Regional Climate Modeling and the FUTURE program

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PICES

Fisheries and Oceans Canada | Pêches et Océans Canada

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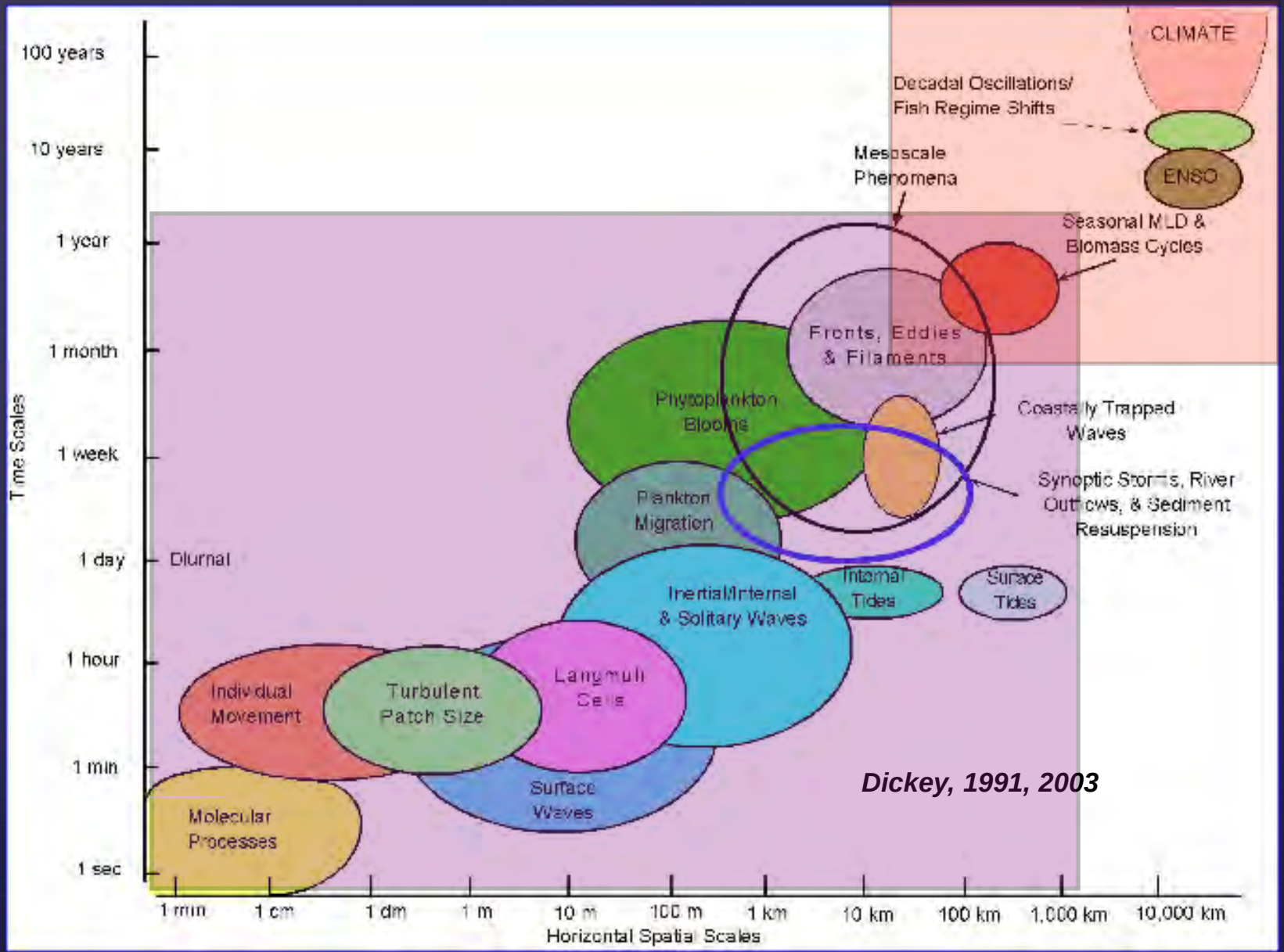
RUTGERS THE STATE UNIVERSITY OF NEW JERSEY

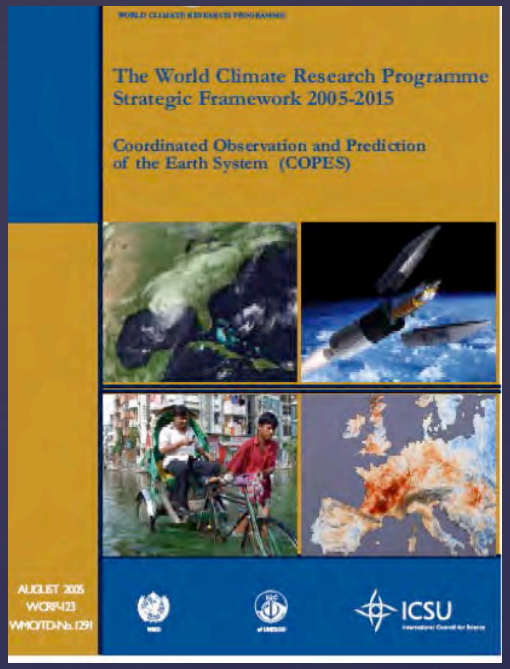
When will we be able to resolve sufficient scales?



Outline

- *Motivation: Why regional models?*
- *Overview of PICES Regional Climate Model working group activities & achievements (WG29)*
- *Future directions*

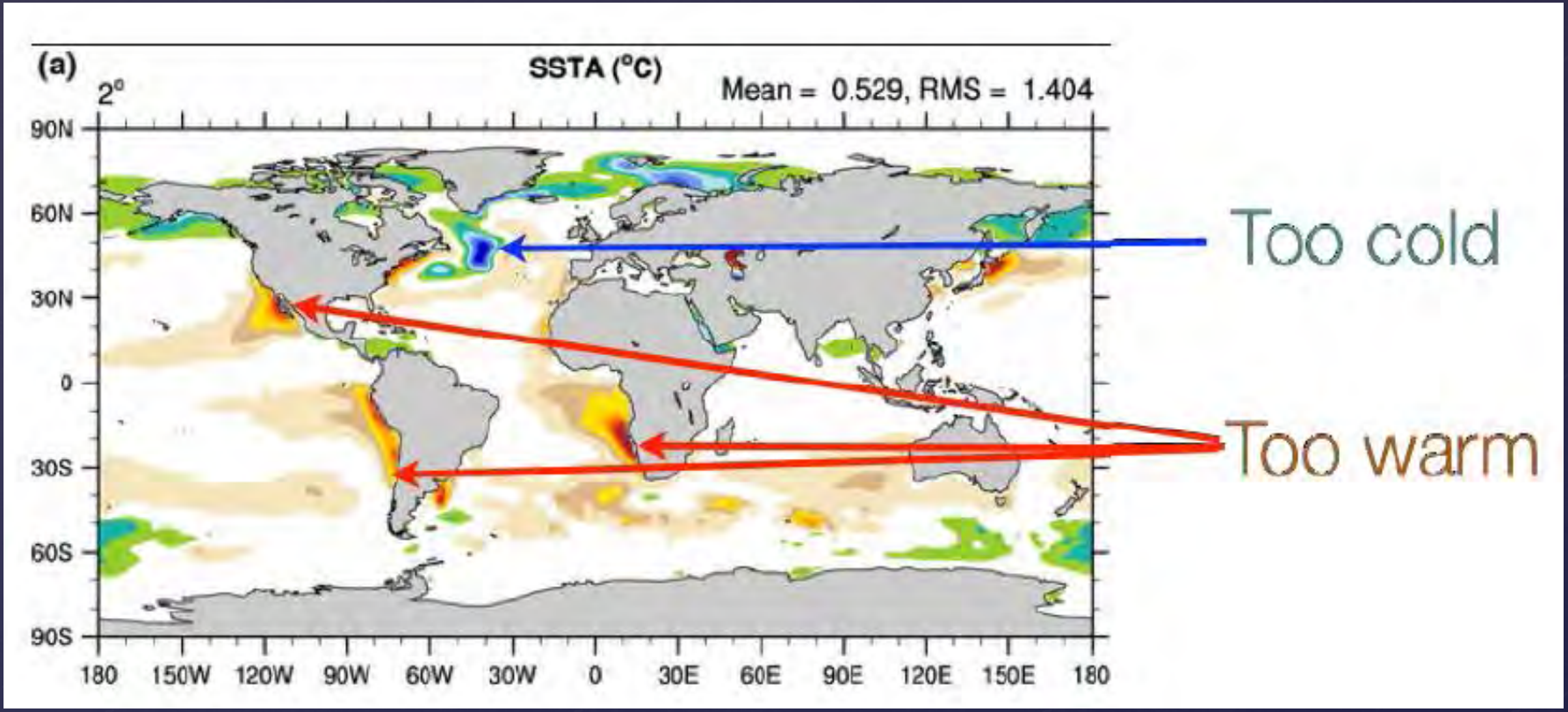
Why regional climate models?



WCRP strategic framework:

- Improved predictions of changes in statistics of regional climate, especially extreme events, are required to assess impacts and adaptation
- Recognizes the need to improve representation of weather and climate link
- Working hypothesis is that the internal dynamics of the system are more accurately represented at higher resolution

Why Regional Models?



"Models still show significant errors ... The ultimate source of most is that many important small-scale processes are not represented explicitly in models …"

Randal et al., 2007.

The PICES FUTURE Program

How do ecosystems respond to natural and anthropogenic forcing, and how might they change in the future?

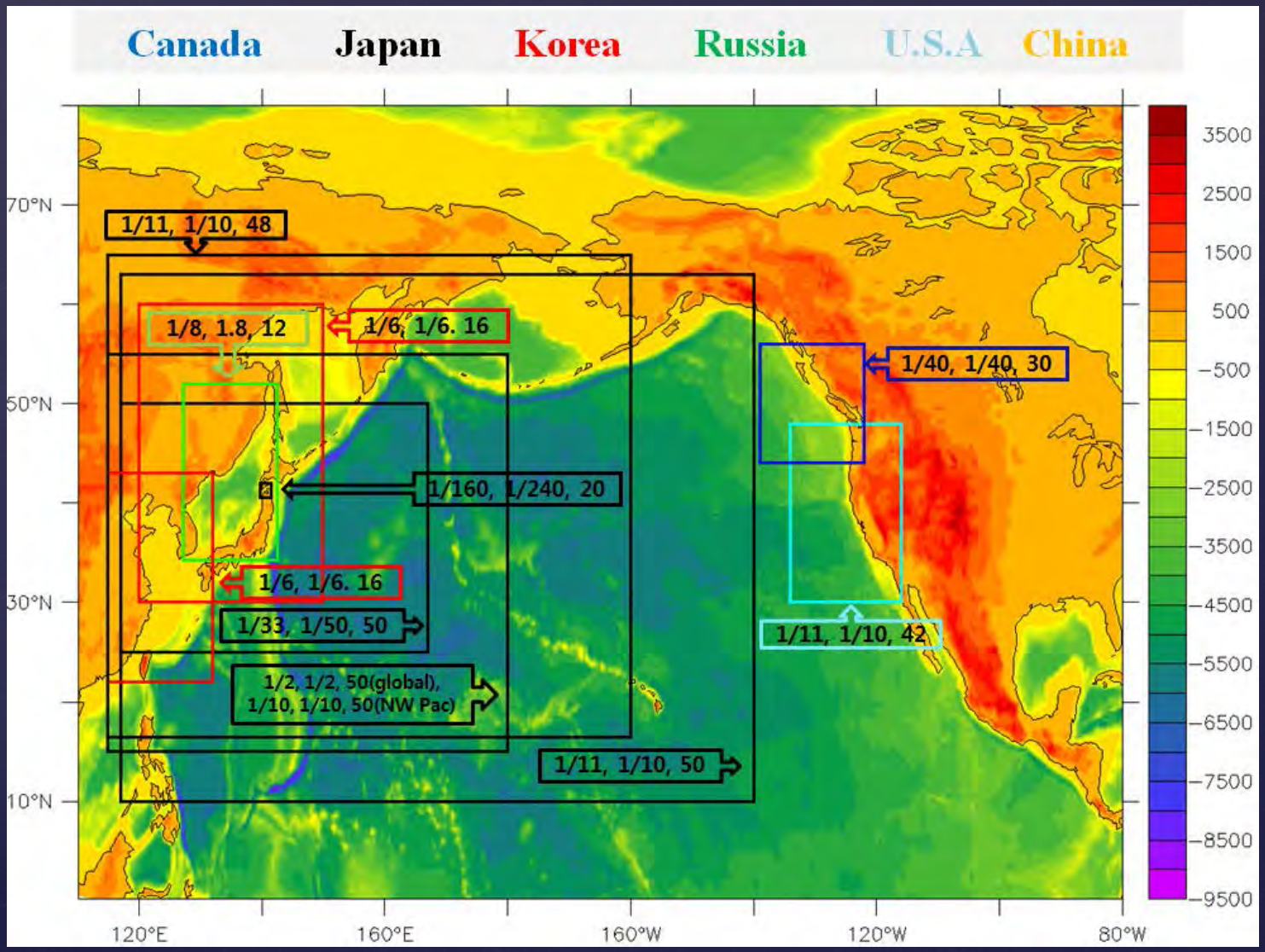
PICES Activities in Regional Climate Modeling

1. Assemble a comprehensive review of existing regional climate modeling efforts;

2. Assess the requirements for regional ecosystem modeling studies (e.g., how to downscale the biogeochemistry);

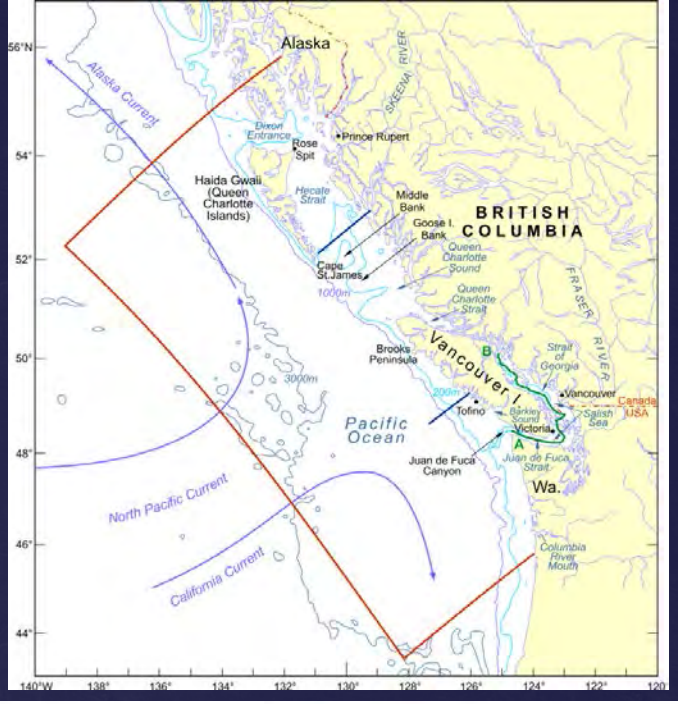
3. Continue the development of RCM implementations in the North Pacific and its marginal seas;

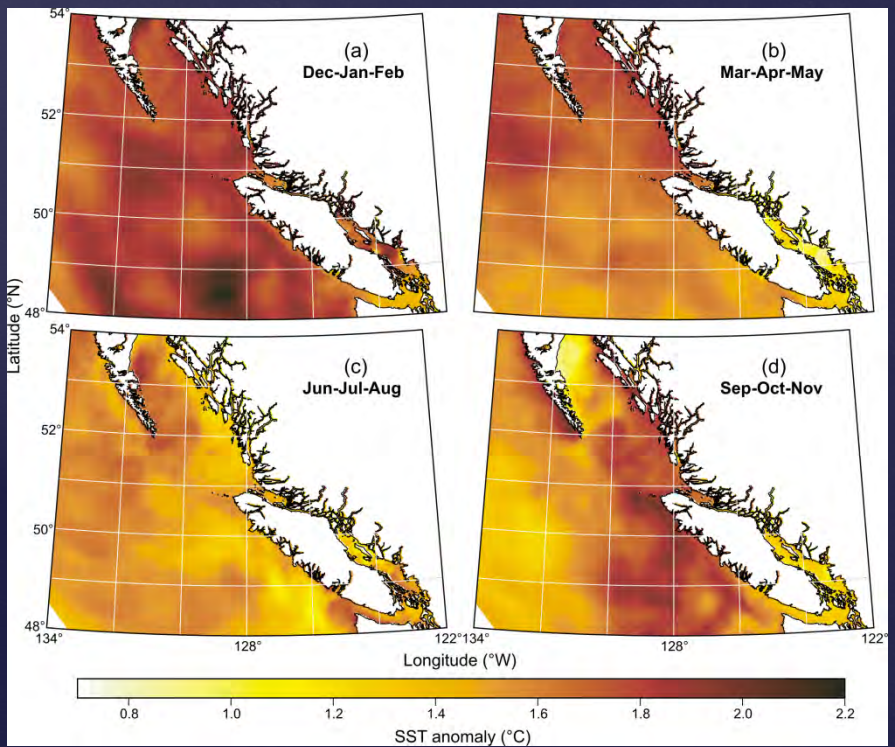
PICES Regional Modeling Activities

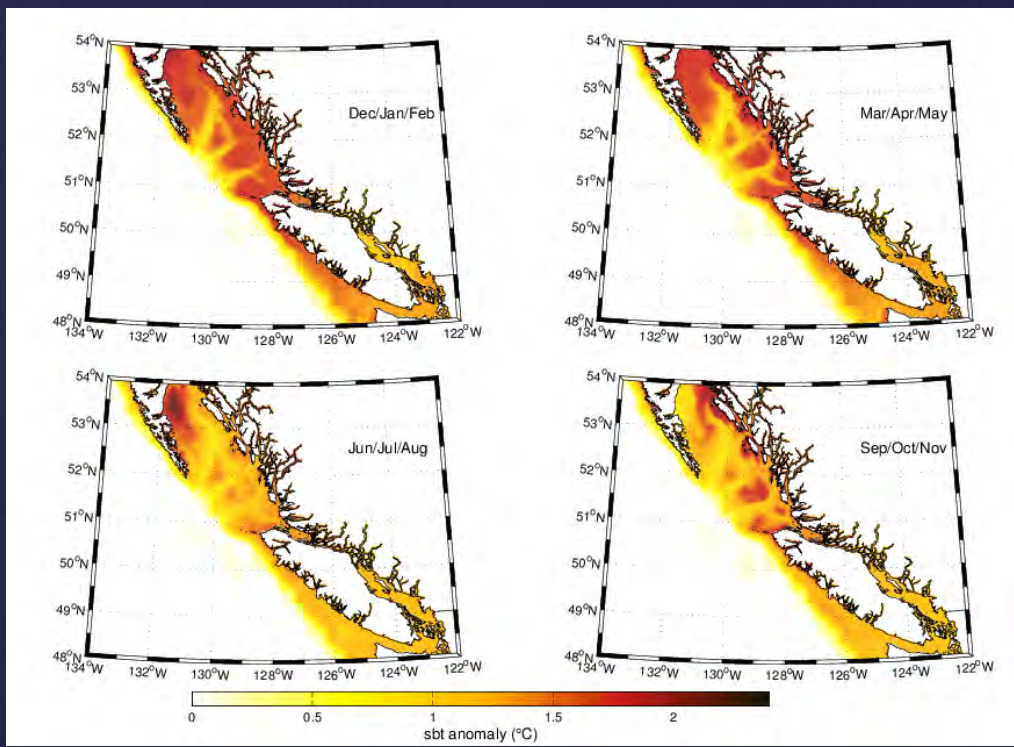


British Columbia RCM

- ROMS with 3km horizontal resolution & 30 sigma levels in vertical
- Applied "pseudo global warming" approach to Masson & Fine (JGR, 2012) 1995-2008 hindcasts
  - Projections for 2065-2078
  - CRCM/CGCM3 (NARCCAP) forcing

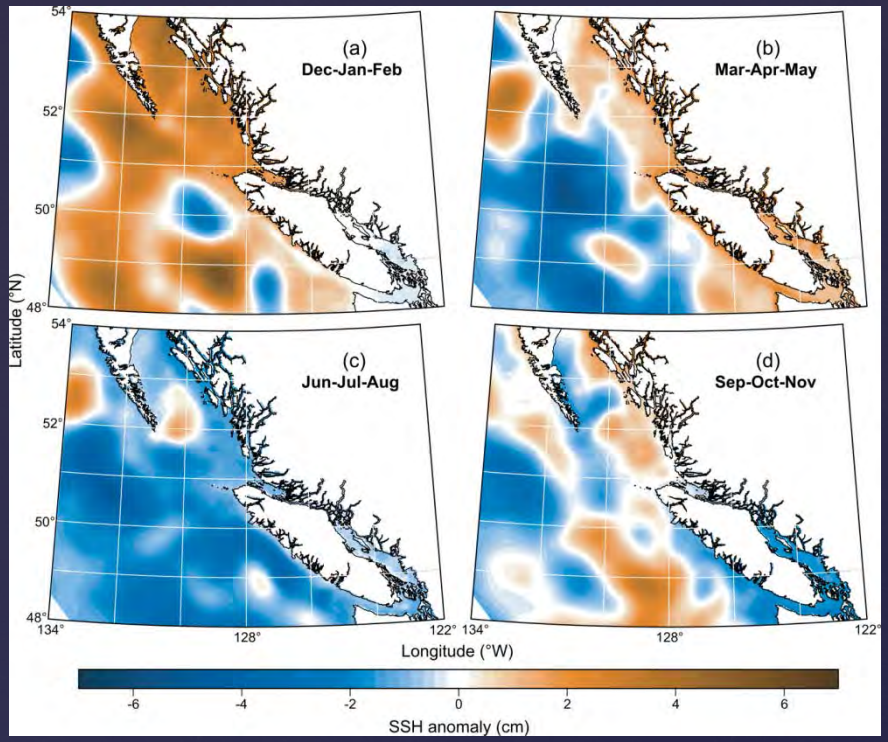


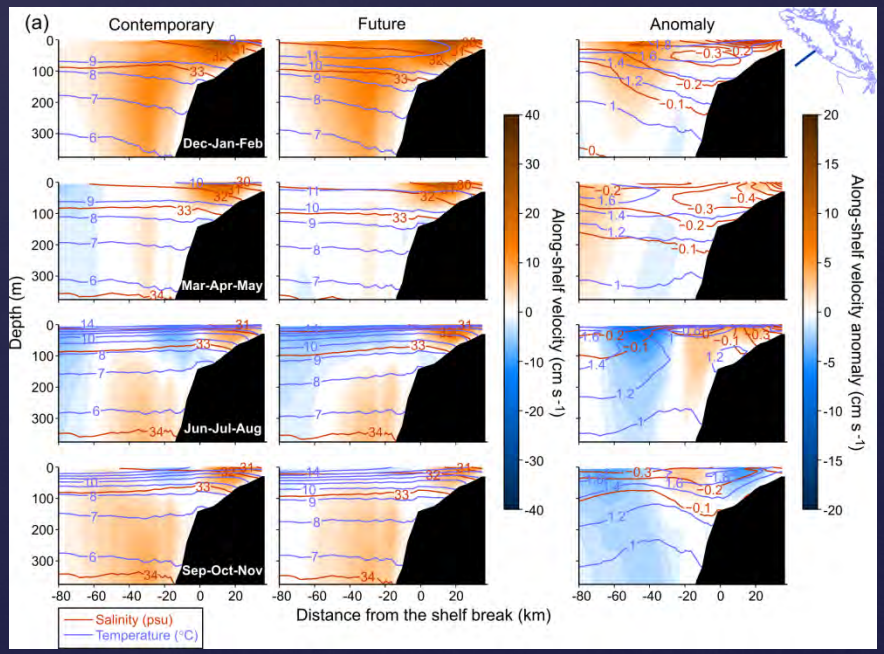




BC RCM Results

1. Sea surface height anomalies
   - Generally higher in winter & lower in summer ➡ more winter flooding
2. No appreciable changes to upwelling on Vancouver Island shelf
3. Some changes in seasonal currents
4. Stronger winter winds & Haida Eddies
5. More details in Morrison et al (AO, 2014) & Foreman et al (AO, 2014)





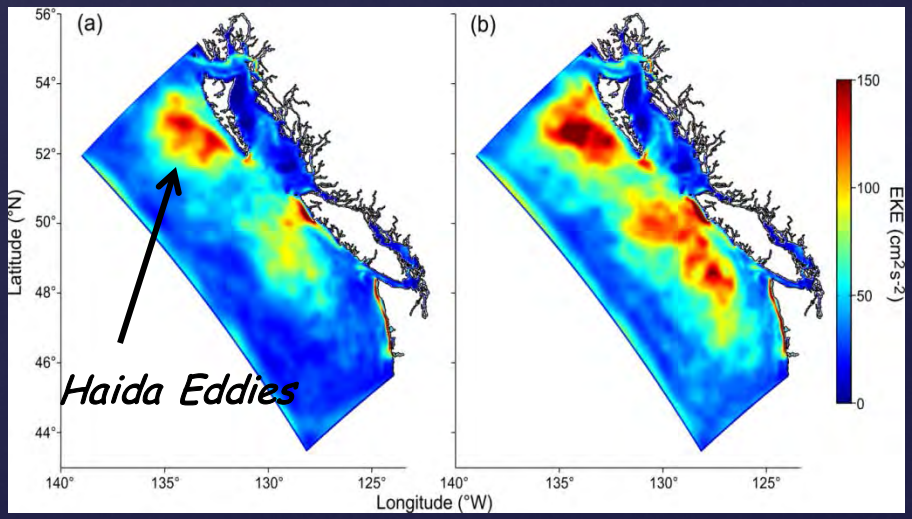
Sample Ecosystem Implication

Haida Eddies

- carry plankton, larvae, & nutrients offshore (Whitney & Robert, 2002)
  - reduce productivity on shelf but increase productivity offshore
  - Pacific cod recruitment in Hecate Strait shows strong negative correlation with mean sea level (high ➡ bigger eddy) previous winter
  - re-stock fish populations around seamounts

- Projected to become stronger

contemporary & future eddy kinetic energy



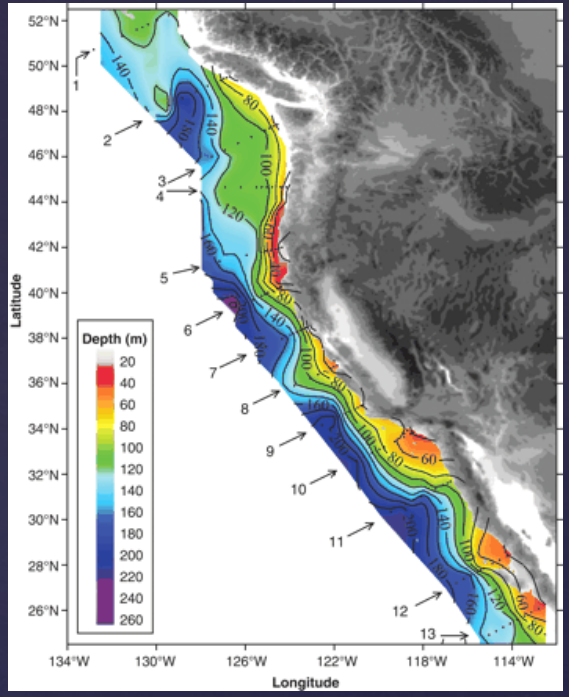
BC RCM with Biogeochemistry

Angelica Pena et al.

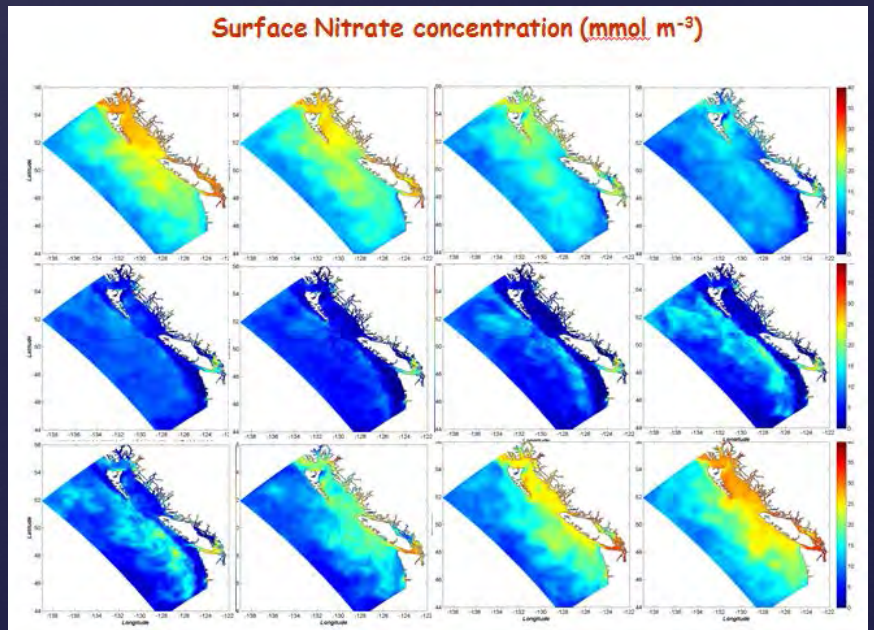
- BC shelf has a naturally low pH, O_2, and $CaCO_3$ saturation states
  - prone to hypoxia and ocean acidification
  - Need to develop projections for biogeochemistry too

- Biogeochemical model
  - NPZD (3N, 2P, 2Z, 3D)
  - O2, DIC and Alkalinity

- increased vertical resolution from physical model

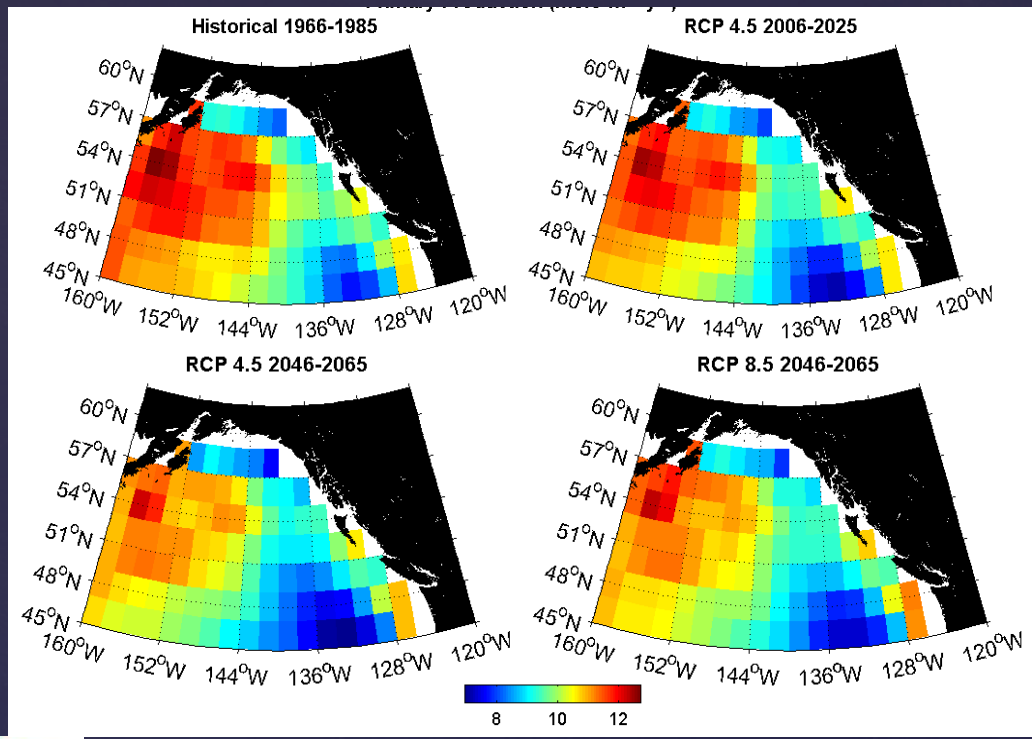


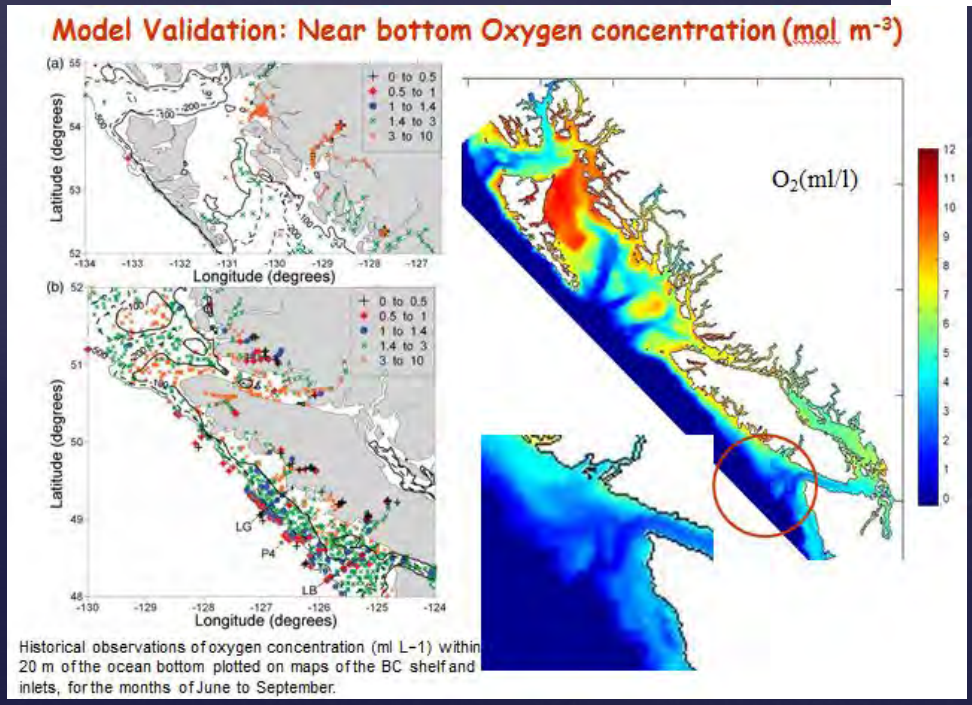
Distribution of the depths of the undersaturated water (aragonite saturation < 1.0; pH < 7.75) Feely et al. (Science, 2008)



BC RCM with Biogeochemistry

- *Tricky to downscale some initial conditions from GCM to coastal region*



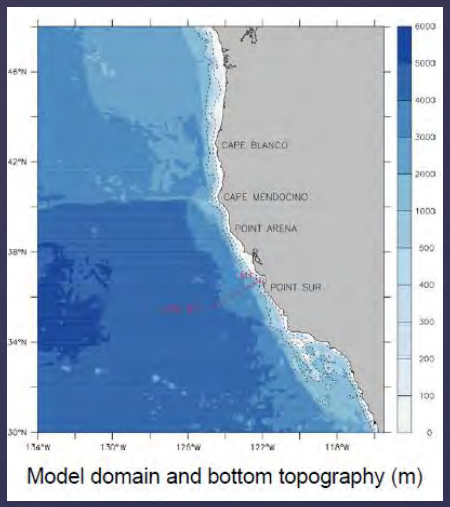


Primary production (Christian & Riche, 2013)

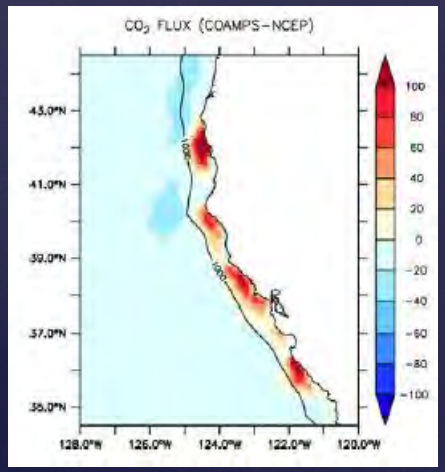
- *Evaluations and simulations continuing*

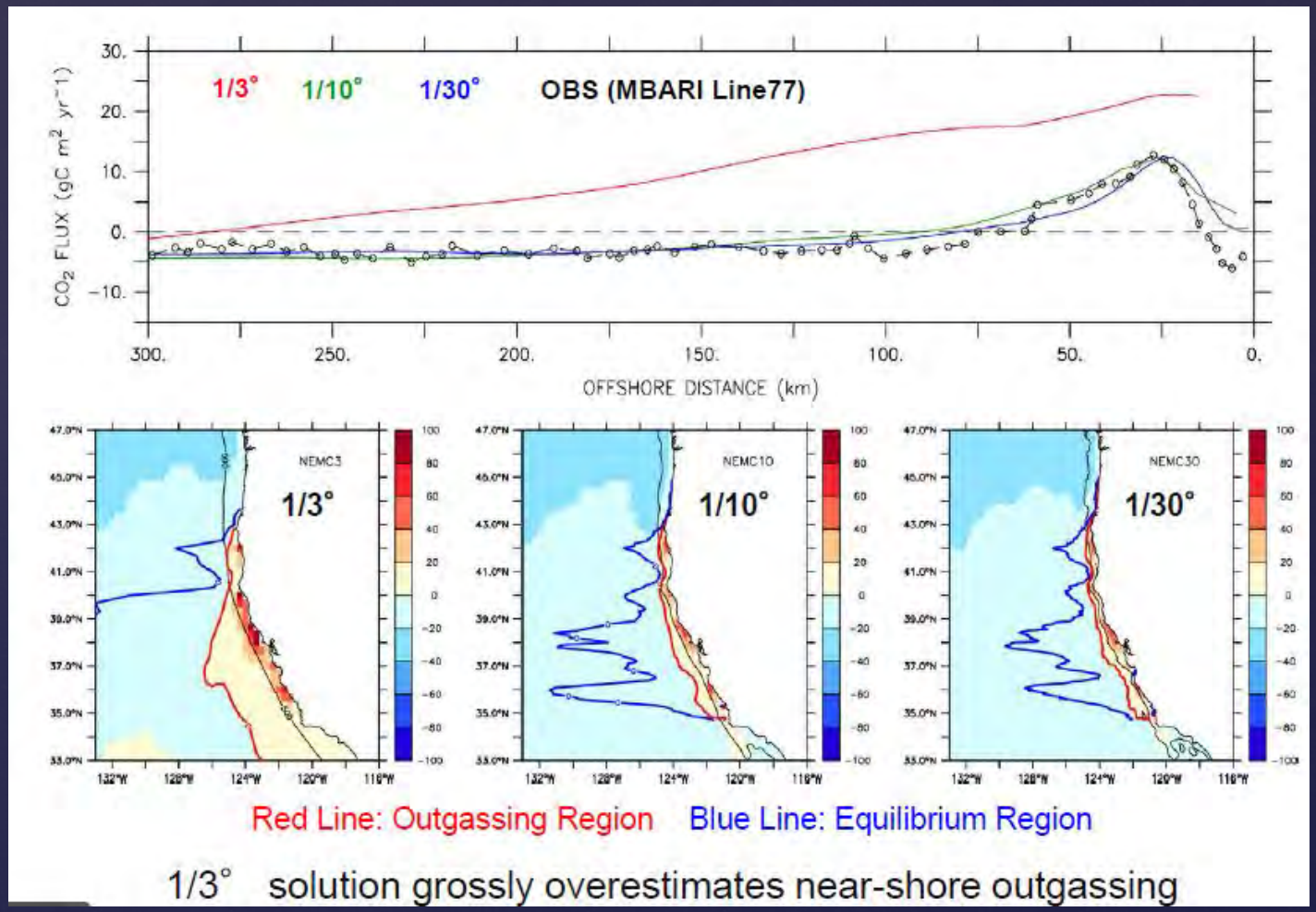
Impact of Horizontal Resolution on CO_2 Air-Sea Exchange in the California Current

Fiechter et al., Global Biogeochemical Cycles, 2014



Model domain and bottom topography (m)

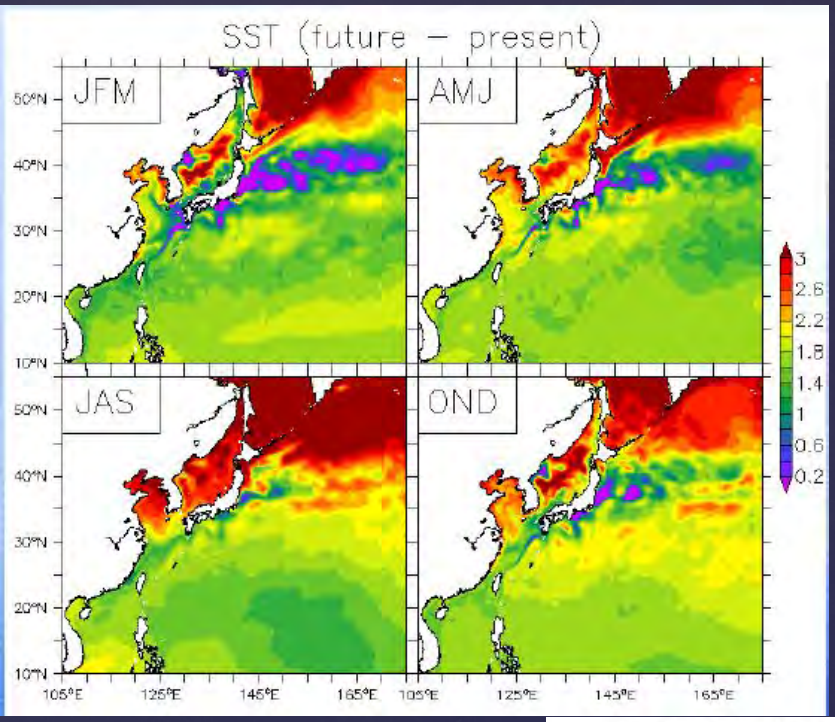


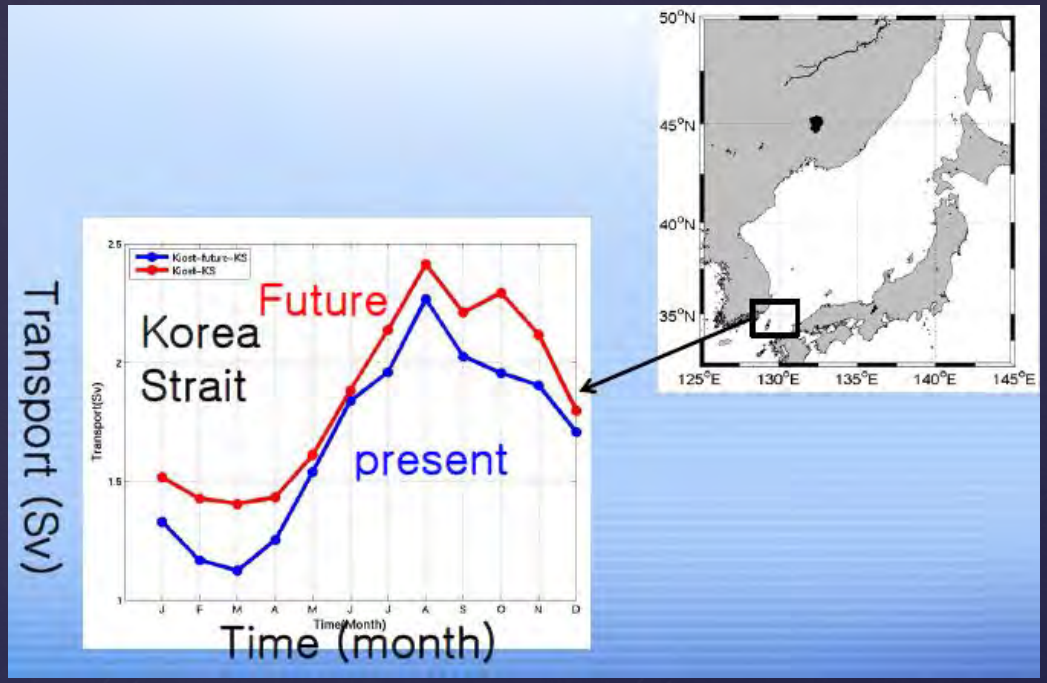


- *ROMS + NEMURO with carbon chemistry, 1999-2005*
- *Wind resolution imp't; enhanced out-gasing southward of California capes*

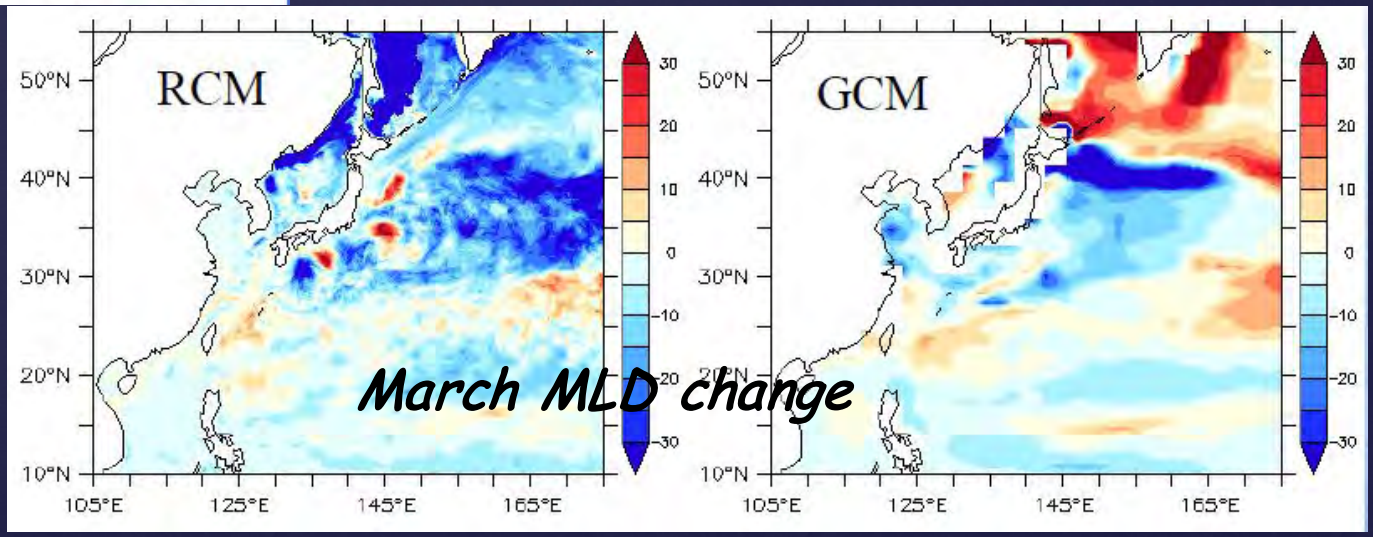
KIOST RCM for Northwest Pacific

Chan Joo Jang et al.



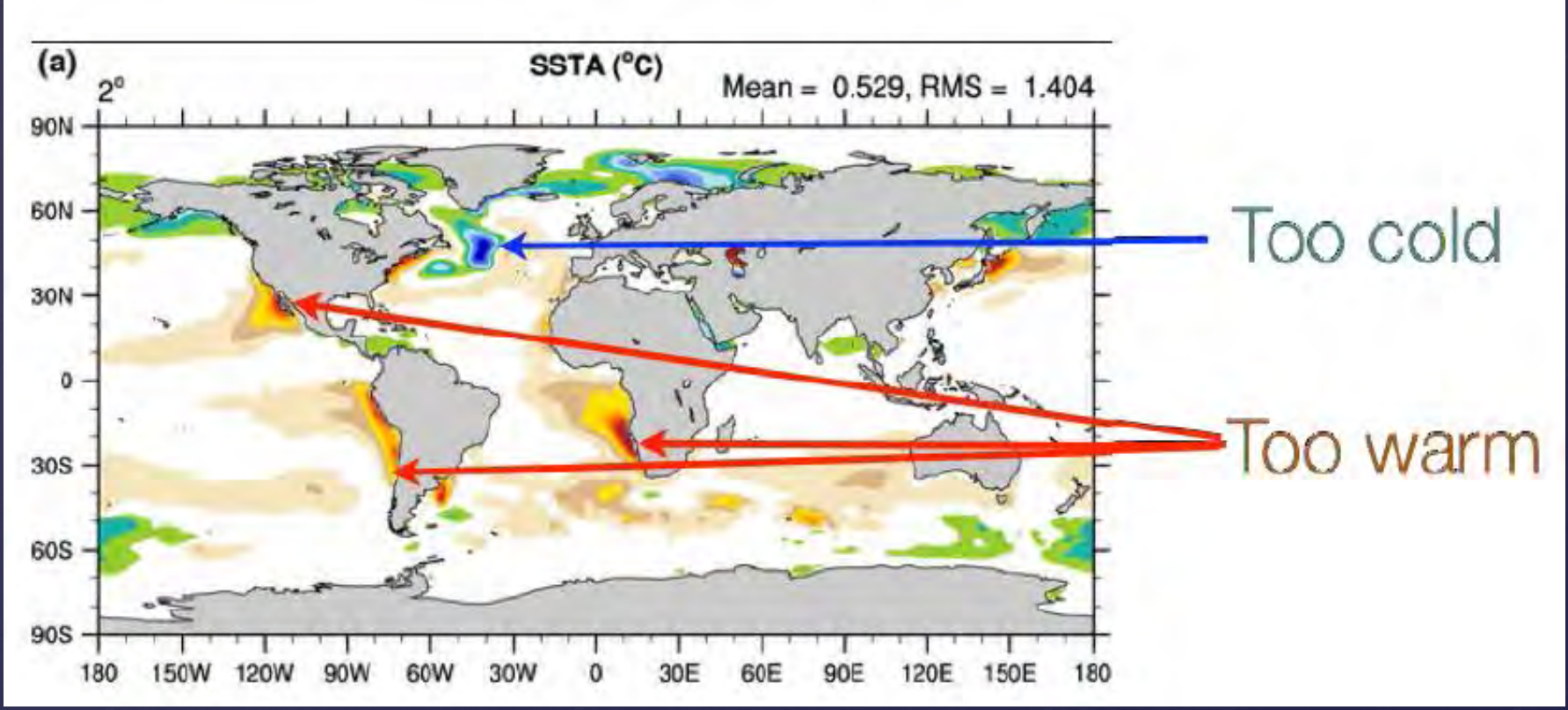


- *10km resolution & 30 layers*
- *1981-2000 & 2081-2100*
- *Multi-GCM forcing important*
- *2-way atmospheric coupling modifies SSTs*



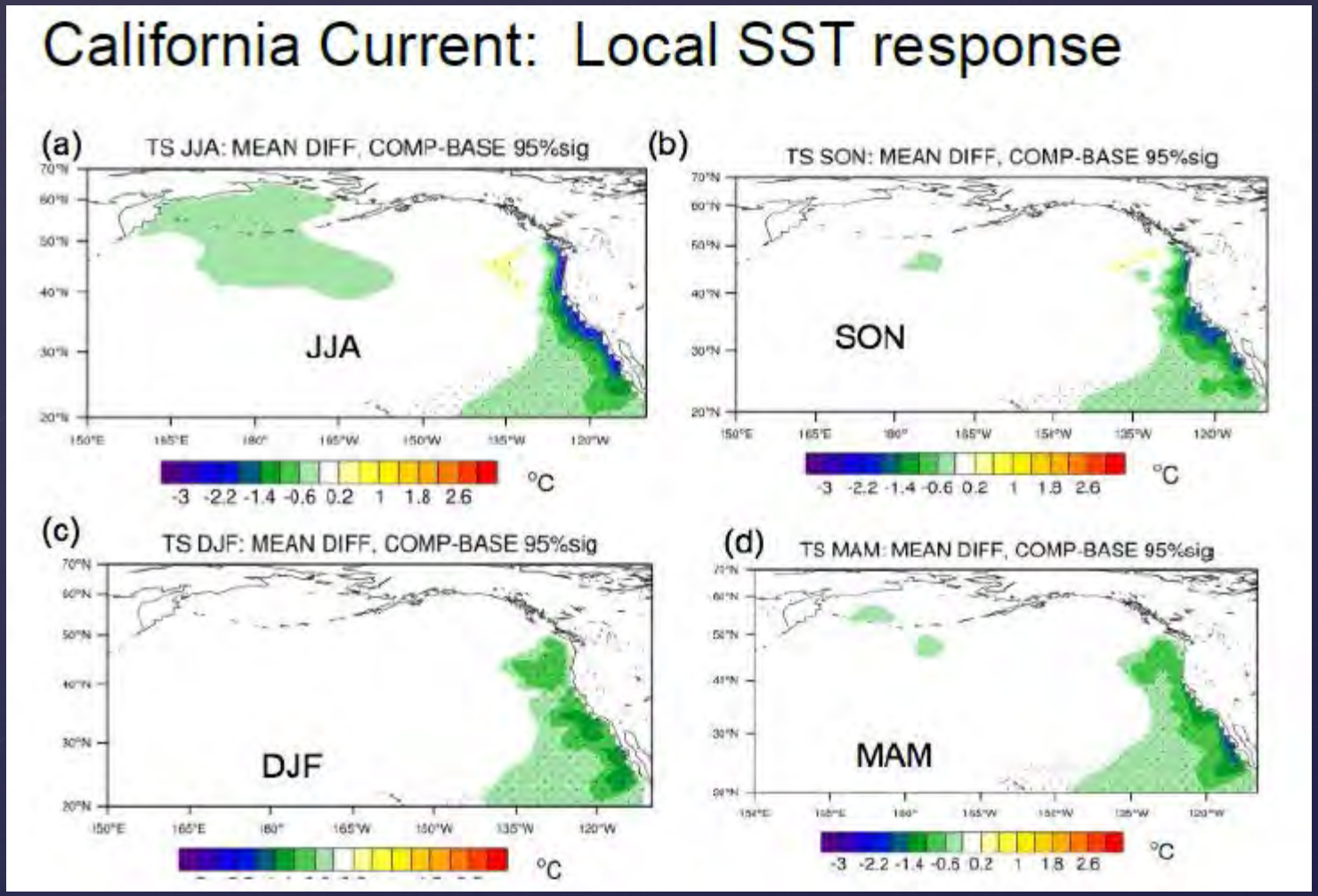
California Current 2-way Coupled Modeling

Enrique Curchitser et al.



- *Embed ROMS in NCAR-CESM with 2-way coupling to address some GCM biases in coastal regions*
  - *Higher spatial resolution of winds, ocean topography & physics, etc*
- *In California Current System, coupling dampens the upwelling signal of cold SSTs*
- *Different mechanisms important elsewhere*

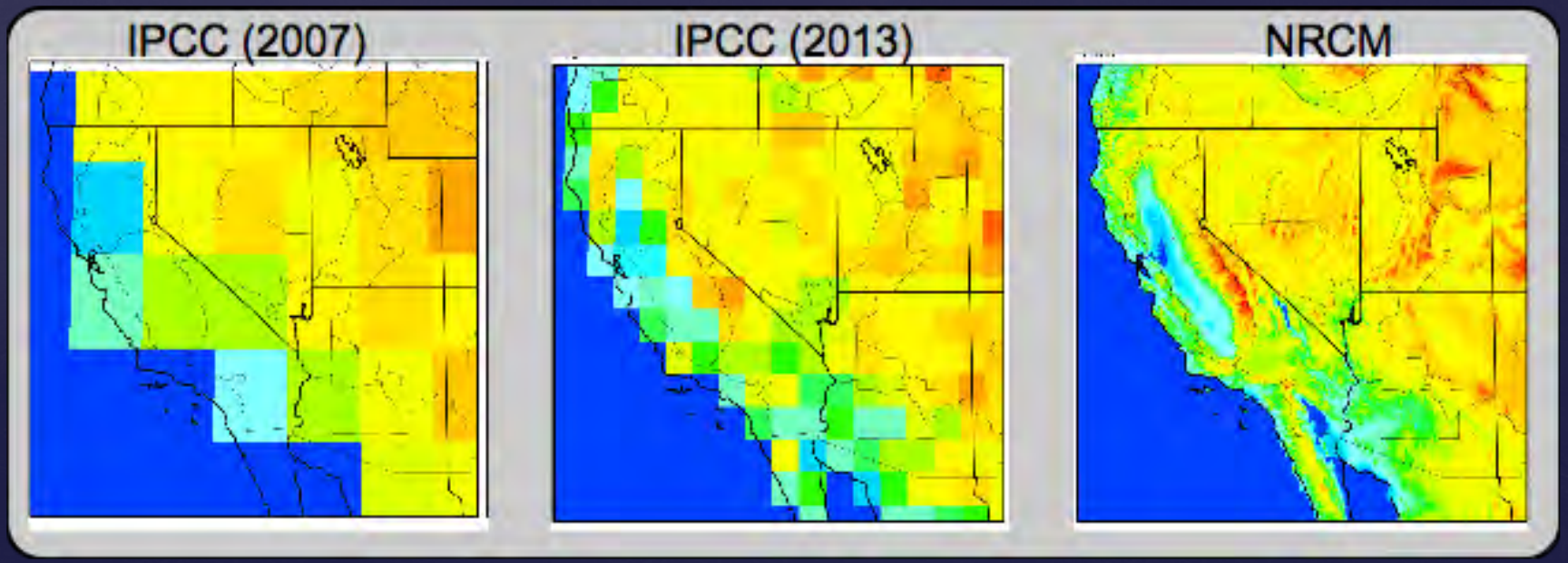
CCS 2-way Coupled Modeling



- *Higher resolution reduces warming bias by better representing upwelling*
- *But feedbacks via coupling are important*
  - *atmos feels affect of cooler waters (low cloud, heat flux changes)*
  - *coupling dampens upwelling signal solely due to cooler SSTs*

The future of FUTURE: Improving Predictions of Regional Changes in Weather, Climate and Ecosystems

* Better capture and investigate important space/time scale interactions
* Develop approaches for reducing biases
* Inform the development of next-generation Earth System Models
* Apply the model to challenging science and important societal questions
* Assist decision-makers to plan for regional changes



From the latest IPCC Assessment Report

"In summary, there is high confidence that downscaling adds value to the simulation of spatial climate detail in regions with highly variable topography (e.g., distinct orography, coastlines) and for mesoscale phenomena and extremes. Regional downscaling is therefore complementary to results obtained directly from global climate models. These results are from a variety of distinct studies with different RCMs".

IPCC AR5, WG1 Report, Chapter 9,
Evaluation of Climate Models, Section 9.6.4


Thank you !
Questions welcome.
Thanks to all members of WG29