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Der Wissenschaftsfonds.

Influence of the horizontal resolution of numerical weather models on ray-traced delays for VLBI analysis

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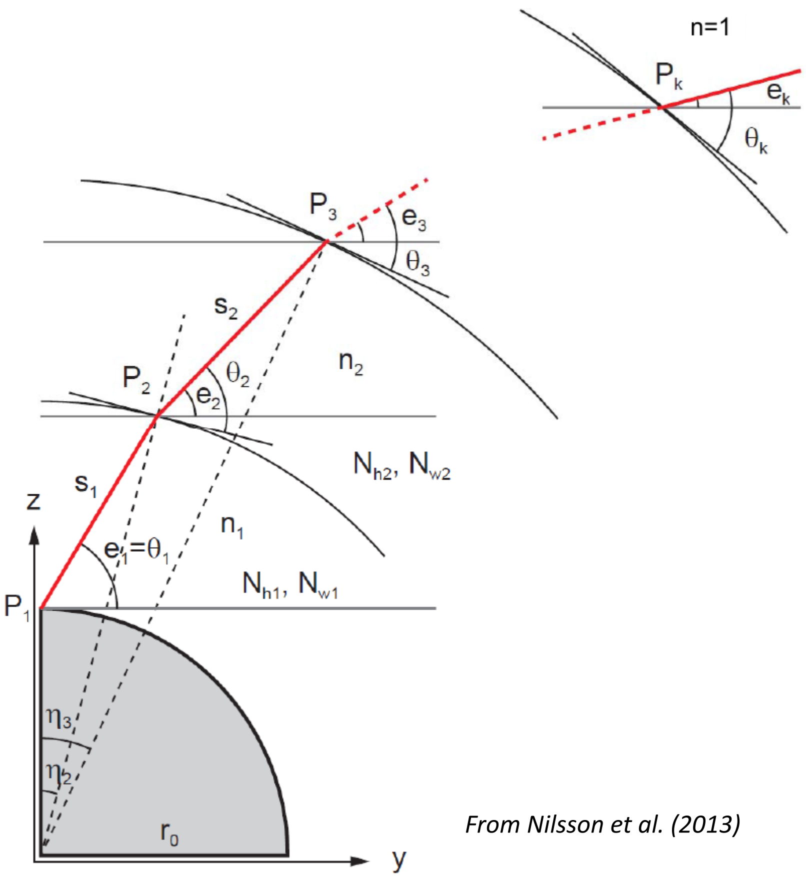
Ray-tracing



From Nilsson et al. (2013)

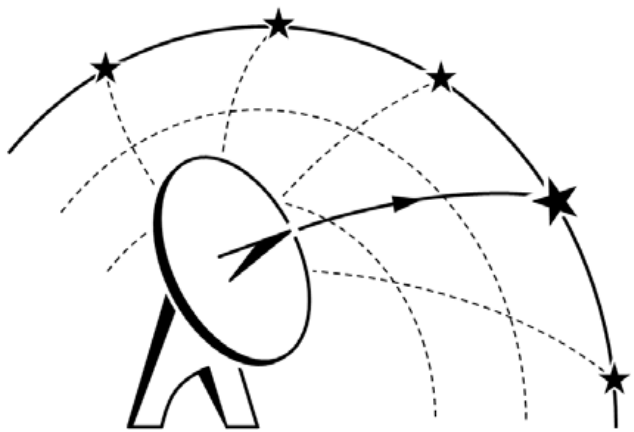
- For each observation
  1) Iterative reconstruction of the ray path through the troposphere
  2) Calculation of the delay
- Different approaches for path determination
  - E.g. piecewise-linear method
- Meteorological information from numerical weather models (NWM)
  - E.g. from ECMWF[1)]
- Derivation of refractivities for path and delay estimations

[1)] European Centre for Medium-Range Weather Forecasts

Ray-tracer RADIATE

- Ray-tracing program RADIATE developed within the project RADIATE VLBI[1)]
  - Capable of different ray-tracing approaches, e.g. piecewise-linear

- With program RADIATE we want to achieve the main goals within project RADIATE VLBI
  - Determination of ray-traced delays for all VLBI observations since 1979
  - Creation of new improved tropospheric delay models using the ray-traced delays
  - Improvement of the VLBI analysis by the use of the ray-traced delays and the new delay models



[1)] Ray-traced Delays in the atmosphere for geodetic VLBI

Motivation and methodology of the research

- NWM as main input for ray-tracing
  - → main impact on resulting delays
- Besides the general selection of an appropriate NWM also the horizontal resolution can be chosen
  - → possibility of significant impact on delays
- Research using ray-traced delays from program RADIATE
- Comparisons to determine the impact
  1) Direct comparison of ray-traced slant delays (RD) using a specific NWM with different horizontal resolutions
  2) Comparison of VLBI analysis results from applied ray-traced delays regarding baseline length repeatability (BLR) and station coordinate repeatability (SCR)

Data for the research

- NWM “ECMWF Operational” with
  - 25 pressure levels
  - Temporal resolution of 6 hours
  - Horizontal resolution of 0.125° x 0.125° **<u>or</u>** 1° x 1°

- IVS CONT11 campaign (Sept. 15 – 29, 2011) as observational data input

Ray-traced delays (RD) for CONT11

- Enhanced vertical resolution of the NWM by interpolation at discrete height levels
- Extended meteorological data up to 84 km through standard atmosphere model for height levels not supported by the NWM
- Ray-traced delays (RD) from piecewise-linear approach
- Delays at exact observation time
  - Through linear interpolation of the delays calculated at the two adjacent epochs of the NWM

Direct comparison of ray-traced delays (RD)

- Differences Δ between RD from NWM(0.125°) and NWM(1°)
  - Δstd: differences in slant total delay

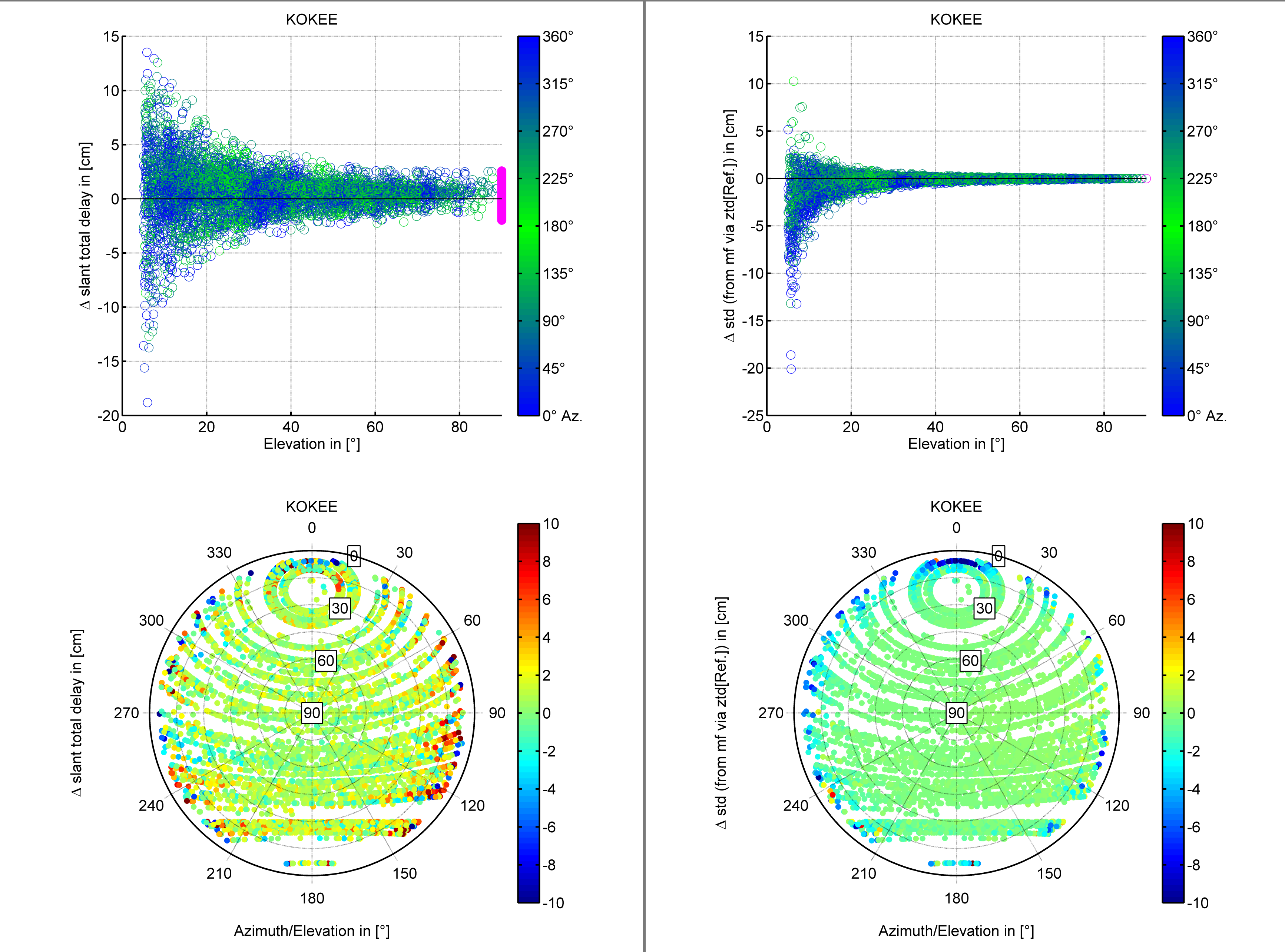
$$\boxed{\Delta std = std_{NWM(0.125^\circ)} - std_{NWM(1^\circ)}}$$

  - Δstd_{mf}: differences in slant total delay calculated from mapping factor mf
    - A kind of “scaled” variant of Δstd

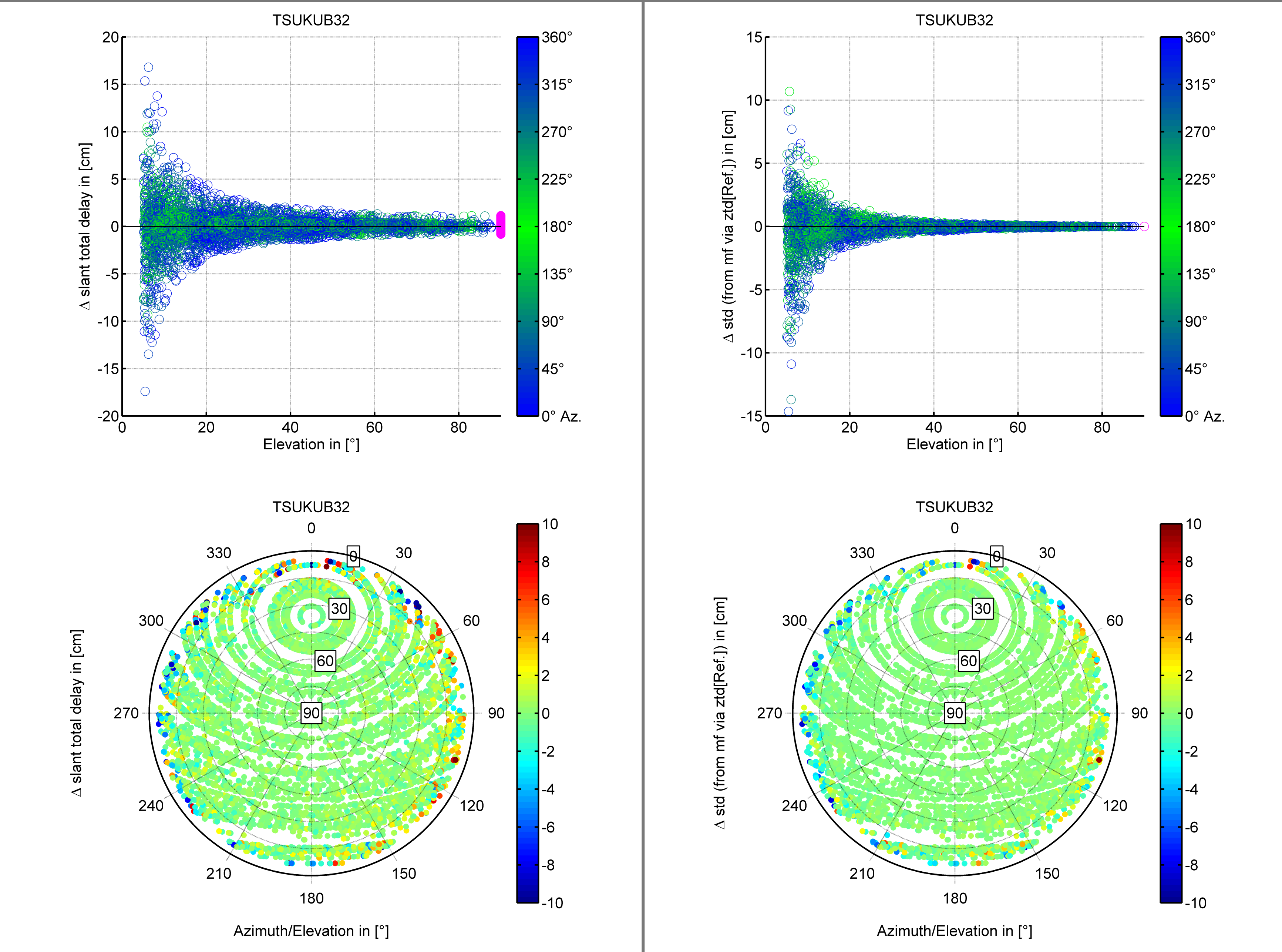
$$\boxed{\Delta std_{mf} = std_{NWM(0.125^\circ)} - (std_{NWM(1^\circ)} / ztd_{NWM(1^\circ)}) * ztd_{NWM(0.125^\circ)}}$$

$$\boxed{mf = std / ztd}$$

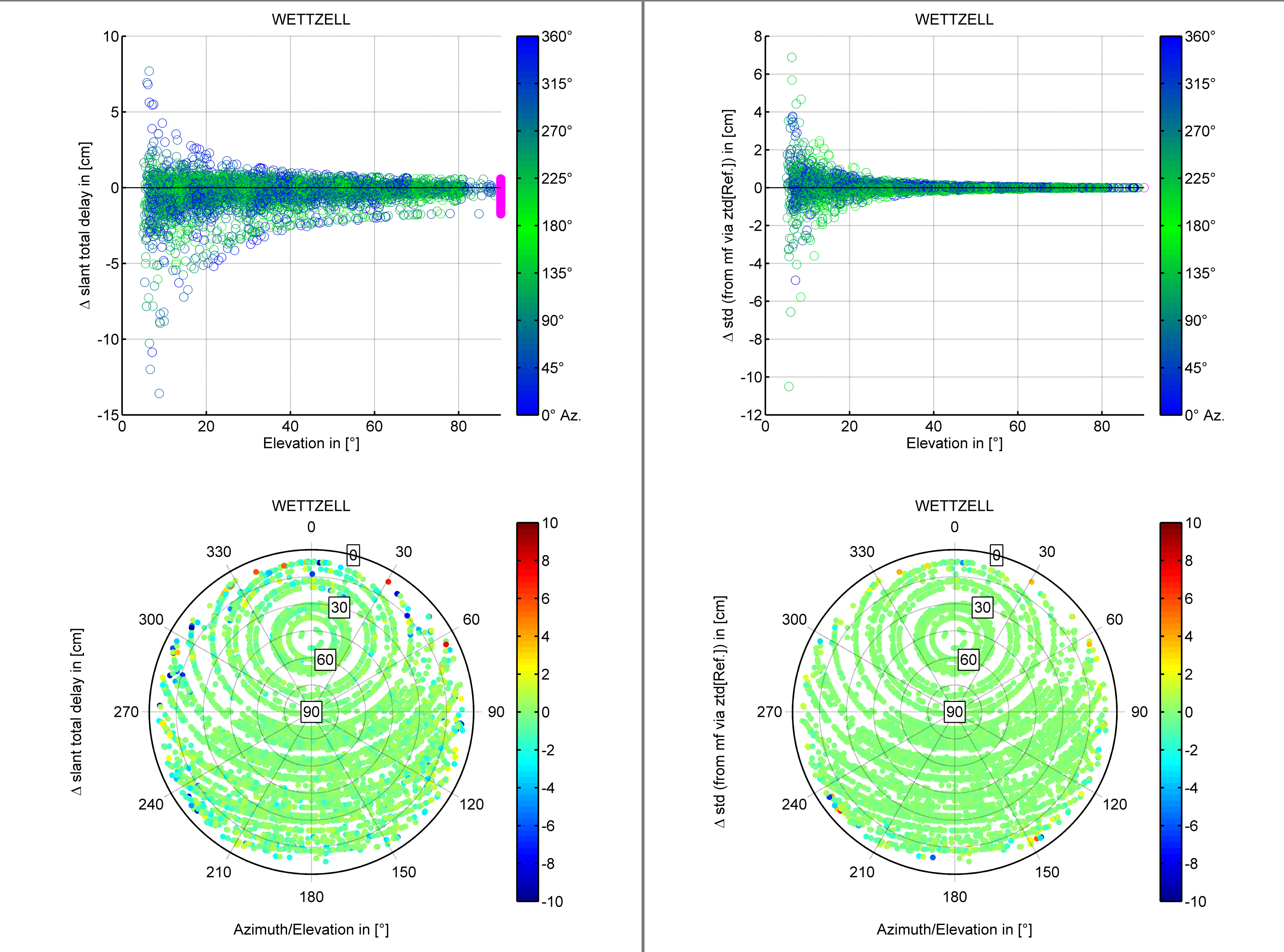
Differences RD(0.125°) – RD(1°) at KOKEE



Differences RD(0.125°) – RD(1°) at TSUKUB32



Differences RD(0.125°) – RD(1°) at WETTZELL



Conclusions from direct RD comparison

- Δstd w.r.t. to all CONT11 stations
  - At elevation angles larger than 10°
    - Δstd at the level of a few cm
    - For most stations mainly around 1-2 cm
  - At elevation angles smaller than 10°
    - Δstd rises significantly
    - At 1° even up to a few dm
  - General size of Δstd is mainly caused by the differences in the wet delay
- Δstd_{mf} w.r.t. to all CONT11 stations
  - Differences very small
  - Outliers at low elevation
  - Special behaviour at a few stations like KOKEE and TSUKUB32
    - Differences significantly increased at low elevation compared to quite small and homogenous differences at higher elevation

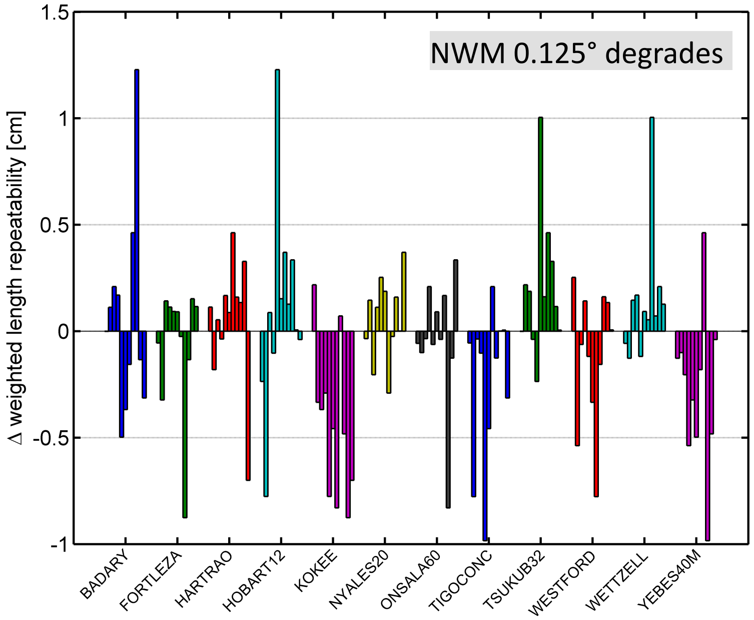
VLBI analysis

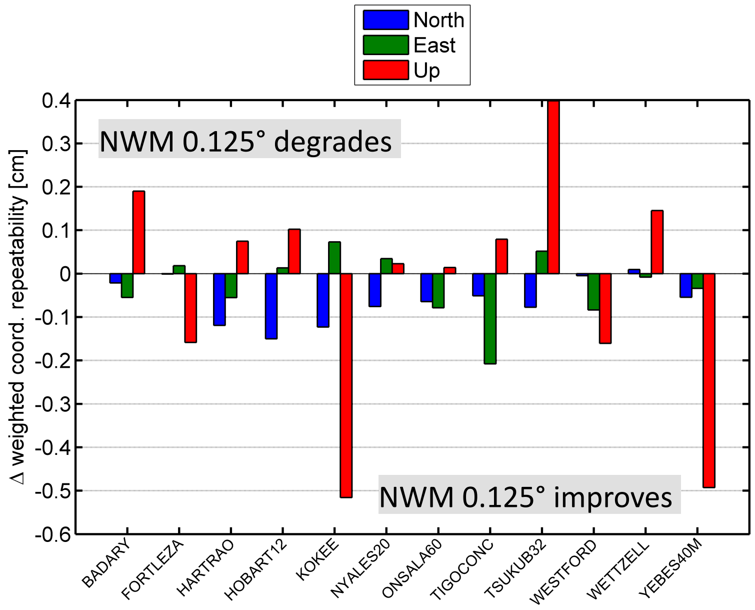
- Application of ray-traced delays to VLBI analysis of CONT11
  - With RD calculated using NWM(0.125°) or NWM(1°)

- Investigation of impact on analysis with two different parameterizations
  1) **Ray-tracing only:**
     - ray-traced slant delays as a priori input
     - no estimation of ZWD (zenith wet delays) or tropospheric gradients

  2) **Ray-tracing, est. ZWD 1h, est. gradients 6h:**
     - ray-traced slant delays as a priori input
     - estimating ZWD every hour with relative constraints of 1.5 cm
     - estimating tropospheric gradients every 6 hours with rel. constr. of 0.05 cm

Ray-tracing only

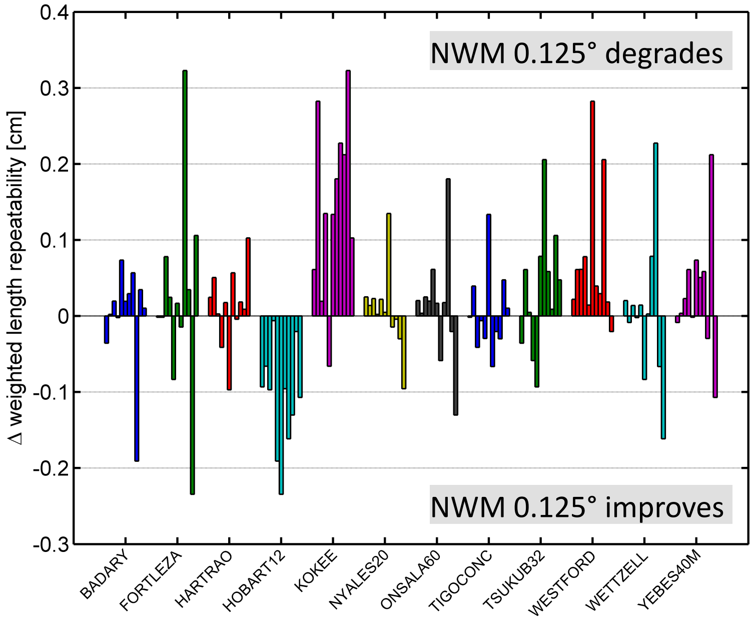




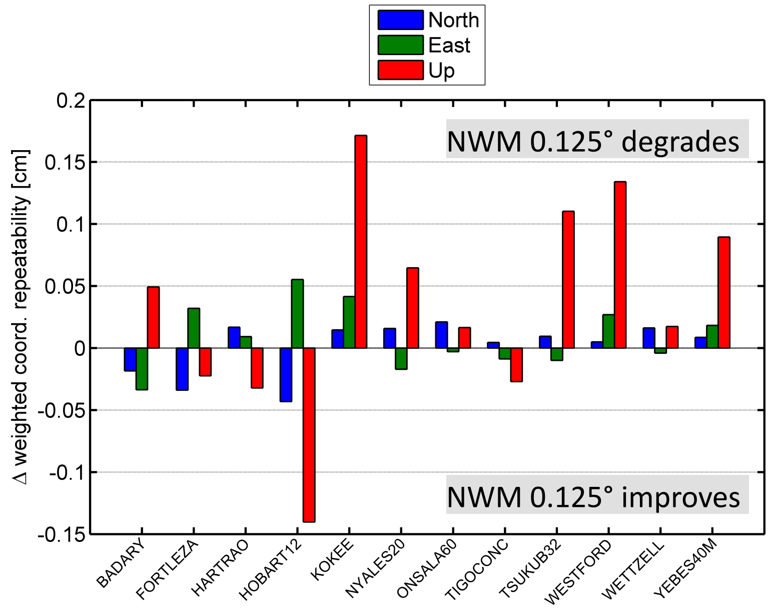
- Average of ΔBLR = -0.5 mm
- No clear trend of improvement in case of NWM(0.125°)
  - Only 34 of 66 baselines improved
- Baselines of KOKEE influenced the most
  - Also visible in ΔSCR of up-direction

- ΔSCR at very low mm-level
- KOKEE, TSUKUB32, YEBES20 show larger Δ in up-direction
  - Effect may come from larger ΔRD at low elevation
  - Note: inverse effect for TSUKUB32
- Trend: North-direction improved by NWM(0.125°), but not significantly

Ray-tracing, est. ZWD 1h, est. gradients 6h



- Average of ΔBLR = +0.2 mm
- No trend for impact of resolution derivable
- Δ for most baselines below +/- 1 mm
- Baselines of KOKEE influenced the most
  - Also visible in ΔSCR of up-direction
  - Oppositely influenced compared to "ray-tracing only"-results



- ΔSCR at sub-mm-level in North- and East-direction
- Δ of up-component a bit larger for some stations
- No trend derivable
- General impact on SCR is too small to be significant

Conclusions on the impact

- In principle horizontal resolution of NWM shows an impact on RD
  - Increasing impact with decreasing elevation angles
  - Significant effect only for low elevation
- Impact on VLBI analysis
  - No clear trend of improvement in case of NWM(0.125°)
  - General effect quite small
  - Impact depending on parameterization of VLBI analysis
    - With additional ZWD and gradient estimation effect of NWM resolution almost negligible
- Outlook: research on longer time series

Thanks for your attention!

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FWF
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