CLIMATOLOGICAL ANALYSIS OF ALASKA BLOCKING PATTERNS, 1958-2014

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ABSTRACT

Rapid changes to the climate and environment of greater Alaska are often physically interconnected and linked to oceanic and atmospheric processes that vary across disparate space and time scales. Previous studies have also suggested that synoptic-scale circulation patterns over Alaska have especially profound impacts on the occurrence of temperature and moisture extremes, but there has yet to be a long-term assessment of mid-tropospheric circulation across the region, which may influence the temporal variability of such extreme events. Here, an Alaska Blocking Index (ABI) for the 1958–2014 period is created and analyzed, representing the climatological, mid-tropospheric circulation field over Alaska. This metric is developed over the domain (54–76°N, 125–180°W) by merging daily, gridded 500 hPa geopotential height (GPH) fields derived from the ERA-40 (1958–1978) and ERA-Interim (1979–2014) reanalyses. Climatological characteristics of the seasonal and annual ABI values are evaluated, and periods of prevalent blocking conditions are identified and subsequently analyzed with respect to a number of reanalysis-derived climate and environmental variables as well as the prominent modes of Pacific climate variability.

The ABI has exhibited positive trends since 1979, especially during summer, autumn, and annually. Many of the extreme high ABI values occur since 2000, including the highest annual values in 2013 and 2014. Anomalous blocking patterns in winter and summer are associated with diminished terrestrial snow depth and sea-ice cover, positive near-surface air temperature anomalies, and poleward advection of heat and moisture across Alaska and its bordering seas. Vector wind comparisons at the 500 hPa level between ABI, Pacific North American (PNA) pattern, and Pacific Decadal Oscillation (PDO) extremes reveal distinguishing dynamic characteristics as the ABI center of action and its associated anticyclonic wind field are shifted well north about central Alaska relative to the PNA and PDO. Forthcoming analyses will look further into ABI relationships with regional Arctic change and potential downstream linkages between Alaska blocking and North American mid-latitude climate.

INTRODUCTION AND OBJECTIVES

Widespread surface air temperature (SAT) warming around Alaska has been associated with numerous impacts in the west Arctic, including sea and glacial ice losses (Gardner et al. 2013; Stroeve et al. 2014), vegetative increase on the tundra (Jorgenson et al. 2015) and an increase in fire weather conditions and large wildfire events (Hayasaka et al. 2016). Atmospheric blocking, persistent ridging in the mid-tropospheric GPH field common around the North Pacific storm track (Barripedro et al. 2006), has been linked to the Pacific-North American (PNA) pattern in winter (Renwick and Wallace 1996) and relatively short-term changes in regional climate in other seasons. Environmental change stemming from multidecadal temperature trends and associated atmospheric circulation regimes is often linked to low frequency ocean sea surface temperature (SST) shifts, such as those characterized by phases of the Pacific Decadal Oscillation (PDO; Bieniek et al. 2014).

In this study, we characterize and evaluate the long-term atmospheric circulation over Alaska through the development of a 500 hPa GPH index about the region, termed the Alaska Blocking Index (ABI). Through the development of the ABI, our goal is to better understand seasonal GPH characteristics and their linkages to ongoing climate and environmental changes around Alaska. We also compare the ABI to the PDO and PNA to assess spatiotemporal links between atmospheric circulation over greater Alaska and large-scale Pacific ocean-atmosphere climate variability.

ABI DEVELOPMENT

- Daily mean 500 hPa GPH values created from ERA-40, 1958-1978 (Uppala et al. 2005) and ERA-Interim, 1979-2014 (Dee et al. 2011) by averaging datasets across the standard 6-hourly time steps to create ABI
- Datasets are interpolated onto a 0.5° x 0.5° gridded domain over the period of record
- A Blackmon low-pass filter is applied to daily ABI to minimize high frequency variability and preserve relevant synoptic-scale features in the 500 hPa GPH field
  - Similar methods are employed in creating the McLeod and Mote (2015) Greenland Blocking Index (GBI)
- ABI seasonal means, standard deviations, and linear trends (for DJF, MAM, JJA, and SON) are calculated

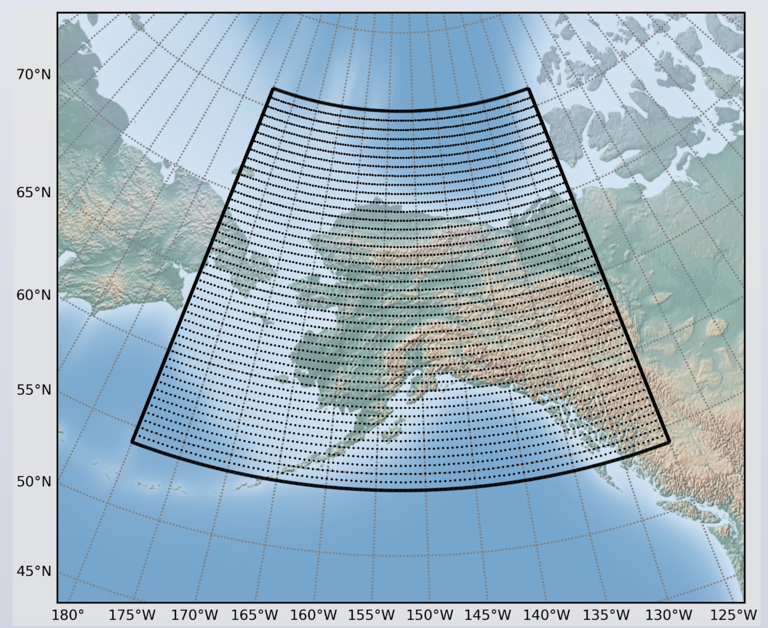

Figure 1. Spatial domain for the Alaska Blocking Index (ABI), centered over Alaska, extending from 54–76°N and 125–180°W.

SUPPORTING DATA AND ANALYSIS

- ERA-Interim SAT, SST, 500 hPa GPH and vector winds, integrated heat flux (IHF), integrated vapor transport (IVT), sea-ice coverage, and terrestrial snow depth over ABI domain are composited by ten highest/lowest ABI years since 1979 (years since 2000 in **bold**)

Period	Highest Years	Lowest Years
DJF	**2014**, 1985, **2013**, **2009**, 1989, **2005**, 1982,1980, 1995, 2003	1999, **2006**, 1990, 1987, **2012**, 1984, 2002, 2001, 1992, 1991
MAM	2002, 1990, 1996, 1989, **2005**, **2013**, **2014**, 1995, 2004, 1997	1985, 1986, 1982, 1980, 1999, 2001, 1994, **2012**, 1984, 1992
JJA	2004, **2007**, **2013**, **2005**, 1989, 1993, 1987, 1979, **2010**, 2001	1981, **2011**, 1983, **2008**, 1996, 1986, 1984, 1988, 2002, 2003
SON	**2006**, **2012**, 2002, 1986, **2014**, 1991, 1995, **2013**, 2003, **2010**	**2011**, 1994, 1990, 1992, 1983, 1999, 2004, 1987, 1988, **2009**
Annual	**2014**, **2013**, **2005**, 2004, 1989, 1995, 2002, 1996, 2003, **2009**	1999, 1992, 1987, **2011**, 1984, 2001, 1994, 1988, 1990, 2008

- PDO (JISAO) and PNA (CPC) indices are compared to ABI through 1) detrended Pearson correlations of seasonal values (below) 2) composite plots of 500 hPa vector winds (see *Figure 6*)

Index	PNA	PDO
ABI_{DJF}	+0.20	+0.15
ABI_{MAM}	-0.07	+0.15
ABI_{JJA}	+0.22	+0.15
ABI_{SON}	+0.11	**+0.35**
ABI_{Annual}	+0.13	+0.24

Bold value is significant at p < 0.05

RESULTS: ABI CLIMATOLOGY

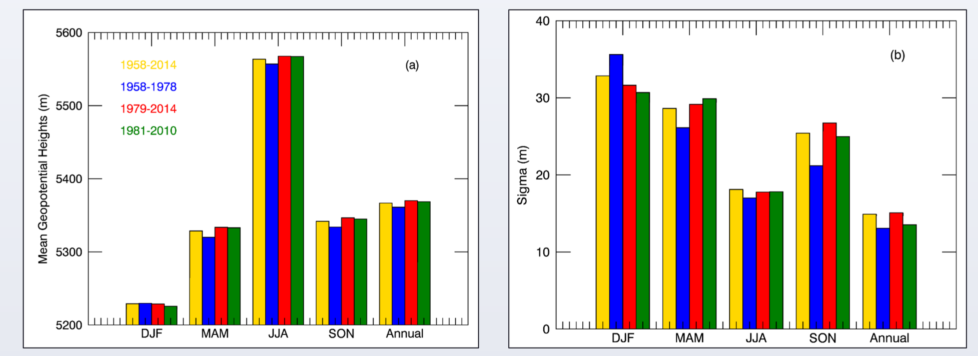

Figure 2. Means (a) and sigmas (b) of the ABI (in meters) by different period divisions for winter (DJF), spring (MAM), summer (JJA), autumn (SON), and annually (Jan–Dec).

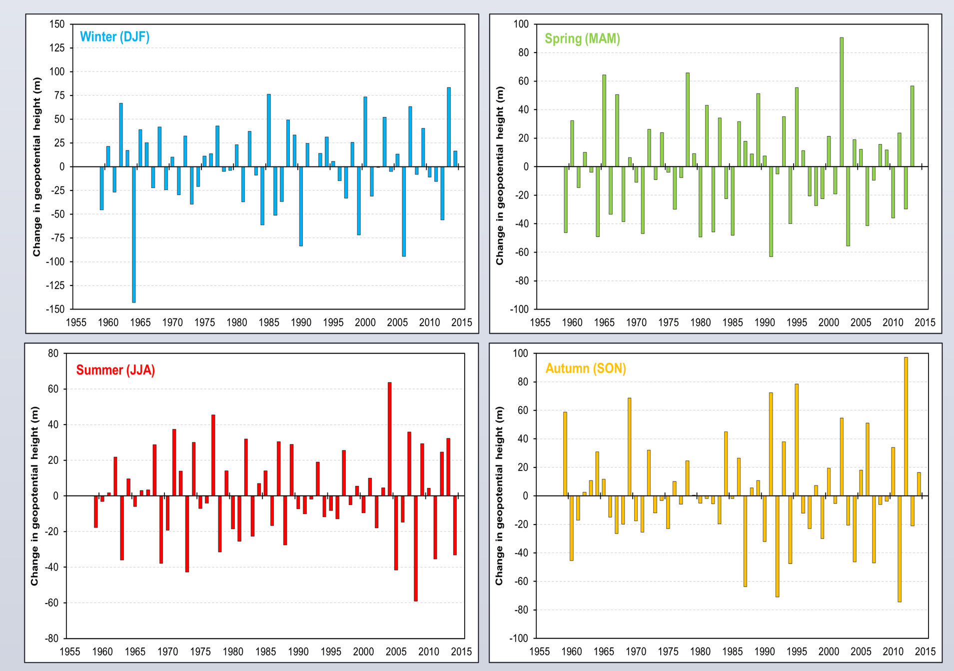

Figure 3. Interannual change in the ABI height values (in meters) by season, 1958–2014.

RESULTS: ABI VERSUS PACIFIC TELECONNECTIONS

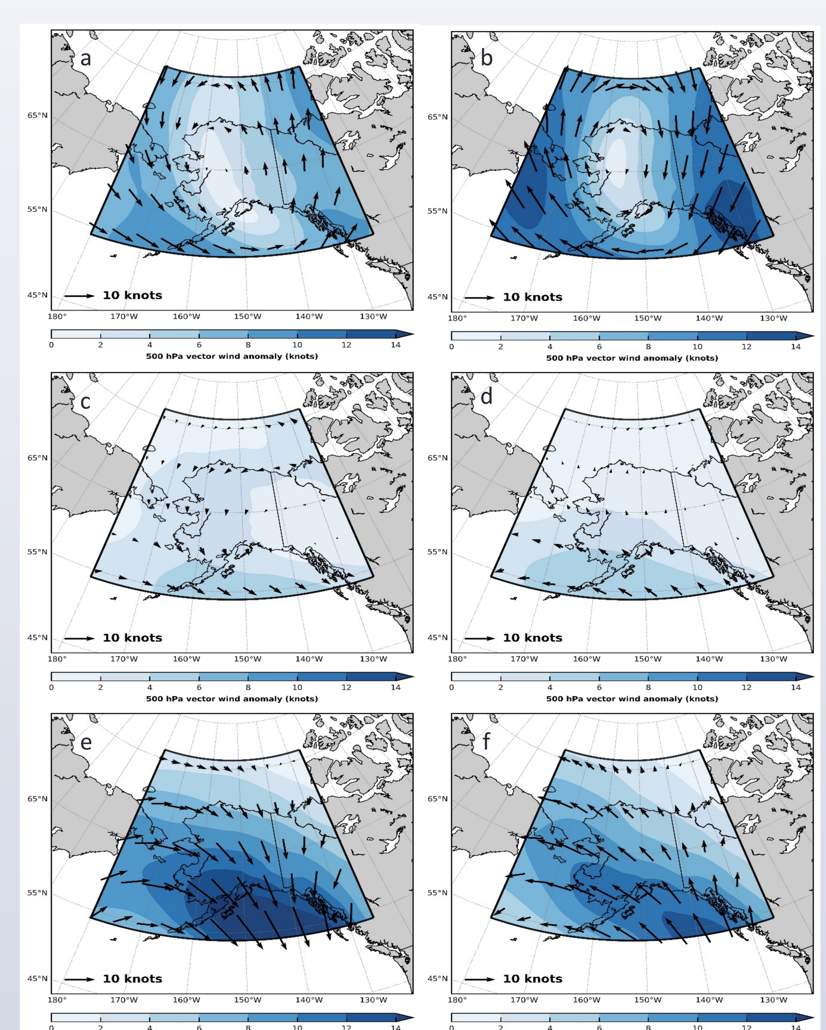

Figure 6. 500 hPa vector wind composites by negative (≤-1 sigma; left column) and positive (≥+1 sigma; right column) anomalies of the ABI (a and b), PDO (c and d), and PNA (e and f). Anomalies are presented with respect to the 1981–2010 climatological mean.

RESULTS: ABI TRENDS

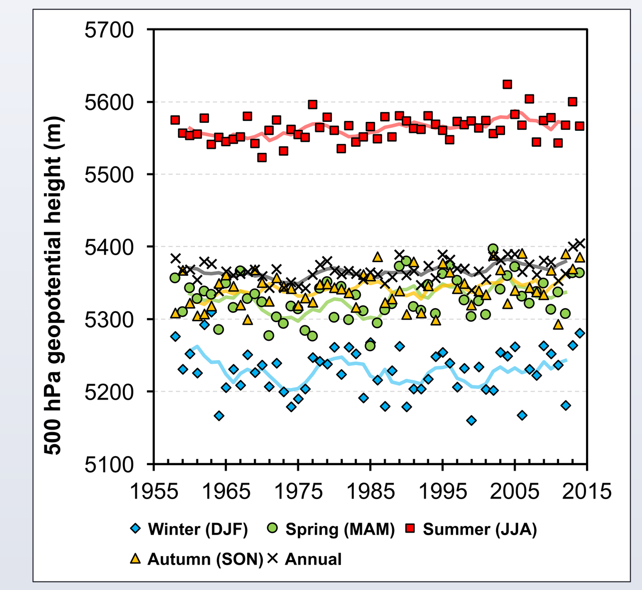

Figure 4. Time series of seasonal and annual ABI values (in meters), 1958–2014. A 5-year running mean is fit to each of the time series.

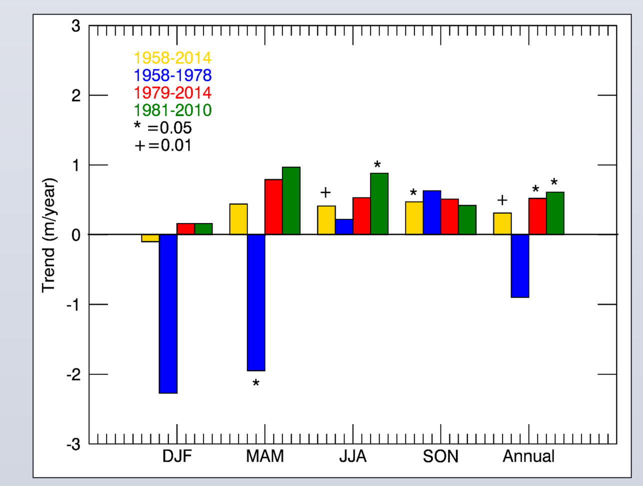

Figure 5. Linear trends of seasonal and annual ABI values (in meters/year) for the different period divisions. Bars with asterisks (*) and plus signs (+) indicate significant trends at p < 0.05 and p < 0.01, respectively.

RESULTS: ABI COMPOSITES

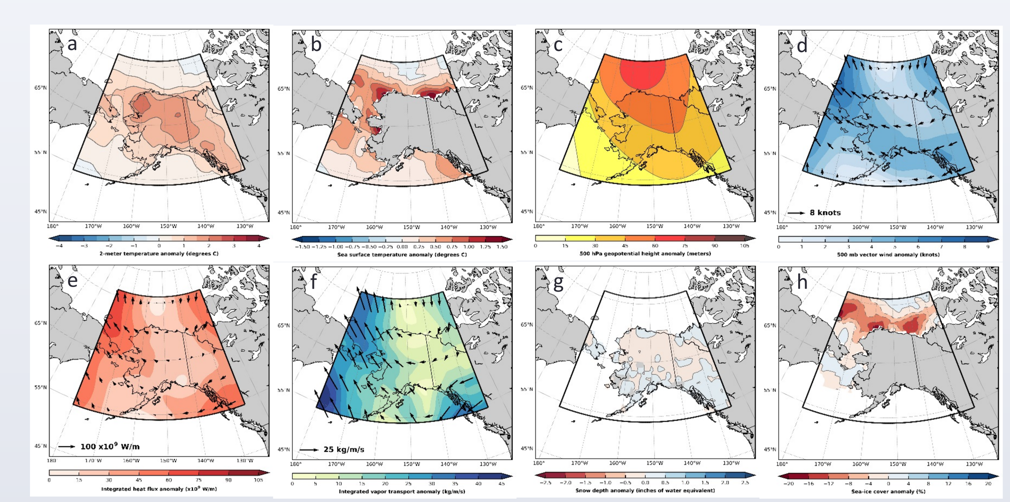

Figure 7. Composite anomaly plots of a) SAT, b) SST, c) 500 hPa GPH, d) 500 hPa vector winds, e) IHF, f) IVT, g) snow depth, and h) sea-ice cover based on the difference between the ten highest and lowest ABI summer values (JJA) since 1979.

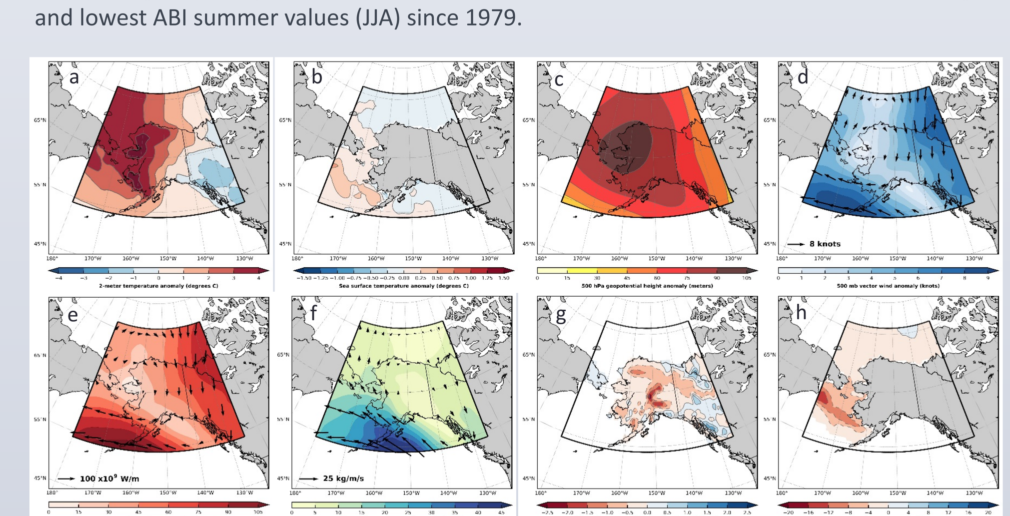

Figure 8. Composite anomaly plots of a) SAT, b) SST, c) 500 hPa GPH, d) 500 hPa vector winds, e) IHF, f) IVT, g) snow depth, and h) sea-ice cover based on the difference between the ten highest and lowest ABI winter values (DJF) since 1979.

CONCLUSIONS AND FUTURE WORK

The development of the ABI allows the mid-tropospheric flow across greater Alaska to be monitored through time, while also providing an atmospheric metric to broadly contextualize weather and climate variability across Alaska and adjacent environments. In our ABI analysis, we identify the seasonal and annual means and interannual variability of the ABI, which are generally increasing over the latter portion of the ABI record, 1979–2014. These positive trends are statistically significant across climatological spring and summer and the yearly time series, and they are characterized by a number of extreme height values since 2005. Mid-level winds during ABI extremes differ in strength, direction, and location from the PNA and PDO modes, suggesting that the upper-level blocking pattern over Alaska distinctly influences the regional climate. Composite ABI differences (in high versus low years) are further linked to a number of climatic and environmental characteristics, including diminished snow and marginal sea-ice cover, warmer lower tropospheric air temperatures, and northward (southward) flows of heat and moisture along the Bering Sea (Alaska-Yukon borderlands). These physical characteristics are dynamically linked to the synoptic-scale environment that is defined by the presence of upper-air anticyclones over Alaska.

The ABI represents a regional climate indicator that can be compared against other studies that identify Arctic Amplification-related impacts at multiple scales, especially those focused on identifying variations in the shape and strength of the Northern Hemisphere 500 hPa GPH field. ABI applications may also extend to broader-scale analyses involving hemispheric/global climate change effects on regional atmospheric circulation. There has been increasing scientific interest directed toward investigating North American high-latitude warming and its effects on lower latitude climates (Overland et al. 2015). Future research may further explore these themes by evaluating spatial patterns of seasonal tropospheric air temperature across Canada and the contiguous United States by phase of the ABI. Beyond the potential teleconnection with North American climate patterns, this type of analysis will also allow for further comparison against the PNA, which has been shown to strongly influence temperature and precipitation regimes across the continental United States (Leathers et al. 1991).

Environmental conditions and the climate across Alaska are projected to continue to change substantially during the 21st century (Wang and Overland 2015). Future work will explore ABI events in greater detail at the seasonal and sub-seasonal timescales, including links to other emerging Arctic climate patterns, as anticyclonic conditions are an increasingly common climatological phenomena across both the Pacific and Atlantic sectors of the Arctic (Belleflamme et al. 2015; Hanna et al. 2016).

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