Quantifying the Impact of Atmospheric Blocking on the Mean State of the North Atlantic Sector of the Arctic

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Introduction

Recent changes in low-frequency atmospheric circulation in the North Atlantic sector of the Arctic (NAA) have increased sensible heat and moisture advection from the mid-latitudes into the region (Mattingly et. al, 2016). This, in turn, has altered the surface energy budget over the Greenland Ice Sheet (GrIS) and adjacent sea ice and contributed to unprecedented melt and freshwater runoff events, as was evident on 08 July 2012, where approximately 40% of the ice sheet's surface experienced melt (Nghiem et al. 2012). This and other intense melt events in subsequent years, along with record or near-record warmth and lack of sea ice in the Arctic Ocean, provide an exceptional opportunity for timely investigation on the multiple ways in which large-scale atmospheric circulation drives land- and sea-ice changes across the NAA.

Research Goals

To anticipate and reduce the negative consequences of these extreme events, the objectives of this research are to:

1. *Quantify the contributions from large-scale atmospheric circulation and moisture transport to ice melt events across multiple time scales;*
2. *Understand how atmospheric blocking and Rossby wave breaking impact, and are impacted by, the transport of moisture from mid-latitudes into the NAA; and*
3. *Investigate the role of this moisture advection in altering radiative and turbulent fluxes, winds, precipitation, surface melting, and snow accumulation in the NAA.*

Climatology of Blocking Over Greenland

- Blocking exhibits interannual variability with number of days with blocking increases in frequency from 1980-2017.
- Shift to more frequent blocking in recent years is more pronounced in summer than winter.

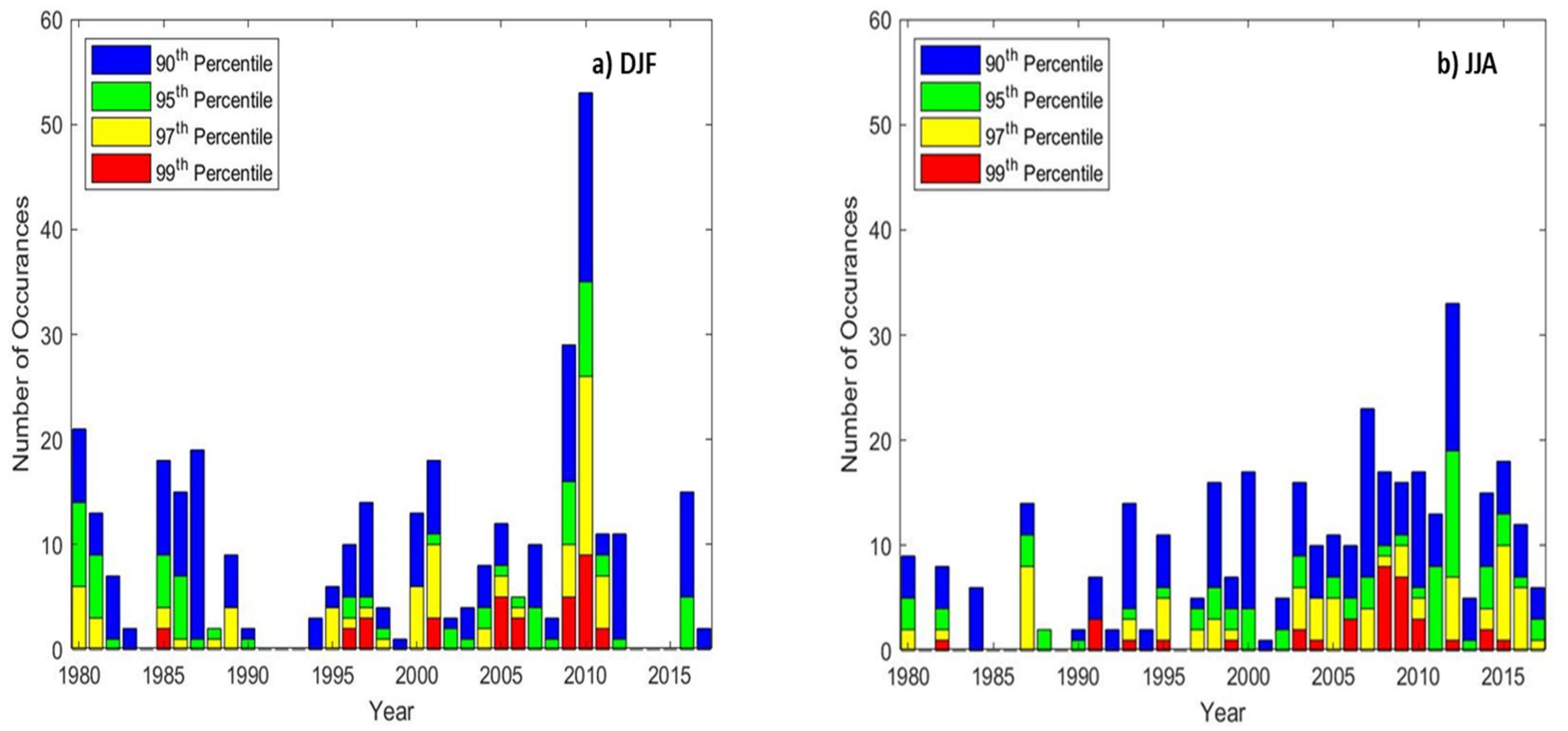


Figure 3: Frequency of extreme single day Greenland Blocking events per year from 1980-2017 at varying thresholds.

- Shift to more frequent extreme blocking in recent years has seasonal dependence at the 90th percentile, but by the 97th and 99th percentiles, that seasonality largely disappears.
- The most extreme blocking events (above the 97th and 99th percentiles) thus are more common in the 2nd half of the data record (1980-2017) in both seasons (DJF and JJA).

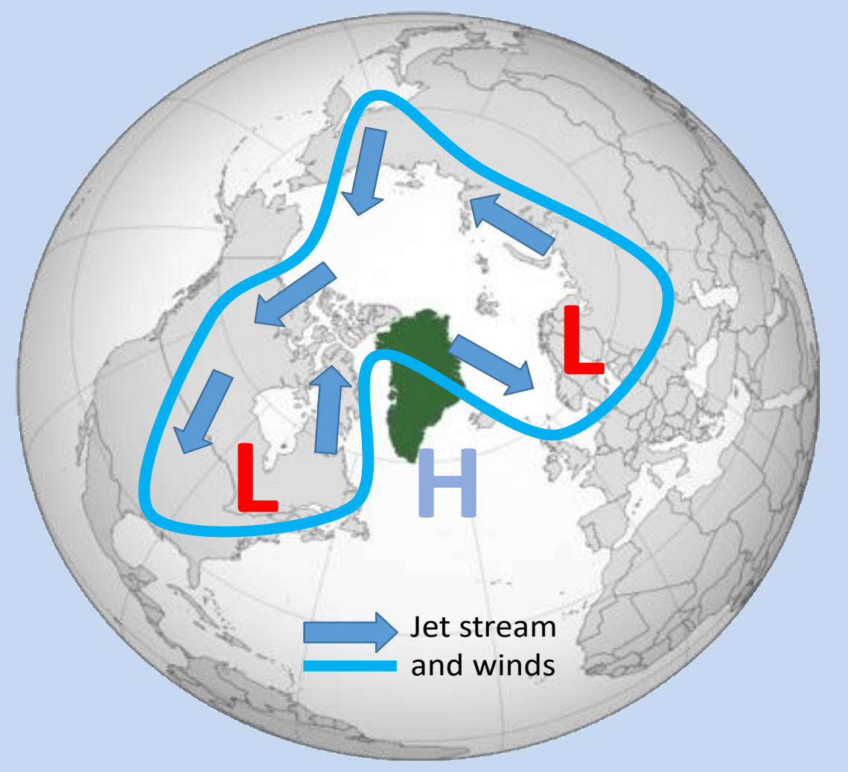
Table 1: Seasonal likelihood of above average IVT days within varying extreme GBI thresholds (top). Seasonal likelihood of above average GBI days within varying extreme IVT thresholds (bottom).

Percentile of GBI Values	Season	Total Occurrences within GBI Percentile	Percent of Occurrences	
			1980-1999	2000-2017
90th	DJF	343	43	57
	JJA	351	28	72
95th	DJF	172	37	63
	JJA	175	26	74
97th	DJF	103	30	70
	JJA	105	27	73
99th	DJF	34	21	79
	JJA	35	17	83

Greenland blocking

What is Greenland Blocking?

- Unusual waviness in the jet stream, centered over Greenland
- Occurs when there is a breaking of synoptic-scale Rossby waves resulting in a quasi-stationary high pressure system that blocks circulation.
- Typically results in a large-scale reversal of the meridional geopotential height gradient (Pelly & Hoskins, 2003).



Effects:

- Warm temperatures and melt over Greenland
- Cold temperatures and snow over US and Europe

Impacts to DoD operations:

- Changes in sea ice concentration
- Snow and ice melt
  - Freshwater input changes the expected acoustic profile
- Unusual cloud cover and precipitation

Figure 1: Schematic depicting an extreme block (ridge), and associated flow over Greenland and the North Atlantic sector of the Arctic (NAA).

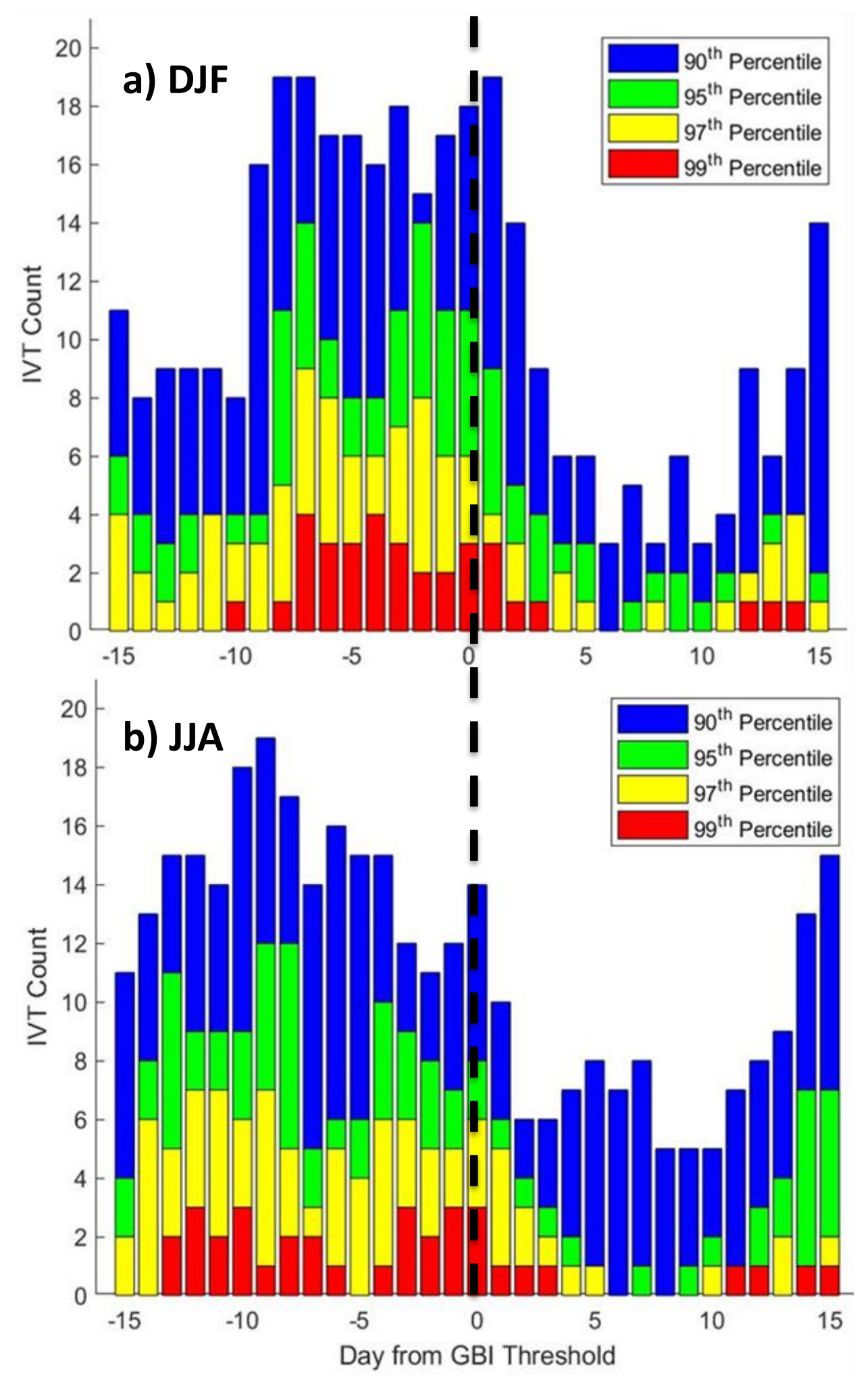
Greenland Blocking & Moisture Transport

Table 1: Seasonal likelihood of above average IVT days within varying extreme GBI thresholds (top). Seasonal likelihood of above average GBI days within varying extreme IVT thresholds (bottom).

	DJF			JJA		
GBI Percentile	Days with high IVT	Total days	Percent (%)	Days with high IVT	Total days	Percent (%)
90th	266	343	**78**	222	350	**63**
95th	148	172	**86**	131	175	**75**
97th	92	103	**89**	77	105	**73**
99th	32	34	**94**	27	35	**77**
	DJF			JJA		
IVT Percentile	Days with high GBI	Total days	Percent (%)	Days with high GBI	Total days	Percent (%)
90th	217	343	**63**	172	350	**49**
95th	116	172	**67**	90	175	**51**
97th	71	103	**69**	56	105	**53**
99th	29	34	**85**	21	35	**60**

Covariability of blocking and moisture transport

- As the extremity of blocking increases, the likelihood of above average moisture transport also increases near Greenland.



- Above-average moisture transport is more likely on an extreme blocking day than high blocking is on an extreme moisture transport day. These trends are stronger in winter than in summer.

Persistence of above-average moisture transport

- For both seasons, highest frequency of above-average moisture transport occurs prior to peak blocking.
- Peak winter moisture transport occurs closer in time to peak blocking event than in summer.
- Peak blocking (97th and 99th percentiles) tends not to be followed by above average moisture transport between 5 and 10 days out.
- The relationship between moisture transport and blocking has not been explored yet, but is suggested for future work.

Figure 5: Persistence of above-average moisture transport from-15 to 15 days centered on day of peak blocking (black dashed line).

Data & Methods

The analyses in this study were based on two publicly available datasets:

- Daily gridded surface pressure and wind and mid-to-upper tropospheric geopotential height, wind, and specific humidity, from the ERA-Interim reanalysis (1° lon x 1° lat, Dee et al., 2011) collected during the period 1980-2017.
- Daily NOAA Greenland Blocking Index (GBI; Hanna et al., 2013) defined as the mean 500 hPa geopotential height for the 60°–80° N, 20°–80° W region.

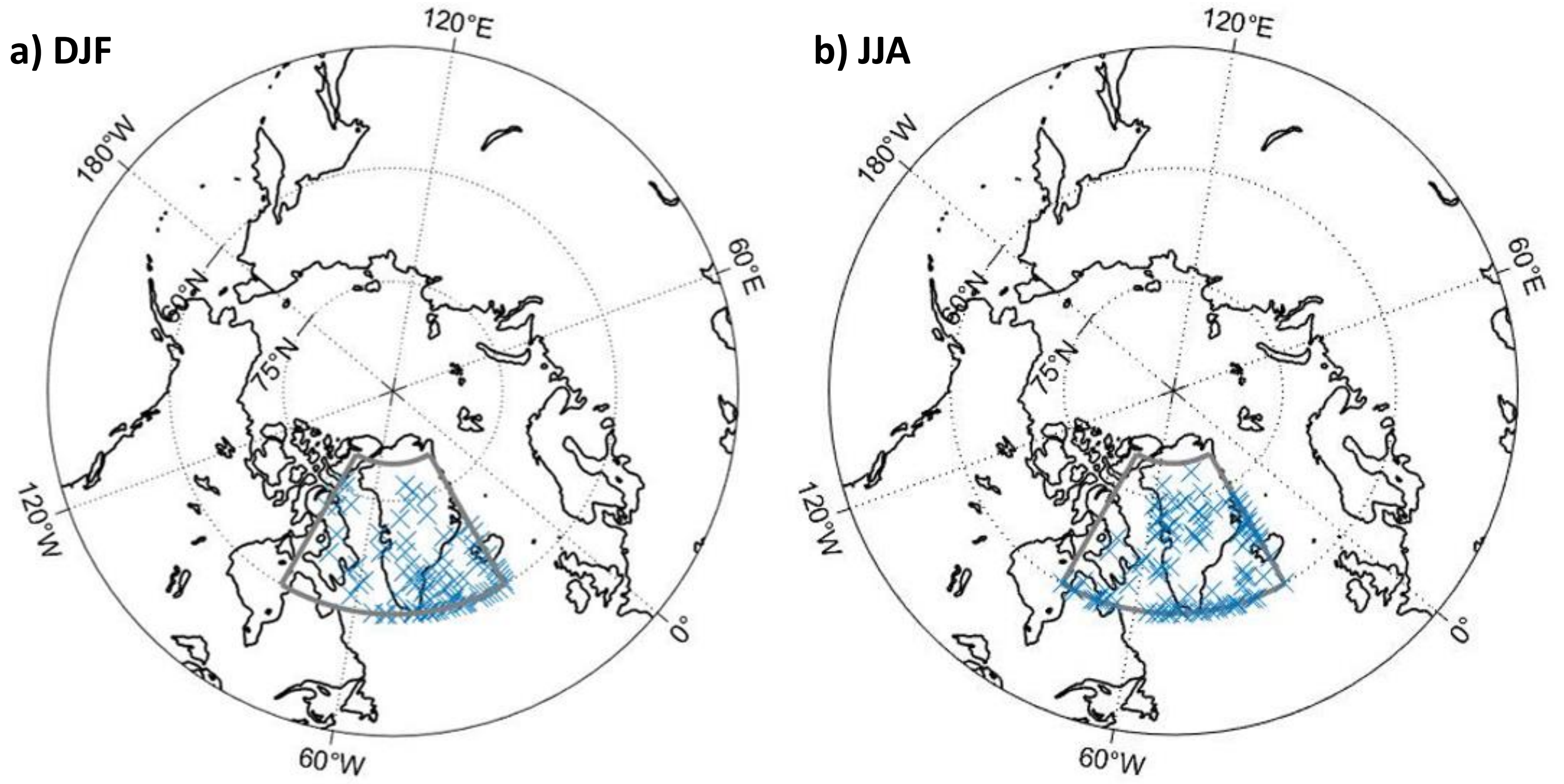


Figure 2: Location of the highest 500mb geopotential height (blue x) on each GBI day in the 97th percentile.

Integrated Vapor Transport (IVT)

- Based on Mattingly *et al*., 2018, using the adapted IVT equation (Rutz *et al*., 2014).
- IVT calculations were used to evaluate moisture transport near the GrIS (55-80N by 15-85W).
- Atmospheric moisture transport is an important consideration for Greenland surface conditions.

$$IVT = \frac{1}{g}\int_{1000hPa}^{200hPa} qV\,dp$$

g= gravitational acceleration $(m\,s^{-2})$
q= specific humidity $(kg\,kg^{-1})$
V= vector wind $(m\,s^{-1})$
dp= difference between pressure levels

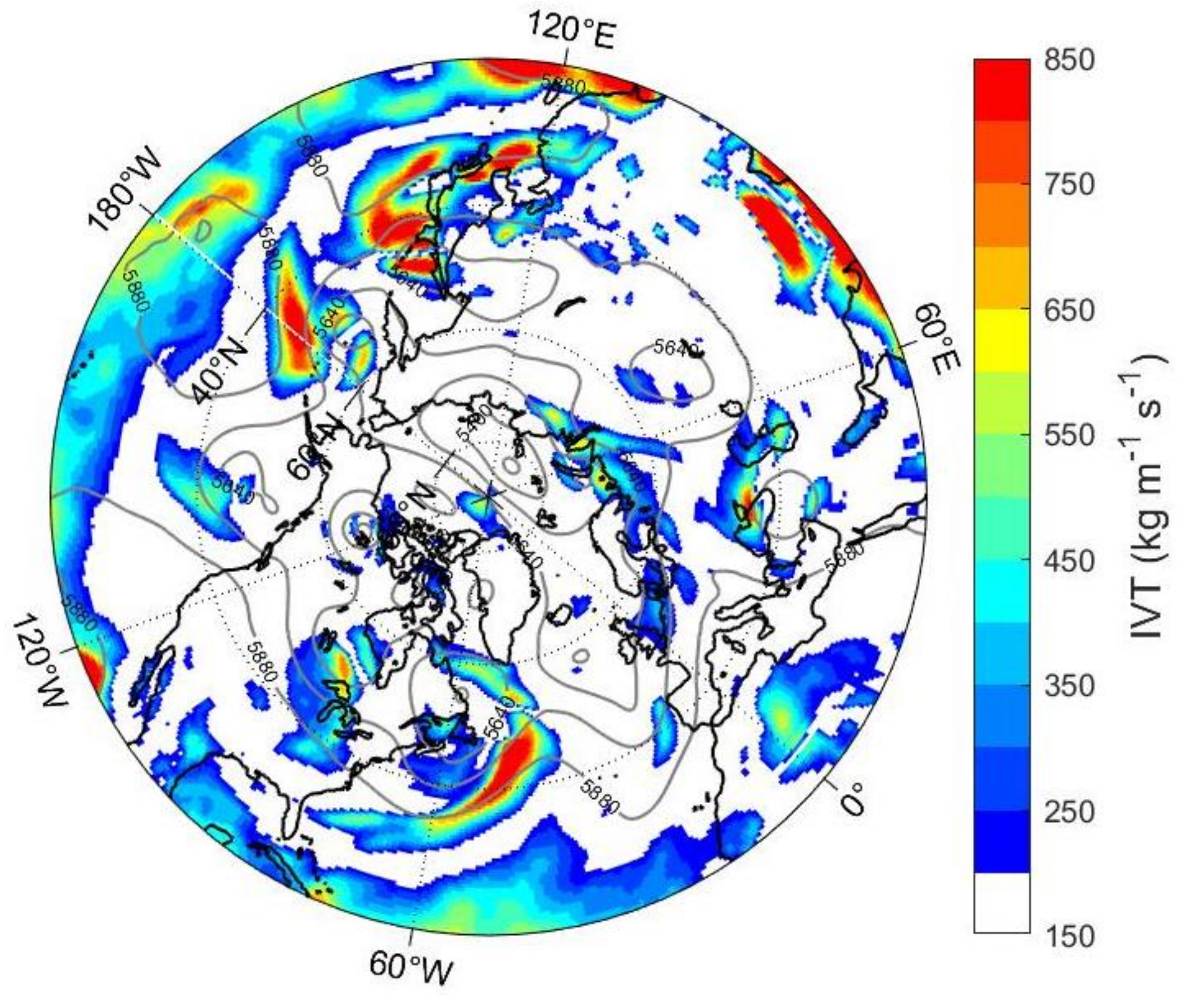


Figure 3: Integrated vapor transport (shading, kg m^{-1} s^{-1}), and 500 hPa heights (contours), for one of the top ten highest GBI value days for the period 1980-2017.

Summary and Future Work

The major results of this work are as follows:

- An understanding of frequency, seasonality, and spatial sense of extreme Greenland blocking (Fig. 1, Fig. 2, Table 1).
- Covariability of extreme blocking and moisture transport near Greenland (Table 2).
- Persistence of above average moisture transport around peak blocking (Fig. 5).

Future work will relate blocking and moisture transport to the overall energy budget and impact on the Greenland ice sheet, and will examine how this impacts surface winds and precipitation as well as surface melt and sea ice concentration.

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