Determination of Arctic sea ice variability modes on interannual time scales via K-means cluster analysis

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● Since 1970s the northern hemisphere (NH) sea ice cover has experienced a substantial long-term decline superim-posed onto the strong internal variability

➡ this study aims to identify robust patterns of the NH sea ice variability on interannual time scales disentangled from the long-term change change

● Unsupervised learning methods:
Principal component analysis (**PCA**) yields valuable low-dimensional representation, but it has a number of limitations
Clustering methods – aggregate data in clusters/modes based on their distance to simultaneously minimize distance be-tween data points in a given cluster and maximize the distance between the centers of the clusters
➡ K-means cluster analysis

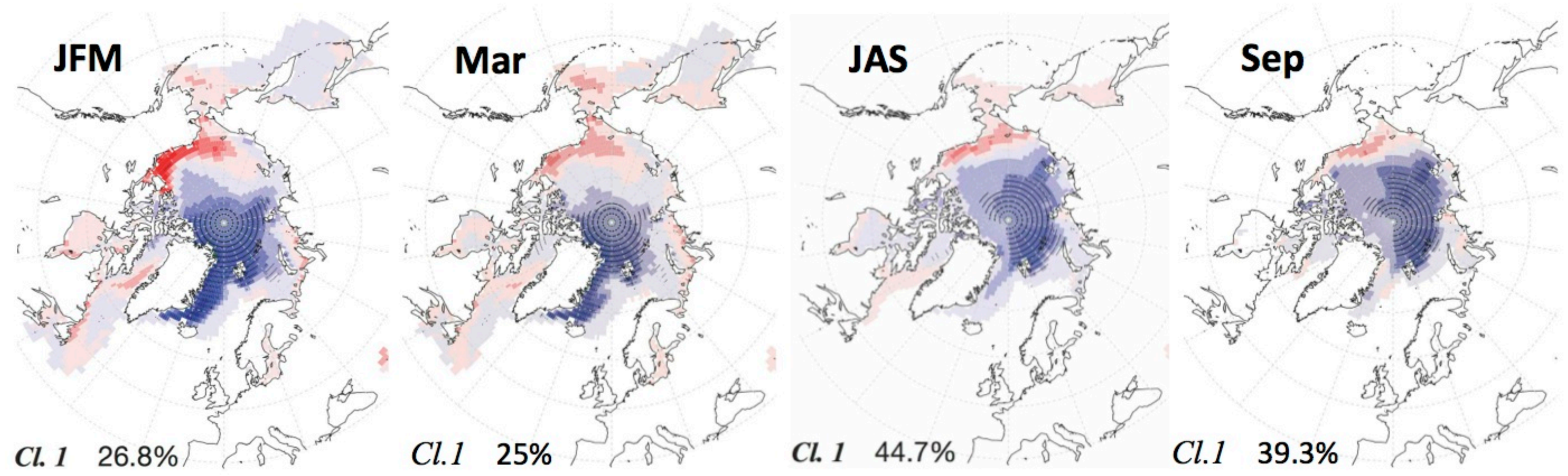
● Use **sea ice thickness (SIT),** from two reconstructions with NEMO/LIM2 (Guemas et al., *Clim. Dynamics* 2014), has potential to store the sea ice system memory crucial for interannual variability and predictability

● Use ERA-40 and ERA-Int reanalyses

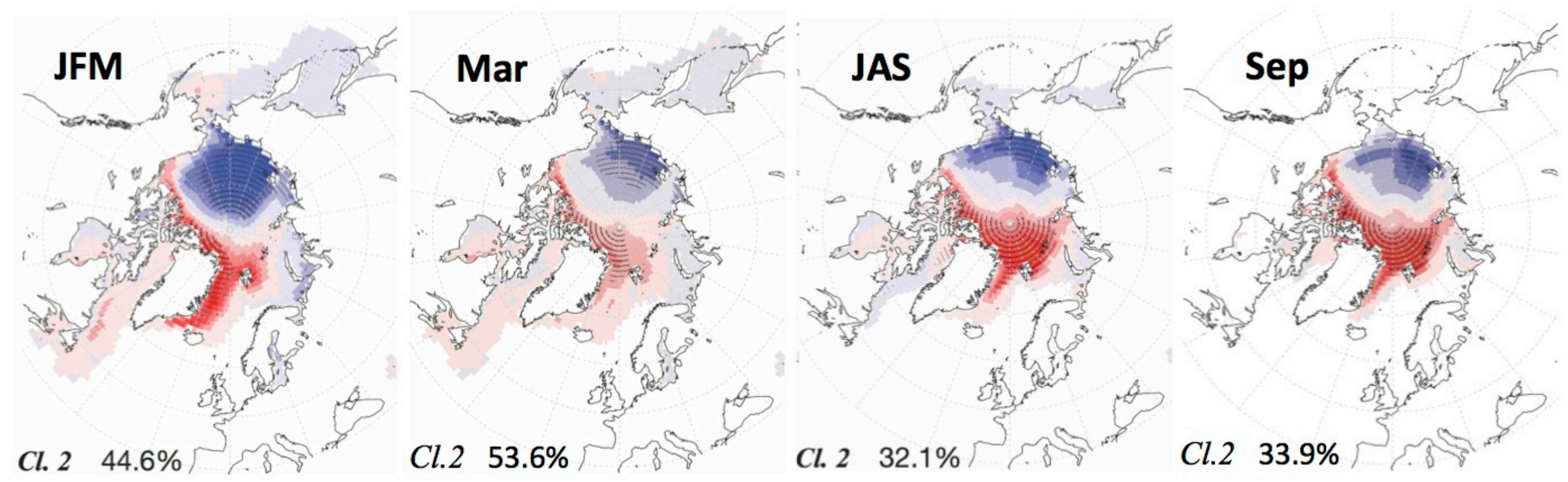
● To filter out long-term climate change we have to go beyond linear detrending
⇒ use 2nd order polynomial residuals to obtain invariant SIT cluster patterns with respect to an increase of the order of poly-nomal fit (the same goes for PCA modes)

● **Optimal number of SIT clusters is K=3**

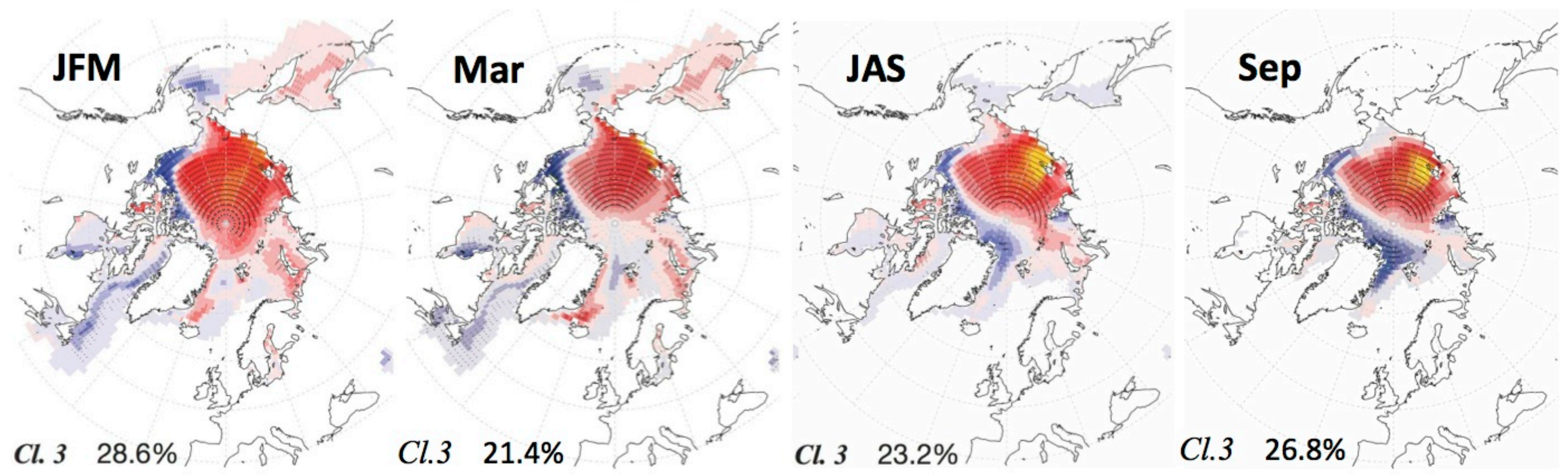
Cluster 1 = Central Arctic Thinning (**CAT**) mode SIT(SIT$^{(Ar)}$) - r2

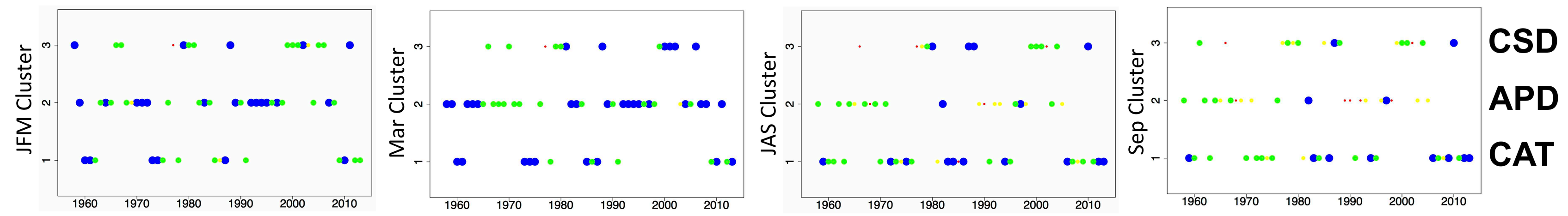


Cluster 2 = Atlantic Pacific Dipole (**APD**) mode SIT(SIT$^{(Ar)}$) - r2

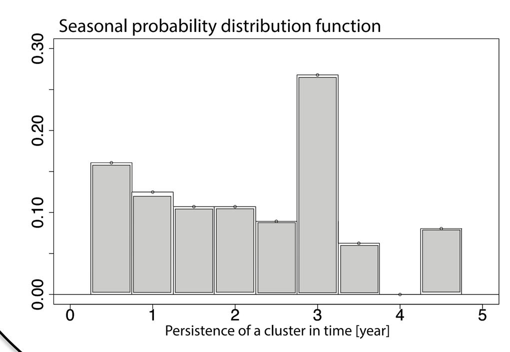


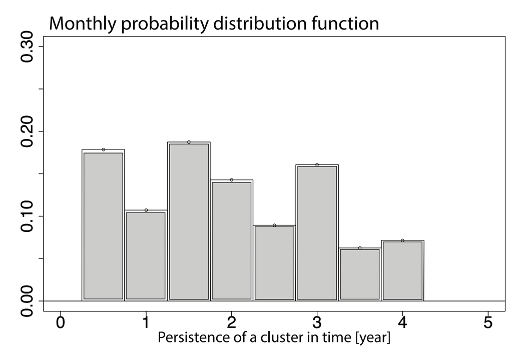
Cluster 3 = Canadian Siberian Dipole (**CSD**) mode SIT(SIT$^{(Ar)}$) - r2

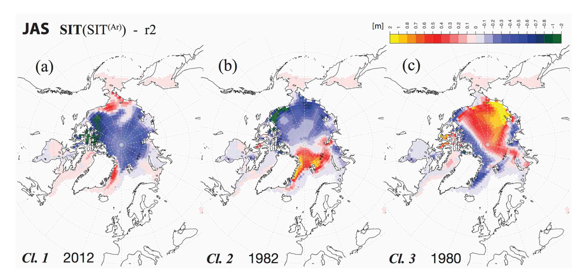




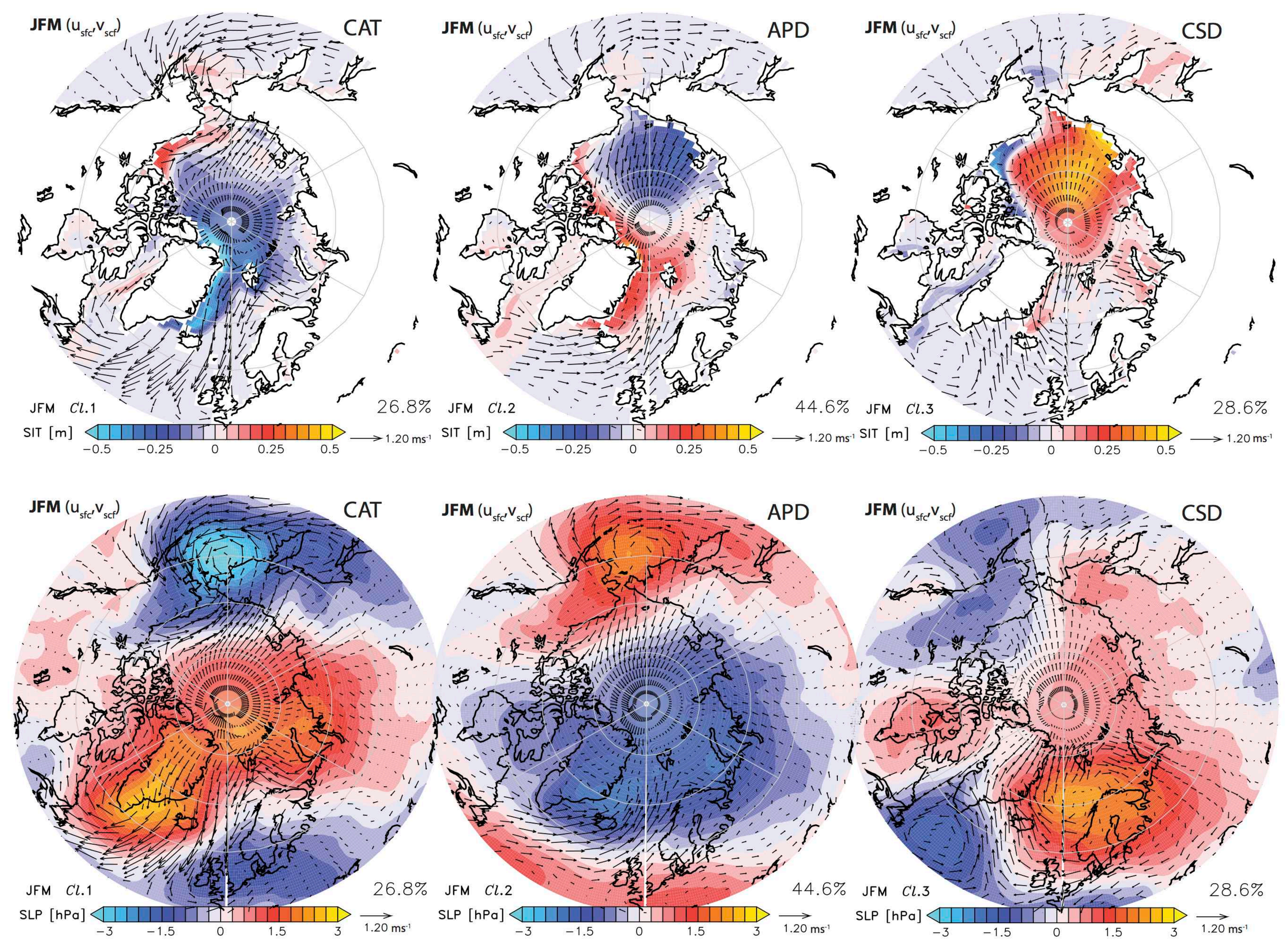
The SIT cluster patterns over the 1958-2013 period are robust, i.e. very similar in different seasons and months, and their time series of occurrences have many commonalities with predominant persistence of a cluster on interannual time scales.







Examples of cluster occurrences



The associated sea level pressure and surface wind clusters are key for the formation of SIT clusters firstly through change in the Beaufort gyre and the Transpolar drift.

● **Removing 2nd degree polynomial approximation of the long-term change change leads to robust interannual K-means cluster (mode) patterns**

● Optimal number of the NH SIT clusters is **K=3**:
Cl. 1 = **CAT** (central Arctic thinning) mode,
Cl. 2 = **APD** (Atlantic-Pacific dipole) mode,
Cl. 3 = **CSD** (Canadian-Siberian dipole) mode, and they have similar patterns, and their time series of occurrences, in different months and seasons

● Time series of cluster occurrences has **substantial persistence on interannual time scales** (p>70%)

● Surface wind is important for depositing climate signal in SIT that is accumulated and released on interannual time scales