B207

Assessing Social Impact of Storm Surge and Sea Level Rise Compound Effects in Viti Levu, Fiji

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Introduction

Climate change threatens small island states and the South Pacific region is among the most affected areas. The compounding effects of storm surges and sea level rise (SLR) are among the main hazards of flooding and extreme events [1]. While storm surges often caused by tropical cyclones (TCs) may result in significant temporarily displaced population numbers due to infrastructure damage and flooding, the SLR may alter the coastlines for good and may result in a permanent displacement of the exposed population.

The study focuses on Viti Levu, the biggest and most populous island in Fiji, estimating SLR and storm surge-induced impact on the coast and population.

Methodology

The following datasets were used in the study:

- NASA's Shuttle Radar Topography Mission (SRTM) for topography data
- General Bathymetric Chart of the Oceans (GEBCO) for bathymetry data
- The Gridded Population of the World, Version 4 (GPWv4) data provided by NASA Socioeconomic Data and Applications Center (SEDAC) for population density.

The average wind speed and SLP values were taken from the d2PDF and d4PDF long-term ensemble projections, while the SLR values were taken from the IPCC AR5 reports RCP2.6 and RCP8.5 scenarios.

In addition, IBTrACS database is used for past TCs.

The numerical storm surge modelling uses the governing shallow water equations (free surface η (θ, ϕ) and momentum fluxes P and Q in the latitudinal and longitudinal directions, 1-3).

$$\frac{\partial \eta}{\partial t} + \frac{1}{R\cos\theta}\left[\frac{\partial P}{\partial \phi} + \frac{\partial Q\cos(\theta)}{\partial \theta}\right] = 0\,, \quad (1)$$

$$\frac{\partial P}{\partial t} + \frac{gh}{R\cos\theta}\frac{\partial \eta}{\partial \phi} = -fQ + \frac{\tau_s^{\phi}-\tau_b^{\phi}}{\rho_w} - \frac{h}{\rho_w R\cos\theta}\frac{\partial P}{\partial \phi}, \quad (2)$$

$$\frac{\partial Q}{\partial t} + \frac{gh}{R}\frac{\partial \eta}{\partial \theta} = fP + \frac{\tau_s^{\theta}-\tau_b^{\theta}}{\rho_w} - \frac{h}{\rho_w R}\frac{\partial P}{\partial \theta}, \quad (3)$$

where t is the time, h is the water depth, D is the total depth (D= η+h), P is the atmospheric pressure, R is the Earth radius, f is the Coriolis force, ρ_w is the seawater density (1025 kg/m^3), and g is the gravitational acceleration (9.8 m/s^2).

Estimating inundation scope on the island

Despite being mountainous (86.9% of the territory is located >20 m above sea level), prominent portions of low-lying (<5 m) areas found in the south-eastern, southern, western, north-western parts of (Fig. 1a).

SLR remains an important factor for both 50 yr. and 100 yr. return period (1/100 yr. and 1/50 yr.) storm scenarios. The highest inundation is estimated under the RCP8.5 1/100 yr. storm. In either scenario, the inundated area increases by 48%-91%, compared to the historical climate (Fig. 1 b).

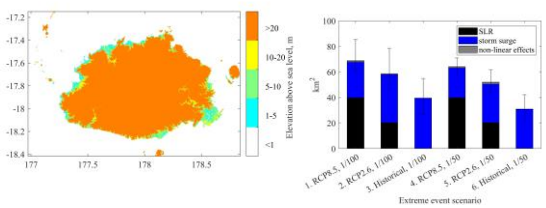

Figure 1. Topography of Viti Levu (a), estimated inundated areas under different storm scenarios (b)

Estimating exposed population on the island

Many low-lying coastal areas also has a higher population density (Fig. 2a), exceeding a relatively sparse national population density (48.6 /km^2) several times. The results show that the western coast of Viti Levu is the most vulnerable. The estimated directly exposed population is estimated at 2,450-6,958 for the 1/100 yr. extreme event and 2,420-5,150 for the 1/50 yr. extreme event. These are larger numbers than under historical climate conditions (Fig. 2b).

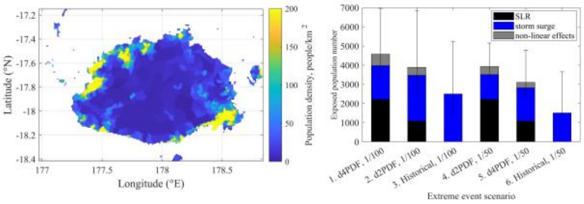

Figure 2. Population density map (a), estimated exposed population under different storm scenarios (b).

Historical TCs records and tendencies

96 typhoons that have passed over in the proximity to Viti Levu of at least 3° radius were tracked between the 1978 and 2021 typhoon seasons. While their average minimal central pressure has been 966 hPa, the most intense storms were below 920 hPa (Fig. 3).

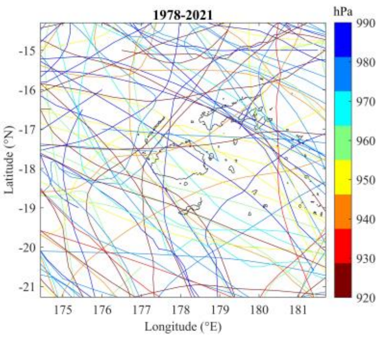

Figure 3. TC tracks in the proximity to Viti Levu.

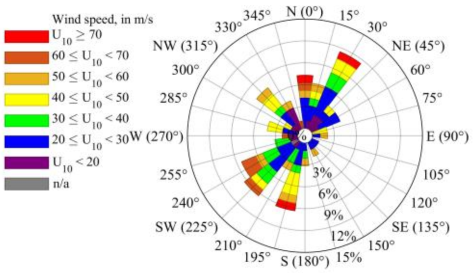

Figure 4. TC frequency and strength by angle.

More than one in nine TCs have approached the island from the 30° angle. The strongest TCs exceeded 70 m/s of speed. The most intense and strongest cyclones tend to come from this angle, as well as 0° and 195° angles (Fig. 4). Some recorded TCs exceed the estimated 1/100 storms for the future climate.

Conclusions

Future compound effect-related inundations may directly affect up to 0.4-1.16% of the island population. The number exceeds the numbers for the storms under the historical climate conditions (0.25-0.87%). 0.18-0.36% of the population may become permanently displaced. These numbers are significantly lower than the Internal Displacement Monitoring Center records [2]. However, this can be explained by a more conservative approach regarding the 'exposed population' used in this study.

Winds blowing from the west are the most devastating for the Viti Levu Island. Meanwhile, the IBTrACS records show the northwestern cardinal direction to be the most common angle for the TCs. A northwestern direction is also common, but it does not have records of extreme TCs since 1978. Furthermore, it is important to note that TCs have a tendency to enter the island in multiple directions, while the numerical model assumes a single direction and constant wind speed.

References

[1] Little, C.M. et al., "Joint projections of US East Coast sea level and storm surge," *Nature Climate Change*, vol. 5, pp. 1114-1120, 2015.

[2] Internal Displacement Monitoring Center (2020). Fiji. Available online at: https://www.internal-displacement.org/countries/fiji (accessed January 19, 2021)