Impact of reduced sea ice conditions in the Barents-Kara Seas on wintertime Euro-Atlantic atmospheric circulation

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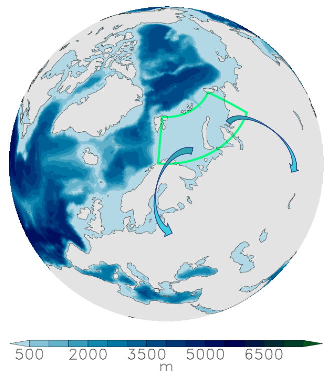
Scientific Goal

The goal is to assess the impact of reduced sea ice conditions in the Barents-Kara Seas (BKS) on lagged atmospheric circulation anomalies during wintertime over the Euro-Atlantic sector, by using a new model approach.



Rationale

Late autumn sea ice variability in the BKS has shown to significantly influence late winter atmospheric circulation over the Euro-Atlantic sector[1,2,3]. This can have implications for the severeness of winters due to the impact on the leading mode of variability (NAO in the Euro-Atlantic sector).
Part of the reason why the BKS are a critical region in terms of sea ice loss is the large variability and trend of sea ice and related surface heat fluxes during the boreal winter season (esp. November) compared to other regions of the Arctic Ocean.

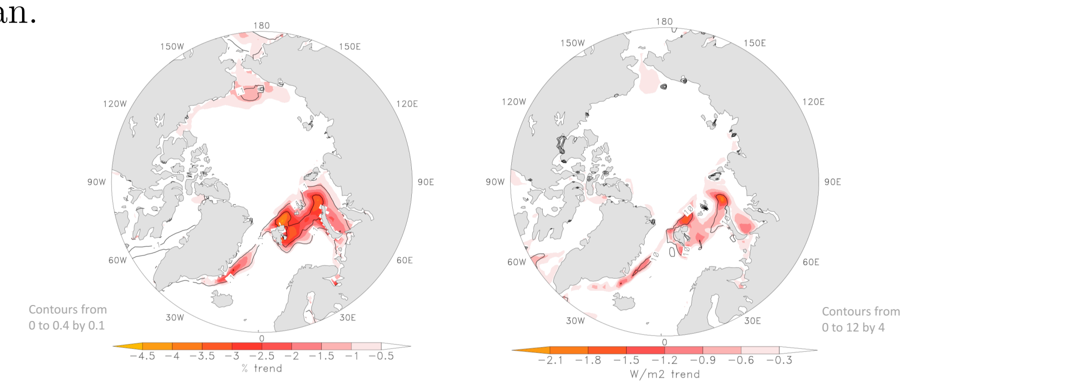


FIGURE 1: Trend (colour) and standard deviation (lines) of sea ice cover (left) and surface turbulent heat fluxes (sensible+latent heat, *right*) during the boreal winter season (DJF).

Tool: A seasonal prediction system

The impact of sea ice extent (SIE) anomalies is studied performing initialized ensemble forecasts of boreal winter seasons (November to April) using a (fully-coupled) state-of-the-art seasonal prediction system, the **CMCC-SPS3**[4]**:**

- based on CESM1.2 with an ocean model component replacement (NEMO 3.4 instead of POP2)
- CAM 5.2 with model top at 0.3hPa → *stratosphere-resolving*

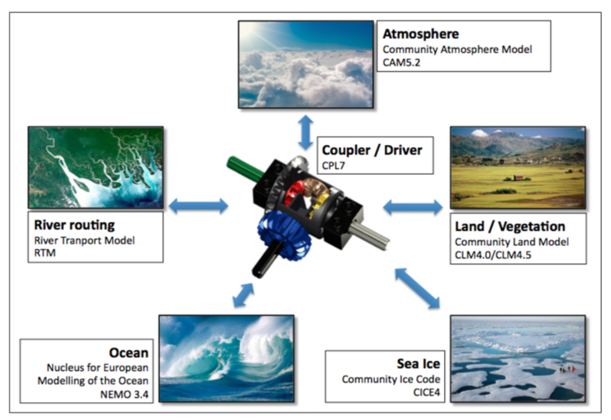


FIGURE 2: The seasonal prediction system CMCC-SPS3.

- Ensemble generation: Perturbations are generated by combining the initial states of the atmosphere, land and ocean components (10 for atmosphere, 4 for ocean, 3 for land), using different techniques. Out of these 120 possible combinations, 10 members are randomly chosen for this study.

Experimental Set-up

Characteristics \ Experiment	CONTROL	ICE-FREE
Start date	1st November	
Integration length	6 months (Nov – Apr)	
Period	1993 - 2015	
Ensemble size	10	
Sea surface restoring on T	-	dQ/dT = -5000 W/m² during November

TABLE 1: Summary of the experimental set-up.

Implementing sea ice-free conditions: Conditional heat supply to the upper ocean

$$Q_{ns} = Q^0_{ns} + \begin{cases} \frac{dQ}{dT}(SST_{Model} - SST_{Target}), & if\ SST \leq -1.5 \\ 0 & otherwise \end{cases}$$

Q_{ns} = non-solar heat fluxes (after nudging), Q^0_{ns} = initial non-solar heat fluxes (before nudging)
SST_{Target} = Target model sea surface temperature (-1.5°C),
SST_{Model} = Actual simulated sea surface temp. dQ/dT = retroaction term (heat supply; W/m²/K)

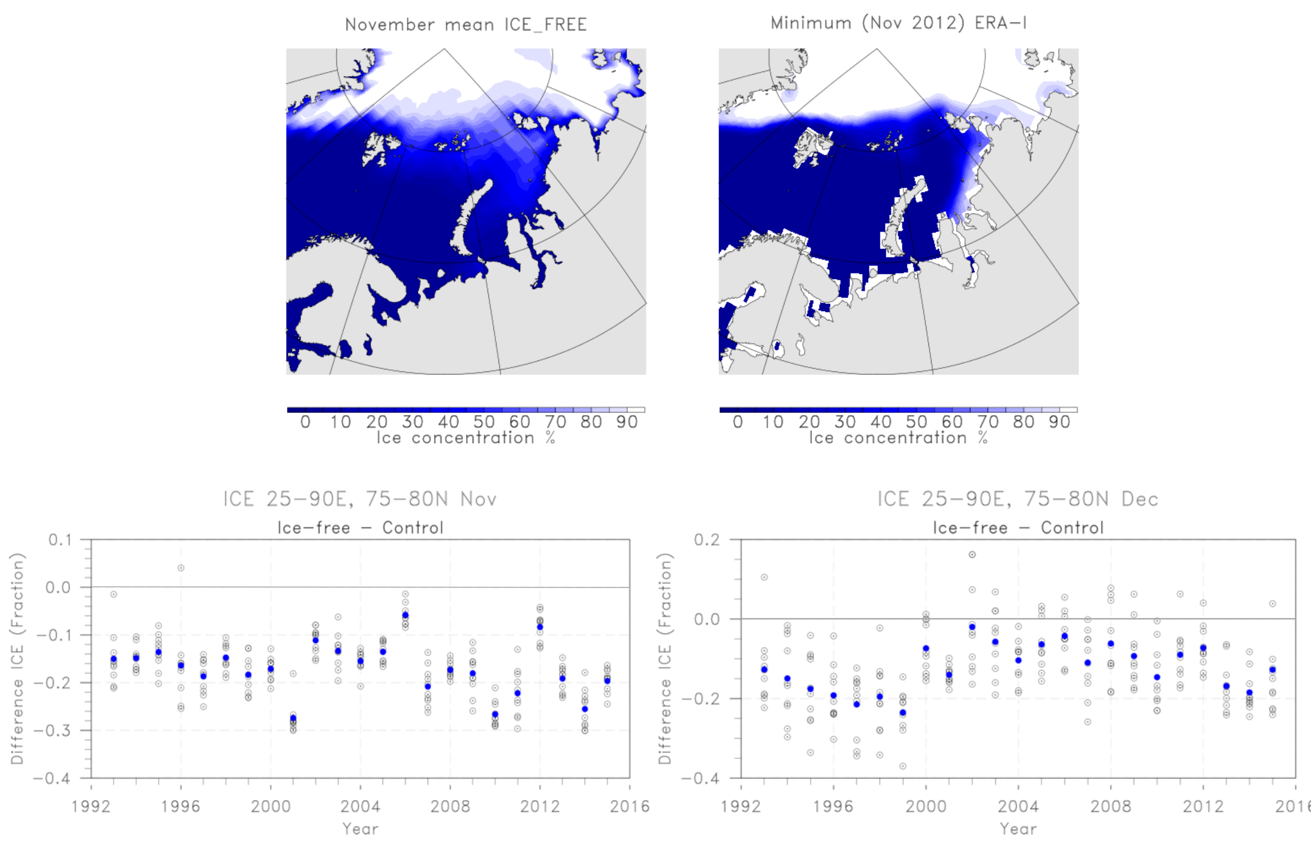


FIGURE 3: *Top:* November mean sea ice concentration in the ICE-FREE experiment (averaged over all years and members) compared to sea ice cover during a typical sea ice minimum year (here Nov 2012). *Bottom:* Interannual variability and ensemble spread in sea ice removal in the BKS (*left* November, *right* December).

Results: Response to sea ice loss in the BKS

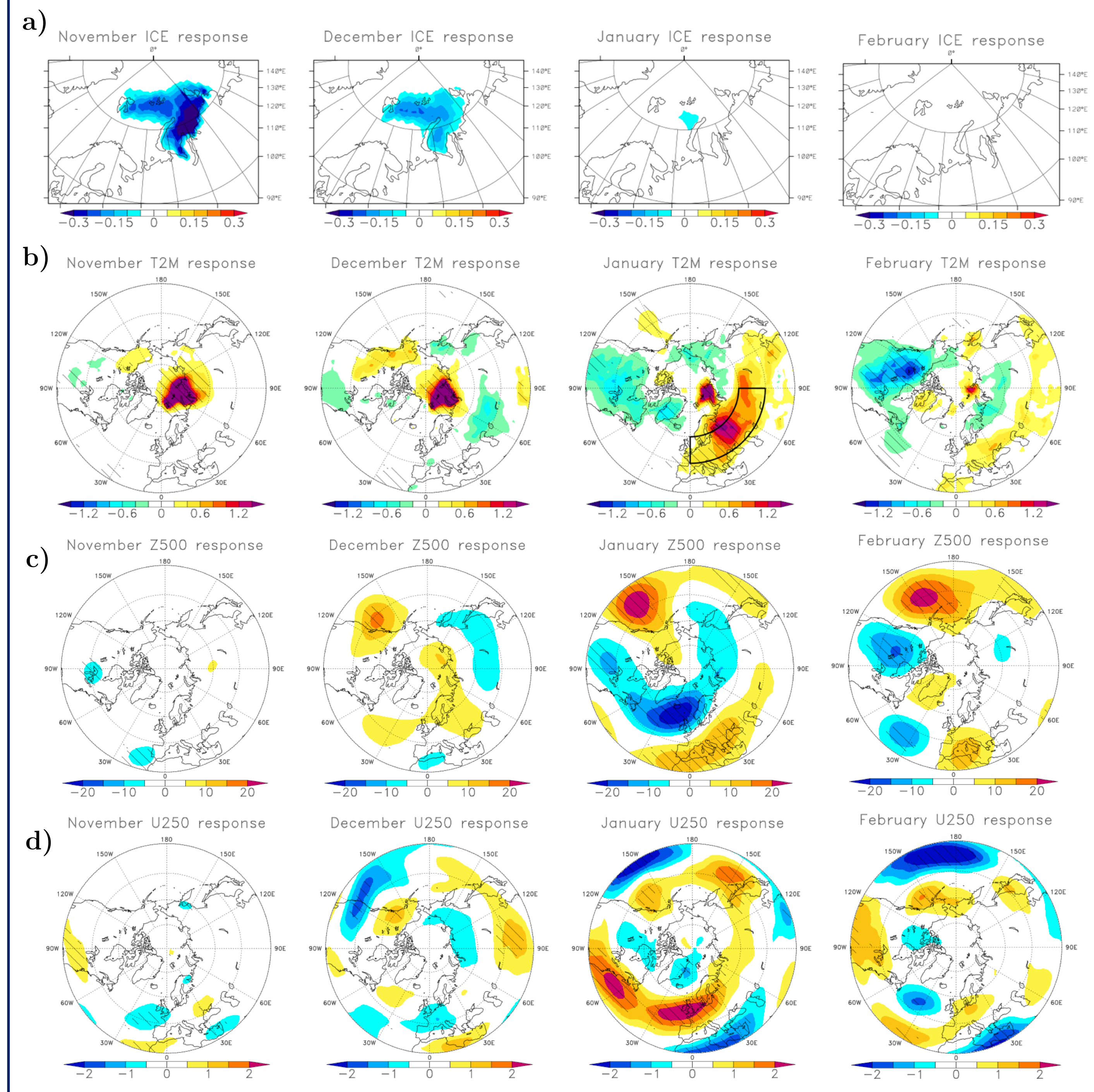


FIGURE 4: Response to reduced sea ice conditions in the BKS (a) from November to February in ICE-FREE averaged across all members (230): 2m-temperature (b), geopotential height at 500m (c) and zonal wind at 250 hPa (d).

Outcomes & Outlook

- The same heat supply to the upper ocean layer results in different amounts of sea removal for each year, depending on the sea ice cover at the beginning of integration
- Sea ice loss in the BKS leads to a fast, local, thermodynamic reponse (warming) in response to positive surface heat flux anomalies (not shown)
- In January, there is a positive NAO-like circulation response over the Euro-Atlantic sector: a prounounced surface warming over Eurasia, Z500 and U250 dipole structure which imply a northward shift of the eddy-driven jet stream
- This positive NAO-like response may be associated with a bias in the model eddy-driven jet stream (not shown)
- An increased ensemble size is needed to infer robustly about the lagged atmospheric circulation response (constructive interference with climatological wave pattern and impact on the North Atlantic storm track)

References

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[4] Fogli, P.G, Iovino, D. CMCC–CESM–NEMO: Toward the New CMCC Earth System Model. CMCC Research Paper 248 (2014).