University: University of Hawaii

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Partners or Cooperative Project: Partners Project (Period: 06/03/09-09/30/10)

Project Title: Validation of the High-Resolution WRF-NMM/LSM over the Hawaiian Islands

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Section 1: Summary of Project Objectives:

The main goals of this study are (i) to improve the performance of the high-resolution WRF-NMM model by using two-way nesting procedures coupled with the Noah land surface model (LSM) and better land surface conditions; (ii) to evaluate the performance of the WRF-NMM/LSM in an operational setting; (iii) to evaluate the high-resolution WRF-NMM/LSM forecasts statistically; (iv) to conduct model sensitivity tests with different vertical resolutions; (v) to compare the GFS (Global Forecast System) TPW (Total Precipitable Water) within the regional domain with the observed TPW from satellites.

Section 2: Project Accomplishments and Findings:

(a) We have improved the performance of the high-resolution WRF-NMM model by using two-way nesting procedures (Version 3) and better land surface conditions. However, one of the main problems we found is that the land surface properties, such as: land use, vegetation fraction, soil type and coastlines for the inner domains are interpolated from the mother domain even if we have input high resolution land surface data to the inner domains. We didn't find the same problem in WRF-ARW/LSM (For details, please see Section 2(a) of the Final Project Report for S09-75790).

(b) Because of the problem noted above in the nesting procedures, statistical evaluation of high resolution model performance against surface stations for Oahu was made using WRF-ARW/LSM output during a two-month period, June-August 2009. Based on our statistical evaluation, the WRF/LSM's performance for Oahu is comparable to the MM5/LSM model as found by Nguyen et al. (2010).

(c) From model sensitivity tests with different vertical resolutions, it has been determined that higher vertical resolution will improve the representation of the trade-wind inversion in the model. We have set up WRF-NMM with 38 levels and its performance is better than the RSM model by Wang et al. (1998;WAF) which uses only 28 levels.

(d) During the February 19-April 2, 2006 wet period over the Hawaiian Islands, Tu and Chen (2010; WAF) found a close relationship between the temporal variations of TPW and rainfall. Periods with higher TPW had a notable southerly wind component. They also found that for the March 31, 2006 Kahala Flood case, the high resolution K index from the WRF model provided a good forecast guidance for the prediction of areas where heavy precipitation might occur. The KI contains information for both the lapse rate and the moisture at the 850-hPa and the 700-hPa levels with the maximum values along the axis of the warm, moist tongue. The horizontal distribution of KI has a maximum axis along the low-level moisture convergence, which coincides with the axis of the low-level warm, moist tongue. The model predicted horizontal distribution of TPW in the regional domain is in reasonably good agreement with TPW observed by satellites.

(e) Under summer trade-wind conditions, rainfall over Oahu is only slightly larger if the upstream moisture content, measured by RH (%) at the 925-hPa level, is higher with linear correlations of only about 0.1 or less (Hartley and Chen 2010). The other two main large-scale parameters that influence rainfall amount are trade-wind speed and trade-wind inversion height (TWI). Days with high rainfall generally coincide with strong trade winds, but not all days with strong trades produce significant rainfall. The daily trade-wind orographic rainfall and trade-wind speed are weakly correlated with maximum correlation of ~ 0.3 along the ridge tops of the Ko’olau Mountains. Trade-wind cumuli can grow taller when the TWI height is higher. However, not all higher trade-wind inversion days produce more orographic rainfall over the Ko’olau Mountains as the maximum correlation between the daily rainfall and trade-wind inversion height is only slightly greater than 0.2. For a subtropical island of relatively small size, such as Oahu, with ridge tops comparable or slightly higher than the LCL, orographic lifting alone is inadequate for the initiation of precipitation. Pre-existing trade-wind cumuli are needed for the initiation of orographic rainfall over the Ko'olau Mountains. Thus, the use of satellite and radar observations to monitor upstream cloudiness and trade-wind showers is imperative for short-term forecasts of summertime orographic precipitation over Oahu.

Section 3: Benefits and Lessons Learned: Operational Partner Perspective

Recent improvements to the WRF-NMM land surface conditions have greatly improved the output of winds and temperatures near the main Hawaiian Islands. This gives the forecasters more confidence in the output for utilization or model blending in preparation of their forecasts. There have been several cases where the model showed significant skill in forecasting the development and placement of prefrontal convective bands which can bring disruptive rainfall to the climatologically dry and populated areas of the state.

Section 4: Benefits and Lessons Learned: University Partner Perspective

The main benefits to the university are the exposure of students to operational forecasting and better understanding of the forecast challenge in the operational environment. It also informs the students regarding research directions that would benefit NWS operations. Our students attend weather briefings at the NWS forecast office. Nathan Smith worked at the NWS forecast office as a volunteer. Smith did a case study on a rapidly intensifying Kona storm.

Section 5: Publications and Presentations

Nguyen, H. Y.-L. Chen, and F. Fujioka 2010: Numerical Simulations of island effects on airflow and weather during the summer over the Island of Oahu. *Mon. Wea. Rev.*, **138**, 2253–2280.

Hartley, T. and Y.-L. Chen 2010: Characteristics of summer trade-wind rainfall over Oahu. *Wea. Forecasting*, **25**, 1797-1815.

Tu, C. and Y.-L., Chen 2011: Favorable Conditions for the Development of a Heavy Rainfall Event over Oahu during the 2006 Wet Period. *Wea. Forecasting* (In Press).

Jayawardena, S., Y.-L. Chen, A. J. Nash and K. Kodama, 2010: Analysis of an unusual heavy rainfall period over the Hawaiian Islands during 19 February - 2 April, 2006. *J. Appl. Meteor. and Climate* (In review).

Smith, N. P., 2009: Dynamic and thermodynamic contributions to the evolution of a rapidly intensifying kona low. *MS Thesis*, Dept. of Meteorology, Univ. of Hawaii.

Tu, C., 2008: Favorable conditions for the development of a heavy rainfall event during the 2006 wet period. *MS Thesis*, Dept. of Meteorology, Univ. of Hawaii.

Section 6: Summary of University/Operational Partner Interactions and Roles;

The model verification in the operational settings is made by the NWS Honolulu forecast office. Statistical evaluation was done by the UH team. Part (e) is based on Ms. Hartley's MS thesis. She is currently working at the National Weather Service Forecast Office, Eureka, California.