Borealization and snow crab: research update and rebuilding considerations

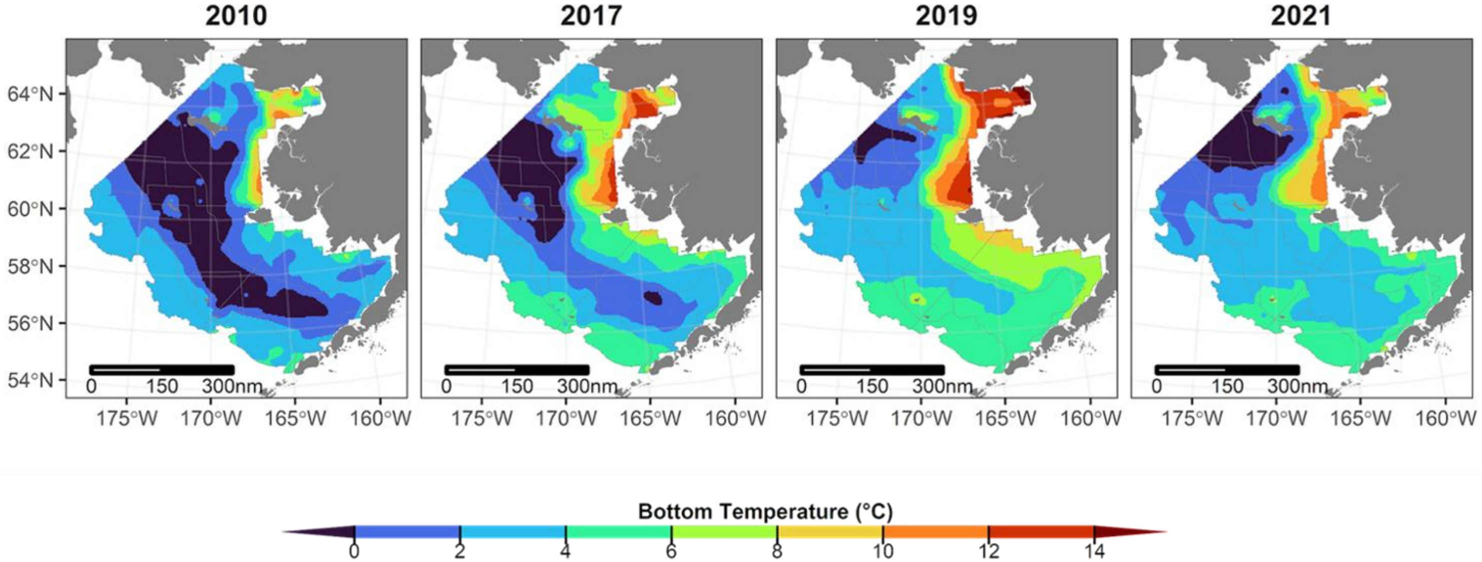
Mike Litzow, with contributions from Erin Fedewa, Brendan Connors, Lisa Eisner, David Kimmel, Trond Kristiansen, Mike Malick, and Jens Nielsen

Outline

- Update borealization approach with 2022 data
- Review evidence for attribution of borealization to human causes
- Evaluate time blocks considered for rebuilding projections – which is most plausible in current climate?

Update borealization approach with 2022 data

Collapse coincides with rapid borealization



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Recent warming leads to a rapid borealization of fish communities in the Arctic

Maria Fossheim[1]*, Raul Primicerio[2], Edda Johannesen[1], Randi B. Ingvaldsen[1], Michaela M. Aschan[2] and Andrey V. Dolgov[3]

Arctic marine ecosystems are warming twice as fast as the global average[1]. As a consequence of warming, many incoming species experience increasing abundances and expanding distribution ranges in the Arctic[2]. The Arctic is expected to have the largest species turnover with regard to invading ...

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SEA ICE RETREAT ALTERS THE BIOGEOGRAPHY OF THE BERING SEA CONTINENTAL SHELF

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[2]*Alaska Fisheries Science Center, National Marine Fisheries Service, 301 Research Court, Kodiak, Alaska 99615 USA*

Abstract. Seasonal ice cover creates a pool of cold bottom water on the eastern Bering Sea continental shelf each winter. The southern edge of this cold pool, which defines the ecotone between arctic and subarctic communities, has retreated ~230 km northward since the early 1980s. Bottom trawl surveys of fish and invertebrates in the southeastern Bering Sea (1982–2006) show a coincident reorganization in community composition by latitude. Survey catches ...

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Borealization of the Arctic Ocean in Response to Anomalous Advection From Sub-Arctic Seas

Igor V. Polyakov[1,2], Matthew B. Alkire[3], Bodil A. Bluhm[4], Kristina A. Brown[5], Eddy C. Carmack[5], Melissa Chierici[6], Seth L. Danielson[7], Ingrid Ellingsen[8], Elizaveta A. Ershova[4,9], Katarina Gårdfeldt[10], Randi B. Ingvaldsen[4,11], Andrey V. Pnyushkov[12], Dag Slagstad[8] and Paul Wassmann[4]*

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Review Article

Possible future scenarios in the gateways to the Arctic for Subarctic and Arctic marine systems: II. prey resources, food webs, fish, and fisheries

Franz J. Mueter[1,*], Benjamin Planque[2], George L. Hunt, Jr[3], Irene D. Alabia[4], Toru Hirawake[5], Lisa Eisner[6], Padmini Dalpadado[7], Melissa Chierici[2], Kenneth F. Drinkwater[7], Naomi Harada[8], Per Arneberg[2], and Sei-Ichi Saitoh[4]

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RESEARCH ARTICLE

Deep demersal fish communities respond rapidly to warming in a frontal region between Arctic and Atlantic waters

Margrete Emblemsvåg[1,2] | Karl Michael Werner[3] | Ismael Núñez-Riboni[3] | Romain Frelat[4] | Helle Torp Christensen[5] | Heino O. Fock[3] | Raul Primicerio[2]

[1]Møreforsking AS, Ålesund, Norway
[2]The Arctic University of Norway, Tromsø, Norway
[3]Thünen Institute of Sea Fisheries, Bremerhaven, Germany
[4]Wageningen University and Research, ...

Abstract
The assessment of climate impact on marine communities dwelling deeper than the well-studied shelf seas has been hampered by the lack of long-term data. For a long time, the prevailing expectation has been that thermal stability in deep ocean layers will delay ecosystem responses to warming ...

Ecosystem properties associated with borealization

Arctic

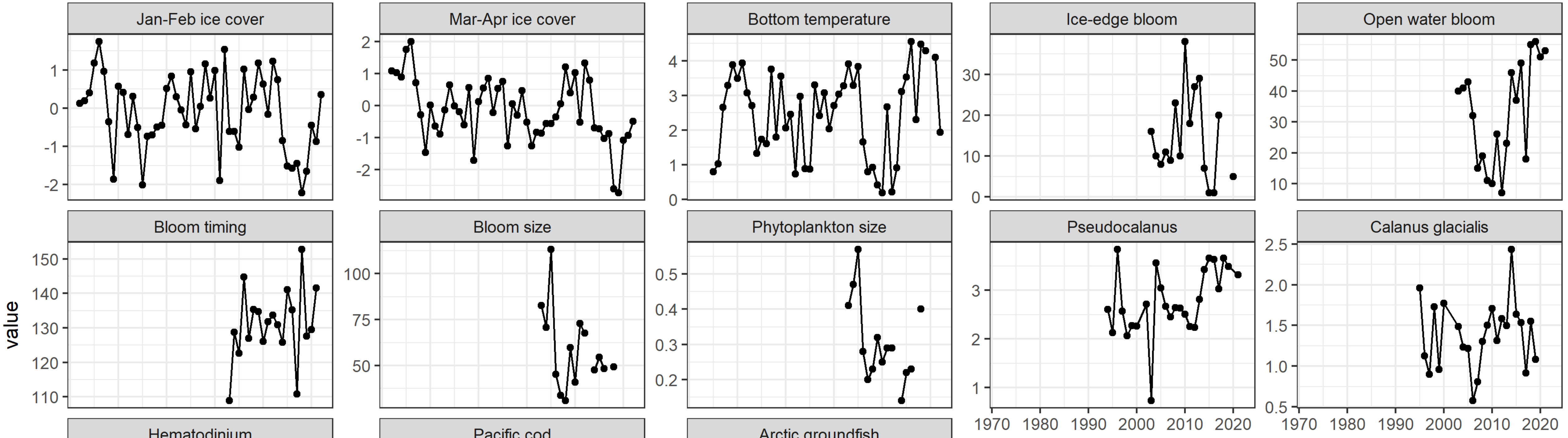
- More ice
- Late ice retreat
- ★ Cold summer bottom temp
- Ice-associated blooms
- Earlier blooms
- Aggregated phytoplankton
- Larger blooms
- Benthic production
- More *Calanus*
- ★ Less *Hematodinium*
- More Arctic groundfish
- ★ Fewer Pacific cod

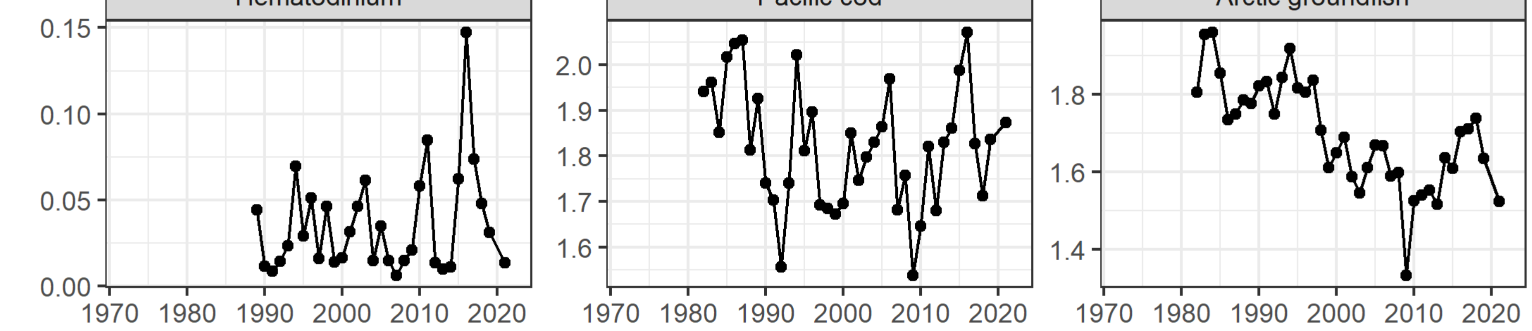
Subarctic

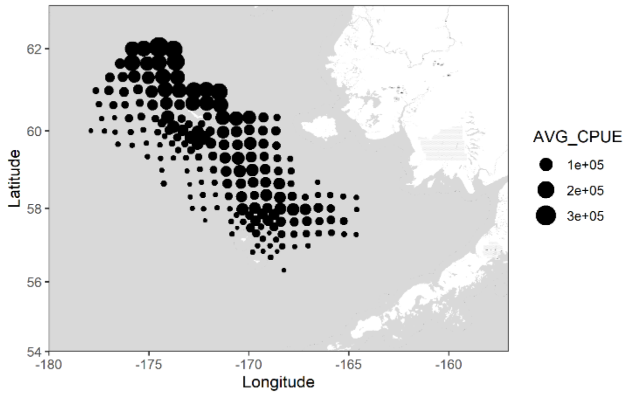
- Less ice
- Early ice retreat
- ★ Warm summer bottom temp
- Open-water blooms
- Later blooms
- Smaller phytoplankton
- Smaller blooms
- Pelagic production
- More *Pseudocalanus*
- ★ More *Hematodinium*
- Fewer Arctic groundfish
- ★ More Pacific cod

★ Hypothesized proximate mechanisms

Borealization index: Individual time series

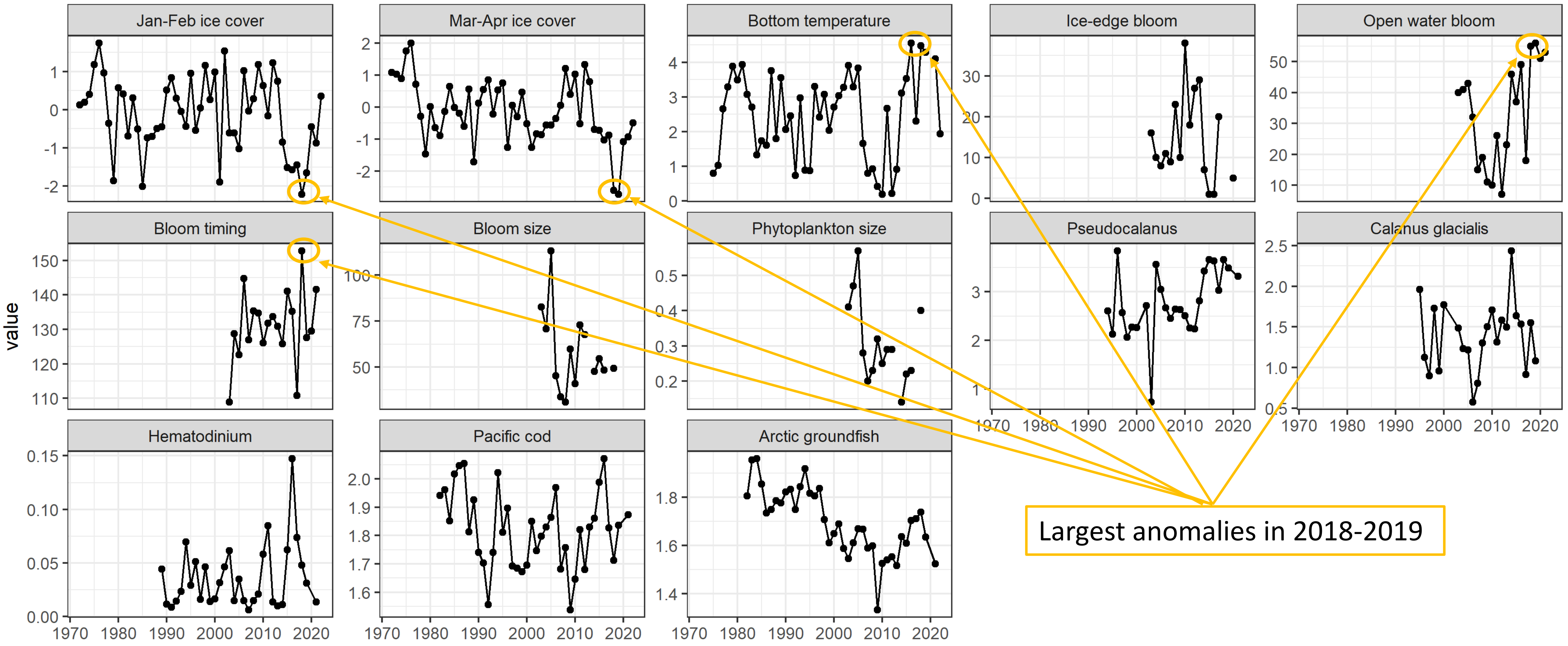






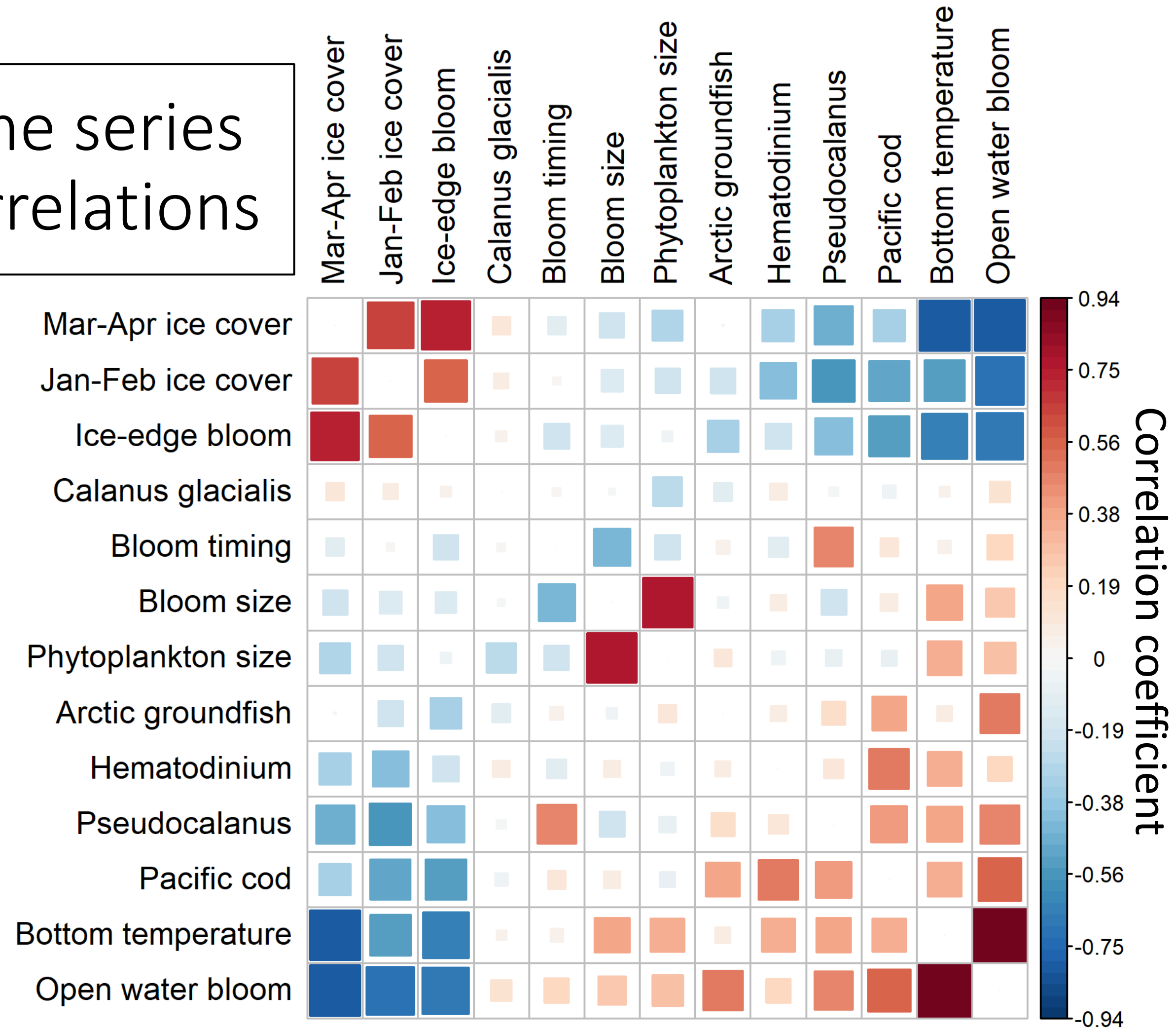
Focused on core of immature range

Borealization index: Individual time series



Create borealization index by summarizing variability shared across time series

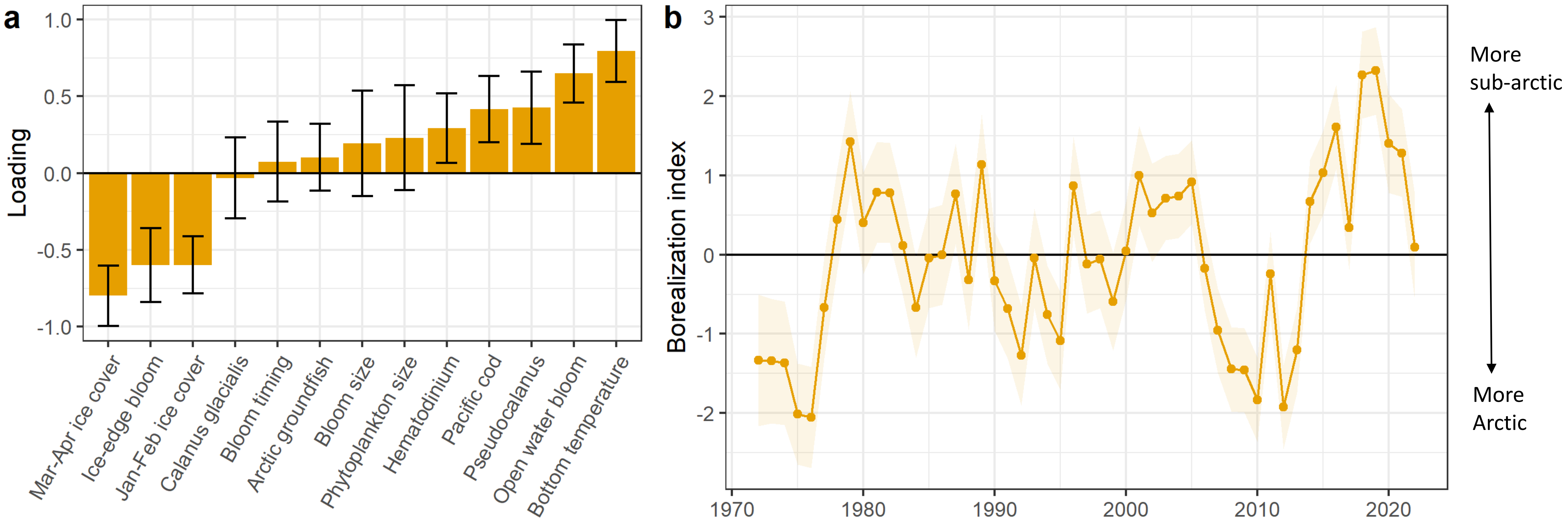
Time series correlations



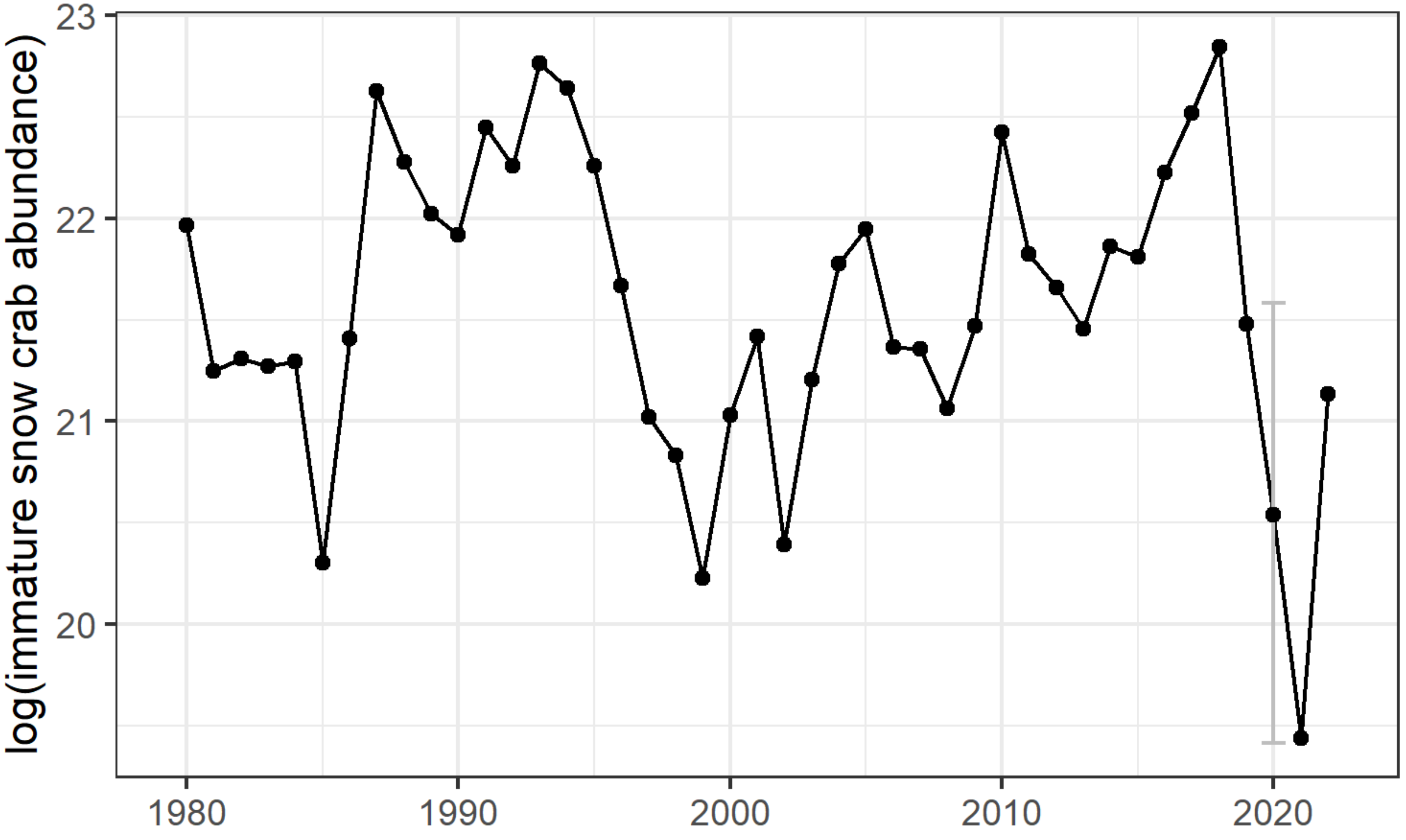
Borealization index

- Dynamic Factor Analysis model
- Eight candidate formulations (1 or 2 trends, each with 4 candidate error / variance-covariance matrices)
- Best model is 1-trend, different variances, no covariance

Borealization index – loadings and trend updated for 2022



Response variable:
Immature abundance 1980-2022,
with estimated 2020 value and uncertainty



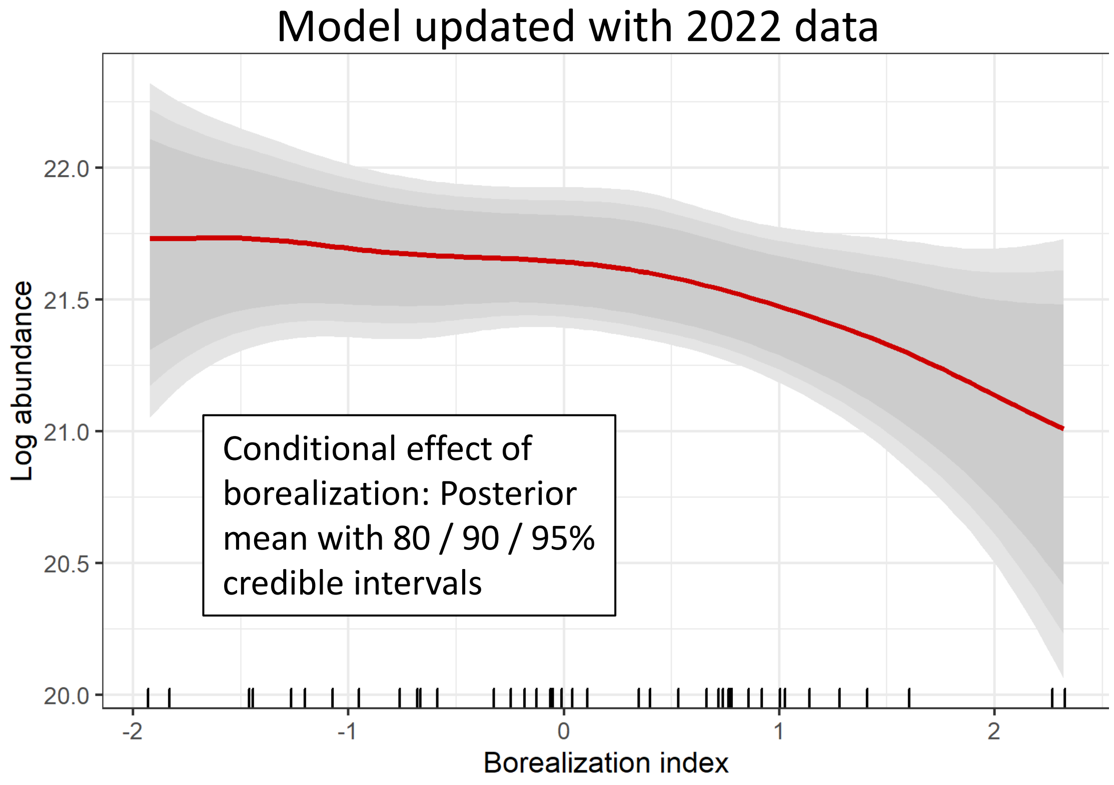
Multiple imputation using:

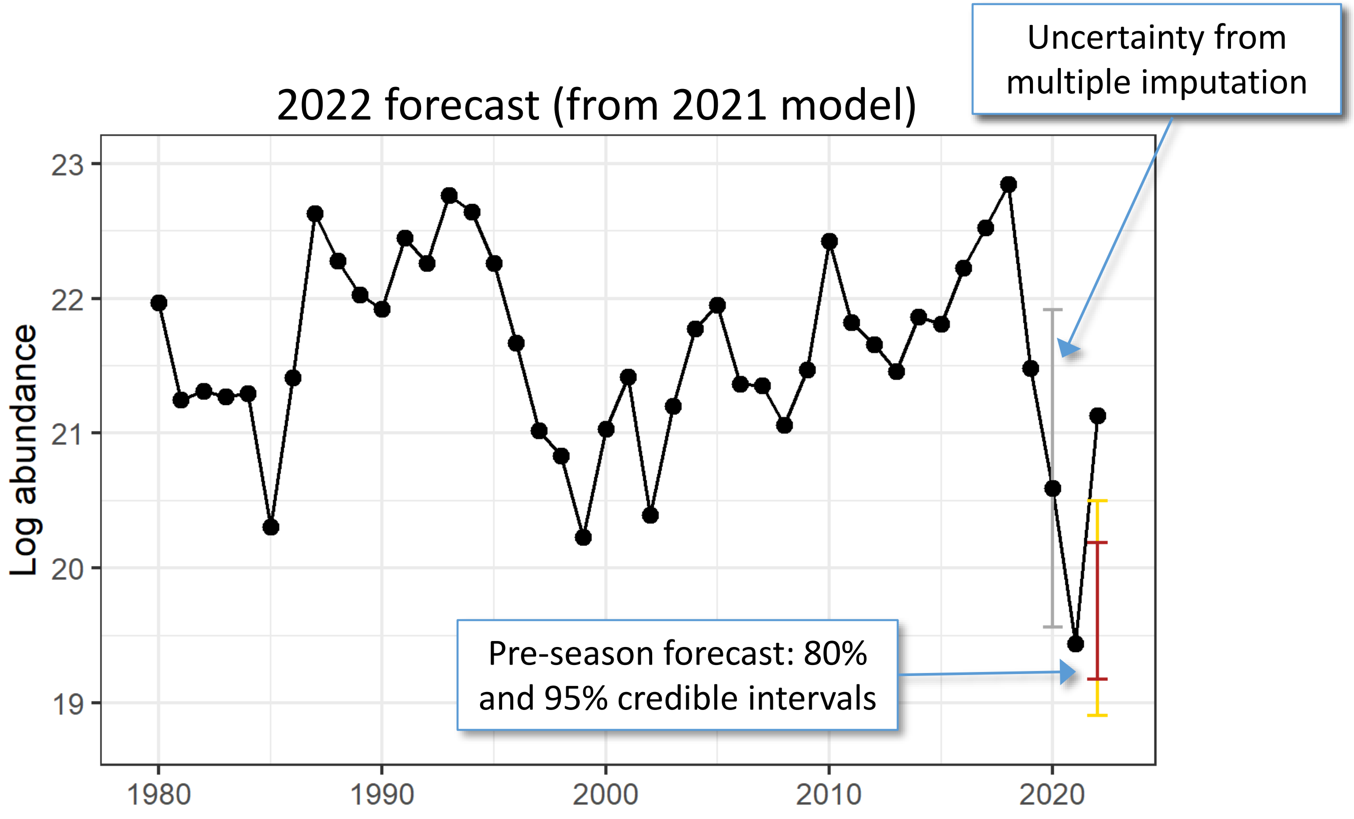
- Model mature male snow crab abundance
- Model mature female snow crab abundance
- Model age3+ pollock biomass
- Model age2+ yellowfin biomass
- Model female Alaska plaice biomass

Borealization effects on abundance

Bayesian autoregressive regression model:

$$abundance_{t+1} \sim abundance_t + s(borealization\_trend_t) + \varepsilon$$



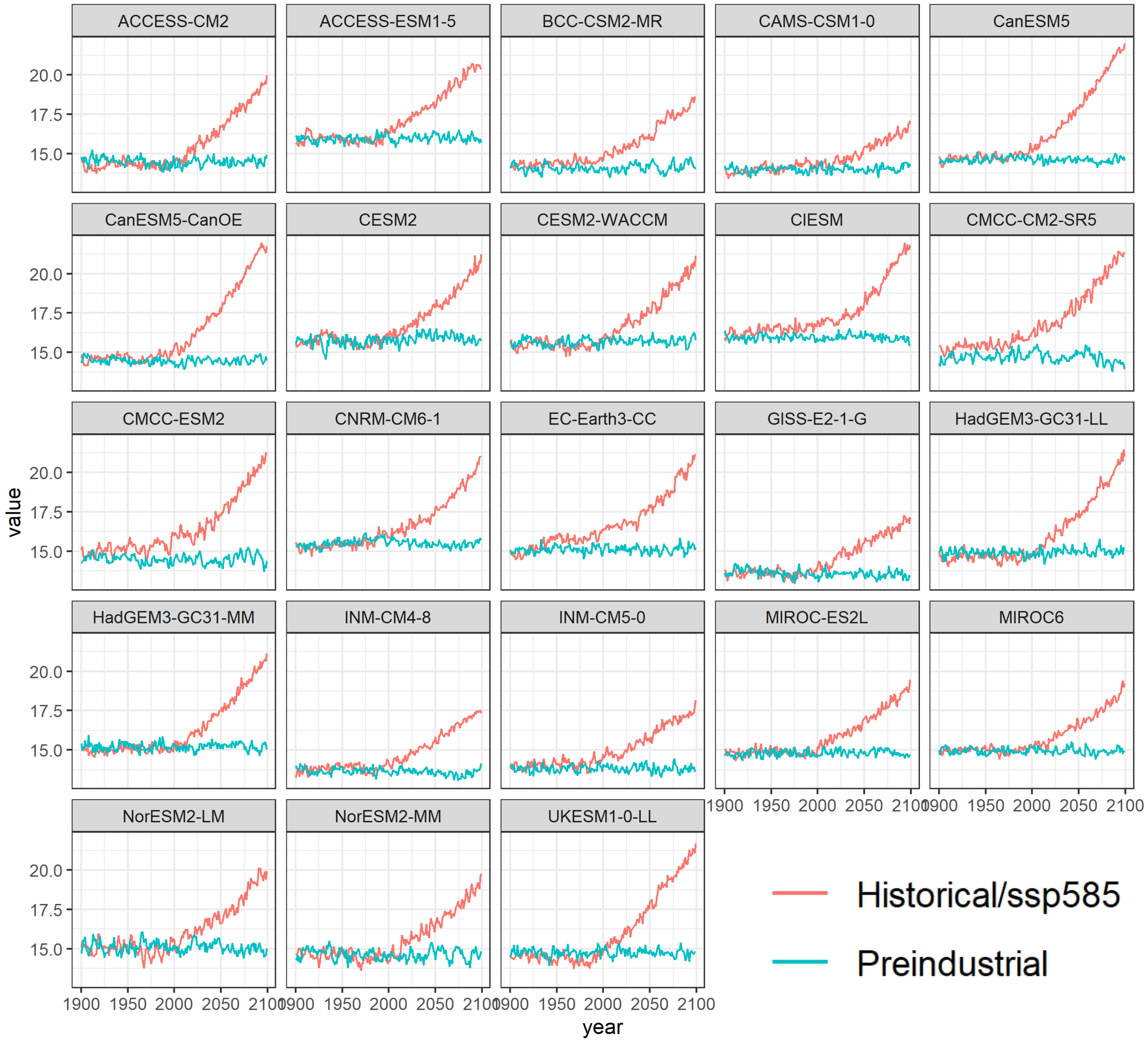


Attribution of Bering Sea borealization to human-caused global warming

23 CMIP6 models

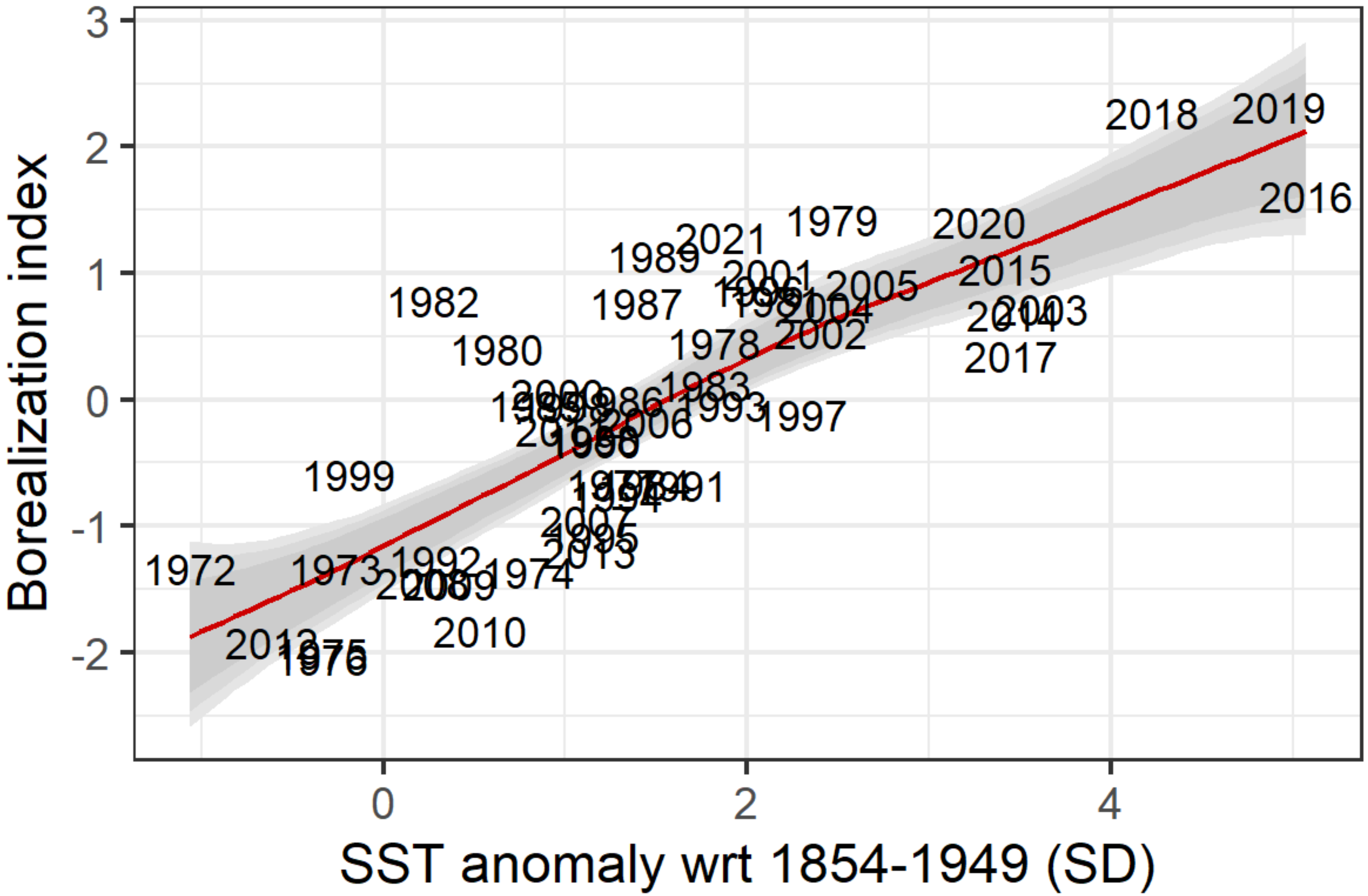
- Weighted for bias, autocorrelation, low-frequency prediction (compared with observations)
- Corrected for differences in climate sensitivity and predicted warming rate (~~model democracy~~)

North Pacific sea surface temperature



Borealization maps onto annual sea surface temperature

Posterior mean with 80 / 90 / 95% credible intervals



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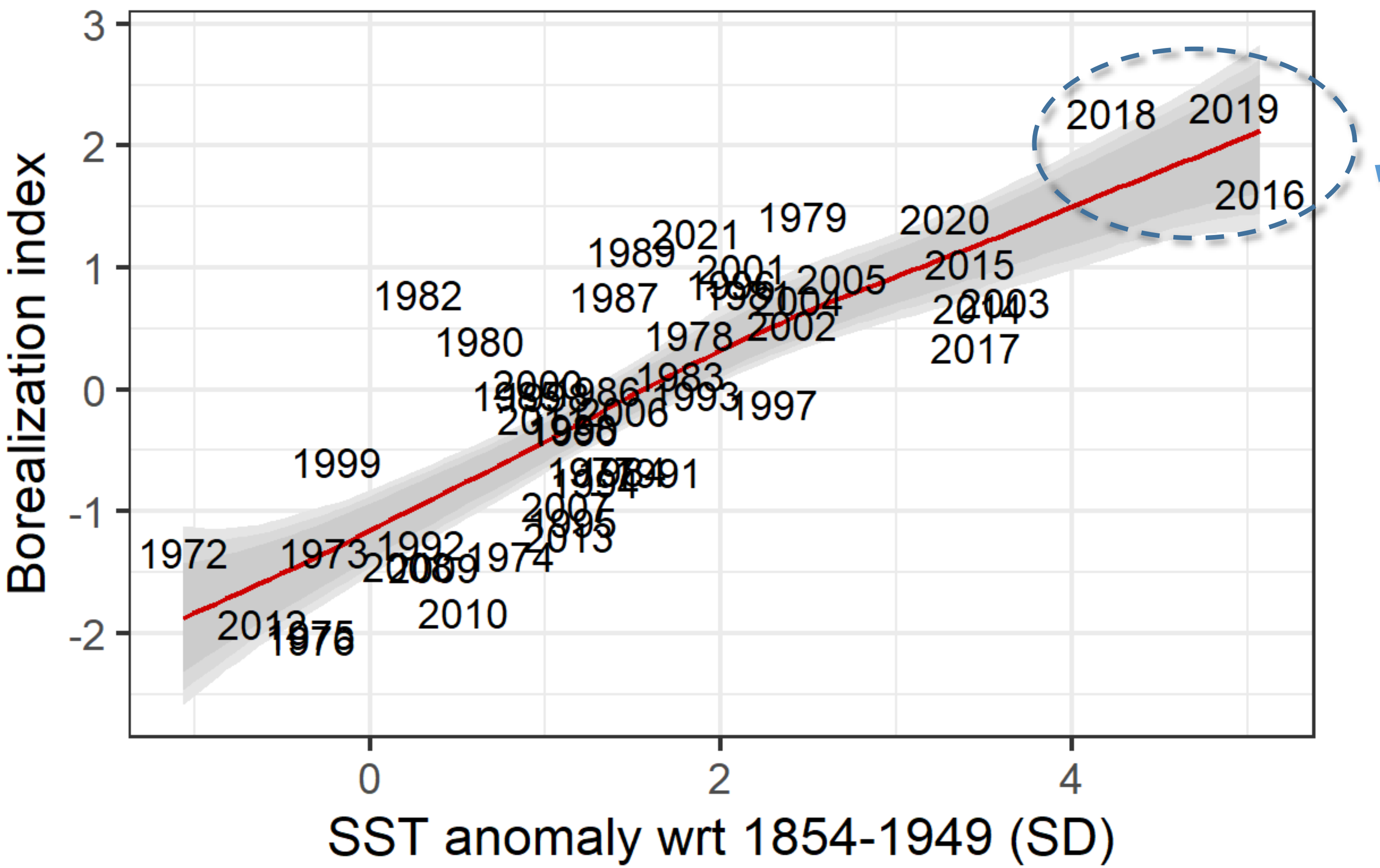


Highest borealization values occur at SST > 4 SD

Two attribution statistics:
Fraction of Attributable Risk (FAR) and Risk Ratio

FAR: how much of the risk for an event is due to human activity?

$$\text{FAR} = 1 - \frac{\text{preindustrial probability}}{\text{current probability}}$$

FAR = 0 → equally likely with / without human influence

FAR = 0.5 → twice as likely with human influence

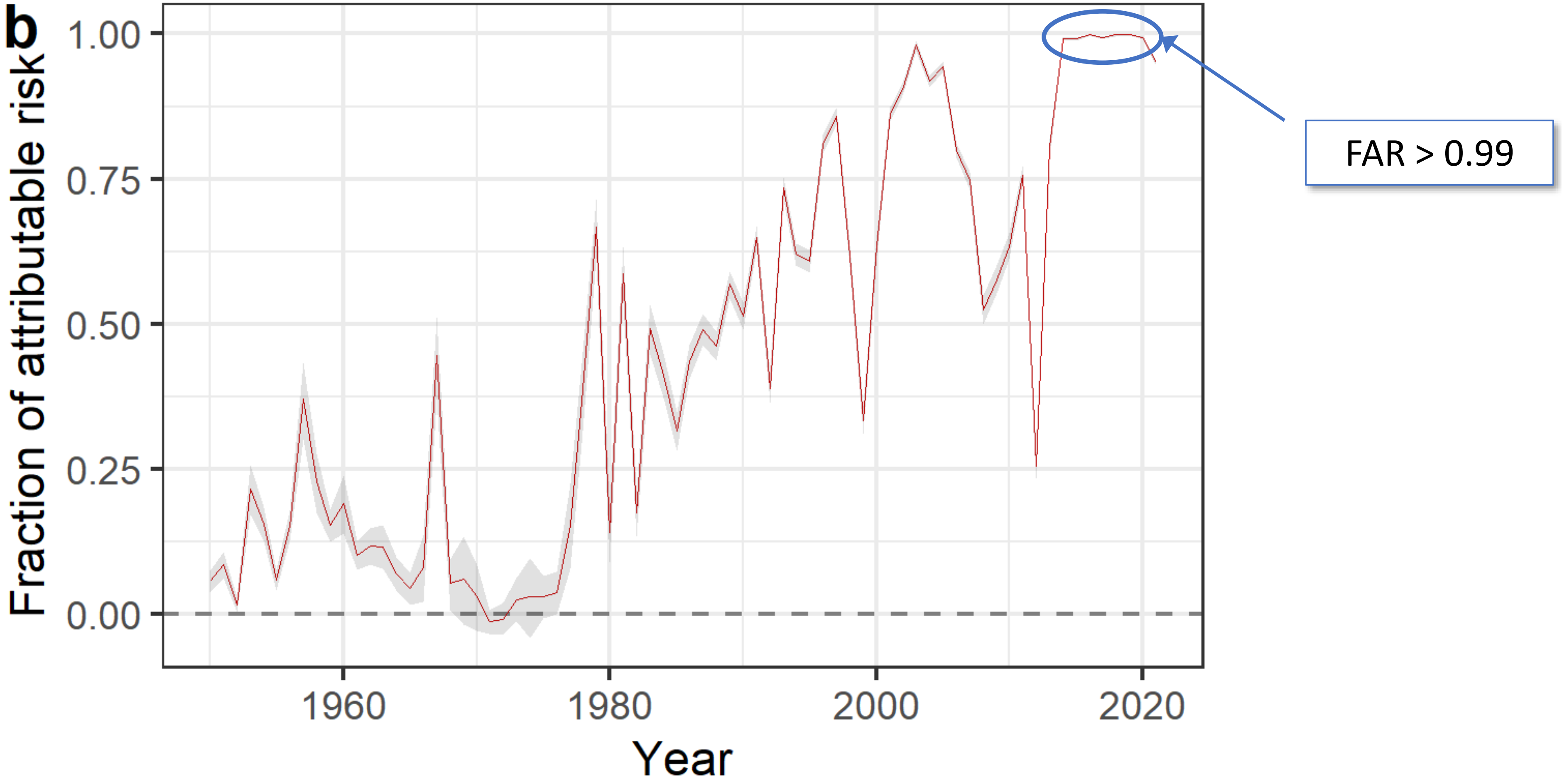
FAR = 1 → only possible with human influence

Risk Ratio: how much more likely is an event due to human activity?

Risk Ratio = 1 / (1-FAR)

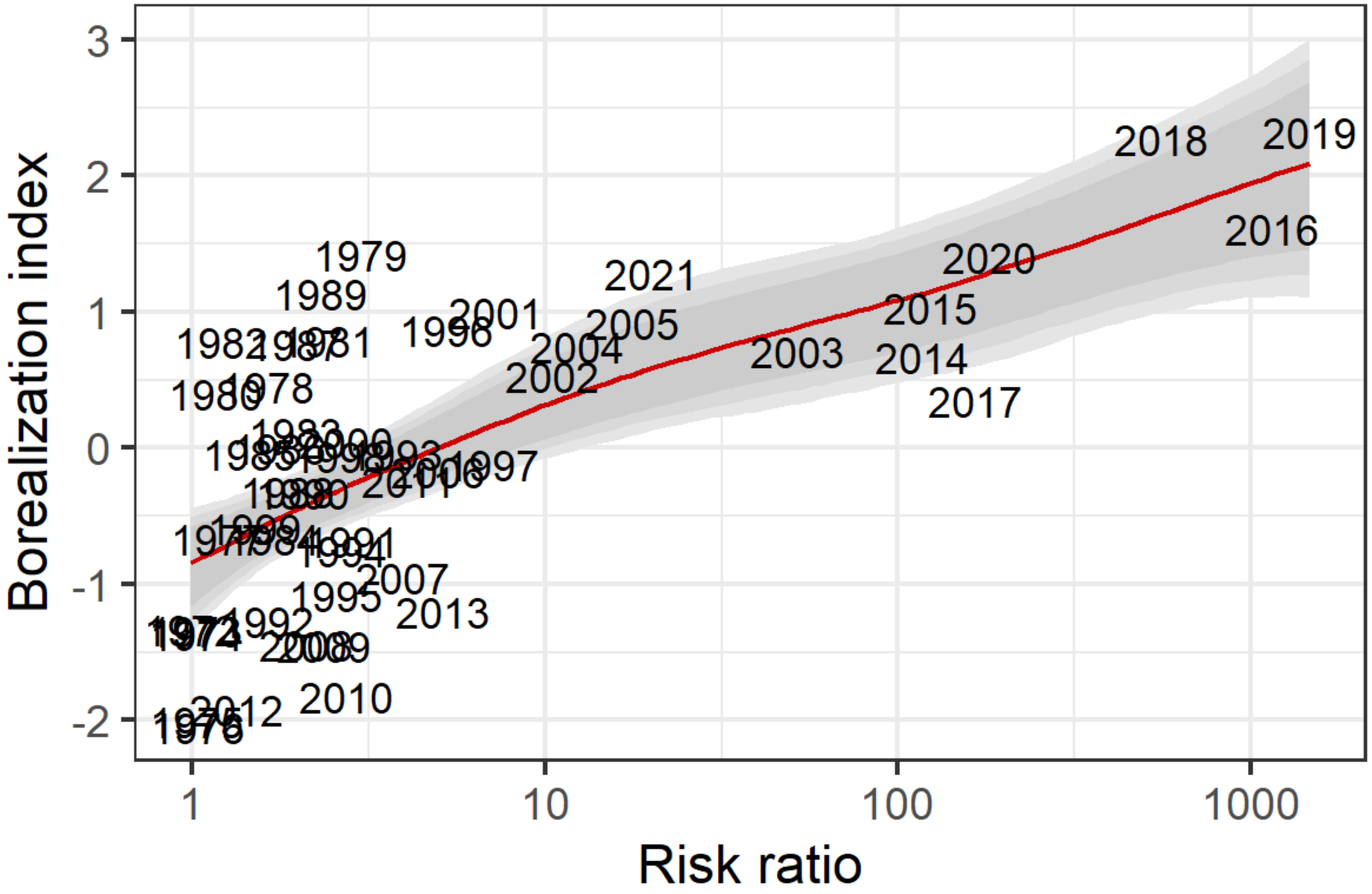
Recent Bering Sea SST extremes are human-caused

Posterior mean with
95%
credible intervals



Rapid borealization events occur during human-caused SST extremes

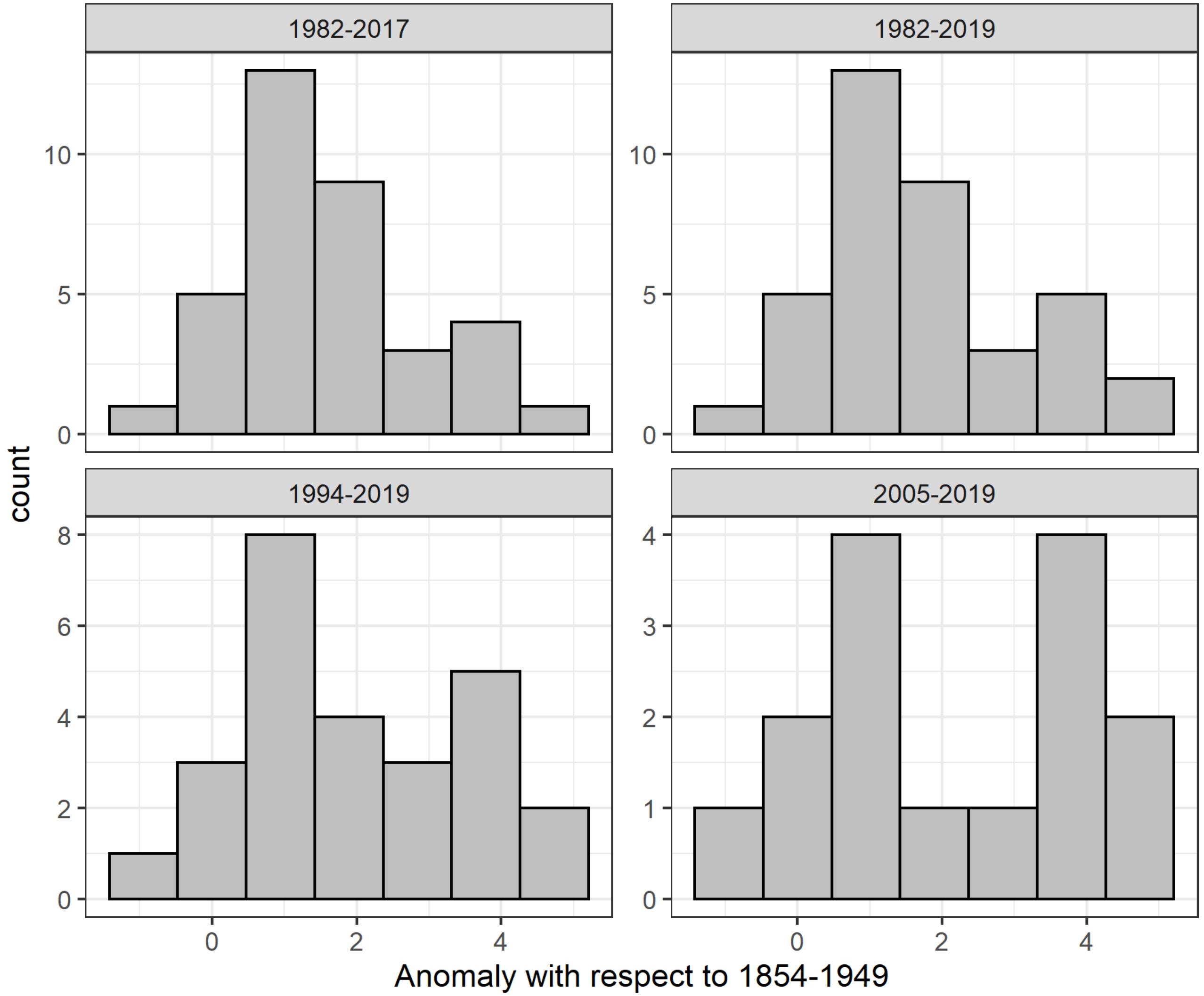
Posterior mean with
80 / 90 / 95%
credible intervals



Evaluating candidate time blocks of *M* and *R* for rebuilding projections

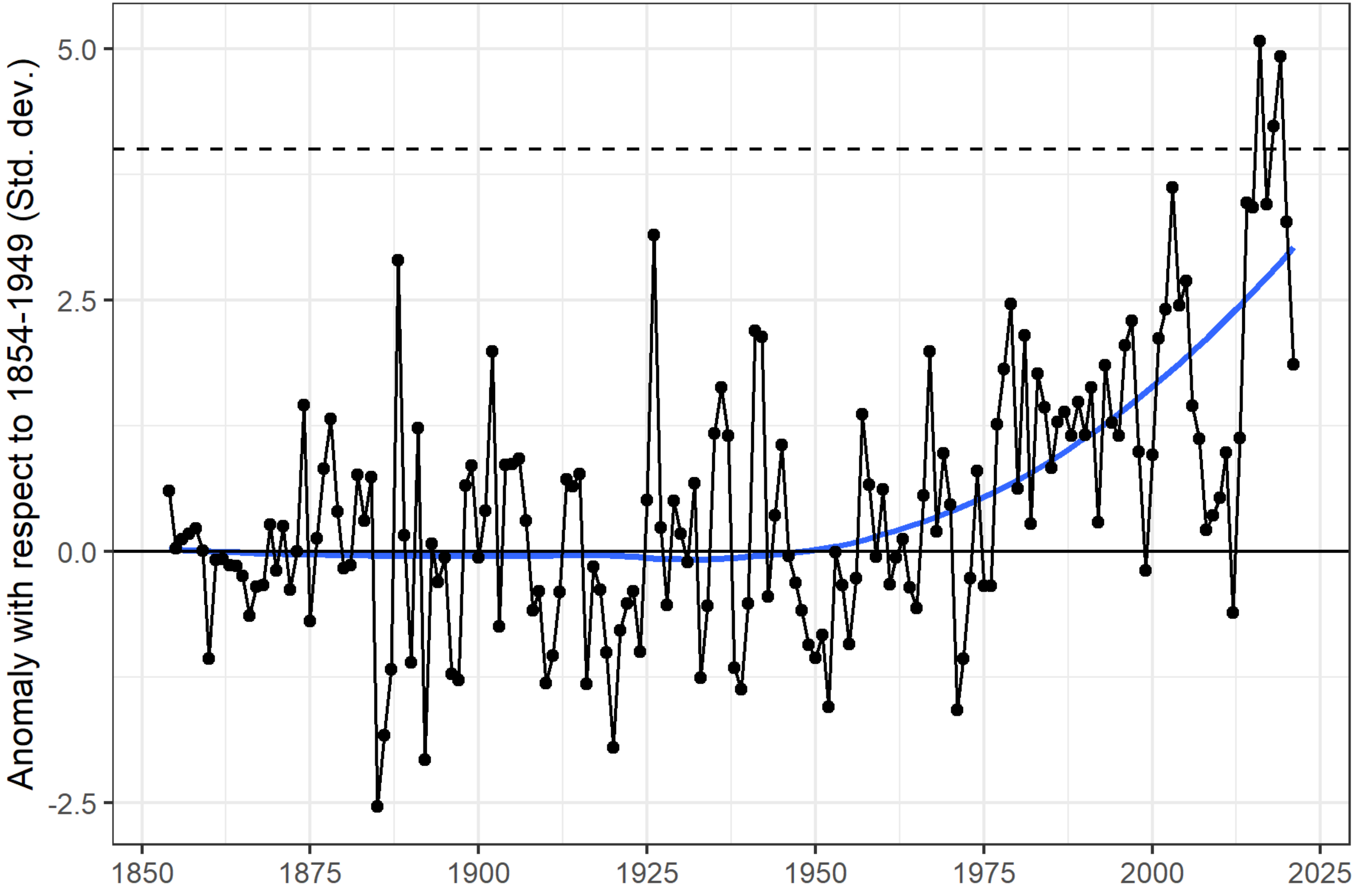
Which time block is the most plausible representation of the current climate?

Annual SST anomaly distributions for four proposed time blocks



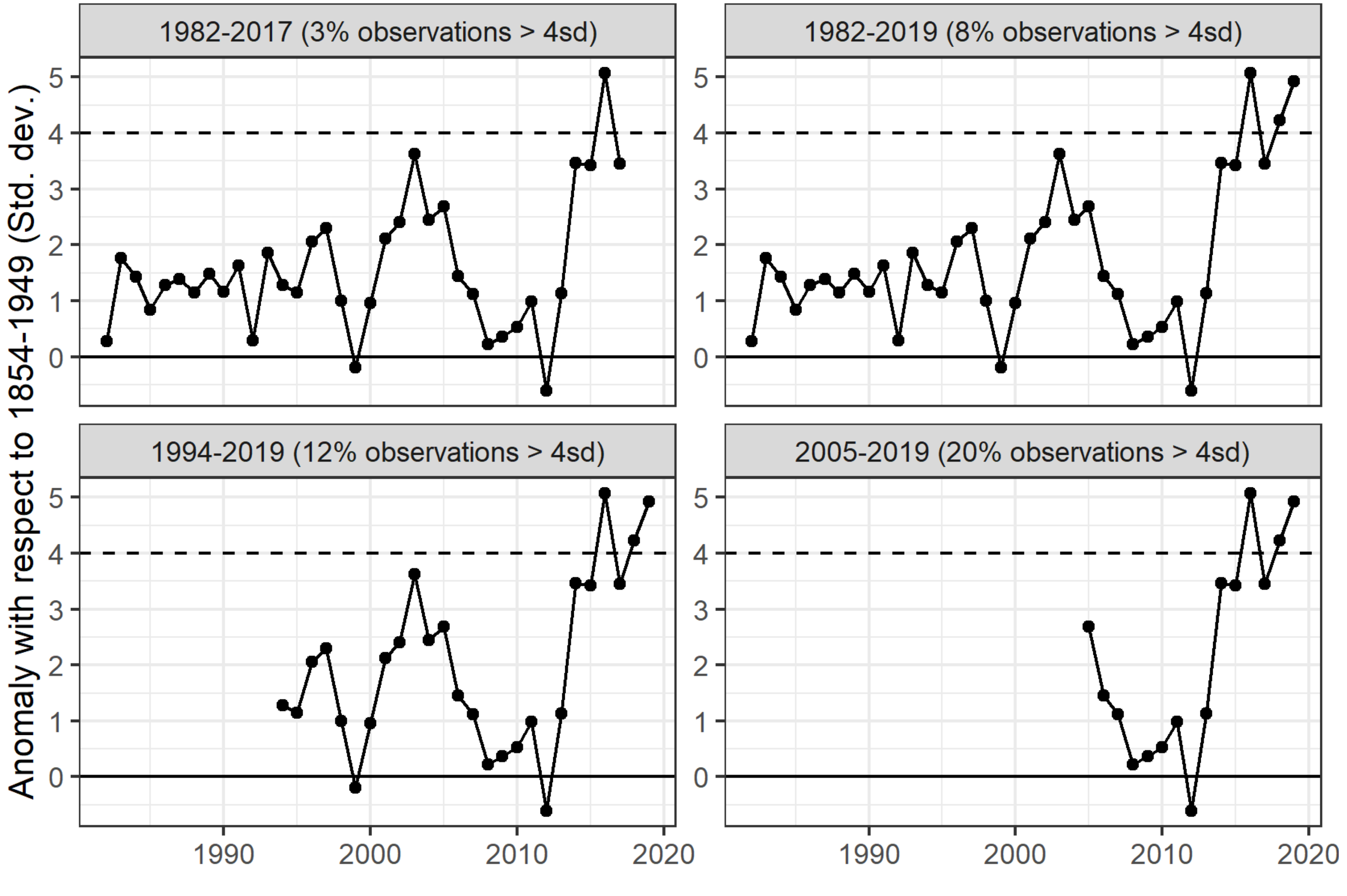
Metric for comparing time blocks with estimated current climate: proportion of SST anomalies > 4SD

Observed SST
1854-2021



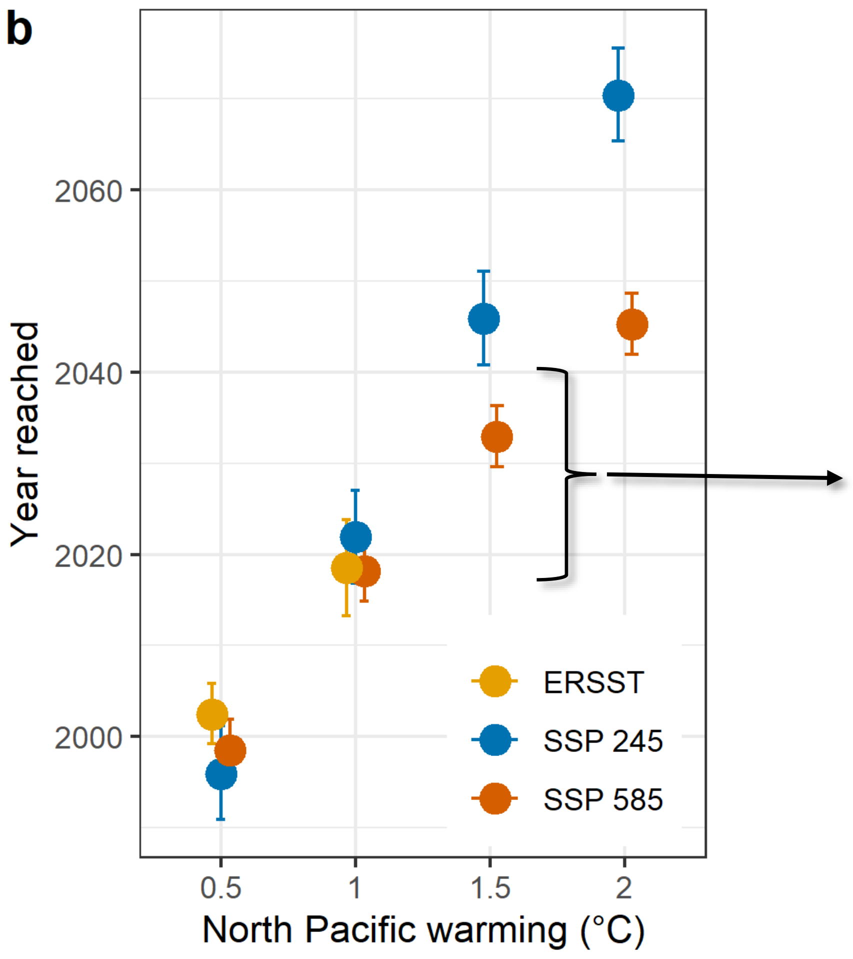
Pre-1950:
mean = 3.42°,
SD = 0.50°

Candidate time blocks for rebuilding projections



Estimating warming rate to define current climate

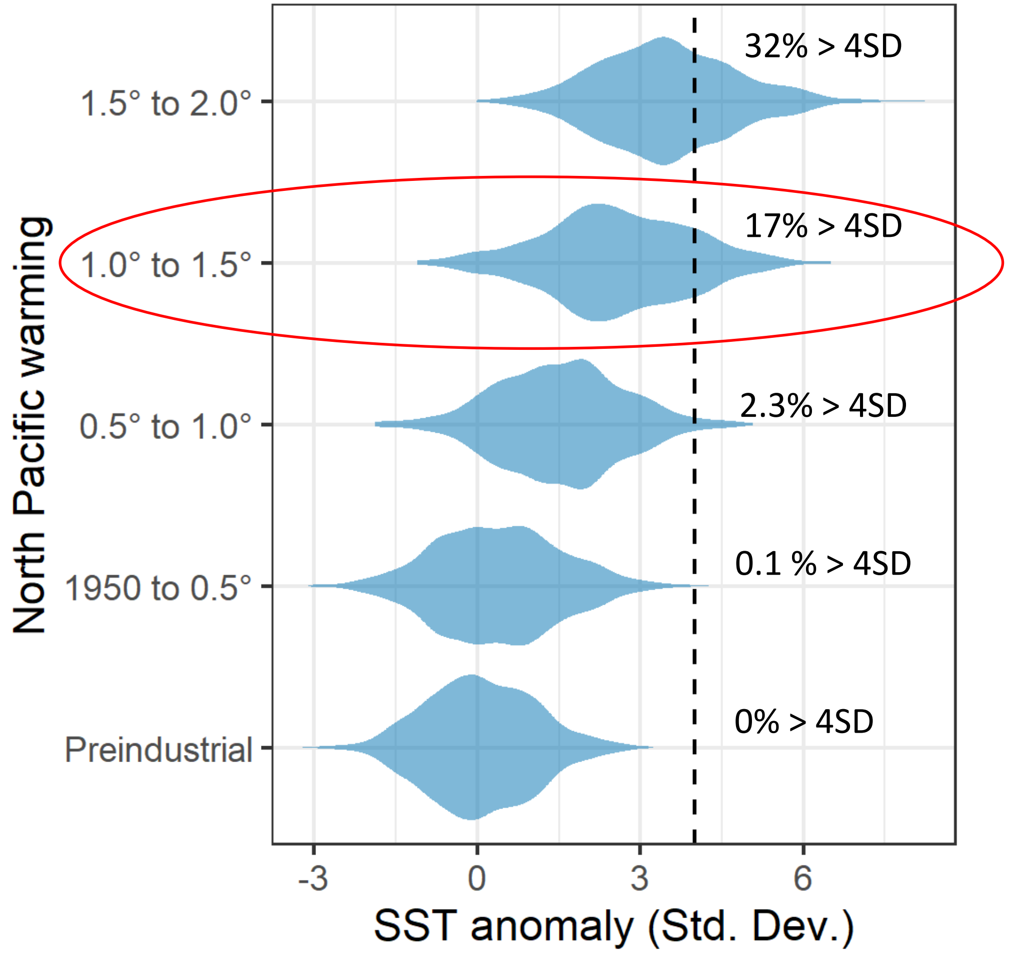
Estimated timing that North Pacific reaches 0.5°, 1.0°, 1.5°, and 2.0° above preindustrial climatology



North Pacific is currently between 1.0° and 1.5° warmer than preindustrial (very high confidence)

Projection time blocks compared with estimated current climate

Eastern Bering Sea SST distributions for different North Pacific warming levels (weighted CMIP6 projections)

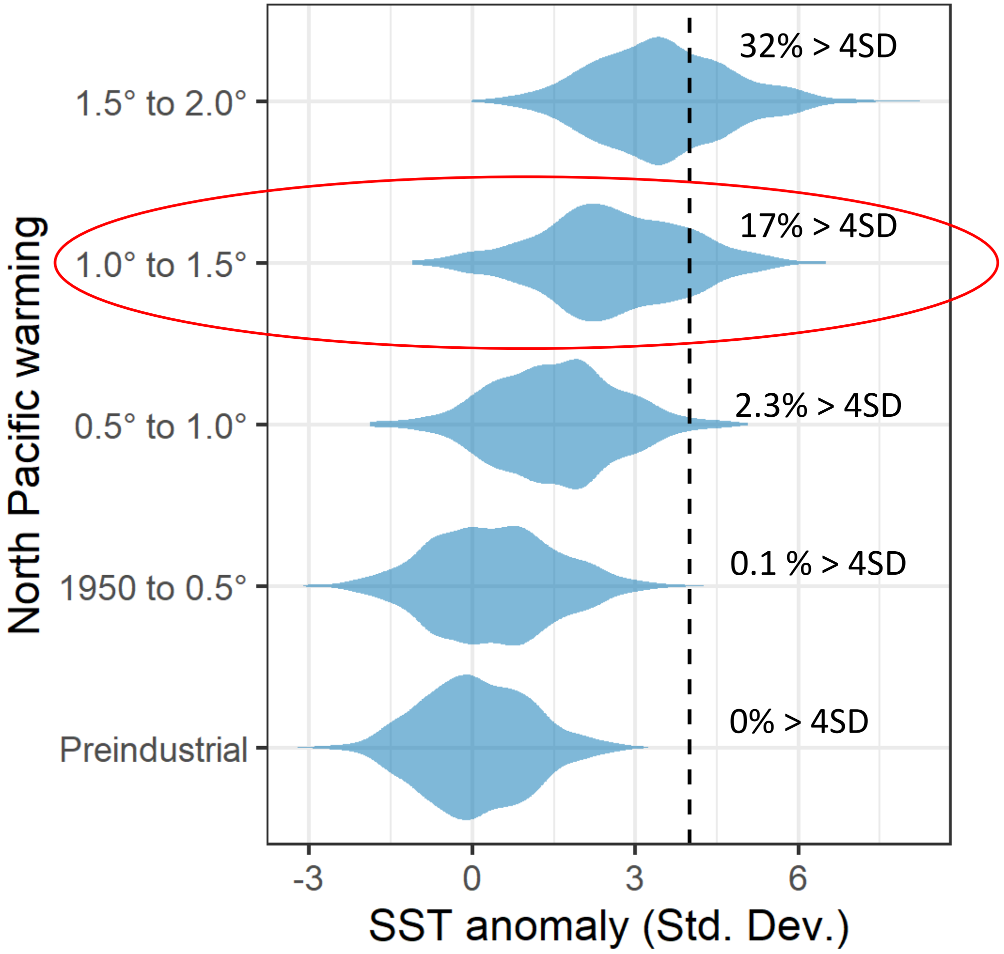


Conclusion: 2005-2019 is the most plausible representation of current climate

Uncertainties

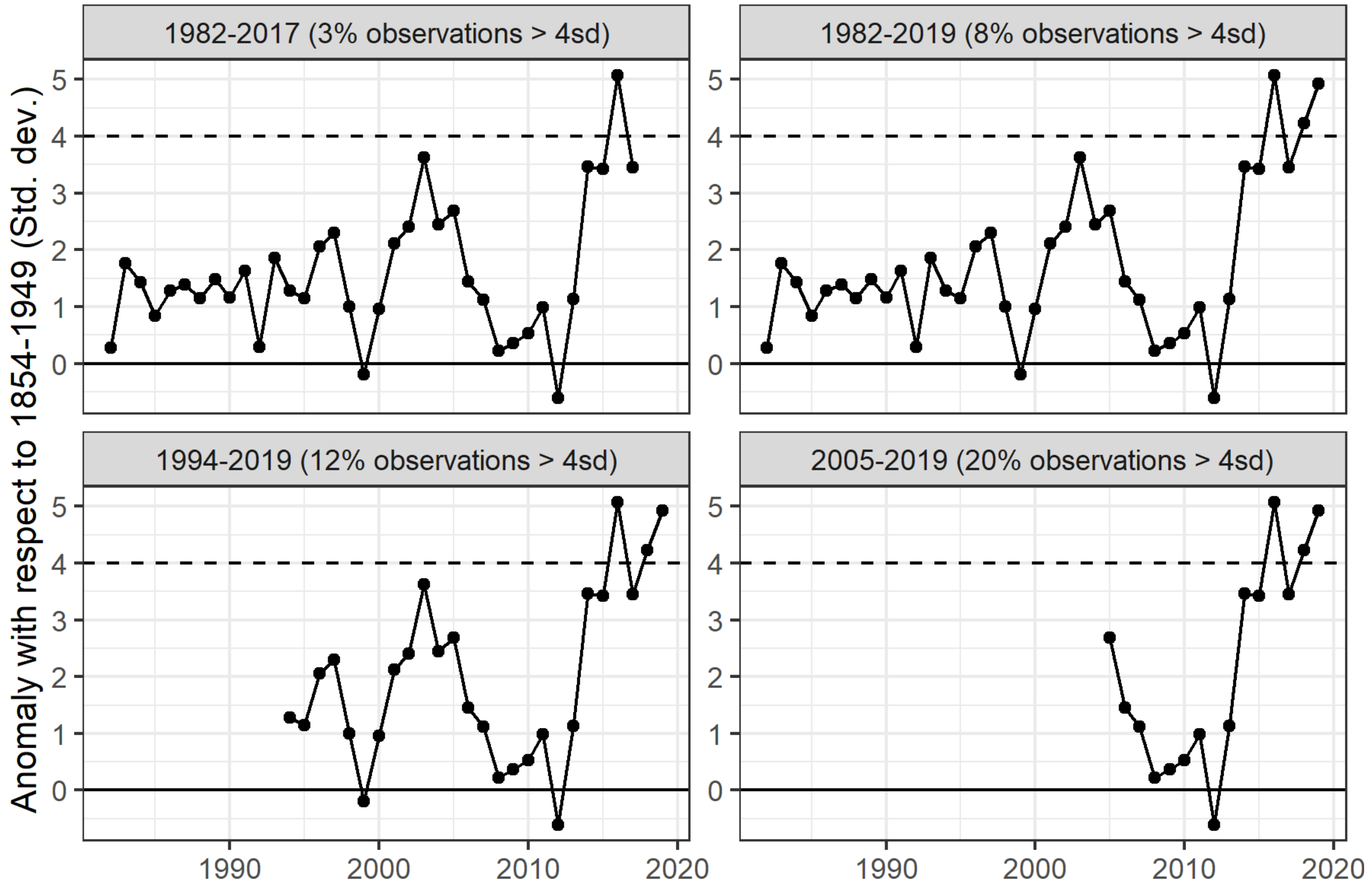
- Ability of global models to replicate regional variability
- Ability of models to capture atmosphere-ocean interactions in addition to thermodynamics
- Sensitivity to model-weighting approach

Eastern Bering Sea SST distributions for different North Pacific warming levels (weighted CMIP6 projections)



Projection time blocks compared with estimated current climate

Time blocks (observed Eastern Bering Sea SST)



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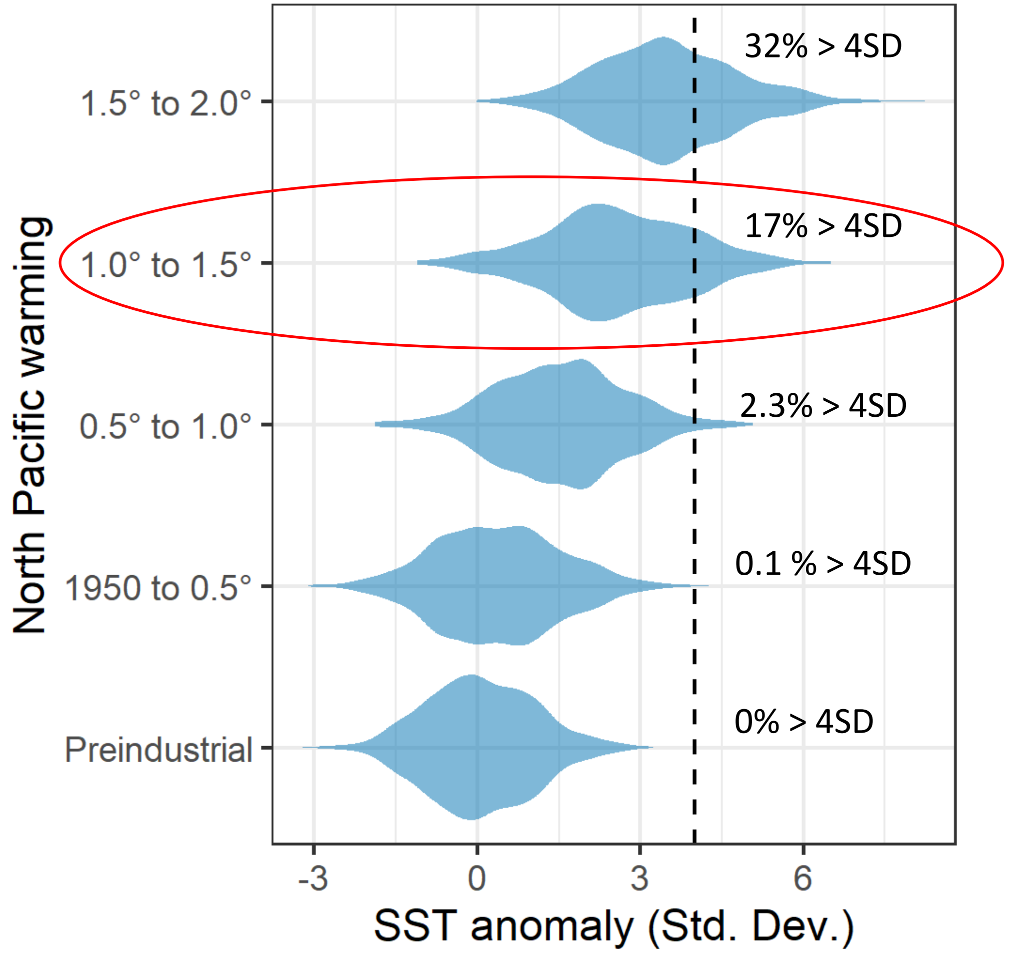

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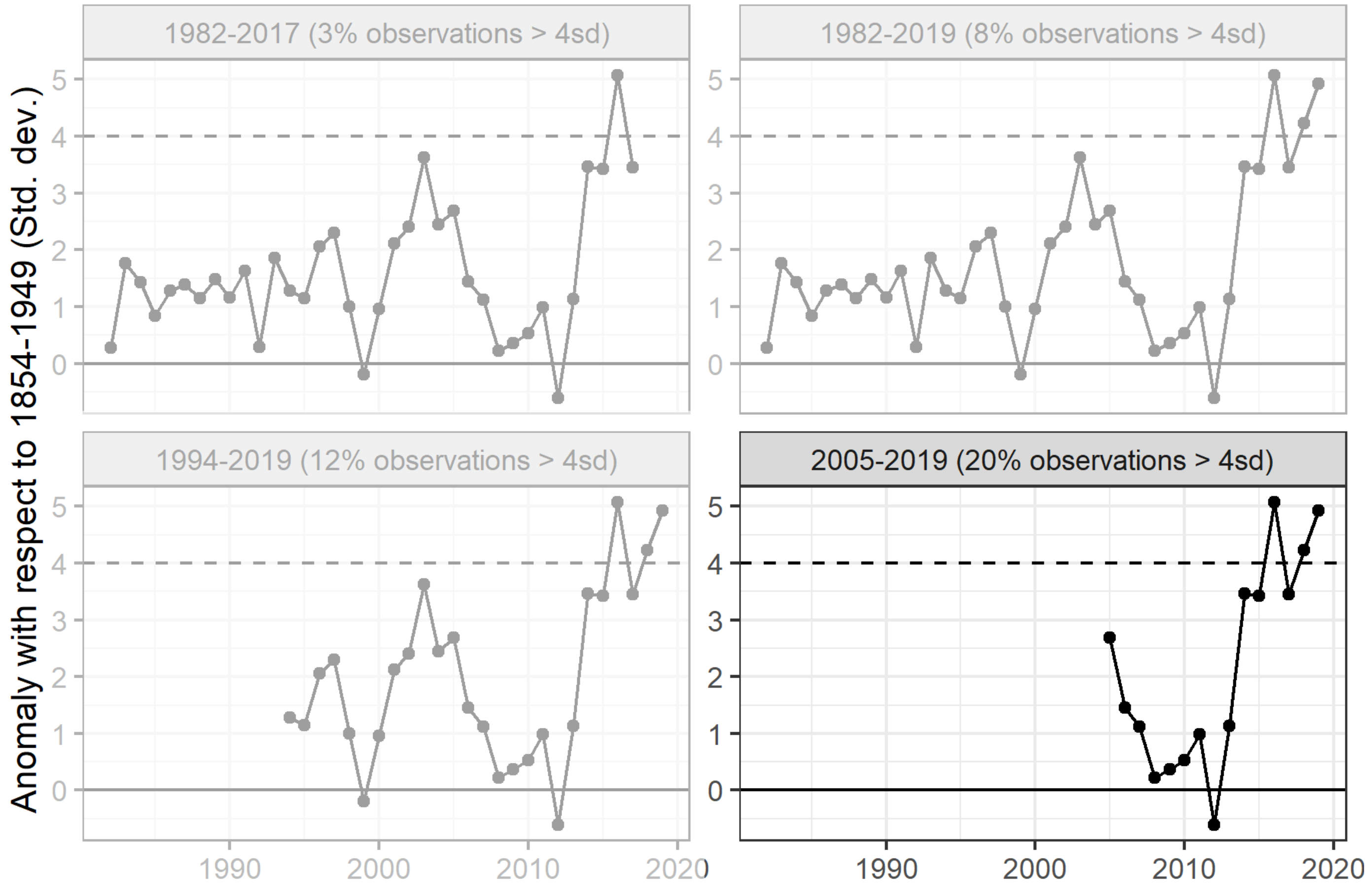

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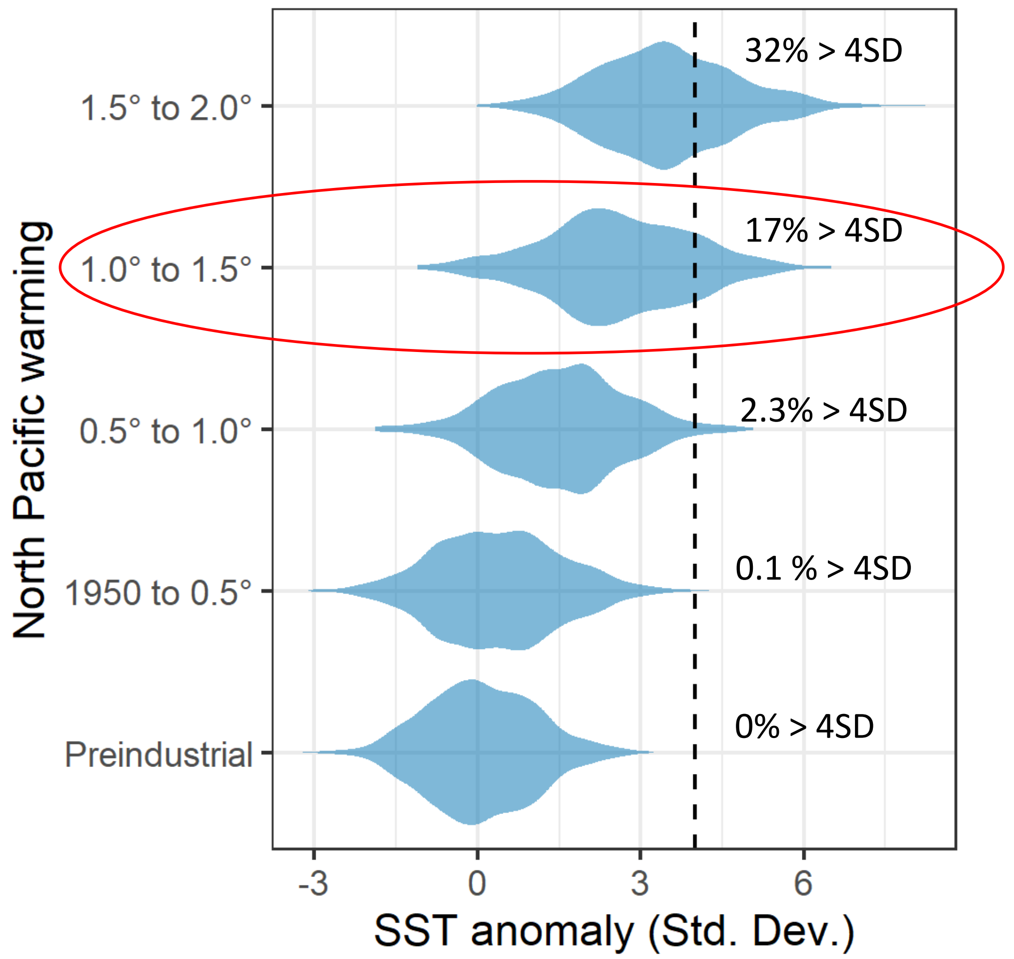

Questions