# UPDATE ON VLBI DATA ANALYSIS AT ESOC

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# VLBI data analysis at ESOC ... Outline

Part I
Remember ..

Part II
Watch now ..

Part III
Coming soon ..

# Part I … Motivation

ESOC's Navigation Support Office started in 2015 to enhance processing capabilities for VLBI tracking data

- complete ESOC's capabilities in generating independent EOPs
- contribute to the IVS service as analysis centre
- enhance our contribution to the IERS service with UT1-UTC and nutation products
- enable NAPEOS to combine all space-geodetic techniques at the observation level

# Part I … Challenges

- Incorporate new observation type in existing software packages NAPEOS
- NAPEOS is
  - a NAvigation Package for Earth Observation Satellites
  - mainly used for satellite orbit determination and prediction
  - able to process various data types: GNSS, SLR, DORIS, Altimetry, …
  - capable of combined processing of different data types

## Advantages

**No need to start from scratch!**

- already existing modules, algorithms, parameter types …
- combined processing almost for free

## Disadvantages

**No chance to start from scratch!**

- tricky bookkeeping for types, links, parameters …
- integration and testing effort

# Part I … Results achieved in 2016

- Database handling done
- Observation reading (NGS) done
- Basic VLBI observation modelling done

- No observation weighting yet
- No parameter estimation yet (clock offset only)
- 1h sessions only

- O-C residuals

RMS

Phase I: 10 cm level

# Part II … Current status

- Full implementation of Consensus model done
  - Gravitational delay added
  - Review of coordinate time scales (TT, TCG, TDB, TCB)
- Validation of observation modelling against VieVS successful

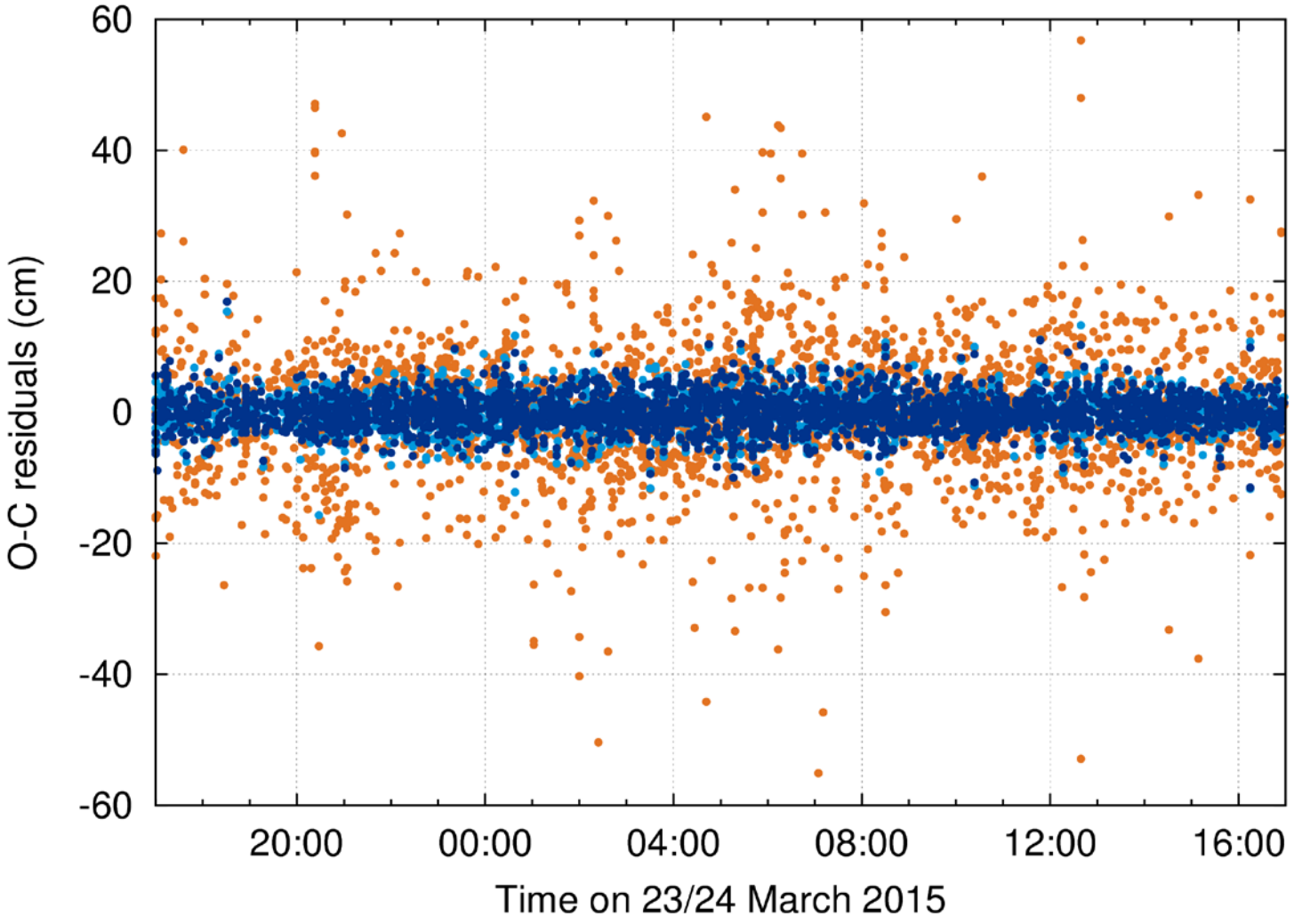
- Estimation of piece-wise linear clocks enabled
- Estimation of tropospheric wet zenith delays and gradients (North/East) enabled

- O-C residuals

RMS

| Phase II: | 2-3 cm level |
|---|---|

# Part II … Example residuals




I5MAR23XA_N004
24H SESSION
21 BASELINES
2850 OBSERVATIONS

| | RMS |
|---|---|
| pwl clocks / 6 h | 10.46 cm |
| + pwl ZPD / 1 h | 2.77 cm |
| + pwl TG / 24 h | 2.61 cm |

# Phase III ... next steps

- Add observation weighting
- Add outlier detection
- Add cable delay
- Add instrumental delay due to thermal deformation
- Implement automatic clock jump detection
- Implement clock model
- Add partial derivatives for remaining parameters
- Do full parameter estimation (VLBI)
- Do combined parameter estimation (VLBI + GNSS + ...)
- Participate in the next VASCC for validation of VLBI delay model

# Questions for you ...

On the sound usage of coordinate time systems

- Consensus model for VLBI connects 2 systems: BCRS and GCRS
- But there are 4 coordinate times: TCB and TCG and their scaled versions TDB and TT
  - ? Which coordinate time systems have to be used in a sound theoretical formulation of the Consensus model?
  - ? How do you deal with different mass parameter values (GM) from IERS conventions and JPL ephemeris?
  - ? Can we neglect scaling effects for mass parameters and barycentric coordinates when aiming for ps-level accuracy?

# Usage of coordinate time systems

| BCRS | TCB | TDB |
|---|---|---|
| Coordinate time | $t = TCB$ | $t^* = TDB = Ft + t_0{}^*$ |
| Spatial coordinates | $x$ | $x^* = Fx$ (1) |
| Mass parameter | $\mu$ (2) | $\mu^* = F\mu$ (1) |
| **GCRS** | **TCG** | **TT** |
| Coordinate time | $T = TCG$ | $T^{**} = TT = LT$ |
| Spatial coordinates | $X$ | $X^{**} = LX$ |
| Mass parameter | $\mu$ | $\mu^{**} = L\mu$ (2) |

$F = 1 - L_B$ $\quad L = 1 - L_G$

$t_0{}^* = -6.55 \times 10^{-5} s$
$L_B = 1.550519768 \times 10^{-8}$
$L_G = 6.969290134 \times 10^{-10}$

JPL ephemeris (DE405/421)

Quasar position (ICRF)

Consensus model for VLBI

Observable (proper time ~ TT)

1. Rescale JPL ephemeris readings from TDB → TCB
2. Use mass parameter in TCB for Consensus model, but in TT for tidal effects

Mass parameter given in IERS conventions and JPL ephemeris do not always coincide

Ref.: Klioner (2008), A&A 478, 951-958

# Conclusion

- ESOC's Navigation Support Office continues its effort towards VLBI data analysis
- VLBI observation model is fully implemented and tested
- Parameter estimation is on-going
- Current O-C residual level: 2-3 cm
- We need your opinion on open modelling issues (e.g. coordinate time systems, cable delay)
- We need your experience in VLBI data analysis (e.g. parameterization)

→ We stay in touch!

# Please stay tuned …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