Statistical assessment of the CMIP6 polynya activity in the Weddell Sea

Work in pogress – methods, figures and results can be subject to change

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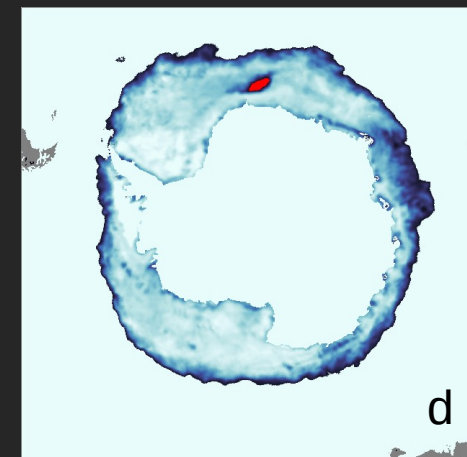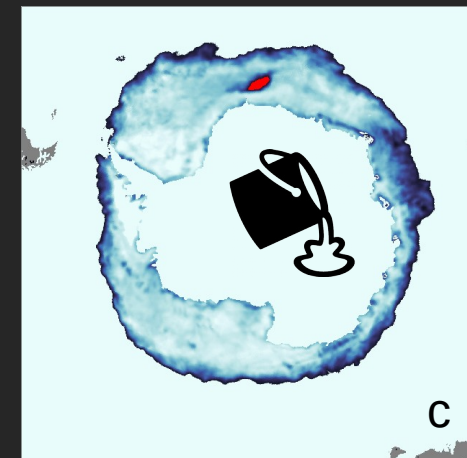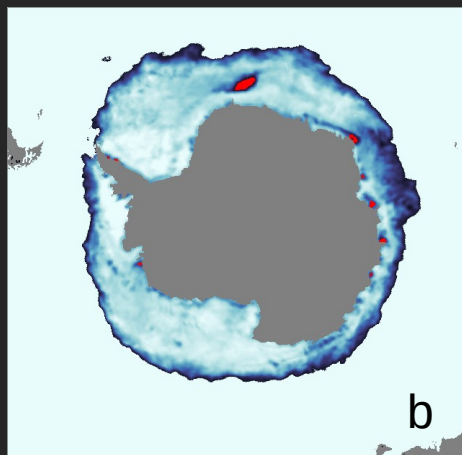[3] University of Gothenburg, Faculty of Science, Department of Marine Sciences, Sweden (sebastiaan.swart@gu.se)

Polynyas in the Weddell Sea: Frequency and location

I. Analyze satellite based datasets of daily sea ice coverage (1978-2020)

II. Analyze output from the Climate model inter-comparison project phase 6 (1850-2015 + future projections)
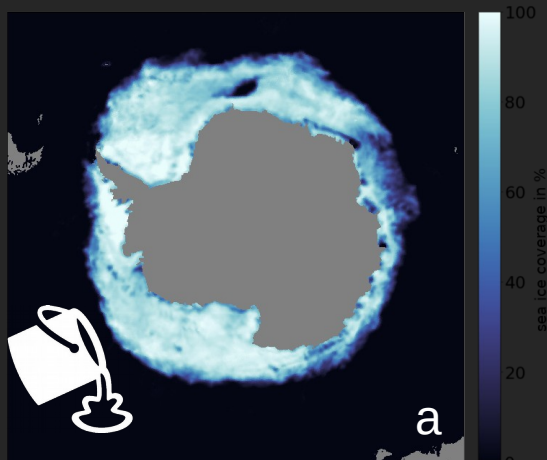
Method

a) Use flood fill algorithm on sea ice data map (threshold 15/30%)

b) Area with sea ice concentration < threshold value → polynyas

c) Use flood fill algorithm on antarctic fast land to subtract continental area and coastal polynya area

d) Regions with sea ice concentration < threshold → open water polynyas

Polynya and sea ice areas (animation of the method at work)

model: CAMS-CSM1-0 , date = 1-1850

sea ice plot (siconc)

area classification

sea ice covered
partly covered
open water

coastal polynya
sea ice area
sea ice area Wed. Sea
open water Polynya

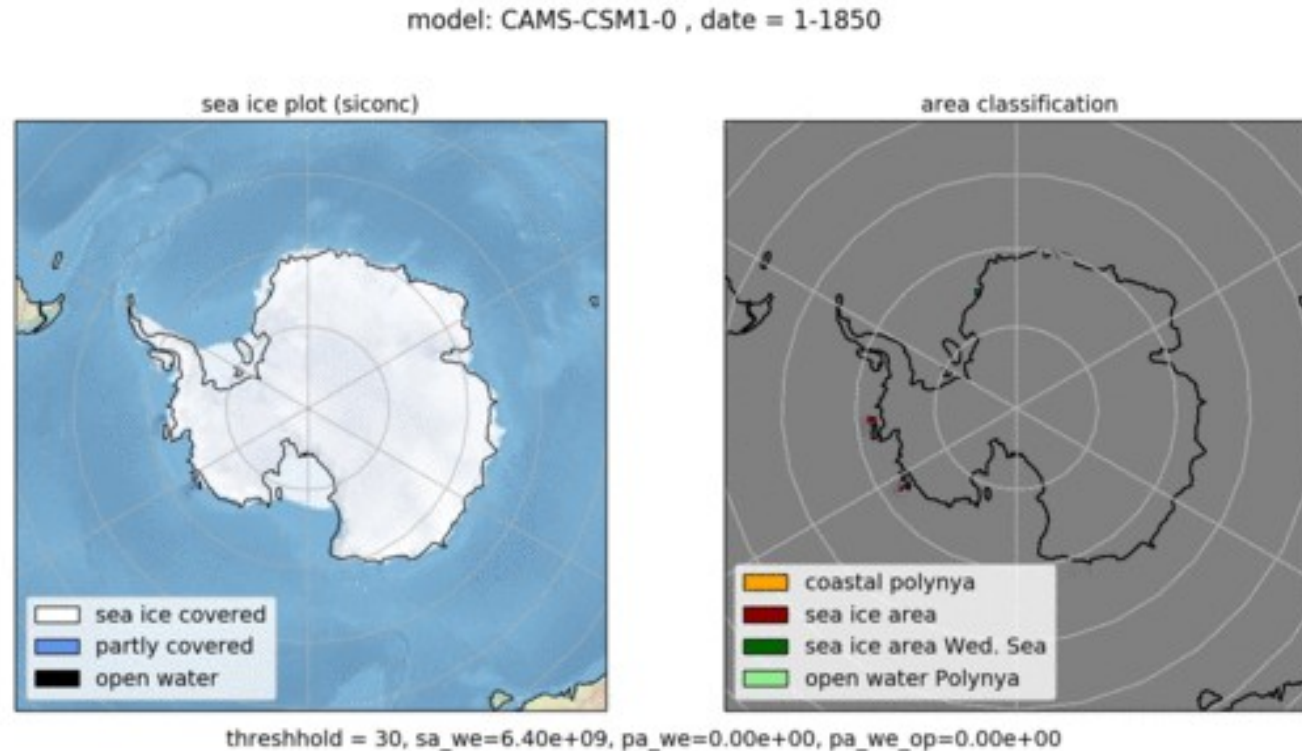threshhold = 30, sa_we=6.40e+09, pa_we=0.00e+00, pa_we_op=0.00e+00

Figure 2

… for 27 models, 2000 time steps – about 60.000 sea ice maps in total

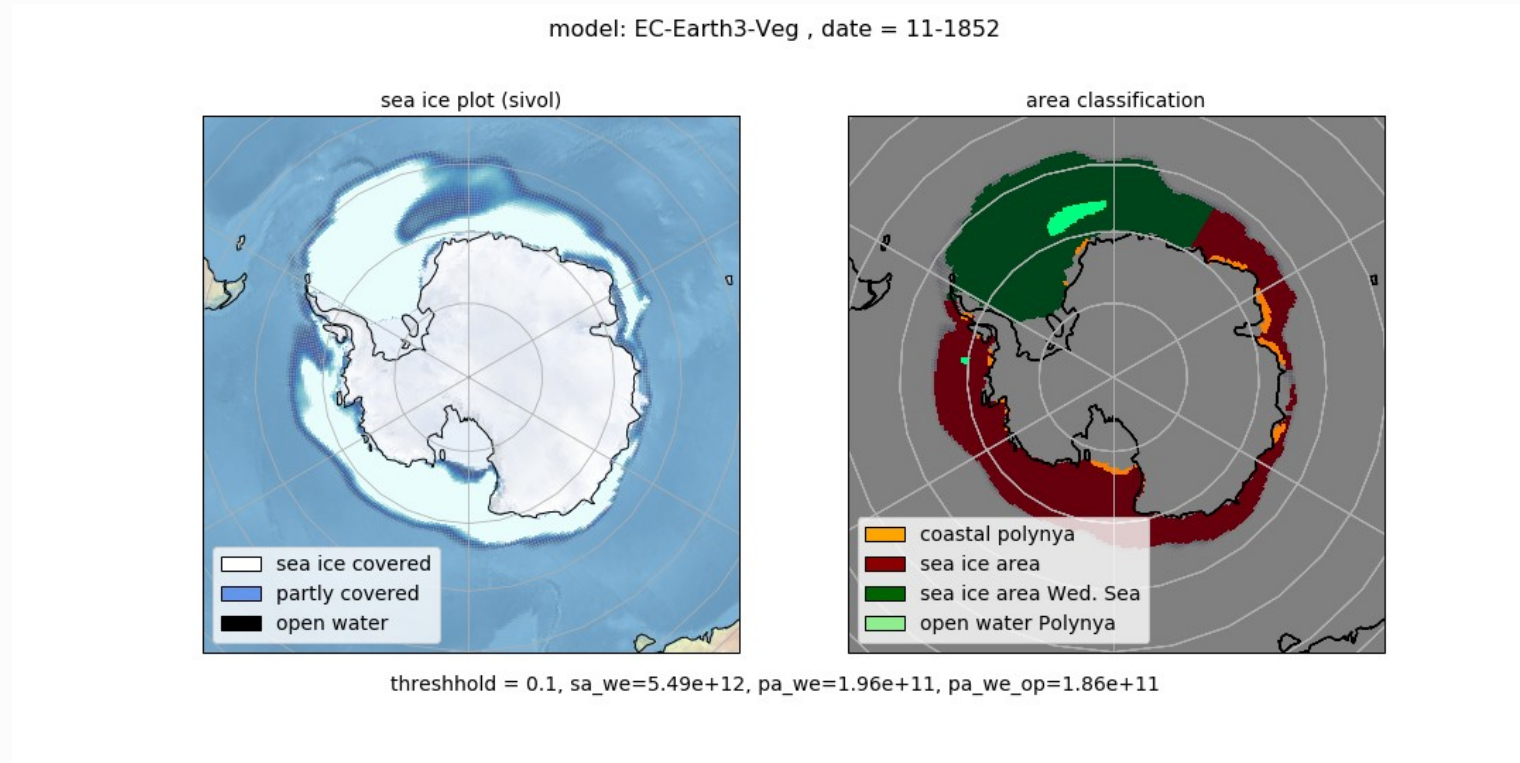# Polynya and sea ice areas (static image for pdf output)

Figure 2

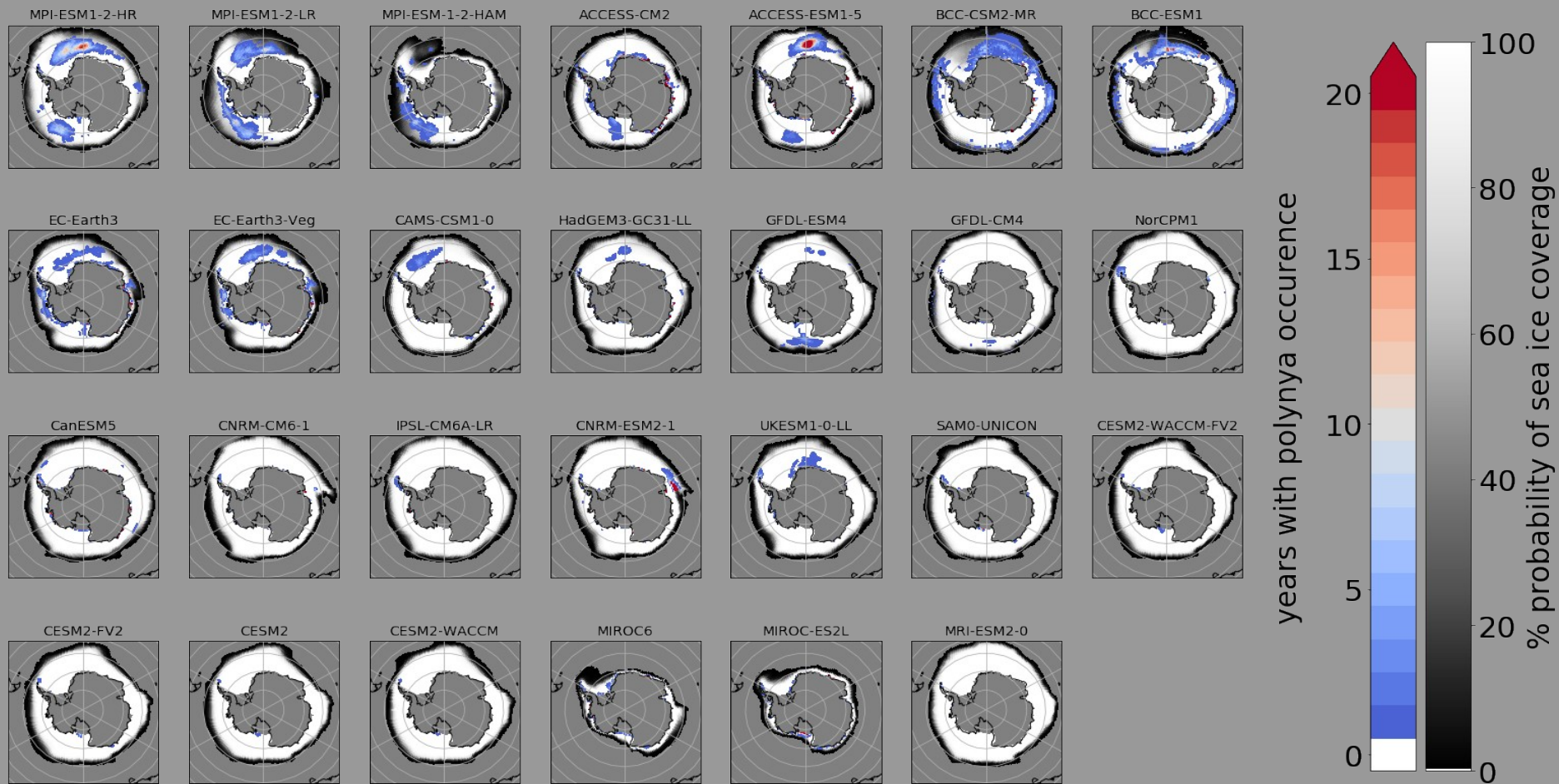… for 27 models, 2000 time steps – about 60.000 sea ice maps in total

Figure 3: The black and white color shows the average sea ice covered area (above threshold of 30% sea ice concentration) for September. The colors encode the number of years a polynyas occurred within the 165 years of the historical model run for each grid cell.

Open water polynyas are most common in the central Weddell Sea, few models form them in the Ross sea.

The models ACCESS-ESM1-5, EC-Earth3(-Veg), GFDL-ESM4, MPI-ESM1-2-(LR/HR), HadGEM3-GC31-LL show re-occurring open water polynyas in the Weddell Sea.

The models ACCESS-CM2, CanESM5, CESM2, CESM2-WACCM, CNRM-(WACCM/CM6-1/ESM2-1), GFDL-CM4, IPSL-CM6A-LR, MIROC(6/ES2L), MRI-ESM2-0, SAM0-UNICON, UKESM1-0-LL show no open water polynyas.

Polynya activity in CMIP6 models and satellite product over time

Figure 5: Yearly maximum polynya area in the Weddell Sea between May and November for the historical run of the CMIP6 models (right) and a satellite based sea ice product (OSI-450) at the bottom. Open water polynyas are frequently happening in MPI-ESM1-2-HR, NorCPM1, ACCESS-ESM1-5, GFDL-ESM4, CAMS-CSM1-0, EC-Earth3-Veg and CanESM5, often in consecutive years. The BCC models are showing large polynyas in the Weddell Sea almost every year.

The models CNRM-CM6-1, CNRM-ESM2-1, IPSL-CM6A-LR, UKESM1-0-LL, CESM2/(-WACCM-(FV2)) and SAM0-UNICON show no open water polynyas, but coastal polynyas are present in all CMIP6 models.

For comparison: the 1974-1976 Weddell Sea Polynya was about 2.5e5 km² large, the 2017 Weddell Sea Polynya about 0.8e5km² .
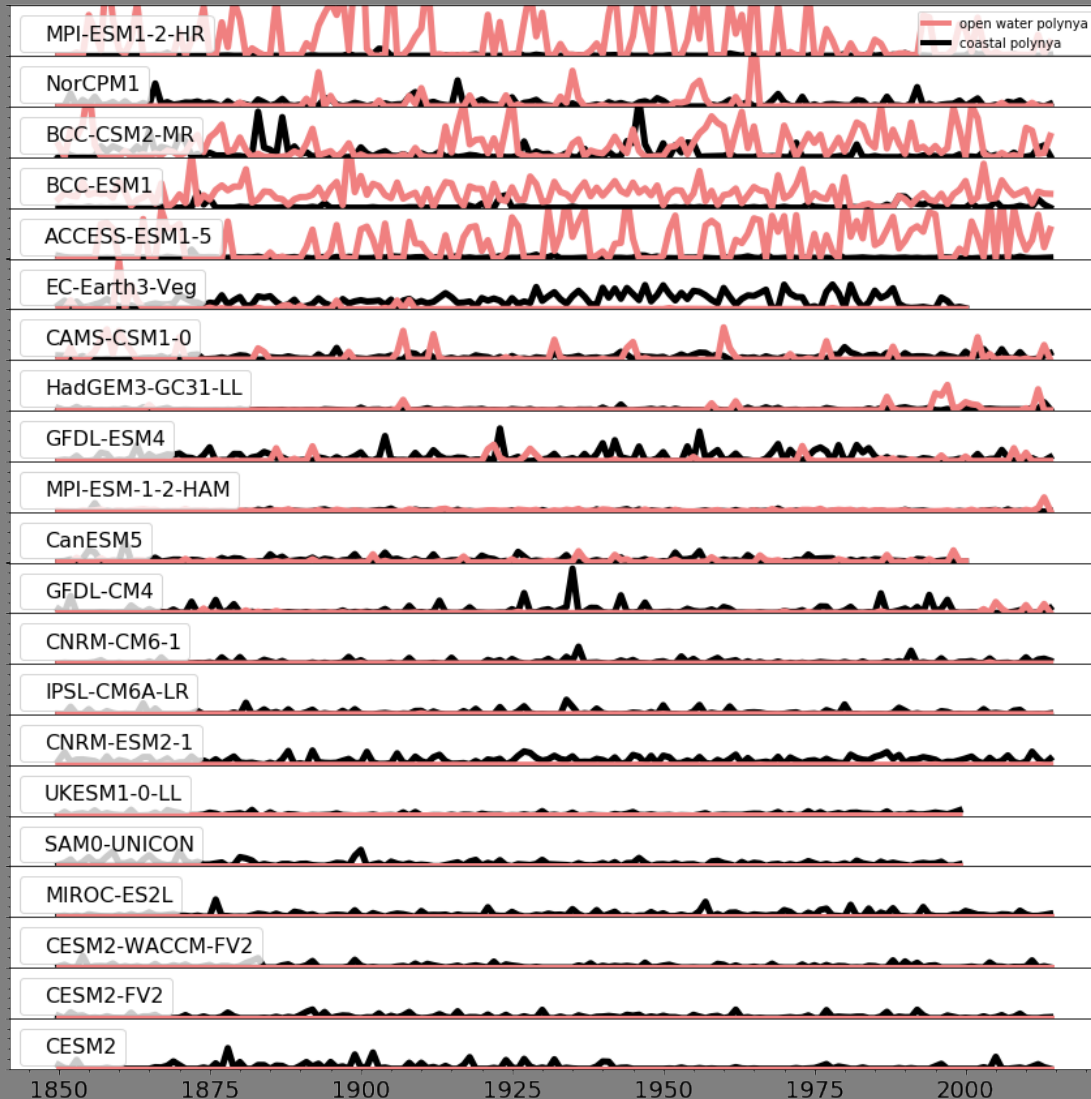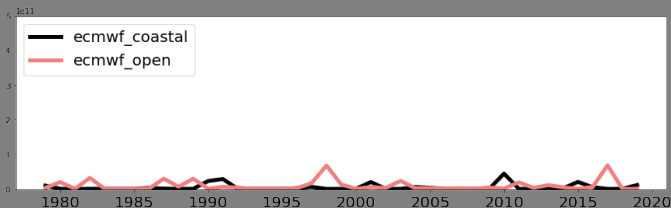
model	atmos	natNomRes atmos	ocean	natNomRes ocean	landIce	seaIce	number of years w open water polynyas	max open water polynya area in mio km²
MPI-ESM-1-2-HAM	ECHAM6.3	250 km	MPIOM1.63	250 km	none	unnamed	160	0.141
MPI-ESM1-2-LR	ECHAM6.3	250 km	MPIOM1.63	250 km	none/prescribed	unnamed	n.a.	n.a.
MPI-ESM1-2-HR	ECHAM6.3	100 km	MPIOM1.63	50 km	none/prescribed	unnamed	163	1.503
NorCPM1	CAM-OSLC	250 km	MICOM1.1	100 km	none	CICE4 (same grid as ocean)	29	0.759
BCC-CSM2-MR	BCC_AGCM	100 km	MOM4	50 km	none	SIS2	141	0.672
BCC-ESM1	BCC_AGCM	250 km	MOM4	50 km	none	SIS2	162	0.722
ACCESS-ESM1-5	HadGAM2	250 km	ACCESS-OM2 (MOM5)	100 km	none	CICE4.1 (same grid as ocean)	97	0.633
ACCESS-CM2	MetUM-Had	250 km	ACCESS-OM2 (GFDL-MOM5	100 km	none	CICE5.1.2 (same grid as ocean	n.a.	n.a.
EC-Earth3	IFS cy36r4	100 km	NEMO3.6	100 km	none	LIM3	n.a.	n.a.
EC-Earth3-Veg	IFS cy36r4	100 km	NEMO3.6	100 km	none	LIM3	27	0.481
CAMS-CSM1-0	ECHAM5_C	100 km	MOM4	100 km	none	SIS 1.0	40	0.32
HadGEM3-GC31-LL	MetUM-Had	250 km	NEMO-HadGEM3-GO6.0	100 km	none	CICE-HadGEM3-GSI8	17	0.252
GFDL-ESM4	GFDL-AM4	100 km	GFDL-OM4p5	50 km	GFDL-LM4.1	GFDL-SIM4p5	29	0.163
GFDL-CM4	GFDL-AM4	100 km	GFDL-OM4p25	25 km	GFDL-LM4.0.1	GFDL-SIM4p25	68	0.109
CanESM5	CanAM5	500 km	NEMO3.4.1	100 km	specified ice shee	LIM2	70	0.119
CNRM-CM6-1	Arpege 6.3	250 km	Nemo 3.6	100 km	none	Gelato 6.1	5	0.013
CNRM-ESM2-1	Arpege 6.3	250 km	Nemo 3.6	100 km	none	Gelato 6.1	5	0.001
IPSL-CM6A-LR	LMDZ	250 km	NEMO-OPA	100 km	none	NEMO-LIM3	5	0.01
UKESM1-0-LL	MetUM-Had	250 km	NEMO-HadGEM3-GO6.0	100 km	none	CICE-HadGEM3-GSI8	1	0
SAM0-UNICON	CAM5.3 wit	100 km	POP2	100 km	none	CICE4.0	0	0
MIROC-ES2L	CCSR AGC	500 km	COCO4.9	100 km	none	COCO4.9	0	0
MIROC6	CCSR AGC	250 km	COCO4.9	100 km	none	COCO4.9	0	0
CESM2-WACCM-FV2	WACCM6	250 km	POP2	100 km	CISM2.1	CICE5.1 (same grid as ocean)	0	0
CESM2-WACCM	WACCM6	100 km	POP2	100 km	CISM2.1	CICE5.1 (same grid as ocean)	0	0

Overly frequent open water polynya activity   open water polynya activity on decadal timescale or in small areas only

Details about the models in table are derived from Core Controlled Vocabularies (CVs) for use in CMIP, https://github.com/WCRP-CMIP/CMIP6_CVs

Results

- 27 CMIP6 models were analyzed for their polynya activity
- Half of the CMIP6 models show open water polynyas
- strongest activity can be observed in Weddell Sea around Maud Rise
- Second hot spot for open water polynyas in CMIP6 is the Ross Sea
- Time scale between polynya occurrences lies between few years and several decades
- Polynya activity in consecutive years is common, indicating the importance of preconditioning in the water column

Data sources:

CMIP6 dataset reference:

Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., and Taylor, K. E.: Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization, Geosci. Model Dev., 9, 1937–1958, https://doi.org/10.5194/gmd-9-1937-2016, 2016.

Sea ice product:

OSI SAF (2017): Global Sea Ice Concentration Climate Data Record v2.0 - Multimission, EUMETSAT SAF on Ocean and Sea Ice, DOI: 10.15770/EUM_SAF_OSI_0008. http://dx.doi.org/10.15770/EUM_SAF_OSI_0008