University: University of Hawaii

Name of University Researcher Preparing Report: Yi-Leng Chen

NWS Office: Honolulu

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Type of Project (Partners or Cooperative): Partners

Project Title: Applications of high-resolution weather models to improve weather forecasting over the Hawaiian Islands

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Section 1: Summary of Project Objectives:

The main objectives of this research are (1) to improve high-resolution (with grid size as small as 1.5 km) experimental forecasts using models that properly depict the island terrain and land surface condition over the Hawaiian Islands; (2) to bring the model data to NWS operations as guidance grids within WFO HFO's Interactive Forecast Preparation System/Graphic Forecast Editor (IFPS/GFE) at a 2.5-km resolution; (3) to study recent record-breaking heavy rainfall period during February 15-April 1, 2006; (4) to test the performance of the Weather Research Forecast Model over the Hawaiian Islands.

Section 2: Project Accomplishments and Findings:

(1) We validated the high-resolution MM5 models for the nested Oahu and Maui county domains with a horizontal 1.5-km resolution and 2-km resolution, respectively, using the model output and surface observations from July-August 2004. We also studied the island-scale airflow and weather during the same period. DaNa Carlis of NWS used the high (~2 km) resolution model simulation to study the physical process leading to the development of the Maui vortex in the Central Valley and the effects of diurnal cycle on the island-induced airflow over Maui. He completed his PhD dissertation under the supervision of Dr. Chen. High resolution MM5/LSM experimental runs are conducted once daily (http://www.soest.hawaii.edu/MET/Faculty/mm5/index.html).

(2) We performed daily experimental runs for the Hawaiian Islands using the WRF-NMM model with a 9-km resolution for the State of Hawaii, 1.5-km horizontal resolution for Oahu and Kauai-Niihau, a 3-km resolution for Maui-Molokai-Lanai and Hawaii (http://www.soest.hawaii.edu/MET/Faculty/mm5/WRF/index.html). The daily 9-km resolution run for the State of Hawaii has been added to the numerical modeling suite at HFO.

3) From our test of WRF-NMM for the Hawaiian Islands, we found some problems with WRF-NMM:

a. Domain shift to the SW of the proposed domain configuration.

b. Due to the shift, we have to estimate the i,j coordinates for inner hi-res domains in order to obtain the correct domain configuration.

c. Interpolation of the initial boundary conditions from the GFS model are skewed and cause the inner domain for the Oahu run to display a box-like structure in the 2-m temperature graphics. The same type of structure shows up in the 2-m RH graphics as well. We found that the landmask and land use for the high resolution nested domains are problematic since these data are interpolated from the large-scale domain in WRF-NMM. The box-like structure in the 2-m temperature is caused by the fact that this box is defined as the land area but the enclosed area has a large portion over the ocean. A large portion over land for Oahu is defined as ocean by the landmask. We also run WRF-ARW daily with a 6-km resolution state domain nested in a large-scale domain with a 18-km resolution (http://www.soest.hawaii.edu/MET/Faculty/wrf/arw/) and didn't find the same problem.

d. We cannot run WRF-NMM on 32-bit processors; we can only run on 64-bit nodes.

e. Precipitation is being accumulated every 3 hours, even though we have requested 1-hr accumulated rainfall in the namelist.input file. we fixed this problem by accumulating the precipitation over the entire 48-hr forecast period and writing grads scripts to calculate the 1-hr precipitation.

Because of the above problems, WRF-NMM high resolution runs for the island-scale domains are not very useful at this time. DaNa Carlis is working at NCEP now. He will look into the above problems with our colleagues at NCEP. We are also working with NWS Honolulu Forecast Office on the domain size and grid spacing needed by the forecasters for the State domain and the individual island-scale domains.

4) We are studying the recent record-breaking heavy rainfall period during February 19-April 2, 2006. High-resolution simulations of this record-breaking heavy rainfall period for the Island of Oahu (February 19-April 2, 2006) with a 1.5-km resolution were made by Hiep Nguyen using MM5/LSM, WRF-NMM and WRF-ARW. All three models under-predict rainfall on the leeside of the Koolau mountains with a maximum rainfall axis concentrated on the windward slopes. For the Kohala heavy rainfall event on the leeside of East Oahu in the morning of March 31, all three models failed to capture the localized heavy rainfall. Instead, the high-resolution models all predicted moderate orographic rainfall amount on the windward side. A close study of the evolution of radar echoes shows that this heavy event was caused by the northward movement of an intense thunderstorm that moved onshore from the south and was anchored by the terrain. This intense storm was missed by all three high-resolution models. It is apparent that for this type of event, high-resolution models have their limitations. Data assimilation using

radar and satellite data in the model initial conditions in the mesoscale domains by including pre-existing storms may improve short-term high-resolution model forecasts of this type of event.

Section 3: Benefits and Lessons Learned: Operational Partner Perspective

Forecasters at the National Weather Service in Honolulu were able to view the high resolution WRF-NMM using the AWIPS Display 2-Dimensions (D2D) software, as well as in the Graphical Forecast Editor (GFE) starting in August of 2007. In addition to the boundary-condition problems with the local domains, the state-scale domain of the WRF-NMM does not cover the entire domain of the NWS Honolulu graphical forecast area, so they could not use the raw model fields to populate their forecast grids. There were forecasters who requested that we expand the state-scale domain to cover the entire GFE domain. Otherwise, forecasters could utilize model output and GFE Smart Tools to make significant adjustment to the gridded forecast, when needed. Because of the relatively poor performance of high resolution models over the islands in the past, many forecasters are very skeptical of output from high resolution models. However, the WRF-NMM seemed to outperform the high-resolution RSM model which NCEP runs for the Hawaiian Islands.

Section 4: Benefits and Lessons Learned: University Partner Perspective

The main benefits to the University are the exposure of our students to the challenges faced in operational forecasting and the opportunity to conduct research directly related to problems that are important to forecasters.

Section 5: Publications and Presentations

1. Yang, Y., and Y.-L. Chen, 2007: Effects of terrain heights and sizes on island-scale circulations and rainfall for the island of Hawaii during HaRP. *Mon. Wea. Rev*. (In press).

2. Esteban, M. and Y.-L. Chen, 2007: The impact of trade-wind strength on precipitation over the windward side of the island of Hawaii. *Mon. Wea. Rev.,* (In press)

3. Nguyen, H. V., 2006: Numerical simulations of airflow and weather during the summer over the Island of Oahu. MS Thesis, Dept. of Meteorology, Univ. of Hawaii, Honolulu, HI 96822, 159pp.

4. Yang, Y., Y.-L. Chen and F. Fujioka, 2007: Effects of trade-wind strength and direction on the leeside circulations and rainfall of the island of Hawaii. *Mon. Wea. Rev*. (Accepted with revisions).

5. Carlis, D. L., 2007: Numerical Simulations of Island-scale Airflow and the Maui Vortex Under Summer Trade-wind Conditions. PhD Dissertation, Howard University Press, Washington, DC 20059

Presentations:

1. Chen, Y.-L., 2007: Mesoscale weather analysis and prediction over Hawaii. MMM/National Center for Atmospheric Research, Boulder, CO. July 18, 2007 (invited).

2. Nguyen, H. N. and Y.-L. Chen 2007: High-resolution simulation of heavy rainfall events over the Hawaiian Islands. Pacific Disaster Center/MHPCC, Maui, Hawaii, July 30, 2007.

3. Carlis, D. L. and Y.-L. Chen 2007: Numerical simulations of the diurnal variation of the Maui Vortex and island-scale airflow under summer trade-wind conditions. International Pacific Research Center, Honolulu, Hawaii, February 28, 2007.

4. Carlis, D. L. and Y.-L. Chen 2004: Numerical model validation of summer trade-wind conditions on Maui. 26th Conference on Hurricanes and Tropical Meteorology, Miami, FL 2004.

5. Carlis, D. L. and Y.-L. Chen 2008: Numerical simulations of the Maui Vortex under summer trade-wind conditions. Symposium on the Linkages among Societal Benefits, Prediction Systems and Process Studies for 1-14-day Weather Forecasts, New Orleans, LA 2008.

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

1) Validation and study of the diurnal cycle of island-scale circulation for the Oahu-MM5/LSM model was performed by Hiep Nguyen (a MS student). He completed his MS thesis in December 2006 under the supervision of Dr. Chen. For the Maui county MM5/LSM model, the efforts were performed by DaNa Carlis.

2) The daily MM5 runs are conducted by UH and assisted by DaNa Carlis. The output is viewed by NWS forecasters regularly. The UH team (Nguyen and Chen) and DaNa also have set up the WRM-NMM model for the Hawaiian Islands. With the help of Ross Ishida of the Research Computing Facility of SOEST (School of Ocean and Earth Science Technology, UH), Gloria Fletcher (NWS) and DaNa Carlis brought the daily WRF-NMM 9-km output for the State of Hawaii to NWS AWIP system.

3) An MS student is working on the analyses of record-breaking heavy rainfall period under the supervision of Dr. Chen.