TORNADO'S SHEAR

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ABSTRACT

If a tornado's rotary winds has a horizontal shear inversely proportional to the radius, there will be no friction and its duration will be relatively long. That result is due to combining two pieces of physics: Bernoulli's law applied to the closed circular streamlines of flow and the cross-stream force balance between the outward centrifugal force and an inward pressure gradient. Observational verification of the theory will be difficult but essential.

Keywords: Tornado's shear, frictionless tornado

1. Introduction

An existing elementary model of a tornado [1] is augmented theoretically here by adding more physics. This approach may or may not alleviate the prevailing confusion surrounding the inner workings of a tornado. But some light will be shed on a question that has probably not been asked before. How can a 200 mph wind last more than a few seconds without being utterly destroyed by friction? Typically these storms last many minutes to several hours. In the field of hydrodynamic instability there is a philosophy that the expected structure (wavelength)to emerge from certain fluid flows (in the lab or a geophysical situation) is that one which is most unstable by some measure, like the growth rate [2]. Contrast that with the idea that what can be seen persisting in nature has as its chief characteristic the least amount of friction. One designation is: the principle of least friction. A velocity function in circular

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geometry with zero associated friction is known to be v=const/r [3], with a suggested application to a solid cylinder rotating in a fluid. Maybe the tornado incorporates that function too.

Whether the motion at the core of a tornado is down (as I believe [1]) or up (as many think) can be decided by observations taken in 2003 [4]. On June 24 a short cone shaped probe was placed base down on a road in South Dakota a few minutes before an F4 tornado went right over it. Inside the probe continuous records of pressure, temperature and relative humidity were made, but only the extremely low pressure trace was printed in the article. However, for the present purpose the core flow direction does not matter.

2. Proposal

Through a vertical tornado consider a horizontal plane intersecting it, somewhere between the cloud base and the ground. There will be closed circular streams of flow in this plane. Apply Bernoulli's law to each closed streamline or loop, which has been done a few times before [5].That produces Equation 1. Also construct the horizontal cross-stream force balance on every fluid particle moving along a given streamline: the radially outward centrifugal force equals an equal inward pressure gradient. That gives Equation 2. (The Coriolis force does not enter this sufficiently small-scale problem.)

Equations 1 and 2 are two equations in the two unknowns, pressure and velocity. By eliminating the pressure between them, there results one differential equation in one unknown, velocity, which is linear and easily solved to give

$$v = \frac{const}{r} \tag{1}$$

Where v is the rotary speed and r is the radial coordinate, and that form has no friction.

Proposing that Equation (1) can serve as a model for the rotary winds of a tornado amounts to a prediction which would be difficult to verify with observations because of the great power of those winds to destroy scientific instruments. The prediction means that the fastest winds are just outside the core and they decrease in magnitude radially in a very specific way until essentially vanishing in the environment. However, there is qualitative consistency with observations in the sense that the pressure inside the core is probably lower (for sure at ground level) than the ambient value creating the possibility that the inward pressure gradient could balance the outward centrifugal force on the winds.

Indirect support for the present treatment of the tornado comes by comparison with the analogous analysis of the hurricane [5]. Similarities are the circular geometry, application of Bernoulli's law to closed streamline loops, zero friction, and maximum wind speed and pressure near the center. Differences are the smaller horizontal scale, substitution of the centrifugal for the Coriolis force in the cross-stream force balance, and the approximate factor of two in the maximum wind speed. The hurricane can only rotate counter-clockwise in the northern hemisphere whereas the tornado can rotate either way. The fact that it only goes one way most of the time might mean that some large-scale phenomenon is involved in the generation process inside the cloud.

When Bernoulli's equation and the cross-stream force balance for the hurricane are combined to eliminate pressure, the differential equation for the radial velocity becomes [5]

$$\frac{dv}{dr} = -f \tag{2}$$

Where f is the Coriolis parameter which is locally constant near a given latitude. Such a velocity shear has zero friction. Equation (2) is consistent with the known sizes, latitude and maximum wind speeds of North Atlantic hurricanes, for example.

3. Conclusion

A forecast is made, based on dynamical reasoning, that a tornado's rotary winds should have a particular type of horizontal shear, inversely proportional to the radial distance from the central axis of the funnel. If the tornado can achieve this velocity structure, it has a good chance of maintaining its integrity a relatively long time because the laminar friction force is zero theoretically. This forecast poses a challenge to observational verification due to the destructive nature of the storm.

References

[1] Kenyon, K. E. and D. C. Kenyon (1989) AnElementary Model of a Tornado. *Geophy. Res. Letters*, 16, 1281-1283.

[2] Drazin, P. G. and W. H. Reid (1991) Hydrodynamic Stability. Cambridge University Press, New York, 515 pp.

[3] Batchelor, G. K. (1967) An Introduction to Fluid Mechanics. Cambridge University Press, San Diego, p. 203.

[4] Schlatter, T. (2003) Weatherqueries, Weatherwise Magazine, May/June, pp. 56-58.

[5] Kenyon, K. E. (2019) Bernoulli Loops with no Friction. Euro. Int. J. of Sci. and Tech., 8,