past, present, future of coastal upwelling and ecosystem in california

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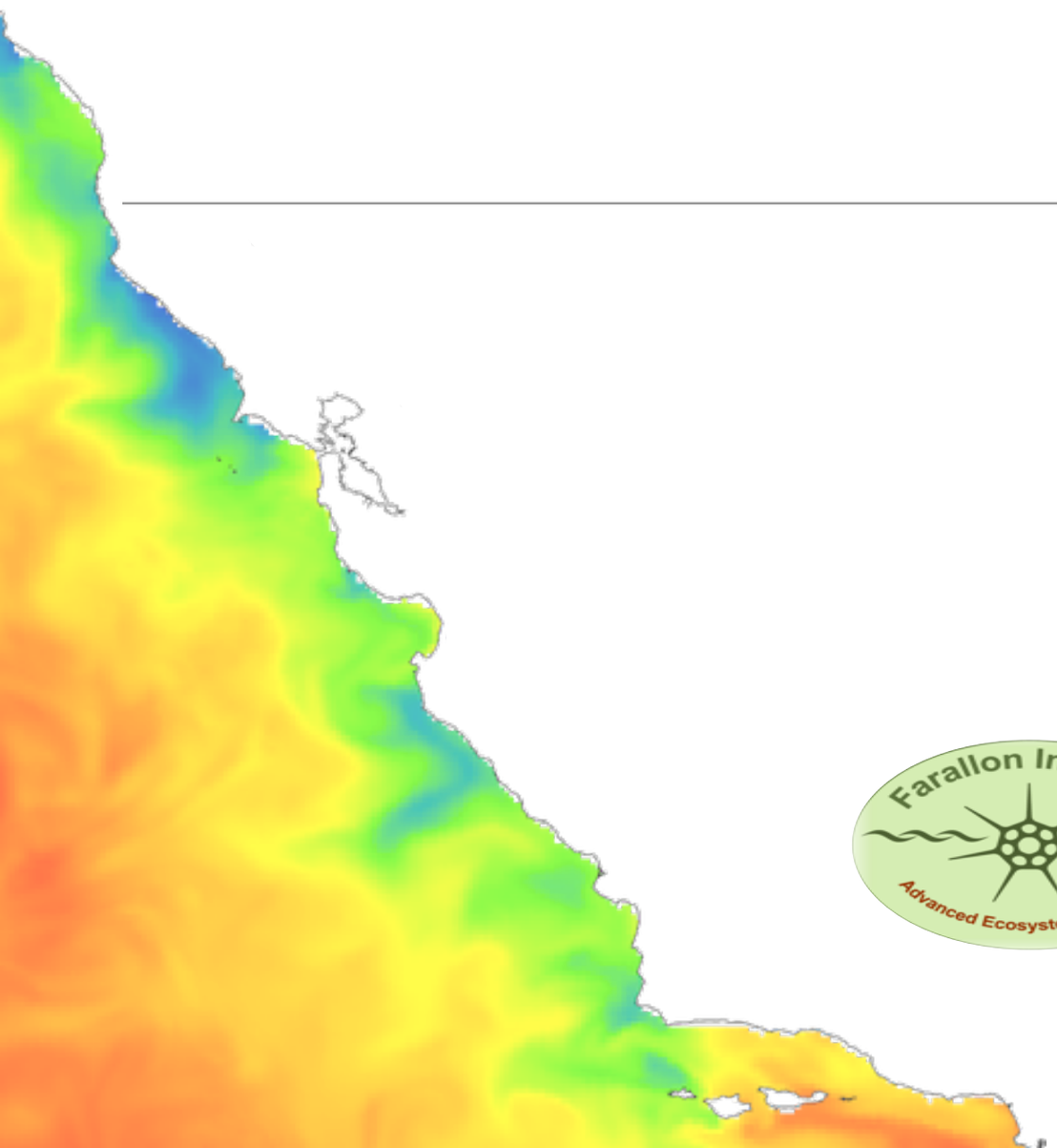
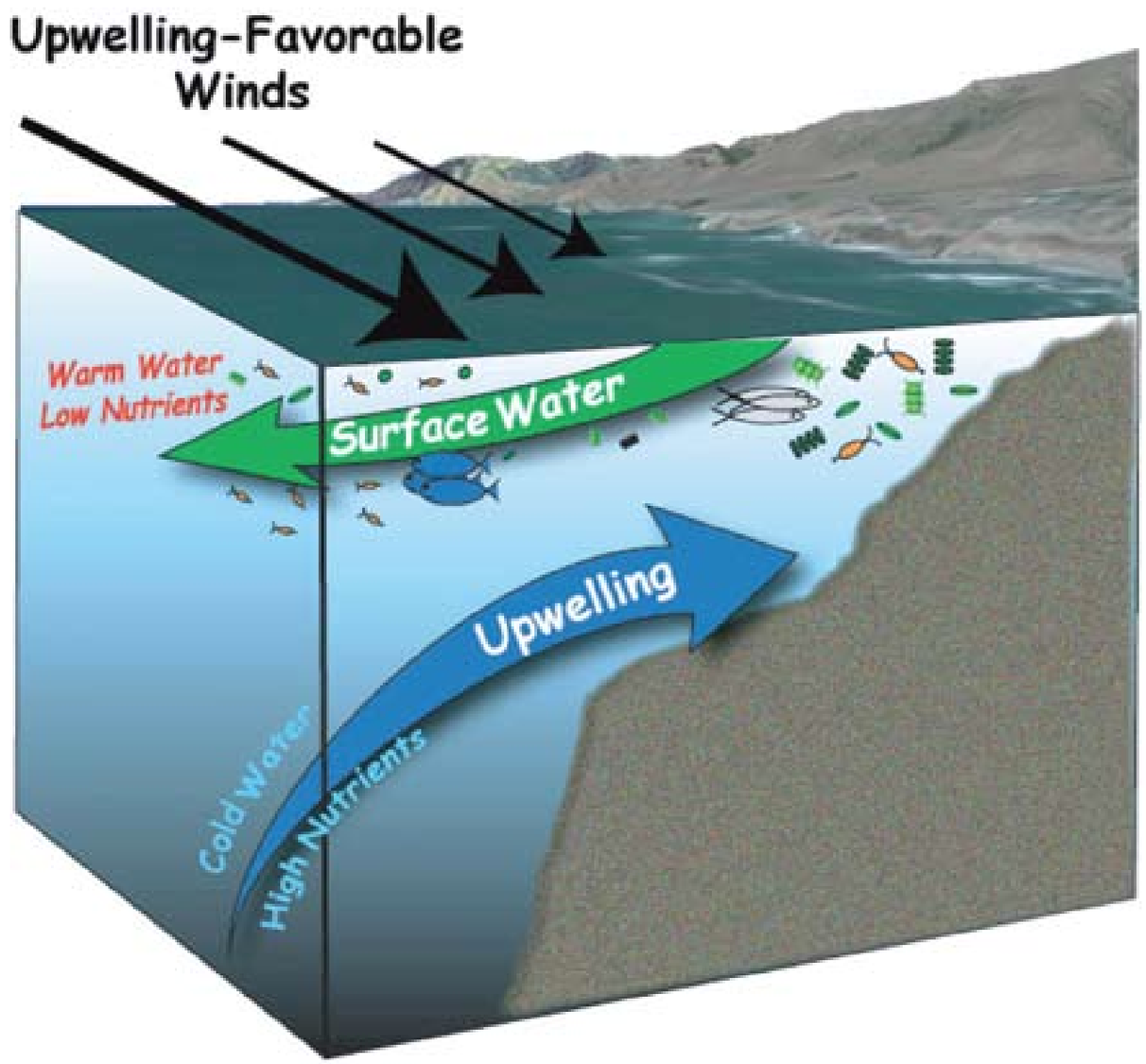
steven j. bograd \ noaa-nmfs



roadmap

- coastal upwelling & ecosystem
- present
  - modes of variability
  - implications for the ecosystem
  - drivers
- past
  - what ocean & land have in common?
  - what the past tell us?
- future
  - upwelling & climate change
  - bakun hypothesis
- summary

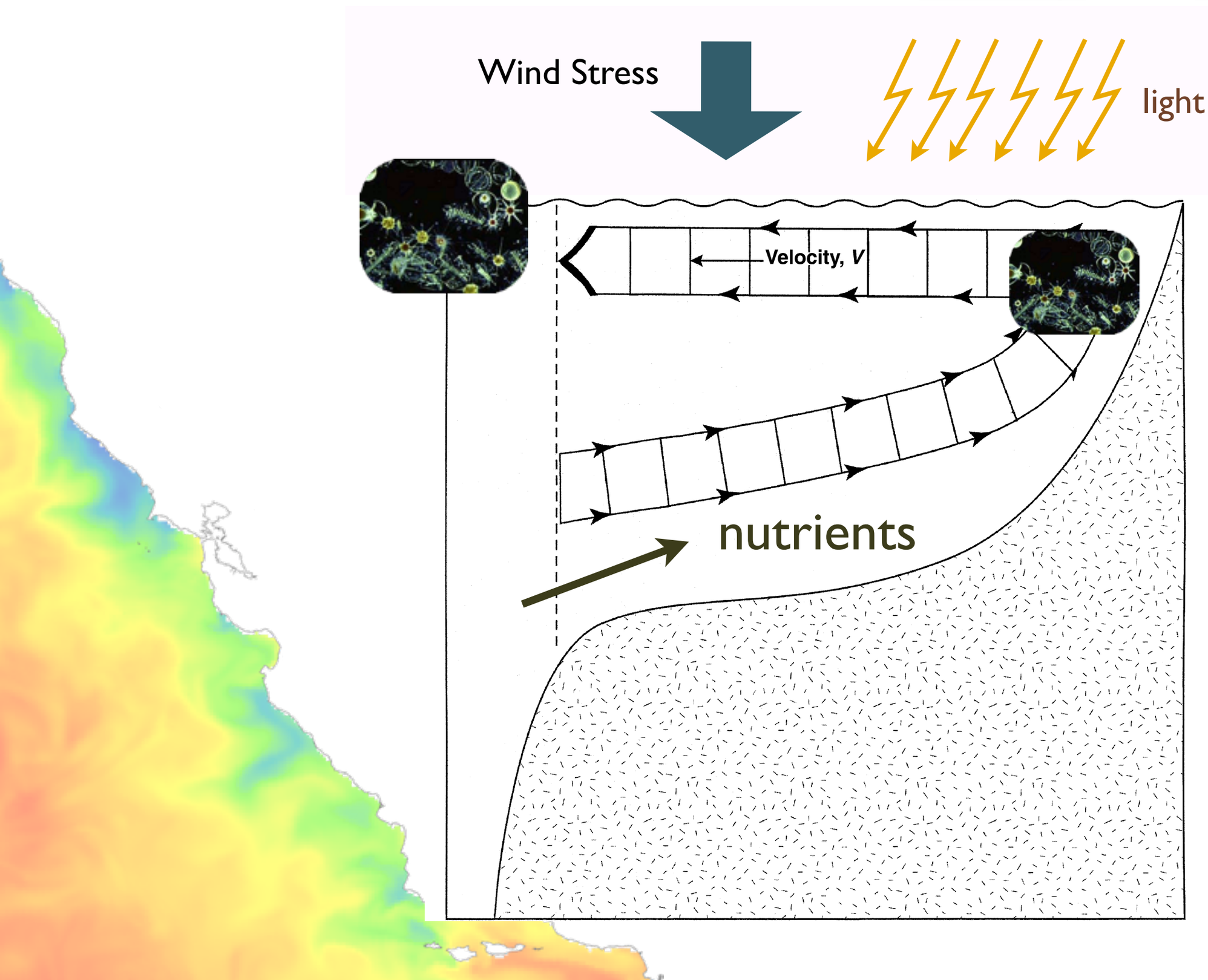
coastal upwelling



Kudela et al., 2008

atmospheric driver
ocean physical and chemical response
biological implications

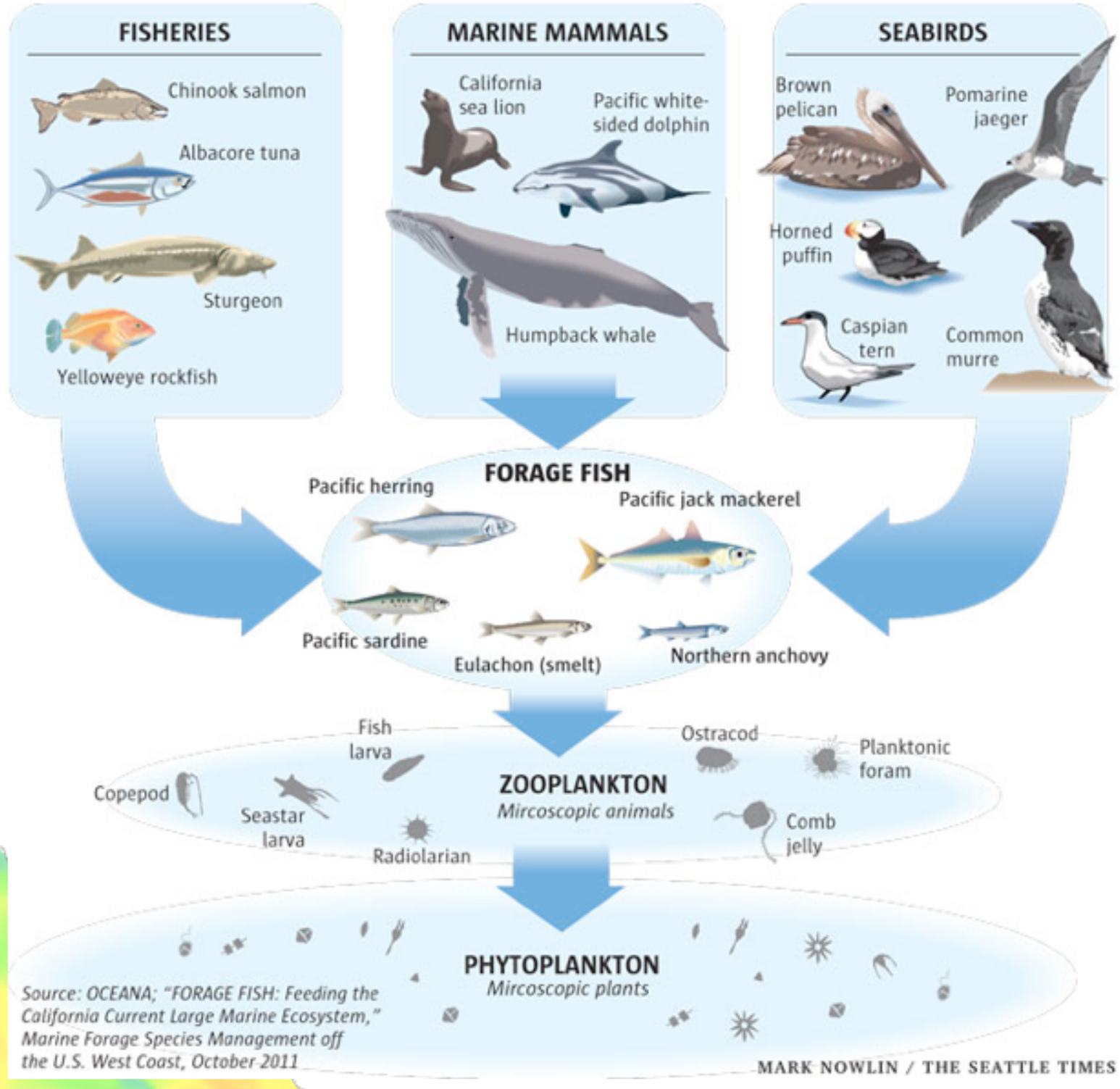
conveyor belt & primary productivity



Botsford et al., 2006

The ocean food web

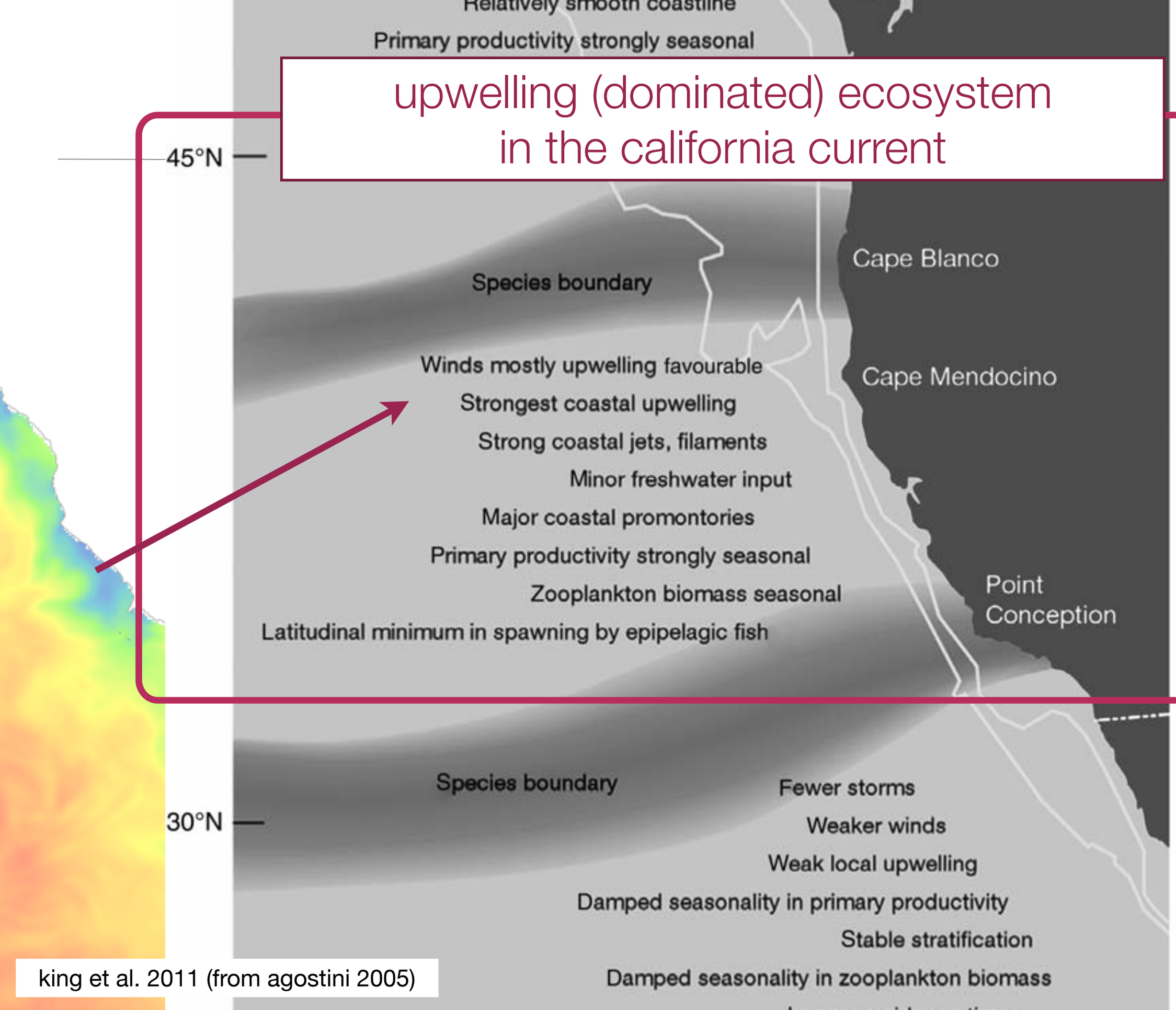
Along the U.S. West Coast, most major fish, mammal and seabird species rely on forage fish for food – a group of about 30 species of small schooling fish. Scientists increasingly recognize that maintaining this small group of fish is key to ocean health.



Source: OCEANA; "FORAGE FISH: Feeding the California Current Large Marine Ecosystem," Marine Forage Species Management off the U.S. West Coast, October 2011

MARK NOWLIN / THE SEATTLE TIMES

upwelling (dominated) ecosystem in the california current



king et al. 2011 (from agostini 2005)

ecosystem-based management

POLICY FORUM

ECOLOGY

Ecosystem-Based Fishery Management

E. K. Pikitch,[1*] C. Santora,[1] E. A. Babcock,[1] A. Bakun,[2] R. Bonfil,[3] D. O. Conover,[4] P. Dayton,[5] P. Doukakis,[1] D. Fluharty,[6] B. Heneman,[7] E. D. Houde,[8] J. Link,[9] P. A. Livingston,[10] M. Mangel,[11] M. K. McAllister,[12] J. Pope,[13] K. J. Sainsbury[14]

16 JULY 2004 VOL 305 SCIENCE www.sciencemag.org

Perspective

Integrated Ecosystem Assessments: Developing the Scientific Basis for Ecosystem-Based Management of the Ocean

PLoS BIOLOGY

Phillip S. Levin*, Michael J. Fogarty, Steven A. Murawski, David Fluharty

Review

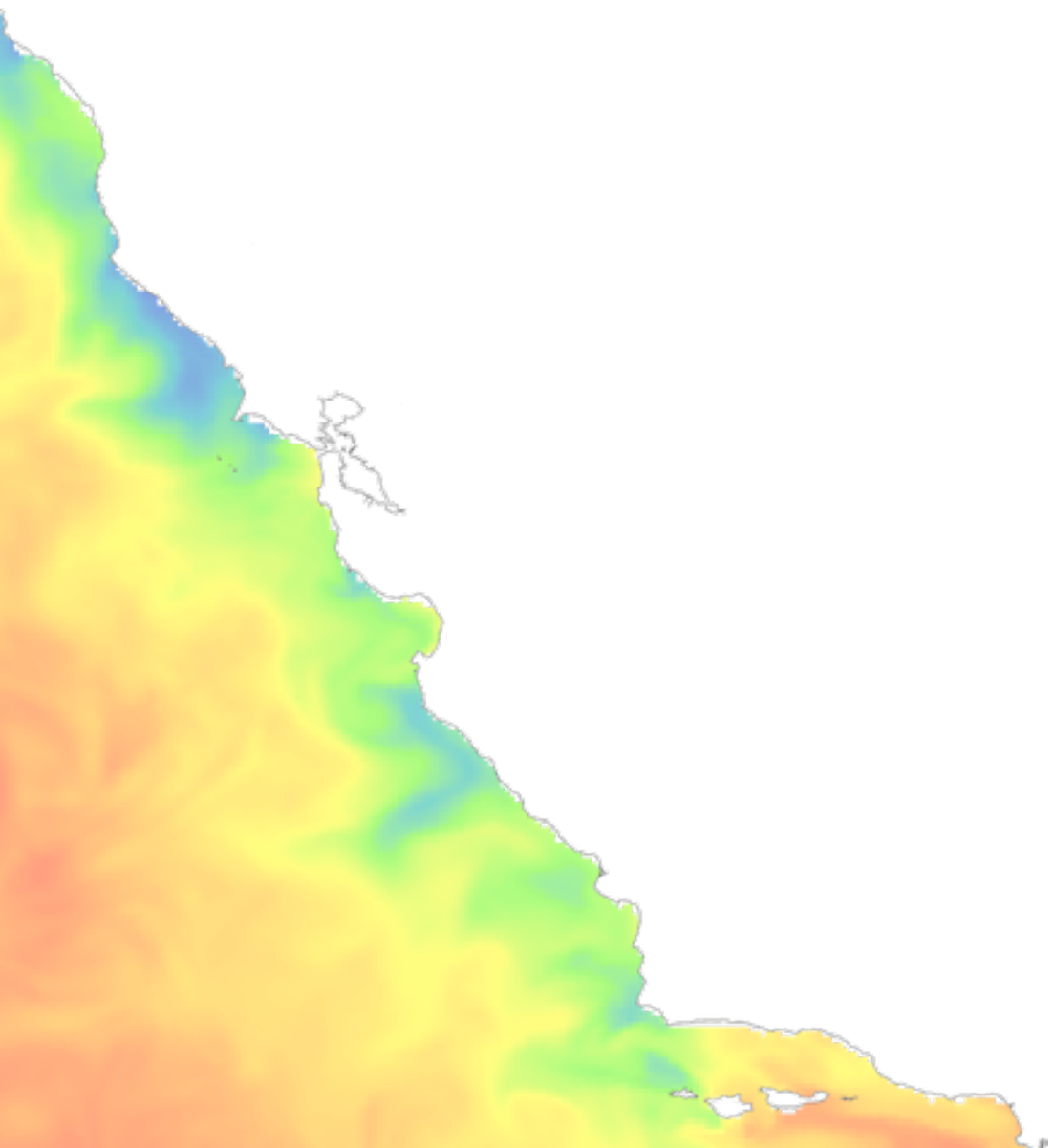
Trends in Ecology and Evolution Vol.23 No.6

Ecosystem oceanography for global change in fisheries

Philippe Maurice Cury[1], Yunne-Jai Shin[1], Benjamin Planque[2], Joël Marcel Durant[3], Jean-Marc Fromentin[4], Stephanie Kramer-Schadt[5], Nils Christian Stenseth[3,6], Morgane Travers[1] and Volker Grimm[7]

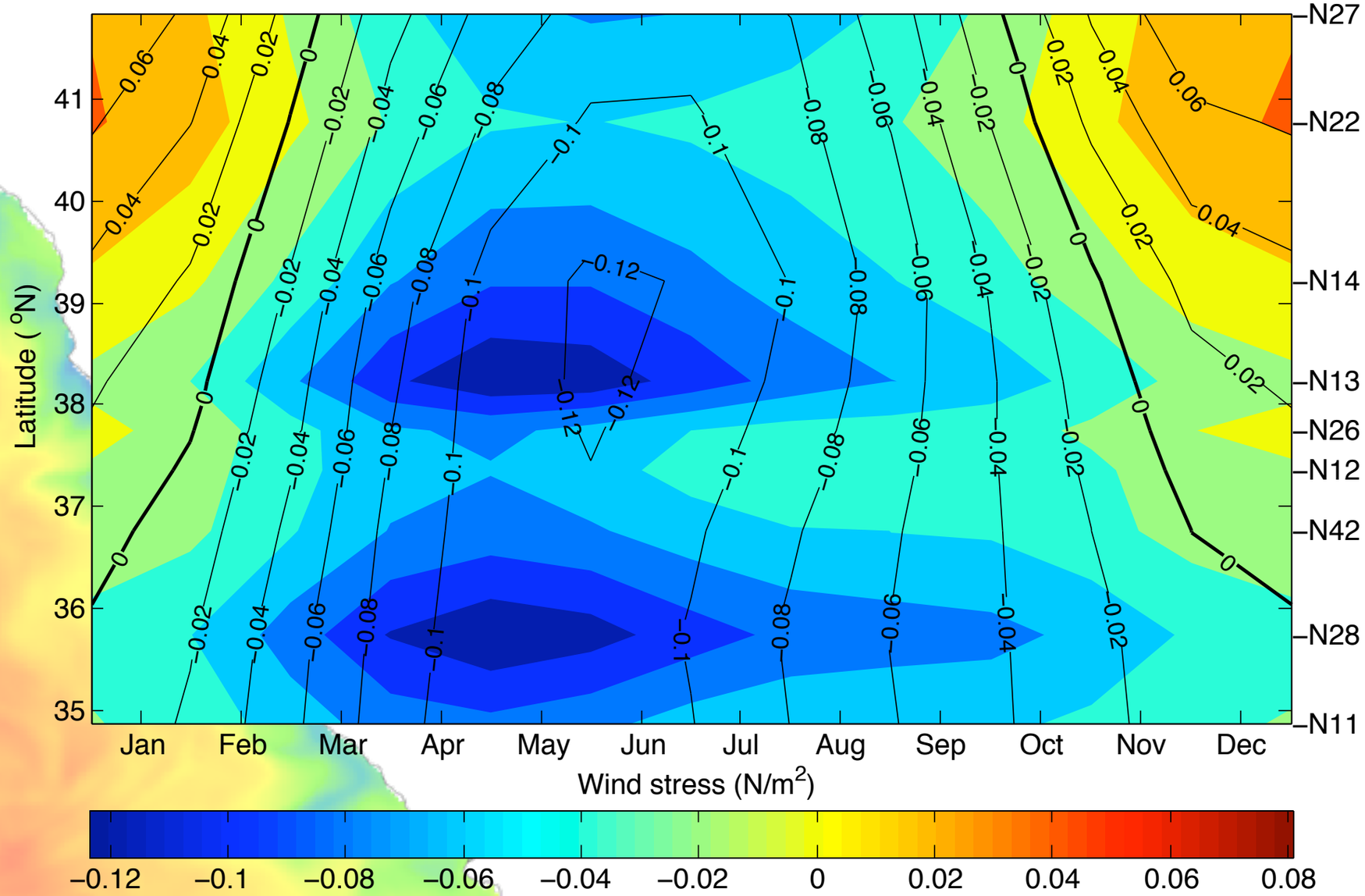
present

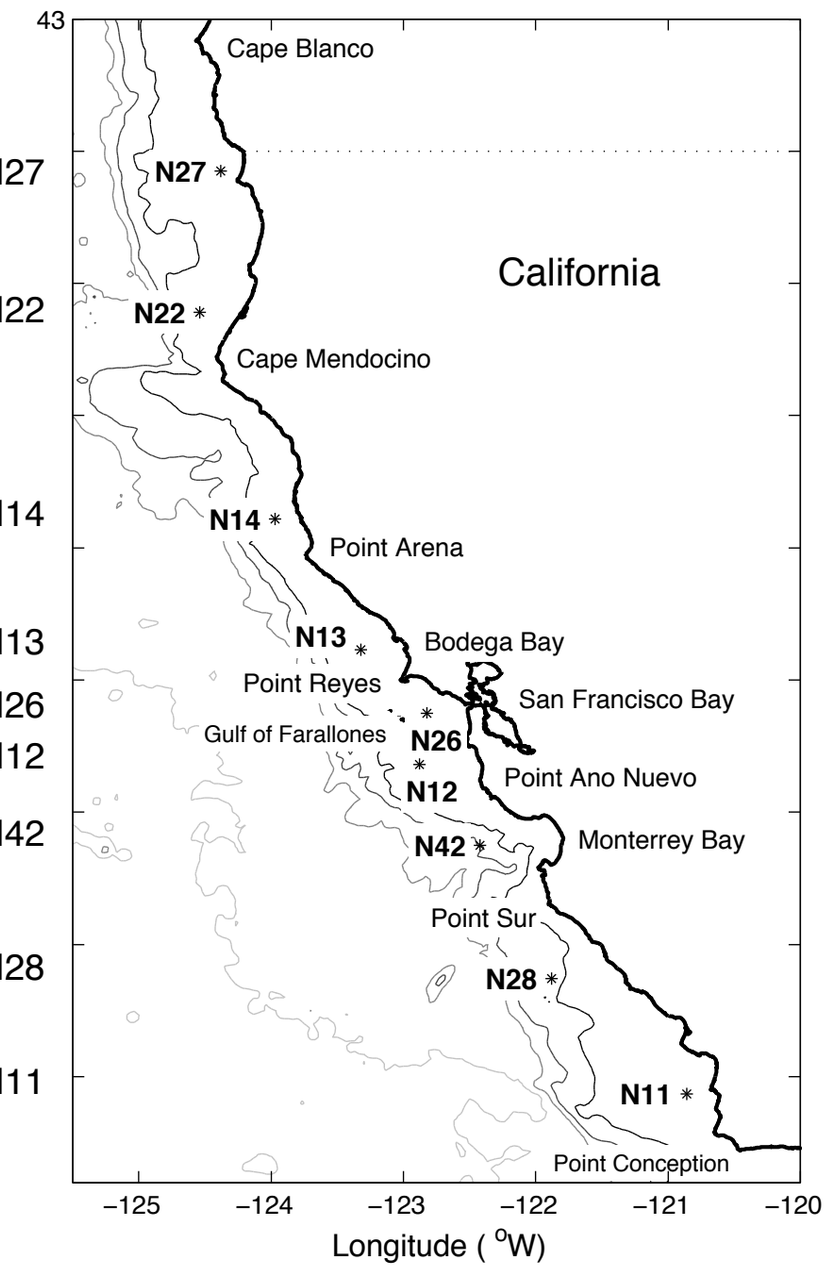
seasonality and modes of variability



seasonal cycle

upwelling season (march - july)





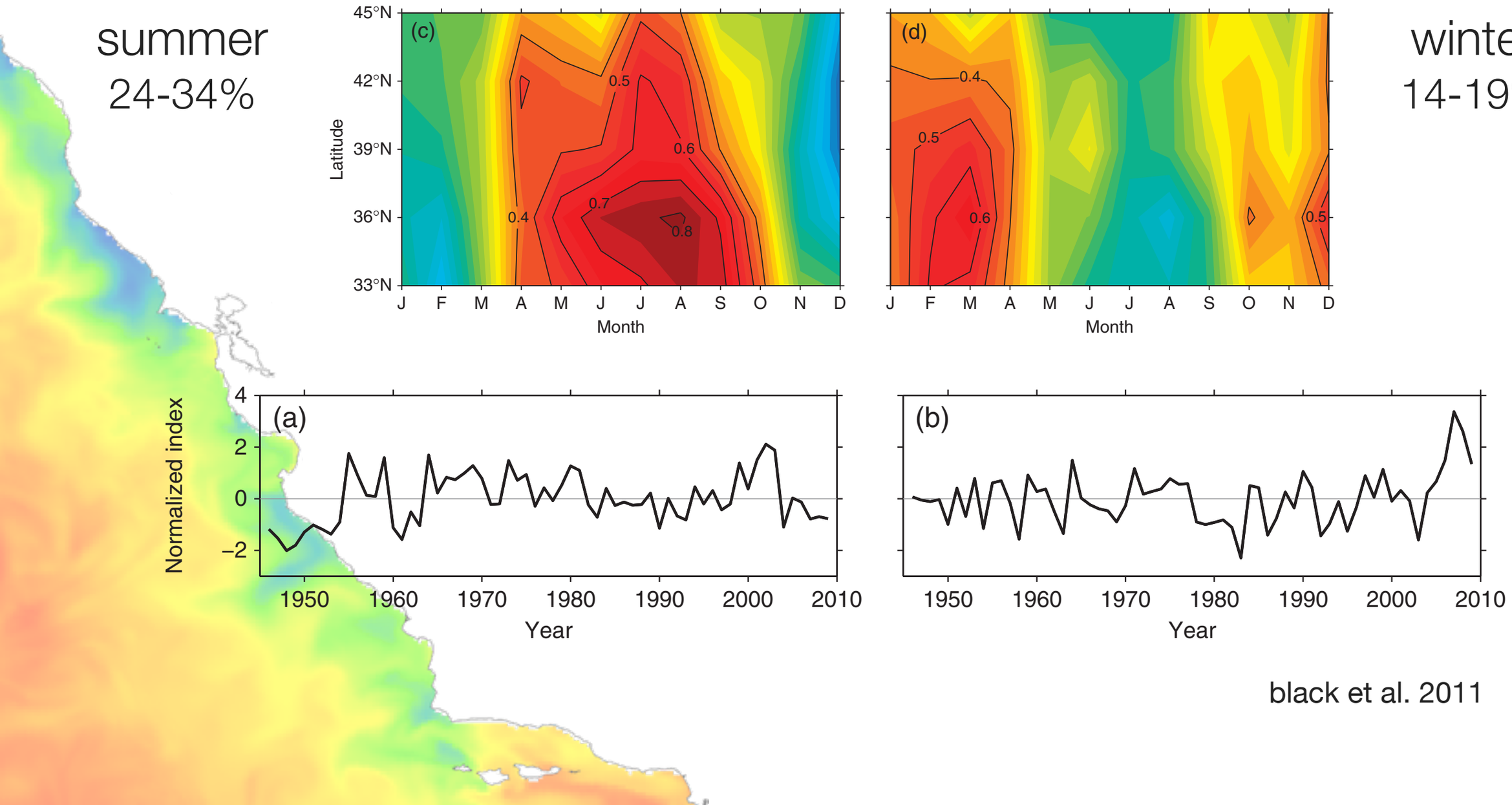
garcía-reyes & largier, 2012

variability modes

principal component analysis of upwelling index

summer
24-34%

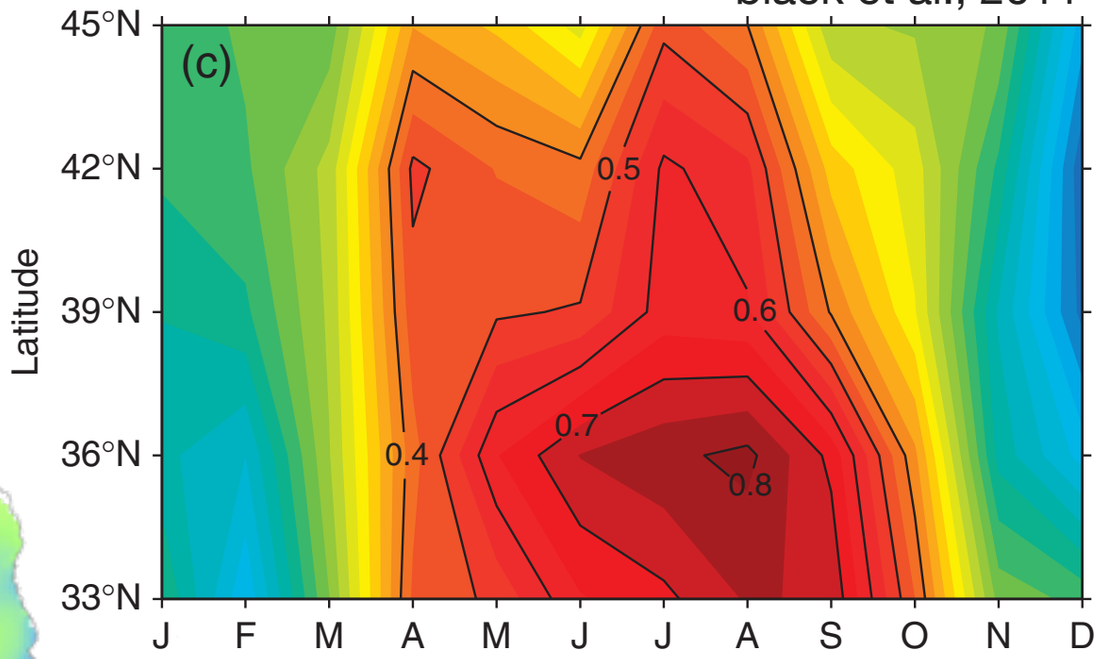
winter
14-19%

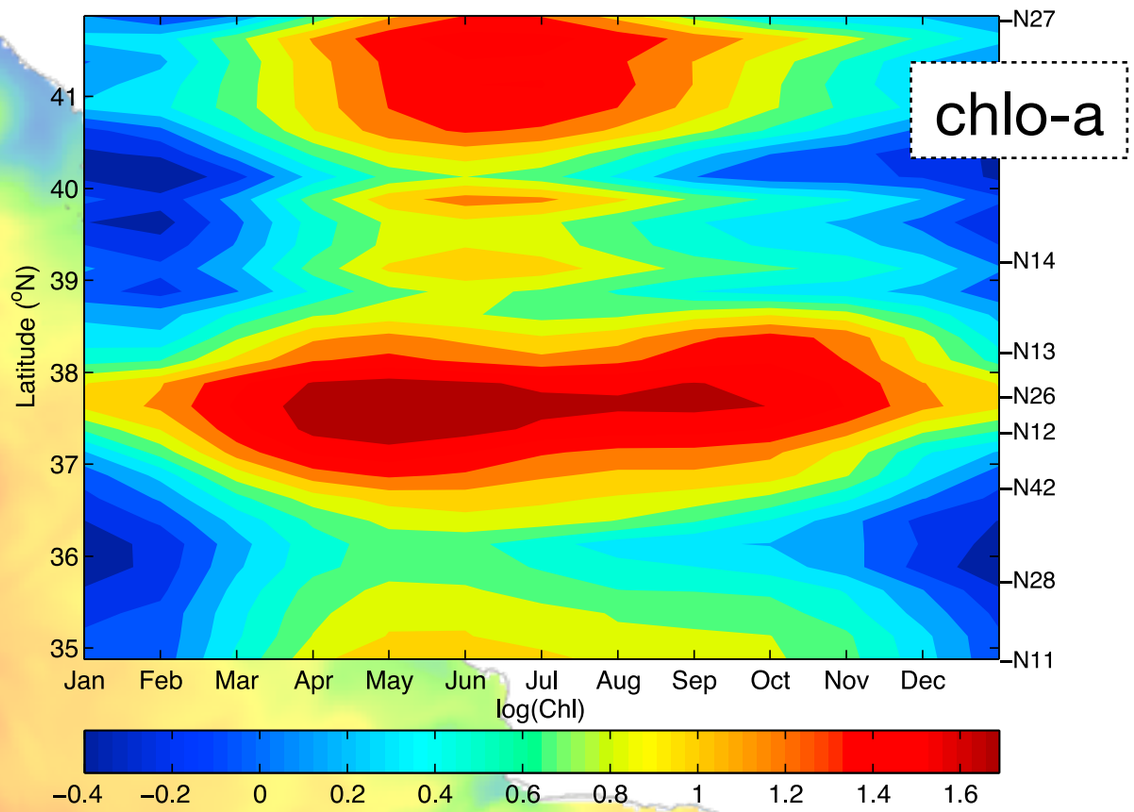


black et al. 2011

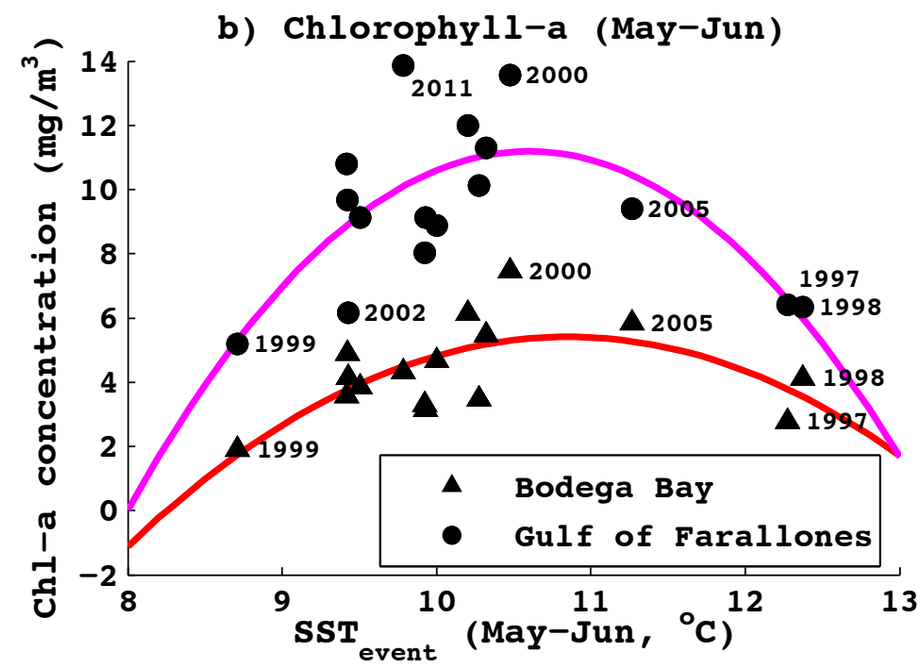
summer mode & biological productivity

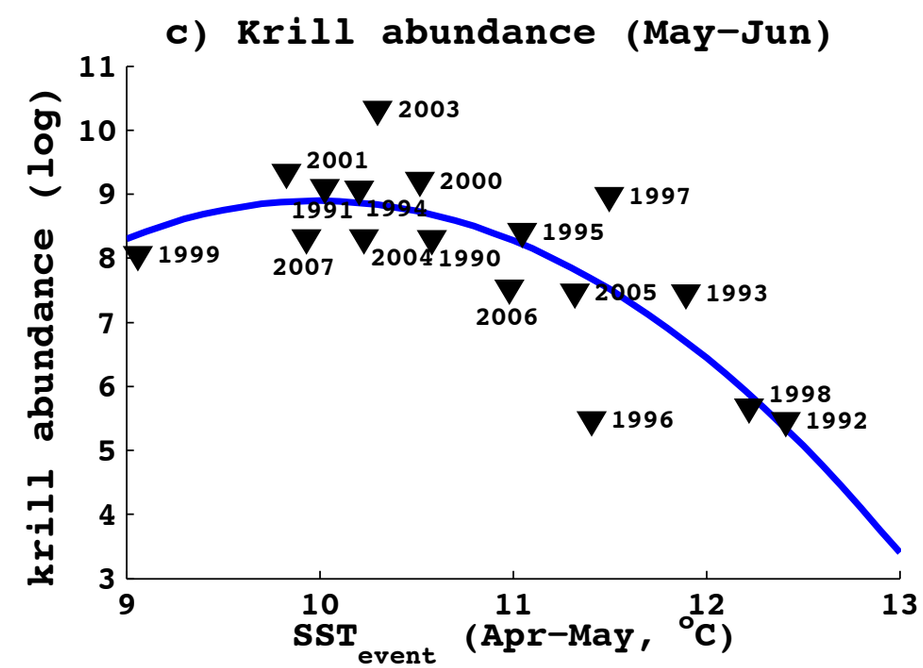
black et al., 2011





garcía-reyes & largier, 2012





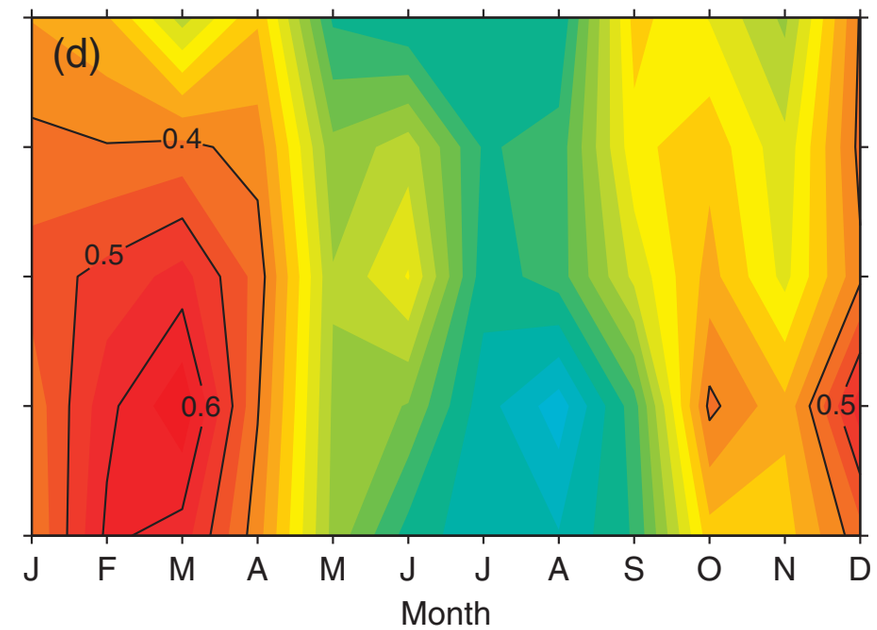
garcía-reyes et al. 2013

winter mode

second principal component

upwelling index

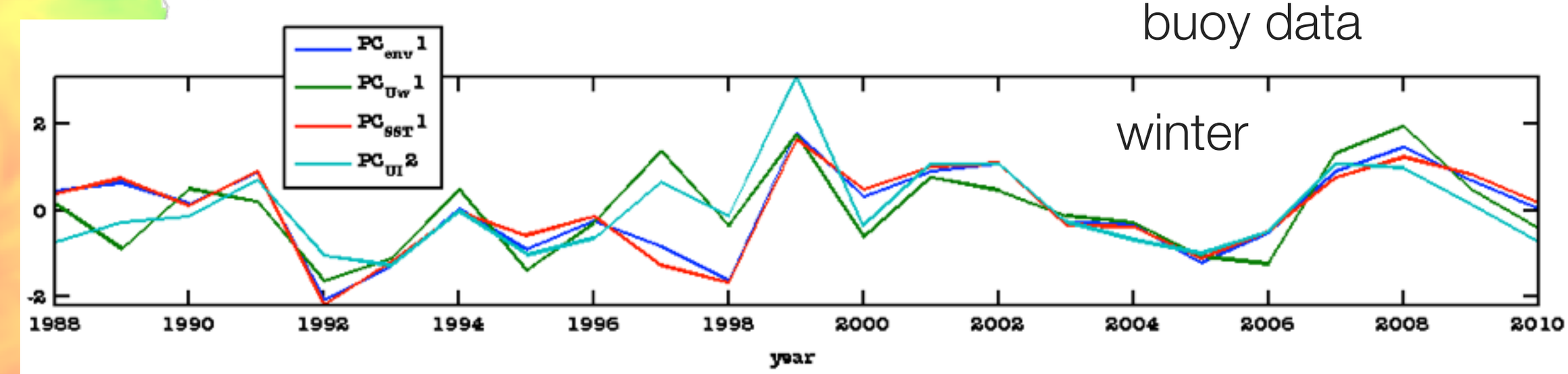
winter



black et al., 2011

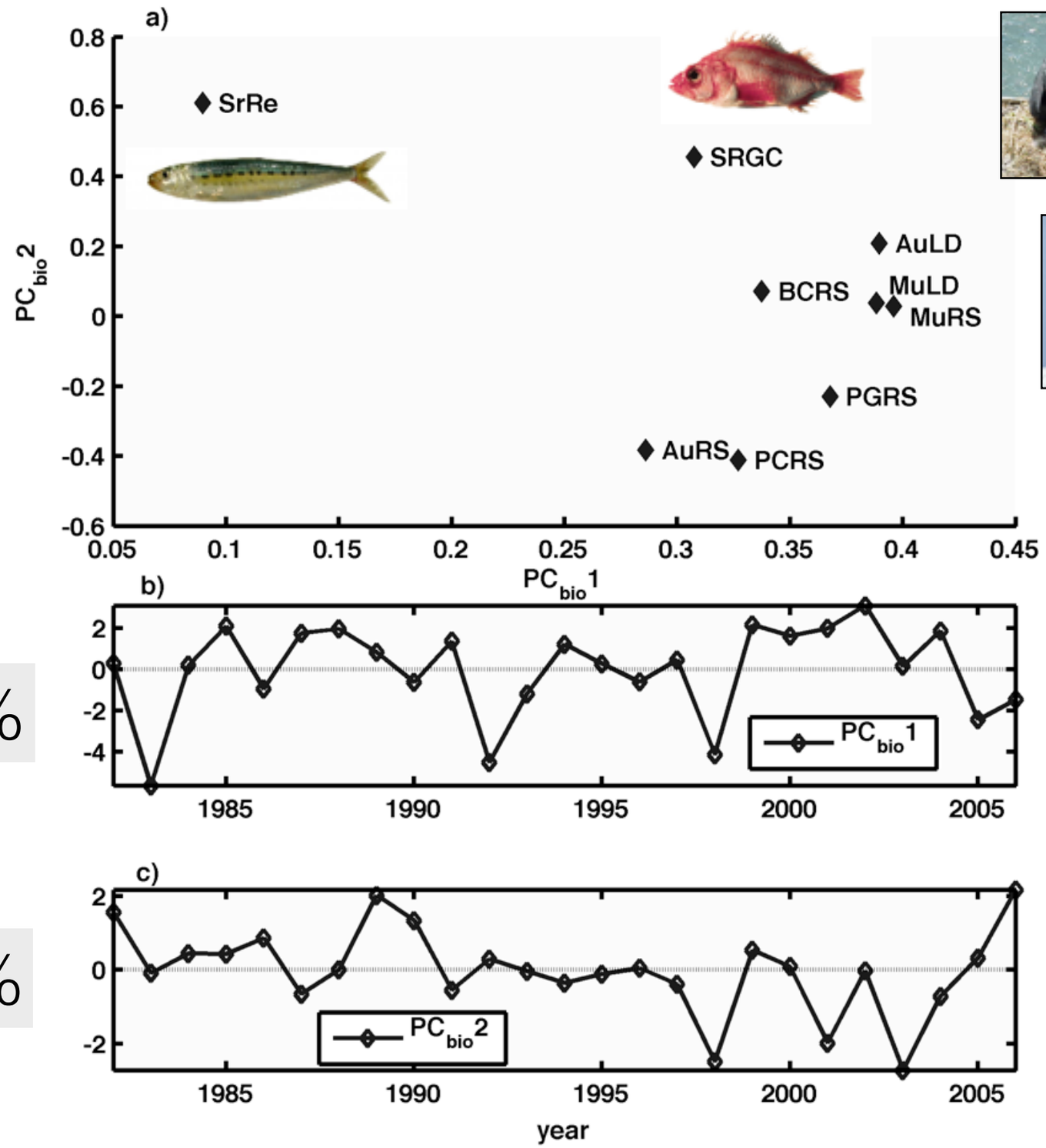
buoy data

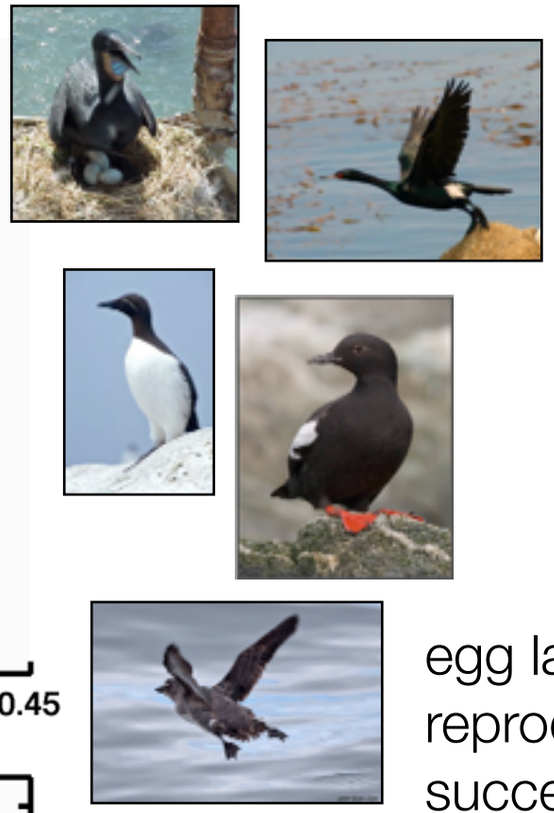
winter



garcía-reyes et al. 2013

biological productivity





egg lay-date, reproductive success, growth

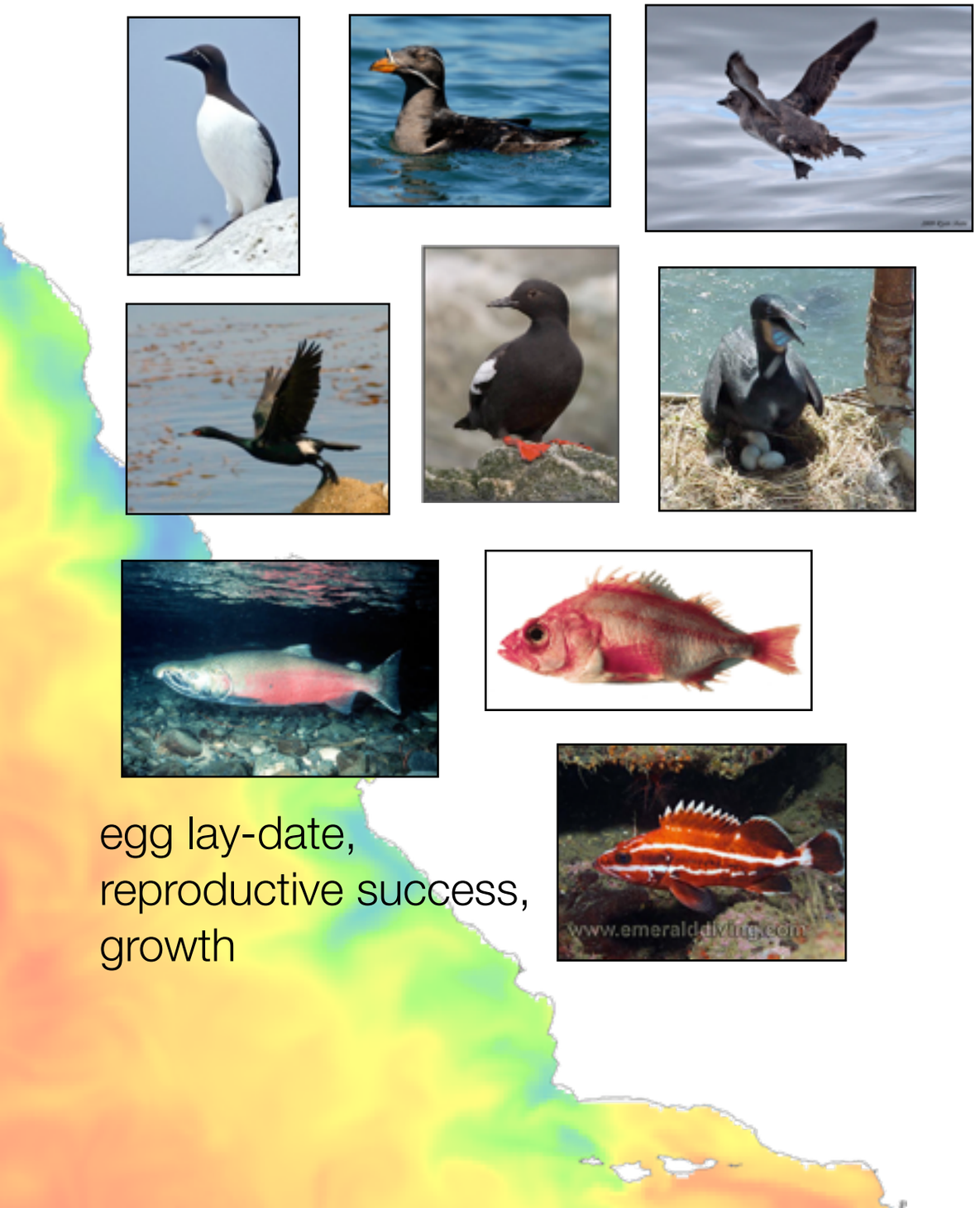
56%

16%

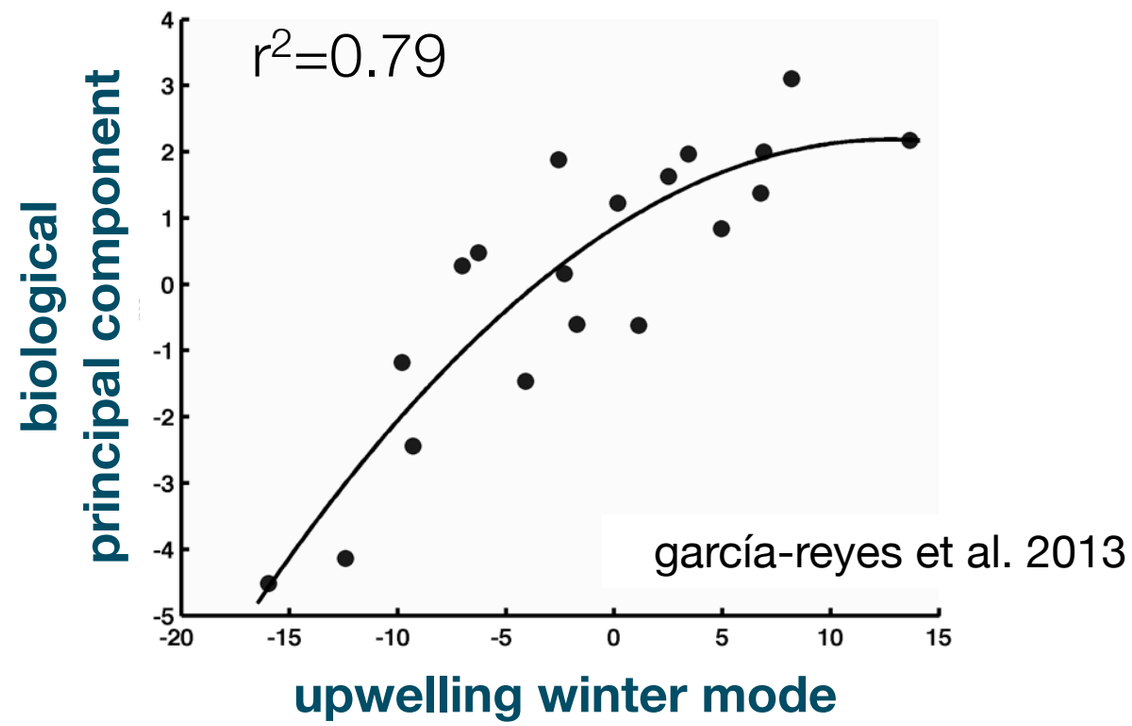
principal components

García-Reyes et al. 2013

biological productivity



egg lay-date,
reproductive success,
growth

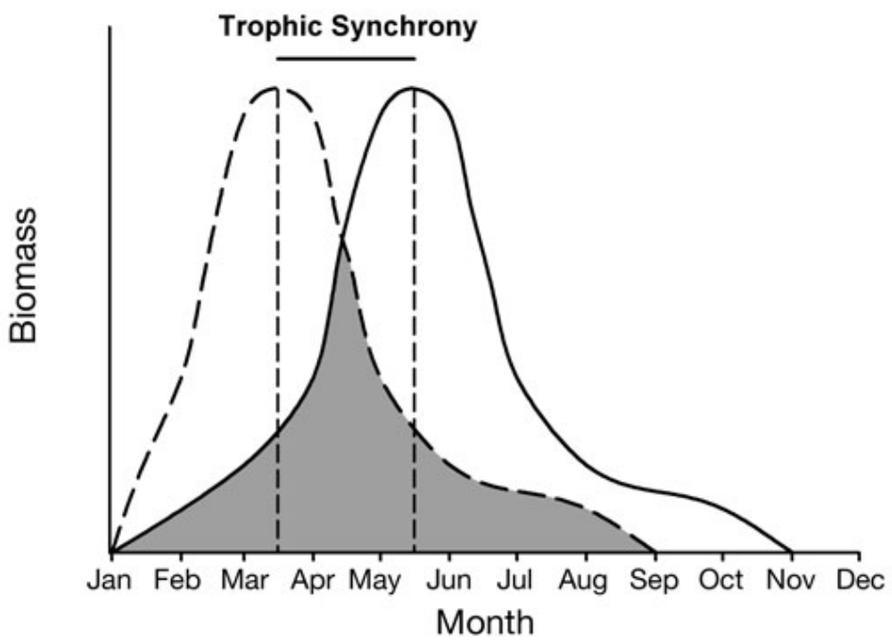


García-Reyes et al. 2013

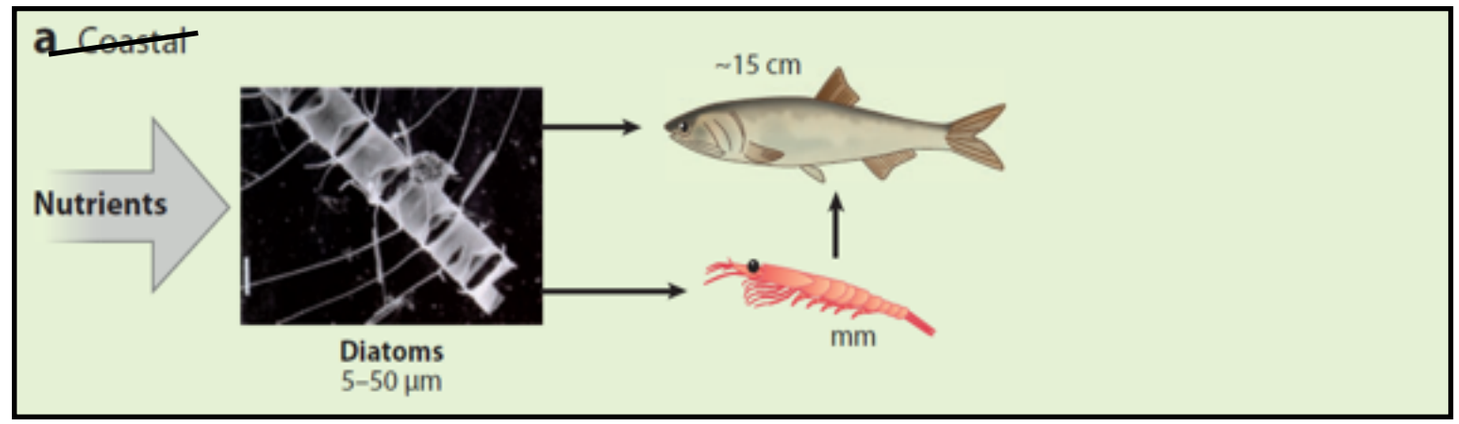
sst & winds

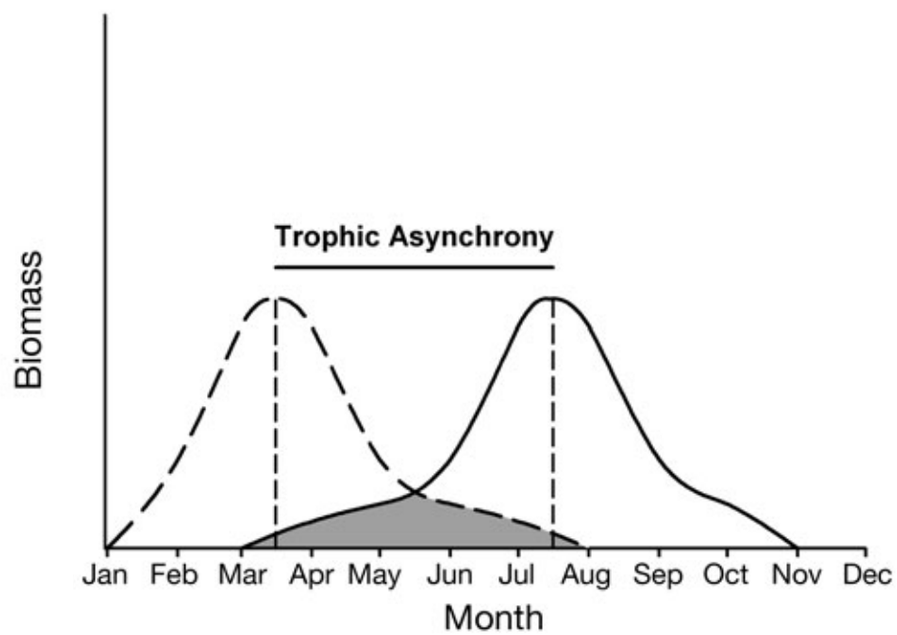
pre-conditioning

match-mismatch: time and biomass

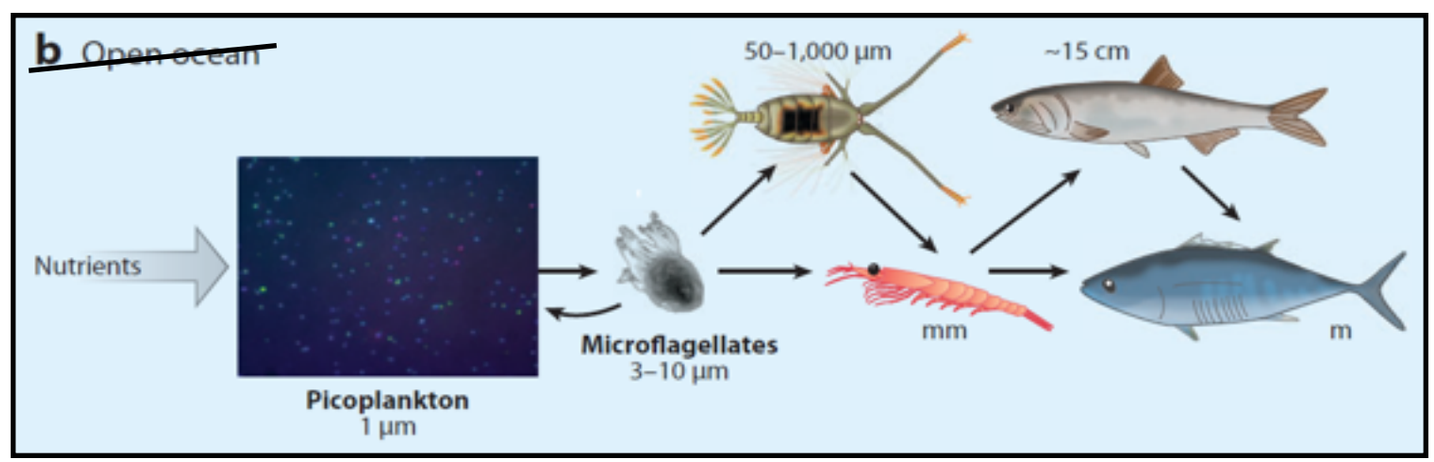


winter upwelling





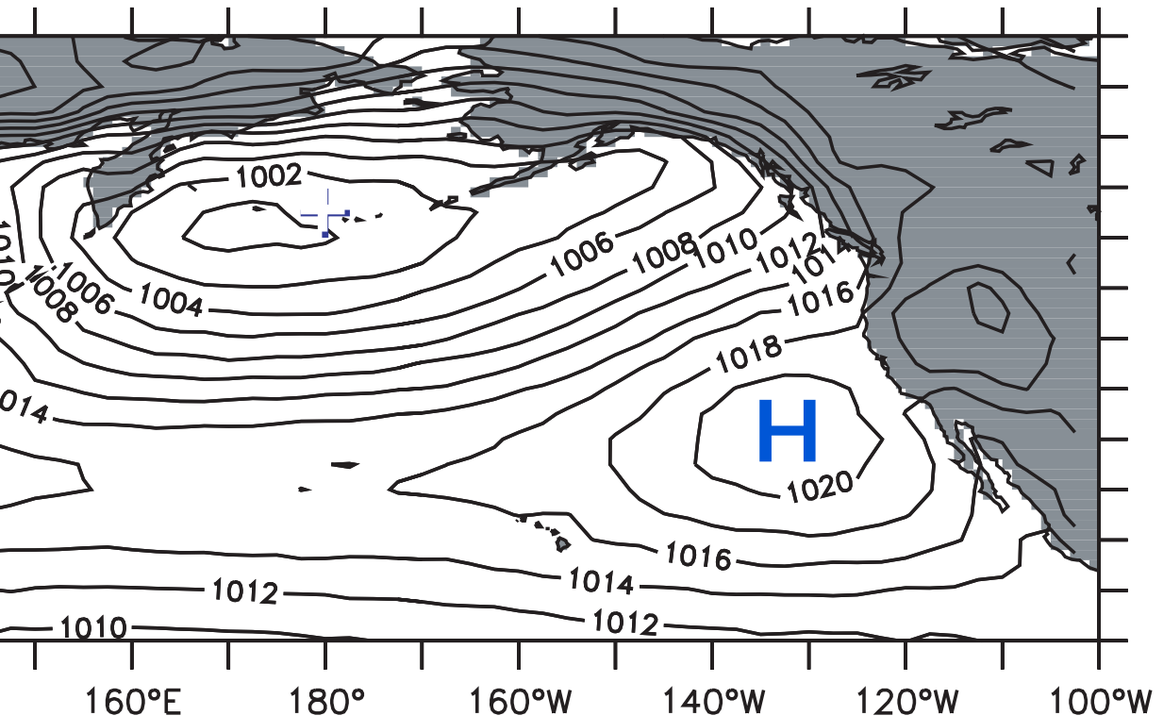
delayed winter upwelling (spring)



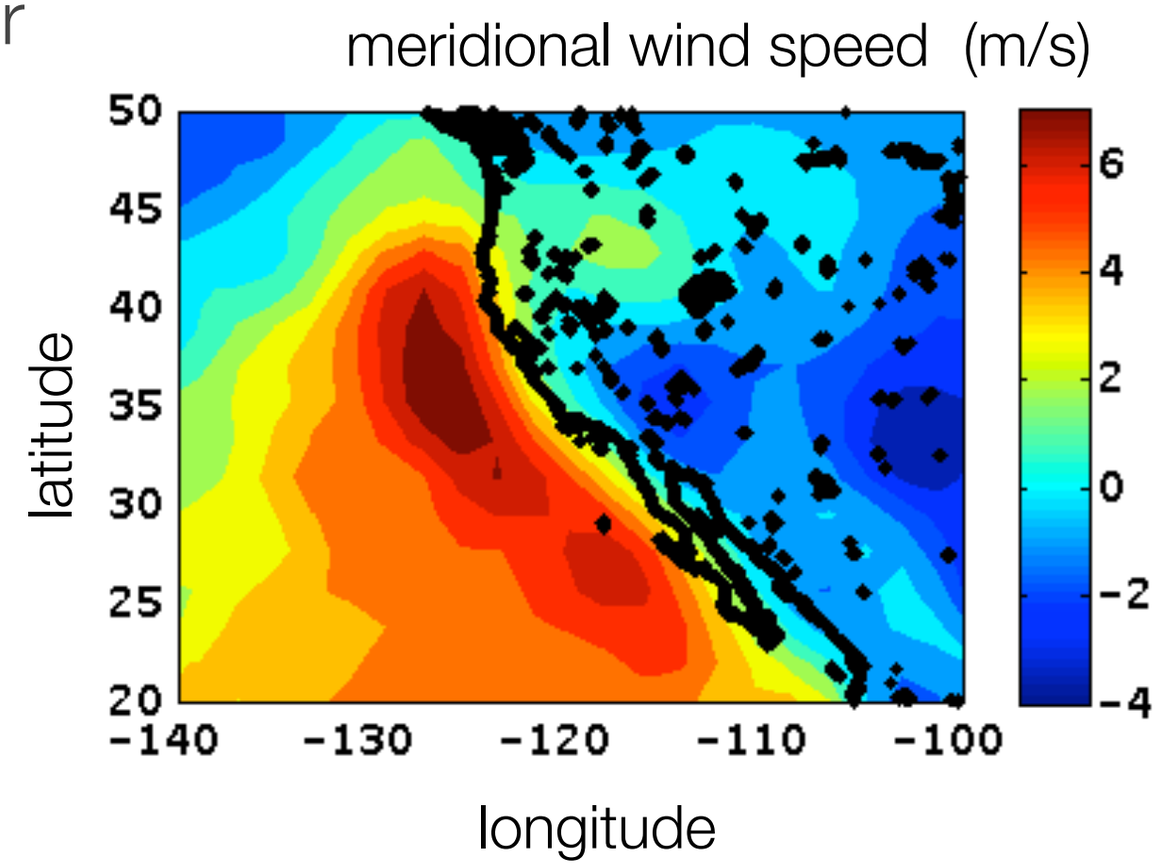
adapted from chavez et al. 2010

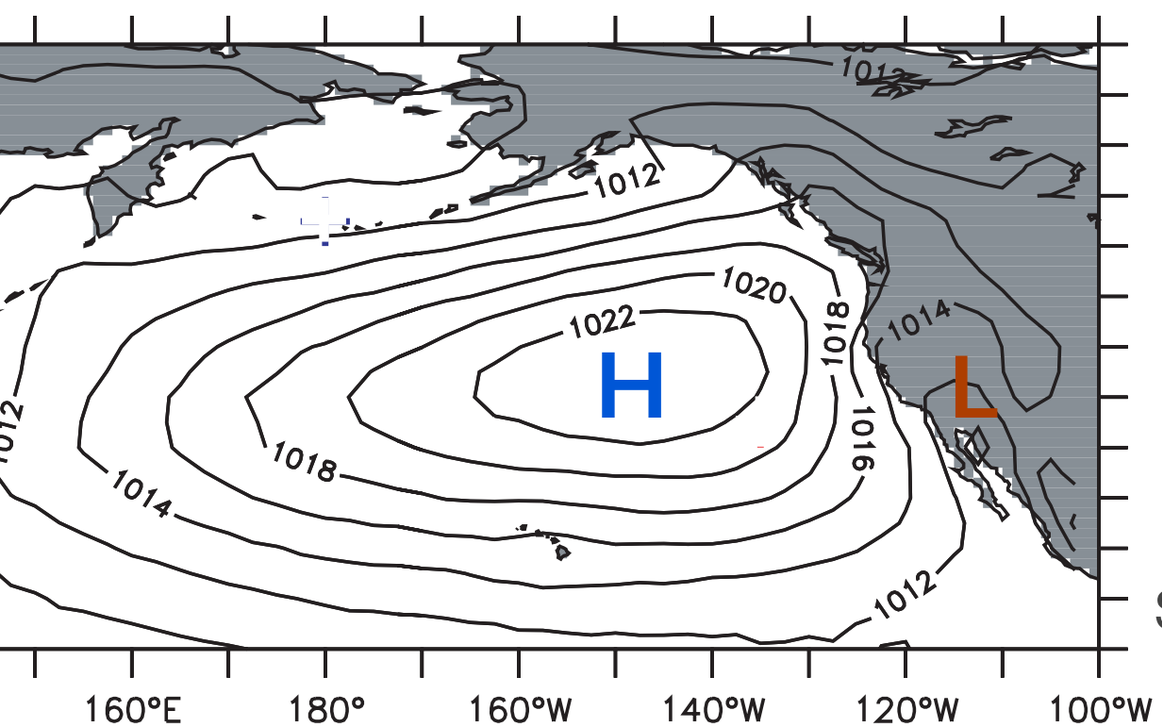
durant et al. 2005

atmospheric drivers



winter

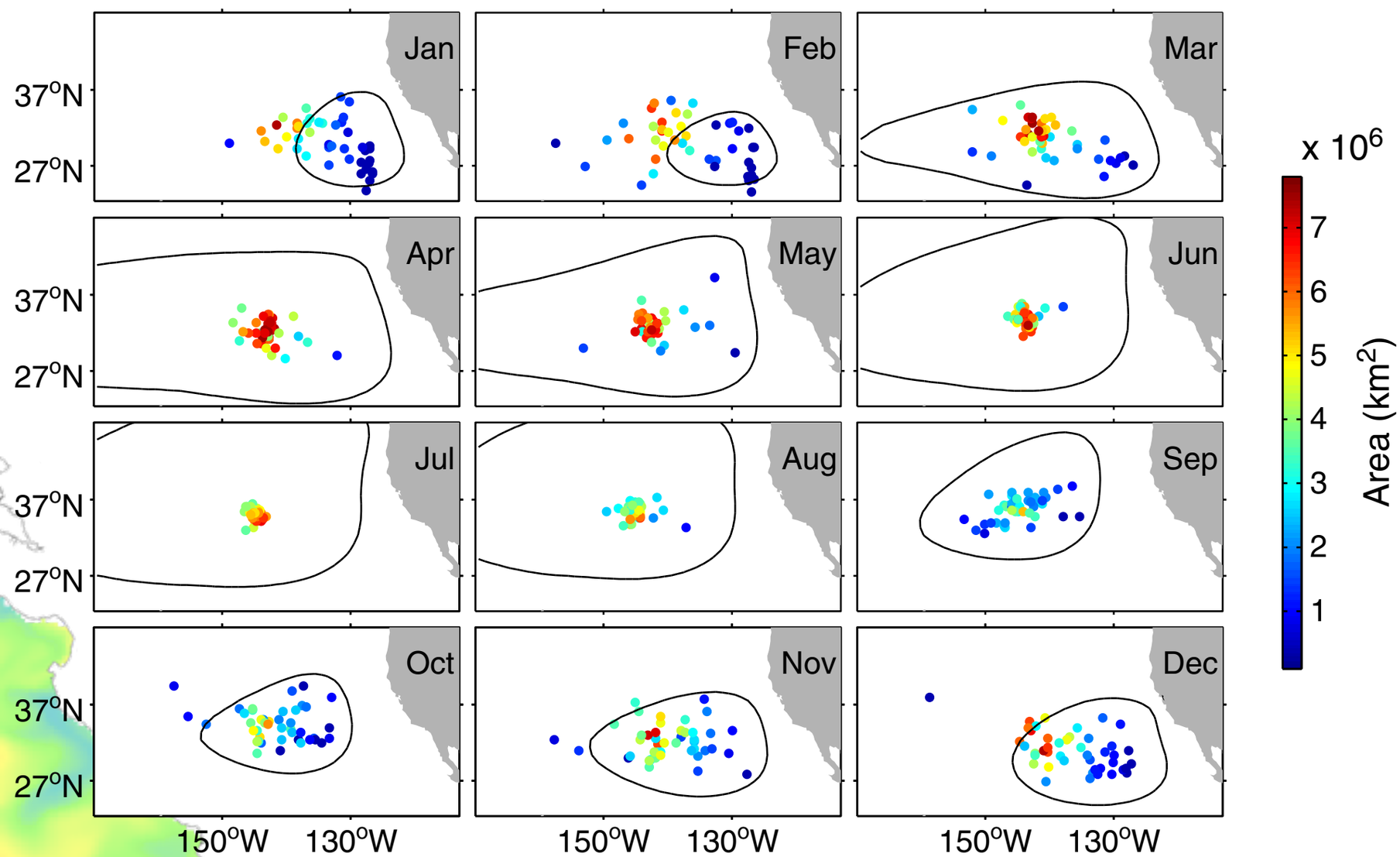




summer

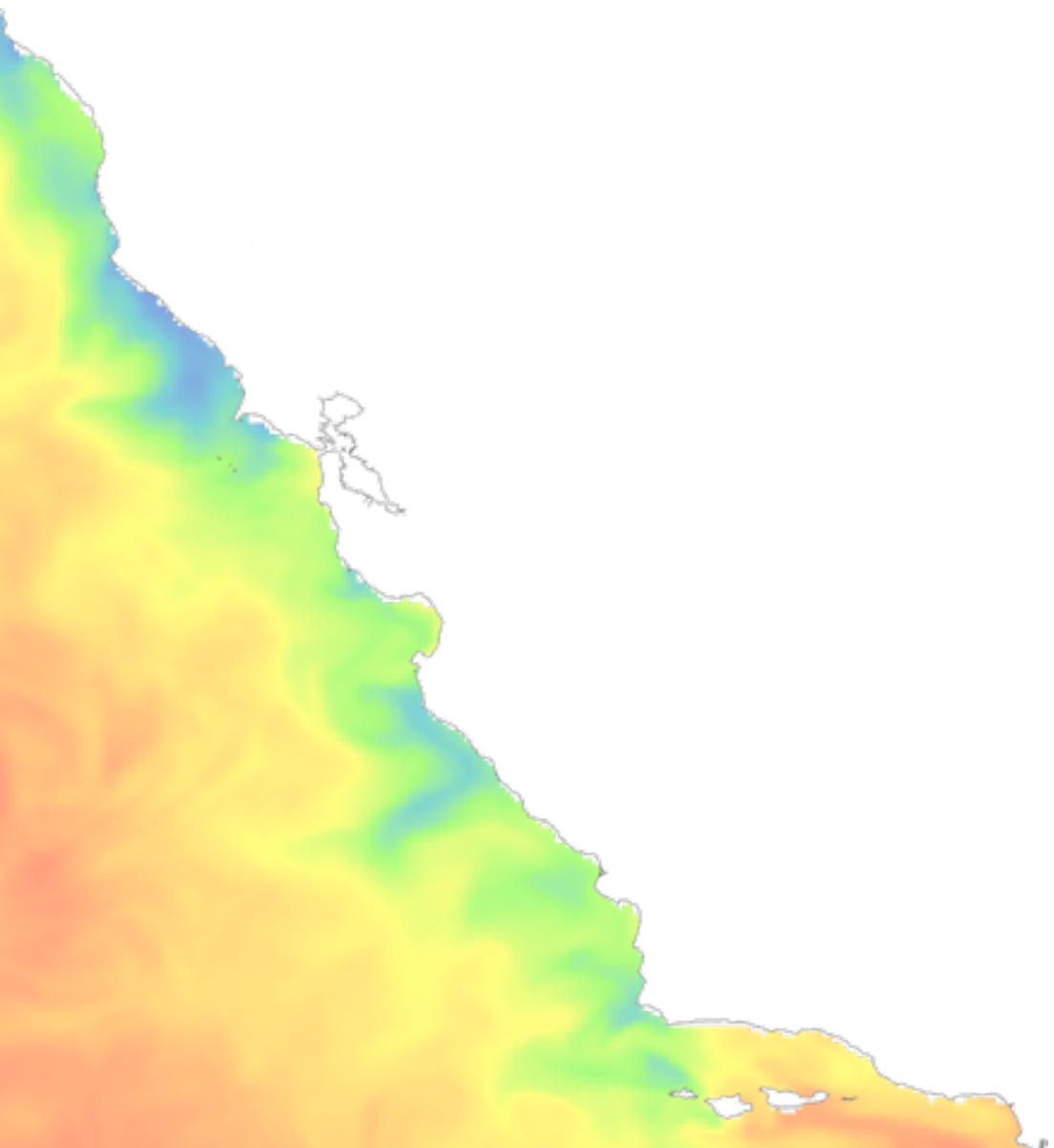
ocean pressure dominates winds:
winter (72% - 6%)
summer (21% - 8%)

ocean pressure system variability

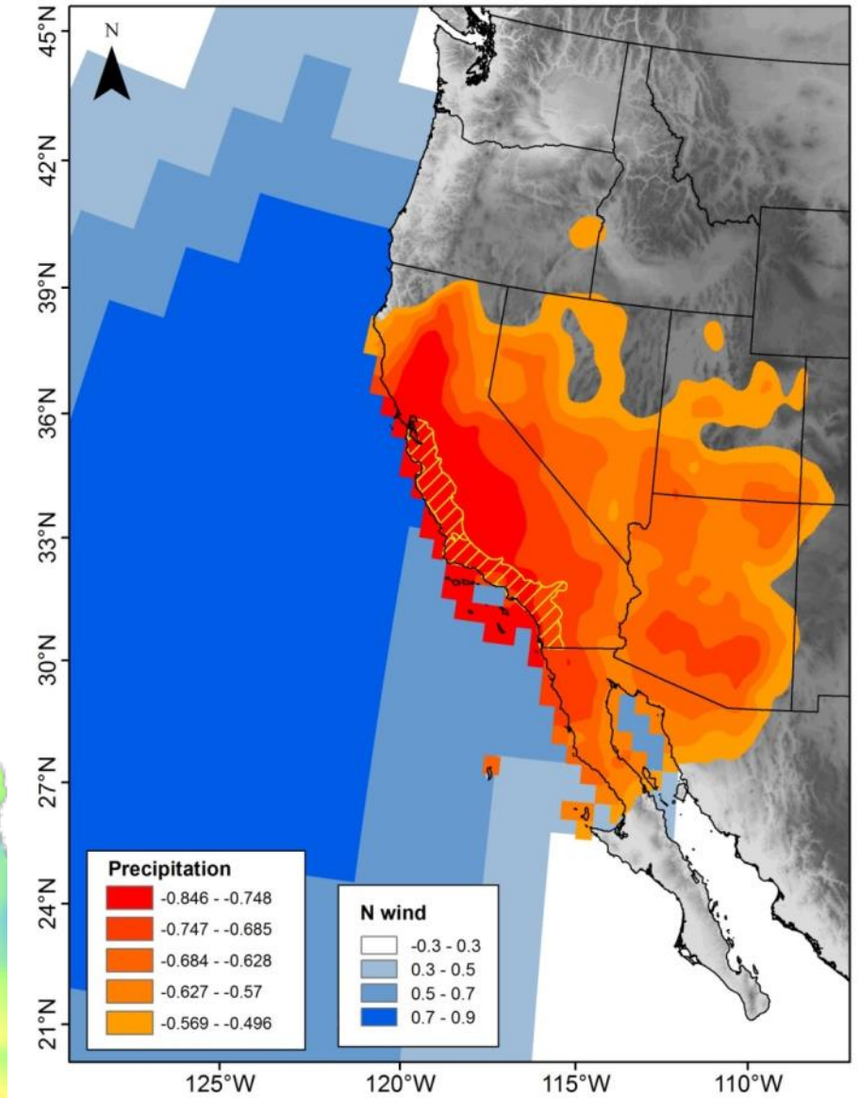


schroeder et al., 2013

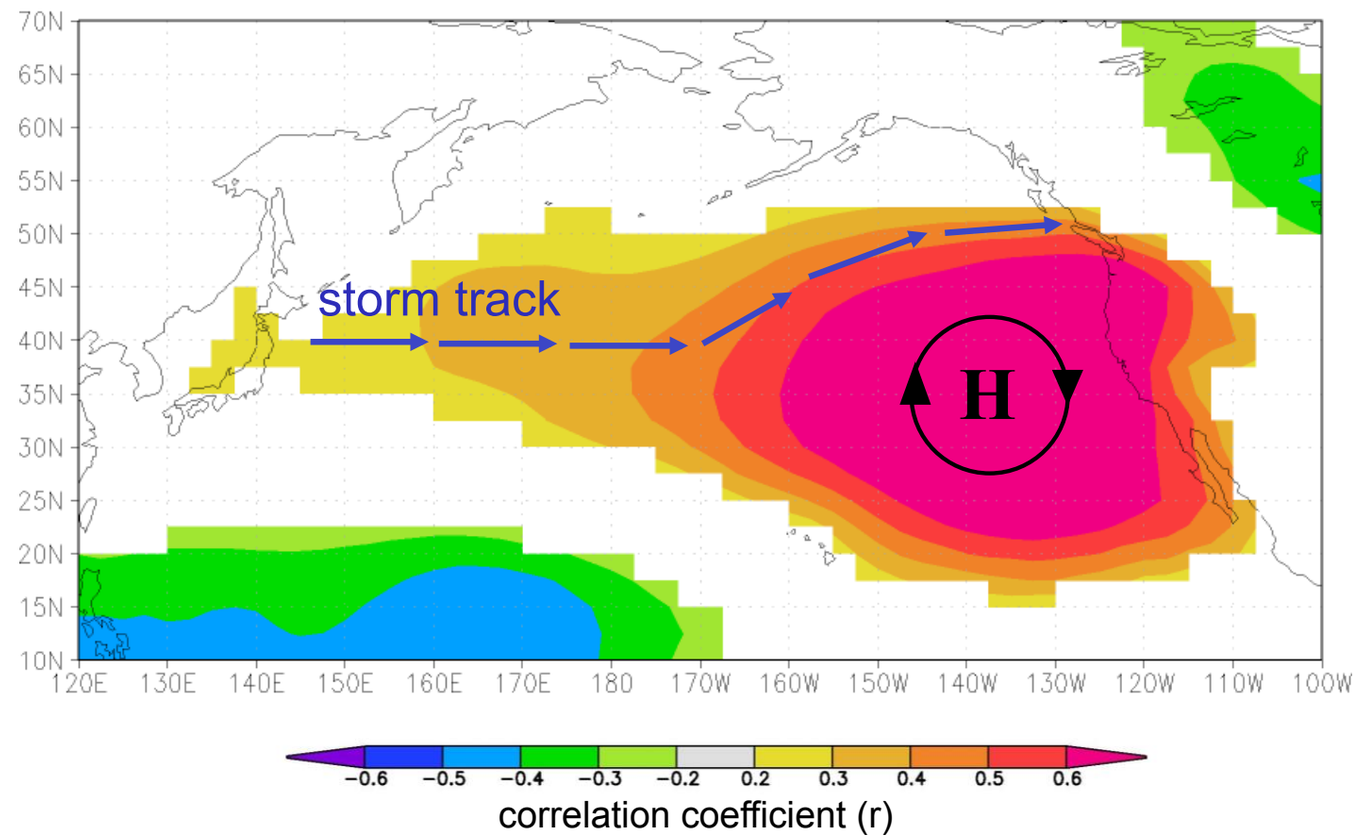
past



precipitation

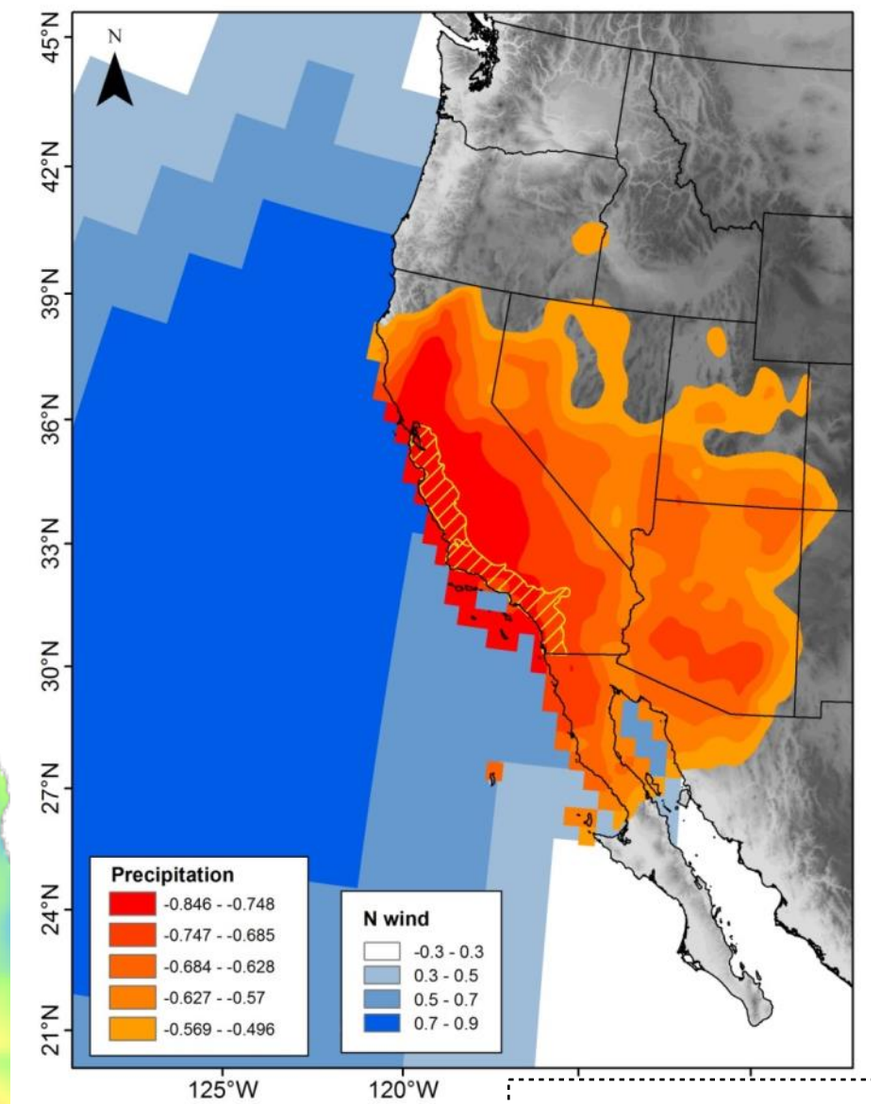


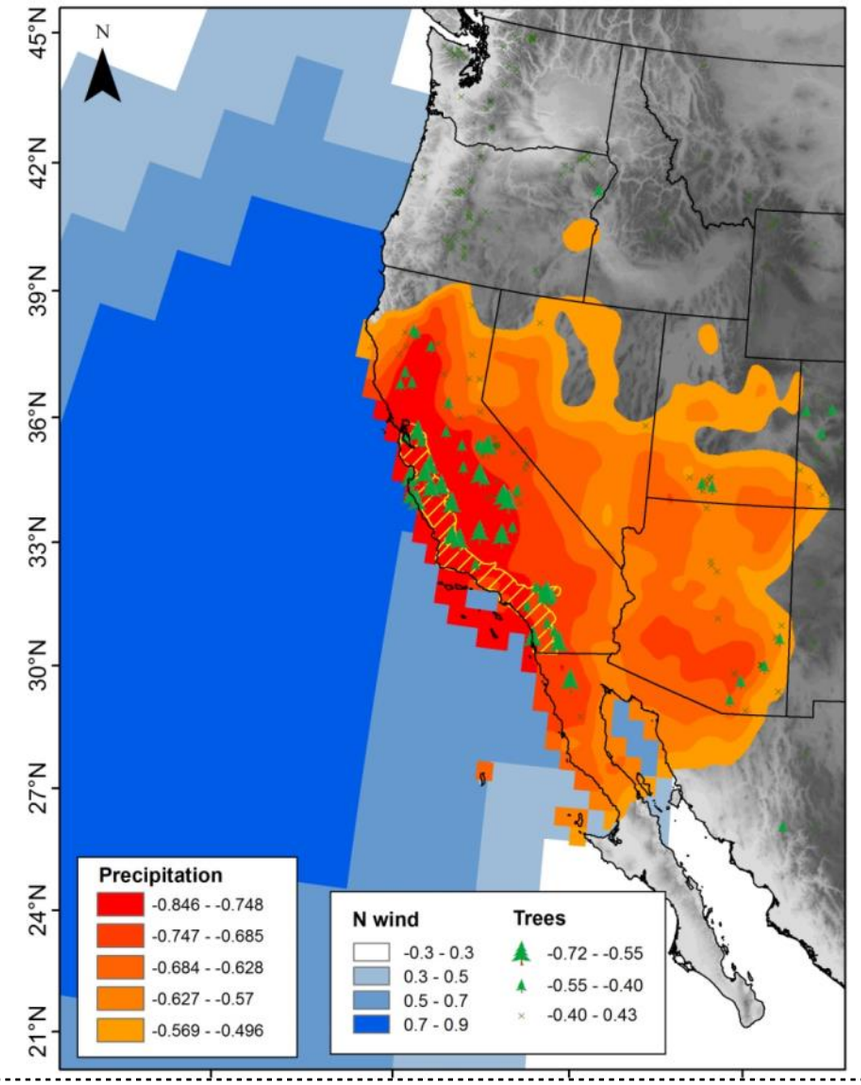
black et al., submitted



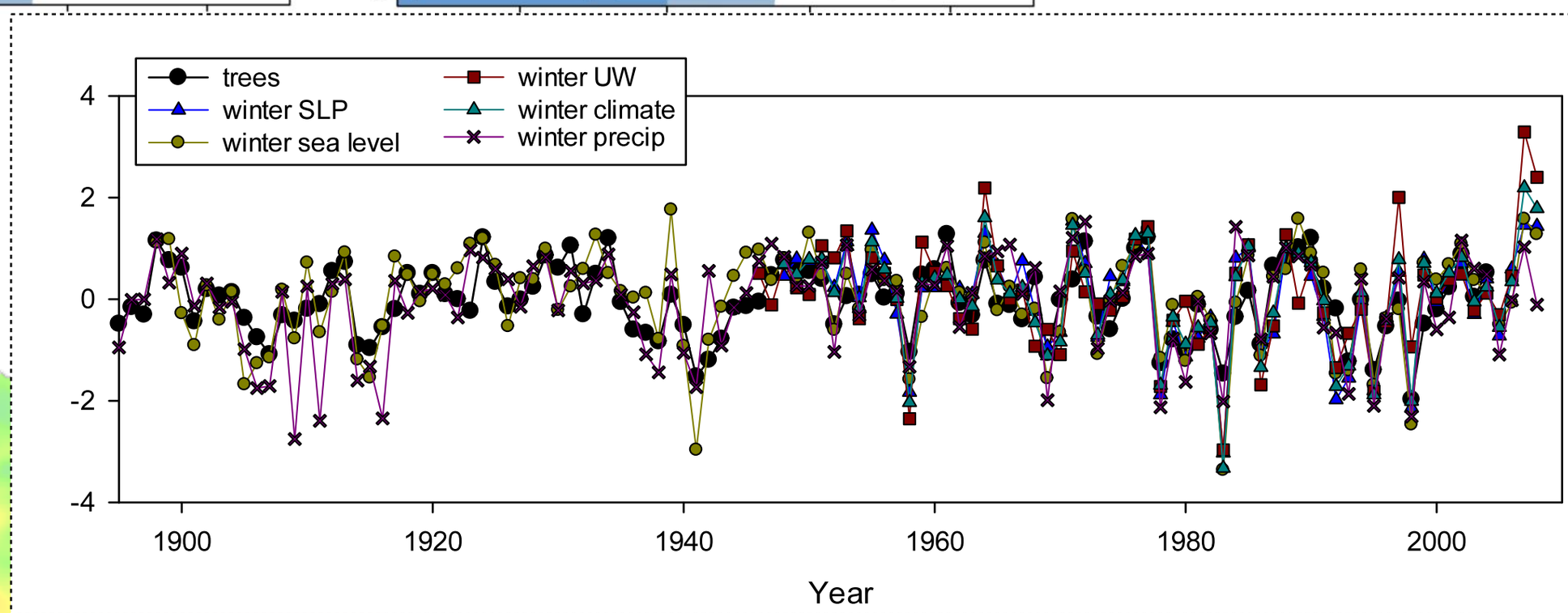
correlation between:
rain - - orange
wind - - blue
with atmospheric pressure

blue oak growth rings

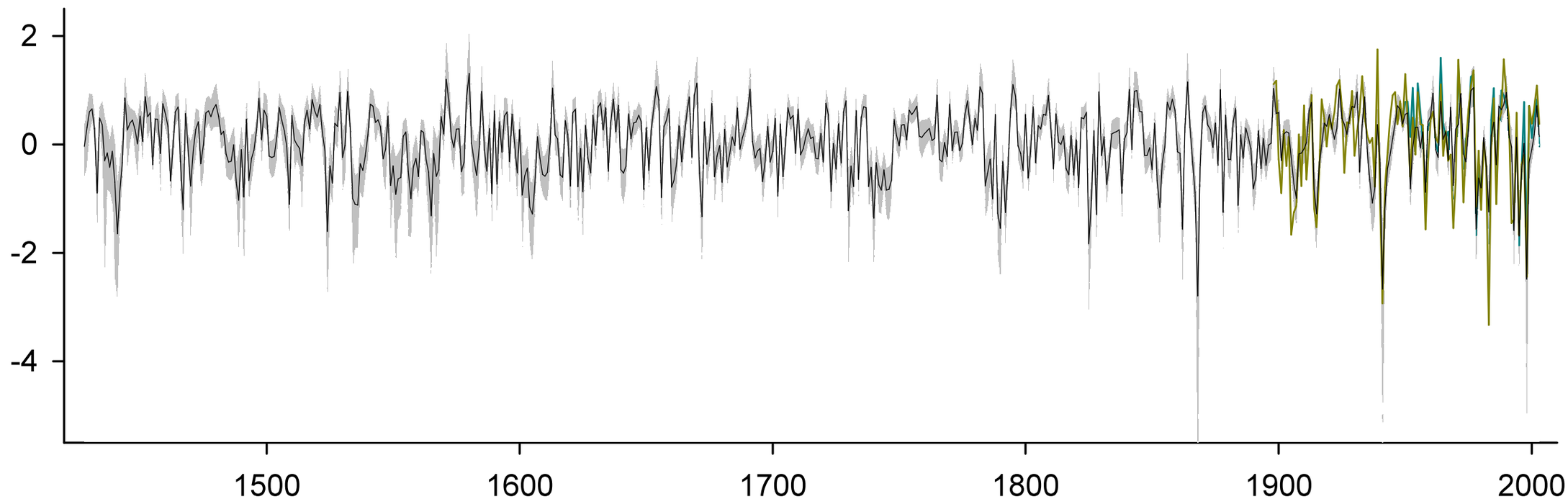




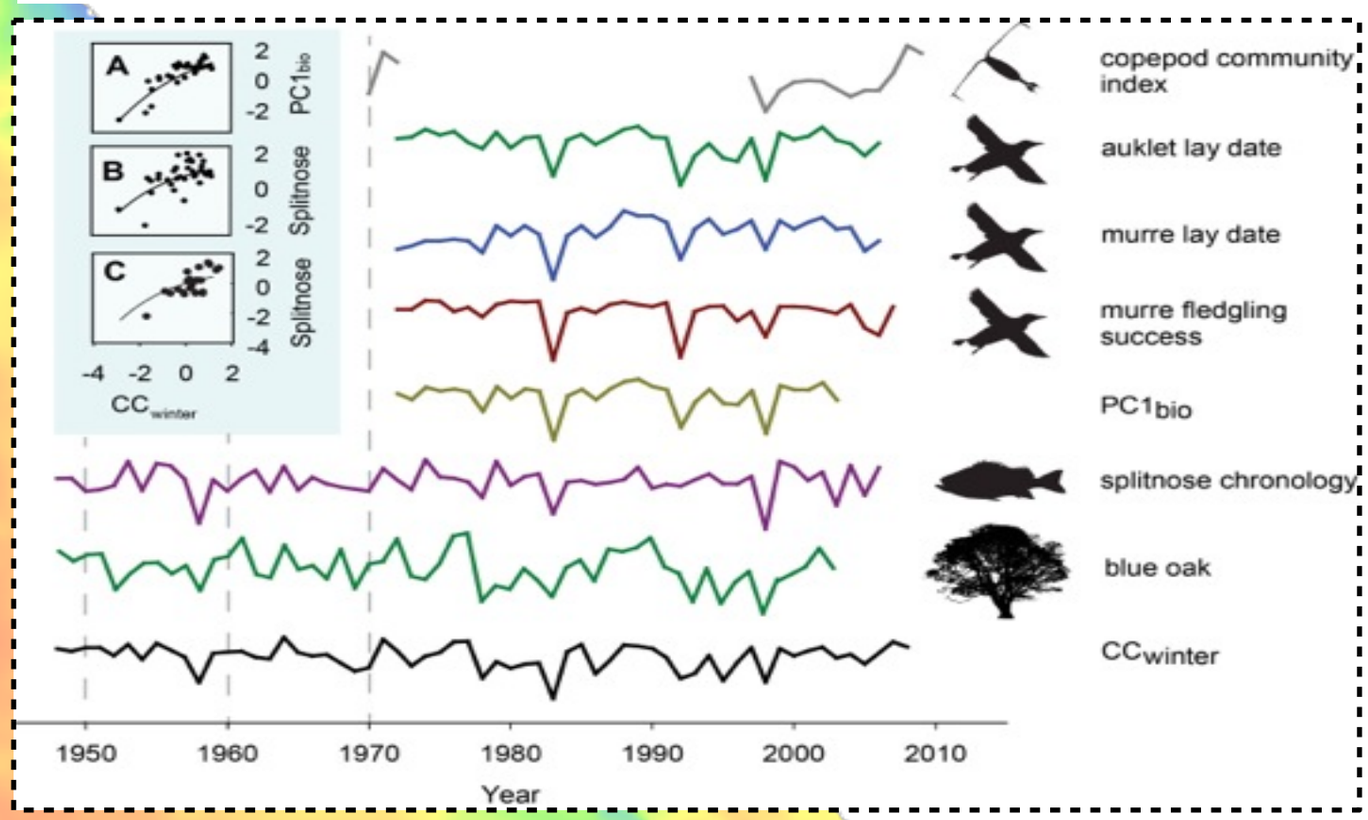
black et al., submitted



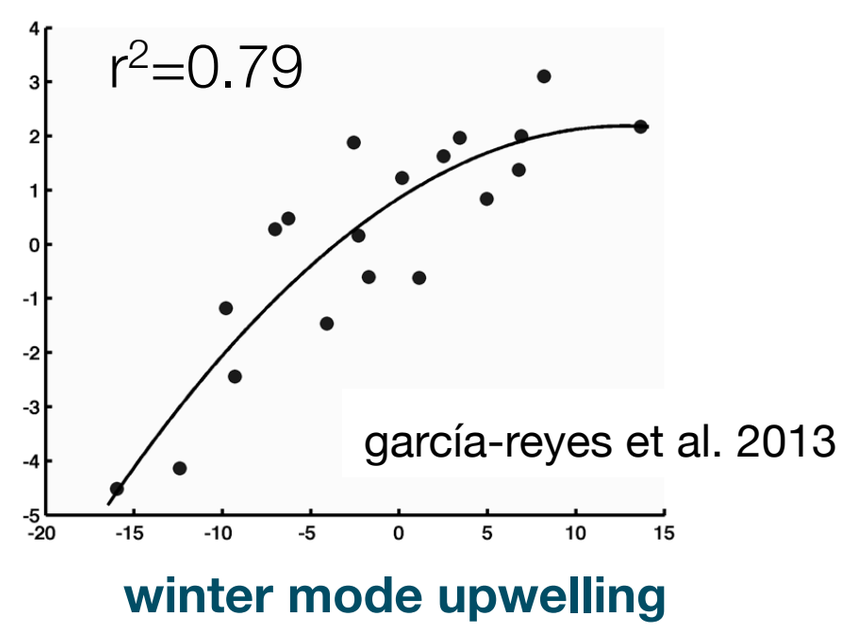
winter climate reconstruction



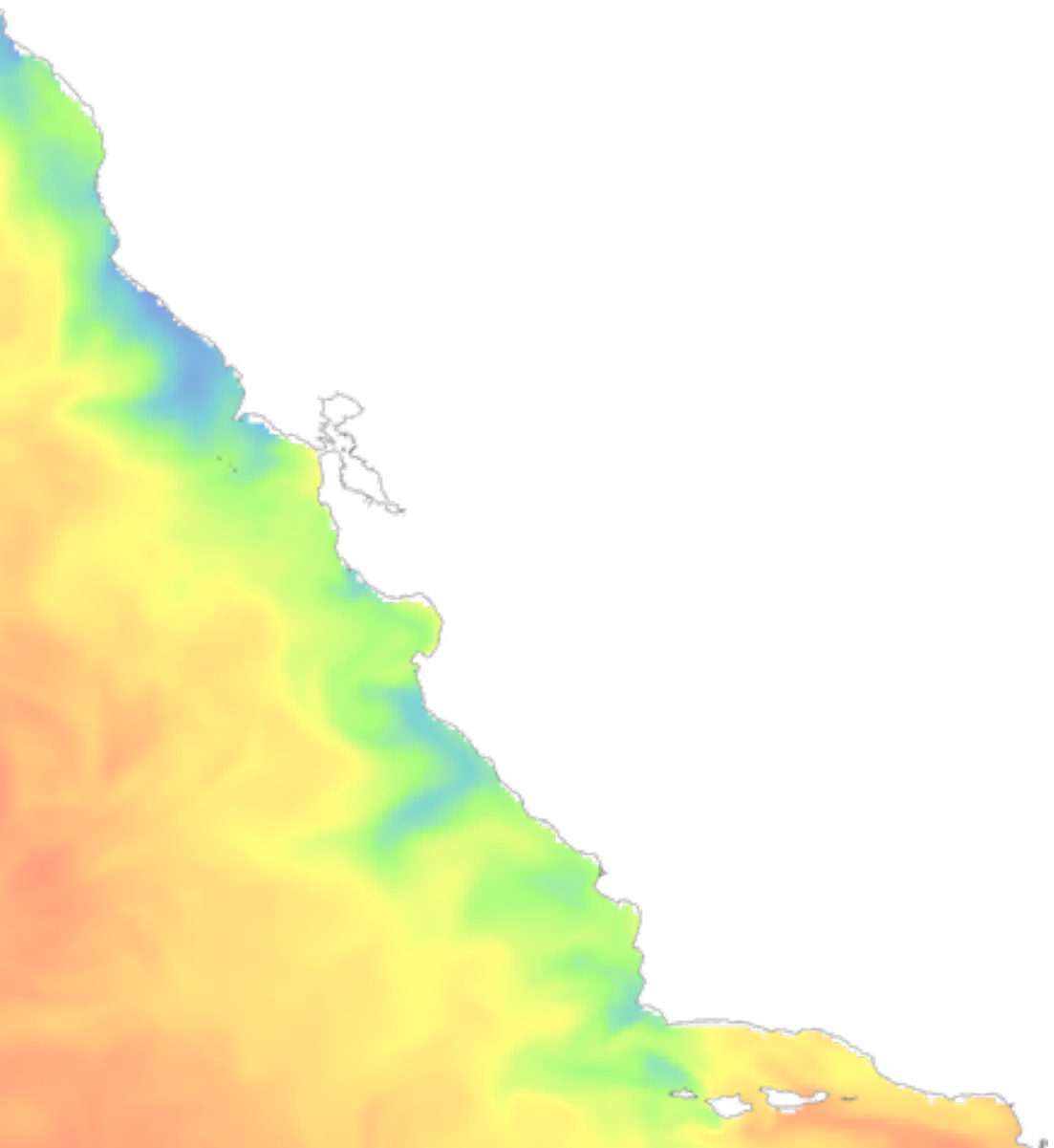
black et al., submitted



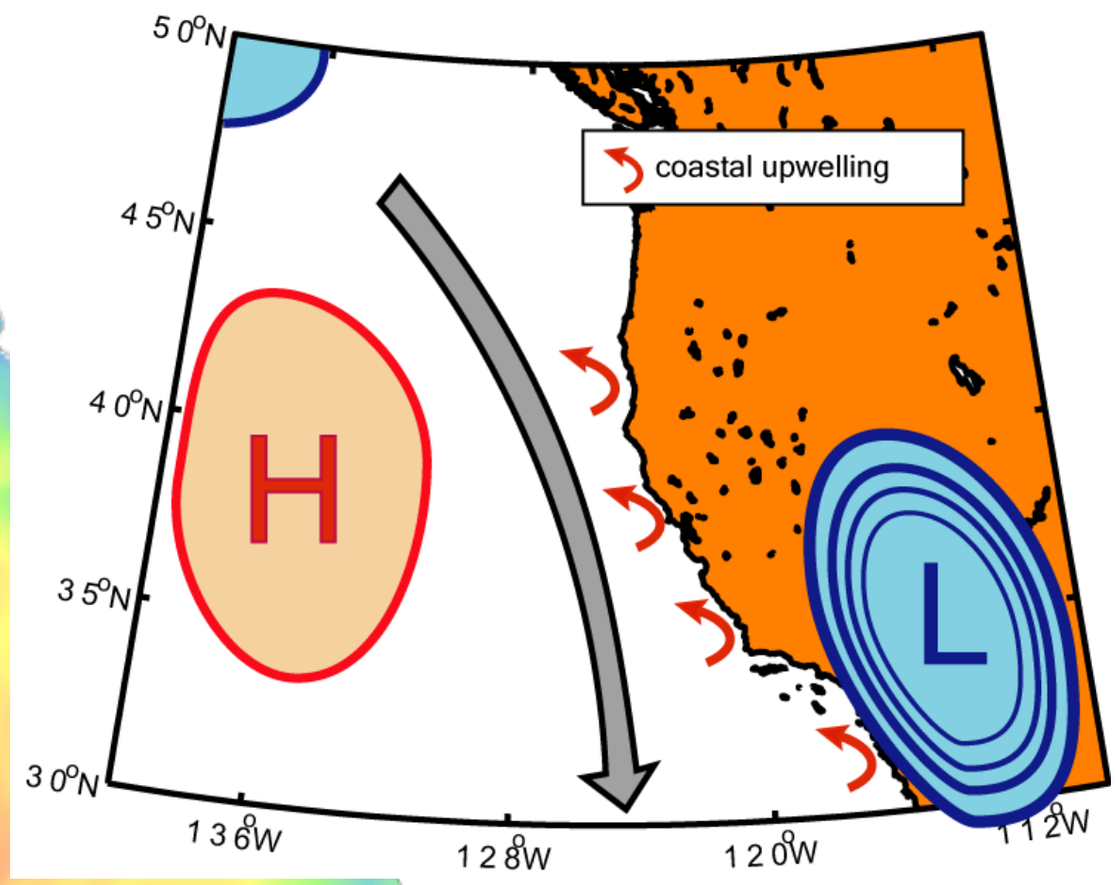
biological principal component



future

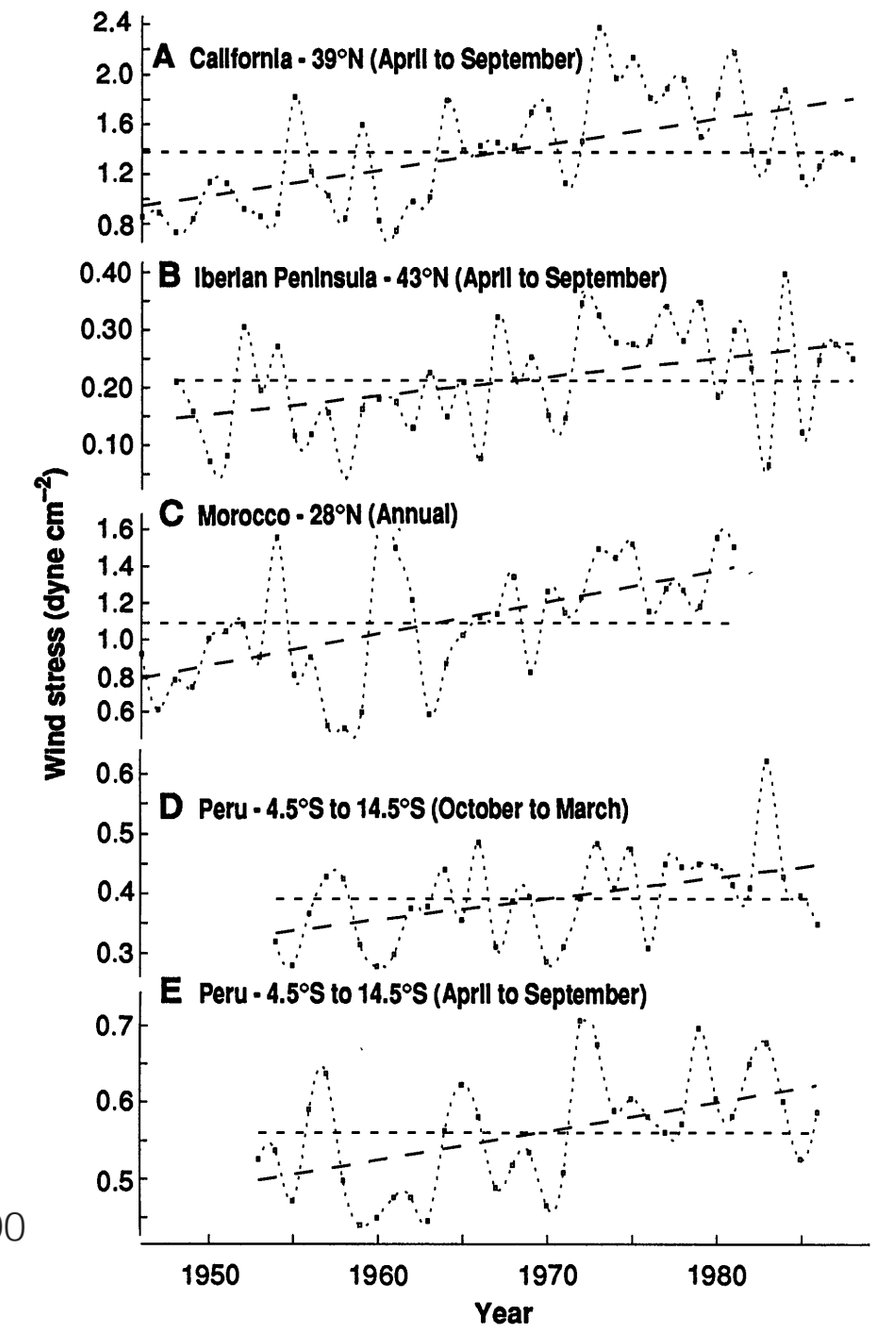


bakun hypothesis: wind intensification



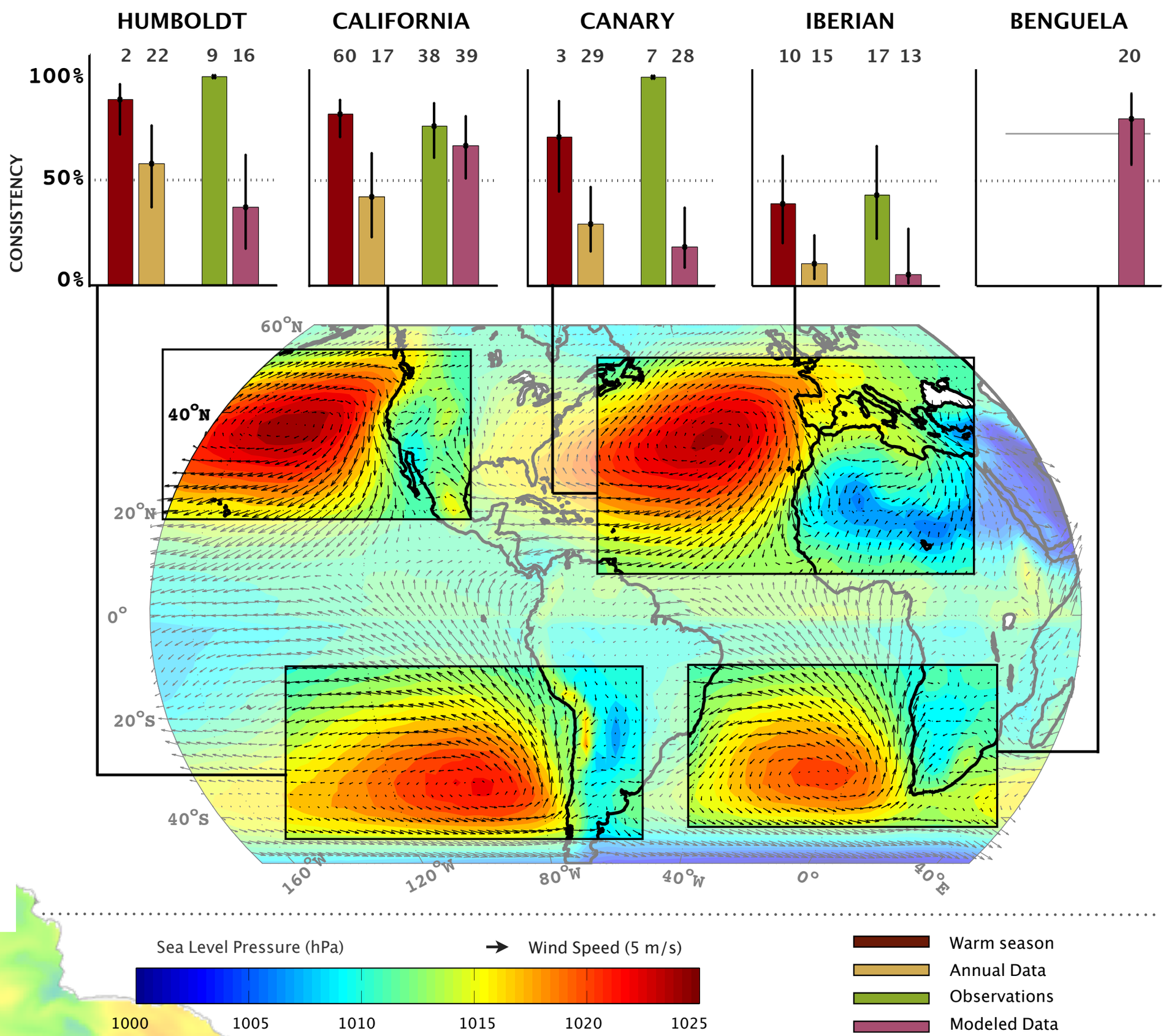
Global Climate Change and Intensification of Coastal Ocean Upwelling

ANDREW BAKUN



bakun, 1990

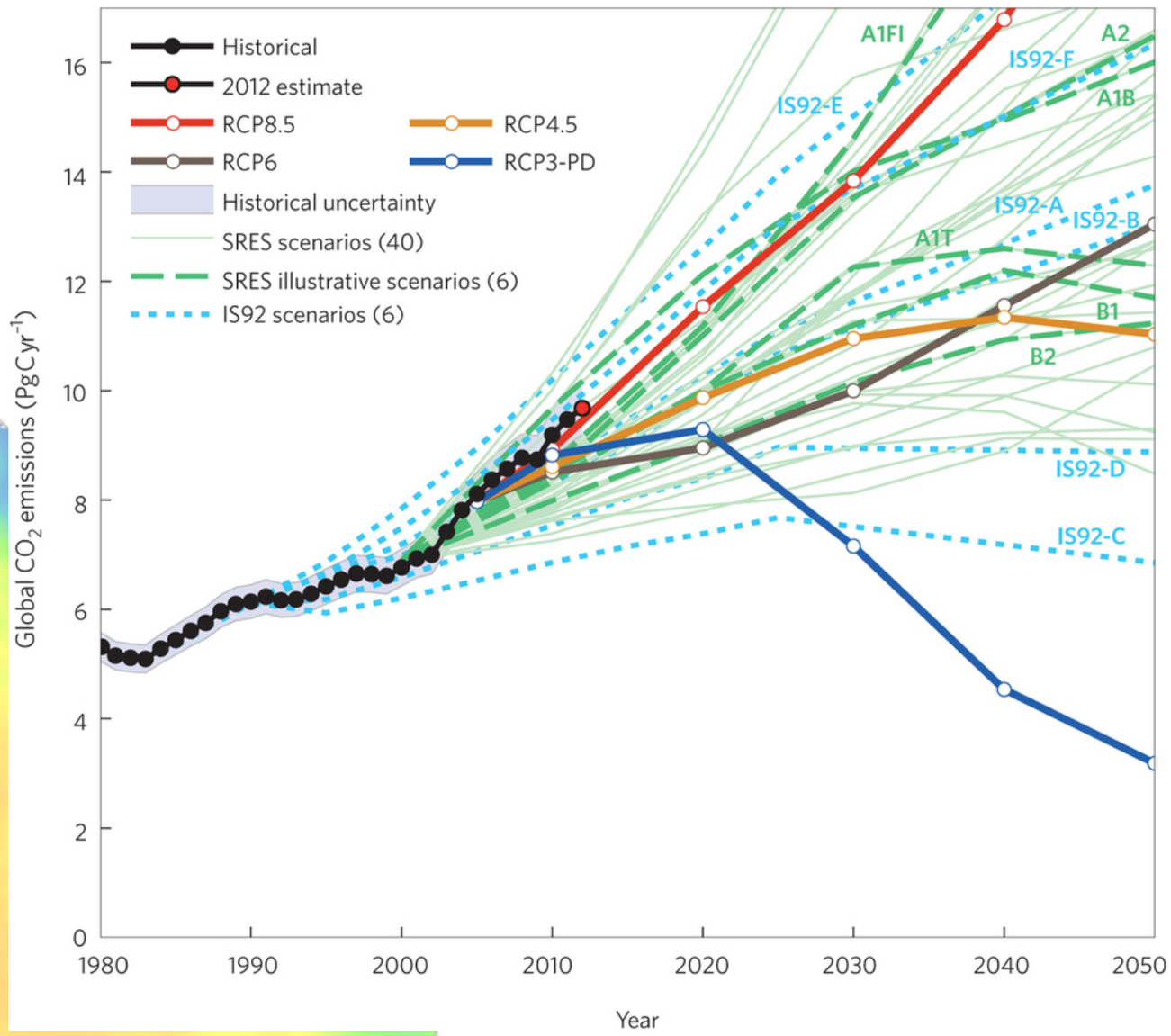
meta-analysis of linear trends on upwelling-favorable winds



sydeman et al., in prep.

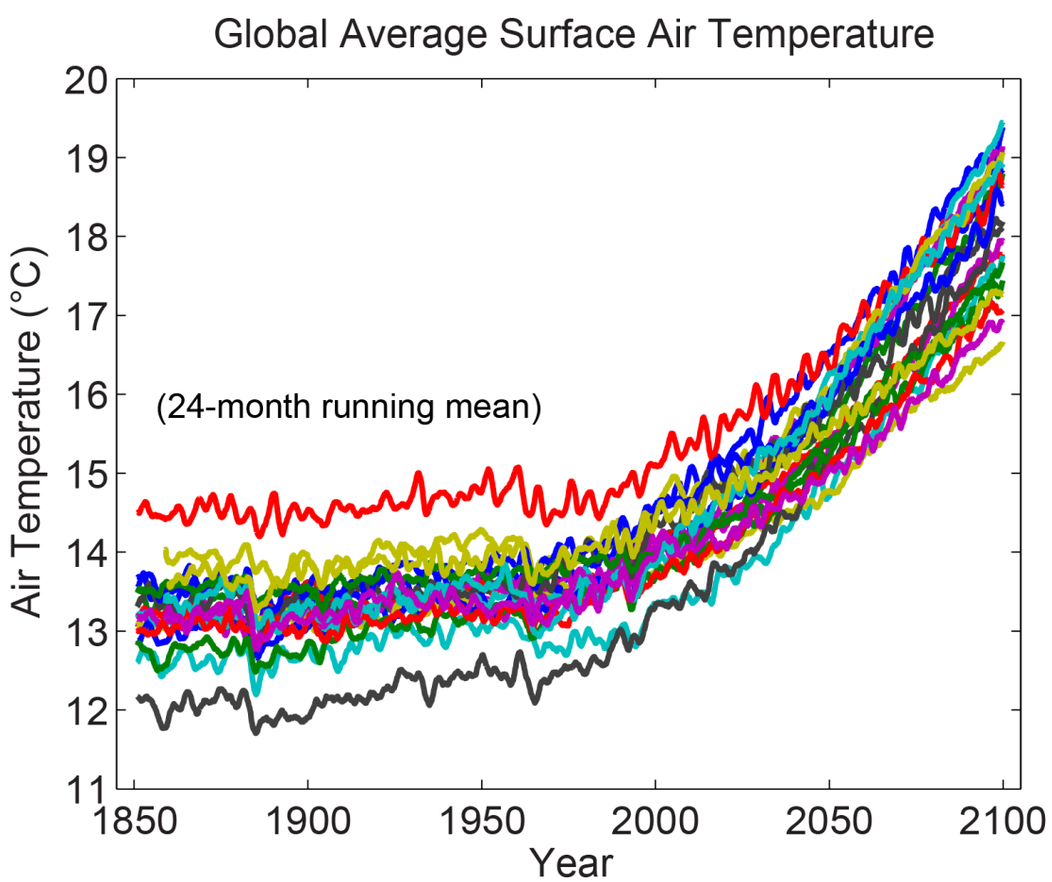
back to the future

global climate models included in the IPCC AR5

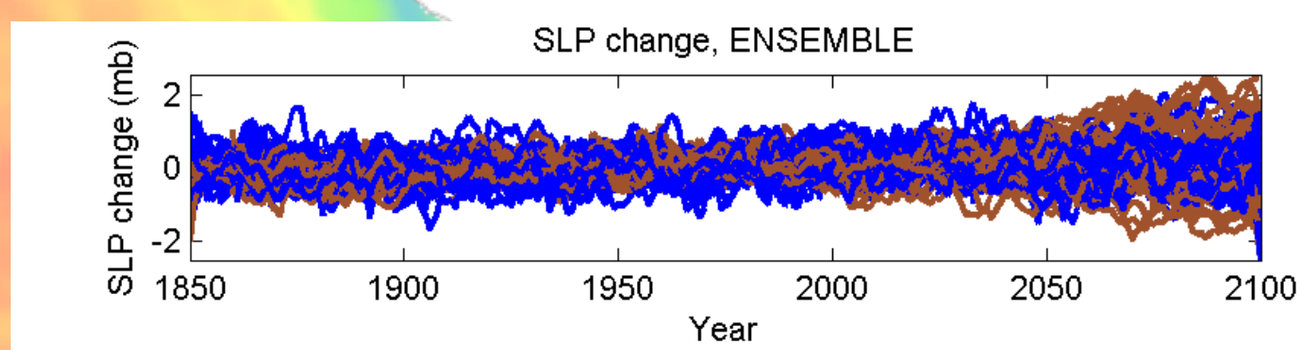


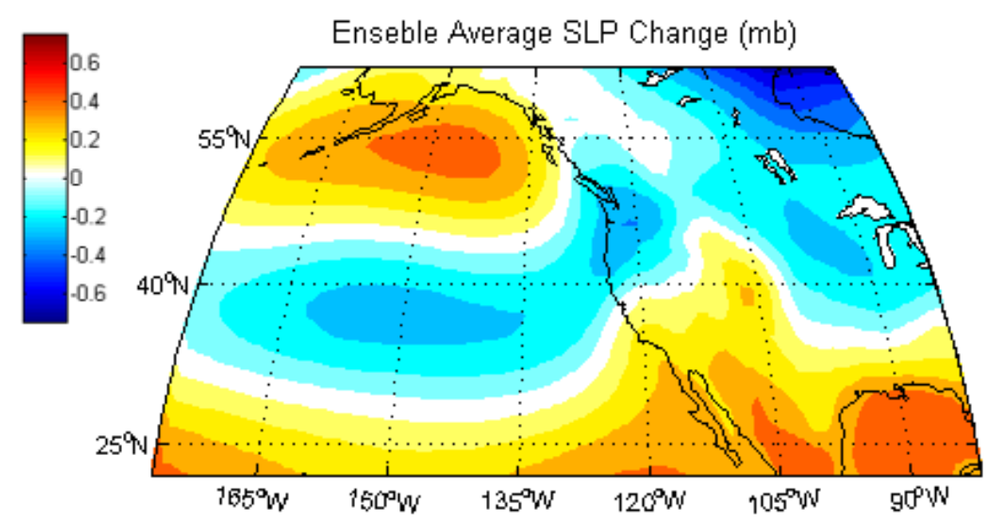
IPCC Models Included		
Modeling Center	**Model (# of versions)**	**Country**
CCCma	CanESM2	Canada
CMCC	CMCC (3)	Europe
CNRM-CERFACS	CNRM-CM5	France
CSIRO-BOM	ACCESS1 (2)	Australia
CSIRO-QCCCE	CSIRO-Mk3.6.0	Australia
IPSL	IPSL-CM5 (3)	France
MOHC	HadGEM2-A	UK
NCAR	CCSM4	USA
NCC	NorESM1 (2)	Norway
NOAA GFDL	GFDL (4)	USA
NSF-DOE-NCAR	CESM1 (5)	USA

bakun hypothesis: global model projections



Process Prediction	Pass	Fail
1. future surface warming	✓	
2. increased heating of continental surface air mass relative to ocean surface air mass	✓	
3. intensification of the continental Low relative to the Pacific High during summer		✗
4. increased land-sea pressure gradient		✗
5. intensified alongshore winds during summer		





in summary

- upwelling in california shows two modes of variability, driven by different atmospheric processes, and with differential impacts on the ecosystem

- winter mode is driven by large-scale north pacific high pressure system
  - allows the use of global climate models to study future variability
  - new hypothesis of how upwelling is going to change with climate are needed

- winter mode impacts terrestrial and marine ecosystems
  - allows the use of long-lived organisms to study past variability
  - increment of extreme negative events in recent decades