GNSS zenith delays and gradients in the analysis of VLBI Intensive sessions

Kamil Teke[(1)], Johannes Böhm[(2)], Matthias Madzak[(2)], Younghee Kwak[(2)], Peter Steigenberger[(3)]

[(1)]Department of Geomatics Engineering, Hacettepe University, Ankara, Turkey

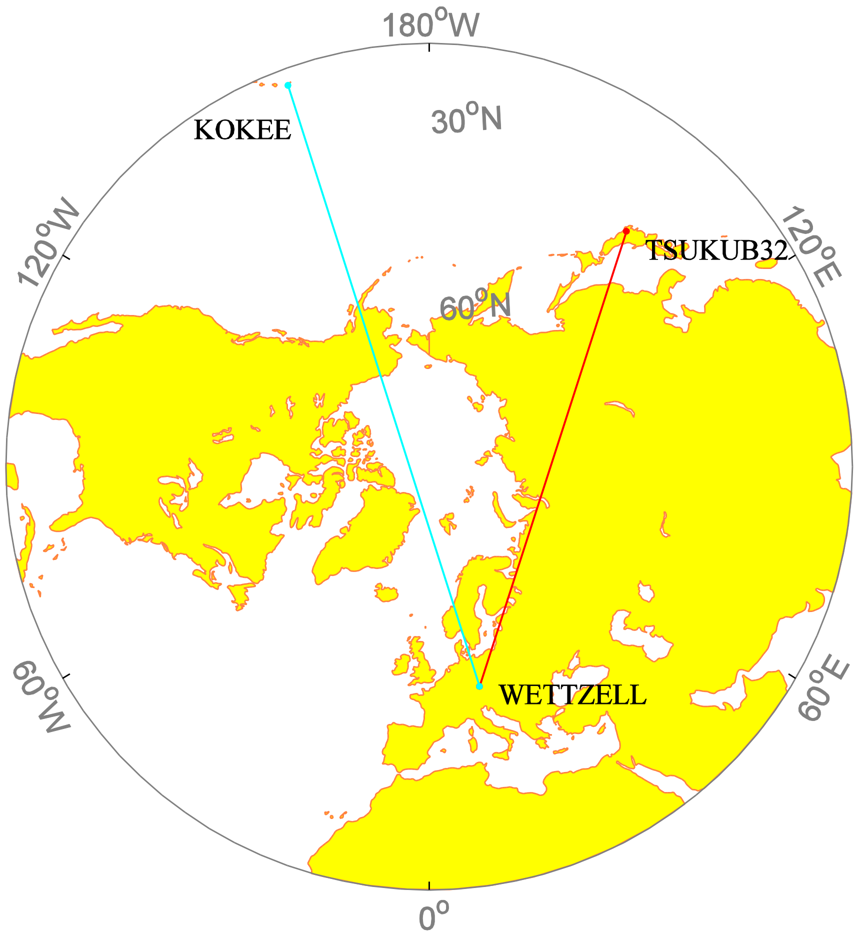
[(2)]Department of Geodesy and Geoinformation, Technische Universität Wien, Vienna, Austria

[(3)]German Space Operations Center, Deutsches Zentrum für Luft- und Raumfahrt, Oberpfaffenhofen, Germany

INT1 and INT2 sessions

- 1434 INT1 sessions (2.Jan.2008 - 31.Dec.2014)
- only the baseline: **WETTZELL-KOKEE**

- 451 INT2 sessions (5.Jan.2008 – 21.Jun.2014)
- only the baseline: **WETTZELL-TSUKUB32**



GNSS CODE zenith delays and gradients

- Bernese GNSS Software version 5.3 (Dach et al. 2007)
- Hydrostatic a priori zenith delays from 6 hourly global grids of ECMWF
- The estimated parameters from a global double difference solution are;
  - piece-wise linear zenith wet delays at 2 hours with VMF1
  - piece-wise linear gradients at 24 hours with Chen and Herring (1997)
  - station coordinates, satellite orbits, and ERP
- Elevation-dependent weighting with $\sin^2\varepsilon$ and 3 degrees elevation cut off
- Full information about the models and the analysis strategy of the CODE contribution to the 2nd IGS reprocessing campaign (repro2: 1 day solution) is provided at ftp://ftp.unibe.ch/aiub/REPRO_2013/CODE_REPRO_2013.ACN)

Calculation of GNSS slant wet delays and azimuthal asymmetric delays at VLBI observation epochs

GNSS ZWD and gradients are linearly interpolated to the observation epochs of INT1 and INT2 sessions

ZWD_{GNSS}@VLBI are derived after correcting the excess delay due to the height differences between the co-located VLBI and GNSS antennas using mean zenith total troposphere ties

ZWD_{GNSS}@VLBI are mapped to the observation line of sight with VMF1 and gradients with Chen and Herring (1997)

VLBI Solutions (Troposphere specific parameterisation)

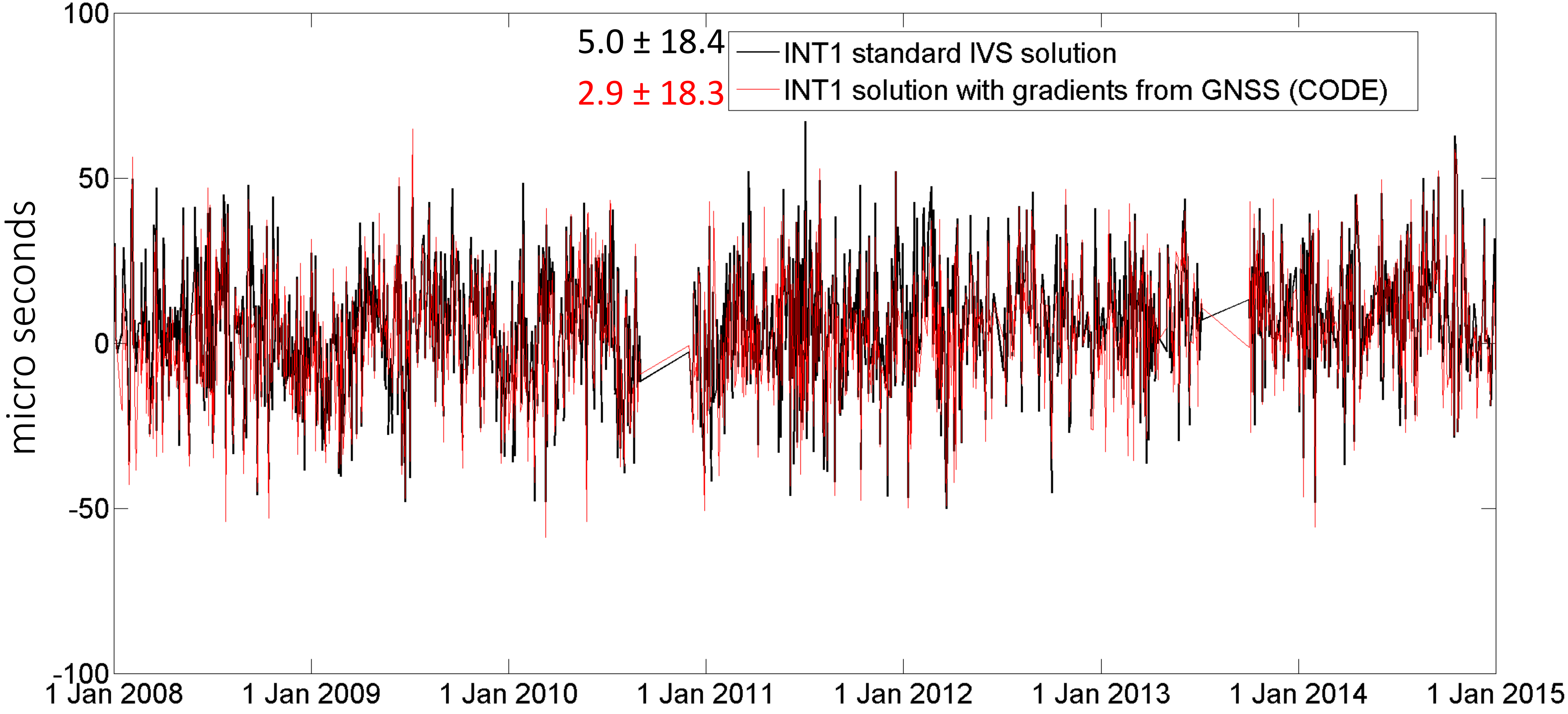
	Estimated parameters	A priori reduced from each observation
standard Intensive solution	ZWD offset, offset and rate between clocks, UT1	ZHD
solution with gradients from GNSS CODE	ZWD offset, offset and rate between clocks, UT1	ZHD, **gradients***
solution with ZWD and gradients from GNSS CODE	ZWD offset, offset and rate between clocks, UT1	ZHD, **ZWD***, **gradients***
solution with ZWD and gradients from GNSS CODE without height corrections	offset and rate between clocks, UT1	ZHD, **ZWD***, **gradients***

ZWD*, **gradients*** are from GNSS CODE

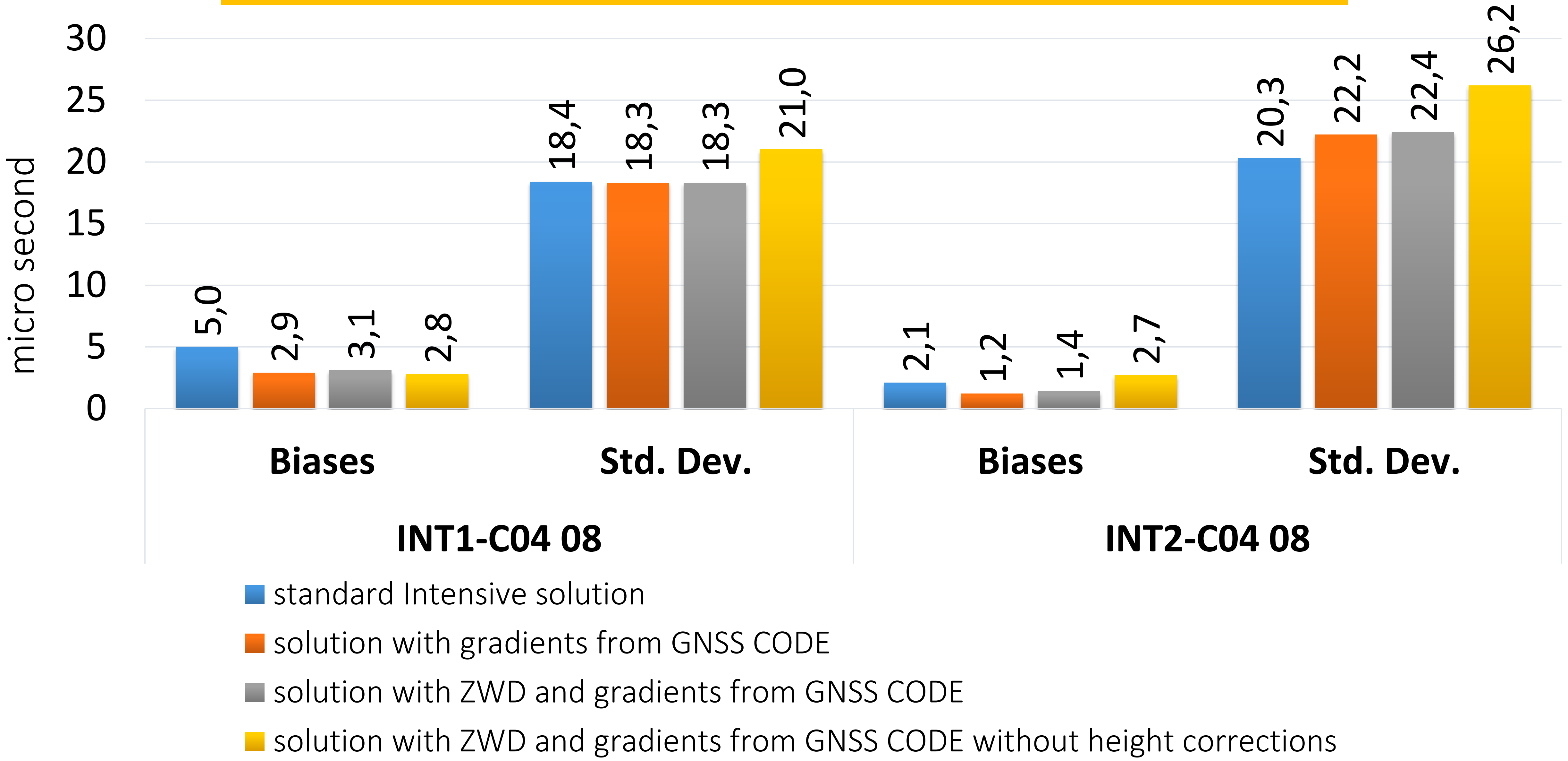
VLBI Solutions (common parameterisation)

- Vienna VLBI Software version 2.2 (Böhm et al.2012)
- Gauss-Markoff least-squares adjustment
- Elevation-dependent weighting and elevation cut off are not applied
- ZHD from the surface pressure values (Saastamoinen 1972, Davis et al. 1985)
- VMF1, Böhm et al. (2006) and Chen and Herring (1997)
- Source coordinates are fixed to ICRF2 (Fey et al. 2009)
- Antenna coordinates are fixed to VieTRF13b (Krásná et al. 2014)
- Nutation offsets are fixed to IAU2000A model plus IERS C04 08 (Bizouard and Gambis 2009) corrections.
- Polar motion coordinates fixed to IERS C04 08 plus high frequency tidal terms (Petit and Luzum 2010)
- Geodynamic corrections e.g. Petrov and Boy (2004), Lyard et al. (2006) are introduced to antenna coordinates for each observation a priori to the parameter estimation
- One offset and a rate between clocks are estimated
- ΔUT1 is estimated with respect to IERS C04 08 (zonal tides and high frequency tidal terms are corrected a priori to the adjustment)

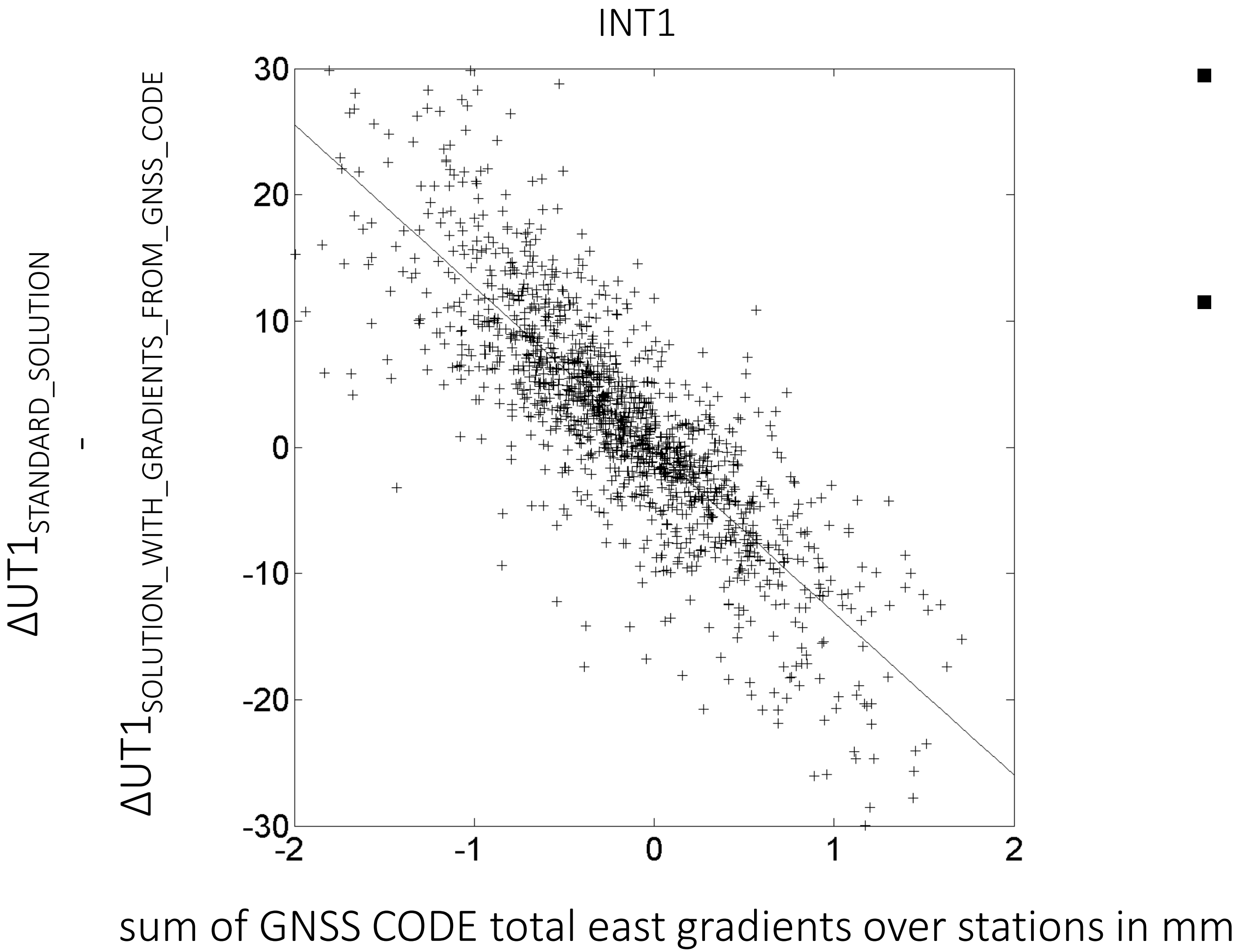
ΔUT1 estimates of INT1 w.r.t. C04 08



biases and standard deviations of ΔUT1 differences



Linear impact of east gradients on ΔUT1 estimates of INT1 and INT2



- 1 mm sum of east gradients over the stations have a linear impact of about 13 µs on ΔUT1 for INT1 and 11 µs for INT2
- no significant linear impact of the sum of north gradients over the stations on ΔUT1 for INT1 and INT2

LOD from ΔUT1 estimates of Intensive sessions

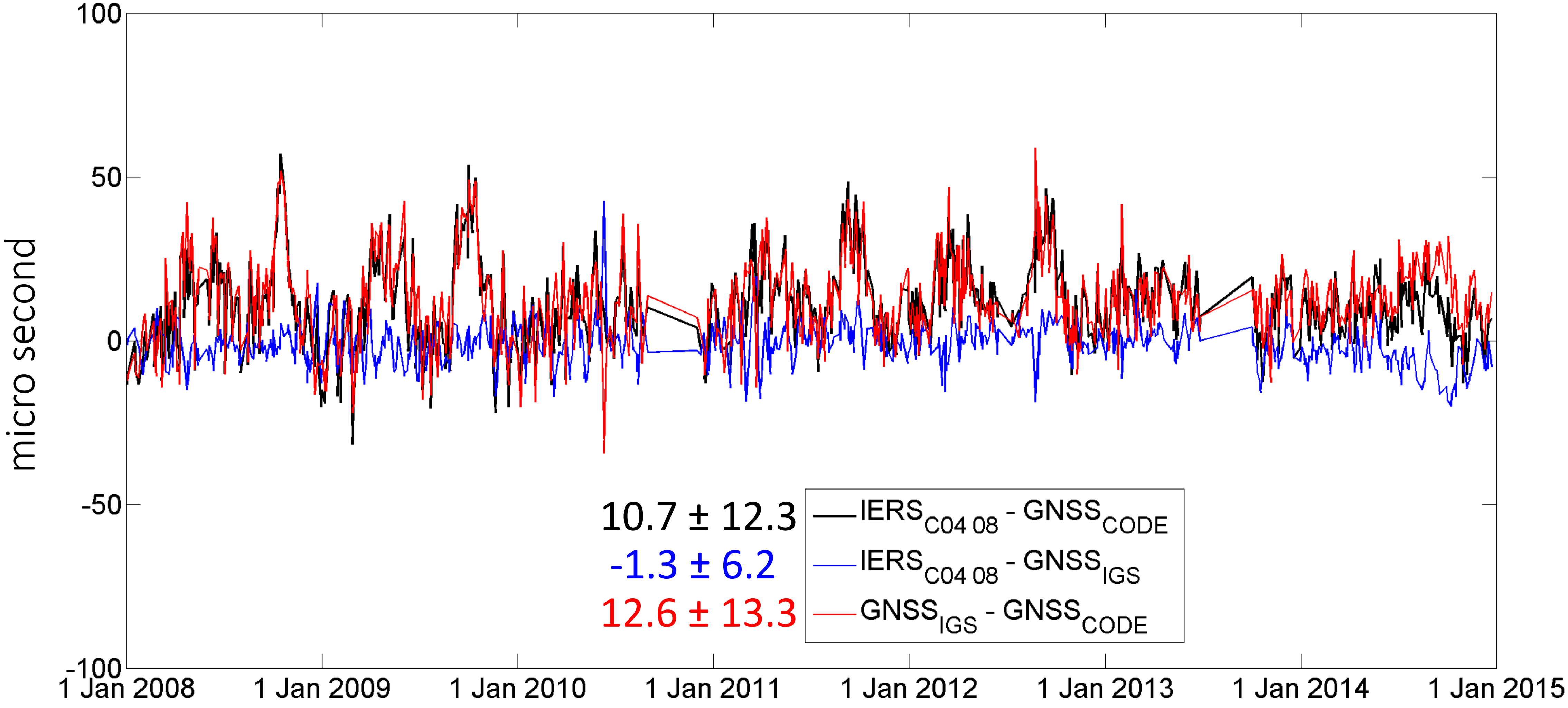
Calculation of LOD from ΔUT1 estimates:

$$\mathrm{LOD}(t_0)=\left(\frac{\Delta\mathrm{UT1}(t_2)-\Delta\mathrm{UT1}(t_1)}{t_2-t_1}\right)\times 1\,\mathrm{day} \qquad (t_2-t_1< 1.2\,\mathrm{day})$$

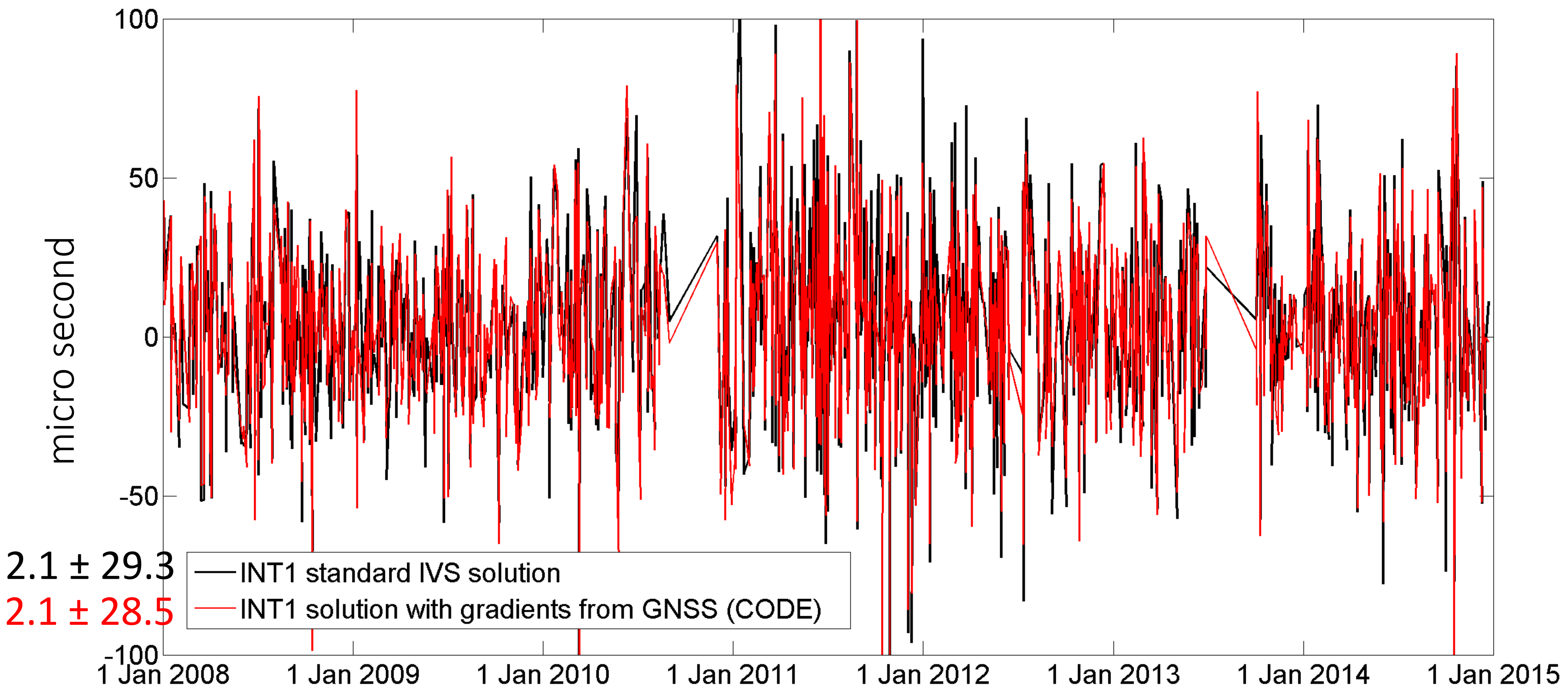
Calculation of LOD formal errors from those of ΔUT1 estimates using general law of error propagation:

$$\sigma_{\mathrm{LOD}(t_0)}=\frac{\sqrt{{\sigma_{\Delta\mathrm{UT1}(t_1)}}^2+{\sigma_{\Delta\mathrm{UT1}(t_2)}}^2}}{t_2-t_1}$$

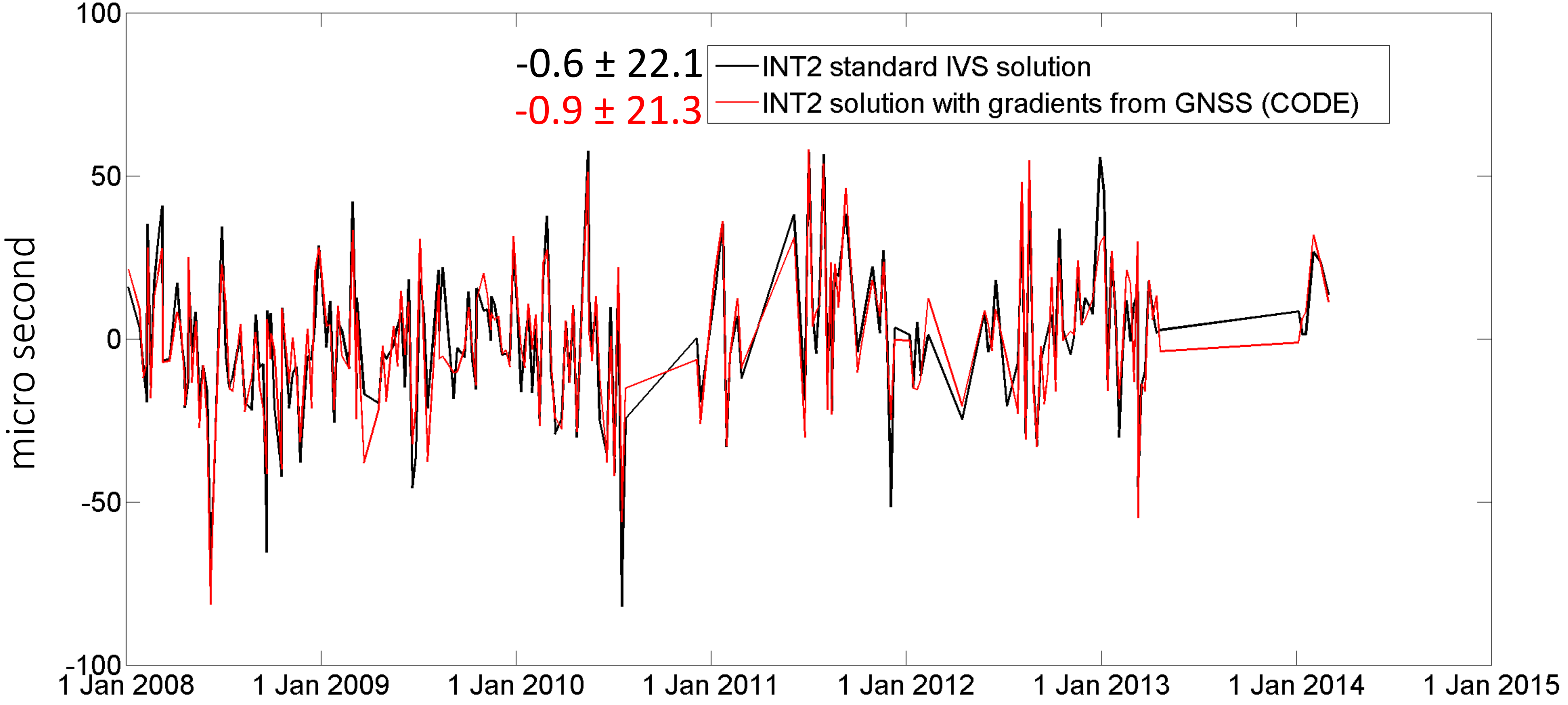
LOD differences between C04 08, CODE, and IGS at INT1 LOD epochs



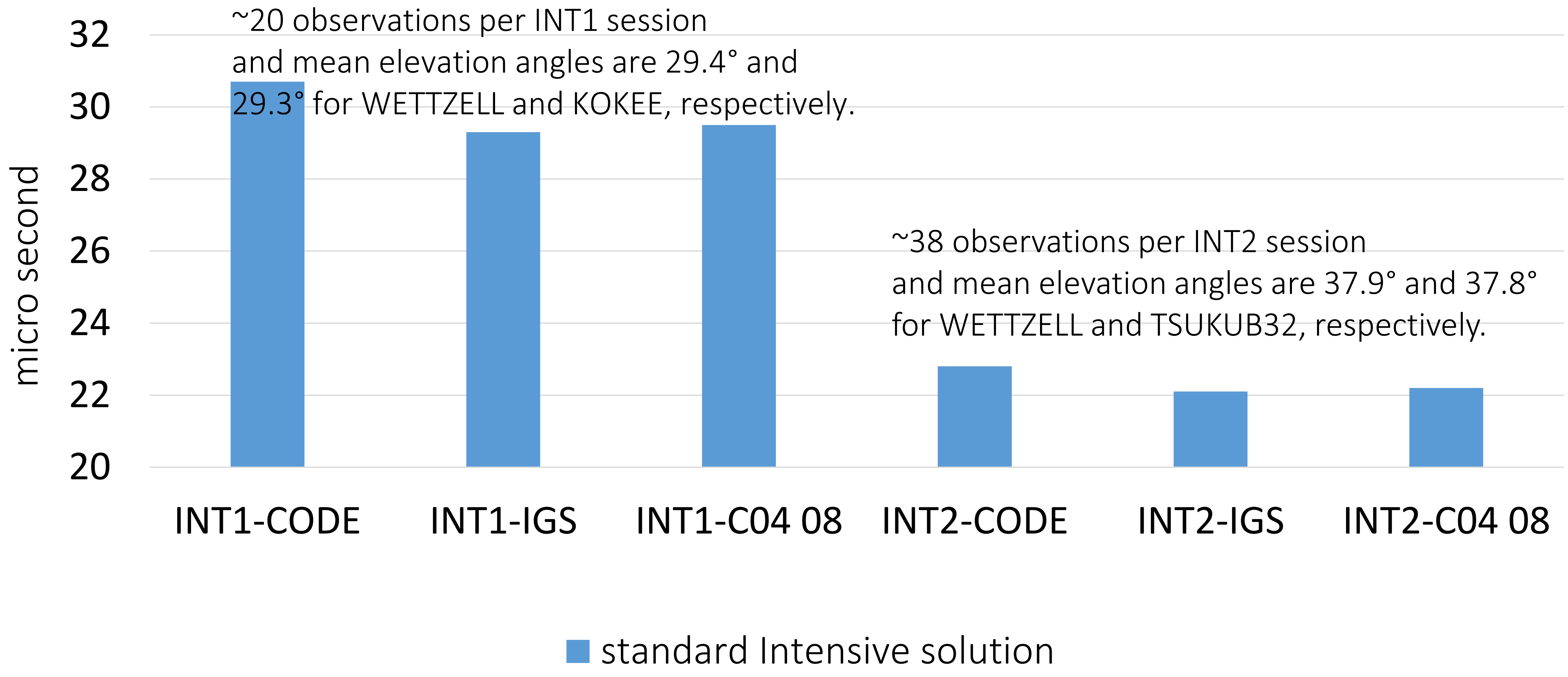
LOD differences: INT1 – IGS at INT1 LOD epochs



LOD differences: INT2 – IGS at INT2 LOD epochs



standard deviations of length-of-day (LOD) differences



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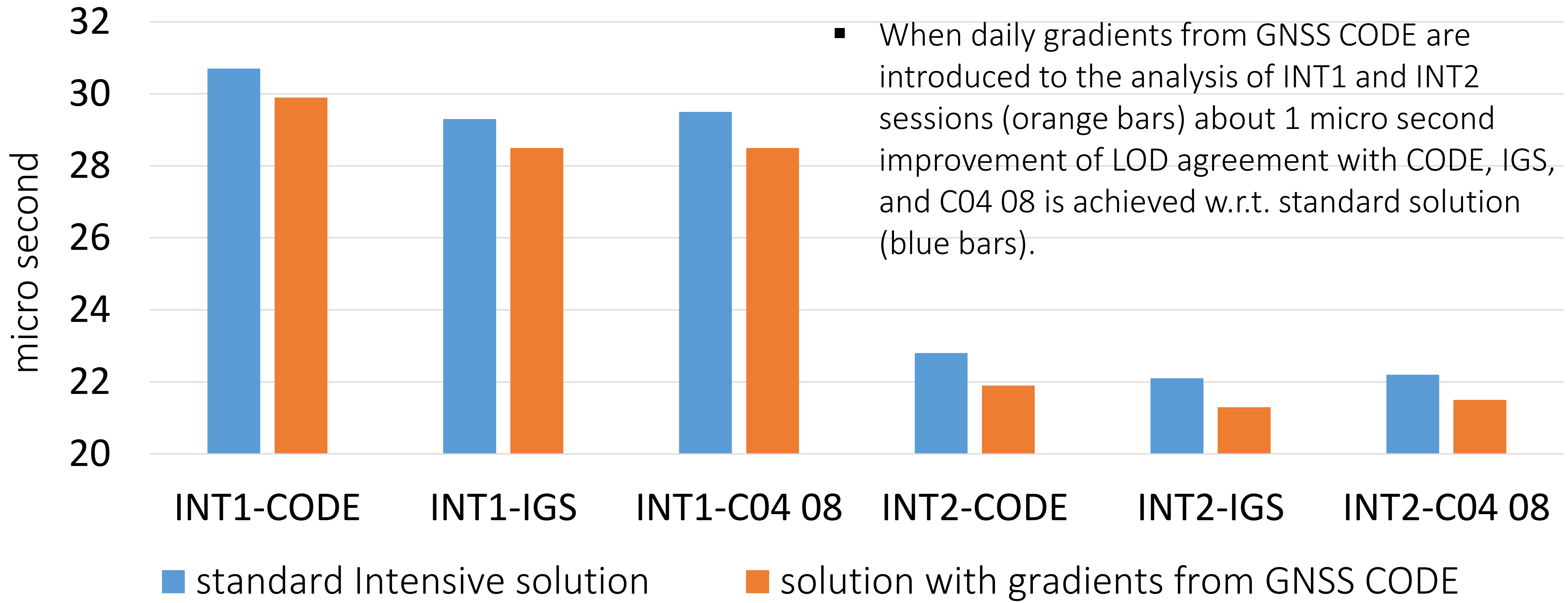
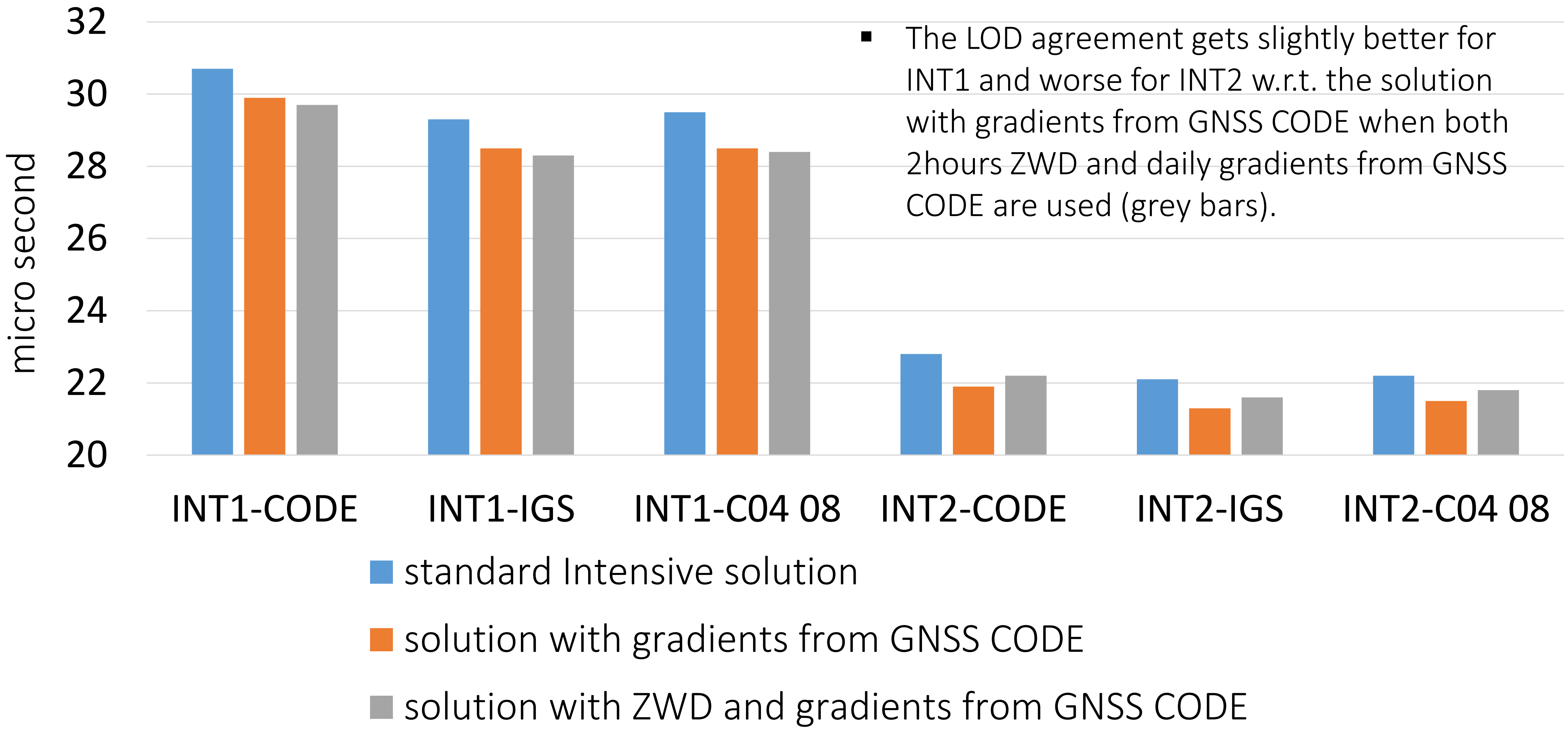


- When daily gradients from GNSS CODE are introduced to the analysis of INT1 and INT2 sessions (orange bars) about 1 micro second improvement of LOD agreement with CODE, IGS, and C04 08 is achieved w.r.t. standard solution (blue bars).

- LOD from CODE (at 12 UT), IGS (at 12 UT), and C04 08 (at midnight) are lagrange interpolated to the LOD epochs of Intensive sessions before calculating the difference

standard deviations of length-of-day (LOD) differences



- The LOD agreement gets slightly better for INT1 and worse for INT2 w.r.t. the solution with gradients from GNSS CODE when both 2hours ZWD and daily gradients from GNSS CODE are used (grey bars).

Conclusions

- There is a significant linear impact of east gradients on ΔUT1 estimates of Intensive sessions i.e. about 13 µsec per 1 mm sum of east gradients over the observing stations for INT1, and about 11 µsec for INT2.
- INT2 reveals a better LOD agreement than INT1 with GNSS CODE, IGS, and C04 08 in terms of mean biases and standard deviations of LOD differences.
- We get the best agreement of LOD, in standard deviation of LOD differences, between IGS and when ZWD are estimated and gradients are introduced from GNSS CODE with the value of 21.3 µsec.
- 1 micro second improvement of LOD agreement with CODE, IGS, and C04 08 with respect to the standard solution is obtained when daily gradients from GNSS CODE are introduced to the analysis of INT1 and INT2 sessions.
- We do not see any additional significant improvement of LOD when 2 hourly GNSS CODE zenith wet delays are reduced from Intensive observations a priori to the parameter estimation.

Thanks for your attention!