Models linking climate to lower trophic levels: Status and future - Canada

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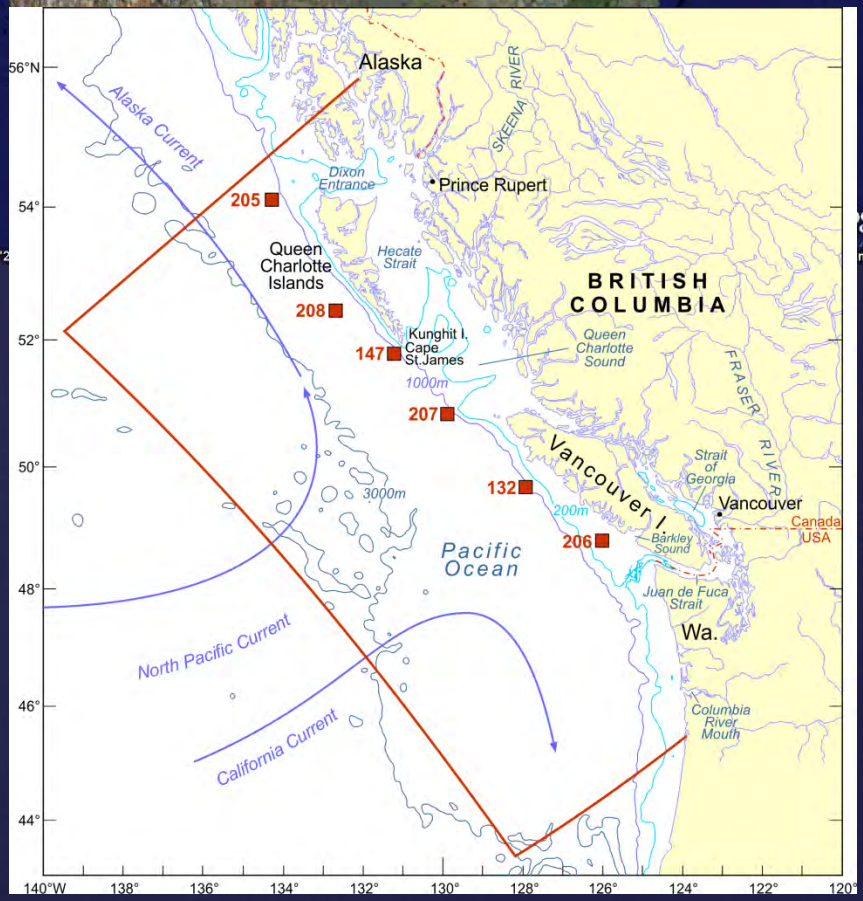
Fisheries and Oceans Canada | Pêches et Océans Canada

Environment Canada | Environnement Canada

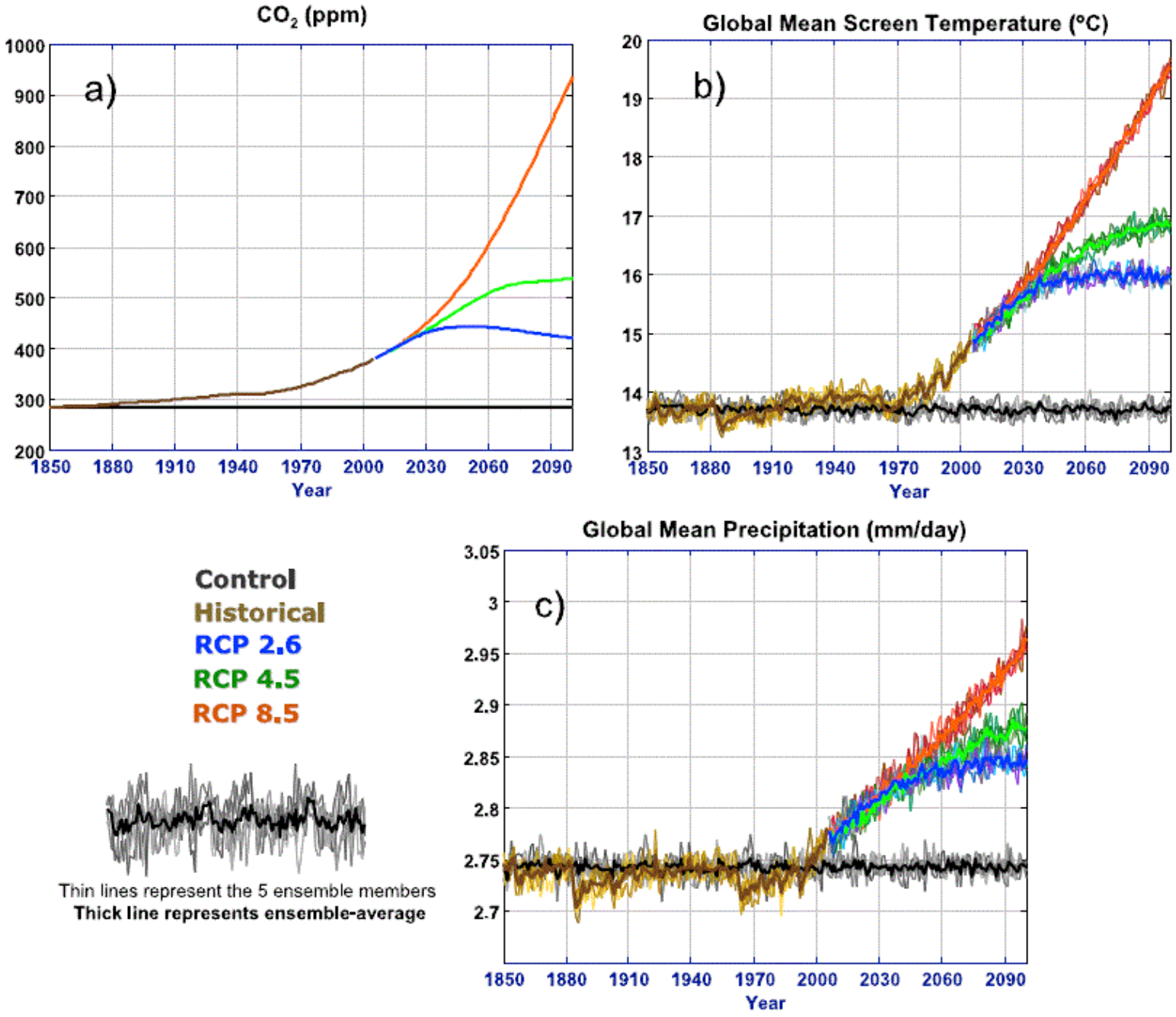
Outline

a) Canadian GCM
b) Canadian RCMs
   a) Atmos only
c) BC RCM
   a) Ocean only
   b) Coupled biogeochemical
d) Summary



Canadian GCM (CanESM2)

- AR5 earth system model
- Atmosphere: 2.81° horizontal resolution
- Ocean: approx 1.41° longitude & 0.94° latitude
  - Based on NCAR CSM ocean model
  - 40 vertical levels: 10 to 400m thick
  - http://www.ec.gc.ca/ccmac-cccma/default.asp?lang=En&n=3701CEFE-1 for more details
- Includes carbon cycle (land & ocean)
- 5 member ensembles for both historical & each RCP future run



Sample CanESM2 output: Fig 1, Arora et al (2011)

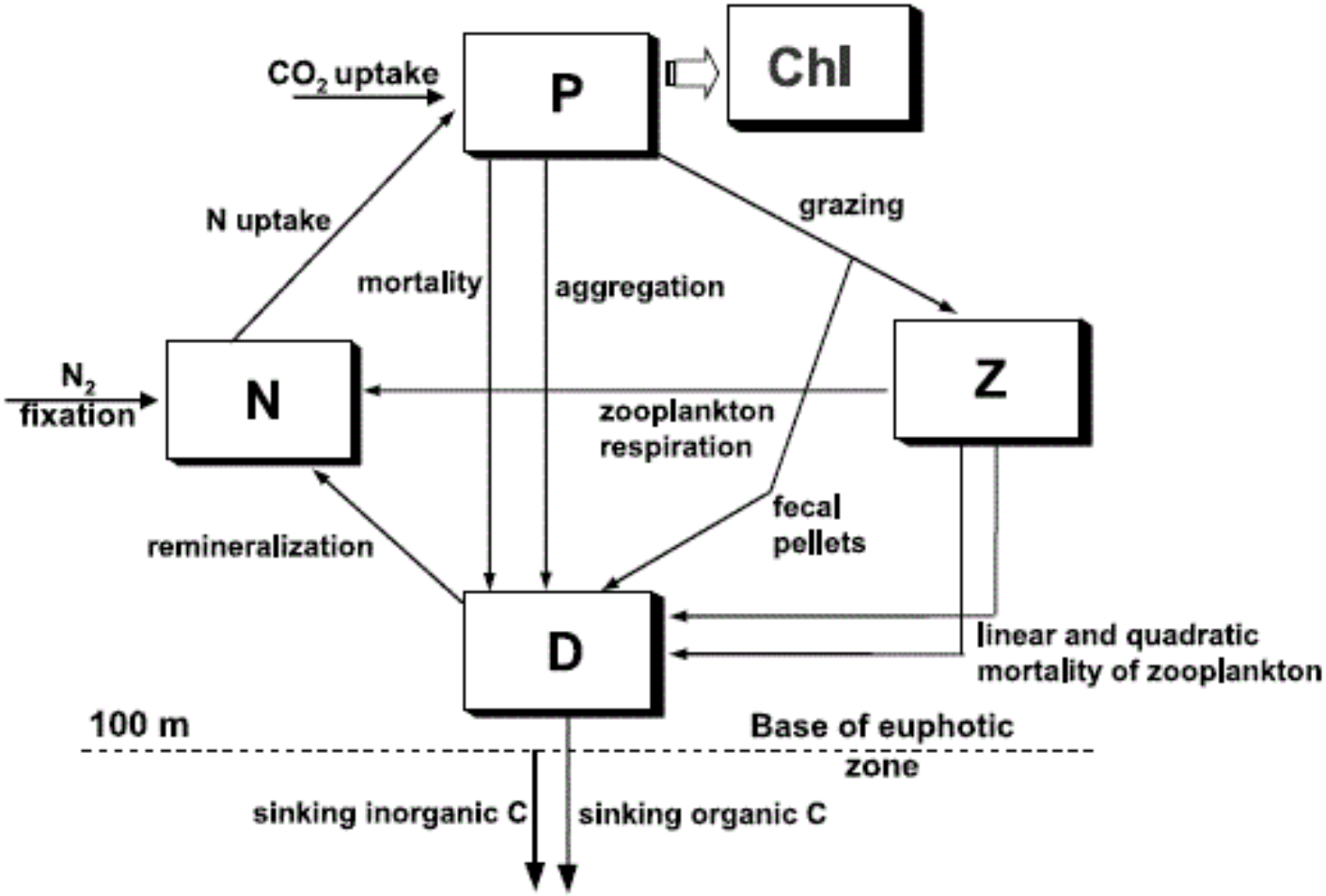


Figure 2. Schematic of the ocean ecosystem model (CMOC). Ecosystem compartments are inorganic nitrogen (N), phytoplankton (P), zooplankton (Z), and detritus (D). Chlorophyll (Chl) is a semiprognostic quantity derived from phytoplankton by a light-dependent chlorophyll-to-nitrogen ratio but carried as a separate tracer. Sedimentation of organic carbon is derived from detritus concentration, with a sinking velocity of 10 m d^{-1}; sedimentation of inorganic carbon is calculated from the organic flux at the base of the euphotic zone via a temperature-dependent rain ratio.

Christian et al. (2010)

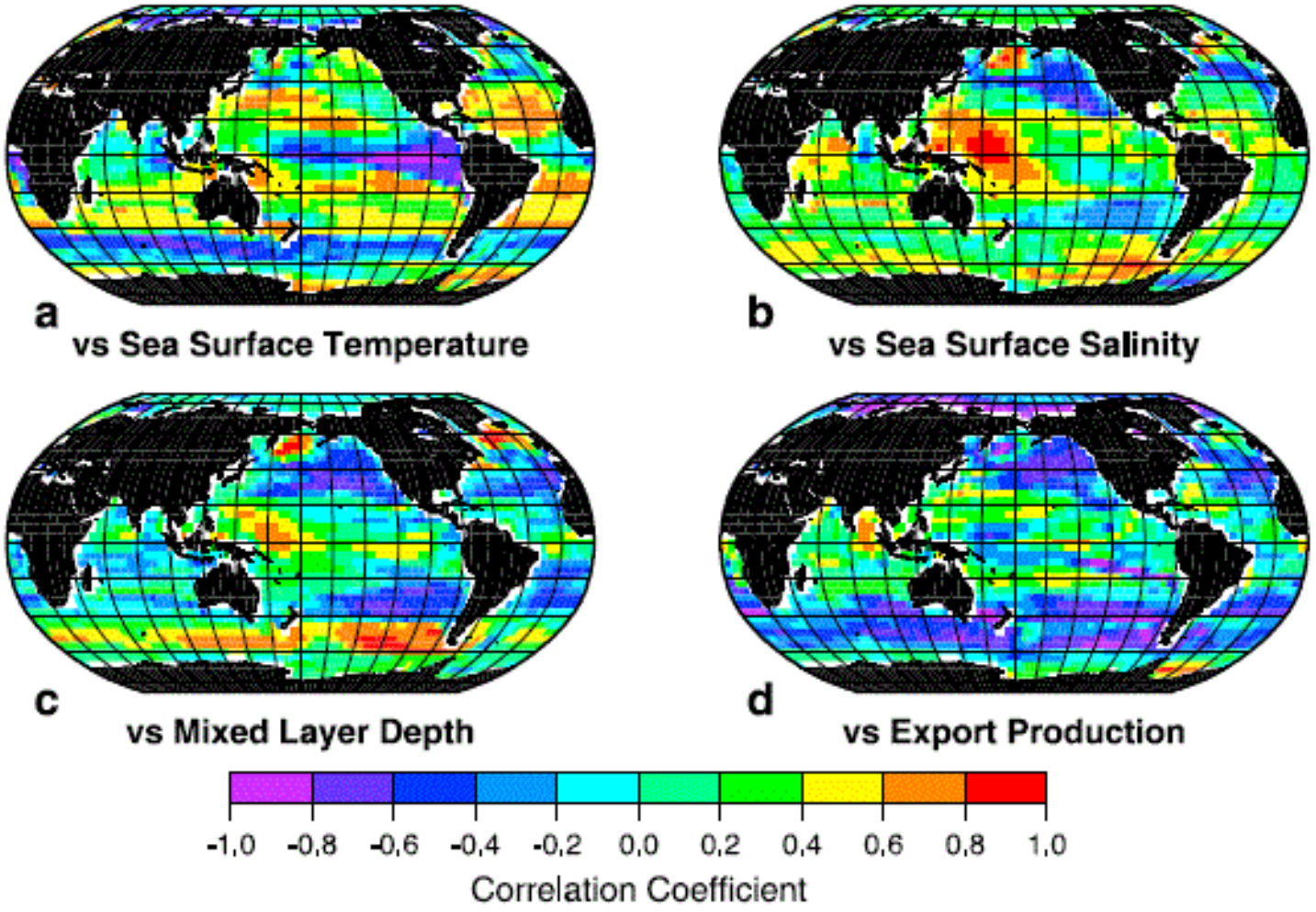


Figure 12. Correlation coefficient (r_{xy}) of ocean-atmosphere CO_2 (positive upward) flux with sea surface temperature, sea surface salinity, maximum winter mixed layer depth, and export production. Export production is defined as organic carbon sedimentation across 100 m. Based on annual means except for mixing depth.

Christian et al. (2010)

Canadian GCM Plans for AR6

1. Switch ocean model to NEMO
   - Similar to French & Hadley GCMs
     - will this skew GCM ensemble statistics ?
   - 1° resolution but some testing with 0.25°

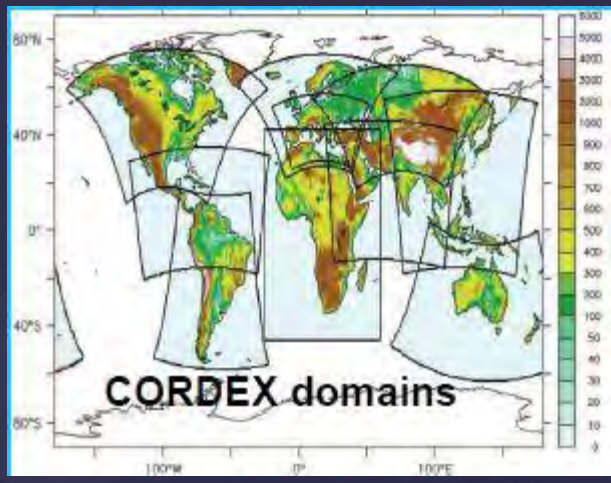
2. More advanced biogeochemistry (> 6 tracer fields in AR5 GCM)
   - Multiple phytoplankton functional groups (vs 1 now)
   - Iron cycle
   - Oxygen & nitrification/N2O production
   - Eventually, ocean aeolian iron fluxes directly coupled to dust erosion/transport in land & atmospheric models

3. High resolution Arctic regional model

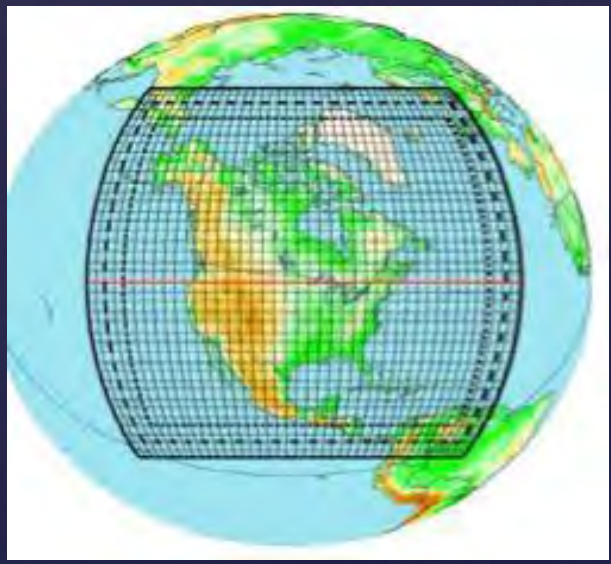
Canadian RCMs

For AR4 and earlier, 1 RCM jointly developed/run by Environment Canada & UQAM/Ouranos

- No active ocean; specified SST

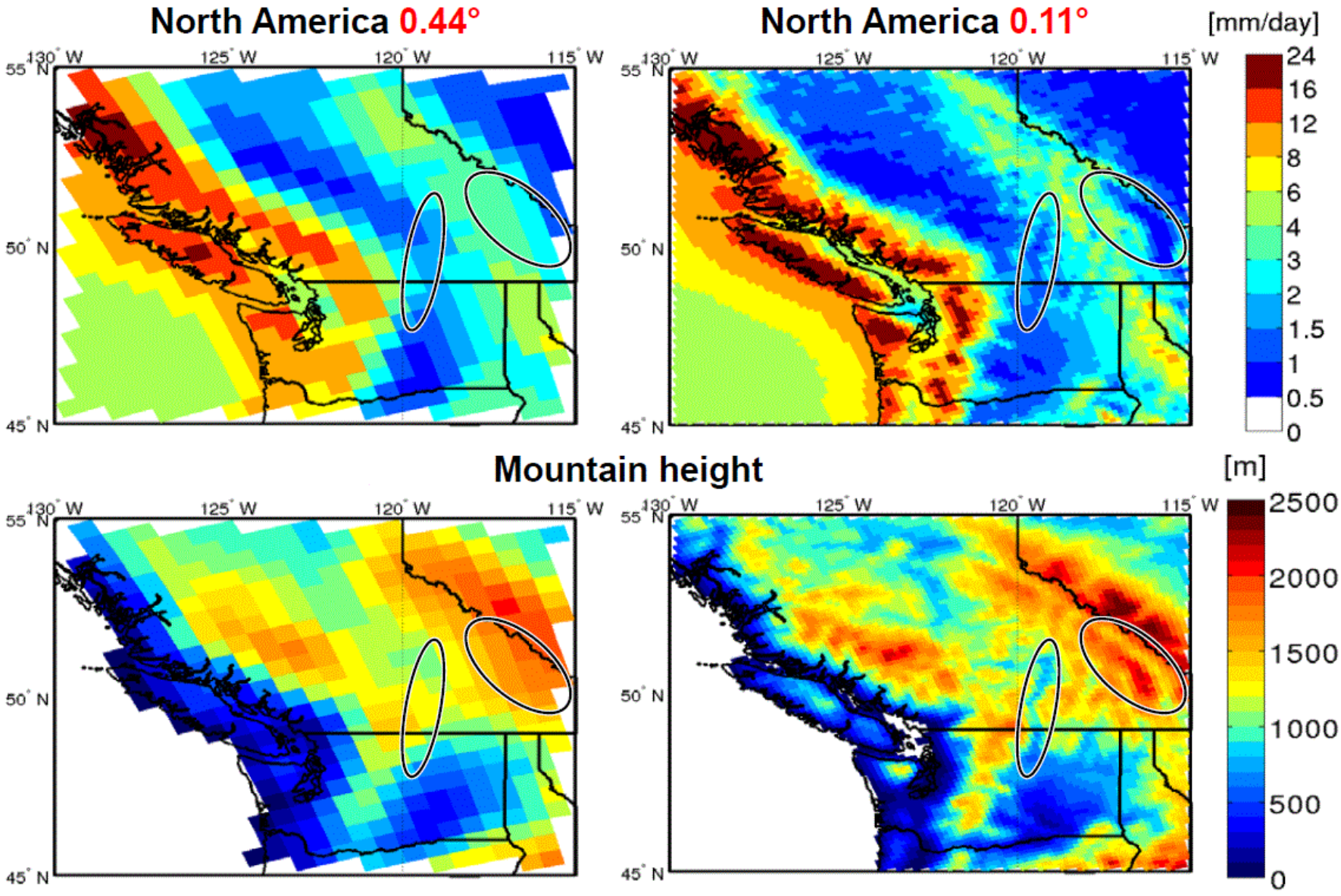


- For AR5, 2 RCMs but still no active ocean
  1. CanRCM4: (EC/CCCma)
     - Same atmospheric physics as GCM
     - 50 and 25km resolutions
  2. CRCM5: (UQAM/Ouranos)
     - GEM atmospheric physics (same as Canadian operational weather forecast models)
     - RCP4.5 with CanESM2 & MPI boundary forcing on CORDEX North America 0.44° grid
     - Some runs with 0.11° grid



CRCM5 Precipitation Comparison

Total precipitation, DJF 1988-1997, West coast



BC Ocean-only RCM

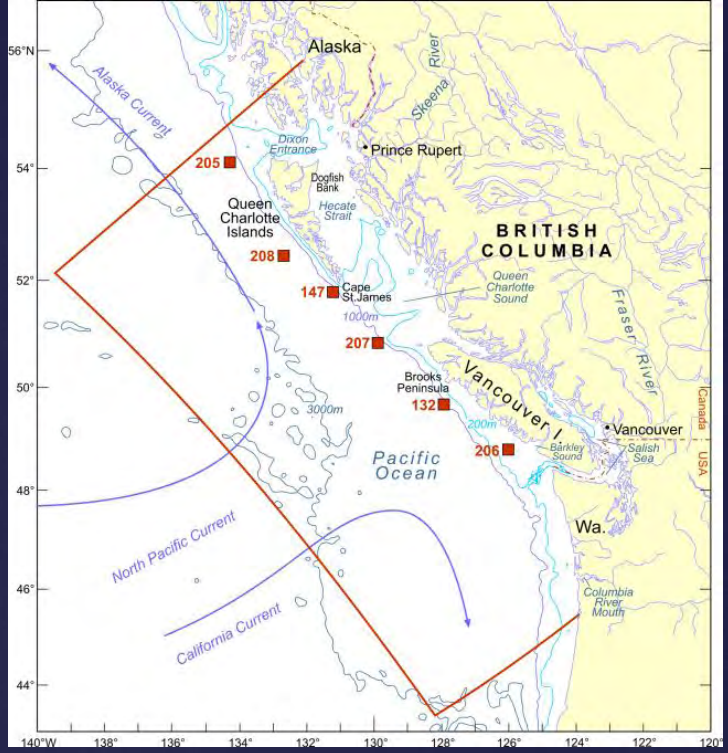
- Projections from North American Regional Climate Change Assessment Program (NARCCAP)
  - 4 GCMs, 6 RCMs, 11 combinations - IPCC AR4 A2 scenario

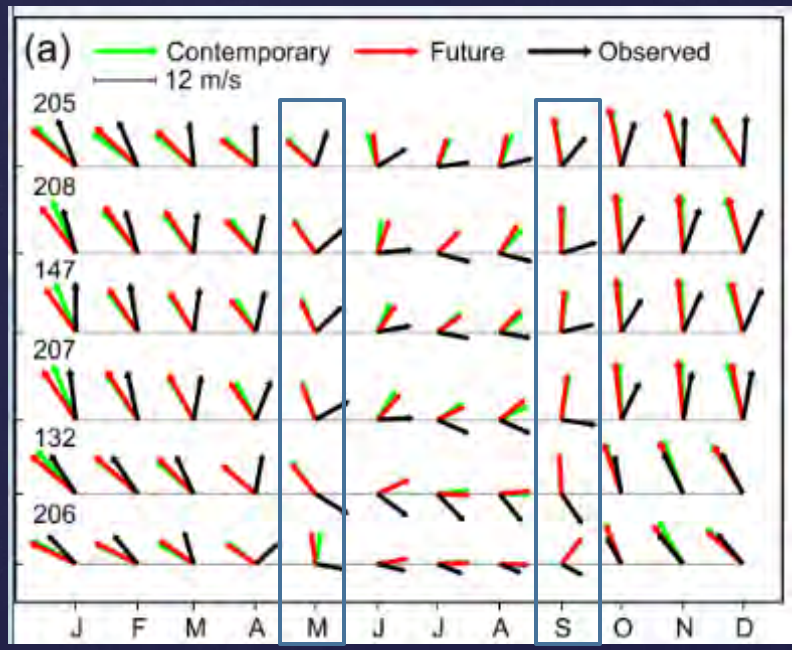
RCMs:
- ~50 km resolution vs >1° for GCMs
- atmospheric only; no active ocean
- periods: 1970-1999 & 2040-2069

- But RCMs don't reproduce offshore downwelling/upwelling winds & transitions accurately off BC

➡ direct use of RCM forcing could generate misleading ecosystem conclusions

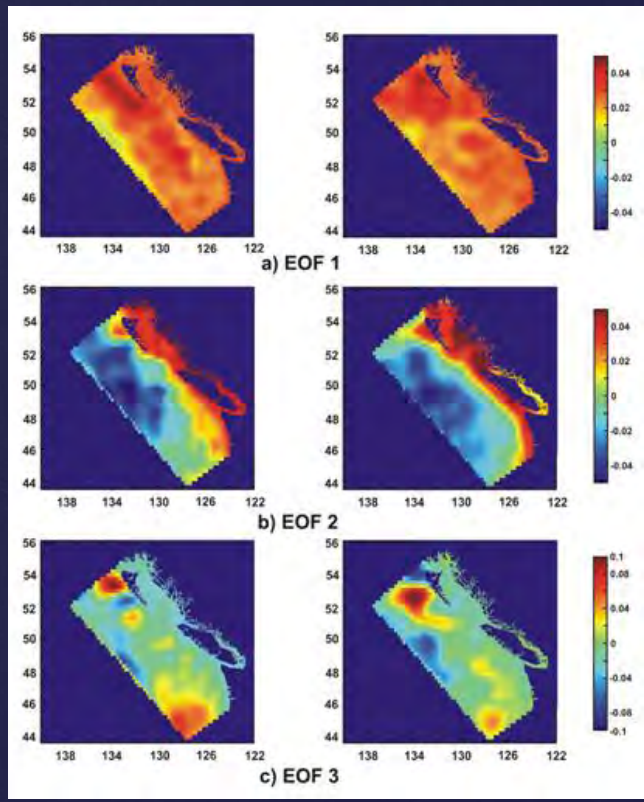
- adopted an anomaly approach



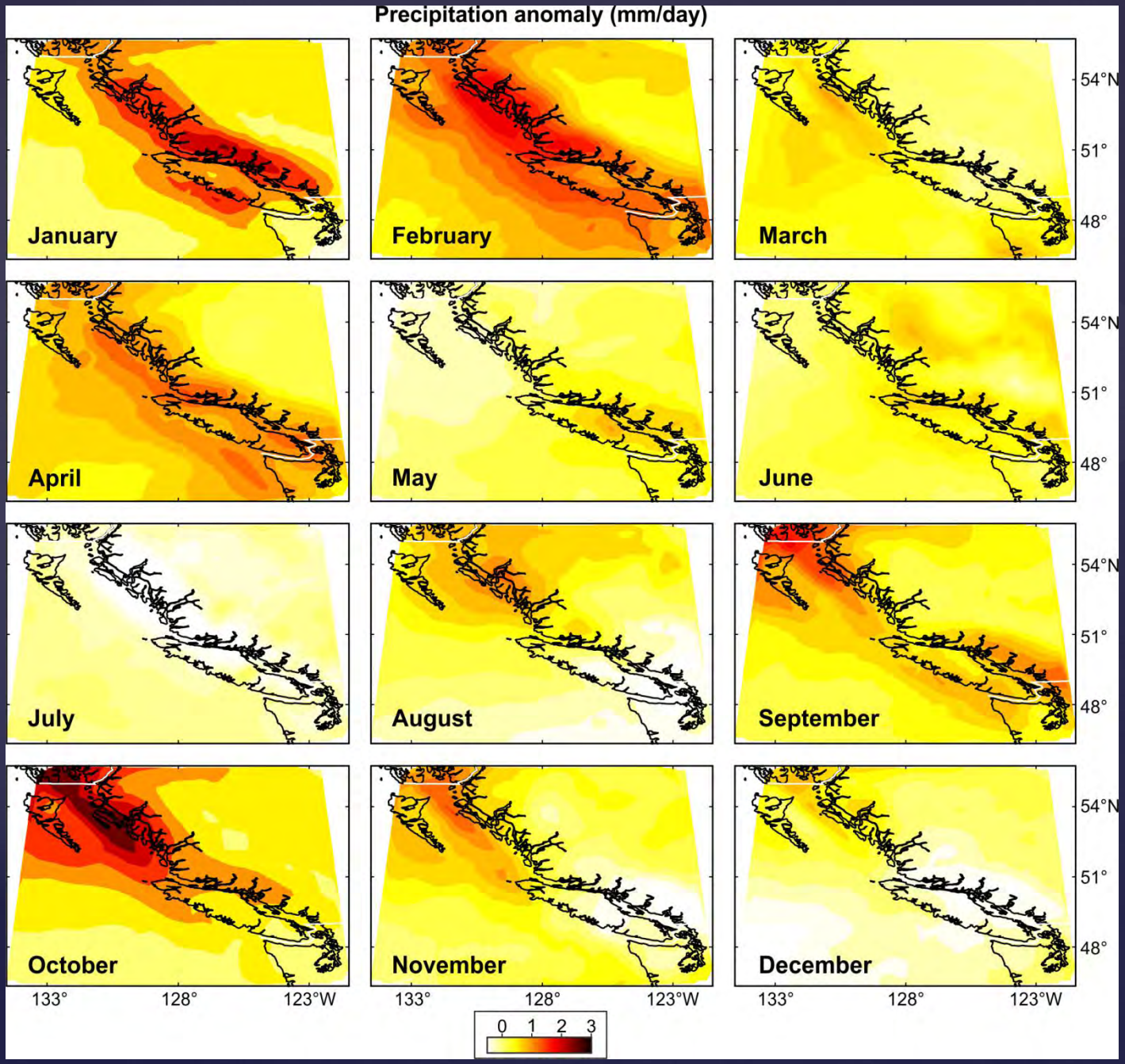


Future Forcing Strategy

- Add NARCCAP RCM or GCM monthly average anomalies (2040-2069 minus 1970-1999) to the forcing & initial fields used by Masson & Fine in their 1995-2008 ROMS hindcast of the BC shelf (3km)
  - JGR 2012
  - 3km horizontal resolution
  - 8 tidal constituents
  - 3 hourly winds (NARR)
  - bulk formula heat flux (NARR)
  - monthly discharge from 21 main rivers
  - monthly open boundary forcing (SODA)
- so far only used CRCM/CGCM3 NARCCAP combination
- More details in Tuesday talk @ 11:05



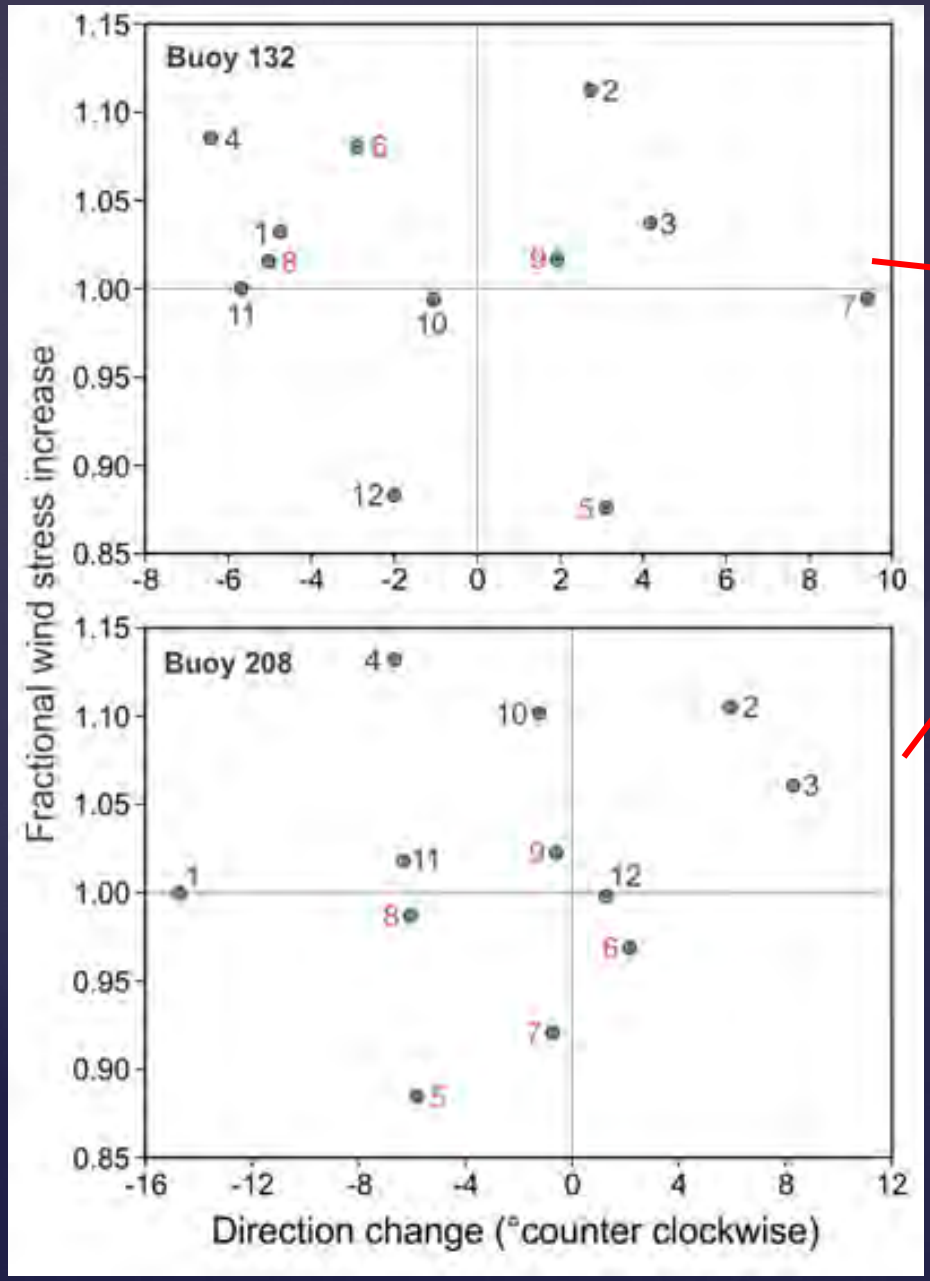
ROMS & AVISO SSH EOFs

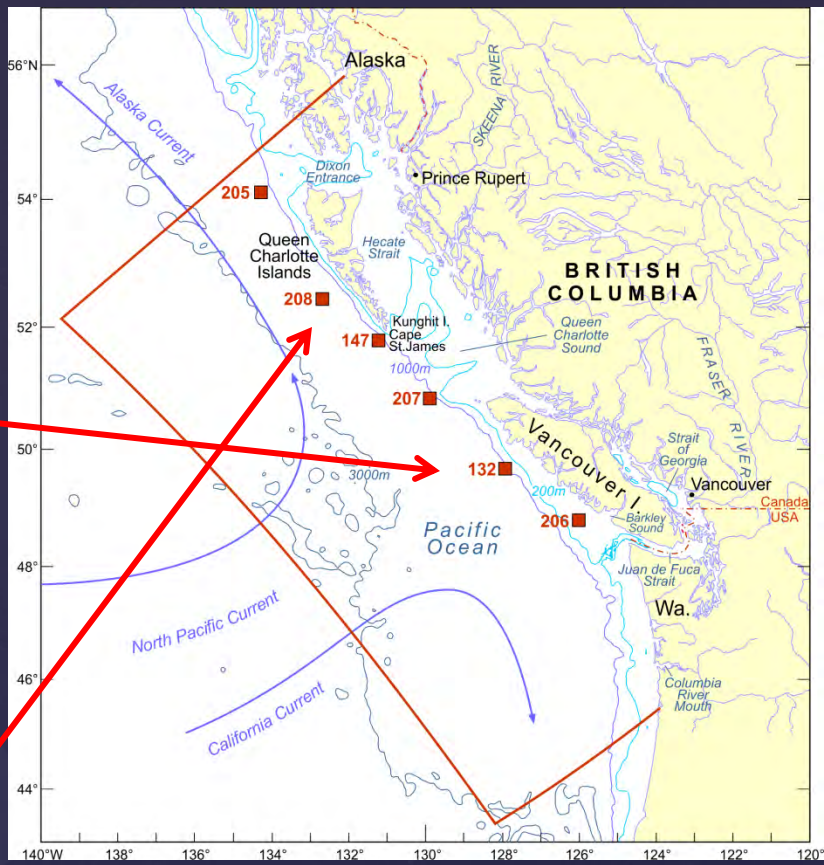


Precipitation Anomalies

- Monthly-averaged differences 2040-2069 minus 1970-1999
- Generally wetter in winter & dryer in summer
- Average annual anomaly ~ +0.5mm/day

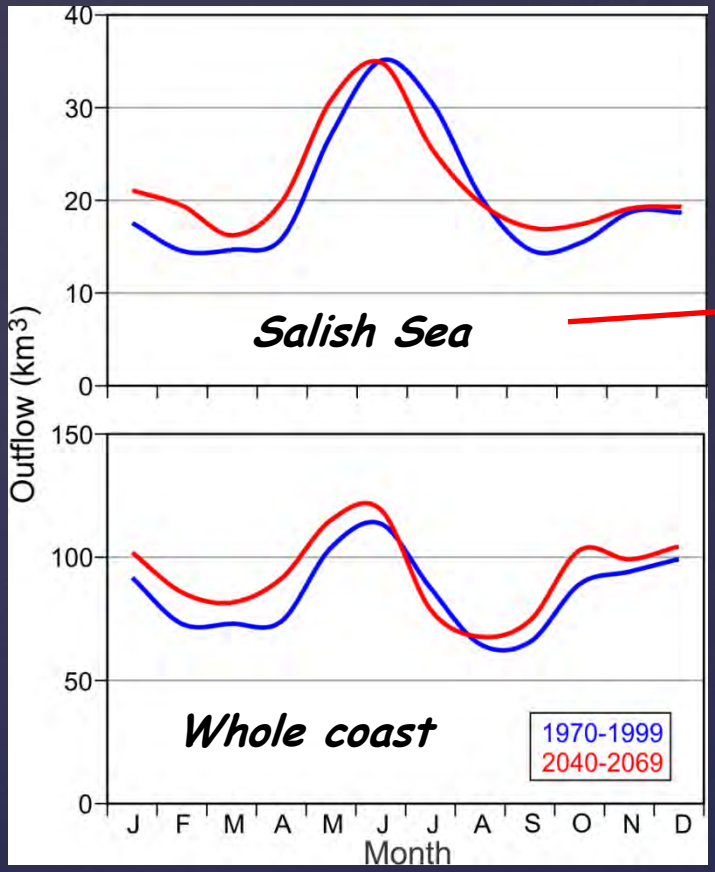
Wind Anomalies

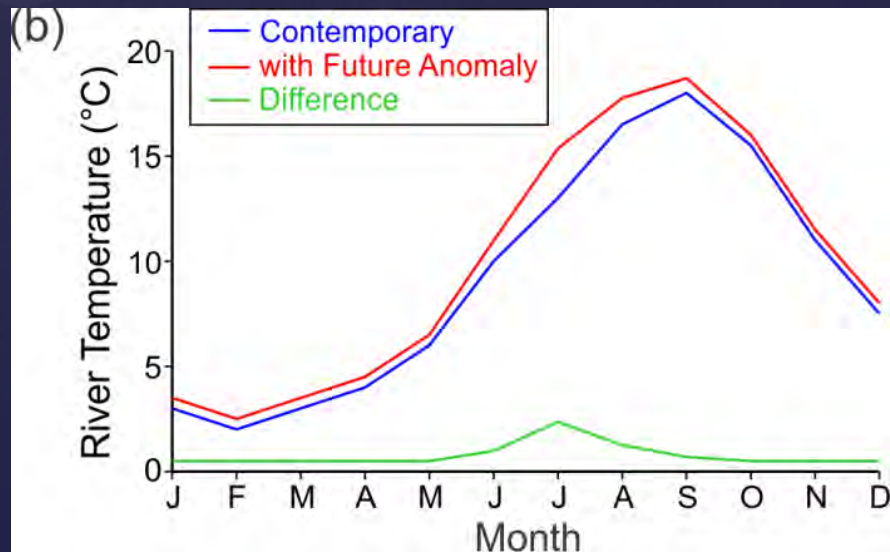




- *Numbered dots = months*
  - *Red = upwelling months*
- *Generally stronger winter winds*
- *Perhaps, stronger summer upwelling winds at buoy 132*

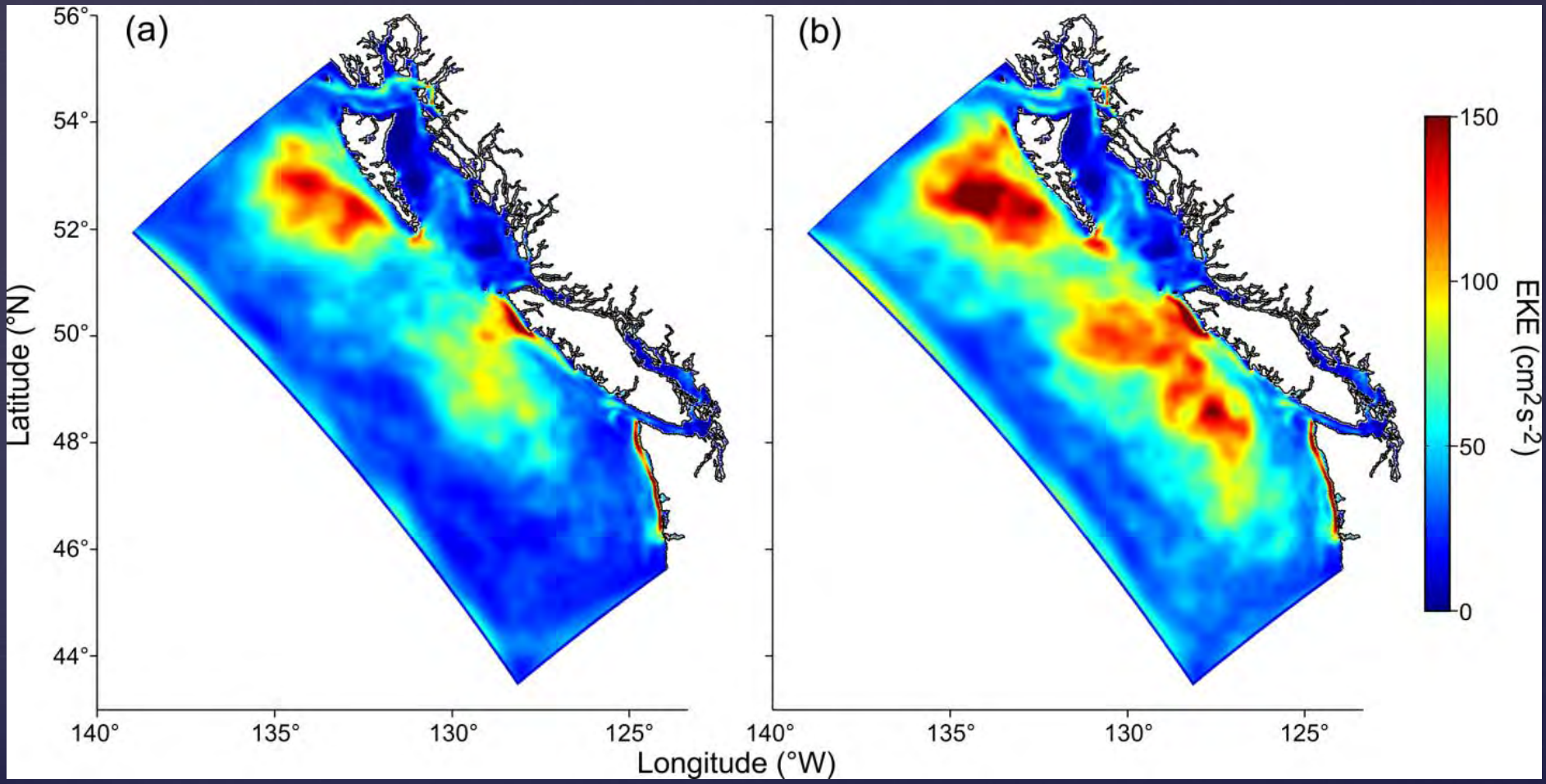
Contemporary & Future Freshwater Discharges





- *21 sub-basins*
- *Except for June-August, more discharge*
- *Warmer river temperatures*

Model Results: Eddy Kinetic Energy



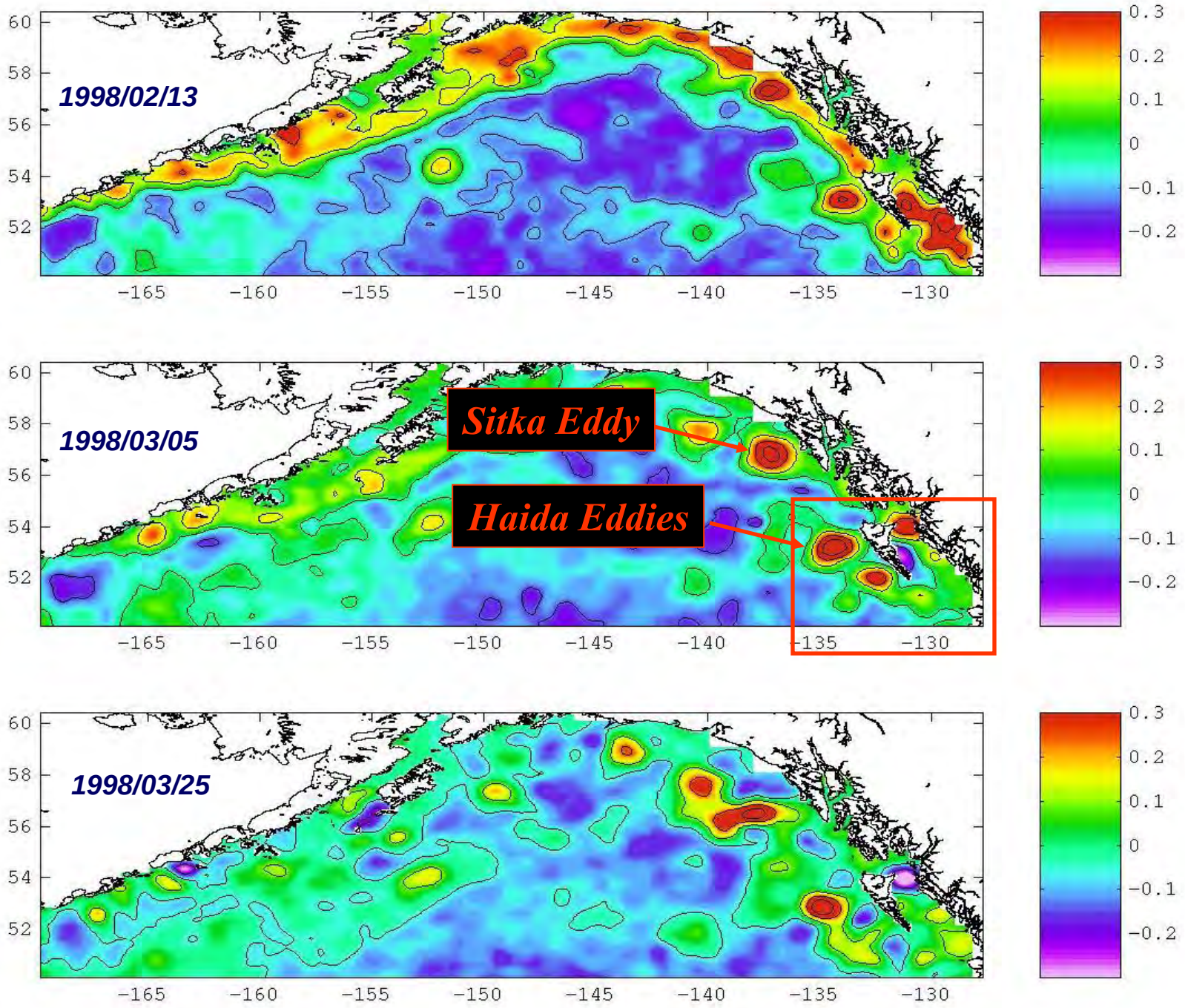
contemporary

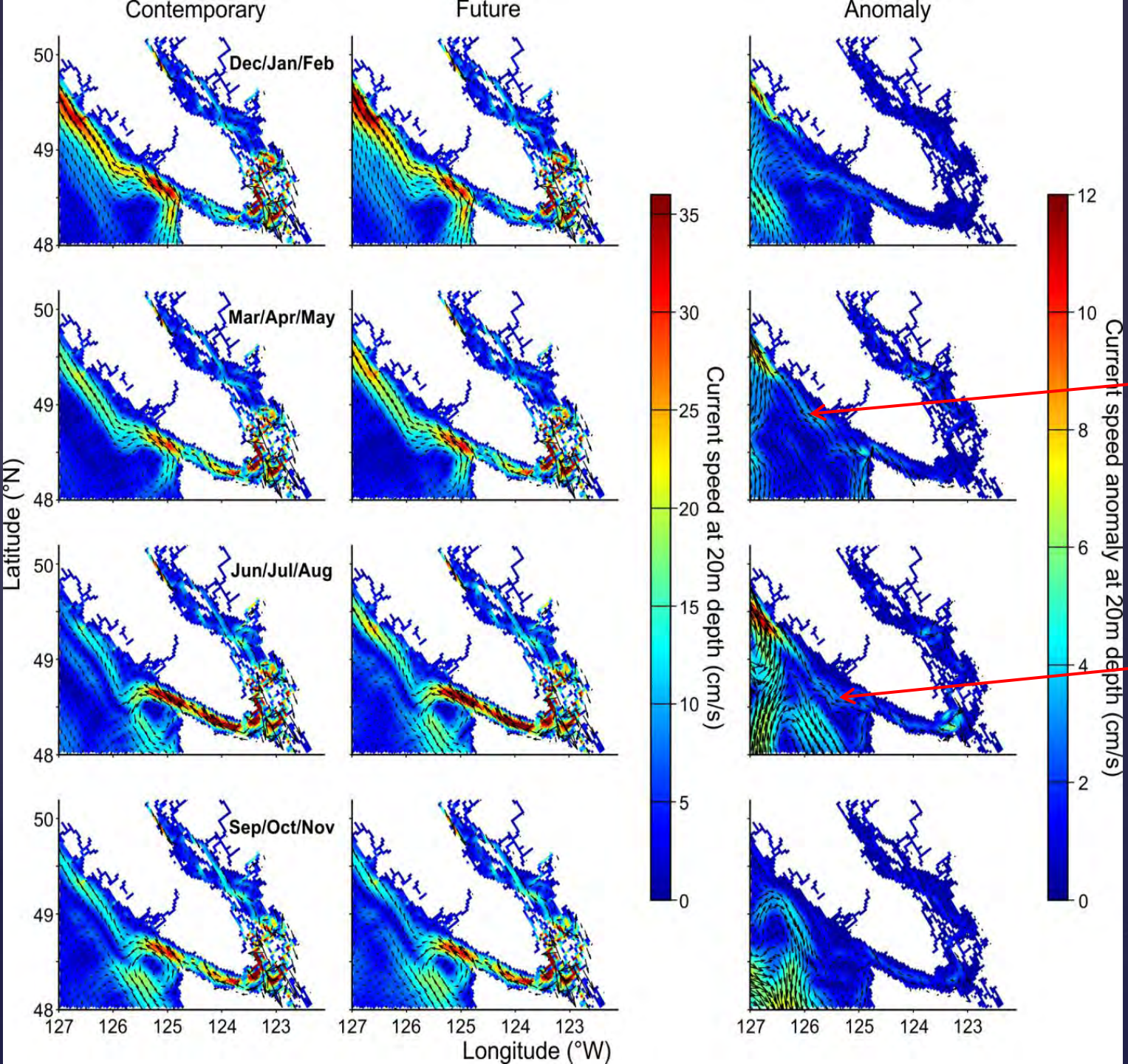
future

- Stronger, not more, Haida Eddies due to stronger winter winds

SSHa

TOPEX/ERS

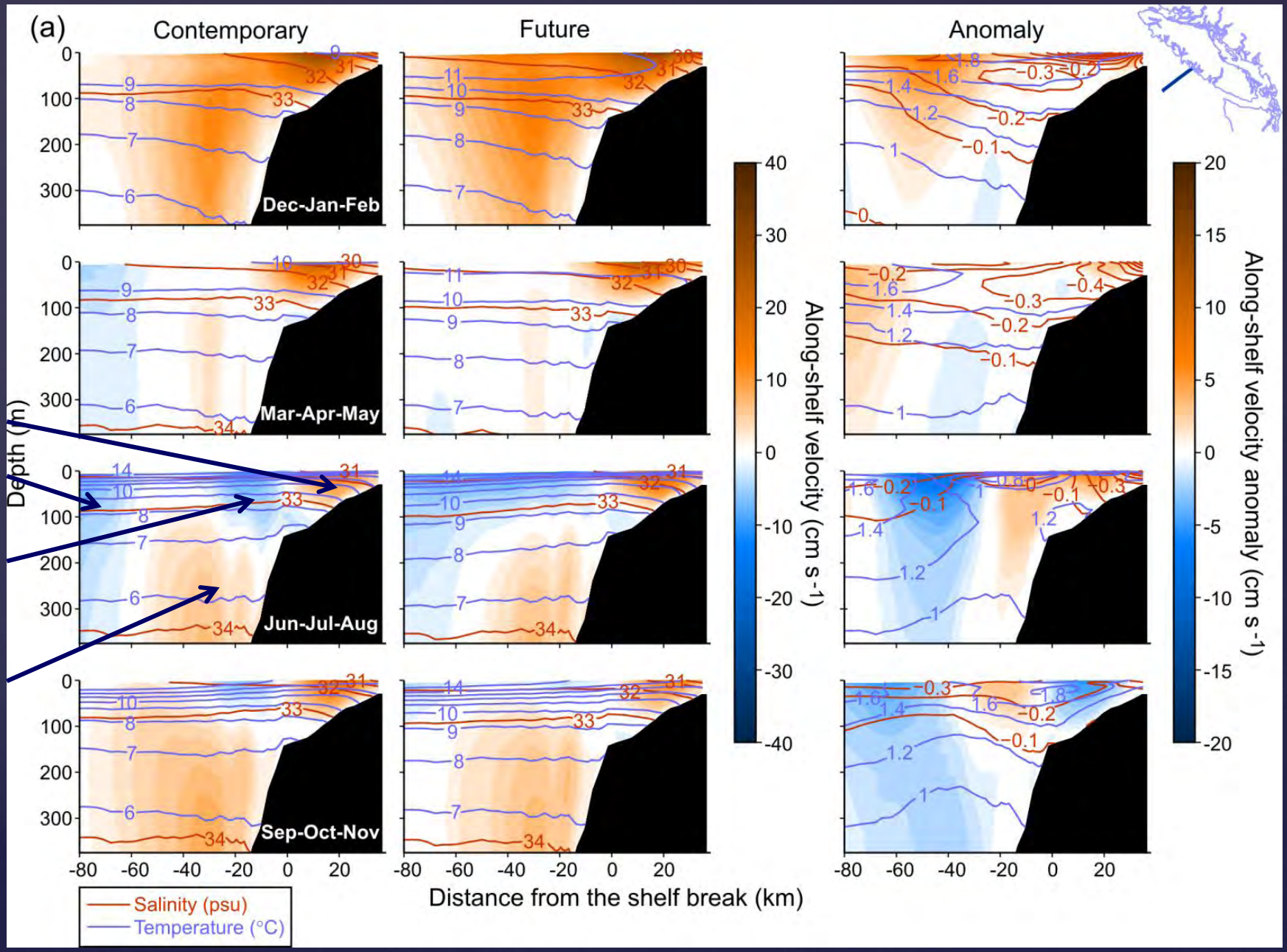




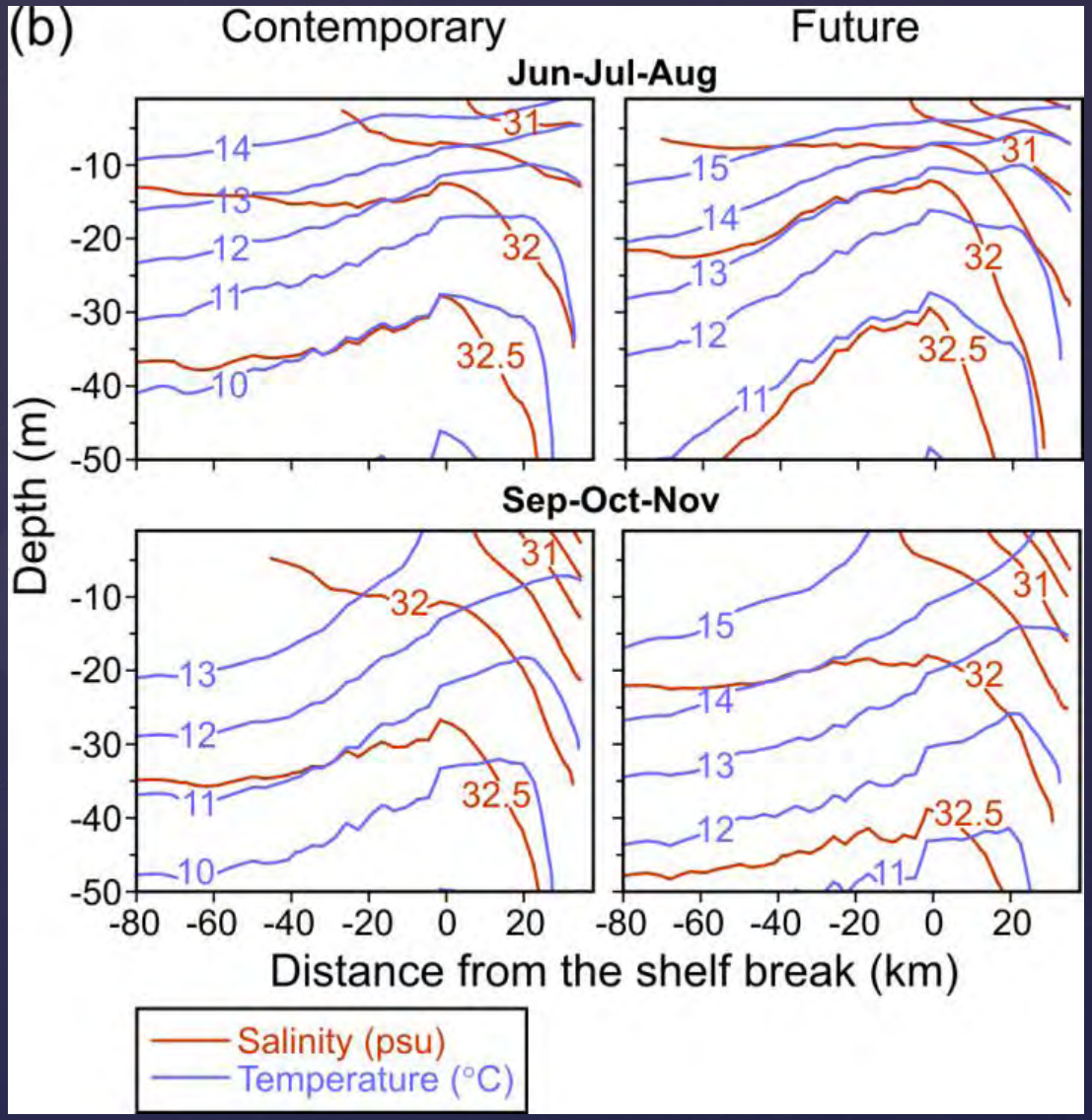
Results

- 20m flows
- Stronger Vancouver Island Coastal Current
- Little change in Juan de Fuca Eddy amplitude (timing too)

Results: Flows, temperatures, salinities off Vancouver Island



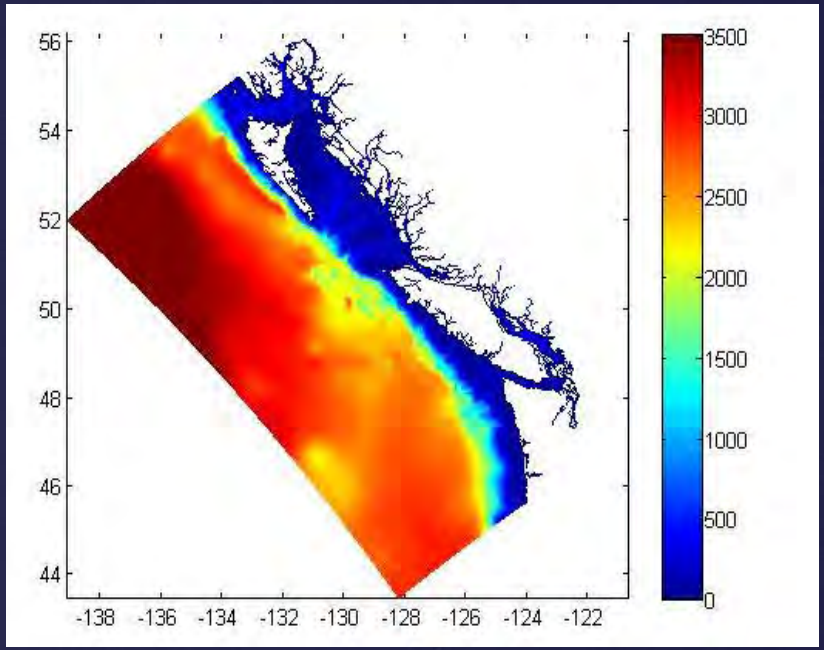
Is there more upwelling?



Not conclusive: T is warmer & coastal current is fresher but isotherms & isohalines not much steeper

Coupling to Lower Trophic Model

ROMS BC RCM + NPZD-O_2-pH

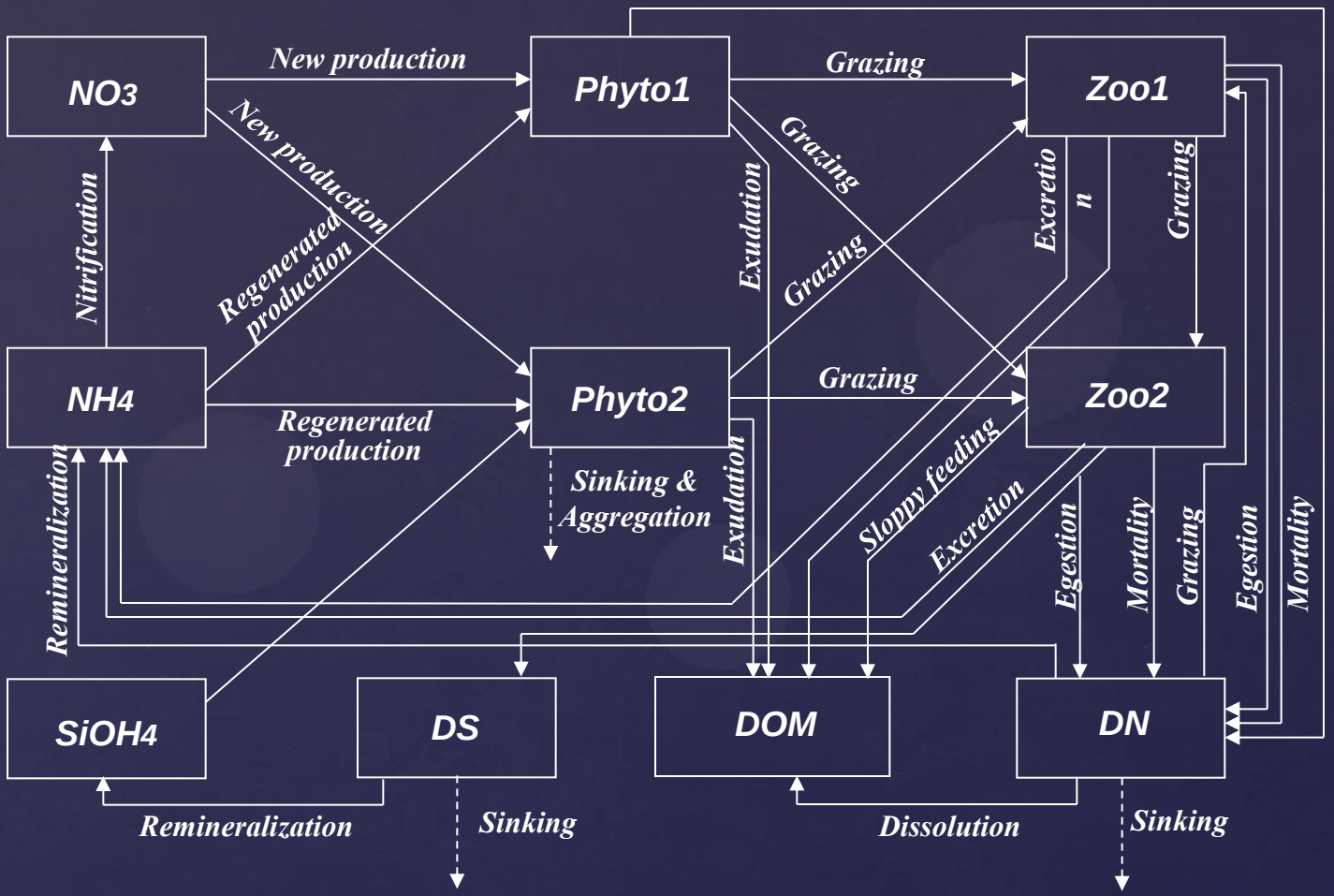


Objectives:

- To detect, understand and predict climate change impacts on:
  - Plankton productivity
  - Nutrient supply, oxygen and carbon content
- Evaluate the potential risk (likelihood) for the development of hypoxia events and corrosive conditions

- More details in Angelica Peña's talk, Tuesday Session 2 @ 16:10

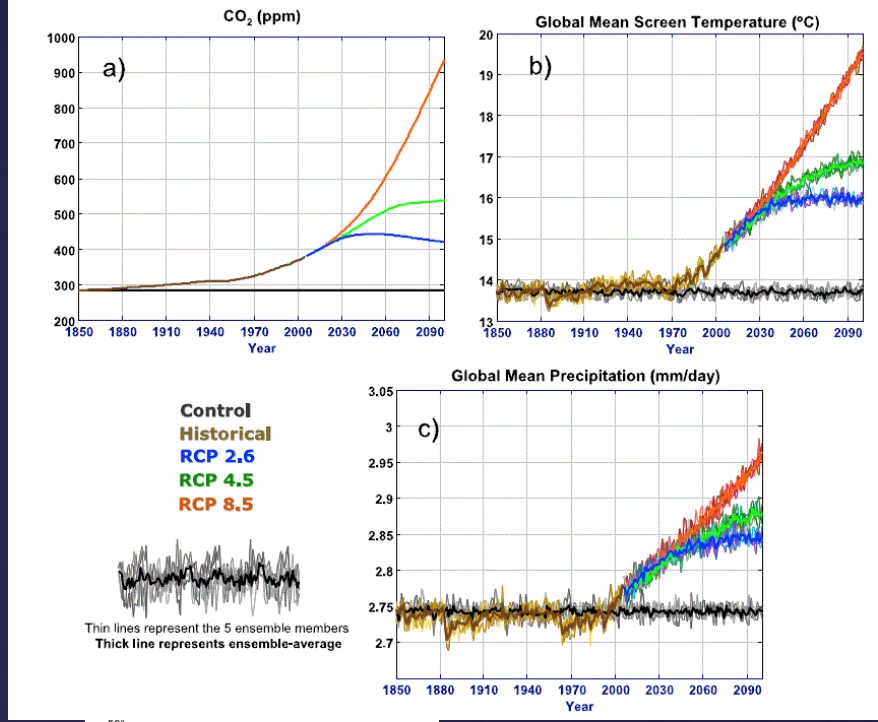
Biogeochemical model

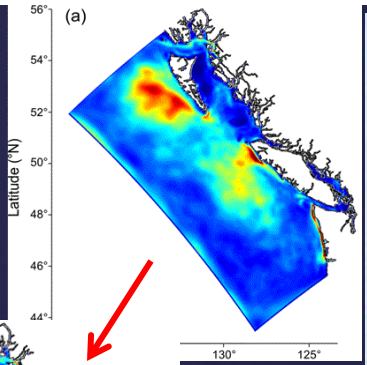


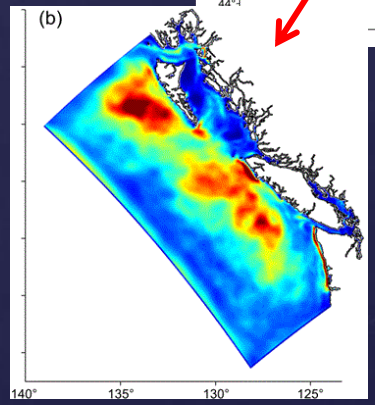
- Cycle of several biogeochemical elements (N, C, Si(OH)4 and O_2)
- Two-types of phytoplankton and of zooplankton
- Dynamic chlorophyll compartments
- Temperature dependence of physiological rates

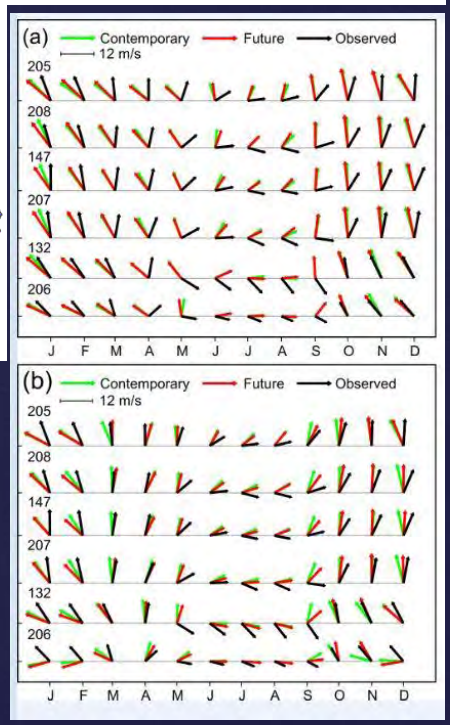
Summary

- Status & plans for Canadian GCM and RCMs
- Development of, & results from, BC ocean-only RCM
  - Future work
- Plans for biogeochemical coupled BC RCM









Summary

- BC RCM projections:
  - More EKE (winter)
  - Stonger Haida, Goose Island Bank, Middle Bank, Rose Spit Eddies in some seasons
  - Stronger Vancouver Island coastal current
  - Little (if any) change in upwelling & JdF Eddy
  - Can't comment on California Undercurrent
- More details in 2 recent Atmosphere-Ocean papers