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Regional links between atmospheric variability and the sea-ice-ocean system in the Southern Ocean

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Current global warming has resulted in a distinct sea-ice loss in the Arctic. In contrast, the sea-ice area (SIA) in the Southern Hemisphere (SH) has slightly increased over the past decades. This seems even more counter-intuitive since the surface temperature over the Southern Ocean has also increased during this time. Thus, we take up the hypothesis that changes in the atmospheric circulation are responsible for the absence of the sea-ice decline. The dominant feature of the SH atmospheric variability is the Southern Annular Mode (SAM), whose index showed an increase for the past decades.

Using ERA-40 reanalysis data and satellite-borne observations (HadISST1) for 1979-2001 we detect synchronous variability in the mean sea-level pressure (SLP), sea-surface temperature (SST) and sea-ice concentration (SIC) fields. Although the Antarctic region is characterized by its circumpolar structure, the inter-annual variability of the Southern Ocean climate system shows a distinct asymmetry. Thus we propose that the Southern Ocean climate system is split into two regimes.

The western half of the Southern Ocean is defined as the non-annular regime which is dominated by the Amundsen Low pressure system. The region reveals a dipole structure in SIC and SST anomalies. Depending on the strength of the Amundsen pressure system, the state of the see-saw in the ice-ocean system changes. The eastern half of the Southern Ocean is defined as the annular regime and characterized by an approximately zonal symmetry in the variations of SIC, SST and SLP. Although the recent increase in SH sea-ice cover is largest in the Amundsen-Ross sector, the dipole structure of the non-annular regime cancels this trend. Thus, we find that sea-ice changes in the annular regime are more important for explaining the recent positive hemispheric SIA trend.

Since changes in the strength of the Amundsen low appear to dominate changes in the SAM-index, the recent hemispheric SIA trends, which mainly occur in the annular regime, can not be related to the recent SAM increase. The SAM-index rather seems to describe the state of the see-saw in the non-annular regime. Therefore we introduce regional SLP-indices for each of the two regimes. Indeed, the SIA increase outside the dipole region is correlated to the local SLP-index. These findings show that there is a clear regional link between the atmosphere and sea-ice.

In order to sustain these results which base on a rather short observational period, we investigate simulations performed with the NCAR Community Climate System Model version 3 (CCSM3). This model shows a good representation of the simulated variability compared to observations.