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Orographic Influences on Typhoon Tracks in the Vicinity of Taiwan

Taiwan Island's unique geographical location in the western Pacific Ocean puts itself interacting with, on average, three to four tropical cyclones (TCs) each year. Two thirds of the island is occupied by the Central Mountain Range (CMR), which has high peaks comparable to those in the Colorado Rocky Mountains, only with a significantly steeper topographical gradient. Drawing other TC-relevant connections between the United States and Taiwan is the hurricane-prone island of Puerto Rico. Puerto Rico is a "scaled down" Taiwan in terms of geographic size but has a similar central-mountain-range feature with different orientation (CMR is mostly oriented in west-east direction in Puerto Rico but in north-south direction in Taiwan).

The Central Weather Bureau (CWB), Taiwan's National Weather Service, has identified nine climatologically-based categories of TC tracks which often lead to Taiwan's severe weather events and heavy rainfalls (CWB; FAQ for Typhoon, Fig. 6). The most common ones among these TC tracks either pass over the northern tip of the island or bifurcate the CMR. Terrain affects these TCs well before any rain bands appear over the island and influence their tracks. The unique topography of the island also contributes to vortex shearing which has been shown to break down the TC eyewall at the time of TC landfall. In some cases, the eyewall may reconstruct itself after crossing the terrain, and then intensify again as the TC moves over the Taiwan Strait, for example, Typhoon Fanapi (2010) discussed in Yang et al. (2018). Two typhoon case studies were conducted in this research: Typhoon Maria (2018), which tracked over the northern tip of Taiwan but did not make landfall, and Typhoon Fanapi (2010), the eyewall of which made landfall over Hualien, on the island's central west coast.

Typhoon Maria intensified from a tropical storm in the Pacific Ocean on July 4th, and dissipated on July 12th, 2018, after making landfall in China. The TC was upgraded to super typhoon status July 6th at approximately 00:00 UTC, with maximum sustained winds of 260 km/h. As the TC's wind field came into a range close enough to affect Taiwan, July 10th at 10:12 UTC, super

typhoon Maria had undergone an eyewall replacement cycle and weakened, now with sustained winds of approximately 180 km/h. Using data derived from the National Central University C-POL radar located 25 km south west of Taipei, it was observed that the CMR contributes to effects which enhance precipitation on the windward side and to reduce rainfall on the lee side. An area of enhanced reflectivity was observed where the CMR ridge line tapers to a point at the northern tip of the island, which may have been caused by the terrain, channeling wind flow that focused into an area of convergence which appears in the same location as the TC's rain bands pass by the island.

Due to the steep terrain, which hinders radar beam penetration at various elevation angles, radar sites are needed on all sides of the island for adequate overland coverage and range out to sea. Taiwan has an established a dense network of seven operational radar sites to compensate for blind spots (CWB; Chang 2012). Data, collected by the CWB's S-Band radars RCCG and RCHL, as well as mosaic images compiled from all CWB radar sites, was analyzed to make observations of typhoon Fanapi's track path over the CMR. On September 19th, 2010 at around 03:00 UTC, typhoon Fanapi made landfall over Hualien, on Taiwan's east-central coast. At landfall, the TC had maximum sustained winds of 205 km/h. The TC brought extensive precipitation related flood damage and mass wasting events to the island. Various terrain effects were observed, including the integrity of the eye-wall as it passed over the mountains. Terrain height may have also directly influenced the route that the TC took, as it appeared to follow a steep ridge line of mountain peaks southward, until there was an opportunity for the storm to cross over the island on westward heading. This path coincided with a drop, in mountain elevation, which lead to the TC's eventual exit region on the Chianan Plain and out to the Taiwan Strait.

The goal of this exploratory study was to learn about how and why Taiwan's steep terrain may produce possible track deflections to invading typhoons, as they approach the island from the east or south over the western North Pacific Ocean. Factors which tend to influence how a TC tracks over a mountainous island include the storms size ratio to the island size, environmental Froude number, TC's propagation speed, and thermodynamical stability or Brunt-Vaisala frequency experienced when TC moving directly over the mountain (Lin et al. 1999). The steep slope of Taiwan terrain also introduces certain limitations when collecting radar data around the island; on the other hand, a Doppler radar is an excellent observational platform to detect

important weather phenomena such as a locally enhanced precipitation area, a TC with eyewall replacement cycle, and a TC with multiple eyewalls.

The study took place in Taiwan over a seven-week period from July to August 2018, as part of the Partnerships for International Research and Education (PIRE) project funded by the National Science Foundation (NSF) in the United States and the Ministry of Science and Technology (MOST) in Taiwan. The research was conducted partly in the Convection and Precipitation Laboratory at National Taiwan University (NTU) and partly in the Radar Meteorology Laboratory at National Central University (NCU). The main purpose of this research and educational project for me was to gain international collaboration experience with scientists and professors who were conducting cutting-edge research in their respective fields. Overall, the University at Albany's PIRE project with Taiwan seeks to build extreme weather resiliency and international collaborations, though the improved weather and climate prediction, and the improved emergency response strategies.

Reference:

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