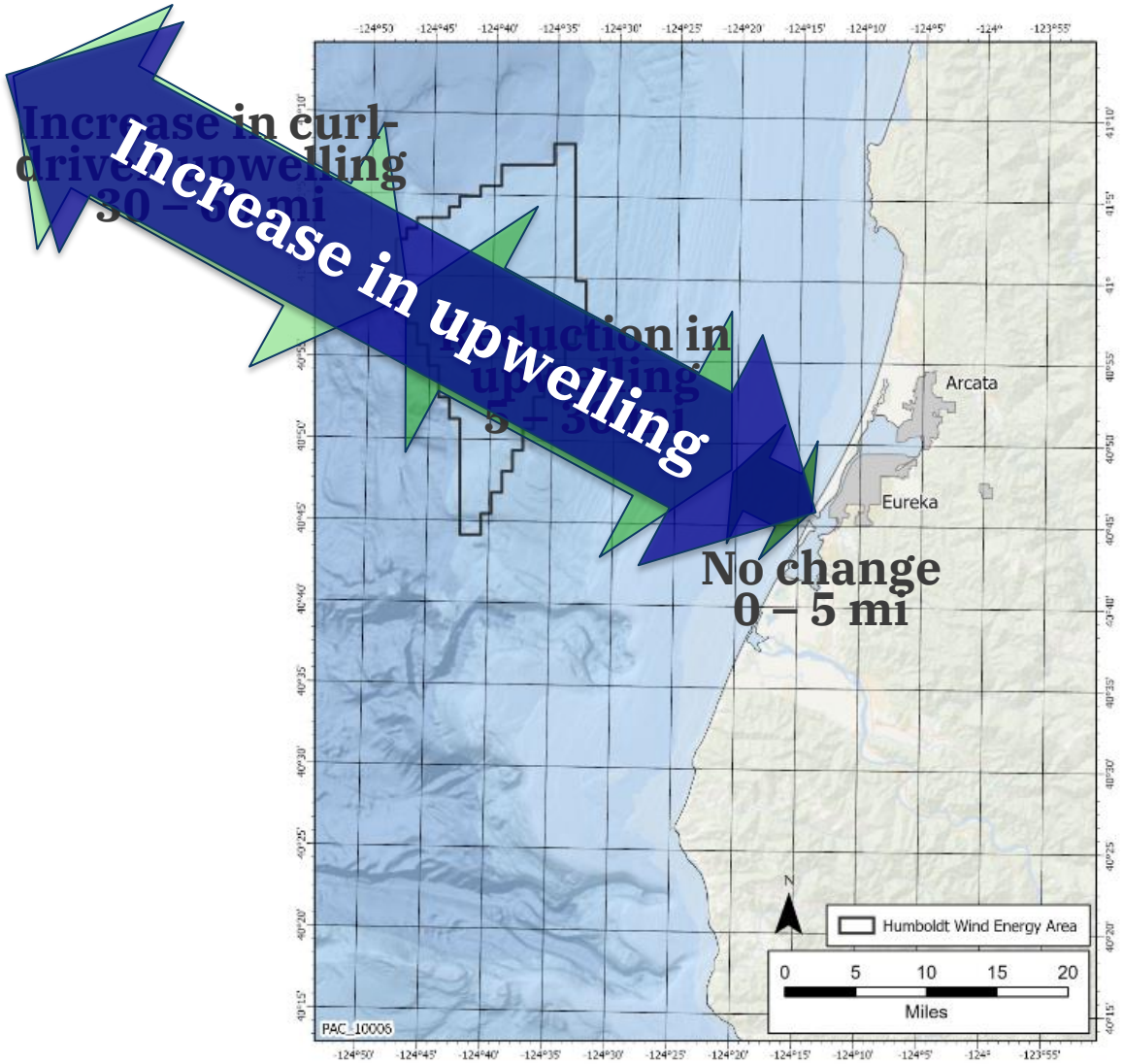
Enhancement in upwelling

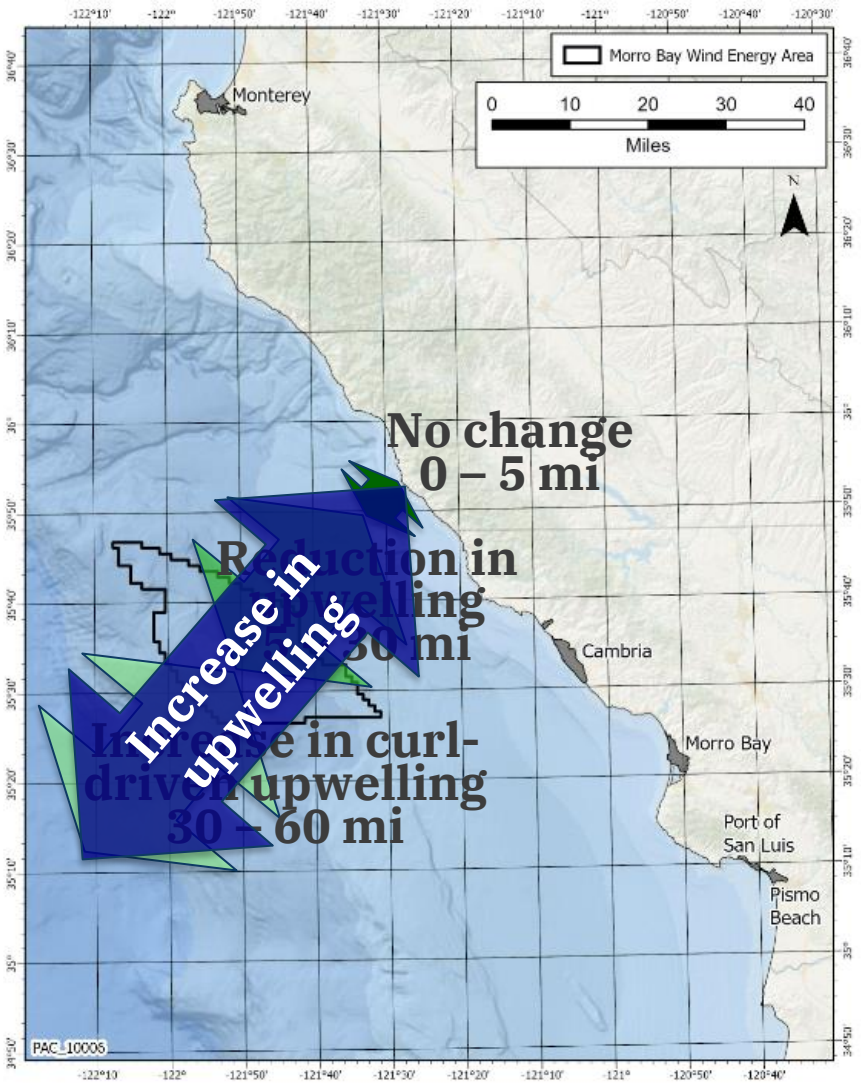


Reduction in upwelling

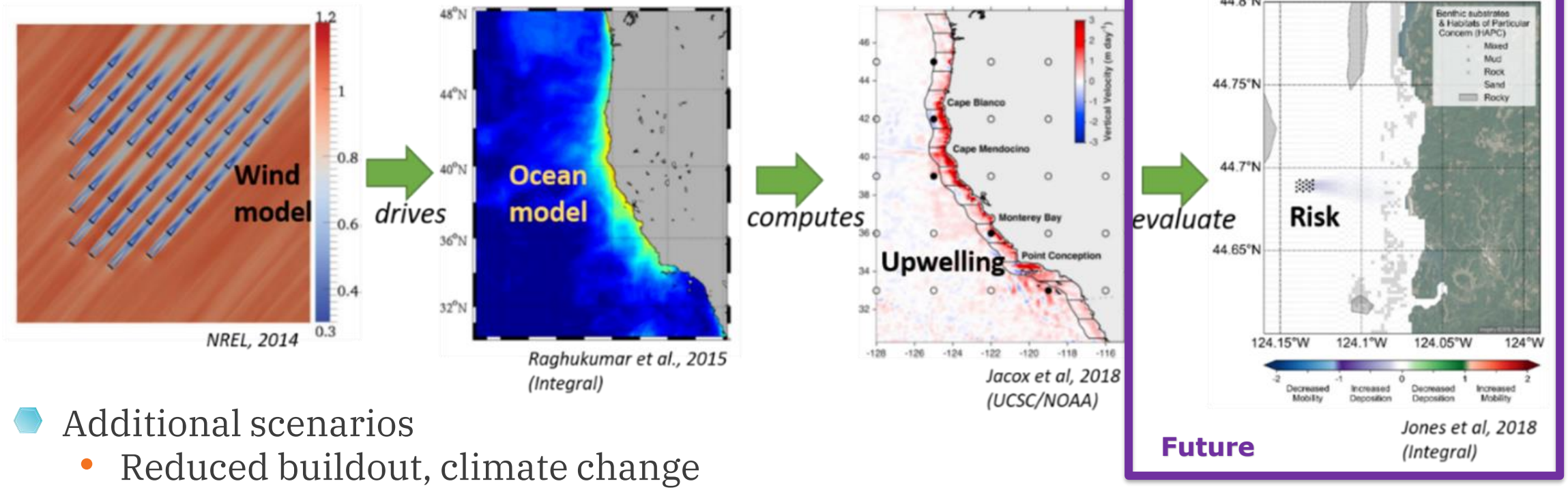
Key Findings

The ecosystem is NOT modeled!





Future Needs



- Additional scenarios
  - Reduced buildout, climate change
- Near-field effects of structures
- Fully coupled atmospheric-ocean circulation modeling
- Ecosystem modeling
  - Biogeochemistry, upper trophic levels
- Risk assessment: effects on fisheries and socio-economics

Additional Information

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- Raghukumar et al. (2023) **Projected cross-shore changes in upwelling induced by offshore wind farm development along the California coast**, Communications Earth & Environment, 4, 116. https://www.nature.com/articles/s43247-023-00780-y
- Raghukumar et al. (2022) **Effect of Floating Offshore Wind Turbines on Atmospheric Circulation in California**, Frontiers in Energy Research, 10. https://www.frontiersin.org/articles/10.3389/fenrg.2022.863995/full
- Integral Consulting Inc. (2022) **An Assessment of the Cumulative Impacts of Floating Offshore Wind Farms**, Ocean Protection Council Report, C0210404, Sacramento, CA. https://www.opc.ca.gov/2022/02/new-findings-from-first-ever-study-of-offshore-wind-development-on-coastal-upwelling-now-available/
- **NOAA Operational Upwelling Indices** https://oceanview.pfeg.noaa.gov/products/upwelling/cutibeuti

Acknowledgements

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