MH370 Detection and Tracking

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1. Previous Paper.

In the previous paper titled MH370 GDTAAA WSPRnet Analysis Flight Path Report dated 31st December 2021, we tracked MH370 from take off to the end of flight.

Since the previous paper was published we have made a number of improvements in the GDTAAA software and WSPRnet data processing.

One of the key changes is a tighter definition of the WSPRnet SNR anomalies.

Previously we considered anomalies ≥ 1.0 standard deviation (SD) marked in red, ≥ 0.5 SD marked in orange and ≥ 0.25 SD marked in yellow.

Now we only consider anomalies ≥ 1.0 standard deviation (SD) marked in red and ≥ 0.75 SD marked in orange.

Figure 1 is an example from the previous paper showing the flight path of MH370 up to 17:56 UTC and the position of all other aircraft in the vicinity of MH370.

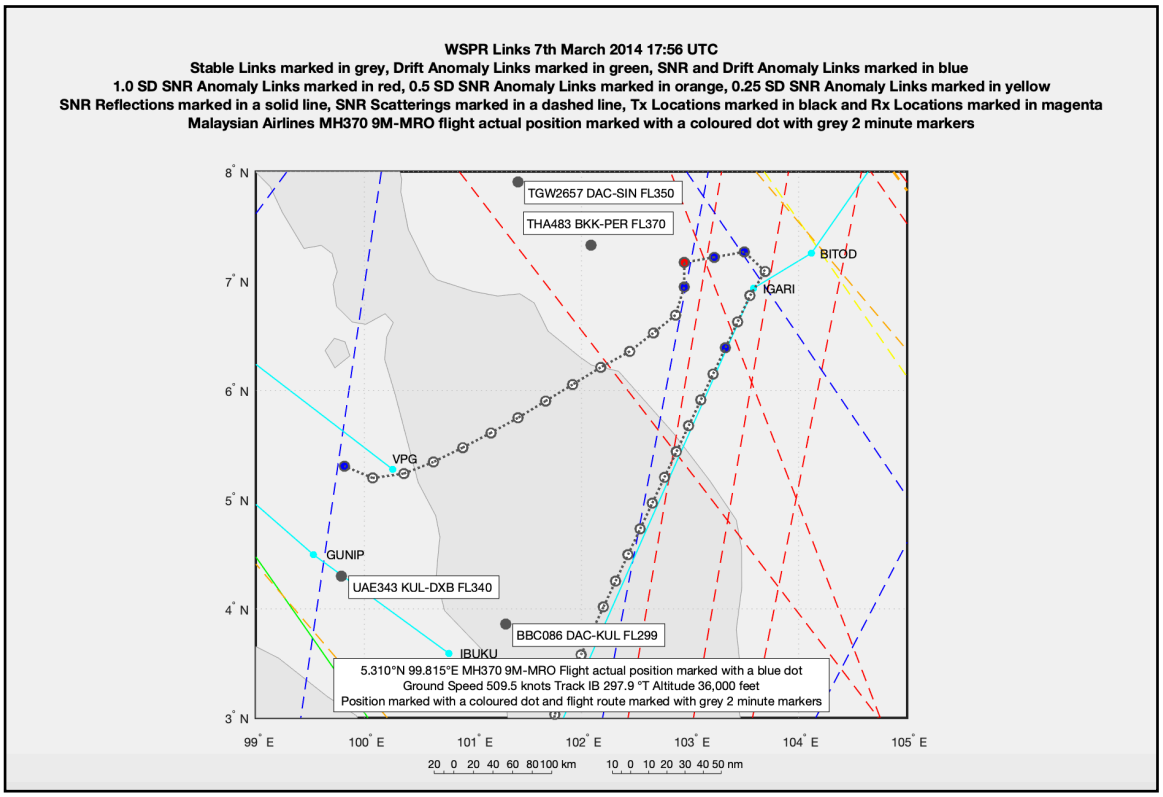

Figure 1: Example Figure from the Previous Paper at 17:56 UTC.

2. Maidenhead Grid Locators.

The WSPRnet data includes the Maidenhead grid locators for each transmitter and receiver.

Many of the Maidenhead grid locators in the WSPRnet database are only 4 characters and were previously discarded or transformed artificially to 6 characters with the suffix of “mm” that indicates the centre of the grid square.

We require 6 character Maidenhead grid locators for the accurate plotting of WSPRnet links.

We use the attached table to correct the 4 character Maidenhead grid locators to the correct 6 character Maidenhead grid locators for the MH370 relevant WSPRnet links in 2014. The table is sourced from information found in the internet for each of the relevant call signs. We use other Maidenhead Grid correction tables for other flights at other times.

https://www.dropbox.com/s/ecfzy2kqjcsmtd1/Call%20Sign%20Locators.xlsx?dl=0

3. Known Start Position.

We use a known start position at 17:56 UTC of 5.310°N 99.815°E.

This is derived from the civilian Terminal Area Radar (TAR) data for the Penang Airport TAR based at Butterworth Air Force Base.

The altitude of MH370 at this start position is assumed to be 36,000 feet, which fits the ground speed of 509.5 knots derived from the radar data. The track is 297.9°T, which is also derived from the radar data.

https://www.dropbox.com/s/a79ghir4h6iz2np/Kota%20Bharu%20and%20Butterworth%20Primary%20Radar.xlsx?dl=0

The start position also matches an anomalous WSPRnet link with a SNR deviation of 182% and a drift of -1 Hz/min.

The drift is almost permanent at -1 Hz/min although it was 0 just prior to 17:56 UTC.

We now disregard any drift anomaly that is permanent or almost permanent during the time period ± 3 hours around the test datum.

The mean SNR for the WSPRnet link between the transmitter call sign WB8ELK at the grid location EM64oj and the receiver K9AN at the grid location EN50wc for the time period 17:56 UTC ± 3 hours is -8.3390 dB.

The SD is 3.1107, the actual value at 17:56 UTC is -14 dB and the actual deviation is 5.6610 dB or 182% SD.

spotnum	date (y-m-d)	txCall	txGrid	rxCall	rxGrid	MHz	Watts	SNR	drft	km	az	mode	kpw	spotQ	version
186092148	2014-03-07 15:26:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-7	-1	646	350	2	3230	2602	
186093376	2014-03-07 15:30:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-8	-1	646	350	2	3230	2512	
186094810	2014-03-07 15:34:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097116	0.2	-4	-1	646	350	2	3230	2871	
186095140	2014-03-07 15:36:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-4	-1	646	350	2	3230	2871	
186106152	2014-03-07 16:14:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097116	0.2	-5	-1	646	350	2	3230	2781	
186106703	2014-03-07 16:16:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-8	-1	646	350	2	3230	2512	
186107815	2014-03-07 16:20:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097116	0.2	-8	-1	646	350	2	3230	2512	
186108864	2014-03-07 16:24:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097116	0.2	-7	-1	646	350	2	3230	2602	
186109375	2014-03-07 16:26:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097114	0.2	-11	-1	646	350	2	3230	2243	
186111509	2014-03-07 16:34:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-6	-1	646	350	2	3230	2692	
186111982	2014-03-07 16:36:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-9	0	646	350	2	3230	2423	
186113220	2014-03-07 16:40:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-13	-1	646	350	2	3230	2064	
186114318	2014-03-07 16:44:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-4	-1	646	350	2	3230	2871	
186114615	2014-03-07 16:46:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097113	0.2	-6	-1	646	350	2	3230	2692	
186116002	2014-03-07 16:50:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-8	-1	646	350	2	3230	2512	
186117423	2014-03-07 16:56:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097114	0.2	-9	-1	646	350	2	3230	2423	
186118892	2014-03-07 17:00:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-8	-1	646	350	2	3230	2512	
186119572	2014-03-07 17:04:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097116	0.2	-7	-1	646	350	2	3230	2602	
186121415	2014-03-07 17:10:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-7	-1	646	350	2	3230	2602	
186123095	2014-03-07 17:16:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097113	0.2	-8	-1	646	350	2	3230	2512	
186125748	2014-03-07 17:26:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097114	0.2	-7	-1	646	350	2	3230	2602	
186126671	2014-03-07 17:30:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-5	-1	646	350	2	3230	2781	3.0.1_r246
186129241	2014-03-07 17:40:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-12	-1	646	350	2	3230	2153	
186130290	2014-03-07 17:44:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-12	-1	646	350	2	3230	2153	
186130616	2014-03-07 17:46:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097114	0.2	-12	0	646	350	2	3230	2153	
186133205	2014-03-07 17:56:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097114	0.2	-14	-1	646	350	2	3230	1974	
186134284	2014-03-07 18:00:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-12	-1	646	350	2	3230	2153	
186135353	2014-03-07 18:04:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-8	-1	646	350	2	3230	2512	
186135869	2014-03-07 18:06:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097114	0.2	-9	-1	646	350	2	3230	2423	
186137725	2014-03-07 18:14:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-6	-1	646	350	2	3230	2692	
186138207	2014-03-07 18:16:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097113	0.2	-7	-1	646	350	2	3230	2602	
186139152	2014-03-07 18:20:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-10	-1	646	350	2	3230	2333	
186140067	2014-03-07 18:24:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-13	-1	646	350	2	3230	2064	
186142724	2014-03-07 18:36:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097113	0.2	-7	0	646	350	2	3230	2602	
186144496	2014-03-07 18:46:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097113	0.2	-9	-1	646	350	2	3230	2423	
186145740	2014-03-07 18:50:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-12	-1	646	350	2	3230	2153	
186146671	2014-03-07 18:56:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097113	0.2	-9	-1	646	350	2	3230	2423	
186148641	2014-03-07 19:04:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-5	-1	646	350	2	3230	2781	
186149086	2014-03-07 19:06:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097113	0.2	-11	-1	646	350	2	3230	2243	
186150957	2014-03-07 19:16:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097115	0.2	-12	0	646	350	2	3230	2153	
186152627	2014-03-07 19:24:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097119	0.2	-12	-1	646	350	2	3230	2153	
186154293	2014-03-07 19:34:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097119	0.2	-9	-1	646	350	2	3230	2423	
186155429	2014-03-07 19:40:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097118	0.2	-6	-1	646	350	2	3230	2692	3.0.1_r246
186156701	2014-03-07 19:46:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097118	0.2	-11	0	646	350	2	3230	2243	
186157417	2014-03-07 19:50:00	WB8ELK	EM64oj	K9AN	EN50wc	14.09712	0.2	-5	-1	646	350	2	3230	2781	3.0.1_r246
186158103	2014-03-07 19:54:00	WB8ELK	EM64oj	K9AN	EN50wc	14.09712	0.2	-11	-1	646	350	2	3230	2243	
186158591	2014-03-07 19:56:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097118	0.2	-13	-1	646	350	2	3230	2064	
186160022	2014-03-07 20:04:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097121	0.2	-9	-1	646	350	2	3230	2423	
186161827	2014-03-07 20:14:00	WB8ELK	EM64oj	K9AN	EN50wc	14.09712	0.2	-9	-1	646	350	2	3230	2423	
186163254	2014-03-07 20:20:00	WB8ELK	EM64oj	K9AN	EN50wc	14.09712	0.2	-14	-1	646	350	2	3230	1974	
186163697	2014-03-07 20:24:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097121	0.2	-9	-1	646	350	2	3230	2423	
186164196	2014-03-07 20:26:00	WB8ELK	EM64oj	K9AN	EN50wc	14.09712	0.2	-11	0	646	350	2	3230	2243	
186164913	2014-03-07 20:30:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097121	0.2	0	-1	646	350	2	3230	3230	3.0.1_r246
186165873	2014-03-07 20:34:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097121	0.2	-5	-1	646	350	2	3230	2781	
186166169	2014-03-07 20:36:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097119	0.2	-5	-1	646	350	2	3230	2781	
186166945	2014-03-07 20:40:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097121	0.2	-8	-1	646	350	2	3230	2512	
186168123	2014-03-07 20:46:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097121	0.2	-5	-1	646	350	2	3230	2781	
186169042	2014-03-07 20:50:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097121	0.2	-1	-1	646	350	2	3230	3140	3.0.1_r246
186169487	2014-03-07 20:54:00	WB8ELK	EM64oj	K9AN	EN50wc	14.097121	0.2	-10	-1	646	350	2	3230	2333	
							Mean	-8.3390							
							SD	3.1107							
							AD	5.6610							
							AD%	182							

Table 1: WSPRnet Links between WB8ELK and K9AN at 17:56 UTC ±3 hours.

The local and global view of the known start position and the anomalous WSPRnet link between WB8ELK and K9AN are shown in Figures 2 and 3 below.

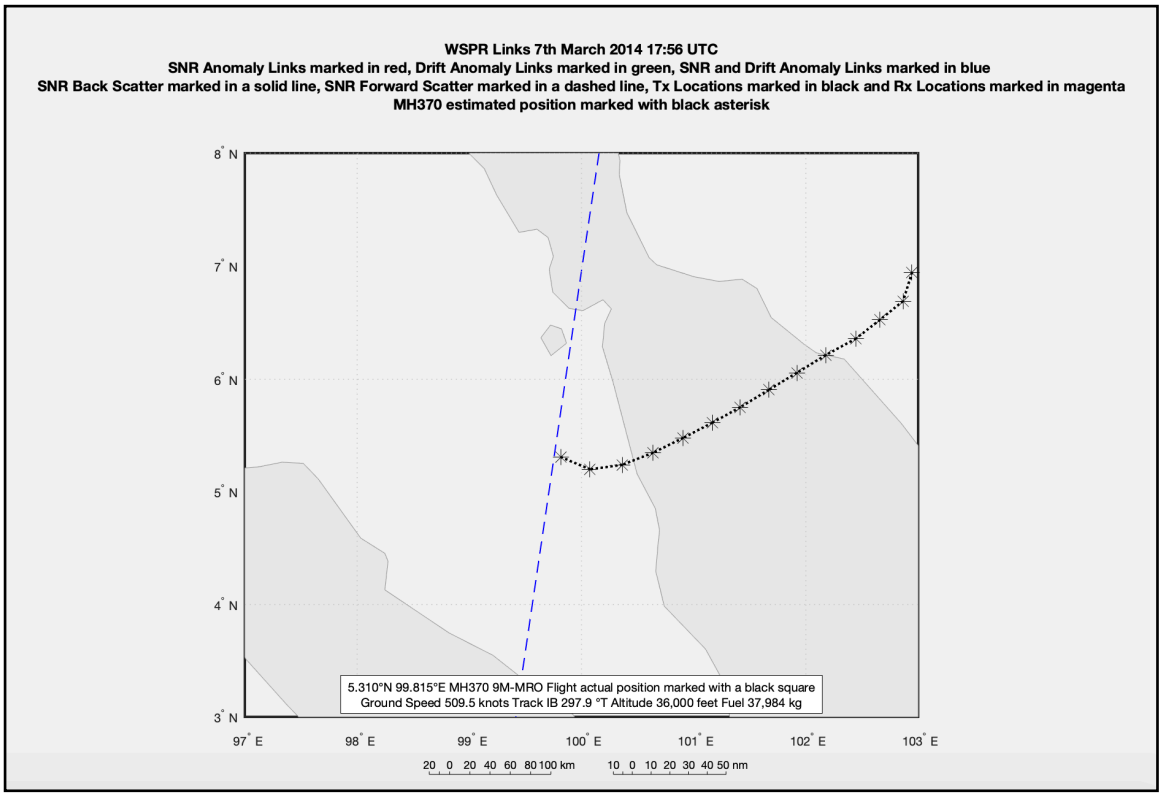

Figure 2: GDTAAA progress indicator for MH370 at 17:56 UTC Local View.

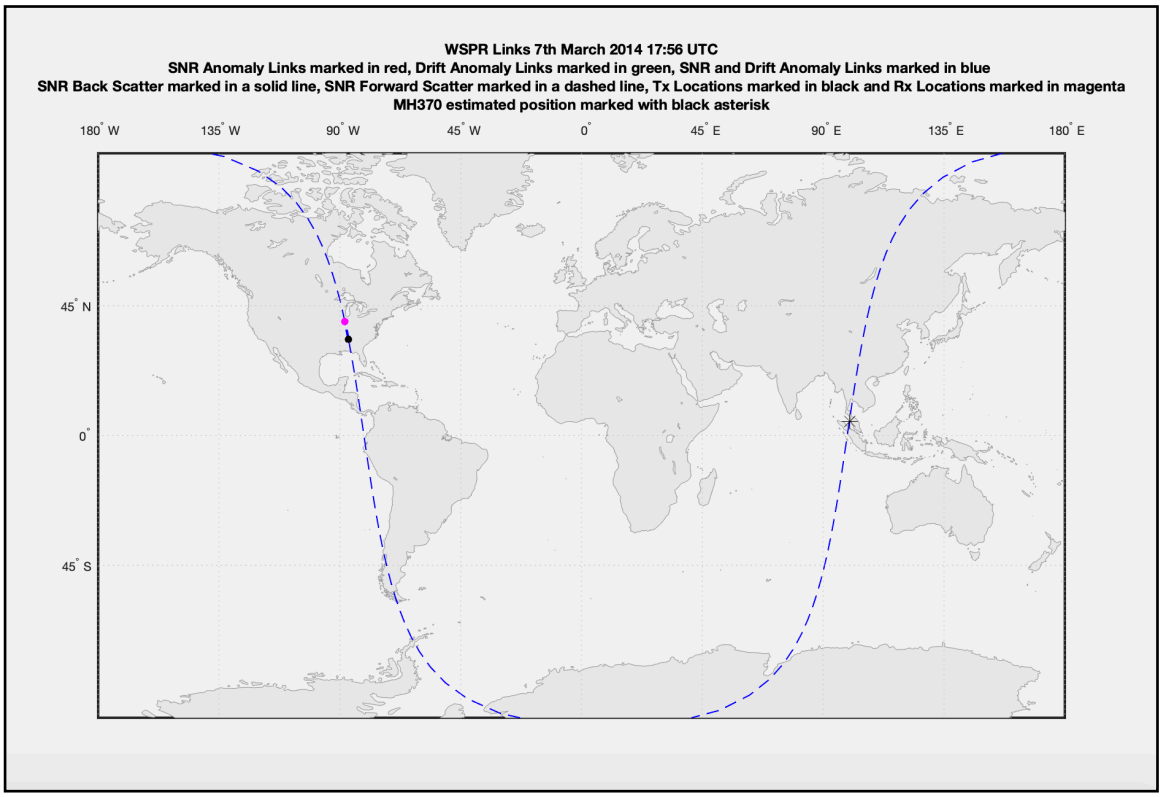

Figure 3: GDTAAA progress indicator for MH370 at 17:56 UTC Global View.

4. Boeing 777-200ER Limitations.

There is a limit to how far a Boeing 777-200ER can travel in two minutes. The maximum ground speed is determined by the maximum true air speed and the wind speed and direction.

There is a limit to how fast a Boeing 777-200ER can turn in two minutes. The maximum bank angle allowed by the Flight Control System is 20°.

There is a limit to how far a Boeing 777-200ER can ascend or descend in two minutes. The flight level change allowed by the Flight Control System prevents stalling at too high an angle of attack or overspeed at too high a descent speed.

The Boeing 777-200ER has a nominal ground speed of 500 knots and a maximum indicated air speed of 330 knots or a maximum Mach of 0.87, whichever is lower.

The Boeing 777-200ER can ascend and descend up to 2,500 fpm.

The Boeing 777-200ER has a maximum operating pressure altitude of 43,100 feet.

At 500 knots in straight and level flight an aircraft will travel 30.9 km in 2 minutes.

At 500 knots and a maximum bank angle of 20° a Boeing 777 can turn a maximum of 90° left or right with a turn radius of 18.5 km in 1.9 minutes and such a turn will slow the aircraft down.

5. GDTAAA software.

The GDTAAA software calculates every two minutes the following flight data:

(a) The Ground Speed (GS) from the distance travelled (using a Vincenty calculation based on the WGS84 world geodetic system) since the last known position and the time difference to the time of the last known position.

(b) The Track (TRK) including initial bearing and final bearing from the last known position (using a Vincenty calculation based on the WGS84 world geodetic system).

(c) The wind speed (WSPD), wind direction from (WDIR), Outside Air Temperature (OAT) and the delta Saturated Air Temperature (∂SAT) at the estimated position, Pressure Altitude (PA) and time using the GDAS historic world weather data supplied by NOAA.

(d) Mach Speed (MACH) derived from the OAT at the given PA.

(e) The Geometric Altitude (GA) based on the PA as well as the local surface pressure and surface temperature from GDAS.

(f) The True Air Speed (TAS) based on the MACH and the OAT.

(g) The GS and TRK based on the TAS and the wind speed (WSPD) and direction (WDIR) at the PA for comparison with (a) and (b).

(h) The Heading (HDG) based on the TRK, GS, TAS, WSPD and WDIR.

(i) The Fuel Burn Rate (FBR) based on the MAS Engineering data for 9M-MRO, MACH, PA and ∂SAT.

(j) The Aircraft Gross Weight (GWT) and Fuel Remaining (FR) based on the known fuel amount at take off (and as communicated in the ACARS message at 17:06:43 UTC) and the FBR each two minutes.

The GDTAAA software also calculates for every Inmarsat Data Communications (IDC) Log entry from 18:25:27.421 UTC onwards the following flight data:

(k) The GA that matches the Burst Offset Timing (BTO) for interpolated position at the time of the IDC log entry.

(l) The GS, TRK and Rate Of Climb (ROC) that matches the Burst Offset Frequency (BFO) for the interpolated position at the time of IDC log entry.

The GDTAAA software also depicts:

(m) The MH370 flight path every two minutes.

(n) The great circle path projected onto the earth's surface using a spherical model of the earth and the 6 character Maidenhead grid locators for the transmitter and receiver for each WSPRnet link. In reality the propagation path is refracted in the ionosphere and reflected from the earth's surface in one or more hops in stages between the transmitter, ionosphere, the earth's surface and the receiver. The propagation path of any particular rays are only reflected, deflected or scattered by MH370 when the rays are on the way down from the ionosphere or on the way up to the ionosphere. We use Proplab-Pro V3.1 software which incorporates the IRI2007 International Reference Ionosphere and a topographic database of the Earth's surface to analyse ray path propagation.

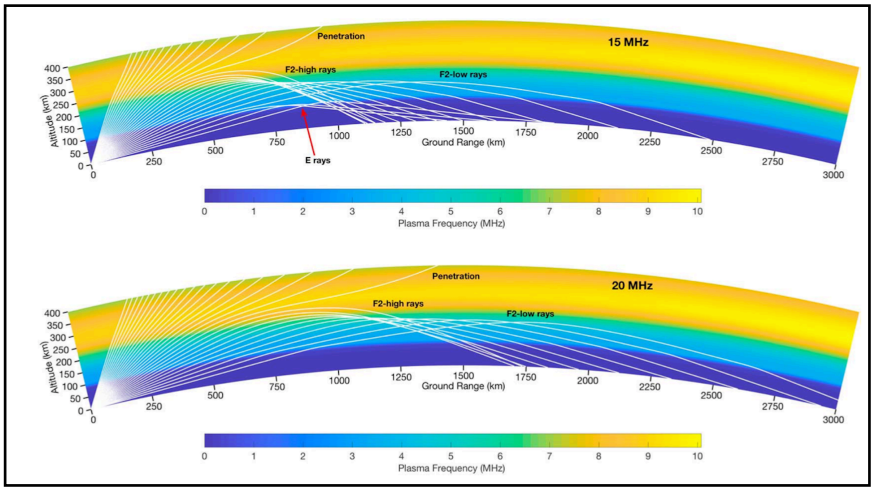

Figure 4: Typical Ionospheric Propagation of High Frequency Radio Waves

6. Relevant WSPRnet links.

The relevant WSPRnet links are initially defined as those links intersecting a circle around the last known position of MH370 with a radius of the maximum distance MH370 could travel in two minutes.

In reality a Boeing 777-200ER can go almost anywhere in the forward direction within the circle, but is limited by a lack of aerobatic capability from reaching points in the rear half of the circle.

In this simple example there is only one relevant WSPRnet link.

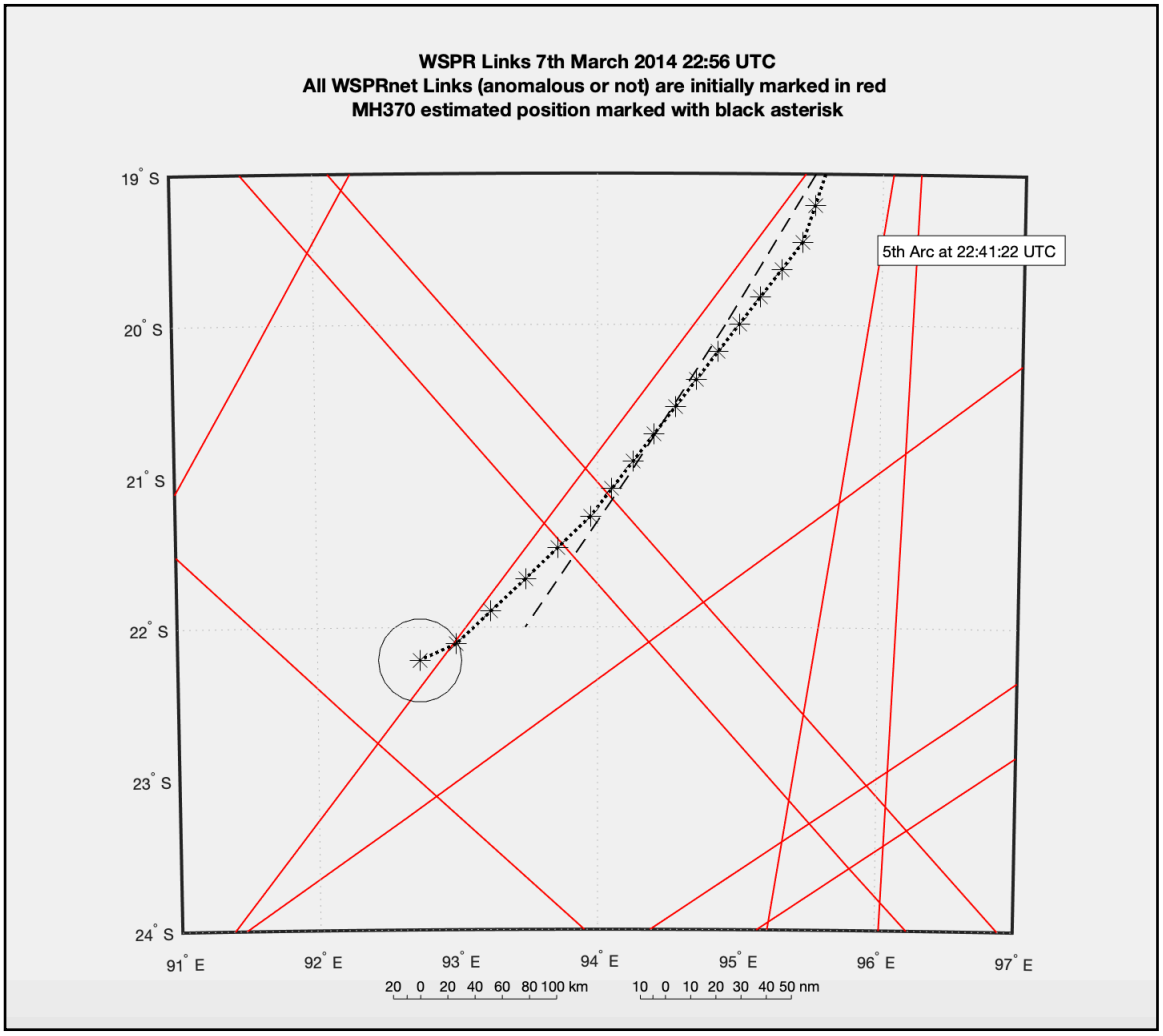

Figure 5: WSPRnet links in the vicinity of MH370 at 22:56 UTC Local View.

In this example, the relevant WSPRnet link, is between the transmitter (Tx) call sign WK0I at the grid location EM12lu and the receiver (Rx) JH1GYE at the grid location PM96mi and following analysis is found not to be an anomaly.

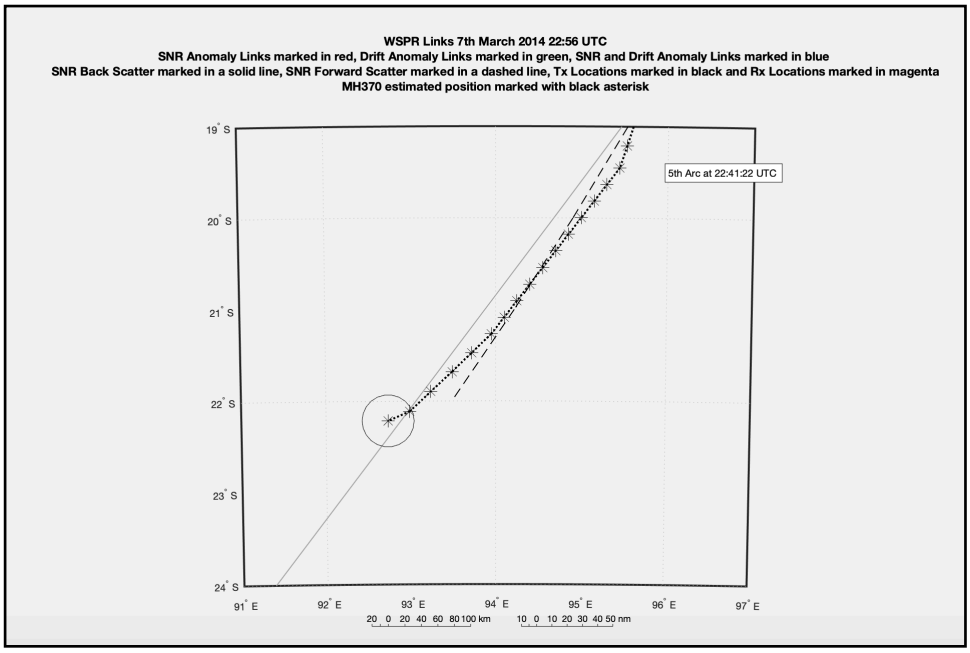

Figure 6: Single relevant WSPRnet link at 22:56 UTC Local View shows no anomaly.

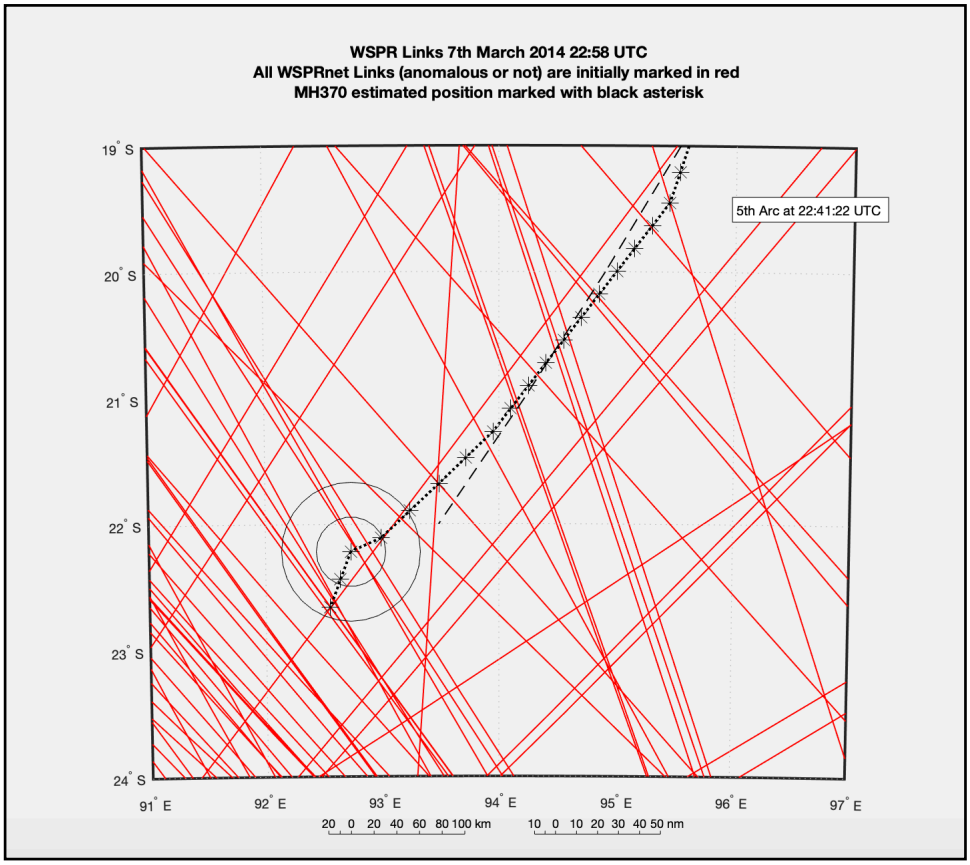

Figure 7: Multiple WSPRnet links at 22:58 UTC Local View.

The relevant WSPRnet links are therefore now defined as those links intersecting a circle around the last known position of MH370 with a radius of the maximum distance MH370 could travel in four minutes. In this example there are now 9 relevant WSPRnet links. Each WSPRnet links is then analysed to see if it is an anomaly or not.

There are three WSPRnet link anomalies in this case, which are greater than one standard deviation. If once again there were no relevant WSPRnet links, then the circle is widened to six minutes and so on.

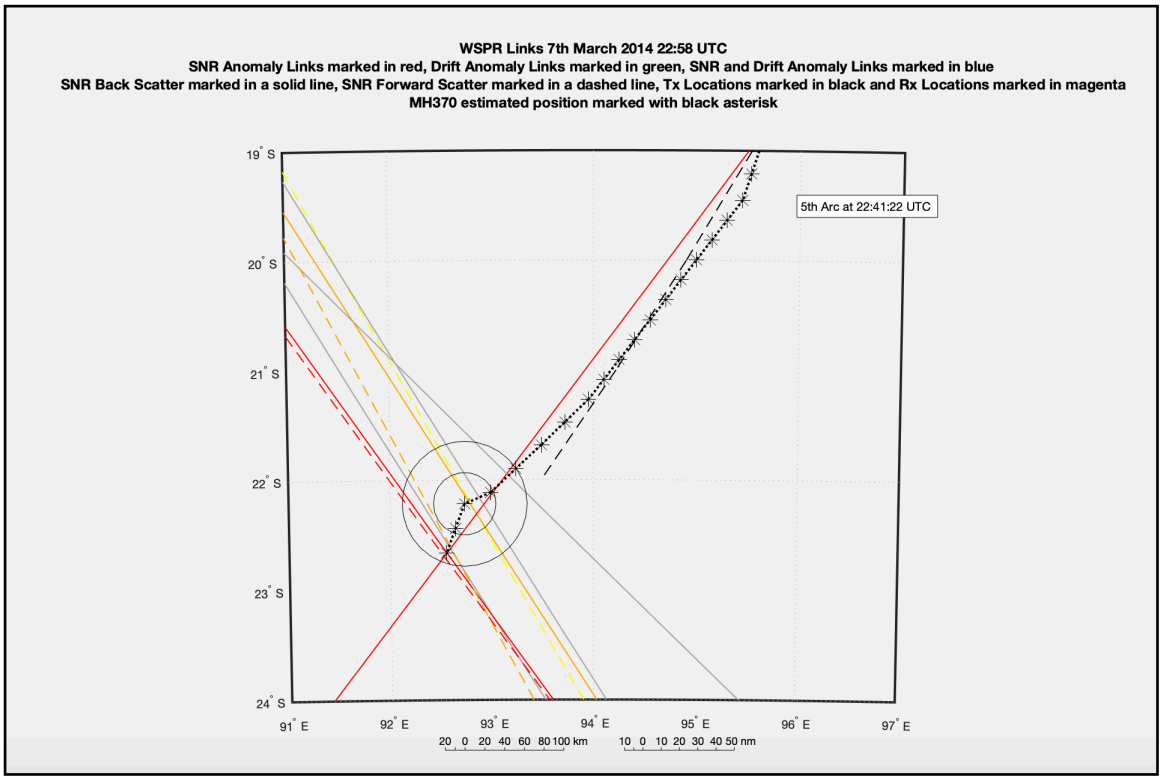

Figure 8: Anomalous WSPRnet links at 22:58 UTC Local View.

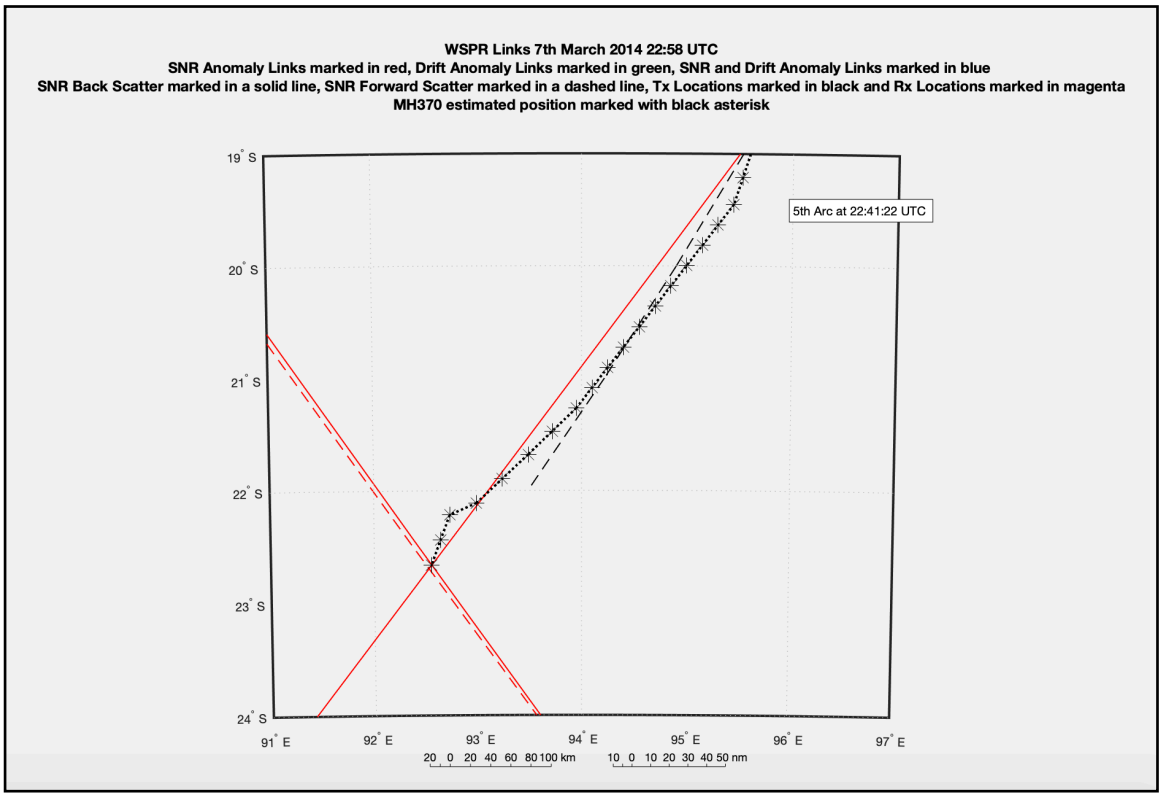

Figure 9: GDTAA position indicator at 22:58 UTC Local View.

The three anomalies greater than one standard deviation are:

(a) Tx W3HH at EL89vb to Rx VE1MDO at FN84aq 104% SD.

spotnum	date (y-m-d)	txCall	txGrid	rxCall	rxGrid	MHz	Watts	SNR	drft	km	az	mode	kpw	spotQ	version
186159354	2014-03-07 20:00:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-26	0	2367	38	2	2367	658	0.8_r3058
186161519	2014-03-07 20:12:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-27	0	2367	38	2	2367	592	0.8_r3058
186162909	2014-03-07 20:20:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-23	0	2367	38	2	2367	855	0.8_r3058
186165261	2014-03-07 20:32:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-21	0	2367	38	2	2367	986	0.8_r3058
186166768	2014-03-07 20:40:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-21	0	2367	38	2	2367	986	0.8_r3058
186169109	2014-03-07 20:52:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-18	0	2367	38	2	2367	1184	0.8_r3058
186170652	2014-03-07 21:00:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-16	0	2367	38	2	2367	1315	0.8_r3058
186172790	2014-03-07 21:12:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-19	0	2367	38	2	2367	1118	0.8_r3058
186175015	2014-03-07 21:24:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-20	0	2367	38	2	2367	1052	0.8_r3058
186176774	2014-03-07 21:34:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-13	0	2367	38	2	2367	1512	0.8_r3058
186178403	2014-03-07 21:42:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140287	1	-12	1	2367	38	2	2367	1578	0.8_r3058
186183046	2014-03-07 21:54:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140287	1	-15	0	2367	38	2	2367	1381	0.8_r3058
186185426	2014-03-07 22:06:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-16	0	2367	38	2	2367	1315	0.8_r3058
186187360	2014-03-07 22:18:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-12	0	2367	38	2	2367	1578	0.8_r3058
186188862	2014-03-07 22:26:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140287	1	-5	0	2367	38	2	2367	2038	0.8_r3058
186190659	2014-03-07 22:38:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-17	-1	2367	38	2	2367	1249	0.8_r3058
186192115	2014-03-07 22:48:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-10	0	2367	38	2	2367	1710	0.8_r3058
186193572	2014-03-07 22:58:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-8	0	2367	38	2	2367	1841	0.8_r3058
186194706	2014-03-07 23:06:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-10	0	2367	38	2	2367	1710	0.8_r3058
186196237	2014-03-07 23:16:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140287	1	-8	0	2367	38	2	2367	1841	0.8_r3058
186198112	2014-03-07 23:28:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-9	0	2367	38	2	2367	1775	0.8_r3058
186199903	2014-03-07 23:38:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-13	0	2367	38	2	2367	1512	0.8_r3058
186201143	2014-03-07 23:46:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-9	0	2367	38	2	2367	1775	0.8_r3058
186202828	2014-03-07 23:56:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140287	1	-11	0	2367	38	2	2367	1644	0.8_r3058
186204725	2014-03-08 00:08:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-8	0	2367	38	2	2367	1841	0.8_r3058
186205965	2014-03-08 00:16:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-16	0	2367	38	2	2367	1315	0.8_r3058
186207798	2014-03-08 00:28:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-8	0	2367	38	2	2367	1841	0.8_r3058
186209540	2014-03-08 00:38:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-11	0	2367	38	2	2367	1644	0.8_r3058
186211150	2014-03-08 00:50:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-10	0	2367	38	2	2367	1710	0.8_r3058
186212234	2014-03-08 00:58:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-8	0	2367	38	2	2367	1841	0.8_r3058
186213512	2014-03-08 01:08:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-12	0	2367	38	2	2367	1578	0.8_r3058
186214998	2014-03-08 01:18:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-9	0	2367	38	2	2367	1775	0.8_r3058
186216150	2014-03-08 01:28:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-12	0	2367	38	2	2367	1578	0.8_r3058
186217252	2014-03-08 01:36:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-13	0	2367	38	2	2367	1512	0.8_r3058
186218444	2014-03-08 01:44:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-11	0	2367	38	2	2367	1644	0.8_r3058
186219626	2014-03-08 01:52:00	W3HH	EL89vb	VE1MDO	FN84aq	10.140288	1	-13	0	2367	38	2	2367	1512	0.8_r3058
							Mean	-13.6111							
							SD	5.3893							
							AD	-5.6111							
							AD%	-104							

Table 2: WSPRnet Links between W3HH and VE1MDO at 22:58 UTC ±3 hours.

(b) Tx W3HH at EL89vb to Rx OZ7IT at JO65df 142% SD.

spotnum	date (y-m-d)	txCall	txGrid	rxCall	rxGrid	MHz	Watts	SNR	drft	km	az	mode	kpw	spotQ	version
186175088	2014-03-07 21:24:00	W3HH	EL89vb	OZ7IT	JO65df	10.140287	1	-18	0	7662	38	2	7662	3831	2.21_r2286
186177011	2014-03-07 21:34:00	W3HH	EL89vb	OZ7IT	JO65df	10.140287	1	-16	0	7662	38	2	7662	4257	2.21_r2286
186188848	2014-03-07 22:26:00	W3HH	EL89vb	OZ7IT	JO65df	10.140287	1	-11	0	7662	38	2	7662	5321	2.21_r2286
186192162	2014-03-07 22:48:00	W3HH	EL89vb	OZ7IT	JO65df	10.140288	1	-17	0	7662	38	2	7662	4044	2.21_r2286
186193673	2014-03-07 22:58:00	W3HH	EL89vb	OZ7IT	JO65df	10.140288	1	-12	0	7662	38	2	7662	5108	2.21_r2286
186194727	2014-03-07 23:06:00	W3HH	EL89vb	OZ7IT	JO65df	10.140288	1	-12	0	7662	38	2	7662	5108	2.21_r2286
186196334	2014-03-07 23:16:00	W3HH	EL89vb	OZ7IT	JO65df	10.140288	1	-16	-1	7662	38	2	7662	4257	2.21_r2286
186199817	2014-03-07 23:38:00	W3HH	EL89vb	OZ7IT	JO65df	10.140288	1	-15	0	7662	38	2	7662	4470	2.21_r2286
186201242	2014-03-07 23:46:00	W3HH	EL89vb	OZ7IT	JO65df	10.140289	1	-26	0	7662	38	2	7662	2128	2.21_r2286
186202905	2014-03-07 23:56:00	W3HH	EL89vb	OZ7IT	JO65df	10.140289	1	-23	0	7662	38	2	7662	2767	2.21_r2286
186204674	2014-03-08 00:08:00	W3HH	EL89vb	OZ7IT	JO65df	10.140289	1	-17	0	7662	38	2	7662	4044	2.21_r2286
186211217	2014-03-08 00:50:00	W3HH	EL89vb	OZ7IT	JO65df	10.140289	1	-24	0	7662	38	2	7662	2554	2.21_r2286
186212121	2014-03-08 00:58:00	W3HH	EL89vb	OZ7IT	JO65df	10.140289	1	-24	0	7662	38	2	7662	2554	2.21_r2286
186214868	2014-03-08 01:18:00	W3HH	EL89vb	OZ7IT	JO65df	10.140289	1	-22	0	7662	38	2	7662	2980	2.21_r2286
186216385	2014-03-08 01:28:00	W3HH	EL89vb	OZ7IT	JO65df	10.14029	1	-21	0	7662	38	2	7662	3193	2.21_r2286
186217416	2014-03-08 01:36:00	W3HH	EL89vb	OZ7IT	JO65df	10.14029	1	-24	0	7662	38	2	7662	2554	2.21_r2286
186218434	2014-03-08 01:44:00	W3HH	EL89vb	OZ7IT	JO65df	10.140289	1	-24	0	7662	38	2	7662	2554	2.21_r2286
							Mean	-18.9412							
							SD	4.8922							
							AD	-6.9412							
							AD%	-142							

Table 3: WSPRnet Links between W3HH and OZ7IT at 22:58 UTC ±3 hours.

(c) Tx AD4PT at EM12kx to Rx JH1GYE at PM96mi 101% SD.

spotnum	date (y-m-d)	txCall	txGrid	rxCall	rxGrid	MHz	Watts	SNR	drft	km	az	mode	kpw	spotQ	version
186193393	2014-03-07 22:58:00	AD4PT	EM12kx	JH1GYE	PM96mi	28.126081	5	-19	0	10348	318	2	2070	978	2.11_r2263
186203097	2014-03-07 23:58:00	AD4PT	EM12kx	JH1GYE	PM96mi	28.12608	5	-22	0	10348	318	2	2070	805	0.8_r3058
186209422	2014-03-08 00:38:00	AD4PT	EM12kx	JH1GYE	PM96mi	28.12608	5	-20	0	10348	318	2	2070	920	0.8_r3058
186217623	2014-03-08 01:38:00	AD4PT	EM12kx	JH1GYE	PM96mi	28.126079	5	-24	0	10348	318	2	2070	690	2.11_r2263
							Mean	-21.2500							
							SD	2.2174							
							AD	-2.2500							
							AD%	-101							

Table 4: WSPRnet Links between AD4PT and JH1GYE at 22:58 UTC ±3 hours.

7. Antipode of WSPRnet Transmitters.

GDTAAA shows WSPRnet links from the transmitter W4MO at EL87tc at 23:58 UTC in all directions being received by 25 different stations around the world. The great circle paths all meet at the antipode of the transmitter location.

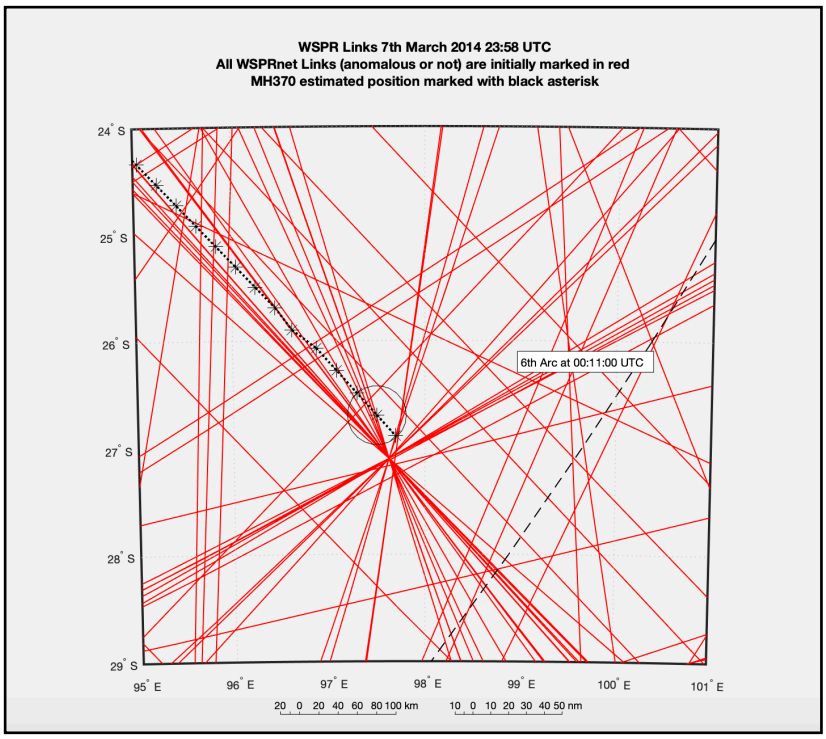

Figure 10: Multiple WSPRnet links at 23:58 UTC Local View.

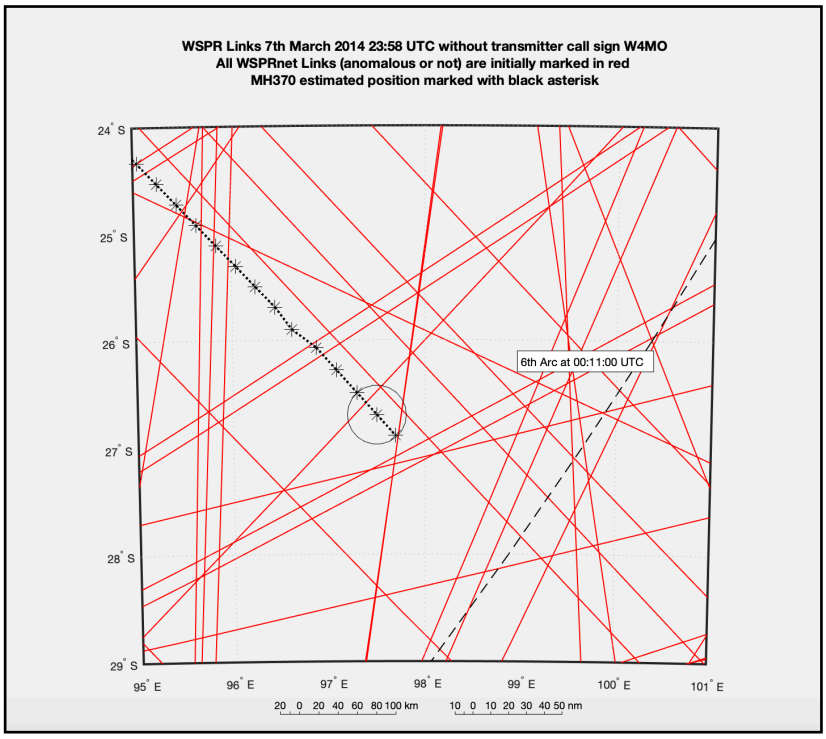

Figure 11: Multiple WSPRnet links at 23:58 UTC Local View without transmitter W4MO.

Out of the 25 WSPRnet links from the one transmitter there was one SNR anomaly of 152% and one drift anomaly. None of the other 3 WSPRnet links were anomalous.

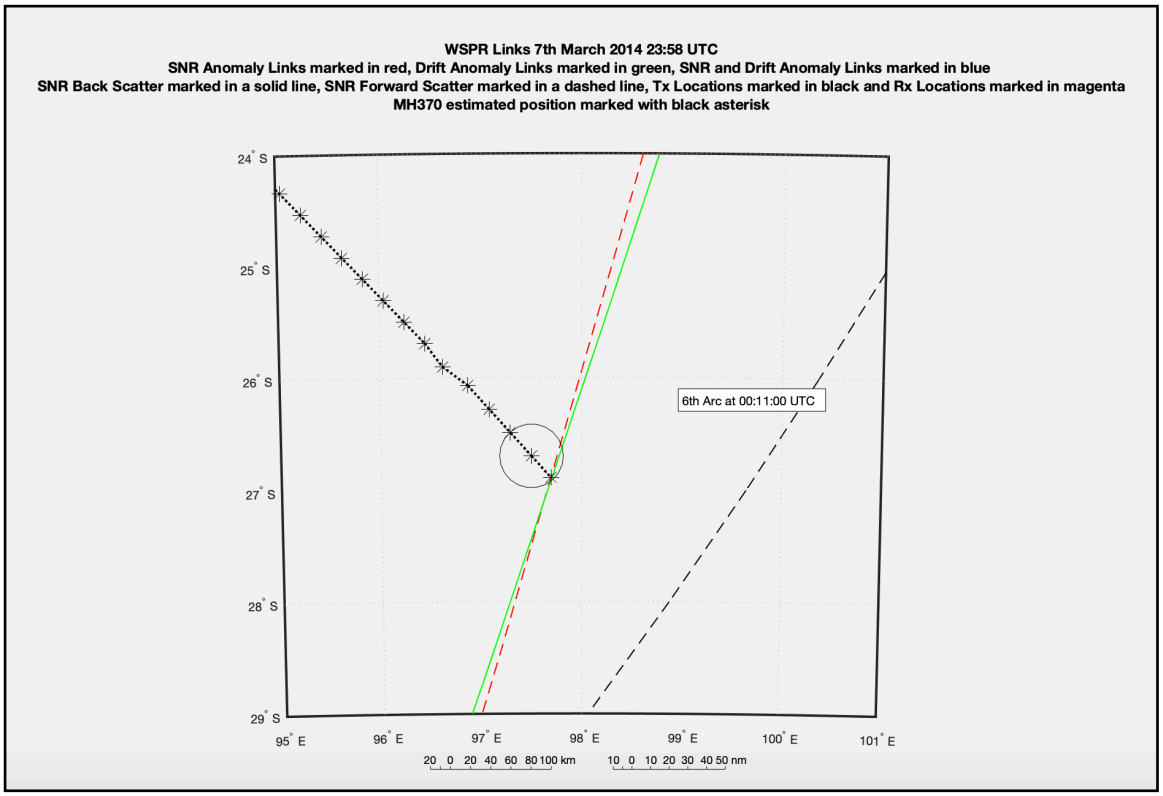

Figure 12: GDTAA progress indicator at 23:58 UTC Local View.

8. Number of WSPRnet Links.

In the MH370 time frame there are 63,075 WSPRnet links between 7th March 2014 17:50 UTC and 8th March 2014 00:30 UTC, which have a propagation distance ≥500 km, a software code = 0, a transmission frequency between 0.1 MHz and 30 MHz and a transmission power between 0 dBm and 43 dBm.

This gives on average 315 WSPRnet links every 2 minutes.

We can usually find up to 15 WSPRnet links within the area reachable by a Boeing 777-200ER in the next two minutes.

In total there are 4.5 billion WSPRnet links in the WSPRnet database.

A useful tool to run SQL queries on the database can be found at:

http://wspr.rocks/livequeries/

9. Inmarsat Anchor Points.

For example, at 22:44 UTC we have a position indicator giving an estimated location of MH370 at 21.268°S 93.950°E.

At the last anchor point on the 5th Arc at 22:41:22 UTC at an estimated location of 21.028630°S 94.146447°E, we calculated an altitude of 22,195 feet giving a BTO residual of zero and we calculated a ground speed of 509.7 knots and a track of 220.7°T giving a BFO residual of zero.

The Inmarsat data provides two values at each arc, the Burst Timing Offset (BTO) and the Burst Frequency Offset (BFO).

BTO gives the distance between the satellite and aircraft, by working out the roundtrip time from ground station to satellite to aircraft and back again. The satellite ephemeris is known. The ground station position in Perth, Australia is known.

BFO gives the relative velocity between the satellite and aircraft, by working out the Doppler shift between ground station and satellite, aircraft and satellite, the Doppler compensation in the aircraft satellite data unit (SDU), the EAFC effect at the ground station and the eclipse effect at the satellite. The SDU compensation algorithm is known. The EAFC effect is known. The eclipse effect is known.

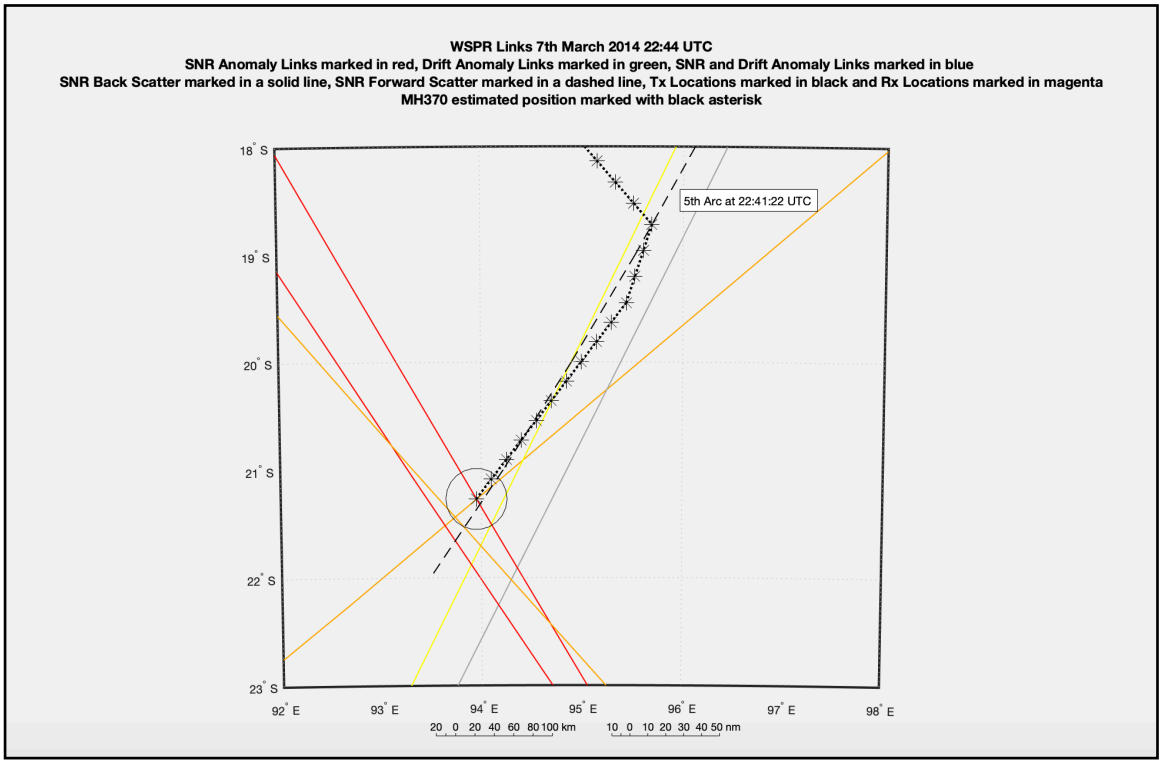

Figure 13: Anomalous WSPRnet links at 22:44 UTC Local View.

10. Two Minute Granularity.

WSPRnet data is only available every two minutes.

At the last known position we draw a circle around that point representing where the aircraft can be at the current estimated ground speed after two minutes.

In reality this is only feasible in the current direction of flight and the blue lines represent the limits if a turn is taking place.

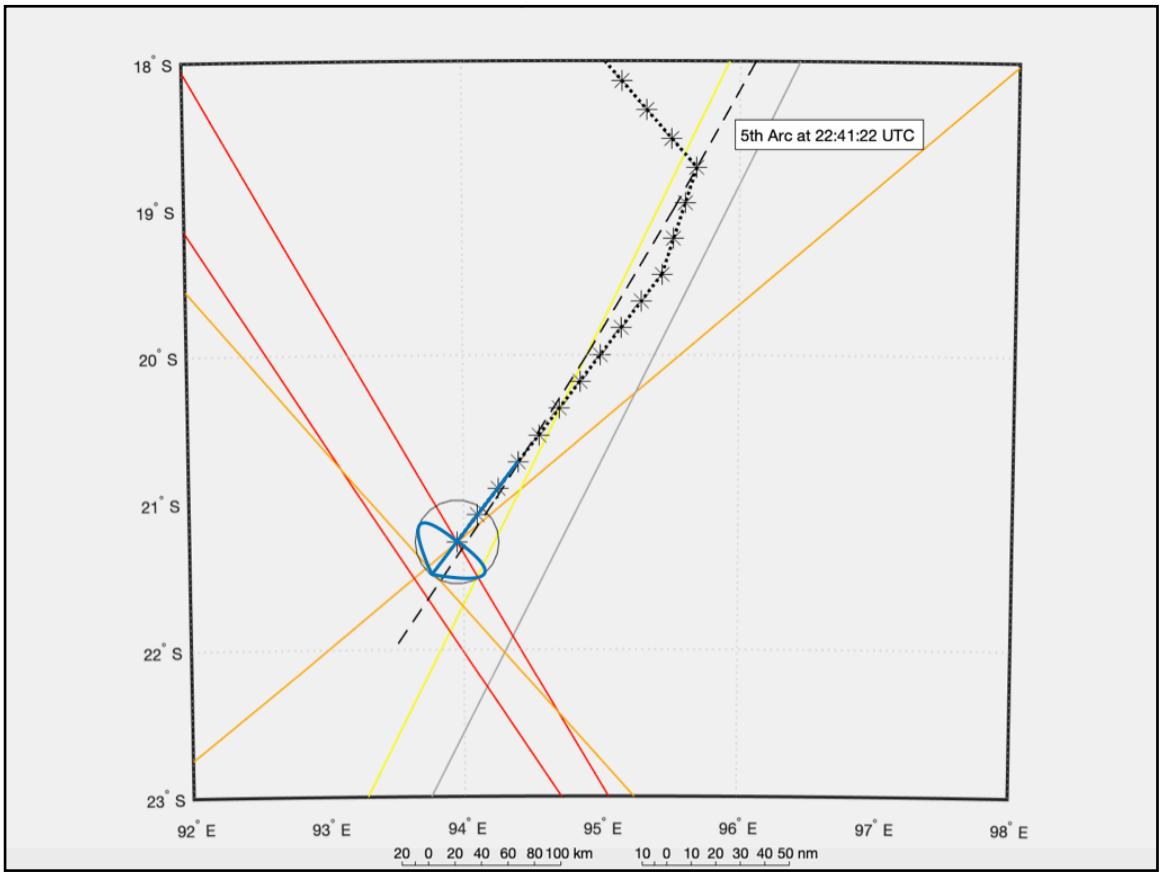

Figure 14: MH370 Possible Turn Envelope at 22:44 UTC Local View.

11. Null Relevant WSPRnet Links.

At 22:46 UTC we find no WSPRnet links that match the aircraft's forward path, although there are anomalous WSPRnet links intersecting the circle around the last known position of MH370 with a radius of the maximum distance MH370 could travel in two minutes as shown in Figure 15. When we check two minutes later at 22:48 UTC, we find a progress indicator at the intersection of dual SNR and drift anomalous WSPRnet link marked with a blue dashed line and the circle around the last known position of MH370 with a radius of the maximum distance MH370 could travel in four minutes as shown in Figure 16.

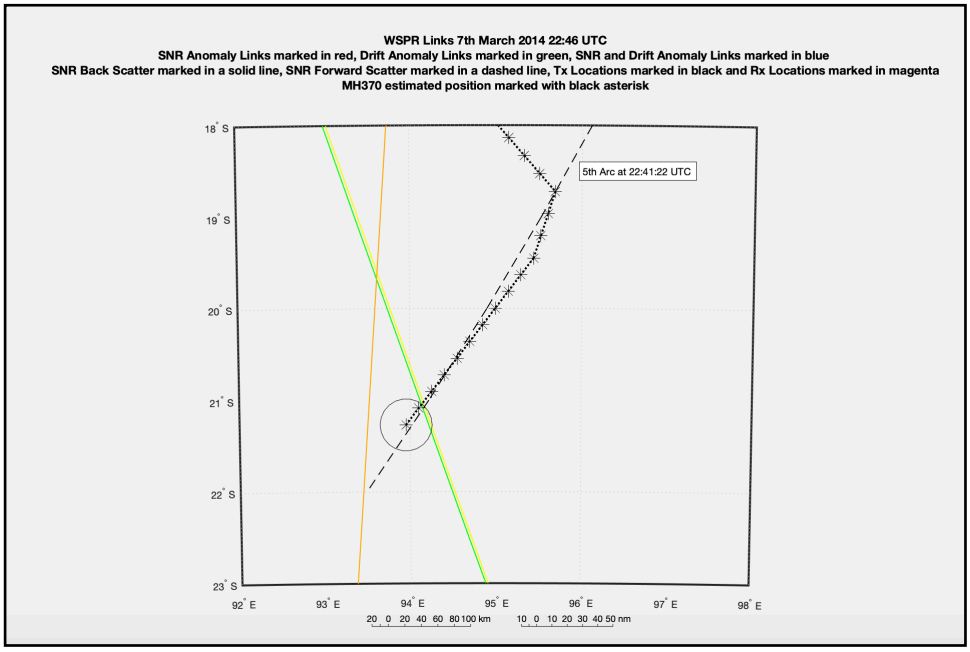

Figure 15: Anomalous WSPRnet links at 22:46 UTC Local View.

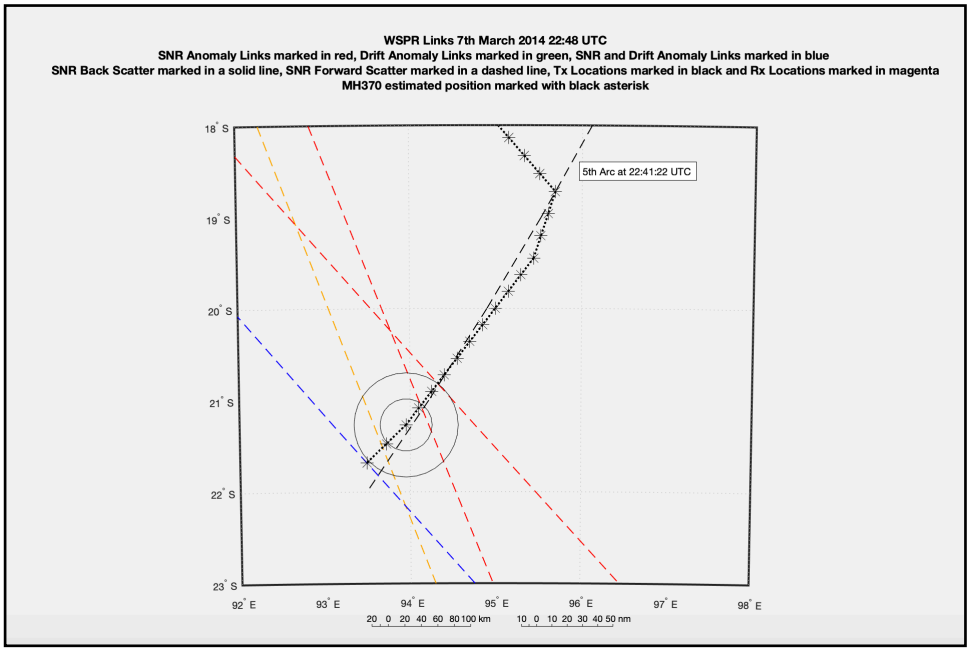

Figure 16: Anomalous WSPRnet links at 22:48 UTC Local View.

This new location then becomes the centre of the circle and we check again at 22:50 UTC and in this case once again find no WSPRnet links that match. We check again at 22:52 UTC and find a double progress indicator with a SNR anomaly and a dual SNR and drift anomaly that matches the expected position of MH370.

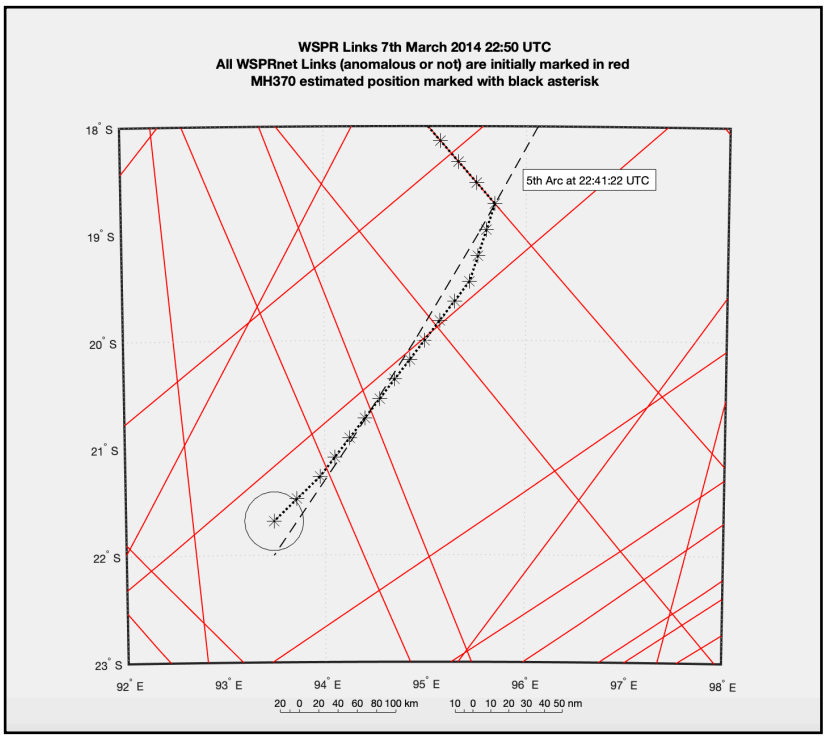

Figure 17: Multiple WSPRnet links at 22:50 UTC Local View.

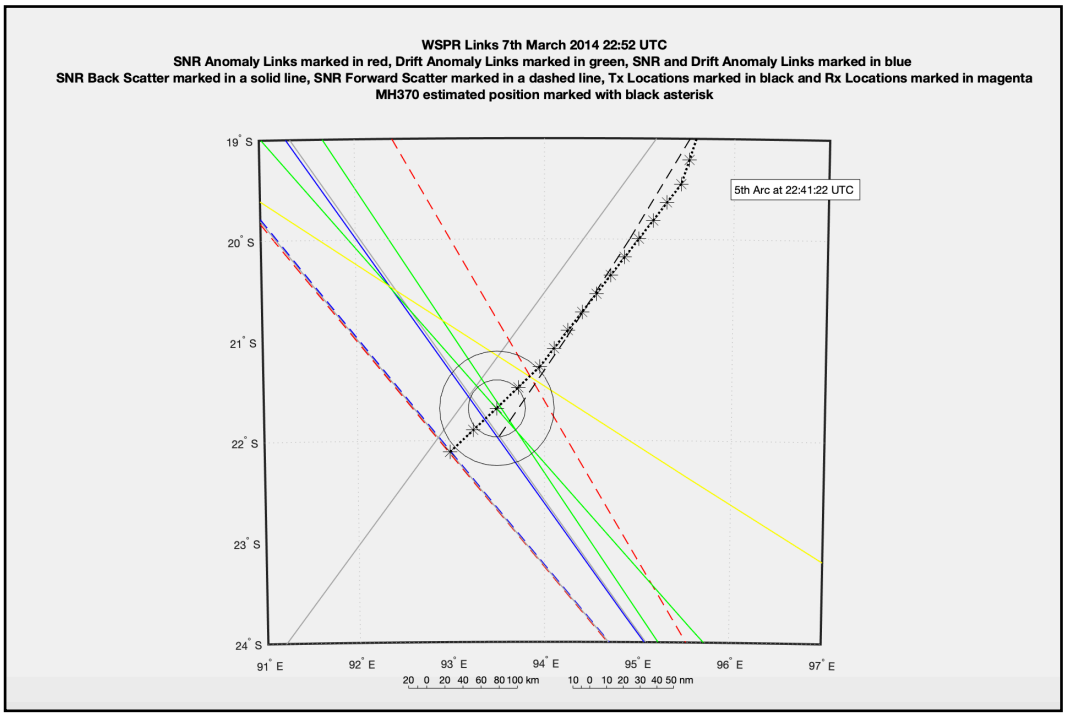

Figure 18: Anomalous WSPRnet links at 22:52 UTC Local View.

12. Great Circle Path Accuracy.

The 6 character Maidenhead locator sub-squares have dimensions of 2.5' of latitude by 5' of longitude.

Two points within the same Maidenhead sub-square 4,607.3 m high x 9,276.6 m wide are always less than 10,357.7 m apart.

For example, at 22:58 UTC MH370 is estimated at 22.658°S 92.552°E at the intersection of the 2 SNR anomalous WSPRnet links marked with a solid line.

If we add one and subtract one from the last letter of the Maidenhead grid locator for just the transmitter, then just the receiver for each link in turn, then the result is as shown below.

This is actually double the maximum possible error from a single sub-square Maidenhead grid locator and results in a rectangle of uncertainty as shown below.

However this illustrates the point that the centre of the intersection of the now wider bands does not move.

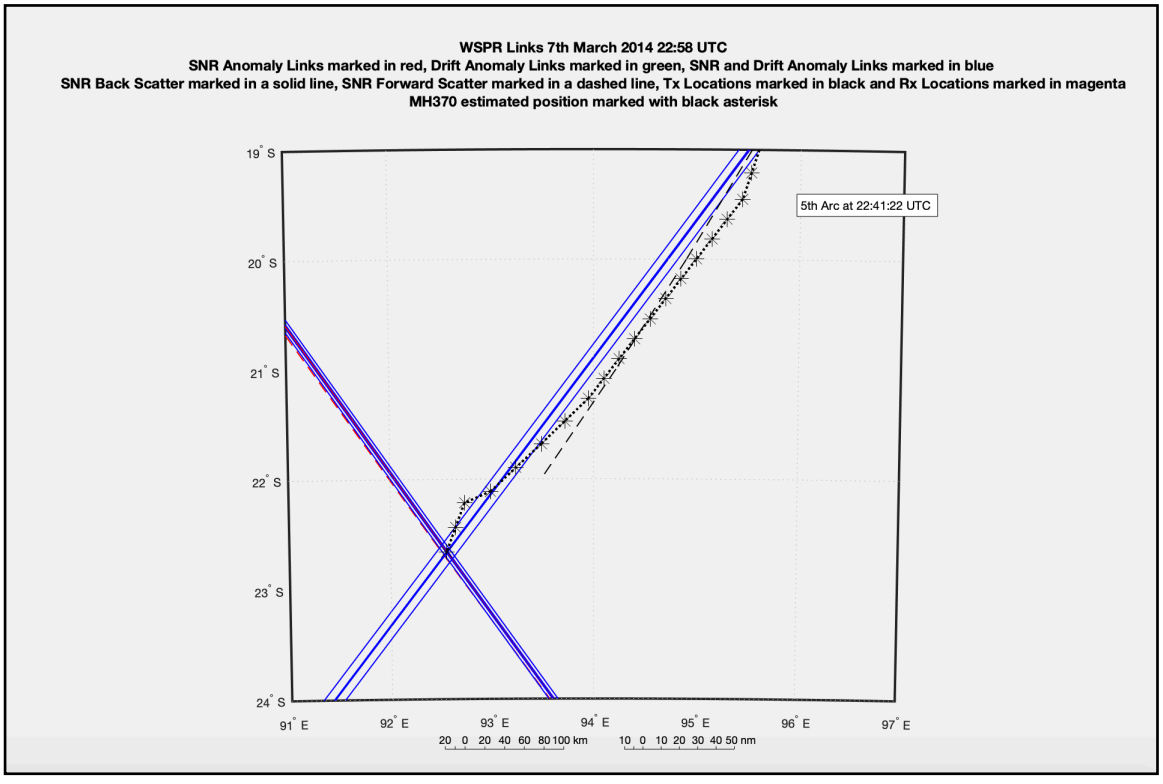

Figure 19: Maidenhead Grid Accuracy at 22:58 UTC Local View.

13. Flight Path Alignment with Anomalous WSPRnet Links.

During the timeframe 21:46 UTC to 22:18 UTC MH370 was found to be following a track of 139.5°T.

This track aligned with the WSPRnet link between Tx DK6NI at JN59ln and Rx G8HUH at IO81mg.

The aircraft follows a great circle path based on WGS84 and the WSPRnet propagation follows a great circle path based on a spherical earth, so they eventually diverge.

However, for 24 minutes between 21:46 UTC and 22:10 UTC they were aligned closely enough to result in WSPRnet SNR anomalies of greater than one standard deviation.

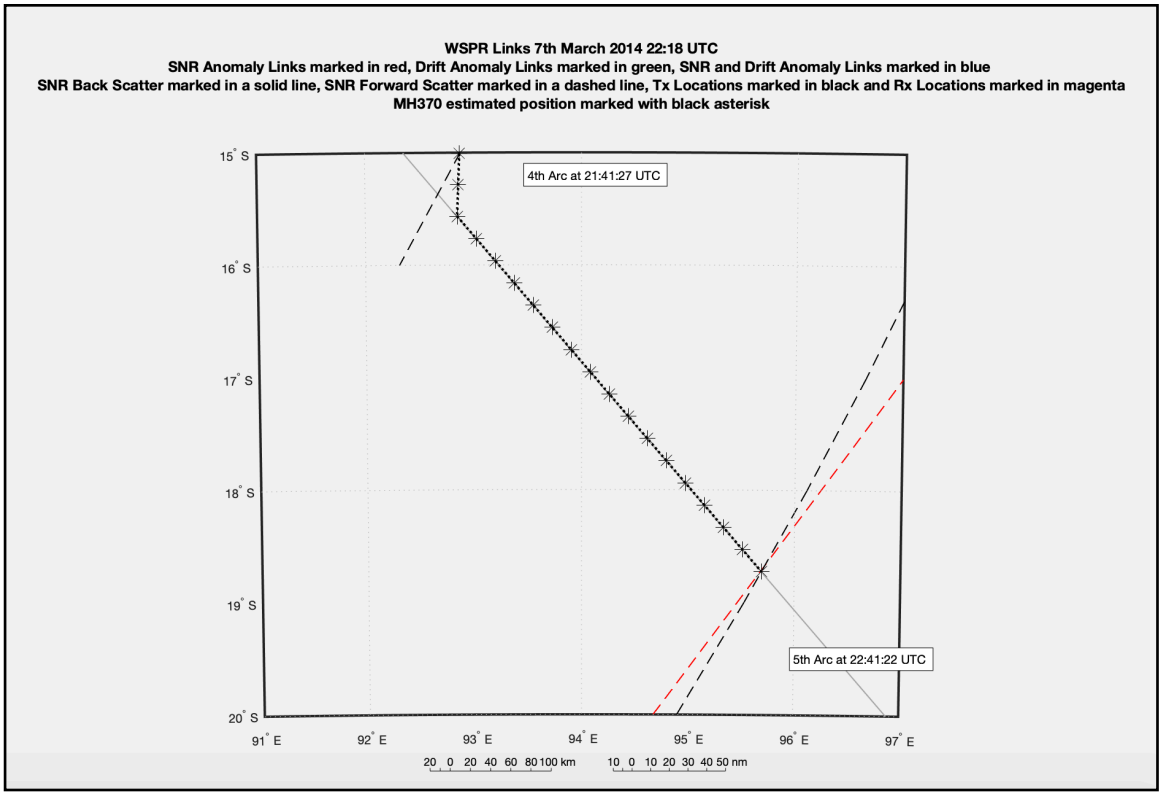

Figure 20: GDTAA progress indicator at 22:18 UTC Local View.

During the timeframe from 21:46 UTC to 22:10 UTC there were 6 SNR anomalous WSPRnet links between DK6NI and G8HUH, both positive and negative, including the single anomaly at 0.77 SD.

On this one WSPRnet link 6 out of 9 transmissions showed a SNR anomaly during this time period between 21:46 UTC and 22:18 UTC

The SNR anomalies were both unusually high and unusually low.

The received signals were both enhanced and reduced.

We assume that there was both reflection enhancing the signal and scatter reducing the signal taking place.

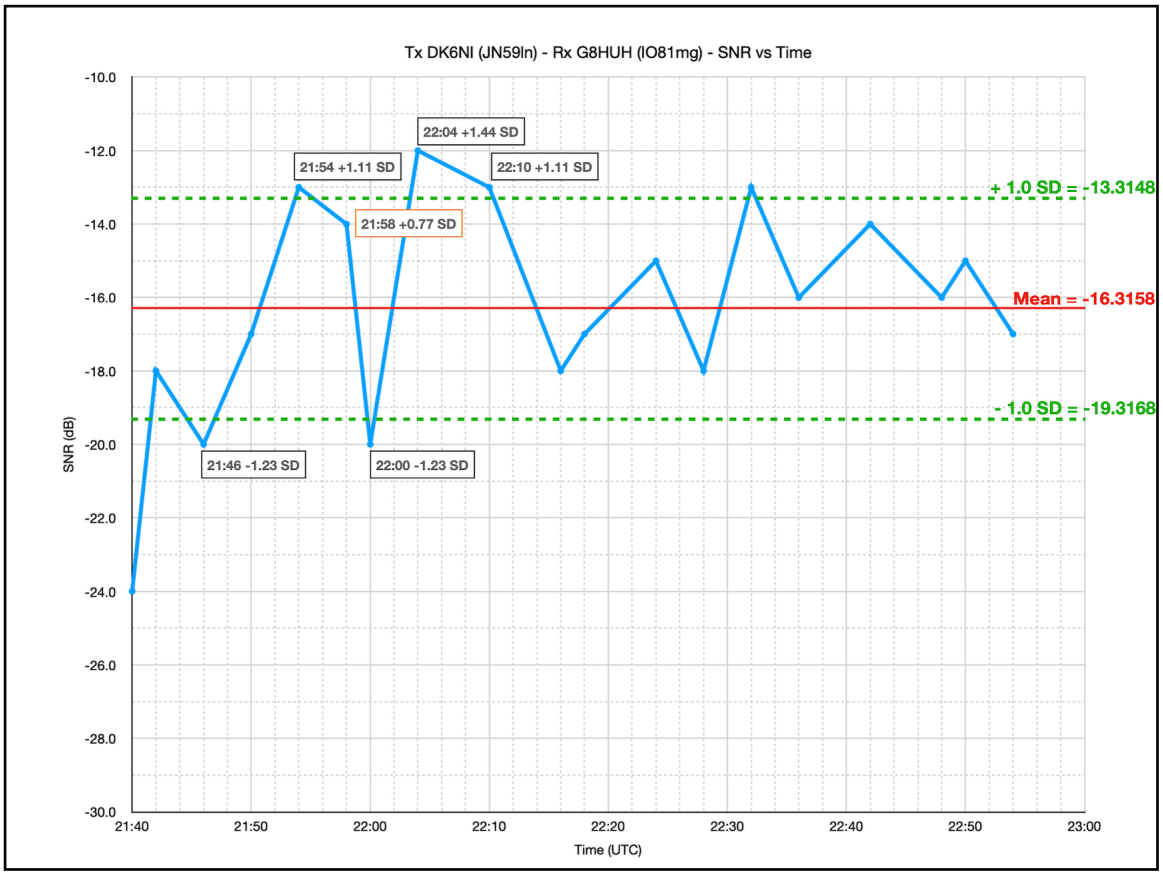

Figure 21: WSPRnet SNR anomalies between 21:46 UTC and 22:10 UTC.

14. Active Pilot.

During the flight of MH370 there was a zig zag flight path. The general trend is in a southerly direction, but there are turns left then right at some points every 8 to 12 minutes. These turns are not all to aviation waypoints and some may have been achieved by an active pilot entering a heading or track adjustment on the Mode Control Panel (MCP). These turns could theoretically have been entered into the Flight Management Computing System (FMCS), but in practice that would have been a time consuming task.

More importantly, during the flight of MH370 there were several flight level changes as confirmed by the combination of the WSPRnet position data with the Inmarsat BTO satellite data. These changes in flight level may have been achieved by an active pilot entering a flight level adjustment on the Mode Control Panel (MCP). These changes in flight level cannot be programmed into the Flight Management Computing System (FMCS).

The changes in flight level in particular (as well as the large number of turns) leads us to the conclusion that there was an active pilot during the entire flight of MH370.

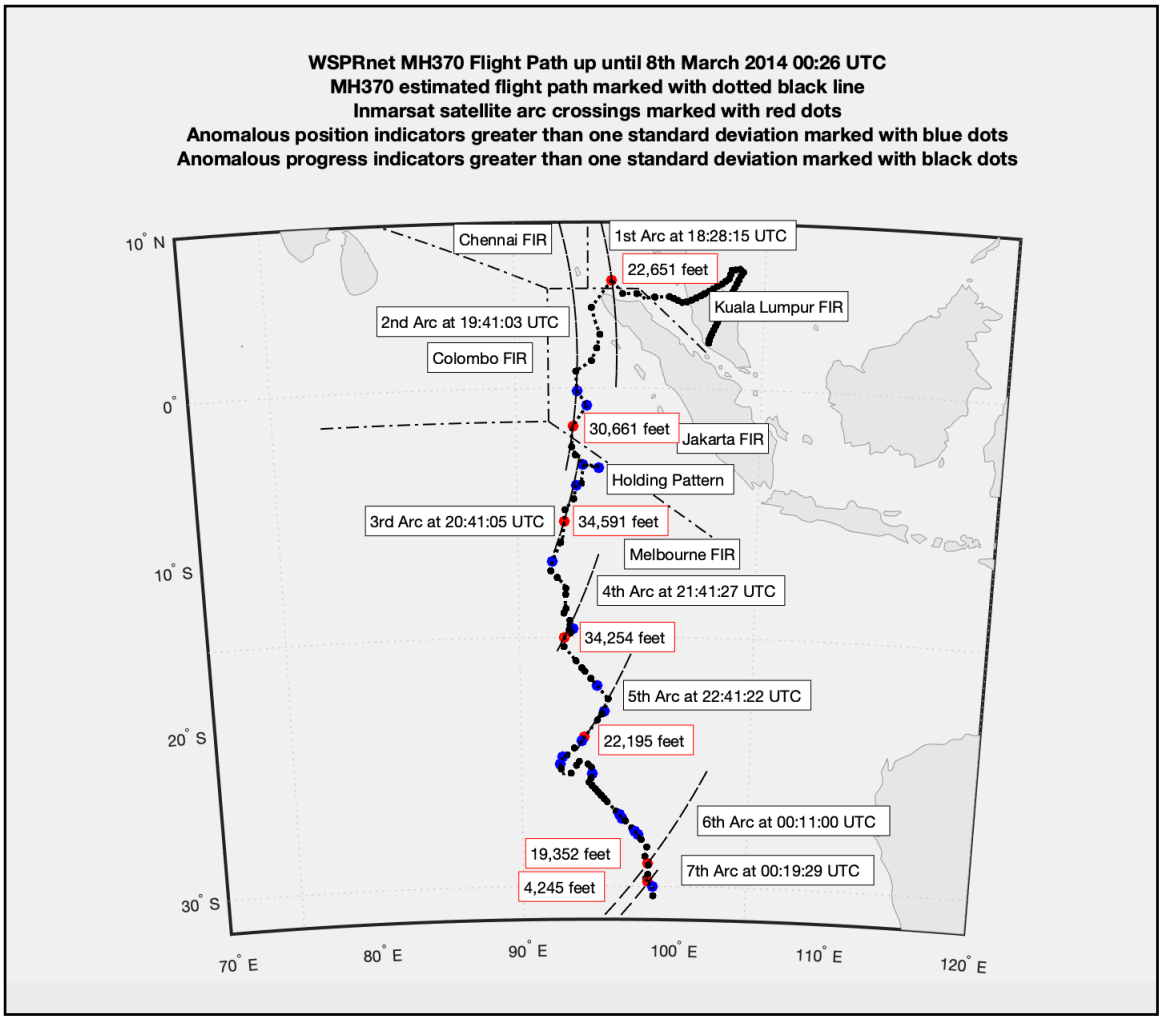

Figure 22: GDTAA position and progress indicators at 00:26 UTC Regional View.

Care is taken when loading cargo on an aircraft and seating passengers that the weight is evenly distributed around the centre of gravity. If the weight is not evenly distributed you can have a situation where the nose is always pitching down or up, or the aircraft is always tending to roll left or right. The aircraft will be trimmed in flight by an active pilot with small adjustments to the flight control surfaces (ailerons, elevator and rudder) to ensure there are no aerodynamic forces causing an imbalance of the aircraft.

The pilot is given a load sheet on departure with the weight of the passengers, luggage, cargo and fuel. The centre of gravity of the aircraft is calculated. As fuel is used during the flight an active pilot may decide to balance the left and right wing fuel tanks.

When fuel exhaustion occurred in the MH370 flight and both engines flame out, then the aircraft will normally fly straight and level for a while until it loses air speed. Eventually the nose will pitch down and speed picks up. Then with increased speed there will be more lift from the wings and the nose will pitch up. If a cross wind lifts one wing, then the aircraft will roll left or right. If all this goes unchecked then a spiral dive will most probably follow as shown by the Boeing end of flight simulations.

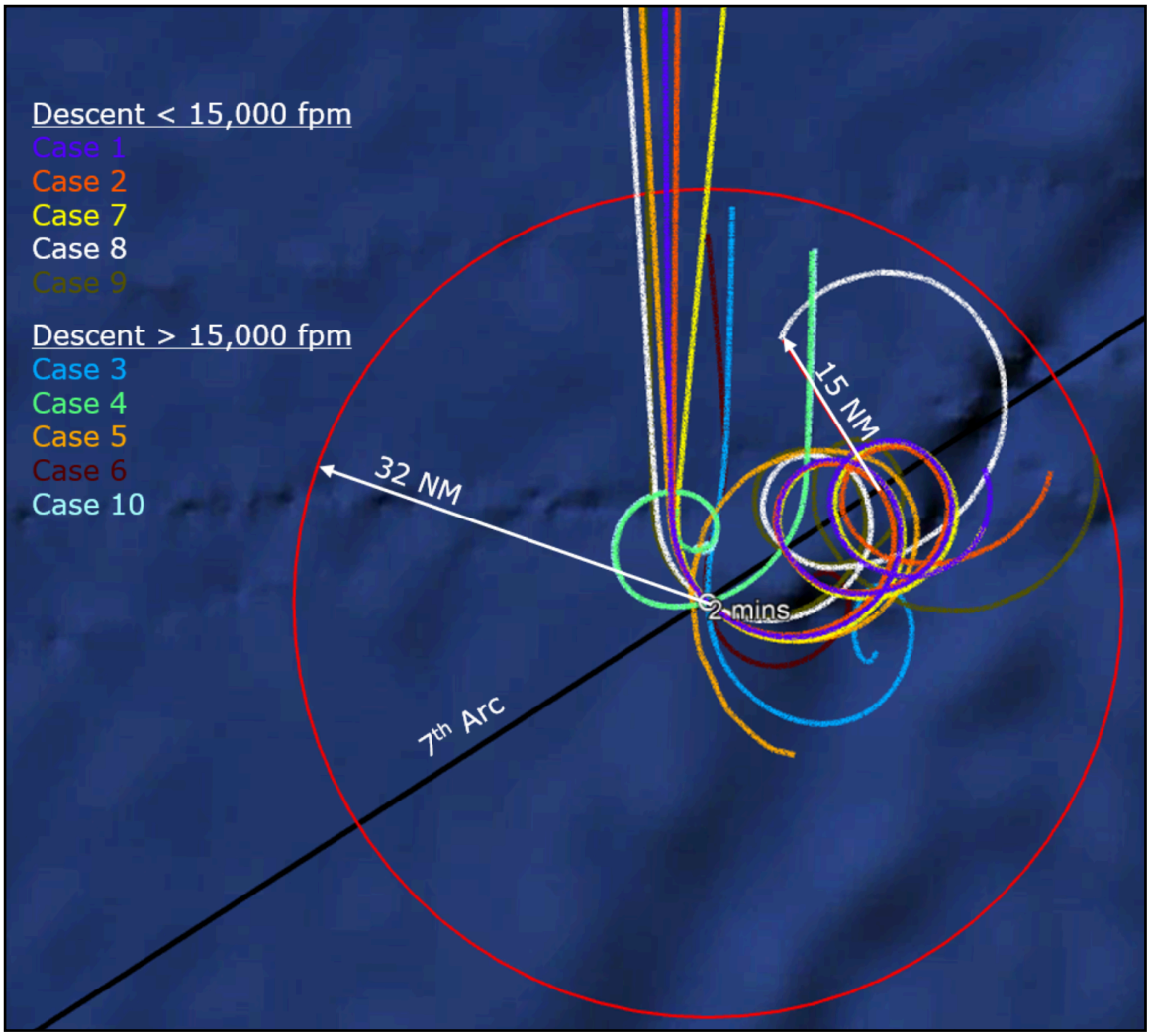

Figure 23: Boeing MH370 End of Flight Simulations.

At the end of flight after the dive indicated by the Inmarsat BFO satellite data at 00:19:29 UTC of 3,826 fpm and at 00:19:37 UTC of 14,310 fpm, it has long since been debated whether MH370 could recover from such a dive or not. We do not know for how long such a dive was in progress. We estimate that MH370 fuel exhaustion took place at 00:11 UTC, the dive was 8 minutes later at 00:19 UTC. The Boeing end of flight simulations showed a dive after 7 minutes 21 seconds on average.

The Boeing MH370 end of flight simulations are without pilot input. In all ten cases that Boeing simulated a spiral developed sooner or later. This is because the wind lifts one wing tip or the other and without pilot input to make a slight correction the aircraft will not keep to the desired flight path. If there is no correction from a pilot input, once the wind catches a wing tip the aircraft starts to roll and a spiral can develop on top of the dive and the phugoid motion, where the aircraft pitches up and climbs and then pitches down and descends, accompanied by speeding up and slowing down. If you want to glide, you have to dive to pick up speed to be able to glide.

In the Boeing end of flight simulations a roll started in all cases. A roll of greater than 1°/ minute started between 138 seconds and 1,152 seconds after the start of the simulation. In 8 cases the roll was to the left and in 2 cases to the right. In 5 cases a rate of descent of 15,000 fpm was achieved. In these 5 cases the simulation started in 3 cases at 40,000 feet and in 2 cases at 35,000 feet and there was one phugoid cycle in 4 cases and two phugoid cycles in 1 case. The average duration of the simulation until a crash was 12 minutes 35 seconds.

In the Boeing end of flight simulations cases 3, 4, 6 and 10 show a swooping descent rather than a gradual descent as in the other cases. These 4 cases also show a descent greater than 15,000 fpm developing after on average 7 minutes 21 seconds. These 4 cases also show turns on average of 40.7°T and up to 51.8°T over a two minute period. These changes in track are all greater than the maximum of 22.85°T over a two minute period as shown by the WSPRnet analysis.

The WSPRnet analysis shows that the end of flight started at a lower altitude. At the 6th Arc at 00:11:00 UTC the altitude was 19,352 feet, at 00:19:29 UTC was 5,458 feet and at 00:19:37 UTC was 4,245 feet. The time until a crash would therefore possibly be less than the average simulation time of 12 minutes 35 seconds, which would place the crash time at 00:23:35 UTC.

The WSPRnet analysis shows a position indicator at 00:22:00 UTC and a progress indicator at 00:26:00 UTC. Thereafter at 00:28:00 UTC and 00:30:00 UTC no anomalous WSPRnet indicators were to be found. The track at 00:20:00 UTC is 152.6°T. The track at 00:22:00 UTC is 130.0°T and 22.6°T to the left of the previous track. The track at 00:26:00 UTC is 175.7°T and 45.7°T to the right of the previous track. The maximum changes in track over a 2 minute period are 22.85°T

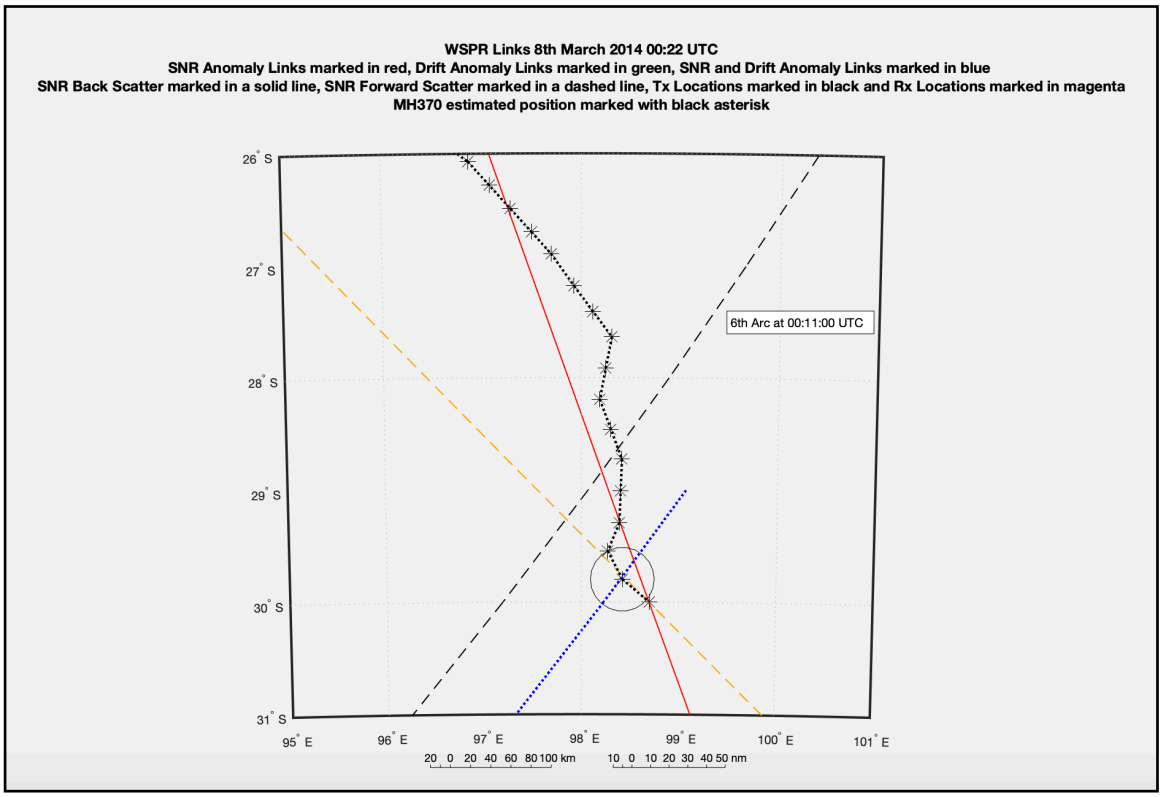

Figure 24: GDTAA progress indicator at 22:22 UTC Local View.

The pilot recovered from the dive at 00:19:37 UTC and MH370 was still flying at 00:22 UTC around 2 minutes later as indicated by an anomalous WSPRnet position indicator. There is also evidence that MH370 was still flying at 00:26 UTC, which is around 6 minutes after the dive, as indicated by an anomalous WSPRnet progress indicator. After that there were no anomalous WSPRnet detections.

The much smaller changes in track by a maximum of 22,85°T over a two minute period lead us to the conclusion that there was an active pilot during the end of flight of MH370.

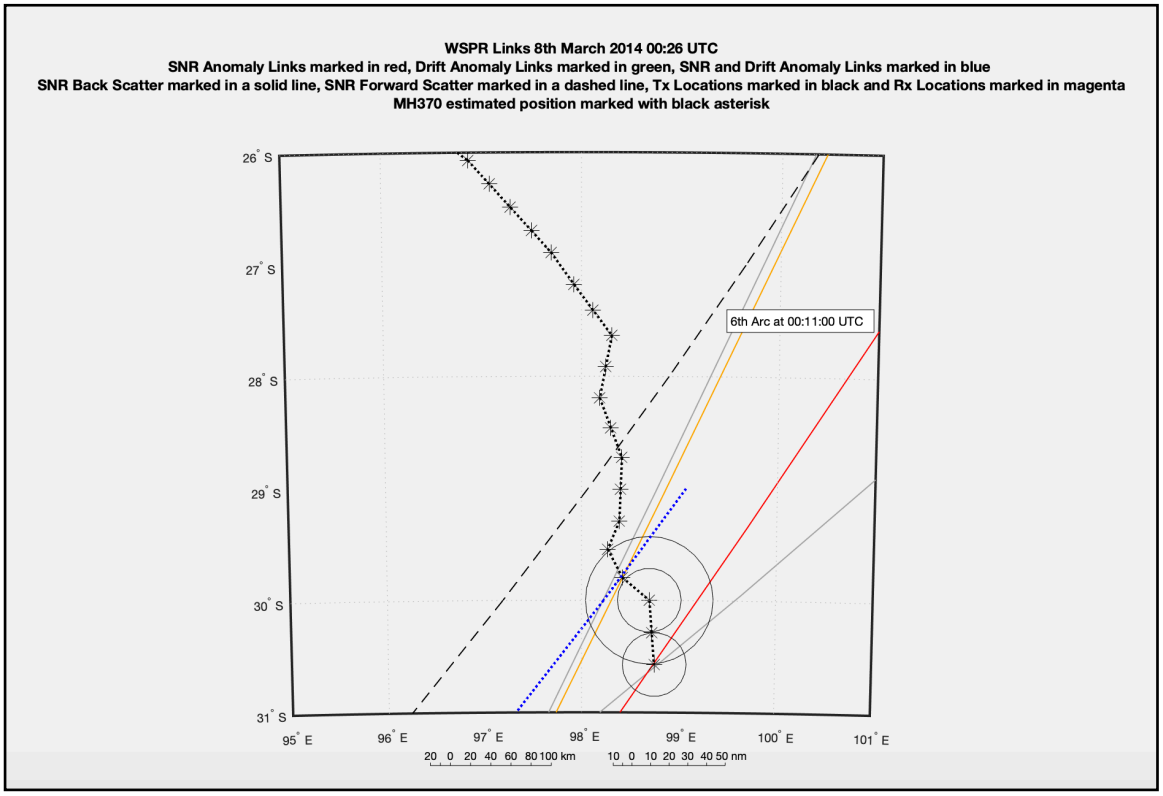

Figure 25: GDTAA progress indicator at 22:26 UTC Local View.

Although MH370 recovered from the dive, it was still probably very difficult to control. The Boeing end of flight simulations show how an aircraft can swoop and dive, pick up speed and climb again, then stall and dive again. We still think that the final crash into the sea was uncontrolled and hence the resulting damage to the 36 items of floating debris that have been recovered. For a controlled landing on water you need the flaps extended and some engine power. After fuel exhaustion you have neither.

After 00:26 UTC all the 25 WSPRnet indicators covering the area reachable by 00:28 UTC and 00:30 UTC and consistent with the flight data following fuel exhaustion, do not show any further WSPRnet anomalies.

15. Summary.

In summary we have found 77 anomalous WSPRnet links in the MH370 rerun along the entire flight path from 17:56 UTC onwards with greater than one standard deviation.

The anomalous WSPRnet links comprise 23 progress indicators marked with blue dots and 54 progress indicators marked with black dots in the chart below.

The 7 Inmarsat Arc crossings are matched and marked with red dots in the chart below.

There was an active pilot until the end of the flight.

The pilot was able to recover from the dive at the 7th Arc.

The dive is indicated by the Inmarsat BFO satellite data at 00:19:29 UTC and 00:19:37 UTC.

There is position indicator at 00:22 UTC and a progress indicator at 00:26 UTC after the time of the dive.

16. Conclusion.

MH370 crashed between 00:22 UTC and 00:27 UTC. At 00:22 UTC the position from the WSPRnet analysis was estimated to be 30.00°S 98.70°E. At 00:26 UTC the position from the WSPRnet analysis was estimated to be 30.57°S 98.75°E.

The crash location is further north than previously thought and up to 42 nmi South East of the 7th Arc.

We have presented evidence that there was an active pilot until the end of the MH370 flight. We have also presented evidence that the pilot may have been disoriented, which can be caused by hypoxia.

To solve the mystery of the disappearance of MH370 we need to find the aircraft and recover the Flight Data Recorder and other evidence from the wreckage.