

Remote sensing of marine debris

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1. What are the key challenges or questions for Earth System Science across the spectrum of basic research, applied research, applications, and/or operations in the coming decade?

The ocean surface is an interface with a tremendously complex dynamics. Monitoring floating marine debris is a growing key challenge to the global observing system and to Earth System Science. Motion of debris is affected by surface currents, winds, waves, and turbulence, the combined effect of which is not adequately measured directly or remotely, simulated with models or understood theoretically. Unlike many other tracers and pollutions, whose concentrations may gradually decrease with time as they mix with large volumes of sea water, floating debris can accumulate in relatively small “garbage patches” or wash ashore at particular “hot spots”. Fast-growing production of plastic materials, not complemented by efficient regulations and mechanisms preventing them from uncontrolled entrance into the environment, creates conditions for fast aggravation of the problem.

In situ observing systems and the science of marine debris are in their infancy. No part of the lifecycle of marine debris (sources, motion, degradation, impacts, sinks) is known well enough to close its balance or make predictions. This is primarily because plastic waste makes its way into the ocean as a result of disasters, accidents, mishandling, or oversight – events that are hard to document in a quantitative way. Also marine debris varies hugely in sizes, shapes and chemical composition (Fig.1), making difficult the development of universal observational methods.



Figure 1. Examples of large and small marine debris: a) 60-foot dock washed by tsunami on March 11, 2011 from Misawa harbor (north Honshu, Japan) and found April 5, 2013 on the Olympic coastline (Washington state, USA); (b) bits of microplastics (from a few millimeters a few centimeters in size) commonly found in many regions in water and on beaches. (Photo credits: Oregon Parks and Recreation Department and Sean P. King / Hawaii Wildlife Fund.)

With the growing knowledge about marine debris distribution in the World Ocean, we are still very far from closing debris budgets. For example, while the study of (Jambeck *et al.*, 2015) suggests that millions of tons of plastic are added annually into the ocean, in situ sampling of microplastics synthesized with numerical models finds only tens of thousands of tons, with

maximum concentrations in the five main garbage patches (*van Sebille et al, 2015*, Fig.2). Similarly, activists of the International Coastal Cleanup remove globally on the order of 10,000 tons every year. It is currently not clear where potentially 99% of plastic marine debris is hiding. Exploration of remote coastlines (such as Alaska, and recently on the shores of Antarctica and in the Arctic ice) and also of the bottom of the ocean do find overwhelming amounts, which still need to be quantified.

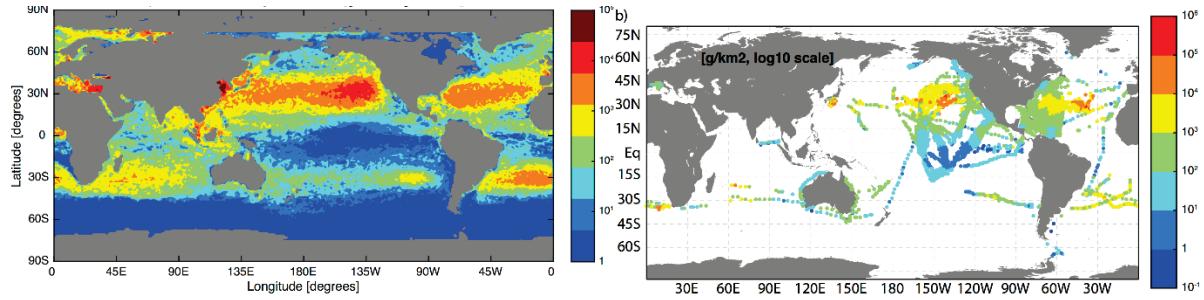


Figure 2. Patterns of the density of microplastics, estimated in (left) a numerical model and (right) from observations. *Van Sebille et al (2015)*

2. Why are these challenge/questions timely to address now especially with respect to readiness?

There is growing recognition of the importance of the marine debris problem. The October 2015 meeting of G7 Ministers of Science listed marine litter (along with the climate change) as one of main challenges for our society. Individual evidences of the harmful events caused by marine debris are getting organized into a concerning ‘big picture’. In many regions microplastics are found practically in every fish or sea bird and, due to their toxicity during production and/or their capability of absorbing chemicals from the sea water, they are becoming an issue for human health.

A number of recent events revealed limitations of our knowledge and highlighted important gaps in the observing system. The March 11, 2011 tsunami in Japan released an estimated 1.5 million tons of debris that drifted towards North America and Hawaii. Thousands of items were found since then on American shores and many of them were traced back to Japan. Many of these objects are a threat to the safety of navigation (ships, boats, docks, large buoys, etc.). Others (such as propane tanks and other gas cylinders, medical equipment) are potentially toxic. Many of the Japan tsunami marine debris items are hosting invasive species, endangering our ecosystem and yet their location and concentration in the ocean are still not known.

In 2012-2014, the boat of fisherman Alvarenga was lost off Mexico and drifted west for 438 days. He was only found after reaching one of Marshall Islands and his partner didn’t survive the journey. Many more lives could be saved after similar accidents at sea if the observing system existed, routinely monitoring large areas of the ocean. Another example is Malaysian Airlines Flight 370 that crashed on March 8, 2014 in the Indian Ocean and is still missing despite the active

international search and the confirmed finding of the airplane flaperon on Reunion Island. Satellite marine debris observations could make such search operations much more efficient and would strengthen NASA interaction with many foreign agencies. Tracking large debris could also reduce the number of ship collisions with marine debris (the number of cargo containers lost annually is estimated to be 10,000) causing an estimated 1 billion dollars per a year in damage. This is especially important in coastal areas where recreational activity involves a large number of small boats.

Marine debris washing onto the shoreline has a strong aesthetic impact on beach users and can affect local tourism business and the market value of real estate. Satellite observations could help to measure trends and warn about anomalous events that could have a significant impact on the economy.

Finally, the marine debris problem provides a unique opportunity not only to raise the interest and awareness of the general public to the ecology but also to educate people. Satellite marine debris observations could provide groups and individuals concerned about local problems with a broader view of state of the marine system.

3. Why are space-based observations fundamental to addressing these challenges/questions?

By its very nature, marine debris is a global problem. It drifts across borders and mixes together in the vast ocean. Even countries located in-land that don't have any marine coastline contribute to the ocean pollution through streams and rivers. These countries are also exposed to marine debris, transported by birds, seafood, and by the wind. Only satellites can provide the coverage on the required large scale.

NASA has large experience with building and maintaining observing systems to address such tasks as climate change, sea level rise, extreme weather events, etc. This experience along with some flying or planned satellite missions can be used in the future marine debris observing system. However, present specifications of these missions are marginally relevant to the marine debris problem and need to be adjusted. In addition, new technologies for direct or indirect marine debris assessment need to be developed and implemented. For different aspects of marine debris observations the following missions seem relevant:

- high-resolution optical imaging
- hyper-spectral ocean colors
- SAR
- lidar
- ocean currents and winds

Calibration of these satellite sensors will require extensive in situ sampling of different types of marine debris.

Pathways of floating debris require advanced measurements of surface currents and winds. Global in-situ measurements of near-surface currents (15 m) are sparse and are obtained from the global drifter array. Presently, satellite-sensed surface currents are not measured directly but derived globally in a simplistic framework using satellite altimetry and scatterometry or in small areas

from SAR images. These estimates exclude important dynamics of the mixed layer that are not measured by today's observing system and not included in theoretical or numerical models of ocean circulation. New technologies, such as a Doppler scatterometer, could provide the next-generation ocean data of which the marine debris research would be one of many applications. In return, observed motion of marine debris, which is present almost everywhere in the ocean, would provide excellent data to validate surface currents. Also, tracking the trajectories of scientific buoys and marine debris would outline main pathways of different types of pollutions across the oceans with a potential of their back-tracking to the source in future accidents. This tracking activity would further encourage the existing Global Drifter Program to introduce new sensors to address the dynamics of the ocean mixed layer in greater details.

Remote sensing of marine debris would involve numerous groups of oceanographers, biologists, fisheries, ecologists and economists.

References:

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