Ecosystem Indicators

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- In the California Current there are numerous indicators to describe the state of the ecosystem
    - Both environmental and biological
    - Long-term time series
    - Wide range of variables and trophic levels

Environmental Indicators

- CalCOFI (1950): Profiles - Temperature, Salinity, Density, Nutrients, Chlorophyl, O2
- Shore Stations (1920's): Temperature and Salinity
- Sea Level (1920's, 1970's)
- NDBC Buoys (1980's): wind, SST, SLP, air temperature
- Moorings: Profiles

- Winter mode of upwelling variability
- MOCI: Multivariate Ocean Climate Indicator

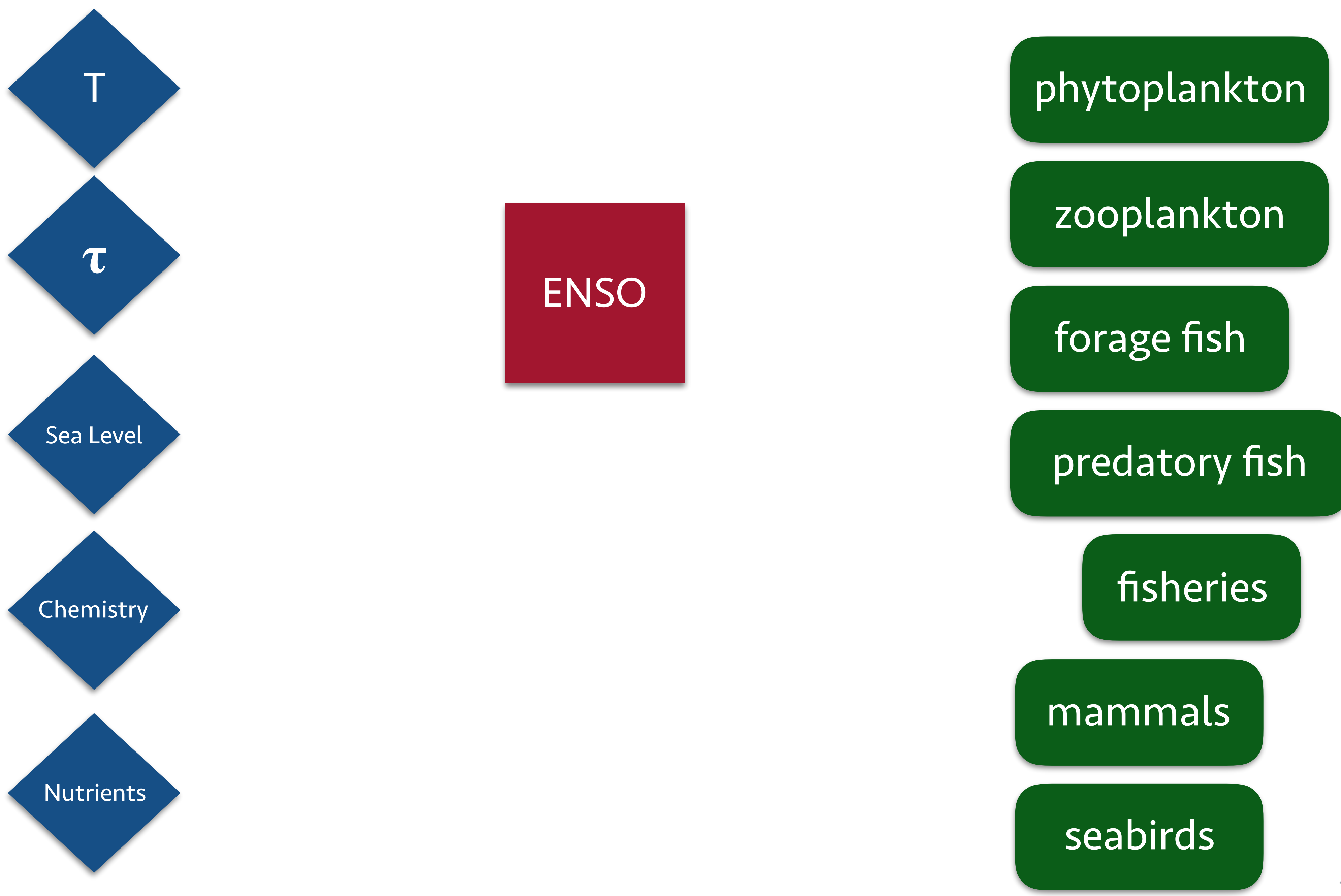
Biological Indicators

- Macro-zooplankton, fish egg and larvae abundance (CalCOFI)
- Copepod Index: zooplankton biomass and community composition (Peterson)
- Juvenile rockfish abundance (cruises) and growth chronologies (otholits)
- Forage fish (Sardine and Anchovy) abundance assessments
- Salmon abundance measured as returns/escapement
- Marine mammals abundance
- Seabirds (abundance @sea, productivity and phenology @ Is.)

Which indicators indicate ENSO?

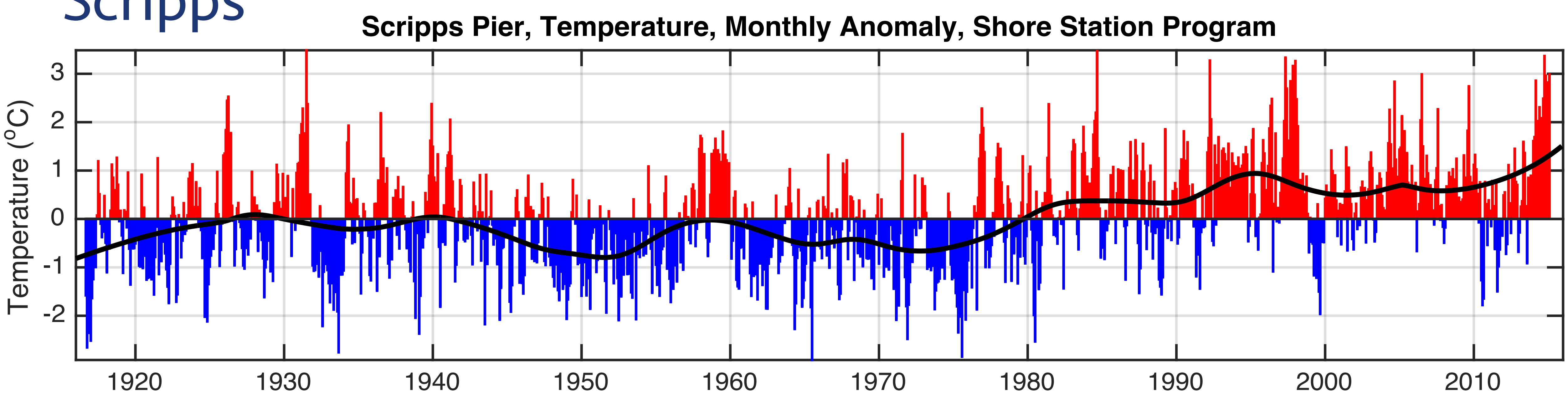
Environmental indicators

Biological indicators

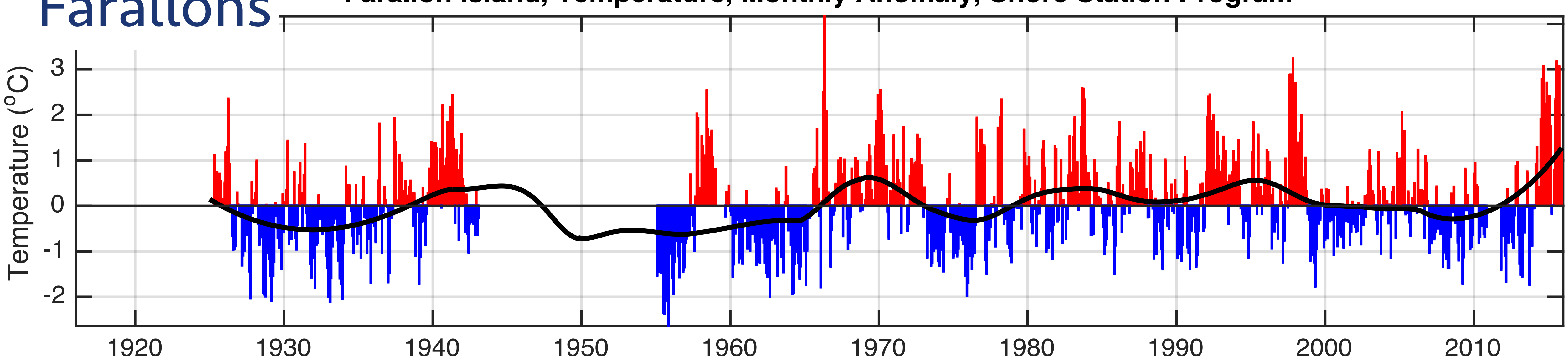


Sea Surface Temperature

Scripps



Farallons



Shore Station Program

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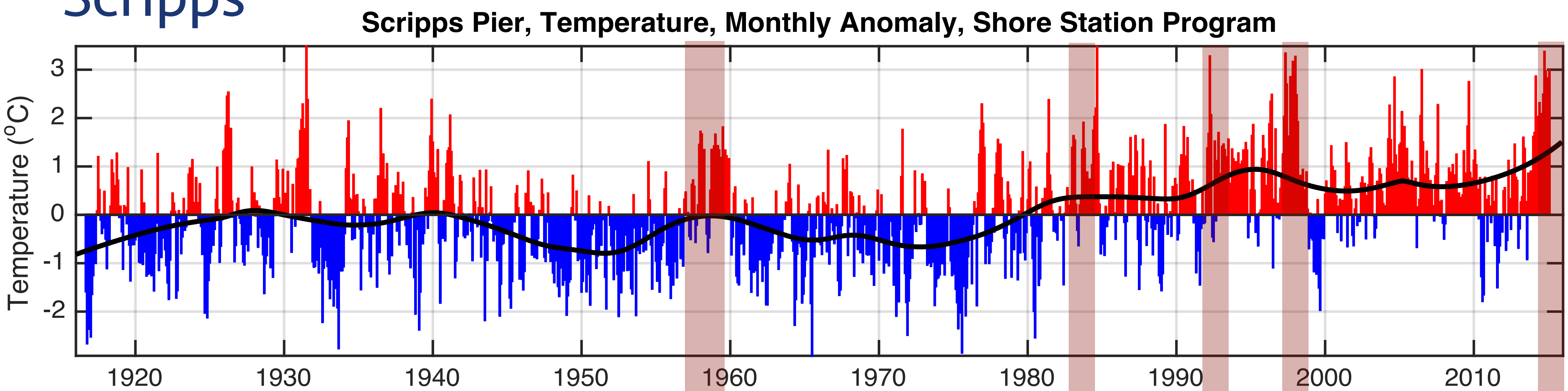
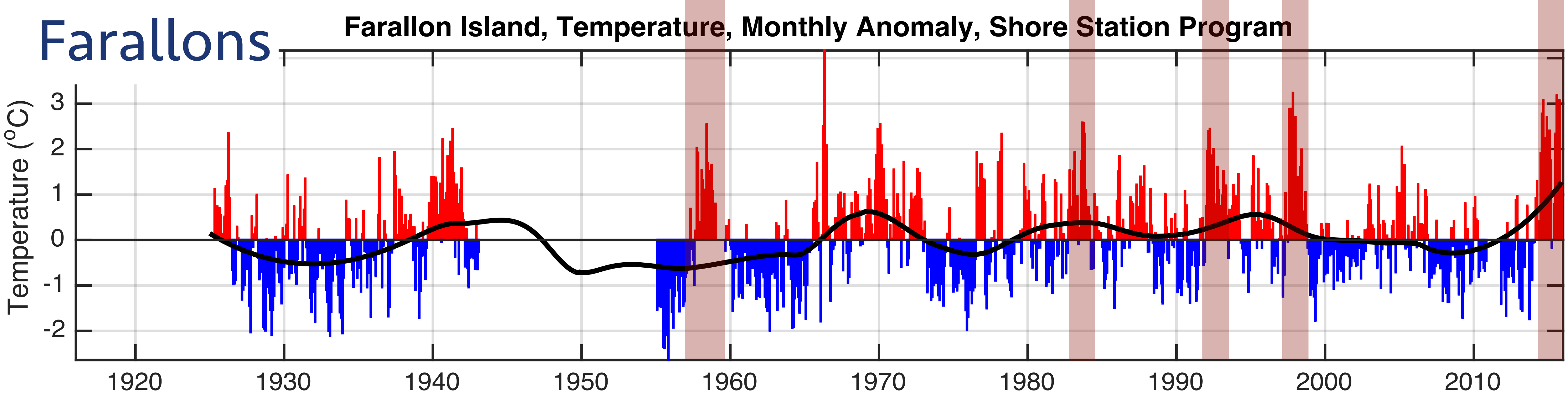
Sea Surface Temperature

Scripps



Farallons



Shore Station Program

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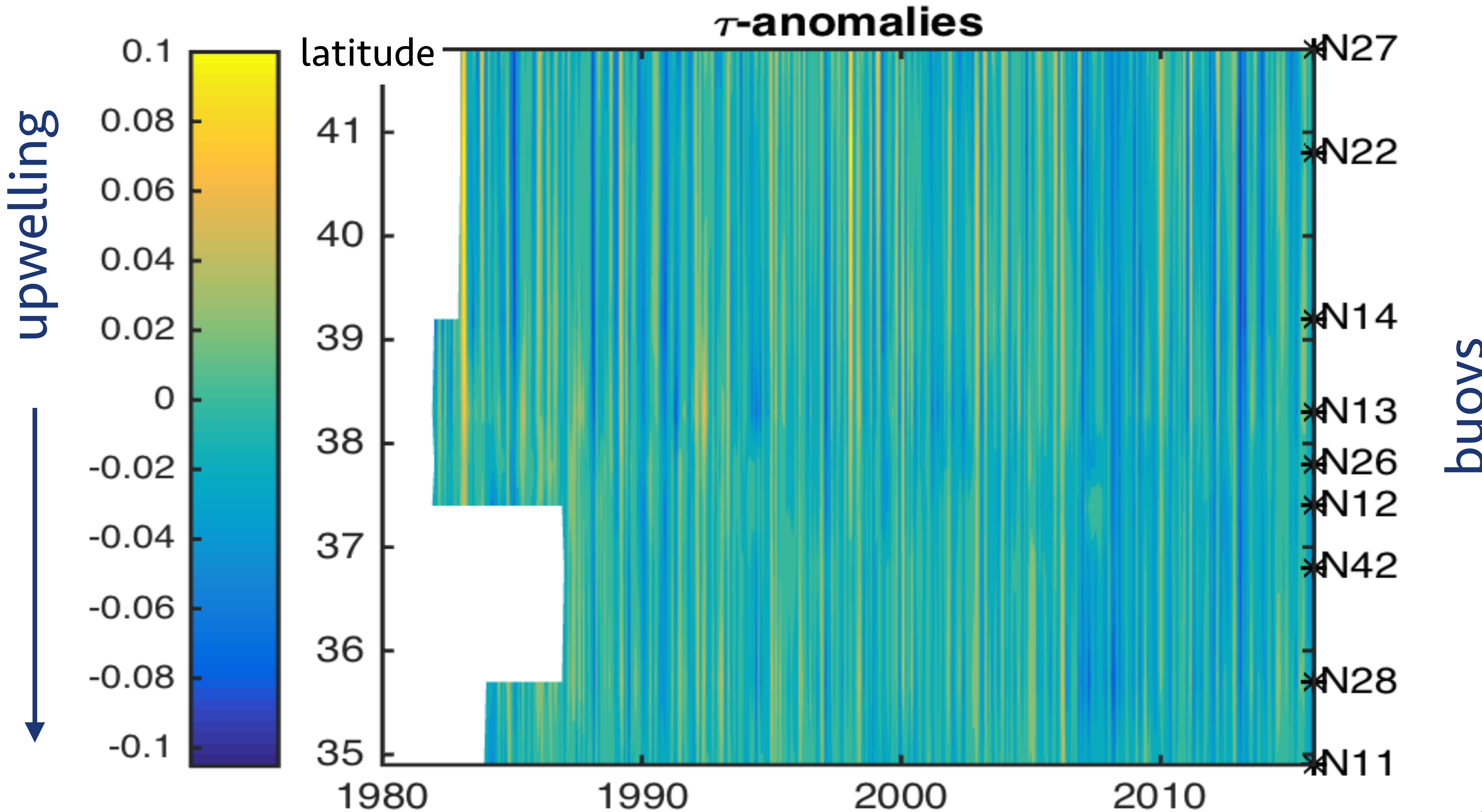
Upwelling-favorable winds



NDBC/NOAA buoys

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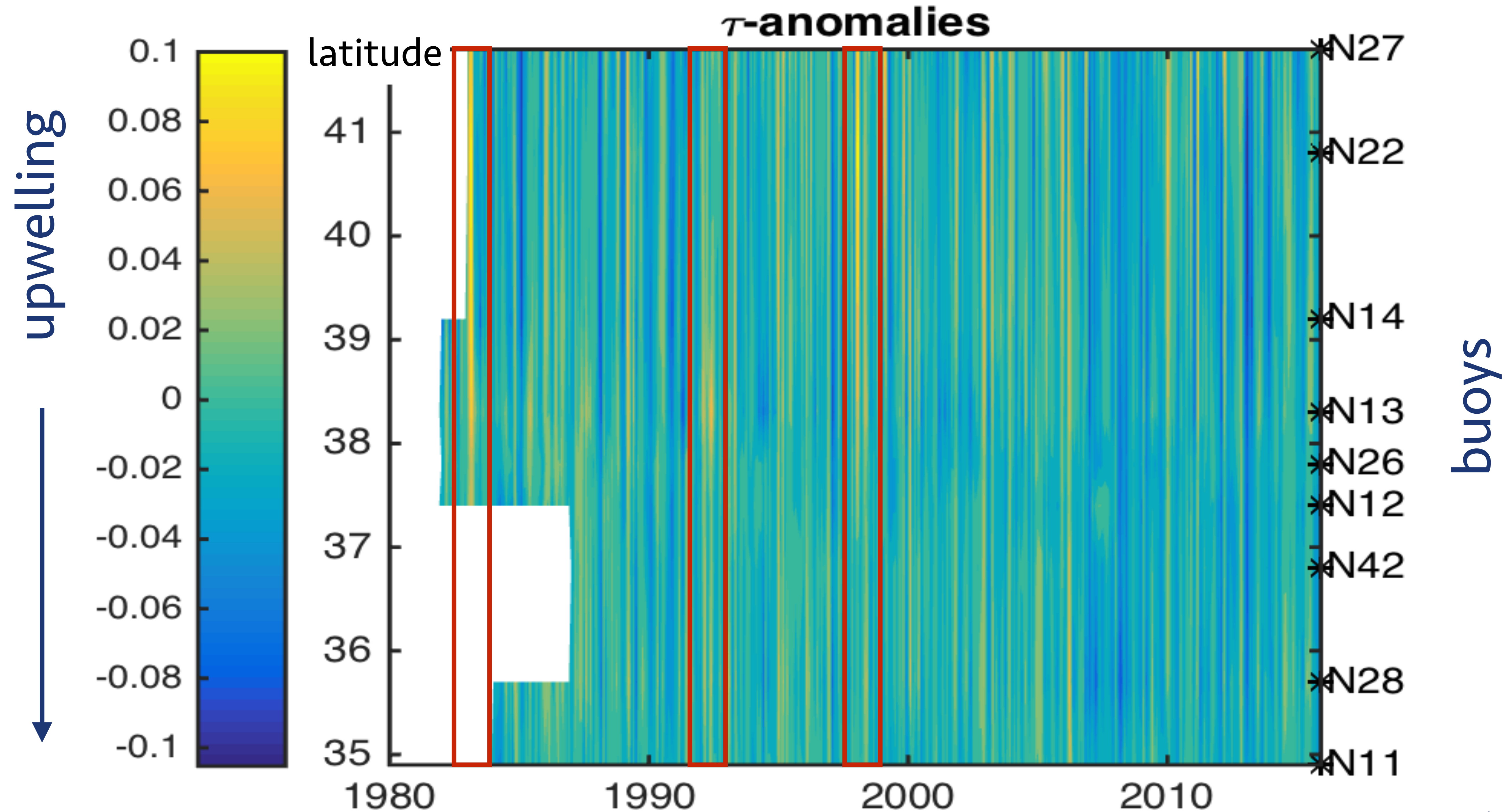
Upwelling-favorable winds



NDBC/NOAA buoys

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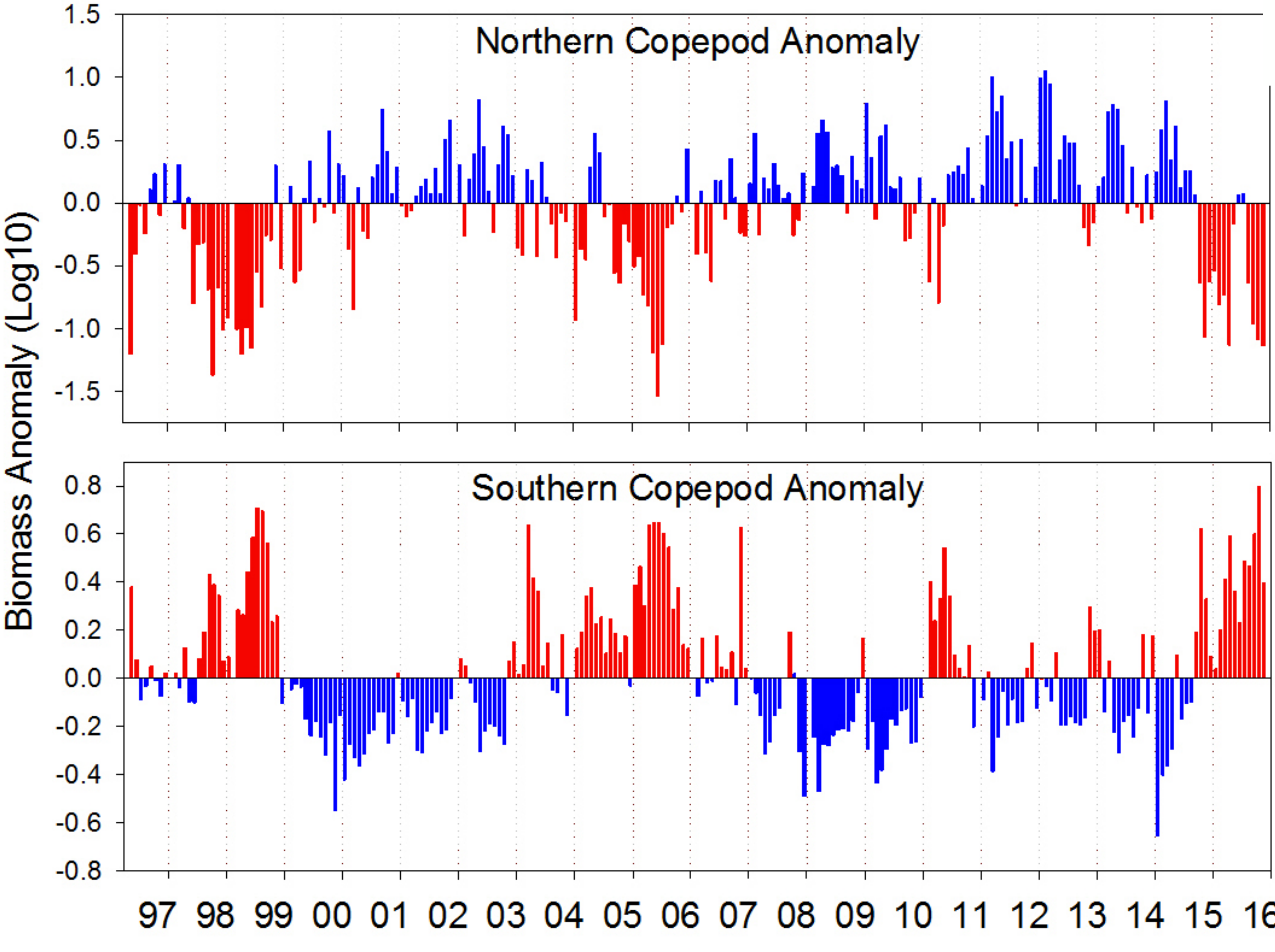

Newport line / NOAA website

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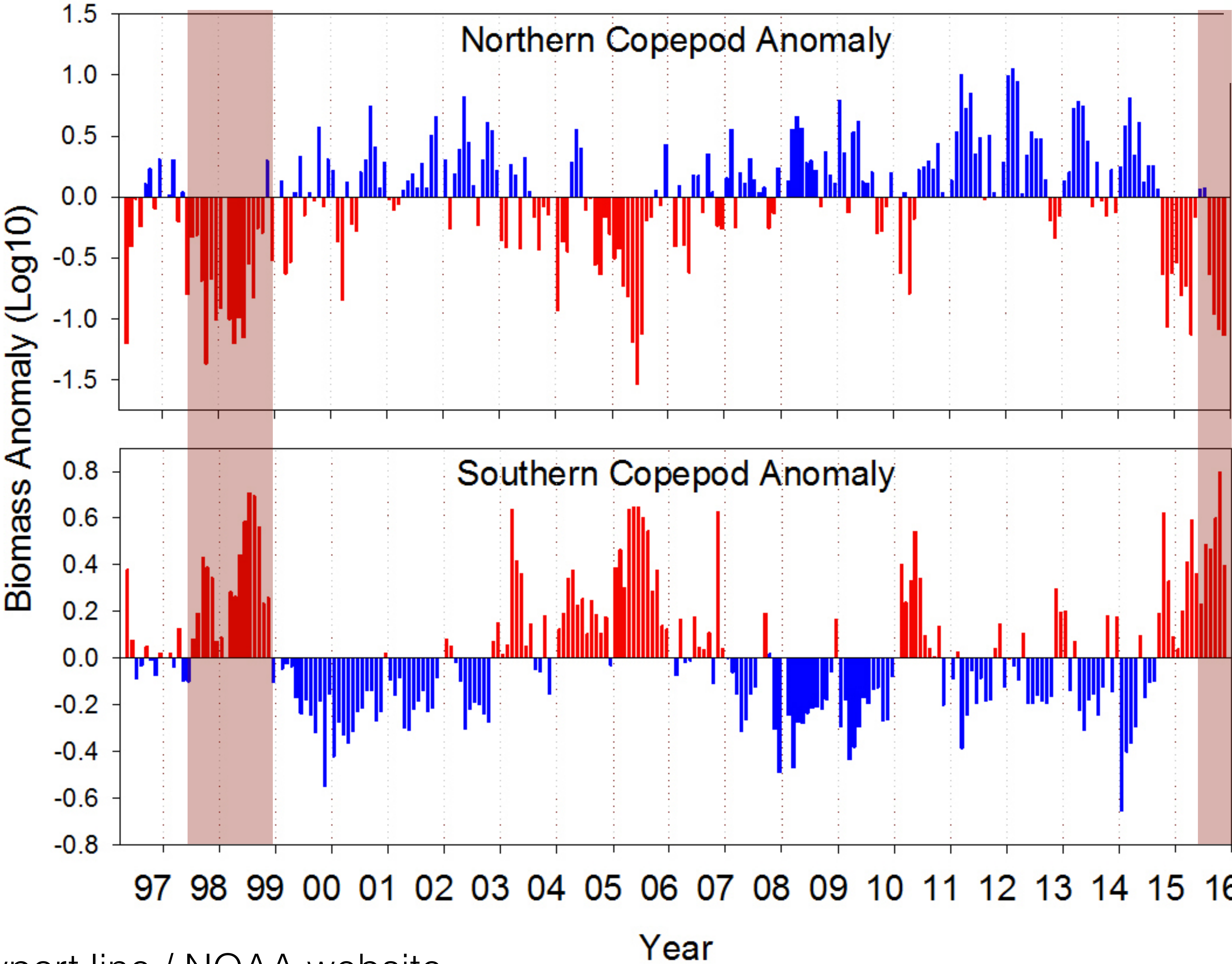

Newport line / NOAA website

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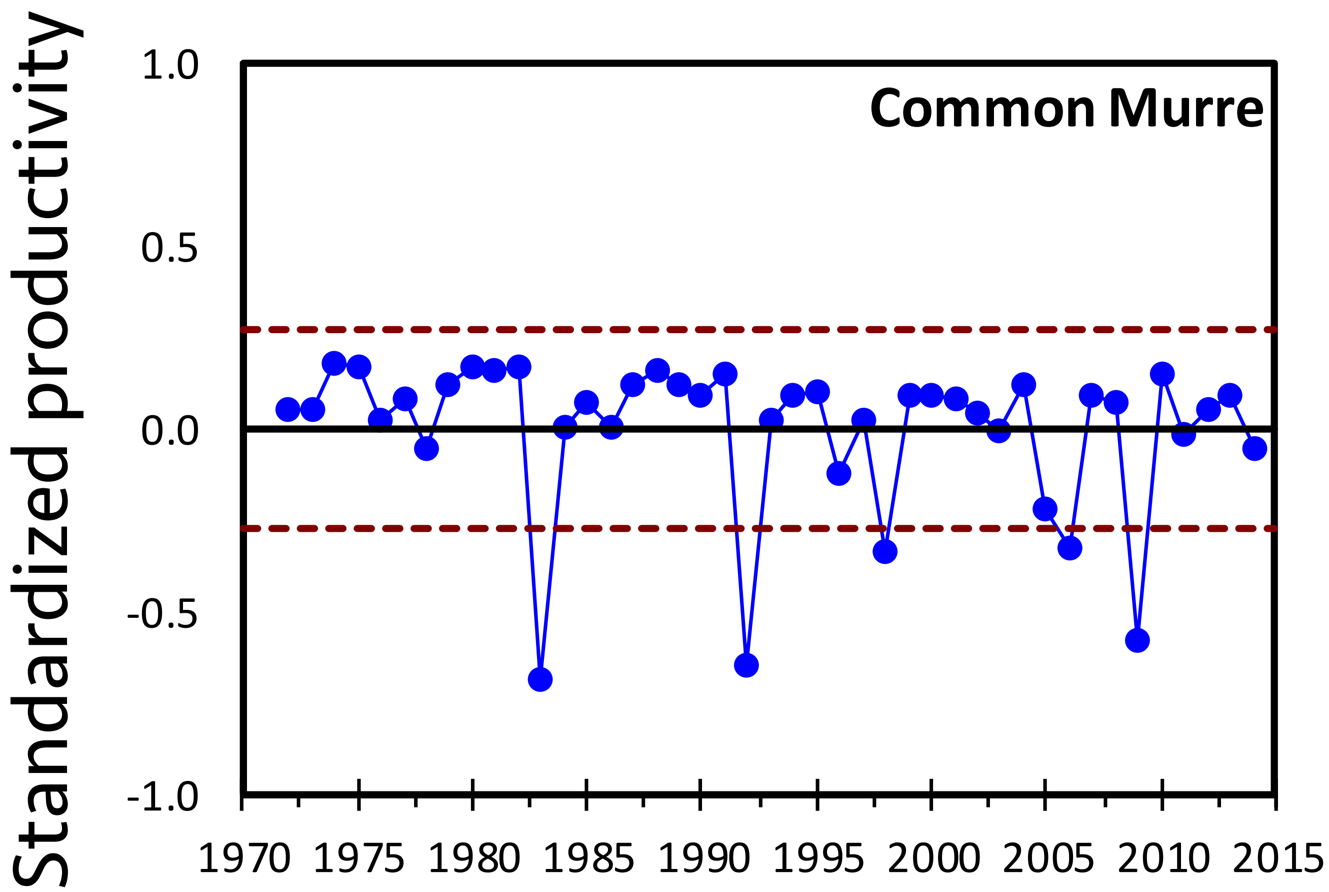
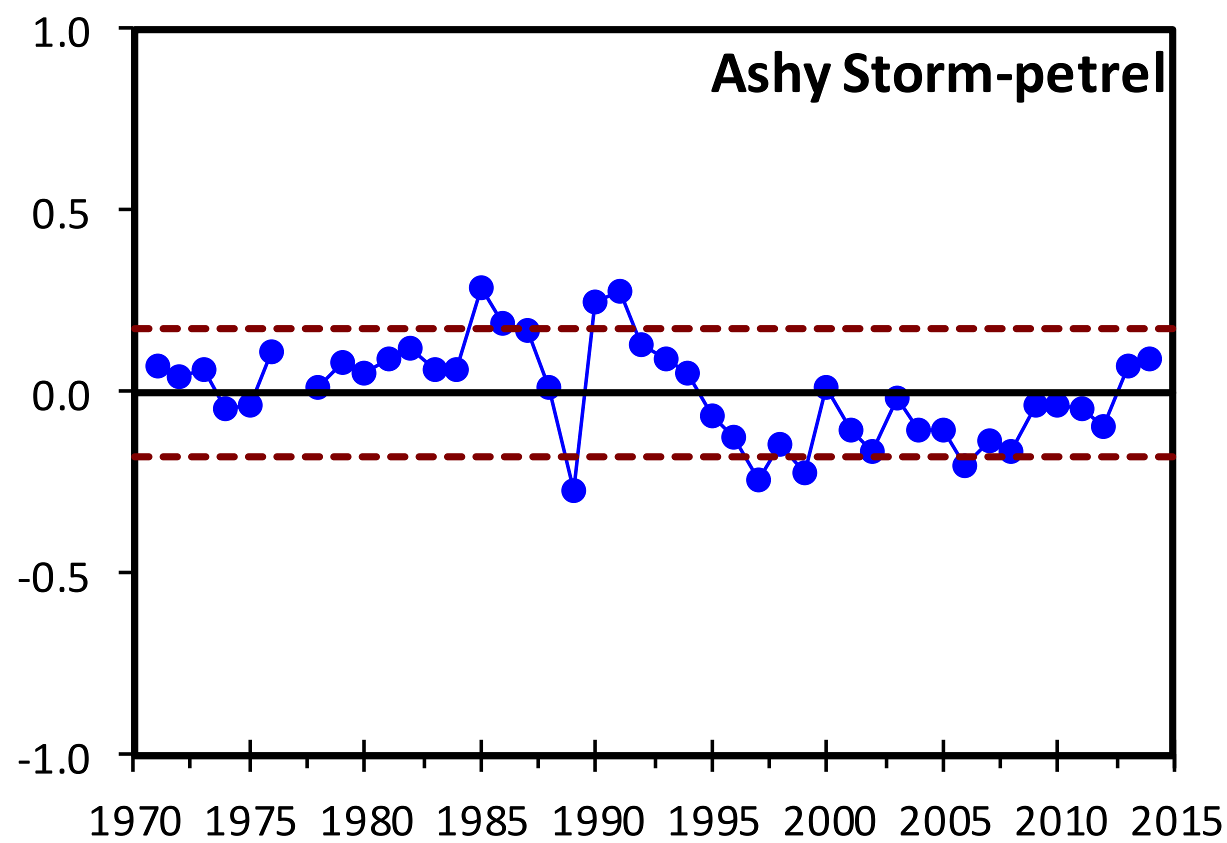
Sea birds





Breeding Success @ Farallon Islands
CalCOFI Rep., Vol 56, 2015

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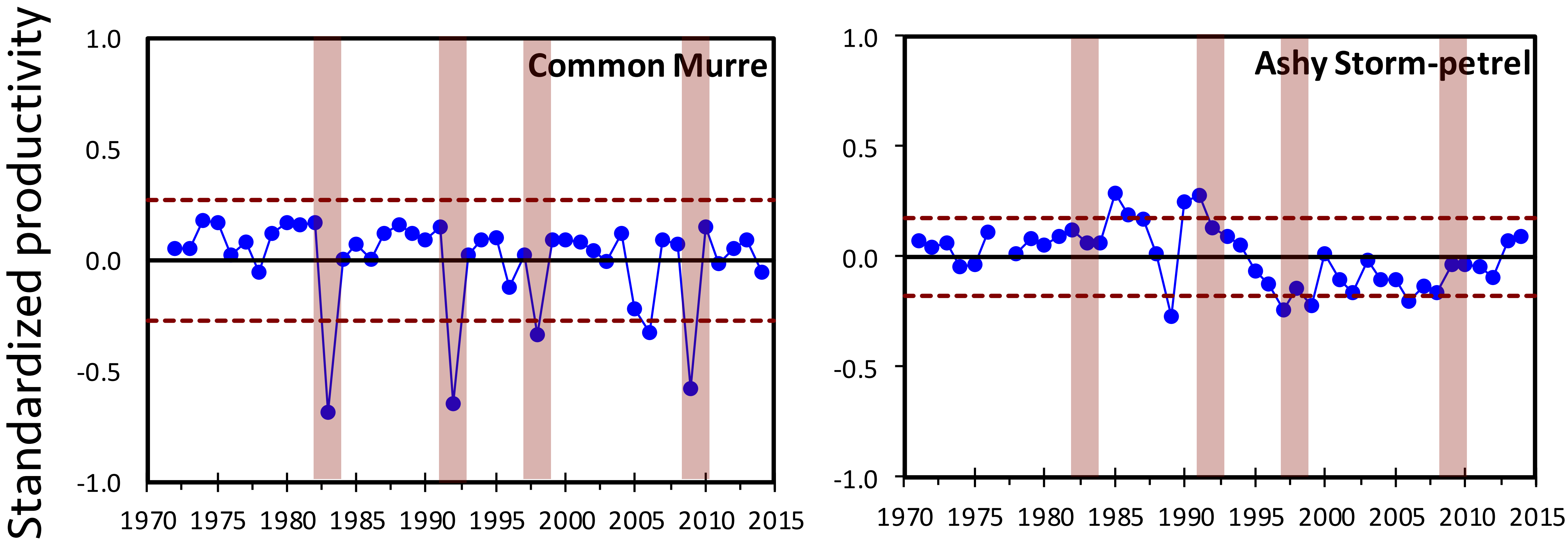
Sea birds



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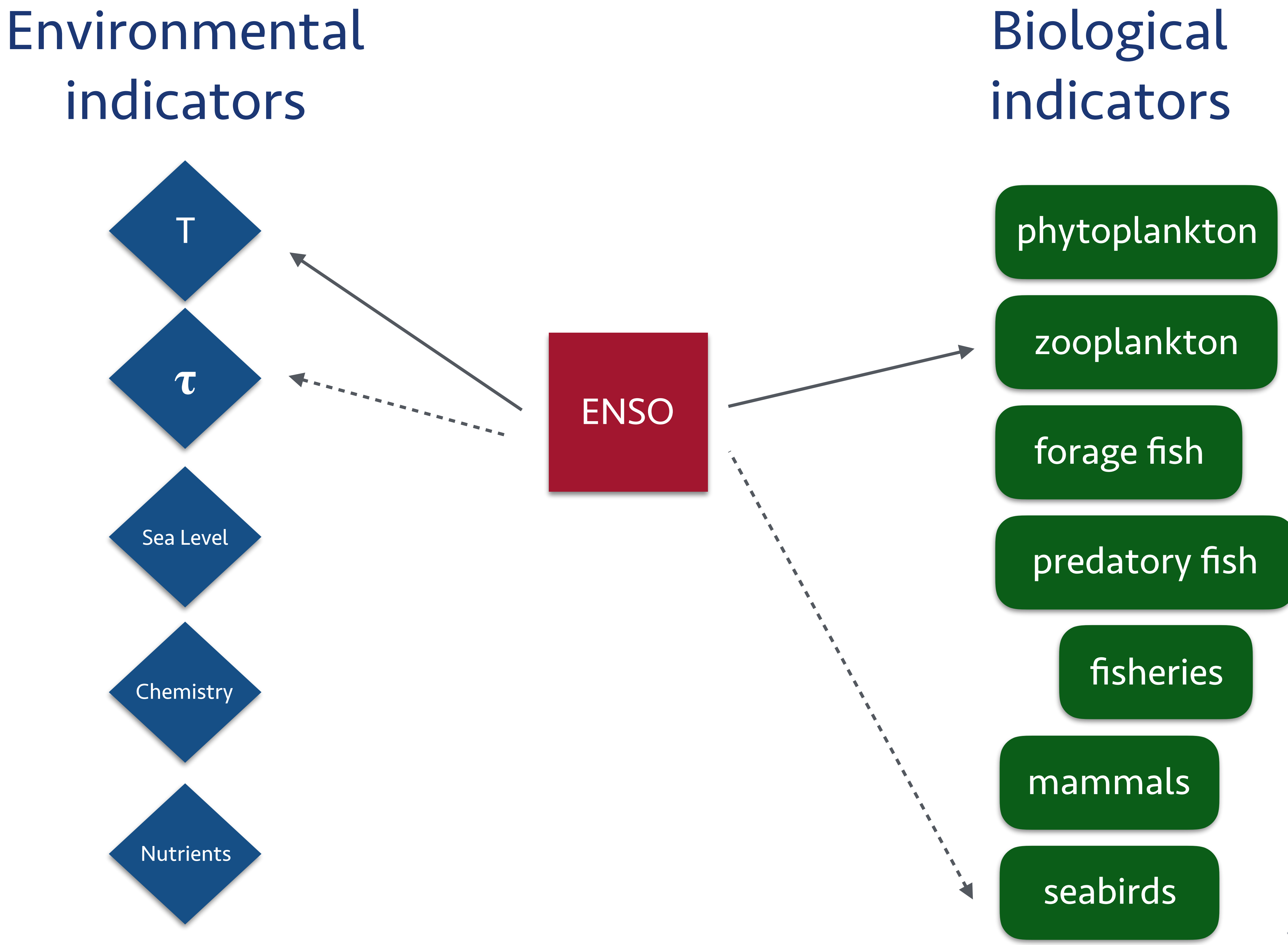
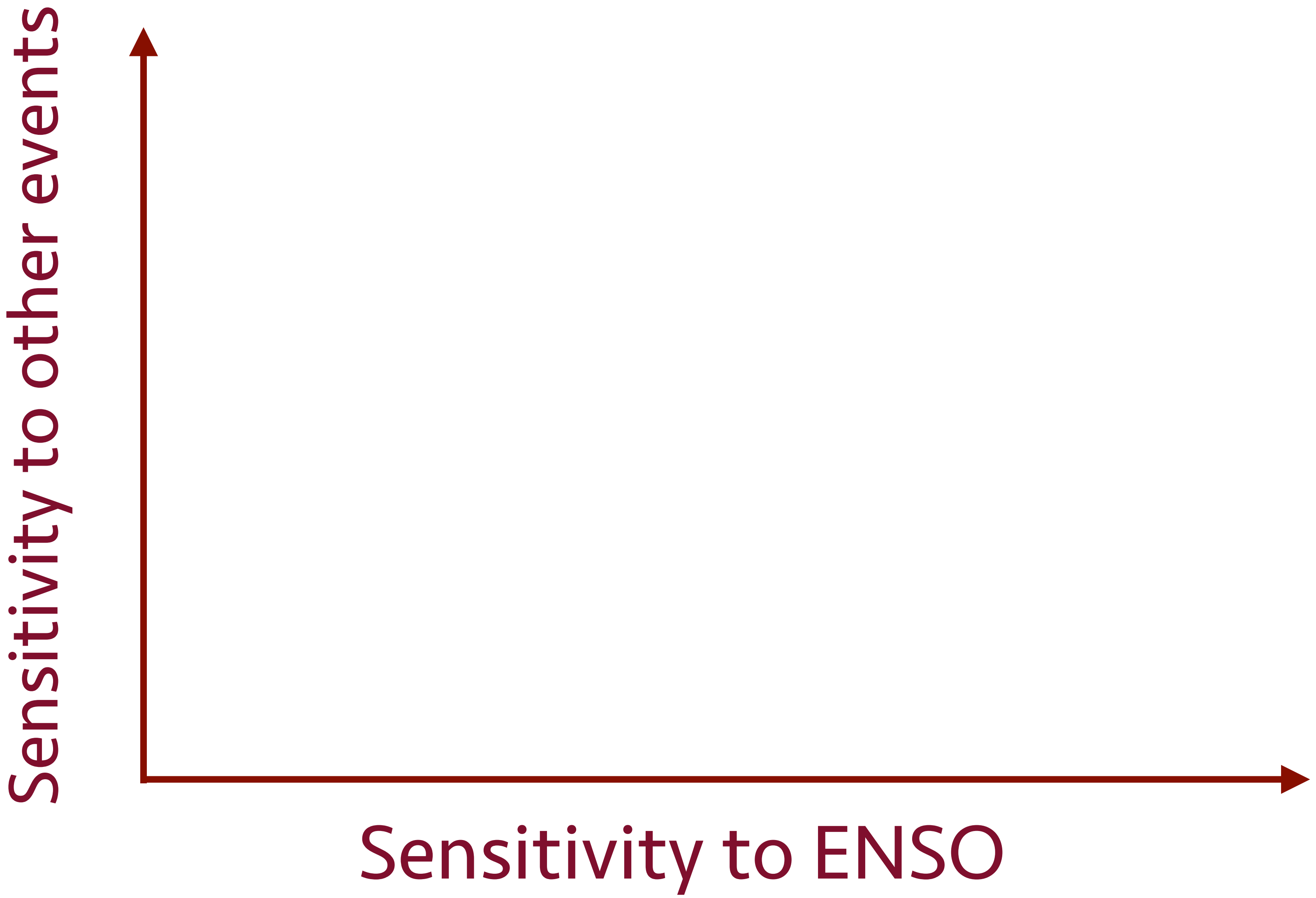
Which indicators indicate ENSO?



To describe the ecosystem state in relation to ENSO



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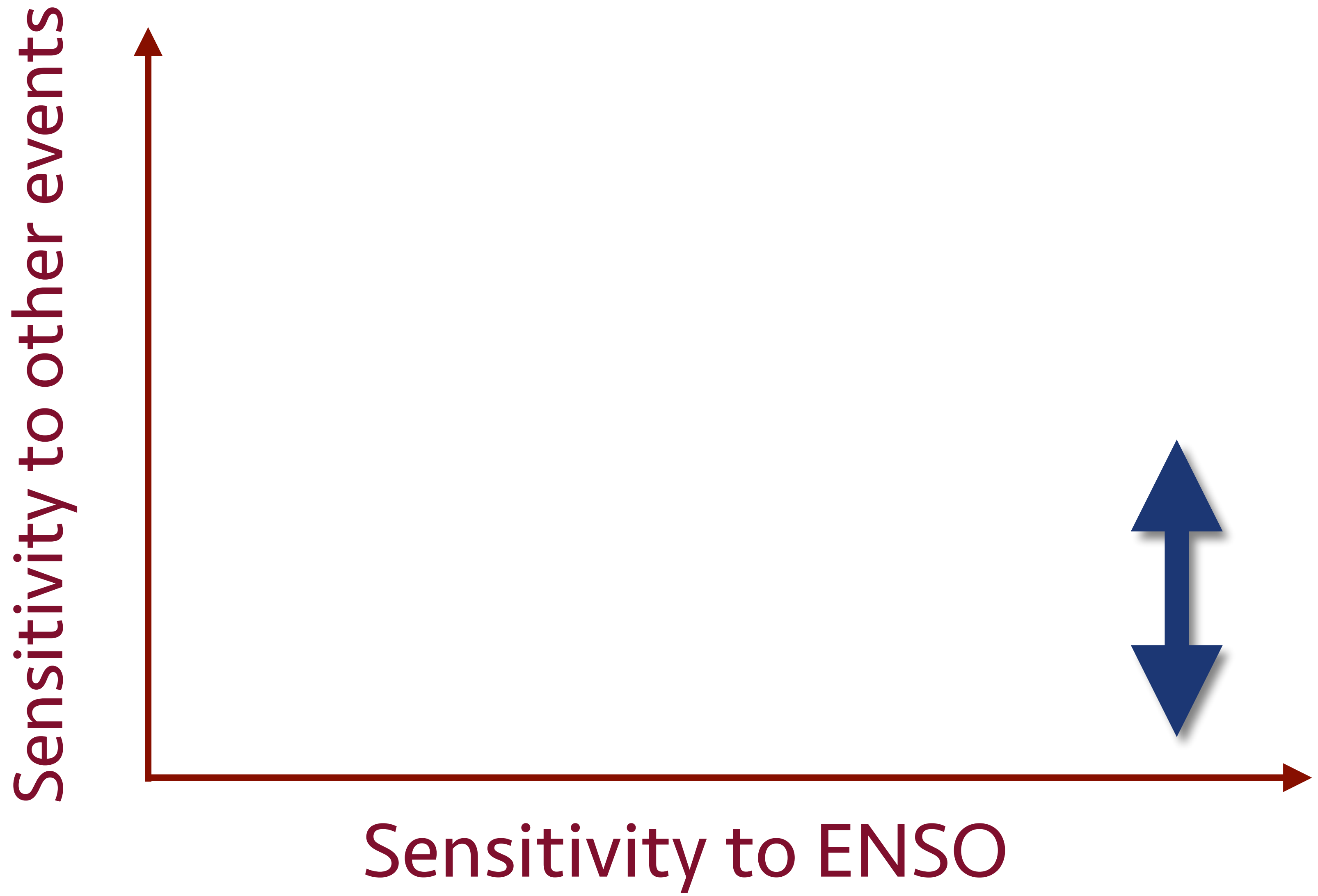

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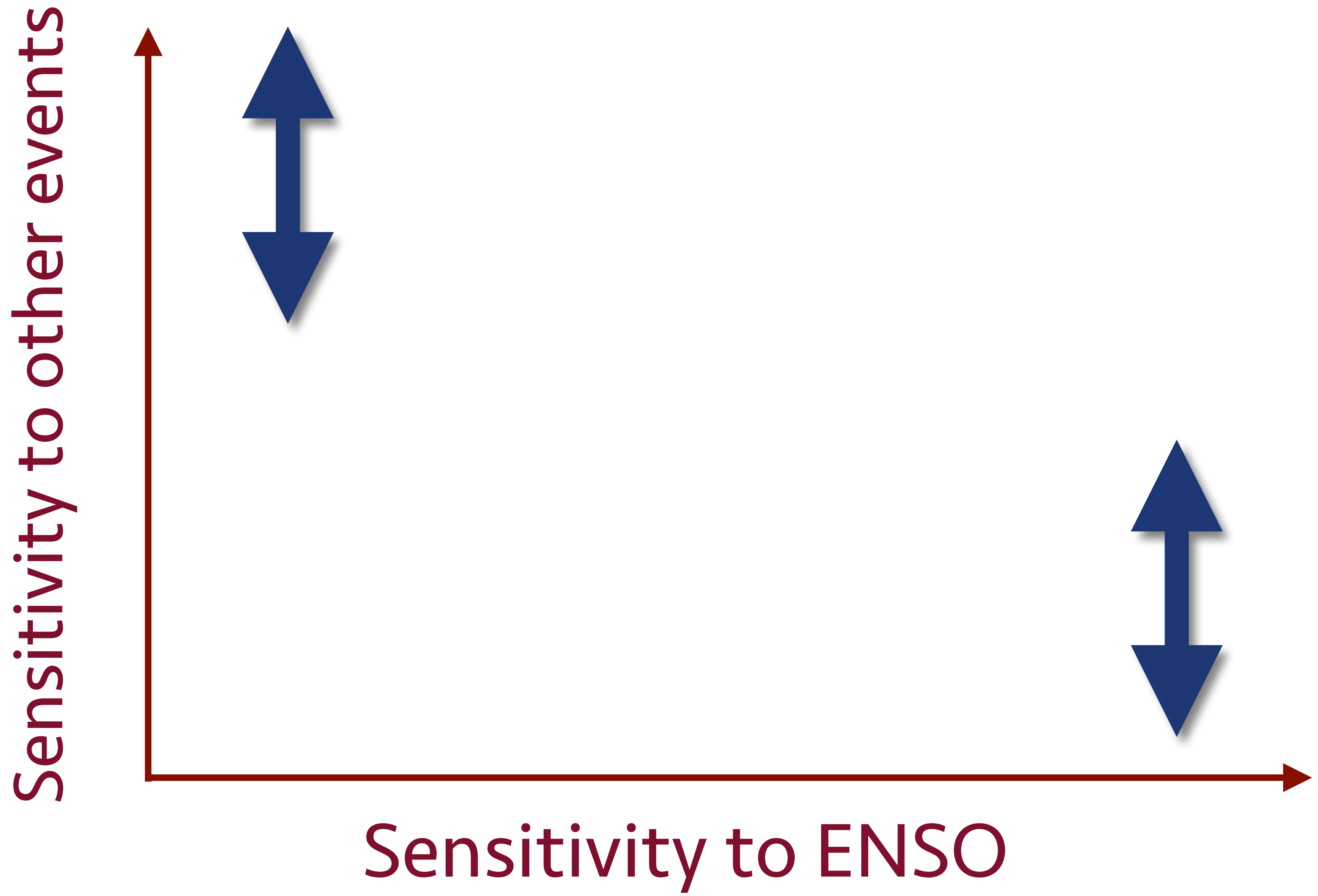

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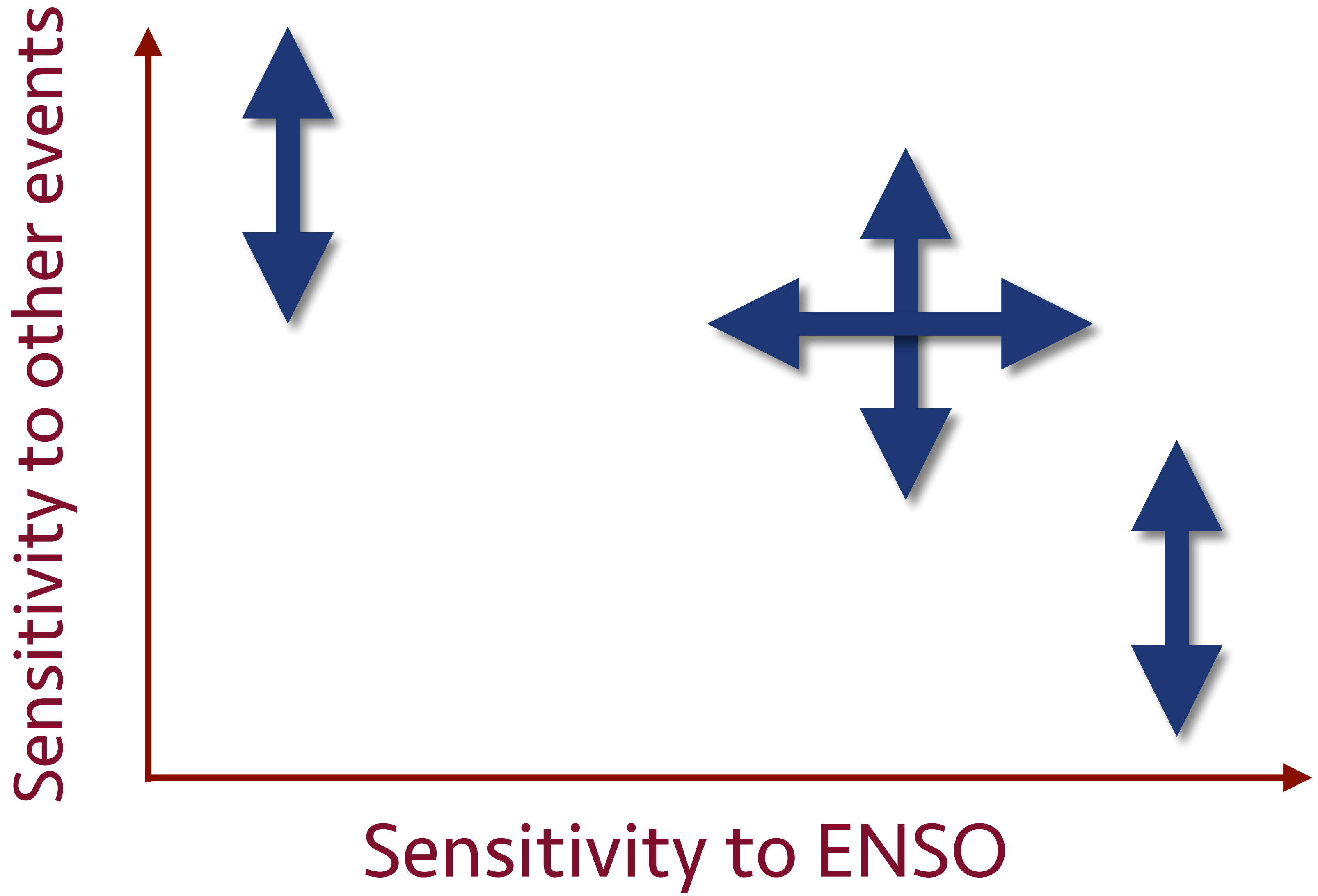

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Environmental Indicators

- In the California Current environmental variables are synchronized by climatic events
- Most variables are impacted by ENSO in different degrees

Multivariate Ocean Climate Indicator

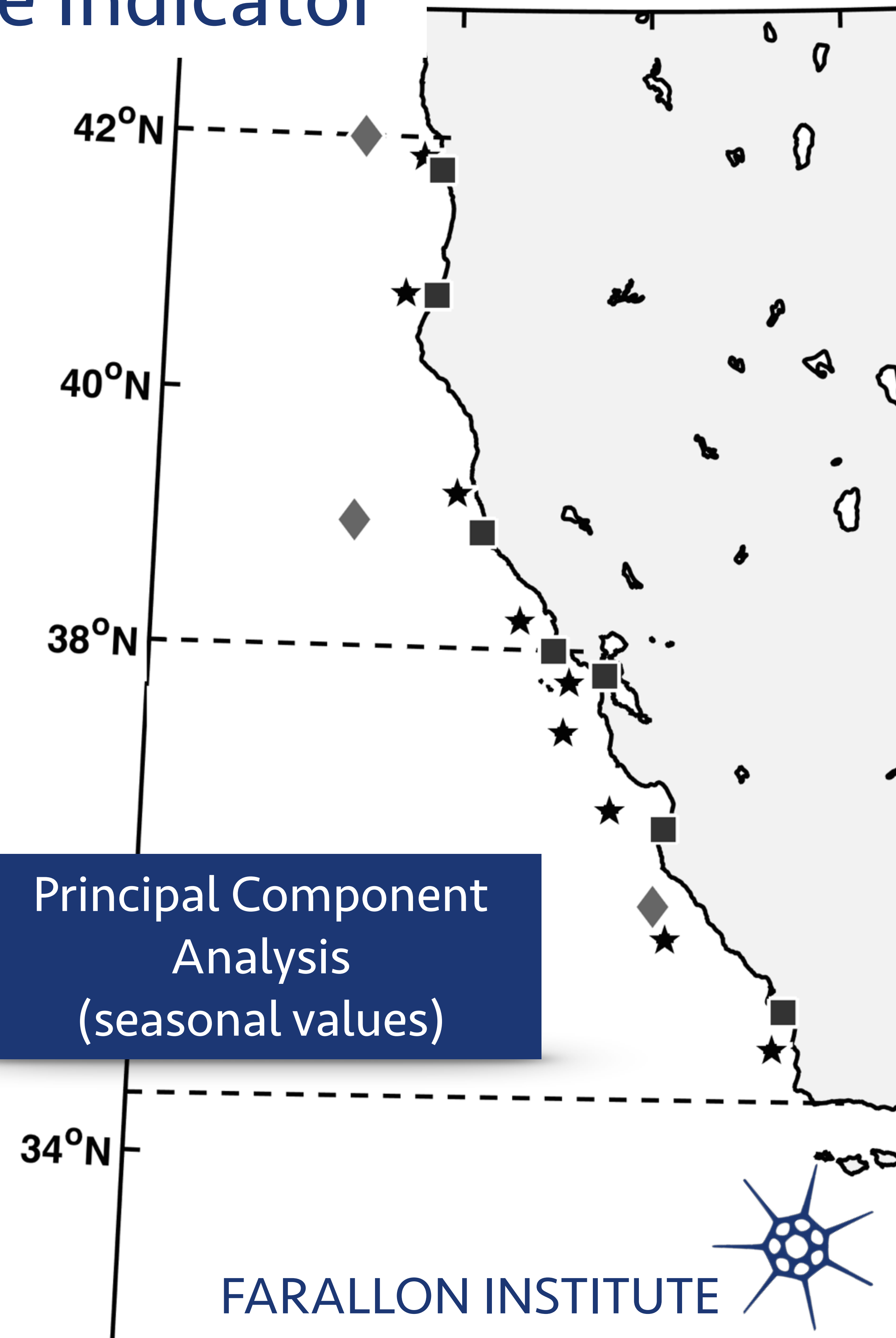
MOCI

★ Alongshore Wind
Sea Surface Temperature
Air Temperature
Sea Level Pressure

◆ Upwelling Index

■ Sea Level

Climate Indices:
MEI
PDO
NPGO
NOI



Principal Component Analysis (seasonal values)

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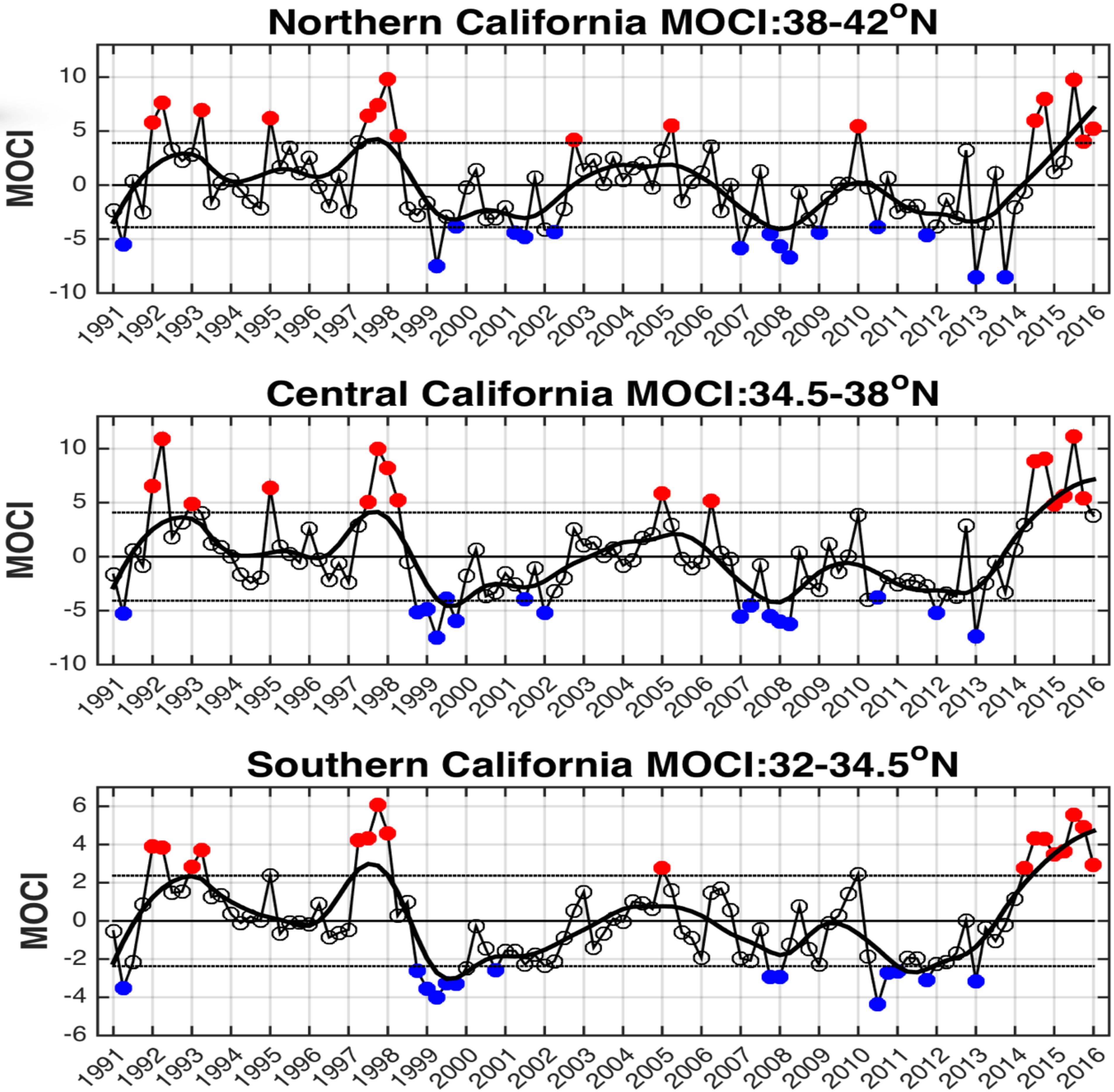
MOCI



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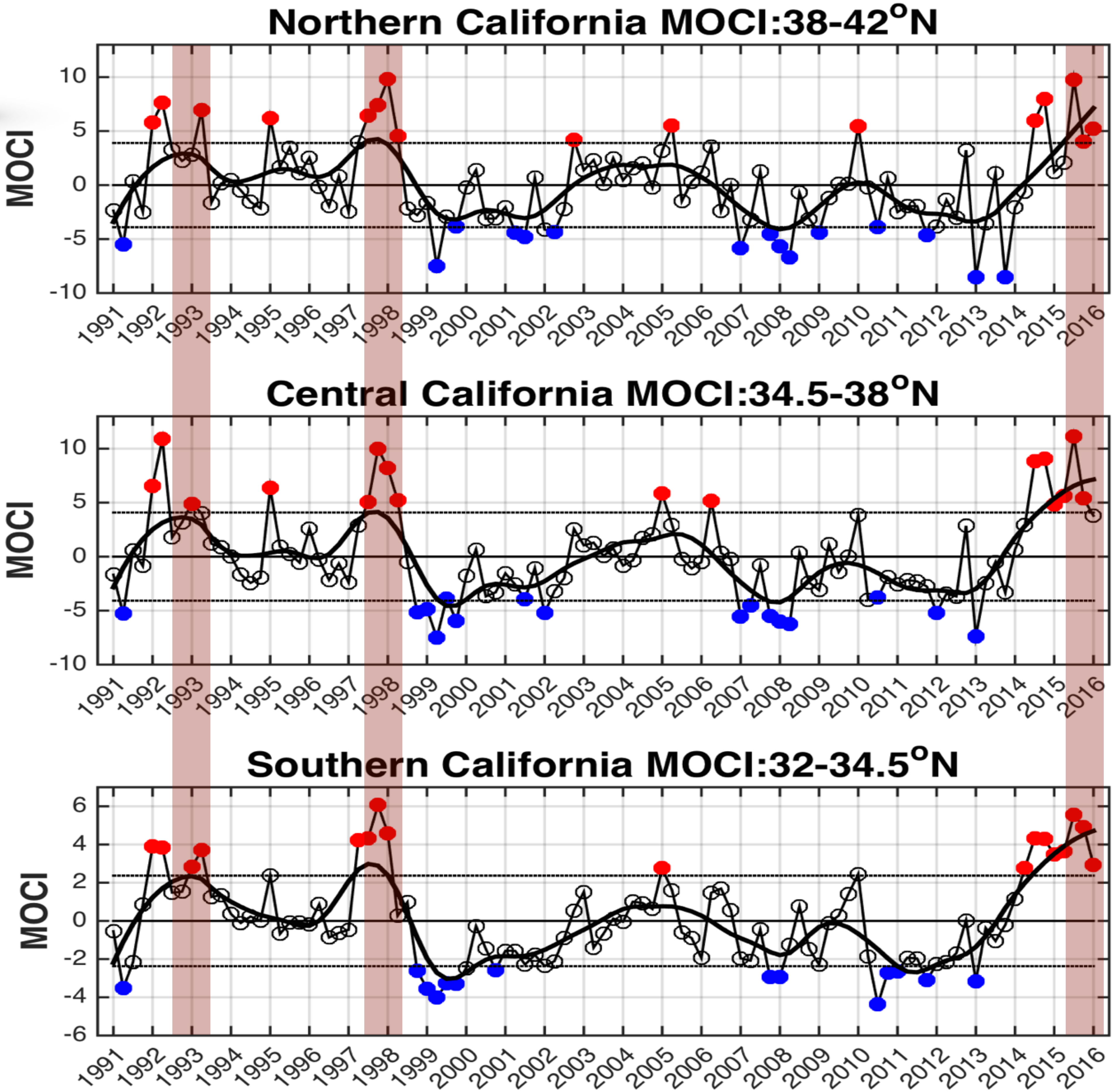
MOCI



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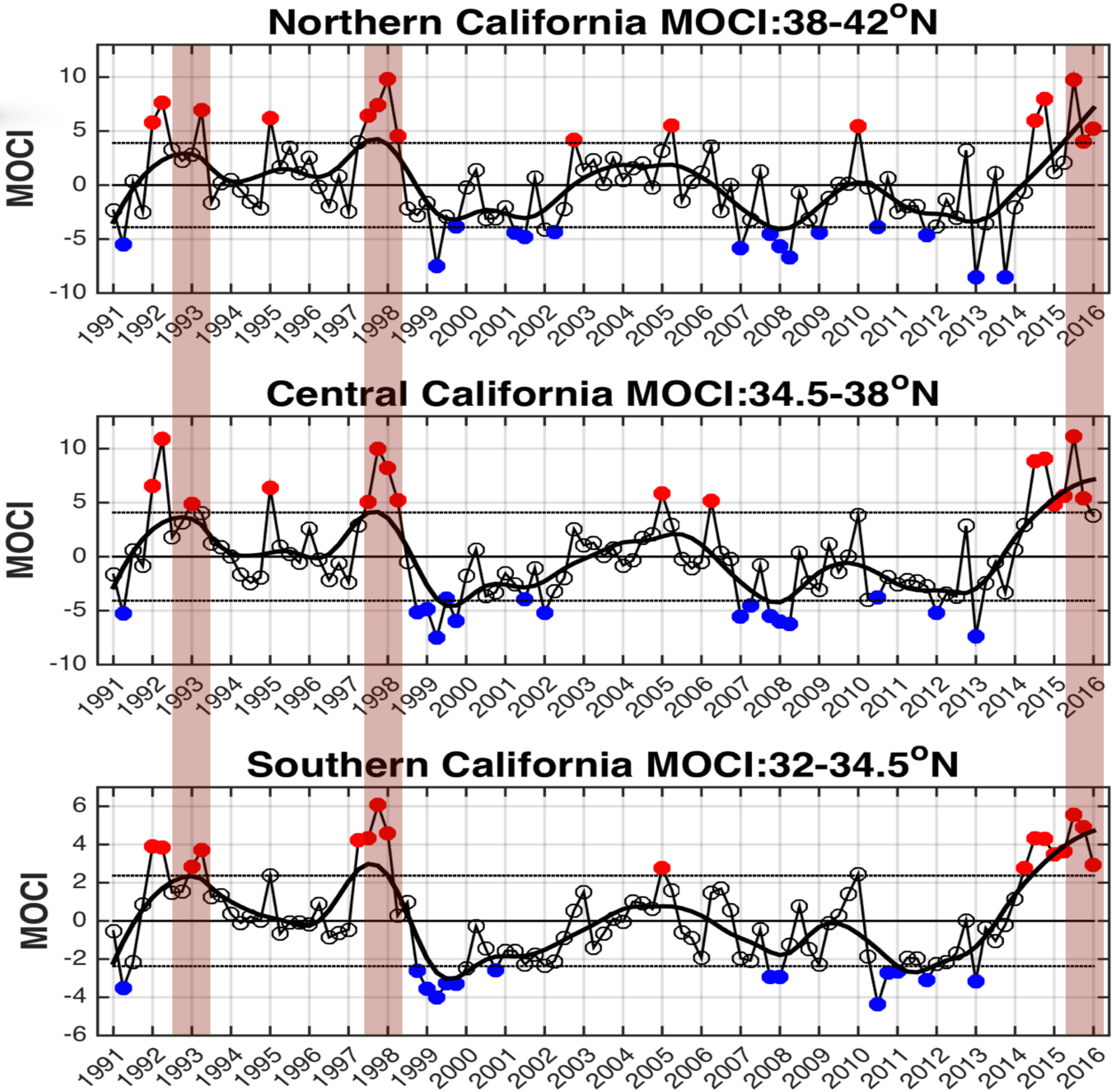
MOCI



Winter EV

72%

70%

58%

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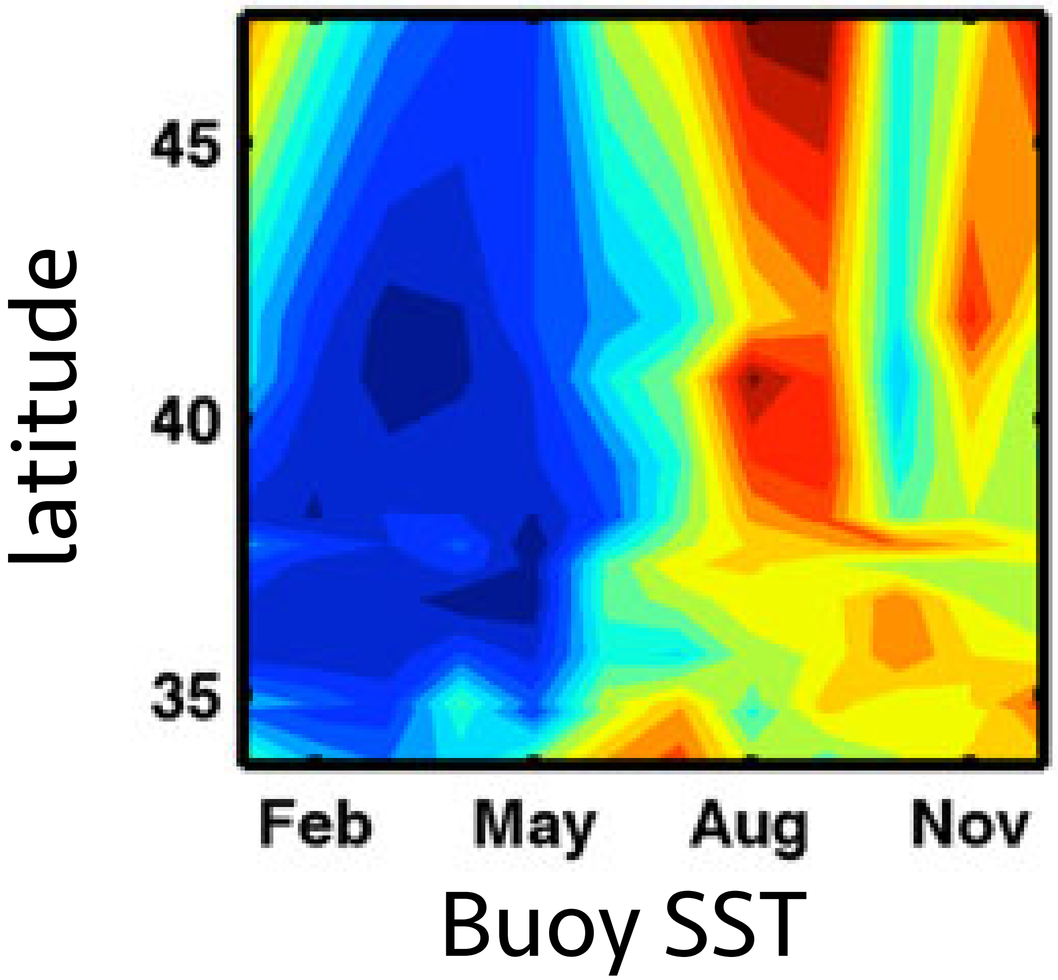
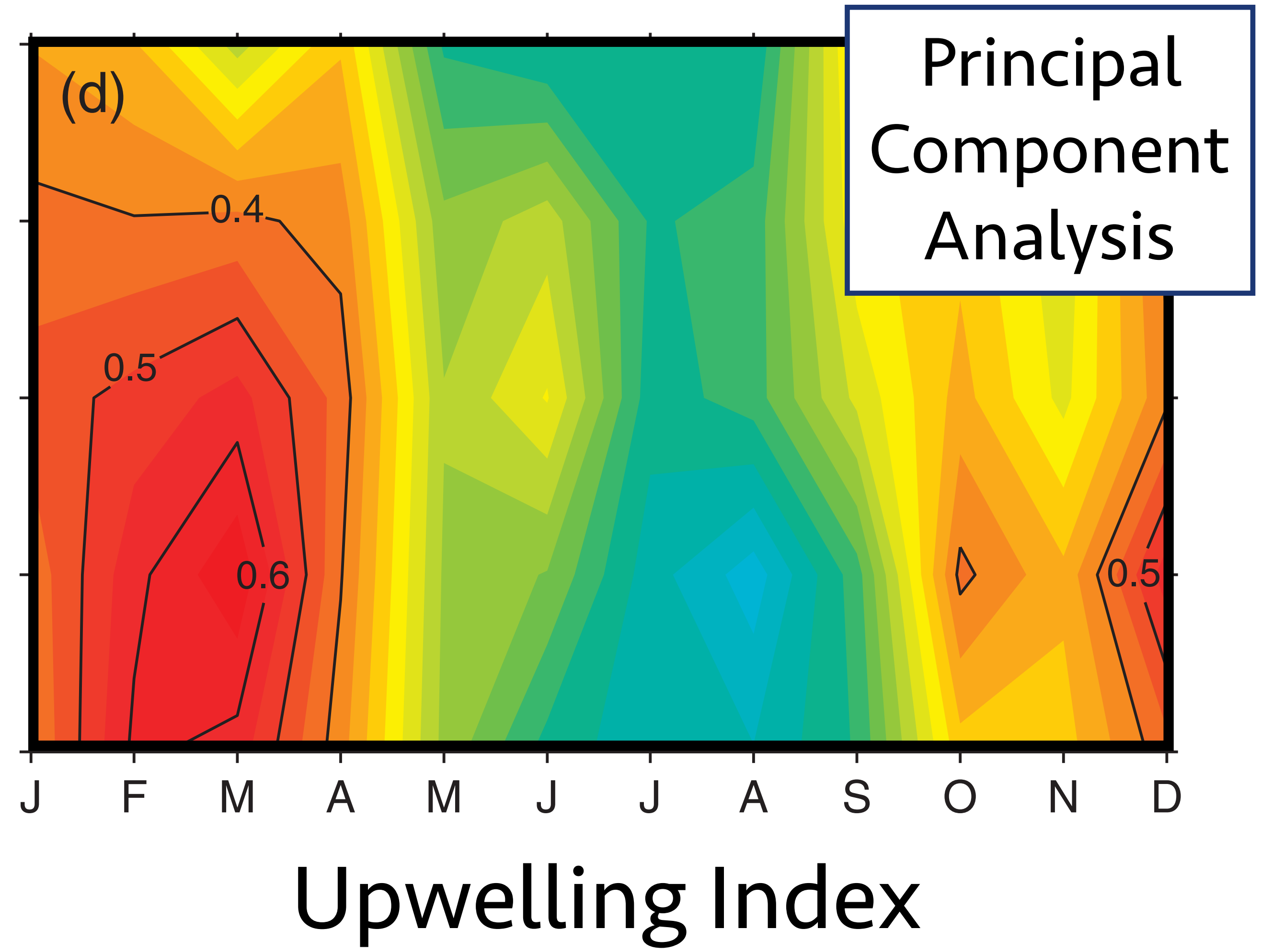
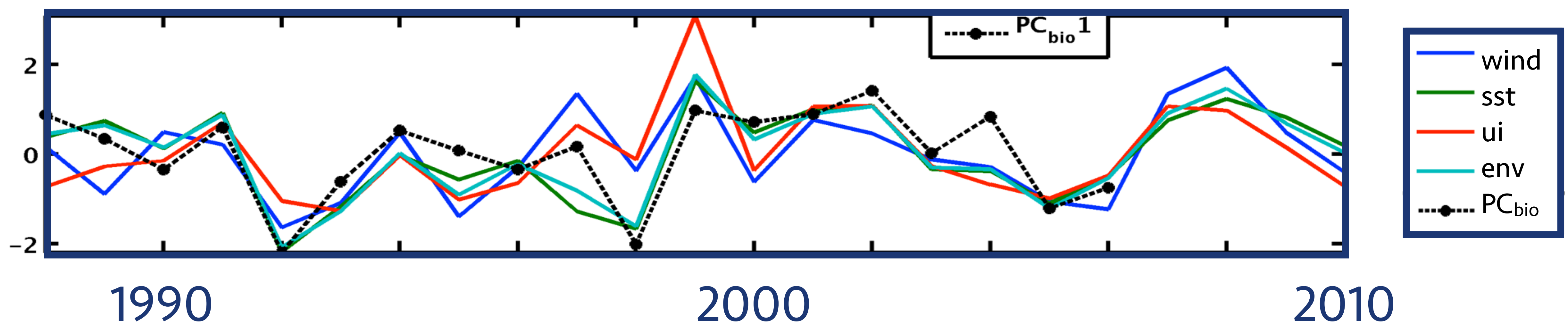
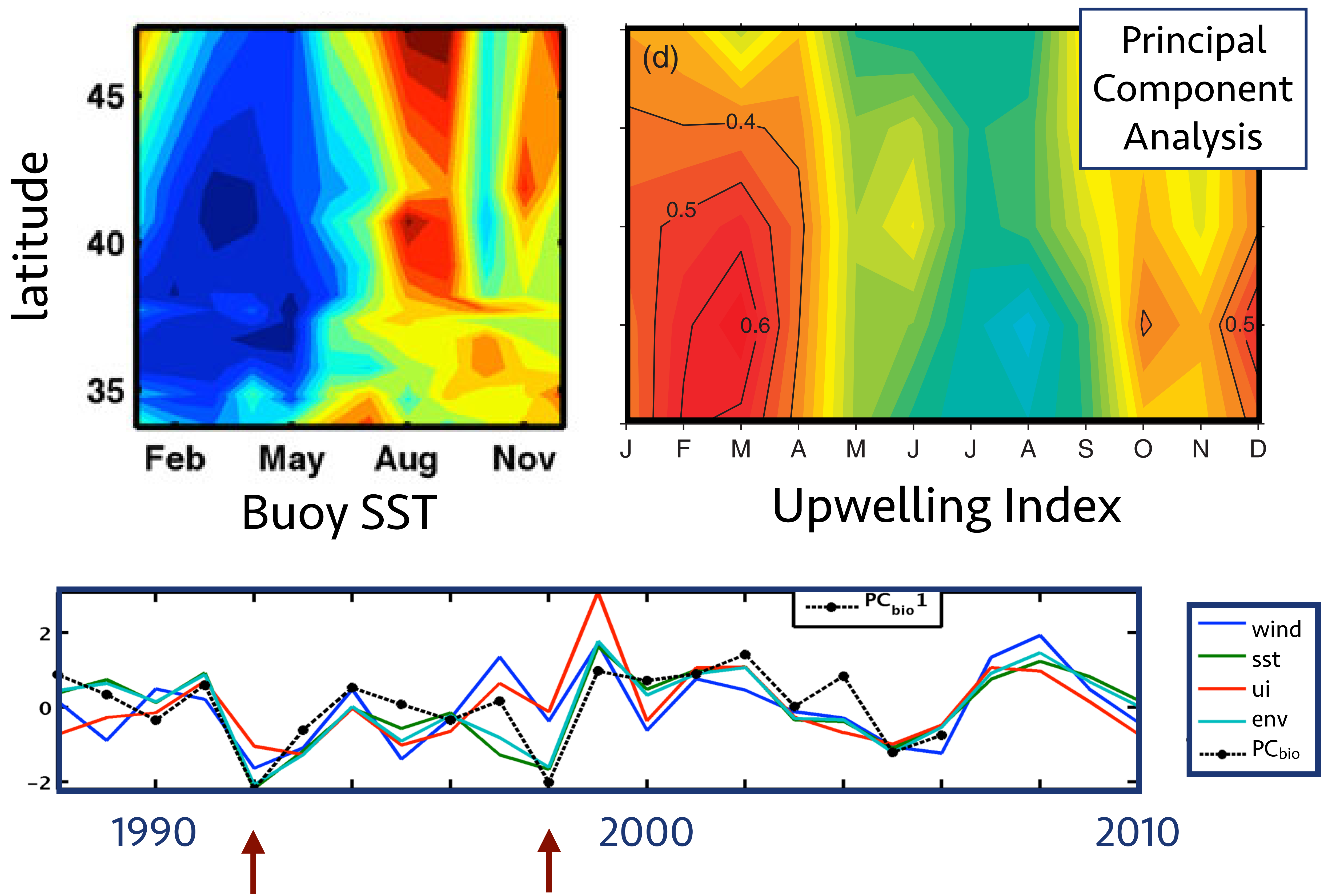
Winter/early spring upwelling







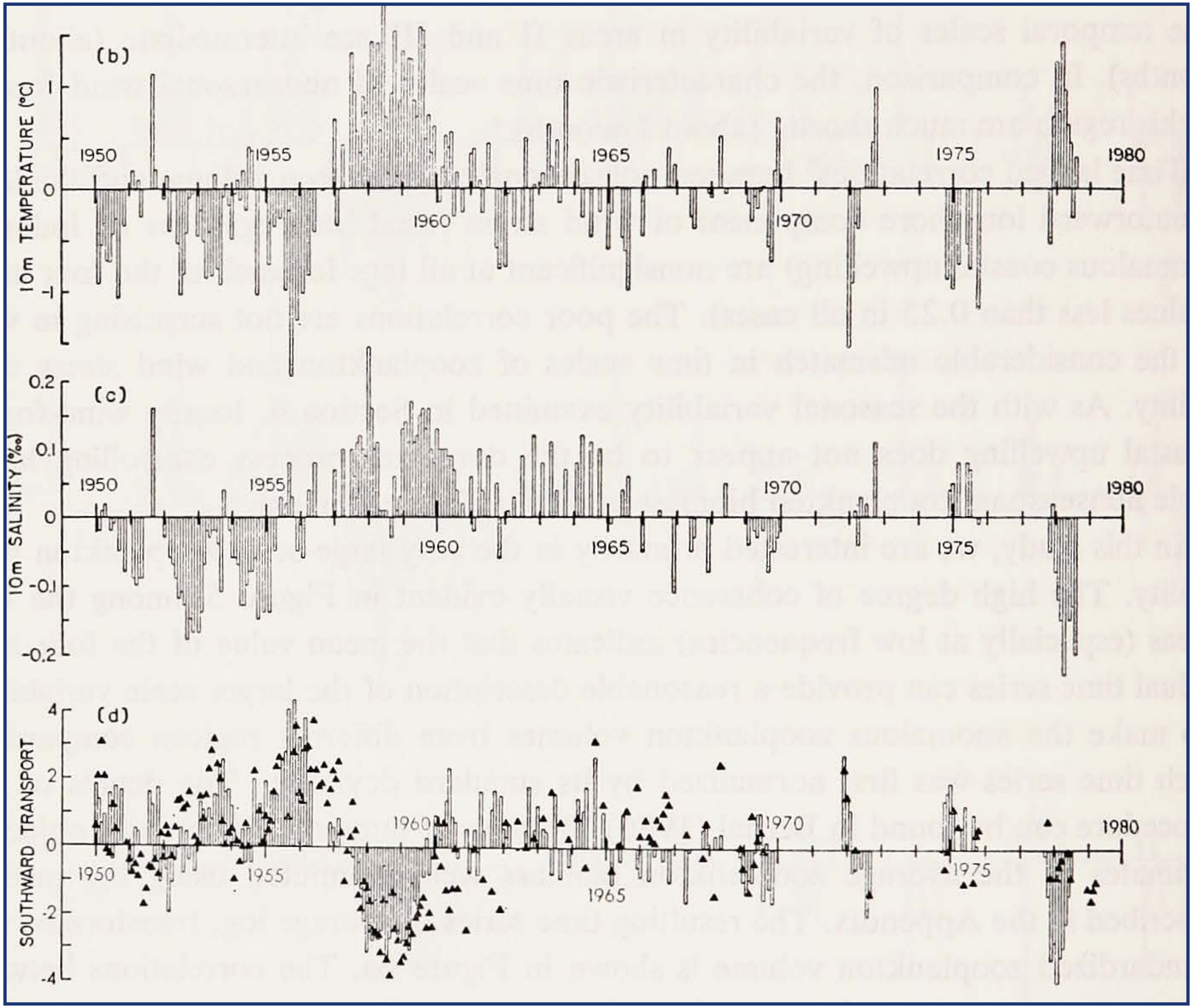
Winter/early spring upwelling



Biological Indicators

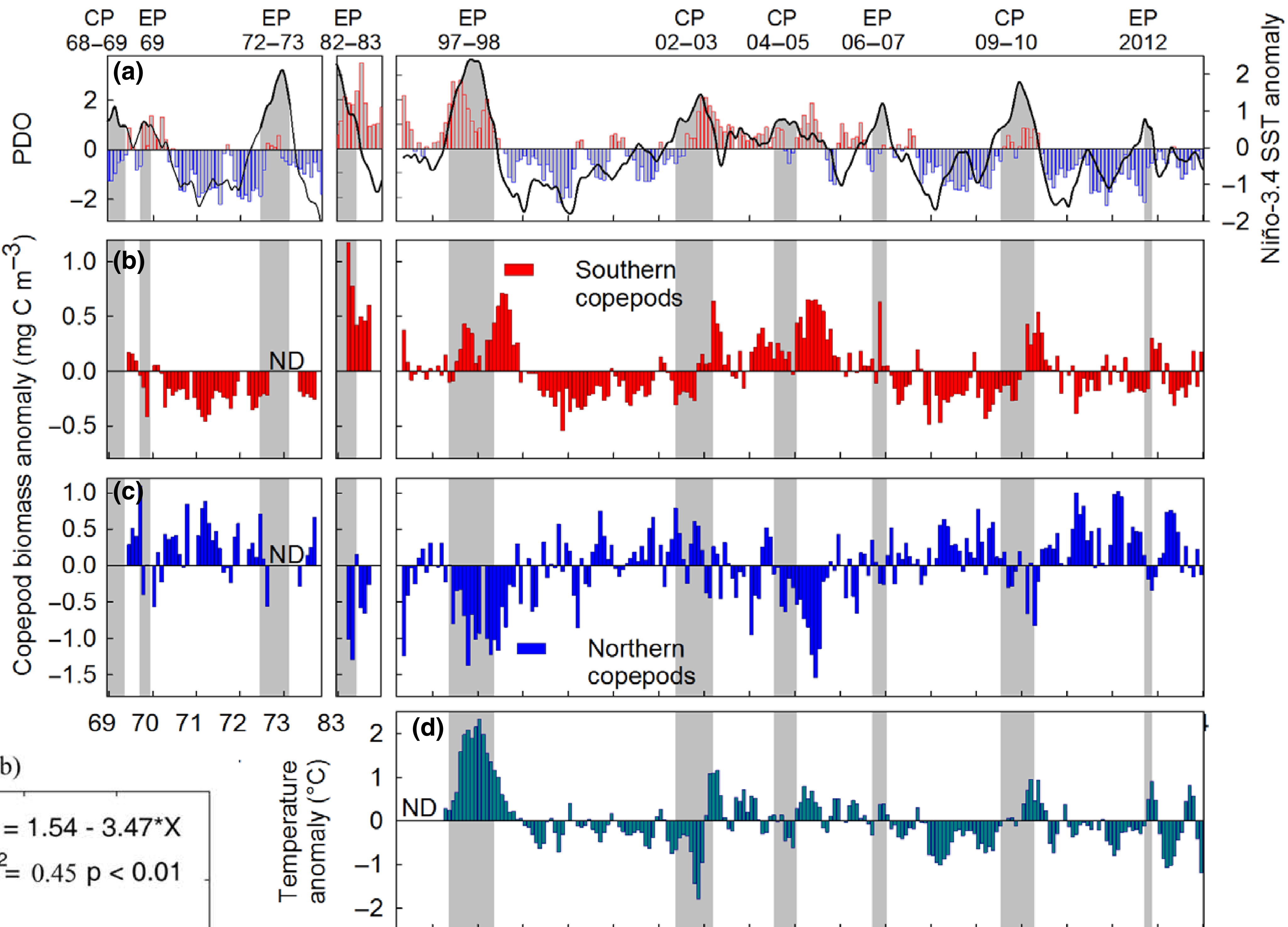
- Biology is more complex
- Environmental impacts:
  - Direct: transport for plankton
    - Physical processes behind not easily resolved due to synchrony

Zooplankton - CalCOFI

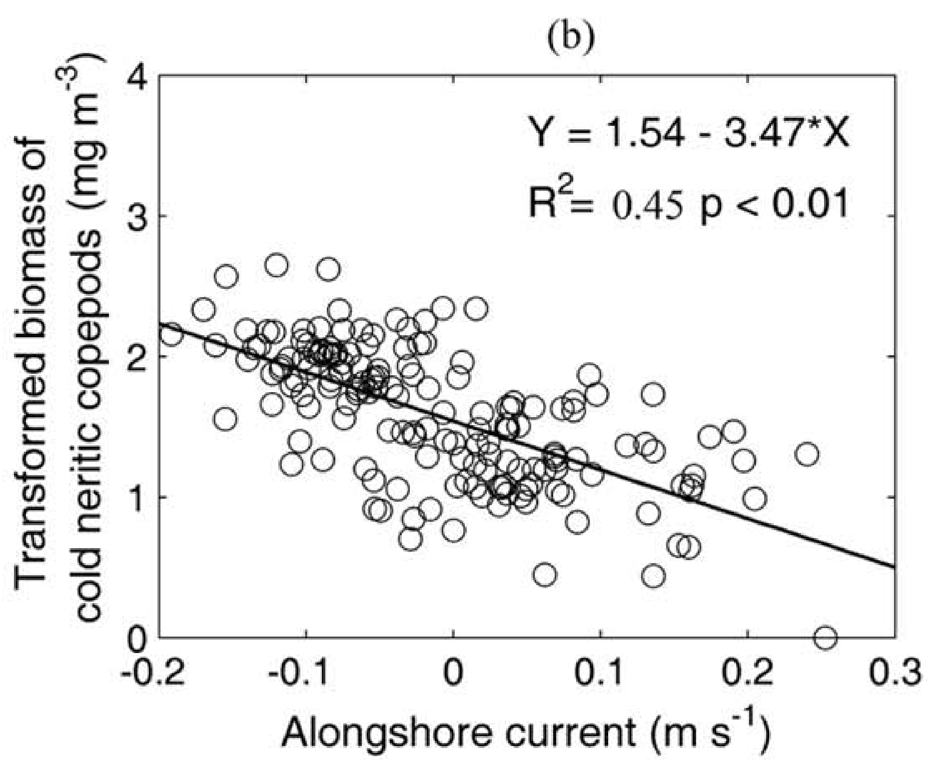


Chelton et al., 1982 JMR

Zooplankton Trinidad Line



Fisher et al. 2015 GCB



Bi et al., 2011 GRL

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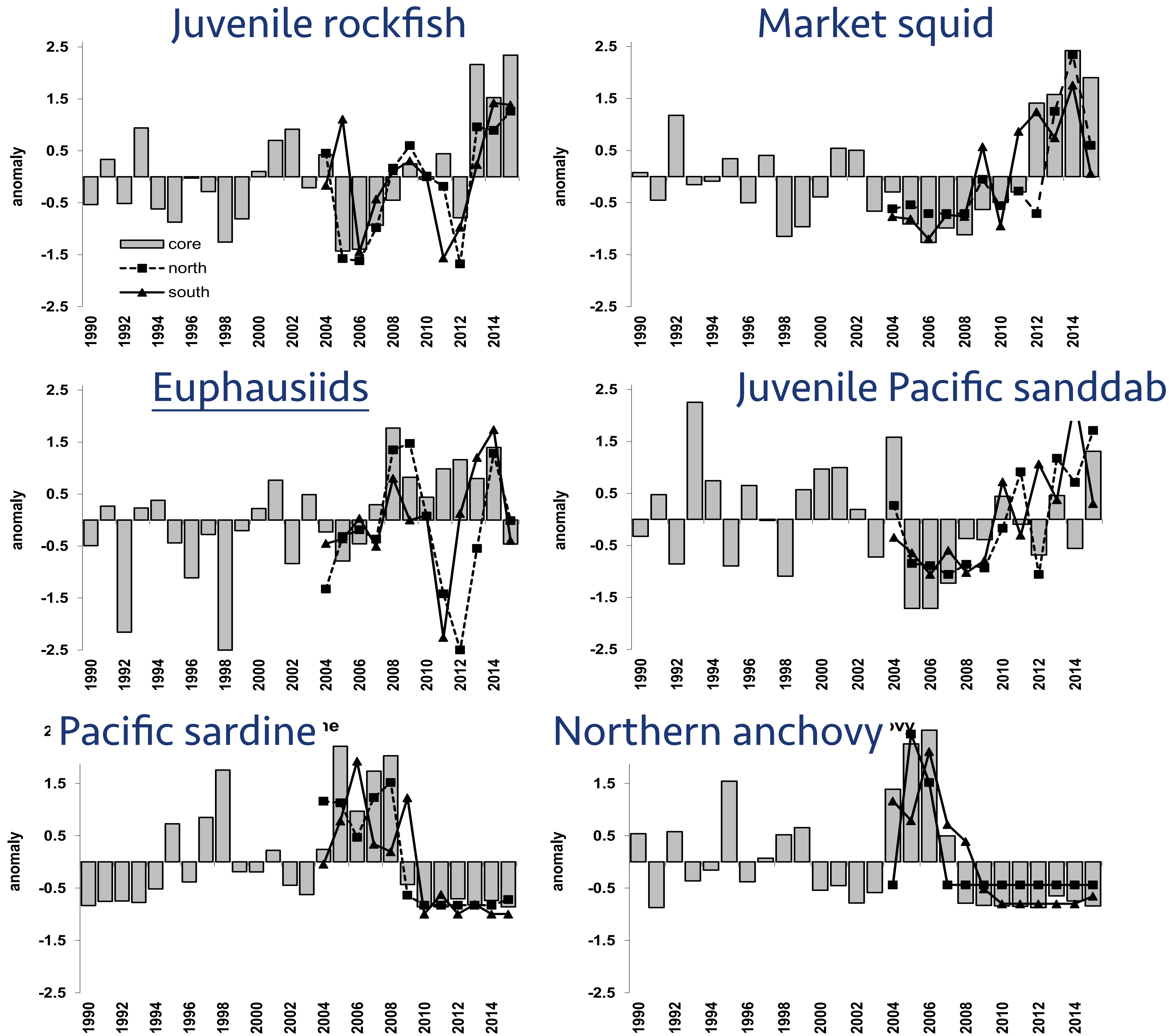
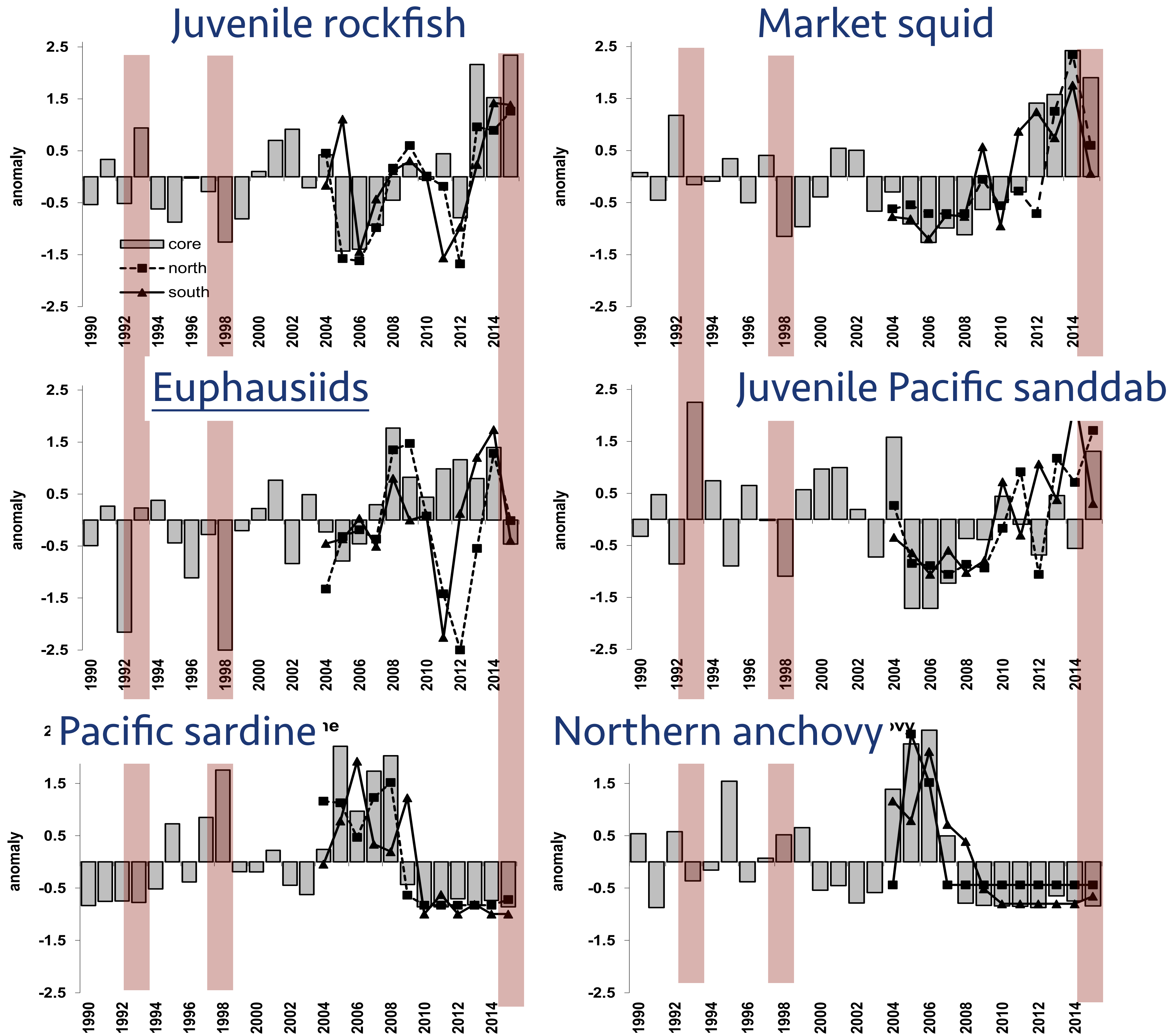
Biological Indicators

- Environmental impacts:
  - Trophic mechanisms: food availability for predators
    - Need of mechanistic models to explain biological variability, correlations can be misleading


Juvenile rockfish
Market squid
Euphausiids
Juvenile Pacific sanddab
Pacific sardine
Northern anchovy
anomaly
core
north
south
2.5
1.5
0.5
-0.5
-1.5
-2.5
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014



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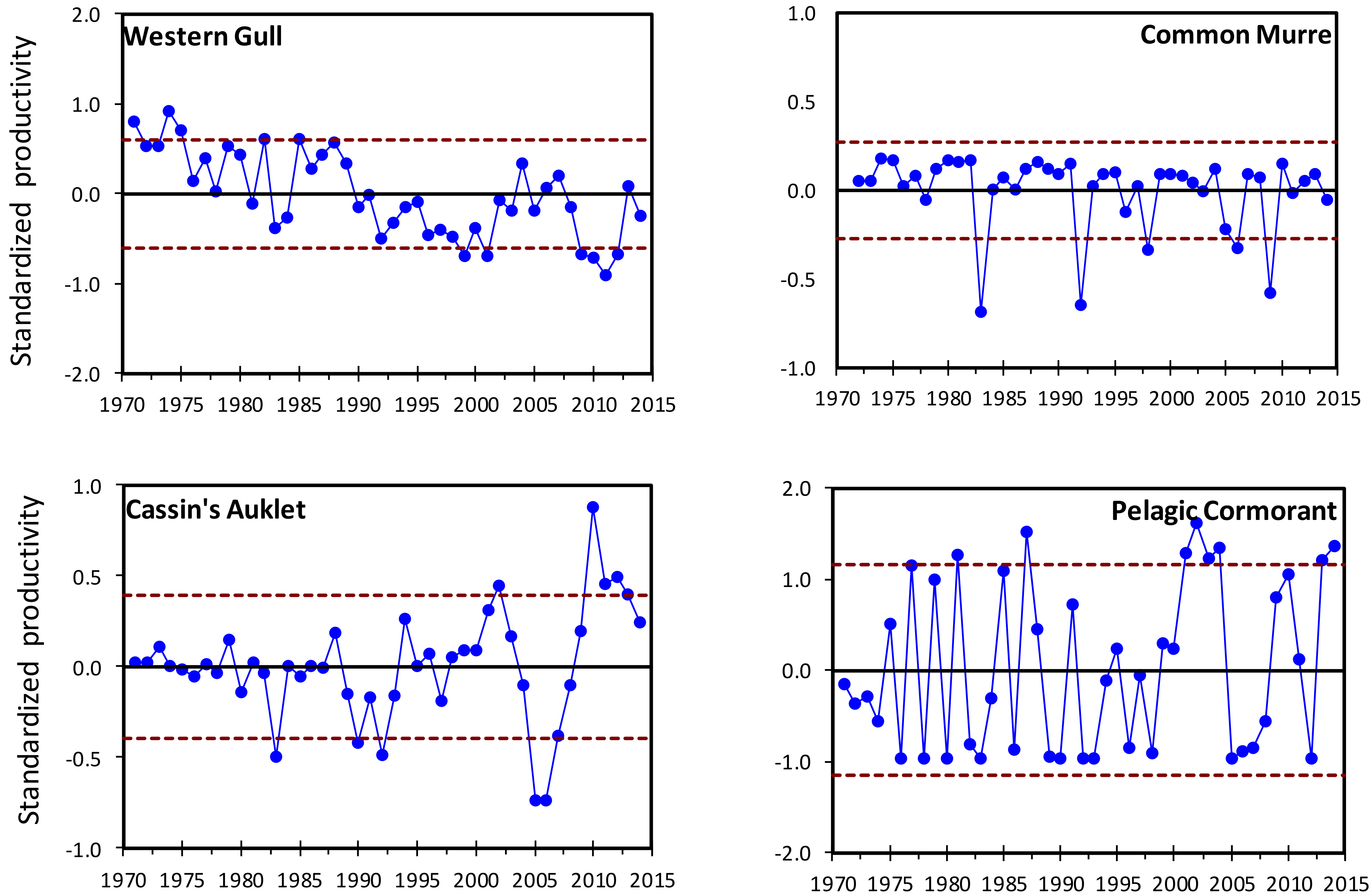
Sea birds



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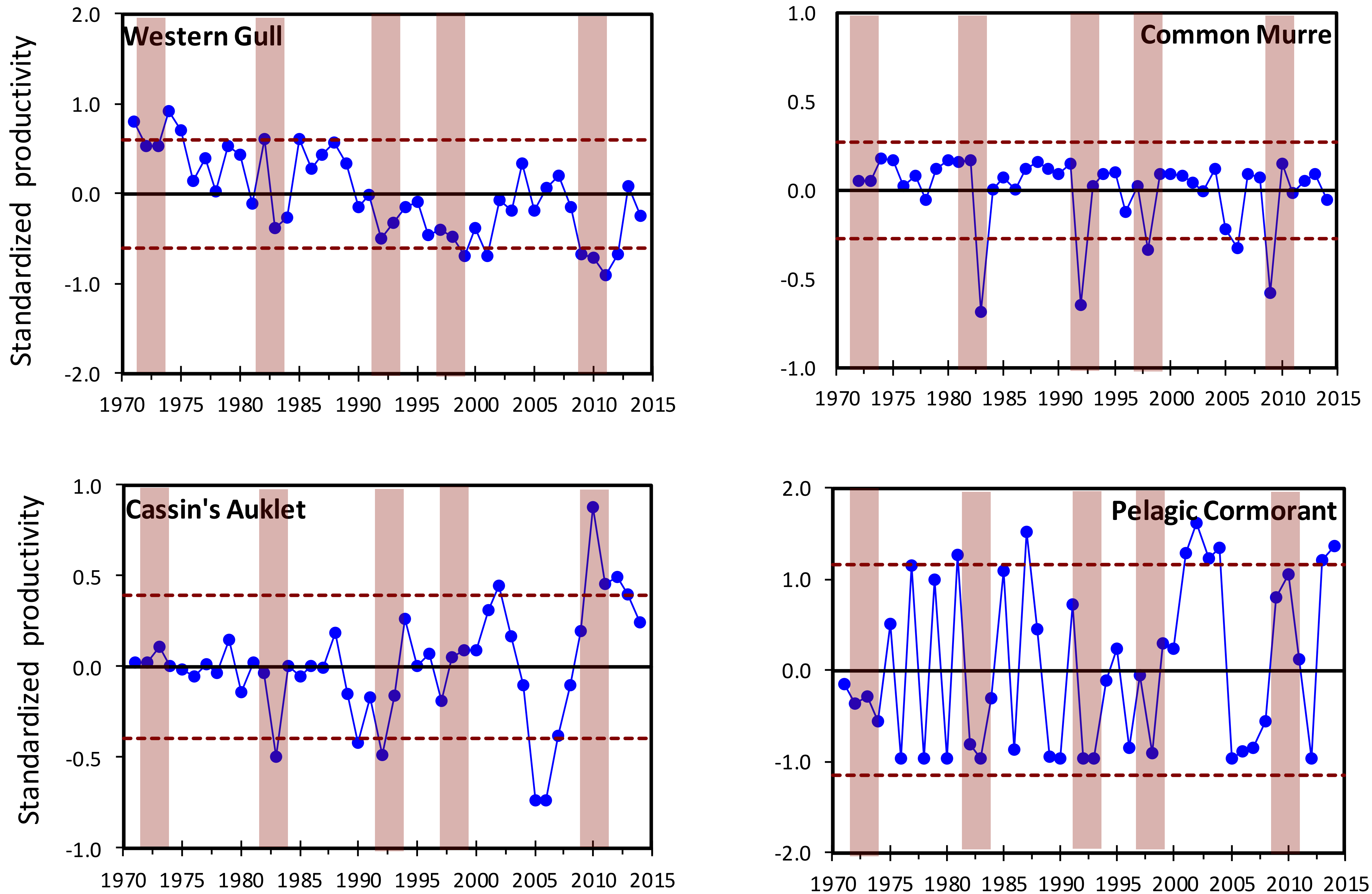

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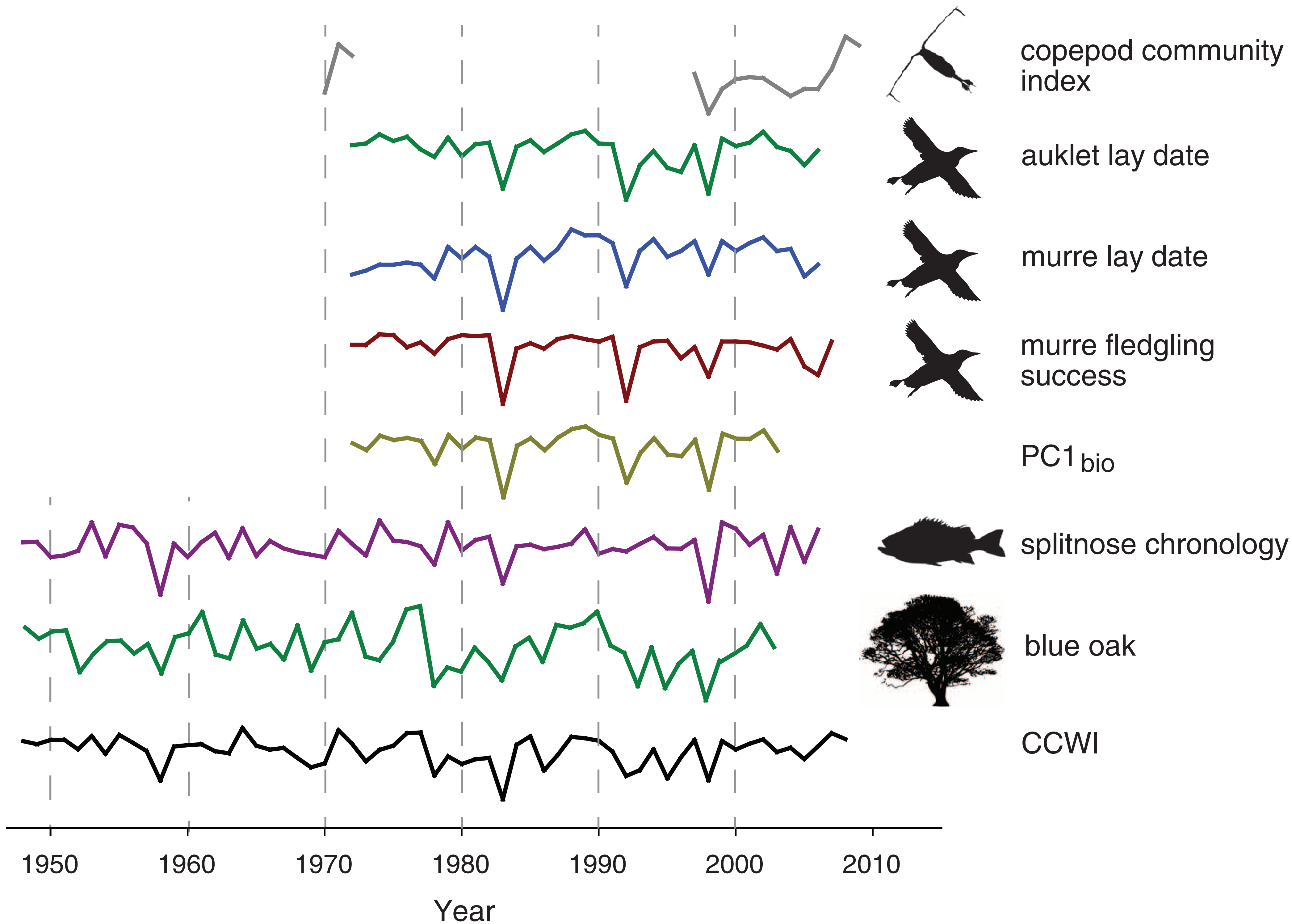
Timing

- In the California Current, many environmental variables are synchronized by climatic events
  - Winter season
  - Highly related to ENSO

…shared by some biological indicators



Black et al., 2014 Sci

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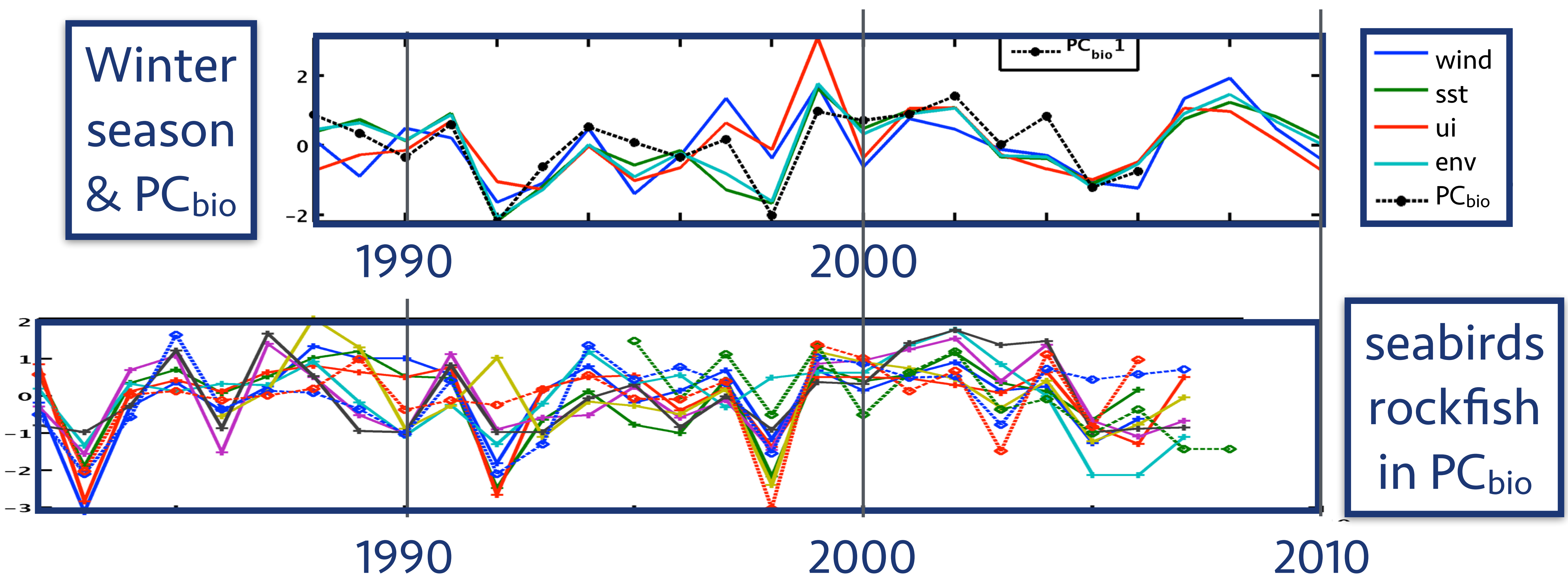
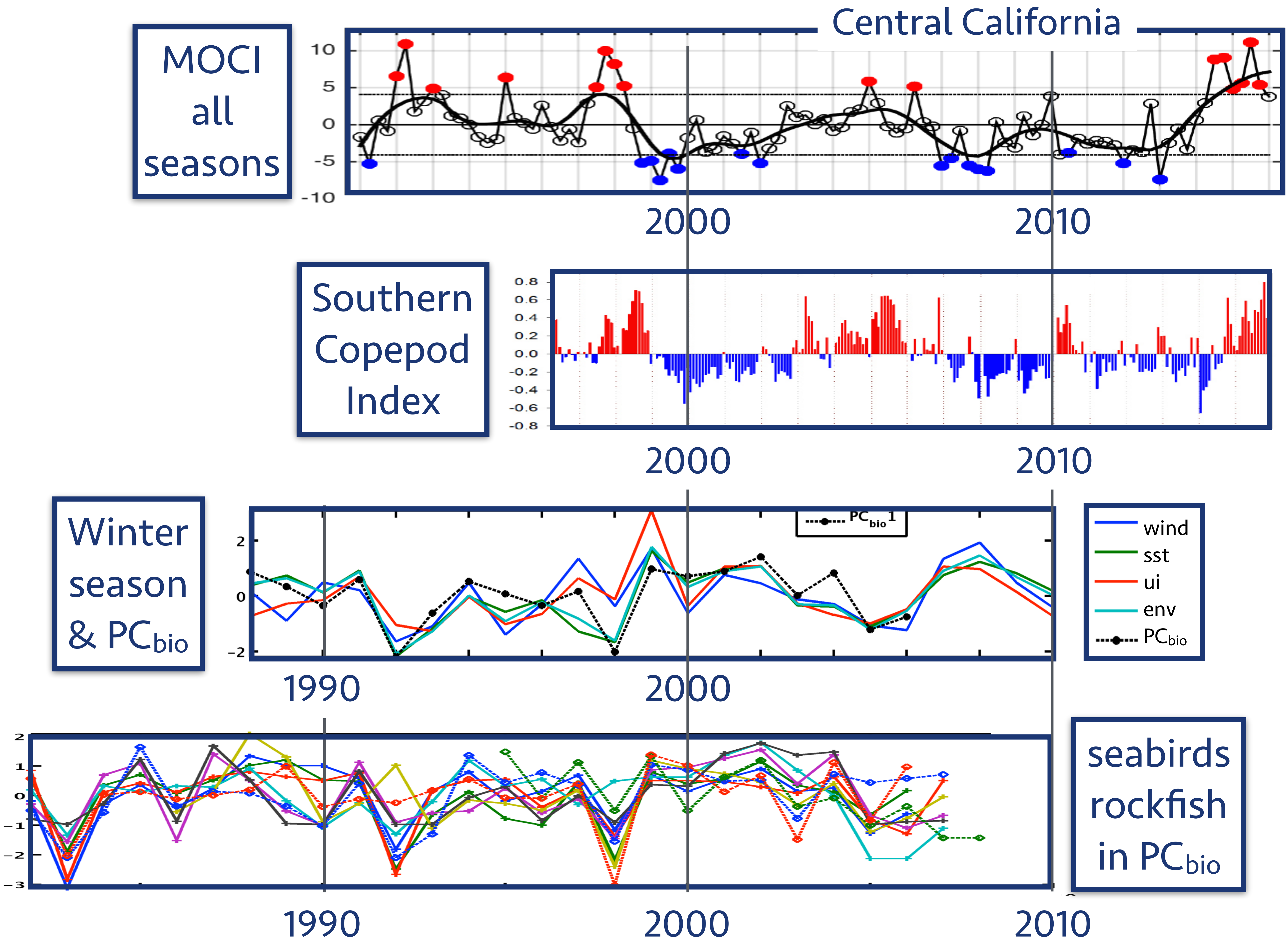
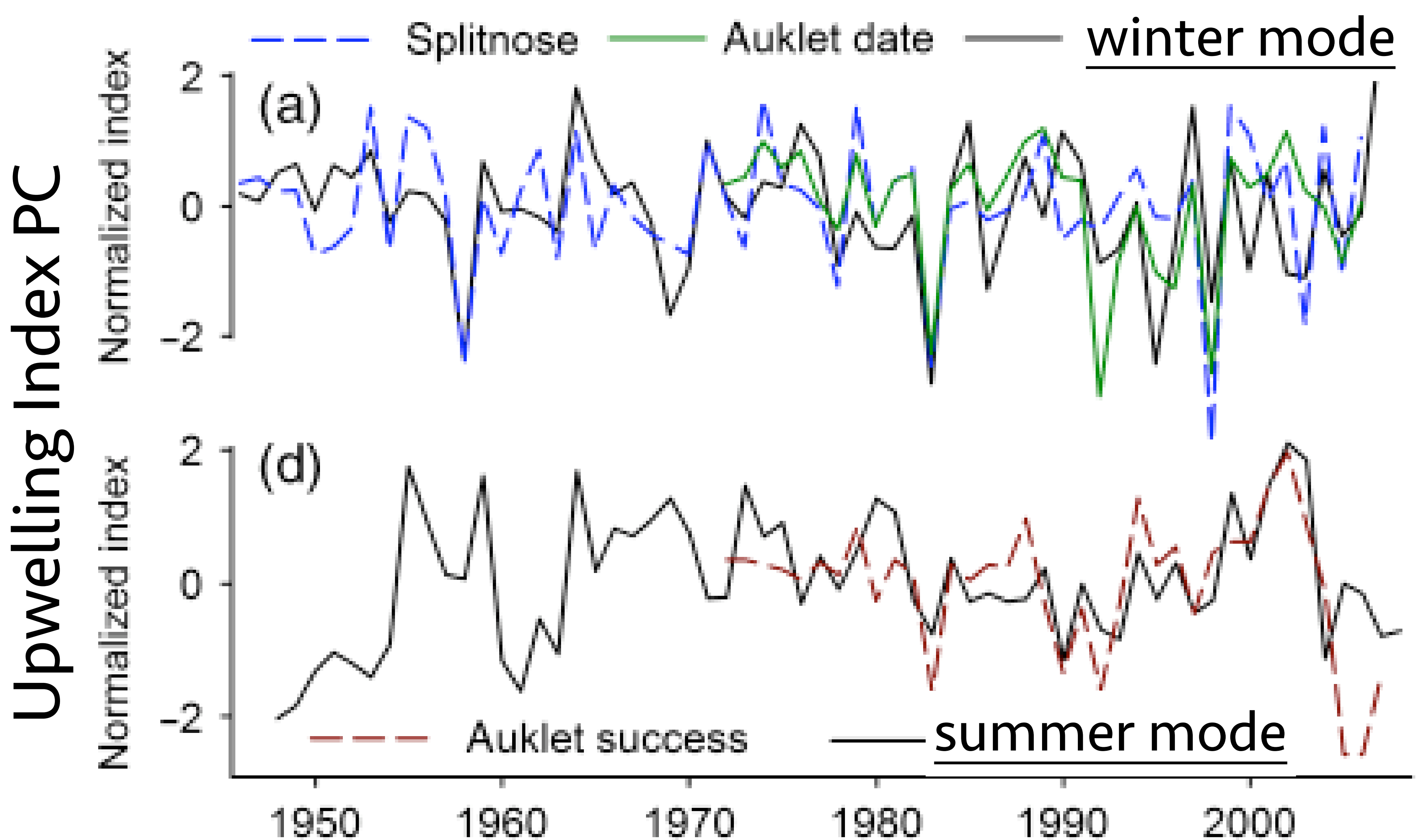


Winter season & PCbio
2
0
−2
PCbio1
wind
sst
ui
env
PCbio
1990
2000
2
1
0
−1
−2
−3
seabirds rockfish in PCbio
1990
2000
2010



MOCI
all
seasons
Central California
10
5
0
-5
-10
2000
2010
Southern
Copepod
Index
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
2000
2010
Winter
season
& PCbio
PCbio1
2
0
-2
wind
sst
ui
env
PCbio
1990
2000
2
1
0
-1
-2
-3
seabirds
rockfish
in PCbio
1990
2000
2010

Winter & summer indicators

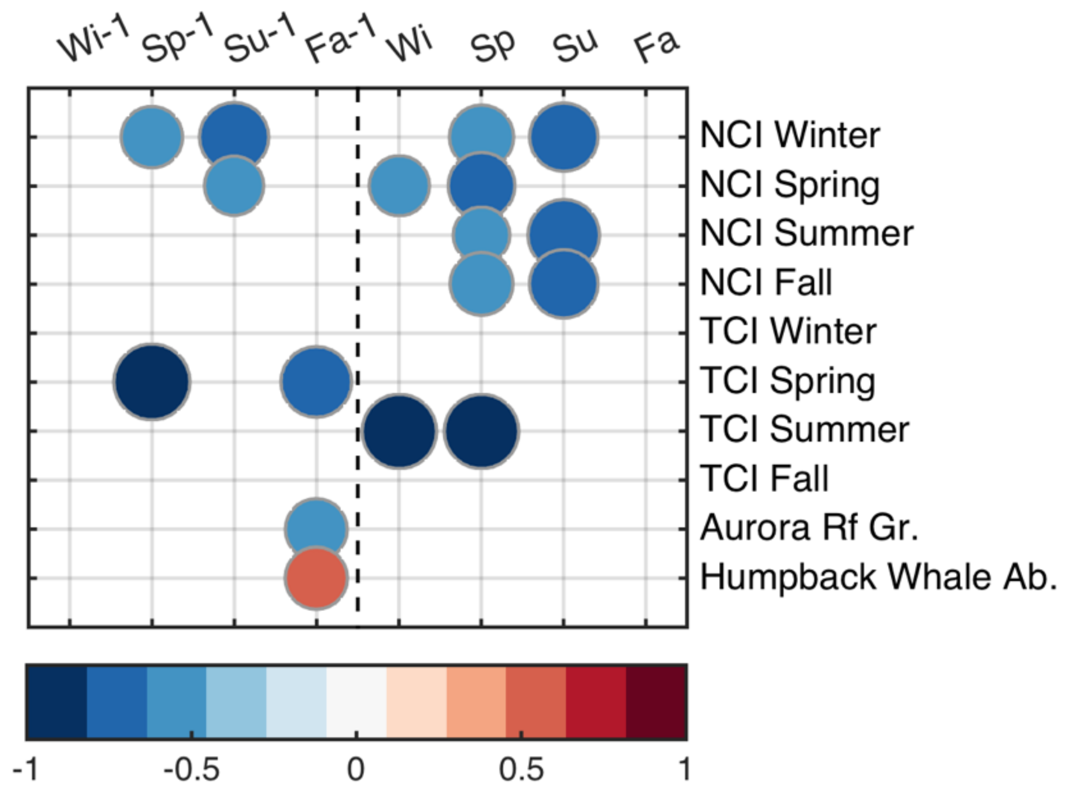


Black et al., 2011 GCB

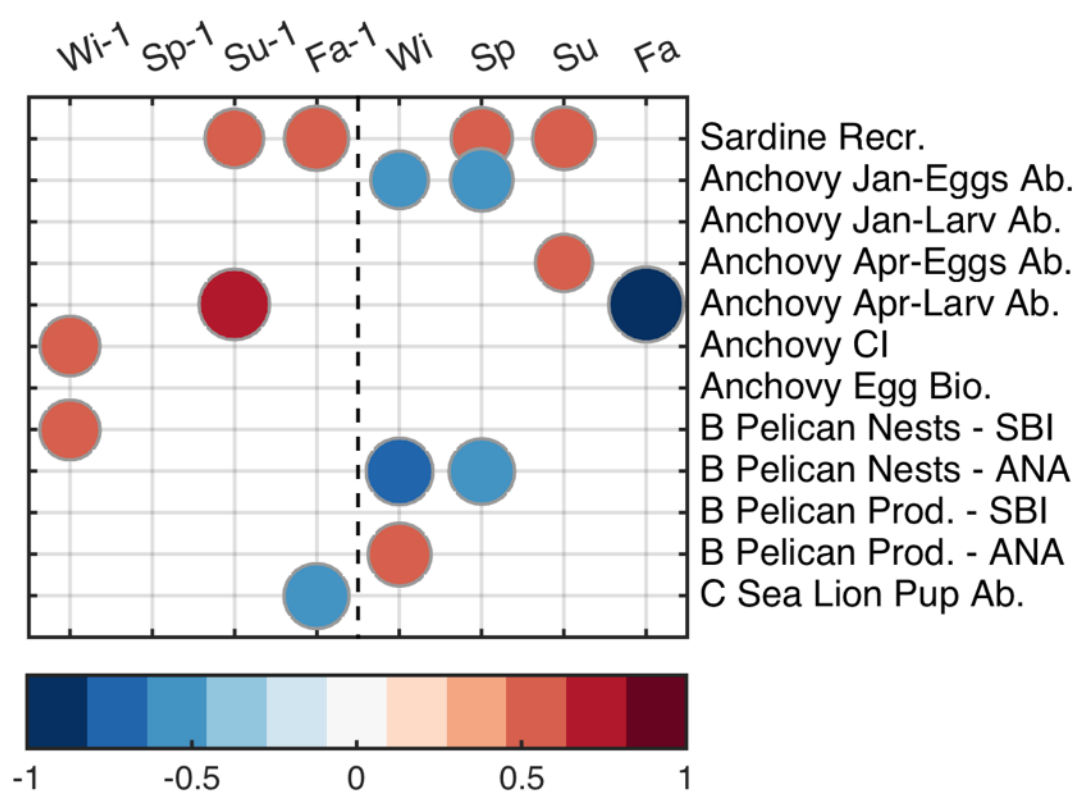
Ecosystem Indicators

- What are indicators indicating:
  - ENSO, other-than-ENSO, ENSO+others
- Need of mechanistic understanding of biological indicators
- Synchrony in the California Current
  - winter, related to ENSO, bio/phy

Northern California MOCI



Southern California MOCI



Central California MOCI