ASTROLABE OBSERVATIONS OF THE SUN ON THE HIPPARCOS REFERENCE FRAME

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ABSTRACT

The results from the 1974/1991 set of Sun observations with astrolabes at Rio de Janeiro, São Paulo and at Calern are discussed from the point of view of the improvement of precision brought by employing Earth Orientation Parameters (EOP) described in the Hipparcos reference frame. The new series of EOP used here are based on the H37P preliminary set of Hipparcos positions, aligned to the ICRS (Vondrak et al. 1996, Vondrak 1996). We introduce the differences between this series and the IERS series previously used for the set of Sun observations (Penna et al. 1996) and the difference on the observation residuals are analyzed. Sorting by zenith distances, it is shown that the residuals dispersion is consistently smaller when the new series is employed (up to a 15 per cent gain for $z = 37°$). Also, the standard deviations for the Standard Weighted Global Solution show the same trend. The gain is reduced, though, for the largest zenith distances. Taking all data together there is no important gain on the precision for the Standard Weighted Global Solution. Confirming the good quality of the IERS stellar reference frame, the values of the parameters describing the orientation of the observational reference frame nearly do not change. As for the parameters describing the Earth orbit, the correction to the obliquity of ecliptic, which formerly displayed an unexpected high value (0.43 arcsec), drops to 0.27 arcsec.

Key words: Earth rotation parameters; astrolabe; solar observations.

1. INTRODUCTION

The corrections to the Earth orbit parameters and to the origin of the reference system obtained from solar observations with astrolabes are referred to the local, instrumental zenith, oriented by FK5 stars, and to the ephemeris time, for the time span treated here. In practice, the mean geographic coordinates are used as the starting point and then corrected for polar motion through the IERS series, plus a small constant, average term from stars observations with the same or nearby astrolabes. In this way changes on the adopted series for the X and Y components of polar motion reflect on the observed minus calculated residual from the Sun's observations.

In this work, we used the new series of EOP, based on the H37P preliminary set of Hipparcos positions, aligned to the ICRS (Vondrak et al. 1996, Vondrak 1996), to re-reduce the 1974 to 1991 series of astrolabe observations obtained at Rio de Janeiro (Penna 1982), São Paulo (Leister 1989) and at Calern (Laclare 1992), and discussed in Penna et al. (1996). The observed minus calculated residuals (μ) were obtained following the usual formula (e.g. Penna 1995) and the analysis followed the Standard Weighted Global Solution (SWGS), as presented by Penna et al. (1996). In the SWGS, corrections are found to the places of equator and equinox, to the obliquity of ecliptic, to the Sun's mean longitude, to the eccentricity, to the longitude of the perihelion, plus corrections to the zenith distances of observation.

2. DATA AND RESULTS

The data set contains 5924 transits of the Sun, by 11 different zenith distances, from 3 centers. Most of the observations (74 per cent) are from Calern (CERGA/OCA, ϕ=+43°44′55″.89, λ=$-0^h27^m42^s.442$), covering the interval from 30° to 70°, to a total of 11 zenith distances, all observed with zerodur reflecting prisms. At São Paulo (IAG/USP, ϕ=−23°00′06″.00, λ=$+3^h07^m52^s.220$), 20 per cent of the observations were taken, with a 30° transparent prism and a 45° zerodur reflecting prism. At Rio de Janeiro (ON/CNPq, ϕ= −22°53′42″.50, λ=$+2^h52^m53^s.479$), 6 per cent of the observations were taken, using a 30° transparent prism.

In Figure 1 the differences on the μ residuals from the solar transits, in the sense H37P based minus IERS series, are displayed. The $\Delta\mu$ differences are presented by zenith distance and segregating east and west transits. A long term trend is clearly shown. It is possibly due to the similar trend observed for the X pole coordinate when the H37P based minus IERS series are considered for the same period. In such cases and since most of the observations were taken very close to the initial meridian, the east and west symmetry is to be expected. Notice that, in this case, variations upon the Y pole coordinate should not be sensed above the data noise. Moreover, the determinations of the Sun diameter would not be affected, as they are calculated from the time of the upper and lower solar limbs transits, at each side of the meridian independently (Laclare et al. 1996).

Finally, in Tables 1 to 4, the improvement on the results brought by using the H37P based series is presented. We remark that, confirming the good quality of the IERS stellar reference frame, the overall precision on the SWGS solution, as well as on all the searched unknowns is practically unchanged whichever the polar motion series used. Tables 1 and 2 bring, for each of the zenith distances of observation, the percentage gain brought by adopting the H37P series. Tables 3 and 4 bring, for the whole period and for the densest campaign respectively, the comparative values obtained from the SWGS solution for the orientation of the observational reference frame and for the Earth orbit parameters, using either of the polar motion series. The largest differences are for ΔA (correction to the equator or declination origin) and for $\Delta\varepsilon$ (correction to the obliquity of the ecliptic). For the latter, the unexpected high value previously found (+0.42 arcsec) is almost halved (to +0.27 arcsec). The correlation (0.3) between these two unknowns and the effect of variations of the X pole coordinate upon the instantaneous latitude for stations close to the initial meridian can account for these results.

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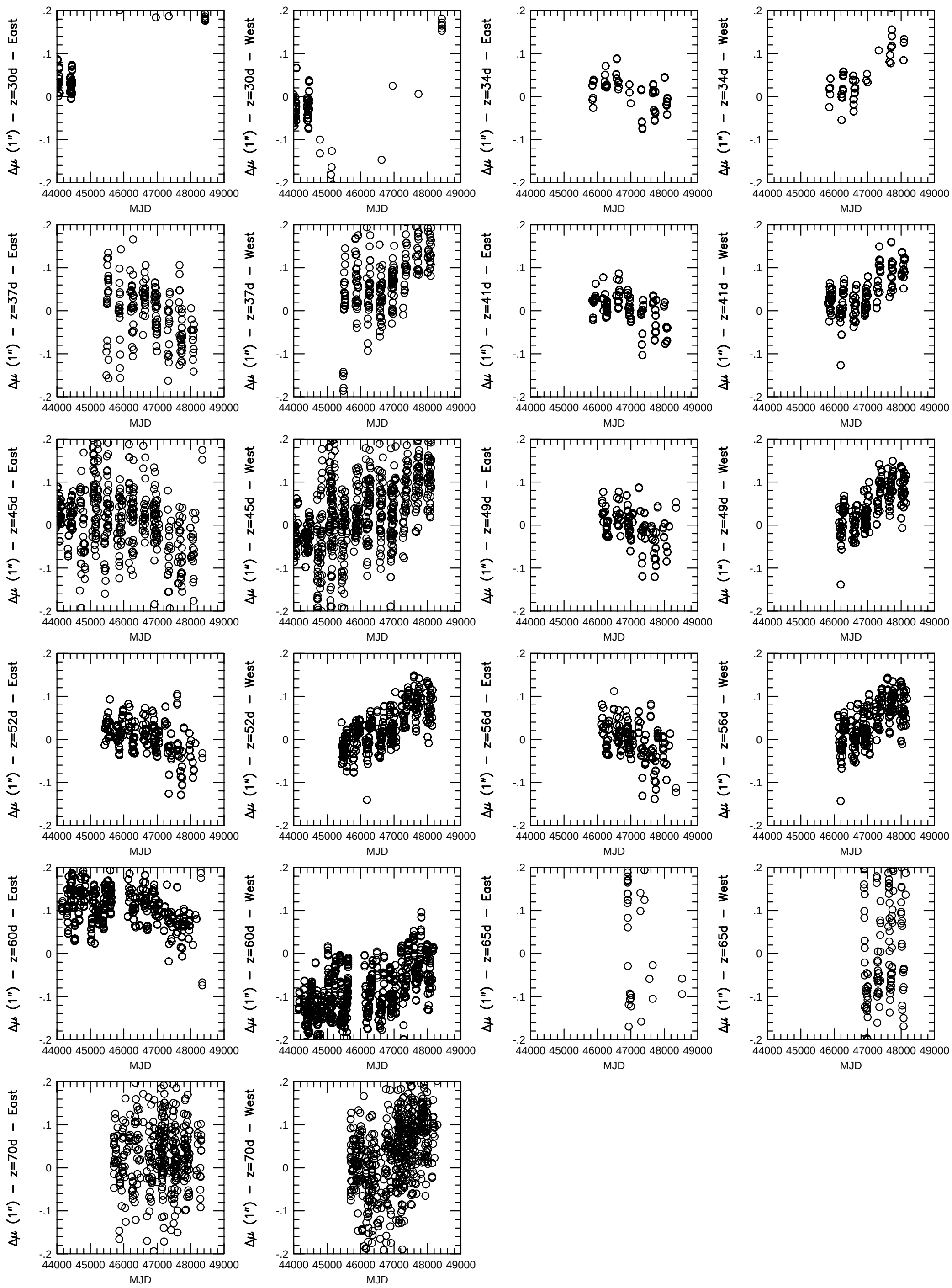

Figure 1. The differences on the μ residuals (i.e. observed minus calculated zenith distance) from the solar transits, in the sense H37P based minus IERS series, arranged by zenith distance (z). The east and west transits are segregated.

Table 1. Standard deviation of the μ residuals, for each zenith distance, relative to the H37P based series. The bottom row compares with the IERS series based results.

zenith distance	30°	34°	37°	41°	45°	49°	52°	56°	60°	65°	70°
standard deviation	$0''.88$	$0''.48$	$0''.62$	$0''.63$	$1''.15$	$1''.01$	$0''.80$	$0''.86$	$1''.14$	$1''.47$	$1''.50$
gain	5%	4%	15%	6%	7%	2%	5%	7%	5%	4%	16%

Table 2. Precision of the standard weighted global solution, for each zenith distance, using the H37P based series. The bottom row compares with the IERS series based results.

zenith distance	30°	34°	37°	41°	45°	49°	52°	56°	60°	65°	70°
standard deviation	$0''.64$	$0''.34$	$0''.46$	$0''.48$	$0''.67$	$0''.70$	$0''.64$	$0''.64$	$0''.85$	$1''.03$	$1''.39$
gain	8%	10%	5%	6%	3%	7%	4%	6%	3%	4%	1%

Table 3. Comparative results from the standard weighted global solution, for the 1974/91 data set. In the headers, ΔA is the equator correction, ΔE is the equinox correction, $\Delta\varepsilon$ is the obliquity correction, ΔL is the Sun's mean longitude correction, Δe is the eccentricity correction and $e\Delta\varpi$ is the longitude of the perihelion correction.

	N° Eq.	$\sigma('')$	ΔA($''$)	ΔE($''$)	$\Delta\varepsilon('')$	ΔL($''$)	Δe($''$)	$e\Delta\varpi('')$
H37P based	5750	0.62	0.07±0.04	0.16±0.06	0.27±0.05	−0.02±0.05	0.12±0.01	0.03±0.01
IERS	5735	0.63	−0.04±0.04	0.17±0.06	0.43±0.05	0.04±0.05	0.10±0.01	−0.00±0.01

Table 4. Comparative results from the standard weighted global solution, for the 1987 campaign. The headers symbols have the same meaning as in Table 3.

	N° Eq.	$\sigma('')$	ΔA($''$)	ΔE($''$)	$\Delta\varepsilon('')$	ΔL($''$)	Δe($''$)	$e\Delta\varpi('')$
H37P based	722	0.53	0.03±0.15	1.40±0.16	−0.18±0.15	1.04±0.15	0.09±0.04	0.00±0.04
IERS	692	0.54	−0.02±0.16	1.33±0.15	−0.38±0.17	1.04±0.05	−0.01±0.04	0.00±0.04