Hurricane's Shear

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ABSTRACT

The radial shear from an elementary theory is proposed to be operating inside a hurricane throughout a major portion of its life cycle: horizontal shear equals the Coriolis parameter. Typical values for the maximum wind speeds at sea level and storm diameters can satisfy this equation, but more detailed observations will be needed in the future for a convincing confirmation.

1. INTRODUCTION

Well-known is the fact that the fastest winds in a hurricane are just outside the eye-wall, and the smallest are approximately zero outside the storm. To be a hurricane the fastest winds must be greater than or equal to about 75 mph by definition. According to a search of the internet the fastest hurricane speed ever recorded was over 150 mph. Storm diameters range from 100 to 2000 km.

It stands to reason that the hurricanes with the highest wind speeds should also be the ones with the largest diameters, but I have not seen a statement of this possible correlation in print. Whether or not both variables increase at the same rate during hurricane growth, appears to be unknown. In other words, is the mean shear a constant of the motion, or what is more likely, do available data support the idea of a systematic increase in mean shear during a hurricane's generation?

There are both a theoretical and an observational basis for asking this question. If the shear ever becomes near to being a constant, what would be the most likely candidate for the constant? For reasons explained below it is the Coriolis parameter f (in Discussion the consequences of f actually not being a constant throughout the lifetime of a hurricane are outlined). Stommel came close when he stated that the offshore shear in the Gulf Stream approaches $0.5f$ and that this fact needs to be explained [1].

A mean wind shear approximately equal to f was experienced by an oceanographic ship while sailing straight west from California to Japan along 35 N [2], alternating stopping on stations and steaming between stations. A couple of hundred km from California a wind of 30 kts suddenly sprang up, a cold and dry wind out of the north, and gradually tapered off in speed over a period of 48 hours. Air properties (wind speed, direction, temperature, humidity) were measured every two hours on the bridge by the officers of the ship, and these data were used to estimate the wind shear.

2. MODEL

Even the simplest model can lead toward increasing the understanding of a complex natural phenomenon like a hurricane. Usually in science the simpler the better as far as explanations are concerned. Therefore, the starting point here begins with Bernoulli's law, which is applied to the curved streamlines, assuming that they are closed loops for ease of presentation. To maintain the flow's structure over a period of many days there must be a radial balance of forces whereby the outward Coriolis force of the counter-clockwise circulation in the northern hemisphere equals in magnitude an inward pressure force; *i.e.* geostrophy is operating.

Bernoulli's law and the geostrophic balance are expressed algebraically as two equations in two unknowns: pressure and velocity. From them one governing equation in the velocity can be obtained by eliminating the pressure, which results in [3]

$$-\frac{\mathrm{d}v}{\mathrm{d}r} = f \tag{1}$$

where v is the velocity tangent to the streamline, r is the radius measured from the hurricane's center and f is the Coriolis parameter as already mentioned.

To see if Equation (1) might have any relevance to a hurricane, try a hypothetical case. Take a diameter of 1000 km (radius of 500 km) and a maximum wind speed of 100 mph, both of which are characteristic numbers for a hurricane. These values give a mean shear of $\frac{\mathrm{d}v}{\mathrm{d}r} = 9 \times 10^{-5}/\mathrm{s}$. At mid-latitudes it is known that the Coriolis parameter is about $f = 7 \times 10^{-5}/\mathrm{s}$. Therefore, it is possible that (1) could be satisfied by a hurricane.

3. DISCUSSION

Hurricanes in the North Atlantic originate at low latitudes as tropical storms, and the Coriolis parameter is relatively small there. Then they drift mainly west and a little bit north resulting in a slow increase in f. At some point their tracks usually bend more north than west, where they may already have strengthened into a hurricane. As all this is happening both sides of Equation (1) are increasing. Whether or not the Equation's RHS and LHS are ever exactly equal or not is not known, nor if they once become equal, then do they remain in lockstep. The Equation should not be taken too literally, but it could serve as a guide.

One feature often mentioned about hurricanes is that the winds are strongest on their northeast sides. For hurricanes of large size the Coriolis parameter will vary over the diameter in the north/south direction. This fast northeast quadrant is not quite consistent with what Equation (1) would suggest; the north part is but not the east.

Several attributes of the model that are convenient for the purpose of discussion are not realistic, such as the streamlines being closed loops instead of spirals that end at the eyewall.

Observational material is difficult, expensive and perhaps dangerous to get, but more is clearly needed. Detailed measurements of interest may be available if the following situation has ever occurred: an isolated small island with a working weather station experiences the spaghetti-line of a hurricane's eye passing across it. Speed along the spaghetti line and direction of the line being more or less constant would be optimum for interpretation.

Notice that on the face of it Equation (1) is independent of origin and growth mechanisms, as well as the velocity of translation, be it a tropical storm or hurricane.

4. CONCLUSION

Horizontal velocity shear equals the Coriolis parameter is an equation that is applied to a hurricane. It was previously derived by combining Bernoulli's law along streamlines of steady flow with the crossstream force balance for large-scale phenomena: geostrophy. A rough estimate indicates that the equation could be operating in a hurricane by inserting into it characteristic values for the maximum wind speeds and diameters from observations. Such a simplified model might nevertheless point the way to obtaining more detailed measurements that would be useful for increasing the level of understanding of such a potentially destructive storm.

CONFLICTS OF INTEREST

The author declares no conflicts of interest regarding the publication of this paper.

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