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Contributions from the Second and Third Internal Gravity Modes for the Vertical Motion Response

Contribuições do Segundo e do Terceiro Modos Internos de Gravidade para a Resposta do Movimento Vertical

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Resumo

Uma série de integrações do Modelo Climático do Centro Nacional de Pesquisas Atmosféricas com uma fonte anômala tropical de calor mostra regiões de pronunciada subsidência e de seca localizadas a 3000 km a oeste da fonte de calor em direção aos pólos para casos do Atlântico e do Pacifico leste tropicais aquecidos.

A alta predictabilidade do movimento descendente e estabelecida dentro dos cinco primeiros dias destas integrações. Os modos normais do conjunto de equações primitivas (adiabática) linearizadas com relação ao estado básico em repouso são usadas para a partição da resposta do modelo em modos de inércia gravidade e de Rossby. A mais importante contribuição para a resposta do movimento vertical, advém dos modos de gravidade somados para todos os modos verticais. A principal ênfase e dada para as contribuições do segundo e terceiro modo vertical interno para resposta do movimento vertical.
Palavras-chave: clima; modelagem atmosférica; ondas atmosféricas

Abstract

In earlier papers of a series of real data integrations of the National Center for Atmospheric Research Community Climate Model with tropical heat anomalies display regions of pronounced subsidence and drying located several thousand kilometers westward poleward of the heating for cases of tropical Atlantic heating and tropical east Pacific heating. This highly predictable sinking response is established within the first five days of these integrations. The normal-modes of a set of adiabatic primitive equations linearized about a basic state at rest are used to partition model response into gravity-inertia and Rossby modes. The most important contribution for the vertical motion response comes from the gravity modes added for all vertical modes. The principal emphasis is given upon the contributions of the second and third internal vertical modes (with equivalent depths on the order of a fews hundred meters) for the vertical motion response.
Keywords: climate; global dynamics; atmospheric waves; atmospheric modeling

1 Introduction

A series of earlier simulations using real data were performed with National Center for Atmospheric Research (NCAR) Community Climate Model (CCM) (a set of diabatic nonlinear primitive equations). These studies were developed by Buchmann *et al.* (1986) and Buchmann *et al.* (1995) and Paegle *et al.* (1987), they investigated the teleconnections between tropical-extratropics to heating source anomalies located at the tropical region.

This paper is the second of a two-part follow-up on the investigations summarized above. The other part of this follow-up study (Buchmann *et al.,* 1995) has shown that the subsidence located westward poleward 3000-5000 km from the heating source in the eastern Pacific ocean is caused by the gravity waves.

The purpose of the present study is to explore the dynamical basis of the tropical-extratropical connections noted in our earlier studies (based only in the contributions of the gravity waves).

Buchmann *et al.* (1995) using a simple model instead of NCAR CCM has demonstred that the decomposition of the response in vertical structure function shows that much of it projects upon the second, third and fourth internal gravity modes. Buchmann *et al.* (1995) said that much of the vertical motion response of our NCAR CCM integrations appears to project onto the second and third internal gravity modes. But, this is not proved yet.

The vertical modes of the Australian Numerical Meteorological Research Center (ANMRC) primitive equation model (Bourke *et al.,* 1977) formed the basis for the projection of global data by Kasahara & Puri (1981). The vertical partition shows a peak at the external mode and a secondary peak at the third internal mode.

Section 2 describe the contributions from the second and third internal (westward and eastward) gravity modes for the vertical motion response. Section 3 presents the conclusions.

2 Partitioning Vertical Motion Response into Contributions from the Second and the Third Internal Vertical Modes for the Gravity Modes

The numerical integrations in this section were done with 9-level NCAR CCM truncated at rhomboidal 15, as described by Paegle *et al.* (1987) and Ramanatham *et al.* (1983) have documented characteristics of this version of the NCAR CCM, wich included convective adjustment, solar and infrared radiation, as well as surface drag and heat and moisture fluxes.

The experiments and controls were projected onto the vertical and horizontal structure functions, as done by Paegle & Mo (1988), these functions are obtained by separeting the solution of the adiabatic primitive equations linearized about a basic state at rest see Kasahara & Puri (1981), Kasahara & Qian (2000) and Qian & Kasahara (2003).

The vertical and horizontal structure functions are similar for those used in a normal-modes initialization for filter in especial the gravity-modes with high-frequencies in particular this is made more common at the operational meteorological centers. The heights and the winds are projected onto these vertical and horizontal structure functions at 9 sigma-levels separating the contribution from the external (barotropic equivalent) vertical mode and 2, 3, 4, 5, 6, 7, 8 and 9 internal (baroclinic) vertical modes that constitute a (Sturm Liouville) problem and the horizontal structure function has as solution for each equivalent depth the Hough functions (that are given approximeted as a serie of associated Legendre polinomials). The fields can be recomposed into sigma space for the Rossby, gravity, Kelvin and Rossby-gravity modes separately and added for all vertical modes see (Buchmann *et al.,* 1995), or for each vertical mode separately (but not done yet). These future results will be shown more further in this section. Vertical motions are computed from the continuity equation. The results are analyzed for a level where sigma is equal .5, corresponding approximately to 500 mb over the oceans.

The response of the vertical motion presents three regions of subsidence. Two located westward poleward of the heating and the third region located over South America. Liked with was found by Buchmann *et al.* (1995).

From the normal mode decomposition the influence of the (westward and eastward) gravity modes for the vertical motion response (experiment minus control) at sigma. 5 for selected day 5 is analyzed by the contributions of the external mode, second internal mode, third internal mode and by the sum of all vertical modes. We don’t see much contributions from the external mode and of the second internal vertical mode compared with the sun of all vertical modes for the vertical motion response. The most important contribution comes more from the third internal vertical mode for the vertical motion field when compared with the sum of all vertical modes. The (westward and eastward) gravity modes at day 7 are similar with those found in day 5.

The most extension region of vertical motion response westward poleward of the heating comes from the internal westward gravity modes when compared with internal eastward gravity modes .

These results above match with the hypoteses mentioned by Buchmann *et al.* (1995) about the second and third internal vertical modes that give the most important contributions for the vertical motion response.

Buchmann (2000) studied the contributions from the Rossby and gravity waves related with the sum of all vertical modes for the vertical motion response.

3 Conclusions

The results from the normal-modes decomposition has shown that the most important contribution for the vertical motion response comes from the third internal vertical mode. These results are similar with the hypothesis put forward by Buchmann *et al.* (1995) and Buchmann (1998). In other words the third internal gravity mode is more likely with the sum of all vertical modes for the vertical motion response, than the other modes separately. Silva Dias *et al.* (1983) in his simulation work has been used an equivalent depth on the order of 250 m (correspondent for the third internal vertical mode).

4 Aknowledgments

This research was performed while the author was visiting the U. Utah in the year of 1990 and at the Department of Meteorology of UFRJ in the years of 1991 and 1992. The code for normal mode decomposition is available at the NCAR.

5 References

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