Climate update

Dec 2024
Kirstin Holsman
NOAA Alaska Fisheries Science Center
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Credit: Kirstin Holsman

Today’s talk

Part 1: Climate challenges continue to grow, with uncertainty about future trajectories

Part 2: Climate-informed tools are available to support future sustainable fisheries (ACLIM)

Part 3: CEFI accelerates the capacity to deliver climate-informed tools and advice

1 Climate challenges continue to grow, with uncertainty about future trajectories

Credit: Kirstin Holsman

WORLD METEOROLOGICAL ORGANIZATION
Weather Climate Water

Greenhouse gases reached record observed levels in 2023.

Real time data indicate that they continued to rise in 2024.

CO_2 420.0 ppm ± 0.2
151% of pre-industrial levels

CH_4 1934 ppb ± 2
265% of pre-industrial levels.

N_2O 336.9 ppb ± 0.1
124% of pre-industrial levels

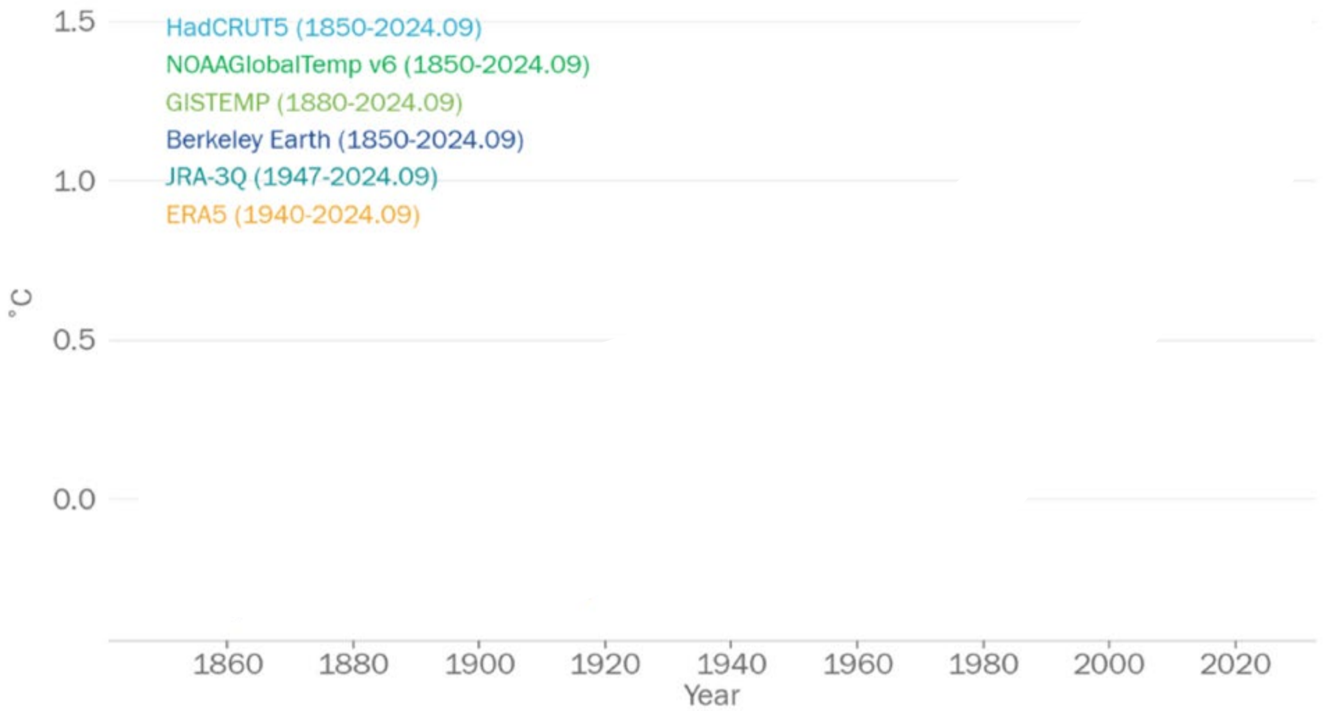

Figure 1: Annual global mean temperature anomalies (relative to 1850–1900) from 1850 to 2024 from six datasets. The 2024 average is based on data from January-September.

January-September 2024 was 1.54±0.13°C above the pre-industrial average.

https://wmo.int/publication-series/state-of-climate-2024-update-cop29

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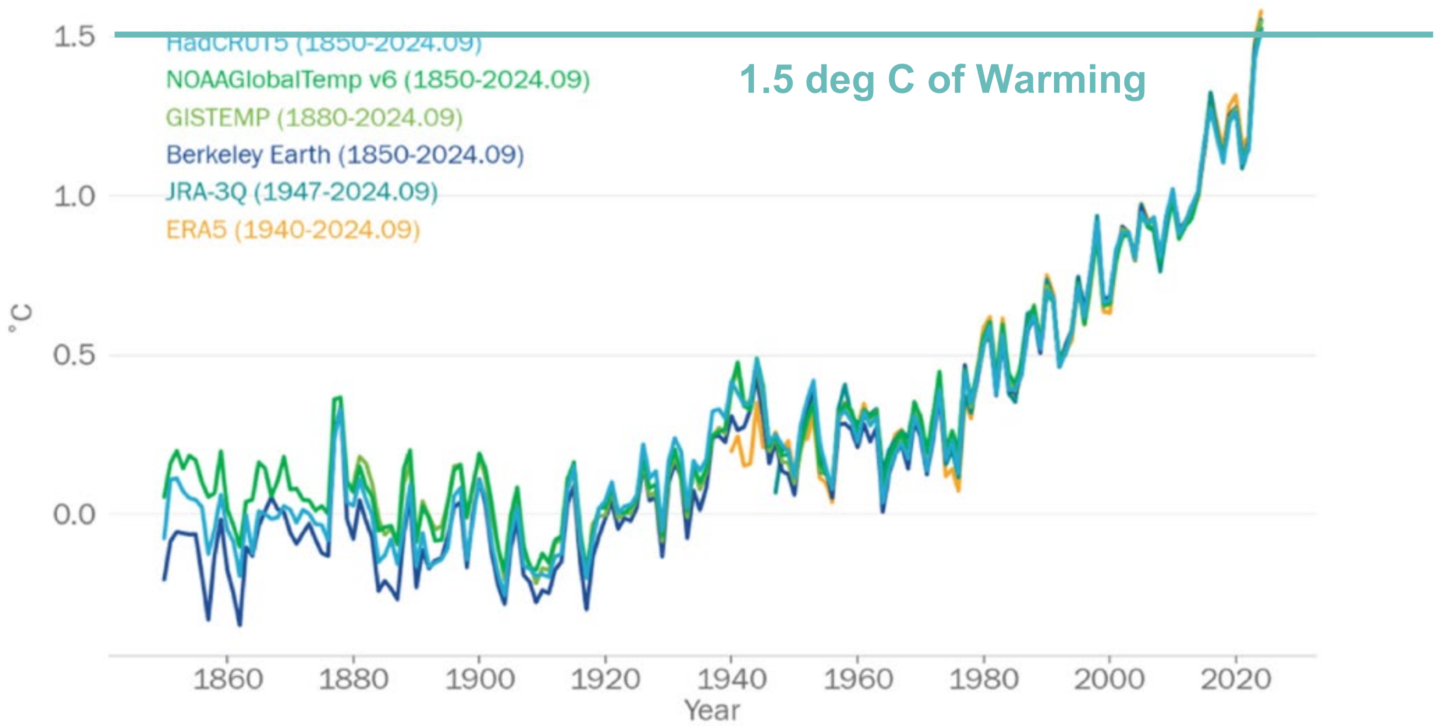
2.0 C of Warming : Critical Tipping point



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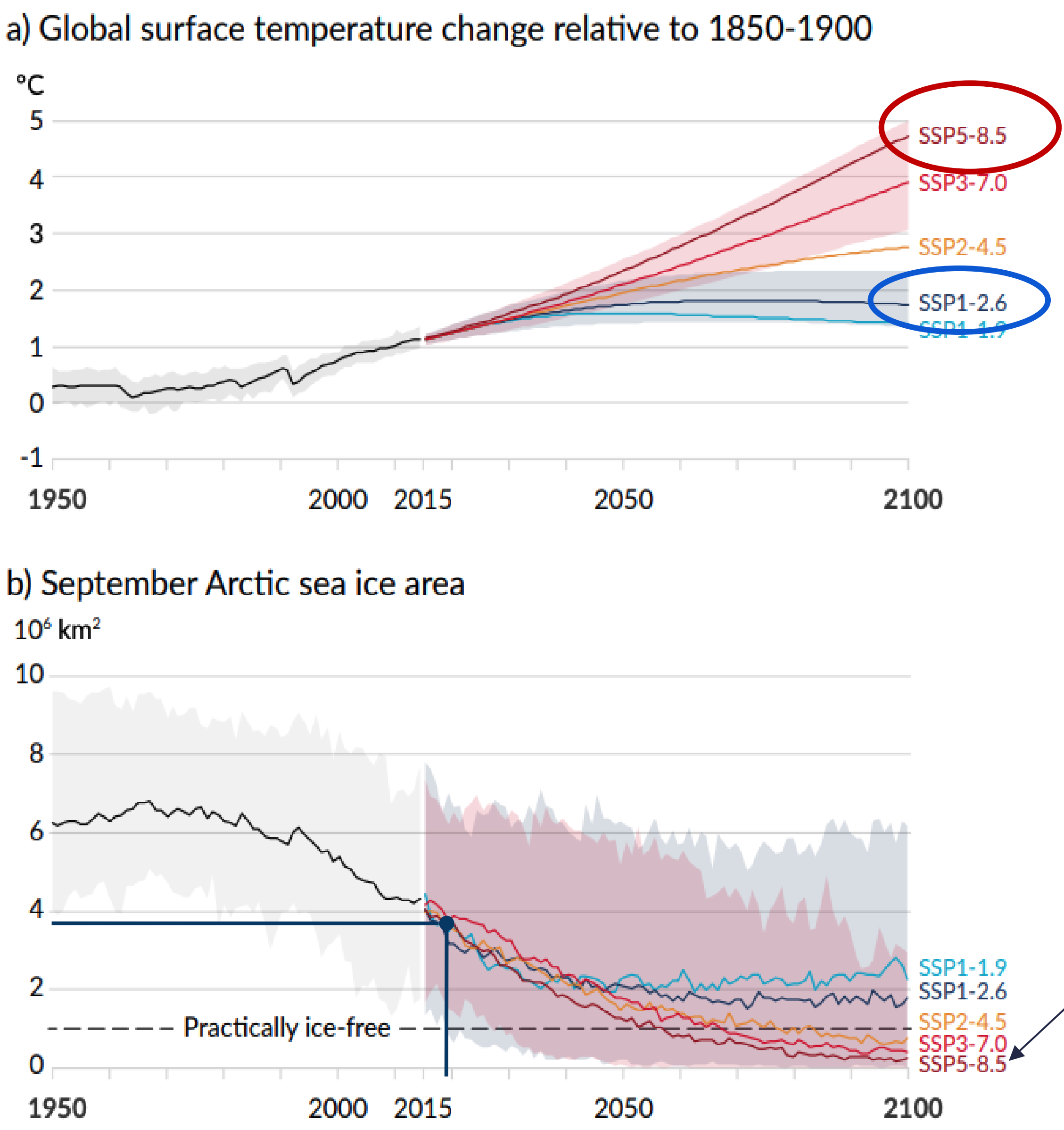
Climate change is expected to continue to impact AK Ecosystems & Fisheries



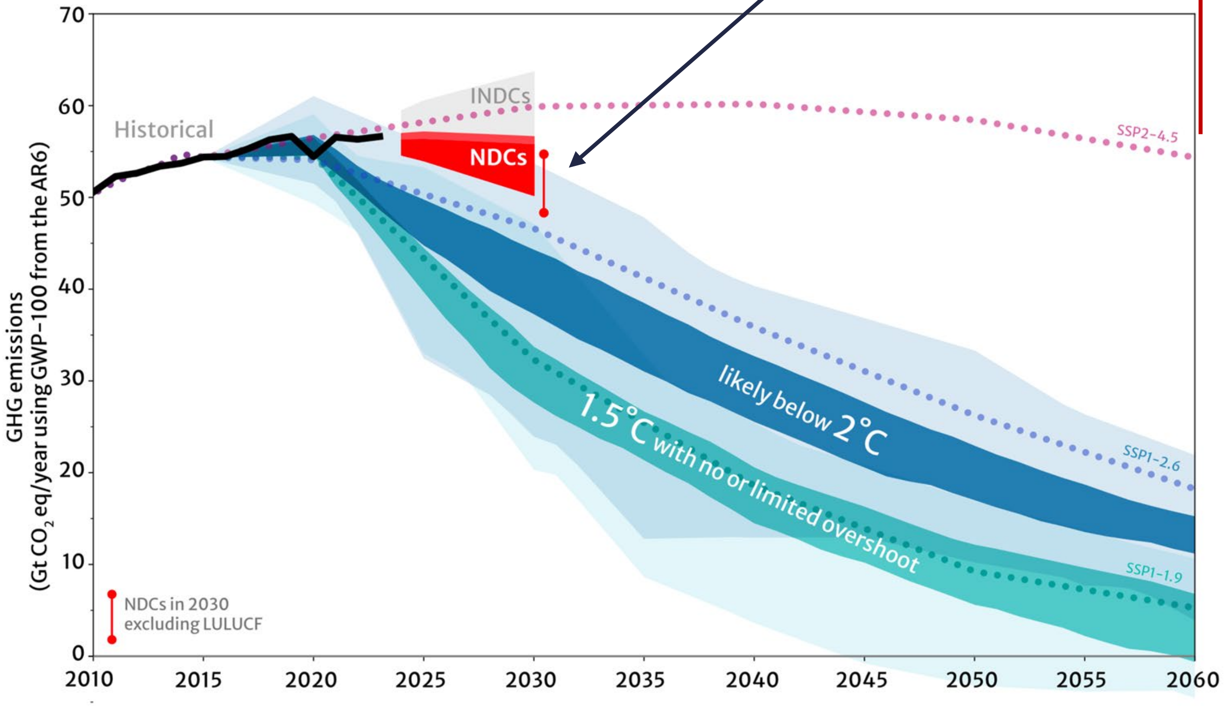
Warming will continue and is greater in scenarios with **low CO_2 mitigation and higher warming**

Sea Ice will continue to decline, more so under scenarios with **high global warming and low CO_2 mitigation**

Figures from the IPCC AR6 WGI Summary for Policymakers: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf

UNFCCC 2024 Nationally Determined Contributions (NDCs) Synthesis report

With full implementation of the 2022 revised NDCs and conditional elements



ACLIM found fisheries have higher risk above this (SSP585, RCP8.5)

ACLIM found fisheries have lower risk in this scenario (SSP126)

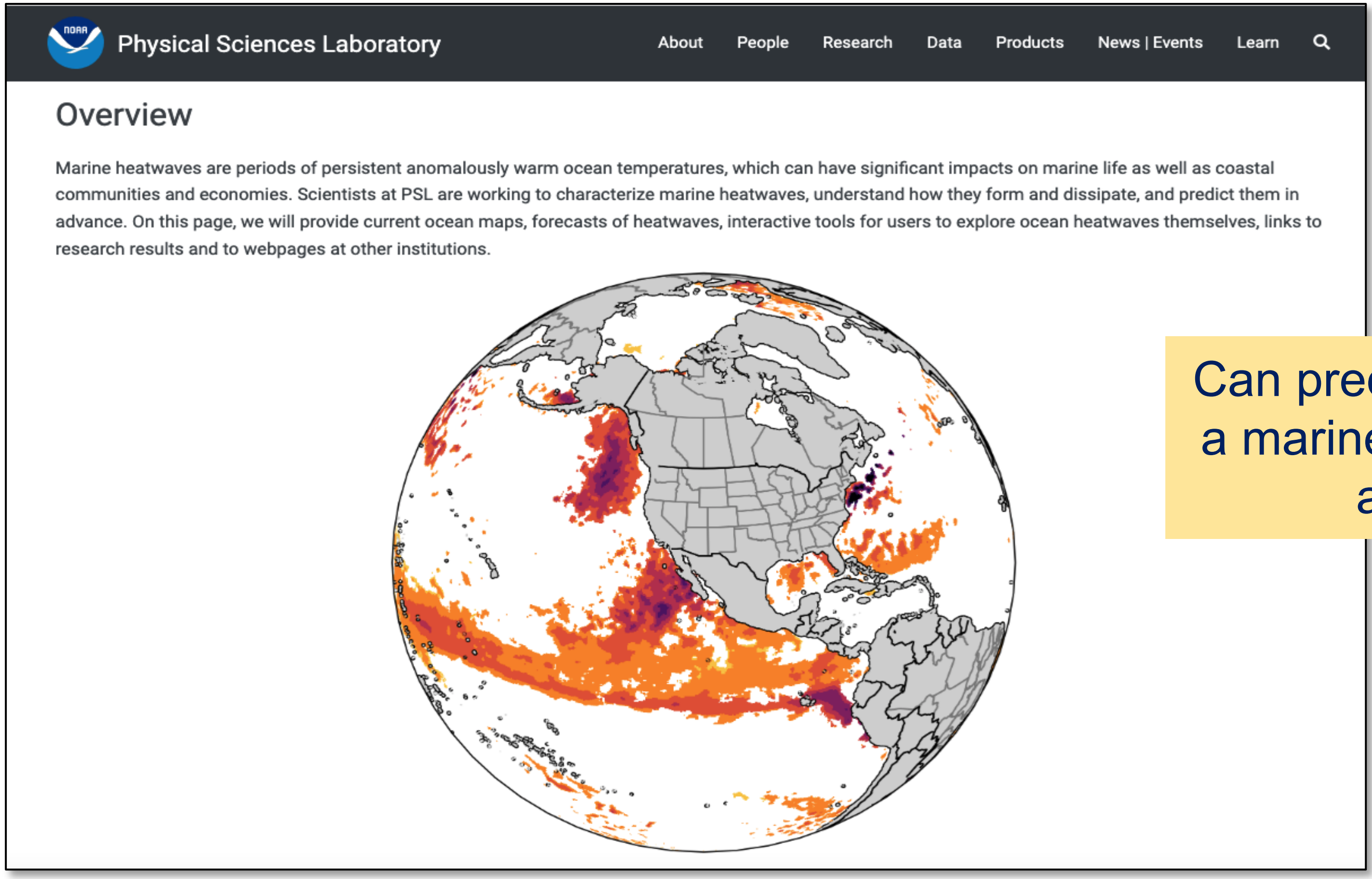
Emissions figure: https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs
Paris Agreement Figure: https://sustainability.yale.edu/explainers/yale-experts-explain-paris-climate-agreement

2 Climate-informed tools are available to support future sustainable fisheries

Credit: Kirstin Holsman

New predictive tools can help fisheries prepare & plan

psl.noaa.gov/marine-heatwaves



Can predict the probability of a marine heatwave 1-12 mo ahead of time

Jacox et al. 2022. www.nature.com/articles/s41586-022-04573-9

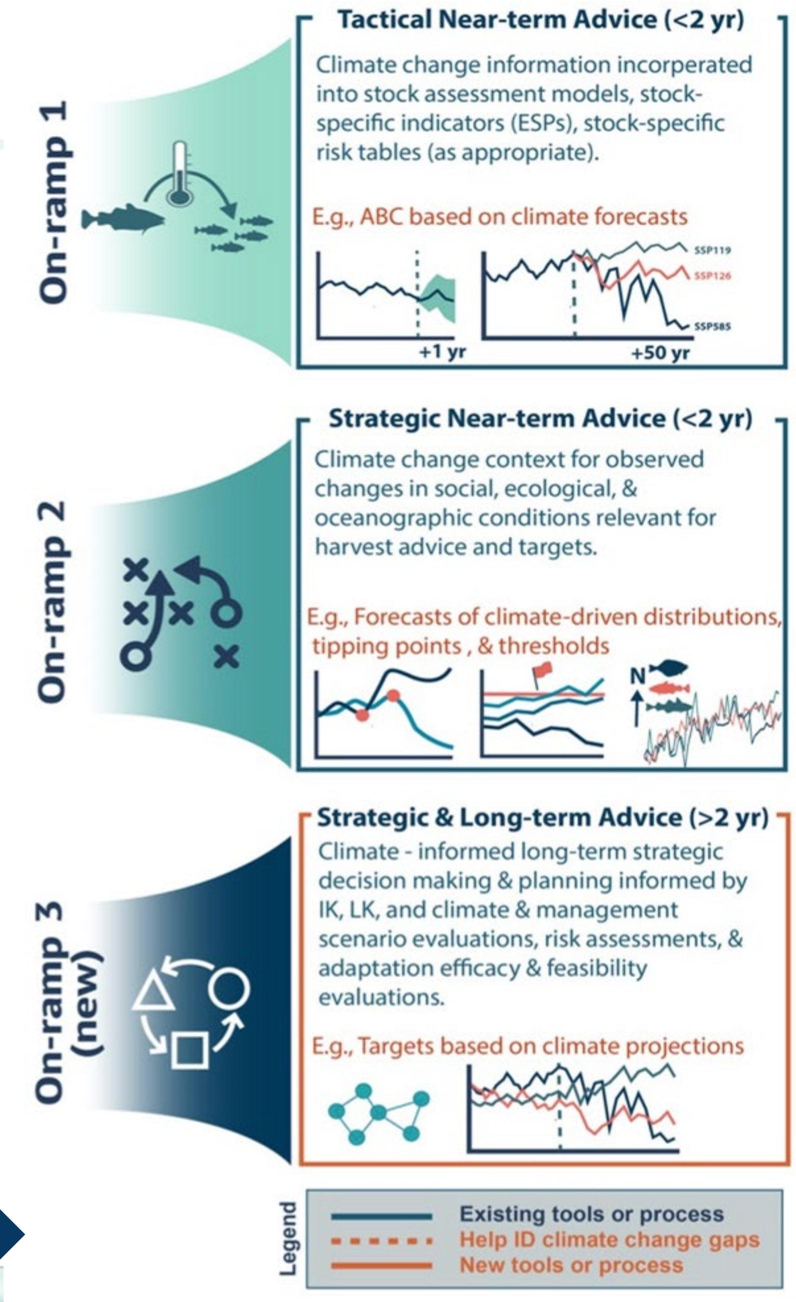
Climate "on ramps" through the Council process

Climate informed annual* stock and ecosystem assessments & EBFM advice

Climate information in near-term ecosystem based management targets

Climate-ready Ecosystem Based Fisheries Management planning, information & design

KEY: Matching climate information & projections to the scale of decision making & advice



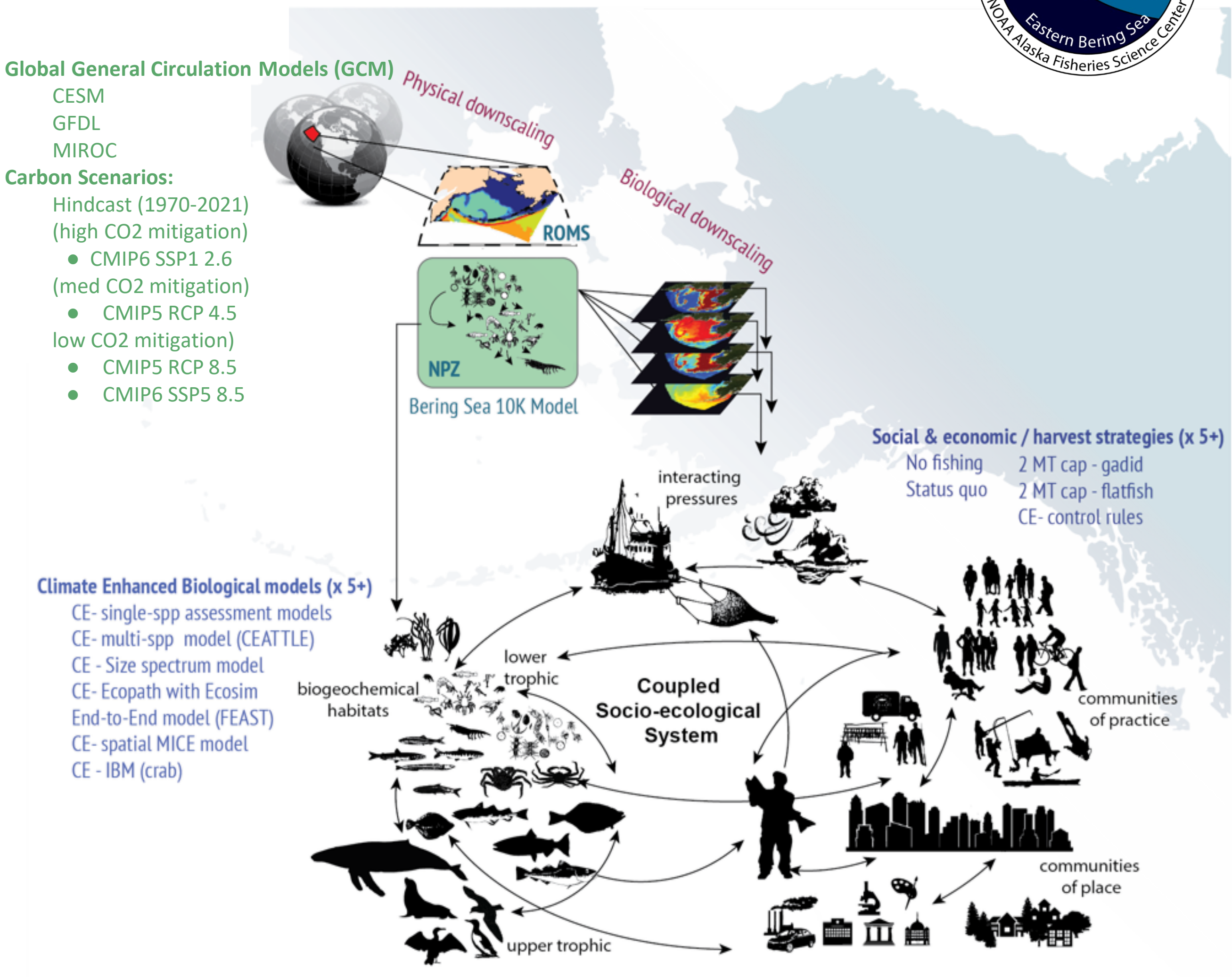
https://www.npfmc.org/climatechangetaskforce/

AFSC Integrated Climate Modeling Projects

ACLIM
The Alaska Climate Integrated Modeling Project
Eastern Bering Sea
NOAA Alaska Fisheries Science Center

GOA-CLIM
The GOA Climate Integrated Modeling Project
Gulf of Alaska
NOAA Alaska Fisheries Science Center

The Alaska Climate Integrated Modeling Project



Goal: To address climate information needs with best available science & tools

What to expect?

- Project physical and ecological conditions under levels of climate change (levels of global carbon mitigation)
- Characterize uncertainty

What can be done?

- Evaluate effectiveness of adaptation actions including those supported by fisheries management

Scenarios form the basis for comparative simulations & Management Strategy Evaluations

Hollowed et al. 2020. https://doi.org/10.3389/fmars.2019.00775

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

ACLIM3 Team

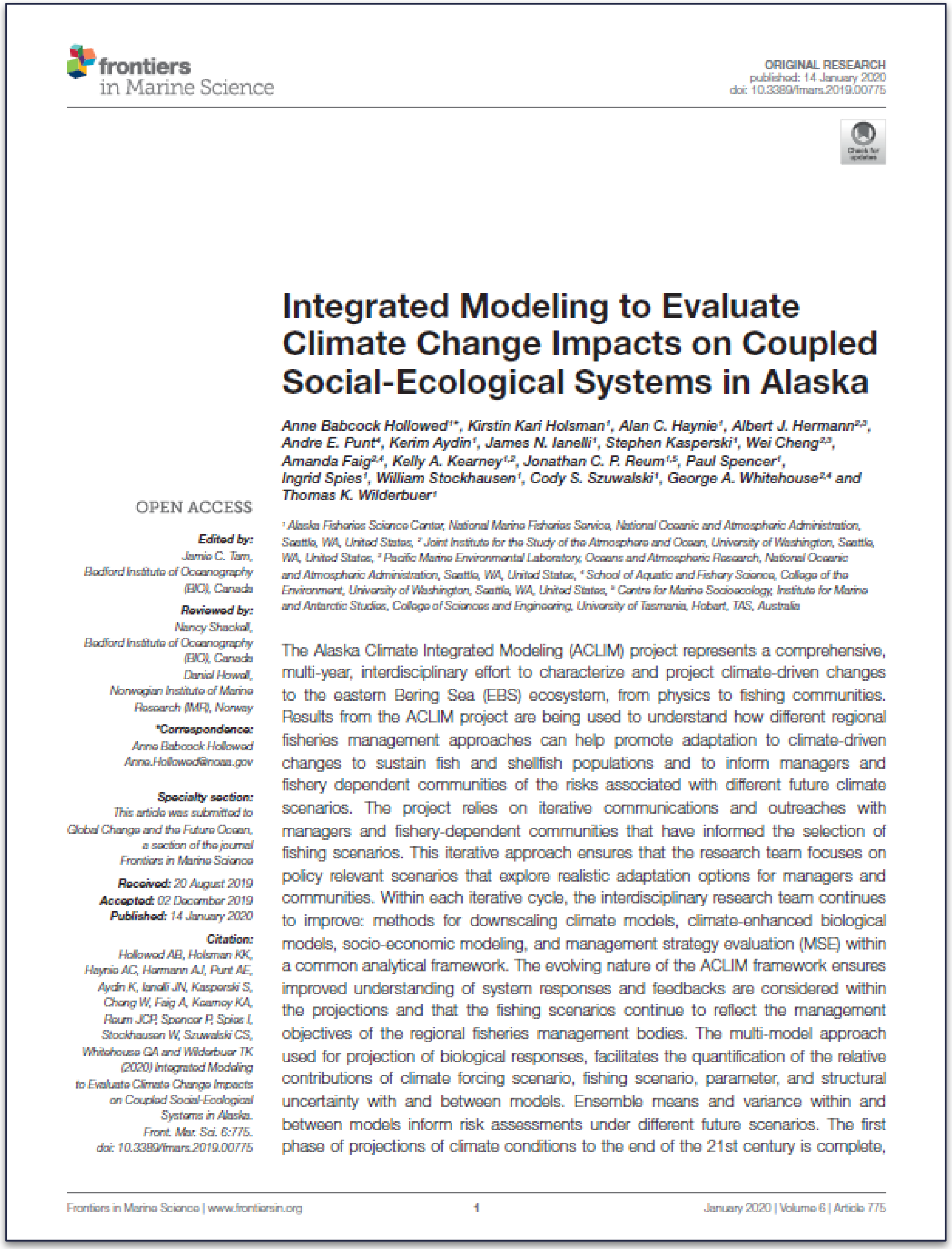
Supporting climate resilience through climate-informed Ecosystem Based Management advice

Kirstin Holsman, Sarah Wise, Andre Punt, Albert Hermann, Cheryl Barnes, Cody Szuwalski, Kerim Aydin, Kelly Kearney, Anne Hollowed, Alberto Rovellini, Andrea Havron, Andy Whitehouse, Anna Amalka Sulc, Carey McGilliard, Catherine Moncrieff, Darren Pilcher, Diana Stram, Ed Farley, Elizabeth McHuron, Elizabeth Siddon, Ellen Yasumiishi, Grant Adams, Ingrid Spies, Ivonne Ortiz, James Ianelli, James Thorson, Jean Lee, Jennifer Bigman, Jeremy Sterling, Jodi Pirtle, Jonathan Reum, Kalei Shotwell, Kate Haapala, Kelly Kearney, Lorenzo Ciannelli, Mabel Baldwin-Schaeffer, Maggie Mooney-Seus, Martin Dorn, Maurice Goodman, Meaghan Bryan, Melissa Haltuch, Melissa Parks, Michael Litzow, Mike Dalton, Molly Graham, Patricia Pinto da Silva, Paul Spencer, Sarah Stone, Serena Fitka, Steve Barbeaux, Trond Kristiansen, Wei Cheng, William Stockhausen, Lia Domke, Anne Beaudreau, Justin Hansen, Angela Abolhassani, Matt Callahan, Brett Holycross

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

Hollowed et al. 2020

ACLIM overview paper



frontiers in Marine Science

ORIGINAL RESEARCH
published: 14 January 2020
doi: 10.3389/fmars.2019.00775

Integrated Modeling to Evaluate Climate Change Impacts on Coupled Social-Ecological Systems in Alaska

Anne Babcock Hollowed[1], Kirstin Kari Holsman[1], Alan C. Haynie[1], Albert J. Hermann[2,3], Andre E. Punt[4], Kerim Aydin[1], James N. Ianelli[1], Stephen Kasperski[1], Wei Cheng[2,3], Amanda Faig[2,4], Kelly A. Kearney[1,2], Jonathan C. P. Reum[1,5], Paul Spencer[1], Ingrid Spies[1], William Stockhausen[1], Cody S. Szuwalski[1], George A. Whitehouse[2,4] and Thomas K. Wilderbuer[1]*

[1] Alaska Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, WA, United States, [2] Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, WA, United States, [3] Pacific Marine Environmental Laboratory, Oceans and Atmospheric Research, National Oceanic and Atmospheric Administration, Seattle, WA, United States, [4] School of Aquatic and Fishery Science, College of the Environment, University of Washington, Seattle, WA, United States, [5] Centre for Marine Socioecology, Institute for Marine and Antarctic Studies, College of Sciences and Engineering, University of Tasmania, Hobart, TAS, Australia

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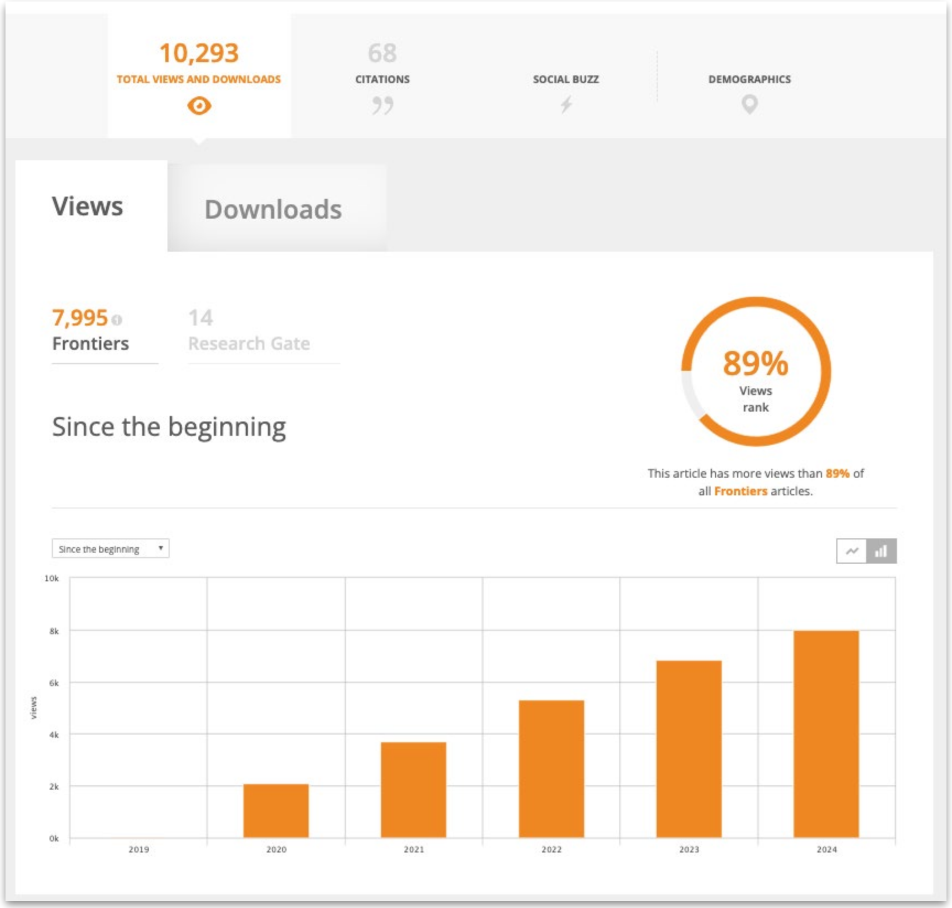
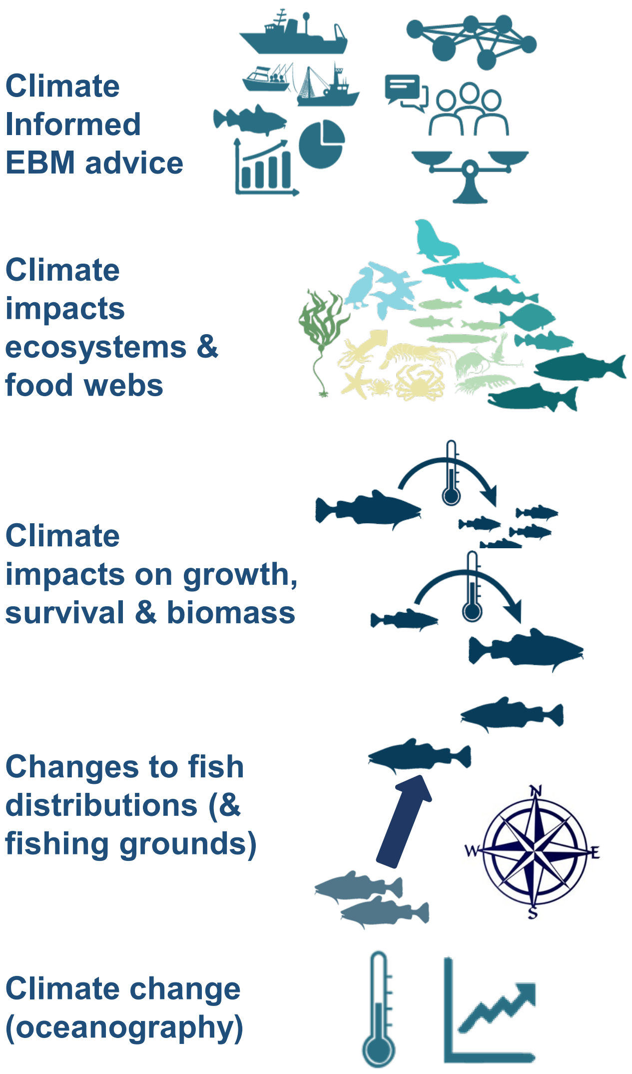
Hollowed AB, Holsman KK, Haynie AC, Hermann AJ, Punt AE, Aydin K, Ianelli JN, Kasperski S, Cheng W, Faig A, Kearney KA, Reum JCP, Spencer P, Spies I, Stockhausen W, Szuwalski CS, Whitehouse GA and Wilderbuer TK (2020) Integrated Modeling to Evaluate Climate Change Impacts on Coupled Social-Ecological Systems in Alaska. Front. Mar. Sci. 6:775. doi: 10.3389/fmars.2019.00775

The Alaska Climate Integrated Modeling (ACLIM) project represents a comprehensive, multi-year, interdisciplinary effort to characterize and project climate-driven changes to the eastern Bering Sea (EBS) ecosystem, from physics to fishing communities. Results from the ACLIM project are being used to understand how different regional fisheries management approaches can help promote adaptation to climate-driven changes to sustain fish and shellfish populations and to inform managers and fishery dependent communities of the risks associated with different future climate scenarios. The project relies on iterative communications and outreaches with managers and fishery-dependent communities that have informed the selection of fishing scenarios. This iterative approach ensures that the research team focuses on policy relevant scenarios that explore realistic adaptation options for managers and communities. Within each iterative cycle, the interdisciplinary research team continues to improve: methods for downscaling climate models, climate-enhanced biological models, socio-economic modeling, and management strategy evaluation (MSE) within a common analytical framework. The evolving nature of the ACLIM framework ensures improved understanding of system responses and feedbacks are considered within the projections and that the fishing scenarios continue to reflect the management objectives of the regional fisheries management bodies. The multi-model approach used for projection of biological responses, facilitates the quantification of the relative contributions of climate forcing scenario, fishing scenario, parameter, and structural uncertainty with and between models. Ensemble means and variance within and between models inform risk assessments under different future scenarios. The first phase of projections of climate conditions to the end of the 21st century is complete,



Also see list of 20+ publications at end of ppt

Key Takeaways from ACLIM to date

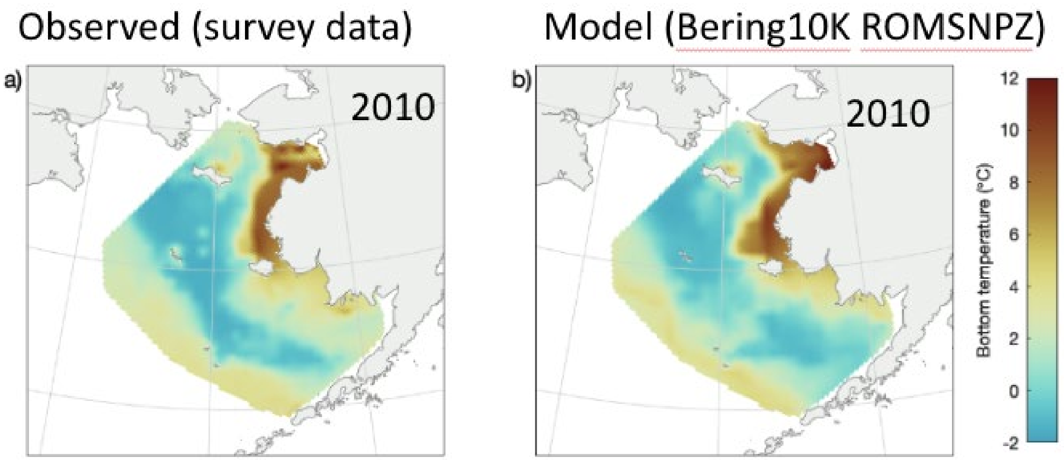


1. Need to account for ecosystem-wide productivity changes
2. Manage predator-prey Interactions using new approaches
3. Need to (and can) adapt to climate-driven species range shifts
4. Expand Ecosystem-Based Fisheries Management through coordination and collaboration
5. Address uncertainty with ensembles and participatory scenario planning
6. Incorporate socio-economic resilience into planning and response
7. Strengthen research and monitoring infrastructure

Key Outcomes of ACLIM to date

1. **Provided baseline engineering capacity for ocean and ecosystems predictions and forecasts**
2. Identified key couplings, and gaps and needs in linked climate- oceanographic- biological- social-economic models
3. Evaluated trajectories under future scenarios, alternative management strategies, alternative harvest control rules → emergent understanding of common pitfalls and best practices
4. Sustained community of practice for climate-informed advice, including support for partnership building around adaptation planning

High-res model reproduces the Bering Sea environment



Kearney K (2021). U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-415, 40 p. link.

Supporting Publications

Szuwalski et al. (2022, 2023), Pilcher et al. (2022), Reum et al. (2020), Whitehouse et al. (2021), Cheng et al. (2021,2023), Hermann et al. (2021,2023), Hollowed et al. (2022), Thorson et al. (2021)

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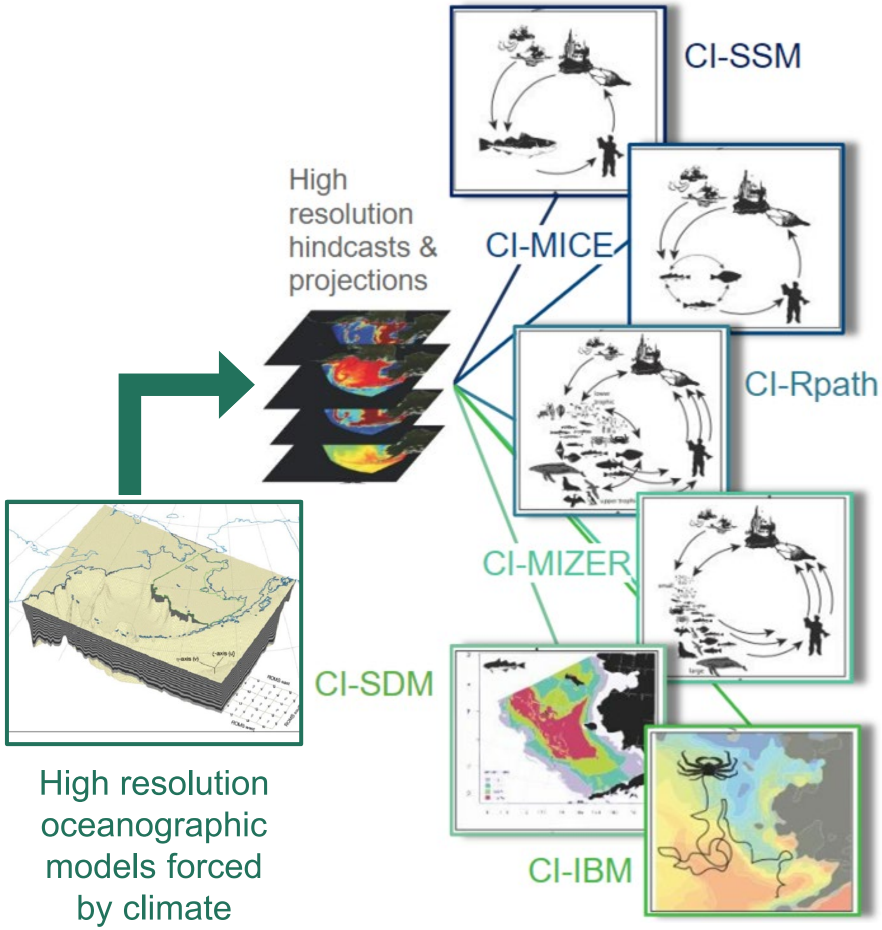

Supporting Publications

Goodman et al. (2024), Punt et al. (2023), Szuwalski et al. (2023), Olmos et al. (2023), McHuron et al. (2024), Barnes et al. (2022), Thorson et al. (2021), Whitehouse et al. (2021), Kearney et al (2020), Pilcher et al. (2022), Hollowed et al. (2020).

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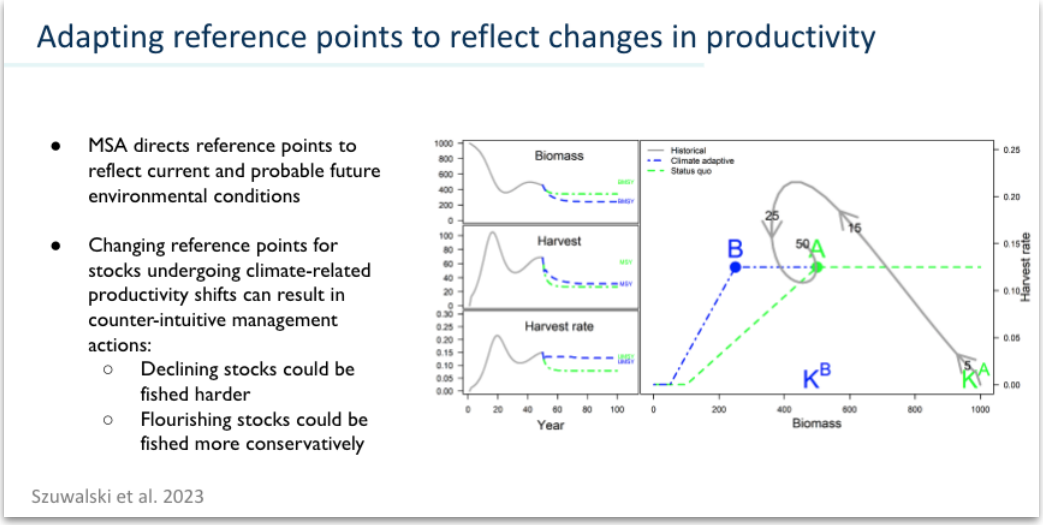
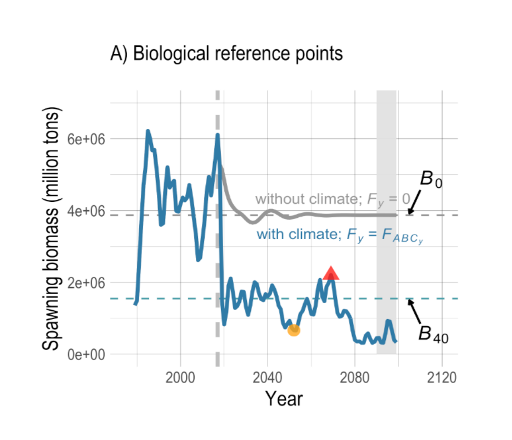
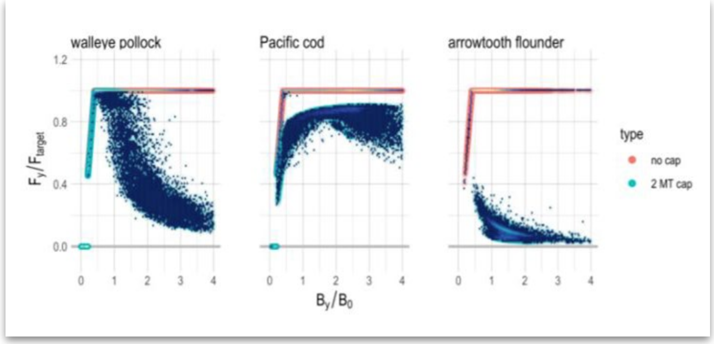


SSB targets under Climate Change; HCRs; 2 mt cap effects





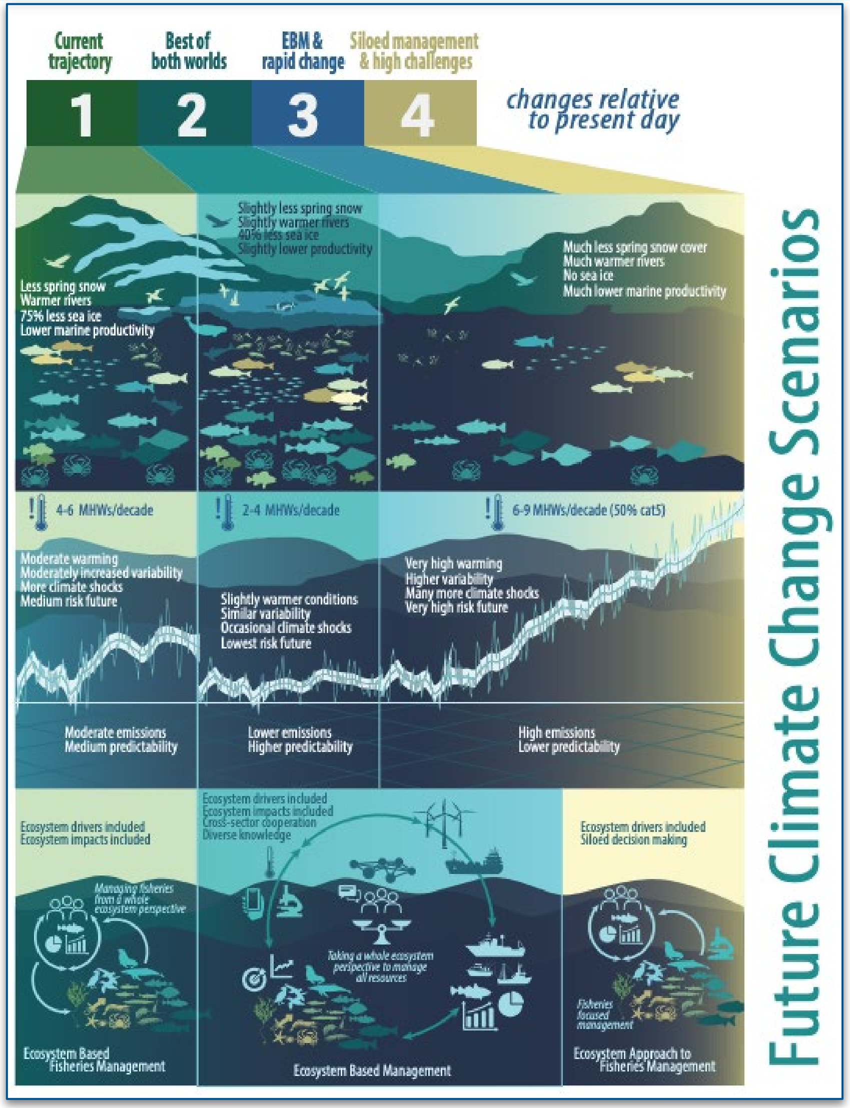
Holsman et al. 2020. https://www.nature.com/articles/s41467-020-18300-3

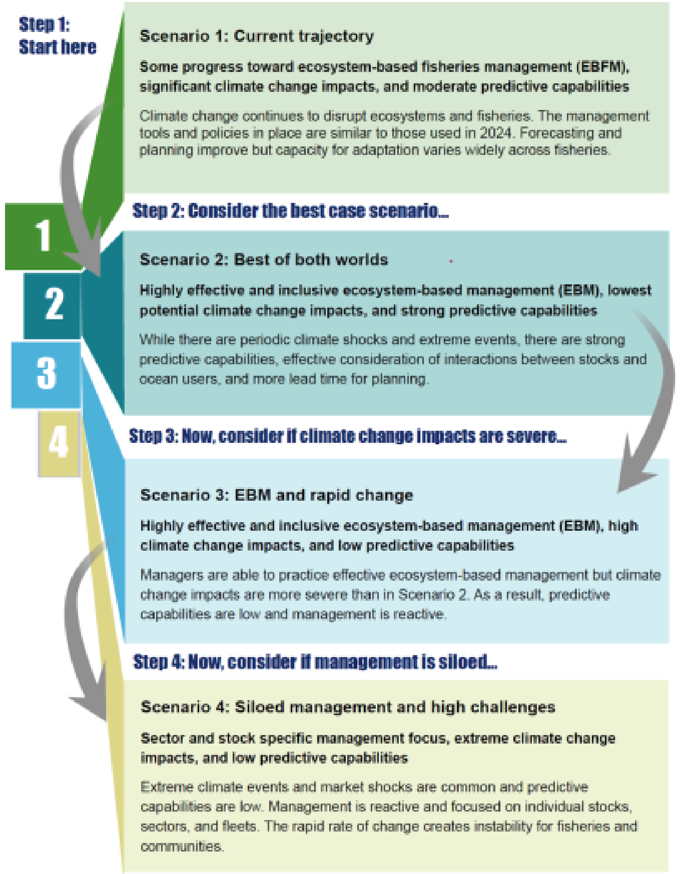
Supporting Publications

Szuwalski et al. (2022, 2023), Pilcher et al. (2022), Reum et al. (2020), Whitehouse et al. (2021), Holsman et al. (2020), Hollowed et al. (2024), Barnes et al., (2022), Hermann et al. (2021,2023), Cheng et al. (2021,2023), Punt et al. (2023), Goodman et al. (2024), McHuron et al. (2024), Punt et al. (2023)

June 2024 NPFMC Climate Scenarios Workshop

Based on ACLIM scenarios, updated by CCTF and refined by CSW planning group





Discussion Roadmap

Step 1: Start here

Scenario 1: Current trajectory

Some progress toward ecosystem-based fisheries management (EBFM), significant climate change impacts, and moderate predictive capabilities

Climate change continues to disrupt ecosystems and fisheries. The management tools and policies in place are similar to those used in 2024. Forecasting and planning improve but capacity for adaptation varies widely across fisheries.

Step 2: Consider the best case scenario...

Scenario 2: Best of both worlds

Highly effective and inclusive ecosystem-based management (EBM), lowest potential climate change impacts, and strong predictive capabilities

While there are periodic climate shocks and extreme events, there are strong predictive capabilities, effective consideration of interactions between stocks and ocean users, and more lead time for planning.

Step 3: Now, consider if climate change impacts are severe...

Scenario 3: EBM and rapid change

Highly effective and inclusive ecosystem-based management (EBM), high climate change impacts, and low predictive capabilities

Managers are able to practice effective ecosystem-based management but climate change impacts are more severe than in Scenario 2. As a result, predictive capabilities are low and management is reactive.

Step 4: Now, consider if management is siloed...

Scenario 4: Siloed management and high challenges

Sector and stock specific management focus, extreme climate change impacts, and low predictive capabilities

Extreme climate events and market shocks are common and predictive capabilities are low. Management is reactive and focused on individual stocks, sectors, and fleets. The rapid rate of change creates instability for fisheries and communities.

Reflect back: what is the set of tools or processes that work in all scenarios?

Key Outcomes of ACLIM to date

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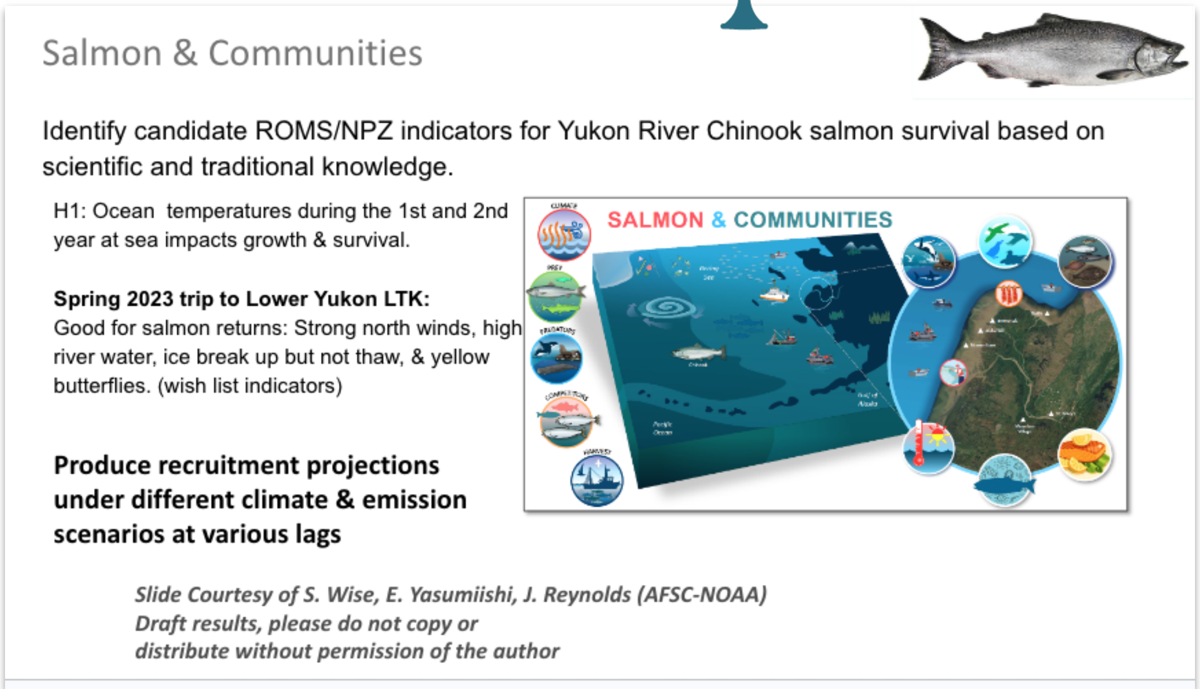
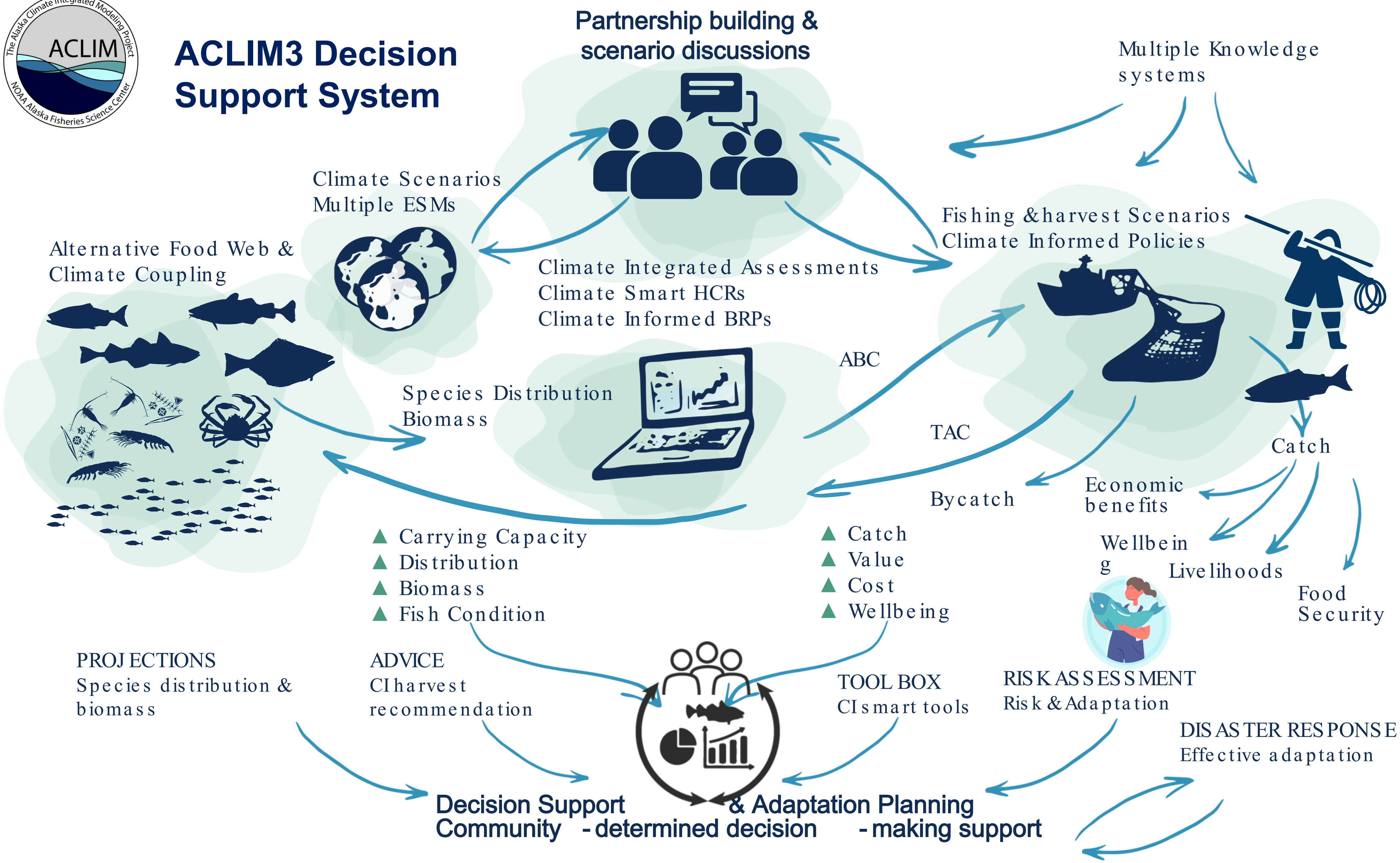


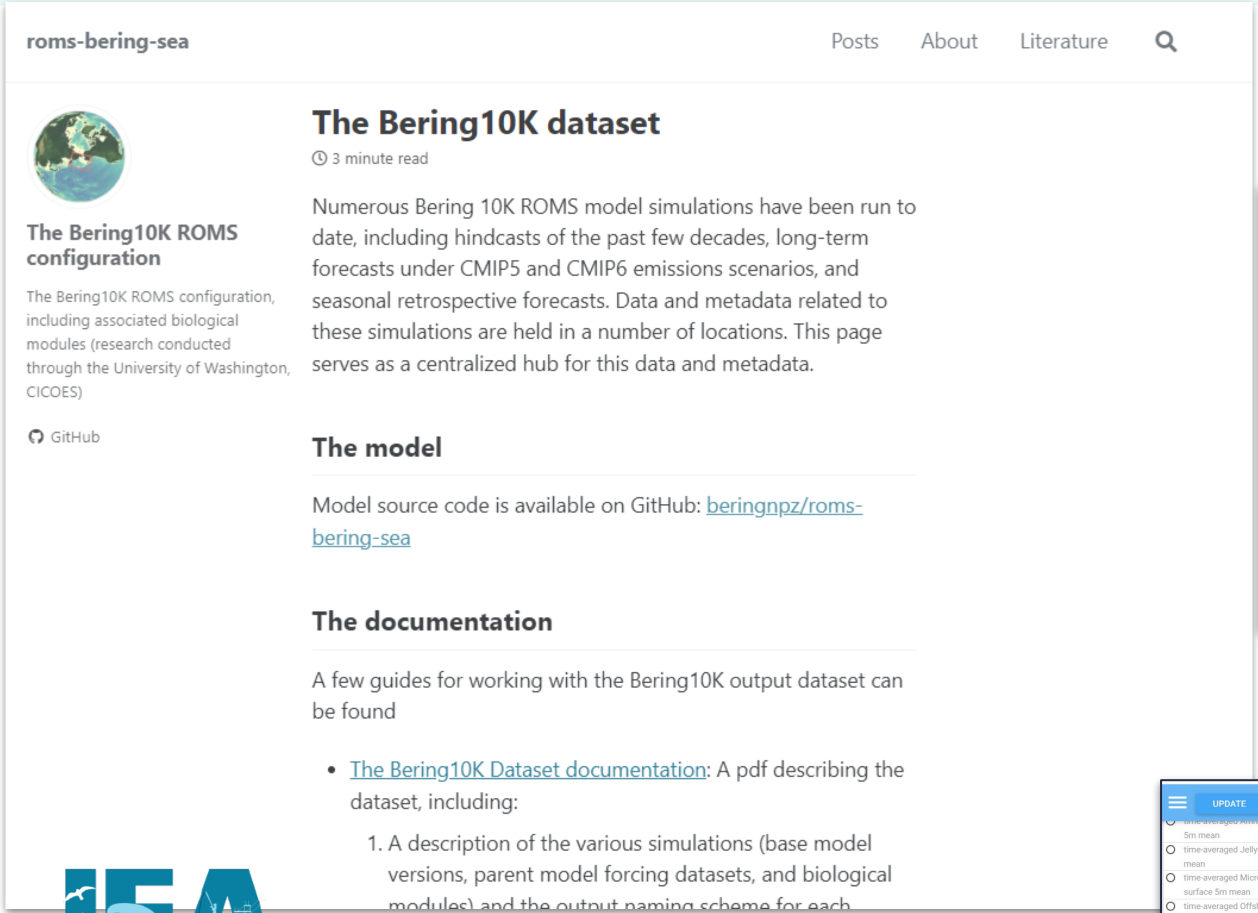
- Conducted preliminary community meetings in lower Yukon to inform household survey. Planned final phase fieldwork for 2025.
- Coordinated Multiple Knowledge systems on Yukon River Chinook marine survival. Continue to coordinate with upriver findings.
- Explored food security as driver in management decision-making

Alaska Fisheries Information Network | Yukon River Drainage Fisheries Association | VOICES ORAL HISTORY ARCHIVES | NOAA FISHERIES

ACLIM3 Decision Support System



Open Science: interactive tools



roms-bering-sea   Posts   About   Literature

The Bering10K dataset

3 minute read

Numerous Bering 10K ROMS model simulations have been run to date, including hindcasts of the past few decades, long-term forecasts under CMIP5 and CMIP6 emissions scenarios, and seasonal retrospective forecasts. Data and metadata related to these simulations are held in a number of locations. This page serves as a centralized hub for this data and metadata.

The model

Model source code is available on GitHub: beringnpz/roms-bering-sea

The documentation

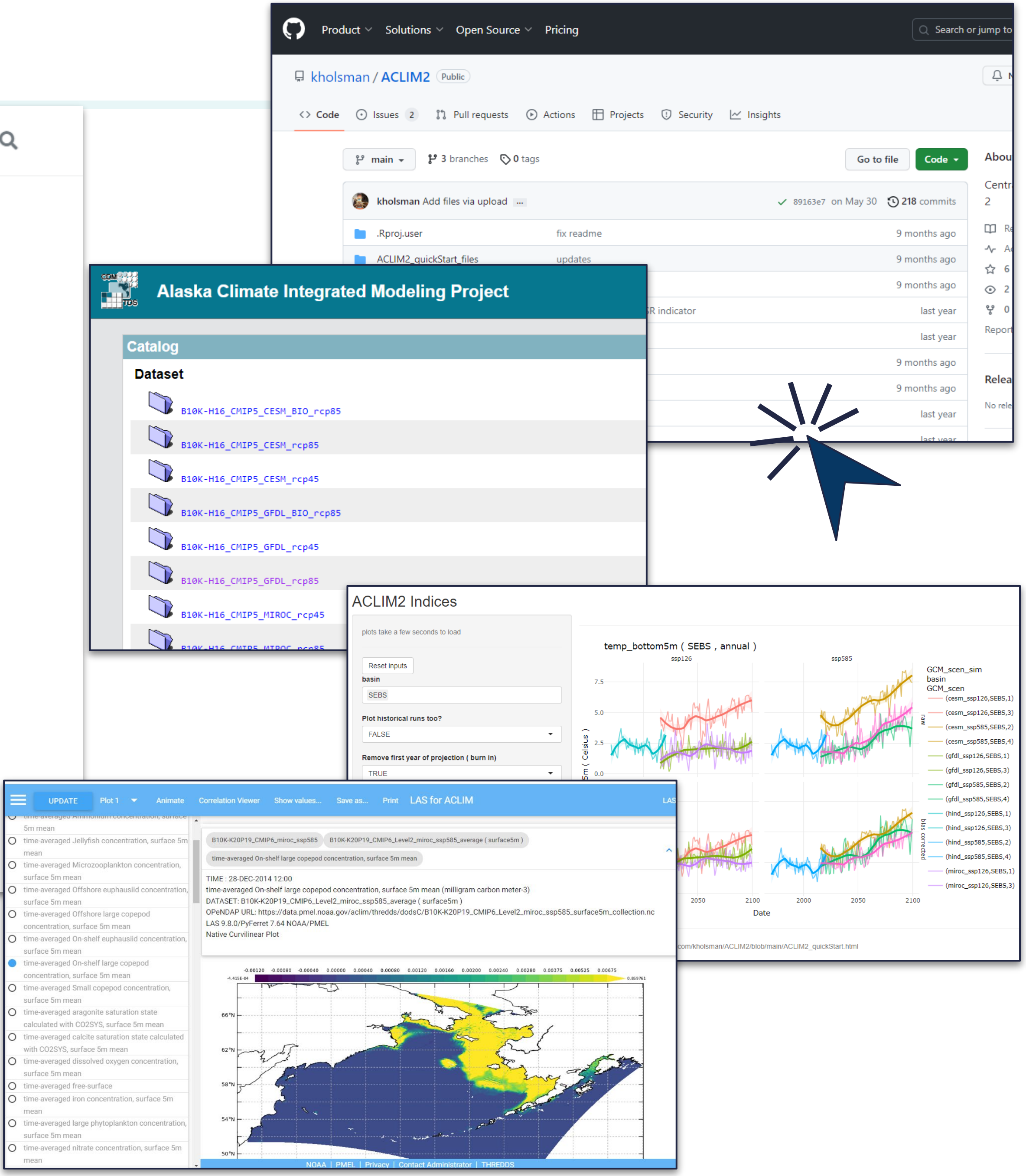
A few guides for working with the Bering10K output dataset can be found

- The Bering10K Dataset documentation: A pdf describing the dataset, including:
  1. A description of the various simulations (base model versions, parent model forcing datasets, and biological modules) and the output naming scheme for each

The Bering10K ROMS configuration

The Bering10K ROMS configuration, including associated biological modules (research conducted through the University of Washington, CICOES)

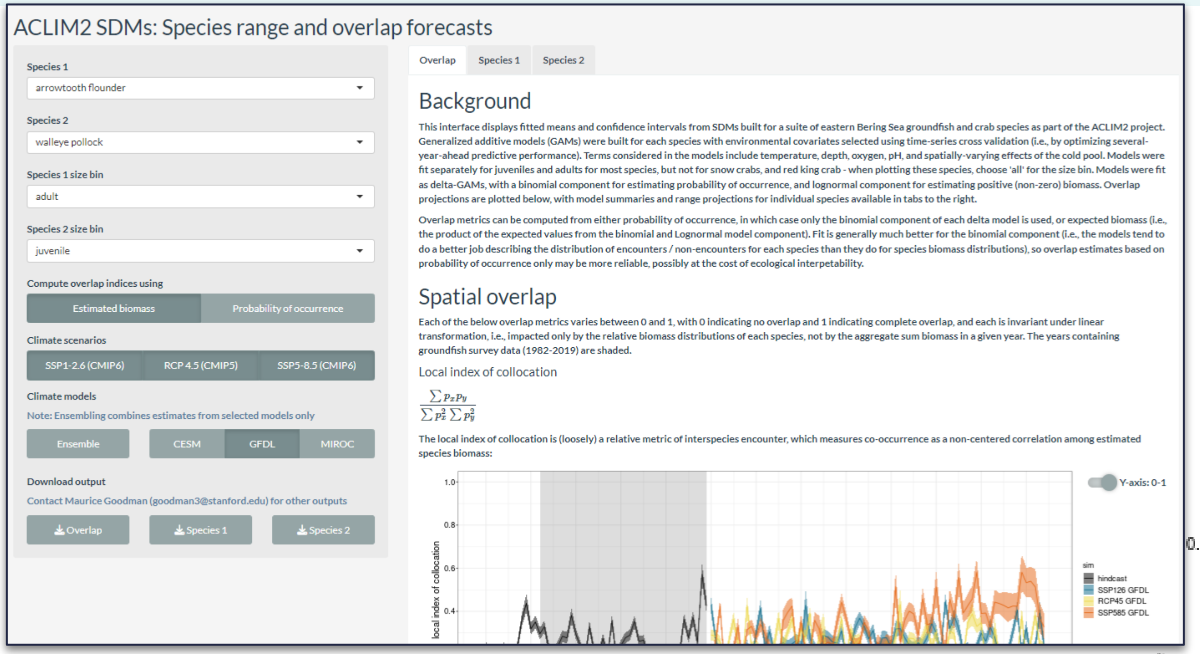
GitHub



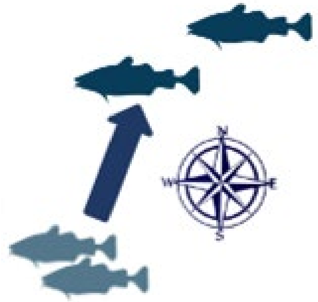
INTEGRATED ECOSYSTEM ASSESSMENT

https://beringnpz.github.io/roms-bering-sea/B10K-dataset-docs

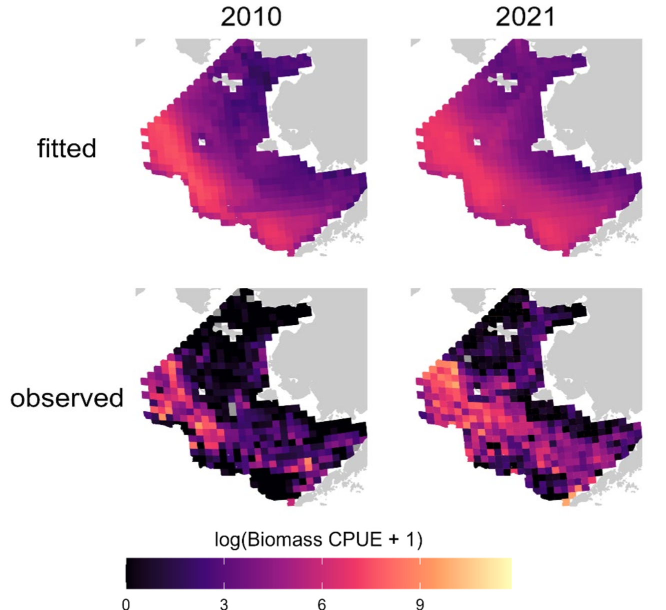
Open Science: interactive tools



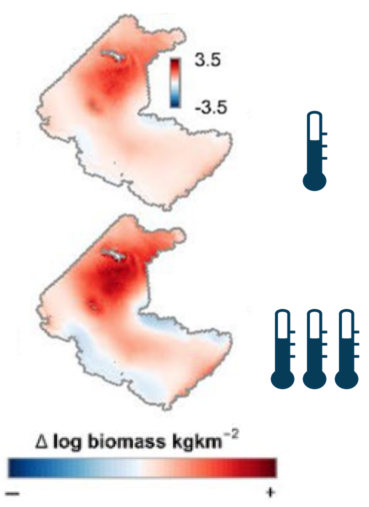
Juv. pollock

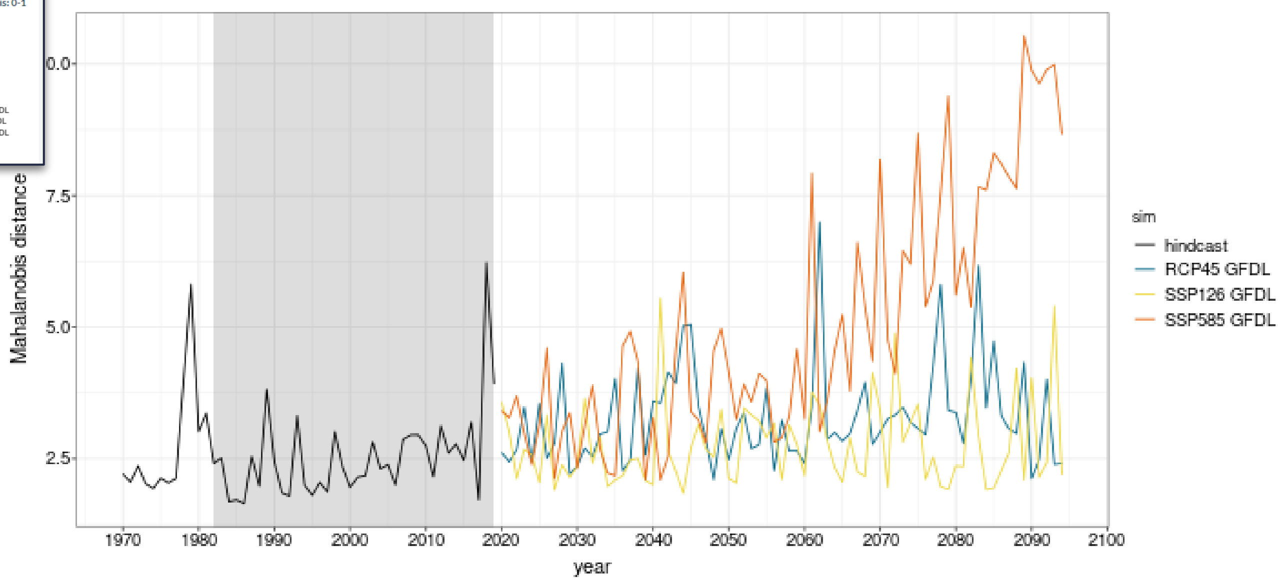


Shifting distributions: Habitat novelty



(2080-2089)- (1995-2015)





Goodman et al. in press.; https://mgoodman.shinyapps.io/aclim2_sdms_explorer/

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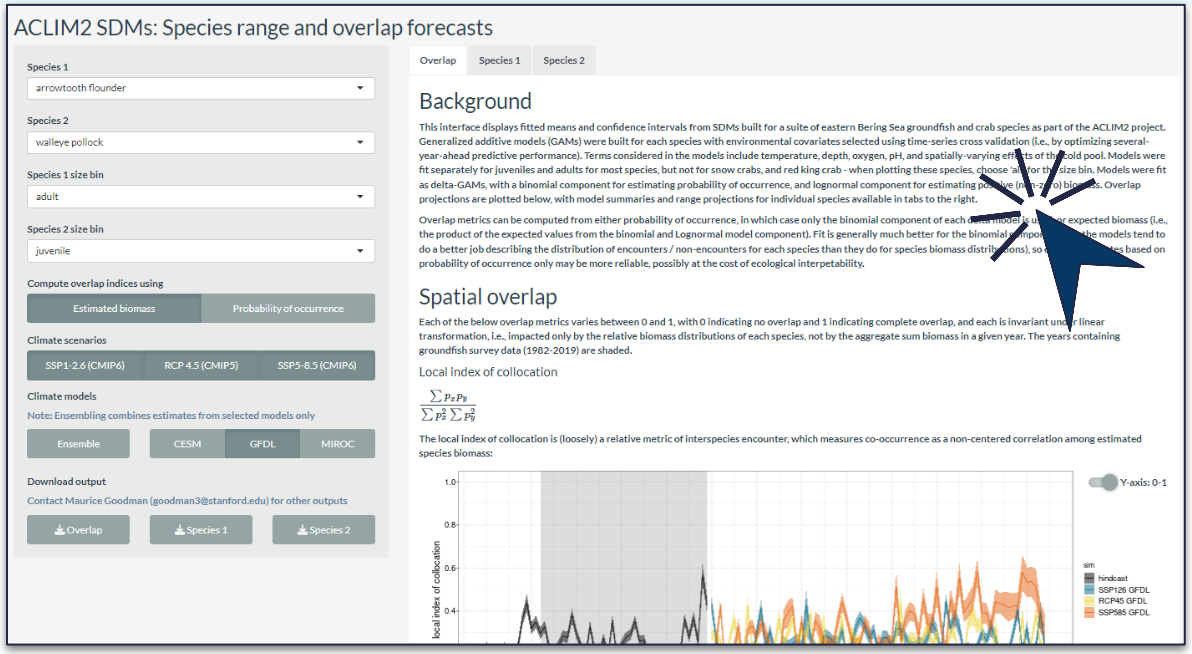

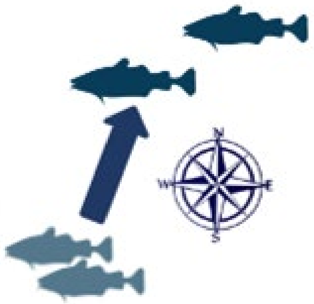

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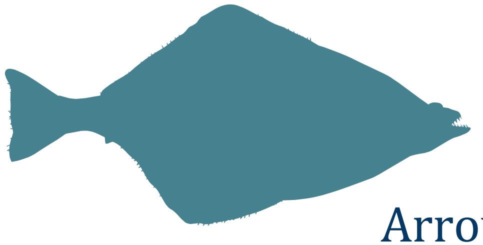
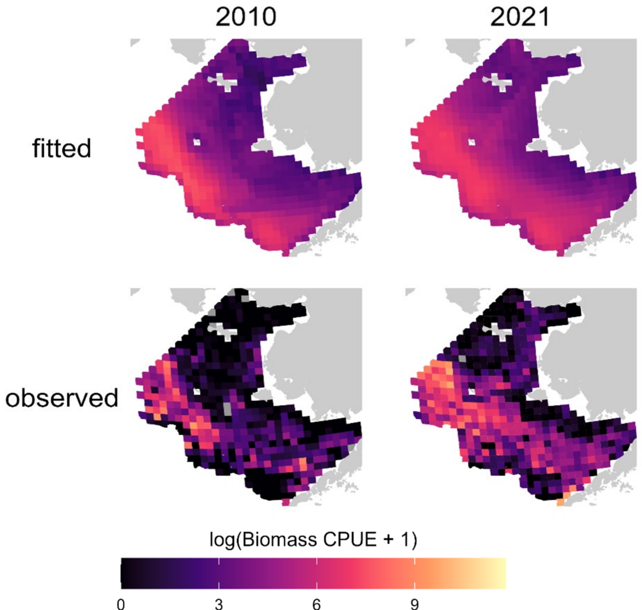


Arrowtooth

Changes in predator & prey overlap



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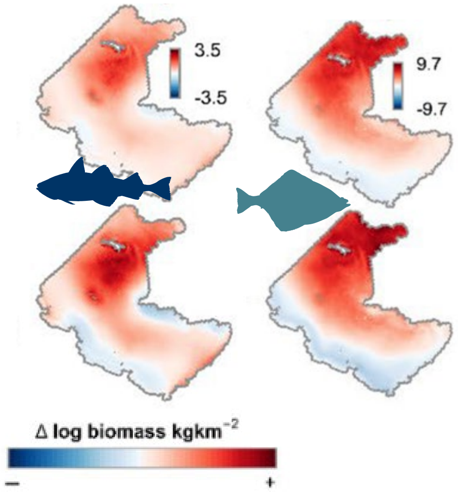
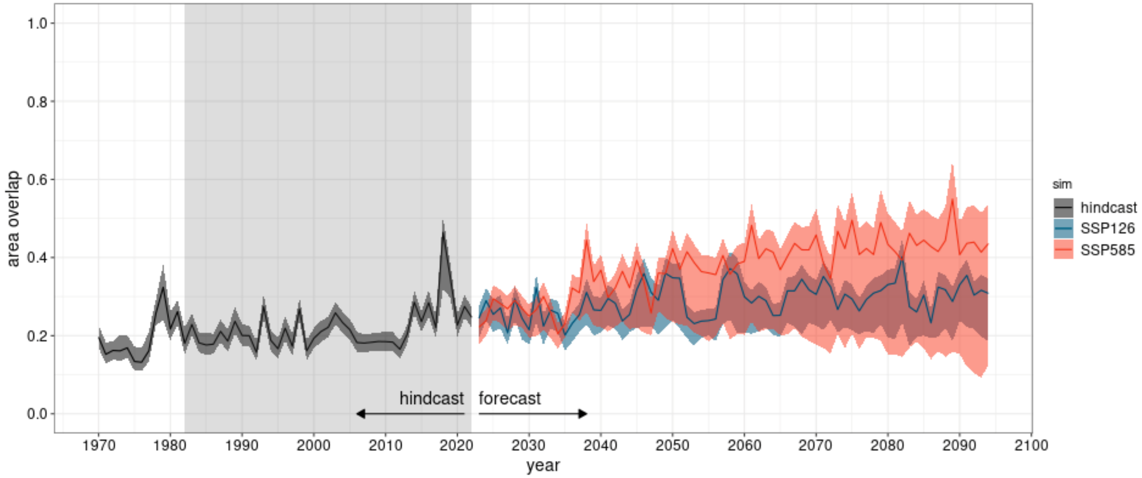




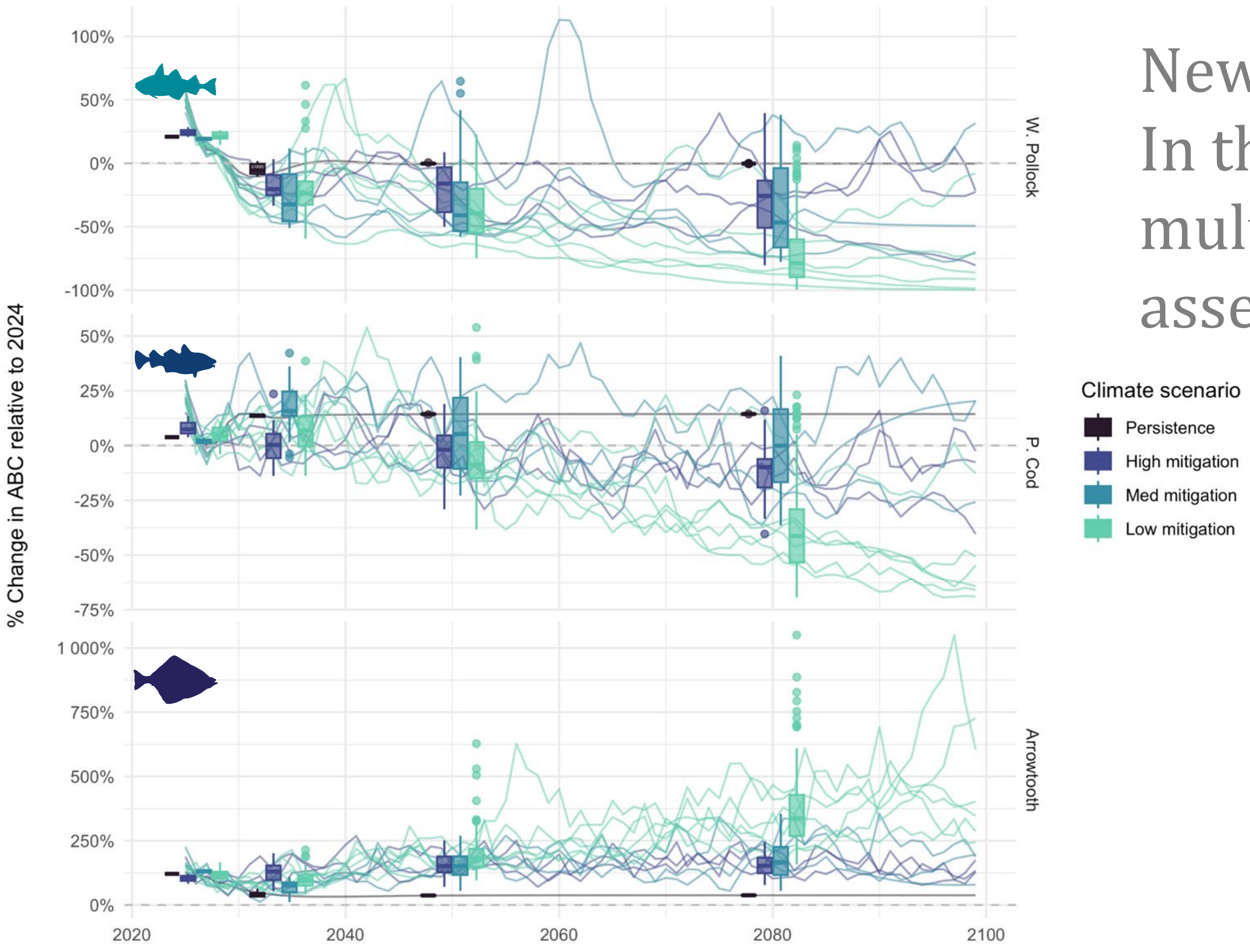
Goodman et al. in press.; https://mgoodman.shinyapps.io/aclim2_sdms_explorer/

Climate information on-ramps in 2024

ESPs, ESRs, Stock assessments

Future ABC

New this year In the multispecies assessment



CEATTLE
Climate-Enhanced Age-based stock assessment model with Temperature specific Trophic Linkages & Energetics

[Link to 2024 Climate-enhanced multispecies assessment (EBS)]

Community of practice is needed. In particular, need capacity to: co-develop, deliver, & refine

Credit: Mark Holsman

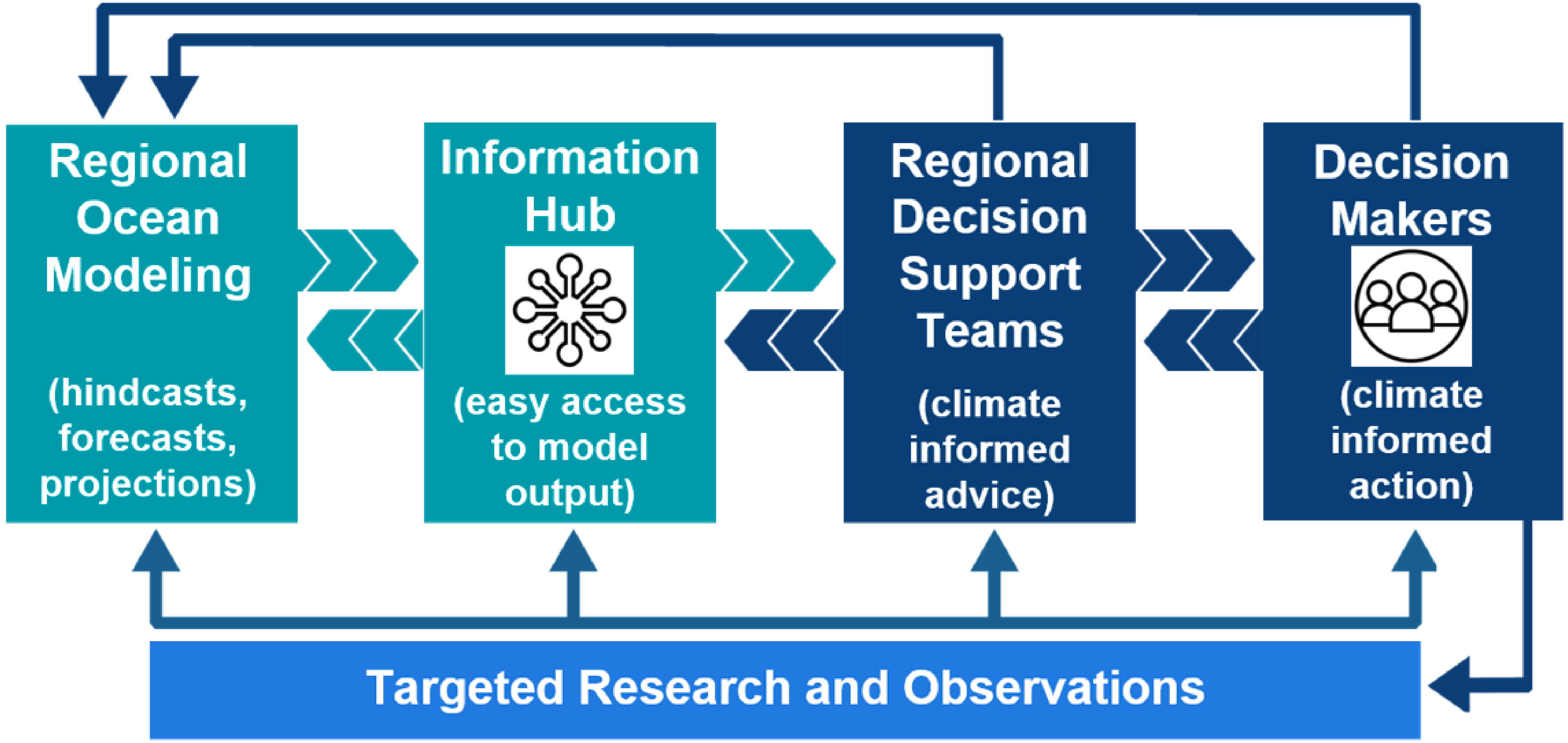
3 CEFI accelerates the capacity to deliver climate-informed tools and advice

Credit: Kirstin Holsman

The Alaska Climate/CEFI Team (ACT)

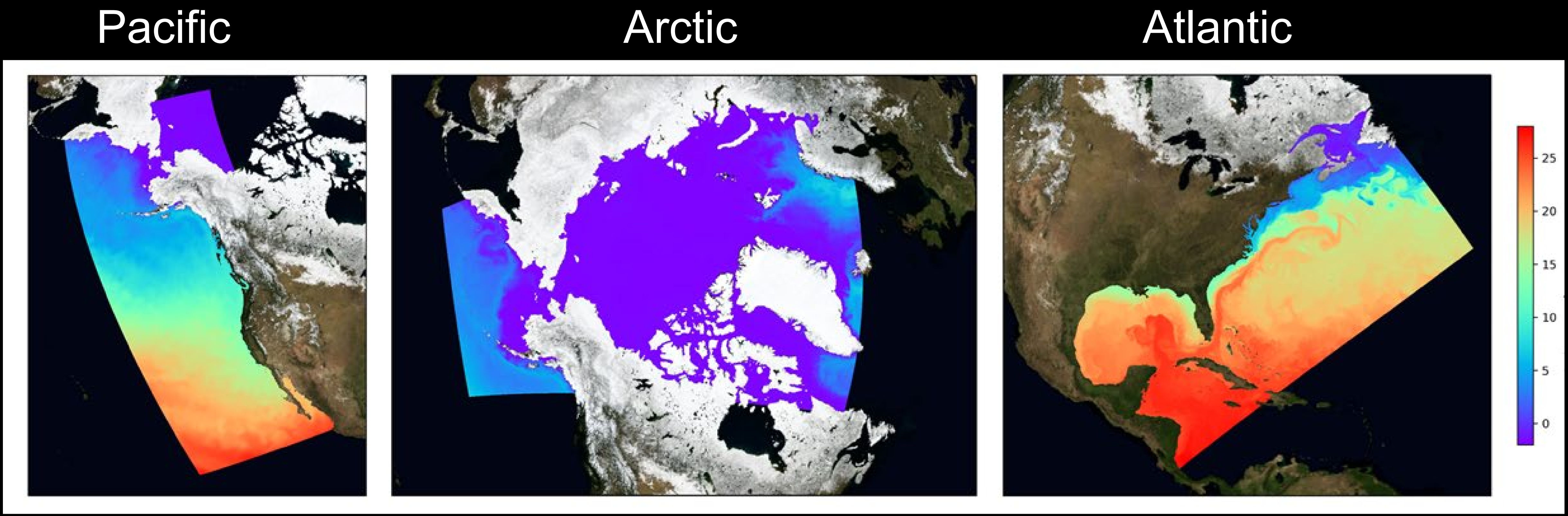
Kirstin Holsman
kirstin.holsman@noaa.gov

CEFI Decision Support System



Alaska’s Climate Ecosystem and Fisheries Initiative

CEFI High resolution oceanographic model (MOM6) grids

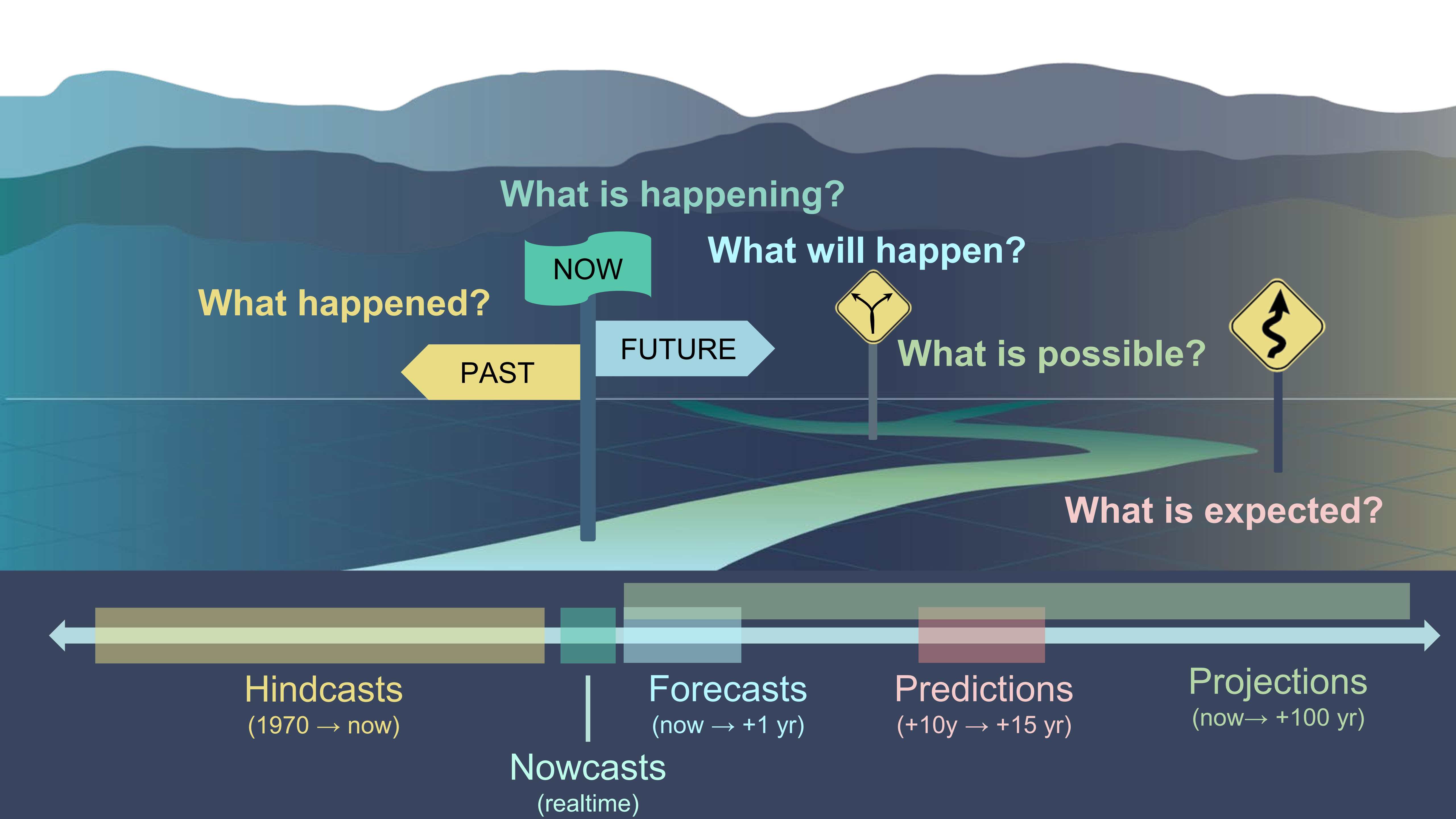


CEFI-OAR High resolution models (operational delivery)

- hindcasts
- seasonal forecasts
- decadal predictions
- multidecadal climate change projections

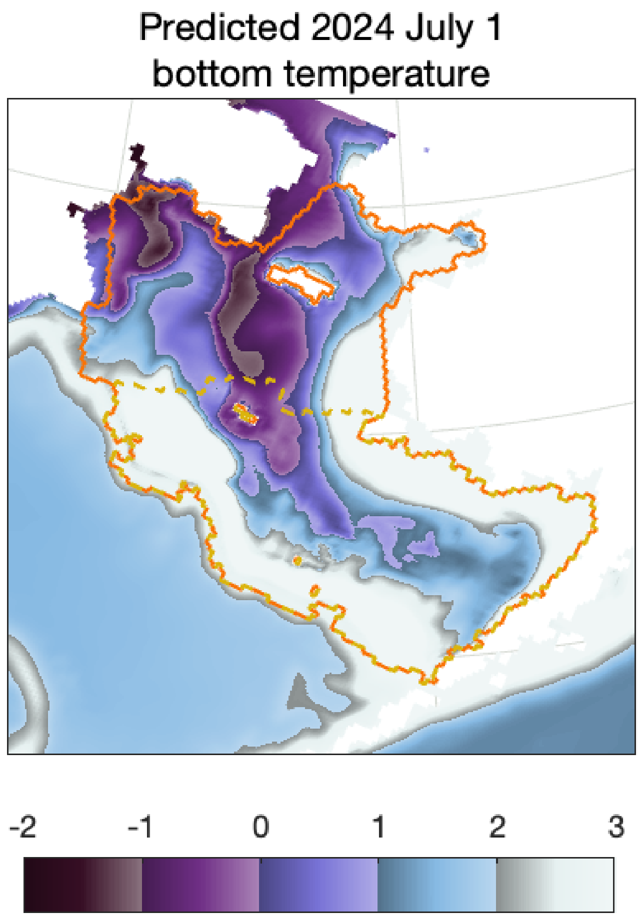
(e.g., sea ice, water temp, pH, winds, currents, zooplankton)

NOAA's Climate Ecosystem and Fisheries Initiative (CEFI)


What is happening?
NOW
What will happen?
What happened?
FUTURE
PAST
What is possible?
What is expected?
Hindcasts
(1970 → now)
Forecasts
(now → +1 yr)
Predictions
(+10y → +15 yr)
Projections
(now→ +100 yr)
Nowcasts
(realtime)

Current Bering10K high resolution oceanographic seasonal forecasts

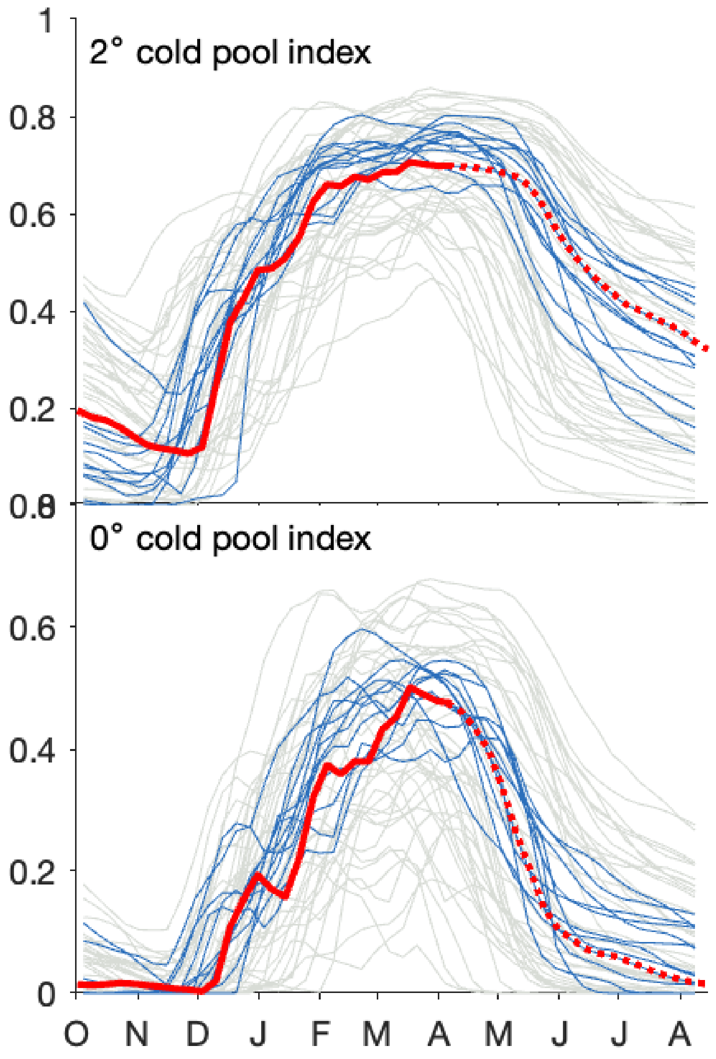
Spring

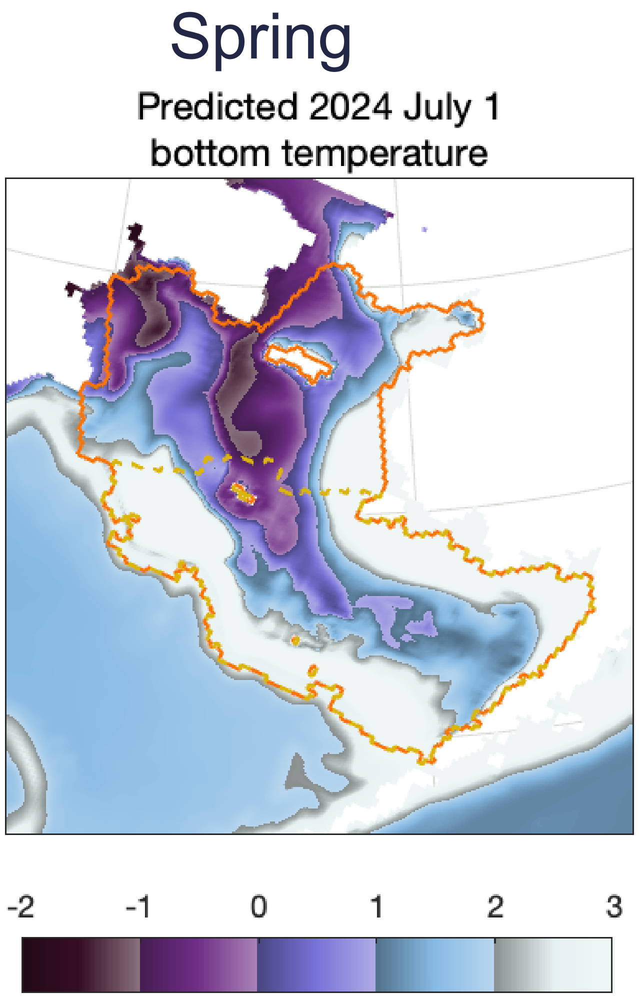


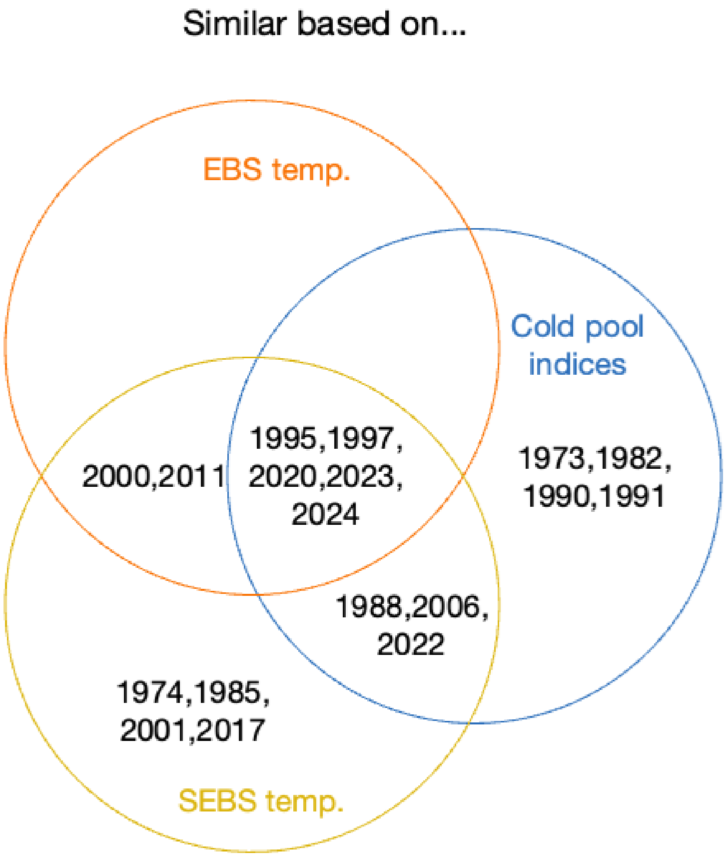
Slide: Kelly Kearney (AFSC)

https://beringnpz.github.io/roms-bering-sea/B10K-dataset-docs/

Current Bering10K high resolution oceanographic seasonal forecasts





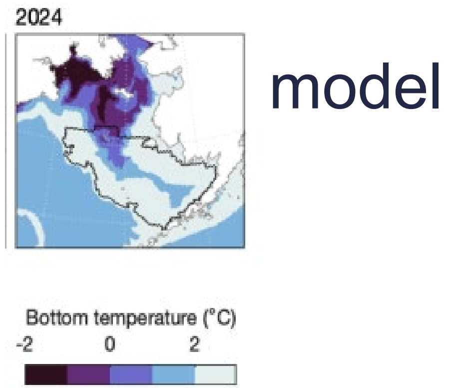


Slide: Kelly Kearney (AFSC)

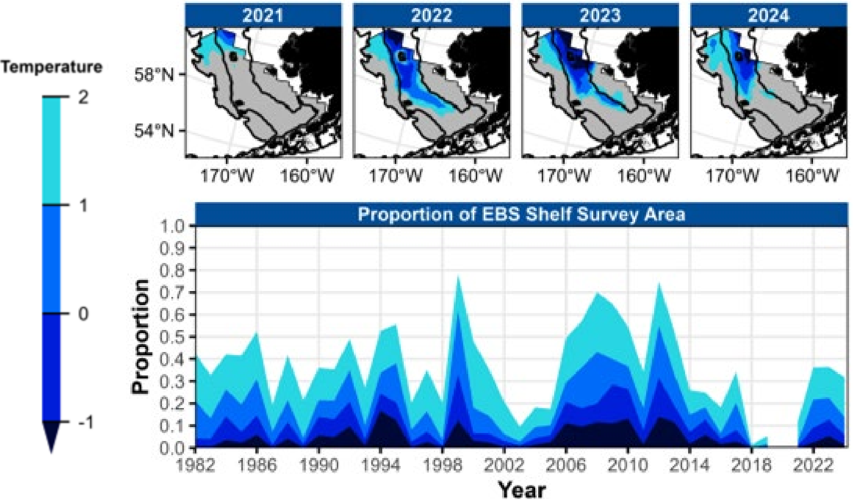
https://beringnpz.github.io/roms-bering-sea/B10K-dataset-docs/

Current Bering10K high resolution oceanographic seasonal forecasts

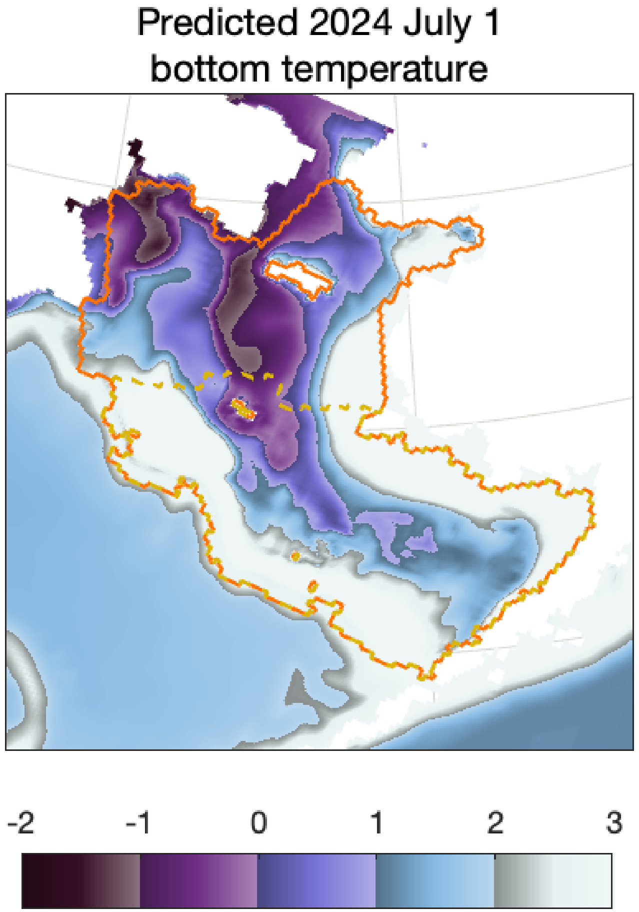
Updated in fall

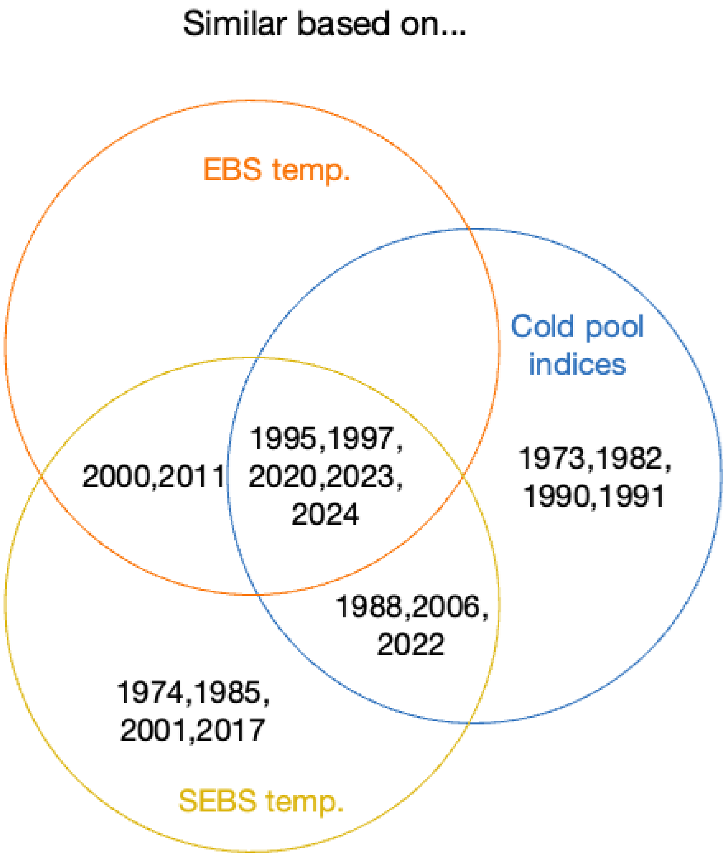


Obs.



Spring



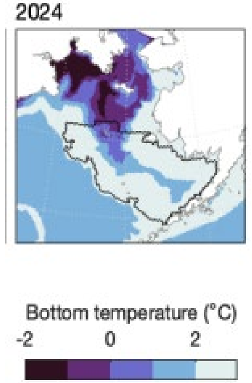


Slide: Kelly Kearney (AFSC)

https://beringnpz.github.io/roms-bering-sea/B10K-dataset-docs/

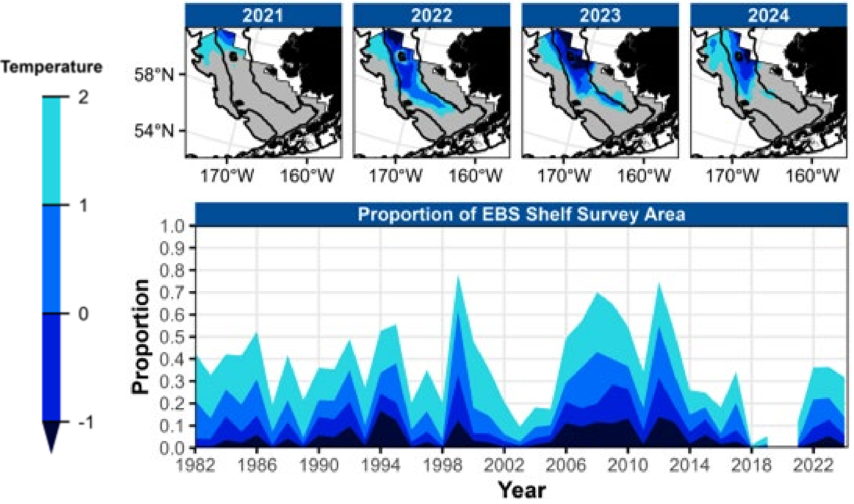
Current Bering10K high resolution oceanographic seasonal forecasts

Updated in fall



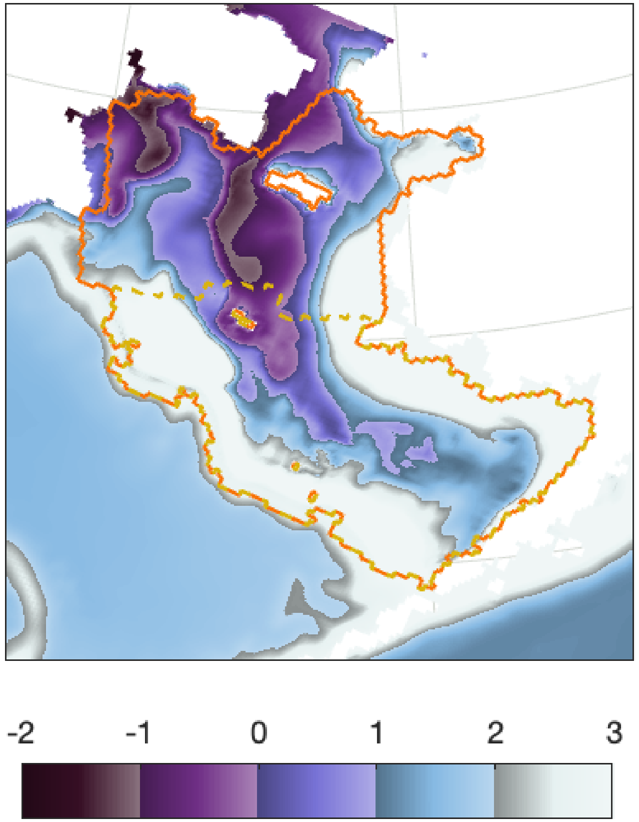
model

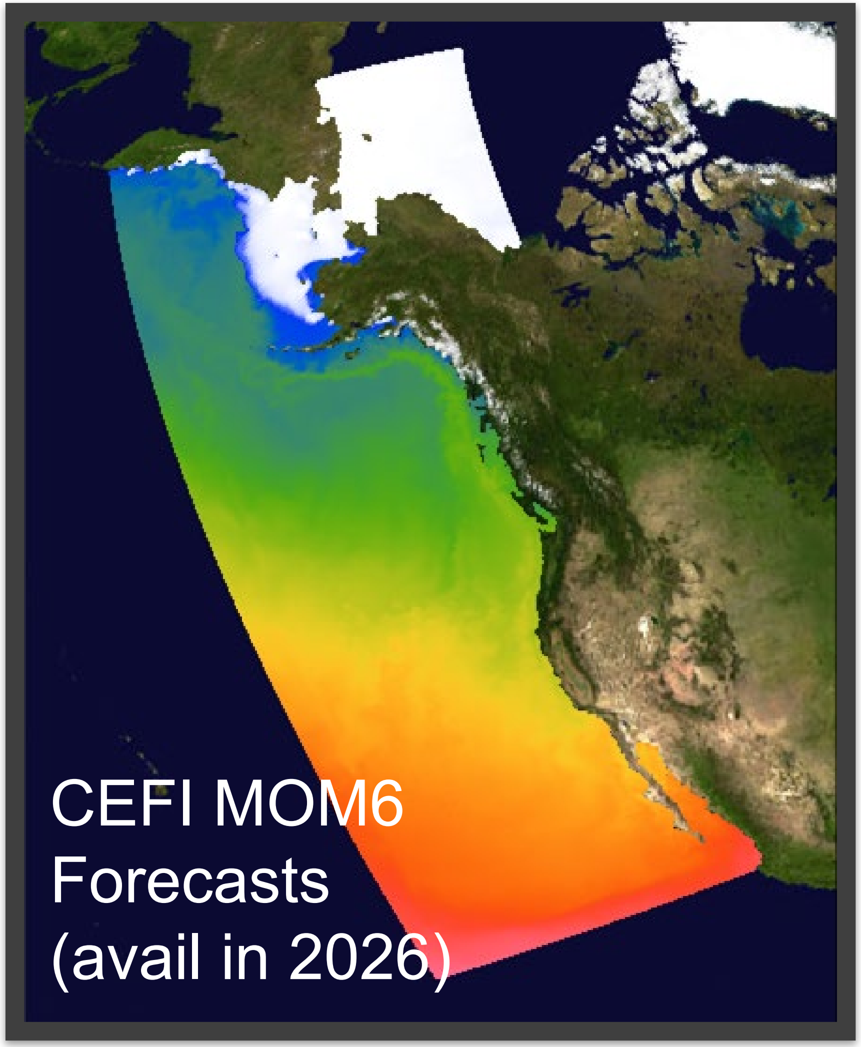
Obs.



Spring

Predicted 2024 July 1
bottom temperature

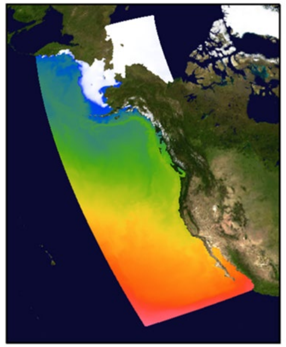




Slide: Kelly Kearney (AFSC)

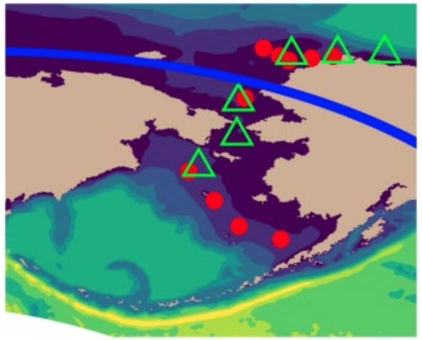
https://beringnpz.github.io/roms-bering-sea/B10K-dataset-docs/

CEFI synergies at work in the Bering Sea



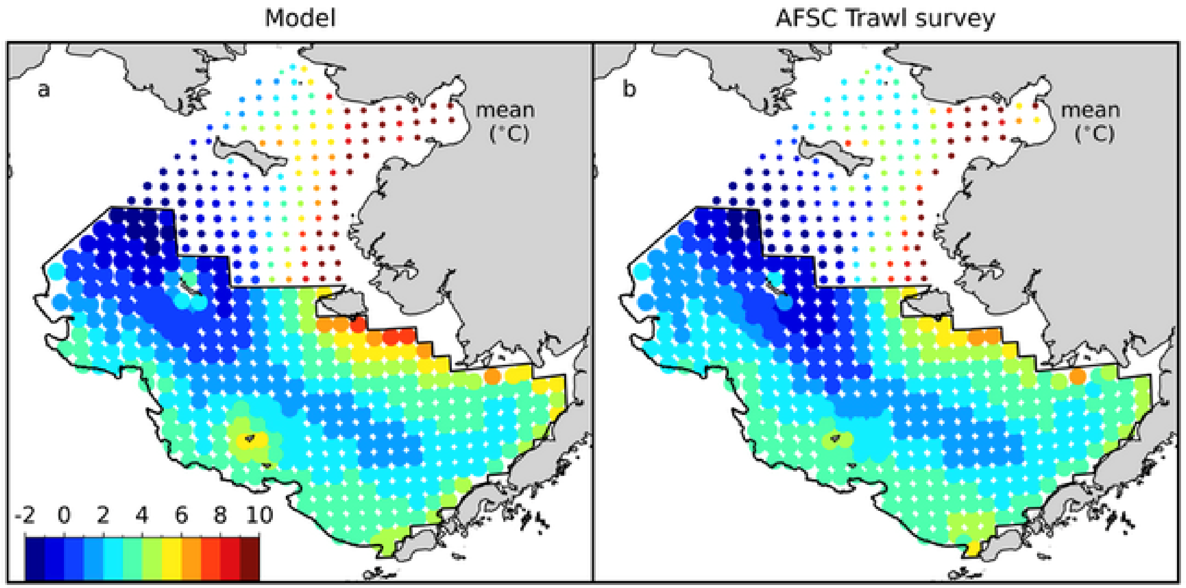
EcoFOCI
Ecosystems & Fisheries-Oceanography Coordinated Investigation

PMEL



fraction of the trawl survey area

MOM6 Bering Sea Cold Pool



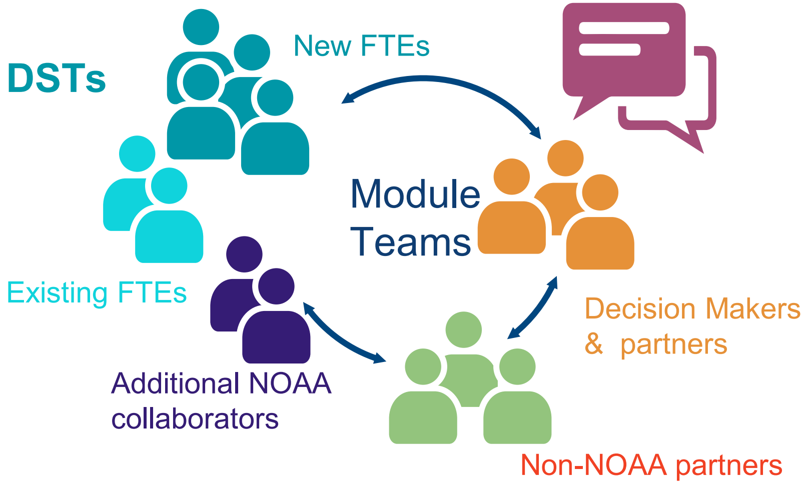
Year	West Coast and Arctic
FY23	Initial Configuration ✔
FY24	Initial hindcast ✔
FY25	Hindcast update, **retrospective seasonal predictions**, initial climate change projections
FY26	Hindcast update, **retrospective decadal predictions**, initial climate change projections
FY27	Hindcast update, **expanded projections,** seasonal outlooks reliably delivered
FY28	All products reliably delivered
FY29	All products reliably delivered

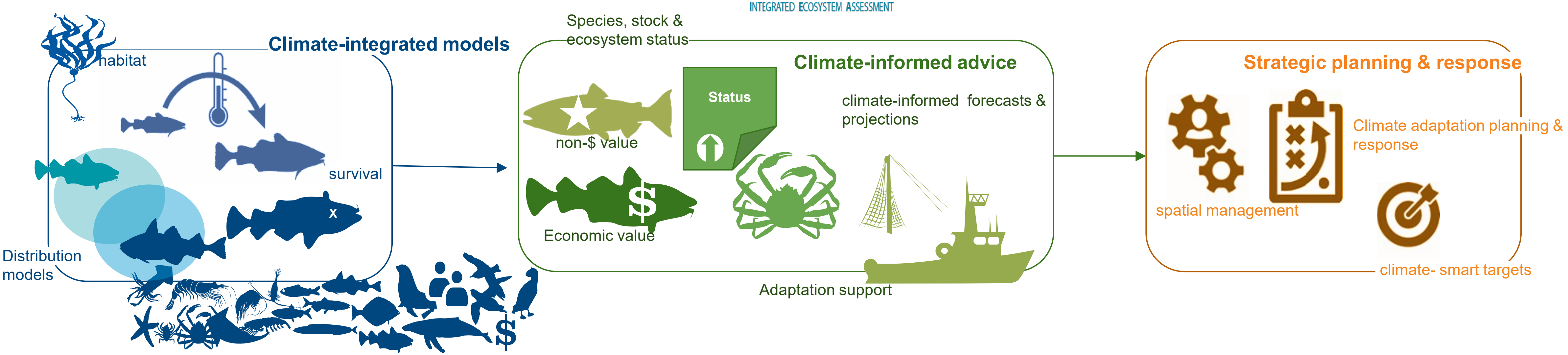
Thanks to Wei Cheng, Vivek Seelanki, Liz Drenkard, Kelly Kearney, Al Hermann, Darren Pilcher, Theresa Morrison, Bob Hallberg and others in the regional MOM6 development forum…

NOAA Climate, Ecosystems, & Fisheries Initiative

Decision Support Teams

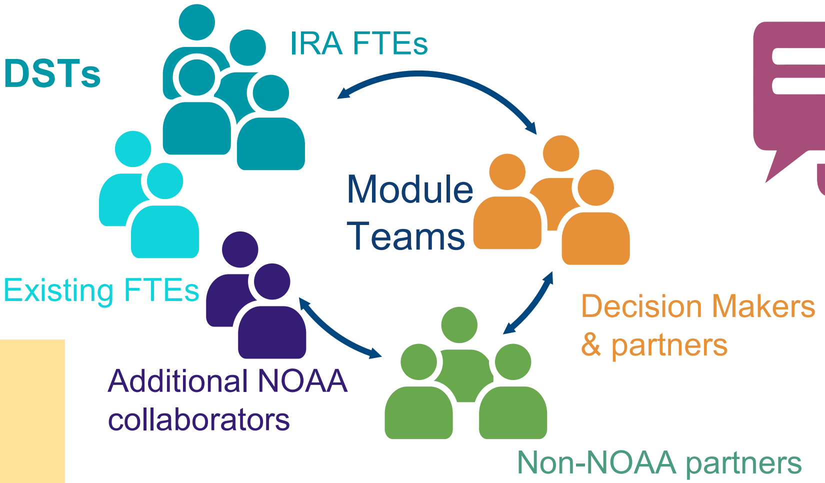
Co-generate regionally, locally, and community tailored tools & advice





What are Decision Support Teams?

Transdisciplinary nested teams that will help deliver climate informed products and advice, specifically tailored to decision maker needs.



1) Understand current capacity for inclusion of climate informed advice
2) Identify near-term needs for CI-advice
3) Identify long-term needs for development
4) Link CEFI, IEA, Stock Assessment, and Other NOAA products to meet needs

Support and co-leverage

not repeat or re-invent

Decision Support Delivery Steps

2023

Step 1: Engagement & Partnership Building

Identify key partners and collaborators and begin or advance discussions around climate change planning and needs

2024

Step 2: Co-identify on-ramps

In coordination and collaboration with partners and decision makers, identify existing and needed climate specific decision support needs

2025

Step 3: Co-identify needs & prioritize

Co-identify needs and prioritize decision support information, needs, and products

2026

Step 4: Design, build & TEST

Match resources and tools to needs and test skill relative to co-identified metrics of performance

2027

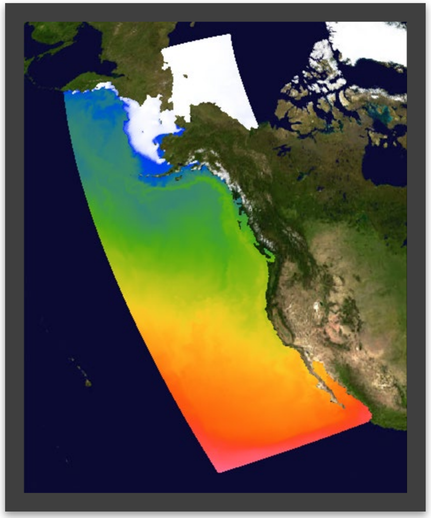
Step 5: Deliver & refine

Deliver decision support tools and advice; iterate and refine products with feedback and engagement

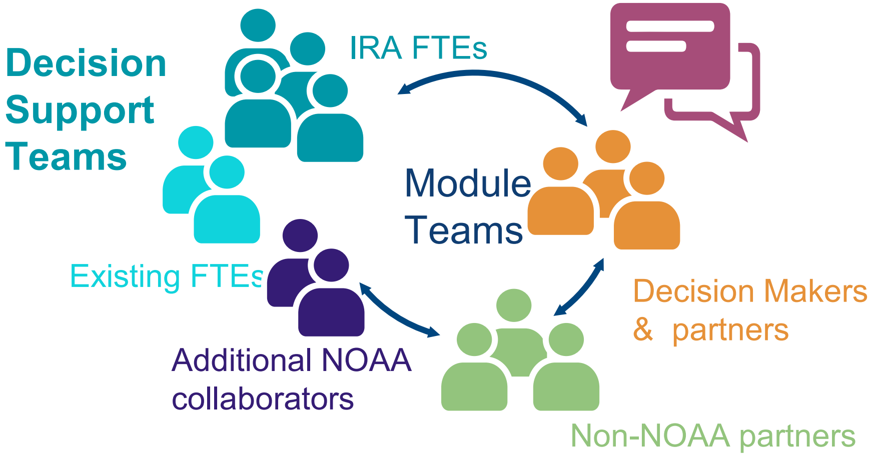
MOM6

Parallel process

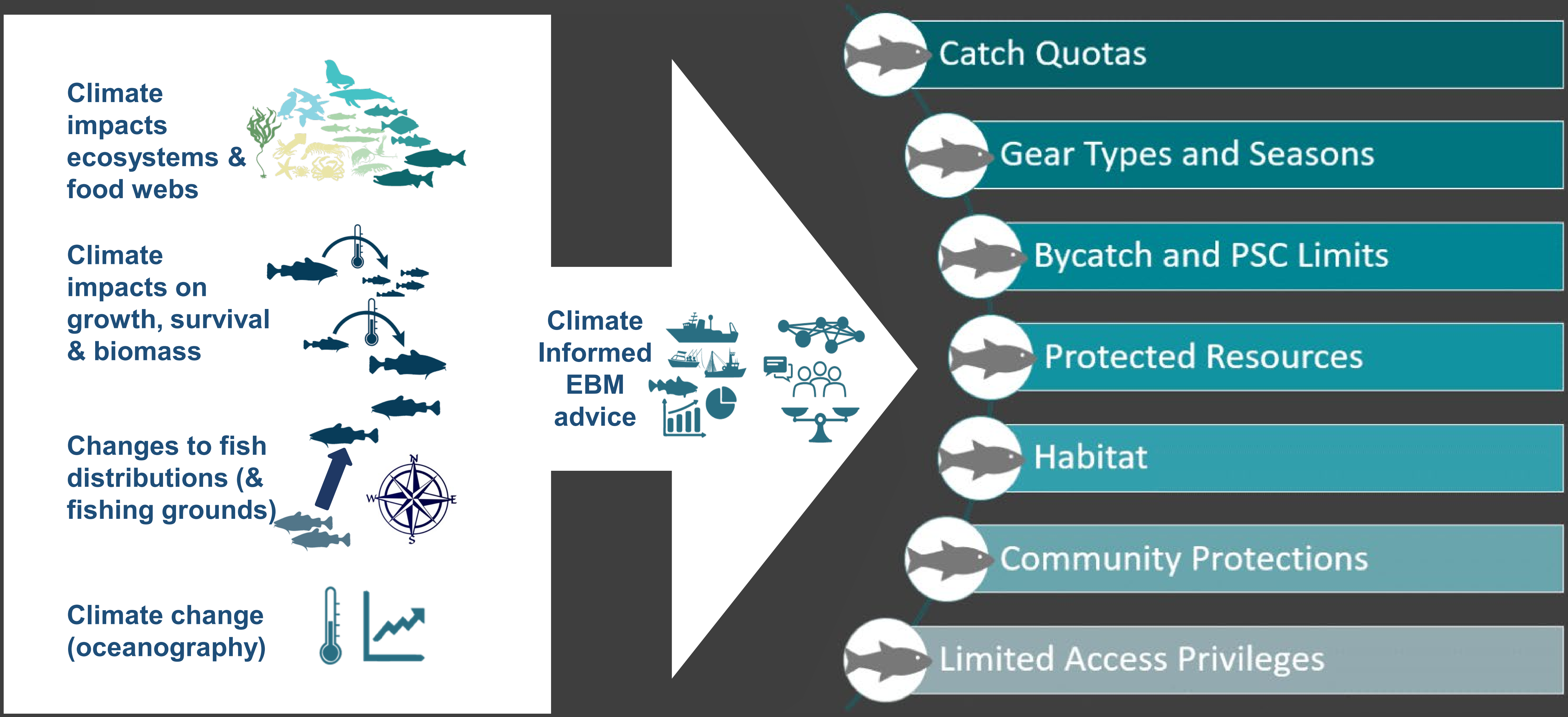
Test ocean model output



- **Is there an existing tool/product that meets the need?**
- **Do the scales match advice?**
- **Does the output skillfully meet needs?**



Types of Management Actions



https://www.npfmc.org/how-we-work/management-policies/

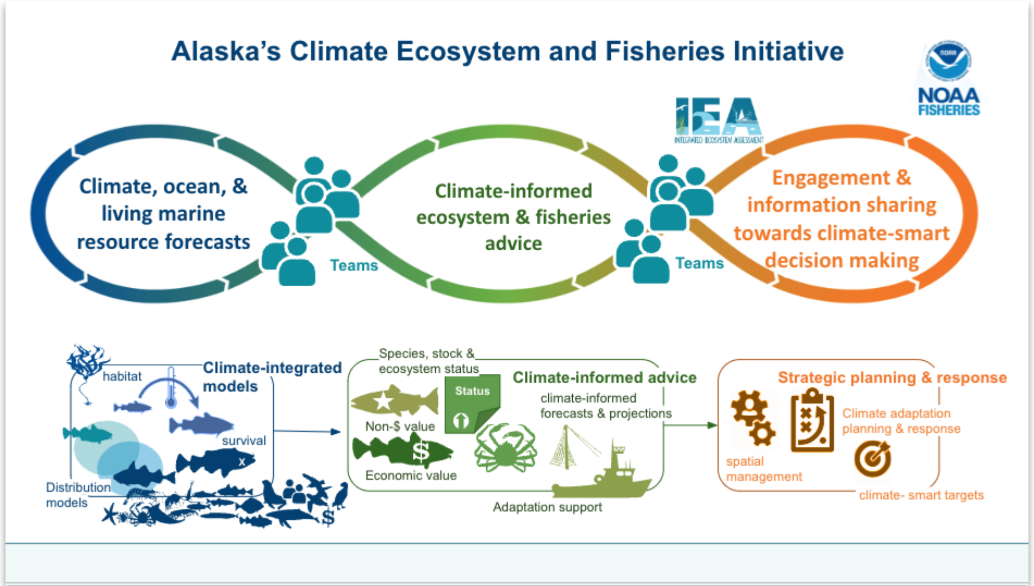
Draft Focal Areas for Alaska CEFI

FOCAL AREA 1: Web accessible and regionally tailored climate change products & trainings (cross cutting)

FOCAL AREA 2: Climate-integrated fisheries assessments and EBM tools

FOCAL AREA 3: Decision support for climate aware regulatory frameworks

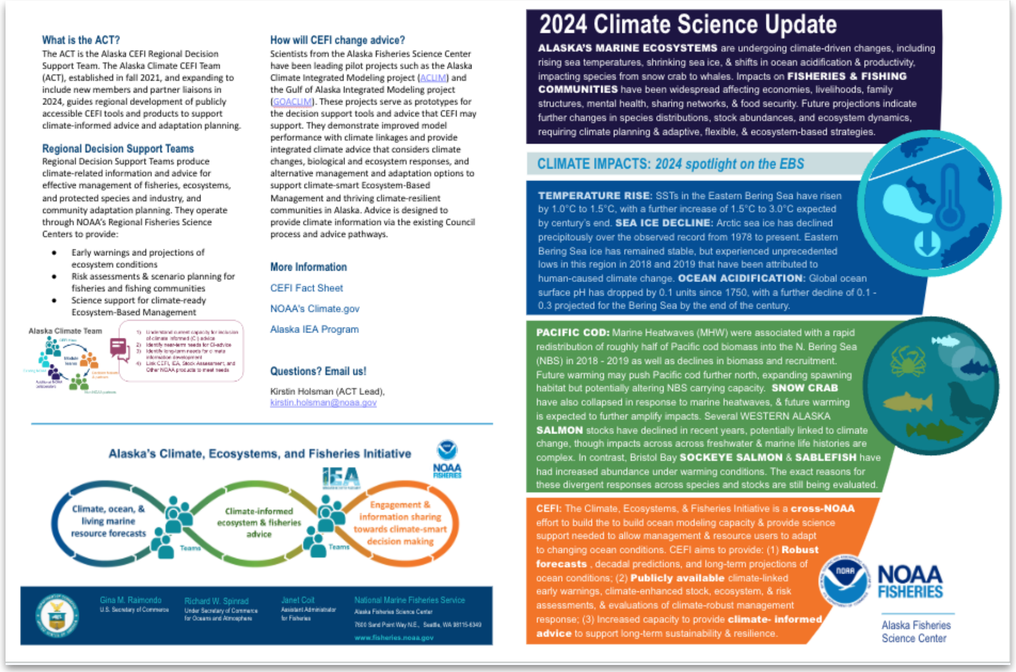
FOCAL AREA 4: Climate resilience community planning and response



Provide via climate information on-ramps in ESPs, ESRs, Stock assessments, ACEPO, etc.

New this year: Prototype Climate information overview

Feedback welcome!



What is the ACT?

The ACT is the Alaska CEFI Regional Decision Support Team. The Alaska Climate CEFI Team (ACT), established in fall 2021, and expanding to include new members and partner liaisons in 2024, guides regional development of publicly accessible CEFI tools and products to support climate-informed advice and adaptation planning.

Regional Decision Support Teams

Regional Decision Support Teams produce climate-related information and advice for effective management of fisheries, ecosystems, and protected species and industry, and community adaptation planning. They operate through NOAA's Regional Fisheries Science Centers to provide:

- Early warnings and projections of ecosystem conditions
- Risk assessments & scenario planning for fisheries and fishing communities
- Science support for climate-ready Ecosystem-Based Management

How will CEFI change advice?

Scientists from the Alaska Fisheries Science Center have been leading pilot projects such as the Alaska Climate Integrated Modeling project (ACLIM) and the Gulf of Alaska Integrated Modeling project (GOACLIM). These projects serve as prototypes for the decision support tools and advice that CEFI may support. They demonstrate improved model performance with climate linkages and provide integrated climate advice that considers climate changes, biological and ecosystem responses, and alternative management and adaptation options to support climate-smart Ecosystem-Based Management and thriving climate-resilient communities in Alaska. Advice is designed to provide climate information via the existing Council process and advice pathways.

More Information

CEFI Fact Sheet

NOAA's Climate.gov

Alaska IEA Program

Questions? Email us!

Kirstin Holsman (ACT Lead),
kirstin.holsman@noaa.gov

Alaska's Climate, Ecosystems, and Fisheries Initiative

Gina M. Raimondo
U.S. Secretary of Commerce

Richard W. Spinrad
Under Secretary of Commerce for Oceans and Atmosphere

Janet Coit
Assistant Administrator for Fisheries

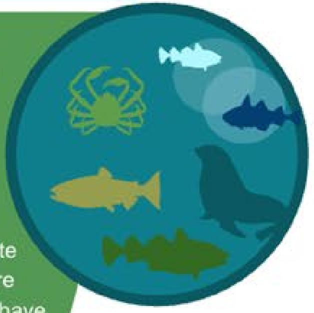
National Marine Fisheries Service
Alaska Fisheries Science Center
7600 Sand Point Way N.E., Seattle, WA 98115-6349
www.fisheries.noaa.gov

2024 Climate Science Update

ALASKA'S MARINE ECOSYSTEMS are undergoing climate-driven changes, including rising sea temperatures, shrinking sea ice, & shifts in ocean acidification & productivity, impacting species from snow crab to whales. Impacts on **FISHERIES & FISHING COMMUNITIES** have been widespread affecting economies, livelihoods, family structures, mental health, sharing networks, & food security. Future projections indicate further changes in species distributions, stock abundances, and ecosystem dynamics, requiring climate planning & adaptive, flexible, & ecosystem-based strategies.

CLIMATE IMPACTS: *2024 spotlight on the EBS*

TEMPERATURE RISE: SSTs in the Eastern Bering Sea have risen by 1.0°C to 1.5°C, with a further increase of 1.5°C to 3.0°C expected by century's end. **SEA ICE DECLINE:** Arctic sea ice has declined precipitously over the observed record from 1978 to present. Eastern Bering Sea ice has remained stable, but experienced unprecedented lows in this region in 2018 and 2019 that have been attributed to human-caused climate change. **OCEAN ACIDIFICATION:** Global ocean surface pH has dropped by 0.1 units since 1750, with a further decline of 0.1 - 0.3 projected for the Bering Sea by the end of the century.



PACIFIC COD: Marine Heatwaves (MHW) were associated with a rapid redistribution of roughly half of Pacific cod biomass into the N. Bering Sea (NBS) in 2018 - 2019 as well as declines in biomass and recruitment. Future warming may push Pacific cod further north, expanding spawning habitat but potentially altering NBS carrying capacity. **SNOW CRAB** have also collapsed in response to marine heatwaves, & future warming is expected to further amplify impacts. Several WESTERN ALASKA **SALMON** stocks have declined in recent years, potentially linked to climate change, though impacts across across freshwater & marine life histories are complex. In contrast, Bristol Bay **SOCKEYE SALMON** & **SABLEFISH** have had increased abundance under warming conditions. The exact reasons for these divergent responses across species and stocks are still being evaluated.

CEFI: The Climate, Ecosystems, & Fisheries Initiative is a **cross-NOAA** effort to build the to build ocean modeling capacity & provide science support needed to allow management & resource users to adapt to changing ocean conditions. CEFI aims to provide: (1) **Robust forecasts** , decadal predictions, and long-term projections of ocean conditions; (2) **Publicly available** climate-linked early warnings, climate-enhanced stock, ecosystem, & risk assessments, & evaluations of climate-robust management response; (3) Increased capacity to provide **climate- informed advice** to support long-term sustainability & resilience.

NOAA FISHERIES

Alaska Fisheries Science Center

What we are planning & what we will do

Oceanographic

Region-specific oceanographic products will be developed for public use to support climate change adaptation. This includes the current Bering10K Regional Ocean Modeling System (ROMS) and the advanced Modular Ocean Model 6 (MOM6). These high resolution, three dimensional ocean models effectively simulate past ocean conditions and lower trophic level dynamics, from phytoplankton to krill, and are instrumental in forecasting future changes.

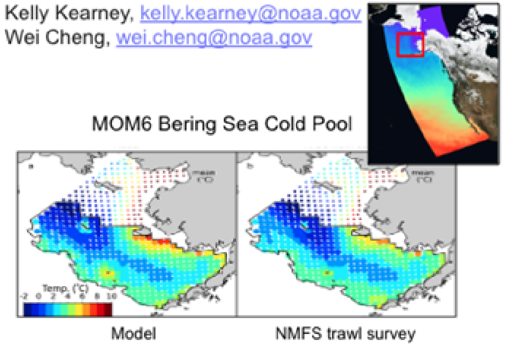
Hindcasts: hindcasts are a powerful tool for reconstructing the climate and environmental conditions of the recent past. Through CEFI, hincasts will be produced to recreate the oceanic and sea ice states over the past several decades. The ACT will evaluate the accuracy of these reconstructions by comparing them with historical ocean observations. Once validated, these model outputs will provide continuous data on ocean conditions from seabed to the surface. This information will enhance understanding of the ocean dynamics during different fishing and harvest seasons, and will help identify the drivers of species population changes, spatial shifts, and broader ecosystem responses to warming and marine heatwaves.

Forecasts: Forecasts from the same models will be updated each season to provide neartem projections of ocean conditions one to twelve months out.

Decadal predictions will provide data-driven outlook of potential ocean conditions up to 10 years into the future.

Long-term projections under high and low warming scenarios will deliver detailed information to support risk analyses and climate adaptation planning.

Kelly Kearney, kelly.kearney@noaa.gov
Wei Cheng, wei.cheng@noaa.gov



MOM6 Bering Sea Cold Pool

Biological

Develop dynamic climate-informed **multispecies distribution models** for Bering Sea groundfish, crab, and marine mammal species.

Assess **changes in spatial overlap** among species based on range projections under various climate scenarios.

Elizabeth McHuron, liz.mchuron@noaa.gov
Maurice Goodman, goodmm2@uw.edu

Link models and use ensemble approaches to quantify relationships between climate-ecosystem variables and **population dynamics** across fish species.

Identify best practices for selecting which climate-ecosystem variables can help predict stock dynamics.

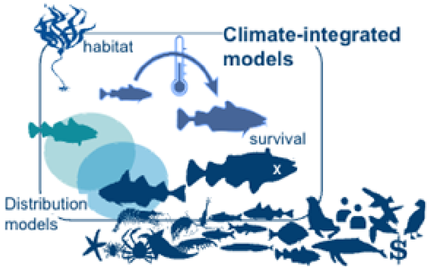
Jennifer Bigman, jennifer.bigman@noaa.gov
Grant Adams, grant.adams@noaa.gov
André Punt, aepunt@uw.edu

Develop **climate-linked harvest control rules** to determine ABC buffers for the North Pacific Fisheries Management Council.

Develop software to produce climate-informed short-term **growth and mortality forecasts** for NPFMC harvest control rules.

Support **climate-informed stock assessments and multispecies models** for groundfish in the Gulf of Alaska and Bering Sea.

Grant Adams, grant.adams@noaa.gov
Kirstin Holsman, kirstin.holsman@noaa.gov
André Punt, aepunt@uw.edu



What we are planning & what we will do

Social & Economic

Develop **social hindcast methodology** with pilot of community responses to climate-induced changes in Alaska fisheries (2018-2023) to better understand community adaptation strategies.

Identify possible **social indicators** using existing data sources to detect and monitor the effects of climate-induced changes associated with resilience and vulnerability of Alaska fishing communities.

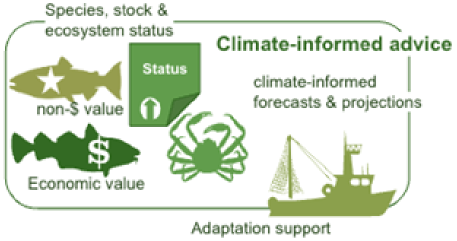
Support development of **publicly accessible, collaborative tools** allowing communities to view CEFI information products on climate-induced shifts in species distributions and ecological and oceanographic conditions.

Explore **pathways and examine barriers** for utilizing social and economic information to inform Council decision-making on climate resilient fisheries management.

Angela Abolhassani, angela.abolhassani@noaa.gov
Sarah Wise, sarah.wise@noaa.gov

Collaboratively identify drivers of Yukon River Chinook salmon marine survival using ROMS ocean temperature outputs, wind hindcasts, and Traditional Knowledge in partnership with the Yukon River Drainage Fisheries Association.

Ellen Yasumiishi, ellen.yasumiishi@noaa.gov
Sarah Wise, sarah.wise@noaa.gov



Council Coordination

In coordination with the Council points of contact, develop a process for **regular reporting of climate change impacts and responses to the Council** through existing pathways (or "on-ramps"). Fisheries Initiative (CEFI) potential projects and outputs could also help support the Council's climate readiness planning. This information will highlight current and proposed synergies between CEFI products and Council planning. Coordination on the development of these products will involve collaboration among the Council, NOAA's Alaska CEFI team (ACT) and partners, and the Alaska Fisheries Information Network.

Facilitate Council planning for climate change impacts on fisheries and fishing communities in Alaska through iterative discussions, workshops, information reporting, and synthesis of medium to long-term impacts on Alaska marine ecosystems. Support management strategy evaluations (MSEs) to evaluate the performance of alternative management measures and assessments under future climate scenarios.

Annual climate-informed advice: Develop interactive and publicly accessible resources for decision making and exploring tradeoffs in annual fisheries management decisions. Support climate-informed biological reference points and harvest control rules.

Rapid response: Support the development and delivery of tools to aid in-season management and navigate emergent climate challenges.

Jodi Pirtle, jodi.pirtle@noaa.gov
Jason Gasper, jason.gasper@noaa.gov
Anne Marie Eich, annemarie.eich@noaa.gov

Katie Latanich, katie.latanich@noaa.gov
Diana Stram, diana.stram@noaa.gov

Kirstin Holsman, kirstin.holsman@noaa.gov
Angela Abolhassani, angela.abolhassani@noaa.gov

Climate change is challenging but solvable

Overall, the latest studies on the net economic implications of decarbonisation – which also account for avoided climate damages – **point to overall benefit from the transition.** - *Prof Valentina Bosetti*

If people are provided with opportunities to make choices supported by policies, infrastructure and technologies, there is an untapped mitigation potential to **bring down global emissions by between 40 and 70% by 2050** compared to a baseline scenario.

-Prof Joyashree Roy

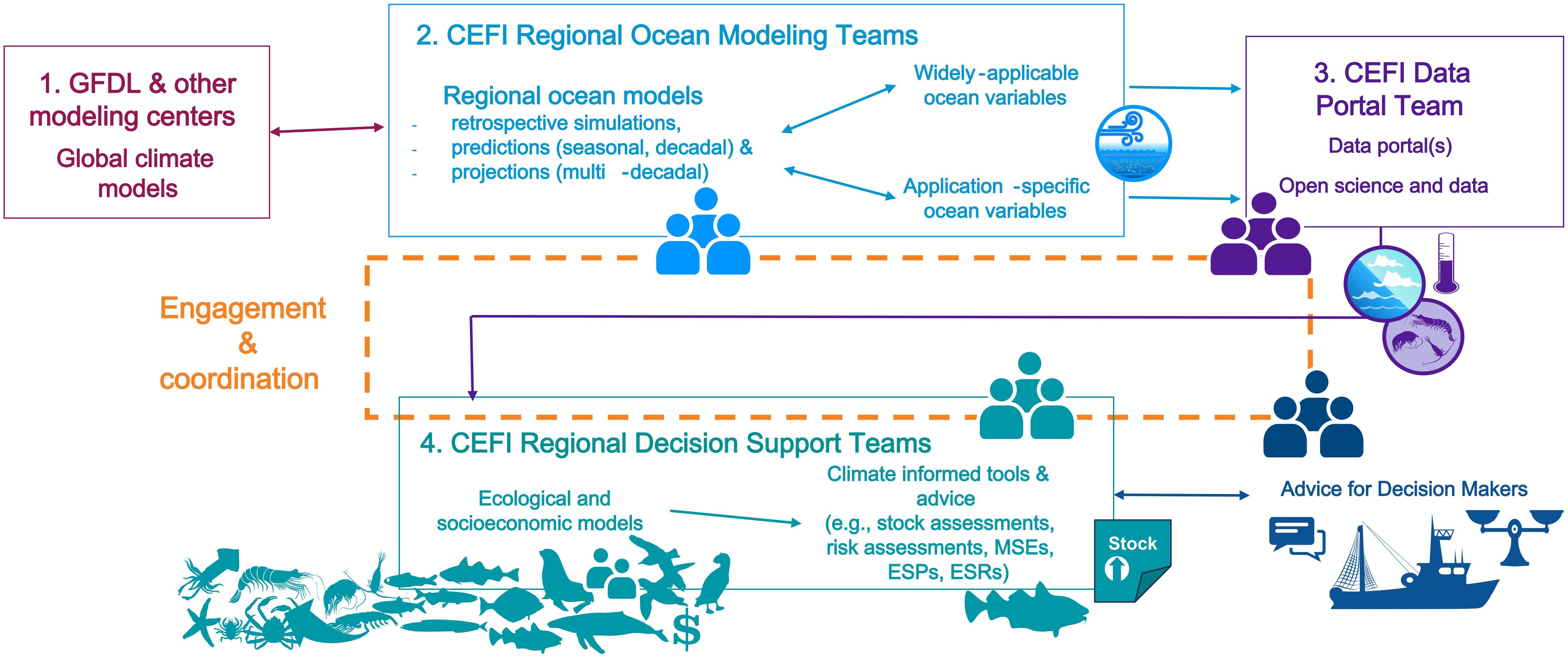
The evidence is clear: there are now mitigation options available in all sectors that could together **halve global greenhouse gas emissions by 2030.** *-Dr Céline Guivarch*

EXTRA SLIDES

EXTRA SLIDES

EXTRA SLIDES

National CEFI Component Workflow



ACLIM Publications (direct & indirect) 1 of 2

(2024) McHuron et al. Current and future habitat suitability of northern fur seals and overlap with the commercial walleye pollock fishery in the eastern Bering Sea Movement Ecology

(2024) Goodman et al. Climate covariate choice and uncertainty in projecting species range shifts: a case study in the Eastern Bering Sea. Fish and Fisheries (in press)

(2024) Hollowed et al. Selecting climate linked decision relevant and adaptation informing community level scenarios for ecosystems through constituent engagement : A case study for the eastern Bering Sea. ICES JMS

(2023) Punt et al. Capturing Uncertainty when Modelling Environmental Drivers of Fish Populations, with an Illustrative Application to Pacific Cod in the Eastern Bering Sea. Fisheries Research

(2023) Bigman, JvS, B J Laurel, K Kearney, A J Hermann, W Cheng, K K Holsman, L A Rogers. Predicting Pacific cod thermal spawning habitat in a changing climate. ICES Journal of Marine Science, fsad096, https://doi.org/10.1093/icesjms/fsad096

(2023) Hermann et al. Applications of biophysical modeling to Pacific high-latitude ecosystems. Oceanography

(2023) Szuwalski, C.S. et al. The collapse of eastern Bering Sea snow crab. Science.

(2023) Olmos, M., et al., Punt, A.E., Szuwalski, C.S. A step towards the integration of spatial dynamics in population dynamics models: Eastern Bering sea snow crab as a case study. Ecological Modelling 485: 110484.

(2023) Szuwalski et al., Unintended consequences of climate-adaptive fisheries management targets. Fish and Fisheries. https://doi.org/10.1111/faf.12737

(2022) Barnes, C.; Essington, T. E.; Pirtle, J; Rooper, C; Laman, E.; Holsman, K.; Aydin, K.; Thorson, J.. Climate-informed models benefit hindcasting but may present challenges when forecasting species-habitat associations. Ecography 2022: e06189 doi:10.1111/ecog.06189

(2022) Pilcher, D.J., J.N. Cross, A. Hermann, K. Kearney, W. Cheng, J.T. Mathis. Dynamically downscaled projections of ocean acidification for the Bering Sea, *Deep-Sea Research II: Topical Studies in Oceanography 198, 105055*

(2022) Hollowed, A. B., A. C. Haynie, A. J. Hermann, K. K. Holsman, A. E. Punt, C. S. Szuwalski. Implications of climate change on the Bering Sea and other cold water systems. Introduction to the special issue of Deep-Sea Research Part II: Topical Studies in Oceanography.

(2022) Punt, A.E., et al., Szuwalski, C.S. 2022. A framework for assessing harvest strategy choice when considering multiple interacting fisheries and a changing environment: The example of eastern Bering Sea crab stocks. Fisheries Research. 252: 106338.

(2022) Szuwalski, C.S.. Estimating time-variation in confounded processes in population dynamics modeling: a case study for snow crab in the eastern Bering Sea. Fisheries Research. 251: 106298.

(2021) Hermann, A. J., Kearney, K., Cheng, W., Pilcher, D., Aydin, K., Holsman, K. K., & Hollowed, A. B.. Coupled modes of projected regional change in the Bering Sea from a dynamically downscaling model under CMIP6 forcing. Deep-Sea Research Part II: Topical Studies in Oceanography, 194 (Dec), 104974. https://doi.org/10.1016/j.dsr2.2021.104974

ACLIM Publications (direct & indirect) 1 of 2

(2021) Cheng, W., Hermann, A. J., Hollowed, A. B., Holsman, K. K., Kearney, K. A., Pilcher, D. J., Stock, C. A., & Aydin, K. Y.. Eastern Bering Sea shelf environmental and lower trophic level responses to climate forcing: Results of dynamical downscaling from CMIP6. Deep-Sea Research Part II: Topical Studies in Oceanography, 193, 104975. https://doi.org/10.1016/j.dsr2.2021.104975

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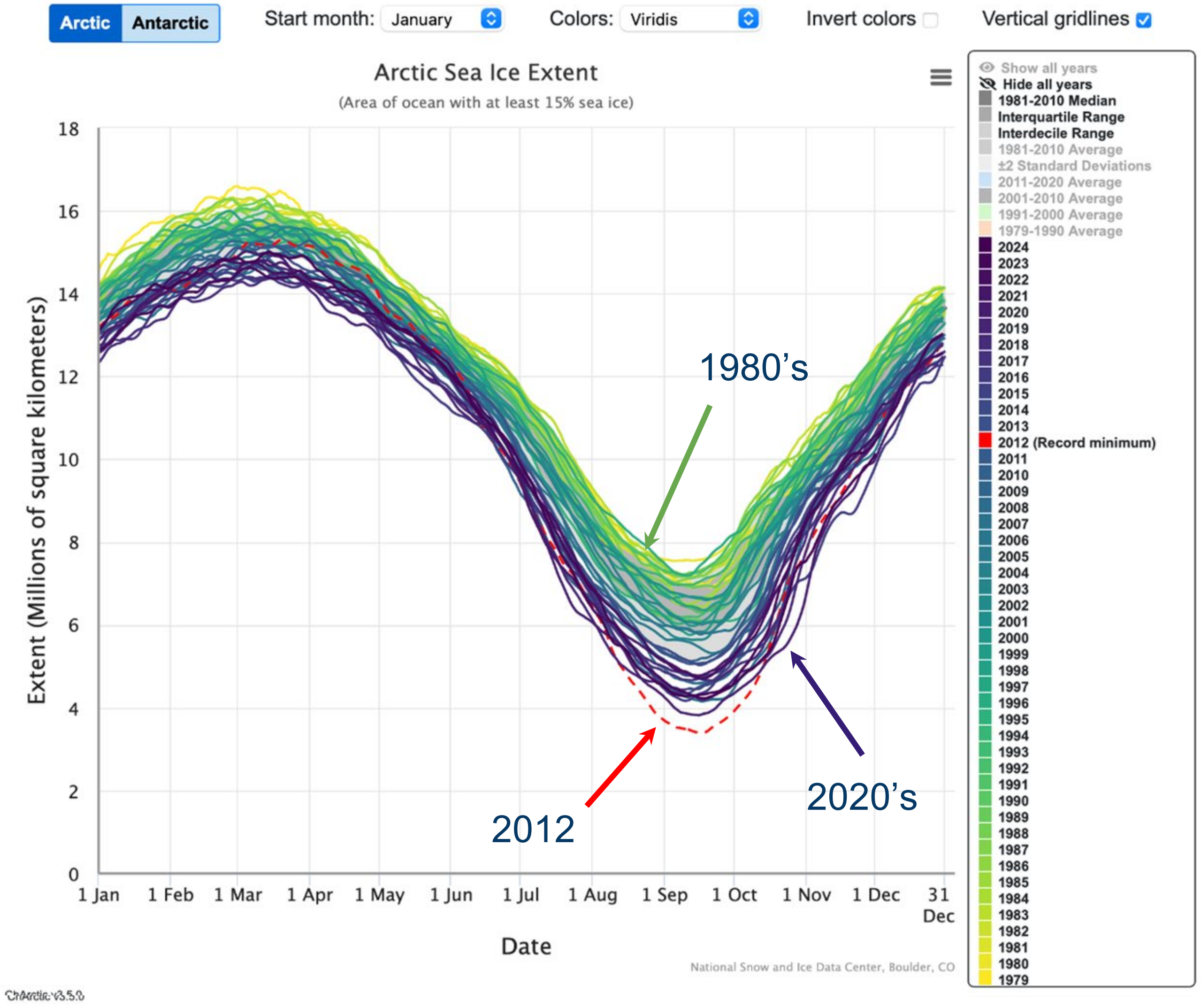
Sea Ice Loss



National Snow and Ice Data Center
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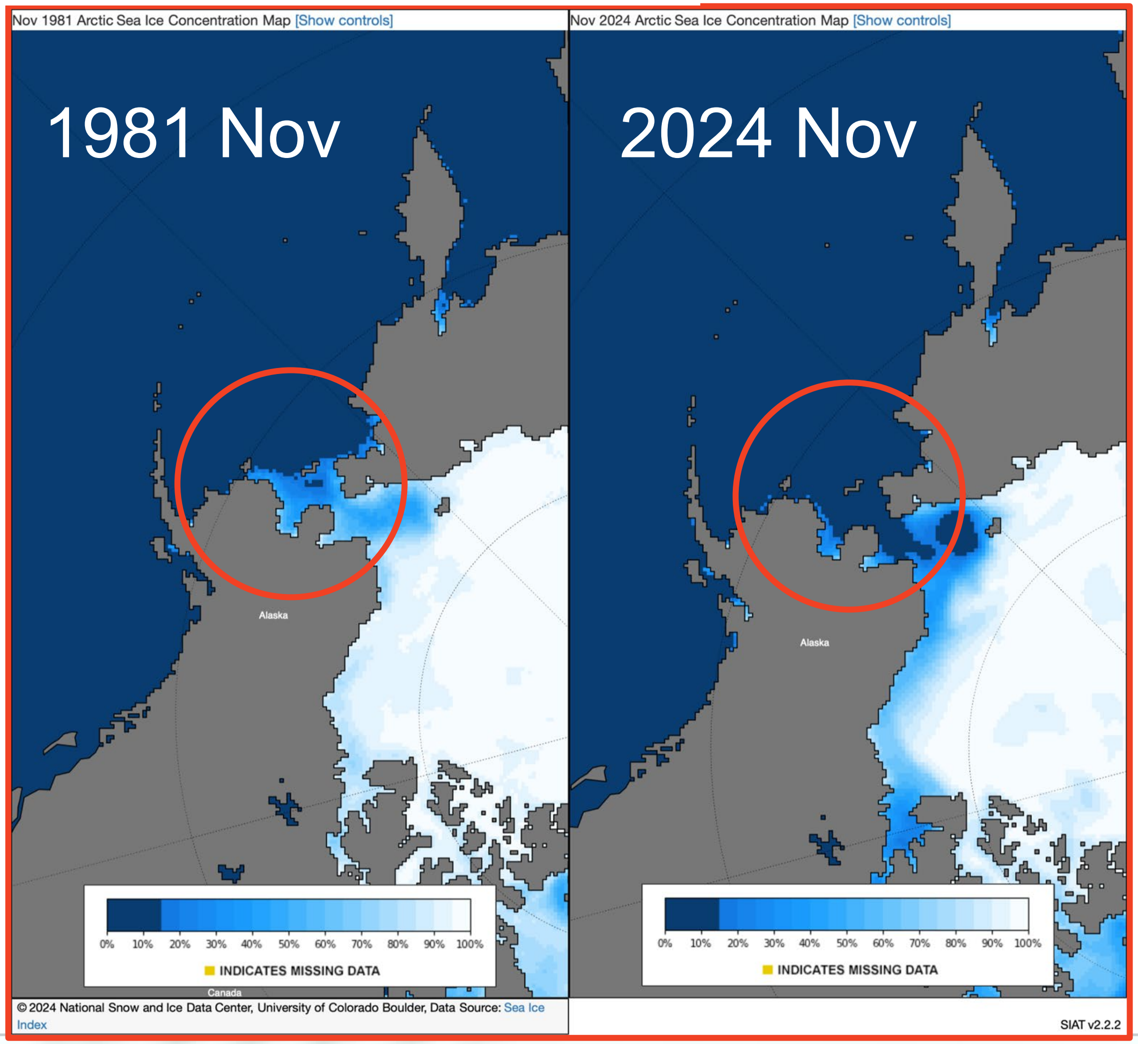
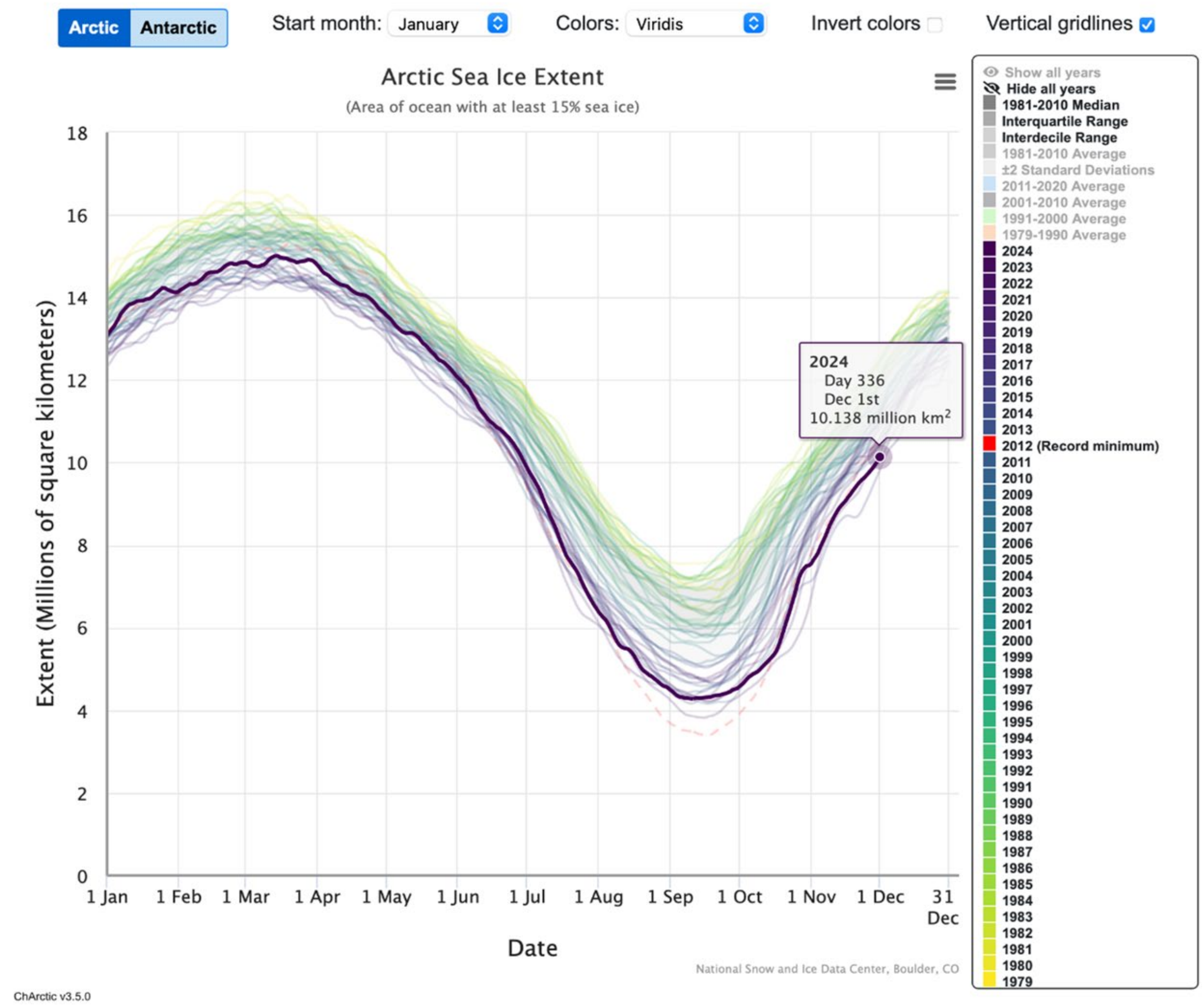


Sea Ice Loss



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