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The response to the off-equatorial heating and its influences to the mid-latitudes

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The response to the heating is one of the fundamental problems in Geophysical Fluid Dynamics. A typical example of such a heating in the terrestrial atmosphere is the one over the Bay of Bengal associated with the Indian summer monsoon. This off-equatorial heating, with its centre around 20N, has large influences upon the mid-latitudes. This talk will explore not only the response to the off-equatorial heating but also the influences of the mid-latitude jet and orography on this response obtained with a primitive equation model. In addition, the formation mechanism for the Bonin high with a deep vertical structure that develops near Japan will be suggested in the light of the numerical results.

1. Introduction

The response to the heating is one of the fundamental problems in Geophysical Fluid Dynamics. A typical example in the terrestrial atmosphere is the one over the Bay of Bengal associated with the Indian summer monsoon. This off-equatorial heating, with its centre around 20N, has large influences upon the mid-latitudes. Since this heating is close to the jet and the Tibetan plateau, such influences upon the response must be taken into account.

2. Numerical experiments

We explore the response to the off-equatorial heating and the influences of the mid-latitude jet and orography on the response with a primitive equation model. First of all, the response to the off-equatorial heating in the stationary atmosphere is obtained to confirm that the response in our time-dependent model is similar to stationary solution (the superposition of the responses to the heatings symmetric and anti-symmetric about the equator)by Gill (1980). To the first approximation, the similarities between the upper-tropospheric anticyclone induced to the west of the heating and the Tibetan high implies that the heating over the Bay of Bengal has the primary role in the formation of the general circulation in Northern Hemisphere summer.

Next, in order to understand the role of the jet, the zonally-averaged zonal wind is included in the basic field. Unlike the response in the stationary atmosphere, the vertical motions are induced on the jet and the stationary Rossby wave is excited. The examination of the upper-tropospheric vorticity balance shows that there exist the positive planetary vorticity advection by the northerlies and the positive vorticity generation by the descent such that they balance the negative relative vorticity advection by the westerlies. The jet not only introduces a non-zero westerly wind speed but also the tilt of isentropes. As a result, a vorticity advection and an adiabatic descent are induced to excite the stationary Rossby wave.

In addition to the localised heating and the westerlies, the orography is included to study its influences. The stationary wave found in the experiment without the orography is suppressed in the experiment with the orography. It is found that the thermally induced descent (ascent) and mechanically induced ascent (descent) cancel out.

The Bonin high with a deep vertical structure observed over Japan in August is absent in all the experiments above. Thus, it is also suggested that the cause of the Bonin high exists in the diabatic heating field other than the one over the Bay of Bengal. Numerical experiments are conducted to find which of the Silk Road cooling and the Western Pacific heating is important in the formation of the Bonin high. In those experiments, the Silk Road cooling or the Western Pacific heating is used along with the Bay of Bengal heating, westerlies and orography. It is found that the Silk Road cooling is required to reproduce the Bonin high. By contrast, the Western Pacific heating, which has been considered to have a large impact on Japan, found to have little importance. The Bonin high is reproduced if the Silk Road cooling is included irrespective of the existence of the Western Pacific heating.

The formation mechanism of the Bonin high with a deep structure is as follows. The cooling over the Silk Road induces descents. The upper-tropospheric convergence associated with those descents act to force vorticity and the stationary Rossby wave is excited. The stationary wave propagates along the intensified jet at the northern margin of the Tibetan high (the Silk Road pattern).

3. Summary

We have explored not only the response to the off-equatorial heating but also the influences of the jet and orography on the response. We have also suggested a novel formation mechanism of the Bonin high with a deep vertical structure in the light of the numerical results.