The need for a dedicated marine plastic litter satellite mission

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Monitoring marine plastic pollution requires repeated, long-term, global and harmonised observations of plastic presence, quantity and type, which satellites can provide. To convince space agencies to take action, coordinated activities are urgently needed to agree on target environments and to integrate in situ and satellite-derived measurements.

Plastic litter comprises the largest proportion of human-originated solid waste material in the oceans, with annual emissions predicted to double by 2050[1]. Given the ecological impacts of this plastic, there is a clear need to end marine plastic pollution, embodied by the resolution signed in March 2022 by the UN Environment Assembly, to forge a legally binding instrument by 2024. Assessing the effectiveness of this instrument in achieving its objectives will require global-scale, high-resolution continuous monitoring of different marine environments.

In situ observation programs alone cannot support such monitoring, nor can they answer fundamental questions about fluxes and deposition fate at the global scale. However, remote sensing (primarily by satellite, but also by drones and airplanes[2]) can contribute to integrated long-term global monitoring[3], and can detect aggregations of litter (with or without plastics) and differentiate from floating vegetation. Thus, by focusing on the right environments, remote sensing could have a key role in marine plastics monitoring and mitigation tracking, complementing sparse and heterogeneous in situ observations.

Here, I evaluate lessons learnt about remote sensing observations of litter accumulations, where this technology can be best leveraged, and call for concerted and collaborative efforts to develop a dedicated mission to monitor marine plastic litter.

Status and advances of the technology

The most mature technology for remote sensing of plastic litter accumulations relies on spectral radiometry: inferring the composition and amount of surface matter from reflected light at the surface of the Earth. Over the marine environment, these retrievals provide estimates of ocean colour, traditionally used to assess biological components such as phytoplankton. This technology also lends itself to the new environmental challenge of monitoring floating marine litter, if carefully interpreted.

Highly concentrated accumulations of floating anthropogenic debris (including plastics and other artificial debris) contaminate the ocean colour signal, making the water anomalously bright. These bright signals are particularly evident over frontal ocean structures owing to high concentrations of plastic items ($\sim 10^6\,km^{-2}$), but are lacking across large scale 'ocean garbage patches' where concentrations of debris are relatively lower; thus, satellite retrievals for monitoring floating debris can only be used in select environments. Algorithms can exploit these spectral anomalies in the visible and near infrared range (400 to 900 nm), allowing floating debris to be mapped. For instance, the MSI multi-spectral sensor on Sentinel 2, aided by machine learning algorithms, was the first attempt in detecting floating debris along frontal structures[4].

Although this technology has verified success in monitoring mixed floating debris accumulations mostly in ocean fronts, it is very difficult — if not impossible — to separate the plastic litter signal from other types of floating litter using current satellites; specific spectral features of plastics are compounded by the coarse spectral bands available and their different spatial resolutions[5]. Yet, laboratory and field experiments reveal a clear spectral fingerprint from plastic polymers in the shortwave infrared range (1000 to 2500 nm), suggesting deployment of sensors at these wavelengths could help distinguish plastics from general floating litter. Even if a satellite were adapted to detect ocean plastics, these would be only visible above the water surface or restricted to the first centimetres below[6], owing to plastic signal removal by water absorption. As such, the environments where direct plastic litter detection is accessible to remote sensing need to be reconsidered.

A change of direction

Despite the issue of water immersion and signal interference, remote sensing still offers opportunities to monitor plastic litter in marine environments beyond ocean fronts. Indeed, plastic accumulations on coastal and riverine shorelines, where signal absorption by water is reduced but brightness anomalies persist, can be monitored in this way.

Shorelines — where waves and wave-produced currents can act as a barrier, pushing plastics back to shore

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and causing accumulation — are key environments that require monitoring. While coastlines have a relatively small area, reported average concentrations of plastics are several times greater than those floating on the ocean. Monitoring dry accumulations on shorelines (beyond the maximum high watermark) also has the practical advantage of established baselines from in situ monitoring programs, potentially allowing validation and comparison with satellite observations if relevant parameters be integrated. On a remote shoreline of Chile, high spatial resolution (1 m) multispectral satellite imagery showed potential for detecting and quantifying marine litter, as well as separating between expanded polystyrene and other types of marine debris[7].

There is also potential for indirect monitoring of riverine fluxes, the main pathway for plastic from land into the ocean. The limited knowledge of riverine inputs and their variability might explain much of the large mismatch in marine plastic mass budgets, motivating monitoring of this environment. Targeting mismanaged landfill sites in river catchment areas would be beneficial. These areas are accessible to satellites because they avoid water absorption interference of polymer signals. When coupled with runoff data, satellite data would thus be able to provide estimates of land-based plastic leakage and assessments of the effectiveness of mitigation measures[8]. Using relatively coarse (30 m) satellite imagery, plastics have been detected in urban areas. Thus, by targeting areas where plastics exhibit strong transport into marine environments (such as landfill sites in river catchments) and by using appropriate wavelengths[9], riverine fluxes could be monitored, adding value to the radiometric technique to be developed into a prototype satellite mission[10].

A new space mission and international collaboration

Although there are constraints and limitations, spectroradiometric remote sensing from satellites offers the possibility for monitoring marine plastic litter, primarily in coastal and river shoreline environments. However, these capabilities are currently in the test phase, with consistent monitoring requiring a dedicated prototype space mission.

Such a minisat (~150 Kg) mission has specific requirements[10]. It would need high spatial resolution (1–5 m) to allow shape anomaly detection[6,7]. It also needs to include visible and shortwave infrared wavelengths[6], allowing the plastic signal to be distinguished from the debris mix, and different polymers to be identified[9]. Hyperspectral resolution would not be required, but high radiometric resolution around polymer features in the shortwave infrared would be, along with some bands in the visible to separate from vegetation. These requirements constrain the width of the observation swath to ~10 km, necessitating careful pointing of the sensor over coastal and riverine areas of interest. Accordingly, revisiting times would have low frequency (every ~10–15 days) which is suitable for the environments of interest. As extra benefits, it is expected that a sensor of this kind would have enough sensitivity to collect data on floating debris near the coast[10] and many of the observation requirements match those relevant to coastal biodiversity.

In preparation, in situ observations (such as proximal spectral radiometry collocated with quadrant measurements of abundance and types of plastics) need to be collected specifically to support the development of the mission's sensor. To plan and deliver these observations, coordination is required across the various emerging initiatives to monitor plastic waste. International coordination will avoid duplication of efforts. Workshops could help engage the community to prioritise critical questions, such as: how to convert current in situ measurements of plastic litter to satellite relevant units using proximal radiometry measurements; is there a need to define a new family of plastic debris variables to match remote sensing products; what are best practices for those additional in situ measurements; what aspects of biological diversity in coastal ecosystems need to be measured in situ to evaluate impact of litter using the same mission?

Radiometry from satellite has proven potential to detect plastics debris relevant to the marine environment. The proposed prototype mini-sat mission[10] focussing on shorelines and on landfills needs the wider community to persuade nations and space agencies to take action. With the European Space Agency Council meeting at ministerial level at the end of 2022, now is the time for this action. The oceans cannot wait another two decades for this critical support from remote sensing of plastic litter.

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Competing interests

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