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PRELIMINARY STUDIES ON DIVERSE THEMES

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PRELIMINARY STUDY ON THE CLIMATOLOGICAL CONTEXT OF THE ATMOSPHERE AND THE FORECAST OF TIME.

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Abstract

The understanding of the behavior of the real atmosphere by the human being and the response in terms of weather forecasting from numerical models are difficult to understand. In this preliminary study, Chaos Theory, Euler and Lagrange models, and atmospheric waves are discussed and criticized.

Keywords: weather forecast; Chaos theory; dynamic models; atmospheric waves

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I - Introduction

The behavior of the atmosphere is always considered chaotic whenever the mathematical models present results that do not correspond to the reality. The fact is that these models do not include all the physical mechanisms in the atmosphere. If rivers are sometimes violent it is the total responsibility of the human being, when they are not imposed to these restrictive margins. The errors in the prediction or the simulation of the atmosphere by numerical mathematical models are due only to the failure to include in these models all the laws of nature involved.

Caution should be exercised in attempting to explain atmospheric phenomena based on hydrodynamic equations, since these do not include the physical processes involved. Likewise, when it is suggested that the atmosphere has waves, what we actually do is to use models whose solution is wave to simulate the real atmosphere and in this way to realize that, in many cases, the simulation made is acceptable.

Simulation of the behavior of the atmosphere is commonly done using numerical mathematical models that follow Richardson's propositions made about a century ago and that continue leading to imperfect answers, not because of the nature, but because it is not possible to include in these models all the mechanisms the atmosphere.

II – Is it the chaotic atmosphere, or are the mathematical models incomplete?

The system of non-linear equations of Lorenz (1963) is a classical mathematical model that presents chaotic behavior. This is related to the nonlinear hydrodynamic equations for the description of convection phenomena. It was Lorenz who created the Chaos Theory and considered the differences that the response of a model could suffer from discrepancies in the input data. Thus the system of nonlinear differential equations representing the atmospheric air, provided different solutions between them. Obviously the solutions originated in the intrinsic nature of the system of nonlinear differential equations used and which are extremely sensitive to small variations in the initial state.

A system of nonlinear partial differential equations leads to unstable results, even in deterministic systems that are highly sensitive to perturbations, leading to solutions that are unpredictable (chaotic). Nonlinearity may lead to a random result. In linear systems, whether analytical or numerical solutions, small variations imposed on the initial condition result in small variations in the final solution and thus the answers differ very little, which does not happen in non-linear systems.

The nonlinear equations of hydrodynamics, or linearized from the primitive equations, are deterministic from the point of view of classical mechanics. The equations in primitive form lead to deterministic chaos according to Lorenz (1963). Based on his findings, Lorenz concluded that predictions of climatic phenomena can only achieve a certain degree of accuracy using mathematical equations that take into account the high degree of uncertainty of events. One of the central ideas of this theory is that randomness or random behavior is governed by non-physical laws, and that these can produce different results from slightly different input data.

As opposed to Kalnay's (2003) account of the predictability of real events in just two weeks, this limitation would not be in the chaotic nature of the atmosphere, but in the system of nonlinear hydrodynamic equations. This is therefore a mathematical problem, which always

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leads to the answers to discrepant values for small differences in the initial input data of the Lorenz model (1963). In current models, the deficiency in the mathematical modeling of the relevant physical mechanisms, or even by a limitation of the knowledge of the real state of the atmosphere, it seems that nothing can be done to reach better answers in longer simulation horizons.

In the real atmosphere, it is the physical processes inherent to it and that act to conduct its behavior, which are diagnosed through the observed meteorological parameters. These physical processes combine in a complex way, making it appear that the atmospheric is chaotic. The imperfection of mathematical models is due to a very limited understanding of what is actually occurring in nature. Nonlinear atmospheric mathematical models present more realistic results than linear models, and yet the answers seem chaotic to us, but this is mathematical rather than physical behavior.

A butterfly flapping wings in some part of the world does not bring the atmosphere to a chaotic state, for example, that tornadoes and hurricanes that may be supposed to be a state of atmospheric chaos have a determined cause and only occur in seasons and relatively well defined locations. Thus, the behavior of the Earth's atmosphere does not depend on the human capacity to represent it by mathematical equations, nor is it considered chaotic or not.

Buchmann et al. (1995) indicated that the low energy existence associated with the low frequencies in the atmospheric environment comes from the interaction, dispersion and dissipation of the high energy connected to the high frequencies generated in the atmosphere by impacting meteorological phenomena and not by the ex- of gravity. This, however, would not explain the presence of chaos permanently, but only a temporary disturbance.

III – Comparing the mathematical models of Euler and Lagrange.

Richardson (1922) has shown that the numerical prediction of the atmosphere can be effected successfully from the knowledge and precise definition of the initial state of the atmosphere. The route taken by meteorologists since then has been to filter the initial state variables in order to remove sources of high frequency disturbances such as gravity waves and sound waves.

The basic equations of fluid mechanics that govern physically the movement of atmospheric air are based on the hypothesis of an atmosphere with the following characteristics: diabetic, compressible, nonhydrostatic, moist, with friction and turbulent viscosity. This is a set of primitive nonlinear equations and so an analytical solution is not possible. Two alternatives are presented for the solution of this set: the solution by numerical methods or the solution with restrictions from the physical point of view and use of the perturbation theory. This last proposition results in a hydrodynamic system of linear equations that has as solution a known or estimated analytical function, usually wave type.

The numerical method used to integrate nonlinear equations has the disadvantage of not taking into account the small scale physical interactions that occur between two grid points, representing phenomena that may be occurring in the real atmosphere. Nevertheless in the analytical solution there is a loss of quality of the physical response of the atmosphere due to the absence of the small scale interactions. It should be borne in mind that the nonlinear terms of the primitive equations may play an important role in the physical explanation of what occurs in the real atmosphere.

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By linearization of the primitive equations and using the perturbation theory for a basic state at rest and also the method of separation of variables, we obtain a system constituted by the equations of the horizontal and vertical structures taking into account the boundary conditions (Matsuno, 1966; Kasahara & Puri, 1981). The horizontal and vertical atmospheric modes can thus be evidenced by remembering that the equations of the horizontal structure are equal to the linearized equations of shallow water, finally resulting in wave-like solutions.

The use of linear or nonlinear models for the physical understanding of the atmosphere brings with it physical advantages and disadvantages. In linearized models, the cancellation of the interaction of perturbation products represents loss of realistic information corresponding to the interaction of small scale phenomena. Moreover, the imposition of many restrictions results in the loss of physical content, although there is more possibility of finding an analytical solution known as a wave-like solution. Fewer constraints represent more physical consideration, but there will be sometimes intractable difficulties to find analytical solutions. The advantages and disadvantages add up and end up causing loss in the physics of the model response.

In the case of non-linear models, there is no concern about obtaining ana- lytic solutions, because these are probably not present. Obviously the search for solution by numerical methods leads to loss of quality in the responses of the models. Thus the responses of linear or nonlinear models are often far from realistic because of the absence of physics in the models.

Finally, the atmosphere in its daily evolution is not embedded in mathematical equations. On the contrary, the equations are the means that the meteorology uses in the attempt to represent or to understand and finally to predict the behavior of the atmospheric air.

IV – Are there atmospheric waves?

It can be said that there are no waves in the hydrodynamic equations. We have wave-type solutions. In the spectrum of the wave solutions the so-called Rossby, Kelvin, Rossby-gravity, and gravity waves to the west and east are prominent, but there are other modes of oscillation with amplitudes, frequencies, length, and wave numbers different from those here (Matsuno, 1966, Kasahara & Puri, 1981). These waves may or may not be present in the real atmosphere. What has been used successfully is to associate certain atmospheric behaviors with some types of wave behavior and thus obtain a reasonable predictability. This is done by associating meteorological events with the frequencies of the wave solutions obtained from the linearized equations.

In the atmosphere, if all these waves exist, then these must be present concomitantly (possibly in the form of energy), interacting physically and having the real atmosphere in response. Otherwise, the atmosphere would not be able to recognize these waves by itself.

Kasahara & Puri (1981) have arrived at a set of linearized equations that contains the vertical and horizontal structure. The vertical structure has the function Sturn-Liouville as self-function and the equivalent height (vertical mode) as the eigenvalue of this equation, with the boundary conditions that are used to obtain it. The equations of the horizontal structure are identical to the linearized equations of shallow water, discussed by Loguet-Higgins (1968), with Hough's function as self-function and frequency as eigenvalue, thus inferring the inertia-gravity and Rossby modes. The solution of the Hough function is given by an approximate series of Legendre associated polynomials.

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Kasahara & Qian (2000) use a set of primitive equations linearized around a basic state at rest for their partition in inertia-gravity, Rossby, acoustic and Lamb modes. They considered, for this purpose, less restrictive hypotheses when compared with those of Kasahara & Puri (1981).

Considerations of the hypotheses referring to Kasahara & Puri (1981) and Kasahara & Qian (2000) can be directed to different solutions, aiming to reduce the physical restrictions and to increase the degree of mathematical difficulties to obtain a solution of the wave type .

The existing waves in the solutions of the linearized equation models are not identified in the real atmosphere because there is no identifier or a one-to-one relation between the modes contained in the response function of the model integration and what actually occurs in the real atmosphere.

V - Conclusions

For the so-called "atmospheric chaos" there is no physical explanation, since one has to consider the real atmosphere in disorder. It is not possible to prove that the atmosphere is chaotic for lack of experiments for such. Even Lorenz's (1963) physical explanation, when he said that "the flapping of butterfly wings could generate chaos in the atmosphere," is difficult to prove scientifically from the observational point of view in the real world.

The real atmosphere is not subordinated to the wave solution that theoretical models advocate. It is not possible to identify the existence of waves in the real atmosphere. What has been done is to associate the solutions of the wave type, derived from the linearized models, to the observed meteorological behavior. In this way the atmospheric energy coming from the atmospheric waves would be compromised, because no waves were identified in the real atmosphere.

A possible alternative for a better understanding of what is happening in the planet's atmospheric environment is to consider that the potential energy of the atmosphere is transferred from matter to the environment. That is, the solar radiation incident on the continents and the oceans returns to the atmosphere in the form of infrared radiation, thus establishing an energy imbalance that initiates the atmospheric air movements. In a way this idea is pursued by the parametrizations, but they are not explicitly contemplated in the equations of the traditional mathematical models. Possibly the solution of this impasse would be to insert physical mechanisms existing in the real atmosphere in the equations of the atmospheric models, in order to improve their performance.

Likewise, it is the systemic characteristic of the atmosphere that is not taken into account in the current models. An air particle that forms part of a cyclone will have its movements governed not only by the advection of momentum of the surrounding particles but also by the fact that it is inserted in the cyclonic system.

In weather forecasting centers, nonlinear models are used that take more realistically into the physics of the atmosphere. In an attempt to increase the fidelity of the models to the real atmosphere, we add physical parameterizations that, unfortunately, are not time dependent.

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Joint modeling has been used successfully to improve and increase confidence in the numerical predictions of weather and climate predictions. Moreover, the contour conditions, oceanographic or meteorological, used in climate modeling are prescribed by mathematical formulas based on observations of nature, and much more than describing the behavior of the existing phenomenon, to the detriment of indicate the physical evolution of it.

If the current mode of modeling the atmosphere continues, there will be a moment in the future when, after much effort to fine-tune the performance of the models, almost nothing can be added to the improvement of performance. It is necessary to rethink the mathematical models and, mainly, the physics that simulates the atmosphere in the models, trying to understand and understand better the physical relations of cause and effect that govern the behavior of the real atmosphere.

Although the models can respond reasonably well, from a dynamic point of view, and still far from the observed, this no longer occurs by the physical side of the atmosphere, since they are based on the mathematical equations of hydrodynamics.

A question that remains in the air is: what do researchers such as Lorenz (1963), Kalnay (2003), and others say, to state that nature behaves in a chaotic way? Is it in the physical behavior of the atmosphere or in the mathematics of the equations of the models used?

The aim of this work is to promote the discussion of some concepts, trying to improve the understanding of the atmosphere, from the dichotomy suggested by the title "Atmosphere" versus "Weather Forecast". It is not the goal to demystify the existing models, but rather to stimulate the scientific thinking of researchers in the meteorological sciences, to seek new ways of approaching the physical processes in the models in order to improve their responses. Of course, a greater insertion of physics parameters in the models will increase the quality of the weather forecasts.

VI – References

Buchmann, J.; Buja. L.E.; Paegle, J.N. & Paegle, J. 1995. The dynamical basis of regional vertical fields surrounding localized tropical heating. *Journal* of *Climate, 8*: 1217-1234.

Kalnay, E. 2003. *Atmospheric Modeling, Data Assimilation and Predictability*. Cambridge University Press. UK. 276 p.

Kasahara, A. & Puri, K. 1981. Espectral representation of the three-dimensional global data by expansion in normal mode functions. *Monthly Weather Review*, *109*: 37-61.

Kasahara, A. & Qian, J.H. 2000. Normal modes of a global nonhydrostatic atmospheric model. *Monthly Weather Review, 128*: 3357- 3375.

Longuet-Higgins, M.S. 1968. The eigenfunctions of Laplace’s tidal equations over a sphere. *Philosophical Transactions of the Royal Society of London*, *262A*: 511-607.

Lorenz, E.N. 1963. Deterministic nonperiodic flow. *Journal of the Atmospheric Sciences*, *20*: 130-141.

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Matsuno, T. 1966. Quasi-geostrophic motions in the equatorial area. *Journal of the Meteorological Society of Japan*, *44*: 25-42.

Richardson, L.F. 1922. *Weather Prediction by Numerical Process,* University Press. London. 236 p.