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# PATN PROPAGATION ERRORS AND STEP LENGTH

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# 1 INTRODUCTION

## *1.1 Purpose*

In this technical note we have summarised the results of an analysis performed on the precise UTC/SBT correlation time provided in the PATN files. This analysis comes after the development of a tool for PATN daily routine processing (ref. 7). It has been noticed that the discontinuities generated at reference times are often greater than one millisecond (accuracy required for the ERS RA off-line processing) and are due to the linear propagation of the delta times.

## *1.2 References*

1. Accurate DELTA TIMES-PATN File format, ER-TN-ESA-GS-0259, Issue 1.2, 2 Dec 1992.
2. ERS-1 Time Correlation: cross-correlation between CPF temperature and PATN step length, JWO/MP/1080/mp, 23 Nov 1993.
3. Time Correlation Accuracy, JWO/MP/0972/imce, 24 Sep 1993.
4. PATN File generation, JW/0759/MP/DS, 28 Apr 1993.
5. UTC-SBT TIME CORRELATION, 21 Sep 1992.
6. ENVISAT OBT/UTC Time Correlation, DOC no EN-TN-ESC-GS-0001, issue 1, 21 Dec 1993.
7. ERS UTC/SBT File Correlation Analysis, PCS/SWLS/1199/02, issue 0.2, 24 Nov 1999.

# 2 BACKGROUND

## *2.1 Precise UTC/SBT Time correlation files (PATN files)*

The time correlation between the Universal Time Coordinated (UTC) and the Satellite Binary Time (SBT) is essential for:

a) Scheduling of the satellite, Ground Station acquisition and Fast Delivery (FD) processing

b) Off-line processing of the ERS instrument

The PATM files generated at ESOC are used for a) purposes. The delta times provided in these files have an accuracy of about 3 milliseconds due to rounding errors in the generation of the files. They are also limited in resolution due to the PATM file format (Reference in msec and step length in nsec). The generation of delta times with better accuracy and resolution is needed for b) above purposes. These PATN files are delivered off-line and are used in the Radar Altimeter off-line processing and for some calibration processing requiring aTime Correlation accuracy better than 1 millisecond. The improvements of PATN delta times respect to PATM are:

1.- Better precision format (reference in microseconds and step length down to picoseconds).

2.- Flag of any anomaly (wrap around, leap second, change of clock frequency).

3.- Provide standard deviation of the linear regression.

4.- Use of Orbit Restitution files (ORRM) to calculate an accurate transmission delay between the S/C and Kiruna Station.

## *2.2 Methodology to generate the PATN files*

The time correlation module uses as input the SBT and the Ground Station Timestamp (GST) of the S-Band telemetry frame, which are stored in the KTTM files (Kiruna Raw Data Time files). All the propagation times are then substracted in order to convert the GST time into UTT time (UTC time at transmission). The atmospheric effects are neglected as they are second order effects. For every Kiruna pass the SBT-UTT samples are collected and an adaptive Least Square estimator is applied (ref. 4) to calculate the step length (UTC time difference of a clock period).

One PATN file per Kiruna pass is generated containing SBT-UTT Reference, step length and other information regarding the linear regression and discontinuities occurred.

# 3 PROPAGATION ERROR AND DELTA STEP LENGTH

## *3.1 Seasonal variation*

The propagation error (discontinuity) is the difference between the UTC time (i) calculated at the SBT of the following PATN file using the current step length (i), and the reference UTC time (i+1) of the following PATN. These discontinuities in time are due to the linear propagation of the delta time and should be less than one millisecond (accuracy required for ERS RA off-line processing). This is not the case for many discontinuities calculated between Kiruna non-consecutive orbits, with values often around 1 millisecond (see fig. 1). First plot of fig. 2 shows the seasonal variation of these discontinuities. In summer, propagation errors greater than 750 microseconds occurs almost every day while in winter it happens few days a month. The second plot of fig. 2 shows the monthly mean value of propagation error considering only consecutive Kiruna orbits. The averaged values present a seasonal fluctuation with minimum around 200 microseconds (winter) and maximum around 340 microseconds (summer).

It is known that there is a drift on the step length of about $\pm$ 5 picoseconds per day (physical effect of the on board clock) and a daily cyclic variation of the PATN step length (see fig. 3). It has been demonstrated (ref. 2) the correlation of this cyclic variation with the temperature fluctuation of the CPF (Platform Controller). The CPF temperatures are supposed to be good estimates of the oscillator temperature, as the ERS oscillator is not thermally controlled. The amplitudes of this daily cyclic variations of step length is also seasonal dependent (see tables 1 and 2). In summer, the amplitudes are around 50 picoseconds greater than in winter.

The delta step length is the difference between the interpolated step length (calculated by connecting two consecutive PATN Delta Times) and the PATN one. It is clear that bigger is the delta step length, bigger is the propagation error (by definition, ref. 1). It can be seen in fig. 4 and fig. 5 that the delta step length decreases during the day. However, we don't expect such a decrease since the interpolated step length has the same daily cyclic effect and amplitude that the PATN step length (ref. 3). Again, the seasonal variation is evident and the accuracy of one millisecond is clearly not reached after Kiruna blind orbits in summer period.

**Table 1:** step length amplitudes for some days in summer'96 / winter'96.

| | **Amplitude of step length (psec)** |
|---|---|
| 9-SEP-1996 | 188 |
| 10-SEP-1996 | 163 |
| 11-SEP-1996 | 196 |
| 12-SEP-1996 | 203 |
| 9-FEB-1996 | 109 |
| 10-FEB-1996 | 131 |
| 11-FEB-1996 | 116 |
| 19-FEB-1996 | 110 |

**Table 2:** step length amplitudes for some days in summer'99 / winter'99.

| | **Amplitude of step length (psec)** |
|---|---|
| 5-SEP-1999 | 151 |
| 6-SEP-1999 | 167 |
| 7-SEP-1999 | 164 |
| 8-SEP-1999 | 141 |
| 5-FEB-1999 | 73 |
| 6-FEB-1999 | 107 |
| 7-FEB-1999 | 108 |
| 8-FEB-1999 | 110 |

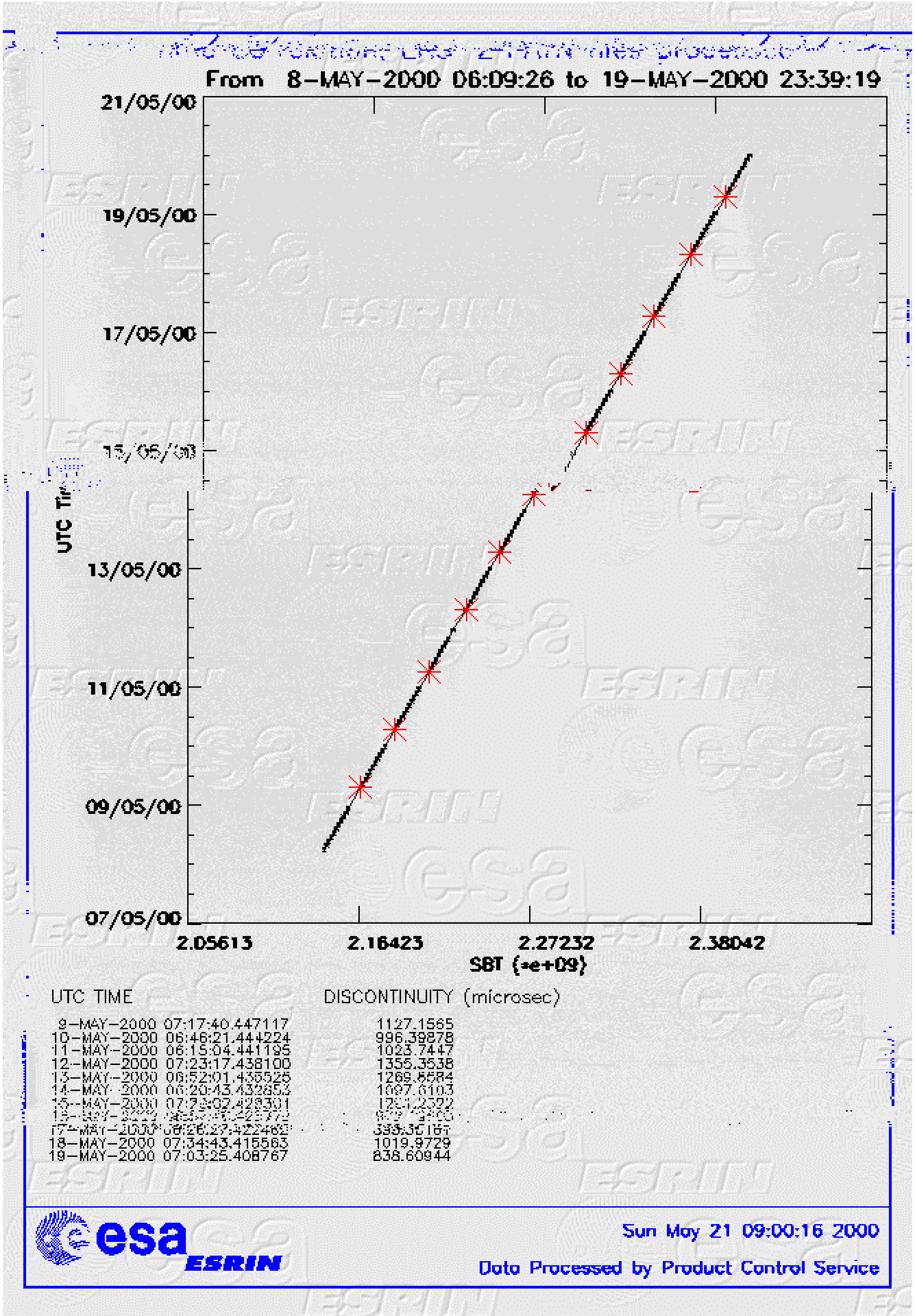


Fig. 1: Time correlation and value of discontinuities bigger than 750 usec (red stars in the plot).

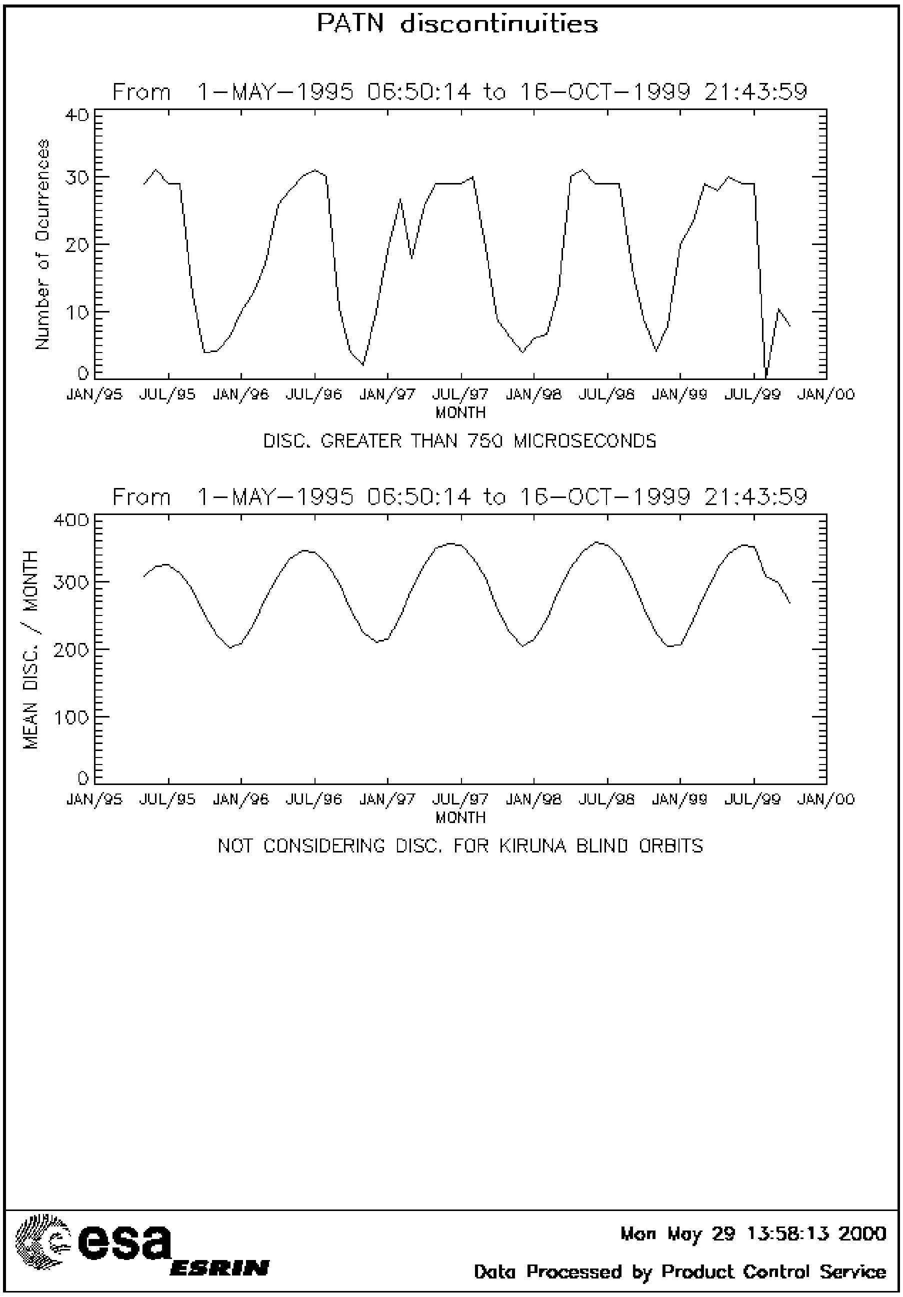


Fig. 2: (Upper) Number of discontinuities greater than 750 microseconds since the beginning of mission. (Lower) Mean value of discontinuity per month since the beginning of mission.

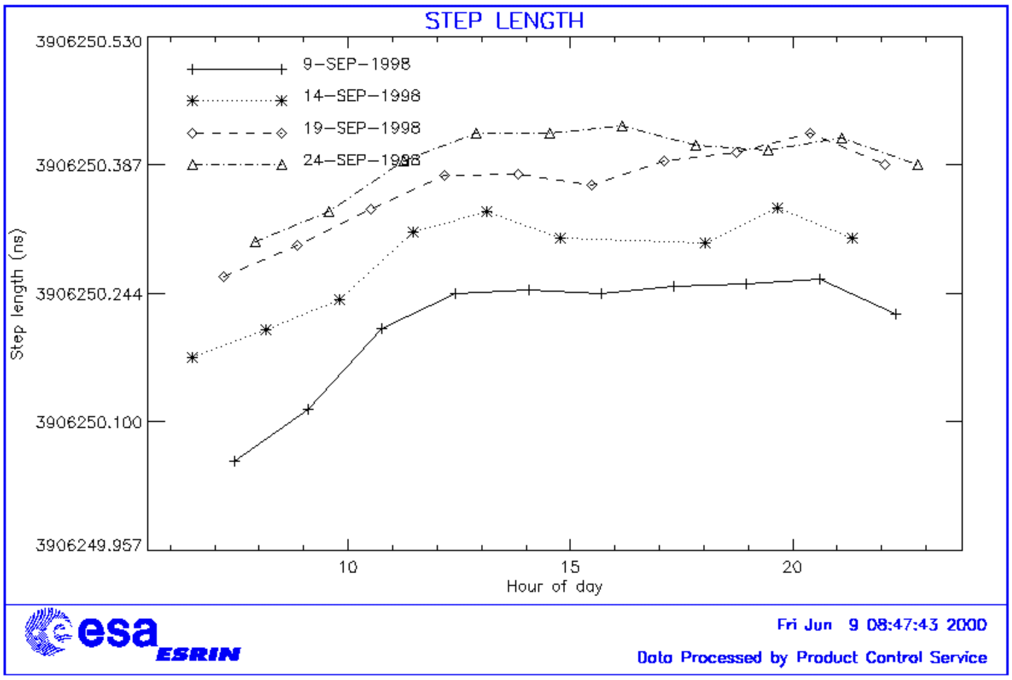


Fig. 3: Step length drift of ± 5 psec / day and daily cyclic variation.

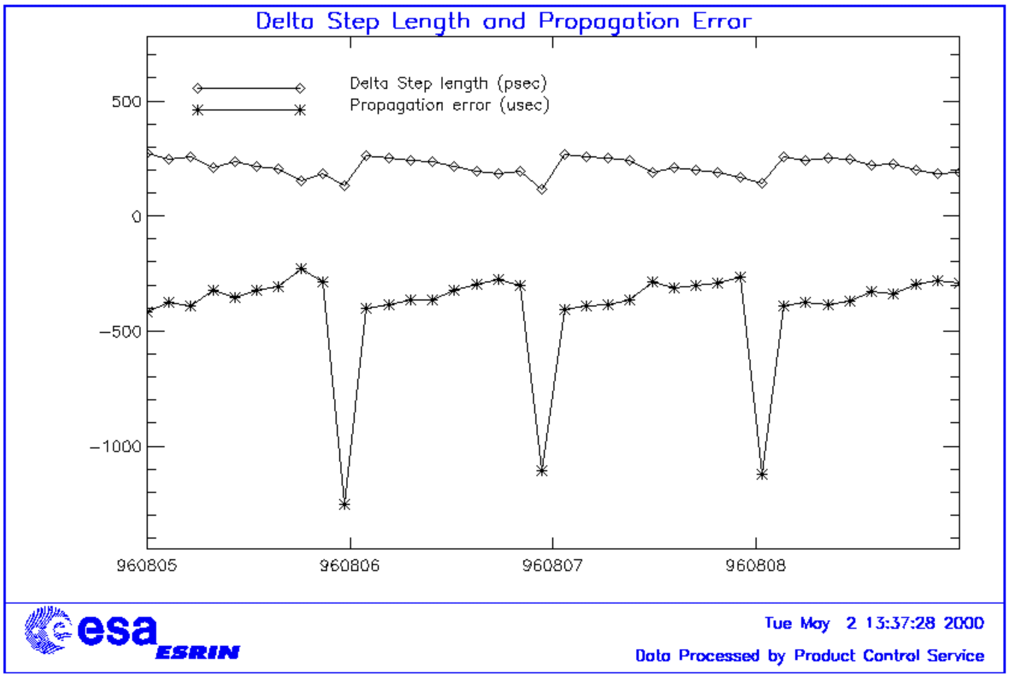


Fig. 4: Delta step length and propagation error for four consecutive days in summer.

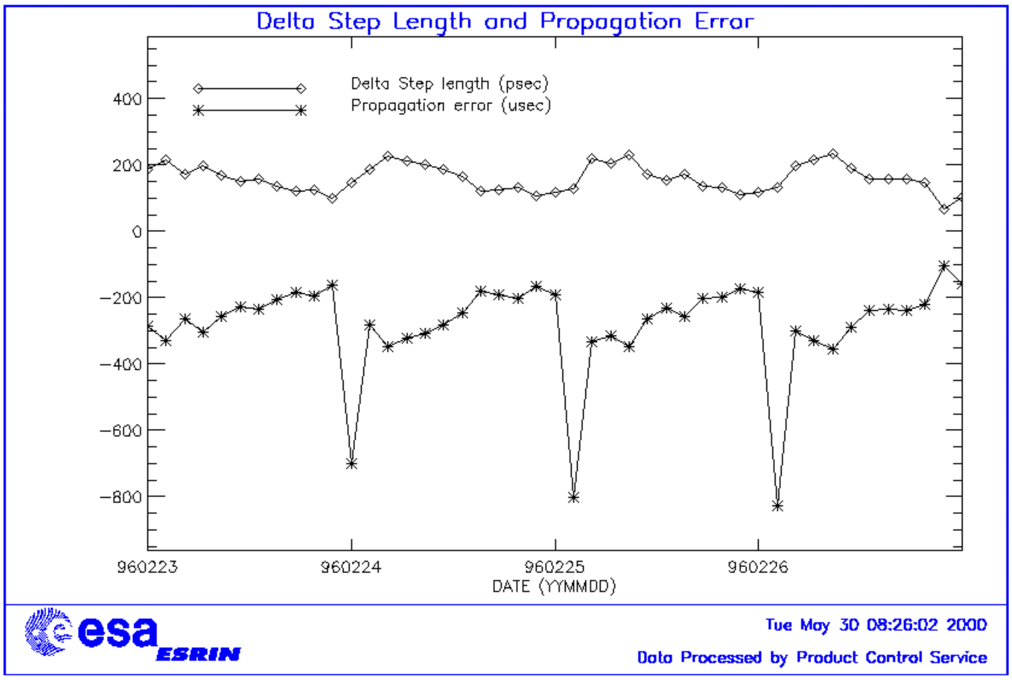


Fig. 5: Delta step length and propagation error for four consecutive days in winter.

## 3.2 *Trend of discontinuities*

In order to have an idea on the quality of the UTC/SBT precise correlation, we have done some statistics on the propagation errors. They are plotted in fig 6. It seems that the averaged discontinuity increases since the beginning of the mission even if with a small rate.

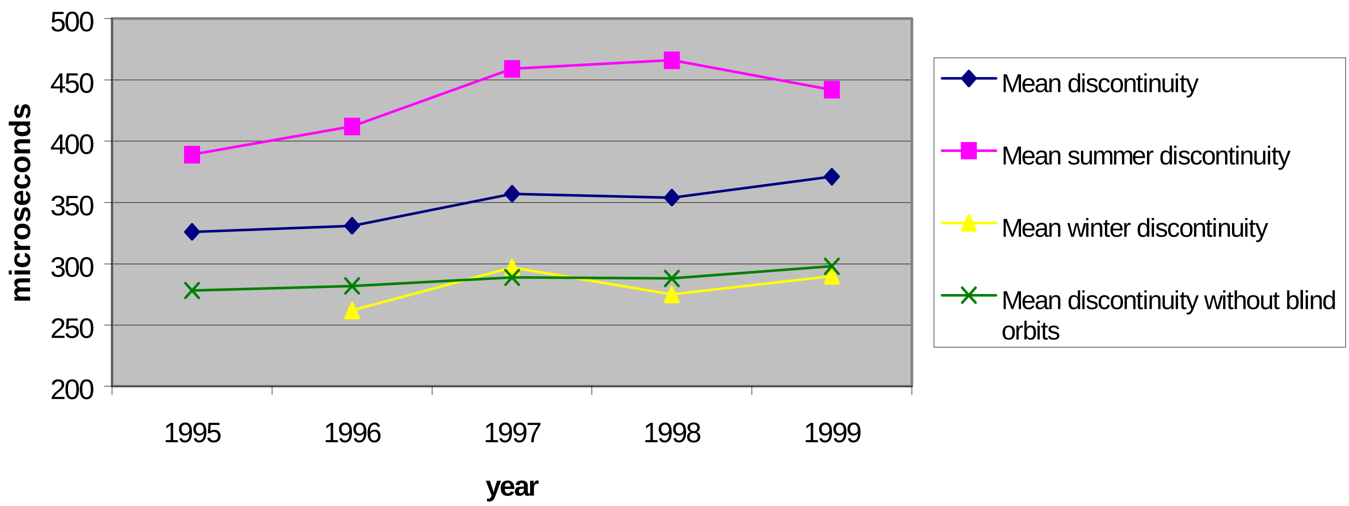


Fig. 6: Evolution on mean propagation error (absolute value) during the ERS2 mission.

## *3.3 Contribution to the time tag bias*

The fact that there is an error in UTC/SBT correlation leads to think that it can have an impact in the time tagging of the radar altimeter data. Since the propagation errors are always negatives (delta step lengths positives) an early time tagging for these data is expected. If we consider that the maximum error in UTC/SBT correlation per orbit is about 300 microseconds (not considering propagation errors between Kiruna blind orbits), then the mean contribution to the time tagging error will be around 0.15 milliseconds early.

It is known that the altimeter measurements of ERS1 and ERS2 are systematically early by about one millisecond. The discontinuity error found in the UTC/SBT correlation is therefore to be considered as a source of error in the ERS time tag bias. The contribution can be estimated in 15-20%.

# 4 CONCLUSIONS

- The daily amplitude of step length is not anymore less than 150 picoseconds as it was established at the beginning of ERS1 mission (ref. 3). In summer, the values can fluctuate between 150 and 200 picoseconds.
- The propagation errors (discontinuities at reference times) are often greater than one millisecond mainly in summer after Kiruna blind orbits.
- There is a daily-based decrease in delta step length that leads to a decrease in propagation error within a day. Since the interpolated and the PATN step lengths have the same features, is it an expected behaviour?.
- The contribution of the time correlation error to the time tag bias (tagging of ERS altimeter products early by one millisecond) is estimated to 15-20%.