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风垂直切变对中尺度地形对流降水影响的研究

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Impacts of vertical wind shear on mesoscale topographical convective precipitation

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摘要 针对长江中下游中尺度地形特点以及暴雨过程发生发展期间风垂直切变的主要观测特征,设计了一系列中尺度地形的三维理想数值试验,分析了干大气地形流和重力波特征,探讨了条件不稳定湿大气地形对流降水的模态分布,在此基础上研究了圆形、直线风垂直切变和切变厚度对中尺度地形对流降水强度和模态分布的影响.结果发现:在 $F_r \approx 1$的干大气条件下,气流遇到地形后分支、绕流和爬升现象同时存在,地形激发的重力波在水平和垂直方向上传播,其在迎风坡、背风坡、地形上游和下游的振幅不同,并组织出不同强度的垂直上升运动.在$F_r > 1$的条件不稳定湿大气下,地形对流降水主要存在三种模态,即迎风坡和背风坡准静止对流降水以及地形下游移动性对流降水,地形对流降水的形成与重力波在低层组织的上升运动密切相关.风垂直切变对地形对流降水的强度和模态分布有重要作用,其中圆形风垂直切变(风随高度旋转)不仅影响地形下游对流降水系统的移动方向,而且影响迎风坡和背风坡山脚处对流降水中心的分布和强度;直线风垂直切变(风随高度无旋转)主要影响地形对流降水的移动速度和强度.风随高度自下而上顺(逆)时针旋转,地形对流系统向下游传播时向右(左)偏移.风垂直切变主要通过影响地形重力波的结构和传播以及对流系统的形成、移动方向和速度,来影响地形对流降水的模态分布,其中对流层中低层的风垂直切变对地形对流降水强度和模态分布有重要影响.

关键词 地形, 对流, 降水, 风垂直切变, 重力波

Abstract: In this study, a set of idealized three-dimensional numerical simulations with mesoscale model are designed to study the impacts of vertical wind shear upon the topographically convective precipitation based on the mesoscale features of topography in the middle-lower valleys of Yangtze River and the main characteristics of vertical wind shear during the rainstorm processes. It is found that the dry airstream will split, flow around and flow over it when encountering a barrier under a condition of $F_r \approx 1$. The topographically generated gravity waves propagate in the horizontal and vertical direction, with different wave amplitude and vertical velocity in the upslope, the lee, the upstream and downstream of the barrier, respectively. Under moist conditionally unstable atmosphere with $F_r > 1$, there are mainly three convective precipitation modes, that is, a quasi-stationary convective precipitation in the upslope and the leeside mountain foot, respectively, and a moving convective precipitation in the downstream. It is also found that the circular vertical wind shear (wind direction changing with height) does not only influence the moving direction of topographical convective precipitation in the downstream, but also affect the intensity and spatial distribution of heavy convective precipitation in the upslope and the leeside mountain foot. The linear vertical wind shear (wind direction not changing with height) mainly impacts the intensity and moving speed of topographical convective precipitation. The topographical convective precipitation systems propagate to the right (left) when the wind veering (backing) with height. The vertical wind shear impacts the topographical convective precipitation distribution by a way of altering the structure and propagation of topographical gravity waves, and changing the formation, moving direction and speed of convective systems, where the vertical wind shear in the middle-lower level exerts an important influence.

Keywords Topography, Convection, Precipitation, Vertical wind shear, Gravity wave

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