UNIVERSITY of HAWAI'I MĀNOA

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M.S. Defense Announcement

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SCHOOL OF OCEAN AND EARTH SCIENCE AND TECHNOLOGY

M.S. Defense Title:

Conditions Favorable for the Occurrence of Trapped Mountain Lee Waves Downstream of O'ahu

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Date: Monday, April 27, 2015
Time: 1:15 PM
Location: IPRC Conference Room, POST 414

Abstract:

The occurrence of trapped lee wave clouds is possible in Hawaii, especially downstream of the island of O'ahu. The Ko'olau and Wai'anae mountain ranges of O'ahu are oriented NW-SE. With a large component of the wind impinging perpendicular to these mountain ranges and the presence of an inversion aloft, trapped lee waves may occur during the wintertime as well as in the summer months. In this study, environmental conditions related to the development of three trapped lee wave events (27 January, 2010—TRAP1; 24 January—TRAP2, 2003; 26 January, 2014—TRAP3) are analyzed using soundings, synoptic charts, satellite images, and high-resolution Weather Research and Forecasting Model (WRF) simulations. All three events are successfully predicted by the high-resolution WRF model. TRAP1 and TRAP2 are initialized with the National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR), and TRAP3 is initialized with NCEP Climate Forecast System Version 2 (CFSv2) output.

Results from a WRF model simulation with a 1-km grid indicate that the trapped lee waves are most significant just beneath the inversion where abundant moisture is present. There are several common factors involved in the occurrence of these trapped mountain wave events: 1) the presence of a well-defined inversion above the ridge tops; 2) abundant low-level moisture; 3) strong low-level winds with Fr > 1 impinging on the mountain ranges; and (4) forward wind shear with increasing wind speed with respect to height. A strong pre-frontal southwesterly flow is the typical synoptic setting for the occurrence of trapped mountain waves in winter, whereas in the summer months the presence of an upper-level disturbance with easterly winds is a necessary prerequisite.

Vertical wind profile is the key element to determine whether trapped lee waves or downslope winds form. None of the favorable wind profiles in winter or summer have critical levels. If a critical level exists in the upper level and wind decreases with height in the low level, a downslope wind storm or mountain wave may occur instead of trapped lee waves.

Sensitivity tests for the 27 January, 2010 case are performed with reduced relative humidity (RH). With lower RH, trapped lee waves have smaller amplitudes and shorter wavelengths suggesting a latent heat release feedback to the environmental flow. The purpose of this study is to determine the synoptic conditions necessary for trapped lee wave development over O'ahu. The study also shows that the high-resolution mesoscale numerical models could possibly provide valuable numerical guidance for the onset, development and dissipation of trapped lee wave events in Hawaii.