WHAT DRIVES EXTREME EVENTS? EVALUATING THE MAJOR CONTRIBUTORS TO TOTAL WATER LEVELS ALONG THE U.S. ATLANTIC COAST

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INTRODUCTION

The combination of waves, tides, and non-tidal residuals determines the magnitude of total water levels (TWLs) at the coast. As the magnitude of extreme TWLs dictates flooding and erosion potential, understanding the relative contribution of individual processes to these events can provide insights into how changes to the wave climate, sea level, and storminess may affect extreme TWLs now and in the future. Here we evaluate the relative contribution of hydrodynamic processes to extreme TWL events to better understand the spatiotemporal variability of coastal flooding and erosion drivers along the Atlantic coast of the United States (U.S.).

METHODS

In this study, TWLs are defined as the linear superposition of measured still water levels (SWLs) from the National Oceanic and Atmospheric Administration (NOAA) water level stations and wave runup. SWLs result from the combination of astronomical tide and nontidal residual. The nontidal residual can be further split into mean sea level, which includes long-term and interannual variability, seasonality, and storm surge, a high-frequency component related to barometric pressure and wind setup.

Seasonality is computed by using a regression model that includes annual and semi-annual harmonics fitted to de-meaned and de-trended monthly SWLs. Mean sea level is calculated by applying a 15-day moving average to SWLs once seasonality is removed, and thus, it includes the relative sea level trend as well as variability related to climate oscillations. After removing seasonality and mean sea level from the original SWL time series, the remaining data is overlapped in two-year blocks, and transformed into the frequency domain, in which a spectral filtering method is implemented to remove the tidal signal from storm surge (Bromirski *et al.*, 2003; Serafin *et al.*, 2017). The astronomical tide is deterministic and computed using the NOAA station's harmonic constituents. The wave runup is estimated from an empirical model (Stockdon *et al.*, 2006) as a function of deep-water wave conditions, extracted from the Global Ocean Waves reanalysis dataset version 2.0 (Peréz *et al.*, 2015), and beach slope, which is averaged from alongshore transects from the U.S. Geological Survey Lidar-derived beach morphology (Doran *et al.*, 2017).

Extreme TWL events are defined using an annual maxima approach (Gumbel, 1958). The relative contribution of the individual processes driving extreme TWL events at each station is analyzed, and we use a non-stationary generalized extreme value distributions to assess the statistical significance of the drivers of extreme TWLs by including the different components as model covariates.

RESULTS

The average absolute magnitude of extreme TWLs varies across stations, ranging from 3.6m - 5.0m. Wave runup and tides are the overall main drivers of extreme TWLs along the U.S. Atlantic coast (Figure 1). The contribution of wave runup is spatially variable, where wave runup predominance generally increases from south to north, associated with higher significant wave heights and smaller tidal contribution during extreme TWLs, like in Montauk, New York (NY), Virginia Beach, Virginia (VA), Duck, North Carolina (NC), and Beaufort, NC. Storm surge is the third largest contributor to extreme events, and its contribution is higher at the mid-north stations, from Beaufort, NC to Atlantic City, New Jersey (NJ), where the main tracks of extratropical storms typically cross the North Atlantic (Camus *et al.*, 2022). The largest mean sea level contributions are not necessarily associated with the largest sea level rise trends. The contribution of the seasonal signal, while small, contributes to extreme TWLs at southern stations more than at northern stations.

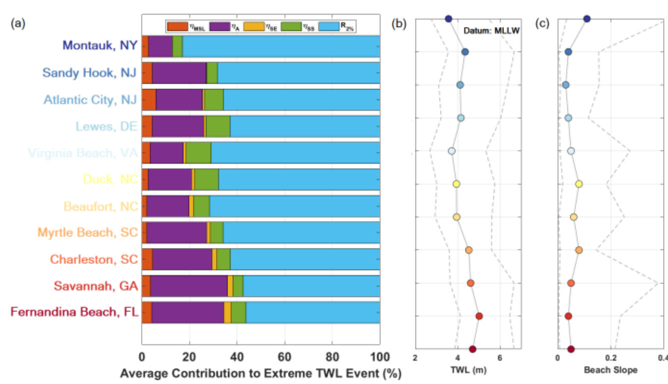

Figure 1 - Average relative contribution of individual components to extreme TWL events, where mean sea level (η_{MSL}) is represented by orange, astronomical tide (η_A) is represented by purple, yellow corresponds to seasonality (η_{SE}), green is storm surge (η_{SS}), and blue is wave runup ($R_{2\%}$) (a). Average magnitude (circles) and range (dashed grey lines) of extreme TWLs (b), and beach slope (c) across the Atlantic coast of the U.S.

Preliminary results from the non-stationary extreme value analysis support wave runup and tides as the main drivers of extreme TWLs for most locations; including these processes as covariates in the extreme value models increased the goodness-of-fit (0.05 significance level) when compared to the stationary model. Storm surge is also a statistically significant driver of extreme TWLs, which suggests that it plays a major role in producing extreme TWLs, although its contribution is not as large as for tides and wave runup. Evaluating how individual processes combine to drive extreme TWLs will help to interpret where future changes to the global climate may most drastically affect regional coastal flooding and erosion.

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