Supporting Information for
"Drivers of Arctic Ocean warming in CMIP5 models"

Clara Burgard[1], **Dirk Notz**[1]

[1]Max Planck Institute for Meteorology, Hamburg, Germany

Contents

Introduction

This supporting information provides more informations about models, data and methods used in our study.

1 Table S1.

Corresponding author: Clara Burgard, clara.burgard@mpimet.mpg.de

Table S 1: CMIP5 climate models used and their ensemble size. Models with a (*/$^{+}$/^{x}) provide a (reasonable) sea water transport across lines/sea-ice transport across Fram Strait/easily computable sea-ice transport across Fram Strait.

Modeling Center/Group	**Model Name**	**Ensemble size**
Commonwealth Scientific and Industrial Research Organization (CSIRO) and Bureau of Meteorology (BOM) *Australia*	ACCESS1.0*$^{+}$ ACCESS1.3*$^{+}$	1 1
Canadian Centre for Climate Modelling and Analysis *Canada*	CanESM2*	5
National Center for Atmospheric Research *USA*	CCSM4	6
Community Earth System Model Contributors *USA*	CESM1-BGC CESM1-CAM5	1 3
Centro Euro-Mediterraneo per I Cambiamenti Climatici *Italy*	CMCC-CM CMCC-CMS	1 1
Centre National de Recherches Météorologiques / Centre Européen de Recherche et Formation Avancée en Calcul Scientifique *France*	CNRM-CM5^{+}	1
Commonwealth Scientific and Industrial Research Organization in collaboration with Queensland Climate Change Centre of Excellence *Australia*	CSIRO-Mk3.6.0	10
LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences and CESS, Tsinghua University *China*	FGOALS-g2^{x}	1
NOAA Geophysical Fluid Dynamics Laboratory *USA*	GFDL-CM3 GFDL-ESM2G^{+} GFDL-ESM2M^{+}	1 1 1
NASA Goddard Institute for Space Studies *USA*	GISS-E2-R^{x}	6
Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais) *UK*	HadGEM2-CC* HadGEM2-ES	1 4
Institut Pierre-Simon Laplace *France*	IPSL-CM5A-LR IPSL-CM5A-MR IPSL-CM5B-LR	4 1 1
Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo) and National Institute for Environmental Studies *Japan*	MIROC5	3
Max Planck Institute for Meteorology *Germany*	MPI-ESM-LR^{+} MPI-ESM-MR*$^{+}$	3 3
Meteorological Research Institute *Japan*	MRI-CGCM3^{+}	1
Norwegian Climate Centre *Norway*	NorESM1-M*$^{+}$ NorESM1-ME*$^{+}$	1 1

2 Definition of the regions

The regions for the temperature calculations in Sec. 4 are defined as follows:

- Barents Sea Opening: 16.5 to 19°E, 70 to 76.5°N
- Bering Strait: 171 to 166°W, 65 to 66°N
- Fram Strait: 11.5°W to 10.5°E, 79.5 to 81.5°N
- Canadian Archipelago: 128.5 to 59.5°W, 70.5 to 82°N
- Denmark Strait: 37 to 22.5°W, 65.5 to 66.5°N
- Iceland-Faroe Channel: 13.6 to 7.4°W, 62.2 to 64.9°N
- Faroe-Scotland Channel: 6.9 to 5°W, 58.7 to 62°N
- Fram Strait East: 0 to 15°E, 77 to 80°N
- Fram Strait West: 30 to 0°W, 77 to 80°N
- Barents Sea: 17.5 to 60°E, 66 to 80°N

3 Calculation of the oceanic heat content

For the calculation of the oceanic heat content, the following formulas were used:

$$H_{\text{tot}} = H_{\text{sens}} + H_{\text{lat}} \tag{1}$$

$$H_{\text{sens}} = \rho_w c_{pw} \int_{66^\circ N}^{90^\circ N} \int_{z_{\text{max}}}^{0} T \; dz \; dA \tag{2}$$

with ρ_w the density of the water (taken as constant ρ_w = 1025 kg/m^3), c_{pw} the heat capacity of the water (3902 $\leq$ $c_{pw} \leq$ 4186 J kg^{-1} K^{-1}, depending on the model - see https://search.es-doc.org/), T the potential water temperature in K, z_{max} the depth of the water column in m and dA the area of the Arctic Ocean domain in the individual models.
Using a constant density between 1015 and 1035 kg/m^3 yields an error of up to $\pm 1\%$ compared to using 1025 kg/m^3. We therefore assume that the error induced by assuming a constant density of 1025 kg/m^3 is negligible.

$$H_{\text{lat}} = -\rho_i L_i \int_{66^\circ N}^{90^\circ N} SIV \; dA \tag{3}$$

with ρ_i the density of the ice (ρ_i = 910 kg/m^3), L_i the latent heat of fusion of fresh ice (L_i=334774 J/kg) and SIV the sea-ice volume in each grid cell.

4 Mass transport in and out of the Arctic Ocean

The sum of the mass transport at the Arctic Ocean boundaries is shown in Fig. S1. This is the sum of the mass transport through the Fram Strait, the Barents Sea Opening, the Canadian Archipelago and the Bering Strait. We set the threshold for a 'reasonable value' to a net mass gain or loss of below 0.25x10^9 kg/s. We do not consider *GFDL-ESM2M*, *MRI-CGCM3* and *MPI-ESM-LR* further in our study, as their mass budget is not closed properly.

5 Figure S1

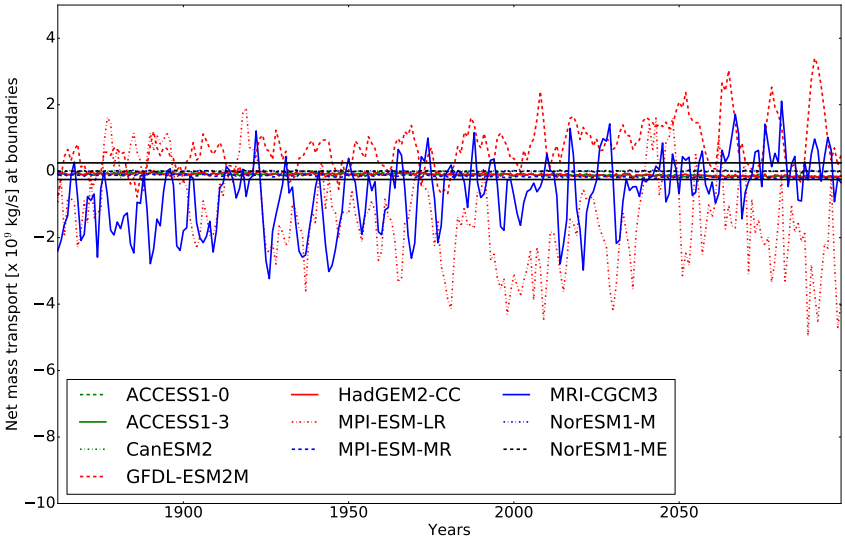

Figure S 1: Mass budget for the Arctic Ocean boundaries for the models providing mass transport across lines. The thick black lines represent our chosen threshold for the variability of the mass budget.

6 Calculation of the meridional temperature gradients

The meridional temperature gradients were calculated as the difference of the mean temperature between the Arctic (66°N to 90°N) and the region south of the Arctic (50°N to 66°N). For the atmospheric gradient, the surface air temperature was used. For the oceanic gradient, the sea surface temperature was used.

7 Calculation of the Arctic Amplification

The Arctic Amplification was computed as the ratio between the surface air temperature increase in the Arctic (66°N to 90°N) and the surface air temperature increase in the tropics (30°S to 30°N) between 1961 and 2099.