On the (A)Synchrony of Long-Term Sea Surface Temperature Trends in the Western and Eastern North Pacific

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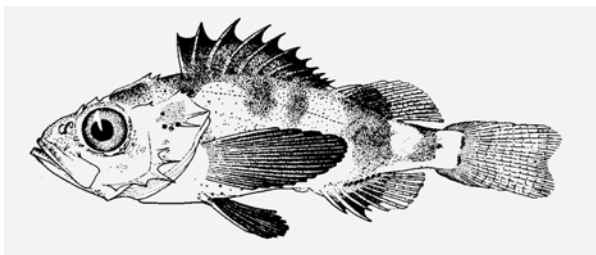

Outline and Objectives

- Compare climate patterns using a variety of statistical methods.
- Apply state-space models to North Pacific SST.

DATA

- UK Meteorological Office, Hadley Centre, SST Dataset (HadISST1.1), and Reynolds OISST.v2
- Monthly, 1-degree resolution, global, 20th century
- California Current, Gulf of Alaska, Oyashio, Kuroshio regions

Compelling Questions

- How do we define & quantify climate variability?
- Are regime shifts real? If so …
  - What is the timing and morphology of climate regimes?
  - What is their 3-D spatial structure?
  - What are their causes & forcing mechanisms?
  - What are the biological responses & pathways?
  - How are regime impacts modulated by local processes?
  - Do North Pacific ecosystems vary in or out of phase?

Methodological Approach

- Apply variety of tools for identifying climate variability.
  - Observations, anecdotal reports
  - Anomaly time series & fields
  - EOF analyses
  - Decomposition of PDO & other indices
  - State-space models of physical & biological series
  - Common trend analyses amongst regions
- Describe temporal co-variability amongst North Pacific Large Marine Ecosystems on climate scales.
- Propose mechanisms for co-variability.
- Develop easy-to-use indices of climate-fisheries linkages.

State-Space Time Series Models

(1) State-space decomposition of time series

Data(t) = Trend(t) + Seasonal(t) + Irregular(t) + Error(t)

Trend - non-linear and non-parametric
Seasonal - non-stationary, changes in phase and amplitude
Irregular - can include AR or non-stationary cyclic term
Error - allow for observational error

Schwing & Mendelssohn (1997), Mendelssohn & Schwing (2002), Bograd et al. (2002), Mendelssohn et al. (2003,2004,2005), Palacios et al. (2004), Schwing et al. (2006)

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(2) Dynamic factor analysis of partial residuals
(trends, seasonals, …)

Compare first two common SST trends in all regions

Schwing & Mendelssohn (1997), Mendelssohn & Schwing (2002), Bograd et al. (2002), Mendelssohn et al. (2003,2004,2005), Palacios et al. (2004), Schwing et al. (2006)

Why State-Space Models?

- Distinguish low-frequency trends, AR, cyclic processes
- Quantify non-stationary seasonality ➡ phenology!
- Avoid rigid assumptions (constant mean, variance)
- Time dependence in model (Kalman filter)
- Rigorous model testing to determine best model
- Long history of time series applications, though new to oceanography
- Matlab system identification toolbox, numerous texts

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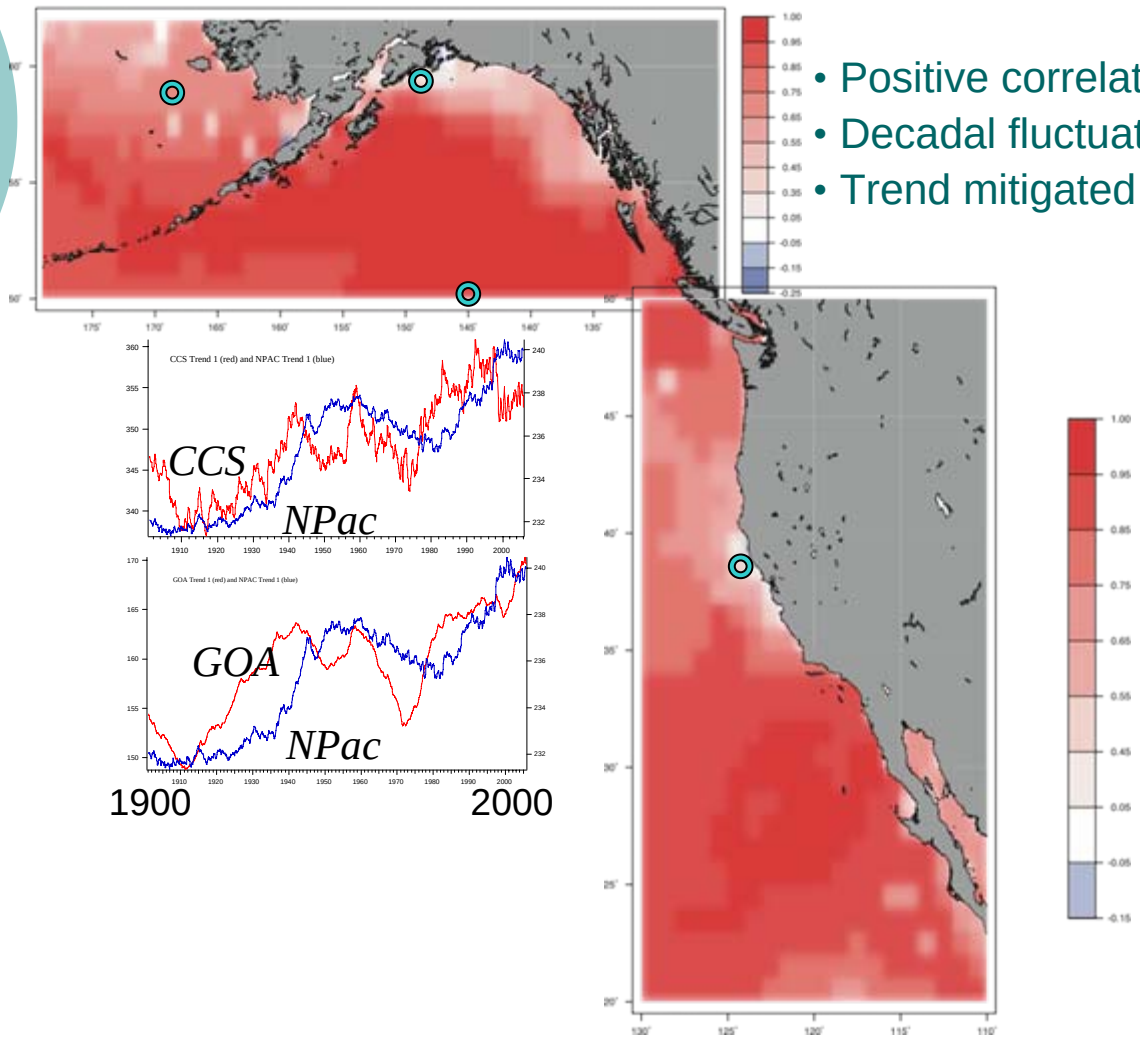
… EOFs also good

Common SST Trends in the Northeast Pacific

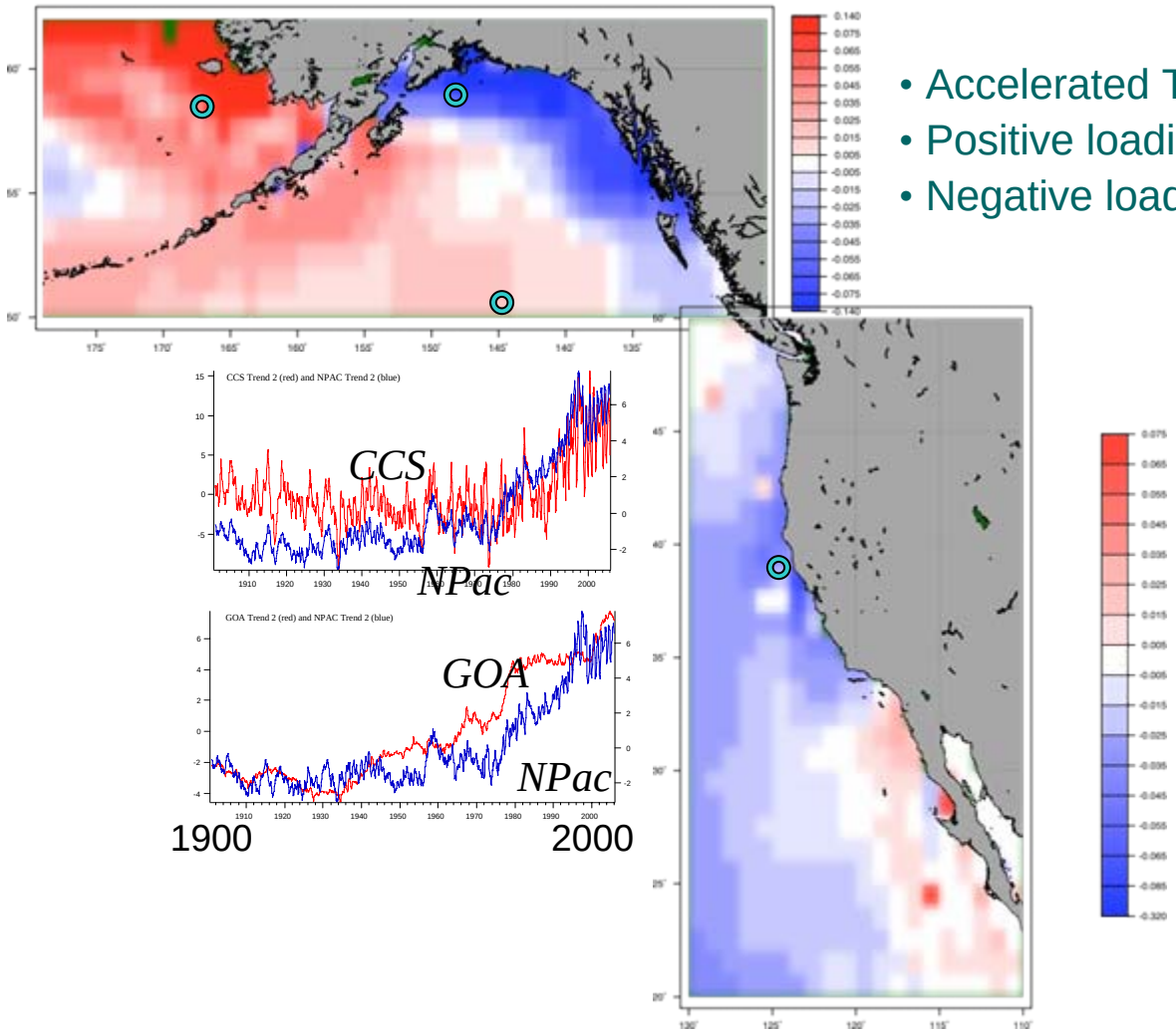


- Positive correlations throughout domain
- Decadal fluctuations on overall warming trend
- Trend mitigated in coastal CCS, northern GOA

Mode 1:

"global SST mode"

Common SST Trends in the Northeast Pacific

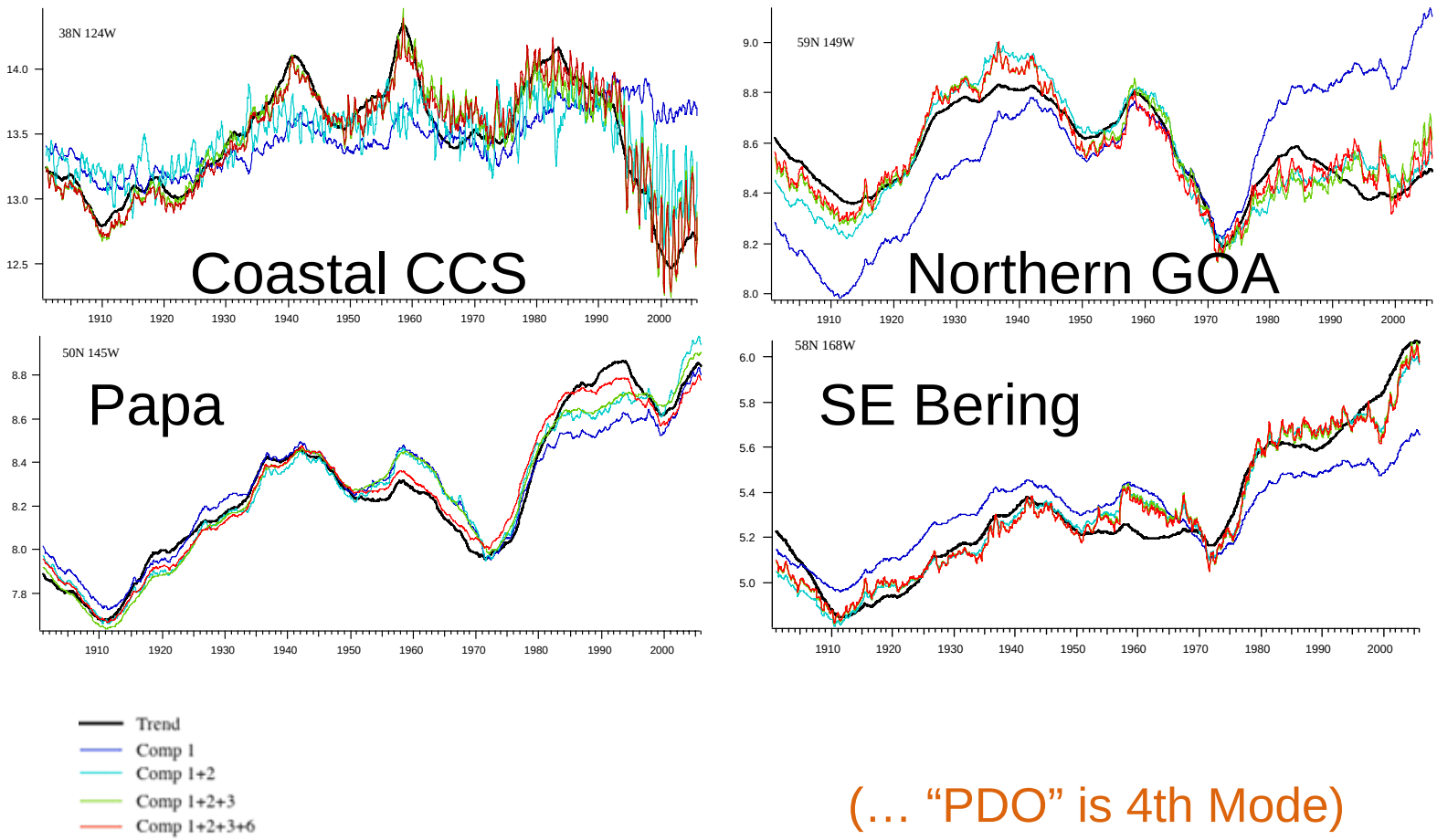


- Accelerated T change since 1970s
- Positive loadings = enhanced warming
- Negative loadings = mitigated warming

Mode 2:

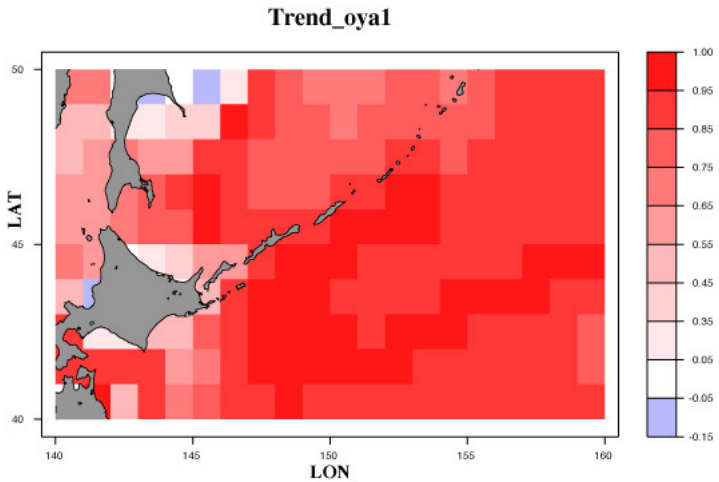
"global warming mode"

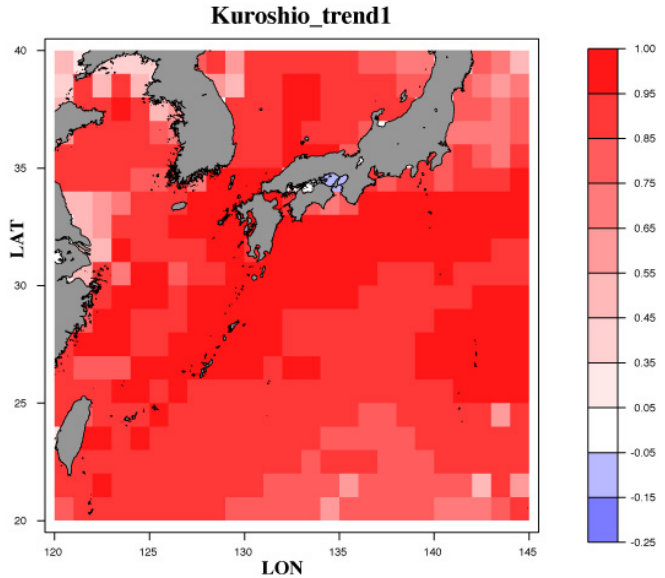
Common SST Trends in the Northeast Pacific



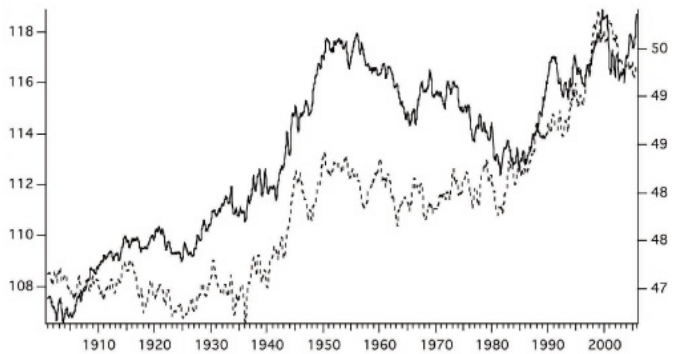
(… “PDO” is 4th Mode)

Common SST Trends in the Northwest Pacific



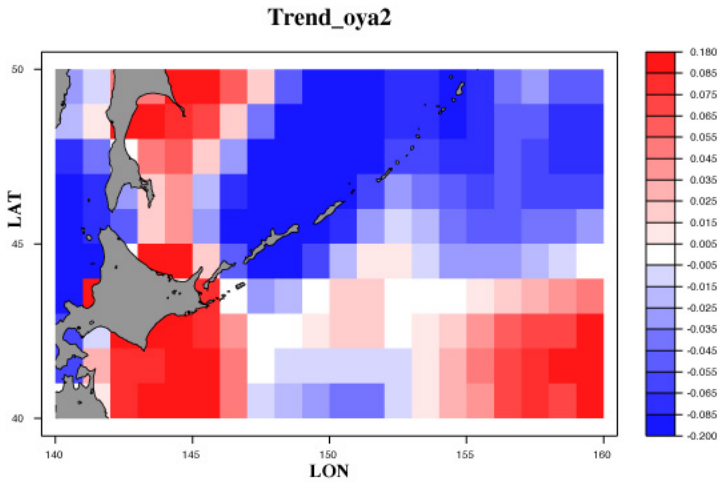


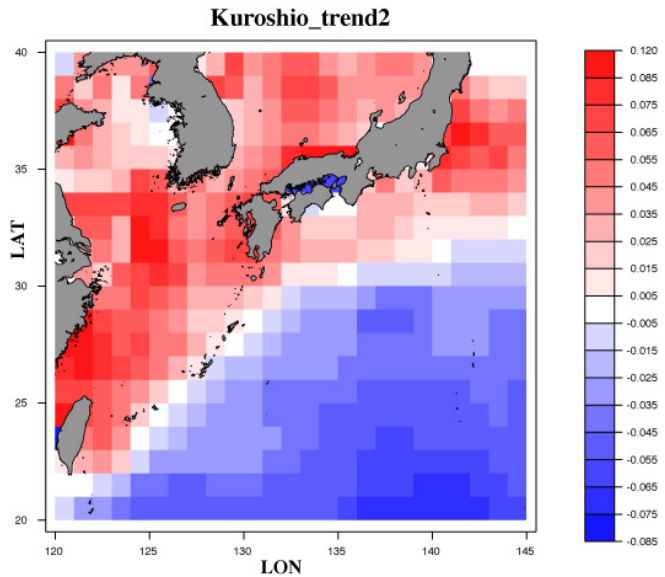
Oya SST Trend1 (solid) and Kuro Trend 1



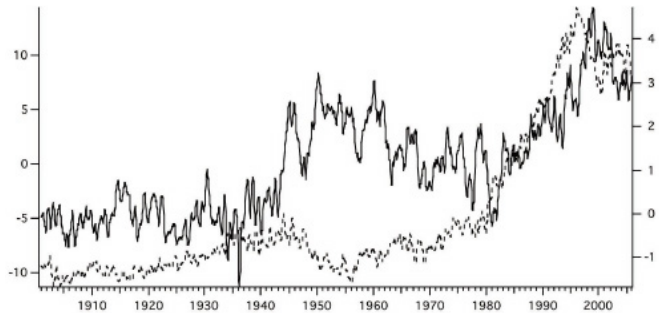
- Overall warming trend, accelerated since 1980s
- Positive correlations throughout domain

Common SST Trends in the Northwest Pacific



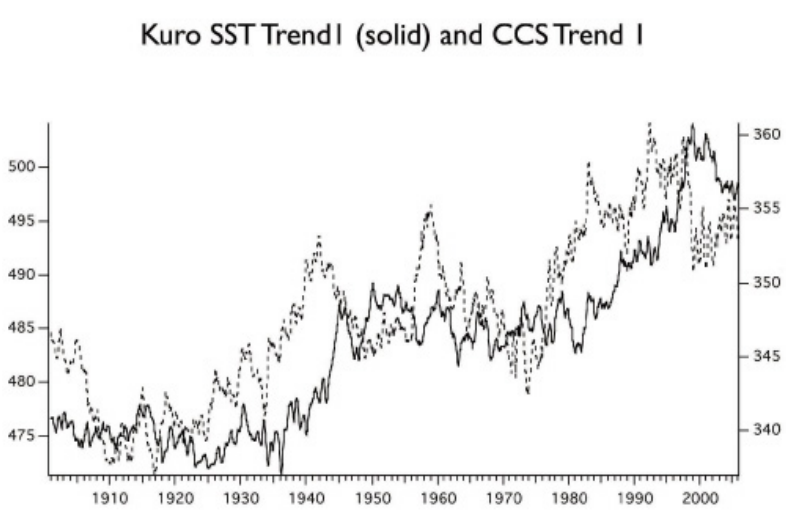


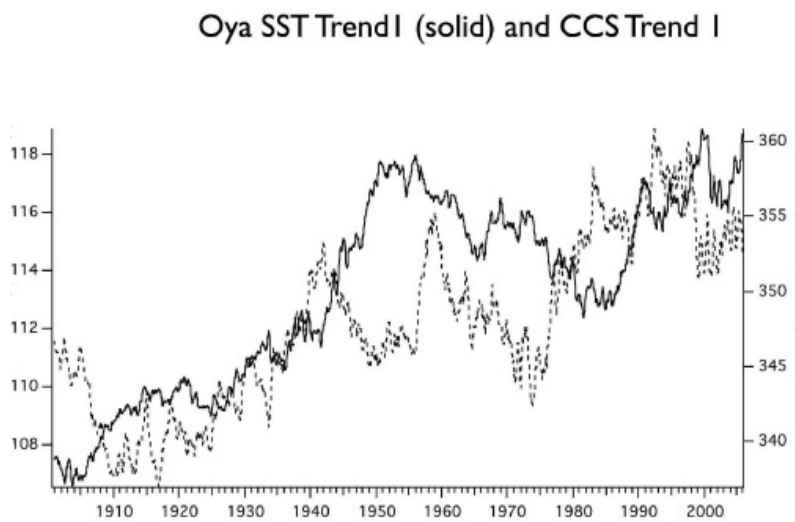
Kuro SST Trend2 (solid) and neg. Oya Trend 2



- Enhanced warming offshore northern Japan, and East Asian Seas

Common SST Trends in the Northwest Pacific





- Similar warming trend in Eastern & Western North Pacific, with lags

Summary

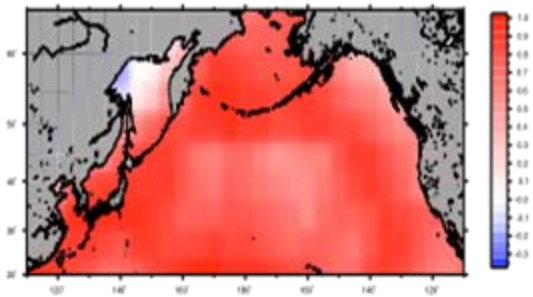
- Different methodological techniques provide unique insight.
- Standard indices of “regime shifts” may be capturing red noise, rather than dominant dynamic processes.
- Biology can respond to red noise … (Hsieh et al., 2005)
- Robust warming trend throughout North Pacific, with decadal modulation.
- Large-scale climate signals are asynchronously modulated by local processes.
- Need climate models that can resolve regional processes (upwelling strength & timing, FW input, …).

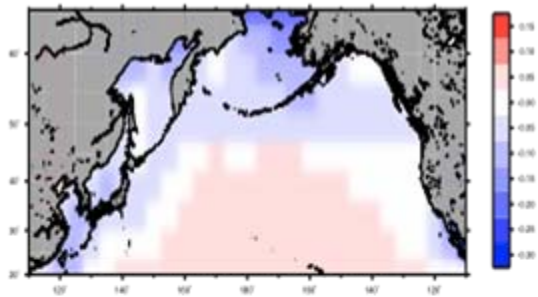
Unanswered Questions

- Are regime shifts real and quantifiable?
- Are they a biological or physical phenomenon (or both)?
- How do we capture their ecological impacts with indices?
- How do local processes modulate large-scale climate forcing?
- What is the sensitivity of marine ecosystems to future climate change scenarios?

Thanks to U.S. GLOBEC, NOAA FATE program!

The PDO Revisited ...





Mendelssohn & Bessey, in prep.

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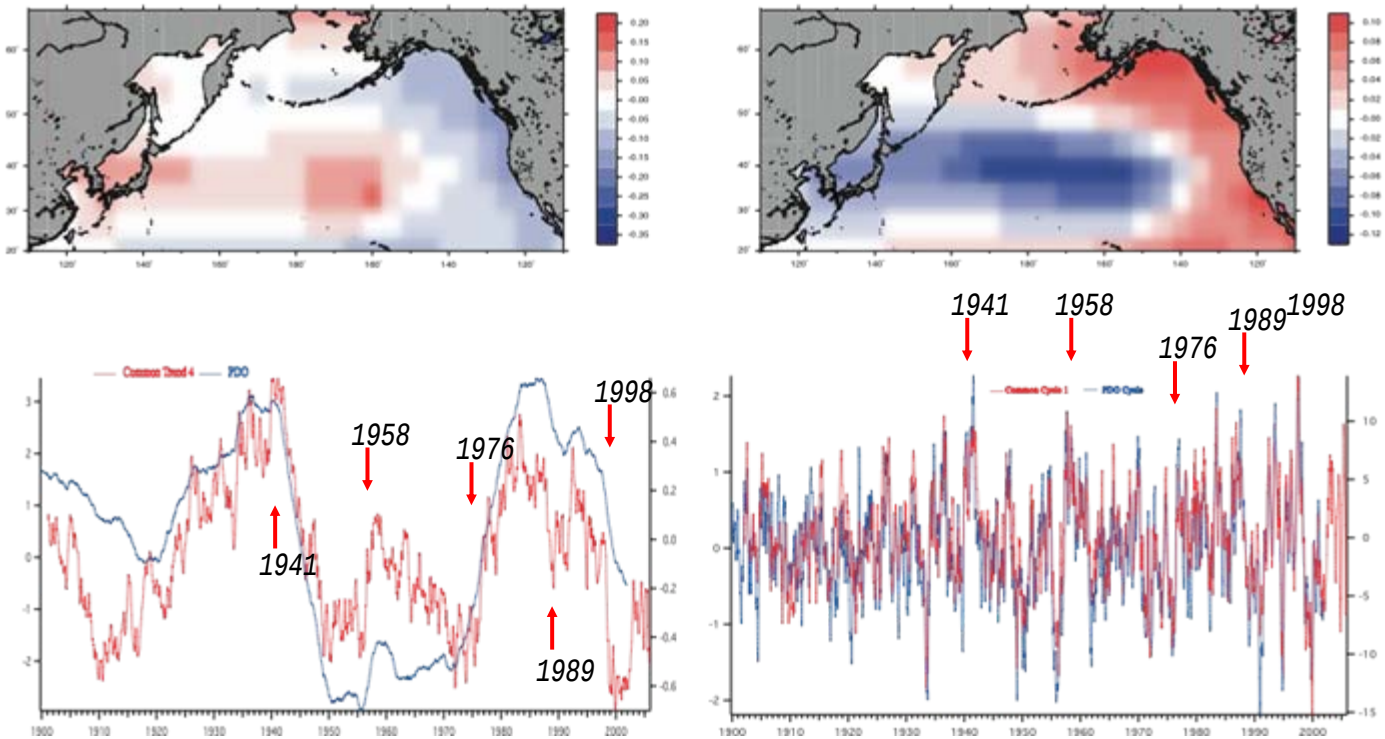

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