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Contribution to analysis of the turbulence periodicity at the Arctowski Station

ABSTRACT: Power spectrum techniques were applied to two time series of wind speed values recorded at the Arctowski Station in order to investigate the influence of turbulent and laminar air flow on the quasi-periodicity of the micro-scale wind structure.

KEY WORDS: Antarctic, wind, spectral structure.

1. Introduction

The behaviour of meteorological elements is characterized by some periodicity. Its scale varies from seconds to many years. Depending on the set of data available, an attempt can be made to estimate the most frequent periods. On the basis of the various kinds of data from the Arctowski Station in 1978–1980, it was possible to determine the periods of the most important meteorological elements, lasting from 2.5 days to two months (Skrzypczak 1983, Cygan 1981, Stepko and Wielbińska, 1981). The measurements carried out at the Arctowski Station during the later expeditions permitted the research of much shorter cycles, particularly in terms of the wind.

The present paper is an attempt to investigate the periods of fast changes in the wind speed (pulsation) by means of spectral analysis, in two cases of air flow differing in character. In order to satisfy the requirements set to the data for which the method of spectral analysis is applied, they must come from periods where some stationarity of the process is retained. Therefore, the data which were already prepared and verified in this respect by D. Kowalski (1983) were used. Thus, examinations were taken of one case of laminar air flow with a small amplitude of wind speed on 11 July, 1981, and another case of turbulent motion with very large amplitude of wind speed, on 27 November, ,1981. The similarity between these cases consisted in the same pressure gradient occurring over some period, giving very similar mean values of the wind speed, in turn, the difference lay in the different directions of air flow (in the first case, from the southeast from over Bransfield Strait; in the second case — from the west, from the slopes of the Island). The objective which the present author set herself was to show the similarities and differences in the occurrence of periodicity in both cases.

2. Data

Selected wind speed records were read every 6 and 12 s. Thus, two different time-series of values were obtained for each of the two different kinds of flow. The set of data obtained from the turbulent flow, read every 6 s, was additionally filtered by means of a simple filter, with the equation $y_i = 1/4\,(x_{i-1} + 2x_i + x_{i+1})$, and analysis covered values sampled every 24 s so as to ensure more accurate evaluation of the larger pulsation periods in the spectrum obtained.

Even a preliminary look at the recorder tape permits the suggestion that the data selected illustrate approximately stationary conditions. Also, periodical changes can be observed in them, which is well illustrated by a fragment of the wind speed record (Fig. 1). Nevertheless, in order to verify the stationarity of the time series analysed, they were subjected

Table I

Statistical characteristics of time series

N°	Kind of time series	Data amount	Mean value	Standart deviation	Variance	Skewnes	Excess coefficient
1	Laminar flow t = 12 s	300 (1 hour)	21.3	2.4	6.0	0.15	2.35
2	Laminar flow t = 6 s	900 (1.5 hour)	21,6	2.3	5.4	0.15	2.82
3	Turbulent flow t = 12 s	300 (1 hour)	20.5	10.7	115.0	0.52	2.75
4	Turbulent flow t = 6 s	900 (1.5 hour)	23.6	10.3	106.6	0.12	2.43
5	Turbulent flow filtered t = 24 s	224 (1.5 hour)	23.5	8.8	77.6	0.12	2.50

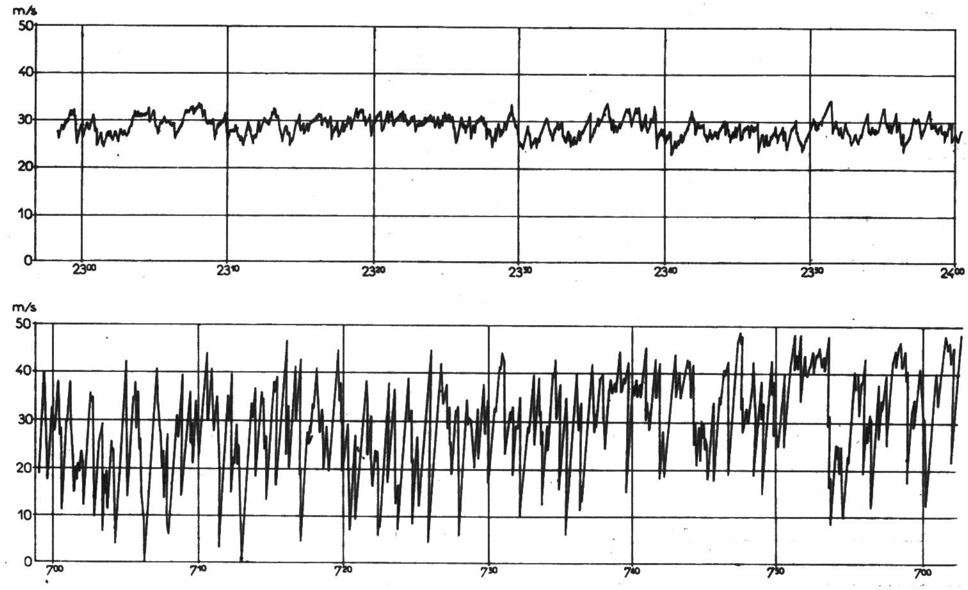

Fig. 1. Fragments of records of wind speed: a) laminar flow, b) turbulent flow

toa a simple parametric test (Bendat and Piersol 1976), giving a confirmation of the hypothesis of stationarity of the samples chosen. Statistical characteristic were also determined for them, which are shown in Table I. It follows from them that the sets of data obtained from two hourly records, both for turbulent and laminar flows, have similar mean values (about 21 m/s), but they are considerably different in the standard deviation (points 1 and 3 in Table I). The extension of each set of values over one and a half hour and reducting the sampling time to 6 seconds resulted in a small increase in the mean wind speed and small changes of the central statistical moments (points 2 and 4 in Table I). This change was much more significant for turbulent flow.

A routine procedure of the "Odra" computer was applied to calculate the power spectrum density function. The analysiss was carried out on standardized data. The spectral functions were estimated by means of both Parzen and Tukey weight functions. The truncation point for the data sampled every 12 s was assumed as m = 30, for those sampled every 6 s, as m = 60.

3. Results

The wind pulsation analysed came, as it was mentioned earlier, from two periods differing in the direction of air flow, in turn their common feature was the similar mean wind speed. The wind amplitudes for turbulent

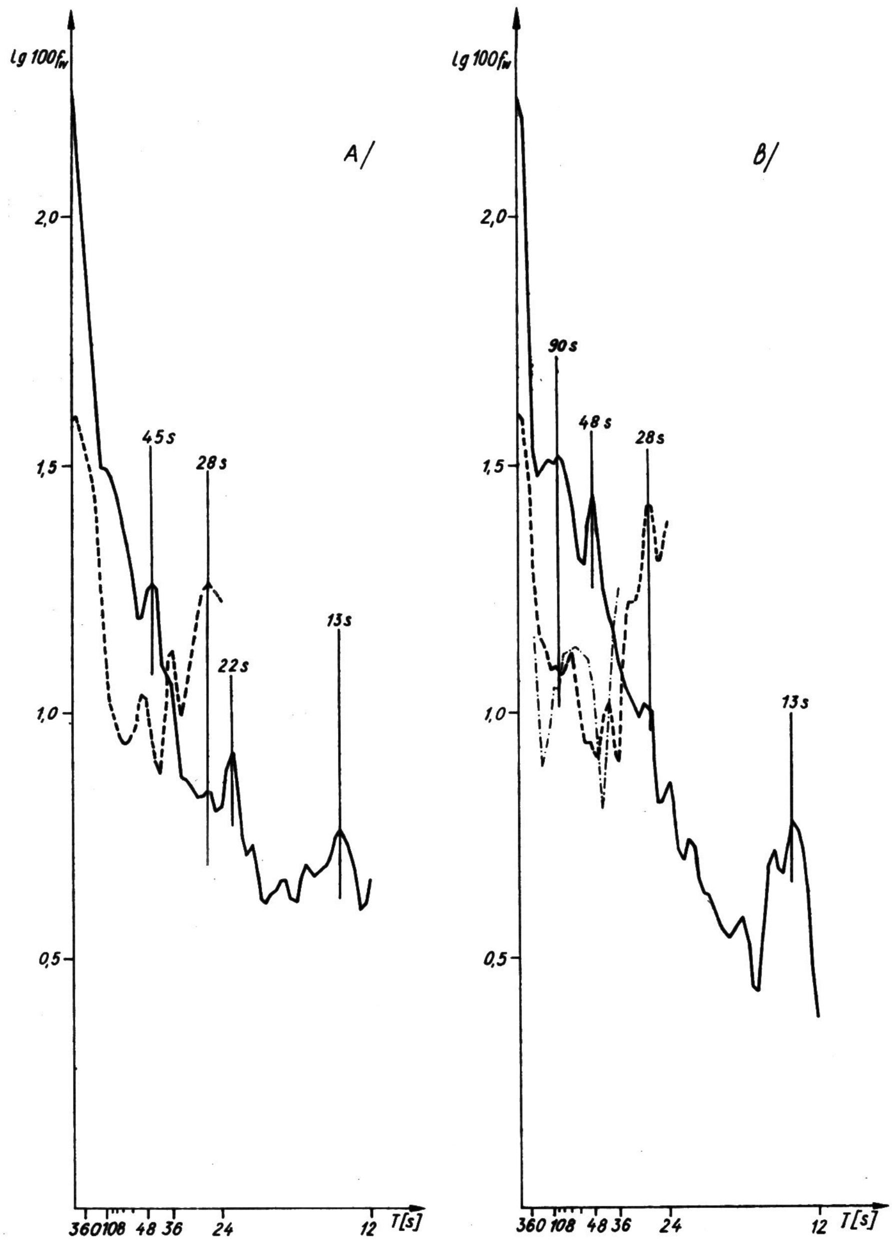

Fig. 2. Windowed normalized spectral density function of wind speed data for two different flows: a) laminar flow, b) turbulent flow, Sampling time is 6 s, truncation point is 60 (solid lines); sampling time is 12 s, truncation point is 30 (dashed line); smpling time is 24 s, truncation point is 20 (dashed-dotted line)

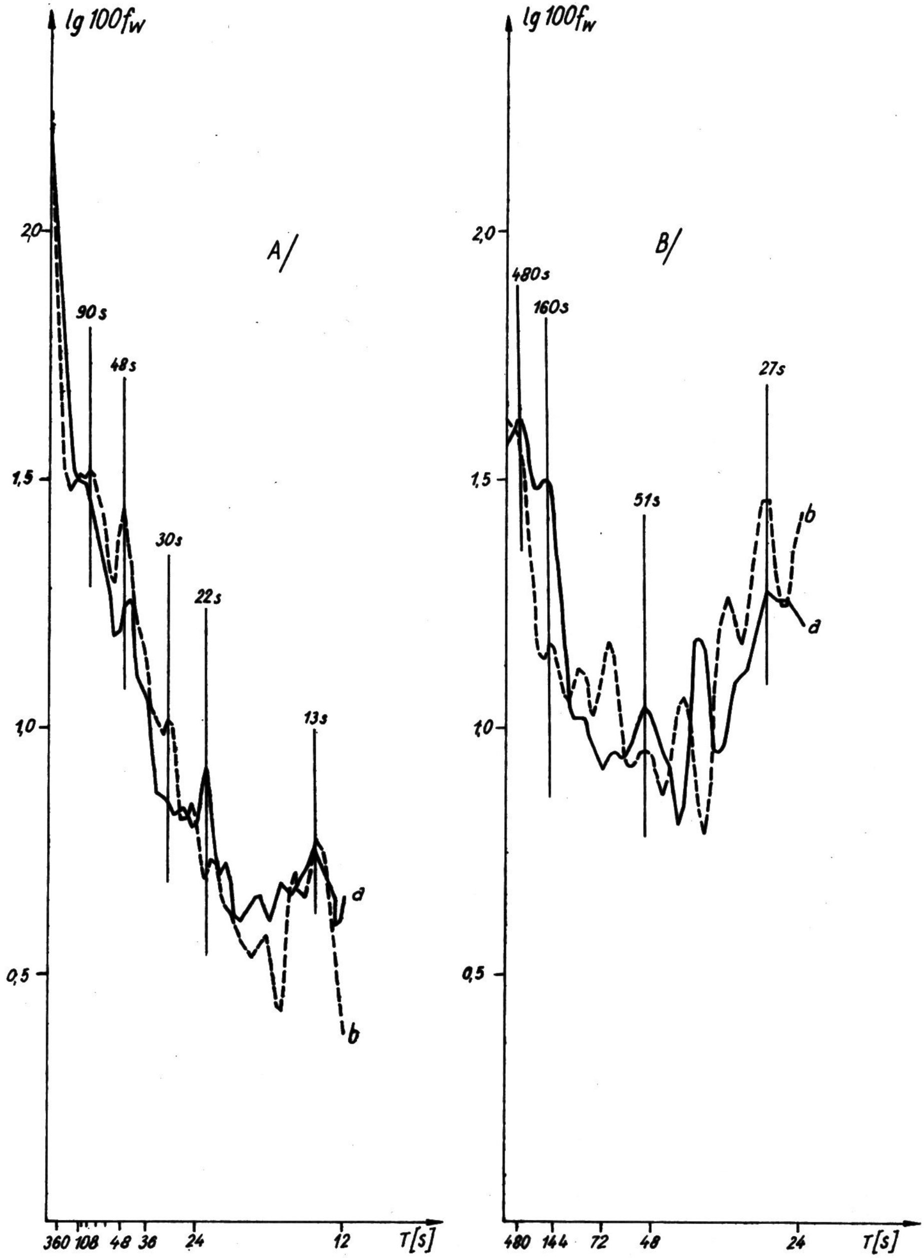

Fig. 3. Comparison of windowed normalized spectral density function of wind speed data for two different discrete sampling times, truncation points and spectral windows.
a) sampling time is 6 s, truncation point is 60; window type is Parzen, b) sampling time is 12 s, truncation point is 30, window type is Tukey. Solid lines illustrate the spectral density functions for laminar flow, the dashed ones — for turbulent flow

flow were very significant, whereas they were small for the laminar one. Despite this, the spectra obtained have a similar character and represent similar periods. The analysis, which led to this conclusion was carried out in two stages. In the first, power spectrum density functions were calculated for laminar and turbulent series with two different ways of sampling — every 6 s and every 12 s — of each of them. Also for each, two different truncation points were used, m = 30 and 60. Fig. 2 shows the results. The power spectrum density functions calculated, indicated the existence of cycles of approximately 13, 22, 28 and 45 s for laminar air flow (Fig. 2a) and of approximately 13, 28, 48 and 90 s for turbulent air flow (Fig. 2b). The maxima of the curves for the different samplings and truncation points do not coincide fully, which is caused not only by the different ways of choice of the parameters of the same analysis, but also by a half-hour increase in the data series, which changes slightly the statistical moments of the set (Table I). The function calculated for the filtered in put data corresponding to turbulent flow (the dashed-dotted line in Fig. 2b) confirms the existence of the about 90-s pulsation period seen also in the other two curves (Fig. 2b).

The other part of the analysis consisted in comparison of the power spectrum density functions of each of the cases: laminar and turbulent, when using two different sets of the parameters of spectral analysis. In the first set, 1 1/2-hour series, 6 s — sampling time, a truncation point of 60 and the Parzen window were taken into account; in the second, in turn, one — hour series, 12 s — sampling time, truncation point of 30 and the Tukey spectral window. The groups of the parameters of analysis thus selected, permitted similarities to be pointed out in the values of the periods of the two kinds of flow. In the first set of spectra obtained, it is possible to distinguish the maxima of the power function, common to the two flows and, at the same time most conspicuous, for periods of about 13, 22, 48 and 90 s (Fig. 3a). For the data with the parameters chosen according to the second set, they correspond to about 27, 51 and 160 s (Fig. 3b). It should also be pointed out that the behaviours and tendencies of the power spectrum density function are similar for the two behaviours. The spectral functions are normalized, which prevents the differences in the energy carried by the wind in the two kinds of flow, to be discerned; in turn, their similar shape can suggest that the periodical structure of the wind speed depends mainly on such parameters of flow as the mean velocity, i.e. on the pressure gradient, on the balance between air masses and on other macro-scale features. In turn, the orographic conditions stimulate local turbulence, determining the magnitude of the gust amplitude, much dependent on the location of measurements points.

In order to confirm otherwise the information provided by the spectral

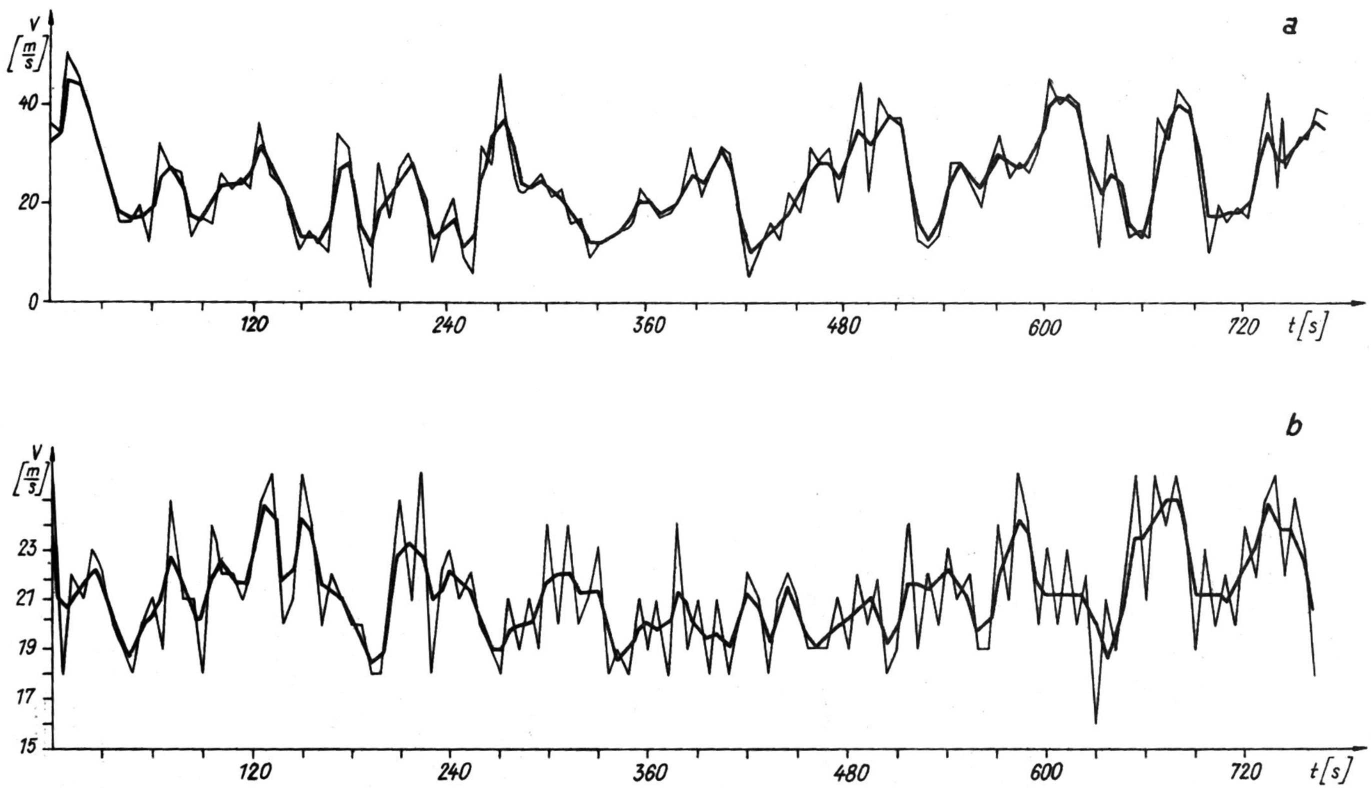

Fig. 4. Fragments of input time series of wind speed read every 6 second and filtered (solid lines) by means of the equation: $y_i = \frac{1}{4}(x_{i-1} + 2x_i + x_{i+1})$ in order to accentuate the 90 and 30 a periods. a) turbulent flow, b) laminar flow. Note the difference in the scaling of vertical axes.

power function, very simple graphic investigations of the in put data themselves were carried out. The values for the two primary series: laminar and turbulent, read discretely every 6 s, were plotted. Also series obtained from the primaries, after applying to them the filter with equation $y_i = 1/4\,(x_{i-1} + 2x_i + x_{i+1})$ (Fig. 4), were plotted on the same curves. This permitted the similarity of the periodical structure of the two kinds of flow, and even the estimation of the most frequent periods, to be pointed out, for periods of about 30 and 90 s, evidenced also by spectral analysis.

4. Conclusions

The analysis performed permits the hypothesis to be put forward, that the structure of unperturbed wind, blowing over the open sea, was in both cases similar, in view of the large similarity between the periods indicated. The strong gustines, characteristic of a case with strong turbulence, was caused by air flow over a rocky ridge of the island, while keeping, however, the basic periods related presumably to unperturbed flow.

5. Резюме

В статье обсуждается попытка исследования периодичности порывов ветра при помощи спектрального анализа, Высчитаны функции плотности спектральной мощности для двух сборов ветра, дующего над станцей „Арцтовски", характерных для ламинарного (со стороны моря) и турбулентного (со стороны острова) течения. Получены периоды в 13, 22, 28 и 45 секунд для ламинарного течения и 13, 28, 48 и 90 секунд для течения, отличающегося сильной турбулентностью (рис. 2). Спектральные функции в обоих случаях (рис. 3) отличались похожим ходом. Это может указывать, что в обеих барических ситуациях ветер обладал такой же квази-периодической структурой над открытым морем. Деформация же скорости, т.е. сильная порывистость в турбулентном течении, вызваны воздействием острова.

6. Streszczenie

Praca jest próbą zbadania okresowości porywów wiatru za pomocą analizy widmowej. Obliczono funkcje gęstości widmowej mocy dla dwóch zbiorów wartości wiatru wiejącego nad stacją Arctowski, charakterystycznych dla przepływu laminarnego (od strony morza) i burzliwego (od strony wyspy). Otrzymano okresy 13, 22, 28, i 45 sekundowe dla przepływu laminarnego i 13, 28, 48 i 90 sekundowe dla przepływu silnie burzliwego (rys. 2).

Funkcje widmowe w obu przypadkach (rys. 3) miały podobny przebieg, co może

sugerować, że w obu sytuacjach barycznych wiatr miał taką samą quasi-okresową strukturę nad otwartym morzem, natomiast zakłócenia prędkości, czyli silna porywistość w przepływie turbulencyjnym, zostały spowodowane przepływem nad wyspą.

7. References

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