Activity report on the project "*MIRROR: a Microplastic Raman Optical Rover to Understand Microplastics Variability Along Beaches of Matagorda Peninsula*"

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Period: October 1st 2024 to December 31th 2024 – We continued to work in the lab on the portable instrument development, rover instrumentation and calibration of the equipment.

During the October to December 2024 period, the project focused on (1) testing the sensitivity of the Near infrared (NIR) spectroscopy in the laboratory. The primary focus was to refine the instrumentation regarding the particle sizes, shapes, colors, and the type of polymer; (2) continue improving the design of the portable Rover with implementation of the NIR portable spectroscopy instrument; and gather remote sensing information on Matagorda Peninsula.

The MIRROR project relies on the development of a compact and robust method to recognize microplastics in the field environment and test it on beach sediments of the Matagorda Peninsula of Texas. To test and improve the method, we continued to undertake a series of laboratory tests to better understand the NIR spectroscopy method. The spectrometer is set up on an optical table to measure controlled and reproducible spectra of plastic samples (Figure 1).

Following the study on using data augmentation to identify plastics (Shriley et al., 2024) using the near-infrared (NIR) spectrometer we focused on the controls on signal variability, including temperature, and mixed plastic compositions. We have continued to improve the optical layout and software analysis. This included the implementation of the machine learning classifier in Python by integrating with the spectrometer API functions. This change was made to integrate the classification model within the fully-automated workflow of the Rover.

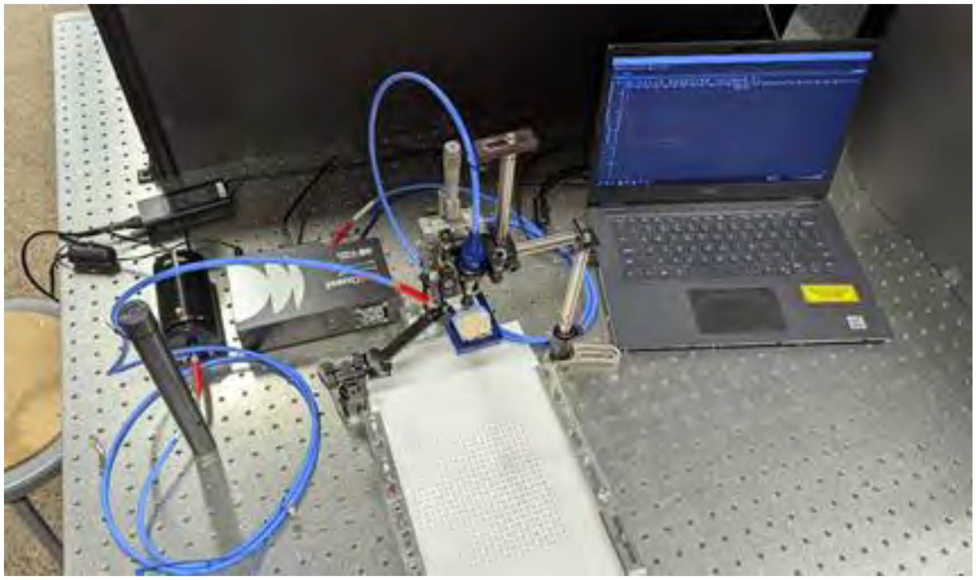

Figure 1: Fiber-coupled near-IR spectrometer for microplastic detection and classification.

MIRROR rover design focused on the functionality of the robotic arm that holds the NIR (near infrared) instruments. During the reporting period, the engineering team focused on the problem of (1) add the spectrometer to MIRROR and embed it with the computer on rover and streaming the signal within a control loop, and (2) identifying the joint coordinate control for each of the joints of the robotics arm, in a function of the desired position of the target virtual point (which corresponds to the focus zone of the near IR spectrometer).

As a result of improving the rover, the spectrometer works autonomously to adjust the height of the emitter/receiver to ensure NIR has a good SNR (signal to noise ratio) when we store the spectrum. For example, figure 2, the algorithm tracks the height (while keeping the laser spot on microplastic bit with 0.2-0.3 mm precision) that gives at least 8,000 (an adjustable parameter) maximum intensity in the received spectrum. The right plot on figure 2 is frozen just for illustration, we are using live data from the spectrometer for this.

We were able to advance on the tracking problem of the arm and are able to position itself for the IR spectrometers scan. According to the control loop of the arm, the movement precision of the arm holding IR spectrometer is about 0.2-0.3 mm that allows the scan of microplastics fragments double that size (about 0.6 mm).

As a first version, a simple scanning mechanism that allows detection of one particle per image was developed and tested in the lab. The infrared arm lab tests were run on having a 3-4 mm microplastic particle at cm distance from the arm and the ability to move the arm in position and read the IR spectra.

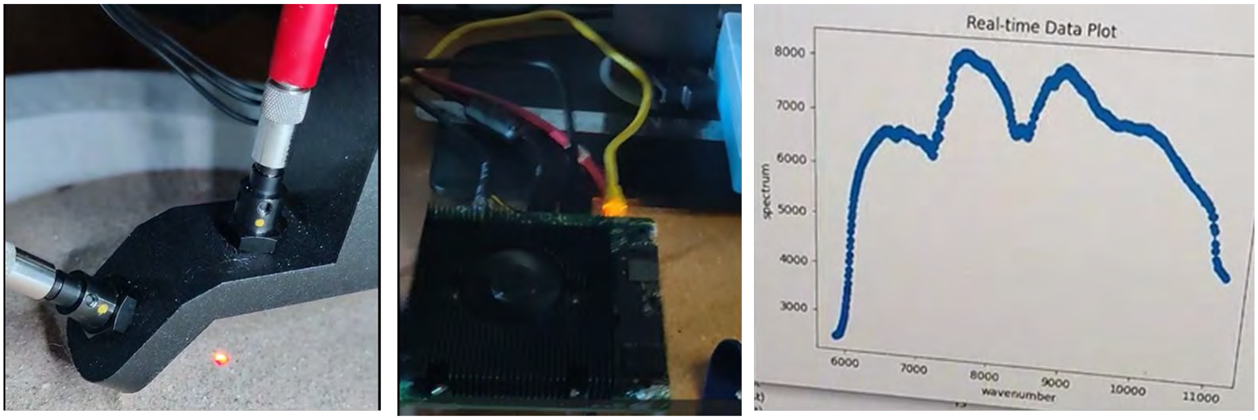

Figure 2. Screen video capture from lab testing of the rover spectrometer. Left image: spectrometer fixed on the rover arm. Middle image: rover computer unit. Right image: example of the continuous spectra measurements from the computer monitor.

FIELD AREA: MATAGORDA PENINSULA BEACH

For a better understanding of the field area, the Matagorda Peninsula beaches, we downloaded the publicly available LIDAR (Light Detection and Ranging) data from the Texas Geographic Information Office website (TxGIO data hub). Satellite images since 1972 have been downloaded to observe the key elements of the peninsula evolution.

The National Elevation Dataset LIDAR collected in 2013 shows that within the overall low elevation of the Matagorda Peninsula (maximum about 20 ft), there are some areas with very low elevations of below 5 feet (see left side of Fig. 3). According to the LIDAR elevation data, the peninsula elevation is mostly around 5 feet or lower (green color on left image of figure 3), with higher elevations (10 to 15 feet) forming dunes along the Gulf of Mexico side (yellow to red color on left image of figure 3). The elevation distribution with lower elevation toward the bay and higher elevation in the dune/ back beach area is typical for barrier islands.

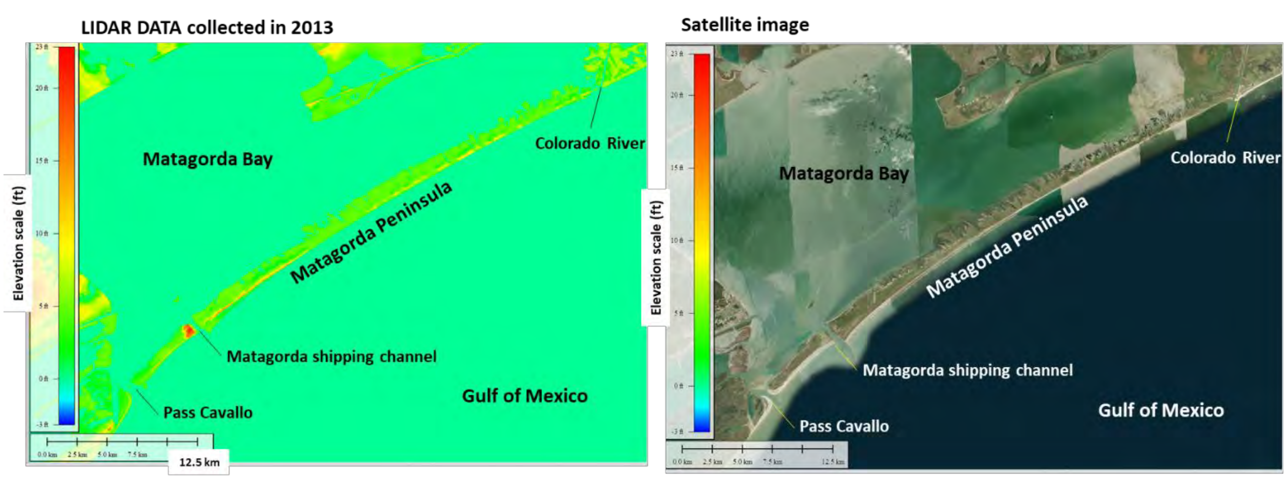

Figure 3. Matagorda Peninsula elevation and image. On the left: digital elevation model (DEM) from LIDAR data collected in 2013. On the right: satellite composite image.

Elevation profiles across the peninsula LIDAR data shows the common width of the peninsula is around 1.5 km with variations between 1 and 2 kilometers. In the areas with elevation below 5 feet it seems to have a smoother topography (profiles 2 and 4 on figure 4). The elevation profiles with 10-15 feet elevation in the dunes area have a more variable topography with one or more trough(s) or "moats" between dunes. That is important because the suspended material (including microplastic) during storms and floods would be trapped in the inter-dune areas.

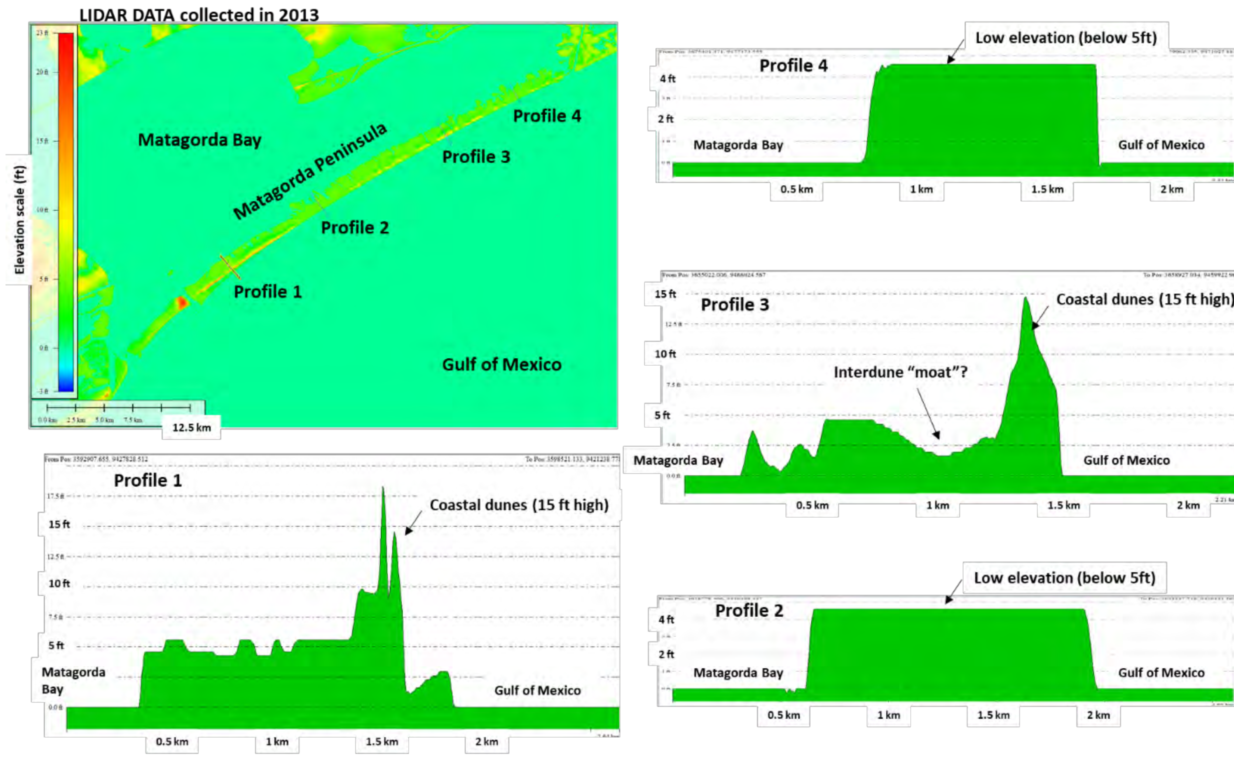

Figure 4. Matagorda Peninsula LIDAR map with the elevation profiles across the peninsula at different locations. Note the peninsula width is between 1 and 2 km, and the elevation varies at some locations less than 5 ft, and in other places it is 15 ft high.

The time-series of satellite images (1972 to present, on figure 5) captures some of the large scale sediment dynamics around Matagorda Peninsula. First observation on the satellite images is the common turbid water plume (with suspended sediments) that is coming out of the Matagorda shipping channel into the Gulf of Mexico (see for example images from 1984, 1999, 2024 on figure 5) Interestingly the sediment plume is extending toward NE along the coast of Matagorda

Peninsula (see images from 1984,1991, 2024 on figure 4) suggesting part of the sediments exiting Matagorda might accrete the peninsula. The second observation is the building of the Colorado River diversion toward Matagorda Bay and the formation of the Colorado Delta that appears on the satellite images since 1991 (Fig. 5). The third observation is the narrowing of the Cavallo Pass (the natural inlet to Matagorda Bay) that was about 2 km in 1972 and reduced to a few hundred meters on the 2024 image (Fig. 5).

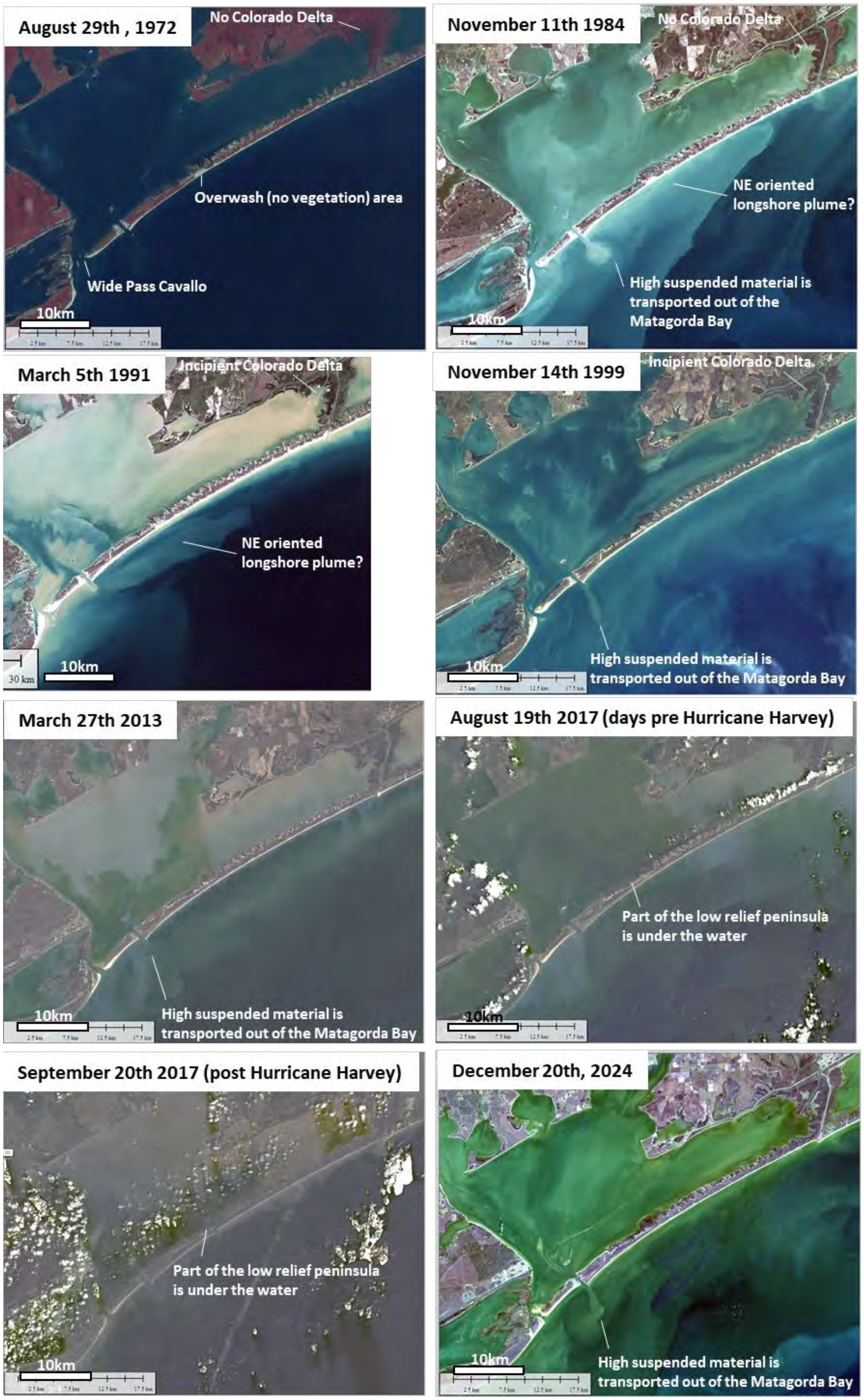

Figure 5. Time series 1972 to 2024 satellite images (LANDSAT).

REFERENCES

Shirley, J.C., Rex, K.A., Iqbal, H., Claudel, C.G., and Baiz, C.R., 2024, Microplastics in the Rough: Using Data Augmentation to Identify Plastics Contaminated by Water and Plant Matter, Submitted to RSC Sustainability

TX GIO Datahub: https://data.tnris.org/