Using CICE5 to explore Barents-Kara sea ice variability from synoptic to seasonal timescales

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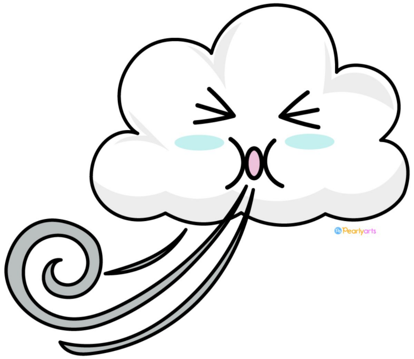
We focus on atmospheric circulation → Barents-Kara sea ice changes in winter

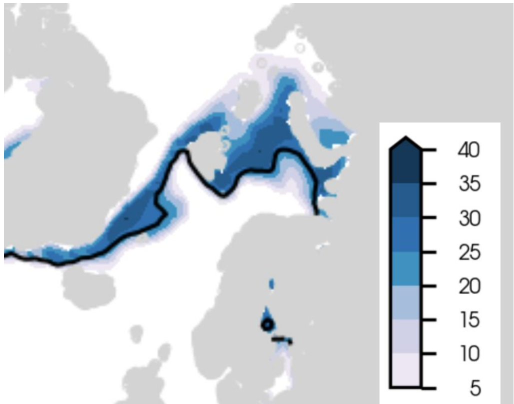
e.g., Fang and Wallace 1994; Deser et al. 2000

Atmospheric circulation

Arctic sea ice changes

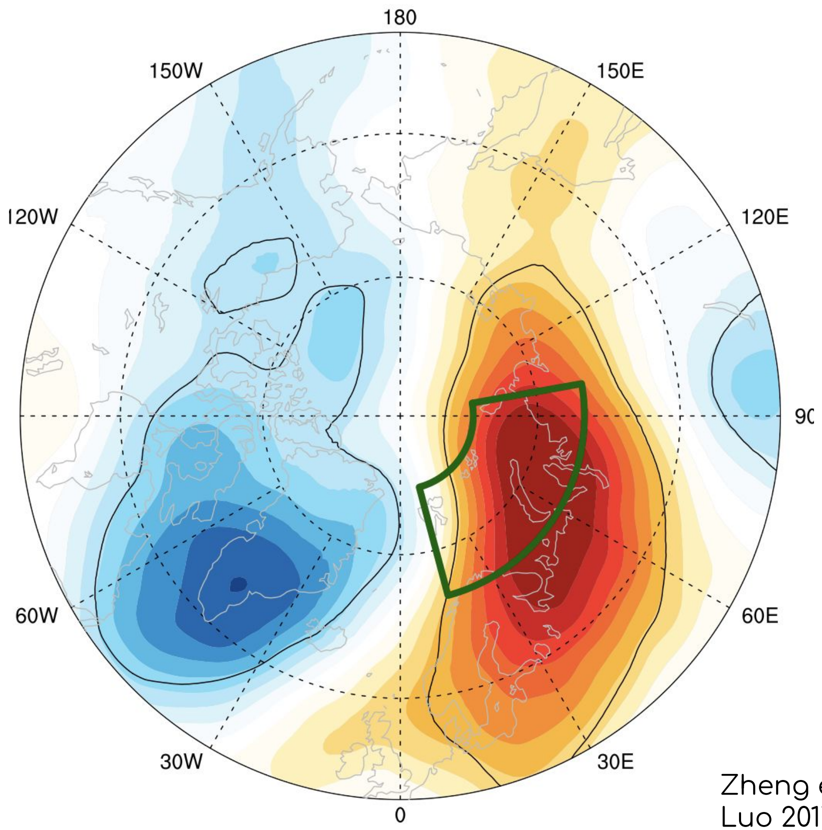


Barents and Kara Seas in DJFM



DJFM daily SIC standard deviation

Q1: What are the important circulation patterns that drive Barents-Kara sea ice changes?

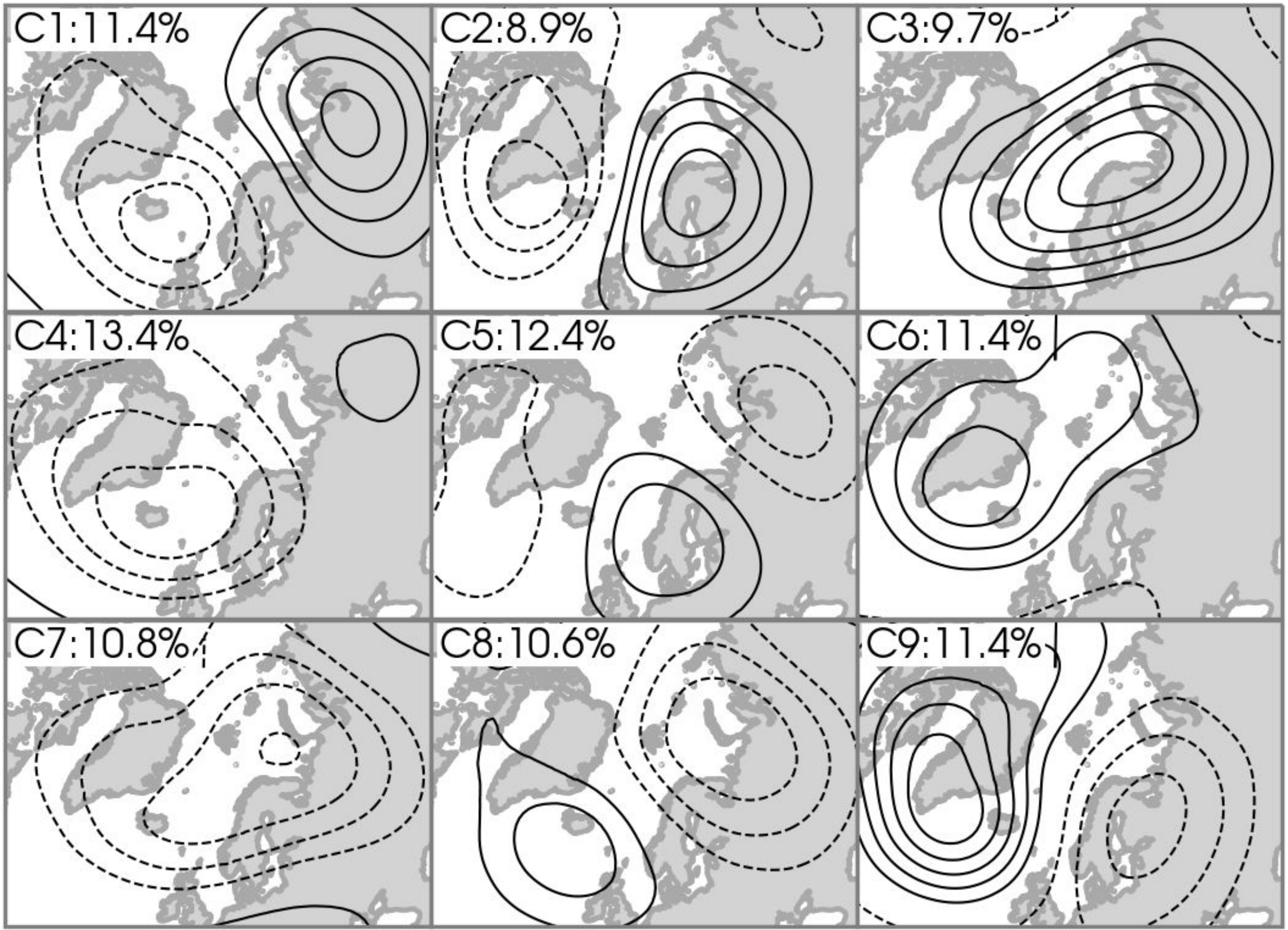


A typical circulation pattern that drives Barents-Kara sea ice loss

Zheng et al. 2022 (also Park et al. 2016; Luo and Luo 2017) and so on

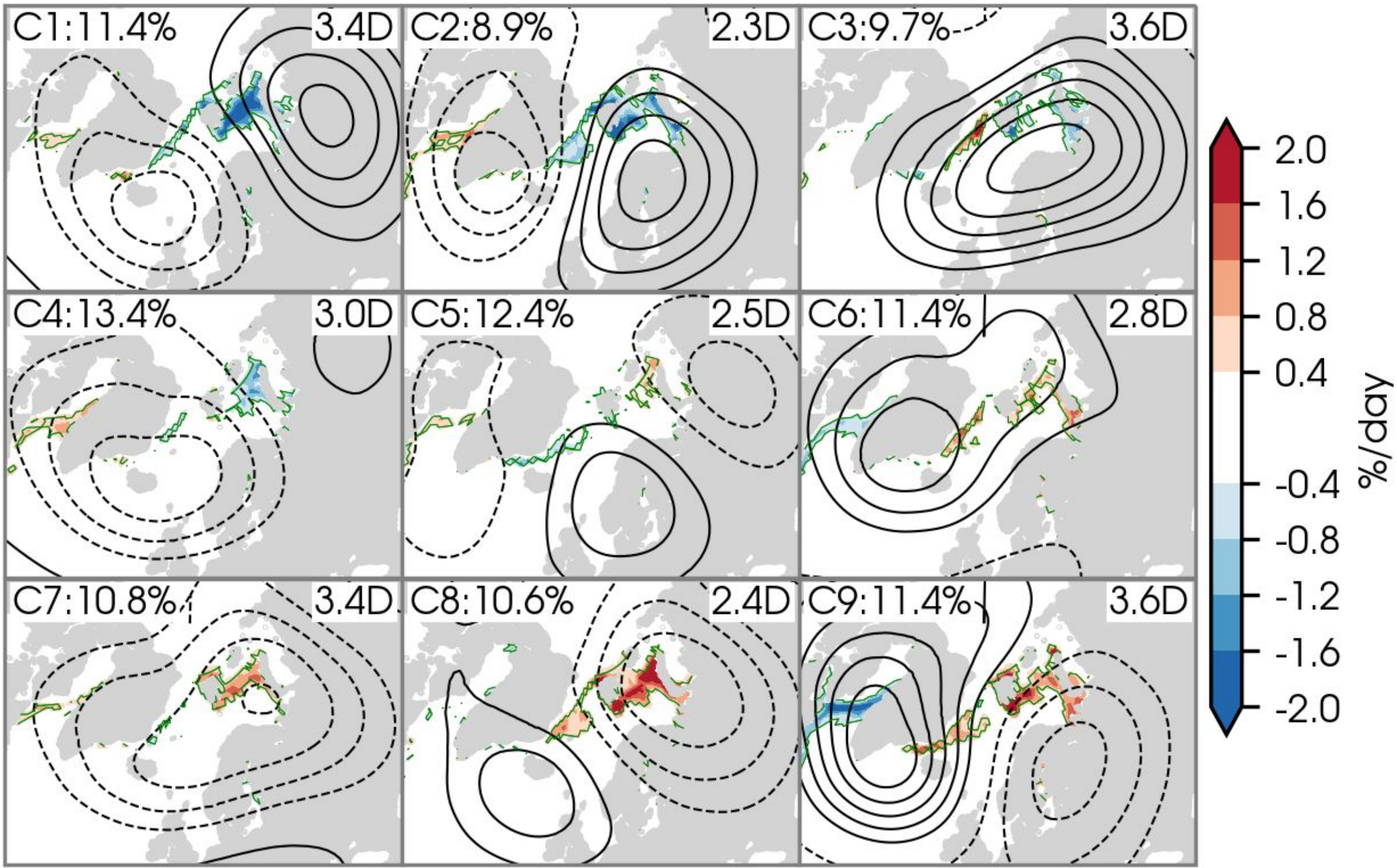
⇒ We use self-organizing maps (SOM) to get all daily circulation patterns. We chose a 3x3 array size.

The SOM result reveals nine high-latitude circulation patterns in the cold season



Z500; 40m intervals; zero line omitted

All patterns are associated with day-to-day sea ice changes to some extents



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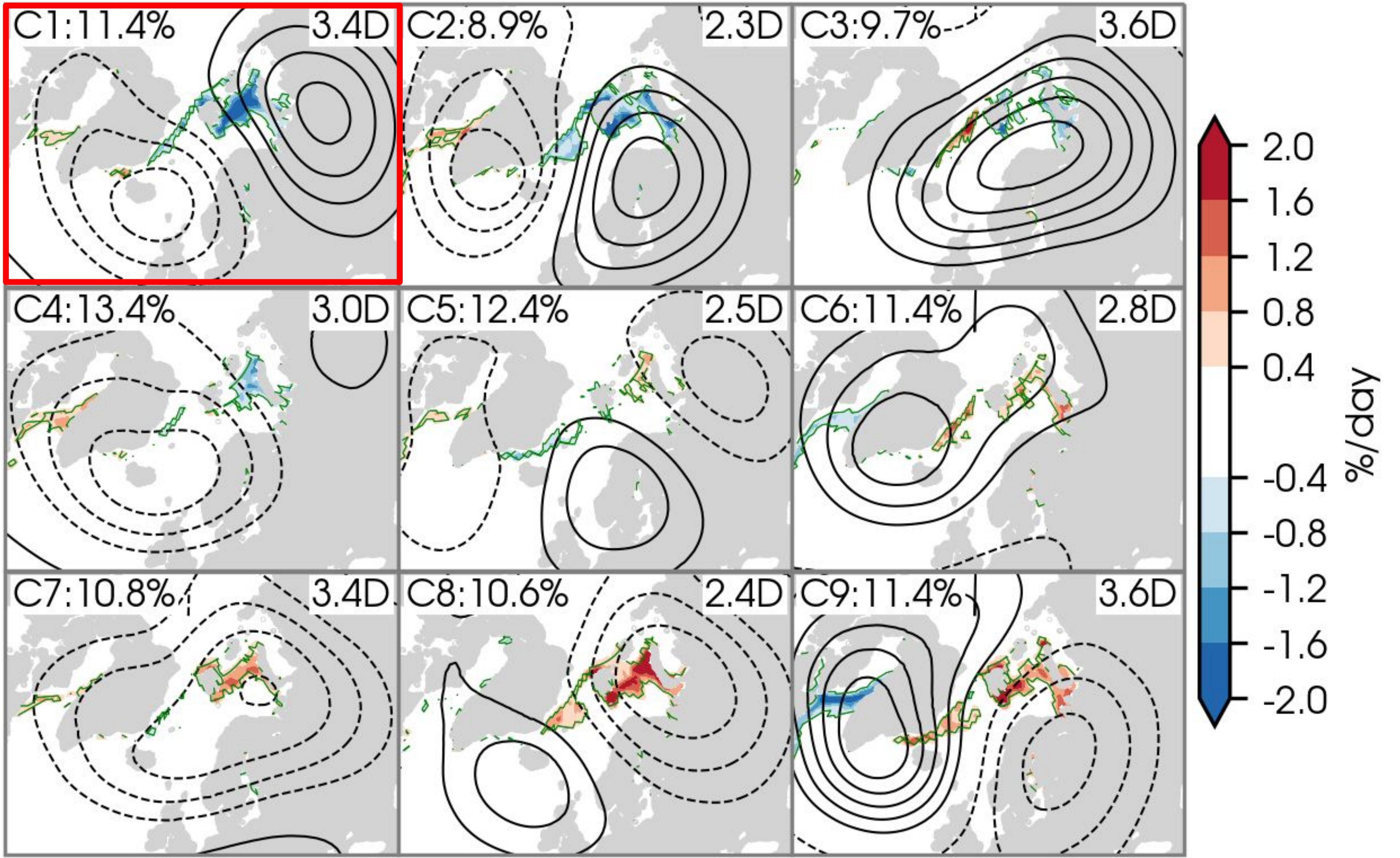
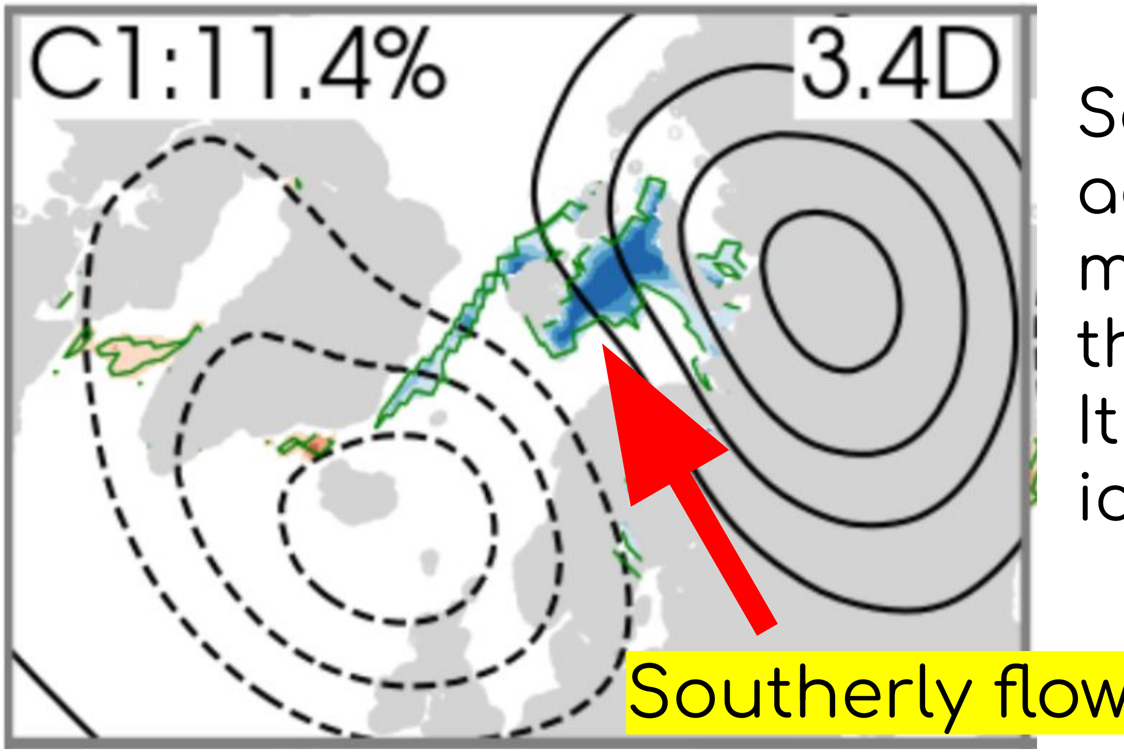


Q2: Ice changes via dynamics versus thermodynamics. Which one is stronger?



Southerly flow advects heat and moisture to melt the sea ice.
It also pushes sea ice northwards!

⇒ We use the CICE5 (sea ice component in CESM2) to assess the relative role of the two processes

We force the CICE5 with atmospheric fields from reanalysis. CICE5 simulates the ice changes from dynamic and thermodynamic processes

$$\frac{\partial h}{\partial t} = -\nabla \cdot (\mathbf{u}h) + S_h$$

Sea ice total change

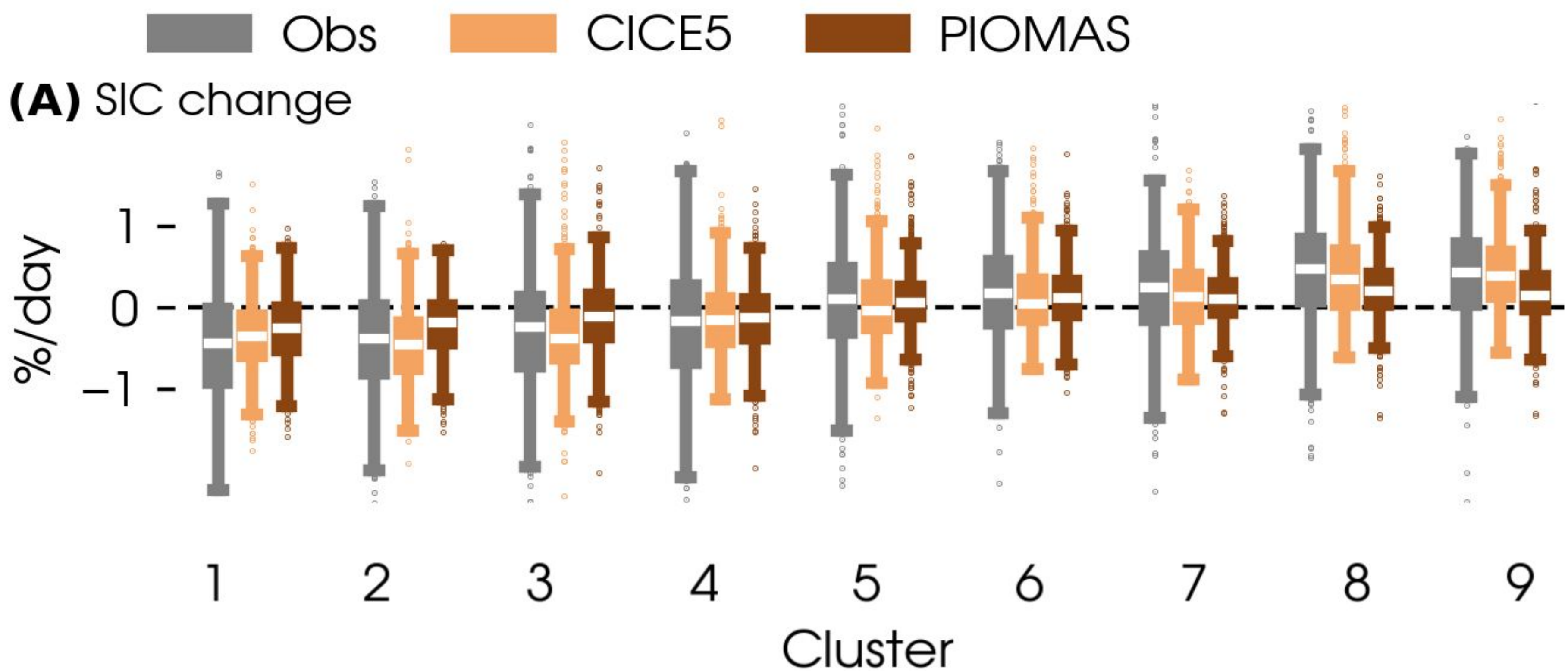
Dynamic change

Thermodynamic change

$$(1-\alpha)F_{SW} + F_{LW} - \sigma T^4 + F_{SH} + F_{LH}$$

Surface layer $+k\frac{\partial T}{\partial z} = -q\frac{dh}{dt}$

Sea ice models largely reproduce the observed sea ice changes

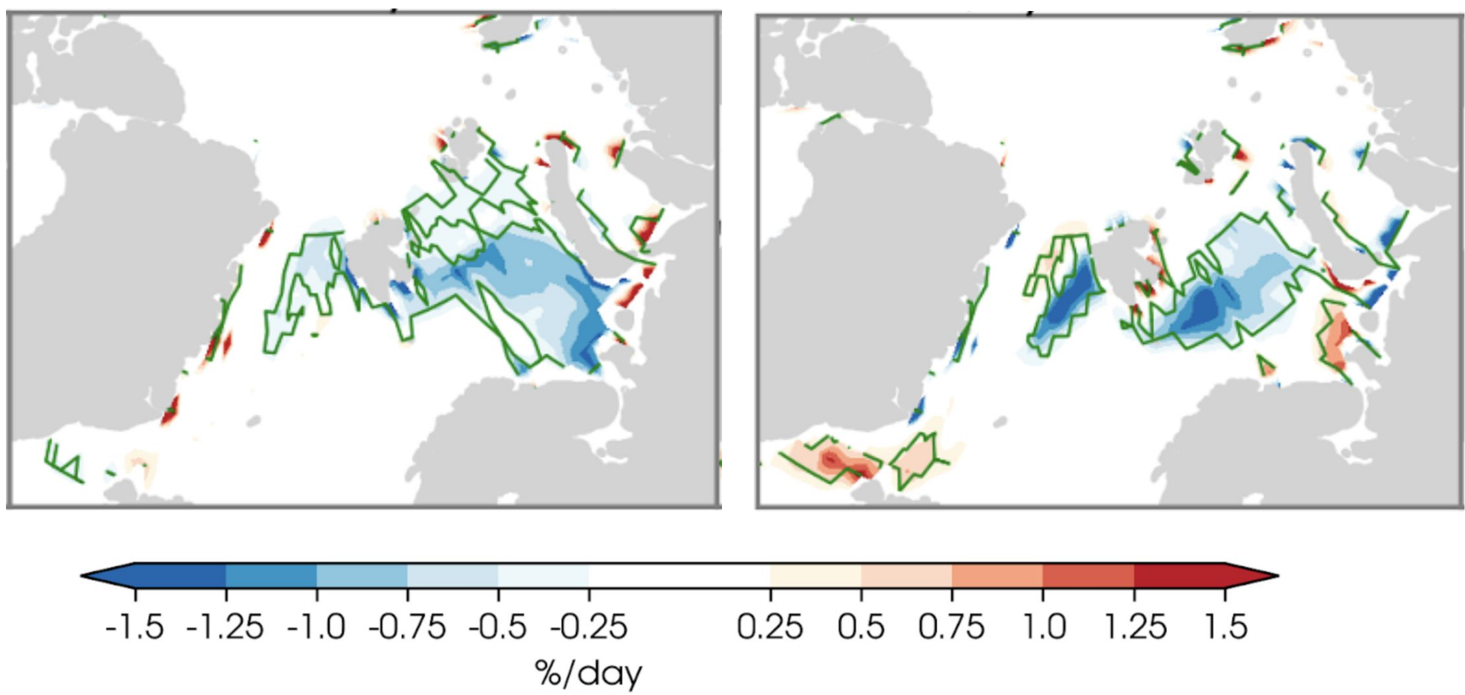


Thermodynamic and dynamic processes similarly contribute to sea ice concentration loss

Thermodynamics

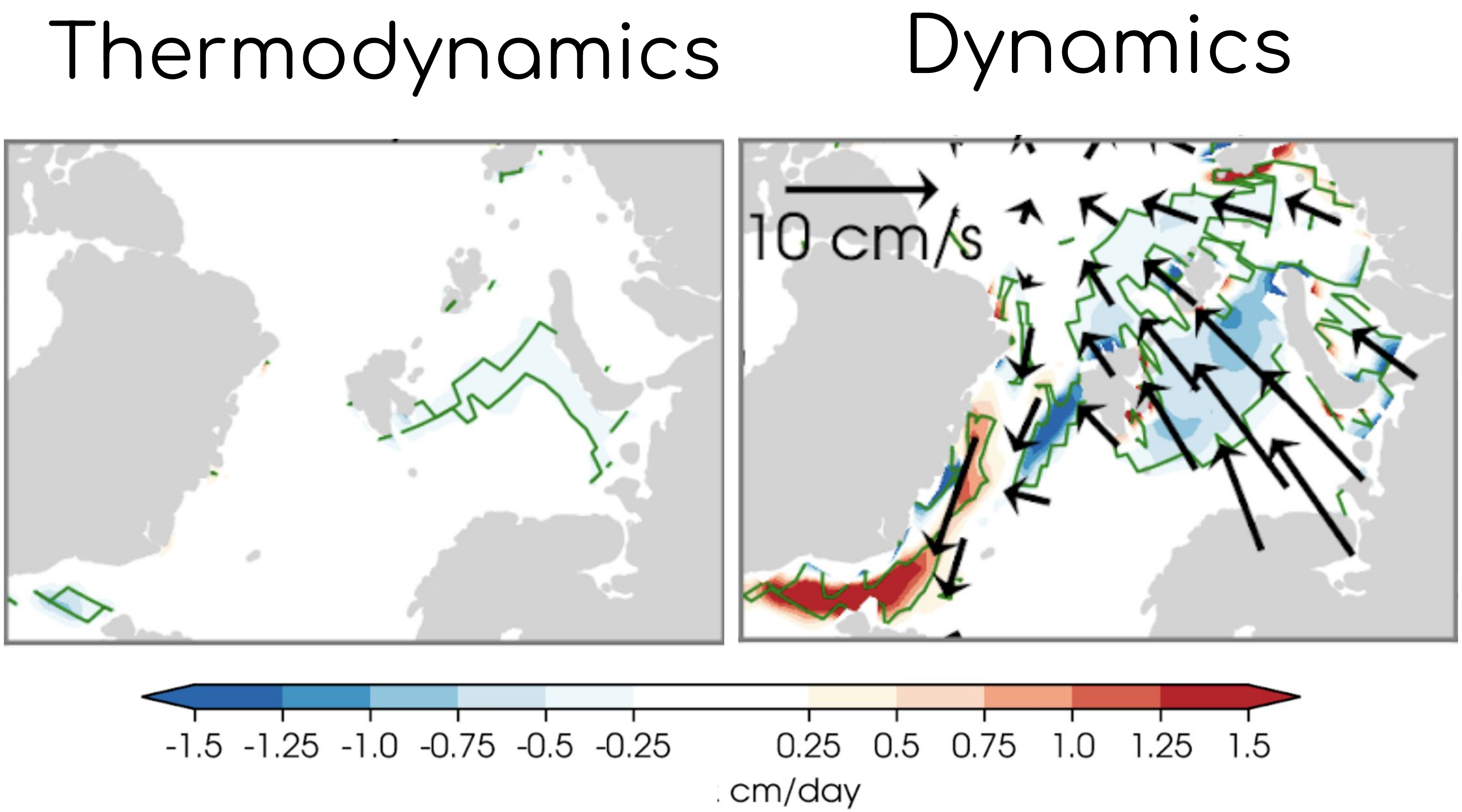
Dynamics

Sea ice concentration changes for cluster 1



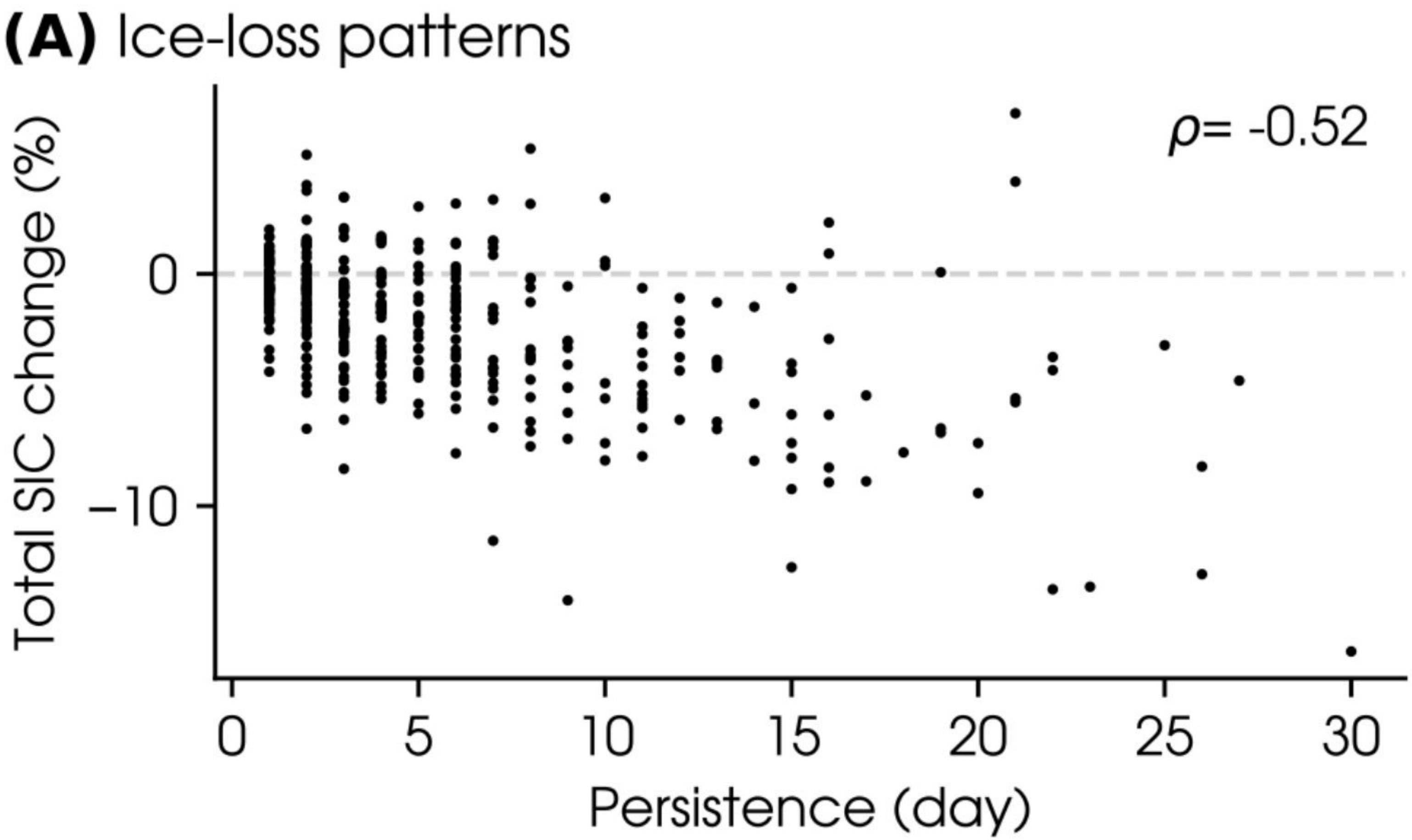
Dynamic processes dominate the sea ice thickness loss

Sea ice thickness (or volume) changes

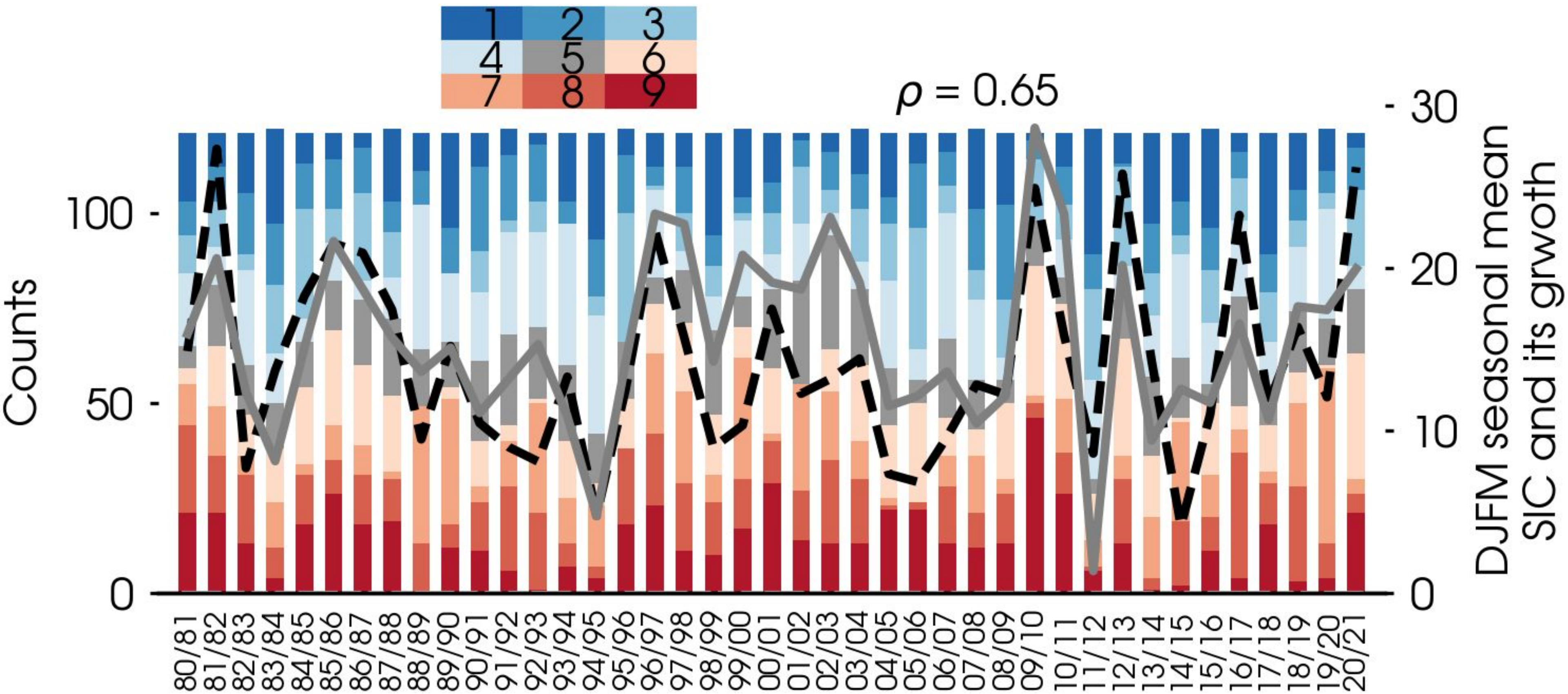


Here only shows the result for SOM cluster 1. Similar results apply to other clusters and PIOMAS

Longer persistence, larger sea ice loss



Persistence of circulation patterns shapes seasonal sea ice concentration



Summary

- The most important circulation pattern for BKS sea ice loss is a high pressure over Urals and a low pressure over Iceland

- Dynamic processes are particularly important for sea ice loss/growth on short time scales

- Daily circulation patterns and their persistence help explain BKS sea ice variability from daily to seasonal timescales