



Comparison of Relative Water Levels at the U.S. Naval Academy and Annapolis City Dock in Response to Local Meteorological Forcing Conditions



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Abstract

Continuous water levels measurements were collected at City Dock, Annapolis, MD from 10 February – 05 March 2018 and compared to those collected at the National Oceanic and Atmospheric Administration (NOAA), National Ocean Service’s (NOS) Center for Operational Oceanographic Products and Services (CO-OPS) Annapolis Tide Gauge, (Station ID: 8575512) located at Hendrix Oceanography Laboratory (HOL) at the U.S. Naval Academy (USNA). Data was collected over the same time period to investigate differences in recorded water levels between the two locations. Meteorological data from a local, custom weather station (Onset HOBO) was used to identify potential forcing conditions that could explain noted water level differences between these two sites. Results will be used to identify conditions where there may be a higher (or lower) risk of nuisance flooding at Annapolis City Dock than what can be predicted using the NOAA water level data measured at USNA.

Study Area and Methods



Figure 1. Map of study area in Annapolis, MD. Triangles mark the location of the NOAA tide gauge (black); the Onset HOBO weather station and water level sensor (green); and the RBR-Solo water level sensor. Map inset from U.S Geological Survey (2018).

In addition to water levels observations made by the NOAA tide gauge located in HOL, water levels were measured from 10 February – 05 March 2018 at Annapolis City Dock using an RBR-Solo water level sensor (1 sample/second) and near the USNA Visitors Center using an Onset HOBO water level sensor (1 sample/minute) **Fig. 1** shows deployment locations. The HOBO water level sensor was co-located with an Onset weather station that recorded wind direction, wind speed, air temperature, and precipitation. **Fig. 2** shows instrument set-up and deployment, and an example of a nuisance flooding event at City Dock during this study. For analysis, all observations were hourly averaged and demeaned to show differences with respect to the mean water level at a given location which allows for direct comparison.

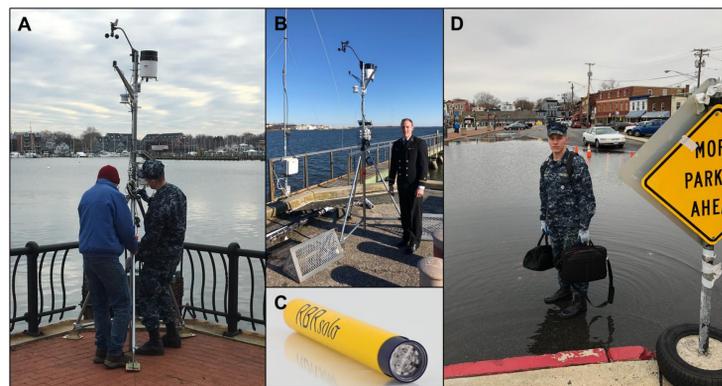


Figure 1. (A) MIDN 1/C Spalding and Mr. Andrew Keppel setting-up the Onset HOBO weather station and water level sensor; (B) MIDN 1/C McGrath next to the Onset HOBO weather station; (C) RBR Solo water level sensor, and; (D) MIDN 1/C McGrath standing in the flooded street at City Dock, Annapolis during a nuisance flooding event.

Results

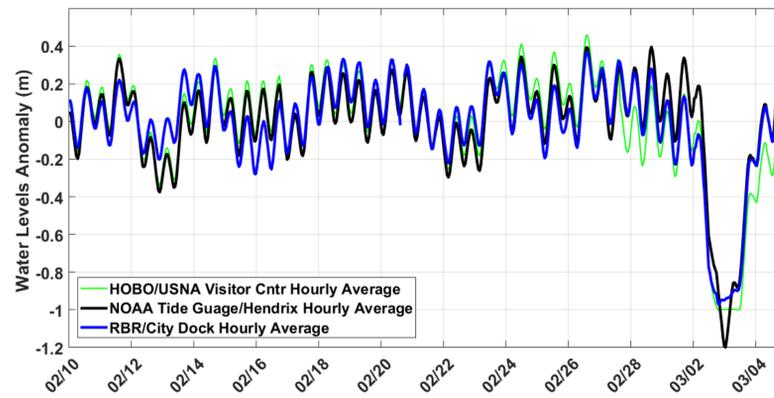


Figure 3. Hourly averaged water levels (m from mean water level) measured at the NOAA tide gauge (black line), the RBR-Solo water level sensor at City Dock (blue line), and the Onset HOBO water level sensor on the USNA Yard (green line).

Fig. 3 shows the hourly averaged water levels (m above/below mean water level) measured at each location from 10 February – 05 March 2018. The timing of low and high water at each site is generally the same but the relative water levels measured between stations varied over the course of the study. Some high water levels recorded at City Dock were higher than the corresponding high water levels recorded at the NOAA tide gauge and Onset station, others were lower. A similar variation is seen in low water levels, with some lows measured at City Dock being higher and some being lower than those measured at the other sites. **Figs. 4a** and **4b** shows the difference in the measured water levels between the RBR sensor at City Dock and the Onset HOBO logger and the NOAA tide gauge, respectively.

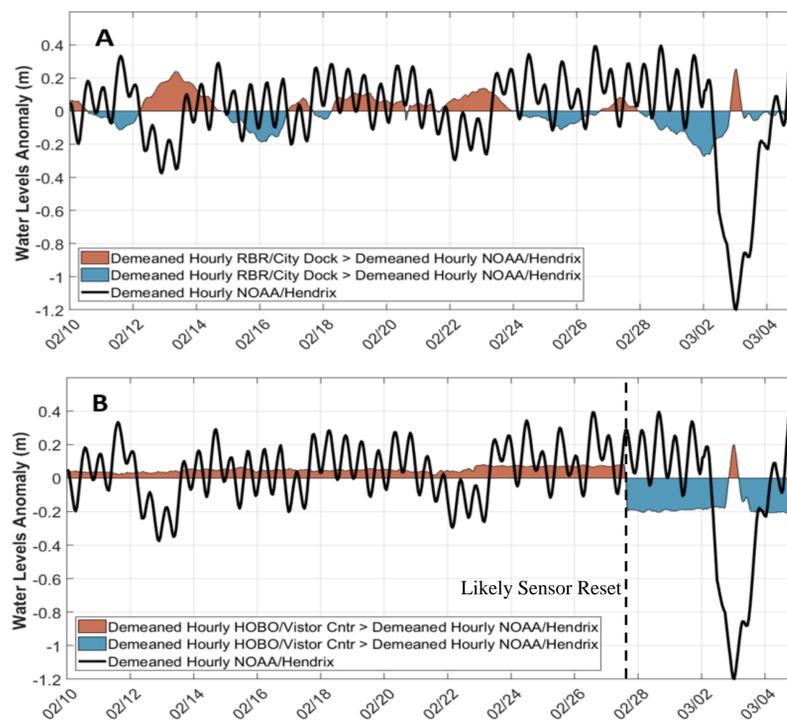


Figure 4. Observed differences in the demeaned hourly averaged water levels measured at the NOAA station and: (A) The RBR Solo water level sensor at City Dock and (B) the Onset HOBO water level sensor on the USNA Yard. Red shaded areas indicate times when the remote station levels were higher than those measured at the NOAA tide gauge and blue shaded areas indicate times when they were lower. Hourly NOAA tide gauge water levels are shown by the black line as a reference.

Discussion

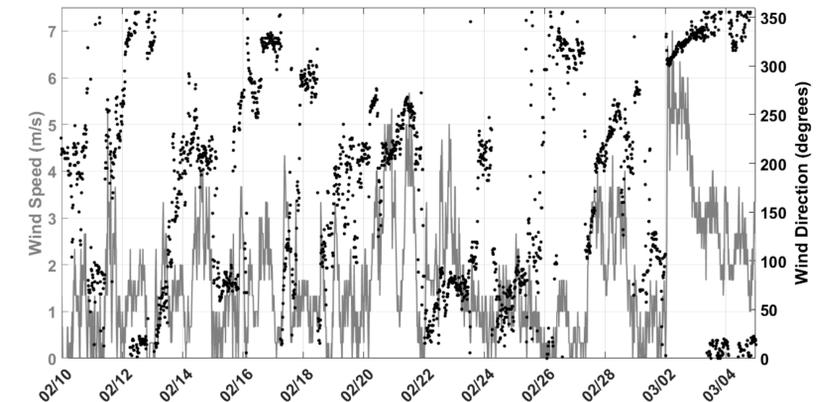


Figure 5. Wind speed and direction measured by the HOBO Onset from 10 February through 05 March.

The preliminary results suggest that synoptic-scale wind forcing (**Fig. 5**) likely explains the observed water level differences between City Dock and the NOAA tide gauge in the HOL. Higher and lower high low water levels and higher and lower low water levels observed at City Dock appear to be related to the wind direction and vary on the meteorological synoptic scale. While more research is required to establish and quantify this relationship, this result could potentially help explain discrepancies between water level forecasts/observations centered upon the NOAA tide gauge location and the flooding experienced at City Dock. Multiple nuisance flooding events occurred during this study, some related to storm events passing the region. The largest of these events occurred during a Nor-Easter on 02-03 March 2018 which resulted in both anomalously high and low water levels. Precipitation (**Fig. 6**) and localized integrated runoff may also explain some of the differences, but our results suggest wind forcing is the primary driver.

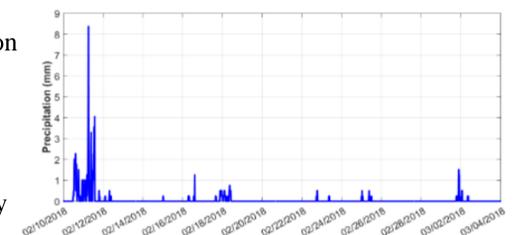


Figure 6. Precipitation measured at the Onset weather station from 10 February – 05 March 2018.



Figure 7. Picture of City Dock during a nuisance flooding event in October 2017 (Belt, D. Annapolis Patch, 2017. Annapolis Streets Flooded Tuesday; Flood Advisory Until 2 AM: <https://patch.com/maryland/annapolis/annapolis-streets-closed-severe-flooding>, accessed 03 January 2018.)

Conclusions

- Water levels measurements collected from 10 February – 05 March 2018 showed differences in the relative high and low water levels at City Dock, Annapolis, MD as compared to those collected at the NOAA/NOS/CO-OPS Annapolis tide gauge at the USNA
- Synoptic-scale wind forcing is likely the primary factor contributing to the observed differences in water levels
- Future research will better quantify the observed water level differences and the factors contributing to nuisance flooding at City Dock, Annapolis, MD (**Fig. 7**)

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