Marine regime shift detection and attribution

Claudie Beaulieu

Ocean and Earth Science, University of Southampton

National Oceanography Centre, Southampton

UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL

Collaborators and funding

- Harriet Cole, FRS Marine Laboratory, Marine Scotland Science
- Stephanie Henson, Andrew Yool and Tom Anderson, National Oceanography Centre, Southampton
- Lee de Mora, Momme Butenschon and Icarus Allen, Plymouth Marine Laboratory
- Claire Enright, Erik Buitenhuis and Corinne Le Quéré, University of East Anglia
- Rosa Barciela and Ian Totterdell, Met Office

Outline

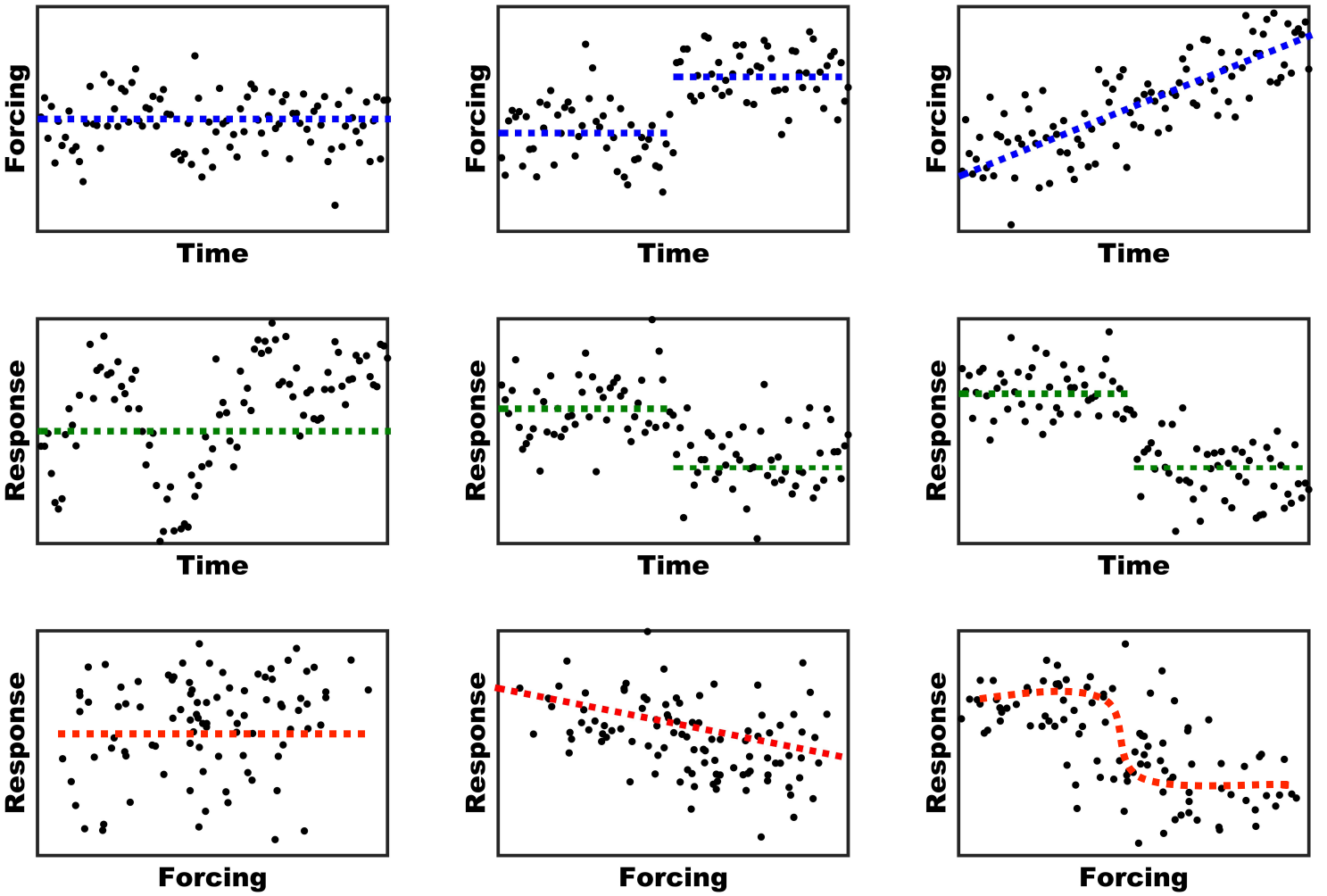
- Classification of abrupt changes in the climate system and ecosystems (forcing-response)
- Statistical perspective: how to identify and characterize abrupt changes
- Case of study: Gulf of Alaska 1977 regime shift simulated by ocean biogeochemical models

Abrupt changes classification

White noise forcing – red noise response

Shift forcing – shift response

Threshold effect

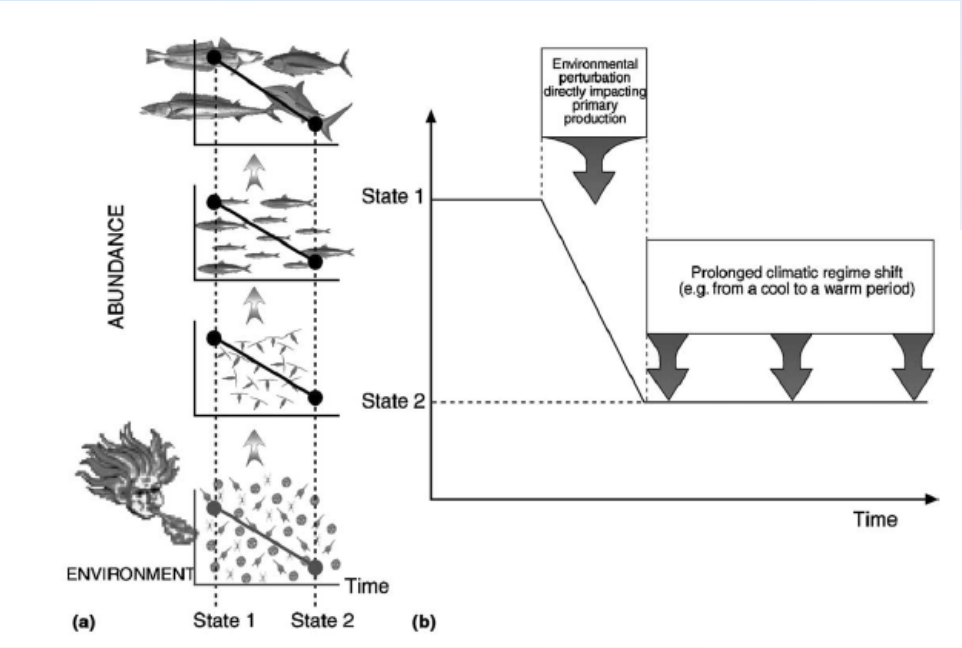


Adapted from Andersen et al., 2009

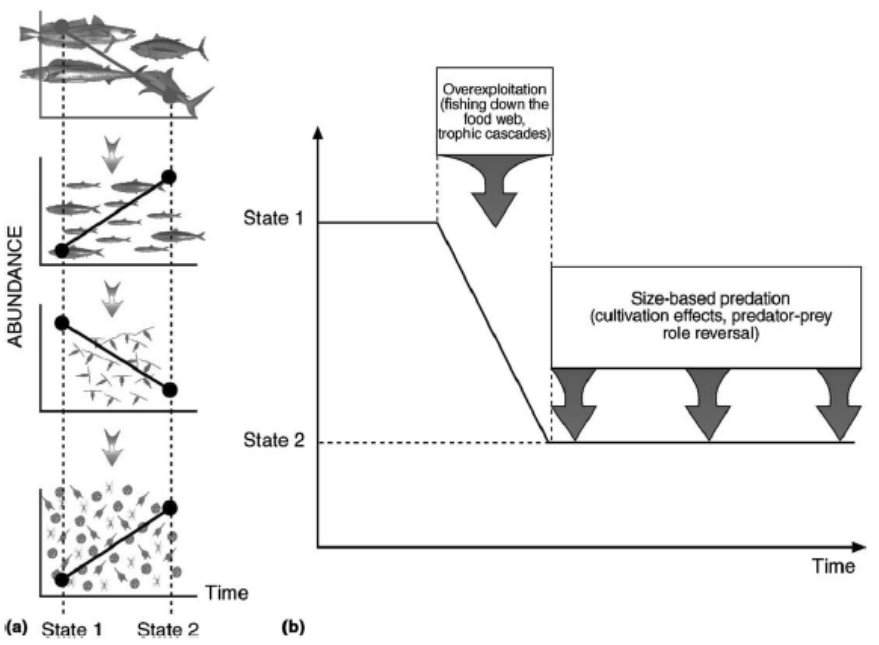
Change in response > change in forcing (IPCC, 2007)

Marine regime shift forcings

Bottom-up

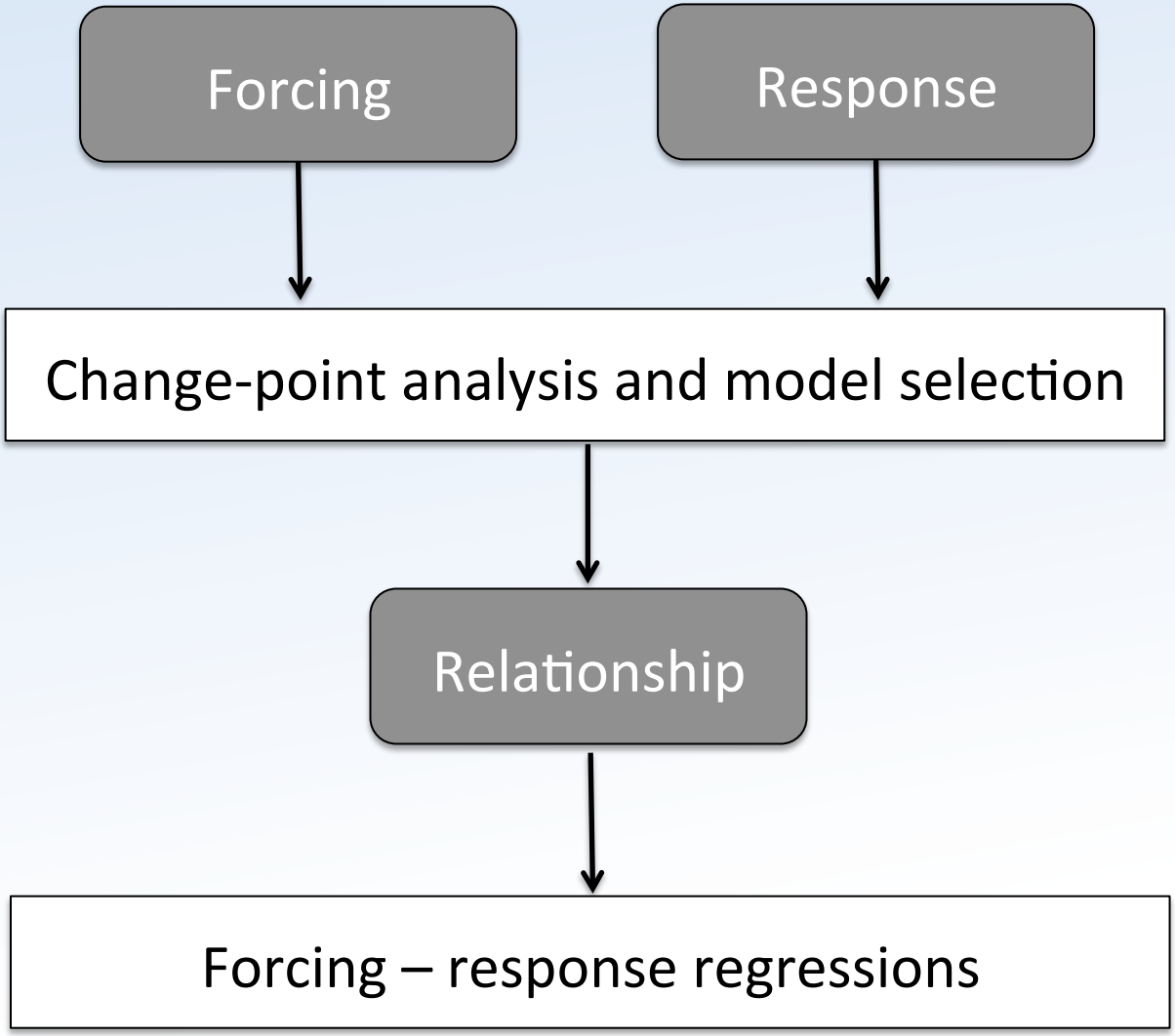


Top-down



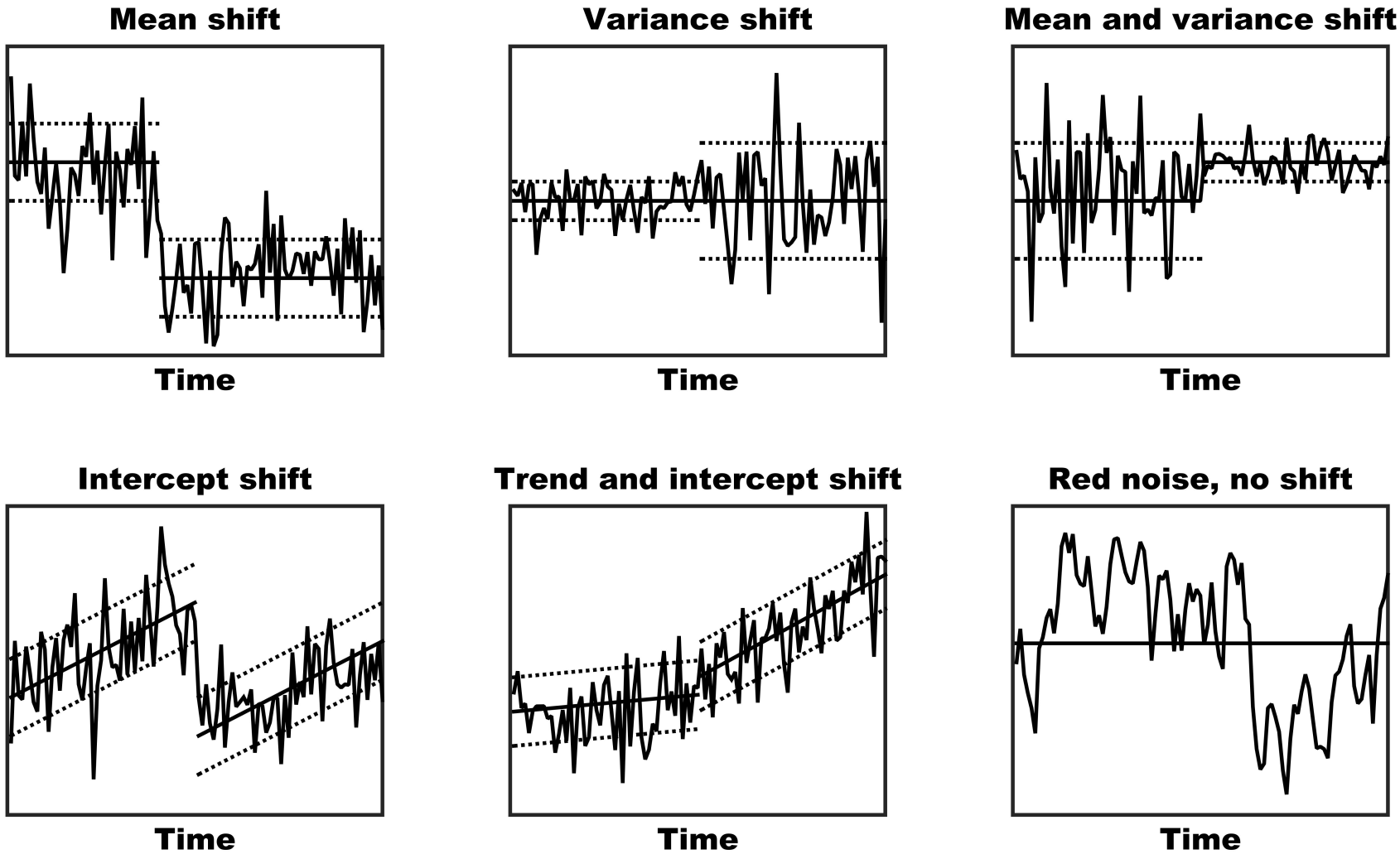
Cury and Shannon., 2004

Framework used



Adapted from Bestelmeyer et al., 2011

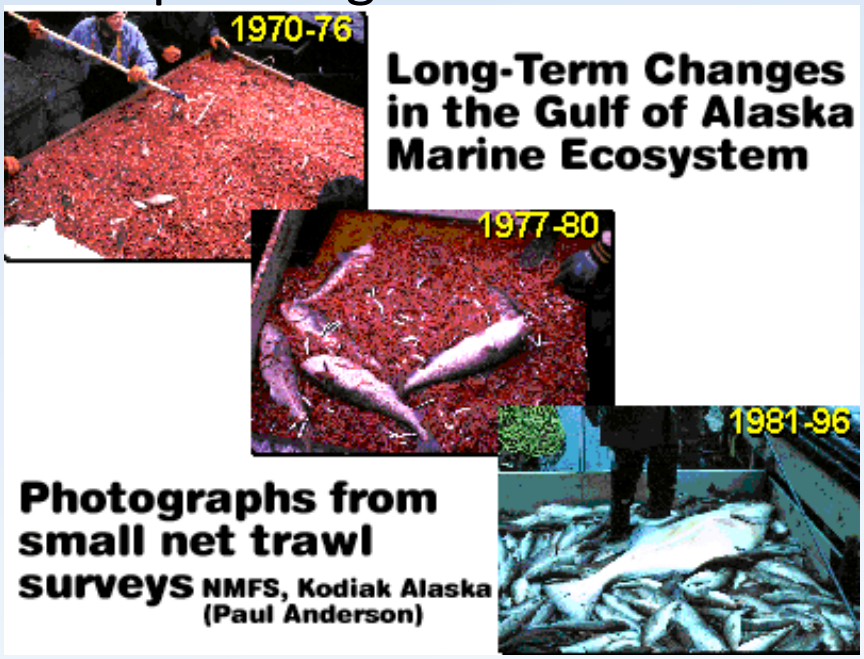
How to distinguish different types of change



Beaulieu et al., 2012

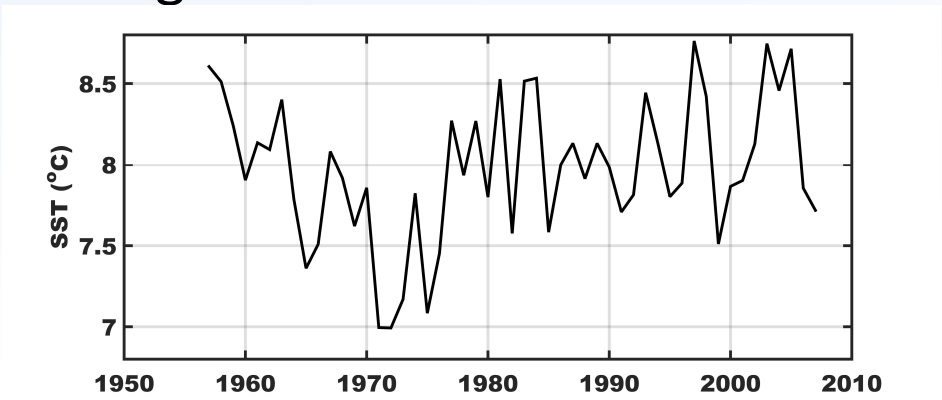
Late 1970s shift in the Gulf of Alaska

Abrupt changes in fish catch



http://www.thenakedscientists.com/HTML/articles/article/brucewrightcolumn1.htm/

Regional increase in SST of 1°C



- Data gaps in space and time challenge determining the chain of events
- Two hypothesis:
  - Limiting nutrient
  - Limiting light

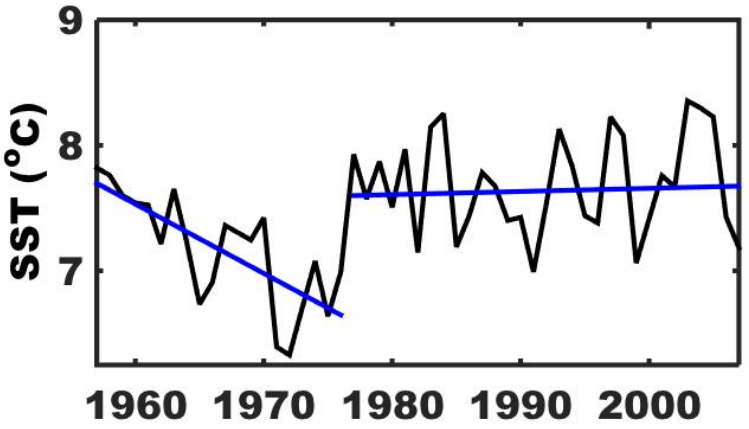
Do ocean biogeochemical models simulate the Gulf of Alaska shift?

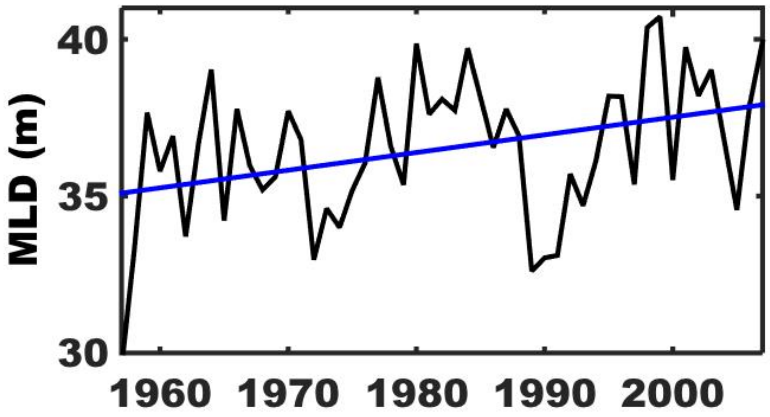
- If OBGC models were able to accurately simulate regime shifts
  - Lead to a better understanding of the mechanisms
  - Potential for predictability
- Hindcast simulations from 5 ocean biogeochemical models part of the i-MarNet project (http://imarnet.org/)
  - HadOCC, Diat-HadOCC, MEDUSA, ERSEM, PlankTOM10
- 58 years runs (1950 to 2007) using the CORE2 interannual forcing fields
  - downwelling irradiance (short- and long-wave)
  - precipitation (rain and snow)
  - air temperature
  - humidity
  - meridional and zonal winds
- Within an identical physical framework (NEMO ocean circulation model coupled with CICE sea-ice model)

Do ocean biogeochemical models simulate the Gulf of Alaska shift?

- We extracted from 1957-2007:
  - sea surface temperature (SST)
  - mixed layer depth (MLD)
  - surface dissolved inorganic nitrogen (DIN)
  - silica (SI)
  - iron (FE)
  - surface chlorophyll (CHL)
  - integrated primary production (PP)
  - total surface phytoplankton (PHY)
  - zooplankton biomass (ZOO)

Results on simulated physics

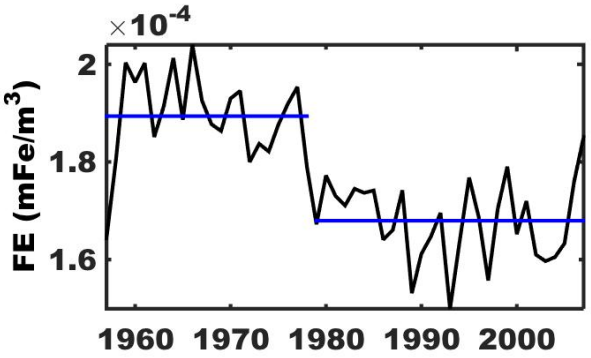


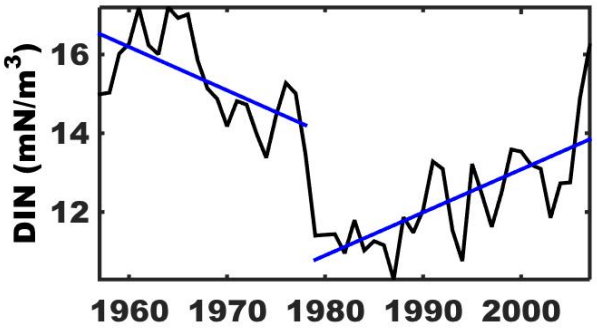


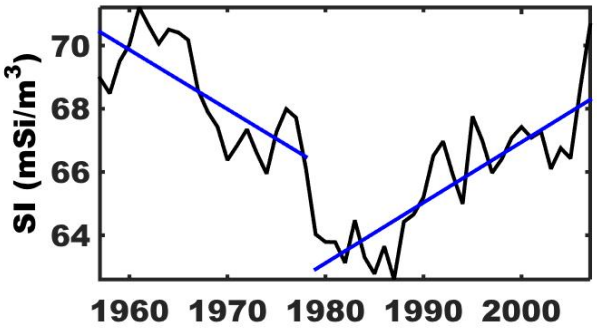
Same abrupt change found in observed SST

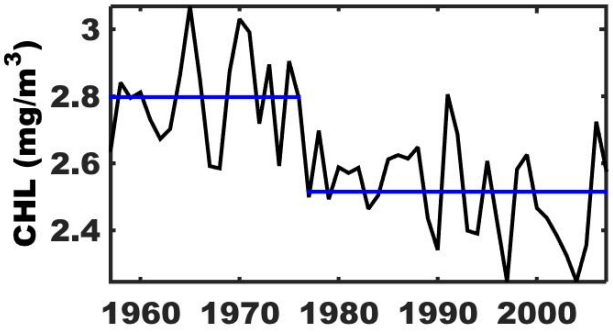
Beaulieu et al., in prep

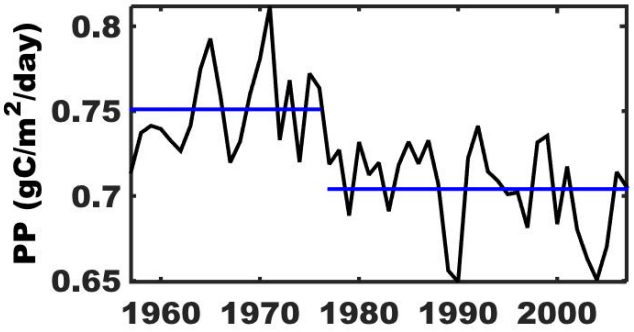
Shifts in the Diat-HadOCC model





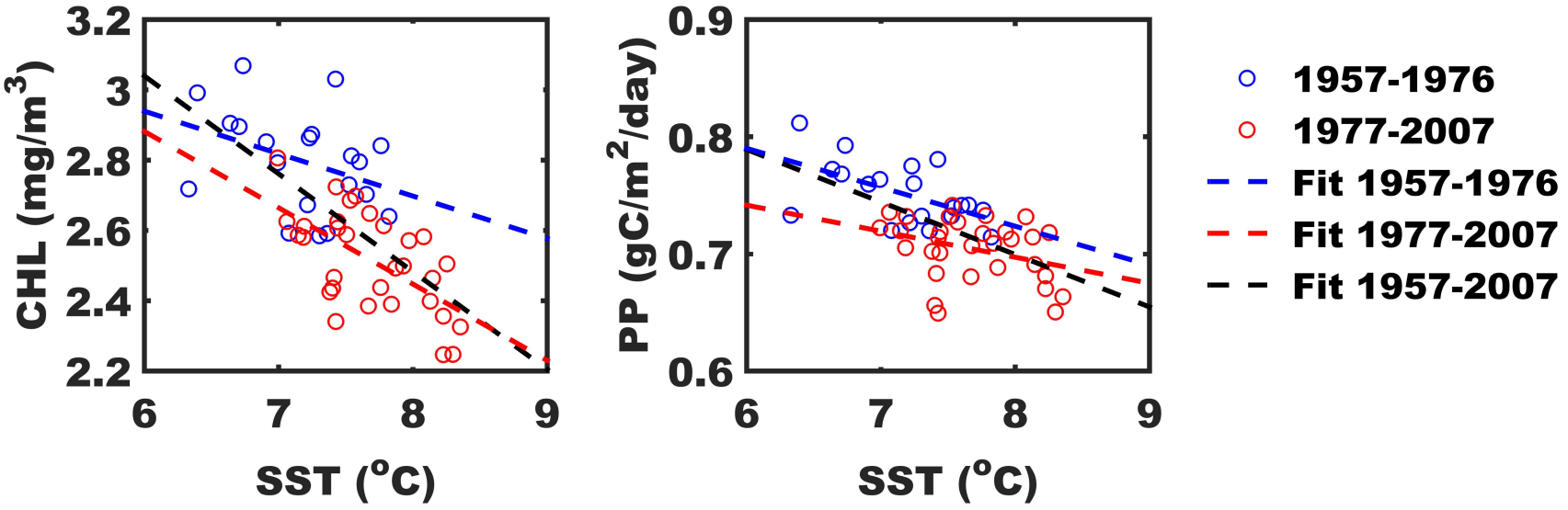






Beaulieu et al., in prep

Forcing-response relationship



Consistent with a linear relationship

Summary

- The models show consistency on the mechanisms/chain of events responsible for the shift:
  - increase in sea surface temperature
  - decrease in nutrients
  - decrease in biological productivity
- We detect abrupt changes both in the forcing and response, but find no indication that a threshold was crossed
  - relationship between SST and productivity is somewhat linear and similar before and after 1977
- Some controls may be missing (e.g. top-down)
- Current and future work
  - Formal and extended detection and attribution framework (both stochastic and deterministic)