AR conference, June 26, 2018

Extreme, transient Moisture Transport in the high-latitude North Atlantic sector and Impacts on Sea-ice concentration:

associated Dynamics, including Weather Regimes & RWB

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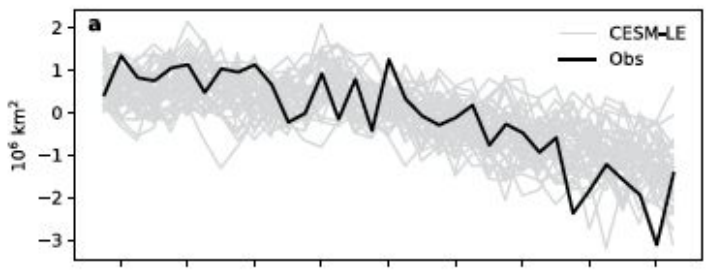
Many studies about hydrological impacts of ARs in terms of precip. Here the focus is on impacts in terms of sea-ice melt

- The Arctic is warming at a rate that is more than twice that of the global average - referred to as Arctic Amplification
- Associated with Arctic Amplification is a sharp decrease in Arctic sea-ice extent over the observational period (from 1979).
- Superposed on the negative trend is quite a significant interannual variability

September sea-ice extent anomalies from obs (black) and CESM-LE



From Yang and Magnusdottir (2018)

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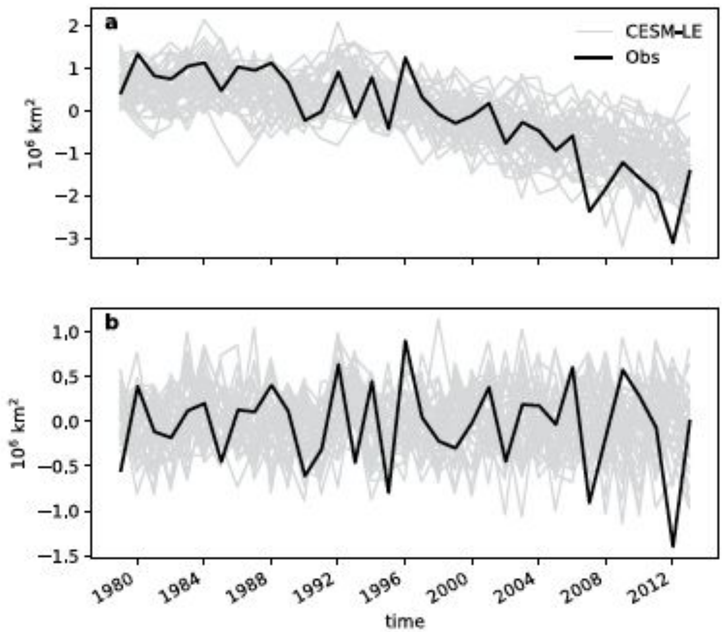


From Yang and Magnusdottir (2018)

Hypothesis: Springtime moisture transport into the Arctic preconditions the sea-ice pack for the following September minimum extent

e.g., Kapsch et al (2013), Park et al (2015) (winter)

- Examined in terms of extreme events (Yang and Magnusdottir 2017, 2018)

Data

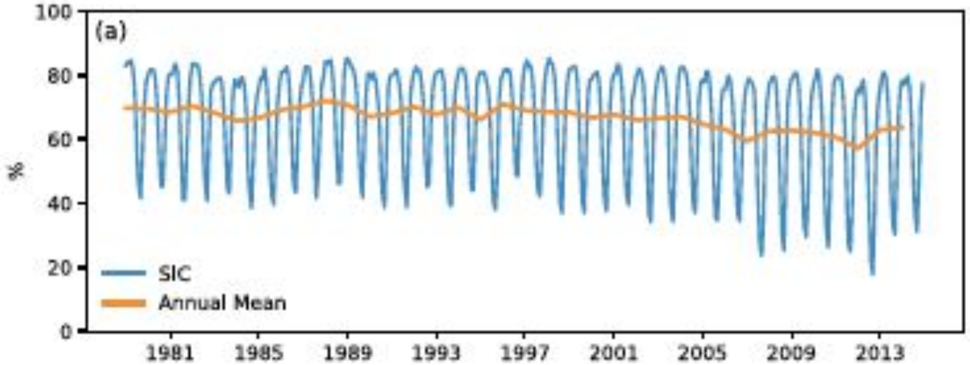
- Sea-ice concentration (SIC): daily satellite data starting in 1979 from NSIDC
- Meteorological fields: ERA-Interim reanalysis

Methods

- daily vertically integrated meridional moisture transport across 70N – pick out the top 15% of days: extreme days
- Define ‘extreme events’ as at least 3 consecutive extreme days, preceded and followed by non-extreme days

Sea-ice concentration (SIC) area average over ocean areas north of 70N (monthly, annual)

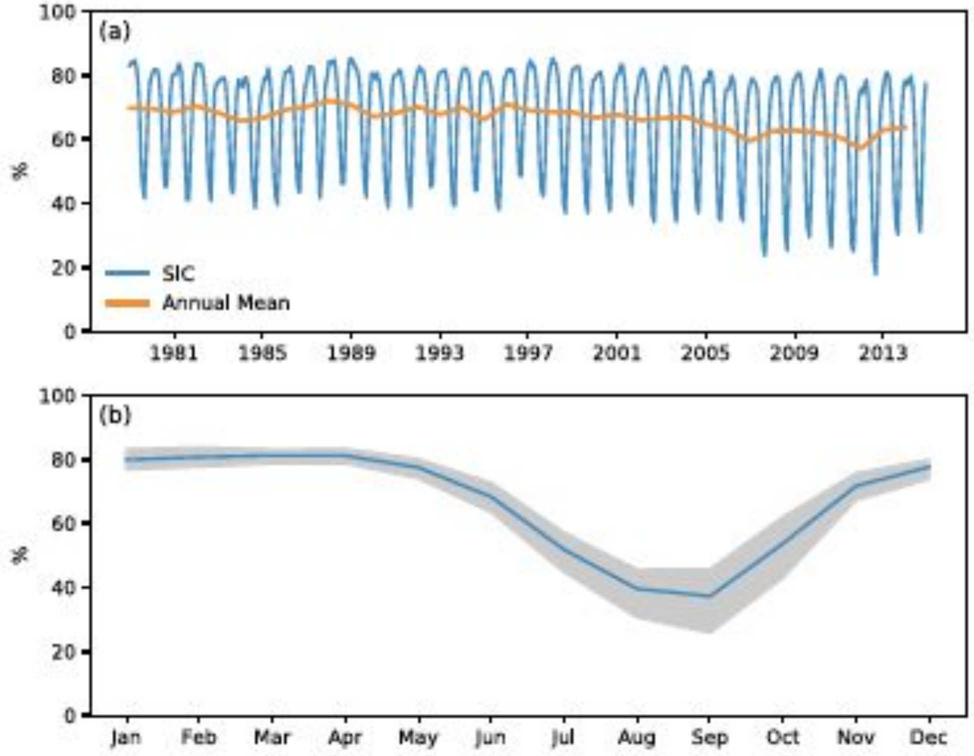
Large seasonal cycle



Sea-ice concentration (SIC) area average over ocean areas north of 70N

Large seasonal cycle

SIC minimum in Sept, 90th and 10th percentile shaded

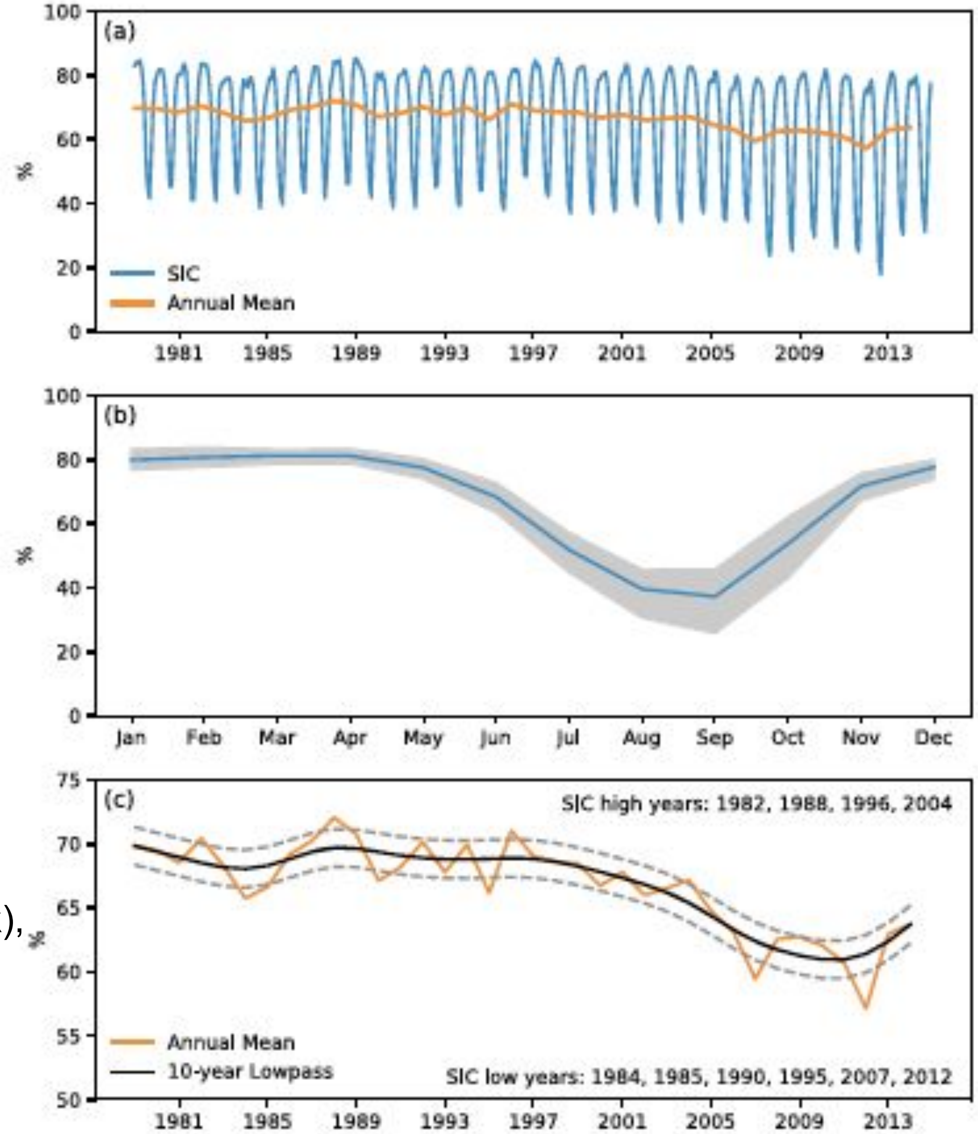


Sea-ice concentration (SIC) area average over ocean areas north of 70N

Large seasonal cycle

SIC minimum in Sept

SIC annual mean (orange) low-pass filtered SIC (black), one sdev above and below (dashed)



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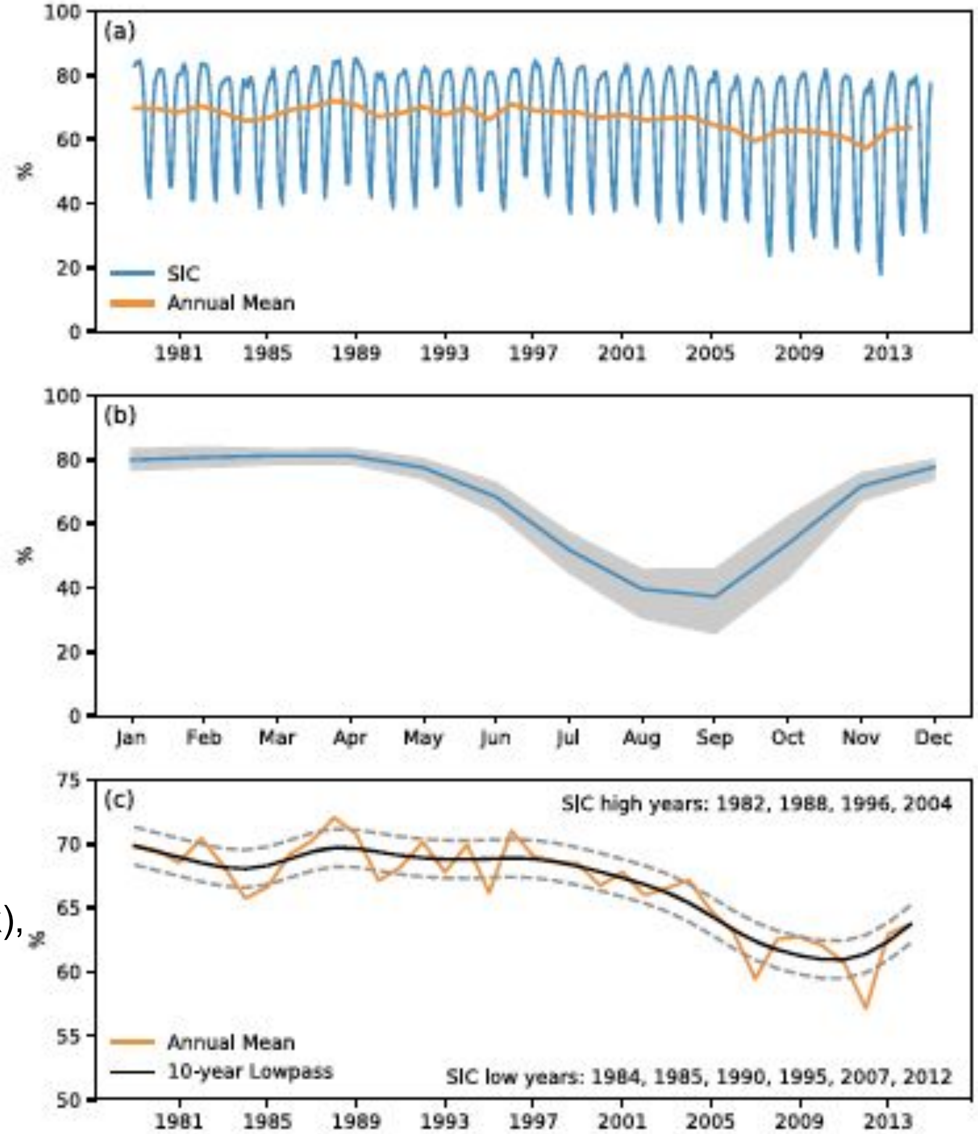
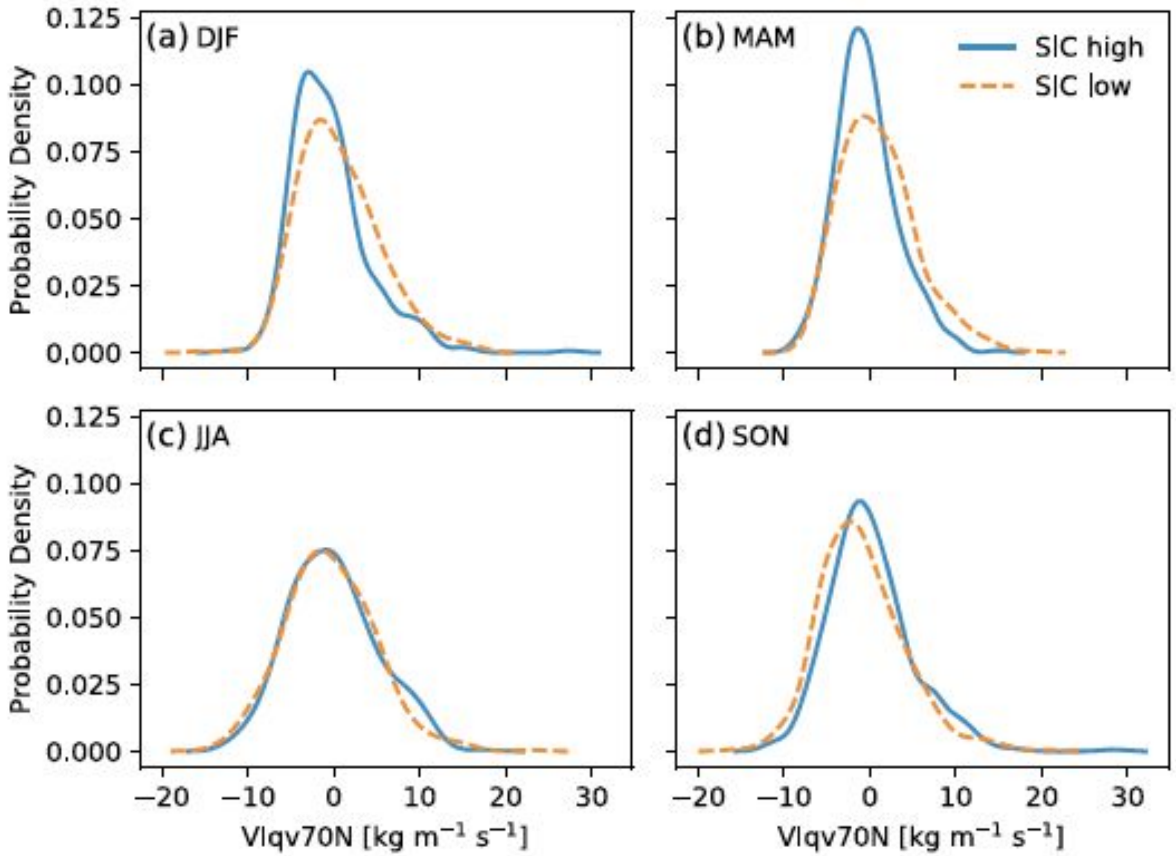


Pick out the low & high years for composite analysis

Seasonal variability in daily vertically integrated, meridional moisture transport into Arctic

Composite low vs high SIC years

pdf of vertically integrated meridional daily moisture flux anomaly, zonally averaged at 70N for SIC high (blue) and low (orange)



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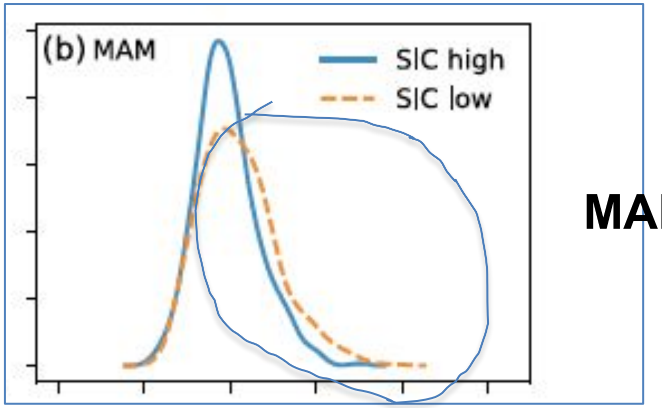
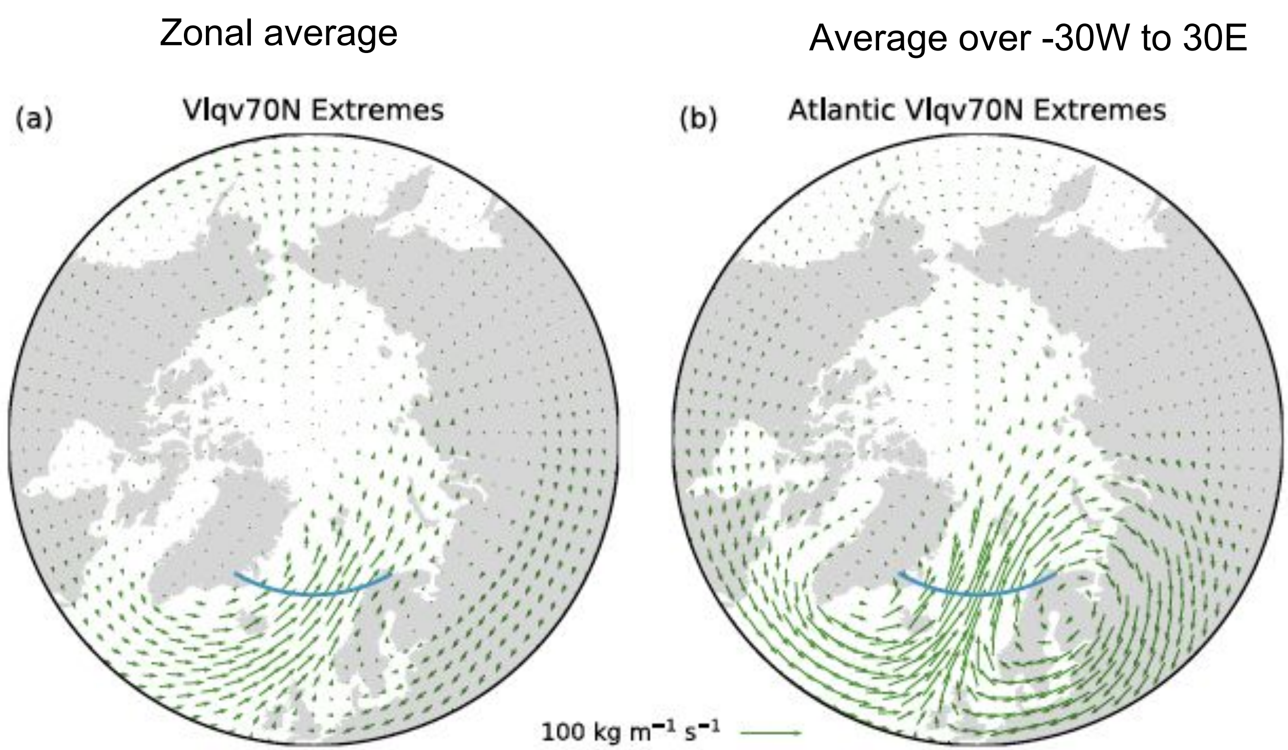


MAM

Motivates examining the spring season

• daily vertically integrated meridional moisture transport across 70N – pick out **the top 15% of days: extreme days**

Composites for **MAM**



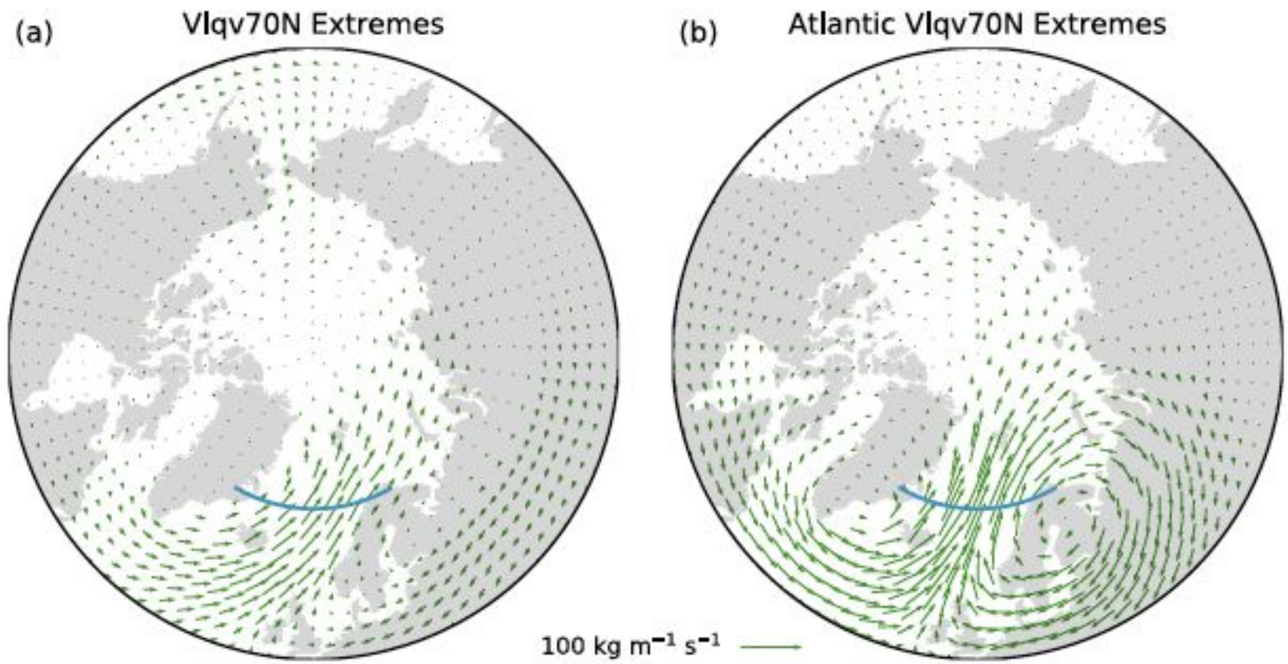
Dominated by the Atlantic sector

From now on focus on Atlantic VIqv70N

Zonal average

Average over -30W to 30E

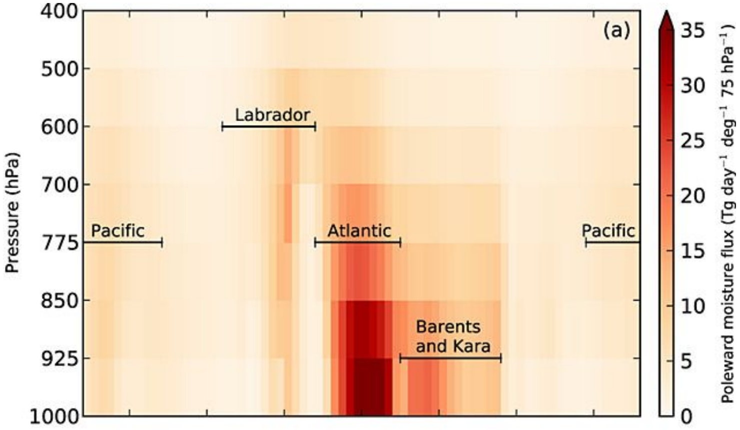
Composites for **MAM**



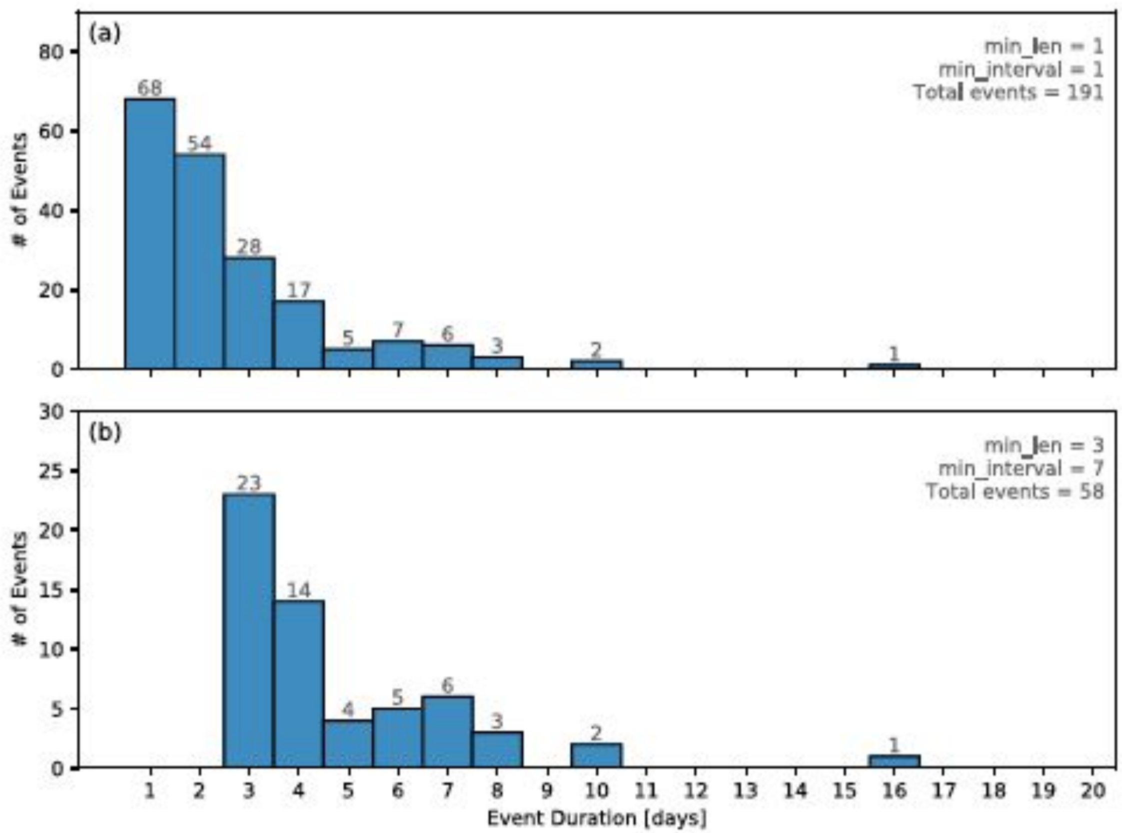
Moisture transport into the Arctic is dominated by the flux in North Atlantic sector

Other studies have found that the moisture flux into the Arctic is dominated by the N Atlantic

From the study by Woods et al (2013) for DJF



Extreme events for 1979-2014 **MAM**



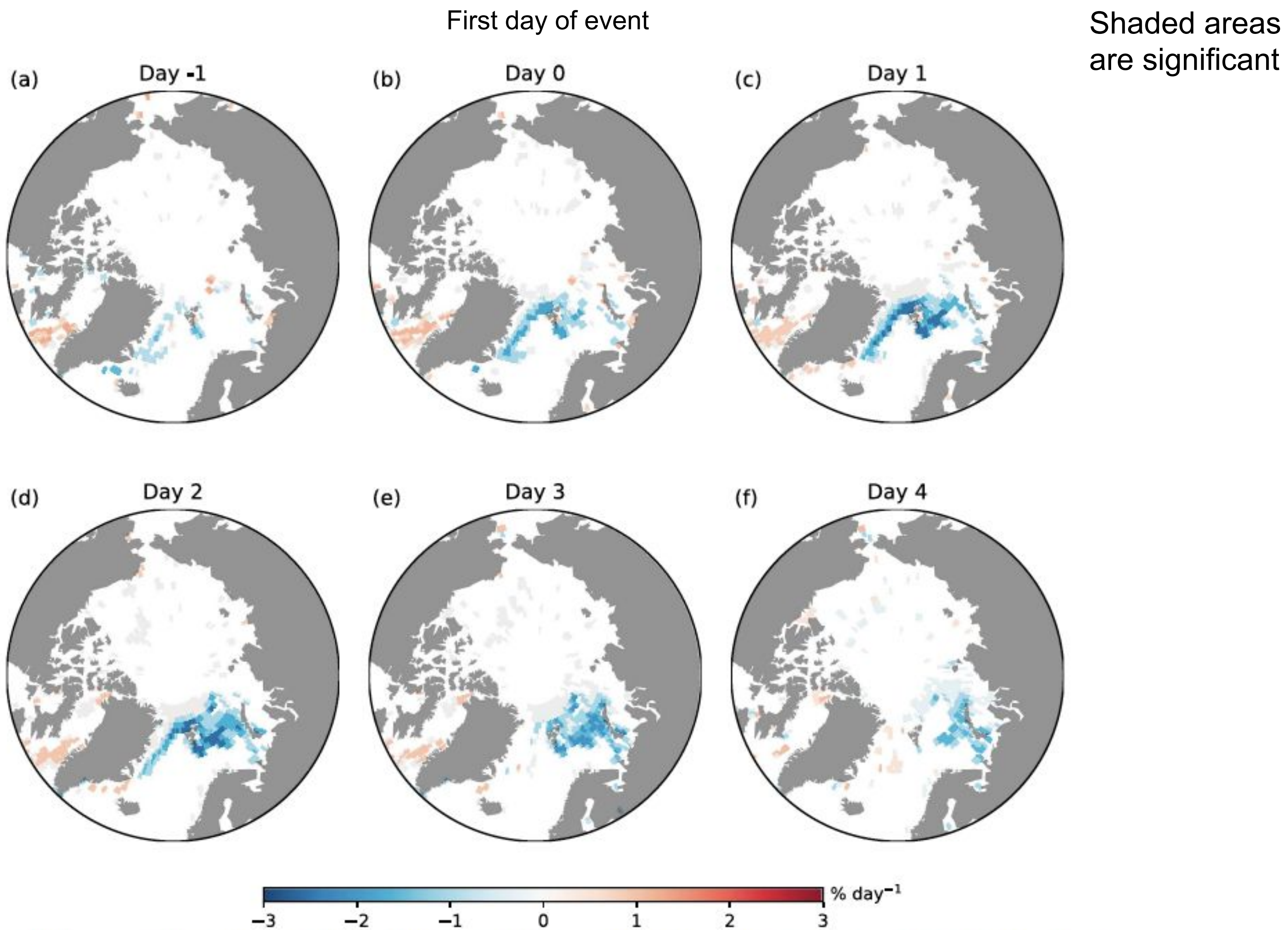
Extreme days

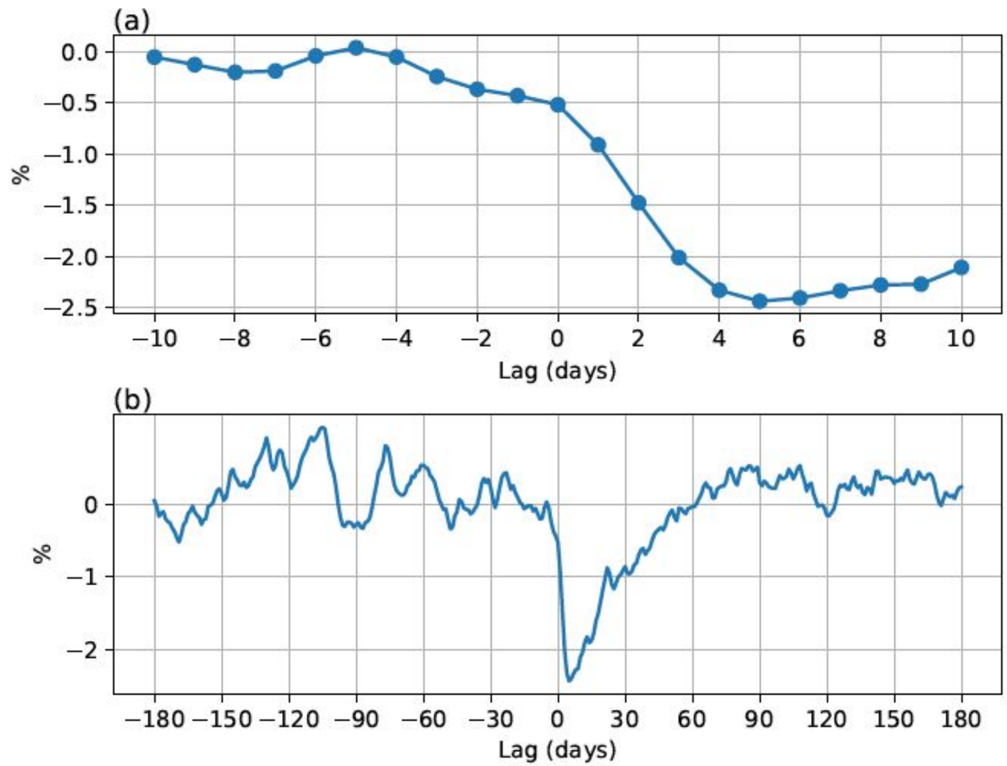
Extreme events

Only extreme days, lasting at least 3 days separated by at least 7 days of non-extreme conditions

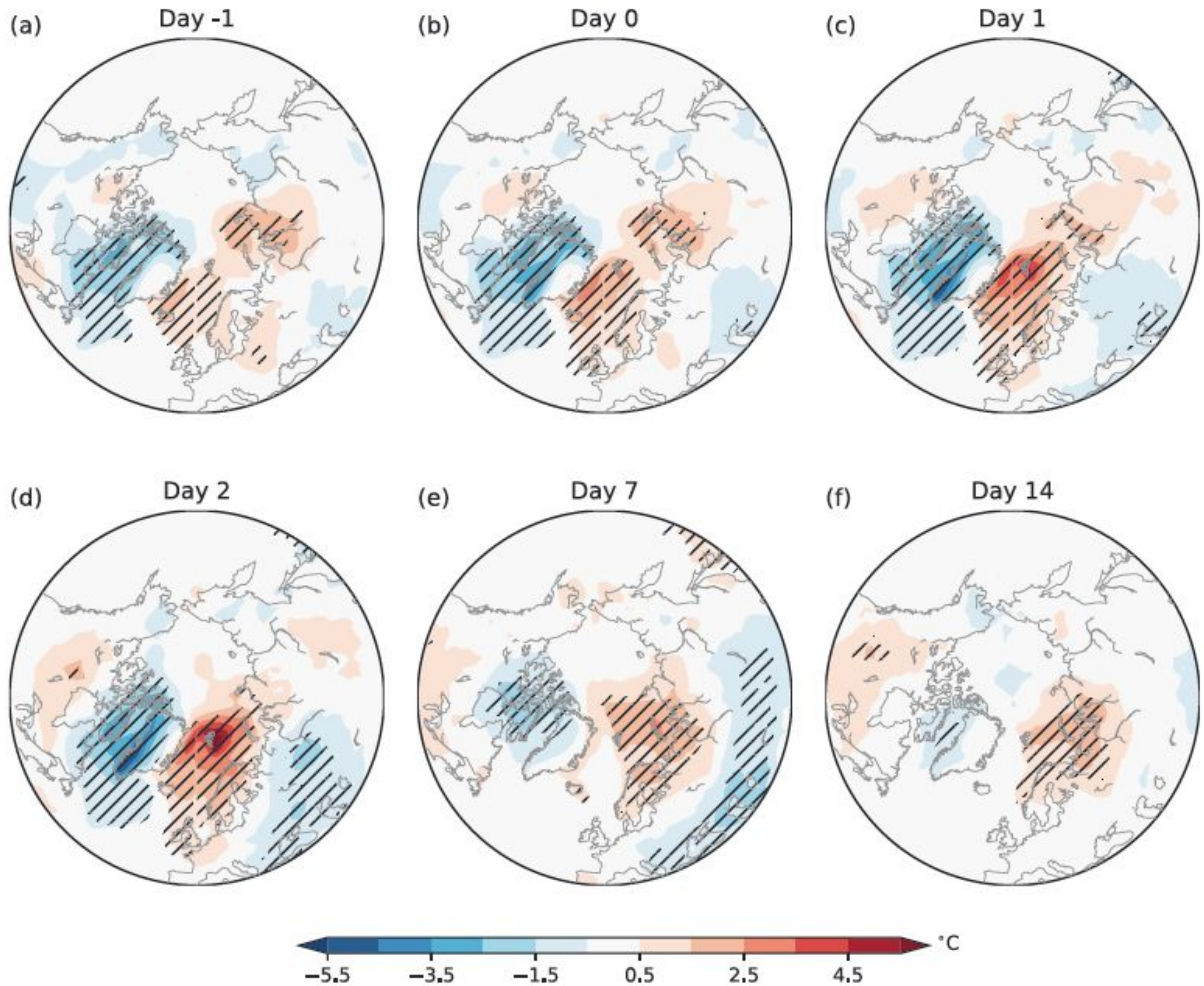
Duration (days)

extreme moisture flux. MAM composite of SIC at lags -1, 0, 1, 2, 3, 4 days

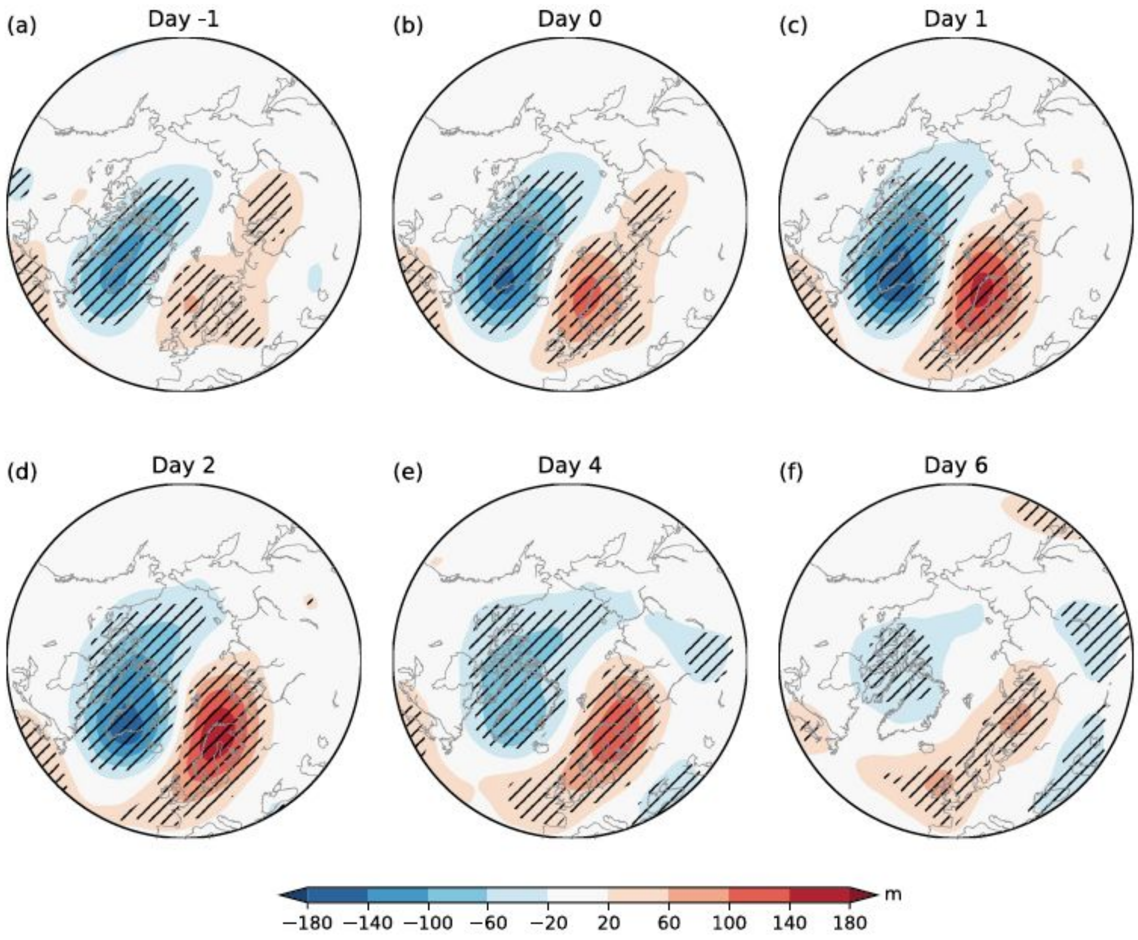




Composite of SIC anomaly averaged over the Greenland-Barents-Kara Seas as a function of lag days extreme moisture flux. MAM composite of T_{sfc} at lags -1, 0, 1, 2, 7, 14 days

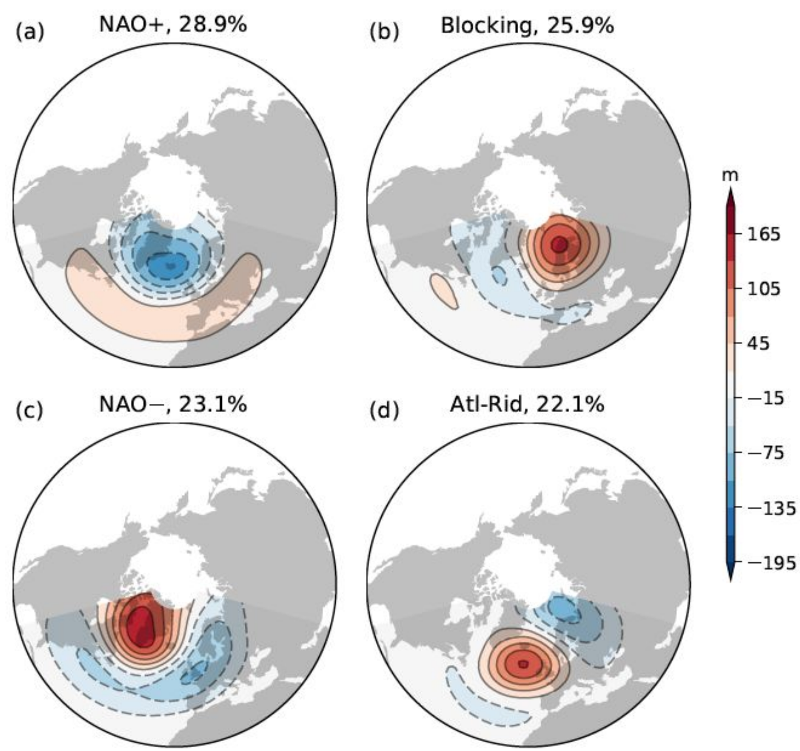


extreme moisture flux. MAM composite of Z500 at lags -1, 0, 1, 2, 4, 6 days

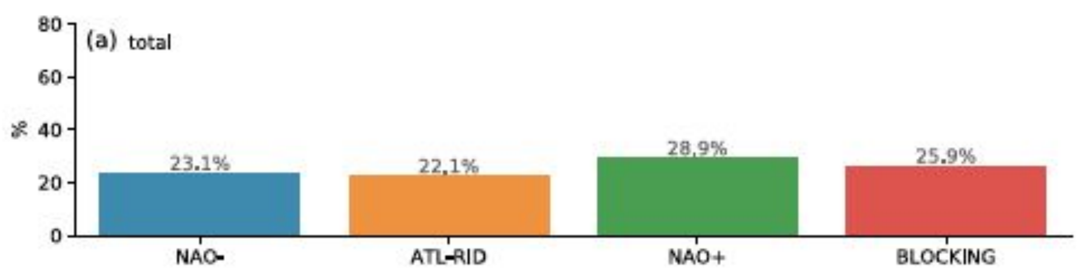


The four dominant daily weather regimes in the N Atlantic sector

Climatology

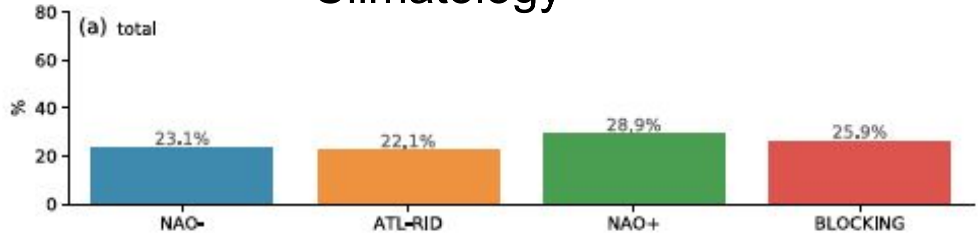


Relative frequency for MAM

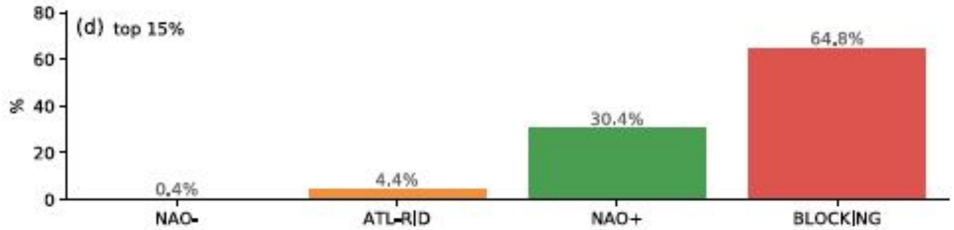


Relative frequency of N Atl. Daily weather regimes for MAM, 1979-2014, all days

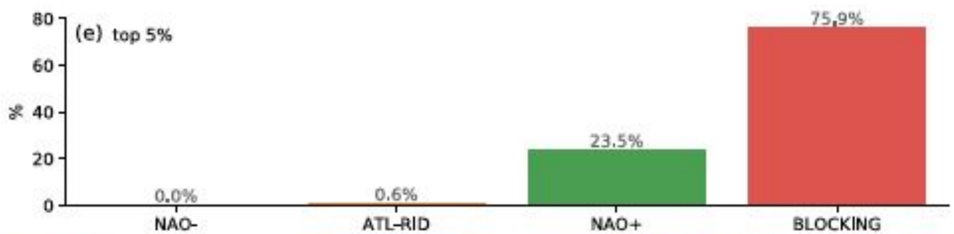
Climatology



Only for days when Atlantic VIqv70N is in the top 15%

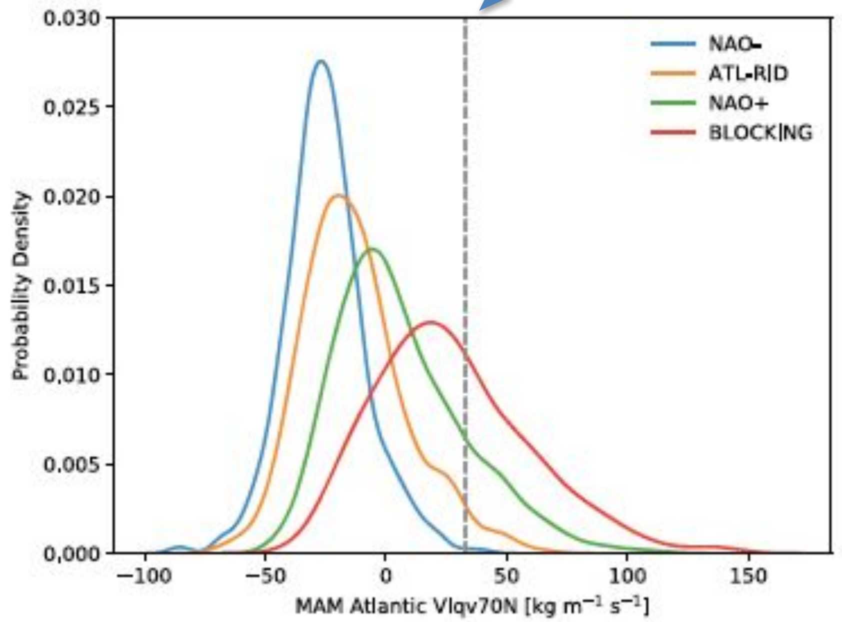


Only for days when Atlantic VIqv70N is in the top 5%



PDF of moisture flux for each weather regime

85th percentile of all moisture flux daily values



Blocking dominates

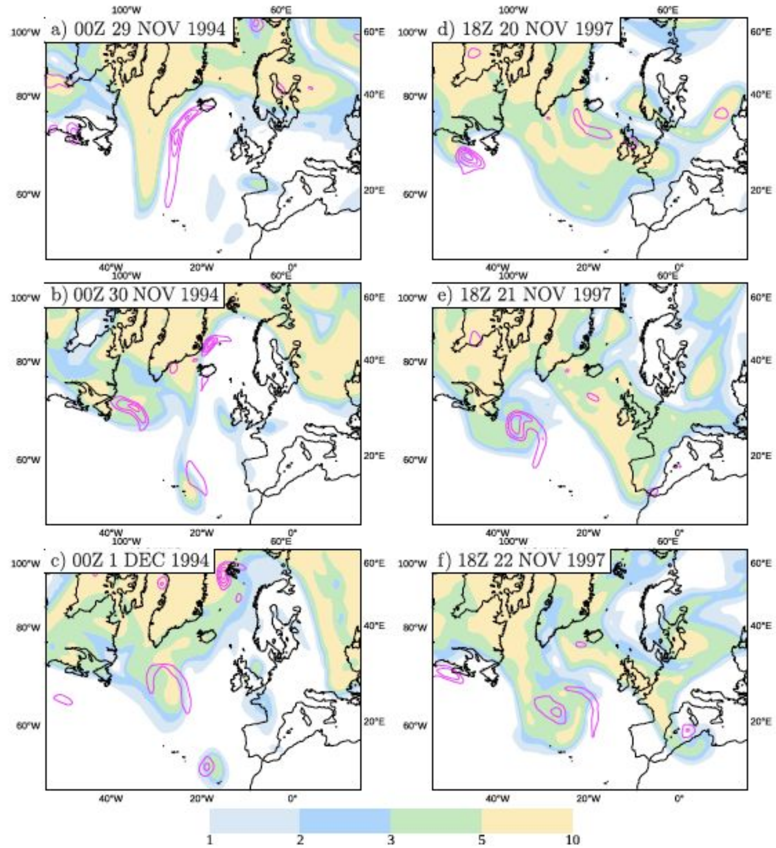
Figure 10. Probability density function (PDF) of Atlantic-Vlqv70N for each of the four North Atlantic weather regimes. The vertical dashed line shows the 85th percentile of all the MAM Atlantic-Vlqv70N daily values.

From Michel et al (2012)

Example of building Scandinavian Block

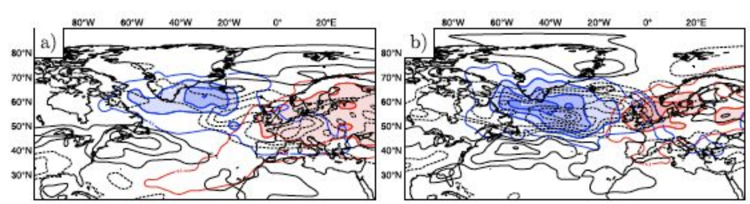
Example of decay of Scandinavian Block

Anticyclonic RWB



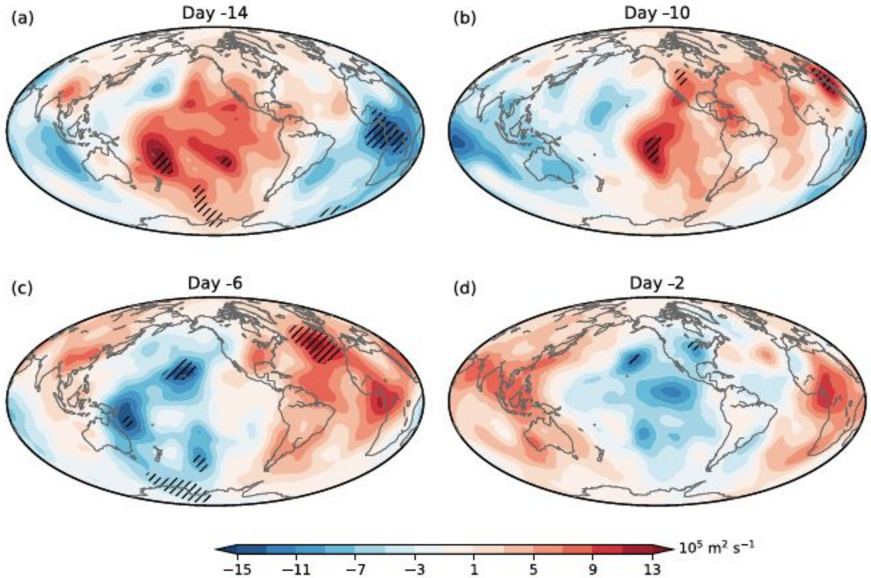
Cyclonic RWB

Onset dominated by anticyclonic RWB

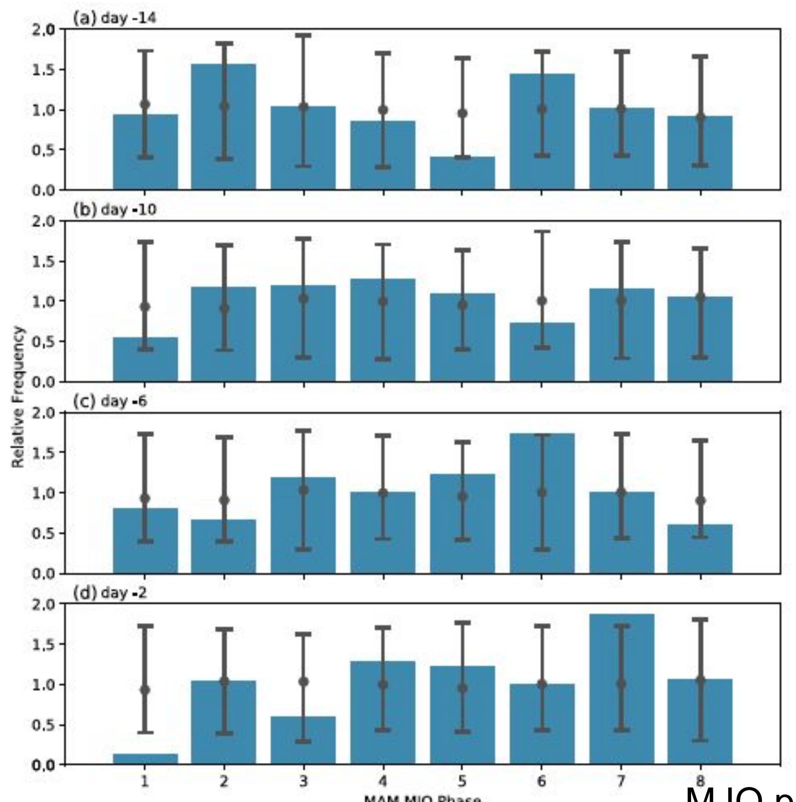


Decay dominated by cyclonic RWB

Lag composites of MAM 200 hPa velocity potential



Relative frequency



MJO phase

Conclusions

- Almost all the extreme moisture transport in daily data takes place through the N Atlantic sector. Focus on Atlantic MAM extreme moisture flux events

- Lag composite analysis shows that these extreme events are accompanied by a substantial SIC reduction lasting around a week. T_{sfc} anomalously high over the sea-ice loss area and low west of Greenland and over interior Eurasia.

- The Scandinavian Block weather regime is mainly responsible for the extreme moisture transport (65% of days), NAO+ (30%)

- The extreme moisture events appear to be preceded by eastward propagating large-scale tropical convective forcing by as long as 2 weeks but the signal is weak

- In summer there is net export of moisture out of the Arctic under a very strong anticyclonic circulation. The ice-albedo mechanism of sea-ice loss dominates in thermodynamic effects summer, downward longwave surface flux dominates in spring.

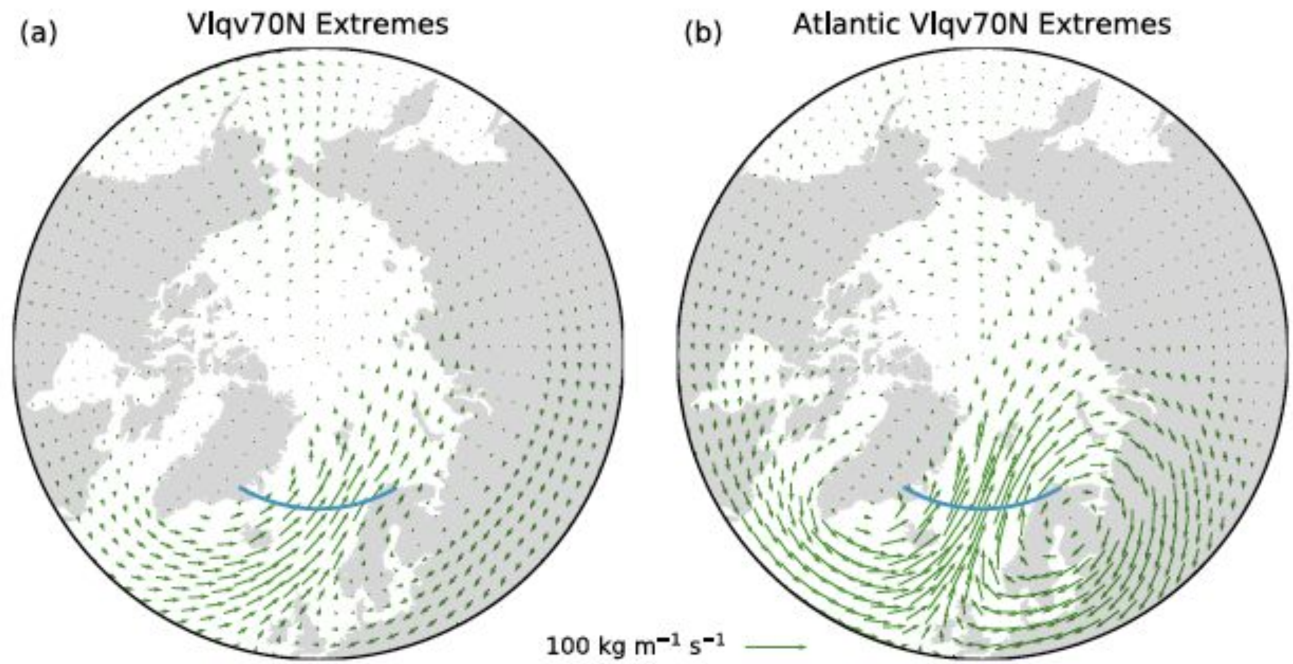
Hypothesis: Springtime moisture transport into the Arctic preconditions the sea-ice pack for the following September minimum extent

e.g., Kapsch et al (2013)

- daily vertically integrated meridional moisture transport across 70N – pick out the top 15% of days: extreme days

Composites for **MAM**

Zonal average | Average over -30W to 30E



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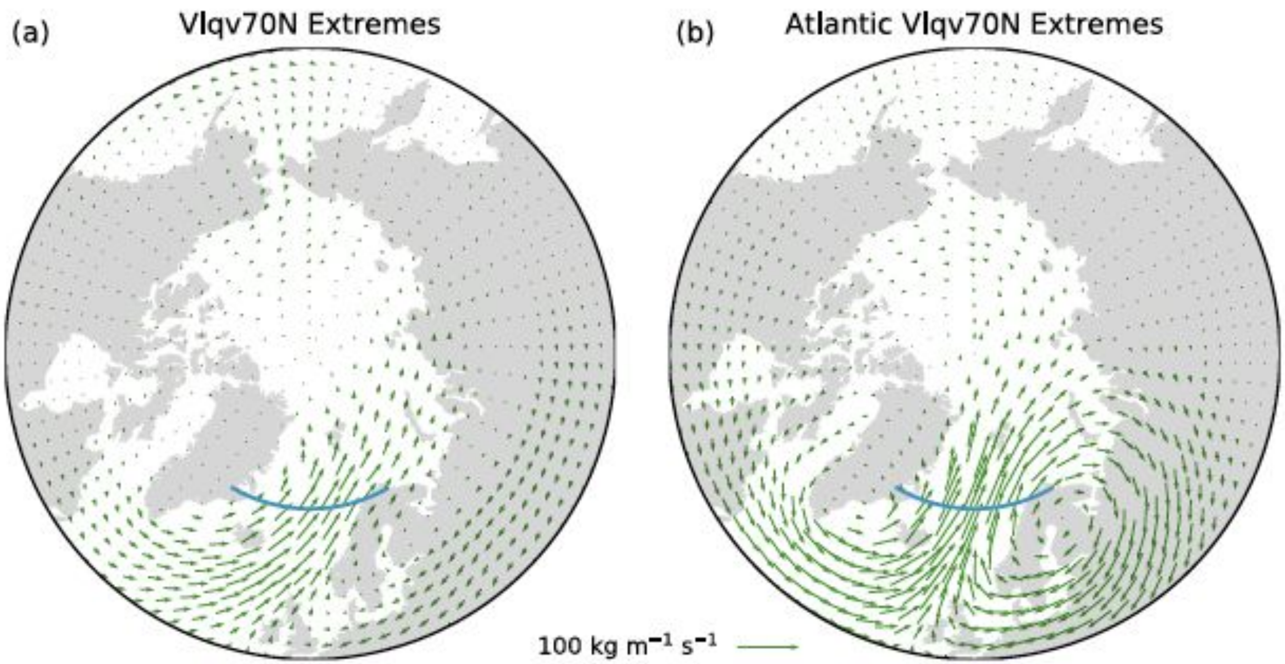
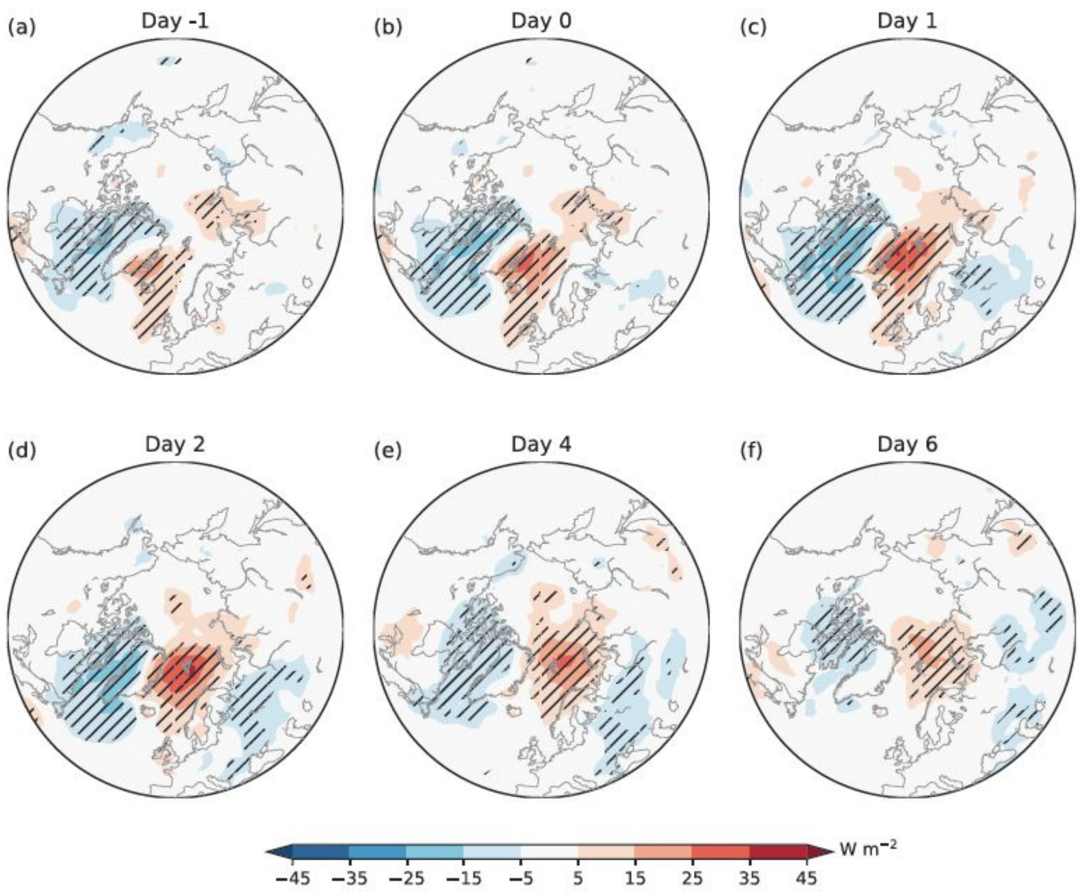


extreme moisture flux. MAM composite of sfc downward LW flux at lags -1, 0, 1, 2, 4, 6 days



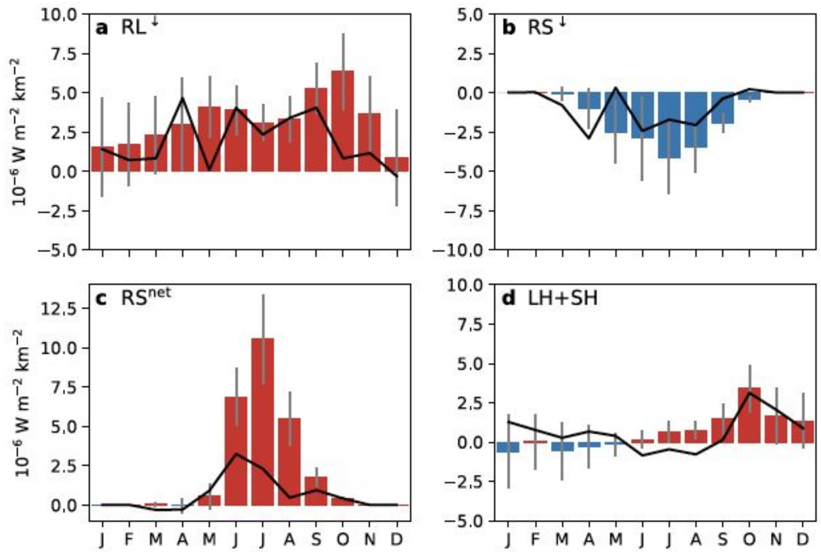
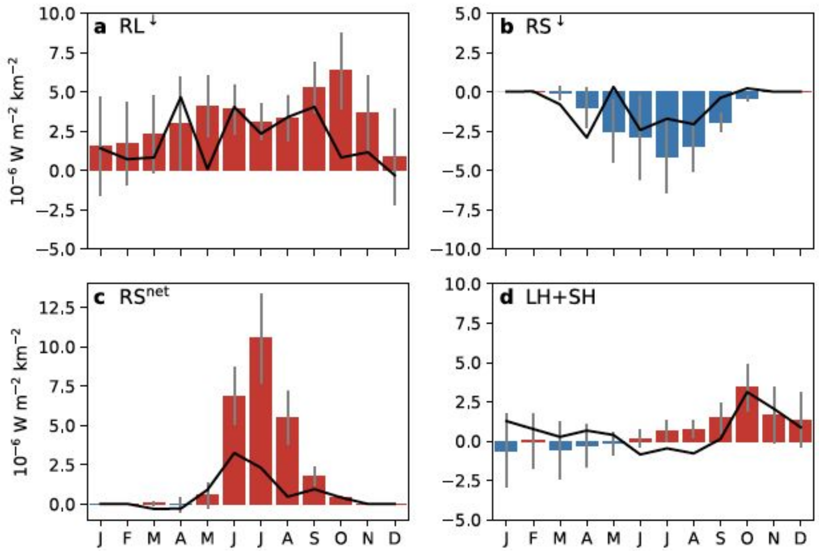


Figure 4. Regressed surface heat fluxes averaged over the Arctic (north of 70N) on the −SIE09hp for each month. (**a**–**d**) Are downward longwave radiation ($RL^{\downarrow}$), downward shortwave radiation ($RS^{\downarrow}$), net shortwave radiation (RS^{net}), and latent plus sensible heat fluxes (LH + SH), respectively. The heat fluxes are defined positive downward in (**a**–**c**), but positive upward in (**d**).



a RL↓
b RS↓
c RS^{net}
d LH+SH
10^{-6} W m^{-2} km^{-2}
10.0
7.5
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0
12.5
J F M A M J J A S O N D

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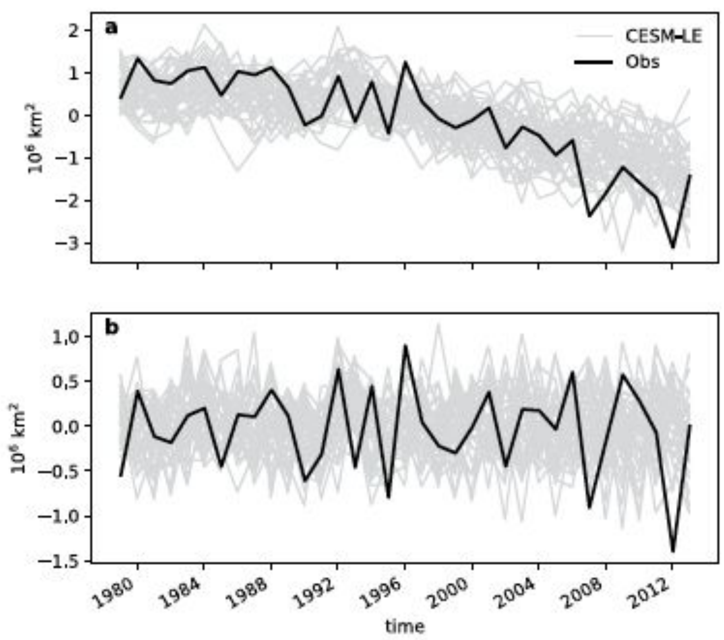
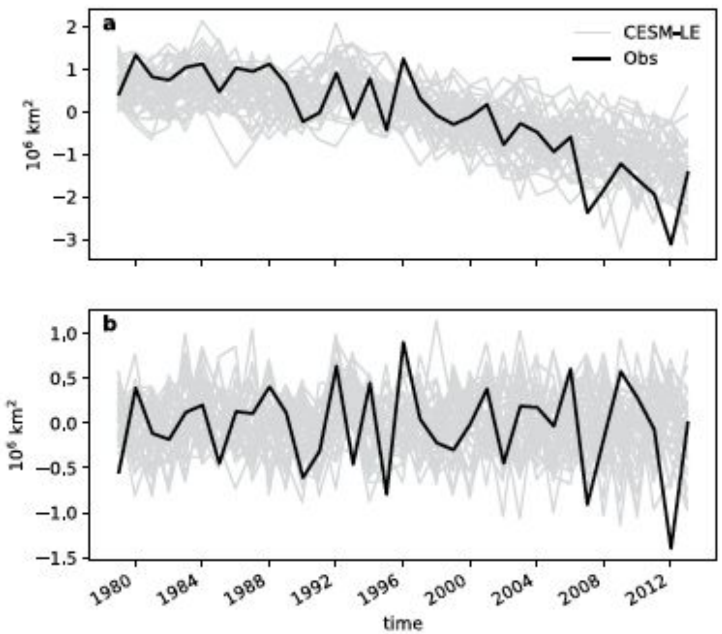
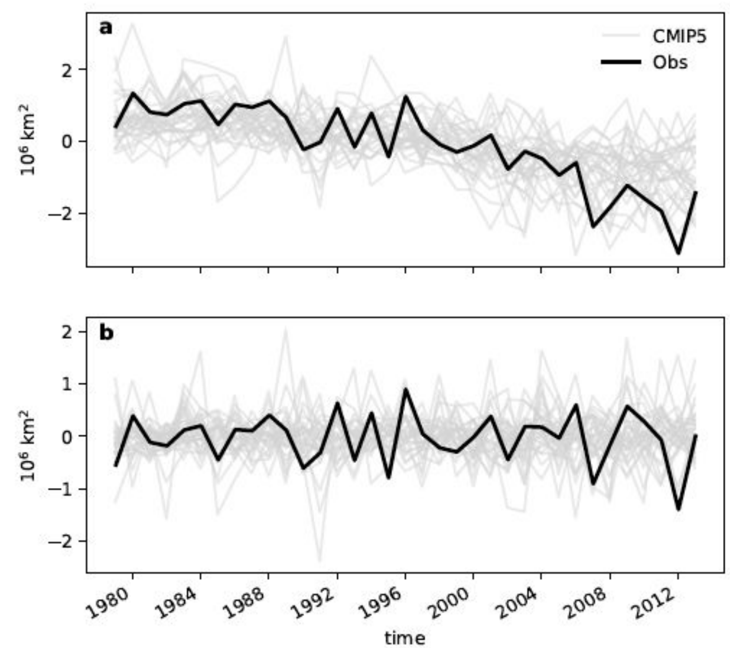


From Yang and Magnusdottir (2018)

40 ensemble members in CESM-LE



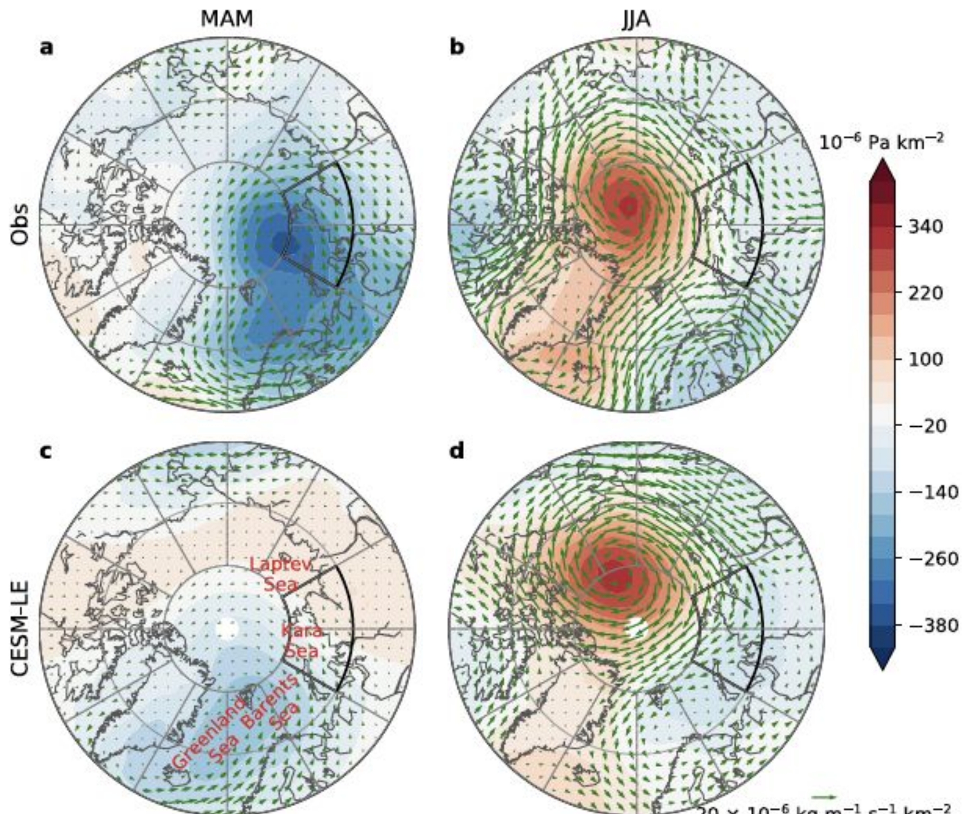
From 30 CMIP5 simulations from different models



SLP and integrated moisture flux associated with negative anomalies of high-pass filtered Sept sea-ice anomalies

ERA-I

CESM-LE



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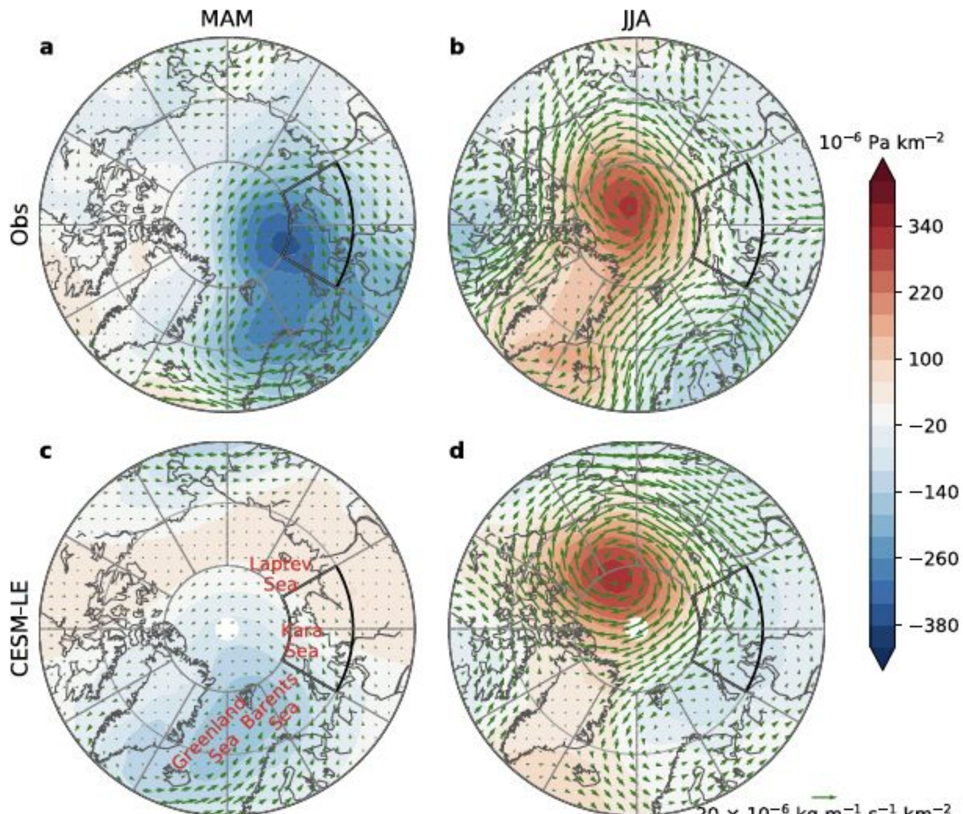
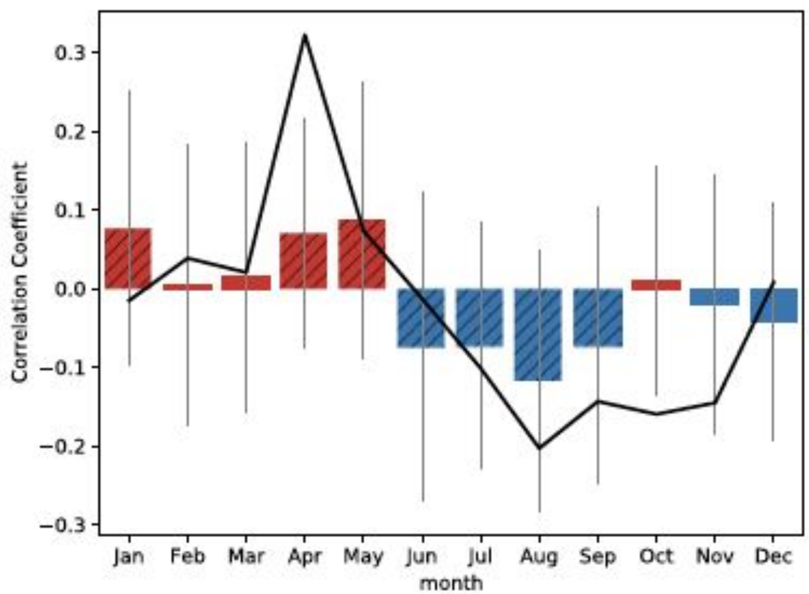
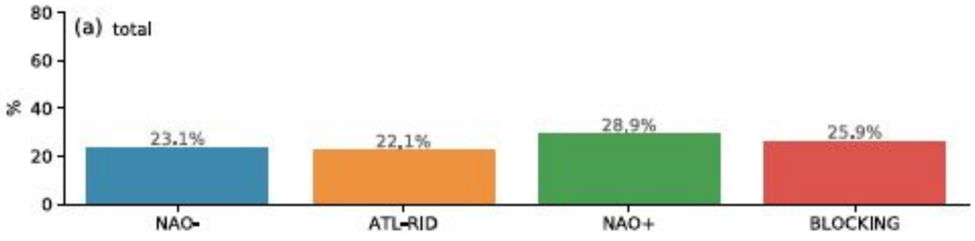


Net export of moisture in summer



Correlation between moisture flux and low sea-ice index for each month as seen in observation (black line) and the 40 ensemble members of CESM-LE (ensemble mean, vertical gray line 1 stdev above and below)

Relative frequency of N Atl. Daily weather regimes for MAM, 1979-2014, all days



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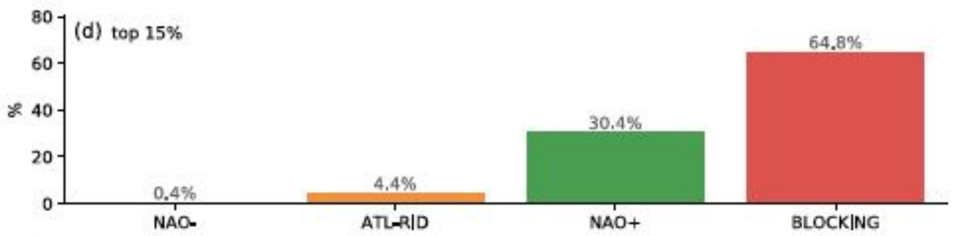

Blocking dominates

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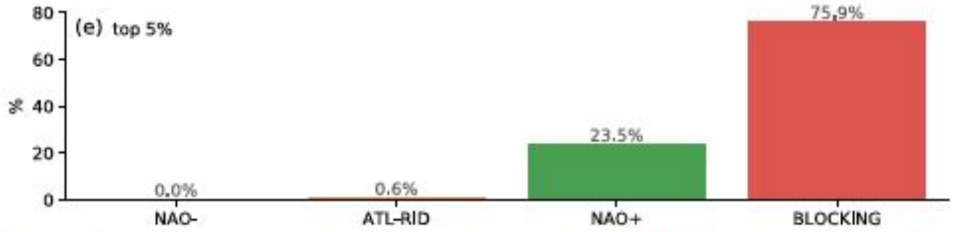

Conclusions

- MAM, extreme, daily moisture transport into the Arctic preconditions the sea-ice for the melt season, leading to minimum sea-ice extent in the following September.
- Almost all the extreme moisture transport in daily data takes place through the N Atlantic sector
- Lag composite analysis shows that these extreme events are accompanied by a substantial SIC reduction lasting around a week. T_{sfc} anomalously high over the sea-ice loss area and low west of Greenland and over interior Eurasia.
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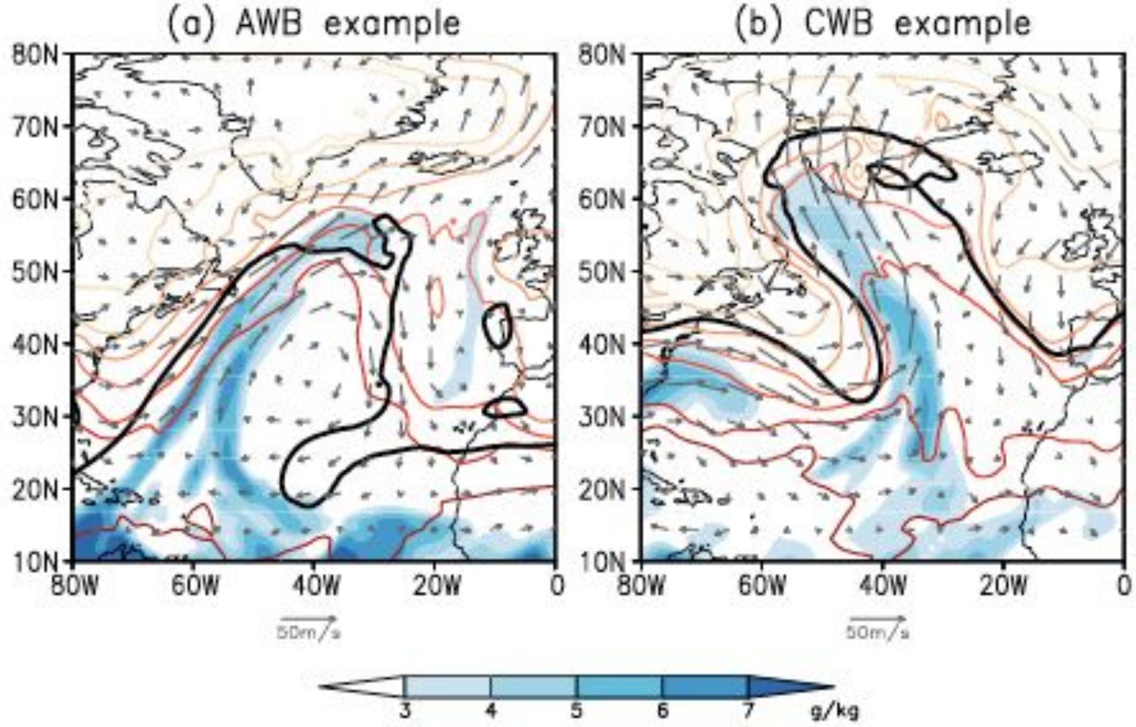
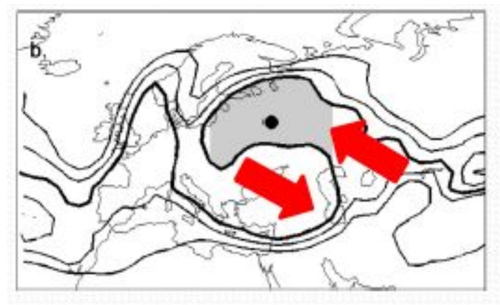
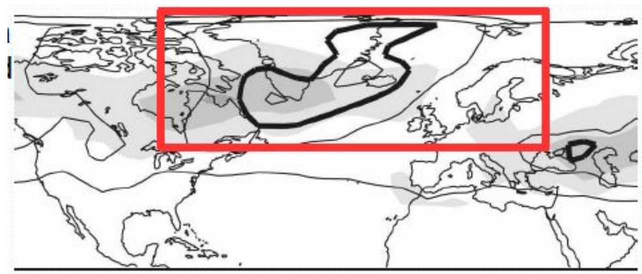
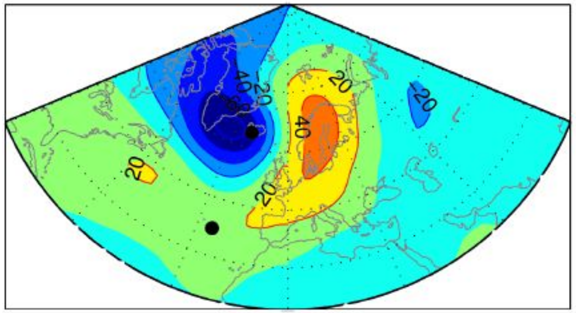


Figure 5. Mixing ratio of water vapor (shading), potential temperature (colored contours), and horizontal wind (arrows) on 700 hPa for (a) an anticyclonic wave breaking on 8 January 2006 and (b) a cyclonic wave breaking on 22 January 2007. The potential temperature contour interval is 5 K. The thick solid black line is the potential temperature contour on the 2 PVU surface that is used to identify Rossby wave breaking events.

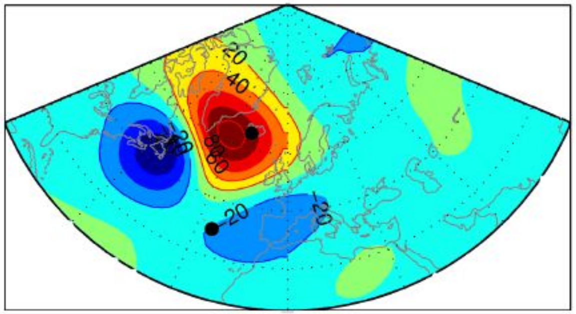

b



hgt 500mb pp cwb



hgt 500mb nn cwb



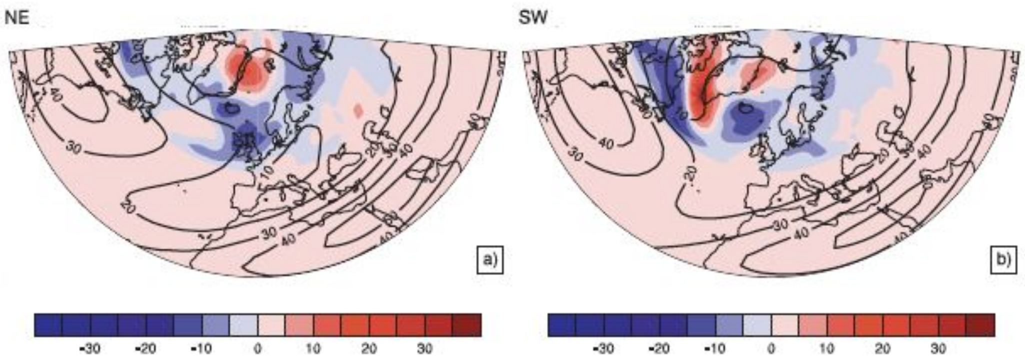


FIG. 5. The composite of zonal wind and $\partial E_y/\partial y$ on the 350-K isentropic surface when cyclonic RWB takes place within (a) the NE domain and (b) the SW domain. Contours are zonal wind (m s^{-1}; contour interval of 10 m s^{-1}), and shading is $\partial E_y/\partial y$ (10^{-5} m s^{-2}). To emphasize higher latitudes, $\partial E_y/\partial y$ is only plotted north of 50°N.

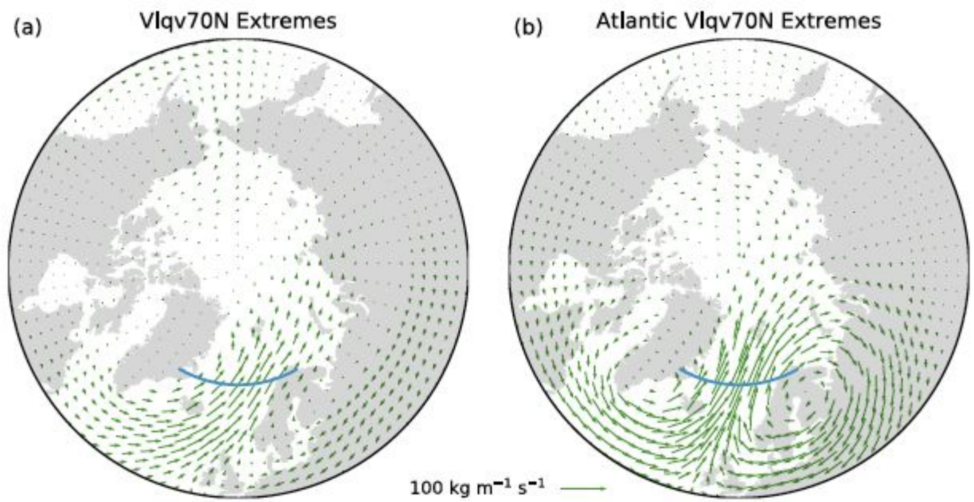
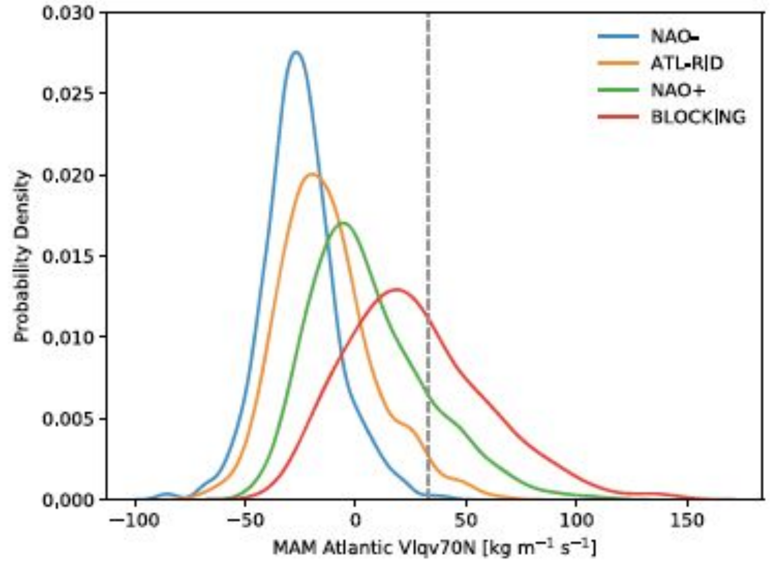


Figure 3. Composites of MAM vertically integrated moisture transport (VIq**v**) for extremes of (a) VIqv70N and (b) Atlantic-VIqv70N. The blue solid lines show the defined Atlantic longitude range 30°W–30°E at 70°N.



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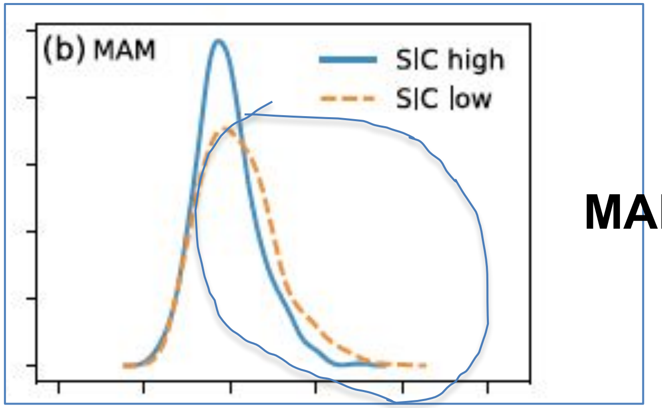
Seasonal variability in daily vertically integrated, meridional moisture flux into Arctic

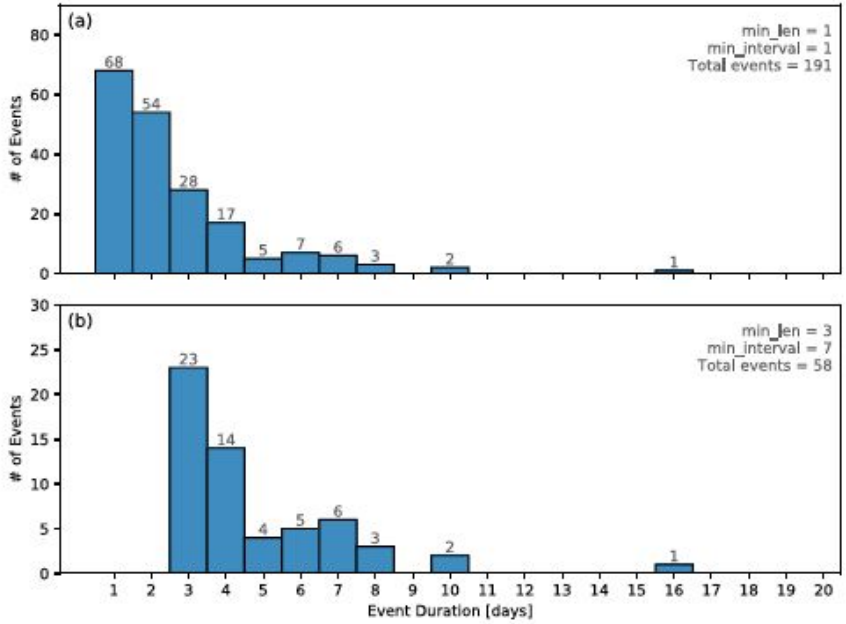
Composite low vs high SIC years



MAM

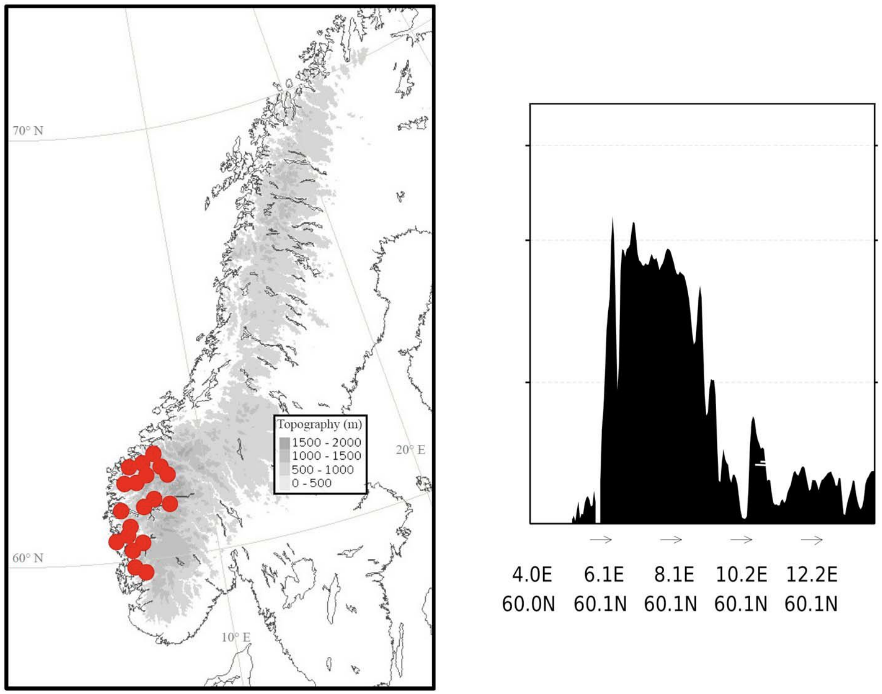
Motivates examining the spring season

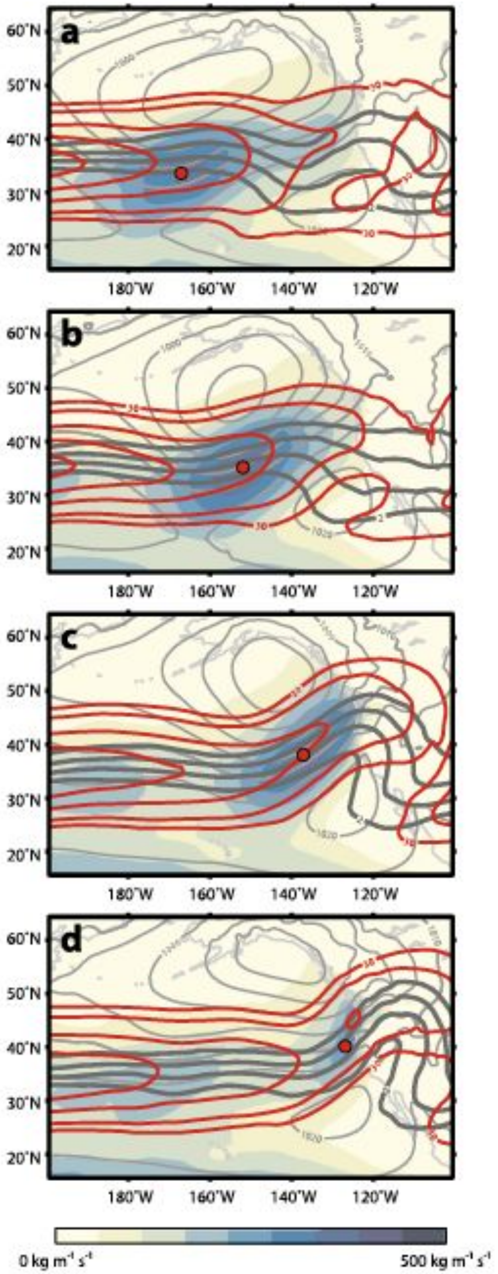
Extreme events



For 1979-2014

Only events lasting at least 3 days separated by at least 7 days of non-extreme conditions


70° N
60° N
20° E
10° E
Topography (m)
1500 - 2000
1000 - 1500
500 - 1000
0 - 500
4.0E 6.1E 8.1E 10.2E 12.2E
60.0N 60.1N 60.1N 60.1N 60.1N


a
b
c
d
60°N
50°N
40°N
30°N
20°N
180°W
160°W
140°W
120°W
0 kg m⁻¹ s⁻¹
500 kg m⁻¹ s⁻¹