Regional multi-year predictability of Antarctic sea ice
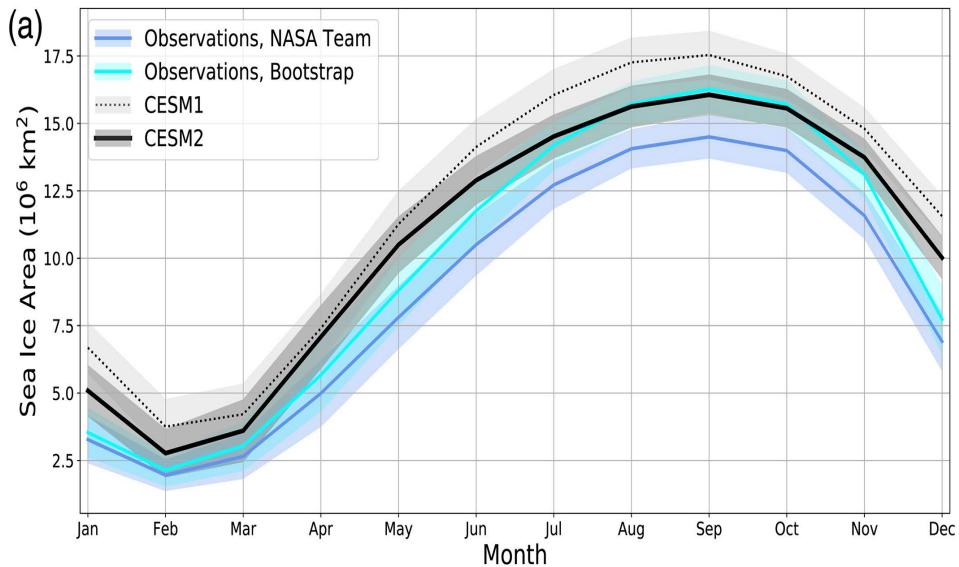## and its implications for ecosystems

Marika Holland

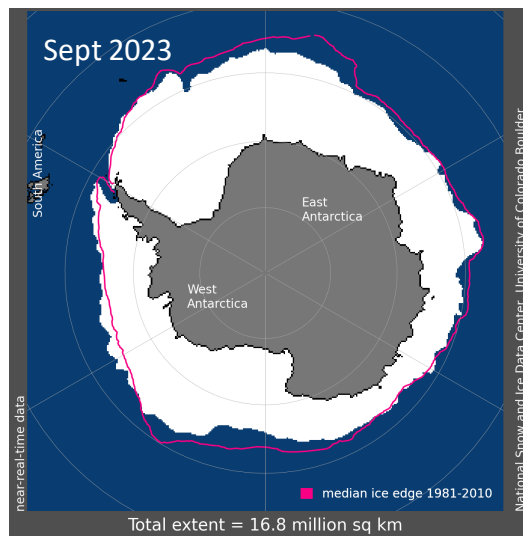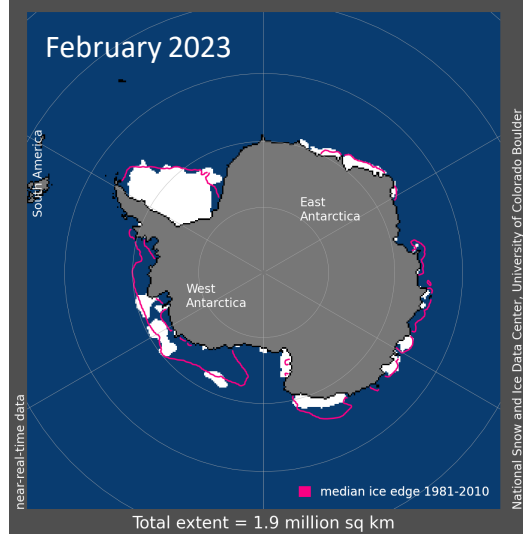Kristen Krumhardt, Laura Landrum, Alice DuVivier, and Stephanie Jenouvrier
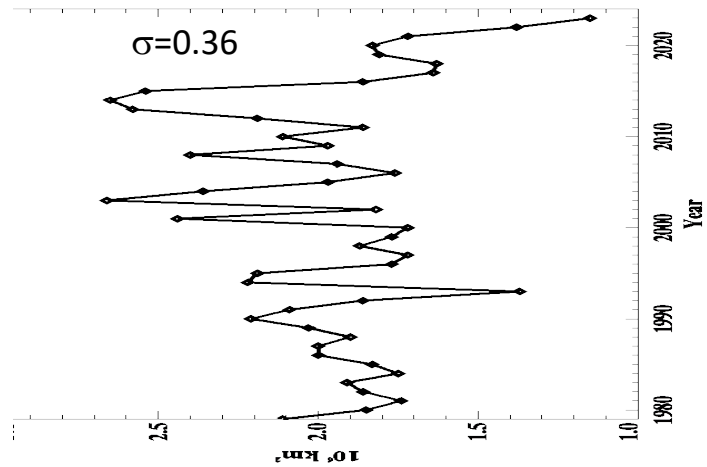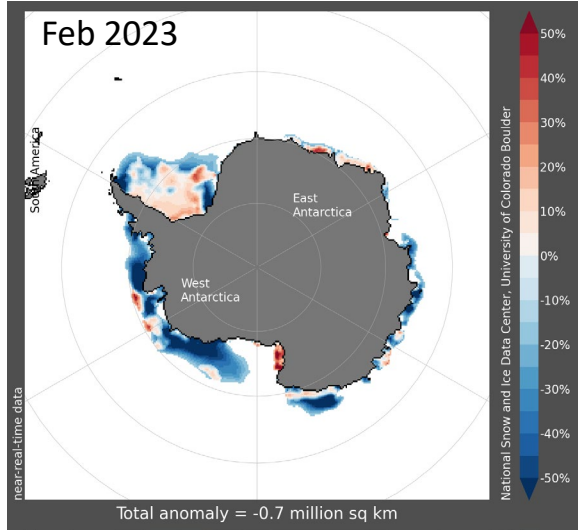
CESM Annual Meeting
2024

Antarctic Sea Ice

(a)

Singh et al., 2020

February 2023

Total extent = 1.9 million sq km

Sept 2023

Total extent = 16.8 million sq km

NSIDC Sea Ice Index

February Ice Area SH

σ=0.36

September Ice Area SH

σ=0.48

Feb 2023

Total anomaly = -0.7 million sq km

National Snow and Ice Data Center, University of Colorado Boulder

near-real-time data

Sept 2023

Total anomaly = -1.5 million sq km

National Snow and Ice Data Center, University of Colorado Boulder

near-real-time data
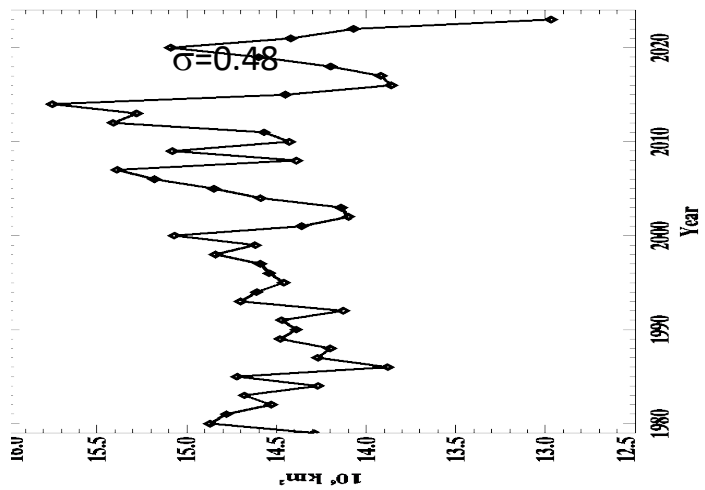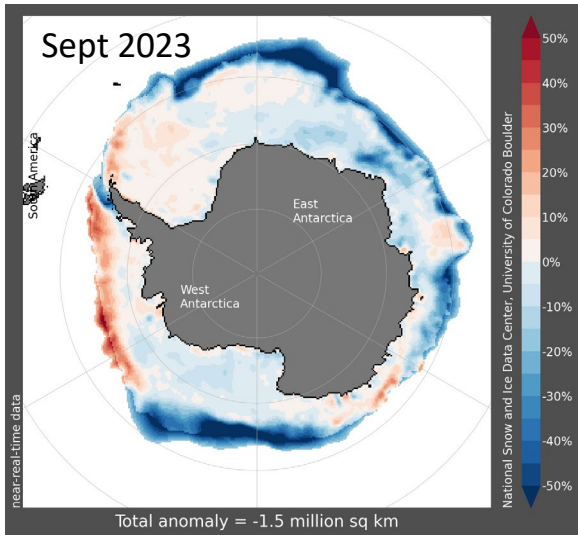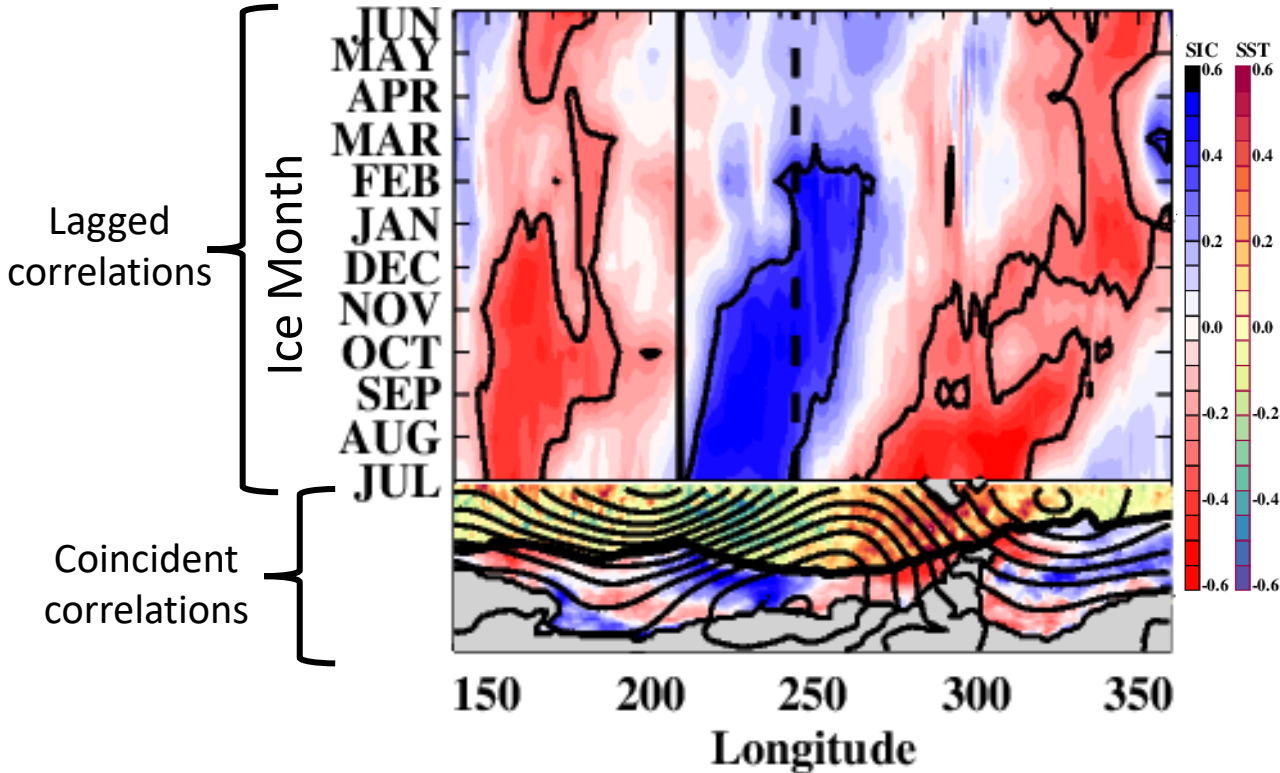
NSIDC Sea Ice Index Anomalies

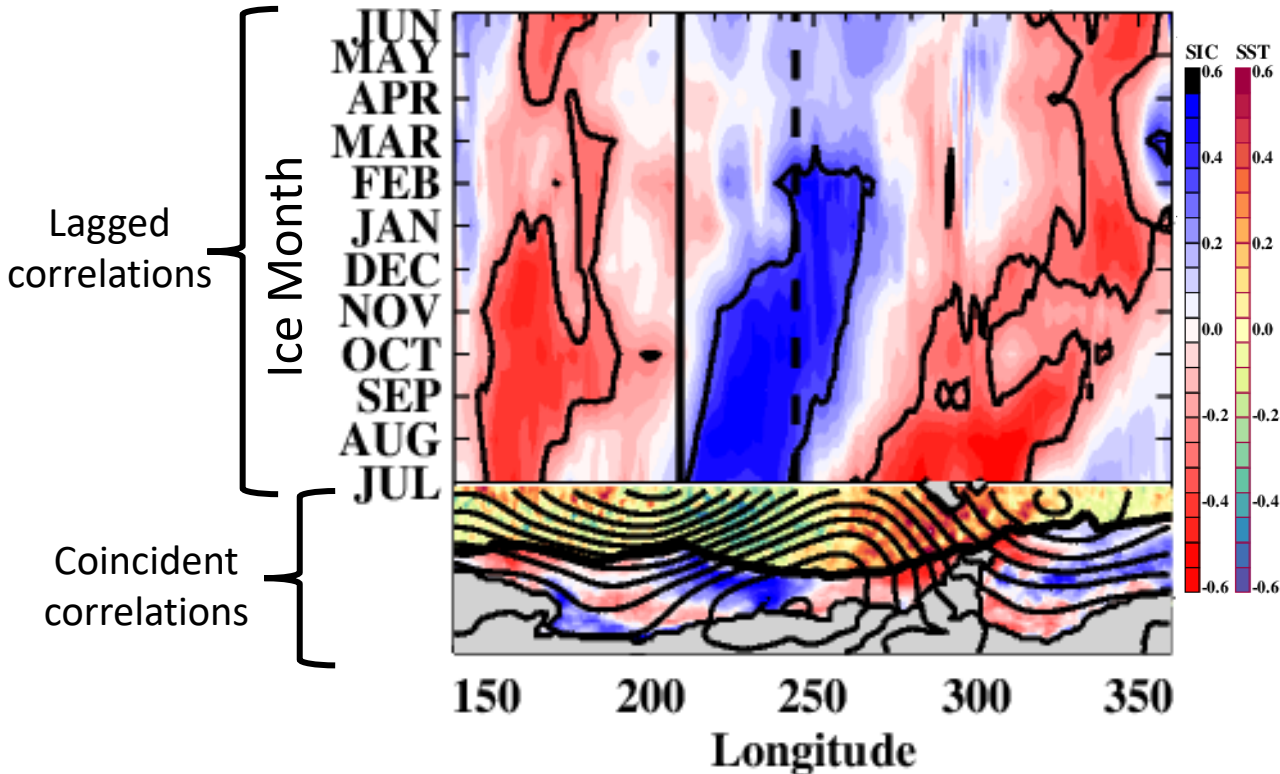# Observations suggest ice predictability on seasonal+ timescales

For July ASL Variability

Relationship of sea ice to Amundsen Sea Low variability
(Holland et al, 2018)

Observations suggest ice predictability on seasonal+ timescales

For July ASL Variability

Lagged correlations

Coincident correlations

Ice Month

Longitude

SIC   SST

Relationship of sea ice to Amundsen Sea Low variability
(Holland et al, 2018)

Modeling studies also suggest predictability

Here we further explore:
- Mechanisms
- Regional interactions
- Impacts on ecosystems

Climate model experiments

Sets of "perfect model" initialized predictions

- CESM2 simulations

- 2-year "predictions"

- Initializations performed for the first of Jan, March, May, July, Sept, and Nov

- Initialized with CESM2 Large Ensemble conditions with round-off level air temperature difference

# Predictability of Hemispheric Total Sea Ice Area

ACC SH Ice Area
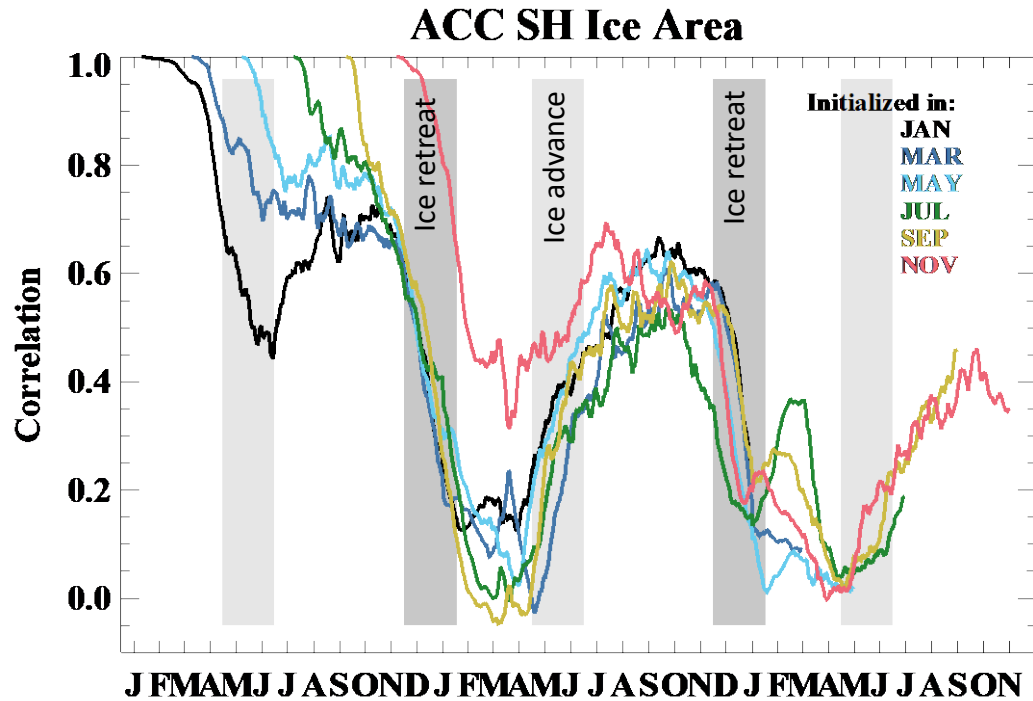
For all initialization times:

- Predictability is high for several months

- Is lost as ice retreats

- Remains low during summer

- Increases as ice advances

- Remains high through winter

- Properties occur over 2-year timescale
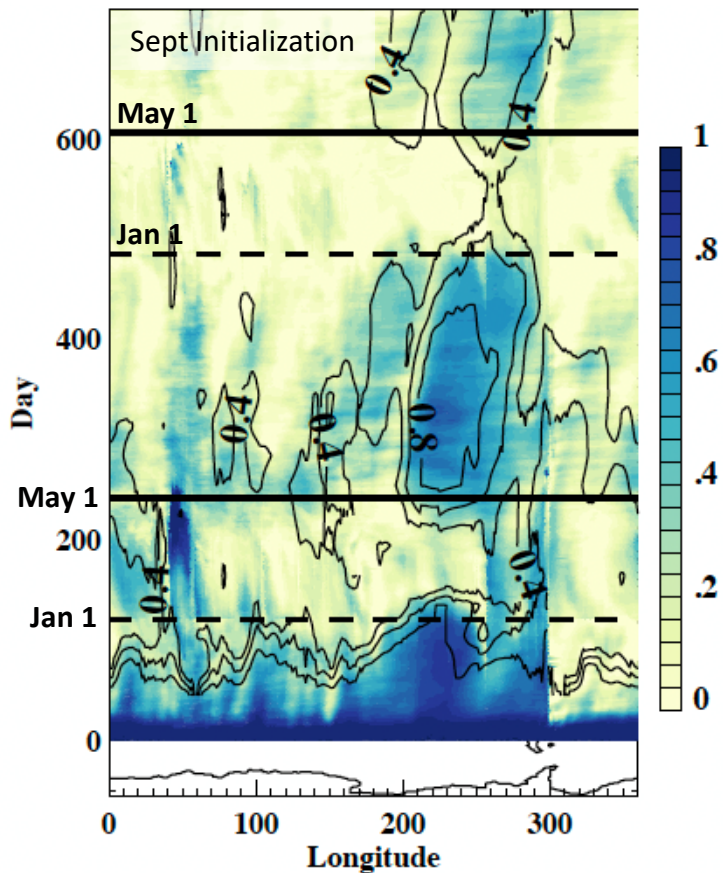
Predictability of Regional Sea Ice Area

ACC of Ice (colors) and ice-edge SST (lines)
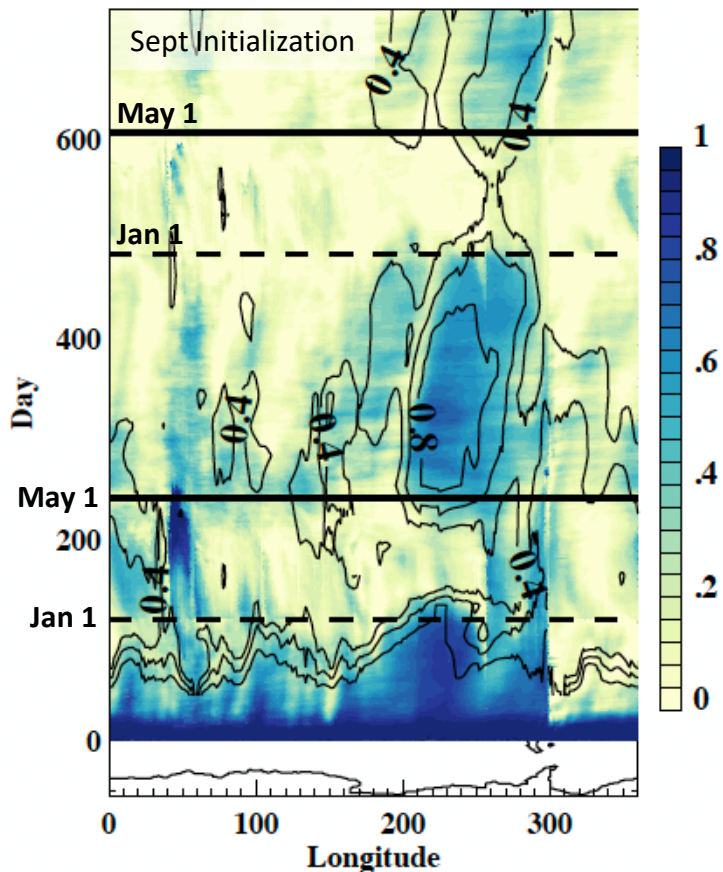
- The loss/re-emergence of predictability is evident

- Predictability varies regionally

- For our simulations, the Ross and Bellingshausen/Amundsen Seas are particularly predictable

- Ice and ice-edge SST predictability tightly aligned

Predictability of Regional Sea Ice Area

ACC of Ice (colors) and ice-edge SST (lines)
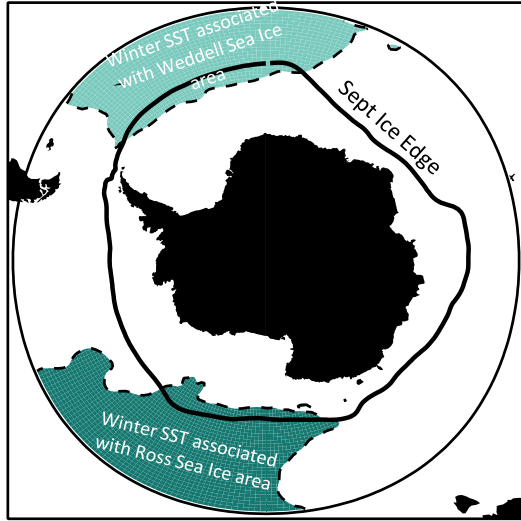

(e) SST ACC at JUL Edge-SEP Init
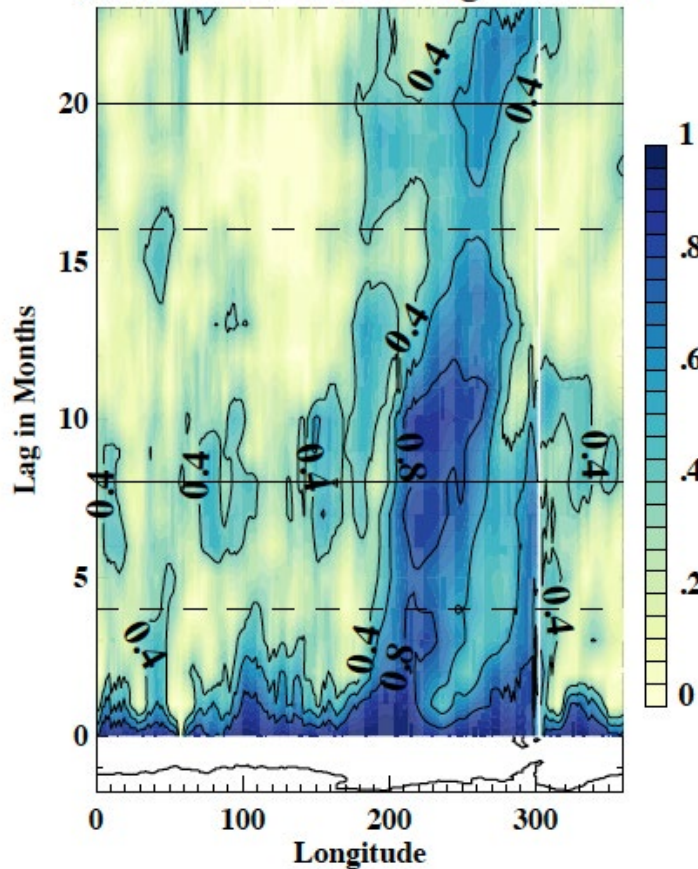
Predictability of SST at location of winter ice edge:

- Retained during summer
- weaker loss/re-emergence signal

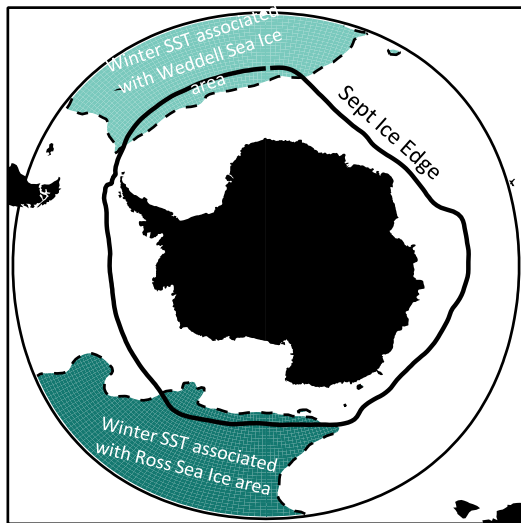# Mechanism of Predictability and Regional Dependence

September Conditions

Winter SST associated with Weddell Sea Ice area

Sept Ice Edge

Winter SST associated with Ross Sea Ice area

Regional sea ice-related winter SST anomalies occur along the ice edge.

Mechanism of Predictability and Regional Dependence

September Conditions

Regional sea ice-related winter SST anomalies occur along the ice edge.

March Conditions 6 months later

6 months later

During summer ice retreats to the continent losing predictability. Sea ice-related SSTs that originated in winter are retained north of the ice edge and advected eastward.

Mechanism of Predictability and Regional Dependence
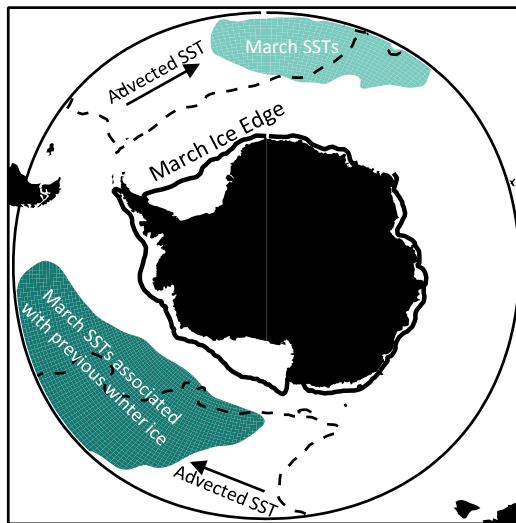

September Conditions

Regional sea ice-related winter SST anomalies occur along the ice edge.
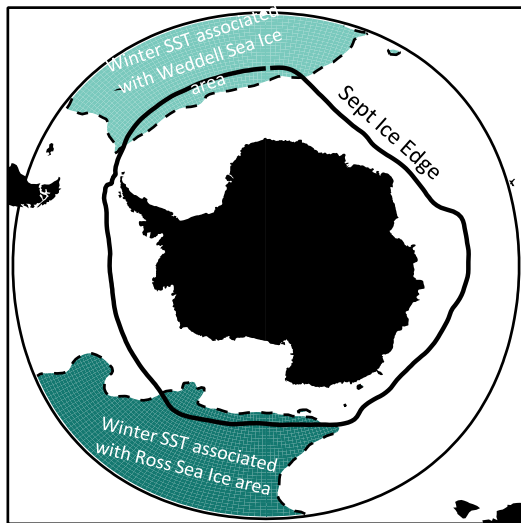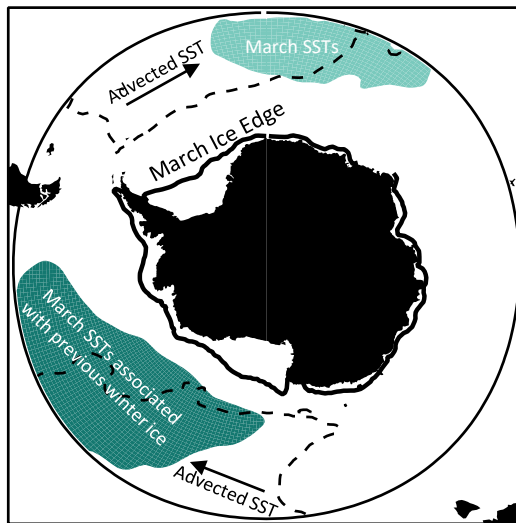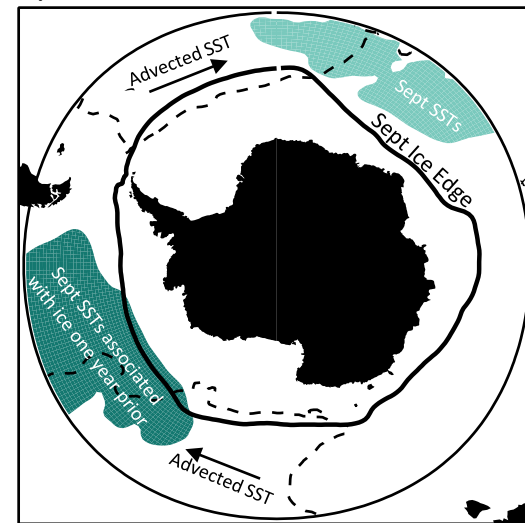
6 months later

March Conditions 6 months later

During summer ice retreats to the continent losing predictability. Sea ice-related SSTs that originated in winter are retained north of the ice edge and advected eastward.
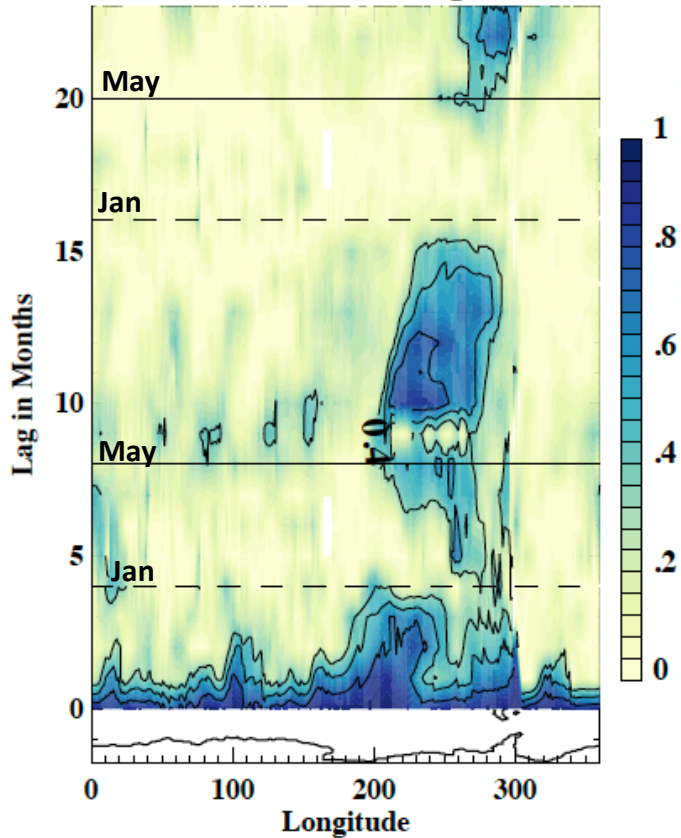
6 months later

September Conditions One Year Later

As ice advances the next fall, it can re-encounter advected SST anomalies. However, in some regions these have advected out of the sea ice zone resulting in a loss of ice predictability.
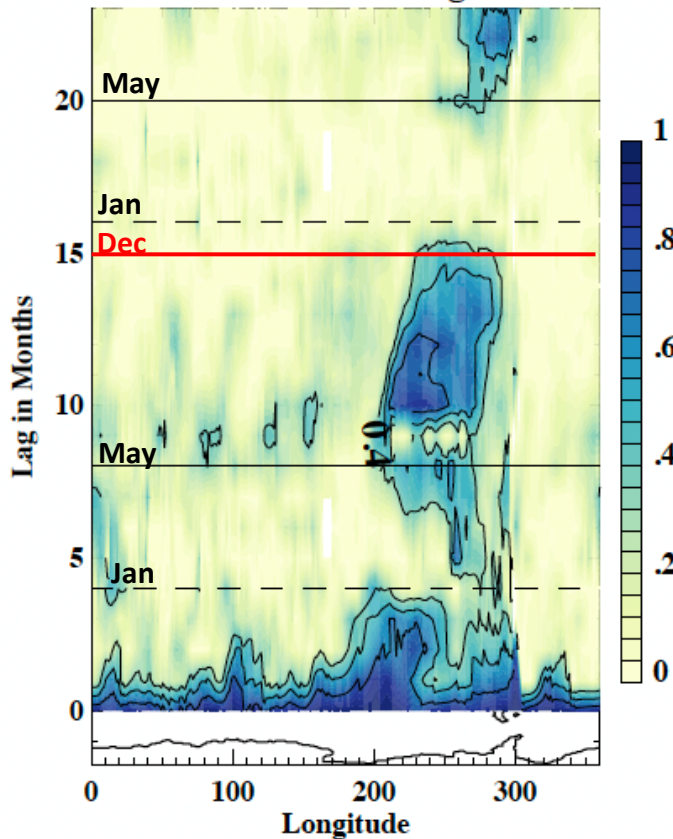
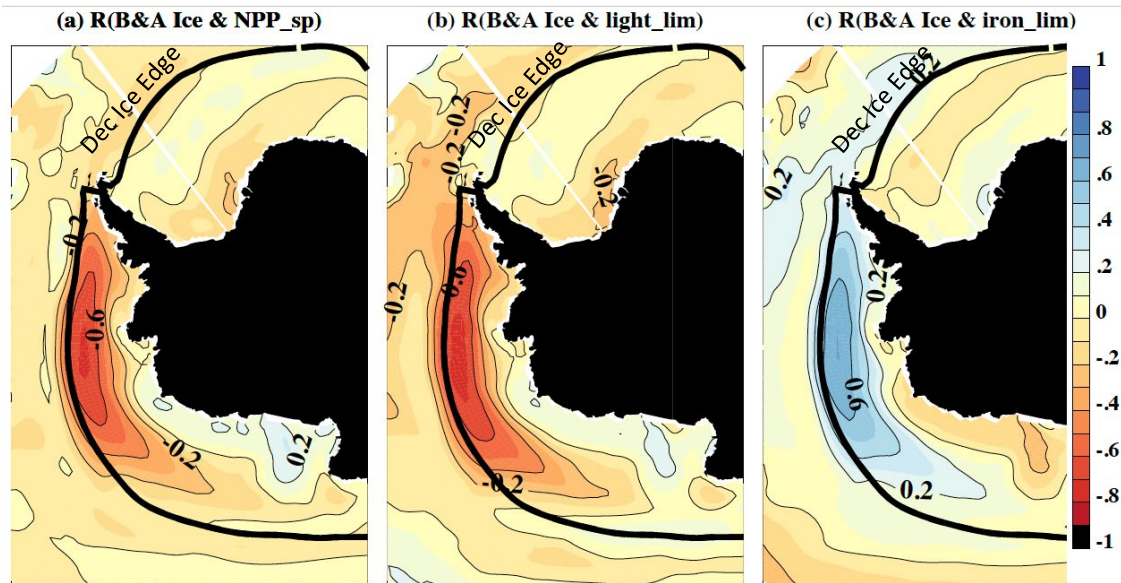# Implications for Biology?

ACC of Simulated Net Primary Productivity

Implications for Biology?

(e) NPP ACC at Mon Edge-SEP Init

Correlation of B&A Sea Ice and Biological Conditions

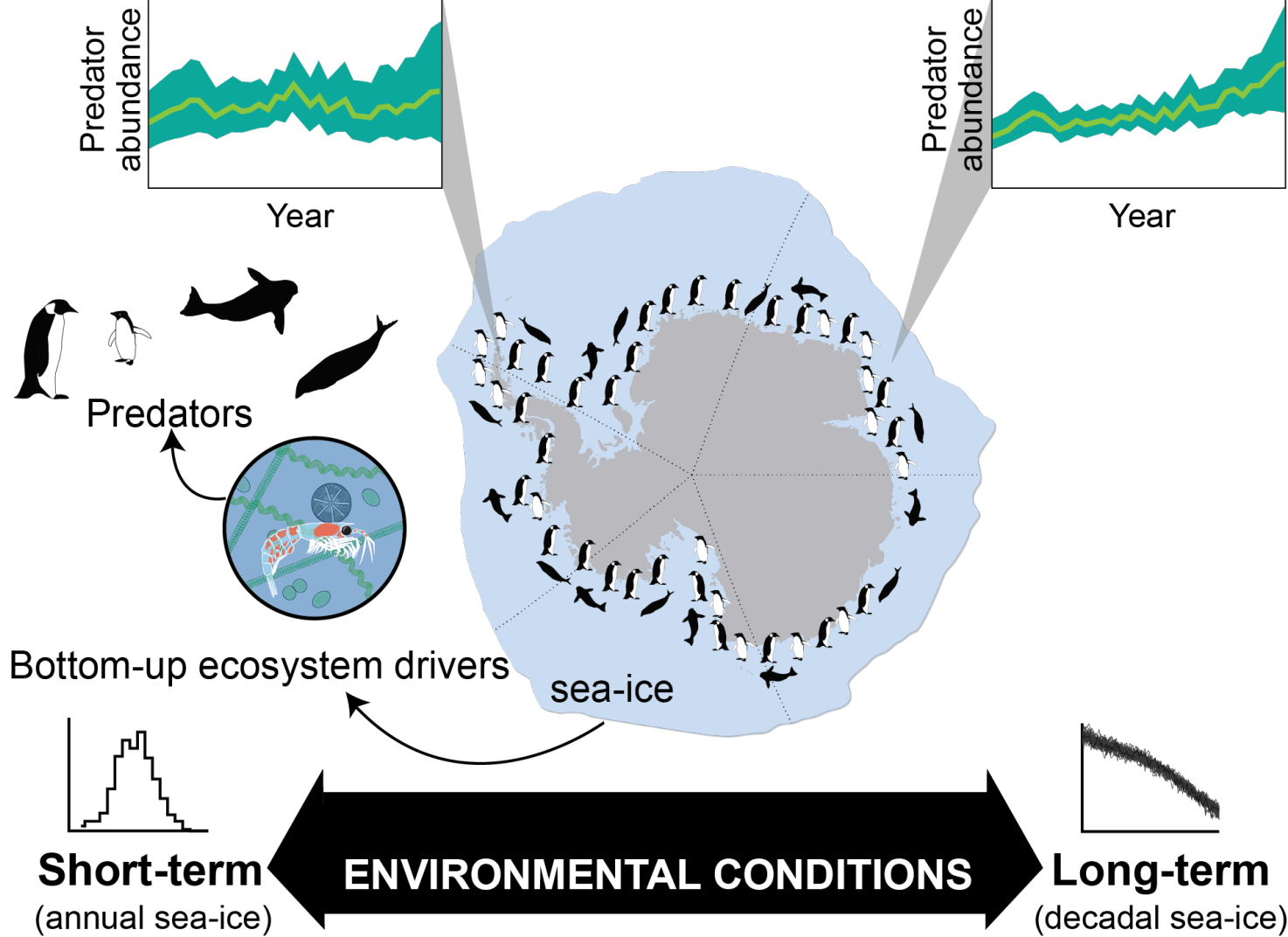(a) R(B&A Ice & NPP_sp)   (b) R(B&A Ice & light_lim)   (c) R(B&A Ice & iron_lim)

- December NPP highly related to December sea ice
- This is due to the influence of sea ice on light limitation
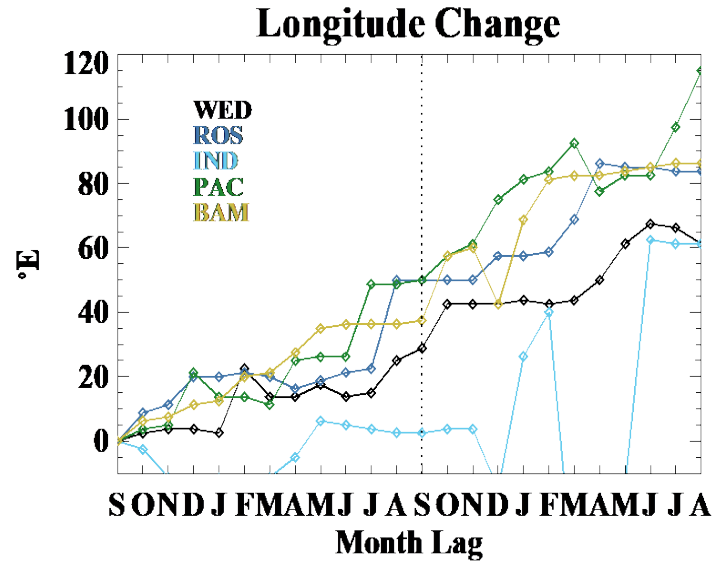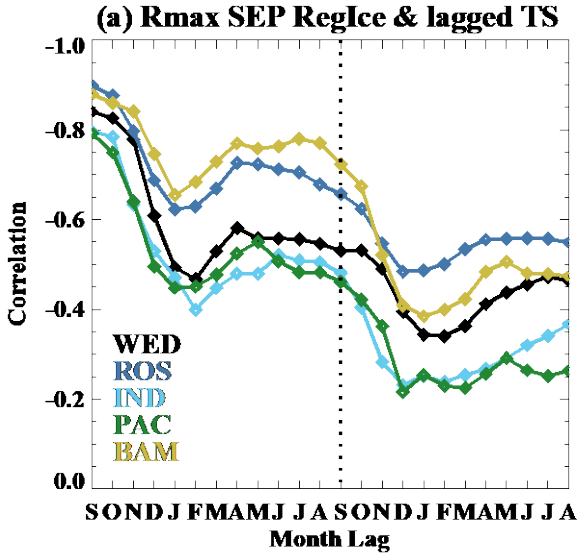- Iron becomes more limiting because of increased production

Summary

- Winter Antarctic Sea ice is predictable on multi-year timescales but this varies regionally

- The predictability arises from long-lived ocean temperature anomalies that are advected and impart predictability downstream.

- The location of these relative to the sea ice leads to seasonally and regionally-dependent predictability.

- The predictability in sea ice can impart predictability to the marine ecosystem due to its influence on light availability

Thanks for your attention!
Questions?

Predator abundance / Year (left graph)

Predator abundance / Year (right graph)

Predators

Bottom-up ecosystem drivers

sea-ice

Short-term
(annual sea-ice)

ENVIRONMENTAL CONDITIONS

Long-term
(decadal sea-ice)

How does this differ across regions?

(a) Rmax SEP RegIce & lagged TS

WED
ROS
IND
PAC
BAM

Longitude Change
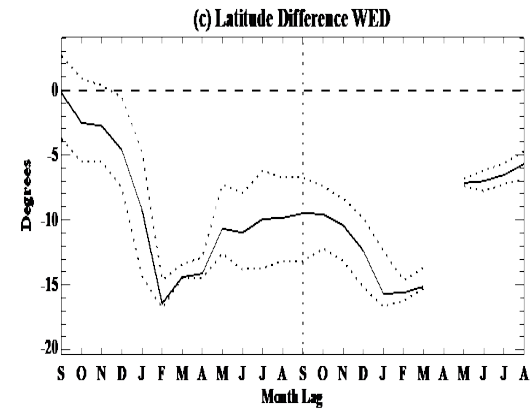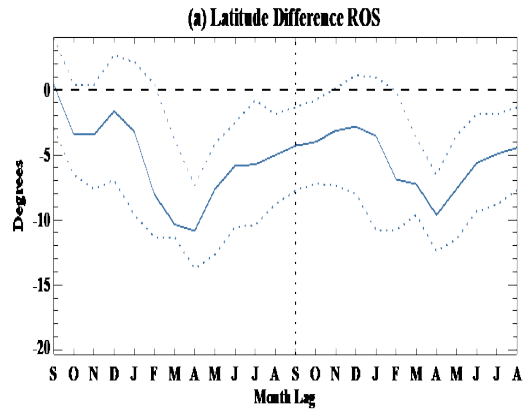
WED
ROS
IND
PAC
BAM

How does this differ across regions?

(a) Rmax SEP RegIce & lagged TS
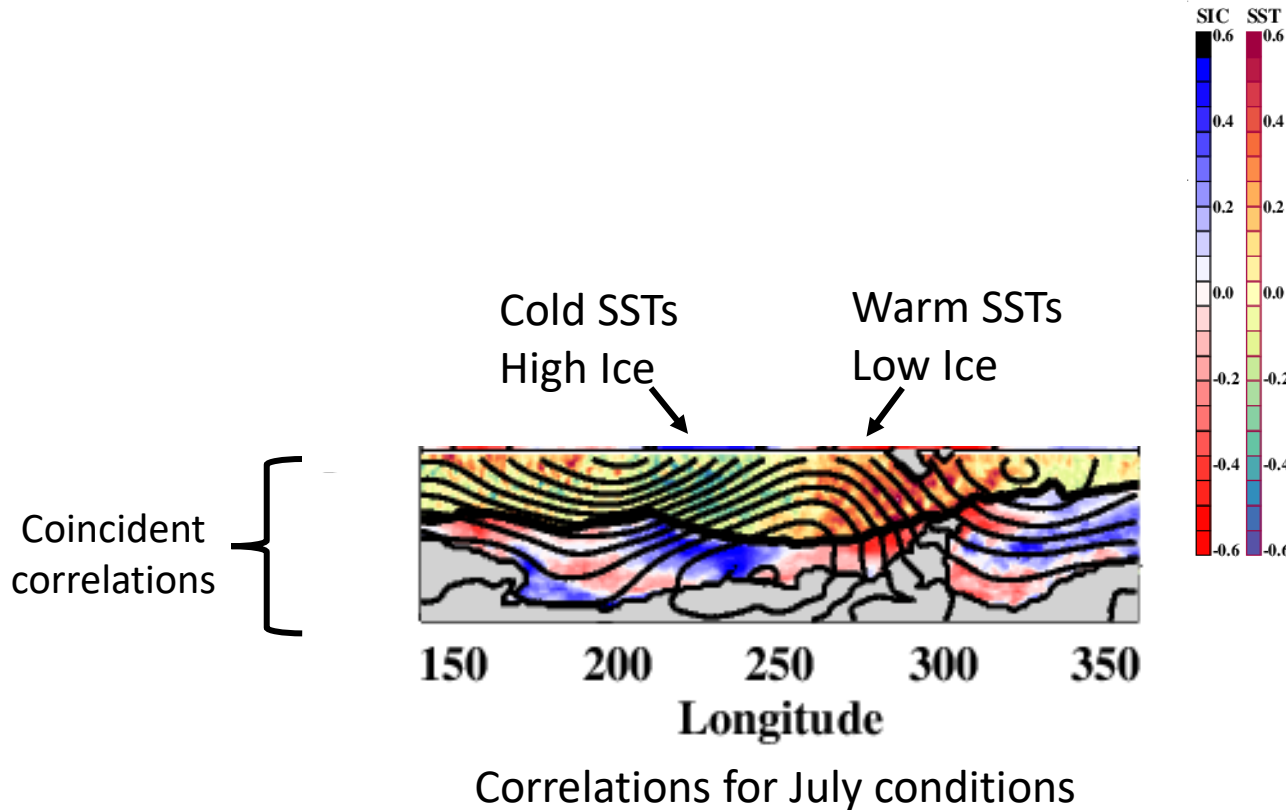
Longitude Change
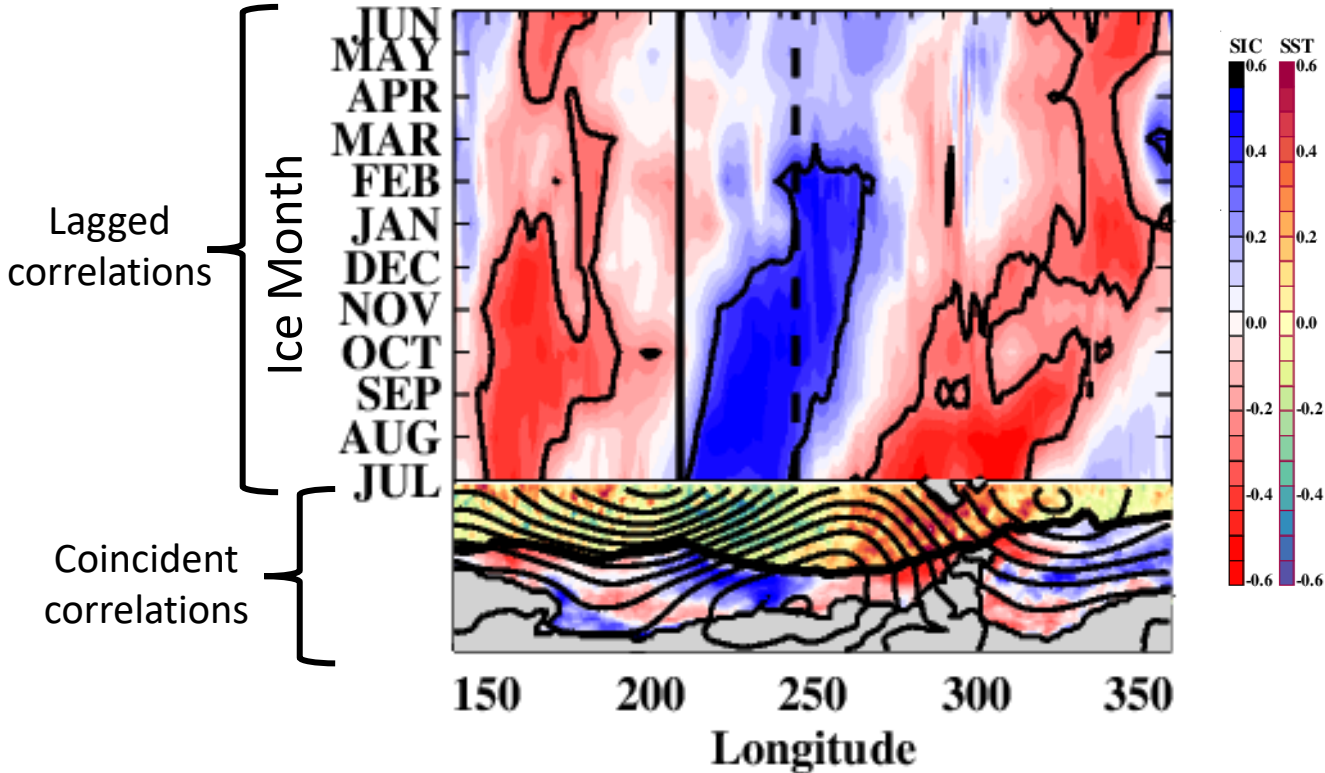
(a) Latitude Difference ROS

(c) Latitude Difference WED
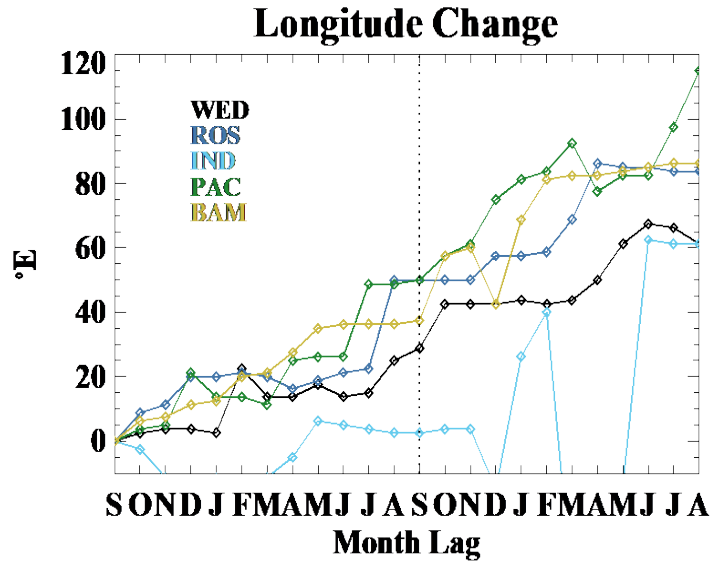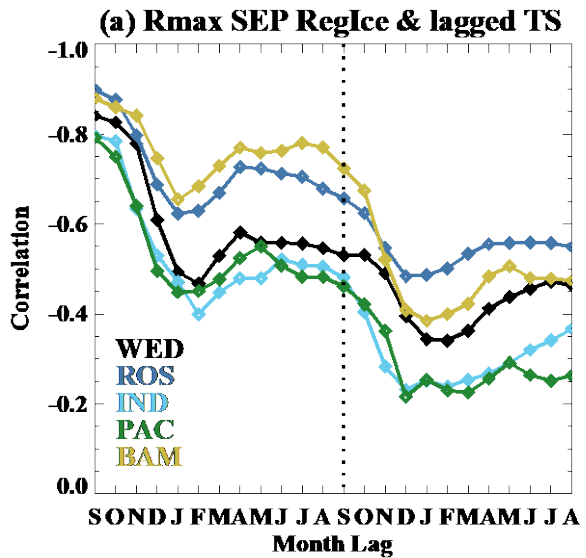
Observations suggest ice predictability on seasonal+ timescales

Relationship of sea ice to Amundsen Sea Low variability
(Holland et al, 2018)

Cold SSTs High Ice

Warm SSTs Low Ice

Coincident correlations

Correlations for July conditions

Observations suggest ice predictability on seasonal+ timescales

For July ASL Variability

Lagged correlations

Ice Month

Coincident correlations

JUN
MAY
APR
MAR
FEB
JAN
DEC
NOV
OCT
SEP
AUG
JUL

150   200   250   300   350

Longitude

SIC   SST
0.6   0.6

0.4   0.4

0.2   0.2

0.0   0.0

-0.2   -0.2

-0.4   -0.4

-0.6   -0.6
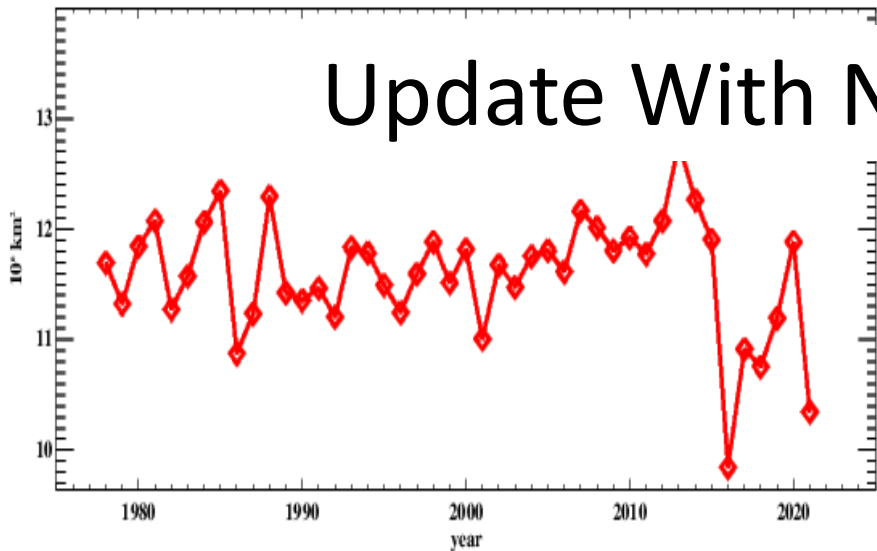
Relationship of sea ice to Amundsen Sea Low variability
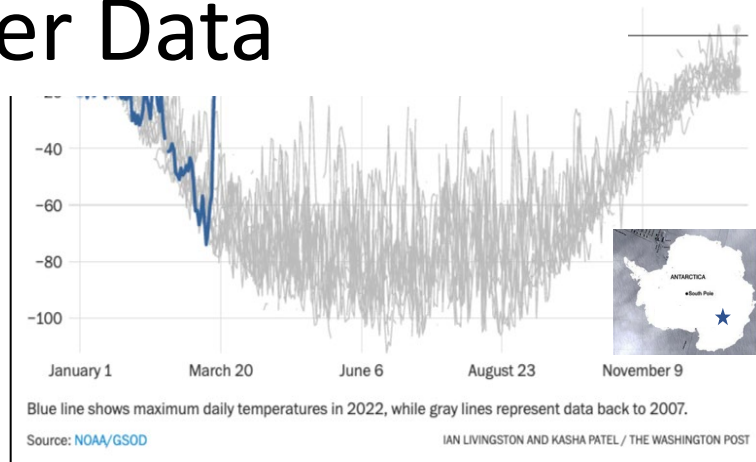(Holland et al, 2018)

Surprises in the Antarctic System

Observed Southern Hemisphere Ice Area in November

Observed Maximum Daily Air Temperatures at Concordia Station

Update With Newer Data

From NSIDC Sea Ice Index

From The Washington Post

Implications for biology
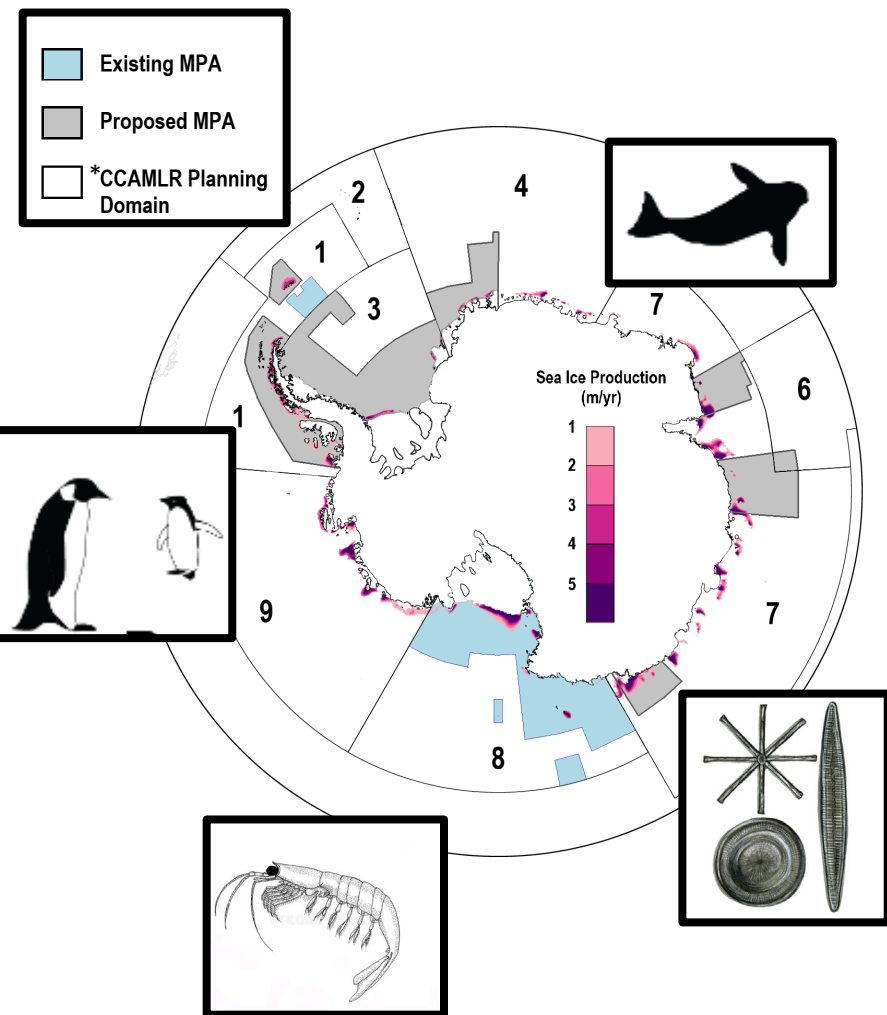
- Ultimate goal to understand how these aspects of predictability transition through the ecosystem

- How these relationships will change in a warming climate

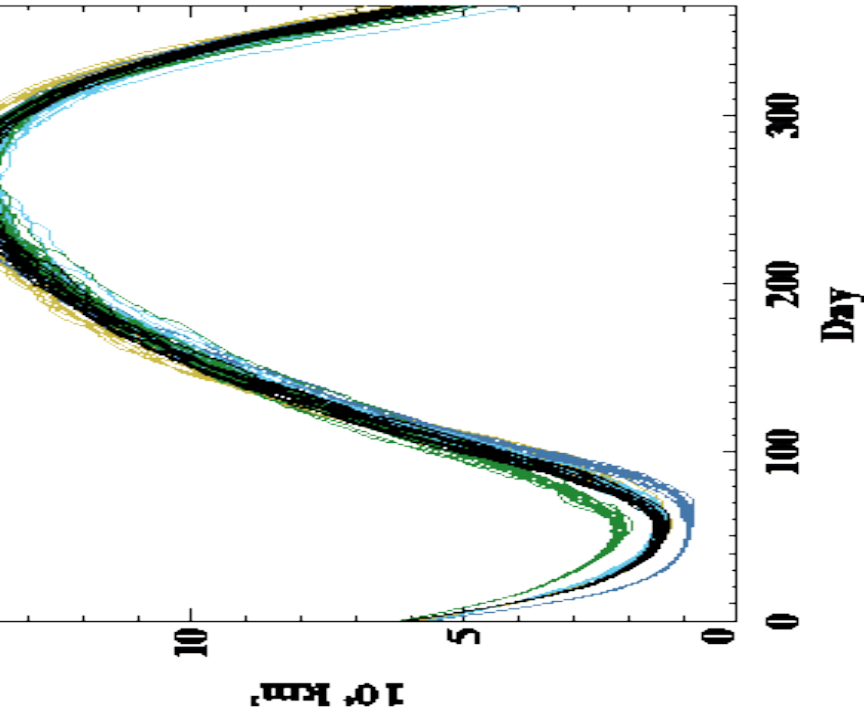- What that implies for planning for Antarctic marine protected areas

*CAMMLR=Commission for the Conservation of Antarctic Marine Living Resources

Methods:
Climate model experiments

Jan 1 Ensemble Set

Sets of "perfect model" predictions

- Ensemble predictions initialized from the CESM2 historical simulations

- Initializations are performed for the first of Jan, March, May, July, Sept, and Nov

- 15 members initialized from 5 different CESM2 members (so 75 members)

- Run 2-year "predictions"