CEATTLE

Climate-enhanced multi-species Stock Assessment

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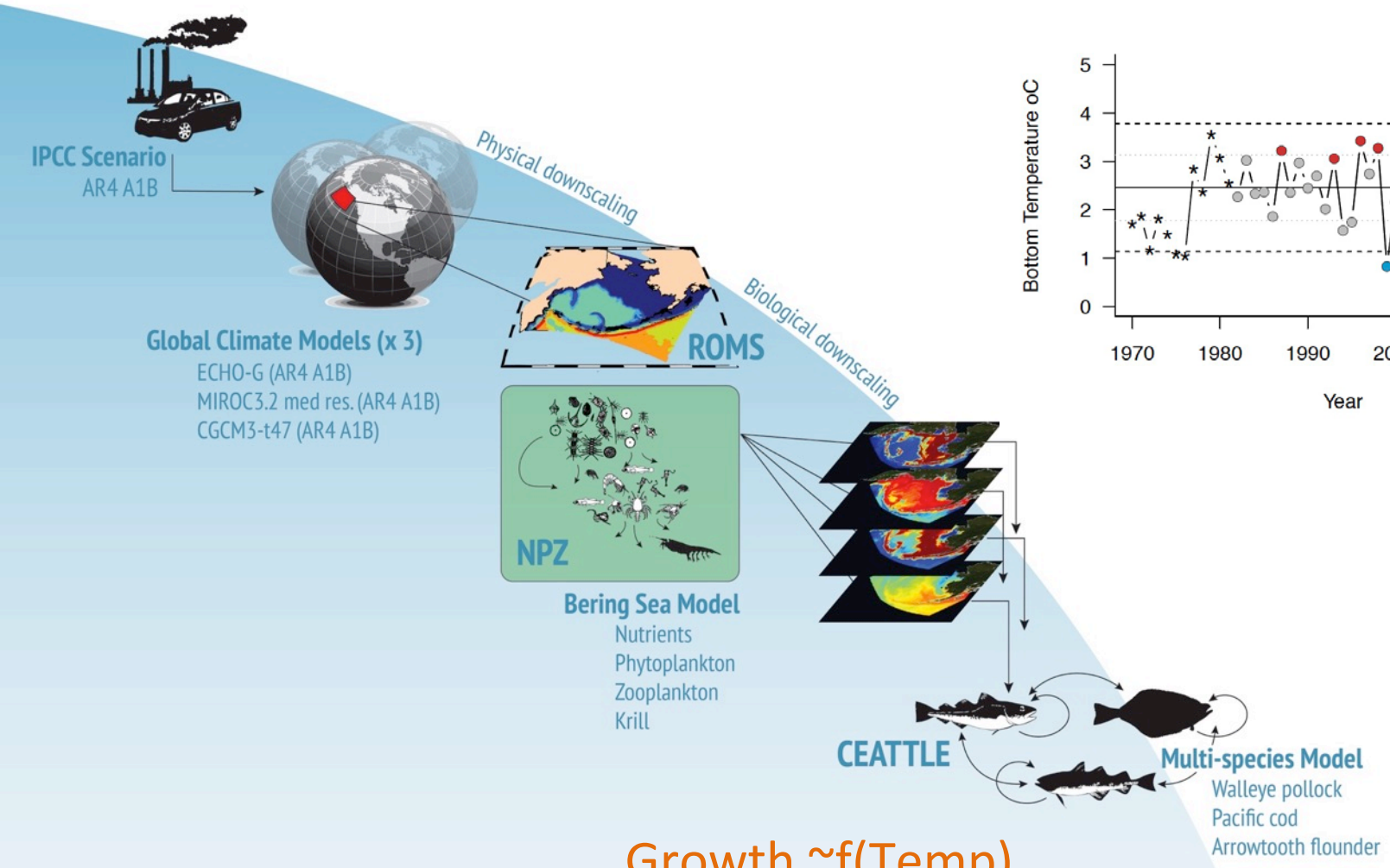
James N. Ianelli
Kerim Aydin
Ingrid Spies
Grant Adams
Kelly Kearney

2018 Nov. Plan Team

Climate-Enhanced Assessment Models

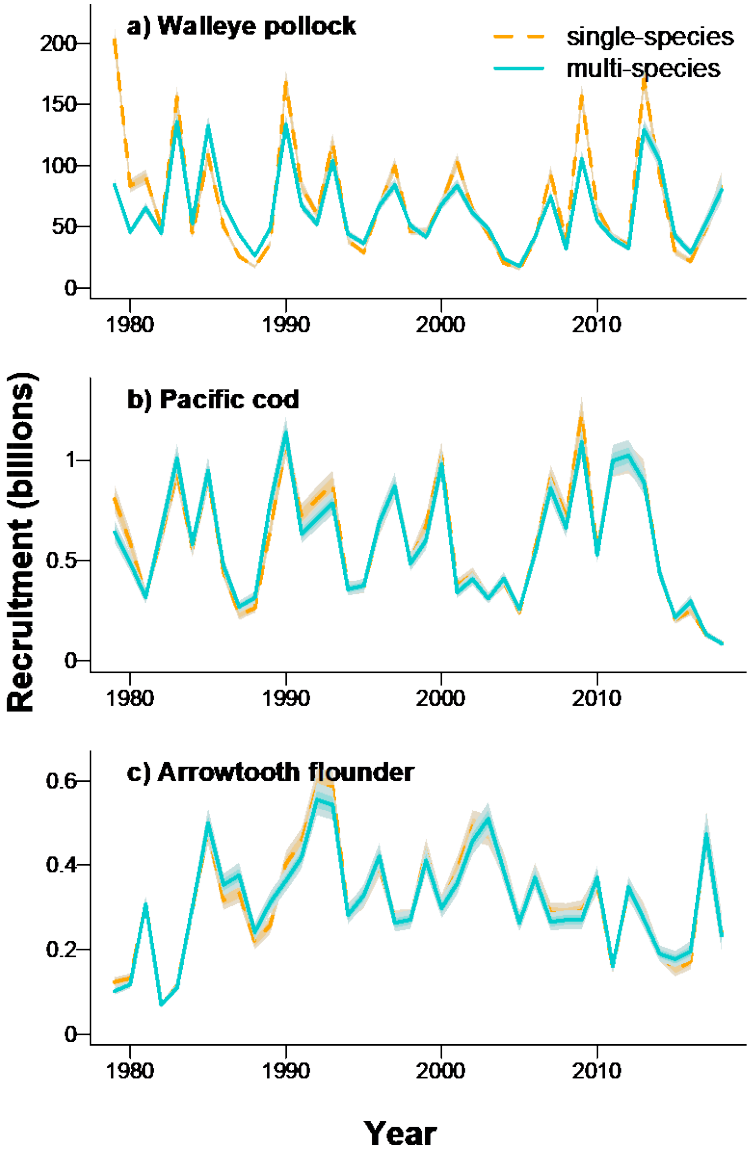


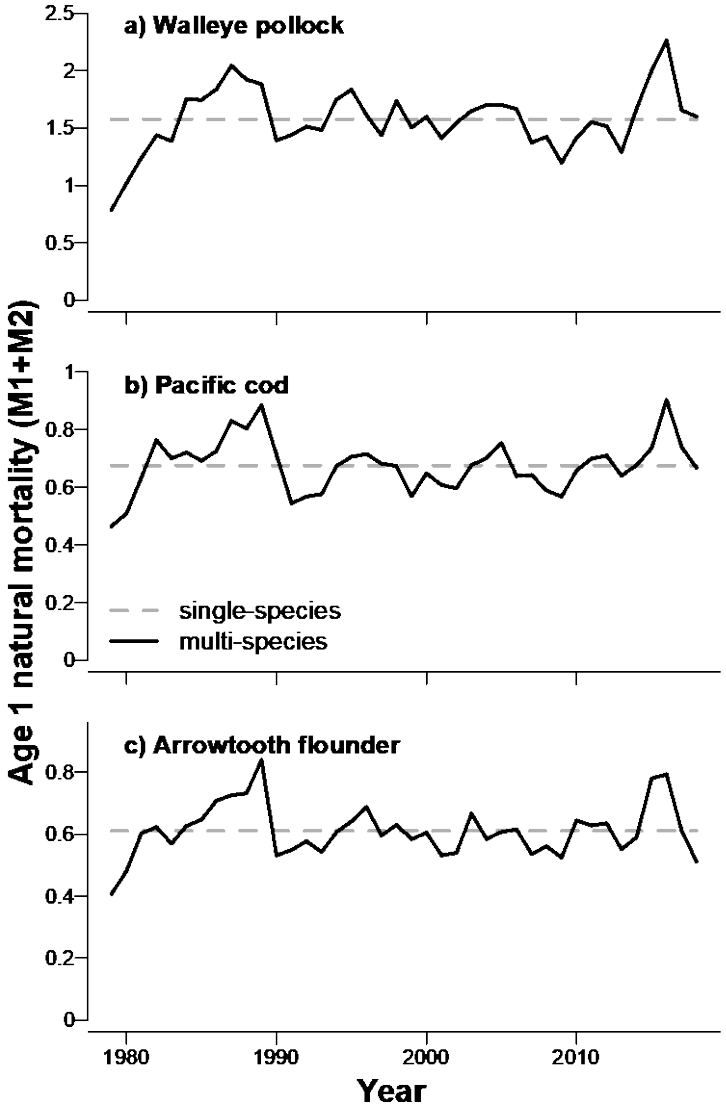
Holsman et al. in prep

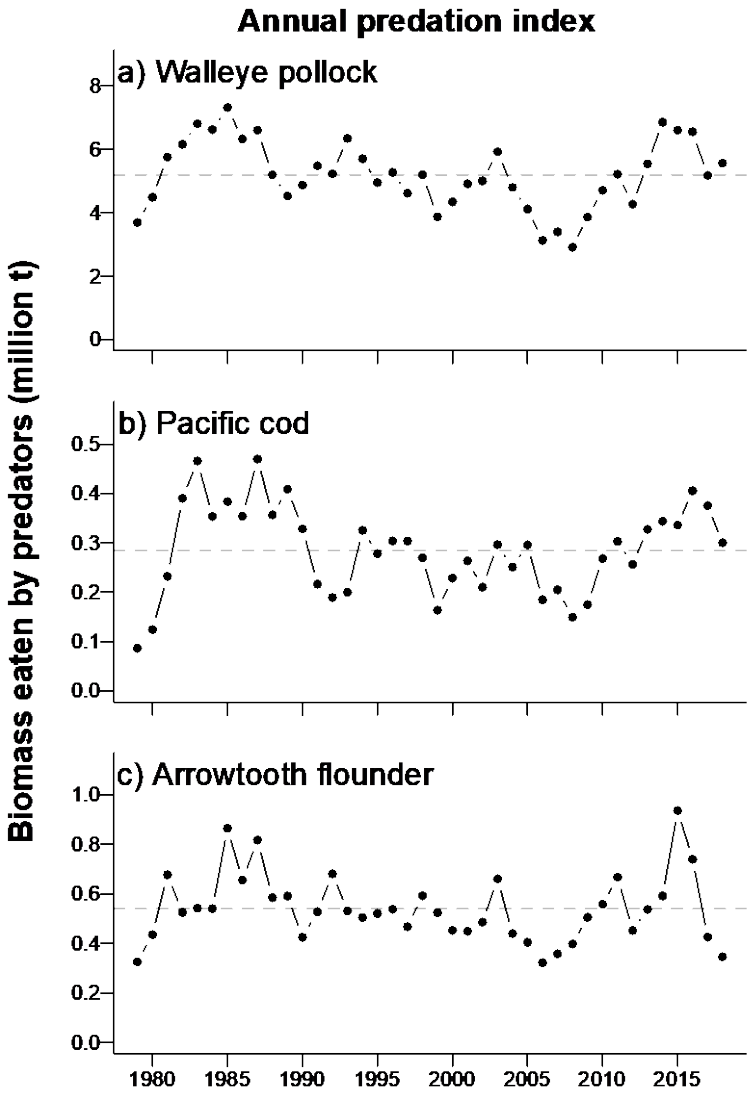
Growth ~f(Temp)

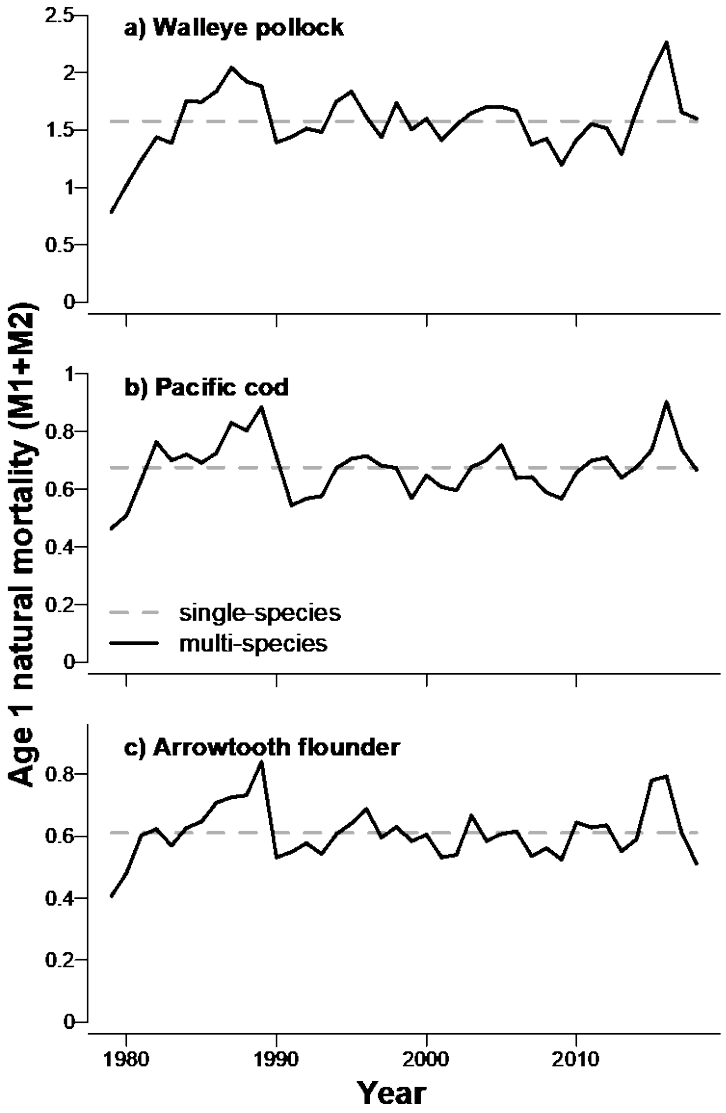
Mort ~f(Temp, N_{pred})

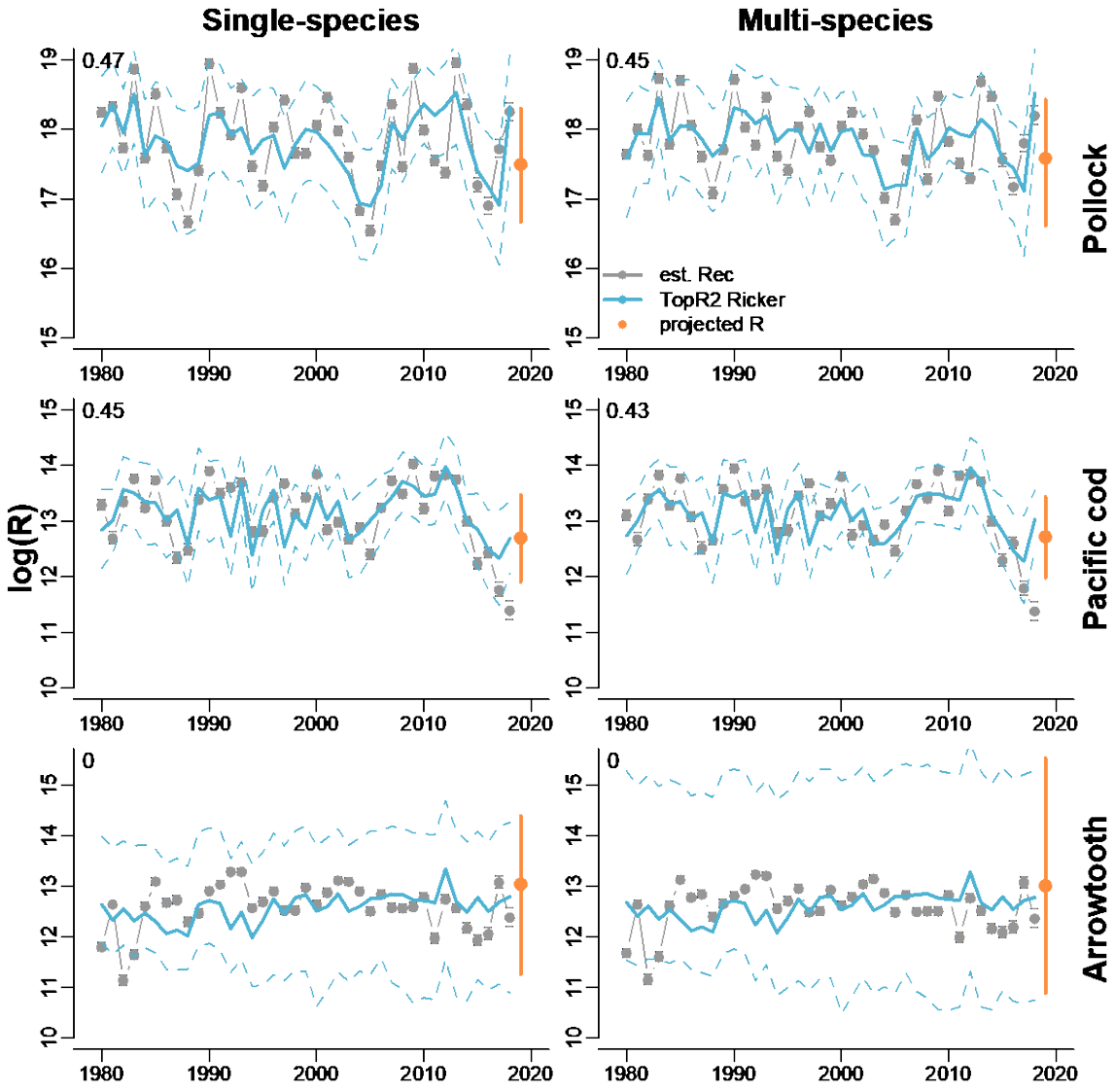
Rec ~f(Temp, Zoop, etc.)


a) Walleye pollock
single-species
multi-species
b) Pacific cod
c) Arrowtooth flounder
Recruitment (billions)
Year


a) Walleye pollock
b) Pacific cod
single-species
multi-species
c) Arrowtooth flounder
Age 1 natural mortality (M1+M2)
Year

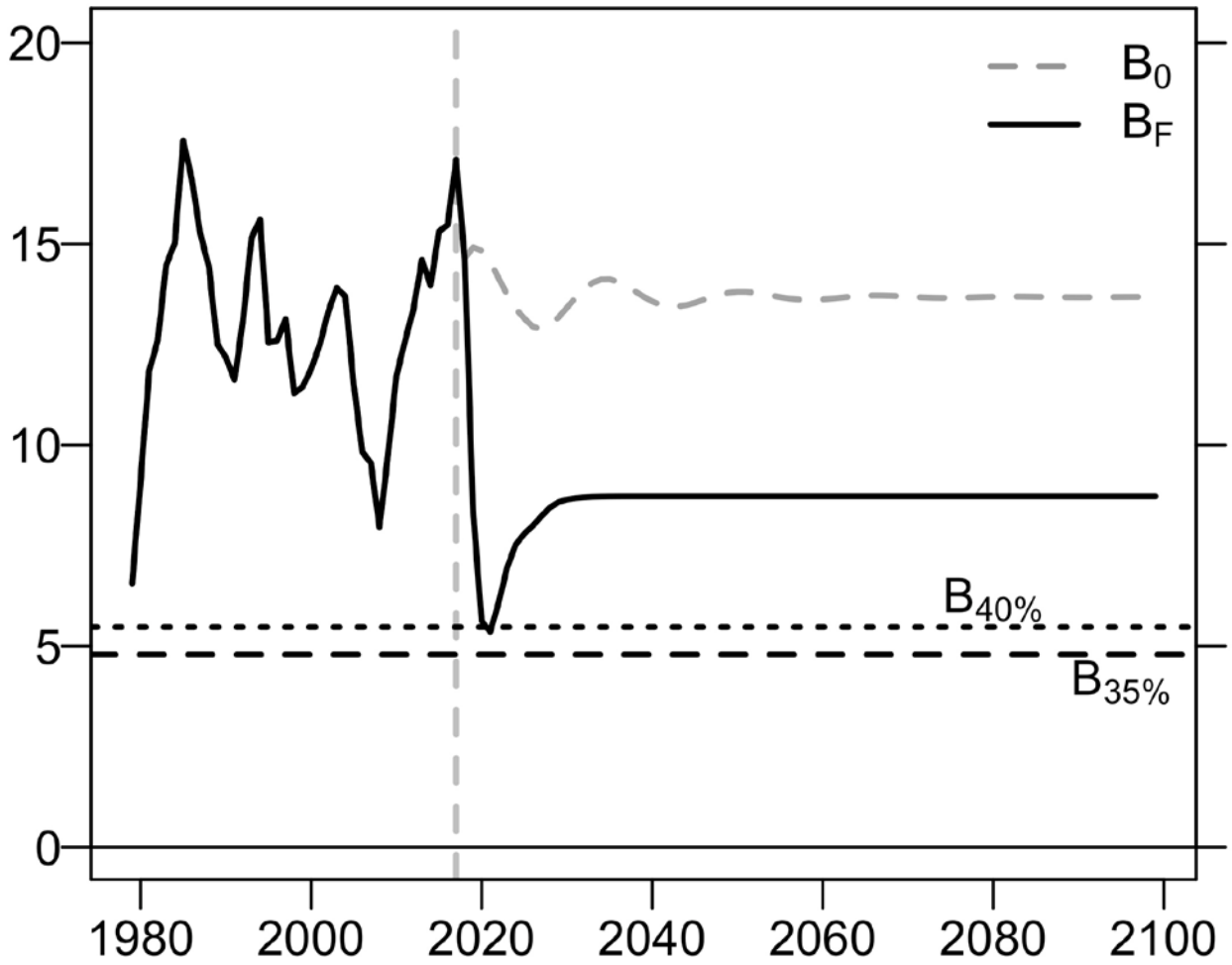

Annual predation index
a) Walleye pollock
b) Pacific cod
c) Arrowtooth flounder
Biomass eaten by predators (million t)
1980
1985
1990
1995
2000
2005
2010
2015

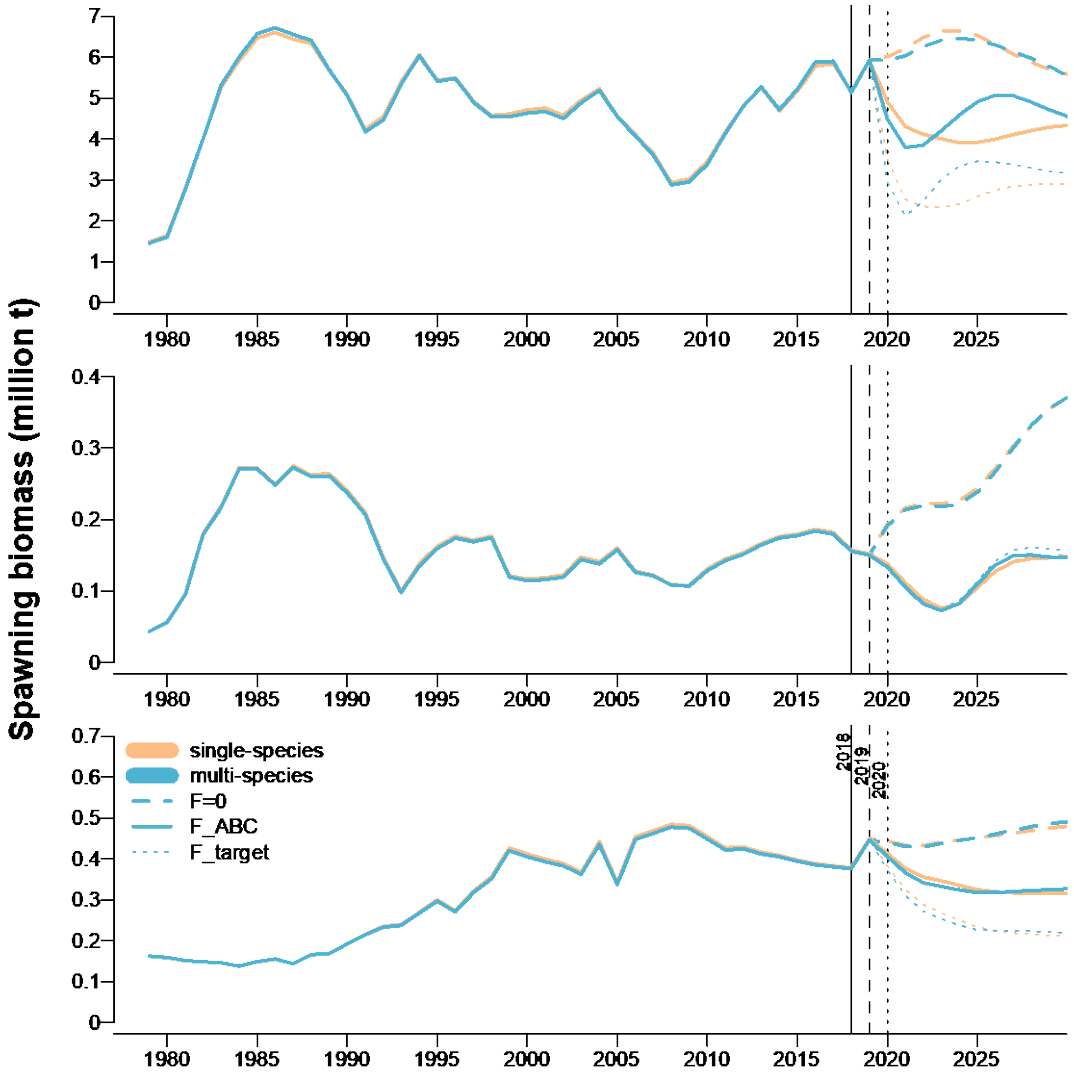

a) Walleye pollock
b) Pacific cod
c) Arrowtooth flounder
single-species
multi-species
Age 1 natural mortality (M1+M2)
Year
1980
1990
2000
2010


Single-species
Multi-species
0.47
0.45
0.45
0.43
0
0
est. Rec
TopR2 Ricker
projected R
log(R)
Pollock
Pacific cod
Arrowtooth
1980
1990
2000
2010
2020

Plan Team Discussion:

Consider projecting pollock assessment with climate-specific recruitment based on hindcast estimates of ROMSNPZ for [current year] and 9 month forecasts for [current year +1]


20
15
10
5
0
1980
2000
2020
2040
2060
2080
2100
B_0
B_F
$B_{40\%}$
$B_{35\%}$


Spawning biomass (million t)
single-species
multi-species
F=0
F_ABC
F_target
2018
2019
2020
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025

As estimated or recommended in 2017 for:

Quantity	Walleye pollock		Pacific cod		Arrowtooth flounder	
	SSM	MSM	SSM	MSM	SSM	MSM
2017 M (age 1)	0.9	1.692	0.38	0.801	0.269	0.746
2017 Average 3+ M	0.3	0.311	0.38	0.38	0.226	0.227
Projected (age 3+) B_{2018} (t)	13,464,854	12,313,165	869,106	842,670	495,141	486,705
Projected SSB_{2018}(t)	5,831,610	5,852,470	231,702	226,771	395,277	391,310
*Projected $SSB_{0,target}$(t)	5,354,407	3,833,194	394,392	368,614	445,020	417,477
*Projected SSB_{target}(t)	3,173,340	3,101,376	197,965	190,330	178,019	167,000
**Target 2100 B/B_0	0.593	0.809	0.502	0.516	0.4	0.4
F_{target}	0.329	0.366	0.263	0.268	0.107	0.117
$F_{ABC,2018}$	0.161	0.168	0.202	0.202	0.053	0.055
ABC_{target}	3,657,230	3,978,190	185,006	184,317	55,944	59,904
ABC	1,954,180	2,034,666	147,374	144,210	28,695	29,398

** SSB is based on the projected SSB at 2100 (equilibrium)*

*** Target biomass ratios at year 2100 are based on Fmsy proxy of B/B_0=0.4, given the constraint that $B/B_0 > 0.35$ for every projection year.*

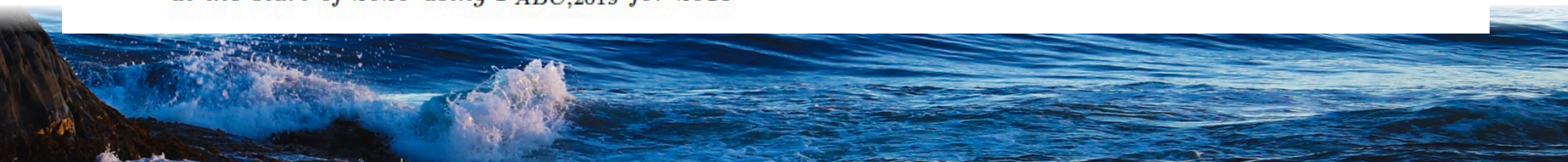
As estimated or recommended this year (2018) for:

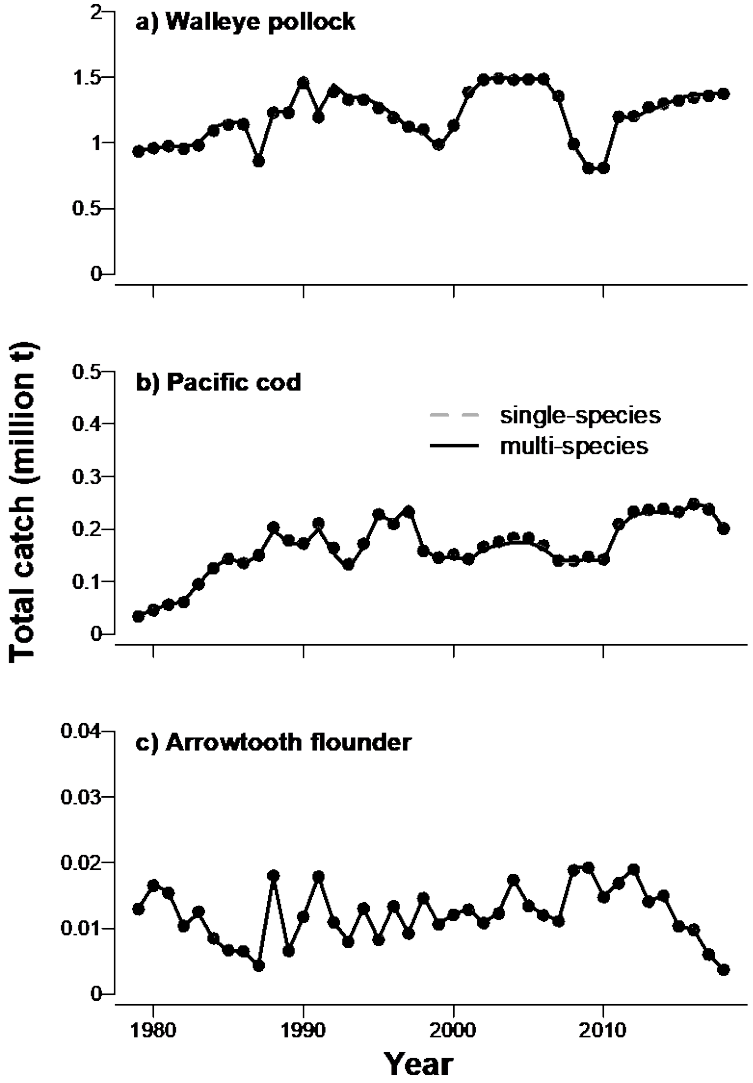
Quantity	Walleye pollock		Pacific cod		Arrowtooth flounder	
	SSM	MSM	SSM	MSM	SSM	MSM
2018 M (age 1)	1.574	1.599	0.675	0.668	0.611	0.512
2018 Average 3+ M	0.308	0.308	0.38	0.38	0.227	0.227
Projected (age 3+) B_{2019} (t)	10,707,945	10,267,813	460,269	450,423	516,849	512,967
SSB_{2018} (t)	5,154,540	5,138,950	157,532	155,408	378,963	376,279
% change in SSB (t)	-11.7	-13.0	-13.5	-13.5	-1.2	-1.1
Projected SSB_{2019} (t)	5,936,460	5,931,980	152,085	150,041	449,872	446,635
Projected SSB_{2020} (t)	4,911,660	4,494,340	138,325	133,529	413,567	405,854
*Projected $SSB_{0,2100}$ (t)	5,890,027	5,454,678	311,210	306,294	488,820	496,647
*Projected $SSB_{target,2100}$ (t)	2,872,060	3,159,189	164,408	168,170	195,537	198,700
**Target 2100 B/B_0	0.488	0.579	0.528	0.549	0.4	0.4
F_{target}	0.112	0.113	0.5	0.508	0.007	0.007
$F_{ABC,2019}$	0.166	0.224	0.309	0.333	0.057	0.066
ABC	2,272,840	2,965,770	132,921	139,485	35,846	41,145
ABC_{2020}	1,914,190	2,283,970	116,827	120,091	32,524	36,956

** $SSB_{0,2100}$ and $SSB_{target,2100}$ are based on the projected SSB at 2100 (equilibrium) given $F = 0$ and $F = F_{target}$, respectively.*

*** Target biomass ratios at year 2100 are based on Fmsy proxy of B/B_0=0.4, given the constraint that $B/B_0 > 0.35$ for every projection year.*

Projected SSB_{2019} (t) refers to SSB at the start of 2019 and Projected SSB_{2020} (t) refers to SSB at the start of 2020 using $F_{ABC,2019}$ for 2019




a) Walleye pollock
b) Pacific cod
c) Arrowtooth flounder
single-species
multi-species
Total catch (million t)
Year
2
1.5
1
0.5
0
0.4
0.3
0.2
0.1
0.04
0.03
0.02
0.01
1980
1990
2000
2010

ACLIM
The Alaska Climate Integrated Modeling Project

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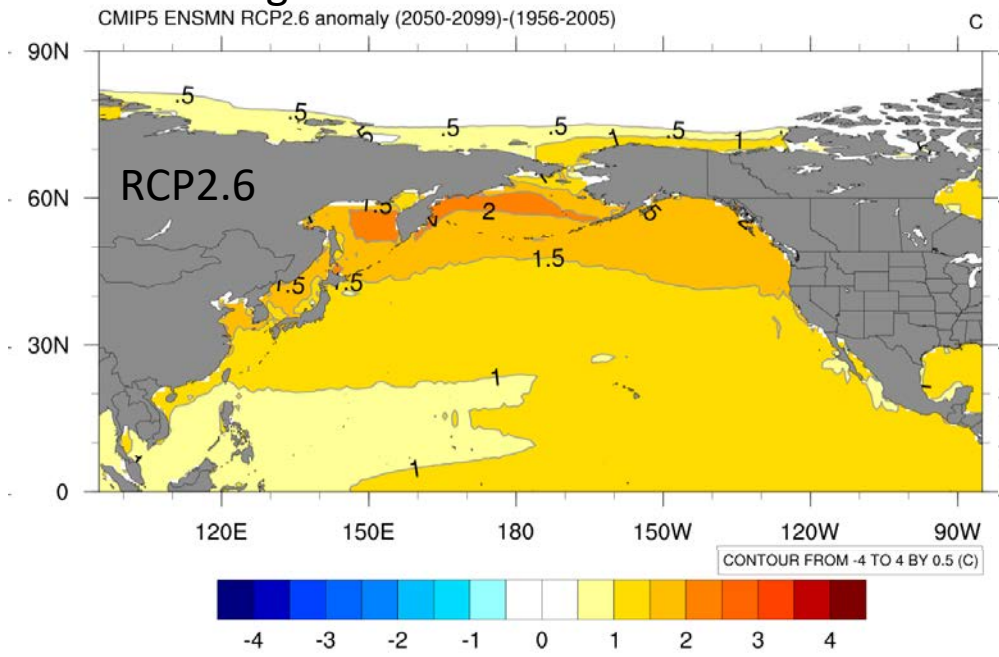
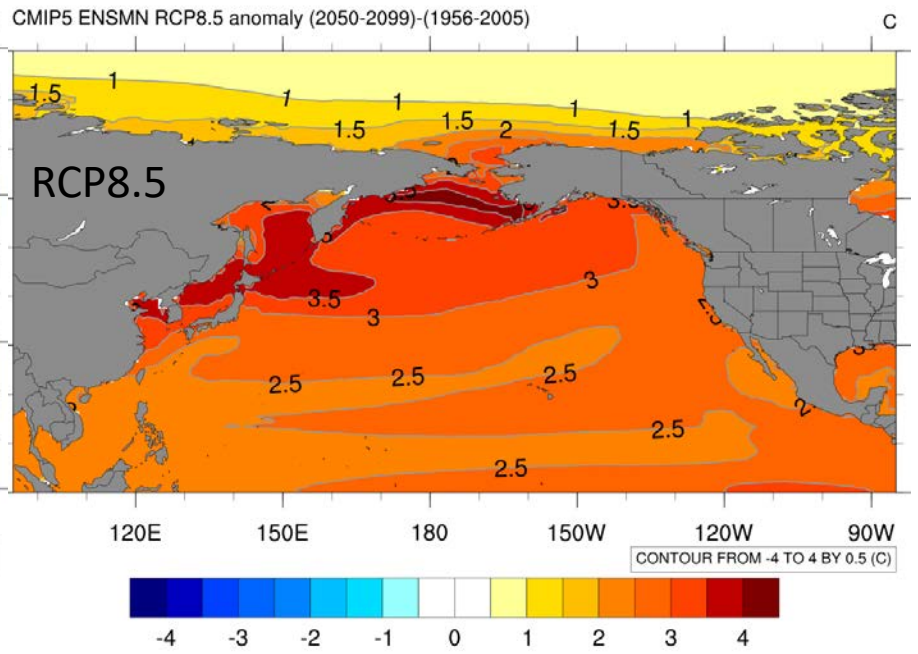
Jonathan Reum, UW
Paul Spencer, NOAA
William Stockhausen, NOAA
Cody Szuwalski, NOAA
Thomas Wilderbuer, NOAA
Trond Kristiansen, NOR

CMIP5 ENSMN Annual SST anomaly (°C)
(2050 to 2099) - (1956 to 2005)

CO2 mitigation scenario



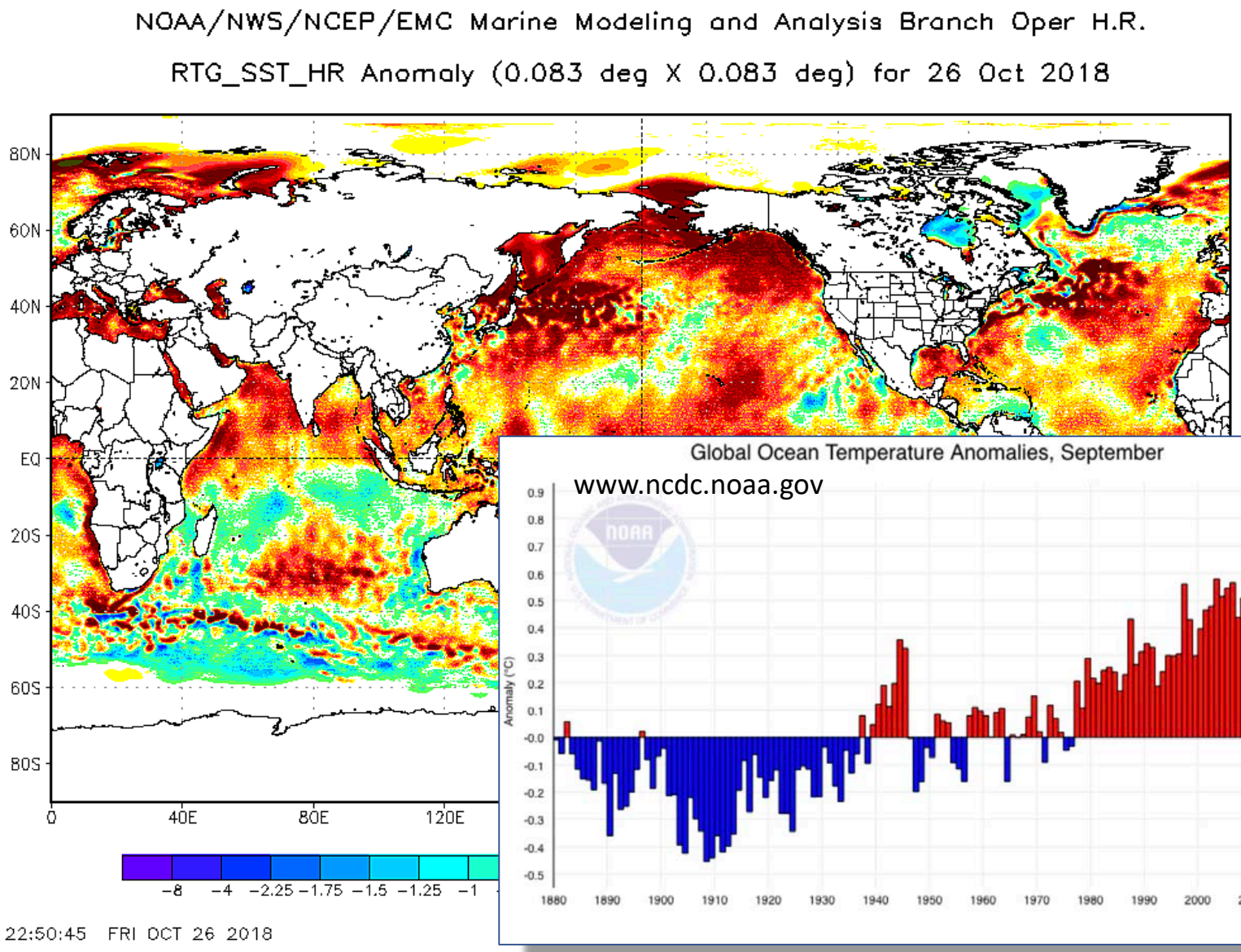
High baseline scenario ("Business as usual")



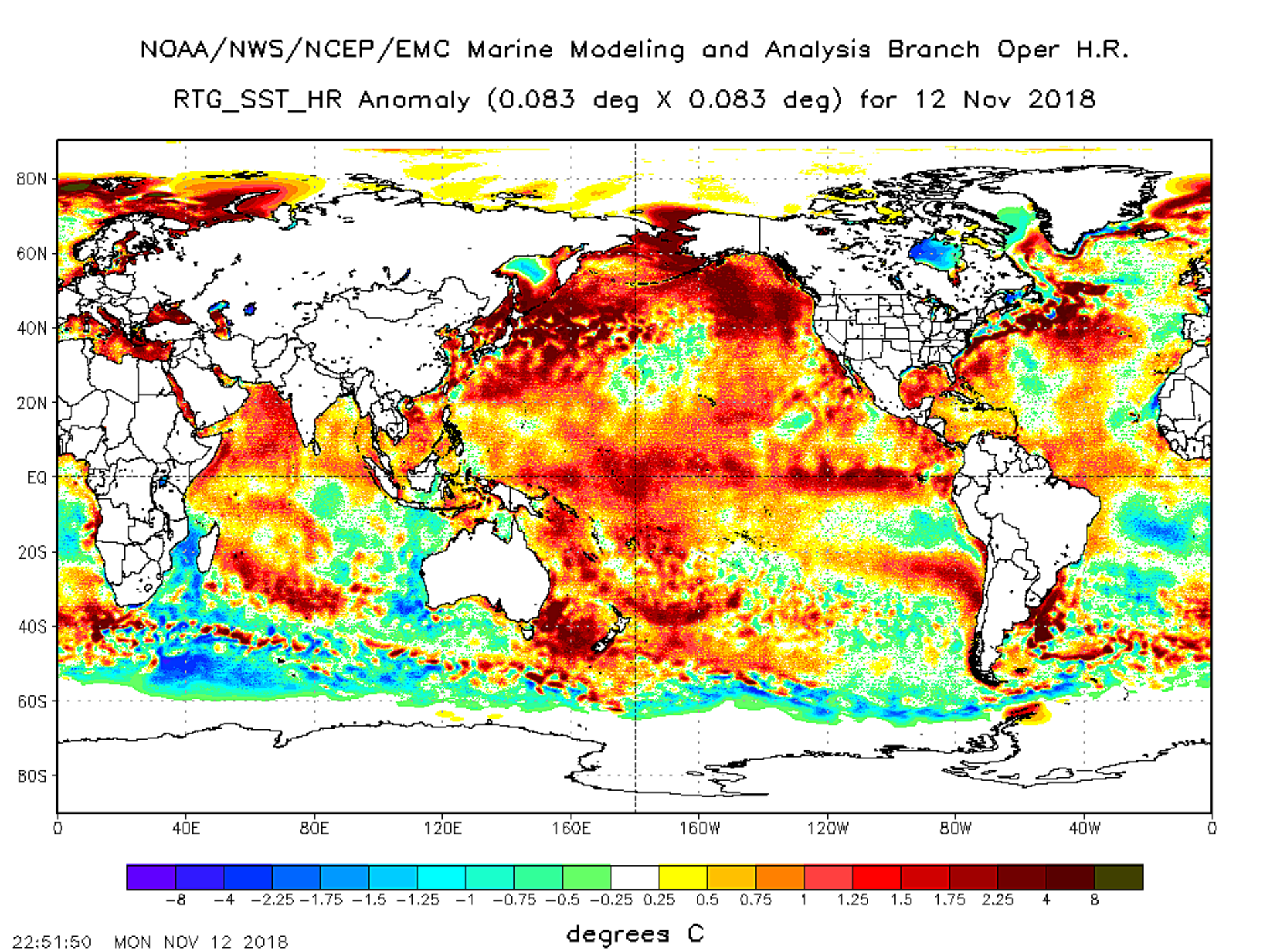
Projection data from CMIP5 (Taylor et al., 2012) avail. at: www.esrl.noaa.gov/psd/ipcc/ocn

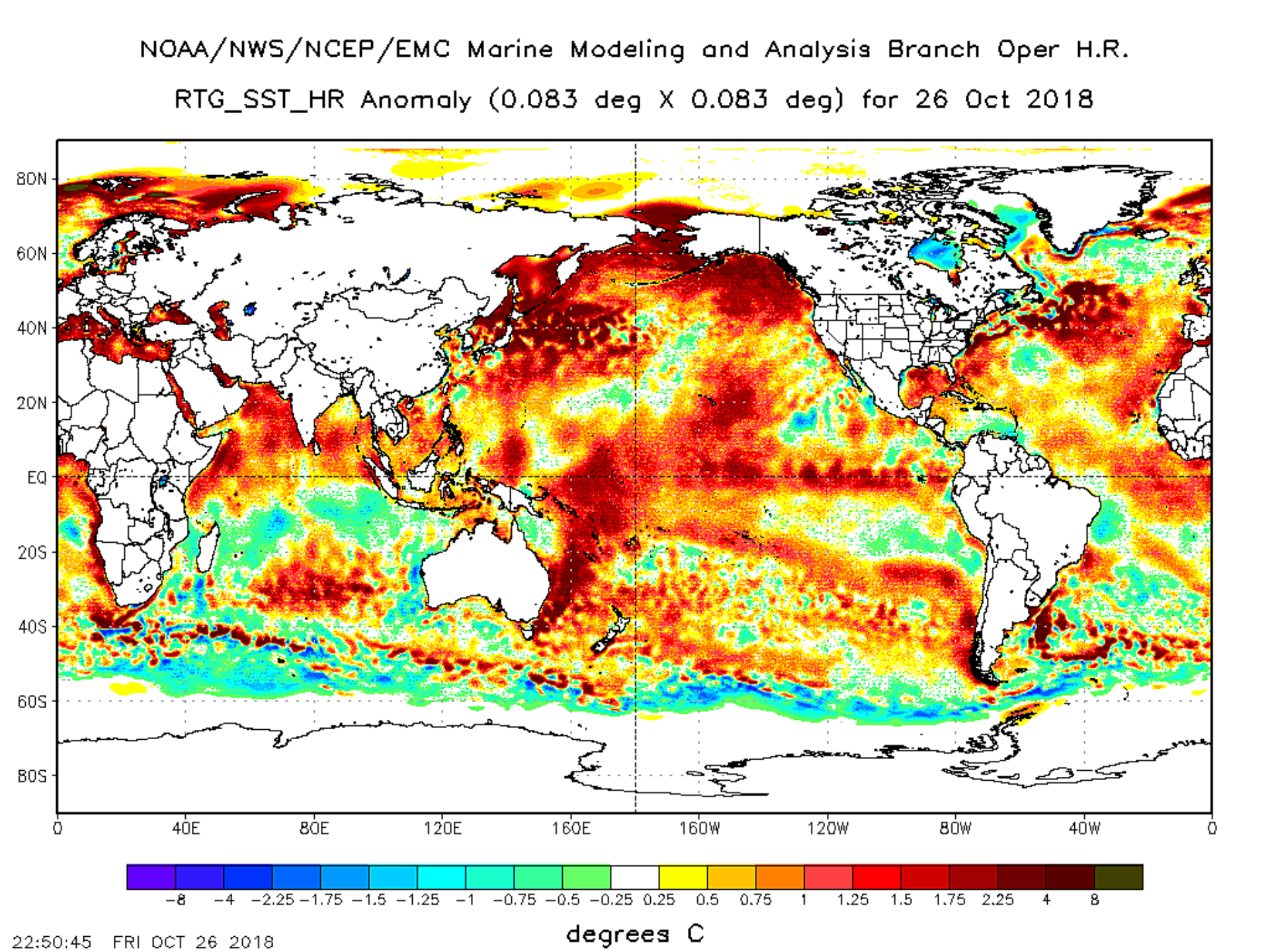
Modified from Fig. 6.2 Holsman et al. 2018 [in] Barange et al. (Eds.) 2018. Impacts of climate change on fisheries and aquaculture. TP 627.

Anomaly from 1961-1990 climatology, 1 degree, weekly resolution



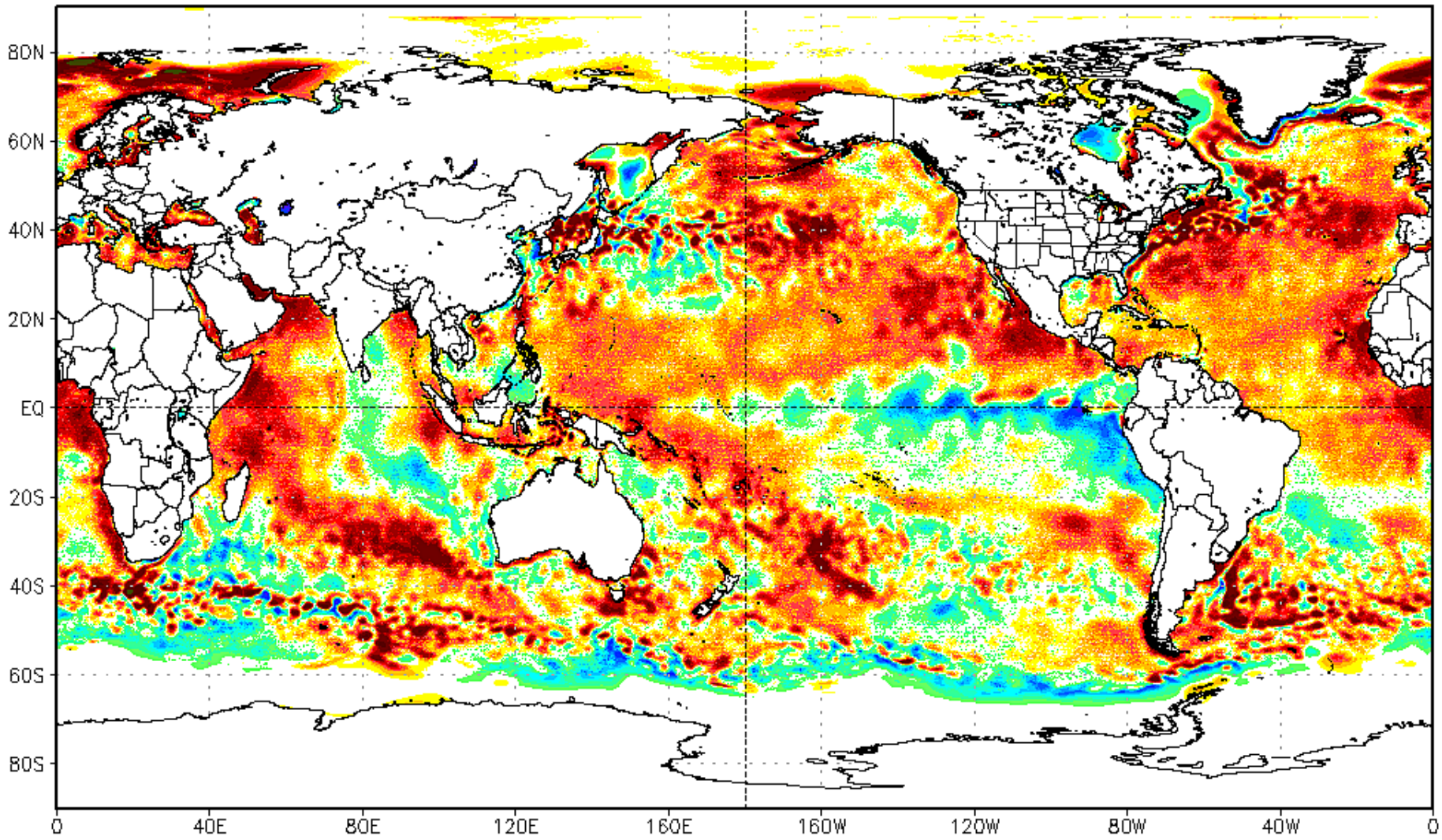
http://polar.ncep.noaa.gov/sst/rtg_high_res


NOAA/NWS/NCEP/EMC Marine Modeling and Analysis Branch Oper H.R.
RTG_SST_HR Anomaly (0.083 deg X 0.083 deg) for 12 Nov 2018
80N
60N
40N
20N
EQ
20S
40S
60S
80S
0
40E
80E
120E
160E
160W
120W
80W
40W
0
−8 −4 −2.25 −1.75 −1.5 −1.25 −1 −0.75 −0.5 −0.25 0.25 0.5 0.75 1 1.25 1.5 1.75 2.25 4 8
degrees C
22:51:50 MON NOV 12 2018


NOAA/NWS/NCEP/EMC Marine Modeling and Analysis Branch Oper H.R.
RTG_SST_HR Anomaly (0.083 deg X 0.083 deg) for 26 Oct 2018
80N
60N
40N
20N
EQ
20S
40S
60S
80S
0
40E
80E
120E
160E
160W
120W
80W
40W
0
−8 −4 −2.25 −1.75 −1.5 −1.25 −1 −0.75 −0.5 −0.25 0.25 0.5 0.75 1 1.25 1.5 1.75 2.25 4 8
degrees C
22:50:45 FRI OCT 26 2018

NOAA/NWS/NCEP/EMC Marine Modeling and Analysis Branch Oper H.R.

RTG_SST_HR Anomaly (0.083 deg X 0.083 deg) for 13 Nov 2017



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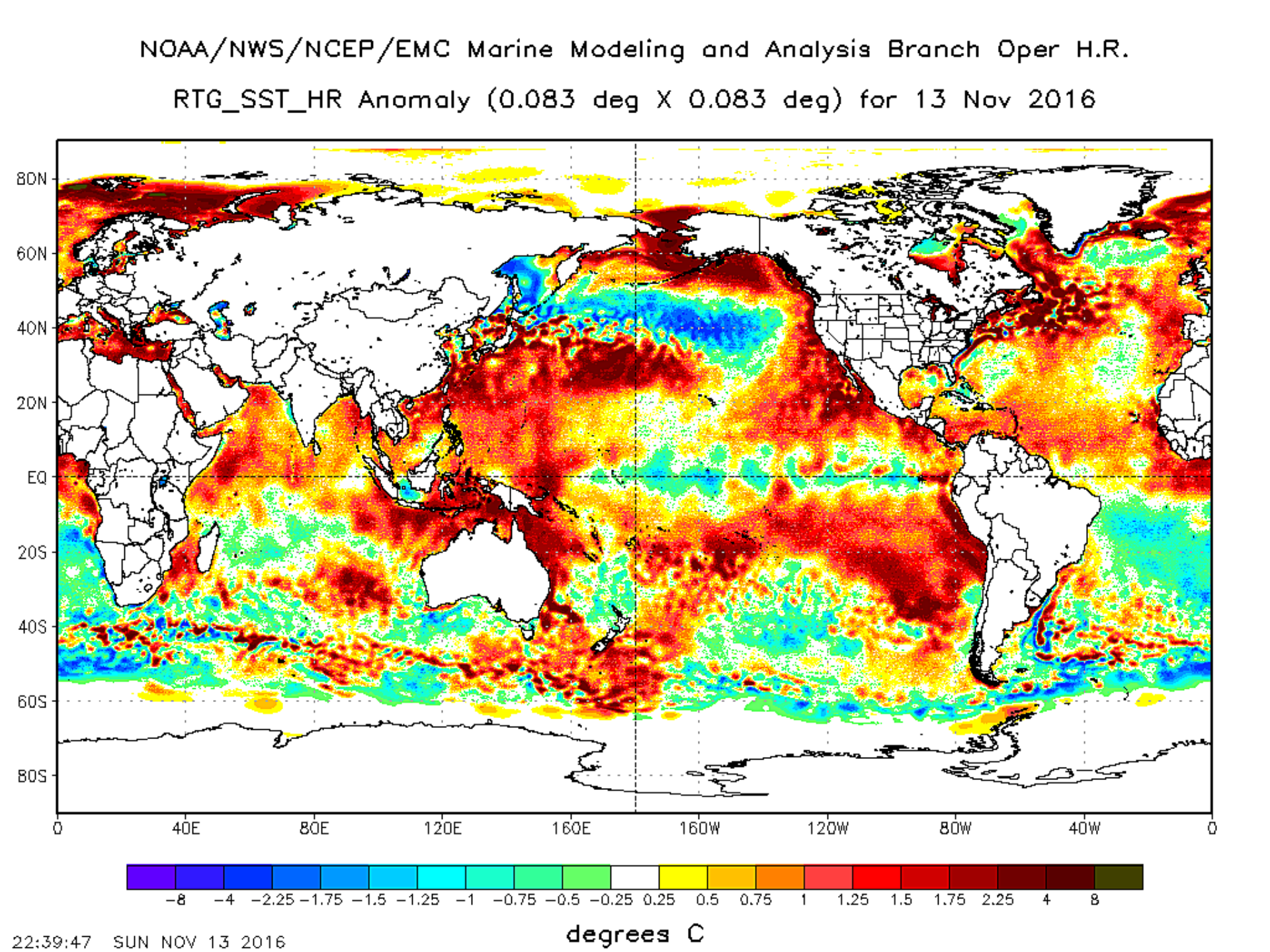
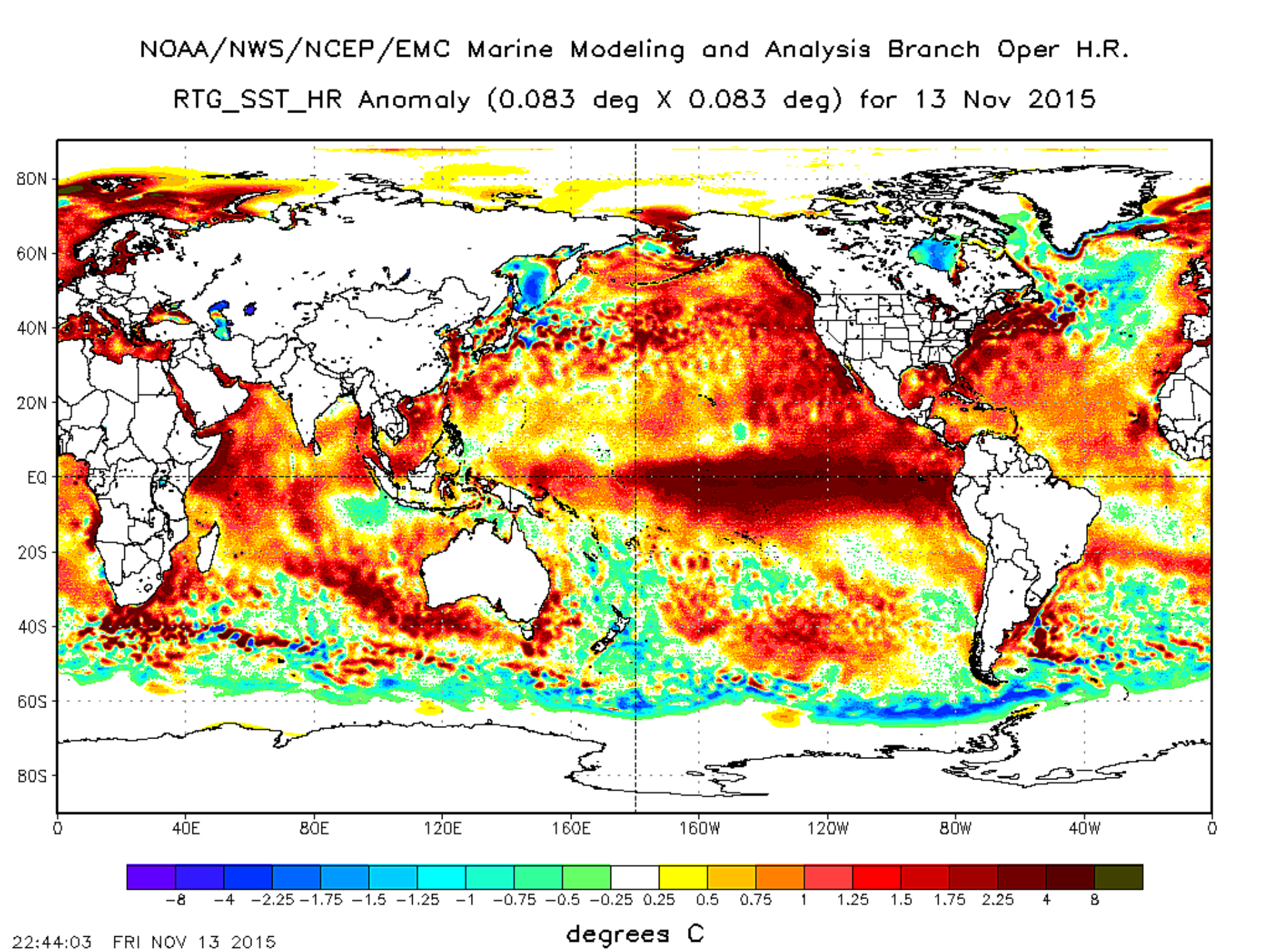

NOAA/NWS/NCEP/EMC Marine Modeling and Analysis Branch Oper H.R.
RTG_SST_HR Anomaly (0.083 deg X 0.083 deg) for 13 Nov 2016
80N
60N
40N
20N
EQ
20S
40S
60S
80S
0
40E
80E
120E
160E
160W
120W
80W
40W
0
−8 −4 −2.25 −1.75 −1.5 −1.25 −1 −0.75 −0.5 −0.25 0.25 0.5 0.75 1 1.25 1.5 1.75 2.25 4 8
degrees C
22:39:47 SUN NOV 13 2016


NOAA/NWS/NCEP/EMC Marine Modeling and Analysis Branch Oper H.R.
RTG_SST_HR Anomaly (0.083 deg X 0.083 deg) for 13 Nov 2015
80N
60N
40N
20N
EQ
20S
40S
60S
80S
0
40E
80E
120E
160E
160W
120W
80W
40W
0
−8 −4 −2.25 −1.75 −1.5 −1.25 −1 −0.75 −0.5 −0.25 0.25 0.5 0.75 1 1.25 1.5 1.75 2.25 4 8
degrees C
22:44:03 FRI NOV 13 2015

nature COMMUNICATIONS

ARTICLE

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Longer and more frequent marine heatwaves over the past century

Eric C.J. Oliver[1,2,3], Markus G. Donat[4,5], Michael T. Burrows[6], Pippa J. Moore[7], Dan A. Smale[8,9], Lisa V. Alexander[4,5], Jessica A. Benthuysen[10], Ming Feng[11], Alex Sen Gupta[4,5], Alistair J. Hobday[12], Neil J. Holbrook[2,13], Sarah E. Perkins-Kirkpatrick[4,5], Hillary A. Scannell[14,15], Sandra C. Straub[9] & Thomas Wernberg[9]

Progress in Oceanography 141 (2016) 227–238

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journal homepage: www.elsevier.com/locate/pocean

A hierarchical approach to defining marine heatwaves

Alistair J. Hobday[a,*], Lisa V. Alexander[b,c], Sarah E. Perkins[b,c], Dan A. Smale[d,e], Sandra C. Straub[e], Eric C.J. Oliver[b,f], Jessica A. Benthuysen[g], Michael T. Burrows[h], Markus G. Donat[b,c], Ming Feng[i], Neil J. Holbrook[b,f], Pippa J. Moore[j], Hillary A. Scannell[k,l], Alex Sen Gupta[b,c], Thomas Wernberg[e]

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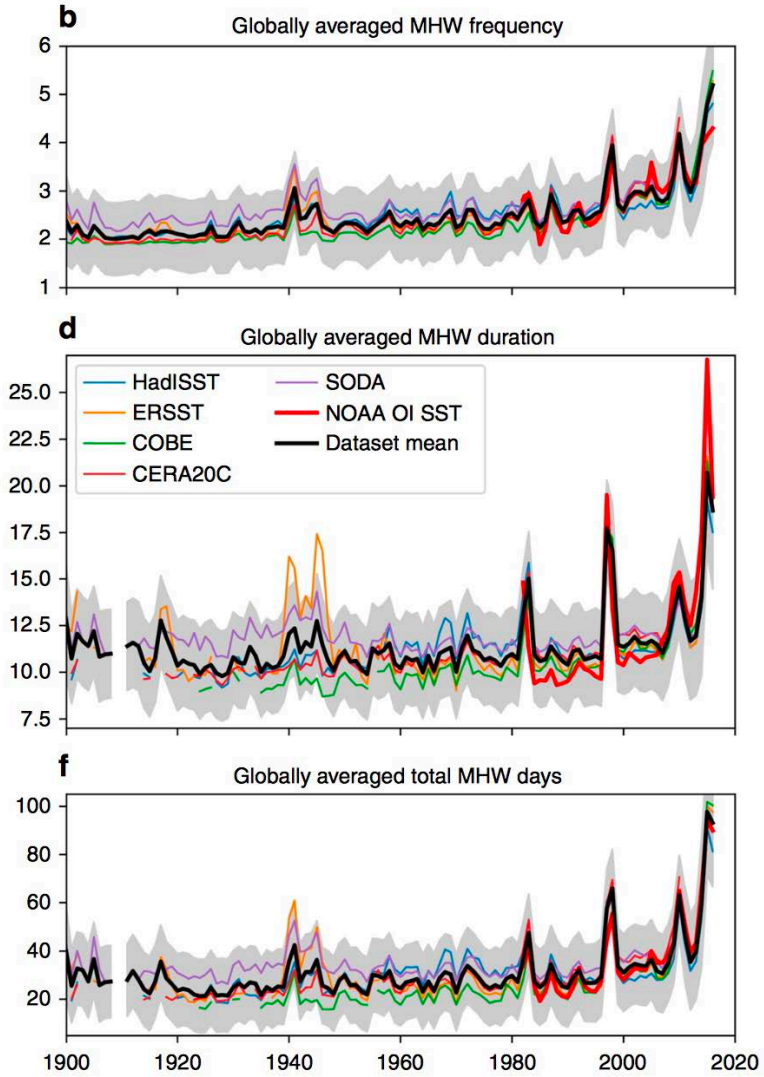

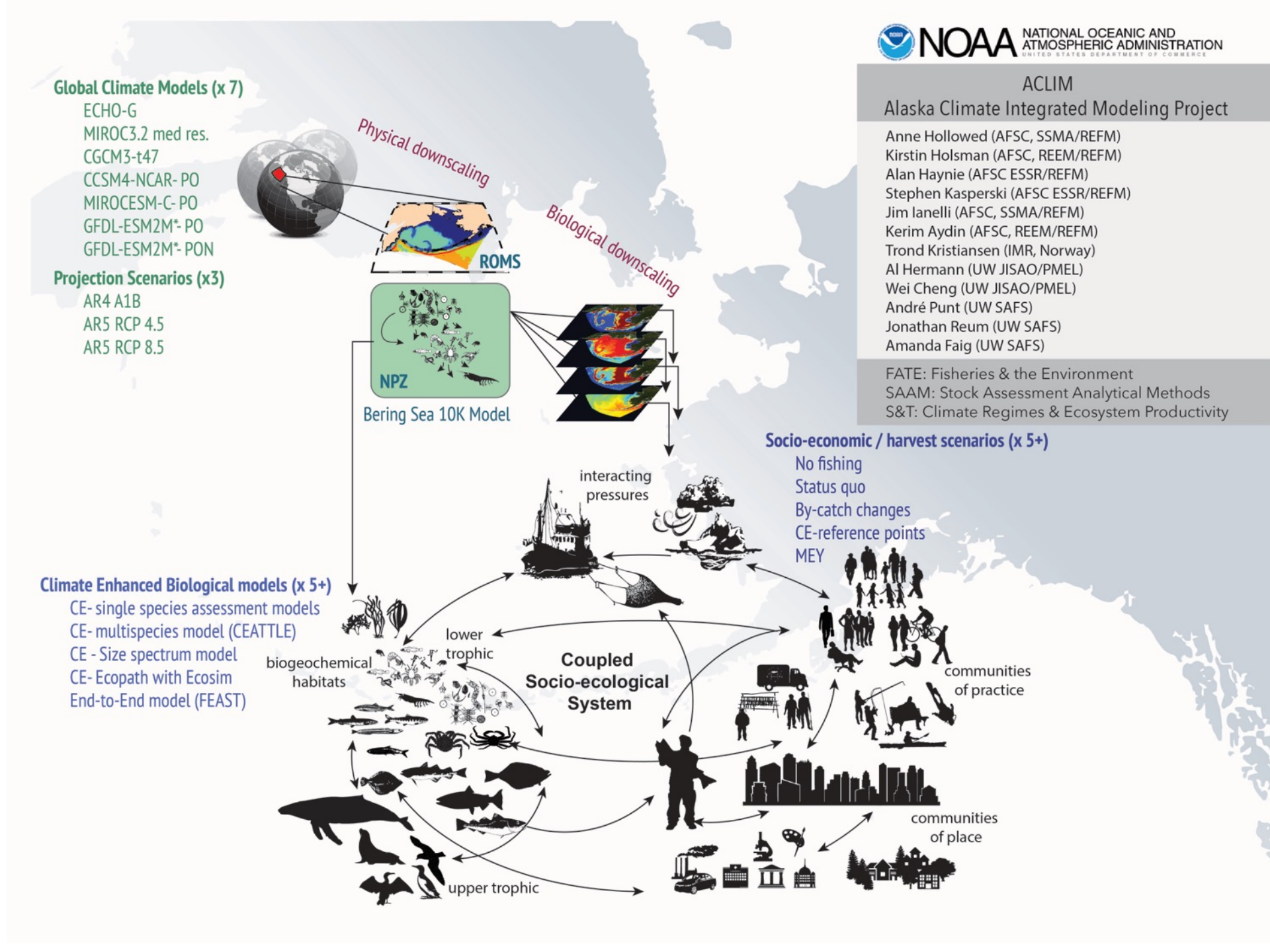
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UNITED STATES DEPARTMENT OF COMMERCE
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André Punt (UW SAFS)
Jonathan Reum (UW SAFS)
Amanda Faig (UW SAFS)
FATE: Fisheries & the Environment
SAAM: Stock Assessment Analytical Methods
S&T: Climate Regimes & 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)
lower trophic
biogeochemical habitats
Coupled Socio-ecological System
communities of practice
communities of place
upper trophic

The ACLIM team


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Andre Punt


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Amanda Faig

Christine Stawitz

Kelly Kearney


Paul Spencer


Michael Dalton


Darren Pilcher


Tom Wilderbuer


Cody Szuwalski

William Stockhausen

Ingrid Spies

Improve management **foresight** in a changing climate

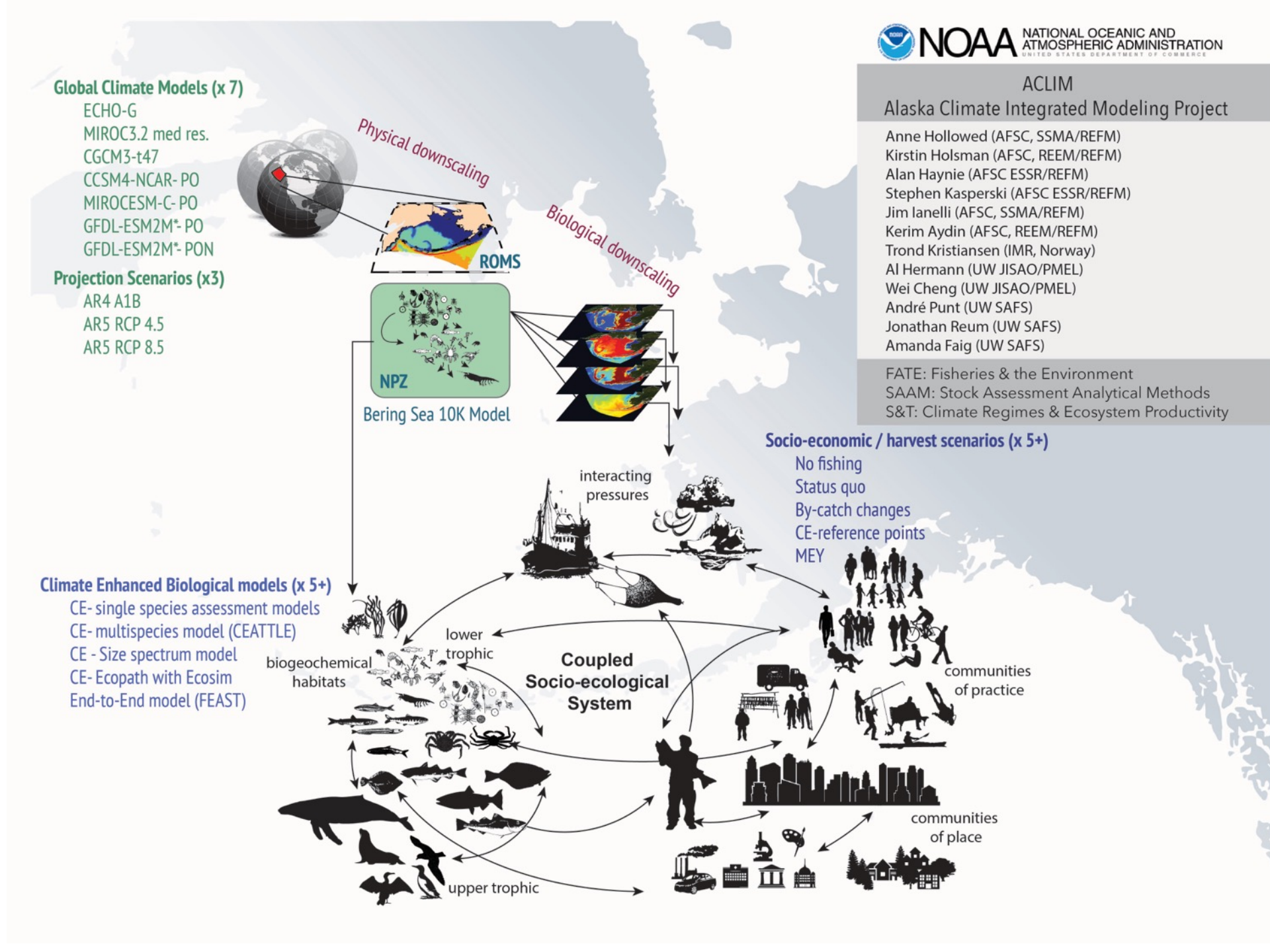
Protect **adaptive capacity** in fish and fisheries

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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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
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Biological downscaling
NPZ
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Socio-economic / harvest scenarios (x 5+)
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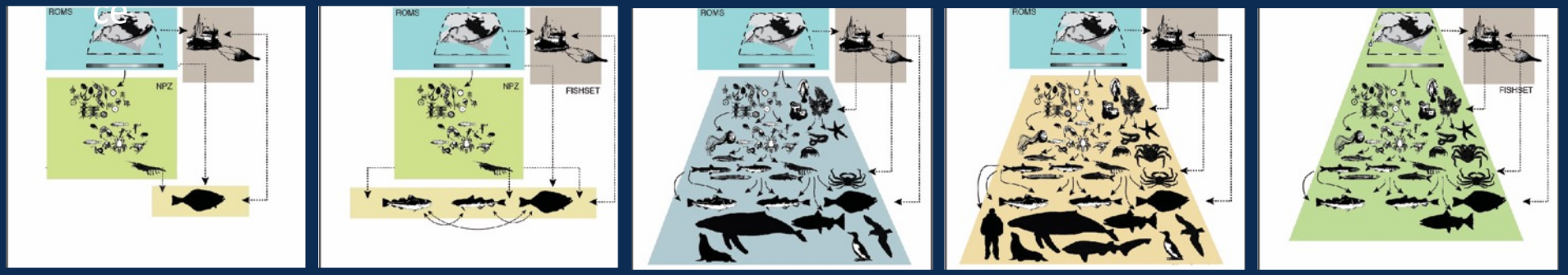
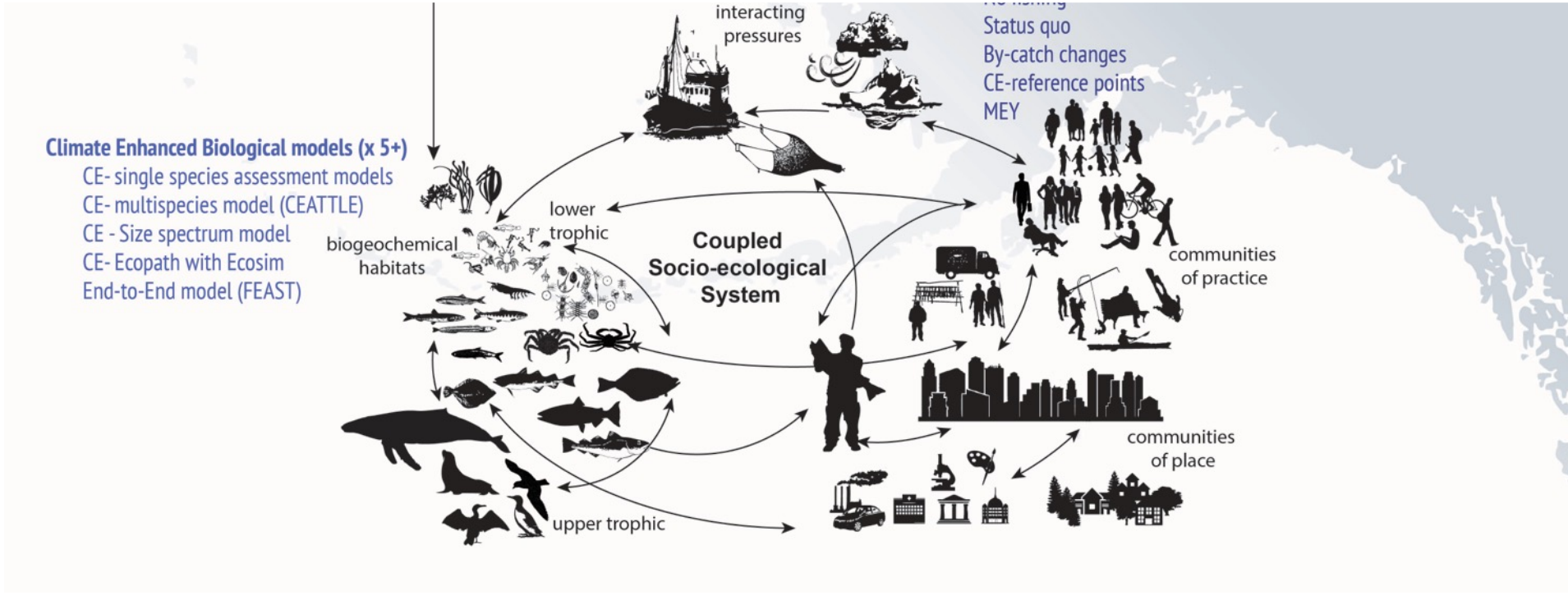
Climate Enhanced Biological models (x 5+)
CE- single species assessment models
CE- multispecies model (CEATTLE)
CE - Size spectrum model
CE- Ecopath with Ecosim
End-to-End model (FEAST)
lower trophic
biogeochemical habitats
Coupled Socio-ecological System
communities of practice
communities of place
upper trophic

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

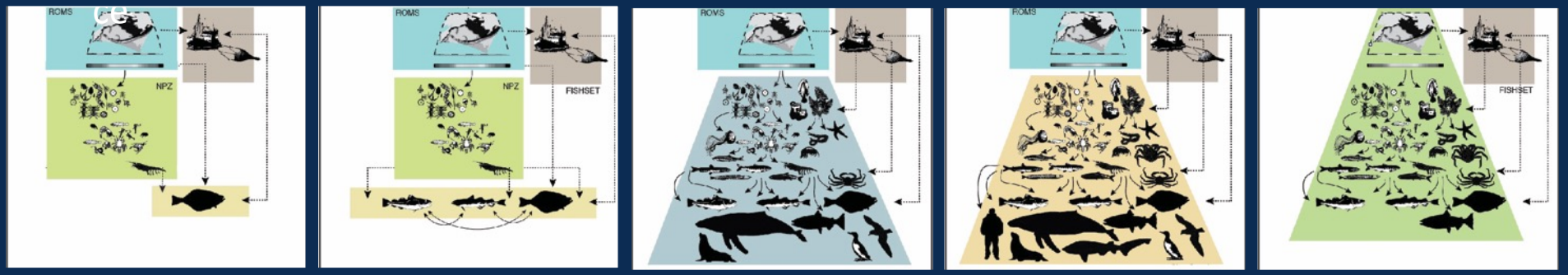


Fast
Statistical
Implicit ecosystem noise

Slow
High resolution
Explicit ecosystem interactions

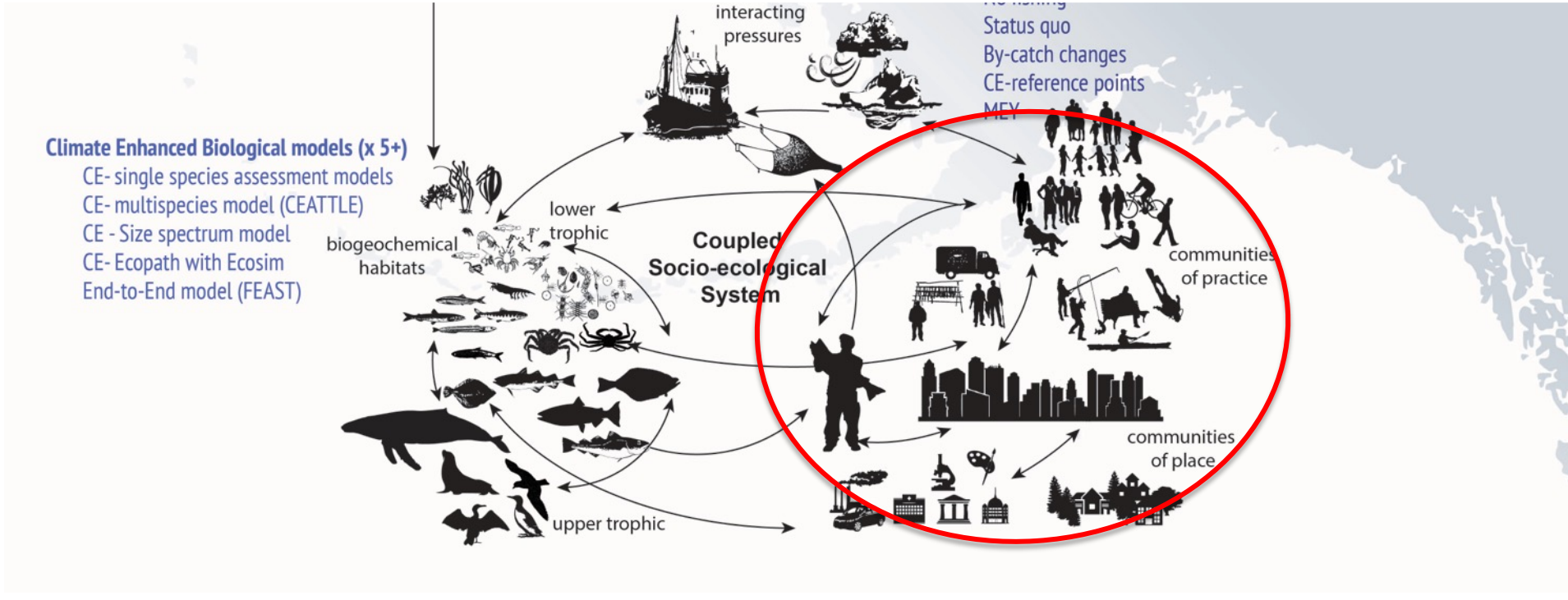


CE-SSM | CE-MSM | CE-EwE | CE-MIZER | FEAST



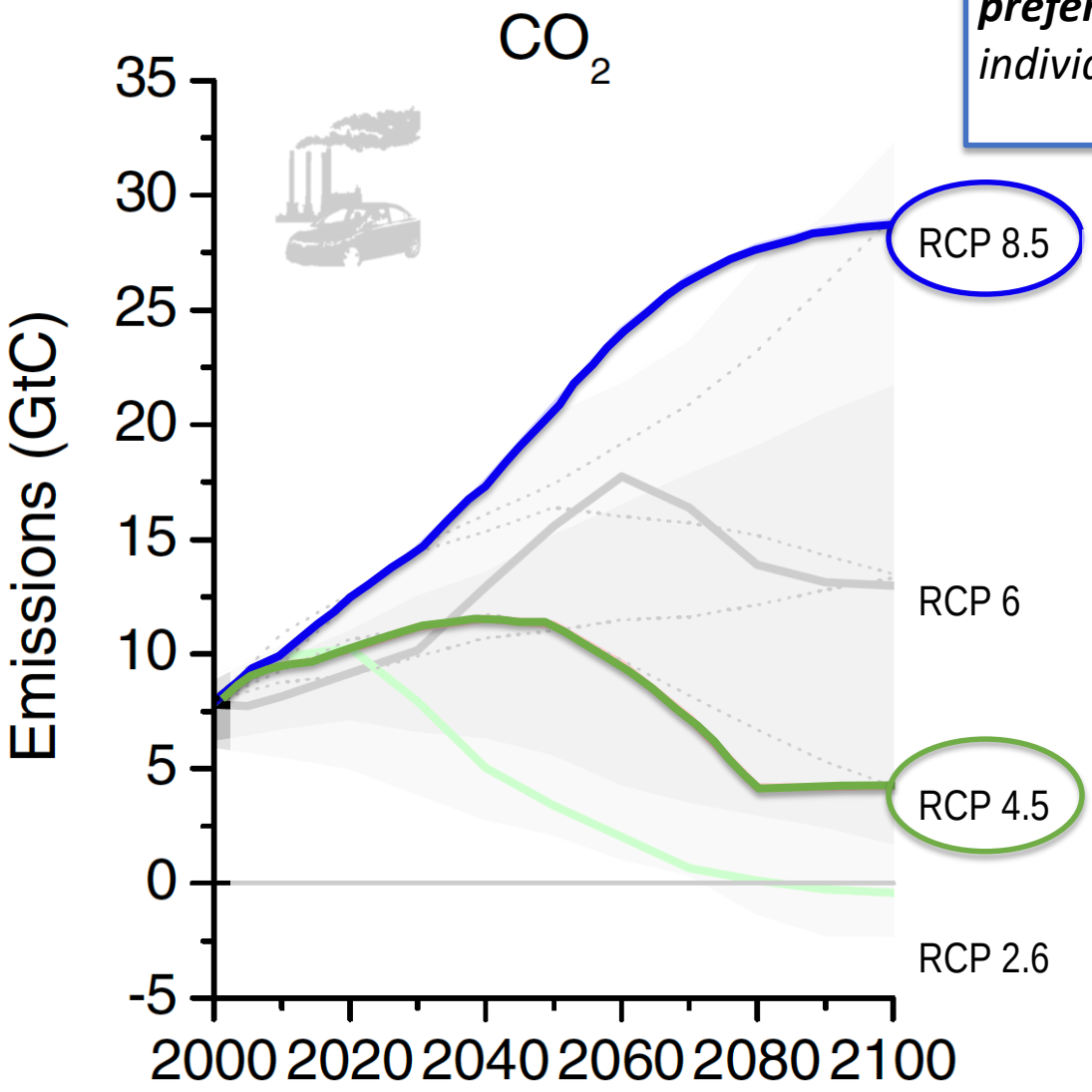
Fast
Statistical
Implicit ecosystem noise

Slow
High resolution
Explicit ecosystem interactions



Carbon Emission Scenarios

> *"**plausible descriptions** of how the future may evolve with respect to a range of variables…they are not meant to be policy prescriptive, (i.e. **no likelihood or preference is attached** to any of the individual scenarios of the set)"*
>
> *van Vuuren et al. 2011*

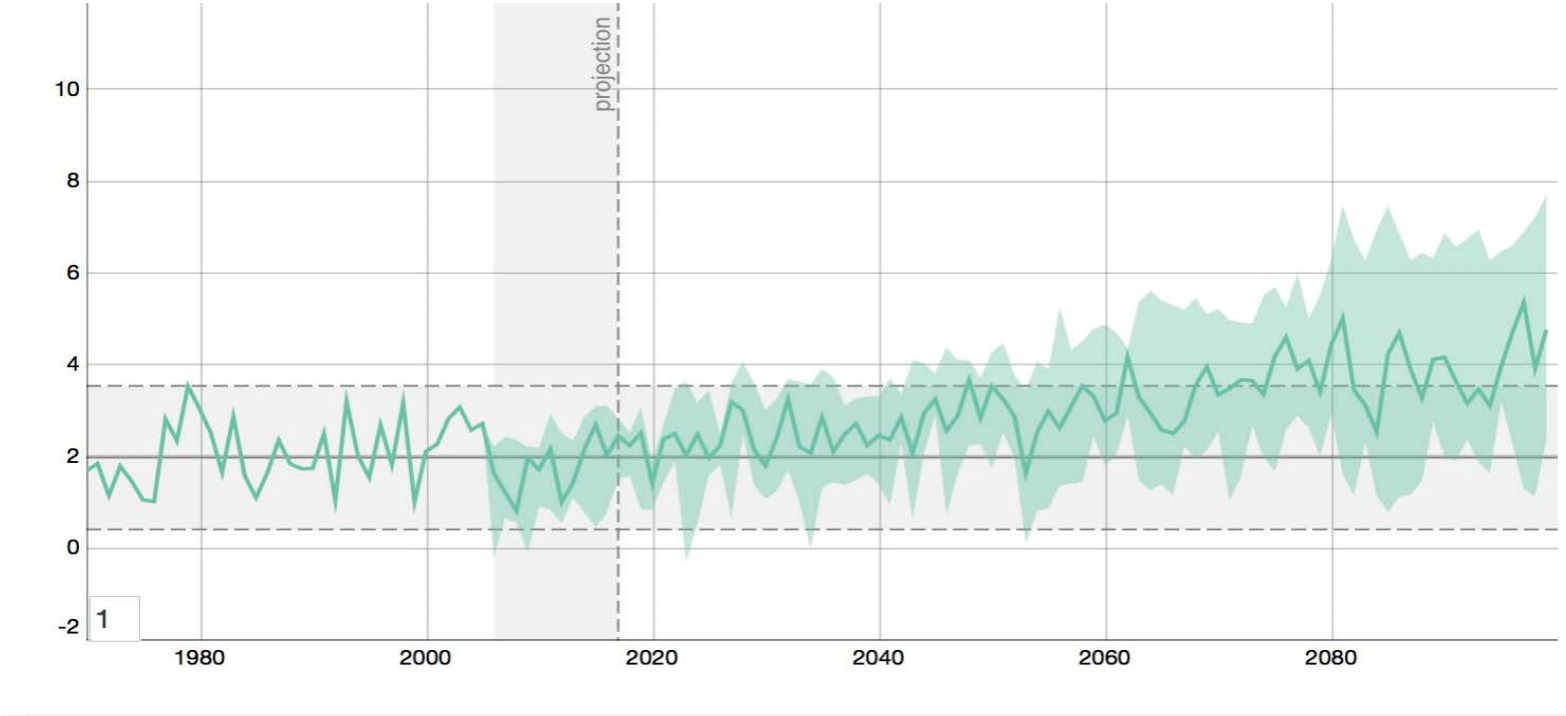


High-Baseline
"Business as usual"

Medium-low

https://kholsman.shinyapps.io/aclim/

Summer Bottom Temperature (°C)

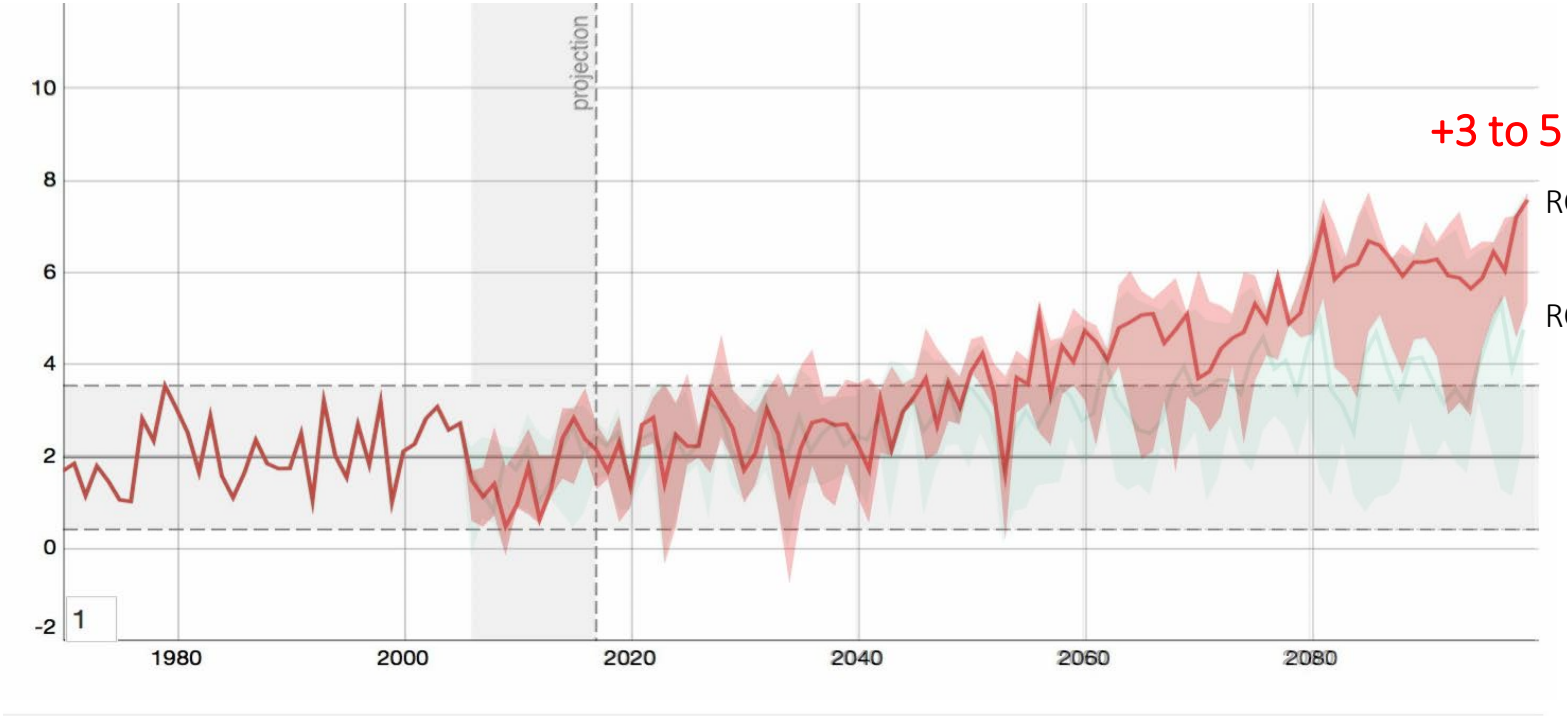


RCP 4.5

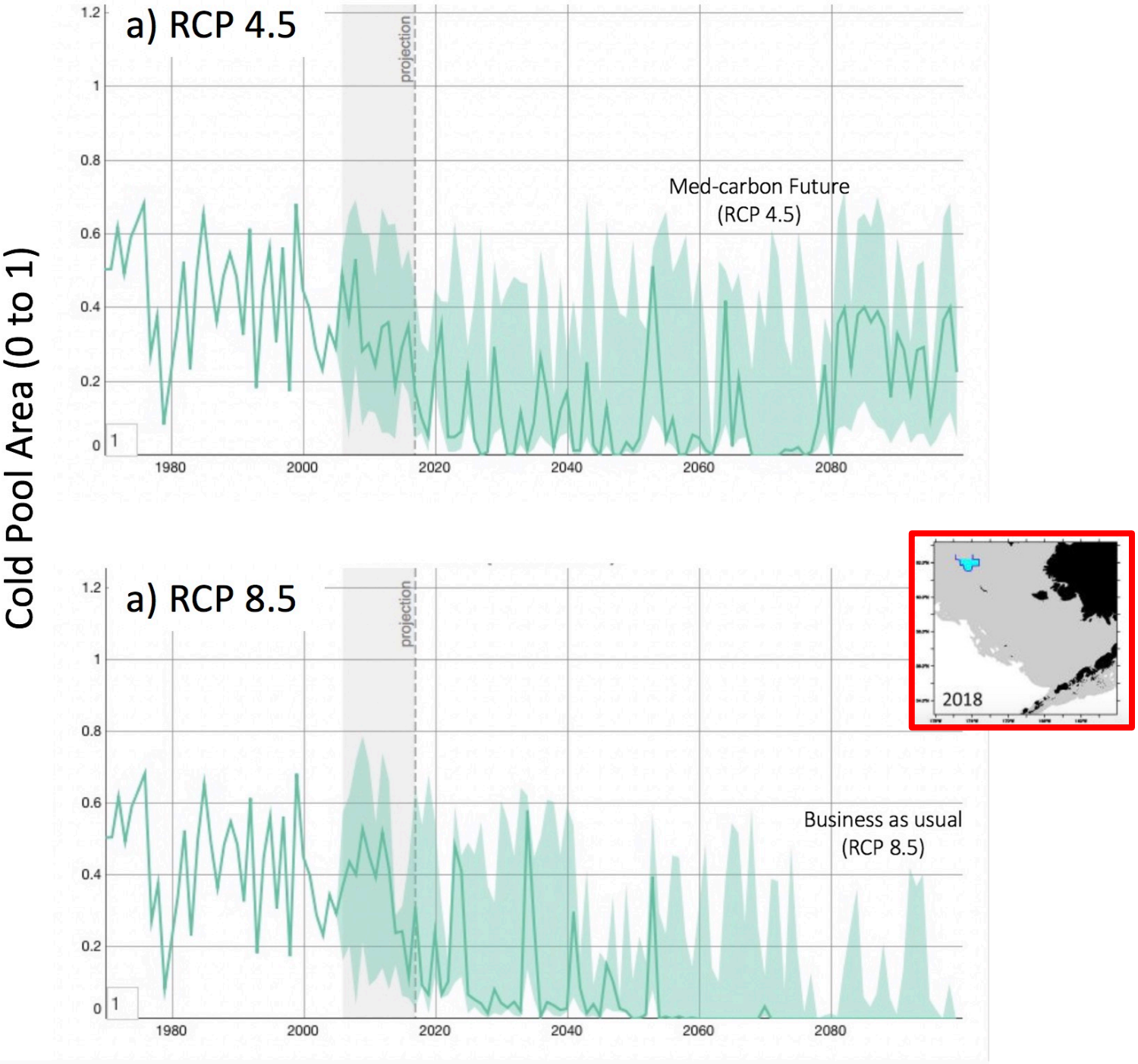
Based on Hermann et al. in review

https://kholsman.shinyapps.io/aclim/

Summer Bottom Temperature (°C)



Based on Hermann et al. in review

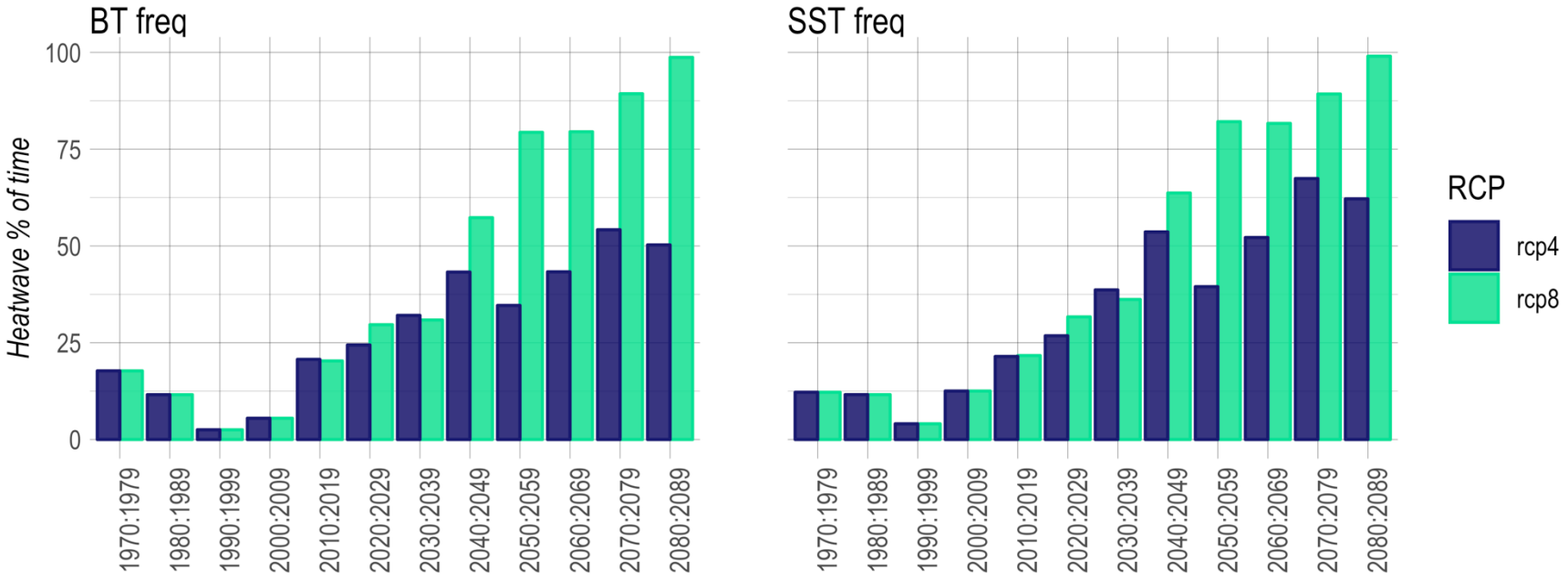

Cold Pool Area (0 to 1)
a) RCP 4.5
projection
Med-carbon Future
(RCP 4.5)
a) RCP 8.5
projection
Business as usual
(RCP 8.5)
2018
1.2
1
0.8
0.6
0.4
0.2
0
1980
2000
2020
2040
2060
2080

Marine heatwaves will likely increase in frequency and duration

Heatwaves
Now ~ 21% of the time
2050 ~ 30-77% of the time
2100 ~ 60-90% of the time

Duration

Marine heatwave analysis based on downscaled ROMSNPZ hindcast + projections, and 1970-2000 climatology.

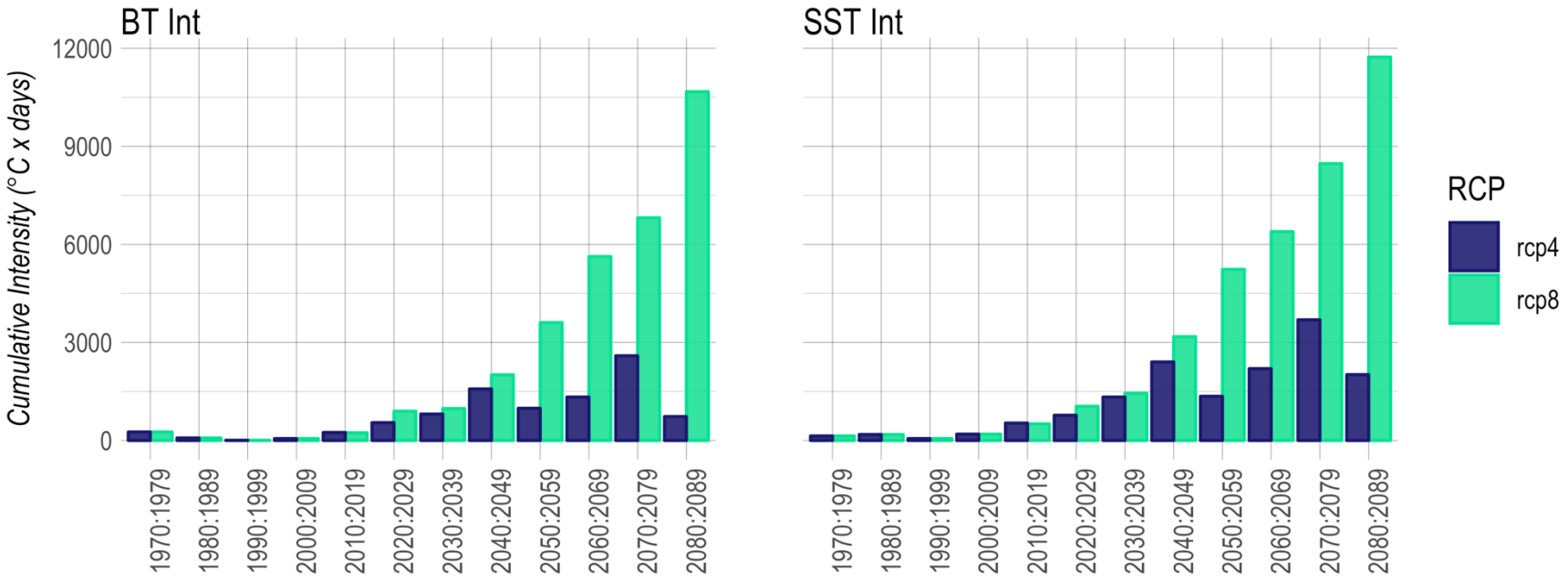


ROMSNPZ: K. Kearney, A. Hermann, W. Cheng, K. Aydin, 2018
Heatwave analysis: K. Holsman, 2018, based on Hobday et al. (2016)
Data source: NOAA PMEL, AFSC REEM Program, IEA, MAPP Bering Seasons,ACLIM

Marine heatwaves will likely increase in intensity

Intensity

Marine heatwave analysis based on downscaled ROMSNPZ hindcast + projections, and 1970-2000 climatology.



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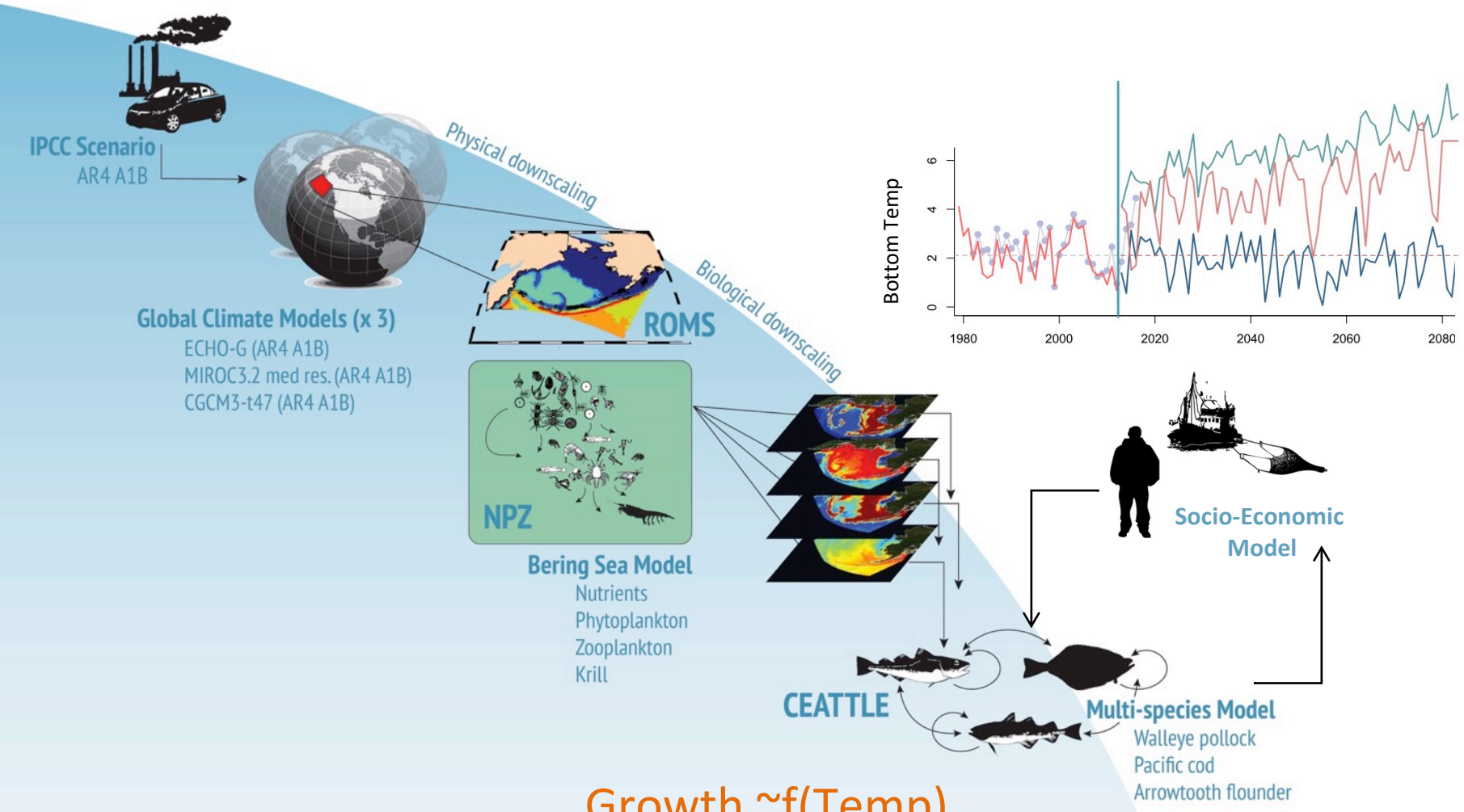
Heatwave analysis: K. Holsman, 2018, based on Hobday et al. (2016)
Data source: NOAA PMEL, AFSC REEM Program, IEA, MAPP Bering Seasons,ACLIM

Climate-Enhanced Assessment Models

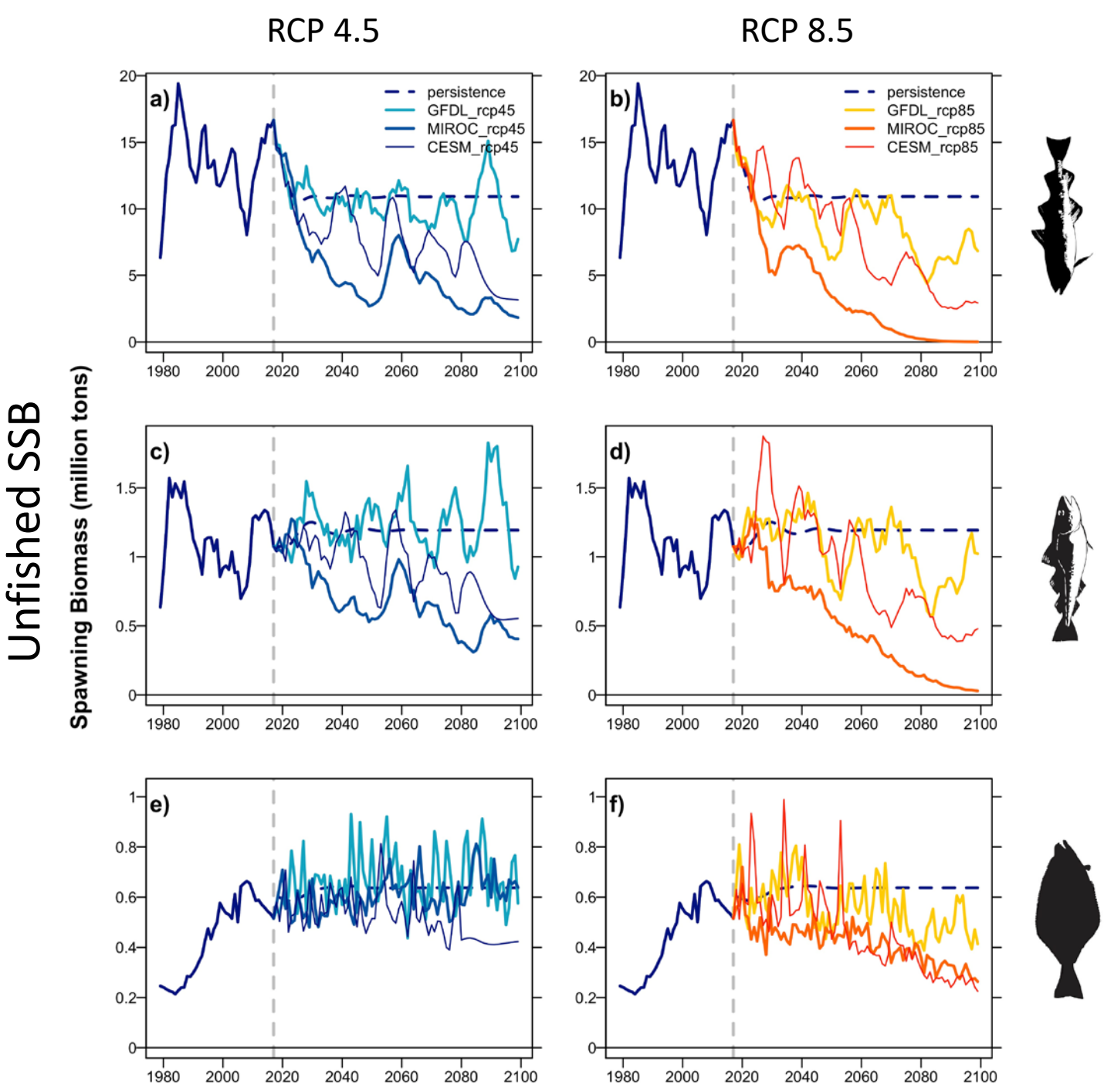


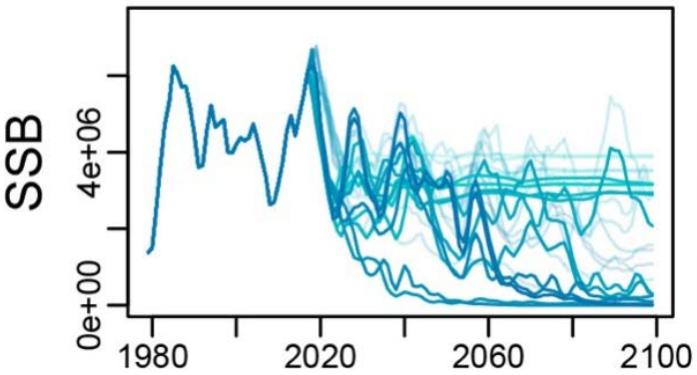
Holsman et al. in prep

Growth ~f(Temp)

Mort ~f(Temp, N_{pred})

Rec ~f(Temp, Zoop, etc.)

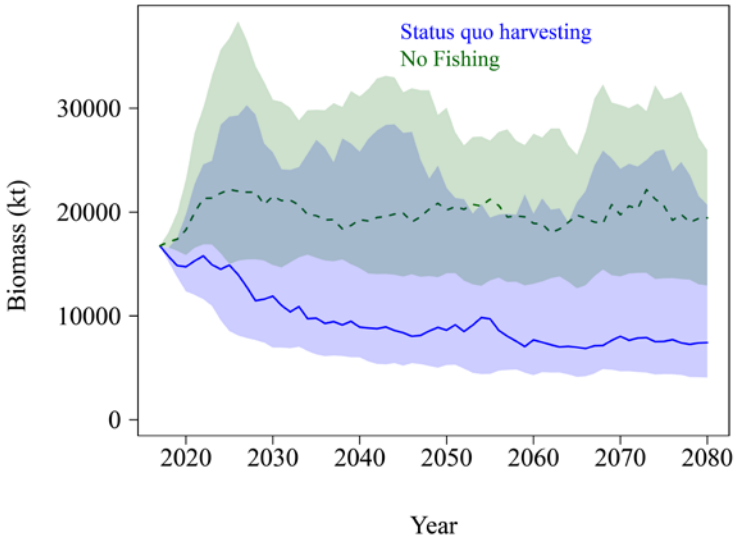

RCP 4.5
RCP 8.5
Unfished SSB
Spawning Biomass (million tons)
a)
b)
c)
d)
e)
f)
persistence
GFDL_rcp45
MIROC_rcp45
CESM_rcp45
GFDL_rcp85
MIROC_rcp85
CESM_rcp85
1980
2000
2020
2040
2060
2080
2100



CEATTLE model

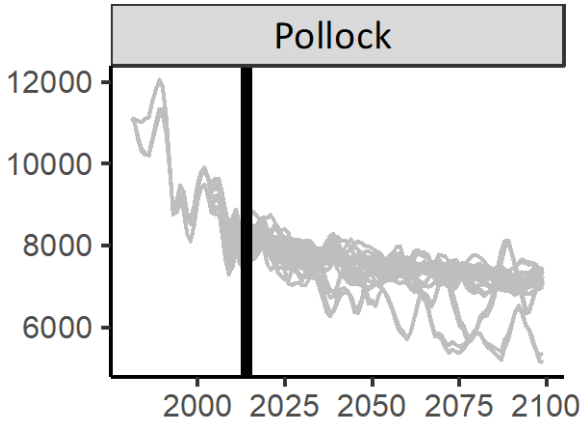
Pollock spawning biomass

Ecologically-enhanced single spp



Spencer et al. in prep

Bering Sea Size-spectrum model



Reum et al. accepted

Discussion :

Are there control rules or scenarios that ACLIM could evaluate over the next year?

- climate-specific reference points
- Effects of changes in weight at age or changes in distribution.