The Role of Upper-level Jet Imbalance in a Gravity Wave of Depression Organized Near Complex Terrain

Abstract

The aim of this work is complementary to the work of Ruppert & Bosart, (2014), to better understand the high-amplitude mesoscale gravity wave (MGW) event of 7 March 2008 which impacted the sensible weather over a large portion of the Southeast United States. Their study suggests that the genesis of the wave of depression occurred near the Texas–Mexico border around 0200 UTC on 7 March as a strong cold front arrived at the foot of Mexico's high terrain and was able to excite a deep gravity wave in association with direct mountain contact. However, our study focuses on the other possibly relevant component in the MGW genesis in response to flow imbalance as air parcels decelerate through the geostrophic jet streak exit region. We investigated whether this upper tropospheric gravity wave energy source was able to communicate with the lower troposphere, in conjunction with terrain impact. We compare our simulations with published and other available observations. Our study hypothesizes that the genesis of the primary, long-lived MGW, which was manifested by a solitary wave of depression associated with rapid sinking motion and adiabatic warming near the lower Rio Grande River Valley, had coupling to the upper levels. This can be evident by the imbalance, defined in terms of flow departure from a balanced or equilibrium state (mainly depicting the degree of cross-jet ageostrophy). Several unbalanced flow diagnostic tools were applied to high-resolution WRF-ARW from a double-nested cloud scale numerical simulation and were used to validate the hypothesis. To assess the role of unbalanced dynamics in the generation of a mesoscale gravity wave (Koch et al., 1999; Kaplan et al.,2011), we used primary metrics, the magnitude of Lagrangian Rossby numbers which suggest that the waves are due to a spontaneous adjustment process (Ramamurthy et al., 1993; Spiga et al., 2008). Additionally, more sophisticated indicators are examined as provided by the large residual of the nonlinear balance equation (Zhang et al., 2000, 2001; Hertzag et al., 2001). The outcomes of this research will further enhance the current understanding of wave genesis, facilitating a more sophisticated comprehension of the mechanisms underlying propagation, amplification, and interaction of the MGW.

References

Hertzog, A., C. Souprayen, and A. Hauchecorne (2001), Observation and backward trajectory of an inertia-gravity wave in the lower stratosphere, Ann. Geophys., 19, 1141–1155.

Kaplan, M. L., Vellore, R. K., Lewis, J. M., & Young, M. (2011). The role of unbalanced mesoscale circulations in dust storms. Journal of Geophysical Research: Atmospheres, 116(D23).

Koch, S. E., & Siedlarz, L. M. (1999). Mesoscale gravity waves and their environment in the central United States during STORM-FEST. Monthly weather review, 127(12), 2854-2879.

Ramamurthy, M., R. Rauber, B. Collins, and N. Malhotra (1993), A comparative study of large amplitude gravity wave events, Mon. Weather Rev., 121(11), 2951–2974.

Ruppert, J. H., & Bosart, L. F. (2014). A case study of the interaction of a mesoscale gravity wave with a mesoscale convective system. Monthly Weather Review, 142(4), 1403-1429.

Spiga, A., Teitelbaum, H., & Zeitlin, V. (2008, September). Identification of the sources of inertia-gravity waves in the Andes Cordillera region. In Annales Geophysicae (Vol. 26, No. 9, pp. 2551-2568). Göttingen, Germany: Copernicus Publications.

Zhang, F., S. E. Koch, C. A. Davis, and M. L. Kaplan (2000), A survey of unbalanced flow diagnostics and their application, Adv. Atmos. Sci., 17, 165–183, doi:10.1007/s00376-000-0001-1.

Zhang, F., S. Koch, C. Davis, and M. Kaplan (2001), Wavelet analysis and the governing dynamics of a large amplitude mesoscale gravity wave event along the east coast of the united states, Q. J. R. Meteorol. Soc., 127, 2209–2245.