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: January 1st 2025 to March 31th 2025 – We continued to work in the lab on the portable instrument development, rover instrumentation, calibration of the equipment and testing the rover. Additional remote sensing data on Matagorda Peninsula was also analysed.

During the January to March 2025 period, the project focused on (1) continuous testing of the sensitivity of the Near infrared (NIR) spectroscopy in the laboratory on microplastics particles collected from the sediment. The primary focus was to understand the limits of the instrumentation regarding the particle sizes, shapes, colors, and the type of polymer; (2) continue adjust the portable Rover algorithms and testing the Rover and NIR portable spectroscopy instrument outside the lab; (3) analyze high-resolution remote sensing information on Matagorda Peninsula beaches.

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. We continued to undertake a series of laboratory tests to better understand the NIR spectroscopy method. The near-infrared (NIR) spectrometer and the data augmentation to identify plastics (Shriley et al., 2024) was tested on multiple microplastic particles separated from beach sediments. The samples used were collected during a previous trip from San Jose Island of Texas. The results show the methods are robust, and most measurements resulted in a spectral curve used for polymer identification (Figure 1). Using the method on multiple particle sizes and polymer types some key observations were made: (1) there is a limit of about 1 mm (the smallest particle to be identified), and (2) the darker particles needed longer time measurements and black particles (that contain carbon) are difficult to identify.

In order to identify smaller than 1 mm particles, a method would be to collect continuous spectra with the python API as the MIRROR arm is focusing on the particle. This way, with the spot size of about 0.9 mm (Figure 2), the microplastics classifier might work at various signal-to-noise ratios.

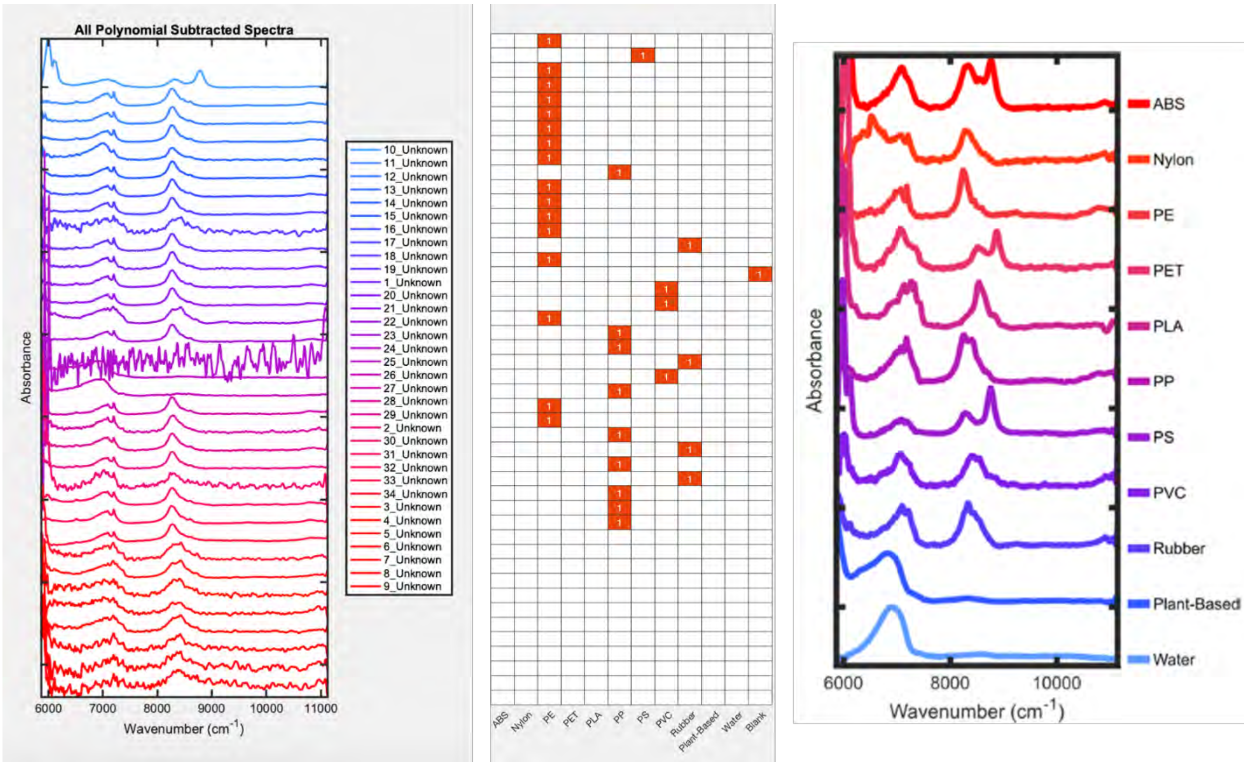

Figure 1. Testing laboratory NIR measurements on beach microplastics. The test was done on multiple particles collected from sediments on San Jose Island. Left image: spectra of multiple particles sampled; each particle spectral curve has a different color. Middle image: microplastics identified by polymer type according to the spectral curve. Right image: typical NIR spectra for main plastics found in the environment (from Shirley et al., 2024).

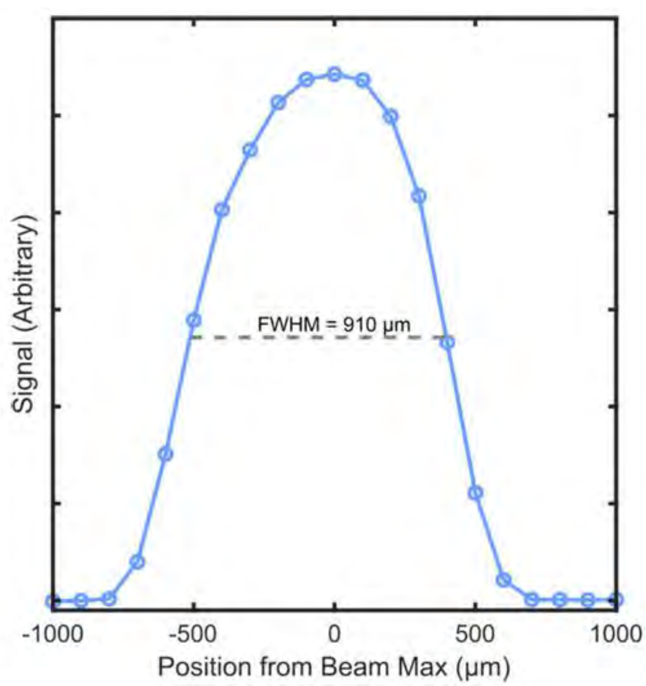

Figure 2. Beam profile at the beam waist of the NIR white light determined via a razor blade on a translation stage. The y-axis is the derivative of the integrated transmission over the detector range and is shown in arbitrary units. The x-axis is the position from the beam center in micrometers. (from Shirley et al., 2024)

The engineering team was able to solve the “arm tracking problem”, so now the arm is able to position itself accurately above the particle of interest for the IR spectrometer scan. According to the control loop, the precision is about 0.2-0.3 mm which allows for testing microplastics that are bigger than 1mm (Figure 3). For the detection of smaller microplastics, improvements in the algorithms are required.

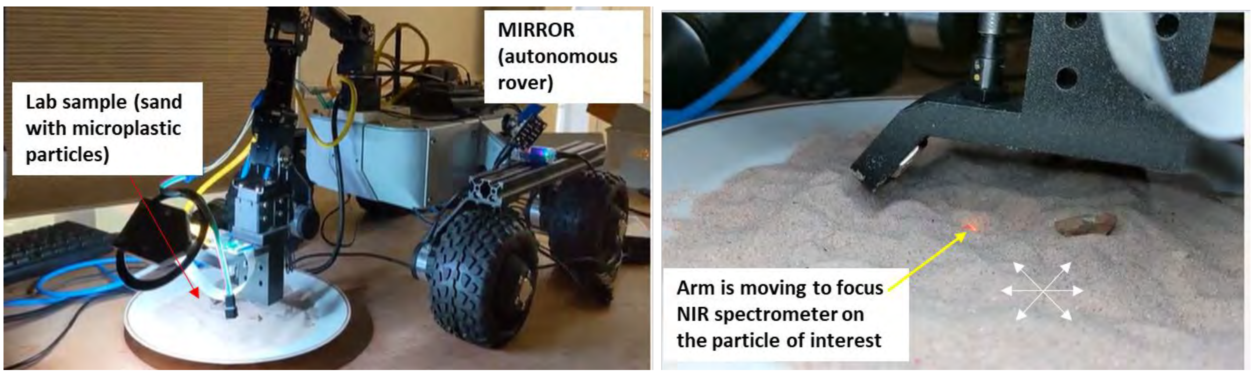

Figure 3. Lab testing of the MIRROR rover’s automatic arm for accurate location. Left image: the rover moving the arm above a sand sample with microplastic particles. Right image: detail with the spectrometer point moving above the microplastic particle of interest.

As the first version, the MIRROR rover is able to detect one microplastic fragment per image as the robot is driving in a straight line. After multiple lab tests, the rover was also tested outside the lab on the University of Texas campus. The rover was tested during the night so the sunlight would not interfere with the spectroscopy instruments. The outside MIRROR test allowed the rover to prove its autonomy (no connection to the lab sources, monitors) and perform as expected correctly positioning above an photo identified microplastic particle and collecting the spectral curve (Fig. 4). A video with the MIRROR rover test can be seen on YouTube here: https://www.youtube.com/watch?v=I9oKsh0WbN4

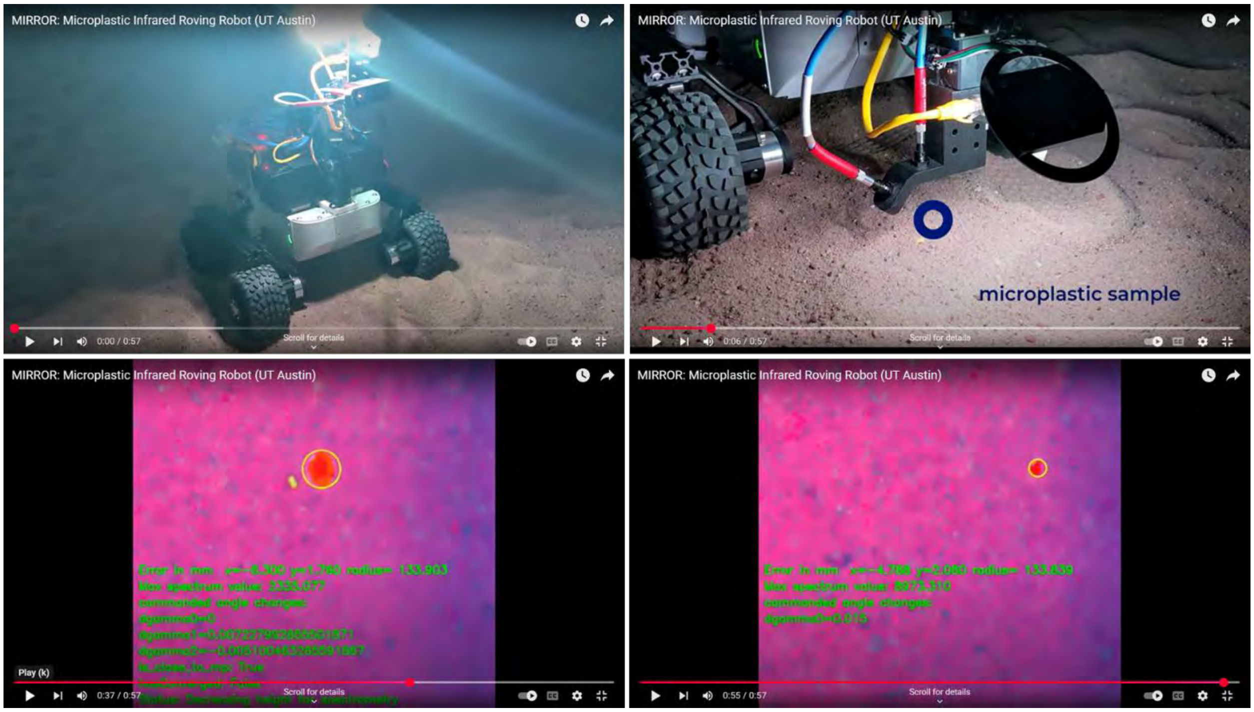

Figure 4. Images from the outside lab MIRROR rover testing. Top left: The rover is lowering its arm, in position to collect spectral data. Top right: The rover is locating the microplastic particle based on a photo identification algorithm. Lower left: rover camera view of the microplastic particle (large yellow area), and spectrometer beam (red dot). Lower right: the spectrometer beam is over the microplastic particle collecting the spectral response. The video of the rover testing can be accessed at: https://www.youtube.com/watch?v=I9oKsh0WbN4

Before field deployment on the Matagorda peninsula, more outside tests need to be performed. Right now one single microplastic particle analysis "per view" can be performed. The vertical accuracy of the arm needs to be better controlled because this controls the spectrometer beam and the size limit of the particles able to be measured.

ADDITIONAL REMOTE DATA FROM FIELD AREA: MATAGORDA PENINSULA BEACH

In addition to the National Elevation Dataset LIDAR collected in 2013, a higher resolution 2018 LIDAR data collected in January 2019 in Matagorda area was downloaded from USGS (3DEP Lidar Explorer) (Fig. 5). The more recent LIDAR has a higher resolution with sub-meter grid and less than 10 cm vertical accuracy. The new dataset confirms the previous observations of the Matagorda Peninsula elevation with high values around 20 ft (~7m).

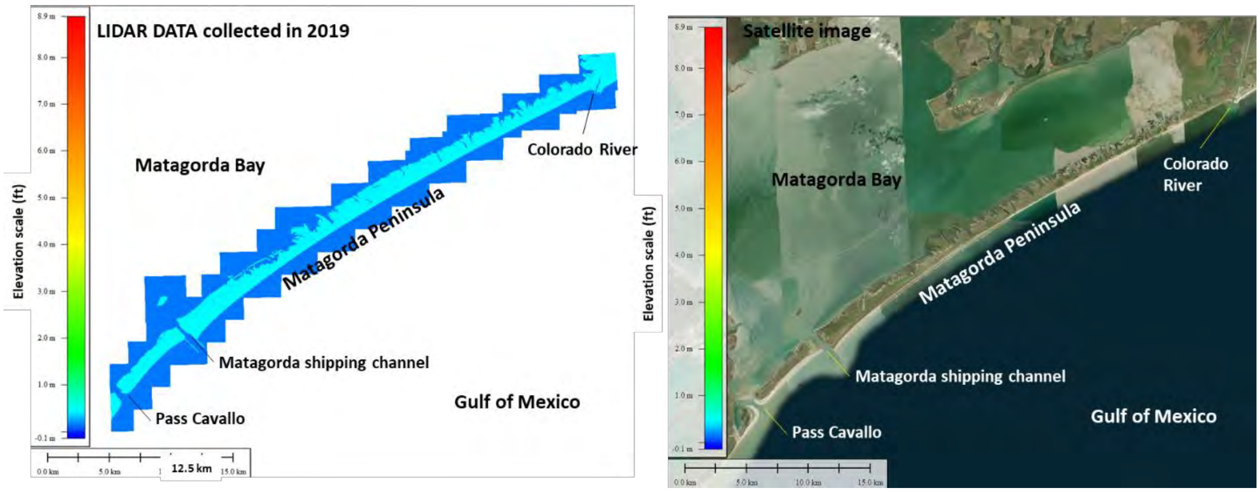

Figure 5. Matagorda Peninsula high resolution 2018 LIDAR data. On the left: digital elevation model (DEM) from 2018LIDAR (collected in January 2019). On the right: satellite composite image.

The higher resolution 2018LIDAR data, in addition to overall high and low topographic areas and the width of the peninsula, allow the identification of dune fields forming ridges, across-peninsula overwash channels, and overwash fans (Fig. 6). The detailed topography that determines the variable morphologies of the peninsula is critical to understand the role of the plastics/ microplastics accumulation. The complexity of the Matagorda Peninsula topography is easily observed on higher resolution LIDAR with multiple sets of coastal dunes and intervening troughs. The relief between dunes crest and troughs vary between decimeters to a few meters. This observation is important because during the storms, parts of the barrier are flooded and the troughs act like water filters for debris (plastics included).

Another observation is that Matagorda Peninsula has multiple overwash channels (see lower images on figure 6) formed during the storms when ocean water flew into the bay. Some of the more recent formed channels still have water in them while others are filled with sediments. This observation suggests part of the beach sediments (plastic included) is transported into the bay when the ocean water rushes in during the storms.

A specific importance for this project is given by the beach profile, an area that will be the main analysis target. More specifically the area from the shoreline to the dune areas.

The beach profile shows, at the time of LIDAR acquisition January 24 to 29 2019 the beach width (between shoreline to the base of the dune field) of tens of meters (Fig. 7). What it looks as a steep beach profile on long profiles of figure 6, in more detail and measured gradients indicate a rather gentle slope of the beach with up to a 1.5 degrees. On the detailed beach profile (top of figure 7) it is also apparent a berm with about 1 foot high formed in front of the shoreline. That might be the case because the LIDAR data was collected during the winter when the stronger waves set an erosional profile with prominent beach berms.

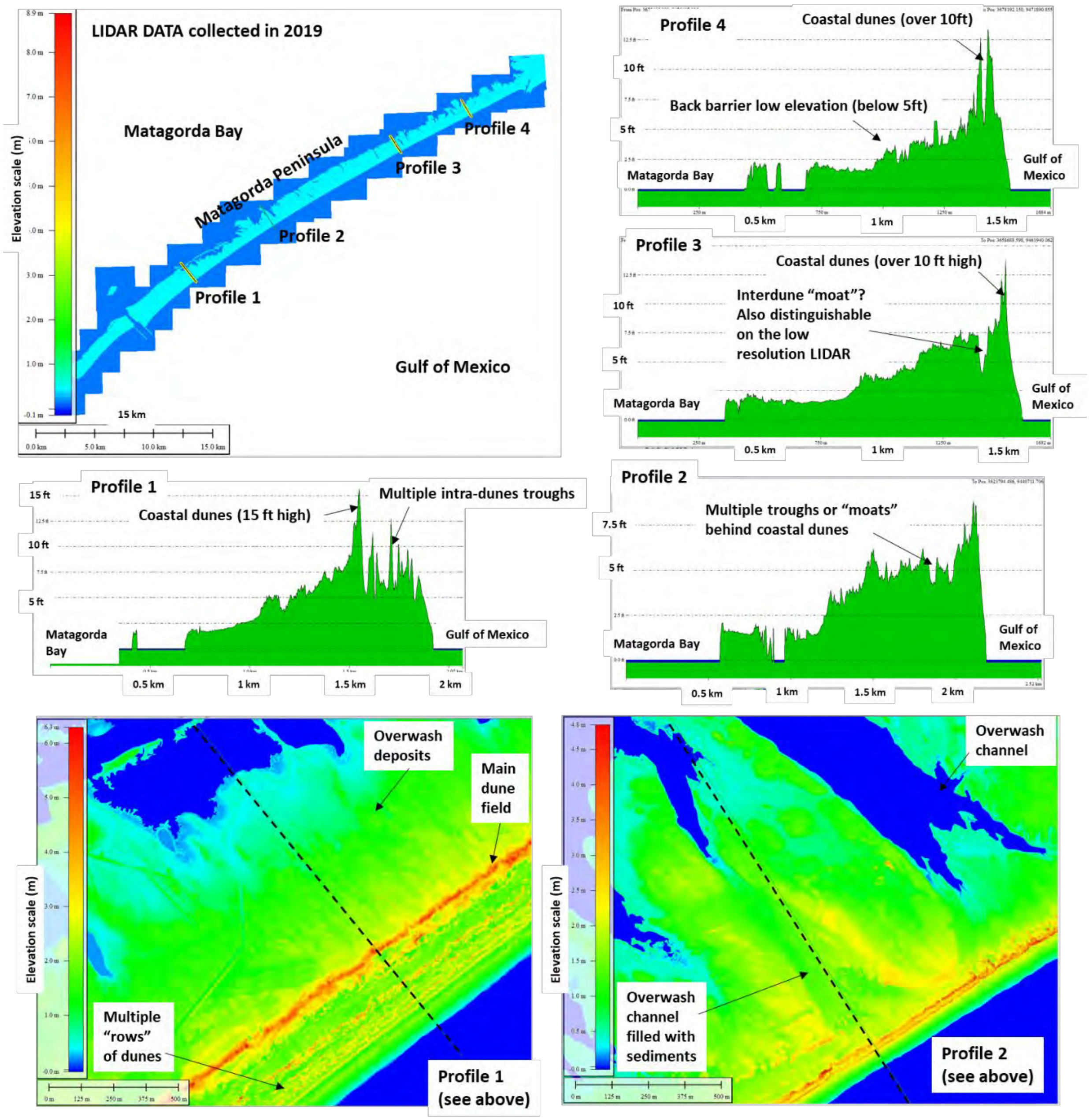

Figure 6. Matagorda Peninsula 2018LIDAR map with the elevation profiles across the peninsula at different locations (similar to profiles on 2013 LIDAR data on previous report). Note that in addition to peninsula width (between 1 and 2 km), the elevation across peninsula is more variable with multiple sets of coastal dunes and some larger troughs or moats (profiles 3 and 4). The multiple set of dunes would likely "filter the storm water capturing the debris (plastics included) between dunes. At the bottom, detailed elevation maps in the area of profiles 3 and 4.

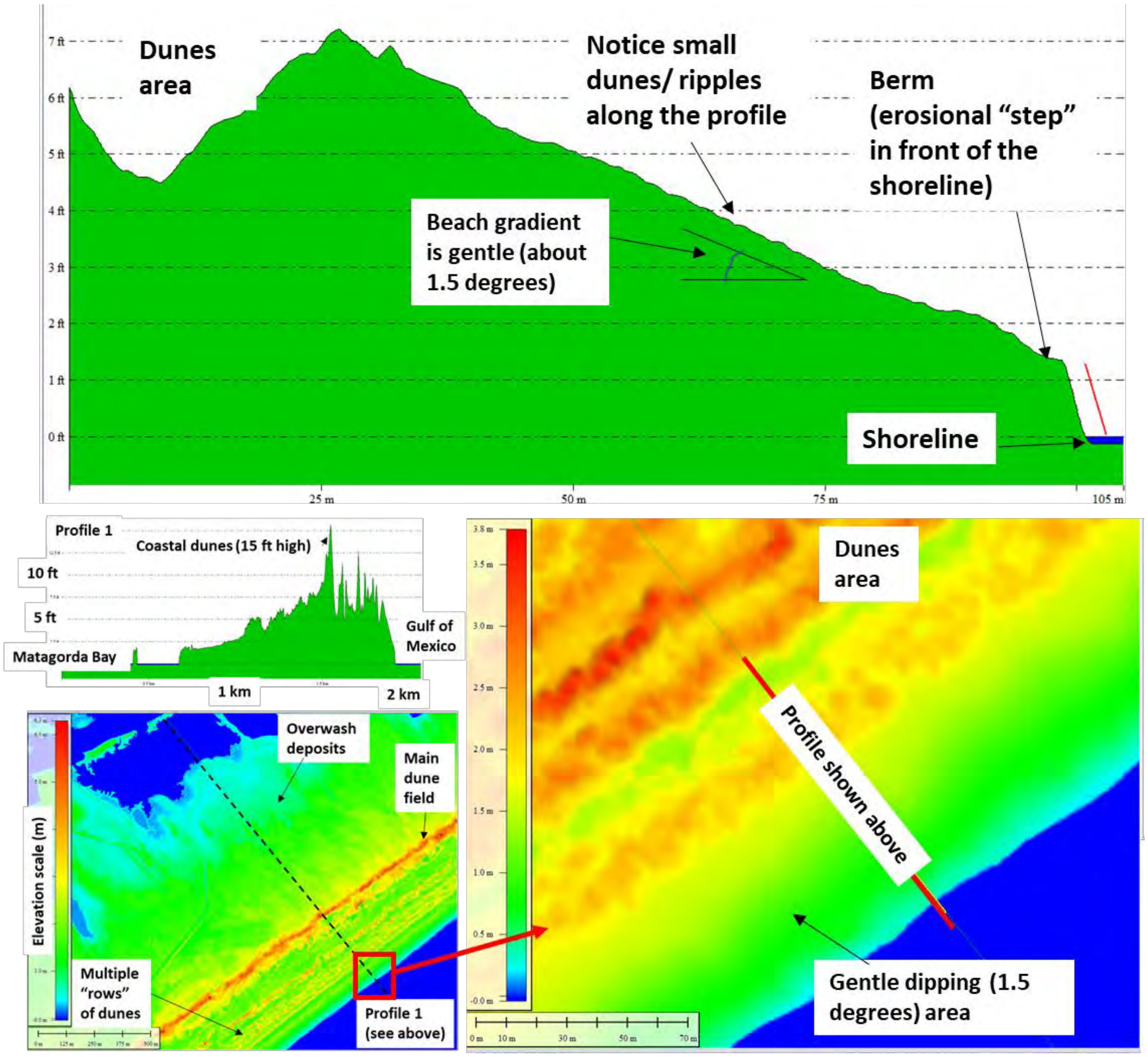

Figure 7. Top image: detail profile across the beach area. Lower left images, the area of profile 1 (from figure 6) detailed. Lower right image: location of the elevation profile from the shoreline to the dune area.

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/

3DEP Lidar Explorer: https://apps.nationalmap.gov/lidar-explorer/#/