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Application of the NCEP Regional Spectral Model to Improve Weather Forecasting in Hawaii

YI-LENG CHEN[1], Y. ZHANG[1], S.-Y. HONG[2], K. KODAMA[3] and H.-M. H. JUANG[4]

[1]*Department of Meteorology, University of Hawaii, Honolulu, Hawaii, U.S.A.*
[2]*Department of Atmospheric Sciences, Yonsei University, Seoul, Korea*
[3]*National Weather Service Forecast Office, Honolulu, Hawaii, U.S.A.*
[4]*Climate Prediction Center, NCEP/NOAA, Washington, D. C., U.S.A.*

Heavy rainfall and high winds affecting the Hawaiian Islands pose significant hazards to society and constitute special regional forecast challenges. Although significant weather over the Hawaiian Islands is generally associated with synoptic/mesoscale disturbances, heavy rainfall and high wind events are frequently localized in nature because of the present of steep terrain. Rainfall distributions associated with heavy rainfall events usually have large spatial variability related to orographic effects and local winds. Strong local winds associated with orographic effects are frequently undetected by routine National Weather Service (NWS) observations.

The hydrostatic version of the operational Regional Spectral Model (RSM) with a 10km resolution implemented in early 1997 shows improvements over the Global Forecast System (GFS) runs. However, localized heavy rainfall and high wind events are not well simulated by the RSM because the complex island terrain is not adequately resolved by the 10-km horizontal grid. Preliminary applications of the nonhydrostatic version of the RSM (referred to as the Mesoscale Spectral Model, MSM) in Hawaii at high resolutions (≤ 3 km) show improvements over the 10-km RSM in simulating localized heavy rainfall and high wind events. Nevertheless, the MSM poorly resolves the diurnal cycles of temperature and wind within the boundary layer over the Hawaiian Islands due to the fact that the heterogeneous surface properties are not adequately represented by the MSM. In this work, the MSM has been coupled with an advanced Land Surface Model (LSM) with improved lower boundary conditions for three sub-regions of the state of Hawaii: the Hawaii-Maui-Molokai domain at a 3-km resolution, the Oahu domain at a 1.5-km resolution, and the Kauai domain at a 1.5-km resolution.

Our results suggest that (a) over land with adequate representation of the terrain and local boundary conditions at the surface, the coupled MSM/LSM shows improvements over the RSM and MSM in simulating the diurnal heating cycle and the thermally induced island circulations. The daytime cold bias and over-estimation of trade-wind speeds at the surface experienced by the RSM and MSM are largely removed by the coupled MSM/LSM; and (b) the high-resolution (≤ 3 km), coupled MSM/LSM demonstrates substantial improvements over the 10-km RSM in simulating localized heavy rainfall and high wind events over the Hawaiian Islands. Major model bias is that the MSM/LSM tends to over-estimate (under-estimate) precipitation on windward (lee) side of steep mountains.

Keywords: Mesoscale modeling; heavy rainfall; high winds