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Seismic Monitoring of Hurricane Patricia

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Recent studies have shown that hurricanes in the ocean generate seismic signals that can allow us to monitor their temporal evolution of their intensity, but we still do not know what kind of seismic data are the best tools in order to monitor a hurricane.

In this paper, 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 record the time evolution of hurricane intensity most faithfully and for monitoring purposes, we should focus only on these stations. The southern group shows signals from the hurricane but it also shows strong effects of nearby coastal (trapped) waves which make it problematic for monitoring purposes. The northern group seems too far away in general as seismic signals from the hurricane becomes much weaker.

This hurricane developed from category 1 to category 5 within 24 hours (Oct. 22) 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 shows a rapid increase of seismic energy for higher frequencies up to 1 Hz too, although the maximum energy is at about 0.15 Hz. Also there are 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.