Photo: Mark Holsman

ACLIM: The Alaska Climate Integrated Modeling Project

Kirstin Holsman & Stephen Kasperski

ACLIM PIs:
Anne Hollowed[1], Kirstin Holsman[1], Alan Haynie[1], Stephen Kasperski[1], Jim Ianelli[1], Kerim Aydin[1], Wei Cheng[2,3], Al Hermann[2,3], Trond Kristiansen[4], Andre Punt[5]

1. NOAA Fisheries, Alaska Fisheries Science Center
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

NOAA FISHERIES

The ACLIM team


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

YOU!

Photo: Mark Holsman

our science is only as good as the questions we ask

Photo: Mark Holsman

Introduction to ACLIM

Photo: Mark Holsman

Introduction to ACLIM

Preliminary results

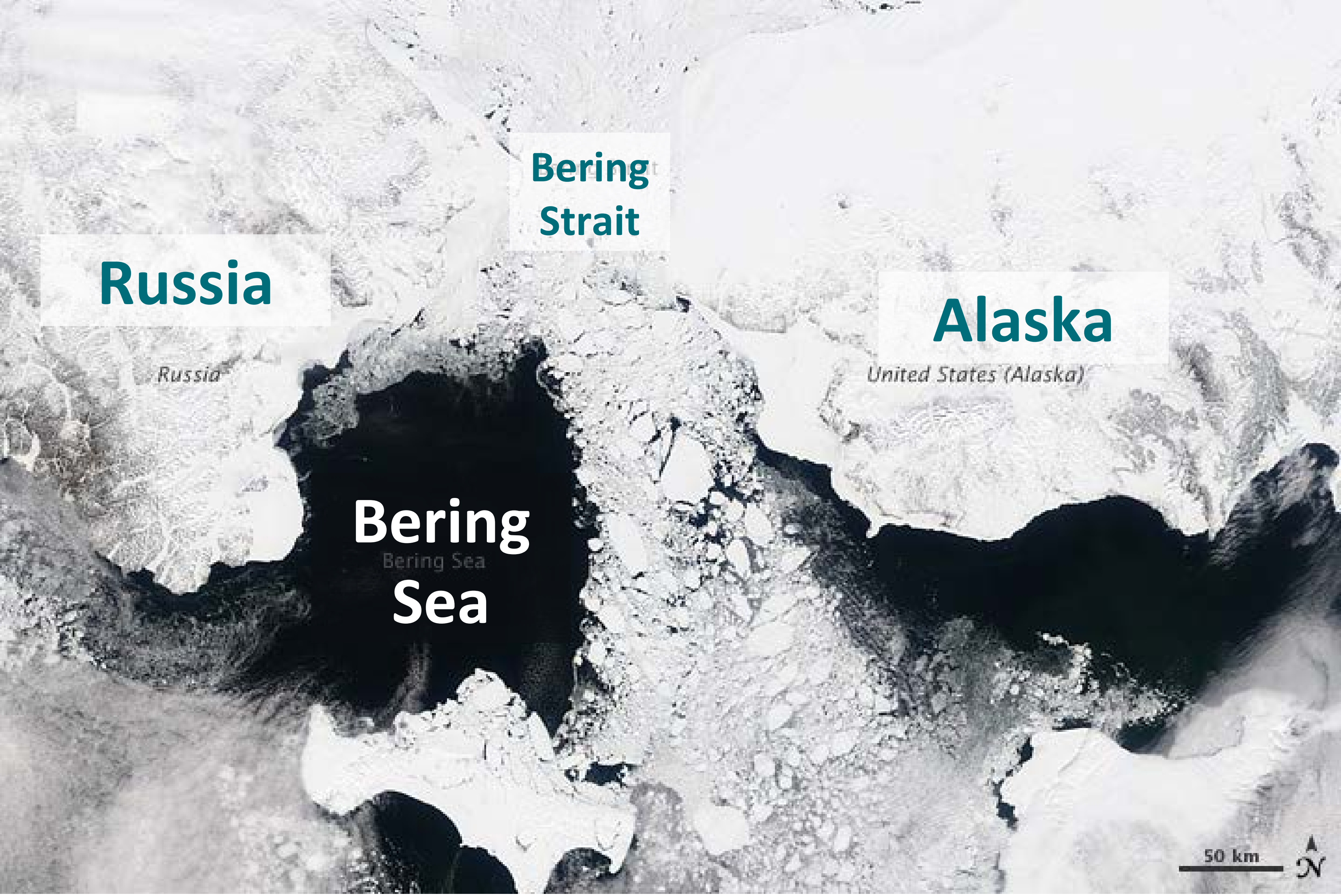
Photo: Mark Holsman

Introduction to ACLIM

Preliminary results

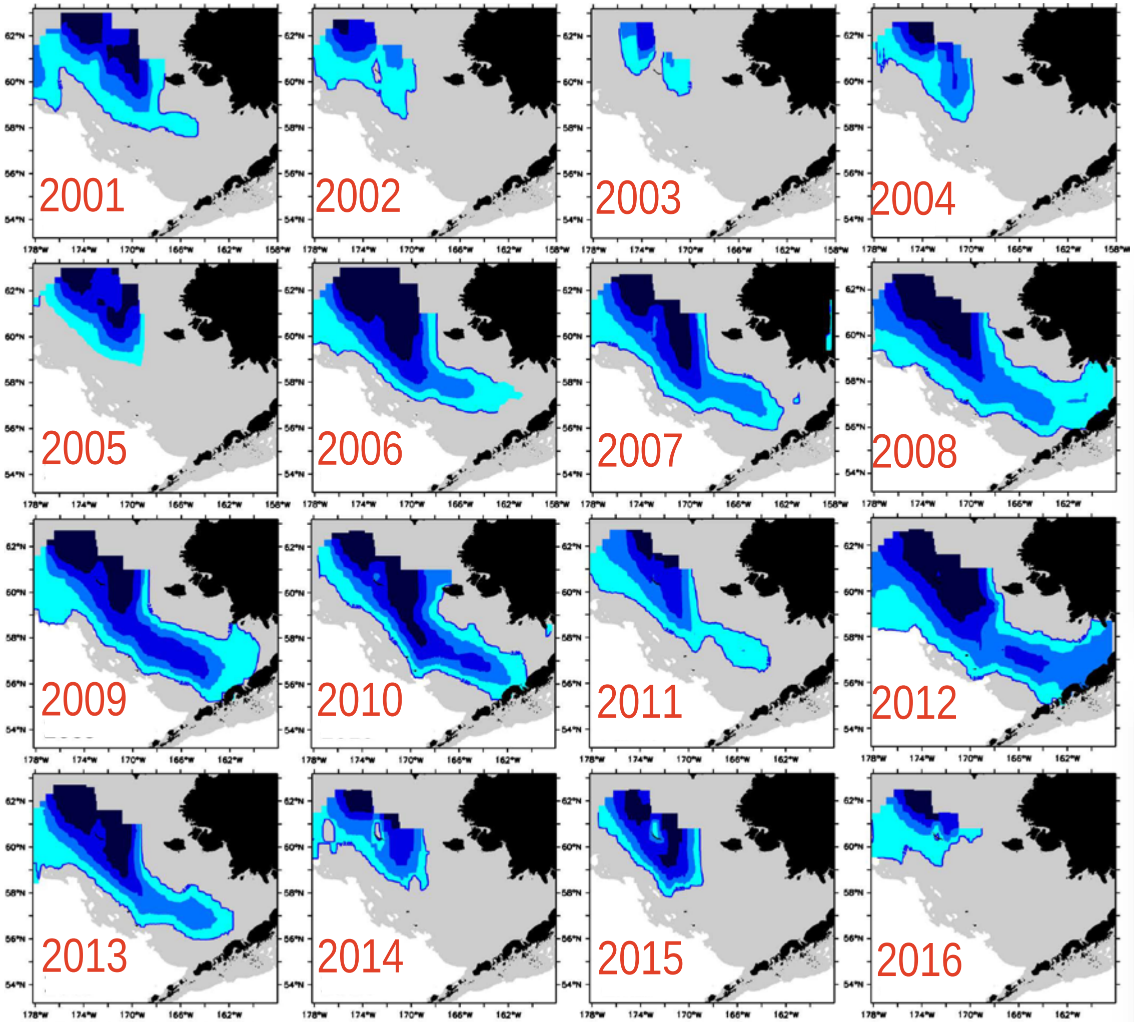
Discussion of fishing scenarios

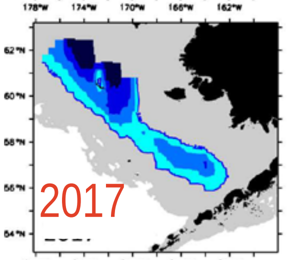
Photo: Mark Holsman

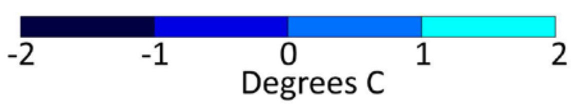


NASA MODIS image by Jesse Allen

Bering Sea “Cold Pool” 2001-2017

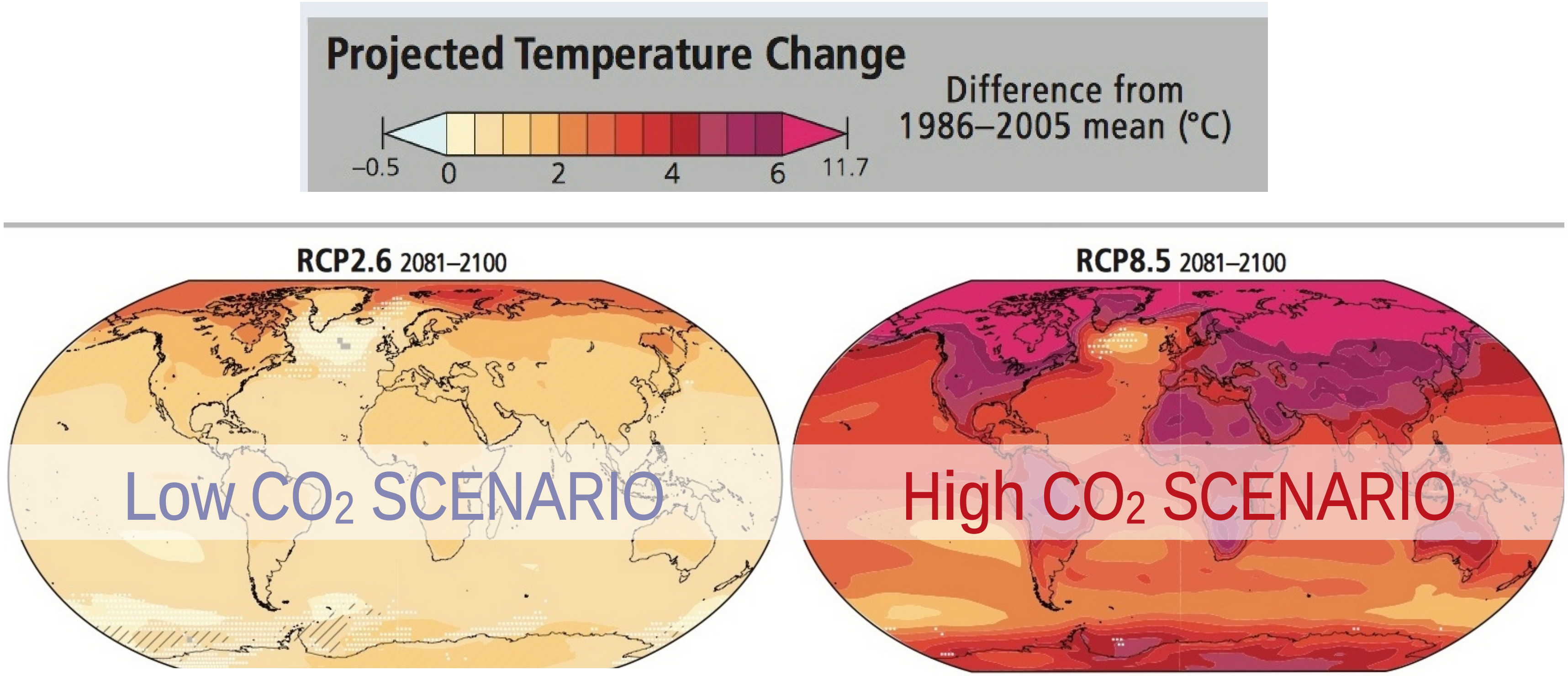






Graphic: J. Overland, P. Stabeno, M. Wang, C. Ladd, N. Bond, and S. Salo, PMEL/NOAA

Intergovernmental Panel on Climate Change (IPCC)
5th Assessment Report (2013, 2014)

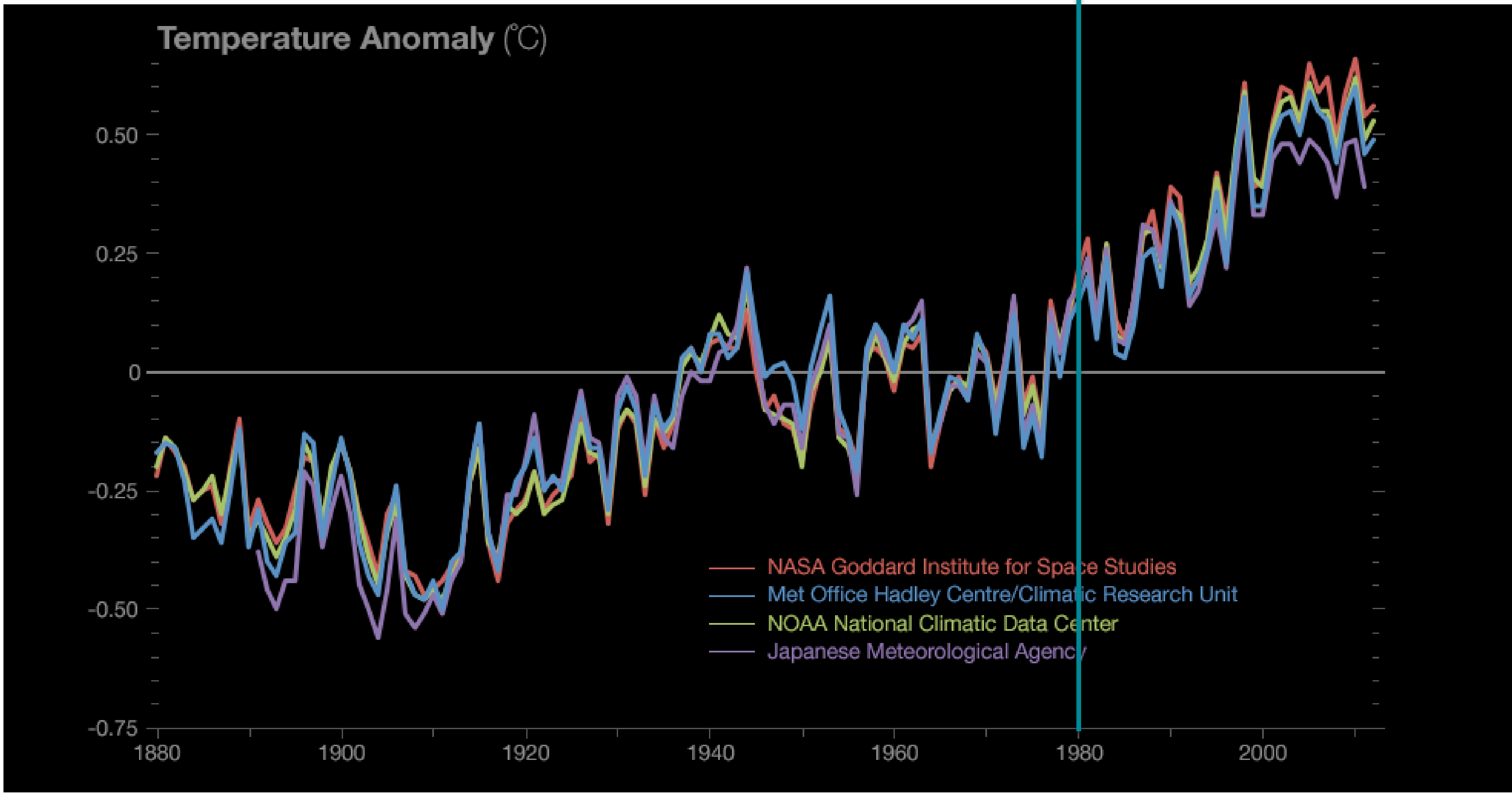


"Paris COP21 agreement"

"Business as usual"

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

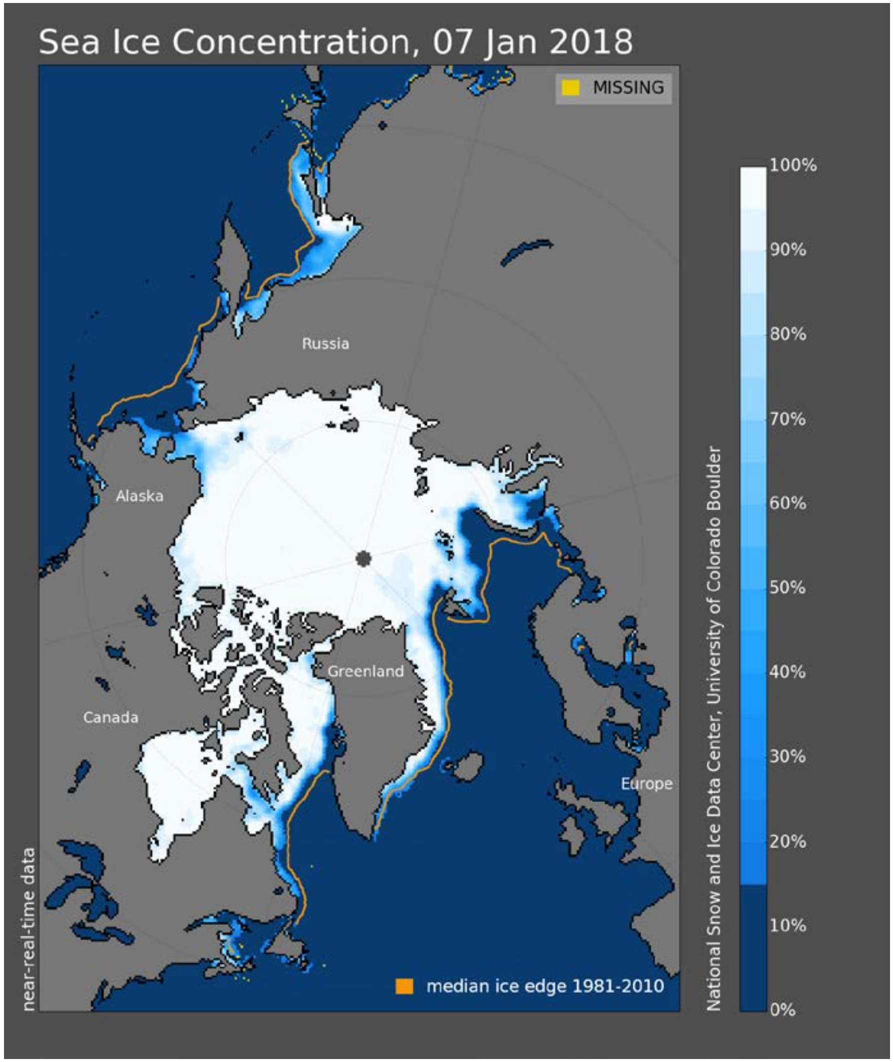
1980

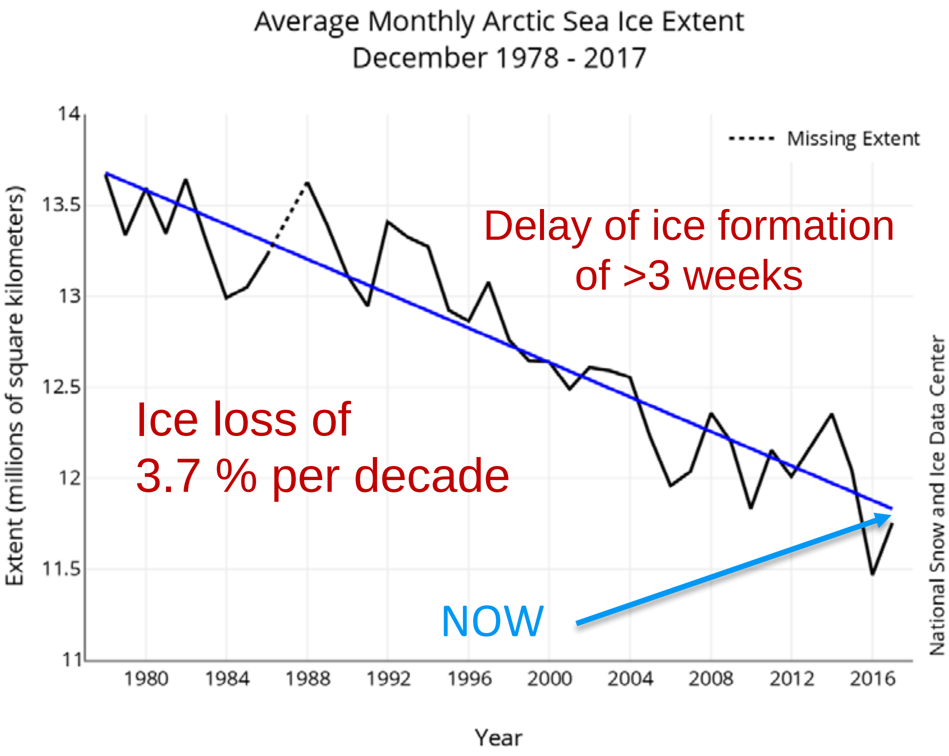


CLIMATE 365

climate365.tumblr.com | go.nasa.gov/climate365

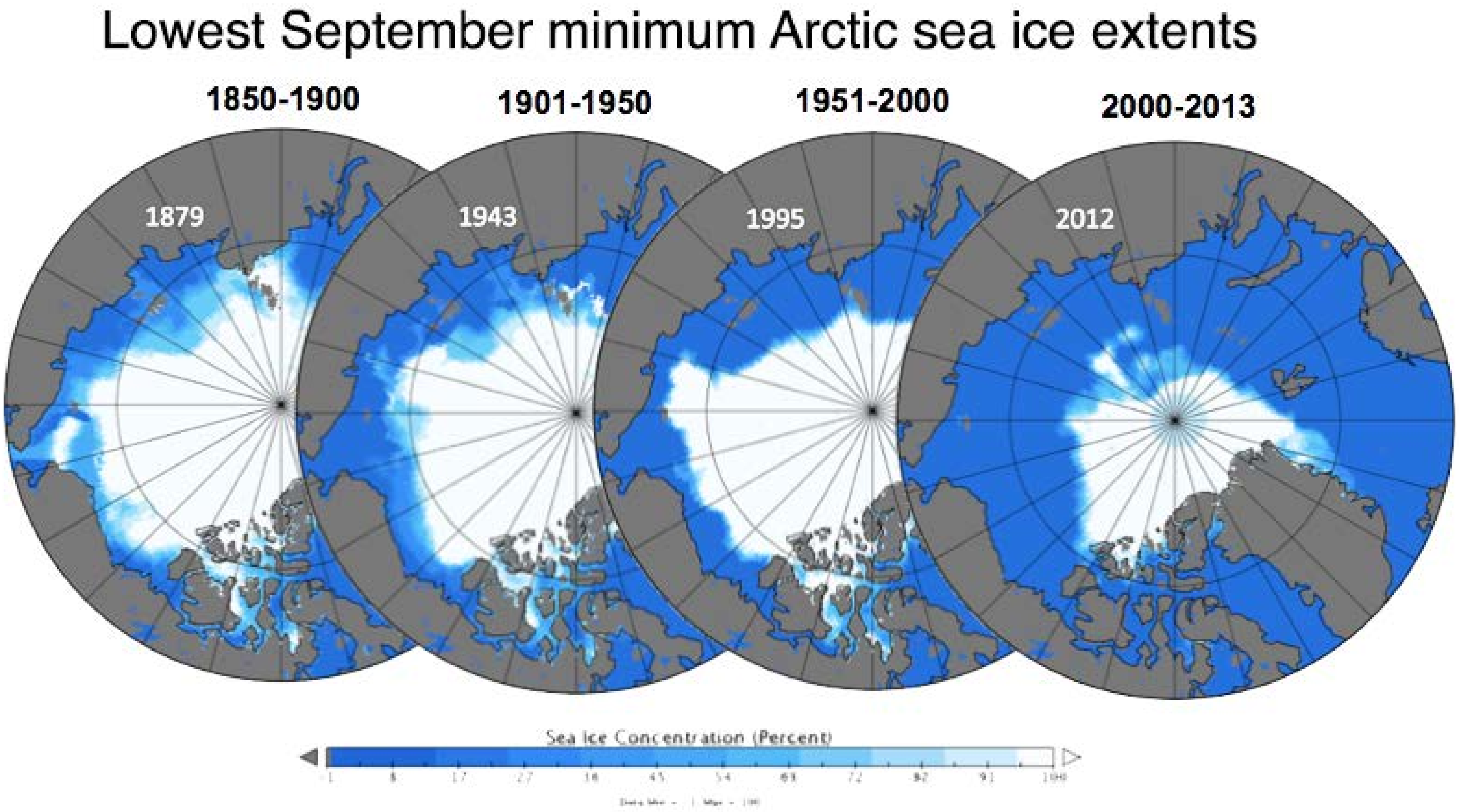
NOAA FISHERIES





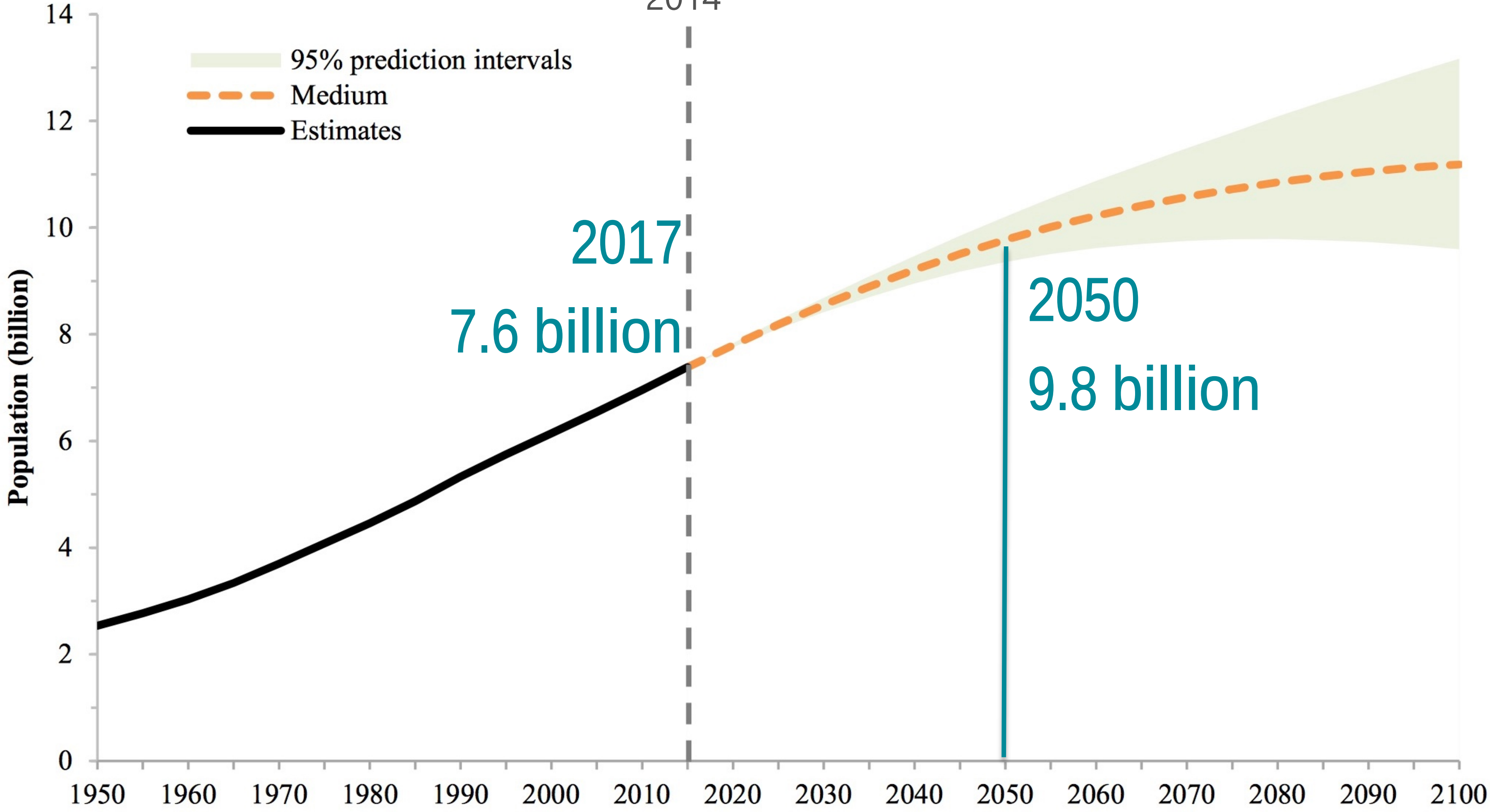
http://nsidc.org/arcticseaicenews/

http://nsidc.org/arcticseaicenews/



Global Population

"The health of our planet as well as our own health and future food security all hinge on how we treat the blue world,"
FAO Director-General José Graziano da Silva, 2014



Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). *World Population Prospects: The 2017 Revision*. New York: United Nations.

Improve management **foresight** in a changing climate

Photo: Mark Holsman

Project changes in Bering Sea ocean conditions and fish populations

Physical, biological, & socioeconomic change; now - 2100

Photo: Mark Holsman

Project changes in Bering Sea ocean conditions and fish populations

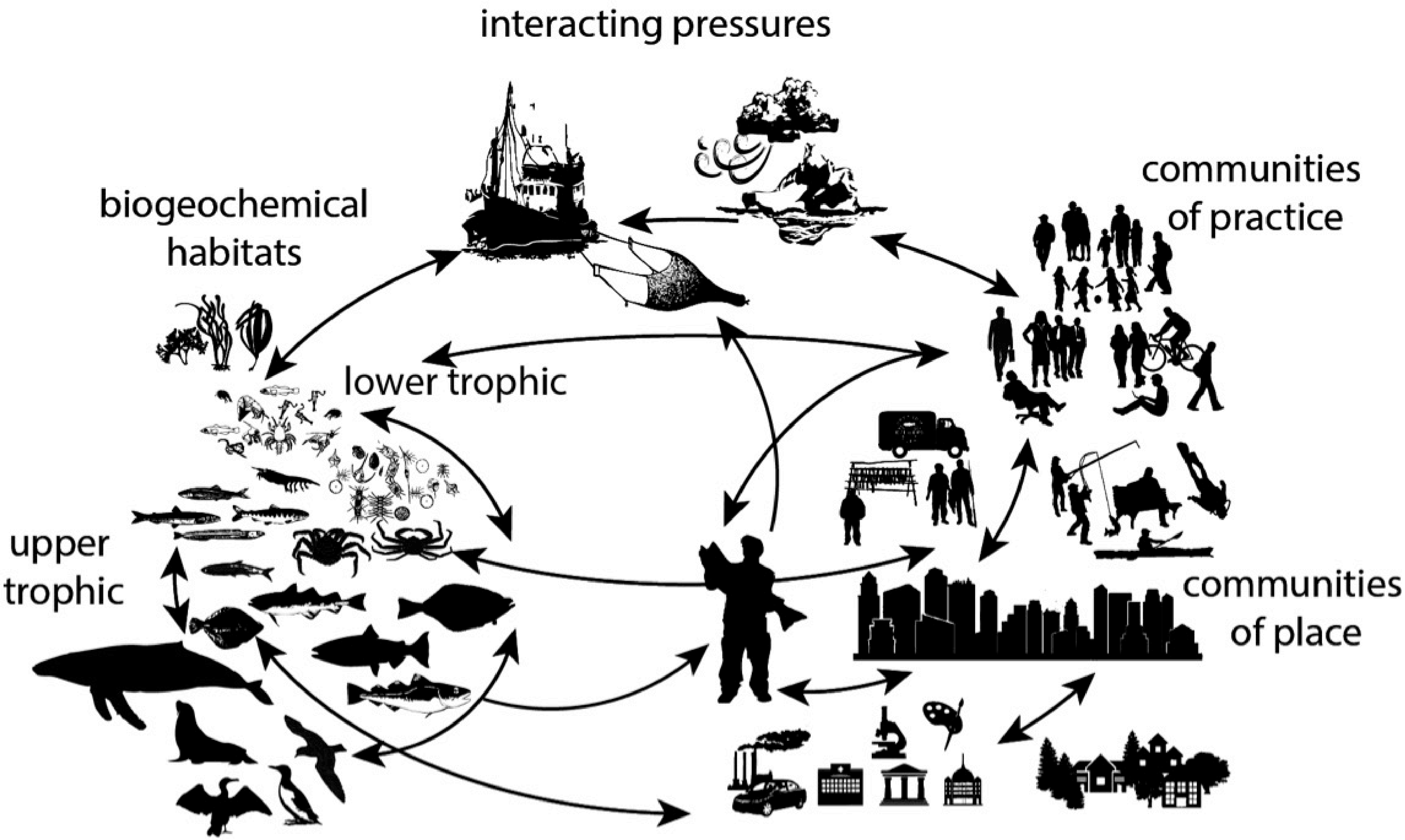
Physical, biological, & socioeconomic change; now - 2100

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

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

Photo: Mark Holsman

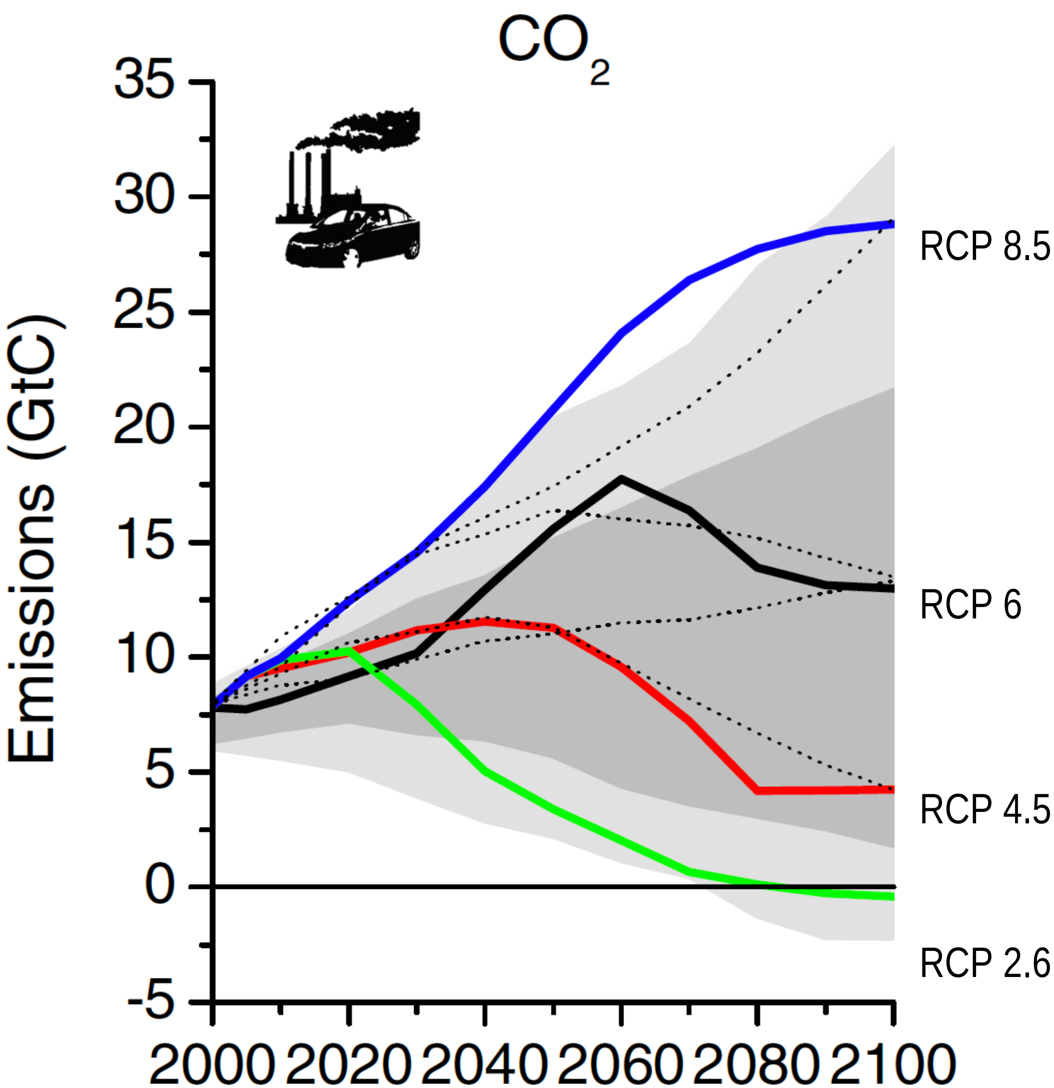
ACLIM utilizes a fully integrated approach



Carbon Emission Scenarios

*“**plausible descriptions** of how the future may evolve with respect to a range of variables”*

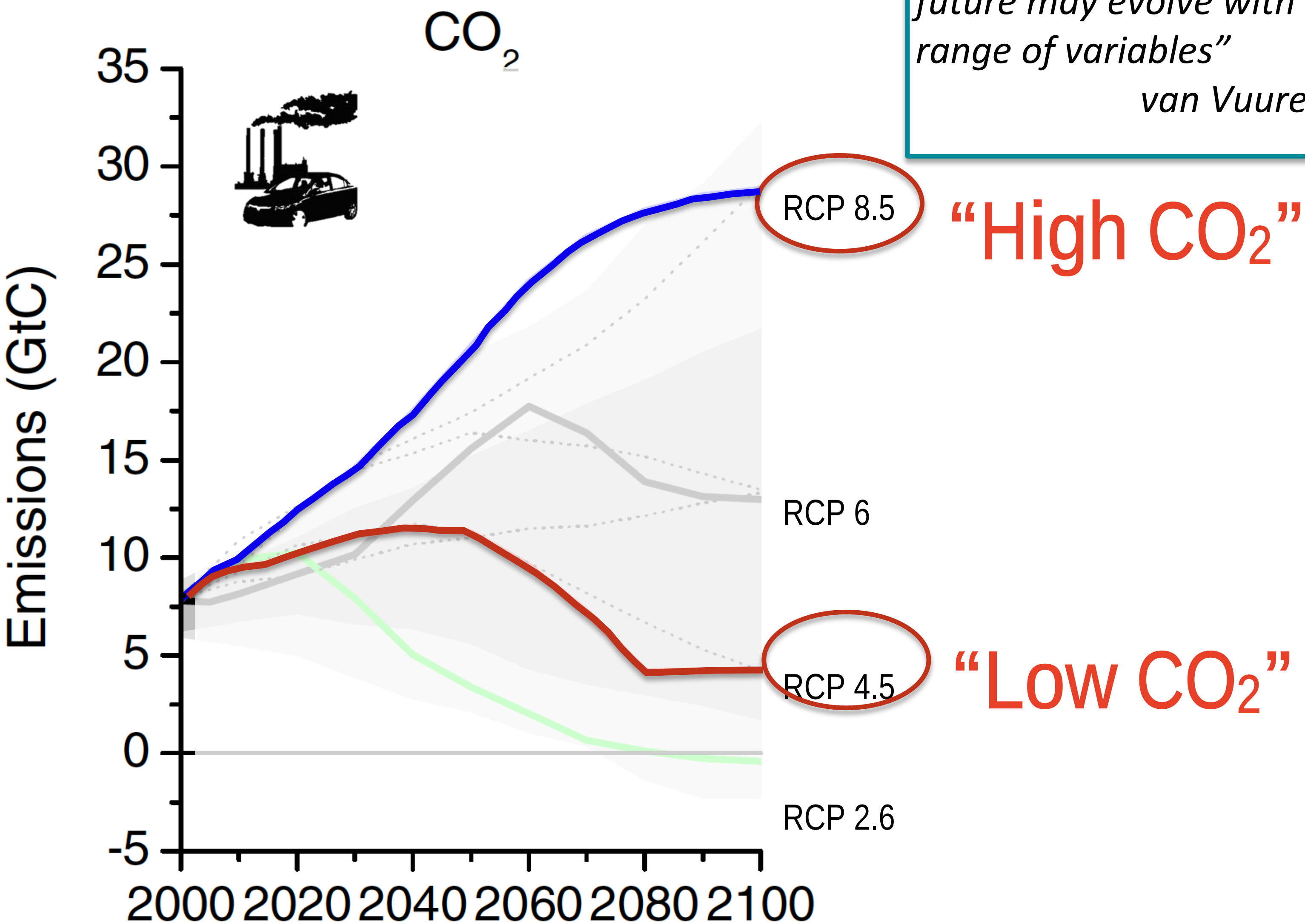
van Vuuren et al. 2011



“High reliance on fossil fuels”

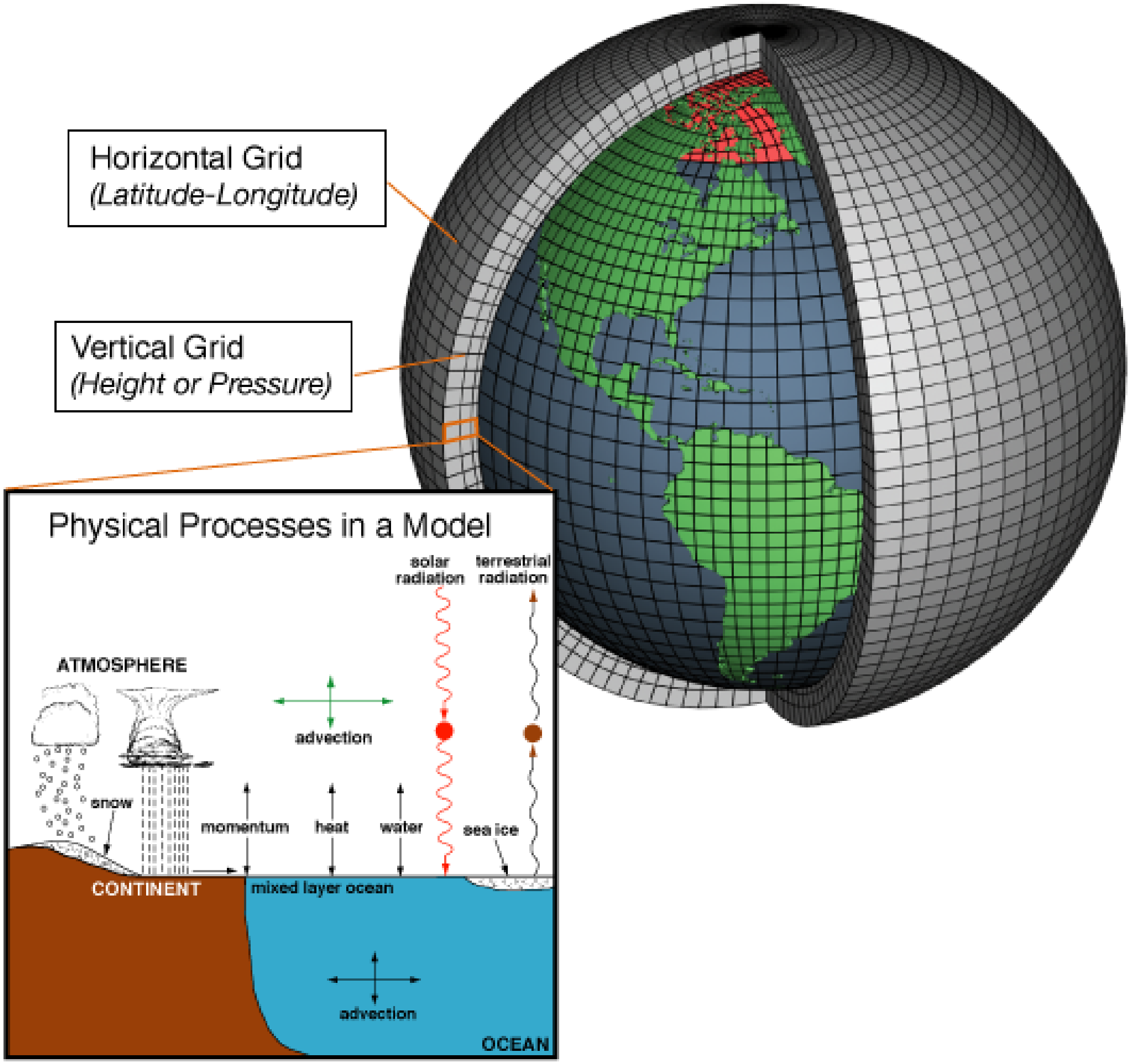
“Significant global reduction in carbon use”

Carbon Emission Scenarios

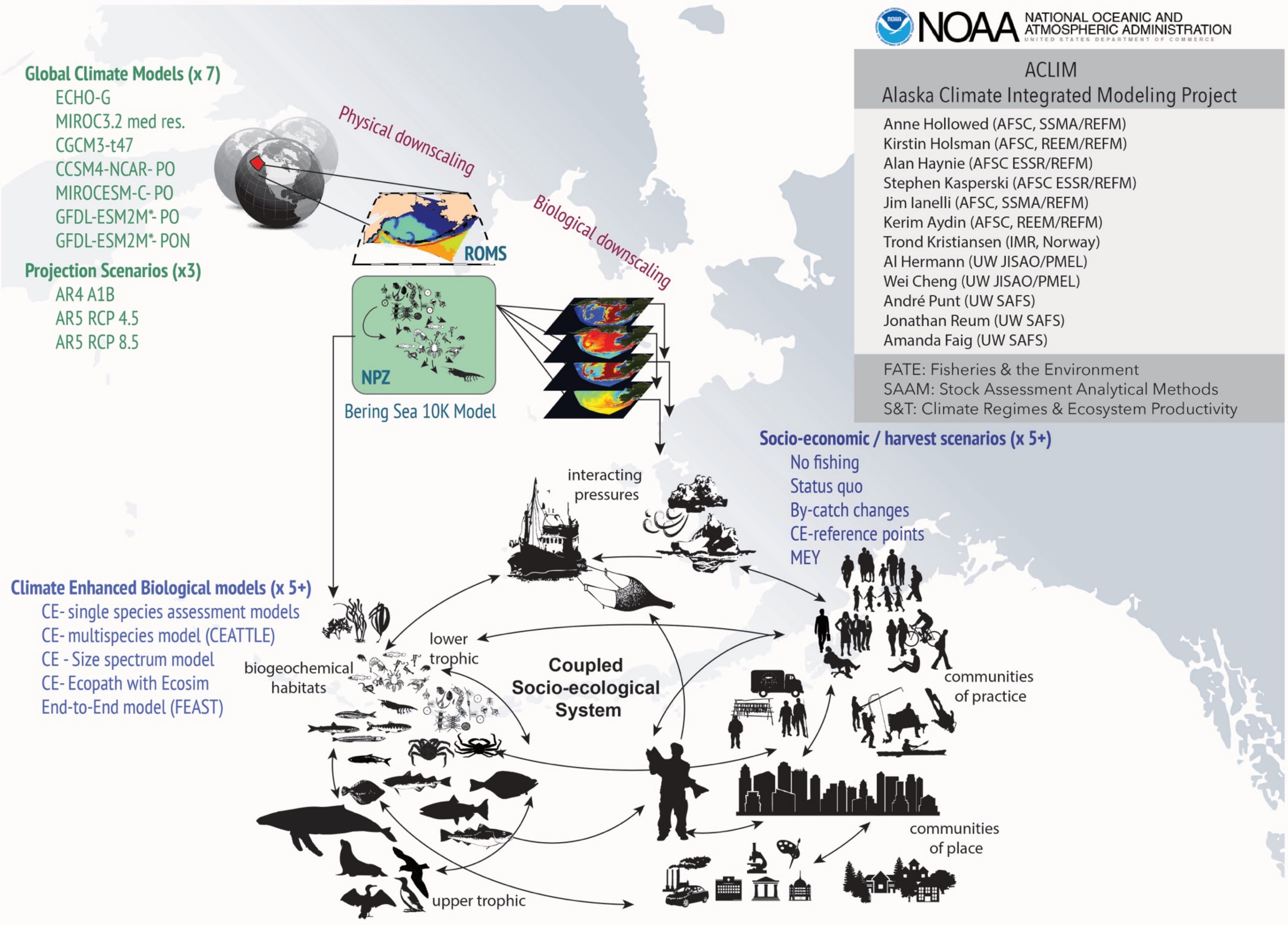


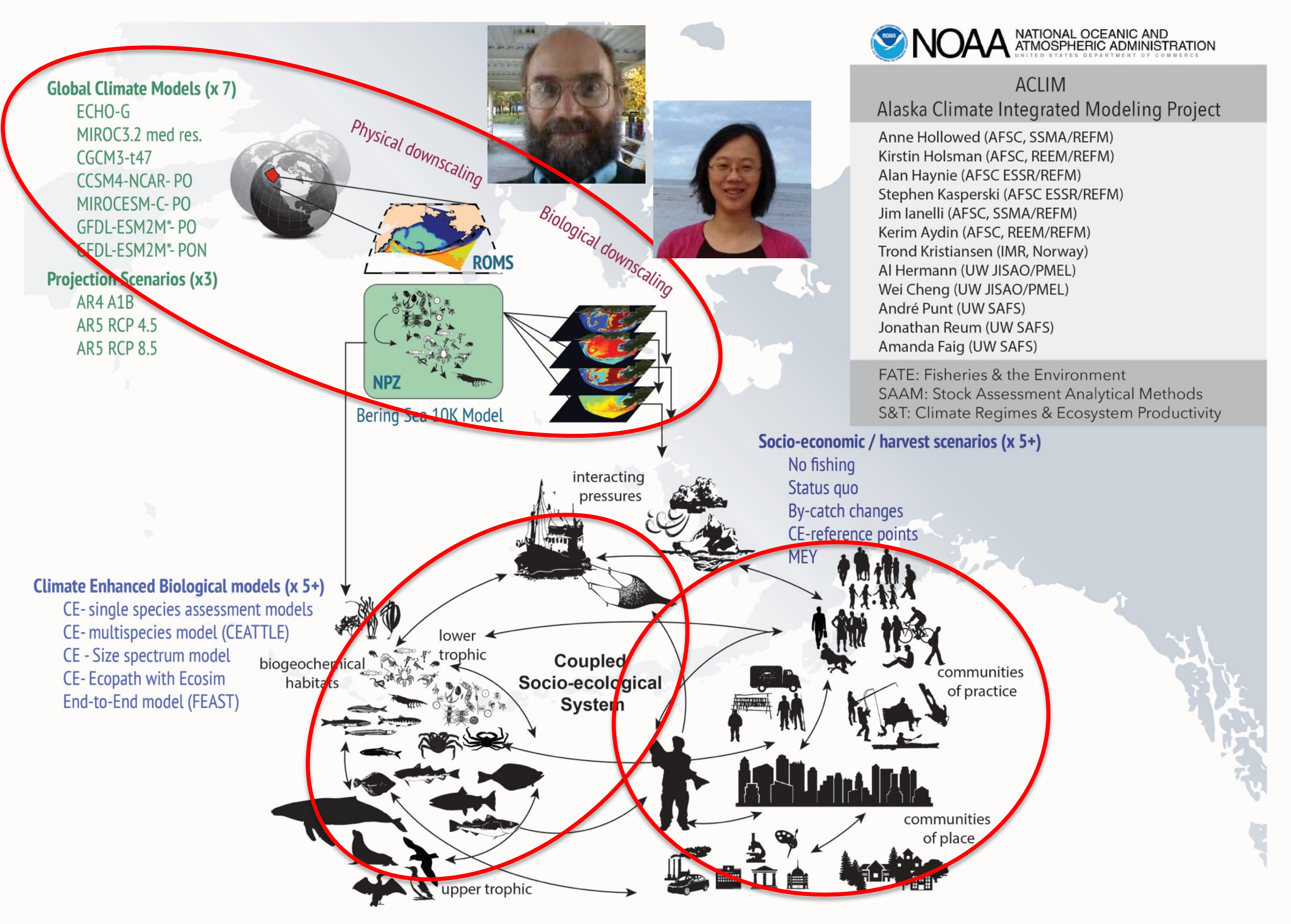
*"**plausible descriptions** of how the future may evolve with respect to a range of variables"*

van Vuuren et al. 2011

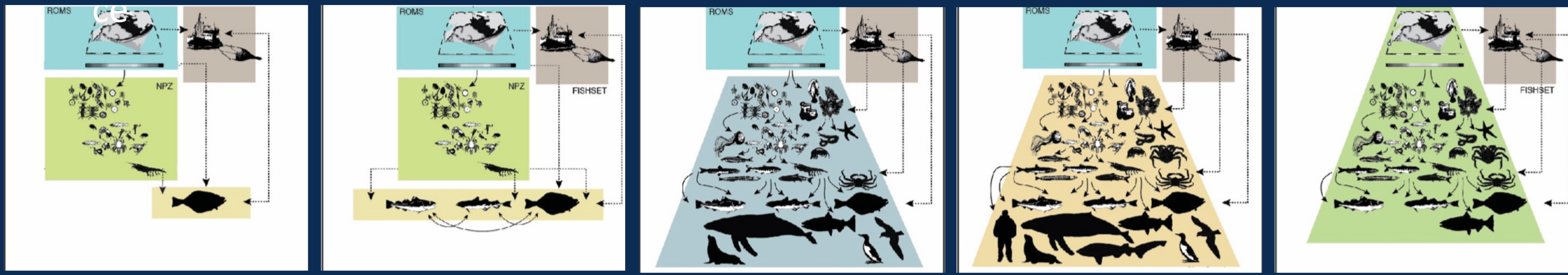

Horizontal Grid
(Latitude-Longitude)
Vertical Grid
(Height or Pressure)
Physical Processes in a Model
solar radiation
terrestrial radiation
ATMOSPHERE
advection
snow
momentum
heat
water
sea ice
CONTINENT
mixed layer ocean
advection
OCEAN

Source: GFDL


NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
UNITED STATES DEPARTMENT OF COMMERCE
ACLIM
Alaska Climate Integrated Modeling Project
Anne Hollowed (AFSC, SSMA/REFM)
Kirstin Holsman (AFSC, REEM/REFM)
Alan Haynie (AFSC ESSR/REFM)
Stephen Kasperski (AFSC ESSR/REFM)
Jim Ianelli (AFSC, SSMA/REFM)
Kerim Aydin (AFSC, REEM/REFM)
Trond Kristiansen (IMR, Norway)
Al Hermann (UW JISAO/PMEL)
Wei Cheng (UW JISAO/PMEL)
André Punt (UW SAFS)
Jonathan Reum (UW SAFS)
Amanda Faig (UW SAFS)
FATE: Fisheries & the Environment
SAAM: Stock Assessment Analytical Methods
S&T: Climate Regimes & Ecosystem Productivity
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
Physical downscaling
ROMS
Biological downscaling
NPZ
Bering Sea 10K Model
Socio-economic / harvest scenarios (x 5+)
No fishing
Status quo
By-catch changes
CE-reference points
MEY
interacting pressures
Climate Enhanced Biological models (x 5+)
CE- single species assessment models
CE- multispecies model (CEATTLE)
CE - Size spectrum model
CE- Ecopath with Ecosim
End-to-End model (FEAST)
biogeochemical habitats
lower trophic
Coupled Socio-ecological System
communities of practice
communities of place
upper trophic


NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
UNITED STATES DEPARTMENT OF COMMERCE
ACLIM
Alaska Climate Integrated Modeling Project
Anne Hollowed (AFSC, SSMA/REFM)
Kirstin Holsman (AFSC, REEM/REFM)
Alan Haynie (AFSC ESSR/REFM)
Stephen Kasperski (AFSC ESSR/REFM)
Jim Ianelli (AFSC, SSMA/REFM)
Kerim Aydin (AFSC, REEM/REFM)
Trond Kristiansen (IMR, Norway)
Al Hermann (UW JISAO/PMEL)
Wei Cheng (UW JISAO/PMEL)
André Punt (UW SAFS)
Jonathan Reum (UW SAFS)
Amanda Faig (UW SAFS)
FATE: Fisheries & the Environment
SAAM: Stock Assessment Analytical Methods
S&T: Climate Regimes & Ecosystem Productivity
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
Physical downscaling
ROMS
Biological downscaling
NPZ
Bering Sea 10K Model
Socio-economic / harvest scenarios (x 5+)
No fishing
Status quo
By-catch changes
CE-reference points
MEY
Climate Enhanced Biological models (x 5+)
CE- single species assessment models
CE- multispecies model (CEATTLE)
CE - Size spectrum model
CE- Ecopath with Ecosim
End-to-End model (FEAST)
interacting pressures
lower trophic
biogeochemical habitats
Coupled Socio-ecological System
communities of practice
communities of place
upper trophic

CE-SSM | CE-MSM | CE-EwE | CE-MIZER | FEAST

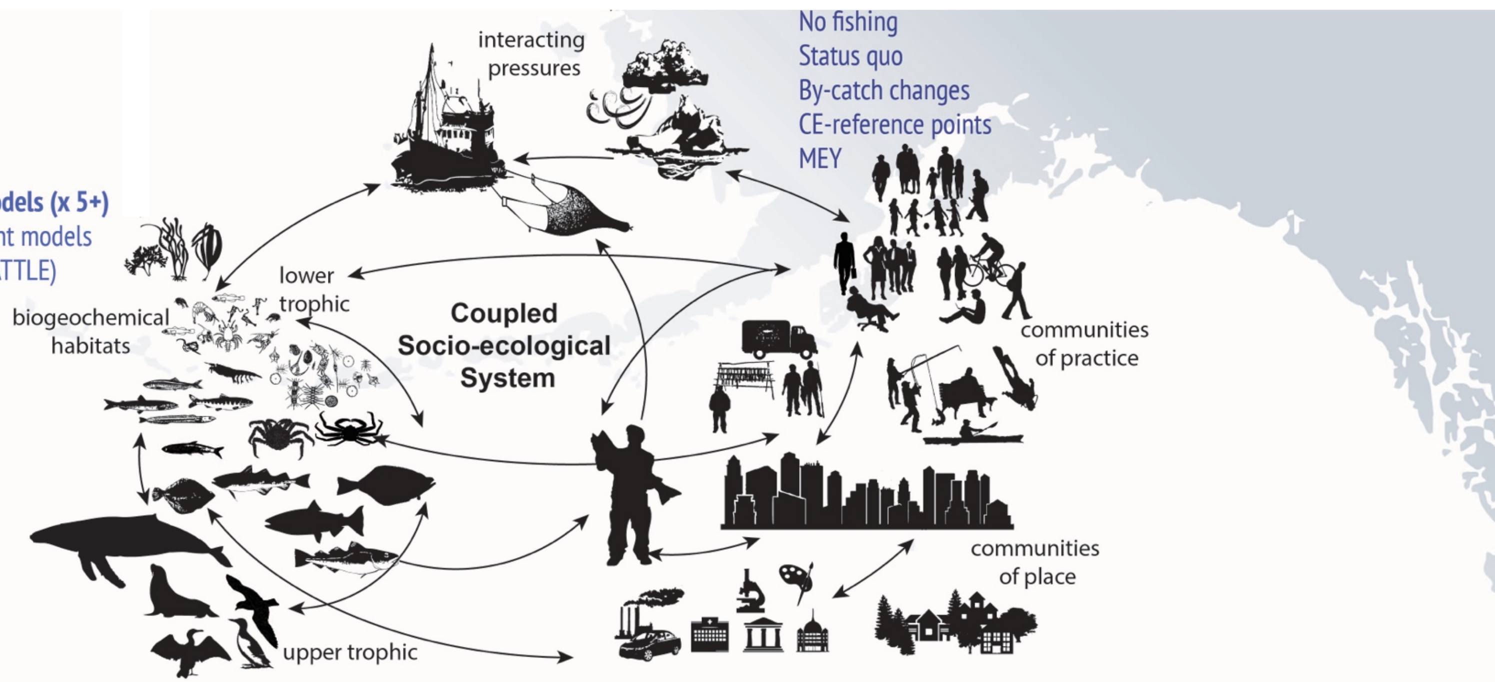


Fast
Statistical
Implicit ecosystem noise

Slow
High resolution
Explicit ecosystem interactions

Climate Enhanced Biological models (x 5+)

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

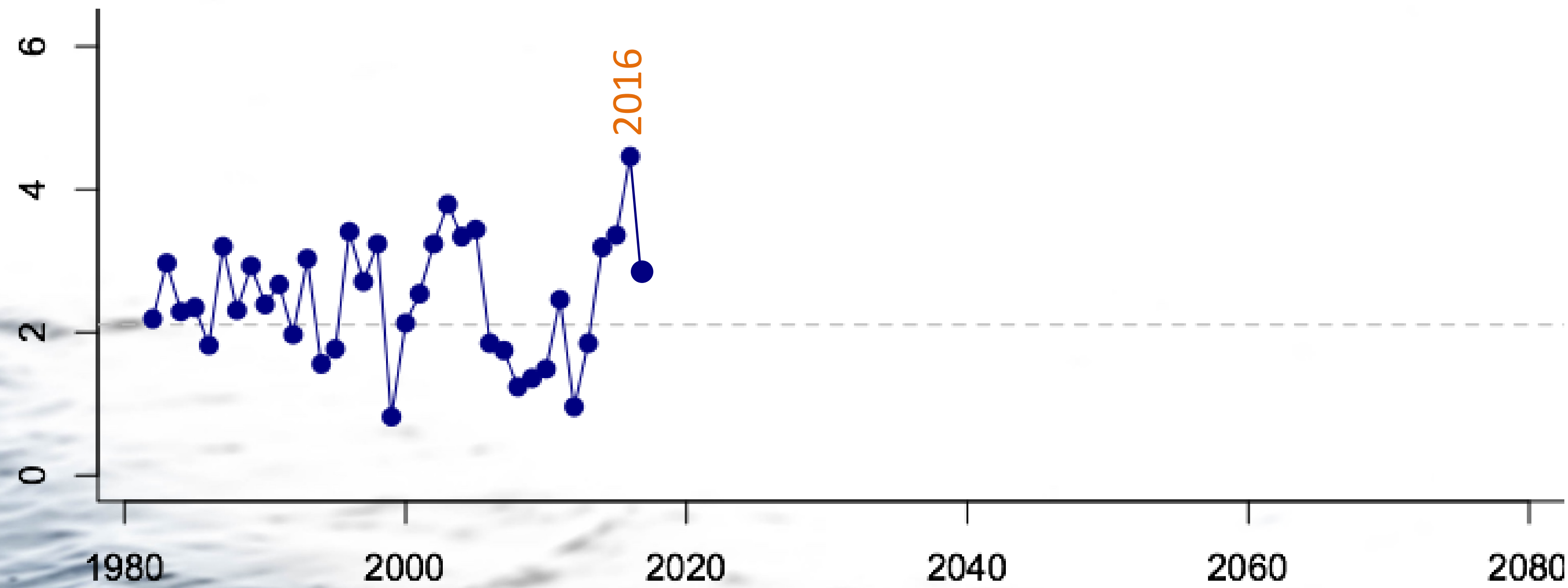


Preliminary Results

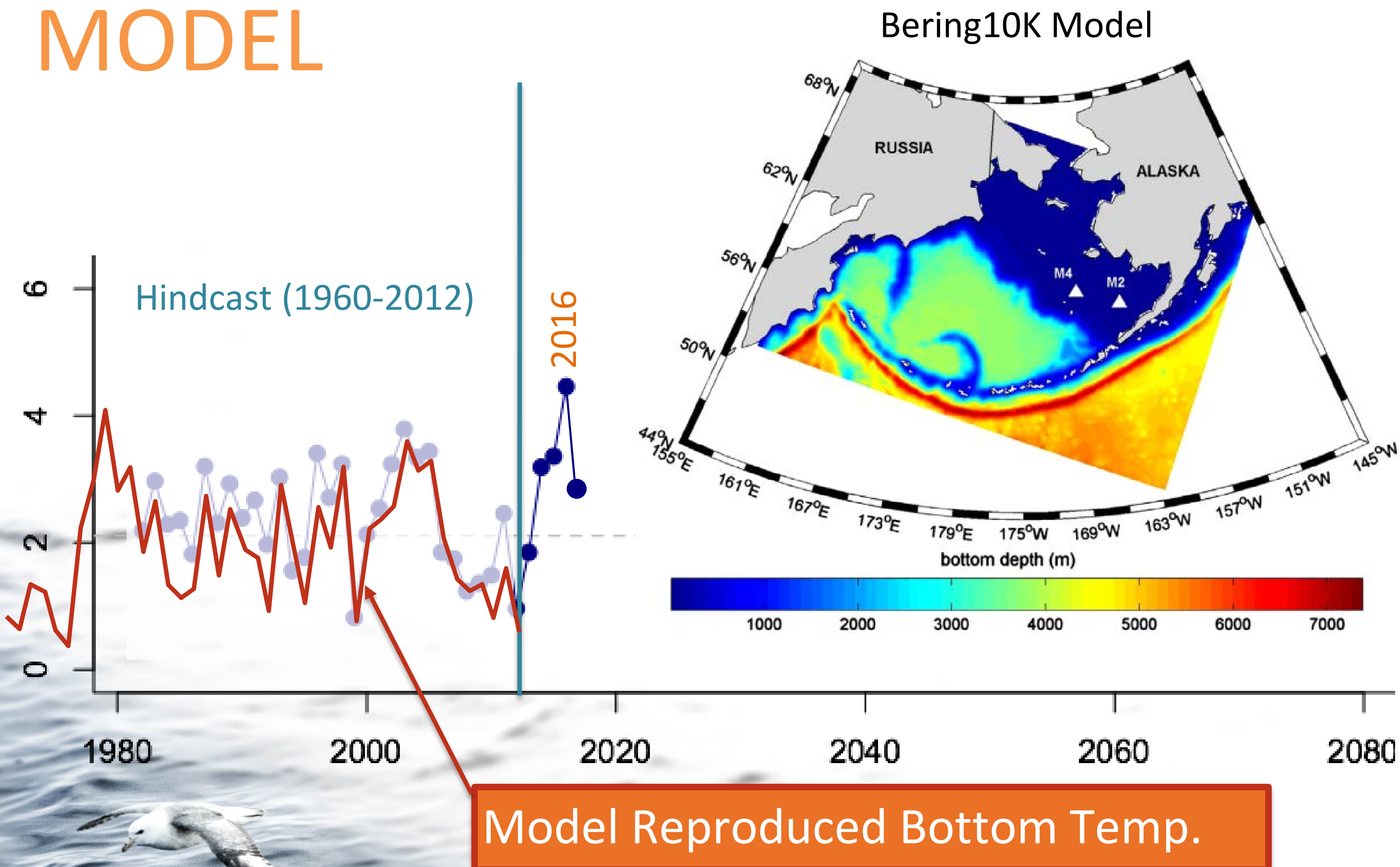
(physical projections)

Photo: Mark Holsman

Summer Bottom Temperature (°C) OBSERVED



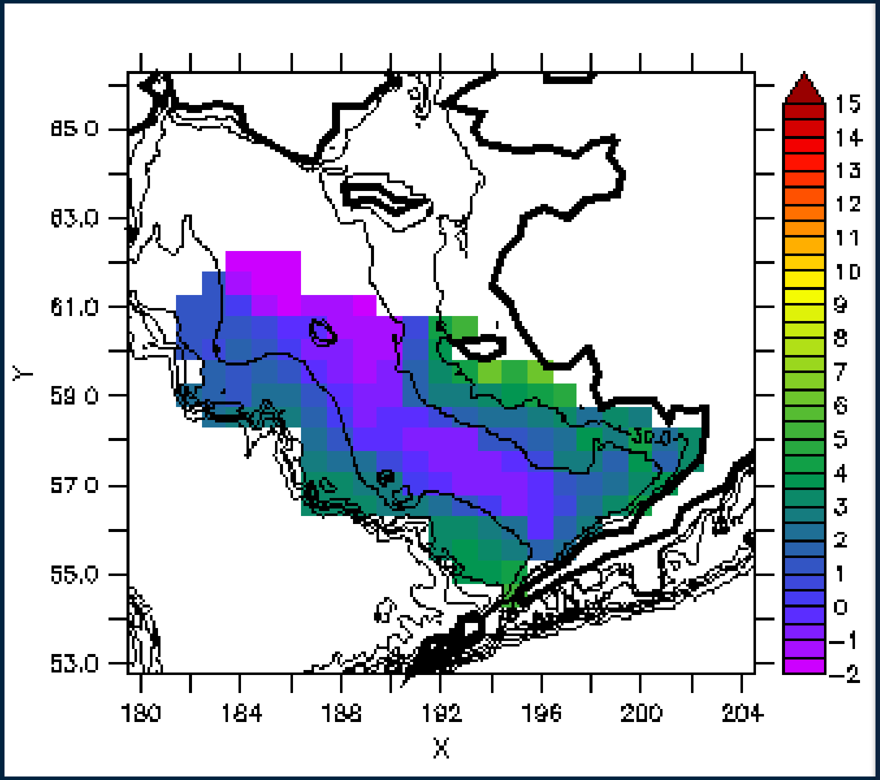
Summer Bottom Temperature (°C) MODEL



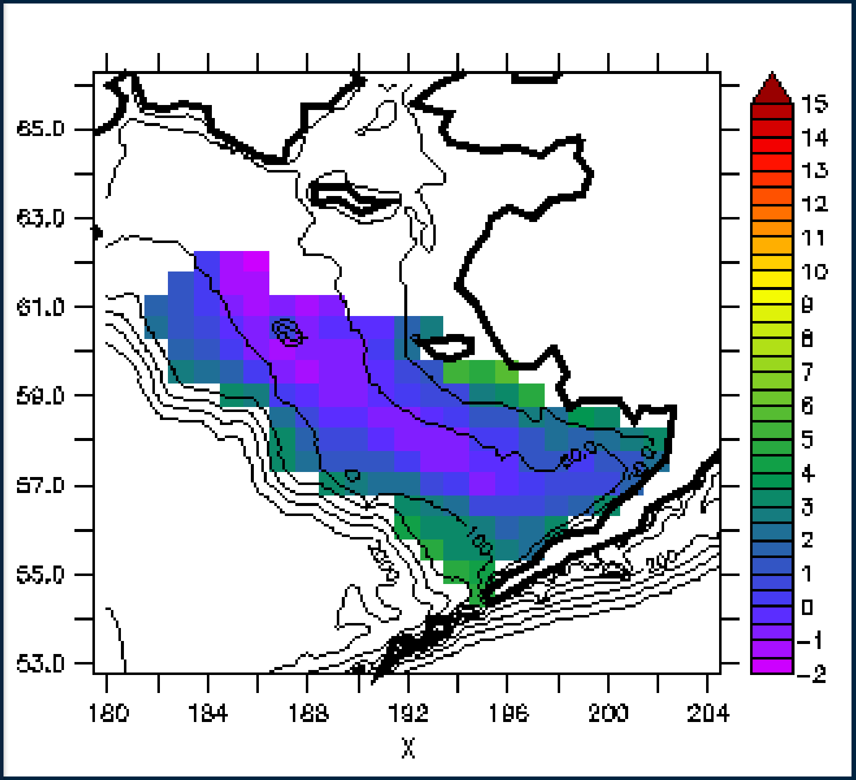
“Bering10K” Regional Oceanography Model

Bottom T. (^oC) Summer 2009

DATA



MODEL

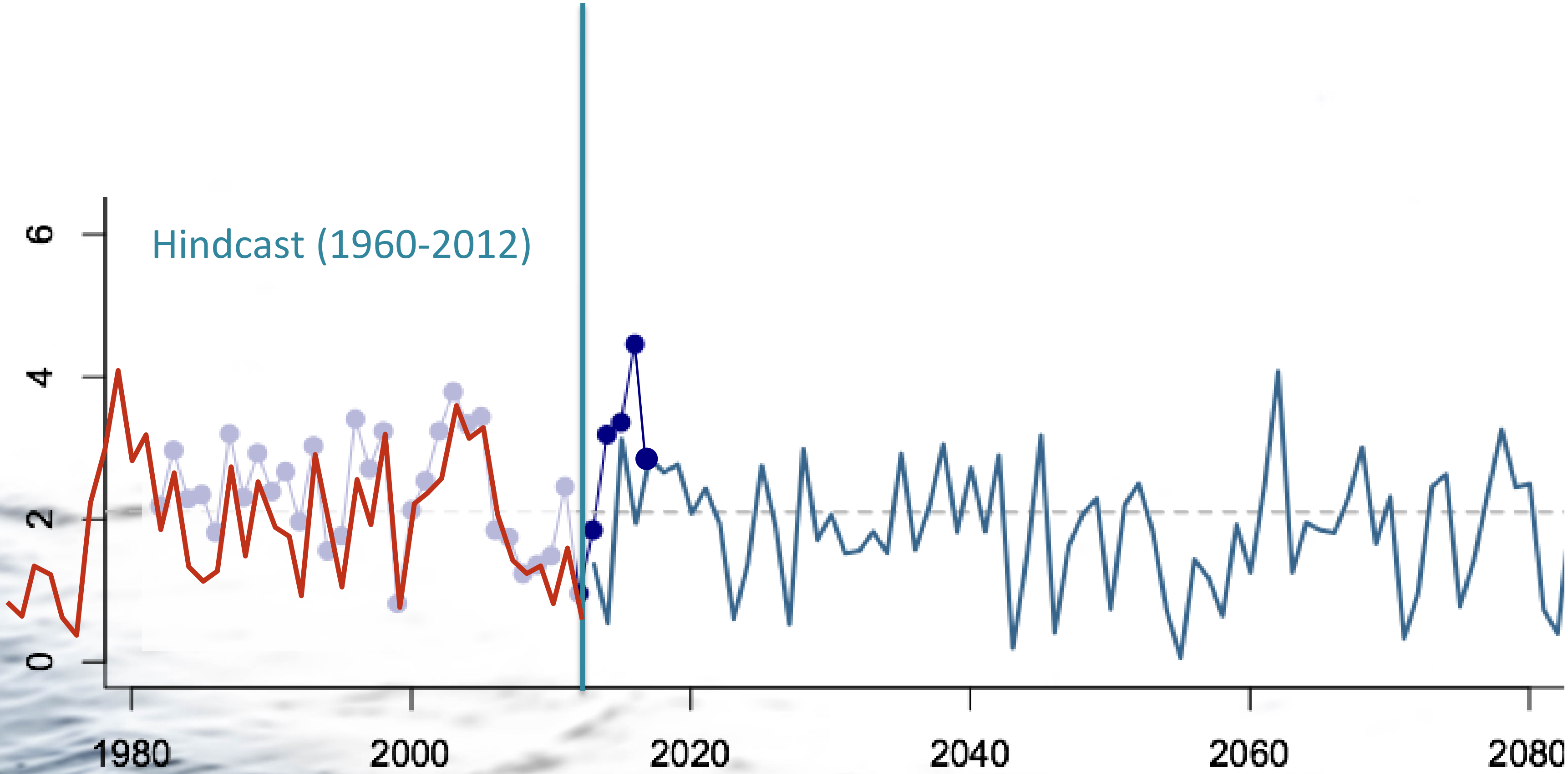


NOAA FISHERIES

Slide courtesy of A. Hermann

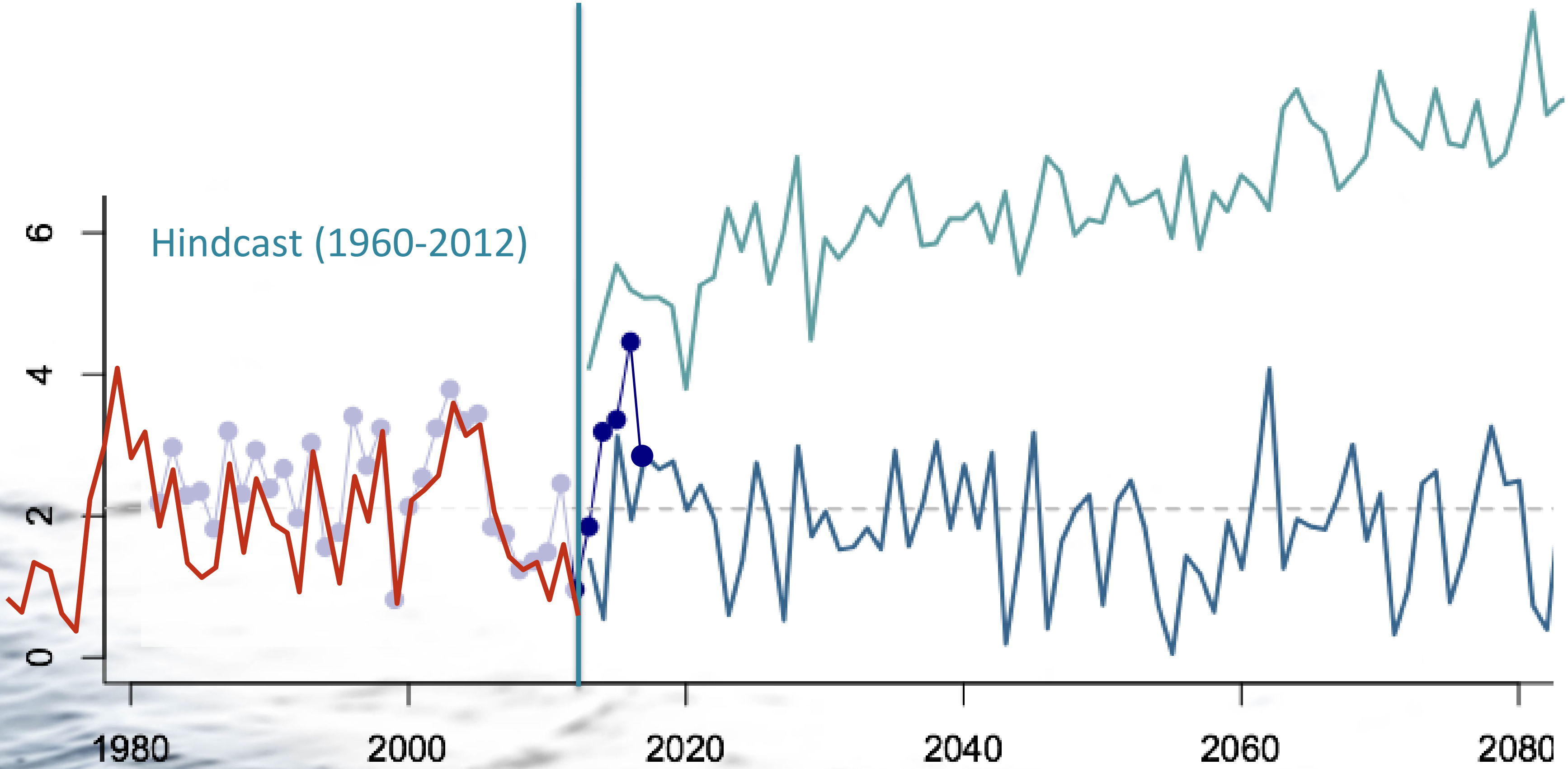
Summer Bottom Temperature (°C) MODEL

Draft results; please do not reproduce



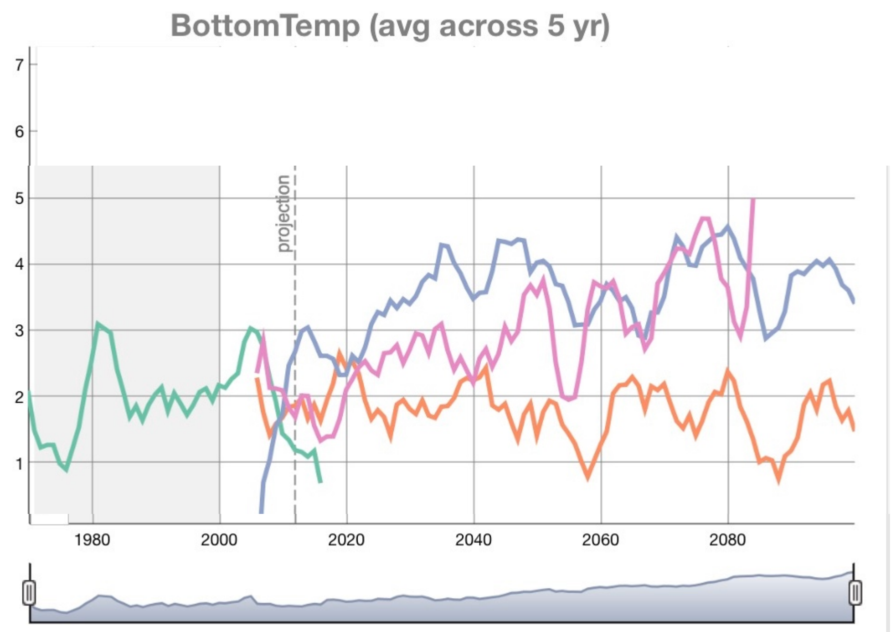
Summer Bottom Temperature (ºC) MODEL

Draft results; please do not reproduce

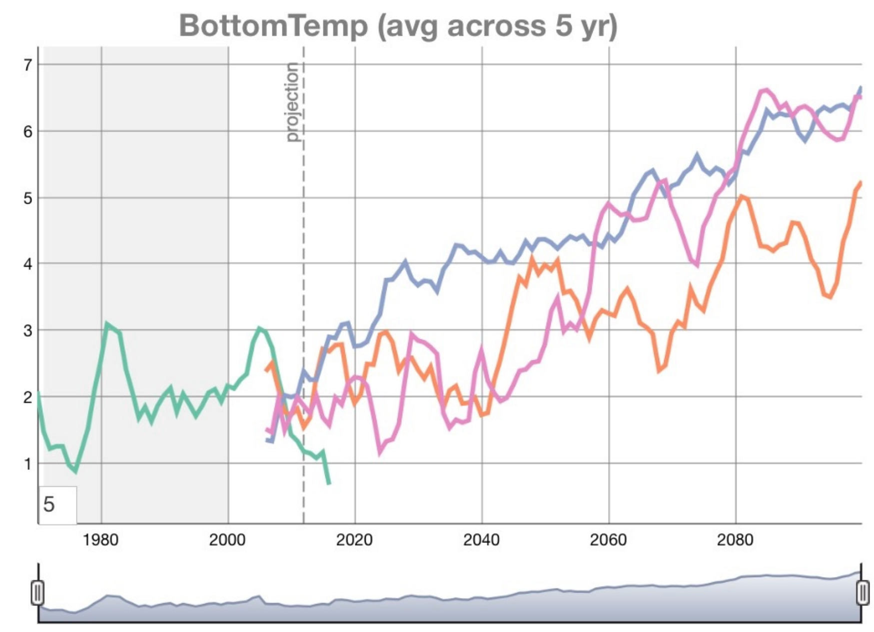


Bottom Temperature (°C)

Low CO_2 Scenario (RCP 4.5)



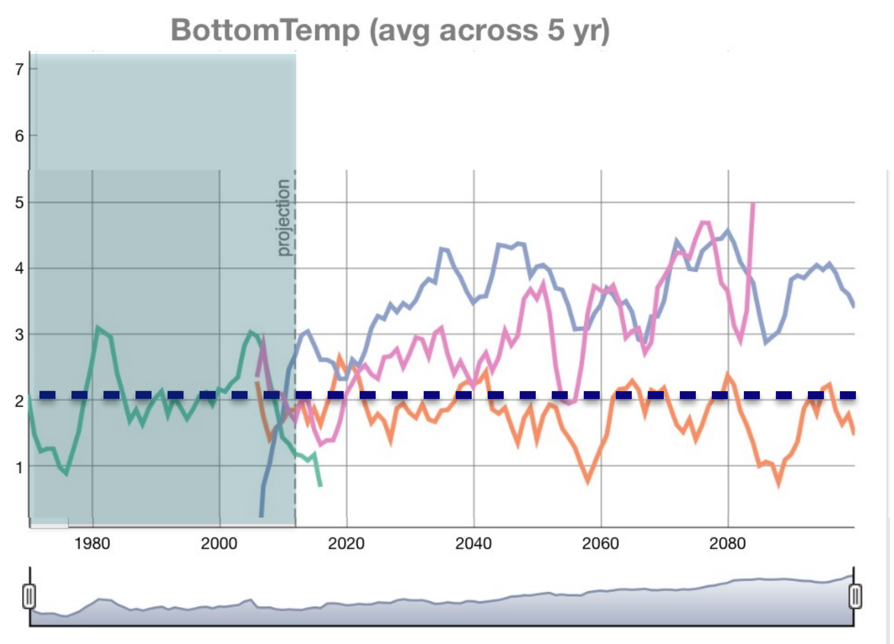
High CO_2 Scenario (RCP 8.5)



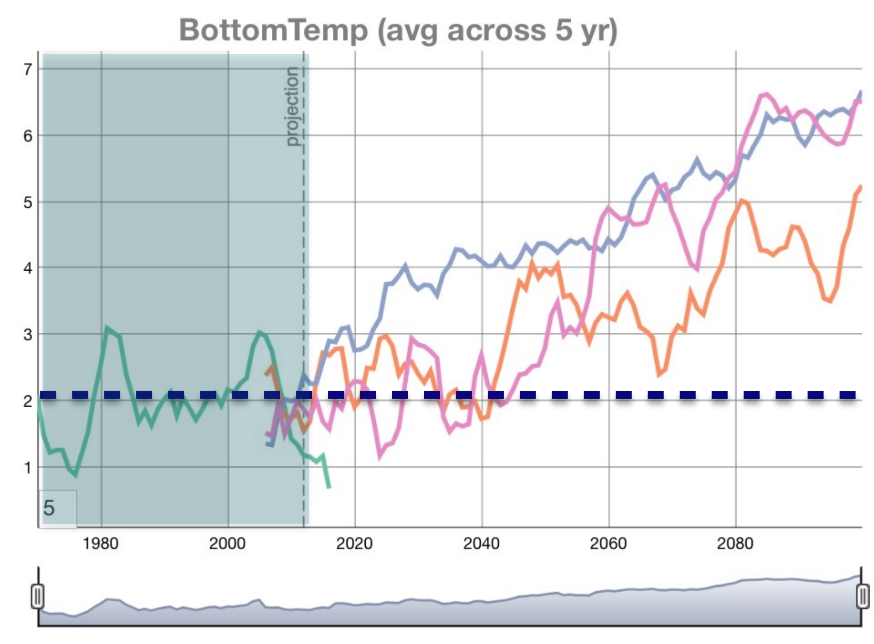
Holsman et al. in prep; draft results, please do not cite or copy

Bottom Temperature (°C)

Low CO_2 Scenario (RCP 4.5)



High CO_2 Scenario (RCP 8.5)

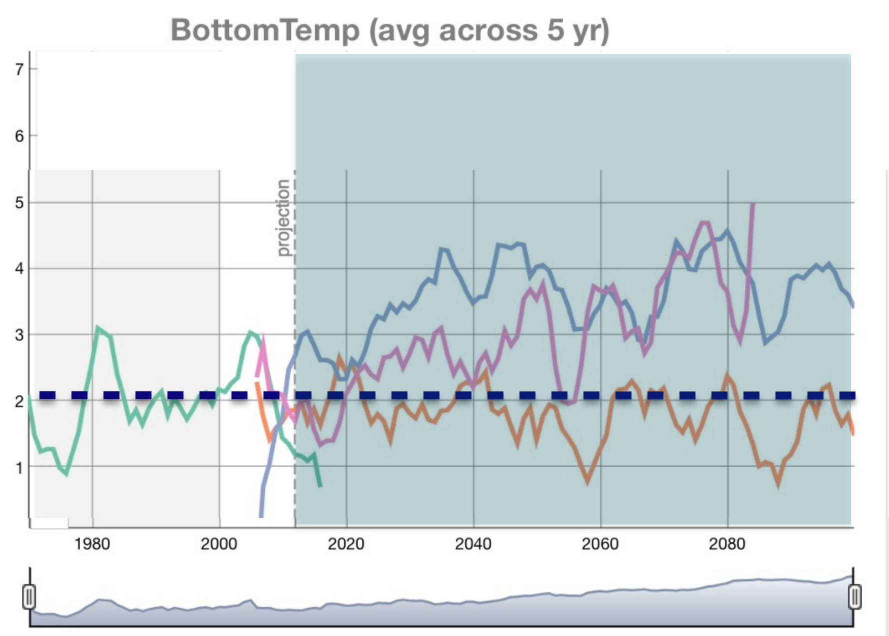


Holsman et al. in prep; draft results, please do not cite or copy

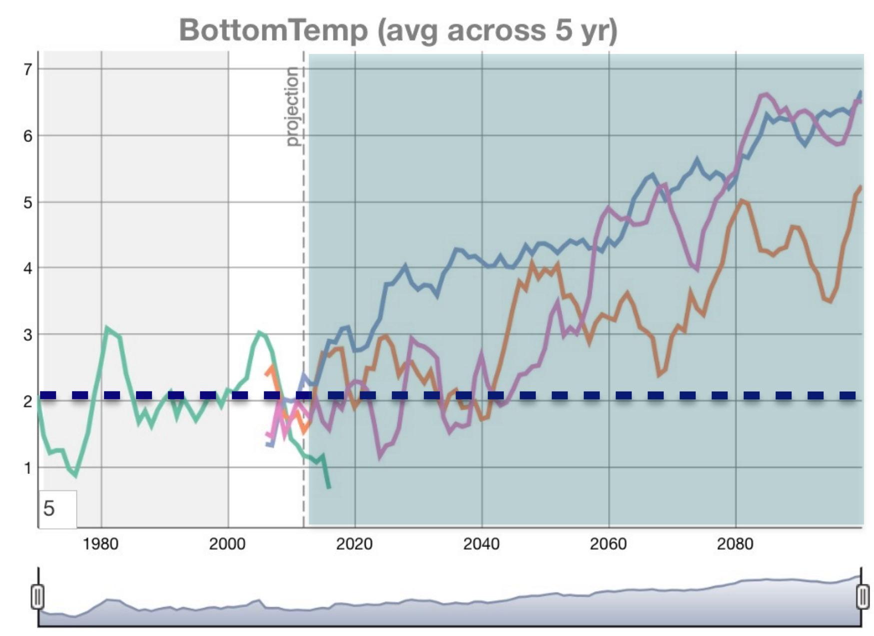
NOAA FISHERIES

Bottom Temperature (°C)

Low CO_2 Scenario (RCP 4.5)



High CO_2 Scenario (RCP 8.5)

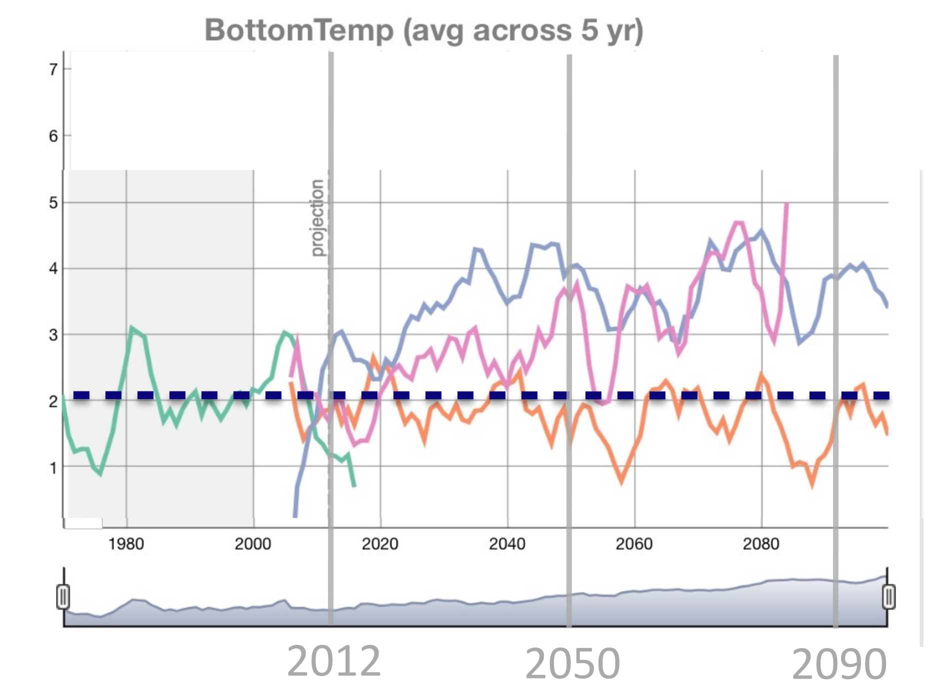


Holsman et al. in prep; draft results, please do not cite or copy

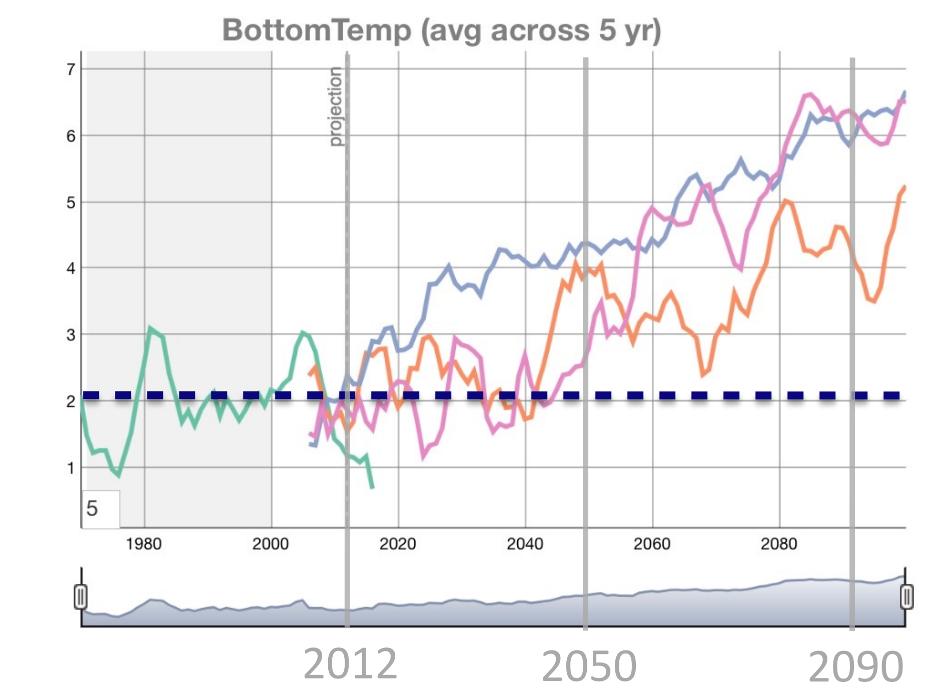
NOAA FISHERIES

Bottom Temperature (°C)

Low CO_2 Scenario (RCP 4.5)



High CO_2 Scenario (RCP 8.5)

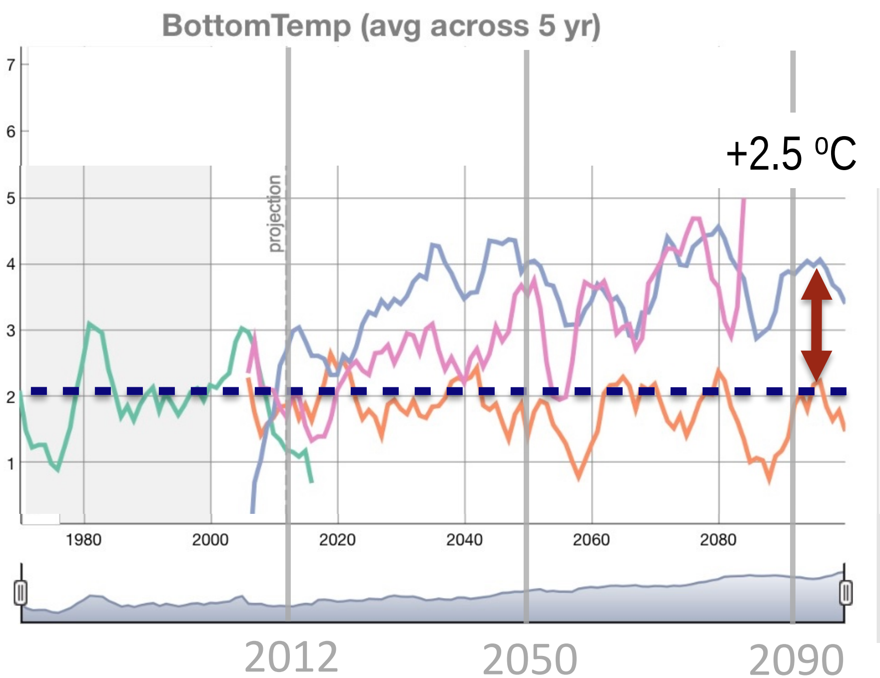


Holsman et al. in prep; draft results, please do not cite or copy

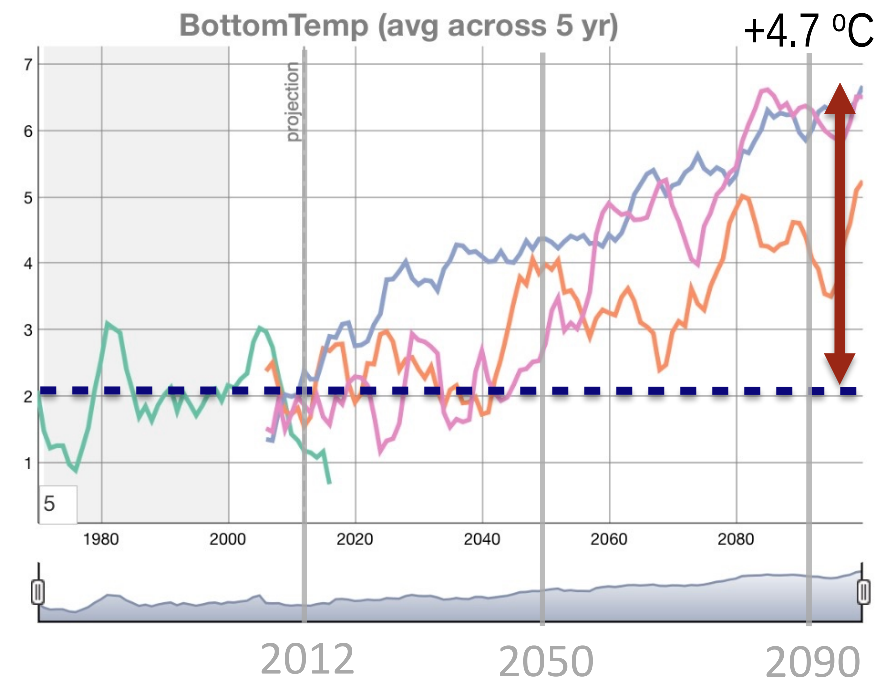
NOAA FISHERIES

Bottom Temperature (°C)

Low CO_2 Scenario (RCP 4.5)



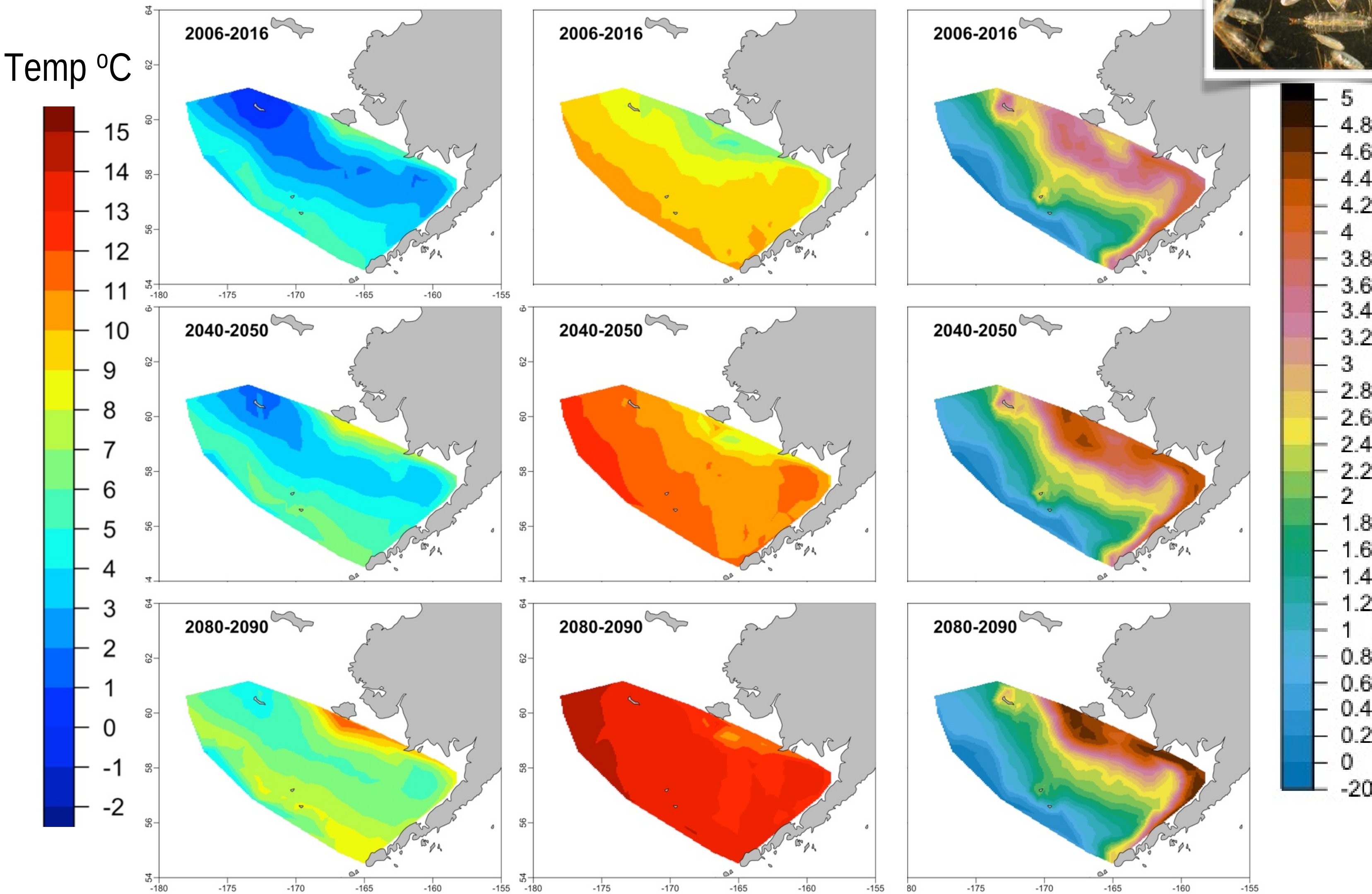
High CO_2 Scenario (RCP 8.5)



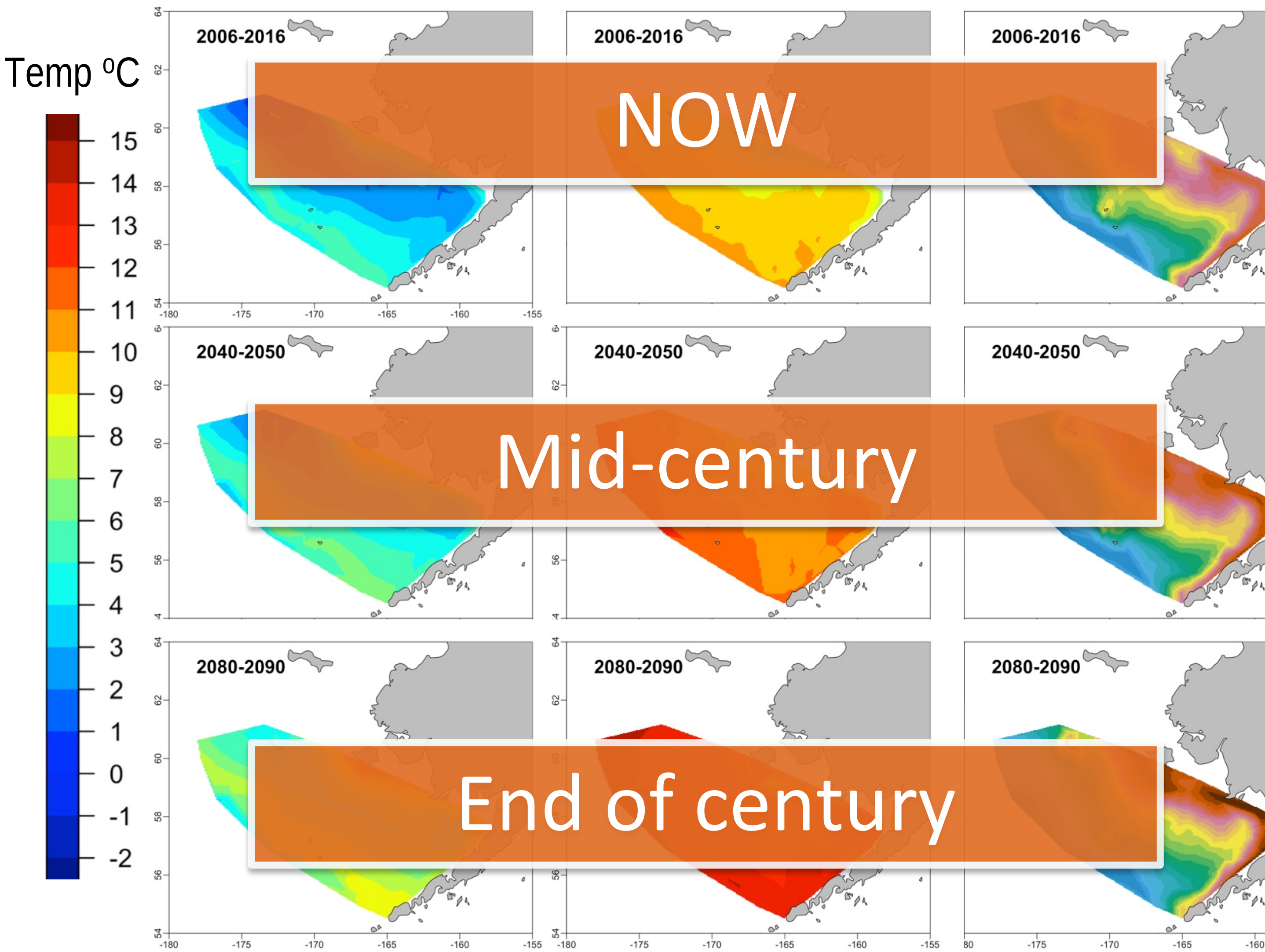
Holsman et al. in prep; draft results, please do not cite or copy

NOAA FISHERIES

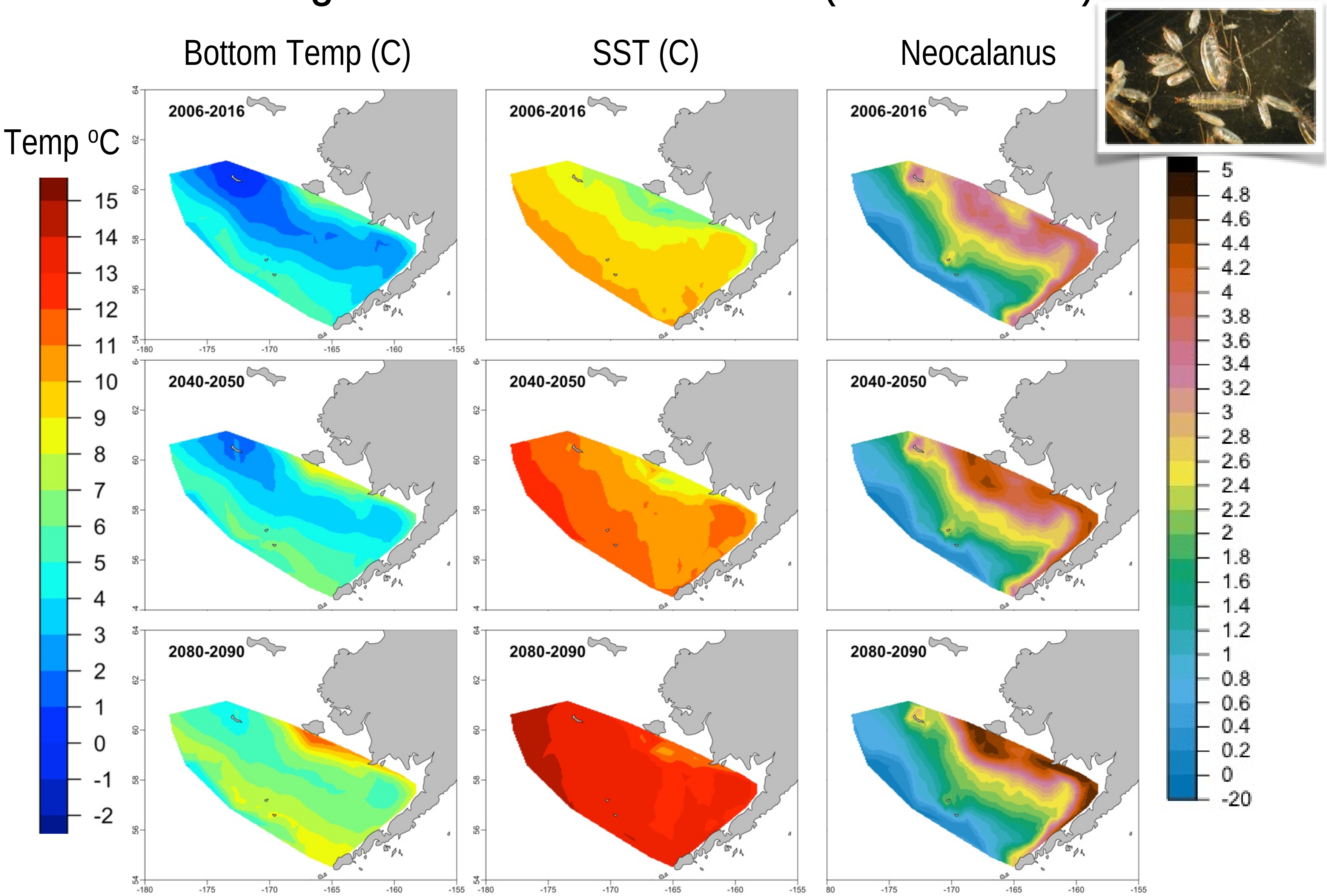
Average of all “warm” scenarios (ESM RCP 8.5)



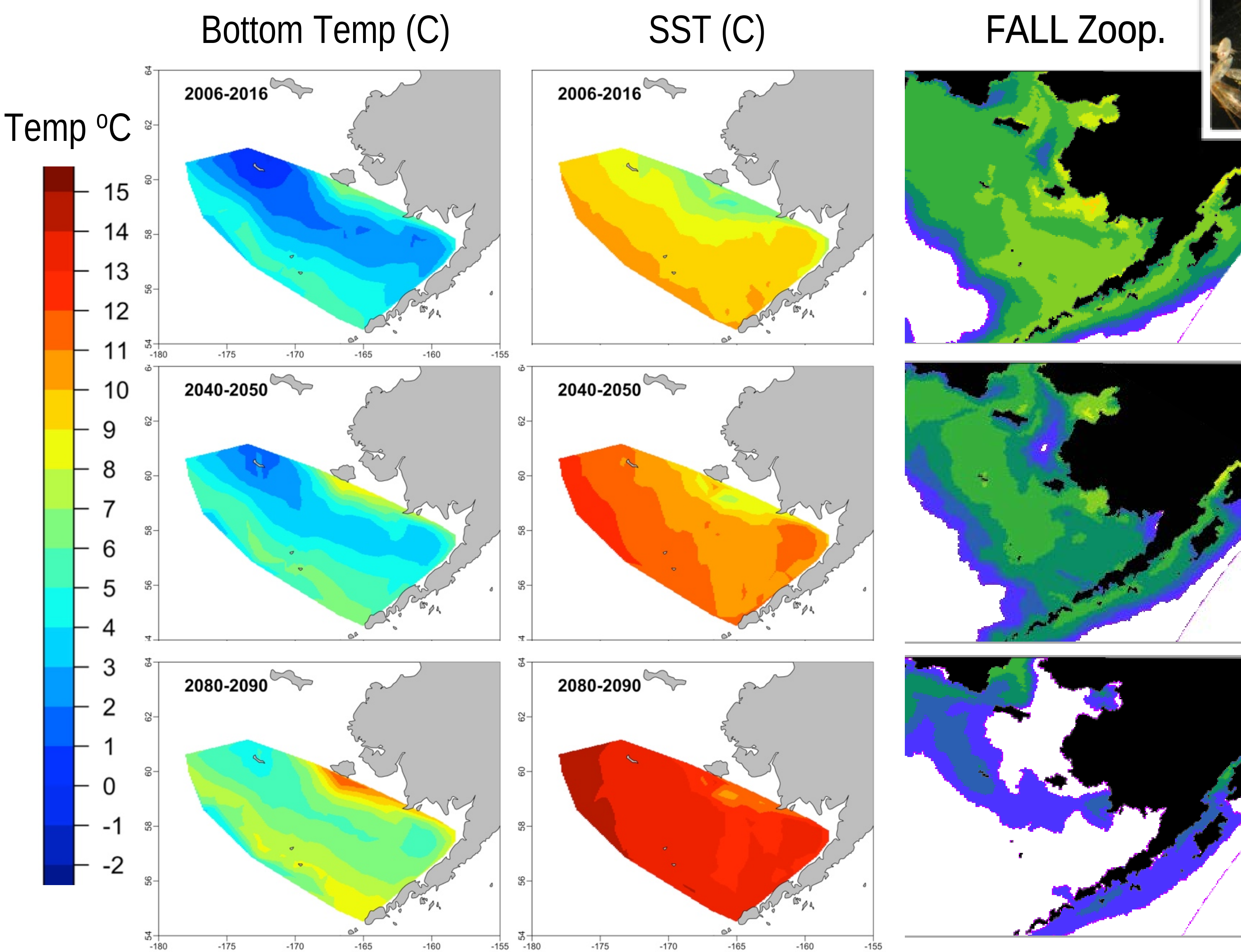
Average of all "warm" scenarios (ESM RCP 8.5)



Average of all “warm” scenarios (ESM RCP 8.5)



Average of all “High CO_2” scenarios (ESM RCP 8.5)



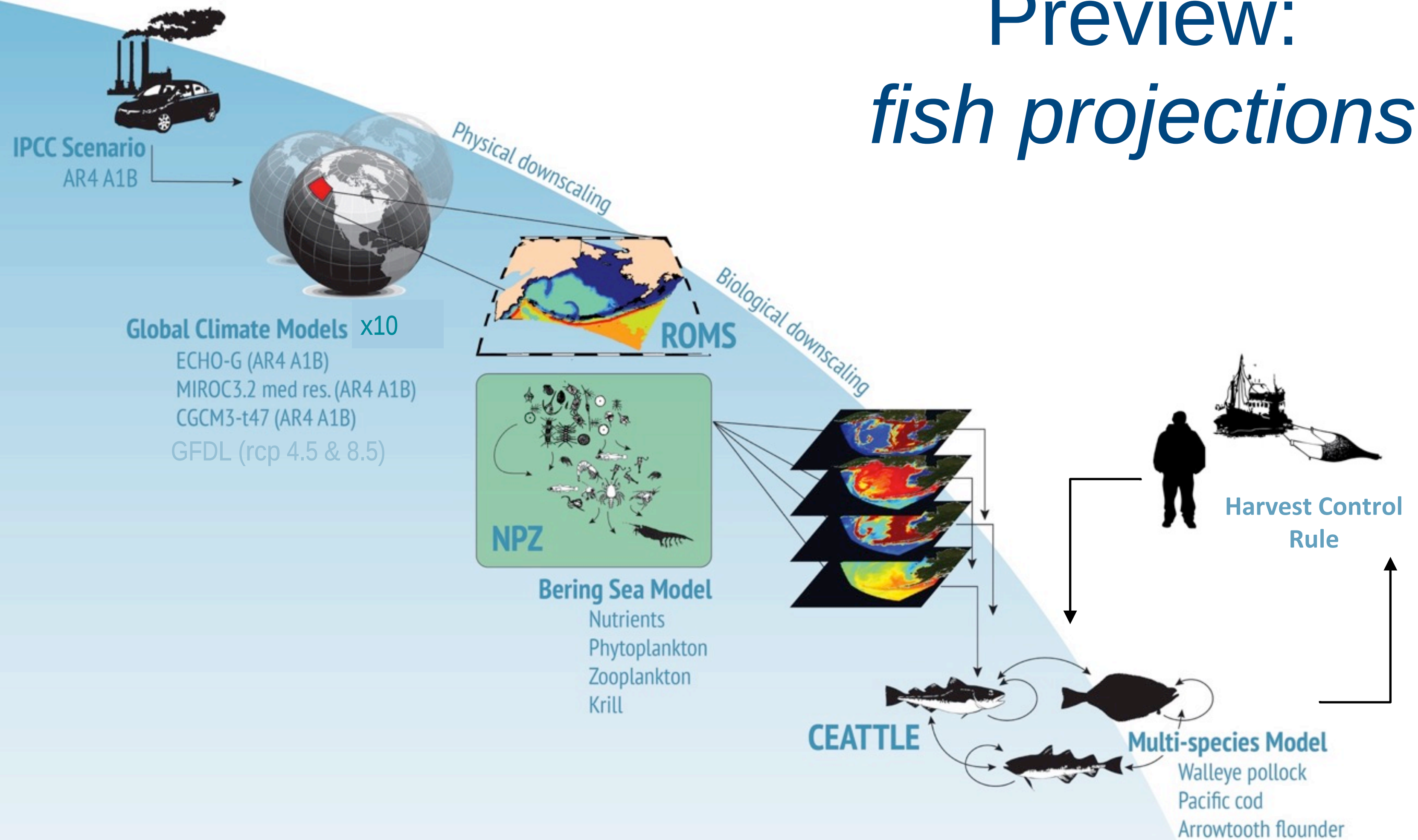
Preliminary Results

(fish projections)

No fishing & “Status quo”
assuming <u>we don’t adjust our management </u>but the climate changes

Photo: Mark Holsman

Preview:
fish projections

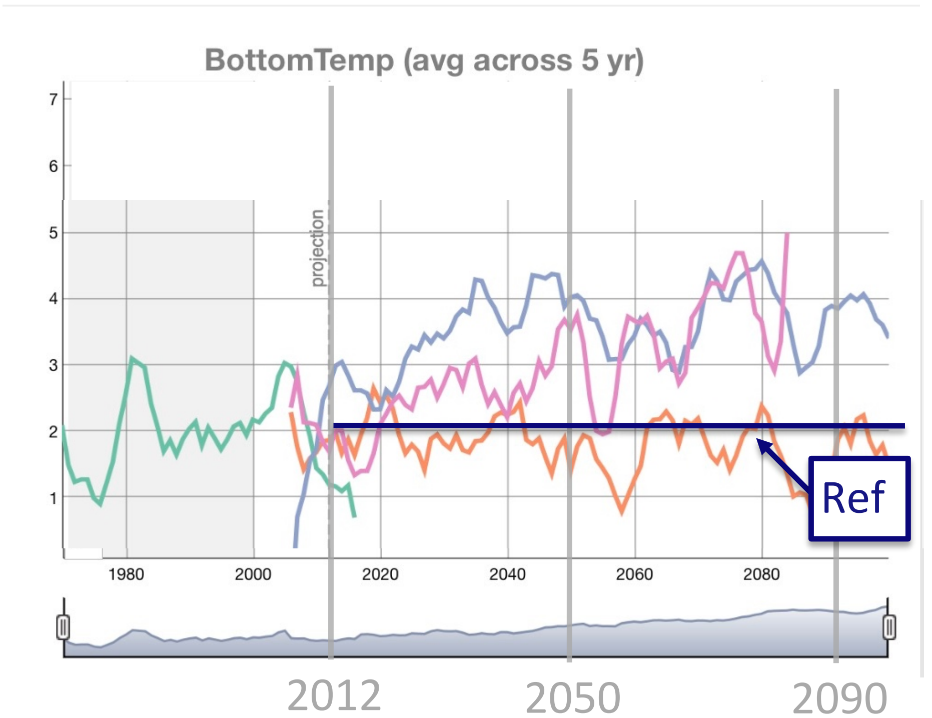


Holsman et al. in prep

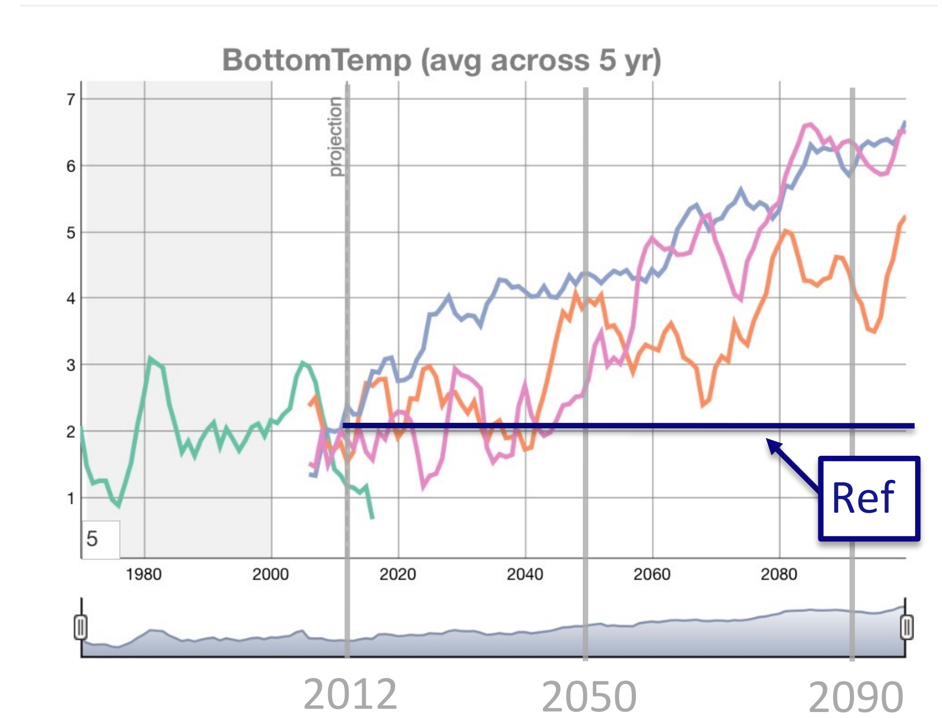
Climate-specific Harvest & Population Projections

Bottom Temperature (°C)

Low CO_2 Scenario (RCP 4.5)



High CO_2 Scenario (RCP 8.5)

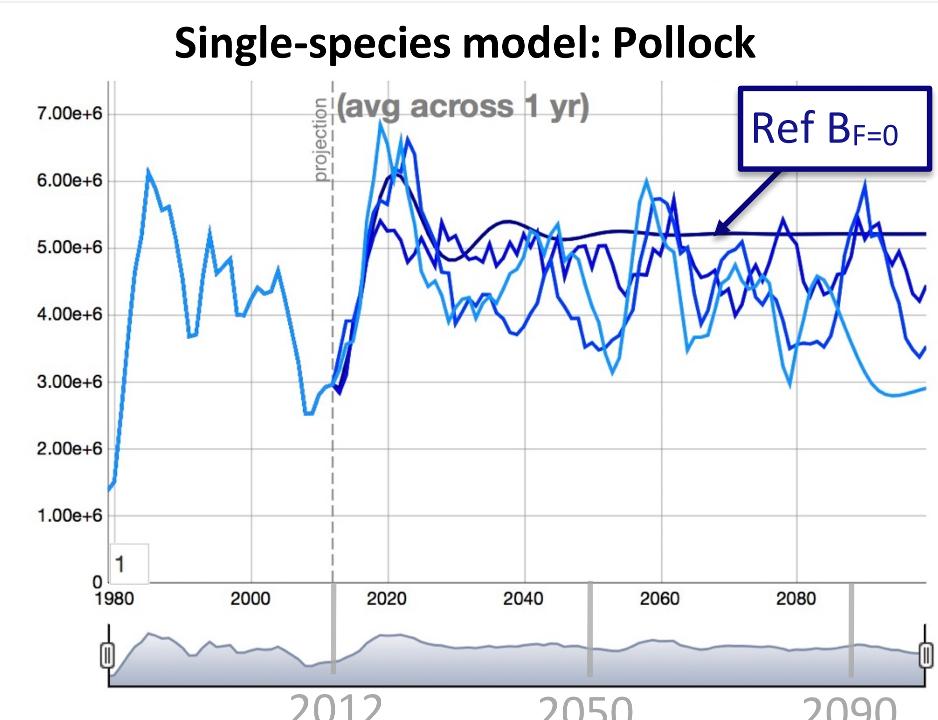


Holsman et al. in prep; draft results, please do not cite or copy

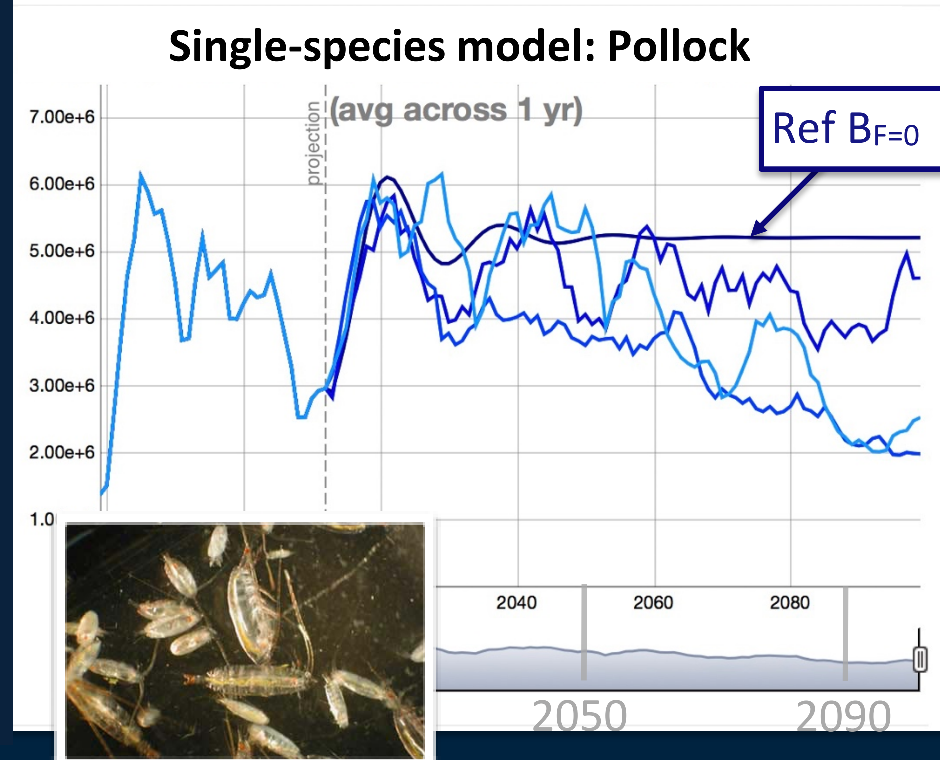
NOAA FISHERIES

Unfished Spawning Biomass (F=0)

Low CO_2 Scenario (RCP 4.5)



High CO_2 Scenario (RCP 8.5)

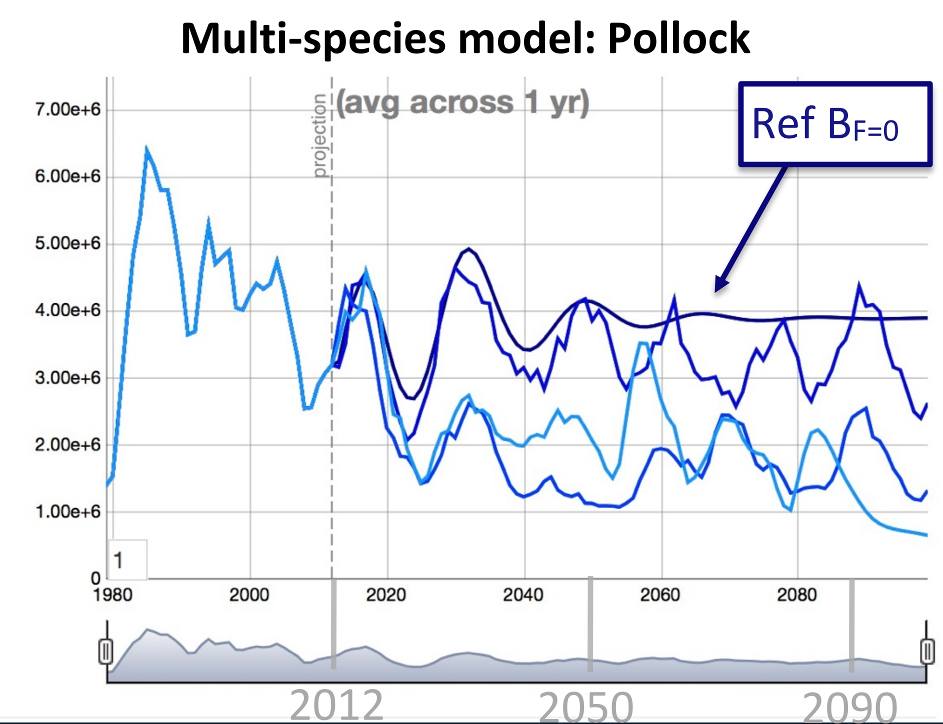


Holsman et al. in prep; draft results, please do not cite or copy

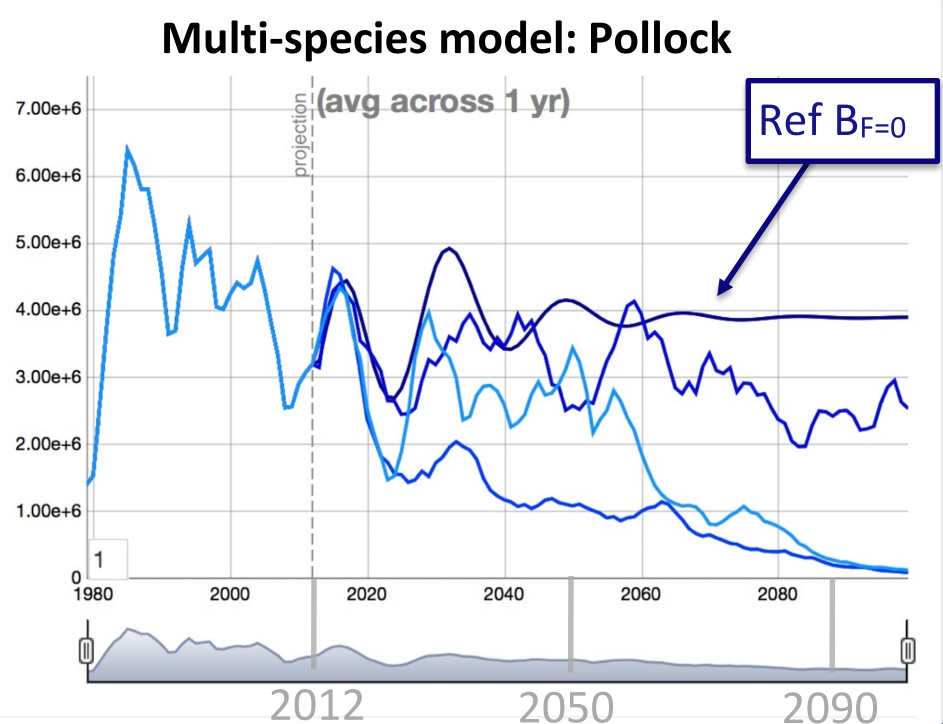
NOAA FISHERIES

Unfished Spawning Biomass (F=0)

Low CO_2 Scenario (RCP 4.5)



High CO_2 Scenario (RCP 8.5)

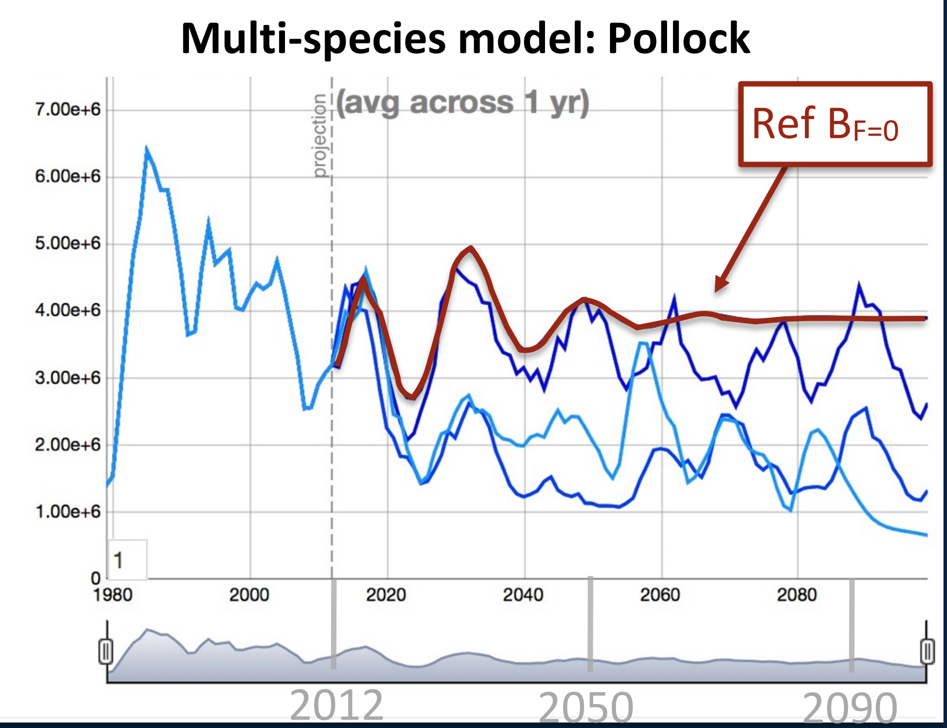


Holsman et al. in prep; draft results, please do not cite or copy

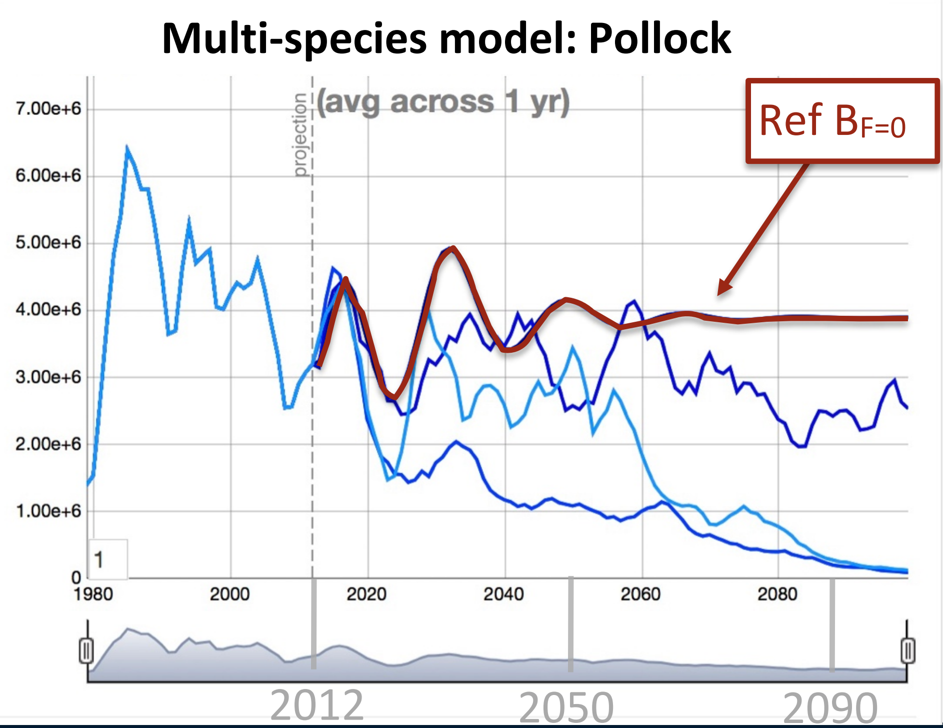
NOAA FISHERIES

Unfished Spawning Biomass (F=0)

Low CO_2 Scenario (RCP 4.5)



High CO_2 Scenario (RCP 8.5)



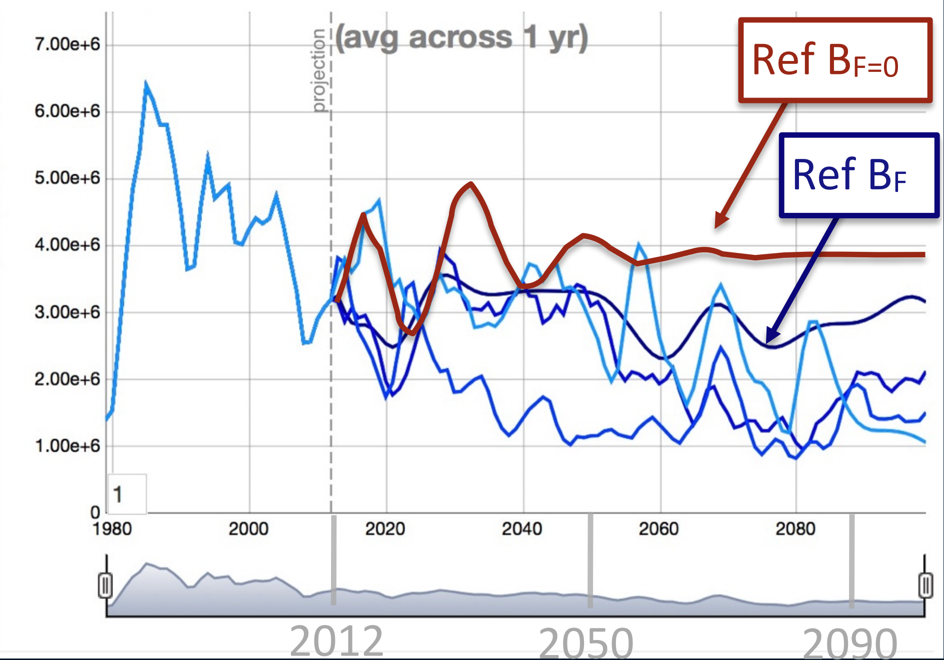
Holsman et al. in prep; draft results, please do not cite or copy

NOAA FISHERIES

Fished Spawning Biomass

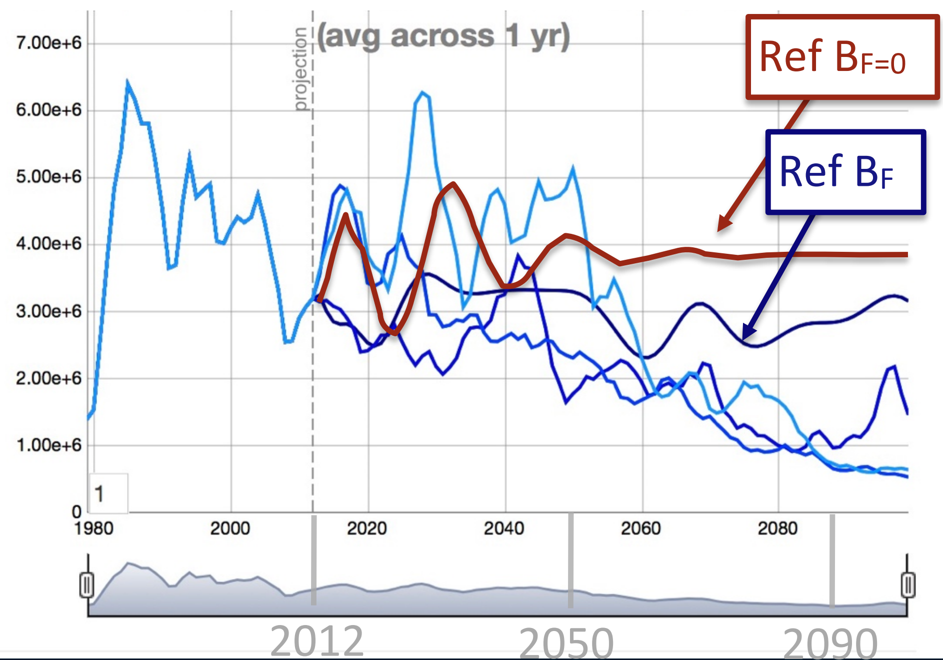
Low CO_2 Scenario (RCP 4.5)

Multi-species model: Pollock



High CO_2 Scenario (RCP 8.5)

Multi-species model: Pollock



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

NOAA FISHERIES

Single-species model

	Low CO_2	High CO_2
$B_{F=0}$	-33%	-42%
B_F	-30%	-35%

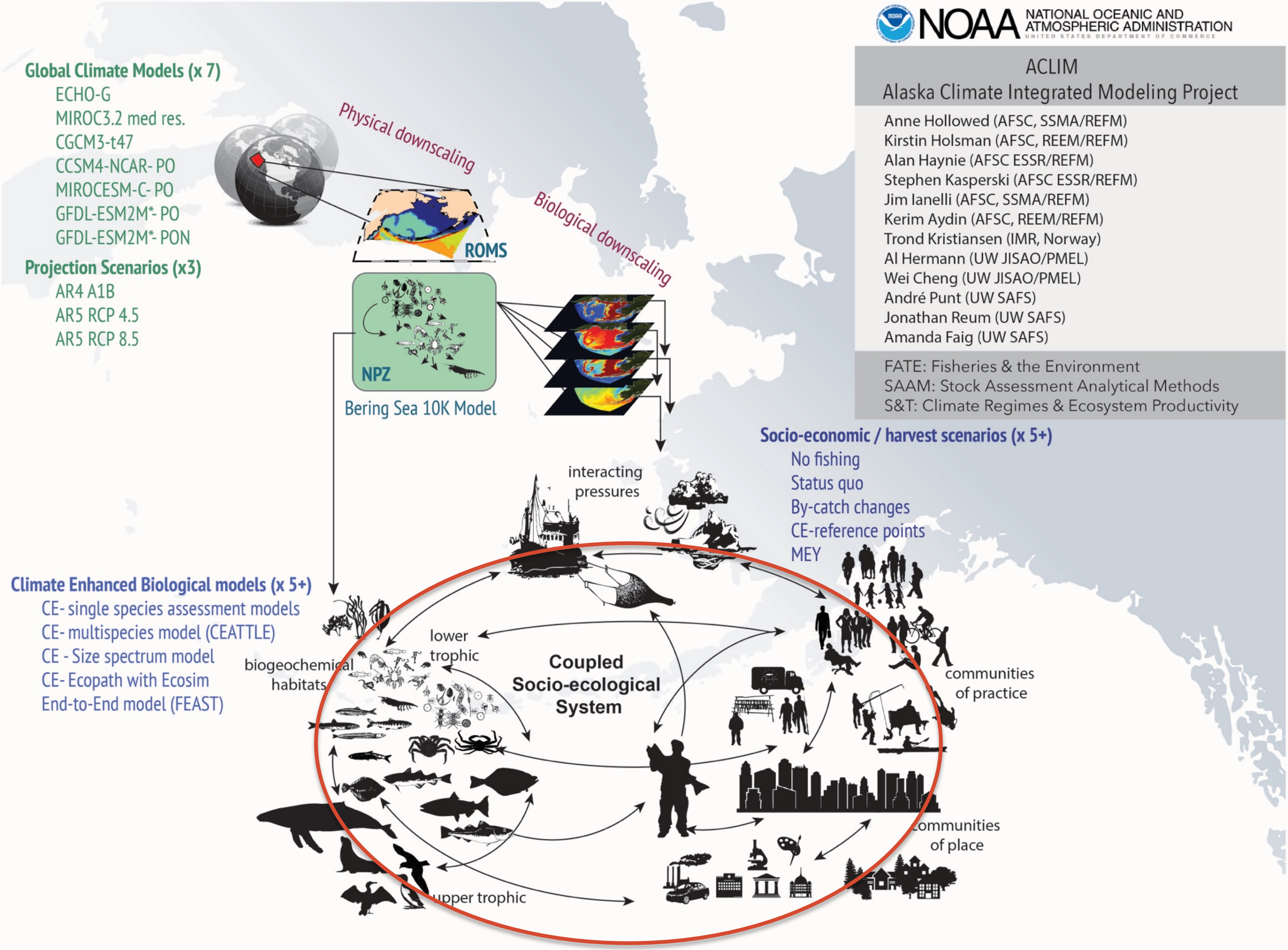
Multi-species model

	Low CO_2	High CO_2	
$B_{F=0}$	-64%	-76%	"Climate only"
B_F	-54%	-72%	"Climate + Fishery Management"

Preliminary Results

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

Photo: Mark Holsman


NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
UNITED STATES DEPARTMENT OF COMMERCE
ACLIM
Alaska Climate Integrated Modeling Project
Anne Hollowed (AFSC, SSMA/REFM)
Kirstin Holsman (AFSC, REEM/REFM)
Alan Haynie (AFSC ESSR/REFM)
Stephen Kasperski (AFSC ESSR/REFM)
Jim Ianelli (AFSC, SSMA/REFM)
Kerim Aydin (AFSC, REEM/REFM)
Trond Kristiansen (IMR, Norway)
Al Hermann (UW JISAO/PMEL)
Wei Cheng (UW JISAO/PMEL)
André Punt (UW SAFS)
Jonathan Reum (UW SAFS)
Amanda Faig (UW SAFS)
FATE: Fisheries & the Environment
SAAM: Stock Assessment Analytical Methods
S&T: Climate Regimes & Ecosystem Productivity
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
Physical downscaling
ROMS
Biological downscaling
NPZ
Bering Sea 10K Model
Socio-economic / harvest scenarios (x 5+)
No fishing
Status quo
By-catch changes
CE-reference points
MEY
interacting pressures
Climate Enhanced Biological models (x 5+)
CE- single species assessment models
CE- multispecies model (CEATTLE)
CE - Size spectrum model
CE- Ecopath with Ecosim
End-to-End model (FEAST)
biogeochemical habitats
lower trophic
Coupled Socio-ecological System
communities of practice
communities of place
upper trophic

The Human Connection

Improving Management Foresight

Improving Management Foresight

- 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.

Improving Management Foresight

- 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.

Overview – "Socioecon-ACLIM"

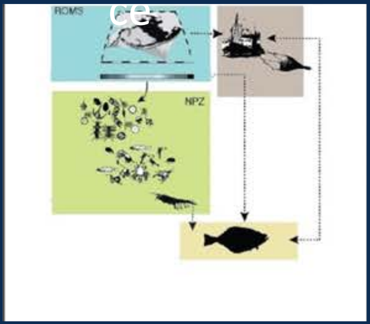
- Coupling biological and economic models
- Fishery mechanisms
- Management tools

Overview – “Socioecon-ACLIM”

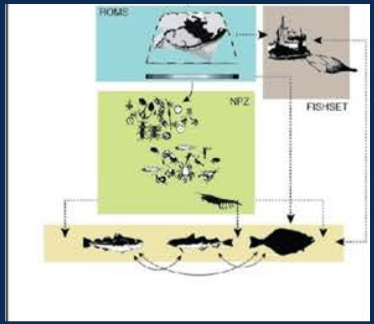
- Coupling biological and economic models
- Fishery mechanisms
- Management tools
- <u>Help! We need your input!</u>

Coupling Biophysical / Biological
&
Economic Models & Policies

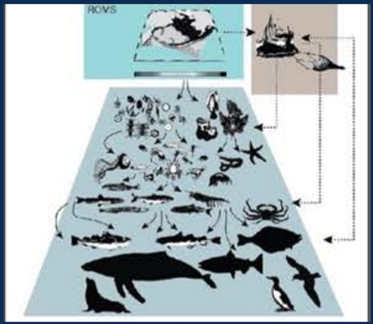
CE-SSM



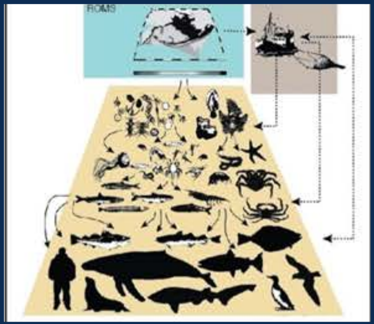
CE-MSM



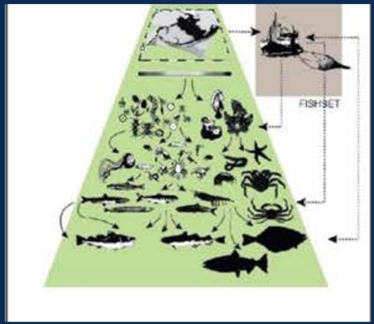
CE-EwE



CE-MIZER



FEAST



Fast
Statistical
Implicit ecosystem noise

Slow
High resolution
Explicit ecosystem interactions

ACLIM utilizes economic models of different complexity

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

Status Quo Management under the Ecosystem Cap

- For each species, TAC <= ABC
- The sum of all TACs <= 2 MMT
- In 2017, Sum(ABCs) = ~ 4 MMT

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

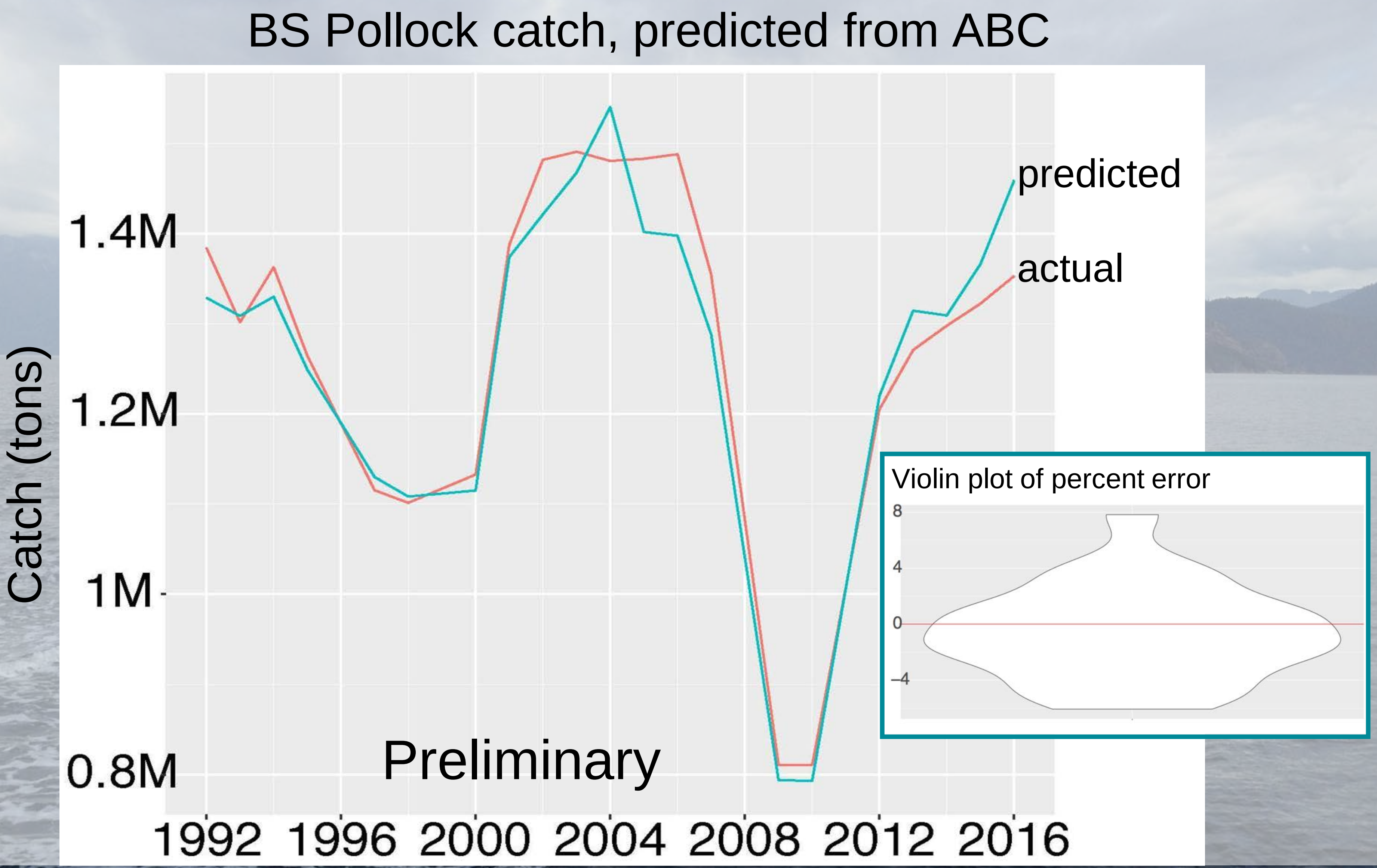
Biomass – TAC - Catch Model for Projections

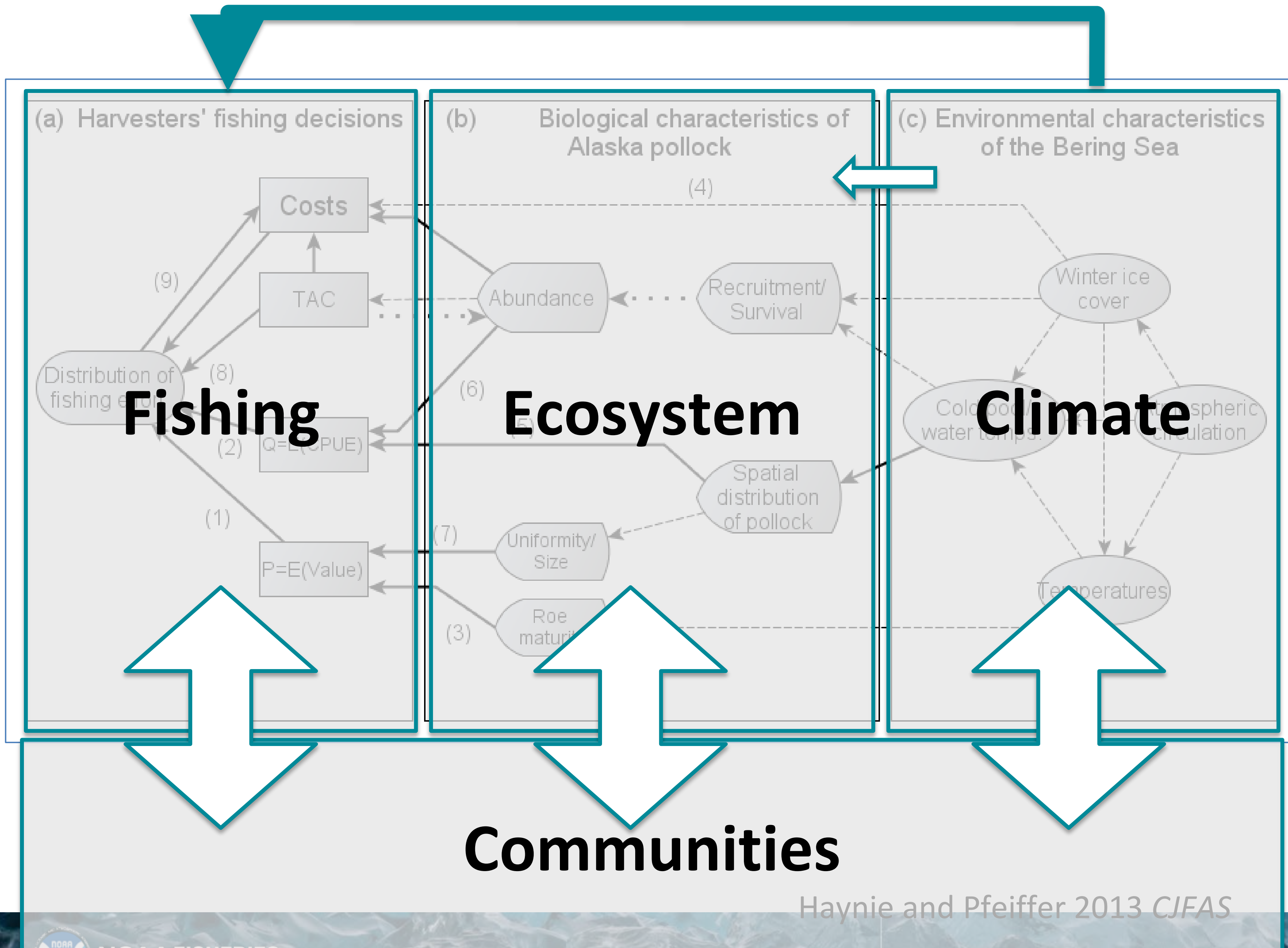
1. Use ABC to predict TAC
   - Observe past Council decisions
   - Model relationship between Council & ABC
   - Impose 2 Million metric ton cap

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

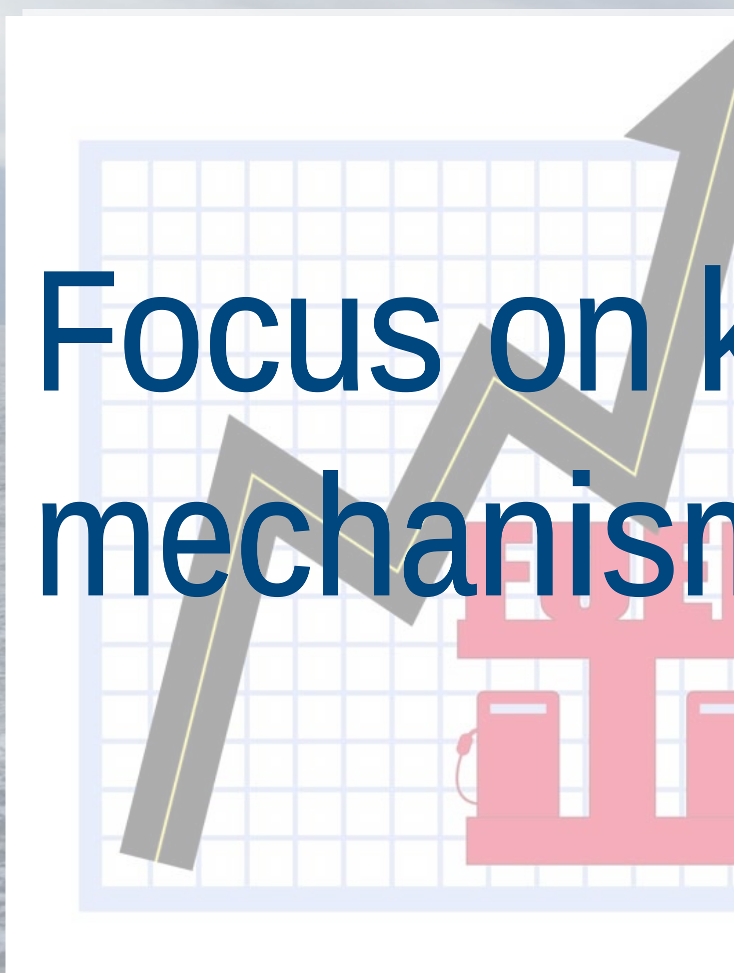
Bering Sea Pollock, historical evaluation

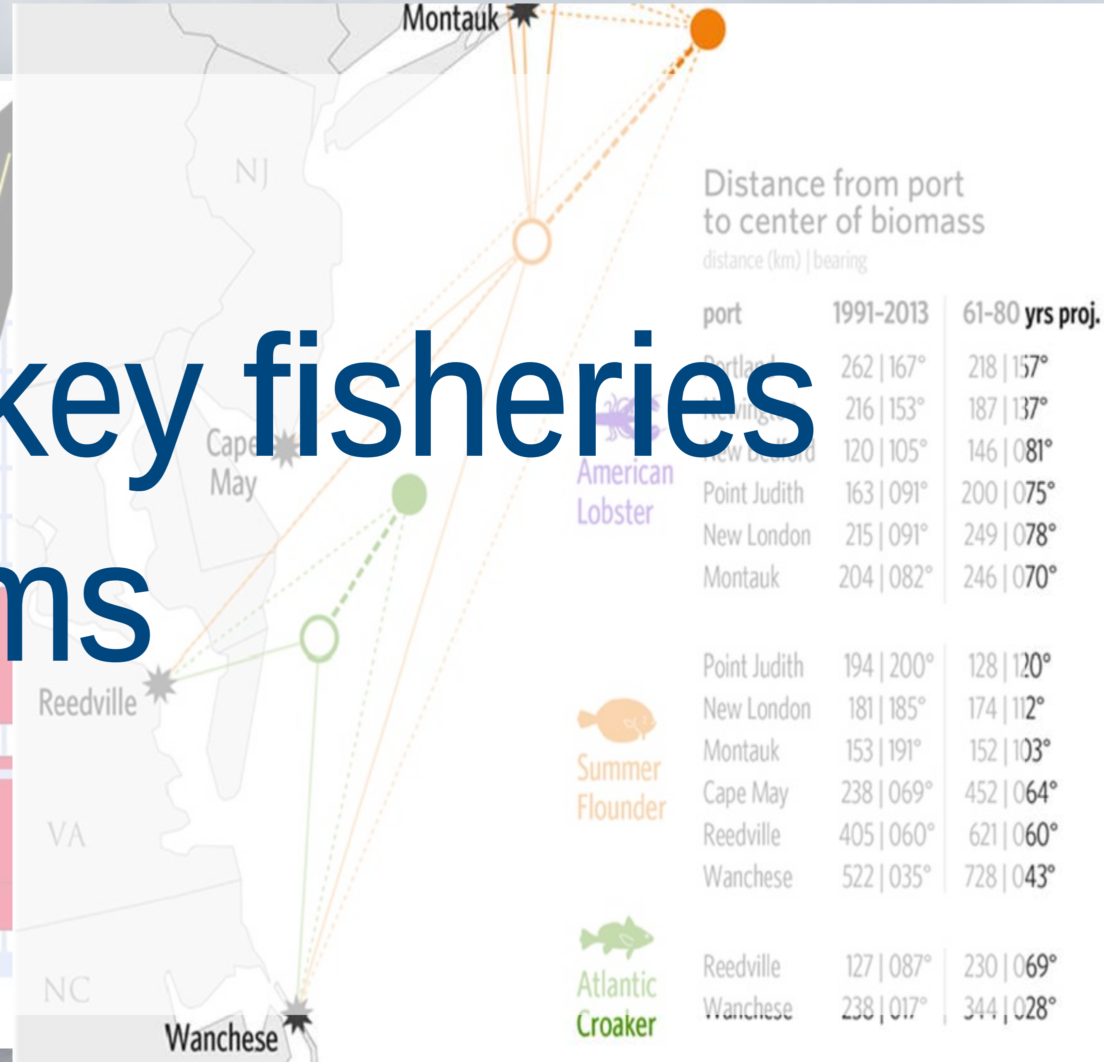




Haynie and Pfeiffer 2013 *CJFAS*

Translating global changes to fisheries changes





Focus on key fisheries mechanisms

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

Can we simplify these further?

- 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 - develop thresholds
- 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?
- What are the biggest challenges to management and fishery adaptation?
- 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:

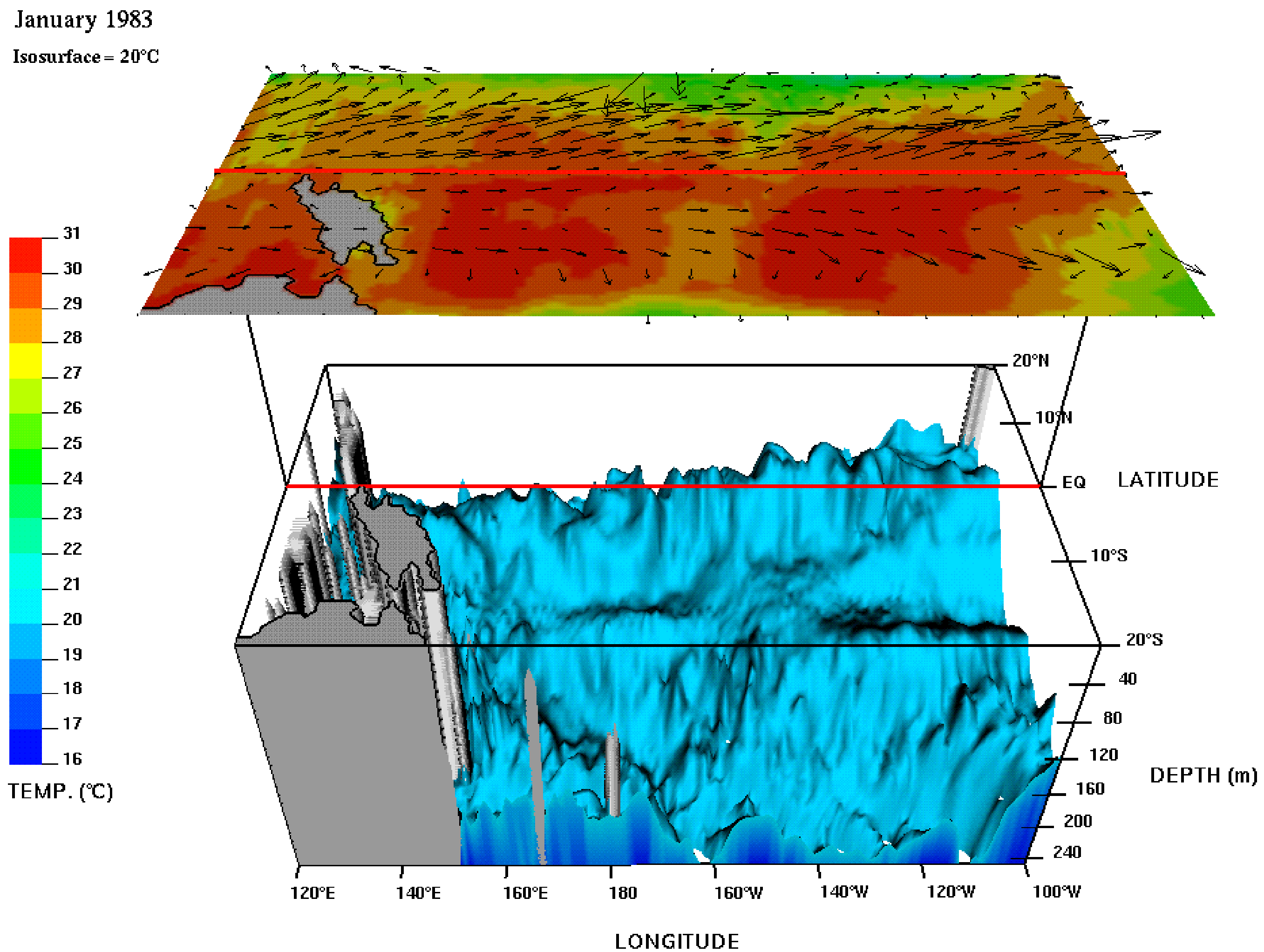
- Fisheries & the Environment (FATE)
- Stock Assessment Analytical Methods (SAAM)
- Climate Regimes & Ecosystem Productivity (CREP)
- Economics and Human Dimensions Program
- NOAA Integrated Ecosystem Assessment Program (IEA)
- NOAA Research Transition Acceleration Program (RTAP)

NOAA FISHERIES

kirstin.holsman@noaa.gov
stephen.kasperski@noaa.gov

EXTRA Slides follow

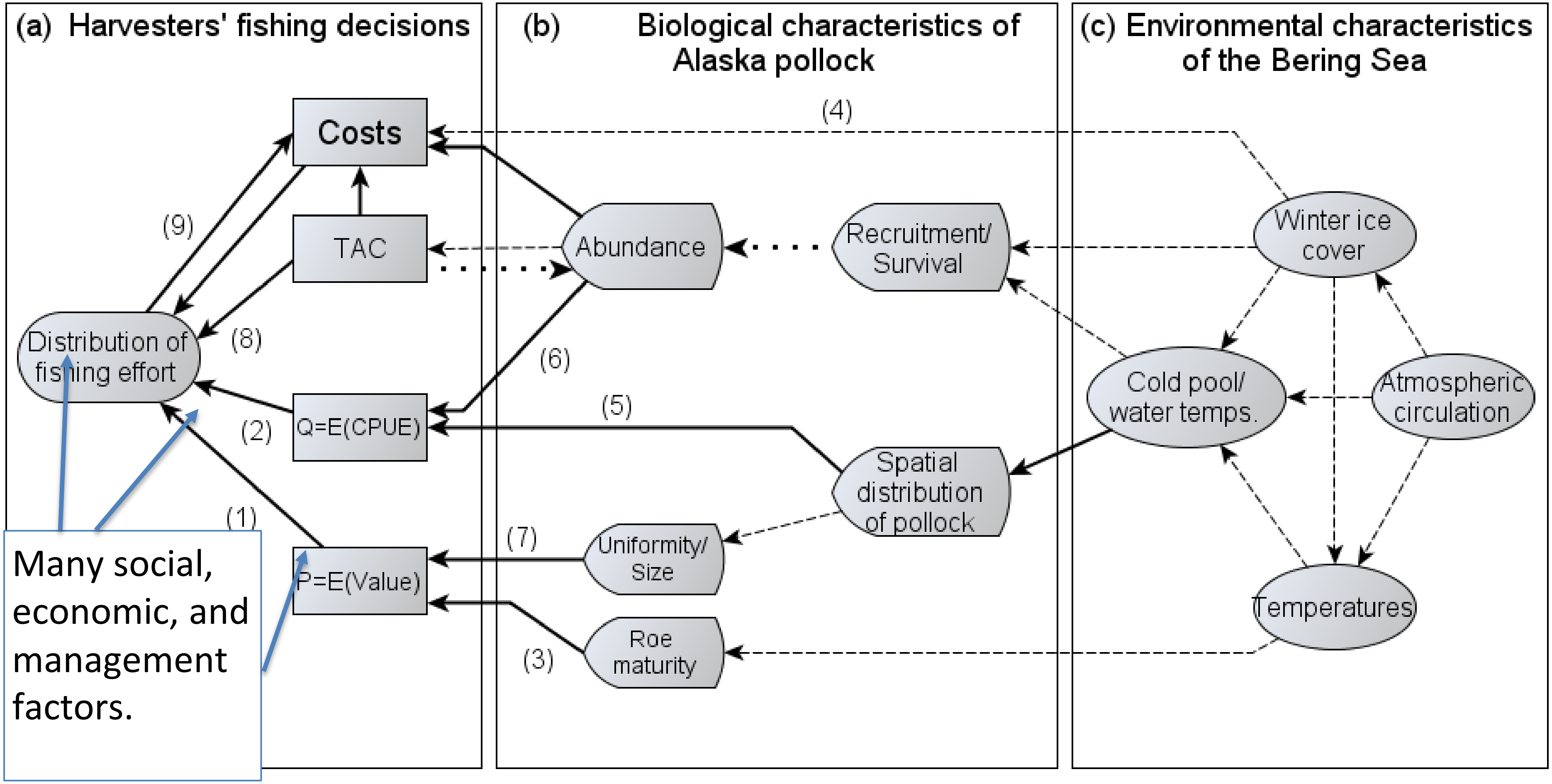
NOAA FISHERIES



Source GFDL:

Modeled ocean temperature and surface current distribution over the tropical Pacific Ocean region obtained from a GFDL coupled ocean-atmosphere model used to predict El Nino/Southern Oscillation (ENSO).

Fishery Mechanisms	Why this might increase	Why this might decrease
Fish prices	Driven by consumer demand, income and/or scarcity	Driven by fishing and aquaculture demand or smaller populations
Change in relative price of premium fish	Concentrated wealth interacting with scarcity	Increased value of protein for humans or input to aquaculture
Number of species fished	Markets may develop for other species; invasives or changes	Environmental change may lead to the decline of some species
Fishing and processing costs	Increased fuel costs or carbon tax. Land or labor costs may increase.	Improved or more selective fishing or processing technology
Priority on conservation	Change in demand or strength of conservation measures	Change in weak stock policies; change in the Endangered Species Act
Change in protection of fishing communities	Additional concern about preserving the distribution of fishing opportunities	Change in number of people in remote areas; more large fishing vessels.



Haynie and Pfeiffer 2013 *CJFAS*

Single-species model

	Low CO_2	High CO_2
$BF_{=0}$	-33% (+/- 13%)	-42% (+/- 27%)
B_F	-30% (+/- 5%)	-35% (+/- 13%)

Multi-species model

	Low CO_2	High CO_2
$B_{F=0}$	-63.5% (+/- 23%)	-76% (+/- 36%)
B_F	-54% (+/- 13%)	-72% (+/- 16%)

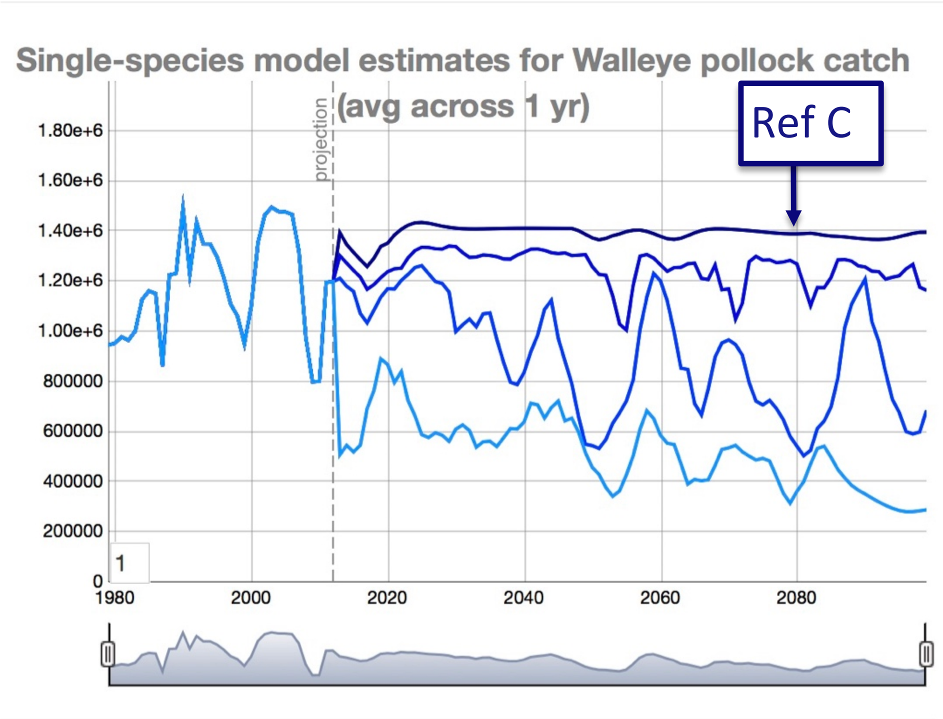
Preliminary Results

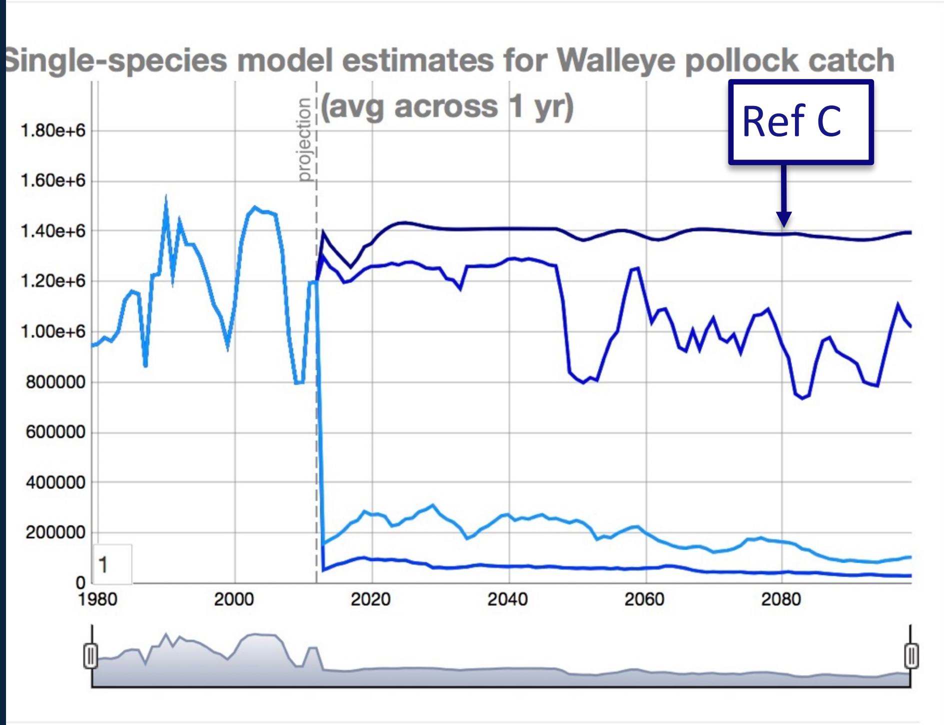
"Status quo"
assuming we don't adjust our management but the climate changes

Photo: Mark Holsman

Projected catch (t)

Low CO_2 Scenario (RCP 4.5)	High CO_2 Scenario (RCP 8.5)



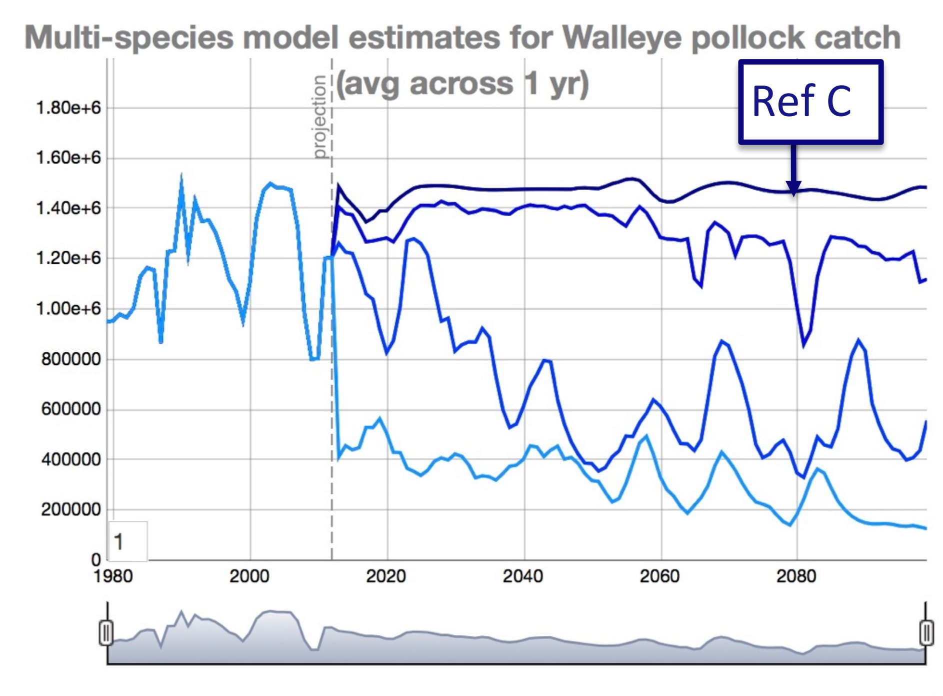


Holsman et al. in prep; draft results, please do not cite or copy

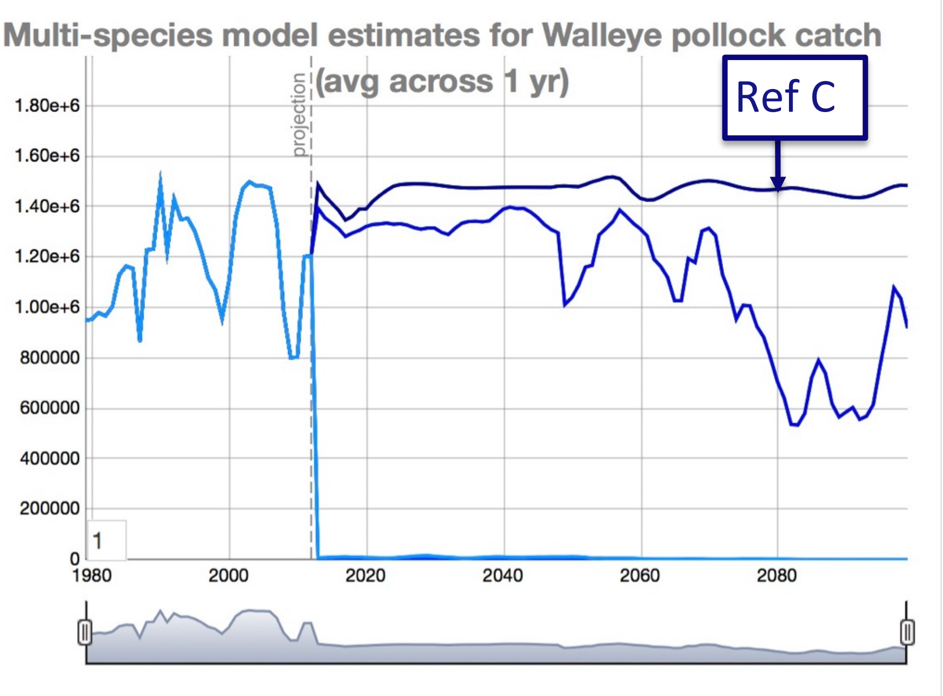
NOAA FISHERIES

Projected catch (t)

Low CO_2 Scenario (RCP 4.5)



High CO_2 Scenario (RCP 8.5)

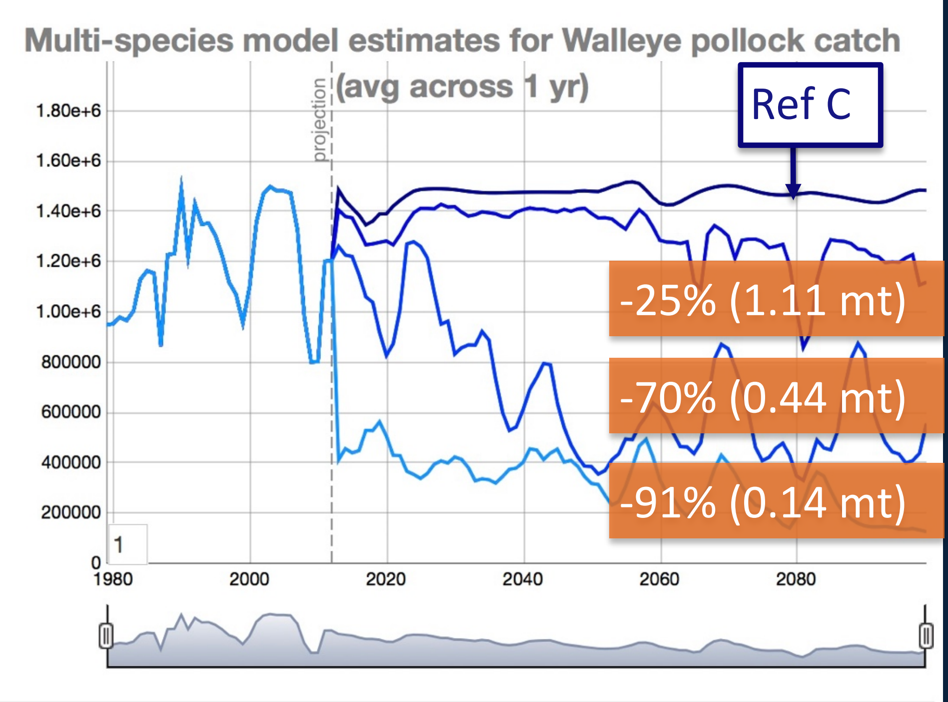


Holsman et al. in prep; draft results, please do not cite or copy

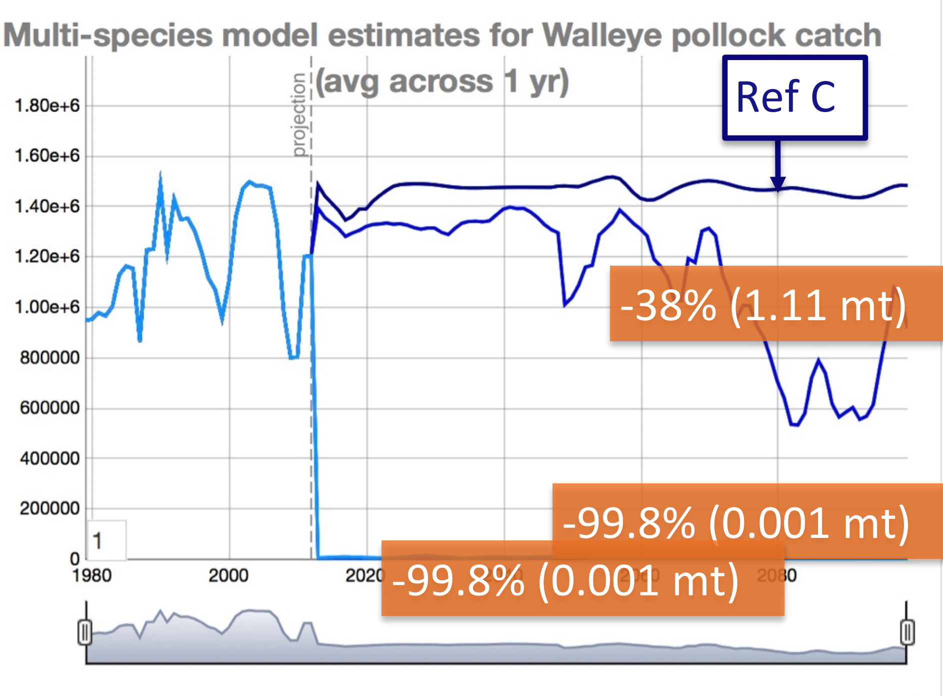
NOAA FISHERIES

Projected catch (t)

Low CO_2 Scenario (RCP 4.5)



High CO_2 Scenario (RCP 8.5)

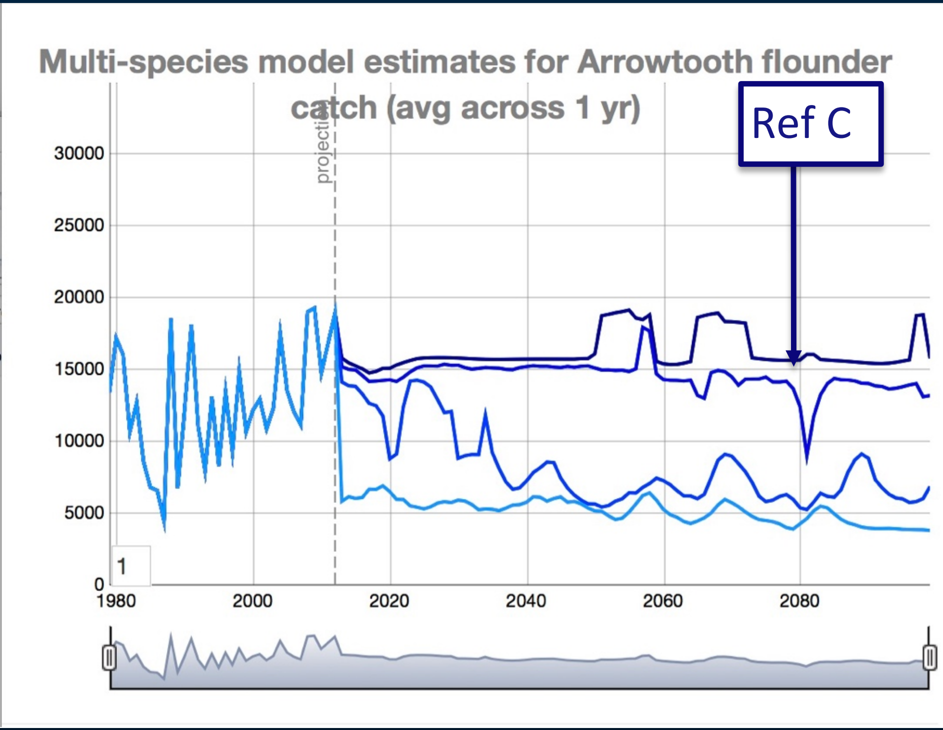


Holsman et al. in prep; draft results, please do not cite or copy

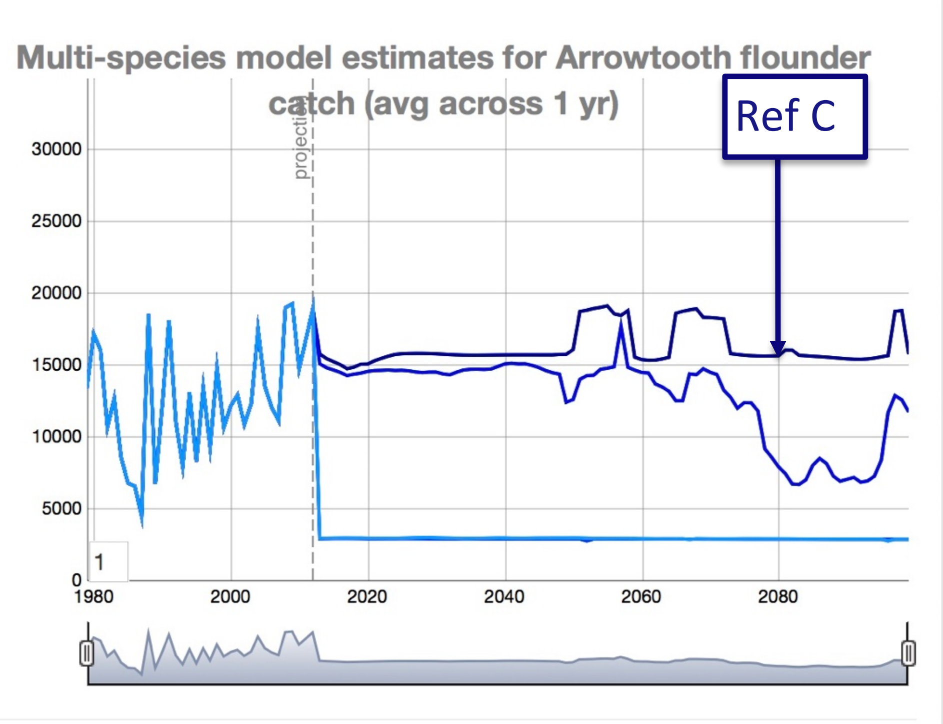
NOAA FISHERIES

Projected catch (t)

Low CO_2 Scenario (RCP 4.5)

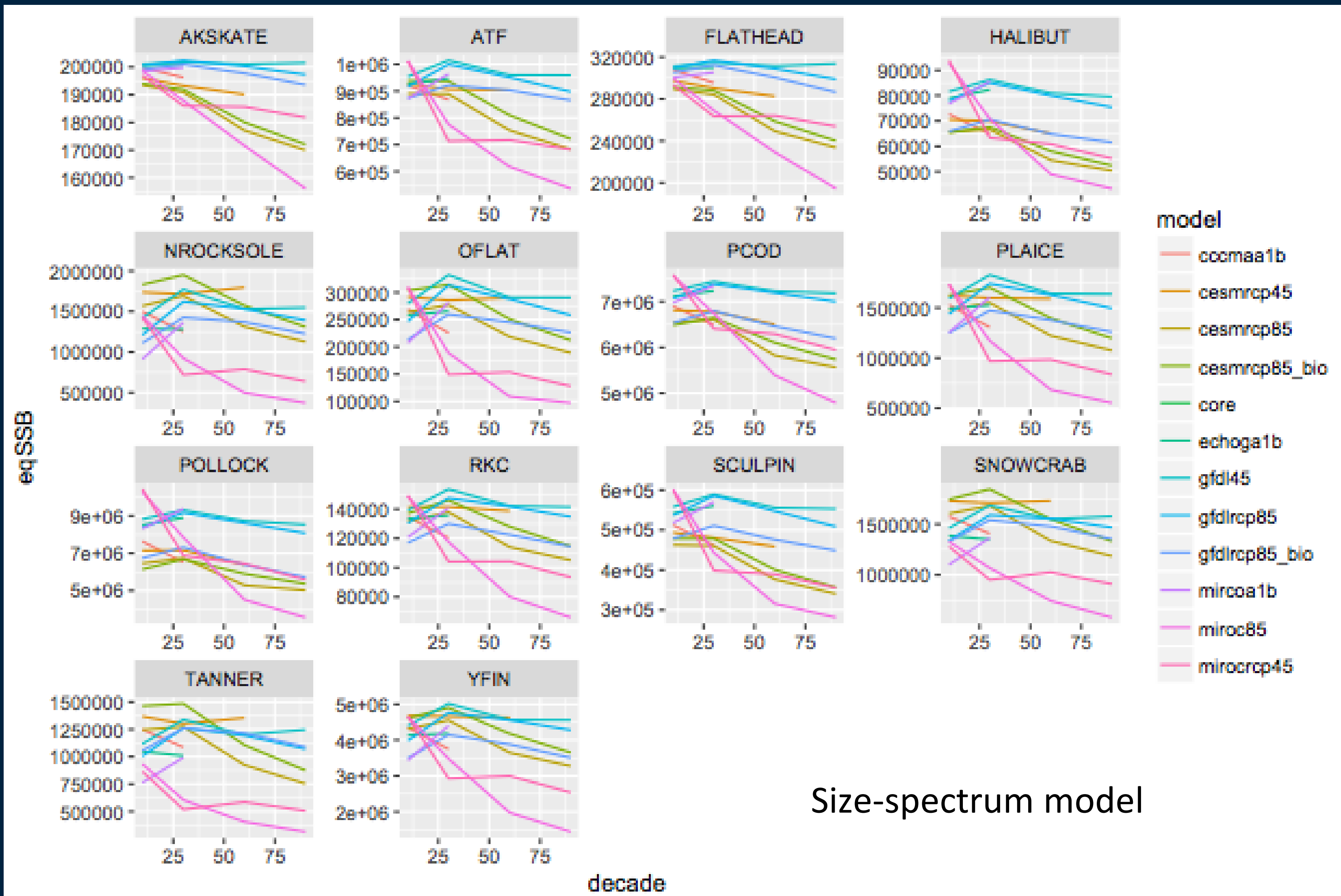


High CO_2 Scenario (RCP 8.5)



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

NOAA FISHERIES


AKSKATE
ATF
FLATHEAD
HALIBUT
NROCKSOLE
OFLAT
PCOD
PLAICE
POLLOCK
RKC
SCULPIN
SNOWCRAB
TANNER
YFIN
eqSSB
decade
25 50 75
model
cccmaa1b
cesmrcp45
cesmrcp85
cesmrcp85_bio
core
echoga1b
gfdl45
gfdlrcp85
gfdlrcp85_bio
mircoa1b
miroc85
mirocrcp45
Size-spectrum model