# Toward a Regional Climate Model for the British Columbia Continental Shelf


Mike Foreman[1], Badal Pal[2], Bill Merryfield[2], Diane Masson[1], John Morrison[1], Wendy Callendar[13], Thomas Grime[14], Eric Salathé[5]

[1]Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney BC

[2]Canadian Centre for Climate Modelling and Analysis, Victoria BC

[3]School of Earth and Ocean Sciences, University of Victoria

[4]Department of Mechanical Engineering, University of Victoria

[5]Climate Impacts Group, University of Washington, Seattle


University of Victoria

Fisheries and Oceans Canada | Pêches et Océans Canada

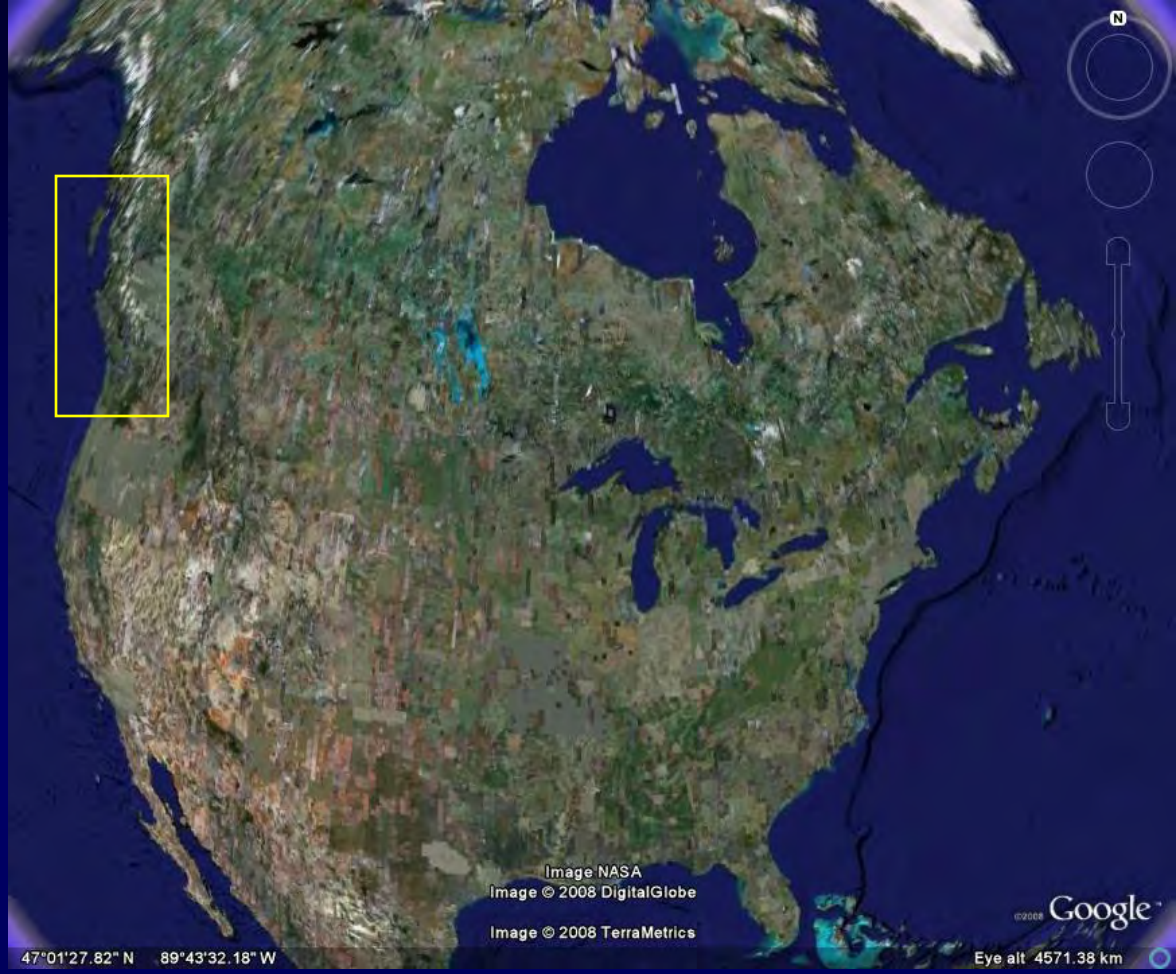
IOS

CLIMATE IMPACTS GROUP

CCCma

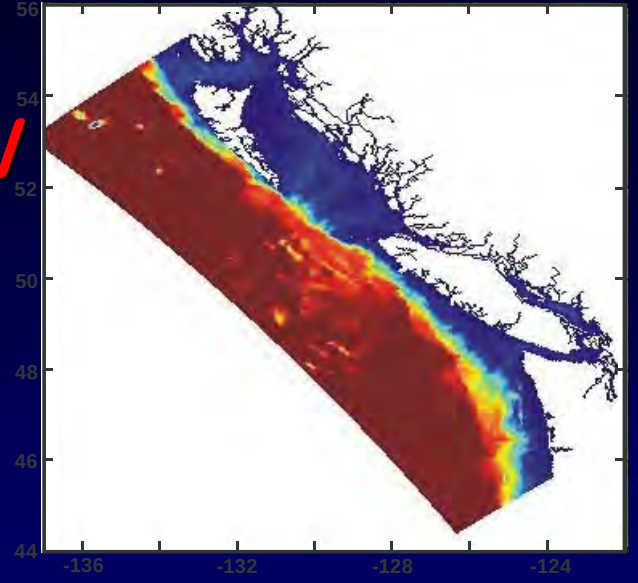
Environment Canada | Environnement Canada

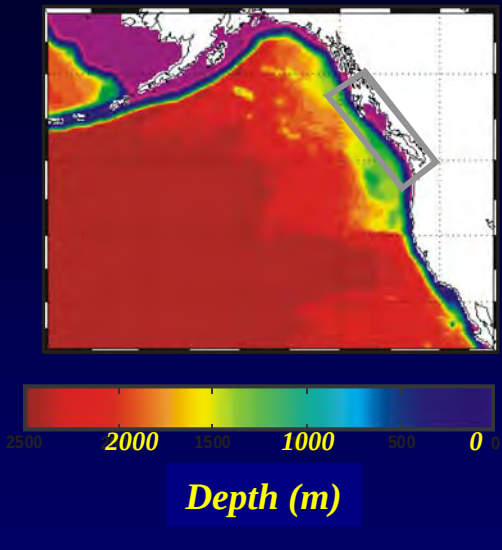
# Outline




- RCM details
- Required forcing & progress to-date
- Historical trends & relevant ecosystem issues
- Summary & future work

# The BC Shelf Model




Regional Ocean Modeling System (ROMS): Masson

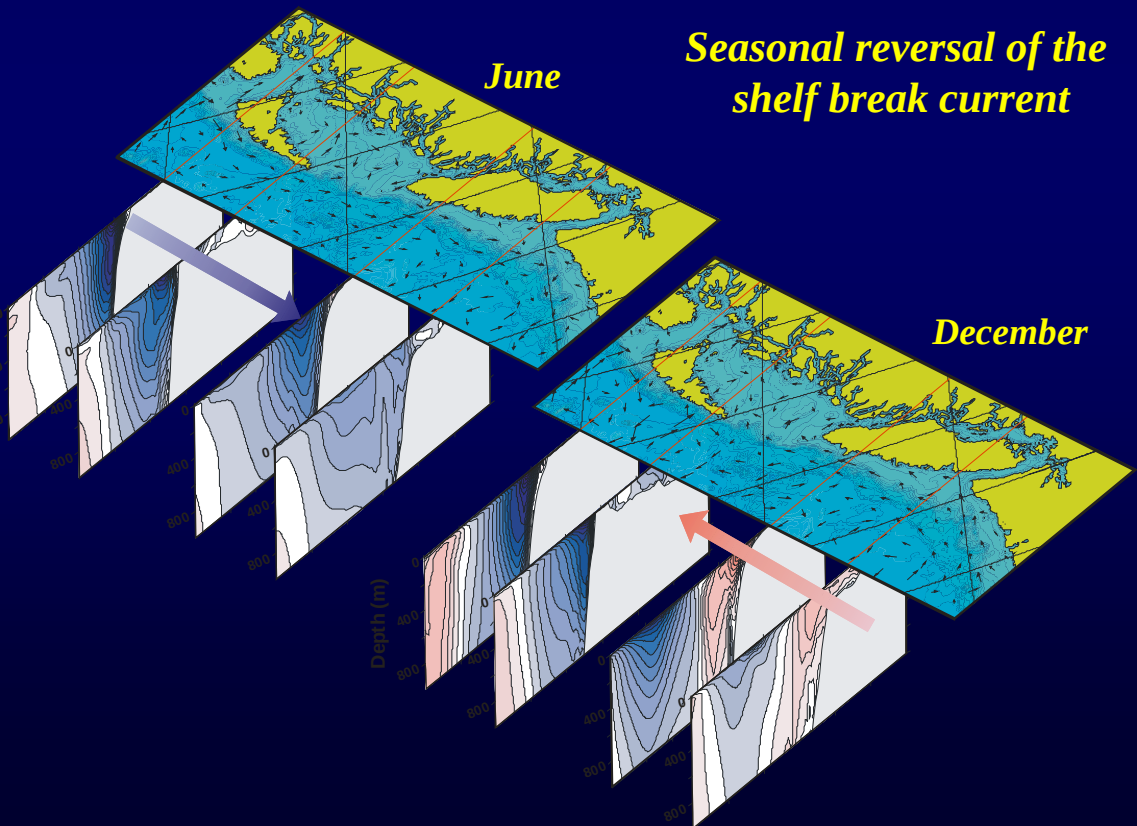
- 3km resolution
- forcing: tides, wind, heat flux, freshwater discharge, open boundary

Over annual seasonal cycle, the model behaves realistically for

- tides
- thermal stratification (including summer upwelling)
- reversal of the shelf break current (northward in winter, southward in summer)
- eddy generation

New HP 256-cpu machine just delivered

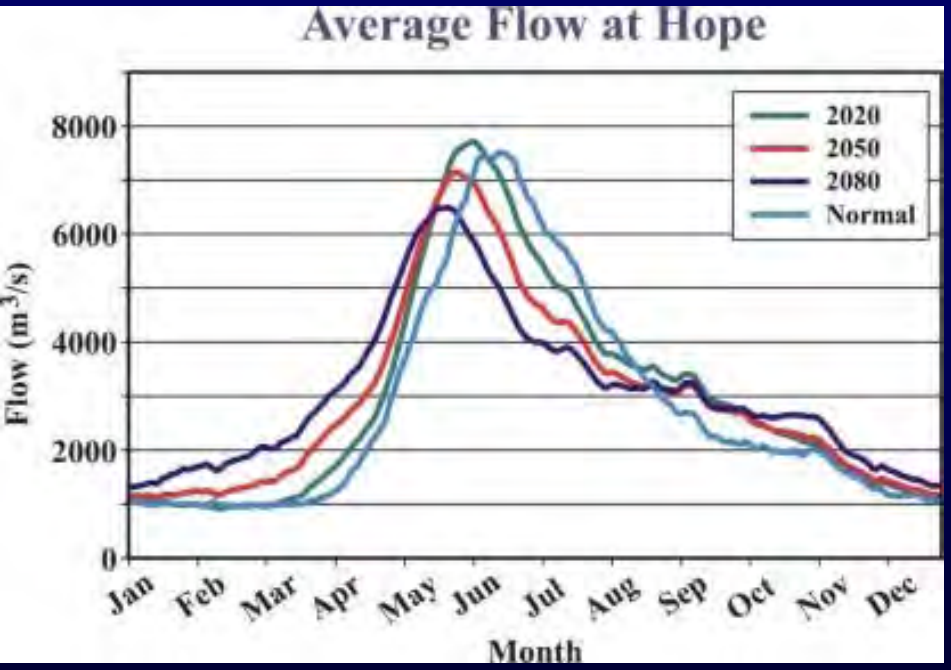
- will make decadal runs feasible

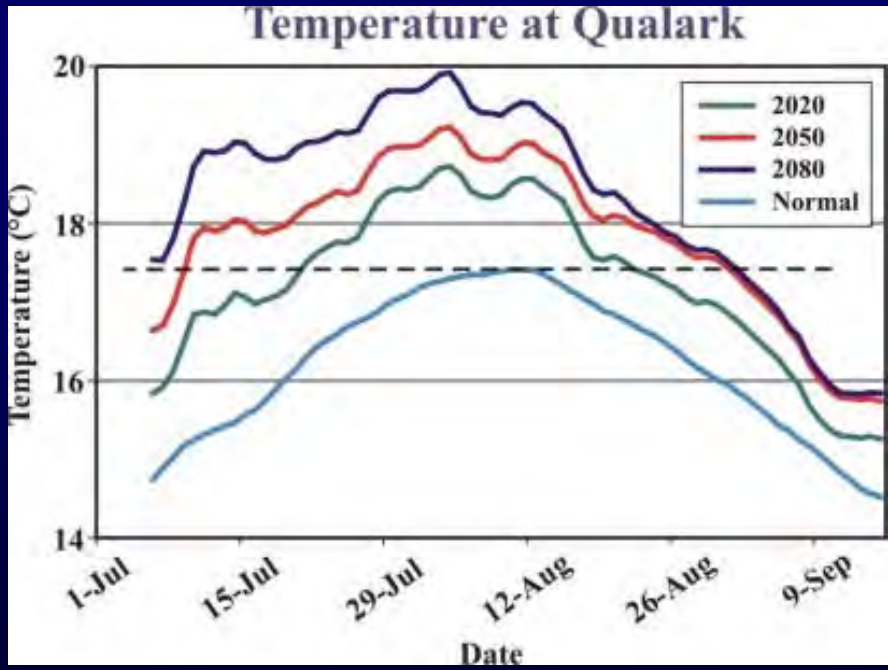



Seasonal reversal of the shelf break current

# Future Forcing for the RCM

1. Tidal forcing unchanged
2. Wind & heat flux thru interpolation from GCMs and/or RCMs
3. Oceanic initial conditions & boundary forcing from ocean component of GCMs (or Enrique's NEP nested model)
4. Freshwater runoff by downscaling precipitation & temperature from RCMs

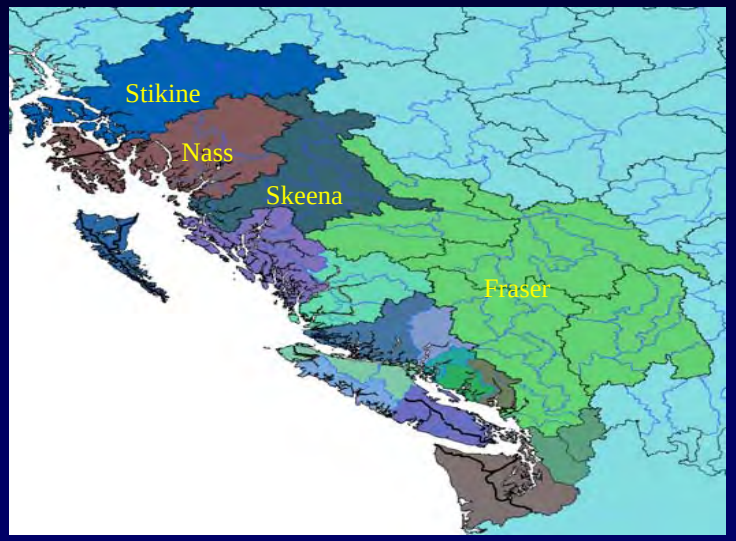


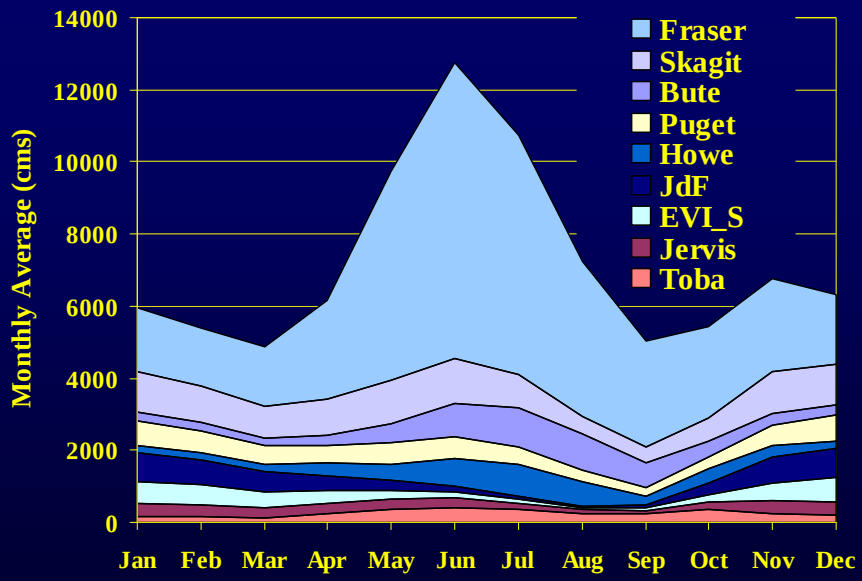




*Fraser River projections: Morrison et al., J. Hydrology, 2002*

# Freshwater Flux along the BC Coast

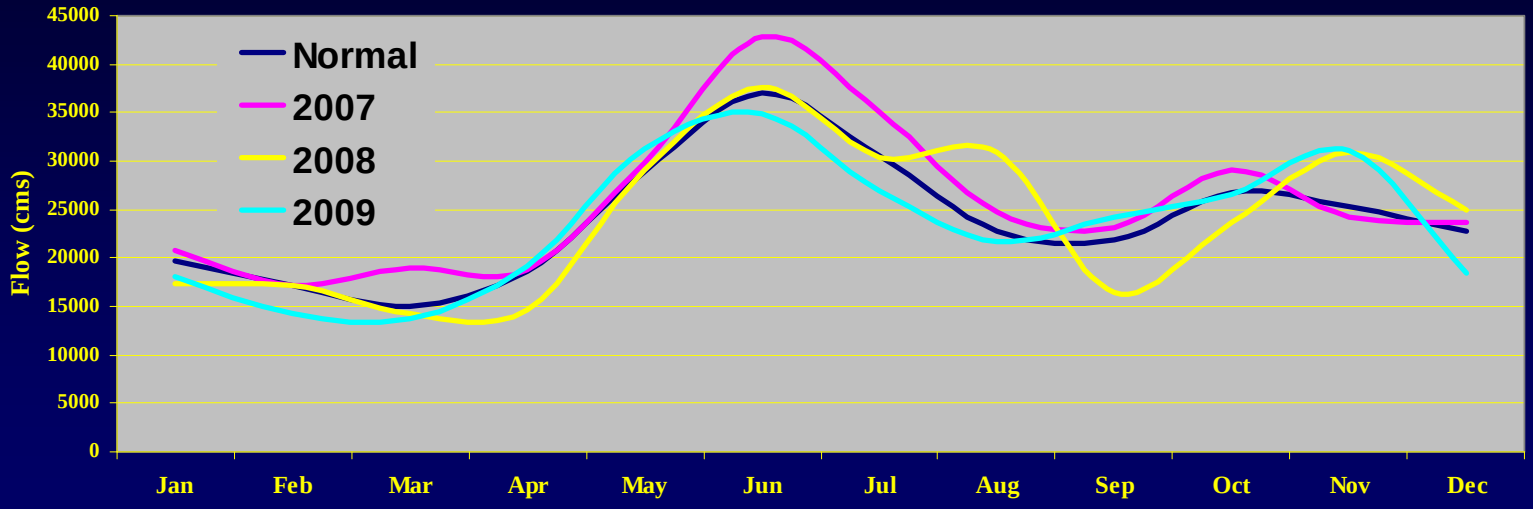
- Baroclinic flows largely determined by salinity rather than temperature
  - freshwater discharges generate coastal currents which are imp't to marine ecosystems
- Total drainage basin ≈ 610,000 km² but 40% is ungauged (mountainous, sparsely populated)
- Technique developed to estimate ungauged runoff using precipitation, terrain, storage capacity etc. within watersheds
  - Verified with historical observations
  - will be used with future projections

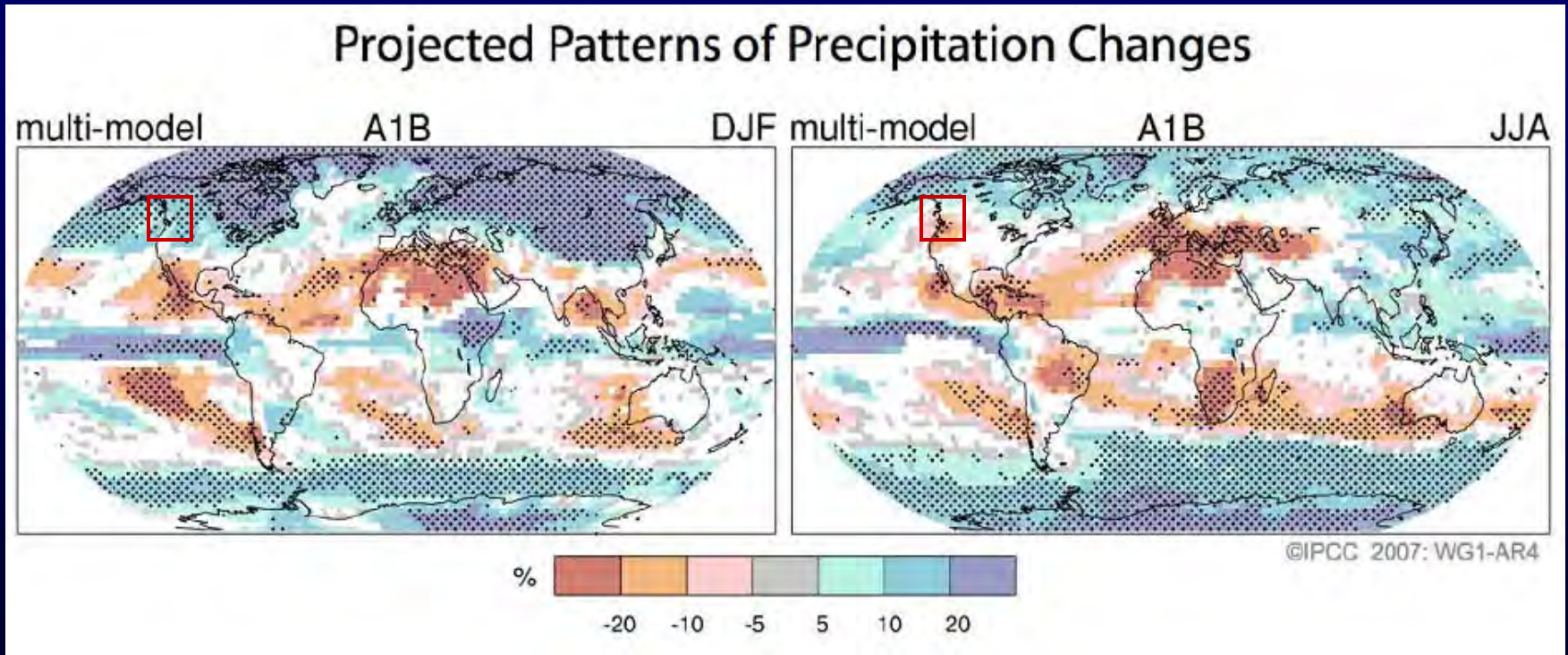



Salish Sea Runoff

# Recent & Projected BC Freshwater Fluxes



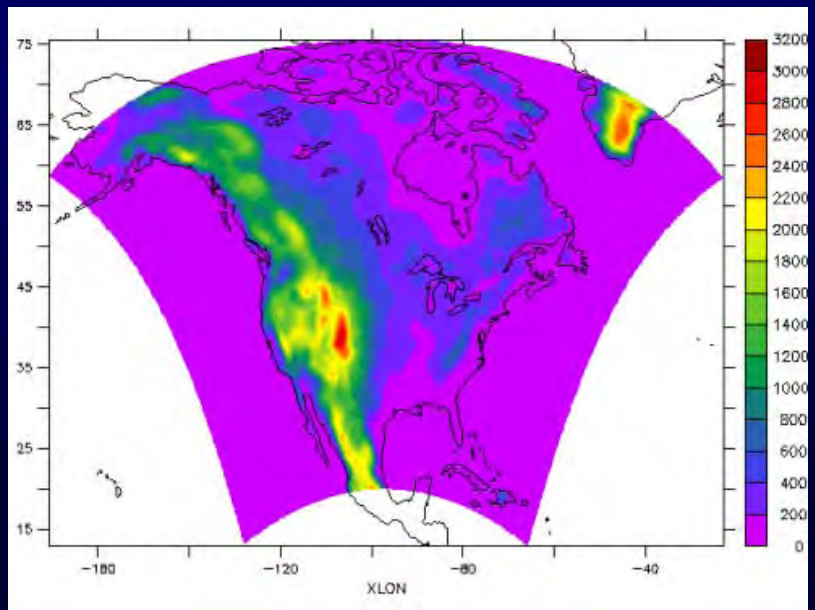
# Ensemble of Regional Climate Models

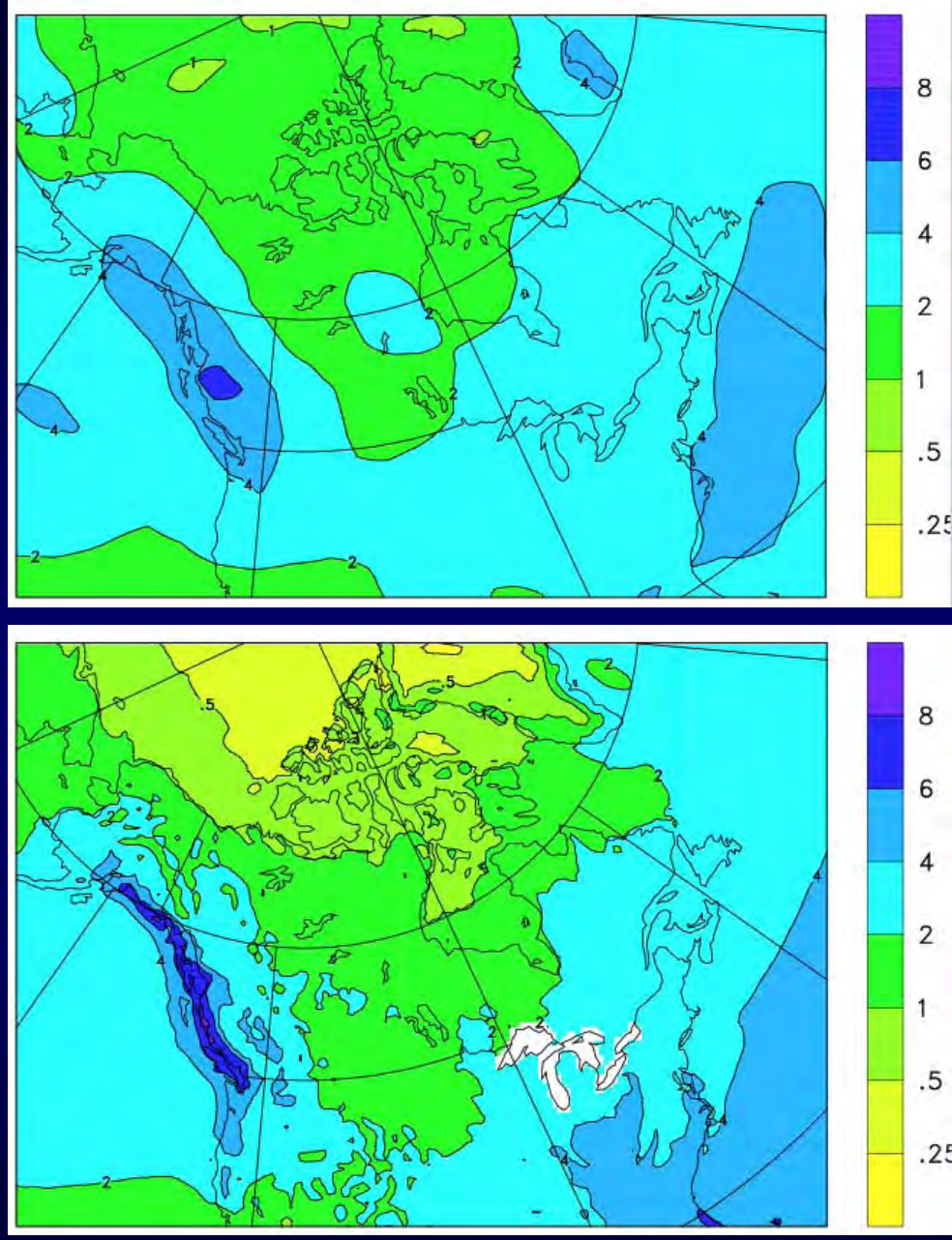
- 6 RCMs in North American Regional Climate Change Assessment Program (NARCCAP)

- 50 km resolution

- 1971-2000 & 2041-2070 (A2) simulations

- http://www.narccap.ucar.edu



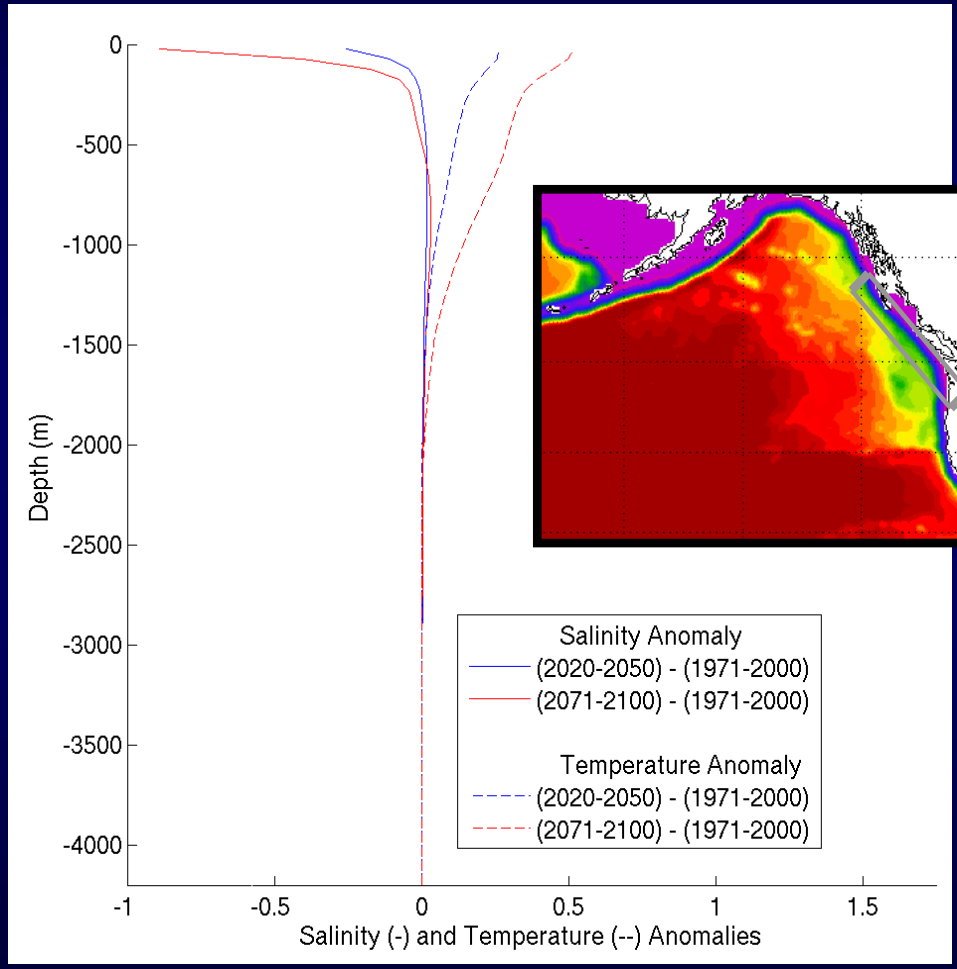

Mean (1971-90) daily precipitation (mm) as computed by top): the CCCma global climate model, bottom): the CRCM.

# Changes in Oceanic Salinities & Temperatures

- Lateral boundary & initial 3D salinity & temperature fields for future simulations will either be
  - anomalies added to present-day climatologies
  - or from Enrique's model

- Anomalies computed from CCCma CGCM3.1 T47 SRES A2 run #4 -- Averages over shelf model domain

- BC waters are becoming fresher & warmer



# Historical Trends & Future Projections of Offshore Winds


- network of 15 offshore buoys with observations back to 1958
- Looked at recent trends & future projections
- How well do GCMs & RCMs represent these winds?

# GCM Wind Analyses

- 10m winds from 18 GCMs
- Interpolate to buoy locations
  - evaluate accuracy by comparing monthly & seasonal averages over specific periods
  - compute future projection anomalies
- Merryfield et al (2009)

Table 1: Climate models used in this study and their atmospheric resolutions

| Symbol | Institution/Model | Atmospheric resolution* | Horiz grid dimensions lon × lat |
|---|---|---|---|
| a | BCCR/BCM2.0 | T63L31 | 128 x 64 |
| b | CCCMA/CGCM3.1(T47) | T47L31 | 96 x 48 |
| c | CCCMA/CGCM3.1(T63) | T63L31 | 128 x 64 |
| d | CCSR/MIROC3.2(med) | T42L20 | 128 x 64 |
| e | CNRM/CM3 | T63L45 | 128 x 64 |
| f | CSIRO/Mk3.5 | T63L18 | 192 x 96 |
| g | GFDL/CM2.0 | 2.5° × 2°L24 | 144 x 90 |
| h | GFDL/CM2.1 | 2.5° × 2°L24 | 144 x 90 |
| i | GISS/AOM | 4° × 3°L12 | 90 x 60 |
| j | GISS/EH | 5° × 4°L20 | 72 x 46 |
| k | GISS/ER | 5° × 4°L20 | 72 x 46 |
| l | INM/CM3.0 | 5° × 4°L21 | 72 x 45 |
| m | IPSL/CM4 | 2.5° × 3.75°L19 | 96 x 72 |
| n | MIUB/ECHO-G | T30L19 | 96 x 48 |
| o | MPI/ECHAM5 | T63L31 | 192 x 96 |
| p | MRI/CGCM2.3.2 | T42L30 | 128 x 64 |
| q | UKMO/HadCM3 | 3.75° × 2.5°L19 | 96 x 72 |
| r | UKMO/HadGEM1 | 1.875° × 1.25°L38 | 192 x 144 |

*Horizontal resolution is described by spectral truncation or grid box dimensions as appropriate, and vertical resolution by the number of model levels, e.g. L31.

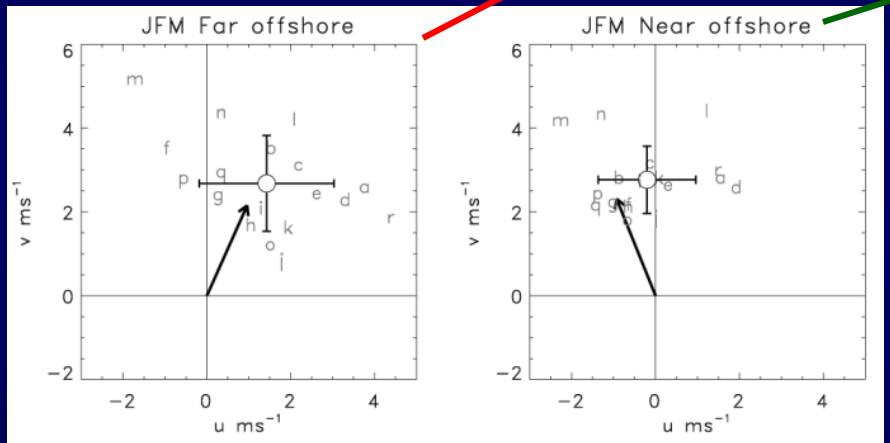
# Evaluation of 1976-95 Seasonal Average Winds

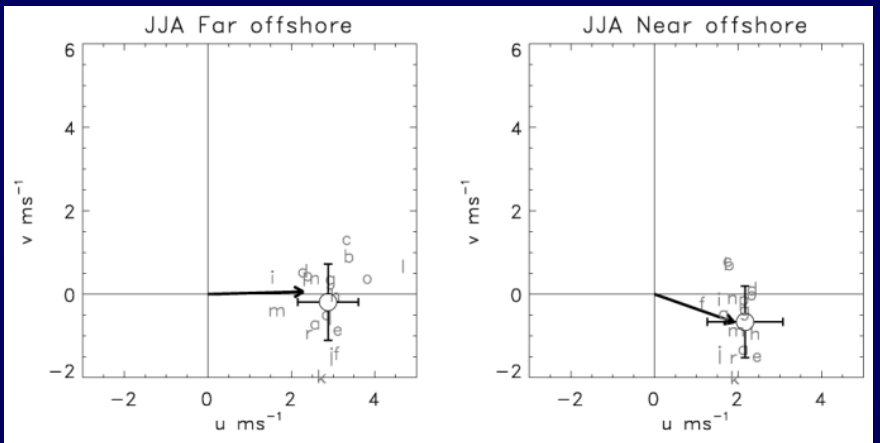

Table 1: Climate models used in this study and their atmospheric resolutions

| Symbol | Institution/Model | Atmospheric resolution* | Horiz grid dimensions lon × lat |
|---|---|---|---|
| a | BCCR/BCM2.0 | T63L31 | 128 x 64 |
| b | CCCMA/CGCM3.1(T47) | T47L31 | 96 x 48 |
| c | CCCMA/CGCM3.1(T63) | T63L31 | 128 x 64 |
| d | CCSR/MIROC3.2(med) | T42L20 | 128 x 64 |
| e | CNRM/CM3 | T63L45 | 128 x 64 |
| f | CSIRO/Mk3.5 | T63L18 | 192 x 96 |
| g | GFDL/CM2.0 | 2.5° × 2°L24 | 144 x 90 |
| h | GFDL/CM2.1 | 2.5° × 2°L24 | 144 x 90 |
| i | GISS/AOM | 4° × 3°L12 | 90 x 60 |
| j | GISS/EH | 5° × 4°L20 | 72 x 46 |
| k | GISS/ER | 5° × 4°L20 | 72 x 46 |
| l | INM/CM3.0 | 5° × 4°L21 | 72 x 45 |
| m | IPSL/CM4 | 2.5° × 3.75°L19 | 96 x 72 |
| n | MIUB/ECHO-G | T30L19 | 96 x 48 |
| o | MPI/ECHAM5 | T63L31 | 192 x 96 |
| p | MRI/CGCM2.3.2 | T42L30 | 128 x 64 |
| q | UKMO/HadCM3 | 3.75° × 2.5°L19 | 96 x 72 |
| r | UKMO/HadGEM1 | 1.875° × 1.25°L38 | 192 x 144 |

*Horizontal resolution is described by spectral truncation or grid box dimensions as appropriate, and vertical resolution by the number of model levels, e.g. L31

***winter*** ***summer***



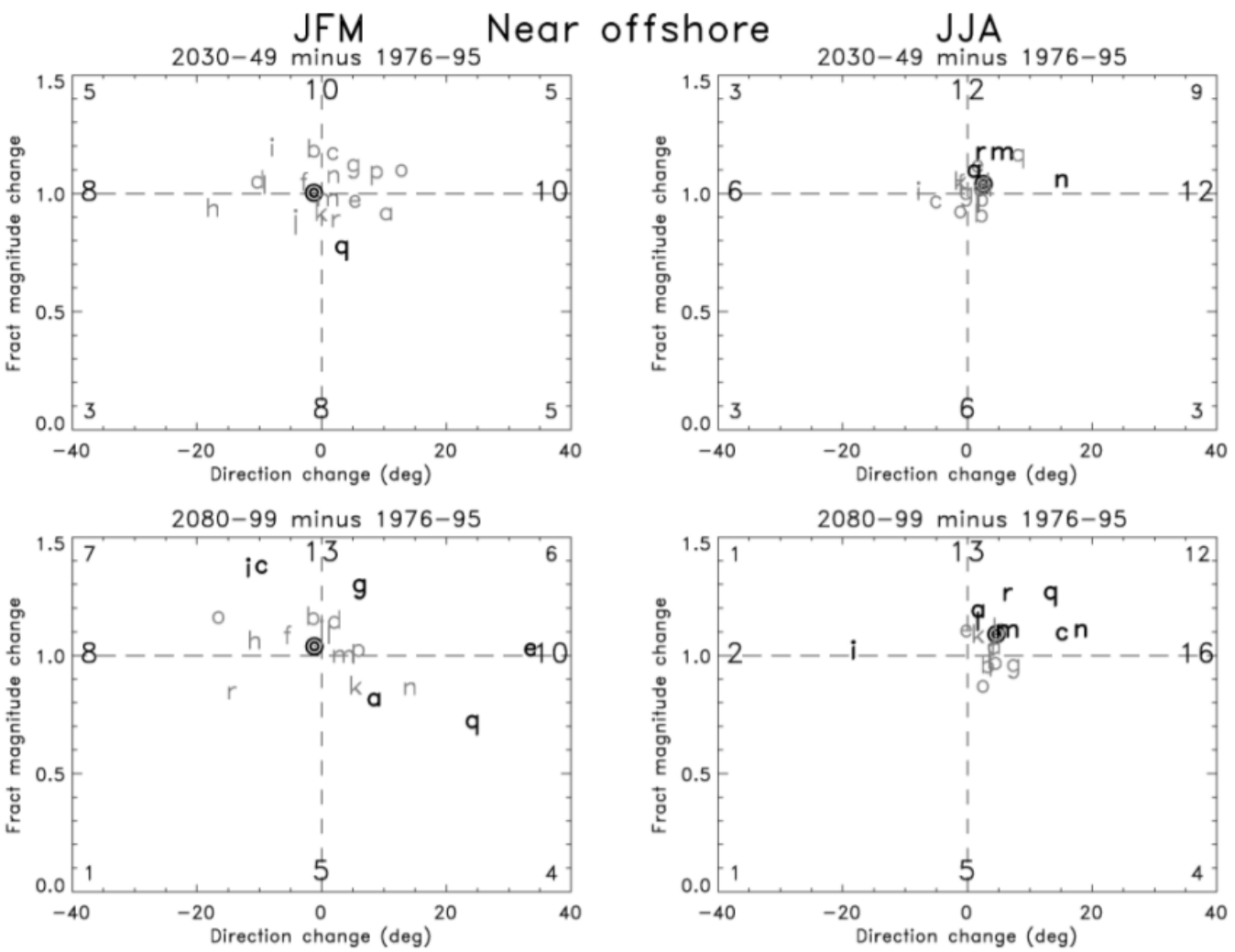

# GCM Wind Projections (scenario A1B) along the BC Shelf

**winter** **summer**

**2030-49**

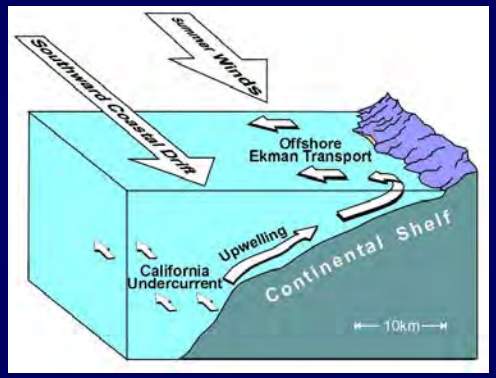
**2080-99**

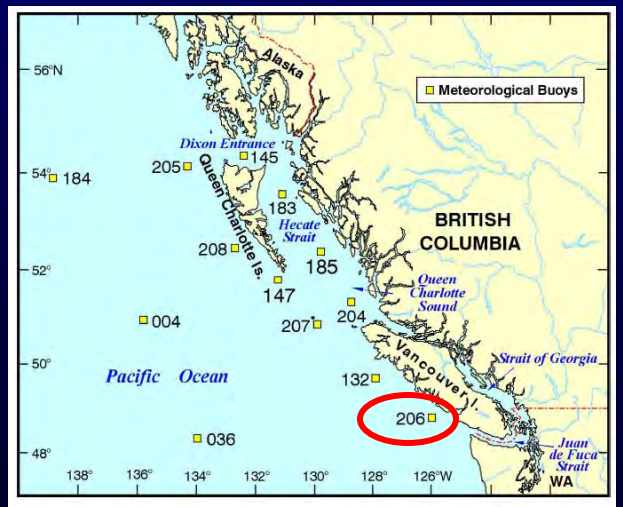
**5% increase in magnitude, 5° rotation counterclockwise**



# Observed Changes in Upwelling Timing

- Upwelling brings nutrients to ocean surface
  - Ecosystem productivity



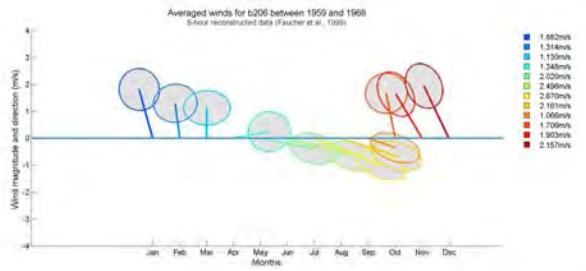

1959-68

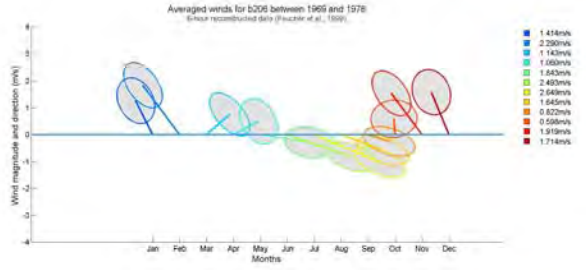
1969-78

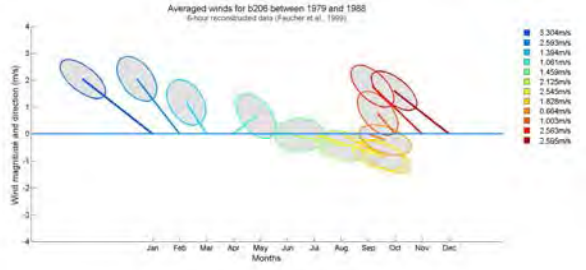
1979-88

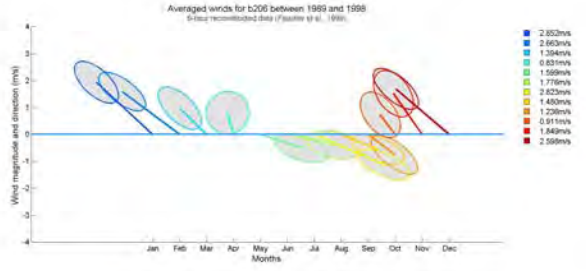
1989-98

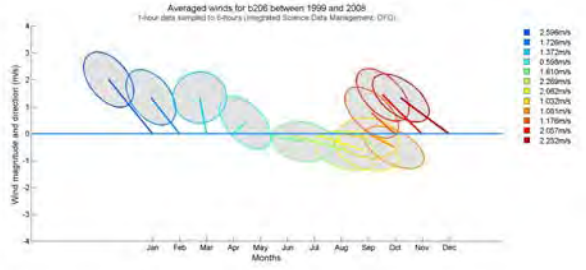
1999-2008



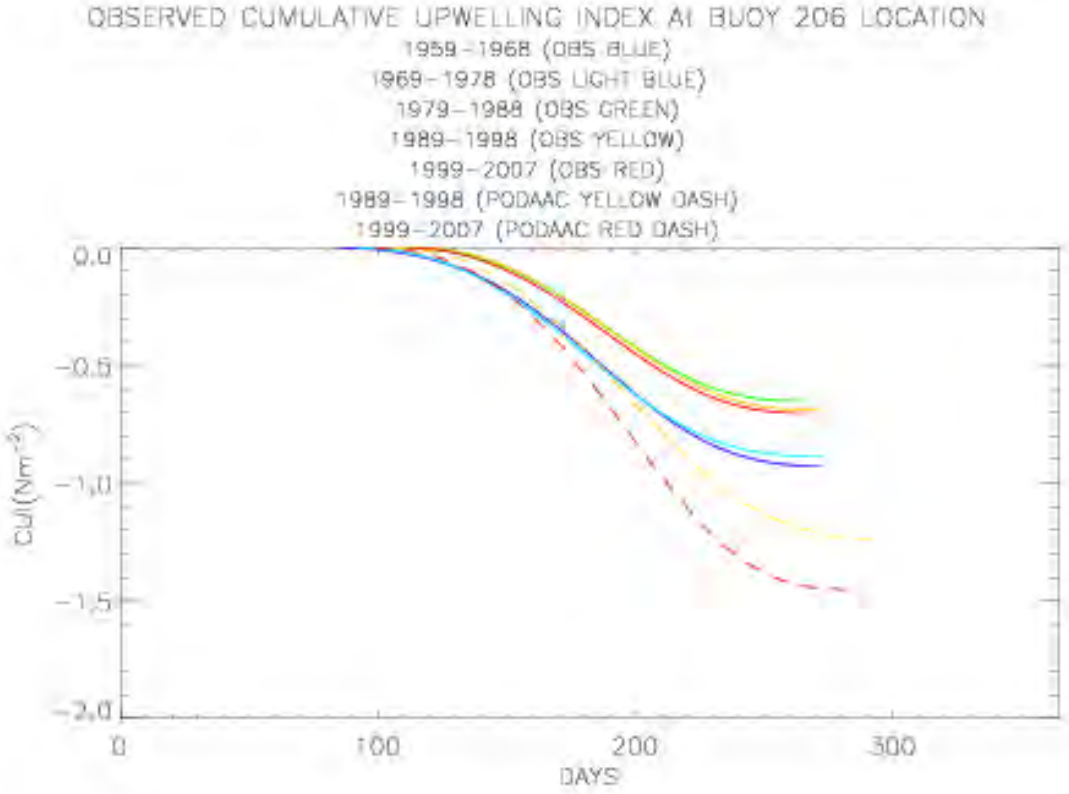



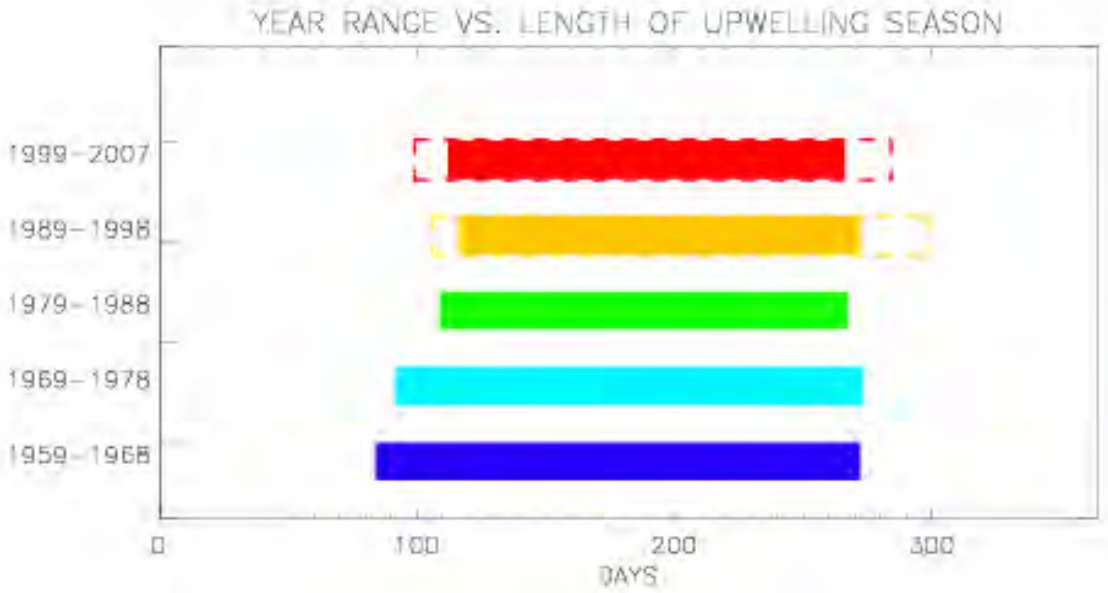



# Changes in Upwelling Magnitude & Timing

- Cumulative upwelling index (Schwing et al, 2006) integrates the wind stress over the upwelling period

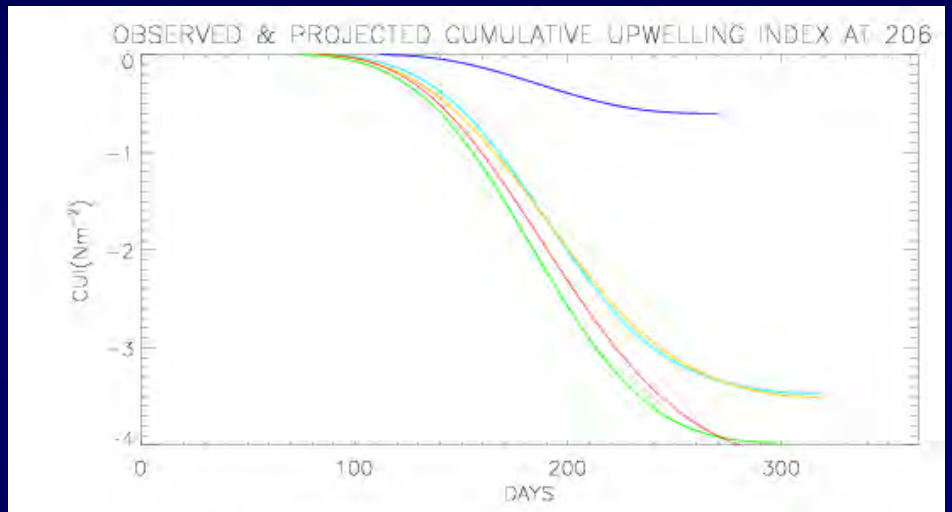
- Bograd et al (2009) found similar trend off Washington state

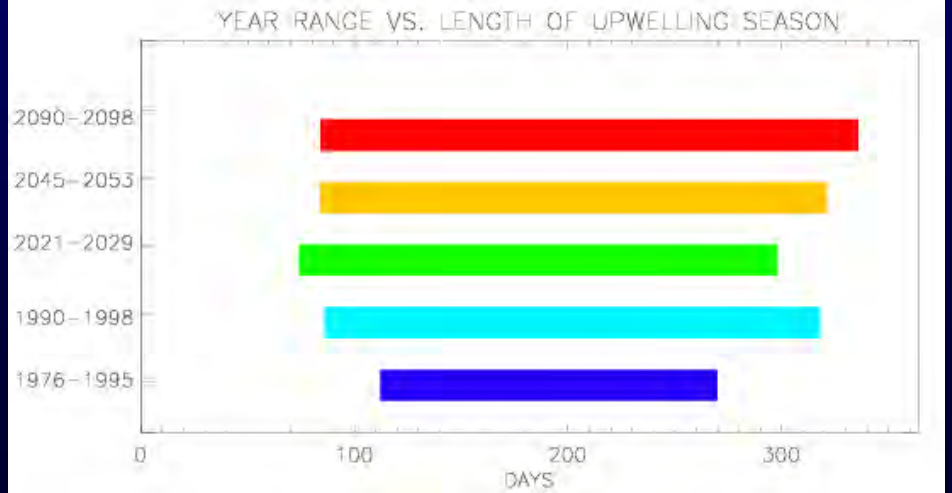



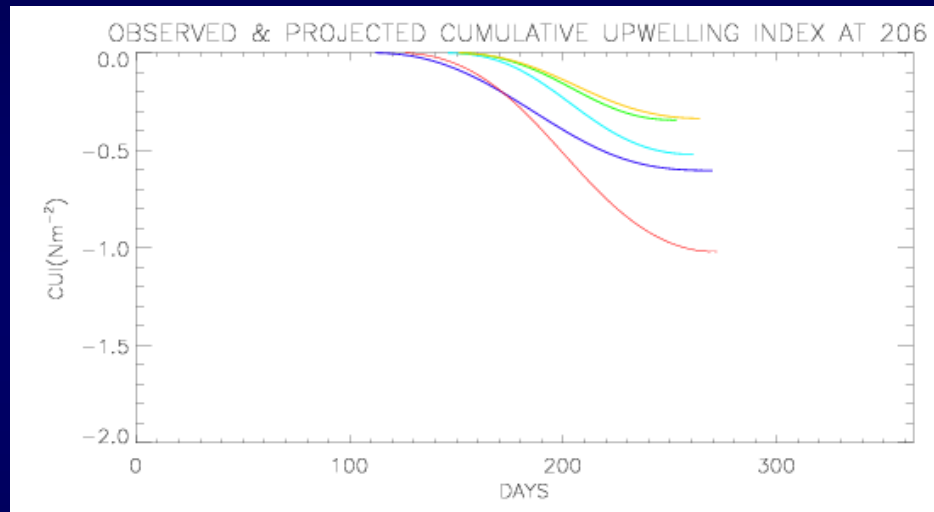
# Projected Changes in Upwelling Timing from 2 RCMs

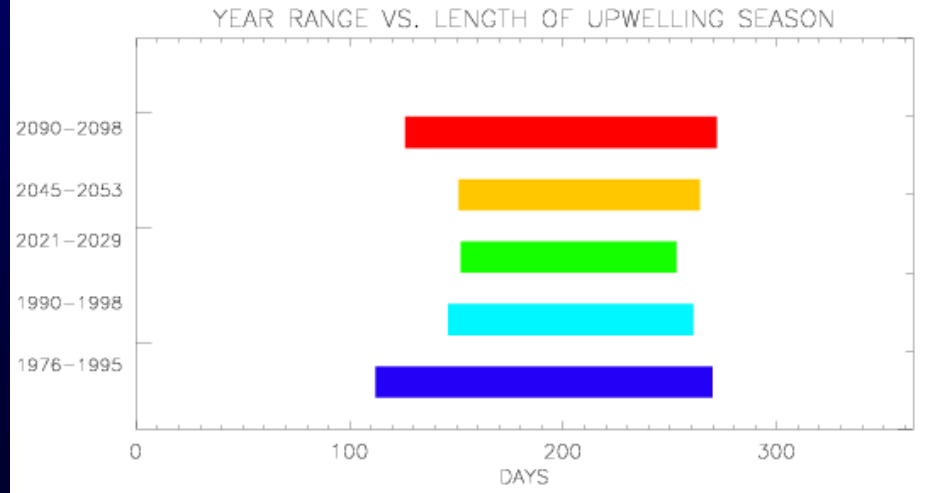

## Univ Wash RCM




## Can RCM



# Summary

- development of BC shelf, ocean-only, RCM continues
- Parallel efforts in downscaling to assemble forcing, initial & lateral boundary conditions
  - Historical analyses suggest changes in magnitude & timing of winds & freshwater discharges
  - will have important ecosystem consequences
- Decadal runs now possible with new 256-cpu computer