On the impact of gravitational deformation on VLBI-derived parameters

Sahar Shoushtari[1,2], Susanne Glaser[1,2], Kyriakos Balidakis[1], Robert Heinkelmann[1,2], James Anderson[1,2] and Harald Schuh[1,2]

1:GFZ German Research Center for Geosciences, Space Geodetic Techniques,Telegrafenberg, 14473, Potsdam, Germany

2:Technische Universität Berlin, Chair of Satellite Geodesy, Straße des 17.Juni 135, 10623 Berlin, Germany

EGU 2020 Session G2.2

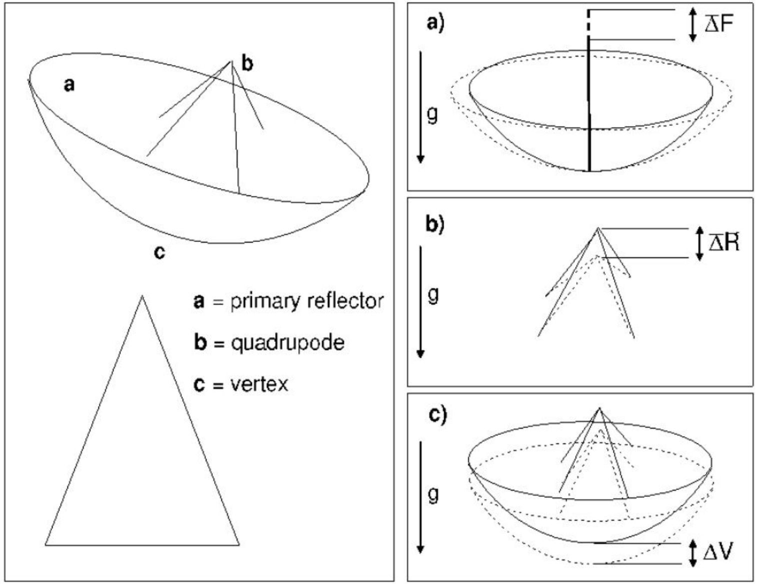
GFZ Helmholtz Centre POTSDAM

Technische Universität Berlin

Purpose

- Consideration of systematic effects of VLBI technique due to the large dish mass, currently with maximum magnitude of Path delay about -100 mm in case of Effelsberg telescope (Artz et al. 2014)
- Investigation of possible improvements in scale inconsistency of 1.37 ppb between VLBI and SLR in ITRF 2014 (Altamimi et al. 2016) due to gravitational deformation
- Importance of applying the correction of gravitational deformation in upcoming IVS ITRF2020 solutions (IVS newsletter 55, 2019)

Introduction



(Sarti et al. 2010)

Length variation in case of primary focus radio telescopes:

$$\Delta L(e) = \alpha_F \, \Delta F(e) + \alpha_V \, \Delta V(e) + \alpha_R \, \Delta R(e)$$

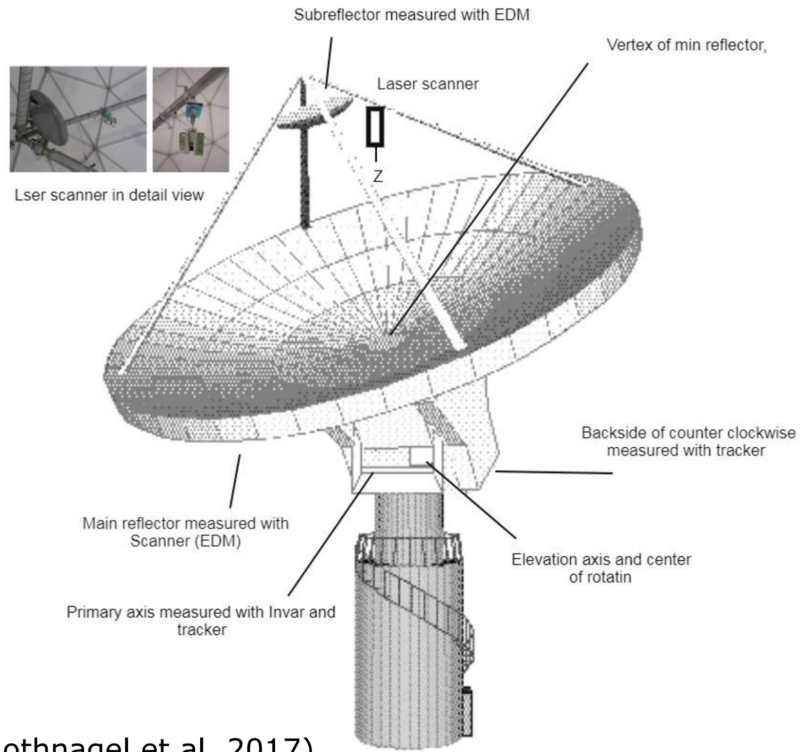
Secondary focus radio telescopes:

$$\Delta L(e) = \alpha_F \, \Delta F(e) + \alpha_V \, \Delta V(e) + 2\alpha_R \, \Delta R(e)$$

where ΔL, e and $\alpha_{F,\ V\ \&\ R}$ are representing signal variation, elevation and telescope specific linearly dependent scaling coefficients respectively.

(Clark and Thomsen 1988)

Estimation of coefficients of length variation function



(Nothnagel et al. 2017)

- Terrestrial Triangulation and Trilateration (TTT)
- Finite Element Model (FEM)
- Laser Scanning (LS)
- Electronic Distance Measurement (EDM)
- Drone photogrammetric technique (Eschelbach et al. 2019)

List of radio telescopes with gravitational deformation model

Radio telescope	Diameter of Dish [m]	Country	Reference
Gilcreek	26	Alaska	Clark & Thomsen. (1988)
Hobart	26	Australia	Dawson, et al. (2005) (not published)
Medicina	32	Italy	Sarti, et al. (2010)
Noto	32	Italy	Sarti, et al. (2010)
Yebes	40	Spain	Nothnagel, et al. (2014)
Effelsberg	100	Germany	Artz, et al. (2014)
Onsala	20	Sweden	Nothnagel, et al. (2018)

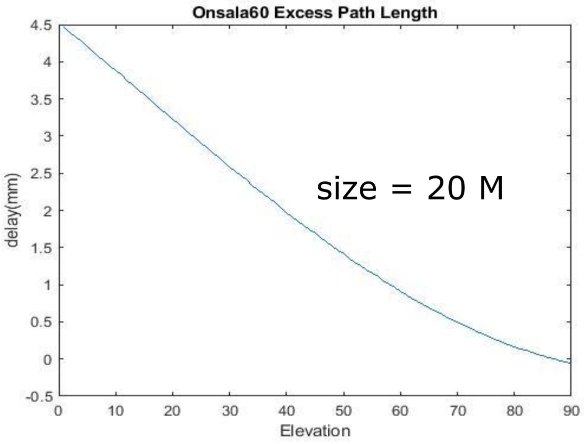
- IVS analysis coordinator John Gipson recommended to apply the effect of gravitational deformation to the next realization ITRF2020

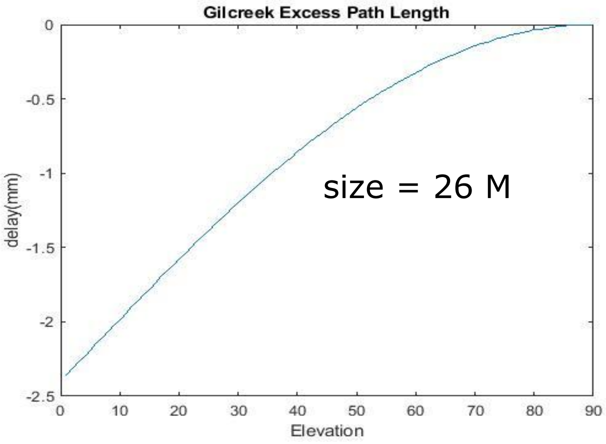
Challenge?

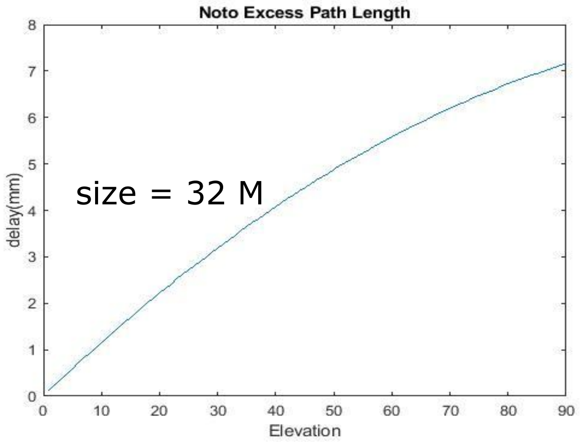
- Only a few radio telescopes are provided with gravitational deformation model

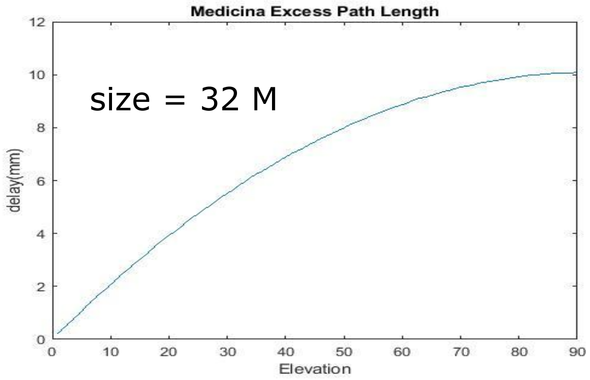
- Every station has a unique model

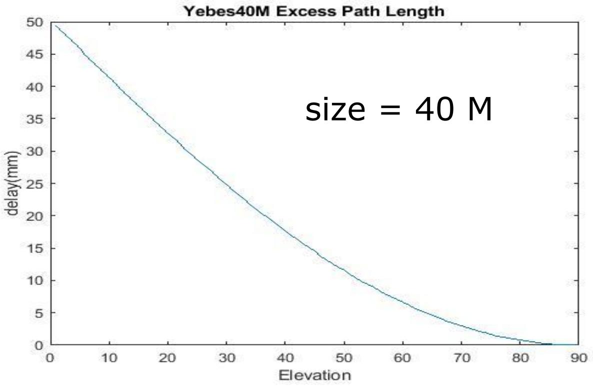
Summary of models: **Elevation dependent effect**

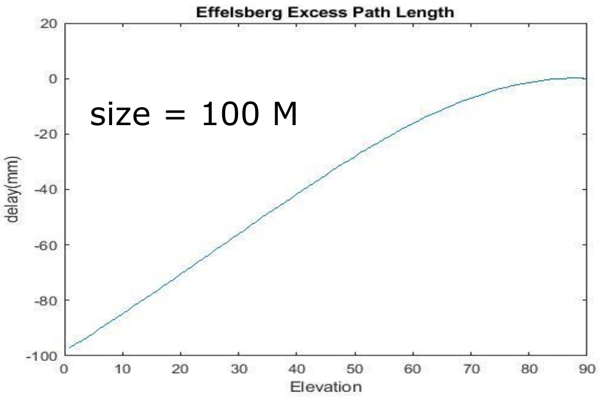












Data taken from IVS
(https://ivscc.gsfc.nasa.gov/IVS_AC/apriori/gravity_deform_model_v2019Nov21.txt)

Related works

Station	ΔU [mm]	ΔE [mm]	ΔN [mm]	#sess
DSS65	0.0	0.0	0.0	86
MATERA	0.0	0.0	0.0	632
MEDICINA	8.9	0.0	0.0	345
NOTO	6.7	0.0	0.0	150
NYALES20	0.0	0.0	0.0	912
ONSALA60	0.0	0.0	0.0	632
WETTZELL	0.0	0.0	0.0	2,612

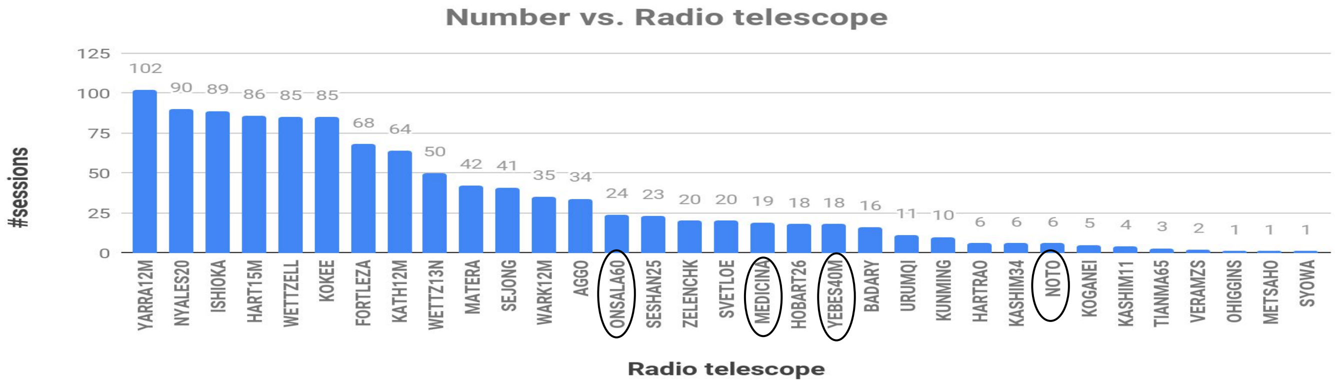
- Study done by Sarti et al. in 2010
- Estimating gravitational deformation model for Medicina and Noto (multi-year solution)
- The model uniquely impacts the Up component of the station for which it was applied

- Differences of local geodetic coordinates of some Eu VLBI stations: grav. def. model - without grav. def. model

Data Description

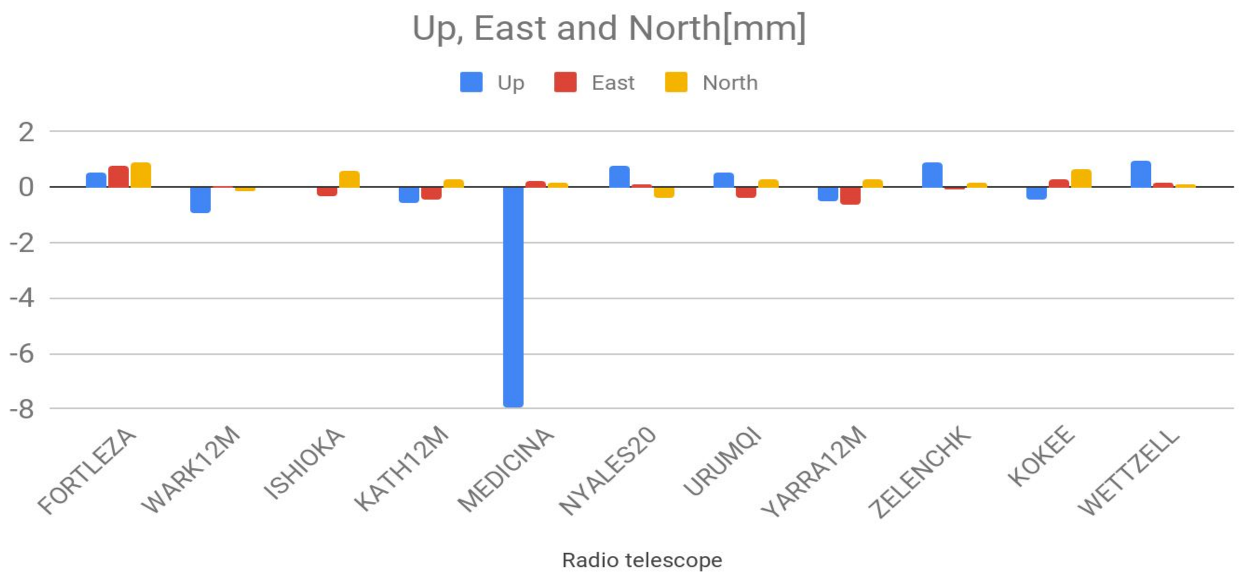
- Focus on the standard IVS VLBI R1 and R4 sessions
- Data processed in Software PORT (Potsdam Open-source Radio interferometry Tool)
- ~104 + ~12 sessions in PORT (2019)
- 33 radio telescopes including 4 with grav. model:

  Medicina, Noto, Onsala60, Yebes40M



Evaluation of one session (2019-08-08-XE)

	With & Without
#Observations	4447
#Unknowns	1444
DOF	3003



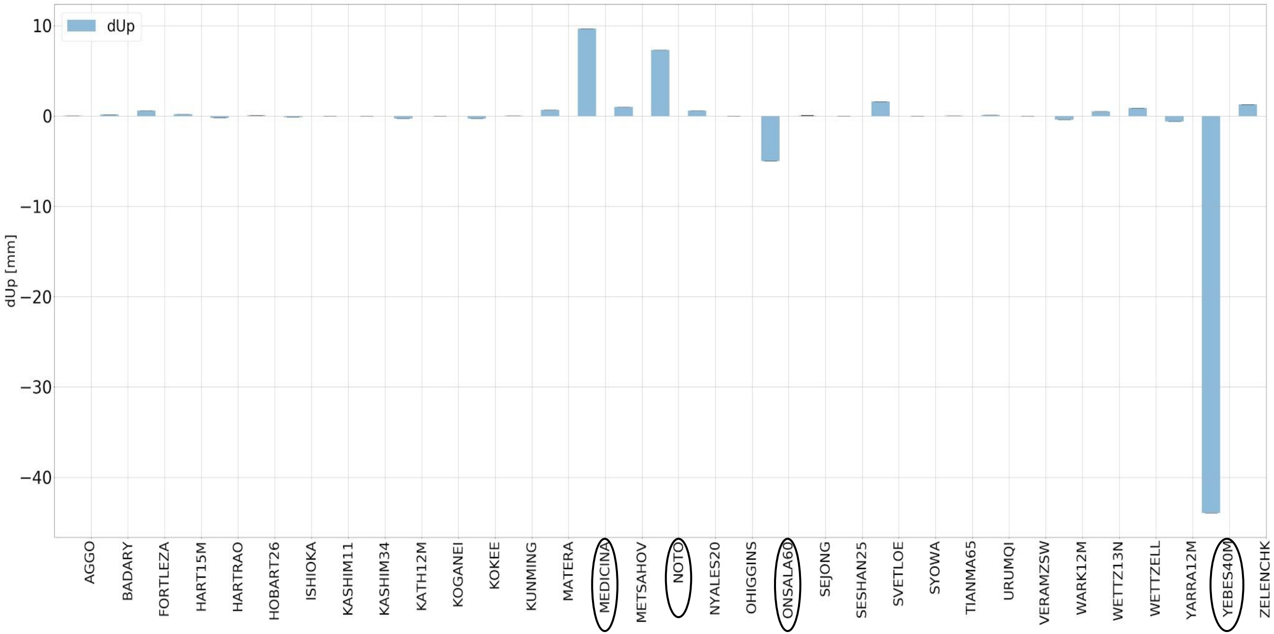
- Differences = With model - Without model

Helmert param.	with - without	Formal error
Tx [mm]	0.01	0.55
Ty [mm]	-0.18	0.55
Tz [mm]	-0.26	0.54
Rx [mm]	-0.01	0.75
Ry [mm]	-0.05	0.60
Rz [mm]	0.02	0.68
Sc [mm]	0.74	0.53

EOP param.	with - without	Formal error
x pole [mas]	-0.0079	0.0000
y pole [mas]	-0.0028	0.0000
dUT1 [ms]	-0.0004	0.0000
nutdx [mas]	0.0008	0.0000
nutdy [mas]	0.0002	0.0000

Change in components(Up)

Average of dUp component for each telescope where grav. def. model applied - Average of dUp component for each telescope where grav. def. model not applied

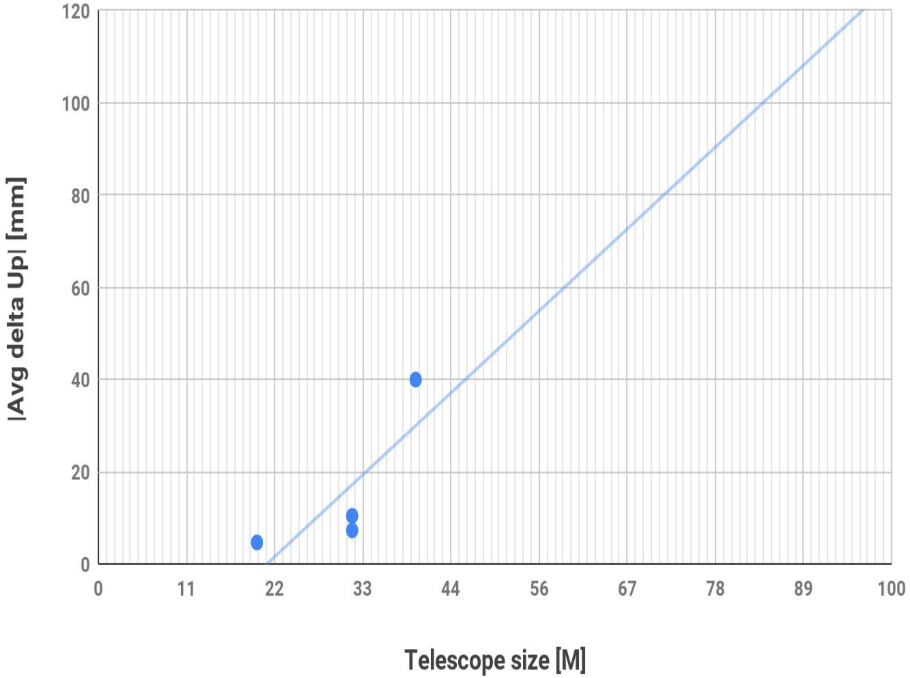


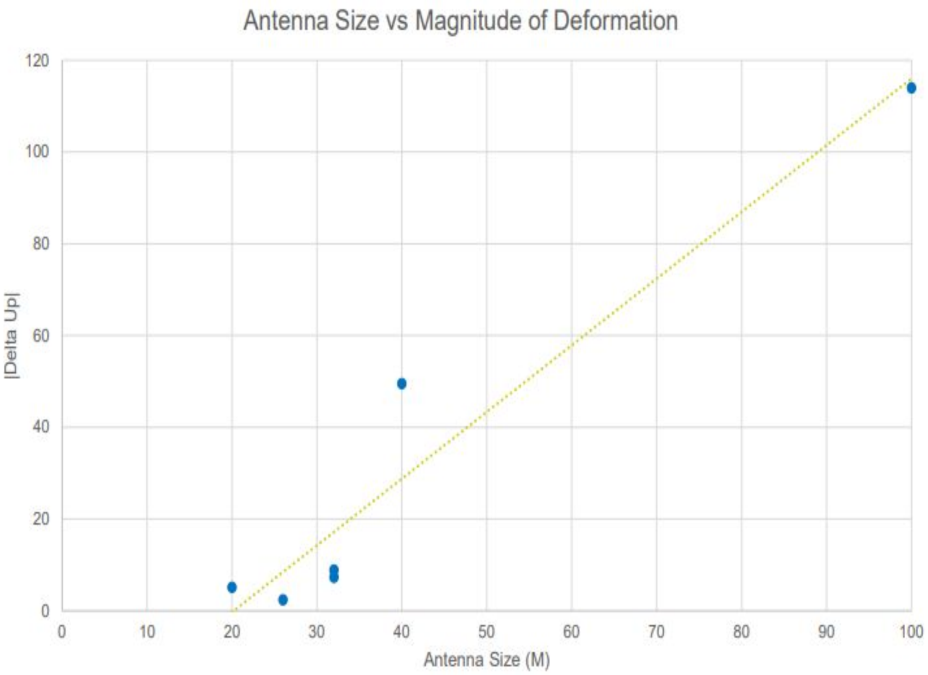
- **Twofold reason in case of Yebes 40M:**
  - **Gravitational deformation** mostly due to movements of the main reflector.
  - On Nov 11, 2011, the operation of the telescope was changed from **an automatic, deliberate elevation-dependent** readjustment of the sub-reflector for maximizing the gain to a **fixed sub-reflector** position throughout all geodetic and astronomical VLBI sessions.

GFZ
Helmholtz Centre
POTSDAM

Technische Universität Berlin

Effect on Up vs. Size

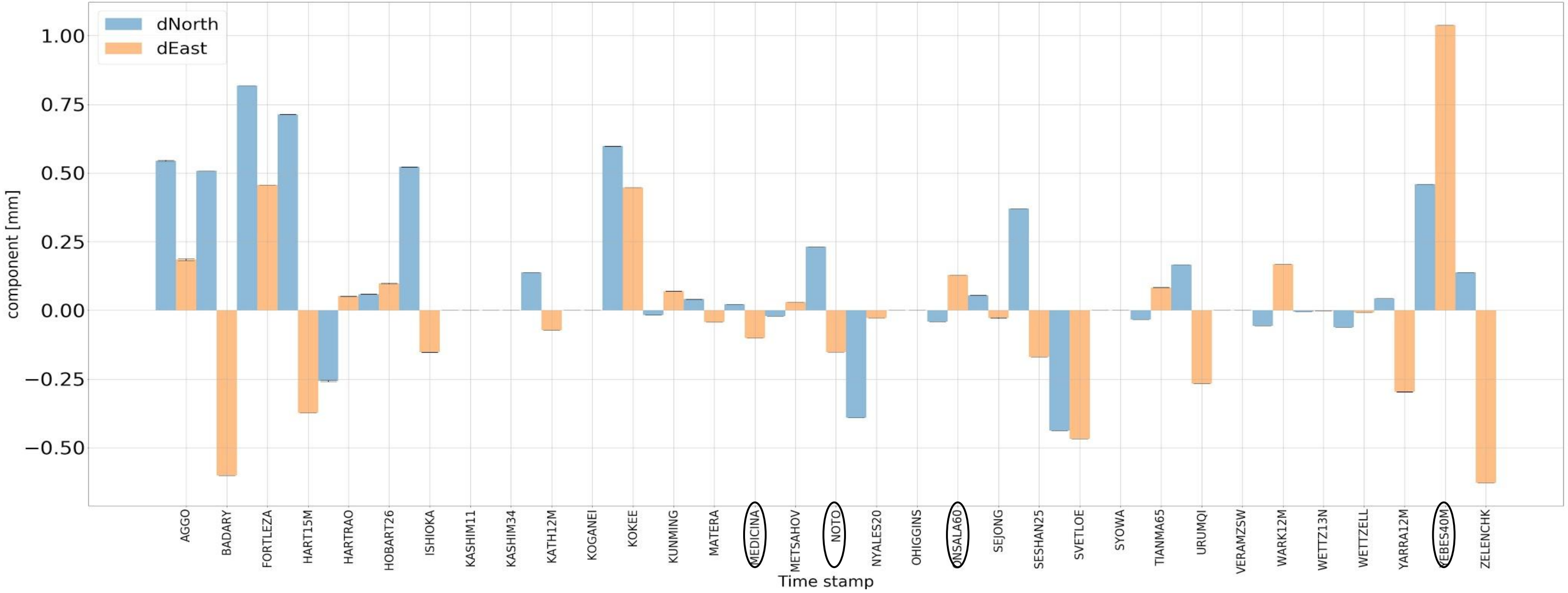




John Gipson NVI,Inc/NASA GSFC, 2019

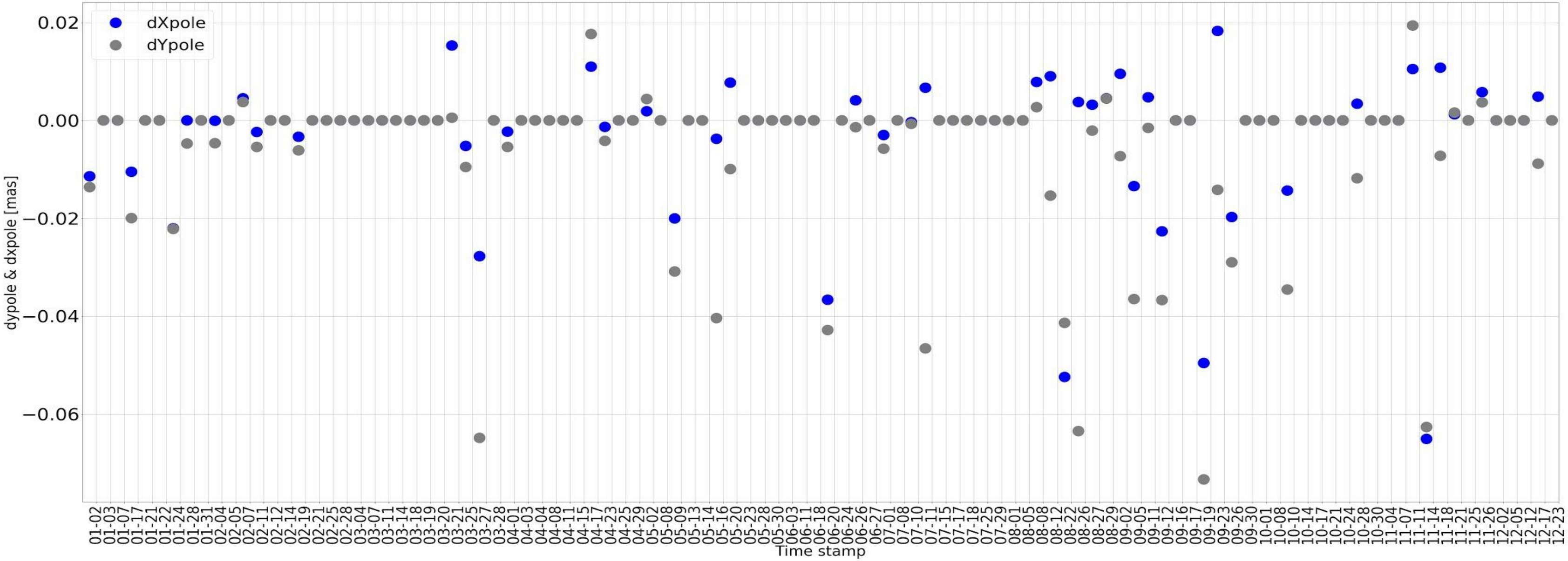
Change in components(East/North)

dEast/dNorth (with) - dEast/dNorth (Without)

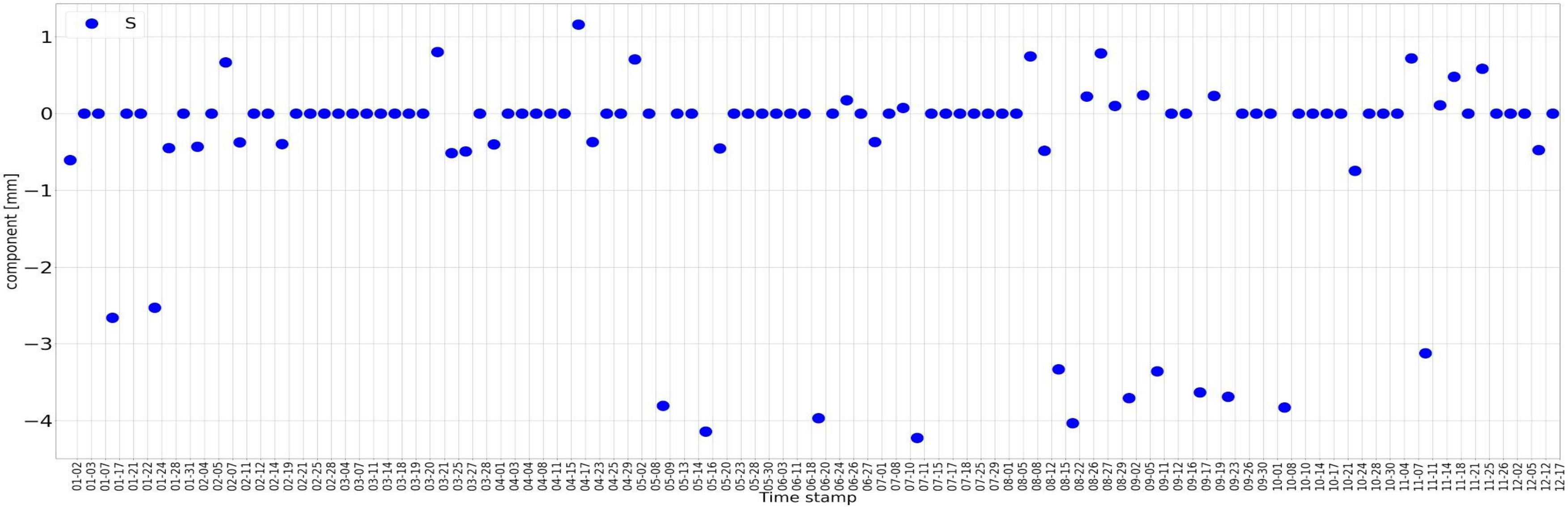


Change in EOP components
(X pole/Y pole)

dX/dY pole (With) - dX/dY pole (Without)



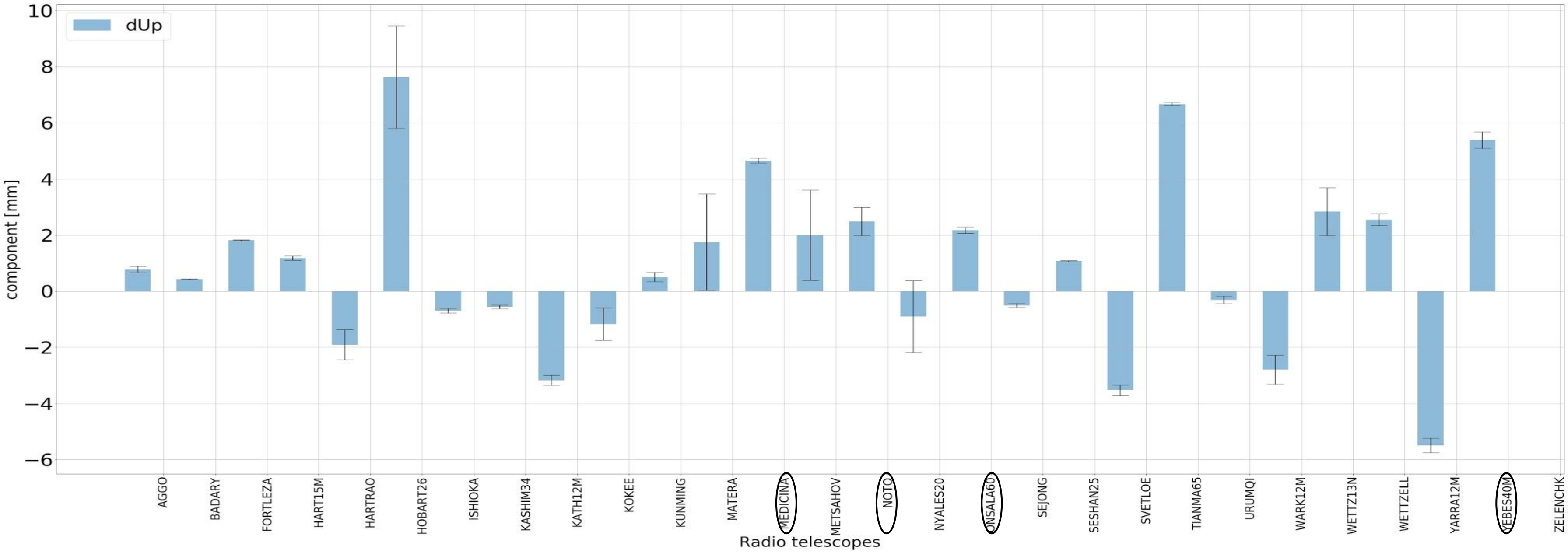
Effect on Helmert parameters(Scale factor)
Effects appeared almost 0 in case of Tx, y & z and Rx, y & z



- Only sessions with (a) radio telescope(s) provided with grav. def. model appeared with a scale factor other than 0

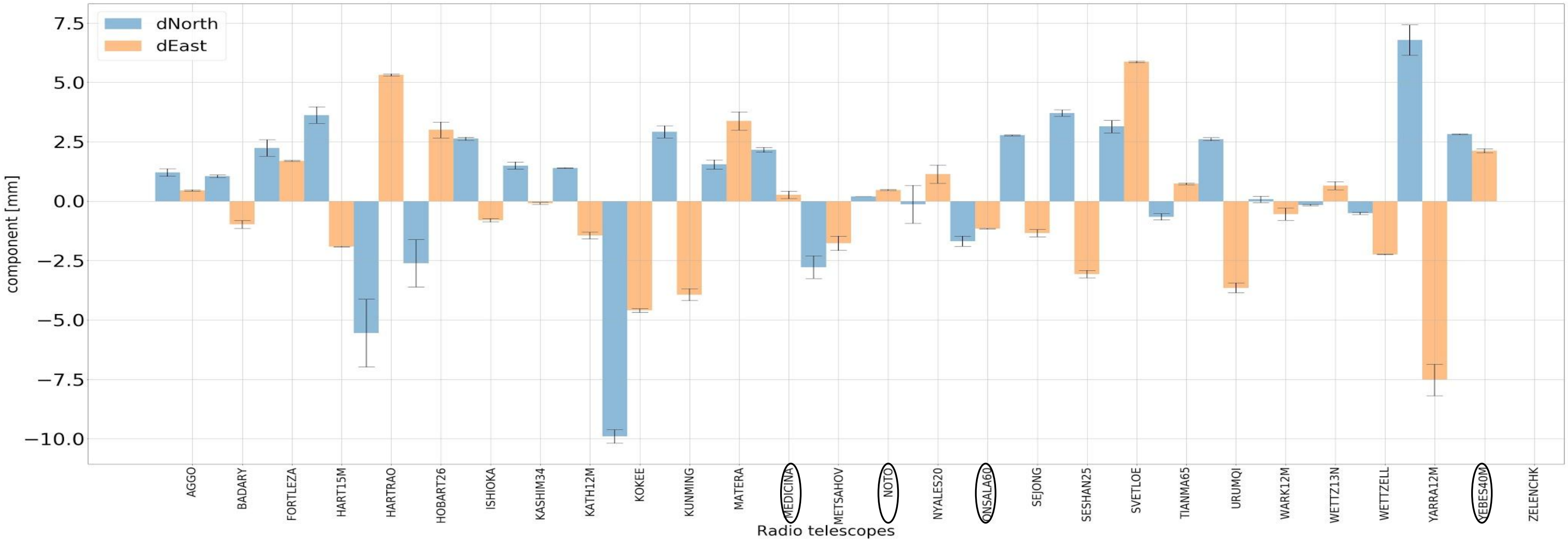
Remove stations from NNT/NNR
Up component

Radio telescopes incl.(dUp) - Radio telescopes excl.(dUp)



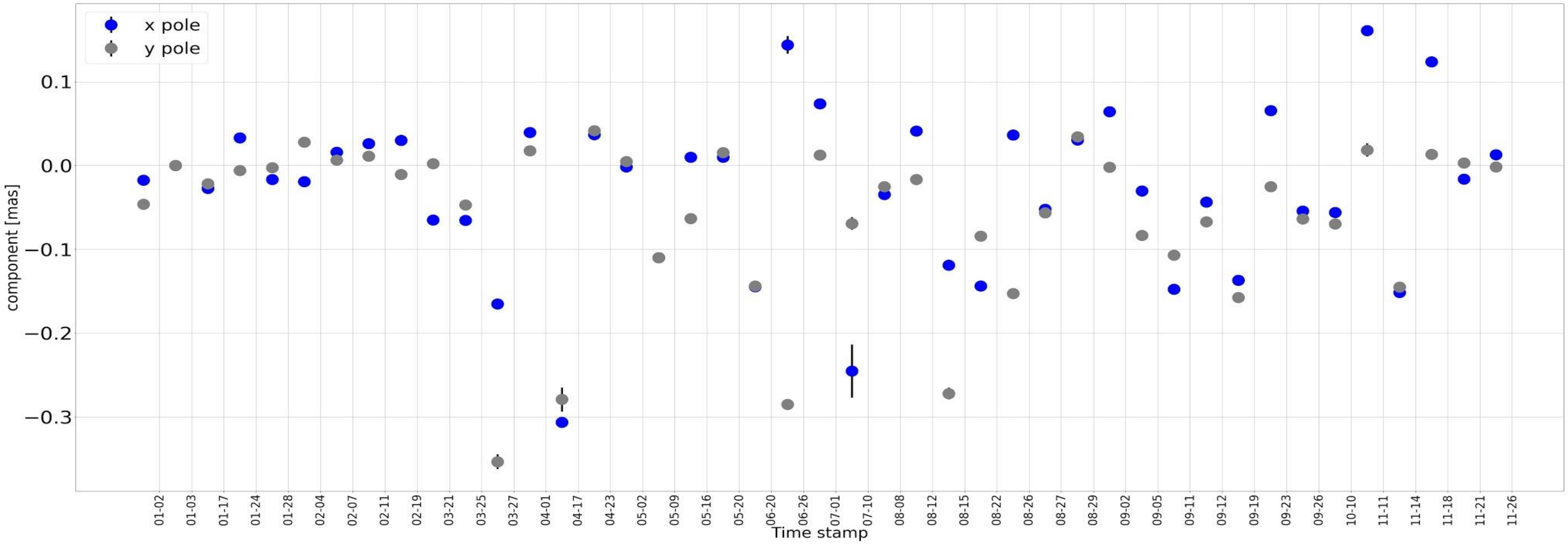
Remove stations from NNT/NNR North/East component

Radio telescopes incl.(dNorth/dEast) - Radio telescopes excl.(dNorth/dEast)



Remove stations from NNT/NNR -> EOP (X pole/Y pole) effects on other param. (Nutdx, Nutdy, dUT1) were almost 0

Radio telescopes incl.(X/Y pole) - Radio telescopes excl.(X/Y)



GFZ
Helmholtz Centre
POTSDAM

Technische Universität Berlin

Conclusions

- Gravitational deformation is a telescope-specific elevation-dependent effect
- Neglecting gravitational deformation causes bias in station height with an absolute average of 2.29 mm for sessions in 2019
- Any shift in VLBI station consequently affects the scale factor in ITRF which in this study, it had an effect with an average of -0.46 mm
- Gravitational deformation has no considerable systematic effect on Earth Orientation Parameters (EOPs), but excluding telescopes with gravitational model from datum realization by removing them from NNT and NNR constraints cause an impact on EOP with average of -0.03 and -0.06 mas in x and y poles, respectively

Thank you for your interest

Chat will be on Mon, 04 May, 16:15–18:00

Contact:
sahar.shoushtari@gfz-potsdam.de

Acknowledgements: Practical parts have made use of data from IVS data sessions.

References

Altamimi et al. (2016) ITRF2014: A new release of the International Terrestrial Reference Frame modeling nonlinear station motions

Artz et al. (2014), A complete VLBI delay model for deforming radio telescopes: the Effelsberg cas

Bergstrand et al. (2018), A gravitational telescope deformation model for geodetic VLBI, Journal of Geodes

Clark and Thomson (1988) Deformations in VLBI Antennas, NASA Technical Memorandum 100696

Gipson et al. (2019) Impact of Gravitational Deformation of VLBI Antennas on Reference Frame, EVGA Meeting 2019 Gran Canaria, Spain

Heinkelmann R (2013), VLBI geodesy: observations, analysis, and results. In: Geodetic sciences – observations, modeling and applications.

Nothnagel et al. (2019) A VLBI delay model for gravitational deformations of the Onsala 20 m radio telescope and the impact on its global coordinates

Sarti et al. (2009), Gravity dependent signal path variation in a large VLBI telescope modelled with a combination of surveying methods.

Sarti et al. (2009), Laser scanner and terrestrial surveying applied to gravitational deformation monitoring of large VLBI telescopes' primary reflector.

Sarti et al., (2010), Height bias and scale effect induced by antenna gravitational deformations in geodetic VLBI data analysis, Journal of Geodesy

Schuh H. & Behrend D (2012), VLBI: A fascinating technique for geodesy and astrometry.

Schuh and Bohm (2013), Very Long Baseline Interferometry for Geodesy and Astrometry, in Guochang Xu (editor): Sciences of Geodesy II, Innovations and Future Developments

Sovers et al. (1998), Astrometry and geodesy with radio interferometry: experiments, models, results