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

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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
- Includes carbon cycle (land & ocean)
- 5 member ensembles for both historical & each RCP future run
Sample CanESM2 output: Fig 1, Arora et al (2011)

CO₂ (ppm)

Global Mean Screen Temperature (°C)

Global Mean Precipitation (mm/day)

Control
Historical
RCP 2.6
RCP 4.5
RCP 8.5

Thin lines represent the 5 ensemble members
Thick line represents ensemble-average
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.
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

North America 0.44°

North America 0.11°

Mountain height
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

- 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
Precipitation Anomalies

- 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

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

Contemporary
Future
Anomaly

Depth (m)
Along-shelf velocity (cm s⁻¹)
Along-shelf velocity anomaly (cm s⁻¹)

Salinity (psu)
Temperature (°C)

VICC
CC
SBC
CUC
Is there more upwelling?

Not conclusive: $T$ is warmer & coastal current is fresher but isotherms & isohalines not much steeper
Coupling to Lower Trophic Model

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 O2)
- 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)
  - Stronger 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