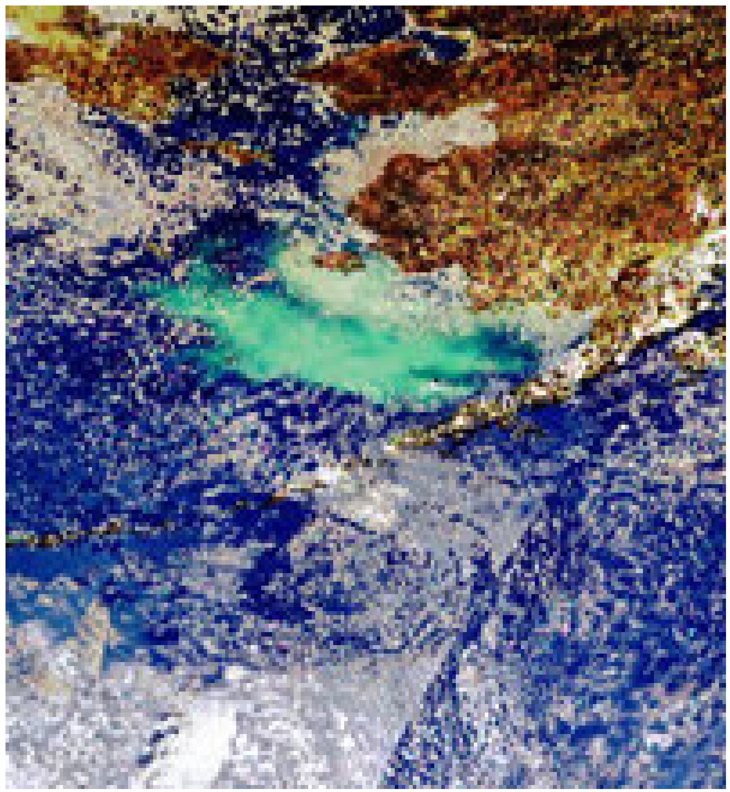
Response of Fish Population Changes to Climate Events*

James Overland, Nick Bond, Andrew Bakun, Juergen Alheit, James Hurrell, David Mackas, and Arthur Miller



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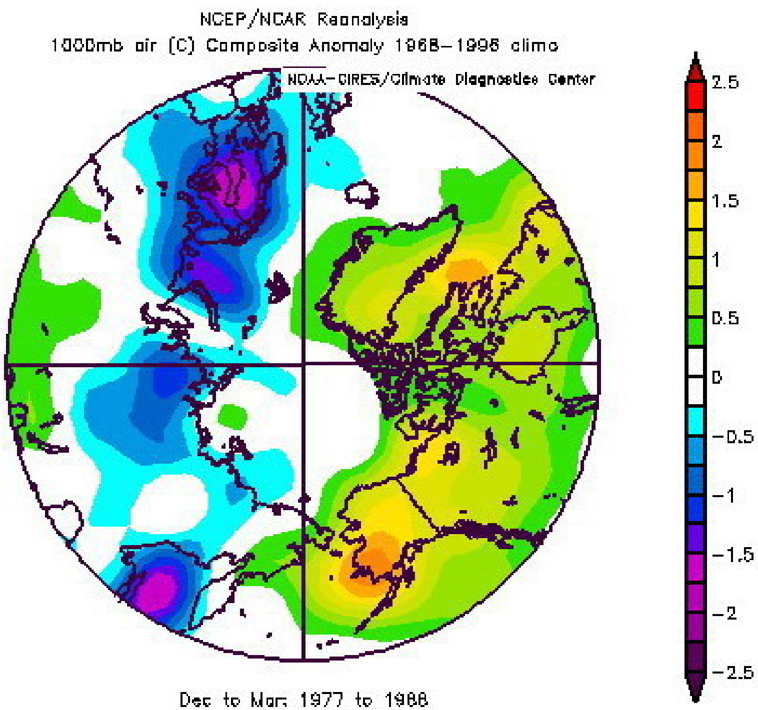
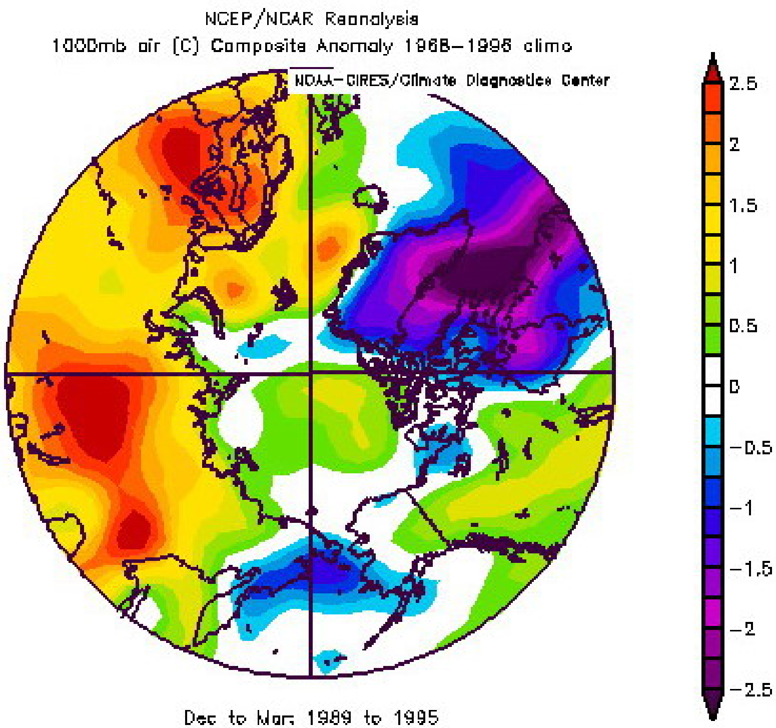
First Concept - Climate

- Decadal climate variability more “event-like” and less regular oscillations
- Large and long deviations from averages
- Stochastic: Little predictability

N. Hemisphere has Two Robust Climate Patterns

Near Surface Air Temperature Anomalies



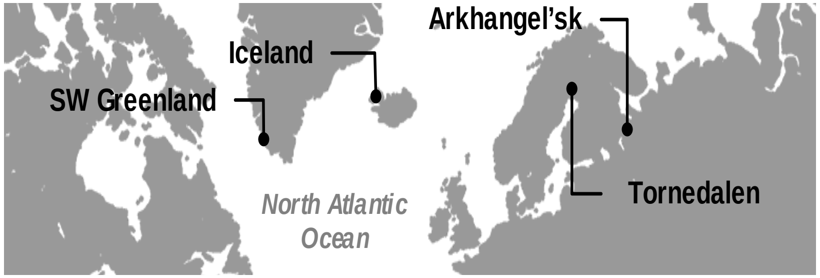


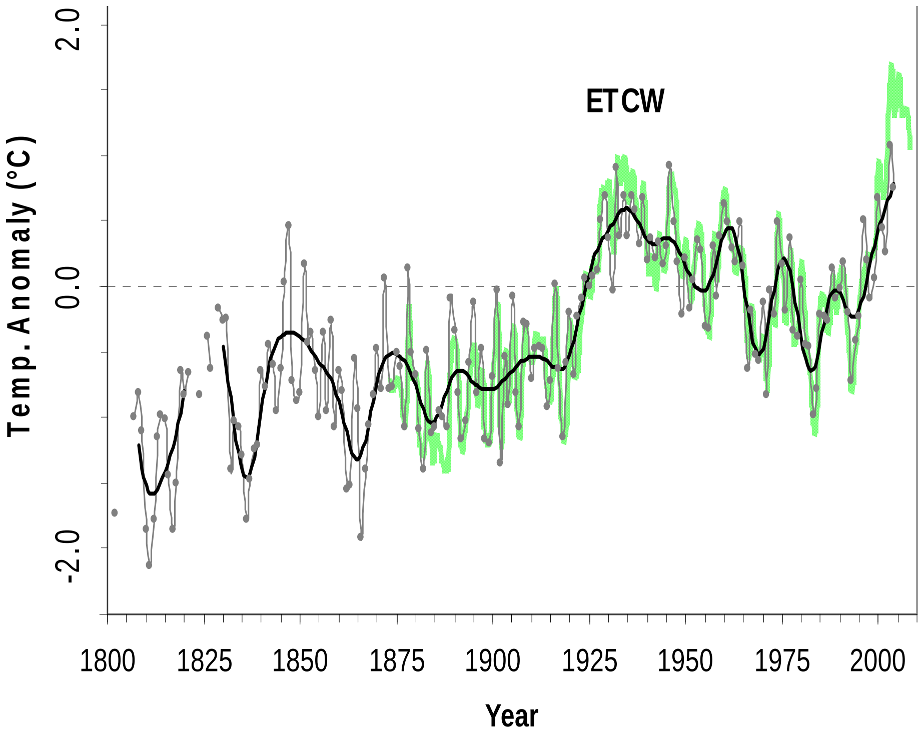
1977-1988 (PNA+)
Pacific North American
Related to PDO and
North Pacific (NP) Pattern

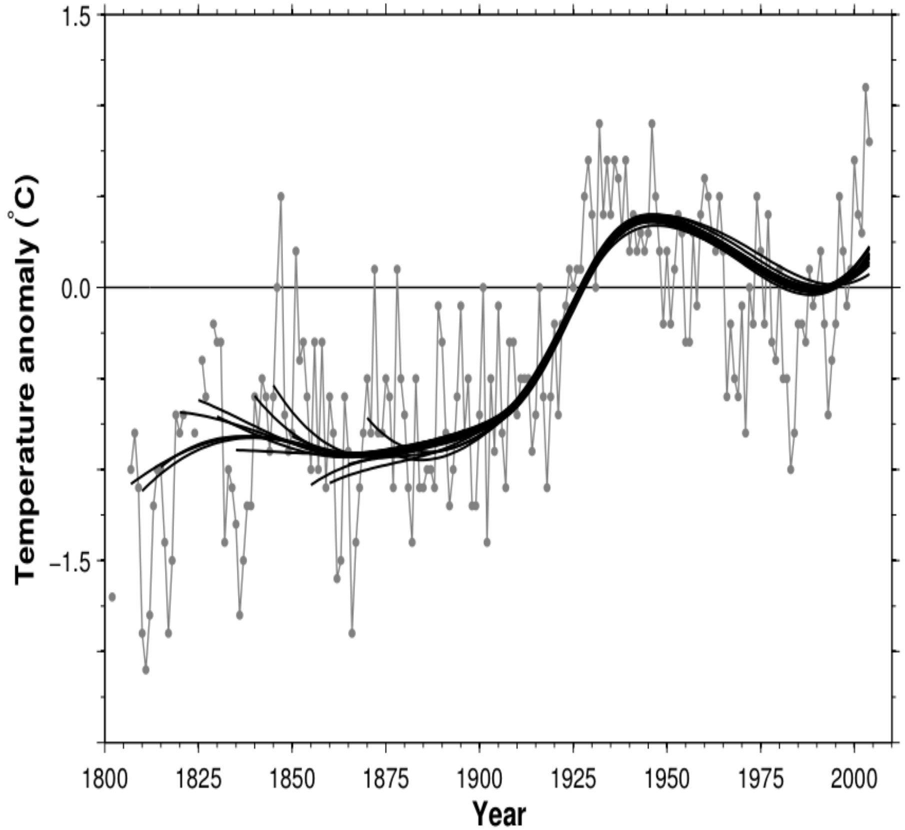
1989-1995 (AO+)
North Atlantic Oscillation(NAO)
/Arctic Oscillation(AO)

Northern North Atlantic

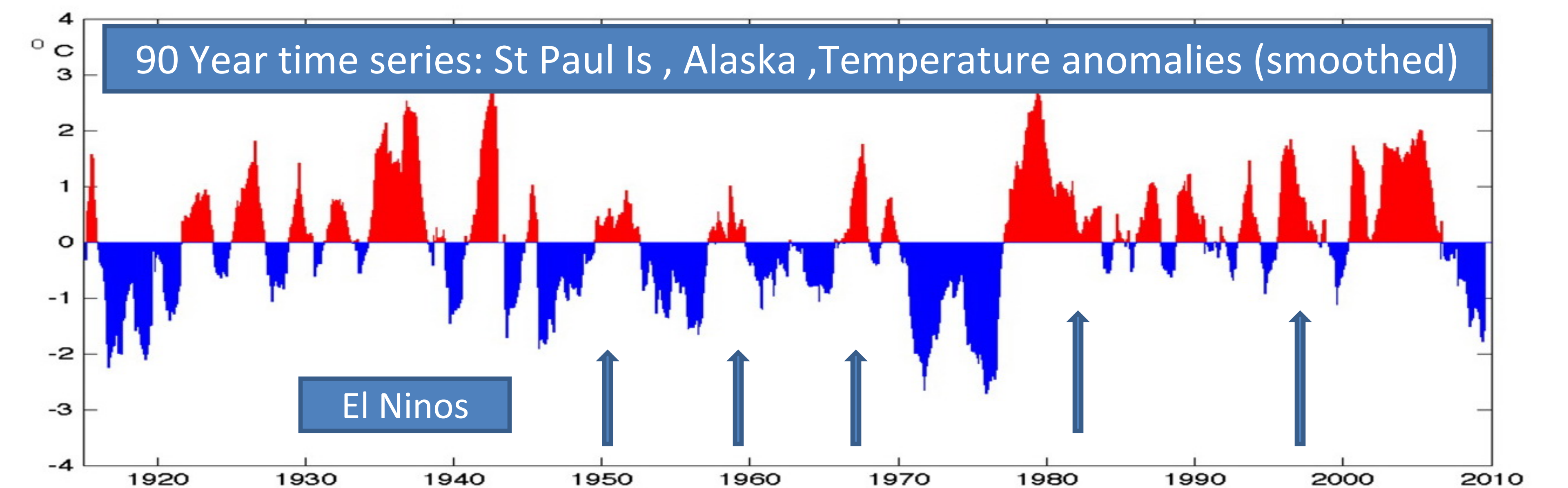
Variability on all time scales



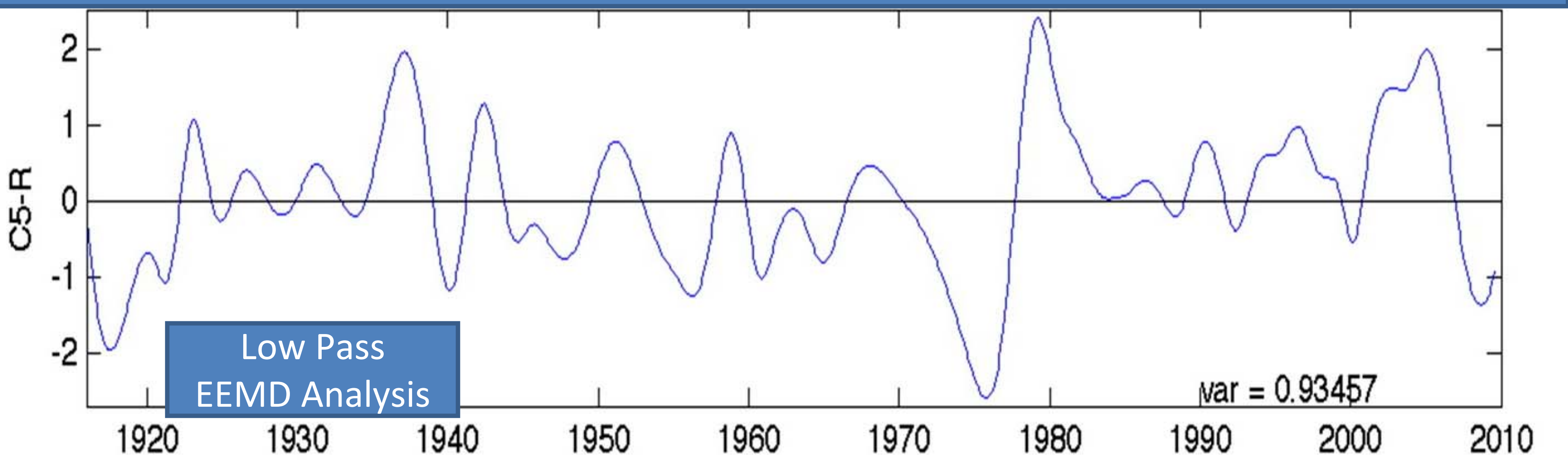




Composite annual mean surface air temperature record derived from four stations beginning in 1800 (*Wood, 2010*).



Three multiple-year cold (1910s, early 1970s, 2007+) and three warm (mid-1930s, 1978-81, 2000s) periods
(many short events are related to ENSO)



Notable Examples:

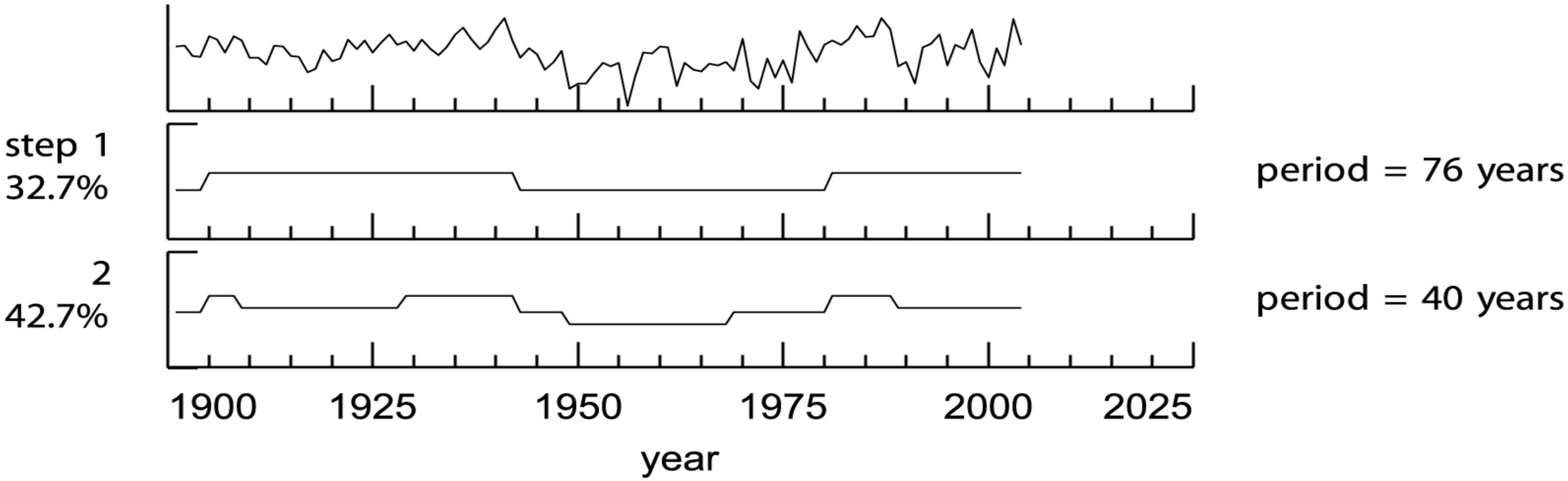
- Early 20th century warmth in North Atlantic
- Mid-1970s regime shift in North Pacific
- Recent switch from very warm to cold in the Bering Sea

Appear to be large, random events

(not regular oscillations)

due to natural variability

A square oscillator can be fit to the Pacific Decadal Oscillation (PDO) timeseries to give "multiple stable states"



BUT: Other simple times series models without multiple stable states (e.g., red noise) fit the PDO data equally well

CONCLUSION: *Cannot determine underlying process model from data alone for records shorter than 200 years.*
Past history provides little information for anticipating future shifts and episodic events

Overland et al. (2006)

Second Concept: Ecosystems/Fish Populations

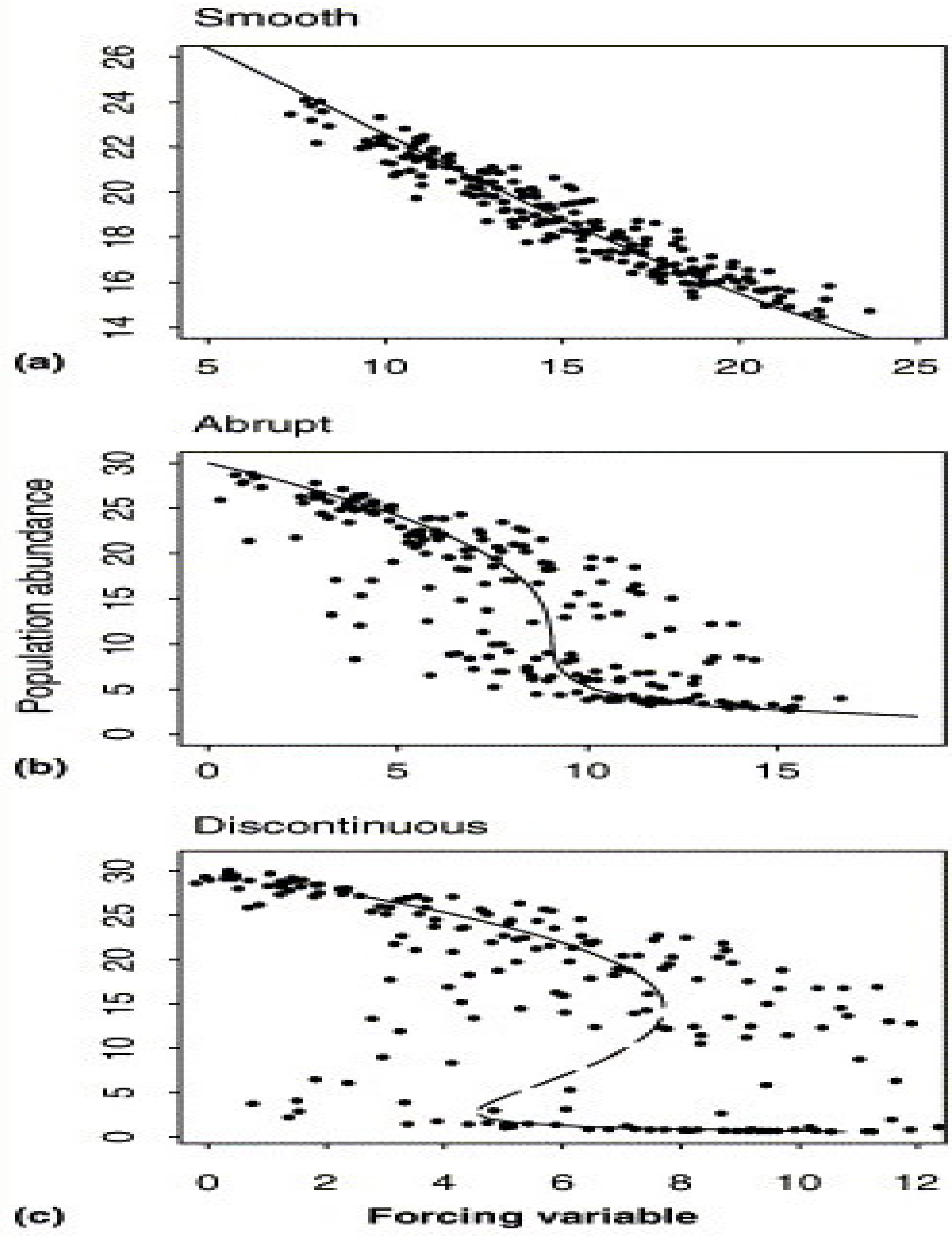
The responses to climate shifts by biological systems are diverse because intervening processes introduce amplifications, time lags, hysteresis, and non-linearities, *leading a variety of climate to ecosystem transfer functions:*

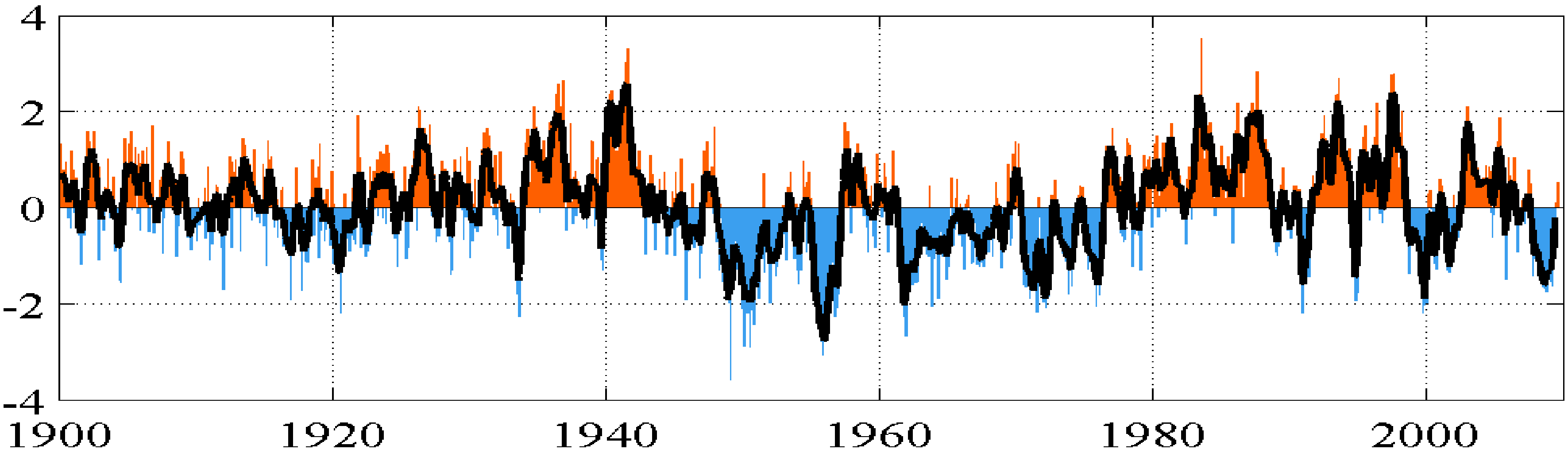
1) red noise of the physical system to redder (lower frequency) noise of the biological response,
2) climatic red noise to discontinuous biological shifts,
3) transient climatic disturbance to a prolonged ecosystem trend,
4) transient disturbance to sustained ecosystem regimes.

All of these ecosystem response characteristics are likely to be active.

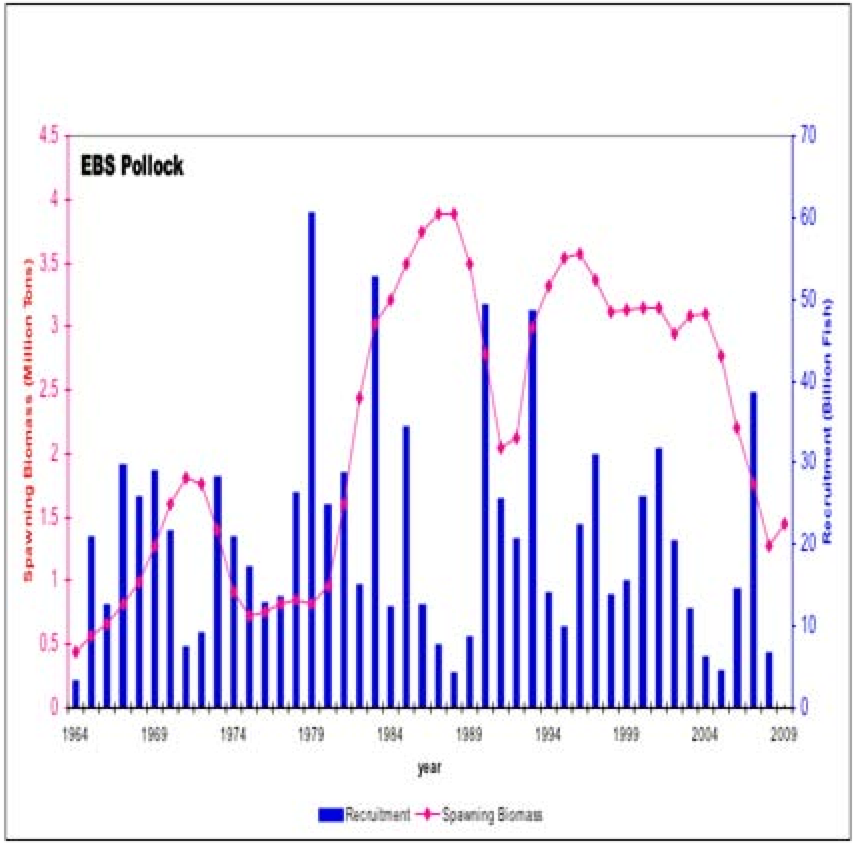
For simple predator prey models, different ranges of parameters give qualitatively different population/climate responses.

(Collie et al. 2004)

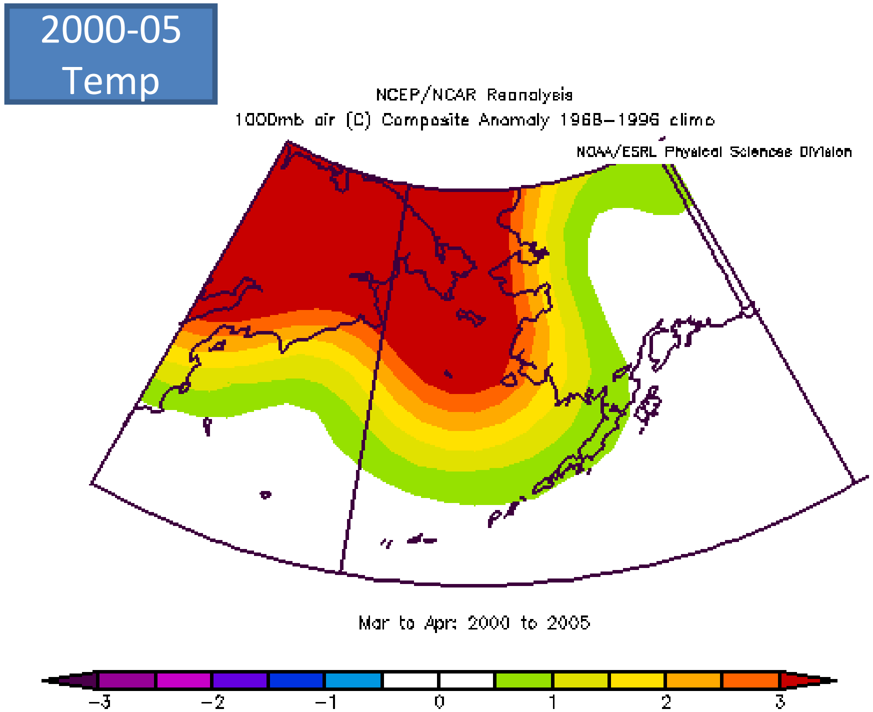


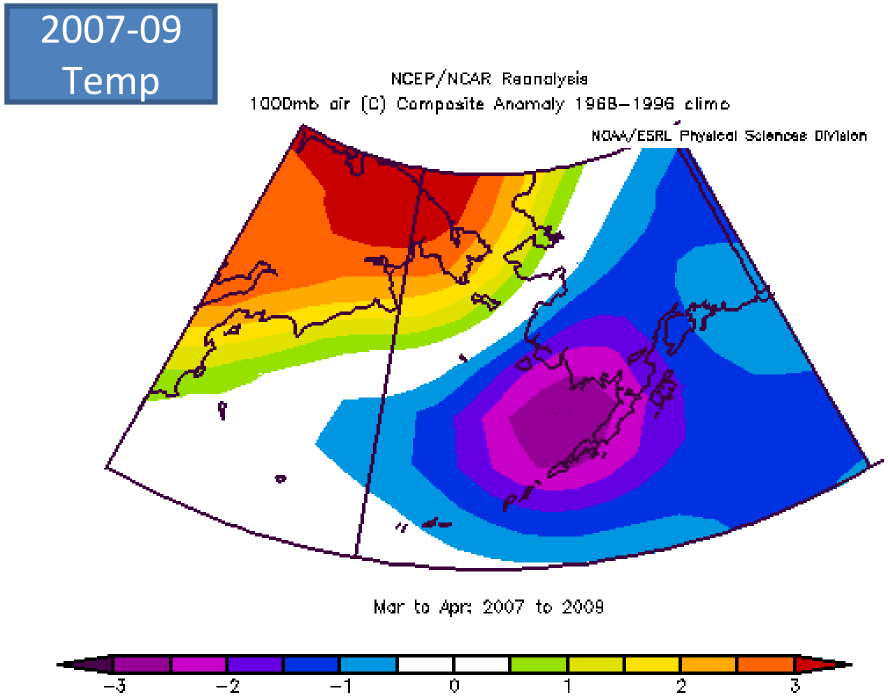


Bering Sea:
It took a decade for pollock to dominate the ecosystem after the climate regime shift and strong recruitment in the mid-1970s



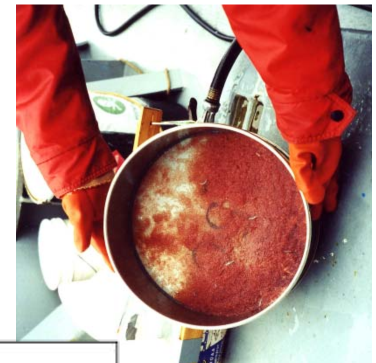
Recent conditions in southern Bering Sea: Six years of warmth followed by cold





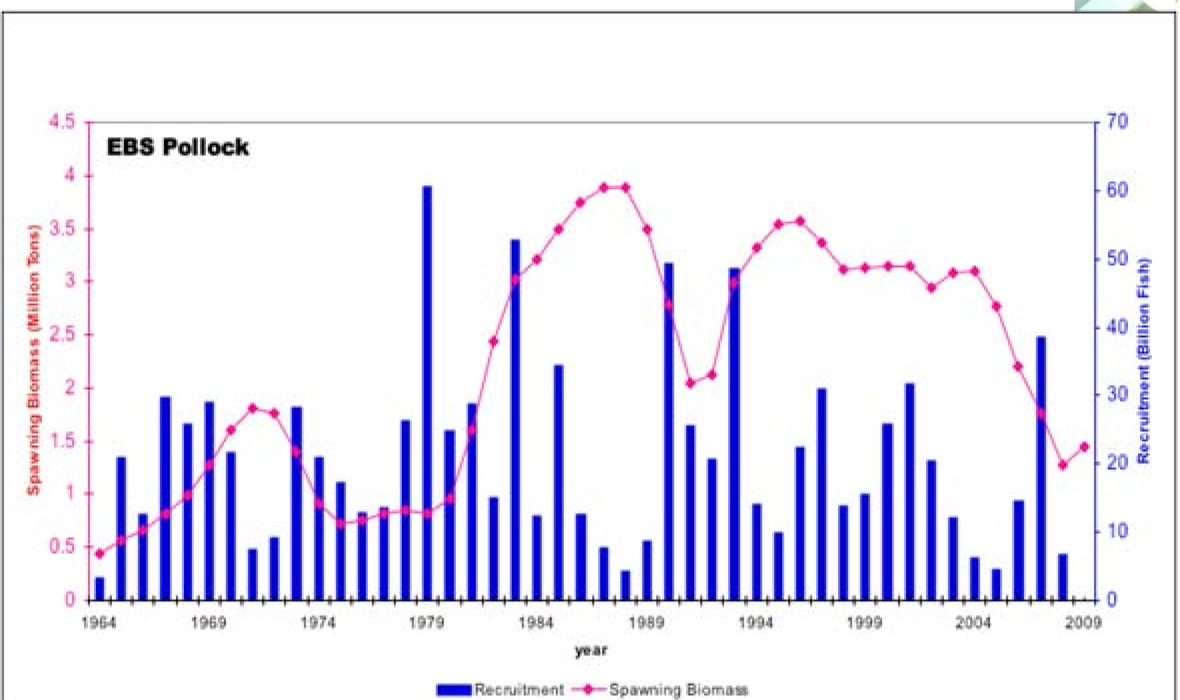
Southern Bering Sea Ecosystem Changes: Unforeseen Consequences

Warm temperatures previously favored pollock over Arctic species.
But low prey availability during the recent period of extreme warmth, and more predators, followed by cold temperatures, has resulted in a biomass loss of 30%

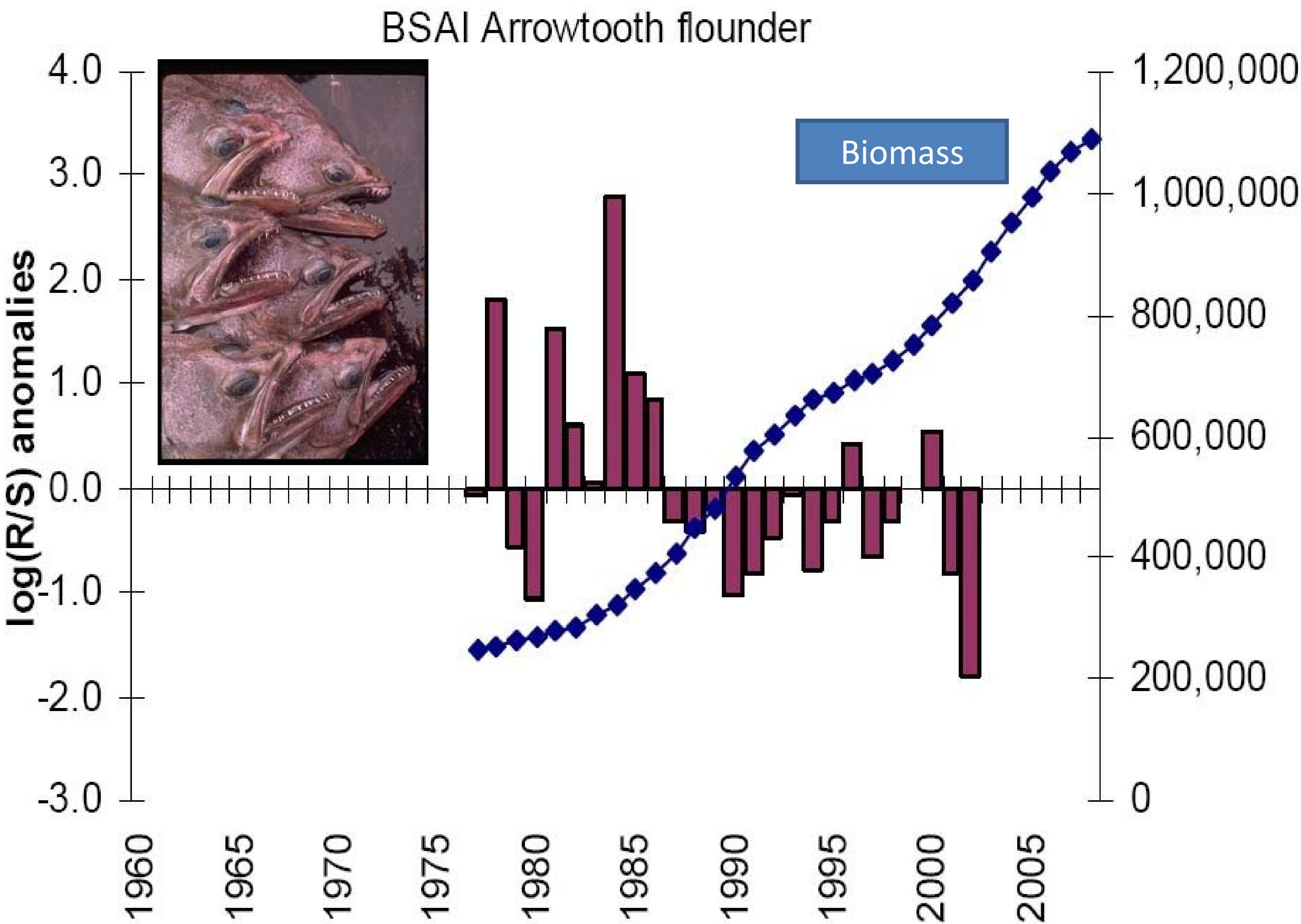


2000

2001



Increase in Pollock Predator over 20 Years



Conclusions

- Climate: Decadal variability more “event-like” than regular oscillations. Large and long deviations from averages. Limited to stochastic projections.

- Ecosystems/Fish Populations: *a variety of climate to ecosystem transfer functions* resulting in a mix of slow fluctuations, lags, prolonged trends, and step-like changes in response to climate variability. Simple, consistent relationships apt to be rare.

- But there are obviously substantial responses in ecosystems to interannual to decadal variations in climate. Important to recognize that these responses vary with time scale and confounding factors.