Surface Currents in the Coupled Ocean-Atmosphere System Workshop, February 22-23, 2020, La Jolla CA

Roles of large-scale, mesoscale, and submesoscale ocean currents in transport and accumulation of floating debris and marine biota in the North Pacific "garbage patch", studied in FloatEco project.

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Project Overview

Goals

The interdisciplinary multi-institutional project FloatEco (Floating Ecosystem), partly funded by NASA, includes close collaboration between physical oceanographers, marine biologists, ecologists, and citizen scientists.

The project will advance understanding of (i) the complex ocean circulation in the mixed layer, (ii) the role of air-sea coupling in determining the fate of the matter floating on or near the ocean surface, and (iii) the survivorship of invertebrate communities on marine debris and the increasing connectivity between coastal and pelagic ecosystems. Also it will advance the knowledge of how marine species respond to plastic habitats and their adjustment to anomalous conditions along debris trajectory. This information will help to prepare for impacts of climate change and rising production of plastic on the global ecosystem.

Summary

Marine debris floating on or near the ocean surface are collected by converging surface currents. Thus creating a unique floating ecosystem in the eastern North Pacific Garbage Patch. The project team will study the ocean dynamics and its coupling with the atmosphere, the processes maintaining the garbage patch, the sorting of the marine debris based in their windage, shape and buoyancy, and the composition and evolution of marine biota associated with marine debris. The 2011 tsunami in Japan brought evidence that coastal marine species can cross ocean and survive in pelagic oceanic areas for a long time. Every year millions of tons of marine debris entering the ocean provide growing substrate for new ecosystem. The project studies the marine ecosystem associated with the marine debris in the North Pacific Garbage Patch, identify the coastal species and determine the role of marine debris in dispersal of coastal species.

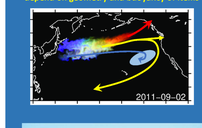
Ocean Voyages Institute chartered expedition (SV Kwai) have collected physical and biological data in Summer 2018 and will continue in the next year. 10 experimental drifting buoys were deployed in November 2018. They tracking data are being used to study the effect of windage and buoy geometry on their drift.

In addition, one mixed layer experimental buoy is ready for deployment. The buoyancy of this experimental buoy can be set to be very weak and thus mimicking the transport of microplactic in vertical water column. Another experiment will include varying the buoyancy of the float, which will reproduce the daily vertical migration of plankton in the mixed layer. Biological panels added to the float will provide data of marine growth rate and diversity of species (coastal/pelagic). The real time data transmitted from the float including the visual data will allow monitoring the drift and bio fouling in real time.
Biological data are already being collected from the floating marine debris mostly as ghostnets, which will be tagged with satellite trackers. Once the whole data collection will be completed it will represent a new dataset on marine biota in the North Pacific Garbage Patch.

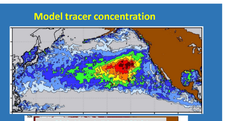
Satellite data and numerical modeling are very important components of the project. The SCUD drift model is employed to plan sailing routes and generalize the project data. In turn, the collected observational data will expand the modeling capabilities, range of parameters and lead to expanded applicability, to different types of marine debris, marine plankton or oil spills. The data collected by drifting buoys will help in understanding of the role of vertical structure in the mixed layer, the coupling of the surface currents and surface winds. With improved understanding of the underlying processes and better model parameters then the modeling approach could be applied on variety of marine problems, such as chlorophyll blooms. Also the project's findings will help in preparation of future satellite missions , e.g. PACE, SWOT or WACM. Potentially, the project conclusions could lead in improvement of ocean model parameterizations in models like e.g. HYCOM.

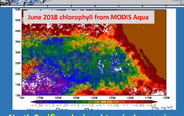
Underlying ideas of FloatEco

Model simulations of debris from the 2011 tsunami in Japan suggest that its pathways depend on geometry and buoyancy of items



Model tracer concentration





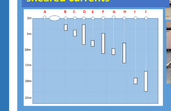
20-m dock arrived in Oregon in 2012, bringing >100 Japanese coastal species, some are known invaders.

North Pacific pelagic subtropical ocean is nutrients poor. Asian and North American coastal ecosystems are disconnected. Floating debris may play important role in sustaining pelagic ecosystem.

The fact that flux of Asian coastal species never stopped suggests that they have established on marine debris floating in the "garbage patch". FloatEco project studies physical and biological processes sustaining this floating ecosystem".

Set of drifters to measure cumulative effect of the shear

Drifter array to study debris interaction with vertically sheared currents

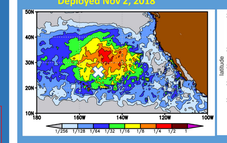


Lagrangian Drifters Lab, Scripps IO

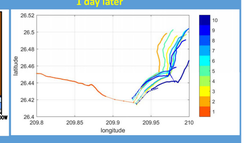
Maersk Launcher

The Ocean Cleanup

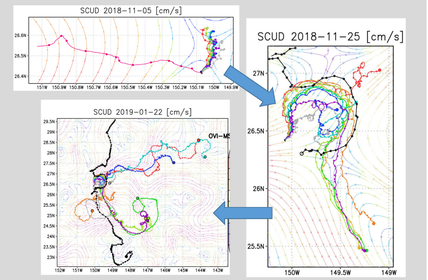
Deployed Nov 2, 2018



1 day later



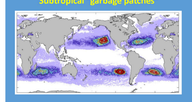
Character of trajectories changes with time



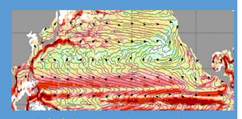
Ekman dynamics implies verifiable effects of vertical shear.

Physics of "garbage patches"

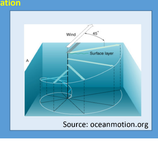
Subtropical "garbage patches"



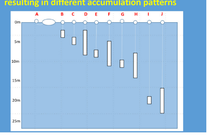
Multi-year mean streamlines of near-surface currents, derived from drifters, converge toward garbage patches



Ekman dynamics is responsible for GP formation

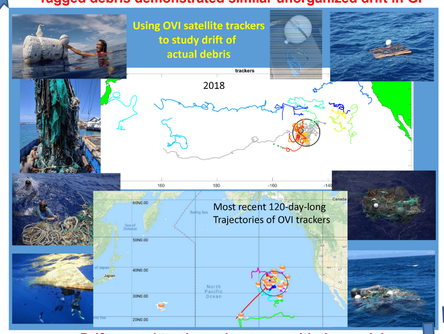


Drift of objects having drag centered at different depths should systematically differ, resulting in different accumulation patterns

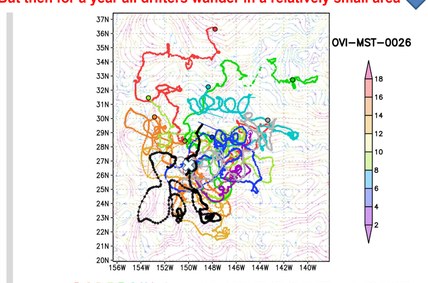


Tagged debris demonstrated similar unorganized drift in GP

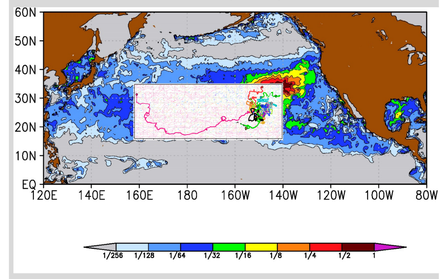
Using OVI satellite trackers to study drift of actual debris



But then for a year all drifters wander in a relatively small area

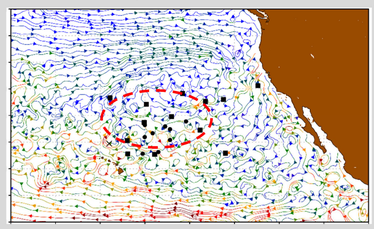


Late northeastward drift is consistent with shift of the GP



Currents in GP are dominated by eddies

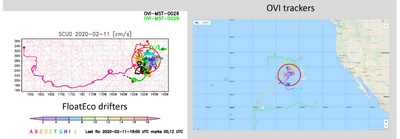
Snapshot of model streamlines

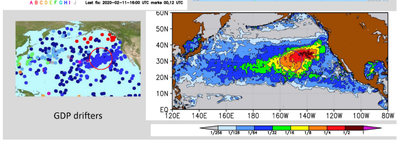


Eddy swamp

Drifters and trackers also agree with the model

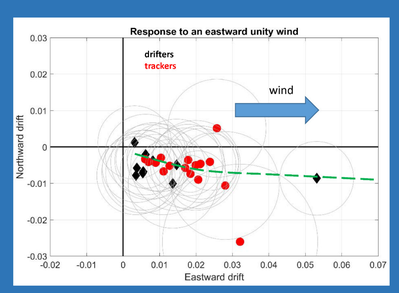
The large-scale pattern of the garbage patch is consistently outlined by drifters, nets and model.





Drifters & trackers response to local wind

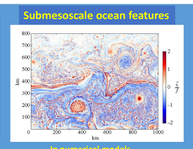
First estimates of real debris response to the wind



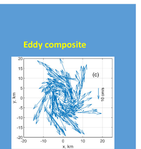
Strong convergencies were found in submesoscale eddies

Submesoscale ocean features

In satellite images

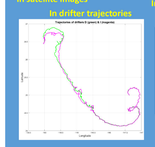


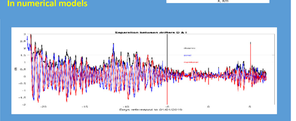
In numerical models



Eddy composite

In drifter trajectories



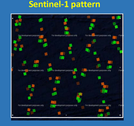


A pair of drifters, drogued at 5m and 20m were trapped in small eddy for a month. I some weeks the drifters were separated by only 200 m.

Guiding boats into SAR-observed slicks

SAR – slicks – marine debris – microplastics relation

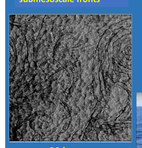
Sentinel-1 pattern



1000 km

IAMOCEAM boat on Sentinel-1A SAR image taken July 23, 2019

Example of SAR image of submesoscale fronts

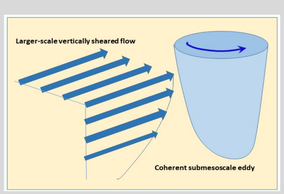


20 km

Microplastics in a slick, observed in August 2019 by Algalita Marine Research

Hypothesis: Vertically coherent eddies trap objects with a broad range of properties and modify the way how these objects respond to the wind.
This interaction reduces differences in the drift caused by differences in geometry.

Next step: How coherent eddies integrate the vertical shear of the background flow?

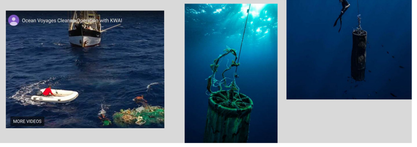


Partners inspected drifters and searched for debris

Often close interaction is found between floating objects

Close interaction between objects in the garbage patch

- Inspection of drifters revealed damages to biological panels and obvious signs of interaction with fishing gear
- Cleanup by OVI found high debris concentrations near tagged nets.
- Also confirmed by preliminary statistical analysis of historical drifter data.



CONCLUSIONS

- Objects of different geometry and buoyancy respond differently to the same ocean conditions.
- However, in the "garbage patch" objects with properties, varying in a broad range, are mixed and do not stratify.
- This may be because of strong eddies (mesoscale and submesoscale) that are ubiquitous in the area and can trap different objects in eddy cores and move them along the same path.
- Interaction of coherent eddies with the vertical shear is important and needs to be studied.

Next step: The experimental mixed layer float

A mixed layer float, capable to maintain neutral buoyancy in the upper ocean, will be used to study how 3D motion of weakly buoyant particles of microplastics rectifies in their horizontal drift under various wind conditions. In the second phase, the float will be programmed to mimic the vertical migrations of zooplankton. These data will help improve bio-physical models. Float is equipped with a camera that will survey biological activity. Retrieval of the drifters will be attempted to download full-size video-information and to collect biofouling samples. The float is on board SV "Blue Moon" and ready for deployment weather conditions permitting.

Volunteers and Partners

The Swim
Algalita
The Ocean Cleanup
eXXpedition

Greenpeace
Polynesian Voyaging Society
Figure 8 Voyage
Rick Pelton S/V Anais

Jim Linderman S/V Lyric
Russ Johnson
Ray McCormack S/V Firefly
Campbell Farrell

N. Treneman – OSU
HI-MDAP members
and many others

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