

Ecosystem Status Report:

Gulf of Alaska, Aleutian Islands & Bering Sea Climate and Oceanography Update

Bridget Ferriss
Elizabeth Siddon
Ivonne Ortiz
Stephani Zador

NPFMC Groundfish Plan Teams
September 19, 2023



NOAA
FISHERIES

Outline: Climate & Oceanography

1. North Pacific Conditions (2022-2024)
 - a. Sea level pressure, sea surface temperature & climate indices
 - b. SST forecasts for North Pacific

2. Large Marine Ecosystem Conditions (2023)
 - Bering Sea
 - Aleutian Islands
 - Gulf of Alaska



Key Messages

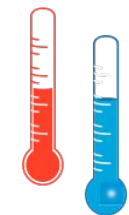


- **N. Pacific:**

- 2023 cool to average La Niña conditions transitioning to warming with upcoming El Niño; AI still warm



- **Eastern Bering Sea (EBS):** Continued period of average SST with “abnormally normal” oceanographic conditions over the EBS shelf in 2023.



- **Aleutian Islands (AI):** Cooler conditions in spring and summer than last year but still above 1985-2014 mean with warm winter and late summer



- **Gulf of Alaska (GOA):** Continued multi-year period of average SST, low-average transport/mixing; El Niño is coming



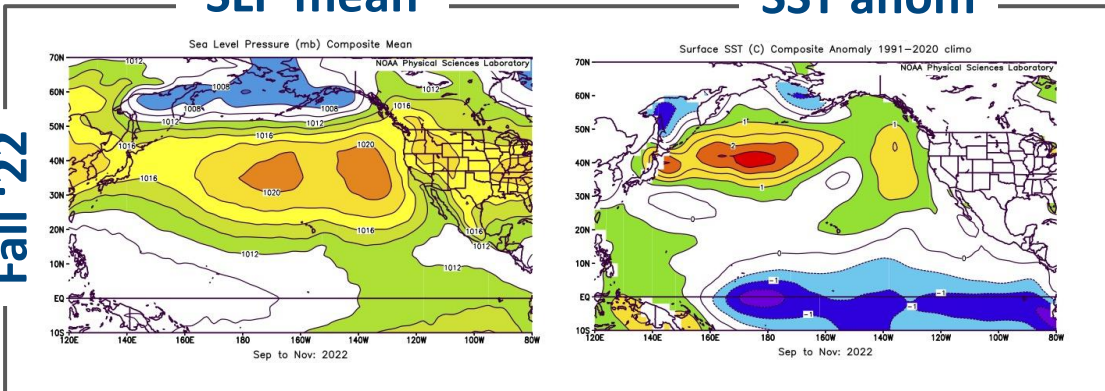
NOAA
FISHERIES

Fall & Winter 2022/2023 SLP & SST

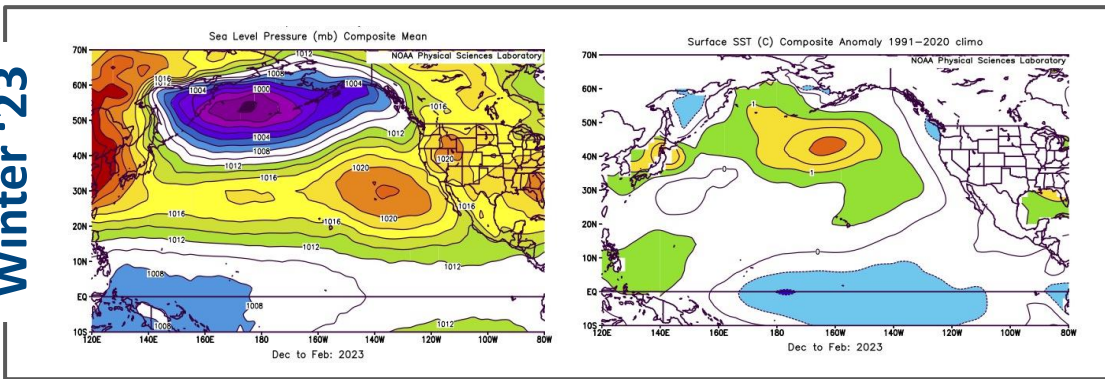
Bond

SLP mean

SST anom



Fall '22



Winter '23



N.Pac: Positive SLP
NBS: Negative SLP into Chukchi Sea
BS: Winds from the west

CN.Pac: Positive SLP
WBS: Negative SLP
GOA: Anomalous clockwise wind; coastal upwelling
EAI: Winds from west

EBS: Cool SST on shelf
EGOA & AI: warmer than average SST
Trop.Pac.: Cool SST (La Niña)

EBS & GOA: average SST on shelf
WAI: above average SST
Trop.Pac.: weakening La Niña



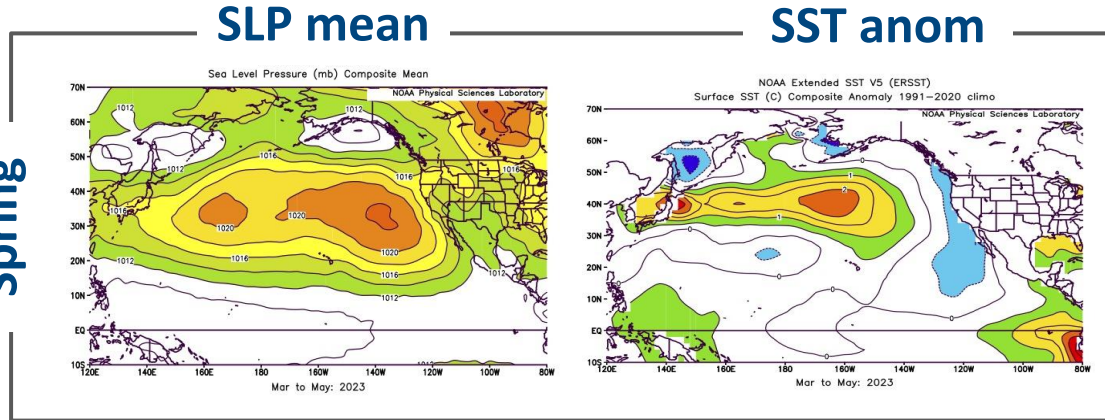
Spring & Summer 2023 SLP & SST

Bond

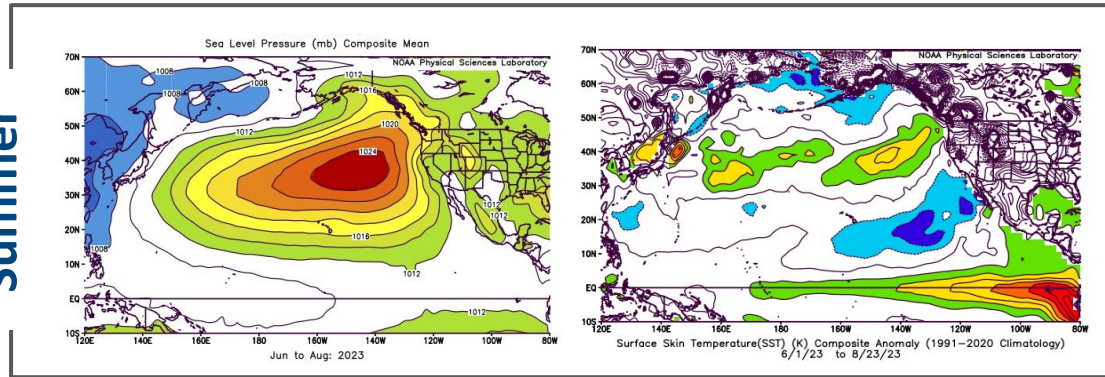
N.Pac & AI: Strong positive SLP
BS: Winds from the west
WGOA: Winds from northwest

N. Pac: negative SLP in north and positive south of 40°N.
 Winds from southwest between dipole.
EGOA: positive SLP & lower precipitation

Spring



Summer



EBS: cool SST conditions on shelf
AI & GOA: cooling/average SST
Trop.Pac: Average SST

EBS: cool SST
AI: cooling/average SST
GOA: cool SST
Trop.Pac: Strong warming (El Niño June '23).

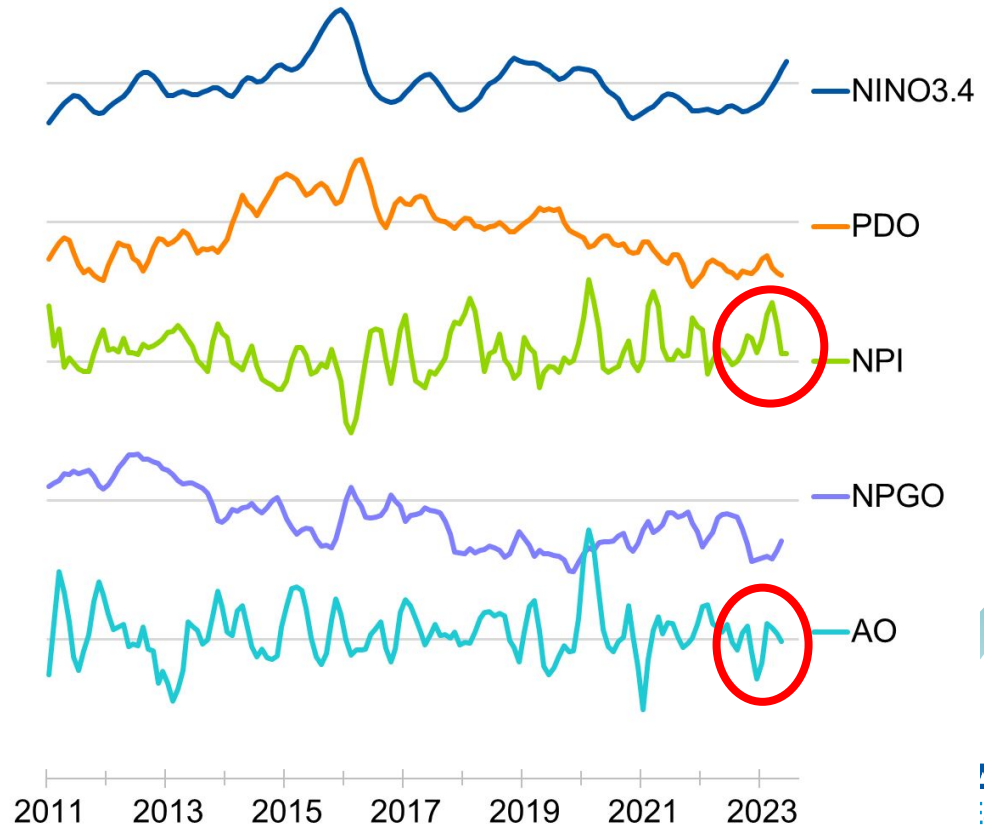


North Pacific Climate Indices

Bond

Bering Sea

- **NPI** Positive values mean weak Aleutian Low and calmer conditions.
- **NPI** positive since 2020 (La Niña and declining PDO). strongly positive winter 22/23 (weak AL); near-neutral in summer 2023
- **AO** measures the polar vortex; mostly positive since the spring of 2021; neg. end of 2022; pos 2023.

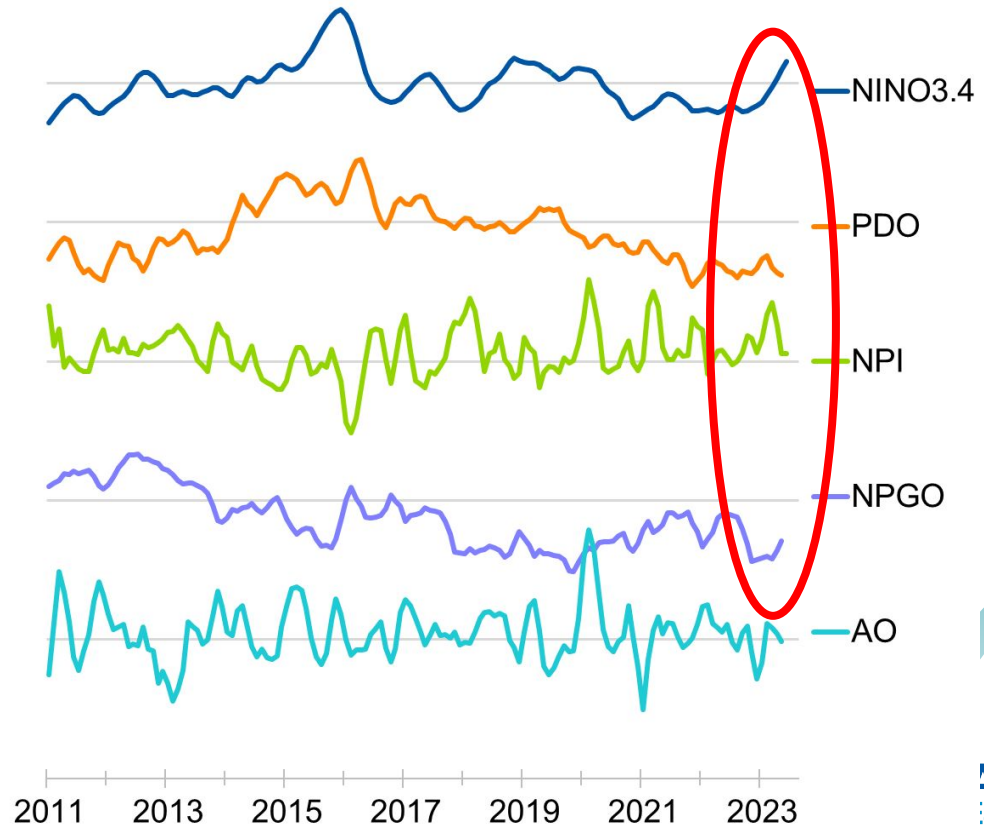


North Pacific Climate Indices

Bond

AI & GOA

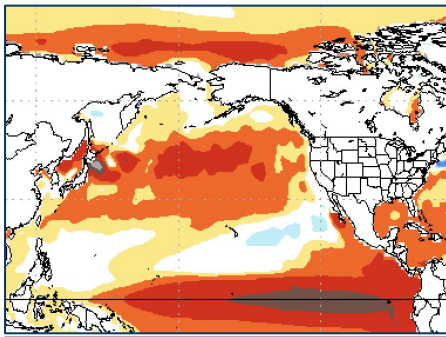
- **NINO3.4** negative (La Niña) spring 2020-winter 2023; El Niño started June '23; predicted to be strong
- **PDO** negative since winter 2019/2020
- **NPI** positive since 2020 (La Nina and declining PDO). strongly positive winter 22/23 (weak AL); near-neutral in summer 2023
- **NPGO** decline since 2012; neg. since 2017; moderate end of 2022 then decline in 2023



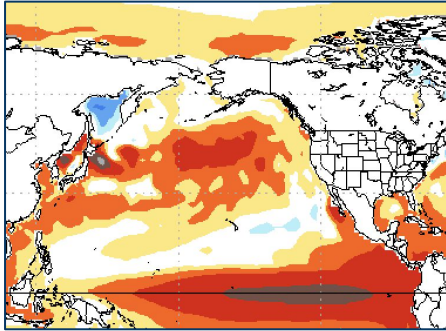
SST Projections from the National Multi-Model Ensemble

Bond

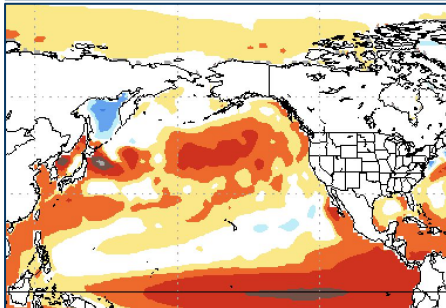
Oct - Dec
2023



Dec 23 -
Feb 24

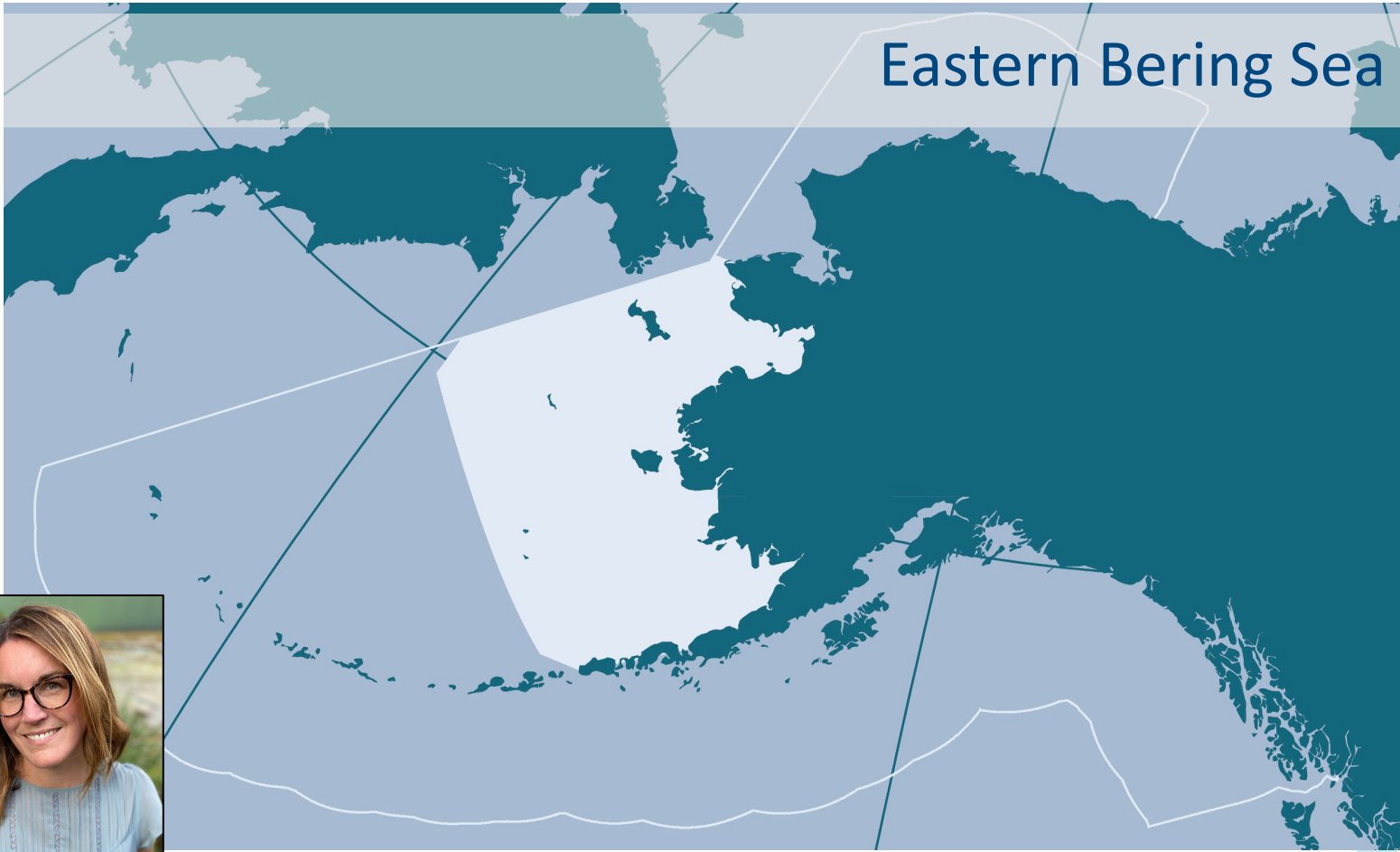


Feb -
April
2024



- **Oct-Dec'23:** El Niño in tropical Pacific. Modest warming for W. Aleutian Islands, SE Bering Sea shelf, and E Gulf of Alaska.
- **Dec-Feb'24:** Similar to fall. Tropical Pacific has SST anomalies $>2^{\circ}\text{C}$, strong El Niño.
- **Feb-Apr'24:** Warming along PNW coast and EGOA. Sea ice could extend south of 60°N and as far south as Bristol Bay.

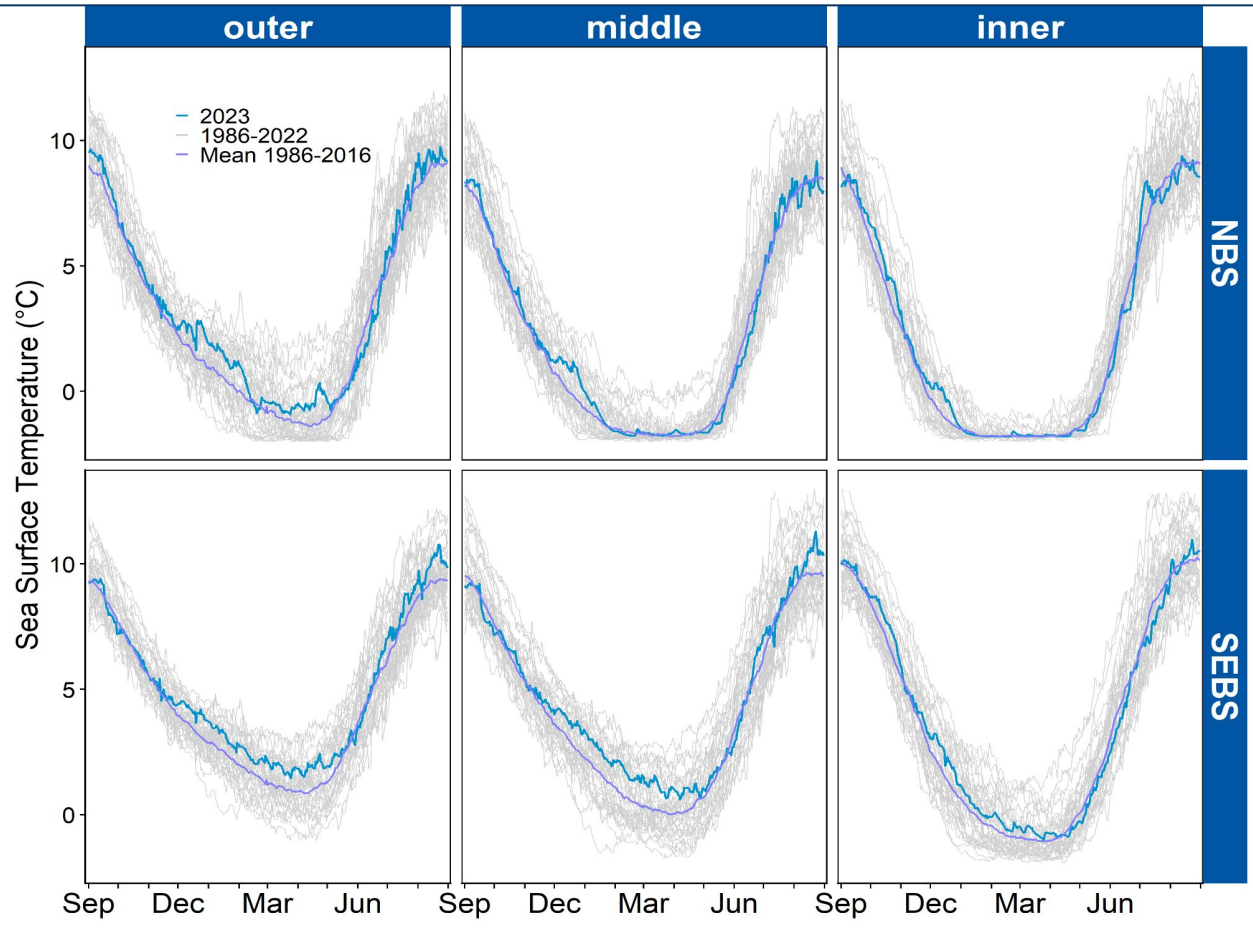
Eastern Bering Sea



NOAA
FISHERIES

Sea Surface Temperature

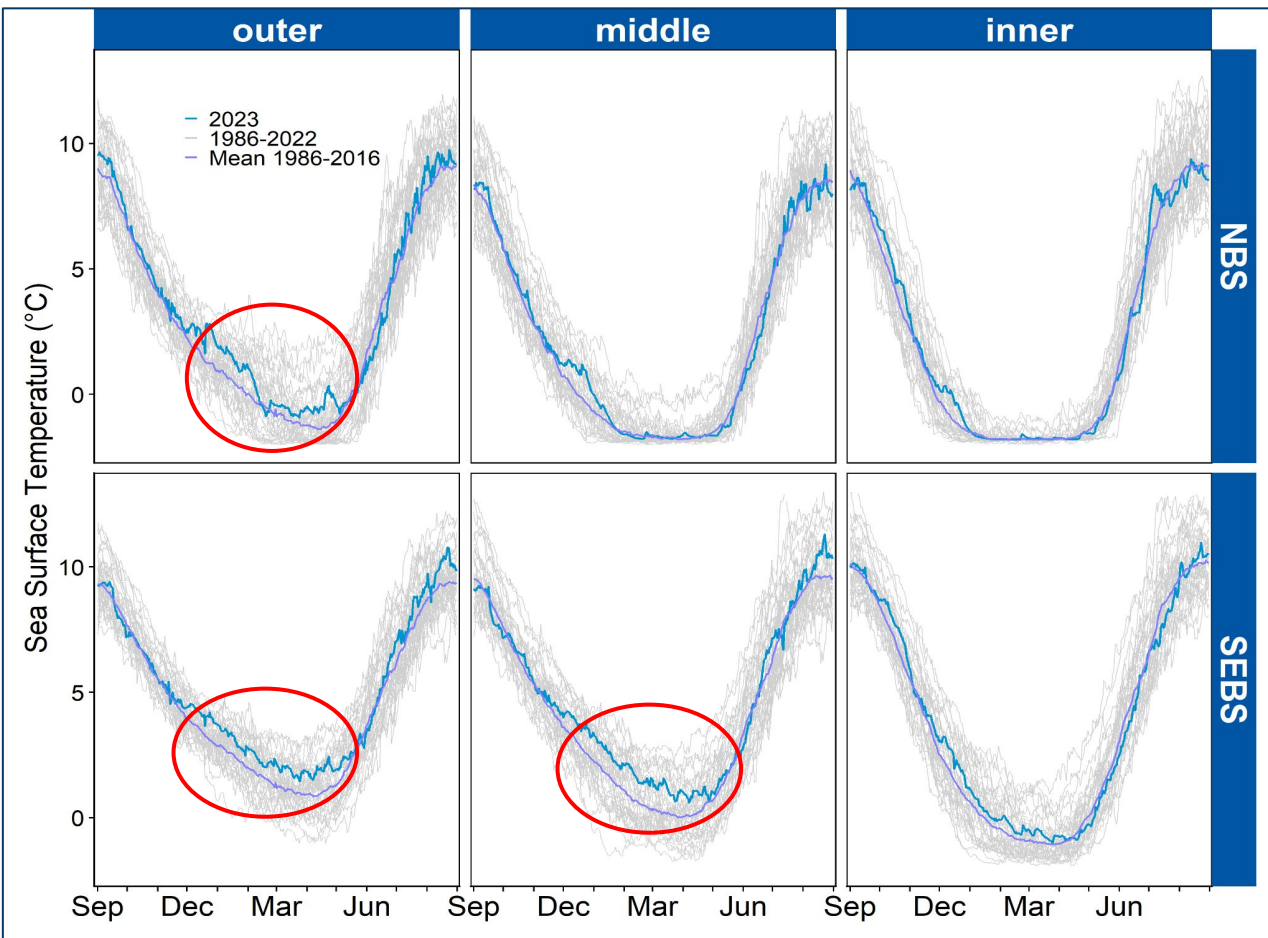
Lemagie & Callahan



- SSTs were similar to the long-term mean in fall 2022 and spring/summer 2023
- SSTs were slightly above the long-term mean in winter 2022/2023, especially in the outer domain and southern middle domain

Sea Surface Temperature

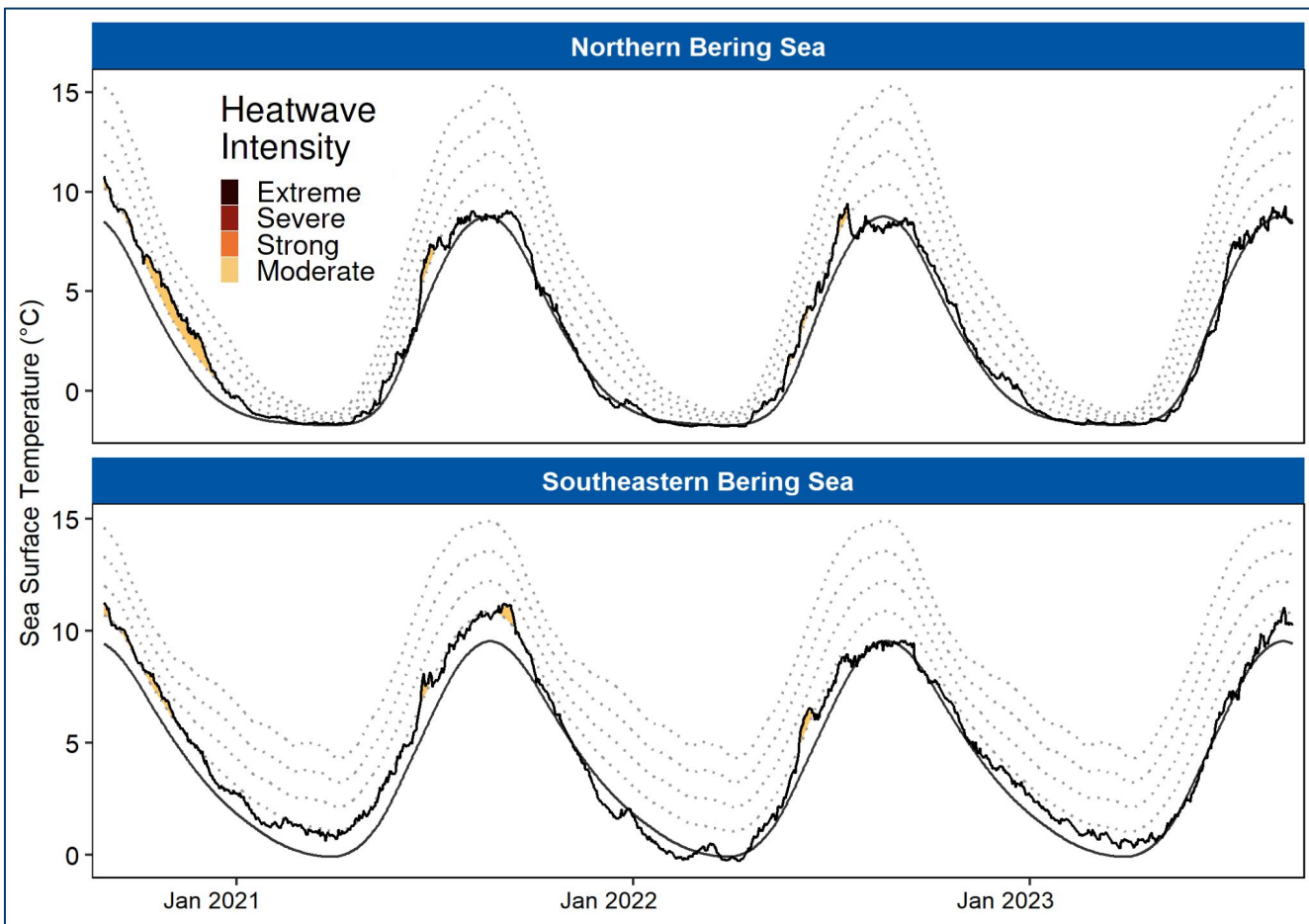
Lemagie & Callahan



- SSTs were similar to the long-term mean in fall 2022 and spring/summer 2023
- SSTs were slightly above the long-term mean in winter 2022/2023, especially in the outer domain and southern middle domain

Marine Heatwave Index

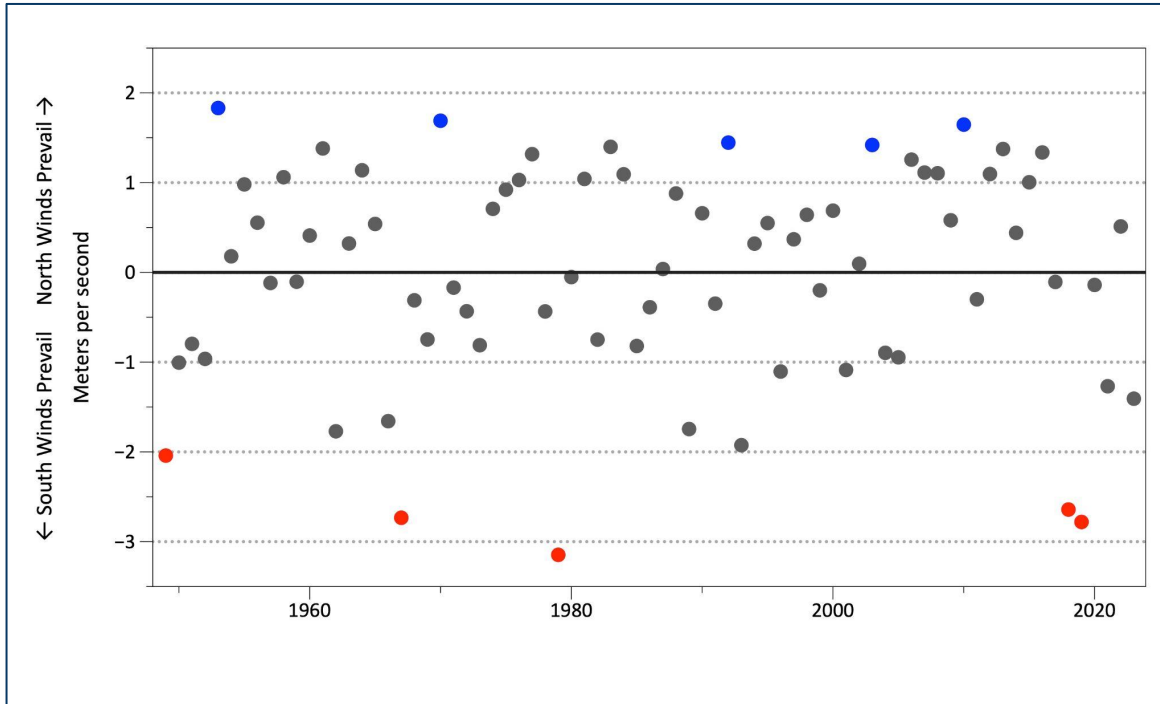
Lemagie & Callahan



- MHWs have been brief and infrequent since 2021

Winter Winds (Nov. - Mar.)

Thoman

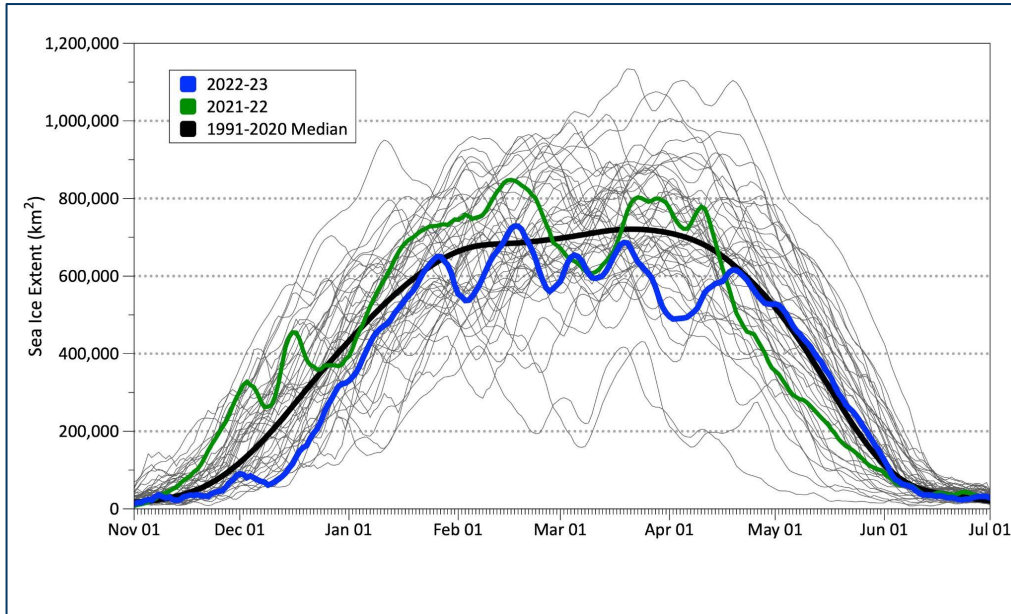


- Winds were more southerly (from the south) in winter 2022/2023
- Southerly winds bring warmer air over the EBS
- 6 of the past 7 winters had southerly winds

- Winters ending in 2018 and 2019 were among 5 years with the strongest south winds, which contributed to low sea ice extent in those years.

2023 Sea Ice

Thoman

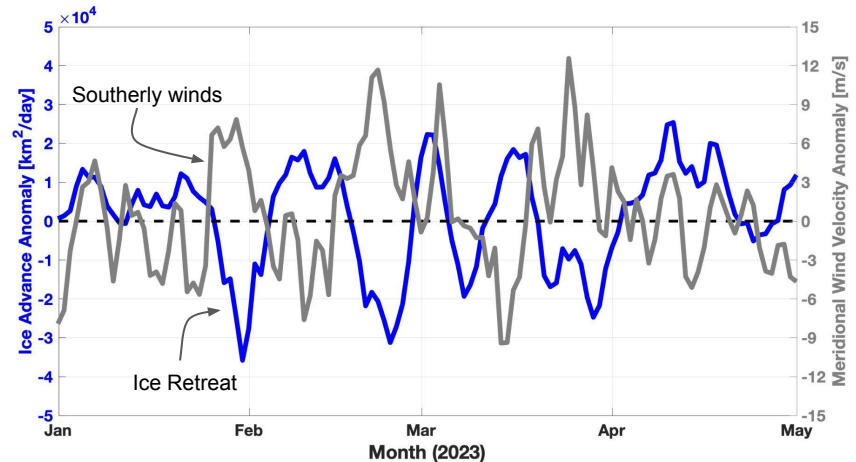
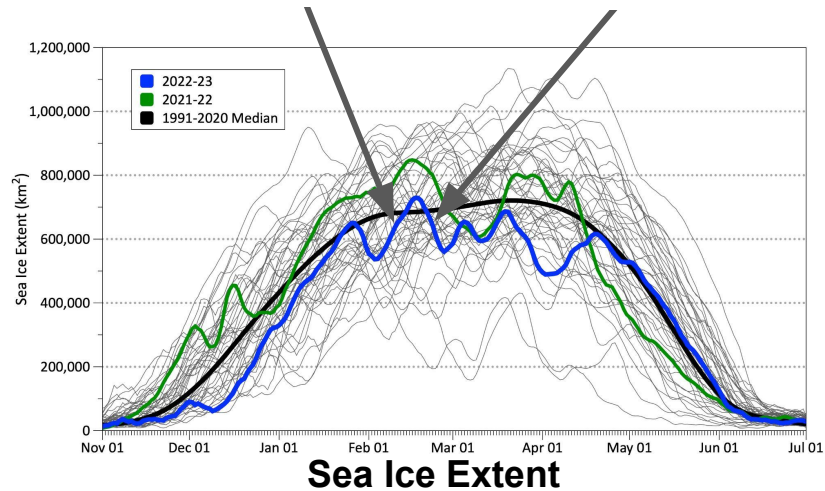
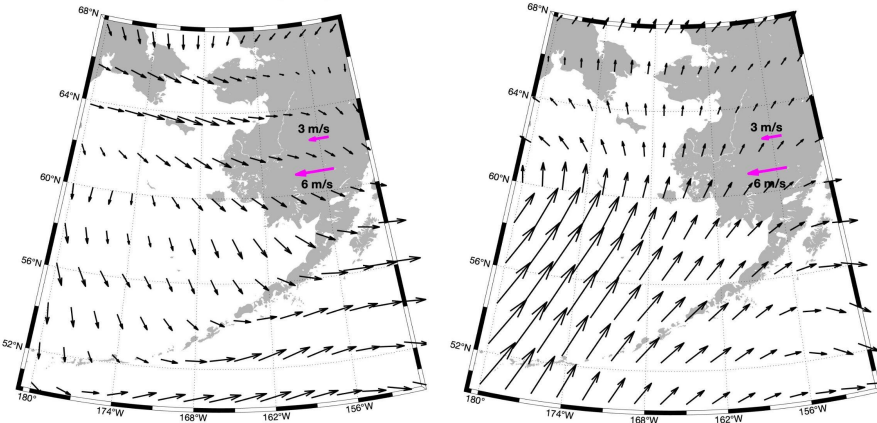


- Ice phenology shifted ~1 month later than 2021/2022
- Delayed sea ice growth in Nov & Dec:
 - Stormy weather
 - Slow freeze-up in the Chukchi
 - Impact of Merbok
- Ice melt-out in spring was slowed by cold April temperatures
- Maximum ice extent occurred February 17; sea ice did not reach St. Paul Island (9th year in past decade)

- Short term variability in sea ice extent is correlated to anomalous wind events
- Ice generally **advances** with **northerly** (from the north) winds and **retreats** with **southerly** winds

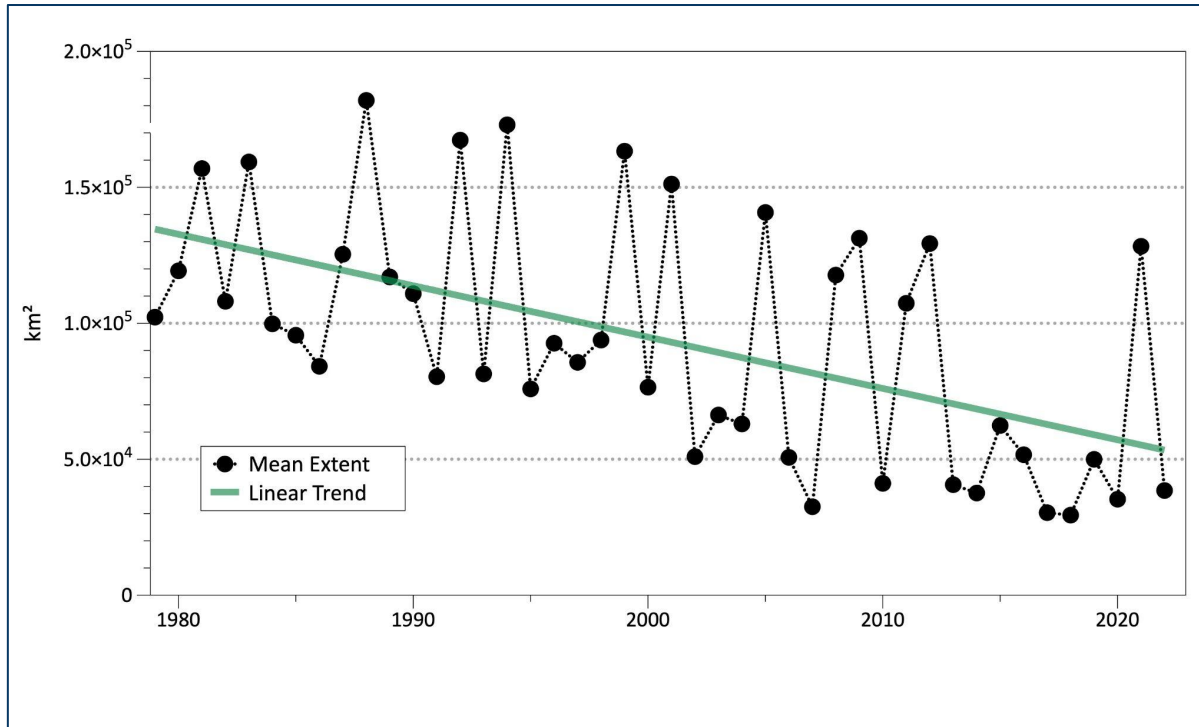
Feb-01 to Feb-14 (2023)

Feb-15 to Feb-28 (2023)



Early Season Ice Extent (Oct.-Dec.)

Thoman



- 2022 was similar to most years since 2013 (except 2021)
- 2022 was lower than any year prior to 2007
- Early season ice extent has decreased 55% over 45-year time series

Bering Sea Ice Thickness

Thoman

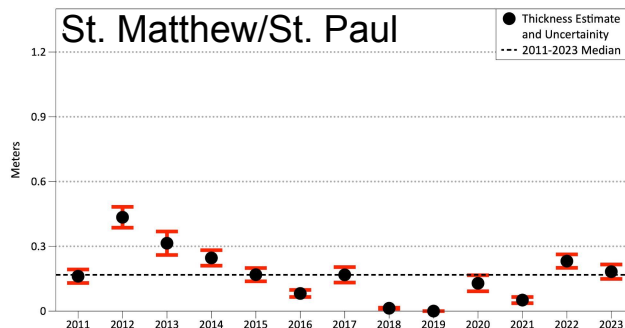
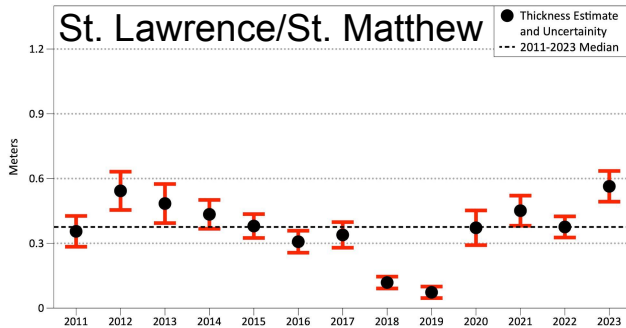
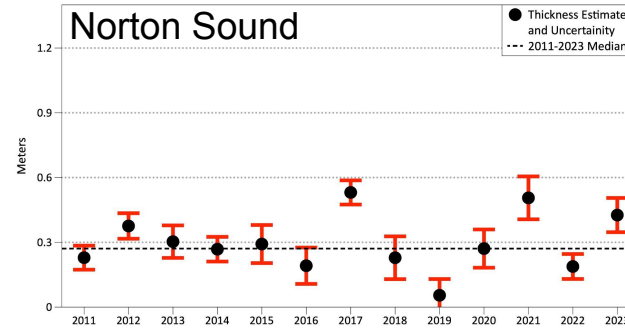
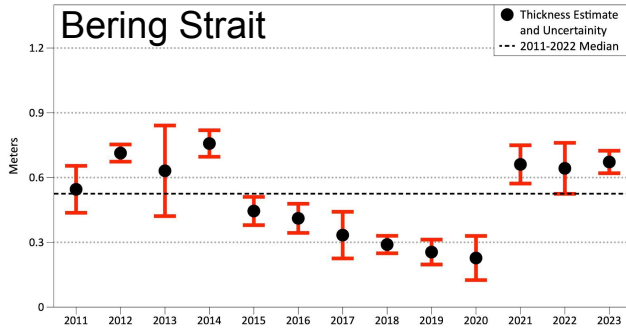


- 3rd week of March
- Ice thickness is related to duration or residency of ice over the shelf
- Abundance of ice-associated algae correlated to ice duration?

Source: Alfred Wegener Institute, <https://www.meereisportal.de/en/>

Bering Sea Ice Thickness

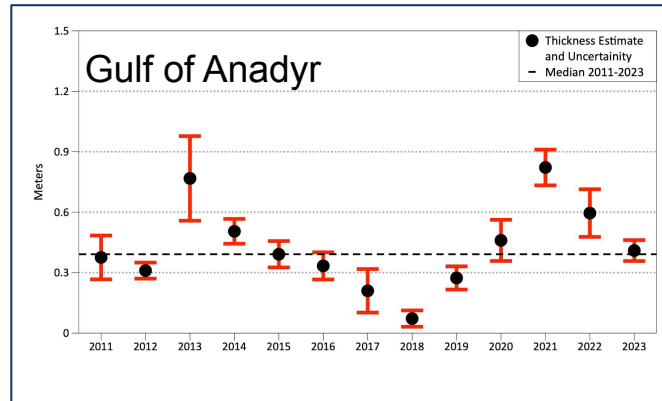
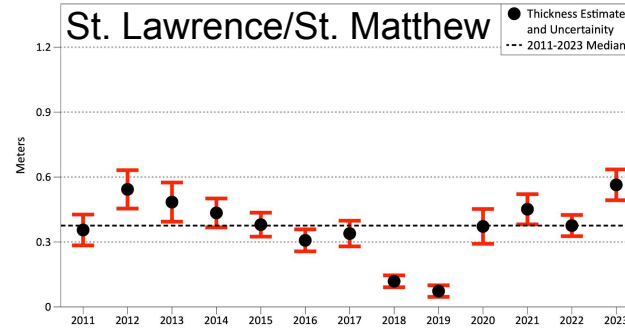
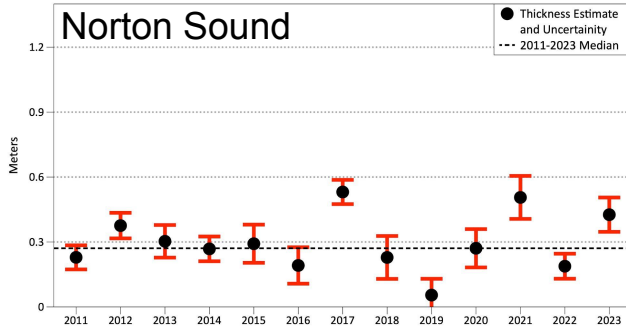
Thoman



- Ice thickness was higher in Norton Sound and St. Lawrence to St. Matthew than 2022
- St. Lawrence to St. Matthew ice thickness was the highest since 2013
- Other regions close to the 13-year median

Bering Sea Ice Thickness

Thoman



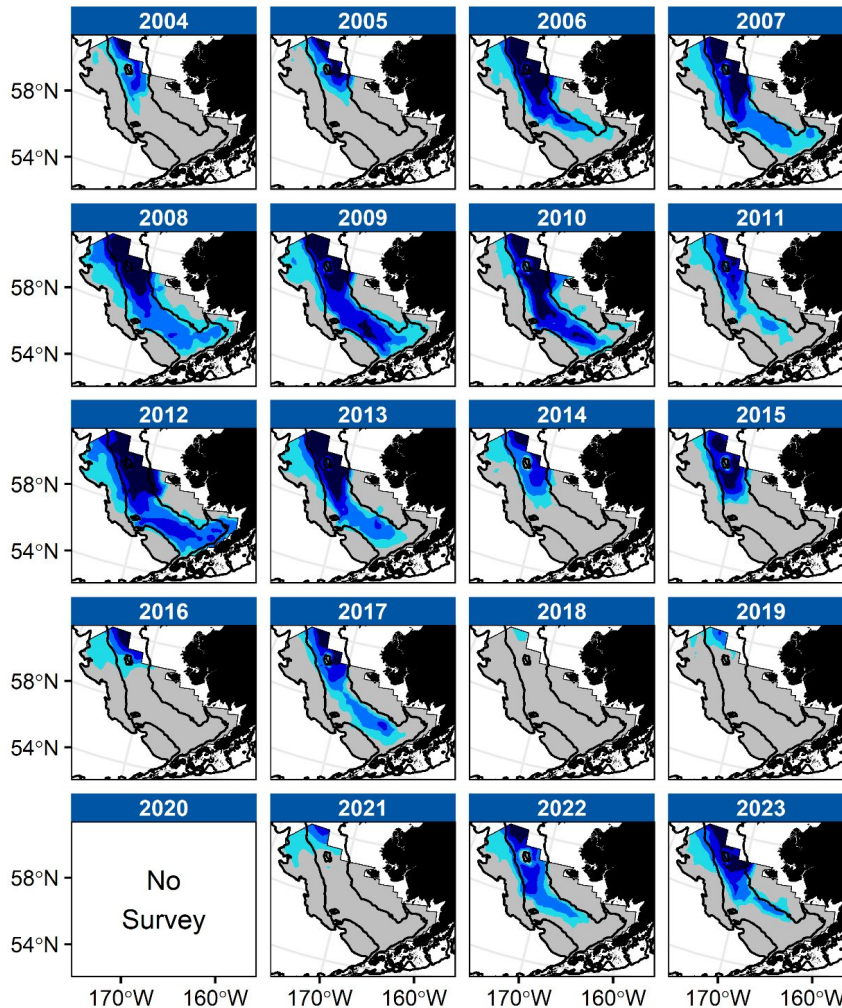
- Ice thickness was higher in Norton Sound and St. Lawrence to St. Matthew than 2022.
- St. Lawrence to St. Matthew ice thickness was the highest since 2013.
- Other regions close to the 13-year median.
- Gulf of Anadyr had lower ice thickness than 2022.

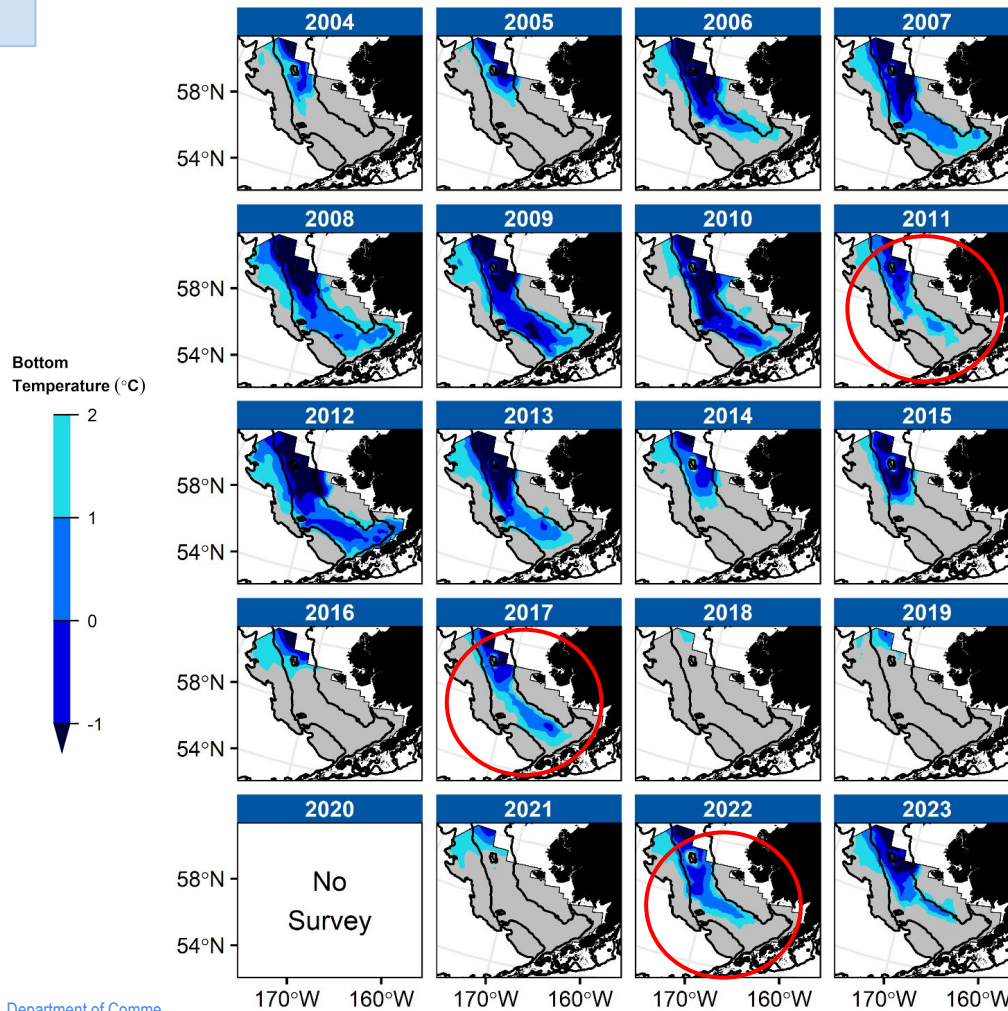
Cold Pool

Rohan & Barnett

- Average cold pool extent
 - *Slightly larger than 2022*
- Footprint of the cold pool was similar to 2011, 2017, and 2022
- Cold tongue along the inner front was shifted inshore

Bottom Temperature (°C)

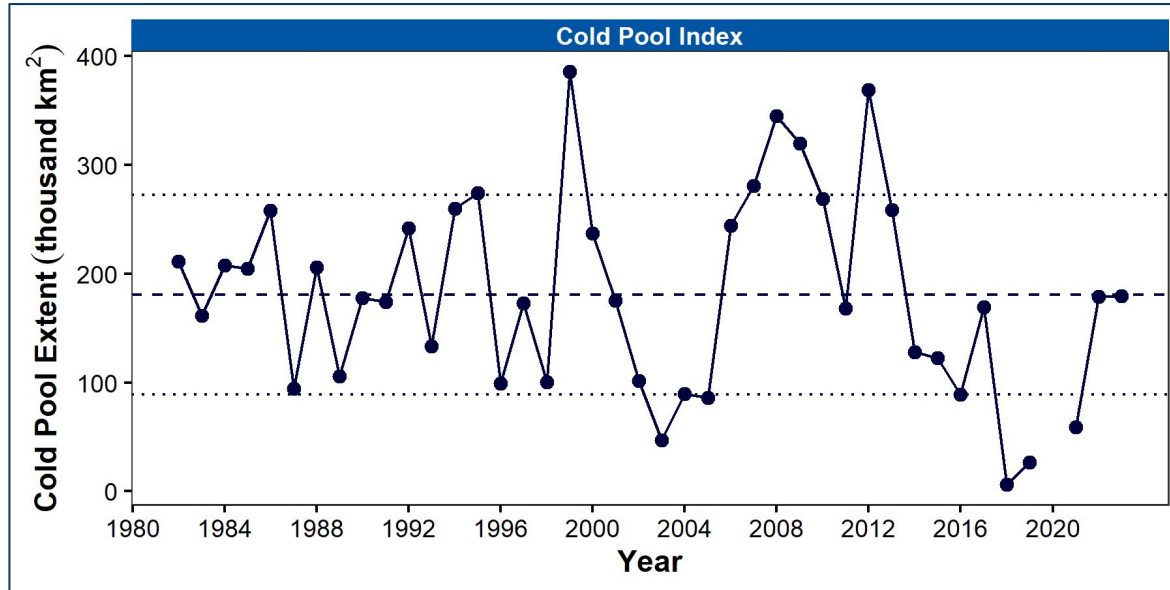




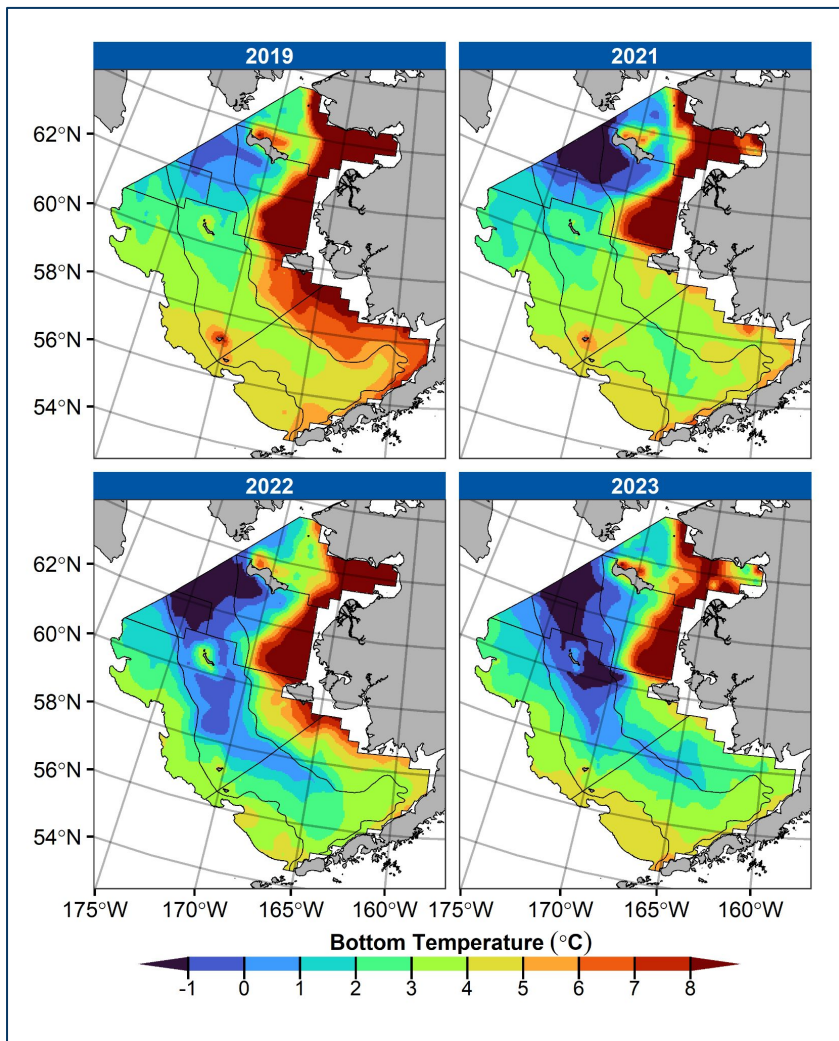
- Average cold pool extent
 - *Slightly* larger than 2022
- Footprint of the cold pool was similar to 2011, 2017, and 2022
- Cold tongue along the inner front was shifted inshore

Cold Pool

Rohan & Barnett



- Average cold pool extent
 - *Slightly larger than 2022*
- Footprint of the cold pool was similar to 2011, 2017, and 2022
- Cold tongue along the inner front was shifted inshore



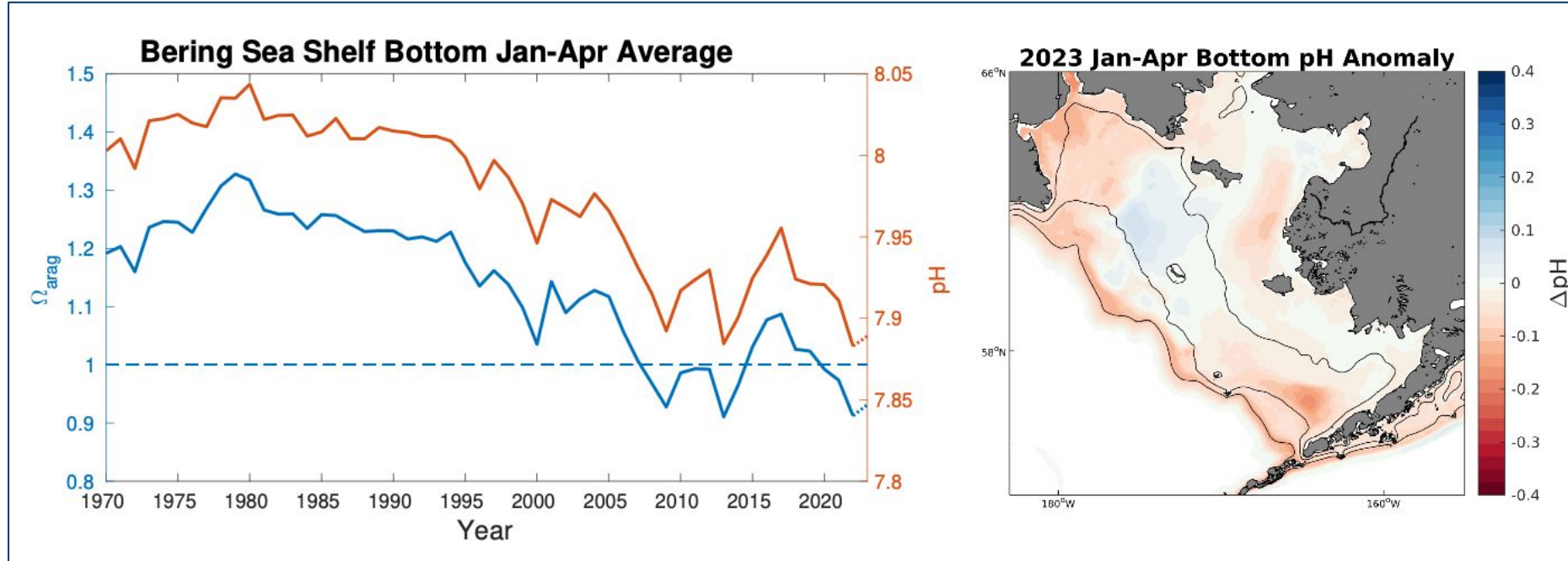
Cold Pool

Rohan & Barnett

- Bottom and surface temperatures were slightly colder than time series average
- Very cold bottom temperatures south of St. Matthew Island for the first time since 2015
- Coldest bottom temperatures in the southern inner domain since 2013

EBS Ocean Acidification

Pilcher & Monacci



- Through Jan-Apr of 2023, Ω_{arag} and pH continuing near lowest values
- Multi-year outer shelf low pH anomaly diminished somewhat, though still present in southeastern shelf

EBS Climate & Oceanography

Sea Surface Temperature (SST)



- Average SSTs in fall 2022 and spring/summer 2023; moderate warming in winter 2022/2023
- MHWs have been infrequent and brief since 2021

Continued average conditions over the EBS shelf

Sea ice



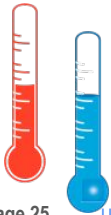
- Ice season shifted ~1 month later (delayed freeze-up and later melt-out)
- Max ice extent occurred in mid-February
- Ice thickness was above average north of St. Matthew Island

Sea ice impacts stratification, production of ice algae, and the cold pool

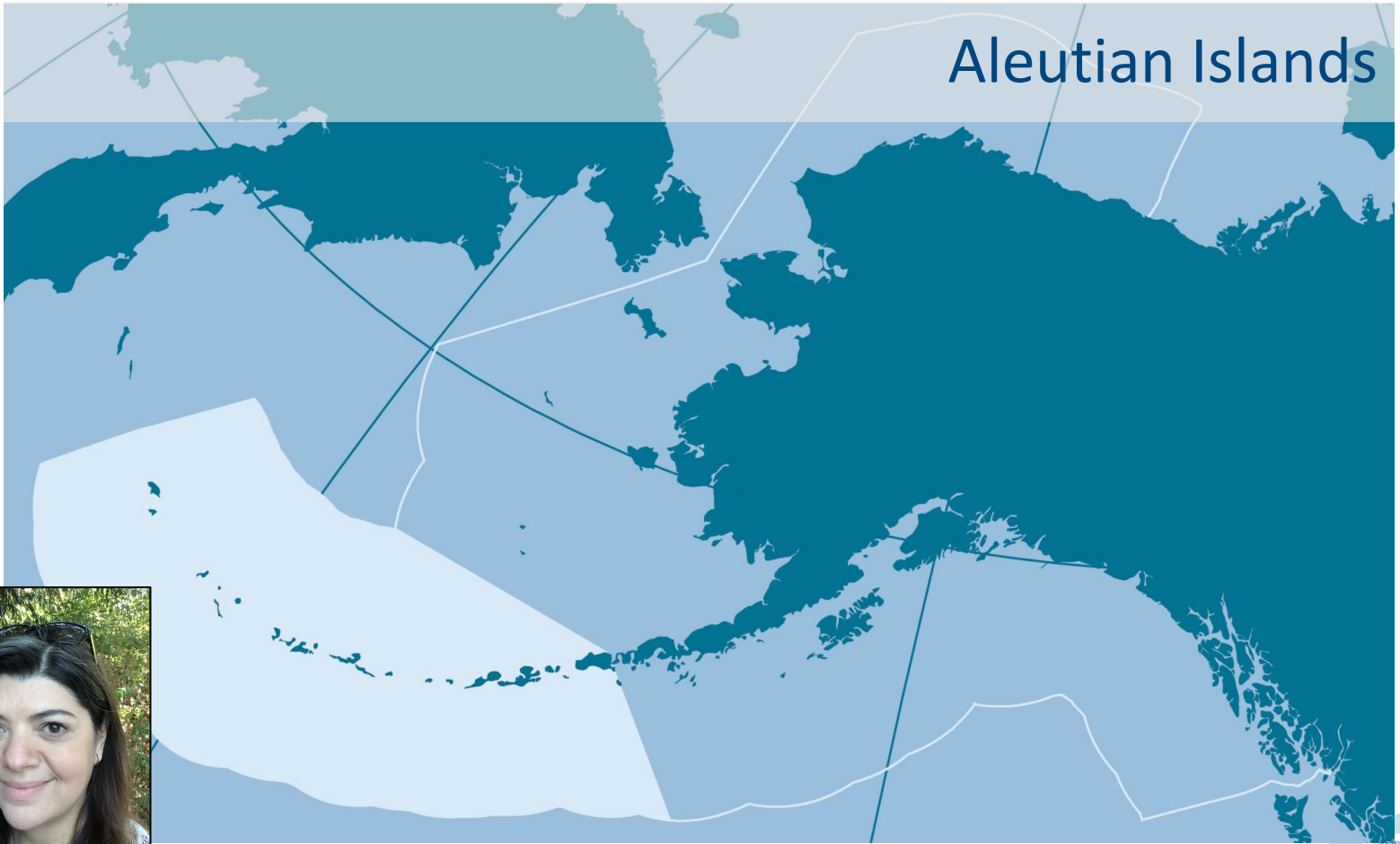
Cold pool

- 2023 cold pool extent was average; spatially resembles 2011, 2017, & 2022
- Cold tongue along the inner front was shifted inshore

Cold pool extent impacts distribution and movement of fish and crab stocks



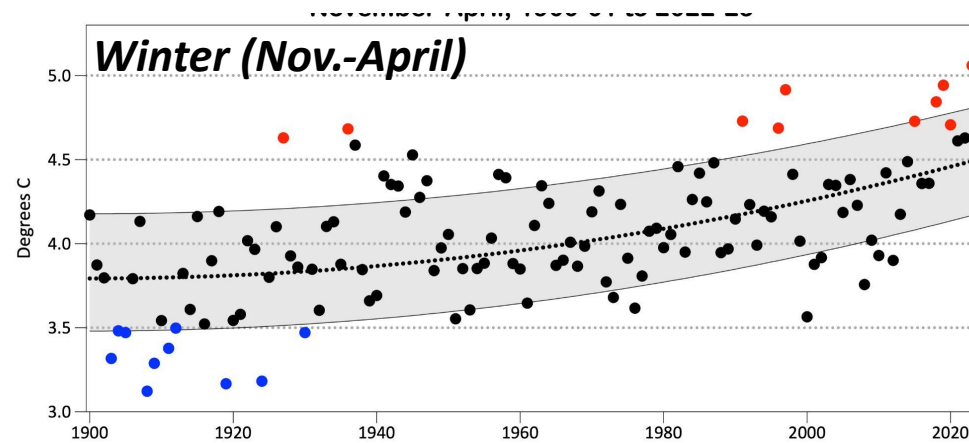
Aleutian Islands



NOAA
FISHERIES

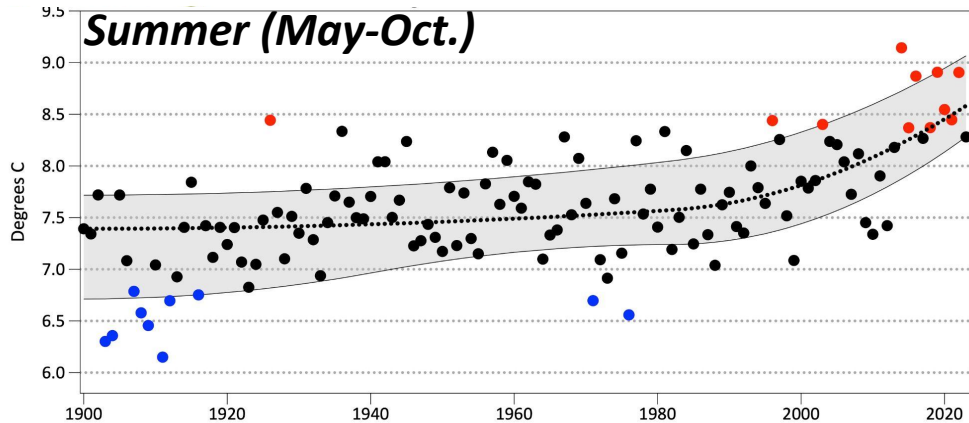
Long-Term AI Sea Surface Temperature

Thoman



- AI NMFS area shelf SST (NOAA's Extended Reconstructed SST, ERSSTv5) with B-spline regression $\pm 1SD$

- Winter (Nov.-April '22/'23) warmest on ERSSTv5 record; warming long-term trend $\sim 0.75^{\circ}C$



- Summer (May-Oct. '23) colder than long term trend with overall increasing trend $\sim 1^{\circ}C$

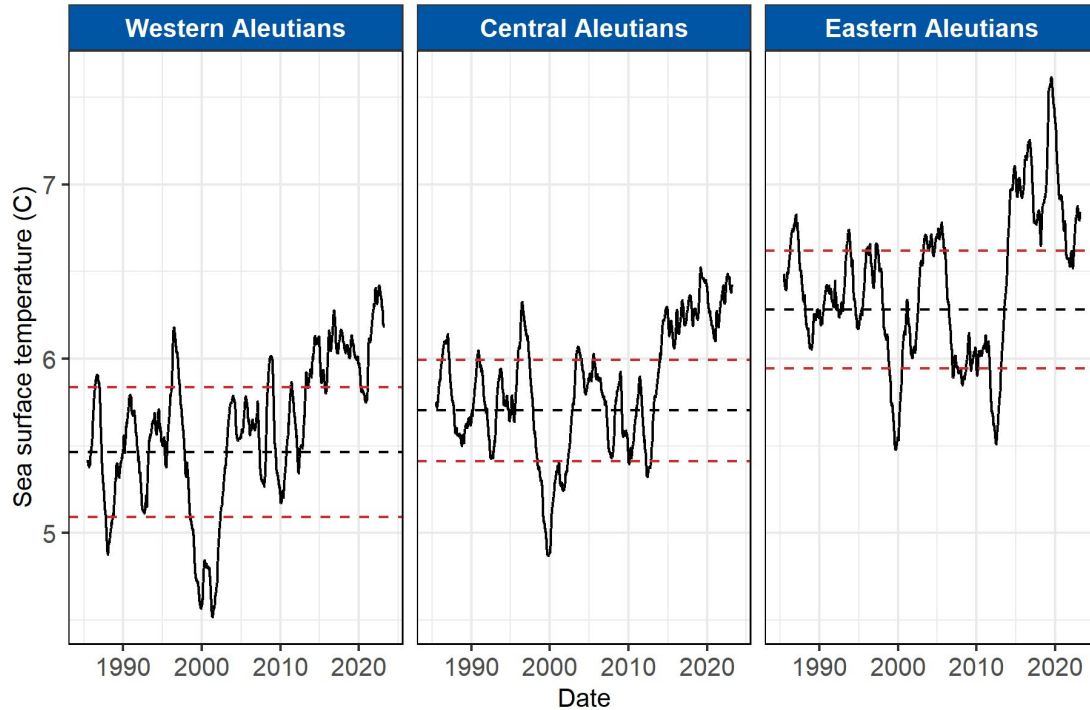
- Summer 2023 data point is preliminary

Estimated \pm One Std. Dev. Ten Warmest
 Estimated Median Ten Coldest

Data source: ERSSTv5
 and B.Brettschneider/NWS Alaska
 2023 estimated

AI SST & Marine Heatwaves 2023

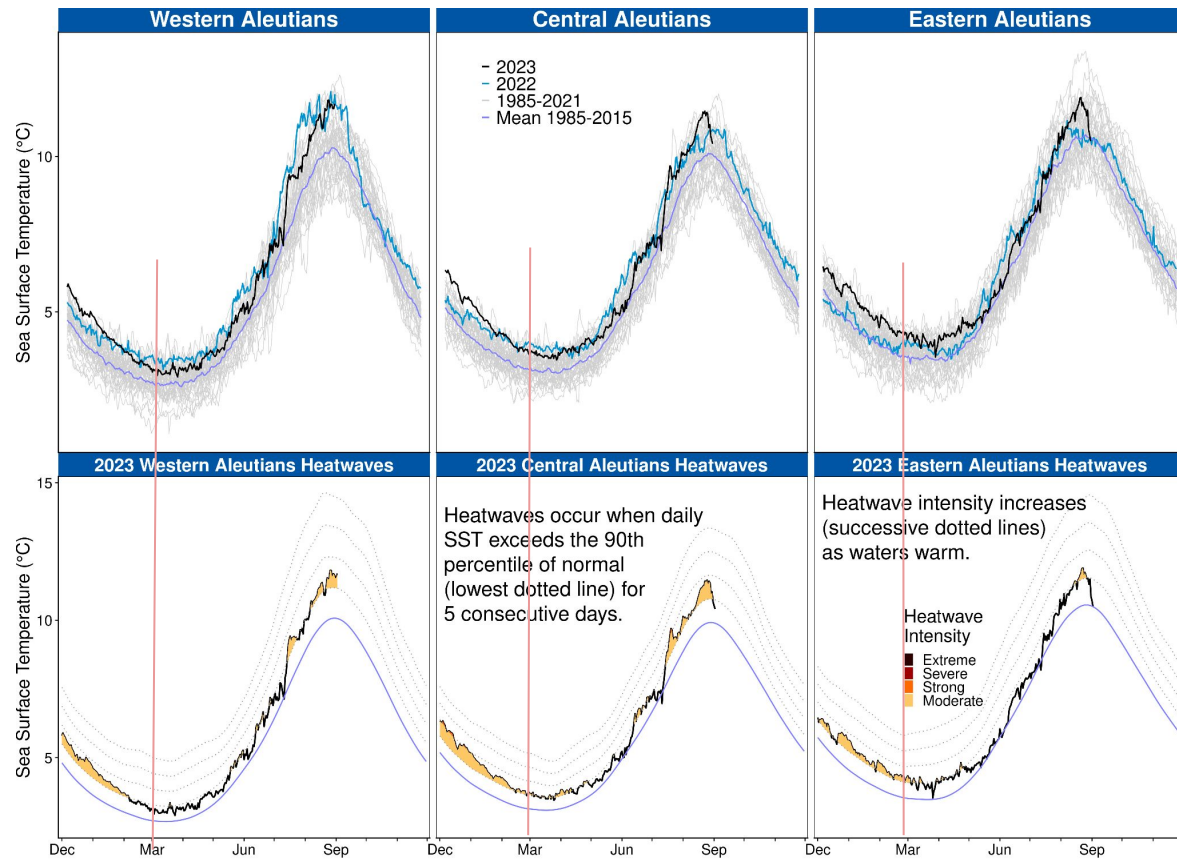
Lemagie, Callahan



- Continued warm temperature above 1985-2014 mean
- All three regions have trended anomalously warm ($> 1\text{sd}$ above mean) for last 10 years

AI SST & Marine Heatwaves 2023

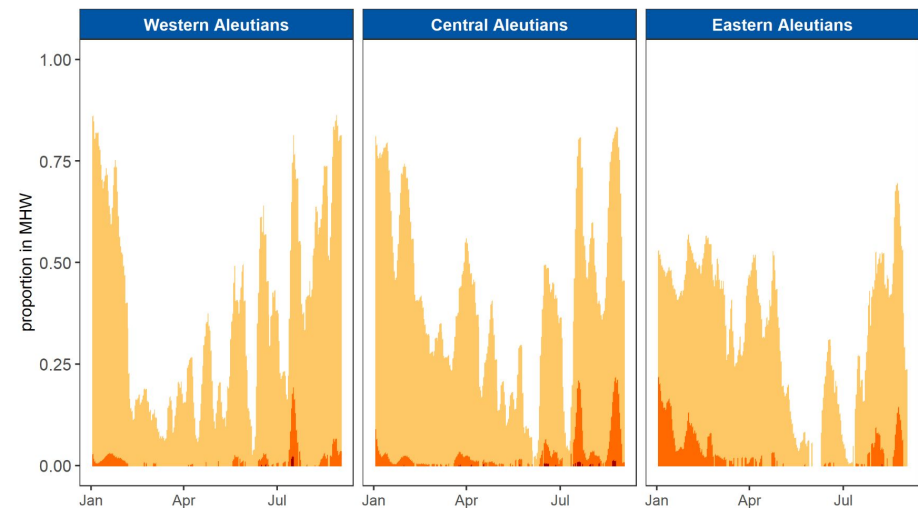
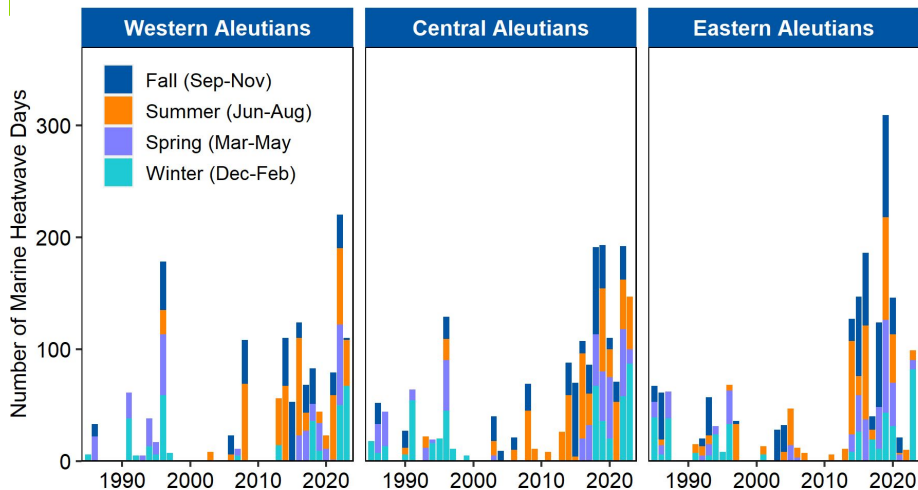
Lemagie, Callahan



- Warm winter across AI with moderate MHW
- Fewer heat waves in spring and summer, return to moderate heatwave in late summer
- Despite cooling, still continued warm temperature above 1985-2014 mean

AI SST & Marine Heatwaves 2022

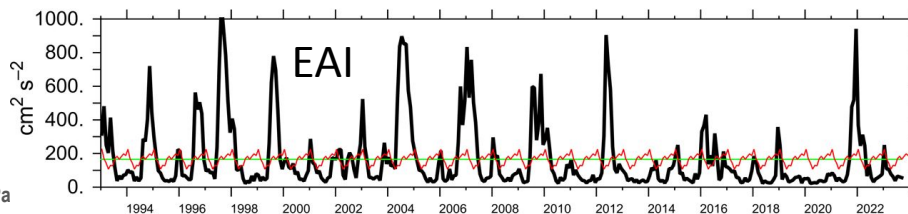
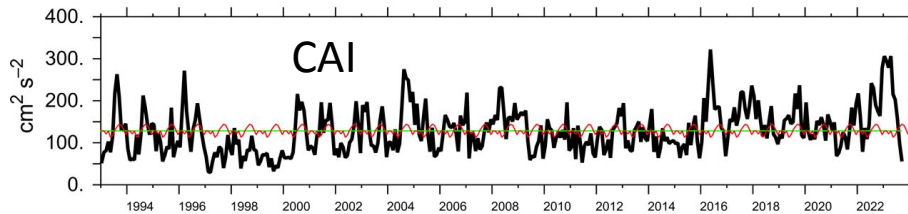
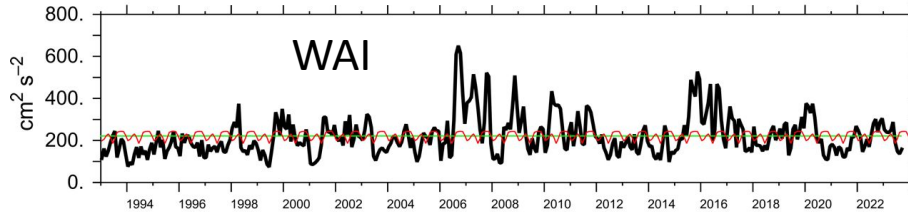
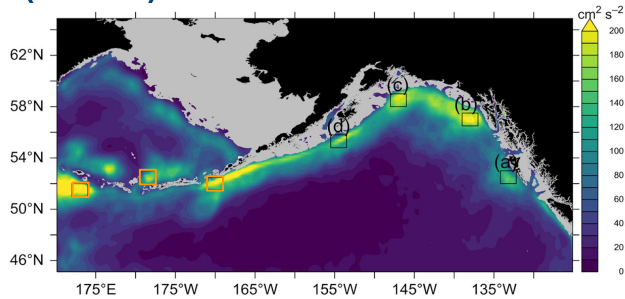
Lemagie, Callahan



- Less area in MHW than last year
- WAI, CAI at times over $\frac{3}{4}$ in MHW during winter and late summer
- EAI: MHW tended to be triggered by warm water in small portion of the region

Average Eddy Kinetic Energy (EKE) Jan 1993 - Dec 2022

Eddies in the AI Cheng & Ladd



EKE indicates strength and frequency of eddies, which can influence flow and transport of heat, salinity, and nutrients

- Monthly climatology in red, 1993-2022 mean in green
- WAI below long term mean
- CAI high EKE in 2022 weakening in 2023, currently below mean
- EAI below or near mean, potentially back to lower flow through Unimak Pass

AI Climate & Oceanography

Sea Surface Temperature (SST)



- One of warmest winters on record
- Cooling in spring, early summer followed by return to MHW in late summer
- Sustained SST above average across AI for last 10 years

Sustained warmer SST may have longer impacts on phenology, productivity

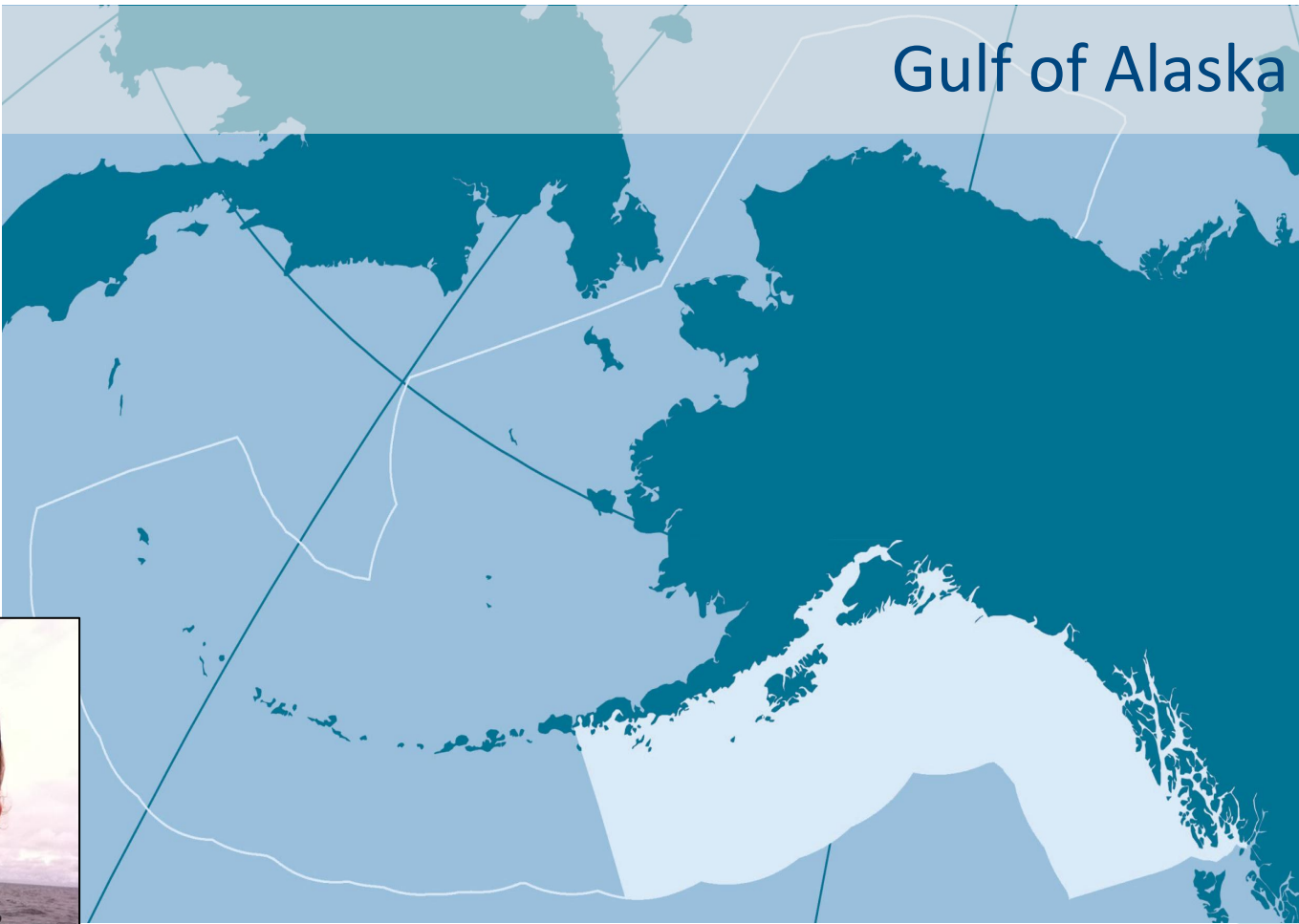
Transport



- EAI (Unimak Pass): Following peak in 2021-2022, EKE weakened in 2023
- CAI: below average after 5 consecutive years above average EKE
- WAI: Lower than average EKE

Likely lower than average volume, heat, salt and nutrient fluxes to the Bering Sea

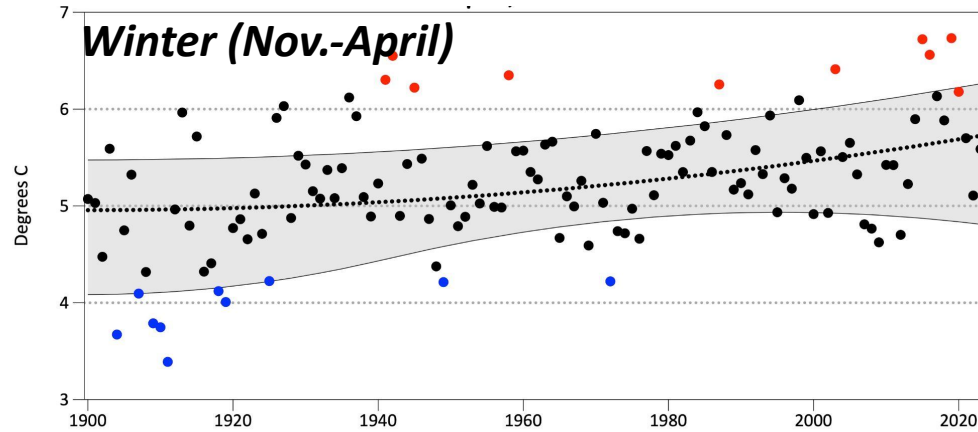
Gulf of Alaska



NOAA
FISHERIES

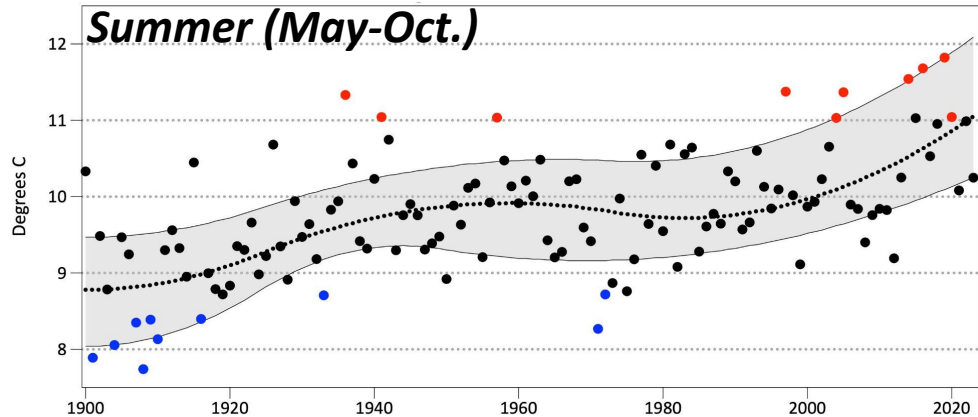
Long-Term GOA Sea Surface Temperature

Thoman



GOA shelf SST (NOAA's Extended Reconstructed SST, ERSSTv5) with B-spline regression $\pm 1SD$

- Winter (Nov.-April '22/'23) SST close to median; slight increasing trend



● Summer (May-Oct. '23) below median SST of increasing trend over long-term

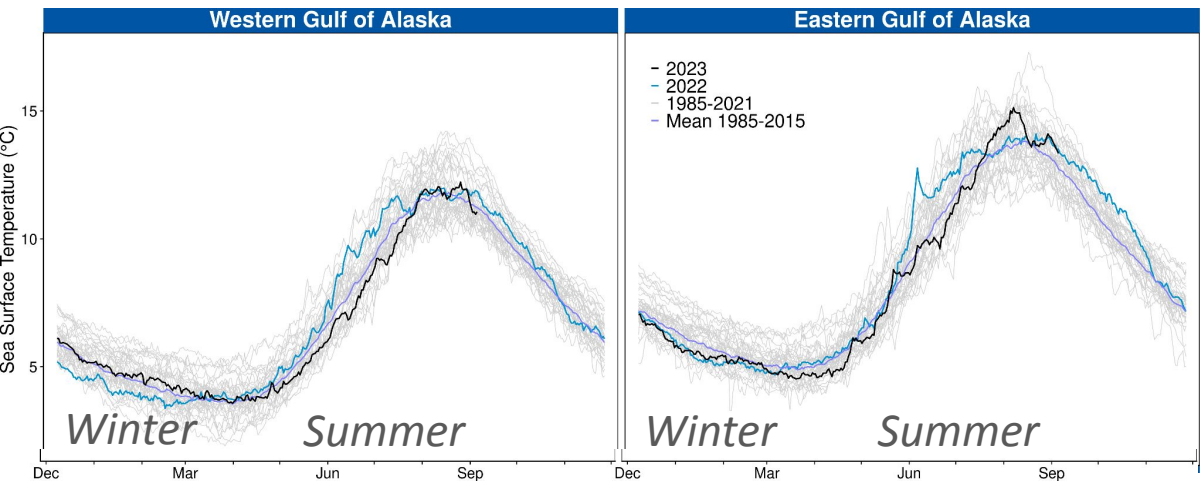
- Preliminary summer 2023 data point (will probably increase)

Estimated \pm One Std. Dev. ● Ten Warmest
 ●● Estimated Median ● Ten Coldest

Data source: ERSSTv5 and
 B.Brettschneider/NWS Alaska

GOA SST & Marine Heatwaves 2023

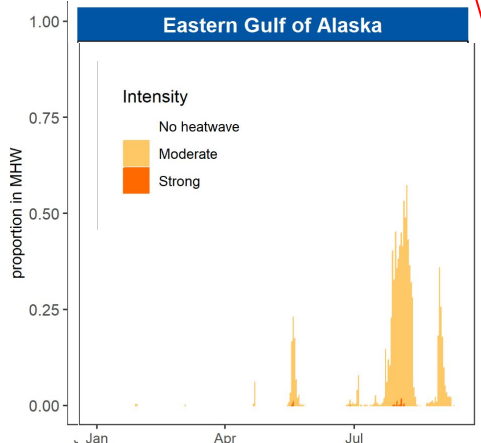
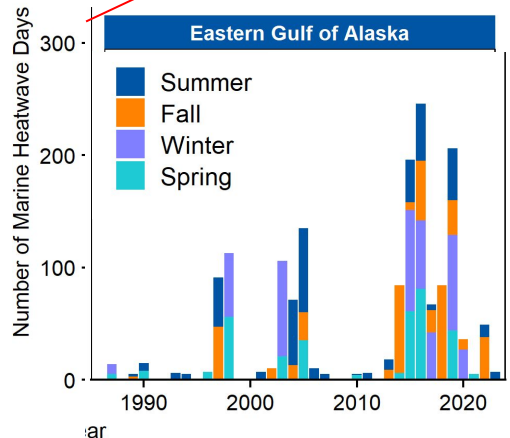
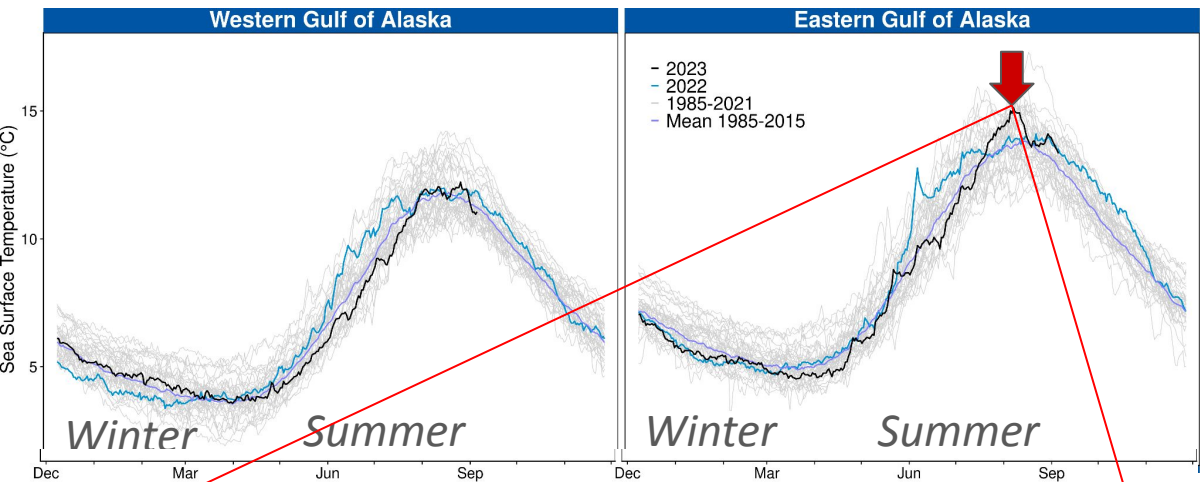
Lemagie, Callahan



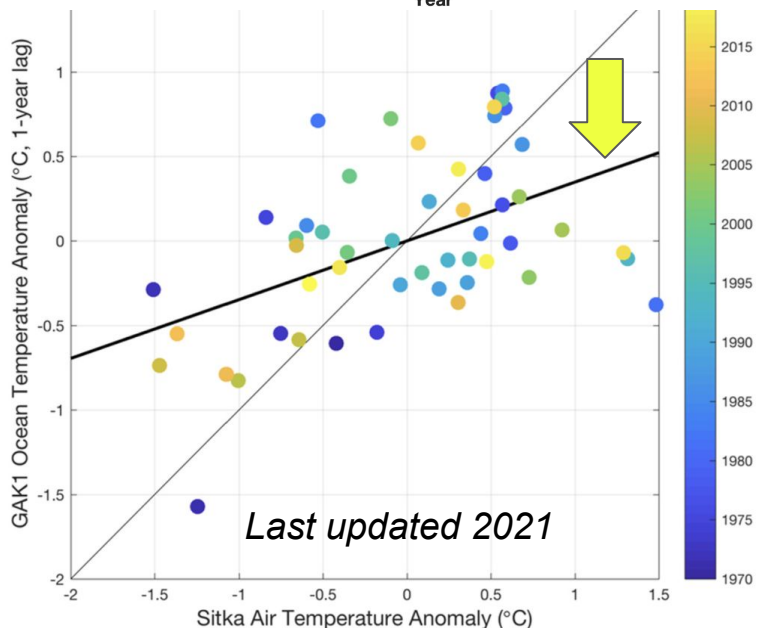
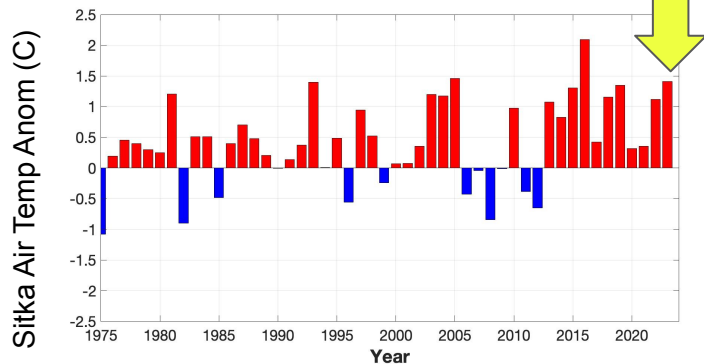
- 2023 SST (black) generally average winter, spring, summer with warm July/August (EGOA) (1985-2015 baseline)

GOA SST & Marine Heatwaves 2023

Lemagie, Callahan



- 2023 SST (black) generally average winter, spring, summer with warm July/August (EGOA) (1985-2015 baseline)
- EGOA MHW (July/August) covered ~50% area at peak
- 2023 is fourth consecutive year of no persistent MHW conditions



NGOA SST Forecast 2024

Hennon, Danielson

Danielson et al. 2022. Deep Sea Res. Part II

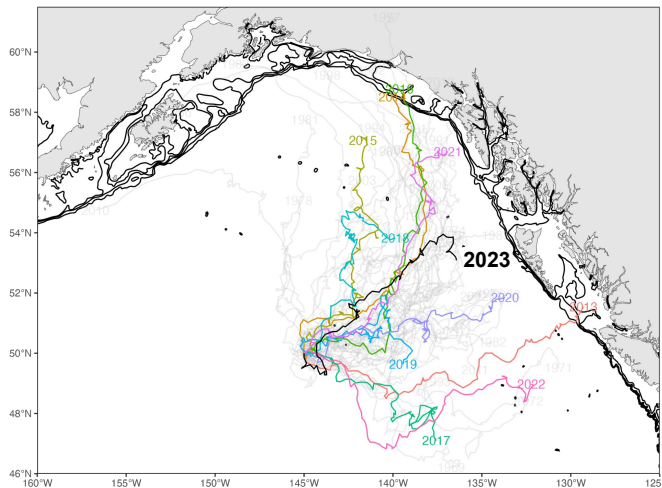
- Sitka Air temperature anomaly data through August, 2023 (1850-present)

2022 and (partial) 2023 Sitka temps. ~ 1.0°C-1.5°C warmer than average

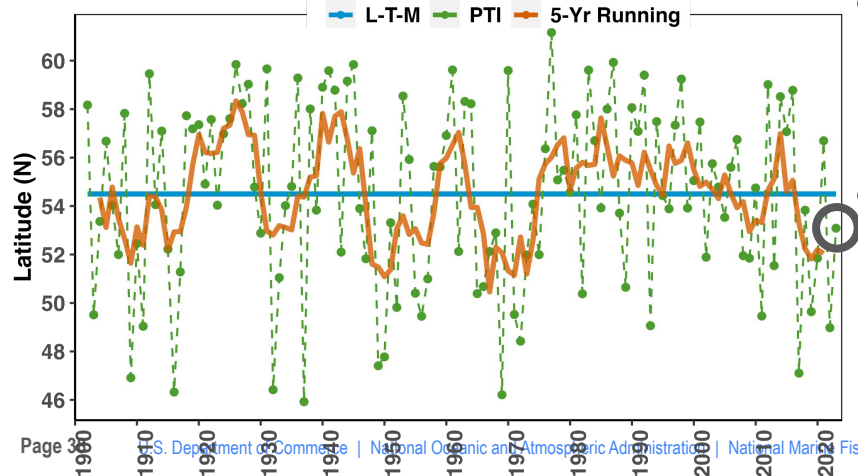
Expect ocean temps at GAK1 to be elevated by 0.3°C-0.5°C in 2024

Winter GOA Ocean Surface Currents: Papa Trajectory Index

Stockhausen



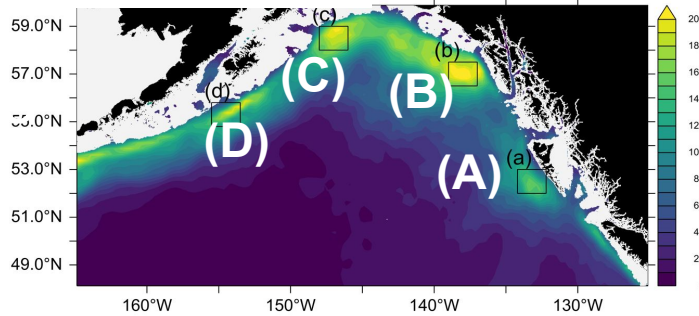
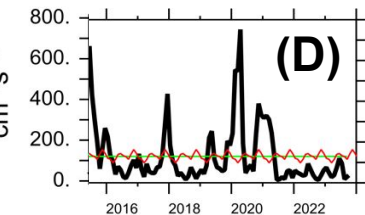
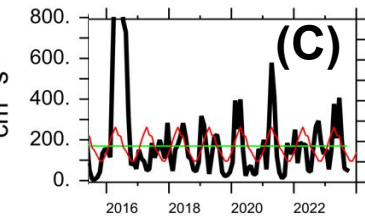
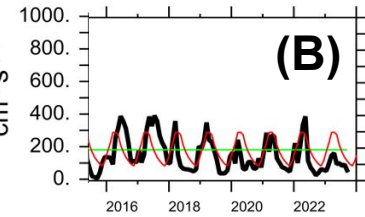
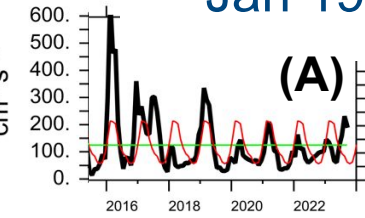
- Simulated surface drifter released from Ocean Station Papa on Dec. 1, 2022, for 90 days.
- 2022/2023 trajectory typical of time series
- Six of the last seven years have ended below the mean
- Reflects surface winds in Dec (from southwest; NE transport), Jan (from south; N transport) and Feb (from west; E transport)



Eddy Kinetic Energy (EKE) in the GOA

Cheng & Ladd

Jan 1993 - Aug 2023



- EKE related to strength of cross-shelf transport of heat, salinity, and nutrients.

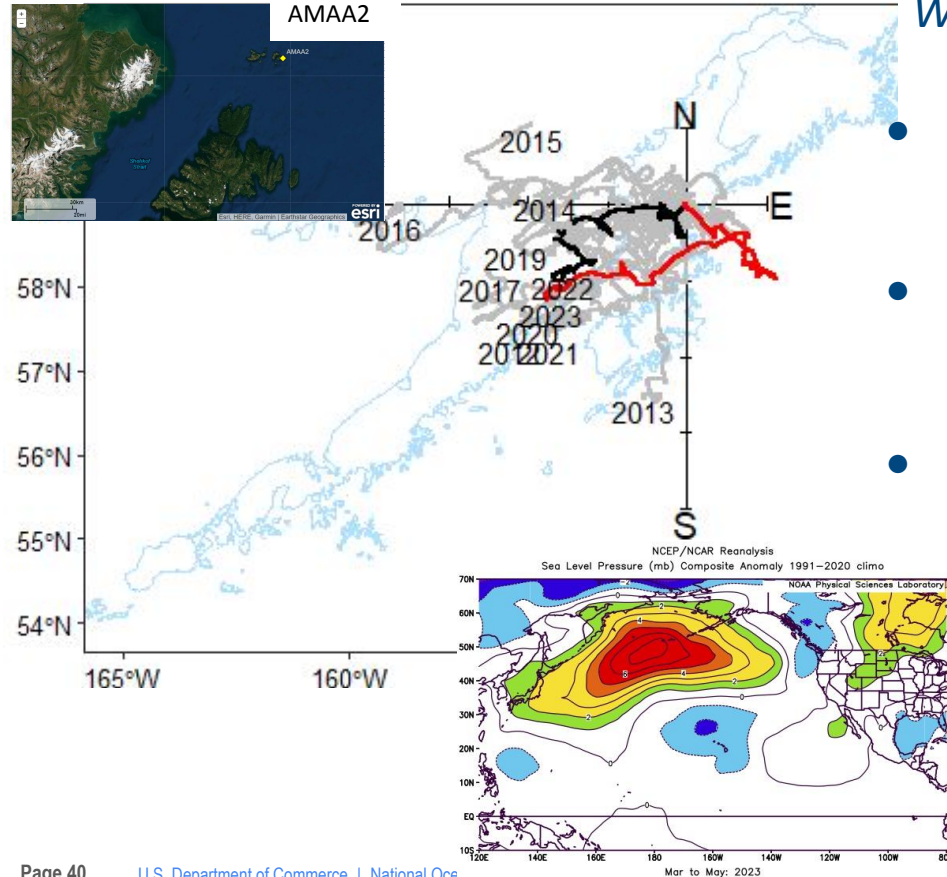
- 2023 EKE (black line) is close to seasonal climatology (red line) except Region A (2023 is higher)
- WGOA: (C) increased from 2022; (D) remained lower
- EGOA: (A) higher than 2022 and seasonal ave, (B) lower than 2022

Shelikof Spring Wind Direction

L. Rogers, E. Lemagie, M. Wilson

Wilson & Laman (2021) Fisheries & Oceanography

2022 2023



- April-May surface winds off NE Kodiak indicating the direction of coastal flow
 - 2023 (red): Offshore (to the SE) in April; May winds to the SW (down Shelikof St.)
 - 2022 (down Shelikof St.): Predict good recruitment of 2023 pollock age-1 year class
- 2023 Retention of age-1 pollock in favorable habitat mixed?

GOA Climate & Oceanography

Continued multi-year period of similar ocean conditions *(El Niño)

Climate



- Long-term summer (and slight winter) SST warming across GOA
- Transition to El Niño (potentially strong); continued period of negative PDO, weak Aleutian Low may moderate the impact

Sea Surface Temperature

- 2023: Cool to average SST across GOA shelf, warm July/Aug in EGOA
- 4th consecutive year of no persistent MHW conditions (but brief summer warming in EGOA)
- 2024: winter SST average (NMME) to 0.3°C-0.5°C warmer NGOA (Sitka air temperature)



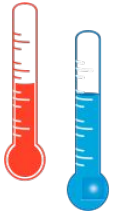



Transport

- Fall '22/Winter '23: moderate (northward/westward transport) (PTI)
- Winter/Spring'23: anomalous clockwise winds more frequent in counterclockwise dominated system); relaxed downwelling (e.g., Shelikof St)
- Eddies: ranged below to above average cross-shelf transport of heat, salinity, and nutrients from eddies (SEAK unusually high EKE)



Key Messages

- ● **N. Pacific:**
 - 2023 cool to average La Niña conditions transitioning to warming with upcoming El Niño; AI still warm
- ● **Eastern Bering Sea (EBS):** Continued period of average SST with “abnormally normal” oceanographic conditions over the EBS shelf in 2023.
- ● **Aleutian Islands (AI):** Cooler conditions in spring and summer than last year but still above 1985-2014 mean with warm winter and late summer
- ● **Gulf of Alaska (GOA):** Continued multi-year period of average SST, low-average transport/mixing; El Niño is coming

Thank You

Alaska Fisheries Science Center Ecosystem Status Reports

<https://www.fisheries.noaa.gov/alaska/ecosystems/ecosystem-status-reports-gulf-alaska-bering-sea-and-aleutian-islands>



Bridget.Ferriss@noaa.gov (Gulf of Alaska)
Elizabeth.Siddon@noaa.gov (Eastern Bering Sea)
Ivonne.Ortiz@noaa.gov (Aleutian Islands)
Stephani.Zador@noaa.gov

