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Timebias corrections to predictions

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Abstract *This talk aims to highlight the importance to an SLR observer of an accurate knowledge of the timebias corrections to predicted orbits, especially for low satellites. Sources of timebias values and the optimum strategy for extrapolation are discussed from the viewpoint of the observer wishing to maximise the chances of getting returns from the next pass. What is said may be seen as a commercial encouraging wider and speedier use of existing data centres for mutually beneficial exchange of timebias data.*

Introduction

The real behaviour of low satellites is never in exact agreement with even the best predictions. The principal reasons are that modelling the effect of atmospheric drag is difficult, and the perturbations due to solar radiation pressure are not predictable in advance. ERS-1 is much larger and somewhat lower than either Starlette or Ajisai and consequently presents the biggest headaches in making predictions. Despite the problems, detailed elsewhere in these proceedings, the prediction teams do an excellent job in providing orbits and thereby give observing stations the best possible chance of tracking the satellites successfully. Fortunately, most of the deviation from the predicted orbit appears as an along-track error and can be corrected by applying a suitable timebias to the predictions (as has been done very successfully for Lageos for many years now). For a particular set of predictions observing stations can, for each satellite, model the history of the behaviour of the timebias with time and extrapolate to predict the timebias at the time of observation of the next pass.

At Herstmonceux we have been working to improve the accuracy of our extrapolation of timebias values. This talk outlines our findings, indicates the benefits to be gained from increased use of the data centres and shows how helpful good timebiases can be if you have English weather and are trying to keep us with Grasse!

Why do we need accurate timebiases?

We see three distinct advantages:

Ease of satellite acquisition. This is always important, at whatever stage of the pass the satellite is first acquired. But it is especially important at the very beginning of a pass, necessarily at low elevation, when accurate pointing helps to minimise the time spent in searching for returns. Ease of acquisition is also important when there has been a break of a few days in the sequence of observations, because of cloud or technical downtime, where accurate knowledge of the timebias correction can lead to immediate recovery of the satellite. This second point emphasises the usefullness of having access to continuous records of timebias data in order to base any extrapolation on the best available data set.

Improved telescope tracking. If an incorrect timebias is used to compute the telescope position during a pass, the offsets from the reference position on the detector will depend on time and the observer will have to insert ever-changing manual corrections in order to keep the satellite image. By contrast a correct timebias results in little or no guiding, provided that the pointing model for the telescope is well-determined.

Better noise elimination. When the timebias is exactly right the returns from the satellite always appear at the same place in the range window. This means that the window can be made very small and so the amount of noise reaching the detector can be drastically reduced. This improvement in the ratio of signal to noise is particularly valuable for daylight ranging.

The second and third advantages can still be gained (even in cases where an accurate timebias is not available beforehand) if the first few good returns from the satellite are used in real time to convert a range offset into a timebias correction. This technique is routinely applied for multi-photon detection systems where the identity of true returns is not in doubt. But for single photon detection in daylight, or using an intrinsically noisy detector such as a SPAD, it is not always easy for the software to pick out the track, and some form of manual intervention may be required.

Where can we get timebiases?

Originally we used only our own history of passes to make extrapolations to current behaviour. This was quite satisfactory during periods of continuous good weather, but was often very frustrating when trying to recover satellites after a break of two or three days due to cloud or instrumental problems.

Then, for Ajisai and Starlette, we tried using Bendix's timebias data from many stations in addition to our own. We immediately found a great improvement in the quality of our extrapolation and could use narrower range windows right at the start of the pass. We also found that the change from using elements to using IRVs gave better consistency in the timebias histories.

When ERS-1 was launched we, like everyone else, had mixed success in finding it. When we had a reasonable history and the solar activity was not too wild, we got good passes. But at other times, once we had failed to get passes for a day or two, it became increasingly difficult to recover the satellite. We were very pleased when DGFI agreed to use the pass data that they receive from many stations to produce timebias functions for ERS-1. This gave, and continues to give, valuable additional weight to timebias trends.

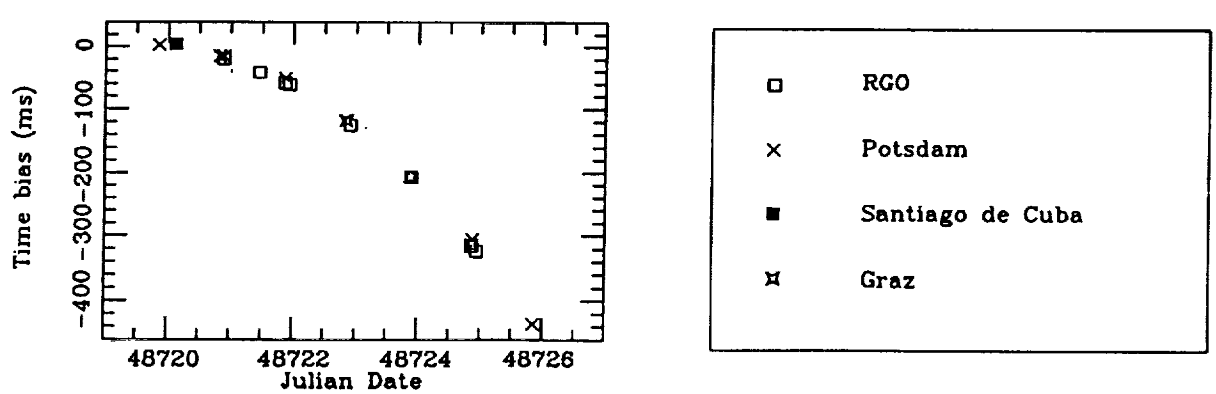

Figure 1: *ERS-1 timebiases from EDC for IRV set A920407 and symbol key*

Since then, following the establishment of the European Data Centre (EDC), a small number of stations have begun to make regular deposits of their timebias data for ERS-1 soon after the observations. We often get EDC data from Graz and Potsdam—and occasionally from Wettzell and Santiago de Cuba. Figure 1 shows a plot of the data deposited for IRV set A920407 at the beginning of 1992 April. The interagreement between the values from different stations is striking and gives great confidence that all timebiases have been reduced to a common system. But, with all the stations close together in Europe, it is clear that the data are clumped together in time: indeed, sometimes they are all clouded out simultaneously! The addition of more data points from other stations at other longitudes around the world would give much better "round the clock" coverage.

How can we best use timebias histories?

ERS-1 Over the last two or three months we have been investigating how best to predict future timebias values from whatever timebias history we had available on a particular day. This usually consisted of a small number of values covering a few days.

First we looked at the timebiases shown in Figure 1 which cover a period of about a week and are all referred to the same IRV set from DGFI. Our approach was to see, in retrospect, how well the observed values available up to a certain day could be used as predictors for the points which followed. The results of our trial fits are shown in Figure 2. First we fitted to data for the first two days only; next we used data for the first three days; then the first four days and so on. For each

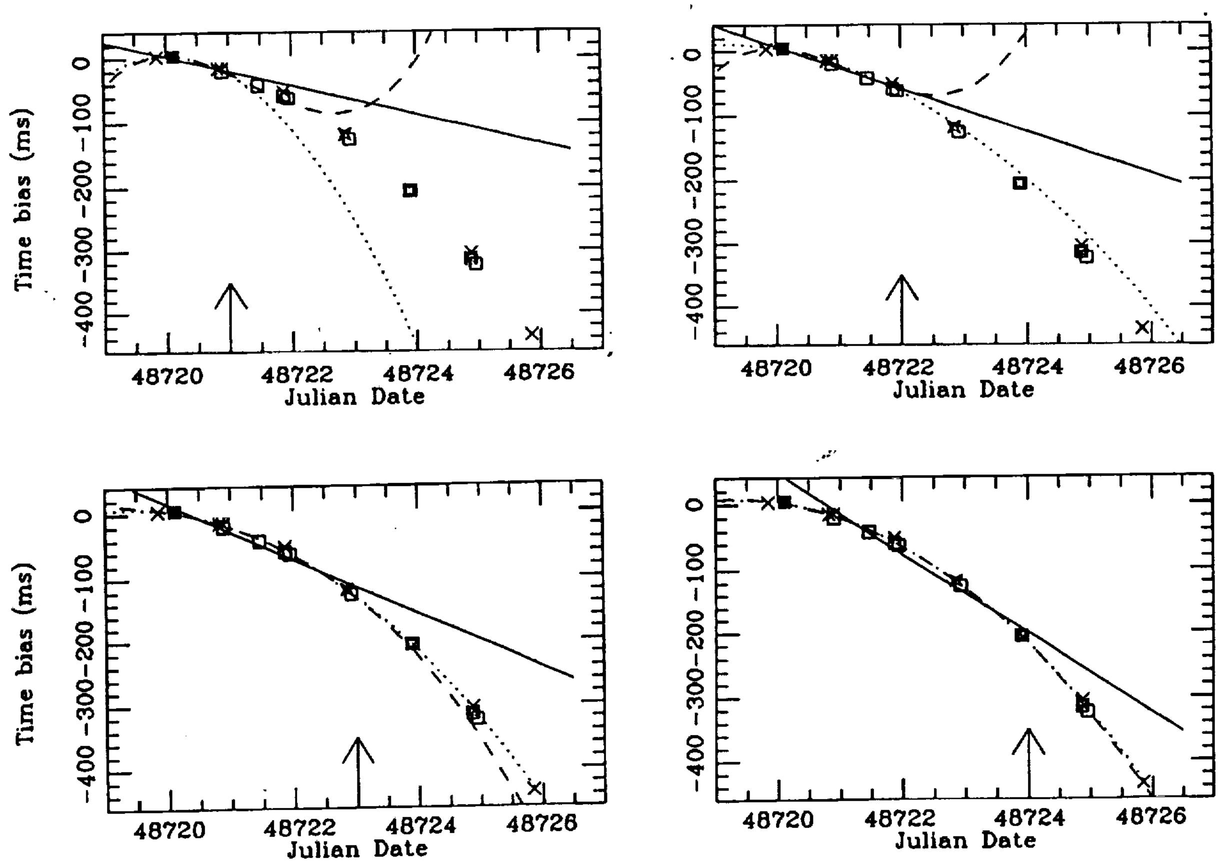

Figure 2: *Successive fits to ERS-1 timebiases from EDC*

trial we fitted the data with functions of three different orders—linear (represented by a solid line in Figure 2), quadratic (dotted line) and cubic (dashed line). Only points to the left of the vertical arrow at the bottom of each plot were included in the fit. We then looked at the next few points to the right of the arrow to see how well, or how badly, each of the attempted fits represented the data which followed. From this examination we drew a number of preliminary conclusions:

- Use the simplest function which gives a *reasonable* fit to the data (even if it is not the *best* fit)—it will generally be better for extrapolation than a higher order function;
- Use only linear fits for the first 2 or 3 days—there are too few data points to justify anything fancy;
- It would be helpful to have quick timebias deposits by all stations and better longitude coverage. This would:
    - fill the gaps in the European data;
    - add data points to strengthen the fit;
    - provide actual timebias values closer to the time of observation than are available now.

More recently we tried a new experiment based on normal point data for ERS-1 passes extracted from the CDDIS database and reduced to give timebiases. [We had hoped to use directly the Bendix values, but there are currently unexplained discrepancies between their derived values of timebias and ours, so we have worked entirely from the normal point data. This effect also appears to exist in the Bendix timebiases for Ajisai and Starlette, but to a lesser extent which does not prevent their use in revealing long-term trends]. In this case we took the data set shown in Figure 3 which covers a week in early May and is referred to IRV set A920505 from DGFI. It is clear that

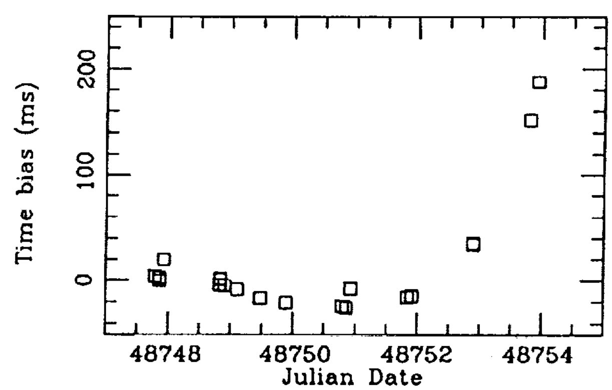

Figure 3: *ERS-1 timebiases from CDDIS normal points*

the longitude coverage is more uniform and the daily density of points is higher. However, there is a drawback as far as immediacy is concerned in that the turn round time for data input can be longer than for EDC, so that some of the data are relatively old. We then followed the same procedure that we used for the EDC data and made trial fits to subsets of the data to see how well the extrapolated curves acted as predictors for what was subsequently observed. The plots in Figure 4 again show that the higher order fits are wildly ineffective for the first few days, and only begin to make more sense later. But around day 48752 the data take a wholly unexpected turn towards large positive values and the trends evident in the early points are no longer relevant. This sudden change of behaviour is probably due to solar activity, and in such circumstances it is wise to abandon the early points of the data set and start the fit again from part way through.

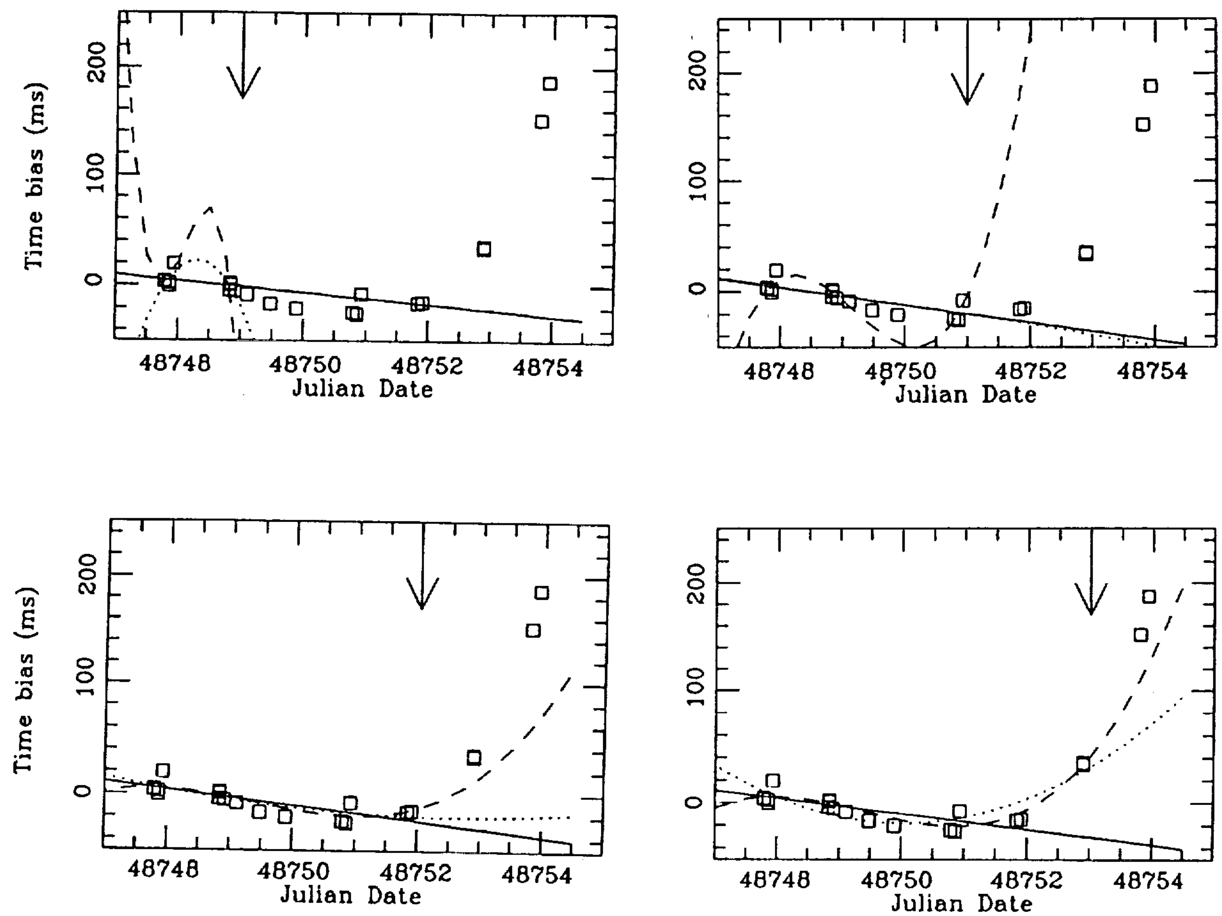

Figure 4: *Successive fits to ERS-1 timebiases from CDDIS*

Our additional conclusions as a result of this exercise were:

- For ERS-1 it is necessary to examine the data and functions daily in order to pick up unexpected trends in good time;
- Better longitude coverage is essential for early warning of departures from previous behaviour;
- Access to the raw data is very useful for making value judgements on the quality of the fit of any functions!

Ajisai and Starlette Generally the prediction of timebiases for these satellites is much more straightforward than for ERS-1 since they are relatively unaffected by atmospheric drag and solar radiation pressure. Indeed orbit predictions can run quite satisfactorily for several weeks so that a long timebias history can be established for one IRV set. Over such an interval timebias corrections usually behave sensibly and, even when the corrections get quite large, a good history with respect to one set of IRVs allows meaningful extrapolation to get accurate values.

What can be done to improve?

We think that all stations can share the clear benefits to be gained from the daily examination of trends in timebiases for ERS-1 by depositing their timebias values with data centres as soon as possible after the pass has ended. Then, by retrieving a comprehensive set of timebiases obtained worldwide, and using it as the basis for extrapolation, the "hit rate" can be significantly improved. Alternatively, but probably with greater delay, stations can retrieve normal point data and derive timebiases from them.

It would be very worthwhile to extend the system to include Ajisai and Starlette; and to make sure that provision is made for rapid feedback of Topex/Poseidon data.

Finally the proper commercial: we think that timebiases are just like washing powder—use the right one and your whole life is transformed for the better!

Figure 5: *"New improved Timebias"*

Acknowledgements

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