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Poleward ocean heat transports, sea ice processes and sea ice variability in NorESM1-M simulations

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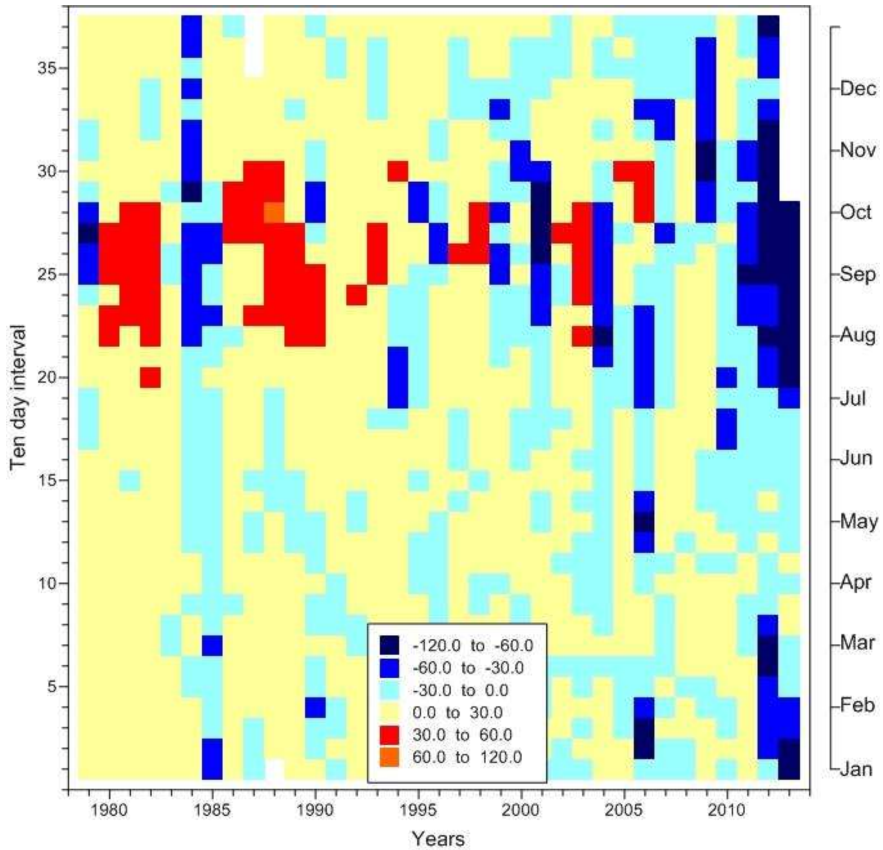
WORKSHOP ON PREDICTABILITY OF CLIMATE IN THE NORTH ATLANTIC SECTOR JUNE 11TH BERGEN

How does increased poleward ocean heat transport affect sea ice reduction?

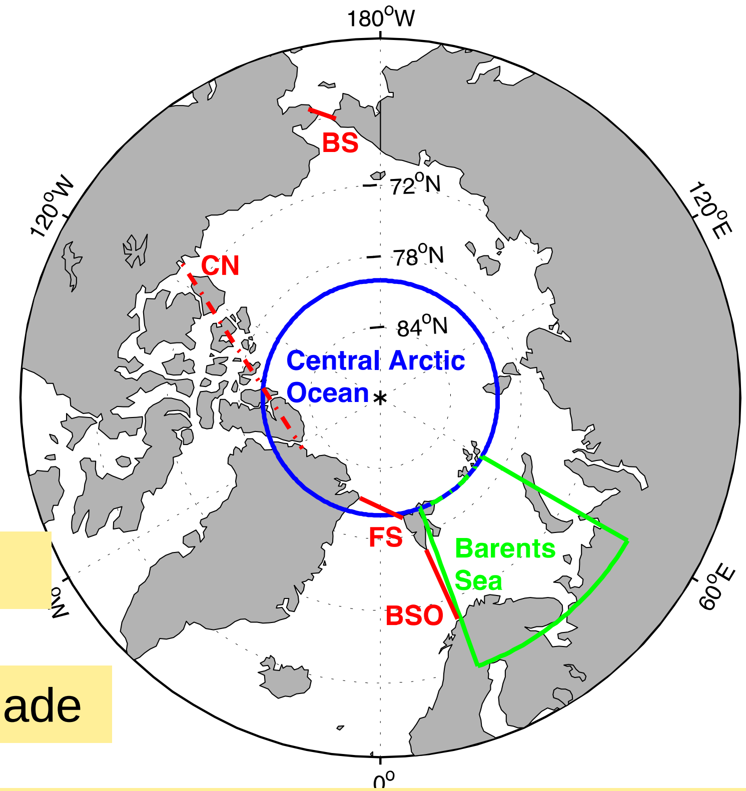


Sea ice area anomalies (10^{-3} km^2) for the area north of Svalbard and Franz Josef Land (WNB, 81-83°N, 15-60°E)

From Ivanov et al. (in prep)

How does increased poleward ocean heat transport affect sea ice reduction?

- Increased top melting?
- Increased bottom melting?
- Decreased ice growth due to decreased congelation below the sea ice?
- Decreased ice growth due to frazil ice formation?



Parameterized processes and available as output

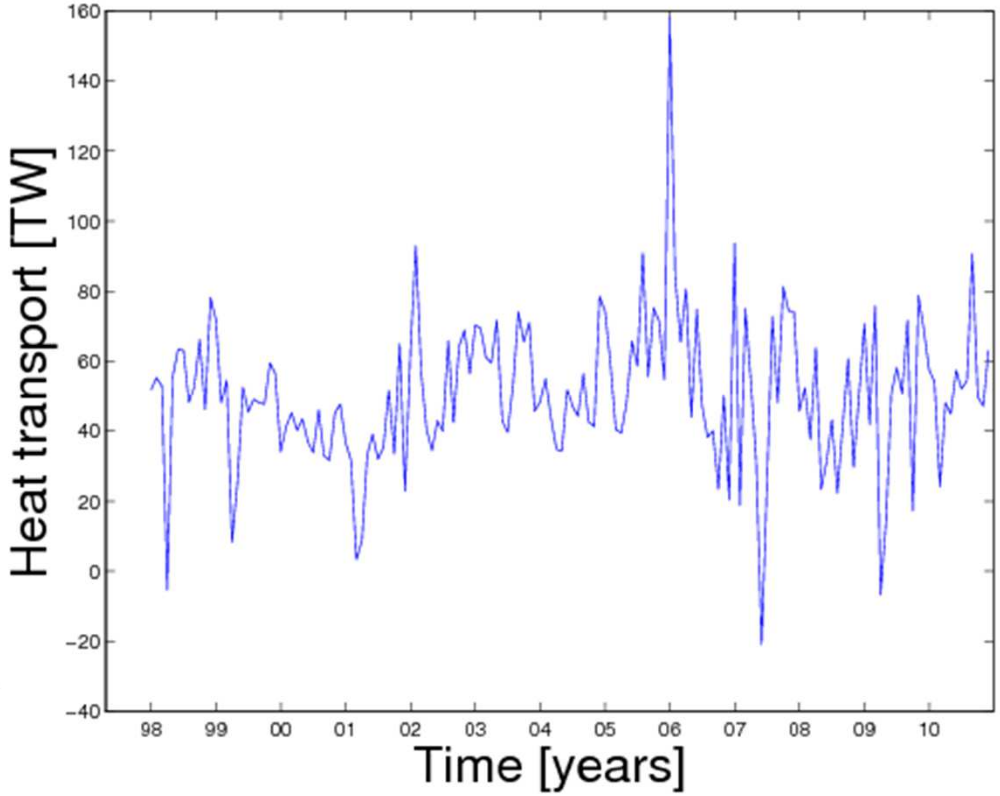
Variability and trends: Monthly time series are made

All time series of sea ice related variables are made by summarizing values in each grid cell where sea ice is present (i.e. sea ice concentration greater than 0)

Observed and modelled Barents Sea Opening (BSO), Bering Strait (BS), Canadian Archipelago (CA), and Fram Strait (FS) heat fluxes

	BSO	BS	CA	FS
Observed	79.6 ±13.4	5.6 ±3.2	7.7 ±7.4	30.8 ±20.4
CNRM-CM5	43.1 ±15	6.7 ±19	4.9 ±1	12.2 ±1
MRI-CGCM3	47.4 ±16	2.8 ±4	2.1 ±1	9.3 ±4
NORESM1-M	53.6 ±13	2.5 ±4	11.8 ±2	35.6 ±8

From current meter moorings in BSO which have been operated since September 1997 [Ingvaldsen et al., 2004]:



Langehaug, H. R., F. Geyer, L. H. Smedsrud, and Y. Gao, Arctic sea ice decline and export in the CMIP5 historical simualtions, Ocean Modelling, 2013.

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Means (kg s^{-1})

Central Arctic Ocean

Process	Mean
Bottom melting	4.3e+07
Top melting	7.4e+05
Congelation growth	9.2e+07
Frazil growth	1.5e+07

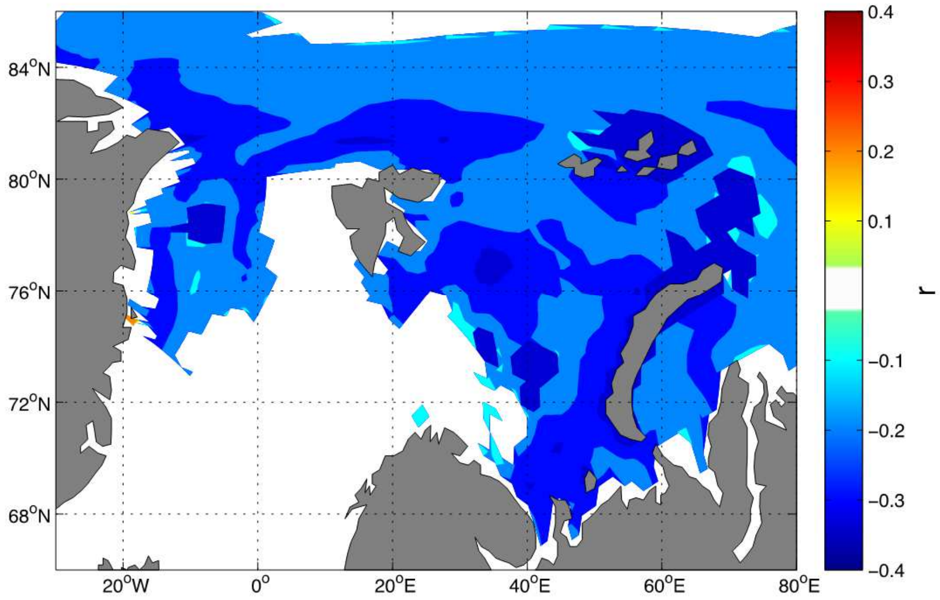
Barents Sea

Process	Mean
Bottom melting	3.2e+07
Top melting	1.4e+06
Congelation growth	2.4e+07
Frazil growth	8.3e+06

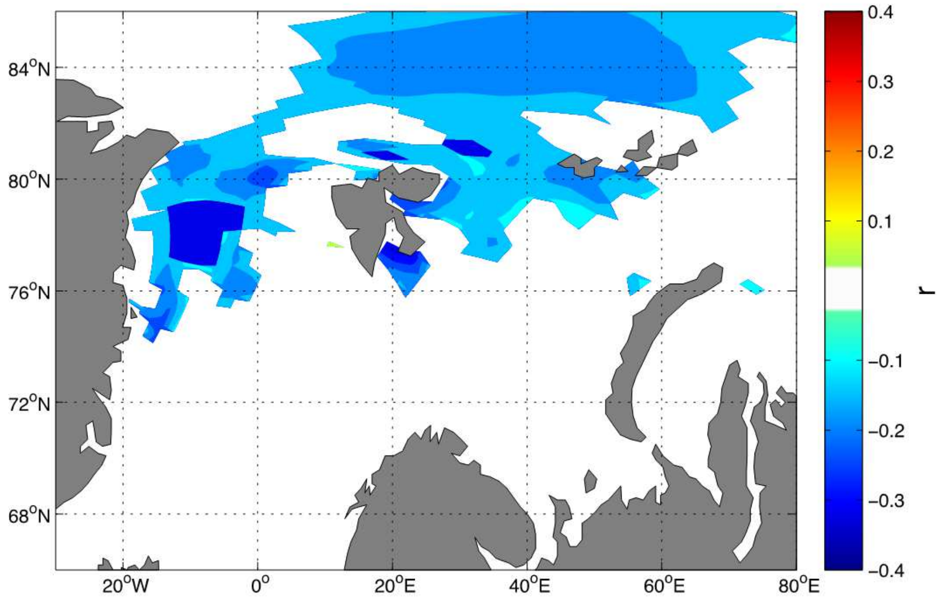
How are these processes related to the variable heat transport through the different gateways?

Correlations between heat transports and congelation growth

BSO



Fram Strait



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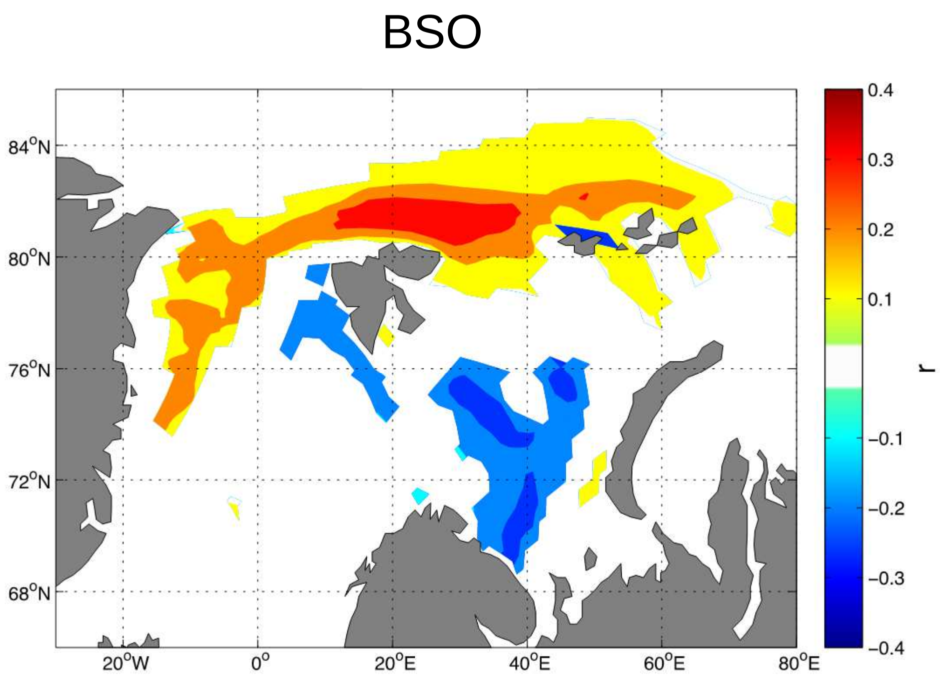
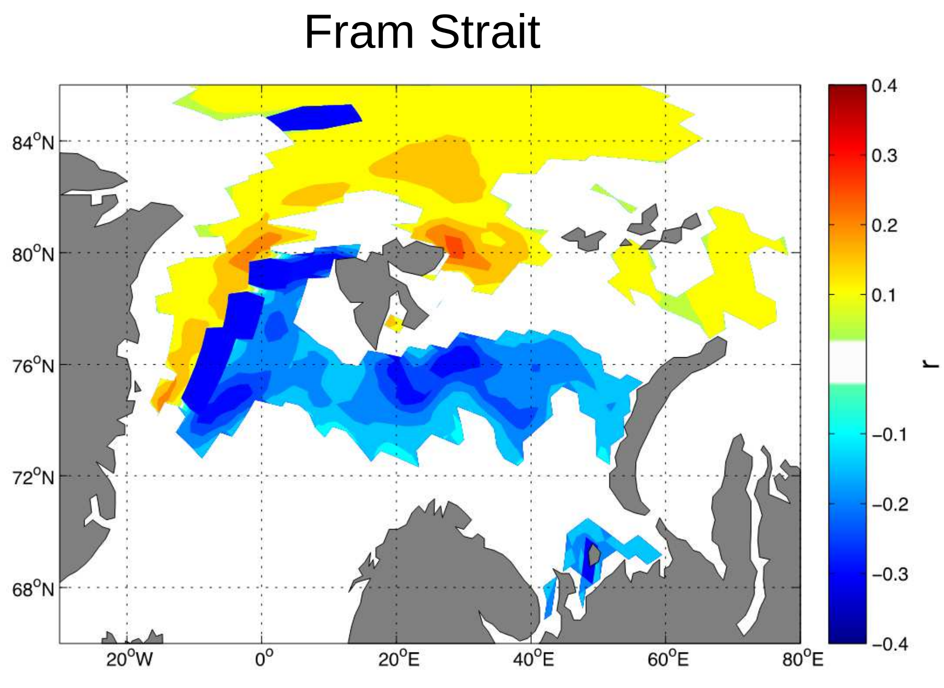
Correlations between heat transports and bottom melting





More heat, less congelation, less bottom melting

Peak correlations and lags between heat transports in different gateways and sea ice extent:

What is the direct relationship between heat transport and sea ice extent?

Central Arctic Ocean ($>80^oN$)

Gateway	Correlation
BSO	-0.17@0
FS	-0.24@0

Barents Sea ($<80^oN$, $>20^oE$, $<60^oE$)

Gateway	Correlation
BSO	-0.41@-1
FS	-0.26@0

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Conclusions: Mean state and variability

Barents Sea:

- Freezing processes balance melting processes, but variability is mainly determined by congelation
- One month lag between BSO heat transport and Barents Sea ice extent

Central Arctic Ocean:

- Congelation is most important for mean sea ice production, while variability in sea ice extent is mainly caused by bottom melting

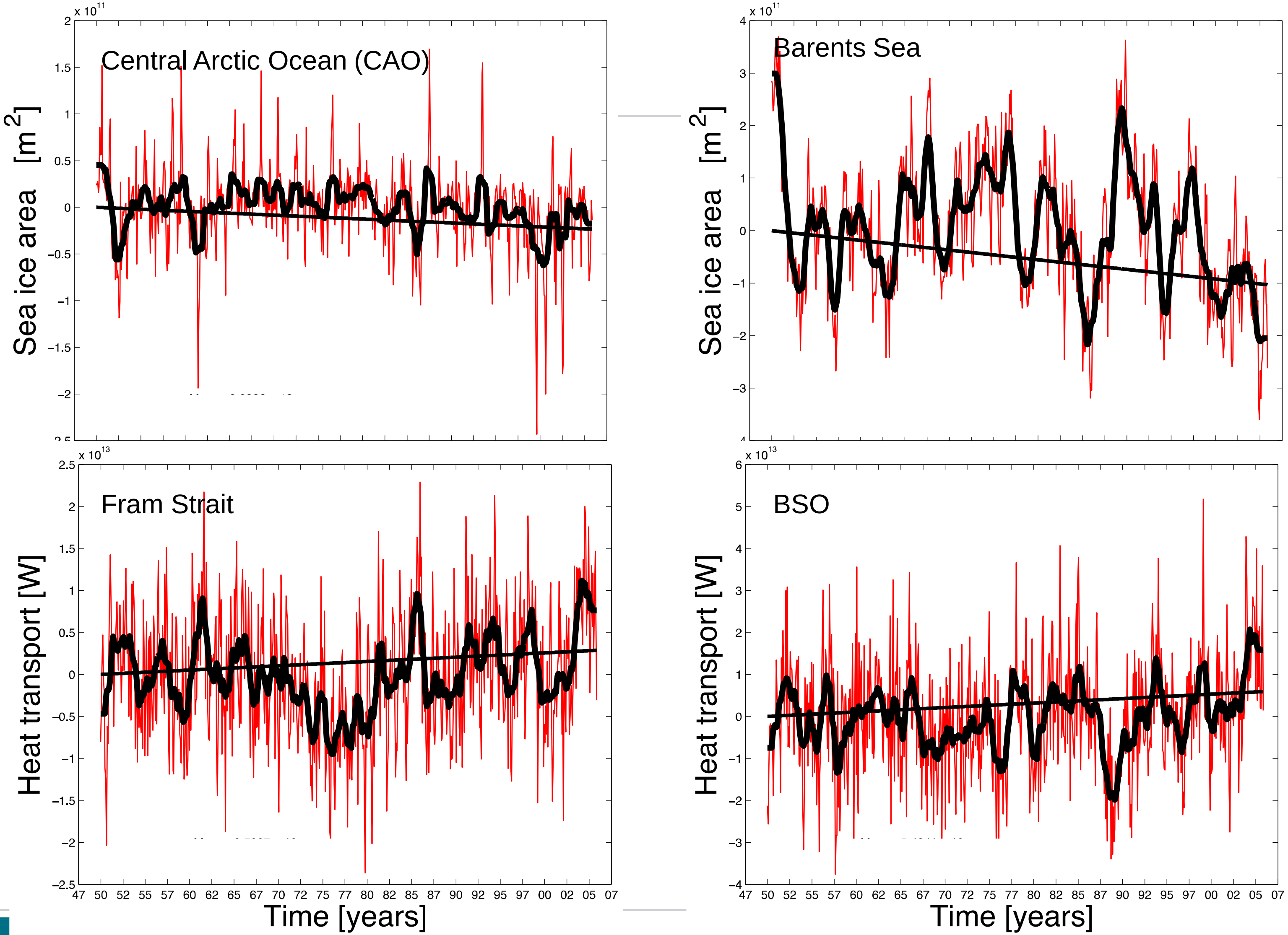
Trends (kg s^{-1})

Central Arctic Ocean

Process	Mean	Trend	Relative trend
Bottom melting	4.3e+07	10675	0.00025
Top melting	7.4e+05	1203	0.0016
Congelation growth	9.2e+07	4242	4.6e-05
Frazil growth	1.5e+07	136	9.2e-06

Barents Sea

Process	Mean	Trend	Relative trend
Bottom melting	3.2e+07	-4557	-0.00014
Top melting	1.4e+06	-572	-0.00042
Congelation growth	2.4e+07	-10278	-0.00042
Frazil growth	8.3e+06	-2691	-0.00033


Central Arctic Ocean (CAO)
Barents Sea
Fram Strait
BSO
Sea ice area [m^2]
Heat transport [W]
Time [years]
x 10^11
x 10^13

Trends (kg s^{-1})

Central Arctic Ocean

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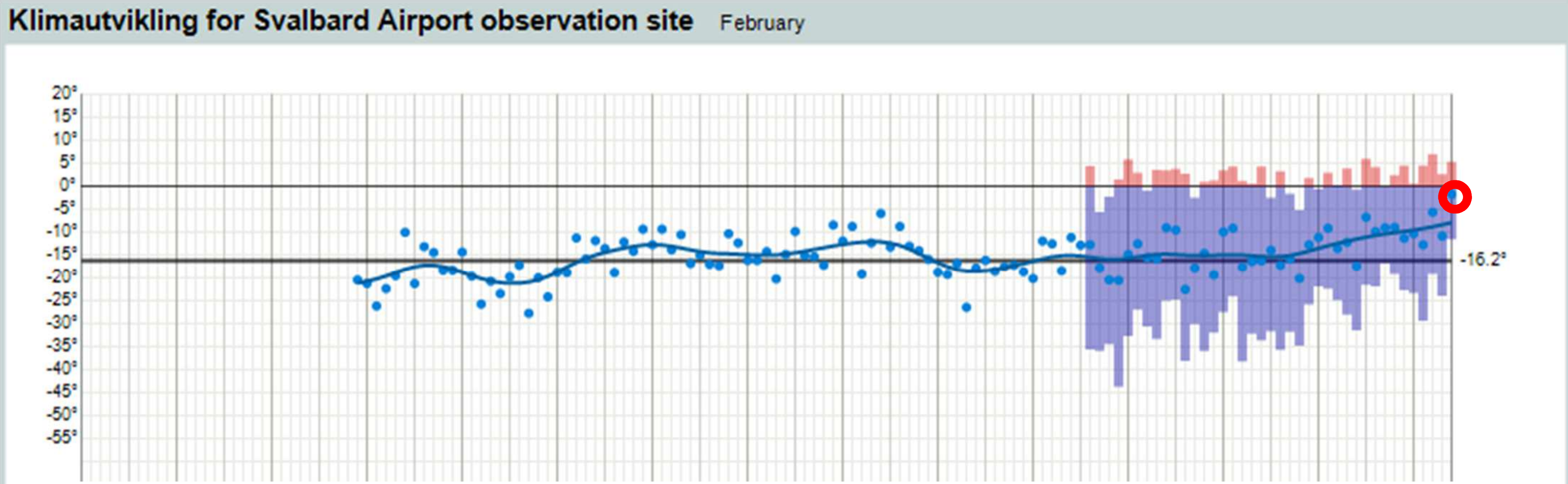

Ivanov et al (in prep):

North of Svalbard:

- A moderate heat flux at the ice-free ocean surface (100 W/m^2) is able to produce a homogeneous water layer, extending from the surface and deeper down than the warm core AW
- Upward heat flux effectively melts sea ice from below

Conclusions: Trends

- Central Arctic Ocean: Biggest trend in bottom melting (positive)
- Barents Sea: Biggest trend in congelation growth (negative), and therefore also negative trend in bottom melting due to less ice to be melted
- Both Central Arctic Ocean and Barents Sea ice covers respond to increased advection of heat in the ocean (in the FS and BSO, respectively)
- Central Arctic Ocean is increasingly affected by top melting and a warming atmosphere