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# BEPPOSAX REENTRY PREDICTIONS

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## GROUND IMPACT UNCERTAINTY WINDOW

Currently BeppoSAX is approaching the reentry into the densest layers of the earth atmosphere. The expected residual lifetime of the satellite was computed by propagating its last available state vector (epoch: 29 April 2003, 07:08 UTC) with a numerical trajectory predictor including all the relevant perturbations. Concerning the predicted solar flux at 10.7 cm and the geomagnetic planetary index  $A_p$ , the last 3-day forecast, issued by the NOAA Space Environment Center, was adopted.

Using for the final orbits of BeppoSAX the ballistic parameter estimated by fitting the altitude decay observed during 34 hours, the ground impact time window shown in Table 1 was obtained for the main debris. The confidence level associated with such a window is approximately 90%.

**Table 1**

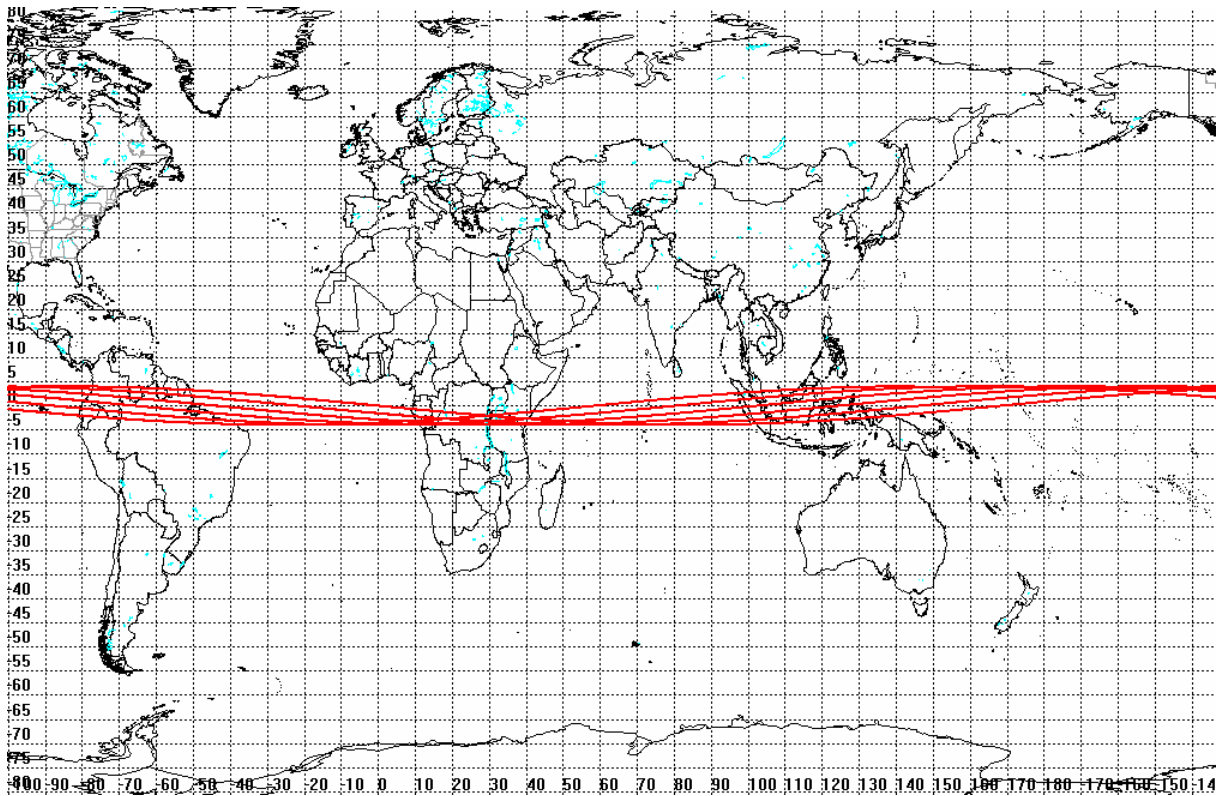
**Ground Impact Time Window for the BeppoSAX Main Debris**

Impact Window	Impact Date	Impact Time
Opening	29 April 2003	20:35 UTC
Nominal Impact	29 April 2003	23:51 UTC
Closure	30 April 2003	05:17 UTC

During the last four days, three upper stage reentries have occurred: one over Brazil (a Russian Proton stage), in the morning of April 26, one over Central America (an American Atlas-Centaur stage), in the afternoon of April 27, and a third one over China (a Russian Soyuz stage), in the morning of April 28. A European Ariane third stage will reenter as well in the coming 36 hours, in between 7.6 degrees North and South. It should be emphasized that none of the above mentioned reentry events is related to BeppoSAX.

## AREAS OF THE PLANET POTENTIALLY INVOLVED

Due to the current uncertainty on the reentry time, significant areas of the equatorial belt in between 4.36 degrees North and South might still be affected by the impact of the surviving fragments of BeppoSAX. The sub-satellite ground tracks potentially at risk are shown in Figure 1 and their coordinates are provided in Table 2.



**Fig. 1 – Sub-satellite tracks potentially at risk during the impact time window given in Table 1**

**Table 2**

**Geographical Coordinates of the Ground Tracks Potentially at Risk**

LAT (deg)	LON (deg E)
1.6029	213.6535
2.3416	225.1714
2.9729	236.7
3.4678	248.2397
3.8034	259.7891
3.9642	271.3448
3.9427	282.902

3.74	294.4558
3.3655	306.0018
2.8364	317.537
2.1773	329.0606
1.4184	340.574
0.5945	352.0805
-0.2566	3.5849
-1.0961	15.0926
-1.8855	26.6085
-2.5887	38.1366
-3.1731	49.6786
-3.6117	61.2342
-3.8842	72.8008
-3.9777	84.3737
-3.888	95.9477
-3.619	107.5174
-3.1833	119.0781
-2.601	130.627
-1.8992	142.1636
-1.1103	153.6894
-0.2705	165.2079
0.5815	176.7239
1.4069	188.2426
2.1677	199.7684
2.8289	211.3046
3.3602	222.8523
3.7368	234.4103
3.9415	245.9758
3.9645	257.5441
3.8051	269.1104
3.4704	280.67
2.9762	292.2194
2.3451	303.7573
1.6063	315.2844
0.7938	326.8037
-0.0552	338.3197
-0.9018	349.8378
-1.7071	1.363
-2.4341	12.8996
-3.0494	24.45
-3.5243	36.0142
-3.8368	47.5901
-3.9723	59.1737
-3.9243	70.7595
-3.6952	82.342
-3.2956	93.9163
-2.7439	105.4794
-2.0659	117.03
-1.2929	128.5694
-0.4605	140.1006

0.3931	151.6283
1.2284	163.1576
2.0073	174.6935
2.6939	186.2393
3.2564	197.7967
3.6689	209.3652
3.9122	220.9422
3.9749	232.5233
3.8542	244.1036
3.5556	255.6783
3.0931	267.2436
2.4881	278.7977
1.7685	290.3408
0.9676	301.8754
0.1221	313.4056
-0.7292	324.9369
-1.5471	336.4744
-2.2939	348.0226
-2.9351	359.5842
-3.441	11.16
-3.788	22.748
-3.9598	34.3446
-3.9484	45.9445
-3.7542	57.5422
-3.3863	69.1327
-2.8619	80.7121
-2.2055	92.2791
-1.4474	103.8344
-0.6226	115.381
0.2308	126.9231
1.0736	138.4662
1.8669	150.015
2.5741	161.5735
3.1626	173.1438
3.605	184.7258
3.8807	196.3171
3.9769	207.9138
3.8891	219.5109
3.6214	231.1035
3.1861	242.6876
2.6036	254.2608
1.9009	265.823
1.1105	277.3764
0.2689	288.9249
-0.5853	300.4735
-1.4128	312.0276
-2.1752	323.5919
-2.8372	335.1695
-3.3681	346.7612
-3.743	358.3658

-3.9443	9.9798
-3.9625	21.598
-3.7967	33.215
-3.4548	44.8255
-2.9526	56.4255
-2.3137	68.0131
-1.5678	79.5889
-0.7495	91.1554
0.1033	102.7169
0.9514	114.2788
1.7555	125.8461
2.4784	137.423
3.0867	149.0119
3.552	160.6131
3.8526	172.2245
3.9743	183.8425
3.9115	195.462
3.667	207.0782
3.2523	218.6867
2.6866	230.285
1.9965	241.8726
1.2137	253.4513
0.3747	265.0249
-0.4818	276.5984
-1.3161	288.1771
-2.0897	299.7658
-2.7665	311.3678
-3.315	322.9844
-3.7093	334.6144
-3.9309	346.2546
-3.9692	357.9
-3.8224	9.5451
-3.4974	21.1845
-3.0094	32.8142
-2.3813	44.432
-1.6425	56.0384
-0.8275	67.6356
0.0259	79.2281
0.8782	90.8211
1.6897	102.4199
2.4227	114.029
3.0431	125.651
3.5218	137.2864
3.8362	148.9336
3.9716	160.5887
3.9214	172.247
3.6878	183.9034
3.282	195.5536
2.7227	207.1949
2.0364	218.8267

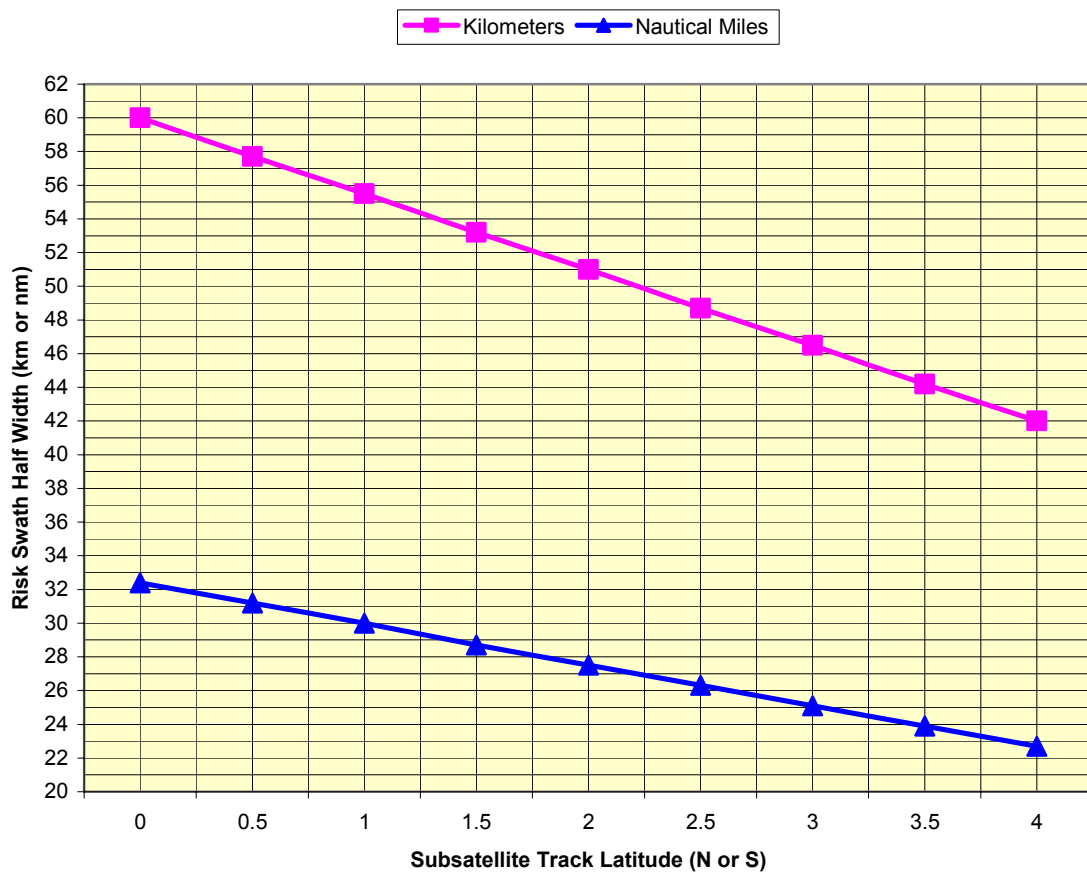
1.2548	230.4507
0.4146	242.0707
-0.4453	253.6917
-1.2846	265.3192
-2.0642	276.9582
-2.3044	280.8411
-2.5325	284.7258
-2.7475	288.6123
-2.9481	292.5007
-3.1334	296.3909
-3.3023	300.2829
-3.454	304.1767
-3.5875	308.0721
-3.7023	311.9691
-3.7977	315.8676
-3.8732	319.7673
-3.9284	323.6682
-3.963	327.57
-3.9767	331.4726
-3.9696	335.3757
-3.9416	339.2792
-3.8929	343.1828
-3.8238	347.0863
-3.7345	350.9896
-3.6256	354.8925
-3.4976	358.7948
-3.3512	2.6964
-3.1872	6.5972
-3.0064	10.4971
-2.8099	14.396
-2.5985	18.2938
-2.3735	22.1904
-2.1361	26.0858
-1.8875	29.9798
-1.629	33.8721
-1.3621	37.7624
-1.0881	41.6501
-0.8087	45.5339
-0.5255	49.4119
-0.2403	53.2797
0.0447	57.1277
0.3262	60.9318
0.5968	64.6104
0.8324	67.8458
0.9658	69.6982
0.992	70.064

Taking into account the predicted dispersion of the fragments and the trajectory inaccuracies, the half width of the risky ground swath  $\Sigma$  associated with the above

mentioned ground tracks is a function of the sub-satellite latitude  $\lambda$ , North or South, as given by the following equation:

$$\Sigma(km) = 42 + 258.95 \sin(3.978^\circ - |\lambda|). \tag{1}$$

Figure 2 shows how the risky ground swath half width  $\Sigma$  varies as a function of the sub-satellite latitude  $\lambda$ , North or South, both in kilometers and nautical miles. As an example, the half width of the risky ground swath associated with a sub-satellite point on the equator ( $\lambda = 0^\circ$ ) is 60 km, that is all the locations at less than 60 km from the sub-satellite track are potentially at risk. The swath half width decreases as higher latitudes, North or South, reaching the minimum value of 42 km at  $\lambda = \pm 3.978^\circ$ .



**Fig. 2 – Half width of the risky ground swath as a function of the sub-satellite track latitude**

The countries or territories that might still be potentially hit by the BeppoSAX falling fragments are:

- **Africa:** Burundi, Congo, Democratic Republic of Congo, the Pagalu Island of Equatorial Guinea, Gabon, Kenya, Rwanda, São Tomé and Príncipe, Seychelles, Somalia, Tanzania;

- **Asia:** Indonesia, Malaysia, Maldives, Singapore;
- **Oceania:** Baker Island (USA), Federated States of Micronesia, Howland Island (USA), Kiribati, Marshall Islands, Nauru, Palau, Papua New Guinea;
- **South America:** Brazil, Colombia, Ecuador, French Guiana, Guyana, Peru, Suriname, Venezuela.

The following countries or territories of the equatorial belt in between 4.36 degrees North and South are instead not included anymore – with a confidence level of 90% or higher – in the areas at risk for the BeppoSAX falling fragments: Cameroon, Central African Republic, the continental Equatorial Guinea, Ethiopia, Sudan, Uganda, Cap Palmas, at the border between Liberia and Côte d'Ivoire, the Niger river delta, in Nigeria, Brunei, Jarvis Island (USA).

## LONGITUDINAL RISK TIME WINDOWS

A nominal impact time for the BeppoSAX main debris may be associated with any sub-satellite point of the risky ground tracks shown in Figure 1. By taking into account an impact uncertainty of  $\pm 10$  minutes and the time needed for the small centimeter sized particulate produced by the event to rain down through the affected air space (+ 20 minutes), a risk time window of 40 minutes can be associated with any specific location along the final sub-satellite tracks, as follow:

$$\text{Risk Time Window} = \text{Predicted Main Debris Impact Time (UTC)} \left\{ \begin{array}{l} +30 \text{ min} \\ -10 \text{ min} \end{array} \right. . \quad (2)$$

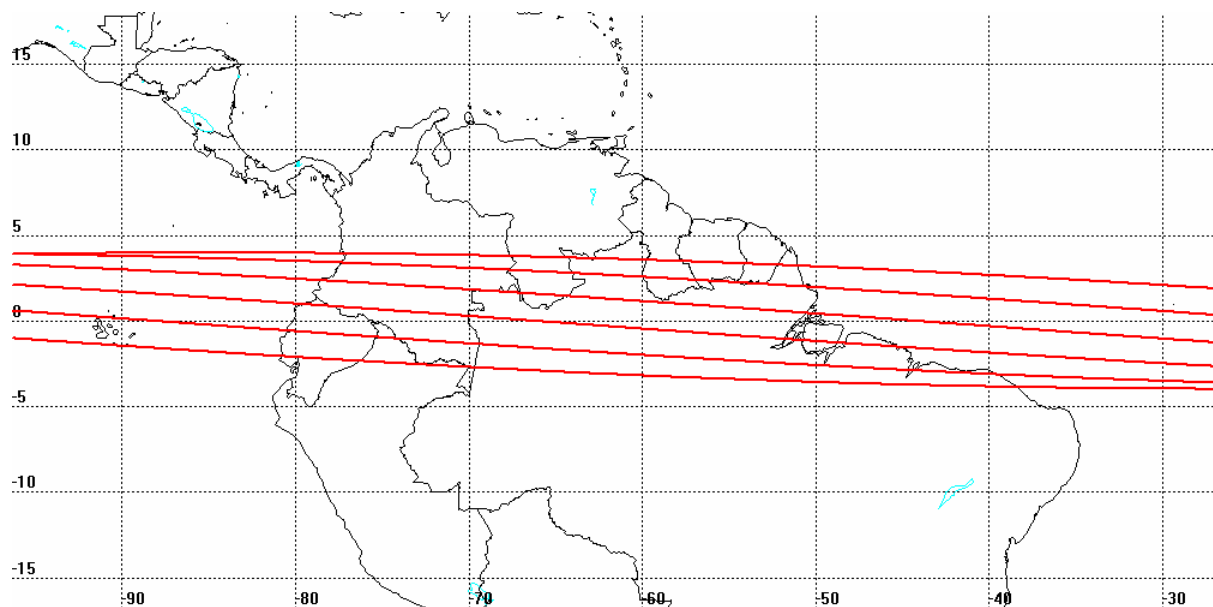
Table 3 lists the impact risk time windows, as a function of longitude, for the sub-satellite ground tracks potentially at risk, shown in Figures 1 and 3-6.

**Table 3****Impact Risk Time Windows (UTC) Along the Risky Ground Tracks**

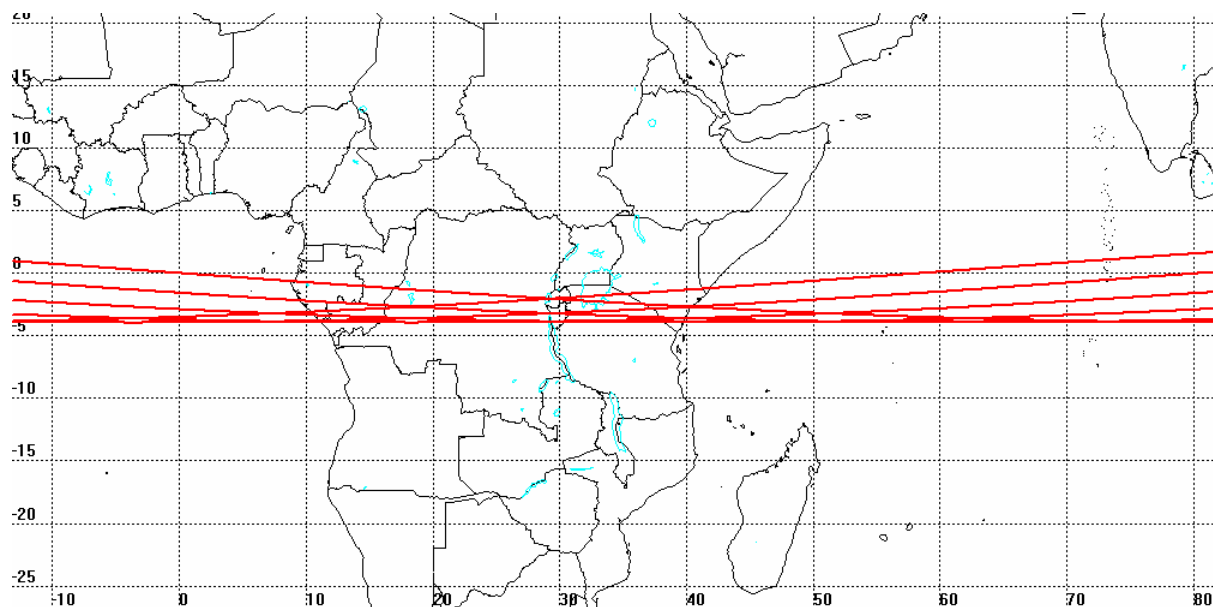
<b>Longitude Band</b>	<b>Track No. 1</b>	<b>Track No. 2</b>	<b>Track No. 3</b>	<b>Track No. 4</b>	<b>Track No. 5</b>	<b>Track No. 6</b>
<b>180° – 120° W</b>	29 APR 2017-2112	29 APR 2150-2245	29 APR 2323 30 APR 0018	30 APR 0056-0152	30 APR 0228-0323	30 APR 0403-0458
<b>120° – 60° W</b>	29 APR 2032-2127	29 APR 2205-2301	29 APR 2338 30 APR 0033	30 APR 0112-0218	30 APR 0243-0340	30 APR 0418-0514
<b>60° W – 0°</b>	29 APR 2047-2143	29 APR 2221-2316	29 APR 2353 30 APR 0048	30 APR 0128-0222	30 APR 0300-0356	30 APR 0434-0529
<b>0° – 60° E</b>	29 APR 2103-2158	29 APR 2236-2331	30 APR 0008-0104	30 APR 0142-0238	30 APR 0316-0412	30 APR 0449-0545
<b>60° – 120° E</b>	29 APR 2118-2215	29 APR 2251-2347	30 APR 0024-0120	30 APR 0158-0253	30 APR 0332-0427	30 APR 0505-0600
<b>120° – 180° E</b>	29 APR 2135-2230	29 APR 2307 30 APR 0003	30 APR 0040-0136	30 APR 0213-0308	30 APR 0347-0443	30 APR 0520-0615

### CONTINENTAL RISK MAPS

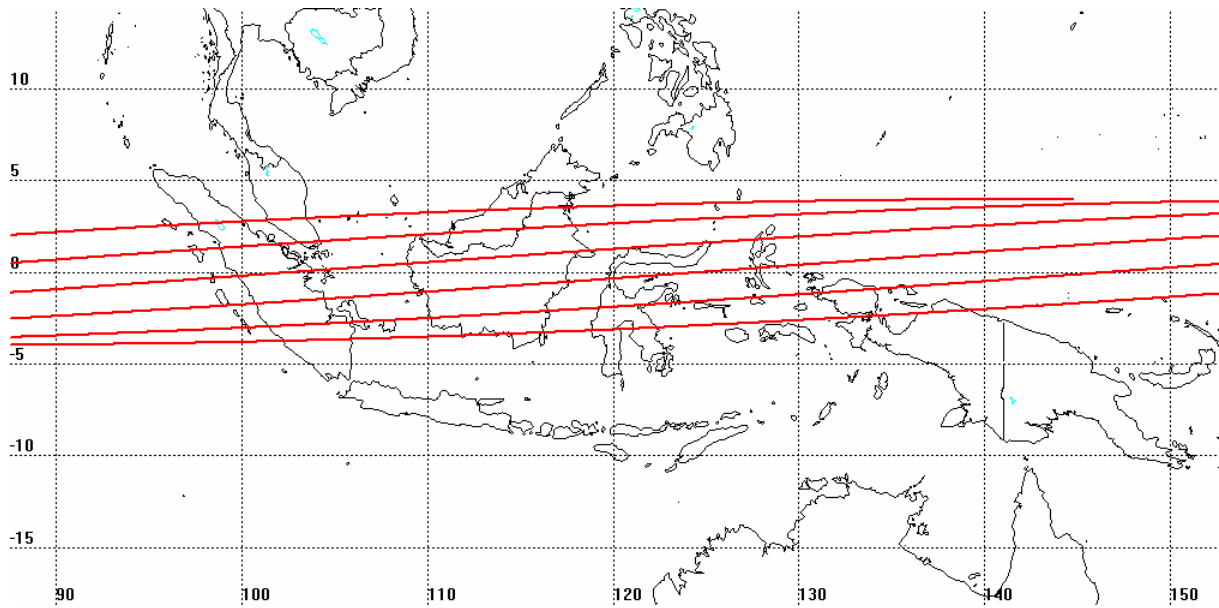
The sub-satellite ground tracks at risk are presented in further detail, for specific continental areas, in the following maps (Figures 3-6).



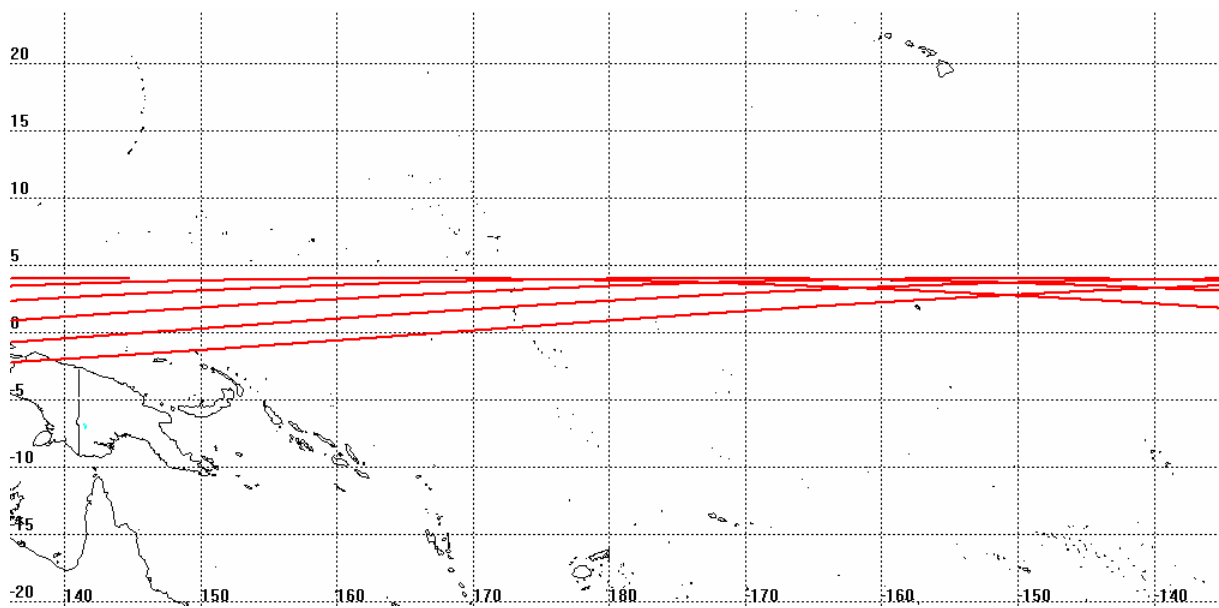
**Fig. 3 – Sub-satellite tracks potentially at risk over South America**



**Fig. 4 – Sub-satellite tracks potentially at risk over Africa and Maldives**



**Fig. 5 – Sub-satellite tracks potentially at risk over Southeast Asia**



**Fig. 6 – Sub-satellite tracks potentially at risk over Oceania**

## **NEXT UPDATE**

The next bulletin will be issued as soon as new significant results are available.

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