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Vortex Cotes's Spiral in An Extratropical Cyclone in the Southern Coast of Brazil

Ricardo Gobato[1]*, Alireza Heidari[2], Abhijit Mitra[3] and Marcia Regina Risso Gobato[1]

[1]*Green Land Landscaping and Gardening, Seedling Growth Laboratory, Brazil.*

[2]*Faculty of Chemistry, California South University, United States of America.*

[3]*Department of Marine Science, University of Calcutta, India.*

***Corresponding author:** Ricardo Gobato, Green Land Landscaping and Gardening, Seedling Growth Laboratory, 86130-000, Parana, Brazil.

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Abstract

An "explosive extratropical cyclone" is an atmospheric phenomenon that occurs when there is a very rapid drop in central atmospheric pressure. This phenomenon, with its characteristic of rapidly lowering the pressure in its interior, generates very intense winds and for this reason it is called explosive cyclone, "cyclone bomb" CB. It was determined the mathematical equation of the shape of the extratropical cyclone, being in the shape of a spiral called "Cotes's Spiral." In the case of CB, which formed in the south of the Atlantic Ocean, and passed through the south coast of Brazil in July 2020, causing great damages in several cities in the State of Santa Catarina, South- ern Brazil. With gusts recorded of 116 km/h, atmospheric phenomenon – CB hit southern Brazil on June 30, the beginning of winter 2020, causing destruction in its influence over. In five hours, the CB traveled a distance of 257.48 km (159.99 miles), at an average speed of 51.496 km/h (31.998 miles/h)27.81 knots, moved towards ENE, with a low pres- sure center of 986 mbar, 07:20 UTC, approximate location 35 ◦ S 45 ◦ W, and 5 hours after 12:20 UTC had already grown and had a low pressure center of 972 mbar, approximate location 34 ◦ S 42 ◦ 30'W. The temperatures of the clouds and the surface near the low-pressure center of the CB. The temperature in the center of the CB is approximately 45 ◦ C at 07:20 UTC, July 1, 2020. Five hours later, at 12:20 UTC, in the low-pressure center of the CB, the temperature varies from 45 ◦ C to -30 ◦ C, indicating that the CB increases in size and further tapers its core, sucking a great amount of steam to high altitudes of water where it condenses quickly.

Introduction

With winds of 100 km/h "explosive extratropical cy- clone" left a trail of destruction in Santa Catarina, Paraná and Rio Grande do Sul, Southern Brazil on Tuesday, June 30, 2020. The phenomenon known as the "cyclone bomb" caused heavy rains, where gusts of wind destroyed houses, caused tree falls, debris and the destruction of the energy network, [9] main Chapecó located 27°06'17"S 52°36'51"W, Santa Catarina, Southern Brazil [10], was the most affected by cyclone.

Tropical cyclones are compact, circular storms, gen- erally some 320 km (200 miles) in diameter, whose winds swirl around a central region of low atmospheric pressure. The winds are driven by this low-pressure core and by the rotation of the Earth, which deflects the path of the wind through a phenomenon known as the Coriolis force. As a result, tropical cyclones rotate in a counterclockwise (or cyclonic) direction in the Northern Hemisphere and in a clockwise (or anticyclonic) direction in the Southern Hemisphere [9,11-15]. The occurrence of cyclones is relatively common for the region at this time of year, but the recent phe- nomenon has been exacerbated by other meteorological and atmospheric factors. This phenomenon, with this feature to lower the pressure inside quickly generates very strong winds and so that name of explosive cyclones [5-9]. For large-scale occurs, the tropical cyclones influence and are influenced by the weather and other atmospheric phenomena

point of view, the call synoptic condition. A very intense circulation of heat and humidity from the North region, with emphasis on the Amazon and Bolivia, increased the occurrence of the cyclone more sharply, reaching Paraguay, Uruguay and northern Argentina, as well as the south-Brazilian coast [15-21].

In mathematics, a spiral is a curve which emanates from a point, moving farther away as it revolves around the point. [1-4] The characteristic shape of hurricanes, cyclones, typhoons are a spiral [5-8]. There are several types of turns and determining the characteristic equation of which spiral the "cyclone bomb" (CB) [9] fits into is the goal of the work.

The Synoptic Letters, from July 1, 2020, at 00:00 UTC and 12:00 UTC, respectively, from Navy Hydrography Center, Brazil's navy [22], show the CB generated a low pressure 976 mbar inside it, 12:00 UTC, generating two atmospheric currents that moved at high speed. In a northwest-southeast direction, Bolivia and Paraguay, crossing the states of Parana and Santa Catarina, and this draft that hit the south of Brazil, which caused the destruction of the affected states. Another moving to Argentina, southwest-northeast direction, due to high area of high pressure (1022 mbar). Both enhanced the phenomenon.

As stated in the introduction the characteristic shape of hurricanes, cyclones, typhoons are a spiral [1-4]. There are several types of turns and determining the characteristic equation of which spiral the CB fits into is the goal of the work. In mathematics, a spiral is a curve which emanates from a point, moving farther away as it revolves around the point. After an analysis of the different types of spirals, it was found that the shape that came closest to the CB spiral, Figure (1), is a "Cotes's Spiral". It was determined the mathematical equation of the shape of the extratropical cyclone, being in the shape of a spiral called "Cotes's Spiral".

Cotes's Spiral" and Conclusions

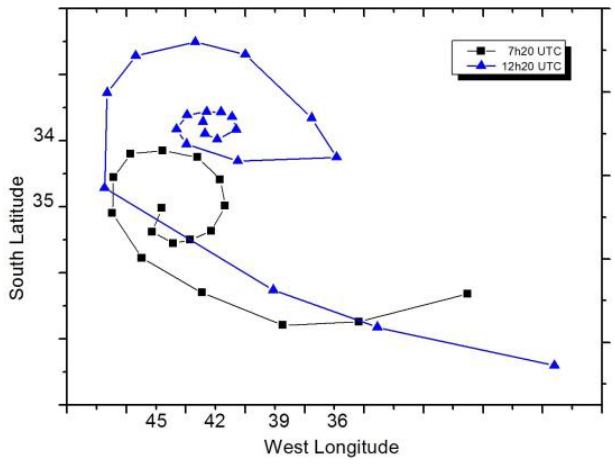

Figure 1: It represents the coordinates of the points collected from Figure (1), in Longitude and Latitude, using The Isobaric [30-31] found in Figures (2) and (3) [Authors].

After an analysis of the different types of spirals [24-31], it was found that the shape that came closest the CB spiral, Figure (1), is a "Cotes's Spiral" [26]. It was determined the mathematical equation of the shape of the extratropical cyclone, being in the shape of a spiral called "Cotes's Spiral" [24-26] A spiral that gives the solution to the central orbit problem under a radial force law (Figure 1)

$$\ddot{r} = -\mu[r]^{-3}\hat{r} \qquad (1)$$

where μ is a positive constant. There are three solution regimes,

$$r = A\sec(k\theta + s),$$

$$\text{where } k^2 = 1 - \frac{\mu}{h^2}, \text{ when } \mu < h^2$$

$$r = A\csc(k\theta + s),$$

$$\text{where } k^2 = \frac{\mu}{h^2} - 1, \text{ when } \mu > h^2$$

$$r = \frac{A}{\theta + s} \qquad (2)$$

when $\mu = h^2$

where A and s are constants, and h is the specific angular momentum [26]. The case $\mu > h^2$ gives an epispiral, while $\mu = h2$ leads to a hyperbolic spiral. Analyzing the shape of the Spiral shape called "Cotes's Spiral." for $\mu < h^2$ [24, 25], it appears that adding two constants to Equation (3) makes the nec- essary adjustments for the Isobaric ones. In the case of CB, the spiral that gives the solution to a radial force law is given by Equation (1): $\ddot{r} = -\mu[r]^{-3}\hat{r};$ where:

$$r = A\sec(k\theta + s),$$

where

$$k^2 = 1 - \frac{\mu}{h^2}, \qquad (3)$$

when $\mu < h^2$

An adjustment in Equation (3) is necessary to obtain the graph of Figure (5). Then, adding the constants

B 0 and *C* where for μ < h.

$$r = BA\sec(k\theta + s) + C, \qquad (4)$$

Where

$$k^2 = 1 - \frac{\mu}{h^2}, \qquad (5)$$

(Figure 2,3)

when $\mu < h^2$

The datas the of of the points coordinates collected from Figure (1), in Longitude and Latitude, They were obtained [22,23,30,31]. With the location of the low pressure center (986 mbar) of the CB at 35◦S 45◦W, at 07:20 UTC, and the low pressure center (972 mbar)

of the CB at 35◦S 42◦30'W, at 12:20 UTC, Figures (1) and (2). In this Figure (5) the shape of the CB is represented, using as a parameter the isobaric ones observed in Figures (1) and (2).

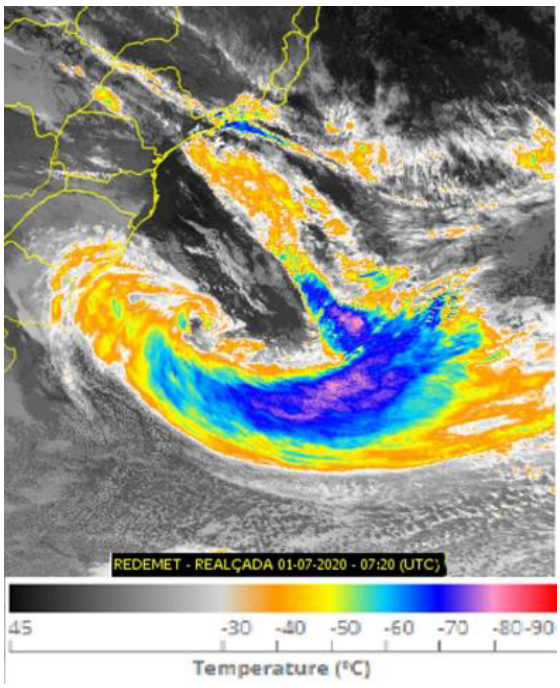

Figure 2: Image of the CB moving to the Atlantic OCEAN. Enhanced Image of cloud Temperature, July 1, 2020, 07:20 UTC, Redemet. (Adapted) [23, Authors]

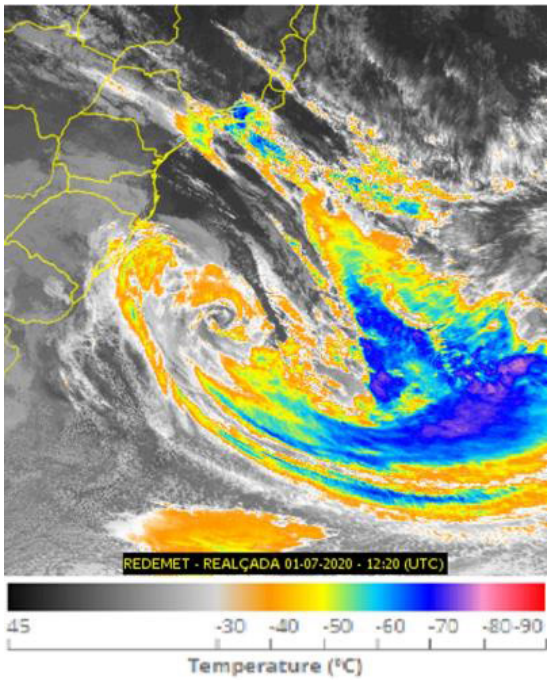

Figure 3: Image of the CB moving to the Atlantic Ocean. Enhanced IMAGE of cloud Temperature, July 1, 2020, 12:20 UTC, Redemet. (Adapted) [23, Authors]

The Figures (2) and (3) show the temperatures of the clouds and the surface near the low-pressure center of the CB. The temperature in the center of the CB is approximately 45ºC at 07:20 UTC, July 1, 2020, Figure (2). Five hours later, at 12:20 UTC, in the low-pressure center of the CB, the temperature varies from 45ºC to -30ºC, Figure (3), indicating that the CB increases in size and further tapers its core, sucking a great amount of steam to high altitudes of water where it condenses quickly.

An "explosive extratropical cyclone" is an atmospheric phenomenon that occurs when there is a very rapid drop in central atmospheric pressure. This phenomenon, with its characteristic of rapidly lowering the pressure in its interior, generates very intense winds and for this reason it is called explosive cyclone, CB [5-9]. It was determined the mathematical equation of the shape of the extratropical cyclone, being in the shape of a spiral called "Cotes's Spiral." In the case of CB, which formed in the south of the Atlantic Ocean, and passed through the south coast of Brazil in July 2020, causing great damages in several cities in the State of Santa Catarina.

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None.

Conflicts of Interest

No Conflicts of Interest.

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