NEW SOLUTION OF EARTH ORIENTATION PARAMETERS 1900-1992 FROM OPTICAL ASTROMETRY, AND ITS LINKING TO ICRF AND ITRF

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- ♦ **Solution of Earth Orientation Parameters;**
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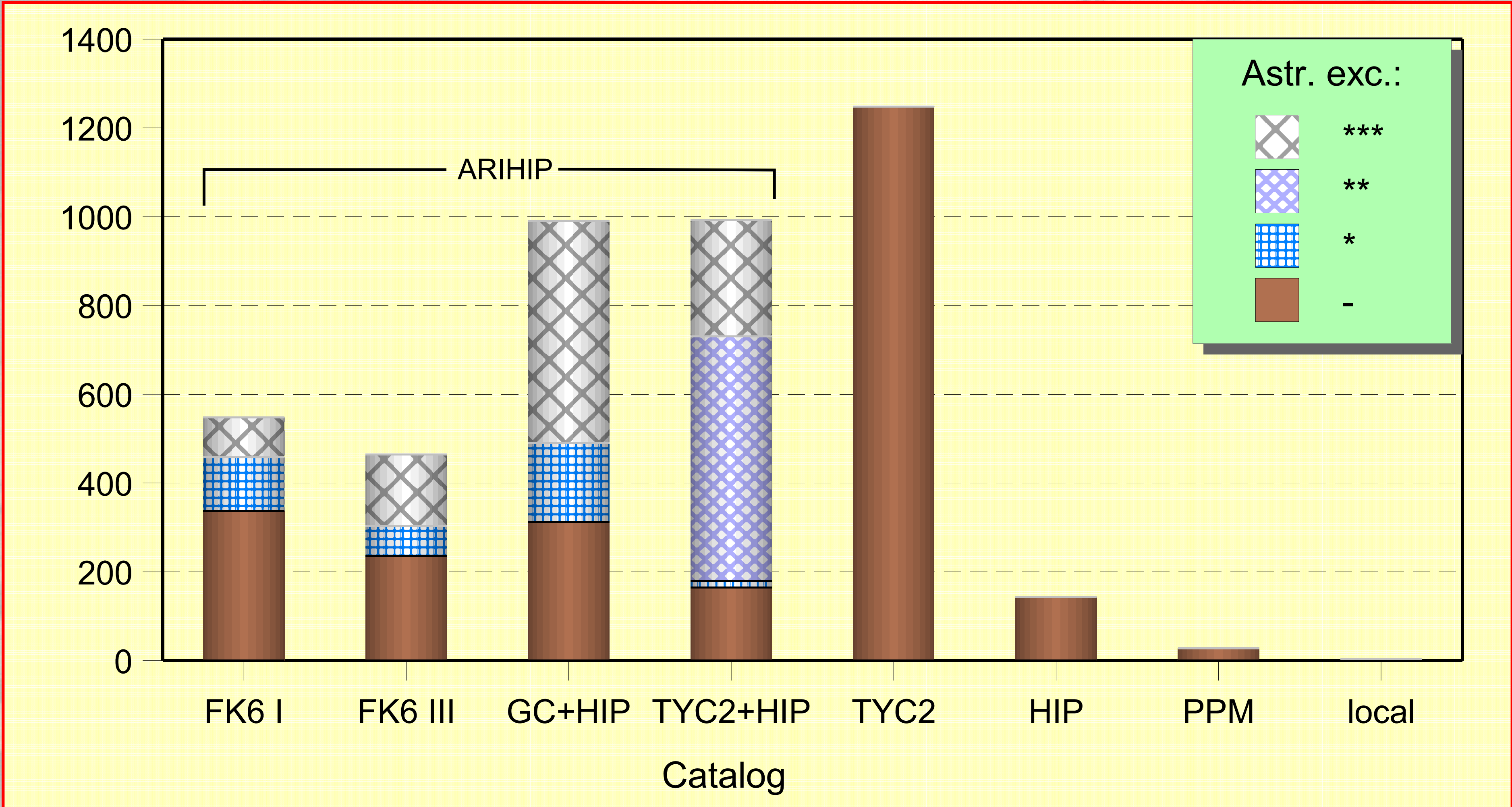
- ♦ **Conclusions.**

Introduction (Catalog EOC-4):

- ♦ Between 1991 and 2003, we collected about 4.5 million optical observations of latitude / universal time / altitude variations at 33 observatories in 1899.7-2002.6;
- ♦ We recently combined these observations with astrometric catalogs ARIHIP (Wielen et al. 2001), Tycho-2 (Høg et al. 2000) and some other to derive EOC-4 (Vondrák & Štefka, *Astron. Astrophys*. 2010):
  - New approach assuring compatibility with Hipparcos/Tycho at their mean epoch (1991.25) and consequently to ICRF;
  - EOC-4 contains 4418 different objects (stars, components of multiple systems, photocenters), out of which 599 have significant periodic motions.


1400
1200
1000
800
600
400
200
0
ARIHIP
Astr. exc.:
***
**
*
-
FK6 I
FK6 III
GC+HIP
TYC2+HIP
TYC2
HIP
PPM
local
Catalog

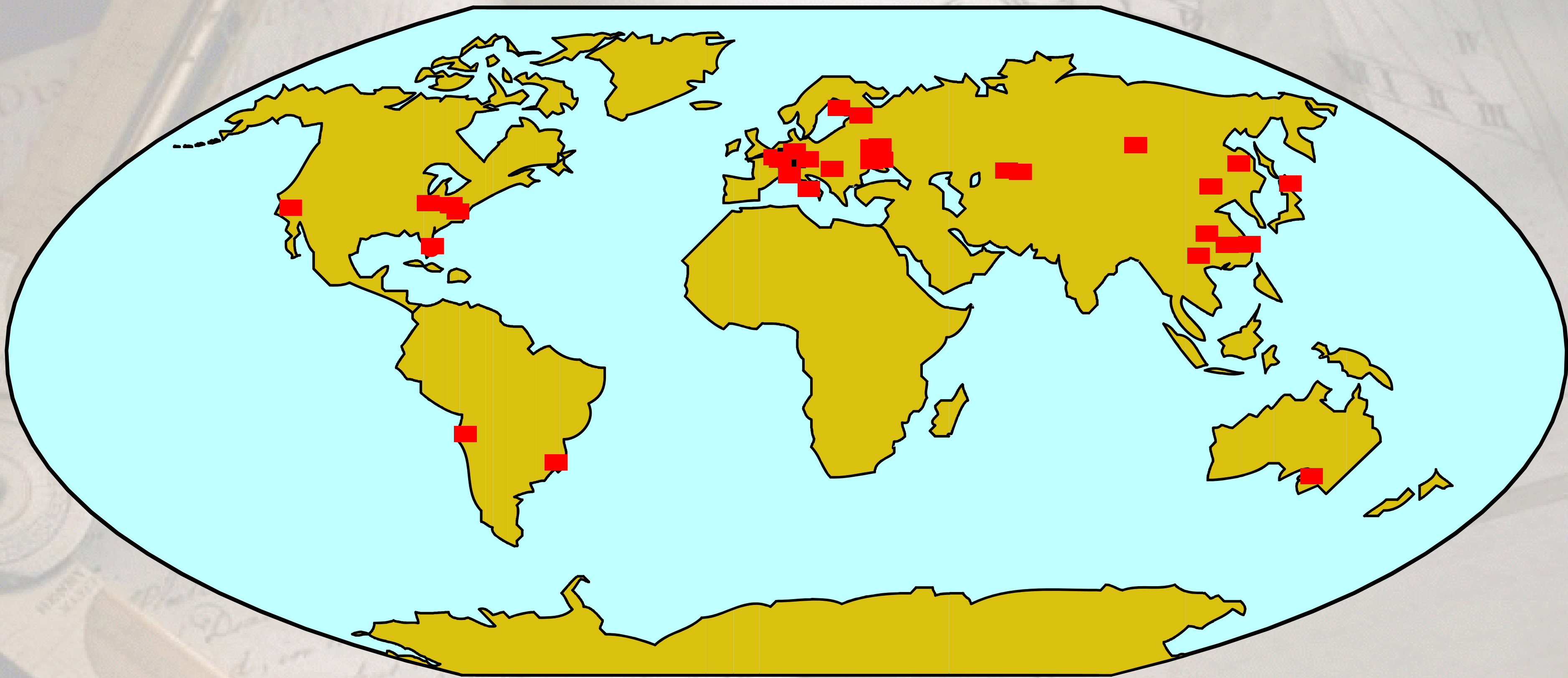
Solution of EOP

- **Input data, based on observations of individual stars:**
  - **Instantaneous latitude $\Delta\varphi$;**
  - **Universal time UT0-UTC;**
  - **Altitude differences δh.**
- **Solved parameters:**
  - **At 5-day intervals:**
    - **polar motion x, y, Universal time UT1- UTC (only after 1956);**
  - **For each instrument:**
    - **constant, linear, semi-annual and annual deviation in latitude/longitude (dev_φ, dev_λ), and rheological parameter $\Lambda = 1 + k - l$;**
  - **For the whole interval:**
    - **celestial pole offsets dX, dY wrt IAU2000 nutation and IAU2006 precession, as quadratic function of time.**

Observations used:

- ♦ **Data from 47 instruments at 33 observatories:**
  - ▸ **10 PZT's (φ, UT0):**
    - ★ 3 at Washington; 2 at Richmond and Mizusawa; 1 at Mount Stromlo, Punta Indio & Ondřejov;
  - ▸ **7 photoelectric transit instruments (only UT0):**
    - ★ 3 at Pulkovo; 1 at Irkutsk, Kharkov, Nikolaev & Wuhang;
  - ▸ **16 visual zenith-telescopes & similar instruments (only φ):**
    - ★ 7 ZT at ILS stations; 2 ZT at Poltava, 1 ZT at Belgrade, Blagoveschtchensk, Irkutsk, Jósefoslaw & Pulkovo; FZT at Mizusawa; VZT at Tuorla-Turku;
  - ▸ **14 instruments for equal altitude observations - AST, PAST, CZ (δh):**
    - ★ 1 AST at Paris, Santiago de Chile, Shanghai, Simeiz & Wuhang; 2 PAST at Shaanxi, 1 PAST at Beijing, Grasse, Shanghai & Yunnan; 1 CZ at Bratislava, Prague & Ondřejov.

Geographic distribution of participating observatories



Simplified observation equations:

$$\Delta\varphi = x\cos\lambda - y\sin\lambda - dX\cos\alpha - dY\sin\alpha + dev_{\varphi} + \Lambda D_{\varphi}$$

$$15\cos\varphi(\mathrm{UT0}-\mathrm{UTC}) = 15\cos\varphi(\mathrm{UT1}-\mathrm{UTC}) + \sin\varphi(x\sin\lambda + y\cos\lambda) +$$
$$+\cos\varphi\tan\delta(dY\cos\alpha - dX\sin\alpha) + dev_{UT} + 15\Lambda D_{\lambda}\cos\varphi$$

$$dh = 15\cos\varphi\sin a(\mathrm{UT1}-\mathrm{UTC}) + x(\cos\lambda\cos a + \sin\varphi\sin\lambda\sin a) -$$
$$- y(\sin\lambda\cos a - \sin\varphi\cos\lambda\sin a) + dY(\sin q\sin\delta\cos\alpha - \cos q\sin\alpha) -$$
$$- dX(\sin q\sin\delta\sin\alpha + \cos q\cos\alpha) + dev_{\varphi}\cos a + dev_{UT}\sin a +$$
$$+\Lambda(D_{\varphi}\cos a + 15D_{\lambda}\cos\varphi\sin a),$$

φ, λ are geographic coordinates of the instrument,
α, δ, a, q are right ascension, declination, azimuth, parallactic angle,
D_{φ}, D_{λ} are rigid Earth tidal variations of the local vertical.

- ♦ Celestial reference frame is realized by EOC-4;
- ♦ More strict criteria to exclude outliers:
  - >0.7″ (instead of 0.8″) for deviations from monthly average;
  - >2.5σ_o (instead of 2.7σ_o) for residuals;
  - Thus, 2.7% of observations were excluded;
  - σ_o = 0.184″ (instead of 0.190″);
- ♦ Terrestrial reference frame is realized by adopting geographic coordinates of the stations and correcting the observations for the motions from NUVEL-1A.
  - We also expect that coordinates of each station can have apparent seasonal deviations due to refraction anomalies.

For each station, we estimate systematic deviations in latitude/universal time in the form:

$$dev_{\varphi,UT} = A^{\varphi,UT} + A_1^{\varphi,UT} T + B^{\varphi,UT} \sin 2\pi t + C^{\varphi,UT} \cos 2\pi t + D^{\varphi,UT} \sin 4\pi t + E^{\varphi,UT} \cos 4\pi t,$$

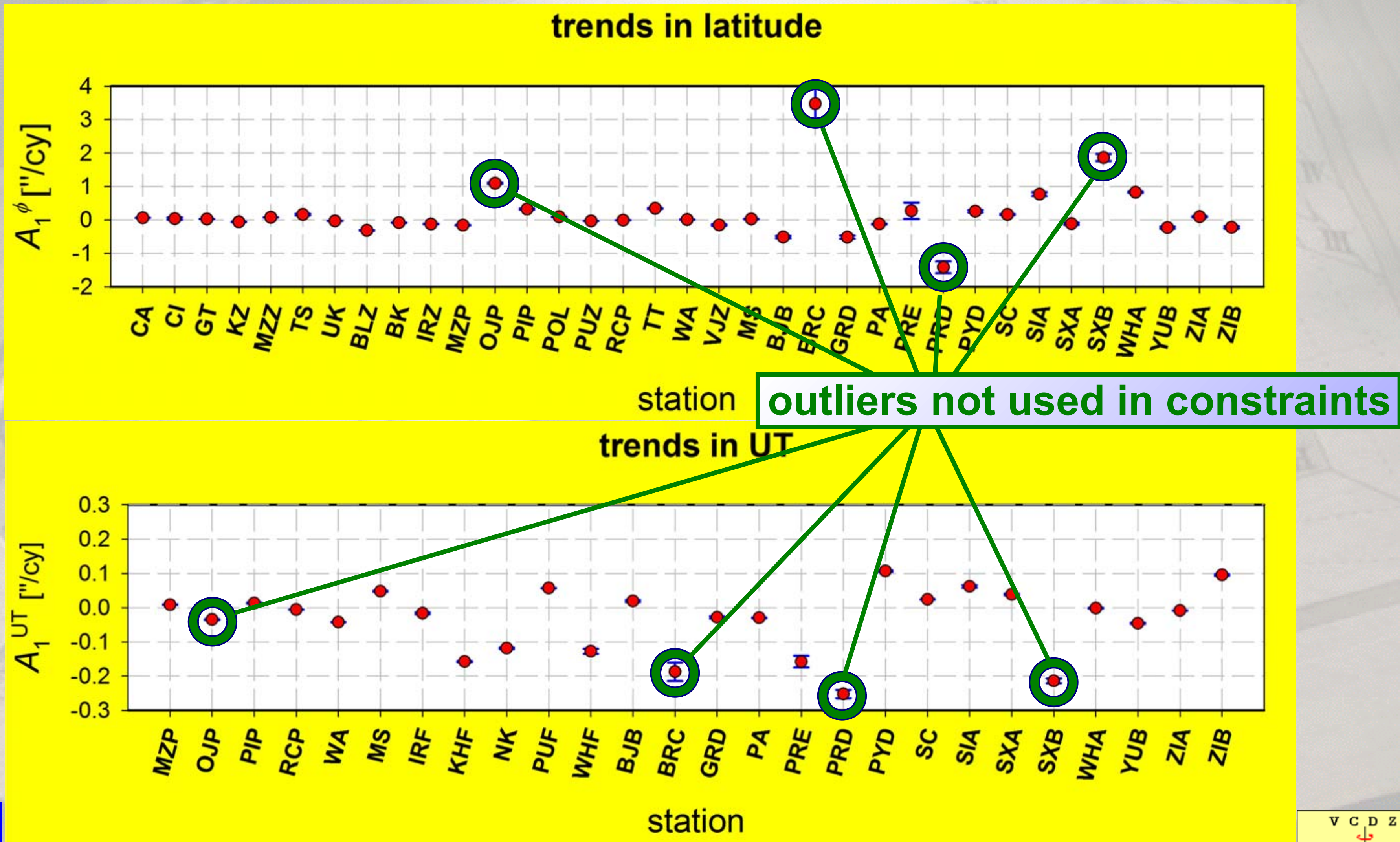
where T is measured in Julian centuries from MJD= 32000 (latitude) and 43000 (for UT) , t in years from the beginning of Besselian year. These 12 parameters are tied by the following 18 constraints (λ is the longitude of the station)

$$\sum pA^{\varphi} \begin{Bmatrix} \sin\lambda \\ \cos\lambda \end{Bmatrix} = \sum qA_1^{\varphi} \begin{Bmatrix} \sin\lambda \\ \cos\lambda \end{Bmatrix} = \sum pB^{\varphi} \begin{Bmatrix} \sin\lambda \\ \cos\lambda \end{Bmatrix} = \sum pC^{\varphi} \begin{Bmatrix} \sin\lambda \\ \cos\lambda \end{Bmatrix} =$$

$$= \sum pD^{\varphi} \begin{Bmatrix} \sin\lambda \\ \cos\lambda \end{Bmatrix} = \sum pE^{\varphi} \begin{Bmatrix} \sin\lambda \\ \cos\lambda \end{Bmatrix} = 0\,,$$

$$\sum pA^{UT} = \sum qA_1^{UT} = \sum pB^{UT} = \sum pC^{UT} = \sum pD^{UT} = \sum pE^{UT} = 0\,.$$

In all our previous solutions, we applied the summations to the stations that finished observations after 1962, with weights proportional to the length of the interval covered by observations (p) and its third power (q). So, e.g., the trend of the polar motion of our solution is given as a weighted mean of A_1^{φ} of all stations in latitude, projected into x, y axes.

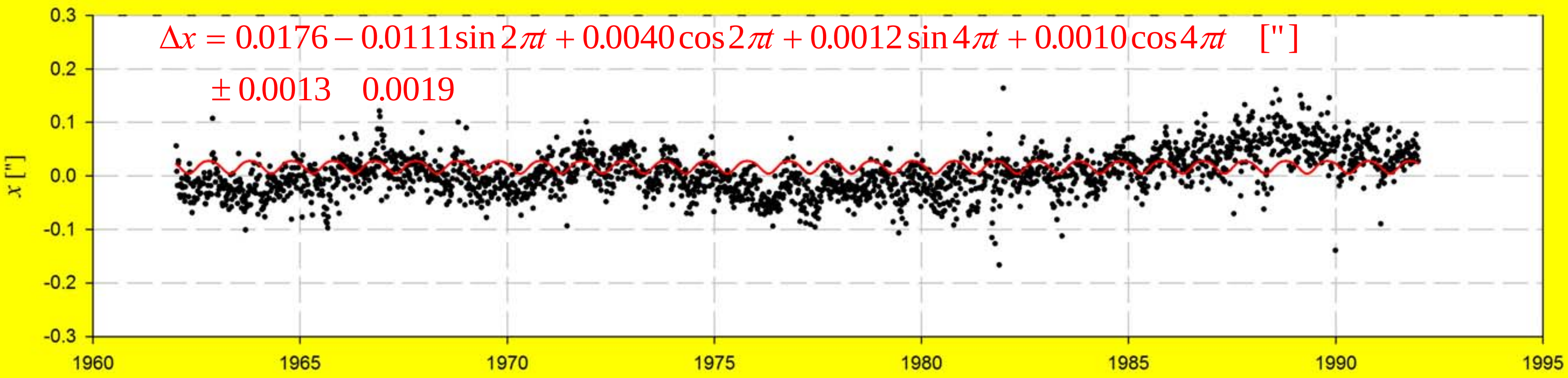


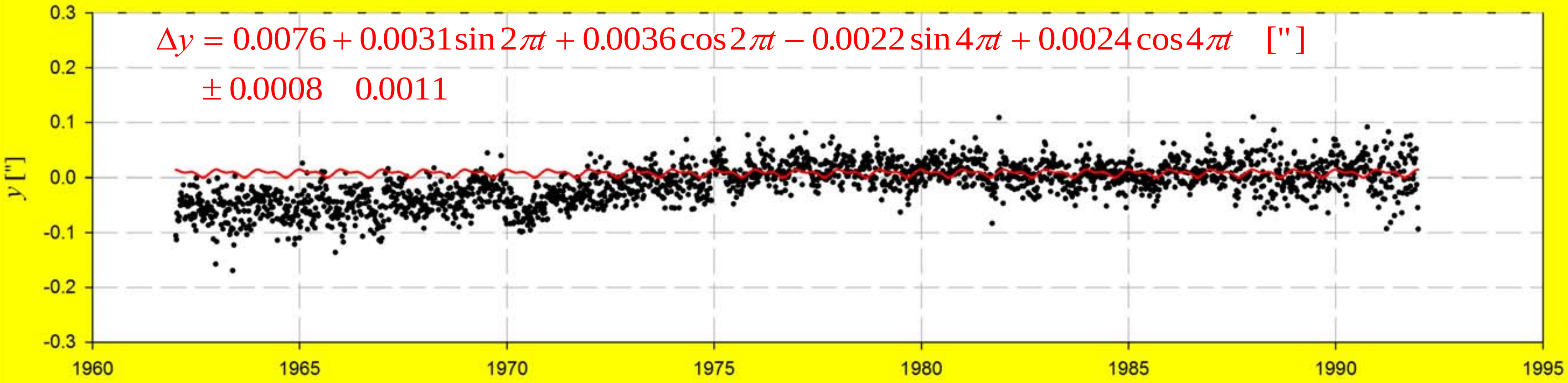
trends in latitude
A_1^{ϕ} [''/cy]
4
3
2
1
0
-1
-2
CA CI GT KZ MZZ TS UK BLZ BK IRZ MZP OJP PIP POL PUZ RCP TT WA VJZ MS BJB BRC GRD PA PRE PRD PYD SC SIA SXA SXB WHA YUB ZIA ZIB
station
outliers not used in constraints
trends in UT
A_1^{UT} [''/cy]
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
MZP OJP PIP RCP WA MS IRF KHF NK PUF WHF BJB BRC GRD PA PRE PRD PYD SC SIA SXA SXB WHA YUB ZIA ZIB
station

Comparison with space techniques (solution IERS C04):

- ♦ Linear trend of the solution is fixed to the most stable stations, as explained above;
- ♦ Bias and seasonal effects are estimated from the differences of pole coordinates x, y and UT between IERS C04 and our optical astrometry solution. Only the data after 1978 (when space techniques became dominant) are used.

Differences C04-OA09 - polar motion

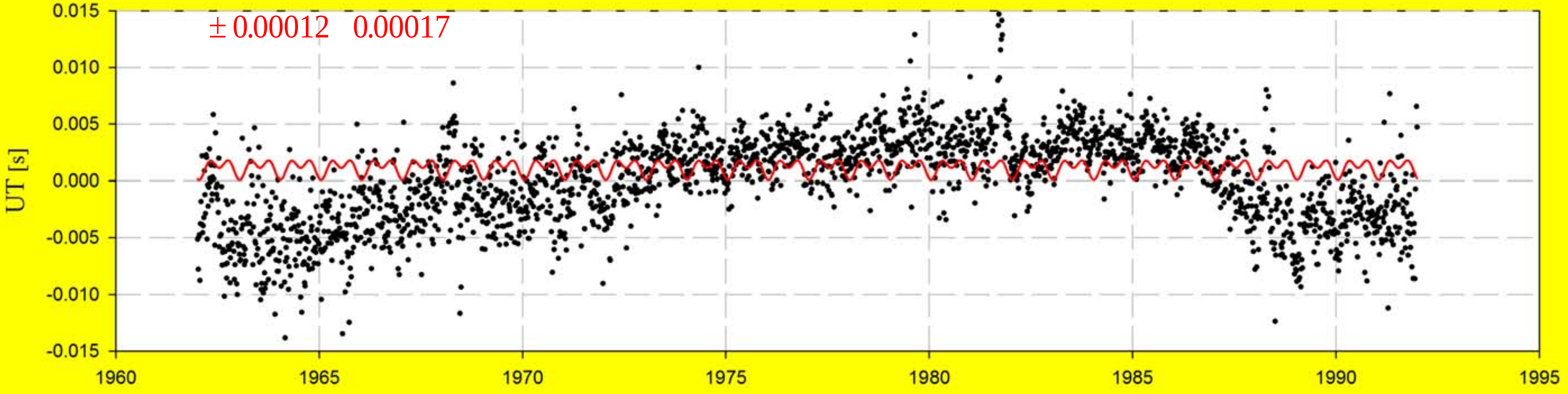




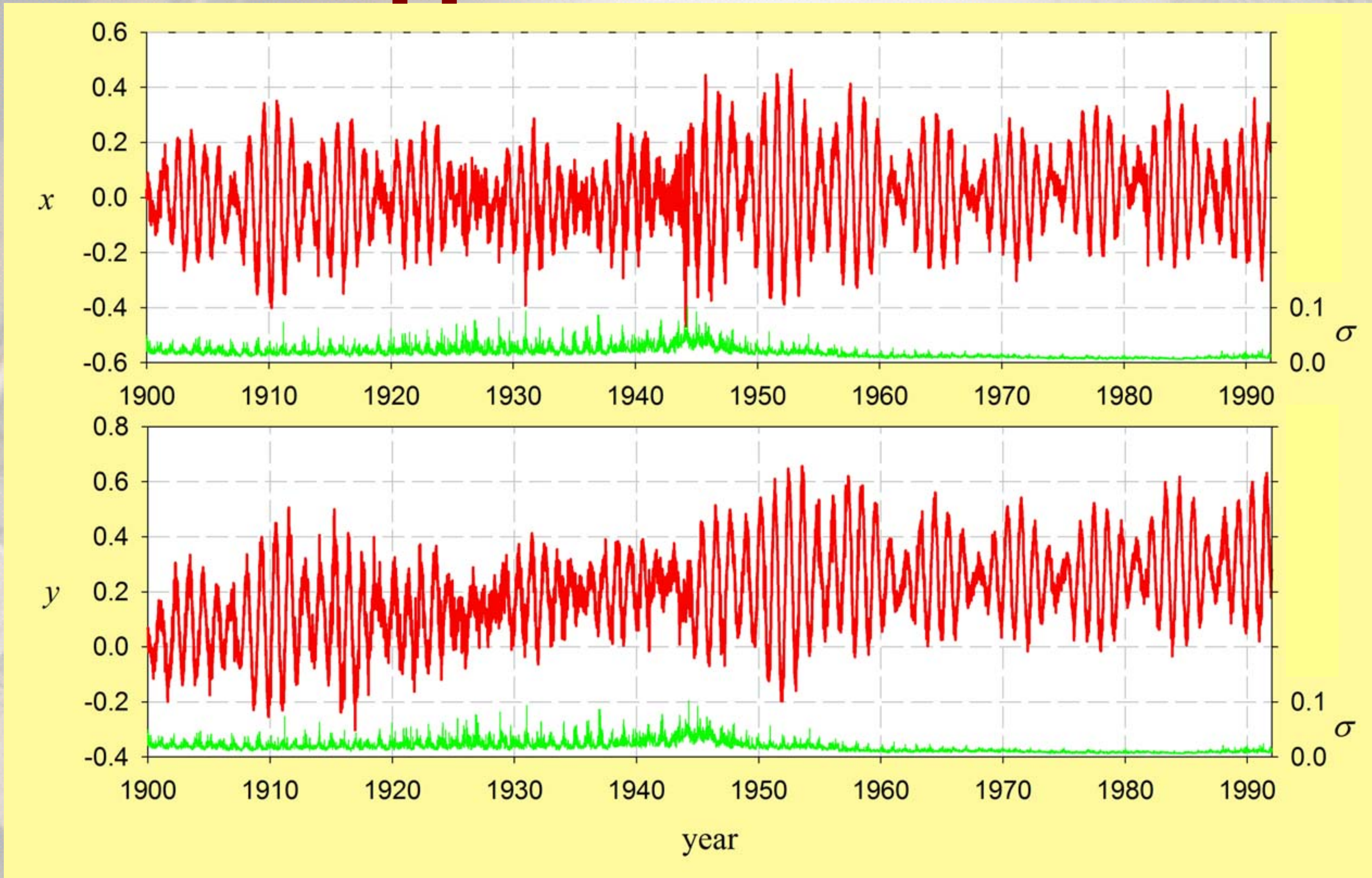
Differences C04-OA09 - Universal time

$$\Delta UT = 0.00116 - 0.00016\sin 2\pi t - 0.00050\cos 2\pi t - 0.00029\sin 4\pi t - 0.00047\cos 4\pi t \quad [s]$$

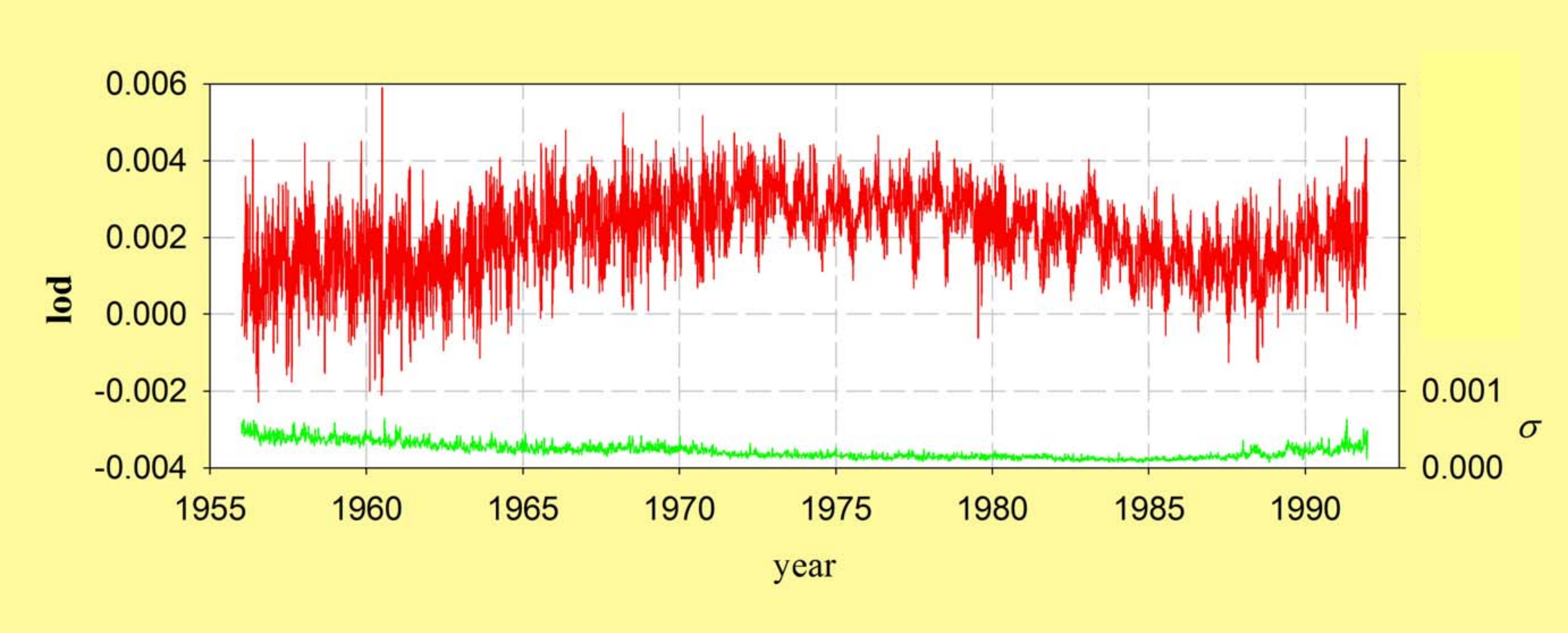
$$\pm 0.00012 \quad 0.00017$$



Polar motion [″]:



Length-of-day, computed from UT1-TAI [seconds]:



Celestial pole offsets:

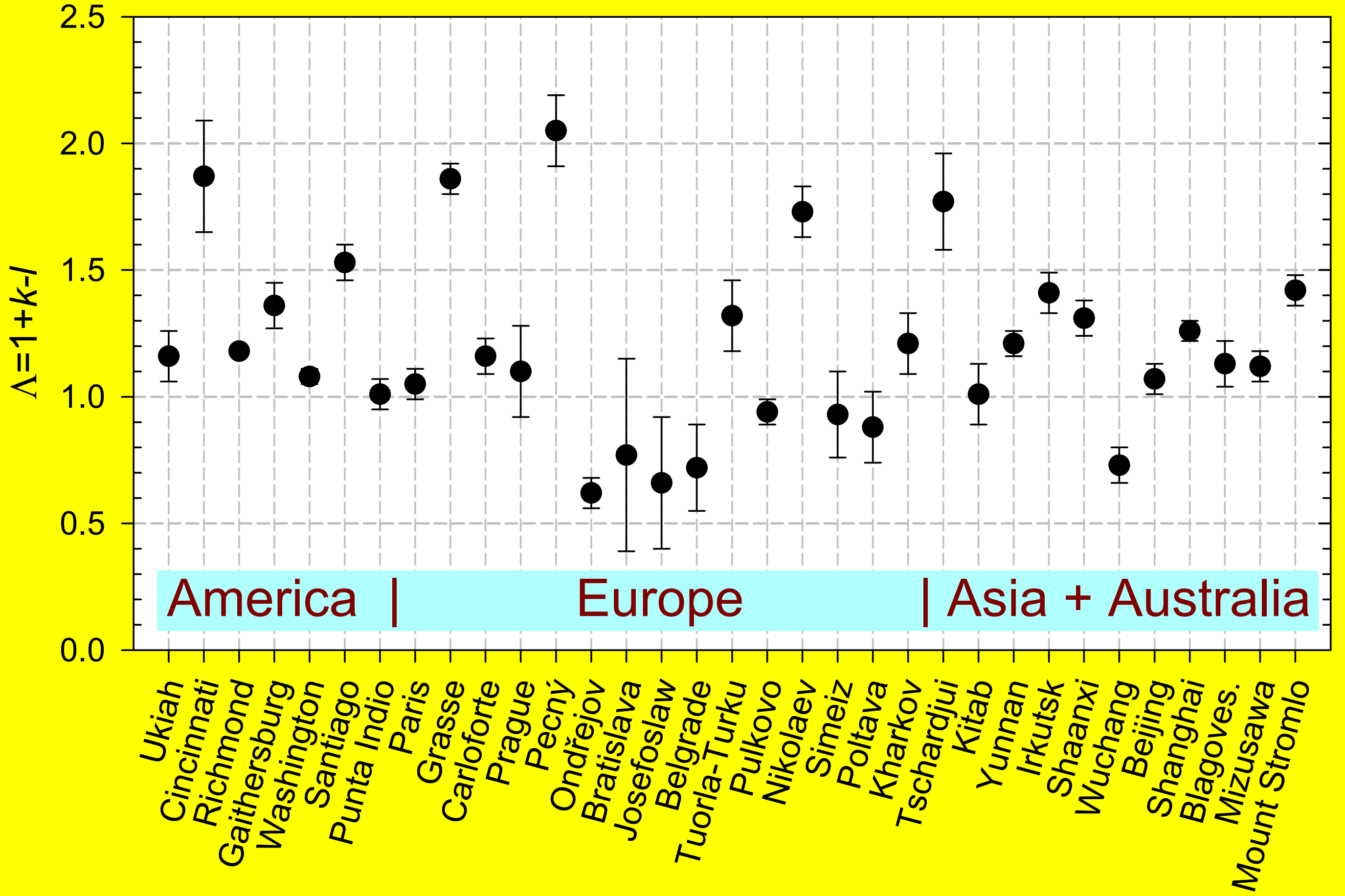
$$dX = -7.4 + 29.0T + 29.0T^2 \; [mas]$$

$$dY = -6.1 + 8.9T - 1.2T^2 \; [mas]$$

$$\pm 0.4 \quad 1.1 \quad 3.4$$

T in centuries from 1956.0

Rheological parameter $\Lambda = 1 + k - l$



Conclusions:

- ♦ 4505442 individual observations, based on catalog EOC-4, were used in the new solution covering the interval 1899.7-1992.0;
- ♦ Solution is linked to terrestrial reference frame via the solution by space techniques (bias + seasonal terms, 1978.0-1992.0), and via the most stable stations corrected for NUVEL-1A motions (trend, 1899.7-1992.0);
- ♦ New solution yields slightly better results than the ones based on previous versions of EOC:
  - The average standard error of one observation is $\sigma_o = 0.184''$ (former value = $0.190''$).

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