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LUMI

From coarse to crisp: evaluating the impact of horizontal resolution on global ocean-sea ice simulations

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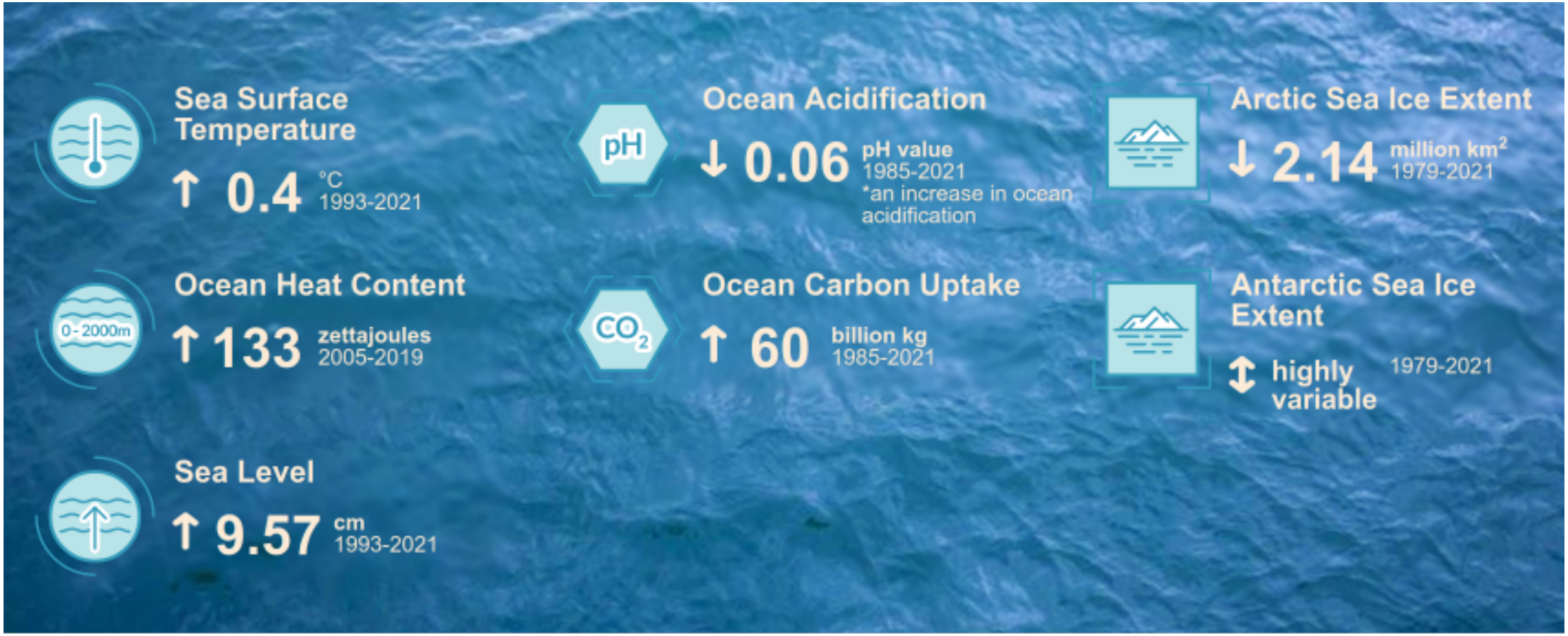
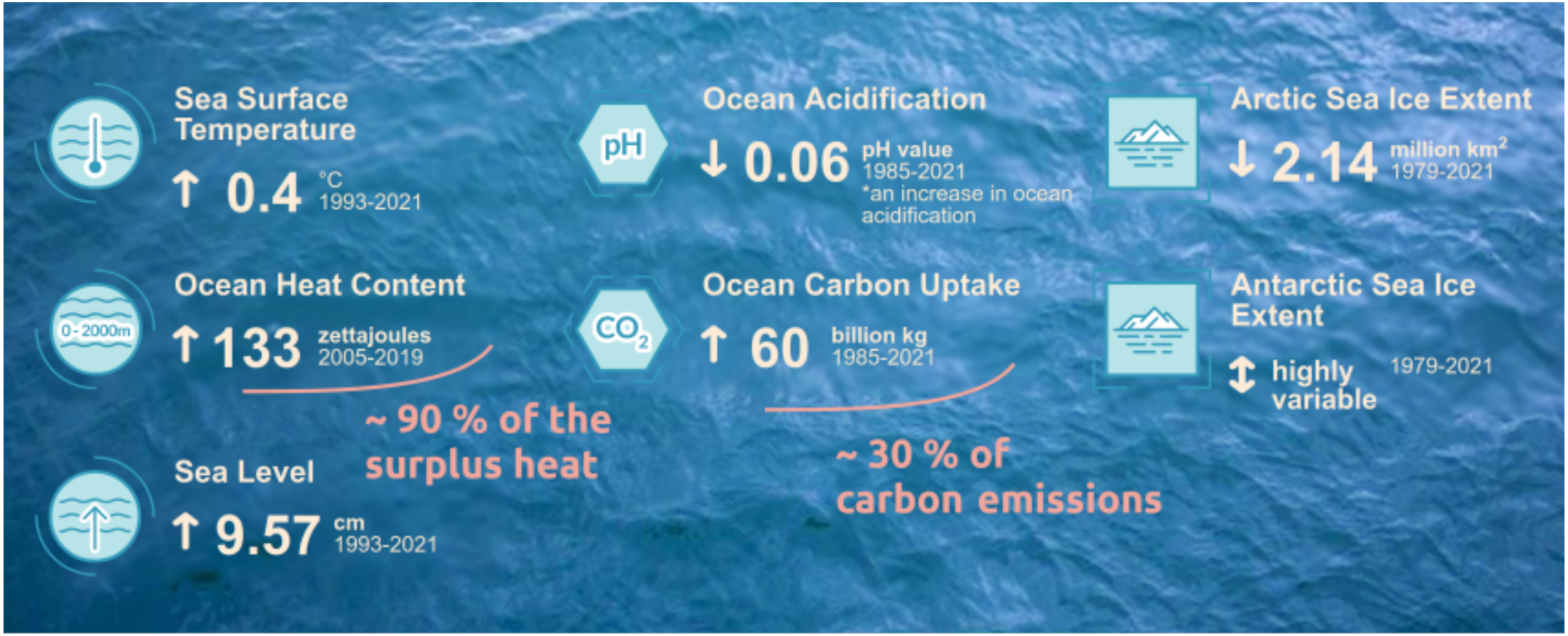
Changes in the world ocean



https://marine.copernicus.eu/ocean-climate-portal

Changes in the world ocean



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Models as tools to understand the ocean

Numerical ocean models: solve the Navier-Stokes equations on a 3D grid to simulate the ocean dynamics

Used for:

- reconstructions of the past
- short-term marine and weather forecasts
- long-term climate projections

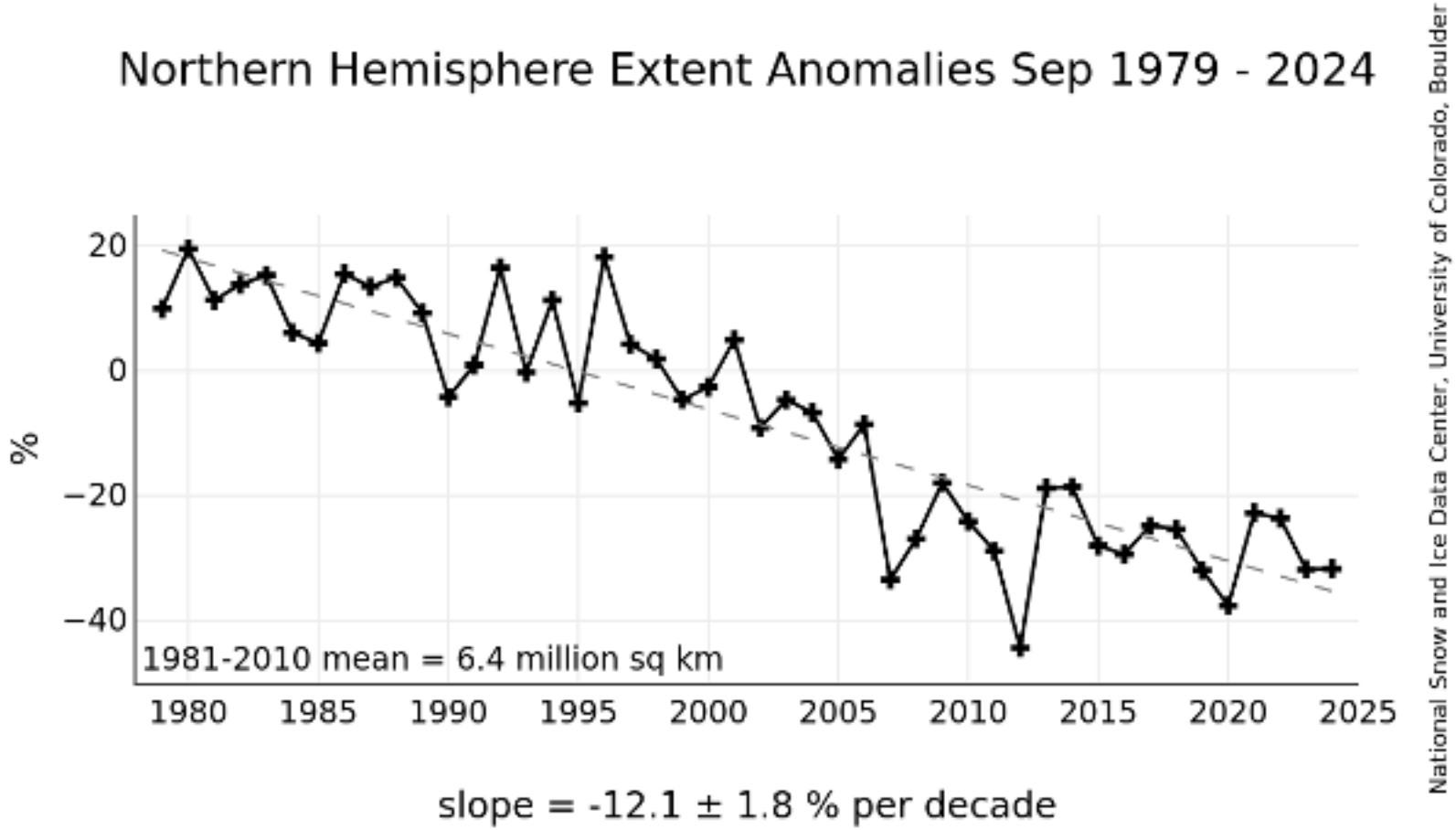
Our research objective

> Evaluate the impact of horizontal resolution on global ocean-sea ice simulations

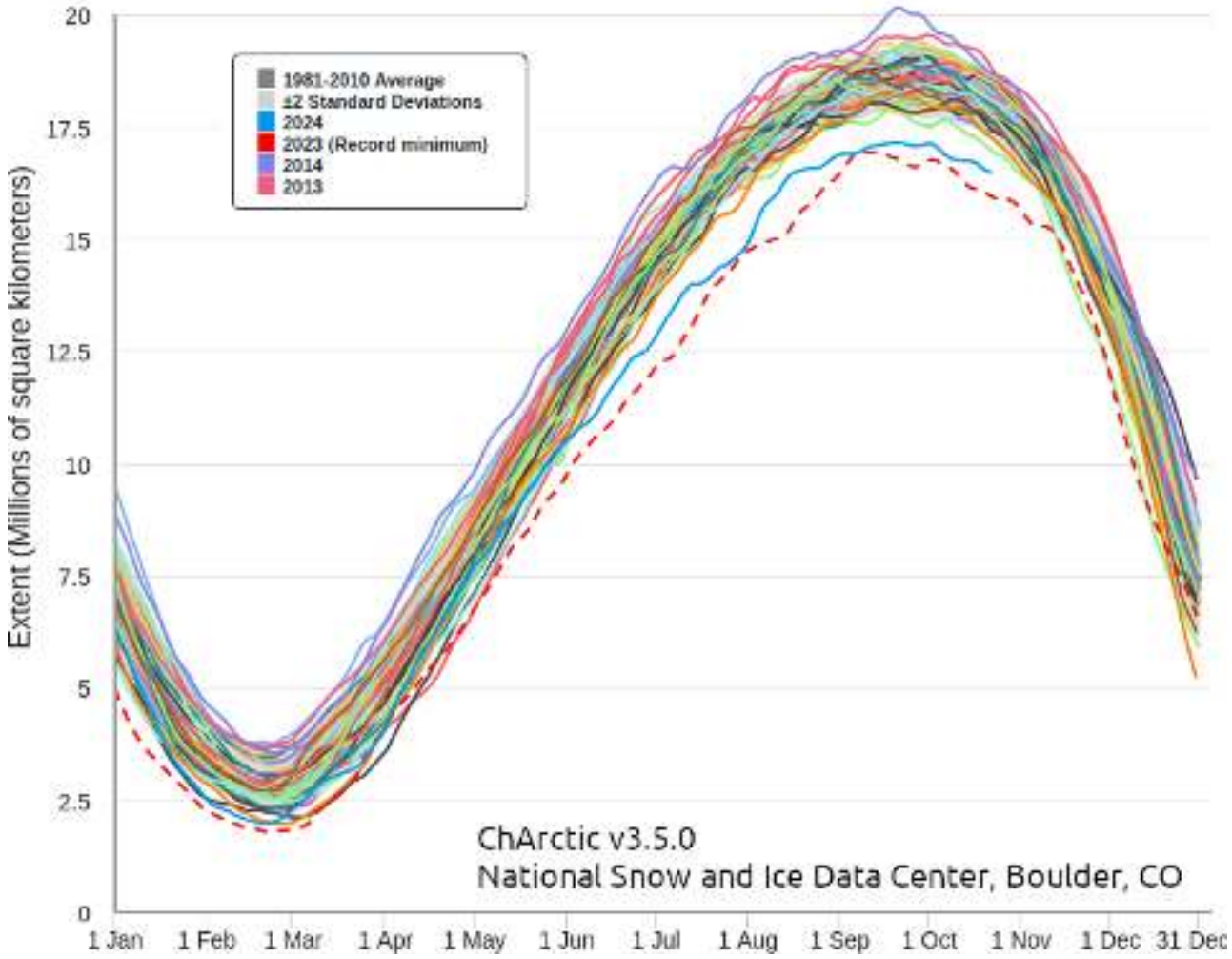
In particular:

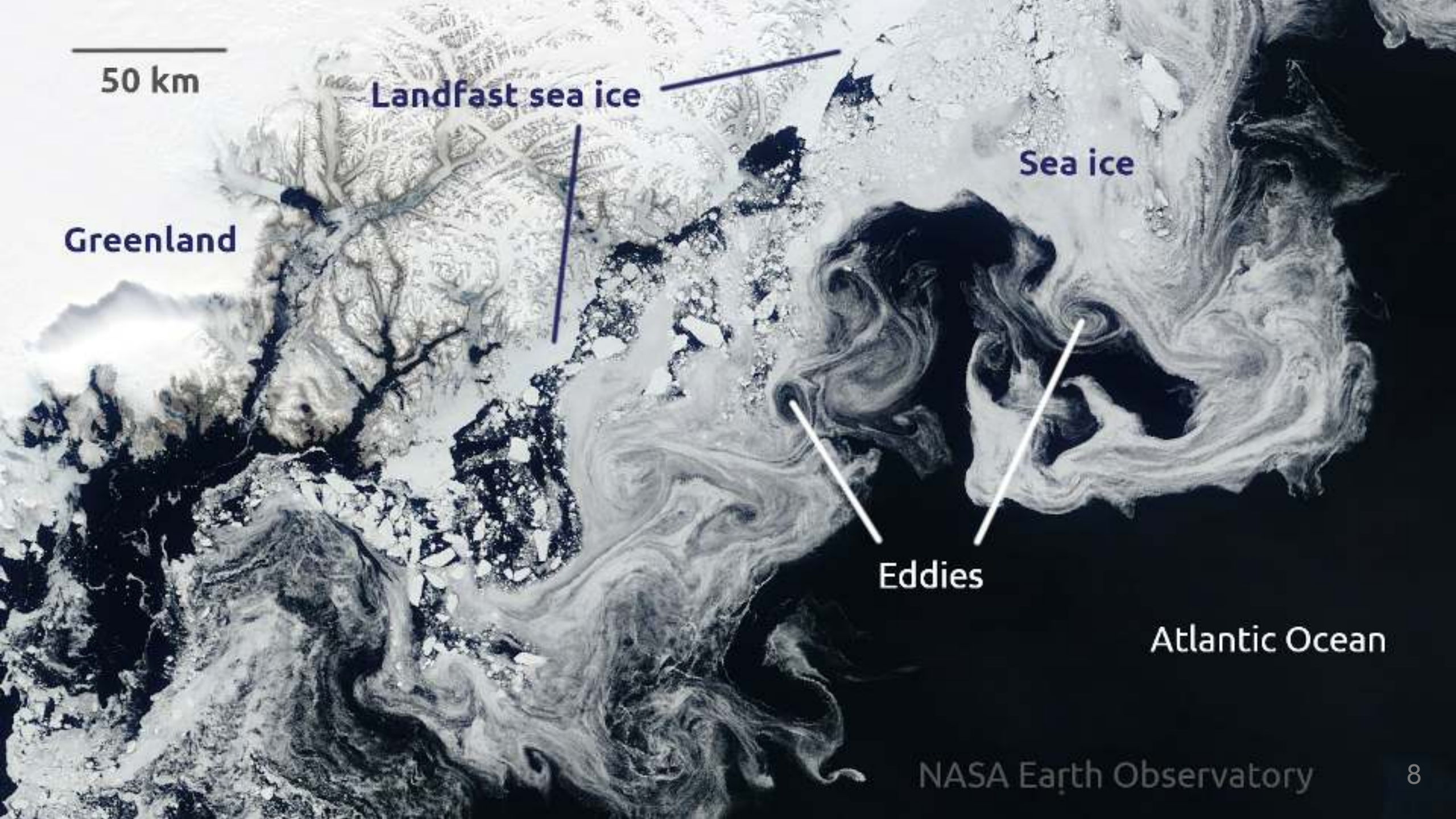
- ocean at high latitudes
- sea ice in the Arctic and the Antarctic
- recent sea ice lows

Declining Arctic sea ice extent



Variable Antarctic sea ice extent




50 km
Landfast sea ice
Sea ice
Greenland
Eddies
Atlantic Ocean
NASA Earth Observatory

Why higher horizontal resolutions could help

- Finer representation of the coastline and bathymetry:
  - Landfast sea ice and polynyas
  - Transport through narrow straits
- Better simulation of small-scale processes:
  - Ocean currents and eddies
  - Sea ice dynamics (ridging, fracturing)
- Improved representation of the ice edge and marginal ice zones

Model and experimental setup

NEMO (**N**ucleus for **E**uropean **M**odelling of the **O**cean), version 4.2.2, including the sea ice model **SI³** (**S**ea **I**ce modelling **I**ntegrated **I**nitiative)

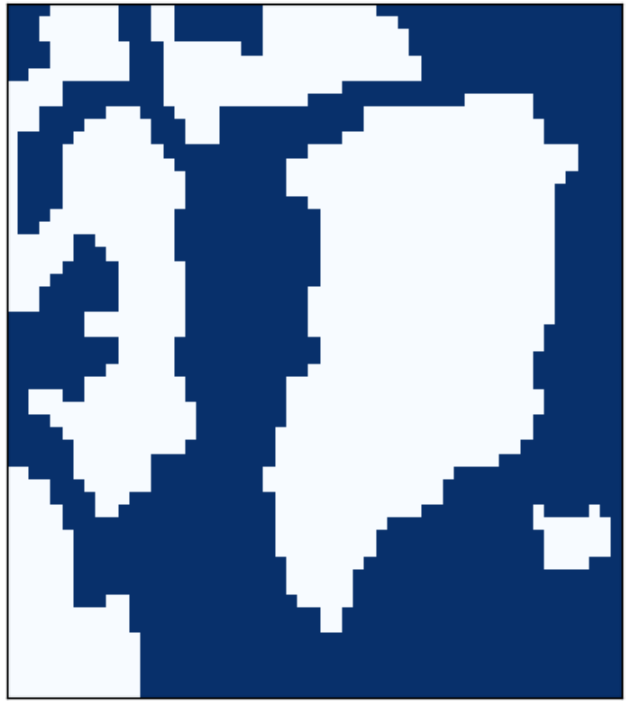
- Driven by fields from the atmospheric reananalysis ERA5
- Run over 1960-2023
- In 3 global configurations with increasing horizontal resolution

Model configurations

Configuration	eORCA1	eORCA025	eORCA12
Horizontal resolution (°)	1	1/4	1/12
Horizontal resolution (km)	~ 50	~ 15	~ 5
Horizontal grid size	360 x 331	1 440 x 1 206	4 320 x 3 605
Vertical levels	75	75	75
Time step (s)	2 700	1 350	360
Time steps per year	11 680	23 360	87 600

Increasing horizontal resolutions

eORCA1



eORCA025

eORCA12

Specifics of running NEMO

- CPU-only (**LUMI-C**)
- Large inputs/outputs (**LUMI-P**)
  - Inputs: atmospheric fields to drive the ocean-sea ice model (3.5 TB)
  - Outputs:
    - Global 2D and 3D fields
    - At daily and/or monthly frequency
    - Over 1960-2023
    - Written by an external program (**XIOS**, **X**MLs-**IO-S**erver)

Experiment management

Experiments split into *legs*:

```
Start from: rest

0001 - 1960-01-01 - 1960-12-31 - completed - 8018888
0002 - 1961-01-01 - 1961-12-31 - completed - 8018889
0003 - 1962-01-01 - 1962-12-31 - running   - 8018890
0004 - 1963-01-01 - 1963-12-31 - submitted - 8021568
...
```

- Run jobs submitted on the `standard` queue (all at once, with Slurm dependency)
- Post-processing jobs submitted on the `small` queue (as the experiment runs)

2-program run jobs

```
srun --nodes=${SLURM_JOB_NUM_NODES}
--ntasks-per-node=${SLURM_NTASKS_PER_NODE} --cpu-bind=cores
--multi-prog ./program_configuration_file.txt
```

With the `program_configuration_file.txt`:

```
0   ./xios_server.exe
1   ./xios_server.exe
2   ./nemo.exe
... ./nemo.exe
127 ./nemo.exe
128 ./xios_server.exe
129 ./xios_server.exe
130 ./nemo.exe
...
```

Configuration requirements

Configuration	eORCA1	eORCA025	eORCA12
Problem size per year (*)	$1.04\ 10^{11}$	$3.04\ 10^{12}$	$1.02\ 10^{14}$
Number of cores (NEMO + XIOS)	120 + 8	1 257 + 23	2 512 + 48
Wall-clock time per year (h)	1	3	~ 66
Computational cost per year (core-hour)	128	3 900	~ 168 000
Normalized computational cost (**)	1.23	1.28	~ 1.64
Output size per year (GB)	3.7	49	~ 600

(*) grid size x time steps (**) 10^{-9} core-hour per unit problem size

Our projects on LUMI

	Preparatory	Regular
LUMI-C (CPU hours)	478 000	7 000 000
LUMI-G (GPU hours)	0	0
LUMI-P (TB hours)	150 000	230 000
Goal	Setup and test eORCA12	1960-2024 (65 years) eORCA1 1960-2024 (65 years) eORCA025 1995-2024 (30 years) eORCA12

Current status and outlook

eORCA1 and eORCA025:

- Simulations completed
- Preliminary validation of the results

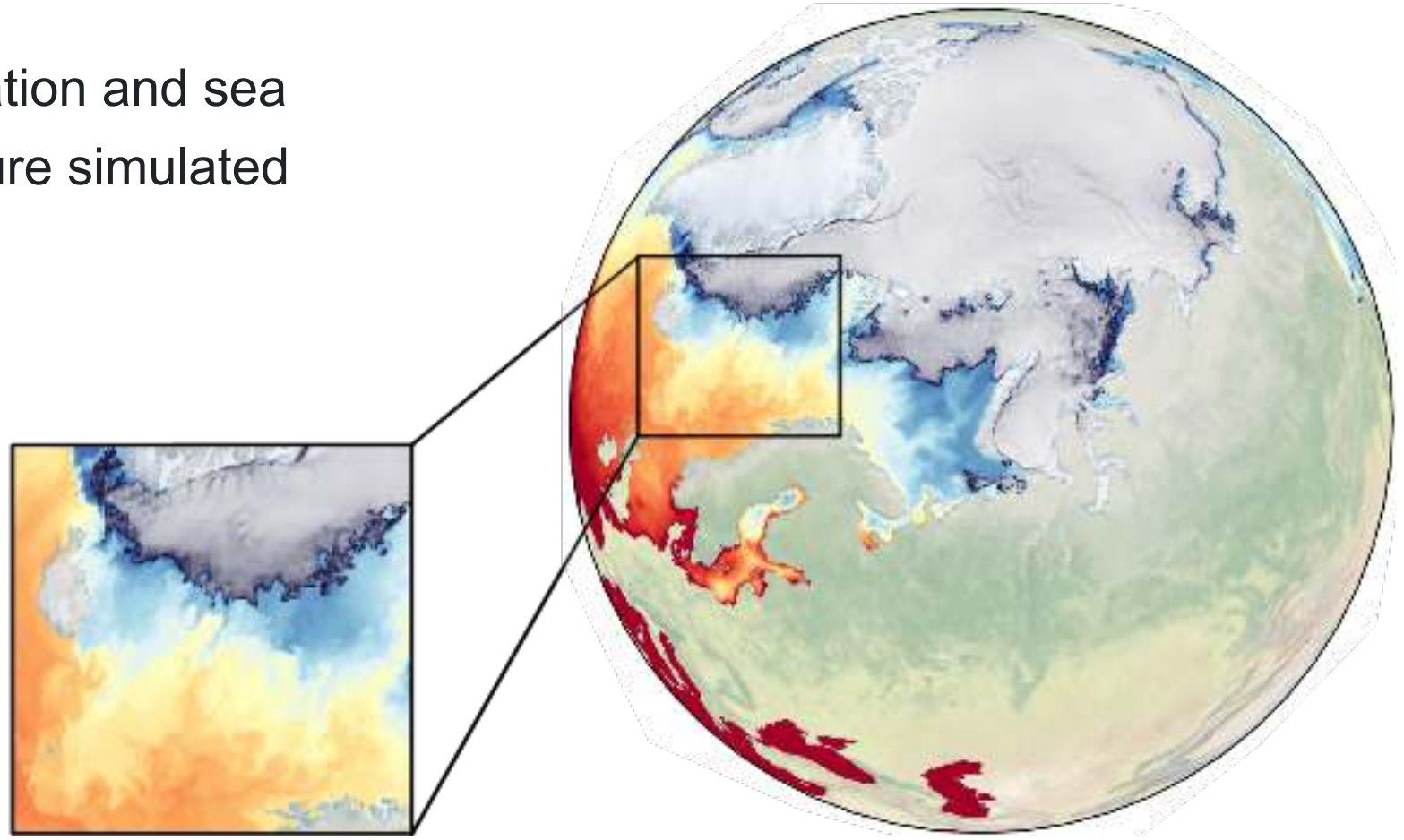
eORCA12:

- 2 years successfully run in the preparatory project
- Simulation to be launched in the regular project

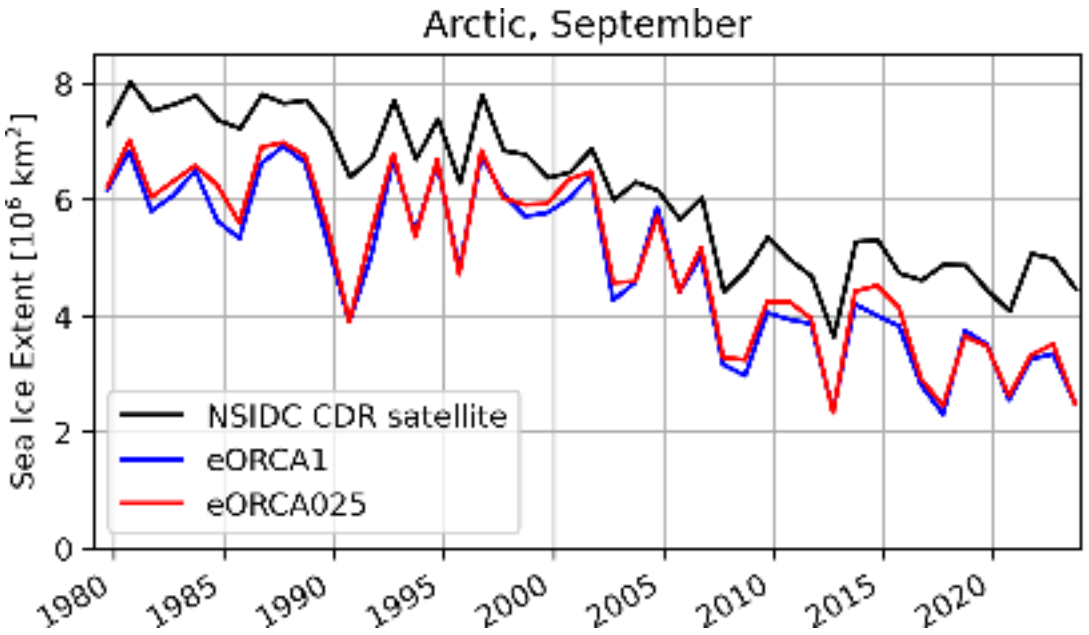
> Evaluate the impact of horizontal resolution on global ocean-sea ice simulations

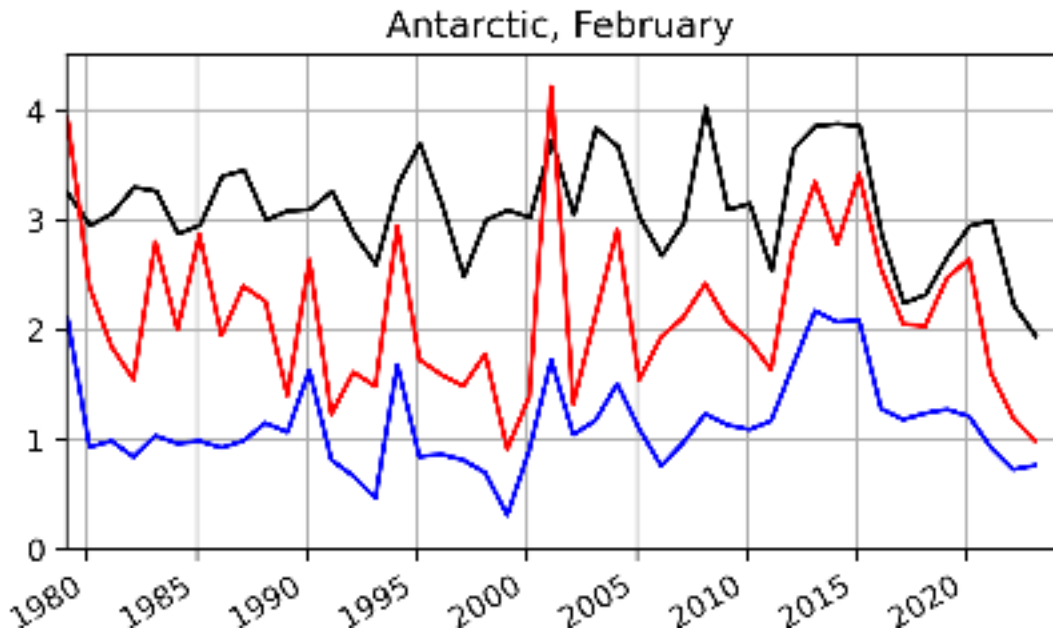
First glance at eORCA12 results

Sea ice concentration and sea surface temperature simulated on June 15, 1961



Minimum sea ice extent





Thank you!