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First analysis of gross-errors in ERS-1 altimeter data in the Mediterranean Sea.

by

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Abstract: Radar altimeter data from the first 35-day repeat tracks of ESA's ERS-1 satellite have been analyzed for gross-errors in an area covering the Mediterranean Sea. Pairs of values which after the subtraction of the OSU91A geoid were more than 0.3 m different were extracted for a first inspection. If the difference could not be explained by the depth variations, and did not occur on repeat tracks then the largest value was marked as an outlier. Using this procedure approximately one per mille of the data was identified as possible gross-errors.

1. Introduction.

Satellite radar altimeter data include just as all geophysical data gross-errors. These errors are generally due to an erroneous land mask, so that data which are supposed to be collected at sea really are partly at sea and partly on land, see e.g. Tscherning (1990).

It is in the nature of gross-errors, that they may not be errors, but be real observations. They should therefore not be eliminated, but have assigned a large error estimate (down-weighted) or simply flagged as gross-errors. We will in the following describe the procedure we have used to detect possible gross-errors of ERS-1 altimeter measurements in the Mediterranean Sea, which is the area of interest for the GEOMED project.

Our analysis has been limited to the area bounded by latitude 30° in South and 47° in North, -5° in West and 40° in East which fully includes the Mediterranean Sea. We describe here the analysis of the tracks from the first four 35-day repeat periods. There were totally 23279 data points in the area from this period. The data distribution corresponding to the first 35-day repeat period is shown in Fig. 1.

2. Method for gross-error detection used.

Gross-errors will here be measurements, where the by us estimated error largely exceeds the error estimate associated with the data as supplied by ESA. This error estimate expresses

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a scatter of the data, which originally is formed as the mean value of 20 0.05 sec values. This means that the quantity also includes information about the signal variation in the 1 sec period.

We have in earlier investigations in the Norwegian Sea (see Knudsen et al.(1992a,b)) used the criteria that the scatter should be below 0.20 m in order to identify a possible gross-error. However, due to the strong variation of the gravity field in the Mediterranean Sea large values could simply signify a strong local geoid variation. We therefore decided not to use the value of the scatter in order to identify a possible gross-error.

A gross-error may be masked by a large bias. We therefore subtracted the contribution of OSU91A (Rapp et al.,1991) from the data. Values which after this subtraction numerically exceeded 10 m were then deleted, since we in this area expect the standard deviation of the values (after subtraction of OSU91A) to be below 3 m (cf. Arabelos & Tziavos, 1992, Table 9).

The data were then divided in segments, where a new segment was identified if the distance to the last point was more than 22 km, corresponding to approximately 3 sec time difference. This gave 977 segments in the area to be further analyzed.

They were analyzed by comparing consecutive pairs of points, so that pairs where the difference was larger than 0.3 m were marked for further analysis. Such a difference corresponds to a deflection of the vertical of slightly more than 3", which generally only occurs due to large variations in the bottom topography. Converted to gravity units it corresponds to a change of about 20 mgal over the distance of 22 km. This again correspond to a Bouger plate effect produced by a change in the bottom topography of 200 m.

Since we had to our disposal the bottom topography with a 5' resolution (ETOPO5), we could then compare the topographic signal with the altimetric visually, see Fig. 2. However, this procedure was not always succesful due to the bad quality of the bathymetric information.

Inspecting Fig. 3, it is clear that the bottom topographic information is erroneous. The part of the measurements from degree 42 to degree 43.5 must surely be caused by the topography, but nothing shows up. Here we should remember that older bathymetric measurements were not very reliable at large depths. 200 m height changes were difficult to measure at 3000 m depth.

However, the procedure turned out to be useful, since some large data variations clearly were caused by the topographic variations.

This procedure could have been improved using an improved geoid model, computed from gravity data and topographic data as described in (Tscherning, 1990), and it will be tried later.

We have, however, from the repeated measurements several estimates of the height of the sea surface. And it is obvious, that if large spikes are not repeated (and if we are not close to the coast), then there is something wrong. The comparison of repeat tracks is illustrated in Fig. 4 and 5, where gross-errors easily are seen.

3. Detected gross-errors.

Following the above described procedure 349 of the 977 tracks were found to include point pairs with numerical differences exceeding 0.3 m. Of these only 16 were identified as having gross- errors, and totally 46 points were identified, see Table 1. 17 of these values had assigned a standard deviation larger than 0.20 m. (Of the total dataset 20 % has assigned a standard deviation larger that 0.20 m).

Table 1. Gross-errors detected in the Mediterranean area from the first 4 35-day repeat tracks. The track number 1 is the first track in the 1 35 day repeat period.

Observation time	track no.		Observation time	track no.
230289643.8	0074		230289727.5	0074
230549266.5	0117			
232147011.0	0382	to	232147023.7	0382
232581703.8 *	0454		232581704.7 *	0454
232581734.2 *	0454		232835079.7	0496
232879191.1	0503		233313706.7	0575
234736395.8	0811		235649592.9	0962
235734196.5	0976		235943516.1	1011
235943518.1	1011		235949655.7	1012
235949656.7	1012		235949657.7	1012
237500901.6	1269	to	237500920.7	1269
237894861.7	1334		237894925.9	1334
237894932.7	1334		237985528.6	1349
237985529.6	1349		239408213.2	1585
239408216.2	1585		239711720.6	1635
239711727.5	1635		239790155.7	1648
240490356.8	1764			

NOTE ! points with an * are located in the Atlantic.

However, of the tracks, a large number (406) included 3 or less datapoints. Here more errors may be hidden. These points must be further analyzed using supporting data such as gravity data and other altimeter data (from other ERS-1 tracks or other missions).

The list of suspected errors will be updated when new data are analyzed and stored on a computer with access possible via Internet. We would appreciate if other investigators send us information about other values which they would regard as possible gross-errors.

4. Conclusion.

Approximatly 1 per mille possible gross-errors have been detected in the ERS-1 altimeter data from the first tracks analyzed. This is very typical for geophysical data. The cause of these errors is still unclear, since it only in a few cases seems to be related to a wrong land mask.

The second author of this paper has had the tedious task of inspecting all graphs showing possible errors. We hope that the task will be nearly 100 % automatized in the near future. Then we will also be prepared to inspect the global set of altimeter data with the purpose of detecting gross-errors.

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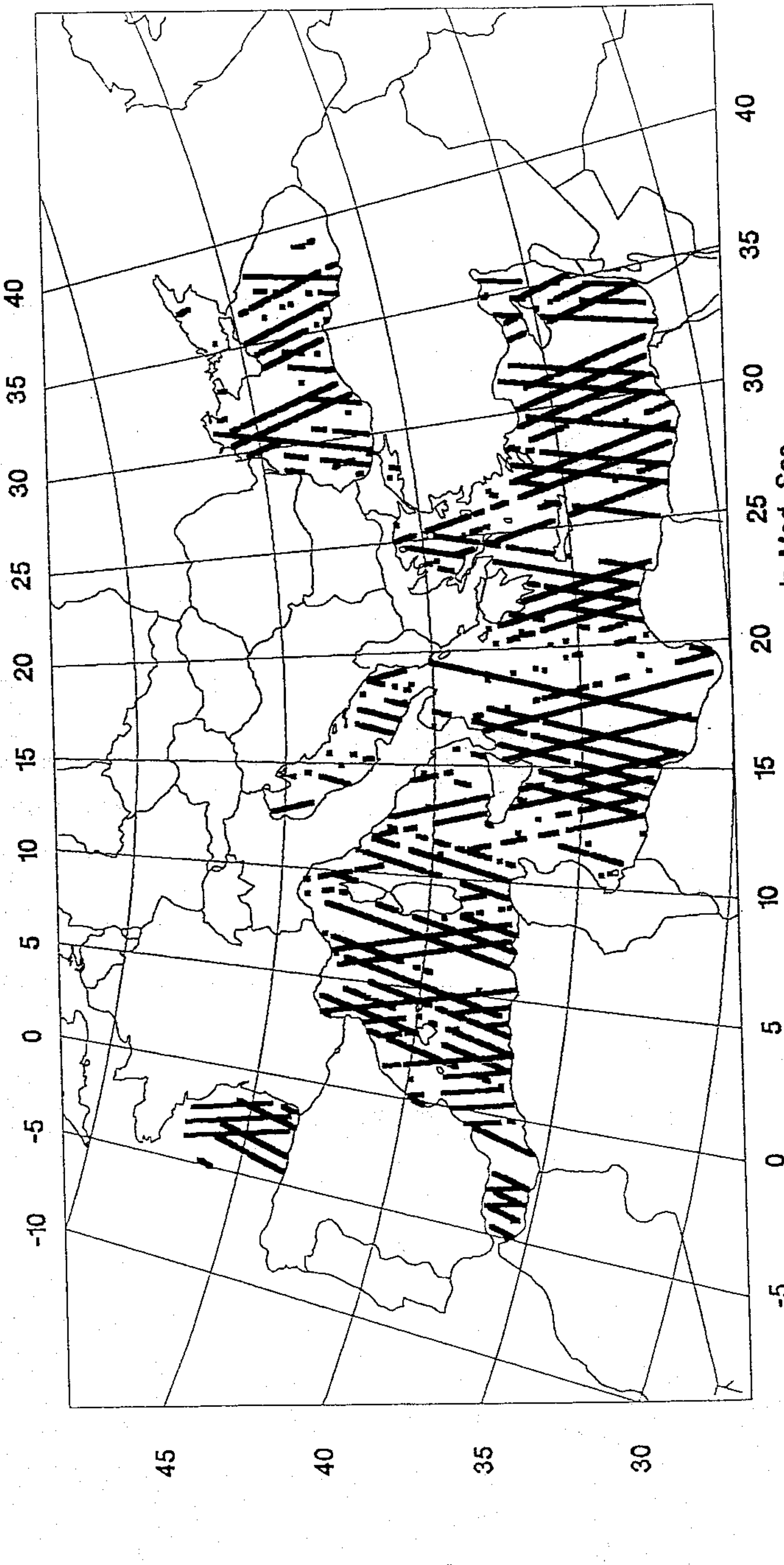

Figure 1. ERS-1 data coverage in Med. Sea.

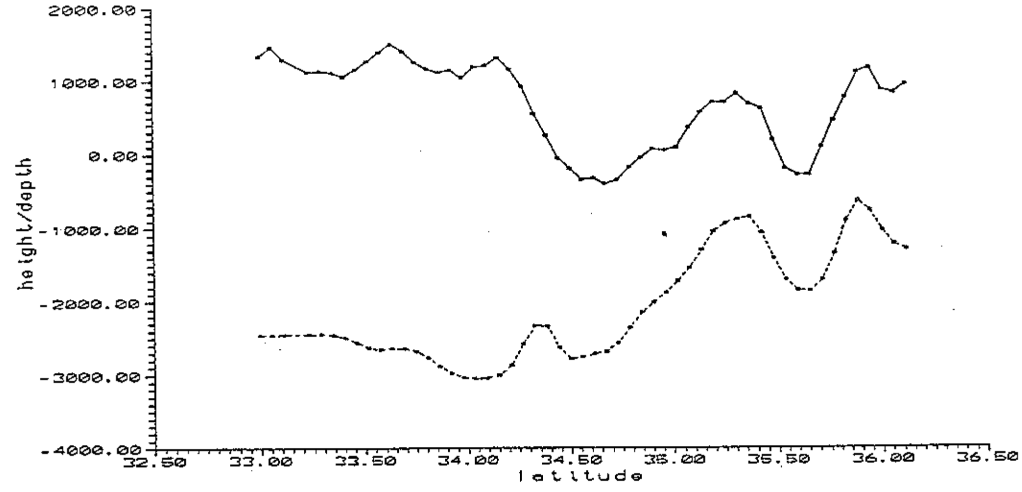

Figure 2. This figure shows a segment of track 2221, where the variations in the track (full line)
and the seafloor topography (dotted line) corresponds nicely.
Note that the track height is exaggerated by a factor 1000.

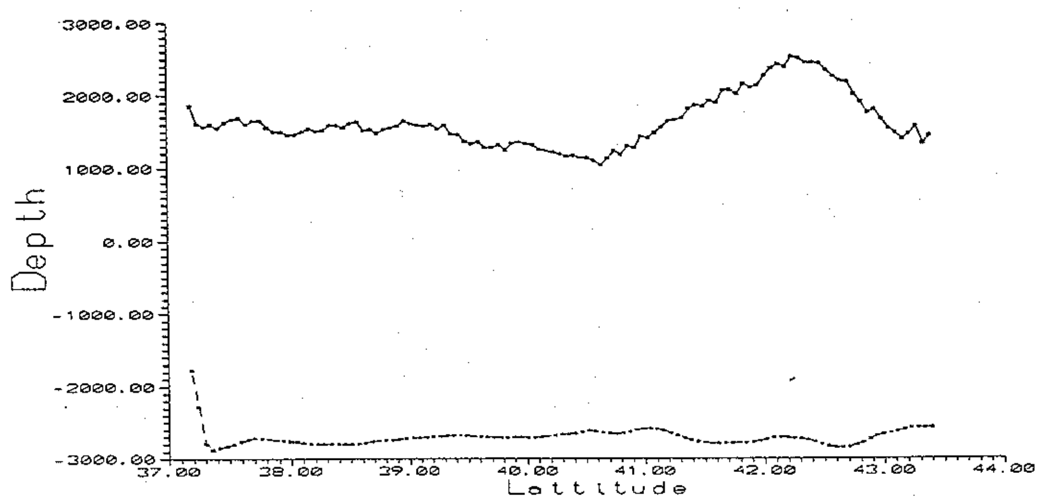

Figure 3. This shows a graphical comparison between track 89 and the seafloor topography.
Note that the ssh-values of the track (full line) are exagerated by a factor 1000.

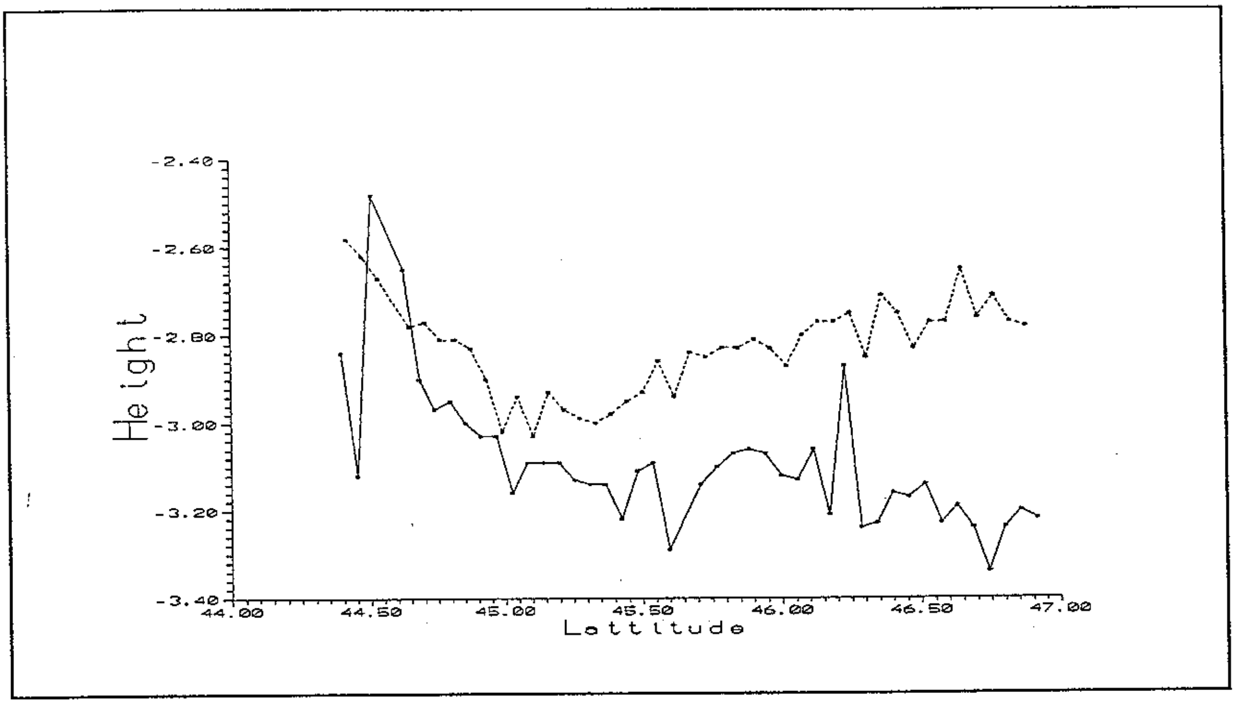

Figure 4. This is a graph comparing two tracks, 454 & 955 (full & dotted line). Two errors are clearly seen on track 454, namely the start of the graph at 44.30 and the spike at 46.20. (Note that this example is situated in the Atlantic)

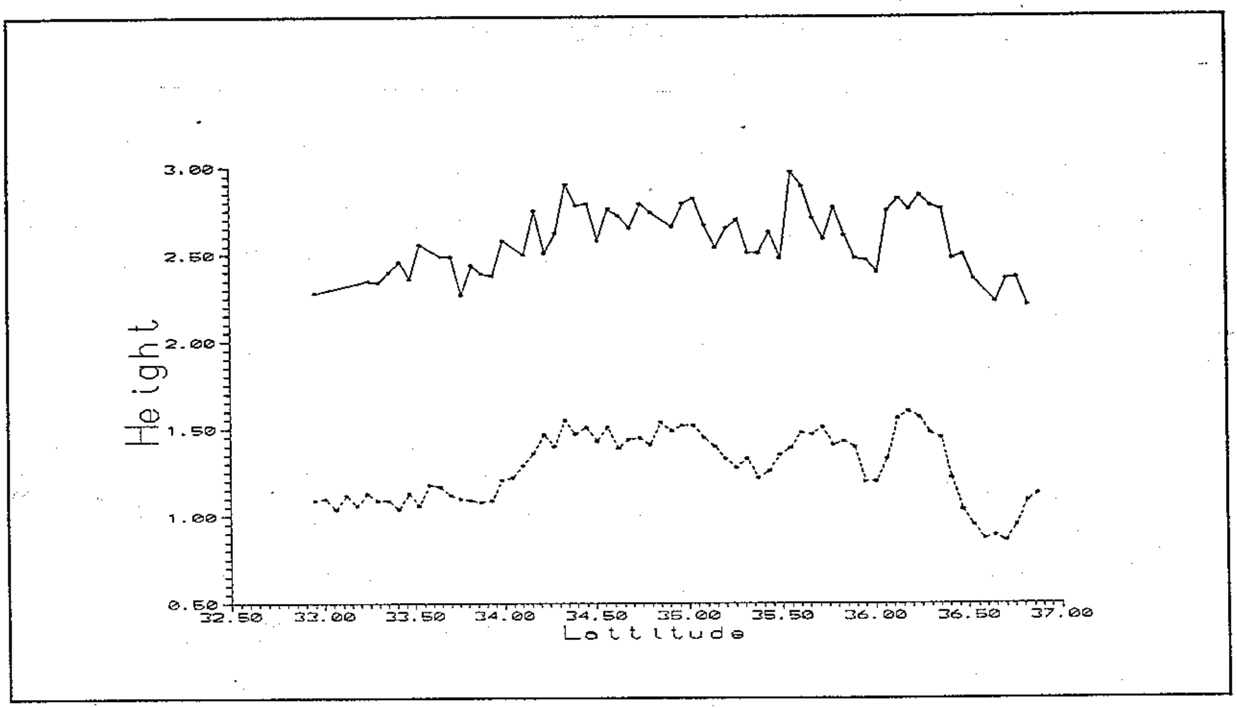

Figure 5. Shown here are the tracks 103 & 604 (full & dotted lines)
It's the same track but for two different 35 day periods.
It is seen that track 103 differs from track 604 by being more ragged and spiky, looks like there's a lot of noise on the track. The track has not been included on the error list but maybe it should.