UTCr
A rapid realization of UTC

Time department

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Impact of a rapid realization of UTC

- On UTC contributing laboratories:
  - More frequent assessing of the UTC(K) steering, and consequently better stability and accuracy of [UTC(k)];
  - Traceability to UTC will be enhanced.

- On users of UTC(K):
  - Access to a better "local" reference, and indirectly, better traceability to the UTC "global" reference;

- On GNSS:
  - Better synchronization of GNSS times to UTC, through improved UTC and UTC(k) predictions: case of UTC(USNO) for GPS, UTC(SU) for GLONASS, UTC(k) used in the generation of Galileo ST, BeiDou ST.

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Implementation of UTCr

- September 2011: UTC contributing laboratories have been invited to participate on a voluntary basis to a pilot experiment.
- January 2012: Pilot experiment started, with the target of reporting to the CCTF in September 2012;
- Decision on the routine production of UTCr to be taken end of 2012;

Characteristics of UTCr for the pilot experiment

- Chosen features
  - Based on daily data reported (daily) by contributing laboratories, independently of the report for the monthly UTC computation
  - Weekly access to daily values of [*UTCr*-*UTC*(*k*)]
  - Automatically generated weekly solution over four weeks of data (sliding solution)
  - Weighting scheme similar to ALGOS
  - Linear frequency prediction (to start with)
  - Steered to UTC (loosely defined)

- Expected properties
  - Stability of UTCr comparable to UTC since:
    - Interval of calculation covers one month aproximately and the weighting procedure is the same as for UTC
    - Participating laboratories (expected to) represent 50% of the clocks in UTC and 70% of the total clock weight in UTC
  - Accuracy ensured by steering to UTC over common interval

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The UTCr pilot experiment

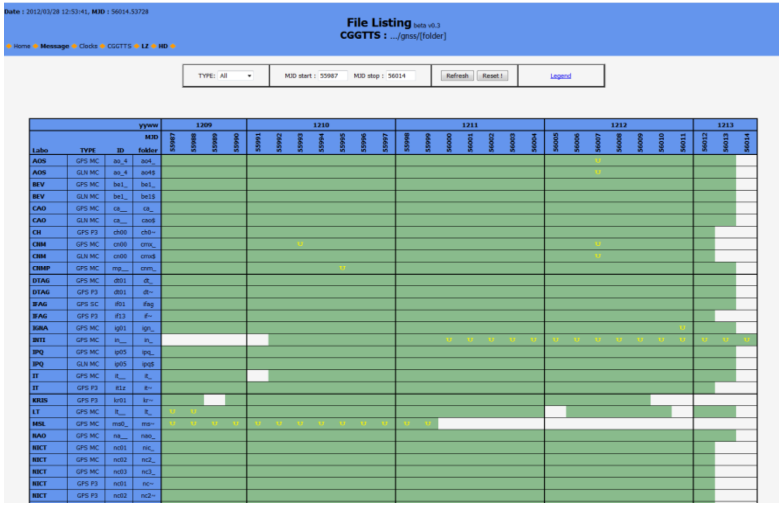
- Calendar of events
  - First data report: 01/01/2012
  - First computed week (YYWW): 1205 published 27/02/2012
  - First "operational publication": week 1208 published the next Wednesday on 29/02/2012

- Computation in four steps
  - Data checking
  - Computation of time links
  - Stability algorithm => 'free scale' EALr
  - Steering to UTC => UTCr

Step 1: Data reporting and checking

- Daily data, reported daily by contributing laboratories.
  - Data of day D must be uploaded before day D+2, 12:00 UTC
- Each laboratory has an individual account on tai.bipm.org ftp server, different from the "labotai" account (for UTC).
- The standard file naming convention must be respected, see guidelines in **ftp://tai.bipm.org/UTCr/Documents/.**
- Automatic tasks carried out.

•detection of input data
•checking the format of known data file (based on file names)
•report on unknown or new data file (in order to include new data in data set, done manually)
•report on known data file

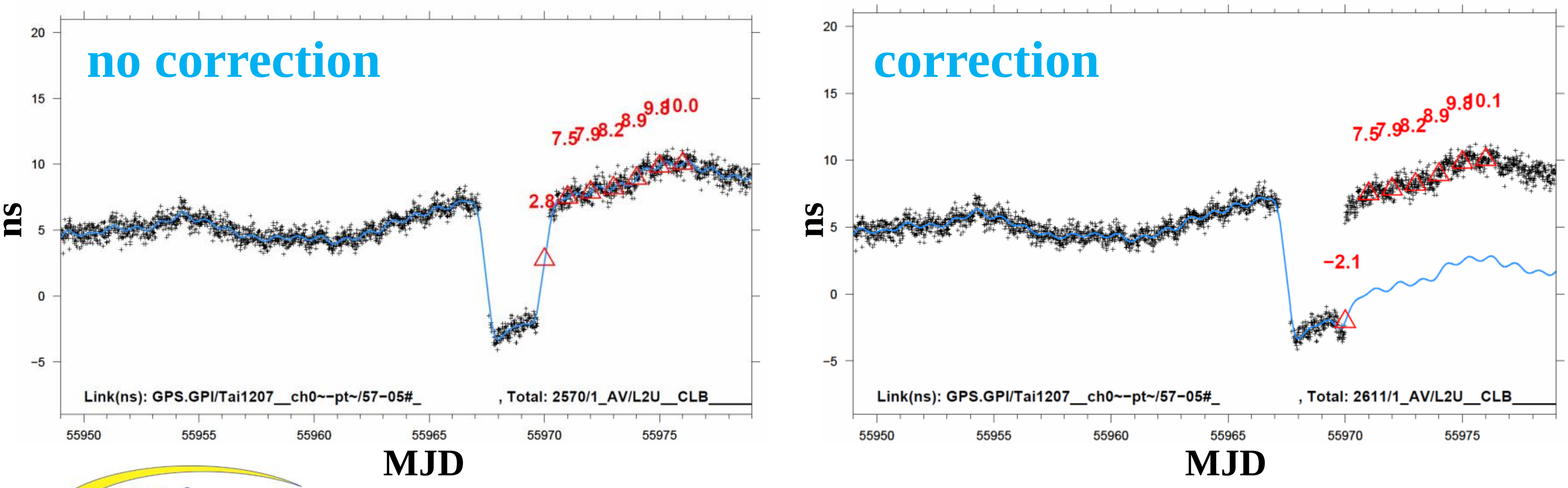


- When in operational use, there will be only automatic interaction with laboratories for data correction, etc...

Step 2: Computation of time links

- Based on CGGTTS (code) data only.
- To be expanded later (to TW, possibly PPP), if needed.
- Use of Rapid Precise Orbits and clocks products from IGS(GPS) and IAC(GLONASS). Availability: < 1 day.
- Automation of the correction of time steps required for interpolation.

UTC(CH)-UTC(PTB) 1207



Step 3: Stability algorithm

- Algorithm similar to ALGOS, but with **linear prediction only** $h_i'(t)$.

$$UTCr - h_j = \sum_{i=1}^{N} w_i \left[h_i'(t) - x_{i,j}(t) \right]$$

- Daily clock data
- Computation interval between 27 and 31 days, starting with a “TAI standard date”
- Weight computed from stability over 11 past 30-day intervals
  - Maximum weight = $2.5/N_{clocks}$
  - Test for “abnormal behavior”
- Rate over interval computed as $(\Phi_{end} - \Phi_{begin})$/duration

Step 4: Steering

- The steering is based on a weighted average of the differences between UTC and the rapid UTC at dates t_j:

$$D(t_j) = \sum_{k=1}^{N_k} W_k\left([UTCr - UTC(k)](t_j) - [UTC - UTC(k)](t_j)\right)$$

where W_k is the total weight of the laboratory k in UTCr calculation.

- Original plan for the steering function:
  - f(t) is a linear function adjusted to the ensemble of $D(t_j)$.
  - Each month, when UTC is available, f(t) is calculated and applied until the next UTC calculation.

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Step 5: Publication

Every Wednesday before 18:00 UTC on ftp://tai.bipm.org/UTCr/Results/

UTCr_1211
2012 MARCH 21, 13h UTC

The results in this page are established by the BIPM Time Department in the frame of the pilot experiment on a rapid UTC, UTCr. The computed values [UTCr-UTC(k)] are reported.

Date 2012	0h UTC	MAR 12	MAR 13	MAR 14	MAR 15	MAR 16	MAR 17	MAR 18
MJD		55998	55999	56000	56001	56002	56003	56004
Laboratory k		[UTCr-UTC(k)]/ns						
AOS	(Borowiec)	-2.6	-2.4	-1.9	-1.3	-1.9	-1.9	-1.2
BEV	(Wien)	11.9	11.3	10.3	6.5	0.4	-2.3	-5.7
CAO	(Cagliari)	-6291.7	-6290.8	-6293.1	-6291.4	-6298.8	-6308.3	-6300.0
CH	(Bern)	-12.5	-12.3	-12.0	-10.9	-9.8	-9.2	-9.3
CNM	(Queretaro)	-13.8	-15.0	-15.5	-14.9	-17.3	-18.4	-17.1
CNMP	(Panama)	75.8	81.4	85.5	83.1	83.8	83.0	88.0
DTAG	(Frankfurt/M)	6.8	5.1	5.8	5.7	6.8	6.4	7.7
IFAG	(Wettzell)	-620.2	-619.1	-623.8	-627.3	-627.8	-626.7	-627.4
IGNA	(Buenos Aires)	6691.8	6700.6	6711.9	6724.6	6737.0	6747.7	6762.6
INTI	(Buenos Aires)	-26.4	-32.2	-32.6	-32.7	-32.5	-31.6	-36.7
IPQ	(Caparica)	-23.1	-29.1	-27.5	-24.7	-22.6	-16.5	-12.5
IT	(Torino)	1.2	2.3	2.6	3.0	3.4	3.8	4.0
KRIS	(Daejeon)	-8.3	-8.7	-9.4	-	-	-	-
LT	(Vilnius)	42.4	39.1	32.9	35.0	30.1	37.5	43.8
MSL	(Lower Hutt)	67.0	61.2	55.3	-	-	-	-
NAO	(Mizusawa)	54.8	49.9	52.4	54.7	50.1	49.0	50.8
NICT	(Tokyo)	2.5	2.7	2.6	3.1	3.4	3.2	3.2
NIM	(Beijing)	-7.1	-7.5	-8.3	-8.9	-9.8	-9.8	-10.7
NIMT	(Pathumthani)	987.6	1008.5	1026.4	1042.7	1058.3	1074.2	1090.9
NIS	(Cairo)	-782.1	-784.0	-783.8	-786.8	-794.0	-797.0	-799.5
NIST	(Boulder)	-4.1	-5.0	-4.2	-3.9	-6.6	-6.3	-5.2
NMIJ	(Tsukuba)	-8.7	-8.4	-8.5	-8.2	-7.7	-8.0	-8.2
NMLS	(Sepang)	-664.4	-665.1	-667.1	-667.0	-670.4	-672.4	-674.5
NRC	(Ottawa)	-18.1	-14.2	-15.1	-13.9	-13.8	-14.0	-13.6
NTSC	(Lintong)	0.8	2.2	2.1	5.0	4.3	4.5	3.8
ONRJ	(Rio de Janeiro)	-12.3	-9.7	-6.9	-7.5	-7.8	-4.7	-1.9
OP	(Paris)	-24.5	-22.8	-23.7	-21.8	-21.4	-21.8	-24.5
ORB	(Bruxelles)	-0.4	-0.1	0.5	0.0	0.4	-0.5	-1.0
PL	(Warszawa)	15.8	16.5	18.1	16.1	15.0	12.4	12.8
PTB	(Braunschweig)	-3.2	-3.4	-3.6	-3.5	-4.0	-4.0	-4.6
ROA	(San Fernando)	-2.8	-2.2	-2.7	-3.1	-3.5	-3.8	-4.4
SCL	(Hong Kong)	13.8	11.5	5.2	5.5	2.8	-5.8	-2.0
SG	(Singapore)	9.6	9.3	7.5	7.8	7.8	7.4	6.6
SP	(Boras)	-15.7	-15.6	-15.5	-15.6	-15.5	-15.6	-16.0
SU	(Moskva)	1.4	1.2	2.0	2.2	0.6	0.3	0.9
TL	(Chung-Li)	6.4	6.5	5.5	4.9	4.2	2.7	1.3
UME	(Gebze-Kocaeli)	103.3	100.2	104.3	109.5	107.7	105.3	107.1
USNO	(Washington DC)	-0.7	-1.1	-1.2	-1.3	-1.5	-1.5	-1.5
VSL	(Delft)	10.0	8.1	3.6	3.2	4.4	4.5	4.6

These results should not be used as a prediction of UTC.
UTC remains available from the monthly Circular T at
(http://www.bipm.org/jsp/en/TimeFtp.jsp?TypePub=publication).

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Comparisons between UTCr and UTC: clocks

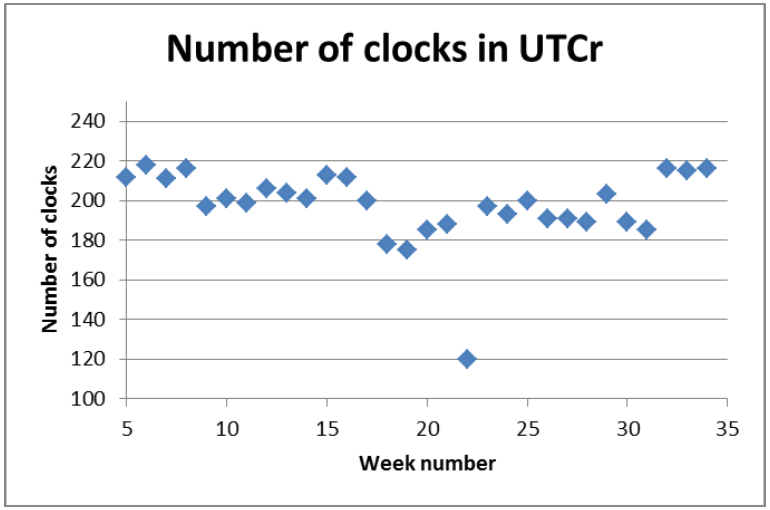
•Comparing the clock populations and statistics for UTCr and UTC over six months:

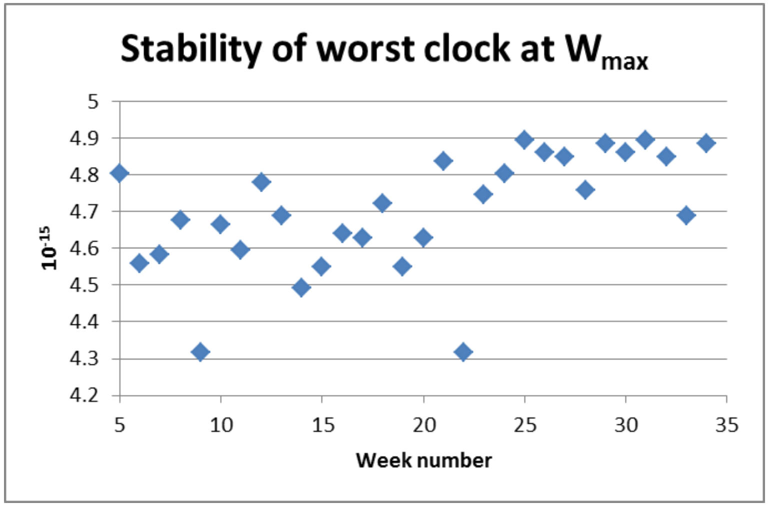
-Some 60% of the TAI clocks are in UTCr

-Maximum weight w_{max} has been kept as 2.5/Nclocks

-Slightly less clocks (in proportion) reach w_{max} in UTCr

-60% of the clocks with globally same behavior implies UTCr 20% less stable than UTC?





	UTCr	TAI
N clocks for weight	210	360
Max weight w_{max}	1.2%	0.7%
Stability at w_{max}@ 1m	4.5-4.7x10^{-15}	4.8x10^{-15}
Total weight @ w_{max}	31-37%	40%

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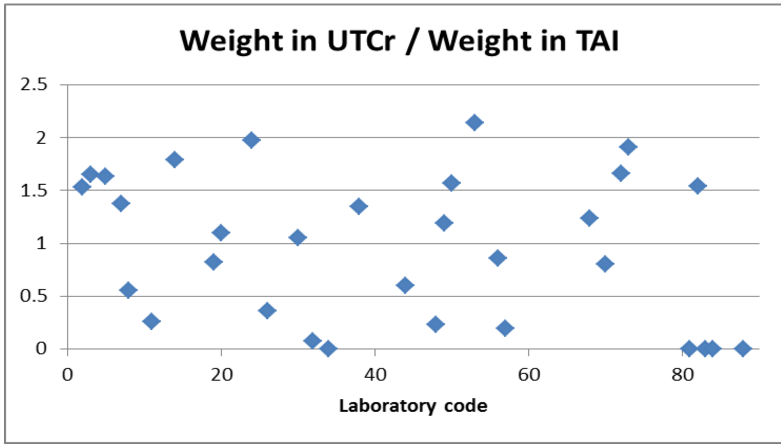
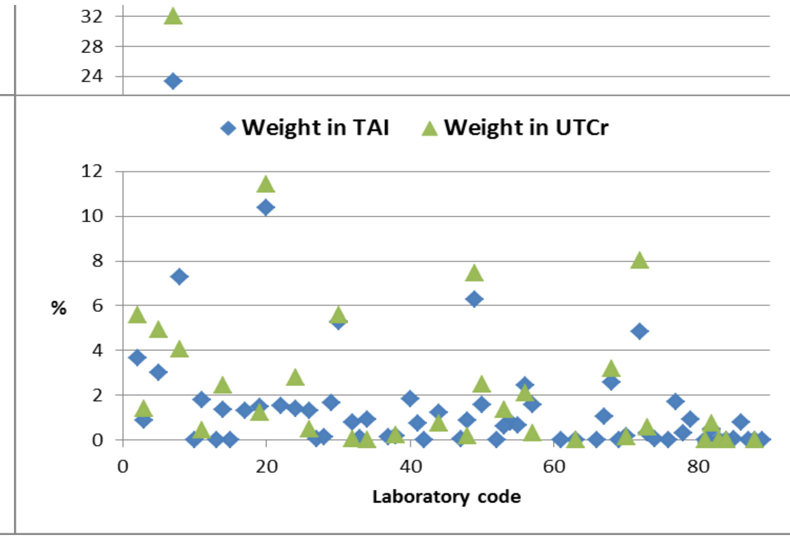
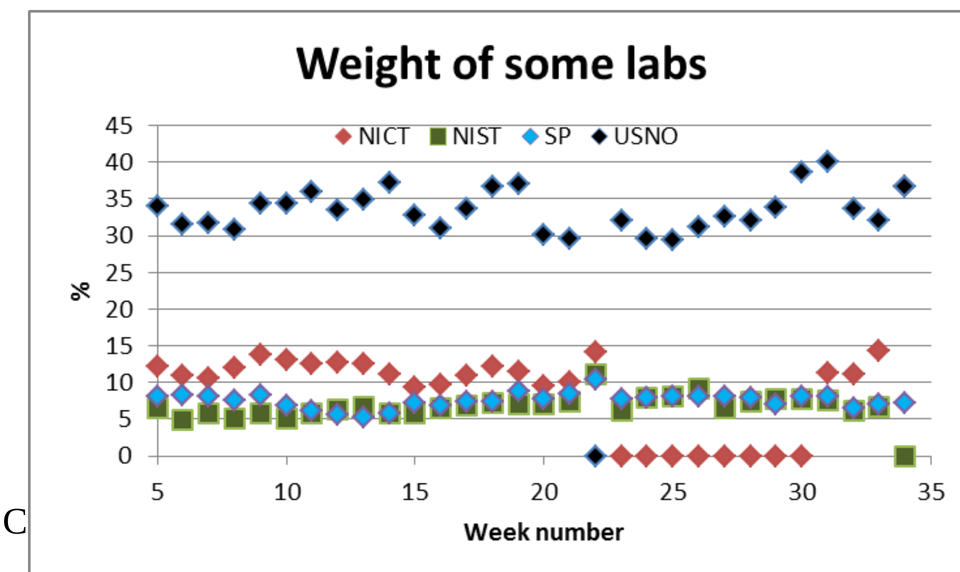
Comparisons between UTCr and UTC: weights

- Some 35-40 labs participate to UTCr and more than 25 have some weight in UTCr (vs 50 in TAI).
- Example for the four weeks in February





- Weight of labs in UTCr is more variable due to “real time” nature of the procedure



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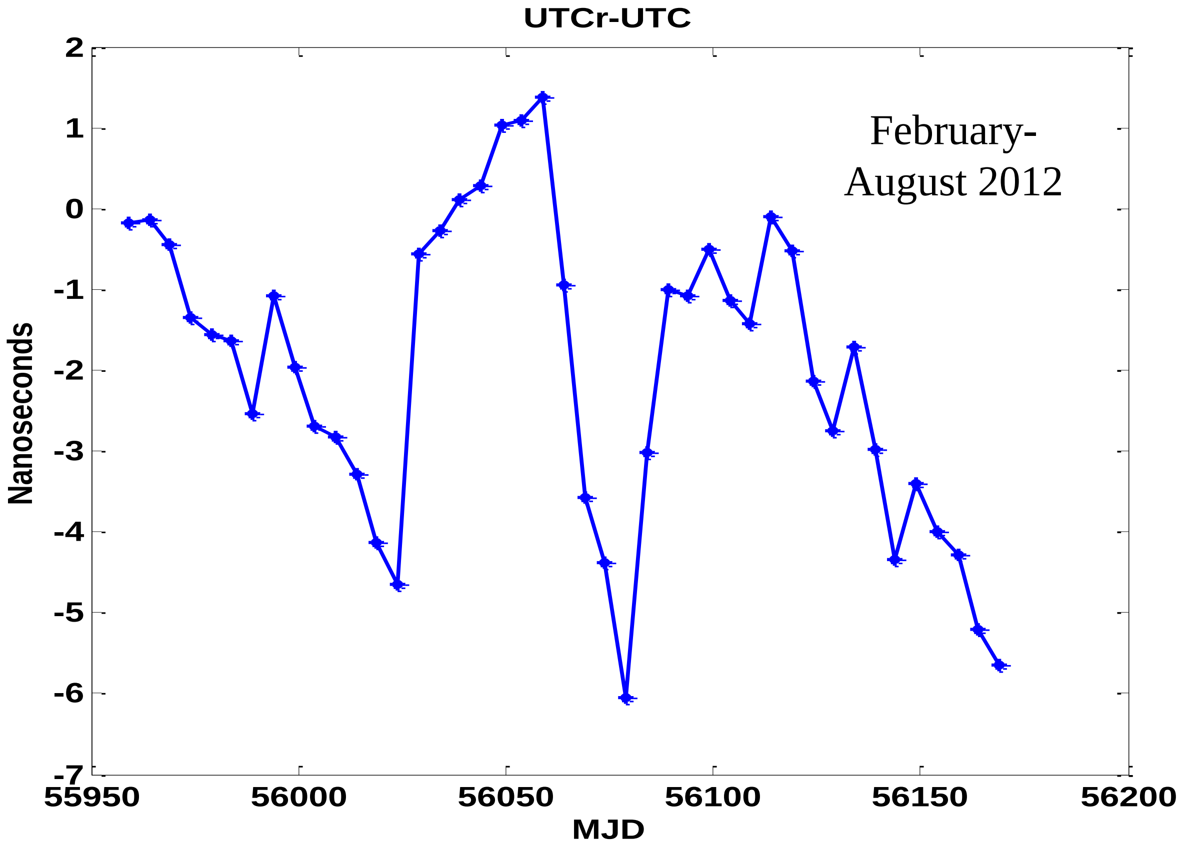
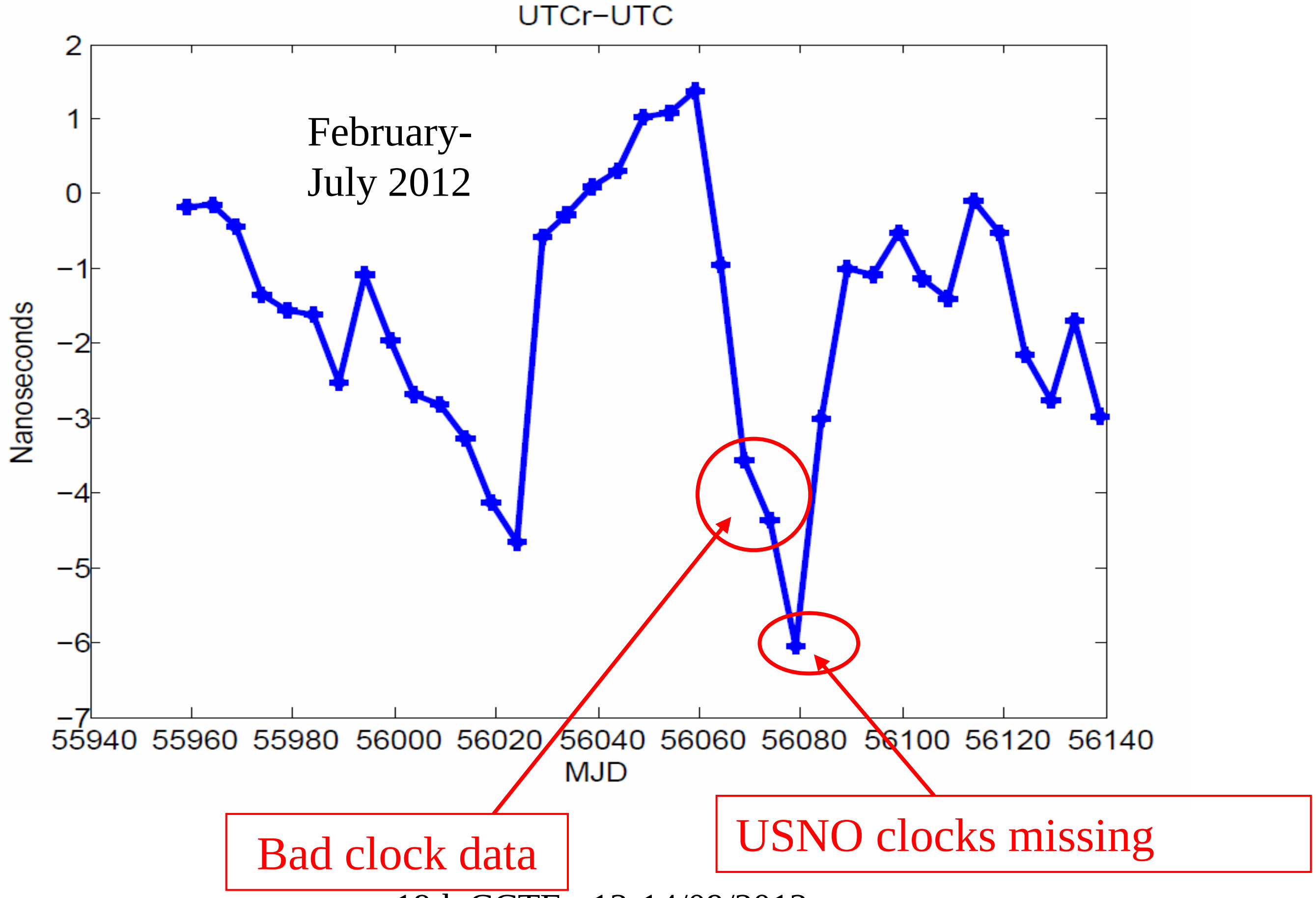
Comparisons between UTCr and UTC: Results (1)

- First seven months (February to August 2012) show large excursions between UTCr and UTC
  - Some drift expected due to the linear prediction in UTCr
  - Initial steering procedure (reset + rate correction) stopped in April
  - A number of features need to be studied in detail



Comparisons between UTCr and UTC: Results (2)

- A detailed study has been carried out over 6 months
- Reveals that several events affected UTCr (errors in clock data, missing data) and explains some of the largest features

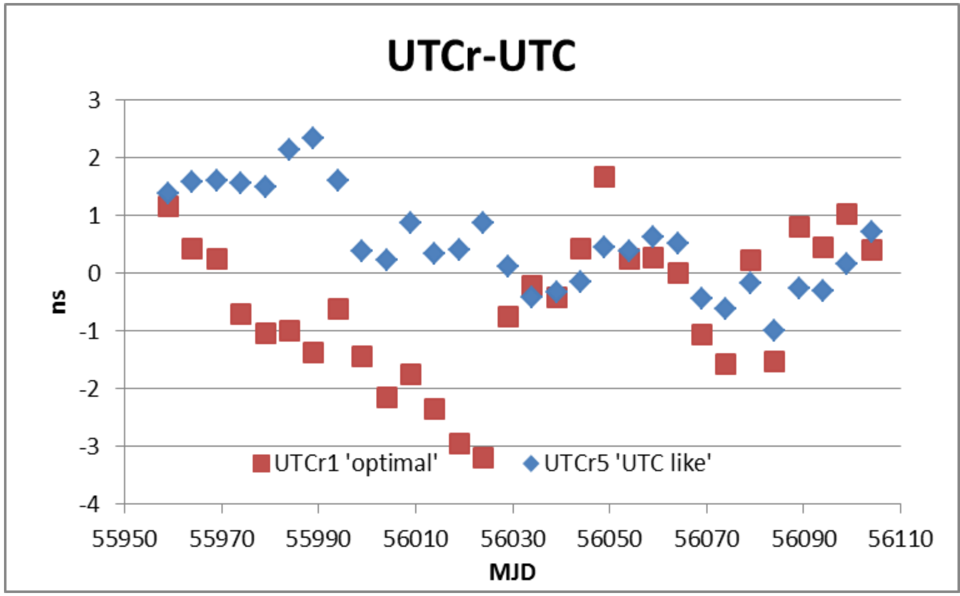


UTCr test computations and comparisons to UTC

Several "a posteriori" test computations have been carried out to test the influence of various parameters on UTCr

- –UTCr1 = "optimal", i.e. correcting errors, restoring late data
- –UTCr2 = UTCr1 + use the exact UTC links
- –UTCr3 = Free "optimal" scale with linear prediction
- –UTCr4 = Free "optimal" scale with quadratic prediction
- –UTCr5 = UTCr4 + TAI steering

- UTCr5 is the most "UTC-like" of all UTCr test computations (using the UTCr links but assuming no error in the clock data)
- UTCr5 – UTC remains in [-1.0 ns, +2.3 ns]



Effect of some of the features in UTCr (1)

Possible influence on UTCr

1. Independent data sets
   1. clocks are not the same:
      1. UTC has twice more
      2. some are in UTCr and not in UTC (e.g. due to incomplete data in UTC interval)
   2. time links are quite different
      - Only CGGTTS for UTC
      - No PPP or TW

1.1.1: UTCr less stable e.g. $5\text{-}6 \times 10^{-16}$ vs. $3\text{-}4 \times 10^{-16}$

~1 to 1.5 ns after one month

1.1.2: thought to be not significant

1.2: estimated by test computation of UTCr with UTC links

typical 1.5 ns offset + < 1 ns noise

2. Algorithm somewhat different
   1. UTCr has no quadratic frequency prediction
   2. UTCr is not (based on) a continuous free scale
      1. Computed on “moving interval” with past rates on “moving past intervals”
      2. Reset to UTC after each Circular T

2.1: May be 5×10^{-16} (per month)

i.e. ~1 ns after one month

2.2.1: Up to 5×10^{-16} for the frequency prediction

i.e. up to 1.5 ns after one month

2.2.2: Introduces discontinuity to compensate all above effects

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Effect of some of the features in UTCr (2)

1. Independent data sets
   1. clocks are not the same:
      1. UTC has ~ twice more
      2. some are in UTCr and not in UTC (e.g. due to incomplete data in UTC interval)
   2. time links are quite different
      - Only CGGTTS for UTC
      - No PPP or TW

2. Algorithm somewhat different
   1. UTCr has no quadratic frequency prediction
   2. UTCr is not (based on) a continuous free scale
      1. Computed on "moving interval" with past rates on "moving past intervals"
      2. Reset to UTC after each Circular T

Possible action

1.1.1: Increase number of participants

1.1.2: thought to be not significant

1.2: Not clear. Not possible to have exactly the same links

- TW may be introduced
- PPP more difficult to automatize?

2. Make algorithm much more similar

2.1 Use quadratic frequency prediction

2.2 Generate a free scale and steer exactly like for UTC.

Nevertheless the scales will eventually wander away

Different approaches for UTCr

- There could have been an internal study in a first phase
  - However no daily clock data was available
  - Should have relied on simulated or interpolated clock data
  - Would not have evidenced problems with data (some quite unexpected)

- Choice of a pilot experiment with *a priori* chosen algorithm
  - Some difficulties encountered and operational practice changed during experiment
  - Data published with strong "Disclaimer"

- *A posteriori* analysis using 6-month pilot experiment
  - Implies possible revision of the algorithm for the near future, towards a more "UTC-like" solution
  - A technique to maintain the time consistency of UTCr with UTC still to be chosen

Conclusions

- UTCr started as a pilot experiment in January 2012
- “regular production” since week 1208, with disclaimer

- 6-month analysis suggests
  - some changes in the operational algorithm
  - to keep the disclaimer

- UTC kept unchanged so far. Will benefit from UTCr due to better anticipation and easier detection of problems (clocks and links).

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Practical information

- If you wish to participate see the information in
  ftp://tai.bipm.org/UTCr/Documents/

- Publication of [UTCr-UTC(k)] every Wednesday on
  ftp://tai.bipm.org/UTCr/Results/