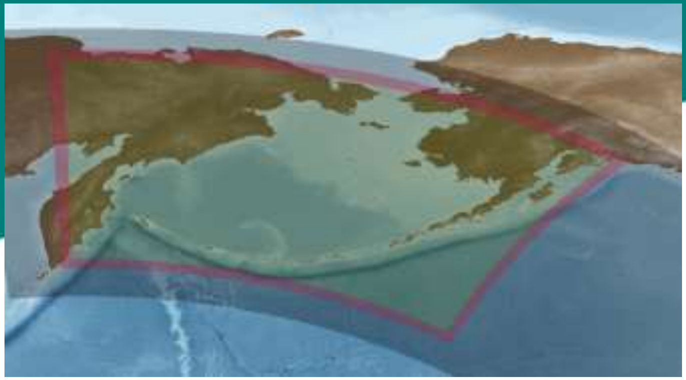
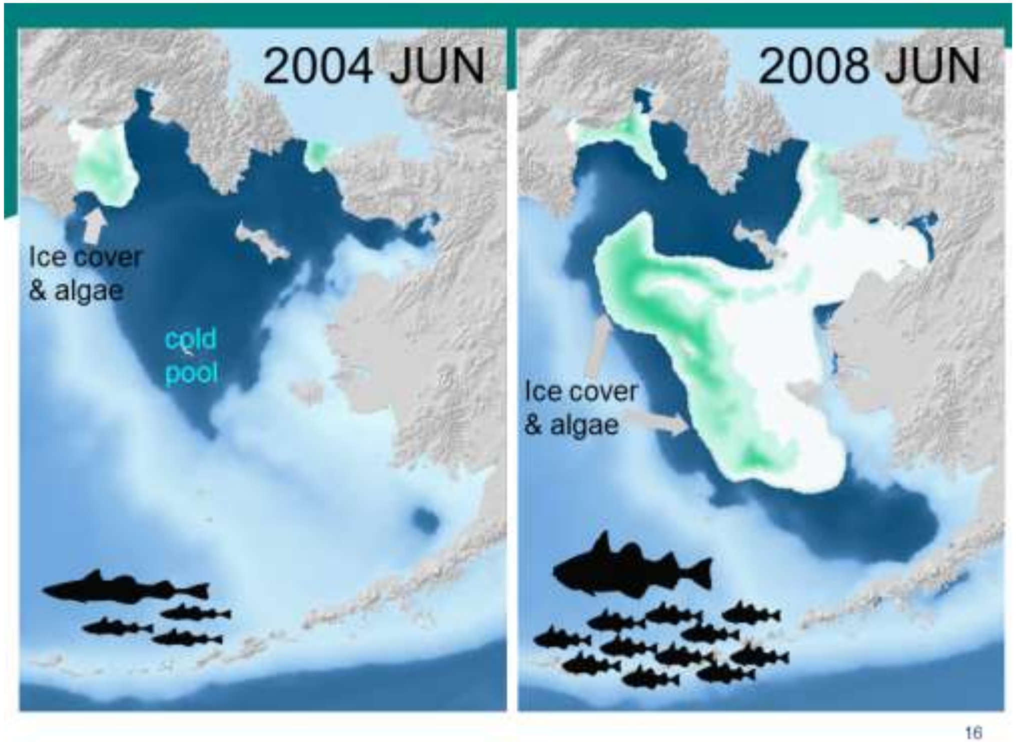
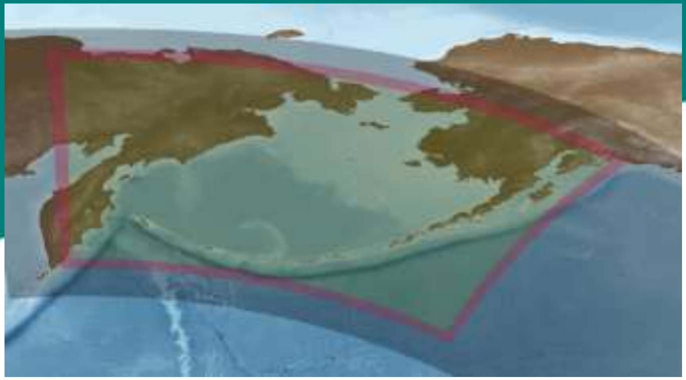


Bering ROMS/NPZ
(Regional Oceanographic model with nutrients and plankton dynamics)

- 3-D, 10km^2 resolution ocean model (10 or 30 vertical layers)
- Developed with NSF/North Pacific Research Board (BSIERP)
- AFSC/PMEL partnership funded by IEA, ACLIM, FATE, MAPP
- Significant advances in ice modeling, ice plankton



NOAA FISHERIES SERVICE



Bering ROMS/NPZ
(Regional Oceanographic model with nutrients and plankton dynamics)

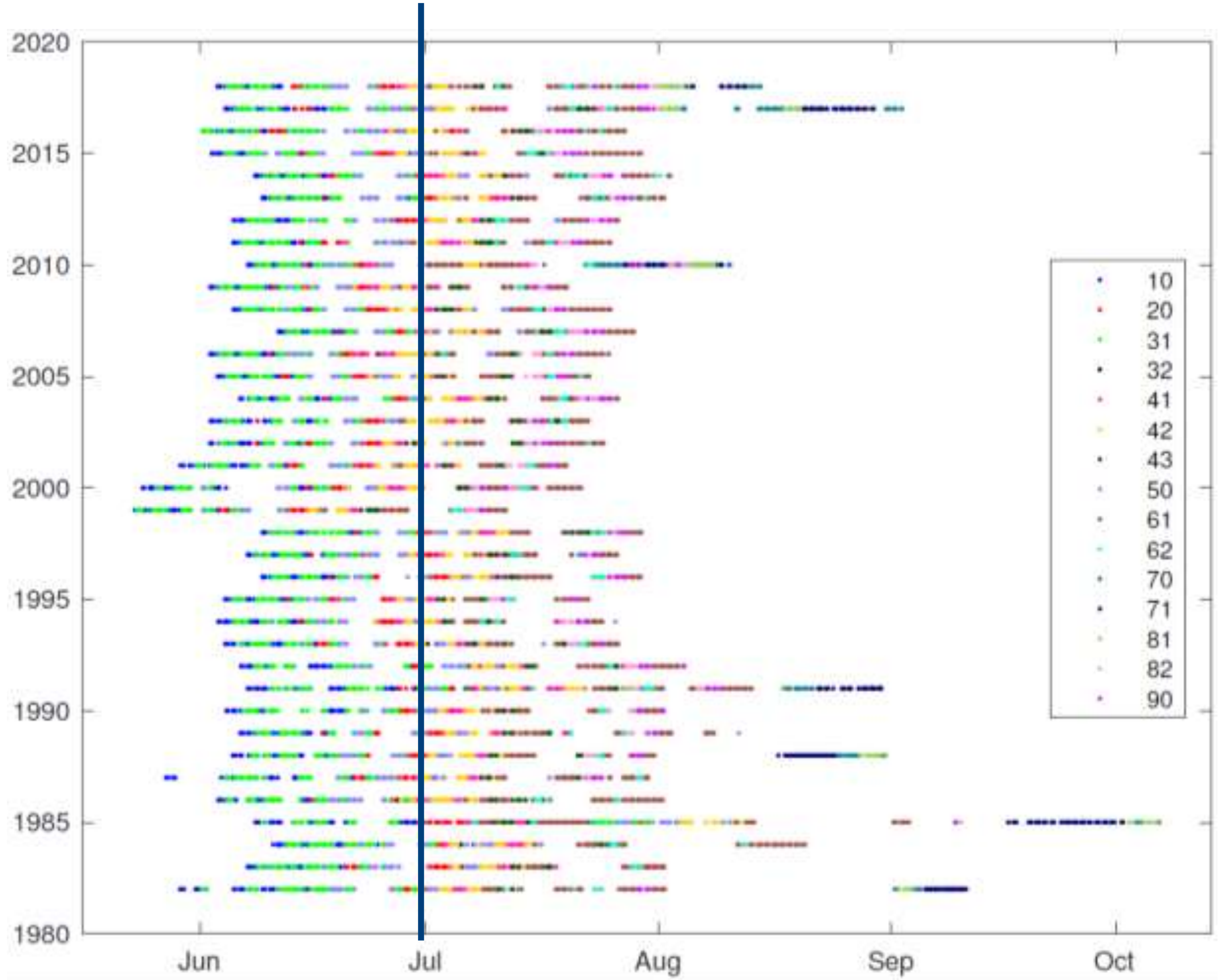
Products
- 48-year hindcast (1970-2018) forced by measured conditions (IEA)
- 9-month forecast (annual) forced by CFS forecasts (MAPP)
- Forecasts to 2100 forced by IPCC model outputs (FATE, ACLIM)

Uses
- Forcing for biological models
    - CEATTLE, others
- Rapid Climate Assessment
- EFH predictive maps
- VAST distribution maps

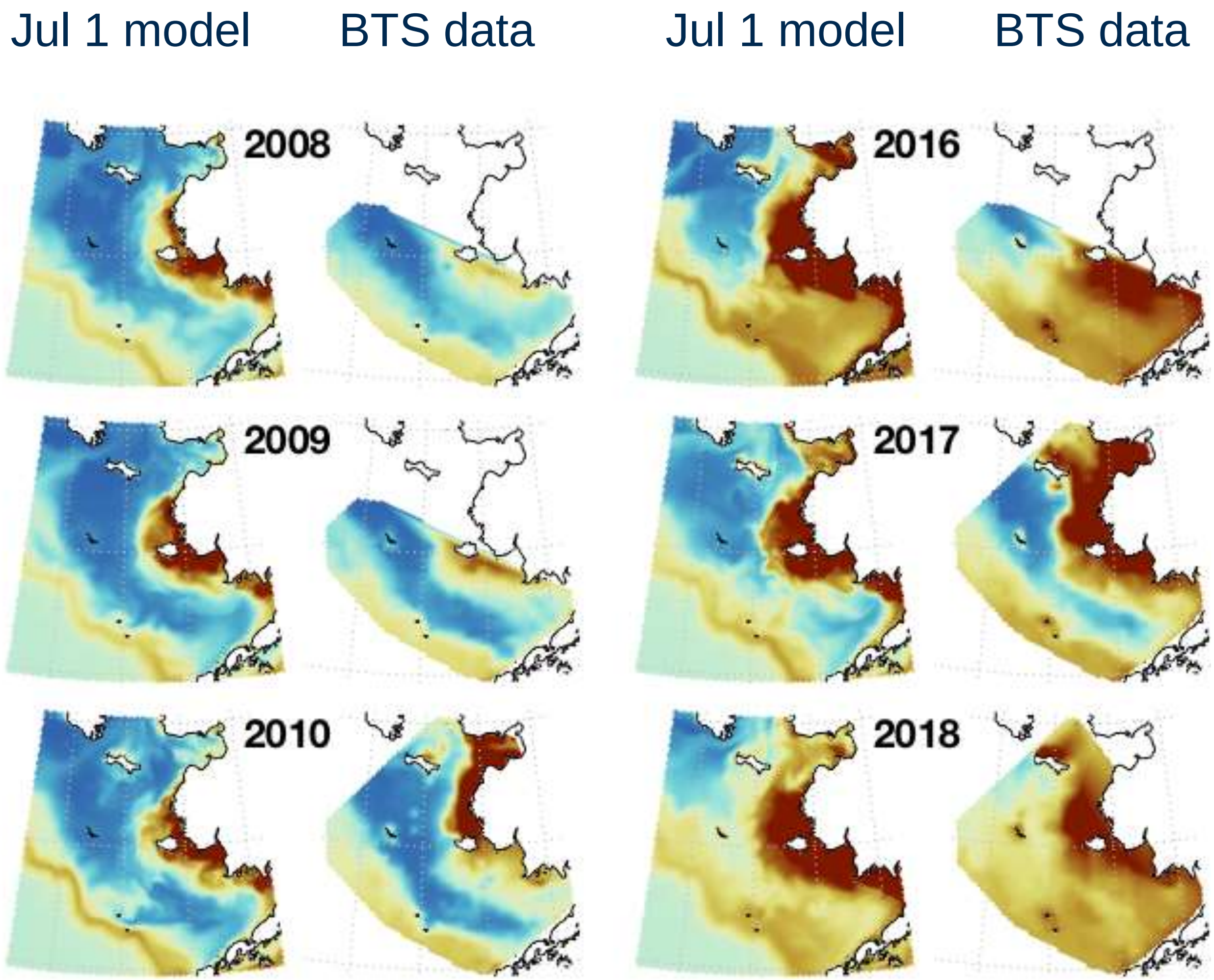
Focus today
- *Has current NBS bottom temperature happened before? (hindcast)*
- *Is it the "new normal"? (IPCC forecasts)*
- *Implications for CEATTLE*

NOAA FISHERIES SERVICE

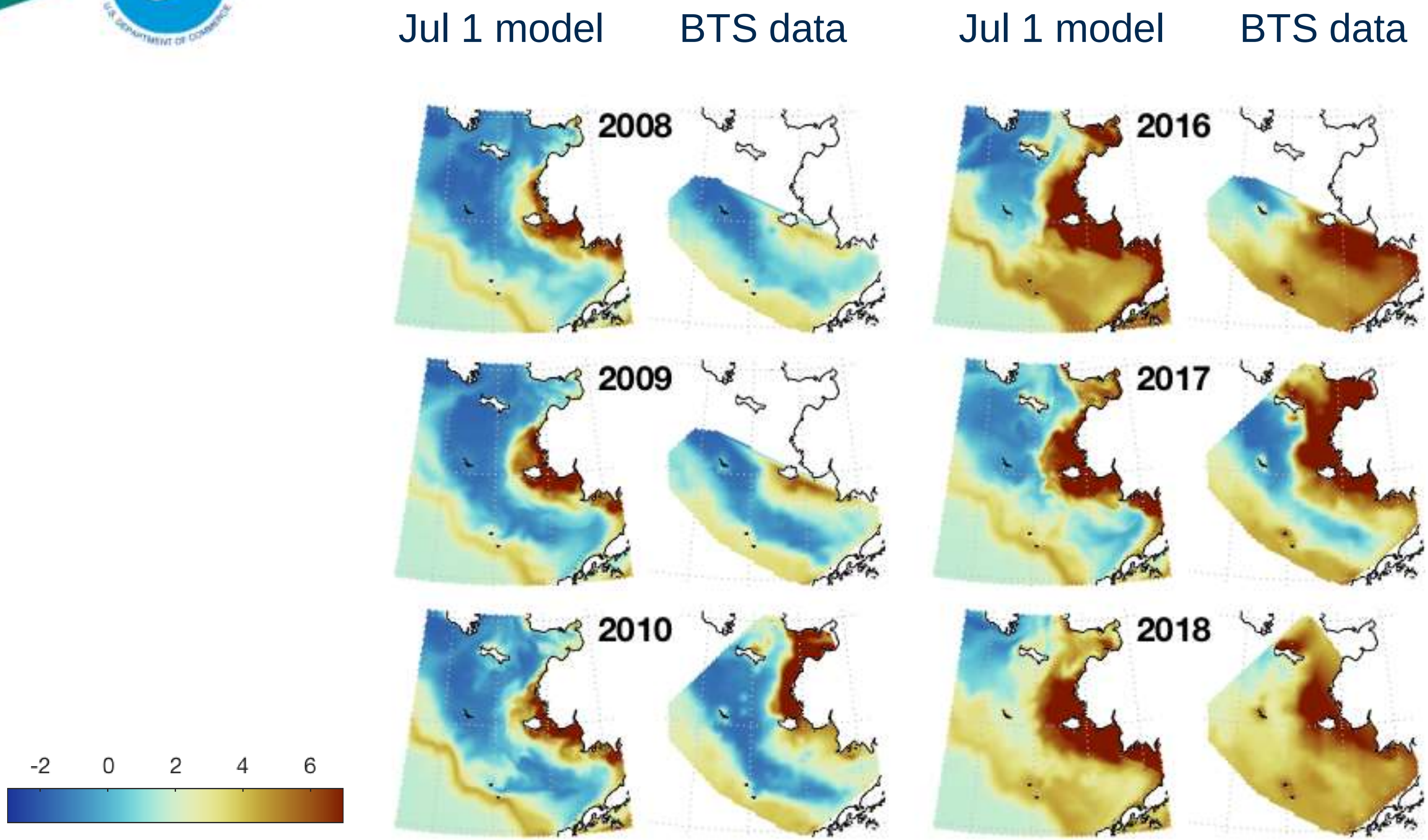
BTS survey dates by stratum



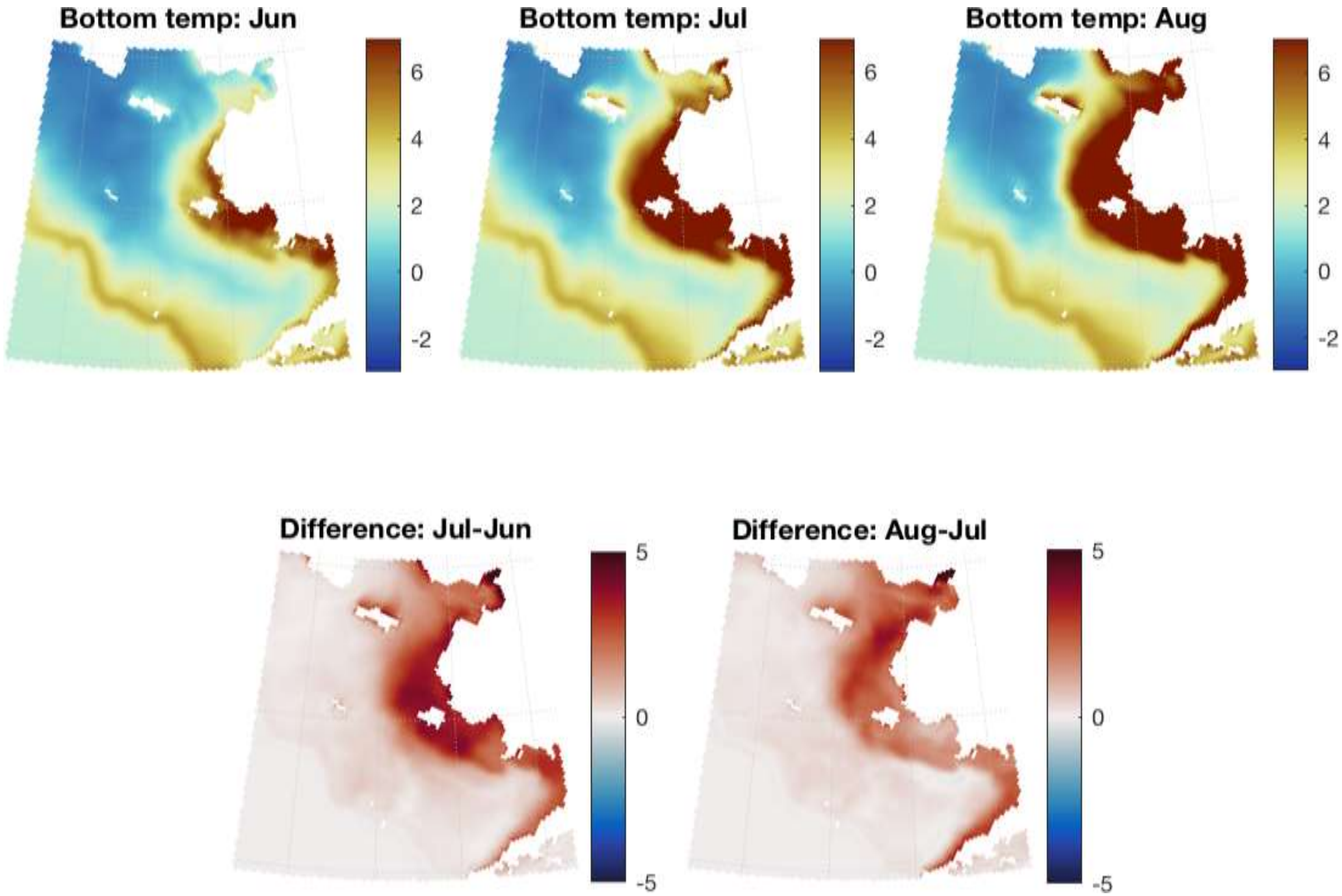
Bottom temperature comparison



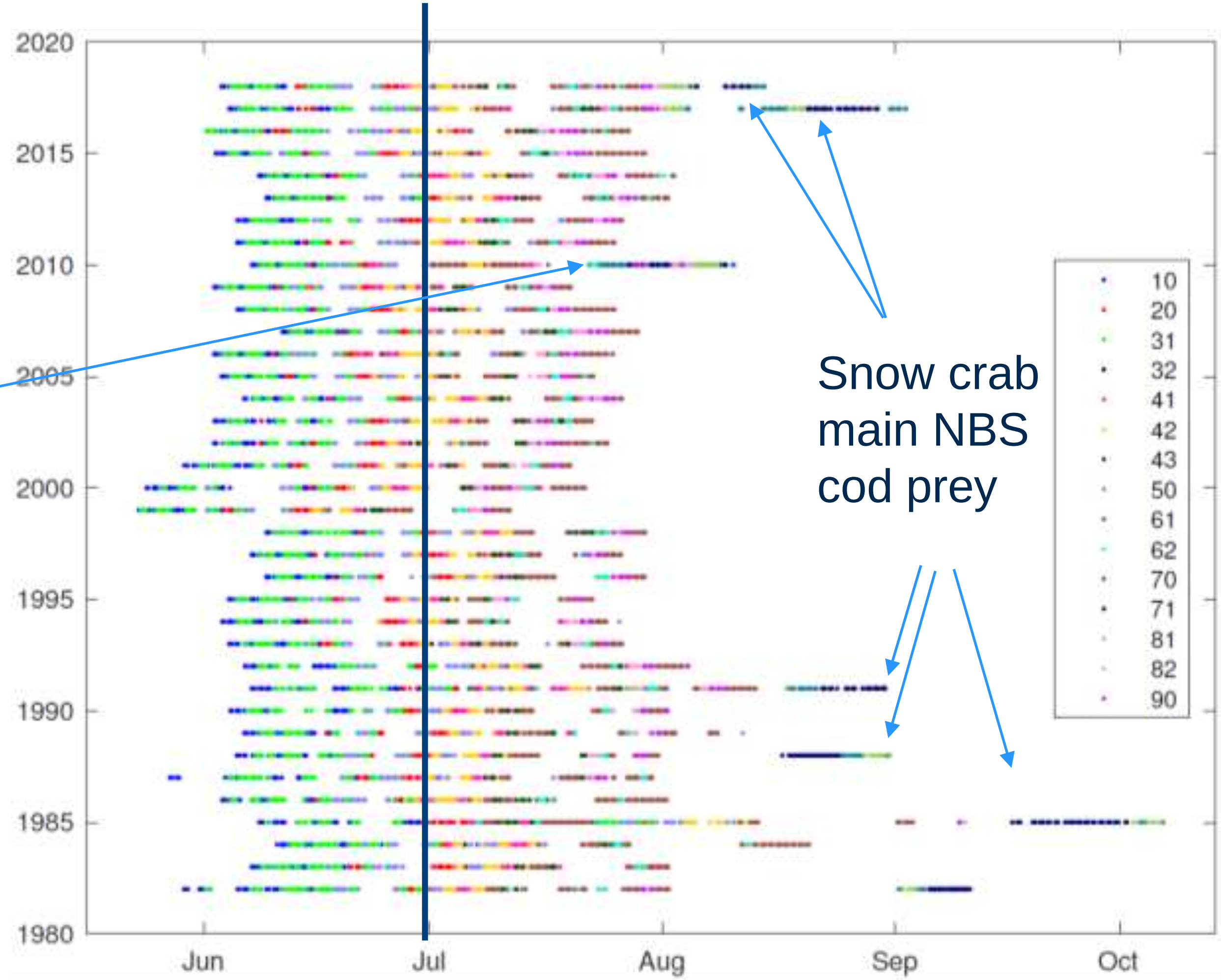
Bottom temperature comparison



Bottom temperature comparison



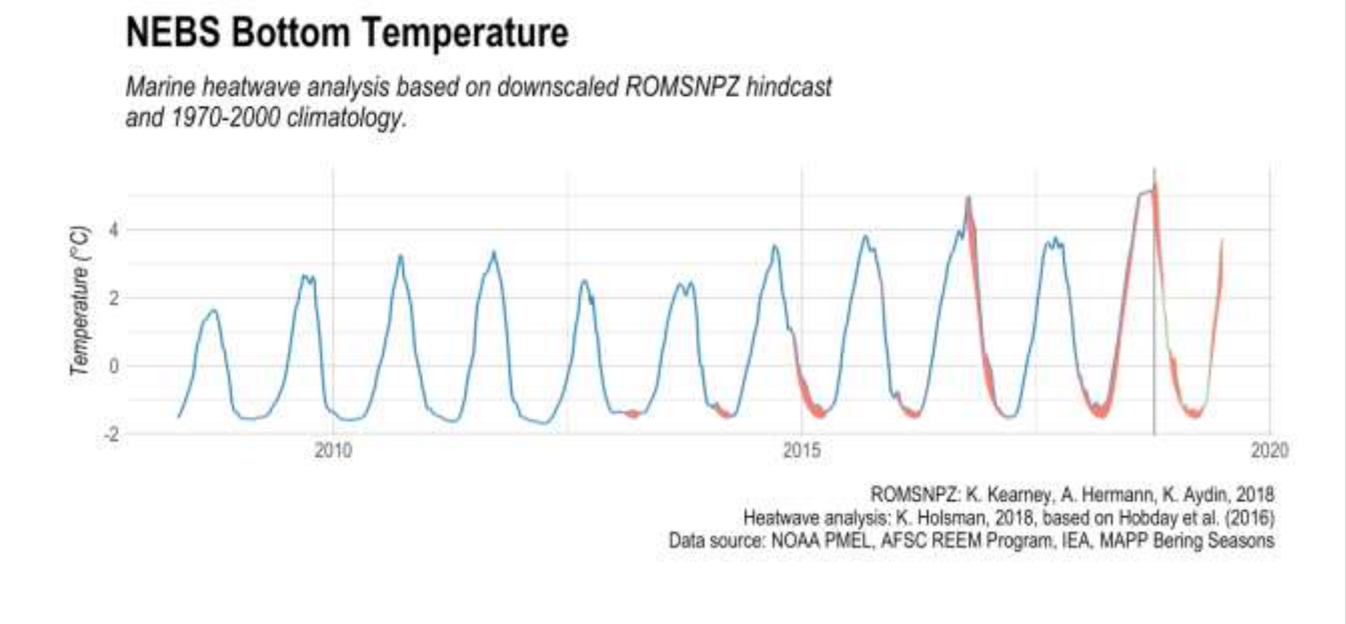
BTS survey dates by stratum



Juvenile flatfish, other benthos main NBS cod prey

Snow crab main NBS cod prey

MARINE HEATWAVE ANALYSIS



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KERIM AYDIN

AL HERMANN

STEVE BARBEAUX

2018

nature COMMUNICATIONS

ARTICLE

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Longer and more frequent marine heatwaves over the past century

Eric C.J. Oliver[1,2,3], Markus G. Donat[4,5], Michael T. Burrows[6], Pippa J. Moore[7], Dan A. Smale[8,9], Lisa V. Alexander[4,5], Jessica A. Benthuysen[10], Ming Feng[11], Alex Sen Gupta[4,5], Alistair J. Hobday[12], Neil J. Holbrook[2,13], Sarah E. Perkins-Kirkpatrick[4,5], Hillary A. Scannell[14,15], Sandra C. Straub[9] & Thomas Wernberg[9]

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A hierarchical approach to defining marine heatwaves

Alistair J. Hobday[a,*], Lisa V. Alexander[b,c], Sarah E. Perkins[b,c], Dan A. Smale[d,e], Sandra C. Straub[e], Eric C.J. Oliver[b,f], Jessica A. Benthuysen[g], Michael T. Burrows[h], Markus G. Donat[b,c], Ming Feng[i], Neil J. Holbrook[b,f], Pippa J. Moore[j], Hillary A. Scannell[k,l], Alex Sen Gupta[b,c], Thomas Wernberg[e]

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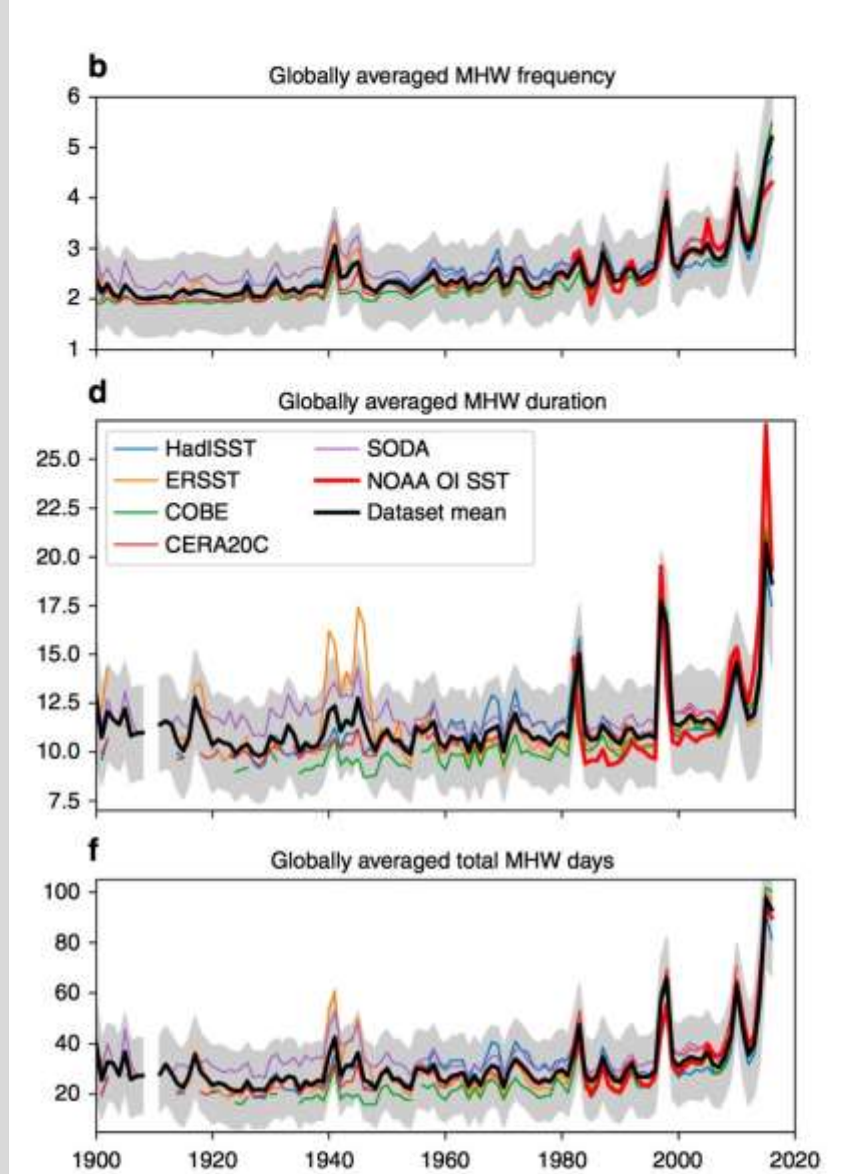
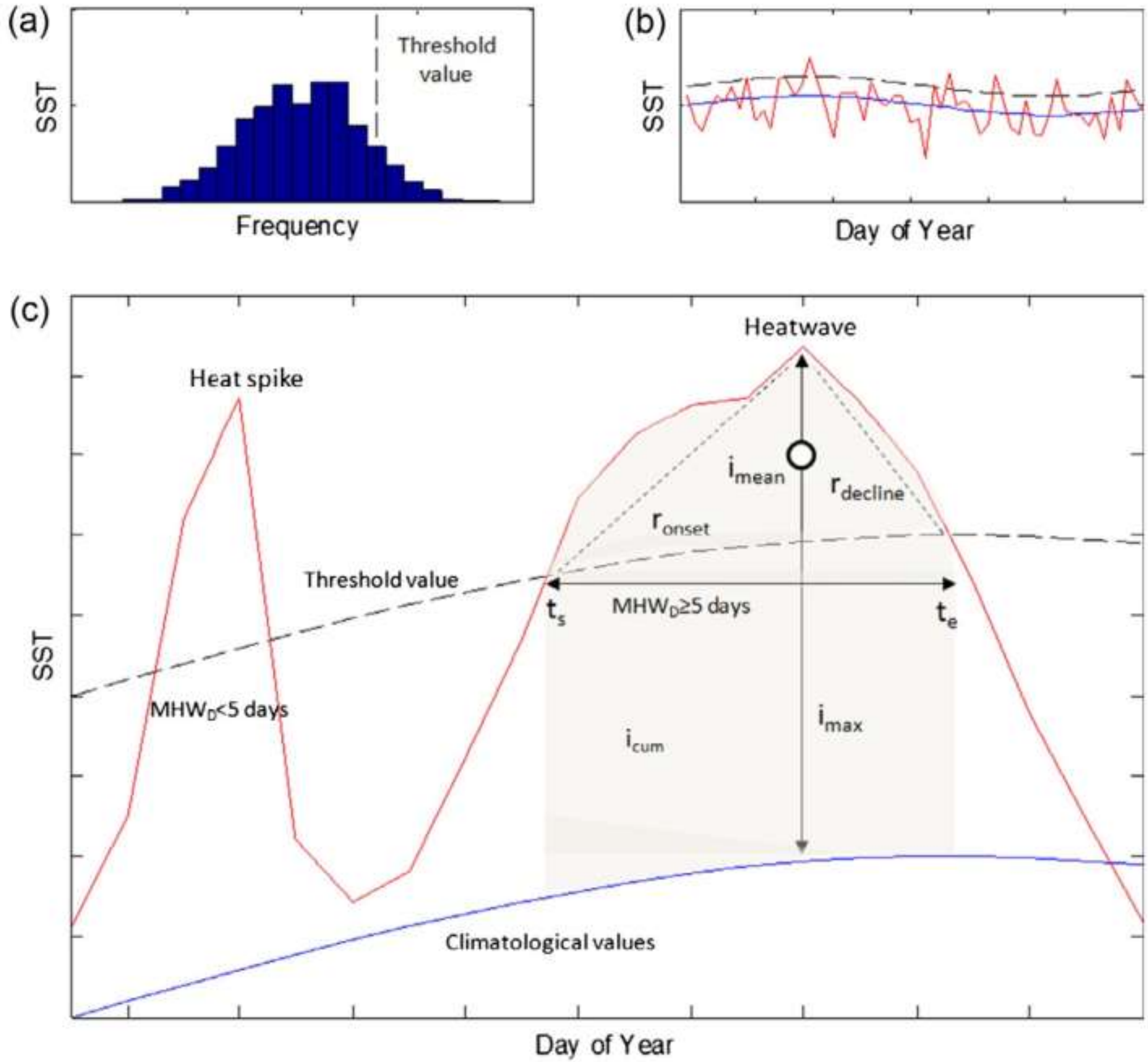
[h] Department of Ecology, Scottish Association for Marine Science, Scottish Marine Institute, Oban, Argyll PA37 1QA, Scotland, UK
[i] CSIRO Oceans and Atmosphere, Perth, Western Australia, Australia
[j] Institute of Biological, Environmental and Rural Sciences, Aberystwyth University, Aberystwyth SY23 3DA, UK
[k] School of Oceanography, University of Washington, Seattle, WA, USA
[l] NOAA/Pacific Marine Environmental Laboratory, Seattle, WA, USA

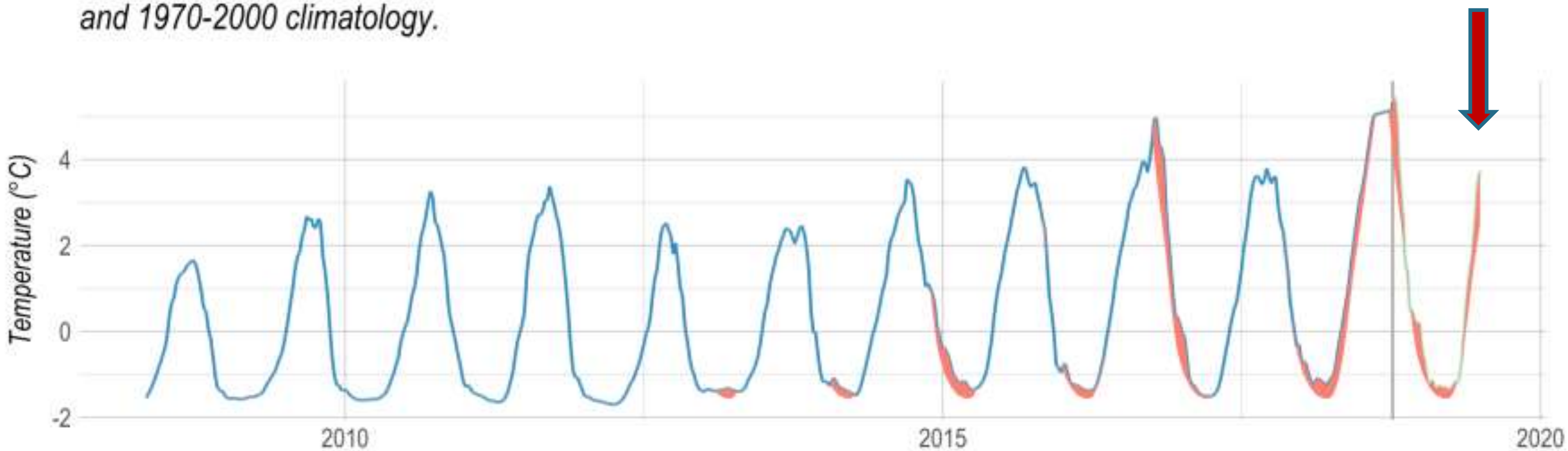



(a)
Threshold value
SST
Frequency
(b)
SST
Day of Year
(c)
Heatwave
Heat spike
i_{mean}
$r_{decline}$
r_{onset}
Threshold value
t_s
$MHW_D \geq 5$ days
t_e
SST
$MHW_D < 5$ days
i_{max}
i_{cum}
Climatological values
Day of Year

NEBS Bottom Temperature

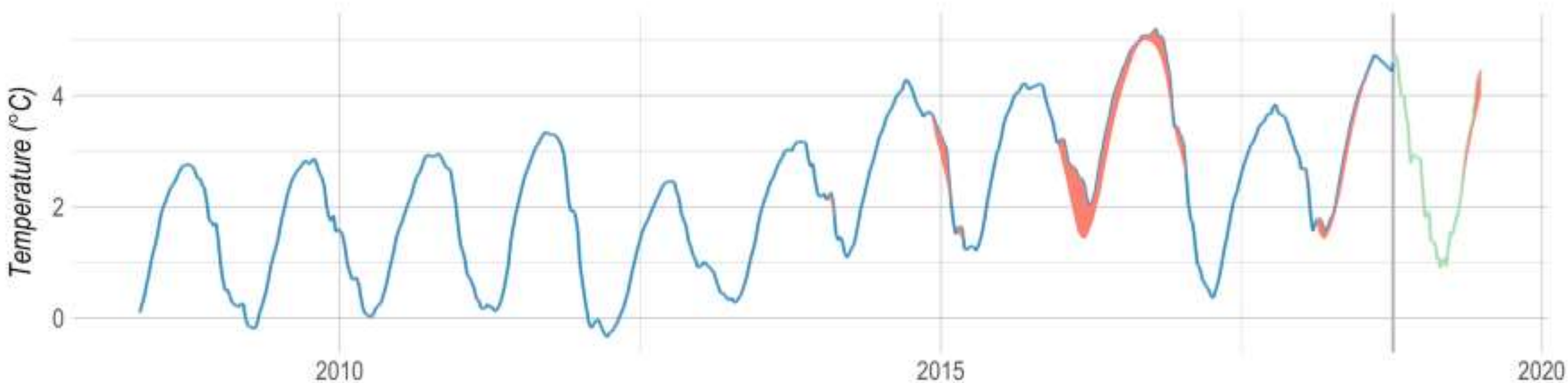
Marine heatwave analysis based on downscaled ROMSNPZ hindcast and 1970-2000 climatology.

Continued HW Expected in 2019



EBS Bottom Temperature

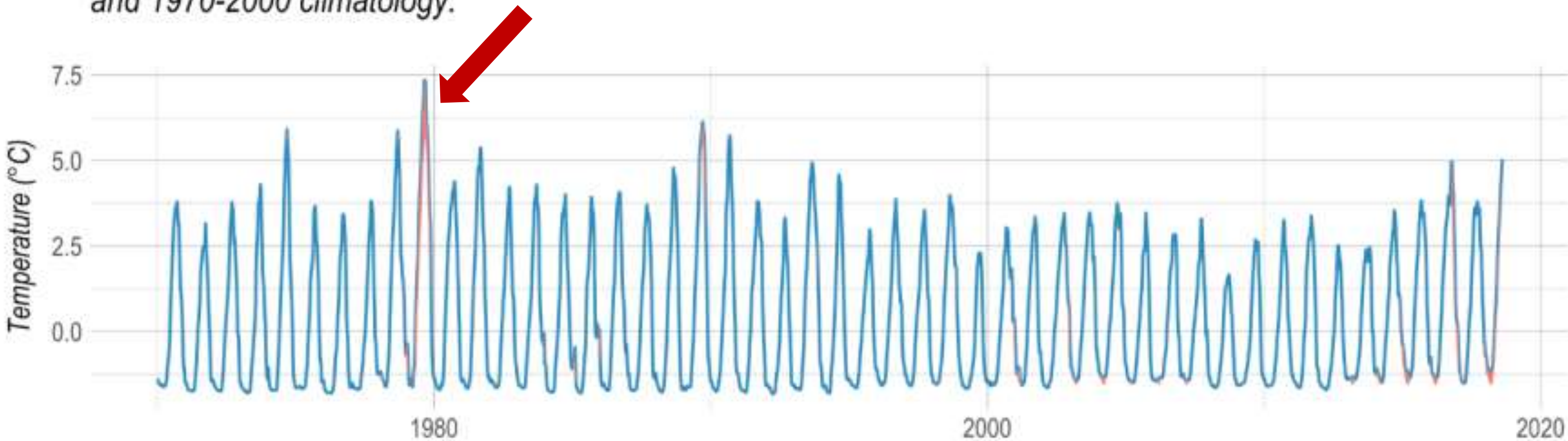
Marine heatwave analysis based on downscaled ROMSNPZ hindcast and 1970-2000 climatology.



ROMSNPZ: K. Kearney, A. Hermann, K. Aydin, 2018
Heatwave analysis: K. Holsman, 2018, based on Hobday et al. (2016)
Data source: NOAA PMEL, AFSC REEM Program, IEA, MAPP Bering Seasons

NEBS Bottom Temperature

Marine heatwave analysis based on downscaled ROMSNPZ hindcast and 1970-2000 climatology.



EBS Bottom Temperature

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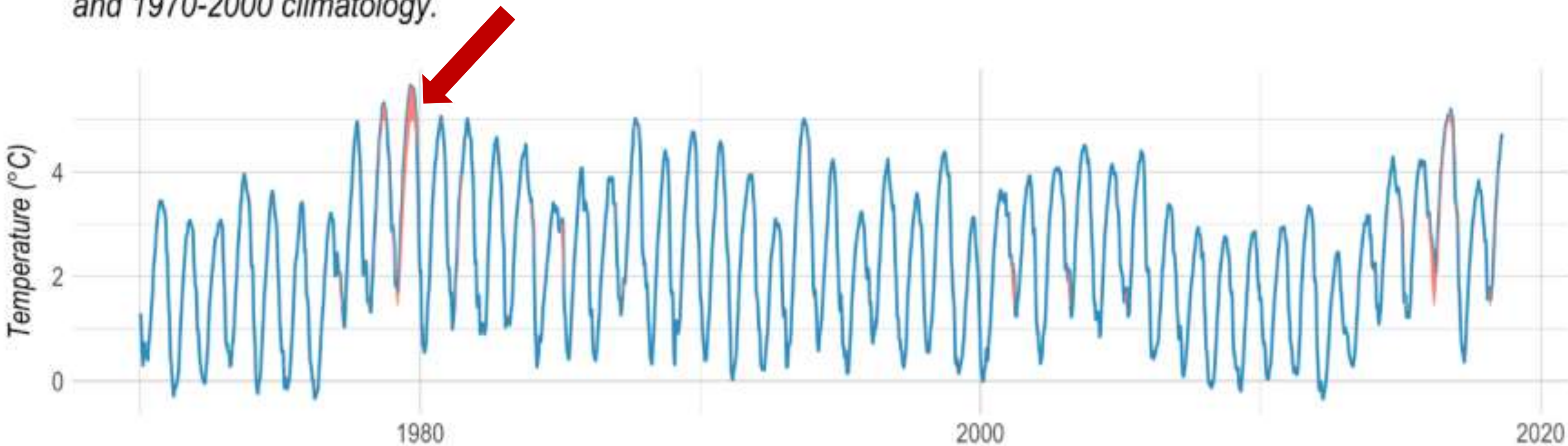

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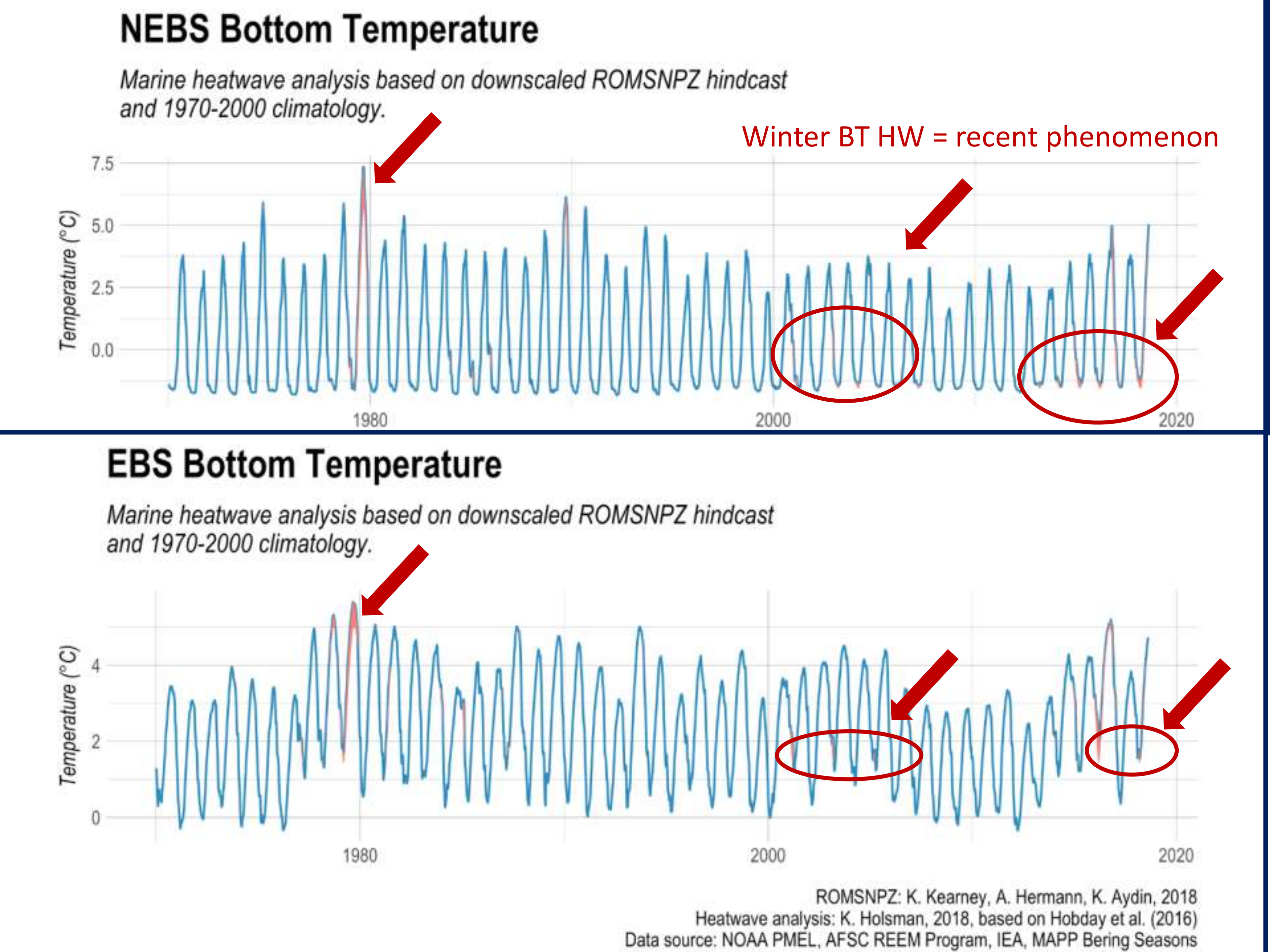
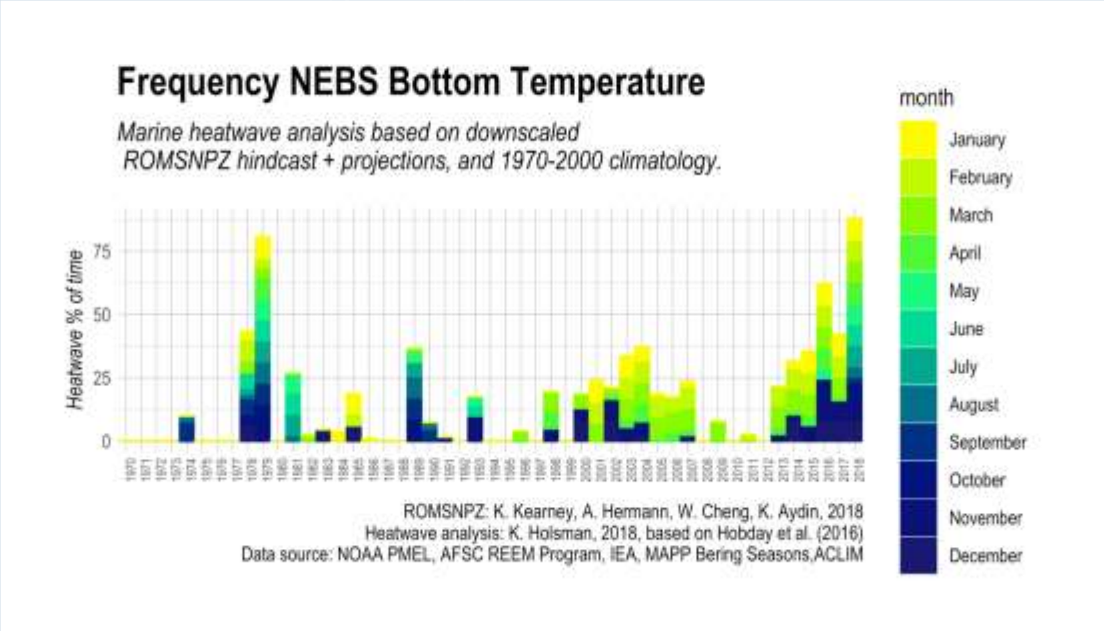
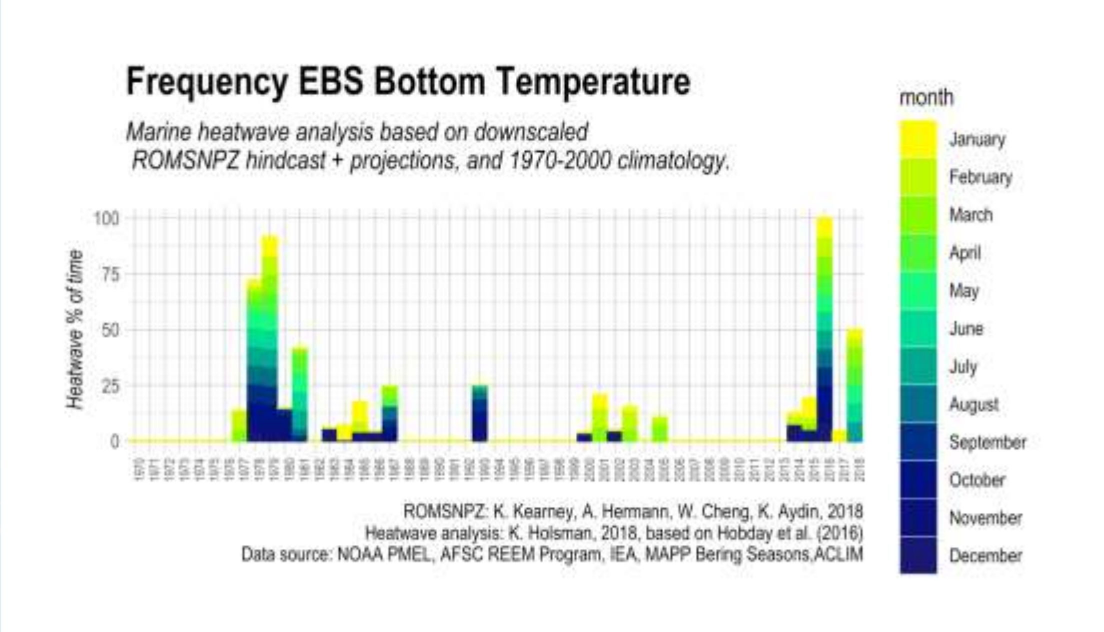

NEBS Bottom Temperature
Marine heatwave analysis based on downscaled ROMSNPZ hindcast and 1970-2000 climatology.
Winter BT HW = recent phenomenon
7.5
5.0
2.5
0.0
Temperature (°C)
1980
2000
2020
EBS Bottom Temperature
Marine heatwave analysis based on downscaled ROMSNPZ hindcast and 1970-2000 climatology.
4
2
0
Temperature (°C)
1980
2000
2020
ROMSNPZ: K. Kearney, A. Hermann, K. Aydin, 2018
Heatwave analysis: K. Holsman, 2018, based on Hobday et al. (2016)
Data source: NOAA PMEL, AFSC REEM Program, IEA, MAPP Bering Seasons





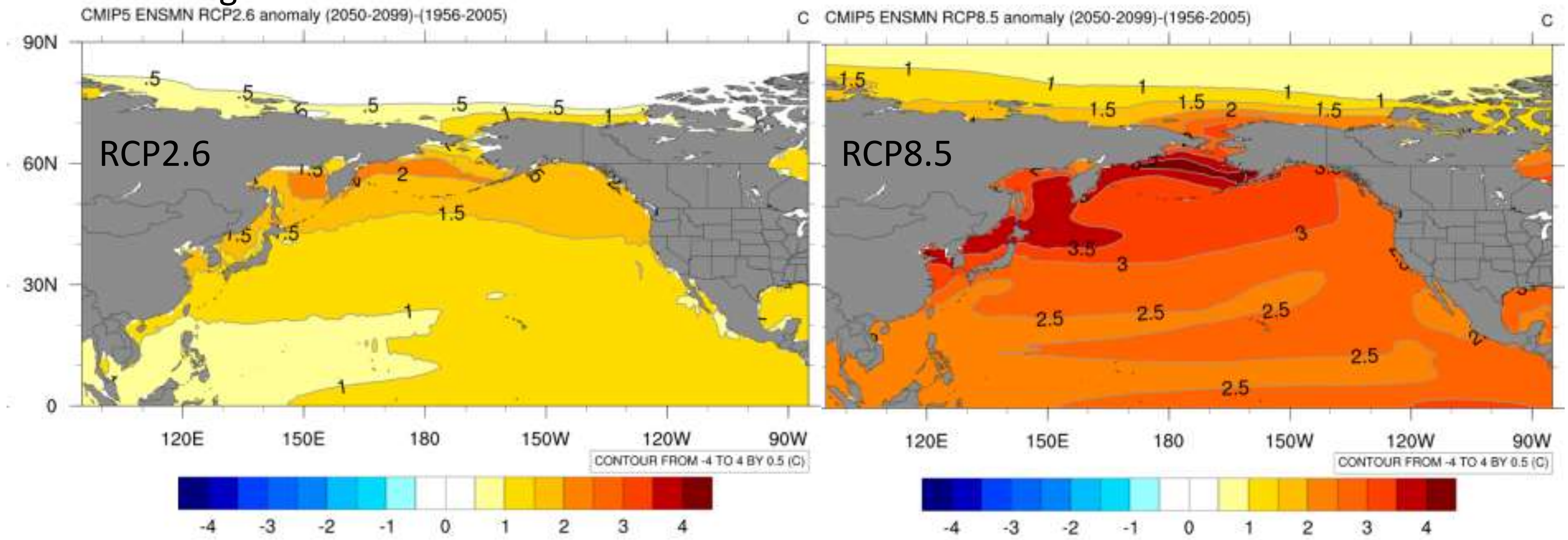
Overwinter survival during winter heat waves?

- Warm prevents direct physiological mortality, BUT
- Warm **with** prey promotes growth
- Warm **without** prey promotes starvation

CMIP5 ENSMN Annual SST anomaly (°C) (2050 to 2099) - (1956 to 2005)

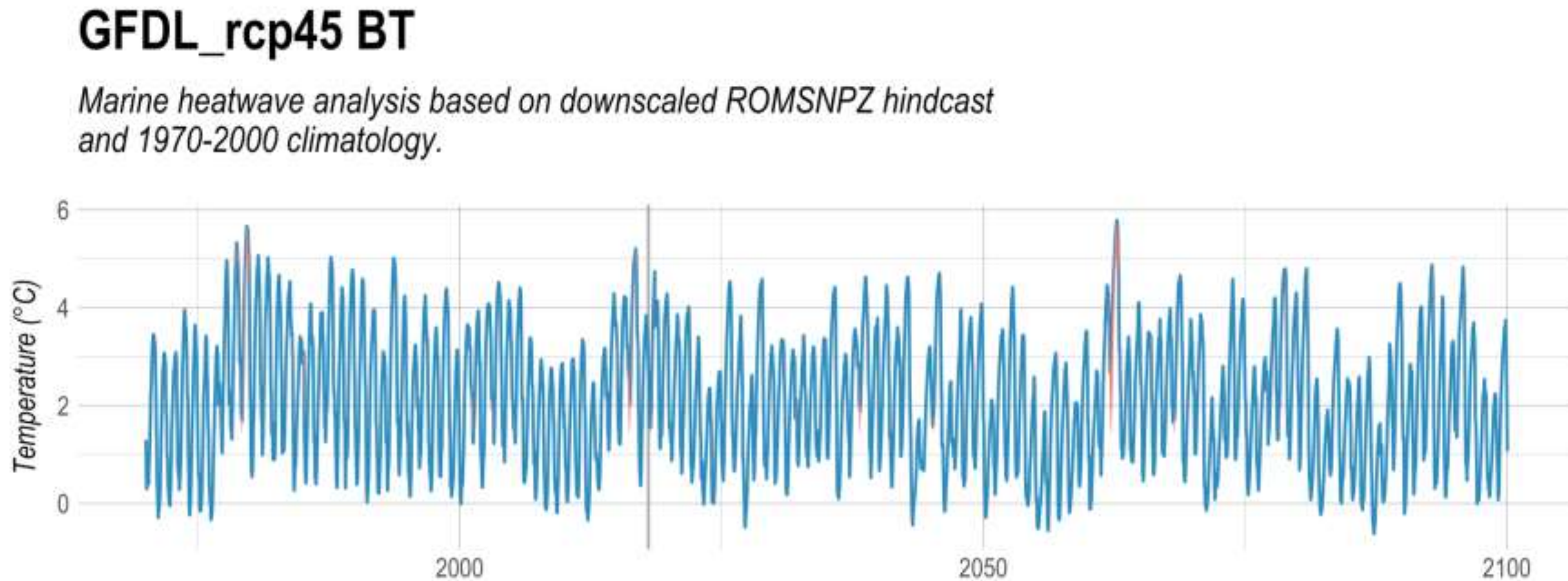
CO2 mitigation scenario

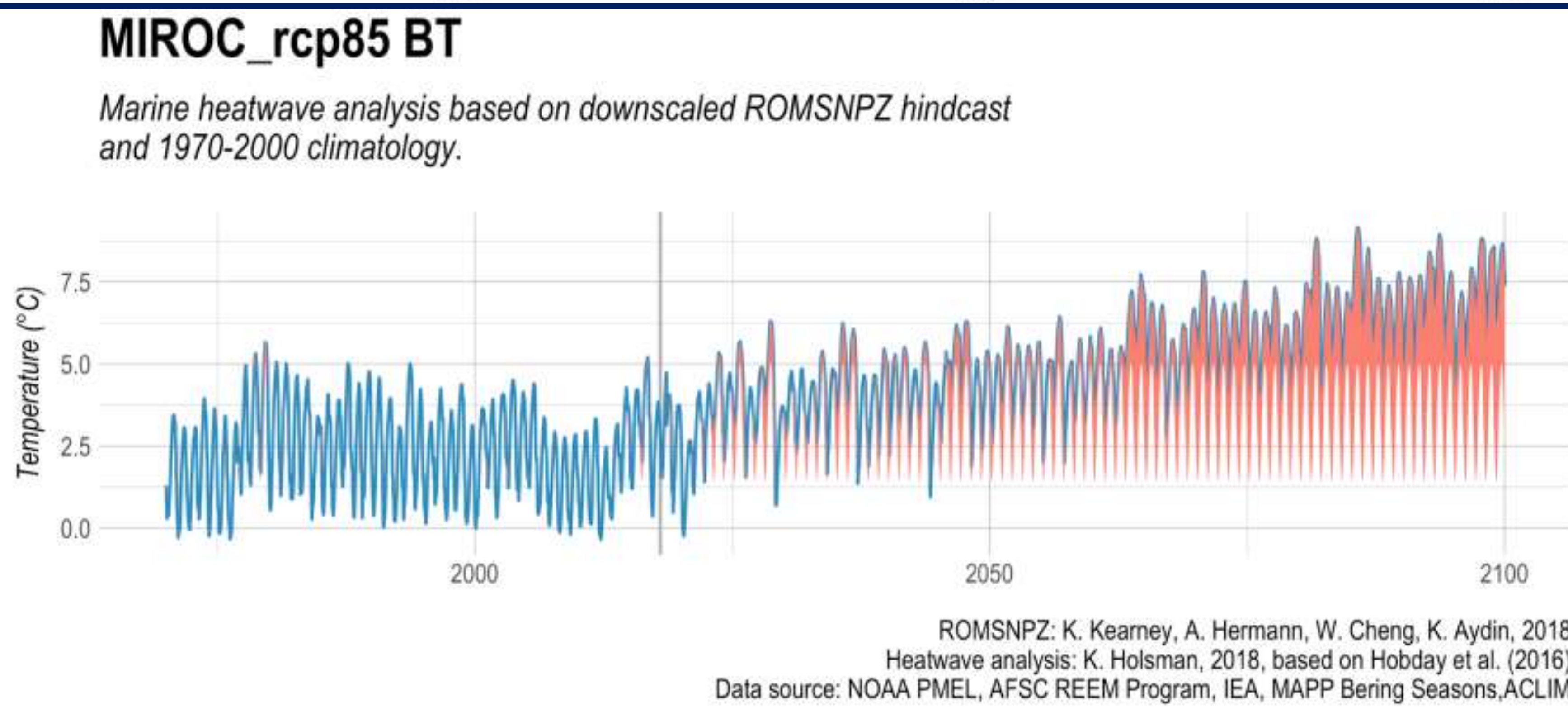
High baseline scenario ("Business as usual")



Projection data from CMIP5 (Taylor et al., 2012) avail. at: www.esrl.noaa.gov/psd/ipcc/ocn

Modified from Fig. 6.2 Holsman et al. 2018 [in] Barange et al. (Eds.) 2018. Impacts of climate change on fisheries and aquaculture. TP 627.


GFDL_rcp45 BT
Marine heatwave analysis based on downscaled ROMSNPZ hindcast
and 1970-2000 climatology.
Temperature (°C)
6
4
2
0
2000
2050
2100

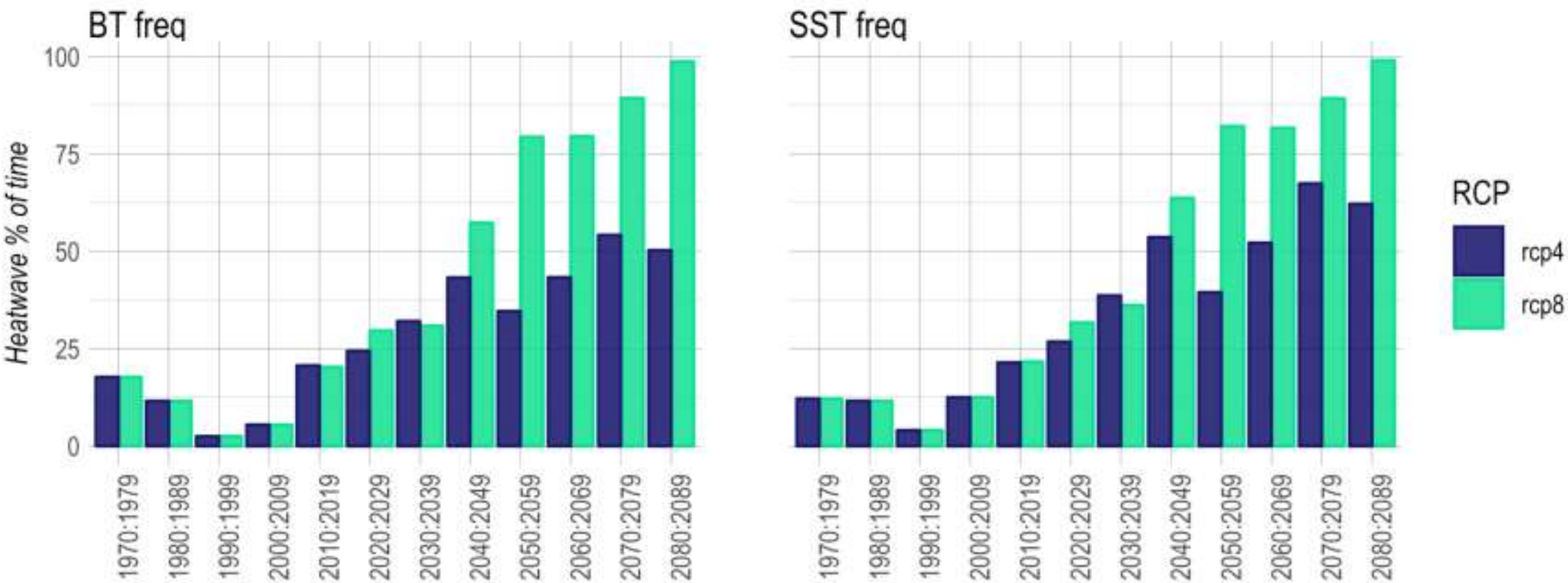

MIROC_rcp85 BT
Marine heatwave analysis based on downscaled ROMSNPZ hindcast
and 1970-2000 climatology.
Temperature (°C)
7.5
5.0
2.5
0.0
2000
2050
2100
ROMSNPZ: K. Kearney, A. Hermann, W. Cheng, K. Aydin, 2018
Heatwave analysis: K. Holsman, 2018, based on Hobday et al. (2016)
Data source: NOAA PMEL, AFSC REEM Program, IEA, MAPP Bering Seasons,ACLIM

Marine heatwaves will likely increase in frequency and duration

Heatwaves
Now ~ 21% of the time
2050 ~ 30-77% of the time
2100 ~ 60-90% of the time

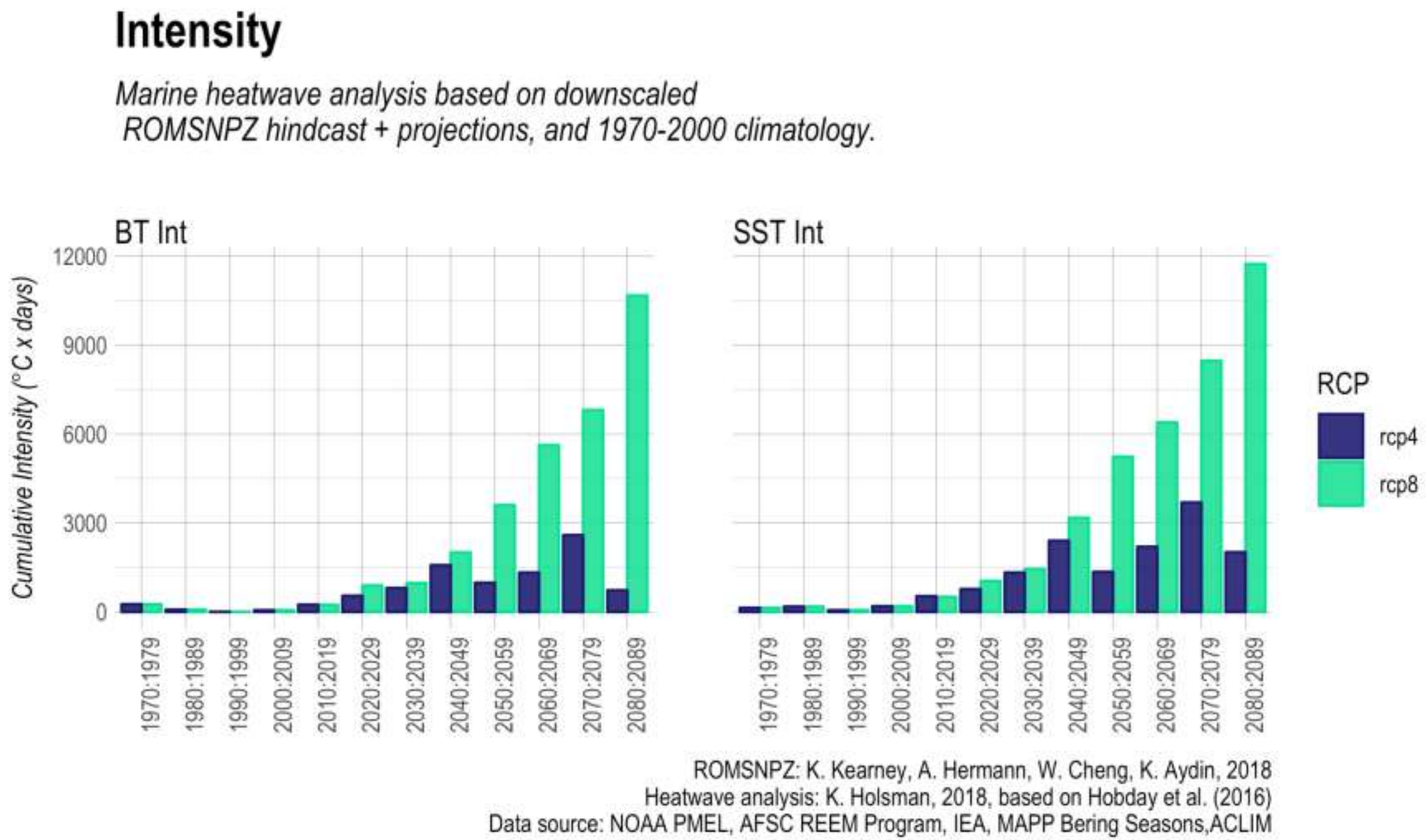
Duration

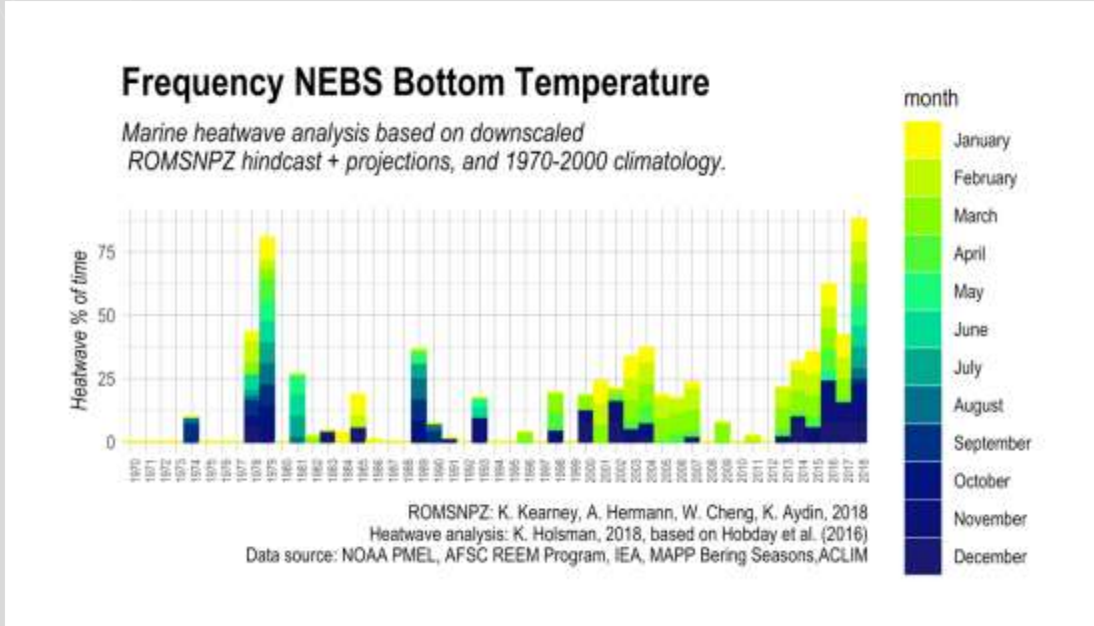
Marine heatwave analysis based on downscaled ROMSNPZ hindcast + projections, and 1970-2000 climatology.

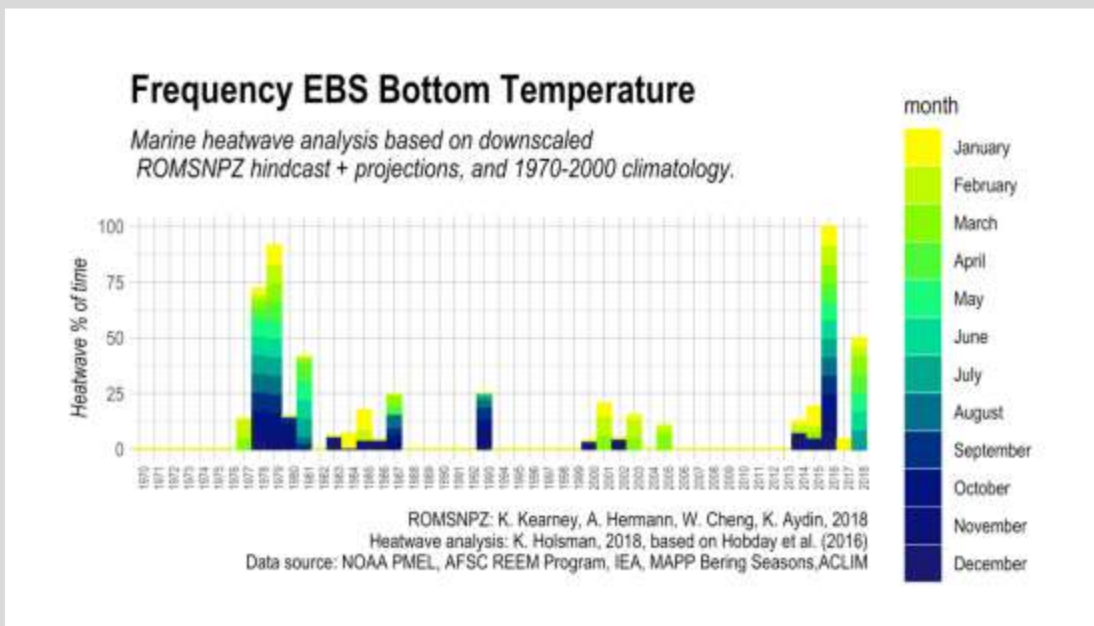


ROMSNPZ: K. Kearney, A. Hermann, W. Cheng, K. Aydin, 2018
Heatwave analysis: K. Holsman, 2018, based on Hobday et al. (2016)
Data source: NOAA PMEL, AFSC REEM Program, IEA, MAPP Bering Seasons,ACLIM

Marine heatwaves will likely increase in intensity

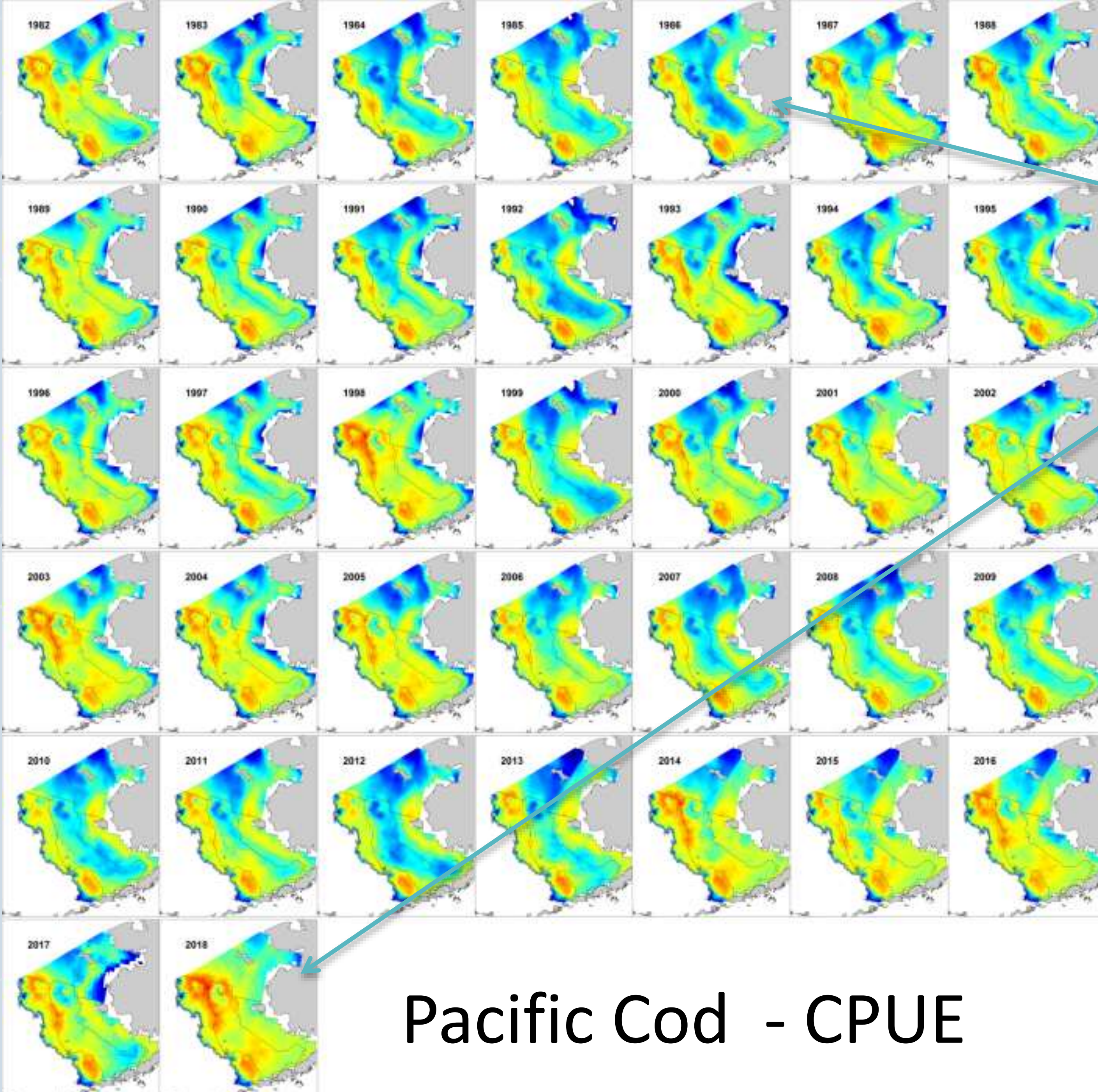



Frequency NEBS Bottom Temperature
Marine heatwave analysis based on downscaled
ROMSNPZ hindcast + projections, and 1970-2000 climatology.
Heatwave % of time
0
25
50
75
month
January
February
March
April
May
June
July
August
September
October
November
December
ROMSNPZ: K. Kearney, A. Hermann, W. Cheng, K. Aydin, 2018
Heatwave analysis: K. Holsman, 2018, based on Hobday et al. (2016)
Data source: NOAA PMEL, AFSC REEM Program, IEA, MAPP Bering Seasons,ACLIM


Frequency EBS Bottom Temperature
Marine heatwave analysis based on downscaled
ROMSNPZ hindcast + projections, and 1970-2000 climatology.
Heatwave % of time
0
25
50
75
100
month
January
February
March
April
May
June
July
August
September
October
November
December
ROMSNPZ: K. Kearney, A. Hermann, W. Cheng, K. Aydin, 2018
Heatwave analysis: K. Holsman, 2018, based on Hobday et al. (2016)
Data source: NOAA PMEL, AFSC REEM Program, IEA, MAPP Bering Seasons,ACLIM

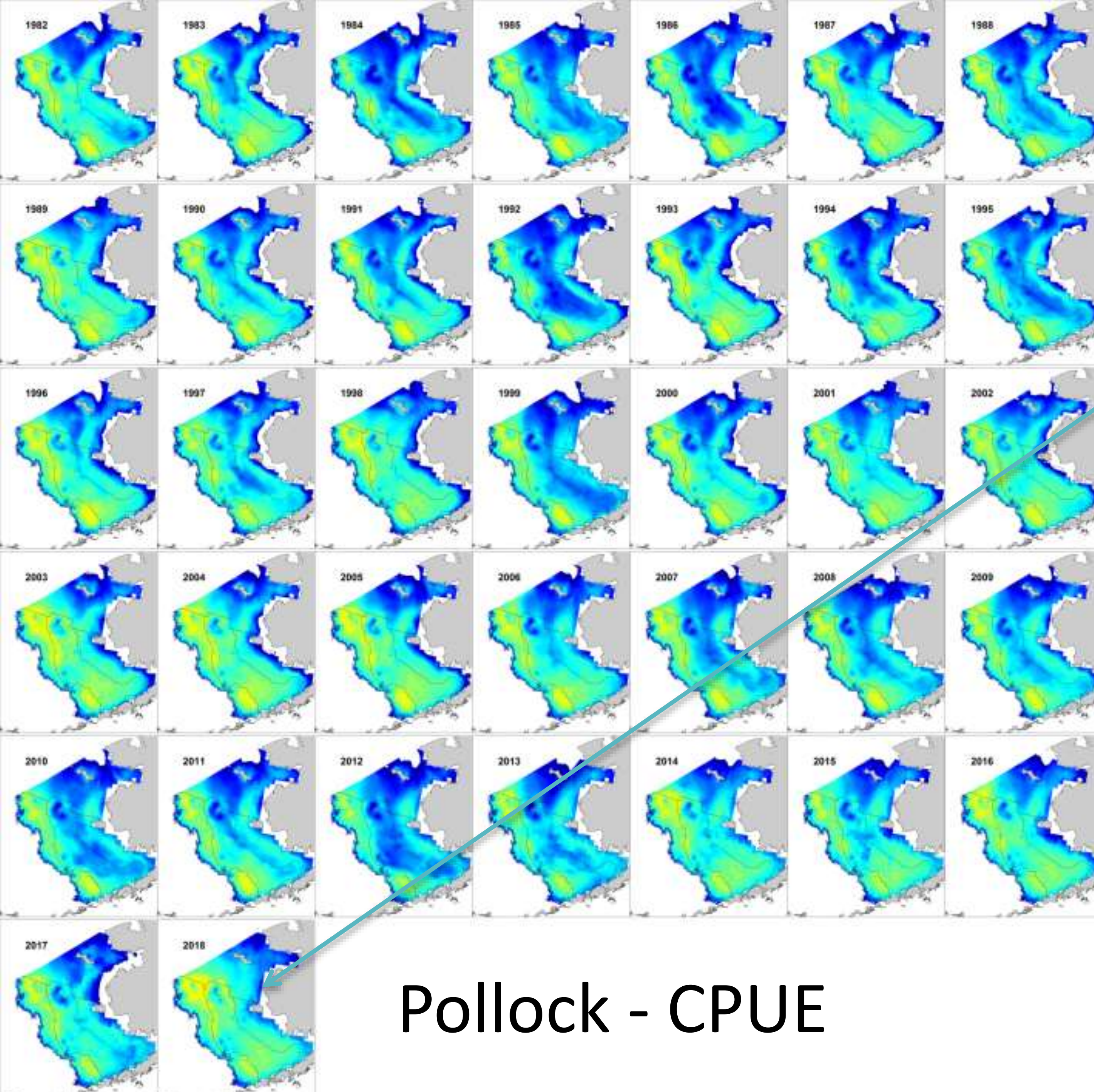
EFH PREDICTED DISTRIBUTIONS (ROOPER)

- Same approach as for 2017 EFH
  - Generalized additive models
  - ROMS hindcasted temperatures
  - Other variables: depth, slope, current speed, tidal current speed, sediment size
- Maps present log-transformed predictions – log(CPUE)
  - Not scaled the same
- Graphs and calculations are on back-transformed data



- Distribution influenced by cold pool
- Bottom temperature most important variable in model
- Consistently ~ 74% of the population is inside the survey area
- No trend over time

Pacific Cod - CPUE



- Distribution influenced by cold pool
- Bottom temperature most important variable in model
- Declining proportion of the population inside survey area
- ~ 77% in 2018

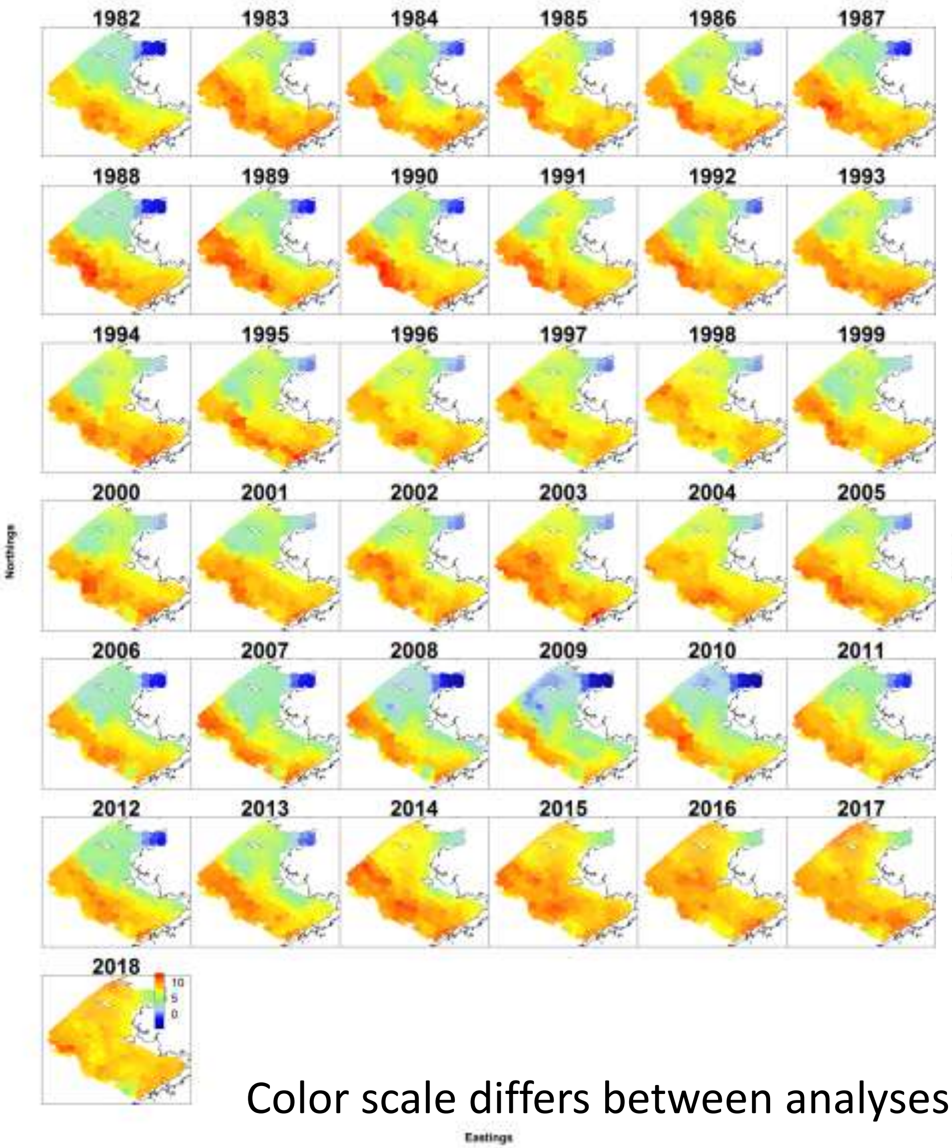
Pollock - CPUE

VAST MODEL (THORSON)

- Multivariate spatio-temporal model that estimates variation in population density across space and time for multiple sizes, ages, and/or species based on survey and fishery data
- Used in ecosystem and stock assessments primarily in the North Pacific and South Africa

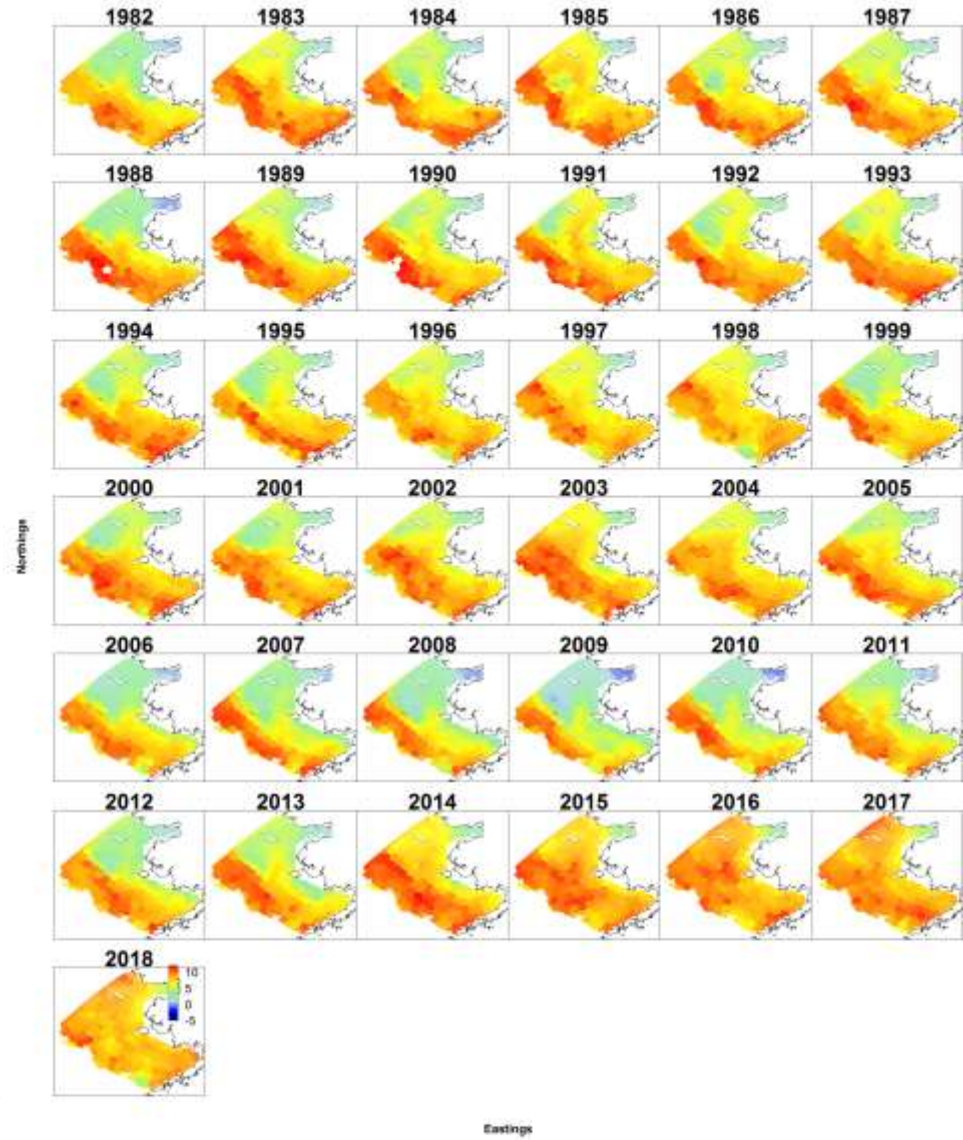
Pollock distribution - Comparing with vs. without temperature

Without temperature



Color scale differs between analyses

With temperature



Pollock distribution - Comparing with vs. without temperature

Conclusions

1. Including temperature has relatively little impact on relative biomass in NBS vs. total