

The Alaska Climate Integrated Modeling (ACLIM) Project

Photo: Mark Holsman

Evaluating EBS fishery management strategies under different climate futures

Kirstin Holsman¹ & Alan Haynie¹

ACLIM PIs:

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Alan Haynie¹, Stephen Kasperski¹, Jim Ianelli¹,
Kerim Aydin¹, Wei Cheng^{2,3}, Al Hermann^{2,3},
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2. NOAA Office of Oceanic and Atmospheric Research, Pacific Marine Environmental Laboratory
3. Joint Institute for the Study of the Atmosphere and Ocean, University of Washington
4. Institute of Marine Research, Bergen Norway
5. School of Aquatic and Fisheries Science, University of Washington



The ACLIM team

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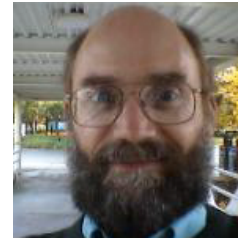
Anne Hollowed



Kirstin Holsman



Alan Haynie



Albert Hermann



Wei Cheng



Andre Punt



Darren Pilcher



Kerim Aydin



Jim Ianelli



Andy Whitehouse



Stephen Kasperski



Cody Szuwalski



Amanda Faig



Jonathan Reum



Michael Dalton



Paul Spencer



Tom Wilderbuer



William Stockhausen

Contributors

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YOU!



NOAA FISHERIES

Introduction to ACLIM



Photo: Mark Holsman

Introduction to ACLIM

Preliminary results



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Introduction to ACLIM

Preliminary results

Discussion of fishing scenarios

**Bering
Strait**

Russia

Alaska

Russia

United States (Alaska)

**Bering
Sea**

Bering Sea

50 km



NASA MODIS image by Jesse Allen

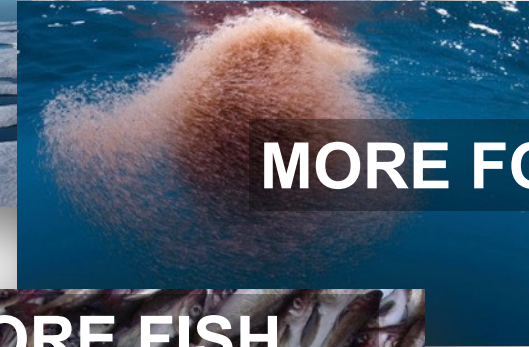
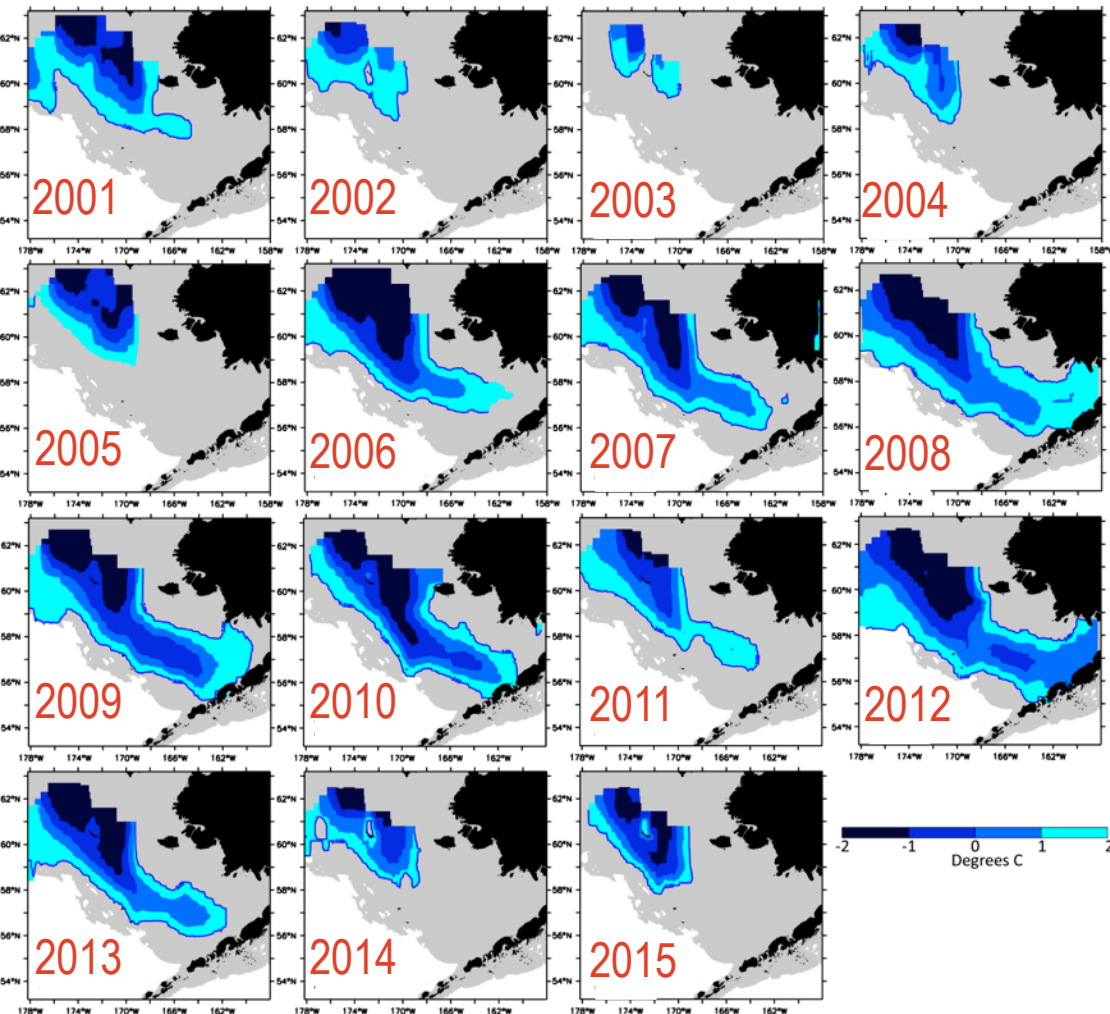


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Bering Sea & Climate variability

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Bering Sea "Cold Pool" 2001-2015

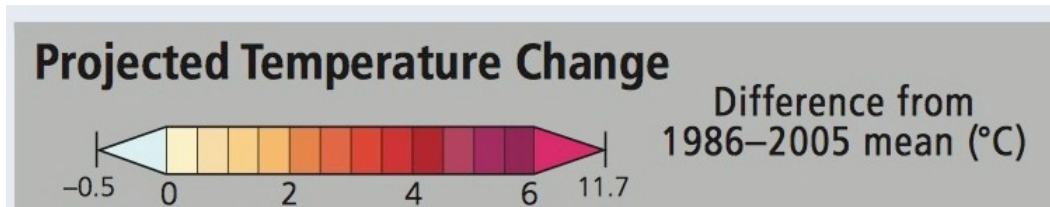


Graphic: J. Overland, P. Stabeno, M. Wang, C. Ladd, N. Bond, and S. Salo, PMEL/NOAA

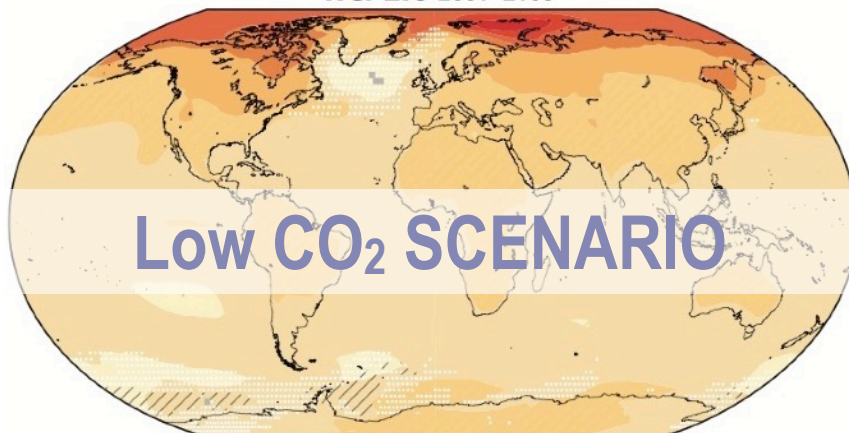
Intergovernmental Panel on Climate Change (IPCC)

5th Assessment Report (2013, 2014)

32 A/CLIM
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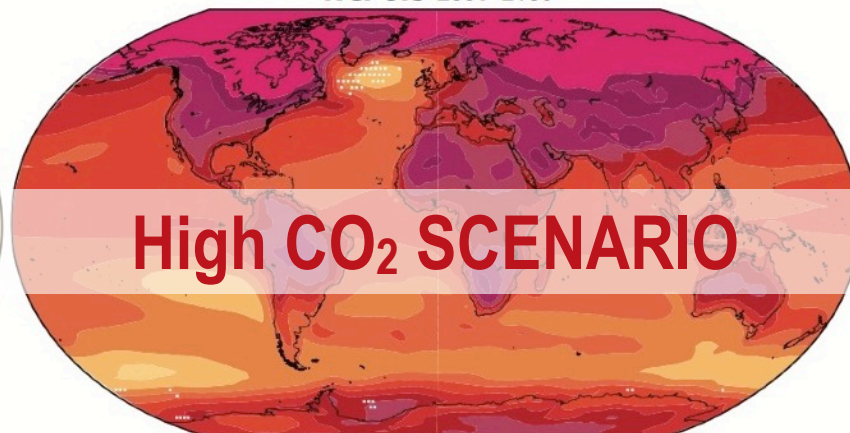


RCP2.6 2081–2100



“Paris COP21 agreement”

RCP8.5 2081–2100



“Business as usual”

<https://www.ipcc.ch/report/ar5/>



NOAA FISHERIES

Improve management **foresight** in a changing climate



Project changes in Bering Sea ocean conditions and fish populations

*Physical, biological, & socioeconomic change;
now - 2100*



Project changes in Bering Sea ocean conditions and fish populations

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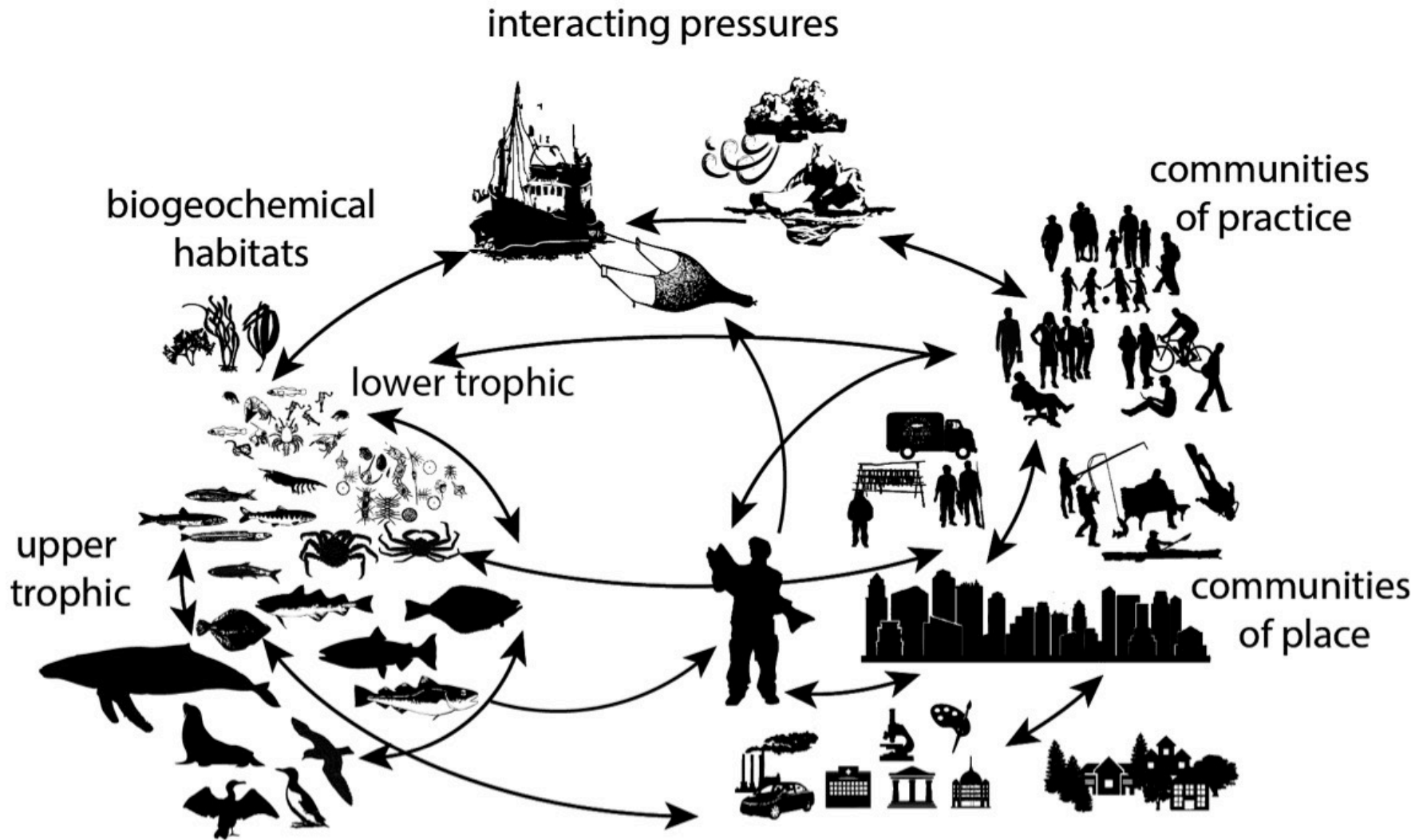
**Evaluate how management can adapt to minimize
negative impacts of future changes**

*gradual change & sudden shocks;
test existing & new tools; estimate risk*



ACLIM utilizes a fully integrated approach

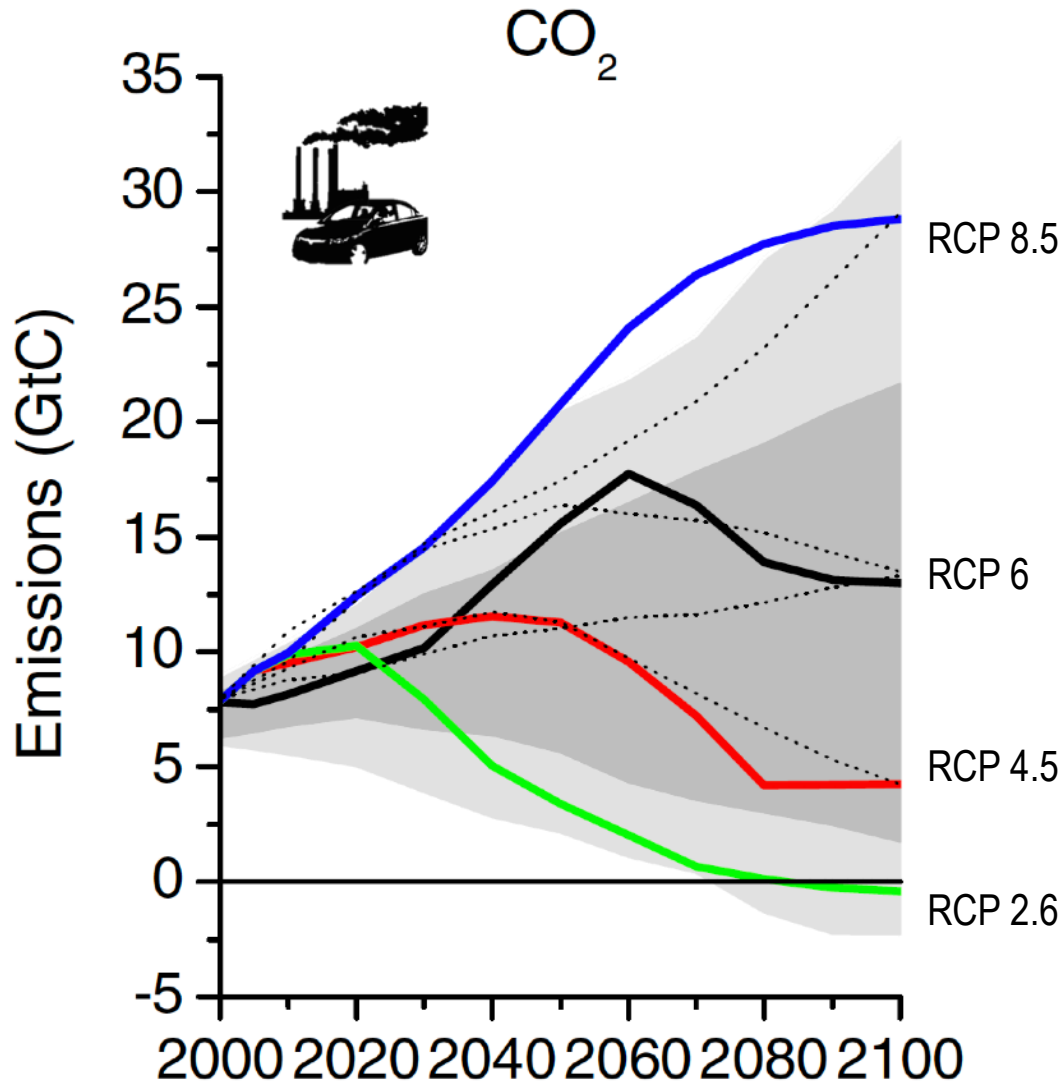
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Carbon Emission Scenarios

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“plausible descriptions of how the future may evolve with respect to a range of variables”
van Vuuren et al. 2011



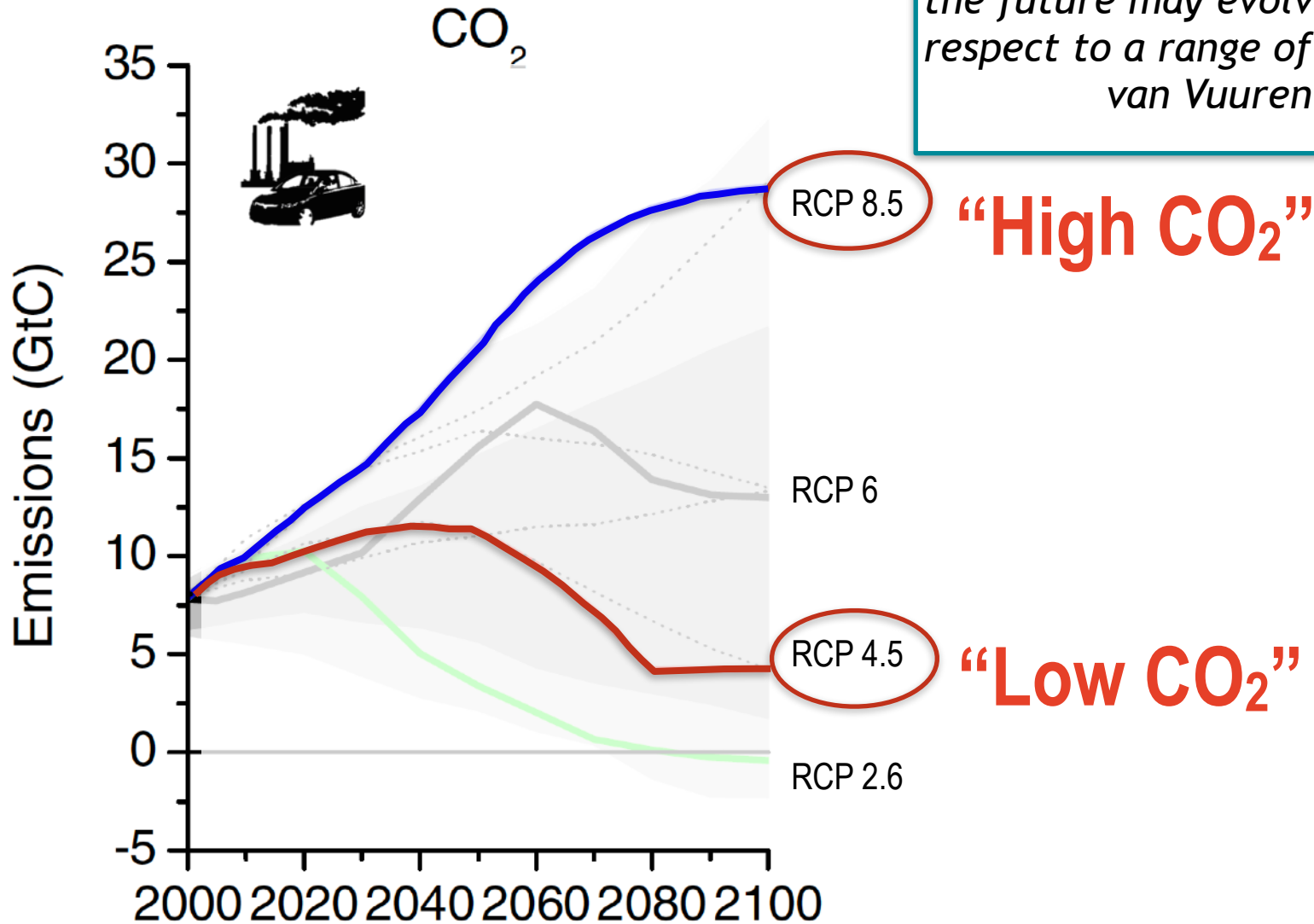
“High reliance on fossil fuels”

“Significant global reduction in carbon use”

Carbon Emission Scenarios

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“plausible descriptions of how the future may evolve with respect to a range of variables”
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Global Climate Models (x 7)

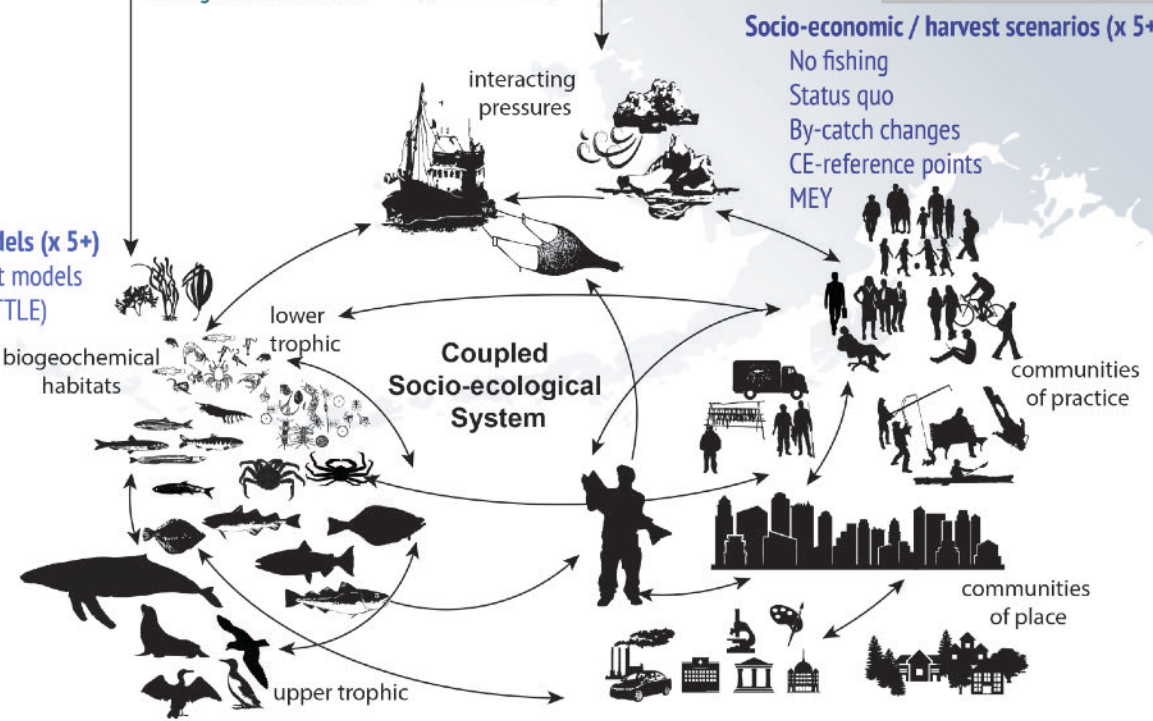
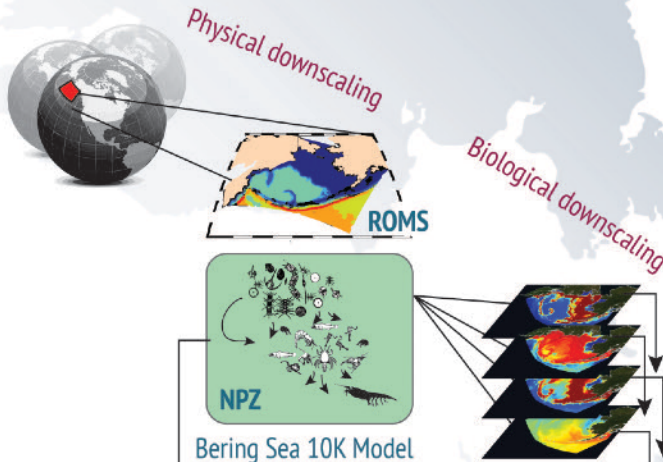
- ECHO-G
- MIROC3.2 med res.
- CGCM3-t47
- CCSM4-NCAR-PO
- MIROCESM-C-PO
- GFDL-ESM2M*-PO
- GFDL-ESM2M*-PON

Projection Scenarios (x3)

- AR4 A1B
- AR5 RCP 4.5
- AR5 RCP 8.5

Climate Enhanced Biological models (x 5+)

- CE- single species assessment models
- CE- multispecies model (CEATTLE)
- CE - Size spectrum model
- CE- Ecosim with Ecosim
- End-to-End model (FEAST)



ACLIM

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- FATE: Fisheries & the Environment
- SAAM: Stock Assessment Analytical Methods
- S&T: Climate Regimes & Ecosystem Productivity

Socio-economic / harvest scenarios (x 5+)

- No fishing
- Status quo
- By-catch changes
- CE-reference points
- MEY

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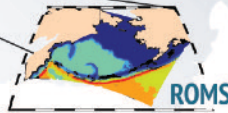
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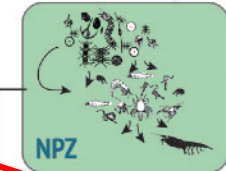
- AR4 A1B
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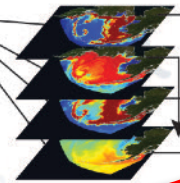
Physical downscaling



Biological downscaling



Bering Sea 10K Model

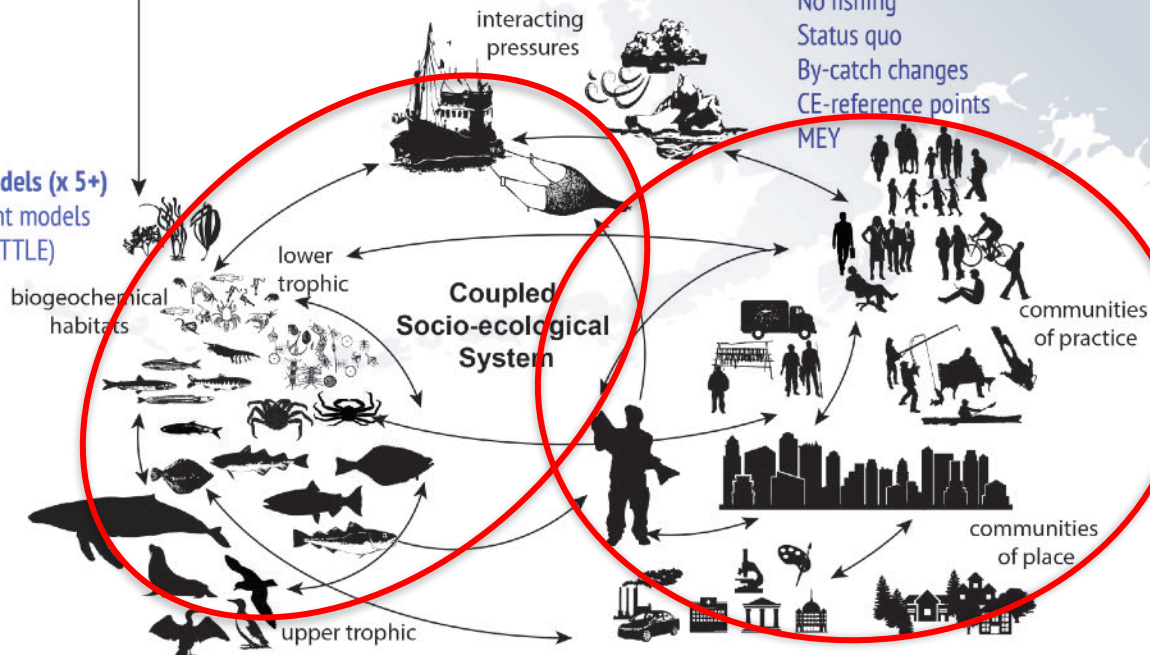


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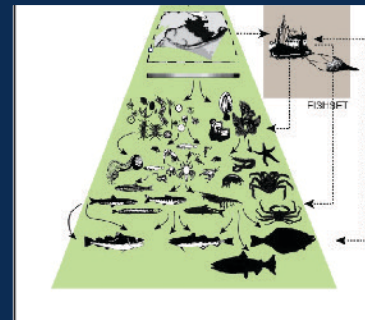
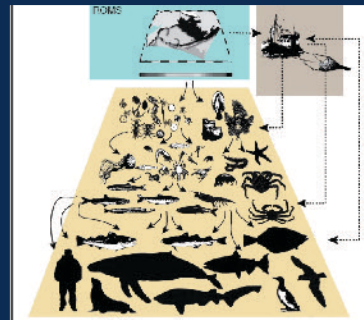
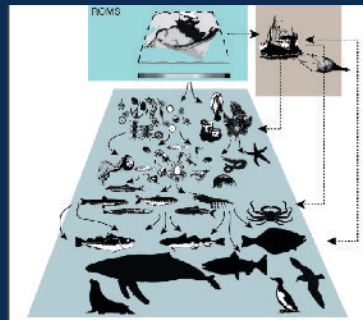
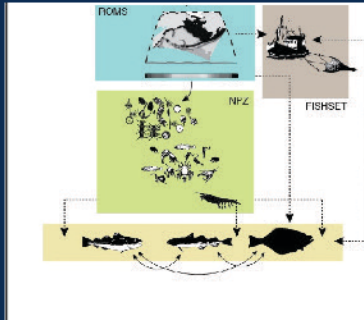
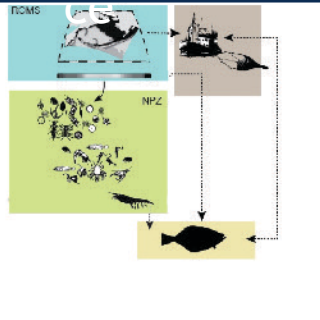
CE-SSM

CE-MSM

CE-EwE

CE-MIZER

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FEAST



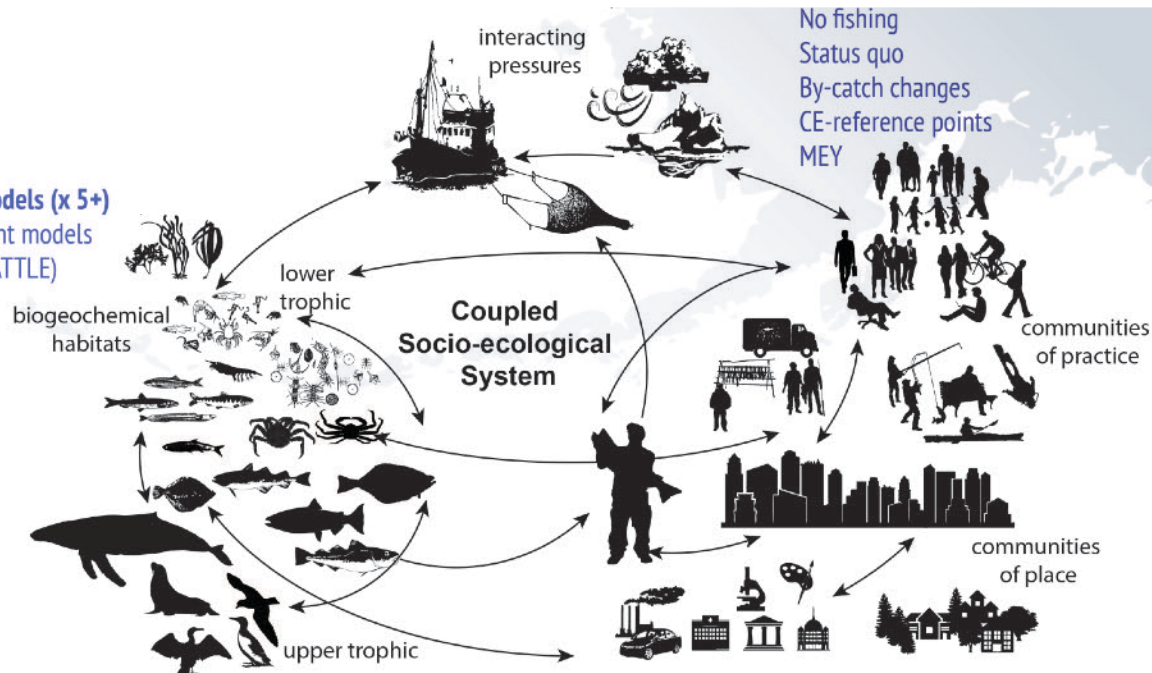
Fast, mcmc
Statistical
Implicit ecosystem “noise”



Slow, high resolution
Mechanistic
Explicit ecosystem interactions

Climate Enhanced Biological models (x 5+)

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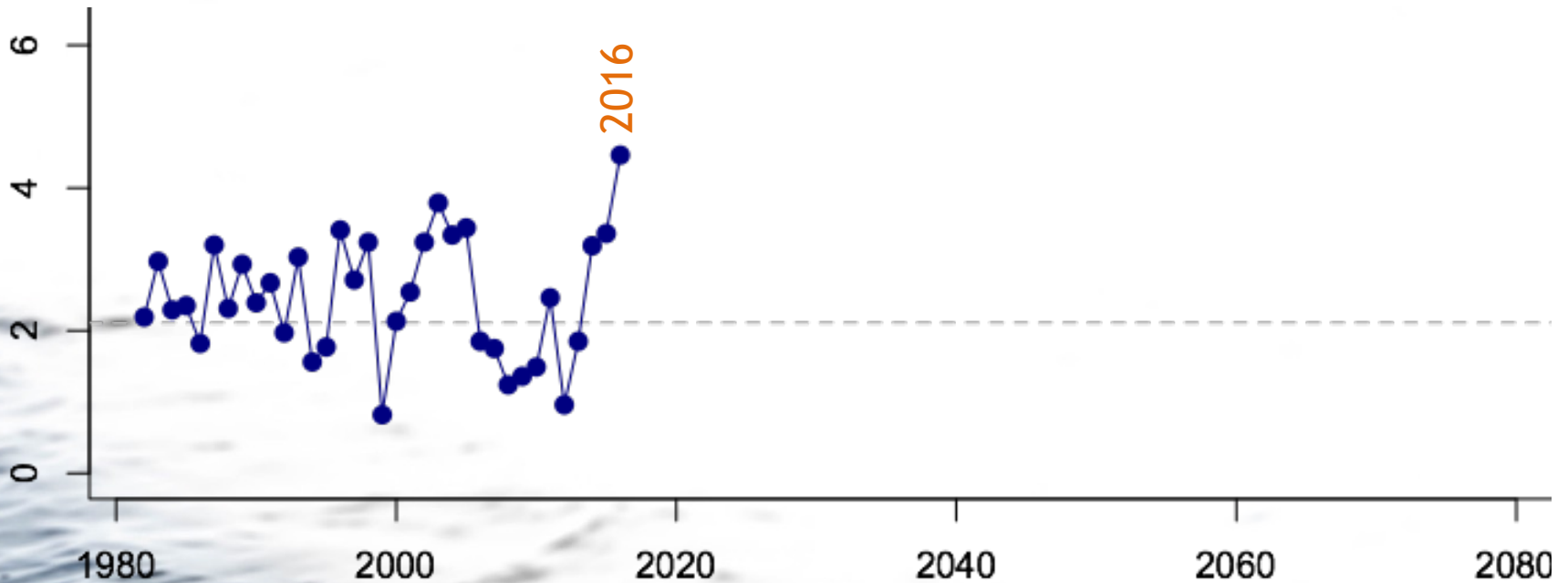
Preliminary Results

(physical projections)

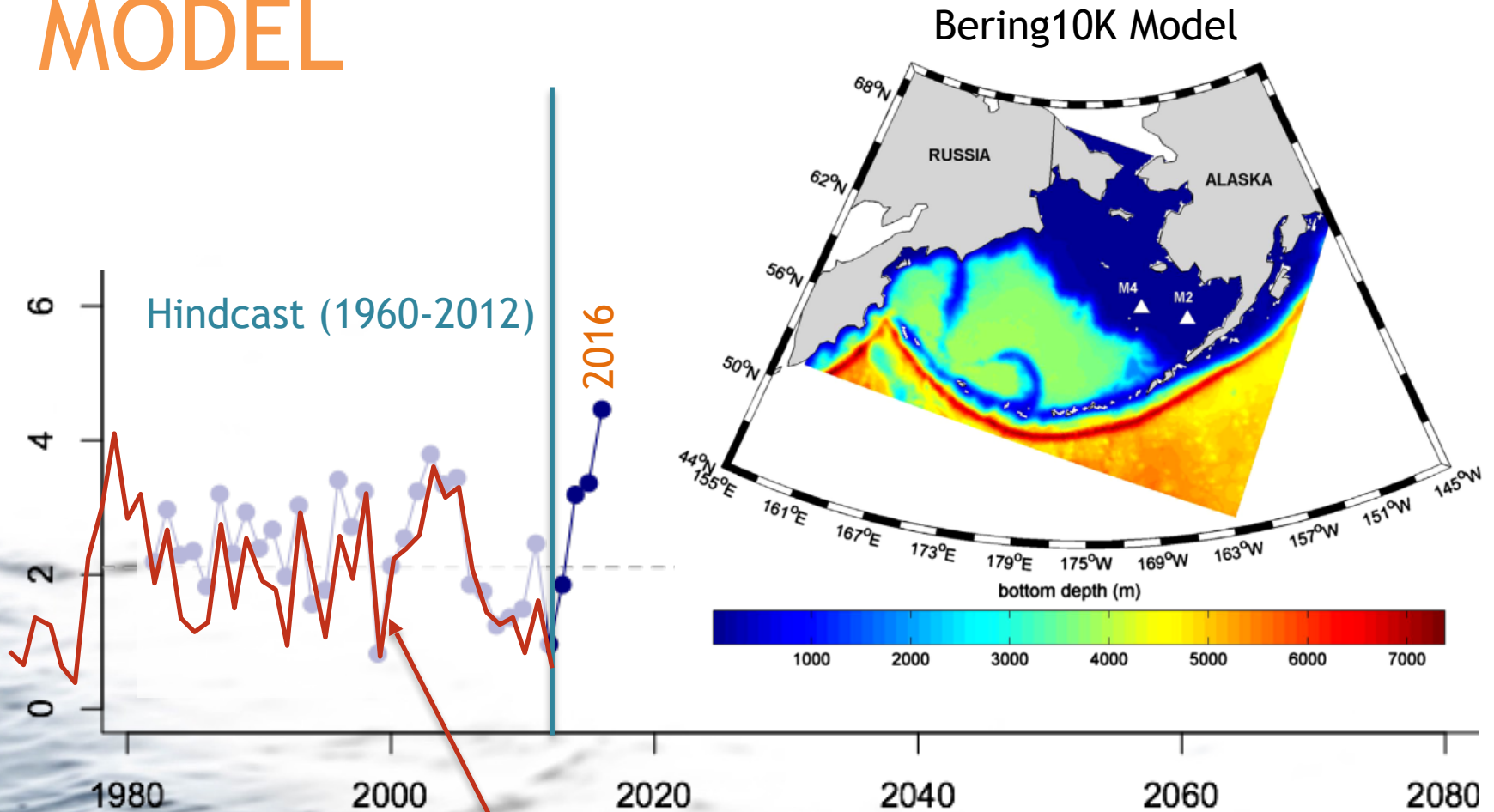


Photo: Mark Holsman

Summer Bottom Temperature (°C) OBSERVED



Summer Bottom Temperature (°C) MODEL

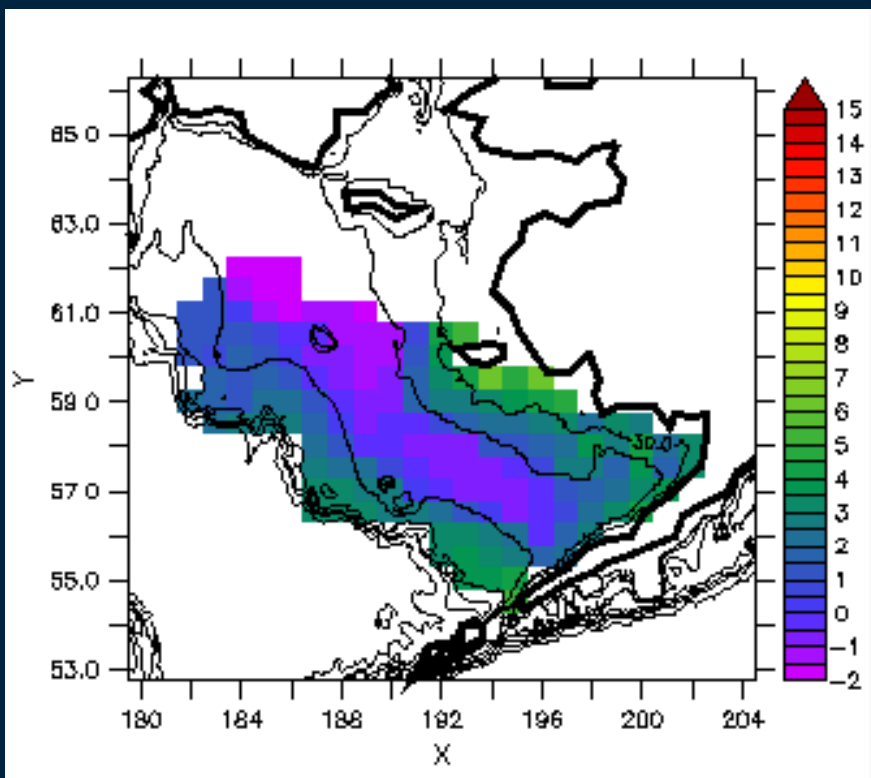


Model Reproduced Bottom Temp.

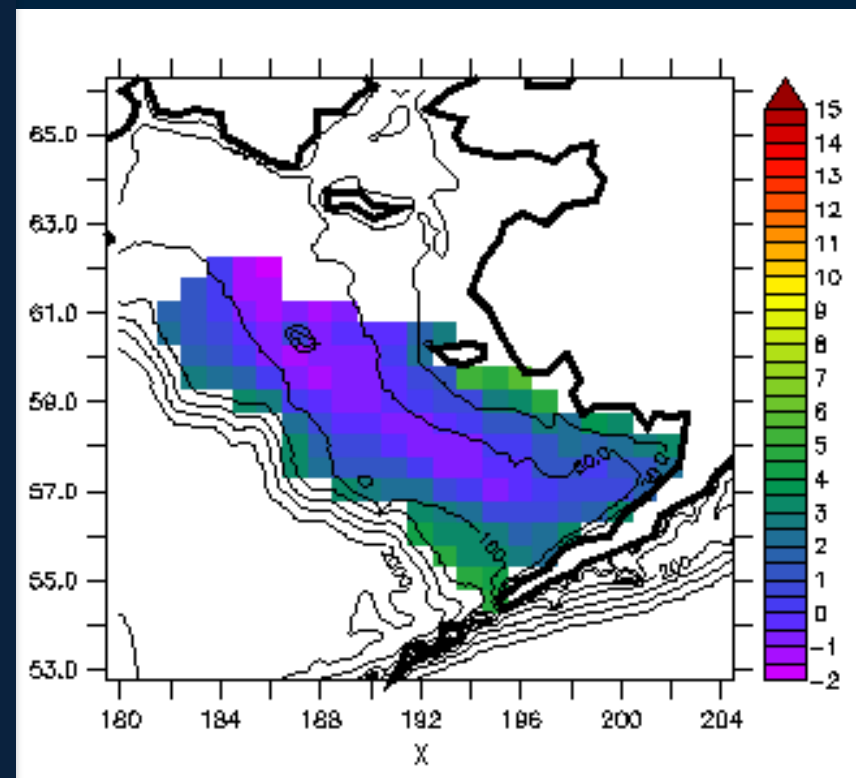


Bottom T. (°C) Summer 2009

DATA

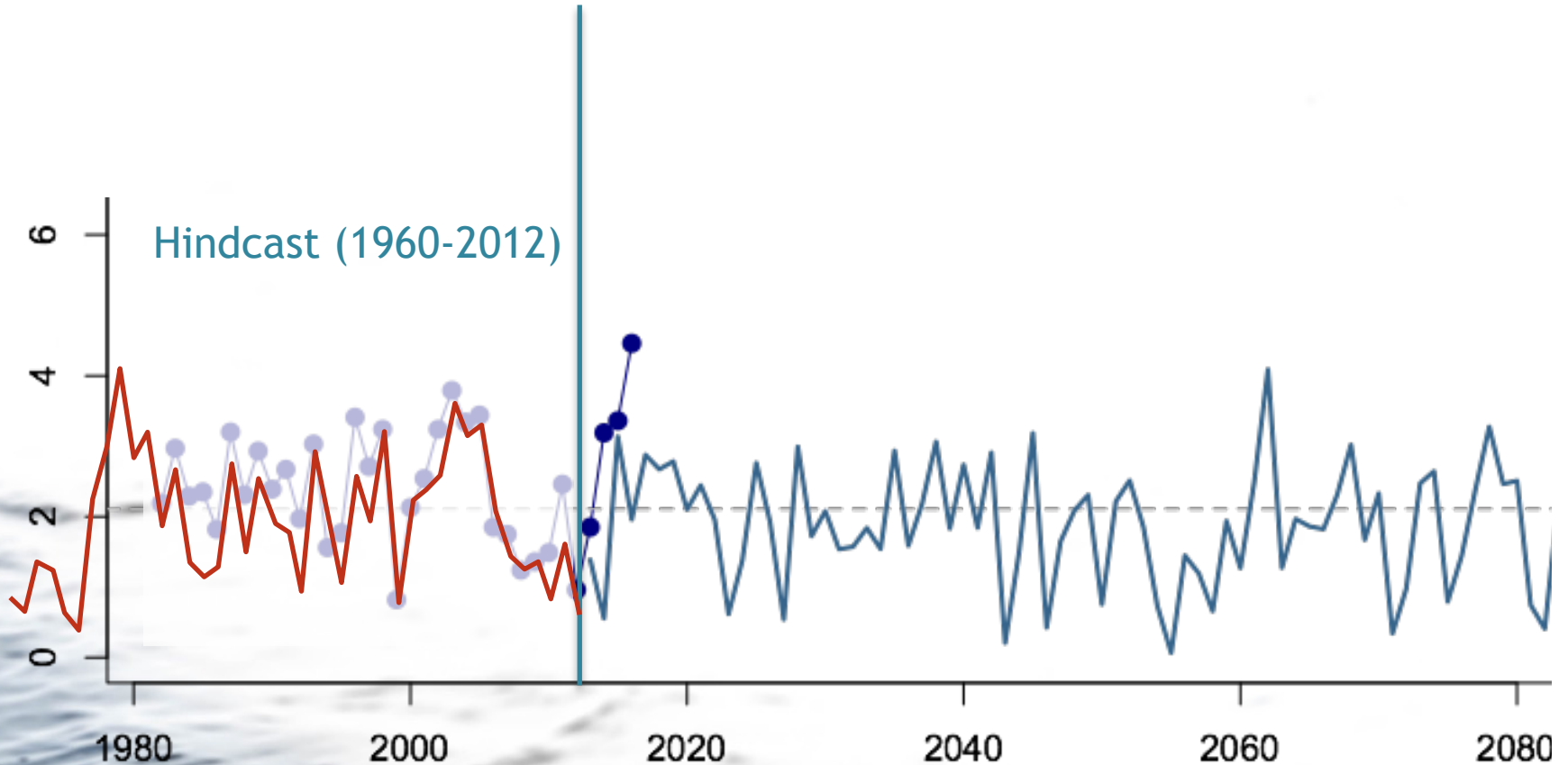


MODEL



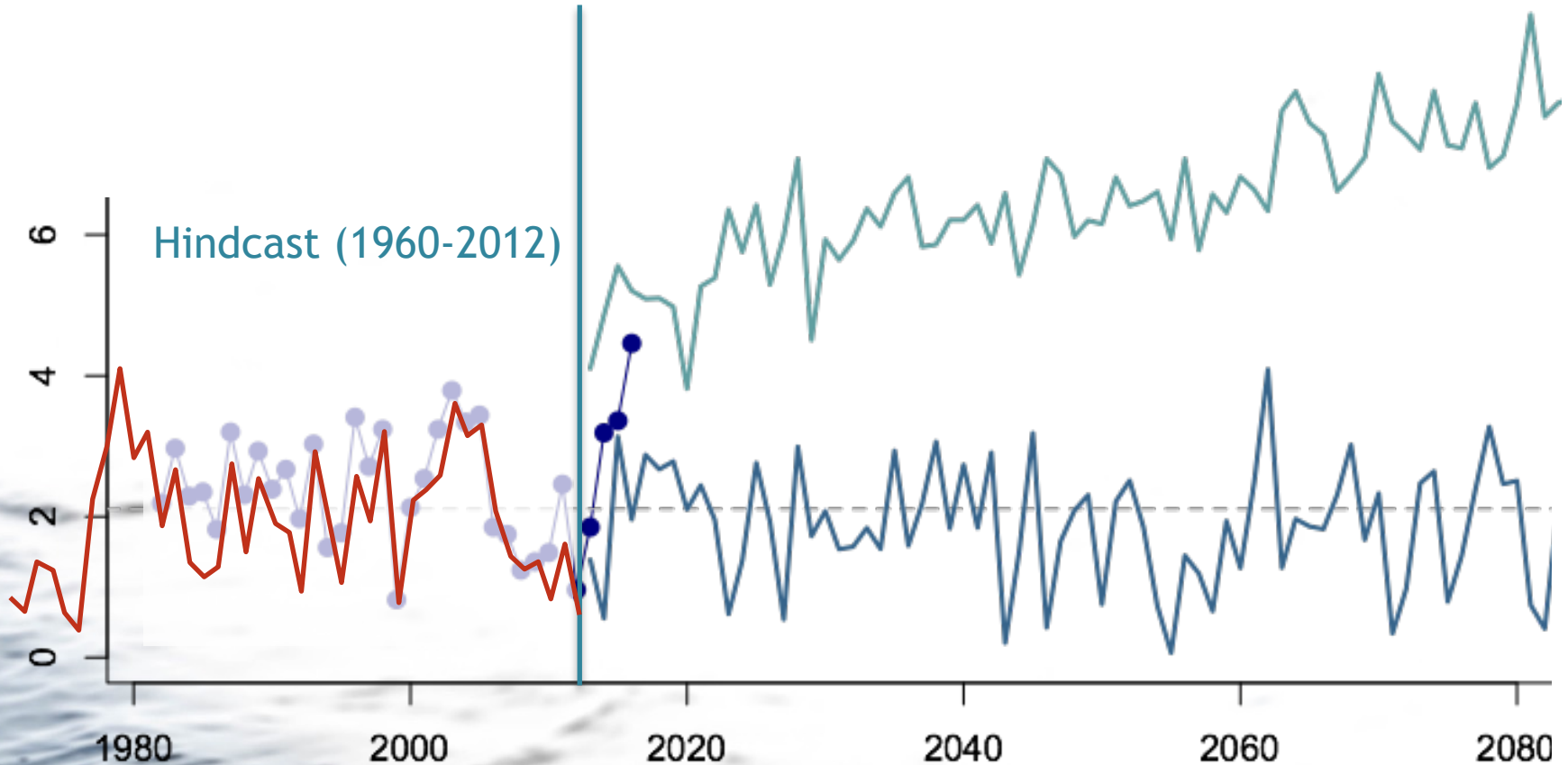
Summer Bottom Temperature ($^{\circ}\text{C}$) MODEL

Draft results; please do not reproduce



Summer Bottom Temperature (°C) MODEL

Draft results; please do not reproduce

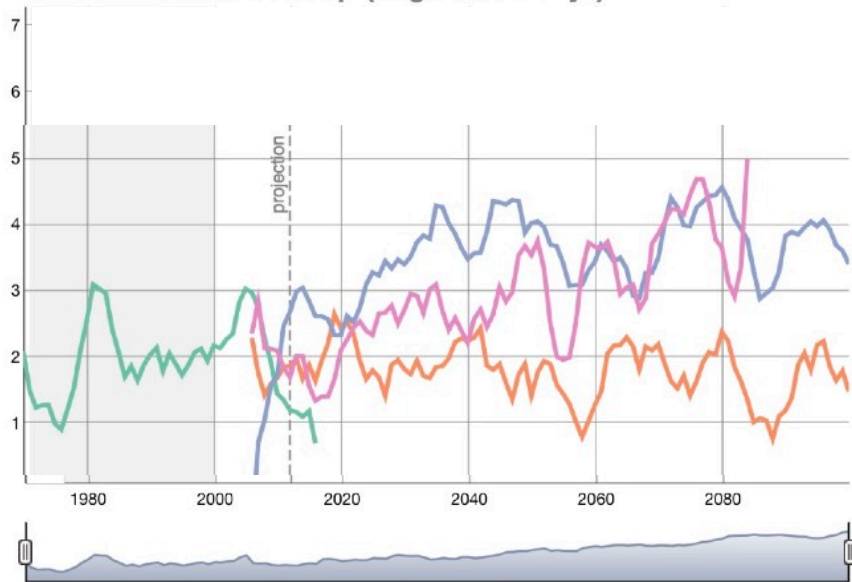


Bottom Temperature (°C)

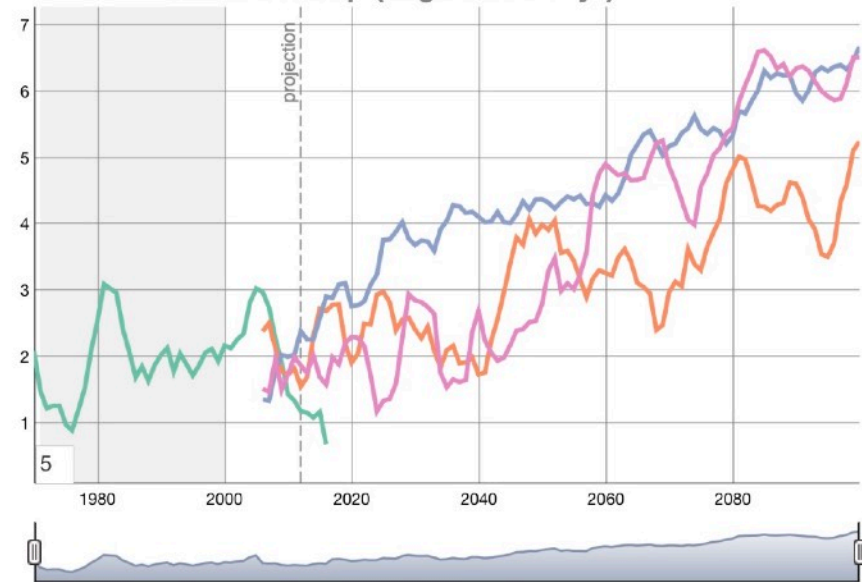
Low CO₂ Scenario (RCP 4.5)

High CO₂ Scenario (RCP 8.5)

BottomTemp (avg across 5 yr)



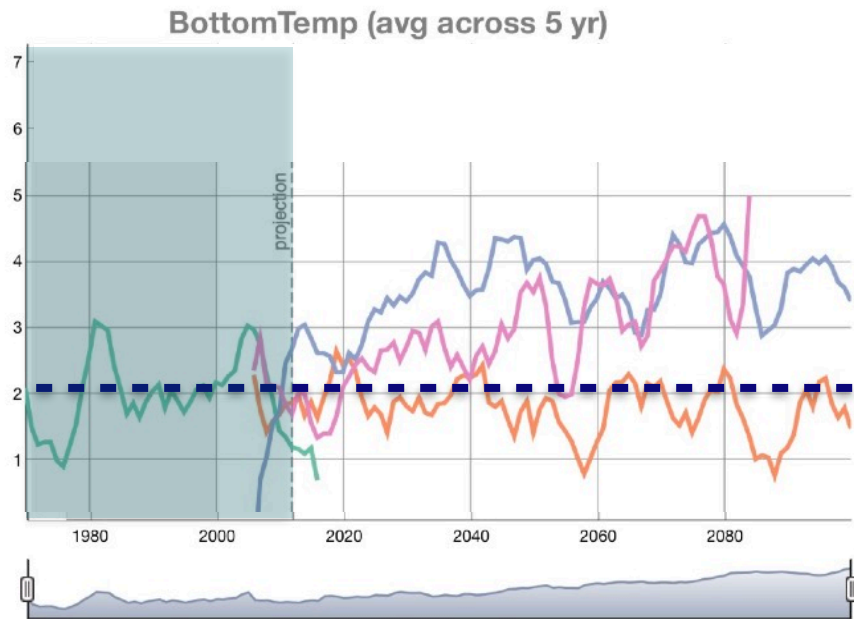
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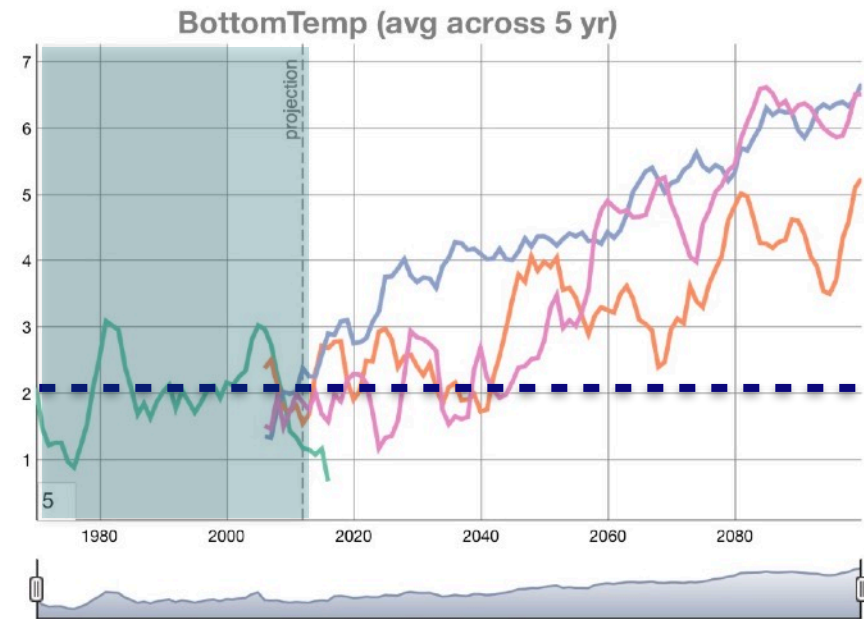
Holsman et al. in prep; draft results, please do not cite or copy

Bottom Temperature (°C)

Low CO₂ Scenario (RCP 4.5)



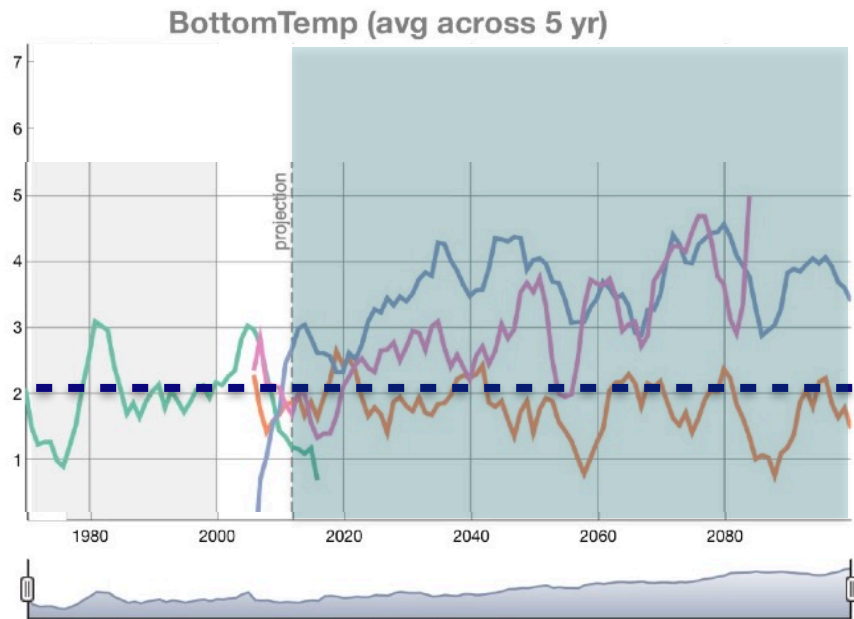
High CO₂ Scenario (RCP 8.5)



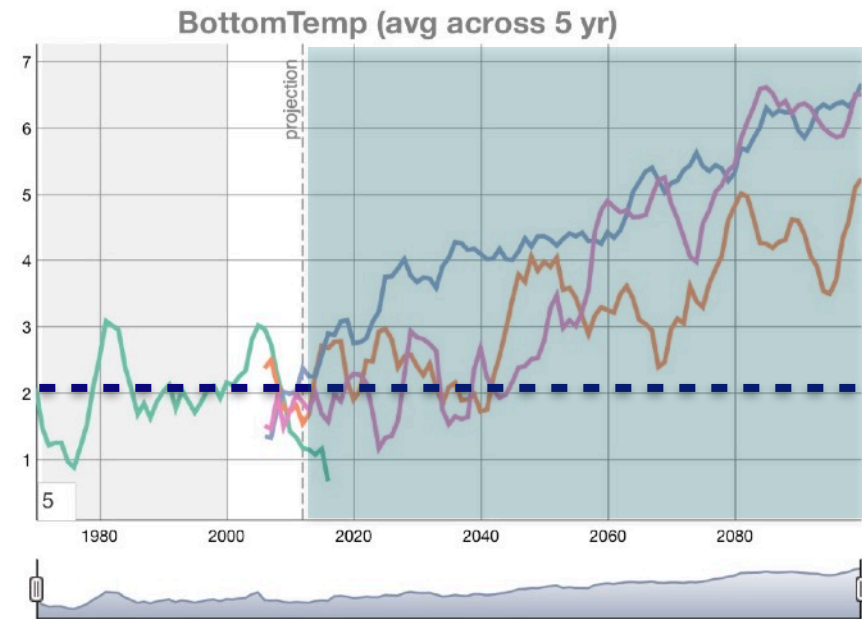
Holsman et al. in prep; draft results, please do not cite or copy

Bottom Temperature (°C)

Low CO₂ Scenario (RCP 4.5)



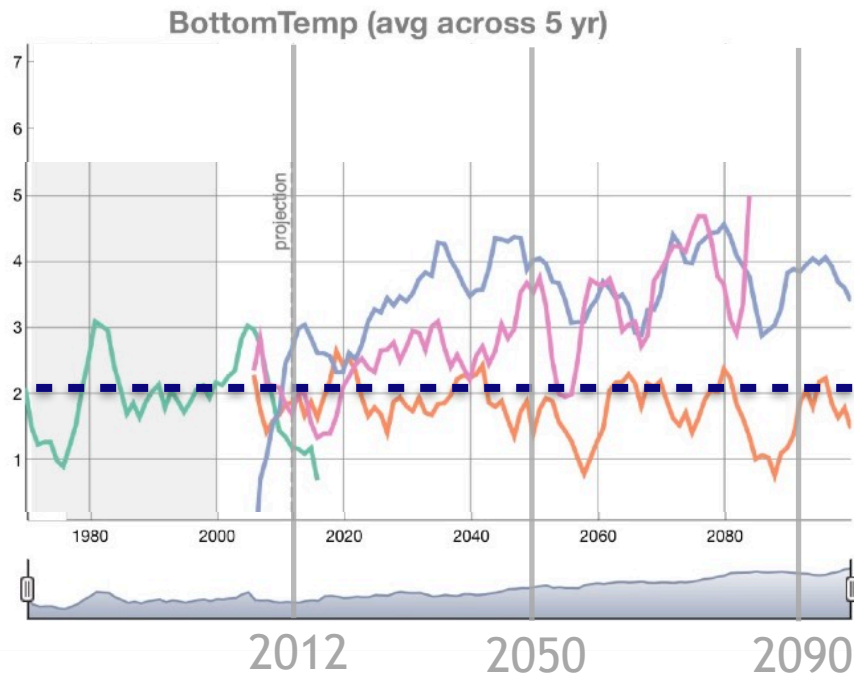
High CO₂ Scenario (RCP 8.5)



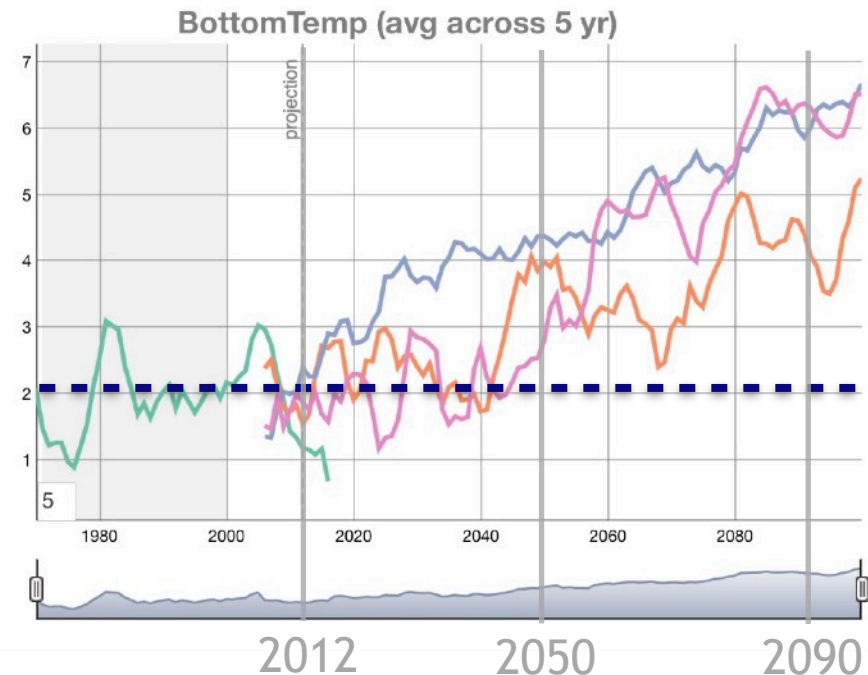
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Bottom Temperature (°C)

Low CO₂ Scenario (RCP 4.5)



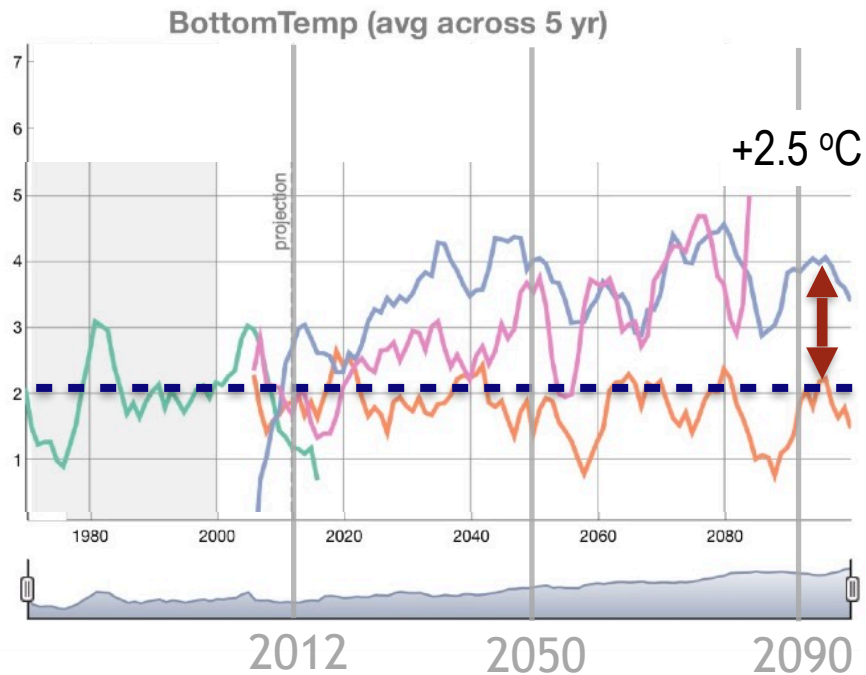
High CO₂ Scenario (RCP 8.5)



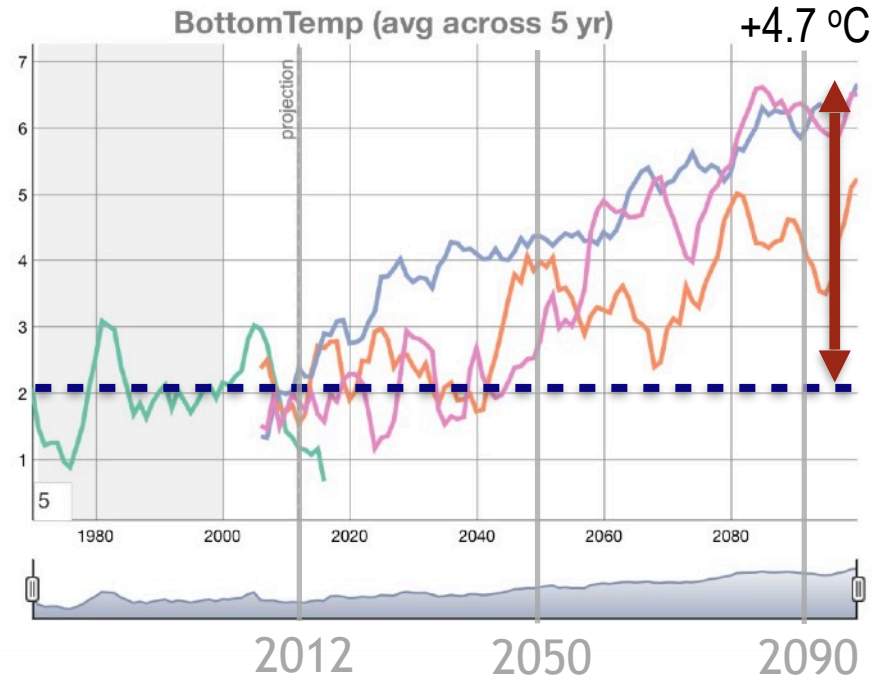
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Bottom Temperature (°C)

Low CO₂ Scenario (RCP 4.5)



High CO₂ Scenario (RCP 8.5)



Holsman et al. in prep; draft results, please do not cite or copy

Average of all "warm" scenarios (ESM RCP 8.5)

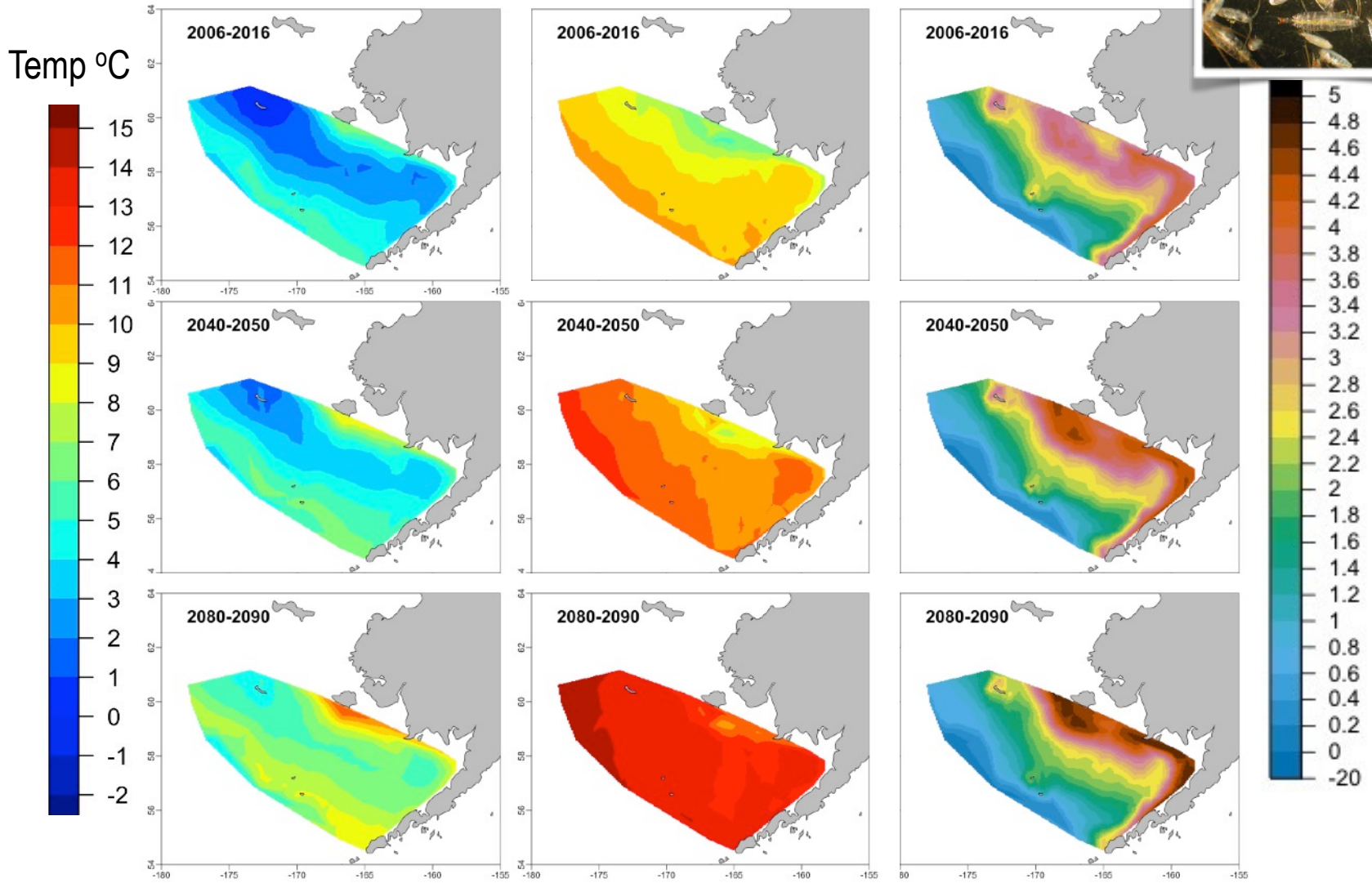
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Bottom Temp (C)

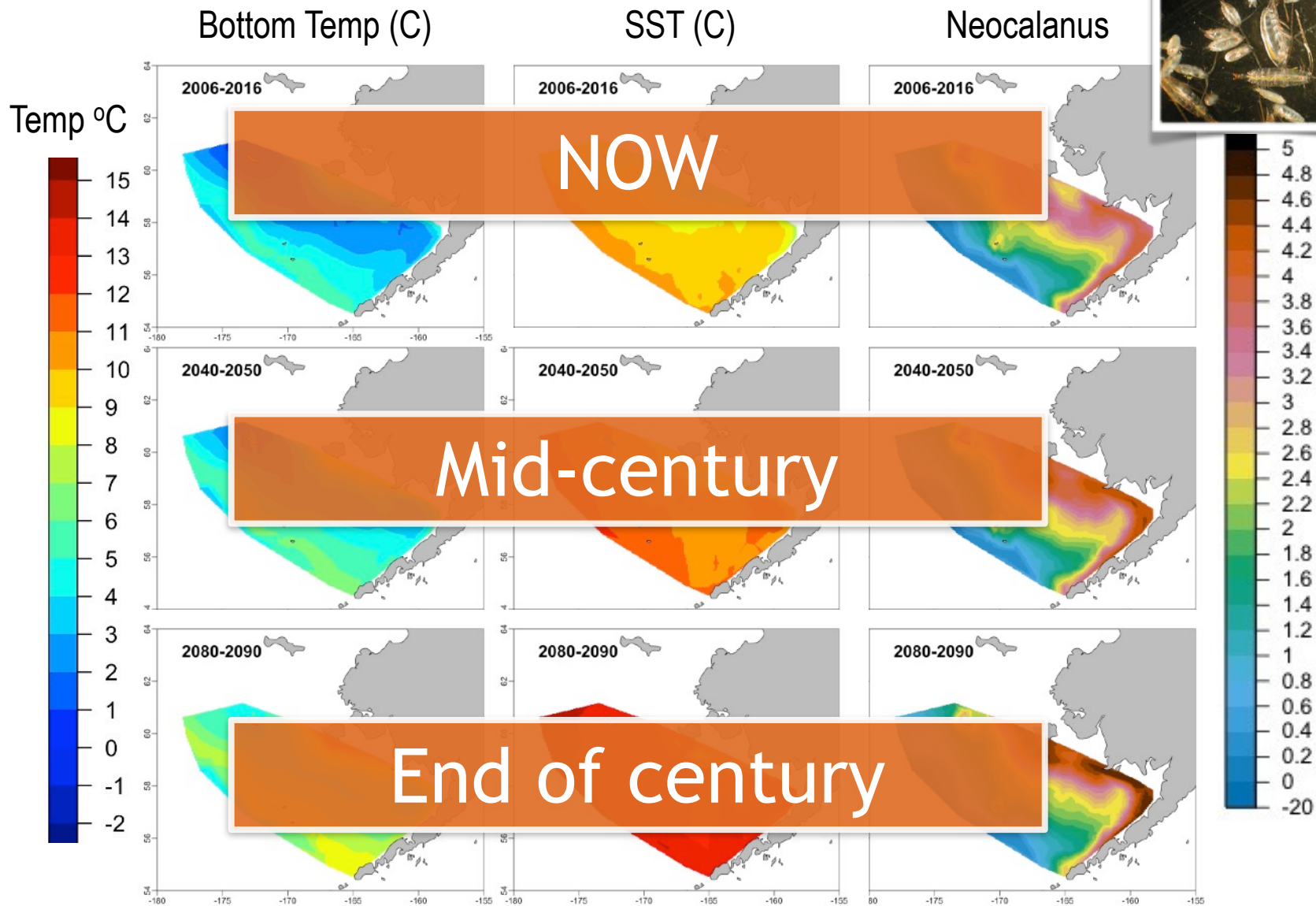
SST (C)

Neocalanus



Average of all "warm" scenarios (ESM RCP 8.5)

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Average of all "warm" scenarios (ESM RCP 8.5)

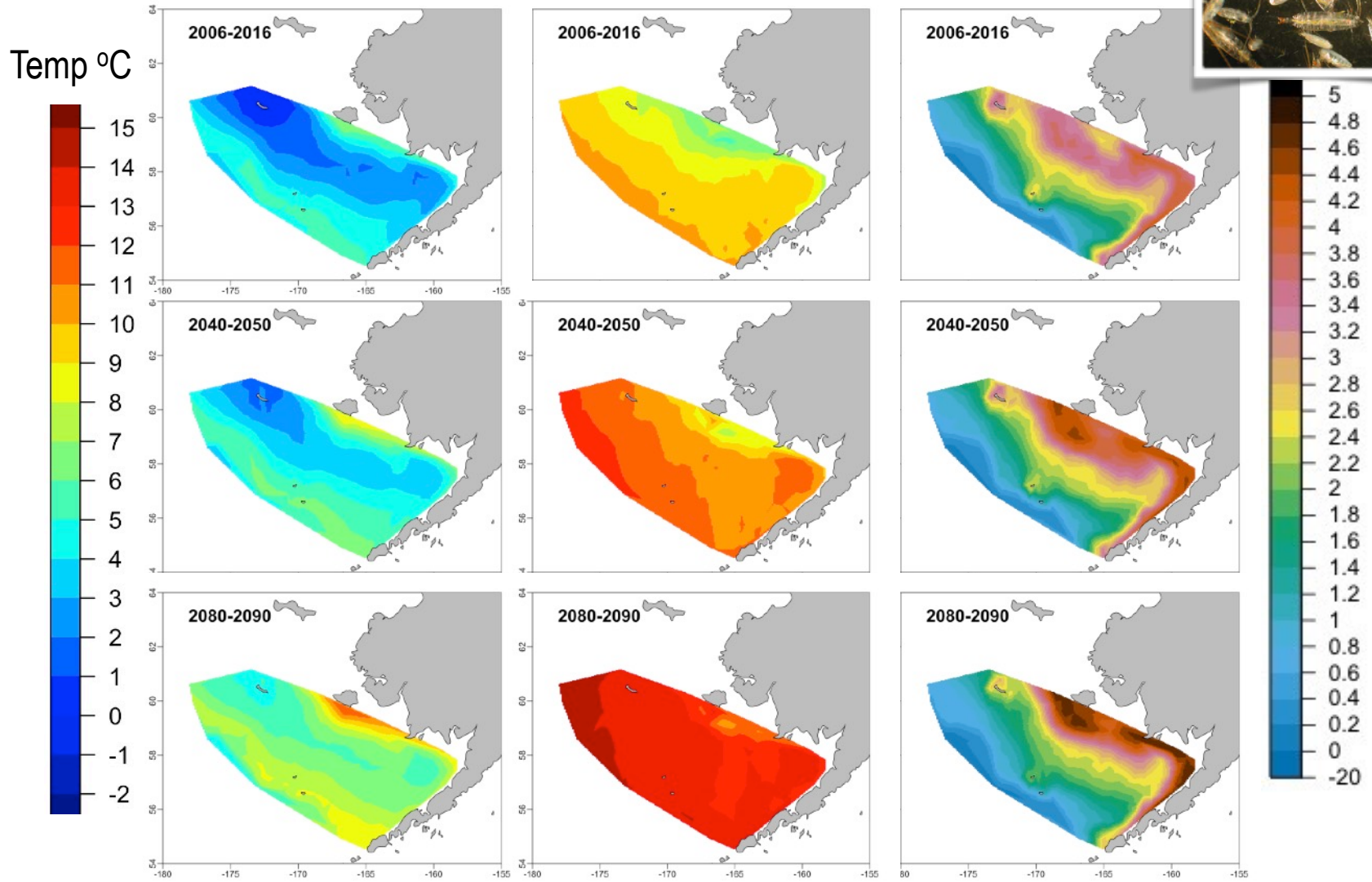
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Bottom Temp (C)

SST (C)

Neocalanus



Average of all "warm" scenarios (ESM RCP 8.5)

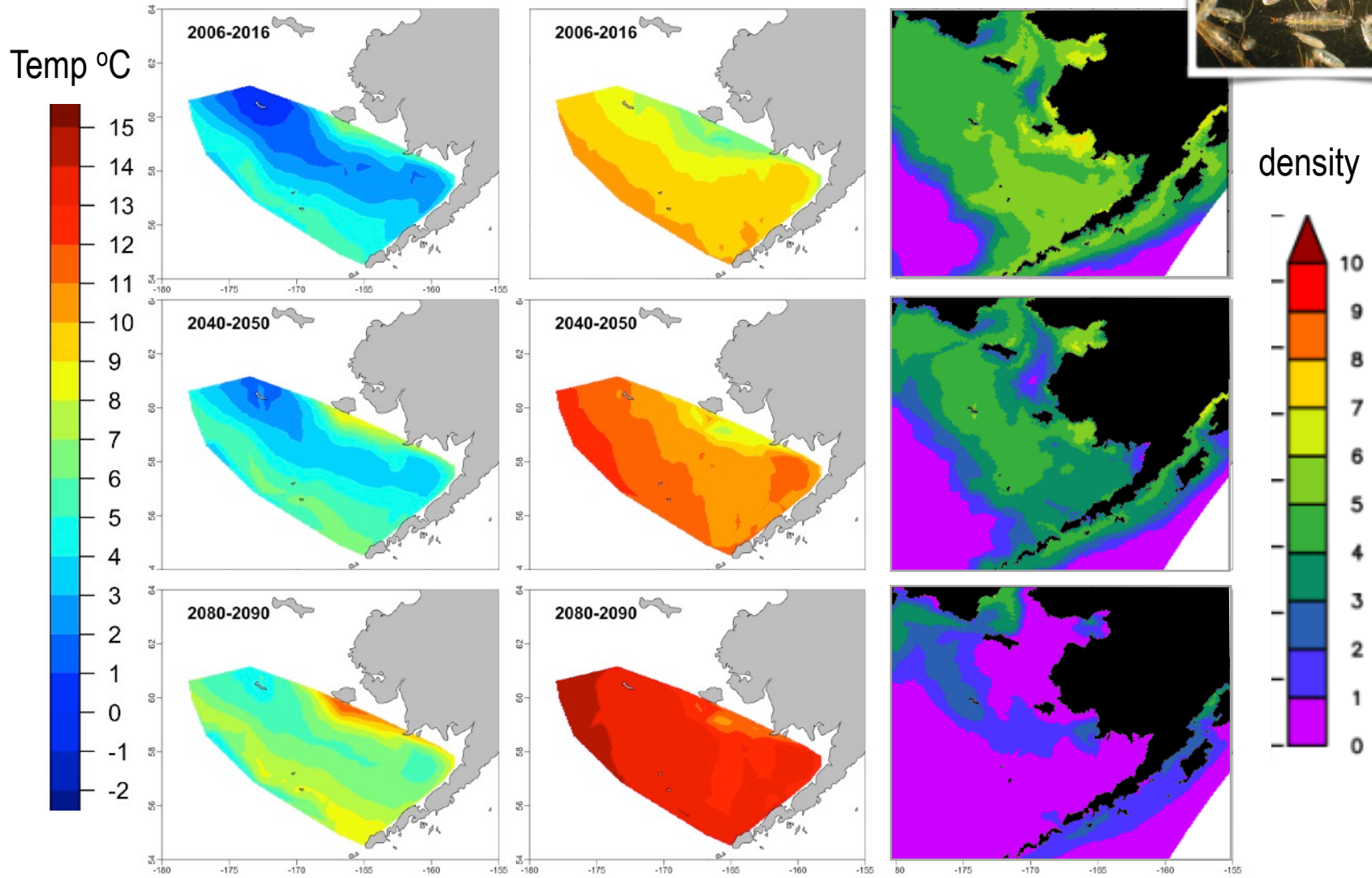
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Bottom Temp (C)

SST (C)

FALL Zoop.



Preliminary Results

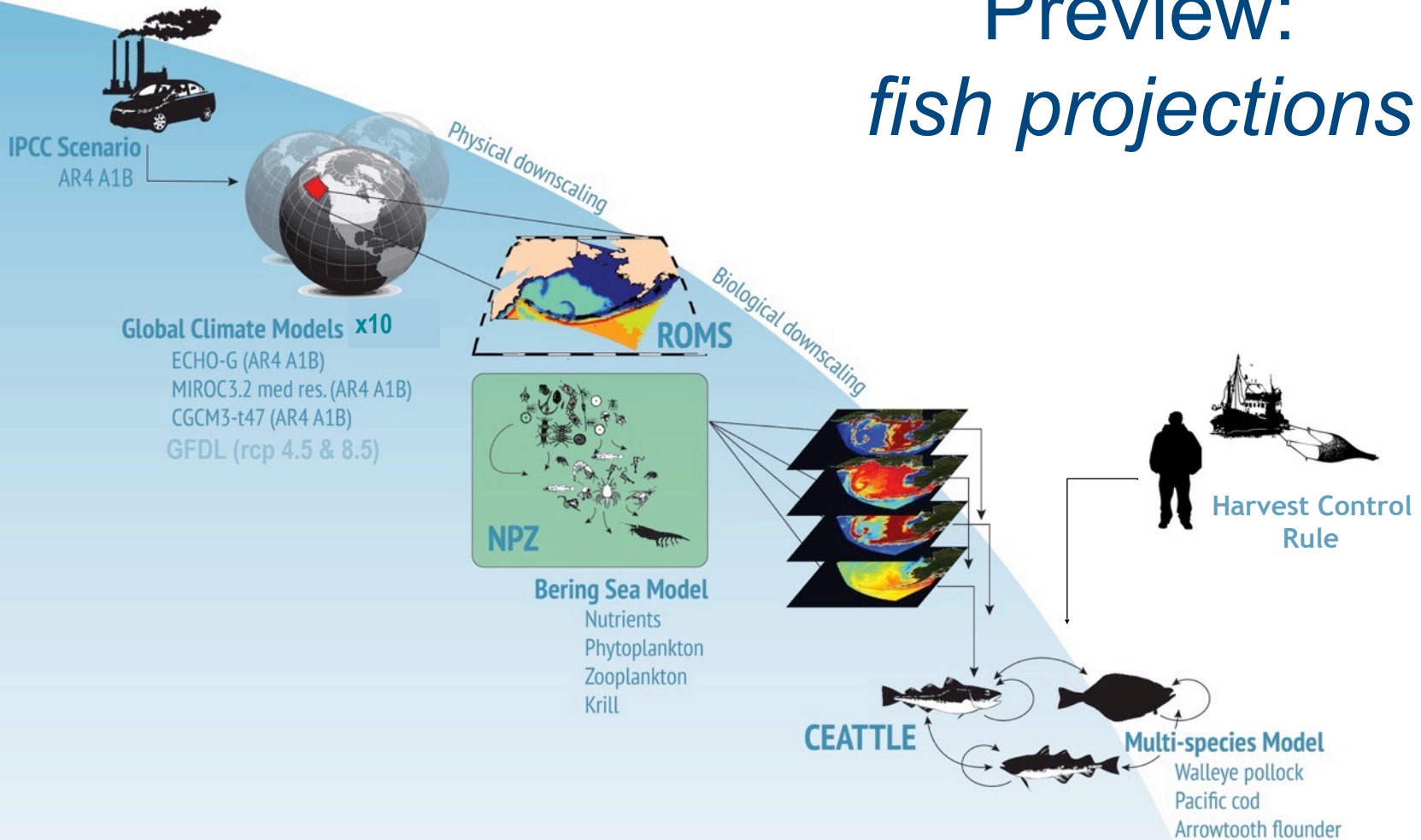
(fish projections)

*No fishing & “Status quo”
assuming we don’t adjust our management but the climate changes*

Photo: Mark Holsman



Preview: *fish projections*

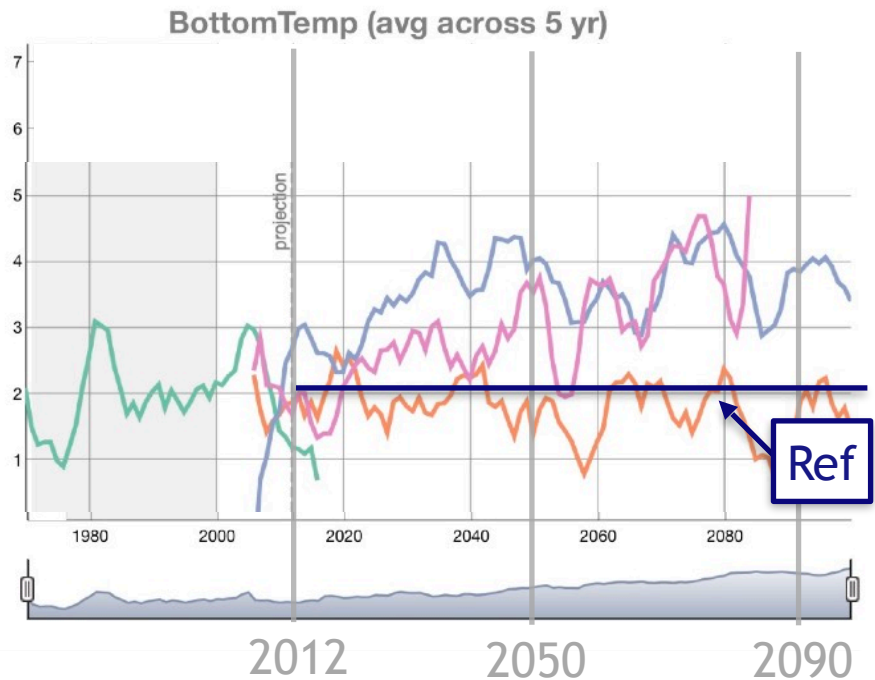


Holsman et al. in prep

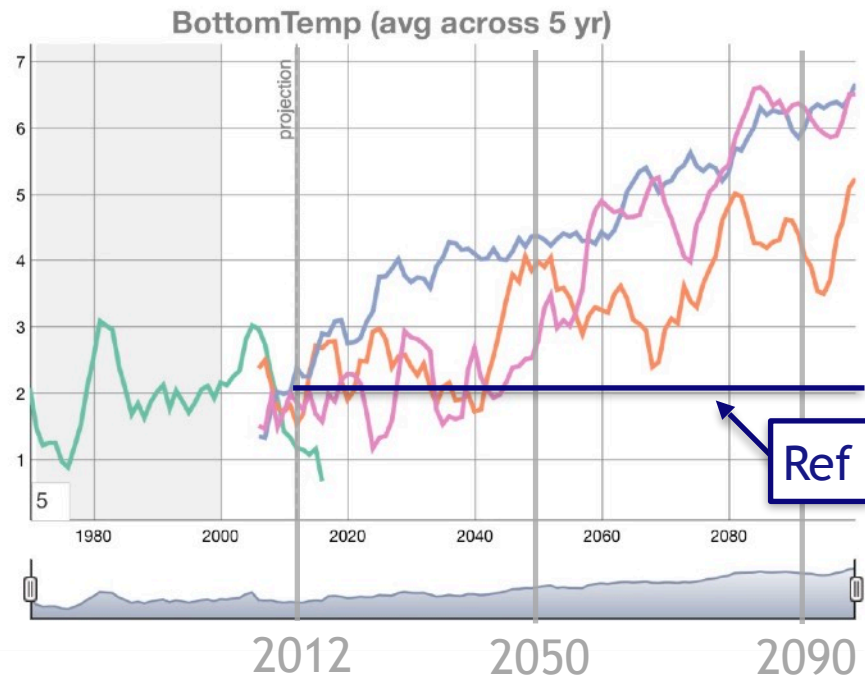
Climate-specific Harvest & Population Projections

Bottom Temperature (°C)

Low CO₂ Scenario (RCP 4.5)



High CO₂ Scenario (RCP 8.5)



Holsman et al. in prep; draft results, please do not cite or copy

Unfished Spawning Biomass ($F=0$)

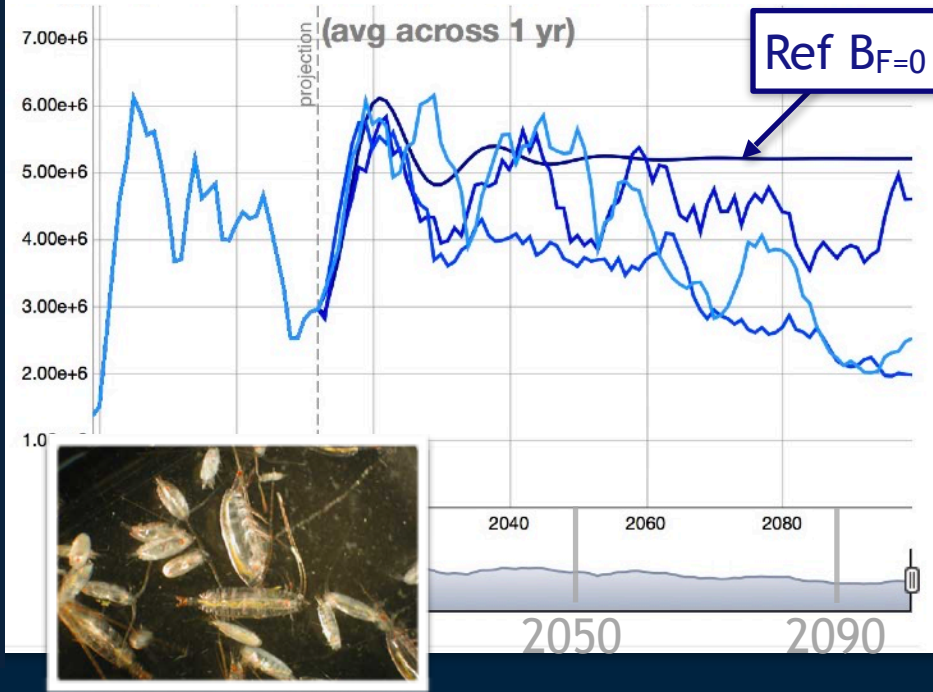
Low CO₂ Scenario (RCP 4.5)

High CO₂ Scenario (RCP 8.5)

Single-species model: Pollock



Single-species model: Pollock



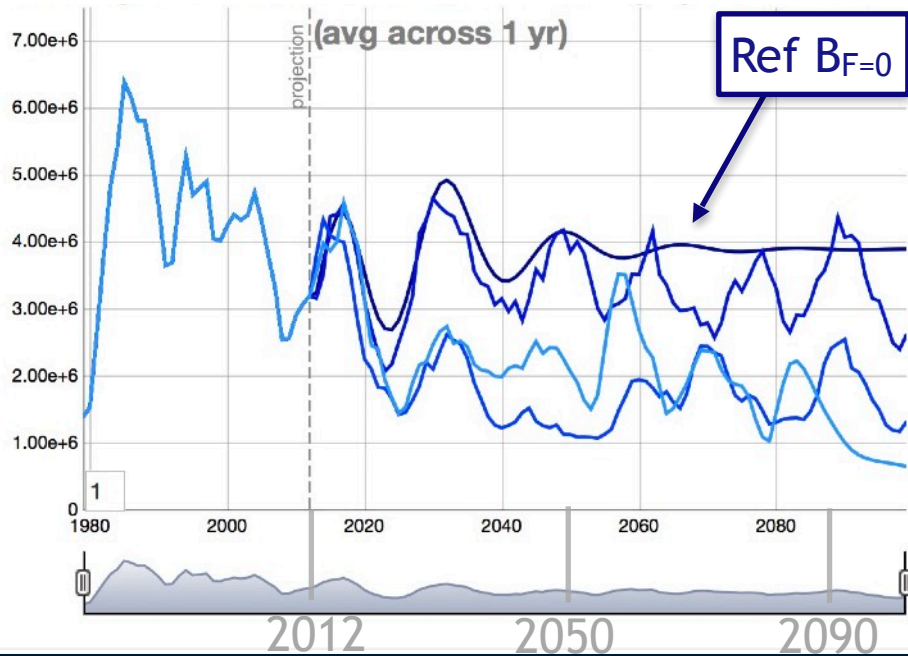
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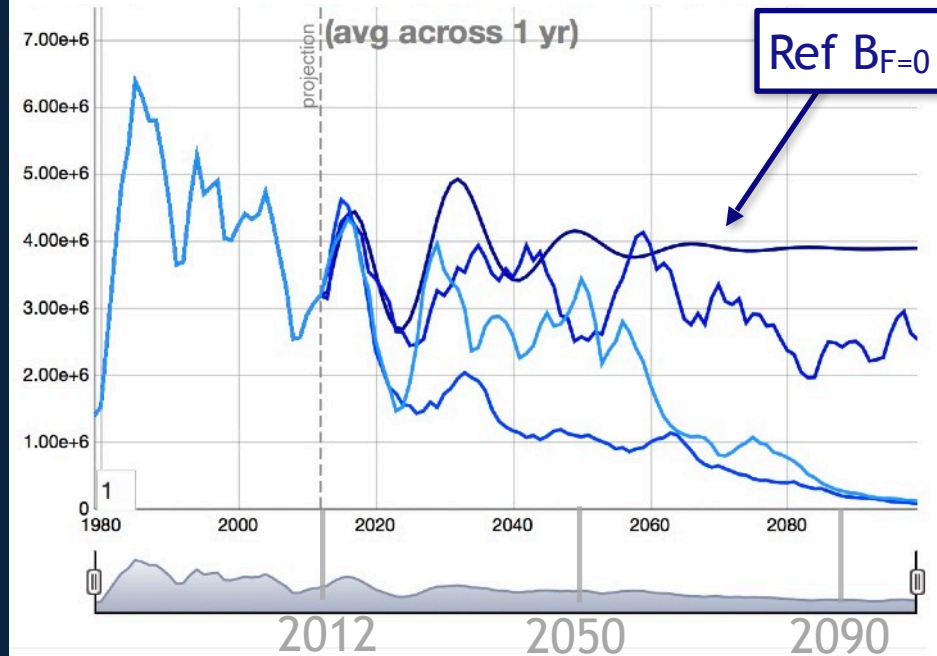
Low CO₂ Scenario (RCP 4.5)

High CO₂ Scenario (RCP 8.5)

Multi-species model: Pollock



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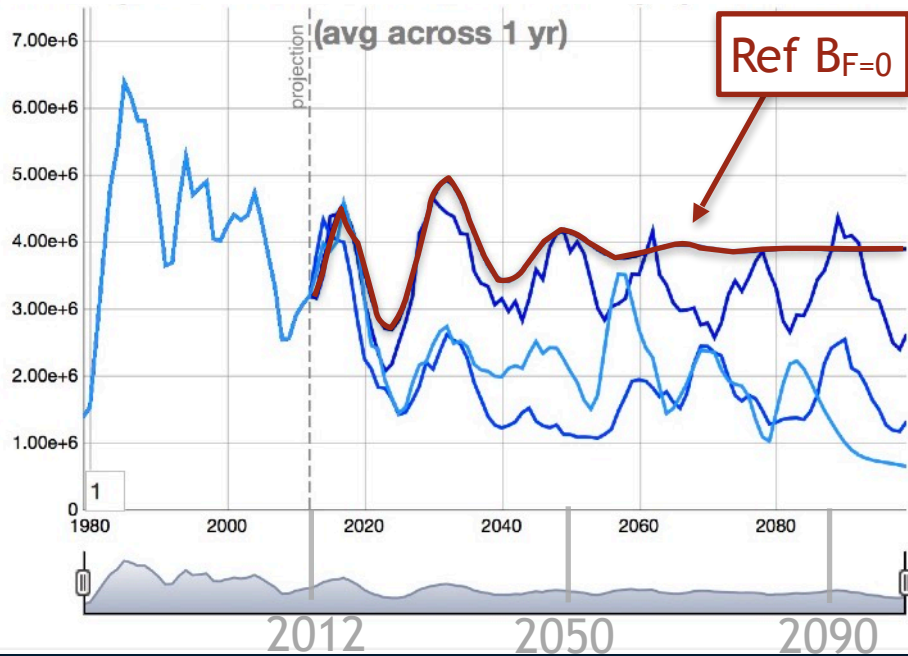
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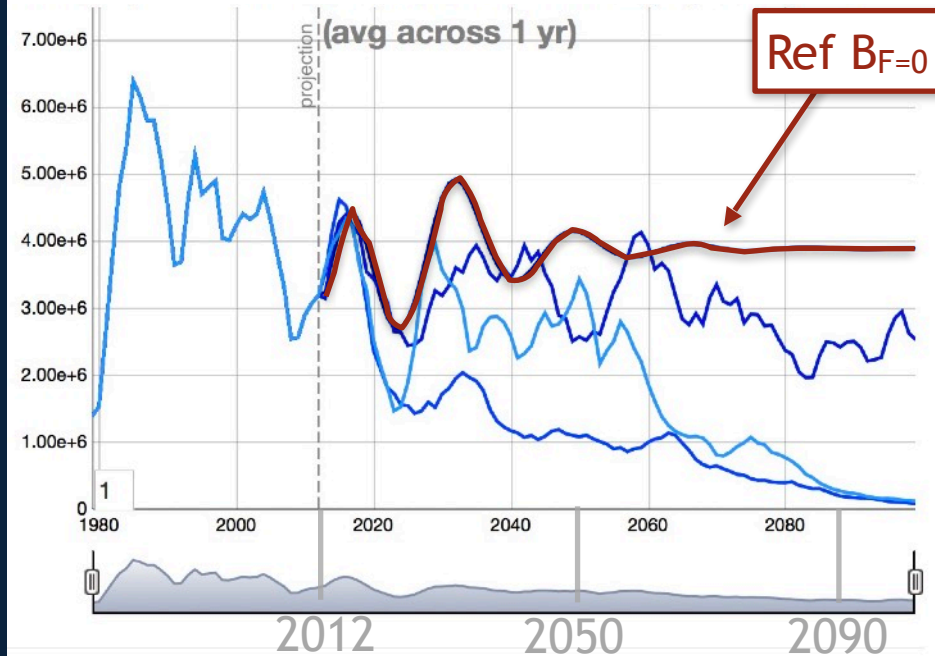
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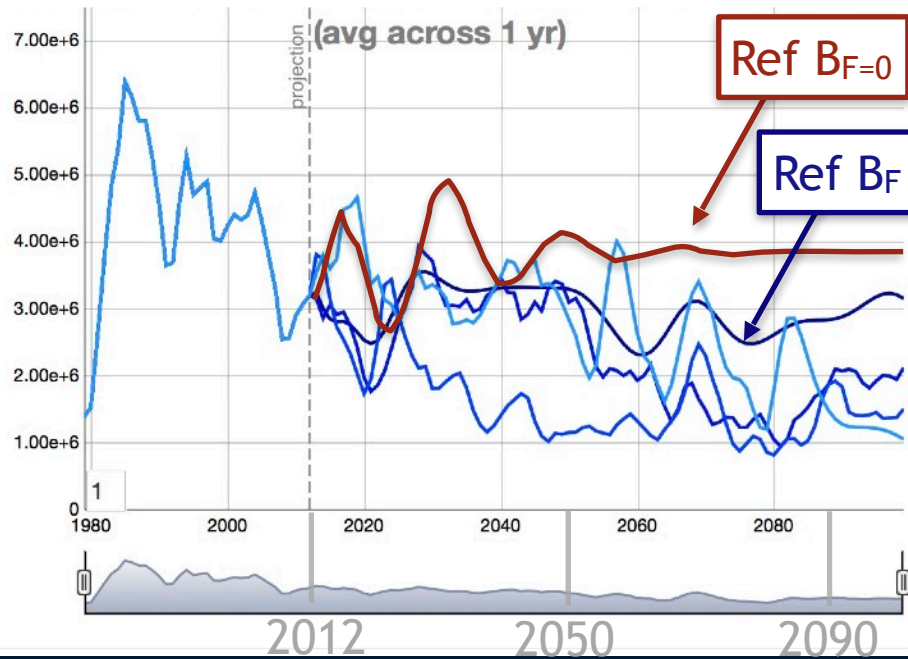
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Fished Spawning Biomass

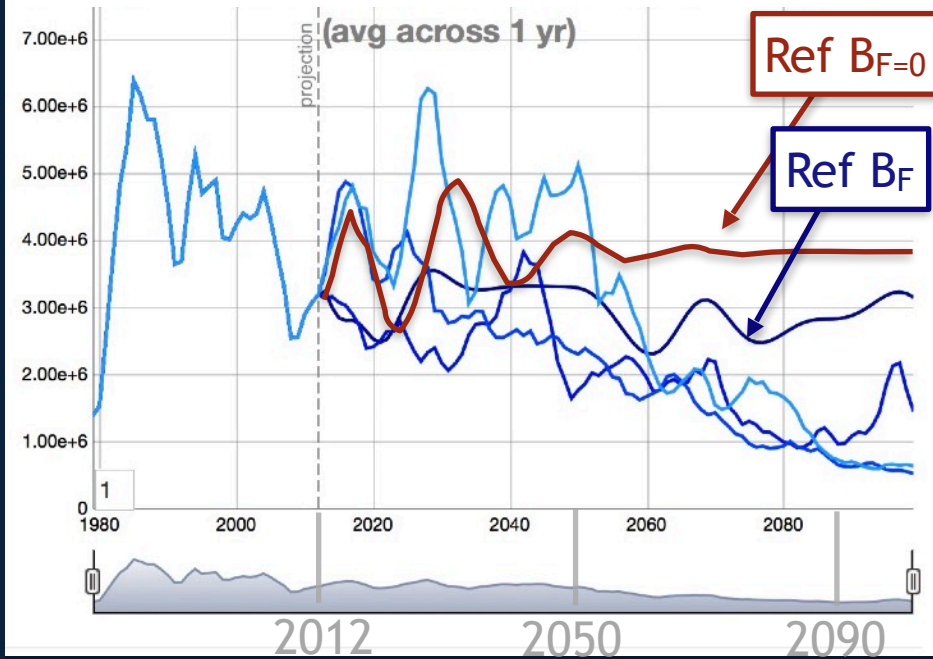
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Single-species model

Multi-species model

	Low CO ₂	High CO ₂
B _{F=0}	-33%	-42%
B _F	-30%	-35%

	Low CO ₂	High CO ₂
B _{F=0}	-64%	-76%
B _F	-54%	-72%

Preliminary Results

“Status quo”

assuming we don't adjust our management but the climate changes

ACLIM

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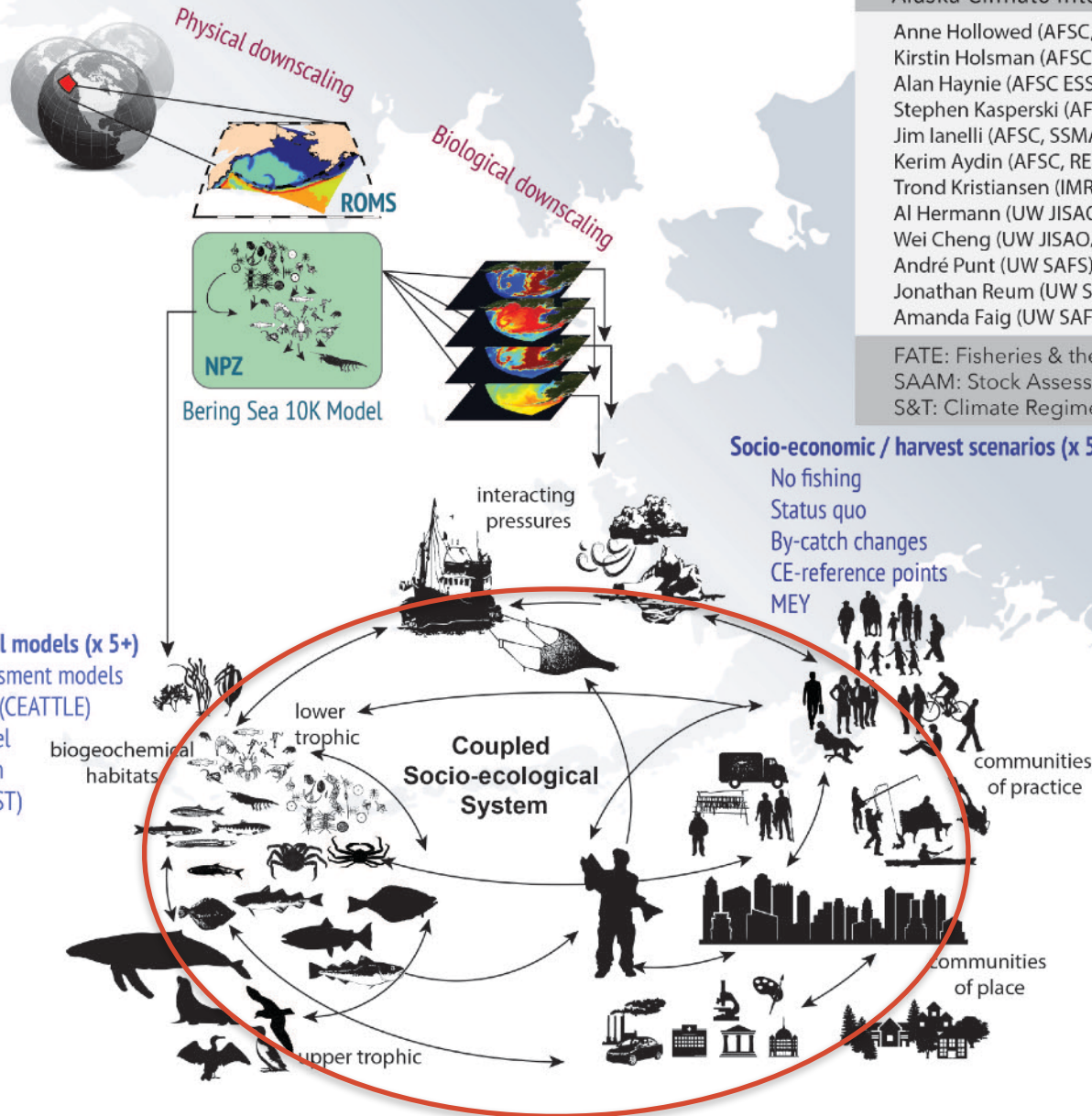
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The Human Connection



Improving Management Foresight



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- We need to be ready for **feasible** outcomes as well as the most likely scenarios.
- We will use the ACLIM tools to consider a wide range of possibilities to help anticipate future challenges.

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Overview – “Socioecon-ACLIM”

- Coupling biological and economic models
- Fishery mechanisms
- Management tools

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- Management tools
- **Help! We need your input!**

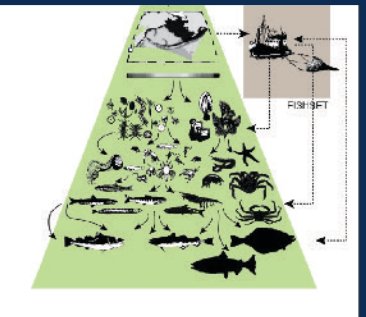
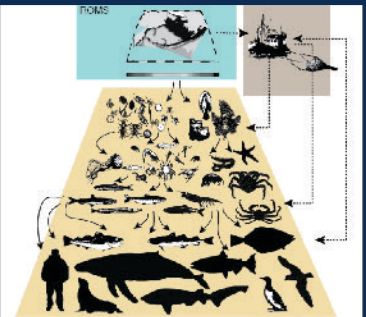
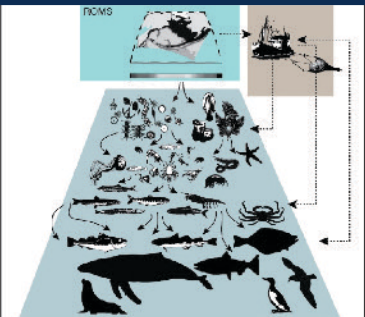
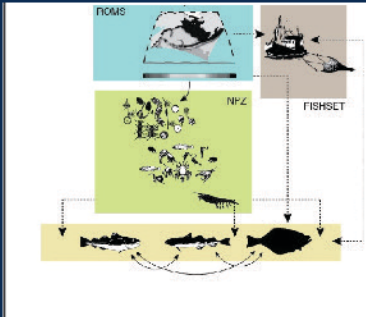
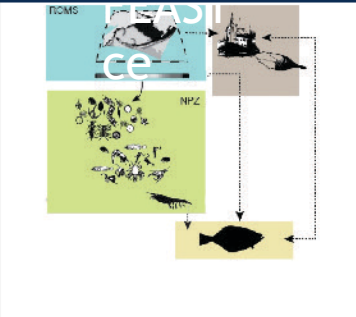
Coupling Biophysical / Biological & Economic Models & Policies

CE-SSM

CE-MSM

CE-EwE

CE-MIZER



Fast, mcmc
Statistical
Implicit ecosystem “noise”



Slow, high resolution
Mechanistic
Explicit ecosystem interactions

ACLIM
utilizes
economic
models of
different
complexity

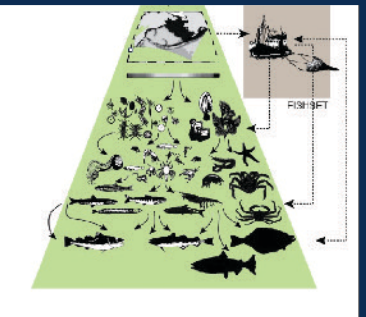
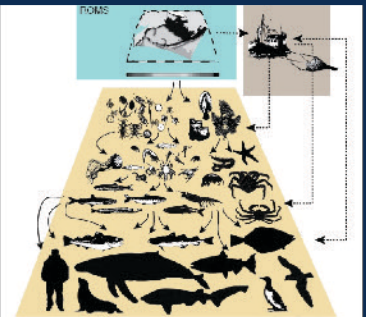
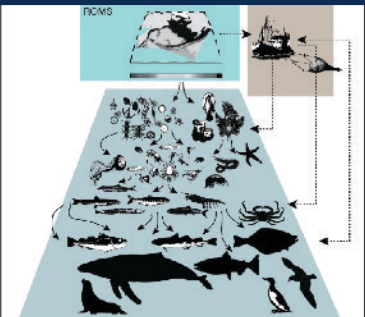
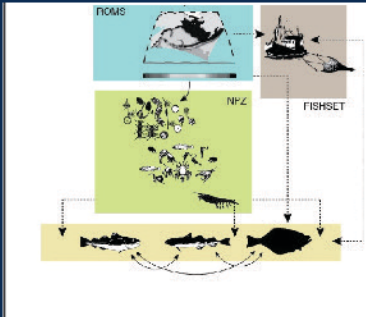
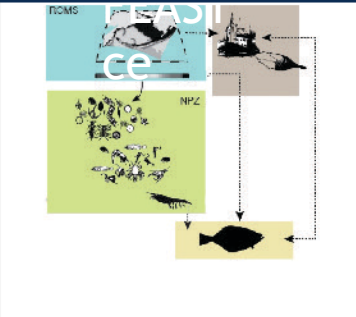
- Effort response to abundance
- Spatial models of fleets responding to shifts in fish distributions.
- Maximum economic yield (MEY)
- Community impact analyses

CE-SSM

CE-MSM

CE-EwE

CE-MIZER



Fast, mcmc
Statistical
Implicit ecosystem “noise”



Slow, high resolution
Mechanistic
Explicit ecosystem interactions

ACLIM
considers
6 general
scenarios
(and many
variations)

- Status quo
- No fishing
- MSY (no 2 MMT cap)
- Max. Economic Yield (MEY)
- Bycatch changes
- Price & cost changes

Status Quo Management under the Ecosystem Cap

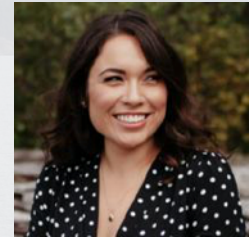
- For each species, $TAC \leq ABC$
- The sum of all TACs ≤ 2 MMT
- In 2017, $Sum(ABCs) = \sim 4$ MMT

The Council chooses TAC reduction for each species below its ABC so the BSAI $TAC < 2$ million MT

Biomass – TAC - Catch Model for Projections

1. Use ABC to predict TAC

- Observe past Council decisions
- Model relationship between Council & ABC
- Impose 2 Million metric ton cap



Amanda Faig

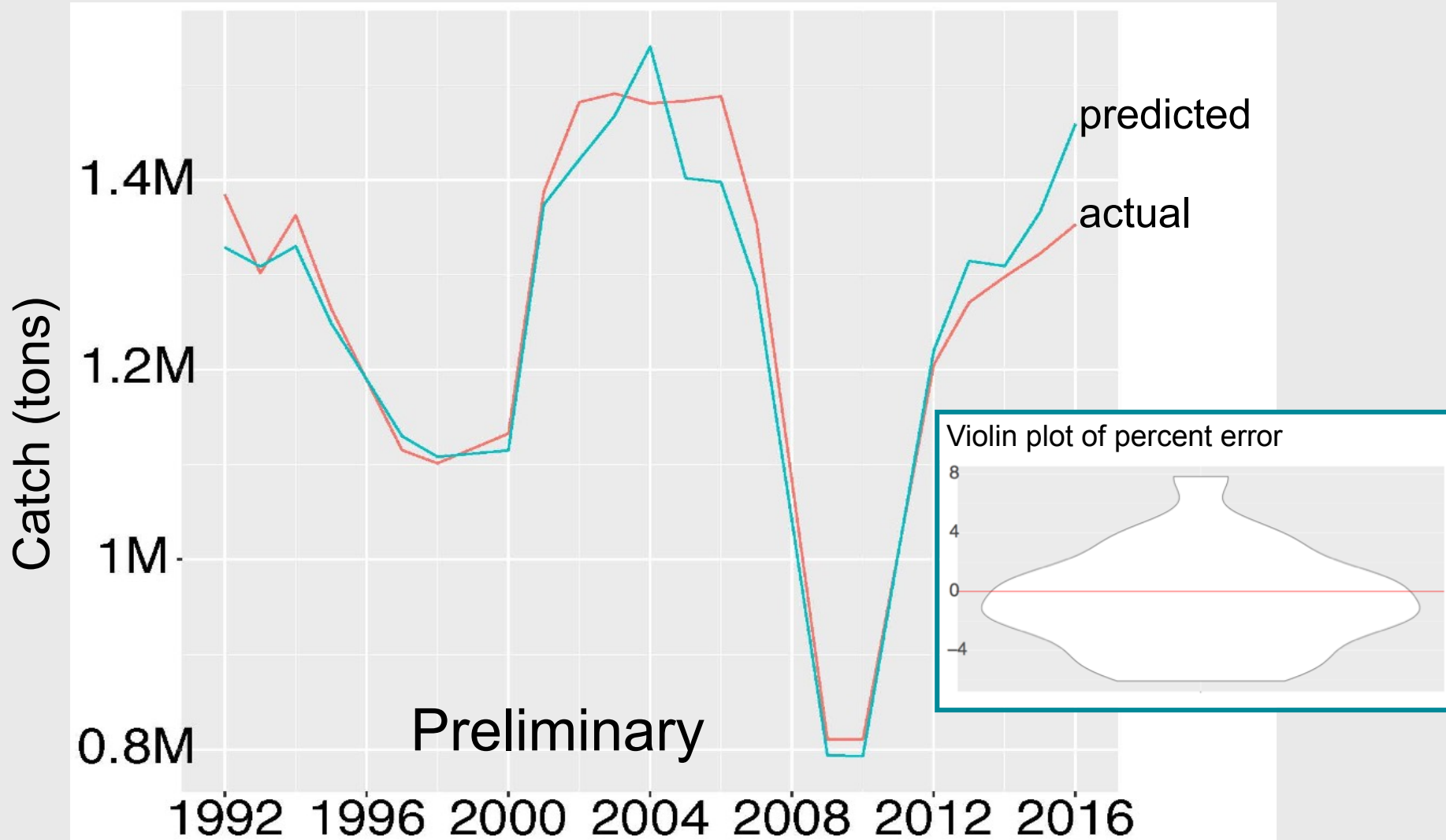
2. Use TAC prediction to predict Catch

- Model catch based on past fishery outcomes, weighted to recent behavior.
- Limit catch to not exceed ABC

Bering Sea Pollock, historical evaluation

BSA-CLIM
October 07

BS Pollock catch, predicted from ABC



Shared Socioeconomic Pathways (SSPs) & Fishery Mechanisms

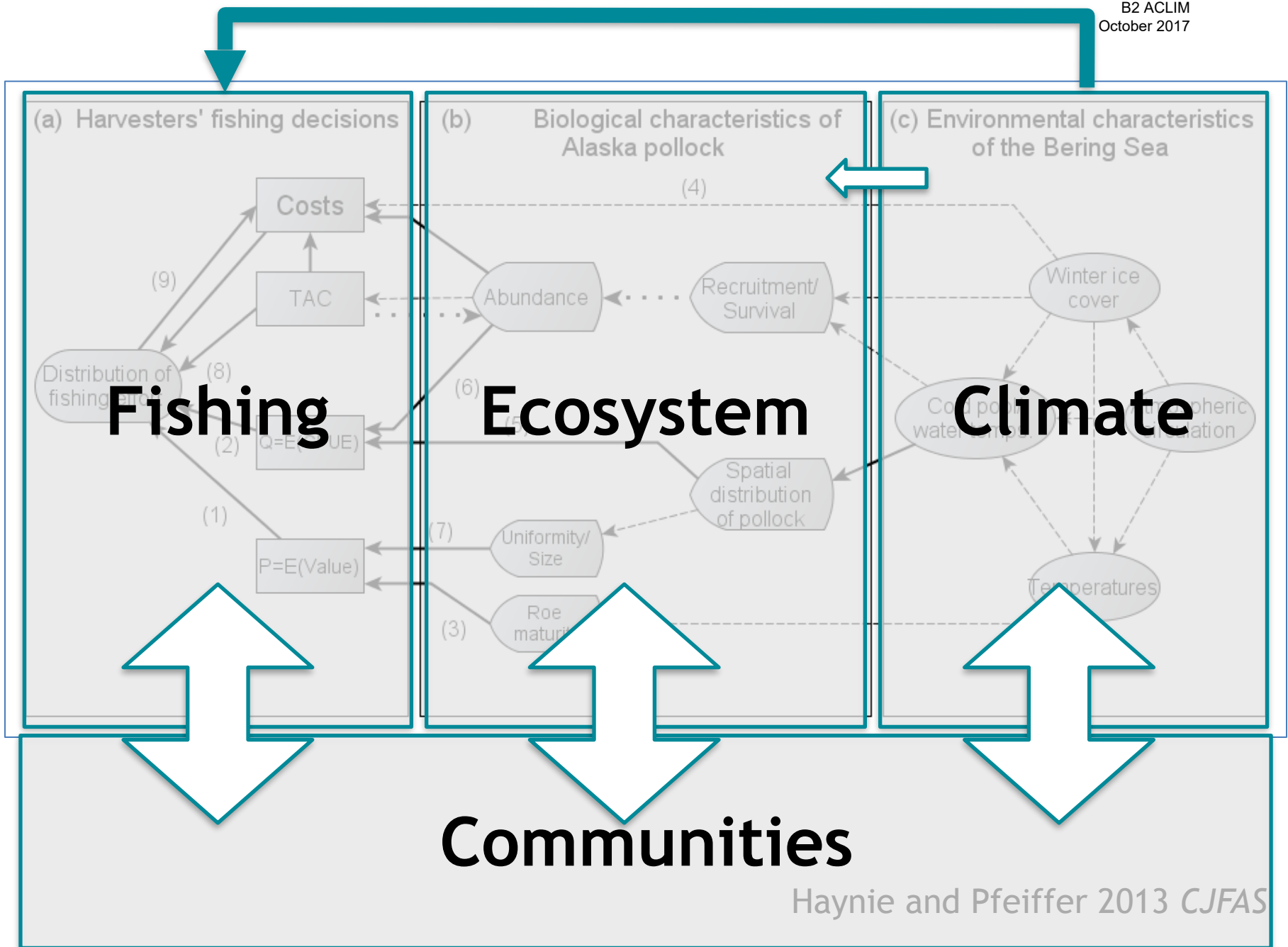
Shared Socioeconomic Pathways (SSPs)

- SSPs capture important elements of changing world economy and global cooperation
- These will have an important impact on whether a 'high' or 'low' carbon world occurs.

Shared Socioeconomic Pathways (SSPs)

- SSPs capture important elements of changing world economy and global cooperation
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However, these factors will interact with 'Fishery mechanisms' that will more directly impact fishing in the North Pacific.



Communities

Fishery Mechanisms

Fish prices

Relative price of
premium fish

Number of species
fished

Costs

Priority on
conservation

Protection of
fishing
communities

Fishery Mechanisms	Why this might <u>increase</u>	Why this might <u>decrease</u>
Fish prices		
Relative price of premium fish		
Number of species fished		
Costs		
Priority on conservation		
Protection of fishing communities		

Can we simplify these further?

Fishery Mechanisms

Fish prices

Relative price of
premium fish

Number of species
fished

Costs

Priority on
conservation

Protection of
fishing
communities

Can we simplify these further?

Fishery Mechanisms

Fish prices

Relative price of
premium fish

Number of species
fished

Costs

Priority on
conservation

Protection of
fishing
communities

- **Net Trip Revenue**
- **Skill in selective harvesting**
- **Flexibility of fishing opportunities**

Characterize expected impacts & uncertainty

- Catch
- Revenue
 - Average returns
 - Variability
 - Fleet & community distribution

Consider Feasible Management Tools

- New technology
- Catch shares
- Dynamic / fixed area closures
- Bycatch reduction incentives
- Revised harvest control rules
- Other suggestions?
- Tools of the future!

Future process

- Understand possible changes
- Council & stakeholders consider outcomes they most want to avoid or achieve
- Evaluate policies based on Council & stakeholder preferences.

The goal of ACLIM is constant improvement

- These models use the best available knowledge about the ecosystem
- As we learn more, the models and projections will be updated.

Take-home Messages

- The Bering Sea is likely to change
- ACLIM tools will evolve & improve
- Continued excellent and responsive management will be essential.

Our questions for you:

- What are we missing?
- How can we best share results with the Council & other stakeholders?

Thanks!

NPRB & BSIERP Team
ACLIM Team
AFSC

*“Behind these numbers lies, of course, an infinity
of movements and of destinies.”*

– von Bertalanffy 1938

...and of people!

Funding:

- Fisheries & the Environment (FATE)
- Stock Assessment Analytical Methods (SAAM)
- Climate Regimes & Ecosystem Productivity (CREP)
- Economics and Human Dimensions Program
- NOAA Integrated Ecosystem Assessment Program (IEA)
- NOAA Research Transition Acceleration Program (RTAP)



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