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Downslope windstorms in southeast Greenland - part I: Definition, seasonality, and regional characteristics of piteraq events

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Abstract. Piteraq events are strong downslope windstorms in southeast Greenland that often damage infrastructure and disrupt transport and subsistence activities of local communities. These wind events are more intense and common in winter than in summer, but with enhanced global warming and declining sea ice in the Arctic, their summer characteristics may become more relevant in the future. Using data from six weather stations and radiosonde data in the region around Tasiilaq in southeast Greenland since 1958 along with local media sources, we explore the evolution, regional variability, and local consequences of piteraq events, focusing on seasonal characteristics. Motivated by operational warning procedures and previous studies, we propose a robust definition of a piteraq based on local wind speed and direction that comprises most reported media reports on piteraq events. Using this definition, we find that the imprint of piteraq events cover regional scales of several 100 km by intensifying the wind speed around eastern slopes of the Greenland Ice Sheet and/or shifting the wind direction to down from the ice sheet. Prior to the piteraq events, the wind around Tasiilaq often turns clockwise from nearly parallel to the coast (from southwest) to down the ice sheet (from northwest), particularly at higher elevations that are less disturbed by topography. In Tasiilaq, the main seasonal differences during the developing and mature phases of a piteraq event are a substantially larger local reduction in relative humidity in summer compared to winter and also a relative warming during summer events as opposed to a relative cooling during winter events. These differences in temperature and relative humidity are likely associated with foehn mechanisms that become more common when more moisture is transported to higher levels in summer, combined with reduced regional sea ice in summer and hence larger moisture contrasts between maritime and continental air masses. Both are factors that are expected to become more dominant in a future climate. Our findings highlight the importance of understanding piteraq events in a spatial and temporal perspective for a better integration in early warning systems in the present and future climate.

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1 Introduction

A piteraq is a strong and often cold wind that blows downward from the Greenland Ice Sheet (GrIS) to the southeastern coast of Greenland, typically in the vicinity of the main regional town Tasiilaq (see red cross in Figure 1a; Cappelen and Jensen, 2021) on Ammassalik Island. These downslope winds sometimes exceed hurricane force, resulting in injuries, fatalities, damage to buildings and infrastructure, and reduced mobility (e.g., Jensen, 1990). Offshore, these winds influence the ocean by enhancing fjord ice export, affecting marine ecology, local freshening of the fjords, and destabilisation of calving glaciers (van As et al., 2014; Oltmanns et al., 2014; Wheel, 2019). Further downstream, piteraq events drive around 20-25% of the heat loss over the Irminger Sea during winter, thus contributing to deep ocean convection and altering the Atlantic meridional overturning circulation and carbon sequestration (Pérez et al., 2013; Oltmanns et al., 2014; Gutjahr et al., 2022). Understanding the characteristics of piteraq events in the current and future climate is therefore important to improve early warnings, mitigate damage, and recognize their role in the larger climate system.

Piteraq events are synoptically driven and often intensified by strong katabatic forcing due to radiative cooling over the GrIS (Heinemann, 1999; Heinemann and Klein, 2002). In some cases, piteraq events are associated with relative warming in Tasiilaq and foehn effects, though this is most common in summer when the wind speed is typically weaker (Rasmussen, 1989; Jensen, 1990; Cappelen and Jensen, 2021). The wind speed during piteraq events is sometimes locally enhanced by channeling mechanisms in valleys and fjords (Klein and Heinemann, 2002), mountain wave breaking (Gutjahr et al., 2022), and interaction with mesocyclones (Klein and Heinemann, 2002). Piteraq events should not be confused with other intense wind events in Greenland such as tip jets, which occur near the southern tip of Greenland, and barrier winds, which blow along the coast and are strongest over the ocean (Moore and Renfrew, 2005; Moore, 2014).

While there is currently no official definition of a piteraq event, early warnings of piteraq events are issued by the Danish Meteorological Institute (DMI) when the predicted wind direction in Tasiilaq is westerly to northerly and the predicted mean wind speed exceeds 15 m s^{-1} or the predicted gust wind speed exceeds 25 m s^{-1} (R. S. Hansen at DMI in Nuuk, 2025, personal communication). Although there is no record of piteraq events defined by the DMI criteria, many piteraq events can be tracked from media coverage including social media, which is where DMI posts early warnings. Along with local news, these media sources of piteraq warnings and occurrences can be used to assess how well piteraq events are represented in numerical forecasting models and observational datasets and how piteraq characteristics matter for the local population.

From a statistical standpoint, Oltmanns et al. (2014) defined "downslope wind events" in southeast Greenland when the wind speed exceeds 14 m s^{-1} and the wind direction is between 270° and 20° (clockwise) in Tasiilaq, while other thresholds for wind speed and/or wind direction were used at a nearby fjord station and in ERA-Interim reanalysis data. Lofverstrom et al. (2026) applied a comparable wind direction threshold (270°–360°) to identify the 100 strongest downslope wind events at a weather station in the ablation zone of the GrIS, west of Tasiilaq, providing a useful point of comparison for the present study. Although Oltmanns et al. (2014) argued that the exact threshold for wind speed and wind direction are not important for their qualitative findings, a consistent definition that corresponds well with both early warnings and piteraq characteristics is useful when investigating piteraq events.

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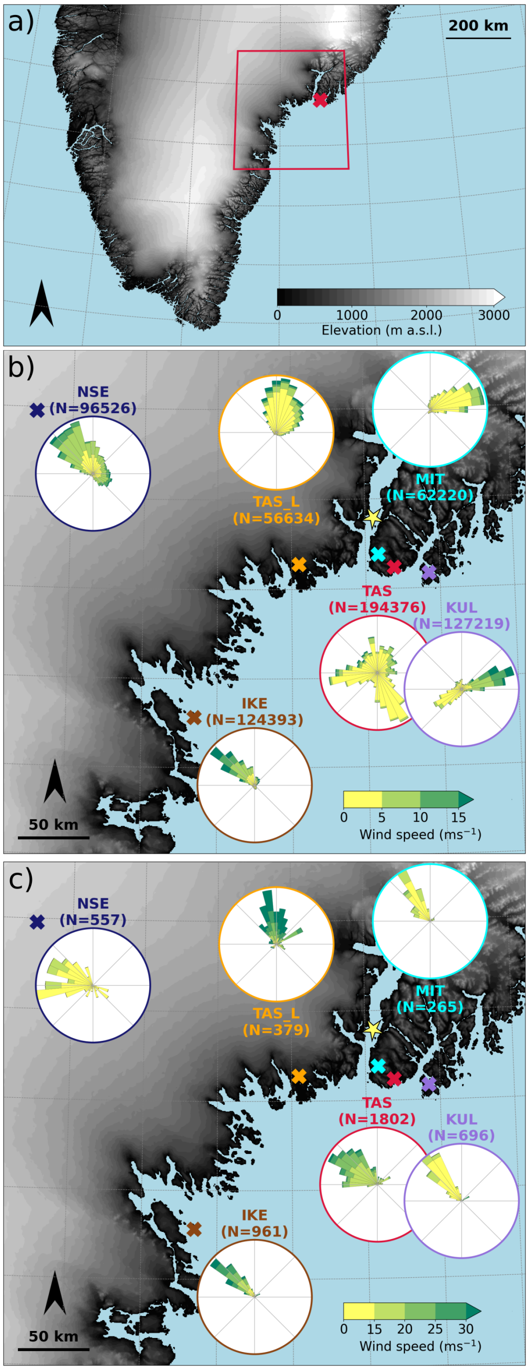

Figure 1. a) Map of south and central Greenland and b)-c) wind roses imposed for near-surface wind from selected AWSs for b) all observations and c) observations when the horizontal wind speed at TAS exceeds 15 m s^{-1}. The red rectangle in a) shows the area covered in b)-c). The yellow star in b)-c) marks the location of the Sermilik fjord. The colored crosses denote the locations for each wind rose and label with the corresponding color in b)-c). The shading (radial length) of each spoke in the wind roses in b)-c) shows wind speed (normalised frequency) for each wind direction bin. Note that each wind rose is based on different time periods and that the scale of the colorbar is different in b and c. N refers to number of observations from each weather station. Grayscale shading shows elevation every 100 m.

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Tasiilaq serves as the reference location for both the statistical study of Oltmanns et al. (2014) and operational forecasting of piteraq events. As the largest settlement in East Greenland, it is a natural focus for assessing societal impacts. This location also has one of the longest climatological time series in East Greenland (Jensen, 2025b) along with vertical soundings that are hitherto unused for piteraq analysis. Nevertheless, as piteraq events are influenced by the complex topography in the region, they vary strongly in space (Cappelen and Jensen, 2021). During the last two decades, new weather stations have been installed near Tasiilaq through the Programme for Monitoring of the Greenland Ice Sheet (PROMICE) (Fausto et al., 2021), offering a unique potential for exploring regional weather variability during piteraq events at different elevations.

Most studies of piteraq events have focused on the winter and spring season, which is when piteraq events are strongest and most common (e.g., Heinemann, 1999; Heinemann and Klein, 2002; Oltmanns et al., 2014, 2015, as well as Figure 2). However, with global warming and the associated reduction in sea ice and snow, along with an increase in water vapour content and clouds in Arctic regions (Serreze and Francis, 2006; Kapsch et al., 2013), southeast Greenland will likely experience a longer and warmer summer season in the future. As a result, the characteristics of the current and recent summer piteraq events may become increasingly relevant within the context of the future climate in the region. Using a regional climate model, Gorter et al. (2014) found that the katabatic forcing in summer weakened over the central GrIS due to weaker near-surface temperature inversions. In contrast, the forcing enhanced over the ablation zone due to an enhanced temperature inversion as a direct consequence of increasing air temperatures along with an ice surface temperature that cannot exceed the melting point. These findings for the ablation zone are in line with simulations of wind in South Greenland from another regional climate model, where summer katabatic winds are expected to be enhanced at the end of the century, in contrast to an overall weakening of the wind at most other locations and times of the year due to changes in large-scale circulation (Lambin et al., 2022). While these studies focused on the impact on katabatic flow, similar seasonal characteristics may be relevant for piteraq events where synoptic forcing dominates. Apart from these studies, seasonal analyses of piteraq characteristics remain limited.

To better understand the role of piteraq events near Tasiilaq under the present and future climate, this study aims to:

1. Use near-surface wind characteristics to establish a definition of piteraq events in Tasiilaq motivated by existing early warning procedures.
2. Attempt a damage inventory and independent consequence-based assessment based on piteraq-related media coverage.
3. Investigate horizontal and vertical weather characteristics from in situ measurements in the region around Tasiilaq during piteraq events.
4. Characterize the evolution of piteraq events and their seasonal variability.

The findings will be supported and extended by part II of the study (Silva et al., 2026), which focuses on the larger spatial dimensions of piteraq events using polar-adapted reanalysis data.

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2 Data and methods

2.1 Automatic weather stations (AWSs)

To analyse piteraq events, we use data from six automatic weather stations (AWSs; see map in Figure 1 and specifications in Table 1) operated by the Danish Meteorological Institute (DMI; Jensen, 2025b), PROMICE (Fausto et al., 2021), and GC-Net (Vandecrux et al., 2023). The longest time series is from the AWS at Tasiilaq (TAS), which is located a few kilometers east of a mountain massif that ranges more than 900 m a.s.l. and is thus sheltered from westerly winds from the GrIS. All AWSs have sporadic data gaps, particularly in the period between 2008 and 2017 at an outlet glacier near Isortoq (TAS_L) on the east side of the GrIS, but also in the 2010s at Tasiilaq (TAS), in the 1990s at Ikermit (IKE), and other shorter periods at all AWSs. All data have been quality controlled by the operators. The sensor height at the station at the ice sheet (NSE) and other remote stations operated by PROMICE and GC-Net vary by up to almost 6 m and 3 m, respectively, due to snow accumulation and melting of snow and ice, and are therefore interpreted with extra caution.

Table 1. Overview of automatic weather stations. More details can be found in the text, including references therein.

Location	Abbreviation	Type of location	Altitude (m a.s.l.)	Operated by	Time period	Temporal resolution
Tasiilaq	TAS	Town	36/50/53*	DMI	Jan 1958 - Aug 2005	3 hours
					Aug 2005 - Oct 2024	1 hour
Ikermit	IKE	Island	85	DMI	Jun 1987 - Sep 2009	3 hours
					Sep 2009 - Dec 2024	1 hour
Kulusuk	KUL	Settlement	35	DMI	Nov 2000 - Dec 2024	1 hour
Mittivakkat Gletsjer	MIT	Glacier	450	PROMICE	May 2009 - Dec 2024	1 hour
Near Isortoq	TAS_L	Glacier	270	PROMICE	Aug 2007 - Dec 2024	1 hour
NASA-SE	NSE	Ice sheet	2360	GC-Net	Apr 1998 - Dec 2024	1 hour

* This station has been moved some hundred meters twice with 19-24 years at each location. The wind climatology has remained very similar across sites (not shown).

2.2 Radiosonde data

To analyse the vertical distribution of wind speed and direction during piteraq events, we use radiosonde data from Tasiilaq provided by Durre et al. (2025). Radiosondes are launched one to four times per day between January 1958 and October 2024. The data is quality controlled by the Integrated Global Radiosonde Archive (Durre et al., 2006).

2.3 Media coverage

A comprehensive search was conducted in media archives for Tasiilaq and surroundings from January 1958 to October 2024 using the keywords "piteraq" and "orkan", where the latter word means a very strong storm in Danish and is more frequently

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used in earlier Danish-language media sources. In addition, piteraq events identified by TAS were cross-checked against media coverage by reviewing publications issued around the relevant dates. The sources for media search include the national newspaper Atuagagdliutit/Grønlandsposten until 1999 (up to weekly updates), the Greenlandic broadcasting Kalaallit Nunaata Radioa (KNR) from 2005, and the national newspaper Sermitsiaq from 2019 onward. The Facebook page "DMI - Kalaallit Nunaat" is also used, where piteraq warnings are reported by DMI since 2022. Finally, the local Facebook group "Tasiilami paasissutissiineq – Tasiilaq info" and the Facebook page "Tasiilaq - Kommuneqarfik Sermersooq", which both date back to 2018, were reviewed. Reports on piteraq events from these two sources mainly share information based on DMI warnings.

2.4 Definition of seasons

Seasonal characteristics are explored by comparing winter (DJF) and summer months (JJAS). September is added to the summer season to attain more data for analysis and is representative for summer conditions as it is the month with the least sea ice along the eastern coast of Greenland (Cappelen and Jensen, 2021).

3 Results and discussion

3.1 Wind climatology

To better understand the extreme horizontal wind speed (hereafter referred to as wind speed) climatology at TAS and establish a robust definition of a piteraq event, we explore the 99th percentile for each month and decade (Figure 2, motivated by Oltmanns et al., 2014). Extreme wind speeds are strongest from November to March and weakest from June to August, with the 99th percentile for all decades ranging from 7.7 m s^{-1} in July to 18.0 m s^{-1} in February. This seasonality of extreme wind speed is in agreement with the seasonality of piteraq frequency reported by Oltmanns et al. (2014).

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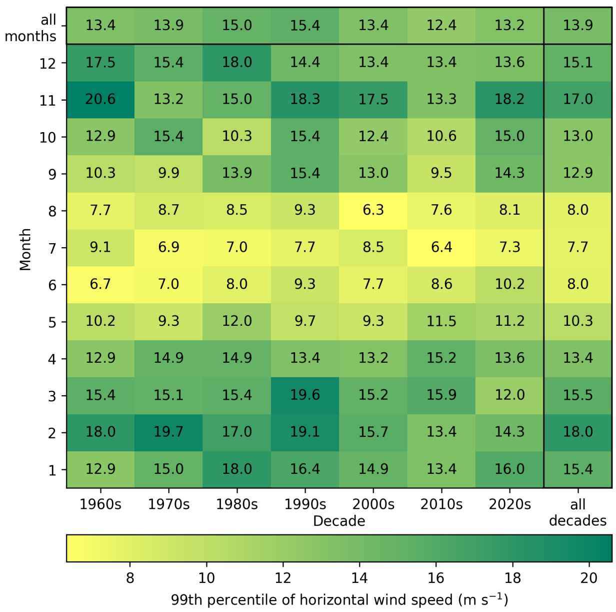

Figure 2. The 99th percentile of the 10 m wind speed from TAS for all or specific decades and months.

Evaluating trends in extreme wind speed should be done with caution due to gaps in data, particularly in the 2010s, and station relocation. While weak negative and positive trends (less than ± 1 m s^{-1} per decade) exist for specific months, longer datasets covering future conditions are needed to explore if these indicative trends are robust and representative for ongoing regional climate change.

The overall 99th percentile for all months and decades is 13.9 m s^{-1}, which is close to the wind speed threshold of 15 m s^{-1} used in piteraq early warning by DMI and the threshold of 14 m s^{-1} used by Oltmanns et al. (2014). For simplicity and consistency with early warning at DMI, we argue that a wind speed threshold of 15 m s^{-1} should be used to define piteraq events at TAS.

Comparing all wind measurements at TAS with only those where the wind speed exceeds the threshold of 15 m s^{-1}, reveals large differences in the dominating wind direction patterns (Figure 1b,c). While winds at TAS are typically below 5 m s^{-1} and most frequently from SSE (due to sea breeze effects in summer; Cappelen and Jensen, 2021), winds stronger than 15 m s^{-1} are almost always from WNW. During these strong wind conditions in TAS, the dominating wind directions at the nearby stations KUL and MIT change from their climatological ENE to NW, but the wind speed remains lower than at TAS (Figure 1c). At MIT, which is located on a local glacier, the reason for the weaker wind speed could be related to katabatic forcing in the down-glacier direction from ENE that opposes synoptic and thermal forcings at larger scales. Another likely reason for these weak winds is snow accumulation around the remote stations, which is largest in winter and spring when also strong winds are more common (Figure 2). This snow accumulation sometimes causes a reduction of the height of wind sensors from 2-3 m down to a few decimeters above the surface (not shown), causing weaker winds due to increased surface drag.

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In contrast to MIT, the wind speed at an outlet glacier of the GrIS on the other side of the Sermilik fjord, TAS_L, increases significantly during strong wind conditions in Tasiilaq compared to climatology. This increase in wind speed is related to no change in the dominating northerly wind direction from down the GrIS. Similarly, the wind on a small island further southwest, IKE, retains a NW direction, which is down the GrIS and out a channeling fjord. Nevertheless, strong wind speeds at these two locations on and near the ice sheet become much more common compared to climatology (note the change of scale of the colorbar in Figure 1), underlining that the strengthening of winds from NW in Tasiilaq and other locations in the region have large spatial scales.

Near the ridge of the GrIS at NSE, the wind direction is restricted to WNW during strong wind events in Tasiilaq (Figure 1c), which is slightly more from west than the climatology at this station (Figure 1b). This anti-clockwise turning of the wind toward westerly wind directions continues 24 hours back in time (not shown), indicating that preconditions of strong downslope wind events may be related to a slightly shifted large-scale wind pattern. The average wind speed at this station at 2360 m a.s.l. on the GrIS is only slightly stronger during strong wind conditions in Tasiilaq than on average and weaker than the downstream stations TAS_L and TAS near the coast, underpinning the role of katabatic forcing on the eastern slope of the GrIS for the downstream acceleration of the wind.

Overall, the shift of wind direction toward NW or W and/or strengthening of the wind speed at all stations highlight that strong wind events in Tasiilaq have large footprints several 100 km away from Tasiilaq.

3.2 Definition of piteraq events

The regional difference between climatological wind patterns and those during strong winds in Tasiilaq indicates that these strong wind events are almost exclusively associated with large-scale downslope winds from the GrIS. Motivated by the 99th percentile of wind speed in Tasiilaq (Figure 2) and the clear distinction of wind directions in the NW wind direction quadrant, we restrict the definition of a piteraq to $270° \leq$ wind direction $\leq 360°$ and wind speed ≥ 15 m s^{-1}. These criteria are in agreement with the DMI-issued criteria for early warning of piteraq events in Tasiilaq and align partly with those by Oltmanns et al. (2014), which included winds from NNE ($\leq 20°$). Reducing to the NW quadrant excludes a few wind events that could be considered a piteraq but also some events that are clearly not a piteraq, such as a barrier wind event on 8 March 2006. As winds from NNE are relatively rare, the choice of wind direction threshold does not change the conclusions of this study.

In addition to the wind speed and wind direction criteria, we merge events that are less than 48 hours apart (in line with Oltmanns et al., 2014). While this restriction ensures that incidents where the wind fluctuates around the threshold are not counted as multiple piteraq events, this period should remain short enough for minimising potential changes in synoptic conditions within one event. For consistency across the two periods with different observation intervals at TAS (see 1), we use 3 hourly data even in recent times when hourly data exist. Finally, for robustness of the definition of a piteraq event, we exclude events where the wind criteria are met for only one time step. Despite well-defined criteria for piteraq events, their detection remains challenging due to data gaps, particularly in the 2010s, and relatively low data coverage, particularly in the previous century.

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3.3 Evaluation of piteraq definition and early warning and impact from media

To get an indication of how well our definition of piteraq events corresponds to societally relevant conditions and consequences for people in and near Tasiilaq, we check how media coverage of piteraq events corresponds to detected piteraq events based on the definition in Section 3.2 and the observations at TAS. We find 38 individual cases of extreme wind in the region around Tasiilaq reported by different media outlets, out of which only 12 are reported before the online archive from 2005 onward. 26 of the 38 media cases are related to early warnings from DMI rather than confirmation of strong winds. The rest of the reported cases were associated with damage to building and infrastructure (4 cases), fatalities (3 cases), missing persons (4 cases), or no reported consequences (2 cases). The reported media cases include piteraq events with a wide range of wind speed intensities and cover 4 out of the 10 most extreme piteraq events. The 6 missing top 10 extreme events date back to 1966-1986, and the relatively low number of reported cases is likely partly due to sparse publication and availability of news before 2005, when the first online archive starts. Also, many of the weakest piteraq events are expected to lead to no or minimal damage due to the local adaptation and preparedness by the community to strong winds, and are accordingly expected not to be reported by the media.

Among the 38 cases reported by the media, 17 cases are not defined as a piteraq event in our dataset. 4 of these 17 cases occurred during periods where data from TAS is not available, and 8 of the remaining 13 cases were early warnings that could have been false alarms. Many of these media reports occurred during conditions very close to our definitions of piteraq events, and some cases seem not to be defined as a piteraq because the events were too short to be detected by the 1-3 hourly sampling frequency at TAS. In other media cases, such as during rescue operations of a fisherman on sea or a skiing expedition 100 km west of Tasiilaq, the lack of detection at the weather station could be related to large spatial variations, where the wind in Tasiilaq was weaker than over the sea or on the GrIS.

With these considerations in mind, we argue that our definition of a piteraq comprises most media reports of strong windstorms near Tasiilaq, suggesting that our definition is not too conservative. While we only found 30% of the piteraq events from 2005 in the online media archive, more events are potentially reported by the media and could be found using different terminology or news archives prior to the digitised editions. However, the lack of coverage of many piteraq events by the media is likely largely related to good local adaptation to strong winds along with few and rare sources of local news for the sparse population in Tasiilaq. Finally, the lack of media reports and warnings of 60% of the most intense piteraq events highlights the challenges of accurately predicting this phenomenon in a region with complex topography.

3.4 Weather evolution during piteraq events

A detailed understanding of the characteristics of piteraq events is attempted by analysing the evolution of key meteorological variables such as wind, air temperature, humidity, and pressure before, during, and after the events for all seasons (Figure 3). In line with Oltmanns et al. (2014), despite their focus on the winter season only, the wind speed gradually increases (decreases) about 24 hours before (after) the peak wind speed (Figure 3a), air temperature decreases slightly before and during the event (Figure 3b), and air pressure decreases until a few hours before the maximum wind speed and increases thereafter (Figure 3c).

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Despite the average cooling of air during the piteraq, relative humidity also decreases (Figure 3d), probably mainly due to drier air masses approaching from higher elevations.

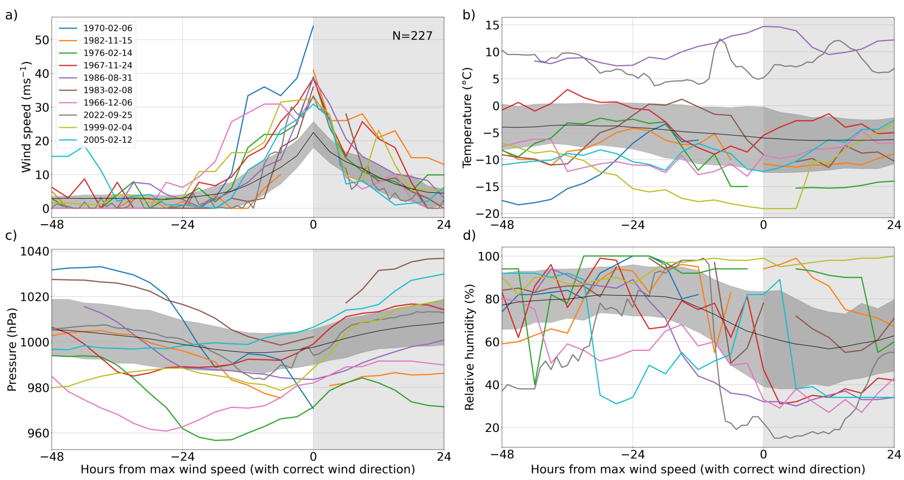

Figure 3. Evolution of a) wind speed, b) 2 m air temperature, c) air pressure, and d) relative humidity at TAS from 48 hours prior to the peak wind speed of the event to 24 hours after. Colors represent the 10 strongest events in terms of maximum wind speed. Black line (grey shading) represents the mean (interquartile range) of all piteraq events. The number N in the upper right corner in a) shows the number of events used for estimating the mean and interquartile range.

While the wind speed during the strongest piteraq events largely follows the same pattern as the events in the interquartile range (compare coloured lines with shading in Figure 3a), the evolution of air temperature, relative humidity, and to some extent air pressure vary more. For example, the extreme events in August 1986 and September 2022 are associated with a general warming instead of cooling during large parts of the event (purple and grey lines in Figure 3b). Another event in February 2005 is associated with an overall increase instead of decrease in relative (light blue lines in Figure 3d) and absolute (not shown) humidity 24 hours prior to the peak along with little net change in temperature over the same period (Figure 3b). The only top 10 events that do not have minimum air pressure prior to the peak wind speed are the events in February 1970 and August 1986 (dark blue and purple lines in Figure 3c). While the latter of these two events features increasing pressure just after the peak wind speed, there is no data after the peak wind speed for the most extreme event in February 1970 because the wind sensor broke during the piteraq. Hence, the true wind speed for this event was probably stronger (Cappelen and Jensen, 2021), and the values of the variables related to this event should thus potentially be shifted in relative time.

The individual top 10 events illustrate that some of the reasons for the variability in the piteraq evolution are likely related to gaps in data, larger measurement errors for extremes, and seasonal differences. Seasonal differences are most clearly visible for temperature and relative humidity, with a mean increase of 4 K (decrease of 3 K) in temperature during the extended summer (winter) during the 24 hours prior to the peak wind speed (Figures 4a,b). The warming tendency during summer piteraq events is likely associated with foehn-like effects that may be enhanced by greater moisture availability at higher elevations in summer due to warmer air and surface melting of the GrIS (Cappelen and Jensen, 2021). This is supported by observations at NSE at

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the upper part of the GrIS, where the relative humidity is higher than at TAS for all the summer piteraq events, but only slightly higher or even lower for the winter events (Figure 5). Finally, as the Sermilik fjord between Tasiilaq and the GrIS is typically nearly ice-free in summer, in contrast to winter, the cold air from the GrIS may mix with relatively warmer air over the fjord before arriving in Tasiilaq. This mixing over the fjord could also inject some moisture to the flow from the GrIS, though likely not enough to reach the levels of moisture associated with the common advection of maritime air masses from south and east of Tasiilaq in summer (Cappelen and Jensen, 2021).

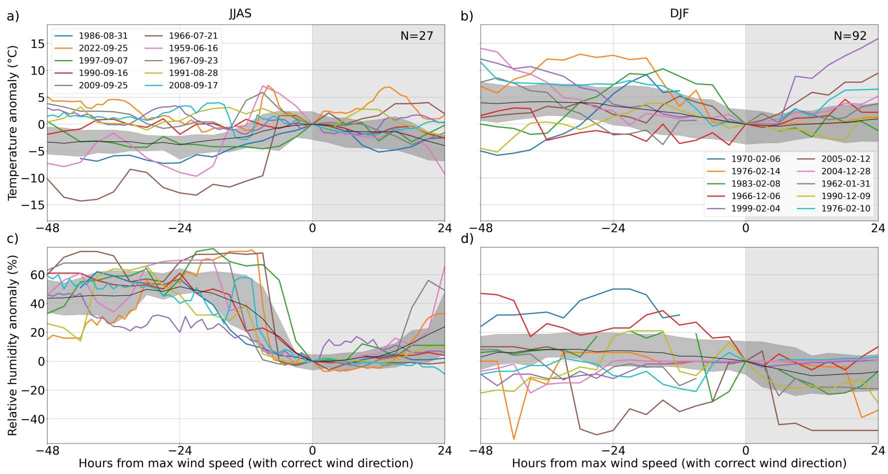

Figure 4. Evolution of a-b) temperature and c-d) relative humidity at TAS relative to the value at the maximum wind speed during a,c) extended summer (June-September) and b,d) winter (December-February). Colors represent the 10 strongest events in terms of maximum wind speed for the respective season. Black line (grey shading) represents the mean (interquartile range) of all piteraq events. The number N in the upper right corner in a) and b) shows the number of events used for estimating the mean and interquartile range for the respective seasons.

An even clearer difference between summer and winter is evident from the evolution in relative humidity 24 hours prior to the maximum wind speed, which has a mean reduction of 52% in summer but only 7% in winter (Figure 4c,d). Some of the weaker reduction in relative humidity during winter compared to summer is attributed to the decrease instead of increase in temperature (Figures 4a,b), particularly for the two events in February 1976 (orange and light blue lines in Figure 4b). However, for some individual events, like the already mentioned event in February 2005 (brown line in Figure 4d), temperature is not the only reason for the weaker overall reduction in humidity in winter, as both absolute (not shown) and relative humidity increase rather than decrease prior to the peak wind speed. In general, absolute humidity mostly follows the same tendencies as relative humidity (not shown), underlining that summer piteraq events are associated with larger transitions from moist to dry air masses than winter events. This larger transition during summer is likely related to more humid and maritime local conditions prior to the onset of the piteraq due to reduced sea ice south and east of Tasiilaq (Cappelen and Jensen, 2021), resulting in larger contrasts in humidity when air masses start being advected from the GrIS instead of from the ice-free ocean.

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The overall seasonal differences in piteraq diagnostics demonstrate that summer piteraq events are associated with more warming and drying compared to the winter events. These summer characteristics of the wind conditions are likely related to melting of ice and lower albedo over the GrIS as well as less sea ice and a larger role of foehn effects.

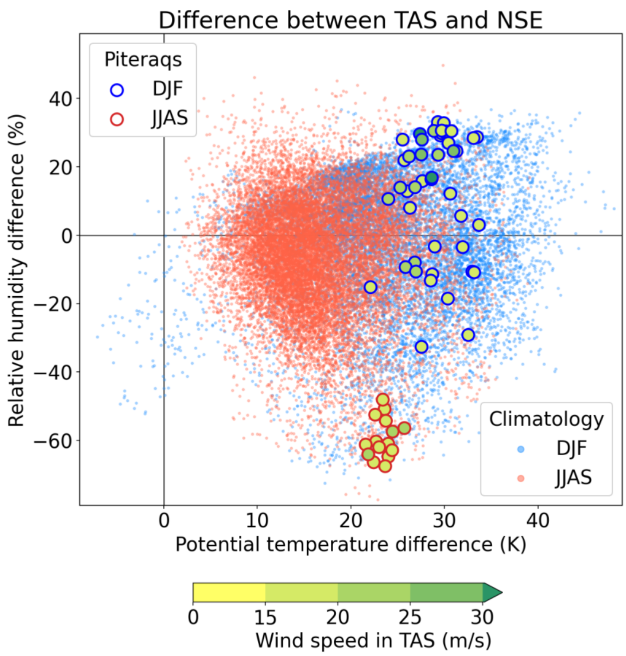

Figure 5. Difference in potential temperature and relative humidity between TAS (50-53 m a.s.l.) and NSE (2360 m a.s.l.) for climatology (small dots) and at the time of maximum wind speed for each piteraq event (large dots with edge). The fill color of each large dot represents the wind speed in TAS, and a red (blue) edge color of the large dots and fill color of the small dots represent extended summer (winter) events.

3.5 Vertical wind profiles during piteraq events

While observational studies of piteraq events have until now been limited to near-surface data, vertical data from radiosondes in Tasiilaq show that winds at higher levels are primarily from NW during piteraq events, with wind speeds mostly around 10-25 m s^{-1} (Figure 6b). This is a remarkable change from the climatology, where winds come from all directions, with a slightly higher prevalence to winds from NE at the lowest levels that was not clearly visible at the weather station (compare Figure 6a with Figure 1b). The strong signal of winds from NW is mostly below 600 hPa, which is approximately the elevation of the GrIS to the west of Tasiilaq. While 52% of the winds are still from NW above 600 hPa, 47 % of the winds are from the SW quadrant (mainly WSW, not shown).

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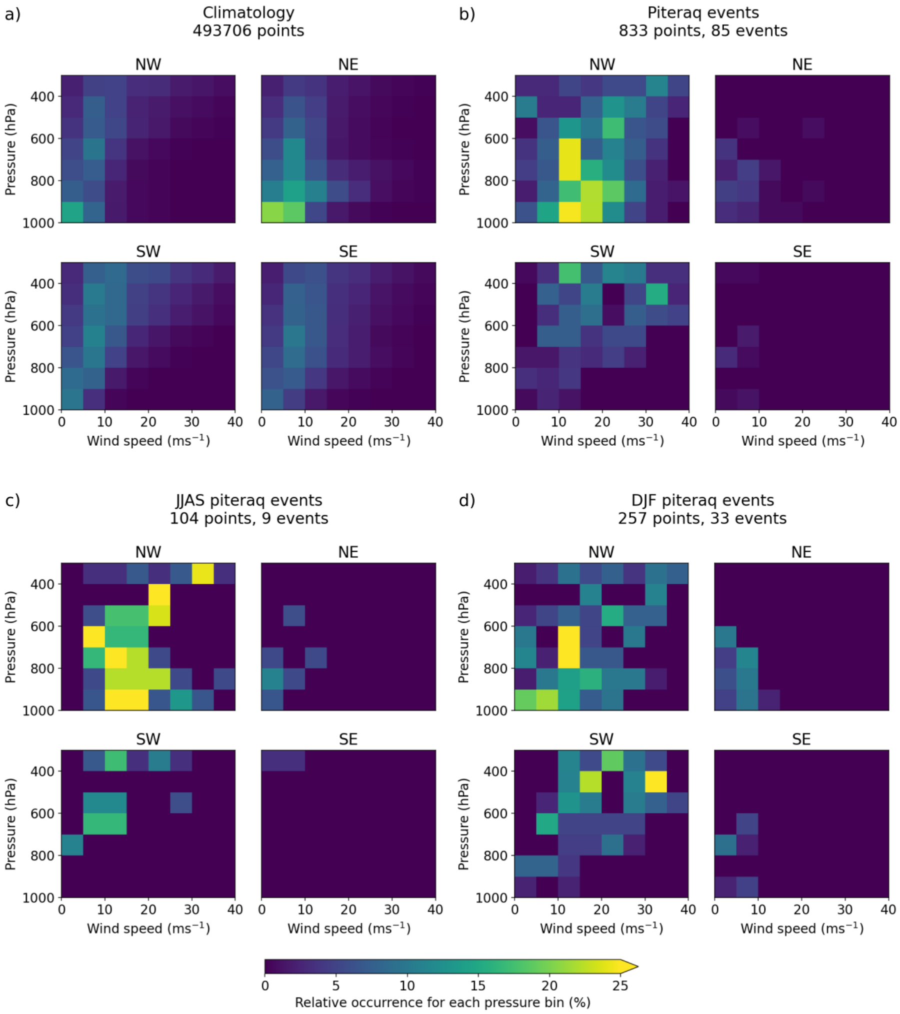

Figure 6. Relative occurrence of binned wind speed and pressure from radio soundings, sorted into four wind direction bins (NW, NE, SW, and SE) and normalized for each pressure bin with 100 hPa bin size for all wind directions in each sub-panel. Data is taken from a) all radio soundings since 1958, and b-d) the radio sounding closest to the maximum wind speed during piteraq events from b) all months, c) June to September, and d) December to February (if available during the piteraq). The title for each subfigure includes the number of data points from the radiosondes used in the given category together with the number of piteraq events with available radio soundings for the categories in b-d.

As launching a radiosonde during a piteraq event is challenging due to harsh weather and short duration, only 31% of the piteraq events have concurrent radiosonde data, including 833 measurements at various heights (indicated in Figure 6b). Using instead the last radiosonde from the period 24 hours prior to the start of each piteraq event, there is data from 80% of the events. For these radiosondes launched prior to the onset of piteraq events, the frequency distribution of wind speed and direction remains similar to those launched during the piteraq events, except for a lower wind speed and a larger fraction of

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wind directions from SW instead of NW (compare Figure 6b with Figure A1b). These differences are likely mainly related to the general evolution of large-scale wind conditions rather than false signals due to the under-representation of piteraq events, as confirmed by a further anti-clockwise wind shift in the radiosondes launched earlier (Figure A1a). The dominance of southwesterly wind directions at all levels above 900 hPa prior to the piteraq events suggests that the onset of a piteraq is triggered by, or at least associated with, a shift in large-scale wind direction from being aligned with the topography to coming down the GrIS, particularly in the lower half of the troposphere. The importance of and shift from southwesterly large-scale wind directions is confirmed by reanalysis data and further explored in the second part of this study (Silva et al., 2026).

The directional wind shift from SW to NW in the lower troposphere is found in both the winter and the extended summer seasons (compare Figure 6c,d with Figure A2), but northwesterly wind directions dominate more in the extended summer both during and prior to piteraq events. The relative availability of radiosondes is similar in both seasons, with 33% (36%) of the extended summer (winter) events being associated with a radiosonde during a piteraq event and 100% (93-98%) prior to a piteraq event. The indicated larger dominance of northwesterly winds in summer could be related to more flow over the mountain to the northwest of Tasiilaq due to a less stable atmosphere further upstream where the relatively cold air from the GrIS mixes with the air over the ice-free Sermilik fjord.

4 Conclusions

Downslope windstorms in southeast Greenland, identified as piteraq events, are systematically defined and explored by combining for the first time in situ observations from six stations near ground and vertical radio soundings in the region around Tasiilaq. These piteraq events are evaluated for societal importance using reports from media. We draw the following conclusions:

1. Our local definition of piteraq events based on meteorological measurements in Tasiilaq encompasses most reported local societal consequences of strong wind events near Tasiilaq.

2. Piteraq events in Tasiilaq are associated with a regional footprint affecting wind conditions several 100 km away from Tasiilaq. At locations on or near the GrIS, changes in wind conditions during piteraq events are dominated by increasing wind speeds. At other locations where other wind forcings dominate, the wind is mainly shifting direction during piteraq events and is in some cases calmer than normal due to opposing wind forcings.

3. The northwesterly wind directions during piteraq events cover deep vertical scales, particularly up to the maximum elevation of the GrIS but also above. Above this, winds turn anti-clockwise toward SW. Prior to the onset of a piteraq, these southwesterly winds dominate more and occur at lower levels, yielding winds more parallel to the southeast coast of Greenland.

4. The largest seasonal differences prior to the maximum wind speed of piteraq events are a much larger drop in relative and absolute humidity along with warming instead of cooling in summer compared to winter. These differences may be

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associated with more moisture in the atmosphere and less sea ice around Tasiilaq in summer. In a warmer and moister future climate, summer characteristics of piteraq events are expected to become more dominant.

Our findings are supported and extended by part II of this study (Silva et al., 2026), which focuses on the spatial evolution of piteraq events and their characteristics based on reanalysis data. Although long-term trends in piteraq characteristics in a changing climate remain challenging to assess due to inconsistencies and gaps in time series data and low model resolution in model products, the seasonal characteristics reported by this study demonstrate that the nature of piteraq events may change in a future climate. More knowledge of the potential future changes of piteraq events should be explored using high resolution models and testing the sensitivity to future climate and the related changes in landuse and sea ice cover. Alongside this, development of early warning systems remains important to reduce the damage and societal consequences that will likely continue to be associated with future piteraq events.

Code and data availability. Data from weather stations are publicly available from Jensen (2025a) and How et al. (2022), and radiosonde data is publicly available at Durre et al. (2025). Media data is available at www.timarit.is, www.knr.gl/da, www.sermitsiaq.ag, and the Facebook pages "DMI - Kalaallit Nunaat", "Tasiilami paasissutissiineq - Tasiilaq info" and "Tasiilaq - Kommuneqarfik Sermersooq". The maps were produced using the publicly available ice surface elevation data from the ETOPO 2022 global relief model at 60 arc-second resolution (NOAA National Centers for Environmental Information, 2026). The code used for the data analysis will be available on Github and published on Zenodo if the manuscript gets accepted for publication.

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Appendix A: Supporting figures

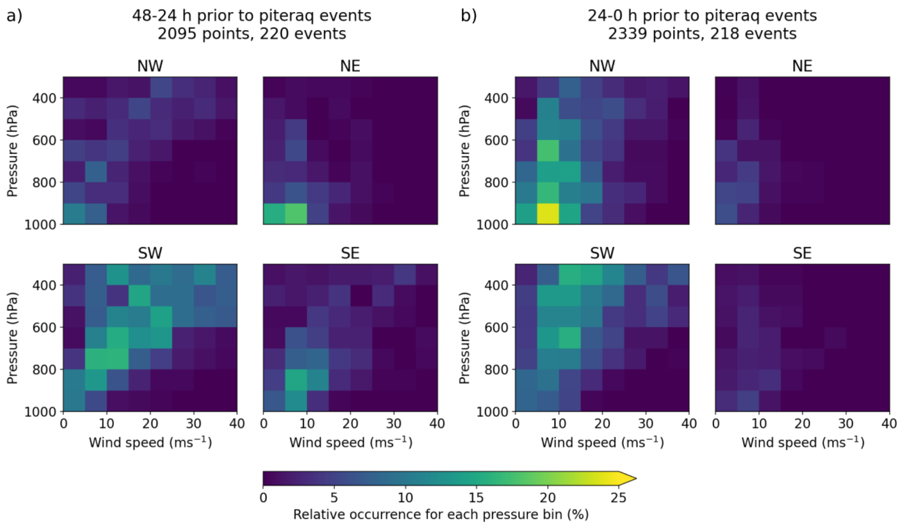

Figure A1. Relative occurrence of binned wind speed and pressure from radio soundings, sorted into four wind direction bins (NW, SE, SW, and SE) and normalized for each pressure bin with 100 hPa bin size for all wind directions in each sub-panel. Data is taken from the latest radio sounding during a) 48-24 hours and b) 24-0 hours before the onset of each piteraq (if available). The title for each subfigure includes the number of data points used in the given category together with the number of piteraq events with available radio soundings.

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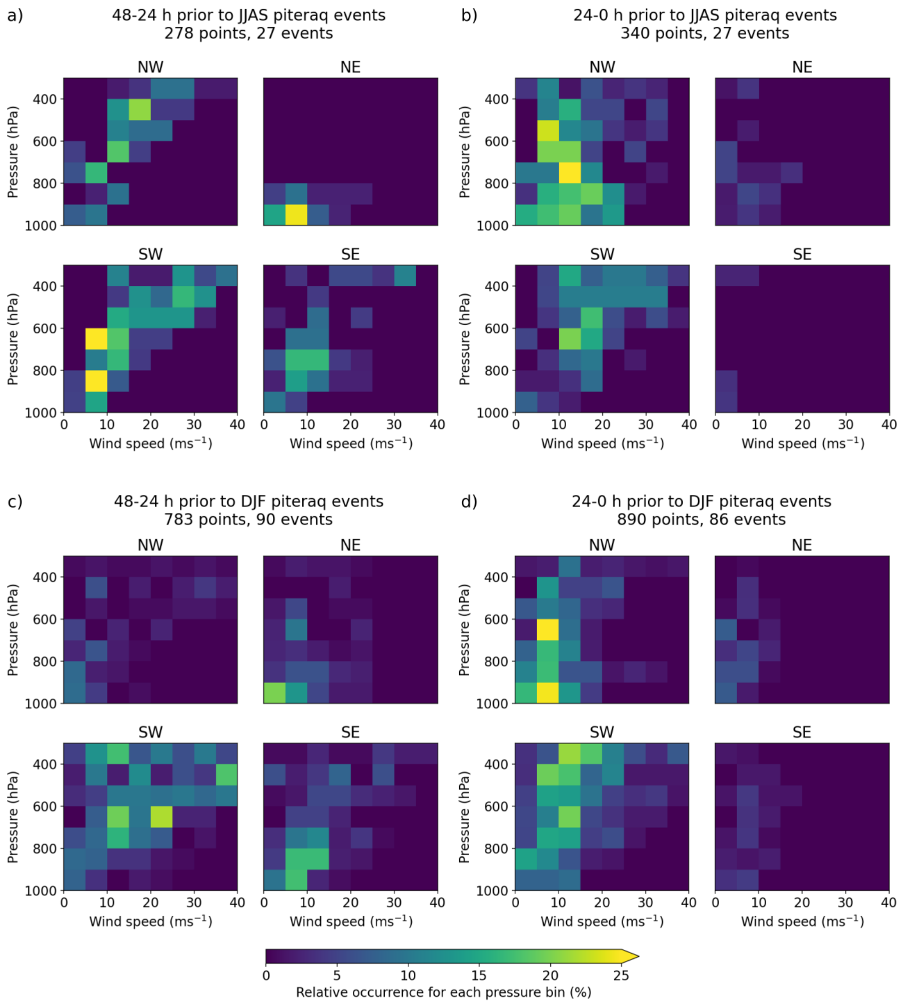

Figure A2. Same as Figure A1, but for piteraq events during a-b) June to September and c-d) December to February.

Author contributions. KFH, TS, and KR designed the study and analyzed the data with input from the other authors. KFH, TS, KR, CDJ, and JHS prepared the data. KFH, TS, and KR wrote the manuscript, and all authors contributed to improvements of the text.

305 *Competing interests.* The authors declare no competing interests.

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Preprint. Discussion started: 13 July 2026

References

Cappelen, J. and Jensen, C. D.: Climatological standard normals 1991–2020 – Greenland, DMI Report 21-12, https://www.dmi.dk/fileadmin/Rapporter/2021/DMI_report_21_12_Greenland.pdf (last access: 23 June 2026), 2021.

Durre, I., Vose, R. S., and Wuertz, D. B.: Overview of the integrated global radiosonde archive, Journal of Climate, 19, 53–68, https://doi.org/10.1175/JCLI3594.1, 2006.

Durre, I., Xungang, Y., Vose, R. S., Applequist, S., and Arnfield, J.: Integrated Global Radiosonde Archive (IGRA), Version 2.2. NOAA National Centers for Environmental Information., [Dataset] https://www.ncei.noaa.gov/pub/data/igra/data/data-por/, https://doi.org/DOI:10.7289/V5X63K0Q, observations from station 04360 Tasiilaq by the Danish Meteorological Insititute. Accessed 17 October 2025, 2025.

Fausto, R. S., van As, D., Mankoff, K. D., Vandecrux, B., Citterio, M., Ahlstrøm, A. P., Andersen, S. B., Colgan, W., Karlsson, N. B., Kjeldsen, K. K., Korsgaard, N. J., Larsen, S. H., Nielsen, S., Pedersen, A. Ø., Shields, C. L., Solgaard, A. M., and Box, J. E.: Programme for Monitoring of the Greenland Ice Sheet (PROMICE) automatic weather station data, Earth System Science Data, 13, 3819–3845, https://doi.org/10.5194/essd-13-3819-2021, 2021.

Gorter, W., Van Angelen, J., Lenaerts, J., and Van den Broeke, M.: Present and future near-surface wind climate of Greenland from high resolution regional climate modelling, Climate dynamics, 42, 1595–1611, 2014.

Gutjahr, O., Jungclaus, J. H., Brüggemann, N., Haak, H., and Marotzke, J.: Air-sea interactions and water mass transformation during a katabatic storm in the Irminger Sea, Journal of Geophysical Research: Oceans, 127, e2021JC018 075, 2022.

Heinemann, G.: The KABEG'97 field experiment: An aircraft-based study of katabatic wind dynamics over the Greenland ice sheet, Boundary-Layer Meteorology, 93, 75–116, 1999.

Heinemann, G. and Klein, T.: Modelling and observations of the katabatic flow dynamics over Greenland, Tellus A: Dynamic Meteorology and Oceanography, 54, 542–554, 2002.

How, P., Lund, M., Ahlstrøm, A., Andersen, S., Box, J., Citterio, M., Colgan, W., Fausto, R., Karlsson, N., Jakobsen, J., Jakobsgaard, H., Larsen, S., Mankoff, K., Nielsen, R., Rutishauser, A., Shield, C., Solgaard, A., Stevens, I., van As, D., Vandecrux, B., Abermann, J., Bjørk, A., Langley, K., Lea, J., Messerli, A., and Prinz, R.: PROMICE and GC-Net automated weather station data in Greenland, https://doi.org/10.22008/FK2/IW73UU, 2022.

Jensen, C. D.: Weather observations from Greenland 1958-2024 [Data set], https://www.dmi.dk/publikationer, accessed on 01-08-2025, 2025a.

Jensen, C. D.: Weather observations from Greenland 1958-2024 - Observational data with description. DMI Report 25-08, Danish Meteorological Institute, Copenhagen, 2025b.

Jensen, P. H.: Piteraq, Atuakkiorfik, Nuuk, ISBN 8755805973, 1990.

Kapsch, M.-L., Graversen, R. G., and Tjernström, M.: Springtime atmospheric energy transport and the control of Arctic summer sea-ice extent, Nature Climate Change, 3, 744–748, 2013.

Klein, T. and Heinemann, G.: Interaction of katabatic winds and mesocyclones near the eastern coast of Greenland, Meteorological Applications, 9, 407–422, 2002.

Lambin, C., Fettweis, X., Kittel, C., Fonder, M., and Ernst, D.: Assessment of future wind speed and wind power changes over South Greenland using the MAR regional climate model, International Journal of Climatology, 2022.

https://doi.org/10.5194/egusphere-2026-3684
Preprint. Discussion started: 13 July 2026

Lofverstrom, M., Herrington, A., Born, A., and Beadling, R.: Towards a realistic representation of katabatic storms in Greenland in reanalysis data and global earth system models, Journal of Geophysical Research: Atmospheres, 131, e2025JD044 674, https://doi.org/10.1029/2025JD044674, 2026.

Moore, G.: Mesoscale structure of Cape Farewell tip jets, Journal of Climate, 27, 8956–8965, 2014.

Moore, G. and Renfrew, I.: Tip jets and barrier winds: A QuikSCAT climatology of high wind speed events around Greenland, Journal of Climate, 18, 3713–3725, 2005.

NOAA National Centers for Environmental Information: [Dataset] https://www.ncei.noaa.gov/products/etopo-global-relief-model, https://doi.org/10.25921/fd45-gt74, 2022: ETOPO 2022 15 arc-second Global Relief Model. NOAA National Centers for Environmental Information. Accessed 10 January, 2026.

Oltmanns, M., Straneo, F., Moore, G., and Mernild, S.: Strong downslope wind events in Ammassalik, southeast Greenland, Journal of Climate, 27, 977–993, 2014.

Oltmanns, M., Straneo, F., Seo, H., and Moore, G.: The role of wave dynamics and small-scale topography for downslope wind events in southeast Greenland, Journal of the Atmospheric Sciences, 72, 2786–2805, 2015.

Pérez, F. F., Mercier, H., Vázquez-Rodríguez, M., Lherminier, P., Velo, A., Pardo, P. C., Rosón, G., and Ríos, A. F.: Atlantic Ocean CO_2 uptake reduced by weakening of the meridional overturning circulation, Nature Geoscience, 6, 146–152, 2013.

Rasmussen, L.: Den dag, Angmagssalik naesten blaeste i havet, Vejret, 2, 3–14, 1989.

Serreze, M. C. and Francis, J. A.: The Arctic on the fast track of change, Weather, 61, 65–69, 2006.

Silva, T., Haualand, K. F., Yde, J. C., Scheller, J. H., Abermann, J., Trügler, A., and Schöner, W.: Downslope windstorms in southeast Greenland - Part II: Multi-scale dynamics and spatial evolution of piteraq events, Weather and Climate Dynamics, 2026.

van As, D., Fausto, R. S., Steffen, K., Ahlstrøm, A. P., Andersen, S. B., Andersen, M. L., Box, J. E., Charalampidis, C., Citterio, M., Colgan, W. T., et al.: Katabatic winds and piteraq storms: observations from the Greenland ice sheet, Geological Survey of Denmark and Greenland Bulletin, pp. 83–86, 2014.

Vandecrux, B., Box, J. E., Ahlstrøm, A. P., Andersen, S. B., Bayou, N., Colgan, W. T., Cullen, N. J., Fausto, R. S., Haas-Artho, D., Heilig, A., Houtz, D. A., How, P., Iosifescu Enescu, I., Karlsson, N. B., Kurup Buchholz, R., Mankoff, K. D., McGrath, D., Molotch, N. P., Perren, B., Revheim, M. K., Rutishauser, A., Sampson, K., Schneebeli, M., Starkweather, S., Steffen, S., Weber, J., Wright, P. J., Zwally, H. J., and Steffen, K.: The historical Greenland Climate Network (GC-Net) curated and augmented level-1 dataset, Earth System Science Data, 15, 5467–5489, https://doi.org/10.5194/essd-15-5467-2023, 2023.

Wheel, I.: The Winds of Change: The effects of katabatic winds on fjord circulation, sea-ice export and glacier stability at Sermilik Fjord and Helheim Glacier, Ph.D. thesis, University of Cambridge, 2019.