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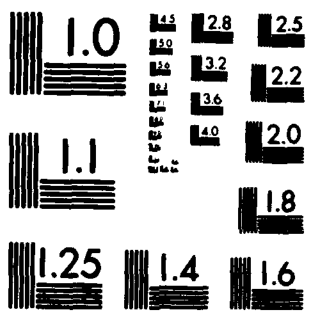

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FOREIGN TECHNOLOGY DIVISION

PERIODICITY OF BORA GUSTS

by

Z. Petkovshek

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By: Z. Petkovshek

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PERIODICITY OF BORA GUSTS

Z. Petkovshek

Department of Meteorology, Superior Technical Organization for Physics, FNT, Ljubljana

One characteristic of the bora is its gustiness. Although a great deal has been written about the bora and the strength of its gusts, hardly anything is found in the literature on the temporal characteristics of the gusts. Therefore, we constructed a very simple instrument for recording bora gusts, and with it we also made some measurements. Although they were few, it can be seen from them that the periodicity of the most powerful gusts is approximately constant; however, it is rather variable from example to example of the bora.

INTRODUCTION

The bora is a relatively cold and very gusty wind. It occurs on the warmer sides of mountain ridges, where it flows through the coldest air and drops down along the slopes beneath the warmest. Thus, the bora frequently arises along the eastern shores of the Adriatic, as well as elsewhere in the world.

A great deal has been written about the bora. The extensive monograph "Local Wind Bora" has taken and combined all the most important works and the latest articles [1]. However, even in this work, which in many places emphasizes the gustiness of the bora and gives maximum velocities in the gusts (these exceed 180 km/hr), we find no data on the frequency, periodicity, or structure of the gusts.

It is known that from time to time, the power of individual bora gusts is the cause of many accidents on roads and at sea after a storm. Such accidents occur, as a rule, all summer long. Therefore, it is worthwhile to devote more attention to the gustiness of the bora and from what has been ascertained, to reduce the number of accidents in which human life is lost.

We have found notes from the summer of 1893 [2] on the gustiness of the bora, and they are certainly the oldest. We find the first successful recording of the period of the gusts in the work by Kesslitz [3] from 1910. Here, he writes that the gusts of the bora appear on a barogram to oscillate with an approximate horizontal interval of 0.3 mm. Considering then the size of the rolls for a week's recording of air pressure (circumference about 40 cm), we obtain an approximate period of the gusts at around 8 minutes, which agree with our recordings. We found nothing in the latest available literature on the period of gusts in the bora.

NATURE OF THE GUSTS

The danger of the bora lies in its gustiness; however, we can be easily misled in evaluating the power of individual gusts. The average value of wind velocity in the bora of course does not provide sufficient information or the proper notions; even data on the maximum velocities in the gusts without judgments which are useful to us do not make possible correct evaluations of the power of the bora and the powerful effects of individual gusts. Thus, we judge data on wind velocity as such, without taking into consideration that the resistance of a body increases at these velocities with the square of the velocity and the power of the wind increases with the cube of its velocity [4].

The quadratic law of resistance, which is also valid for wind velocity in a storm, gives the resistance force F, which acts at a velocity v on a body of a given shape for factor c

$$F = \frac{c \rho S v^2}{2}$$

where ρ is the density of the air and S is the surface cross-section of the body in the flow.

Air density is approximately constant. The majority of bodies (except for spheres and certain other rotational shapes) have different shapes and cross-sections in different directions. So also for a vehicle on the road or at sea, it is generally not the same for whichever side the bora gust is coming from. However, we are primarily interested here in the fact that the force with which a storm resists a sudden gust of twice the velocity is four times as great.

Even greater is the factor of the difference in power, if we compare the potential power of the wind [4]. The mass of air which passes through a cross-section per unit time is

$$\frac{1}{S}\frac{\partial m}{\partial t} = \rho v$$

The energy flow at a unit surface per unit time, which is call the potential power of the current or wind, however, is consequently

$$P = \frac{\rho v \cdot v^2}{2} = \frac{v^3 \rho}{2}$$

This means that the potential power of the wind is proportional to the cube of the velocity and for double the cross-section, the wind in a gust is eight times greater. Thus we can understand better how easily sudden bora gusts can also surprise an experienced driver on the road or sailor at sea, especially in a sailboat.

The gustiness of the bora is thus worthy of attention and investigation not only with respect to variations on velocity but also with respect to periodicity. If we had at our disposal the periodicity of the most powerful gusts as a guide, or if it were possible to estimate the probability of powerful gusts being repeated, there would be, with these data, the possibility of maneuvering vehicles very safely or performing various actions in a storm.

The essence of the effects of the bora is, then, in its gustiness. Thus models which do not take this into account do not capture its essence. However, all the known models of the bora are like this [1]: the experimental model is constructed on the basis of tests in a wind tunnel and only gives fluctuations in slightly turbulent flow behind a ridge. The numerical Arakawa experiment is therefore also quite inadequate. Moreover, it takes into account the contribution of temperature differences in the air masses and the gravitational forces resulting from this, but it gives only the average velocities for flows around the ridge and through a mountain saddle.

THE INSTRUMENT

Let us proceed from the need to define the periodicity of bora gusts with respect to their effect, and to do this with modest means. Therefore, it is convenient for us to measure with an instrument, which is based on the quadratic law of resistance. This simple instrument, which we built out of a barograph, is shown schematically in Fig. 1.

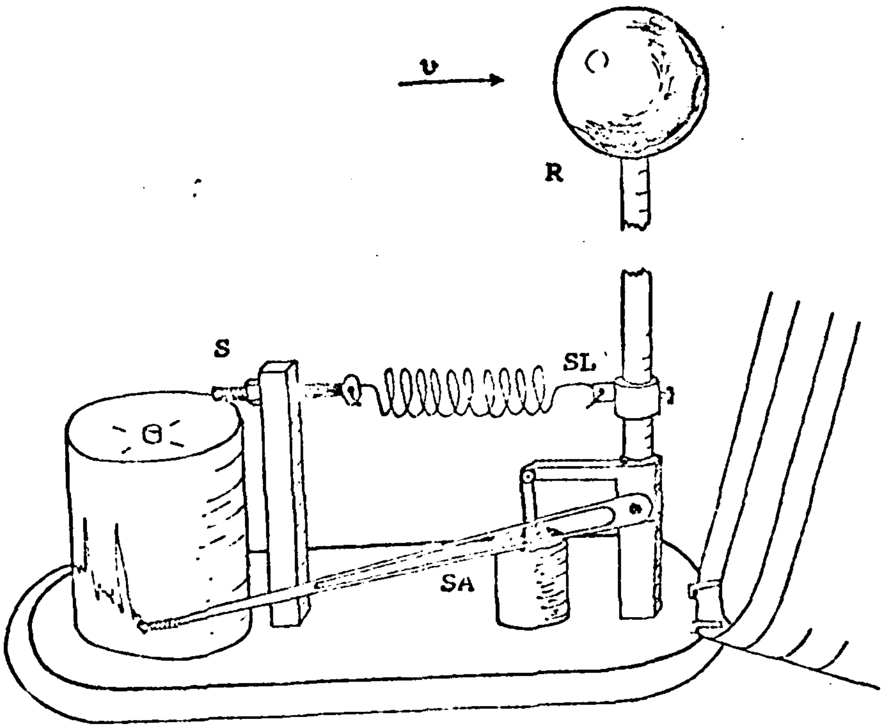

Fig. 1. A simple instrument for recording bora gusts.

The wind velocity in the bora varies rapidly and strongly; however the relative change in velocity is of primary importance. Therefore, the instrument has two possibilities for adaptation: a screw (S) which makes possible variation in the force of the screw pin, and a slide (SL), with which we can readily change the receiver and with it the level for the force of the screw pin.

From measurements in a wind tunnel, we obtained averaged curves for various positions of the screw and slide and for different shapes and sizes of the "sensor" (R): spherical or hemispherical. It is therefore easy, from the averaged curves, to define, from the instrument recording, the instantaneous velocities in individual gusts, and we can also state their distribution over time.

The sensor is movable is only one direction; therefore, we must orient and fasten the instrument such that it turns in the direction transverse to the wind in the bora. Thus we obtain deviations in the direction of transverse flow, i.e. in that direction in which the gusts are strongest. We accordingly record only a unidimensional spectrum for the gusts.

We are primarily concerned with the strongest gusts of the bora in a relatively short time frame, about one hour. Such powerful gusts last several seconds or more, for the most part, and are relatively rare. To this we must add the sensitivity of the instrument at maximum expected velocities, and oscillation around and below the average values for the recording decreases. However, with another instrument setting of greater sensitivity, we readily record some oscillation in the standard longitudinal component of the turbulence as well. Still, these oscillations are recorded somewhat distortedly, due to the stifling of sensor restoration which the shock absorber (SA) causes. Thus first of all prevents shocks and damage to the instrument in restoring the sensor (and pencil) to the initial position upon the unexpected end of a gust. The return time for sensor or pencil position at both extreme positions, or from the upper to the lower limit (but not the reverse), is a few seconds and naturally depends on the sensitivity employed; it is longer for placement for the weakest bora or for transverse velocities. Due to the one-sided effect of shock sbsorption, the pen jumps for such a gust to the position of greatest shift, which corresponds to maximum velocities, and more clearly records, in subsequent moments, oscillations or relatively slow return downward, which is a very brief gust.

In order to obtain sufficient accuracy of recording, we readjusted the clock mechanism for roll rotation so that it corresponded to one revolution of about 1.3 hours, if a one-minute record uses up 3.6 mm of the recording track length. This is better suited to an investigation of the properties mentioned and the structure of the maximum bora gusts.

THE FIRST RESULTS

The first recordings of bora gusts with this instrument are from July and August of 1976. The measurement site was on the island of Pag, 40 m above the ed estuary at Stara Novlja (Fig. 2). The area is about 7 km from the foot of Velebit, from which the boras come down most often from the NE. The instrument was fastened to the living rock at an elevated location, in order to have the least shaking of the entire instrument by the gusts.

Variations in the sensitivity of the instrument, made with the screw and slide, made it possible for us to obtain two types of recording, in principle:

1) recording of the "peaks" of the strongest gusts (Fig. 3); the sensitivity is set for strong gusts and this moves the pen and shifts the sensor from the initial position. Thus we have notices the same high peaks in the velocity distributions; then we can readily determine the average or determine a separate path for the wind from the measurement;

2) recording of transverse velocities (the sensitivity of the instrument is greater); however, the peaks of the powerful gusts are "truncated" (Fig. 4) and we do not know their intensity. Therefore, the structure presented is more accurate around the average values for the bora velocity. We are interested in the first case here.

Up to now, we succeeded, during the period mentioned, in recording 7 examples of not particularly powerful gusts. Only in the first example was the bora so strong (velocities over 23 m/sec) that highway traffic was stopped. From these seven recordings, however, only five were suitable for the analysis of the periodicity of strong gusts, because two had truncated peaks.

The duration of individual gusts is different, from a few dozen seconds to a few minutes. However, it appears (insofar as a proportionally smaller number of examples can provide information) that the duration of the

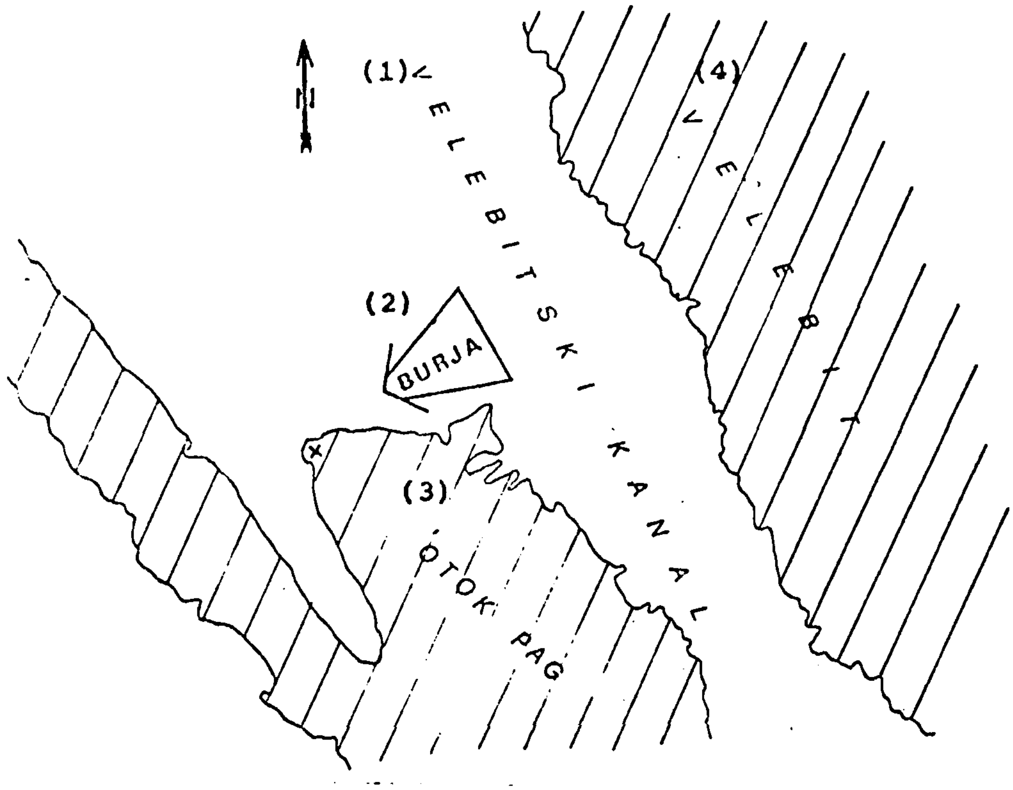

Fig. 2. Map of measurement area.
Key: (1) Velebit Channel; (2) Bora; (3) Pag Island; (4) Velebit.

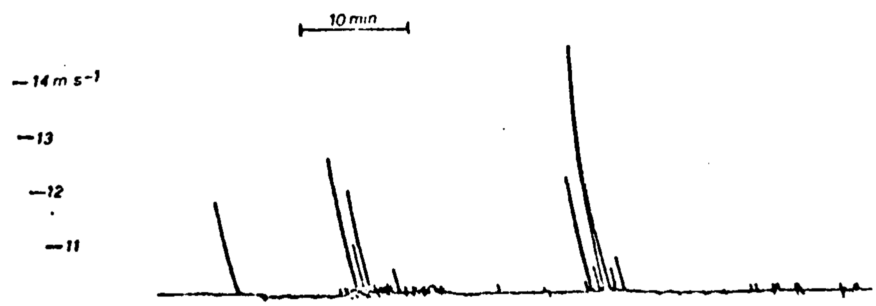

Fig. 3. Example of a recording for the strongest gusts.

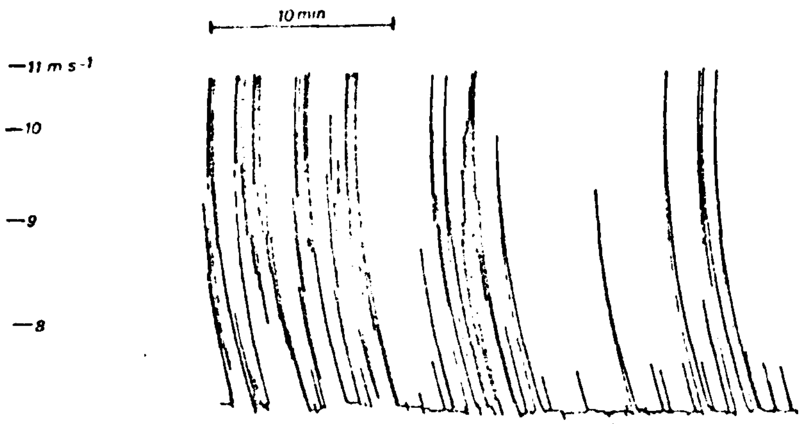

Fig. 4. Part of a recording in the range of average velocities.

gusts is a useful thing to derive. Therefore, we indicate the periodicity of the gusts such that we begin to figure the time for an individual period at the end of the preceding gust and we record the beginning of the next one, in order not to include its duration. In this way, the distributions obtained on the time scale are represented on Fig. 5. We see from them that the periodicity of the bora gusts on different days (or parts of days) is different; but in the period of one hour of time, the repetition of the gusts is the same, in the rough approximation. If we group the individual relative repetitions roughly (slim closed curves in Fig. 5), we can easily estimate the average values of the time interval (Δt) between the gusts. These values are given on the right side of Fig. 5 together with the maximum velocity and time of measurement. In one example, however, the length of the interval between gusts increases.

From these examples, of course, no statistical indices 5 or complicated conclusions can be developed.

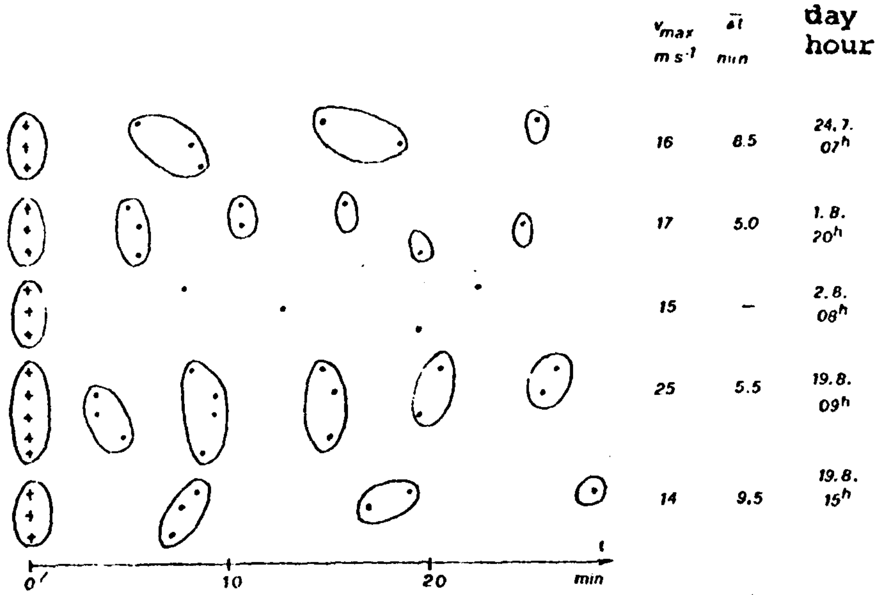

Fig. 5. Relative time distribution of bora gusts for five recorded examples.

However, the examples indicate that in the time of one hour, the periodicity of strong bora gusts is approximately the same. Not without a much larger number of recorded examples would broader statistical processing be possible, which would readily lead to reliable decisions and further deductions for turbulent and other parameters of bora structure.

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Department of Meteorology, Superior Technical Organization for Physics, FNT, Ljubljana

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