A framework for an ecosystem approach to fisheries management under projected climate change

An OAR – NMFS partnership

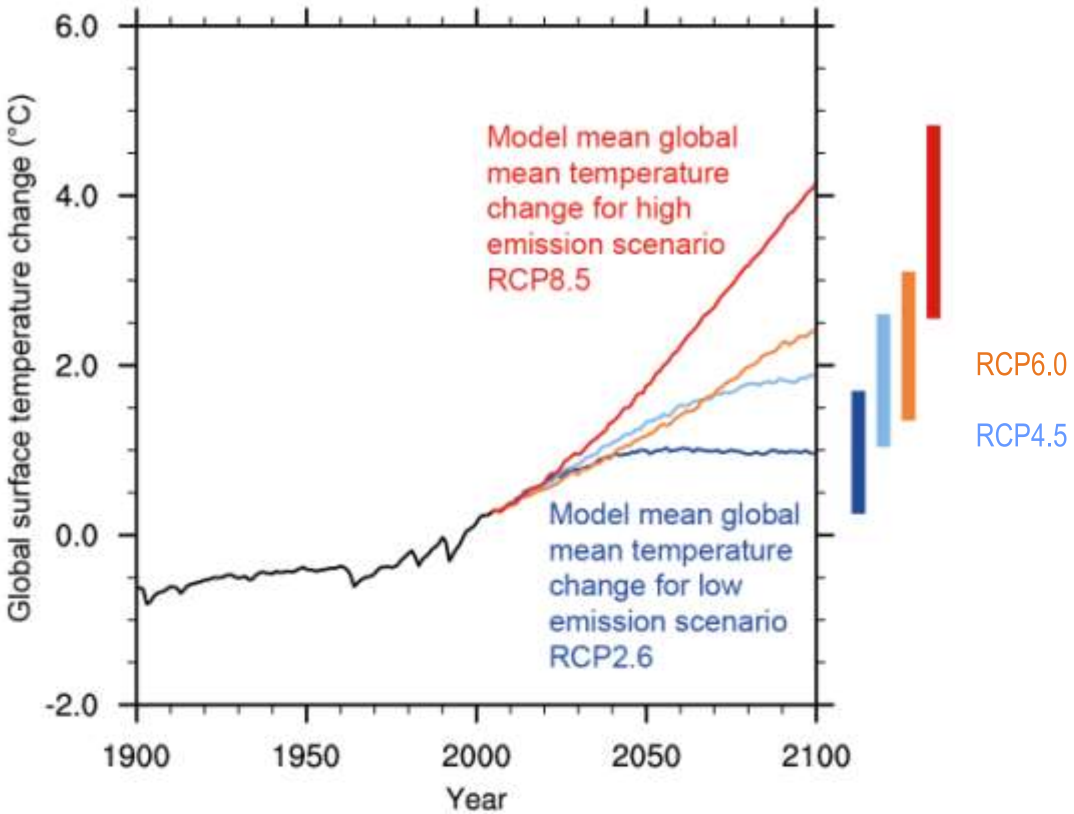
Anne Hollowed and Phyllis Stabeno

Alaska Fisheries Science Center

Pacific Marine Environmental Laboratory

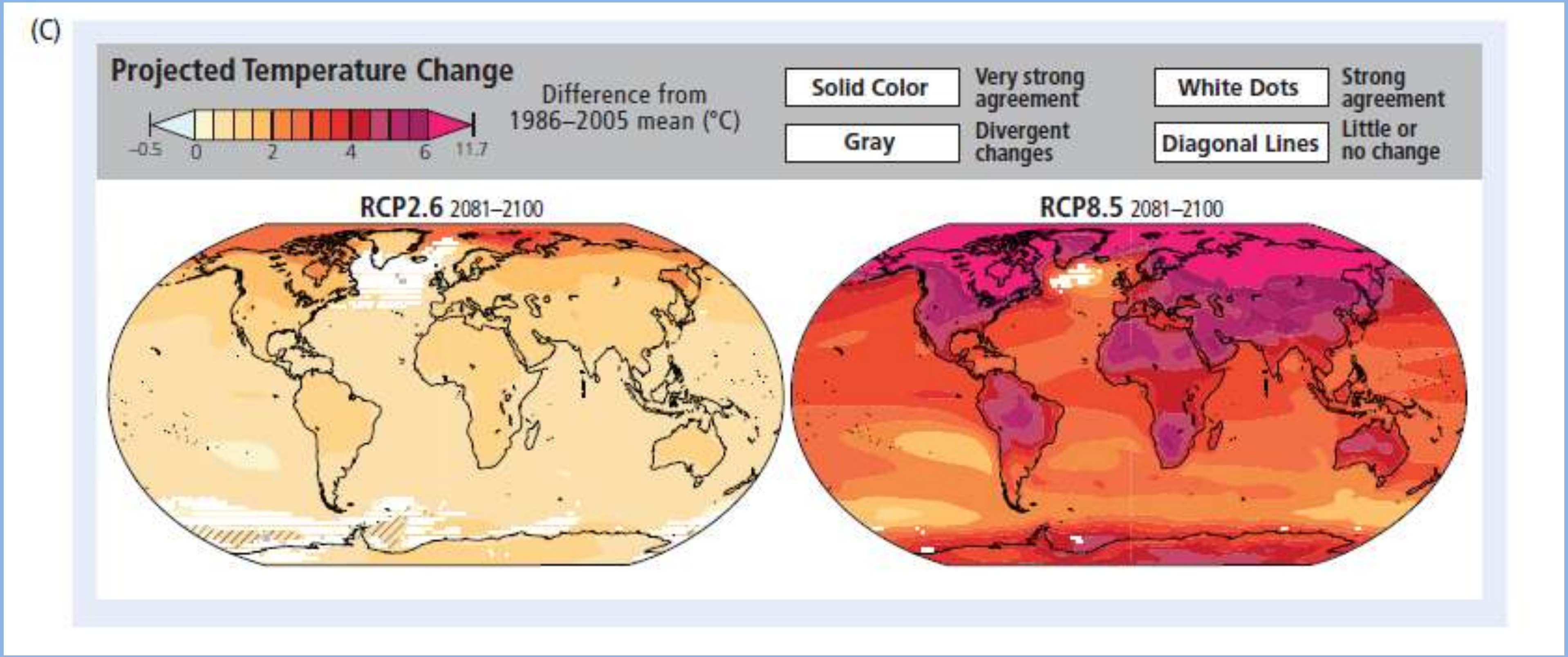
"To what extent is climate change/ocean acidification an ecosystem game changer for fisheries and their management?
Fished ecosystems appear to be undergoing remarkable change, e.g., Gulf of Maine, Gulf of Mexico, California Current, Bering Sea and Arctic Ocean. Can we predict how they will continue to change? " **SAB EBFM Report**

Reasonable Concentration Pathway emission scenarios of global mean temperature change (relative to 1986-2005)



Intergovernmental Panel on Climate Change; 5th Assessment Report, Summary for policy makers http://www.ipcc-wg2.gov/AR5/images/uploads/WG2AR5_SPM_FINAL.pdf

Projected Average Annual Surface Temperature (IPCC AR5 SPM, 2014)

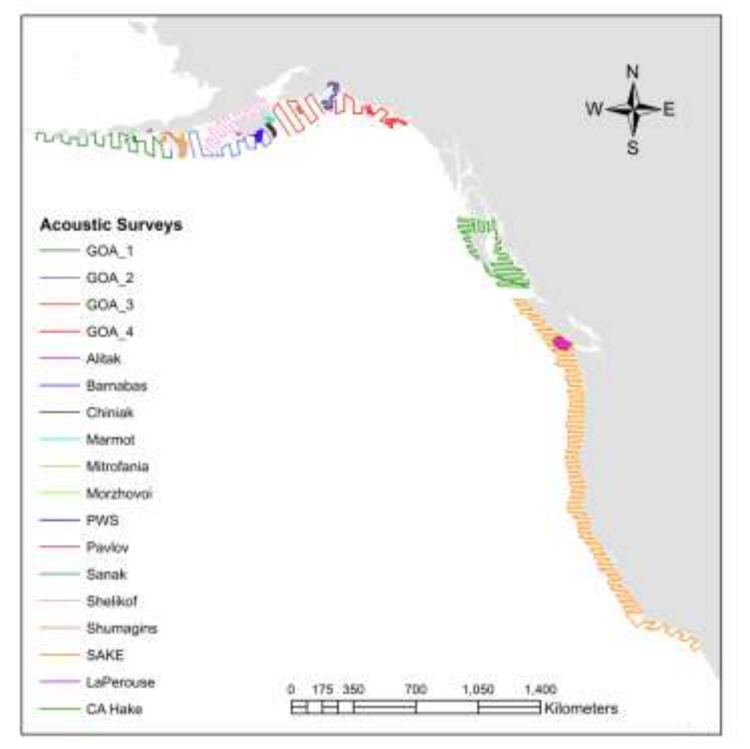


http://www.ipcc-wg2.gov/AR5/images/uploads/WG2AR5_SPM_FINAL.pdf

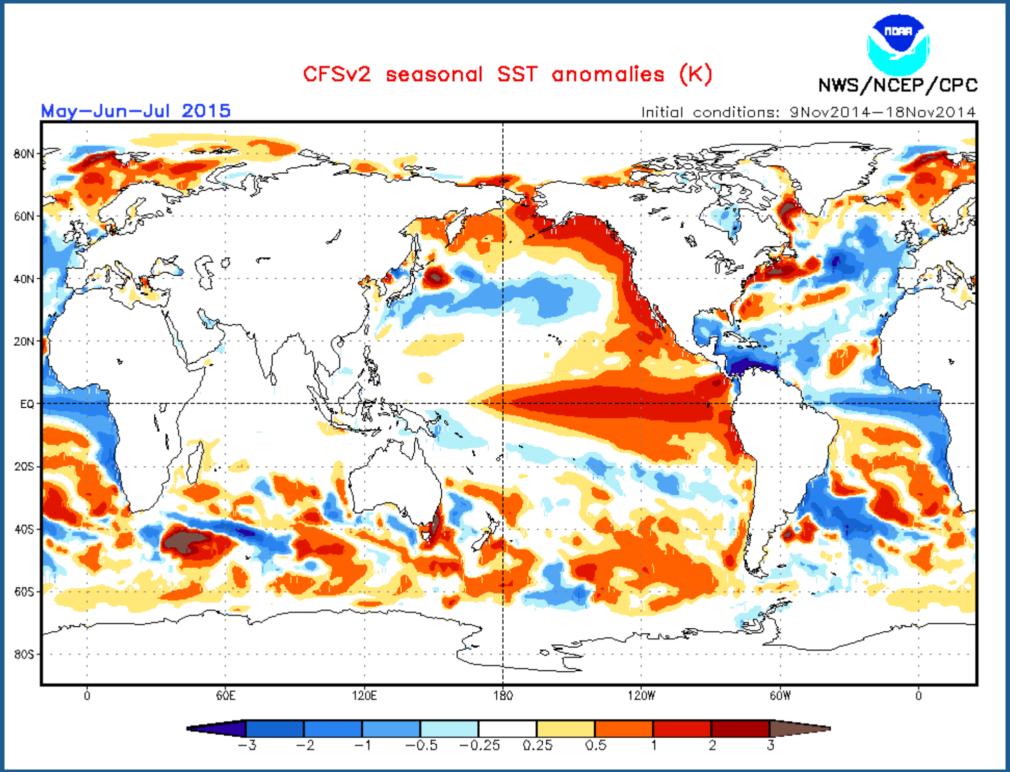
Legend: IPCC= Intergovernmental Panel on Climate Change; AR5 = 5th Assessment Report; SPM=Summary for policy makers; RCP = Representative Concentration Pathway

Forecasting the Unexpected: OAR - JISAO

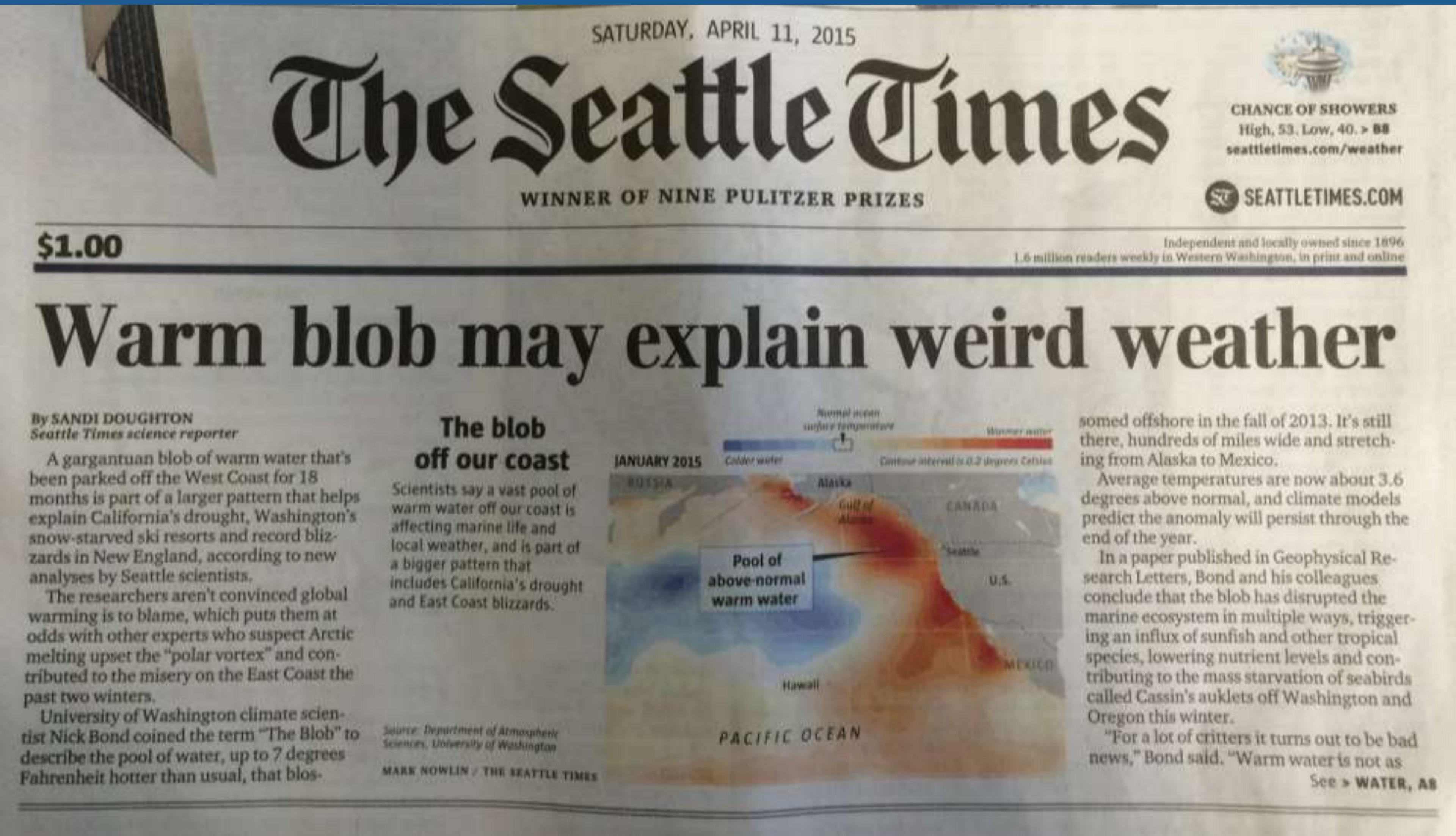
- NOAA's Coupled Forecast System
- Opportunity to observe shifts in fish distribution in 2015.
- US and Canada plan to conduct bottom trawl and acoustic surveys from California to the Gulf of Alaska.



Approximate tracklines for the 2015 U.S. and Canadian acoustic mid-water trawl surveys. Note the La Perouse survey (pink) is not confirmed



2015 SST projection from NOAA's coupled forecast system.



SATURDAY, APRIL 11, 2015

The Seattle Times

WINNER OF NINE PULITZER PRIZES

CHANCE OF SHOWERS
High, 53. Low, 40. > B8
seattletimes.com/weather

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Warm blob may explain weird weather

By SANDI DOUGHTON
Seattle Times science reporter

A gargantuan blob of warm water that's been parked off the West Coast for 18 months is part of a larger pattern that helps explain California's drought, Washington's snow-starved ski resorts and record blizzards in New England, according to new analyses by Seattle scientists.

The researchers aren't convinced global warming is to blame, which puts them at odds with other experts who suspect Arctic melting upset the "polar vortex" and contributed to the misery on the East Coast the past two winters.

University of Washington climate scientist Nick Bond coined the term "The Blob" to describe the pool of water, up to 7 degrees Fahrenheit hotter than usual, that blossomed offshore in the fall of 2013. It's still there, hundreds of miles wide and stretching from Alaska to Mexico.

Average temperatures are now about 3.6 degrees above normal, and climate models predict the anomaly will persist through the end of the year.

In a paper published in Geophysical Research Letters, Bond and his colleagues conclude that the blob has disrupted the marine ecosystem in multiple ways, triggering an influx of sunfish and other tropical species, lowering nutrient levels and contributing to the mass starvation of seabirds called Cassin's auklets off Washington and Oregon this winter.

"For a lot of critters it turns out to be bad news," Bond said. "Warm water is not as

See > WATER, A8

The blob off our coast

Scientists say a vast pool of warm water off our coast is affecting marine life and local weather, and is part of a bigger pattern that includes California's drought and East Coast blizzards.

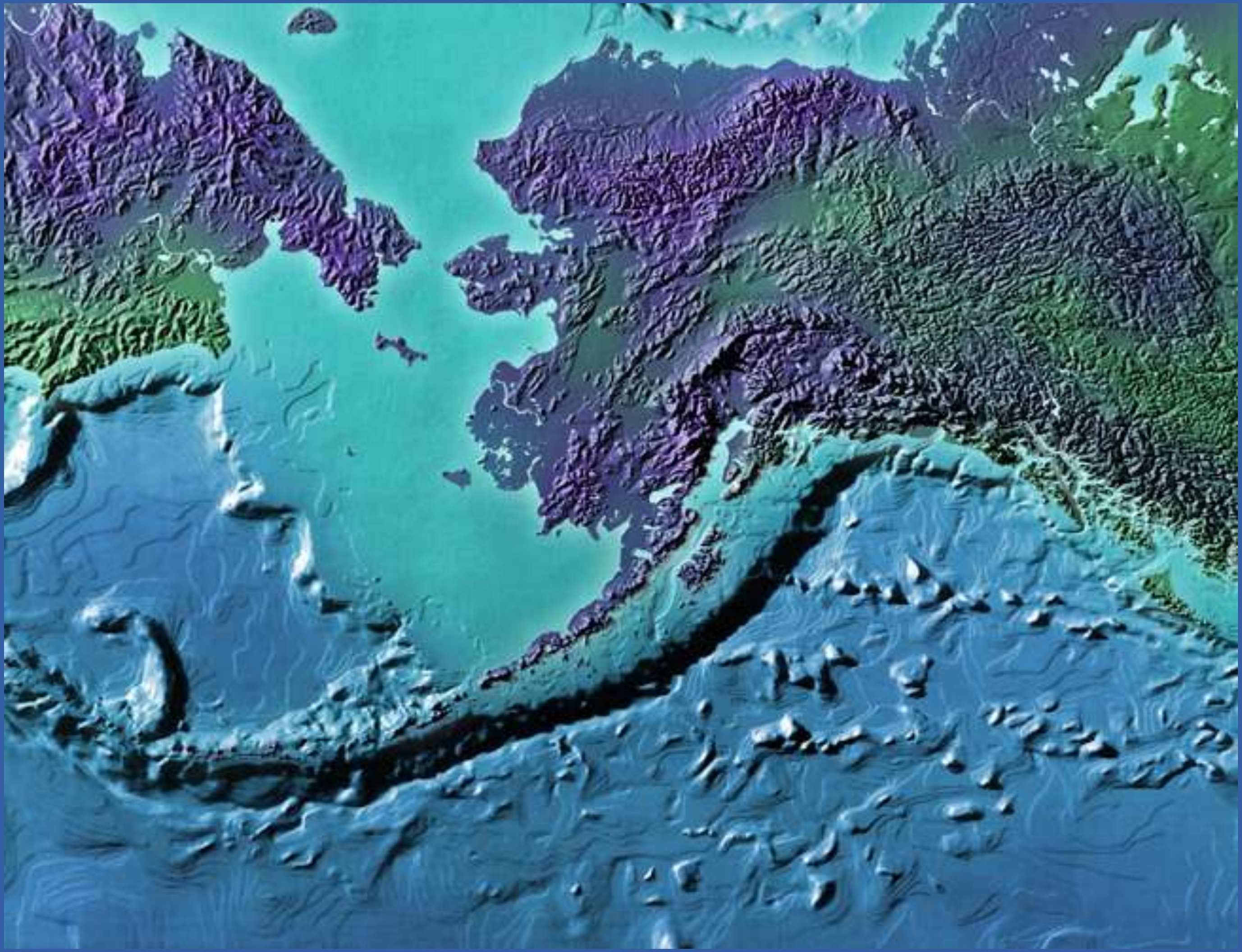
Source: Department of Atmospheric Sciences, University of Washington

MARK NOWLIN / THE SEATTLE TIMES

Possible Impacts of a Changing Climate

Climate Changes	Physical Chemical Impacts	Biological Impacts	Social Economic Impacts
↑ Temperature	↑ Ocean temperature	Δ Productivity	Δ Fishing activities
Δ Precipitation	↓ Sea ice	Δ Phenology & survivorship	Δ Revenues & economies
↑ Atmospheric Carbon Dioxide	↑ Sea level	Δ Species distribution	Δ Industries
	Δ Freshwater	Δ Species abundance	Δ Subsistence use
	↑ Ocean Acidification	Δ Community composition	Δ Community health

Case Study for the Bering Sea

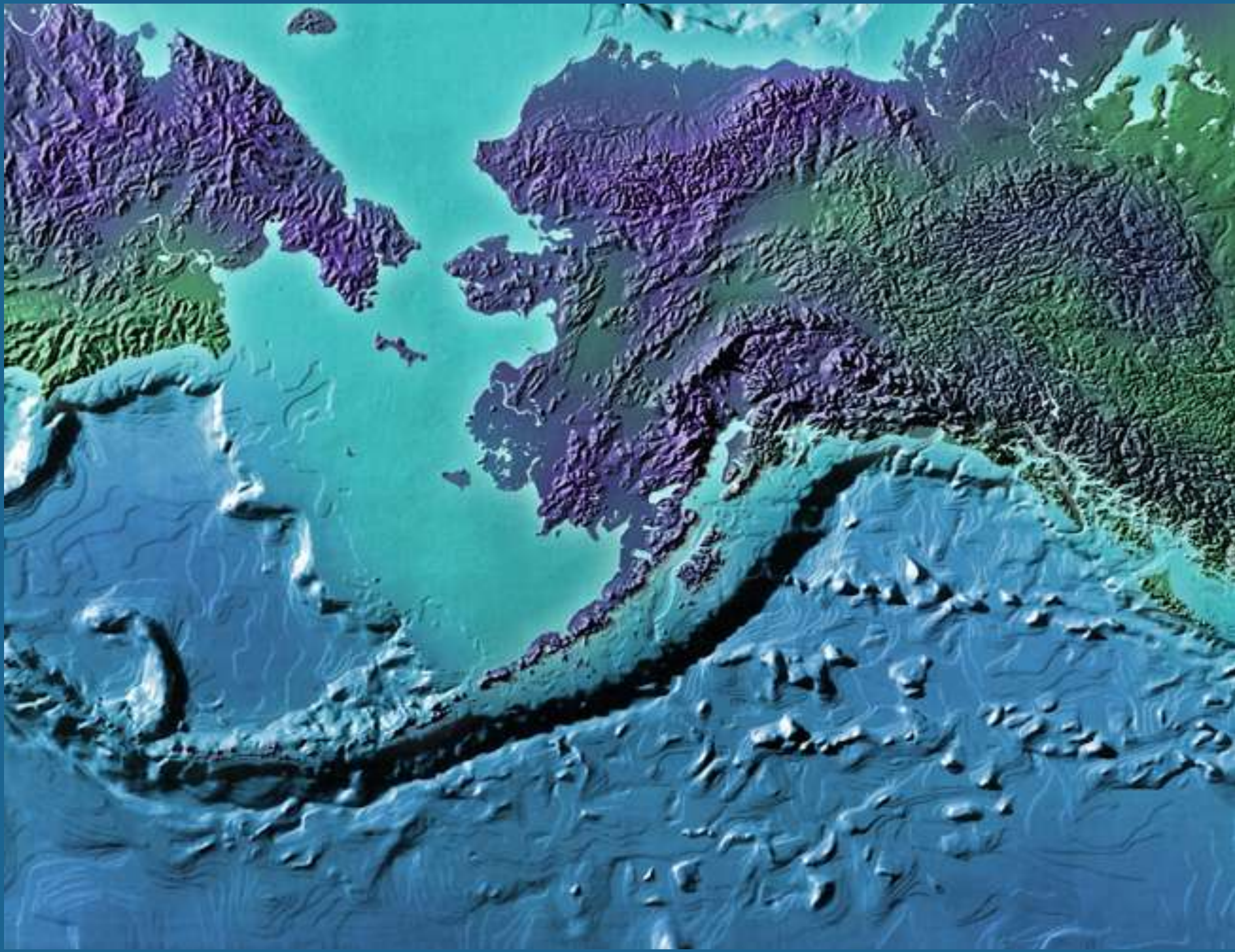


NOAA

The Bering Sea

- Home to a variety of biological resources, including: world's most extensive eelgrass beds; 450 species of fish and shell fish; 35 million birds; 25 species of marine mammals.
- Produces 40% of the total US commercial catch of fish and shellfish (world's largest sockeye salmon fishery.
- Provides ¾ of the subsistence harvest supporting 55,000 Alaska Natives.

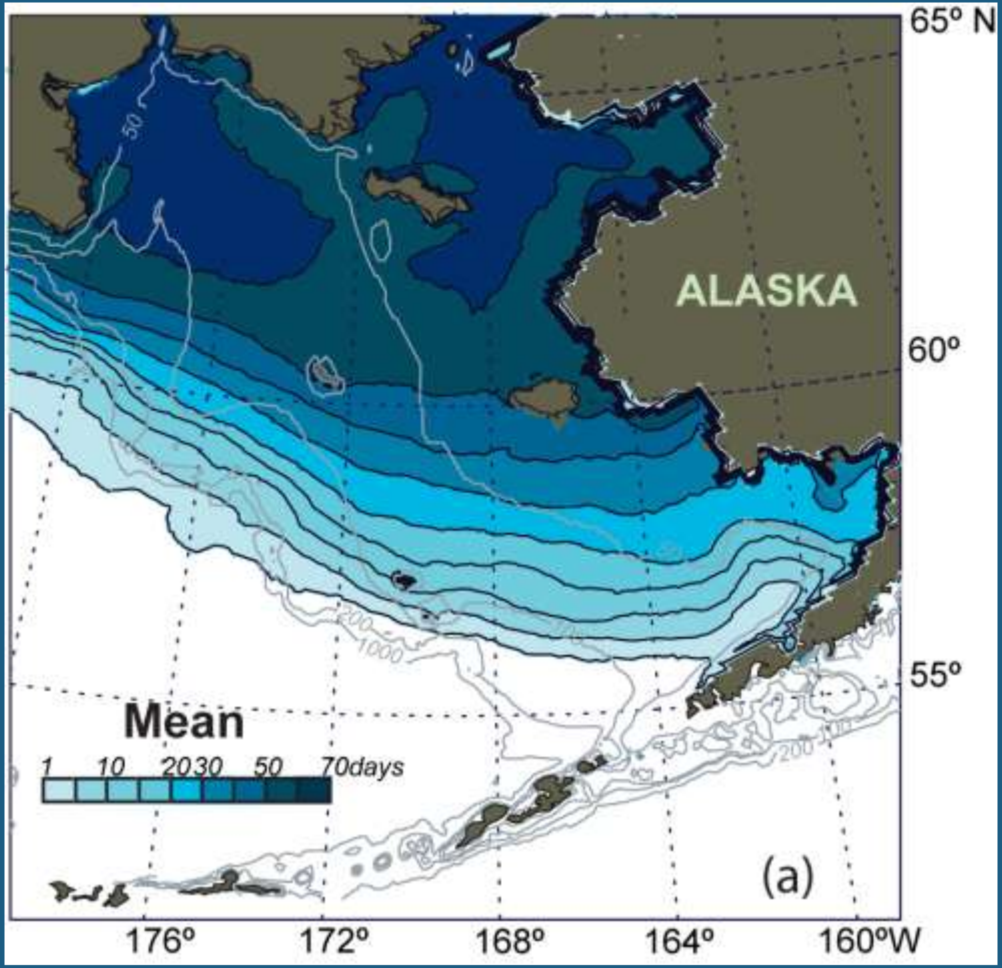
Case Study for the Bering Sea



Interdisciplinary, Integrated, Over 90 PIs

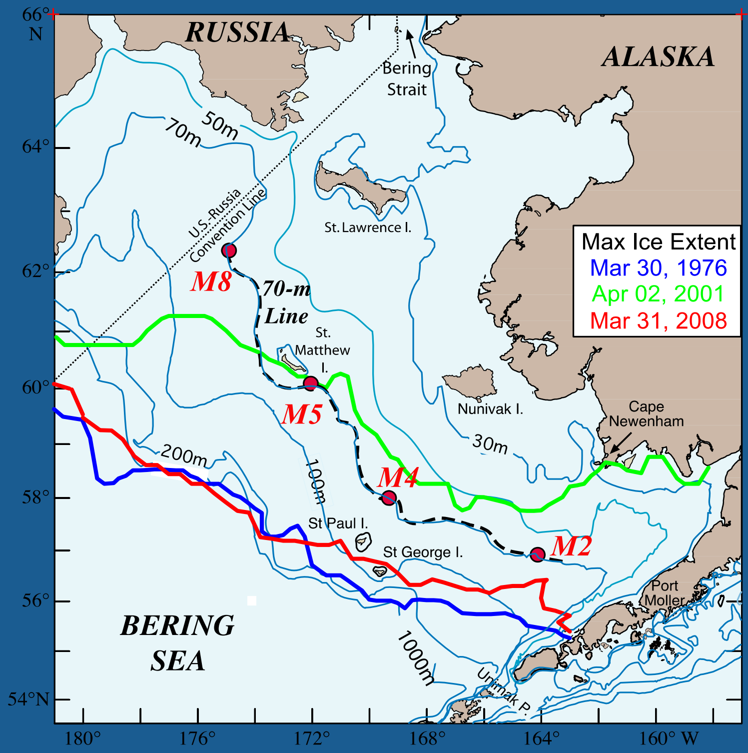
Mean number of days of ice cover March –April

Stabeno et al. 2012, Deep-Sea Research II

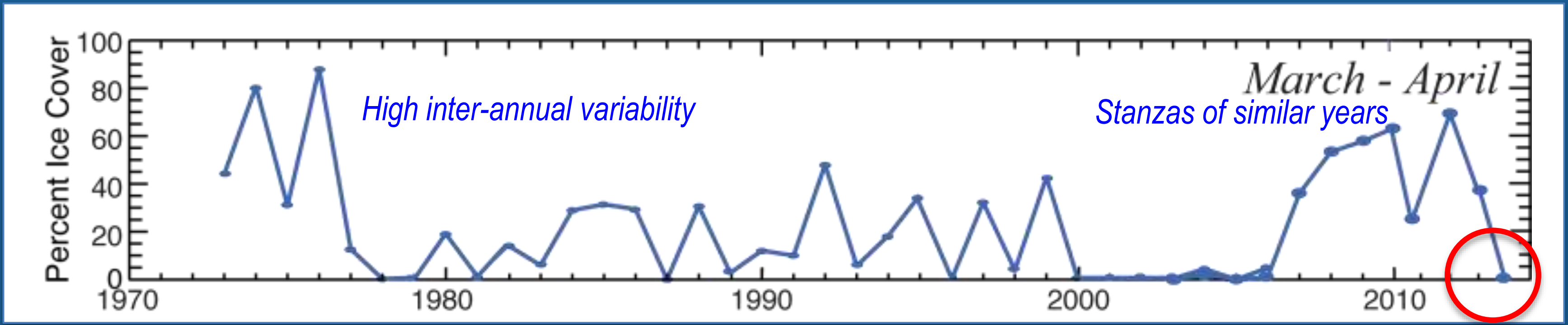


NOAA

Sea Ice



Percent Ice Cover at M2

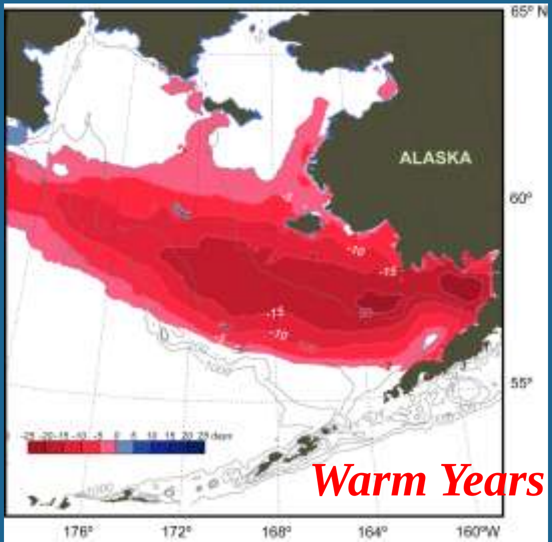


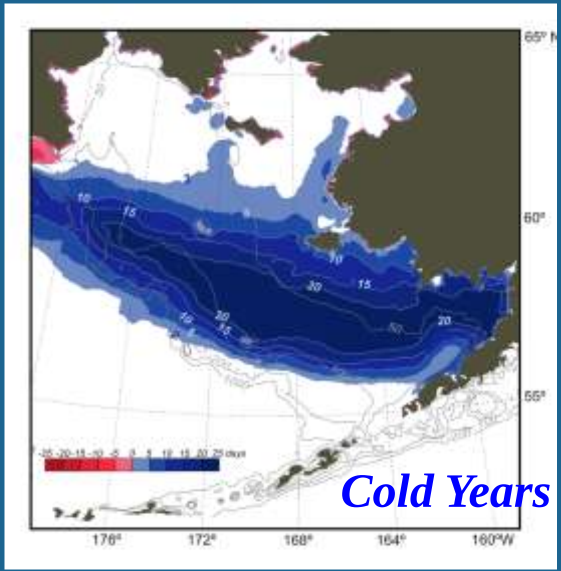
NOAA

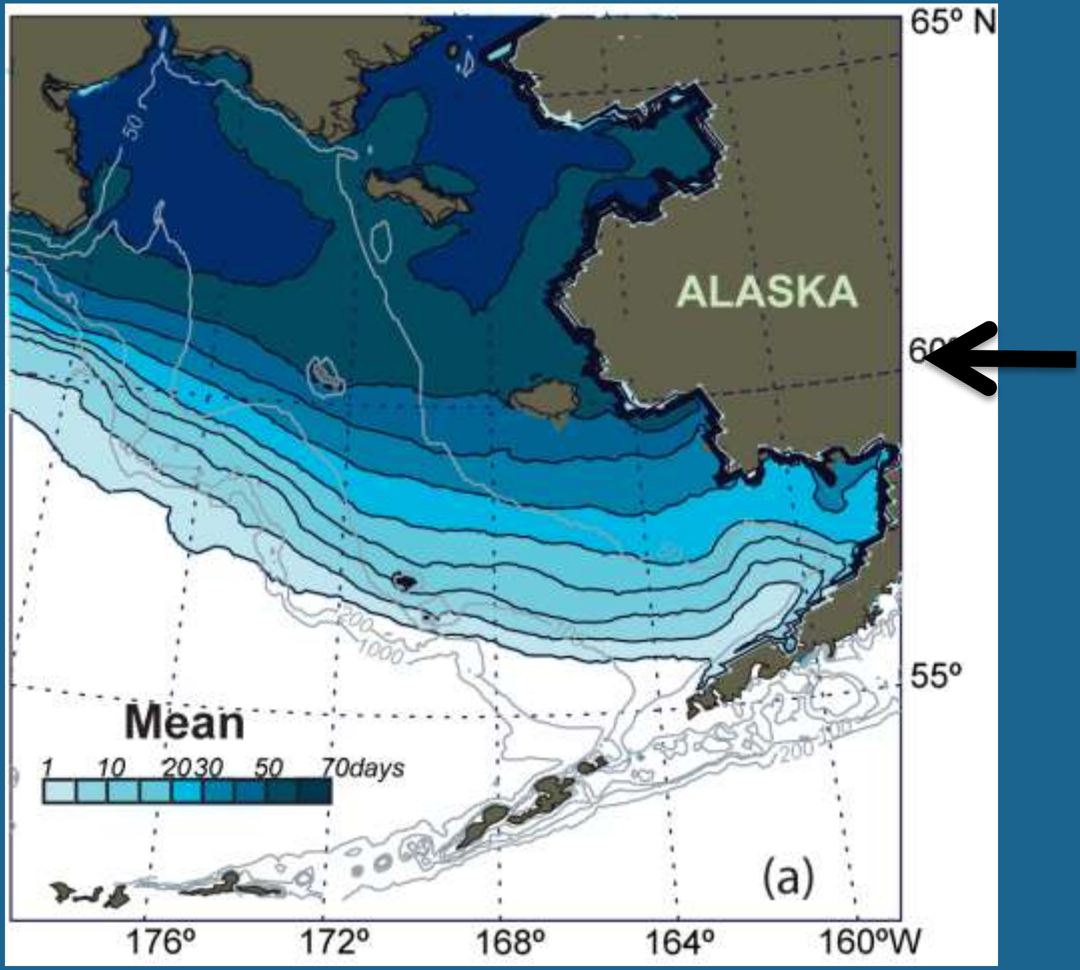
Stabeno et al., 2010; 2012

Mean number of days of ice cover March –April

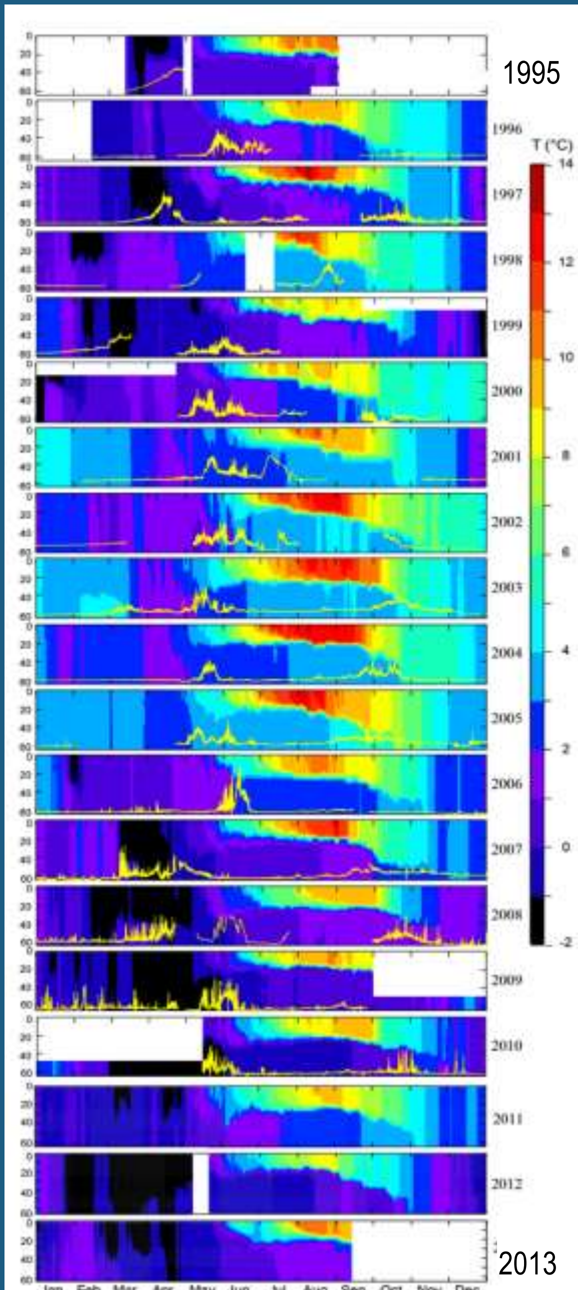
Stabeno et al. 2012, Deep-Sea Research II



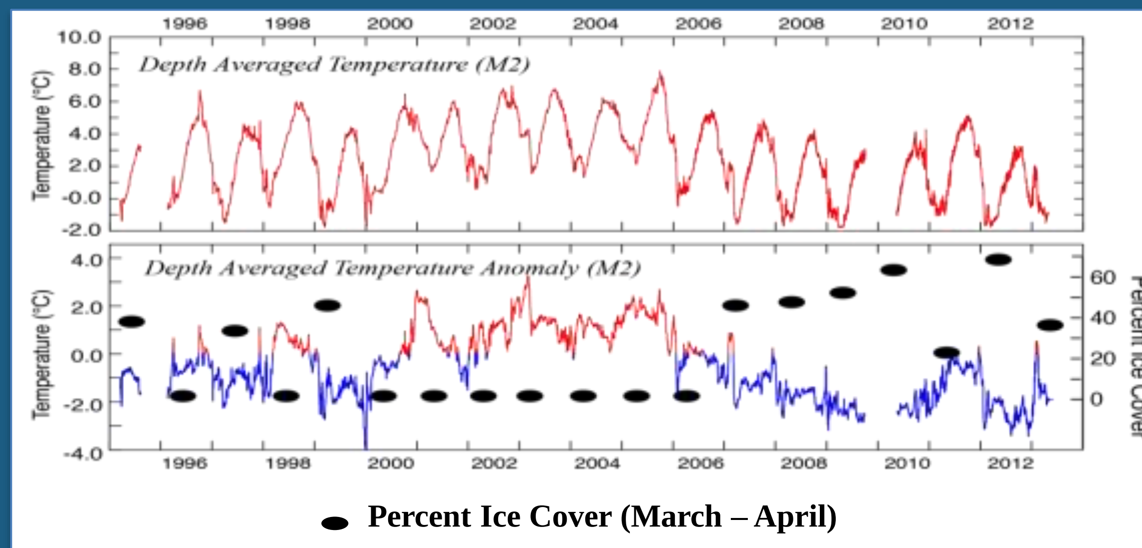




Temperature and Sea Ice at M2



Measurements on M2: currents, temperature, salinity, O_2, fluorescence, pCO_2, nitrate, sound, zooplankton biovolume, and summer met package

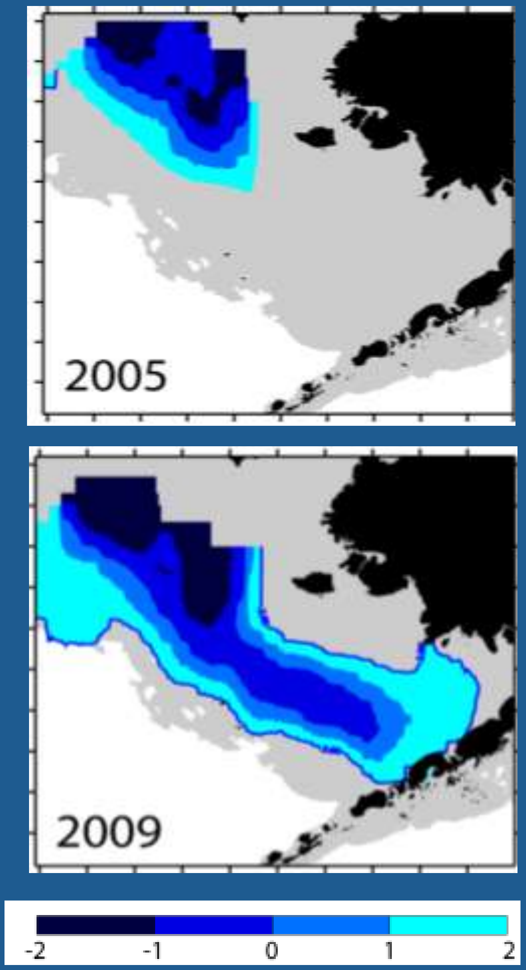


Stabeno et al., 2012

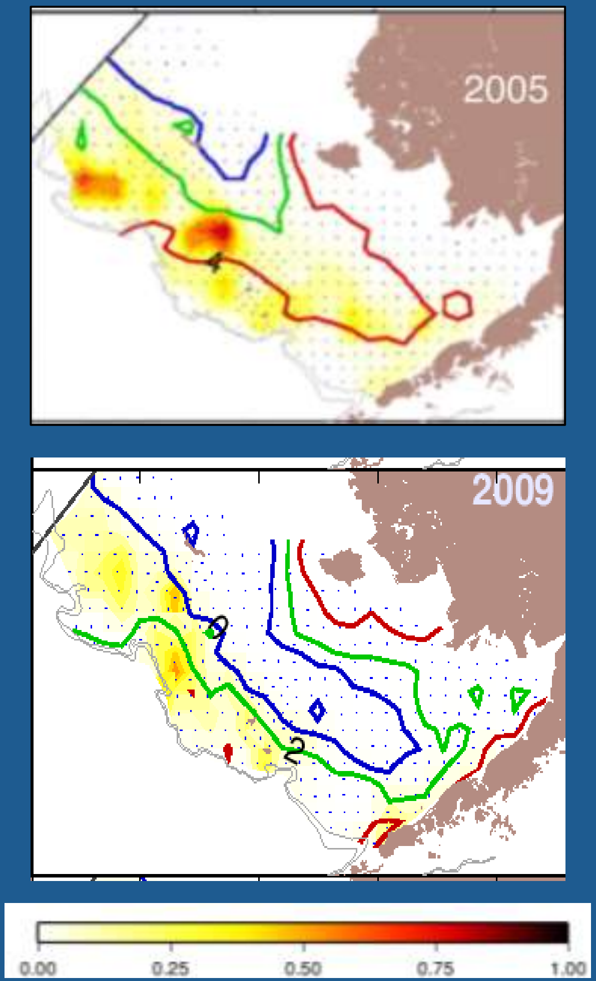
Cold pool and its influence on pollock

Warm (2005)

Cold (2009)



Bottom Temperature (°C)



Relative Abundance of pollock

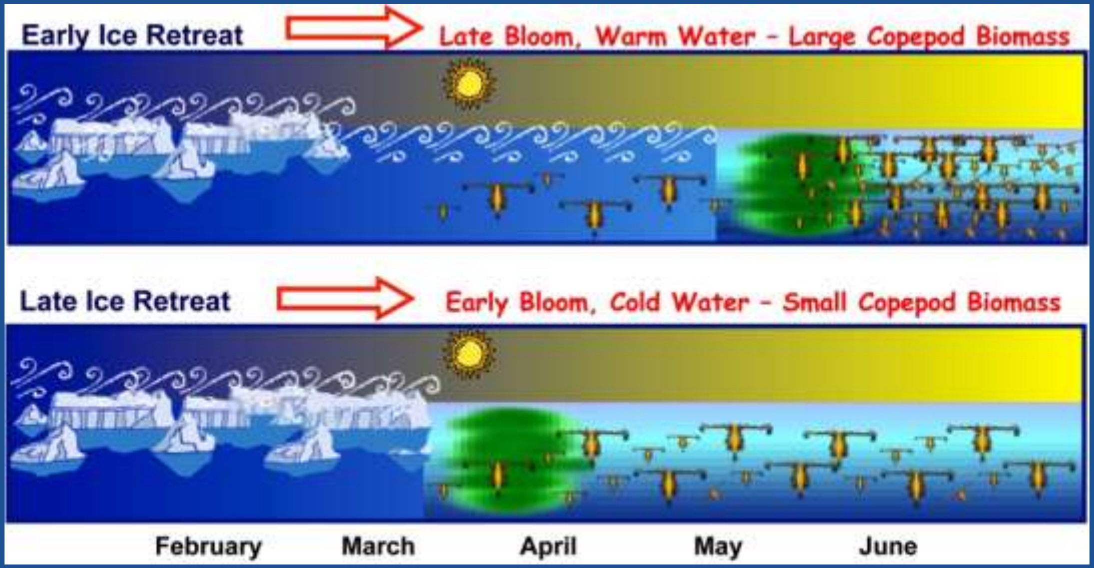
Differences in the extent of the cold pool and relative abundance of pollock in warm and cold years.

Kotwicki et al. 2013, Deep-Sea Research II

Ice and its influence on lower trophic

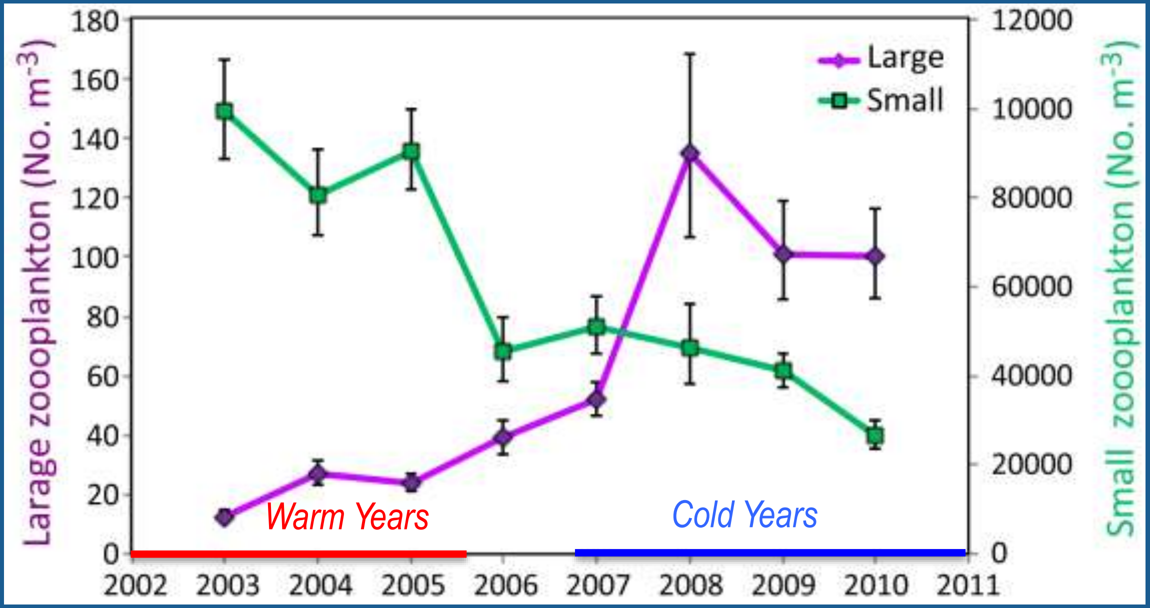
Original Paradigm:

Timing of the spring phytoplankton – zooplankton coupling



Ice extent and timing or retreat impacts the extent of the cold pool (bottom water < 2°C) and the timing of the spring phytoplankton bloom.

Change in abundance of large zooplankton

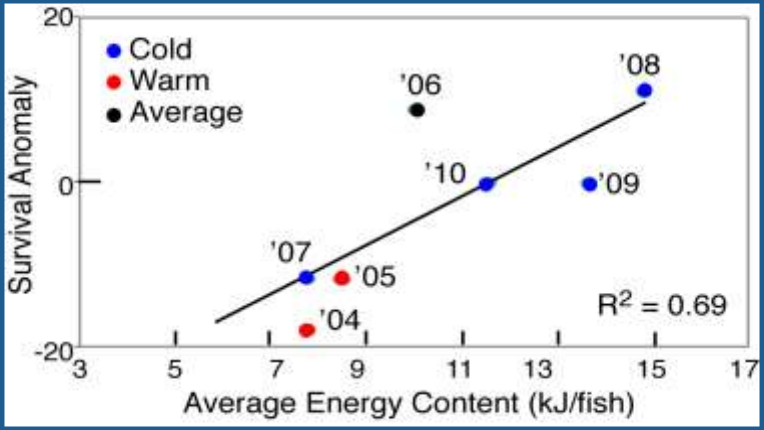


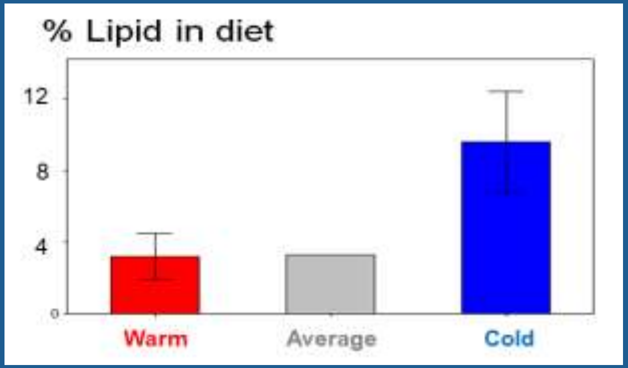
Cold years increased abundance of large zooplankton and successive warm years reduced numbers of zooplankton

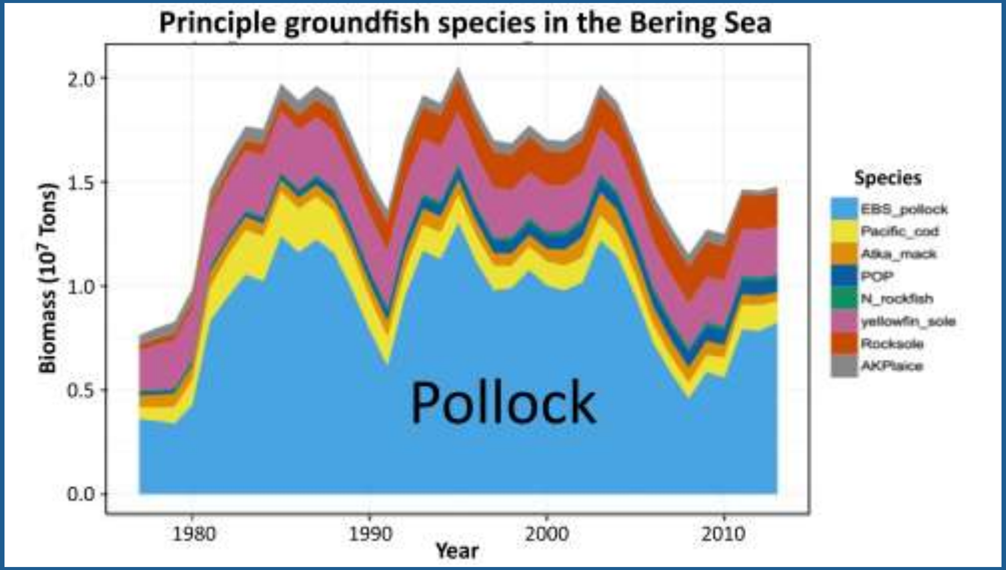
Eisner et al., 2014

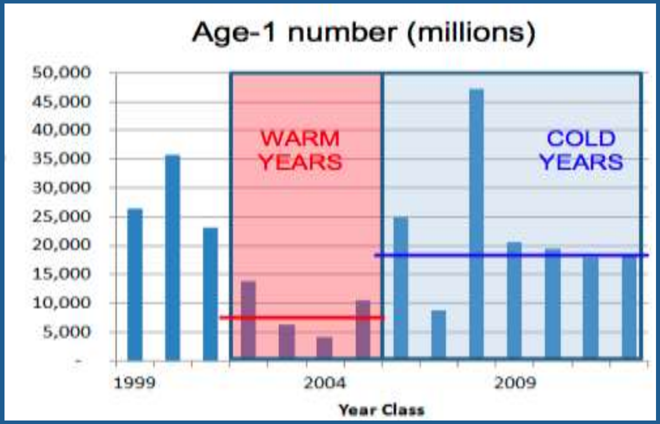
Change in survival of young-of-the-year pollock

As a consequence, age-0 pollock consume richer diets in cold years, better preparing them for their first winter and enhancing survivorship.



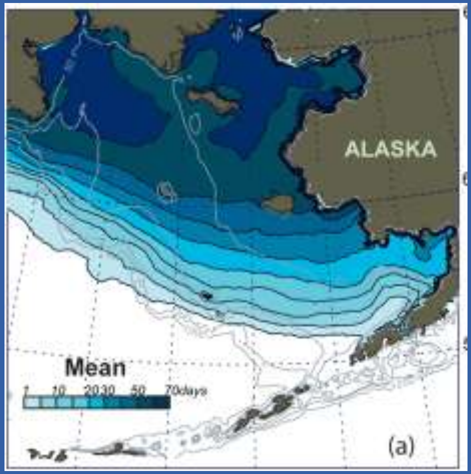






Heintz et al. 2013, DSR II

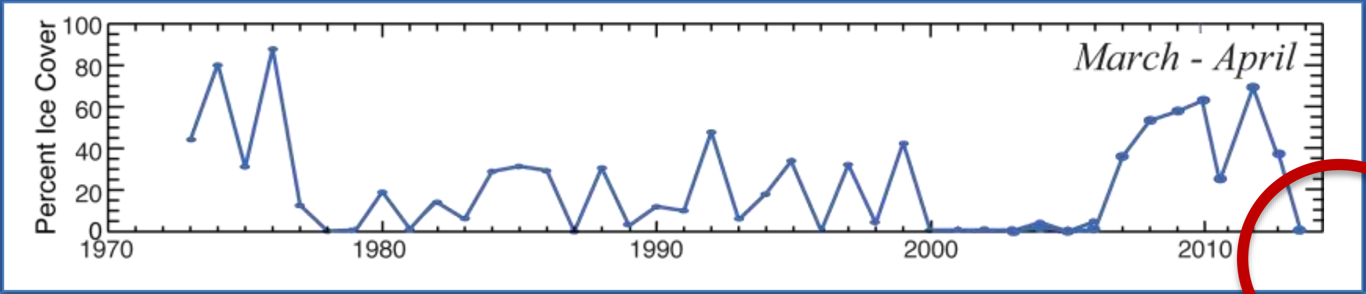
The new paradigm



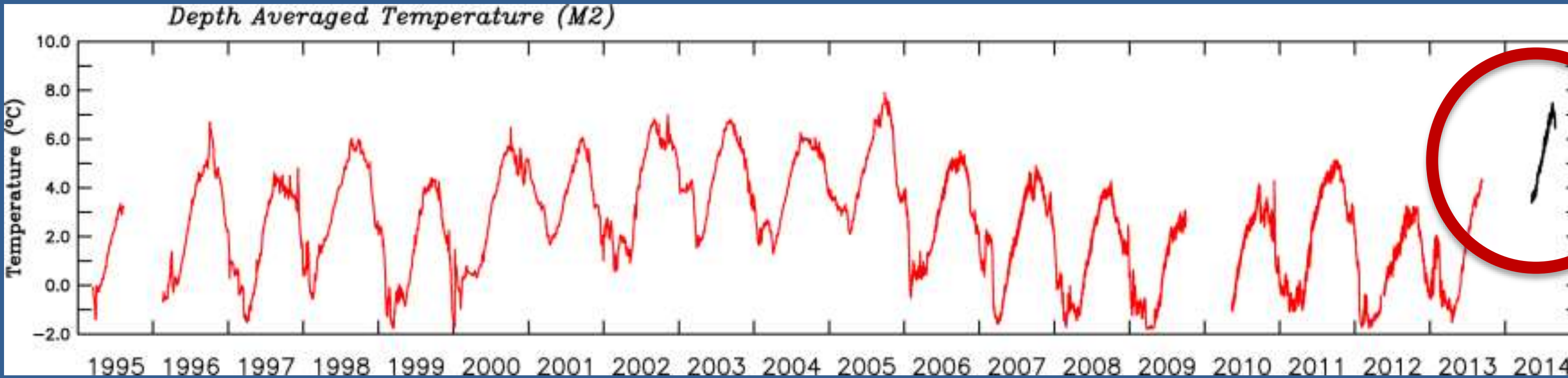
Warming would result in:

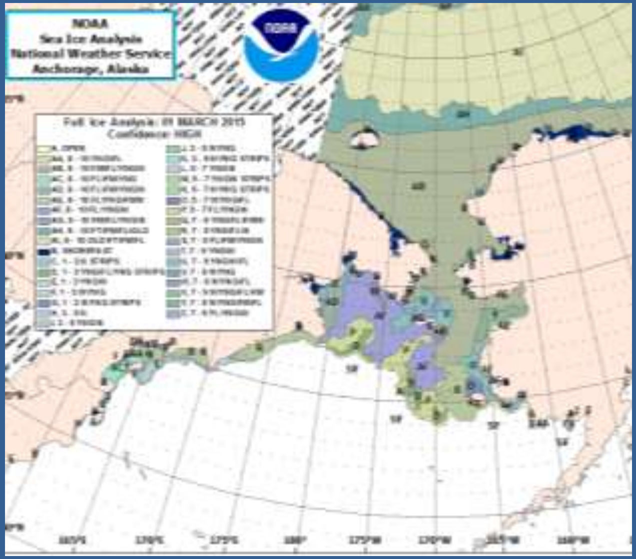
- **Decreased sea ice in the south, but not in the north;**
- **The southern ecosystem will not expand northward;**
- **Large zooplankton abundance will decrease;**
- **Decrease in catch, particularly subarctic species of fish;**
- **Change from interannual variability to stanzas.**

Mechanism *Multiple years of reduced ice* → *Warmer temperature* → *Decrease large zooplankton* → *Poor survival of yoy pollock.*

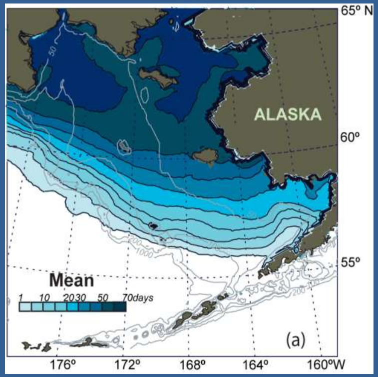


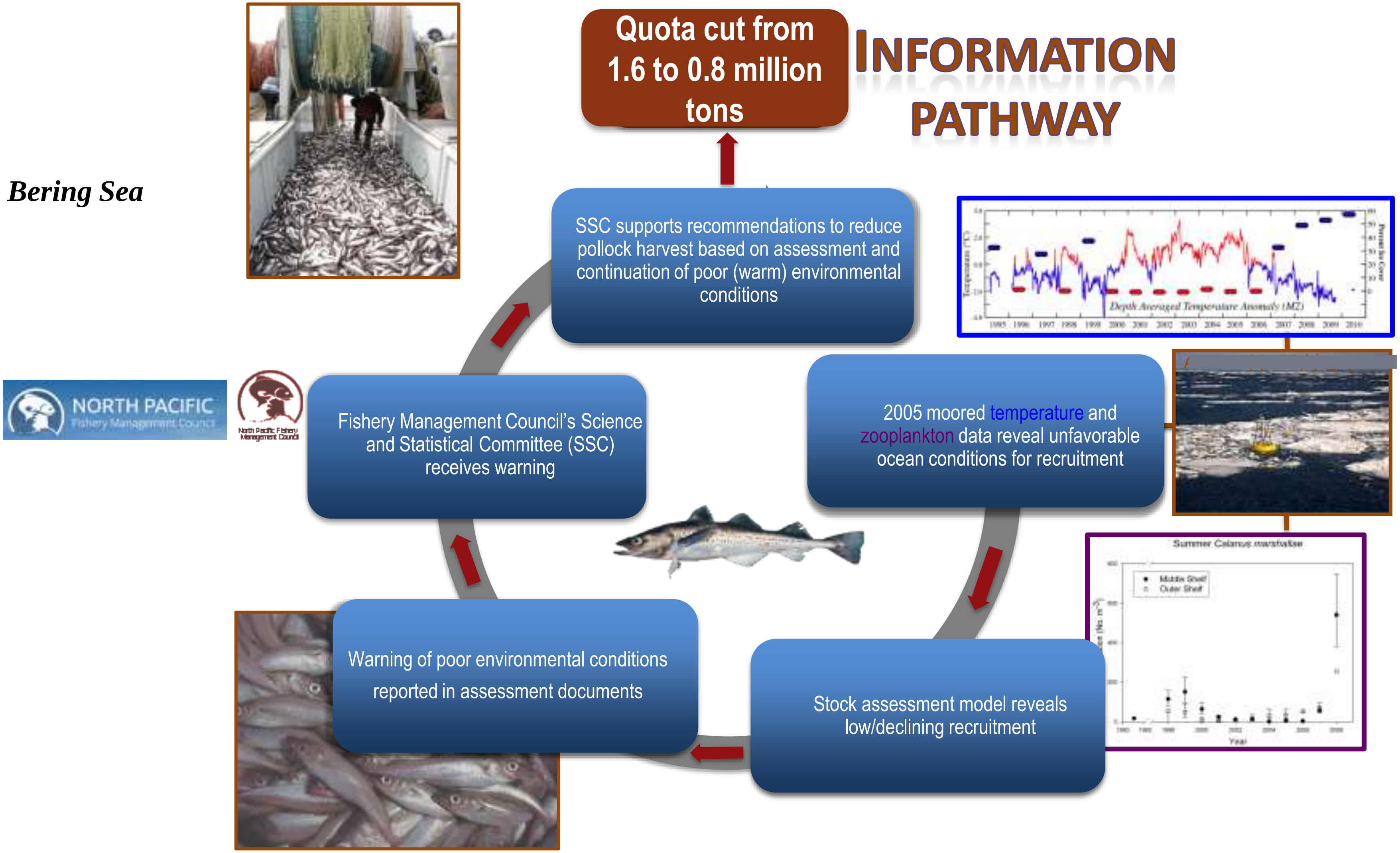
Are we entering another warm period?





March 1, 2015





INFORMATION PATHWAY
Bering Sea
Quota cut from 1.6 to 0.8 million tons
SSC supports recommendations to reduce pollock harvest based on assessment and continuation of poor (warm) environmental conditions
Depth Averaged Temperature Anomaly (MZ)
2005 moored temperature and zooplankton data reveal unfavorable ocean conditions for recruitment
Summer Calanus marshallae
Middle Shelf
Outer Shelf
Year
Stock assessment model reveals low/declining recruitment
Warning of poor environmental conditions reported in assessment documents
Fishery Management Council's Science and Statistical Committee (SSC) receives warning
NORTH PACIFIC
Fishery Management Council

Representative Fishery Pathways: a component of EBFM

- "*The physical, biological, and socioeconomic impacts of climate change in the Arctic have to be seen in the context of often interconnected factors that include not only environmental changes caused by drivers other than climate change but also demography, culture, and economic development*." (Larsen et al. 2014)

- Report on EBFM (NOAA Science Advisory Board July 2014)
- "*Invest in tools for assessing trade-offs [spatial and temporal] of alternative management decisions.*"
- "*Assess and implement best practices for coordinating and integrating ecosystem science across NOAA and with partners.*"

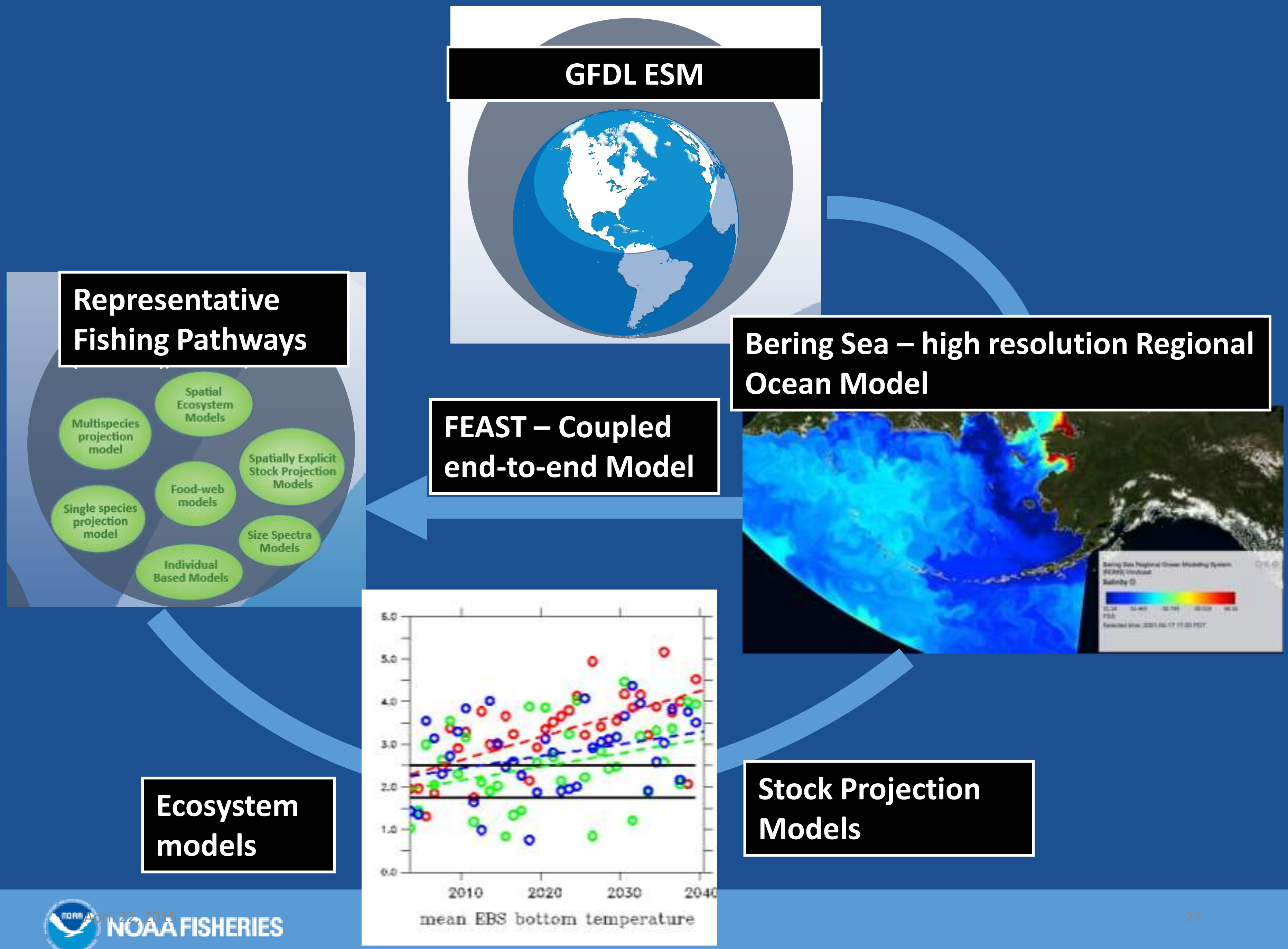
Future Fisheries

- **Demand for protein**
- **World markets**
- **Access to resource - Range expansion to north uncertain**
- **Infra-structure**
- **Bio-economic considerations (fuel, risk)**
- **Sustainable fisheries – Ecosystem Based Fisheries Management**
- **International cooperation**

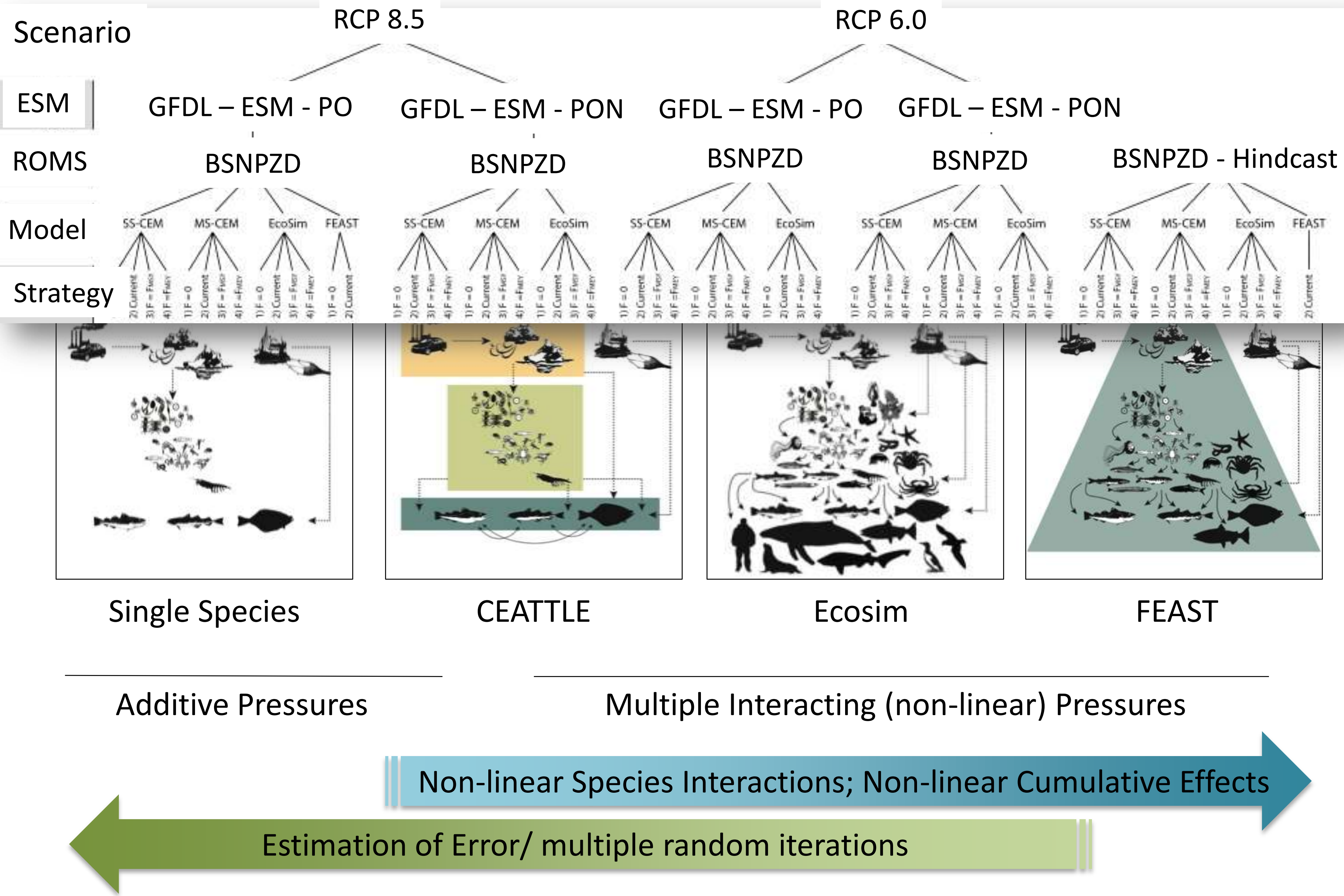
Photo Credit: Sam Zmolek, NOAA Fisheries.
Photo of Dutch Harbor, Alaska

Fisheries Management Challenges

- Shifting Baselines (growth rates, maturation rates, reproductive success) – Fishery dependent and fishery independent monitoring to assess trends
- Shifting fishing characteristics (gear modifications, selectivity, locations, fishing selectivity)
- Tipping Points (ecosystem re-organization)
- Representing and communicating uncertainty
    - Process errors
    - Measurement error
    - Model mis-specification


GFDL ESM
Representative Fishing Pathways
Spatial Ecosystem Models
Multispecies projection model
Spatially Explicit Stock Projection Models
Food-web models
Single species projection model
Size Spectra Models
Individual Based Models
FEAST – Coupled end-to-end Model
Bering Sea – high resolution Regional Ocean Model
Ecosystem models
Stock Projection Models
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2010
2020
2030
2040
mean EBS bottom temperature

(FATE-SAAM)ACLIM: Bering Sea Models

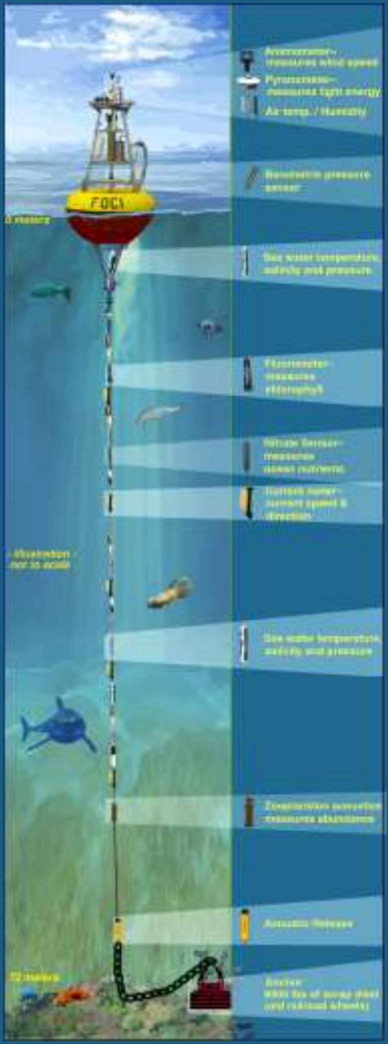


Summary

- Climate Change will impact marine ecosystems and thus fish, fisheries, and fisheries dependent communities
- Integrated Regional Research Teams needed to respond to demand for quantitative projections
- Development of representative fishing pathways will provide foundation for the management strategy evaluation

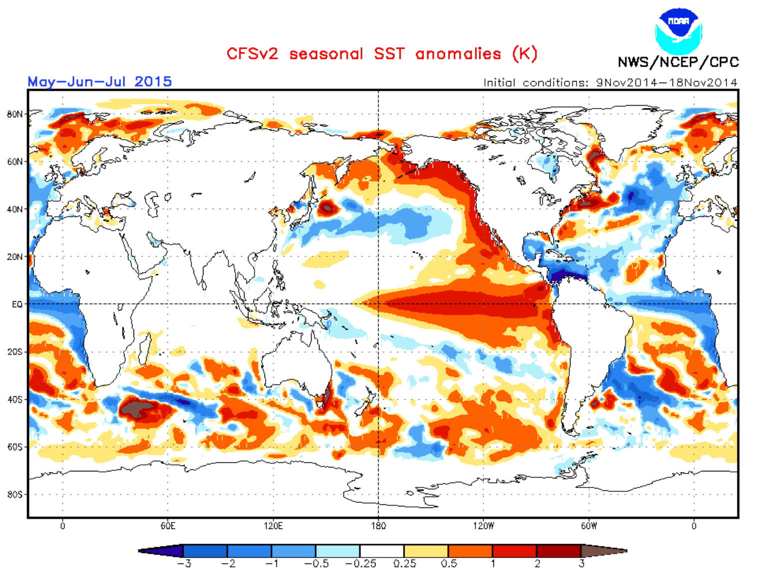
Elements of a Successful Regional Climate Program

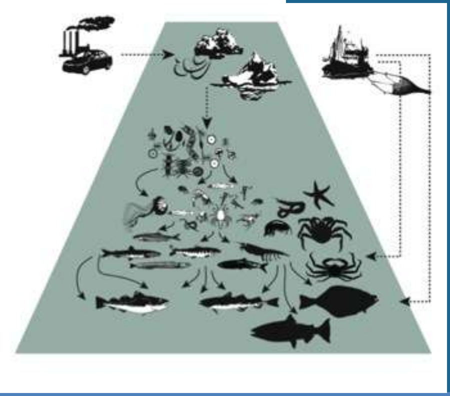
- Legacy of previous interdisciplinary research programs
- Integrated interdisciplinary research teams
- Monitoring (shared techonology)
    - Tested and deployed advanced technologies
    - Developed and tested fishery dependent sampling (underway acoustic)
- Retrospective statistical analysis
- Modeling teams fully integrated into program such with two way feed back with observationalists.



Future Operationalization of OAR – NMFS – Academic Projection Enterprise for Marine Ecosystems

- Maintain core suite of ecosystem indicators/observations
- Short-term climate forecasts used to conduct skill assessment and continued assessment of functional relationships
- Continued data assimilation and integration
- Define ecosystem thresholds for management action under changing climate
- Representative Fishing Pathways - Multi-model ensembles incorporating physical change and biological responses
- US contribution to global climate impact assessment - RFP scenarios 2019/2020





Questions?

Thanks to All of The
Bering Sea Project Investigators

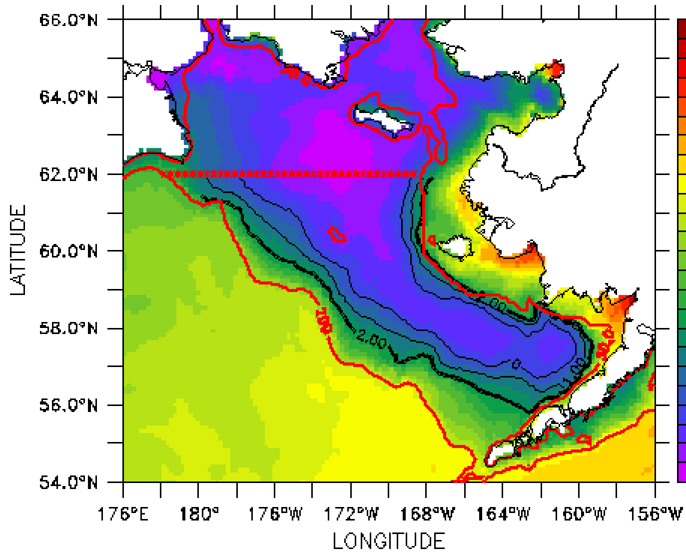
Strategic Issues

- Defining management goals
    - Short-term vs long-term trade-offs
    - Stock boundaries
    - Biological reference points
    - Importance of portfolio (genetic or trophic)
    - Preserve trophic structure perhaps by system level aggregate caps
- Catch shares under shifting access to resource
- Projecting fishers responses.

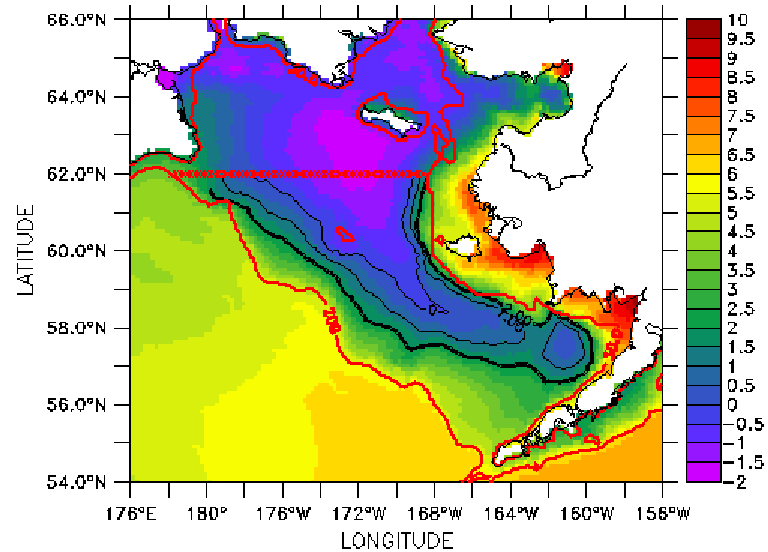
Science Issues: Harvest Control Rules

- **FATE-SAAM: Alaska CLIM Project**
  - No Fishing
  - Sloping control rules
  - MSY (single or multi-species)
  - MEY (single or multi-species)
  - Bycatch management (for Alaska – halibut, salmon)
  - Dynamic models of fisher response
- **World wide census (underway focus of August workshop)**
  - Variety of ways to restore depleted stocks to Bmsy (e.g., 40-10 rule)
  - New Zealand (setting catch at level that would ensure biomass doesn’t drop to a particular level more than xx% of time)
  - Australia (aim for BMEY = 1.2*BMSY as default)
  - South Africa test performance of harvest control rule using MSE
- **Alternative to Multi-species or Multi-fishery alternatives to MSY targets**
  - Andersen et al (In Press) Trade-offs between objectives of ecosystem management of fisheries. Ecological Applications
  - Holsman et al (In Revision) A comparison of fisheries biological reference points estimated from temperature-specific multi-species and single-species climate-enhanced stock assessment models. Deep Sea Research II

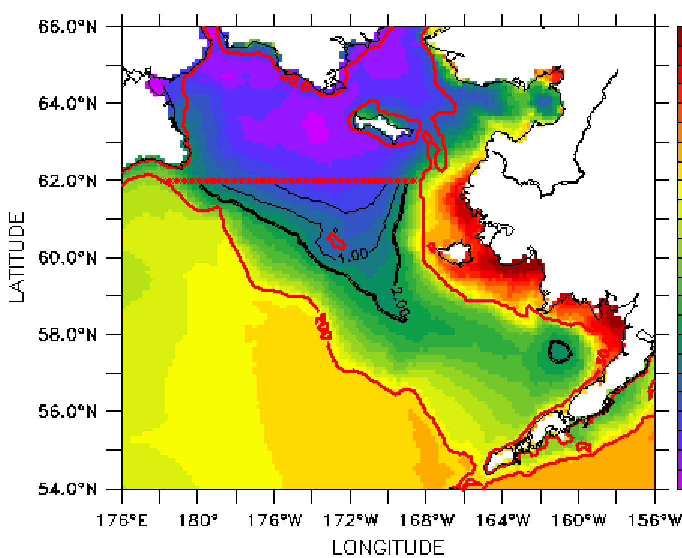
Projected EBS July bottom temperatures in SE Bering Sea (Al Hermann JISAO)



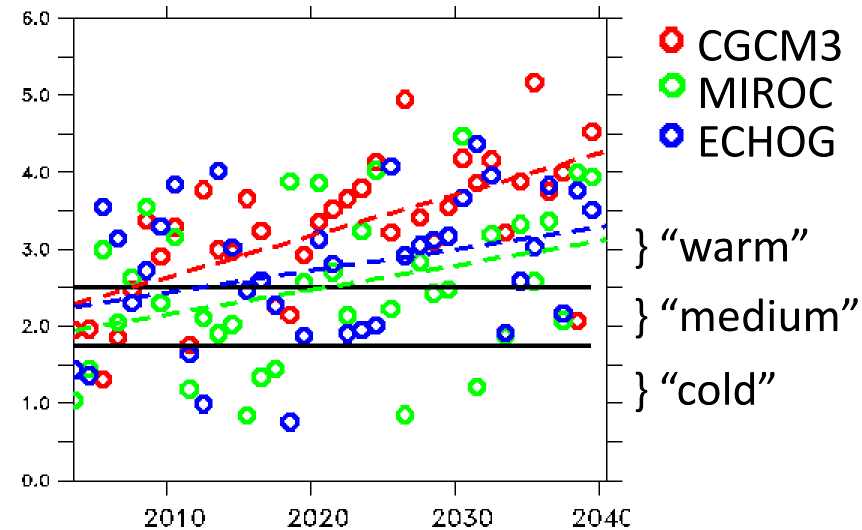
ensemble ave cold year



ensemble ave medium year



ensemble ave warm year



mean EBS bottom temperature