N94-15587

# GEOMETRIC ANALYSIS OF SATELLITE LASER RANGING DATA

B. CONKLIN, S. BUCEY, V. HUSSON, W. DECKER
Bendix Field Engineering Corporation
Seabrook, MD

J. DEGNAN
Code 901/Crustial Dynamics Project
NASA Goddard Space Flight Center

The analysis of simultaneous laser data is investigated using the method of trilateration. Analysis of data from 1987 to 1992 is presented with selected baseline rates and station positions. The use of simultaneous Etalon data is simulated to demonstrate the additional global coverage these satellites provide. Trilateration has a great potential for regional deformation studies with monthly LAGEOS American solutions between 3 - 12 millimeters.

In the 1970s the precision of laser data was about 10 - 15 centimeters and the global distribution of satellite laser ranging stations was poor. Since that time the international laser ranging community has expanded and the precision of the data has improved substantially. Most laser ranging stations now produce data with a single shot precision on LAGEOS below 2 centimeters and much of that data has a single shot precision below 1 centimeter.

During the 1970s the mathematical methods to determine satellite positions using geometric data analysis were improved. The term used for that method is trilateration. The primary advantage of the trilateration technique is independent of orbit. It provides a means of analyzing station positions and data quality in such a way as to lower other outside influences such as satellite drag, radiation pressure, and gravity models that are used in the orbit determination methods. The major disadvantages to trilateration include the need for simultaneous ranging data, the difficulty in separating range biases from the station height, and the fact that the method does not allow for the extraction of the gravity field and other information that can be determined from an orbit determination process. Trilateration is also susceptible to low signal-to-noise ratio and low precision data.

Our method of trilateration requires simultaneous data from four or more laser ranging stations. There are several preprocessing steps that must occur to prepare the data for analysis. The process starts with a monthly LAGEOS fullrate release tape. Software selects the passes in which 4 or more stations have observations during the same timeframe. Once a timeframe has been found a polynomial is fit to the fullrate data for each pass. These polynomials, and other information such as the polynomial statistics and meteorological information, are written to an output file. The process continues through the entire data tape. After all of the polynomials have been determined, simultaneous data points are created at 30 second intervals from the pass polynomials. Poorly fitted passes are removed so that they don't corrupt the solution, although this rarely occurs. Any time intervals within the selected passes that have fewer than 4 stations are deleted. A summary output of the available stations and data yield is also produced at this step. Finally, the remaining LAGEOS tracking data is separated into two sections. One section is for Europe, North Africa, Commonwealth of Independent States. The other section is for the Americas, Easter Island, and Huahine.

To analyze the data geometrically, each section of LAGEOS ranging data is read in by the software. Apriori station positions and station velocities are used to compute each stations position at the middle of the month. The satellite position is determined for each observation so that angle dependent corrections are computed and applied to the data. Once all the data has been corrected an iterative process is started. The observed minus computed values (O-Cs) from each satellite position are determined for each epoch along with an average satellite position. The O-Cs are then edited using a 6-sigma editing criterion and the average satellite position is recomputed. A summary of each stations mean and rms are written to the run summary file along with the total number of observations per station and the number of edits. A sensitivity matrix is then generated. This is done by applying small offsets to each of the station position vector elements and determining what effect each offset has on the O-Cs for all of the epochs. This procedure is performed for each coordinate (ie. 12 times for 4 stations). A P transpose P matrix is generated and then inverted, where P is the matrix of partial derivatives of the O-Cs with respect to the adjusted station position. The O-Cs are then multiplied by the resulting partials and a matrix is then computed. These corrections are applied to the station positions and a new set of average satellite positions are computed and new O-Cs determined. Again these O-Cs are multiplied by the P matrix and reiterated. This iterative process is repeated until the delta rms of the O-Cs between consecutive iterations is less than one percent, or six iterations have been reached. The total change of the station position is determined for both x,y,z and latitude, longitude and height. The baseline lengths are determined for only the stations involved in the solution and saved in a database. This database also contains the month and the number of simultaneous observations between the two stations. A sample summary for a one month period for a European solution is shown in Figure 1. A by-product of the solution is the point distribution plot, a sample of which is shown in Figure 2. Baseline rates are generated from the baselines and a least-squares linear fit of each of the station combinations is computed by weighting the monthly baseline with the number of observations during that month. Some sample baseline rates are illustrated in Figures 3-5.

The method of trilateration also lends itself to doing long term solutions. In this method both the initial station position and the station velocities are determined. This method of analysis is still under development.

The requirement for simultaneous ranging data from 4 stations requires geographic coverage over a broad area, which in turn requires high altitude satellites. The Etalon satellites offer great potential because of their high altitude and visibility to a larger number of stations at one time. However, the Etalon satellites have had a low global ranging priority so they are rarely ranged by more than two stations at any one time. An intense Etalon campaign was performed during May and June of 1992 to determine how well these satellites can be used for Crustal Dynamics research and geometric data analysis. Unfortunately, because of the low Etalon priorities, the campaign yielded no simultaneous ranging data sets from 4 stations and only 1 data set where 3 station ranged simultaneously. LAGEOS 2, scheduled for launch in October 1992, offers the next best opportunity to obtain a large simultaneous ranging data set. In addition, at an inclination of about 65 degrees, there will be an opportunity to obtain simultaneous trans-atlantic data sets on a high priority SLR satellite.

In the future, we expect that simultaneous geometric analysis of data from LAGEOS, LAGEOS2, and Etalon1 and Etalon 2, spread over a period of a few days, will accurately determine baselines and velocities. Future modifications to the geometric analysis software are expected to include the additional determination of range and time biases from individual data sets.

```
SOLUTION FOR  5/90 VERSION 3.1
THE STATIONS BEING SOLVED FOR ARE   7835  7839  7840  7834  7939  7810  1181  1884
THE TOTAL NUMBER OF THIRTY SECOND POINTS =  547
ITERATION  1 MEAN =   0.0005 RMS =  0.0381 M EDITS =   82
7835 POINTS =  243 EDITS = 19 MEAN =   0.61(CM) RMS =  2.79(CM) GRASSE,FRANCE
7839 POINTS =  308 EDITS = 14 MEAN =  -2.14(CM) RMS =  4.98(CM) GRAZ,AUSTRIA
7840 POINTS =  401 EDITS = 25 MEAN =   1.04(CM) RMS =  2.49(CM) ROYAL GREENWICH OBSERVATORY,ENGLAND
7834 POINTS =  251 EDITS =  2 MEAN =  -3.53(CM) RMS =  4.06(CM) WETTZELL,GERMANY
7939 POINTS =  433 EDITS = 15 MEAN =   1.58(CM) RMS =  2.98(CM) MATERA,ITALY
7810 POINTS =  407 EDITS =  7 MEAN =  -0.23(CM) RMS =  3.21(CM) ZIMMERWALD,SWITZERLAND
1181 POINTS =   97 EDITS =  0 MEAN =  -0.02(CM) RMS =  3.86(CM) POTSDAM,GERMANY
1884 POINTS =  258 EDITS =  0 MEAN =   2.01(CM) RMS =  2.77(CM) RIGA,LATVIA
ITERATION  2 MEAN =   0.0003 RMS =  0.0294 M EDITS =   83
ITERATION  3 MEAN =   0.0001 RMS =  0.0260 M EDITS =   83
ITERATION  4 MEAN =  -0.0001 RMS =  0.0238 M EDITS =   79
ITERATION  5 MEAN =   0.0001 RMS =  0.0221 M EDITS =   81
ITERATION  6 MEAN =  -0.0001 RMS =  0.0220 M EDITS =   78
ITERATION  7 MEAN =   0.0000 RMS =  0.0211 M EDITS =   78
ITERATION  8 MEAN =   0.0000 RMS =  0.0209 M EDITS =   74
ITERATION  9 MEAN =   0.0002 RMS =  0.0214 M EDITS =   68
7835 POINTS =  243 EDITS = 15 MEAN =   0.18(CM) RMS =  2.36(CM)
7839 POINTS =  308 EDITS = 14 MEAN =  -0.08(CM) RMS =  2.20(CM)
7840 POINTS =  401 EDITS = 17 MEAN =   0.04(CM) RMS =  1.22(CM)
7834 POINTS =  251 EDITS =  7 MEAN =  -0.09(CM) RMS =  3.26(CM)
7939 POINTS =  433 EDITS =  8 MEAN =   0.05(CM) RMS =  1.36(CM)
7810 POINTS =  407 EDITS =  7 MEAN =  -0.02(CM) RMS =  2.05(CM)
1181 POINTS =   97 EDITS =  0 MEAN =  -0.10(CM) RMS =  3.77(CM)
1884 POINTS =  258 EDITS =  0 MEAN =   0.09(CM) RMS =  1.91(CM)

 7835 OFFSET IN CENTIMETERS   -0.8250   -4.5956   2.2171
 7839 OFFSET IN CENTIMETERS  -12.5536    1.6383  -3.0958
 7840 OFFSET IN CENTIMETERS    3.7155    2.1842   0.9769
 7834 OFFSET IN CENTIMETERS  -15.0631  -10.3012  -3.5499
 7939 OFFSET IN CENTIMETERS    6.5119    0.9027   2.9142
 7810 OFFSET IN CENTIMETERS    1.1438   -0.5387  -0.6604
 1181 OFFSET IN CENTIMETERS   11.1416   -0.7329  -5.1856
 1884 OFFSET IN CENTIMETERS    3.4161   -0.6365   3.8376

STATION 7835 TO STATION 7839 =   764437.0501 M # OF 30 SECOND PTS =   91
STATION 7835 TO STATION 7840 =   932884.7705 M # OF 30 SECOND PTS =  142
STATION 7834 TO STATION 7835 =   753159.1604 M # OF 30 SECOND PTS =  124
STATION 7835 TO STATION 7939 =   877290.0126 M # OF 30 SECOND PTS =  225
STATION 7810 TO STATION 7835 =   349661.2268 M # OF 30 SECOND PTS =  119
STATION 1181 TO STATION 7835 =  1060757.9395 M # OF 30 SECOND PTS =   11
STATION 1884 TO STATION 7835 =  1890491.9961 M # OF 30 SECOND PTS =   87
STATION 7839 TO STATION 7840 =  1183242.7342 M # OF 30 SECOND PTS =  218
STATION 7834 TO STATION 7839 =   302138.4442 M # OF 30 SECOND PTS =  137
STATION 7839 TO STATION 7939 =   719404.9253 M # OF 30 SECOND PTS =  205
STATION 7810 TO STATION 7839 =   610840.0036 M # OF 30 SECOND PTS =  238
STATION 1181 TO STATION 7839 =   616033.6433 M # OF 30 SECOND PTS =    0
STATION 1884 TO STATION 7839 =  1242790.6872 M # OF 30 SECOND PTS =  166
STATION 7834 TO STATION 7840 =   917334.0128 M # OF 30 SECOND PTS =  188
STATION 7840 TO STATION 7939 =  1694490.9600 M # OF 30 SECOND PTS =  311
STATION 7810 TO STATION 7840 =   685045.3282 M # OF 30 SECOND PTS =  299
STATION 1181 TO STATION 7840 =   895488.7178 M # OF 30 SECOND PTS =   96
STATION 1884 TO STATION 7840 =  1683599.7109 M # OF 30 SECOND PTS =  152
```

Fig. 1

JUNE 1988 LAGEOS POINTS

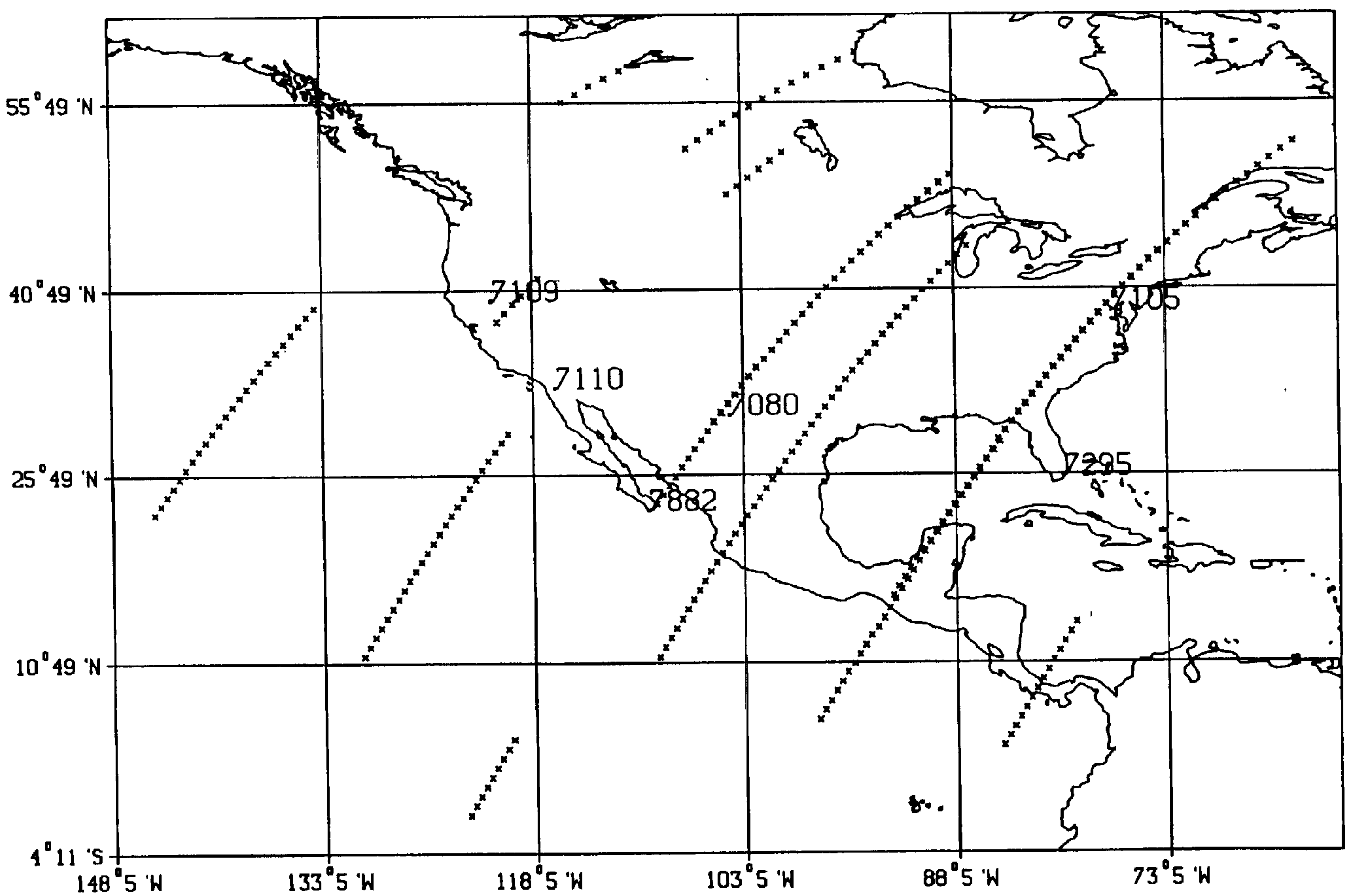


Fig. 2

**GREENBELT - MONUMENT PEAK DATES 7/87 - 12/90**
**BASELINE = 3559741 (M) RATE = -2. (MM/YR)**

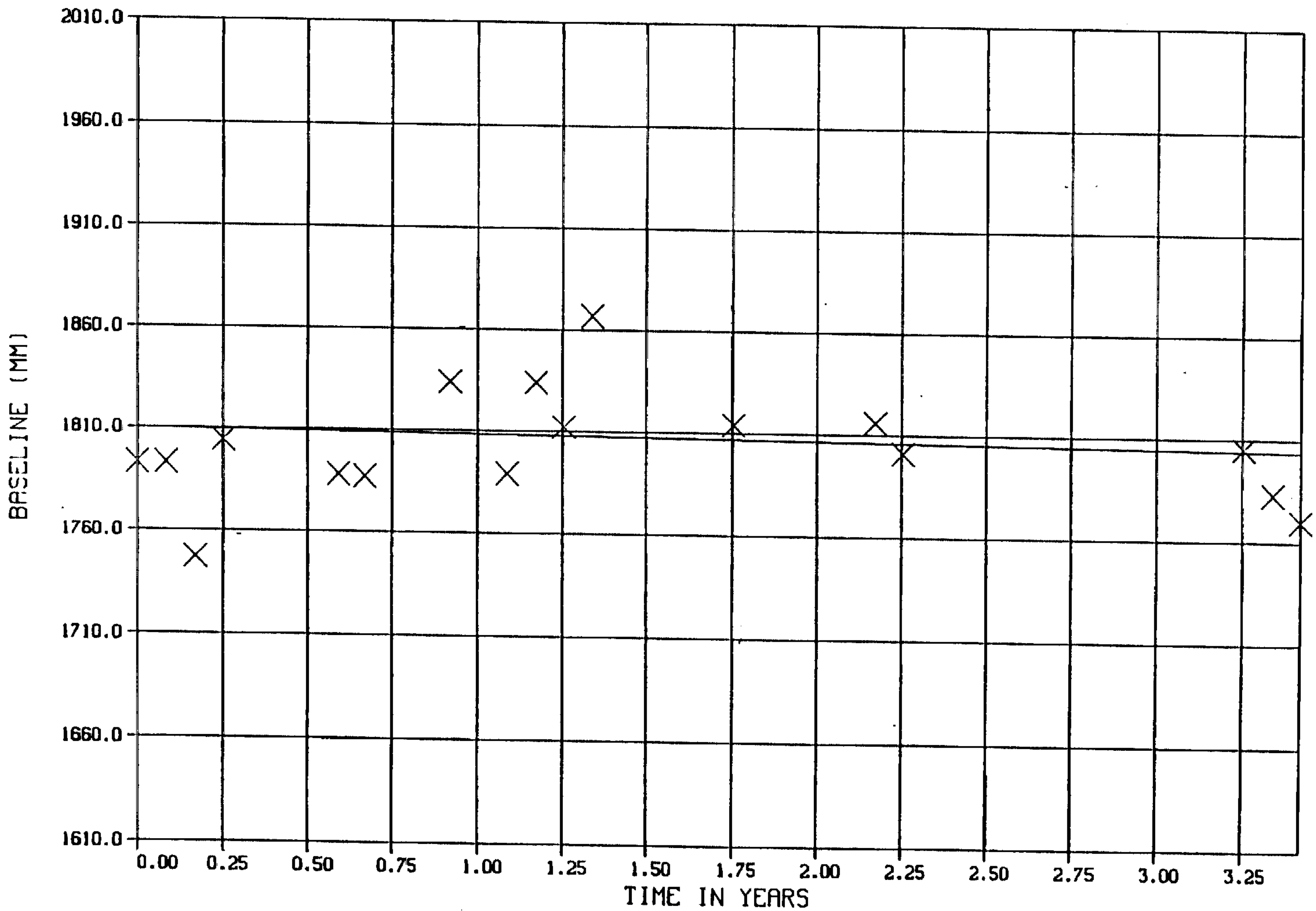


Fig 3

QUINCY - MONUMENT PEAK DATES 7/87 - 12/90
BASELINE = 883601 (M) RATE = -33. (MM/YR)

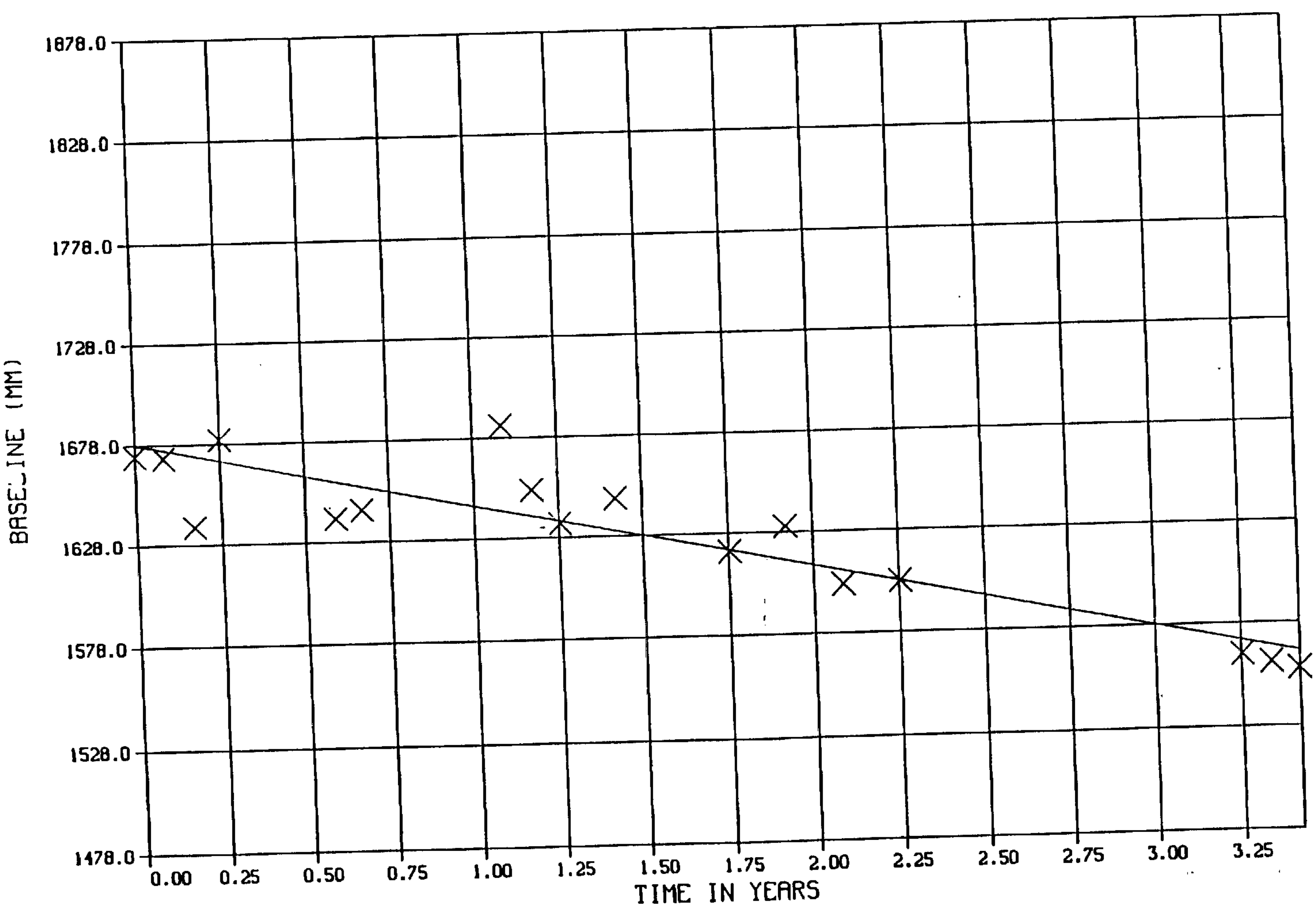


Fig 4

DIONYSOS - HERSTMONCEUX DATES 7/87 - 1/90
BASELINE = 22324305 (M) RATE = 21. (MM/YR)

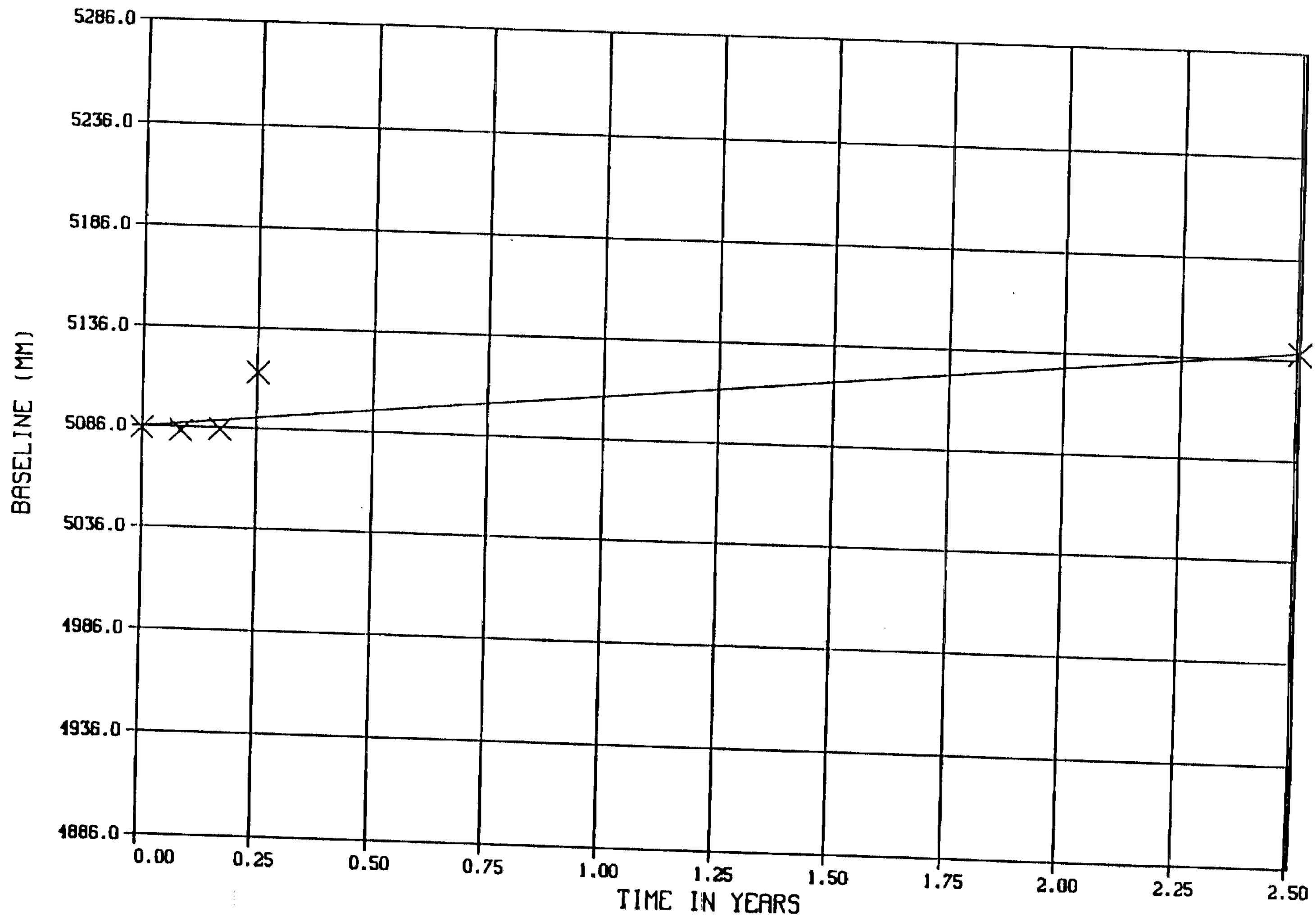


Fig. 5