OF FISH, SEABIRDS, AND TREES: THE PAST, PRESENT, AND FUTURE OF UPWELLING ECOSYSTEMS

➢ Lessons learned from the California Current

..William J. Sydeman on behalf of the “Present, Past, and Future of Upwelling” Team

UNIVERSITY OF SOUTH CAROLINA · Farallon Institute Advanced Ecosystem Research · NOAA National Oceanic and Atmospheric Administration U.S. Department of Commerce · The University of Texas Marine Science Institute

Support provided by: NSF, NOAA, FI, NASA

Climate Change and Upwelling Ecosystems

Changes in the timing and/or magnitude of alongshore winds in EBCS may alter upwelling, nutrient flux, offshore advection, and the form and functions of these key coastal ecosystems. This may include changes in:

a. **habitat qualities (T, S, O2, pH, etc.)**
b. **primary, secondary, etc. productivity,**
c. **phenology (timing of biotic events),**
d. **species' range, distributions, spatial organization,**
e. **species interactions, biological communities,**
f. **fisheries, other ecosystem services, and coastal communities**

Interdisciplinary Team Approach:

Environmental – Steven Bograd, Isaac Schroeder, Marisol Garcia-Reyes, Art Miller, Manu Di Lorenzo, Nate Mantua

Marine Ecology/Bio. Oceanog./Fisheries – Bryan Black, Sarah Ann Thompson, Bill Sydeman, Ryan Rykaczewski, Brian Wells, Jarrod Santora, Andy Bakun

Dendrochonologists (tree ring analysis, upwelling in past at centennial scale (~600 years)

2) Time Series Analysis (present, past, and future):

what is the relationship between the seasonality of upwelling and ecosystem form and function?

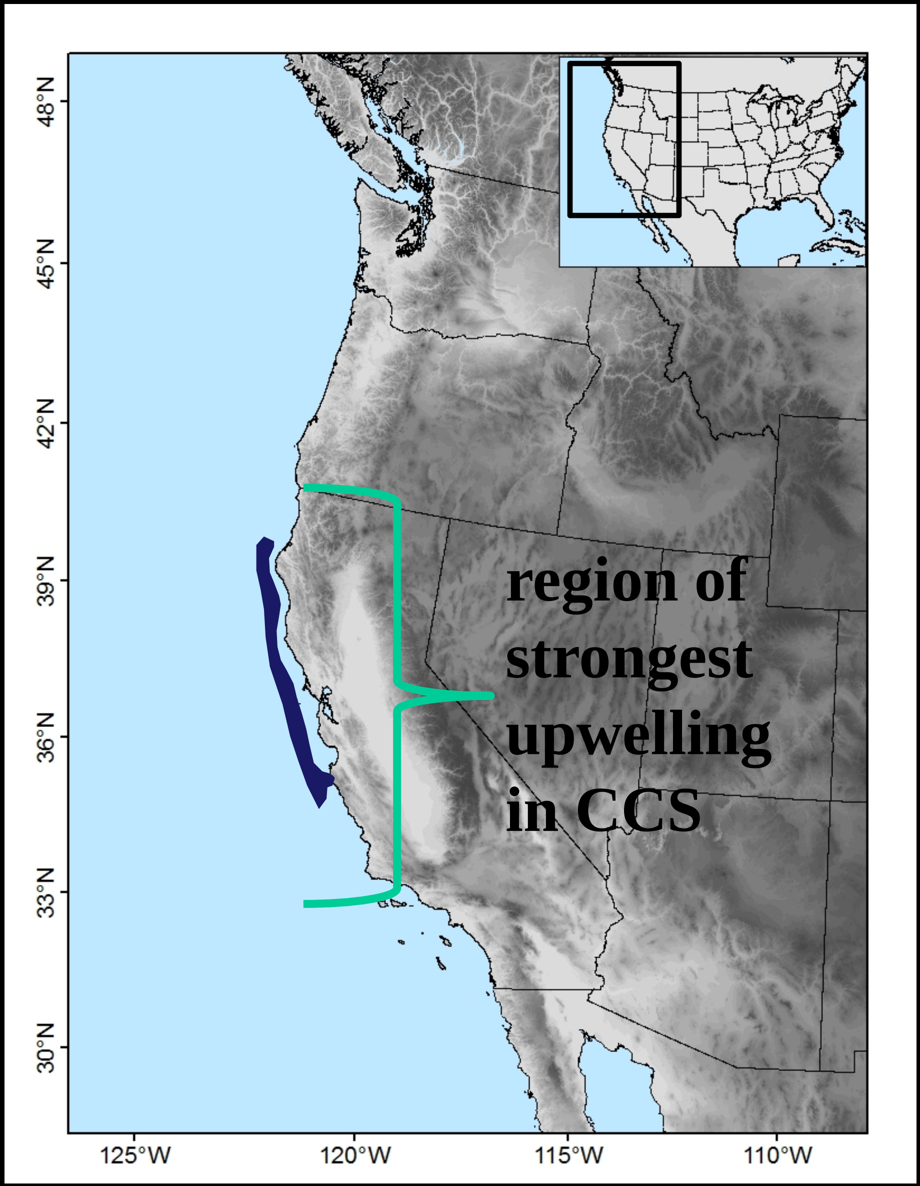
has variability/variance in upwelling changed systematically?

what is the future of upwelling and coastal upwelling ecosystems?

Groundfish Growth: Splitnose rockfish (*Sebastes diploproa*)

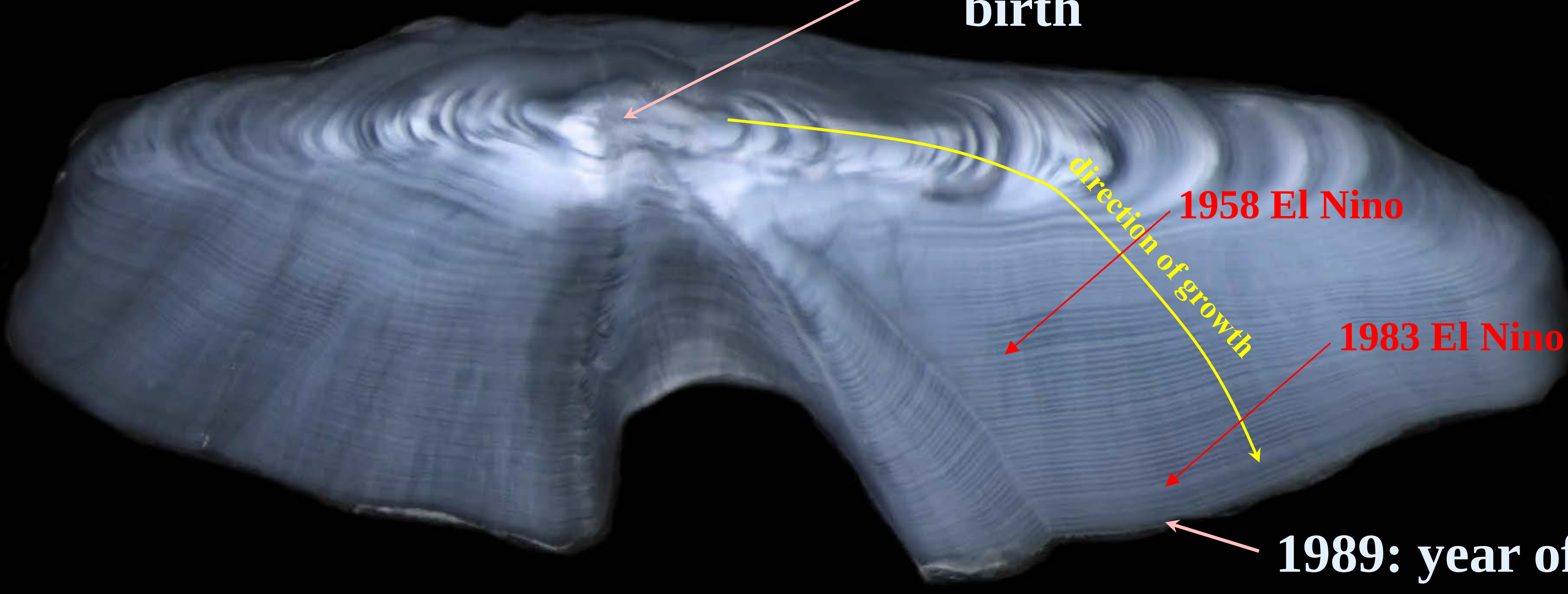
80+ yrs old
300 m depth
Collections 1980 – 2008
1 of ~60 species in the region

Photo credit:Lifted from M. Love's webpage



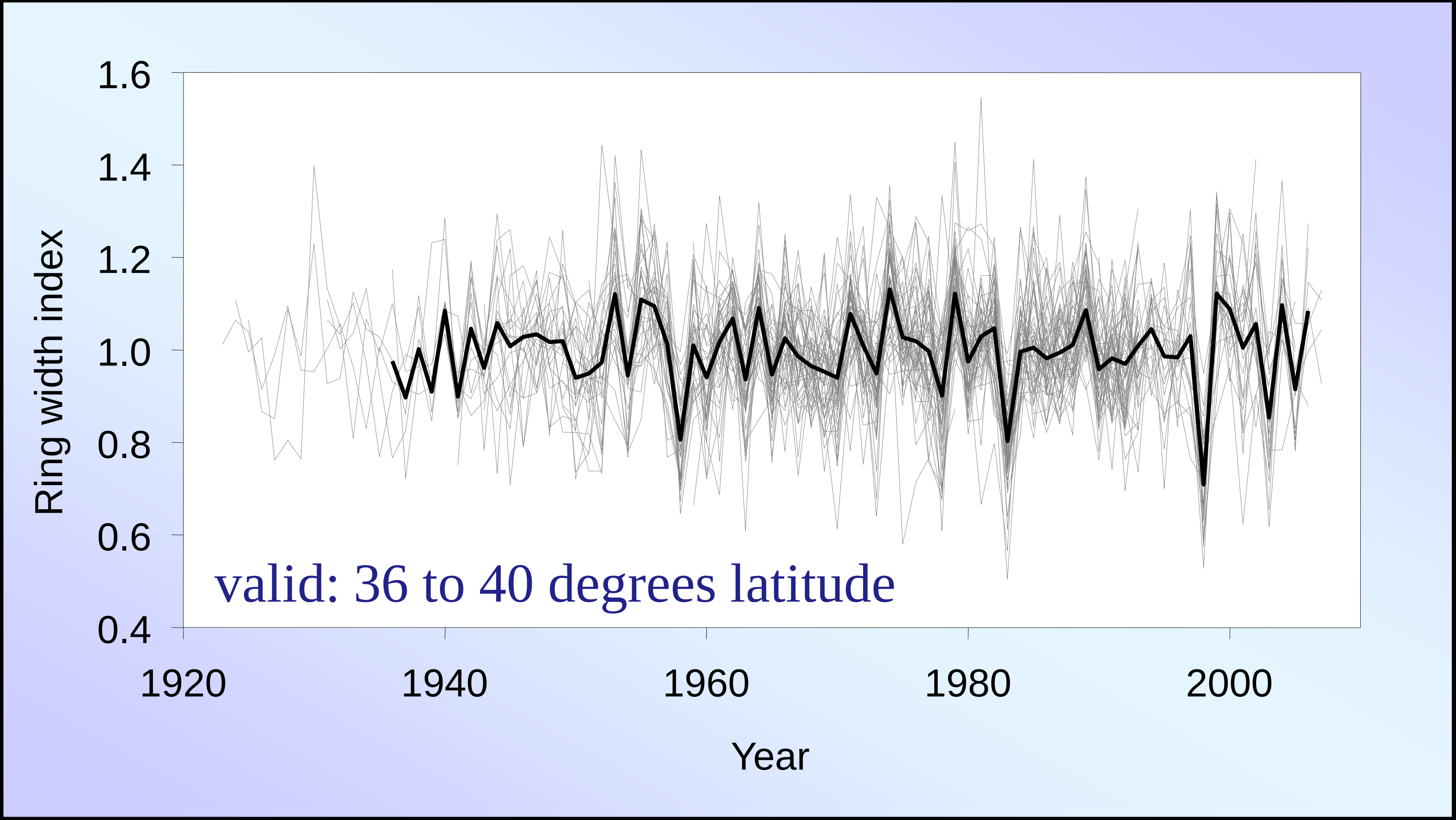
Splitnose otolith

Annual growth increments analogous to trees



Splitnose chronology: 72 otoliths

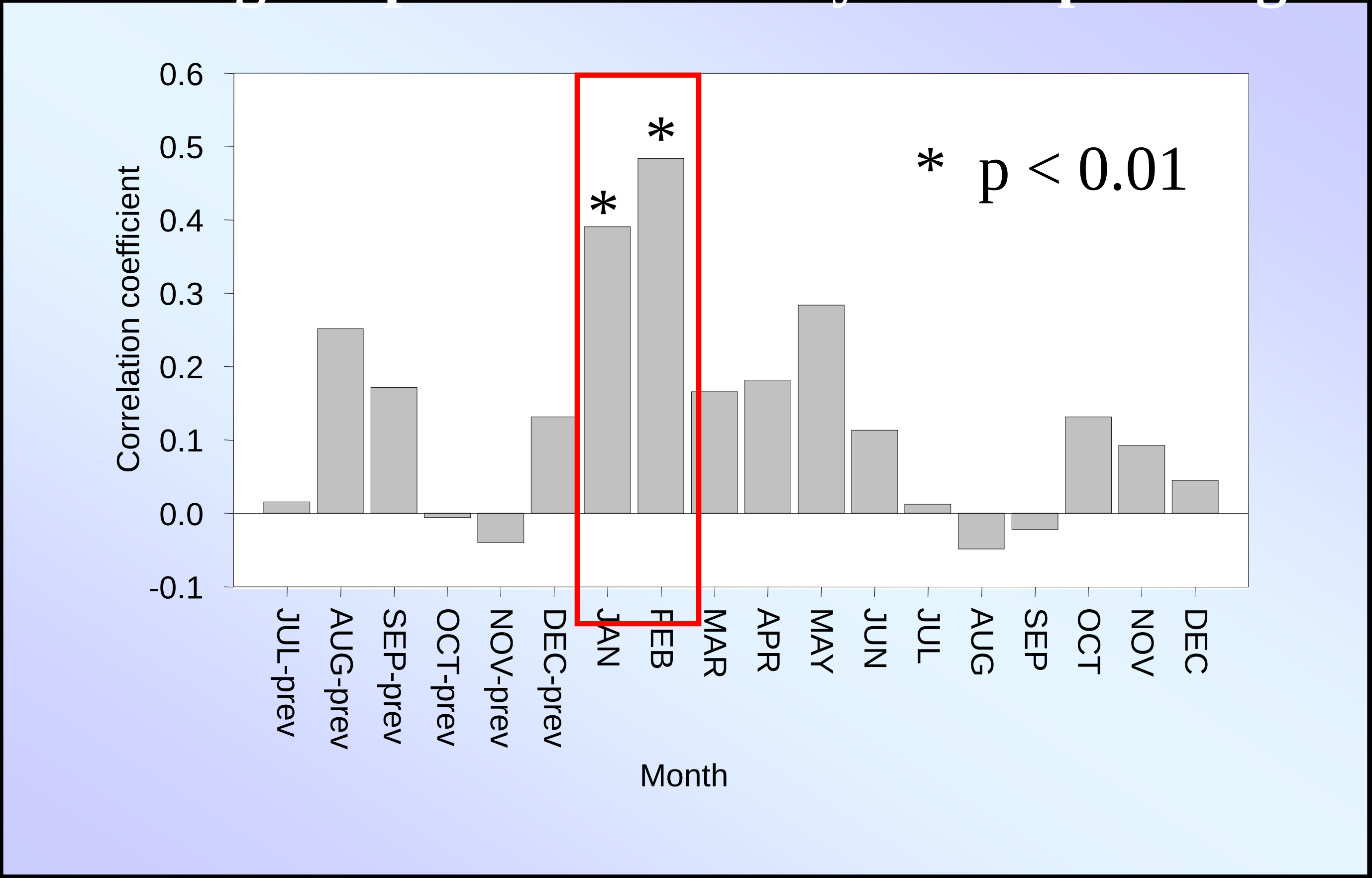
Master chronology



Cross-correlations with upwelling index @ 39N

Splitnose rockfish chronology and monthly upwelling (51 yrs)

- **wintertime (JF) upwelling has strongest effect; no effect seen during the peak of annual cycle of upwelling**



Covariance between fish and seabirds?

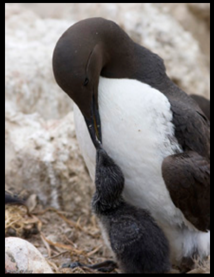
yelloweye rockfish
piscivorous

splitnose rockfish
planktivorous

Chinook salmon
piscivorous

growth-increment chronologies

- **Sub-annual scale of responses**



common murre
piscivorous

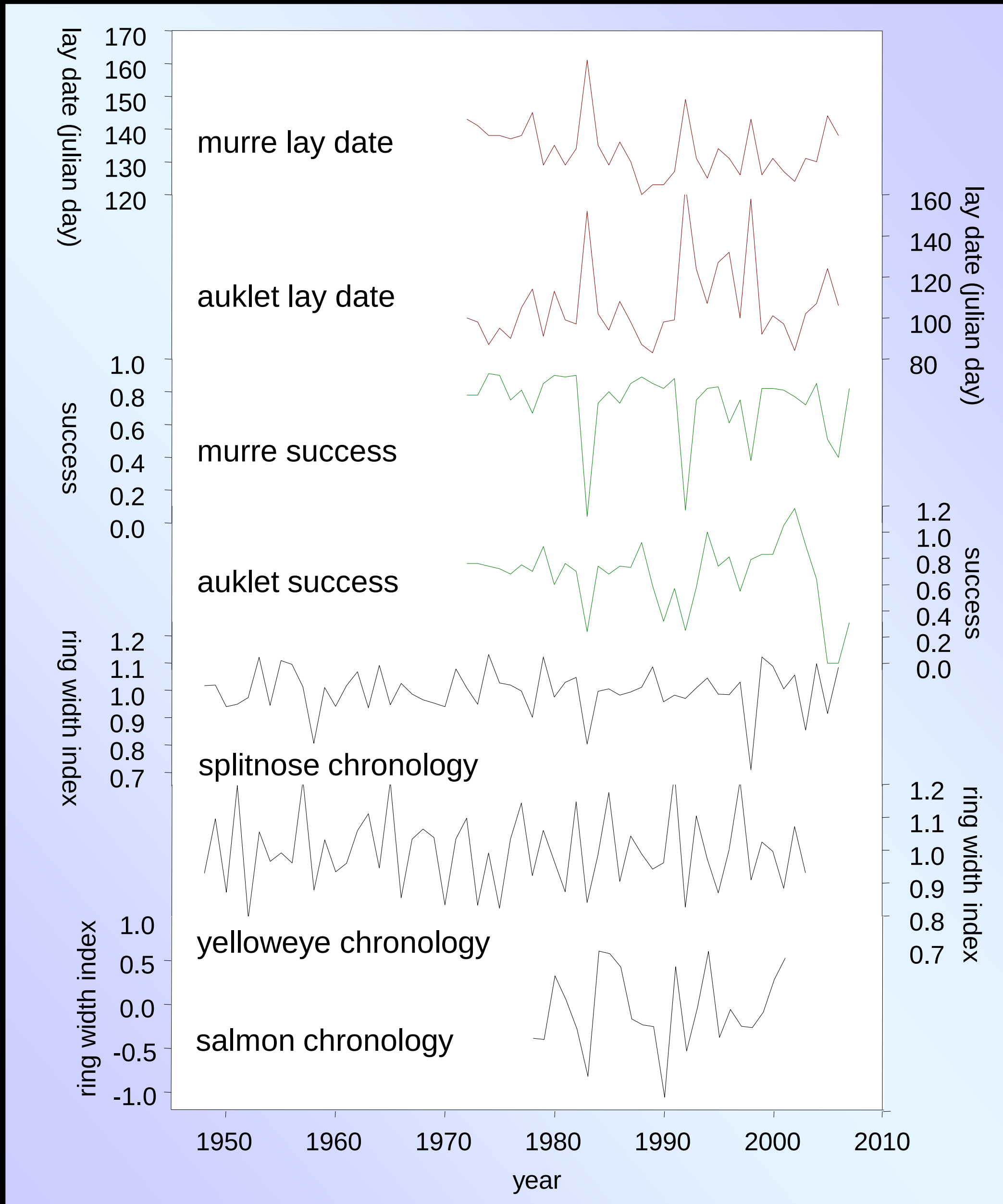
Cassin's auklet
planktivorous

egg-laying dates

and

breeding success

Biotic time series

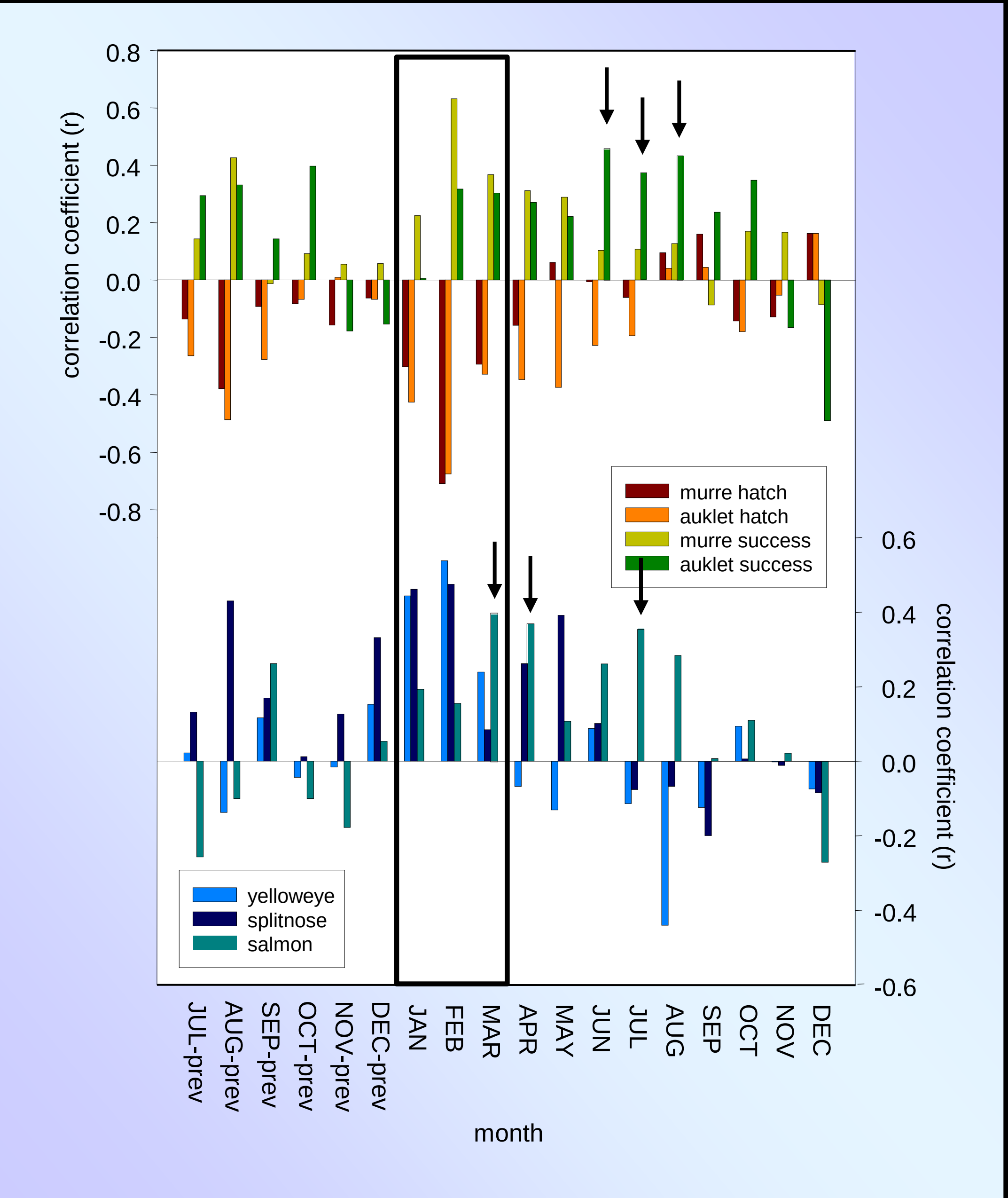


lay date

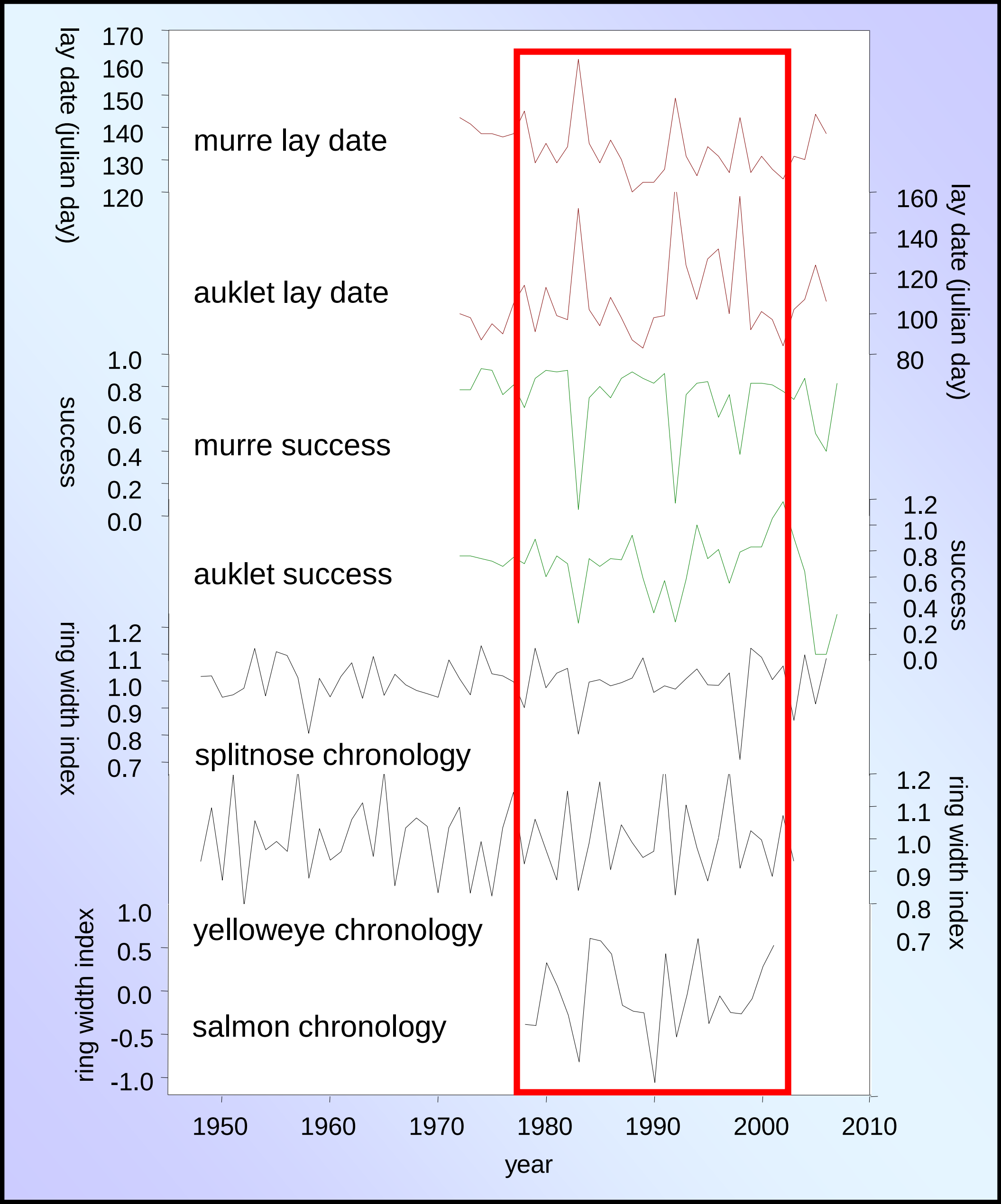
fledgling success

growth-increment chronology

Biotic time series: mostly winter correlations



Combining biotic time series



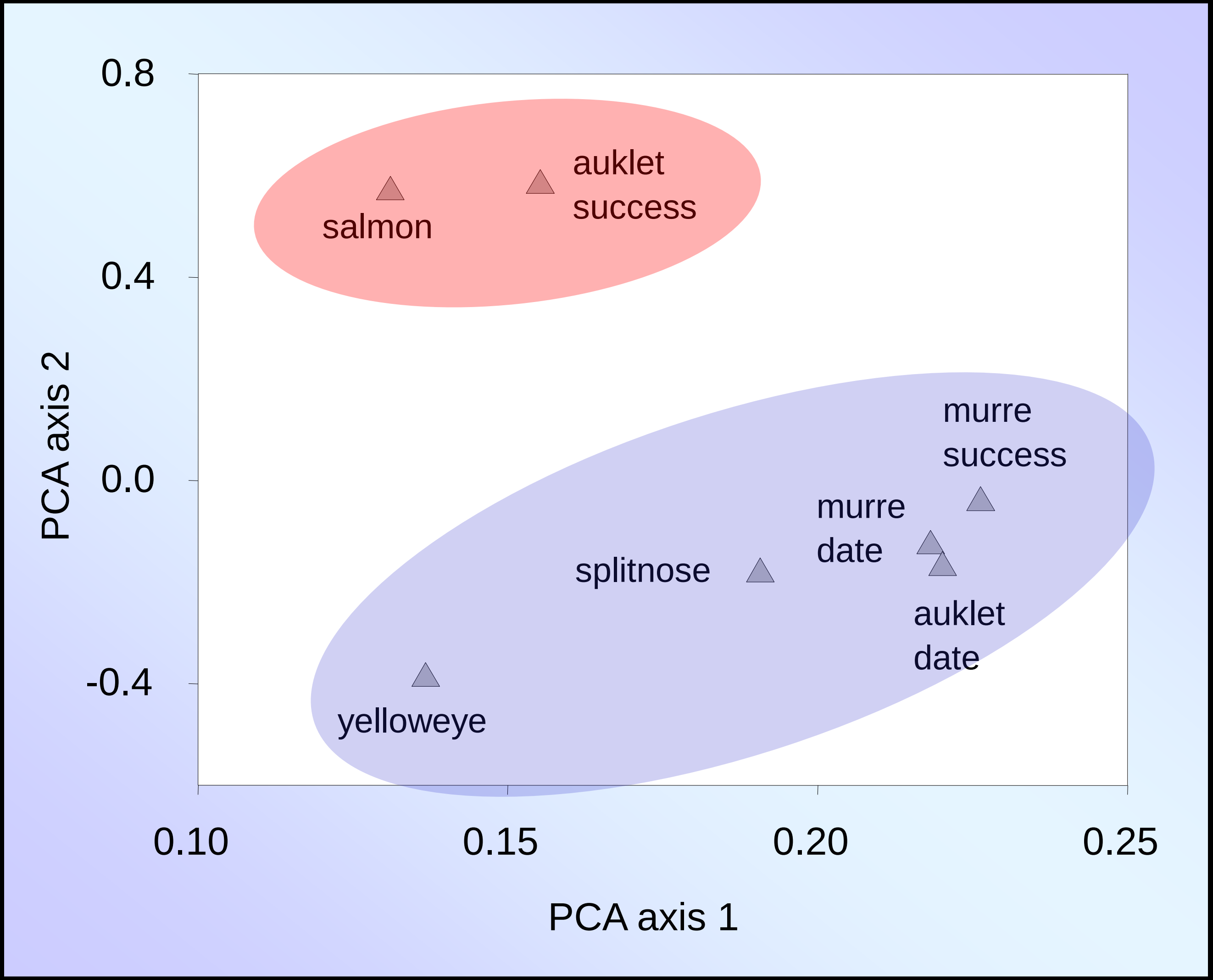
common interval: 1978 - 2001

lay date (seabirds)

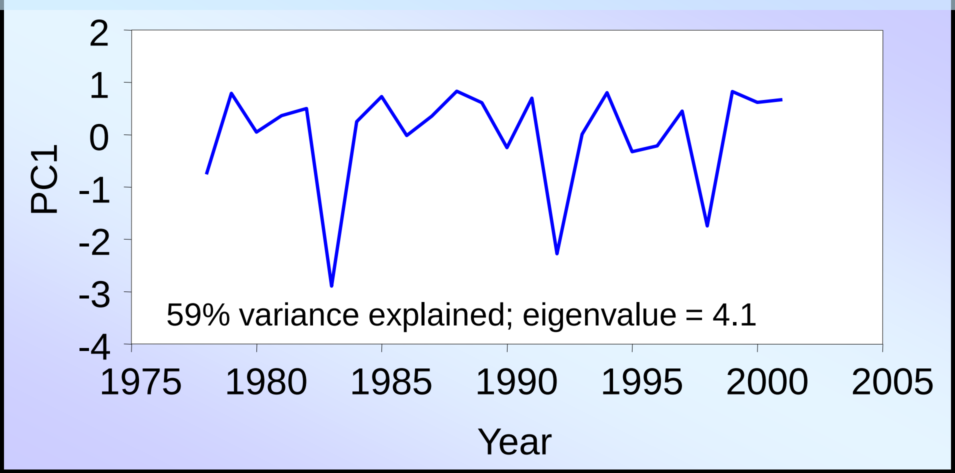
breeding success (seabirds)

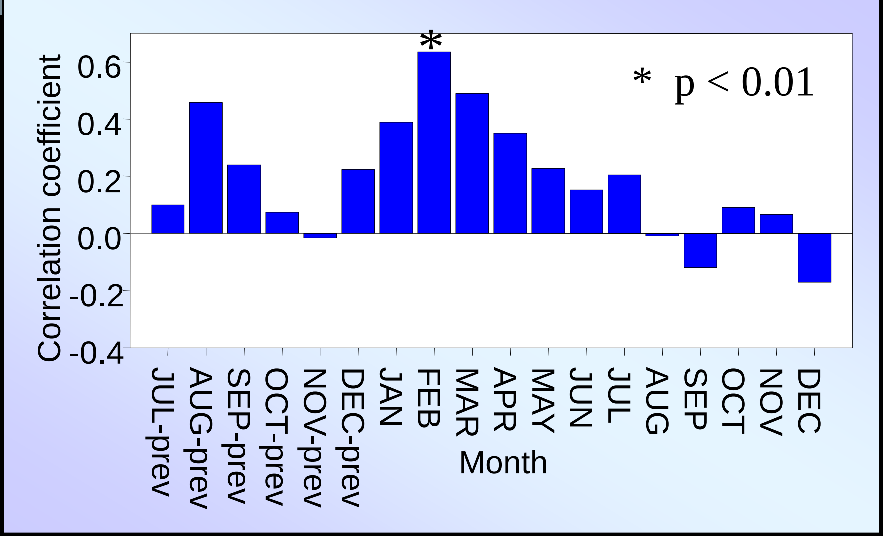
growth (rockfish, salmon)

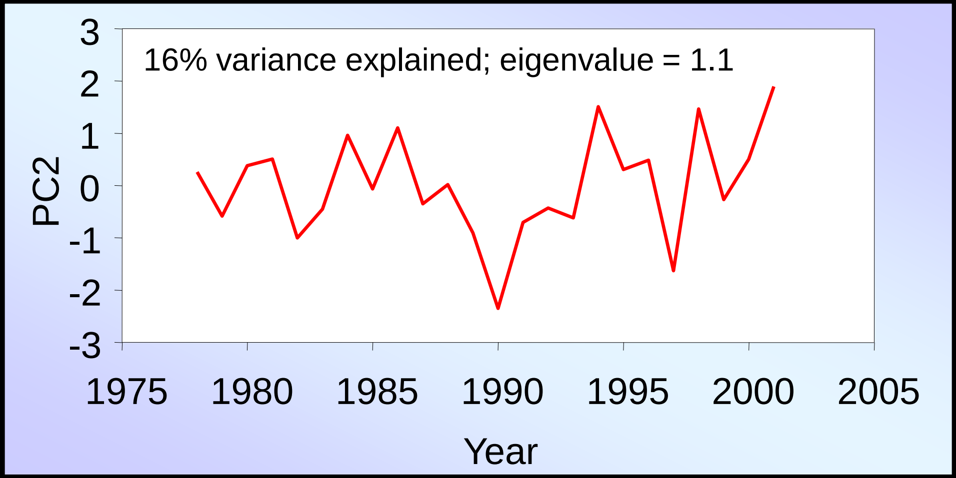
Multivariate response variable (EOF of biotic series)

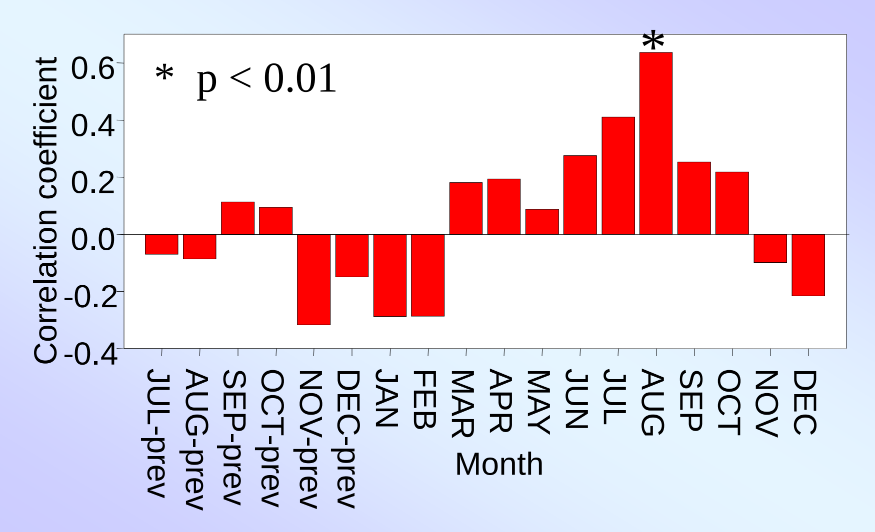


EOF1 and EOF2 fish and bird vs. upwelling: winter sensitive and summer sensitive spp.









Species	Winter/Spring	Summer	Location	Variable
Cassin's Auklet	+ + + + +		Farallon Islands	Lay Date
Common Murre	+ + + + +		Farallon Islands	Lay Date
Cassin's Auklet	+ +	+ +	Farallon Islands	Repro. success
Common Murre	+ + +		Farallon Islands	Repro. success
Rhinoceros Auklets	+		Farallon Islands	Repro. success
Pigeon Guillemot	+		Farallon Islands	Repro. success
Pelagic Cormorant	+		Farallon Islands	Repro. success
Brandt's Cormorant	+		Farallon Islands	Repro. success
Brandt's Cormorant	+		Farallon Islands	Survival
Rhinoceros Auklets	+		Año Nuevo	Repro. success
Splitnose Rockfish	+ + + +		N California	Otolith crn.
Yelloweye Rockfish	+ + + +		N California	Otolith crn.
Aurora Rockfish	+		Oregon	Otolith crn.
Chinook Salmon	+	+	N California	Scale crn.
Pacific Sardine	+		S California	Recruitment
Krill		+	Central CA	Abundance
Chlorophyll-a		+	Central CA	Concentration

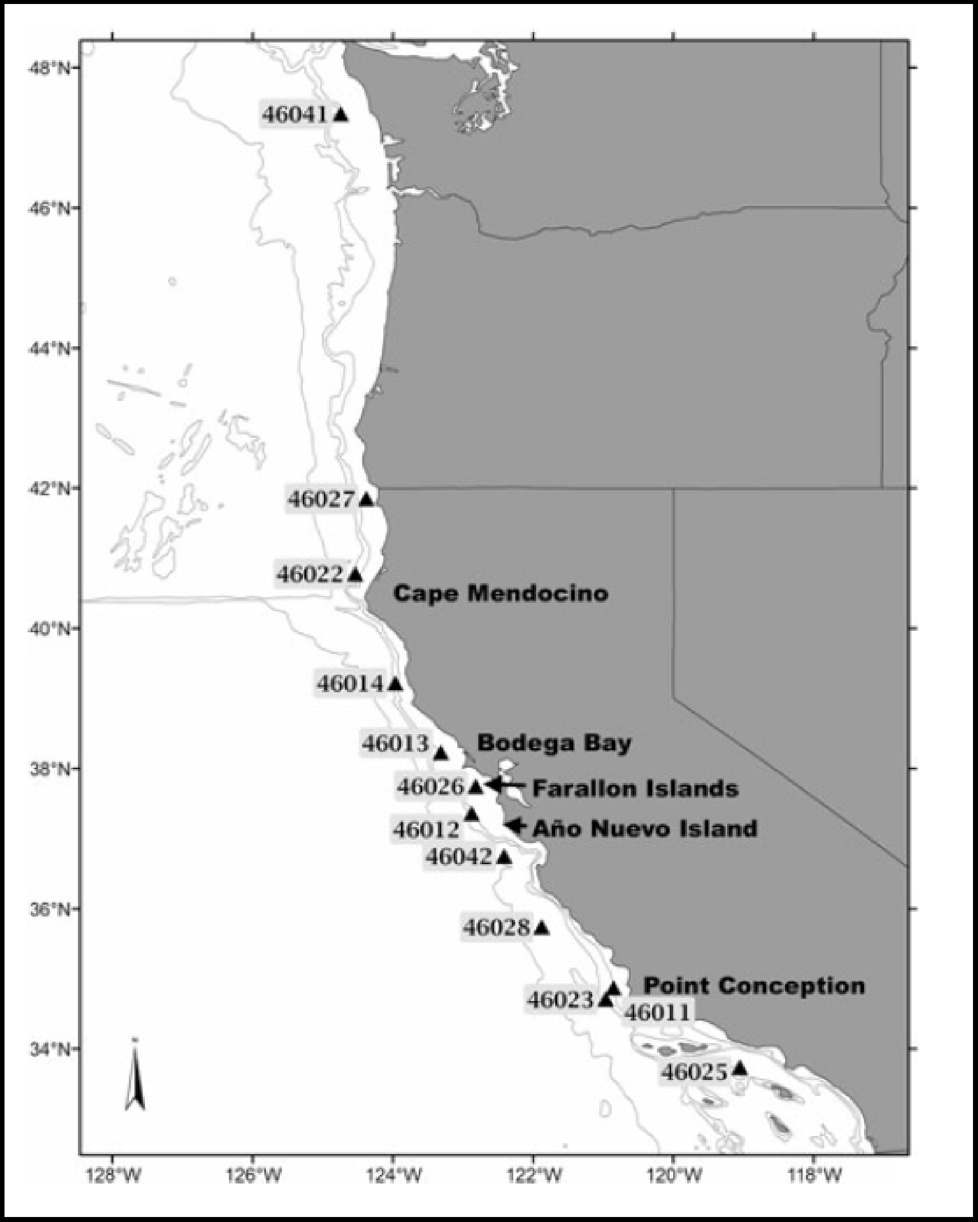
+ Schroeder et al. 2009 + Black et al. 2010 + Black et al. 2011 + Garcia-Reyes et al. 2013

+ Schroeder et al. 2013 + Garcia-Reyes et al. 2014 (but only data in the summer for krill)

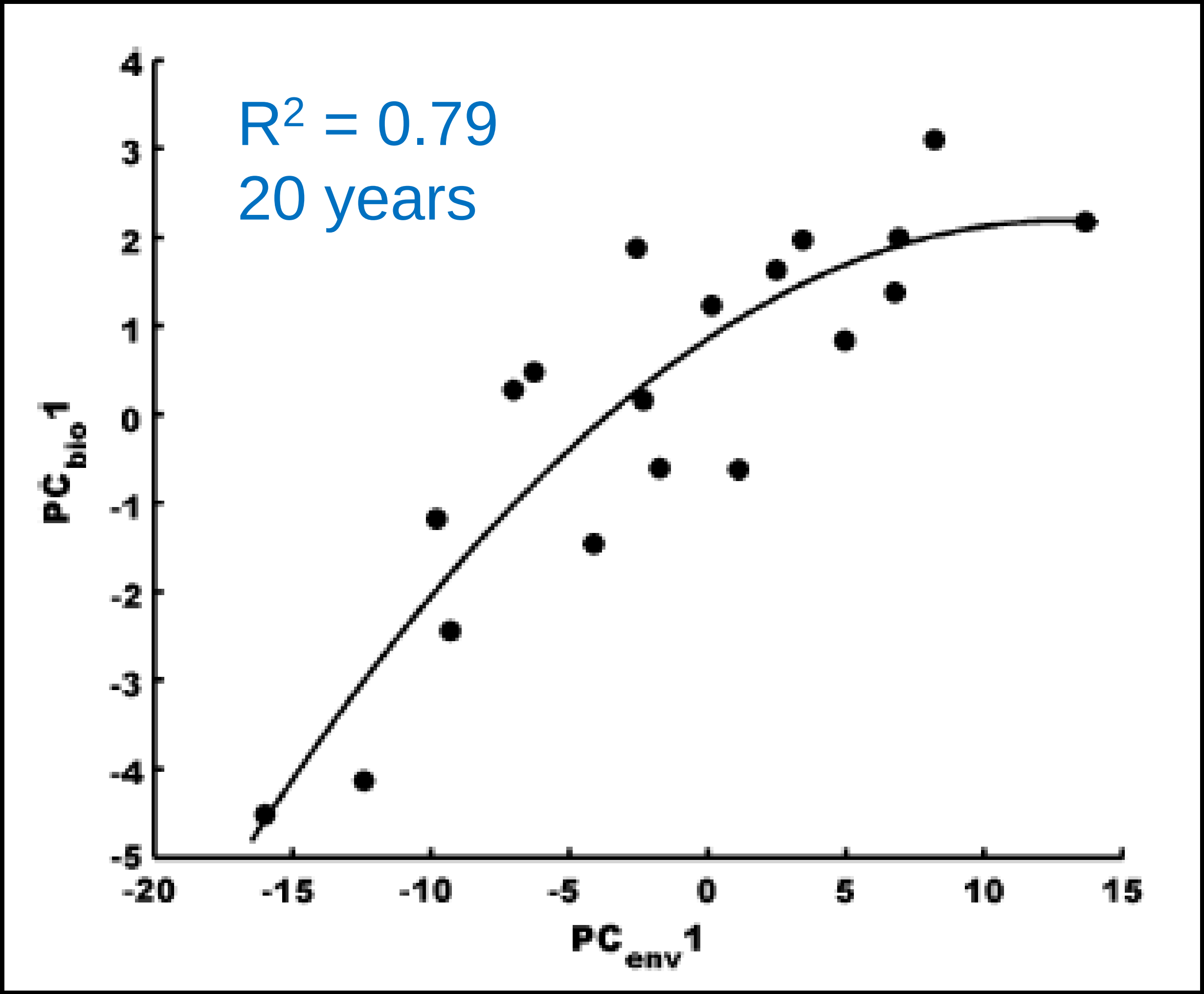
Environment: EOF of SST, wind, and UI

Winds and temps from 12 buoys 1988-2010

Upwelling from same latitudes



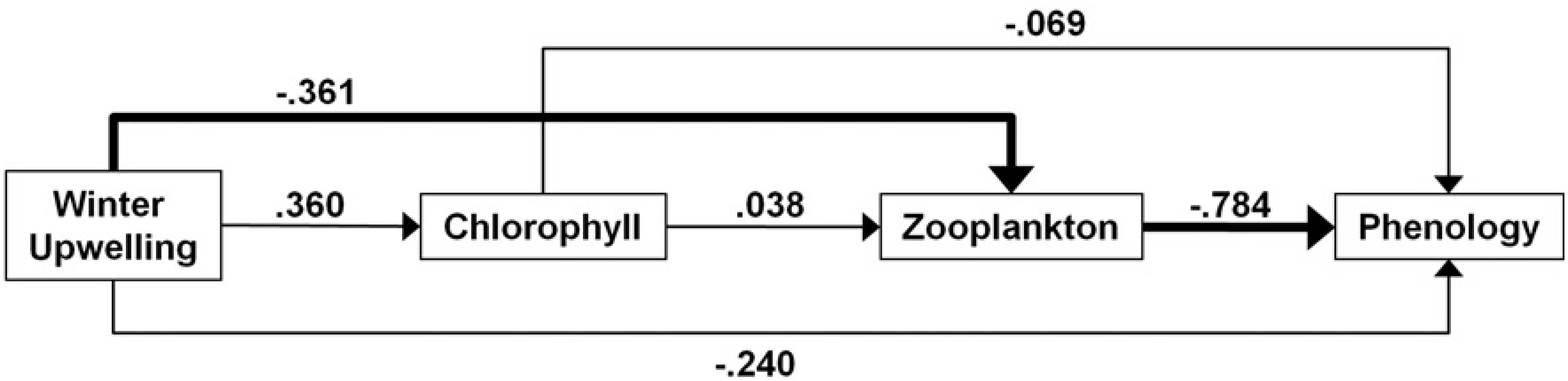
Early season environment explains biotic response



PC_{env} from winds, temps (winter / early spring signal)
PC_{bio} from 9 time series (56% variability explained)

“Bottom-up” Mechanism of Response: Path analysis

Seabird (Cassin’s auklet) laying date: euphausiid key



➢ **changes in food webs related to upwelling determine responses of fish and seabirds; effects to UTL species are indirect operating through predator-prey interactions; focus on MTL species (i.e., euphausiids, forage fishes, and squids) will be key to understanding and predicting UTL response to climate change**

Other Mechanisms of Response

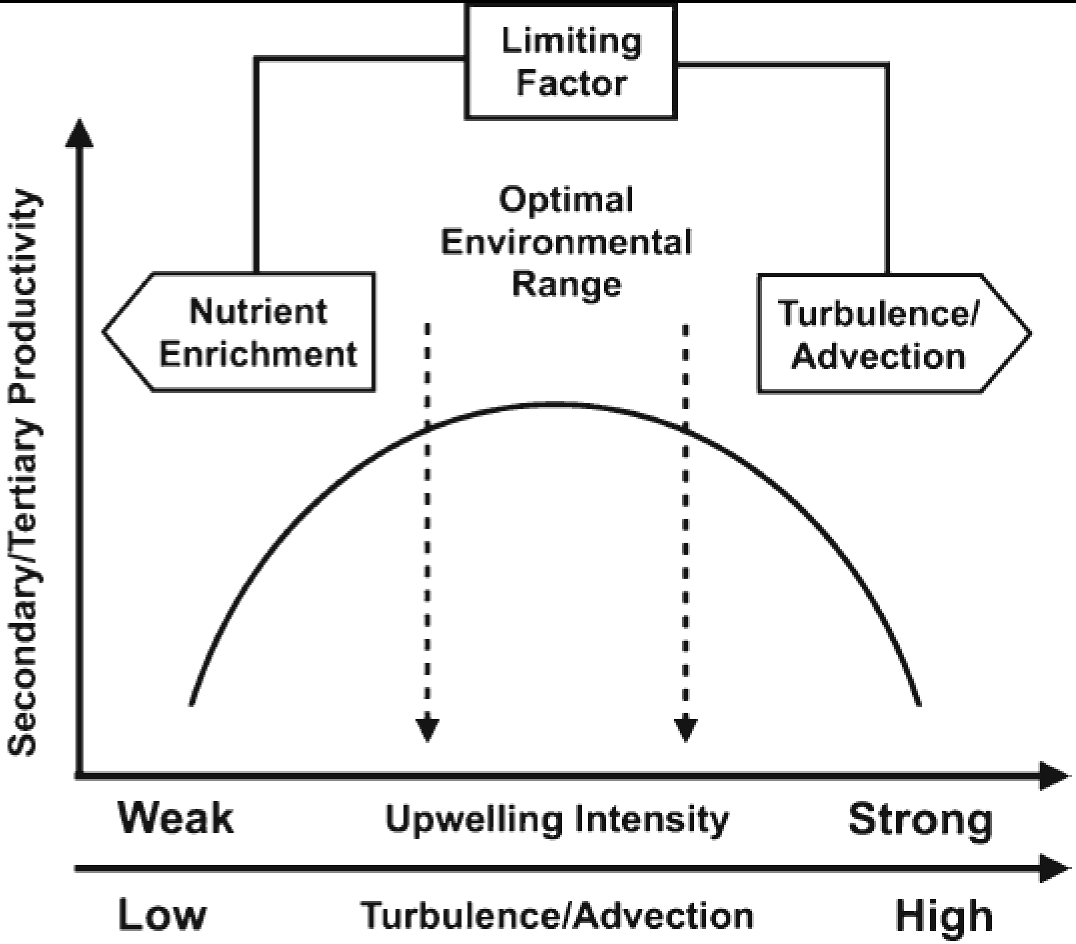


Fig. 2 The "optimal environmental window" shows highest levels of productivity at moderate upwelling intensity. When upwelling is strong, biota can be advected offshore, while at low upwelling intensity nutrients in the upper water column can be limiting to productivity. Adapted from reference [86]

Monthly matrix of Upwelling Index at 39N

year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1946	6	-10	45	36	85	111	140	155	35	59	5	-5
1947	14	-3	2	60	68	122	83	169	81	9	44	1
1948	-4	49	28	7	47	108	148	117	54	12	7	7
1949	40	22	-4	44	67	165	160	74	41	65	-35	11
1950	24	-7	12	72	210	121	205	90	48	-6	0	-58
1951	7	2	90	66	87	170	203	179	33	12	-18	4
1952	-3	2	104	45	100	137	144	126	52	0	0	-45
1953	-39	65	40	42	74	189	174	53	33	20	-23	8
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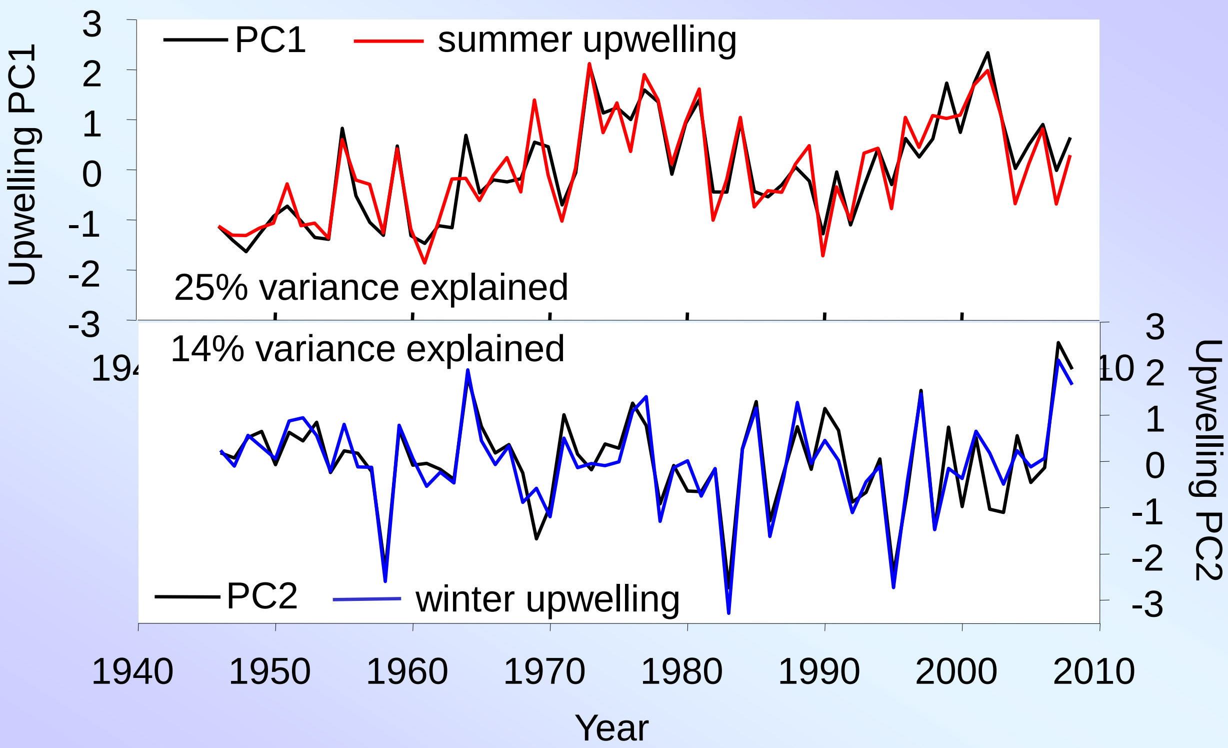
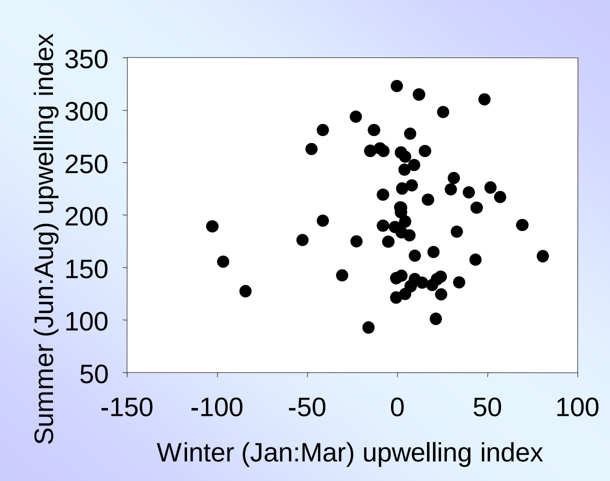
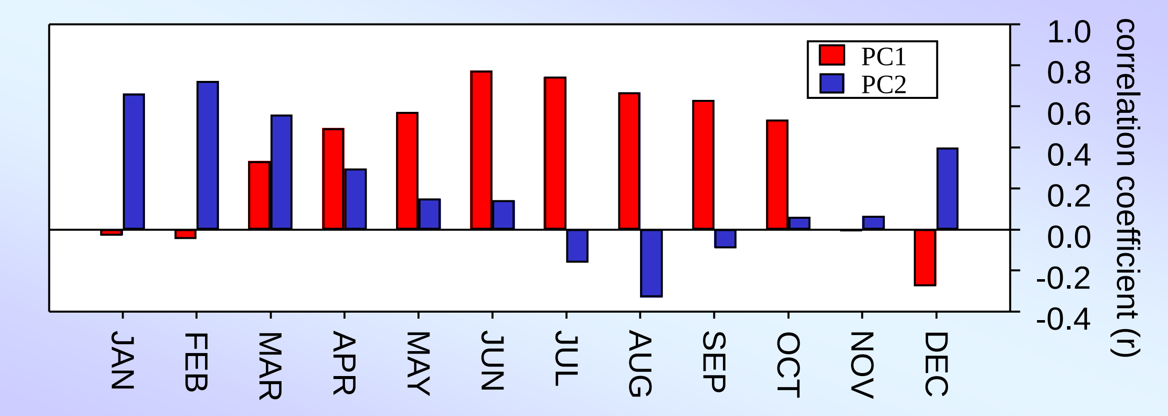
2000	-21	-113	105	21	116	216	302	272	115	64	14	-5
2001	-5	-5	86	127	256	326	365	203	106	91	-12	-18
2002	3	0	33	117	202	388	271	285	130	129	-2	-175
2003	-102	37	20	18	221	302	327	154	140	51	-6	-95
2004	-38	-25	92	73	149	241	145	97	173	45	78	3
2005	-17	4	18	80	64	196	216	209	194	82	40	-37
2006	1	27	0	30	170	202	297	243	170	116	29	4
2007	107	23	112	146	239	228	116	138	105	37	56	26
2008	-1	39	133	150	231	287	170	194	87	65	11	34

Upwelling 39N



winter vs. summer UW

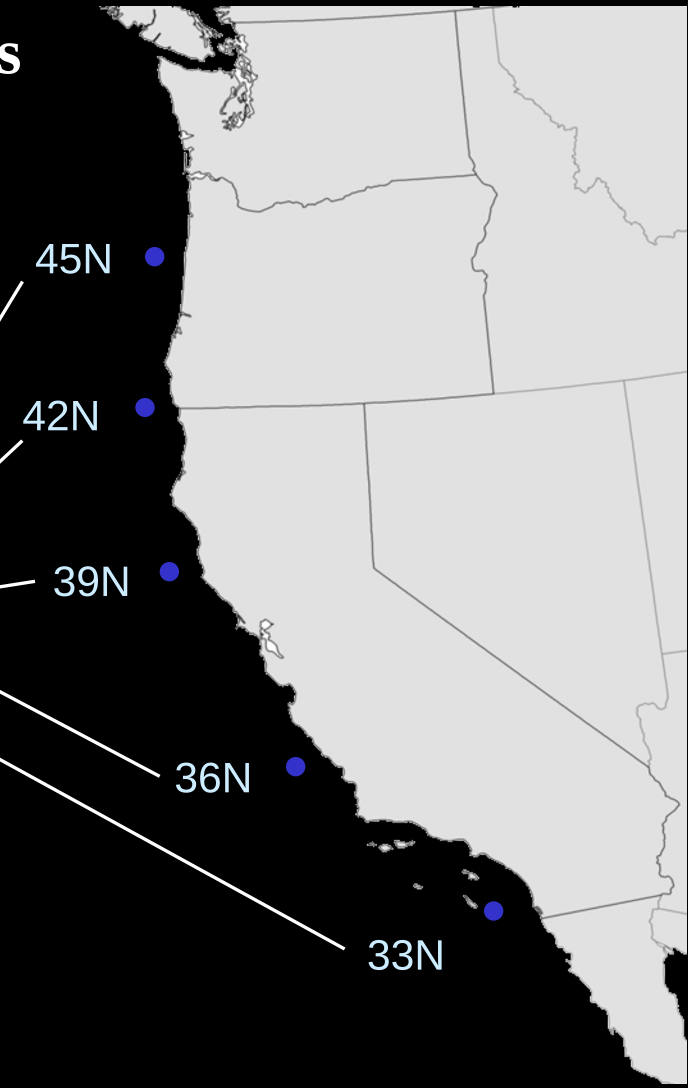




Scaling up: EOF of Upwelling Index across CCS

Principal components repeated at 5 locations

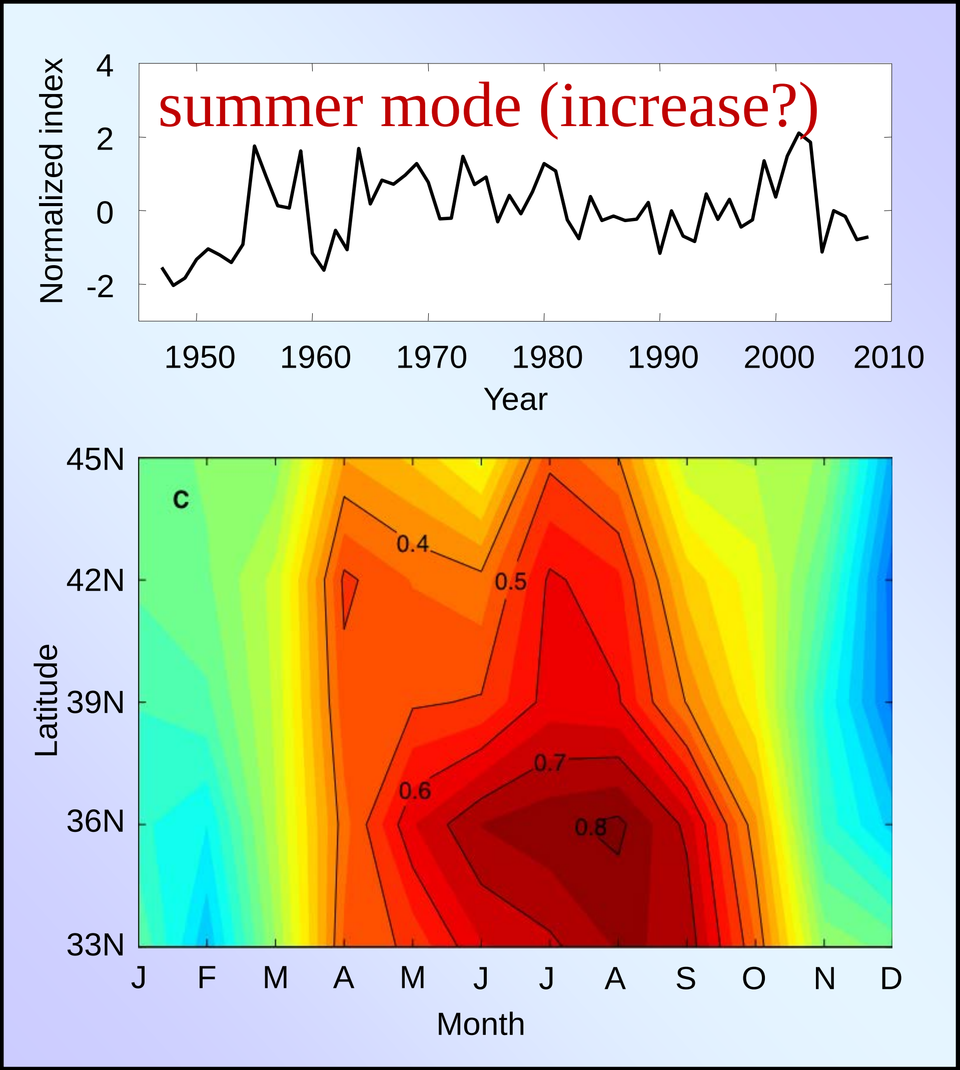
Lat	winter vs. summer: Correl.	winter mode: EV	winter mode: % var	summer mode: EV	summer mode: % var
45 N	-0.01	1.68	14	1.74	15
42 N	-0.01	1.87	16	2.88	24
39 N	0.02	1.71	14	3.03	25
36 N	-0.08	2.24	19	3.61	30
33 N	-0.02	2.22	19	4.08	34

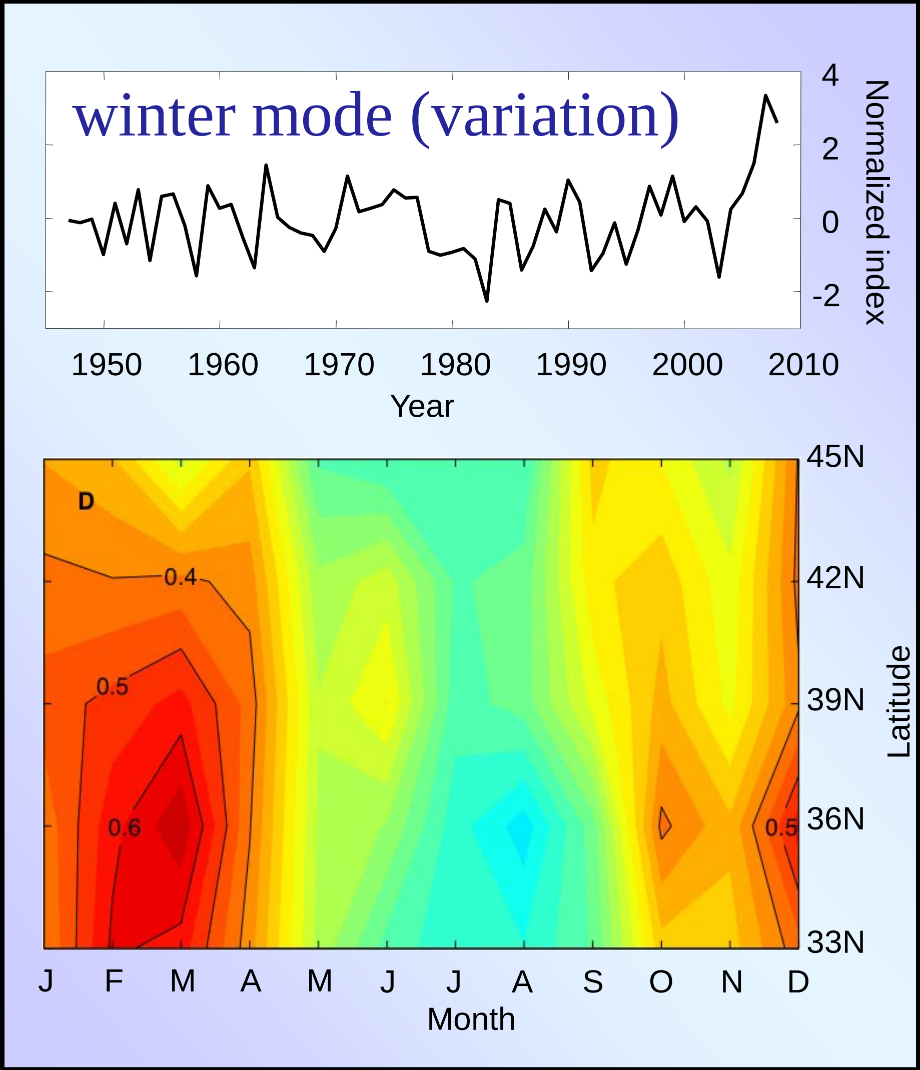


EV = eigenvalue
% var = percent variance explained

Trends in Seasonal Upwelling Index

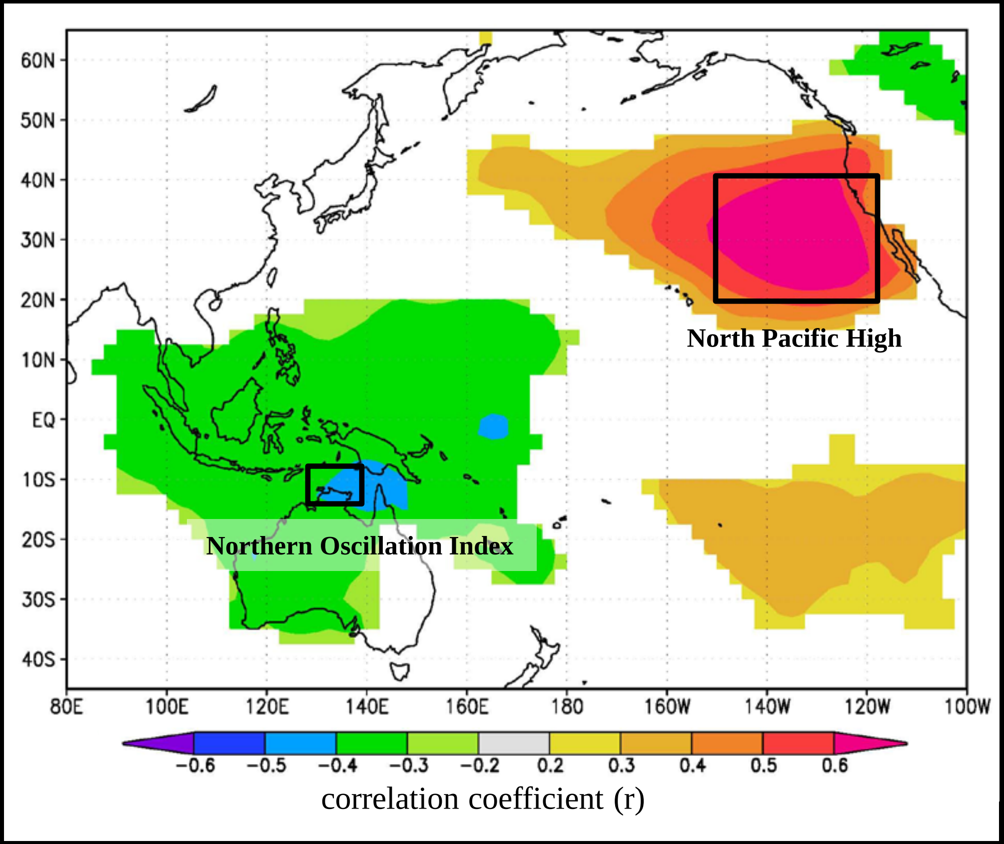
Coastwide analysis (5 upwelling stations)



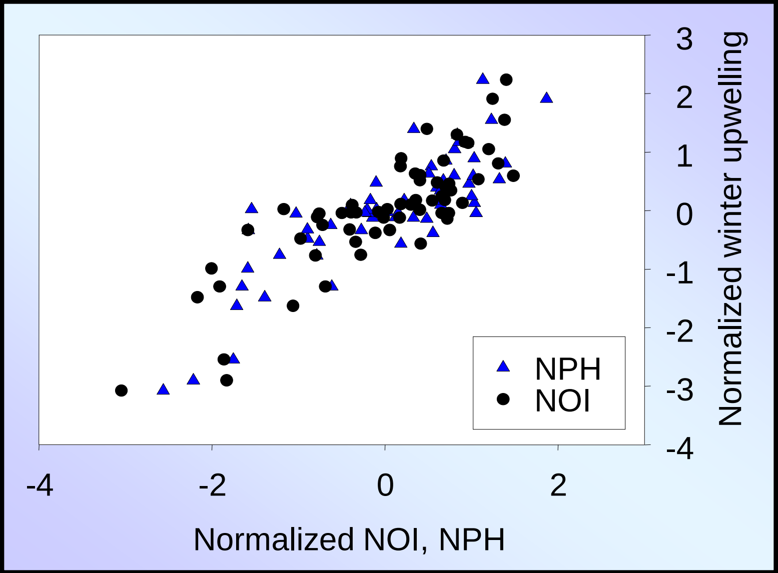


Driver? Winter mode and sea level pressure

Correlation with winter sea level pressure

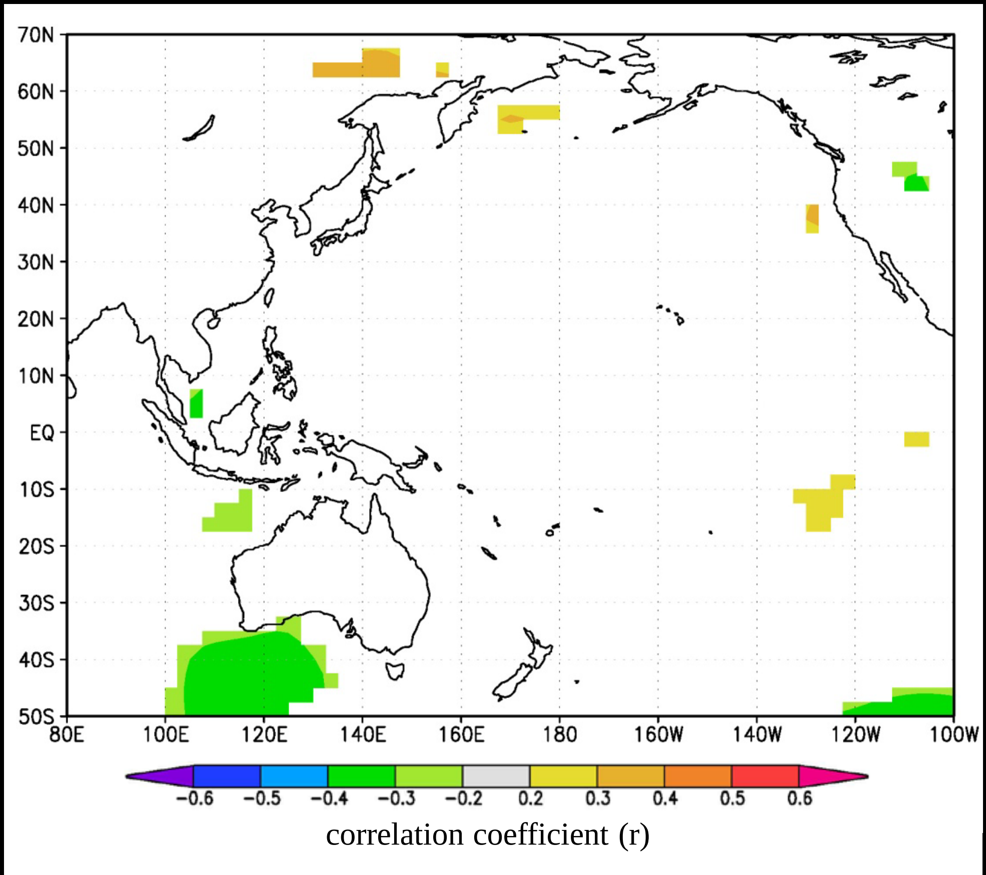


Winter mode vs. NOI and NPH

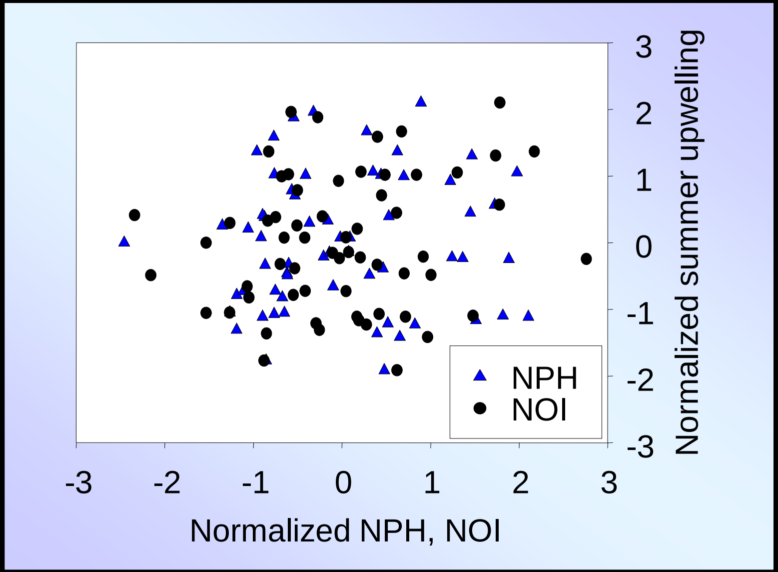


Summer mode and sea level pressure

Correlation with summer sea level pressure



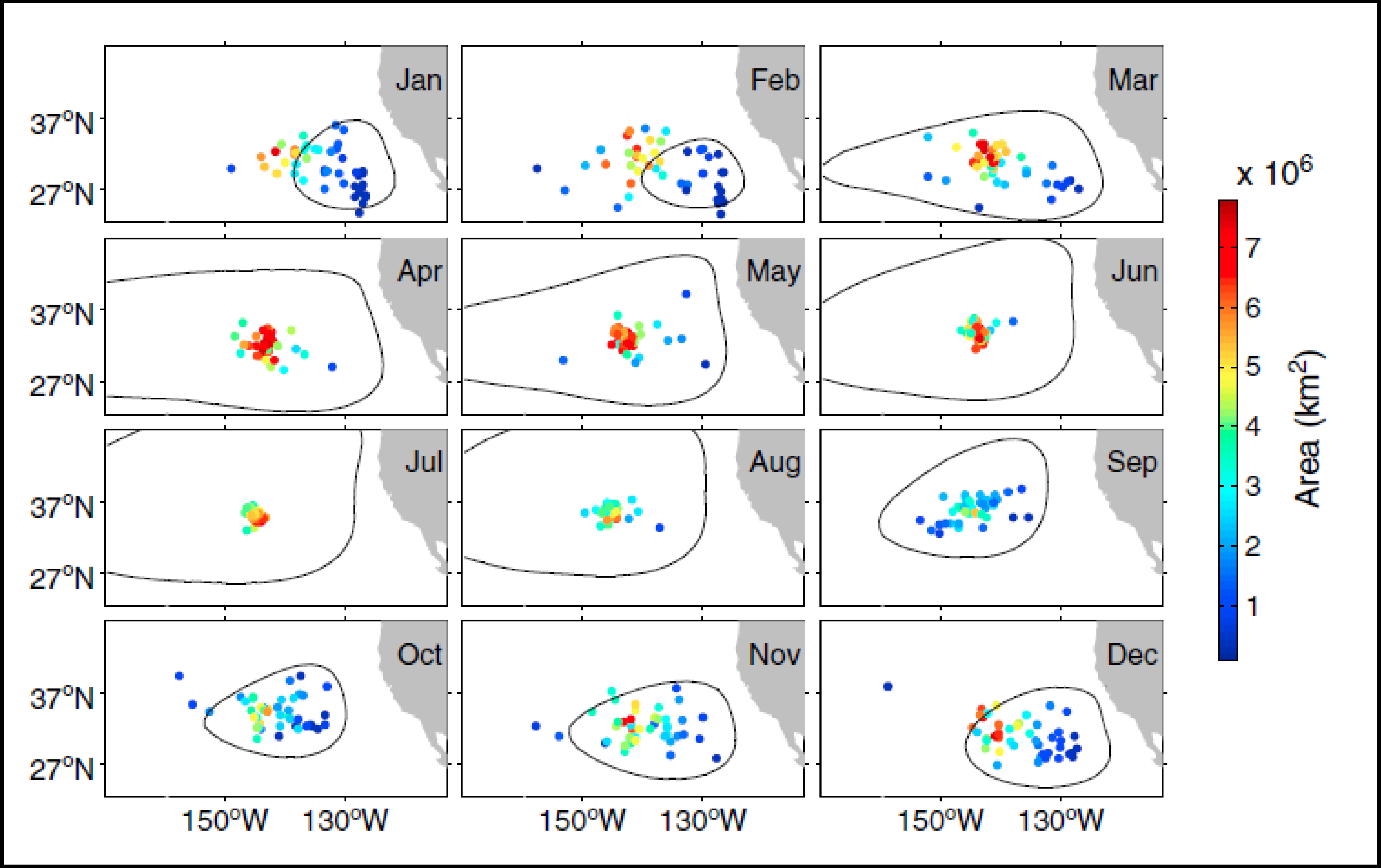
Summer mode vs. NOI and NPH



➢ drivers of summer upwelling poorly understood

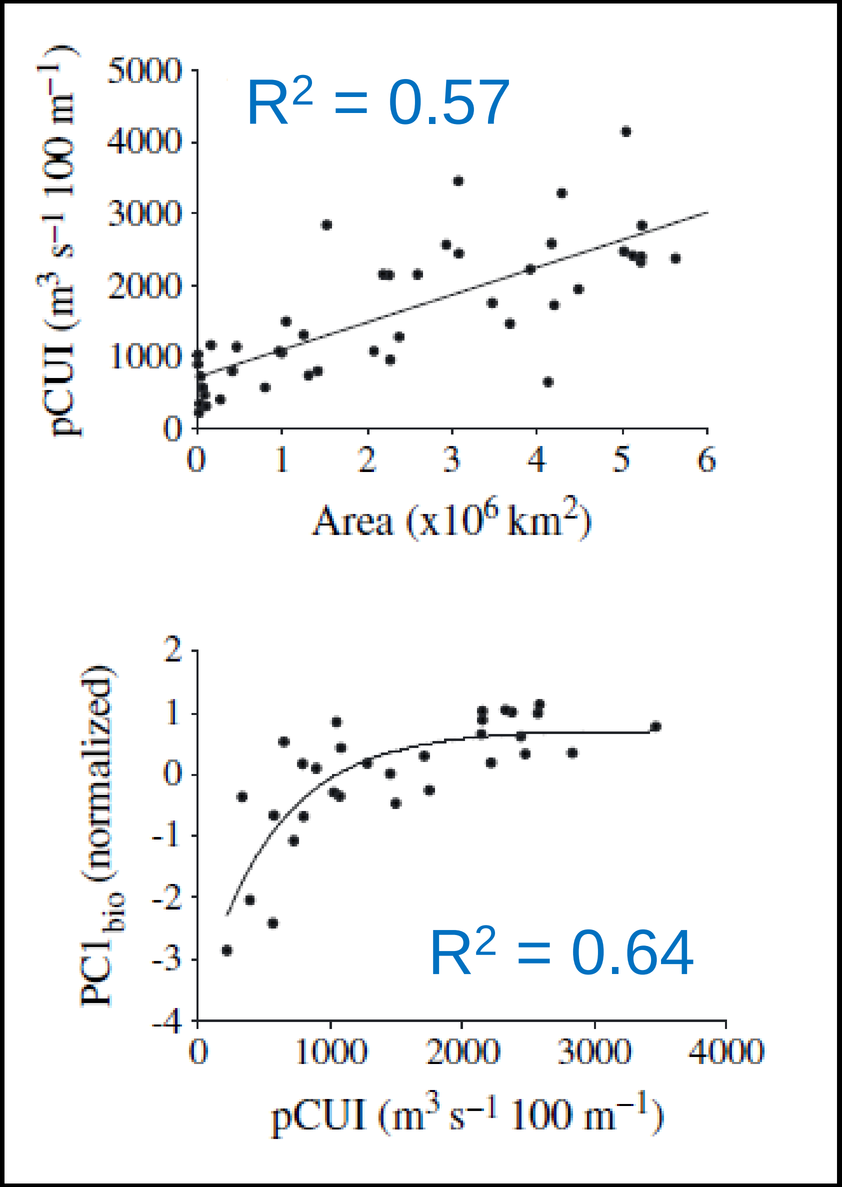
Ecosystem “preconditioning”, North Pacific High

Position (dots) and area of the NPH



Winter mode and the North Pacific High

pCUI = sum of all positive daily upwelling values (Jan-Feb)

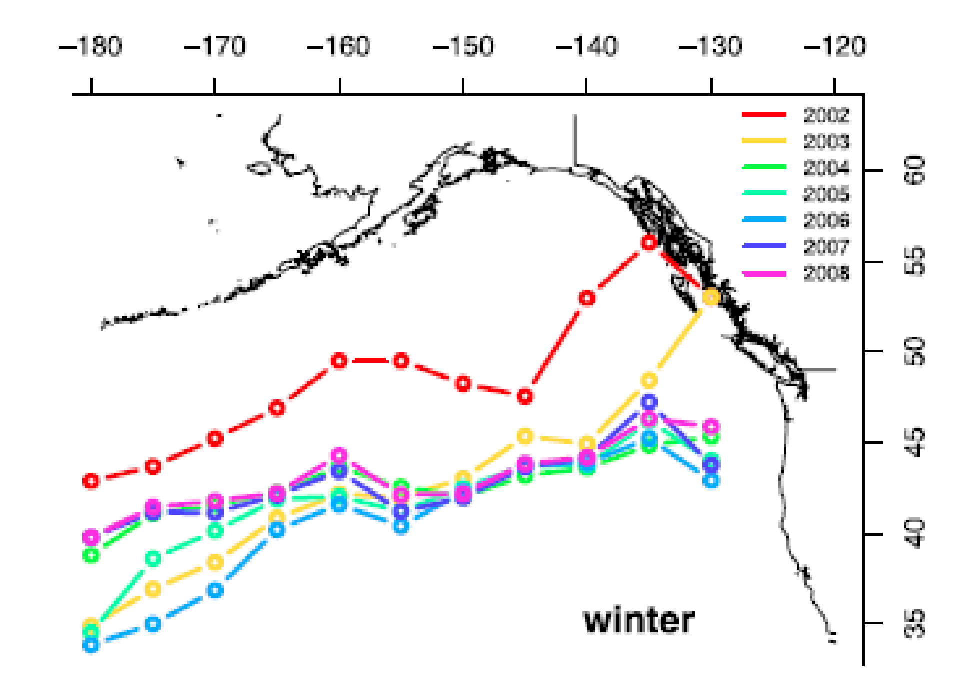


Why winter?

Greatest variability
Lengthen growing season
Pre-condition ("jump start") food web dynamics

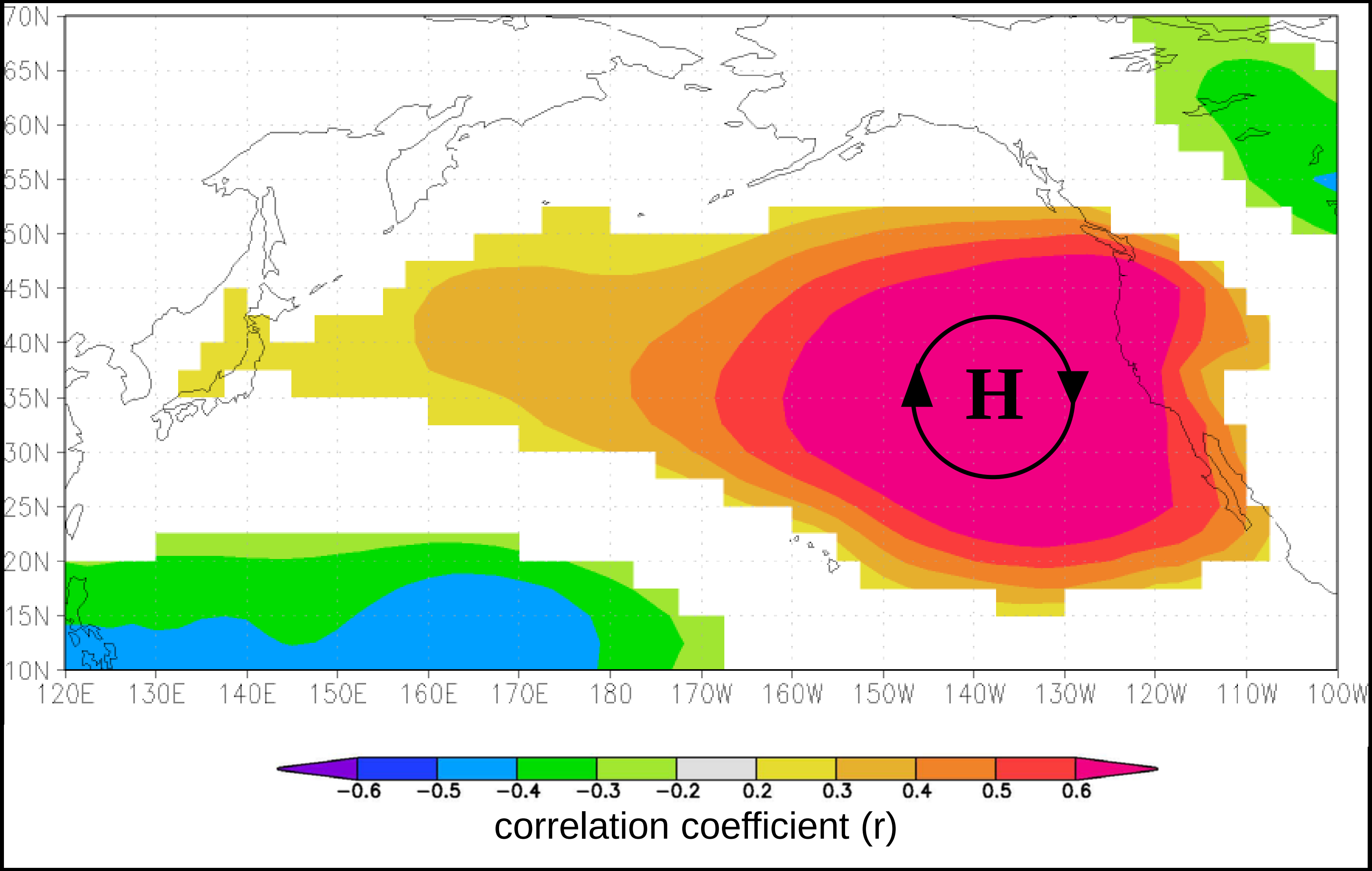
But, also
more than upwelling…

source waters?

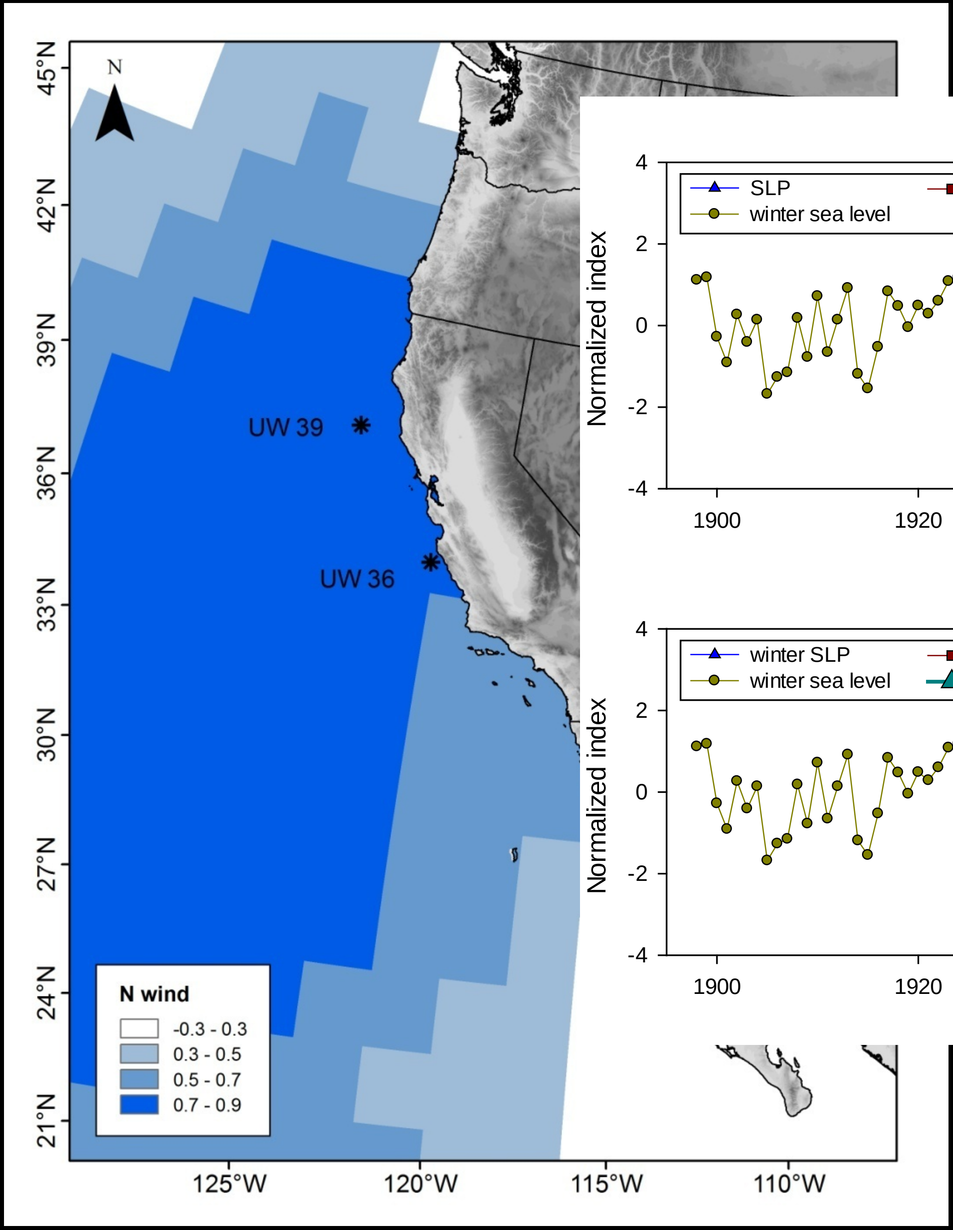


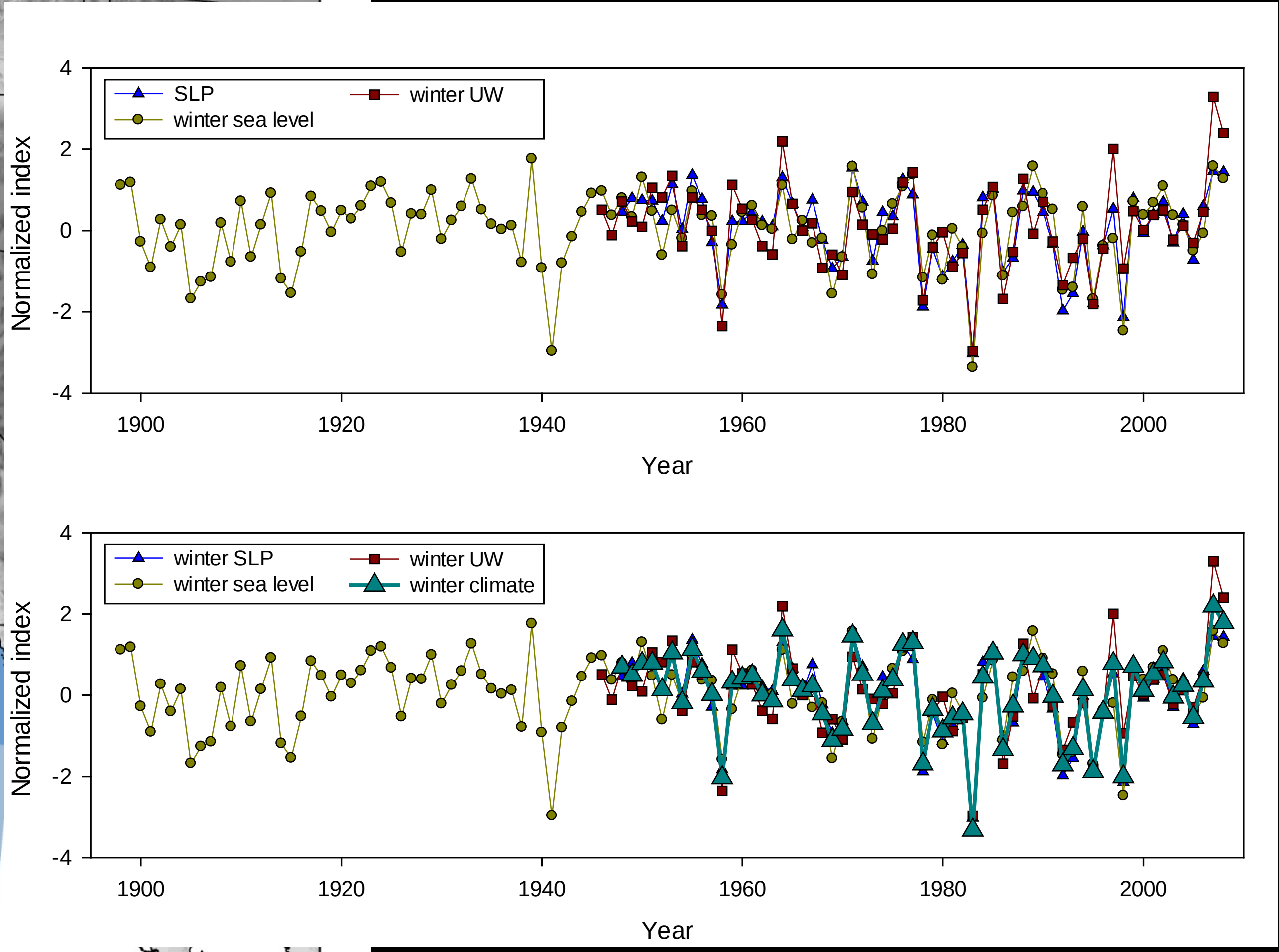
North Pacific Current

Winter NPH: Key to the past and Q: Has Upwelling Become more Variable?



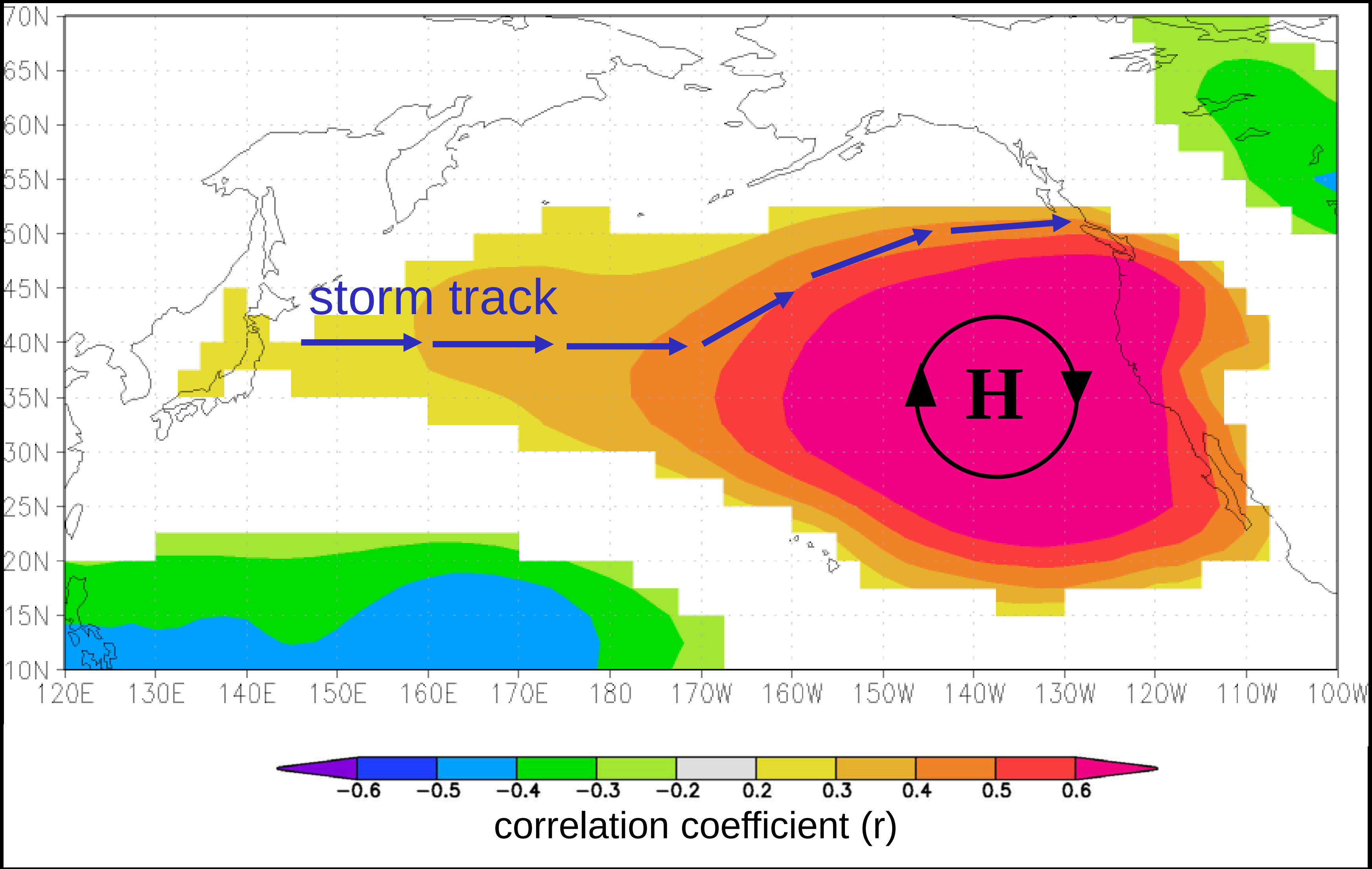
Reconstructing the Past Upwelling



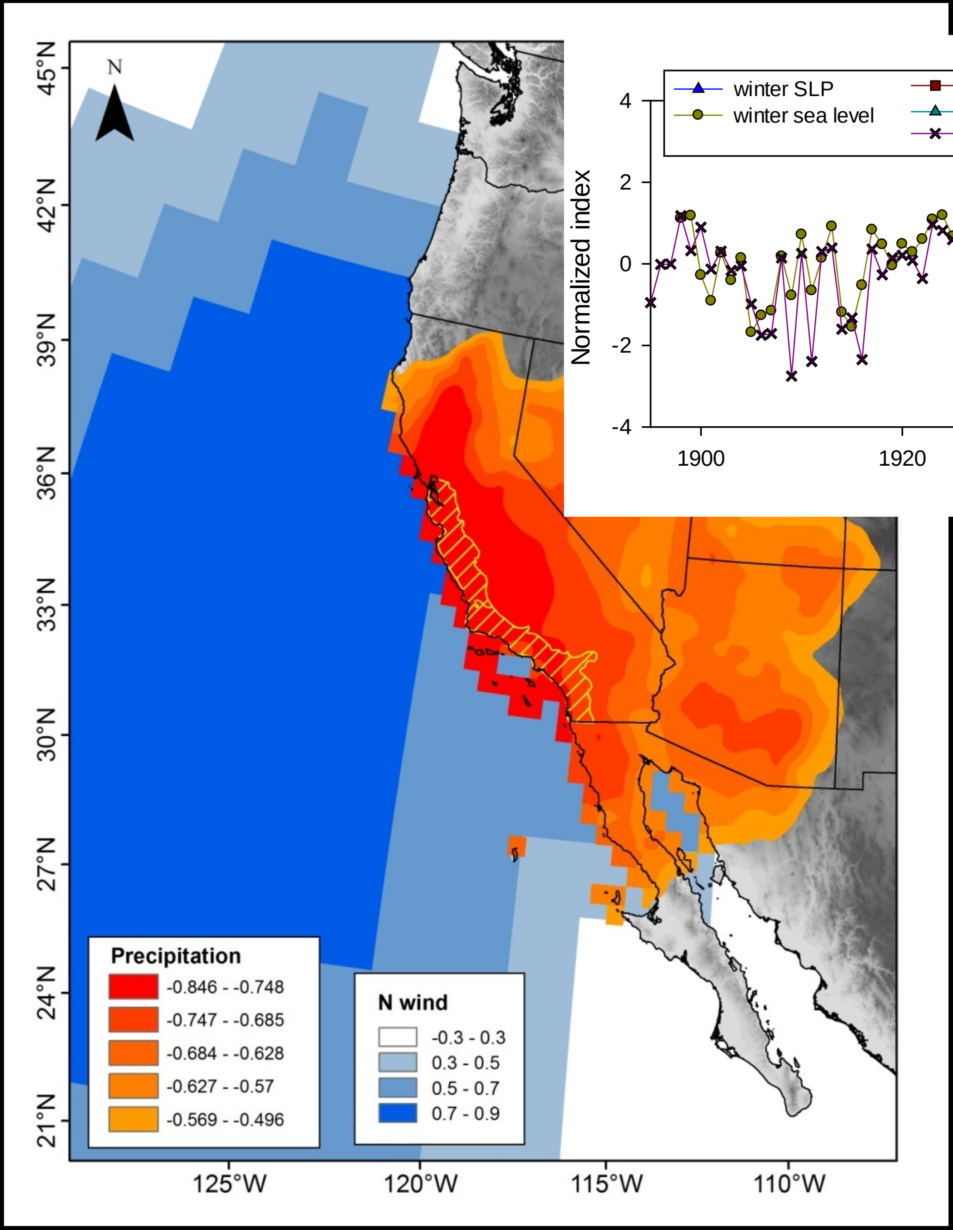


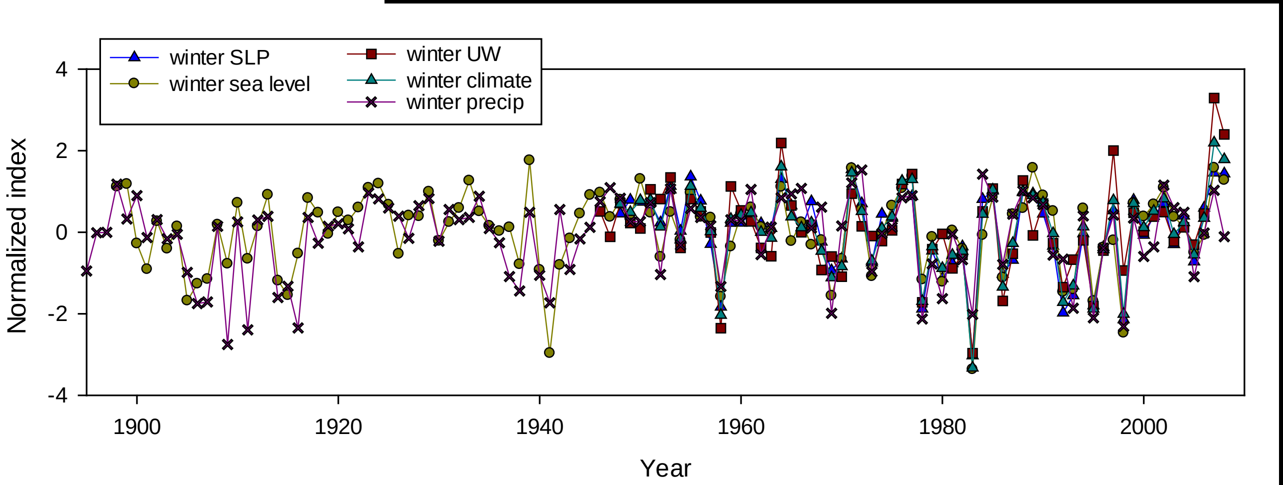
Winter blocking high

Correlation between upwelling and winter sea level pressure

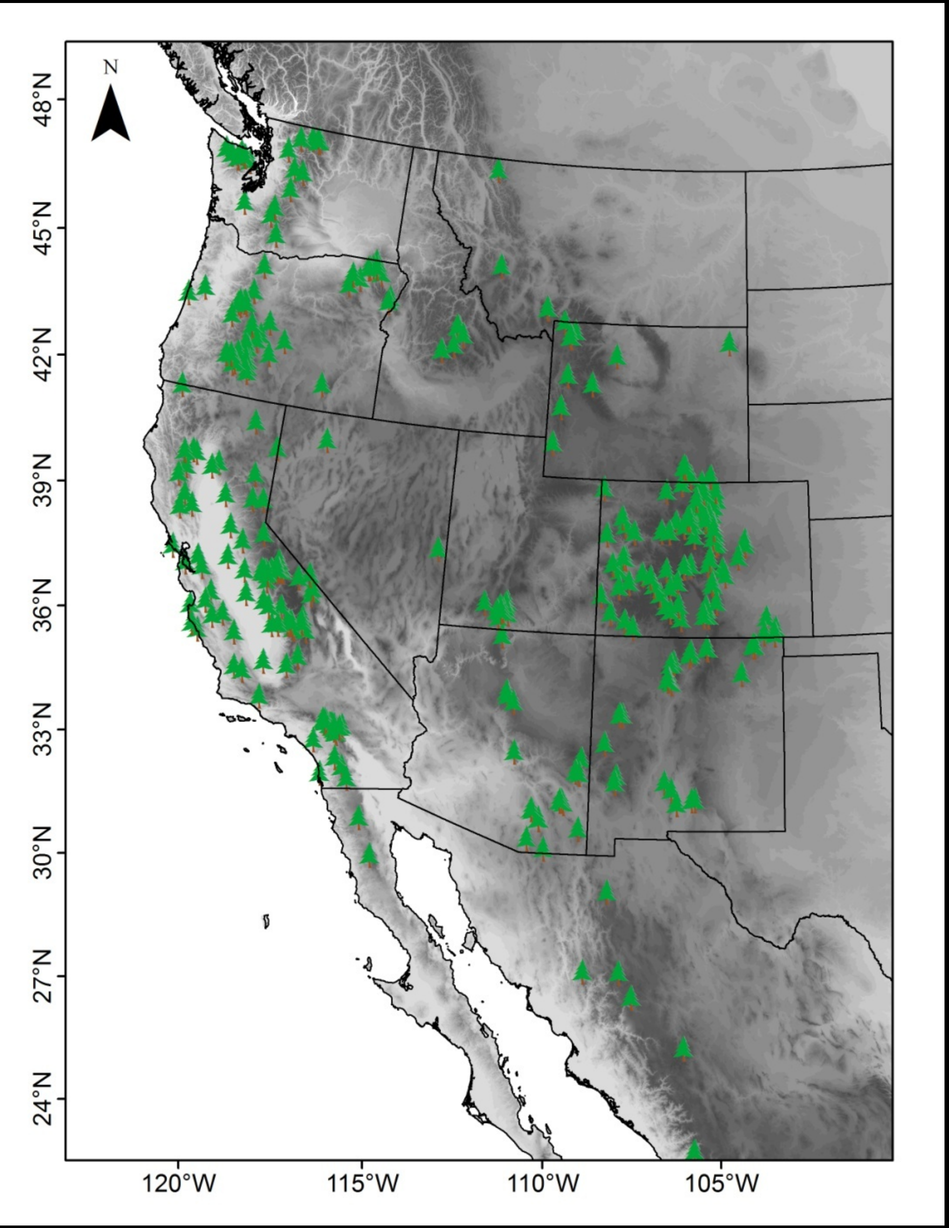


Inverse correlation between NW winds, precip

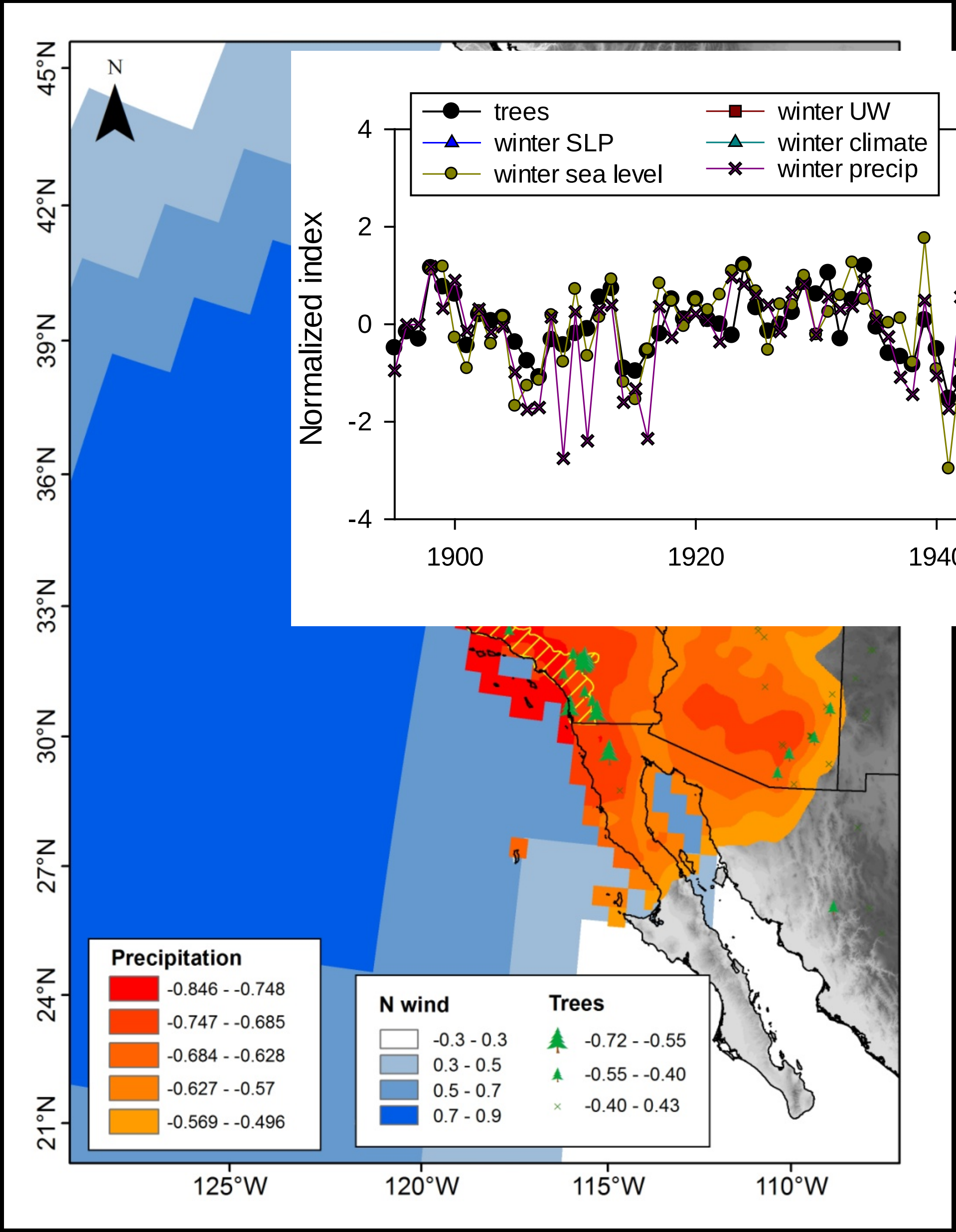


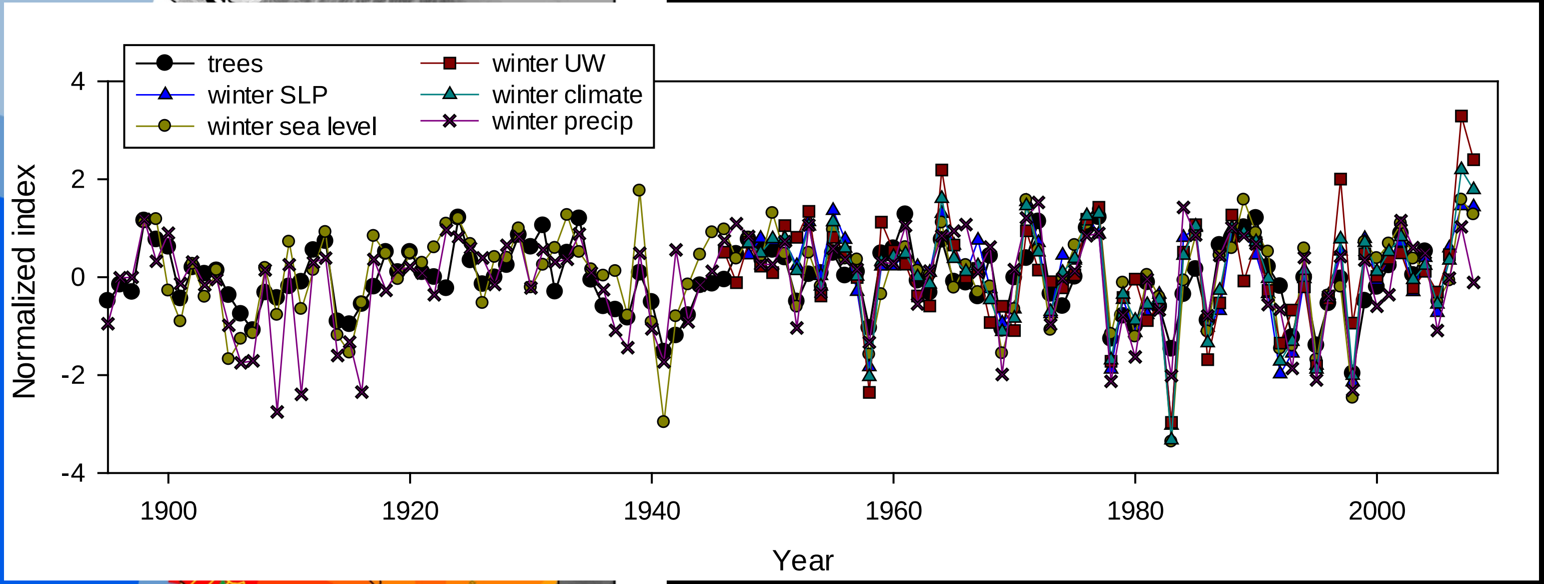


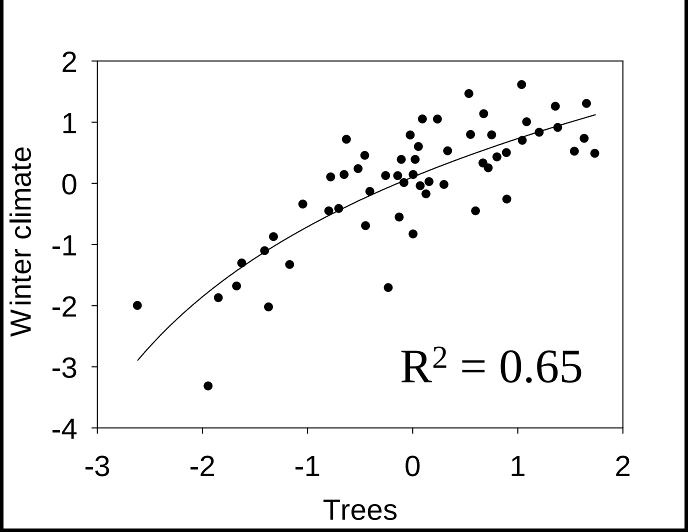
Tree-ring chronology locations



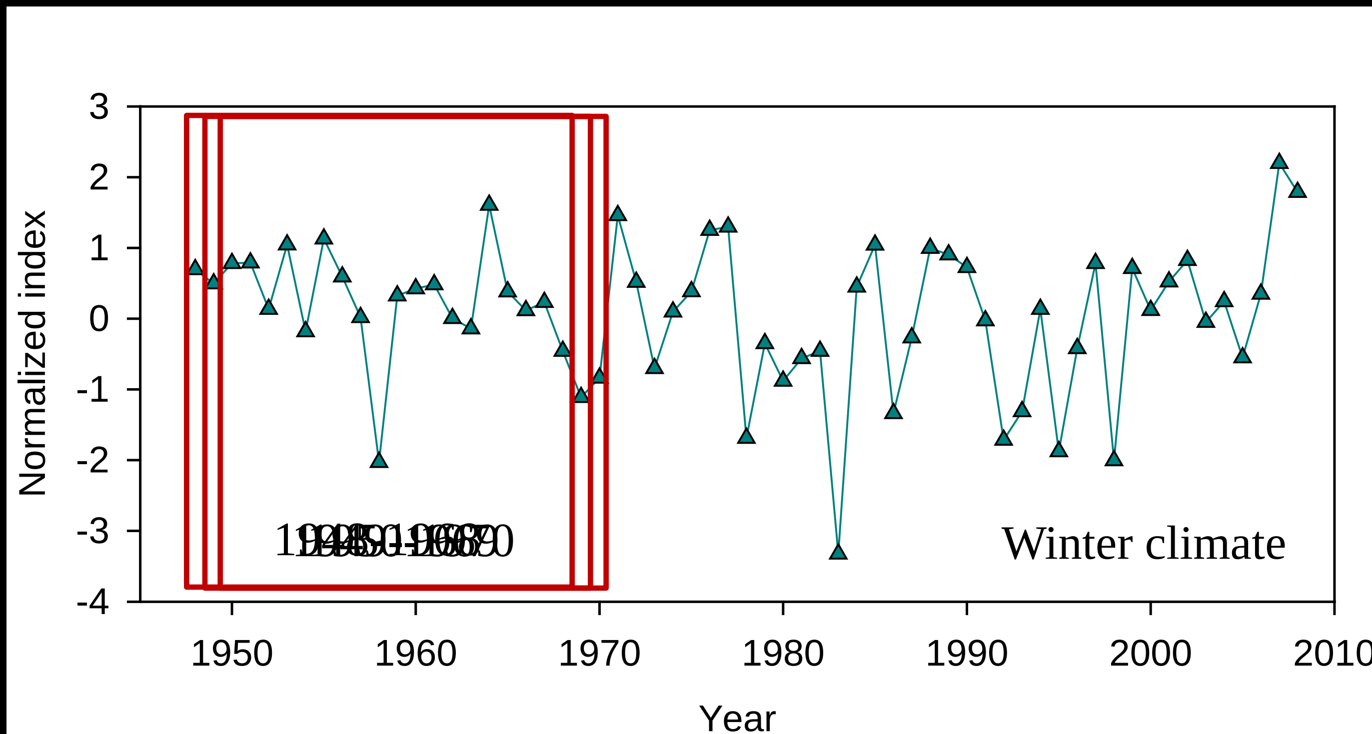
Marine and terrestrial linkages



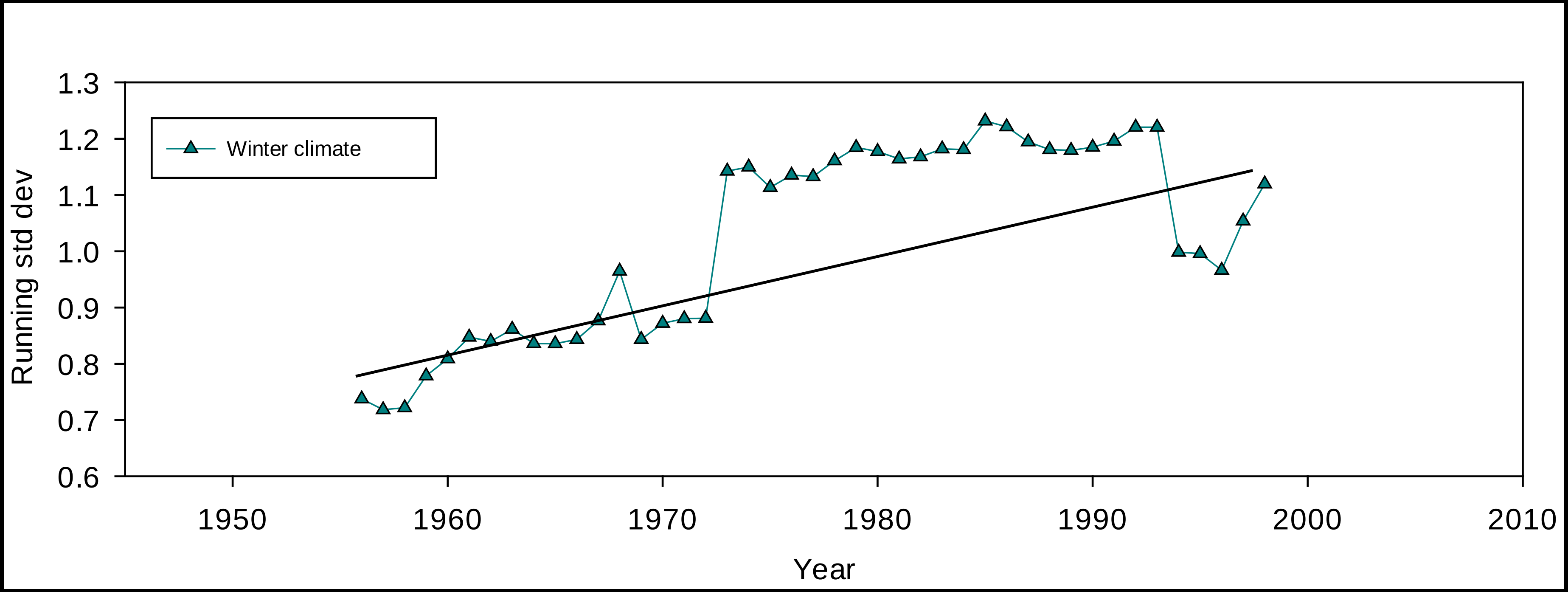




Running standard deviation



Running standard deviation



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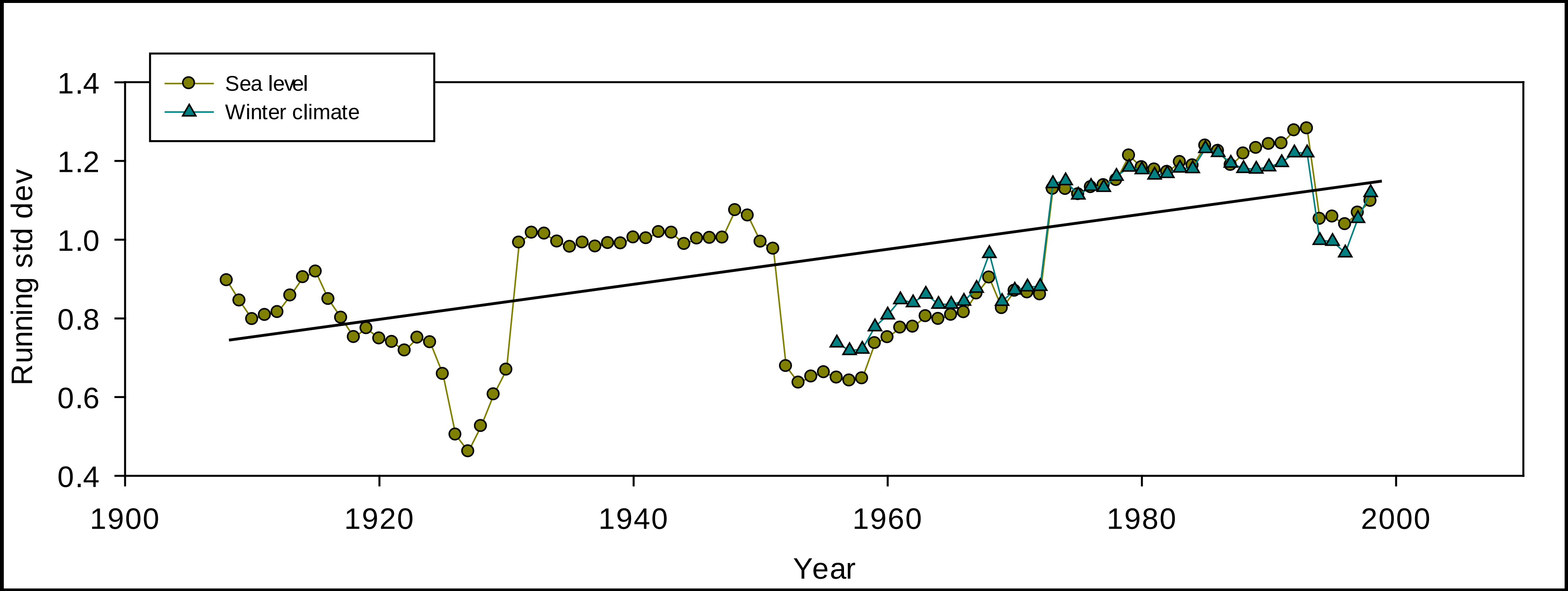

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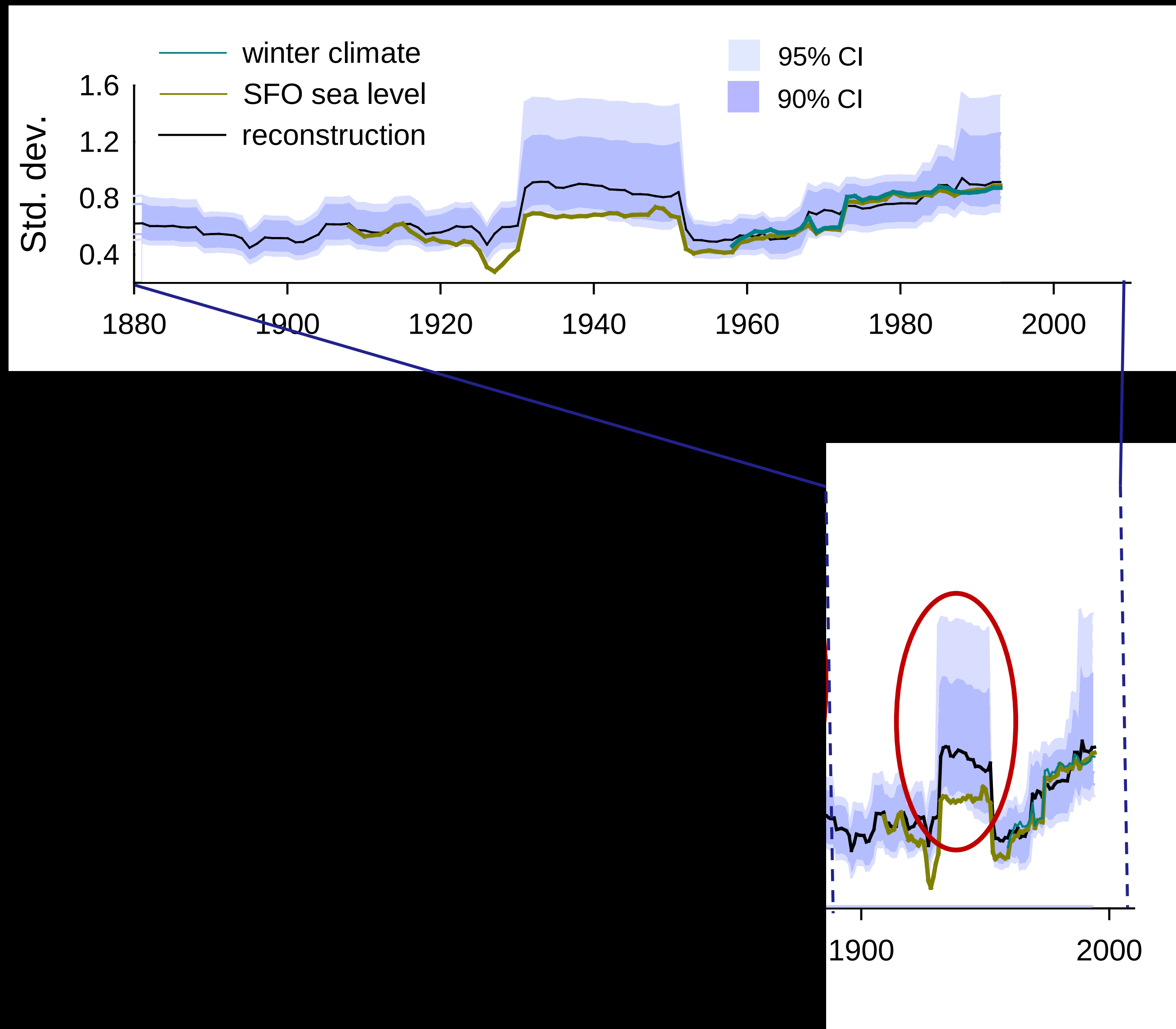
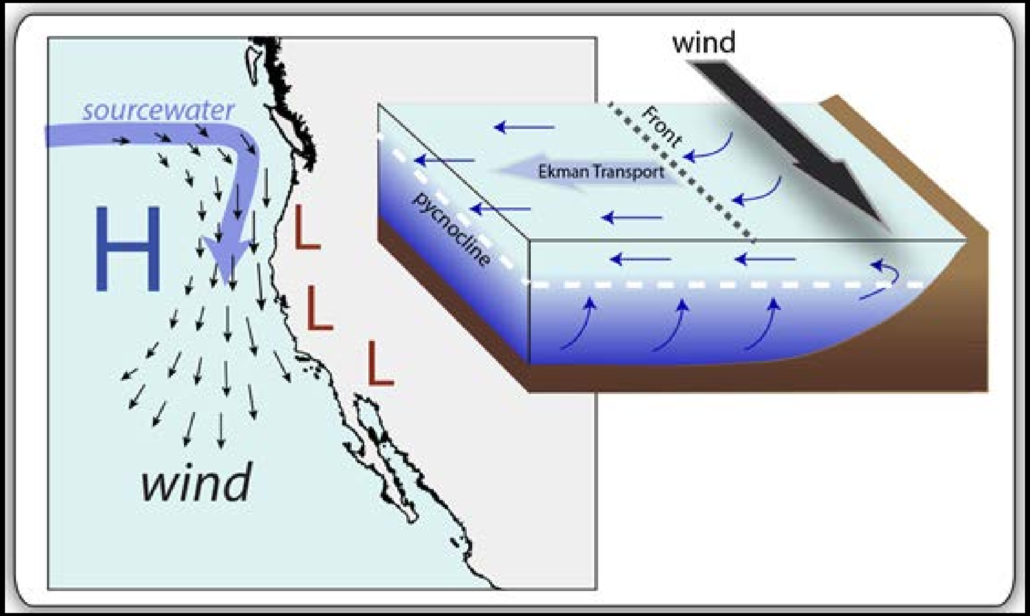
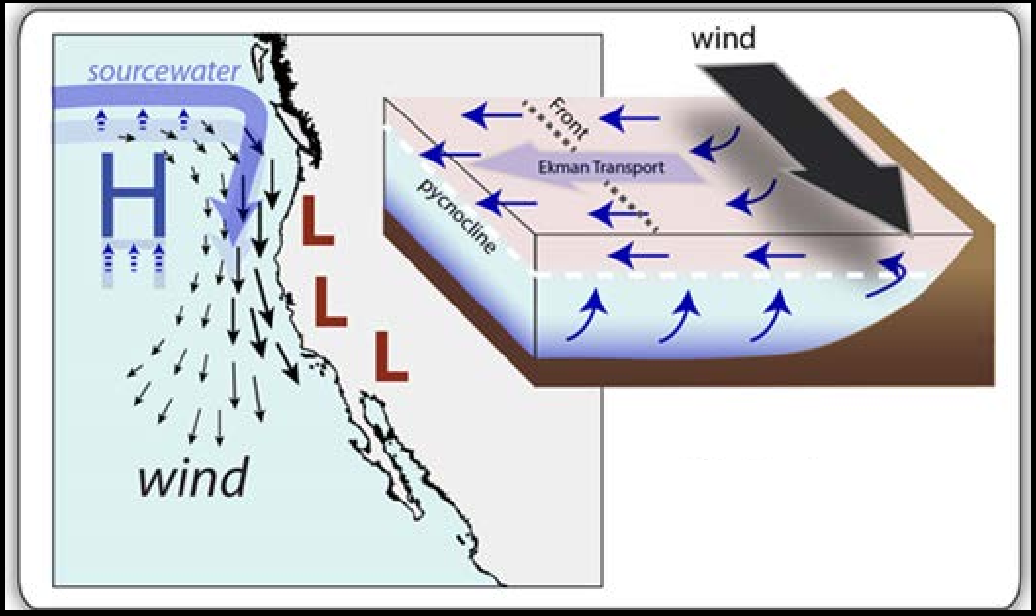


Future changes

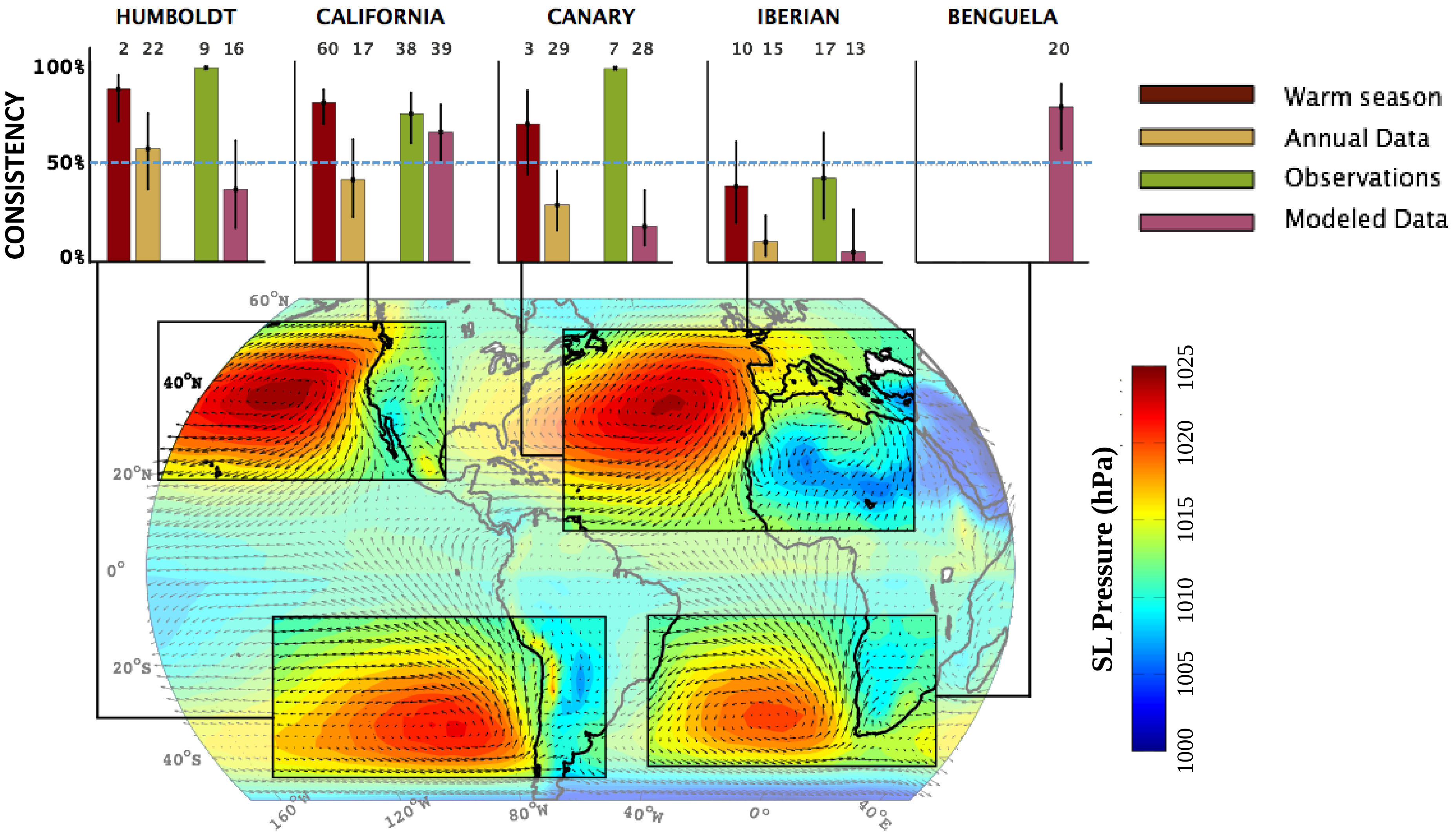
Present



Future



Meta-analysis of literature: winds across EBCS



Meta-analysis: winds