The **MAR-NEMO** coupling : exploring **atmosphere-ocean-ice** interactions in the **Arctic** using high resolution **climate models**

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I. Why coupling models to simulate Arctic climate ?

The Arctic is warming three times faster than the rest of the planet. Key drivers to this strong warming are rapid sea ice decline and ocean heat uptake. Climate models can help us **anticipate the consequences** of the increasing temperatures on local populations and ecosystems **by simulating future climates**. However, **large uncertainties** remain in climate projections due to **poor representation and understanding of key climate processes,** in particular **interaction processes between the ocean, sea ice and atmosphere** in the Arctic that are not well implemented in atmosphere/ocean only models.

In this context, the EU-H2020 funded **PolarRES project** aims at developing the coupled system **MAR (atmosphere) - NEMO (ocean-sea ice**) over the Arctic region at **high spatial resolution (25 km)**. Such coupling will enable the climate community to access **precise data at large scale**. Here standalone models simulations are compared against observation data as the first step in coupling these models.

II. How does it work ?

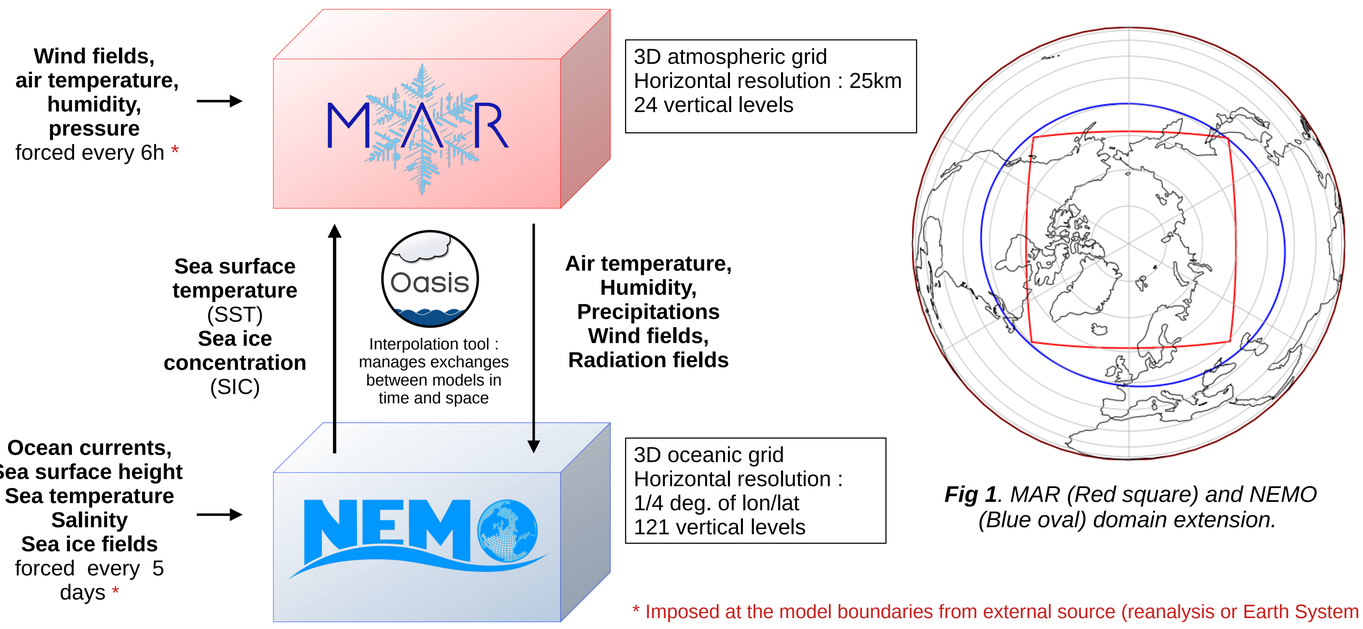


Fig 1. MAR (Red square) and NEMO (Blue oval) domain extension.

* Imposed at the model boundaries from external source (reanalysis or Earth System Model)

III. Are the models working right ?

1. MAR temperature, surface pressure and wind speed

- MAR is compared against *in situ* observation data from automatic weather stations (ECAD[1], NOAA[2]).
- Only stations with an elevation difference of less than 100m with the MAR topography are kept to avoid elevation biases.
- **Despite a cold temperature bias (~-2°C) in winter over the Atlantic sector (Fig. 3), results show fairly good agreement between MAR and the observations (Fig. 2).**

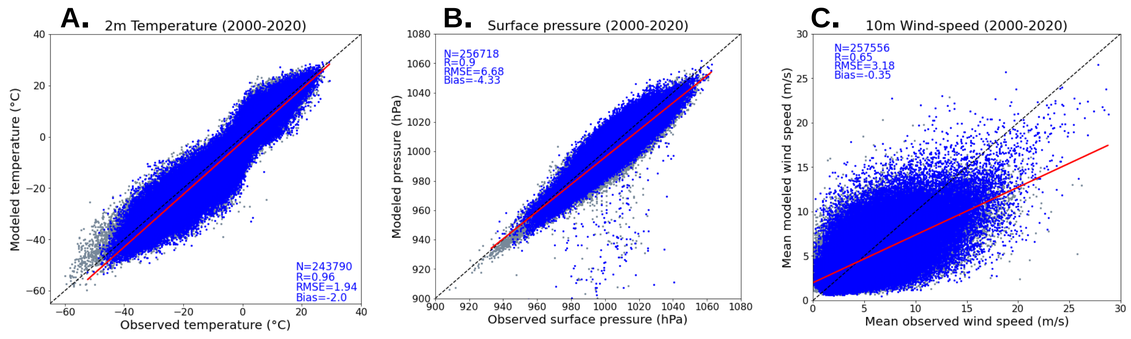


*Fig. 2 : Comparison between daily and modeled **2m- air temperature (A)**, **surface pressure (B)** and **10m – wind speed (C)**. One dot represents one daily observation from one weather station. Blue dots are from stations with at least 75 % of available data from 2000 to 2020, grey dots are from stations with at least 10 % of available data but with less than 75 % .*

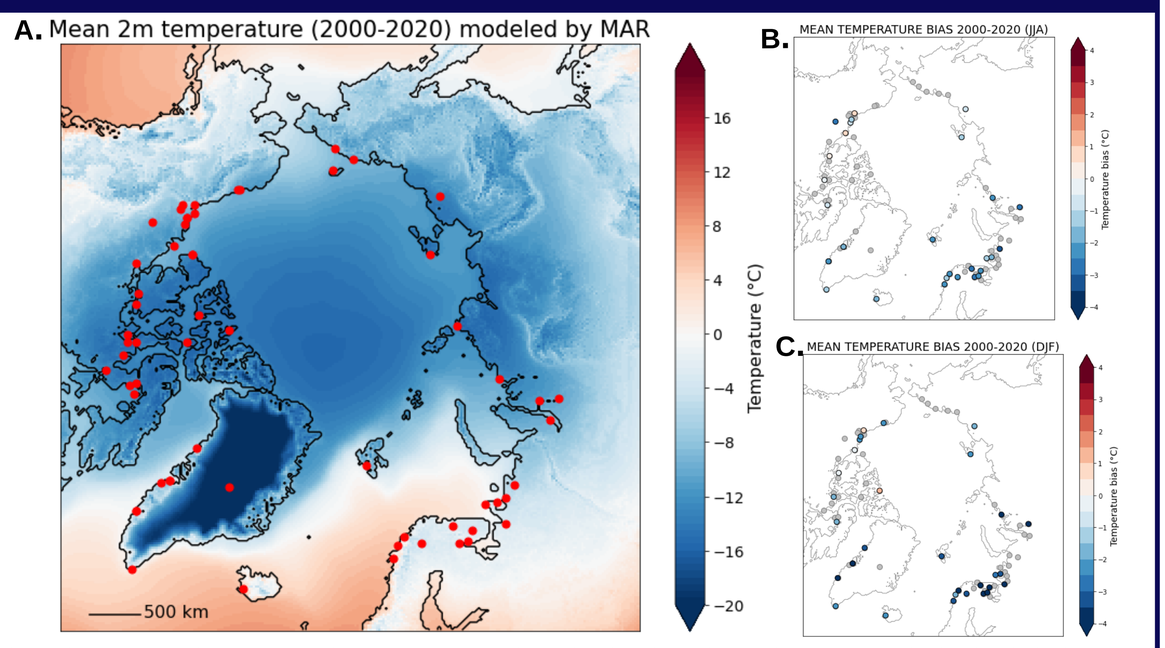
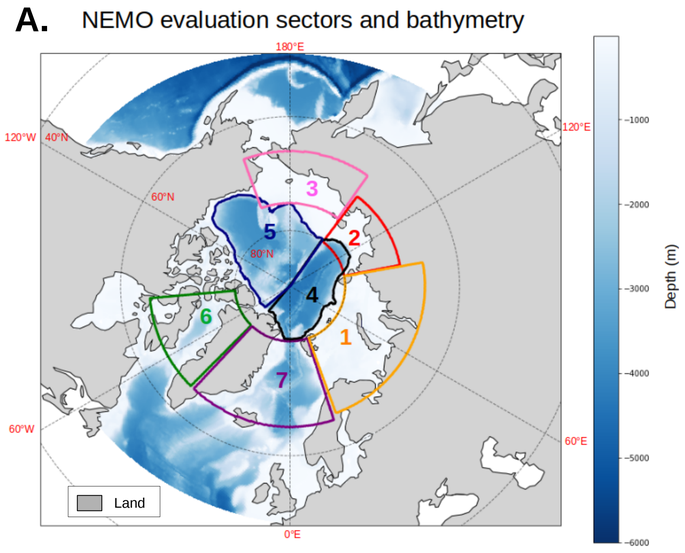


*Fig. 3 : **Plot A**) Mean 2m air temperature modeled by MAR (2000-2020). Location of weather stations used to evaluate MAR in **Fig.2** (red dots). **Plot B)** Mean summer (JJA) temperature bias of MAR in regard to stations with at least 75 % of available data (colored dots). **Plot C)** Same as plot B but for winter (DJF)*

2. NEMO Temperature and Salinity



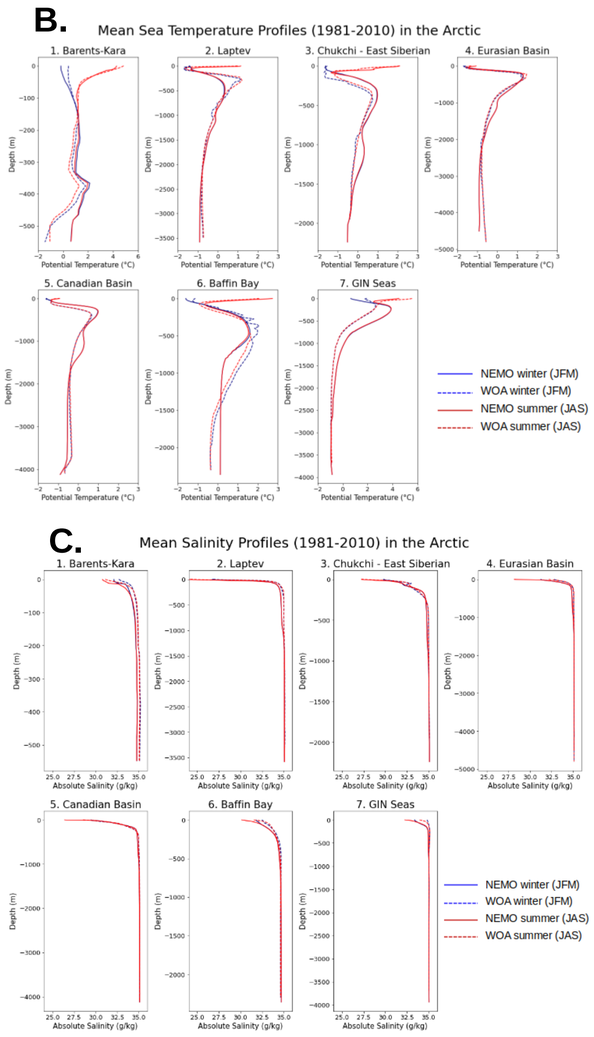


*Fig 4. **Plot A)** Extent of sectors over which data from plot B and C are averaged. Number of sectors corresponds to number of subplots in plots B and C. Modeled ocean bathymetry (color gradient) in m. **Plot B)** Mean sea temperature profiles (1981-2010) in the Arctic Ocean. Note the difference in temperature axis : Barents-Kara and GIN (Greenland-Iceland-Norwegian) seas subplots have a extended axis. **Plot C)** Mean salinity profiles (1981-2010) in the Arctic Ocean. Note the difference in depth between each subplots in plots B and C.*

- NEMO seasonal temperature and salinity mean profiles are compared against gridded observations data from the World Ocean Atlas (2023)[3] .
- **Good representation of the present-day (1981-2010) temperature and salinity fields in the Arctic Ocean by NEMO.**
- **Small biases in temperature in each sector and small bias in salinity in the Barents-Kara seas (sector 1).**

3. NEMO Sea ice extent and concentration

- The 1991-2010 monthly sea ice concentration and mean extent from NEMO are compared against a Copernicus product of satellite observations (SSMIS)[4].
- **Good representation of the mean present-day sea ice extent (1991-2020) (Fig. 5).**
- **BUT there is too much sea ice growth and sea ice melt in the model (Fig. 6).**
  - Overestimation of sea ice concentration maximums.
  - Underestimation of sea ice concentration minimums.

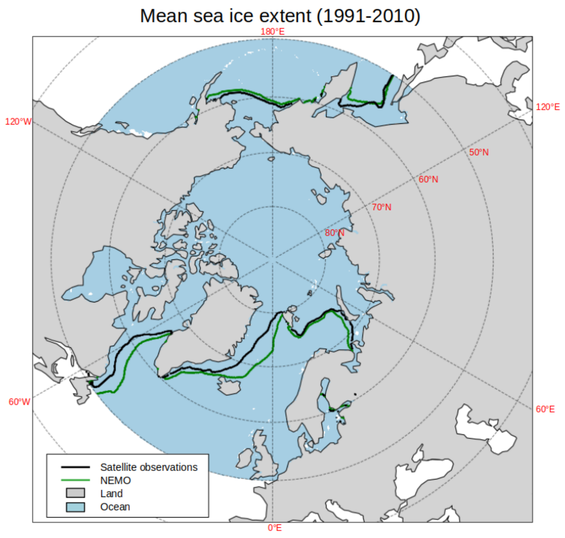


Fig 5. Mean sea ice extent (1991-2010) modeled by NEMO (green lines) and from satellite observations (black lines). These contours represent the 15 % of sea ice concentration limit over the latitude > 50°N limit.

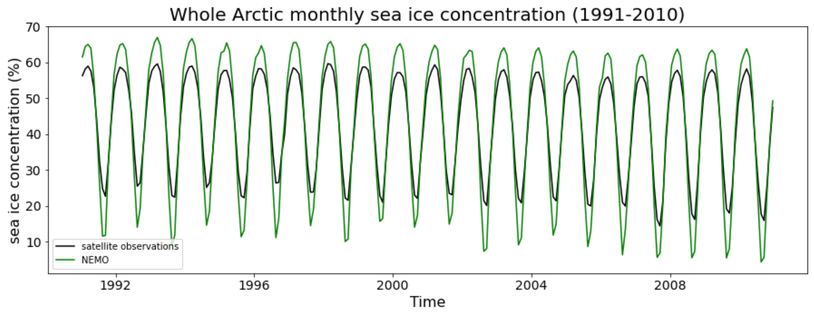


Fig 6. Monthly sea ice concentration averaged over the whole Arctic Ocean where the latitude > 50°N, between 1991 and 2010, modeled by NEMO (green line) and derived from satellite observations (black line).

IV. Take-home messages

1) The MAR-NEMO coupling is a tool that will allow better representation of atmosphere-ocean-sea ice interaction processes in the Arctic climate.

2) Models evaluations show fairly good results in representing the present-day Pan-Arctic climate and ocean state.

3) A few improvements are still to be made with the NEMO sea ice before coupled simulations can be launched.

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4. Copernicus Climate Change Service (C3S) (2020): Sea ice concentration daily gridded data from 1979 to present derived from satellite observations. Copernicus Climate Change Service (C3S) Climate Data Store (CDS). DOI: 10.24381/cds.3cd8b812 (Accessed on 07-03-2024)