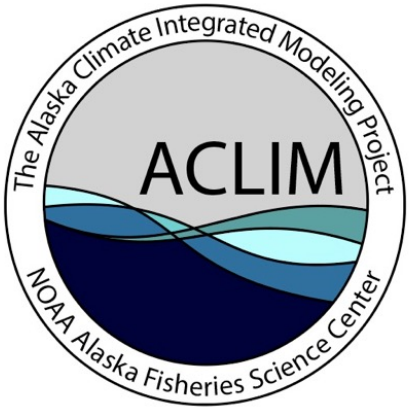
The Alaska Climate Integrated Modeling Project (Phase 2)



Building climate resilience through climate-informed Ecosystem Based Management

Lead PIs: Anne Hollowed, Kirstin Holsman, Alan Haynie, Jon Reum, Andre Punt, Kerim Aydin, Al Hermann

Co-PIs:

Wei Cheng
Jim Ianelli
Kelly Kearney
Elizabeth McHuron
Daren Pilcher
Jeremy Sterling
Ingrid Spies
Paul Spencer
William Stockhausen
Cody Szuwalski
Sarah Wise
Ellen Yasumiishi

Andy Whitehouse
James Thorson
Peggy Sullivan
Amanda Faig
Steve Kasperski
Martin Dorn
Diana Evans
Ed Farely
Enrique Curchitser
Elliott Hazen
David Kimmel
Mike Jacox

Carol Ladd
Stan Kotwicki
Ivonne Ortiz
Kalei Shotwell
Rolf Ream
Elizabeth Siddon
Phyllis Stabeno
Charlie Stock
Chris Rooper
Jordan Watson
Diana Stram
Lauren Rogers
Ben Laurel

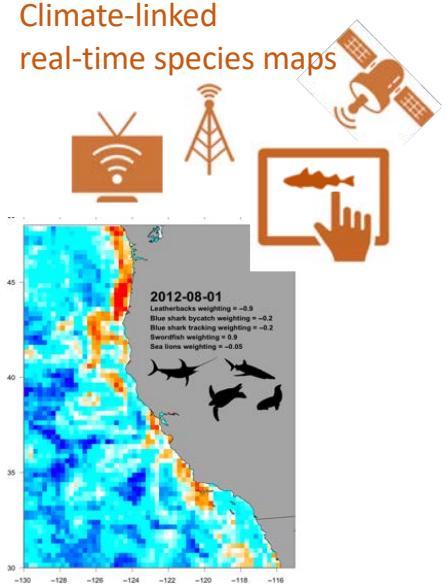
www.fisheries.noaa.gov/alaska/ecosystems/alaska-climate-integrated-modeling-project

E.g., Fishery Climate Adaptation Tools

Adapt in real-time
(incremental adaptation)

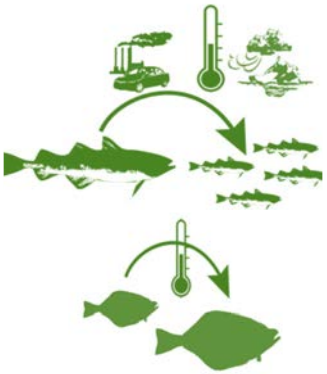
Minimize impacts through holistic planning
(transformational adaptation)

Climate-linked real-time species maps



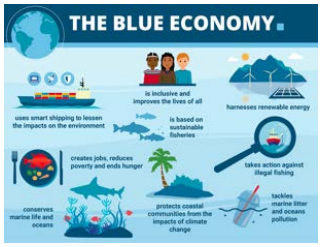
Hazen et al. 2019
https://advances.sciencemag.org/content/4/5/eaar3001

Climate-enhanced stock Assessment models



Holsman et al. 2020
https://www.nature.com/articles/s41467-020-18300-3

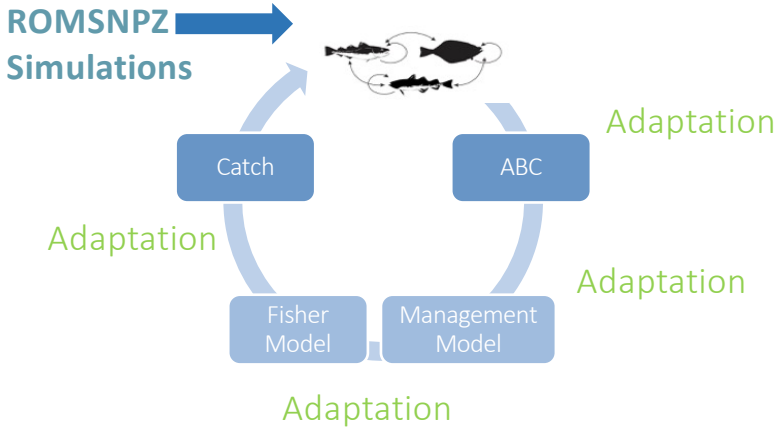
Climate smart long-term strategies

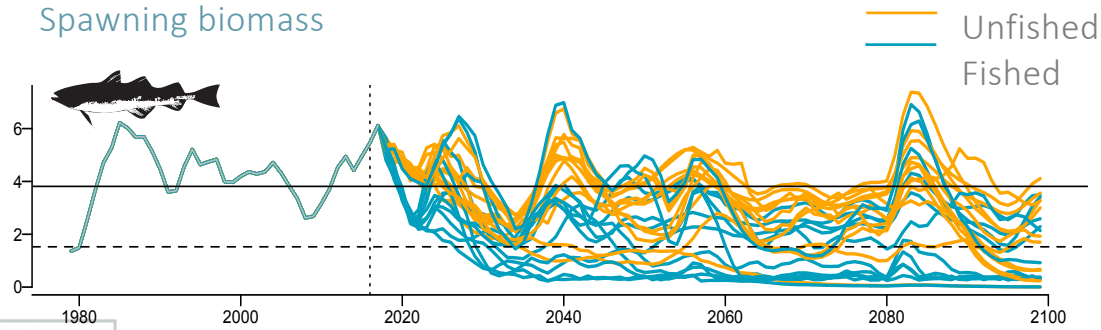


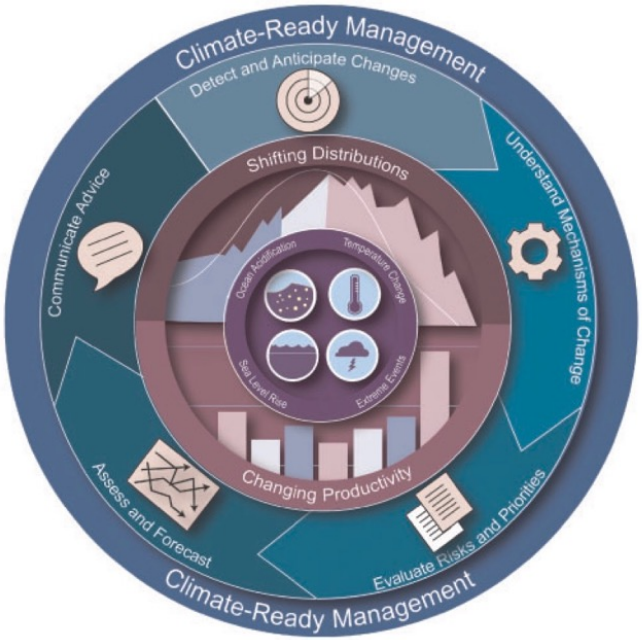
www.blueeconomyconference.go.ke

Santos et al. 2020.
https://www.nature.com/articles/s41893-020-0513-x

Management can reduce risks & support adaptation

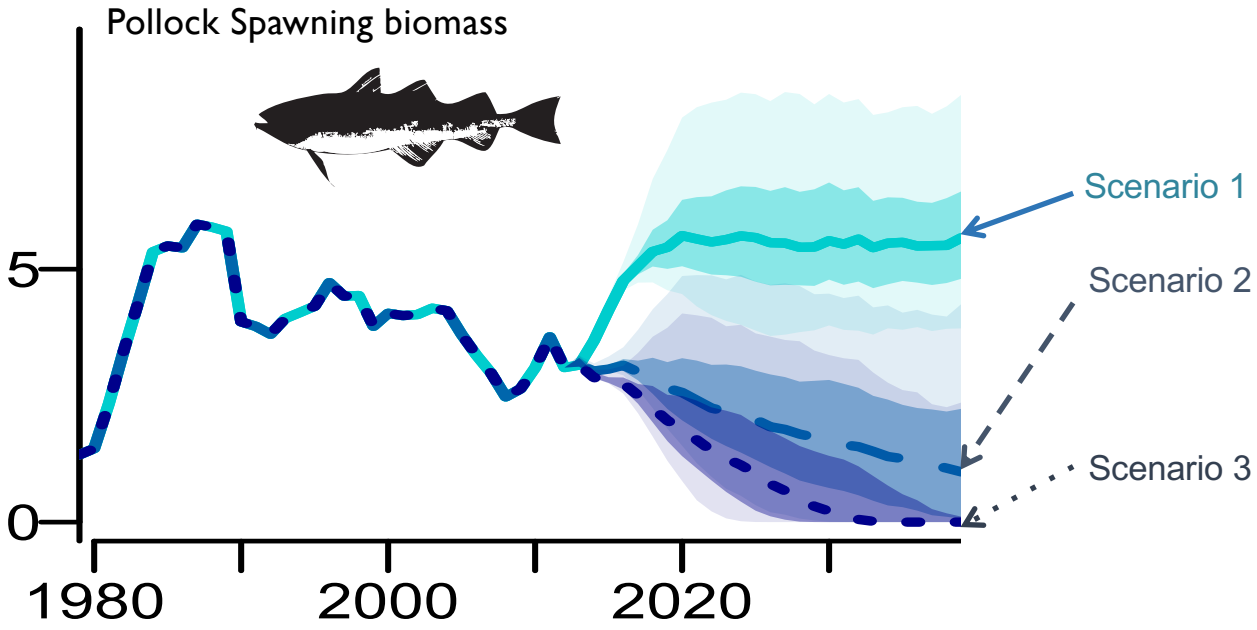






Karp et al. 2019. Accounting for Shifting Distributions and Changing Productivity in the Development of Scientific Advice for Fishery Management. ICES JMS doi: 10.1093/icesjms/fsz048

QUANTIFY RISK AND UNCERTAINTY

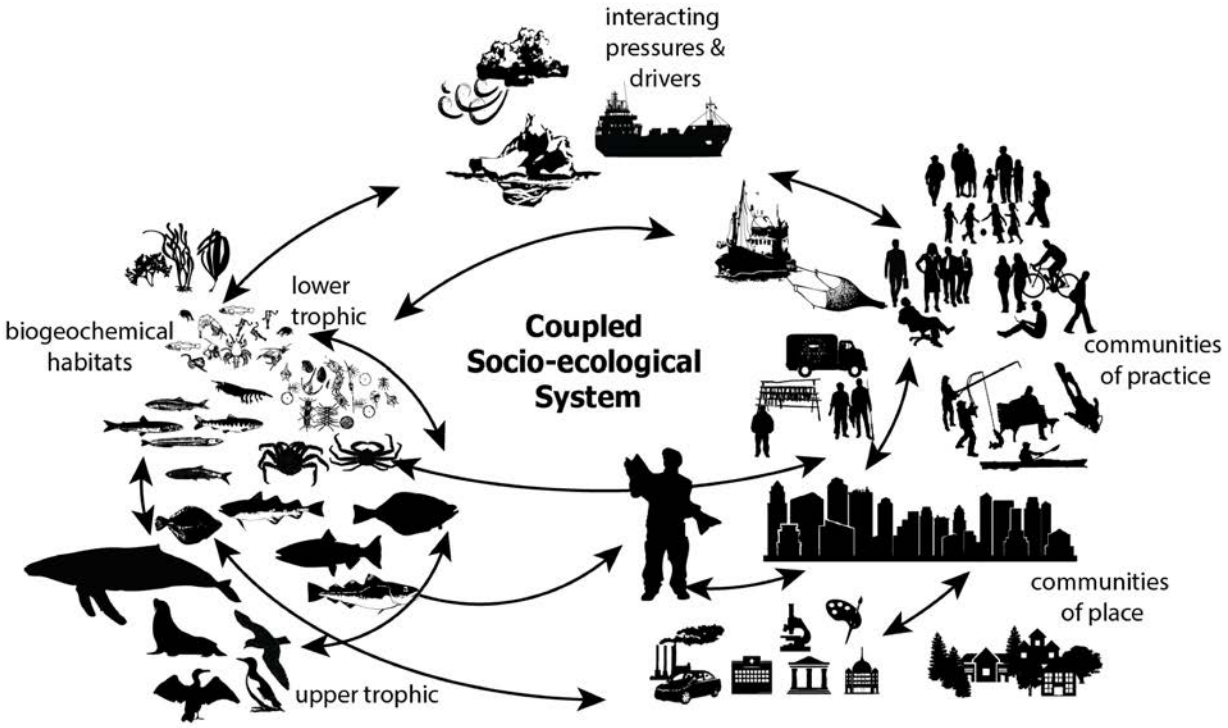


Ianelli, J KK Holsman, AE Punt, K Aydin (2016). Multi-model inference for incorporating trophic and climate uncertainty into stock assessment estimates of fishery biological reference points. Deep Sea Res II. 134: 379-389 DOI: 10.1016/j.dsr2.2015.04.002

Glossary of Terms: Social-ecological system

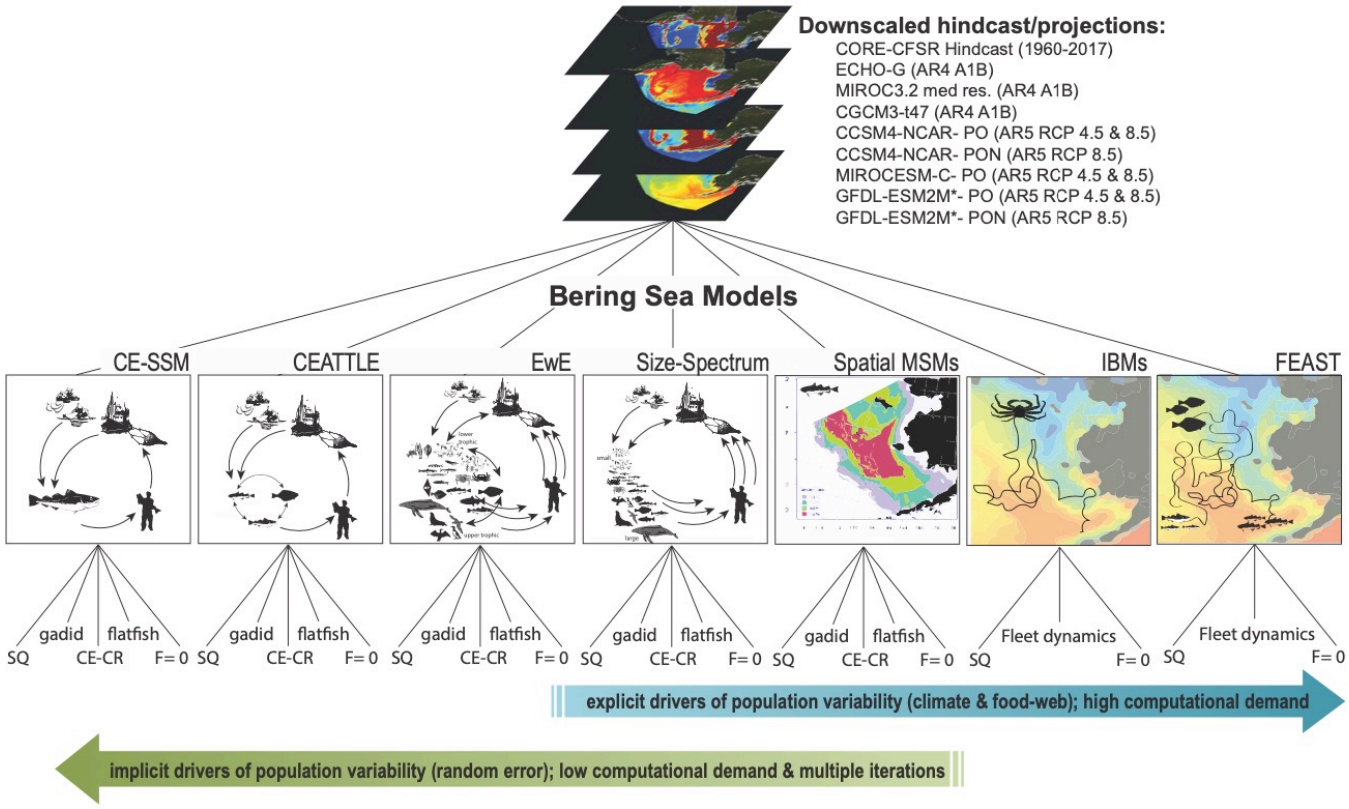
Human and ecological systems *are linked through feedback mechanisms*

Adaptation
Resilience



Adaptation
Resilience

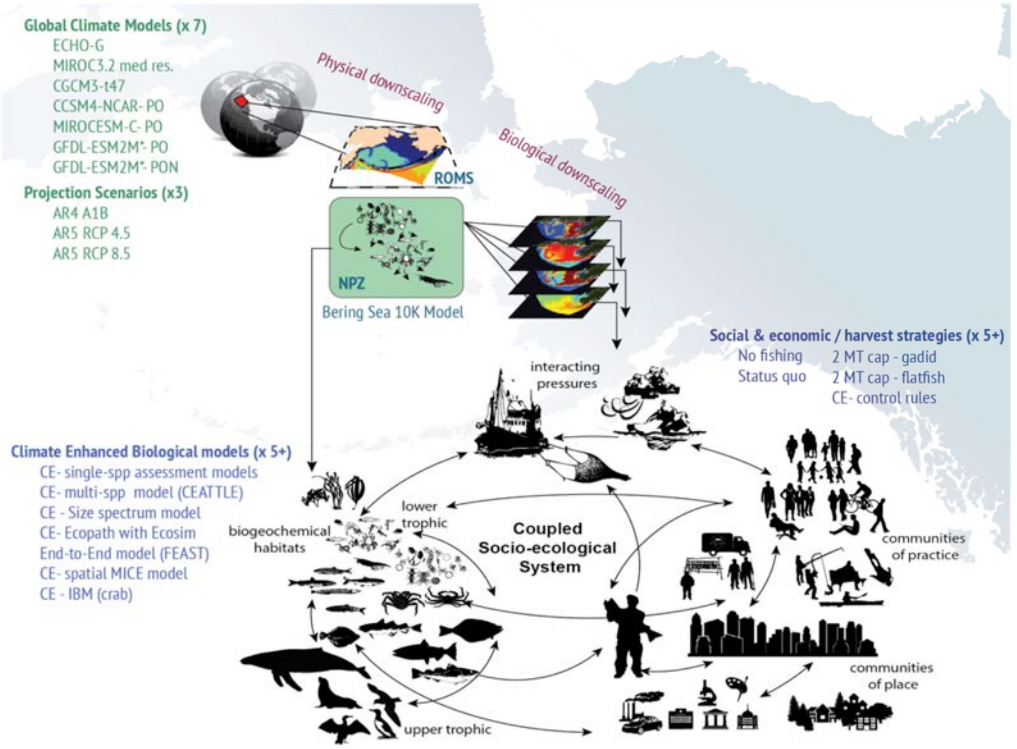
The Alaska Climate Integrated Modeling Project



The Alaska Climate Integrated Modeling Project Phase 2

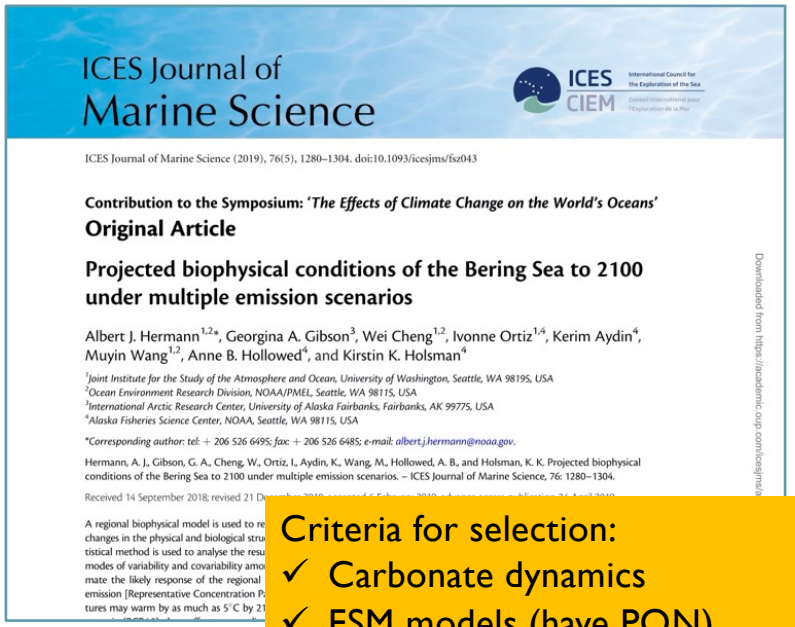
- NBS and SEBS Bering Sea
- Operational suite of coupled socio-ecological models for climate fisheries hindcasts, forecasts, projections and Management Strategy Evaluation

www.fisheries.noaa.gov/alaska/ecosystems/alaska-climate-integrated-modeling-project



Hollowed et al. 2020. Frontiers in Mar. Sci. doi: 10.3389/fmars.2019.00775

Projections: selection of (Global Ocean) General Circulation Models (GCMs)



ICES Journal of Marine Science

ICES Journal of Marine Science (2019), 76(5), 1280–1304. doi:10.1093/icesjms/fsz043

Contribution to the Symposium: *'The Effects of Climate Change on the World's Oceans'*

Original Article

Projected biophysical conditions of the Bering Sea to 2100 under multiple emission scenarios

Albert J. Hermann[1,2]*, Georgina A. Gibson[3], Wei Cheng[1,2], Ivonne Ortiz[1,4], Kerim Aydin[4], Muyin Wang[1,2], Anne B. Hollowed[4], and Kirstin K. Holsman[4]

[1]Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, WA 98195, USA
[2]Ocean Environment Research Division, NOAA/PMEL, Seattle, WA 98115, USA
[3]International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, AK 99775, USA
[4]Alaska Fisheries Science Center, NOAA, Seattle, WA 98115, USA

*Corresponding author: tel: + 206 526 6495; fax: + 206 526 6485; e-mail: albert.j.hermann@noaa.gov.

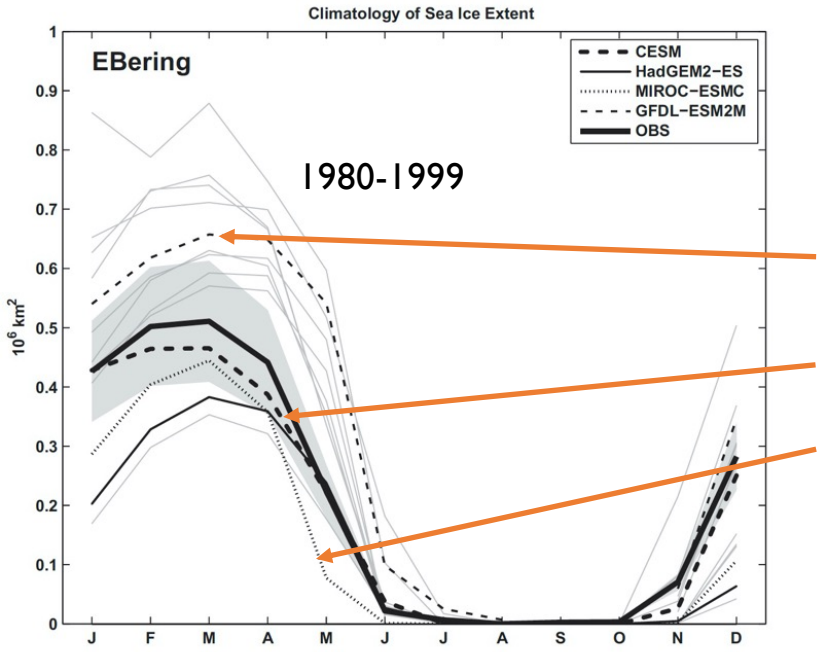
Hermann, A. J., Gibson, G. A., Cheng, W., Ortiz, I., Aydin, K., Wang, M., Hollowed, A. B., and Holsman, K. K. Projected biophysical conditions of the Bering Sea to 2100 under multiple emission scenarios. – ICES Journal of Marine Science, 76: 1280–1304.

Received 14 September 2018; revised 21 D

A regional biophysical model is used to re
changes in the physical and biological stru
tistical method is used to analyse the resu
modes of variability and covariability amo
mate the likely response of the regional
emission [Representative Concentration P
tures may warm by as much as 5°C by 21

Criteria for selection:

- ✓ Carbonate dynamics
- ✓ ESM models (have PON)
- ✓ Realistic timing of Sea Ice melt
- ✓ Spans warm, average, cool



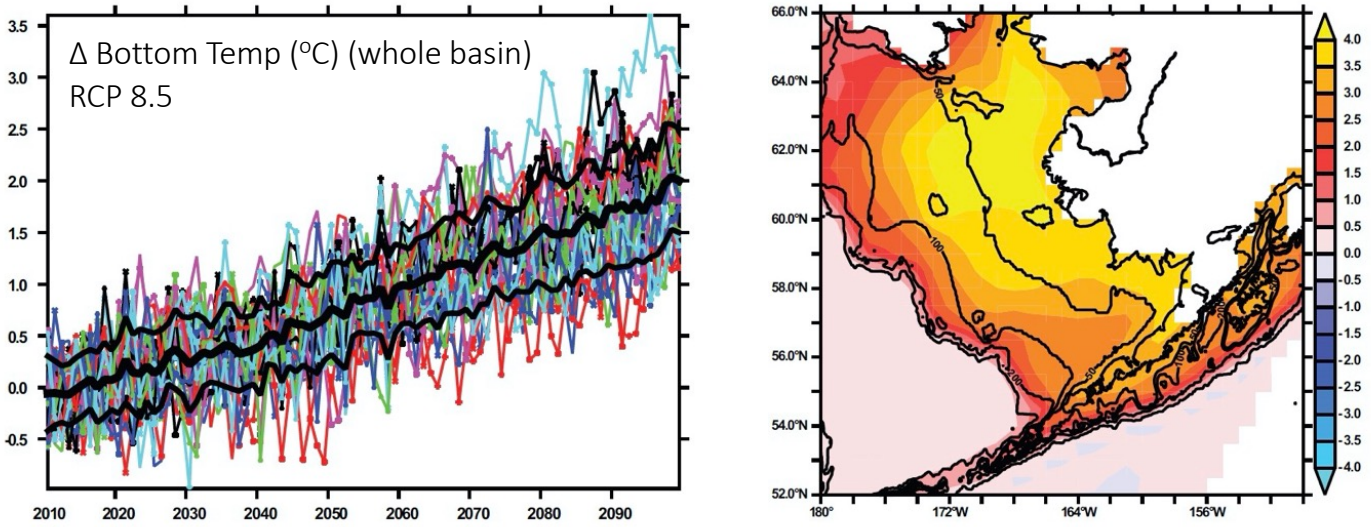
GFDL ESM2M (cooler)

CESM (intermediate)

MIROC ESMC (warmer)

Hermann, A. J., G.A. Gibson, W. Cheng, I. Ortiz1,K. Aydin, M. Wang, A. B. Hollowed, and K. K. Holsman. (2019) Projected biophysical conditions of the Bering Sea to 2100 under multiple emission scenarios. ICES. doi: 10.1093/ices/fsz043

Results: Downscaled Bering10K ROMSNPZ high-resolution model (H16)



INCREASED WARMING (2090-2099)-(2010-2019)

Hermann, A. J., G.A. Gibson, W. Cheng, I. Ortiz1,K. Aydin, M. Wang, A. B. Hollowed, and K. K. Holsman. (2019) Projected biophysical conditions of the Bering Sea to 2100 under multiple emission scenarios. ICES. doi: 10.1093/ices/fsz043

Results: Downscaled Bering10K ROMSNPZ high-resolution model (H16)

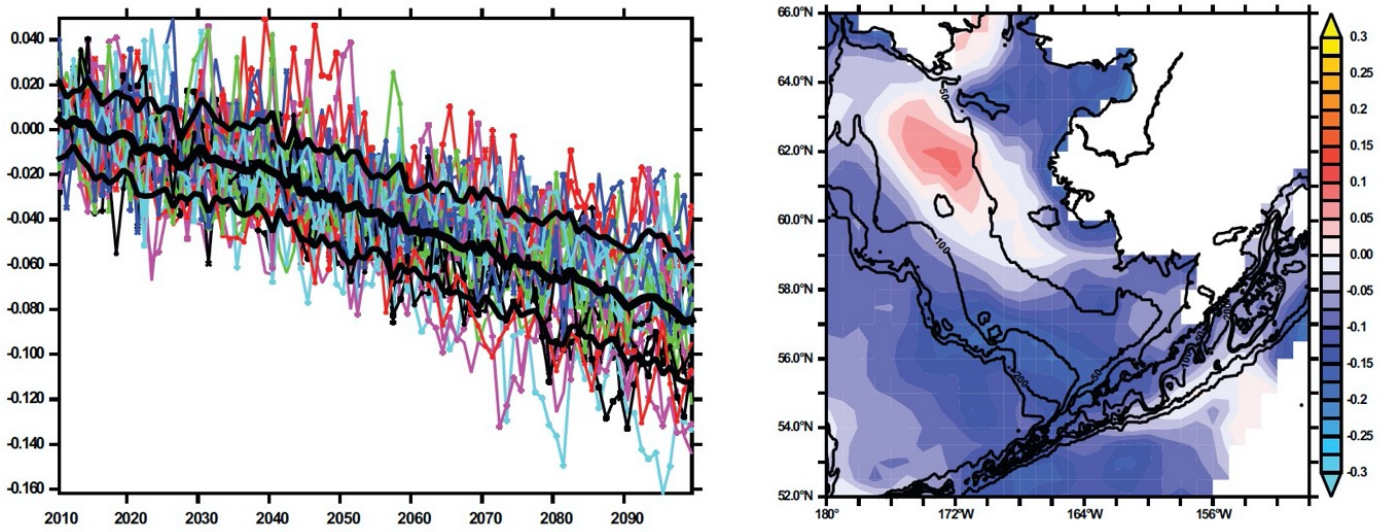


Figure 13. Ensemble results as in Figure 12, for $\log_{10}$ (large crustacean zooplankton).

DECLINES IN LARGE ZOOPLANKTON (2090-2099)-(2010-2019)

Hermann, A. J., G.A. Gibson, W. Cheng, I. Ortiz1,K. Aydin, M. Wang, A. B. Hollowed, and K. K. Holsman. (2019) Projected biophysical conditions of the Bering Sea to 2100 under multiple emission scenarios. ICES. doi: 10.1093/ices/fsz043

Results: Holsman et al. 2020

nature COMMUNICATIONS

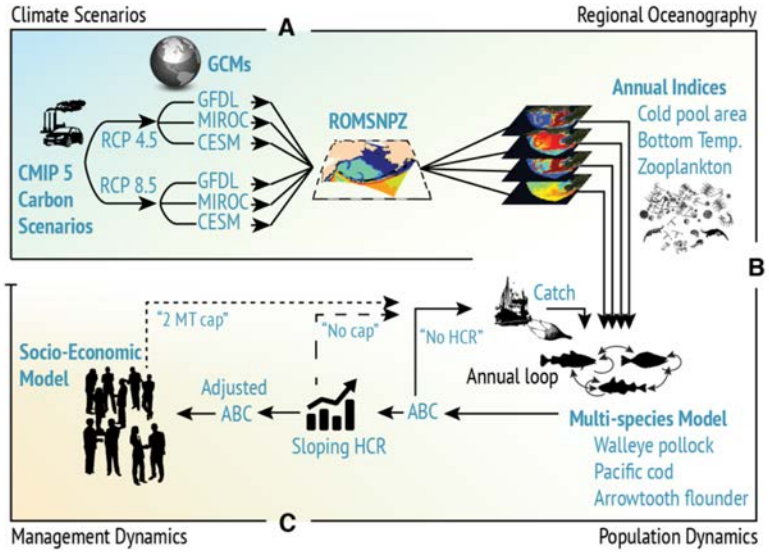
ARTICLE

https://doi.org/10.1038/s41467-020-18300-3 OPEN

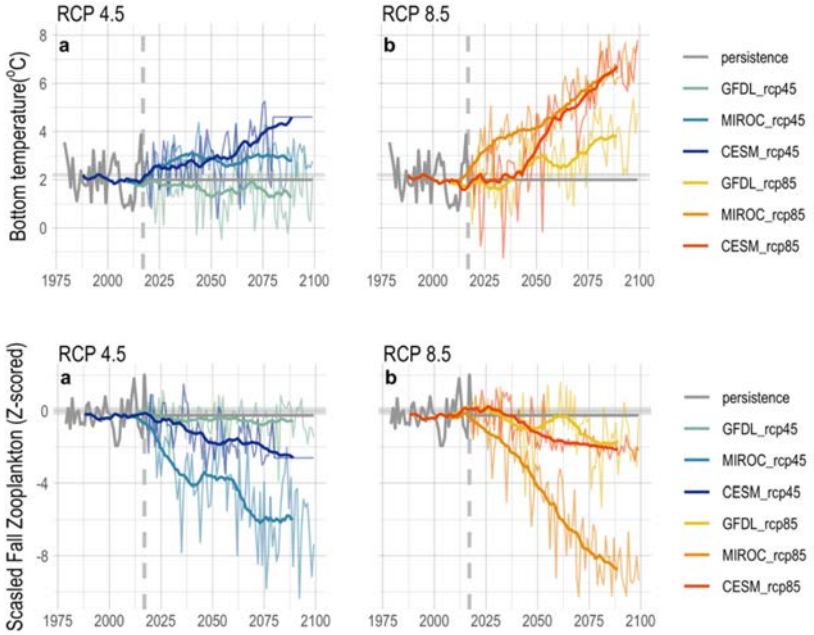
Ecosystem-based fisheries management forestalls climate-driven collapse

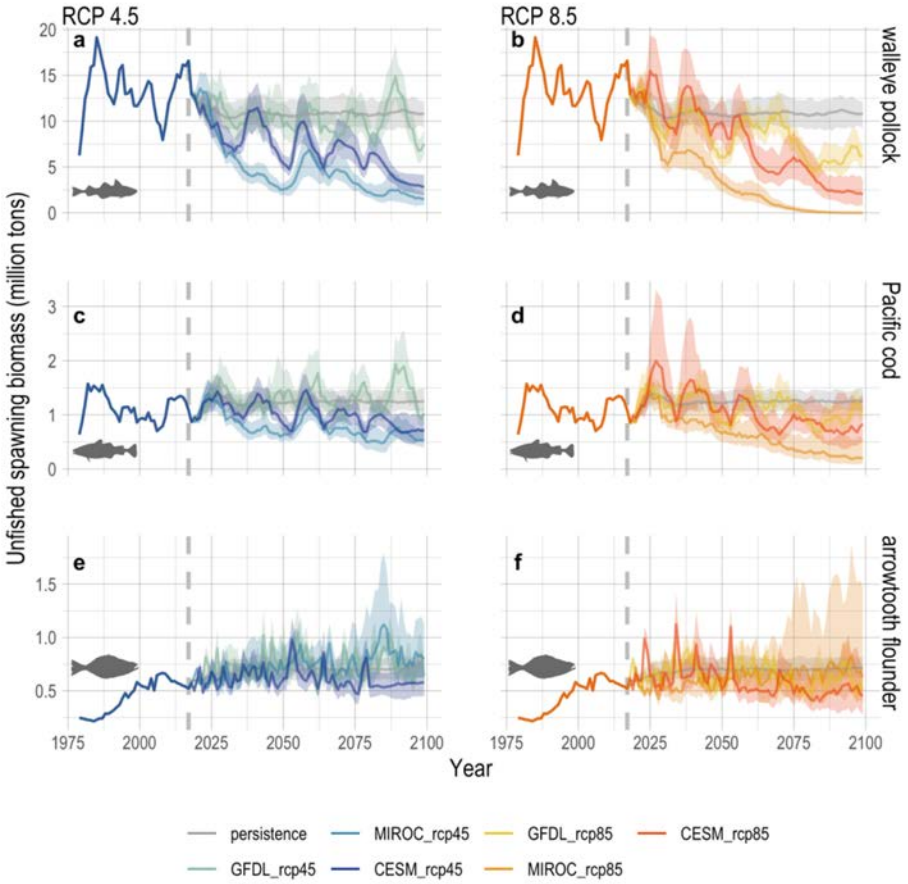
K. K. Holsman[1,2✉], A. C. Haynie[1], A. B. Hollowed[1,2], J. C. P. Reum[1,2,3], K. Aydin[1,2], A. J. Hermann[4,5], W. Cheng[4,5], A. Faig[2], J. N. Ianelli[1,2], K. A. Kearney[1,4] & A. E. Punt[2]

Climate change is impacting fisheries worldwide with uncertain outcomes for food and nutritional security. Using management strategy evaluations for key US fisheries in the eastern Bering Sea we find that Ecosystem Based Fisheries Management (EBFM) measures forestall future declines under climate change over non-EBFM approaches. Yet, benefits are species-specific and decrease markedly after 2050. Under high-baseline carbon emission scenarios (RCP 8.5), end-of-century (2075–2100) pollock and Pacific cod fisheries collapse in >70% and >35% of all simulations, respectively. Our analysis suggests that 2.1–2.3 °C (modeled summer bottom temperature) is a tipping point of rapid decline in gadid biomass and catch. Multiyear stanzas above 2.1 °C become commonplace in projections from ~2030 onward, with higher agreement under RCP 8.5 than simulations with moderate carbon mitigation (i.e., RCP 4.5). We find that EBFM ameliorates climate change impacts on fisheries in the near-term, but long-term EBFM benefits are limited by the magnitude of anticipated change.



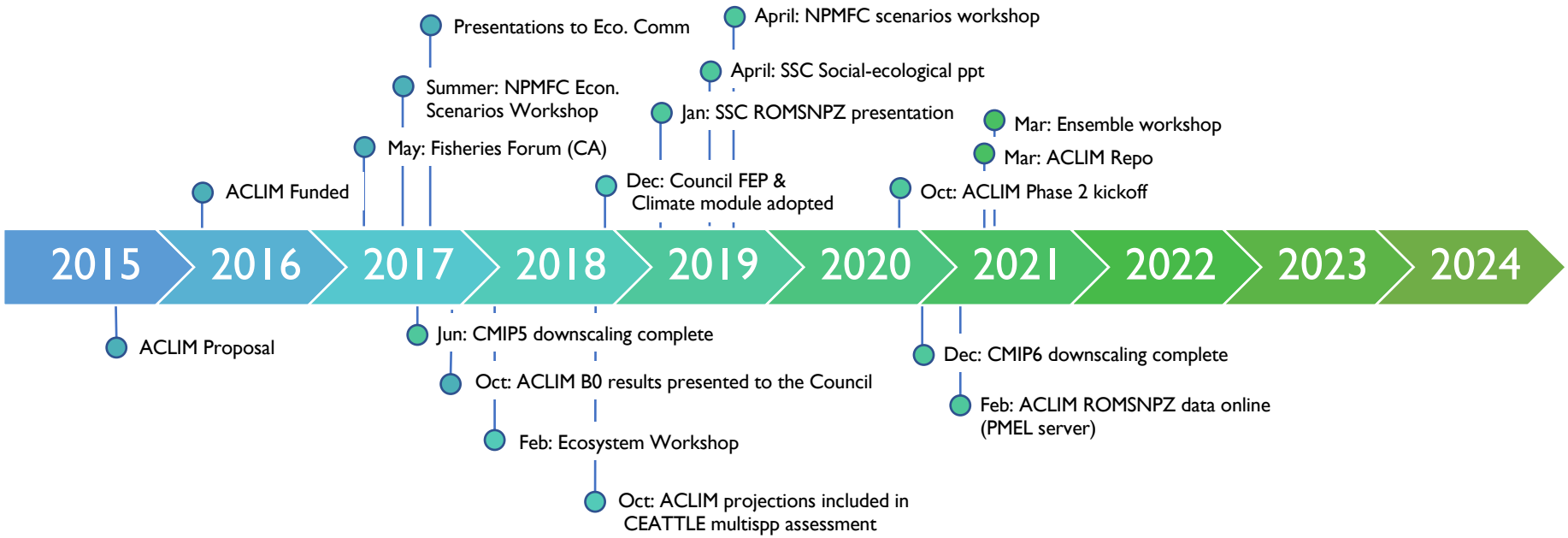
Unfished biomass (no harvest)





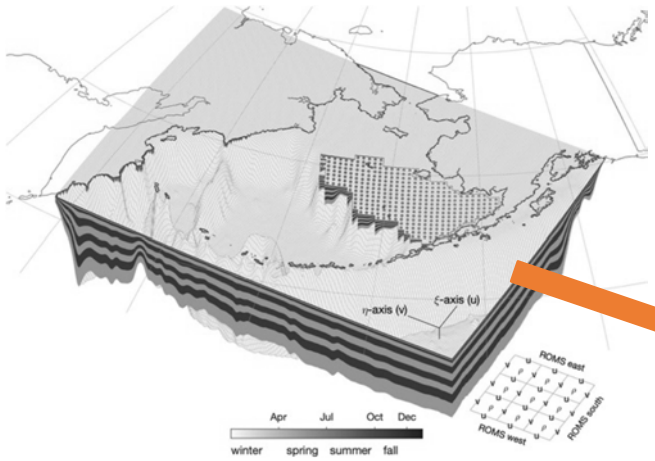
Holsman, K.K., Haynie, A.C., Hollowed, A.B. et al. Ecosystem-based fisheries management forestalls climate-driven collapse. Nat Commun 11, 4579 (2020). https://doi.org/10.1038/s41467-020-18300-3

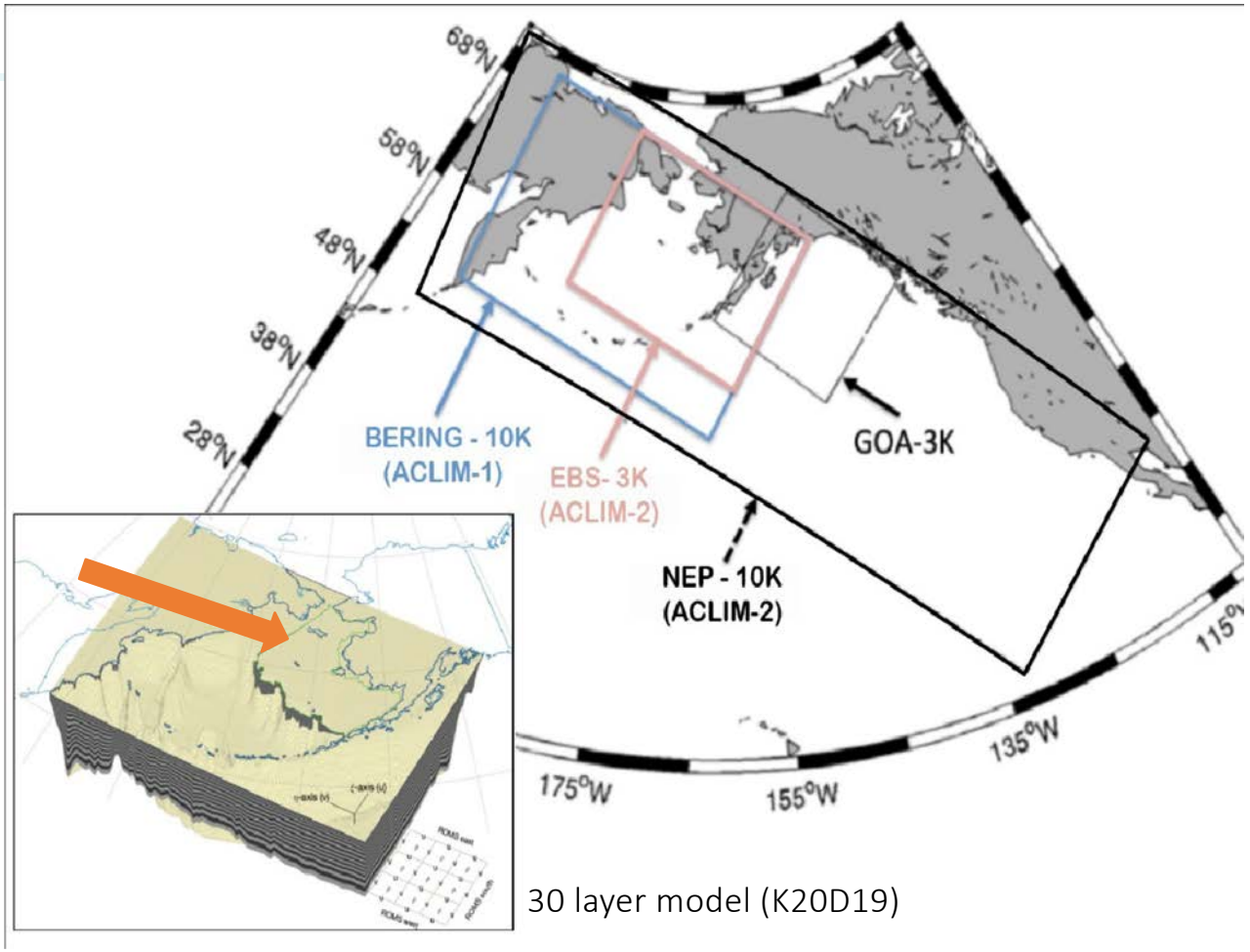
The Alaska Climate Integrated Modeling Project (Phase 2)



ACLIM Phase 2

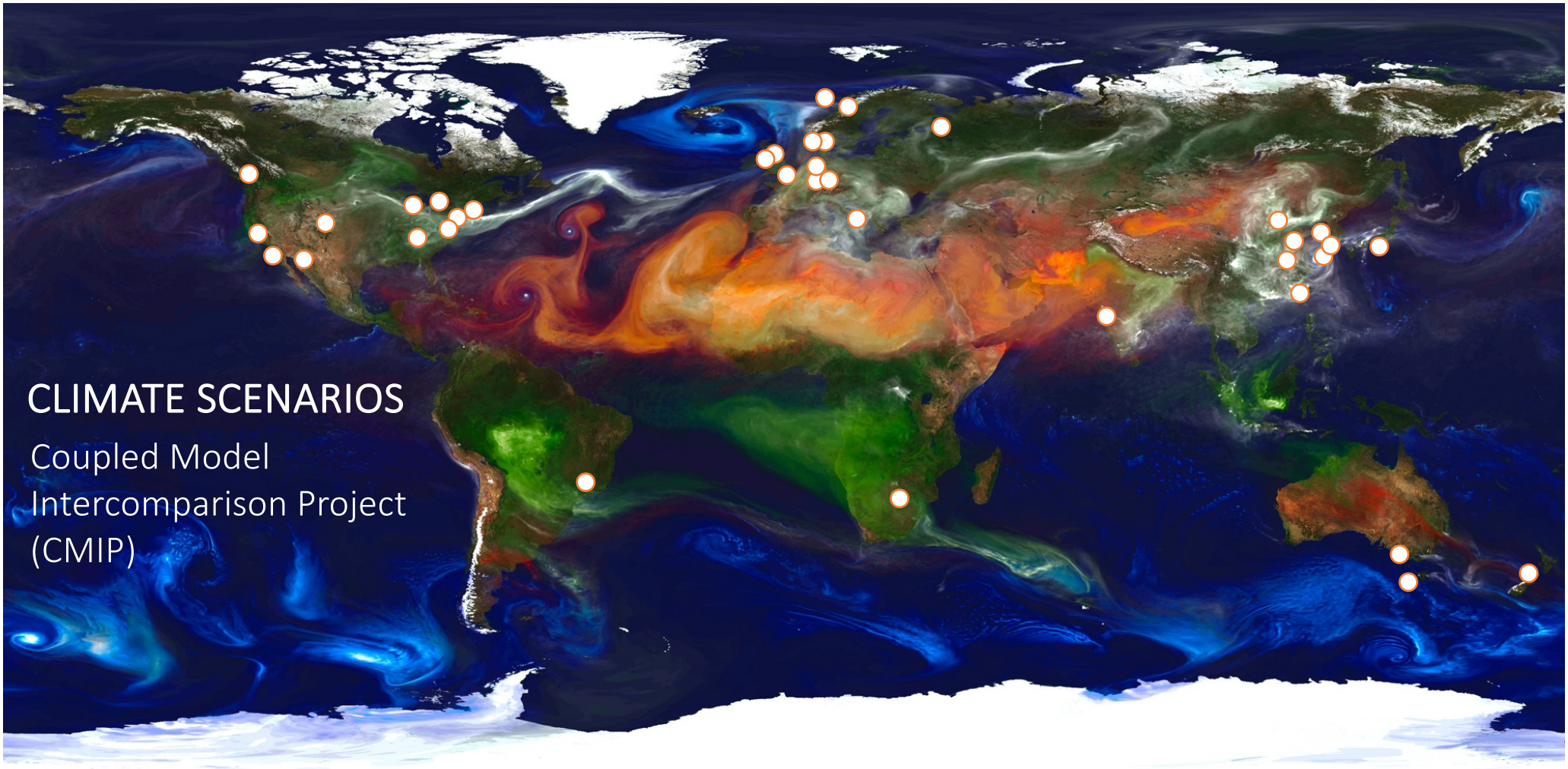
ACLIM 1 : 10layer model (H16)



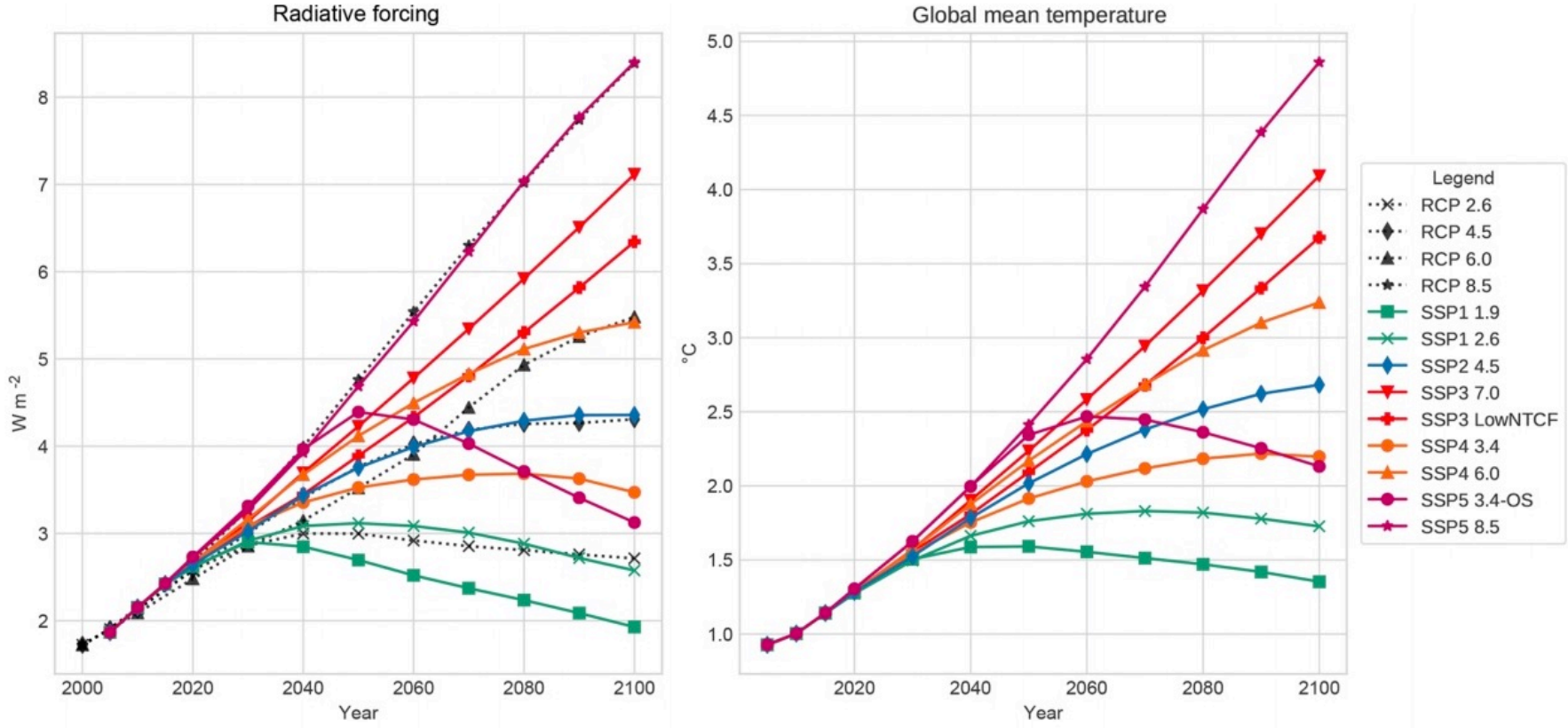


30 layer model (K20D19)

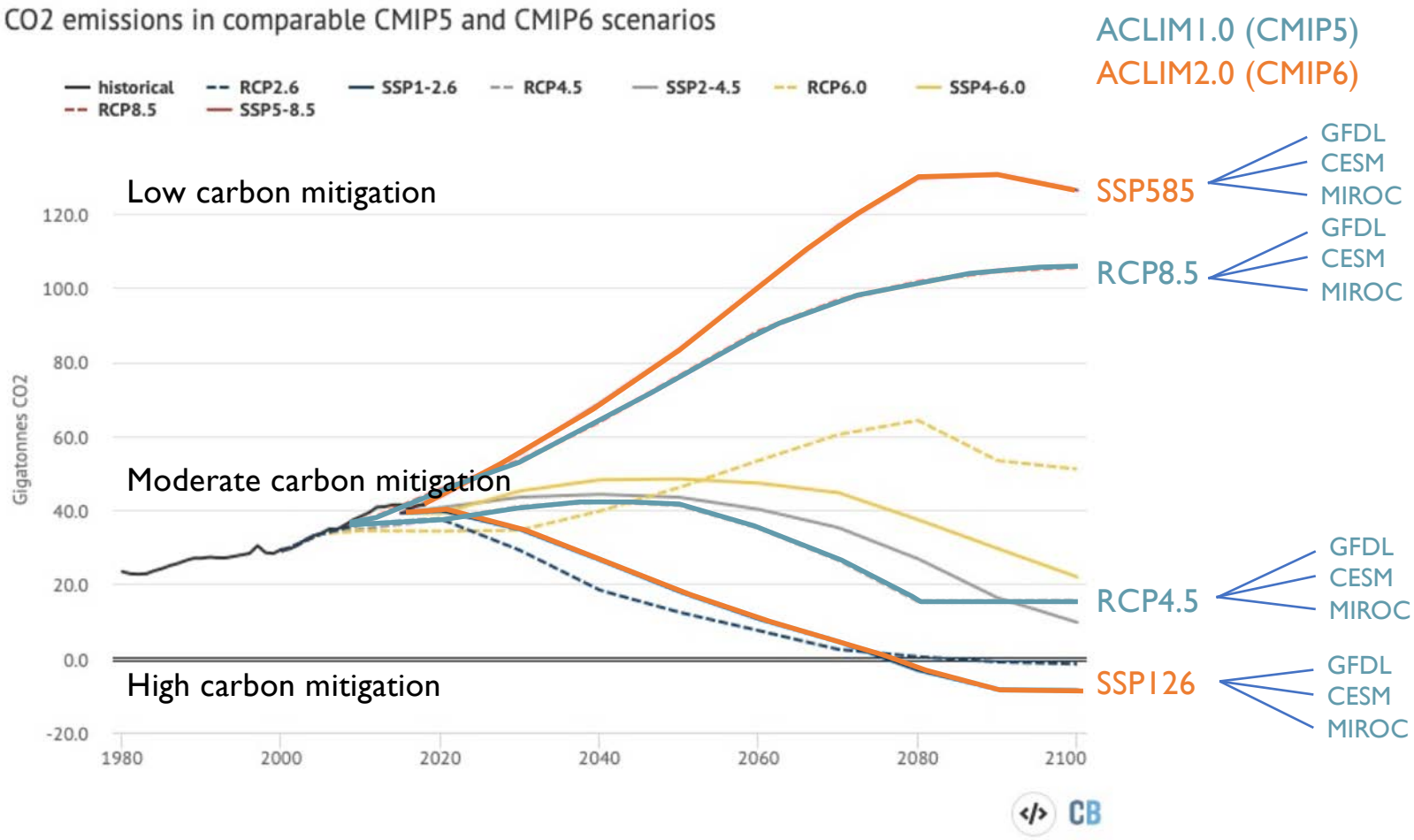
Hermann et al. 2013,2016, 2019; Kearney et al. 2020; Hollowed et al. 2020. Frontiers in Mar. Sci. doi: 10.3389/fmars.2019.00775



This portrait of global aerosols was produced by a GEOS-5 simulation at a 10-kilometer resolution. Dust (red) is lifted from the surface, sea salt (blue) swirls inside cyclones, smoke (green) rises from fires, and sulfate particles (white) stream from volcanoes and fossil fuel emissions.
Image credit: William Putman, NASA/Goddard https://www.nasa.gov/multimedia/imagegallery/image_feature_2393.html



Gidden et al. (2019). Global emissions pathways under different socioeconomic scenarios for use in CMIP6: a dataset of harmonized emissions trajectories through the end of the century. Geosci. Model Dev., 12, 1443–1475, 2019 https://doi.org/10.5194/gmd-12-1443-2019



Future RCP CO2 emissions scenarios featured in CMIP5 and their CMIP6 counterparts, as well as historical CO2 emissions (in black). Data from the SSP database; chart by Carbon Brief using Highcharts.

Getting Started with Bering10K Level 2 & 3 indices

K. Holsman and K. Aydin (Tutorial), A. Hermann, K. Kearney, W. Cheng, I. Ortiz (Bering10K)

The ACLIM Repository **github.com/kholsman/ACLIM2** is maintained by **Kirstin Holsman**, Alaska Fisheries Science Center, NOAA Fisheries, Seattle WA. Multiple programs and projects have supported the production and sharing of the suite of Bering10K hindcasts and projections. *Last updated: Mar 10, 2021*

1. Overview

This repository contains R code and Rdata files for working with netcdf-format data generated from the **downscaled ROMSNPZ modeling** of the ROMSNPZ Bering Sea Ocean Modeling team; Drs. Hermann, Cheng, Kearney, Pilcher,Ortiz, and Aydin. The code and R resources described in this tutorial are publicly available through the **ACLIM2 github repository** maintained by Kirstin Holsman as part of NOAA's **ACLIM project** for the Bering Sea. *See Hollowed et al. 2020 for more information about the ACLIM project.*

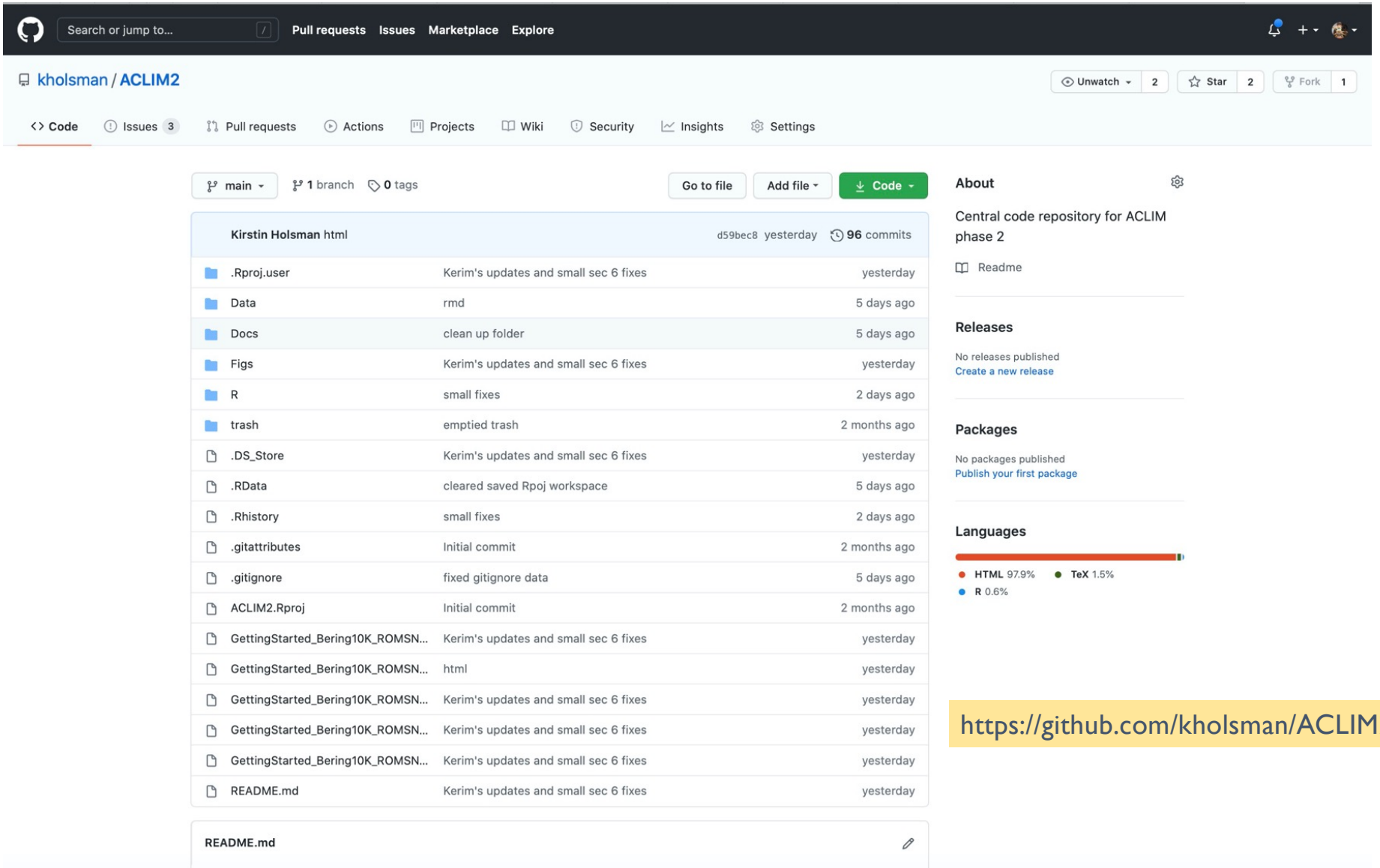
1.1. Resources

We **strongly recommend** reviewing the following documentation before using the data in order to understand the origin of the indices and their present level of skill and validation, which varies considerably across indices and in space and time:

- **The Bering10K Dataset documentation (pdf)**: A pdf describing the dataset, including full model descriptions, inputs for specific results, and a tutorial for working directly with the ROMS native grid (Level 1 outputs).
- **Bering10K Simulaton Variables (xlsx)**: A spreadsheet listing all simulations and the archived output variables associated with each, updated periodically as new simulations are run or new variables are made available.
- A **collection** of Bering10K ROMSNPZ model documentation (including the above files) is maintained by Kelly Kearney and will be regularly updated with new documentation and publications.

1.2 Guidlines for use and citation of the data

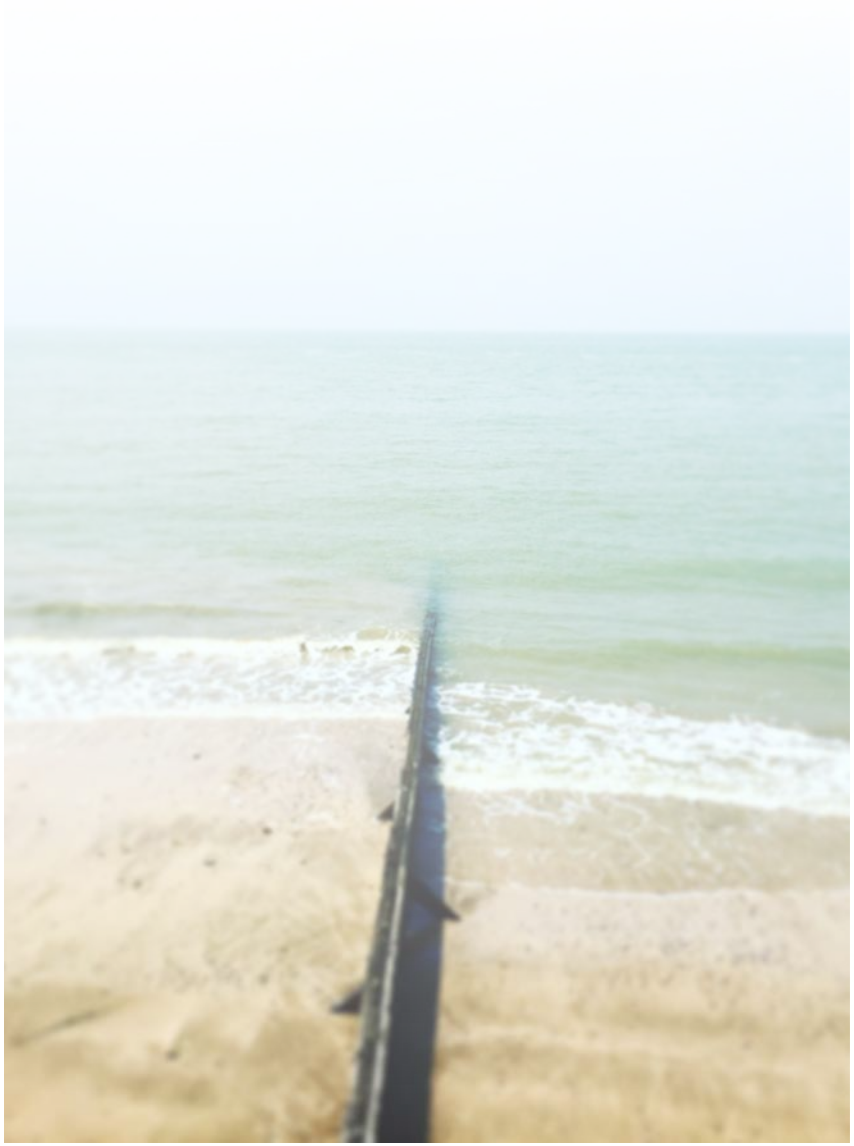
The data described here are published and publicly available for use, except as explicitly noted. However, for novel uses of the data, it is **strongly recommended** that you consult with and consider including at least one author from the ROMSNPZ team (Drs. Hermann, Cheng, Kearney, Pilcher, Aydin, Ortiz). There are multiple spatial and temporal caveats that are best



https://github.com/kholsman/ACLIM2

Email kirstin.holsman@noaa.gov if you are interested in attending

ACLIM2 WORKSHOP – APRIL 2021



ACLIM support

- ACLIM 1.0 funding:
  - Fisheries & the Environment (FATE)
  - Stock Assessment Analytical Methods (SAAM)
  - Climate Regimes & Ecosystem Productivity (CREP)
  - Economic and Human Dimensions Program, AFSC, OAR
  - NMFS Economics and Human Dimensions Program
  - NOAA Integrated Ecosystem Assessment Program (IEA)
  - NOAA Research Transition Acceleration Program (RTAP)
  - Alaska Fisheries Science Center
- ACLIM 2.0 funding:
  - NOAA's Coastal and Ocean Climate Applications (COCA) Climate and Fisheries Program
  - NOAA Integrated Ecosystem Assessment Program (IEA)
  - Alaska Fisheries Science Center

Collaboration support:

MAPP Bering Seasons & FATE EFH

- NPRB & BSIERP Team
- GOA-CLIM Team
- AFSC REEM, REFM, RACE
- ICES PICES Strategic Initiative on climate change and marine ecosystems (SICCME/S-CCME)
- NPFMC Climate change task force, the Ecosystem Committee of the NPFMC

GLOSSARY OF TERMS

- IPCC : UN Intergovernmental Panel on Climate Change
- NOAA : National Oceanic and Atmospheric Administration
- NMFS : National Marine Fisheries Service
- Council : North Pacific Fisheries Management Council
- CE - : “Climate Enhanced” -
- GCM : General Circulation Model (Global in scale)
- RCP : Representative (carbon) Concentration Pathway
- FEP : Fisheries Ecosystem Plan
- ROMS : Regional Ocean Modeling System
- NPZ : Nutrient Phytoplankton Zooplankton Model
- CEATTLE : Climate Enhanced Assessment with Temperature and Trophic Linkages & Energetics Model
- FEAST : Forage and Euphausiid Assessment in Space and Time model
- SES : coupled Social-Ecological System