Local-scale Water Level Differences and Meteorological Drivers in Annapolis, MD

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RESEARCH OBJECTIVES & SUMMARY

(1) Quantify differences in water levels measured in the Severn River at the NOAA Tide Gauge, USNA (ID 8575512) and at City Dock, Annapolis, MD.

(2) Investigate how local-to-synoptic scale meteorological forcing drives observed differences in water levels.

BACKGROUND AND MOTIVATION

Coastal nuisance flooding can adversely impact coastal infrastructure and local economies (*Hino et al., 2019*). Coastal nuisance flooding is a complicated function of relative sea level, astronomical tides, meteorological forcing, and geomorphology of the coastline, making it challenging to predict. Increased coastal development and rising global mean sea level (GMSL) exacerbates impacts of nuisance flooding, especially in coastal communities currently at-or-around sea level, like Annapolis, MD (*MCC, 2018*).

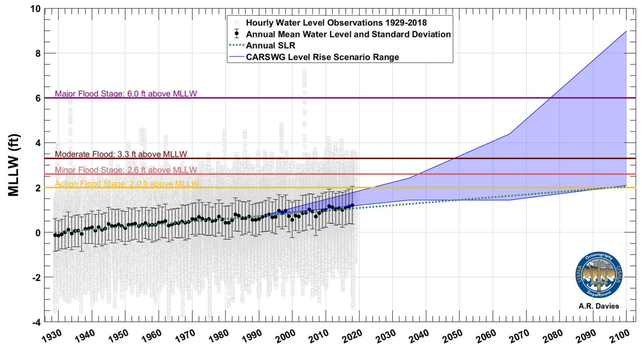

Figure 1. Annapolis, MD hourly (light grey) and annual mean (black dots with stdev.) water levels MD from 1929 to 2018 showing a linear rise in sea level. Plausible future water level scenarios shown for 2035, 2065 and 2100 from the Coastal Assessment Regional Scenario Working Group (*CARSWG; Hall et al., 2016*).

The City of Annapolis, MD, where the U.S. Naval Academy (USNA) is located, has a developed urban waterfront that is important to the local economy. The frequency and duration of nuisance flooding events in Annapolis has increased since 1929 (**Fig. 1**; **Fig. 2a**) and is expected to continue to increase as GMSL continues to rise. A better understanding of the drivers forcing local-scale coastal nuisance flooding are required for Annapolis City decision makers to plan for these events.

Figure 2. (**a**) City Dock, Annapolis during a nuisance flooding event in February, 2018 (Photo Credit: Mr. Luis Rodriguez, USNA Oceanography Dept.) and (**b**) Midshipman 1/C George Davis by the USNA Severn River Watershed Observatory at Hendrix Oceanography Laboratory.

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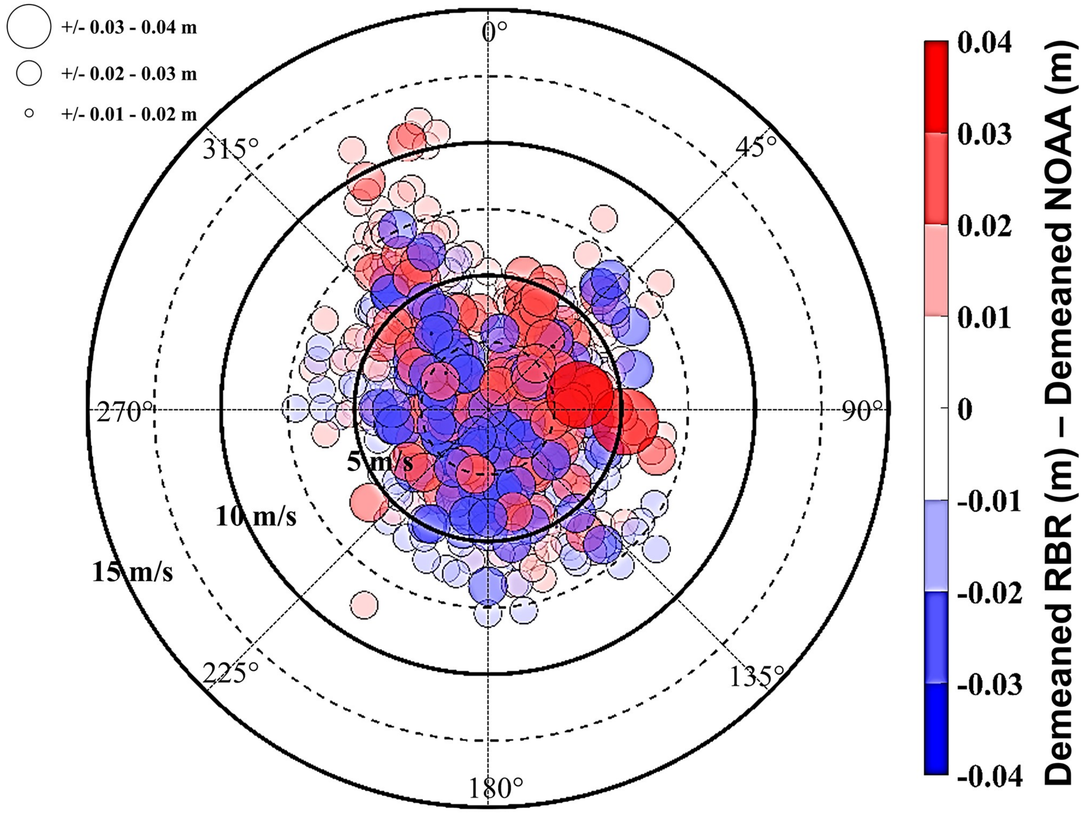

Figure 5. Water level anomaly differences (m) between the demeaned RBR water levels at Annapolis City Dock and demeaned water levels in the Severn River reported at the NOAA Annapolis tide gauge (ID 8575512) from 10 May 2018 - 20 January 2019 plotted against wind direction (degrees) at the time of observation. Data is scaled by color (blue = lower water levels observed at City Dock; red = higher water levels observed at City Dock) and symbol size (larger symbols indicates a larger difference between observed water levels). Solid rings represent wind speed in 5 m/s intervals. Water level difference below one standard deviation (< +/- 0.01m) were considered insignificant.

METHODOLOGY AND APPROACH

Water levels were measured at City Dock, Annapolis, MD from 10 May 2018 - 20 January 2019 using a RBR Solo pressure sensor sampling at 1 Hz. Pressure observations were temporally-averaged to 1-hour intervals as were the 6-minute water levels of the Severn River reported by the NOAA Annapolis Tide Gauge located within Hendrix Oceanography Laboratory (HOL), USNA (**Fig. 3**). Absolute water pressure (dbar) observations were converted to water levels (m) via the hydrostatic equation using atmospheric pressure and density calculated from salinity, temperature, and pressure, all measured at the USNA Severn River Watershed Observatory (SRWO) at the HOL (**Fig. 2b**). Water level comparisons were made by de-meaning hourly RBR Solo pressure measurements and NOAA water levels to a monthly-running mean. Pressure data from the RBR Solo near times of data collection, known sensor problems, and senor re-deployment were removed. Local meteorological data (wind speed and direction) were collected by SRWO and the NOAA KNAK weather station at USNA (**Fig. 3**). Meteorological data was temporally-averaged to match the water level data.

Figure 3. Map of study area in Annapolis, MD near USNA and Annapolis City Dock. Triangles mark the locations for meteorological data collection and circles mark the locations of water level and/or water pressure measurements. Blue symbols indicate NOAA data collection locations while red symbols indicate USNA Oceanography Department sensor deployments (e.g. SRWO). The RBR Solo pressure sensor was deployed at a fixed depth on a piling at the City of Annapolis Harbormaster slip in City Dock, Annapolis, MD.

RESULTS AND DISCUSSION

Results show positive and negative water level anomaly differences between City Dock and the Severn River throughout the data record spanning 10 May 2018 to 20 January 2019 (**Fig. 4a**). In general, water level differences ranged up to a maximum of +/- 0.03 meters. There was no apparent trend in water level differences with respect to tidal phases. Rather, water level differences typically persisted over multiple days, suggesting a relationship with synoptic scale wind forcing that varies on similar time scales (*Sweet et al., 2014*; **Fig 4b**).

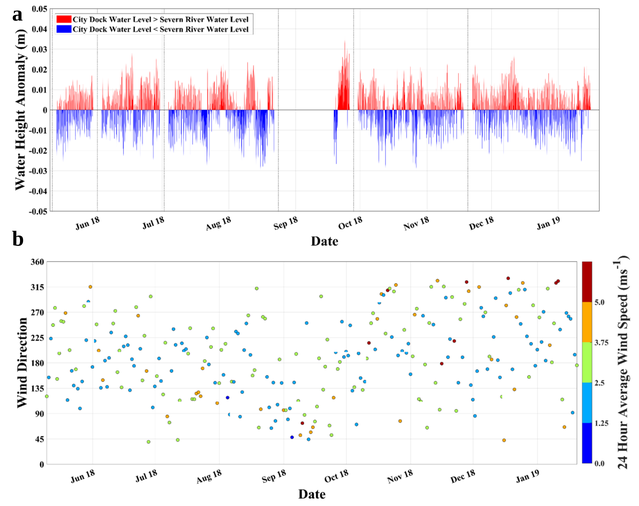

Figure 4. (**a**) Water level anomaly differences (meters; blue = lower water levels at City Dock; red = higher water levels at City Dock) between demeaned RBR water level calculations at Annapolis City Dock and demeaned water levels in the Severn River reported at the NOAA Annapolis tide gauge. (**b**) Daily averaged SRWO wind speed (m/s) and direction (degrees) from 10 May 2018 - 20 January 2019. Gaps in SRWO data were filled by the KNAK ASOS Station (**Fig. 3**).

From 10 May 2018 - 20 January 2019 there were 8,521 coincident data points between the RBR sensor (City Dock), water level (NOAA Annapolis Tide Gauge), and meteorological (SRWO) observations. The highest positive differences in water levels between City Dock and the Severn River tended to coincide with winds from 90º ±15°(**Fig. 4 & 5**). In contrast south-to-southwesterly winds often resulted in negative differences (**Fig. 4 & 5**). Results suggest observed differences in water levels may be a result of complex interactions between tides, local geomorphology and metrological forcing.

CONCLUSIONS AND FUTURE WORK

- Observed water level difference anomalies between City Dock, Annapolis and Hendrix Oceanography Laboratory, Severn River differ up to a maximum of +/- 0.03 meters
- Significant water level differences between the two sites often persisted over multiple days consistent with local-to-synoptic scale wind forcing
- Research will continue to investigate the interaction between factors that impact coastal nuisance flooding in Annapolis and other urban environments.

REFERENCES

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