Modelling the interannual variability of biogeochemical conditions along the British Columbia coast

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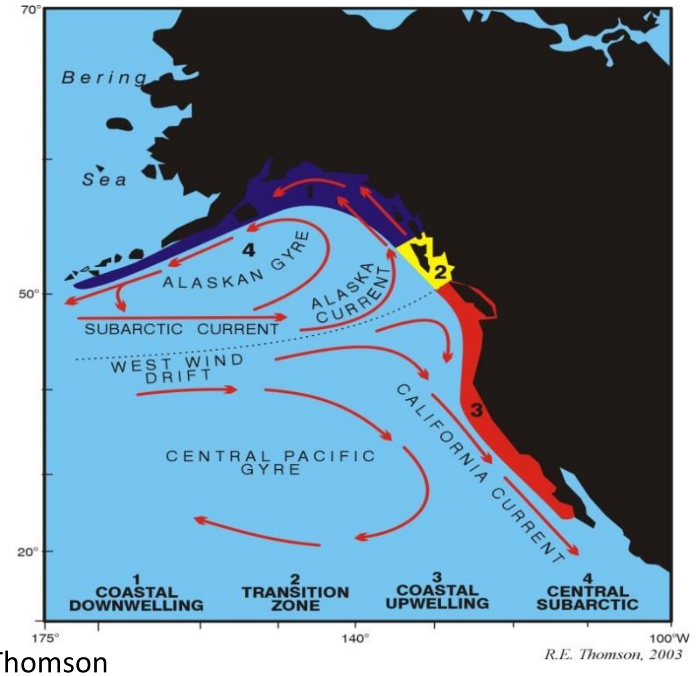
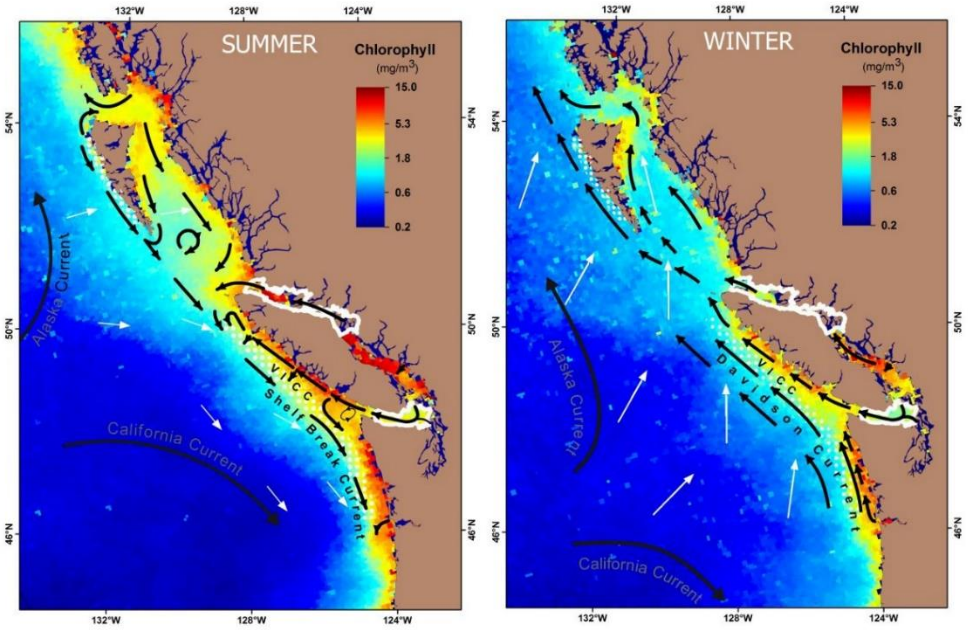
Main features of BC coast

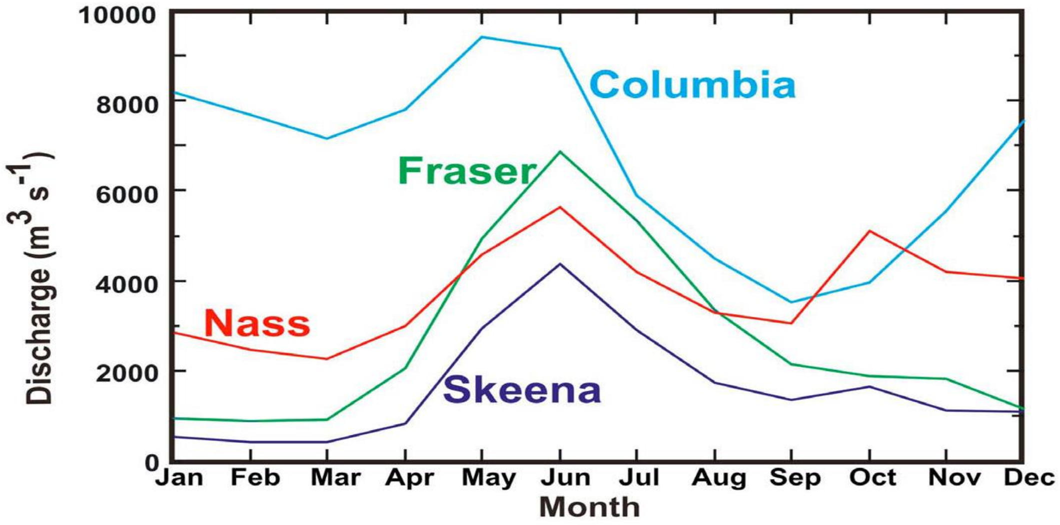
- Coastal Upwelling-Downwelling Domains
- Winds are upwelling favourable in summer and downwelling favourable in winter
- Large freshwater input affects coastal circulation and local stratification
- Very productive coastal region



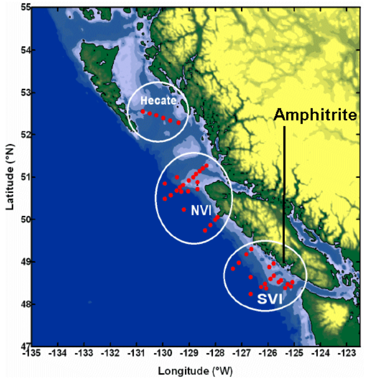
Courtesy of Rick Thomson

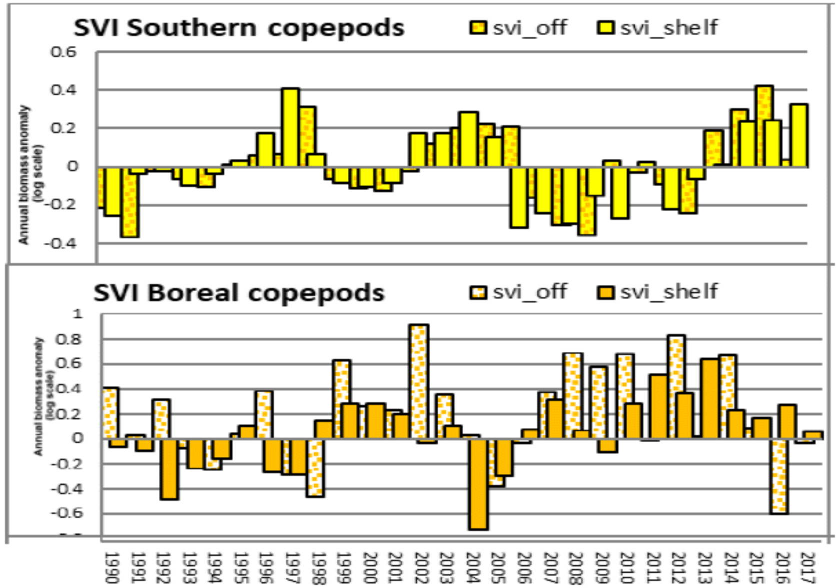


Jackson et al., JGR Oceans, 2015

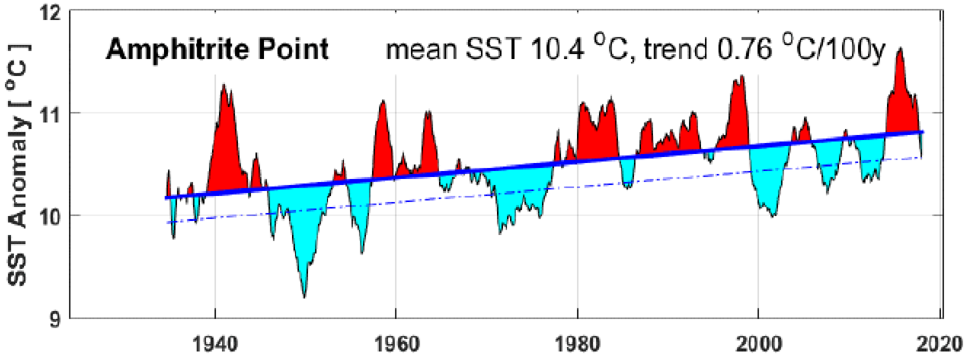


- There is significant interannual to decadal variability
- Local (e.g. upwelling) and remote (e.g. PDO, NPGO) forcing is important
- Natural climate variability is large relative to the long-term anthropogenic trend
- Need for long time-series to characterize the system

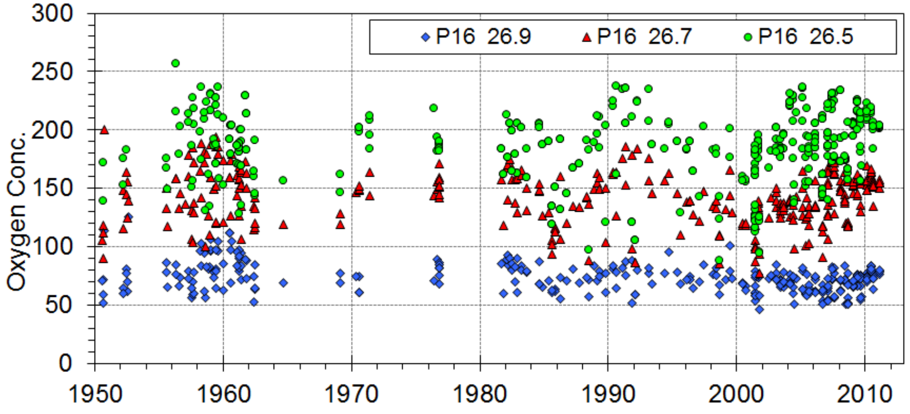




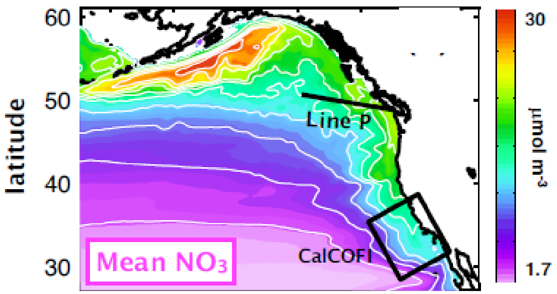
Galbraith and Young, 2018



Chandler, 2018

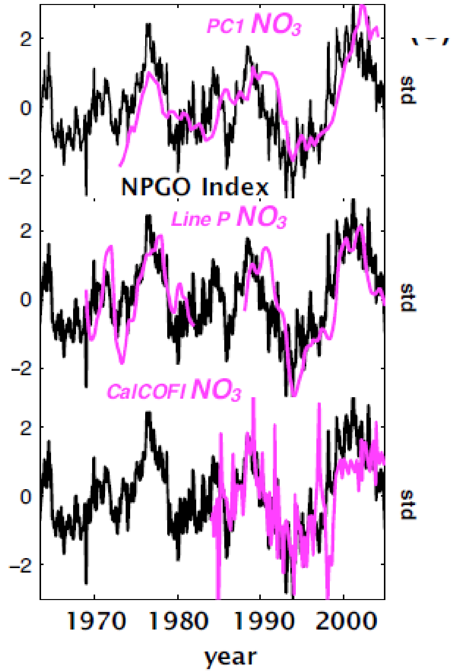


Crawford & Peña, A-O, 2016



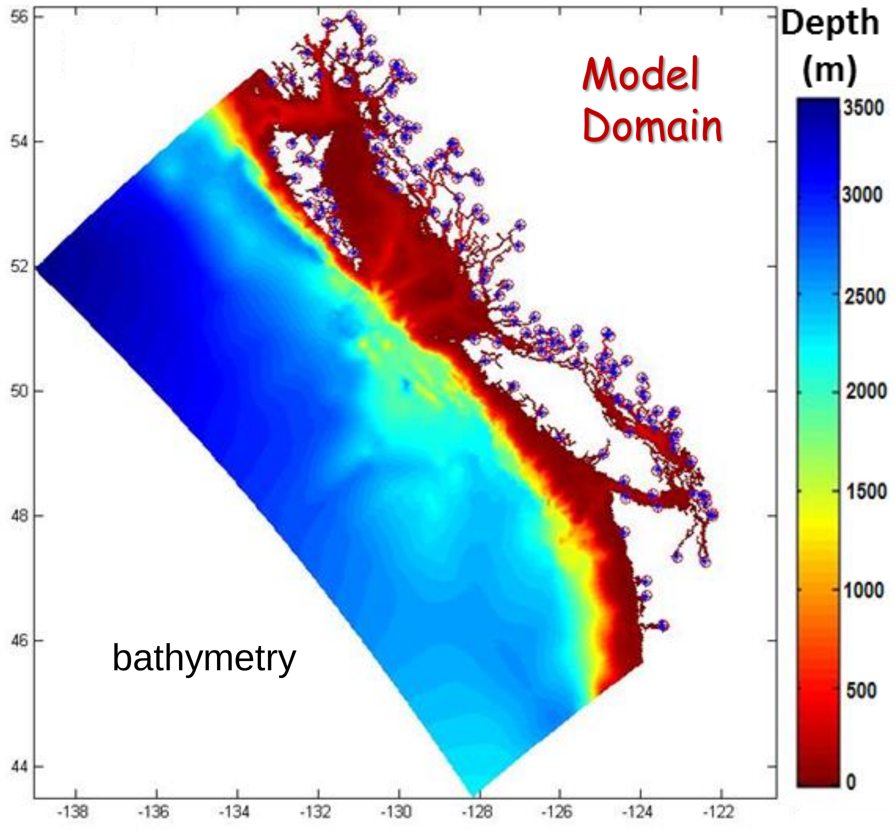
*The **NPGO** index measures changes in the **North Pacific gyres circulation** and explains key physical-biological ocean variables*

Di Lorenzo et al., GRL 2009



Objectives:

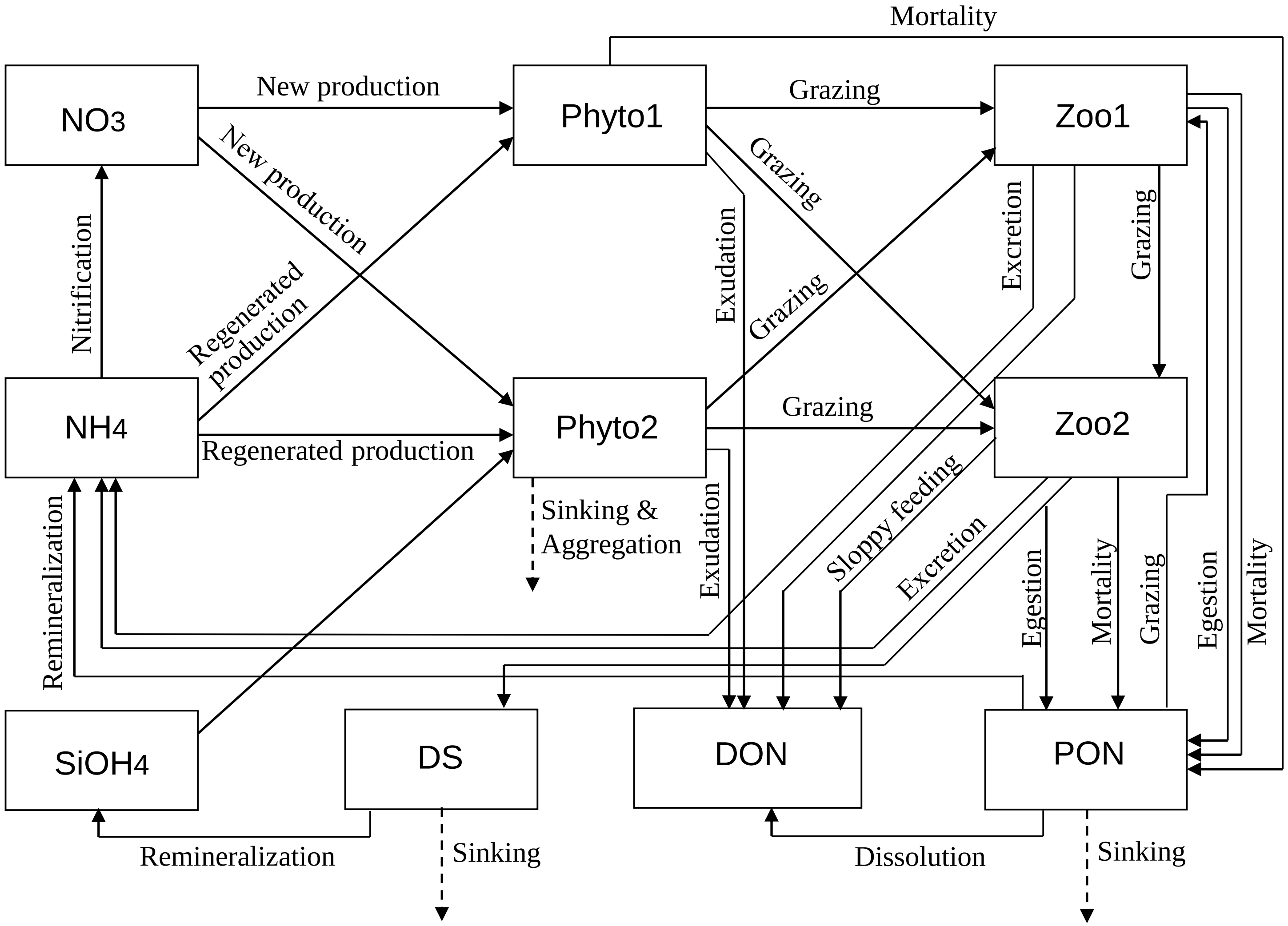
- Examine interannual variability of biogeochemical conditions along the BC coast using a 33-yr hindcast simulation of a physical-biogeochemical model
- Gain a better understanding of the mechanisms driving these changes.
- Improve predictions of climate change responses of this system



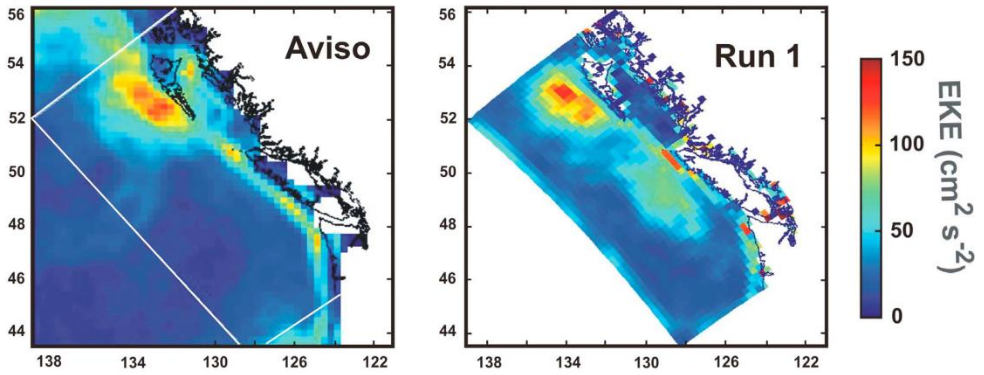
BC coastal model

- Implementation of ROMS (Regional Ocean Modeling System)
- Circulation + biogeochemical (NPZD-O_2-C) model
- Resolution:
  - 3 km horizontal resolution (236 X 410)
  - 42 non-uniform vertical sigma levels, with clustering near the surface.
- Forcing:
  - 8 tidal constituents
  - 3 hourly wind and daily atmospheric forcing from NARR, bulk formula heat flux
  - Monthly discharge from 154 rivers
- Initial and monthly open boundary conditions:
  - SODA reanalysis (temperature, salinity, u and v)
  - WOA13 (nutrients and oxygen)
  - GLODAP (DIC and TA)

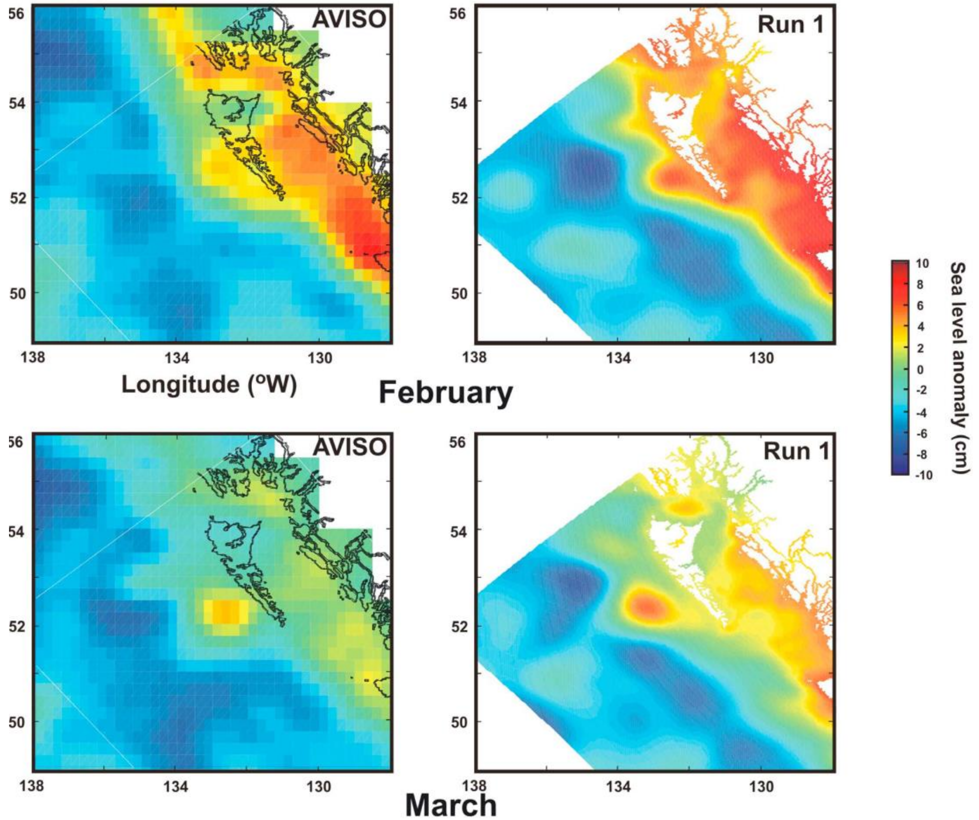
Biogeochemical model:



- NPZD (3N, 2P, 2Z, 3D), dynamic chlorophyll compartments, temperature dependence of physiological rates
- O2, DIC, Alkalinity, Ca Carbonate
- OCMIP air-sea CO2 exchange



Mean EKE (cm^2/s^2) from AVISO data and Model



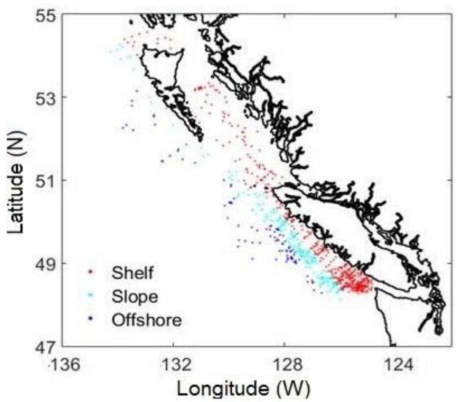
Monthly mean sea level anomaly for February and March for AVISO data and Model (Masson & Fine, 2012).

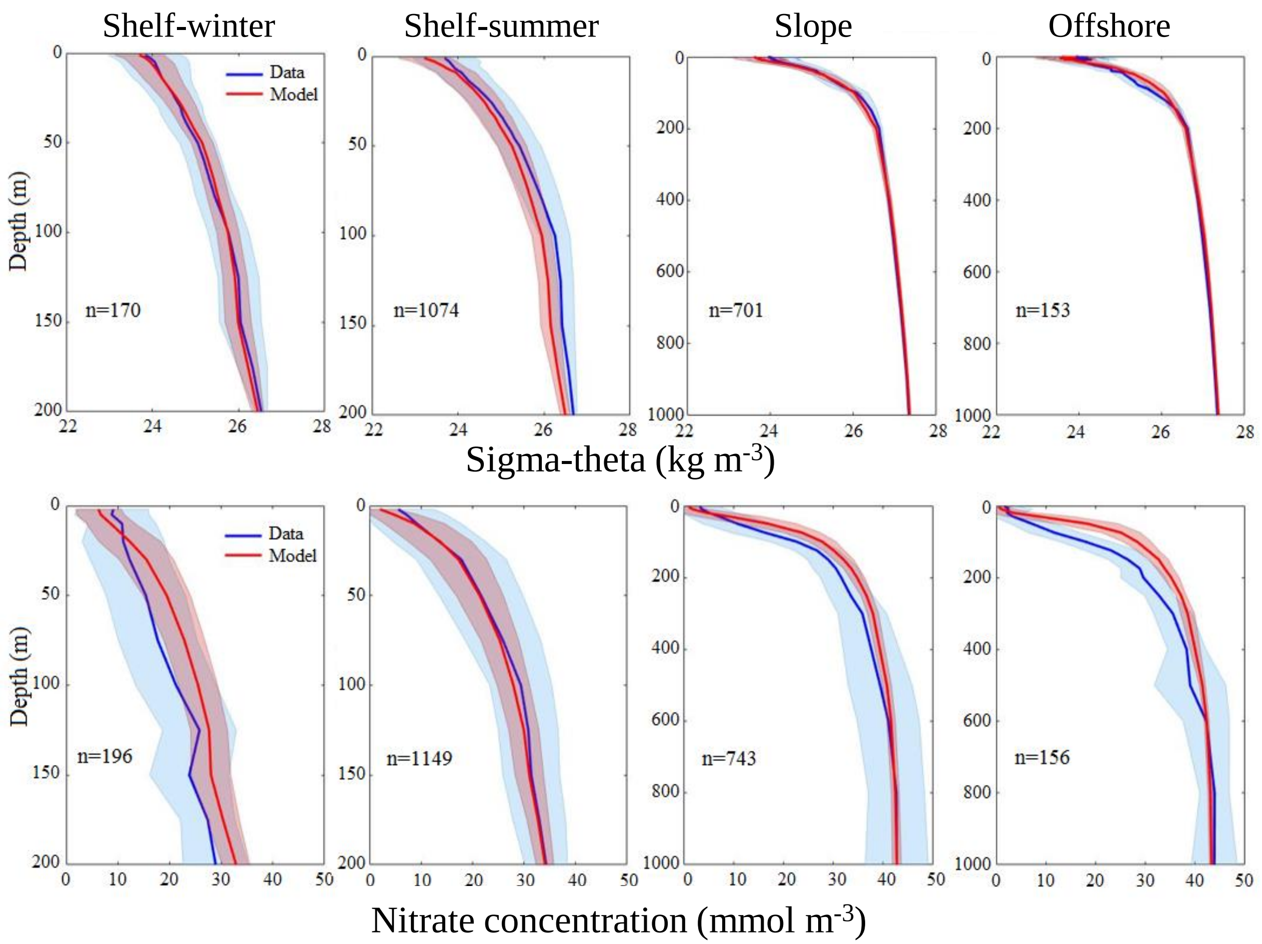
Model validation

Model has been validated against tide gauge, altimetry and geostrophic currents data (1995-2008). The model successfully reproduces the seasonal cycle and interannual variability (Masson & Fine, JGR 2012).

Model simulates reasonably well the main physical processes relevant to biogeochemistry

- Seasonal upwelling
- Eddy field
- California Undercurrent





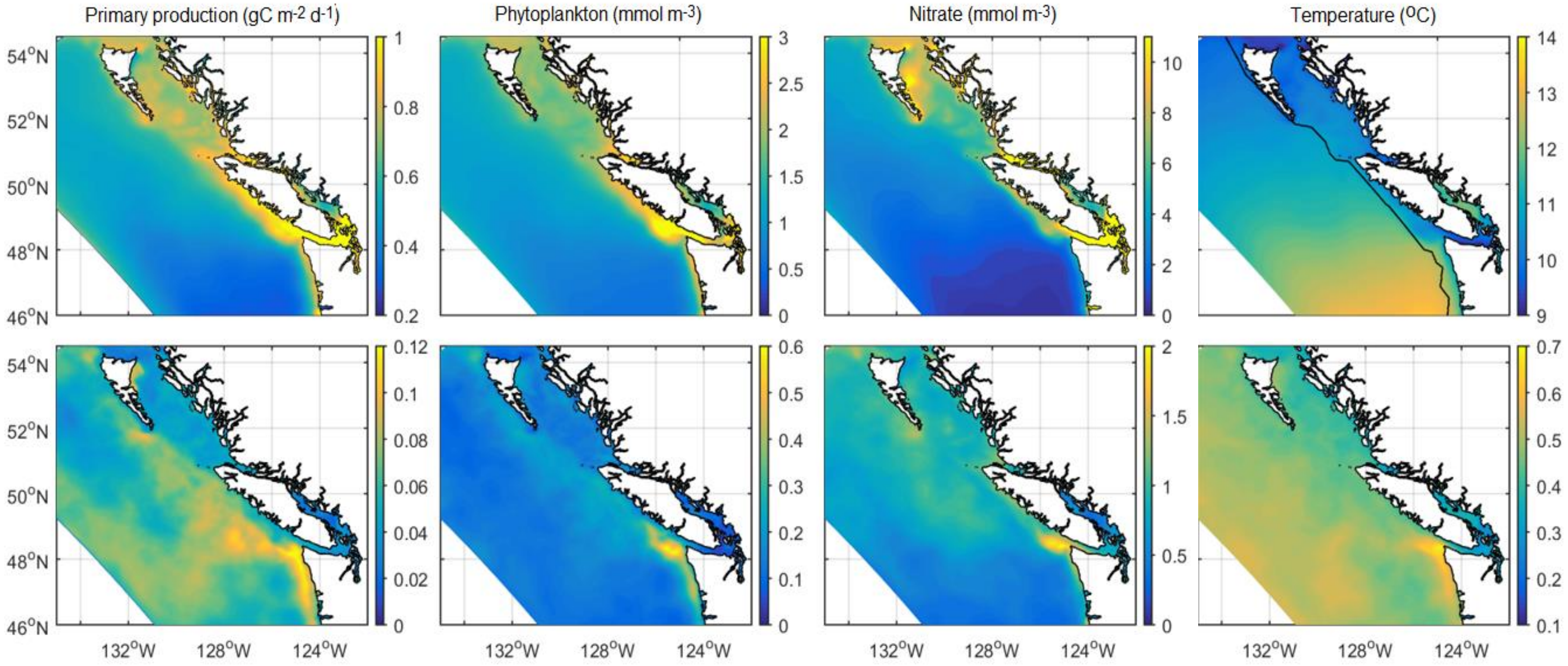
Model validation

- Comparison of model vs in-situ vertical profiles of temperature, salinity, nutrients, and oxygen. The model simulates reasonably well.
- Model simulates reasonably well the vertical structure of the water column and the horizontal distribution of nutrients and oxygen.

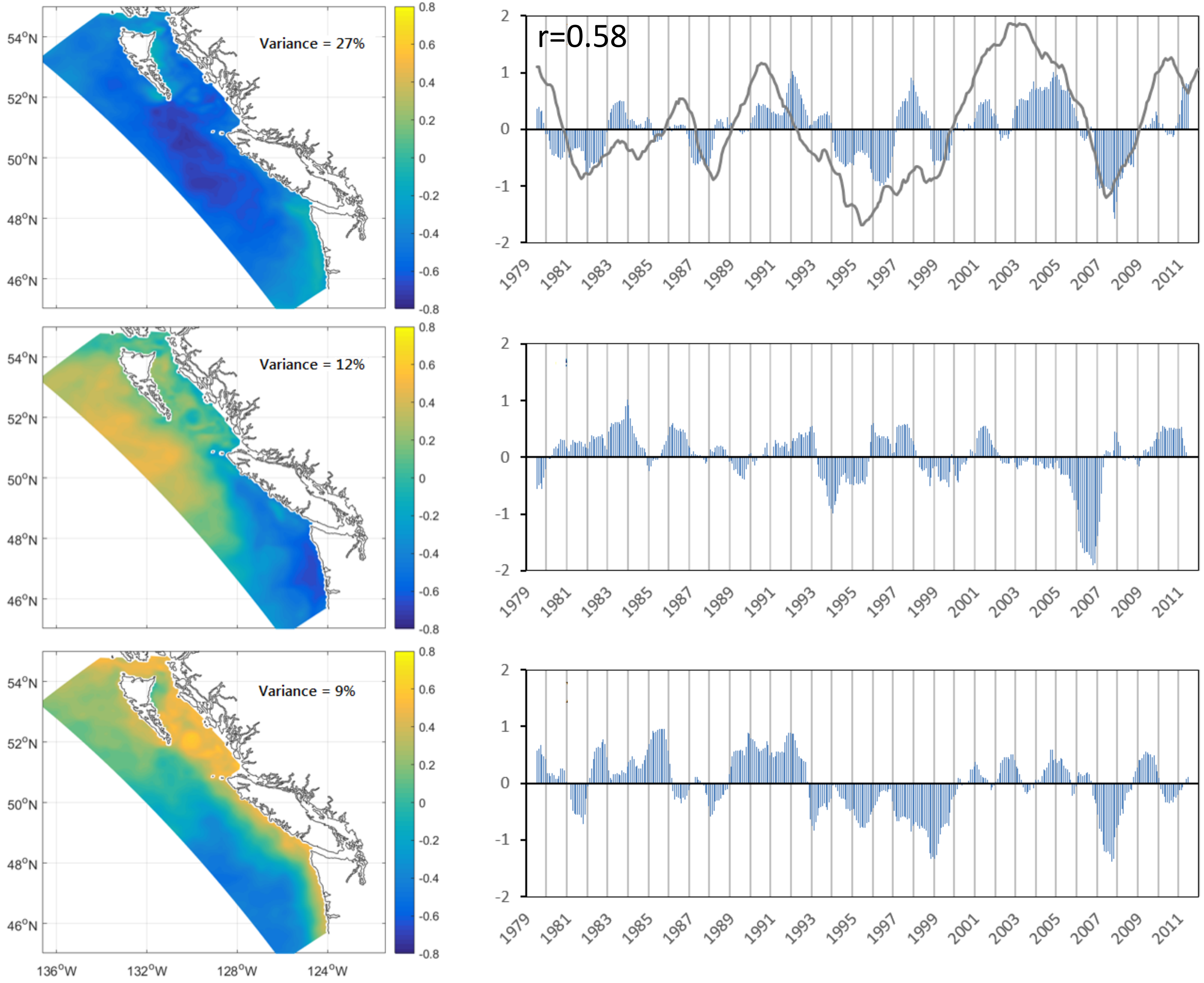
Climatology (1979-2011) of depth-integrated primary production and upper layer phytoplankton biomass and nitrate concentration

Mean

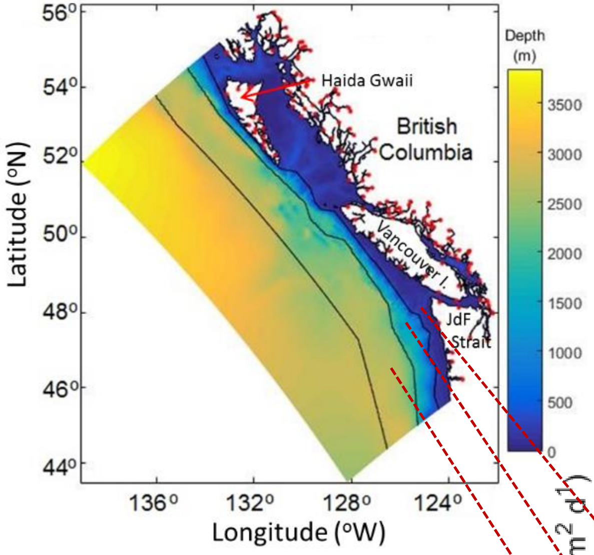
SD

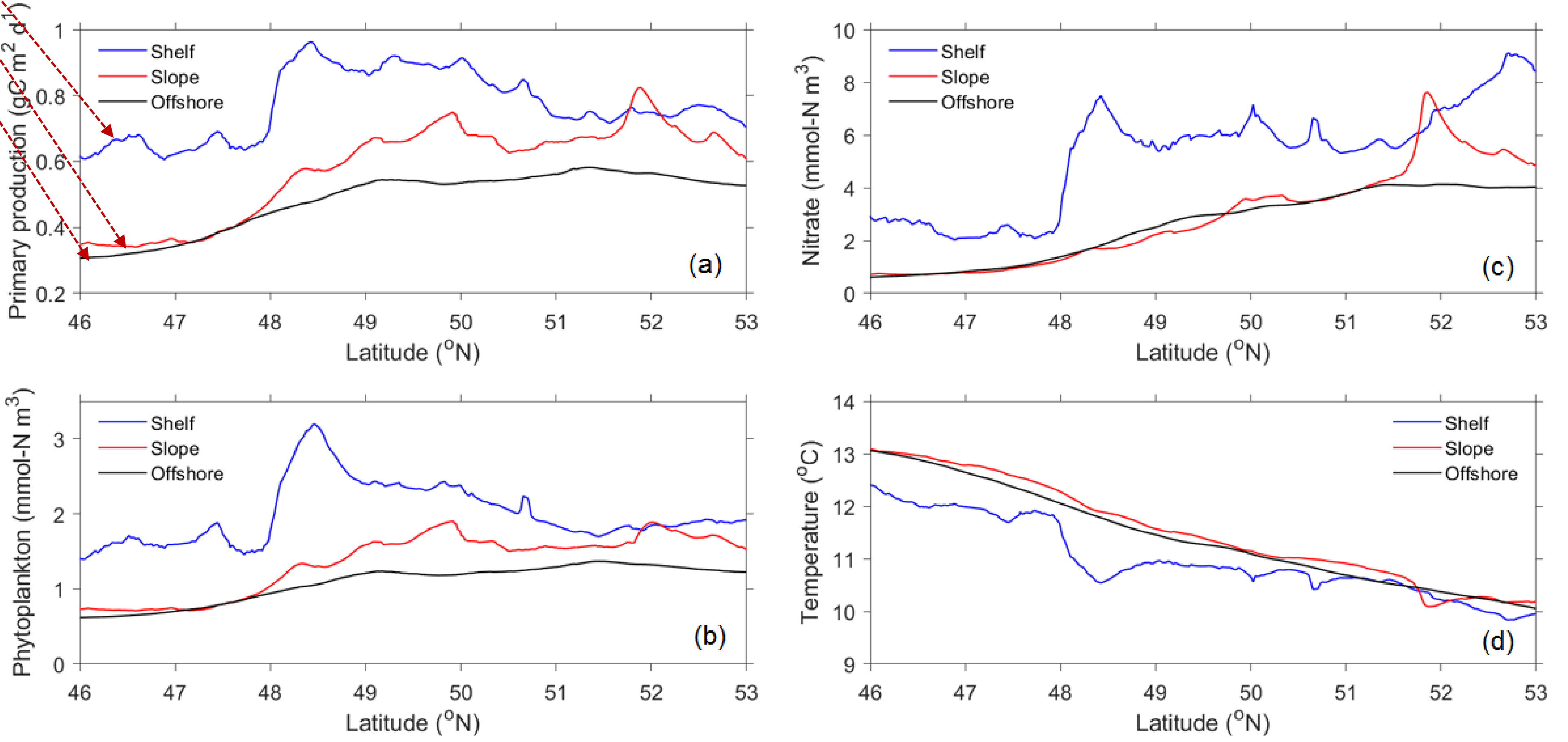


Dominant space-time patterns of primary production

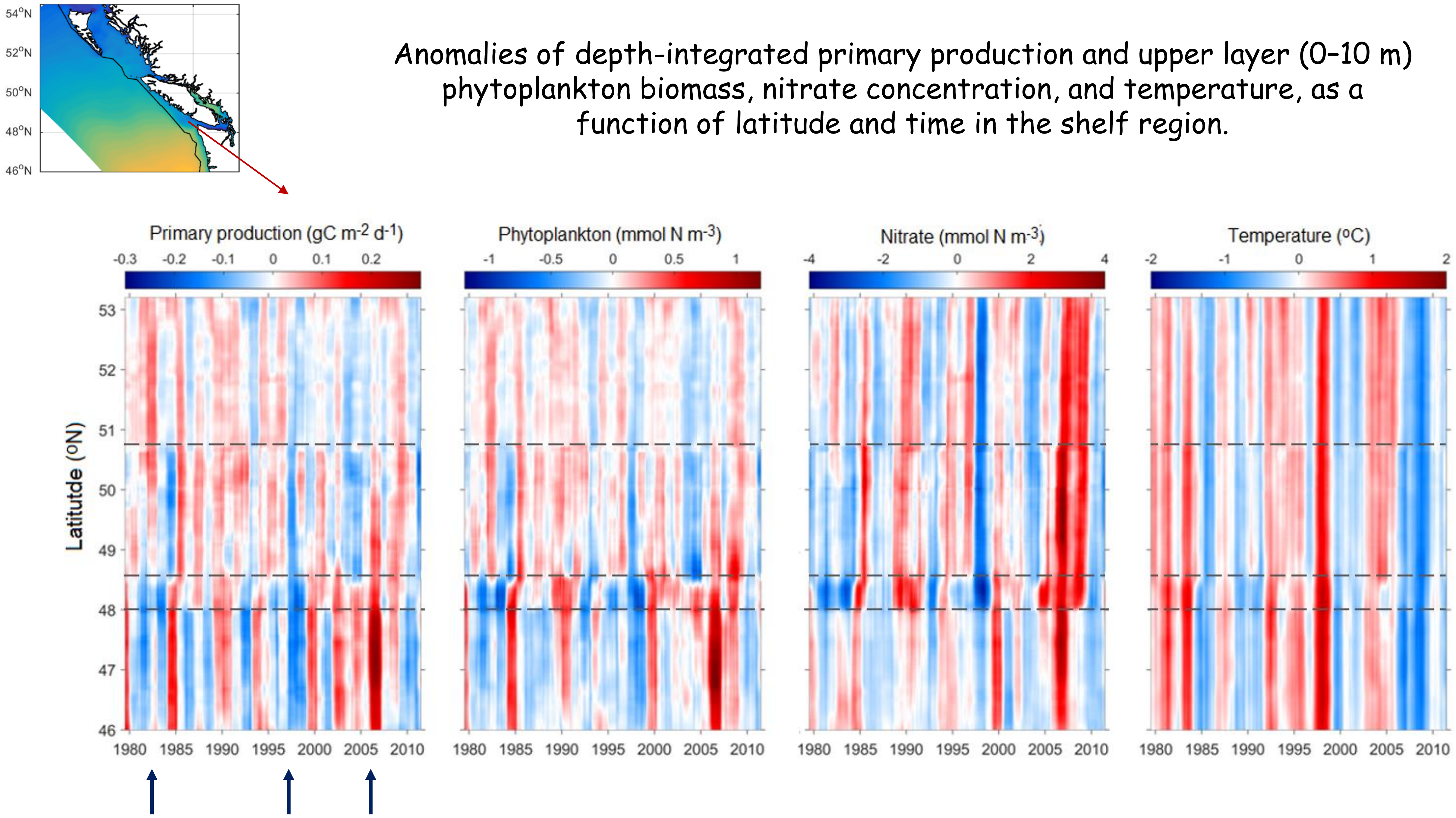


Meridional distribution of simulated mean values on the continental shelf, slope and offshore waters

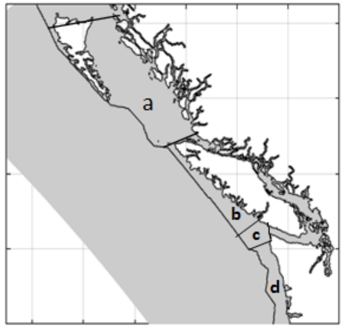


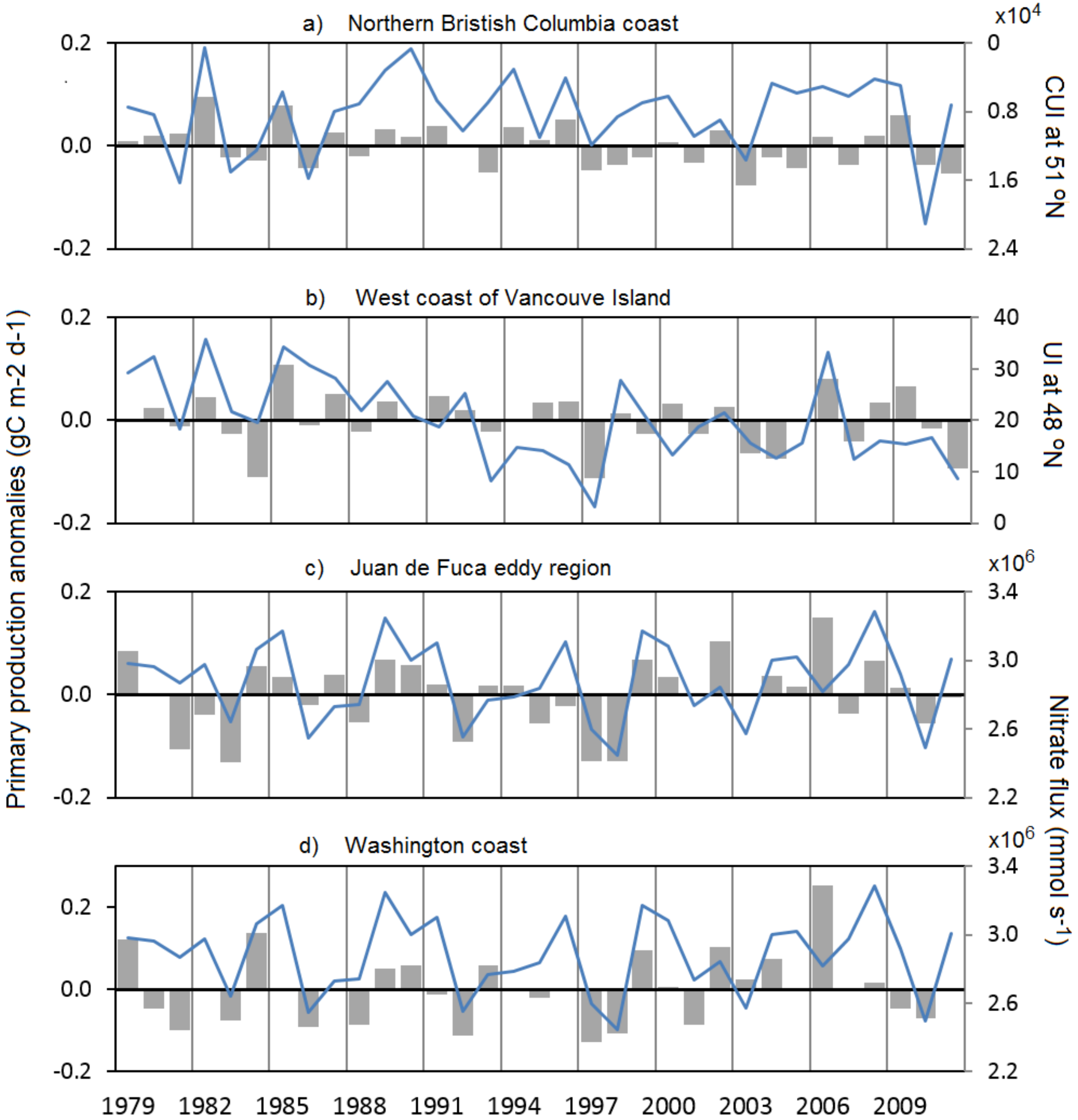


Anomalies of depth-integrated primary production and upper layer (0–10 m) phytoplankton biomass, nitrate concentration, and temperature, as a function of latitude and time in the shelf region.



Annual mean primary production anomalies





Cumulative Upwelling Index at 51° N

r=0.54

Monthly upwelling Index during the upwelling season (Apr. to Sept.) at 48° N

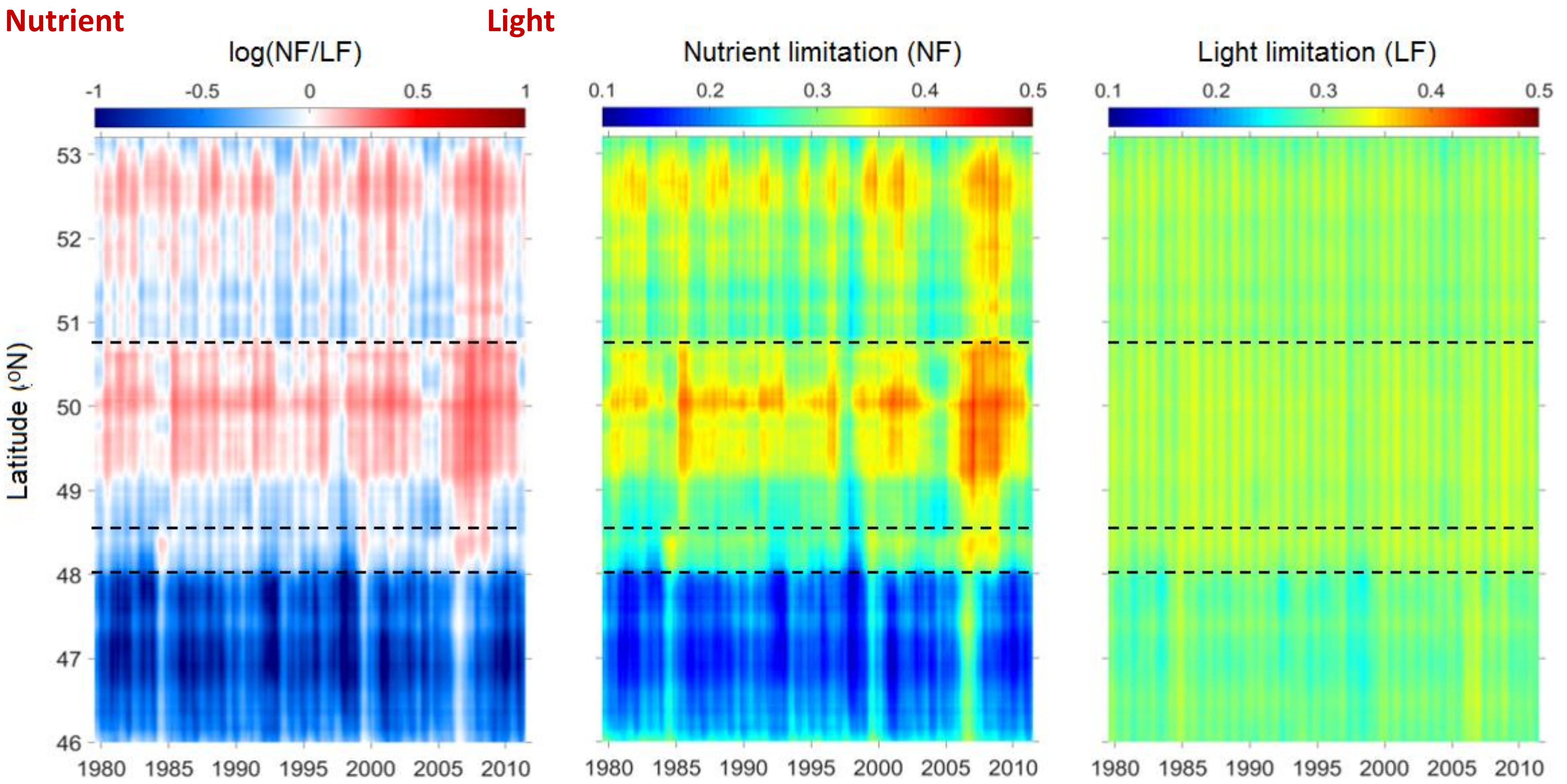
r=0.57

Annual mean nitrate fluxes out of the upper layer of Juan de Fuca Strait

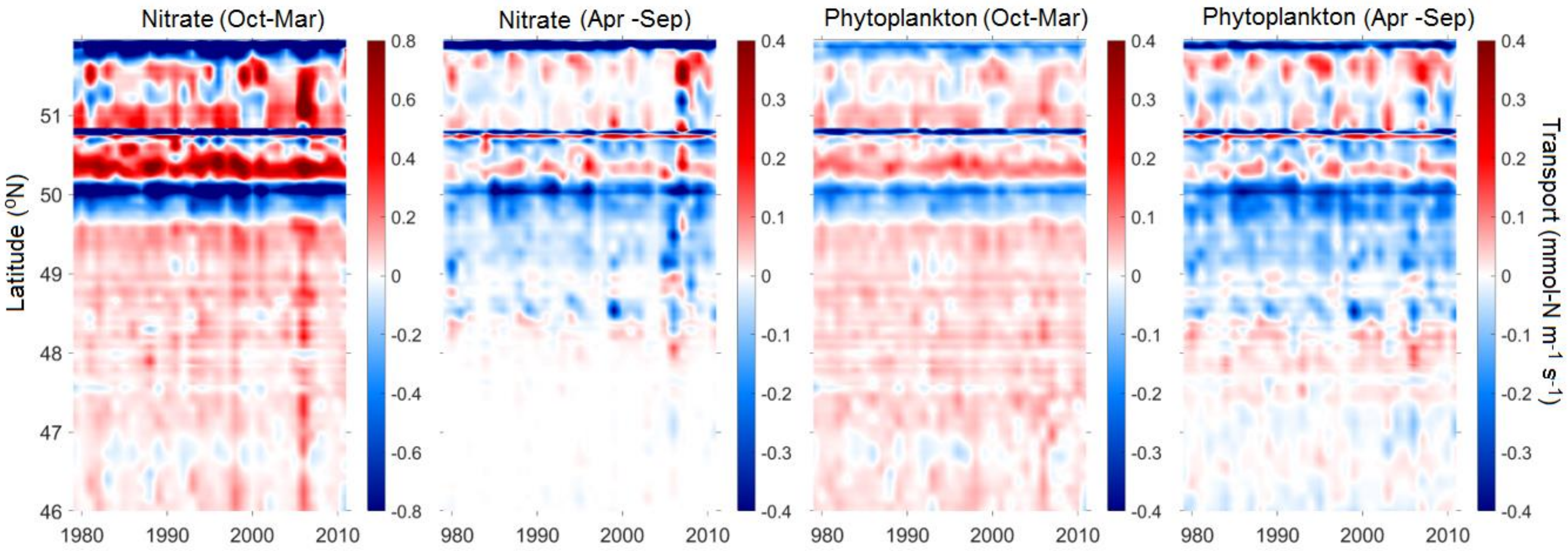
r=0.56

r=0.48

Factors controlling phytoplankton growth in the surface layer (upper 5 m) as a function of latitude and time in the shelf region



Seasonal mean surface layer (0-10 m) transport of nitrate and phytoplankton (mmol-N m^{-1} s^{-1}) across the shelf boundary



Summary

- A 33-year hindcast (1979–2011) of a regional circulation-ecosystem model is used to examine interannual variability of primary production along the British Columbia coast.
- Linkages between simulated primary production anomalies and forcing are explored through correlations to local upwelling winds, outflow from the Juan de Fuca Strait estuarine circulation, and two indices of Pacific Ocean basin-scale variability, the Pacific Decadal Oscillation (PDO) and the North Pacific Gyre Oscillation (NPGO).
- The dominant large scale pattern of interannual variability of primary production is correlated to the NPGO but not the PDO.
- In the shelf region, negative primary production anomalies appear to be primarily associated with El Niño events.
- Along the continental shelf between ~48.6 and 53. 9°N, time-series of annual primary production anomalies are significantly correlated with upwelling winds whereas farther south (between 46 and 48.6°N) the anomalies are correlated with nitrate outflow from the Juan de Fuca Strait.
- Model results indicate that coastal waters off Vancouver Island are rich in nutrients, so phytoplankton growth in this region are less limited by nitrate than on the Washington coast.

Peña et al., Deep-Sea Research II, 2019: doi.org/10.1016/j.dsr2.2019.104637