Orographic Influence on Track Deflection of Tropical Cyclones over Idealized Mesoscale Mountain Ranges

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Mechanisms proposed to explain track deflection of tropical cyclones (TCs) and extratropical cyclones over idealized Southern Appalachian Mountain Range of the U.S. and the Central Mountain Range (CMR) of Taiwan are reviewed briefly and examined by a series of idealized numerical experiments using the Advanced Research WRF (ARW) model and vorticity budget analyses. When a TC is embedded in a uniform, easterly flow and passes over a mountain with a moderate Froude number, it is deflected to the south upstream, moves over the mountain anticyclonically, and then resumes its westward movement. The vorticity budget analysis indicates that the TC movement can be predicted by the maximum vorticity tendency (VT). The orographic effects on the above TC track deflection are explained by: (a) upstream of the mountain, the basic flow is decelerated due to orographic blocking that causes the flow to become subgeostrophic which advects the TC to the southwest, analogous to the advection of a point vortex embedded in a flow. The VT is primarily dominated by the horizontal vorticity advection. (b) the TC passes over the mountain anticyclonically, mainly steered by the orographically-generated high pressure. This makes the TC moving southwestward (northwestward) over the upslope (lee) slope. The VT is mainly contributed by the horizontal vorticity advection with additional contributions from vorticity stretching and the residual term (mainly associated with friction and turbulence mixing). (c) over the lee slope and downstream of the mountain, the northwestward movement is enhanced by asymmetric diabatic heating, making the turning more abrupt. (d) far downstream of the mountain, the VT is mainly contributed by the horizontal vorticity advection.

Effects of landfall location and approach angle on track deflection associated with a TC passing over an idealized and Central Appalachian Mountain are also reviewed and investigated. When the TC landfalls near the northern (southern) tip, it experiences less (more) southward deflection due to stronger (weaker) vorticity advection around the tip. When the TC approaches the mountain range from the southeast and landfalls on the northern tip, center, or southern tip, the track deflections are similar to those embedded in an easterly flow but with weaker orographic blocking. These results are similar to the cases simulated in the dry flow in previous study, except that there is no track discontinuity due to the weaker orographic blocking associated with strong TC convection. When a TC moves along the north-south mountain range from the south, it tends to deflect toward the mountain and then crosses over to the other side at later time. In these cases, the positive VT is influenced by all horizontal vorticity advection, vorticity stretching and residual terms due to longer and stronger interaction with the mountain range. The vorticity stretching is mainly caused by diabatic heating in the moist flow, instead of by lee slope vorticity stretching in the previous study for dry flow. The proposed mechanismThe track deflection toward the mountain for typhoons passing over CMR from the south is similar to the simulated results, thus may be explained by the proposed mechanisms.

The above mechanisms will be further examined by conducting PV budget analysis and sensitivity tests to some key control parameters (e.g., basic-flow and vortex Froude numbers, steepness and mountain aspect ratio). Dynamics of track discontinuity, especially the upstream track looping, remain not well understood, thus will also be explored in the future.