Observations in Mullamullang Cave in 1990- 1991

Sub-Title: The Big Breather Revisited.

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Abstract

A method is described for observing air flow in a large cave by measuring the pressure drop across a constriction in the cave through which all the air flows. The relationship of air flow and consequent pressure drop for the Southerly Buster in Mullamullang Cave, Western Australia is given with the results of observations of barometric pressure and air flow measurements over a sixteen day period.

Introduction.

Mullamullang Cave, Western Australia, has been well known as a barometric breathing cave since the major expeditions in 1966 [1]. The author has made measurements in this cave to try to learn more of the structure of the cave and to find answers to questions of the interactions of barometrically induced air flow and the density motivated airflows that would be expected to operate in the cave. A suitable set of data would enable the testing of the application of the theory proposed by Wigley of barometric flow from porous rock [2].

In 1979, after travelling to Perth for an ASF conference, observations of the air flow and barometric pressure were made in Mullamullang Cave with an electronic recorder for air flow and temperatures and a precision aneroid barometer that was read every 10 to 20 minutes [3]. 54 hours of observations were made. Extensive analysis by Fourier transform showed only part of the response of the cave to the stimulus of changing barometric pressure, as much of the air movement was caused by changes in barometric pressure that had occurred before the observation started and a proportion of the effects of the barometric pressure that was observed would occur after measurement ceased. The attempt to extract more information from this data was abandoned.

Fourier analysis involves separating the component sine functions from which any function is composed. The barometric pressure and the resulting air flow were both analysed to give a list of amplitude of stimulus signal, which is the barometric pressure, and the amplitude and phase of the response, the air flow, for each frequency. The ratios of these gives the response spectrum of the cave. As a rule of thumb, it is good to have a data set at least 10 cycles long at the lowest frequency of interest, as this reduces the effects of truncating the record at the ends. The biggest problem with this approach is that it relies on all frequencies being present in the stimulus signal. In this case some signals a very strong, like the twice daily swing in barometric pressure, but other frequencies may only appear at low amplitude as components of the transient change when an event occurs such as a storm front moving over the cave entrance.

In 1990, on the way to another ASF conference in WA, a new attempt was made to measure the Mullamullang phenomenon. If a substantial improvement was to be made in the analysis of the cave then at least ten times the length of observation was needed and the equipment would have to be left running in the cave for some weeks. It was not practical to use one of the sensitive vane anemometers to measure the air flow as in 16 days of continuous running the possibility of violent wind gusts and the vulnerability of a neat brass anemometer sitting in the middle of a track frequented by hordes of itinerant souvenir hunters made its continuous operation and even eventual recovery doubtful. So another strategy was devised. The Southerly Buster would be used as an orifice - plate flow meter, that is the pressure drop across the constriction would be used as a measure of the flow rate. The Southerly Buster is a constriction of only about four square metres cross-section near the entrance of the cave and is renowned for the fierce wind that often blows through it.

Method

A sensitive electronic manometer had been constructed and calibrated to measure the pressure difference between the inside and outside of the Southerly Buster. The relationship between pressure difference and flow rate is approximately that pressure is proportional to the square of the flow rate, so that if flow changes by a factor of ten then the pressure drop changes by a factor of one hundred. This makes it difficult to measure for all rates so the instrument was made to deliver two outputs, one ten times larger than the other so that if the sensitive trace went beyond full scale deflection on the recorder then the less sensitive trace would be giving a significant reading.

The equipment was buried to avoid unwanted attention, and a pressure tube of 4mm. PVC tube was passed through the Southerly Buster to an area of little air velocity and was hidden, as far as possible, from view. In the instrument package there was a thermometer, a sensitive aneroid barometric transducer and the sensitive pressure transducer. The recorder logged a measurement every 16 seconds from one of the instruments in rotation.

We returned to the instruments on our return trip some two weeks later, and set about the calibration of the Southerly Buster. A section of the passage in the cave was located where the cross sectional area was measured as 35.5 square metres. This area was chosen because for at least 20 metres in either direction the walls were parallel and of uniform roughness. This would ensure that the air flow would be uniform across the area. This area was surveyed, see Figure 1, and the vane anemometer was set up with another recorder to record the velocity of the air flow. This gave a record of 37 hours with simultaneous measurements of pressure drop and air flow. The sampling point in the middle of the passage was assumed to have a velocity exactly 30% greater than the average in the passage. The data were fitted by a least squared error method with a function which is now taken as the calibration of the Southerly Buster.

RESULTS

Figure 2 shows a plot of the hourly averages of pressure drop and air flow and also the fitted function.

The relationship was found to be:

$$P = 0.5035\ F + 0.01609\ F^2$$

Where P is the pressure drop in Pascals and F is the airflow through the Southerly Buster in cubic metres per second.

During the course of the observations there had been a small shift in the zero of the manometer, but several methods exist to correct for this. When the chart was examined, values of air pressure and values of pressure drop were extracted for each hour. These were entered into a computer so that arithmetic and statistical operations could be applied to the data. The resultant data were plotted in the form of total air flow and barometric pressure, see Figure 3. Note the time delay between the variables and the time it takes for flow to catch up to the pressure after a transient swing. By inspection of the data set, it is obvious that there may be components of the cave response with times of the order of ten days and that this data set still may still not have adequately sampled the cave's response.

The task of pre-processing the data, transforming it, and analysing the system response will have to wait for available computing facilities and the time to perform the task.

Conclusions

The method of calibrating a natural constriction as an orifice plate in a flow meter has been shown to be useful. The data collected shows (by inspection) that long period transients have a larger response than shorter period transients, indicating that elements of the system response have long times of equilibration (ten days or more). The presence of one constriction with a significantly square law of pressure drop vs. flow rate raises the possibility of the cave not being a linear system, perhaps the system response could even have chaotic elements.

REFERENCES CITED

[1] Wigley, T.M.L,; Wood,I.D. and Smith,M. (1966). Meteorological Aspects.IN: Mullamullang Cave Expeditions 1966. ED: A.L.Hill. Occasional Paper No.4. Cave Exploration Group South Australia. Adelaide Pp. 40 - 46

[2] Wigley,T.M.L.. (1967) Non-steady flow through porous medium and cave breathing. Journal of Geophysics Research Vol. 72 No.12 Pp. 3199 - 3205

[3] Michie, N.A. (1991) Phenomenal Cave Climates. Cave Leeuwin. IN: Preceedings of the 18th Biennial Conference of the Australian Speleological Federation Ed: Brooks, S. Australian Speleological Federation. Perth Pp. 58 - 65

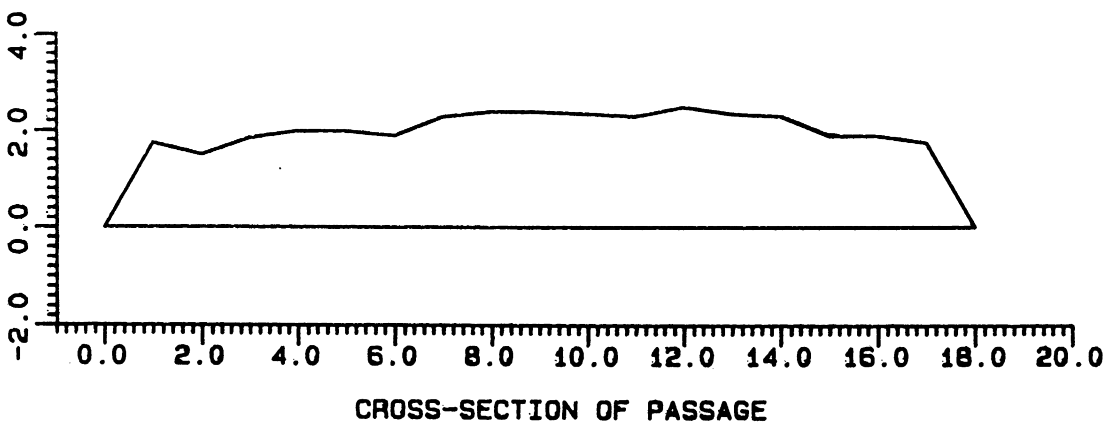

Figure 1. The cross section of the cave where the anemometer was located 1 metre from the ground in the middle of the passage.

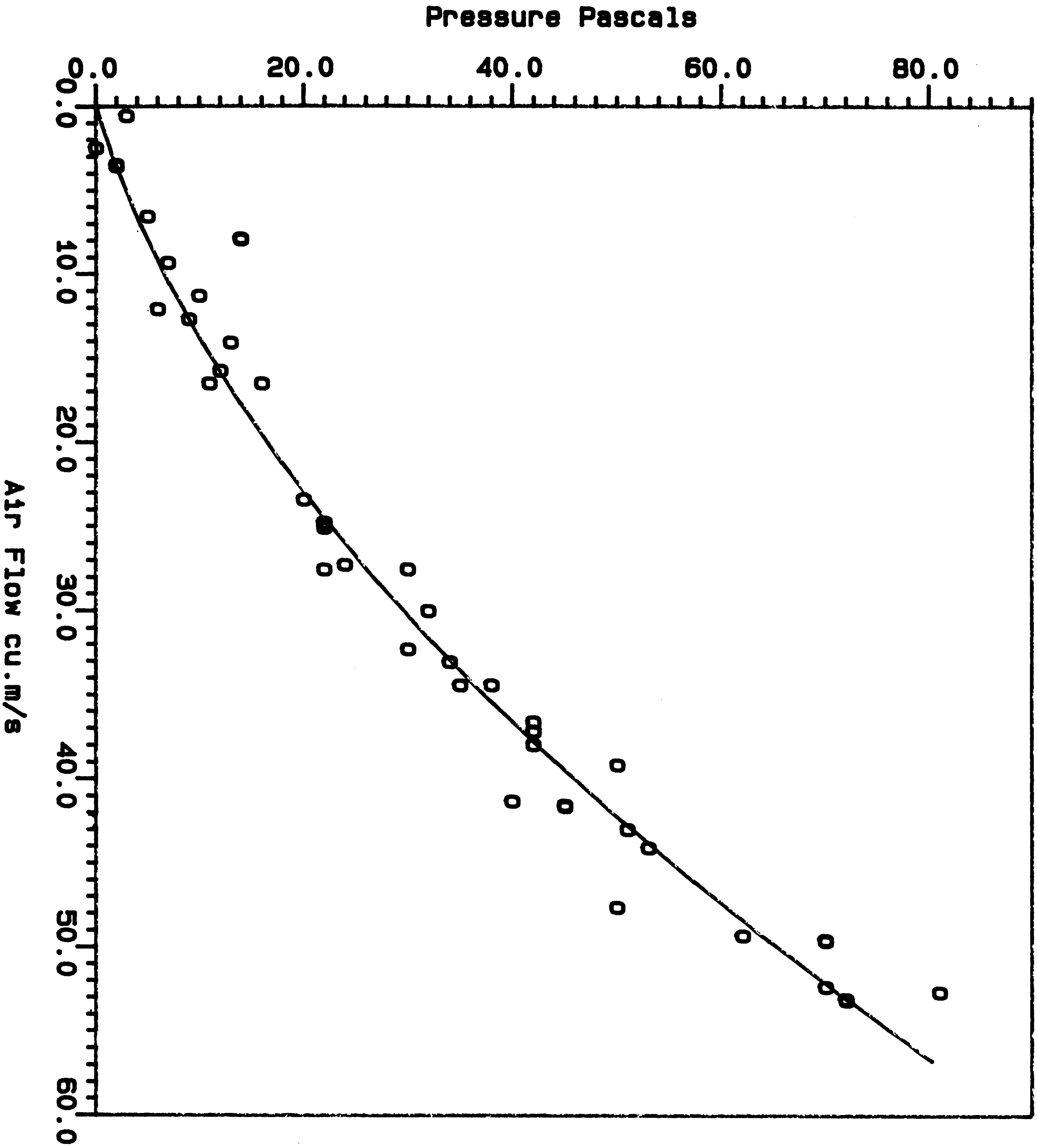

Figure 2. A scatter plot of <the total air flow for the hour> against <the hourly average of pressure drop across the Southerly Buster> with the least squares fitted function.

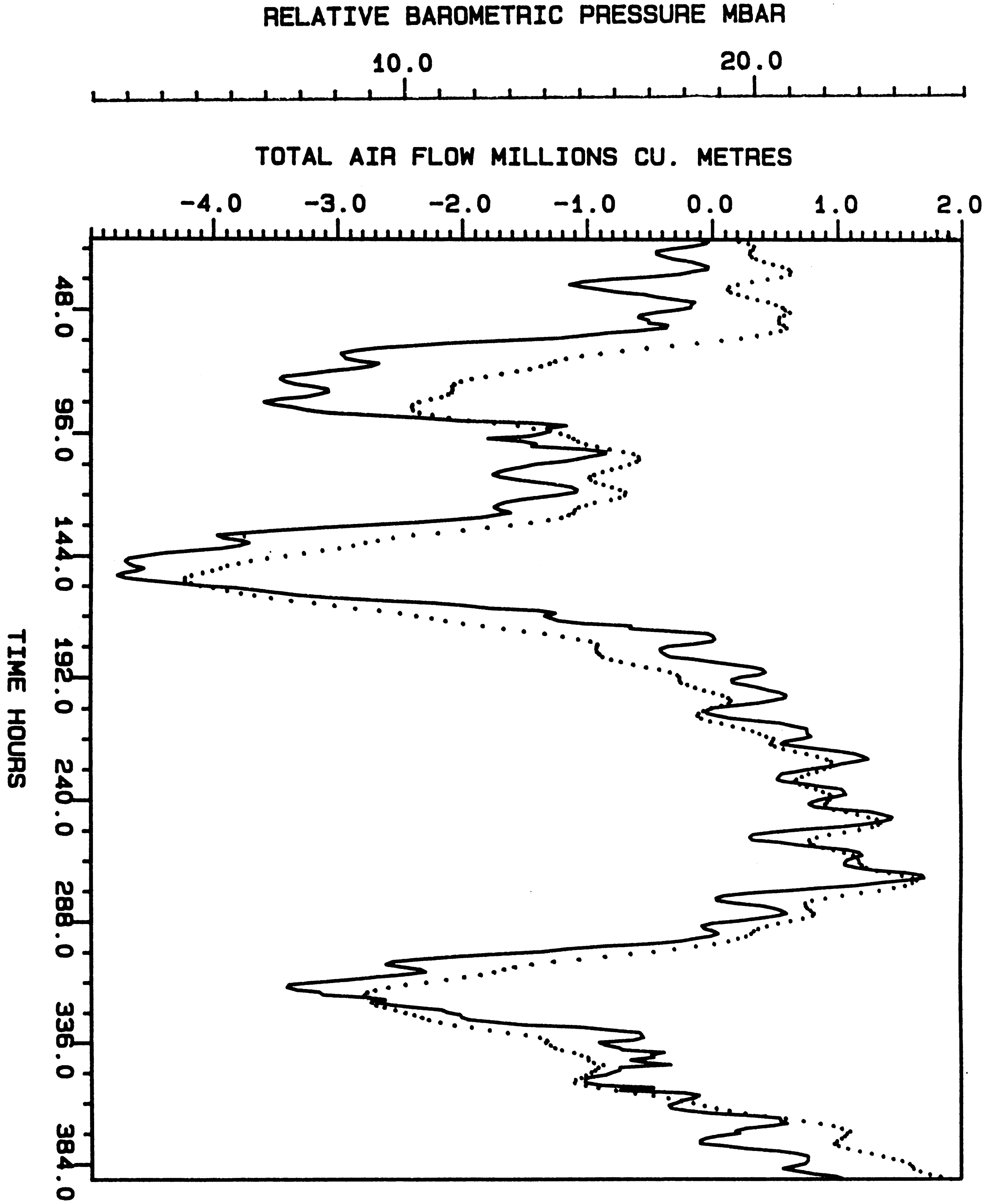

Figure 3. Plot of the barometric pressure (solid line) and the accumulated flow into the cave (dotted line). The time (0 hours) starts at midnight 28th Dec. 1990.