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Henderson Island's Plastic: An Explanation

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ABSTRACT

Plastic has been accumulating on the beaches of Henderson Island in vast quantities according to recent news reports. It is proposed that the plastic is brought to the island by a very broad permanent surface current flowing southeastward past the island. Other characteristics of the flow are that its temperature is relatively high, its depth is shallow (about 100 m), its speed is sluggish (10 - 20 cm/sec), and by broad is meant more than 5000 km along 28 S. Henderson Island is located at the east/west midpoint of this wide warm current (130 W). By knowing more definitely where the plastic is coming from, than the vague suggestions provided by the news sources, it may be possible in the future to slow down or stop the piling up of trash on what were pristine beaches of this World Heritage Site.

1. INTRODUCTION

Henderson Island, of the South Pacific, sits in the middle of the ocean about 120 miles northeast of Pitcairn Island, famous since the mutiny on the Bounty. Henderson Island itself is famous for being a World Heritage Site, and for the lesser known fact that three life boats from the whale ship (Essex), sunk by "Moby Dick", spent several days there on the way to South America. But lately it has made the news because of the tremendous quantity of plastic washing up on beaches that used to be unspoiled. Of course explanations are given for why this is happening. These might be satisfactory to many readers and viewers. However, a different type of explanation is offered here: one with a strong observational base as well as a physical concept behind it.

On the TV screen (KPBS News, 05/16/17, 6:00 pm), a circle was drawn with Henderson Island at the center; the radius being considerably smaller than half the width of the ocean. It is then presumed that Henderson Island is at the middle of a gyre circulating around, and further away were hints of a larger scale system of currents in which the smaller gyre was embedded. How plastic objects floating in these schematic currents get to the island is left to the imagination of persons watching the news. An attempt is now made to do better than that. [Each significant down turn of the stock market is accompanied by a hasty explanation, might be an analogy.]

From a practical view point, by knowing more exactly how the plastic gets to the island, attempts can

then be made to reduce and perhaps stop the accumulation of trash there.

2. A NEW EXPLANATION

Way before plastic was invented, there has likely been a very broad surface flow constantly directed southeast diagonally across the center of the South Pacific, connecting tropical latitudes with mid- and higher latitudes. Henderson Island is located east/west in the middle of this rather sluggish stream of relatively warm surface water. In Figure 1 is shown the sea surface temperatures measured during an oceanographic cruise that sailed along a line of constant latitude (28 S) between South America and Australia during the southern hemisphere winter of 1967 (June and July). Separation distances between measurements were short and the thermometers were very accurate. What immediately strikes the eye is the wide maximum in sea surface temperature whose mid-point is approximately at longitude 130 W, which incidentally is very nearly the longitude of Henderson Island (128 W, and the two latitudes are close too, Henderson is at 24 S).

A question to ask about Figure 1 is: how did all that warm water get to the middle of the ocean in the middle of winter? One wants to know at this point what the depth of the surface flow is. Surrounding the sea surface maximum is a broad mixed layer with an average depth of 100 m (not shown here but see [1]). A mixed layer has an almost constant temperature vertically between the surface and the depth where the temperature begins to decrease rapidly, starting the thermocline. Mixed layers can be made in various ways but when warm water moves to higher latitudes, the surface is cooled from above leading to penetrative convection down to a certain depth. To estimate the amount of warm water moving south the depth scale of 100 m and the longitudinal bandwidth (over 5000 km) of the mixed layer can be used.

Consider next a few particulars of Henderson Island [2], which is a raised coral atoll, *i.e.* relatively small horizontally. Its beaches are on the north side; the other sides have cliffs. Perhaps erosion of former

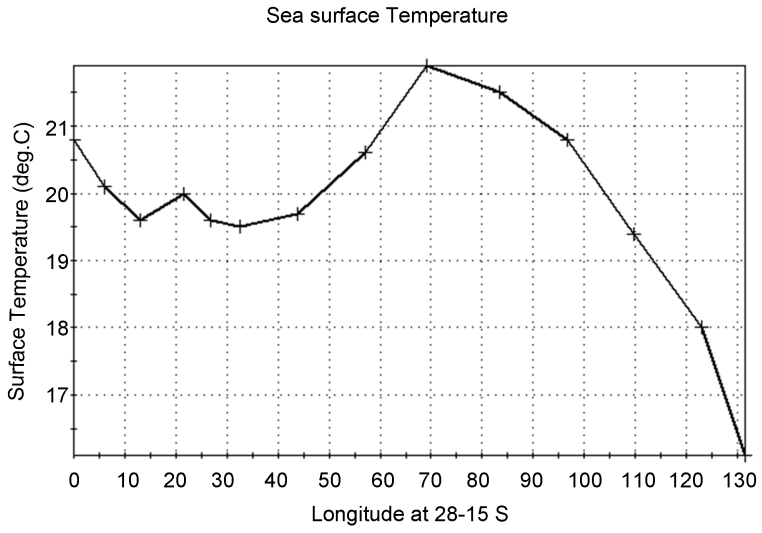

Figure 1. Sea surface temperature as a function of longitude at 28 - 15 S between South America (to the right) and Australia (to the left) adapted from Figure 1 of Reference [1] by block averaging groups of seven adjacent individual measurements and their corresponding longitudes. Longitude scale is in degrees relative to Australia (which is zero) and increasing eastward. For example, 70 equals 130 W.

cliffs by wind and waves over thousands of years caused beaches to develop, which might have been aided by the constant presence of the southeastward flow surrounding the island (e.g. surface waves can be trapped inside currents by refraction [3]). The warm surface flow itself is not caused by the wind but by a difference in surface temperature between the equator and the pole. A difference in surface temperature, even over a large horizontal distance, is an inherently unstable situation such that initially the colder water wants to rush toward the equator causing the warmer water to move toward the pole on top of, and or beside it, in a thermo (haline) circulation, set up and maintained by absorbed solar radiation.

3. DISCUSSION

A broad and sluggish surface flow of relatively warm water diagonally crossing the central South Pacific in a southeasterly direction, although based on fewer observations, is a concept consistent with what has been established in the data rich North Pacific. There is one complete east-west hydrographic section along 35 N, similar to the one along 28 S (**Figure 1** shows SSTs only), but in addition sea surface temperatures from ship-injection data exist in the millions (estimates give about 12 million in a 30 year span). Thus the wide warm northeastward surface flow can be considered to be a permanent feature of the eastern North Pacific at mid-latitudes. A prominent signature of the flow is the large-scale longitudinal maximum in SST in the 5 degree latitude/longitude square averaged data, which is present in every monthly mean map from 1947-1976 at both 35 and 40 N.

If floating plastic gets into one of these broad surface currents, as proposed for the North and South Pacific, it basically cannot get out unless it either sinks in deep water or lands on a beach, since the currents are coherent structures involved in maintaining the ocean's heat balance. How the plastic gets into the wide warm currents to begin with is not completely clear now but future work may shed light on the problem. Some pieces of plastic found on beaches have readable printing showing the country where they were manufactured. Though intriguing such information is not definitive, because, for example, the plastic could be dumped into the ocean from a ship far from land.

Of the North Pacific plastic continually washes up in the southernmost beach on the southernmost Hawaiian island (the big one) [4] where the wide warm northeastward current flows past.

A contrast to the uncertainty in the origin of ocean plastic is the sea turtle, which lays its eggs on a sand beach. From there these turtles can ride the poleward warm surface currents, which occasionally bump into a continent, thousands of miles on their typically long migration journeys. One beach photo from Henderson showed a dead sea turtle caught up in fishing net.

4. CONCLUSION

How does plastic debris get to Henderson Island? Not only is Henderson Island in the middle of the South Pacific but it is also in the middle of a very wide surface current that flows past it in a southeasterly direction. Such a current is deduced to be present at all times by direct observations from an extensive oceanographic cruise at 28 S and by analogy with a similar current in the North Pacific established from an east/west hydrographic section at 35 N as well as by millions of ship-injection temperatures. Offered for consideration is the conclusion that this southeast current is what brings floating trash to the beaches of Henderson Island. Future investigations may reveal how the plastic initially gets into the current. Then efforts can be initiated to stop the flood of garbage piling up on the beaches.

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