

# Can macroalgae mitigate ocean acidification and hypoxia *in situ*?

## Lessons learned from California kelp forests

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CALIFORNIA  
STATE UNIVERSITY  
NORTHRIDGE



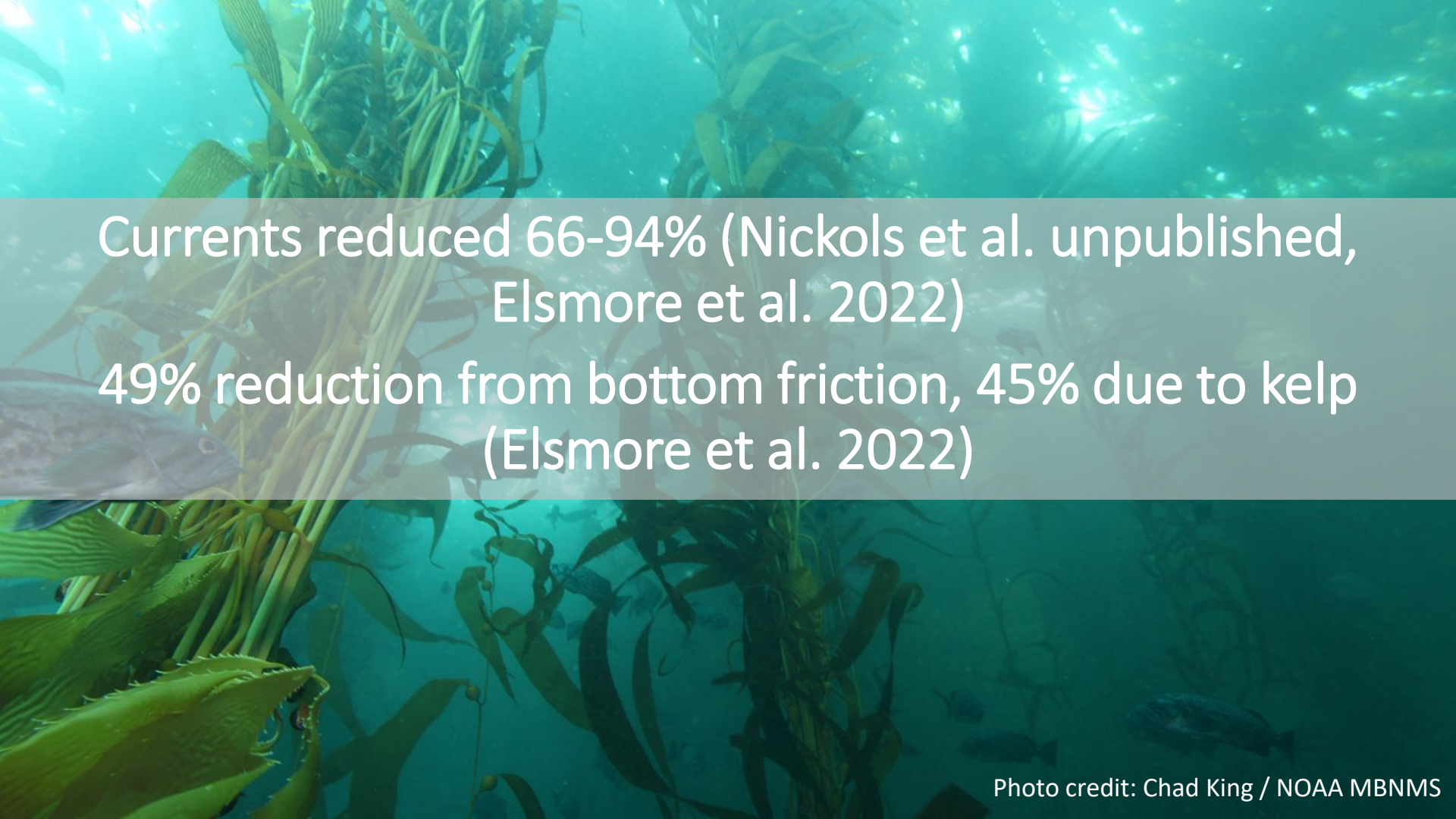
**Sea Grant**  
University of Southern California







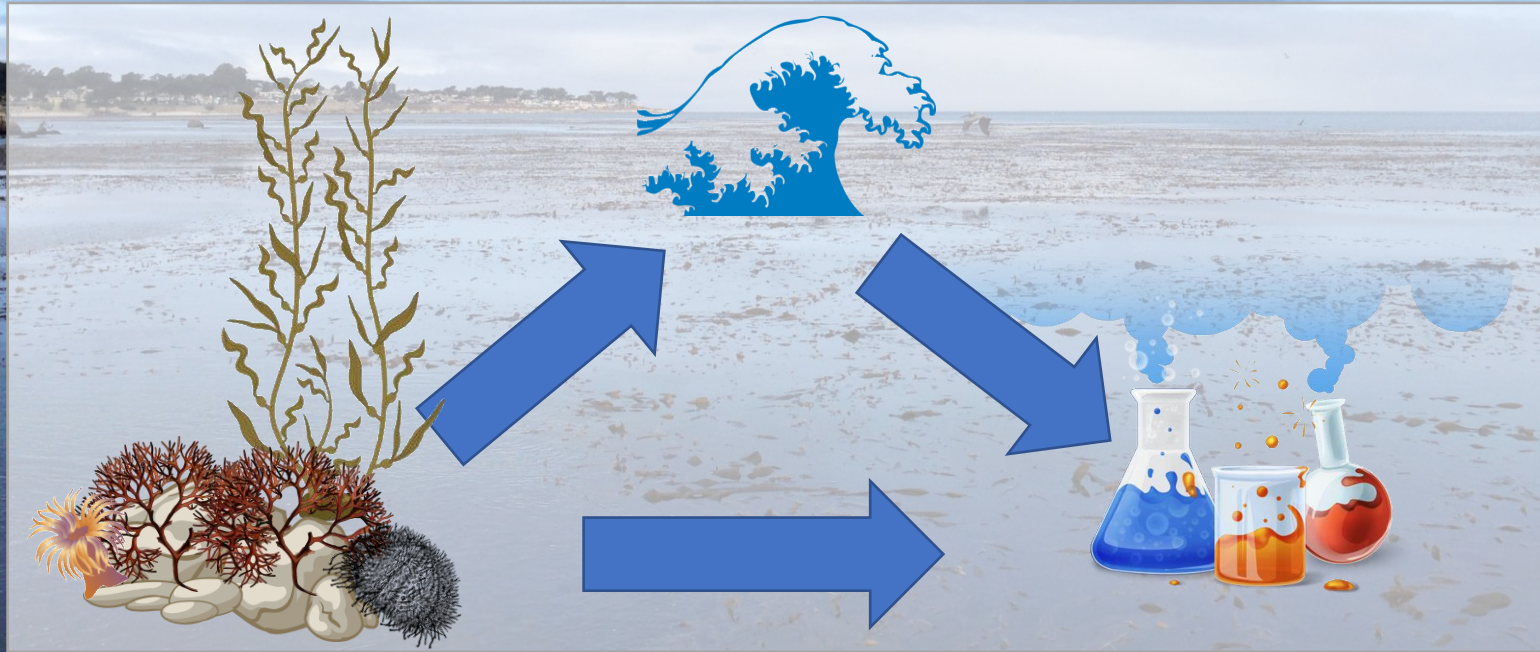
Photo credit: Chad King / NOAA MBNMS

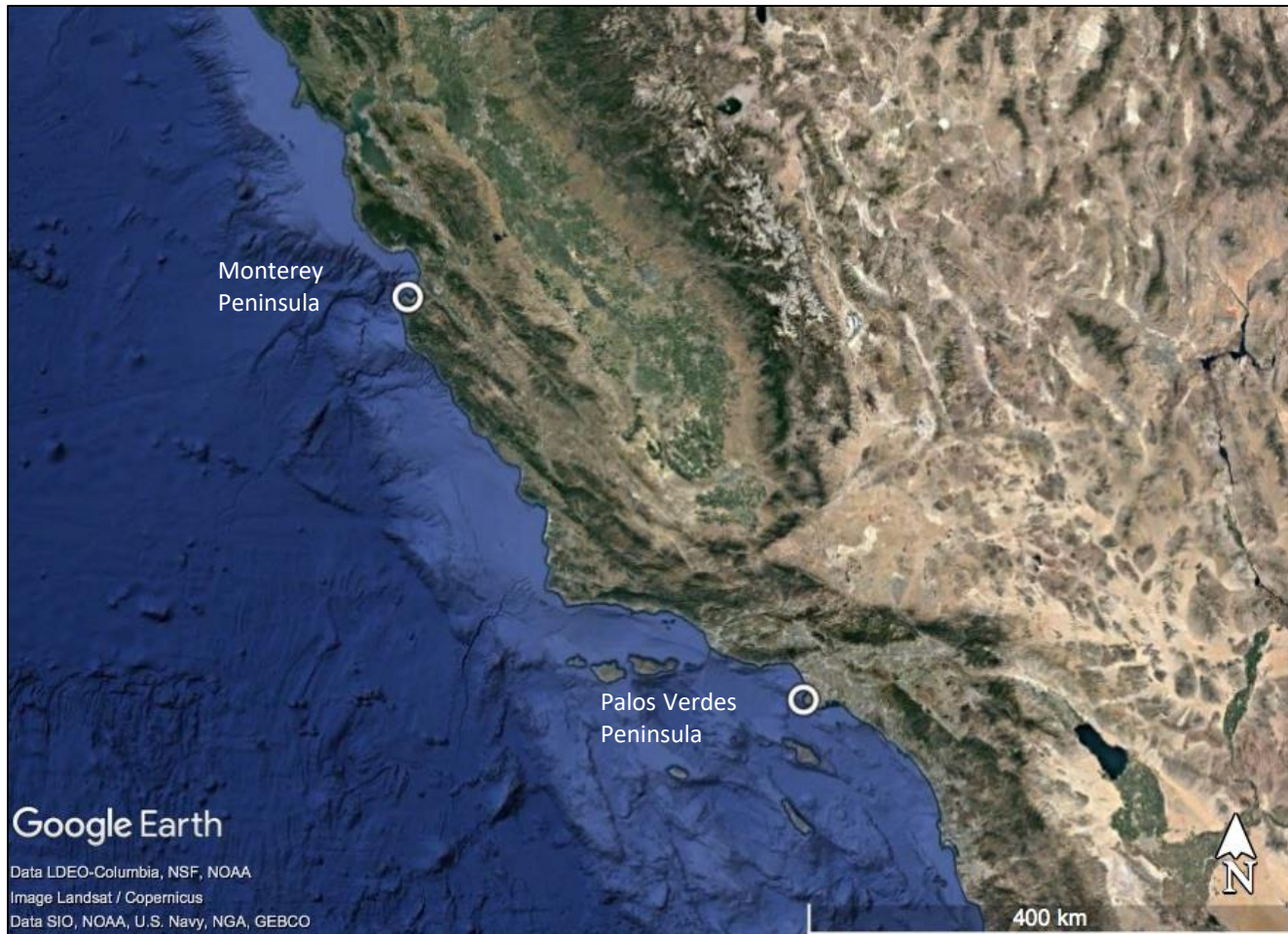
An underwater photograph of a kelp forest. The water is a clear, vibrant blue-green. In the foreground, several stalks of kelp with long, narrow, serrated blades rise from the bottom. A fish is visible on the left side, swimming towards the kelp. The background shows more kelp and the surface of the water with light filtering through.

Currents reduced 66-94% (Nickols et al. unpublished,  
Elsmore et al. 2022)

49% reduction from bottom friction, 45% due to kelp  
(Elsmore et al. 2022)

Where and when can we expect to see amelioration of chemical conditions associated with kelp forests?





Monterey  
Peninsula

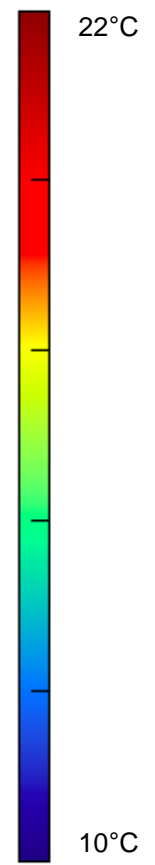
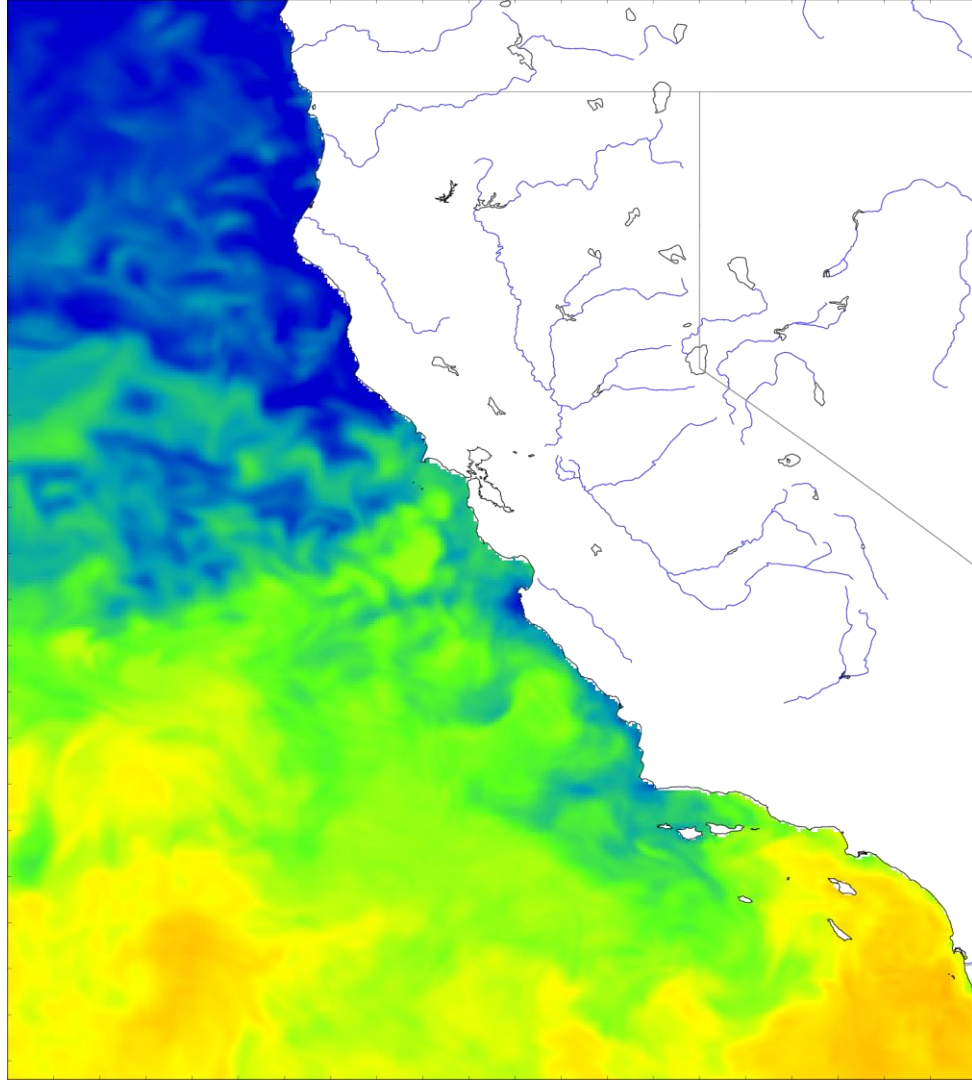
Palos Verdes  
Peninsula

Google Earth

Data LDEO-Columbia, NSF, NOAA  
Image Landsat / Copernicus  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

400 km







Otter Cove  
Wave-exposed – 2019

Hopkins Marine Station  
Wave-exposed – 2013, 2018

Hopkins Marine Station  
Wave-protected – 2013, 2018

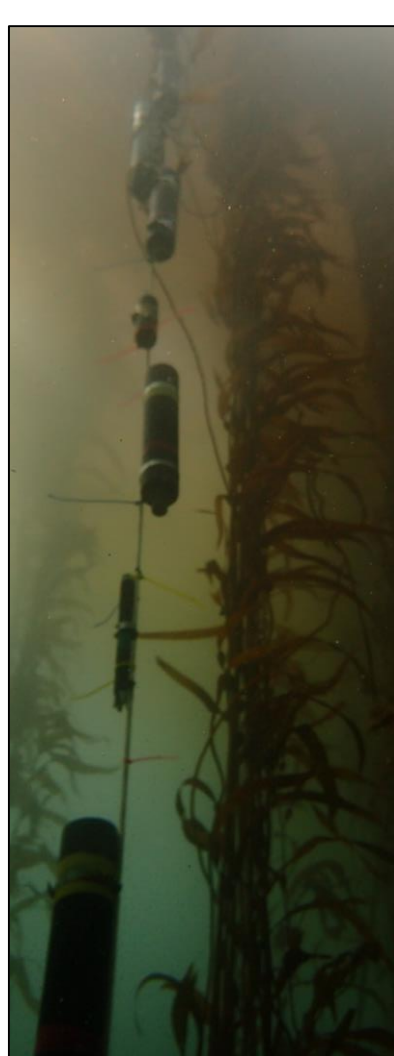
McAbee Beach  
Wave-protected – 2019

Google Earth

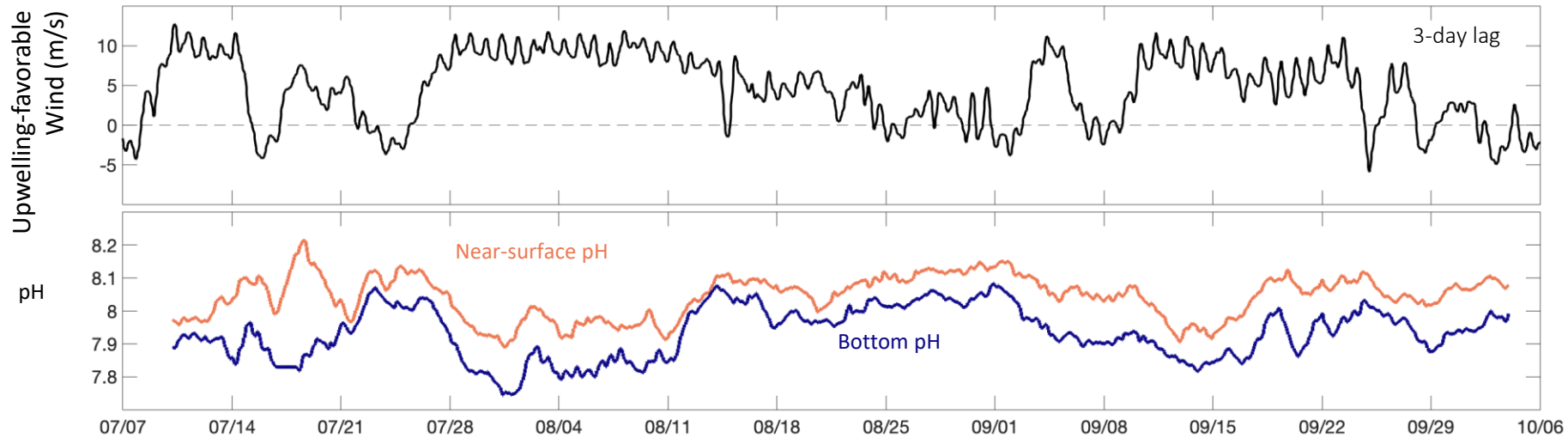
Data CSUMB SFML, CA OPC  
Image © 2020 TerraMetrics



2 km

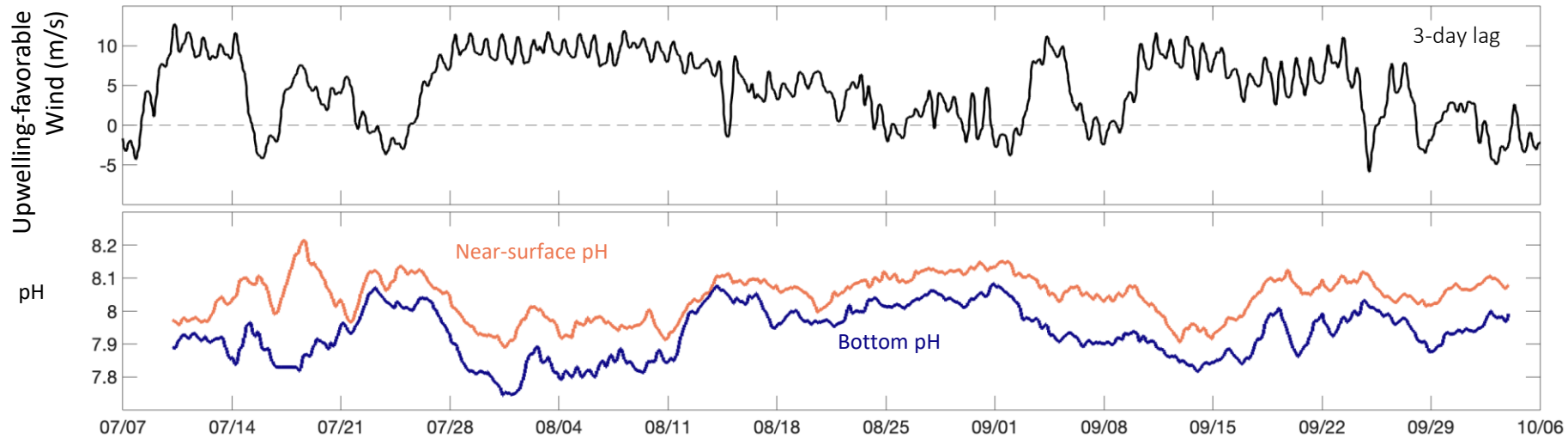


# Low frequency variability inside the kelp forest driven by upwelling

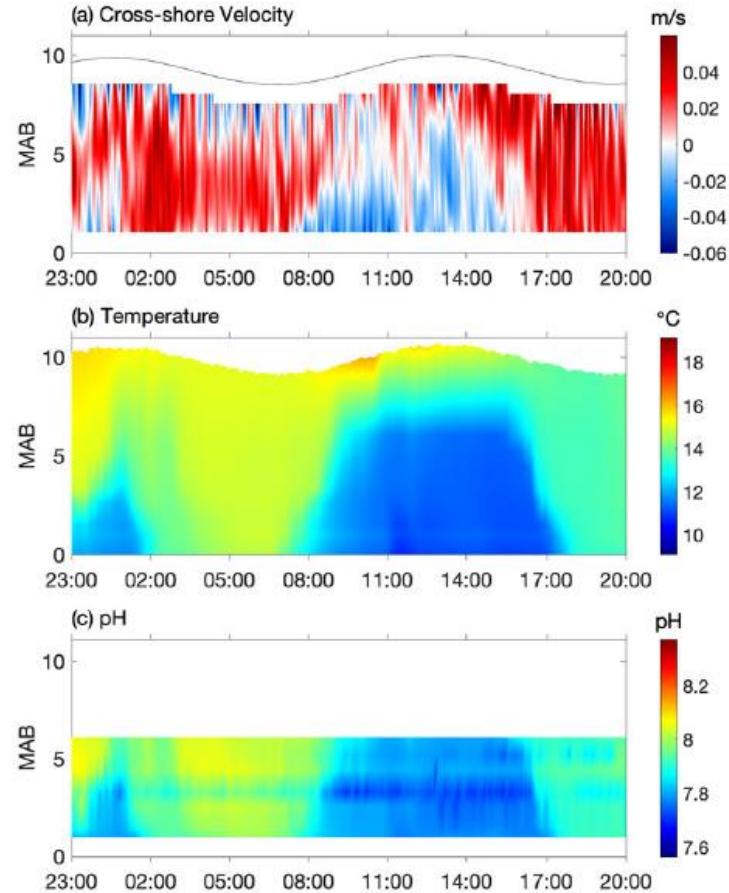


# Low frequency variability inside the kelp forest driven by upwelling

## Minimal difference inside and outside of kelp forest



# High frequency variability driven by internal bores



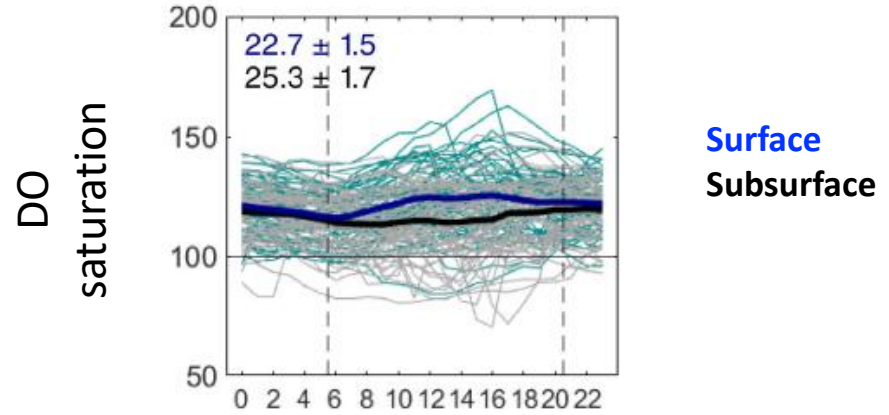


What's happening in the canopy?



# Wave-exposed

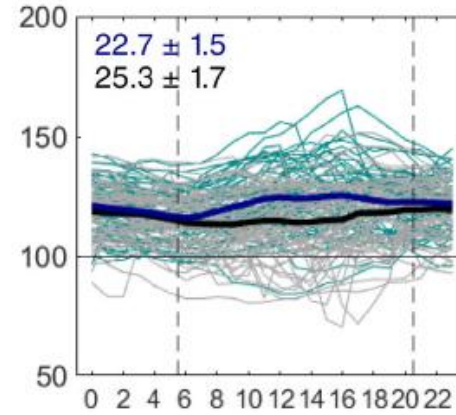
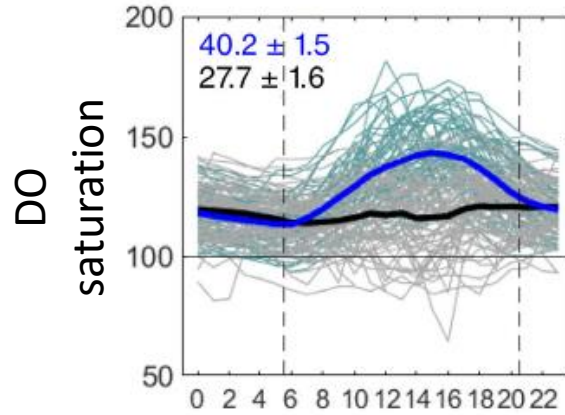
## Outside kelp



# Wave-exposed

## Inside kelp

## Outside kelp

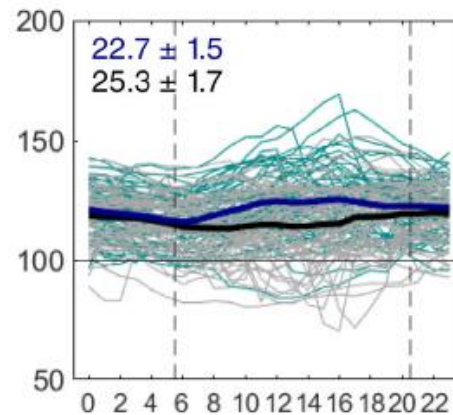
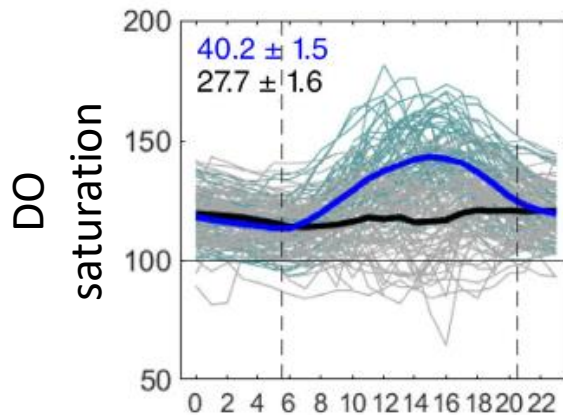


Surface  
Subsurface

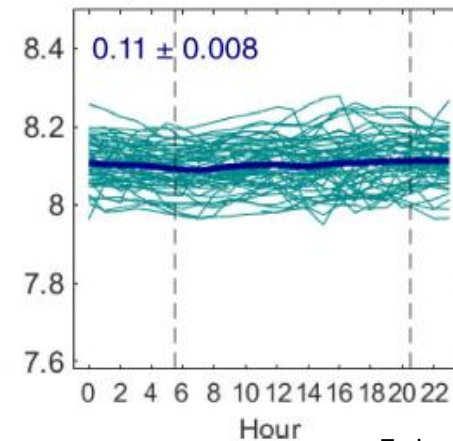
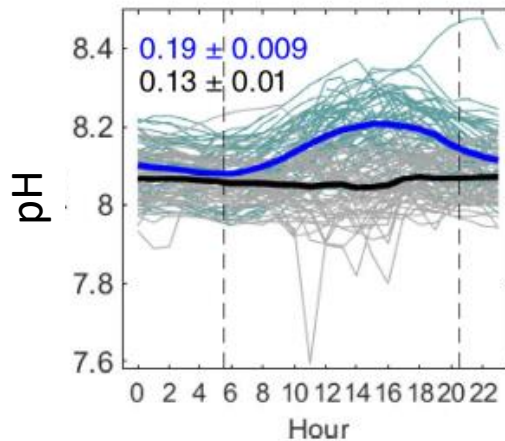
# Wave-exposed

## Inside kelp

## Outside kelp

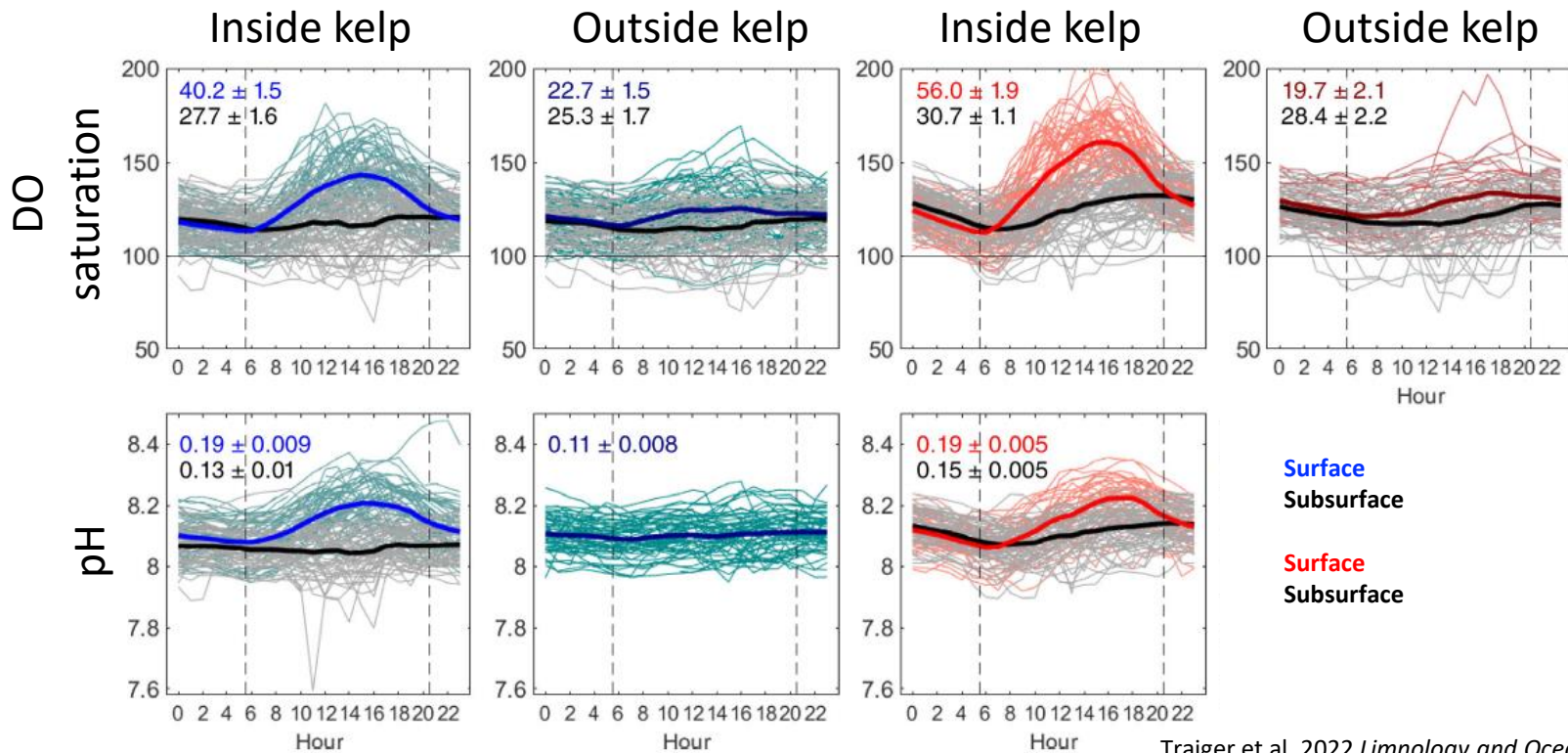


Surface  
Subsurface



## Wave-exposed

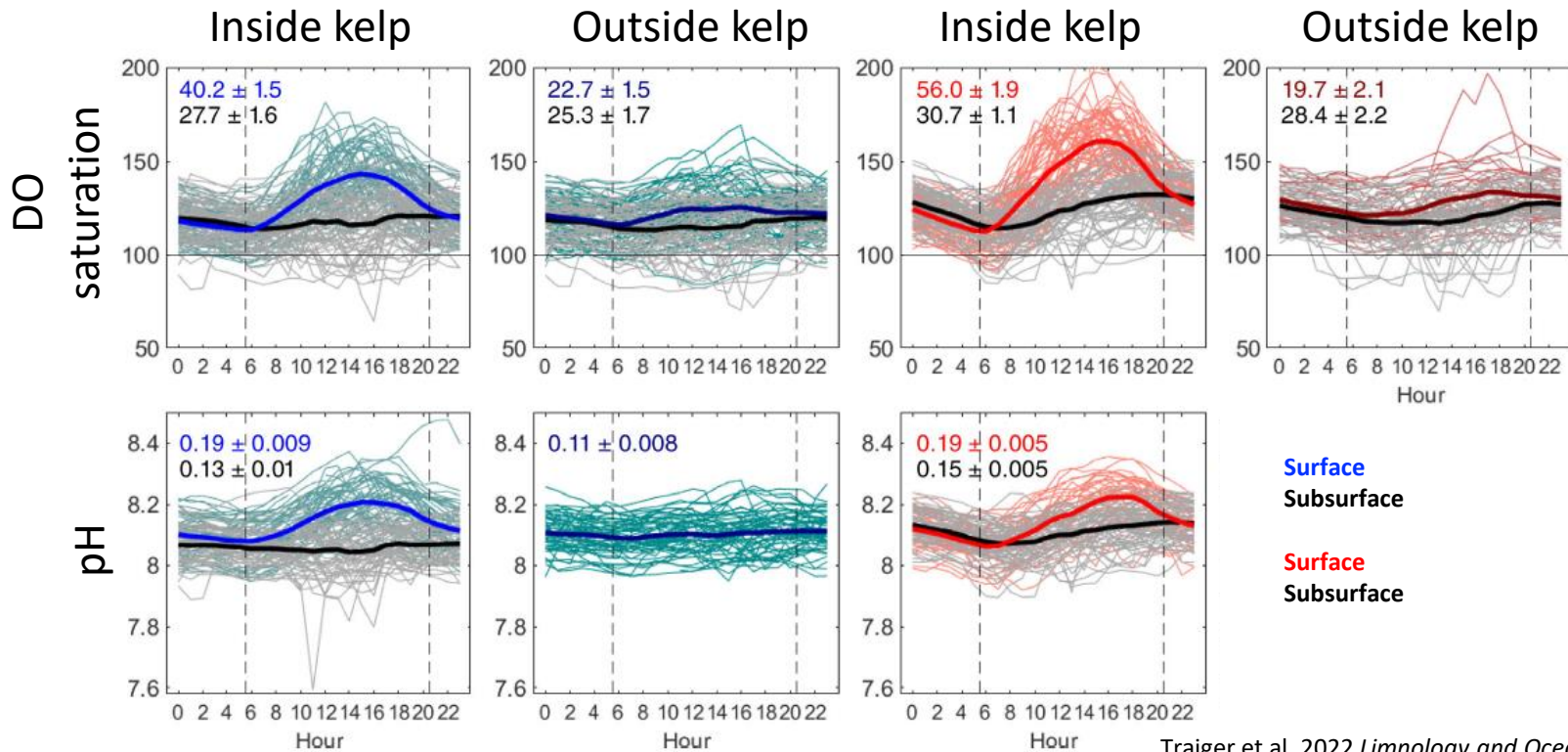
## Wave-protected



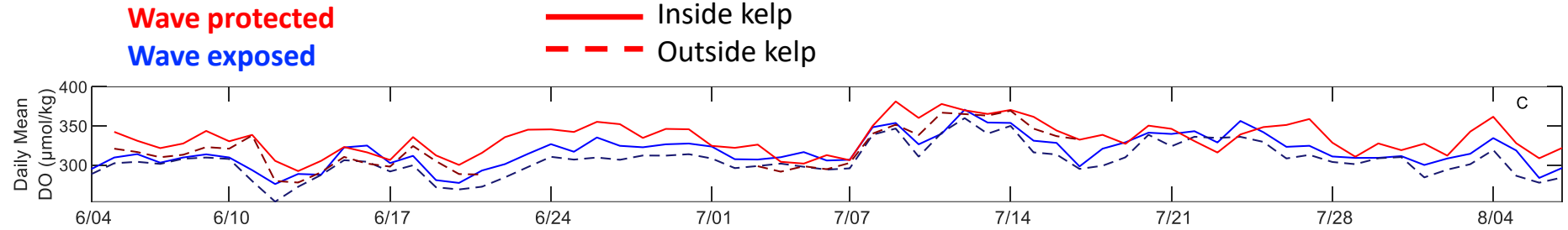
# Highest pH (and DO) at surface with strong daily signal indicates importance of kelp canopy

Wave-exposed

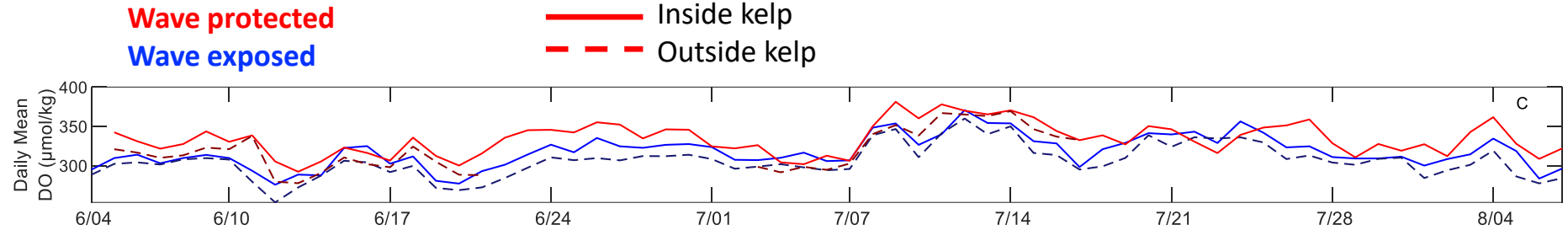
Wave-protected



# Biogeochemical differences between kelp forests



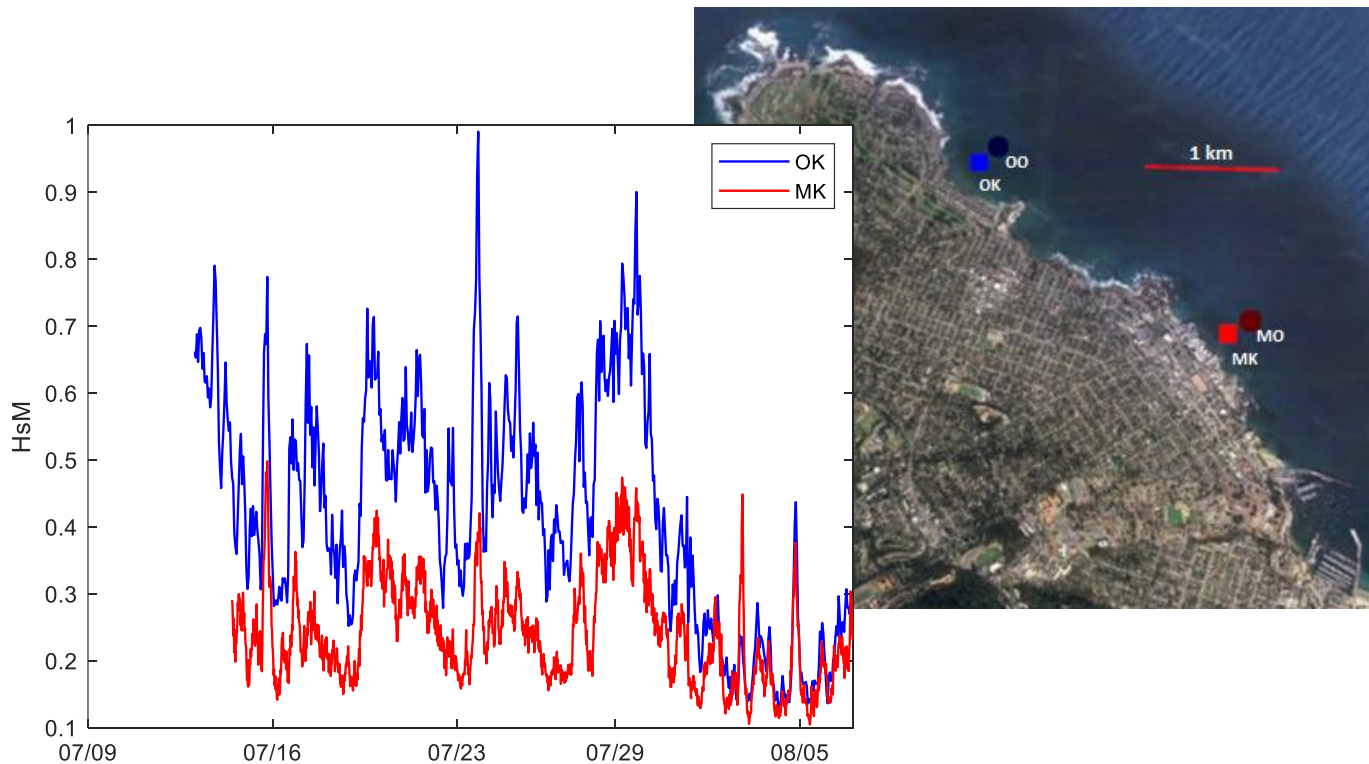
# Biogeochemical differences between kelp forests



Not related to:

- Phytoplankton
- Nutrients
- Kelp density
- Kelp growth

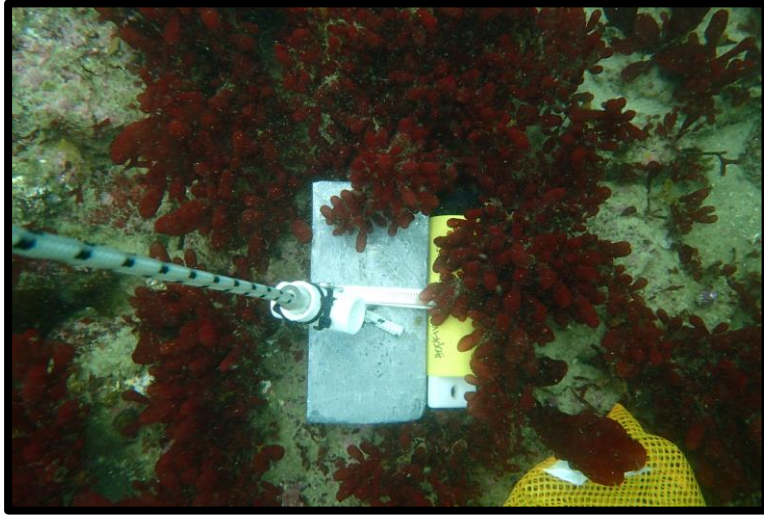
# Kelp forest sites differed in wave conditions



We did see higher pH and DO in kelp forests,  
and higher pH and DO at site with lower wave energy  
however....

- differences inside vs outside are small
  - mean DO 8% higher in kelp
  - mean pH 0.05 pH units higher in kelp
- differences between sites are also small
  - mean DO 6% higher at wave protected

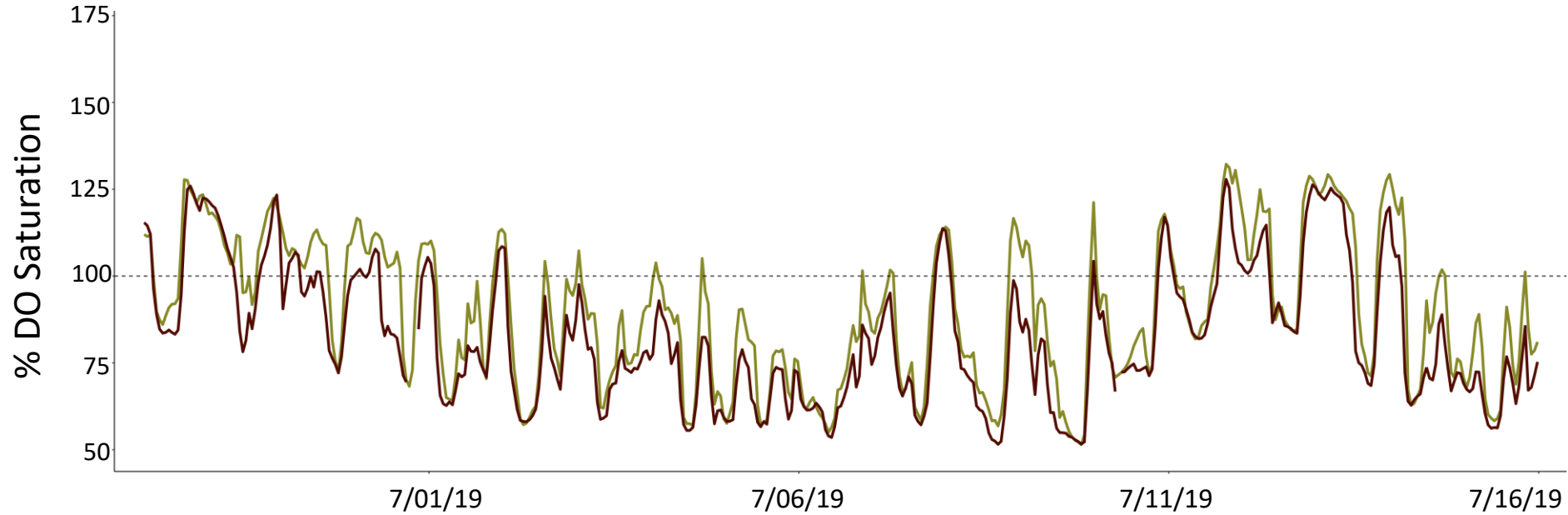
What about understory algal communities?



# Slight difference in magnitude of DO between communities but similar variability

McAbee Beach, Monterey Bay

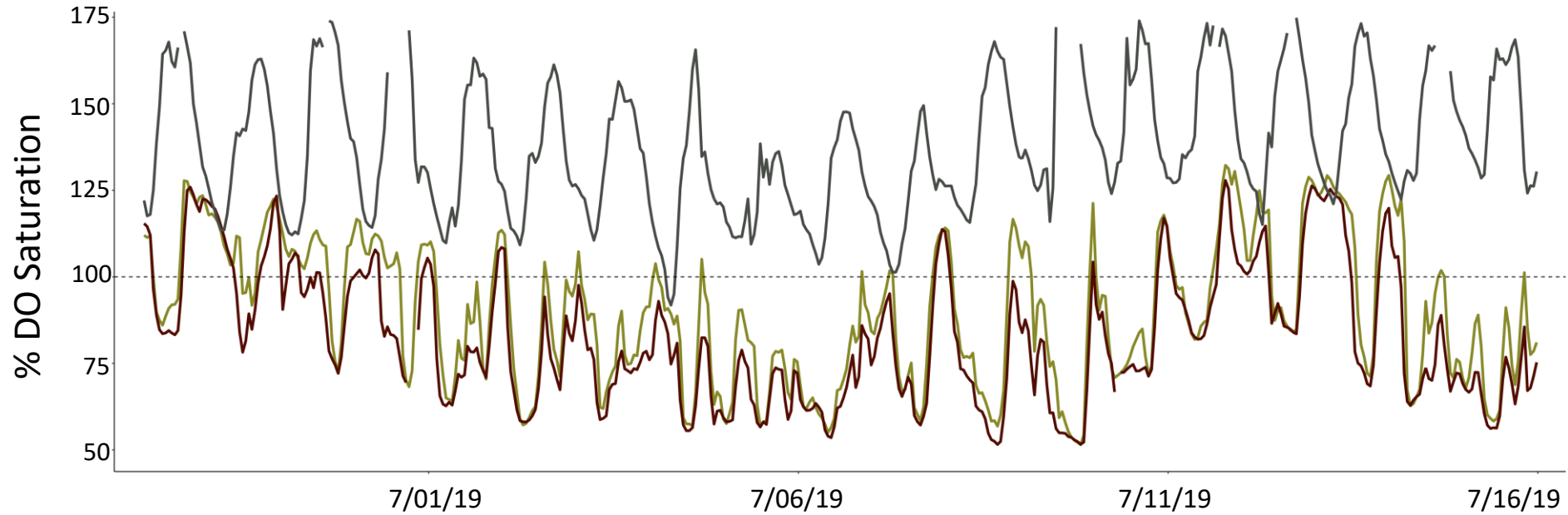
■ Brown Understory  
■ Red Understory



# Clear biological signal in DO at the surface

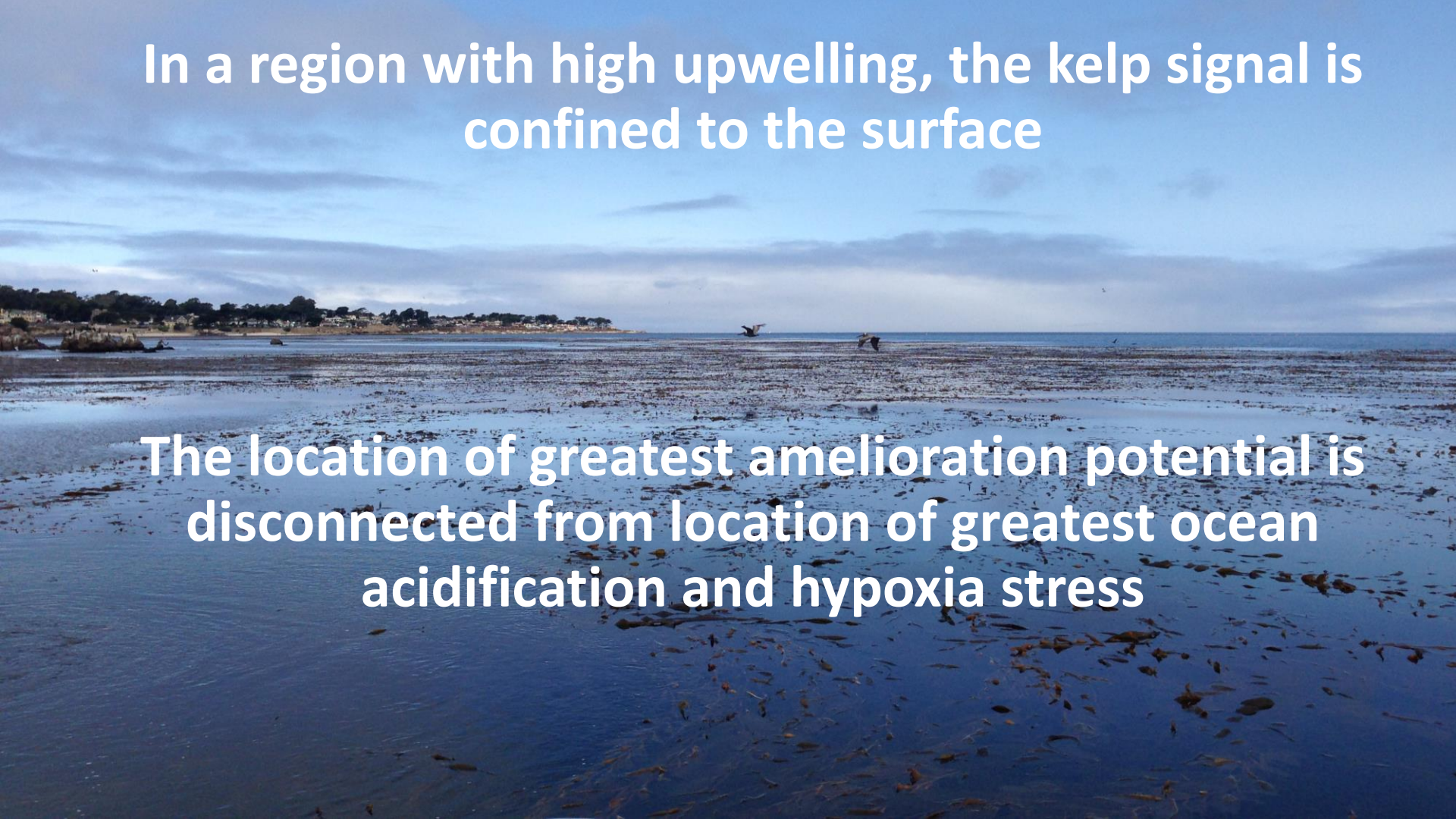
McAbee Beach, Monterey Bay

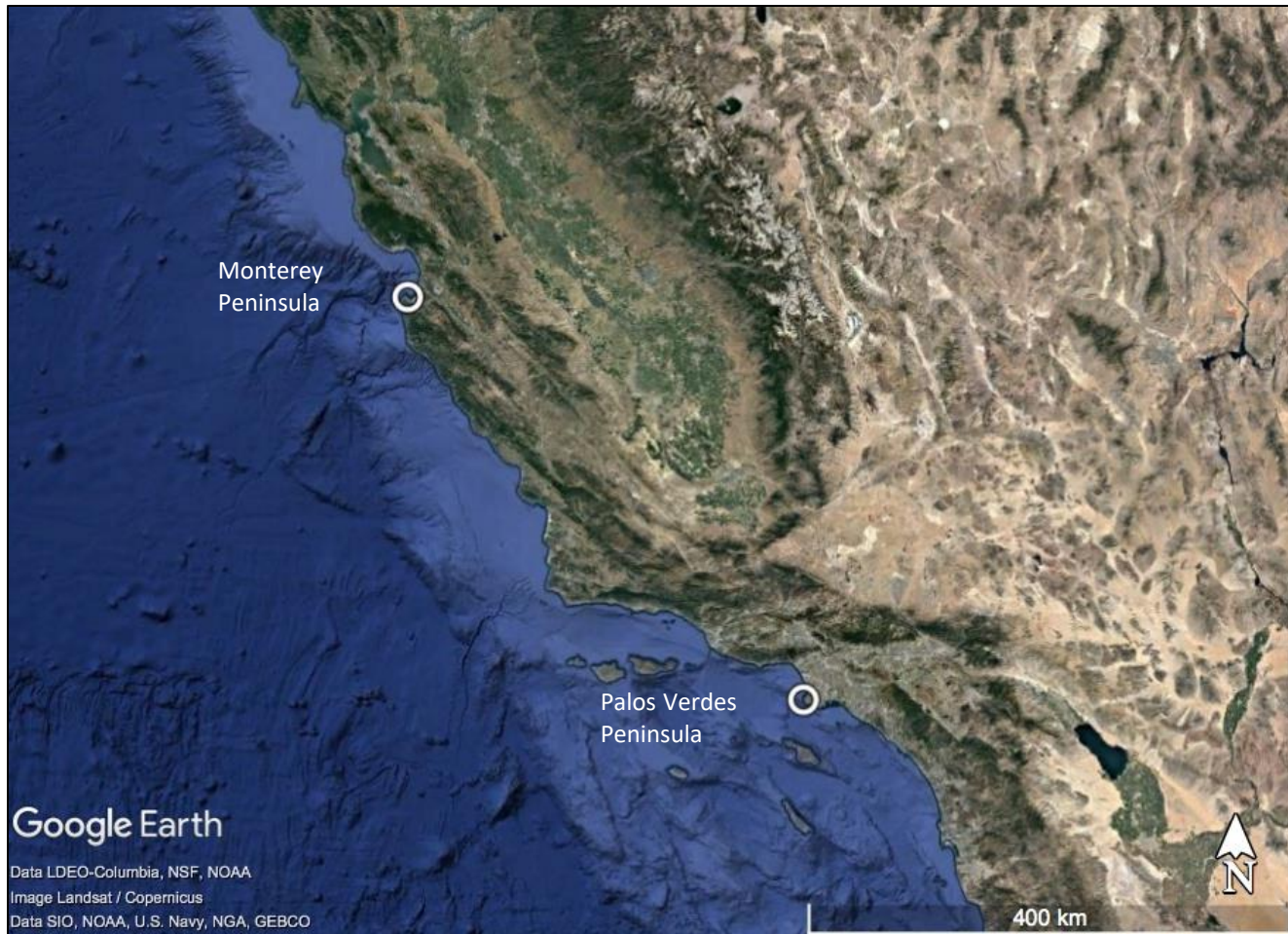
- Surface
- Brown Understory
- Red Understory



**In a region with high upwelling, the kelp signal is confined to the surface**

**The location of greatest amelioration potential is disconnected from location of greatest ocean acidification and hypoxia stress**





Monterey  
Peninsula

Palos Verdes  
Peninsula

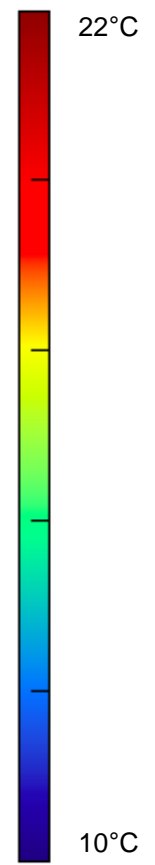
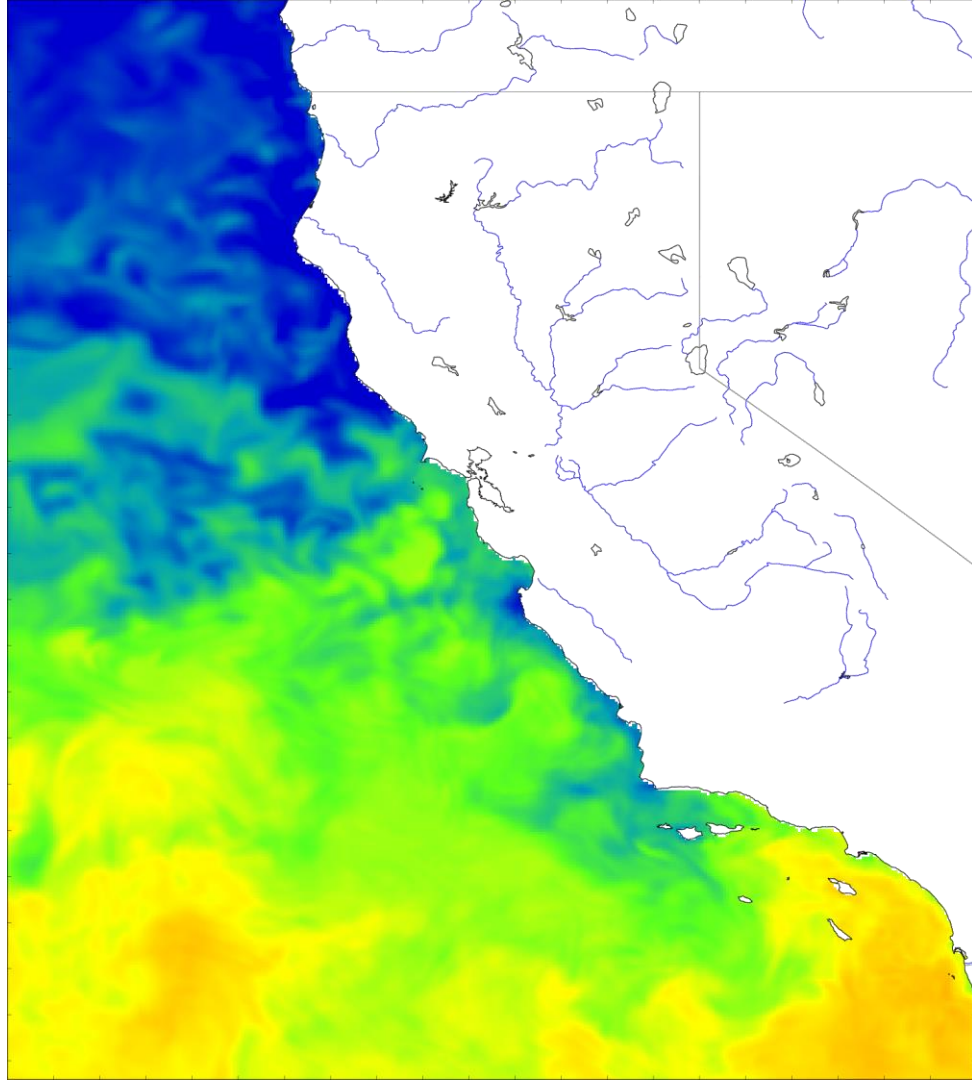
Google Earth

Data LDEO-Columbia, NSF, NOAA

Image Landsat / Copernicus

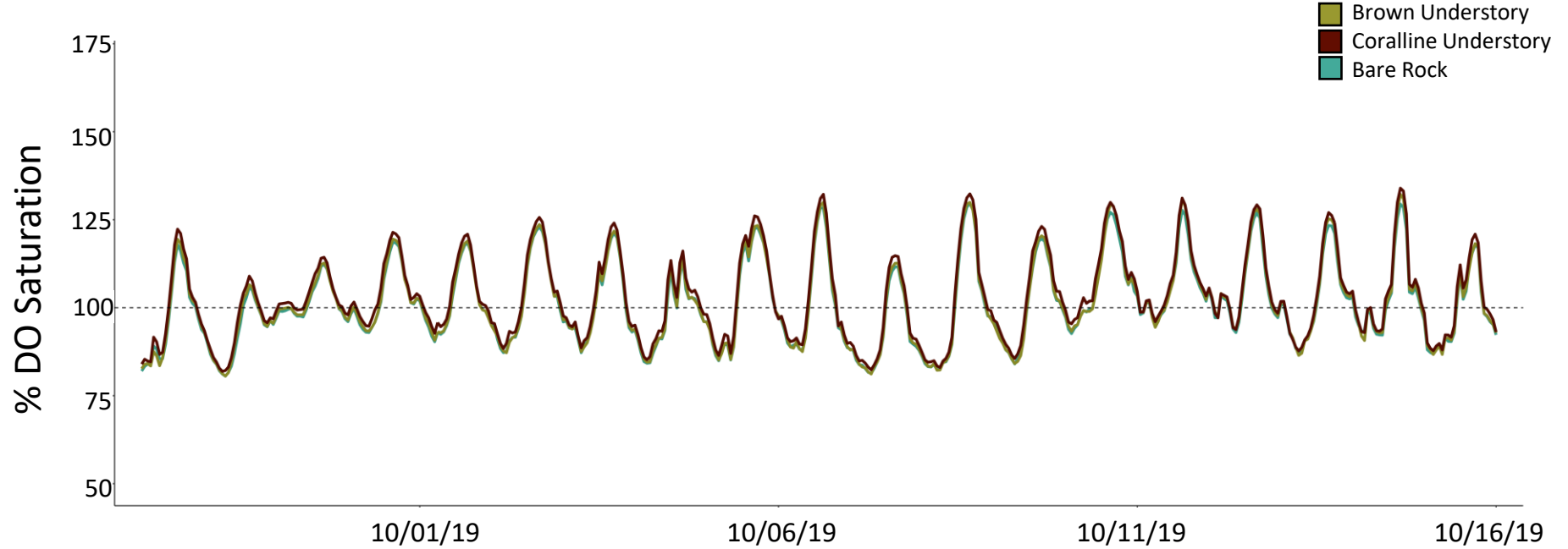
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

400 km



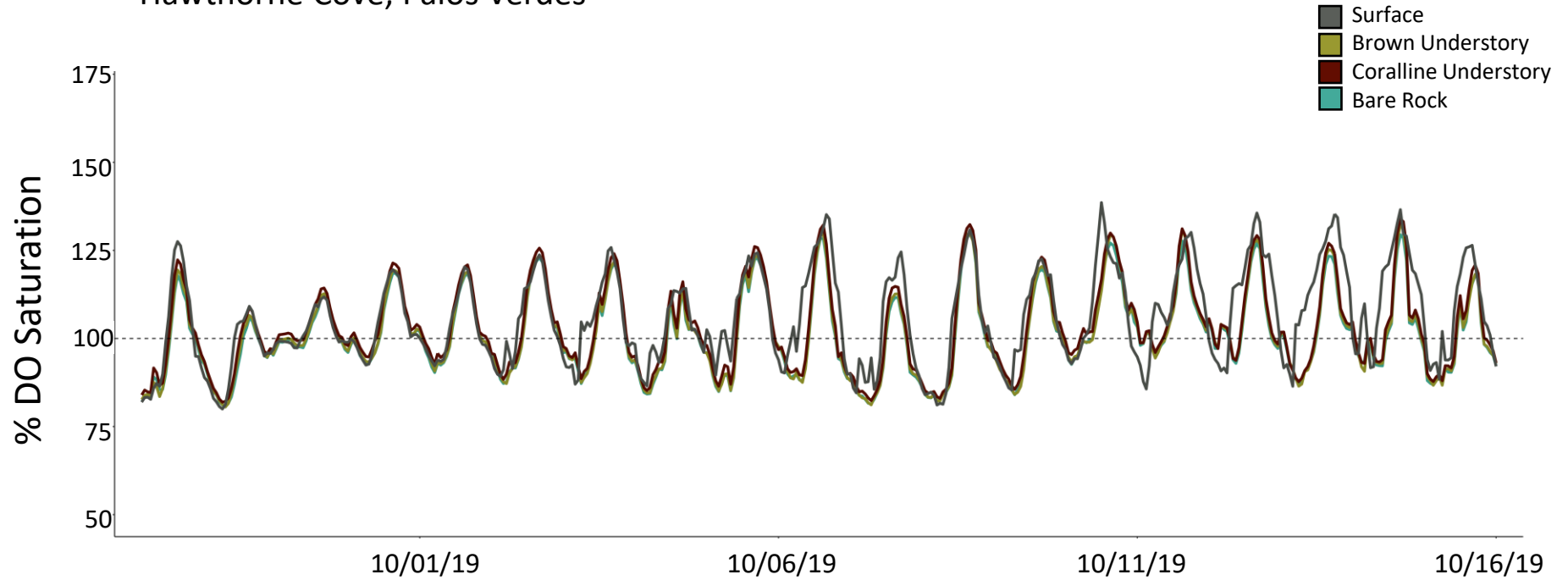
# No difference in magnitude or variability of DO between communities

Hawthorne Cove, Palos Verdes

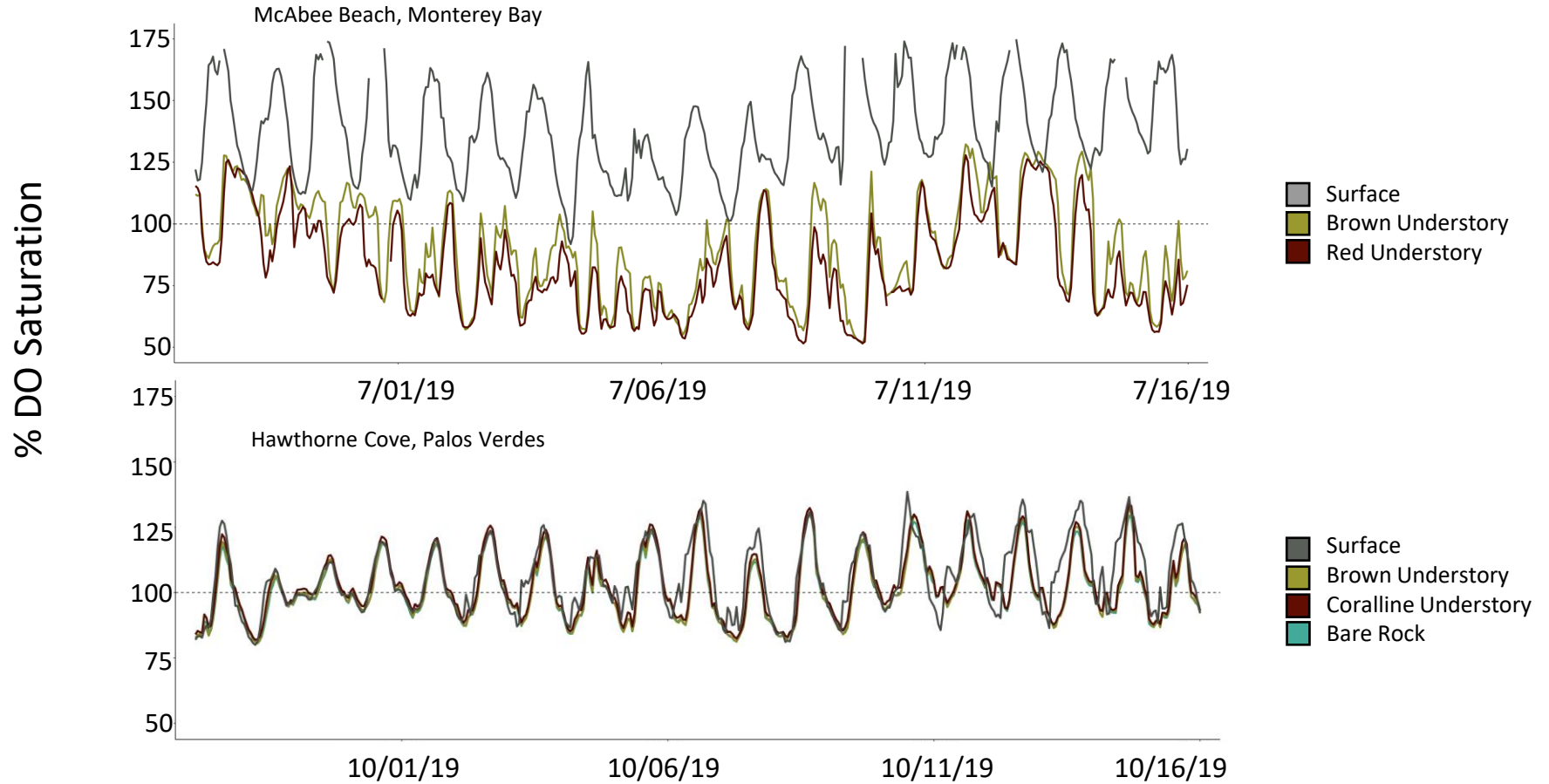


# Well mixed water column at Hawthorne enables kelp signal to reach benthic zone

Hawthorne Cove, Palos Verdes



# Well mixed water column at Hawthorne enables kelp signal to reach benthic zone



Daily Kelp  
Signal:



Day:  
High pH and high  
DO as kelp  
photosynthesizes



Night:  
Low pH and  
low DO with  
respiration

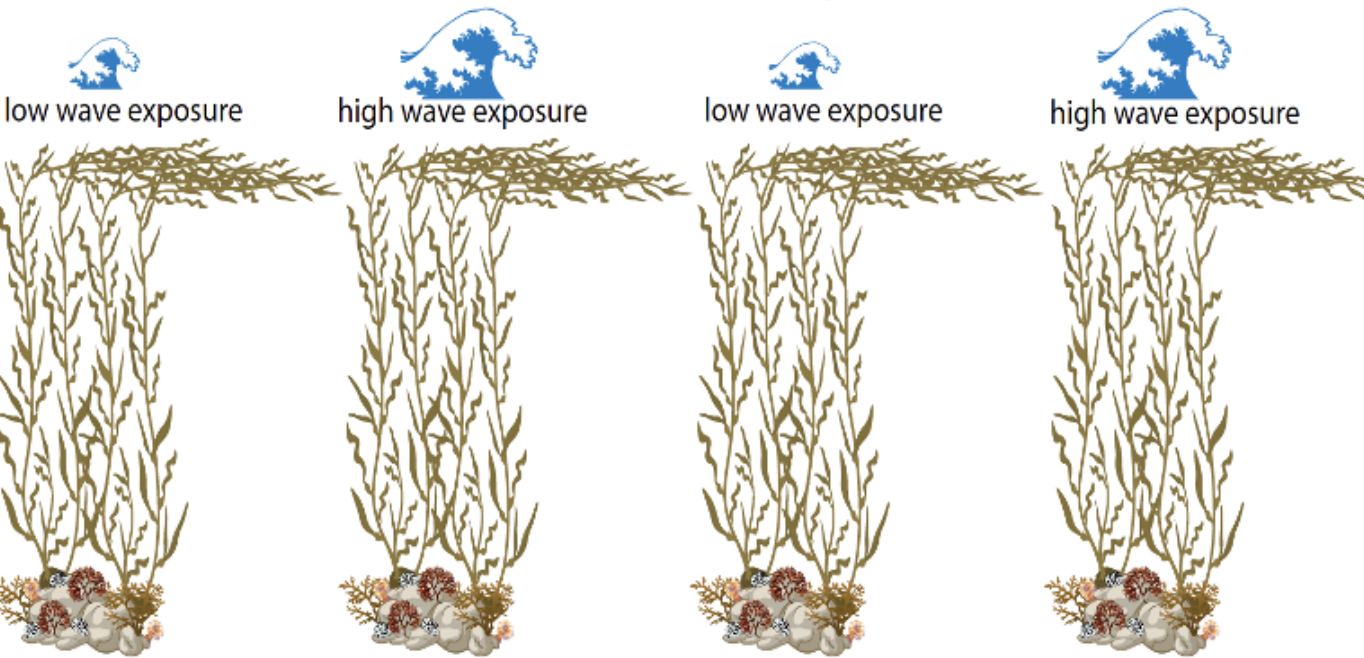
Low upwelling

High upwelling



Upwelling

Highest pH and DO within surface canopy in all scenarios



Strong daily kelp signal


Large scale oceanography drives chemical signature

Stratified

Well mixed

Some daily kelp signal

Minimal daily kelp signal

A wide-angle photograph of a coastal scene at low tide. The foreground is dominated by a vast expanse of shallow water, densely populated with brown, leafy kelp. The water reflects the overcast, blue-grey sky. In the middle ground, a thin strip of land is visible, featuring a small town or village with buildings and trees. The horizon line is low, and the sky is filled with soft, diffused light, suggesting an overcast day. The overall color palette is muted, with various shades of blue, grey, and brown.

Where and when can we expect to see  
amelioration of chemical conditions associated  
with kelp forests?

**Greatest amelioration potential is at surface**

**It depends on the site-specific  
physical context**

A better option?

Stop emitting carbon



# Acknowledgments



## Ecological Oceanography Lab @CSUN

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