Using CryoSat-2 estimates to analyse sub-grid scale sea ice thickness distribution in HadGEM3 simulations for CMIP6

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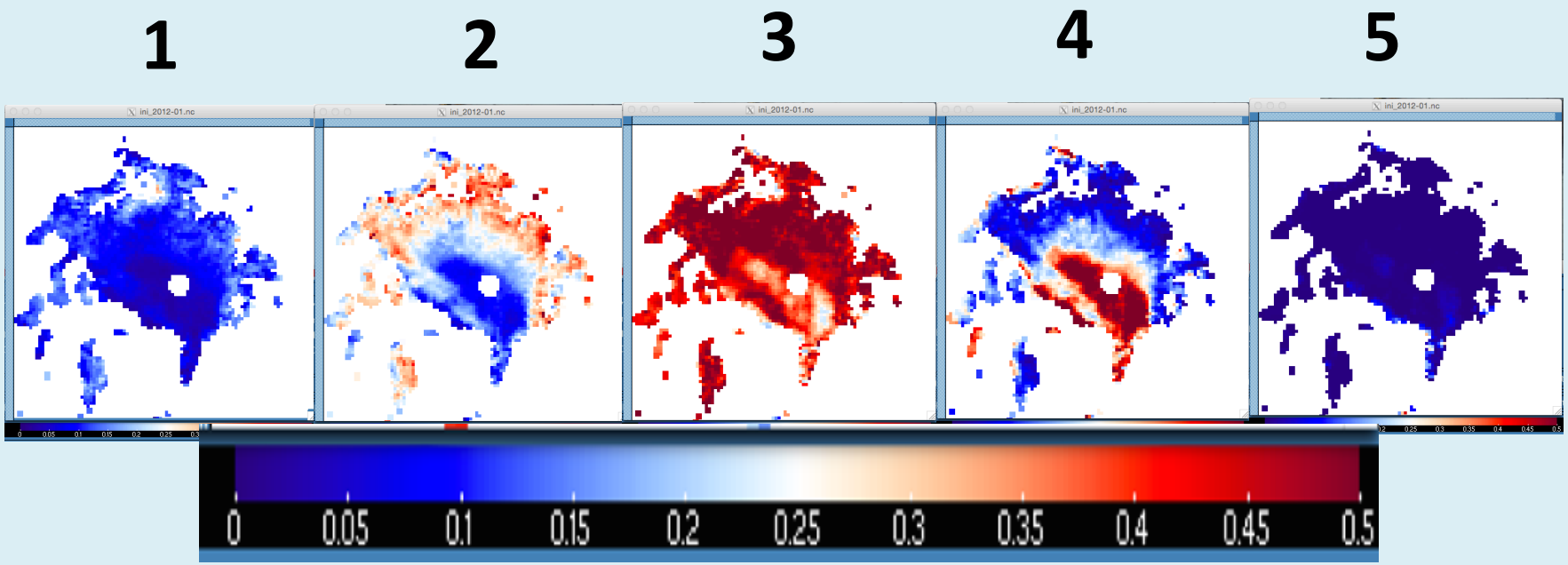
Motivation

- A sub-grid scale sea ice thickness distribution (ITD) is a key parameterization to enable a large-scale sea ice model to simulate winter ice growth and sea ice ridging processes realistically.
- Recent sophisticated developments, e.g. a melt pond model, a form drag parameterization, a floe-size distribution model, fundamentally depend on the ITD.
- In spite of its importance, knowledge is poor about the accuracy of the simulated ITD.

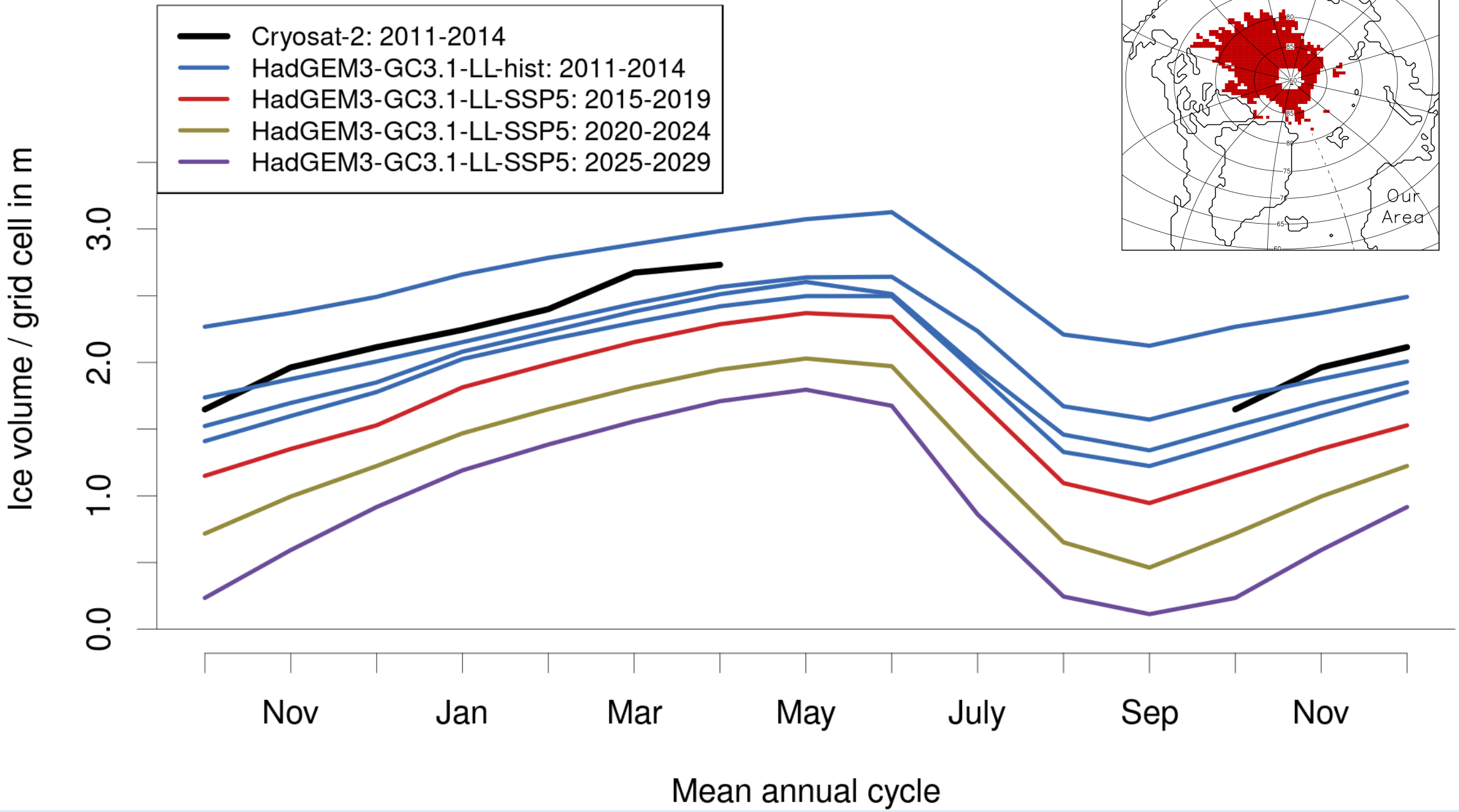
Here, we derive the ITD from individual Arctic sea ice thickness estimates available from the CryoSat-2 (CS2) radar altimetry mission during ice growth seasons since 2010. We bin the CS2 data into 5 ice thickness categories:



Ice Fraction in category
(Jan 2012)

Cat1 [0-0.6]
Cat2 [0.6-1.4]
Cat3 [1.4-2.4]
Cat4 [2.4-3.6]
Cat5 [>3.6] m

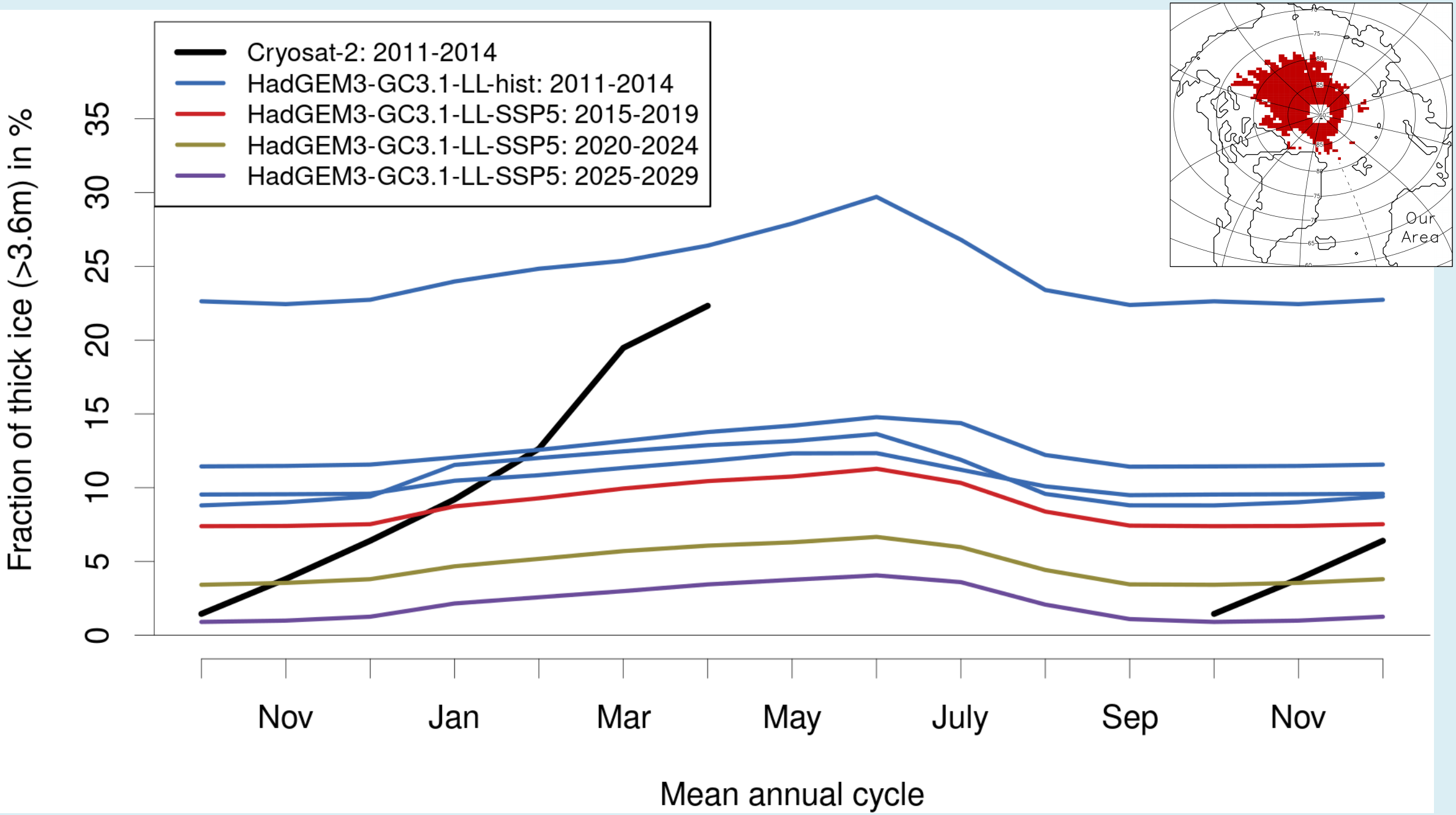
Comparison of ice volume



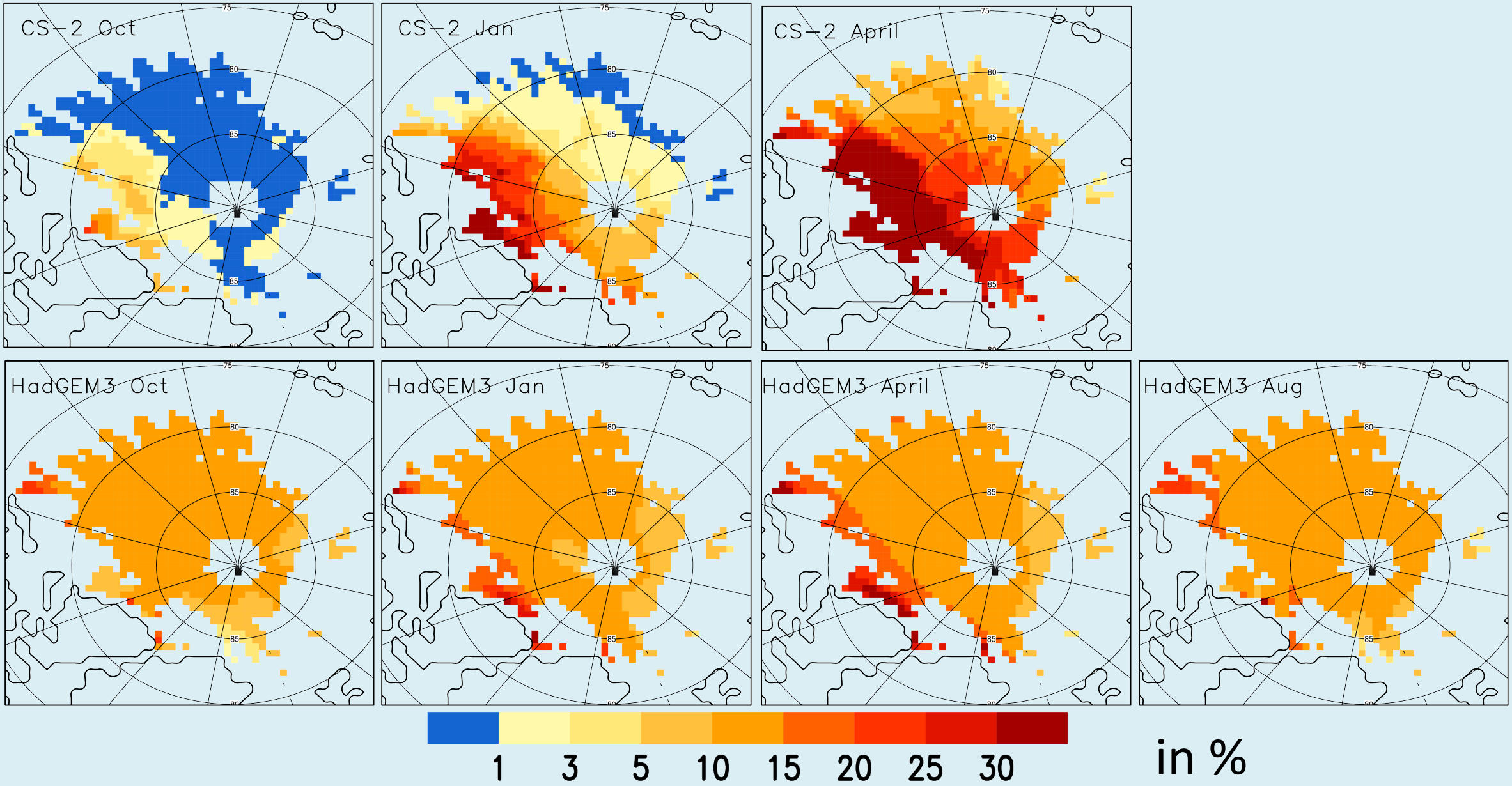
Comparison of ice volume

- Mean values over red region (Central Arctic, Cryosat-2 data most reliable)
- 4 ensemble member from historical run (blue lines) represent annual cycle of mean ice volume (2011 to 2014) realistically.
- Strong decrease in climate projection with mean September sea ice thickness down to 10cm in September in the period 2025 to 2029.

Comparison of thick ice area fraction (h>3.6m)



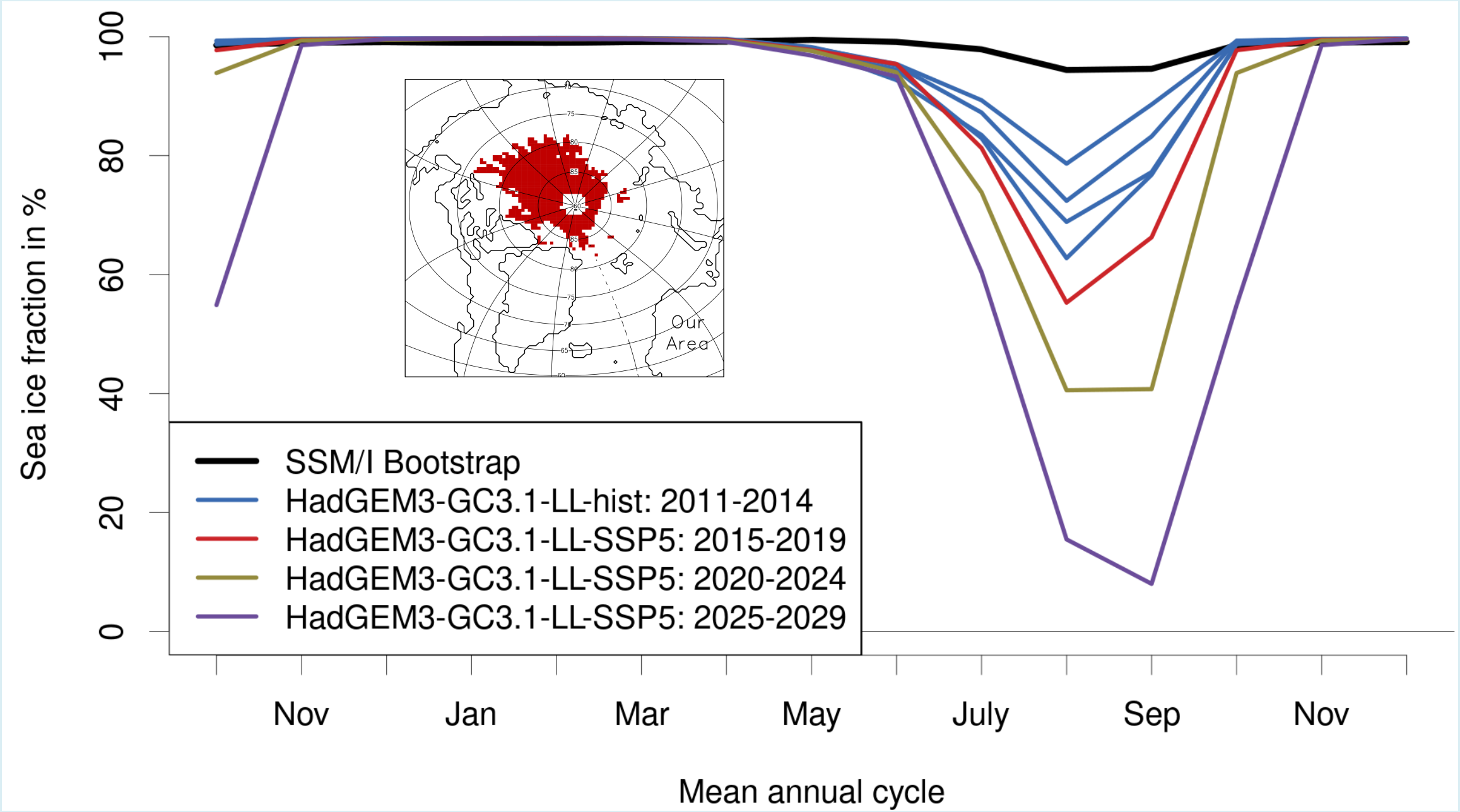
Comparison of thick ice area fraction (h>3.6m)



Comparison of thick ice area fraction (h>3.6m)

- Strong annual cycle according to CS-2: 2% in October vs 22% in April
- Weak annual cycle in all HadGEM3 simulations
- 3 of 4 members from historical simulation show values around 10%, but one member around 25%
- Decrease of thick ice fraction in climate projections, but some thick ice (1-2%) survives summer melt even in 2025-2029 period under nearly “ice-free” conditions.
- **Should we care about the mismatch given mean ice volume seems to be realistic?**

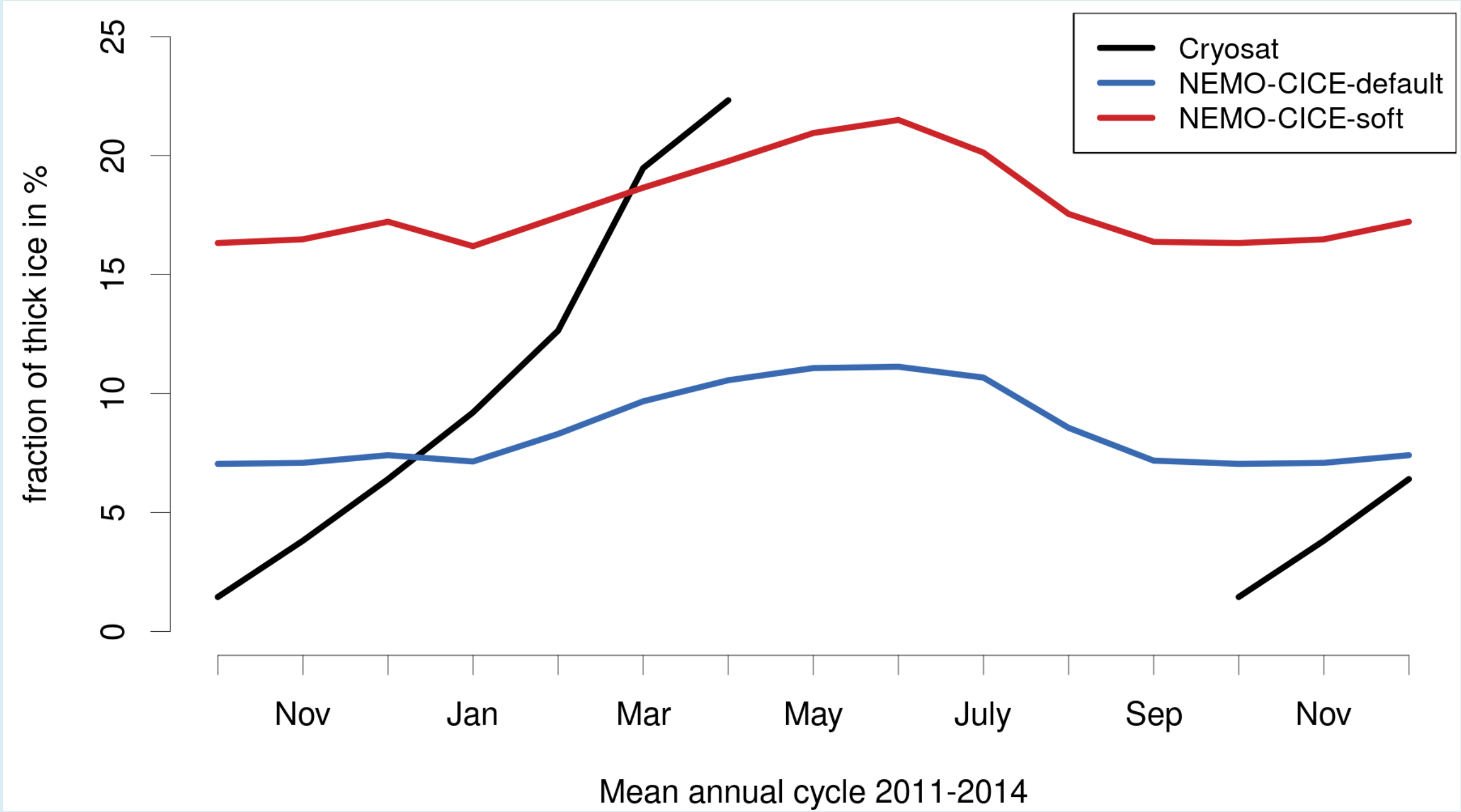
Comparison of ice area fraction



Comparison of ice area fraction

- **HadGEM3 undestimates summer sea ice area fraction.**
- **While thick ice melts too slowly, thin ice melts too fasts.**
- **Strong decrease of summer sea ice are fraction in projections realistic?**

Thick ice area fraction (h>3.6m) in forced NEMO-CICE simulations



Thick ice area fraction (h>3.6m) in forced NEMO-CICE simulations

- NEMO is the ocean model and CICE the sea ice model used in HadGEM3.
- Forced NEMO-CICE simulations and stand-alone CICE simulations (not shown) reveal same behaviour as HadGEM3: very weak annual cycle of thick ice area fraction.
- The amount of thick ice can be increased by modifying the ice strength (here reduced Cf parameter for weaker ice), but not the magnitude of the annual cycle.

Summary

- Sea ice volume simulated realistically in historical HadGEM3-GC3.1-LL runs.
- Cyrosat-2 estimates indicate pronounced annual cycle of thick ice fraction (h>3.6m) in each grid cell: Nearly no thick ice in October, but more than 20% in April.
- HadGEM3 simulations do not represent this neither in historical run nor in future projections, nor do forced ocean-ice or stand-alone simulations with the same sea ice component CICE
- **Missing physical process regarding the decay of sea ice ridges in CICE**