Monitoring the intensity of a hurricane (typhoon) by seismic signals

*Toshiro Tanimoto[1], Anne Valovcin[1], Vala Hjorleifsdottir[2], Felix Rodríguez Cardozo[2]

1. Department of Earth Science, University of California, Santa Barbara, CA93106, USA, 2. Department of Seismology, Institute of Geophysics, UNAM, Mexico

From satellite data, we can learn the location of a hurricane (typhoon) quite accurately. What is hard to get from satellite data is its intensity change and that is why hurricanes hunters (NOAA) still fly into a hurricane to measure pressure and wind near its center. We are exploring an alternative idea of using seismic signals to monitor its intensity change. Our main questions are (i) when a hurricane (typhoon) intensifies, what kind of seismic waves are generated and can be measured on land and (ii) what is the best seismic indicator of an intensifying hurricane?

In this study, we take an example of Hurricane Patricia in 2015 which was the strongest hurricane on record in the eastern North Pacific and North Atlantic basins (Kimberlain et al., 2016). We examine the nature of seismic waves that were excited as the hurricane intensified over anomalously warm waters to the south of Mexico and then reached land near Playa Cuixamala (Oct. 23, 23th hour, UTC). This landfall area was surrounded by many seismic stations from the Mexican National Seismological Service (SSN) which has broadband seismic data (STS-2 type velocity sensors).

We examined temporal variation of power spectral density (PSD) of seismic data for selected 32 stations using the time-frequency plots. The landfall occurred near the center of 32 stations and depending on the distance from the hurricane, we can categorize the characteristics of time-frequency plots into three types, the northern group, the central group, and the southern group. Stations in the central group recorded the time evolution of hurricane intensity most faithfully and for monitoring purposes, we should focus only on these stations. The southern group showed signals from the hurricane but it also showed strong effects of nearby coastal (trapped) waves which made it problematic for monitoring purposes. The northern group seems too far away in general as seismic signals from the hurricane became much weaker.

This hurricane developed from category 1 to category 5 within 24 hours on Oct. 22, 2015, while it was off the coast about 350-400 km; the data in the central group shows a rapid increase of seismic energy around 0.15 Hz (between 0.1 and 0.2 Hz) which matches with intensification of wind speeds of this hurricane. This frequency band is similar to those of secondary microseisms. The integrated power between 0.1 and 0.3 Hz shows a sudden increase of power during the first 6 hours of Oct. 22 and remains at this high level for about a day when the hurricane was the strongest. Seismic amplitudes decay from the coastal stations to the interior, suggesting (obviously) that coastal stations are critical for monitoring purposes.

The data in the central group showed a rapid increase of seismic energy for higher frequencies up to 1 Hz too, although the maximum energy was at about 0.15 Hz. We also noted that there were no significant changes in seismic data below 0.1 Hz.

These observations indicate that we should examine the frequency band from about 0.1 Hz to 0.4 Hz focusing mainly on the stations within about 500 km from the hurricane center. Since the location of hurricane is critical, seismic monitoring has to be conducted together with satellite data.

Keywords: seismic signals from tropical cyclone, Seismic noise, Hurricane and typhoon

