The search for MH370 and ocean surface drift – Part IV

David Griffin and Peter Oke
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Important disclaimer

Foreword

This work is dedicated to the 239 people aboard flight MH370.

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Acknowledgments

Executive summary

This short report re-examines the question of how effective the March-April surface search was for 'ruling out' segments of the 7th arc as being the location of MH370.

One might think that even if the debris field was within a particular day's search box that the probability of detecting the debris could be small because the spacing between the search tracks was necessarily large (in order to cover the vast distances searched) compared to the detection range. This would certainly be correct if either 1) the number of debris items was small, or 2) the debris items were all close to each other.

We now know (from the number of items that have been found washed ashore) that the number of floating debris items was not small. But while we cannot prove that these were not all close to each other and therefore potentially overlooked, the chance of this happening is very low. Winds, waves and ocean turbulence disperse objects, potentially over large distances after a week at sea. The rate of spreading of the debris field increases as time passes, as stretching and shearing by ever-larger ocean eddies takes place.

In this report we show that the debris field resulting from an example crash site at 30.5°S on the 7th arc was 1) largely within the bounds of the area searched during 5 days, and 2) probably spread out across a distance spanning several of the search tracks. Consequently, there were many opportunities for debris to be detected, suggesting that the probability of all debris items being overlooked is small.

Our re-assessment of the surface search benefits from 1) the evidence that an extensive debris field was indeed there to be found, and 2) refined estimates of the surface currents, allowing us to re-assess how well the search boxes overlapped with the potential locations of the debris fields.

1 Introduction

This is our 4th report describing oceanographic drift modelling work done in aid of the search for 9M-MRO (the Boeing 777 aircraft flying Malaysia Airlines service MH370 on 8 March 2014).

Our first report (Griffin et al., 2016) identified the 36°-32°S segment of the 7th arc (especially the region near 35°S) as being the most likely site of the impact, based on where and when debris was seen and not seen on African and Australian shores and during the initial 40-day aerial search (Fig 1.1). This work was a contribution to the First Principles Review ATSB (2016).

The 2nd report (Griffin et al., 2017a) documented additional research recommended by the First Principles Review using a real Boeing 777 flaperon, rather than a replica. We measured its drift characteristics after modifying it to match the damaged one retrieved from Ile de la Reunion. This work did not change our estimate of the most likely location of the impact – it just increased confidence in the modelling by explaining more easily the 29 July 2015 Ile de la Reunion flaperon discovery.

In our third report (Griffin et al., 2017b) we discussed the implications, in terms of locating 9M-MRO, of analyses by Minchin et al. (2017) of some ultra-high resolution (meter-scale) optical images acquired in March 2014. This showed that items seen in the images could very well have been within the southern half of the proposed (36°-32°S) search region, but not the northern half. Recalling that we had already identified this southern half as being more prospective, this extra information gives an additional measure of confidence. Some doubt still exists, of course, because the items may not have been parts of 9M-MRO. For this reason, we have continued to re-examine all the available evidence.

This 4th report revisits one of questions addressed in our earlier reports – the effectiveness of the surface search. To what extent does it rule out various areas as being the location of 9M-MRO? In particular, we have partially relied on the surface search to argue that 9M-MRO is less likely to be north of 32°S than south of 32°S. Other factors are that 1) travel times to Africa are progressively less for more northern sites, so absence of debris findings before December 2016 become harder to explain, and 2) simulated flight paths terminating north of 32°S are progressively less consistent with SATCOM data.

The work that resulted in Fig 1.1 (graphic and caption reproduced from our 3rd report) focussed more on the question of whether hypothetical debris items were within the bounds of the search boxes, than on how likely it was that hypothetical debris fields could have been detected. The probability of being detected was assumed to be equal for all items within the search boxes, regardless of location relative to completed search lines. This probability was low (10 or 20%) on days of very poor weather or wide (>20NM) track spacing but high (often 100%) on other days. This would be an over-estimate for all items not within the detection range of individual aircraft if they were to be interpreted as representing single items. But they were not meant to represent single items. Why not? Because 1) the positions of items relative to the tracks are not known accurately enough on an item-by-item basis, and 2) the detectability of the items as a function of range are not known, either. So what we did was simply to follow each tracked parcel, and

calculate the cumulative probability of it being detected. For example, if the parcel passed through two daily search boxes, each with a POD of 50%, then the cumulative POD is 75%. The map in the right panel of Fig 1.1 shows the spatially-binned arithmetic average of the cumulative PODs of adjacent parcels. These adjacent parcels represent potential crash sites that are too close together for our model to reliably distinguish.

To understand the basis of our estimation procedure, it helps to think about a single hypothetical crash site, rather than many simultaneously.
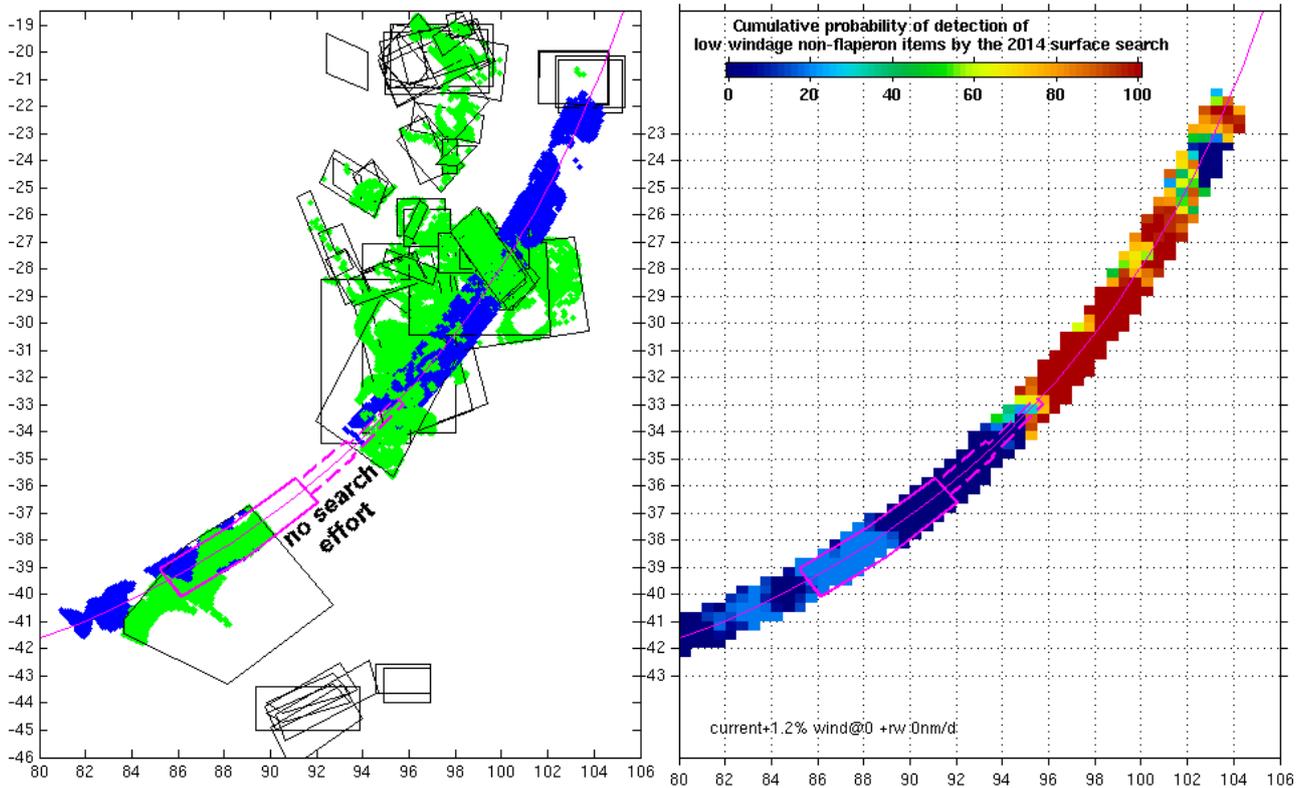
Fig. 1.1. Interpreting the surface search. The left panel shows the daily search areas as black polygons. Green zones are where low-windage debris would have drifted, having entered the water on 8 March 2014 at the locations shown in blue. The cumulative probability of detection (right panel) of potential debris shows that the aerial search effectively ruled out crash sites north of about 33°S but ineffectively searched latitudes south of 34°S. The equivalent analysis for [high-windage] items is very similar.

2 Could the surface search have missed the debris field, had impact been near 30°S, for example?

The potential debris field from an impact near 30°S on the 7th arc was targeted from 28 March to 1 April 2014. Between 8 and 11 aircraft were tasked, with search tracks spaced at 12 to 16NM (see Table 13 and 14 of ATSB 2017). Several of these were fitted with marine surveillance radar. The area intended to be searched each day ranged from 164,087 to 298,636 km^2.

The areas searched from 28 March to 1 April 2014 were designed not just to target the debris field from an impact near 30°S, of course, but for a wider range of hypothetical impact points in 'area A' (ATSB 2017). For choosing the bounds of any future sea-floor search we still need to contemplate a wide range of potential impact points but here we will focus on a single example impact point for demonstration purposes.

For any particular hypothetical point of impact, it is impossible to estimate exactly (i.e. well within detection range) where each of the individual debris items would have been after drifting for 20+ days. But we do think it is possible to estimate the bounds of the debris field with some degree of confidence. We can also say with some confidence that the debris would not have been uniformly distributed, but most likely stretched into a complicated shape. This is because the swirling nature of ocean surface velocities acts like a stirring mechanism.

Our models are informed by satellite observations (of sea level and temperature, as discussed in earlier reports) so they can represent reality on a point-by-point basis but only to a certain degree. The errors of the model, like the random turbulence of the ocean, cause error amplification over this mid-range of time scales. To avoid the pitfall of over-interpreting results from a single model, we therefore use two very similar versions of our ocean model – BRAN2015 and BRAN2016.

Figures 2.1 and 2.2 show that according to both models, the potential debris field was almost certainly overflown on several occasions during this 5-day period. But the models do not agree on which tracks came closest to the items, showing that the probability of detecting single items cannot reliably be estimated. So we must resort to a simpler technique, as follows.

Consider a field of N items, a portion P of which are within the bounds of a day's searching. If these were overflown several times at several places (as shown in Fig 2.1), the probability of detecting any of the P*N items depends on the ratio of the sweep width W (which is twice the detection range R) to the track spacing S. If N is 200 for example, P is 0.5 and W/S is 0.1 on one day, then one can reasonably expect to detect, on average, 200*0.5*0.1=10 items. If this is sustained for 5 days then 50 detections might be expected. Halving N and W (both of which are uncertain) brings this down to 12. The distribution of the items with respect to the tracks would have to be very unlucky for no items to be seen at all.

From these numbers, we suggest that the probability of detecting **at least one** of the N debris items is very high, for this example location. We expect that similar conclusions would be reached for neighbouring locations.
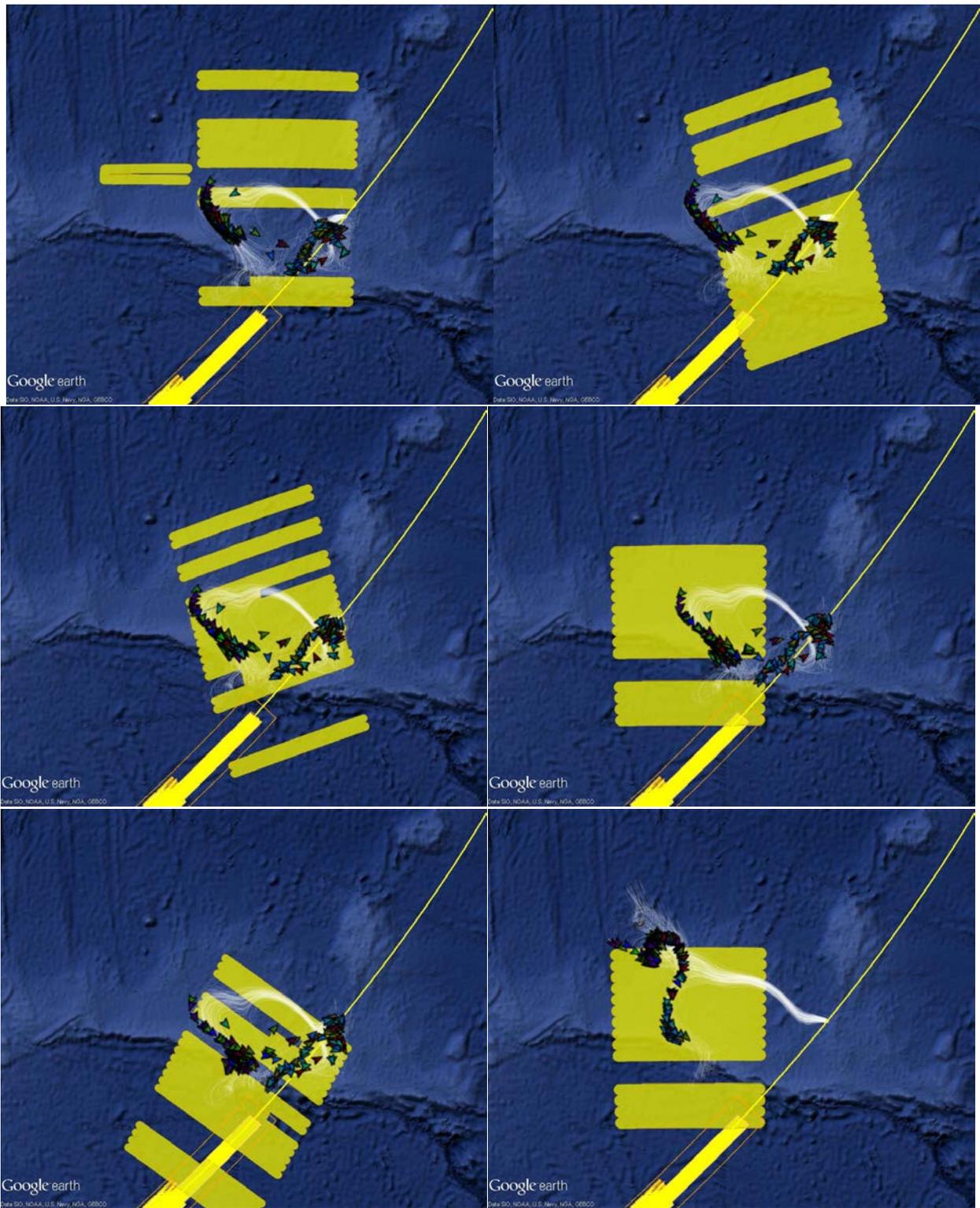
Fig. 2.1. Panels 1 to 5: positions of low-windage debris items on 28 March to 1 April 2014 overlain on the completed search tracks for each day, according to the BRAN2015 model for a hypothetical impact point at 30.5˚S, 97.86˚E. Panel 6: high windage items for 31 March. Trajectory modelling used 1.2% or 3% windage and a small amount of random dispersion (daily random walks of ~ 1.2NM/day). Also shown are the completed sea floor search, the outline of the proposed sea floor search, and the 7th arc. Zoom and pan these images by importing kmz files of [low] and/or [high] windage items into Google Earth.
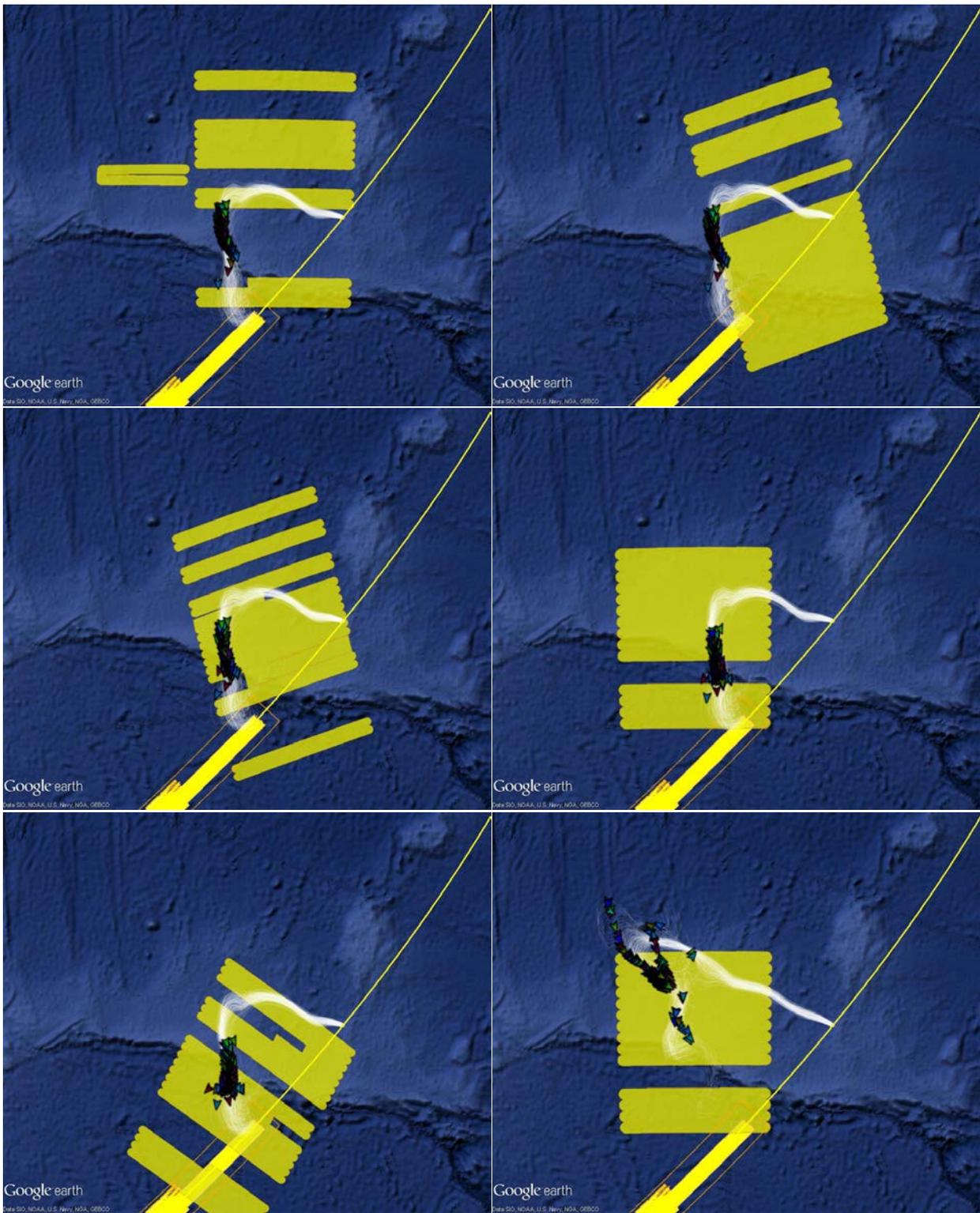
Fig. 2.2. As for Fig 2.1 but using the BRAN2016 model, which is just as likely to be correct. As above: kmz files of [low] and/or [high] windage items.

3 Conclusion

We stand by our earlier conclusion that the surface search had a fairly high chance of detecting a debris field if the impact had been near the segments of the 7th arc postulated at the time of those searches, at least for the section near Broken Ridge that was searched from 28 March to 1 April. It is conceivable that some hypothetical debris fields could have escaped detection by not dispersing very much, and remaining by chance outside the detection range of every overflight but the chance of this would appear to be very small.

If further confidence in the effectiveness of the surface search is sought, we suggest that the following parcels of work may be worth doing:

- field measurements of the radar detection ranges of example pieces of debris – the flaperon that we have used for drift measurements, for example.

- Repeat the work reported here, for all other locations of particular interest, and using other models of the surface drift as well

- Higher-resolution numerical modelling, informed by field data, of the dispersive processes that govern the size of the debris field after 20 days drift. This is a challenging task that we doubt would be more convincing than the approach we have taken, because the rate of mixing and dispersal in the ocean varies so widely that it is impossible to determine if a complicated model is correct for any particular place and time without any corroborating evidence.

4 Glossary

7th arc. The curved line defined by a set of points that are all equidistant from the Inmarsat satellite via which 9M-MRO was in communication with a satellite ground station. This distance is inferred from the Burst Timing Offset associated with the 7th communication since losing contact with traffic controllers. For more detail, see ATSB 2015.

9M-MRO. The designation of the particular Boeing 777 aircraft operating Malaysia Airlines Flight MH-370 on 8 March 2014.

Altimeter. An instrument carried by an earth-observation satellite that measures two quantities extremely accurately – 1) its position in space and 2) the distance to the surface of the ocean directly below – in order to estimate the departure of the sea surface from a reference surface. This project used data from the following missions operated by the respective space agencies: Jason-2 (NASA and CNES), CryoSat2 (ESA), AltiKa (CNES and ISRO). FFI see http://oceancurrent.imos.org.au/glossary.php

BRAN. Bluelink ReAnalysis – Results from a global $1/10^{th}$ degree resolution (~11km at the equator) ocean general circulation model that assimilates ocean observations to constrain the modelled circulation to reality. BRAN2015 is the version of BRAN executed in the year 2015, and spanned just 7 years (2009-2016). It was our first long, data-assimilating model run with 0.1° resolution for the entire globe, as well as having other physics refinements over the 2014 version, which had coarse resolution outside the Australasian region. BRAN2016 was completed in 2016 and spanned the full extent (1994-2016) of the period for which there is data from satellite altimeters. There were no important changes to the model physics, but there was a change from using the NOAA GFDL MOM4 dynamical core to MOM5. A minor error in the output file format (inappropriate compression) of BRAN2016 explains the jagged contours of the SLA maps shown in this report.

GDP. Global Drifter Program, housed at the US National Oceanic and Atmospheric Administration Atlantic Oceanographic and Meteorological Laboratory (NOAA AOML). FFI see http://www.aoml.noaa.gov/phod/dac/gdp_information.php

NM. Nautical mile. Equivalent to one minute of latitude, or 1.85km.

SLA. Sea Level Anomaly. The departure of (non-tidal, and with the quasi-isostatic response to atmospheric pressure subtracted) sea-level from the time-mean value. FFI.

Stokes Drift. Movement in the direction of waves due to the fact that the orbital velocity of a parcel of water, due to the passage of a wave, is not a closed ellipse.

Windage. Strictly speaking, this is defined as the wind-driven motion with respect to the water of a floating object, due to the force of the wind on the object. More commonly, it is taken to be the wind-driven motion with respect to a specific measure of the surface velocity. If that measure does not include the Stokes Drift or other wind-related quantities, then the windage factor (ratio of windage to wind speed) will be a measure of them too.

References

ATSB (2016). MH370 – First Principles Review Report. Australian Transport Safety Bureau, 20 December 2016.

ATSB (2017). The operational search for MH370. ATSB Transport Safety Report. Aviation External Investigation AE-2014-054. Australian Transport Safety Bureau, October 2017.

Minchin, S., Mueller, N., Lewis, A., Byrne, G., Tran, M., 2017. Summary of imagery analyses for non-natural objects in support of the search for Flight MH370: Results from the analysis of imagery from the PLEIADES 1A satellite undertaken by Geoscience Australia. Record 2017/13. Geoscience Australia, Canberra. http://dx.doi.org/10.11636/Record.2017.013

Griffin DA, Oke PR, Jones EM (2016). The search for MH370 and ocean surface drift. CSIRO Oceans and Atmosphere, Australia. Report number EP167888. 8 December 2016. DOI: 10.4225/08/5892224dec08c

Griffin DA, Oke PR, Jones EM (2017a). The search for MH370 and ocean surface drift- Part II. CSIRO Oceans and Atmosphere, Australia. Report number EP172633. 13 April 2017. DOI: https://doi.org/10.4225/08/58fba83e73f2b

Griffin DA, Oke PR, Jones EM (2017b). The search for MH370 and ocean surface drift- Part III. CSIRO Oceans and Atmosphere, Australia. Report number EP174155. 26 June 2017. DOI:https://doi.org/10.4225/08/599344b9beead

Oke PR, Sakov P, Cahill ML, Dunn JR, Fiedler R, Griffin DA, Mansbridge JV, Ridgway KR, Schiller A (2013a). Towards a dynamically balanced eddy-resolving ocean reanalysis: BRAN3. *Ocean Modelling* **67**, 52-70, doi: dx.doi.org/10.1016/j.ocemod.2013.03.008

Oke PR, Griffin DA, Schiller A, Matear RJ, Fiedler R, Mansbridge JV, Lenton A, Cahill M, Chamberlain MA, Ridgway K (2013b). Evaluation of a near-global eddy-resolving ocean model. *Geoscientific Model Development* **6**, 591-615, doi:10.5194/gmd-6-591-2013.