More or less fish in future oceans?
The importance of scale for climate change projections

Tyler Eddy

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THE LIFE AQUATIC

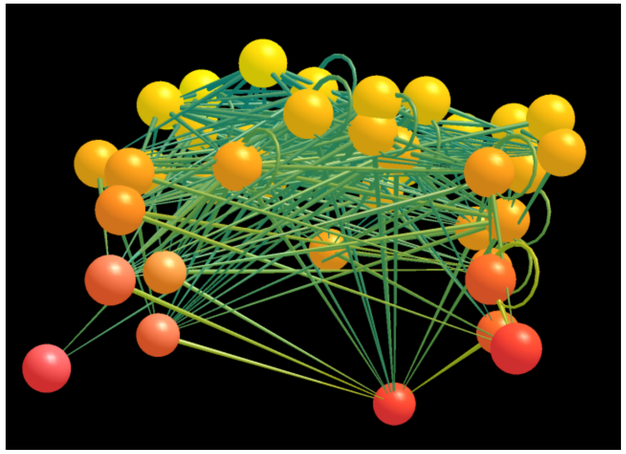
Memorial University

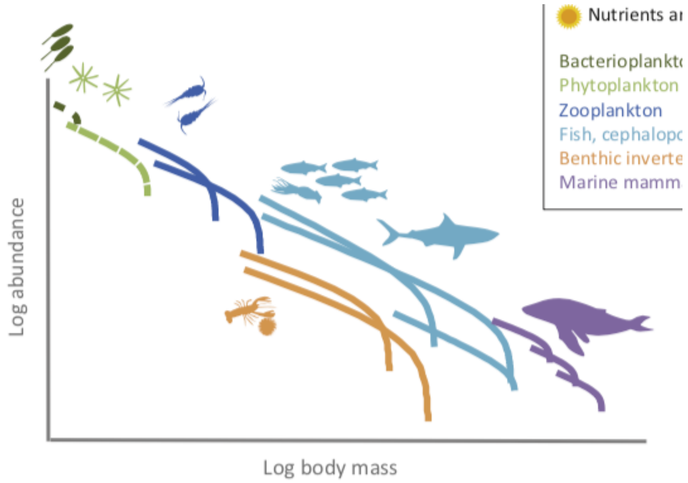
Co-authors

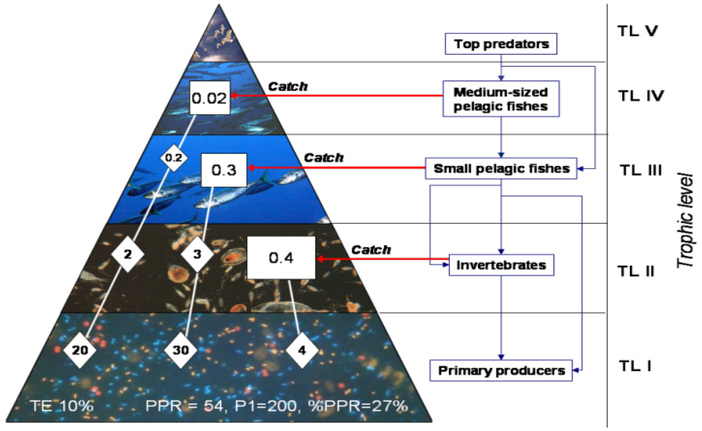
Ryan Heneghan, Beth Fulton, Julia Blanchard, Derek Tittensor, Heike Lotze, Cheryl Harrison, Andrea Bryndum-Buchholz, Daniele Bianchi, Matthias Büchner, Catherine Bulman, David Carozza, William Cheung, Marta Coll, Jason Everett, Eric Galbraith, Simon Jennings, Steve Mackinson, Olivier Maury, Susa Niiranen, Ricardo Oliveros-Ramos, Chiara Piroddi, Anthony Richardson, Jacob Schewe, Yunne Shin, Jeroen Steenbeek, Jan Volkholz, Nicola Walker, Colleen Petrik, Phoebee Woodworth-Jeffcoats, Jonathan Reum

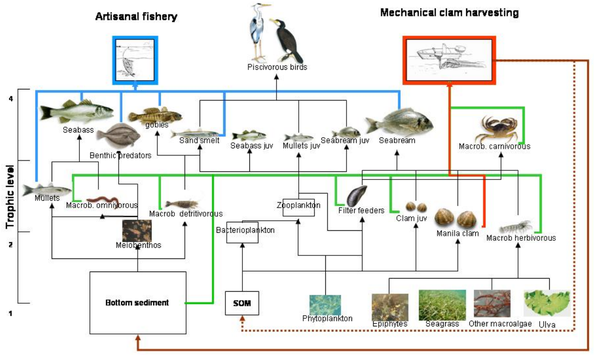
FISHERIES & MARINE ECOSYSTEM
FISH-MIP
MODEL INTERCOMPARISON PROJECT

FishMIP Models









Large Model Diversity:

- Size or age-based
- Food-web
- Species distribution
- Hybrid models

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nature climate change

ARTICLES

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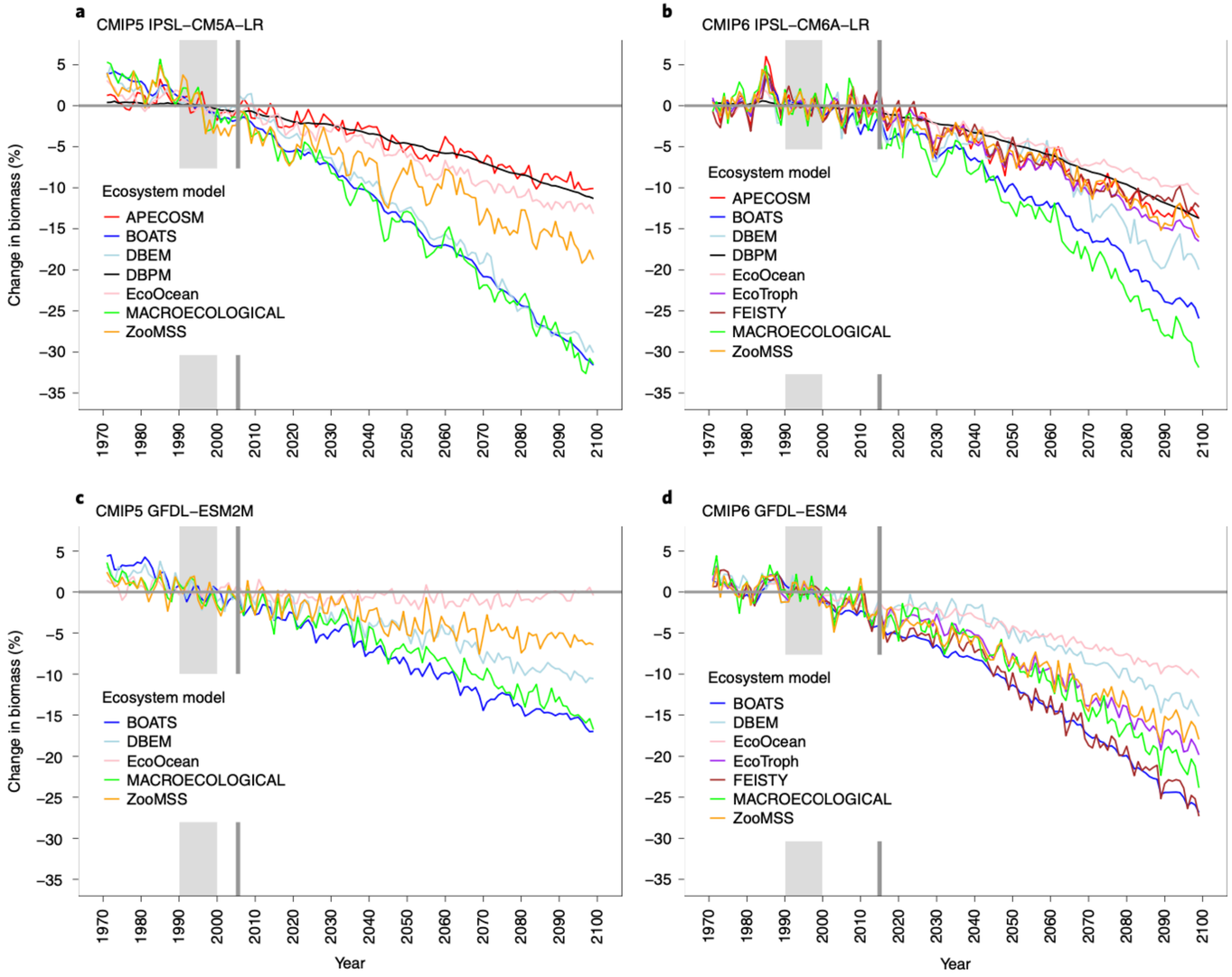
Next-generation ensemble projections reveal higher climate risks for marine ecosystems

Derek P. Tittensor[1,2]✉, Camilla Novaglio[3,4], Cheryl S. Harrison[5,6], Ryan F. Heneghan[7], Nicolas Barrier[8], Daniele Bianchi[9], Laurent Bopp[10], Andrea Bryndum-Buchholz[1], Gregory L. Britten[11], Matthias Büchner[12], William W. L. Cheung[13], Villy Christensen[13], Marta Coll[14,15], John P. Dunne[16], Tyler D. Eddy[17], Jason D. Everett[18,19,20], Jose A. Fernandes-Salvador[21], Elizabeth A. Fulton[4,22], Eric D. Galbraith[23], Didier Gascuel[24], Jerome Guiet[9], Jasmin G. John[16], Jason S. Link[25], Heike K. Lotze[1], Olivier Maury[8], Kelly Ortega-Cisneros[26], Juliano Palacios-Abrantes[13,27], Colleen M. Petrik[28], Hubert du Pontavice[24,29], Jonathan Rault[8], Anthony J. Richardson[18,19], Lynne Shannon[26], Yunne-Jai Shin[8], Jeroen Steenbeek[15], Charles A. Stock[16] and Julia L. Blanchard[3,4]

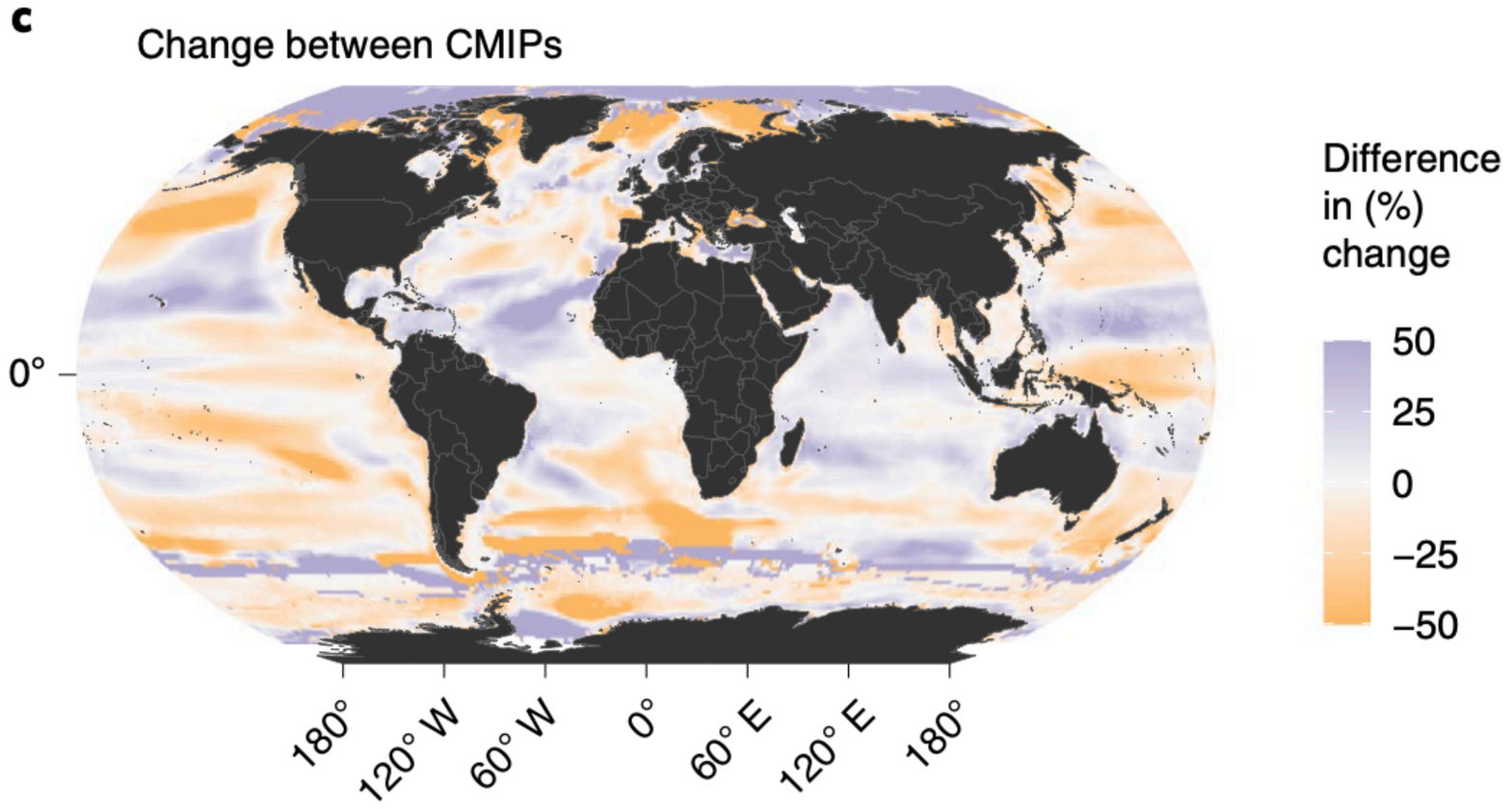
- Mean global decline of ~19% marine ecosystem biomass for CMIP6 by 2099 relative to 1990–1999 (~2.5% more than CMIP5) for high emissions scenario

CMIP5 vs. CMIP6



% Change in total animal biomass

"Regional shifts in the direction of biomass changes highlight the continued and urgent need to reduce uncertainty in the projected responses of marine ecosystems to climate change to help support adaptation planning"



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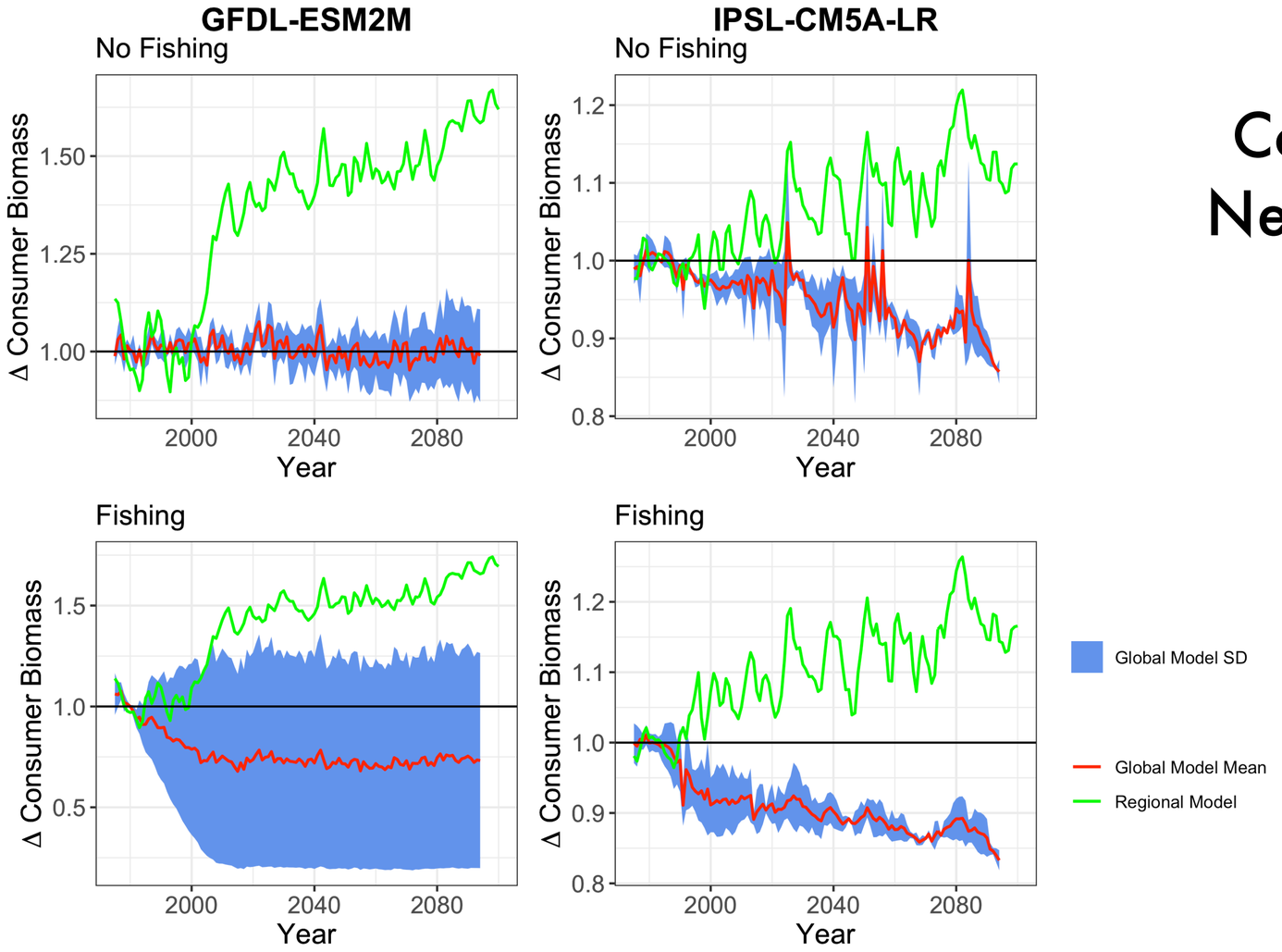
Question

- Do regional FishMIP models agree on future projections for CMIP5 and CMIP6 simulations?

Consumer biomass CMIP5 projections Global and regional FishMIP models



Cook Strait, New Zealand

RCP 8.5 Average of GFDL & IPSL - CMIP5

Region	Regional model	Global models	Agreement
Adriatic Sea	↑	–	✗
Baltic Sea	↓	↓	✓
Cook Strait	↑	↓	✗
East Bass Strait	–	↓	✗
Humboldt Current	–	↓	✗
North Sea	↓	↓	✓
NW Mediterranean	–	↓	✗
SE Australia	↑	↓	✗

RCP 8.5 Average of GFDL & IPSL- CMIP5 CMIP6

Region	Regional model	Global models	Agreement	Agreement
Adriatic Sea	↑	–	✗	NA
Baltic Sea	↓	↓	✓	NA
Cook Strait	↑	↓	✗	✓
East Bass Strait	–	↓	✗	✗
Humboldt Current	–	↓	✗	NA
North Sea	↓	↓	✓	NA
NW Mediterranean	–	↓	✗	NA
SE Australia	↑	↓	✗	NA
Benguela			NA	✓*
East Bering Sea			NA	✓
Hawaii			NA	✓

RCP 8.5 Average of GFDL & IPSL- CMIP5 CMIP6

Region	Regional model	Global models	Agreement	Agreement
Adriatic Sea	↑	—	✗	NA
Baltic Sea	↓	↓	✓	NA
Cook Strait	↑	↓	✗	✓
East Bass Strait	—	↓	✗	✗
Humboldt Current	—	↓	✗	NA
North Sea	↓	↓	✓	NA
NW Mediterranean	—	↓	✗	NA
SE Australia	↑	↓	✗	NA
Benguela			NA	✓ *
East Bering Sea			NA	✓
Hawaii			NA	✓

CMIP5

25% Agreement

CMIP6

80% Agreement

Do regional and global FishMIP models agree on future projections for CMIP5 and CMIP6 simulations?

Do regional and global FishMIP models agree on future projections for CMIP5 and CMIP6 simulations?

Mostly no in CMIP5
Mostly yes in CMIP6

Potential reasons for mismatches between regional and global FishMIP models

- Regional FishMIP models often have greater functional diversity and ecological or taxonomic resolution

- Regional FishMIP models generally include more processes and resolve predator-prey interactions more explicitly than global models

- Coarse spatial resolution of coastal regions in global Earth System Models and FishMIP models while regional FishMIP models are developed at finer scales

Conclusions

- Spatial resolution is an important factor to consider for climate change projections using marine ecosystem models
- Preliminary results suggest better agreement among regional and global FishMIP models in CMIP6 than CMIP5
- The present FishMIP simulation round is poised to tease out contribution of spatial scale to variation in regional and global model projections

THANK-YOU!

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ROMS vs. Earth System Model Coastal Resolution

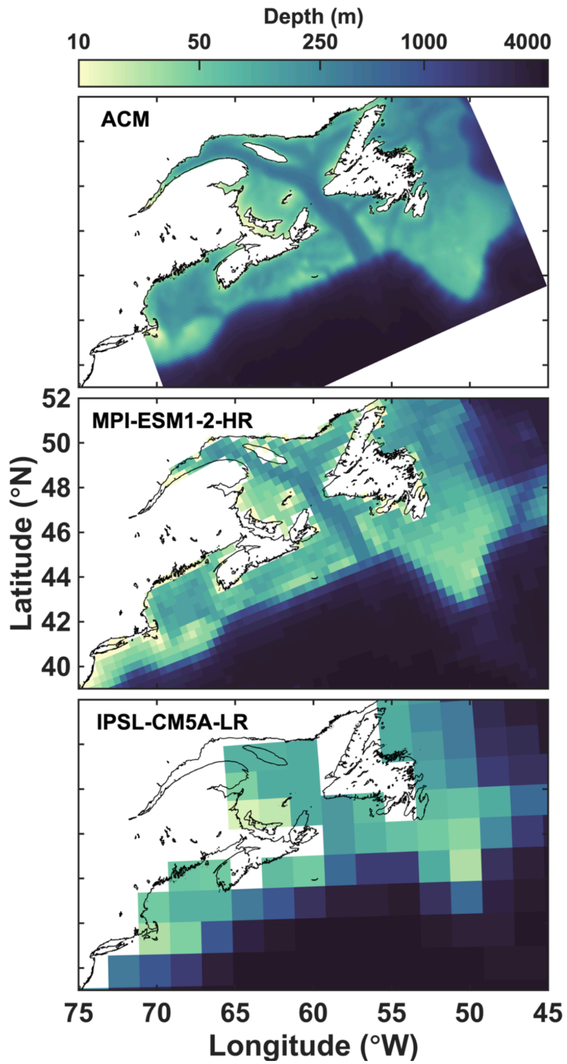


Figure 3. Bathymetry of

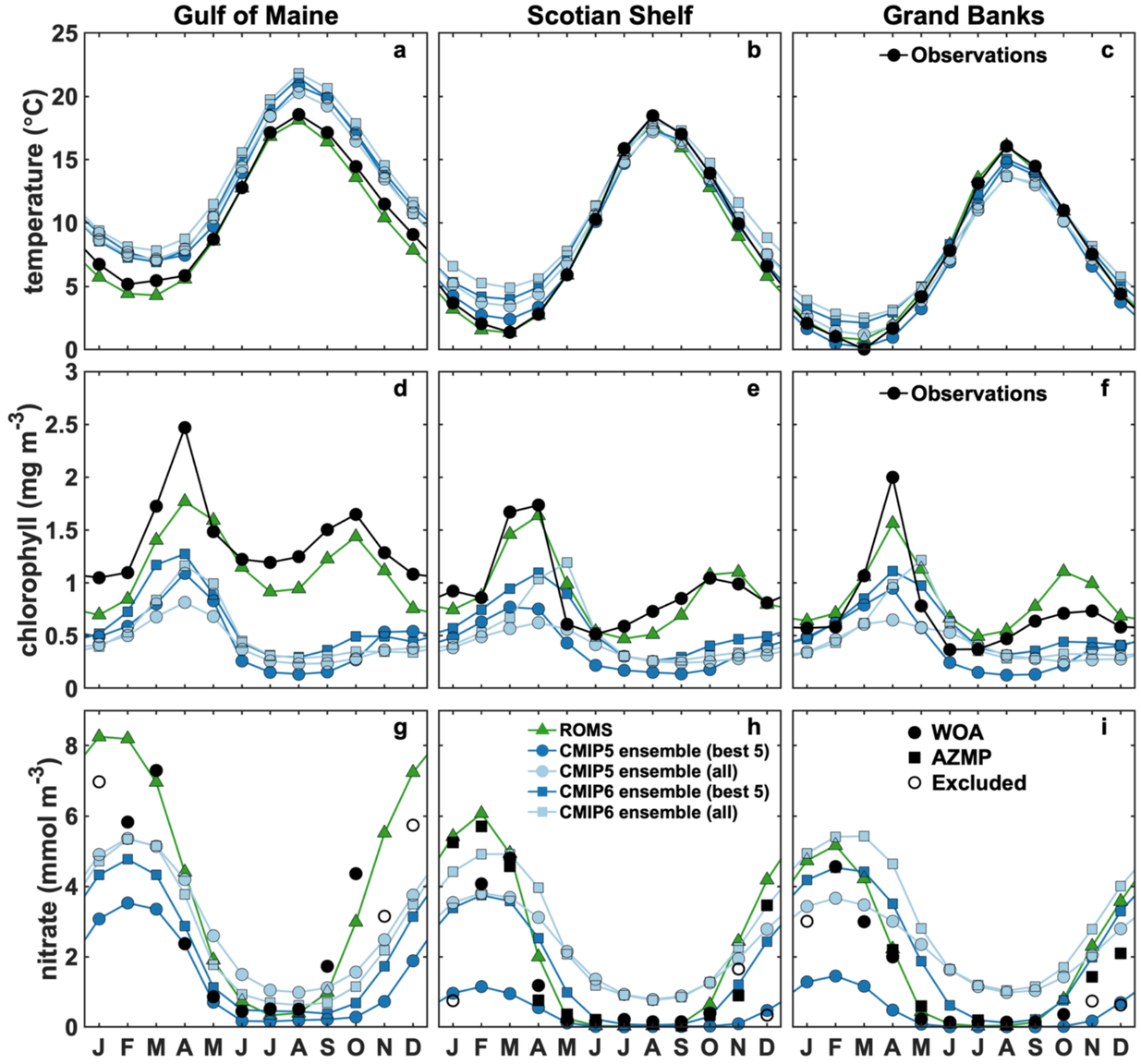
n = 3729 grid cells for Grand Banks

n = 193 grid cells for Grand Banks

n = 13 grid cells for Grand Banks

Laurent et al. 2021 GMD

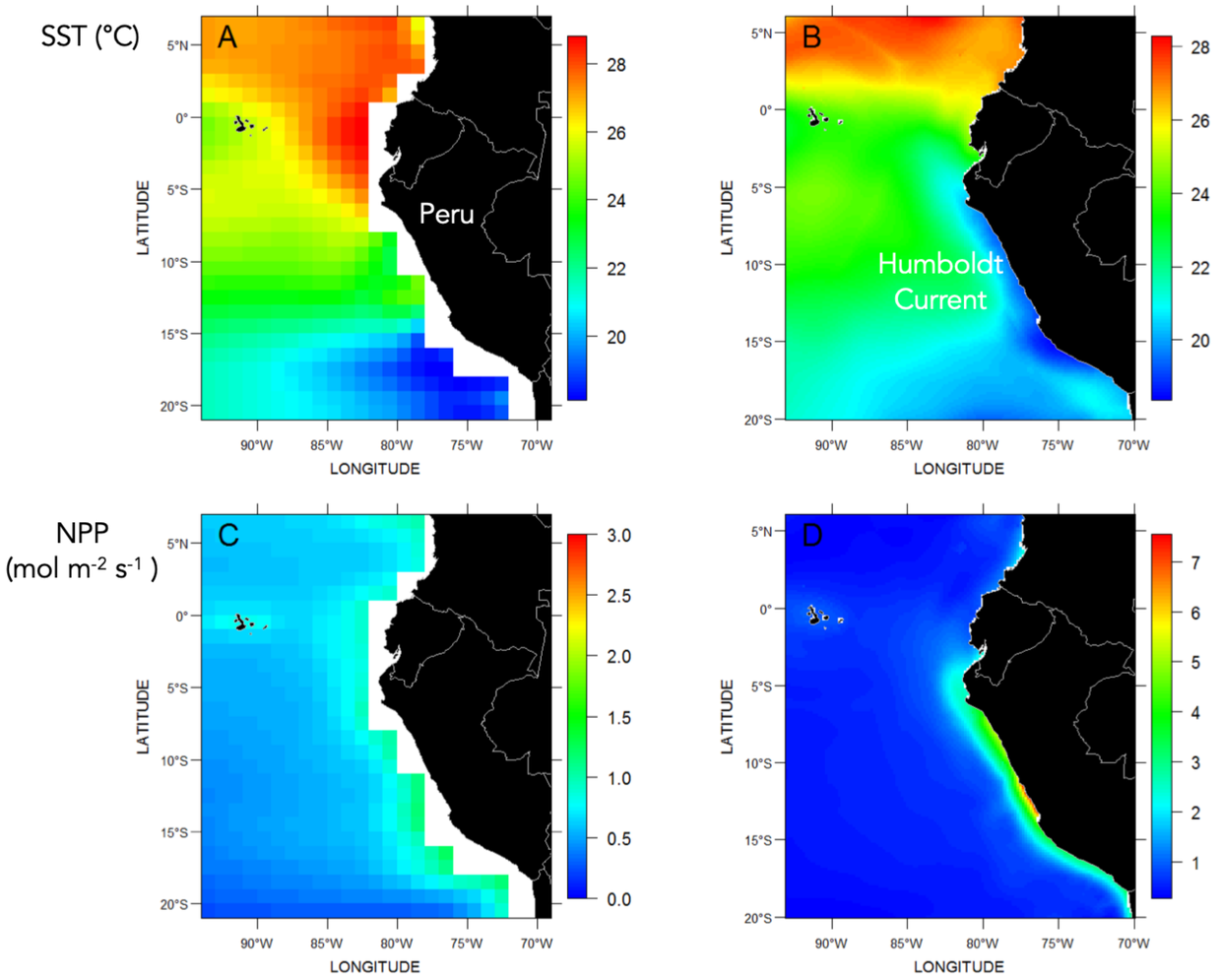
Mean 1999–2010



655 **Figure 4. Observed, ROMS and ensemble means area averaged surface chlorophyll (a-c), nitrate (d-f) and temperature (g-i) in the 3 NWA shelf regions.**

Laurent et al. 2021 GMD

Statistical downscaling



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https://doi.org/10.5194/bg-18-4321-2021

Biogeosciences Open Access EGU

Oceanic primary production decline halved in eddy-resolving simulations of global warming

Damien Couespel[1], **Marina Lévy**[1], **and Laurent Bopp**[2]

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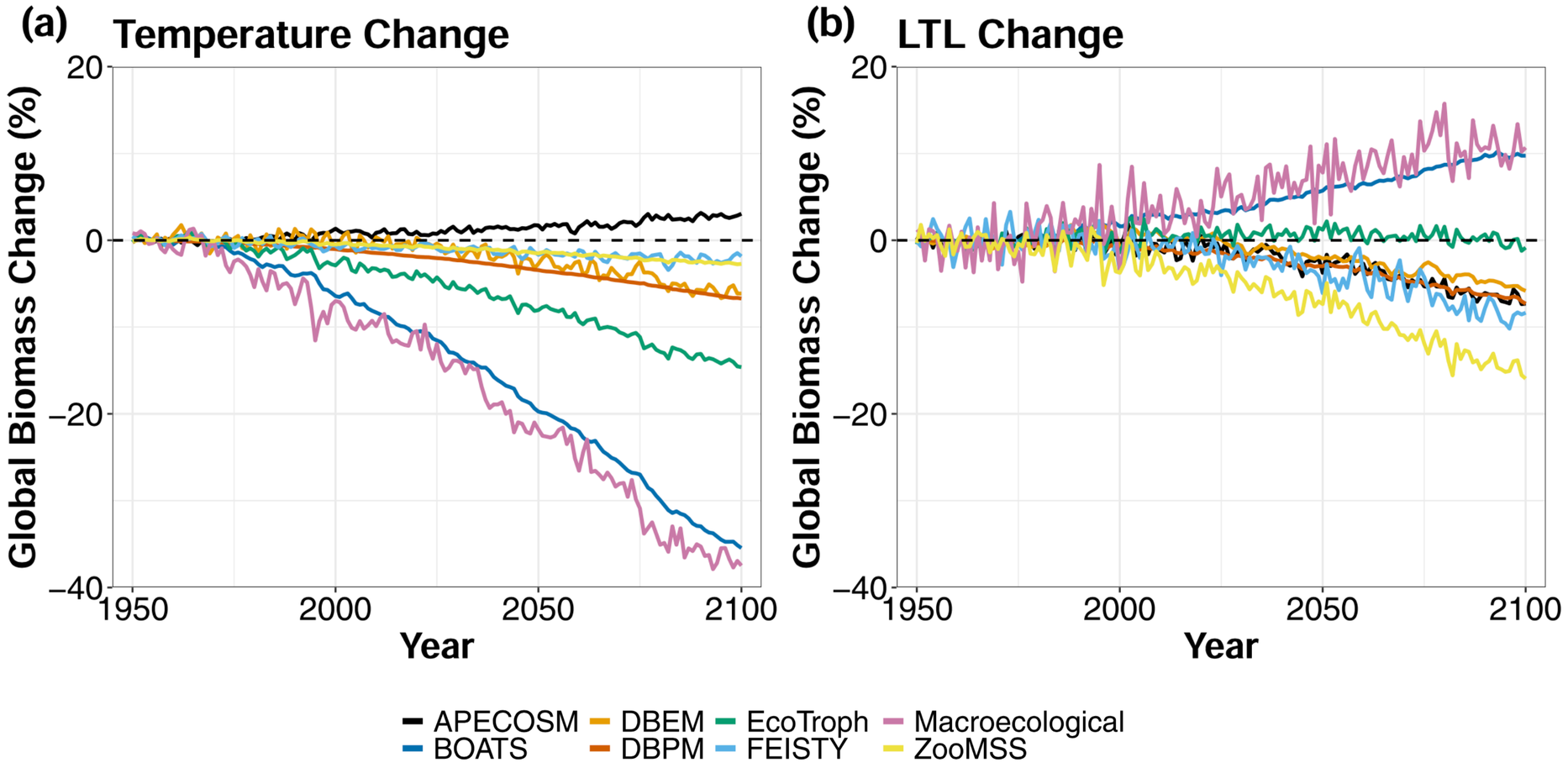
[2]LMD-IPSL, École Normale Supérieure/PSL University, CNRS, École Polytechnique, Sorbonne Université, Paris, France

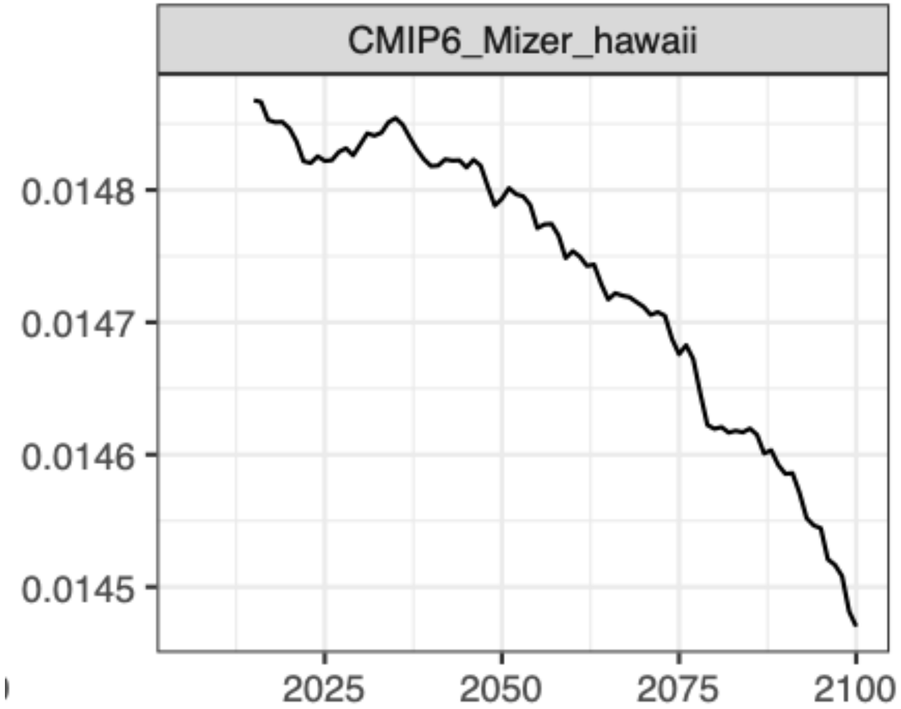
"The simulated decline in primary production in the sub- polar gyre is halved at the finest eddy-resolving resolution (−12 % at 1/27° vs. −26 % at 1°) at the end of the 70 year global warming simulations"

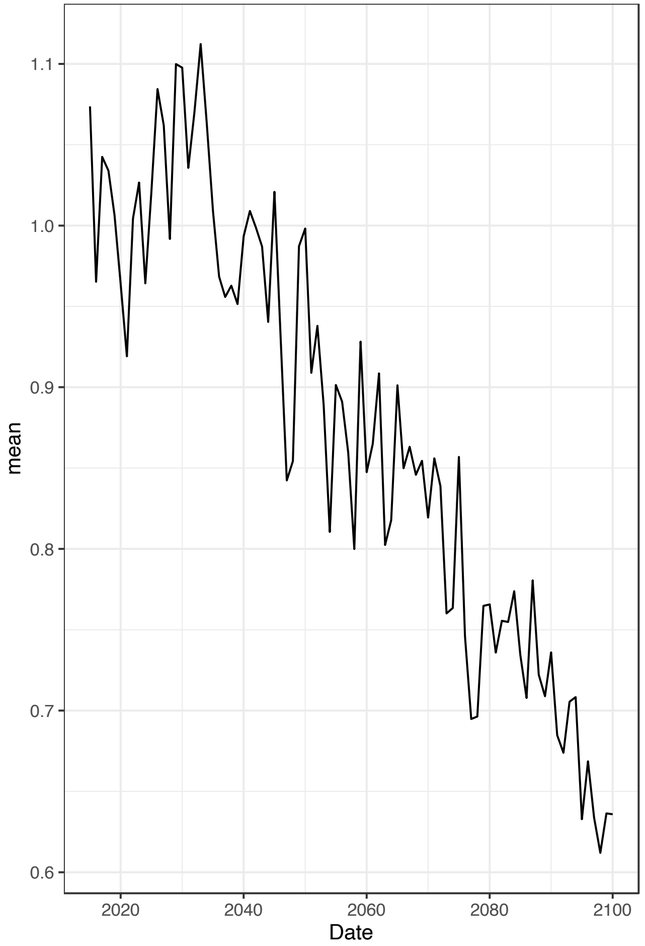
Temp vs. LTL drivers



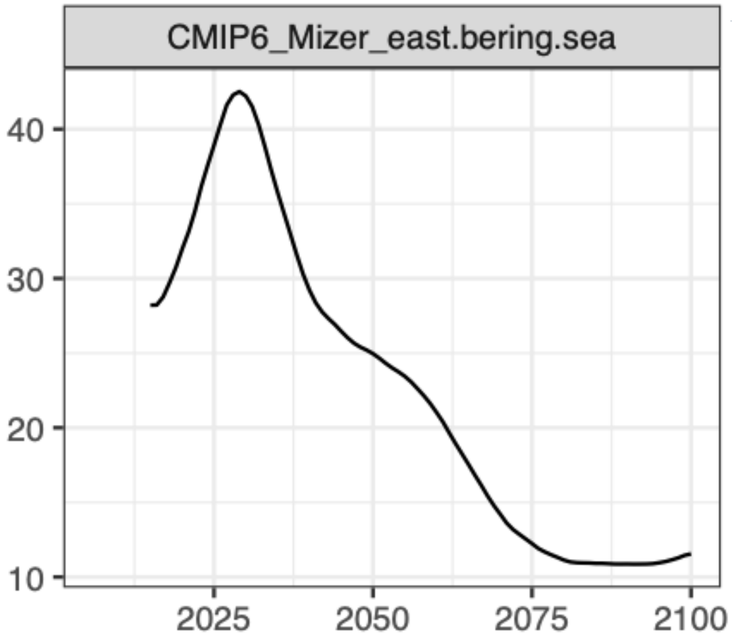
Heneghan et al. 2021 PiO

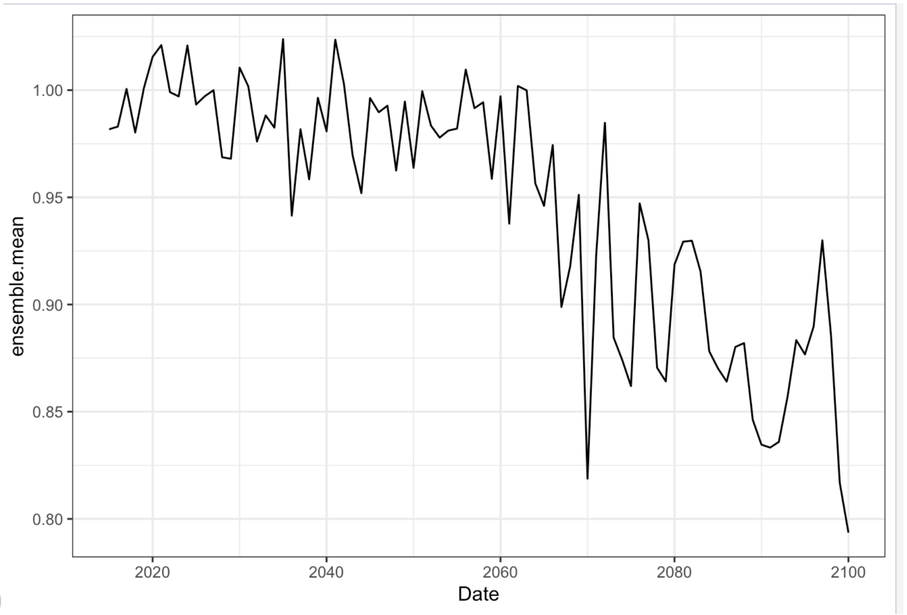
CMIP6 GFDL 8.5, no-fishing mizer Hawaii & global ensemble mean



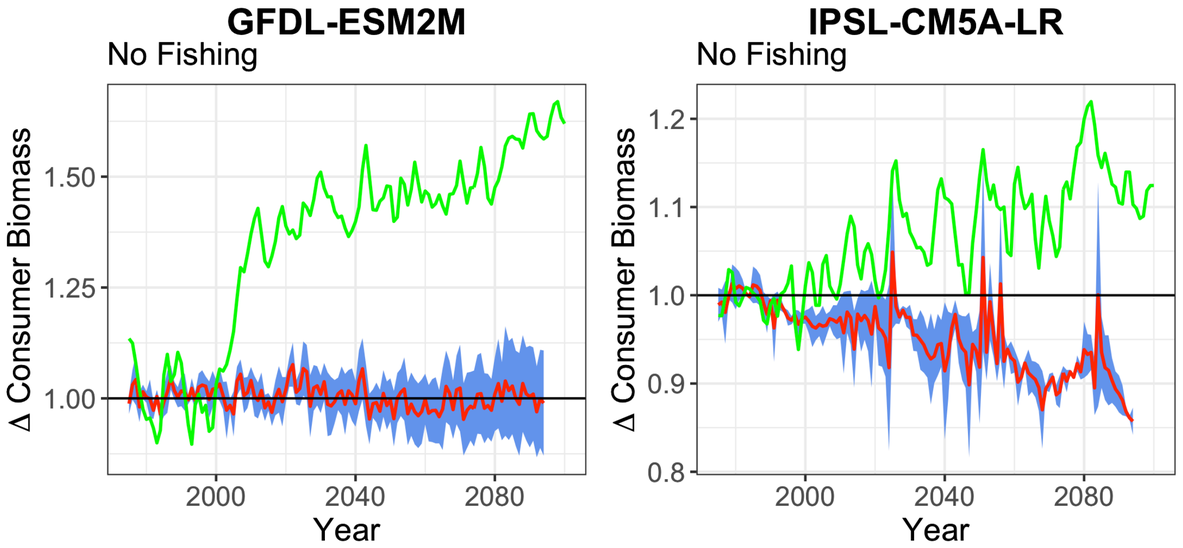


CMIP6 GFDL 8.5, no-fishing mizer EBS & global ensemble mean





EwE - Cook Strait, New Zealand

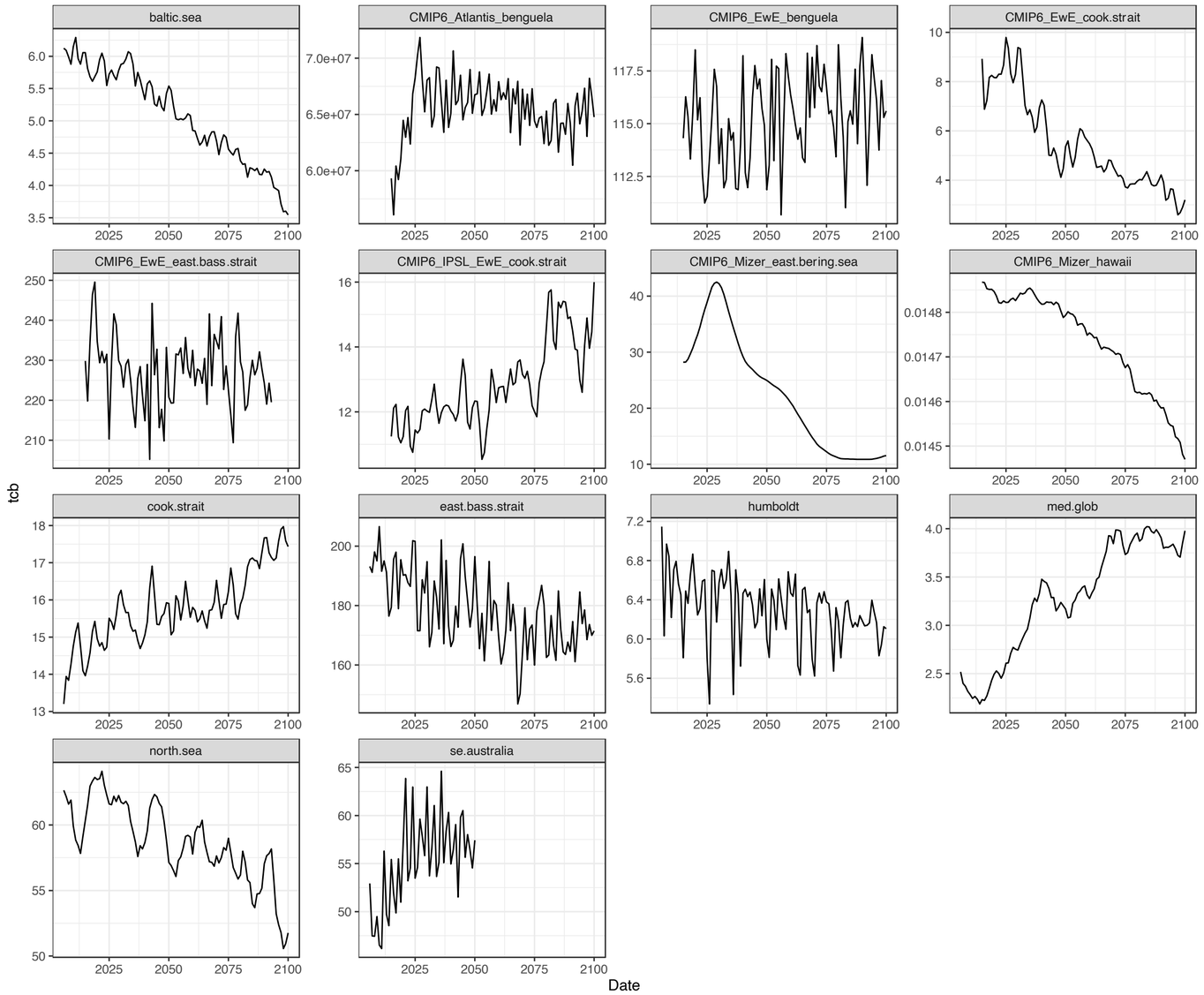


Global Model SD

Global Model Mean

Regional Model

CMIP5 & CMIP6 regional models, no-fishing, GFDL 8.5



The Model Intercomparison (MIP) Experience: Model Ensembles

CMIP
The World Climate Research Programme's Coupled Model Intercomparison Project

ISIMIP
Inter-Sectoral Impact Model Intercomparison Project

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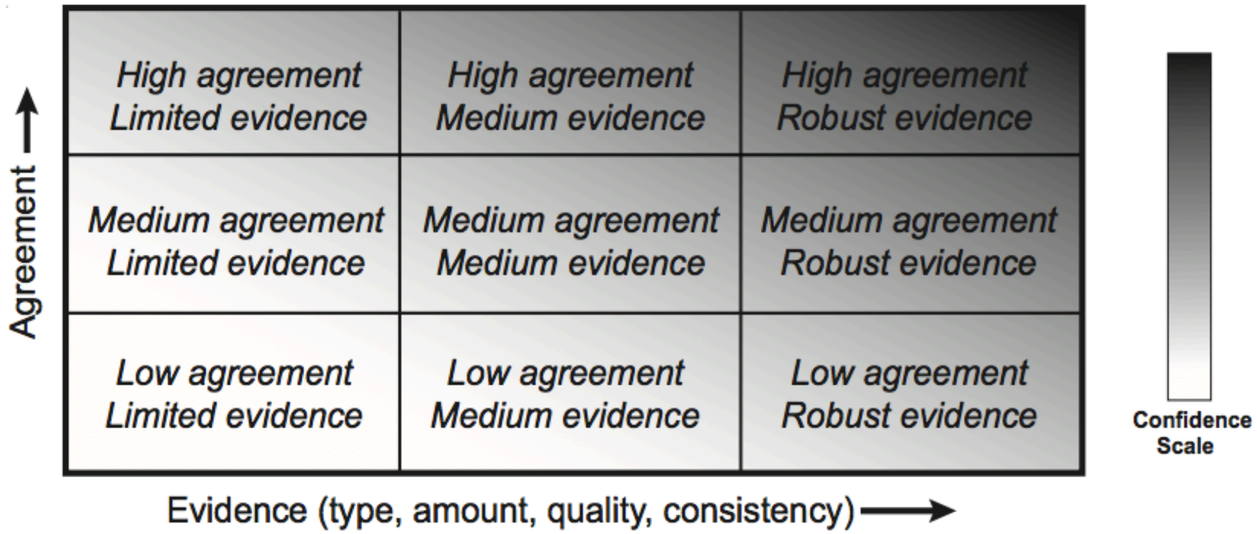
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP



IPCC 2014

Special Collection Call for Submissions

Past and Future Marine Ecosystems

Open for Submissions:
15 January 2023
Submission Deadline:
31 December 2023

Tyler Eddy

Climate change is posing unprecedented risks to marine ecosystems and the essential services they provide to billions of people. The Fisheries and Marine Ecosystem Model Intercomparison Project (FishMIP; www.fishmip.org) aims to project and understand the climate impacts on marine ecosystems and fisheries and to help inform policies that adapt and mitigate them. Our ensemble projects a global decline in potential fish biomass by 2100, but with large uncertainties for different regions of the world. In response to international calls for more robust regional projections, and marking the 10th anniversary of FishMIP, this Special Issue aims to advance research on marine climate impact ensemble modeling. The topics covered include: projections and uncertainties, model evaluation, detection and attribution of past change, and future human-use scenarios to better support policy and decision-making. These advances provide tools urgently needed to help define a safe operating space for human use of the oceans over the rest of the century and beyond.

SPECIAL COLLECTION ORGANIZERS:

Julia Blanchard, University of Tasmania
Cheryl Harrison, Louisiana State University
Kelsey Roberts, Louisiana State University
Camilla Novaglio, University of Tasmania
Kelly Ortega Cisneros, University of Cape Town
Tyler Eddy, Memorial University of Newfoundland

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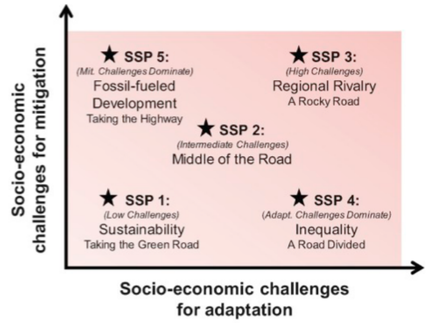
FISHERIES & MARINE ECOSYSTEM FISH-MIP MODEL INTERCOMPARISON PROJECT

AGU ADVANCING EARTH AND SPACE SCIENCE

Fisheries & Marine Ecosystem Model Intercomparison Project (FishMIP)

- Primary production
- Temperature

CMIP
The World Climate Research Programme's Coupled Model Intercomparison Project



Simulations with ensemble of Marine Ecosystem & Fisheries Models

ISIMIP
Inter-Sectoral Impact Model Intercomparison Project

FISHERIES & MARINE ECOSYSTEM
FISH-MIP
MODEL INTERCOMPARISON PROJECT

- Fishing effort
- Marine protected areas

PIK
Potsdam Institute for Climate Impact Research

Conclusions

- Be hard on your models but be nice to your fellow modellers :)

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FISH-MIP
MODEL INTERCOMPARISON PROJECT

IPSL CMIP6 forcings

- A problem with the previous regional extractions affected IPSL-CM6A-LR forcings
- The latitude orientation was flipped for the IPSL global forcings compared to GFDL, so IPSL forcings provided to run your models were incorrect
- GFDL forcings were okay, so your GFDL simulations are unaffected
- However, you will need to re-do your simulations on the IPSL forcings

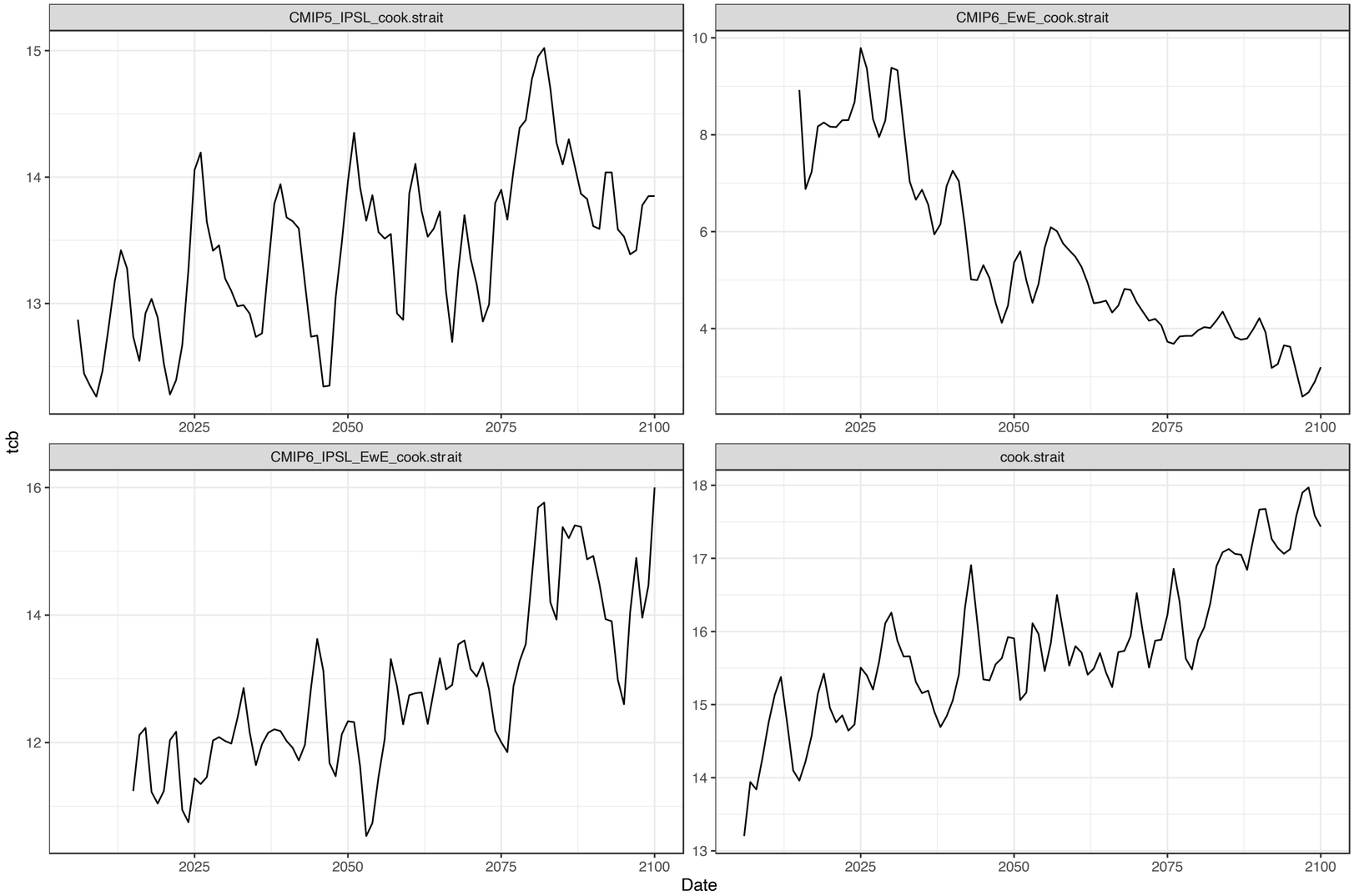
Spatial resolution

- Another factor contributing to regional-global model mismatches is the coarse resolution of coastal regions in global ESMs and MEMs

- Global models often do not represent waters <50 m depth, and at the 1° grid size scale (~100 km by 100 km at the equator) fail to capture key fine-scale coastal processes such as eddies and upwelling – important for nutrient supply, primary production, higher trophic level production, and fisheries production

- Two approaches to achieving increased resolution of drivers are
    (i) through statistical downscaling to a higher resolution grid (although this will be influenced by the ESM that it was downscaled from)
    (ii) through use of a regional biogeochemical model or a regional ocean modelling system (ROMS)

Cook Strait, NZ, no-fishing, RCP8.5, CMIP5 & CMIP6



Historical period - 1975 - 2004