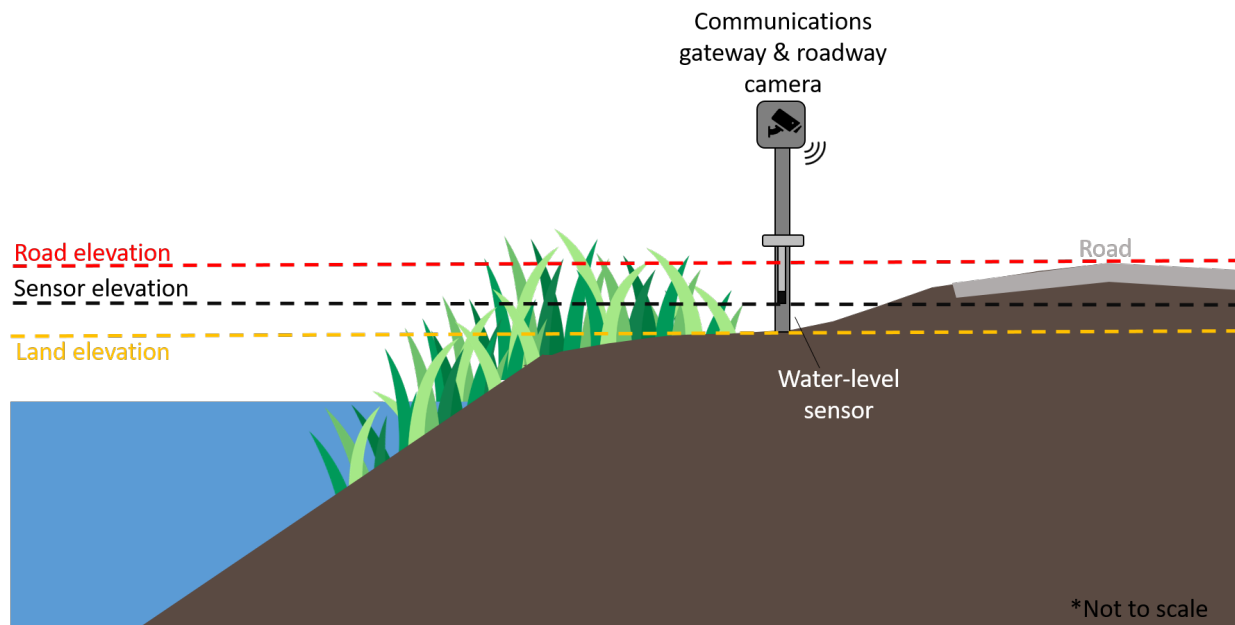
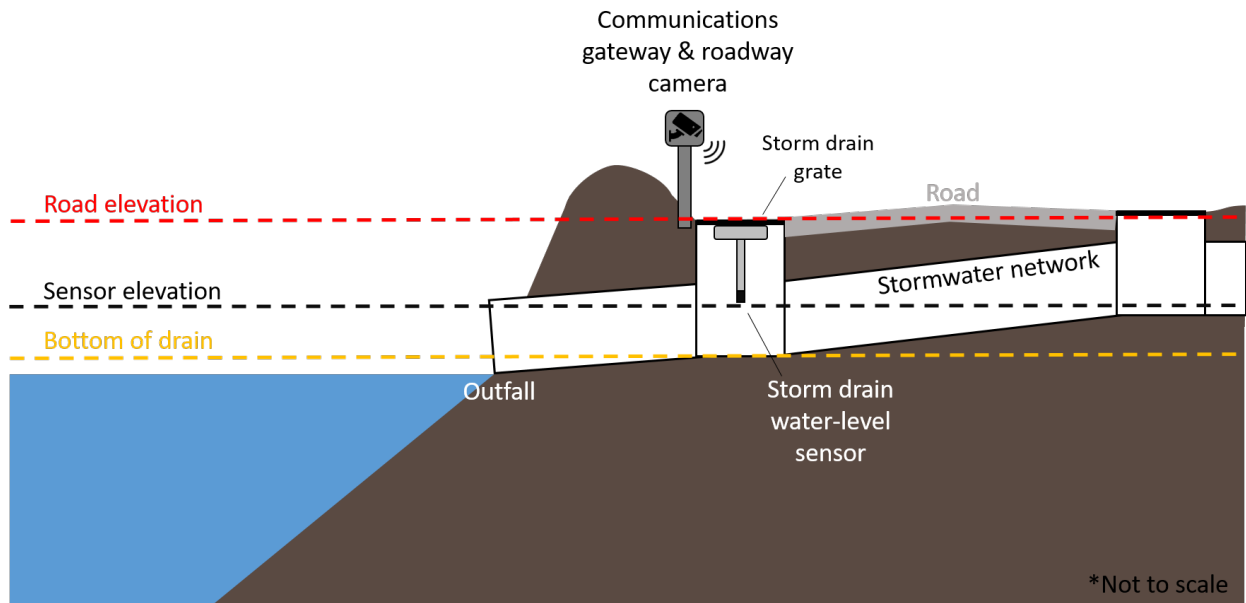
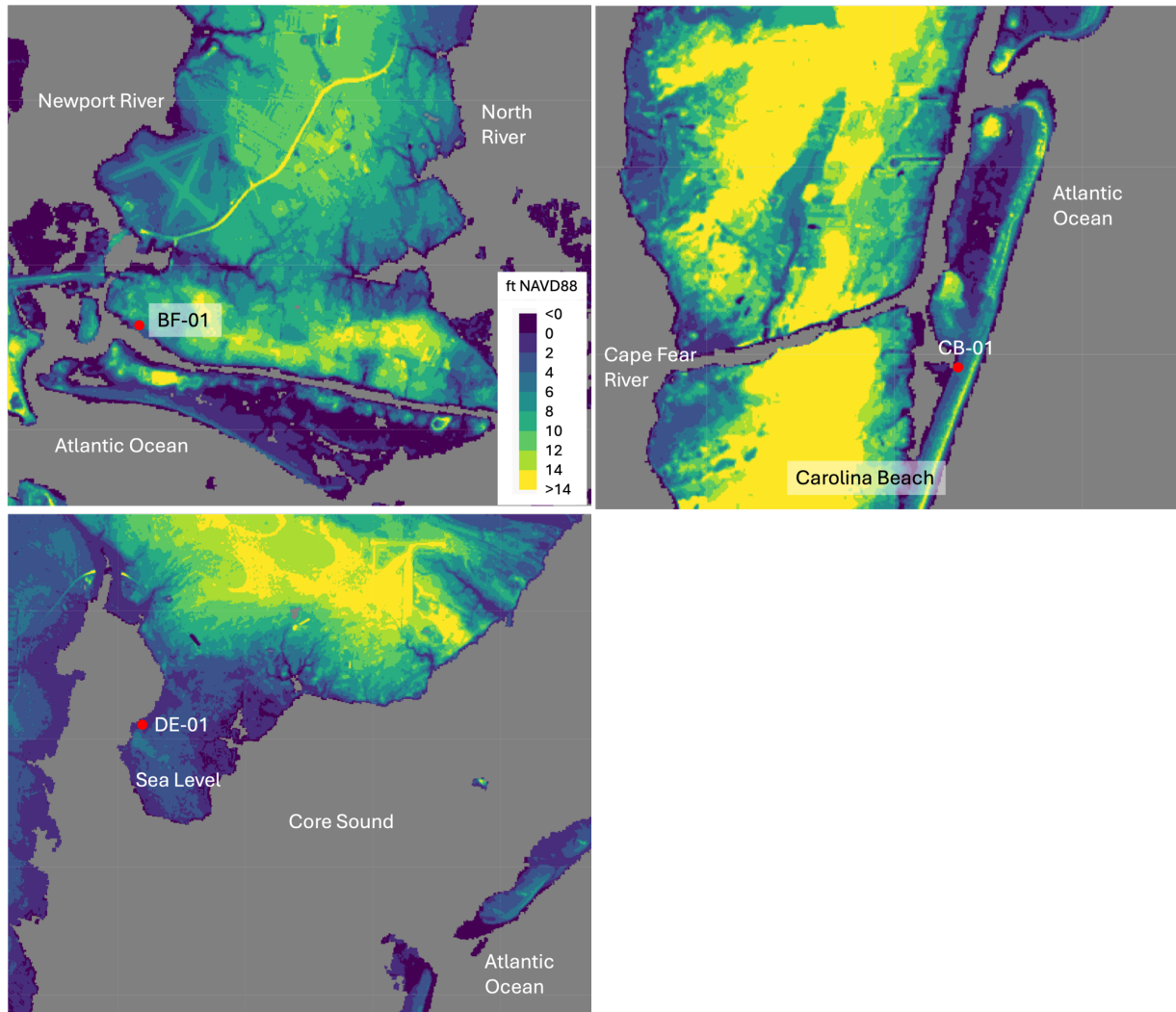


Supplementary Information

Supplementary Figure 1. Flood sensors are located within storm drains or adjacent to roadways, and the paired camera and communications gateway enable real-time display of water levels and photos. Top diagram shows the layout of a storm drain sensor, where the sensor captures water levels as it rises within the storm drain and then overtops the drain onto the road. Bottom diagram shows the layout of a sensor adjacent to a roadway. In this manuscript, we define a flood as water levels exceeding the road elevation.

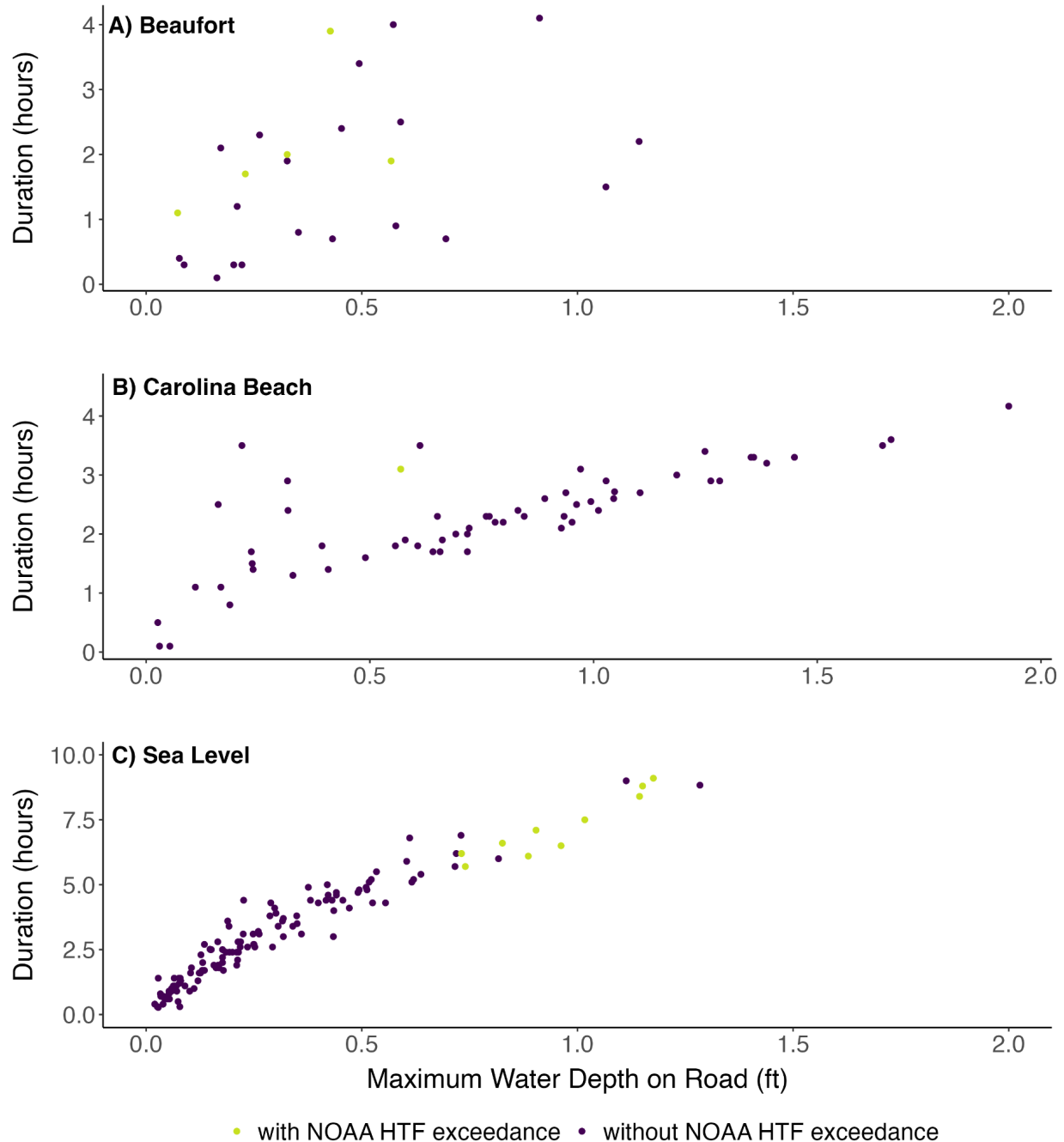


Supplementary Figure 2. Maps of sensor locations. Panels show the location, surrounding elevations, and geographic features for Beaufort, Carolina Beach, and Sea Level sensors. Figure 1 includes a map showing their locations within the state of North Carolina and the United States.



Supplementary Figure 3. Depth and duration for documented floods at each study site.

Purple indicates that there was no exceedance of the NOAA HTF threshold associated with that flood event (as measured by the flood sensors), while light green indicates that there was. Note that the plots only include floods for which sensor depth data are available. In Carolina Beach, four floods occurred for which depth data are missing, and in Sea Level, 19 floods are missing depth data. Floods without depth data are not shown in Supplementary Figure 3, but are shown in Figure 2 in the main text.



Supplementary Table 1. Geographic and elevation information on flood sensors. Table includes geographic coordinates for each sensor analyzed in this manuscript, the elevation of the sensor, and the elevation of the adjacent roadway. Floods are defined as instances when water exceeds the road elevation.

Sensor	Longitude	Latitude	Sensor elevation (ft NAVD88)	Road elevation (ft NAVD88)
Beaufort	-76.66	34.72	-0.51	2.58
Carolina Beach	-77.89	34.05	0.55	2.38
Sea Level	-76.39	34.87	0.69	1.62

Supplementary Table 2. Flood event and tide-gauge threshold exceedance hours, duration, and depth. NOAA HTF and NWS minor flood threshold exceedances are shown for Beaufort (Bft) and Wilmington (Wilm) gauges. The last three rows show data from our flood sensors: Beaufort (Bft), CB (Carolina Beach), and SL (Sea Level). Data are separated based on whether extreme storm days are included (see Methods for more detail).

		Total flood/ exceedance hours		Average flood/ exceedance duration (hours)		Average maximum water level above threshold/on land (ft)	
		Yes	No	Yes	No	Yes	No
NOAA HTF exceedances	Bft	14.6	13.7	1.12	1.25	0.13	0.15
	Wilm	5.2	0.7	1.30	0.35	0.22	0.06
NWS Minor exceedances	Bft	65.5	57.9	1.68	1.70	0.24	0.24
	Wilm	319.2	301.5	1.95	1.91	0.34	0.33
Flood sensors	Bft	73.2	42.7	2.03	1.71	0.53	0.43
	CB	168.3	146.4	2.37	2.29	0.78	0.76
	SL	578.8	506.3	3.66	3.35	0.33	0.31

Supplementary Methods

Calculation of the pressure sensor measurement error

As described in Gold et al. (2023), fully processed data taken from our web database is provided as a water elevation (ft NAVD88). These values include corrections based on the measured sensor height (taken using a real-time kinematic global positioning system) and the local atmospheric pressure (using regionally available, quality-controlled weather data, from NOAA tide gauges and airport weather stations). Therefore our pressure measurements will include errors from these corrections.

To establish measurement variability, pressure measurements need to be compared to a known reference. Our pressure sensor measures air pressure when not submerged and water pressure when submerged. The reference that we use to compare our measured pressure values to is atmospheric pressure when the sensor is not in water. During this time, the pressure measured by the sensor should be atmospheric pressure.

To determine whether the sensor is in water, we assume that the sensor transitions from wet to dry at regular intervals. All of our sensing locations in this paper experience periodic submergence during high tides and dry periods during low tides. Each dry period provides an observation of the error magnitude.

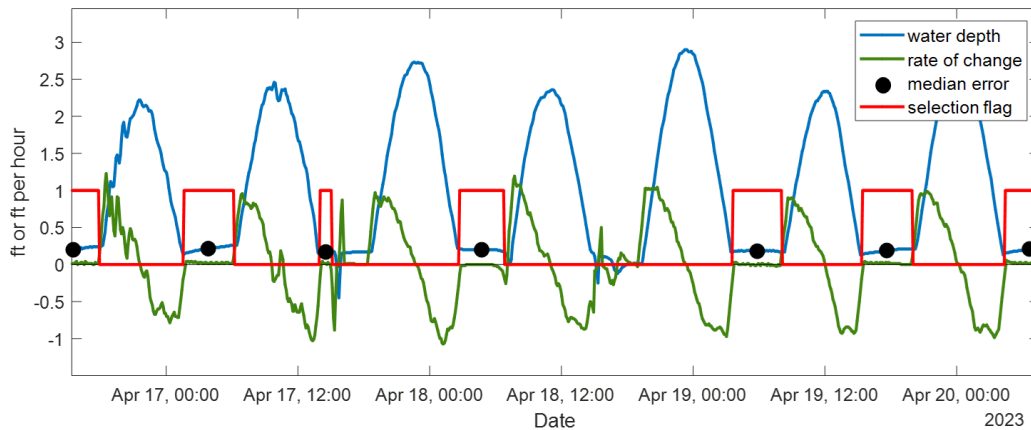
The rules for detecting dry periods in our algorithm are as follows. The values are adjustable parameters for each sensor location.

- 1) The sensor reading for water depth must be within a certain range of zero.
- 2) The slope of the sensor reading must stay within a certain range of zero for a certain duration.
- 3) A dry period cannot recur for a specified period of time.

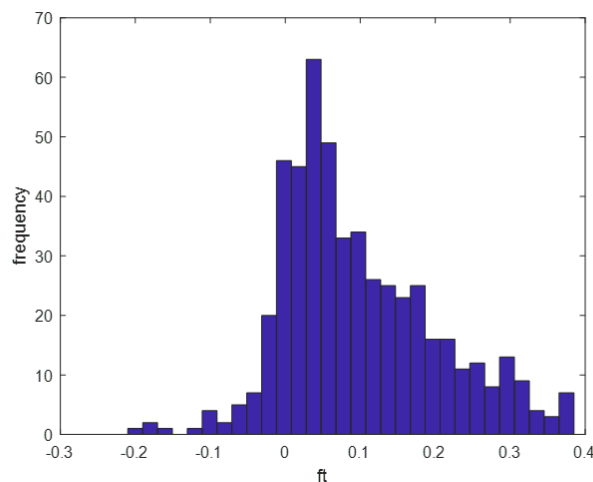
The algorithm is run multiple times while adjusting these parameters in order to eliminate or minimize systematic errors.

The algorithm works as follows. Sensor elevation is subtracted from the water elevation (given in ft NAVD88, which already includes the atmospheric pressure correction) so that the dry values should be zero feet (blue line, Supplementary Figure 4). The slope (green line, Supplementary Figure 4) is then calculated by taking the first difference of these values, which is then scaled by the sample period to yield values in ft per hour. First differences of measured data are inherently noisy, so an empirically chosen 42-minute moving average is applied to the resultant difference. Data points are flagged as potentially dry that meet the water depth and slope criteria, then the durations of runs of flagged values are checked to disqualify runs that do not meet the slope duration and dry period criteria. Finally median values and times are found for each run that passed the above tests (black points, Supplementary Figure 4). This creates a time-series of measurement error estimates. The mean, standard deviation, 5th and 95th percentile of these measurement error estimates are taken to characterize their distribution. An example of the algorithm output is shown in Supplementary Figure 4 for Beaufort. The

distribution of all errors during the study period (one year) in Beaufort is shown in Supplementary Figure 5.



Supplementary Figure 4. An example of the algorithmic output for identifying the measurement error during dry periods in Beaufort. The blue lines are the water depth values in ft, green are the rates of change, red lines with values of 1 indicate areas selected as being dry, and the black dots are the median error values for the dry period in which they are contained. The algorithm parameters tuned for Beaufort include a water depth threshold of 0.4 ft (values further than this from zero are probably not in air), a slope threshold of 0.15 (slope values further than this from zero are probably not in air), a minimum window size of 60 minutes (10 water depth observations), and a recurrence interval of 180 minutes (a dry period cannot re-occur for 30 six-minute observations).



Supplementary Figure 5. The distribution of error values for the sensor in Beaufort over the one-year study period. The mean measurement error is 0.097 ft, the standard deviation is 0.105 ft, the 5th percentile is -0.03 ft, and the 95th percentile is 0.30 ft.

Flood identification during sensor outages and use of the measurement error

Here we detail circumstances where identification of floods were made during sensor outages (either the pressure sensor or the camera), or required use of the distribution (upper and lower bounds) of measurement error.

Beaufort: In Beaufort, cars are often parked in front of the storm drain, obscuring the edge of pavement. In ten instances of flooding recorded by the pressure sensor, water levels were less than 0.3 feet above the pavement, and imagery could not be used to confirm flooding (due to camera outages (2) or cars obscuring the edge of pavement (8)). For these events, the upper bound of the measurement error – calculated as the one week moving average of the 95th percentile of zero gauge pressure – was used to identify a flood: if the maximum measured water depth above the roadway exceeded the 95th percentile of zero gauge pressure, then it was deemed a flood. Using this error metric, only one out of the ten instances was deemed a flood event (flood event 1 on May 10, 2023).

For one flood instance measured by the Beaufort sensor (flood event 26 on December 17-18, 2023), the water level dropped below the edge of pavement briefly (6 min: the sampling interval), but the images showed continuous coverage of the road by floodwaters. Taking the spatial imagery as principal evidence, we combined the multiple flood instances as measured by the pressure sensor into one, which extended the duration of the flood but not the maximum depth.

In Beaufort, there were two days where pressure measurements indicated that flood waters receded briefly from the roadway, but visually it could not be confirmed. In these cases, we use the one week moving average of the 5th percentile of zero gauge pressure as the lower bound in measurement error in order to differentiate continuous versus intermittent floods. In both cases, the lower bound of the measurement error was zero, and therefore the events were classified as two separate floods (flood events 28-29, 32-33).

Carolina Beach: In Carolina Beach, there was one instance of the measured water level briefly dropping below the edge of the pavement at our sensor location (for 12 minutes). Imagery confirmed that water remained on the road. Therefore, we combined the multiple flood instances measured by the pressure sensor into one flood event (flood event 60 on January 9, 2024), which extended the duration of the flood but not the maximum depth.

Four flood events in Carolina Beach occurred during a pressure sensor outage (flood events 15-18), but were confirmed visually through imagery.

Sea Level: In Sea Level, there were 19 floods that were confirmed visually in camera imagery during two outages of the pressure sensor (due to battery loss): from August 31, 2023 to September 7, 2024 (spanning Tropical Storm Idalia) and March 25, 2024 to March 28, 2024.

The camera in Sea Level is aimed slightly tangential to the sensor in order to maximize the field of view of the roadway. Because of this, there were 8 instances where measured water levels exceeded the roadway elevation but the floodwaters did not appear in the camera field of view.

Sea Level is also a rural area with limited ambient light at night, making nighttime floods difficult to identify in imagery (18 instances). For these cases, the upper bound of measurement error was used as an additional line of evidence to classify floods. Using this error metric, 22 instances were deemed flood events (flood events 33, 34, 36, 38, 40, 53, 55, 57, 62, 64, 72, 80, 95, 106, 115, 117, 131-132, 139, 154-156).

There were four days where pressure measurements indicated that flood waters receded briefly from the roadway, but visually it could not be confirmed. Again, we use the lower bound in measurement error to differentiate continuous versus intermittent floods. In all four cases, the lower bound of the measurement error was positive, meaning the measurement of water dropping below the road elevation was biased high, and therefore the events were classified as separate floods (flood events 105-106, 112-113, 136-137, 141-142).

Supplementary References

1. Gold, A., Anarde, K., Grimley, L., Neve, R., Srebnik, E. R., Thelen, T., Whipple, A., & Hino, M. (2023). Data From the Drain: A Sensor Framework That Captures Multiple Drivers of Chronic Coastal Floods. *Water Resources Research*, 59(4), e2022WR032392. <https://doi.org/10.1029/2022WR032392>