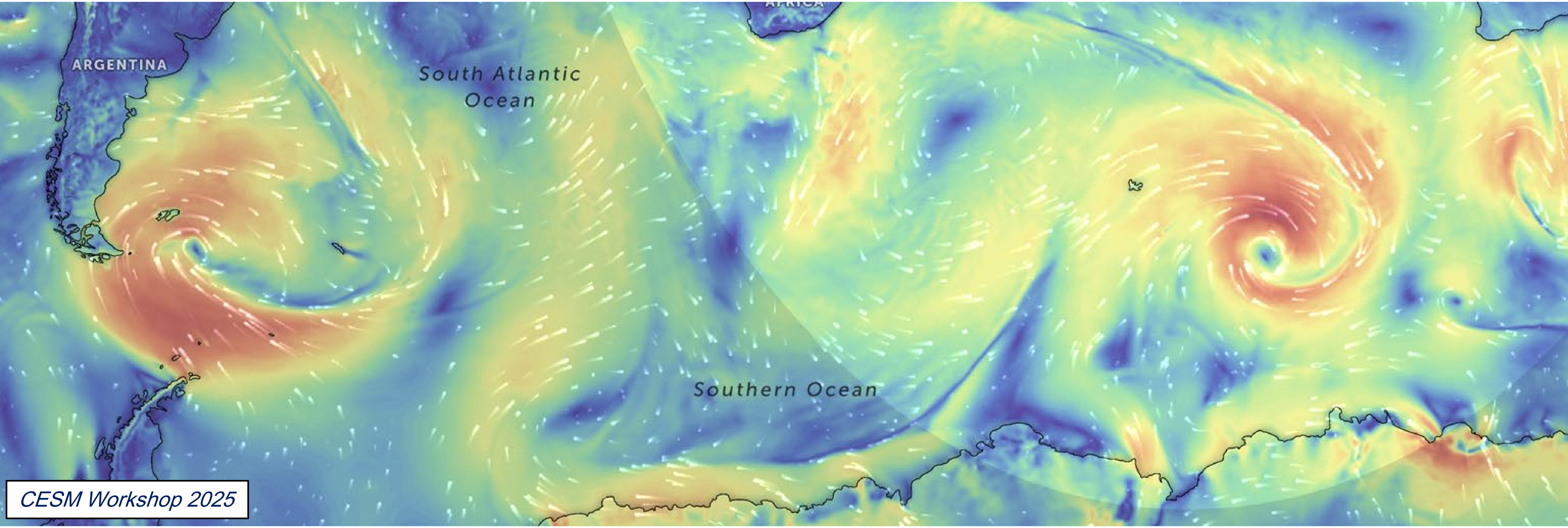
The imprint of Southern Ocean storms on modeled surface chlorophyll, their drivers and satellite biases

https://zoom.earth/maps/wind -speed/ (May 19, 2025)



km/h 0 20 40 60 80 100 120

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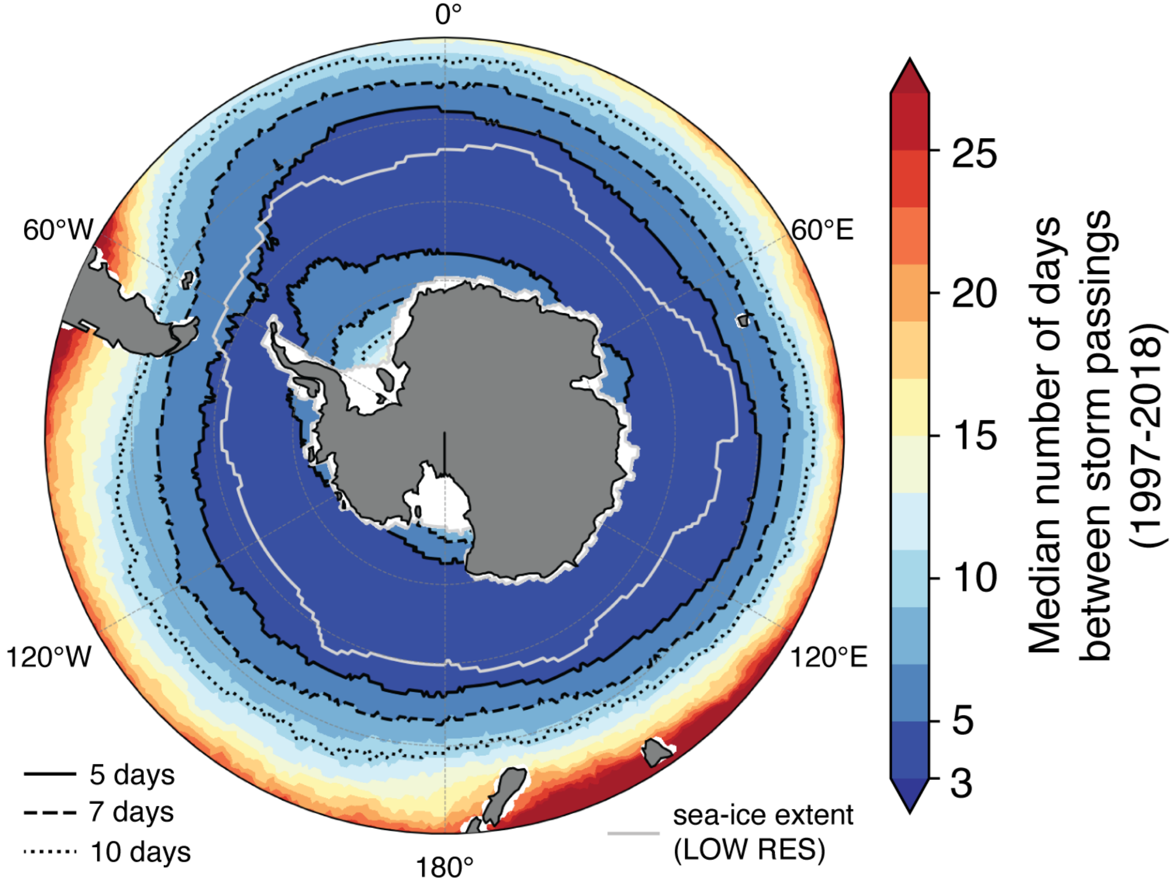
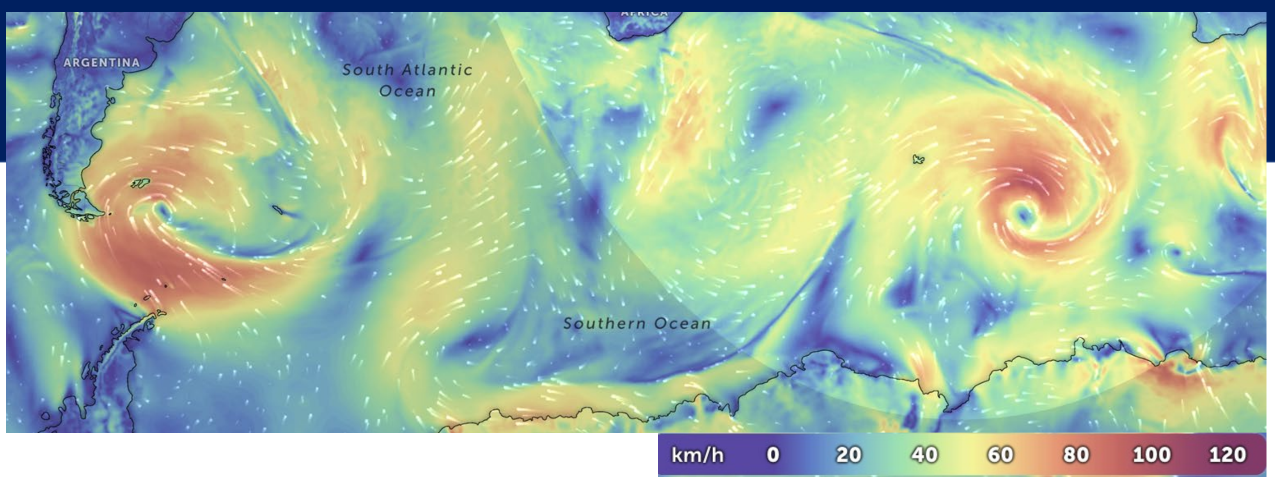
Why storms in the Southern Ocean?





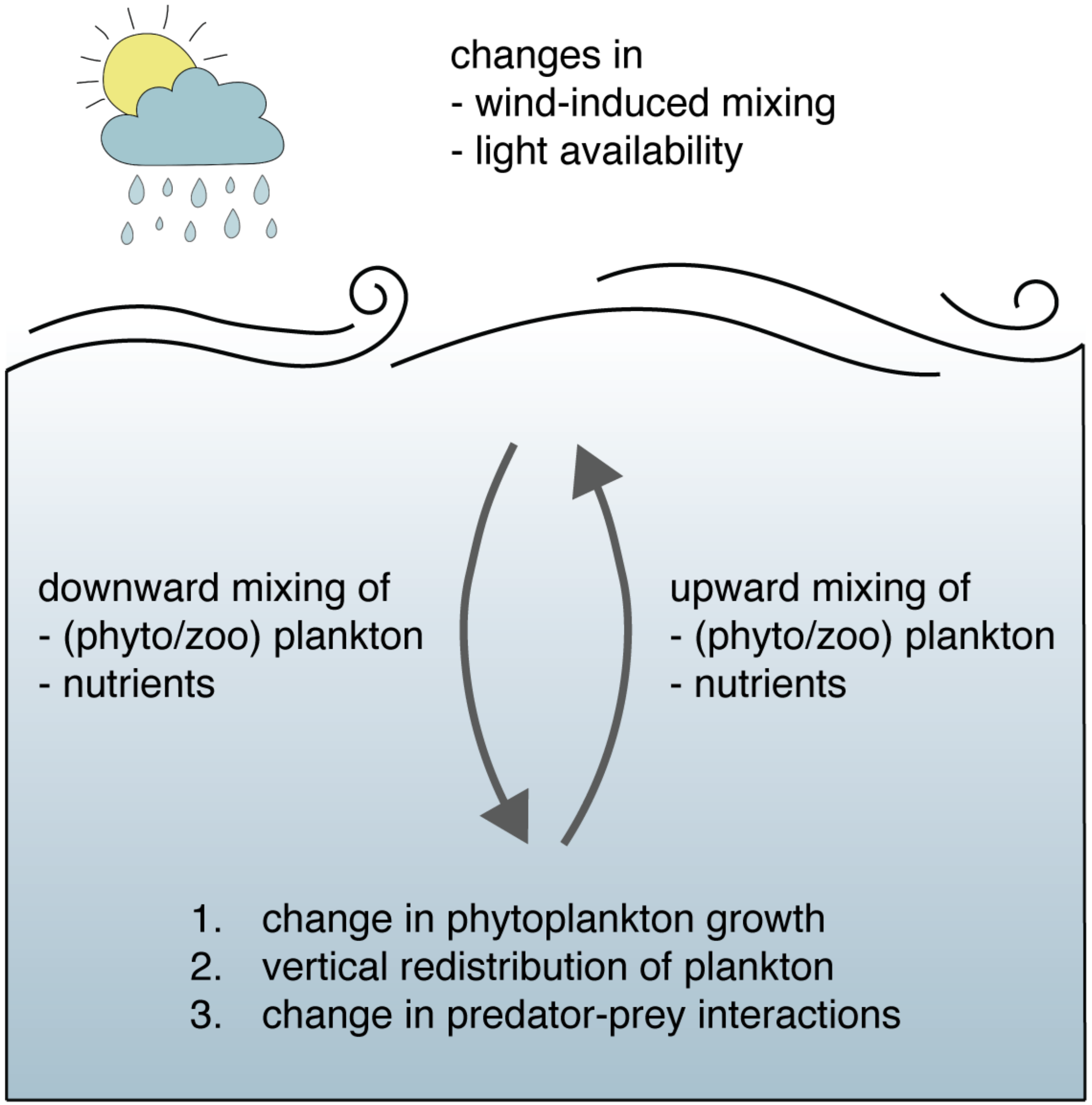
Storms are omnipresent in the Southern Ocean.

How are ocean (biogeochemical) properties impacted?

Based on JRA sea level pressure (Tsujino et al., 2018) and Tempest Extremes storm tracking (Ullrich et al., 2021)

Nissen et al. (2025), in review, Global Biogeochemical Cycles

Storms impact phytoplankton dynamics through various processes



How do storms contribute to sub-seasonal variability of chlorophyll and biological carbon cycling?

Nissen et al. (2025), in review, Global Biogeochemical Cycles

How to quantify the oceanic signature of storms?

Japanese Reanalysis (JRA)

Tsujino et al. (2018)

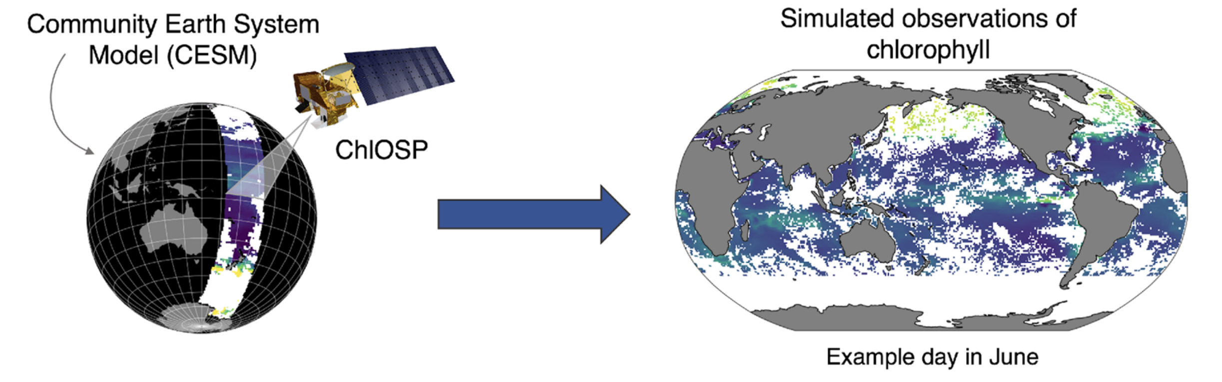
TEMPEST EXTREMES

Ullrich et al. (2021)

Community Earth System Model v2.2
Ocean – sea ice – biogeochemistry setup

Danabasoglu et al. (2020)
Clow et al. (2024, 2025) ⍰ LOW RES
Krumhardt et al. (2024) ⍰ HIGH RES (not in this talk)

Synthetic observations from satellite emulator

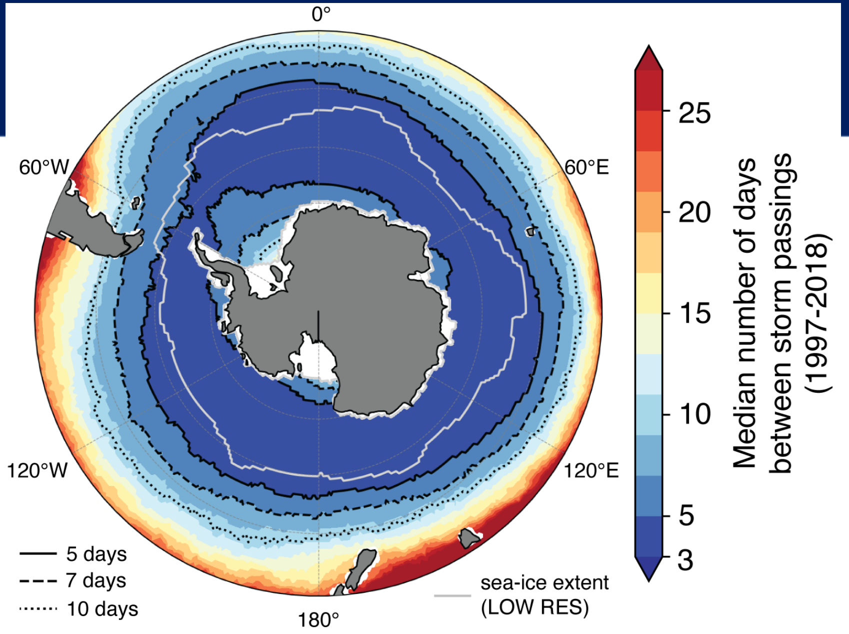


Clow et al. (2024, 2025)

Nissen et al. (2025), in review, Global Biogeochemical Cycles

How to quantify the oceanic signature of storms?

Goal: Isolate variability on synoptic time scales in the storm-impacted area, i.e., within a 1000 km radius around each storm center



Step 1: Subtract daily climatology from daily-averaged CESM output fields to isolate non-seasonal variability.

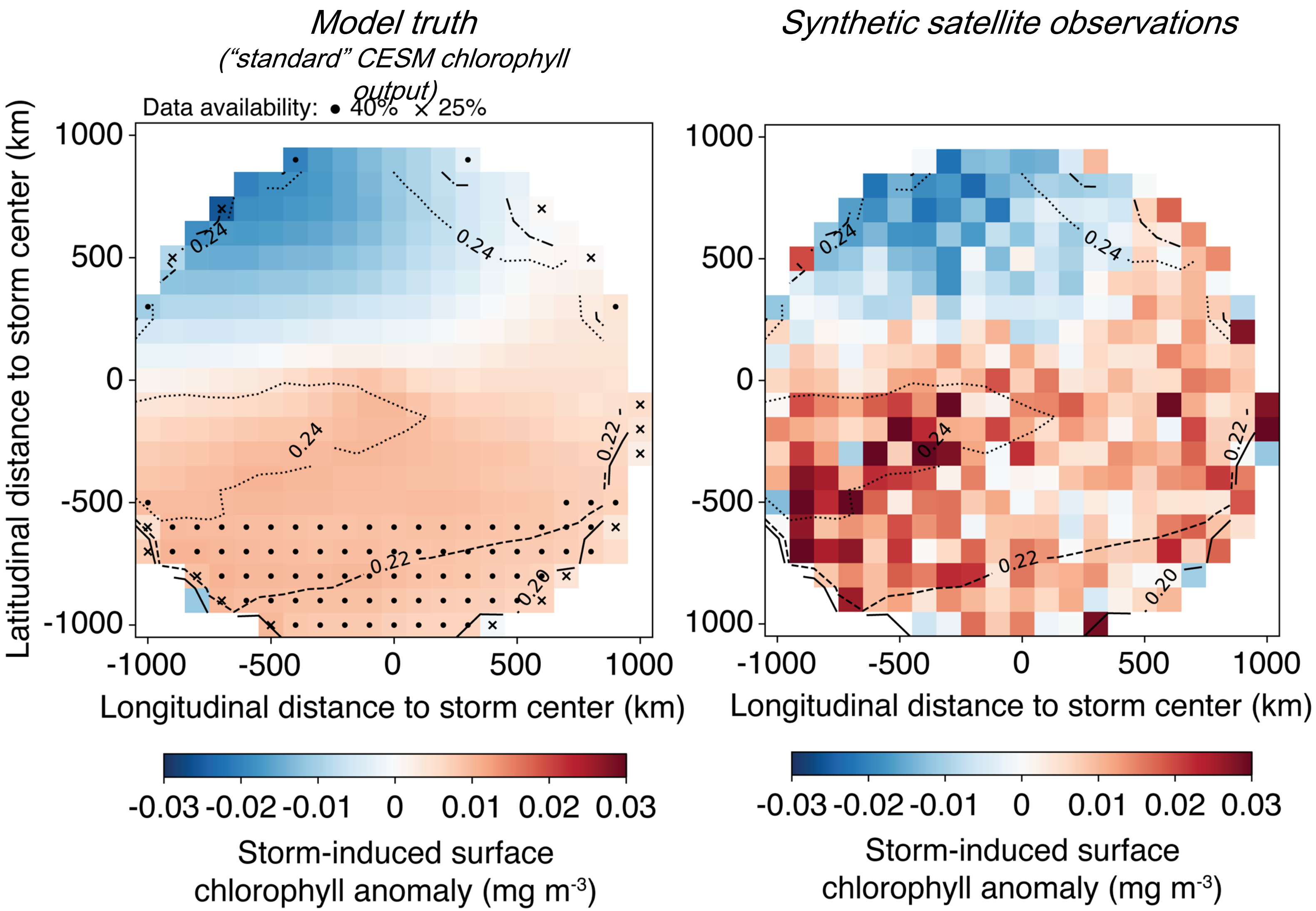
Step 2: Average the anomalies remaining after step 1 over the *five days* preceding the storm passage (→ pre-storm conditions).

Step 3: Subtract pre-storm conditions (step 2) from the non-seasonal variability (step 1) to isolate variability on synoptic time scales.

- 1997-2018
- Southern Ocean south of 40°S
- ice-free waters only
- 9554 storms to analyze

Nissen et al. (2025), in review, Global Biogeochemical Cycles

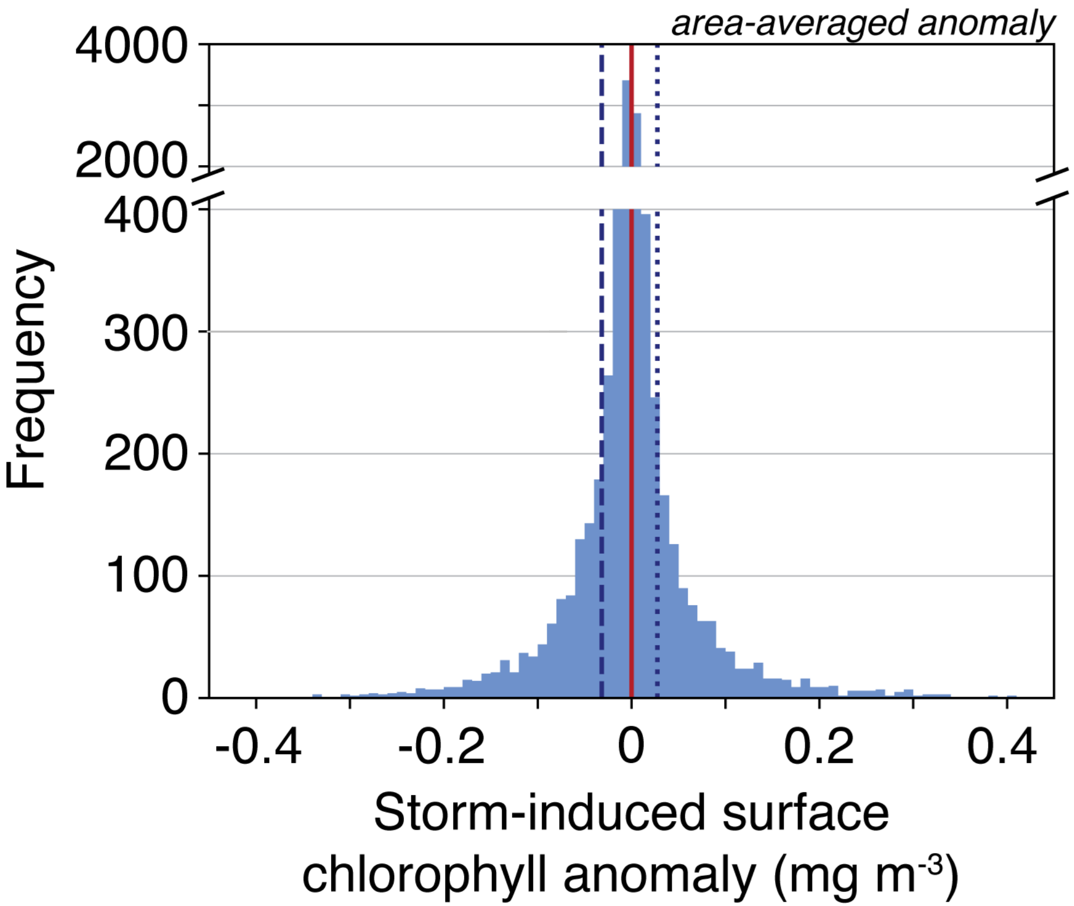
Averaged over all storms, the imprint on surface phytoplankton is small.

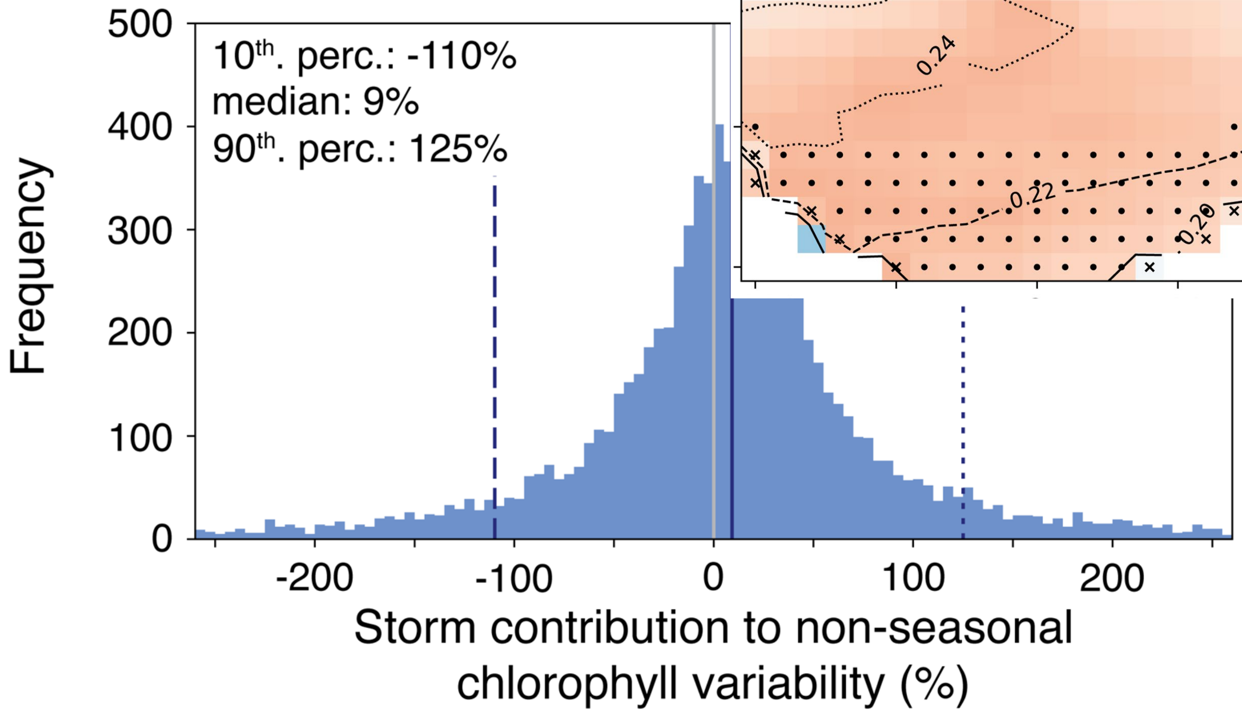


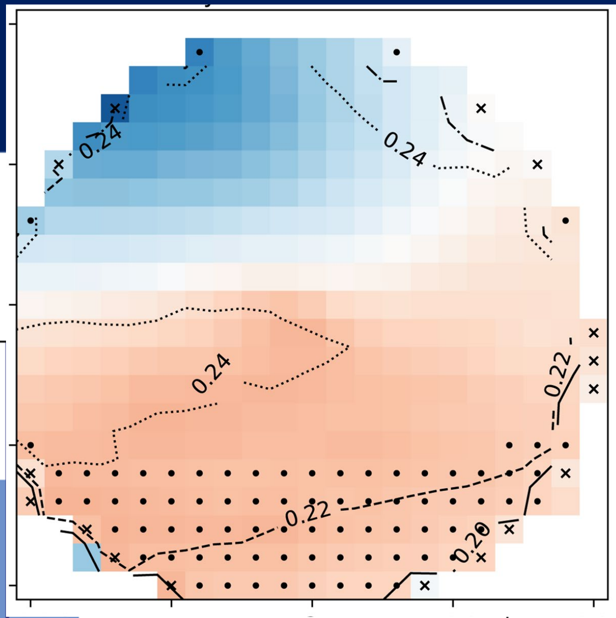
Synthetic satellite observations broadly capture the sign and the pattern.

Nissen et al. (2025), in review, Global Biogeochemical Cycles

Variability in storm -induced chlorophyll anomalies is large.





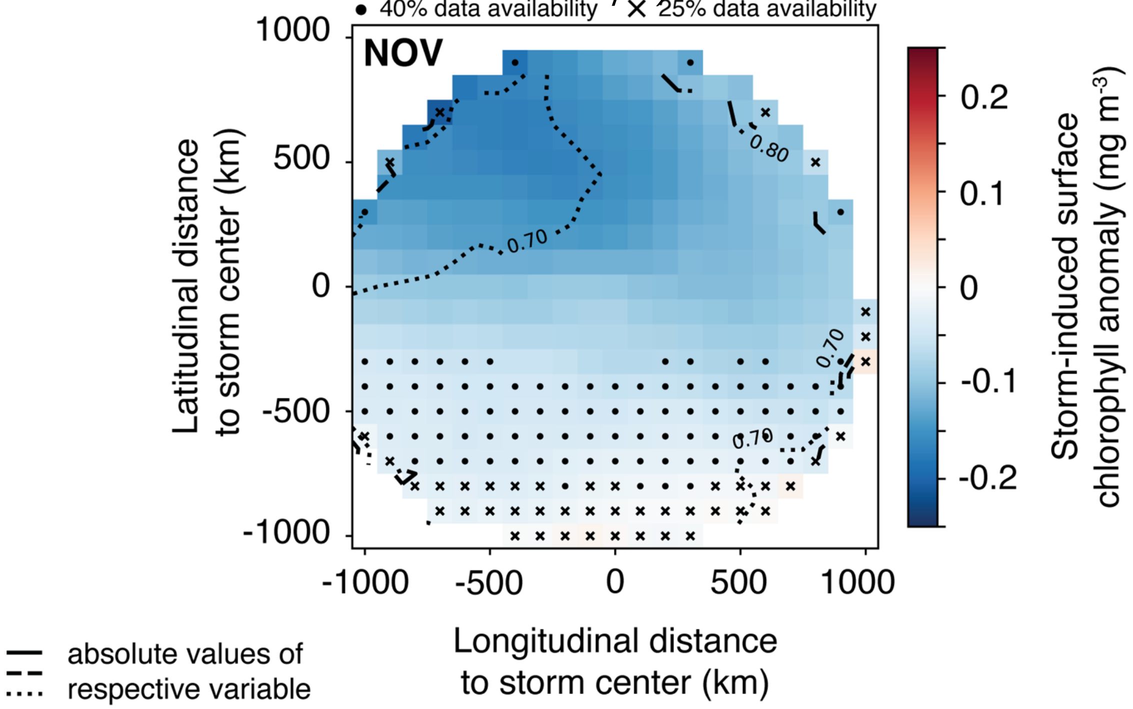


More than 1/3 of storms explain most of the non-seasonal chlorophyll variability.

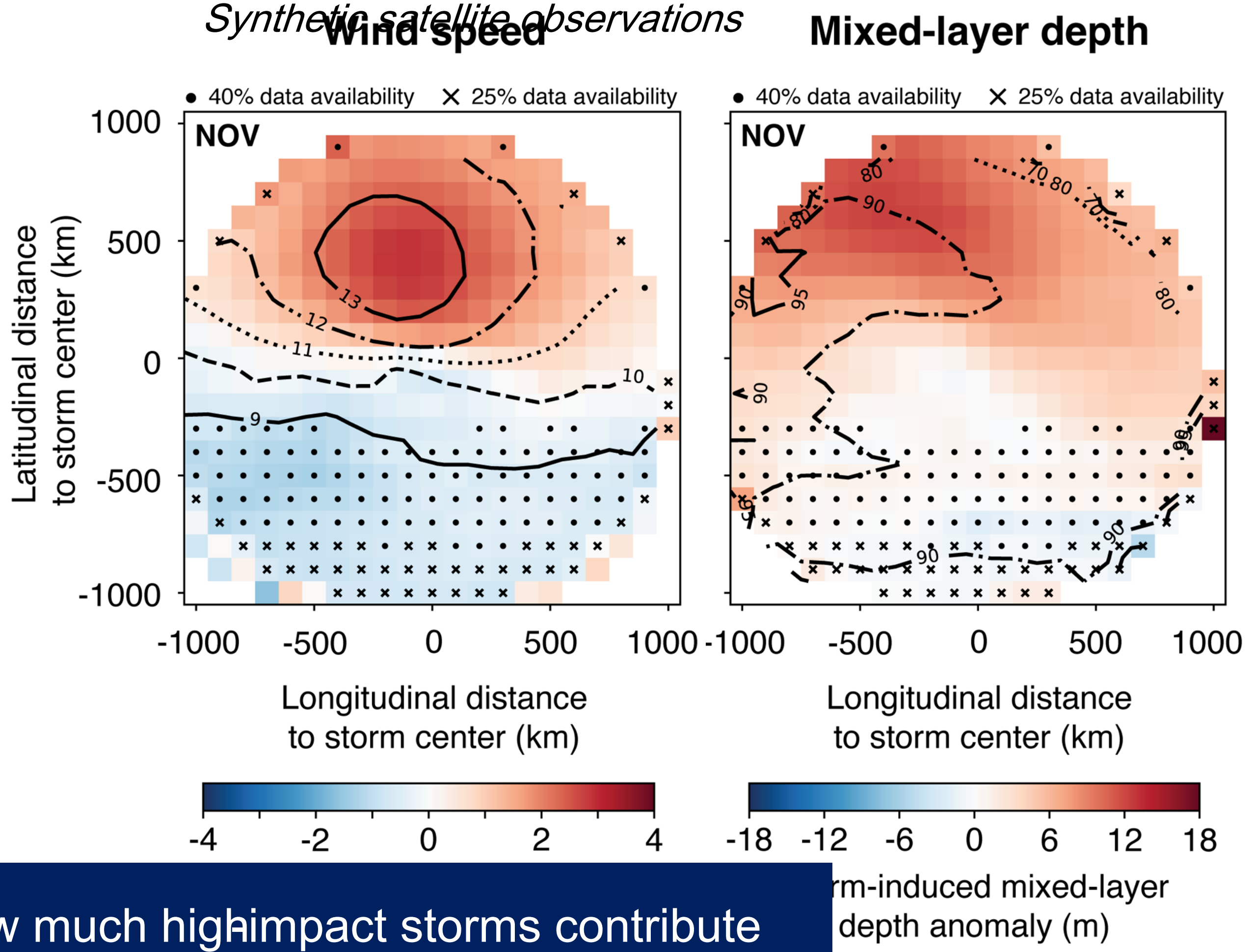
Nissen et al. (2025), in review, Global Biogeochemical Cycles

A subset of storms: storms lower surface chlorophyll by enhancing mixing

Model truth
("standard" CESM chlorophyll output)

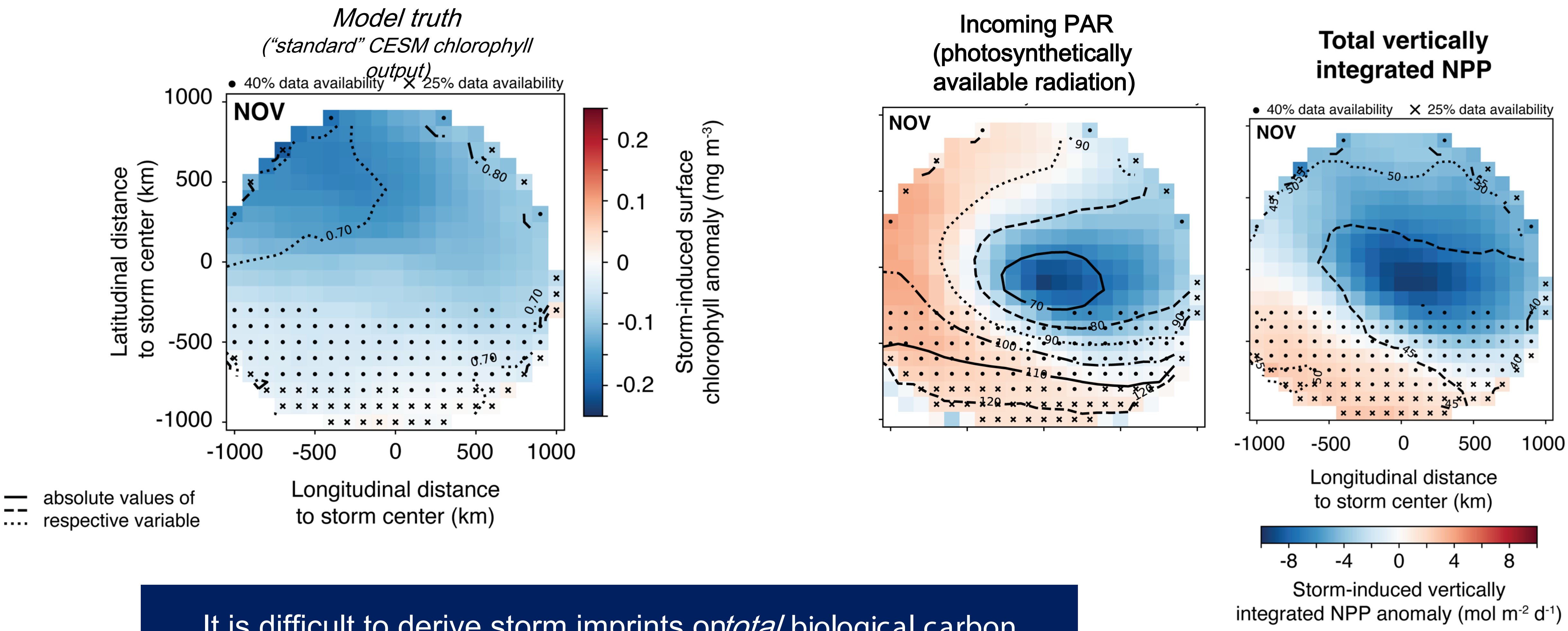


Synthetic satellite observations



Our ability to quantify how much high-impact storms contribute to local chlorophyll variability is limited with satellite data.

Can surface chlorophyll inform on integrated net primary production (NPP)?



It is difficult to derive storm imprints on *total* biological carbon cycling based on satellite-derived surface chlorophyll data alone.

Nissen et al. (2025), in review, Global Biogeochemical Cycles

Summary

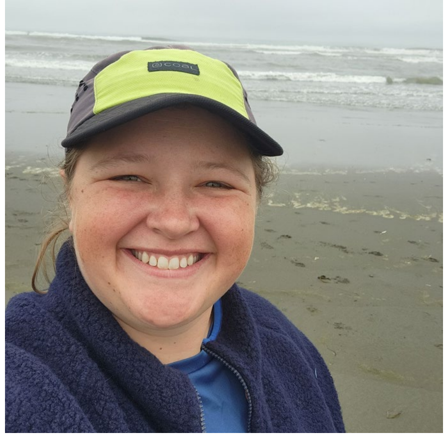
The imprint of Southern Ocean storms on surface chlorophyll, their drivers and satellite biases

Cara Nissen[1,2], Genevieve L. Clow[1], Nicole S. Lovenduski[1], Katherine E. Turner[3], Magdalena M. Carranza[4], Kristen M. Krumhardt[5]

in review, Global Biogeochemical Cycles

1. More than 1/3 of storms explain most of the non-seasonal chlorophyll variability.
2. Synthetic satellite observations broadly capture the sign and the pattern of storm-induced chlorophyll anomalies.
3. For high-impact storms in spring, downward mixing of biomass and reduced light availability dominate the chlorophyll response.
4. It is difficult to derive storm imprints on *total* biological carbon cycling based on satellite-derived surface chlorophyll data alone.

Katy Christensen



Using floats to detect storm imprints in the Southern Ocean
(on-going DOE-funded project)

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