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Strong winds in Poland in the 17th century and their consequences, in light of documentary evidence

Rajmund Przybylak[1,4], Janusz Filipiak[2], Piotr Oliński[3,4], Babak Ghazi[5], Andrzej Araźny[1,4]

[1] Nicolaus Copernicus University in Toruń, Faculty of Earth Sciences and Spatial Management, Poland (rp11@umk.pl)
[2] University of Gdansk, Department of Physical Oceanography and Climate Research, Gdańsk, Poland (janusz.filipiak@ug.edu.pl)
[3] Nicolaus Copernicus University in Toruń, Faculty of History, Poland (olinskip@umk.pl)
[4] Centre for Climate Change Research, Nicolaus Copernicus University, Toruń, Poland (cccr@umk.pl)
[5] University of Nevada Las Vegas, Department of Geoscience, United States of America (babak.ghazi1986@gmail.com)

Corresponding authors: Andrzej Araźny, andy@umk.pl & Rajmund Przybylak, rp11@umk.pl

Abstract. The paper presents a detailed analysis of strong winds in Poland in the 17th century, including their frequency, intensity, and impacts on the natural environment, society and economy. The analysis is solely based on available documentary evidence. Preliminary archival research allowed the construction of a comprehensive database of strong winds for Poland for the study period. The 542 weather notes were used to obtain the following information about strong winds: time, location/region, duration, and indexations of intensity, extent, and damage character. For the first time, 14 years of complete daily weather data were used to analyse the occurrence of strong winds. The methodology follows that utilised by Przybylak et al. (2025) for the analysis of strong winds prior to the 17th century. The number of strong winds in Poland in the 17th century reached 525, with the majority occurring in the second half of the century. In the annual cycle, strong winds were less frequent in summer, whereas the other seasons had similar frequencies. The wind category "fresh and strong breeze" occurred the most frequently (61.9%), followed by "gales" (26.7%). The former category dominated in spring and autumn (58.8%), whereas the latter prevailed in the cold half-year (65%). Each category of strong wind occurred more commonly in northern and north-eastern Poland than anywhere else. In 13.5% of reports of strong winds, information about damage was available – most frequently in winter and autumn and least frequently in spring. The most frequently reported damage and destruction involved buildings (residential, agricultural, churches, etc.) and forests. The availability of daily-resolution data significantly improved the reliability of results on strong wind occurrence, particularly for the mildest analysed category (fresh and strong breeze). The changes in frequency of strong wind events in Poland in the 17th century were more similar to those observed in Northern than Southern Europe.

Keywords: historical climatology, documentary evidence, Poland, strong winds, database.

1. Introduction

Available statistical analyses indicate that strong winds are among the most significant natural disasters, causing great damage worldwide and resulting in the loss of human and animal lives. An investigation

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conducted by Lorenc (2012) in Poland supports this conclusion. Strong winds are second only to floods in terms of damage caused. A similar situation is observed in Europe, where, during the period 2001–20, floods were the most frequent natural disasters (41%), followed by strong winds (27%) (see https://www.statista.com/statistics/1269886/most-common-natural-disasters-in-europe, December 12, 2025). Moreover, modelling works (e.g., Donat et al., 2011; Outten and Sokolowski, 2021) indicate that, in the future, the frequency and intensity of strong winds will increase in Central Europe, including Poland.

The present paper, which focuses on the analysis of strong wind occurrences in Poland in the 17th century and their impacts on the natural environment and society, is a continuation of our studies aimed at reconstructing the occurrence of this extreme phenomenon in the entire historical period, i.e., prior to the start of regular instrumental observations in the mid-19th century (Brönnimann et al., 2019). The first paper already published (Przybylak et al., 2025) covers the period from medieval times (late 13th century – subject to data availability) through the early Little Ice Age (LIA) to 1600. That paper also contains a detailed review of the available literature on the occurrence of strong winds in Poland and Europe, not only for the 13th–16th centuries, but also for the entire historical period (including, for Poland, the contemporary period). For this reason, some of these topics are omitted in the present paper, while others are presented briefly.

The 17th century is climatically very interesting because the majority of millennial temperature reconstructions reveal that this century was, on average, the coldest century of the entire last millennium, both globally and in Europe (see, e.g., Fig. 1 in Juckes et al., 2007 or Mann et al., 2009; Schimanke et al., 2012; PAGES 2k Consortium, 2013). Moreover, it also included the coldest phase of the LIA, known as the Maunder Minimum (1645–1715) (Pfister, 1999; Wanner et al., 2000; Luterbacher et al., 2004; Brázdil et al., 2010; Schimanke et al., 2012). Luterbacher et al. (2001a) also indicated that this period was characterised by high climate variability, enhanced atmospheric ^{14}C concentrations, numerous volcanic eruptions, and very low solar activity. For these reasons, and because we have documentary evidence with daily resolution for more than 30 years of this century (Chrapowicki's diary and Büthner's calendars), we decided to analyse the large sets of strong wind data separately.

To date, no reconstruction of the occurrence of strong winds in the 17th century and their impacts in Poland has been investigated. Such information, although it exists for Europe, is neither abundant nor extensive. Similar to the period prior to 1601, of all European countries, strong winds in the 17th century have been analysed most comprehensively for the Czech Lands (e.g., Brázdil and Dobrovolný, 2000, 2001; Dobrovolný and Brázdil, 2003; Brázdil et al., 2004, 2012; Dobrovolný and Keprtová, 2006). Another area with considerable information on the occurrence of strong winds (especially storm-force winds) and their consequences for the natural environment and society is the western coast of continental Europe and the British Isles, as well as the surrounding seas. This was most often done using logbooks (Wheeler et al., 2009, 2010) or other documentary evidence (e.g., Winn, 1810; Lindgren and Neumann, 1985; Lamb, 1967; Lamb and Frydendahl, 1991; de Kraker, 2013; Pfeifer and Pfeifer, 2013). Other

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proxy data have also been used (further, see, e.g., Lamb and Frydendahl, 1991; Clarke and Rendell, 2009, 2011; Orme, 2014), such as records of sand drift and dune-building (Wilson et al., 2004; Aagaard et al., 2007; Clarke and Rendell, 2009, 2011, for a review) or high-resolution sedimentological and rock magnetic analyses (Hanson and Hall, 2009; Sorrel et al., 2009).

Although historical climatology has advanced greatly in recent decades (see, e.g., Brázdil et al., 2005), strong winds have rarely been the subject of analysis. Most of the papers mentioned here are limited to case studies or provide only a general picture of the location and timing of the strongest winds (i.e., they focus mainly on stormy periods). Notable exceptions include databases of all categories of strong winds, as well as comprehensive climatological analyses of strong wind occurrences and their impacts, such as those presented by Brázdil et al. (2004) and, more recently, by Przybylak et al. (2025). Such an analysis for other parts of Europe, based mainly on documentary evidence (the most precise and reliable source of information on wind characteristics), is urgently needed to enhance our understanding of all aspects of the European climate, not just air temperature and precipitation. Therefore, in this research, we present a comprehensive database of strong winds in Poland for the 17th century, the result of many years of work by a team of historians and climatologists in libraries and archives located in Poland, Lithuania, Belarus, Ukraine and Germany, along with their comprehensive statistical analysis. Compared to our previous article (Przybylak et al., 2025), a new feature is the inclusion of the aforementioned daily weather records (diaries and calendars) from the second half of the 17th century in the database. This high-resolution information on the occurrence of strong winds enables a more reliable comparison of extreme wind conditions in the 17th century against those in contemporary conditions. We hope that the work presented here on strong winds in 17th-century Poland helps to partially fill the knowledge gap about this variable in Central Europe.

2. Area, data and methods

2.1. Area

The analysis of strong winds in the 17th century presented in this research is geographically limited to the area of modern-day Poland (Fig. 1). It must be noted, however, that, in the 17th century, Poland (then known as the Polish–Lithuanian Commonwealth) was one of the largest European countries, with an area of approximately 800,000 to 815,000 square kilometres (almost three times Poland's present size) and a population of 7–8 million (Wyczański, 1965; Topolski, 2015). At this time, it was a multi-ethnic state encompassing the present area of Poland (except the western part), Lithuania, Belarus, Ukraine, and parts of Russia/Baltics (see Fig. S1).

Contemporary Poland is a Central European country extending from the Baltic Sea in the north and the Sudetes and Carpathian Mountains in the south (Fig. 1). The spatial changes in the occurrence of strong winds in the 17th century were investigated for six historical-geographical regions of Poland: Baltic Coast and Pomerania, Masuria and Podlasie, Greater Poland, Masovia, Silesia, and Lesser Poland.

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Comparison with current wind conditions was performed using instrumental data from 14 meteorological stations representing all the mentioned regions (see Fig. 1).

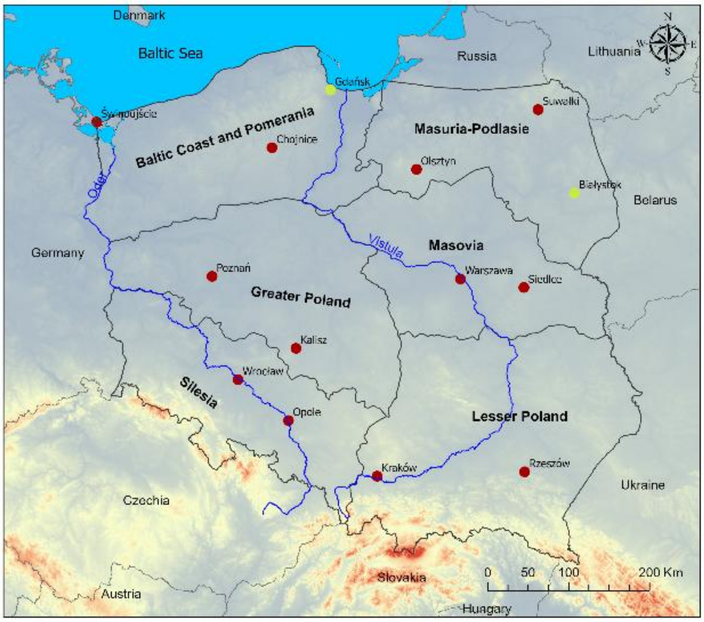

Fig. 1. Geographical location of Poland, main historical geographical regions and contemporary meteorological stations used in the previous paper (red dots, after Przybylak et al. 2025) and green dots (stations added for this paper)

Contemporary wind conditions in Poland are well documented (see, e.g., Araźny et al., 2007; Ustrnul et al., 2014; Wibig, 2021; and Przybylak et al., 2025 for reviews). The average annual wind speed, calculated based on data from 41 stations evenly distributed across Poland (1966–2018), was 3.6 ms^{-1} (Wibig, 2021). The spatial distribution of the largest annual average and extreme wind speeds varies slightly. For example, average winds are highest along the Baltic coast (4–5 ms^{-1}), while extreme winds are most powerful in south-western Poland, followed by the Baltic coast (Wibig, 2021). On average, the weakest winds in Poland are noted in the foothills of the Sudeten and Carpathian Mountains (<3 ms^{-1}).

2.2. Sources and data

Similarly to our paper analysing strong winds from the 13th to 16th centuries (Przybylak et al., 2025), three categories of documentary sources were used: handwritten and unpublished sources, published sources, and “secondary” literature (e.g., articles, monographs). However, for the 17th century, we also used data extracted from the informationally richest sources – daily weather notes – to analyse strong wind events.

The oldest daily weather data source from the 17th century available for Poland is a diary kept by Jan Antoni Chrapowicki from 1656 to 1685 (further referred to as the *Diary*). Jan Antoni Chrapowicki was a nobleman who was a Vitebsk Voivode and a member of the Polish parliament

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(further, see Bokwa et al., 2001; Nowosad et al., 2007; Przybylak and Marciniak, 2010). In the *Diary*, he described the weather on an ongoing, almost daily basis, with only rare instances of retrospective completion (at least in terms of weather records). The difficulty in compiling the weather notes in the *Diary* is related to (i) the fact that Chrapowicki kept them in four main, widely separated areas, located in present-day north-eastern Poland, Belarus, and Lithuania, and (ii) only the original diary for the period 1656–64 has been preserved. The *Diary* for later years is available only from copies manually transcribed in the 18th (1786) and 19th (1852) centuries (Chrapowicki, 1988). The 18th-century copy, although it covers all years of Chrapowicki's *Diary* (1656–85), is less reliable than the 19th-century copy, which covers only five years (1663–67). These copies, unfortunately, particularly 18th-century ones, are not faithful because they contain many simplifications and textual omissions, especially regarding weather conditions (for details, see Nowosad et al., 2007; Przybylak and Marciniak, 2010).

Although the *Diary* covers 1656–85, we selected the first eight years (1656–63) for case study analysis because the data are from the preserved original covering 1656–64 (Chrapowicki, 1978). The last year, however, was excluded from the analysis because until October, Chrapowicki was outside the present territory of Poland, i.e., on his estates located in present-day Belarus (Nowosad et al., 2007).

The second source with daily resolution comes from Gdańsk, a large and important port city on the Baltic Sea. Friedrich Büthner, a professor of mathematics at the then-most-prestigious secondary school in Gdańsk, the Academic Gymnasium (despite its name, an institution that provided university-level education), began publishing the *Calendars* in 1655 (further, the *Calendars*). Although the *Calendars* primarily took the form of astronomical tables, Büthner also included information on expected weather conditions and recorded weather observations in the margins. Complete information regarding Büthner's weather observations was contained in the manuscript "Observationes meteorologicae singulis diebus Calendarii annotatae ab a. 1655 ad a. 1699", which, unfortunately, appears to have been irretrievably lost. However, surviving copies of individual editions of the *Calendars* containing these annotations are still available. On the basis of these materials, it is possible to reconstruct in detail only the occurrence of strong winds that occurred in Gdańsk during two separate three-year periods: 1672–74 and 1691–93.

The daily resolution of information enabled us to more reliably recognise wind conditions during the study period than with rare information from less comprehensive sources. Therefore, the comparison of results for extremely strong winds in Poland with contemporary instrumental data should be more accurate than when using other available sources. For each event of strong wind occurrence in Poland, a detailed reference to the source(s) is given, see https://repod.icm.edu.pl/dataset.xhtml?persistentId=doi:10.18150/ESPWII.

The quality of each source was assessed using the method known as "source criticism" or the "historical method" in the historical sciences. This method, commonly used by historians, enables assessment of the trustworthiness and utility of a historical source, including for interpretation in conducting research into (in our case) the occurrence of strong winds.

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The quality of every source describing strong winds was estimated using three categories: 1 (weak), 2 (moderate), and 3 (high). If there were multiple sources describing the same event, more weight was given to the most credible source. To stratify sources according to these three categories, the following rules were utilised:

Category 1: Information was derived from secondary literature rather than the original source.

Category 2: Information was written centuries after the strong wind occurrence.

Category 3: Information was written in a source in the same period as the strong wind event occurred, and provides precise information.

As mentioned, we primarily used the last category of sources for the analysis, as it provided the most valuable and reliable information.

2.2.1. Database: historical period

The database listing strong-wind occurrences in Poland for the 17th century is available at https://repod.icm.edu.pl/dataset.xhtml?persistentId=doi:10.18150/ESPWII. It extends the existing database, which ends in 1600 (for details, see Przybylak et al. 2025), by another 100 years (up to 1700). The construction of the present database is identical to that of the published, first-mentioned database. This means that it also contains detailed information not only on the timing and duration of strong wind events, but also on their location/region and intensity, and the extent and character of damage. Additionally, the exact text of the original weather note, the source's name, and an evaluation of the source’s quality are provided. Available historical sources contain information of varying quality and content. Sometimes they provide all the necessary information about strong winds, and sometimes the information is very simplified and generalised, which does not allow for the completion of all the desired types of information. For example, in cases of strong winds for which no information is available about a specific place or region, we introduced an additional region category called “Poland”. The time and duration of strong wind events are also often incomplete, being limited to a single year or season. However, in most cases, we have precise information containing the year, month, and day(s) (and often the start and end dates of the event). This varied, imprecise information about the timing of strong wind events introduces peculiarities into the calculated statistics. For example, the frequency of strong wind occurrences calculated by season takes into account all cases with precise timing, as well as cases for which available information is only about the month belonging to the given season, and those for which information is only available about the season itself. In Table 1, we present selected database entries that illustrate varying degrees of detail.

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Table 1. Examples of entries in the strong wind database

Region	Place	Date of occurrence	Description: original	Description: translation	Source	A	B	C	D
A complete record, including details of the exact date and place of occurrence of the phenomenon and associated damage									
Baltic Coast and Pomerania	Koszalin, Western Pomerania	27 Nov 1603	Anno 1603 — Sturm und Wind. Am Sonntage des erten Advents ist unter der Mittags Predigt ein so grosser Sturm Wind gewesen, dass im Kickel tausend grosse Bäume umgewehet, und an andern Orten gantze Zimmer und Wind Mühlengefället. Die Mühlenbach ist dergestalt zugeschlammet gewesen, dass in etlichen Tagen kein Wasser herunter auf die Mühle kommen können..	In the year 1603 — storm and wind. On the Sunday of the First Sunday of Advent, during the midday sermon, such a great storm wind arose that in Kickel [probably a village near Koszalin; auth. suppl.], a thousand large trees were blown down, and in other places, entire buildings and windmills were felled. The mill stream was so choked with silt that for several days no water could flow down to the mill.	Wendtland J.D., Eine Sammlung unterschiedlicher die Historia der Stadt Cöslin betreffende Sachen	2	3	E2	DB DL
Inaccurate record – only fragmentary information on date of occurrence and associated damage									
Masovia	Warszawa	autumn 1602	Wiek XVII zaczął się dla Warszawy niezbyt fortunnie szeregiem klęsk, spadających na miasto jedna po drugiej. W jesieni 1602 roku wielkie szkody wyrządził orkan, zrywając dachy i obalając wieżę u Św. Jana, pod której ciężarem runęło sklepienie kolegiaty.	The 17th century began rather unfavourably for Warsaw, with a series of disasters striking the city one after another. In the autumn of 1602, a great hurricane caused severe damage, tearing off roofs and toppling the tower at St. John's, under whose weight the collegiate church's vault collapsed.	Gieysztorowa I., Od Jagiellonów do Sobieskiego 1526-1696, [in:] Cztery wieki Mazowsza. Szkice z dziejów 1526-1914, edited by S. Herbst, Warszawa 1968	1	3	E2	DB
General record – very fragmented information on the time of occurrence of the phenomenon									
Greater Poland	Jarogniewice	1648	W Jarogniewicach r. 1648 wicher odarł szopę u gumna, poobrywał łaty z poszyciem na mielcuchu, oborze i owczarni i obalił w niwecz wszystkie wrota oraz płoty około podwórza i u ogrodów; również domy u kmieci i zagrodników wiatr wszędy poodzierał i powywracał.	In Jarogniewice, in the year 1648, a wind tore off the shed at the threshing floor, ripped off the planks from the roofs of the granary, cowshed, and sheepfold, and destroyed all the gates and fences around the yard and gardens. Likewise, the wind stripped and overturned the houses of the peasants and smallholders everywhere.	Cieplucha Z. Z przeszłości Ziemi Kościańskiej, Kościan, 1929, p. 5-56	1	3	E2	DB

* Explanations: A – source quality; B – type of strong wind; C – extent of damage of strong wind; D – character of damage of strong wind
Table content (numbers, etc.) is fully described in the database and in the Methods.

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The database of strong wind occurrences in Poland for the 17th century contains 525 records and is based on 542 weather notes. As seen, the number of strong wind occurrences does not match the number of weather notes used. This is because one weather note can contain information about more than one strong wind occurrence. On the other hand, the same case of strong wind can be described in many weather notes available in different historical sources. The matter is further complicated by the fact that the number of historical sources differs significantly from both the number of strong wind events and the number of available weather records. The differences are greater when informationally richer sources (e.g., with daily resolution) are available for the study period. In the 17th century, such sources in Poland include Jan Antoni Chrapowicki's daily *Diary* and Büthner's *Calendars*.

The decadal frequencies of statistics of weather notes documenting the occurrence of strong winds are presented in Fig. 2. Notably, the greatest decadal number of weather notes (>100 cases, except for the decade 1681–90) was found for the second half of the 17th century (Fig. 2a). Such a pattern also appears when we exclude weather notes taken from the richest sources mentioned above, but the number of weather notes do not exceed 20 (see blue colour in Fig. 2a). In the first half of the 17th century, the decade with the richest weather notes describing strong winds is the first decade (20 cases). The majority of weather notes in the historical sources related to just two regions – Baltic Coast and Pomerania (265 cases) and Masuria-Podlasie (199) – while the regions for which fewest were available were Greater Poland and "Poland" (2 and 1, respectively) (Fig. 2b). However, when sources with daily weather notes are omitted, the greatest number of weather notes still relates to the Baltic Coast and Pomerania region (70) but, after that, to Silesia (21).

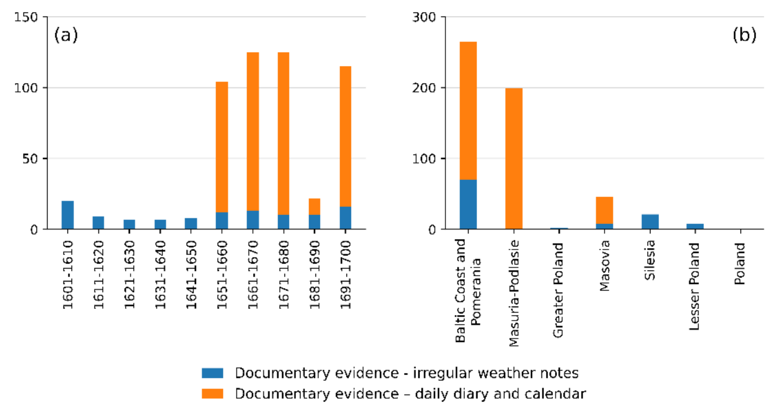

Fig. 2. Number of weather notes relating information on strong winds in the period 1601–1700: (a) for Poland, (b) separately for regions

2.2.2. Database: contemporary period

In the present paper, we compiled sub-daily wind speed data for the same set of 12 Polish meteorological stations, representing all six of the historical geographical regions in the country (Table 2, Fig. 1), as distinguished and used by Przybylak et al. (2025) to characterise winds prior to the 17th century.

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However, we propose a new contemporary period (2011–25), due to the greater availability of accurate data – specifically, the ability to count gusts from so-called "previous weather. For purposes of comparison with historical data extracted from the daily *Diary* (1656–63) and the *Calendars* (1672–74 and 1691–93), for which we have a significantly larger amount of information than for other periods in the 17th century (see Fig. 2), we selected two additional new meteorological stations: Gdańsk on the eastern Baltic Coast and Białystok in north-eastern Poland (Table 2, Fig. 1). These locations correspond with the areas (or places) of each chronicler's activity. Data from all 14 stations listed in Table 2 were downloaded from the website of the Institute of Meteorology and Water Management - National Research Institute (IMGW-PIB) (https://danepubliczne.imgw.pl/). Two data types were collected, i.e. (i) average wind speed every hour and (ii) the highest gust speed for 1-hour intervals.

Table 2. Geographical location of meteorological stations used in the work

No.	Name of meteorological station	H (m a.s.l.)	φ (N)	λ (E)
1	**Gdańsk**	**7**	**54°21′**	**18°38′**
2	*Suwałki*	184	54°08'	22°57'
3	*Świnoujście*	6	53°55'	14°14'
4	*Olsztyn*	133	53°46'	20°25'
5	*Chojnice*	164	53°43'	17°33'
6	**Białystok**	**148**	**53°06'**	**23°09'**
7	*Poznań*	83	52°25'	16°51'
8	*Siedlce*	152	52°11'	22°15'
9	*Warszawa*	106	52°10'	20°58'
10	*Kalisz*	138	51°47'	18°05'
11	*Wrocław*	120	51°06'	16°53''
12	*Opole*	165	50°38'	17°58'
13	*Rzeszów*	200	50°06'	22°03'
14	*Kraków*	237	50°05'	19°48'

Key: station names after Przybylak et al. (2025) given in *italic*; names of new stations given in **bold**

2.3. Methods

2.3.1. Historical period

In the present paper, we employed the same methodology developed and used in our previous paper (Przybylak et al., 2025). This enabled direct comparison of the results presented in both articles. Strong wind cases were assigned to five categories. The first four are consistent with the proposition given by Brázdil et al. (2004, their types T1, T3–T5 in Table 6.1) for the Czech Lands, while the last one (tornadoes) was added by us.

a) Fresh and strong breeze (force according to Beaufort Scale [BS] 5–7)
b) Gale (BS 8–9)
c) Storm (BS 10 and more)
d) Squall (i.e., gusty wind during a thunderstorm)
e) Tornado

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The classification of strong winds into the above categories was originally made by the team member entering the record of strong wind occurrences into the database. In the following step, all propositions were discussed and ultimately accepted by all team members. The same procedure was also used to estimate the degree of damage caused by strong winds. Again, the proposition given by Brázdil et al. (2004) was used, but with a minor modification. Three categories of extent of damage (E0–E2) were utilised:

E0: no information about damage

E1: small damage, damage of lesser extent

E2: large damage, areally extensive damage

Given Poland's coastal location, the E2 category was modified to account for damage at sea (e.g., the destruction or sinking of ships) and losses from storm floods. Information about damage caused by strong winds is sometimes more precise, allowing for the estimation of the type of damage. Brázdil et al. (2004, Table 3) proposed types of damage for the Czech Lands, which we modified for Poland by adding two more categories that precisely describe the influence of the Baltic Sea on coastal areas. Most often, however, the weather notes did not include information on the character of damage, and in such cases, we introduced a separate category, “N/A”. The procedure for determining the final classification of damage types was carried out as described earlier to assess the intensity of strong winds and the extent of their damage. Thus, to characterise damages and losses caused by strong winds, the following nine categories were used:

DO: casualties (lost lives)

DL: wind damage in forests

DP: minor damage to buildings

DB: considerable damage or destruction of buildings

DS: fruit trees uprooted, damage to hop gardens and vineyards

DU: damage to field crops, gardens and orchard harvests

DV: considerable damage/destruction to vessels, including sinking (newly added)

DJ: other damage (e.g., upturned carriages, vessels, injured persons, minor damage to property)

DF: considerable damage/destruction by storm flood or inland flood (newly added)

N/A: information not available

2.3.2. Contemporary period

For comparison with historical strong-wind data, we used contemporary instrumental observations of this variable from stations evenly distributed across Poland (Table 2, Fig. 1). For historical daily weather

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observations from a single location or region, we used data from nearby weather stations. The following statistics were calculated:

1. Average daily, monthly, seasonal, and annual wind speed
2. Highest gust speed for every day, month, season, and year
3. Frequency of gusts >17.0 ms^{-1} calculated for every month and year for each station
4. Frequency of gusts in the following speed intervals:
    a) 8.0–17.1 ms^{-1} (BS 5–7): quite strong, strong, and very strong wind
    b) 17.2–24.4 ms^{-1} (BS 8–9): gale
    c) >24.4 ms^{-1} (BS 10–12): very strong and violent storms, and hurricanes

Comparing historical data with present data is not straightforward. In this paper, we employed two independent methodologies, depending on the resolution and character of the historical data. For irregular weather notes about strong winds, we follow the proposition given by Przybylak et al. (2025). This means that comparison with historical data applied the three categories of modern data listed in point 4 above, particularly those described in points b) and c). Most reliably, however, we can compare only differences and similarities in the study area's annual cycle and spatial distribution, but not the numbers of cases, because many of them in historical time were undetectable. All studied aspects of strong wind occurrences during the study period can be more reliably compared to present conditions in the case of historical data extracted from the daily *Diary* (1656–63) and the *Calendars* (1672–74 and 1691–93), also including the quite strong, strong, and very strong winds (category 4a, BS 5–7), as well as absolute number of cases of all categories of strong winds.

Finally, we note that the IMGW-PIB (Polish weather service) has recently begun cataloguing extreme weather, climate, and water phenomena and has developed a dedicated database; however, the material collected to date is insufficient for a comprehensive analysis.

3. Results

3.1. Historical

The number of strong winds recorded in Poland in the 17th century was 525 (Table 3, Fig. 3; see also database https://repod.icm.edu.pl/dataset.xhtml?persistentId=doi:10.18150/ESPWII). If only irregular weather notes were taken into account, annual and decadal frequencies of strong winds were quite evenly distributed throughout the century, not usually exceeding 5 and 15 cases, respectively (Fig. 3, blue bars). For the second half of the 17th century, two very comprehensive sources are available that present results of daily weather observations by Jan Antoni Chrapowicki in north-eastern Poland (Fig. S2) and Friedrich Büthner in Gdańsk (second category of notes). In the first source, we found as many as 236 notes containing information about the occurrence of strong wind, while in the second, we found only slightly fewer (194) (Fig. 3).

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Table 3. Monthly, seasonal, and annual numbers of strong winds in Poland in the 17th century

Months	Fresh and strong breeze	Gale	Storm	Squall	Tornadoes	All categories
Jan	19	20	12	0	0	51
Feb	27	14	4	1	0	46
Mar	35	6	3	0	0	44
Apr	40	9	3	0	0	52
May	28	16	1	1	0	46
Jun	19	8	1	2	0	30
Jul	23	5	1	4	0	33
Aug	25	5	0	6	2	38
Sep	32	11	1	2	0	46
Oct	26	16	1	0	0	43
Nov	29	11	7	0	0	47
Dec	21	18	1	1	0	41
Winter	**67**	**52**	**17**	**2**	**0**	**138**
Spring	**103**	**31**	**8**	**1**	**0**	**143**
Summer	**67**	**18**	**3**	**13**	**2**	**103**
Autumn	**88**	**39**	**12**	**2**	**0**	**141**
Year	**0**	**0**	**1**	**0**	**0**	**1**
Total*	**325**	**140**	**40**	**18**	**2**	**525**

*NB: The total number of strong winds was calculated based on seasonal values, as we have information about the season for all events (except in one case, only the year is known; this case was added to the annual number of cases), while for 6 cases, there is no information about the month.

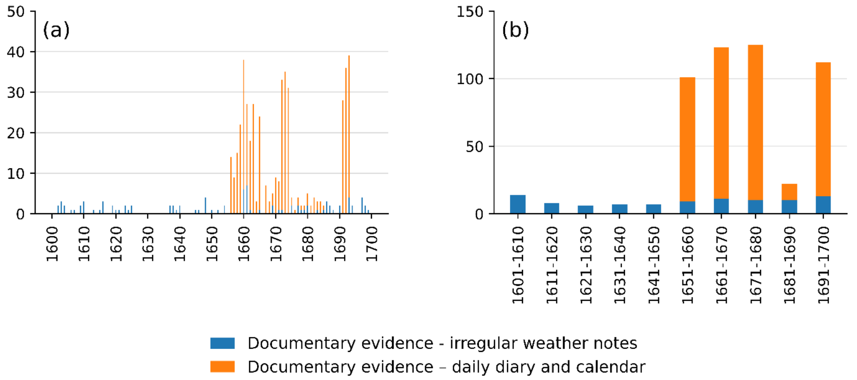

Fig. 3. Number of occurrences of strong wind categories in Poland in the 17th century: (a) annually, (b) by decade

The peak number of strong winds in the annual cycle occurred between November and May (inclusive) and ranged from 44 to 52 cases, excluding December (41). Seasonal totals for autumn, winter, and spring were very similar (~140 cases), though the spring total of 143 was the highest (Table 3). The lowest seasonal total was for summer (103), largely due to low monthly totals in June (30) and July (33). The spatial distribution of strong wind events registered in the historical sources is shown in Figs. 4 and 5. The regions with the greatest numbers of strong winds were the Baltic Coast and Pomerania, and Masuria-Podlasie (Fig. 4), i.e., in northern Poland (Fig. 5); the fewest occurred in the

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Greater Poland region. A relatively high number of strong winds was also noted in the Masovia region. For individual locations (66 sites), the greatest numbers of strong wind reports in the historical sources were found for Gdańsk (202 cases), Łabno (91), and Andrianki (49) (see Fig. 5 and Fig. S2). For the majority of sites (59), the number of registered strong winds is <10.

In the annual cycle, most regions exhibit a clear summer minimum in the occurrence of strong winds (except Lesser Poland and Silesia). Meanwhile, clear seasonal maxima are observed in Masovia (in spring) and Masuria-Podlasie (in autumn) (Fig. 4). For the Baltic Coast and Pomerania, there is no clear seasonal maximum; the frequencies from autumn to spring range narrowly around 70 cases.

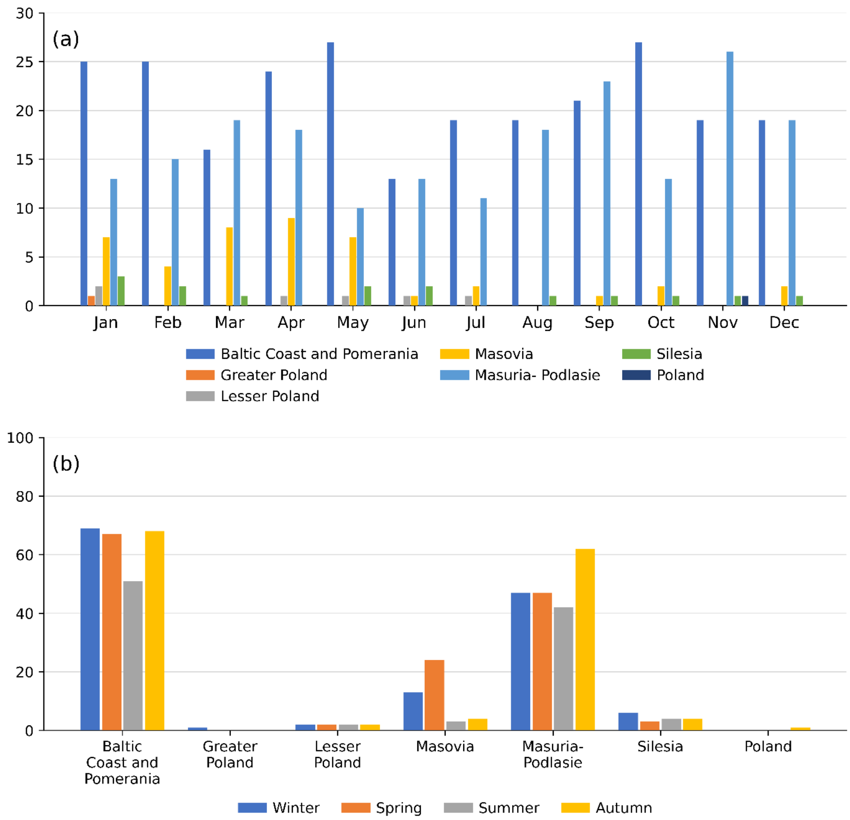

Fig. 4. Number (n) of strong winds of all categories by region, 1601–1700: (a) by month, (b) by season.
Explanation: NB: The total number of strong winds in seasons/years presented in Fig. b is greater than calculated based only on monthly statistics because, in some weather notes, there is information only about the season or even the year of the strong wind occurrence (see also text in 2.2.1 and Table 1).

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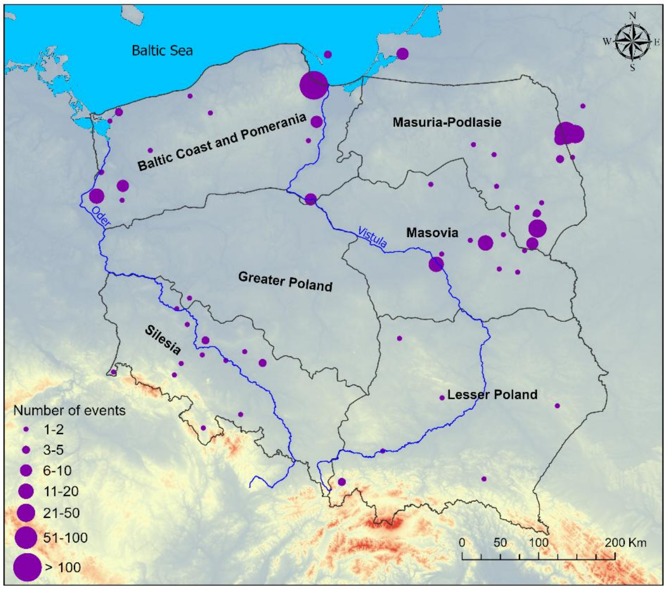

Fig. 5. Spatial distribution and number of strong wind events in Poland, 1601–1700

As shown in Fig. 6, the most abundant category is that representing the weakest strong winds (fresh and strong breeze), with 325 cases (61.9%). A relatively high frequency was also observed for gales (140 cases; 26.7%) and storms (40 cases; 7.6%). The annual cycle of event frequency is distinct for each individual category of strong winds. The fresh and strong breeze category shows two maxima (spring: 103 and autumn: 88) and two minima (summer and winter: both 67) (Table 3, Fig. 6). Gales and storms are most common in winter and autumn, which together account for about two-thirds of all cases in the year, whereas only 11.7% occurred in summer. Strong winds associated with the development of convective clouds (squalls) are observed mainly from May to September, with a maximum (71%) in the summer months (Table 3, Fig. 6). Only two tornadoes were recorded in Poland in the 17th century – both in August.

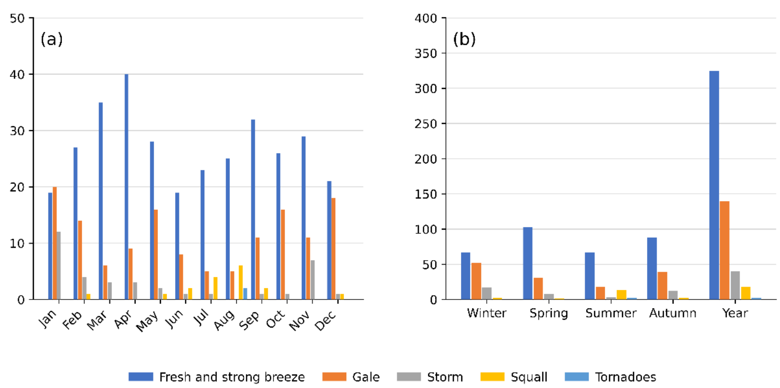

Fig. 6. Number (n) of occurrences of strong wind types in Poland, 1601–1700: (a) by month, (b) by season

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The mildest category of strong winds (fresh and strong breeze) was most frequently noted (54%) in the Masuria-Podlasie region, while the other analysed categories (tornadoes omitted due to very low frequency) were most frequent (≥50%) in the Baltic Coast and Pomerania region (Fig. 7). Relatively large frequencies were noted for fresh and strong breezes in Baltic Coast and Pomerania (35%), for gales in Masuria-Podlasie (14%), for storms in Silesia (13%) and Lesser Poland (12%), and for squalls in Silesia (33%) (Fig. 7). Only storms were registered in all studied regions, whereas the categories "fresh and strong breeze" and "squalls" were recorded in four regions.

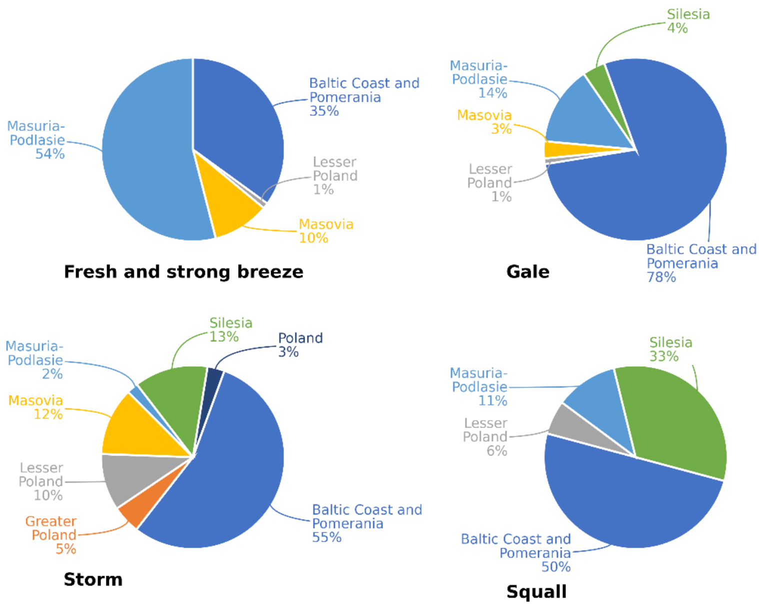

Fig. 7. Relative frequencies (%) of occurrence of strong wind types (tornadoes excluded) in the studied regions of Poland, 1601–1700 (regions with zero value are omitted)

As a result of investigations into strong wind events in Poland, it has been determined that gusts exceeding 17 ms^{-1} pose a threat to the population, economy, and natural environment (Lorenc, 2012). This means that all very strong wind categories (gales, storms, squalls and tornadoes) distinguished using documentary evidence have the potential to cause various types of damage, as listed in the Methods section. This is also the most important reason for the dominance of weather notes in historical sources, because they prioritise the description of the most extreme wind events and their impacts. The exceptions are periods for which regular weather observations and records were conducted (e.g., see *Diary*). These sources also mention strong winds that do not cause any material damage. In our classification, this is the first category of strong winds.

Among the 525 analysed cases of strong winds in Poland in the 17th century, only about 13.5% (71 cases) included information about damage caused (Fig. 8). Such reports were more common for winter and autumn events, while the fewest were observed in spring. Slightly more events were

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attributed to category E2 (large damage) than category E1 (small damage) in all seasons, but particularly in summer (see Fig. 8b). In individual months, this was not always the case (Fig. 8a). Category E0 (no information about damage) includes all categories of strong winds; all cases representing fresh and strong breezes, and about 68% of all events characterising very strong winds (gales, storms, squalls and tornadoes). This means that approximately one in three such events brings destruction.

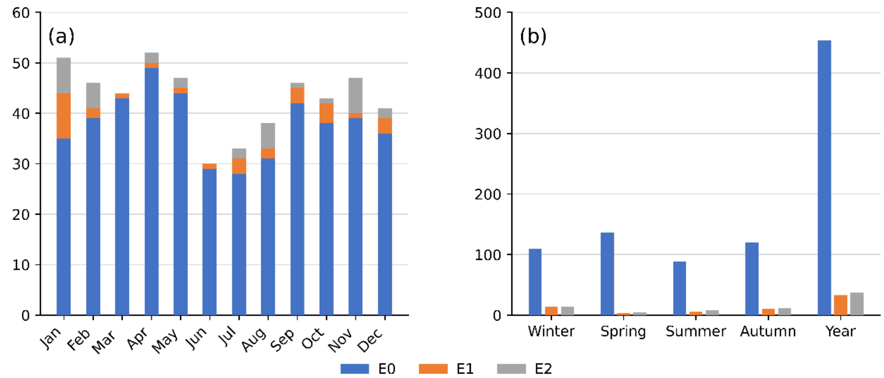

Fig. 8. Number (n) of occurrence of strong winds in Poland, according to extent of damage, 1601–1700: (a) by month, (b) by season
Key: For explanations of abbreviations, see the Methods section.

The two regions together accounting for by far the majority of strong wind events for which no damage was reported were Baltic Coast and Pomerania (46%) and Masuria-Podlasie (43%) (Fig. 9). Only for Greater Poland do all event reports contain information about damage. Meanwhile, the Baltic Coast and the Pomerania region alone accounted for the majority (53–73%) of strong wind events causing either minor (E1) or major (E2) damage (Fig. 9). By contrast, such events were rarely recorded in the Masuria-Podlasie region, despite weather observations having been conducted daily during 1656–85 there. In addition to north-western Poland, winds in Silesia also often caused damage, mainly of category E1 (21%) (Fig. 9). This spatial distribution of damages connected with winds is in line with expectations because, in Poland, westerlies bringing air masses within cyclones from the Atlantic clearly dominate, particularly in the cold half-year. For the E2 type of damage, Lesser Poland (10%) and Masovia (8%) also accounted for relatively large shares of events.

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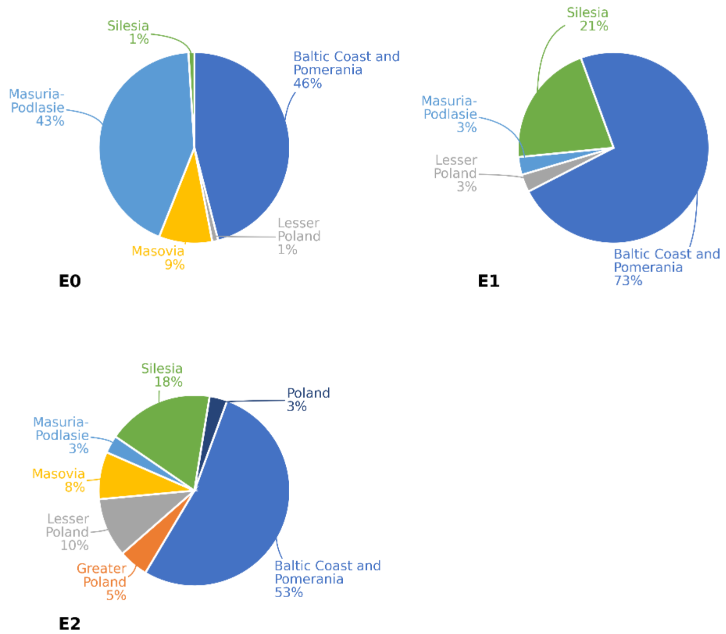

Fig. 9. Relative frequencies (%) of occurrence of strong winds in studied regions of Poland for different types of damage, 1601–1700 (regions with zero value omitted)
Key: For explanations of abbreviations, see the Methods section.

The different types of damage caused by strong winds in Poland in the 17th century are shown in Fig. 10. The most frequently reported damage and destruction associated with strong winds concern buildings (residential, agricultural, churches, etc.). More serious damage to buildings (DB) was recorded slightly less frequently than weaker damage (DP); however, in both cases, the total number exceeded 20 (Fig. 10). There were also relatively frequent descriptions of damage in forests (DL, 16 cases) and of damage to field crops, gardens, and orchard harvests (DU, 8 cases). The frequency of other types of damage ranged from 1 to 4 cases (Fig. 10b). Damage by strong wind was observed most frequently in winter (30 cases, peaking in January) followed by autumn (27 cases, peaking in November) and least in spring (10 cases) (Fig. 10).

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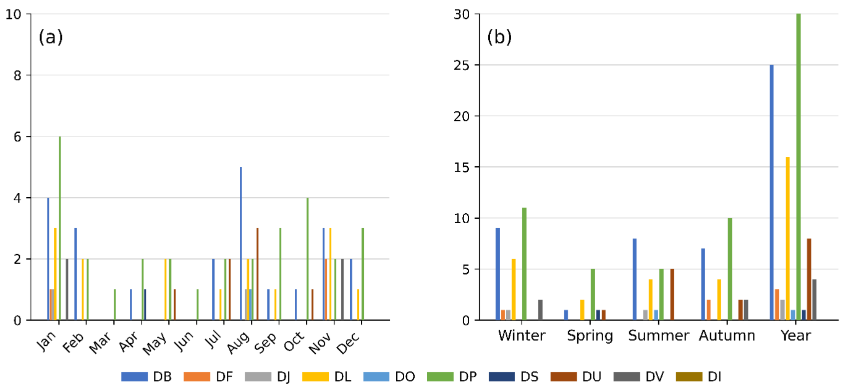

Fig. 10. Number of strong winds in Poland for which character of damage is reported (DB, DF, DJ, DL, DO, DP, DS, DU, DV and DI), 1601–1700: (a) by month, (b) by season and by year
Key: For explanations of abbreviations, see the Methods section.

For the four most frequent types of damage caused by strong winds in Poland in the 17th century, we present occurrences across the six historical geographical regions studied (Fig. 11) and their spatial distribution (Fig. 12). Severe building damage or destruction (DB) was recorded most frequently in three regions: Baltic Coast and Pomerania (50.0%), Silesia (19%) and Lesser Poland (11%), and least in Masuria-Podlasie (4%). A very similar spatial distribution is also observed for damage noted in forests (DL) (see Fig. 11). Two other types of damage (DP and DU) are limited to only three regions (Figs. 11 and 12). Of those three, the Baltic Coast and Pomerania region accounted for 75% of DU damages and 74% of DP. DP was recorded next most often noted in Silesia (23%) and DU in Lesser Poland (13%) (Figs. 10 and 12).

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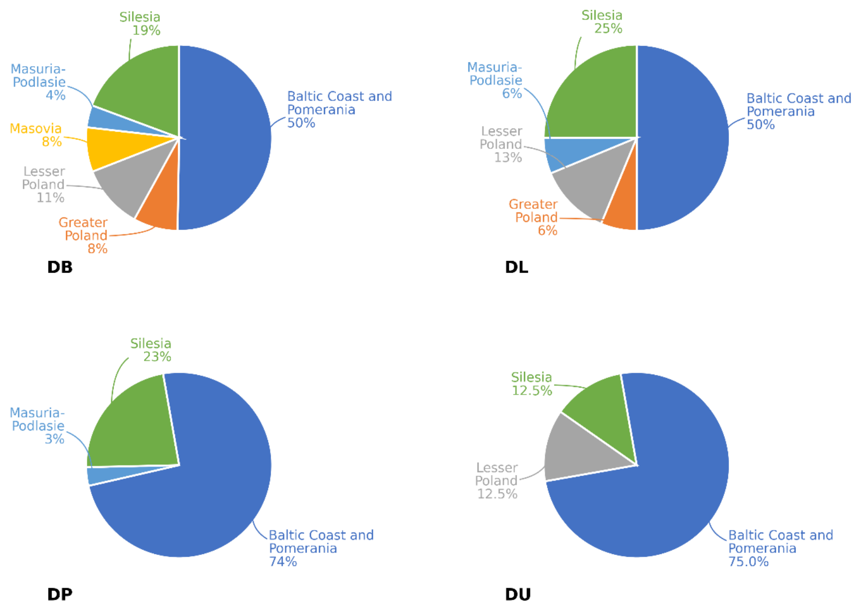

Fig. 11. Relative frequencies (%) of the four most frequent damage categories estimated for particular regions in Poland, 1601–1700 (regions with zero value omitted)
Key: For explanations of abbreviations, see the Methods section.

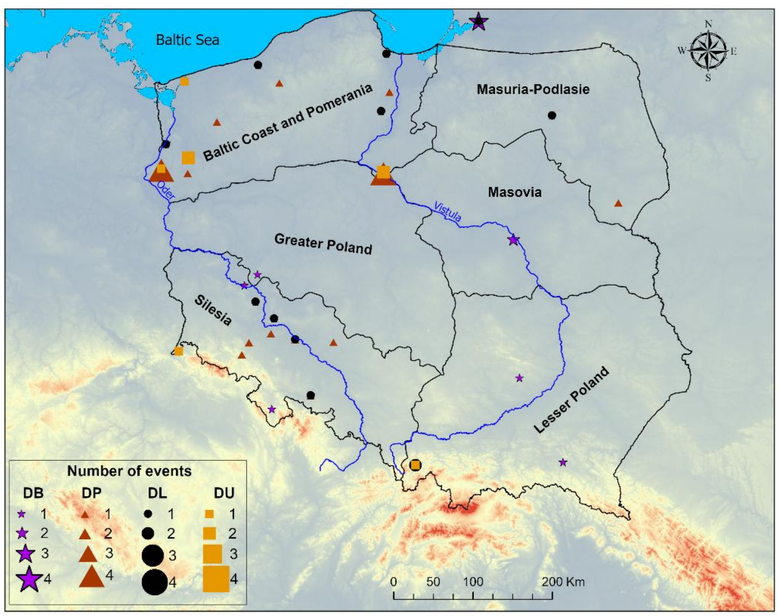

Fig. 12. Spatial distribution and number of the four most frequent categories of damages and losses (DB, DP, DL, DU) caused by strong winds in Poland, 1601–1700
Key: For explanations of abbreviations, see the Methods section.

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3.1.1. Case studies based on daily weather notes

It is obvious that weather information at daily resolution, particularly when it results from observations made by a single person, captures the occurrence of strong winds at the observation site more precisely than information from diverse sources that do not result from regular weather observations. Such data are therefore more reliable for comparison with contemporary instrumental wind measurements. As we already mentioned, for the 17th century we have two such efficient sources of weather information (Chrapowicki's *Diary* and Buthner's *Calendars*) covering the respective periods: (i) 1656–63 (north-eastern Poland) and (ii) 1672–74 and 1691–93 (Gdańsk).

In north-eastern Poland, during 1656–63, among all strong wind types, fresh and strong breezes were most common (Fig. 13). They were most frequent in spring (average 5.7 cases) and least frequent in summer (average 3.2 cases). In the annual cycle based on monthly means (Fig. 13a), the frequency of fresh and strong breezes was greatest in March (2.4 cases) and November (2.3 cases). This type of strong wind was noted most rarely in June (0.6 cases) and October (0.9 cases). The annual course of gales was a little different from that of fresh and strong breezes. Winter accounted for the clear majority of gales, followed by spring, whereas none were noted for summer (Fig. 13). On average, one gale per year occurred during this historical period in north-eastern Poland.

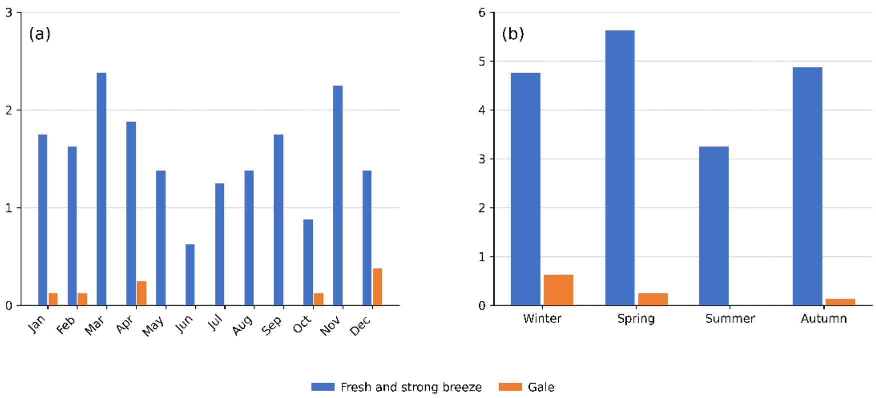

Fig. 13. Mean number of occurrences of strong wind types in north-eastern Poland, 1656–63: (a) by month, (b) by season, (based on Chrapowicki's *Diary*)

Generally, the mean occurrence of fresh and strong breezes in north-eastern Poland corresponds well with that of the Baltic coast (Gdańsk) (cf. Figs. 13 and 14). The main difference is their greater and lower frequency in Gdańsk compared to north-eastern Poland in summer and winter, respectively. On the other hand, marked differences are evident for the frequency of gales. Their frequency is, as expected, many times higher on the Baltic coast than in north-eastern Poland throughout the entire year (cf. Figs 13 and 14). Gales dominate in the cold half-year, but they are also very common in spring, particularly in May (2.3 cases). Notably, they also occurred more frequently in summer on the Baltic coast (zero observed inland) than in winter in north-eastern Poland.

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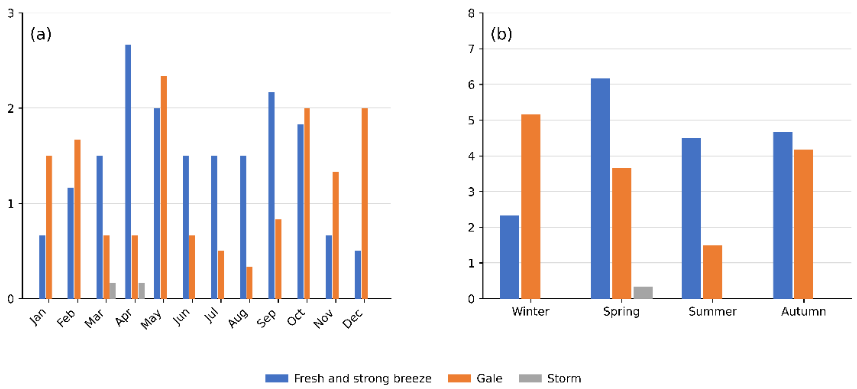

Fig. 14. Mean number of occurrences of different types of strong winds in Gdańsk (Poland), 1672–74 and 1691–93: (a) by month, and (b) by season, (based on Büthner's *Calendars*)

3.2. Contemporary period

A comprehensive analysis of strong wind frequencies over recent decades (1993–2022) based on data from 12 stations evenly distributed across Poland was presented in our previous paper (Przybylak et al., 2025). For the reasons mentioned in Section 2 of the present paper, we utilise data from the most recent period, updated to 2025 (2011–25). Results from this period, mainly the spatial distribution and annual cycle of strong-wind frequency, were used to compare with historical data for the entire century. On the other hand, for periods for which we have daily-resolution weather notes for the 17th century (1656–63, 1672–74, and 1691–93), there is a high probability of reliably assessing changes between the historical and present periods, including for absolute frequencies of strong winds. To improve the comparison between these high-resolution historical data and present wind conditions, data from two new stations (Gdańsk and Białystok) were gathered for the contemporary period. We identified the meteorological stations that we judged to be most representative of the areas/sites for which we have weather notes in historical sources with daily resolution (see Table 2, Fig. 1).

In contemporary Poland, strong winds are most common in the west (the Baltic Coast and Pomerania region and Greater Poland, and the western part of the Silesia region) and in the south-east (the eastern part of Lesser Poland) (Figs. 15 and 16 [see Gdańsk]). The annual number of strong wind events peaks at 20–30 and rarely falls below 10. On the other hand, the fewest strong winds are observed in eastern and north-eastern Poland (Masovia and Masuria-Podlasie). Here, the annual number of strong winds is usually below 10. In the Podlasie sub-region (Białystok) and eastern Masovia (Siedlce), these values are particularly low, ranging from 0–6 to 0–7, respectively (Figs. 15 and 16).

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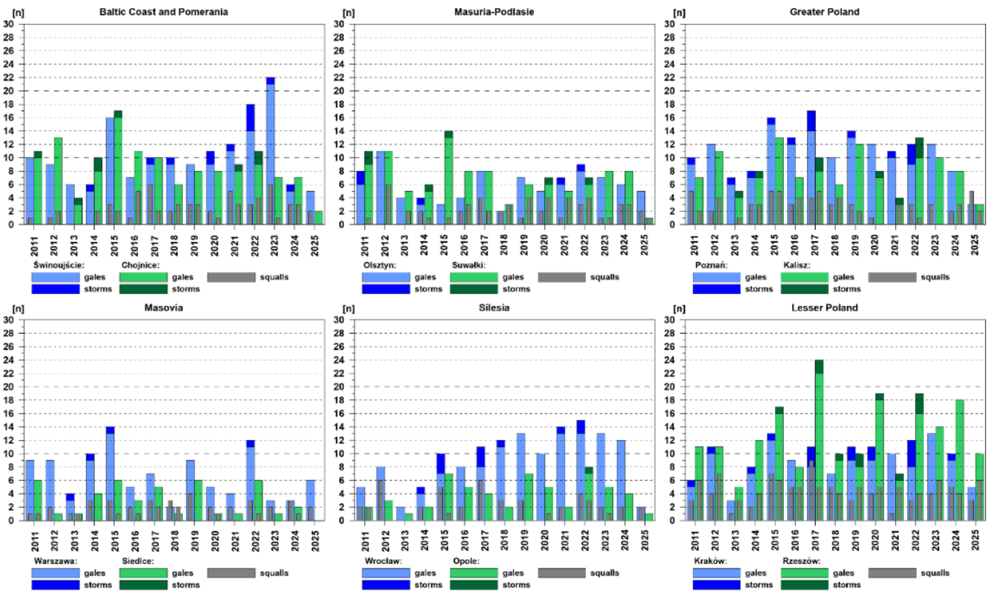

Fig. 15. Year-to-year course of annual number (n) of strong wind categories (gales, storms, and squalls) in Poland, 2011–25

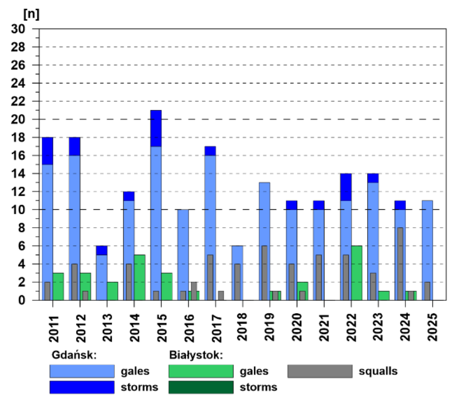

Fig. 16. Year-to-year course of annual number (n) of strong wind categories (gales, storms, and squalls) in Gdańsk and Białystok, 2011–25

The annual cycle is clearly dominated by strong winds (gales and storms) connected with macrocirculation (meteorological fronts) occurring in the cold half-year, averaging 1.5–2 cases per month in the windiest regions (Baltic Coast and Pomerania, Greater Poland, Lesser Poland) (Figs. 17 and 18 [see Gdańsk]). At this time, squalls were rare, occurring only in March and October. On the other hand, squalls, being associated with convective processes, dominate in the warm half-year, particularly in summer. Their long-term average in the summer months ranges from 0.5 to 1.0 across almost all regions (Figs. 17 and 18); the only exception is July in Lesser Poland, averaging ~1.5 squalls.

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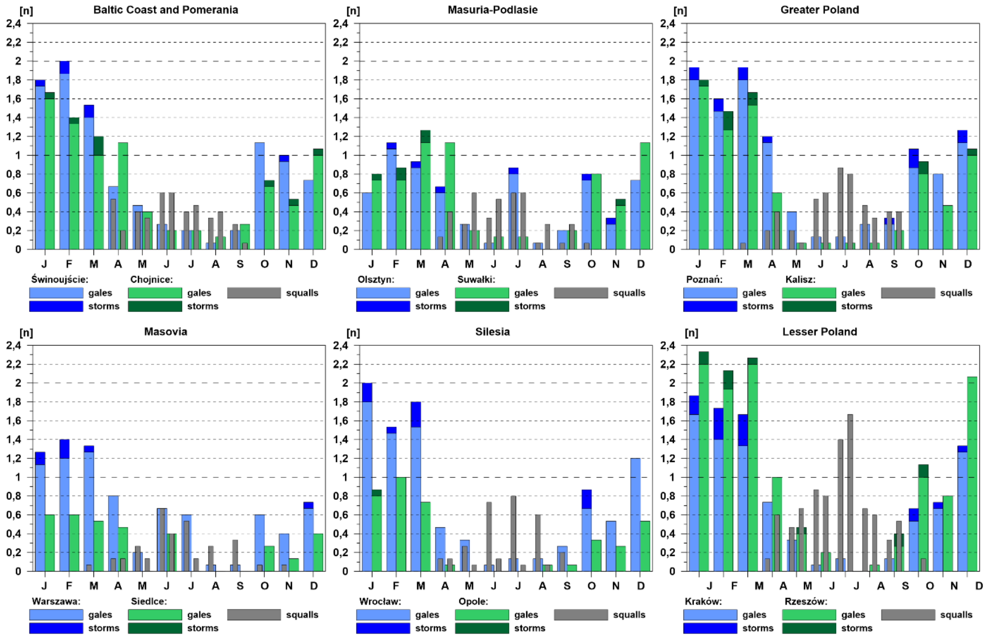

Fig. 17. Annual cycle based on average monthly number (n) of strong wind categories (gales, storms and squalls) in Poland, 2011–25

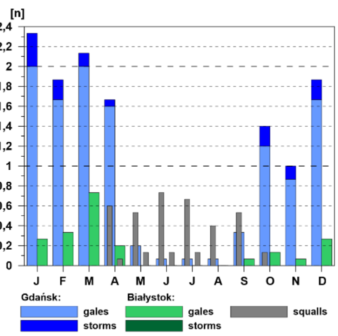

Fig. 18. Annual course based on the monthly average number (n) of strong wind categories (gales, storms, and squalls) in Gdańsk and Białystok, 2011–25

In the period 2011–25, similarly to the longer period (1993–2022) analysed by Przybylak et al. (2025), the highest gust speed exceeded 30 ms^{-1} in most regions except the less windy ones (i.e., Masovia and Masuria-Podlasie) (Fig. 19). The single strongest wind (40 ms^{-1}) was measured in the Baltic Coast and Pomerania region at the Chojnice station on 31 March, 2015. Very high peak wind speeds were also observed in Silesia and Lesser Poland, at 35 ms^{-1} and 34 ms^{-1}, respectively, and occurred in May and July. On the other hand, the lowest peak values (≤25 ms^{-1}) were recorded in the eastern parts of Masovia (Siedlce) and the Masuria-Podlasie (Suwałki) regions (Fig. 19). The lowest monthly peak wind speed in a given year was most likely to occur in the warm half of the year and slightly exceeded 16 ms^{-1}. During the study period, they were most often observed in May, July, and September (Fig. 19). The

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monthly peak gust speeds are significantly higher in Gdańsk than in Białystok, at 31 ms^{-1} and 24 ms^{-1}, respectively, and occur in summer (Fig. 20).

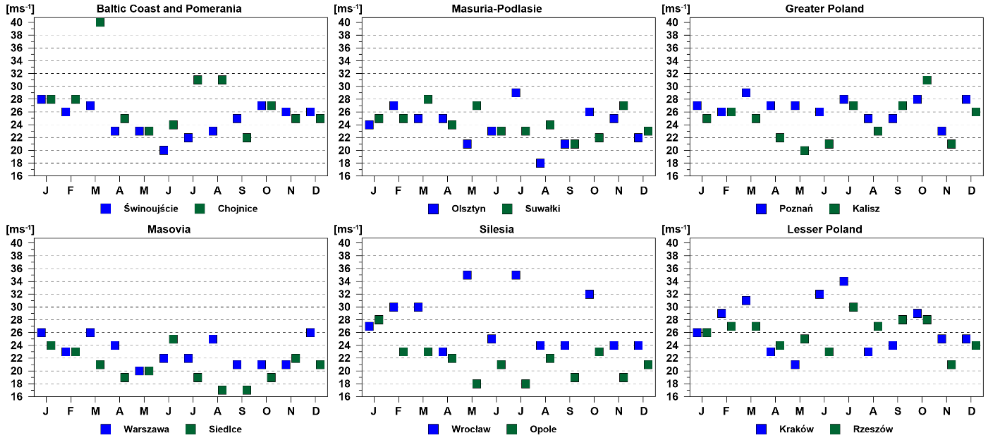

Fig. 19. Monthly peak gust speeds (ms^{-1}) at selected stations in Poland, 2011–25

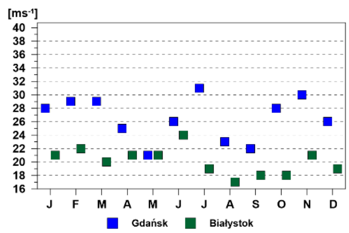

Fig. 20. Monthly peak gust speeds (ms^{-1}) at Gdańsk and Białystok, 2011–25

4. Discussion and conclusions

The present article, analysing strong wind occurrences in the 17th century in Poland and their consequences for the economy and society, is a continuation of our previous work published in 2025 (Przybylak et al., 2025) for the period of the Medieval Warm Period (Medieval Climate Anomaly) and the beginning of the Little Ice Age (i.e., until 1600). The 17th century, as was stated in the Introduction, is considered by many scientists to have been the coldest of the entire millennium and, on average, globally. Przybylak et al. (2025) stated that documentary evidence from the mid-15th century onwards allows for a reliable estimate of the occurrence of certain characteristics of strong winds in Poland (e.g., the annual cycle and spatial distribution), except for the first category, i.e. fresh and strong breezes. Data gathered for the 17th century confirm this opinion, but the availability of information at daily resolution has here allowed us, for the first time, to present a more comprehensive analysis that includes the mildest category of strong winds.

The number of irregular weather notes (i.e., without systematic daily weather observations) for the 17th century, at 111 (Fig. 2), exceeded the number of notes for the 16th century (i.e., 84) (see Fig. 2

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in Przybylak et al., 2025). However, this does not pertain to the numbers of strong winds, which were very similar across the two periods, at 95 and 88, respectively. It must also be noted that the spatial pattern of weather notes describing strong winds remained stable from the 14th to 17th centuries. Throughout those centuries, most information about strong winds was found for the Baltic Coast and Pomerania region, and later for Silesia and Lesser Poland. Also, at present, the strongest winds occur in the regions mentioned above (see Wibig, 2021). On the other hand, significant changes are observed in the seasonal distributions of strong winds between medieval times and the 17th century. In the period 1281–1600, strong winds were most frequent in autumn, whereas their frequencies differed little among the other seasons (Przybylak et al. 2025). In the 17th century, strong winds were less frequent in summer (103 cases), whereas in the other seasons their occurrence was clearly greater and quite similar (138–143 cases) (Table 3). It is worth noting that the availability of systematic, long-term weather observations at daily resolution for the 17th century increased the reliability of our picture of the frequency of occurrence of strong wind categories. During the study period, as with wind speed data from contemporary instrumental measurements, the first wind category (fresh and strong breeze) was more frequent than gales and storms, which dominated in the pre-1600s (chronicles focused mainly on very strong winds). However, the absolute number of occurrences of this mildest strong wind category is still much lower than that obtained from modern instrumental measurements, even for periods for which only weather notes with daily resolution were included. Without daily-resolution information, i.e., using only irregular weather notes from documentary evidence, the "fresh and strong breeze" category occurred with a frequency about 25 times lower than at present. On the other hand, systematic daily weather observations significantly reduced this difference; the frequency was lower in the historical period, but only about 6–8 times less than at present. For example, in Gdańsk and Białystok during 2011–25, the respective average annual frequency of fresh and strong breezes reached 104.6 and 140.1, whereas in historical times it was 17.7 and 18.5. A greater similarity of results across periods was obtained for the frequency of gales and of storms. In north-eastern Poland, gales were recorded twice as frequently in present than historical times, whereas storms were not detected in either period. On the Baltic coast (Gdańsk), differences were even smaller. Gales and storms occurred with respective average annual frequencies of 11.7 and 1.3 in the present time, as compared to 14.5 and 0.3 in historical times. These values indicate that daily-resolution weather data allow the frequency of gales and storms to be reconstructed with very high reliability. On the other hand, for the fresh and strong breeze category, corrections should be introduced to obtain more reliable results; i.e., for Poland, they should be multiplied by 6–8.

As already noted by Przybylak et al. (2025), knowledge of strong winds in Europe in the pre-instrumental period is very limited, particularly regarding works that comprehensively analyse this issue. For this reason, it is not easy to reliably compare the results presented here with those from other parts of Europe. Nevertheless, some comparisons are still possible. For example, in Poland, we identified a slightly greater frequency of all categories of strong winds in the second half of the 17th century (see

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Fig. 4, results from irregular weather notes). Similar results were obtained by Glaser (2001) for Germany, though, the difference was significantly greater than in Poland. Similar results were also obtained for the UK and Scandinavia, where severe storms occurred most frequently at the peak of the LIA, particularly during the Maunder Minimum (Orme, 2014). However, in the area of Europe south of these countries, opposite results were obtained: stronger winds were recorded in the first half of the century under study than in the second. For example, such results were presented for the Czech Lands (Brázdil and Dobrovolny, 2000, 2001; Dobrovolny and Brázdil, 2003; Brázdil et al., 2004, 2012), Switzerland (Pfister, 1999), France (Sorrel et al., 2009) and Portugal (Bao et al., 2007). A reasonable explanation is that NAO indices, according to the NAO reconstruction presented by Esper et al. (2007) and more recently by Cook et al. (2019), were positive and higher in the second half of the 17th century than in the first. During the positive phase of the NAO, as shown in many studies (e.g., Economou et al., 2014; Orme, 2014; Degenhardt et al., 2023 and references therein), Northern Europe is hit by winds and storms more often than Southern Europe because the jet stream is stronger (additionally shifted northwards) and the cyclonic intensity increases and their track moves north.

A comparison of the absolute number of strong winds in Poland in the 17th century and in European countries using documentary sources is possible only for the Czech Republic, where such data exist and, importantly, a consistent methodology for identifying strong winds was applied. In Poland, we documented 525 cases of strong winds across all categories, including 200 cases of gales, storms, squalls, and tornadoes. Brázdil et al. (2004, p. 204) list 298 such cases in their Table 8.1. There may be several reasons for these differences. First, there are still some differences in the classification, particularly for the first category of strong wind (fresh and strong breeze), which is not generally mentioned in the Czech study. The only category mentioned there is “wind without detailed specification”, which could certainly include all the strong wind categories we have listed. Secondly, the differences mainly concern the recognition of strong winds in cases that did not cause any damage to the natural or anthropogenic environment. Thirdly, the differences probably also result from the size of the compared countries (calculations of strong winds were conducted over the entire areas of the countries; Poland is about four times as large as the Czech Republic), their different physical and geographical conditions, as well as their geographical location and openness to the inflow of air masses, especially from the western sector (Atlantic). Finally, differences in the availability and resolution of documentary evidence across the compared countries also play an important role.

The analysis of strong winds in Poland in the 17th century and their consequences for the natural and anthropogenic environment, as presented in this article, largely confirms the results and conclusions of Przybylak et al.'s (2025) study of strong wind occurrence for the period 1451–1600. It also revealed the reliability of the information obtained based on irregular weather descriptions about the four categories of strong winds potentially capable of causing damage ($v>17.0$ ms^{-1}) (i.e., gales, storms, squalls, and tornadoes). A new feature in the analysis of strong winds for the 17th century is the availability of complete daily visual weather observations for fourteen years. These observations

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significantly improved the reliability of results on strong wind occurrences, particularly for the first category – fresh and strong breeze. The people who observed daily weather conditions with sufficient precision also recorded all strong winds, not just those that brought damage to human property or the natural environment as had been common among earlier chroniclers. Our research has shown that, using daily data increased fivefold the records of fresh and strong breezes compared to the available irregular weather descriptions. Although daily data have significantly improved our understanding of strong winds in Poland during the 17th century, it should be remembered that many strong winds, especially fresh and strong breezes, were still not captured. This stems from the fact that the creators of daily weather records likely did not continuously observe the changing weather, as they had many other activities at the same time (Chrapowicki, for example, was a member of Parliament and owner of many estates). Therefore, compared with modern instrumental observations that record wind speed at several-hour resolution, or even continuously, the results remain underestimated. Nevertheless, when daily data are available, the annual course, their spatial distribution in Poland, and the rough frequency relations between the distinguished categories of strong winds appear similar to those presented for modern times. Daily data also allow for a more precise comparison of results (particularly frequency of occurrence) between the historical and contemporary periods, because they often come from a single location (Gdańsk in our case) or region (Podlasie, north-eastern Poland), rather than the entire country (which is possible only when irregular weather notes are available). However, to fully characterise the occurrence of strong winds across Poland, we would need much more of this type of data at daily resolution, especially to capture the scale and character of the damage they cause. But, to our knowledge, such data do not exist for Poland in the 17th century. Therefore, an analysis using all available documentary evidence, as done in this article, remains absolutely necessary.

For a complete reconstruction of anemological (and circulation) conditions in Europe, including its central part, detailed and comprehensive studies of the occurrence of strong winds are needed that would be conducted using similar methods. Currently, such analyses for the 17th century are only available for the Czech Republic and Poland. A positive NAO index, as revealed by this study for the historical period and also documented for the contemporary period (e.g., Hurrell, 1995; Jones et al., 2003; Brázdil et al., 2004; Orme, 2014 and references therein), favours a greater frequency of strong winds (intensification of zonal circulation and cyclonic activity), especially in Northern Europe and particularly in the winter half-year. As we documented in the paper, in many areas of northern Europe (including Poland), stronger winds occurred in the second half of the 17th century, particularly during the Maunder Minimum. At that time, the NAO index was in a positive phase, as compared to the first half of that century, when NAO indices were neutral (Cook et al., 2019). However, not all NAO reconstructions available for the 17th century yield results similar to those presented above, as we are convinced by the reviews of Luterbacher et al. (2001b) and, more recently, Cook et al. (2019). Also, a review of studies investigating relationships between NAO and storminess for the historical period (Orme, 2014) reveals that these relationships are not stationary (i.e., not unambiguous in time). This

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means that further research is urgently needed both to improve the reconstruction of the NAO and to better understand the frequency of strong winds over the last millennium across Europe.

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Author contributions. Rajmund Przybylak: Conceptualisation, Methodology, Investigation, Data collection and selection, Database construction, Literature review, Formal analysis, Visualisation, Validation, Interpretation of results, Writing – original draft, Writing – review & editing, Funding acquisition, Project administration; **Janusz Filipiak:** Conceptualisation, Methodology, Investigation, Data collection and selection, Database construction, Visualisation, Validation, Interpretation of results; **Piotr Oliński:** Conceptualisation, Investigation, Data collection and selection, Database construction; **Babak Ghazi**: Software, Visualisation, Validation, Formal analysis; **Andrzej Araźny**: Conceptualisation, Methodology, Investigation, Formal analysis.

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Data availability. Datasets for this research were derived from the following public domain resources:

1. Repository for Open Data (RepOD), Nicolaus Copernicus University Centre for Climate Change Research collection, as cited in Przybylak et al. (2026), https://repod.icm.edu.pl/dataset.xhtml?persistentId=doi:10.18150/ESPWII
2. The Institute of Meteorology and Water Management (IMGW-PIB) website: https://danepubliczne.imgw.pl/

Supplement. The supplement related to this article is available online at: xxx

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References:

Aagaard, T., Oxford, J., Murray, A.S.: Environmental controls on coastal dune formation; Skallingen Spit, Denmark, Geomorphology, 83, 29–47, https://doi.org/10.1016/j.geomorph.2006.06.007, 2007.

Araźny, A., Przybylak, R., Vízi, Z., Kejna, M., Maszewski, R., Uscka-Kowalkowska, J.: Mean and extreme wind velocities in Central Europe 1951–2005 (on the basis of data from NCEP/NCAR reanalysis project), Geographia Polonica 80 (2), 69–78, 2007.

Bokwa, A., Limanówka, D., Wibig, J.: Pre-instrumental weather observations in Poland in the 16th and 17th centuries. In: Jones P.D., Ogilvie A.E.J., Davies T.D., Briffa K.R. (eds), History and Climate. Memories of the Future? Kluwer/Plenum Publishers, Dordrecht/Boston/London, 2001.

Brázdil, R., Chromá, K., Dobrovolný, P., Černoh, Z.: The tornado history of the Czech Lands, AD 1119–2010, Atmospheric Research 118, 193–204, https://doi.org/10.1016/j.atmosres.2012.06.019, 2012.

Brázdil, R., Dobrovolný, P.: Chronology of strong wind events in the Czech Lands during the 16th–19th centuries. Instytut Geograficzny UJ, Prace Geograficzne 107, 65–70, 2000.

Brázdil, R., Dobrovolný, P.: History of strong winds in the Czech Lands: causes, fluctuations, impacts, Geographia Polonica 74, 11–27, 2001.

Brázdil, R., Dobrovolný, P., Štekl, J., Kotyza, O., Valášek, H., Jež, J.: History of weather and climate in the Czech Lands VI: Strong winds, Masaryk University, Brno, 2004.

Brázdil, R., Dobrovolný, P., Luterbacher, J., Moberg, A., Pfister, C., Wheeler, D., Zorita, E.: European climate of the past 500 years: new challenges for historical climatology. Climatic Change 101: 7–40, https://doi.org/10.1007/s10584-009-9783-z, 2010.

Brázdil, R., Pfister, C., Wanner, H., von Storch, H., Luterbacher, J.: Historical climatology in Europe – the state of the art, Climatic Change, 70, 363–430, https://doi.org/10.1007/s10584-005-5924-1, 2005.

Brönnimann, S., Allan, R., Ashcroft, L., Baer, S., Barriendos, M., Brázdil, R., Brugnara, Y., Brunet, M., Brunetti, M., Chimani, B., Cornes, R., Dominguez-Castro, F., Filipiak, J., Founda, D., Herrera, R., Gergis, J., Grab, S., Hannak, L., Huhtamaa, H., Jacobsen, K., Jones, P., Jourdain, S., Kiss, A., Lin, K., Lorrey, A., Lundstad, E., Luterbacher, J., Mauelshagen, F., Maugeri, M., Maughan, N., Moberg, A., Neukom, R., Nicholson, S., Noone, S., Nordli, Ø., Ólafsdóttir, K., Pearce, P., Pfister, L., Pribyl, K., Przybylak, R., Pudmenzky, C., Rasol, D., Reichenbach, D., Rezničková, L., Rodrigo, F., Rohr, C., Skrynyk, O., Slonosky, V., Thorne, P., Valente, M., Vaquero, J., Westcottt, N., Williamson, F., Wyszyński, P.: Unlocking pre-1850 instrumental meteorological records: A global inventory, B. Am. Meteorol. Soc., 100, ES389–ES413, https://doi.org/10.1175/BAMSD- 19-0040.1, 2019.

Chrapowicki, J.A.: Diariusz cz. I: lata 1656–1664. Instytut Wydawniczy PAX, Warszawa, 1978.

Chrapowicki, J.A.: Diariusz cz. II: lata 1665–1669. Instytut Wydawniczy PAX, Warszawa, 1988.

Clarke, M.L., Rendell, H.M.: The impact of North Atlantic storminess on western European coasts: A review. Quaternary International, 195: 31–41, https://doi.org/10.1016/j.quaint.2008.02.007, 2009.

Clarke, M.L., Rendell, H.M.: Atlantic storminess and historical sand drift in Western Europe: implications for future management of coastal dunes, J. Coast Conserv. 15, 227–236, https://www.jstor.org/stable/41506515, 2011.

https://doi.org/10.5194/egusphere-2026-3524
Preprint. Discussion started: 1 July 2026

Cook, E.R., Kushnir, Y., Smerdon, J.E., Williams, A.P., Anchukaitis, K. J., Wahl, E.: A Euro-Mediterranean tree-ring reconstruction of the winter NAO index since 910 C.E., Climate Dynamics 53, 1567–1580, https://doi.org/10.1007/s00382-019-04696-2, 2019.

Degenhardt, L., Leckebusch, G.C., Scaife, A.A. Large-scale circulation patterns and their influence on European winter windstorm predictions. Clim Dyn 60, 3597–3611, https://doi.org/10.1007/s00382-022-06455-2, 2023.

De Kraker, A.: Storminess in the Low Countries, 1390–1725, Environment and History 19(2), 149–171, https://www.liverpooluniversitypress.co.uk/doi/10.3197/096734013X13642082568570, 2013.

Dobrovolný, P., Brázdil, R.: Documentary evidence on strong winds related to convective storms in the Czech Republic since AD 1500, Atmospheric Research 67–68, 95–116, 2003.

Dobrovolný, P., Keprtova, K.: Spatial analysis of damage caused by strong winds and gales in the Czech lands since AD 1500. Geografie-Sbornik CGS, 111, 1, 51–69, 2006.

Donat, M.G., Leckebusch, G.C., Wild, S., Ulbrich, U.: Future changes in European winter storm losses and extreme wind speeds inferred from GCM and RCM multimodel simulations. Nat. Hazards Earth Syst. Sci. 11, 1351–1370. http://dx.doi.org/10.5194/nhess-11-1351-2011, 2011.

Economou, T., Stephenson, D.B., Ferro, C.A.T.: Spatio-temporal modelling of extreme storms. The Annals of Applied Statistics 8(4), 2223–2246, https://doi.org/10.1214/14-AOAS766, 2014.

Esper, J., Frank, D., Büntgen, U., Verstege, A., Luterbacher, J.R., Xoplaki, E.: Long-term drought severity variations in Morocco. Geophysical Research Letters, 34: L17702, 2007.

Hansom, J.D., Hall, A.M.: Magnitude and frequency of extra-tropical North Atlantic cyclones: A chronology from cliff-top storm deposits, Quaternary International, 195: 42–52, https://doi.org/10.1016/j.quaint.2007.11.010, 2009.

Hurrell, J.W.: Decadal trends in the North Atlantic Oscillation regional temperatures and precipitation. Science, 269, 676–679, 1995.

Jones, P.D., Osborn, T.J., Briffa, K.R.: Pressure-based measures of the NAO: A comparison and an assessment of changes in the strength of the NAO and in its influence on surface climate parameters. In: Hurrell, J.W., Visbeck, M., Kushnir, Y., Ottersen, G. (eds.): *The North Atlantic Oscillation: Climatic Significance and Environmental Impact*. American Geophysical Union, Washington, 51–62, 2003.

Juckes, M.N., Allen, M.R., Briffa, K.R., Esper, J., Hegerl, G.C., Moberg, A., Osborn, T.J., Weber, S.L.: Millennial temperature reconstruction intercomparison and evaluation, Clim. Past, 3, 591–609, https://doi.org/10.5194/cp-3-591-2007, 2007.

Lamb, H.: The Changing Climate, London: Methuen & Co., 1967.

Lamb, H.H., Frydendahl, K.: Historic Storms of the North Sea, British Isles and Northwest Europe, Great Britain, Cambridge University Press, Cambridge, 203 pp., 1991.

Lorenc, H.: Maksymalne prędkości wiatru w Polsce, Monografie, Instytut Meteorologii i Gospodarki Wodnej – Państwowy Instytut Badawczy, Warszawa, 2012.

https://doi.org/10.5194/egusphere-2026-3524
Preprint. Discussion started: 1 July 2026

Lindgren, S., Neumann, J.: Great Historical Events That Were Significantly Affected by the Weather: 7, "Protestant Wind"—"Popish Wind": The Revolution of 1688 in England, Bulletin of American Meteorological Society, 66(6), 634–644, 1965.

Luterbacher, J., Dietrich, D., Xoplaki, E., Grosjean, M., Wanner, H.: European seasonal and annual temperature variability, trends and extremes since 1500, Science, 303, 1499–1503, https://doi.org/10.1126/science.1093877, 2004.

Luterbacher, J., Rickli, R., Xoplaki, E., Tinguely, C., Beck, C., Pfister, C., Wanner, H.: The Late Maunder Minimum (1675–1715) – A Key Period for Studying Decadal Scale Climatic Change in Europe. Climatic Change, 49: 441–462, 2001a.

Luterbacher, J., Xoplaki, E., Dietrich, D., Jones, P.D., Davies, T.D., Portis, D., Gonzalez-Rouco, J.F., von Storch, H., Gyalistras, D., Casty, C., Wanner, H.: Extending North Atlantic Oscillation Reconstructions Back to 1500. Atmos. Sci. Lett., 2, 114–124 (https://doi.org/10.1006/asle.2002.0047), 2001b.

Mann, M.E., Zhang, Z., Rutherford, S., Bradley, R.S., Hughes, M.K., Shindell, D., Ammann, C., Faluvegi, G., Ni, F.: Global Signatures and Dynamical Origins of the Little Ice Age and Medieval Climate Anomaly. Science, 326: 1256–1260, 2009.

Nowosad, W., Przybylak, R., Marciniak, K., Syta, K.: Diariusz Jana Antoniego Chrapowickiego jako źródło do badań klimatu Rzeczypospolitej w II połowie XVII. Klio 9:21–60, 2007.

Orme, L.C.: Reconstructions of Late Holocene storminess in Europe and the role of the North Atlantic Oscillation, PhD work, University of Exeter, 306 pp., 2014.

Outten, S., Sobolowski, S.: Extreme wind projections over Europe from the Euro-CORDEX regional climate models, Weather and Climate Extremes, 33, 100363, https://doi.org/10.1016/j.wace.2021.100363 , 2021.

PAGES 2 k Consortium: Continental-scale temperature variability during the past two millennia. Nature Geoscience, 6, 339 346, 2013.

Pfeifer, K., Pfeifer, N.: Severe storm reports of the 17th century: Examples from the UK and France, 6th European Conference on Severe Storms (ECSS2013), 3–7 June 2013, Helsinki, Finland, DOI: 10.13140/2.1.1057.7287, 2013.

Pfister, C.: Wetternachhersage. 500 Jahre Klimavariationen und Naturkatastrophen (1496–1995). Paul Haupt, Bern, 1999.

Przybylak, R., Araźny, A., Filipiak, J., Oliński, P., Wyszyński, P., Szwaba, A.: Strong wind occurrence in Poland from the 13th to 16th centuries based on documentary evidence, Clim. Past, 21, 1501–1519, https://doi.org/10.5194/cp-21-1501-2025, 2025.

Przybylak, R., Filipiak, J., Oliński, P., Ghazi, B.: Database of strong wind occurrences in Poland in the 17th century based on documentary evidence, Repository for Open Data (RepOD), Nicolaus Copernicus University Centre for Climate Change Research collection, V 1 [data set], https://repod.icm.edu.pl/dataset.xhtml?persistentId=doi:10.18150/ESPWII, 2026.

Przybylak, R., Marciniak, K.: Climate changes in the Central and North-Eastern parts of the Polish–Lithuanian Commonwealth from 1656 to 1685. In: R. Przybylak, J. Majorowicz, R. Brázdil, & M. Kejna (eds.), The Polish climate in the European context: An historical overview (pp. 423–443). New York: Springer, 2010.

https://doi.org/10.5194/egusphere-2026-3524
Preprint. Discussion started: 1 July 2026

Schimanke, S., Meier, H.E.M., Kjellström, E., Strandberg, G., Hordoir, R.: The climate in the Baltic Sea region during the last millennium simulated with a regional climate model, Clim. Past, 8, 1419–1433, https://doi.org/10.5194/cp-8-1419-2012, 2012.

Sorrel, P., Tessier, B., Demory, F., Delsinne, N., Mouazé, D.: Evidence for millennial-scale climatic events in the sedimentary infilling of a macrotidal estuarine system, the Seine estuary (NW France), Quaternary Science Reviews, 28: 499–516, https://doi.org/10.1016/j.quascirev.2008.11.009, 2009.

Topolski, J.: Historia Polski, Wydawnictwo Poznańskie, Poznań, 384 pp., ISBN 978-83-7976-269-9, 2015.

Ustrnul, Z., Wypych, A., Henek, E., Czekierda, D., Walawender, J., Kubacka, D., Pyrc, R., Czernecki, B.: Atlas zagrożeń meteorologicznych Polski (Meteorological hazard atlas of Poland), Instytut Meteorologii i Gospodarki Wodnej – Państwowy Instytut Badawczy, Kraków, 2014.

Wanner, H., Holzhauser, H.P., Pfister, C., Zumbühl, H.: 2000, Interannual to Century Scale Climate Variability in the European Alps, Erdkunde 54, 62–69.

Wibig, J.: Change of Wind. In: Falarz, M. (ed.), Climate Change in Poland: Past, Present, Future, Springer Nature Switzerland, 391–420, 2021.

Wilson, P., McGourty, J., Bateman, M.D.: Mid-to late-Holocene coastal dune event stratigraphy for the north coast of Northern Ireland, The Holocene, 14: 406–416, 2004.

Winn, J.M.: Notes on the meteorology and epidemics of the seventeenth century, Evelyn's Memoirs, edited by W. Bray, Esq., Fellow of the Society of Antiquaries. London: published from the original MSS. in 1819, 1819.

Wyczański, A.: Polska – Rzeczą Pospolitą Szlachecką 1454–1764, Państwowe Wydawnictwo Naukowe, Warszawa, 452 pp., ISBN 83-01-10044-3, 1965.