Agglomerative approach to the analysis of wind regime over Lake Baikal during the existence of the autumnal thermal bar

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Abstract. An approach based on agglomerative hierarchical clustering of wind direction data is proposed to analyze the wind regime over the middle Baikal region. Wind direction data were obtained from an objective National Centers for Environmental Prediction (NCEP) analysis. The constructed maps agree well with the measurement data collected at the meteorological stations in the Irkutsk and Zabaykalsky departments of Hydrometeorological and Environmental Monitoring.

1 Introduction

Lake Baikal, the world's largest freshwater body, has a significant impact on the physical processes that take place in its surrounding areas, particularly meteorological phenomena such as the formation of local winds and precipitation etc. The wind in turn has a significant effect on the hydrodynamic development of the thermal bar, especially during periods of autumnal cooling of the lake [1-3].

As noted in [4], the stability of Lake Baikal, as an integrated system, depends on various factors, including wind conditions. The asymmetric shape of the basin, its orientation, the presence of numerous decaying areas and valleys, as well as a diverse range of landforms and differences in the thermophysical characteristics of the lake and surrounding land, all contribute to the hydrometeorological conditions and, in turn, influence the characteristics of wind regimes over the lake. This is manifested through seasonal periodicity. Due to the rugged coastline, local winds can arise, such as breezes and valley winds, which are particularly prevalent during the cold season, and can have serious consequences. Moreover, the winds are typically stronger in the central area of the lake compared to the upper and lower sections. We will use the rhumb notation for the wind direction (N - north, S -south, E - east, W - west).Winds from the W direction dominate in the Uzury. Winds blow on the Olkhon Island with equal frequency from both the SSE and W directions in the Huzir. Winds blowing from the W and northwest prevalent in the Solnetchnaya [4-5]. Figure 1 demonstrate prevailing wind direction in research domain.

The paper provides an analysis of the features of the wind regime over the part of the Baikal basin corresponding to the middle Baikal in November 2015-2023. According to observations at meteorological stations belonging to the Irkutsk Department of

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Hydrometeorology and Environmental Monitoring (DHEM) and the Zabaykalsky DHEM, as well as data from the operational global data assimilation system of the National Center for Prediction of Environmental Phenomena (NCEP).

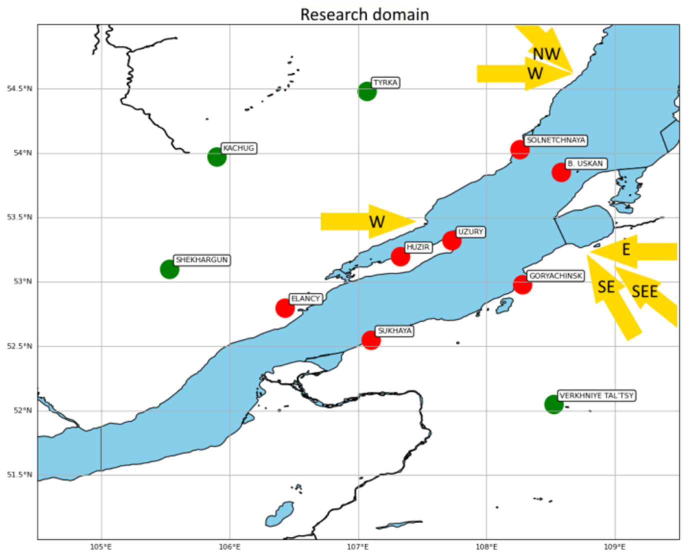

Fig. 1. Middle Baikal with an indication of the location of meteorological stations and the prevailing wind direction**.**

2 Materials and methods

Data from the stations Irkutsk DHEM: Solnetchnaya (No. 30537; 54.03 N; 108.26 E), Bolsoj Uskan Island (No. 30632; 53.85 N; 108.58 E), Uzury (No. 30637; 53.32 N; 107.73 E), Huzir (No. 30629; 53.2 N; 107.33 E), Elancy (from 2019; No. 30721; 52.8 N; 106.43 E) and Zabaykalsky DHEM: Sukhaya (No. 30726; 52.55 N; 107.1 E), Goryachinsk (No. 30731; 52.98 N; 108.28 E) obtained from the [6] website were used in the work.

Surface wind data for 2015-2023 from the NCEP GDAS/FNL Global Surface Flux Grids archive [7] were used to analyse wind direction in the entire study area. This data is provided on a grid with a horizontal resolution of 0.117° x 0.117° and a time interval of 6 hours. Surface wind data is provided in the form of u and v components of the wind velocity vector. These data have been recalculated into the strength and direction of the wind, and the wind direction has been converted to 16-wind compass rose.

Wind mapping plays an important role in the tasks of ecology and environmental research. For example, the purpose of the study [8] is to find the best method for clustering wind speeds in Malaysia when solving engineering problems and selecting wind energy collection zones. The paper also [9] proposes the use of clustering methodologies as a means of converting spatiotemporal wind speed data into statistically representative classes of time profiles for further processing and interpretation.

In [10] a review of clustering methods is presented. Hierarchical clustering is a set of clustering algorithms aimed at creating a hierarchy of nested partitions of the original set of objects. There are two approaches to creating a hierarchy: agglomerative (new clusters are created by combining smaller ones) and divisional (new clusters are created by dividing larger clusters into smaller ones).

The hierarchical clustering algorithm was used on the NCEP analysis data for the month of November from 2015 to 2023 to identify a well-established map of wind directions over the area affecting the Middle Baikal. The modelling area was limited horizontally in latitude from 52° N to 55°N and from 105° E to 110° E.

In our case, we have data on the direction of the wind at each point on the grid. Each point is a set of dimension 1. In order to create a map of the wind directions, we used agglomerative clustering, combining small groups of points into larger groups. The grouping was performed based on the criterion of similarity between groups, which is determined by the distance between groups. There are various ways to define this metric. When selecting a metric for this similarity criterion used in the agglomeration process, it is important to consider the structure of the data being studied. In our case, the data exhibits different densities (Figure 2) and does not clearly exhibit a defined group structure. Therefore, given these characteristics of the original data, it would be best to utilize the Ward's criterion [11-12].

3 Results and Discussion

The prevailing wind directions for the territories where the stations are located in November 2015-2023 were determined on the basis of observations at the stations. Tables 1-2 show the calculated values for considered stations. For the stations of the Irkutsk DHEM, the prevailing winds are West and North-West, and for the stations of the Zabaikalsky DHEM, the prevailing winds are South and South-East.

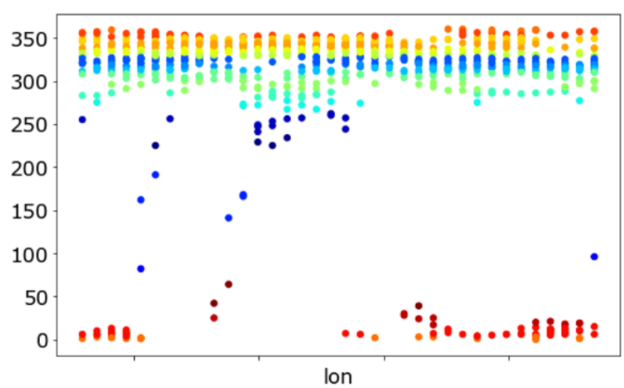

Fig. 2. The example of the distribution of wind directions relative to longitude for one timestamp from the available data.

Table 1. Prevailing (marked gradient green) winds at station Solnetchnaya.

year	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
2015	2	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1
2017	5	0	0	0	0	0	1	0	2	0	3	0	20	1	20	0
2018	8	0	2	0	0	0	0	0	5	0	7	0	19	0	17	0
2019	5	0	1	0	3	0	0	0	3	0	0	0	30	0	16	0
2020	6	0	1	0	1	0	0	0	0	0	2	0	24	0	22	1
2021	6	0	1	0	1	0	0	0	1	0	7	1	20	0	22	0
2022	8	0	2	0	0	0	0	0	4	0	2	0	30	0	9	0
2023	4	0	3	0	0	0	0	0	0	0	2	0	32	0	15	0

Table 2. Prevailing (marked gradient green) winds at station Sukhaya.

year	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
2015	1	5	6	1	0	2	1	11	7	3	2	2	5	0	1	1
2016	0	0	0	0	1	7	15	4	16	5	0	1	2	1	4	0
2017	1	4	0	3	2	7	28	14	36	6	5	8	32	28	5	5
2018	6	9	3	1	8	4	46	22	30	11	6	12	28	25	8	1
2019	5	4	9	2	3	13	50	14	26	13	13	14	26	19	12	1
2020	10	10	16	3	5	9	36	15	38	19	14	20	15	14	6	5
2021	6	11	13	7	6	21	51	14	34	5	5	15	25	11	6	5
2022	25	12	6	4	3	4	3	5	37	34	11	16	7	10	14	10
2023	6	6	6	2	10	9	39	23	40	12	10	8	19	13	14	11

Map of wind variability was built over the area that affects the Middle Baikal region due to spatial agglomerative clustering which groups similar wind directions (Figure 3). Maps were built for 10, 15, 20, 25, 30, 35, 40, 45 and 50 clusters. The difference was less than 5% starting from the division into 40 and 45 clusters, and the process of increasing the number of clusters was stopped. Figure 3 shows maps divided into 40 clusters of wind direction for 2015-2023.

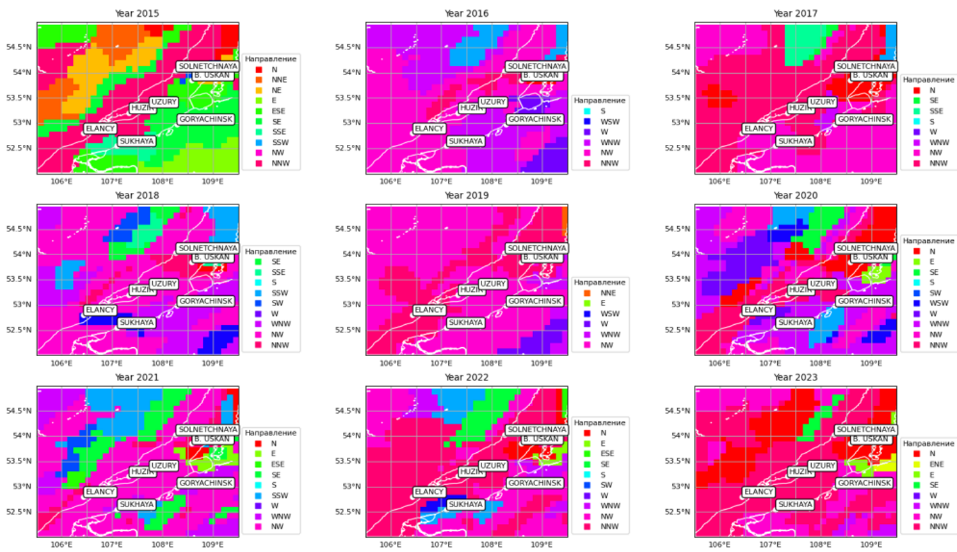

Fig. 3. Maps of wind variability.

4 Conclusions

The obtained maps are in good accordance with the measurement data collected at the meteorological stations in the Irkutsk and Zabaykalsky department for hydrometeorology and environmental monitoring. This method can be used to identify areas where the wind direction remains stable during the period of existence of the thermal bar.

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