CELESTIAL POLE OFFSETS AND UNIVERSAL TIME
- combination of VLBI/GPS measurement

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♦ Combination of VLBI universal time with GPS length-of-day changes.

- Generally, we have two independently measured series:
  - values of a function (celestial pole offsets, universal time) measured by VLBI (low time resolution, direct tie to ICRF);
  - values of the time derivative of the same function (celestial pole offset rates, length-of-day) measured by GPS (high time resolution, indirect tie to ICRF via orbits).
- We combine these two series to obtain the solution
  - sufficiently smooth, whose
  - function values fit well to the first measured series;
  - time derivatives fit well to the second measured series.
- Method of combined smoothing (*Vondrák, Čepek* A&A 2000) - the solution takes over the long-term stability of the first series and short-periodic signal of the second one.

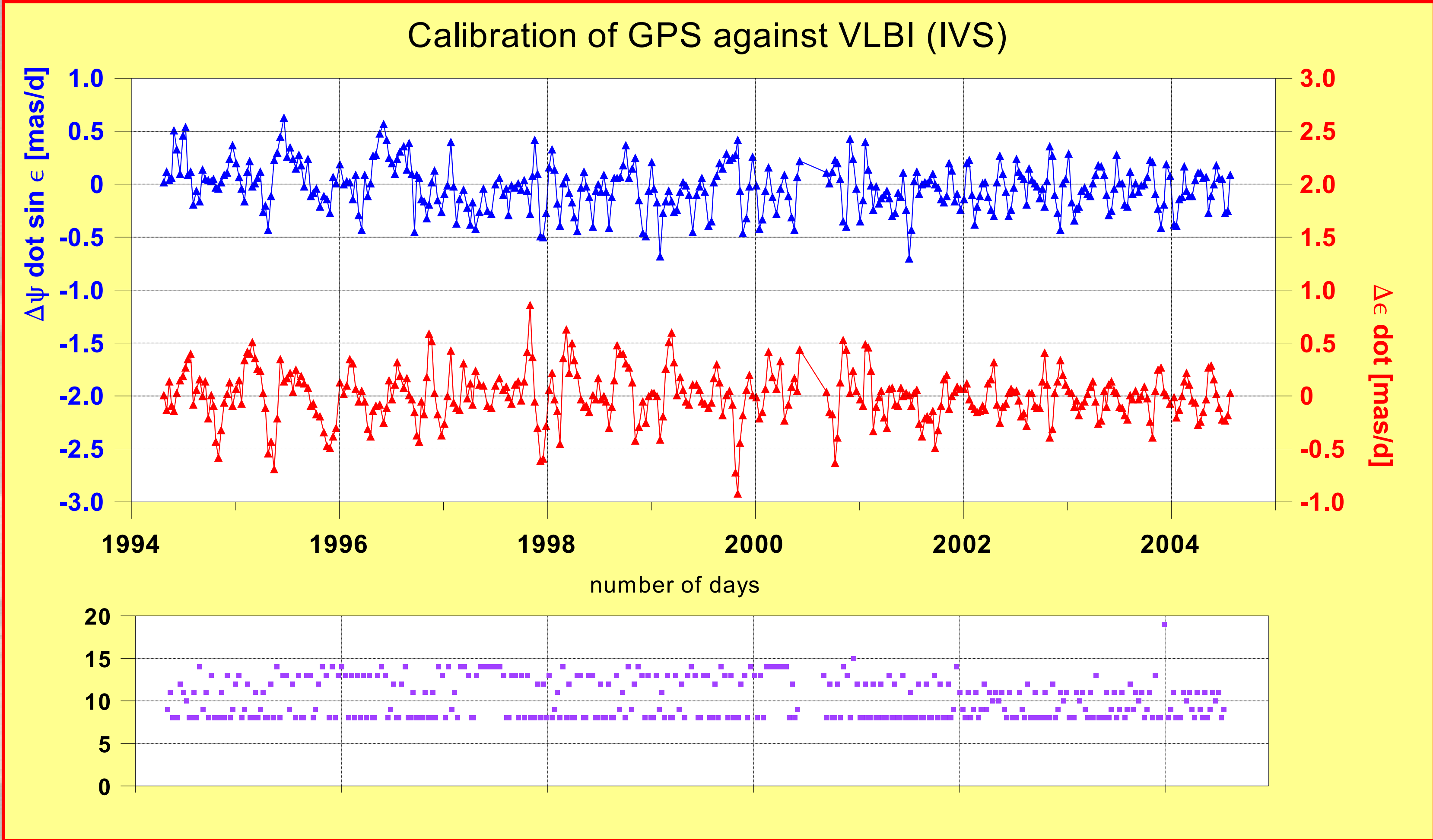
Series used in this study:

- **IVS combined solutions (1979.6 -2004.6, at unequally spaced intervals 1 - 7 days):**
  - ★ **ivs04q3X.eops - celestial pole offsets δX, δY (wrt IAU2000A);**
  - ★ **ivs04q3e.eops - celestial pole offsets $\delta\psi$, $\delta\epsilon$ (wrt IAU1980).**
- **CODE solution (1994.3 - 2004.6, at equally spaced 1-day intervals):**
  - ★ **GPS-based celestial pole offset rates $d\delta\psi/dt$, $d\delta\epsilon/dt$ (wrt IAU1980);**
- **IGS combined solution (1996.5-2004.6, at equally spaced 1-day intervals):**
  - ★ **igs00p02.erp - length of day changes.**

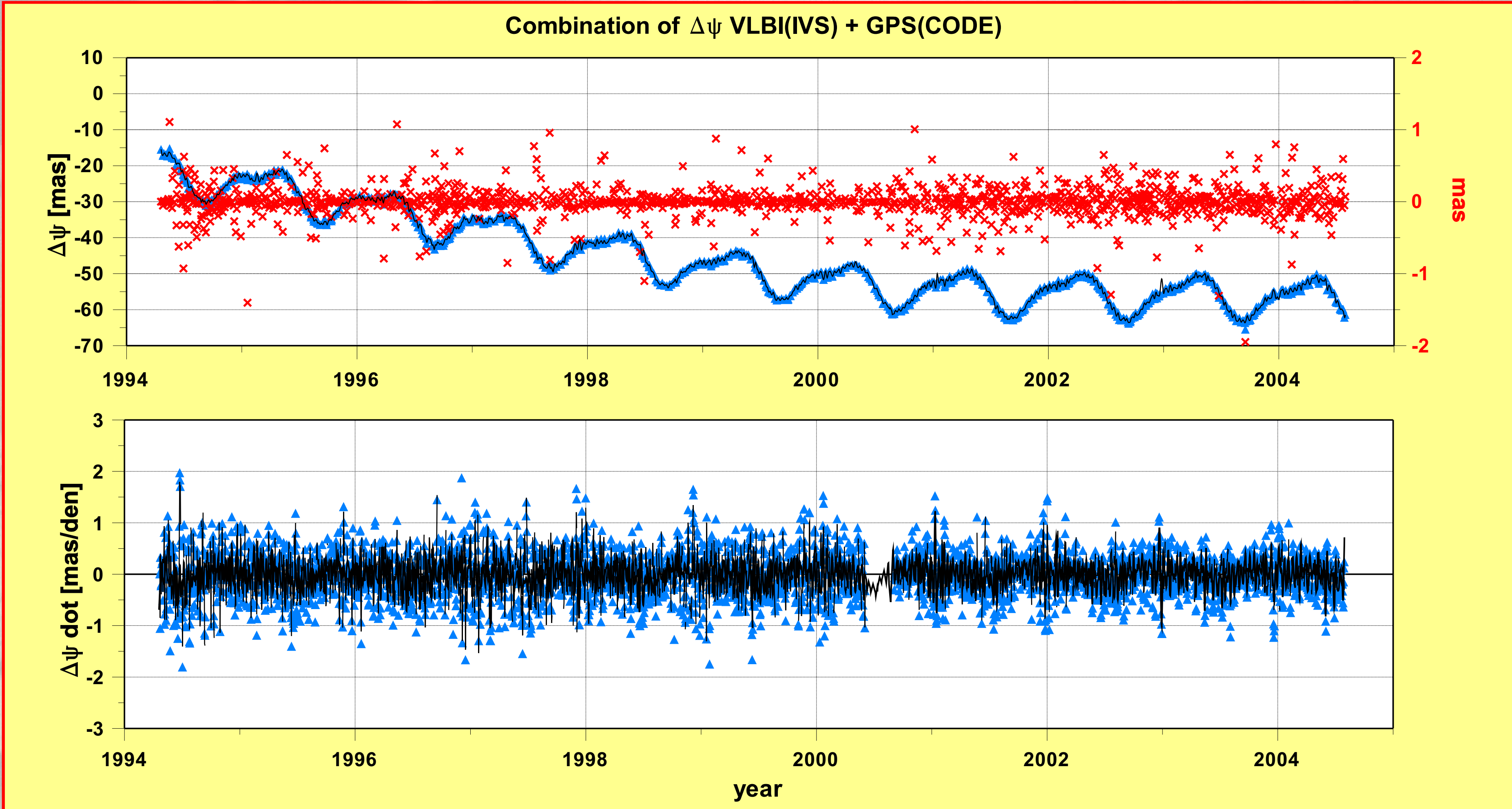
Combination of celestial pole offsets:

- We use the method of 'combined smoothing', applied to:
  - VLBI data (IVS combined solution ivs04qe.eops, in the interval 1994.3-2004.6, referred to IAU1980 model);
  - GPS data (CODE, in the interval 1994.3-2004.6, same model):
    - calibrated to VLBI in long-periodic sense (integer number of VLBI intervals, 8-18 days long);
- Combined results in $\delta\psi$, $\delta\epsilon$ first corrected for the difference IAU2000A - IAU1980, then transformed to δX, δY:
  - $\delta X = 0.39778\ \delta\psi + (0.02236\ \delta\epsilon - 0.00021\ \delta\psi)T$
  - $\delta Y = \delta\epsilon - 0.00889\ \delta\psi\, T$

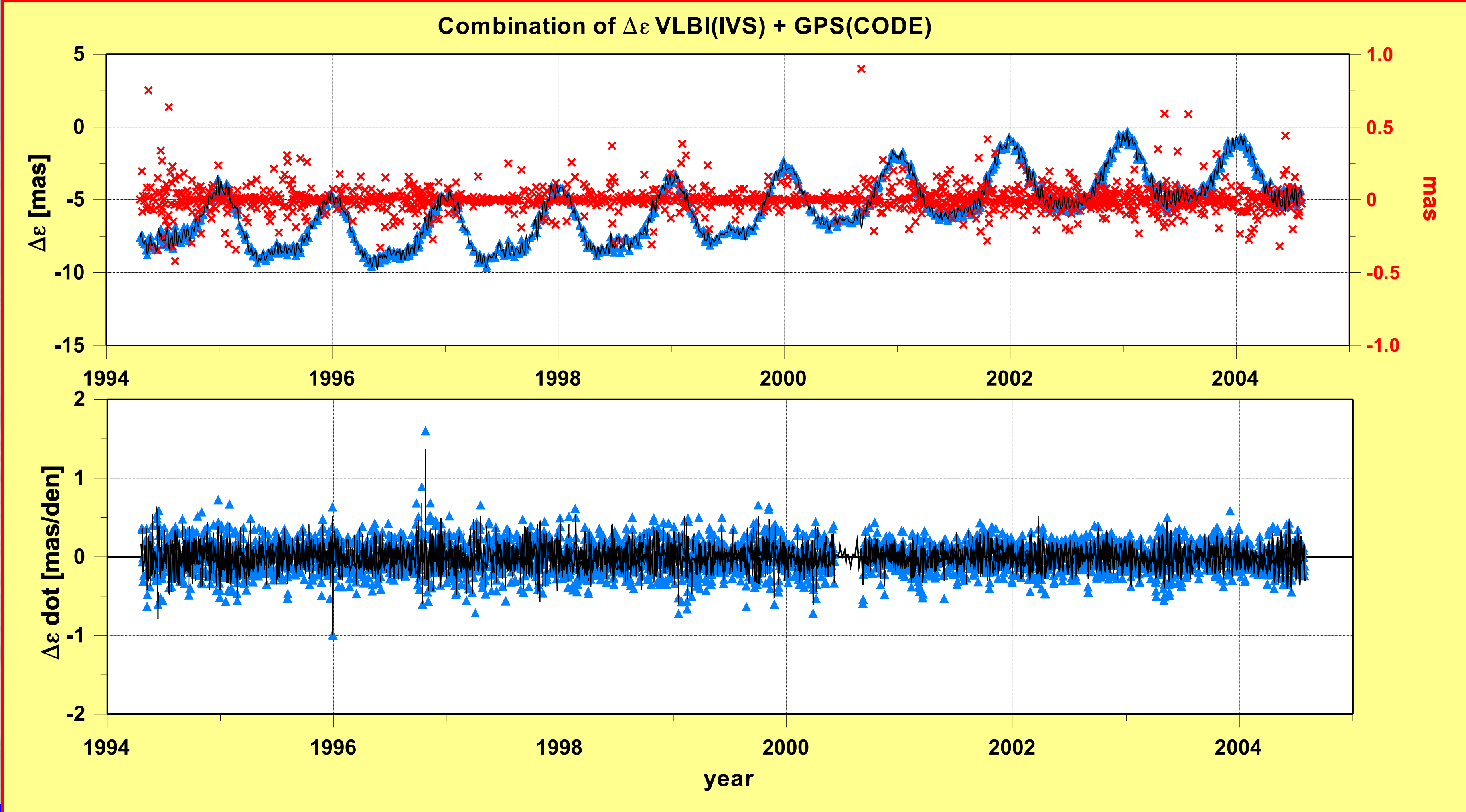
Calibration
(systematic differences, to be removed from GPS):



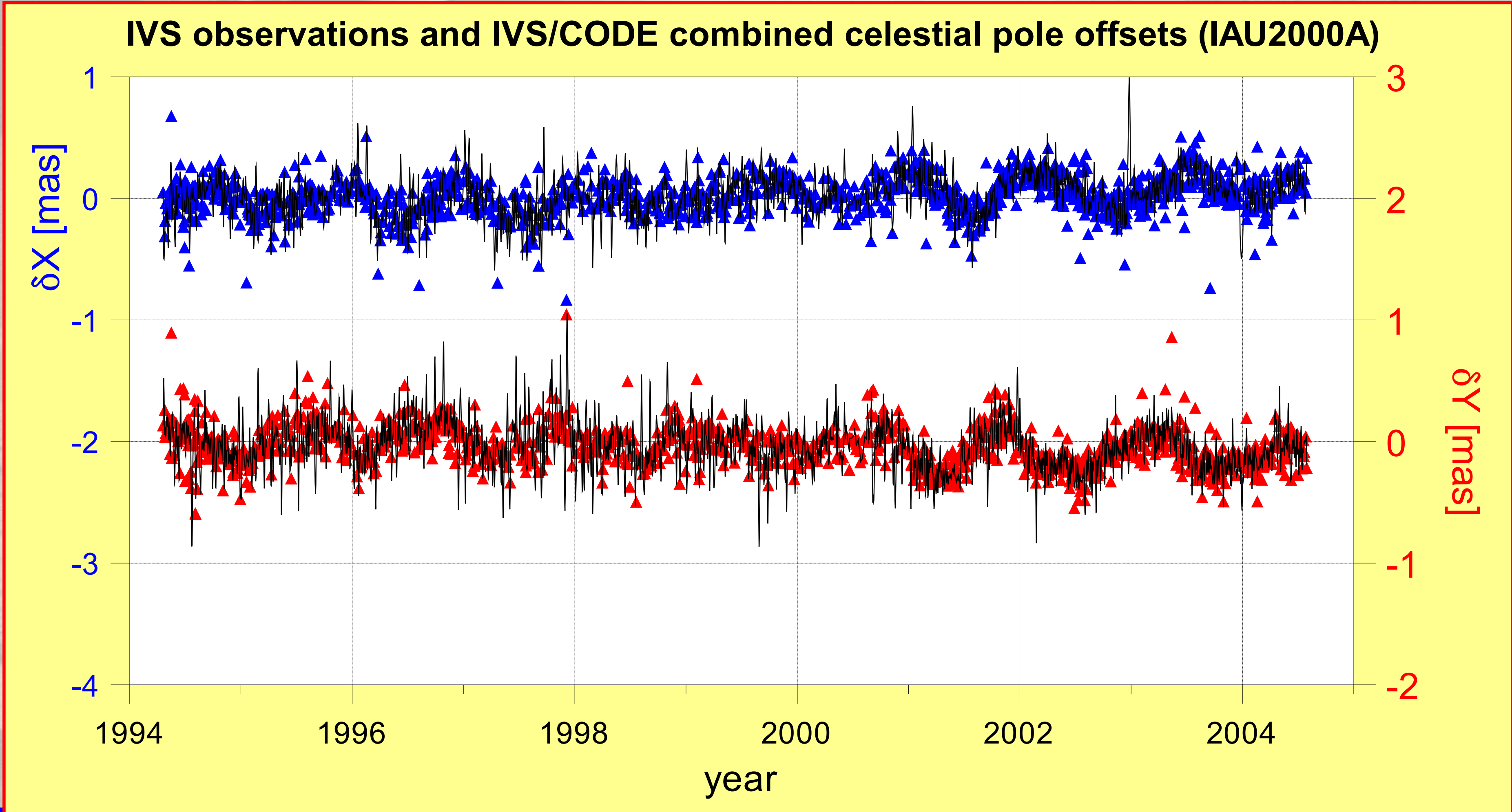
Combination in old system IAU1980 - Δψ:



Combination in old system IAU1980 - Δε:



Combination recalculated into the new system IAU2000:



Statistics of the celestial pole offsets combination IVS/CODE:

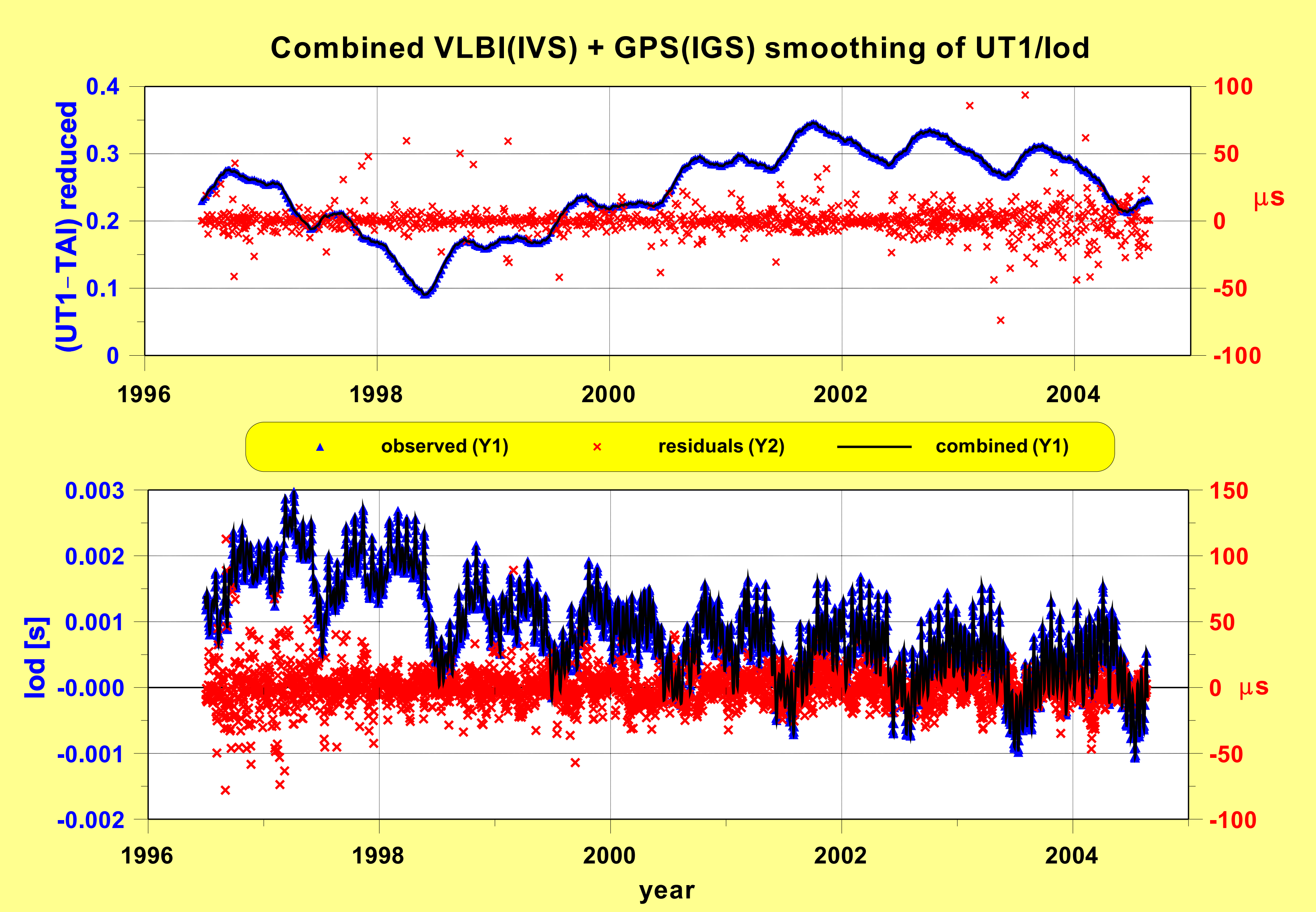
$n_{VLBI} = 1236$, $n_{GPS} = 3661$
$\epsilon = 1d^{-6}$, $\bar{\epsilon} = 0.2d^{-4}$ (coeff. of smoothing)
(corresp. to $P_{min} \sim 14d$, GPS de-weighted)

average uncertainties in	$\Delta\psi$ [mas]	$\Delta\dot{\psi}$ [mas/d]	$\Delta\varepsilon$ [mas]	$\Delta\dot{\varepsilon}$ [mas/d]
à *priori* (reported by IVS and CODE):	0.071	0.071	0.046	0.030
à *posteriori* (computed from residuals):	0.108	0.296	0.048	0.120

VLBI GPS

Combination of UT1/lod:

- We apply the method of combined smoothing to:
  - ★ VLBI data (IVS combined solution ivs04qx.eops, in the interval 1979.6-2004.6);
  - ★ GPS data (IGS combined solution igs00p02.erp, in the interval 1996.5-2004.6);
    - ★ Calibration to VLBI already done by IGS
- to obtain solution in the common interval of determination of UT1-TAI and lod (1996.5-2004.6)



Combined VLBI(IVS) + GPS(IGS) smoothing of UT1/lod
(UT1−TAI) reduced
0.4
0.3
0.2
0.1
0
100
50
µs
0
-50
-100
1996
1998
2000
2002
2004
observed (Y1)
residuals (Y2)
combined (Y1)
lod [s]
0.003
0.002
0.001
-0.000
-0.001
-0.002
150
100
50
0 µs
-50
-100
year

Statistics of the UT1/lod combination IVS/IGS:

n_{VLBI} = 973, n_{GPS} = 2973
$\epsilon = 34d^{-6}$, $\bar{\epsilon} = 34d^{-4}$ (coeff. of smoothing)
(corresp. to $P_{min} \sim 7d$)

average uncertainties in	UT1	l.o.d.
à *priori* (reported by IVS and IGS):	2.5µs	10.2µs
à *posteriori* (computed from residuals):	4.6µs	9.4µs

CONCLUSIONS:

- ♦ Combination with GPS data helps to improve the VLBI-alone solution, both in resolution and accuracy;
- ♦ Calibration of GPS-based celestial pole offset rates to VLBI in a long-term sense is necessary prior to combination:
  - ★ mismodeling of the orientation of satellite orbits in celestial frame (errors up to ±0.5mas/day);
- ♦ Accuracy of VLBI celestial pole offsets is consistent with formal errors, accuracy of GPS celestial pole offset rates is about four times lower than formal errors;
- ♦ Combination of VLBI/GPS UT1 proves that the accuracy is consistent with formal errors, for both techniques.

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- **IVS and IGS for providing their combined solution.**