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重力波在中层大气温度波导中的传播模式研究

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摘要 本文给出了重力波在中层大气温度波导中的导制传播模型，并在此模型的基础上详细讨论了重力波部分导制传播下的对称模式与非对称模式，导出了不同模式下相应的特征函数和色散方程，进一步用离散的方法对两类色散方程进行了求解；同时还利用二维全隐欧拉格式（FICE）对重力波在温度波导中的传播进行了模拟，模拟的结果也成功地展现了对称与非对称两种传播模式.研究表明，下边界的扰动能量在向上传播进入波导区域后被俘获，形成导制传播.不同周期的初始扰动，在波导内均会形成对称与非对称形式两种模式的导制传播，由于两者的行进速度不一致，最终会引起两种不同模式的分离.数值模拟中重力波的水平行进速度与线性模型预测值非常接近.波导中不同模式下重力波的水平波长与初始扰动的水平波长非常一致，然而波导区域内重力波的频率与初始扰动的频率无关，频率不同的初始扰动会激发出相同频率的重力波对称与非对称导制传播模式.这表明在确定的温度波导中，水平波数才是决定重力波传播特性的决定因素.进一步的分析显示，初始扰动的水平波数-频率分布越接近完全导制传播的色散关系时，温度波导中更易于生成以该种模式部分导制传播的重力波.

关键词 重力波 中层大气 温度波导 模式分析 数值模拟

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Wave mode analyses of gravity waves propagating in the mesospheric thermal duct

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Abstract A new model of gravity waves propagating in the mesospheric thermal duct is presented in this paper, partially ducted modes of gravity waves in the thermal duct are discussed in detail. Analytic eigenfunctions and dispersion equations of the symmetric and anti-symmetric modes are individually derived, and numerical solutions of these two dispersion equations are also presented. A two-dimensional full-implicit-continuous-Eulerian (FICE) scheme is also used to simulate propagation of ducted gravity waves; numerical results show that symmetric and anti-symmetric waves can be excited simultaneously after the penetration of initial disturbances into duct area. Wave structures of different wave modes would be separated due to their different travelling velocities in the thermal duct. Calculated horizontal group velocities of ducted gravity waves agree well with those derived from the model analyses, and frequencies of these two ducted gravity waves are almost the same, though these waves are excited by disturbance with different initial frequencies. Both model analyses and numerical simulations indicate that character of the gravity wave is primarily determined by the initial horizontal wavenumber in a certain thermal duct.

Key words Gravity waves; Mesospheric atmosphere; Thermal duct; Mode analysis; Numerical simulation

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