A coupled perspective on the Atmosphere-Sea-Ice variability

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SUMMARY

Ice-atmosphere covariability in the Northern hemisphere on a subseasonal-to-decadal time scale is analysed using reanalysis data. A diagnostic tool is proposed.

The problem

The formulation of Arctic-midlatitudes teleconnections is often shaped around the idea of forcings inside the Arctic region that affect the atmosphere non-locally. Location, magnitude and timing of the forcing involve processes on the decadal and multi-decadal time scale and faster atmospheric processes as well. The problem of the atmospheric response to the forcing lies in the seasonal-to-subseasonal time scale. We present an analysis of ice-atmosphere co-variability that emphasizes the entanglement of the two time scales. Presented results are based on the ERA-Interim reanalysis. Geopotential height (500 hPa) has been used to define indexes of atmospheric circulation (e.g. NAO, Siberian High). Sea-ice cover has been used to define indexes referred to the Labrador sea, the Barents sea and the whole Arctic Ocean (fig. 1). It is found that surface heat fluxes are controlled by the state of ice and atmosphere (fig. 2) and the system shows a peculiar behavior that entangles the two time scales (fig. 3-4). The presented approach can help us formulate questions around Arctic-Midlatitudes interaction in a way that is anchored to observational evidence. Results encourage to explore, under suitable modelling framework, the decadal modulation of the coupled ice-atmosphere interaction on a subseasonal-to-seasonal time scale (e.g. fig. 5 and table 1).

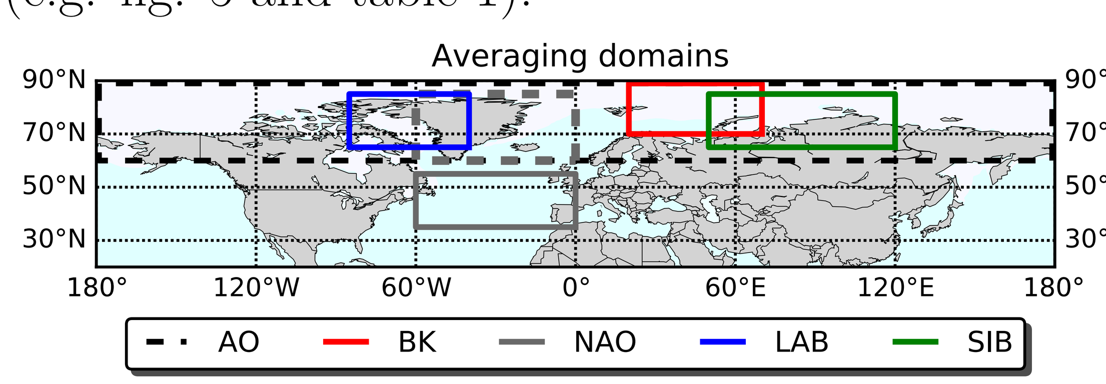

Figure 1: Averaging domains used in the analysis.

METHODS

Two indexes (N,I) are defined to describe the state of one feature of the atmospheric circulation (N) and of Arctic sea ice cover (I). Both are monthly standardized anomalies. Quantities displayed in figure 5 are computed from monthly standardized anomalies $\Gamma(m,y)$ as functions of (N,I) coordinates using the following definitions, where $\langle \dots \rangle = \equiv \sum_{y=1}^{N_{years}} \sum_{m=1}^{5} (\dots)$:

$$\tilde{\Gamma} = \Gamma(N,I) \equiv \frac{\langle \sum_{N'} \sum_{I'} \Gamma(m,y) \delta_{N',N(m,y)} \delta_{I',I(m,y)} \rangle}{\langle \sum_{N'} \sum_{I'} \delta_{N',N(m,y)} \delta_{I',I(m,y)} \rangle}, \delta_{N',N(m,y)} = \begin{cases} 1 & \text{if } N - \Delta N < N' < N + \Delta N \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

and $\delta_{I',I(m,y)}$ is defined similarly. In the presented analysis, Γ can be the tendency of N or I (respectively $\tilde{N}_t$ and $\tilde{I}_t$) or heat fluxes (F). Monthly tendencies are defined as $\Gamma(m+1,y) - \Gamma(m,y)$. 3 datasets have been used but only results from ERA-Interim are presented.

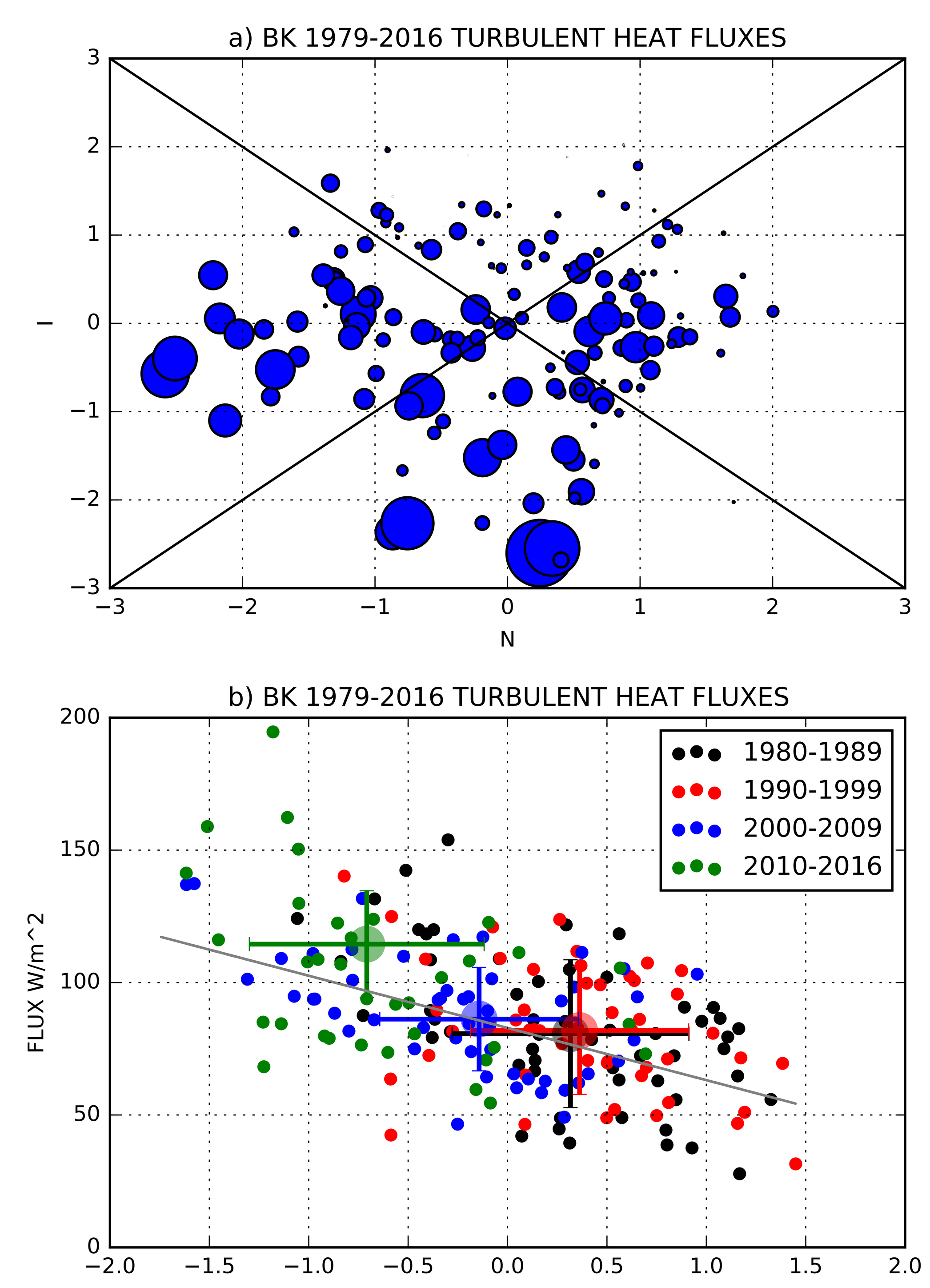

Figure 2: a) Scatter plot of index N_{NAO} and index I_{BK} as defined in section 2, in the cold season (NDJFM) for 1979-2017. The radius of the marker is proportional to the magnitude of anomalous surface turbulent heat fluxes in the BK area. b) Surface turbulent heat fluxes in BK versus a linear combination of the N_{NAO} index and the I_{BK} index. Errorbars correspond to two standard deviations.

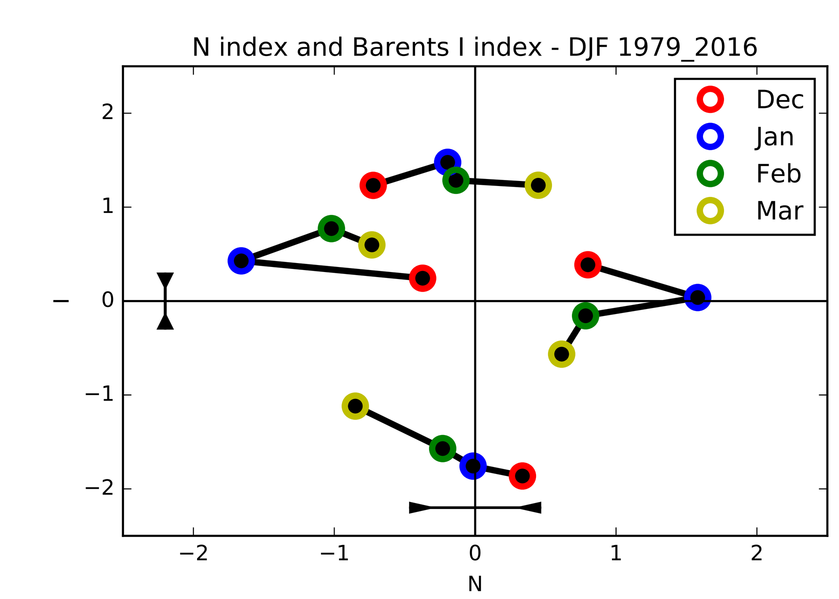

Figure 3: Seasonal evolution of the average N_{NAO} index and I_{BK} index for 4 clusters of years. Clusters are defined selecting individual years that had either the N or the I index above (below) the 88th (12th) percentile in January. Two bars indicate the 95th percentile of the distribution of the difference for each index between December and March from 2000 random clusters.

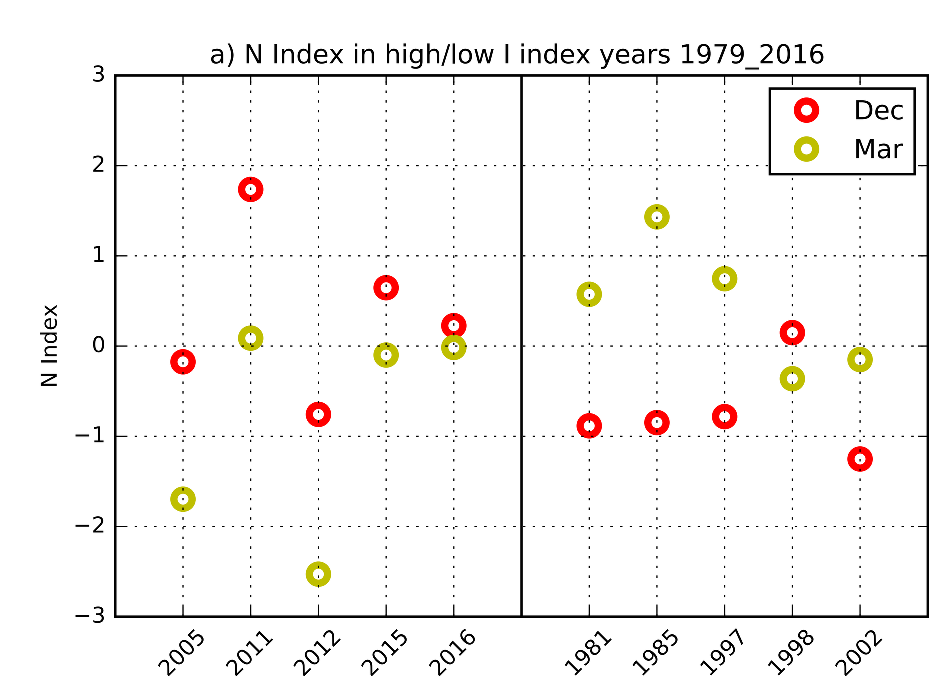

Figure 4: December and February/March values of the N_{NAO} index and the I_{BK} index for individual years used in 2 clusters of figure 3.

DIAGNOSTICS

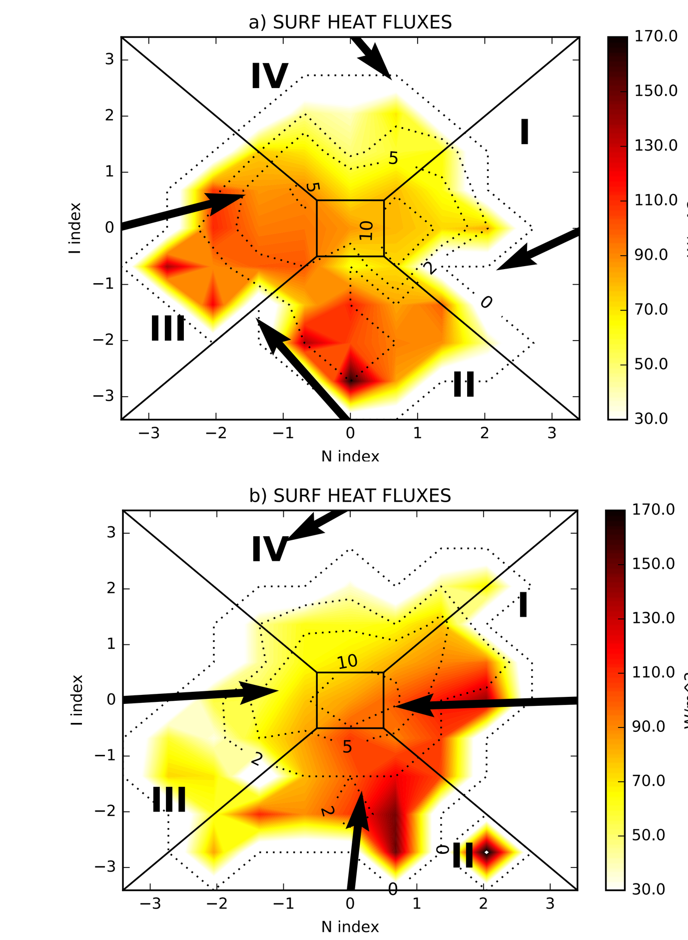

Figure 5: Diagrams of $\tilde{F}$, i.e. surface turbulent heat fluxes averaged using eq. 1, over the Barents-Kara (I_{BK}) seas using a) the N_{NAO} index and b) the Siberian index (N_{SIB}). Arrows indicate the average tendencies $\tilde{N}_t$ and $\tilde{I}_t$ in each of the 4 sectors bounded by solid lines.

INDEXES	I	II	III	IV
NAO/BK	-0.6/**-0.2**	**-0.7**/0.5	0.9/**0.1**	**0.3**/-0.25
SIB/BK	-1.4/**-0.0**	**-0.0**/0.5	1.3/**-0.0**	**-0.5**/-0.1
NAO/LAB	-0.9/**0.2**	**-0.5**/0.8	1.0/**-0.1**	**0.1**/-0.5
NAO/PC	-0.7/**-0.2**	**-0.6**/0.0	1.1/**0.2**	**0.3**/-0.4

Table 1: $\tilde{N}_t$ and $\tilde{I}_t$ for couples of indexes.

MAIN FINDINGS

- A robust relationship is demonstrated between the state of Arctic sea-ice and the subseasonal tendency of the NAO and vice versa.
- It is possible to define sets of case studies with similar ice-atmosphere conditions to test causal links in the aforementioned relationship.

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