EGU General Assembly 2023

CR4.2 CMEMS
April 28, 2023

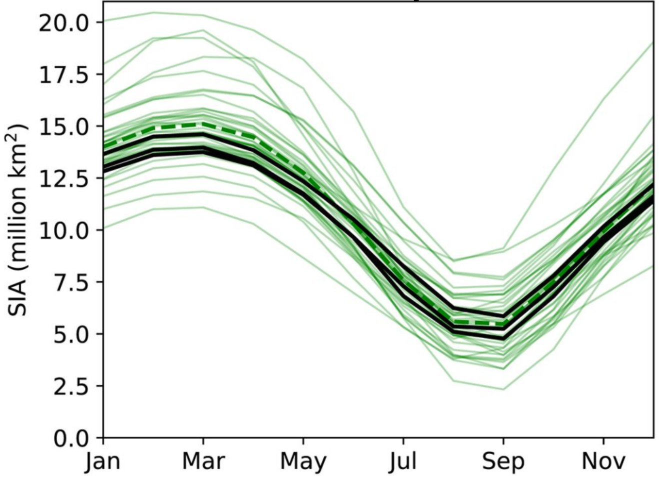
Past and future of the Arctic sea ice in HighResMIP

Julia Selivanova[1,2], Doroteaciro Iovino[2]

1 - University of Bologna, Italy; 2 - Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici, Italy
iuliia.selivanova@unibo.it

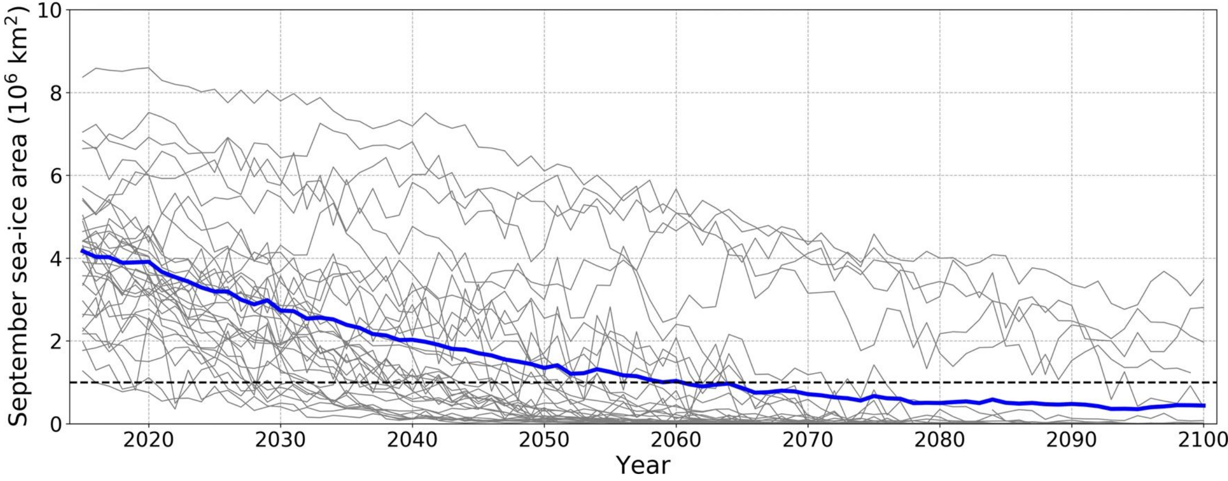
High inter-model spread among coupled climate models in representation of the Arctic sea ice

1979-2014 seasonal cycle in sea ice area



Roach et al. (2020)

September sea ice area



Docquier & Koenigk (2021)

The increased horizontal resolution is widely considered to reduce biases in model simulations.

Does the horizontal resolution impact the representation of sea ice in the recent past and future?

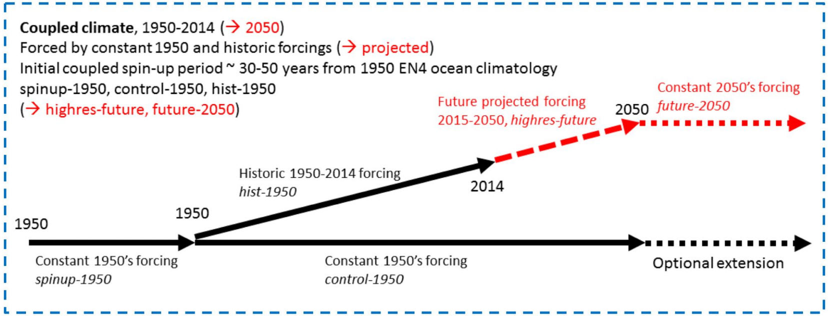
Data

HighResMIP is one of the CMIP6-endorsed Model Intercomparison Projects (MIPs) dedicated to the investigation of the role of horizontal resolution (Haarsma et al., 2016)

Model configuration		**nominal ocean res. (°)**	**nominal atmosphere res. (km)**	**model components**	
				ocean-sea ice	**atmosphere**
CMCC-CM2 (Cherchi et al., 2019)	HR	**0.25**	**100**	**NEMO3.6+CICE4.0**	**CAM4**
	VHR	**0.25**	**25**		
CNRM-CM6-1 (Voldoire et al., 2019)	LR	**1**	**250**	**NEMO3.6+GELATO6**	**ARPEGE6.3**
	HR	**0.25**	**100**		
ECMWF-IFS (Roberts et al., 2018)	LR	**1**	**50**	**NEMO3.4+LIM2**	**IFS cycle43r1**
	MR	**0.25**	**50**		
	HR	**0.25**	**25**		
EC-Earth3P (Haarsma et al., 2020)	LR	**1**	**100**	**NEMO3.6+LIM3**	**IFS cycle36r1**
	HR	**0.25**	**50**		
HadGEM3 (Williams et al., 2018)	LM	**1**	**250**	**NEMO3.6+CICE5.1**	**UM**
	MM	**0.25**	**100**		
	HM	**0.25**	**50**		
MPI-ESM (Müller et al., 2018)	HR	**0.4**	**100**	**MPIOM1.6.3**	**ECHAM6.3**
	XR	**0.4**	**50**		

6 models, 14 configurations with varying ocean and atmosphere horizontal resolution;

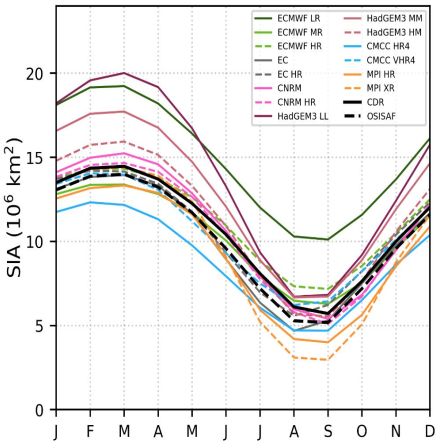
Historical and future runs (1950-2014; 2015-2050);



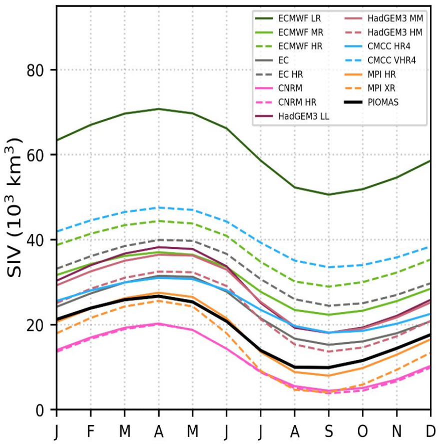
SIC from satellite datasets (NOAA/NSIDC CDR v4; EUMETSAT OSISAF)
SIT and SIV from PIOMAS

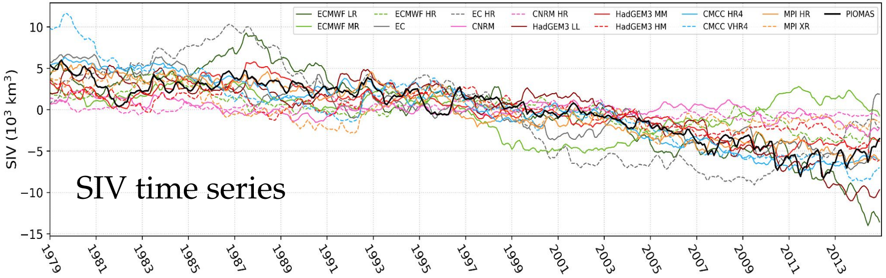
Arctic sea ice over historical period 1979-2014

sea ice area (SIA)

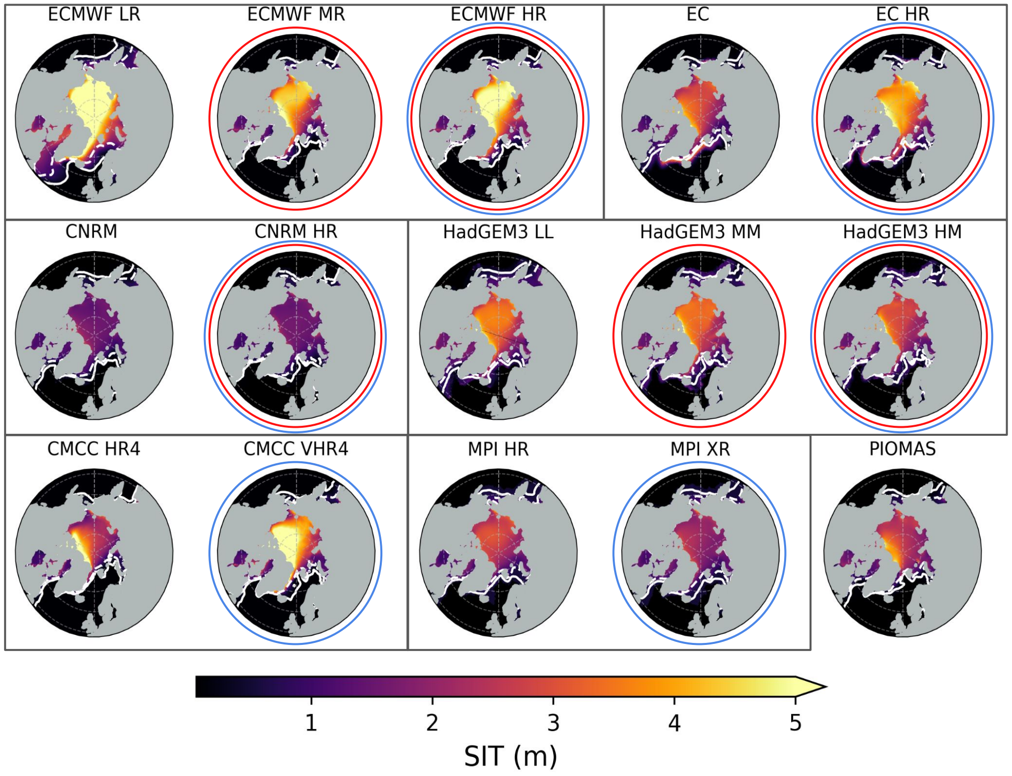


sea ice volume (SIV)





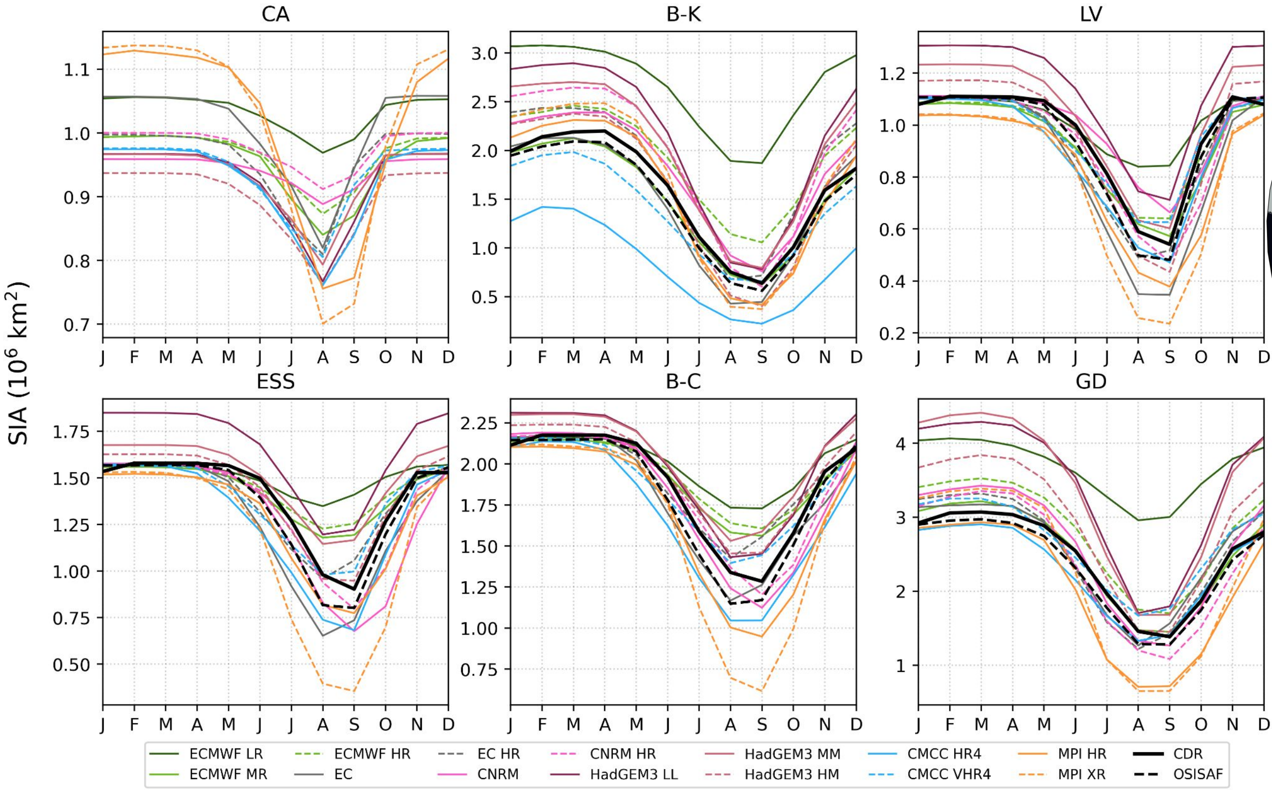
Spatial pattern of March SIT and sea ice edges (15 and 80%)

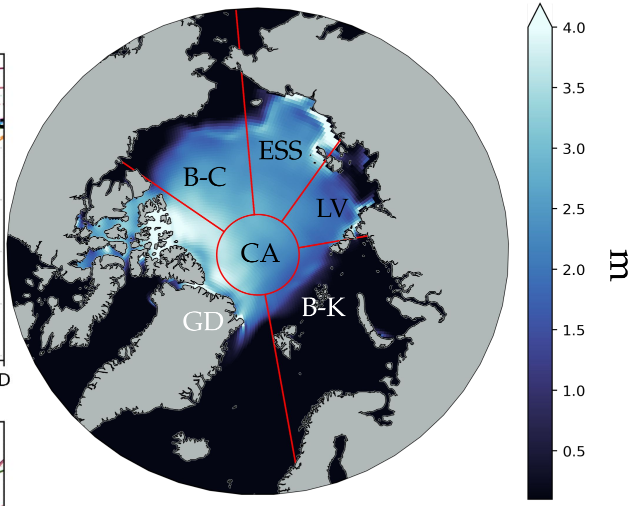


- increase in ocean resolution (red)
- increase in atmosphere resolution (blue)

- Reduced bias in winter SIA with finer ocean resolution;
- Impact of atmosphere resolution is less clear;
- Impact of resolution on SIT/SIV depends on the model.

Seasonal SIA variability at the regional scale



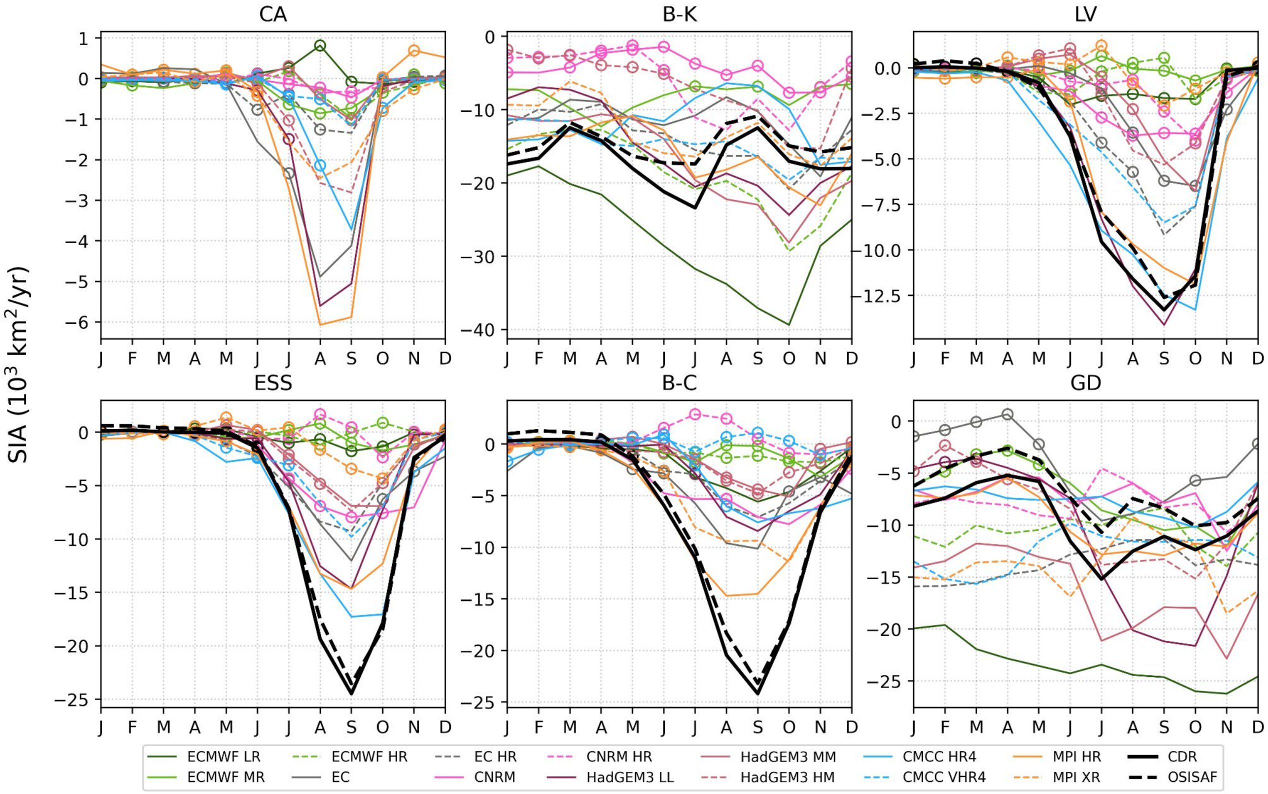


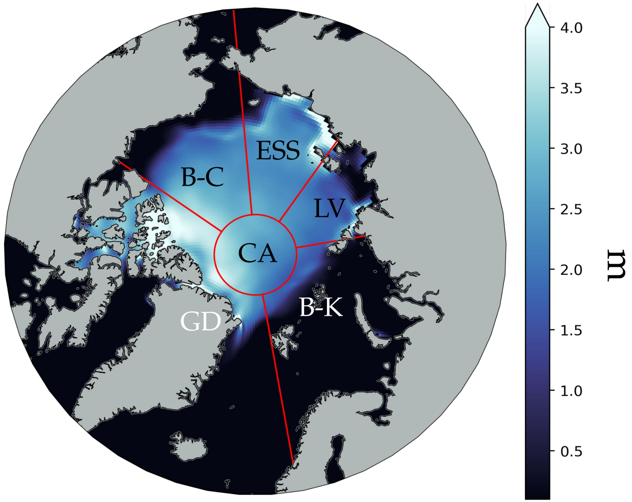
high winter inter-model spread in SIA is in the B-K and GD;

high summer inter-model spread in SIA is in the LV, ESS, B-C;

regional differences in the model performance (biases are not distributed equally across the regions).

Seasonal SIA trends at the regional scale





winter trends are dominated by the B-K and GD;

summer trends are driven by the LV, ESS, B-C;

models generally underestimate SIA trends (except B-K and GD);

generally less agreement with satellite products with increased ocean/atmosphere resolution;

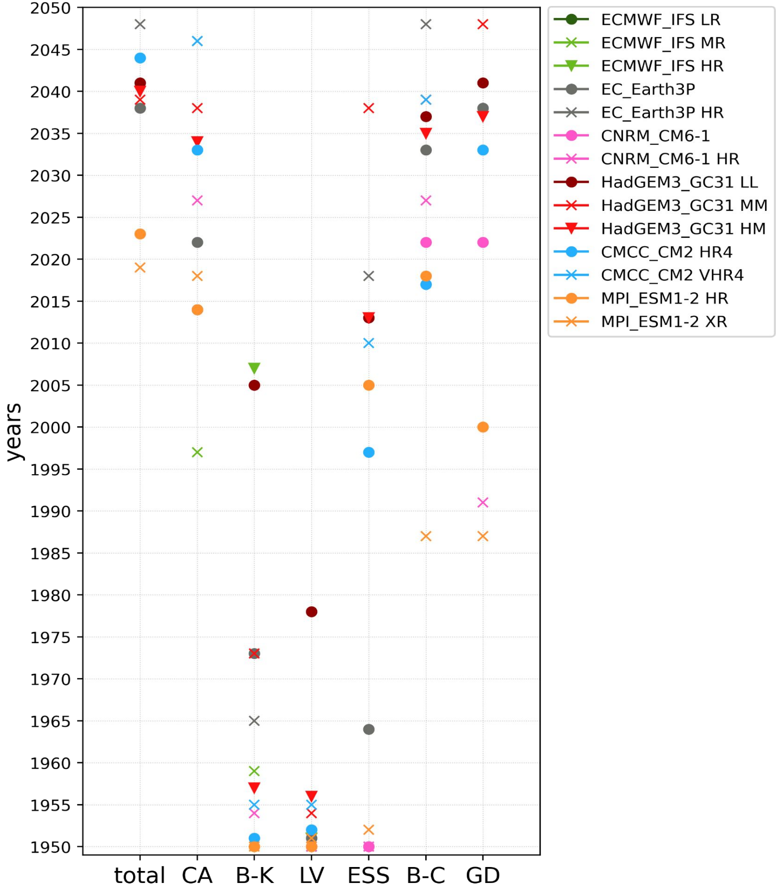
Dots indicate non-significant trends.

When will the Arctic see its first ice-free summer*?

CMIP6 models predict the event to happen between 2044 and 2067

*under 1 million km^2

Timing of first ice-free September in the Arctic and sub-regions



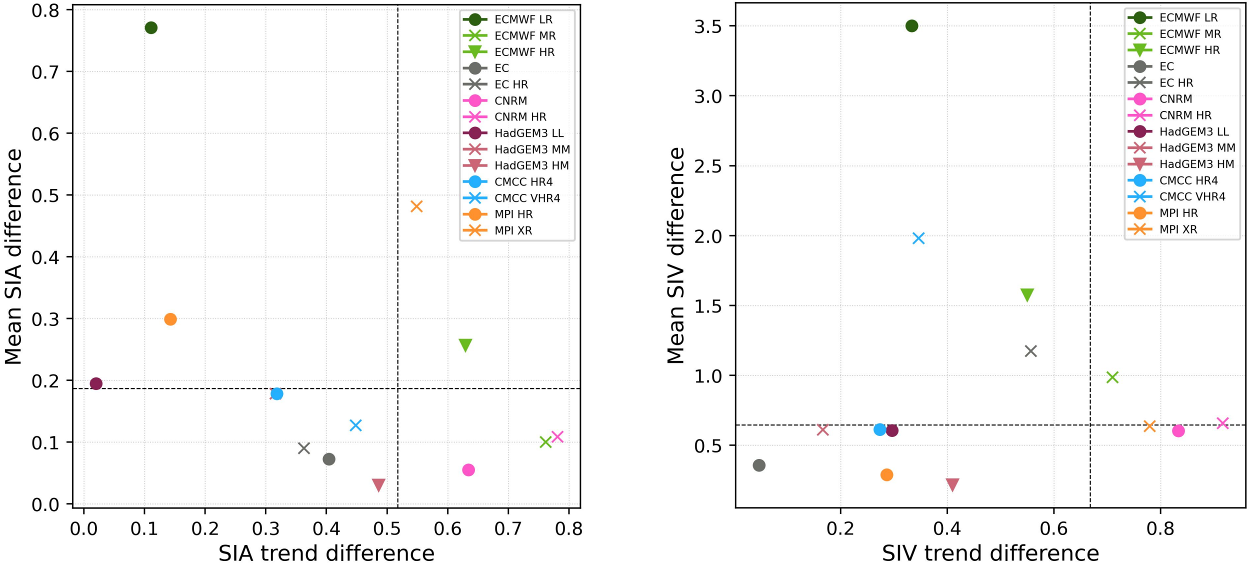
Models show wide range of possible timing of first ice-free summer. No dependence on the horizontal resolution.

Can the model selection narrow down the spread and decrease uncertainty in the model projections?

(the timing of ice-free conditions in the sub-regions refer to the threshold of 25% of the CDR SIA averaged over the 1980-2010 period in the given region)

Model selection based on historical performance (September mean state and trends)

Normalized difference in mean SIA vs SIA trend over 1979-2014 (left). Same for SIV (right).



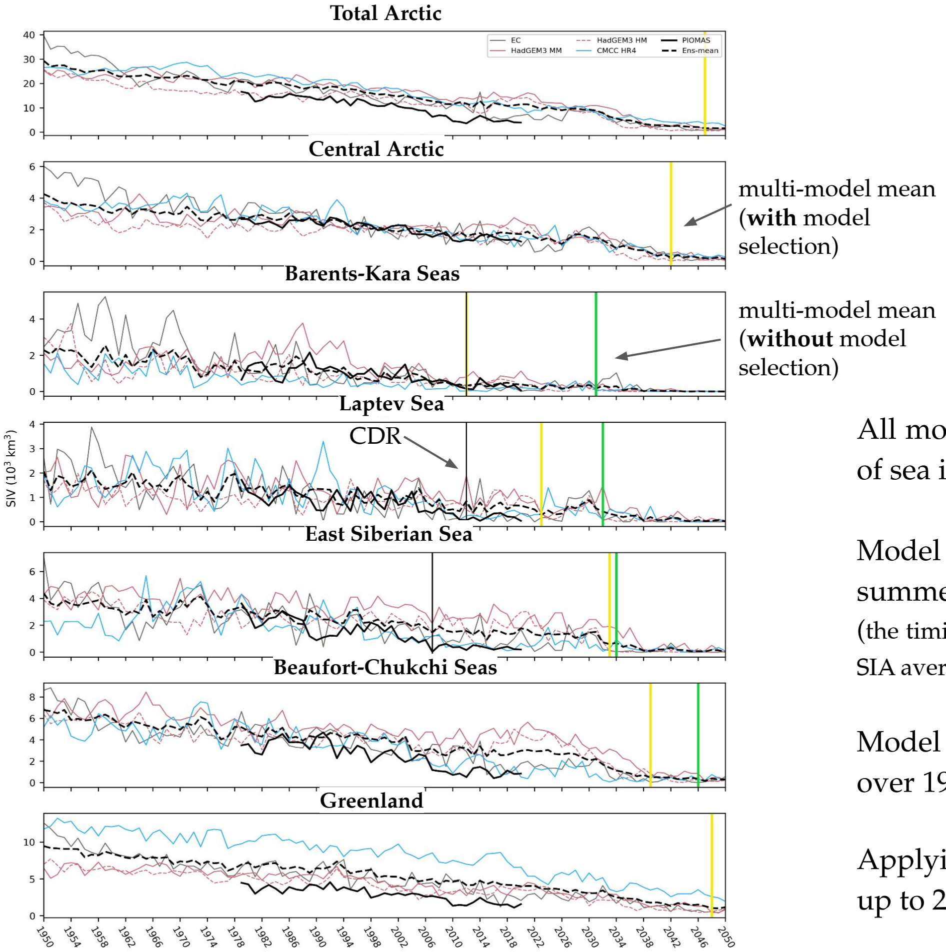
The difference is computed with reference to CDR (for SIA) and PIOMAS (for SIV).

Vertical lines indicate 75th percentile of a set of the model outputs excluding ECMWF-IFR (no future runs).

↓

4 “best-performing” models: HadGEM3 MM and HM, EC-Earth3P LR, CMCC-CM2 HR

Future projections of sea ice in the Arctic regions. SIV time series from 1950 to 2050.



Vertical lines indicate timing of first ice-free September

All models project substantial sea ice shrinking: the Arctic loses nearly 95% of sea ice volume from 1950 to 2050;

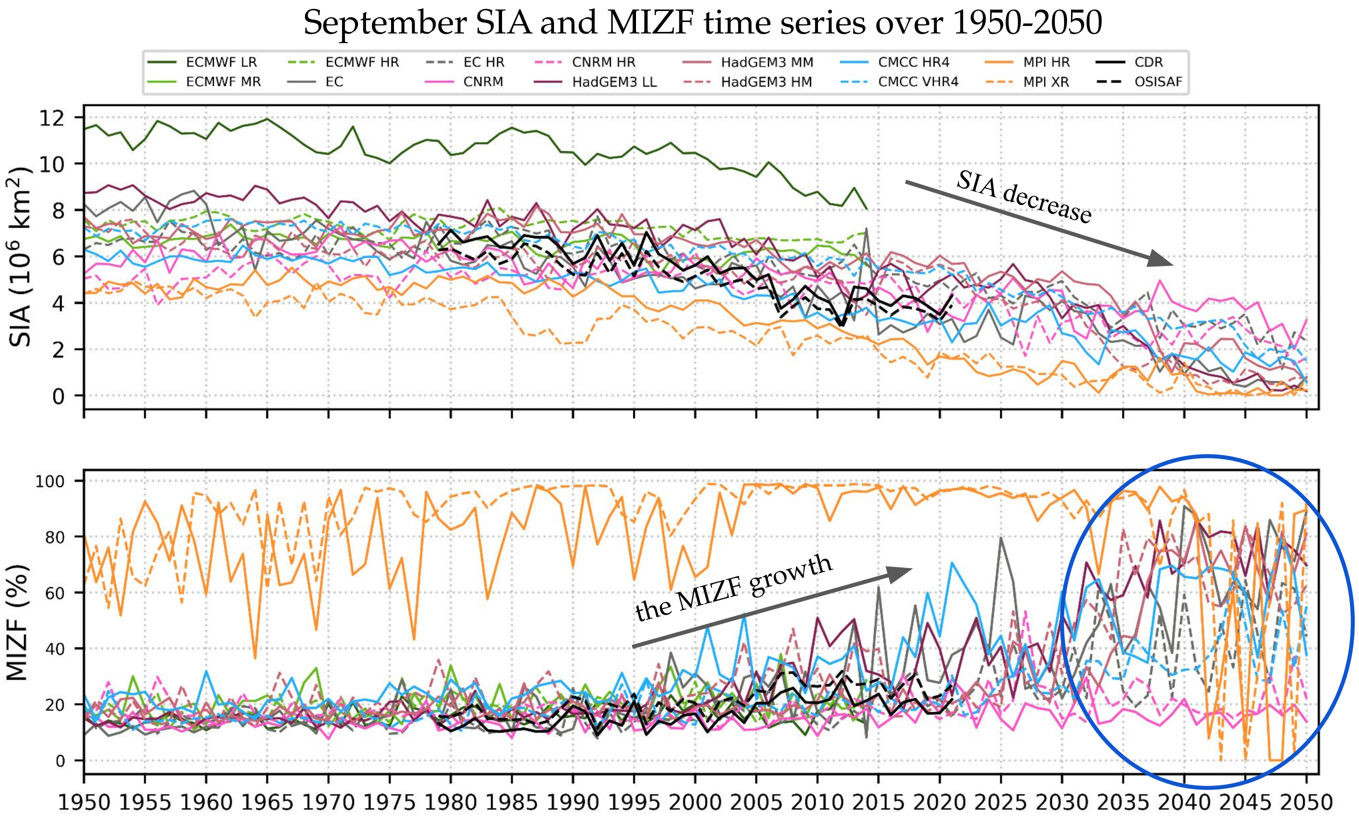
Model selection leads to closer agreement with CDR on the year of ice-free summer in the regions where it already happened;
(the timing of ice-free conditions in the sub-regions refer to the threshold of 25% of the CDR SIA averaged over the 1980-2010 period in the given region)

Model selection leads to closer fit of the SIV multi-model mean to PIOMAS over 1979-2014;

Applying model selection advances the timing of the first ice-free summer up to 2047.

Changes in the structure of sea ice cover

MIZF - the percentage of the Arctic sea ice cover that is MIZ (15-80% SIC; Horvat, 2022)



MIZ-dominance by 2050

Conclusions

- There is no strong relationship between ocean/atmosphere resolution and sea ice cover representation: the impact of horizontal resolution rather depends on the examined characteristic and the model used; however, the refinement of the ocean grid has a more prominent effect compared to the atmosphere: eddy-permitting ocean configurations provide more realistic representations of sea ice area and sea-ice edge.

- A plausible SIT simulation is still challenging: only few models reveal spatial patterns comparable to PIOMAS, with thicker ice off the coast of Greenland and the Canadian Archipelago.

- There are different regional contributions to the inter-model spread at seasonal maximum and minimum: while the winter inter-model spread in SIA is associated with the Barents-Kara Seas and the Greenland ice zones, the summer differences are tied to the the Laptev, East Siberian, and Beaufort-Chukchi Seas.

- Most models underestimate linear trends in SIA, particularly in the Laptev, East Siberian, Beaufort, and Chukchi Seas. The increased ocean/atmosphere resolution generally leads to less negative trends and lower agreement with observations.

- The Arctic loses ~95% of SIV from 1950 to 2050. Together with the overall ice shrinking, we find the shift of the Arctic sea ice cover to the regime similar to the Antarctic. The model physics might require modifications.

- Model selection based on historical performance improves sea ice projections and predicts the Arctic to turn ice-free as early as in 2047.

THANK YOU FOR YOUR ATTENTION!