Project: 1059
Project title: H2020 project Blue-Action
Principal investigator: Dr. Daniela Matei
Allocation period: 2022-01-01 to 2022-12-31

Achievements in 2022

<u>Artic sea ice loss and Eurasian winter cooling</u>

The role of Arctic sea ice (SIC) loss in the recent Eurasian winter cooling is assessed in a multi model ensemble of two sets of AMIP-type experiments for the 1979-2014 period, the AMIP/CMIP6 reference period. The experiments performed with the atmospheric component of the MPI-ESM model part of this multi model ensemble were carried out under this project. In the first experiment (hereafter ALL), the atmospheric model is forced with observed daily sea surface temperature (SST) and Arctic sea ice concentration (SIC). The second experiment (hereafter SICclim) has the same boundary conditions except for the Arctic (SIC), which is prescribed by its daily climatology. The analysis of the how the variability in near surface temperature over Eurasia is affected by Arctic sea ice loss show that in the multi model ensemble the trends in the first two modes of variability lead to contrasting changes. While the trend in the first model of variability leads to warming over both the Arctic and Eurasia under Arctic sea ice loss, the trend in the second mode of variability leads to an Eurasian cooling an Arctic warming (Figure 1b,c). Comparison with the observed trends in these modes of variability shows that during the 1979-2014 period, only the second mode of variability is reporting a significant trend (Figure 1a). Thus, for the first mode of variability, the observed trend lies outside the modelled distribution of the trends. The reason for this discrepancy is unclear and under investigation.

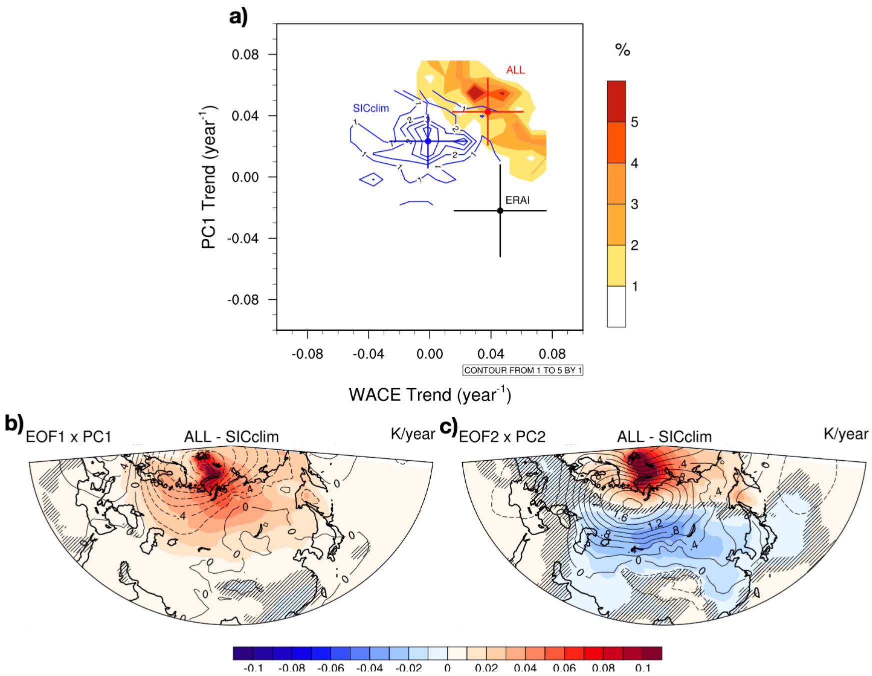

Figure 1: (a) The joint probability density function of the trends of the first (PC1) and second (PC2/WACE) mode in near surface temperature in SICclim (in blue contour) and in ALL (in color shading) from the multi-model ensemble. The blue and red dots/lines are the respective ensemble means/ensemble standard deviations of the PC trends in SICclim and ALL. The black dot is for the trends in ERAI and the respective black lines are showing the 95% confidence interval of the PC trends. Units are in percent. (b) The difference of the ensemble mean trends between ALL and SICclim, associated with PC1 for the near surface temperature (shading, K/year). Contours are for the associated sea level pressure trends (Pa/year). (c) As in (b) but for P2/WACE. The unhatched regions in (b) and (c) are significant at 5% level. From Ghosh et al., in revisions.

Simulated contribution of the interdecadal Pacific oscillation to the west Eurasia cooling in 1998–2013

The Blue-Action large ensemble simulations with six atmospheric general circulation models involved are utilized to verify the interdecadal Pacific oscillation (IPO) impacts on the trend of Eurasian winter surface air temperatures (SAT) during 1998–2013, a period characterized by the prominent Eurasia cooling (EC).

In our coordinated multi-model large ensemble simulations, the internally driven IPO brings a cooling trend over the west part of the EC region during 1998–2013. The cooling driven by IPO is about a quarter of the observed EC in this area. The cooling trend is associated with the phase transition to the strong negative IPO, which drives SLP changes with positive/negative/positive SLP trends situated over the North Pacific/Arctic/Northeast Atlantic regions.

The internal variability intrinsic due to the atmosphere and land is also evaluated using the large ensembles. The EC/west-EC shown in ERA5 is located at the 3.7th/9.63th percentile of the ALL distribution. The spread among ensembles driven by internal variability is more than three times the isolated IPO impacts, which can shadow the modulation of the IPO on the west Eurasia winter climate.

Based on the results presented in this study, the IPO can be expected to reduce the severely cold winters in the west Eurasia regions when it reversed to its positive phase. Still, this hypothesis needs to be verified by further study. This study concerns the internal-driven IPO impact. The external radiative forcing can also alter the decadal SST variations in the Pacific (Meehl et al 2013). When the decadal Pacific SST variations driven by external forcing are in or out of phase with the internally driven IPO, the impacts of the Pacific on Eurasia would be intensified or reduced. It would be useful to compare and also combine the impacts of internally and externally driven Pacific SST variations to improve the climate prediction in the Eurasia region.

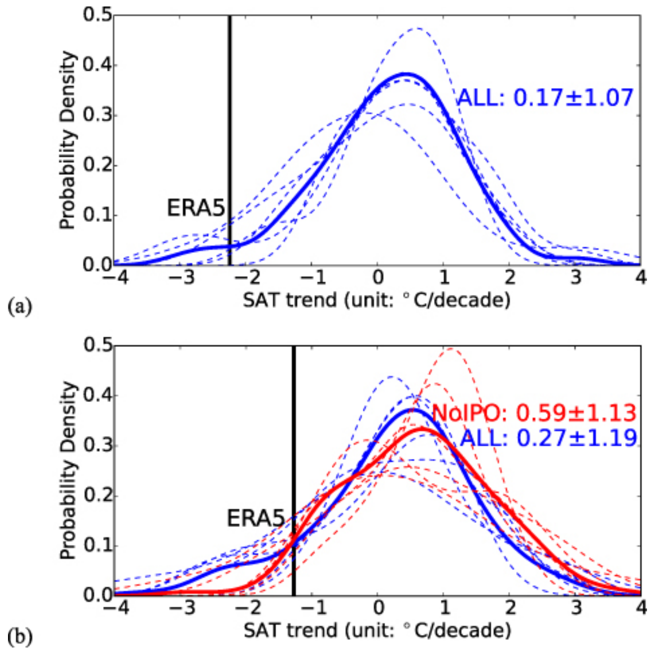

Figure 2. PDFs of 1998–2013 SAT trend averaged over (a) 35° E–120° E and 45° N–60° N and (b) 35° E–70° E and 45° N–65° N estimated from ALL/NoIPO ensembles (blue/red lines). The thin dotted lines show the PDFs estimated from the single model ensembles, and the thick lines show the PDFs estimated from all model ensembles. Black line marks the respective corresponding average in ERA5. Numbers indicate the mean ± standard deviation of the ensemble distributions. From Suo et al., 2022.

References:

L. Suo, G. Gastineau, Y. Gao, Y.C. Liang, R. Ghosh, T. Tian, Y. Zhang, Y.-O. Kwon, O.H. Ottera, S. Yang, D. Matei, 2022: Simulated contribution of the interdecadal Pacific oscillation to the west Eurasia cooling in 1998–2013. Environmental Research Letters 17 (9), 094021.

Meehl G A, Hu A, Arblaster J M, Fasullo J and Trenberth K E, 2013: Externally forced and internally generated decadal climate variability associated with the interdecadal Pacific Oscillation J. Clim. 26 7298–310.

Coupled sea ice sensitivity experiments

Within H2020 project BlueAction, MPI-M has performed sea ice sensitivity experiments with its earth system model MPI-ESM1.2, in which respectively the pre-industrial, present or future arctic sea ice concentration is prescribed. Each of the three sea ice concentrations encompasses 240 simulations (with an integration length of one year). The large number of simulations is necessary to separate the impact of the diminishing arctic sea ice concentration on the northern hemispheric climate from the internal climate variability. The analysis is based on the ensemble mean over all 240 simulations.

The difference in the surface temperature between future and pre-industrial sea ice concentration shows – apart from the well-known warming in the (sub)arctic region – a cooling in the northern hemispheric subtropical belt (Figure 3). One possible mechanism underlying the colder sea surface temperature in the subtropical North Atlantic and North Pacific arises from the difference in the oceanic gyre circulation between future and pre-industrial sea ice concentration (left panels in Figure 4). The latter shows a southward shift of the boundary between the subtropical and subpolar gyre (comparison between left and right panels in Figure 4). The associated changes in the meridional heat transport, especially in the mid-latitudes, might lead to a divergence in the oceanic heat transport in the subtropics and thus to a cooling. A shift in the gyre boundary is generally associated with a shift in the "zero line" of the wind stress curl, caused by changes in the wind field.

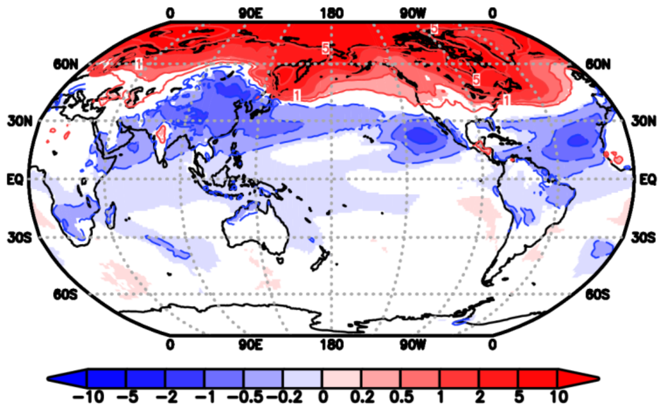

***Figure 3**: Difference in the surface temperature [in °C] between future and pre-industrial arctic sea ice concentration.*

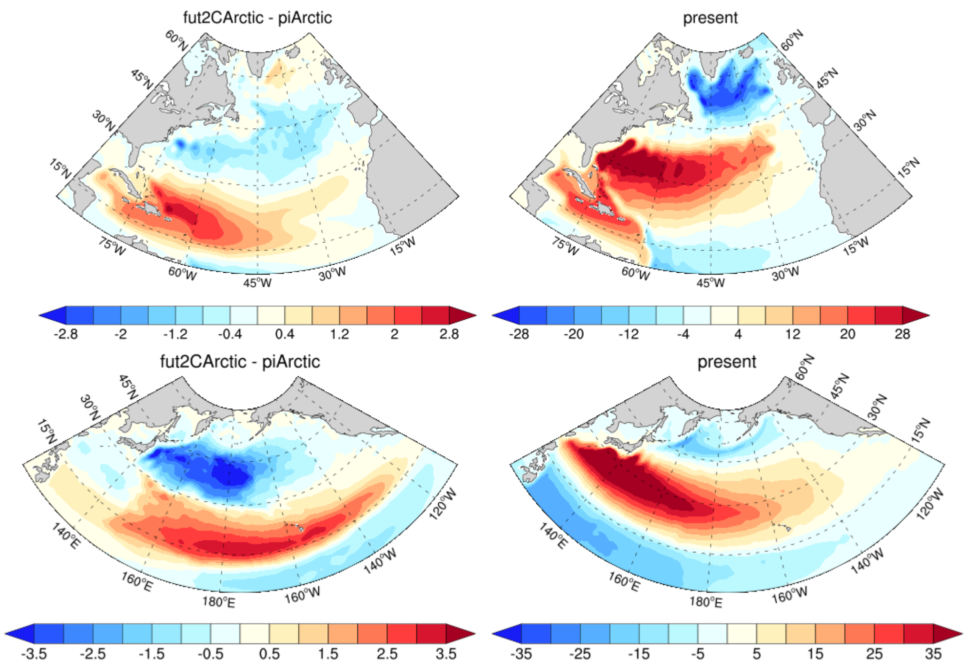

***Figure 4:** Left panels: Difference in the North Atlantic and North Pacific gyre circulation [in 10^6 m^3/s] between future and pre-industrial arctic sea ice concentration. Right panels: North Atlantic and North Pacific gyre circulation [in 10^6 m^3/s] under present arctic sea ice conditions.*

Ocean-eddy-resolving prediction experiments

Analysis of the ocean-eddy-resolving prediction experiments has been taken over by JPI Oceans / JPI Climate project ROADMAP (project 1190, see separate application).