Australian Government
Australian Transport Safety Bureau

CSIRO

MH370

MH370: Aircraft Debris and Drift Modelling

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Background

The ATSB is leading the search for missing Malaysia Airlines flight 370 in the southern Indian Ocean. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) performed drift modelling based on the revised search area defined in the report *MH370 - Flight Path Analysis Update* released on 8 October 2014.

Overview

Looking at past accidents, there is almost always some debris left floating after an aircraft crashes in water. The opportunity to locate and recover debris from the sea surface diminishes rapidly over the first few weeks from the time of a crash. Thereafter some less permeable items of debris will remain afloat for a longer period but they will be increasingly dispersed. To be found ashore, an item of debris must remain afloat long enough and be subjected to the right combination of wind and currents for it to make landfall.

The most recent drift modelling indicated that the net drift of most debris in the sixteen months to July 2015 is likely to have been north and then west away from the accident site. The drift analysis undertaken by the CSIRO further supports that the debris from MH370 may be found as far west of the search area as La Réunion Island.

This is consistent with the currently defined search area.

Introduction

There are several factors which together determine the likelihood of debris from MH370 being detected on the sea surface or washing up on a shoreline on the rim of the Indian Ocean. These are:

» The quantity and nature of any floating debris created by the aircraft impacting the sea surface which in turn is determined by:

- The physics of the impact, including the velocity and attitude of the aircraft, the structural strength of the aircraft and its components and therefore the nature and extent of the failure of the aircraft structure which liberated or created debris;
- The composition and contents of the aircraft including structural components, internal fit-out and what was carried on board including passenger baggage and cargo.

- The physical properties of the debris generated by the impact, i.e. material, size, shape, density which all have an effect on the surface drift of each piece of debris and its permeability.
- The prevailing wind and currents which act over time to move and disperse the debris on the sea surface.
- Time.

Past examples

There are several examples of commercial aircraft impacting water at high speed and what debris may be left on the surface. Below are some examples:

Silk Air flight B737, 19 December 1997: On 19 December 1997, Silk Air flight 185, a Boeing B737, crashed into the Musi River in Sumatra. The aircraft was seen by witnesses to enter the water vertically at high-velocity and disintegrate on impact. Several parts of the tail of the aircraft had separated in-flight during the final descent and landed on shore and these were recovered. However, within 24 Hrs, due to the tidal nature of the river and proximity to the sea, there were no floating objects from the aircraft recovered. Almost the entire aircraft was buried in deep mud at the bottom of the river.

Adam Air B737, 1 January 2007: On 1 January 2007, Adam Air flight 574, a Boeing B737, crashed into the sea off Sulawesi while en route from Surabaya to Manado. On January 11, parts of the aircraft's tail stabilizer were found 300 m offshore. Later, other parts of the aircraft including passenger seats, life jackets, several food trays, several seat cushions, part of an aircraft tire, pieces of aluminium and fibre, an ID card, a briefcase, a flare and a headrest were also recovered from the area. By 13 January, a piece of a wing was also recovered. The total count of recovered objects by 29 January was 206, of which 194 were definitely from the aircraft.

Air France A330, 1 June 2009: On 1 June 2009, Air France flight AF447, an Airbus A330 aircraft, crashed into the Atlantic Ocean off the coast of Brazil. French and Brazilian navies were involved in a surface search and located the first part of floating debris on 5 June 2009. A surface search continued until 20 June 2009, in all over 700 pieces of floating debris were recovered. No further floating debris were located after 20 June, twenty days after the accident.

Air Asia A320, 28 December 2014: On 28 December 2014, Air Asia flight 8501, an Airbus A320 aircraft, crashed into the Java Sea while en route from Surabaya, Indonesia to Singapore. Observations by an Indonesian investigator were that floating wreckage included 3-4 economy seat pairs, some ceiling liner honeycomb material, an escape slide including bottle (it had not inflated), and some seat cushions. Some of the wreckage was recovered more than two weeks after the accident, up to 100 miles away.

Summary

Looking at past accidents, there is almost always some debris left floating after an aircraft crashes in water. The debris will often include those items designed to float including seat cushions, life jackets, escape slides etc but also many items of cabin fit-out, like cabin linings and tray tables, which are made of low density synthetic materials. Similarly aircraft structural components, including flight surfaces, may entrap sufficient air to remain buoyant for reasonable periods and have also been commonly found afloat following a crash. The amount and type of debris varies but it is usually detected and recovered within the first few weeks of the accident before it has been significantly dispersed.

Over time, all floating debris will become water-logged and then sink. For some items of debris this may be relatively fast. For example, items which are buoyant due to entrapped air will sink when the air is released or void spaces become filled, a process which is hastened by the action of wind and waves. Other items constructed of materials which are less permeable, like seat cushions, will float for long periods but they too will eventually sink when the material degrades through chemical and/or mechanical decomposition. This decomposition may take a very long time in the case of some synthetic materials, plastics in particular, but is quicker for items which biodegrade.

In summary, the opportunity to locate and recover debris from the sea surface diminishes rapidly over the first few weeks from the time of a crash. Thereafter, there will be some less permeable items of debris which will remain afloat for a longer period but they will be increasingly dispersed. Dispersal is directly related to the surface drift experienced by the individual items of debris which in turn is related to their physical characteristics: size, shape and density. To be found ashore, an item of debris must remain afloat long enough and be subjected to the right combination of wind and currents for it to make landfall.

Drift models for MH370

On 17 March 2014, 9 days after the aircraft disappeared, the sea surface search for MH370 shifted to the southern Indian Ocean. The Australian Maritime Safety Authority (AMSA) assumed the coordination of search operations. A summary of the first three weeks of search operations can be found on the AMSA website.

In the first weeks of the surface search in the Indian Ocean, a broad area was searched which included some of the current area of the underwater search and some areas adjacent to it. The searchers were guided by early analysis of the data from the aircraft's satellite communication system and satellite imagery which detected several items of interest, none of which were confirmed to have originated from MH370.

A drift modelling working group was set up, comprising a number of organisations including: the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Asia-Pacific Applied Science Associates (APASA), the US Coastguard, the Bureau of Meteorology (BOM) and Global Environmental Modelling Systems (GEMS) to ensure that best practice modelling was put in place for the subsequent search. A number of search and rescue datum buoys were also deployed which were used to measure actual surface drift in the search area and to validate the drift models being used. Similarly, real-time wind and wave data from the search area was used to continuously update the drift model. The surface search for debris ended on 28 April 2014.

Following the release of the *MH370 - Definition of Underwater Search Areas* report on 26 June 2014, a drift model was applied by one organisation to the wide search area defined in the report. The drift modelling was run to provide an indication of when and where the first possible debris would make landfall. This modelling indicated that the first possible landfall was on the west coast of Sumatra, Indonesia and would have occurred in the first few weeks of July 2014. Indonesian search and rescue authorities were subsequently advised of the possibility of debris washing up on their shoreline.

In November 2014, the ATSB asked CSIRO to perform drift modelling based on the revised search area defined in the MH370 - Flight Path Analysis Update report released on 8 October 2014. This modelling indicated that there was an extremely low probability that any debris from MH370 would have made landfall at that time. As the CSIRO modelling was not consistent with the previous modelling performed by a different organisation, the question was asked as to why the two models were yielding different results and an error was found in the way in which BOM wind data was being transferred into the first model. While this error in that model had no impact on the way the surface search was conducted, it was important in order to understand over the course of time where debris might wash up and help verify or discount the various items found on beaches, particularly on the west coast of Australia.

Further refinement to the CSIRO drift modelling has been undertaken since 30 July 2015 with the most recent modelling taking into account the effect of waves (in addition to wind and current) and extending the scope of the area covered to include the western Indian Ocean.

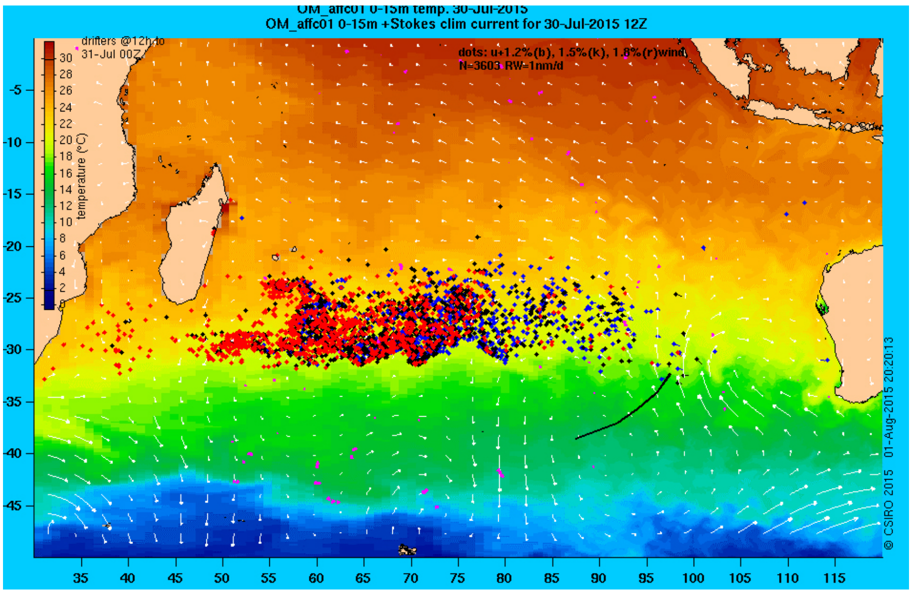
Figure 1 shows the indicative drift as at 30 July 2015, produced from the latest CSIRO modelling (released with permission of CSIRO). It shows the final image from a computer simulation of the movement of potential debris resulting from the crash of MH370 somewhere along the 7th arc between latitude 39°S and 32°S. The simulation was run from 8 March 2014 to 30 July 2015, to see if the flaperon found on La Réunion (21.2°S 57°E) could have drifted there from the MH370 search zone in the intervening time. The movement of the items is calculated from the combined influence of ocean currents, winds and waves. Currents and winds are estimated by the Bureau of Meteorology's operational ocean and weather forecasting systems, while the Stokes drift due to ocean waves is estimated from the NOAA Wavewatch III model. Dr David Griffin from the CSIRO concluded that if the flaperon drifted with an effective leeway factor of about 1.5% then its arrival at La Réunion does not cast doubt on the validity of the present MH370 search area, taking the errors of the ocean, wind and wave models into account. He also concluded that because of the turbulent nature of the ocean, and the uncertainties of the modelling, it is impossible to use the La Réunion finding to refine or shift the search area.

Conclusion

The surface search in the southern Indian Ocean commenced 9 days after MH370 went missing. By this time much of any debris left floating after the crash would likely have either sunk or have been dispersed. The surface search initially, briefly, targeted the correct area based on the initial, and then subsequent work, to reconstruct the aircraft's flight path and therefore the surface search at this point in time represented the best chance to identify and recover any floating debris.

Most recent drift modelling indicated that the net drift of most debris in the months to July 2015 is likely to have been north and then west away from the accident site. The drift analysis undertaken by the CSIRO further supports that the debris from MH370 may be found as far west of the search area as La Réunion Island and is consistent with the currently defined Search area.

Figure 1: Indicative drift from the Search Area as at 30 July 2015



Blue, black and red dots simulate items with leeway factors (applied to the 10m wind velocity) of 1.2, 1.5 and 1.8%. The items originated along the black arc (7th arc) on 8 March 2014. White arrows are the winds for the day shown. Magenta symbols are positions of real drifting buoys (with sea-anchors at 12m) on the day. Their movement has been used to estimate the errors of the ocean current component of the total drift velocity.

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1. The *National Search and Rescue Supplement to the International Aeronautical and Maritime Search and Rescue Manual* defines surface drift (sometimes called total drift) of an object floating on the sea surface as made up of the leeway drift and the movement of the upper layer of the ocean caused by the surface currents, tidal currents and ocean currents. Leeway is the movement of a search object through water caused by winds blowing against exposed surfaces. Generally very buoyant objects float high and exhibit more leeway and therefore their drift is more influenced by prevailing winds, objects floating lower in the water have lower leeways and therefore are influenced more by currents.

2. Permeability of a floating object is related to its composition and the change in its density over time when immersed in seawater and subject to degradation due mechanical wear (wind and wave action, marine growth) and chemical exposure (UV light, oxidation etc). Over time, all floating debris will degrade, absorb or fill with water and lose buoyancy until they sink.