# Several aspects concerning EOP combination

Daniela Thaller [1)], Manuela Seitz [2)]

*(1) Astronomical Institute, University of Bern (AIUB), Switzerland*
*(2) Deutsches Geodätisches Forschungsinstitut (DGFI), Munich, Germany*

# Overview

1. Different **parameterizations** and **continuity**

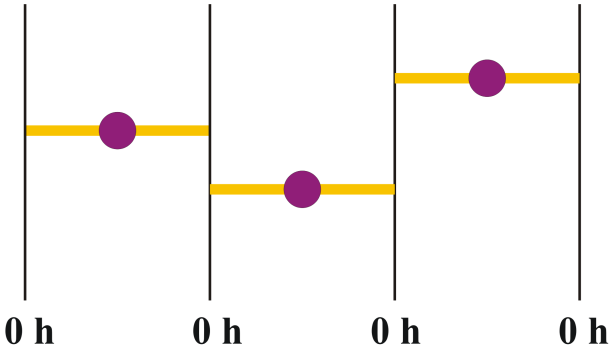
2. Problem of **reference epochs** (VLBI vs. GNSS/SLR/DORIS) and impact of combination strategy

3. **Daily** vs. **multi-year** solutions for deriving EOP time series

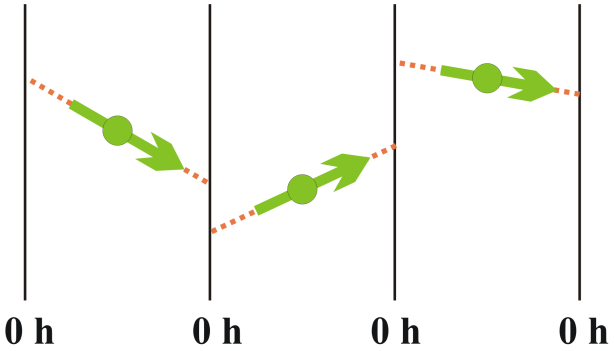
4. **UT/LOD**: VLBI + GPS

All studies are based on the data of the
→ CONT02 campaign
→ project GGOS-D (for long time series)

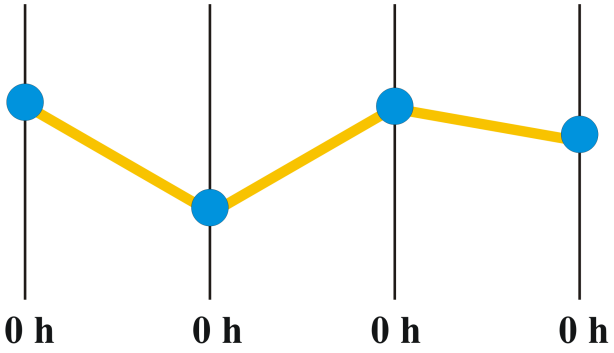
# Parameterization of EOPs




**Offset-only**
Piece-wise constant
***n*** parameters
no continuity at boundaries
continuity constraints not reasonable




Piece-wise linear **Offset+Drift**
***2*n*** parameters
no continuity at boundaries
continuity constraints reduce #parameters to ***n+1***




Piece-wise linear **Polygon**
***n+1*** parameters
“real”continuity at boundaries
no continuity constraints needed
not distinguishable from “offset-only” in SINEX

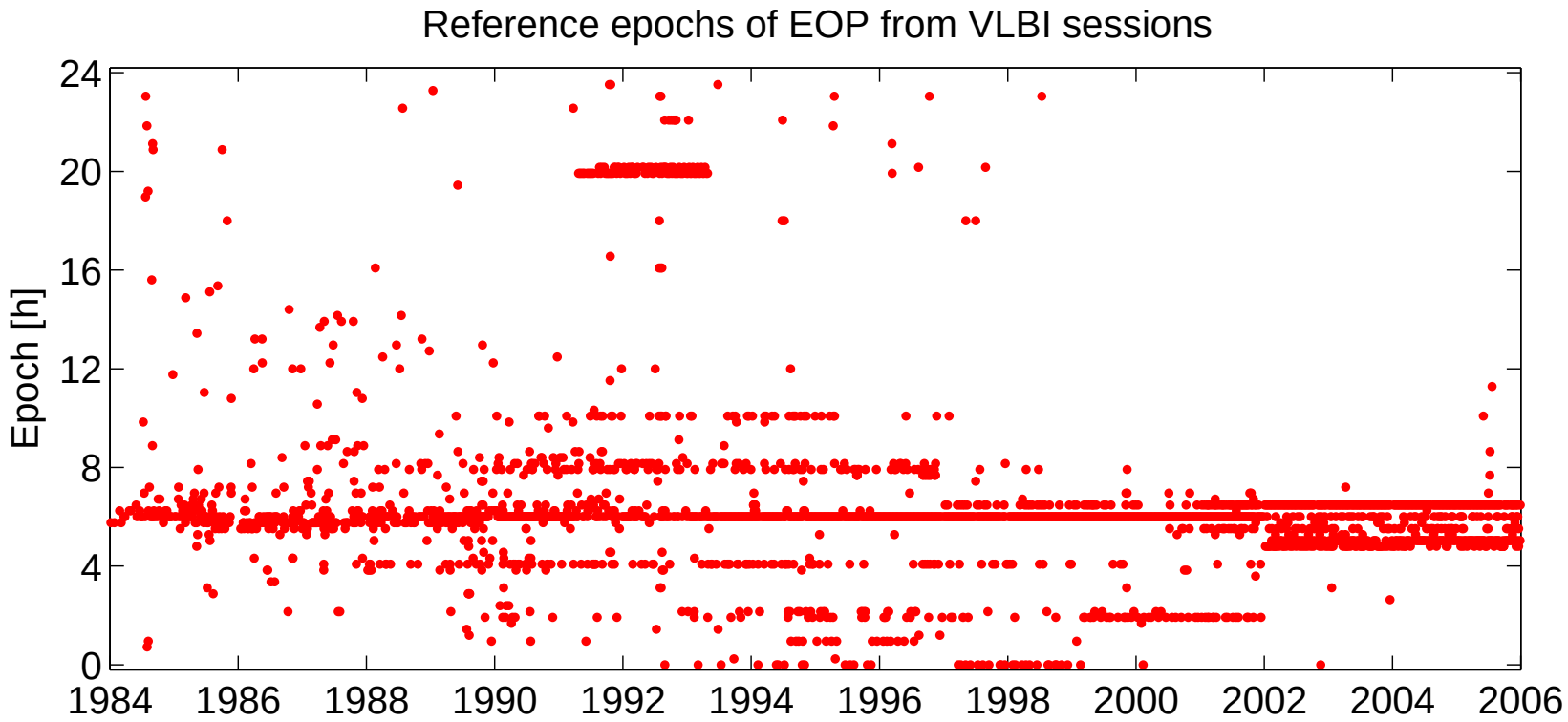
# EOP combination: Problem of reference epoch

**Problems:** a) 24-h VLBI Sessions **NOT 00:00 – 24:00 UTC**

⇒ Epoch of „daily“ EOPs different from 12:00 UTC

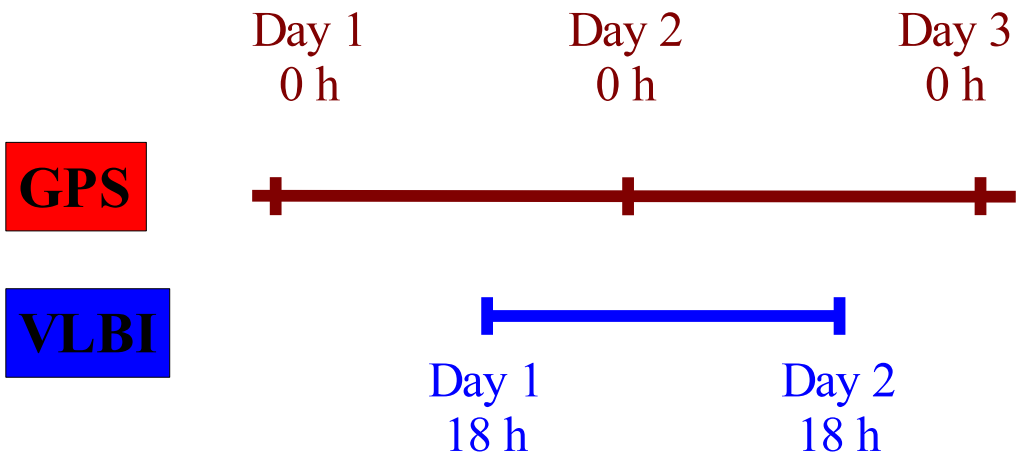
⇒ No clear correspondence to daily GPS-/SLR- EOP

b) **changing** reference epoch from session to session



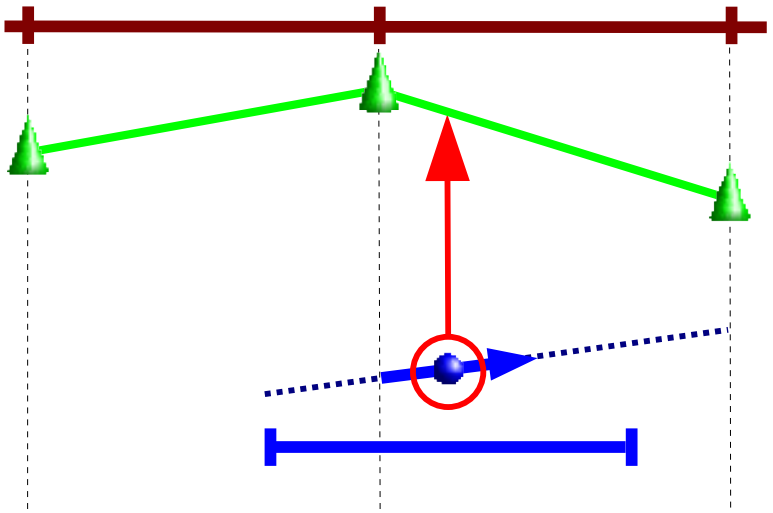
# EOP combination: Problem of reference epoch

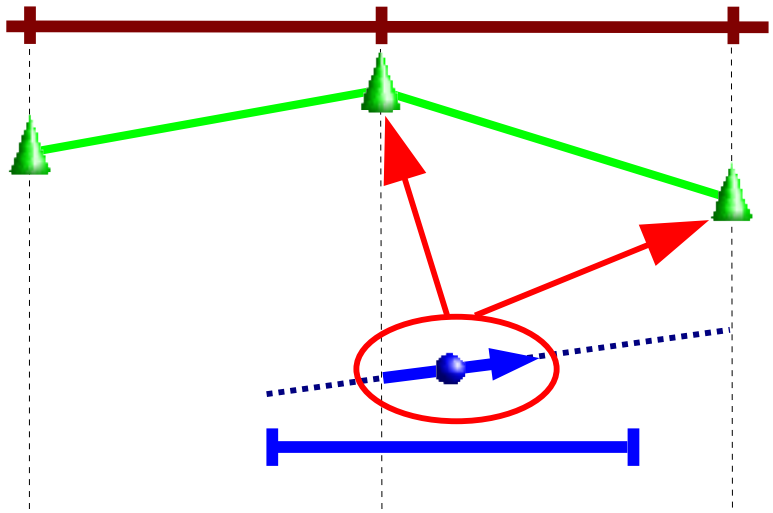
No clear correspondence between validity intervals of ***daily EOPs*** derived from GPS/SLR and from VLBI 24-h sessions



# Reference epoch of EOP: Combination strategy

No clear correspondence between validity intervals of ***daily EOPs*** derived from GPS/SLR and from VLBI 24-h sessions





***Use offset only:***

+ Offset is correctly included into time series
- „Mixture“ of validity intervals
- Contribution to one day only
- ERP drift is ignored

***Use offset + drift:***

+ Offset and drift information are used
- „Mixture“ of validity intervals
- Contribution to one day only

# Reference epoch of EOP: Combination strategy

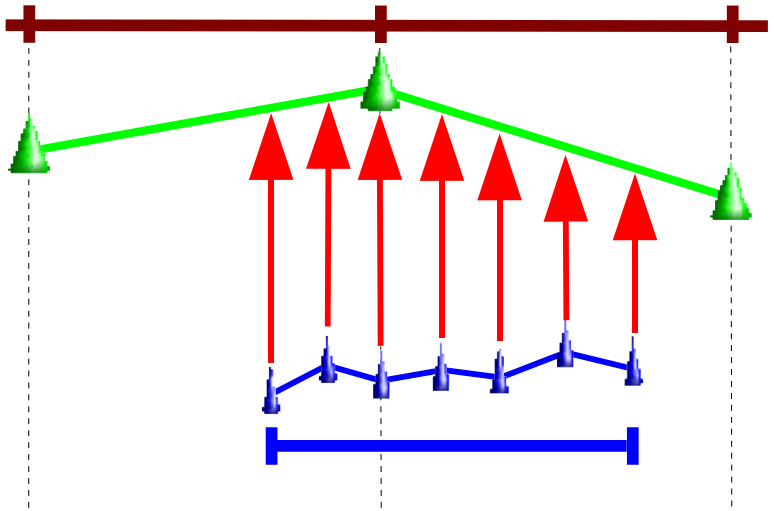
No clear correspondence between validity intervals of ***daily EOPs*** derived from GPS/SLR and from VLBI 24-h sessions

⇒ **Can be avoided if higher temporal resolutions are used in the individual contributions:**

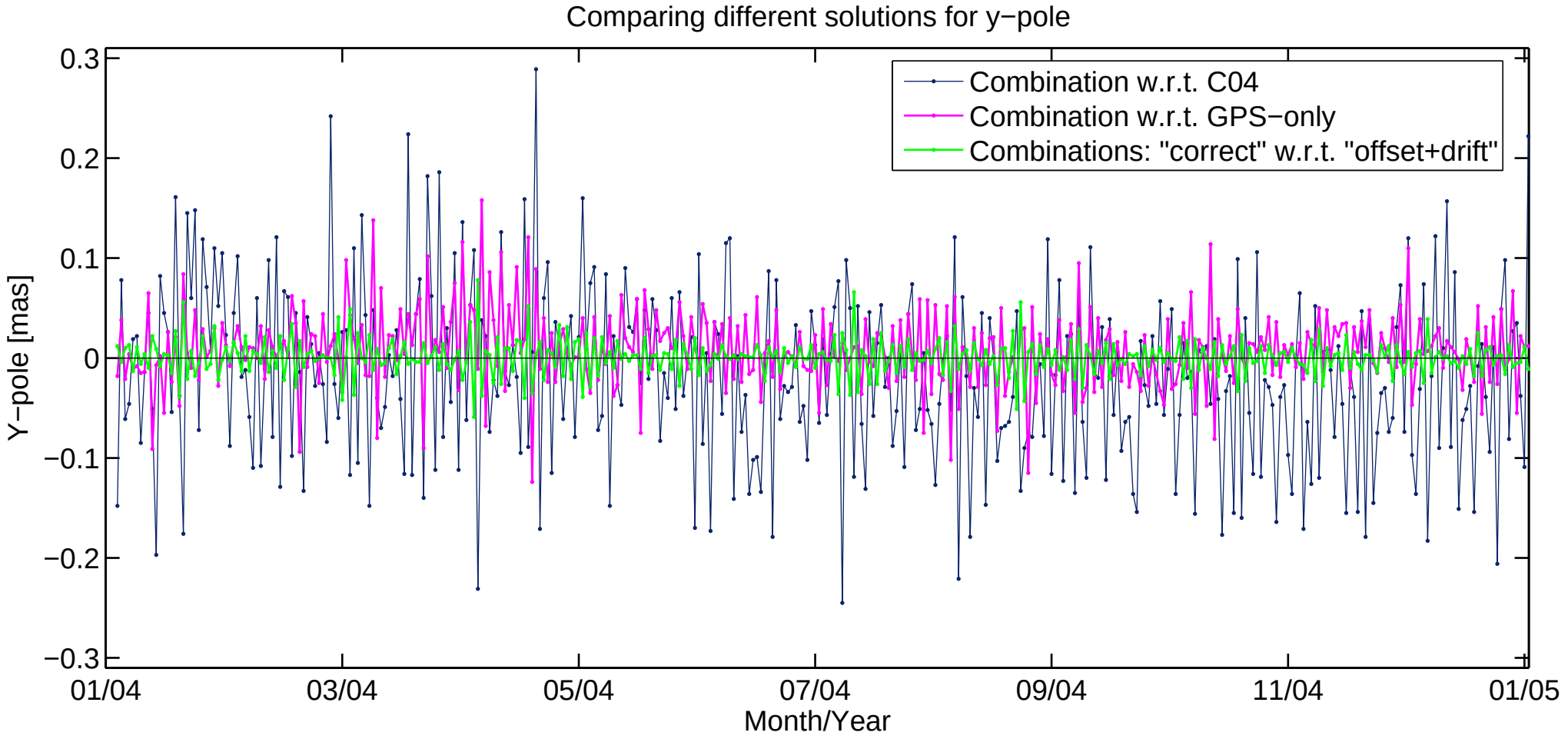
→ At least splitting up at midnight (or even higher resolution)

→ ***Full ERP information*** is correctly included into time series

→ Equivalent to ***correct distribution of observations*** to individual ERPs



# Reference epoch of EOP: Combination strategy




| | *Combination w.r.t. external (C04)* | *Combination w.r.t. single-technique* | *„Correct“ Combination w.r.t. „offset+drift“* |
|---|---|---|---|
| ***WRMS x-pole*** | 89.8 µas | 43.1 µas | 18.2 µas |
| ***WRMS y-pole*** | 82.0 µas | 39.8 µas | 18.3 µas |
| ***WRMS UT*** | 18.4 µs | 8.4 µs | 6.6 µs |

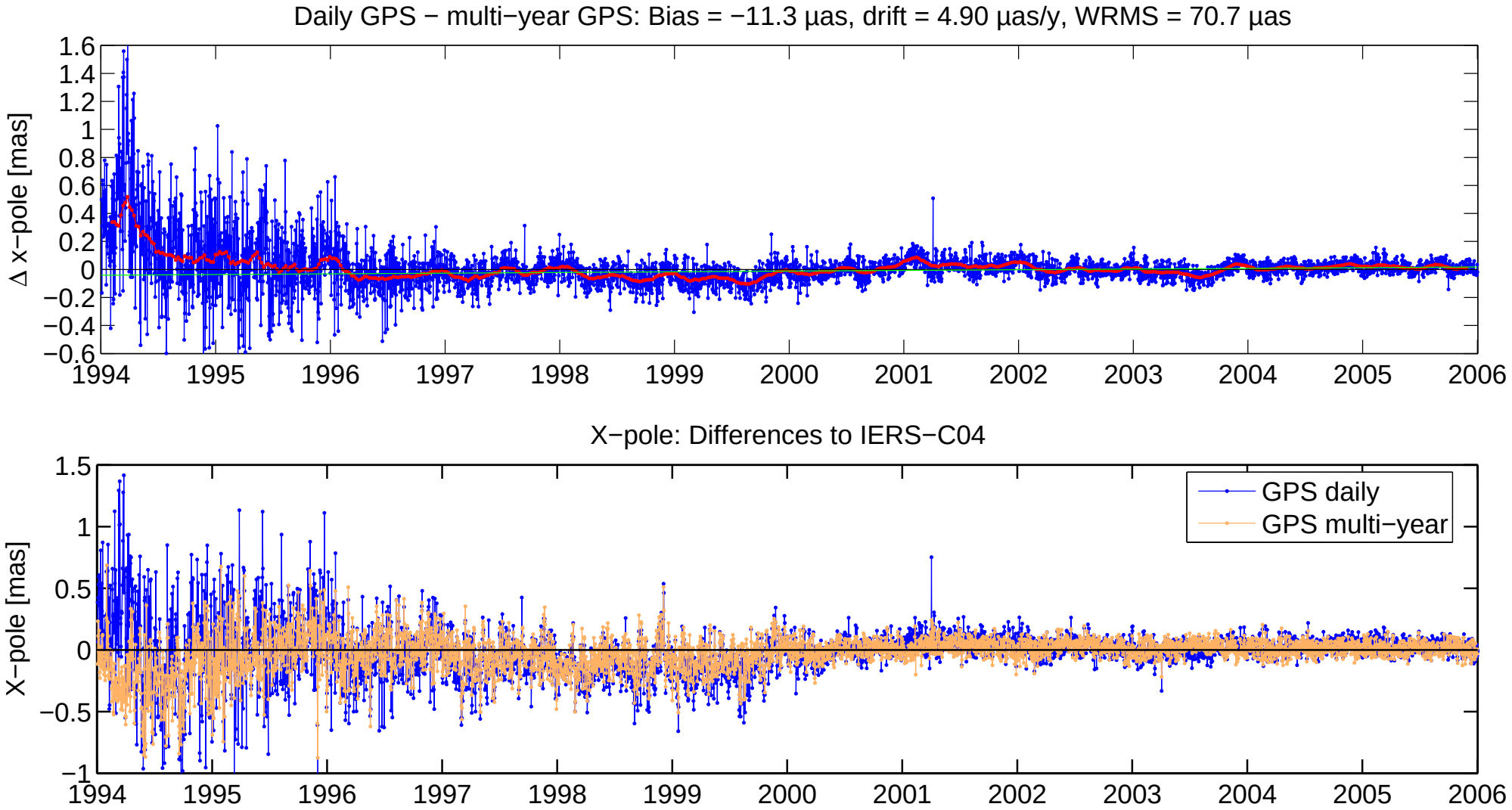
# Daily vs. multi-year solutions

- ***Daily solutions***:
  daily realization of TRF (station coordinates)
  → TRF slightly different from day to day

- ***Multi-year solution***:
  TRF (station coordinates + velocities) together with EOPs
  → fully consistent time series

What is the impact on the time series of EOPs?

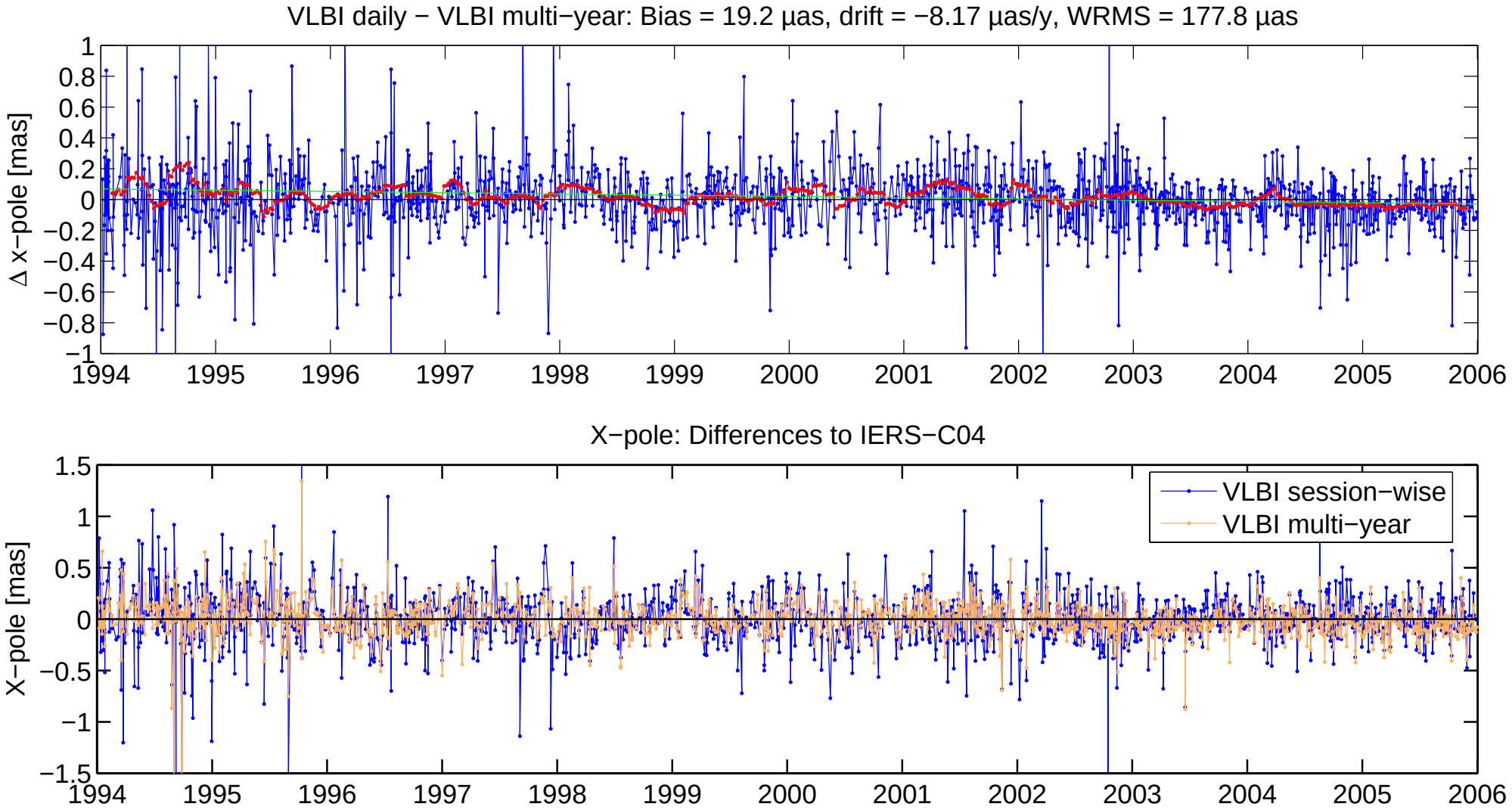
# Daily vs. multi-year solutions for PM: GPS




**WRMS vs. IERS-C04**: X-Pole **112.7 µas** (daily) → **98.0 µas** (multi-year)
Y-Pole **109.9 µas** (daily) → **99.5 µas** (multi-year)

⇒ **Early epochs** benefit most from multi-year solution: small network, weak daily TRF

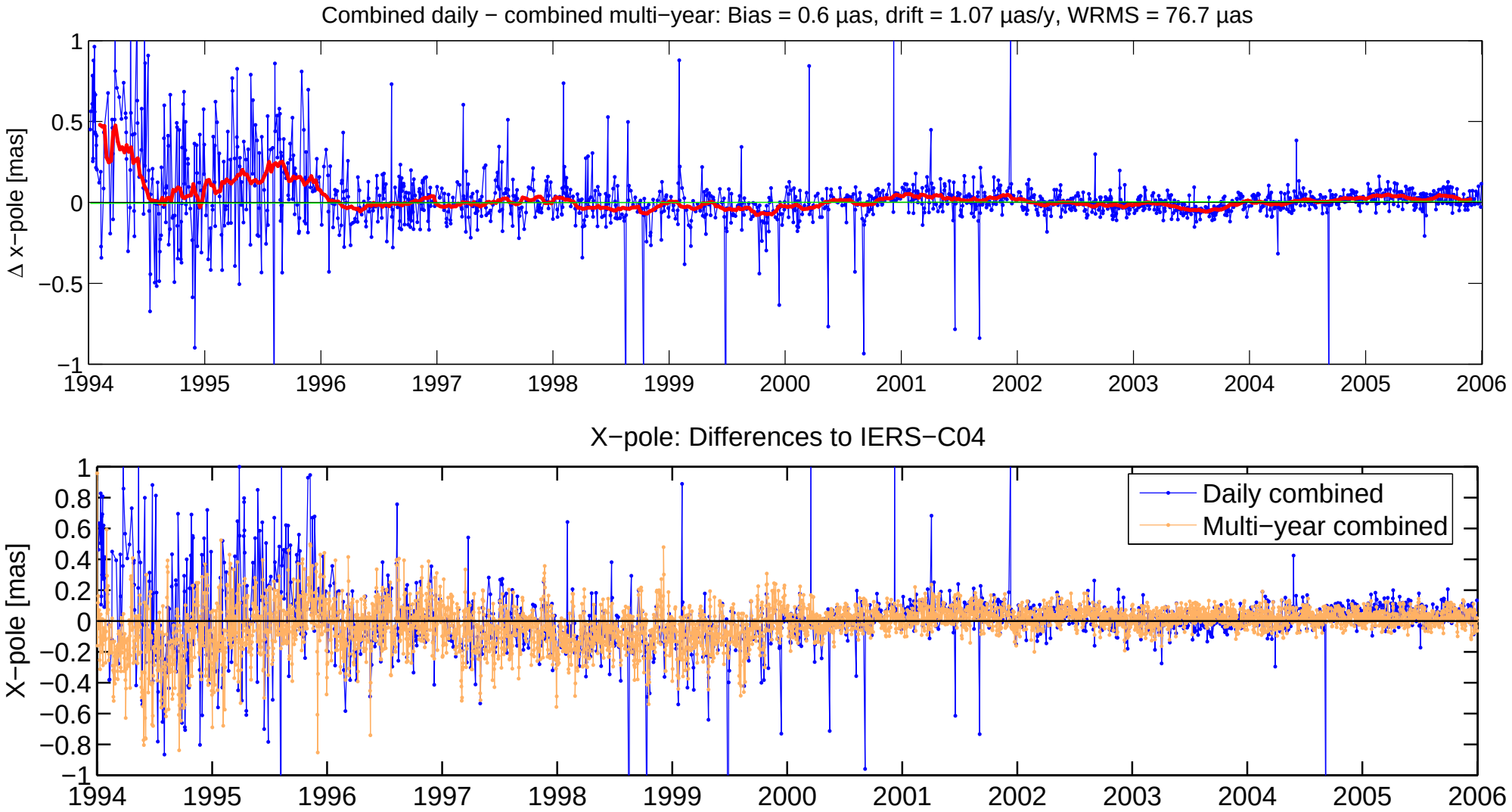
# Daily vs. multi-year solutions for PM: VLBI




**WRMS vs. IERS-C04**: X-Pole **155.6 µas** (daily) → **109.0 µas** (multi-year)
Y-Pole **195.4 µas** (daily) → **100.7 µas** (multi-year)

⇒ **All epochs** benefit from multi-year solution: generally small network, weak daily TRF

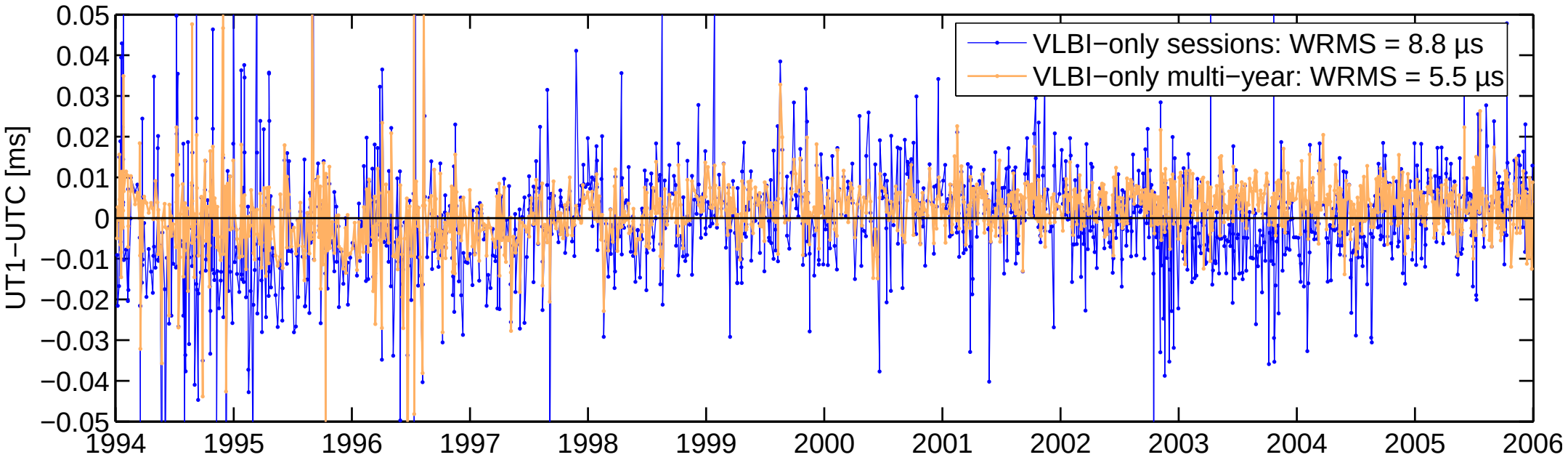
# Daily vs. multi-year solutions for PM: Combination




**WRMS vs. IERS-C04**: X-Pole **104.1 µas** (daily) → **98.1 µas** (multi-year)
Y-Pole **100.4 µas** (daily) → **96.0 µas** (multi-year)

⇒ **Early epochs** benefit most from multi-year solution: small network, weak daily TRF

# Daily vs. multi-year solutions for UT: VLBI

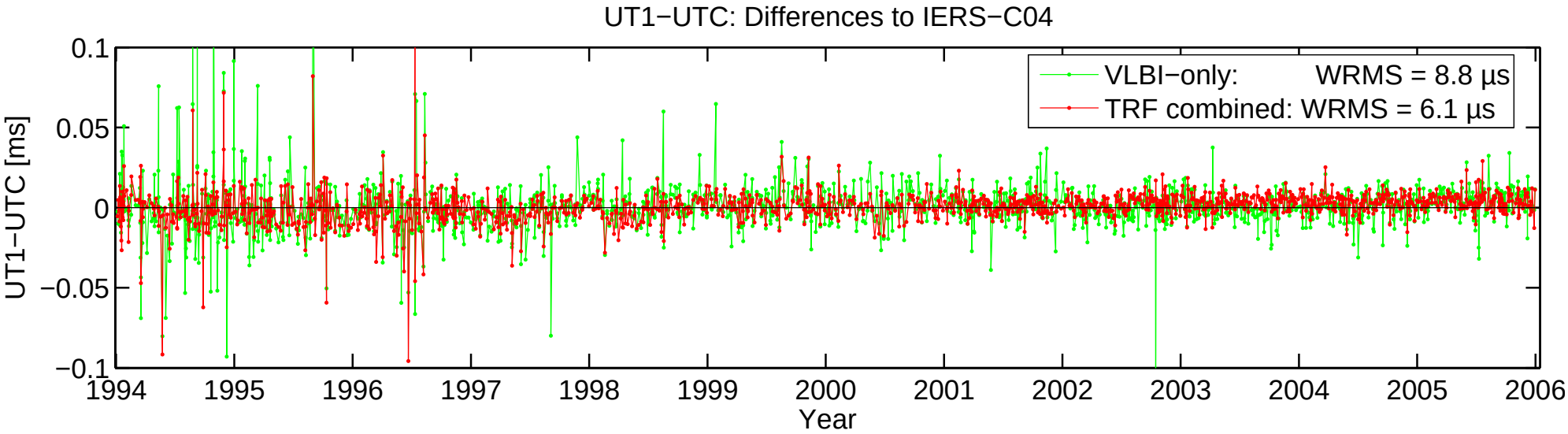



⇒ Similar to pole coordinates

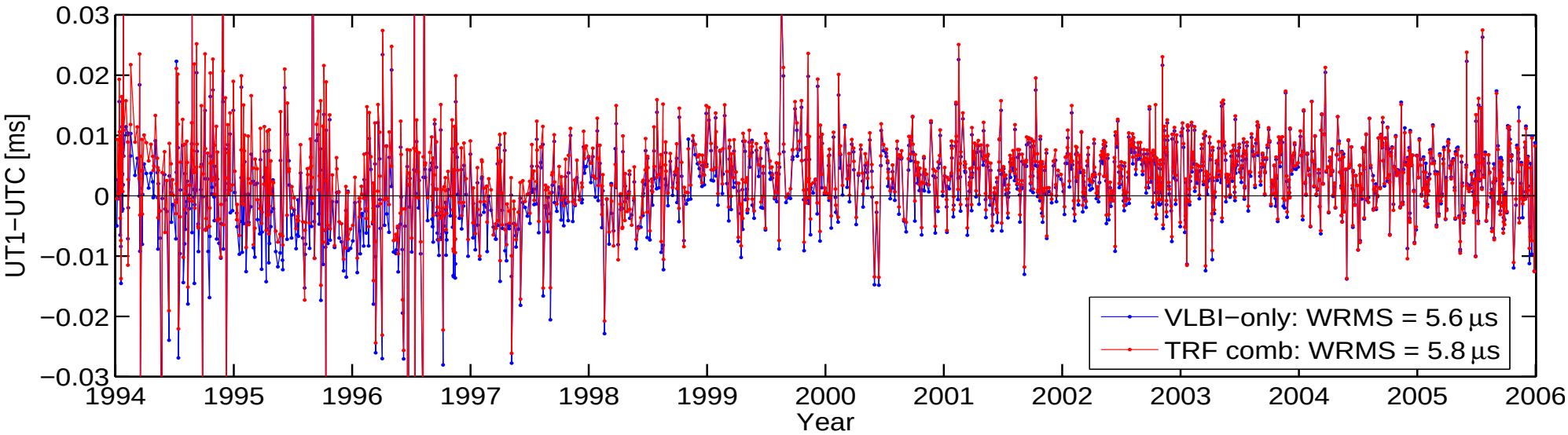
⇒ **All epochs** benefit from multi-year solution: generally small network, weak daily TRF

# Daily vs. multi-year solutions for UT: TRF combined

Session-wise combination: VLBI-only daily TRF weak ⇒ stabilization




Multi-year combination: VLBI-only TRF is already stable enough ⇒ no big impact



# EOP combination: Daily vs. multi-year

Problems with daily realization of TRFs: ***Number of Local Ties*** (LT)

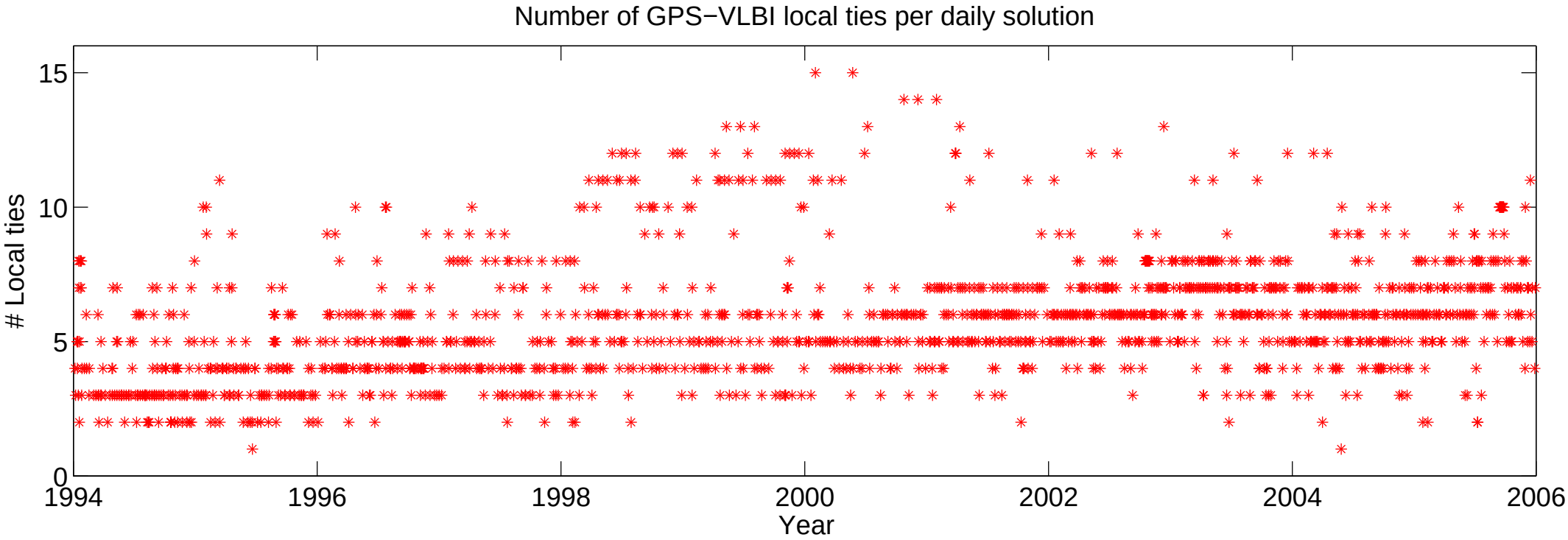
→ **LT per Session** in most cases very small

→ may be even reduced after selection of „good“ local ties

⇒ problematic for „VLBI-only parameters“ (***UT***, ***nutation***)

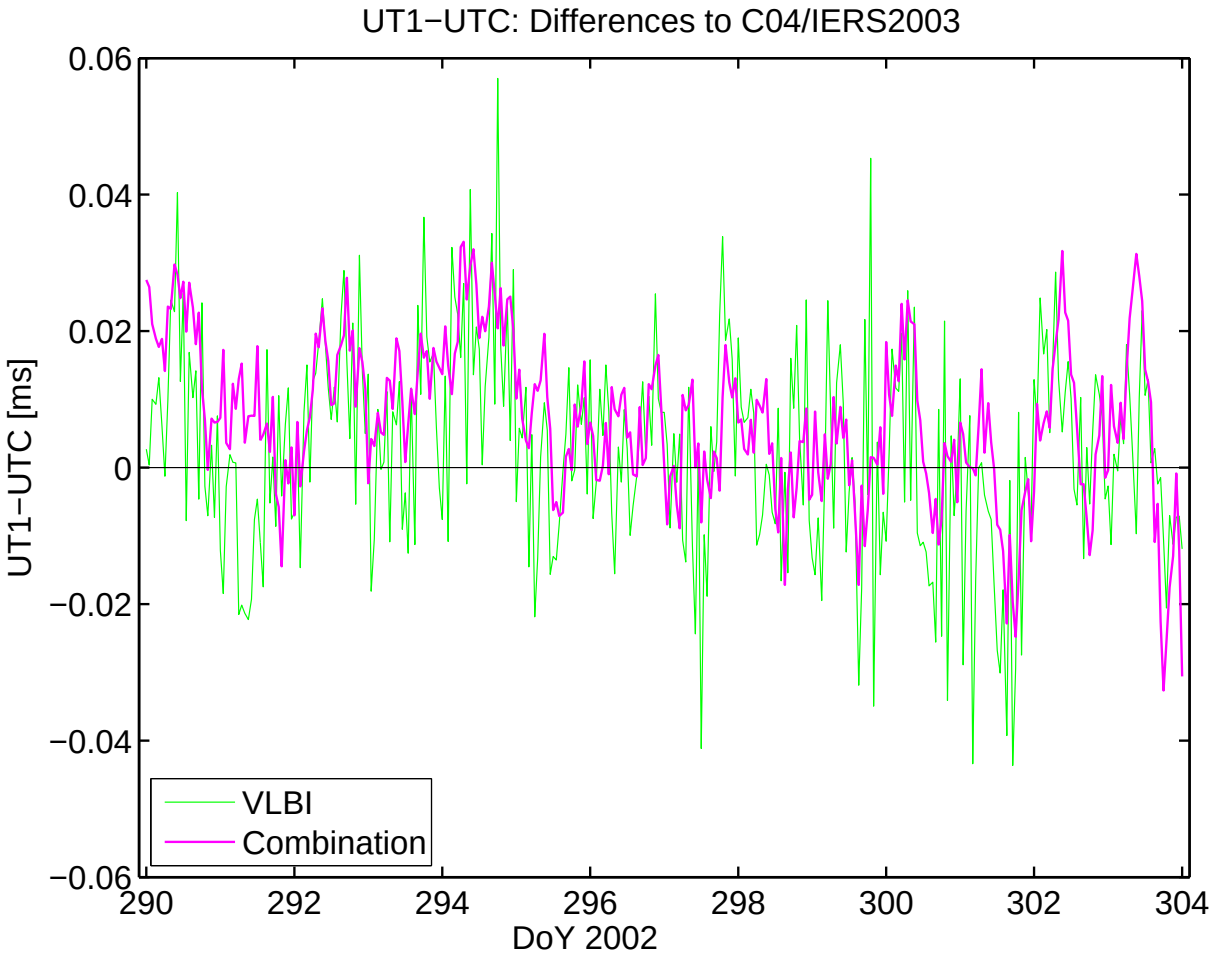
⇒ **Can be avoided if long-term solutions (multi-year) are computed**

Total number of LT in ITRF2008 (after selection): **17**



# UT/LOD combination: Continuous and sub-daily

**Continuous** VLBI contribution (CONT02) ⇒ No „GPS-only“ epochs in combination
**Sub-daily** resolution (1 h)

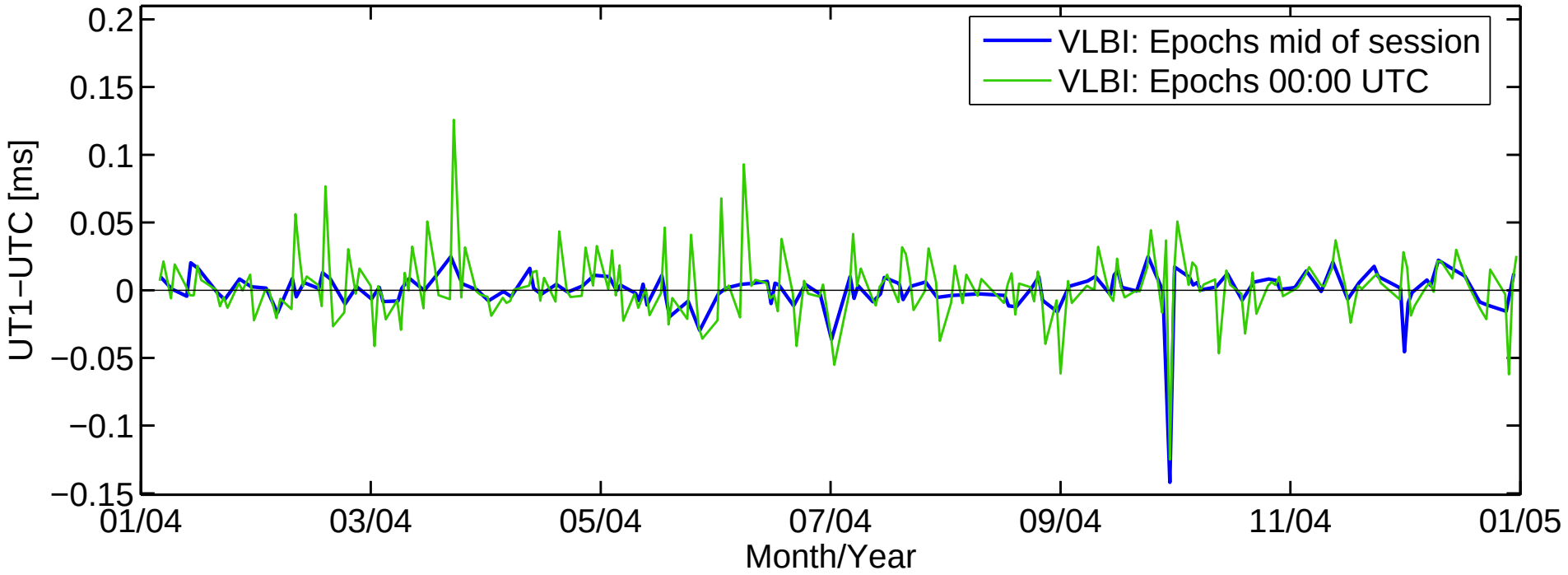



RMS VLBI-only: **15.1 µs**

| ***Combined Parameters*** | ***RMS [µs]*** |
|---|---|
| TRF | **15.2** |
| TRF+Pole | **14.8** |
| TRF+Pole+UT/LOD | **11.9** |
| **TRF+Pole+UT/LOD +Nut.+Trop.** | **11.6** |

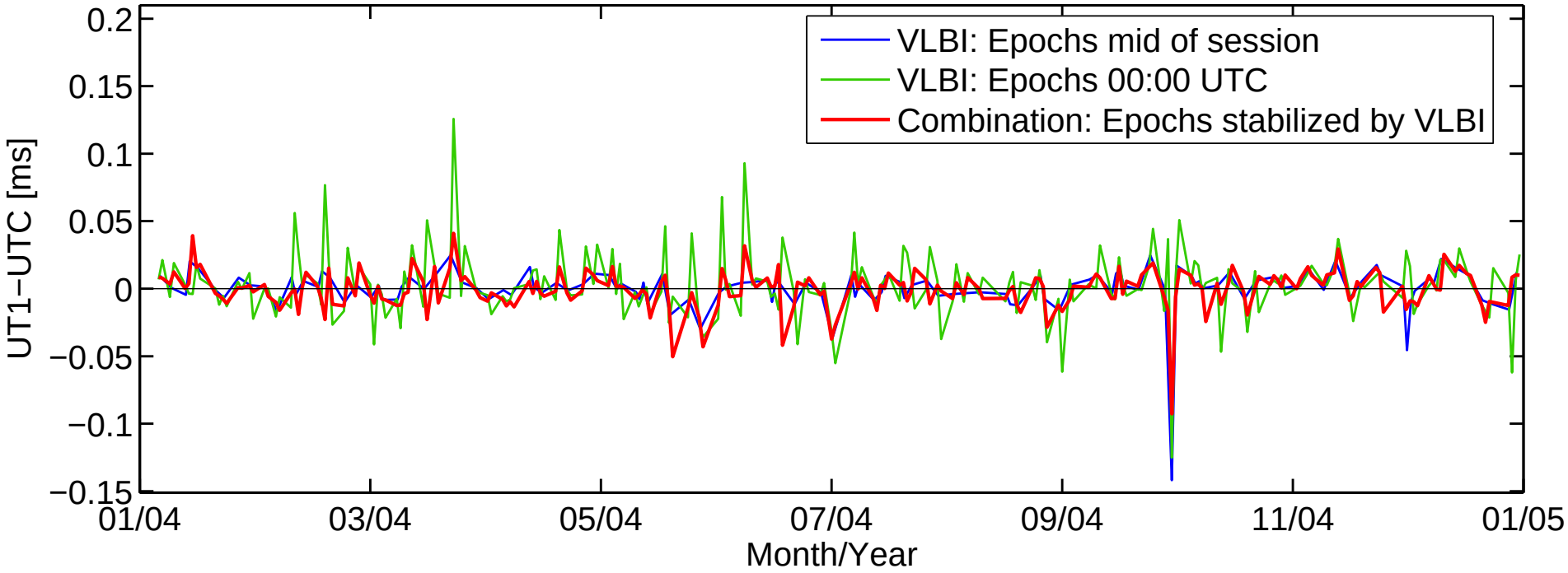
⇒ Combination UT/LOD works fine ⇒ benefit for the resulting UT time series

# UT/LOD combination: 24-h sessions




| *Solution type* | *# Epochs* | *Mean bias [μs]* | *WRMS [μs]* |
|---|---|---|---|
| **VLBI-only: Epochs mid of session (offset+drift)** | 129 | **0.7** | **10.1** |
| **VLBI-only: Epochs 0h (polygon)** | 224 | **0.2** | **15.9** |

# UT/LOD combination: 24-h sessions




| *Solution type* | *# Epochs* | *Mean bias [μs]* | *WRMS [μs]* |
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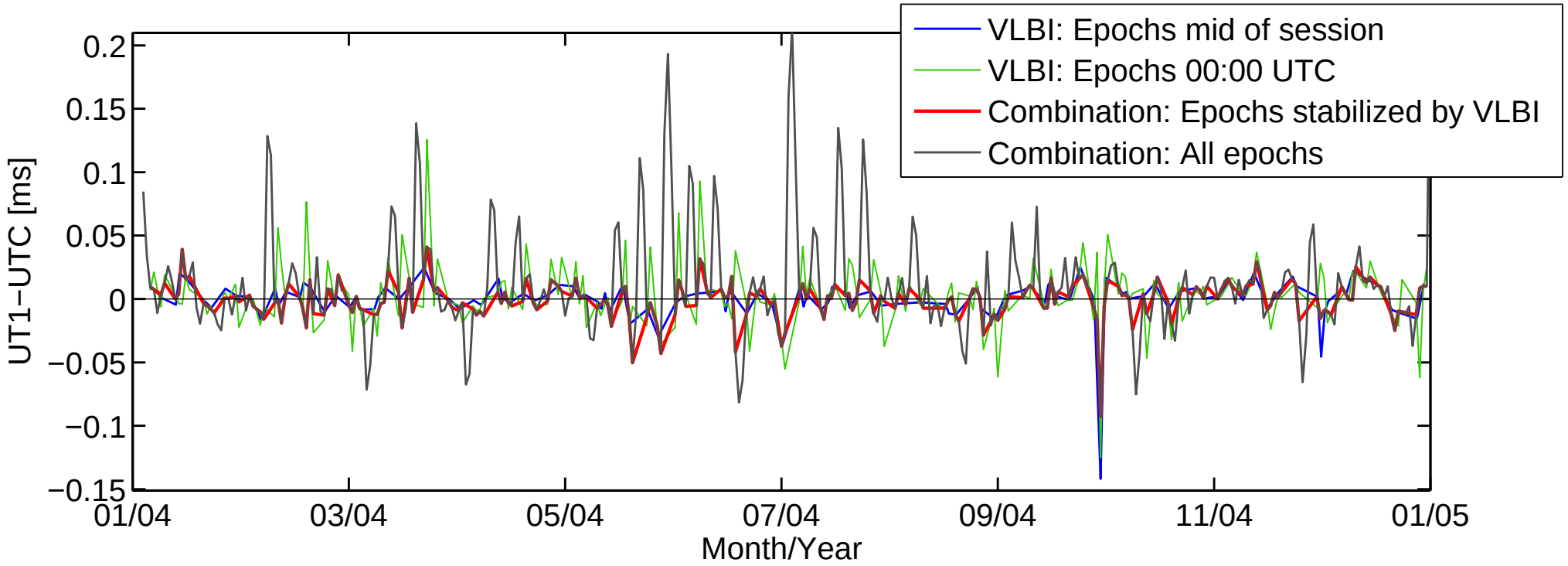
| **VLBI-only: Epochs 0h (polygon)** | 224 | **0.2** | **15.9** |
| **Comb: Only 0h-epochs with contribution of VLBI** | 224 | **-0.6** | **11.3** |

# UT/LOD combination: 24-h sessions




| *Solution type* | *# Epochs* | *Mean bias [μs]* | *WRMS [μs]* |
|---|---|---|---|
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| **VLBI-only: Epochs 0h (polygon)** | 224 | **0.2** | **15.9** |
| **Comb: Only 0h-epochs with contribution of VLBI** | 224 | **-0.6** | **11.3** |
| Combination: All epochs | 365 | 2.0 | 22.6 |

# Summary

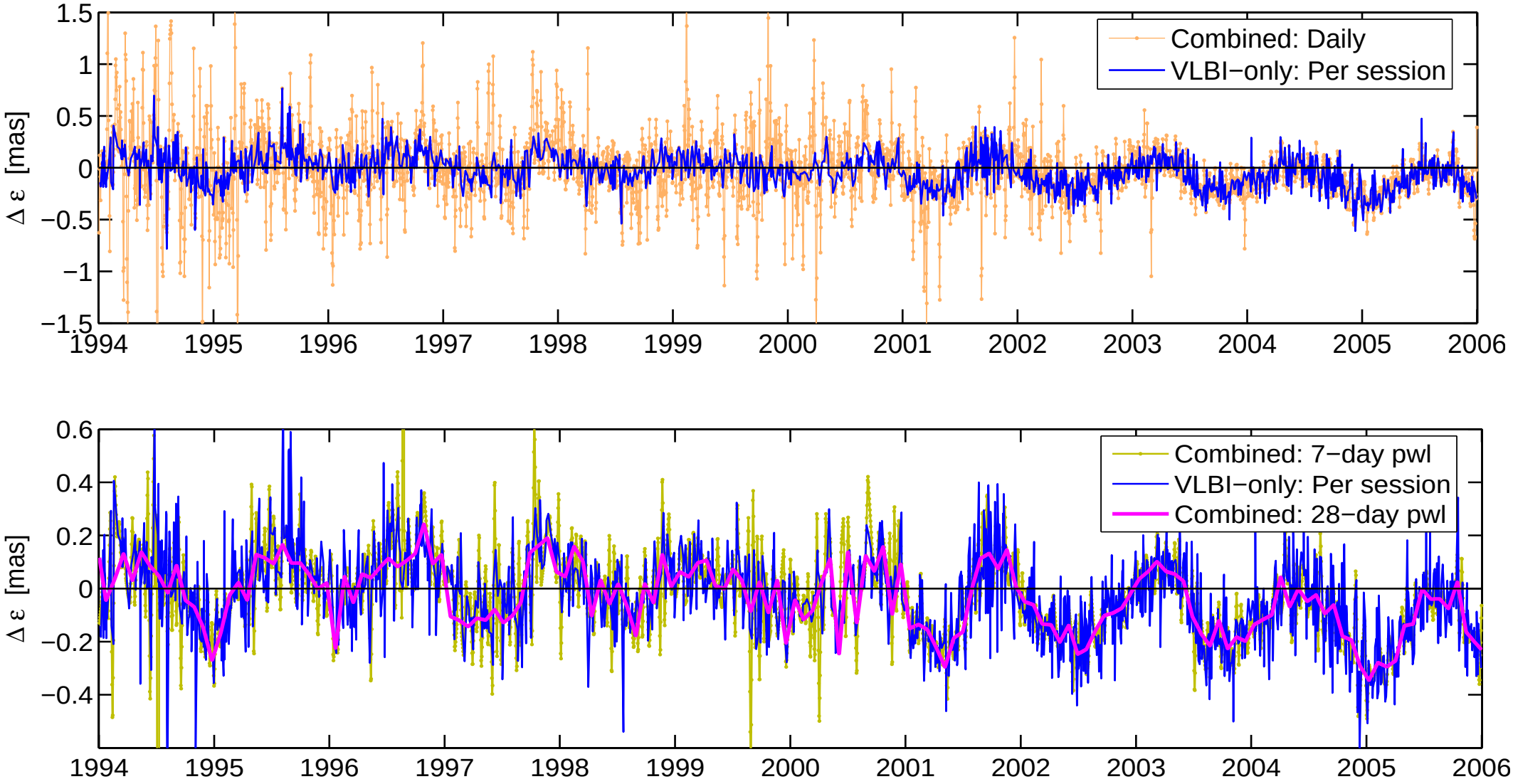
- Problem of different ***reference epochs*** (VLBI vs. satellite-techniques):
  → combination strategy is important

- ERPs from ***long-term solutions*** are more stable than ***daily solutions***
  → especially if daily network is weak

- ***Combination of UT/LOD*** from VLBI and GPS is possible
  → continuous VLBI data (CONT campaigns)
  → epochs with contribution by VLBI
  → problems with "GPS-only" epochs (Densification: Intensive sessions)

***Further aspects*** (not covered here):
- Densification for UT using VLBI Intensive sessions
- Nutation (similar to UT, but lower temporal resolution possible)
- Correlation between sub-daily polar motion and nutation
- EOP useful for selection of good local ties (→ Manuela)

# VLBI/GPS Nutation







***Daily combination***: Problems with „GPS-only“ epochs (similar to UT)

⇒ Use lower temporal resolution (7d, 14d, 28d); main signal is Free-Core Nutation (~432 d)