ISSN 1028-334X, Doklady Earth Sciences, 2006, Vol. 406, No. 1, pp. 120–121. © Pleiades Publishing, Inc., 2006.
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GEOPHYSICS

Spots in the Hurricane Eye

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Presented by Academician Al.Al. Berlin June 15, 2005

Received June 24, 2005

DOI: 10.1134/S1028334X06010296

Tropical cyclones (typhoons, hurricanes) are the largest and most destructive natural whirls arising from the interchange of energy between the ocean and atmosphere. Hurricanes are a primary subject of investigation in the physics of the atmosphere and geophysics [1]. Only a sophisticated understanding of their structures, formation conditions, and evolution will make it possible to predict their appearance and trajectories and, perhaps, to monitor these processes.

The Isabel hurricane (2003), the most powerful one of the past 50 years, demonstrated spots on the periphery of the hurricane eye [2]. The purpose of this work is to analyze the structure and evolution of the spots and to simulate their interaction.

These unusual spots or structures were revealed in the course of examination of the GOES-12 Vostok images of the Isabel movement. Such structures have apparently not been detected in other tropical cyclones. They are likely to develop only in the heaviest hurricanes and/or their origin seems to be related to certain conditions. One of these conditions might be the passage over the area of "hot" water in the ocean when counter-current ascending and descending airflows, velocity gradients, and turbulence are especially high.

It was precisely when Isabel appeared at the water core with $T = 30.5°C$ that such structures emerged near the boundary of the hurricane eye. The wind velocity in the hurricane reached 85 m/s at that time.

The eye looked like a circle, which seemed to be separated into five sectors, each sector including a structure occupying a part of the sector (Fig. 1, *1*). Most probably, the discussed structures represent whirlwinds of the mesocyclone or tornado type. Figure 1 demonstrates hurricane fragments (to be more exact, an "eye")

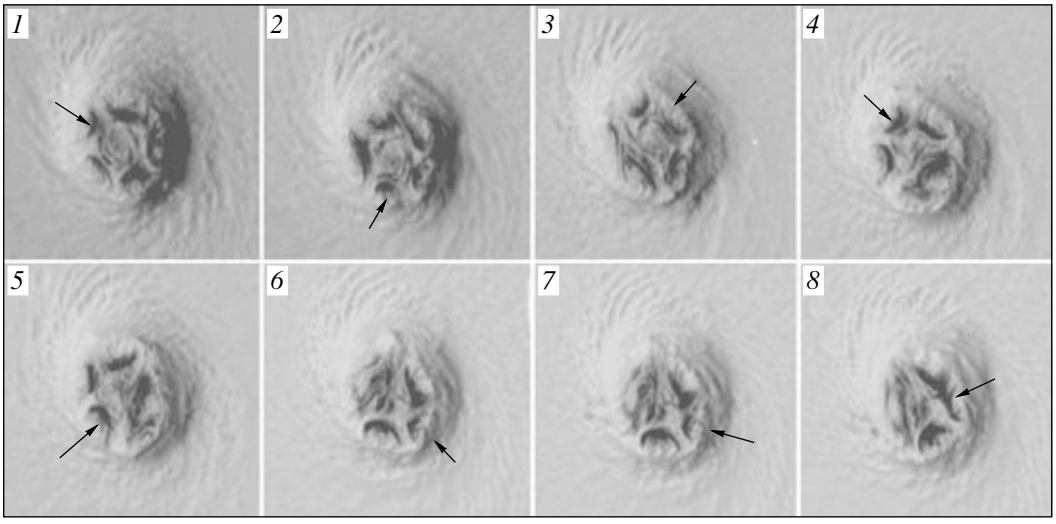

Fig. 1. Evolution of structures (whirls) in the Isabel hurricane eye. Arrow shows the position of one of the whirls at different moments of time.

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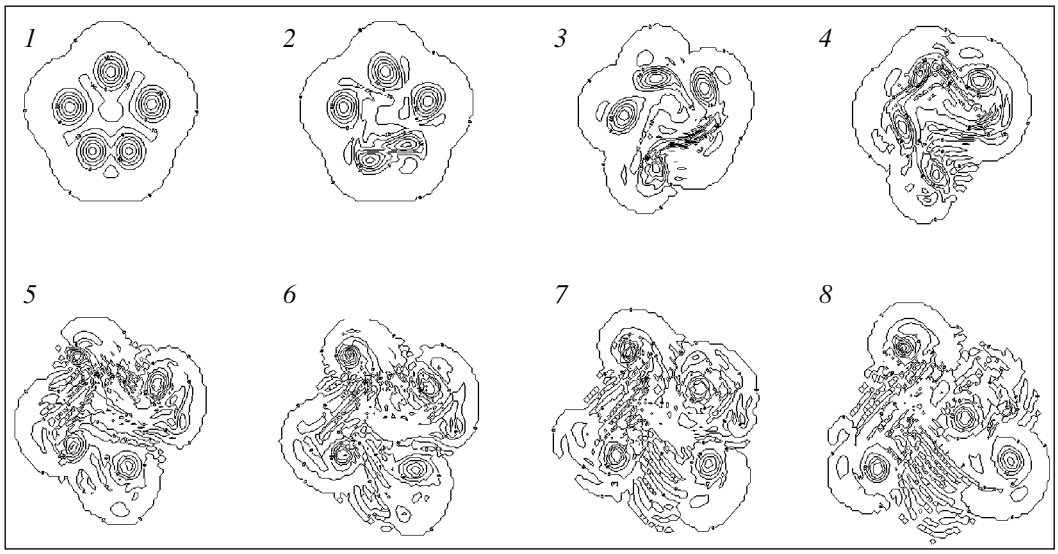

Fig. 2. Evolution of whirls on a 2D model.

at different moments of observation. Thirty satellite images were obtained in 86 min. During that time interval, the eye was 35–40 km across. Each whirl was 10–12 km in diameter. The analysis of observations shows that the system of whirls in the eye of Isabel was gradually transformed and that one out of five whirls began to attract and capture a neighboring whirl (Fig. 1, *1–3*). As a result, a system of four whirls rotating around the center was formed (Fig. 1, *4*). Then, the whirls underwent rather complicated deformations (extension, contraction, and capture of one whirl by another) and three extended whirls were formed (Fig. 1, *8*). Moreover, the transformation of five whirls into four and four whirls into three occurred in time close to the rotation period of whirl systems around the hurricane center.

The system of five whirls rotated around the hurricane center with an average speed of 30 m/s. When a whirl pair merged, the rotation speed of other whirls first increased by 1.5–2 times, then decreased below the average value, and then returned to the average level.

Thus, the motion in the whirl-enclosing layer is far from being stationary. It should be noted that, under certain conditions, the theory of point whirls predicts the unstable rotation of several whirls located in vertices of a regular polygon with the symmetry axis coinciding with the circle center [3].

Numerical experiments on a 2D model [4, 5] with five whirls lying in pentagon vertices helped us to understand the behavior of these structures (Fig. 2).

Comparison of the rotation and transformation of the whirls observed in the Isabel hurricane eye with experiments on the numerical model showed that the whirl behavior in a real tropical cyclone is in general analogous to that displayed in the 2D model; i.e., the system of five whirls transforms into the system of four and then three whirls.

It is not improbable that whirls in the Isabel eye have the axis lying in the horizontal plane. It is these whirls that emerge at the boundary between ascending and descending flows. It is also conceivable that these structures represent toroidal whirls with horizontal or vertical axes (toroids in a certain layer of the atmosphere).

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research, project no. 01-05-64213.

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