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Determination of Arctic sea ice variability modes on interannual timescales via nonhierarchical clustering

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Over the modern observational era, the northern hemisphere sea ice concentration, age and thickness have experienced a sharp long-term decline superimposed with strong internal variability. Hence, there is a crucial need to identify robust patterns of Arctic sea ice variability on interannual timescales and disentangle them from the long-term trend in noisy datasets. The principal component analysis (PCA) is a versatile and broadly used method for the study of climate variability. However, the PCA has several limiting aspects because it assumes that all modes of variability have symmetry between positive and negative phases, and suppresses nonlinearities by using a linear covariance matrix. Clustering methods offer an alternative set of dimension reduction tools that are more robust and capable of taking into account possible nonlinear characteristics of a climate field. Cluster analysis aggregates data into groups or clusters based on their distance, to simultaneously minimize the distance between data points in a given cluster and maximize the distance between the centers of the clusters. We extract modes of Arctic interannual sea-ice variability with nonhierarchical K-means cluster analysis and investigate the mechanisms leading to these modes. Our focus is on the sea ice thickness (SIT) as the base variable for clustering because SIT holds most of the climate memory for variability and predictability on interannual timescales. We primarily use global reconstructions of sea ice fields with a state-of-the-art ocean-sea-ice model, but we also verify the robustness of determined clusters in other Arctic sea ice datasets. Applied cluster analysis over the 1958-2013 period shows that the optimal number of detrended SIT clusters is K=3. Determined SIT cluster patterns and their time series of occurrence are rather similar between different seasons and months. Two opposite thermodynamic modes are characterized with prevailing negative or positive SIT anomalies over the Arctic basin. The intermediate mode, with negative anomalies centered on the East Siberian shelf and positive anomalies along the North American side of the basin, has predominately dynamic characteristics. The associated sea ice concentration (SIC) clusters vary more between different seasons and months, but the SIC patterns are physically framed by the SIT cluster patterns.