Experience from geodetic VLBI observations at Onsala using a digital backend

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Outline

- Introduction
- VLBI-equipment at Onsala
- Parallel observations Mark4/DBBC
- Correlation and analysis results
- Conclusions and outlook

Introduction

- Onsala is the European station with the longest history in VLBI, since 1968
- Onsala is active in both geodetic and astronomical VLBI programs within the IVS, EVN, GMVA
- Currently we operate 2 VLBI telescopes:
  - 25 m for L- to C- band, (18 cm to 5 cm)
  - 20 m for S-band to 115 GHz, (13 cm to 3 mm)
- We are building a VGOS twin-telescope

VLBI-equipment at Onsala(1/2)

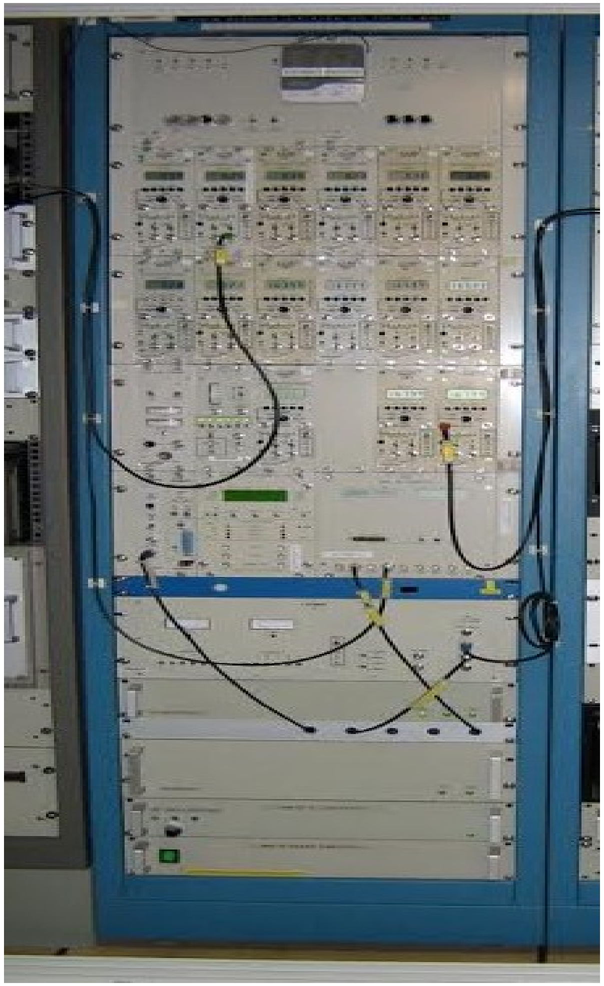
- We have had analog backend, Mark4 rack #2 (!)
  - Problems in maintaining the old equipment
  - Problems with modern requirements
- Since 2010 we have a digital backend, DBBC2
  - Upgraded several times since then
  - Tests for EVN and IVS (zero-baseline, …)
  - Operational use for EVN since mid 2013

VLBI-equipment at Onsala(2/2)

- Our current equipment
  - Mark5B+ connected to DBBC
  - Mark5C, currently used as e-transfer machine

  FlexBuff, future e-VLBI machine
- Equipment to be phased out
  - PC-EVN, for real-time e-VLBI to e.g. Japan
- Mark4 rack is heading to a museum
- Mark5A will be an e-transfer machine

VLBI-equipment at Onsala



Left: Mark4

Right: DBBC

Parallel observations Mark4/DBBC

- We have done numerous parallel observations during IVS sessions between 2012 and 2014, e.g.:

R1-sessions:

R1.553, R1.563, R1.566, R1.567, R1.569, R1.570, R1.572, R1.573, R1.585, R1.591, R1.592, R1.598, R1.599, R1.600, R1.601, R1.602, R1.604, R1.612, R1.615, R1.616

RD-sessions: RD.12.10, RD.13.01, RD.13.03, RD.13.06

EUR-sessions:

EUR.118, EUR.120, EUR.121, EUR.123, EUR.124, EUR.125

T2-sessions: T2.090, T2.093, T2.094

15 days of CONT14 campaign in May

Parallel observations

- We did zero-baseline tests for these parallel sessions using the DiFX installation at Onsala
- Furthermore, for several of these sessions both the Mark4/Mark5A and DBBC/Mark5B+ data were sent to the Bonn correlator
- The Bonn correlator did fringe-tests and produced several databases with two Onsala stations (ON - analog, OD - digital)

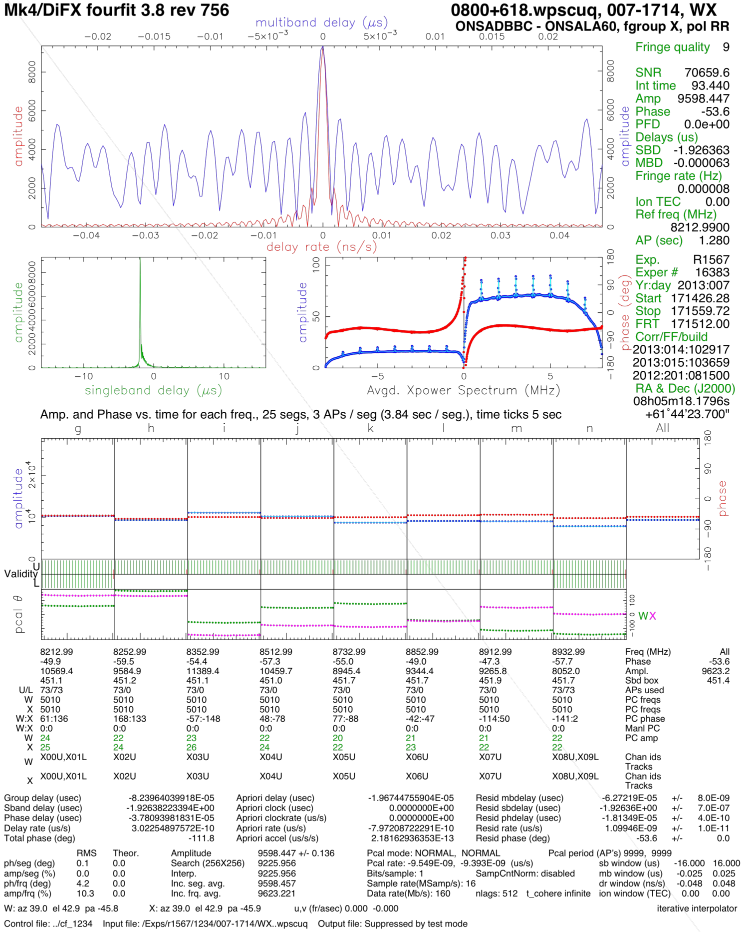
Correlation and analysis results

– In the following we focus on a set of R1 and CONT14 -sessions with both ON (Onsala analog) and OD (Onsala digital):

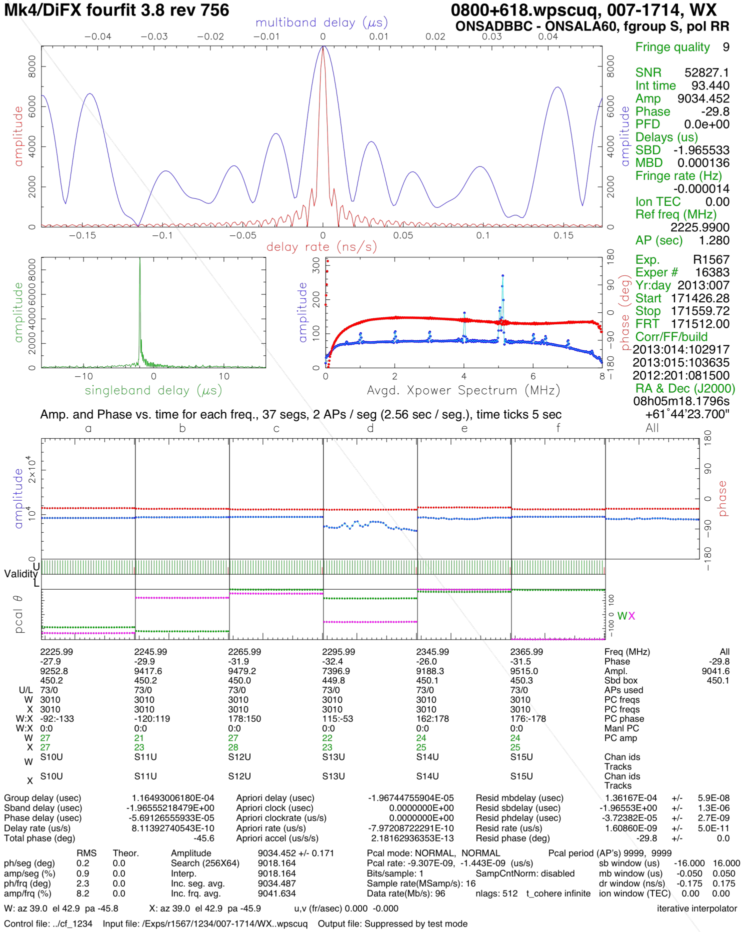
R1553	12OCT01	C1404	14MAY09
R1563	12DEC10	C1405	14MAY10
R1566	13JAN02	C1410	14MAY15
R1567	13JAN07		
R1592	13JUL01		
R1612	13NOV18		

Example: R1.567 zero-baseline

X-band

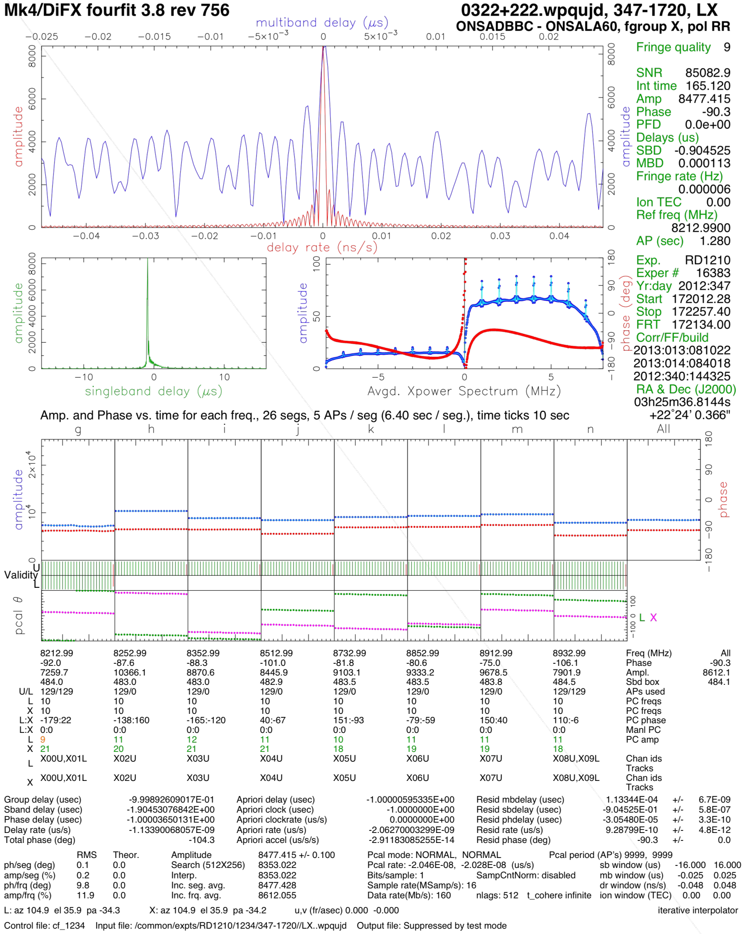


S-band

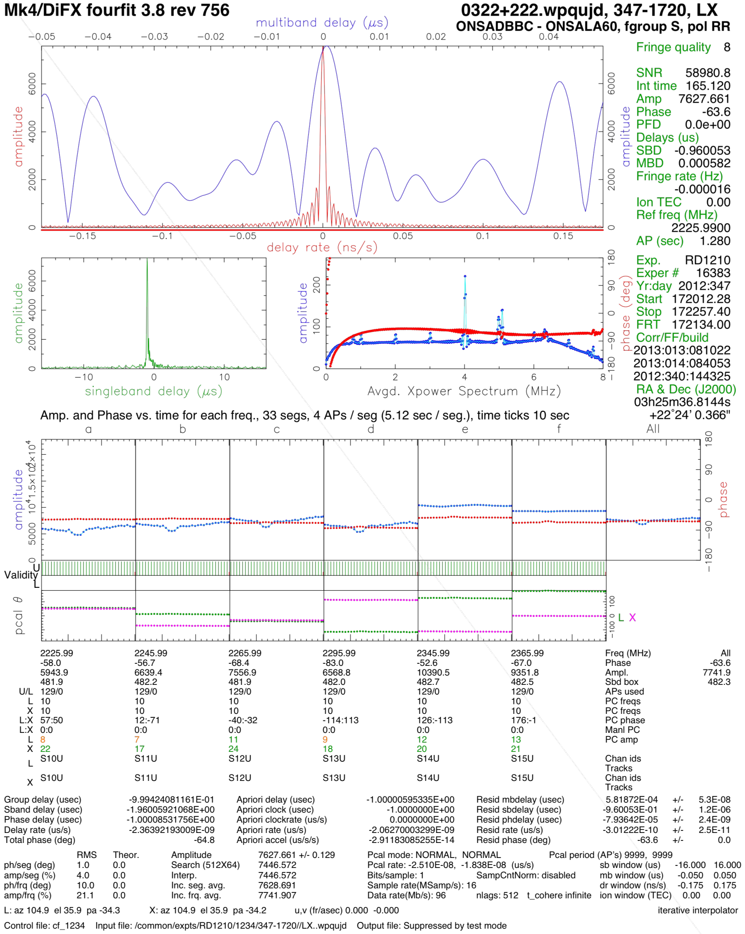


Example: RD.12.10 zero-baseline

X-band



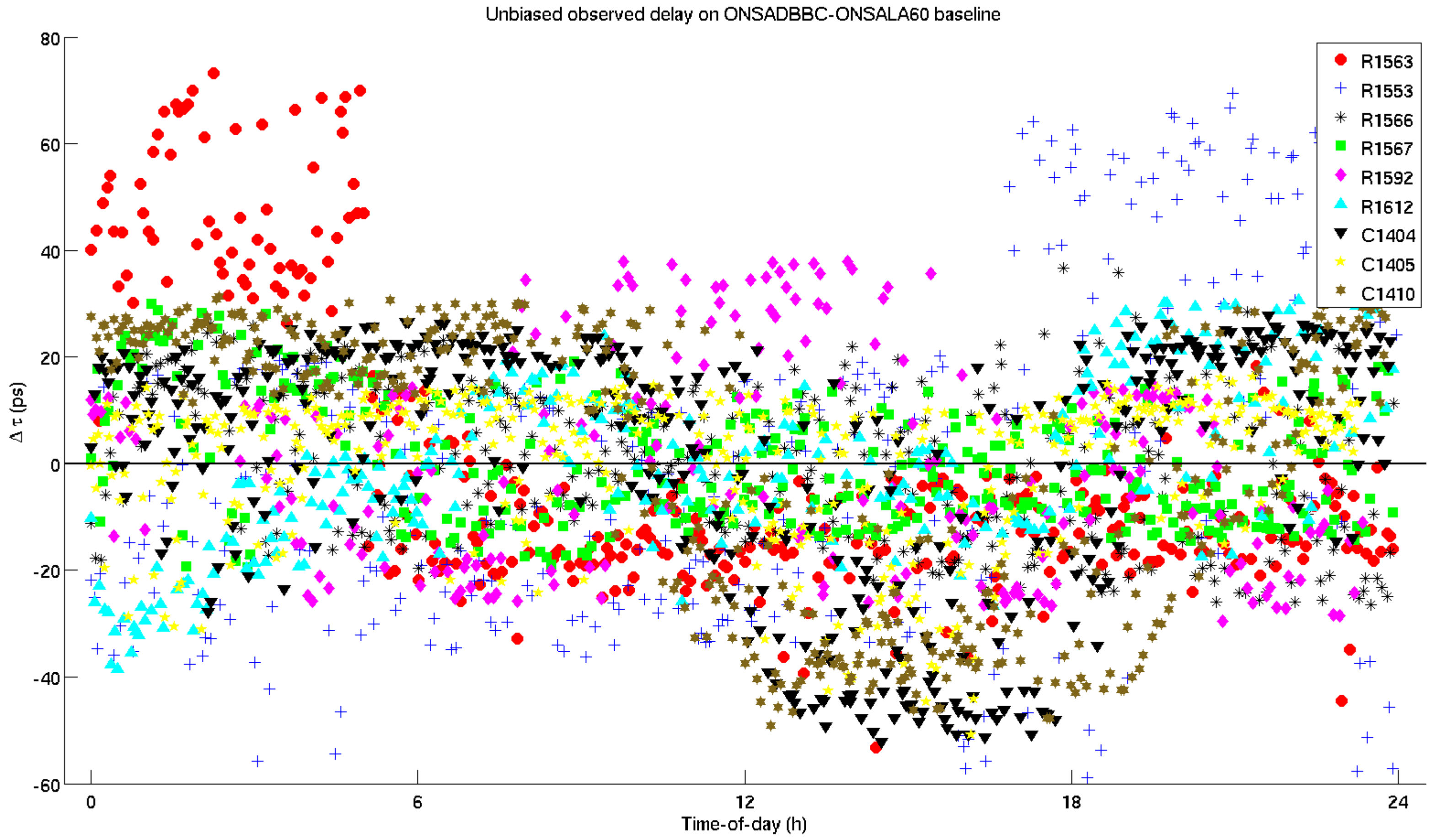
S-band



Data analysis and results

- Comparison of NGS files generated from V002 database
- A few examples:
  - Delay distribution between Od – On
  - Difference between (Od-Wz) – (On-Wz) baselines

Data analysis and results



Data analysis and results

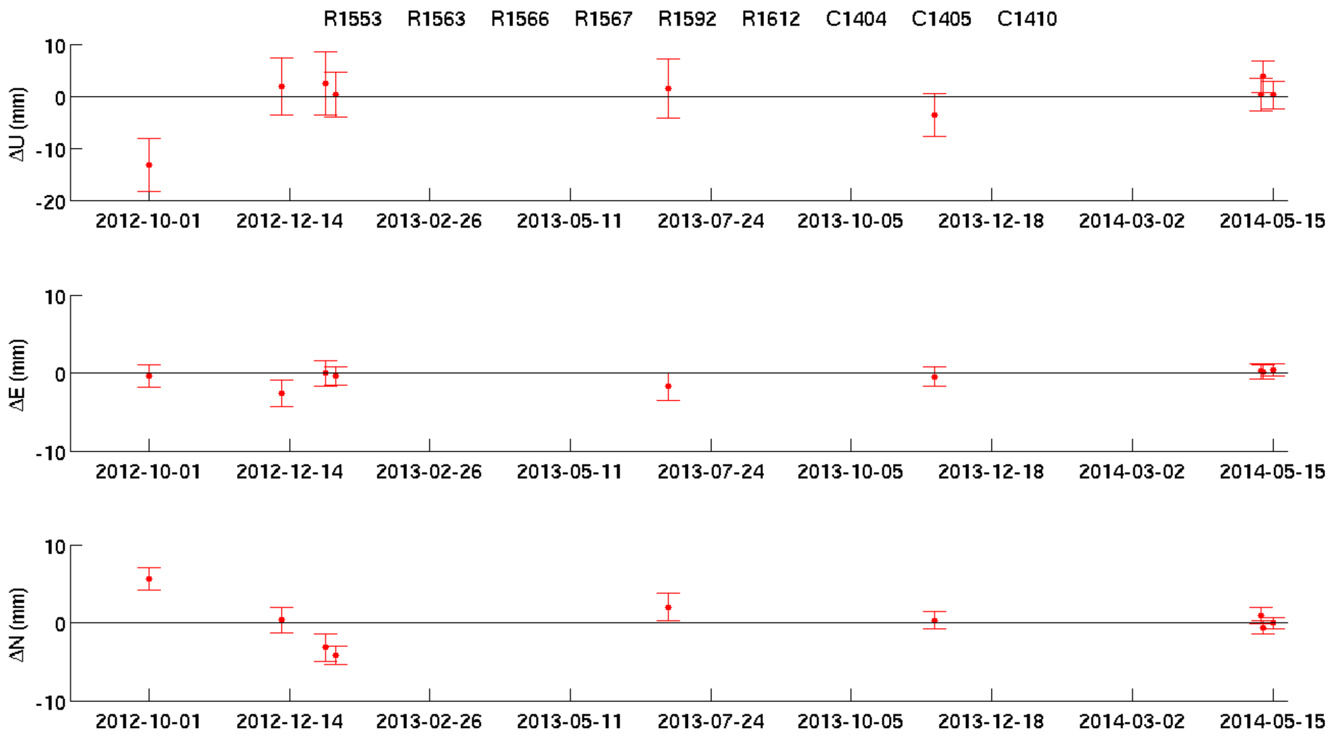
– Session-wise differences on (Od–Wz) – (On Wz) baseline

Session	Bias (ns)	Std. Dev (ps)
R1553	-1900.03	33.9
R1563	-1950.04	40.8
R1566	-1950.08	20.8
R1567	-1950.08	14.8
R1592	-1950.07	21.2
R1612	-1900.02	17.3
C1404	-9950.05	26.4
C1405	-9900.06	16.2
C1410	-9950.04	26.6

Data analysis and results

- Databases processed with Calc11
- nuSolve analysis for individual sessions
- Switching on/off ON/OD and estimation of:
  - Onsala station position (keeping fixed other stations, except Tsukuba and Tigo)
  - EOP
  - Clock and troposphere piece-wise linear (1 h)
- Comparison of results using ON or OD data

Data analysis and results



Data analysis and results

- Some fluctuation in the station position estimate
- Best agreement in East-coordinate
- Differences in the range of sub-millimetre to 5 mm, one over 1 cm

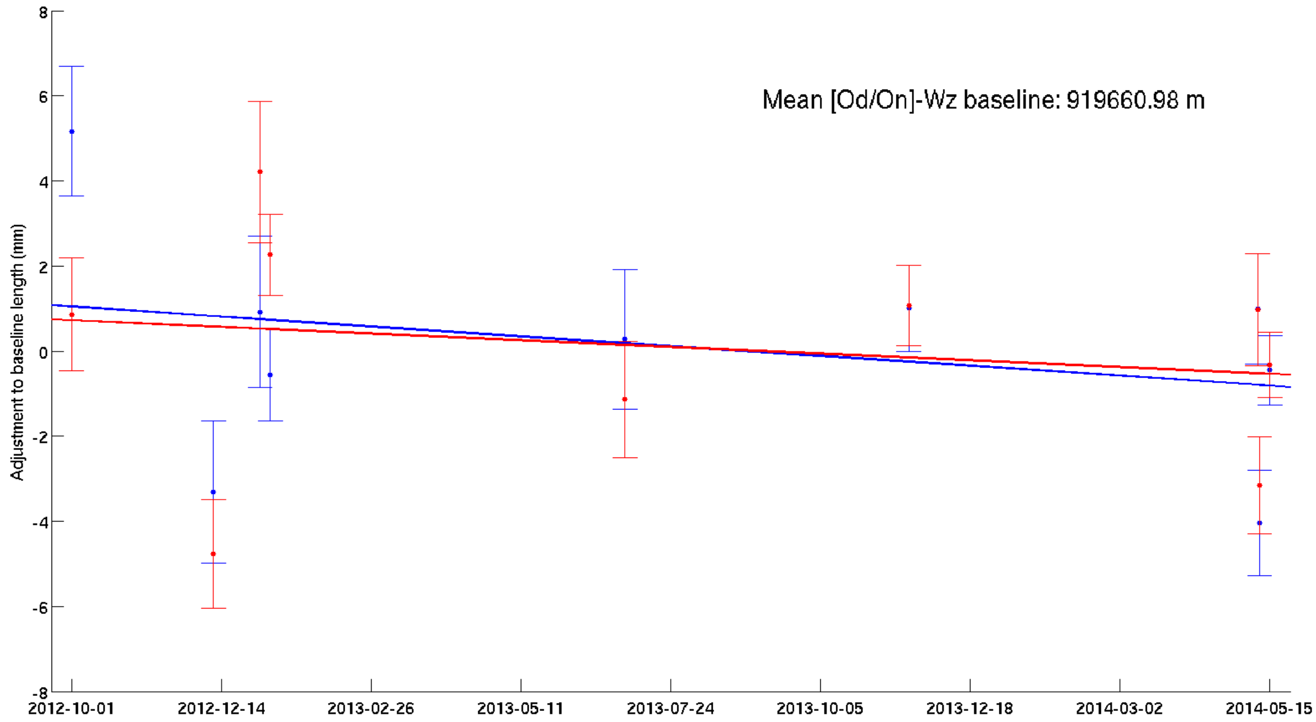
Od-On	U (mm)	E(mm)	N (mm)
WRMS	4.0	0.8	2.2

Data analysis and results

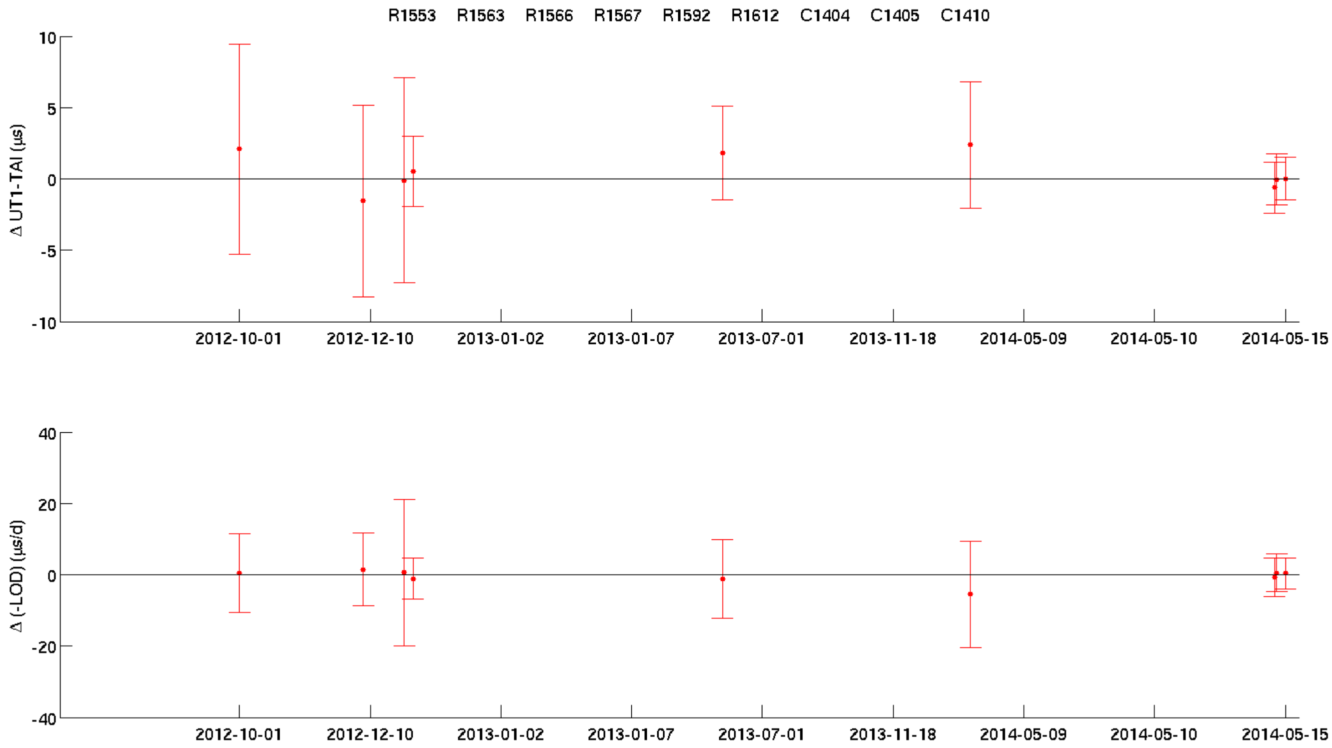
- Measure of repeatability for On/Od-Wz baselines computed as RMS of weighted linear fit

Baseline	RMS (mm)
Od-Wz	2.49
On-Wz	2.53

Data analysis and results



Data analysis and results

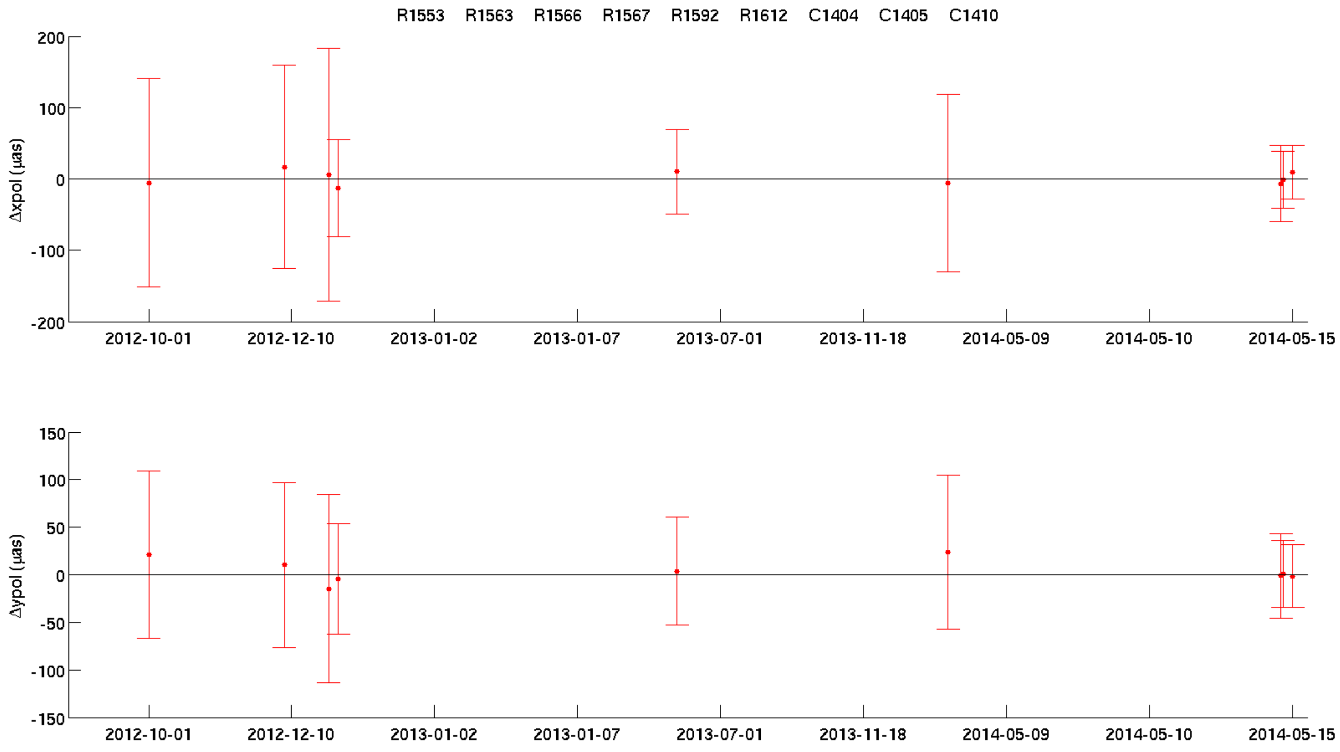


Data analysis and results

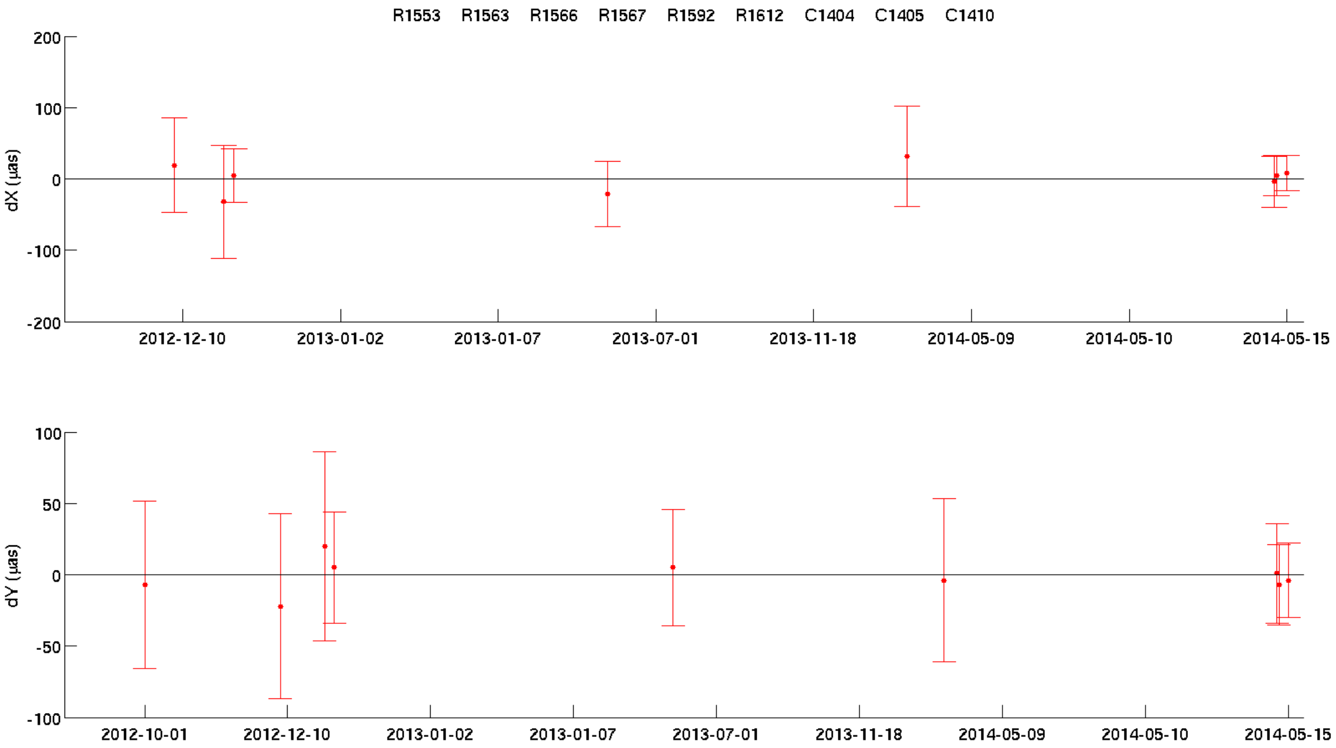
- Good agreement in EOP between DBBC and analog
- Both UT1-TAI and rate term within error limits
- Differences are between of approx. +-2.5 μs in UT1-TAI and +-1.0 μs/d in rate

Od - On	UT1-TAI (μs)	Rate (μs/d)
WRMS	0.78	1.12

Data analysis and results



Data analysis and results



Data analysis and results

- Both polar motion and nutation term differences fall within error limits
- Differences scattered around zero-line - no significant biases detectable

Od - On	WRMS
Xpol (µas)	8.2
Ypol (µas)	7.6
dX (µas)	12.0
dY (µas)	7.7

Data analysis and results

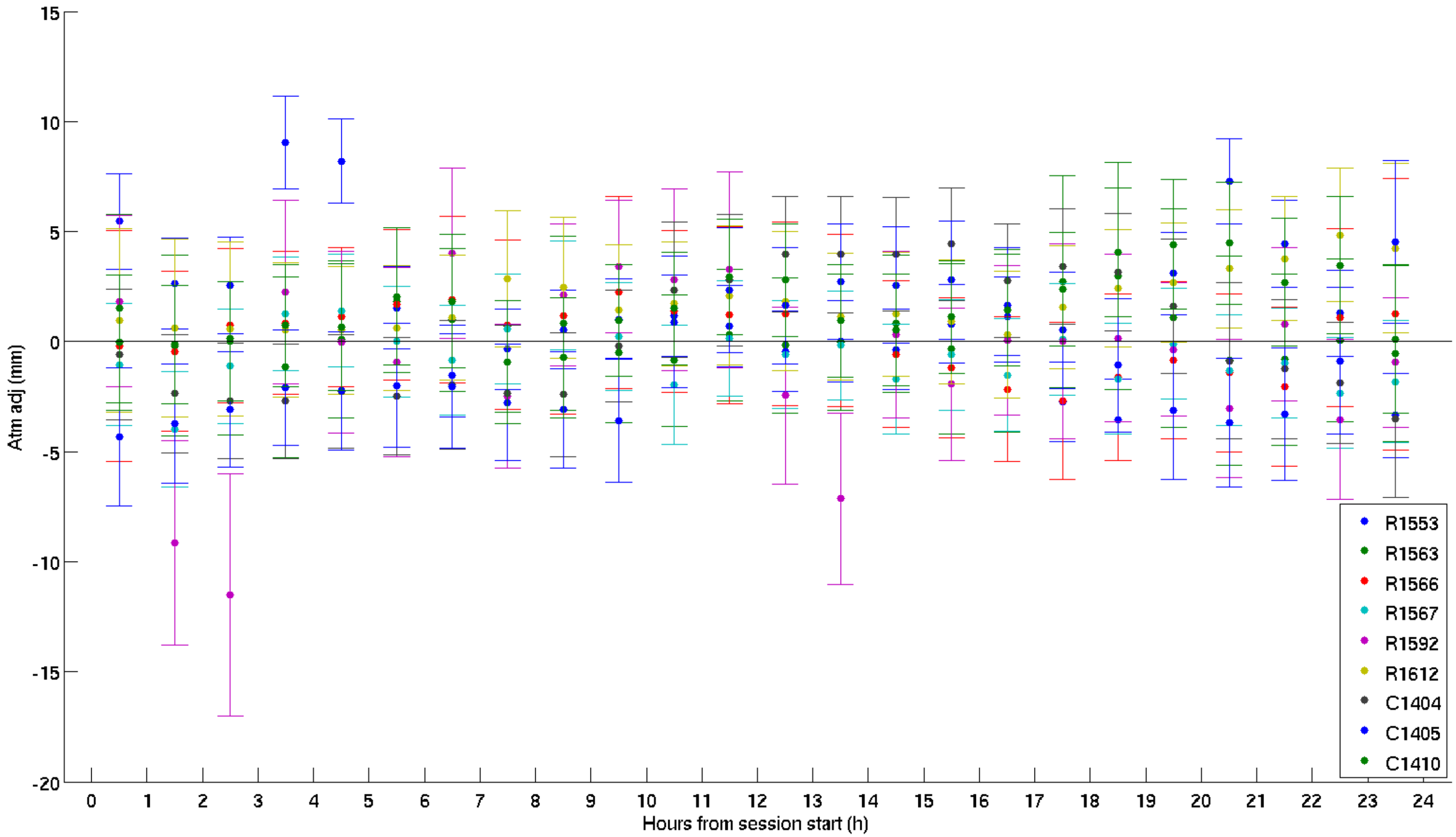
- The differences between ZWD estimates were relatively well within error limits
- Largest single differences in R1553 and R1592
- For R1592 reason is in wx calibration data
- Some issues may arise from interpolation
- WRMS between sessions ranging from 1.0 – 3.3 mm

Data analysis and results

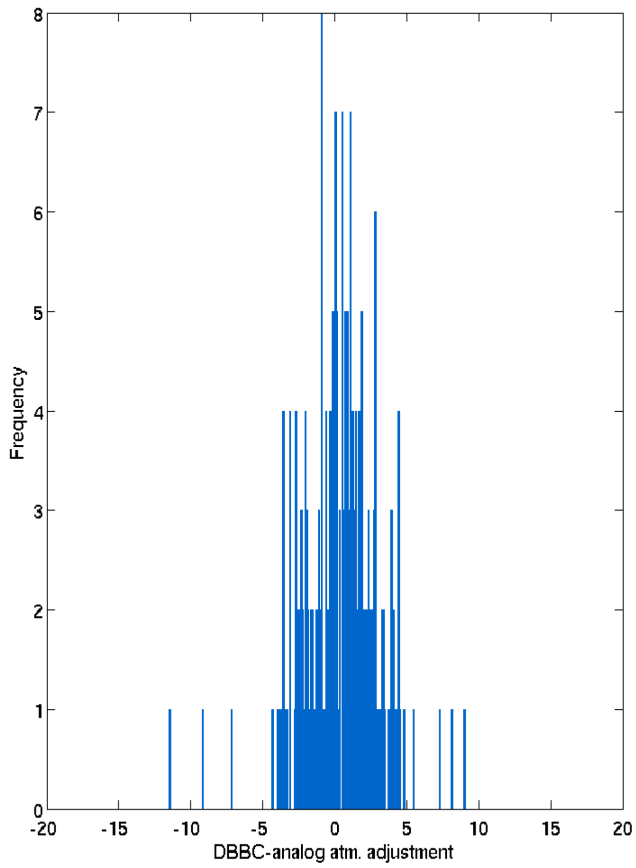
Session	WRMS (mm)
R1553	3.5
R1563	1.0
R1566	1.4
R1567	1.4
R1592	3.3
R1612	2.2
C1404	2.8
C1405	2.7
C1410	2.1

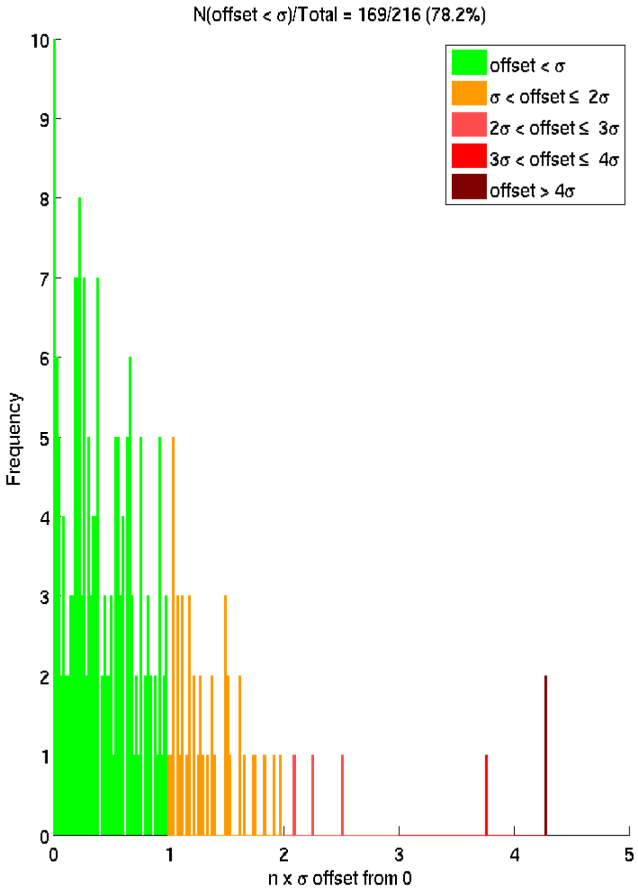
Od - On	Total WRMS
ZWD (mm)	2.6

Data analysis and results



Data analysis and results





Conclusions and outlook

- The digital backend at Onsala performs well for geodetic VLBI observations
- Tested for numerous IVS-sessions
- Databases produced from CONT14 use DBBC
- Zero-baseline tests: no significant differences between the analog and the digital backends

Conclusions and outlook

- Data analysis: no significant differences for the geodetic results of R1 and CONT14 -sessions between the analog and the digital backends in EOP
- Some disagreements in ZWD
  - requires further investigation
- Experiment more with nuSolve
- Analyze more CONT14-sessions
- Compare results from different analysis software

Conclusions and outlook

- Onsala installs a second digital backend (DBBC) in the fall of 2014 to work with Mark5C
- The analog backend has been phased-out completely and will be placed in the museum
- We will use both digital backends operationally for IVS and EVN -production