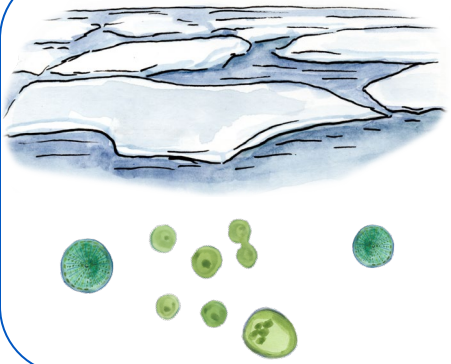
Antarctic Biophysical Connections

Alice DuVivier
& Kristen Krumhardt, Laura Landrum, Marika Holland, and others

2026 Polar Climate Working Group Winter Meeting

February 6, 2026

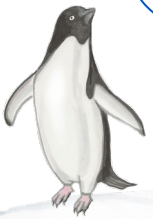
Relationships between ice and ecosystems

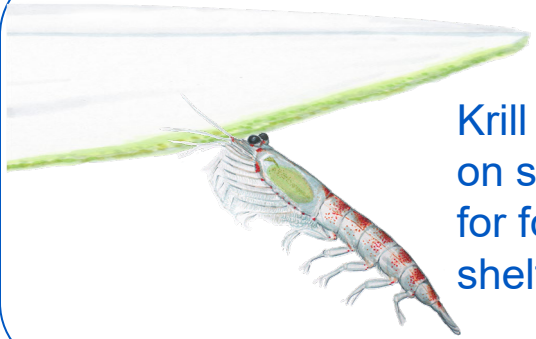


Sea ice controls light availability for phytoplankton

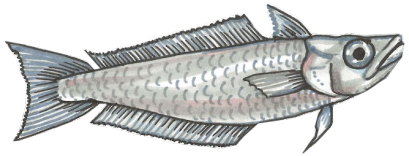
Penguins use sea ice for a stable breeding platform

Sea ice influences access to food in the ocean





Krill depend on sea ice for food and shelter



Antarctic fish are adapted to cold, icy conditions

Southern Ocean Management

CCAMLR

Commission for the
Conservation of
Antarctic
Marine
Living
Resources

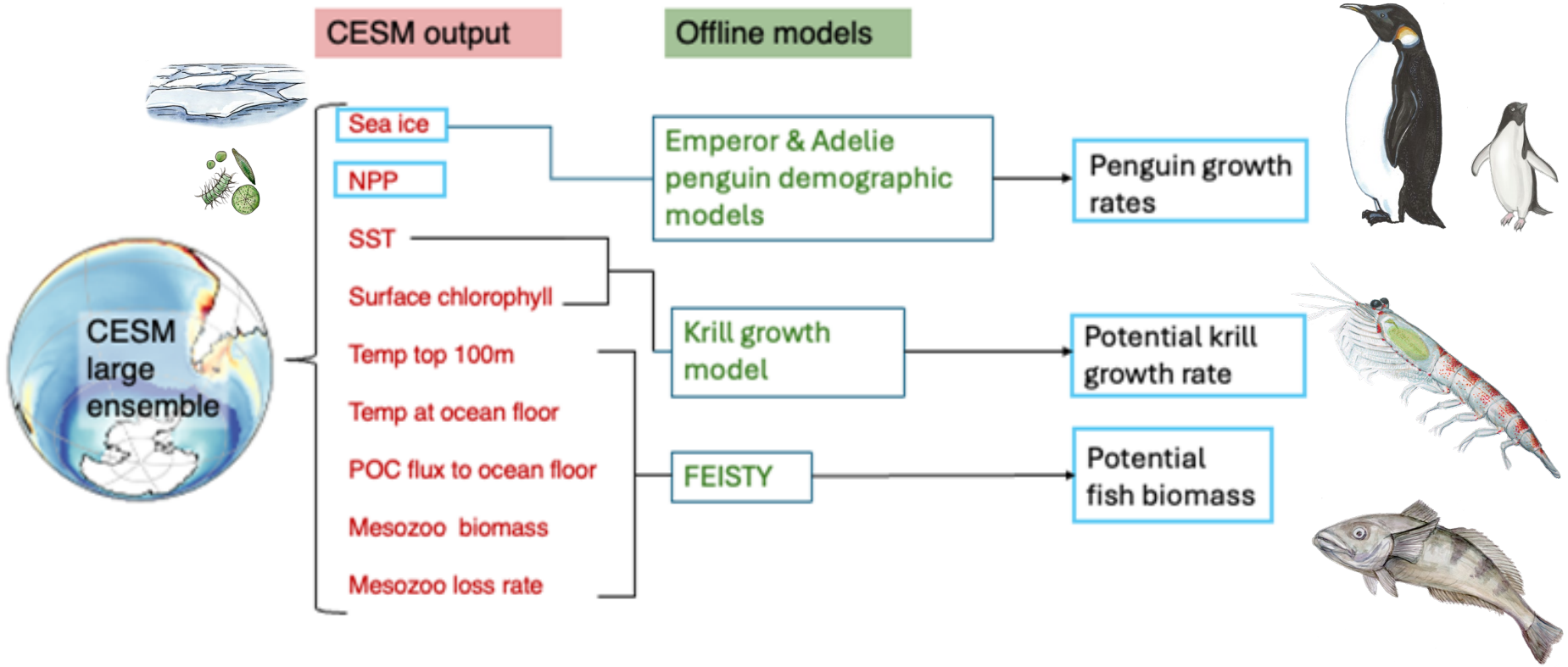
Marine Protected Areas (MPA)

- Adopted (2)
- Proposed (4)

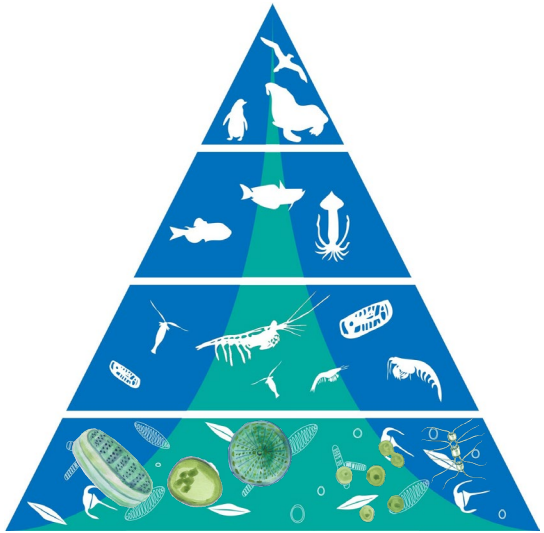
Where are the most important locations for the Antarctic ecosystem?

DuVivier et al. (accepted - Nat. Comm.)

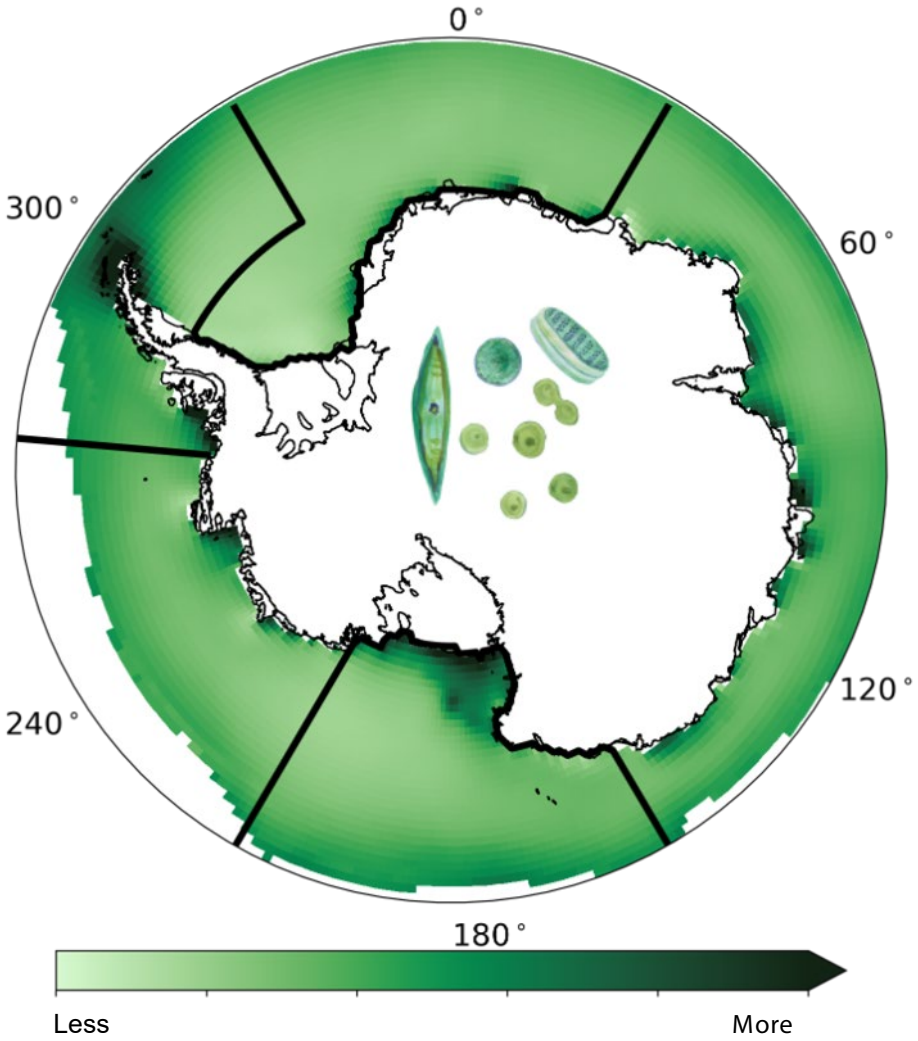
CESM2 Large ensemble + models for krill, fish, penguins



Where is important for phytoplankton?



Antarctic Ecosystem



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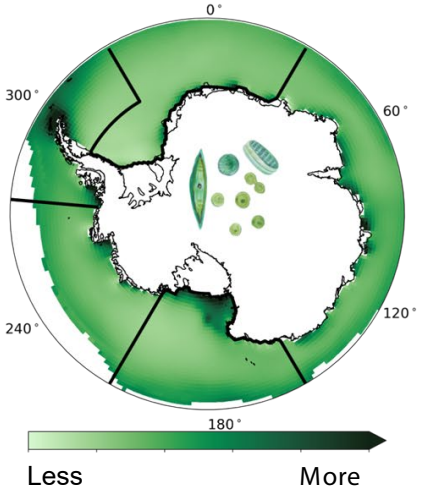
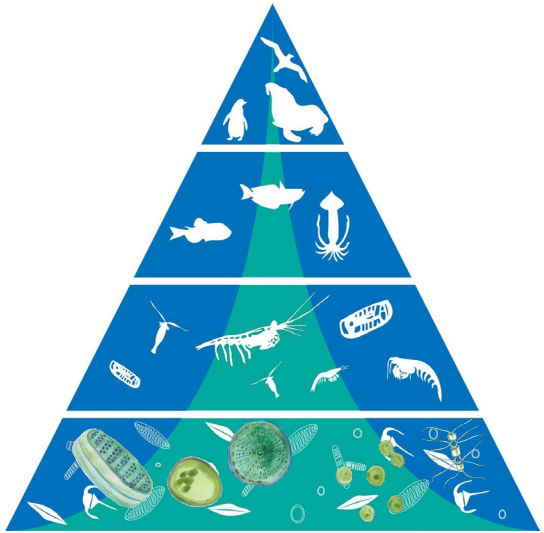
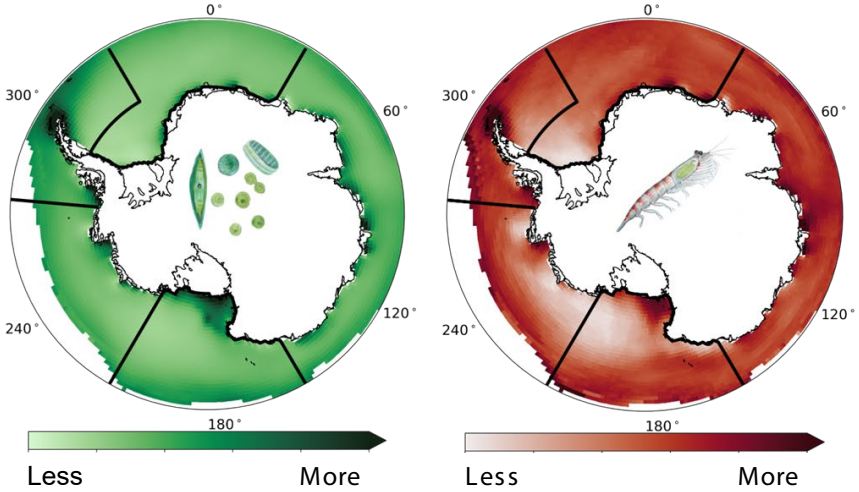
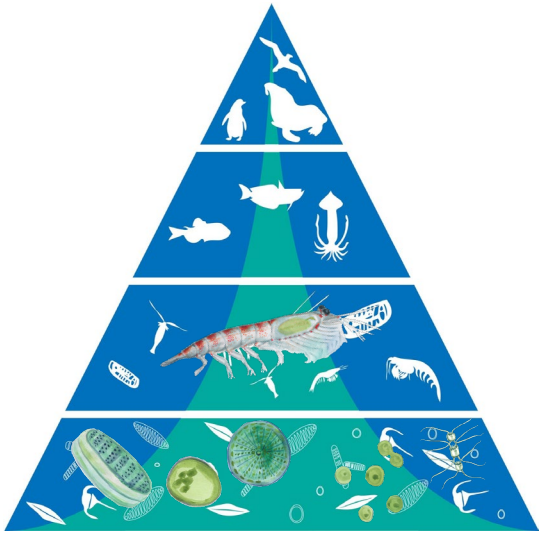




Antarctic Ecosystem

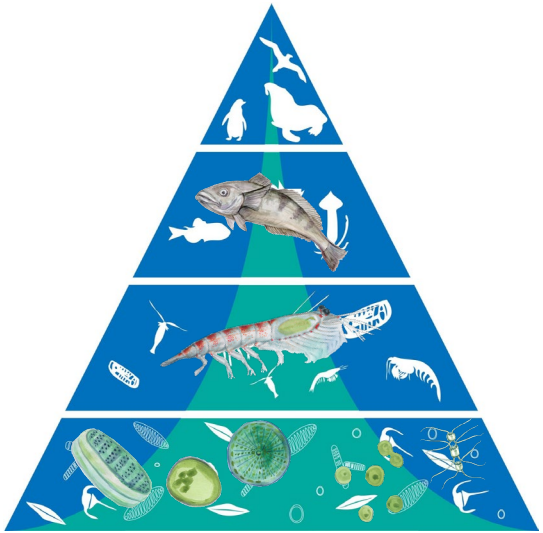
Where is important for krill?



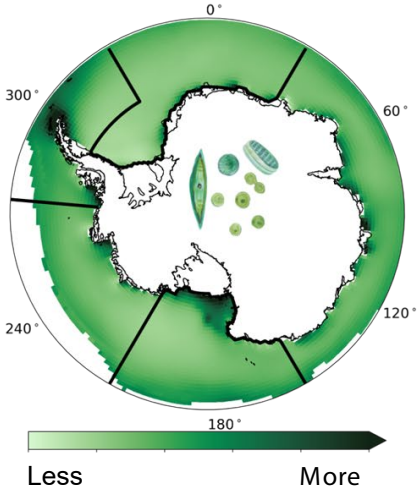


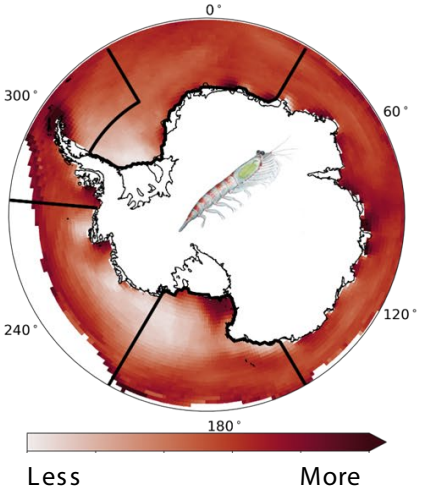
Antarctic Ecosystem

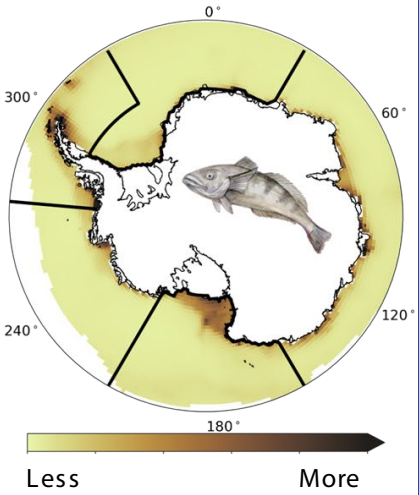
Where is important for toothfish?



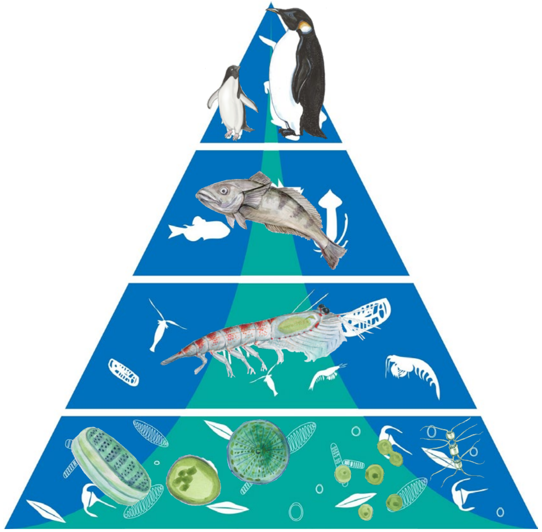
Antarctic Ecosystem



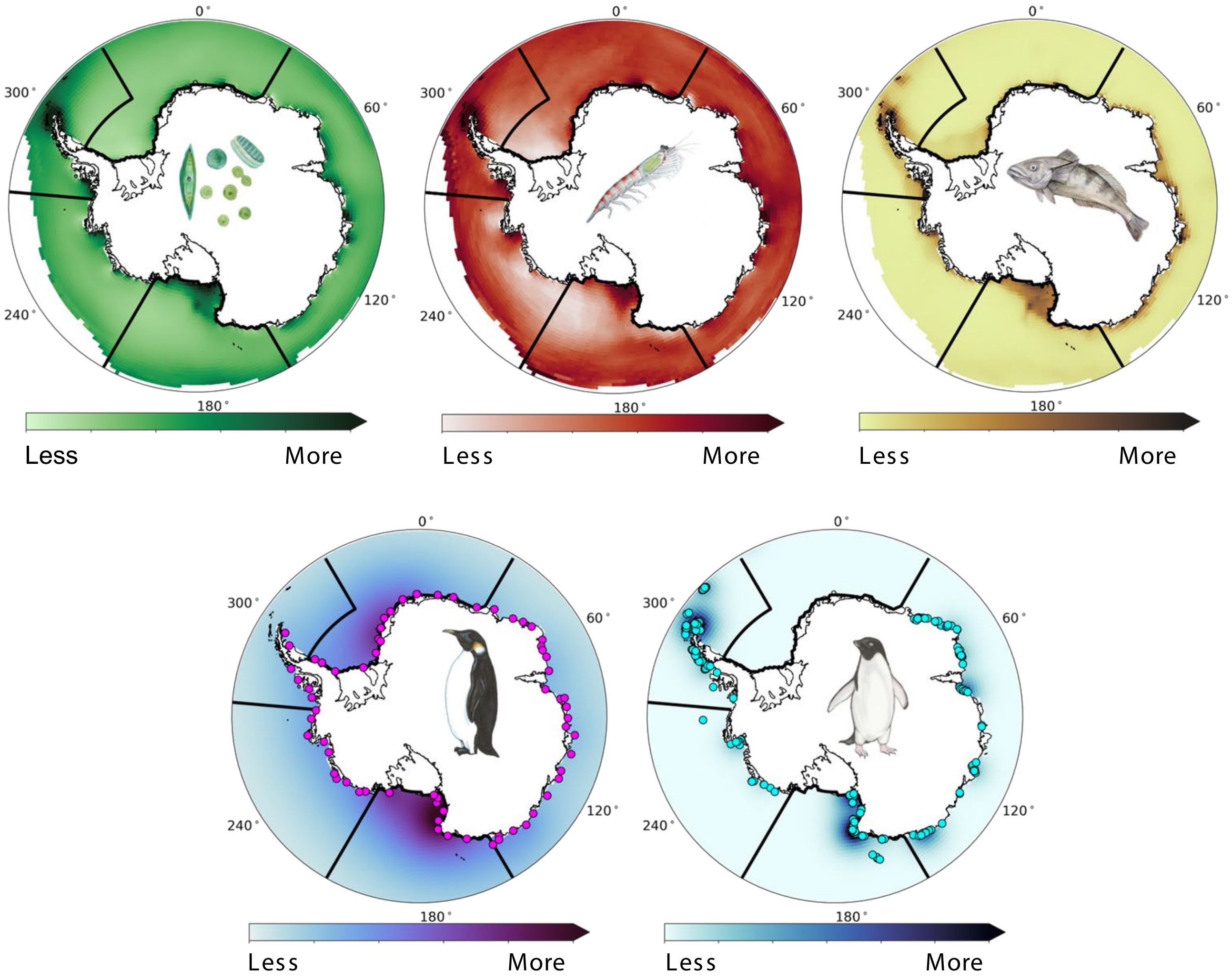




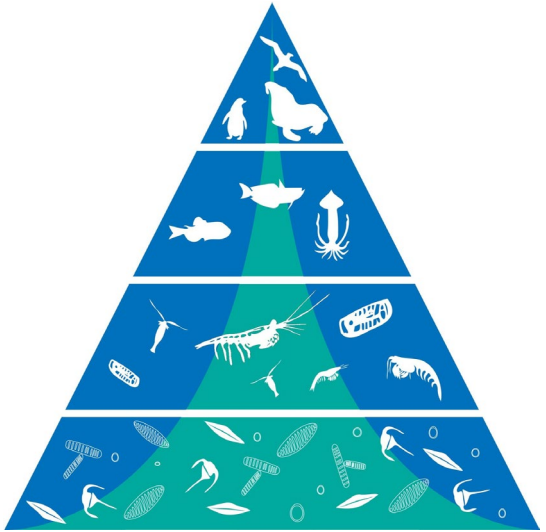
Where is important for penguins?



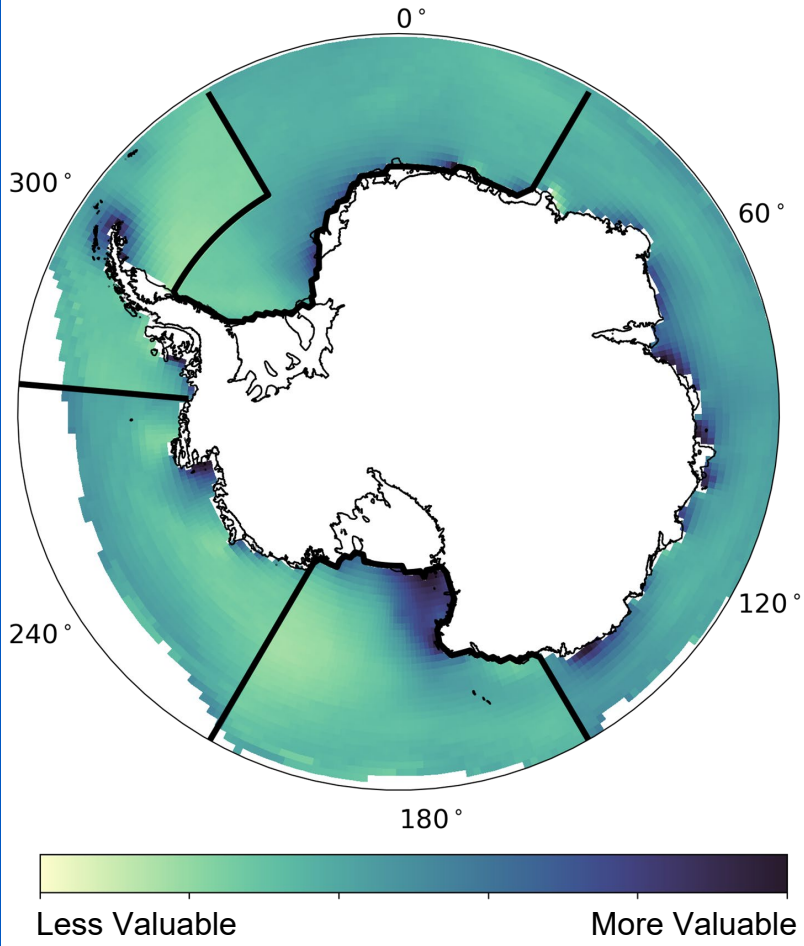
Antarctic Ecosystem



Where are the most important locations for the ecosystem?



Antarctic Ecosystem Value Index



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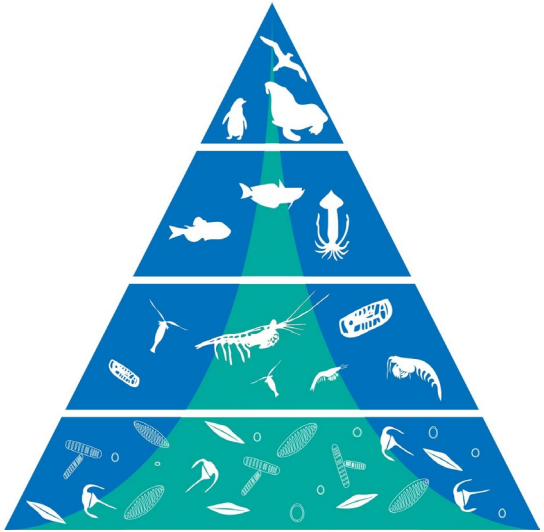
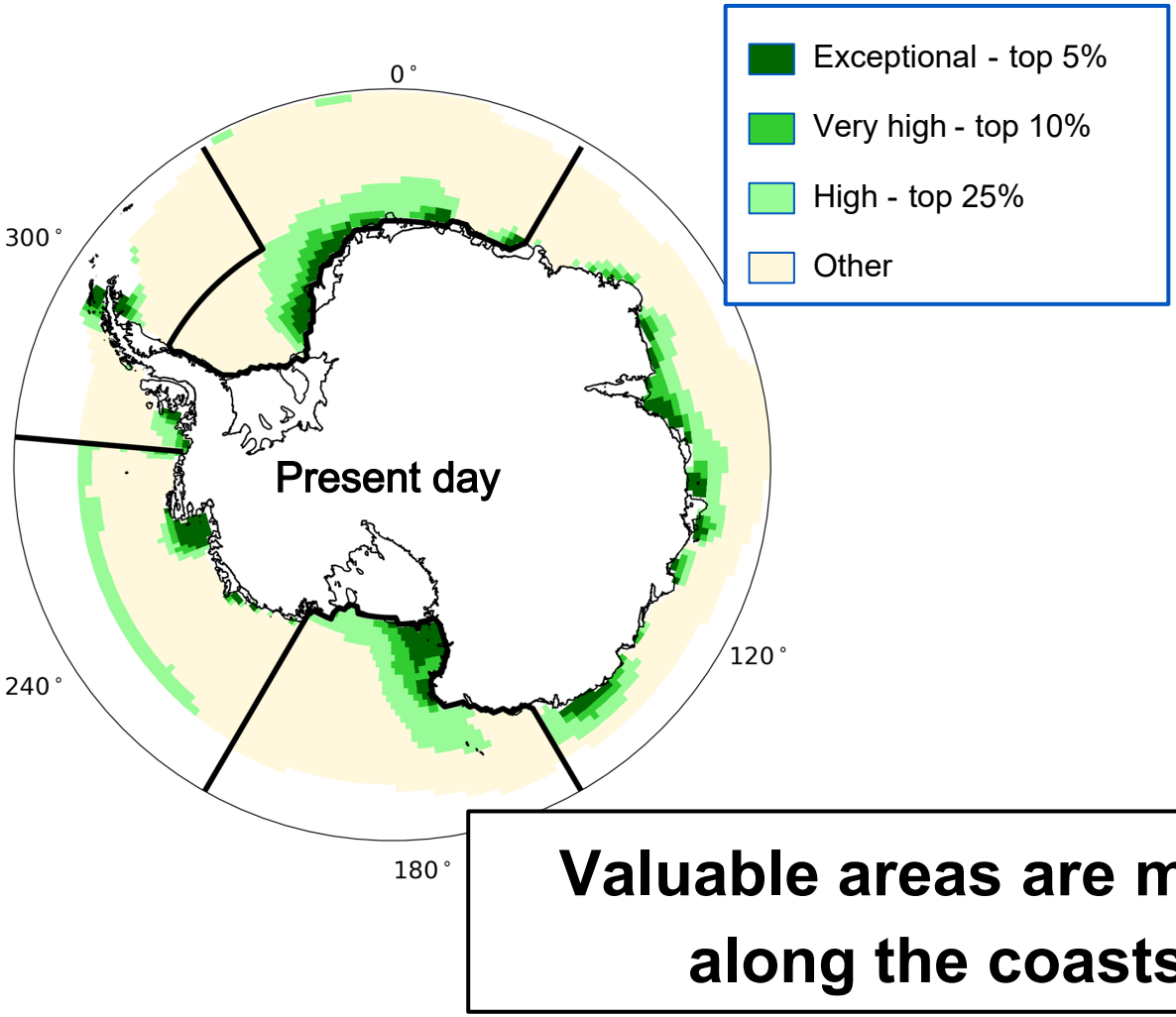
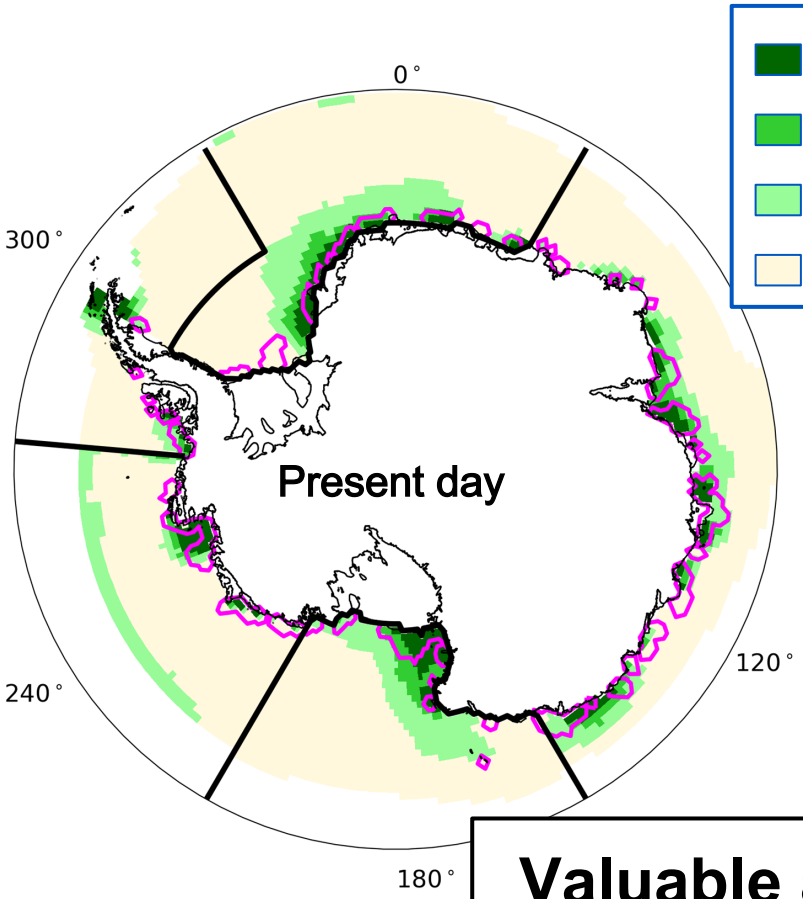




Valuable areas are mainly along the coasts.



Exceptional - top 5%

Very high - top 10%

High - top 25%

Other

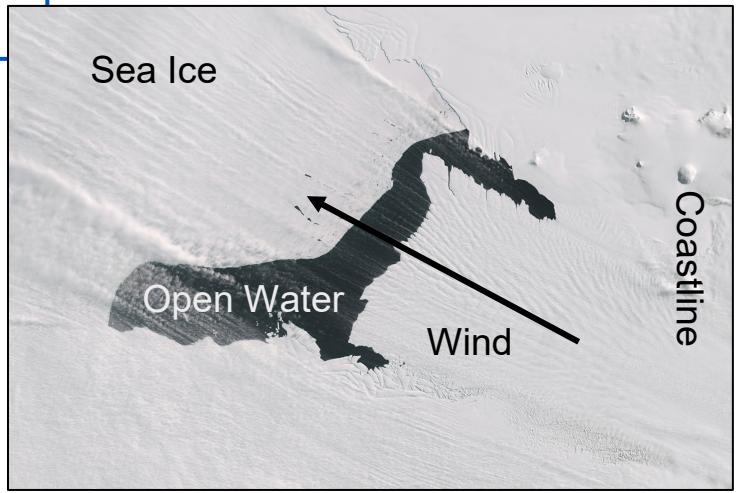
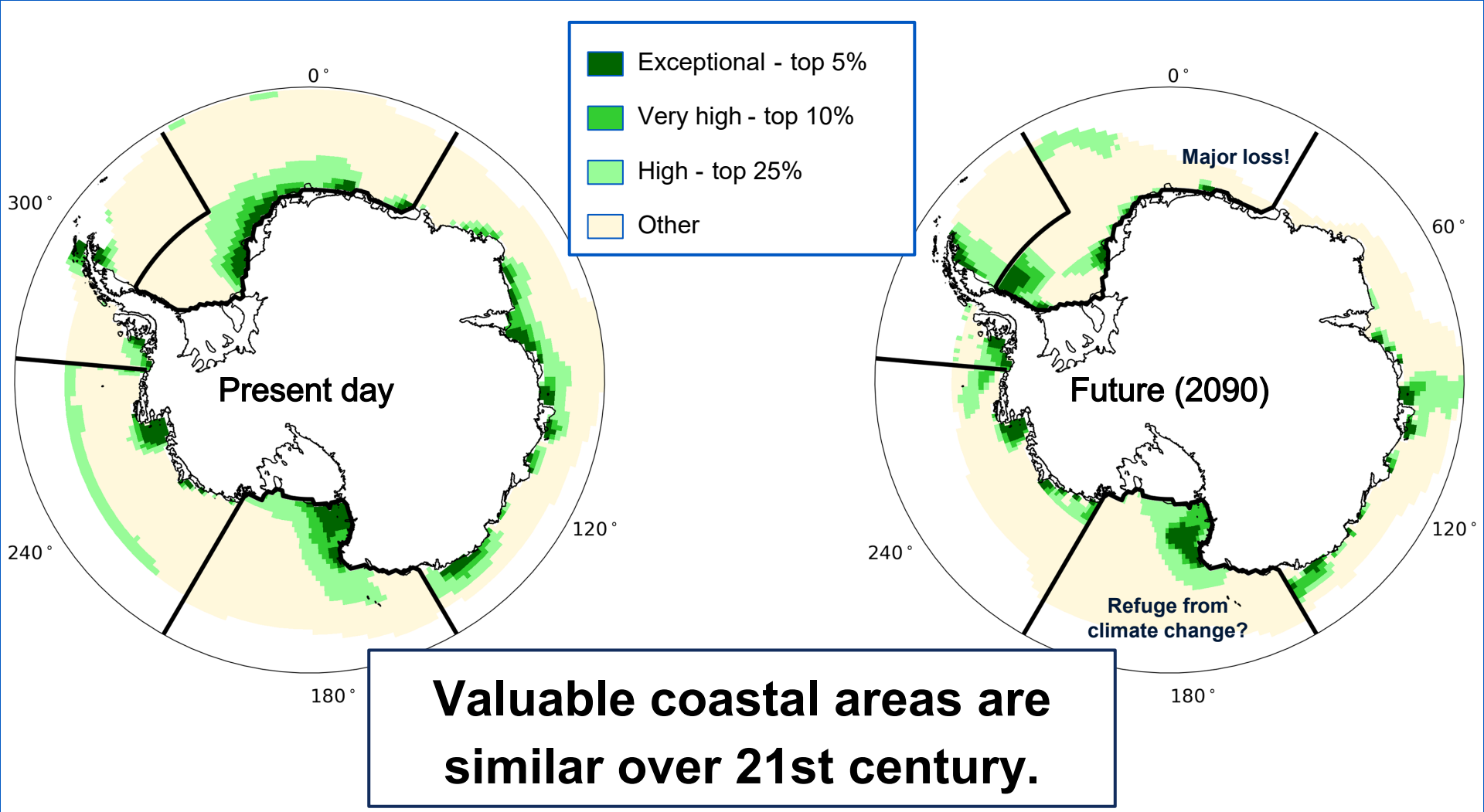


Image: NASA

Valuable areas coincide with coastal polynyas.



Valuable coastal areas are similar over 21st century.

Key Takeaways

Coastal polynyas are valuable across the ecosystem!

Polynyas remain important through entire 21st century!

Top of the food chain (penguins & fish) feel climate impacts first.

Predictability from sea ice imparts predictability to NPP.

DuVivier et al. 2026 (Nat.Comm. - Accepted)

Landrum et al. (In Prep - GRL)

Landrum et al. 2026 (The Cryosphere)
https://doi.org/10.5194/egusphere - 2024 - 3490, 2024

Krumhardt et al. 2026 (Nat.Clim.Chg.)
https://doi.org/10.1038/s41558 - 026 - 02561- 9

Holland et al. 2025 (J.Clim.)
https://doi.org/10.1175/JCLI - D- 24 - 0258.1

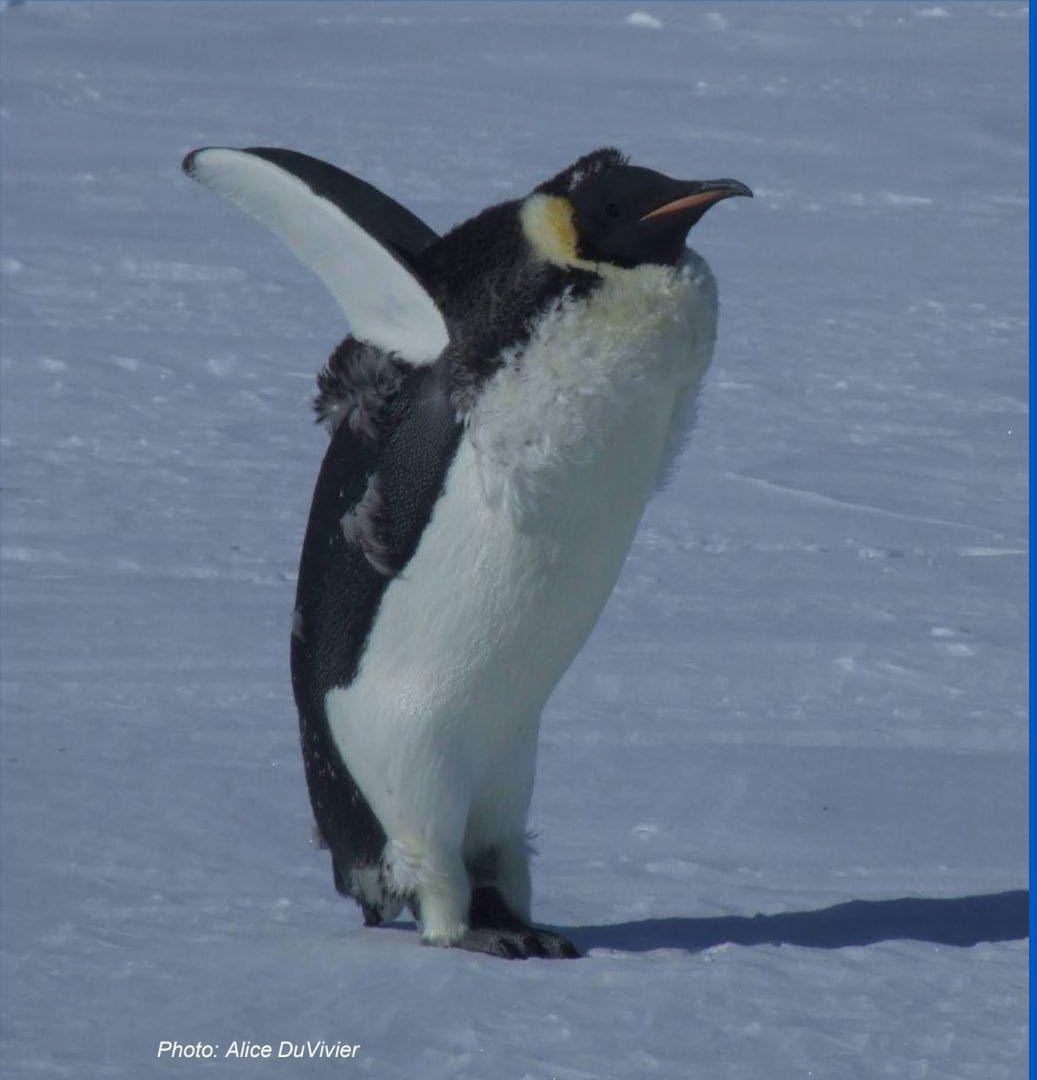
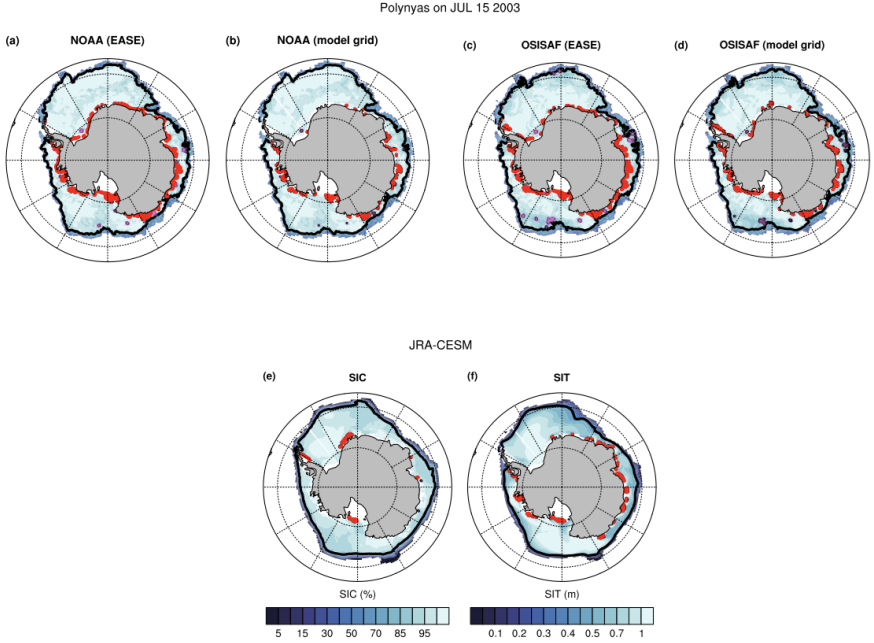


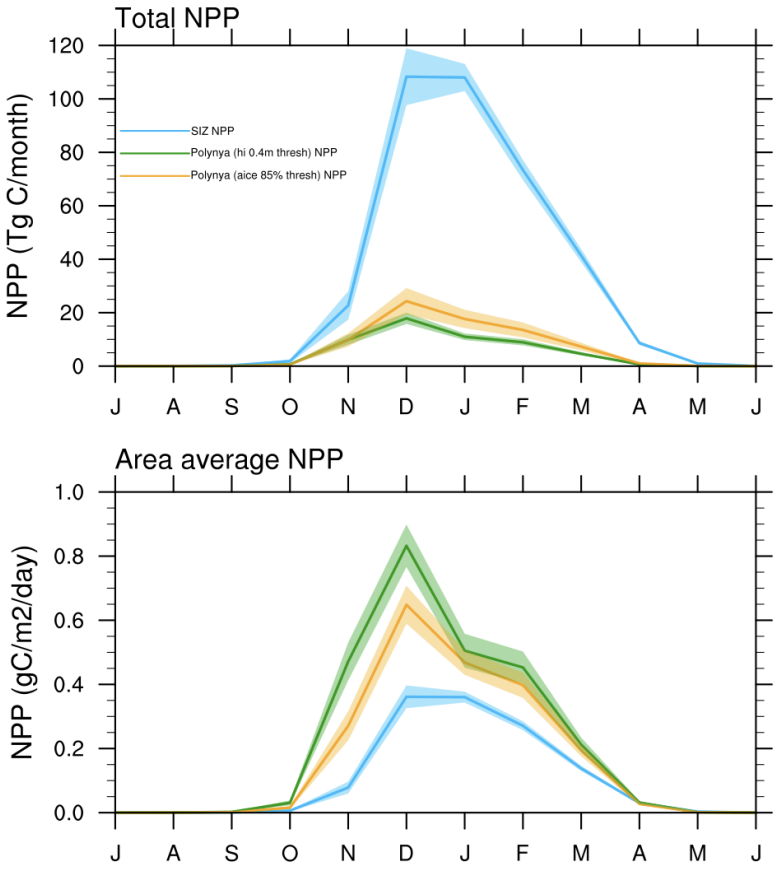
Photo: Alice DuVivier

Thank you for listening!

Questions?

SIC & Polynyas: Landrum et al. 2026





SIC & NPP relationship: Landrum et al. in prep

↑High **Spring** SIC

↓Low **Spring** NPP

↑High **Summer** NPP

Spring SIC High ↑

↓

Spring light low

↓

Spring NPP Low↓

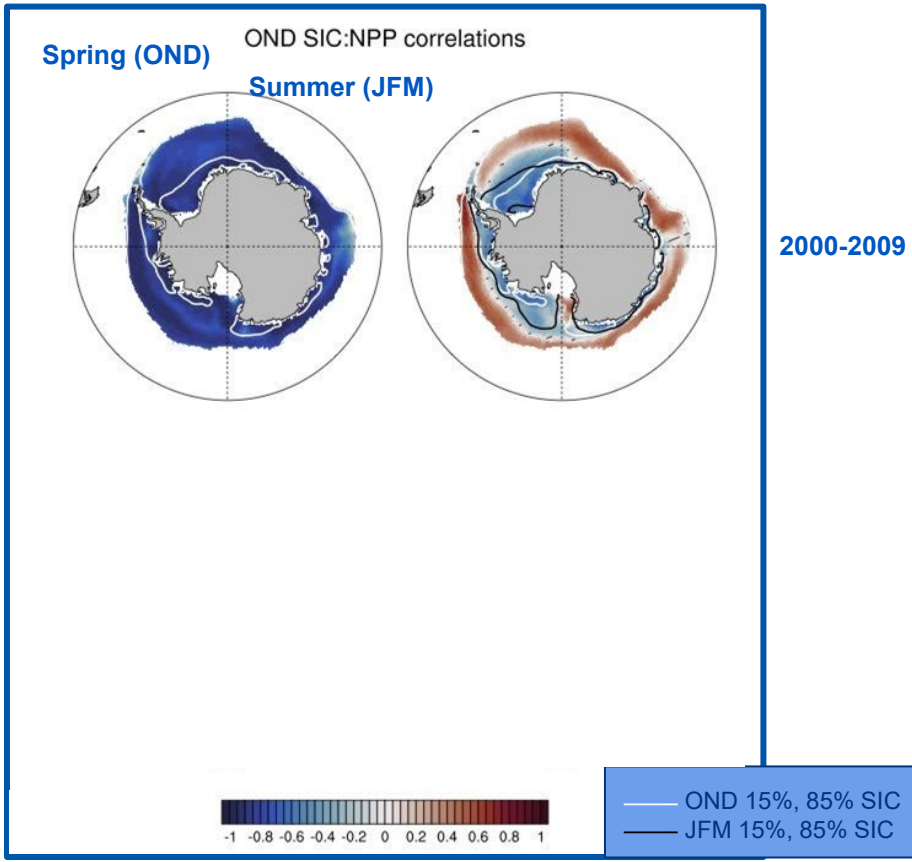
↓

Summer nutrients (Fe) high

↓

Summer NPP high ↑

OND SIC:NPP correlation
CESM2-LE (50 members)



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Spring SIC High ↑

↓

Spring light low

↓

Spring NPP Low↓

↓

Summer nutrients (Fe) high

↓

Summer NPP high ↑

This relationship remains robust through 21st century

OND SIC:NPP correlation
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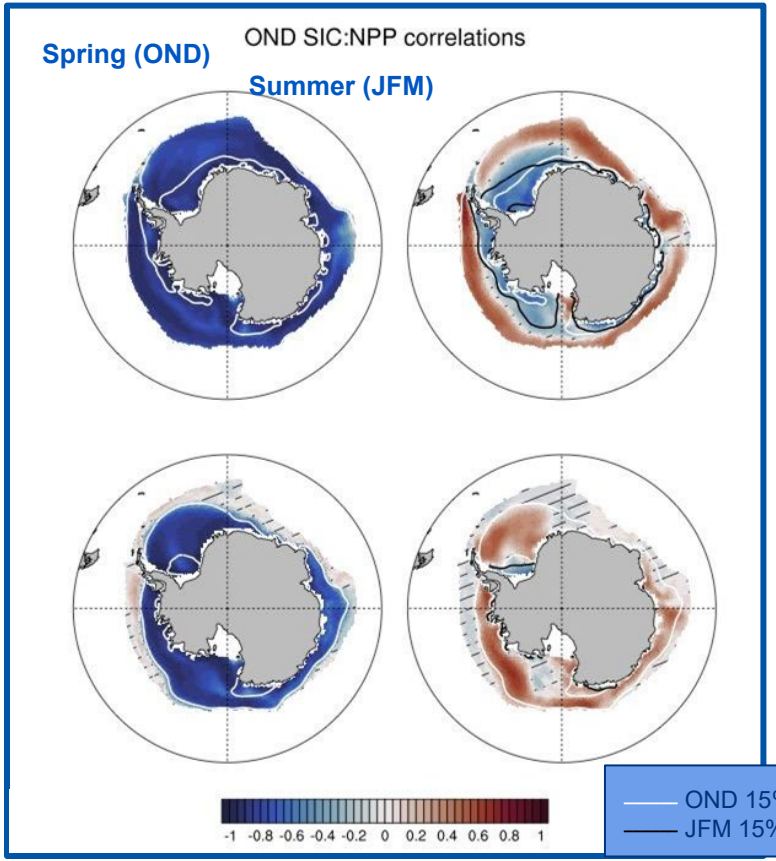
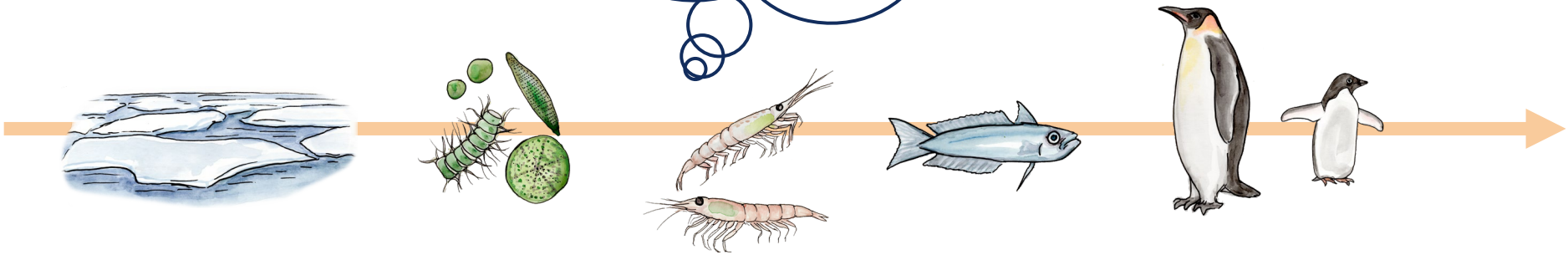


Time of Emergence: Sea ice and ecosystem components

Hypothesis:
The ecosystem is largely controlled by sea ice.
Sea ice will emerge first.

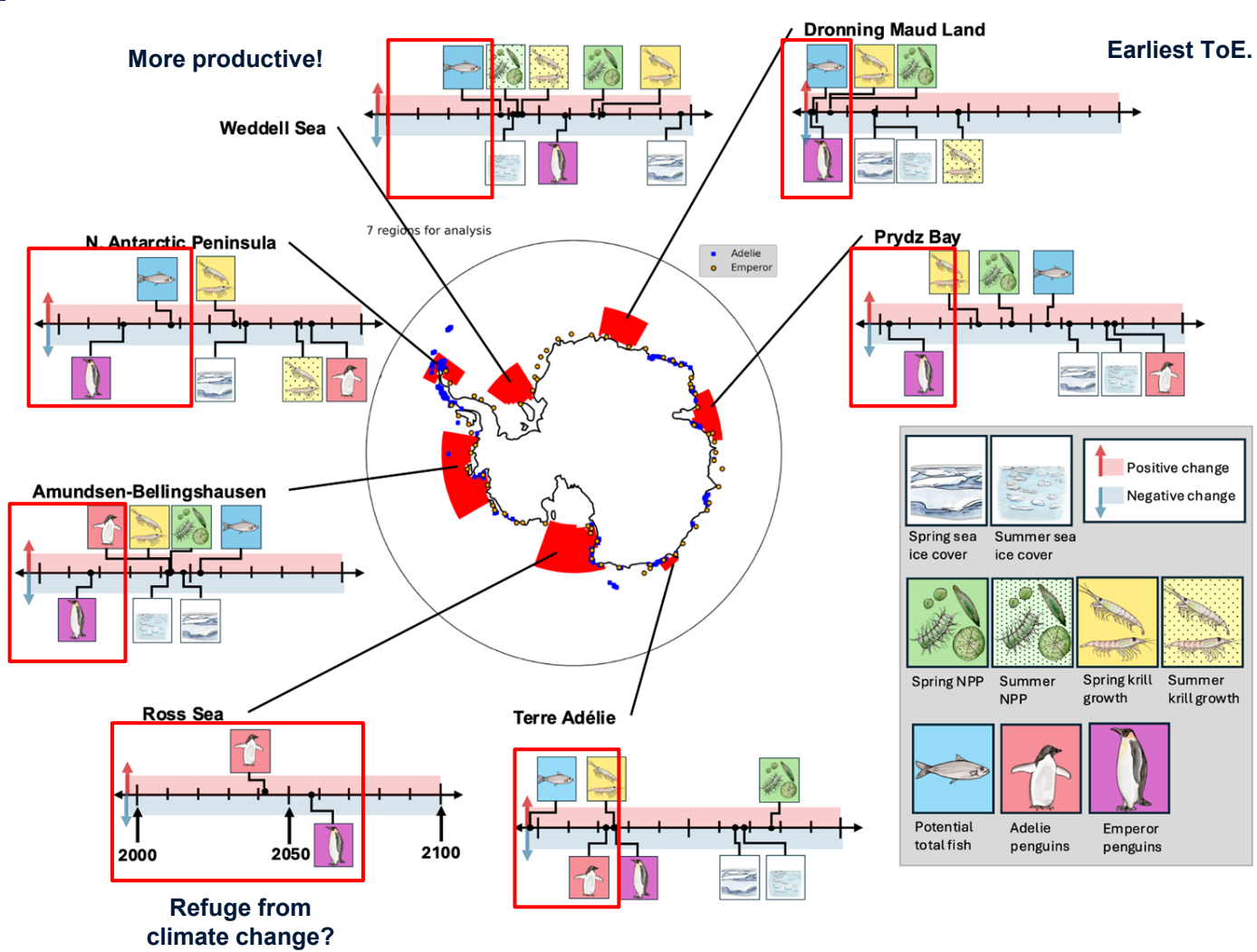


Krumhardt et al. 2026 (Nat.Clim.Chg.)
https://doi.org/10.1038/s41558-026-02561-9

Time of Emergence by region

Changes in either penguins and fish emerge first! - **biotic multipliers**

Minor changes in, e.g., sea ice or ocean temperatures, can have a big effect penguin or fish vital rates (growth, survival, reproduction).

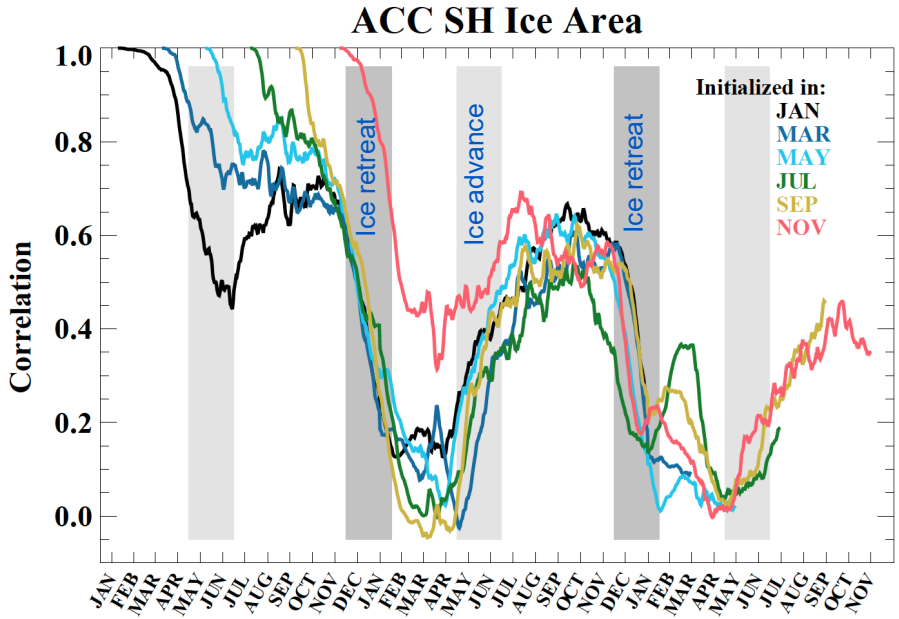


Predictability of sea ice and ecosystem conditions

Sets of CESM2 “perfect model” initialized predictions

- 2-year “predictions” with 75 ensemble members
- Initializations performed for the first of Jan, March, May, July, Sept and Nov
- Initialized with CESM2-LE conditions with pertlim perturbation

Complemented with analysis of CESM2-LE



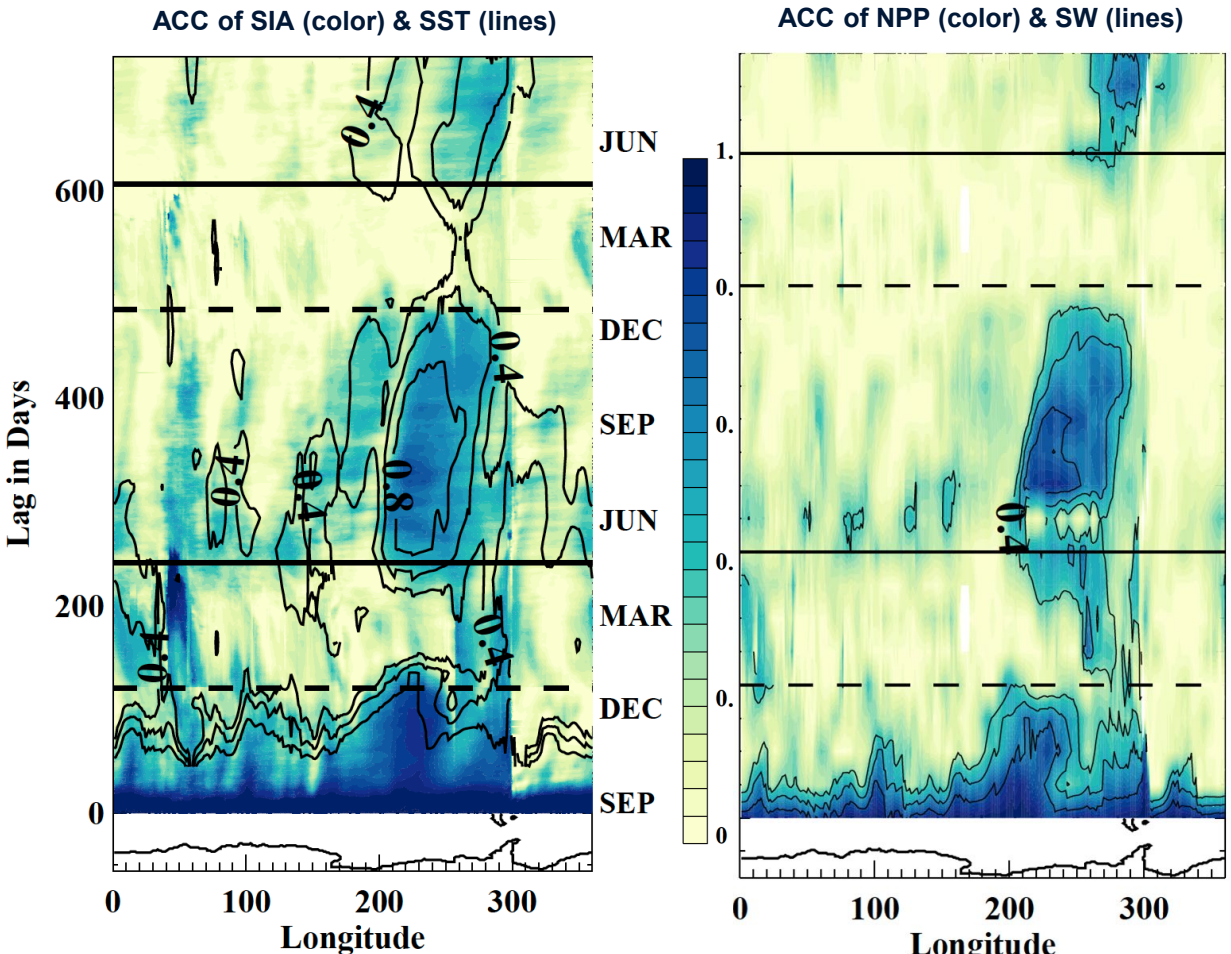
Total hemispheric ice area predictability

- High throughout winter
- Declines during spring ice retreat
- Low in summer
- Re-emerges in 2nd winter

Mostly independent of initialization month

Holland et al. 2025 (J.Clim)
https://doi.org/10.1175/JCLI-D-24-0258.1

Regional Sea Ice and NPP Predictability



September initialization shown. Other initialization months have similar characteristics.

Similar results for KGP.

NPP ACC is very similar to SIC. SI predictability imparts predictability on NPP. At least in Ross/Belingshausen Seas.