http://www.scirp.org/journal/ns Natural Science, 2018, Vol. 10, (No. 5), pp: 178-181

Bernoulli Weather or Not?

Kern E. Kenyon

4632 North Lane, Del Mar, USA

Correspondence to: Kern E. Kenyon, Kernken@aol.com
Keywords: Bernoulli's Law, Weather Systems
Received: April 14, 2018 **Accepted:** May 15, 2018 **Published:** May 18, 2018

ABSTRACT

Thirty five day records of wind speed and atmospheric pressure, measured and recorded every two hours, were obtained on a ship that sailed from California to Japan along latitude 35 N in the spring of 1976. Time variations of two days, which can be seen in the raw data of both variables, were brought out more clearly by a two-step smoothing process followed by a subtraction to reduce both the lower and higher frequencies. Comparing the two similarly processed records shows that when the wind speed is relatively strong, the pressure is relatively weak, and vice versa, at the two day time scale. An argument is given that Bernoulli's law was operating in those weather systems.

1. INTRODUCTION

Question: is Bernoulli's law working at all in weather systems? On my bookshelf are twenty standard texts, old as well as new, covering various meteorological subjects. Bernoulli does not show up in the index of any one of them. Where the speed is greatest, the pressure is least. Can't that law apply to some types of wind storms? No guidance from the literature is available apparently. Although Bernoulli's equation has been found to be useful in so many different fields involving fluid flows [1], the wonder is that meteorology, being one of the older sciences, has not yet grabbed hold of that law. Is it because the space scales of weather features are so much larger than the length scales involved in all of the other available fluid flows to which Bernoulli's law has been applied? But that does not make much sense on the face of it.

Turbulence, exhibited in most atmospheric motions, comes close to being a logical reason why meteorologist ignores Bernoulli, because in basic fluid mechanics books his law is derived from the equations of fluid motion by first neglecting friction. But even there at least one fluid text exists which treats the addition of friction to Bernoulli's equation (Milne-Thompson). In addition, the length scale of a wind storm is so much larger than the scale of turbulent eddies carried along within it that presumably there is very little or no significant dynamical interaction between the two that would affect the law to any great extent.

A choice here is made to move forward. Suppose that over the North Pacific in spring, for example, at sea level and at mid to high latitudes, there lies a large area of relatively cold air. Potentially unstable, the dense cold air has the tendency to rush southward into the warmer air at sea level that is less dense causing it to move up and out of the way. If a trigger mechanism starts that to happen, southward horizontal air flow will take place. One such trigger mechanism is the diurnal warming of the air by the sun which reaches a maximum at local noon. Since the already warmer air heats up faster at low latitudes, and the not so warm air heats up less quickly at high latitudes, the associated destabilizing horizontal pressure gradient set up by the sun is enhanced, and most sharply at noon.

Within the region of air rushing southward one might think that along streamlines Bernoulli's law should be taking effect. In the faster speed of the southward flow the pressure should be lower than in the environment being penetrated, which has no motion, or anyway a much smaller motion. Jump now for inspiration into a rather comprehensive particular sampling of meteorological data taken across the whole North Pacific.

2. DATA ANALYSES

In March and April, 1976, a physical oceanographic cruise went from California to Japan along latitude 35 N, stopping on stations and steaming between 98 equally spaced stations for 35 consecutive days. On the ship's bridge three officers recorded in the captain's log meteorological data measured every two hours local time. After each eight hour watch the officer signed his name in the log. Among the quantitative variables recorded were wind speed and direction, atmospheric pressure, air temperature (dry and wet bulb), total cloud amount and visibility.

My first attempt to study these data concentrated on the diurnal variations because of a very unusual air temperature feature discovered 30 years earlier in the southwestern North Pacific by a Japanese scientist: a minimum at noon that showed up in data averaged over three years from two weather ships positioned off the east coast of Japan. That noon air temperature minimum appeared in the averaged cruise data from 1976 also. It was not present every day but in enough days (1/3 of the total) and with enough "amplitude", scattered throughout the record, that it occurred in the average over all days. In fact, the noon minimum feature was more marked in the cruise data compared to what the Japanese author had reported.

Although the diurnal signal could be seen easily enough in the raw data for all of the variables, it was decided to bring it out more clearly by applying a 13 point running mean to knock down the higher frequencies. Also it looked from the raw data like the diurnal signals themselves were alternating in strength from one day to the next, which was totally unexpected. To explore that possibility 25 point running means were applied to the records already produced by applying the 13 point running means. Then the smoothed records were subtracted from each other in order to show what was left after both high and low frequencies had been reduced: two day variations stood out in all cases like sore thumbs demanding attention. For example, the two day pressure variation (**Figure 1**) has an amplitude exceeding that of the diurnal signal (which is really the well-known semi-diurnal variation).

Exactly the same two step smoothing procedure followed by a subtraction was carried out for the wind speed (**Figure 2**). In fact, **Figure 1** and **Figure 2** were published before and in the same order [2]. However, no discussion regarding a potential relation between the two was given previously; only the fact that both variables exhibited the two day time scale was pointed out. Mainly the interest before was in the correlation between fluctuations in air temperature and the north component of the wind at the two day time scale: north wind corresponded to cold air and vice versa. This result is consistent with a net pole ward flux of heat, conjectured to be a sign that the central physics behind the existence of the variations was working properly, or at least qualitatively and in the right direction.

When on a light table **Figure 1** is superimposed on **Figure 2** (or the other way around), the negative correlation is very noticeable inside large segments of the records. Where the speed is relatively high, the pressure is relatively low, and vice versa, at the two day time scale.

3. DISCUSSION

Right away an objection will come up: the ship was not anywhere close to riding along a streamline,

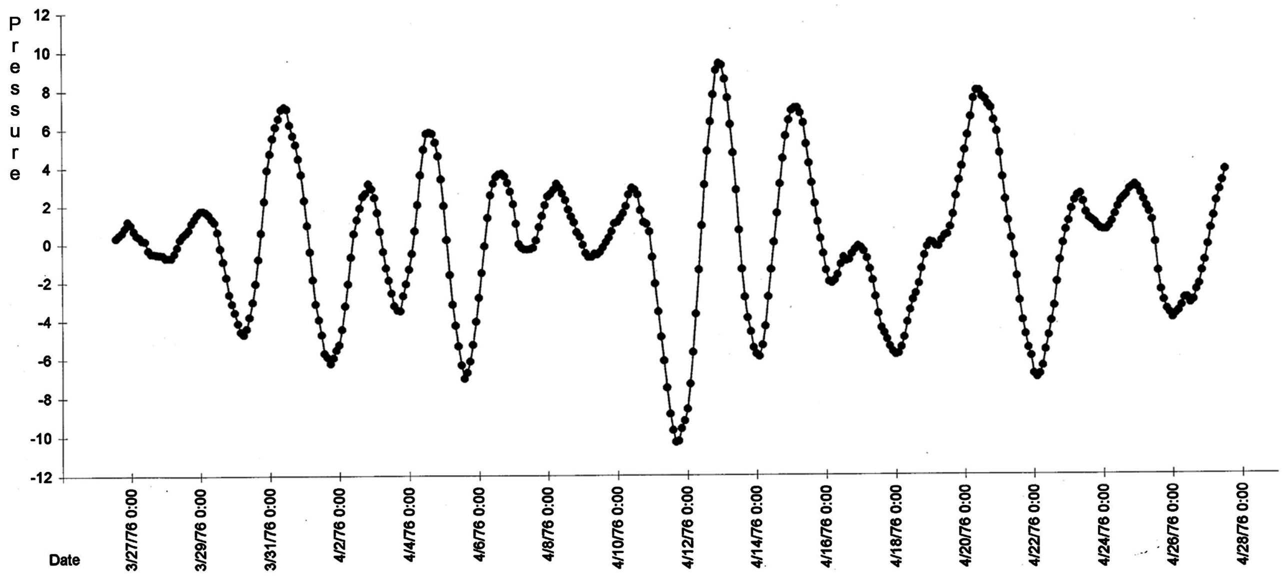

Figure 1. 25 point running mean applied to a 13 point running mean of the raw atmospheric pressure data, followed by subtracting the two smoothed means from each other.

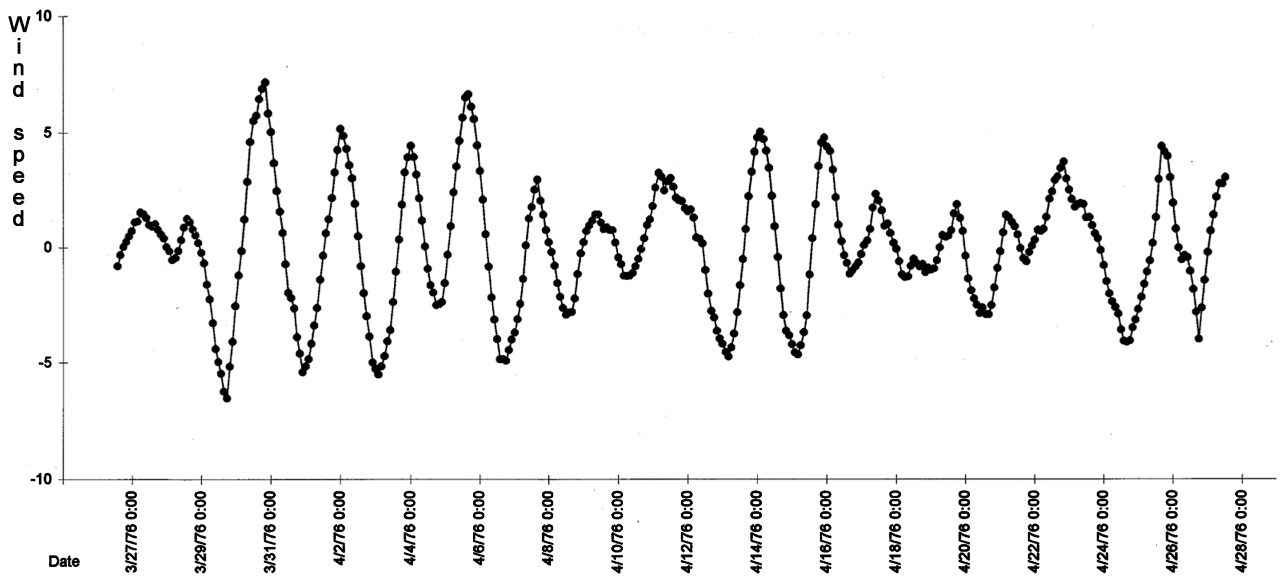

Figure 2. Similar to Figure 1 except for wind speed.

so how can one begin to talk about Bernoulli's law, classically derived to be true along a streamline? The ship headed straight west whereas the cold air started out straight south but then kept bending more and more westward in a clockwise direction. Not only that, mathematically the constant in the equation can be different from one streamline to another in general.

If brushing the mathematics aside seems arbitrary, consider the following argument. Inside the large mass of cold air at sea level and mid- to high latitudes, before the trigger is pulled, the pressure is uniform and velocity is essentially zero. Then when the cold air accelerates southward, it is reasonable to assume that all the streamlines originating within that mass will have the same constant to be put into Bernoulli's equation, and the constant might as well be taken to be zero as anything else.

Therefore, as the ship crosses through the streamlines of the variable flow the pressure and speed should be inversely related in accordance with Bernoulli's law. And that idea is consistent with what appears to have happened to a large extent in **Figure 1** and **Figure 2**, which clearly show that at the time scale of two days the pressure is low when the speed is high and vice versa.

It should be pointed out also the Coriolis force is believed to be the cause of the clockwise bending of the streamlines as interpreted from the cloud patterns from satellites [3]. Since the Coriolis force acts normal to the velocity, which is normal to the streamlines, there should be no conflicting interactions between Bernoulli's law and the Coriolis force.

4. CONCLUSION

During the spring of one year, based on meteorological data at sea level taken every two hours for 35 days between California and Japan, it was concluded previously that all seven variables quantitatively put down in a log book exhibit significant variations with a time scale of two days. New is the correlation at the two-day time scale between wind speed and atmospheric pressure: when the speed is relatively high, the pressure is relatively low, and vice versa. This relationship is reminiscent of Bernoulli's law, which appears to be operating in weather systems, a realm not fully explored before apparently. More work needs to be done.

REFERENCES

1. Kenyon, K.E. (2018) Believing Bernoulli. *Natural Science*, **10**, 142-150. https://doi.org/10.4236/ns.2018.104015
2. Kenyon, K.E. (1996) Bi-Daily Variation of Meteorological Properties at Sea Level across the Pacific along 35 N. *Atmospheric Research*, **43**, 31-46. https://doi.org/10.1016/S0169-8095(96)00003-8
3. Kenyon, K.E. (2018) Climate and Weather of the North Pacific. *Natural Science*, **10**, 163-167. https://doi.org/10.4236/ns.2018.105017