

Article

Remotely Sensing the Source and Transport of Marine Plastic Debris in Bay Islands of Honduras (Caribbean Sea)

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Table S1. Reported plastic debris events along with corresponding coordinates (WGS'84).

Detected Debris Events	Date of <i>In Situ</i> Data Collection	Location of <i>In Situ</i>
September 2014	30/9	16.2193° N, 86.5960° W
November 2015	29/11	16.0667° N, 86.3965° W
October 2016	22/10	16.1843° N, 86.4233° W
November 2016	3/11	16.1182° N, 86.4958° W
October 2017	17/10	16.0367° N, 86.5878° W
February 2018	8/2	16.2516° N, 86.6008° W
March 2018	8/3	16.2955° N, 86.5416° W
October 2018	19/10	16.2999° N, 86.3897° W
September 2019	28/8	14.9827° N, 89.5442° W

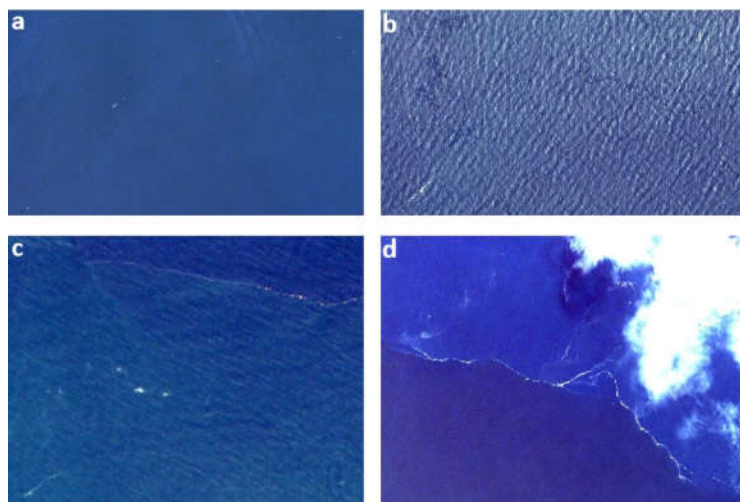
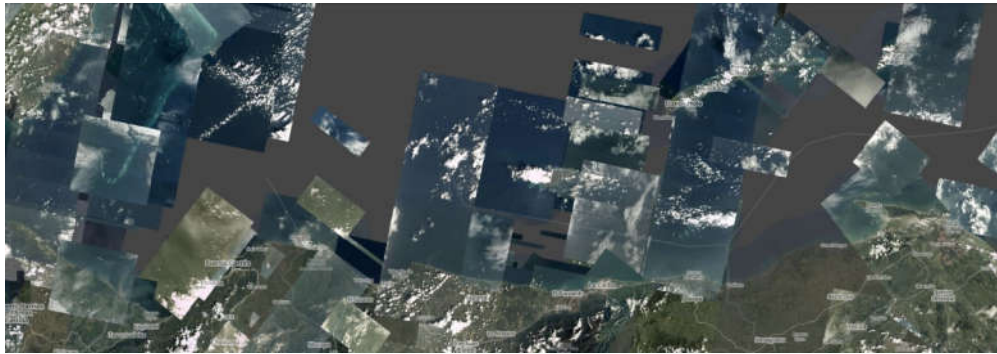


Figure S1. Indicative sea state and weather conditions among the numerous collected and processed satellite data. (a) Plastic debris detection on a Planet image during calm weather and ocean conditions (28/9/2016). (b) Detected plastic debris at rough sea surface on a Planet image (15/7/2017). (c) Plastics were successfully identified and discriminated from *Sargassum* on a Sentinel-2 image during moderate weather condition and calm ocean state (12/1/2017). (d) Discrimination between plastics and foam was more challenging during cloudy weather as well as over areas of intense breaking of waves/ fronts.

(a) Planet Data (September – October 2016)



(b) Sentinel-2 Data (October 2016)



(c) Landsat-8 Data (October 2016)

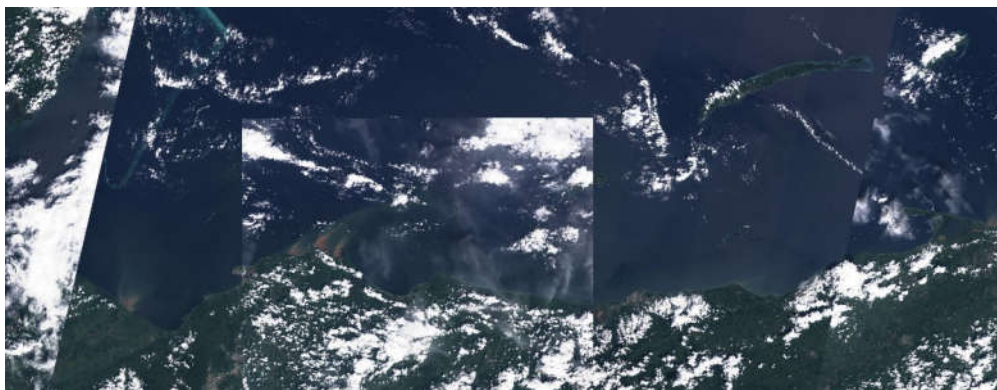


Figure S2. Indicative satellite data for late September and October 2016 plastic debris event. **(a)** Planet satellite images from 3m to 5m spatial resolution. **(b)** Sentinel-2 images at 10 m spatial resolution. **(c)** Landsat-8 images at 30m resolution.

(a) Planet Data (September – October 2017)



(b) Sentinel-2 Data (October 2017)



(c) Landsat-8 Data (September 2017)

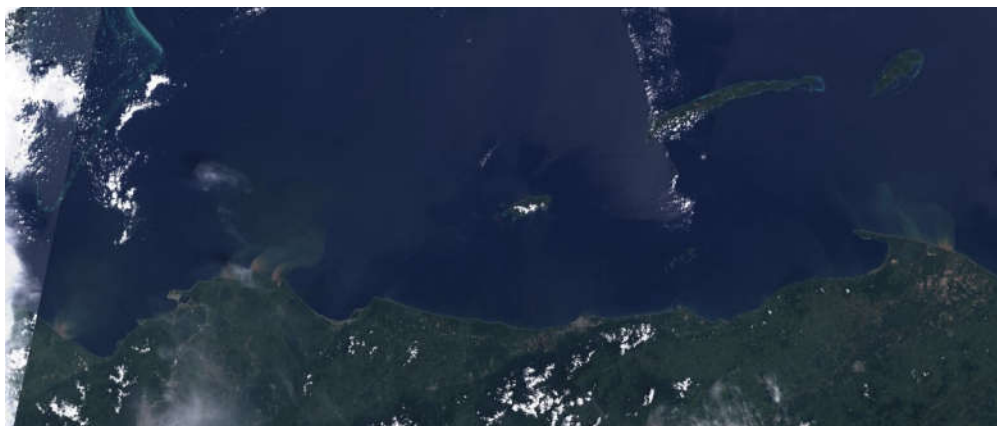
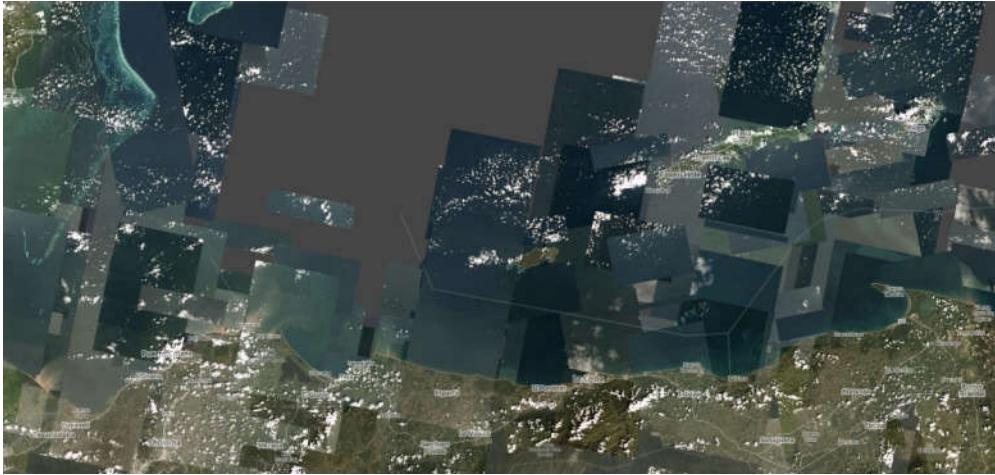


Figure S3. Indicative satellite data for late September and October 2017 plastic debris event. (a) Planet satellite images from 3m to 5m spatial resolution. (b) Sentinel-2 images at 10 m spatial resolution. (c) Landsat-8 images at 30m resolution.

(a) Planet Data (October 2018)



(b) Sentinel-2 (October 2018)



(c) Landsat-8 Data (October 2018)



Figure S4. Indicative satellite data for October 2018 plastic debris event. **(a)** Planet satellite images from 3m to 5m spatial resolution. **(b)** Sentinel-2 images at 10 m spatial resolution. **(c)** Landsat-8 images at 30m resolution.

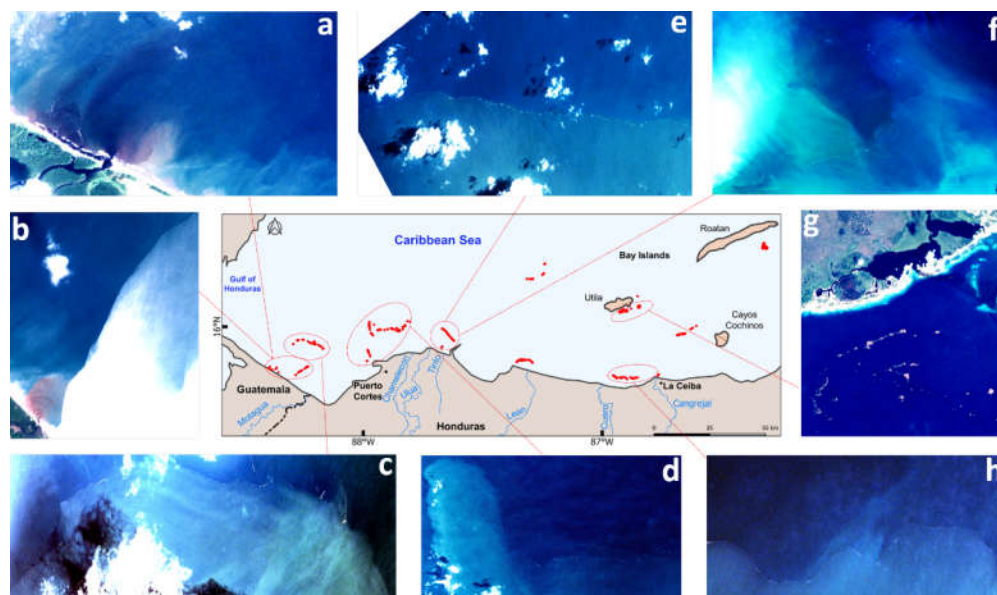


Figure S5. The detected plastics (red dots in the map) and snapshots of the corresponding satellite images at the Gulf of Honduras and Bay Islands during October 2018. (a, b) Detected plastic debris from the discharges of Motagua river on the 22nd of October 2018. (c) One day later (23/10/2018) the plastic debris from Motagua river mouth was detected 12 Km at NE. (d) Plastic debris detected from the Chamelecon river and from Puerto Cortes area on a Planet image during 22/10/2018. (e) Plastic debris derived from Ulua and Tinto rivers (22/10/2018). (f) the same as (e) but on 24/10/2018. (g) Detected large *Sargassum* slicks along Utila coastline (12 October 2018). (h) Plastic discharges of the Cuero and Cangrejal rivers were detected on both Sentinel-2 and Planet during the 23rd of October 2018. Here, a Sentinel-2 image is presented.

Supplementary Text 1:

Detection of plastic debris source and trajectories during October 2018:

During October 2018 (Fig. S5) relatively extended floating plastic debris and *Sargassum* were detected and verified with the collected *in situ* data. On the 12th of October large *Sargassum* slicks were detected and digitized on a Planet image close to Utila island (Fig. S5g). On the 22nd and 23rd of October the detected on Planet data plastic debris indicated that rivers Motagua, Ulua and Tinto contribute to marine plastic pollution. Plastic waste (as observed in the Planet image of the 22nd of October) entered the sea from the harbour of Puerto Cortes, as well as from Chamelecon river. Debris was also recorded (on Planet data) on the 23rd of October at the mouth of Cangrejal river and in addition east of the Cuero river mouth. On the 24th of October (on Sentinel-2 data) plastic debris was detected close to the mouth of Lean river and NW of Utila island. These findings were associated with earlier relatively high precipitation events that occurred between the 2nd and 7th of October as well as the 15th–17th of October. During the aforementioned period the same floating plastic formation was detected on multiple dates allowing its tracking and trajectory detection. In particular, on the 23rd of October a plastic debris formation (~ 1500 m length) from the Cuero river was detected and digitized on a Planet image (Fig. S5h). The same debris formation was detected on 29 October west of Cayos Cochinos islands. The travelling debris direction was SW-NE and its average velocity was 0.07 m/s. The same time period, the direction of prevailing currents was SW-NE and their speed was 0.08 m/s; the wind speed was 2.7 m/s and its direction was ENE. The observed debris direction of SW-NE was mainly constrained from the reported direction of sea surface currents. During this October 2018 event, the total area of detected and digitized plastic debris was 0.154 km² and its estimated weight was 770 tonnes (Table 2).

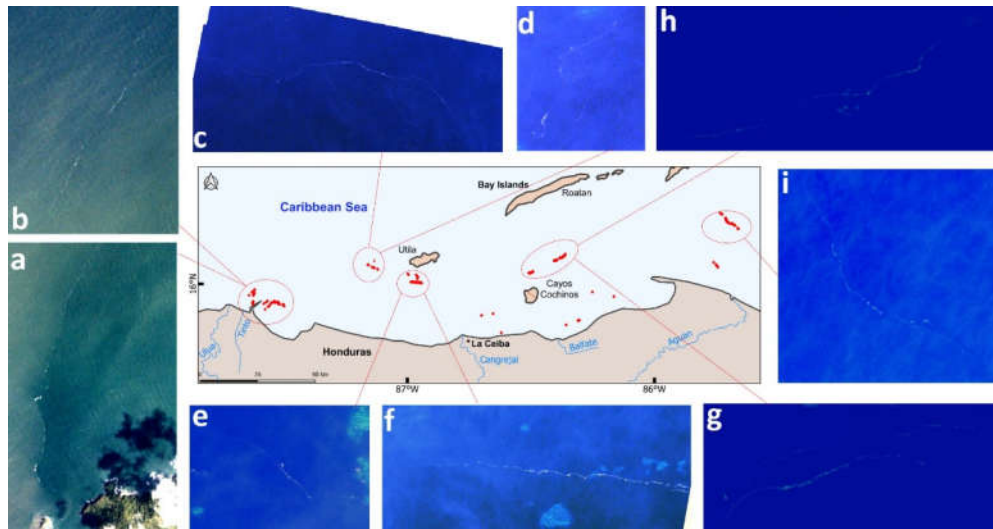


Figure S6. The detected plastic debris (red dots in the map) and snapshots of the corresponding satellite images at the Gulf of Honduras and Bay Islands during late September and October 2016. (a, b) Planet images with the detected plastic debris from the Ulua and Tinto rivers on 28 September 2016. (c, d, e, f) Planet images with the detected debris after 10 days (i.e., 8 October 2016) around Utila island. Its direction was mainly constrained by the concurrent prevailing SW-NE currents direction (derived from CMEMS). (g, h) Detected debris on Landsat-8 images south of the Roatan island and north of Cayos Cochinos after 12 days i.e., 20 October 2016. (i) Detected debris on Landsat-8 on the 20th of October 2016 which is associated with the Aguan river discharges following a SE-NW direction.

Supplementary Text 2:

Detection of plastic debris source and trajectories in late September and October 2016:

During October 2016, debris was detected by a number of satellite images and verified with *in situ* observations. The detected debris and river discharges were associated with the concurrent major rainfall events occurred during 18-22 September and 13-20 October, respectively. Specifically, on the 28th of September 2016 floating plastic debris at the estuarine of Ulua and Tinto rivers was detected on Planet satellite data (Fig. S6). Plastic debris was detected at the mouth of Cangrejal, Balfate and Aguan rivers on a Landsat image (20 October 2016) as well. In an attempt to track floating debris, Planet and Landsat-8 data was used to estimate floating debris trajectories (including average travelling distance and velocity) from 8 to 20 October 2016. In particular, the floating debris formation (with a 5 km length) which was initially detected south of the Utila island (on the 8th of October), after 12 days (on the 20th October) was detected northeast of Cayos Cochinos islands. On the second date it seems that these formations were separated into three smaller parts with a total length of 5km as initially. By tracking debris, it was possible to estimate its average travelling velocity i.e., approximately 0.06 m/s with a SW-NE direction. Indeed, the prevailing currents direction was SW-NE with mean velocity of 0.07 m/s, while NE winds were recorded with a speed of 2.5 m/s. Moreover, on the same dates but more east (20th of October 2016), the detected debris slick, on a L8 image, demonstrated that floating debris derived from Aguan river (Fig. S9c) travelled towards SE-NW mainly due to the prevailing currents in this part of the study region. Overall, the total area with floating plastic debris was 0.055 km² and the estimated plastic weight was approximately 275 tonnes (Table 2).

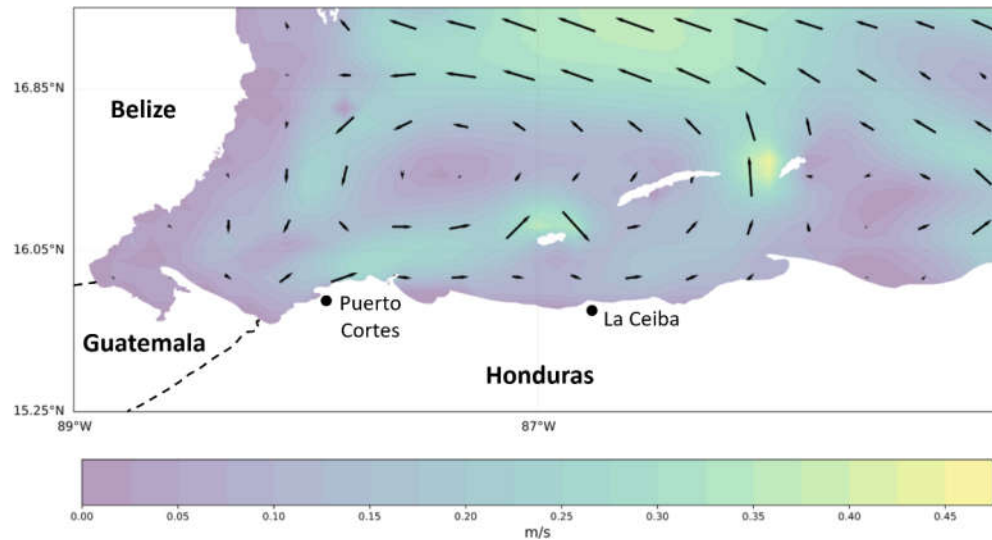


Figure S7. Sea surface currents direction and velocity for the 9th of October 2017 as derived from CMEMS (Global ocean 1/12° physics analysis and forecast daily product). Honduras gyre is recorded west of Roatan island.

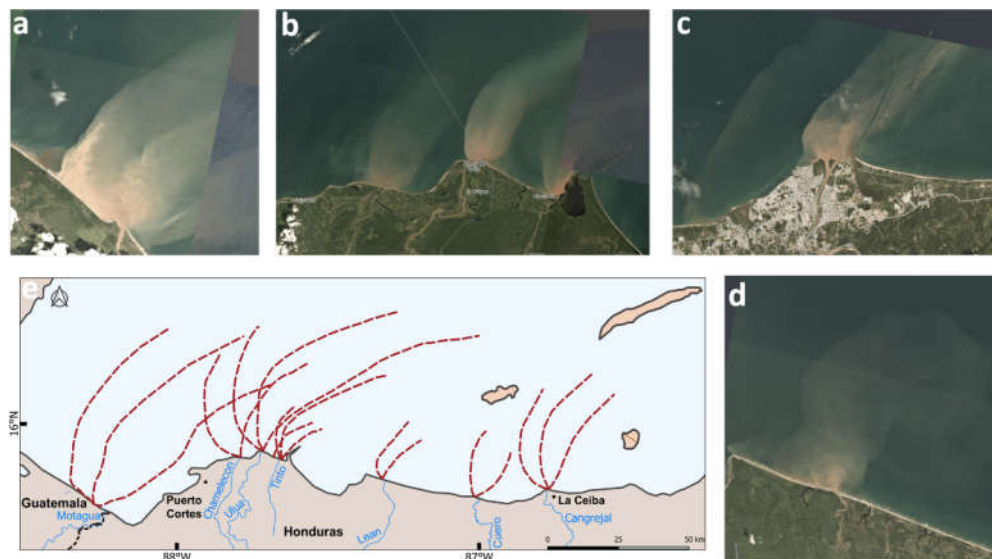


Figure S8. Plastic debris source, corresponding river discharges and estimated debris trajectories based on the multitemporal detections in Gulf of Honduras and Bay Islands during October 2018. (a) Intensive discharges from the Motagua river detected on 22 October 2018. (b) Discharges from the Chamelecon, Ulua and Tinto rivers on 12 October 2018. (c) Cangrejal river discharges detected on 28 October 2018. (d) Discharges from the Lean river detected on 17 October 2018. (e) Estimated marine plastic debris trajectories (red dashed lines) considering both remote sensing and *in situ* data along with the prevailing sea surface currents (CMEMS).

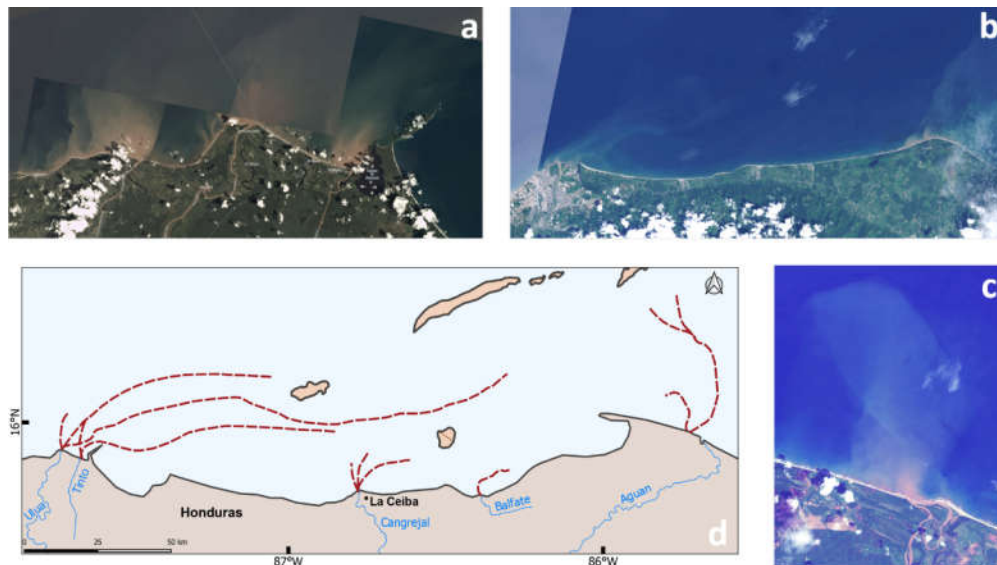


Figure S9. Plastic debris source, corresponding river discharges and estimated debris trajectories based on the multitemporal detections in Bay Islands during late September and October 2016. (a) Ulua and Tinto raging river discharges as recorded during the 28th of September 2016 from Planet data. (b) Detected discharges from the Cangrejal river at 20 October 2016 on a Landsat-8 image. (c) Detected intense Aguan river discharges on the 20th October 2016 on a Landsat-8 image. (d) The estimated plastic debris trajectories (red dashed lines); the debris was travelling similar to the corresponding currents velocity and direction (derived from CMEMS).

Video S1: Plastic pollution along the Motagua river near Zacapa city (late August 2019).

<https://pithos.oceanos.grnet.gr/public/6Fgqkr4wLEqGBPsbz5jza7>



(Recorded by Julio R Guzman Perdomo)