Near real-time monitoring of UT1 with geodetic VLBI

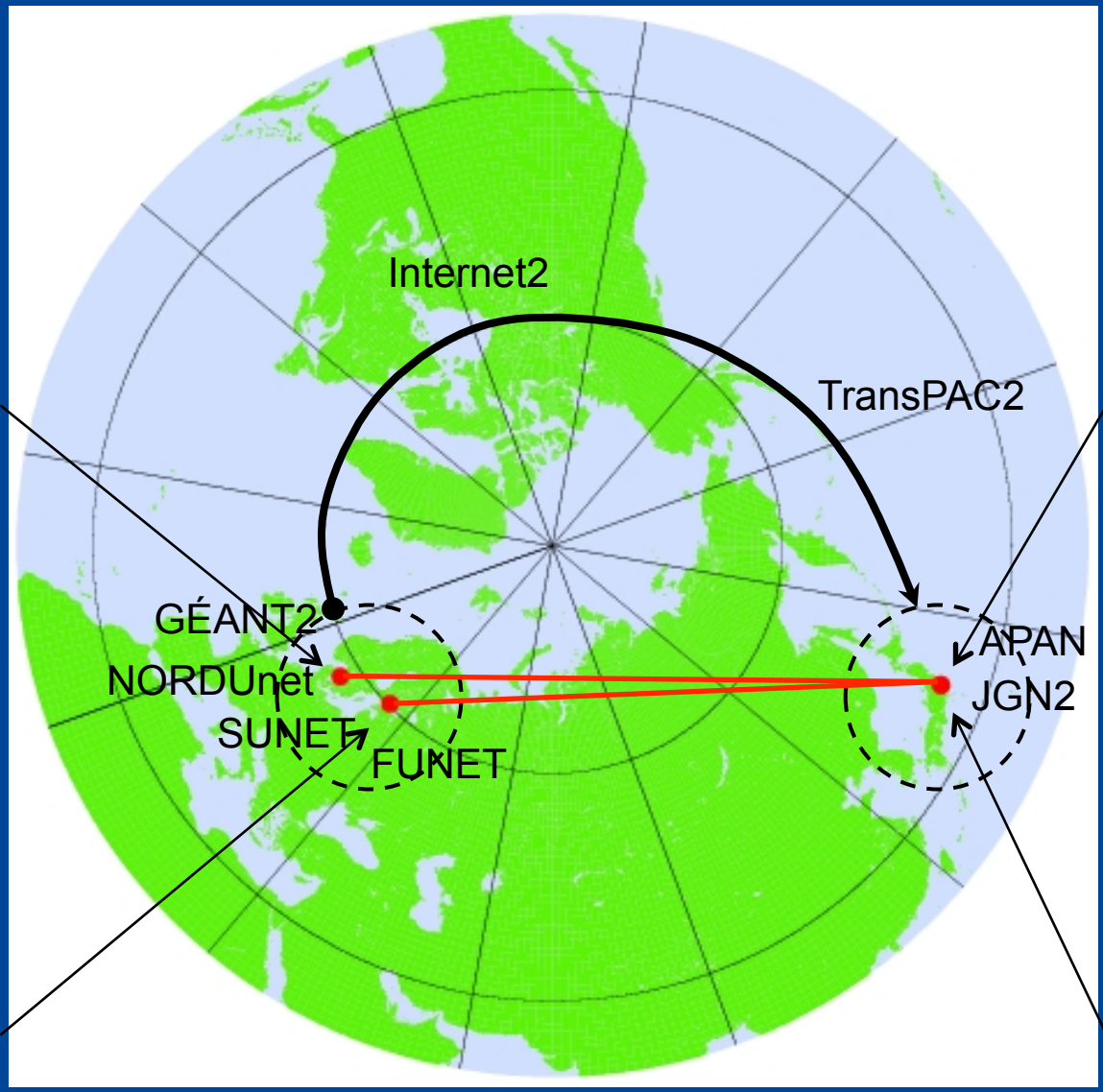
R. Haas, T. Hobiger, M. Sekido, Y. Koyama, T. Kondo, H. Takiguchi, S. Kurihara, K. Kokado, D. Tanimoto, K. Nozawa, M. Uunila, J. Wagner, J. Ritakari, A. Mujunen

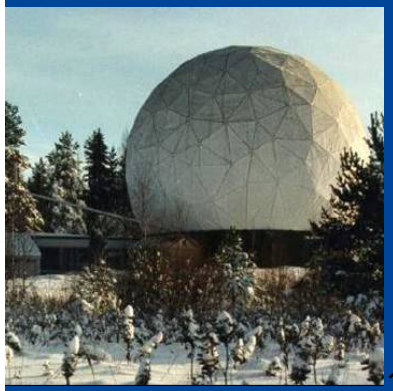
A Fennoscandian-Japanese project:

- Sweden: Onsala Space Observatory (OSO), Chalmers University of Technology
- Japan: National Institute of Information and Communications Technology (NICT), Koganei, and Kashima Space Research Center; Geospatial Information Authority of Japan (GSI), Tsukuba; Advanced Engineering Services (AES) Co. Ltd.
- Finland: Metsähovi Radio Observatory (MRO), Helsinki University of Technology

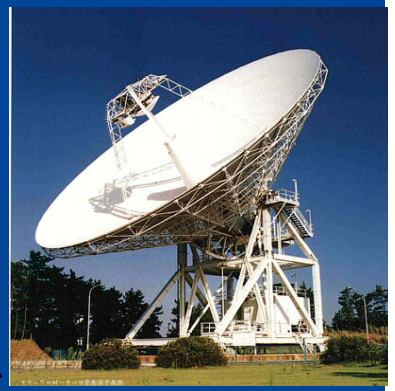
Onsala (20m)

Tsukuba (32m)





Metsähovi (14m)

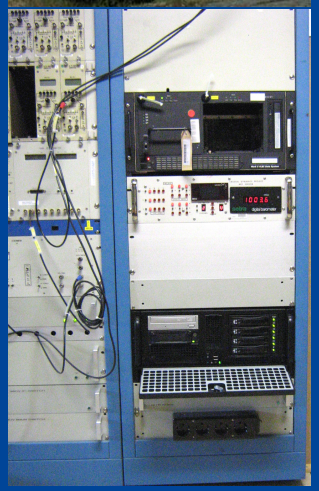


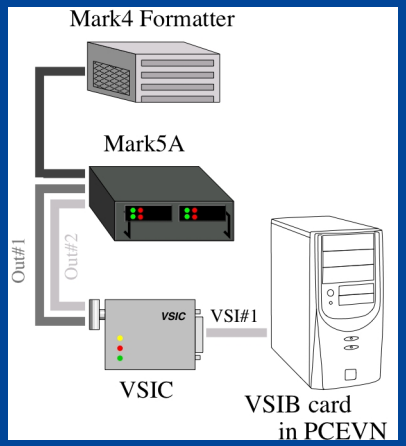
Kashima (34m)

Objectives of the project:

1. Achieve low latency for dUT1 results
   a) ’Intensive-style’ i.e. 1h INT-sessions
   b) Ultra-rapid-24h. i.e. during standard IVS-24h-sessions
   c) ’long intensives’, i.e. several hours INT
2. Effect of different VLBI data rates
3. Consistency of dUT1 observed simultaneously on parallel baselines

Example for data acquisition, data transfer and processing





Mark5A/PCEVN

(128/ 256/512Mbps)

Tsunami

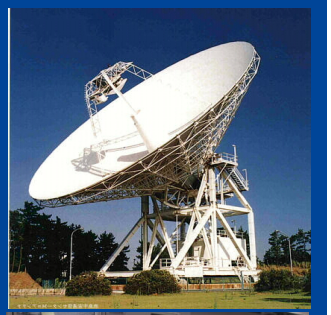
Mk4

Conversion
Mk4 => K5

K5

K5

Correlation:
K5 software
Correlator on
PC cluster



K5/VSSP

Automated:
- Data conversion
- Correlation
- Data analysis

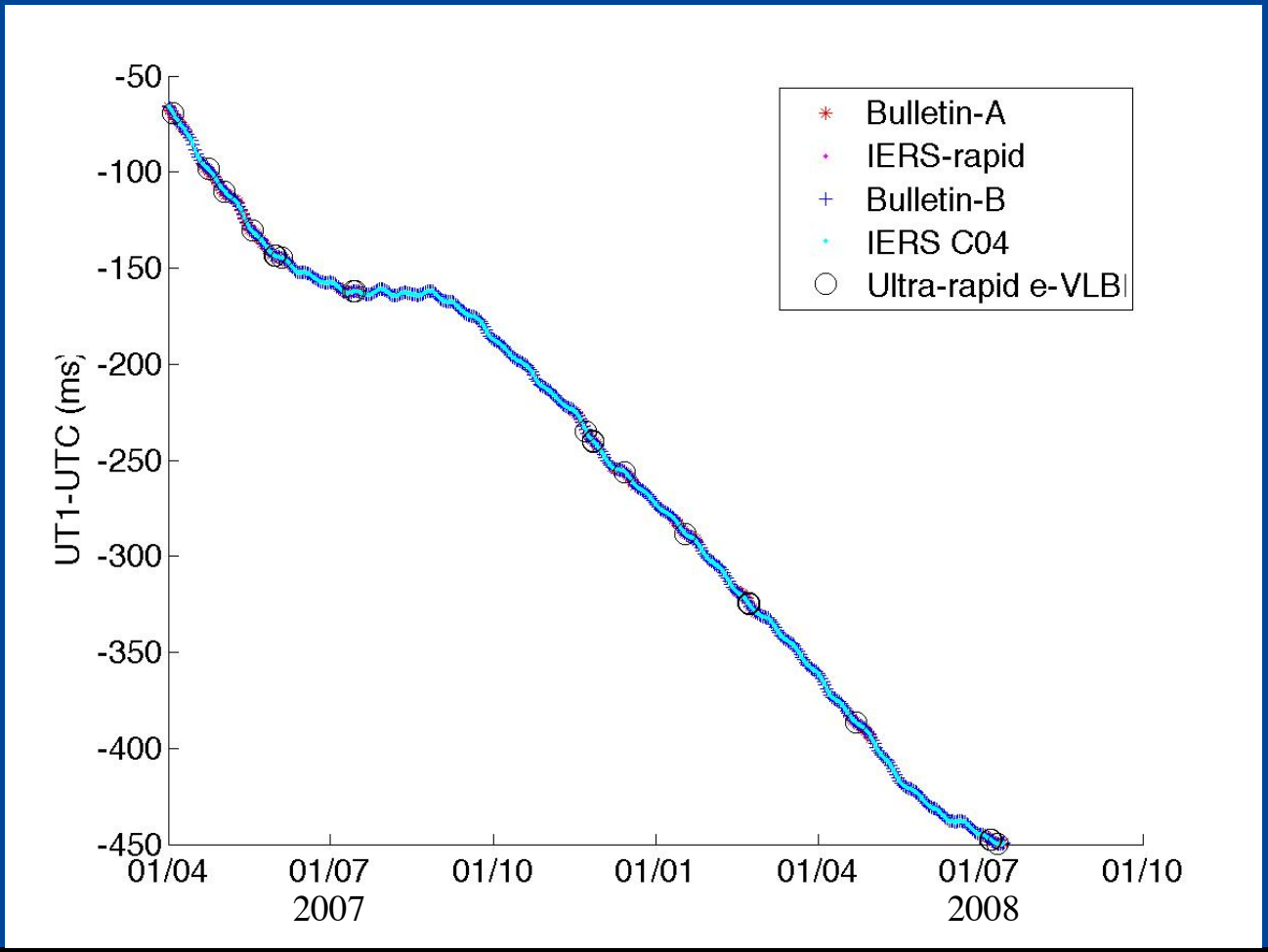
’Intensive-style’ ultra-rapid experiments:

- Start in March 2007
- 41 successful 1h-sessions (Onsala: 35, Kashima: 30, Tsukuba: 11, Metsähovi: 4, Wettzell: 2)
- Latency improved from several hours to a couple of minutes after end of observations
- World record in February 2008 on the baseline Onsala – Tsukuba: dUT1-results within 3.5 minutes after the end of observations (!)

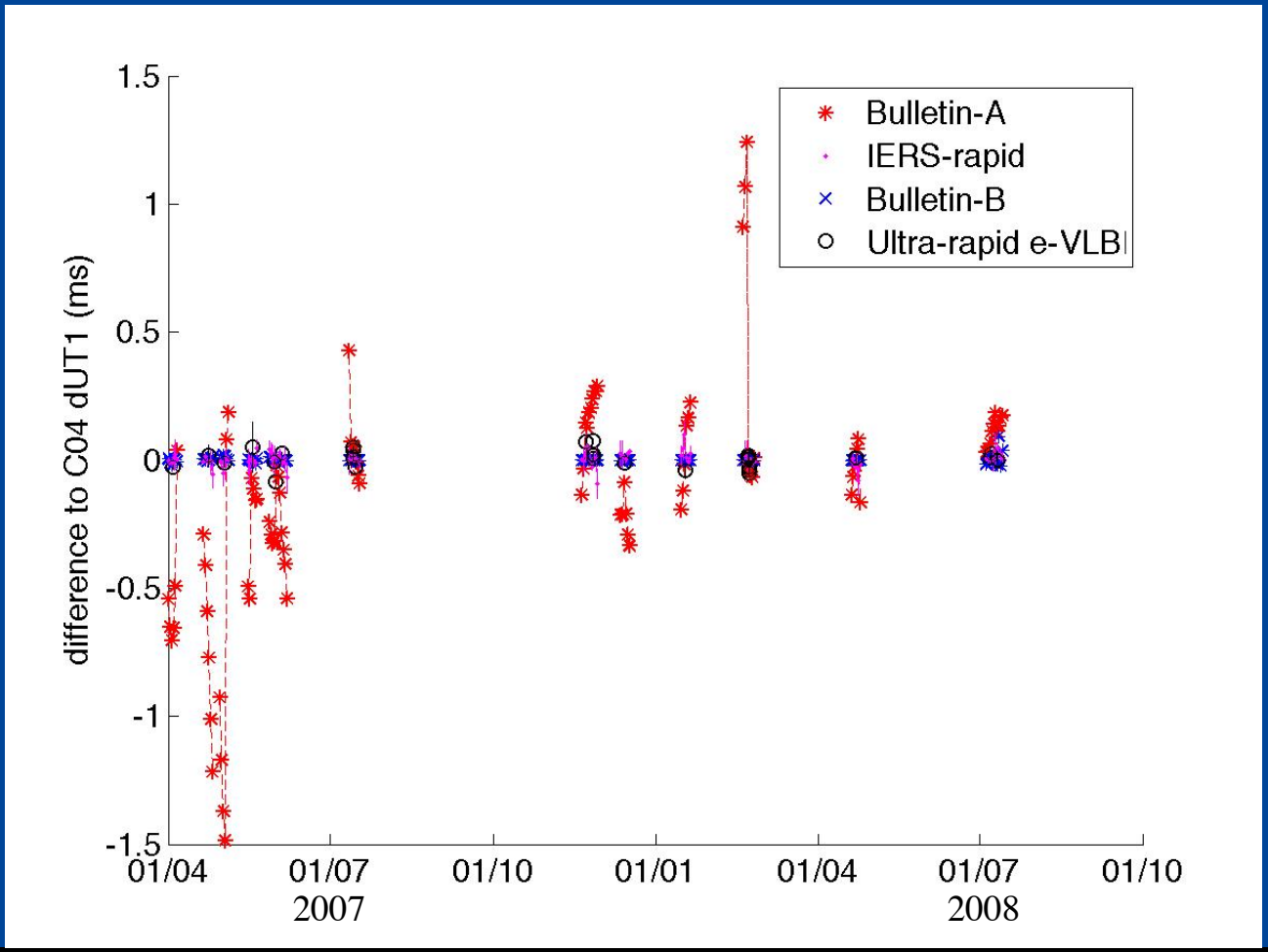
Problems that we had to fight with:

- Unattended telescopes stopped observing
- Difficult to get telescope time for parallel baseline observations
- Scheduling mistakes (e.g. bandwidth)
- Wrong equipment setup or equipment failures (e.g. videoconvertors)
- Data transfer crashed
- ...

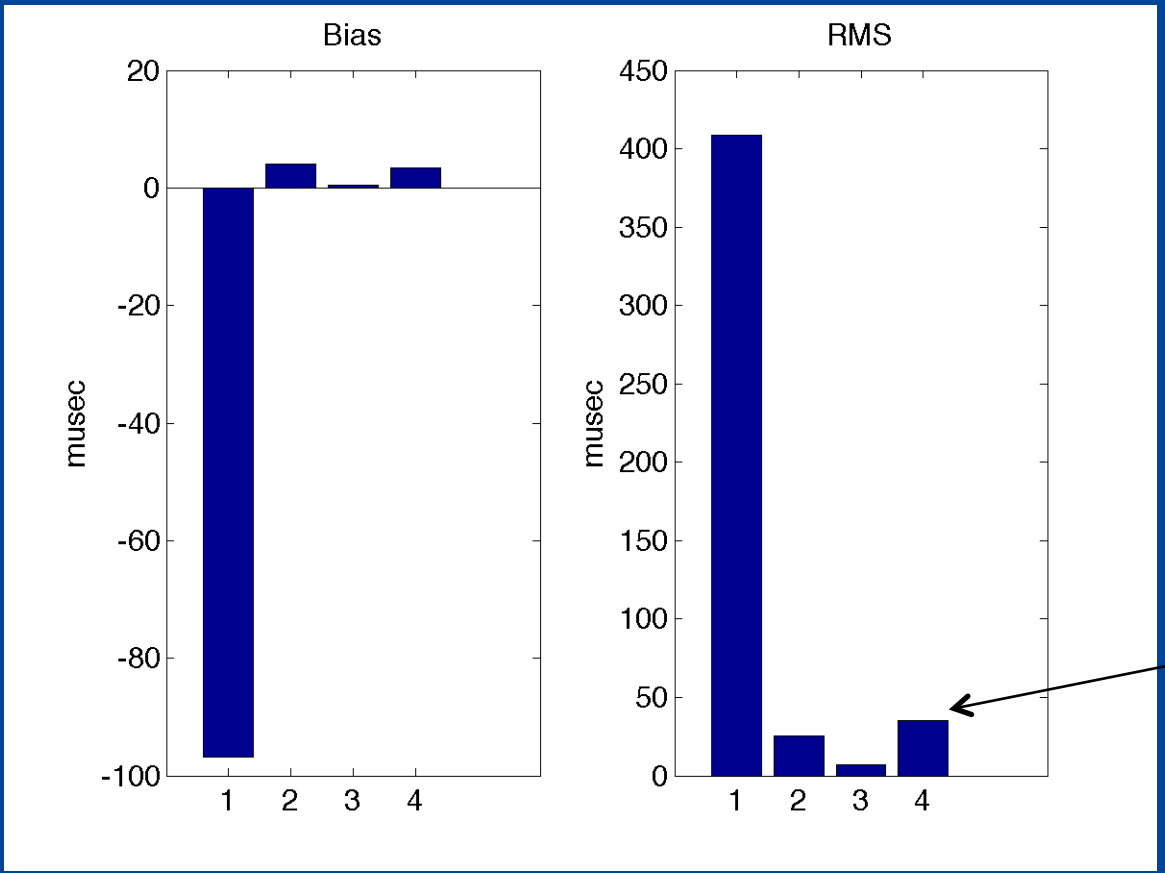
Comparison of the dUT1 results:



Comparison to IERS C04 series:



Comparison w.r.t. C04:



32.8 μs

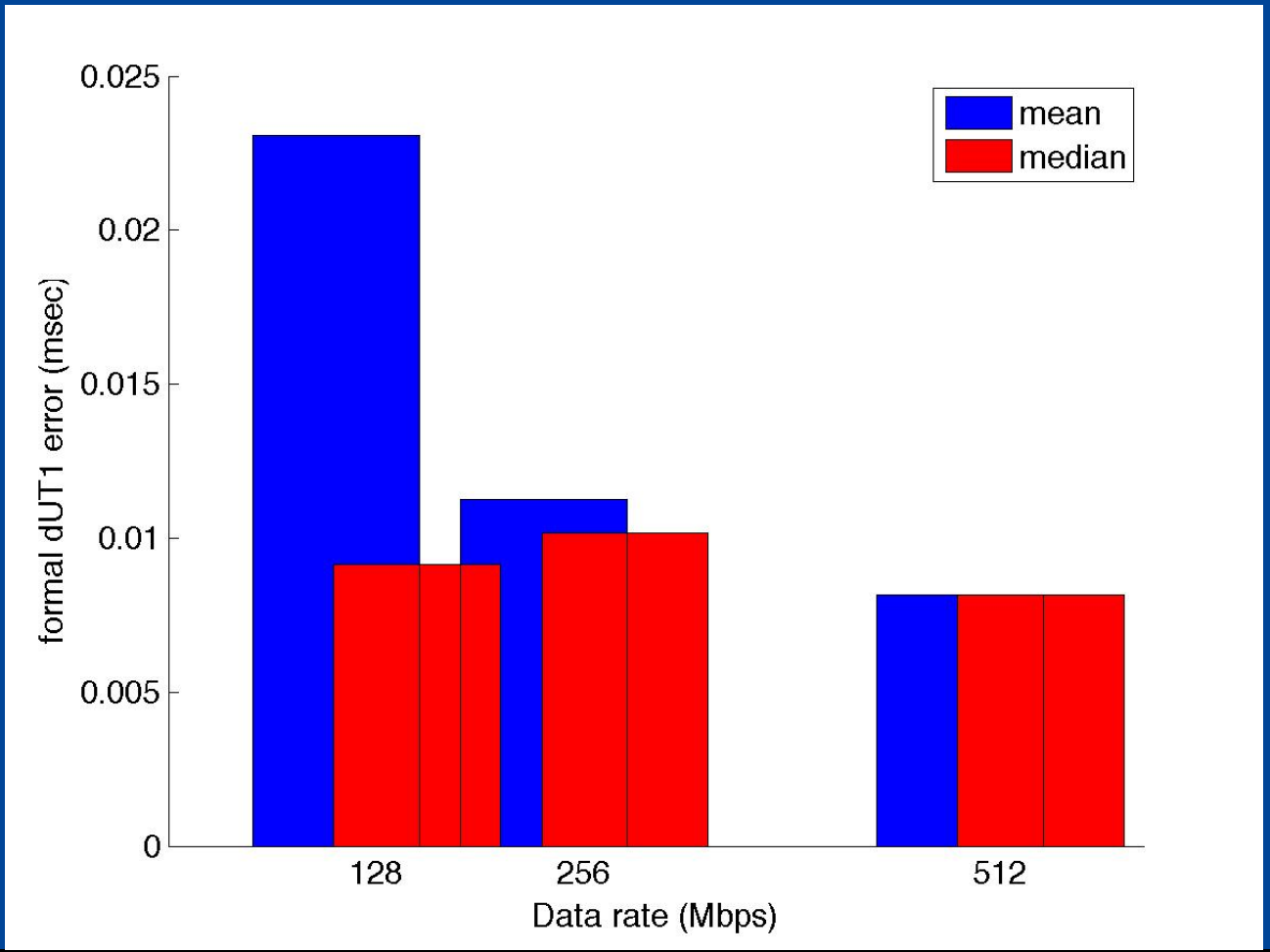
1 Bulletin-A 2 IERS-rapid 3 Bulletin-B 4 UR e-VLBI

RMS-differences w.r.t. C04:

- Bulletin-A: 440.3 (μs)
- IERS-rapid: 28.1 (μs)
- Bulletin-B: 12.7 (μs)
- Ultra-rapid: 32.8 (μs)

- Ultra-rapid e-VLBI roughly on the same level as the IERS-rapid solutions

Effect of data rate on formal uncertainties:



Agreement on almost parallel baselines?

- Unfortunately only very few simultaneous sessions on almost parallel baselines
- Reason: difficult to get telescope time or equipment failures
- Session on 2007-07-14 with 4 telescopes: Onsala, Wettzell, Kashima, Tsukuba
- RMS-agreement: 16.7 μs

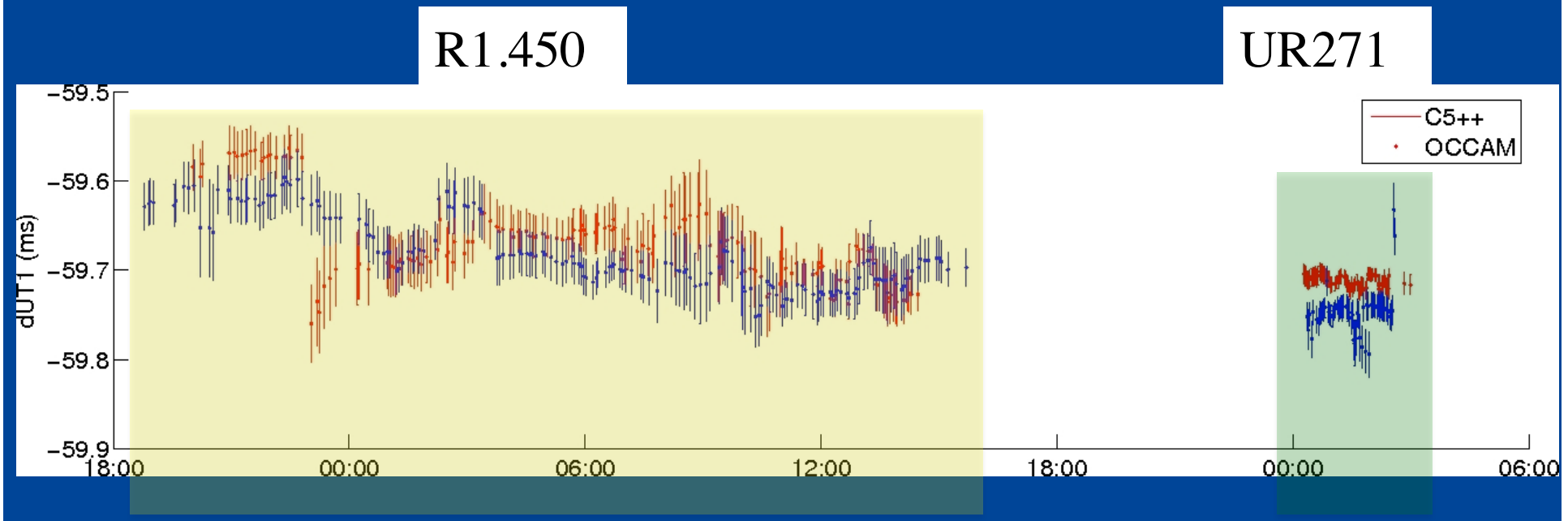
Ultra-rapid-24h dUT1

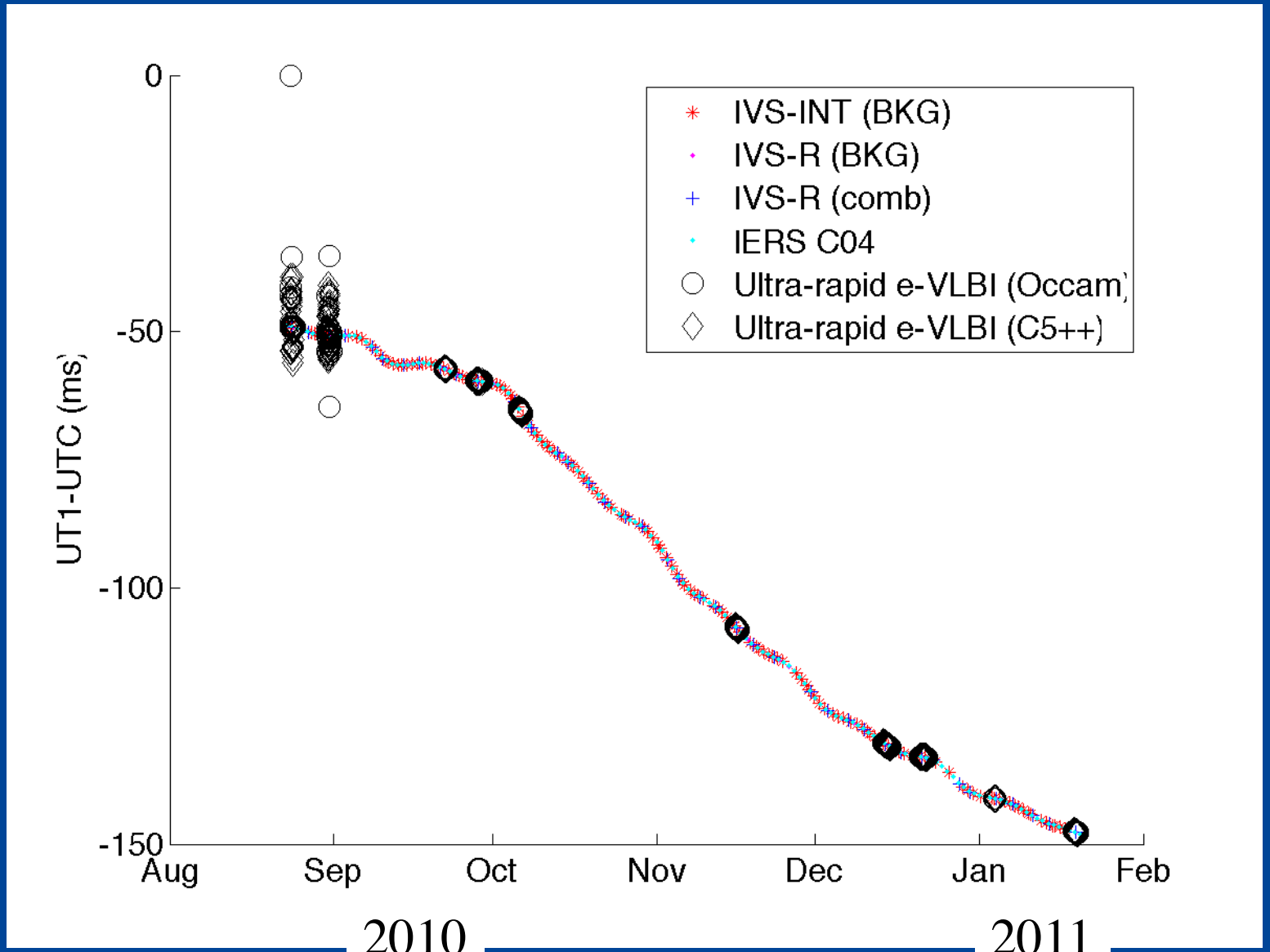
- Standard IVS-sessions that include both Onsala and Tsukuba, e.g. R1, RD, T2
- Potential problem: non-optimized schedules
- Real-time data transfer from Onsala to Tsukuba, data conversion to K5-format
- Near real-time correlation On-Ts
- First analysis when 35 scans are available
- 2009-2011: 15 R1-, 2 T2-, 6 RD-sessions

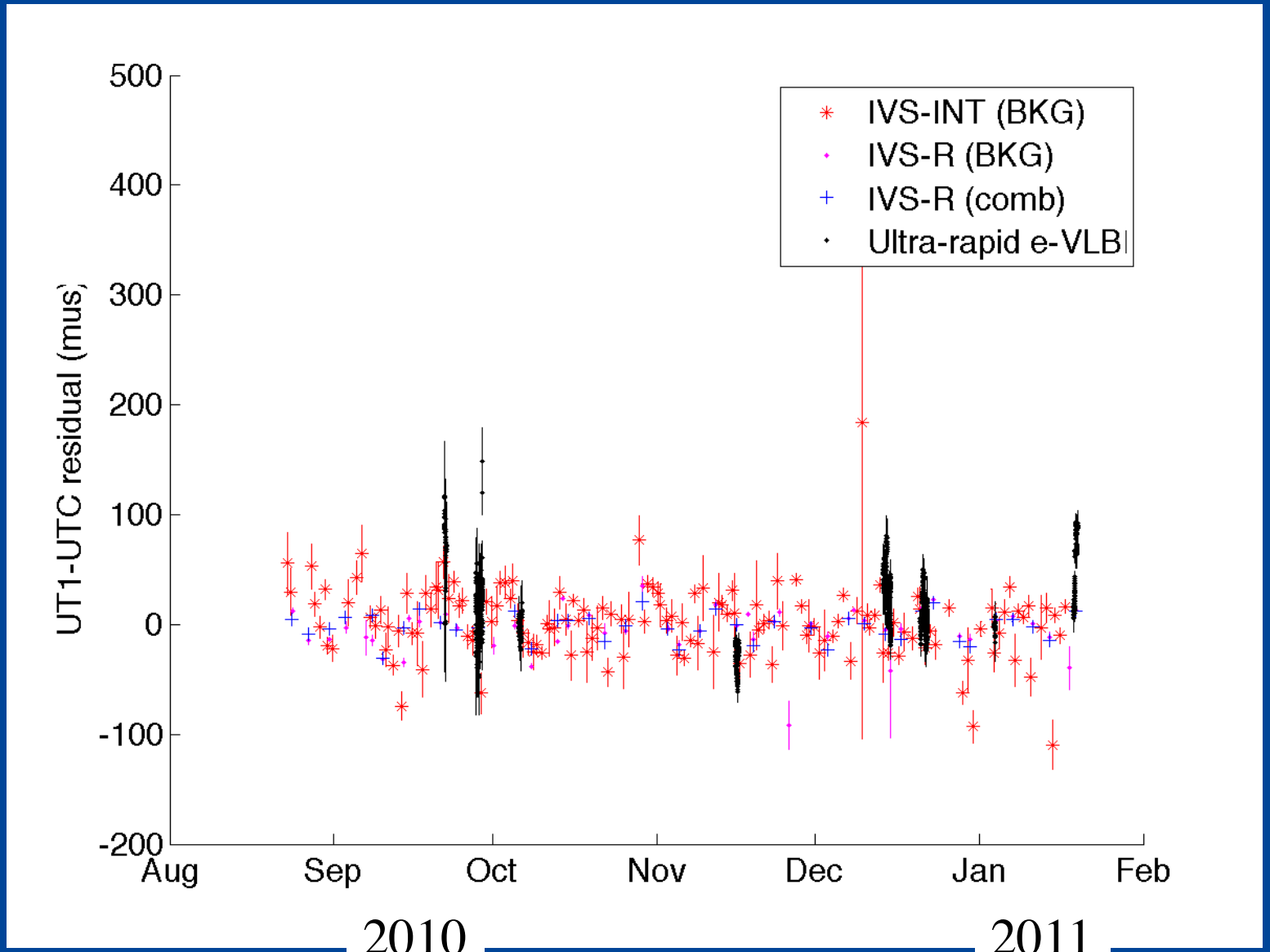
Ultra-rapid-24h dUT1

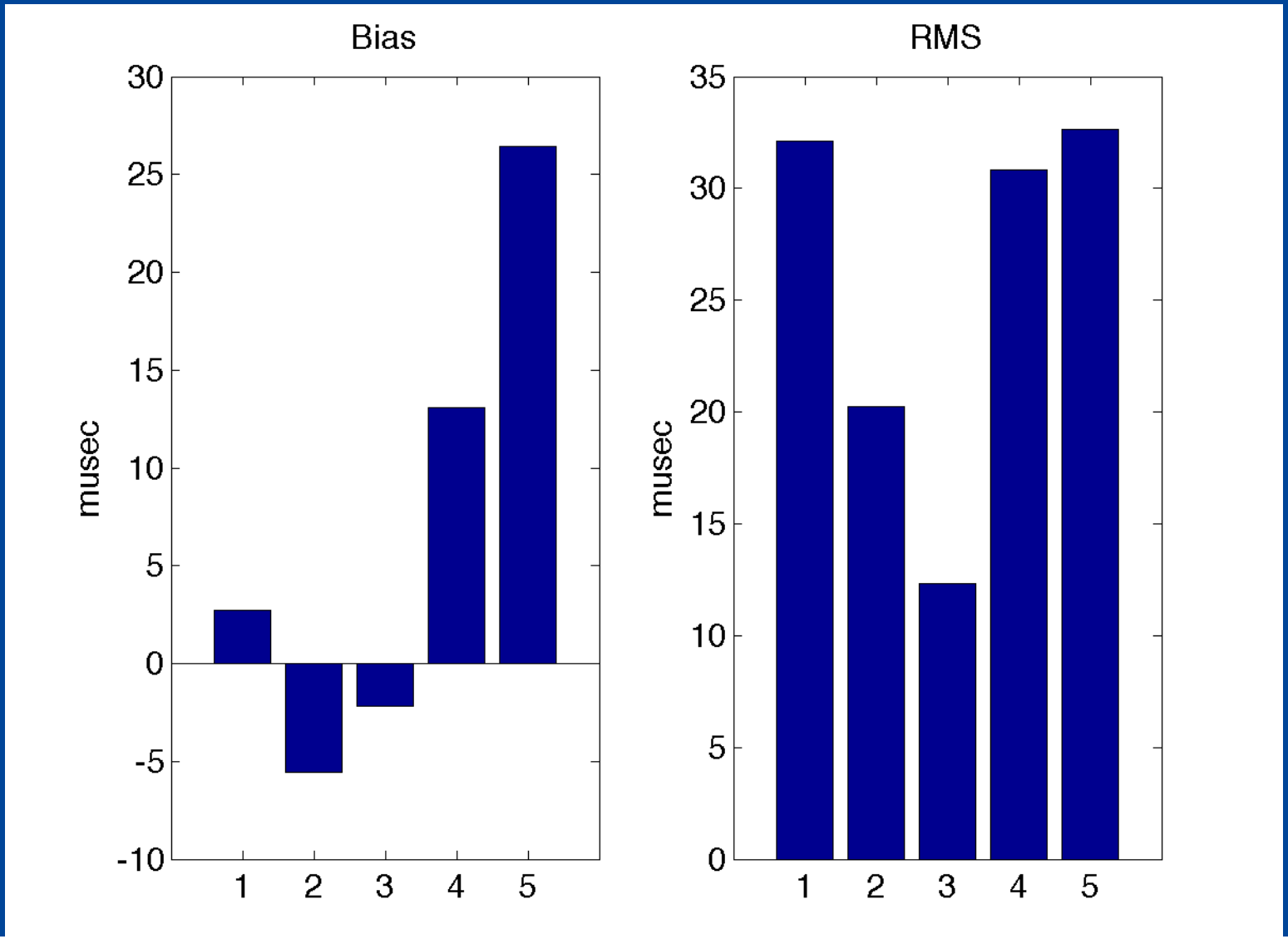
- ’Sliding-window-approach’, i.e. when a new scan comes in the oldest is left out and a new analysis is performed, with two software packages OCCAM and C5++
- Result is a time series of dUT1 while the session is ongoing
- Latency of minutes
- Progress can be monitored on webpage http://www.spacegeodesy.go.jp/vlbi/dUT1/

Examples for ’sliding window’




0
-50
-100
-150
UT1-UTC (ms)
Aug
Sep
Oct
Nov
Dec
Jan
Feb
2010
2011
IVS-INT (BKG)
IVS-R (BKG)
IVS-R (comb)
IERS C04
Ultra-rapid e-VLBI (Occam)
Ultra-rapid e-VLBI (C5++)


IVS-INT (BKG)
IVS-R (BKG)
IVS-R (comb)
Ultra-rapid e-VLBI
UT1-UTC residual (mus)
500
400
300
200
100
0
-100
-200
Aug
Sep
Oct
Nov
Dec
Jan
Feb
2010
2011



1 IVS-INT (BKG) 2 IVS-R (BKG) 3 IVS-R (comb) 4 UR (Occam) 5 UR (C5++)

Conclusions (1/3):

- Real-time e-VLBI including near-real-time correlation and data analysis is possible
- Low latency for dUT1-results achievable, within minutes after end of the observations
- Agreement with IERS final dUT1 much better than any predictions
- Agreement with C04 on the same level than IERS rapid solutions

Conclusions (2/3):

- Simultaneous observations on almost parallel baselines agree on the order of 16.7 μs
- Indication that higher data rates give reduced formal errors
- The concept has been adopted for IVS INT-2 and INT-3 sessions (although in offline mode)

Conclusions (3/3):

- Ultra-rapid-24h sessions show larger biases w.r.t. to C04 than dedicated INT-sessions
- Probably due to non-optimized schedules
- RMS-agreement w.r.t. C04 comparable to INT
- ’Sliding-window’ approach not ideal
- Results from the two software packages do not agree completely

Outlook (1/2):

- Data analysis of UR-24h dUT1 should be improved, e.g. Kalman Filter
- Unified analysis strategy appears necessary => IVS Task Force for Intensives
- Plan for 2011:
  - Continue with UR-24h and ’long-intensives’
  - UR during CONT11, 15 days of continuous dUT1

Outlook (2/2):

- Future: real-time e-VLBI with distributed correlation, (=> VLBI2010)
- Single baselines can be correlated in near real-time during the sessions
- Databases with individual baselines will get merged and complete network will be analyzed during or directly after the end of the observing session
- All EOP will be determined in near-real-time