Herstmonceux/Bern Timebias Service

Roger Wood[1] *& Werner Gurtner*[2]

[1] NERC Space Geodesy Facility, UK
[2] Astronomical Institute University of Bern, Switzerland

Abstract

Individual timebias corrections for all ILRS supported satellite missions are calculated at Herstmonceux every 15 minutes from normal point data deposited hourly at CDDIS. They are made available to the global network in near real time, on demand, from a dedicated timebias server in Bern.

Introduction

In recent years predictions for laser ranging observations have improved enormously. Observing stations now deposit their data in data centres very quickly (generally within an hour of the pass); data centres make the data available equally quickly; and prediction centres collect data, recompute precise orbits and issue fresh predictions daily (for most satellites, but more frequently for very low-flying missions most affected by drag). For the majority of satellites these frequent predictions are sufficient to guarantee instant acquisition and good tracking without the need to apply timebias corrections. However, there are still some contexts in which having a truly up-to-date timebias correction can be very useful: for low-flying satellites; for satellites that have just been manoeuvred; and for those using the longer-term weekly or monthly predictions. These are reviewed in a little more detail here and the remainder of this paper describes the dedicated service that has been set up to meet these needs.

For **low-flying satellites** like CHAMP or GRACE the largest uncertainty in predicting the orbit, even for a few days ahead, arises from the difficulty of modelling the drag on the satellite. Drag is directly dependent on atmospheric density that is itself strongly influenced by the radiation and particle flows from the Sun. It is virtually impossible to make accurate predictions of the day-to-day fluctuations in these flows by extrapolation of previous history, and this makes it likely that the drag actually experienced by a satellite differs from that modelled by the prediction centre. Since drag is essentially an along-track force, the difference from the predicted orbit shows up as an along-track error that can be characterised as a timebias.

In most cases **satellite manoeuvres** are notified to stations a few days beforehand and the relevant prediction centre will issue post-manoeuvre predictions based on the planned alteration to the orbit. In most cases this works very well and it is possible to track a satellite accurately immediately after a manoeuvre. However, there are occasions when the firing of the thrusters does not go exactly to plan or the notification process is incomplete and new predictions are not available in time. This provides a challenge to observers, but there is usually a successful post-manoeuvre observation somewhere in the global network. It is then possible to continue to use the *pre-manoeuvre* prediction with a large timebias correction, and the timebias function becomes better determined as additional observations are made, even though the corrections can get very large.

Some predictions centres continue to compute **longer-term predictions** at weekly or monthly intervals and some users prefer to use these together with a well-determined timebias function rather than the daily predictions.

Timebias calculation

Following the Shanghai workshop a small *ad hoc* working group was set up to establish a scheme for the computation and distribution of timebias functions for all approved satellites and all current prediction sets. The scheme (Wood 1997) was adopted and continues to distribute functions (via the dedicated ILRS email exploder `ilrspred@ilrs.gsfc.nasa.gov`) at about 16:00 UT each day. The functions are fitted to timebiases computed at Herstmonceux using Appleby and Sinclair's (1992) `SOLVE` procedure to process all available normal point data. As recently as two years ago stations often only submitted their normal point data once a day, or once a shift at best, and the latency for the appearance in data centres was correspondingly large. Now that data are submitted and made available hourly it is possible to update timebias functions much more frequently. In addition to the hourly retrieval of data from CDDIS the normal point data used in timebias function solutions are supplemented from two other sources: Herstmonceux data, which are available immediately after a pass; and data for low-flying satellites sent directly from other stations. The Herstmonceux system handles all these inputs automatically and runs the program to fit timebias functions every 15 minutes. Whenever new predictions arrive they are also processed automatically and the corresponding timebias functions computed afresh from the relevant normal point data.

Timebias server

During the course of the EUROLAS workshop on *"Detecting and Eliminating Errors in the EUROLAS Network"* (Wood & Appleby 2002) there was a short discussion on the ways in which the availability of timebiases could be improved. It was agreed that having truly up-to-date timebias corrections was highly desirable, but distributing standard timebias function files many times a day via an exploder was very clumsy, and would create an unnecessary volume of email traffic. The consensus of opinion was that it would be much better to supply enquirers (via a direct TCP/IP link to a server) with timebias values instantaneously evaluated at the epoch of enquiry. Timebias values would be computed for *all* satellites for *all* available prediction sets (sub-daily, daily, weekly and monthly) and would also include corrections computed from GFZ drag functions as appropriate. This concept was implemented in Bern shortly afterwards (Gurtner 2002) and has been in successful operation since then:

Every 15 minutes the most recent timebias function file is downloaded from Herstmonceux to Zimmerwald by anonymous ftp. A server program running on the Zimmerwald station computer accepts TCP/IP connections of enquirers to a dedicated port (7840), computes the current timebiases for all satellites and prediction sets found in the timebias function file, sends them back to the enquirer, and closes the TCP/IP connection. The enquirer then has the most up-to-date timebiases for immediate use. Figure 1 lists the first few lines of a typical returned file:

```
!      Time biases at 20-Sep-2002 10:12 UT
!
! Satellite   Total IRVset LstObs Passes SIC Drag
!            TB[ms]       [hhh:mm] used      [ms]
!
  Ajisai         -1 HON262   2:46    44 1500    0
  Ajisai          2 NSD082   2:46    44 1500    0
  Ajisai         28 RGO100   2:46   167 1500    0
  BeaconC         3 HON262   2:46    23 0317    0
  BeaconC      2371 RGO047   2:46   104 0317    0
  Champ        -115 GFZ818   0:00     0 8002 -115
  ERS2          194 GFZ429   3:58   110 6178    0
  ERS2          -30 HON262   3:58    17 6178    0
  Envisat        26 ESO262   4:41    20 6179    0
  Etalon1        28 HON262  16:55     6 0525    0
  Etalon1        -4 RGO024  16:55    34 0525    0
  Etalon2       -15 HON262  18:22     4 4146    0
  Etalon2       -49 RGO024  18:22    43 4146    0
  GFO1          -13 HON262   3:58    17 8501    0
  GFO1           21 RGO111   3:58    48 8501    0
  . . .
```

Figure 1. *Example of a file of current timebiases.*

This file fragment shows the information provided by the timebias service: date and time stamp; satellite name; timebias correction (including drag correction, if relevant); prediction set identifier; time interval since last pass contributing to the timebias function; the number of passes used in computing the function; the satellite's SIC identifier (as used in the ILRS standard IRV files); and the value of the drag component of the total timebias.

Notice that some of the timebiases for the weekly/monthly predictions can get very large (*e.g.* Beacon-C above) but still be very well determined (to within a few milliseconds). Notice also that, in some cases, even daily predictions can be significantly improved by applying timebias corrections. There is nearly always somewhere in the global network able to observe any given satellite and the latest timebias value used in the calculation is often less than one satellite revolution old.

At present stations' use of the service is somewhat uneven. Two stations download actual timebias values every few minutes; some download prior to each pass to be observed; others access only occasionally (see Figure 2 below for statistics). Obviously the majority of the stations do not make use of this service yet!

Contacts	Host
22321	sfel
13600	mdol
601	ziml
588	grzl
122	gsfc
105	htsi
68	yarl
40	harl
31	hall
27	grsl
18	htsi
17	metl
17	?
9	herl
4	?
4	?
3	tigo

Figure 2. *Some server access statistics 2002 Aug 1– Sep 17*

Recently a **web-based interface to the timebias server** has been added for interactive access at http://aiuas3.unibe.ch/cgi-bin/cgi-time_bias. Click on the link and the complete list of current timebiases appears on the screen.

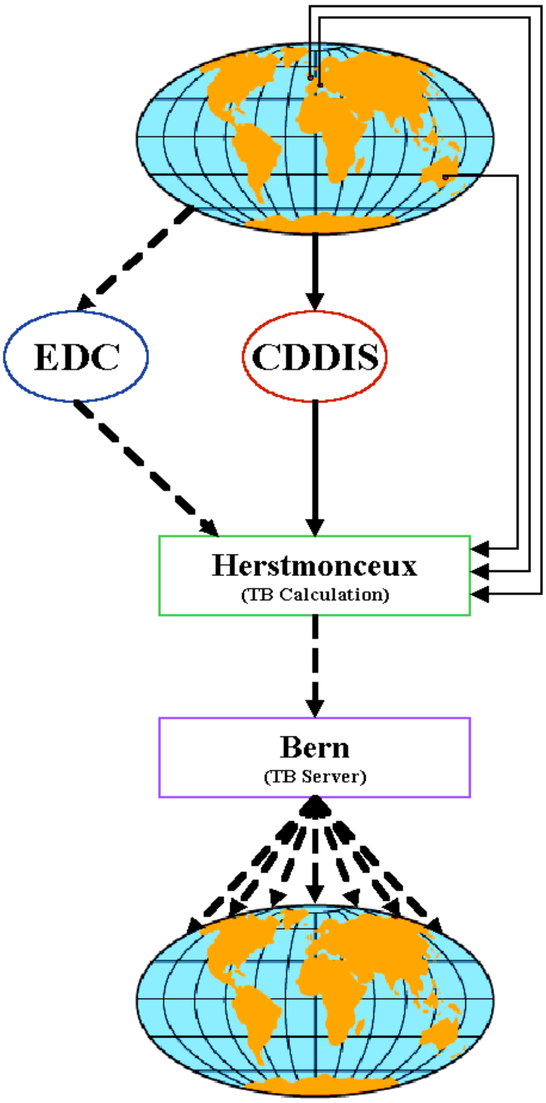

Figure 3. *Schematic of data flow for the Timebias Service*

EUROLAS Near Real-Time Status display

An additional, extremely valuable, source of timebias information is available from another server in Bern: the EUROLAS status display (Gurtner 1999). A number of European stations collaborate by submitting to Bern, every 15 seconds, a standard one-line status message (consisting of station name, date and time, satellite name, number of returns in the current pass, identity of the prediction set used, and applied timebias correction). A single concatenated file is formed from the latest message from each station and returned each time a deposit is made. It is then very simple to display messages sequentially (see Figure 4 for an example) on a screen accessible to the observer, thus allowing virtually instantaneous feedback. Participating stations find this especially useful in the cases mentioned in the introduction: low-flying satellites during times of high or swiftly changing solar activity; and immediately following manoeuvres. *All* stations are urged to access the server and see the benefits for themselves.

```
Grasse_slr    2000-11-04 20:06:25  ERS2       CUR     0  gfz271   0.000
!--------------------------------------------------------------------*
Grasse_slr    2000-11-04 20:07:15  ERS2       CUR    35  gfz271   0.095
!--------------------------------------------------------------------*
Grasse_slr    2000-11-04 20:09:48  ERS2       CUR   213  gfz271   0.091
!--------------------------------------------------------------------*
Grasse_slr    2000-11-04 21:40:06  ERS2       CUR     0  gfz271   0.090
Herstmonceux  2000-11-04 21:40:43  Lageos1    CUR   277  HON309  -0.001
!--------------------------------------------------------------------*
Grasse_slr    2000-11-04 21:40:31  ERS2       CUR    32  gfz271   0.099
Herstmonceux  2000-11-04 21:41:03  Lageos1    CUR   300  HON309  -0.001
!--------------------------------------------------------------------*
Grasse_slr    2000-11-04 21:43:24  ERS2       CUR   559  gfz271   0.099
Herstmonceux  2000-11-04 21:43:47  ERS2       CUR     0  GFZ271   0.068
!--------------------------------------------------------------------*
Grasse_slr    2000-11-04 21:43:24  ERS2       CUR   559  gfz271   0.099
Herstmonceux  2000-11-04 21:44:07  ERS2       CUR     0  GFZ271   0.100
!--------------------------------------------------------------------*
Grasse_slr    2000-11-04 21:43:49  ERS2       CUR   576  gfz271   0.099
Herstmonceux  2000-11-04 21:44:27  ERS2       CUR    14  GFZ271   0.100
!--------------------------------------------------------------------*
Grasse_slr    2000-11-04 21:49:27  ERS2       LST   633  gfz271   0.099
Herstmonceux  2000-11-04 21:49:44  ERS2       LST   409  GFZ271   0.099
```

Figure 4. *Herstmonceux uses NRT display to exploit Grasse success for ERS-2.*

Recently a **web-based interface to the EUROLAS status display server** has been added for interactive access at http://aiuas3.unibe.ch/cgi-bin/cgi-eurostat. Click on the link and the current status file appears on the screen

Future development

One aspect of the present system that may be unsatisfactory for some users is one of synchronising the loading of updated prediction sets into stations' operational systems. At Herstmonceux this is fully automated and new prediction sets are installed, and new timebias functions computed, a few seconds after they arrive by email. At stations, where such updating has to be done manually, it is often the case that observers are using the prediction set *before* the one used by the timebias service. (Naming: since most predictions are now issued daily the immediately preceding set has been termed a "*yesterdaily*"). In order not to inconvenience users it is planned to expand the range of predictions processed by the service to include a yesterdaily for each satellite, but implementation is not straightforward and may take some time.

A further reduction in the cycle time of data upload by stations could even improve the "freshness" of timebiases computed for low satellites to well within one orbital revolution, and lead to a fully automated system of near-realtime timebias generation and distribution.

Conclusions

It seems to us that, even with the excellence and frequency of today's predictions, it is unlikely that the requirement for reliable, near realtime timebiases will disappear entirely. Now that the system has been fully automated, and is easily extensible to include new satellites and new predictions centres, it can continue to provide a valuable service for as long as stations find it useful. We very much hope that the success and ease of use of this scheme for timebias distribution can serve as a prototype for the future distribution of predictions themselves.

Acknowledgements

We are grateful to **Philip Gibbs** at Herstmonceux for the work that he continues to put into the automated computation of timebiases and timebias functions; to **Carey Noll** of the Crustal Dynamics Data Information Service in Washington and **Wolfgang Seemüller** of the European Data Centre in München for their speedy implementation of the ILRS requirements for hourly normal point availability; to **Georg Kirchner** of Graz and **Graham Appleby** of NERC for helpful suggestions on the implementation of this service; and to **Riga**, **Yarragadee** and **Zimmerwald** stations for copying their normal point data for low-flying satellites directly to Herstmonceux immediately following a pass.

References

Appleby, G.M and Sinclair, A.T., 1992, "*Formation of on-site Normal Points*", Proceedings of *8th* International Workshop on Laser Ranging Instrumentation, NASA Conference Publication **3214**, Annapolis, Maryland

Gurtner, W., 1999, "*Near Realtime Status Exchange*", SLRMAIL **372** (see CDDIS web page)

Gurtner, W., 2002, "*Realtime Timebias Computation and Distribution*", SLRMAIL **921** (see CDDIS web page)

Wood, R., 1997, "*A New Standard for Timebias Function Distribution*", SLRMAIL **37** (see ILRS web page)

Wood R. & Appleby, G.M., 2002, Report of EUROLAS workshop on *"Detecting and Eliminating Errors in the EUROLAS Network",* held at Herstmonceux (see ILRS web page)