Geodesy and Geospatial Engineering

VAPOUR

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AGU FALL MEETING
Online Everywhere | 1–17 December 2020

MULTIPATH MITIGATION MAPS FEASIBILITY AND APPLICABILITY AS AN INTERNATIONAL GNSS SERVICE PRODUCT

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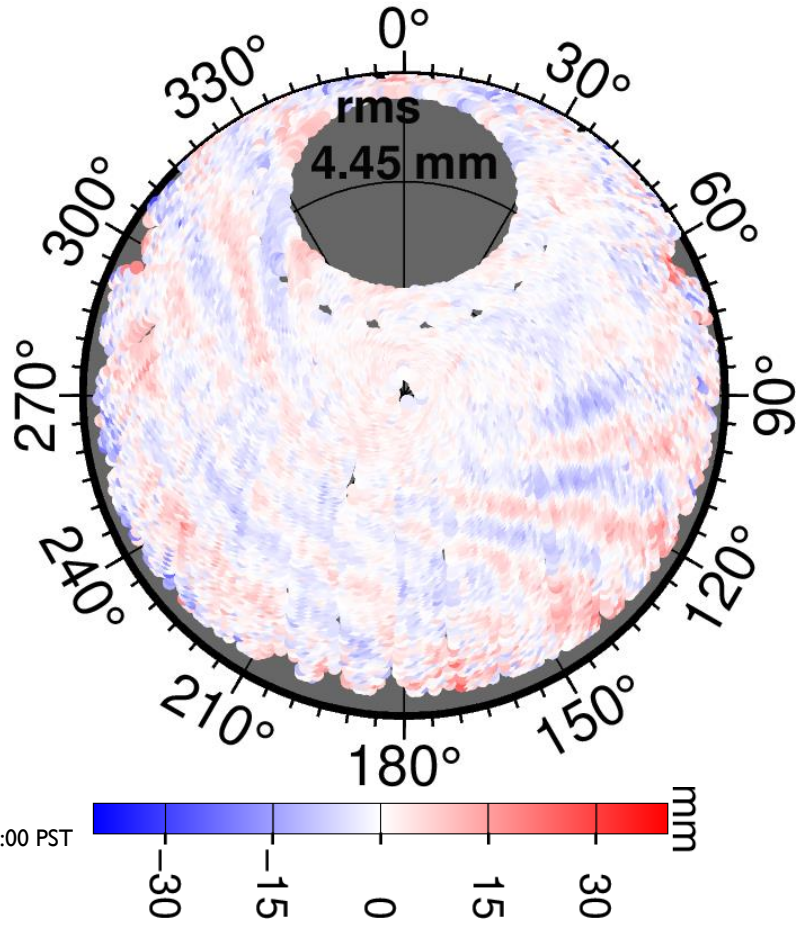
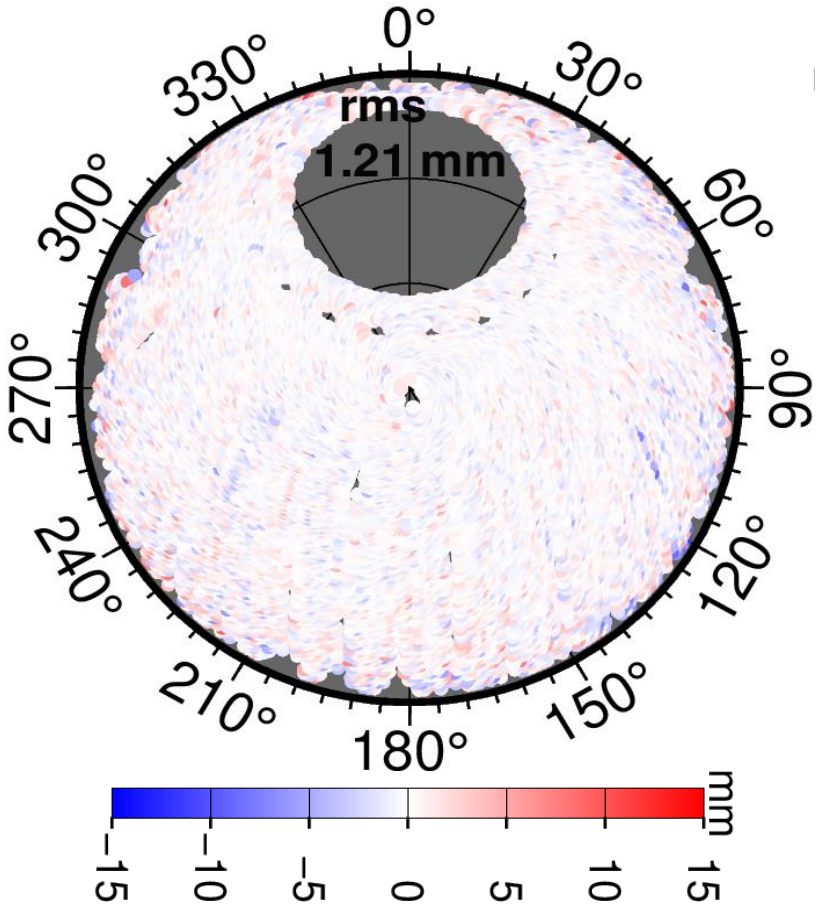
Session Number and Title: G026: Scientific Applications Enabled by the International GNSS Service (IGS) and Associated Improvements to GNSS Products I



Stacked map of carrier-phase post-fit residuals GPS+Galileo+GLONASS+BDS



Corrected post-fit residuals

PAST STUDIES IN MULTIPATH STACKING MAPS AND MOTIVATION OF THIS STUDY

Motivation

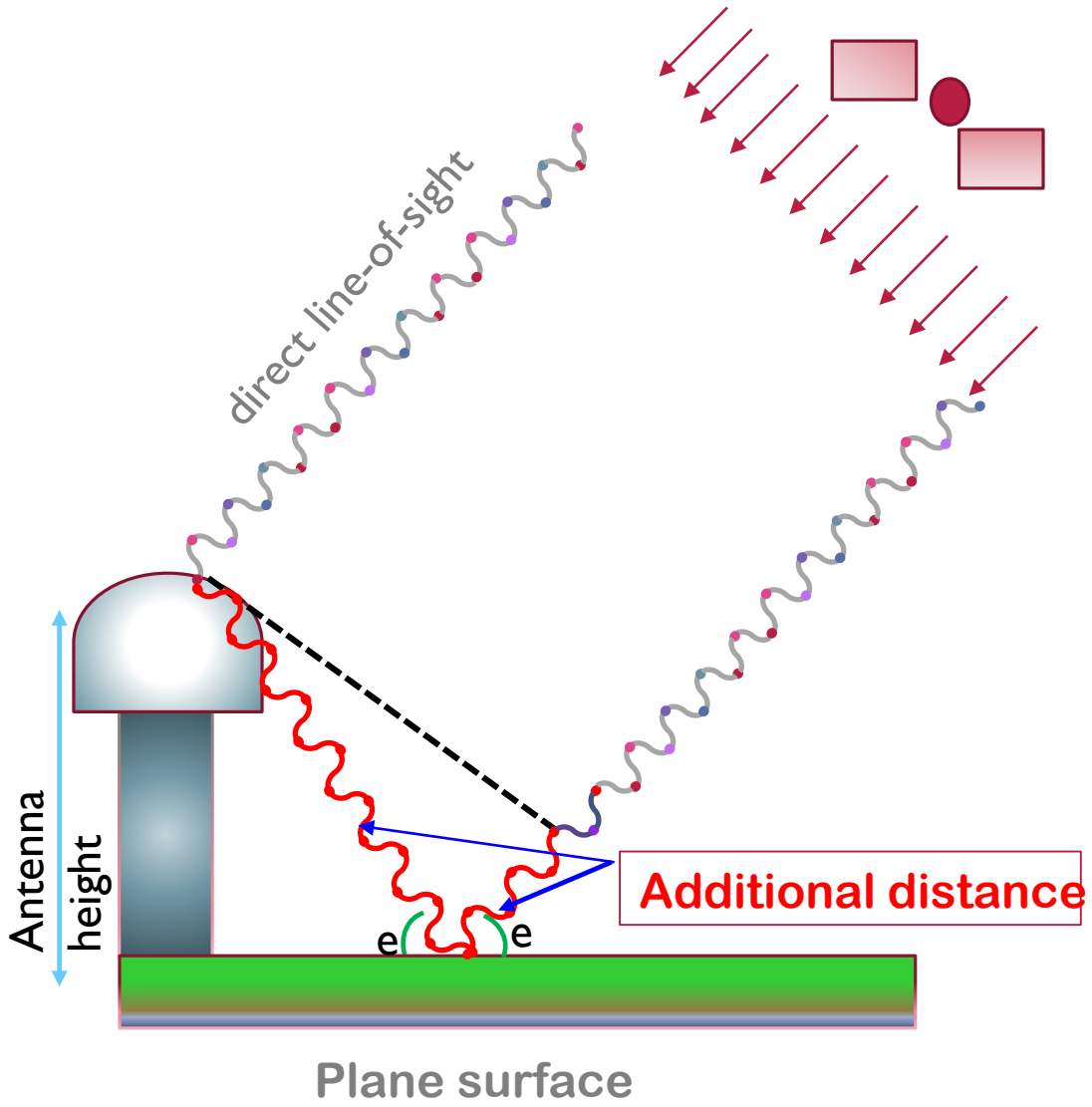
- To implement a variable azimuth resolution (Congruent geometry) to accurately characterizing site-specific effects at both low and high elevations.
- Expand the multipath stacking methods by using multi-GNSS; GPS, Galileo, GLONASS, and BDS
- Responding to IGS call in addressing multipath error for the next ITRF & next reprocessing efforts

Wanninger and May (2000)	ION GPS Proceedings
Iwabuchi et al. (2004)	J Meteor Soc Jpn
Granström C (2006)	Thesis
Bilich and Larson 2007	J Radio Sci
Lidberg et al. (2009)	BKG EUREF
Sidorov and Teferle (2013)	IAG 150 Years Proceedings
Moore et al. (2014)	J Geod
Fuhrmann et al. (2015)	GPS Solut

PROPERTIES OF MULTIPATH: THEORY

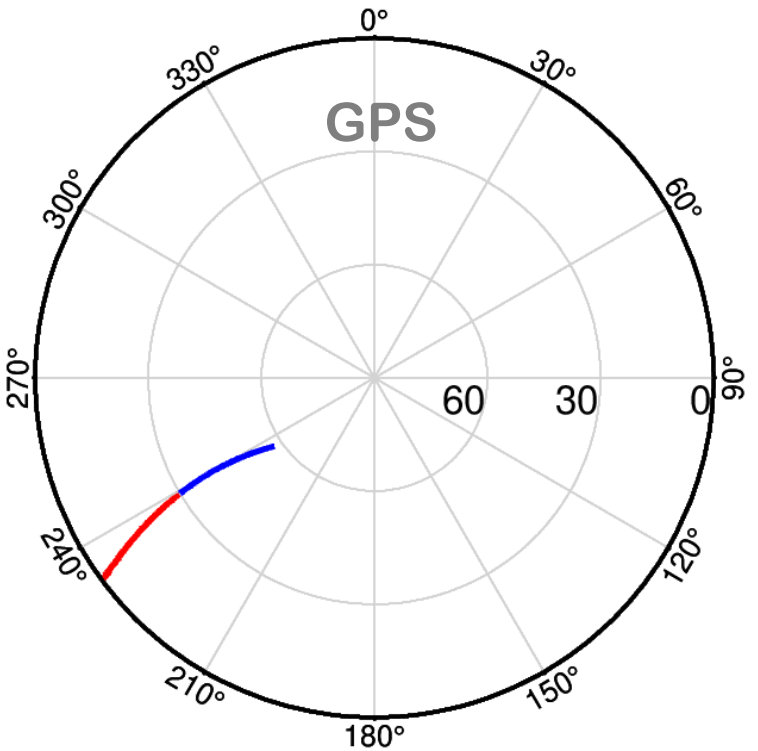
- GNSS signal arrives at the antenna taking different paths. This introduces multipath noise.
- The composite signal received is a combination of the direct line-of-sight signal and the refracted and/or diffracted signal from a nearby object
- The term multipath is used to describe any form of not-line-of-sight reception
- Multipath results in quasi-periodic oscillations in GNSS Signal-to-noise (SNR) ratio, mainly at low elevation.
- The SNR oscillations depend on the properties of the reflecting surface, antenna height H, elevation angle e, amplitude A and phase φ

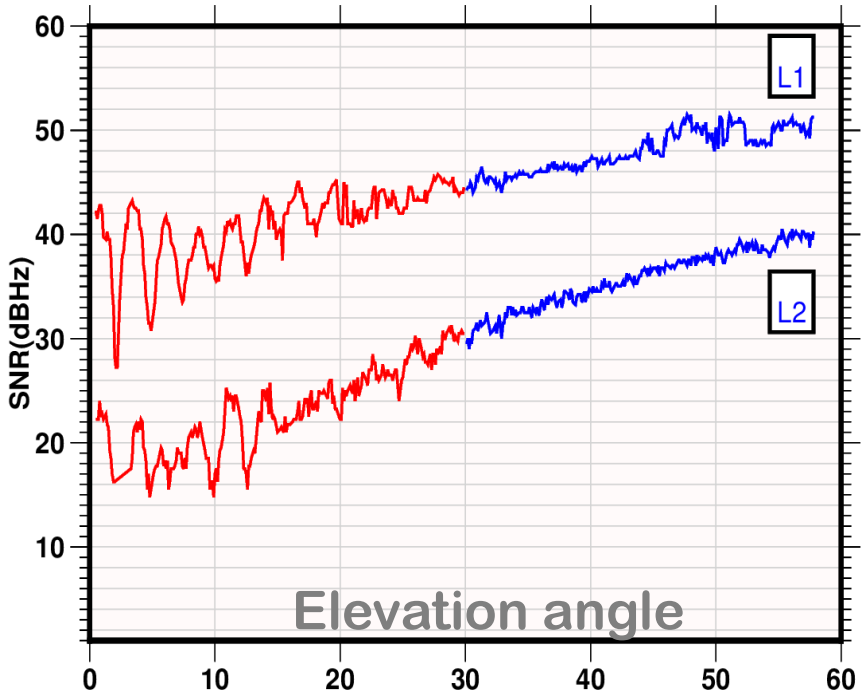
$$\mathrm{SNR} = A\cos\left[\frac{4\pi H}{\lambda}\sin(e) + \varphi\right]$$

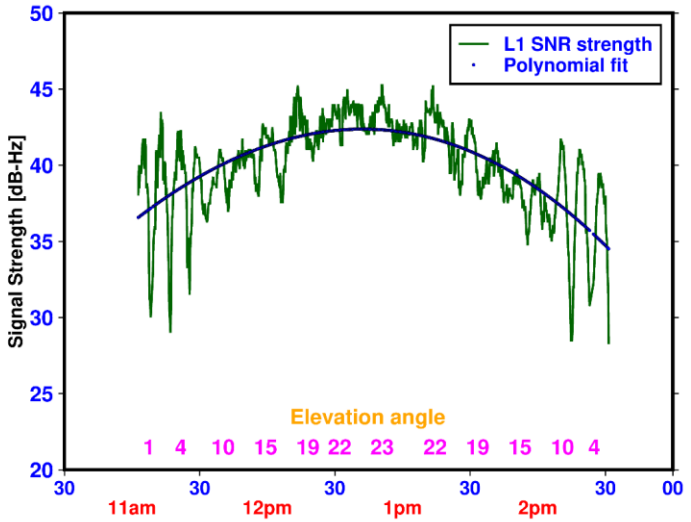


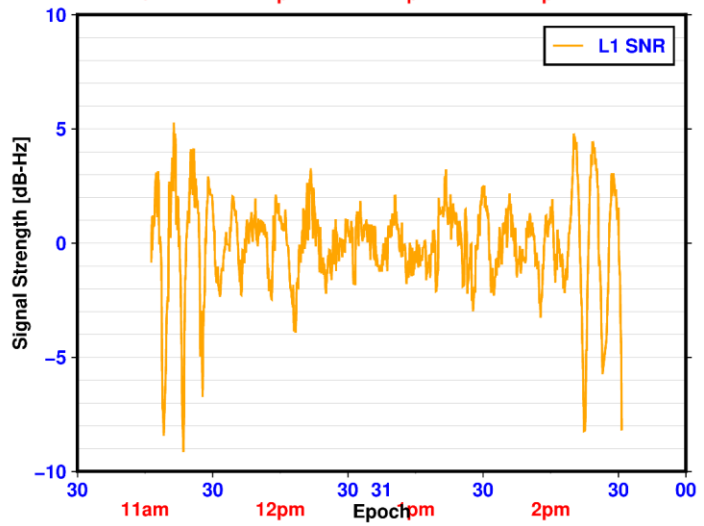
SNR CHARACTERISTI

- Understanding multipath error by mapping SNR
- Correcting for multipath error by modelling SNR



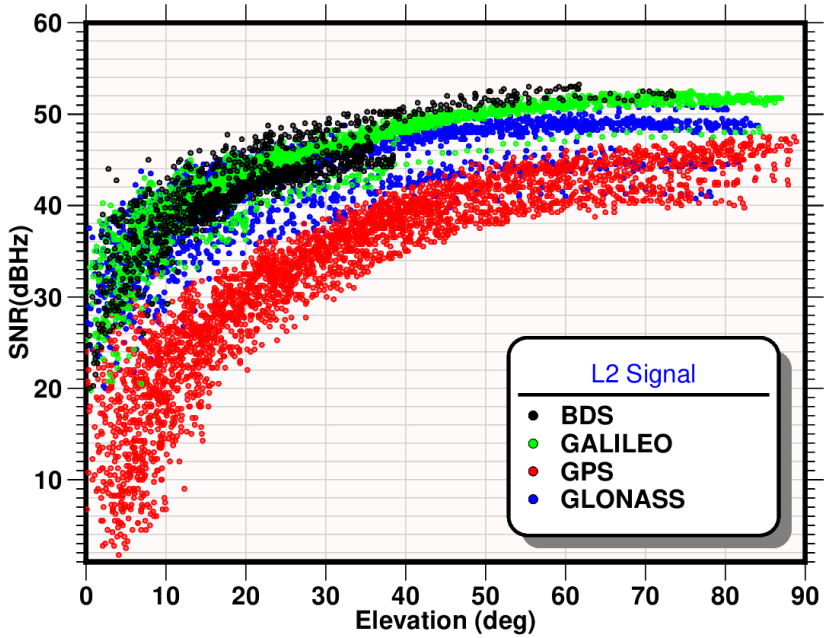


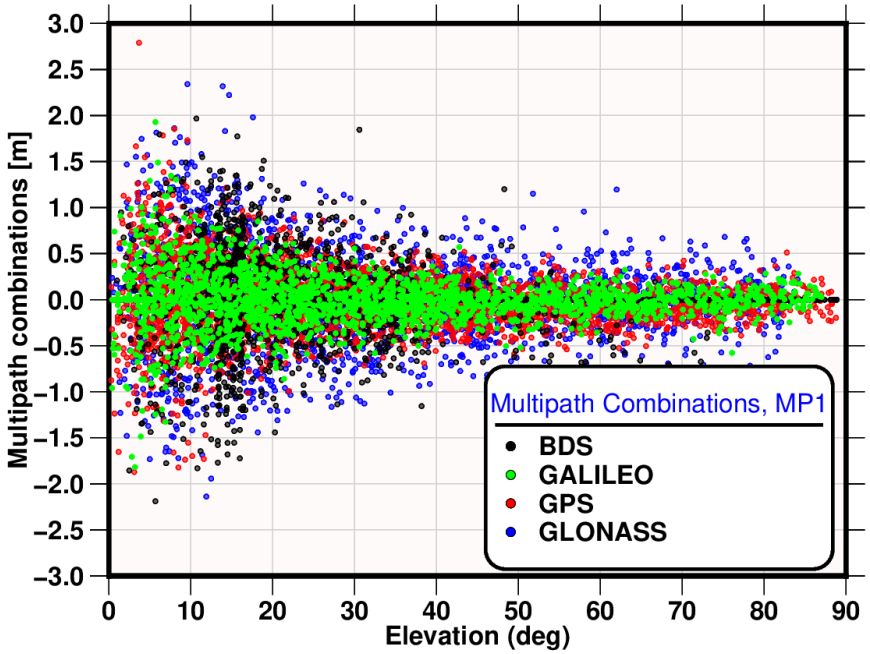




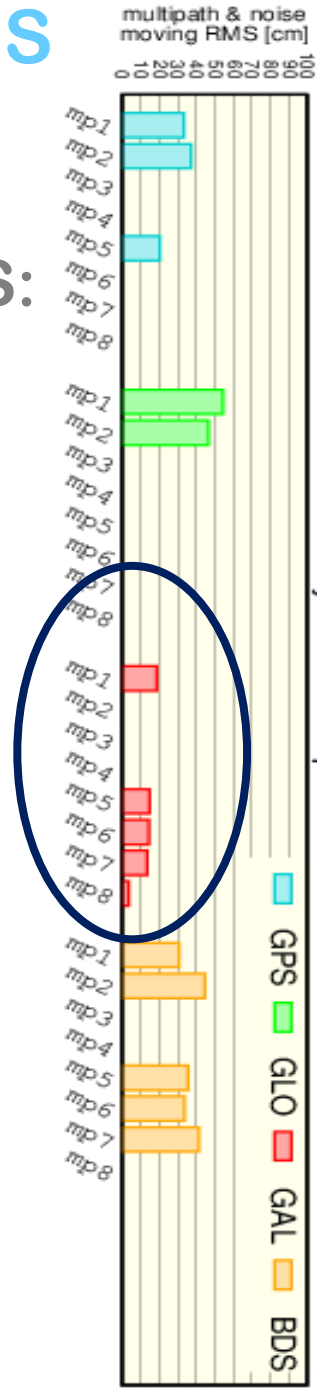
Hours in November 2017

SNR CHARACTERISTICS AND MULTIPATH COMBINATIONS FROM MULTI-GNSS





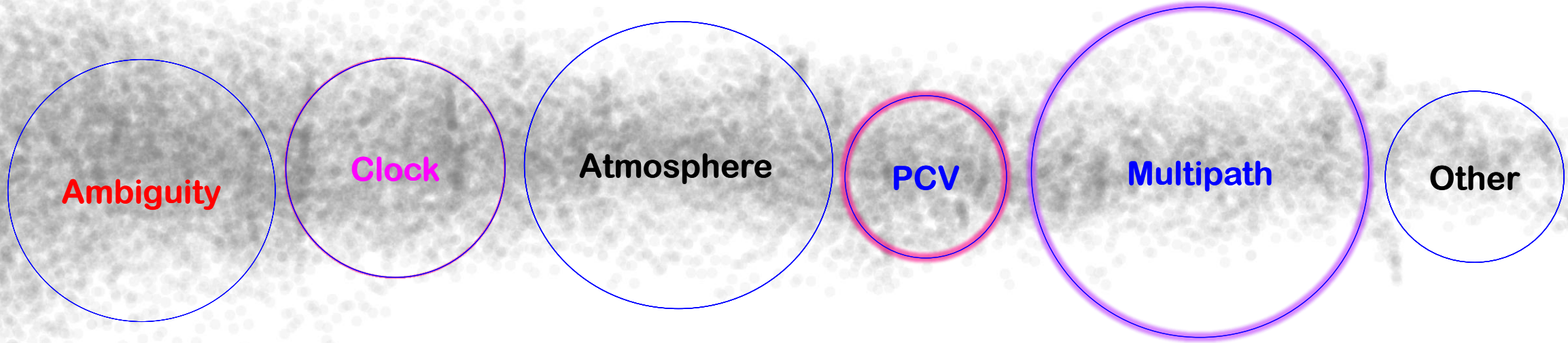
Multipath RMS:
GPS
GLONASS
Galileo
BDS



WHAT DO THE POST-FIT CARRIER RESIDUALS CONTAIN ?

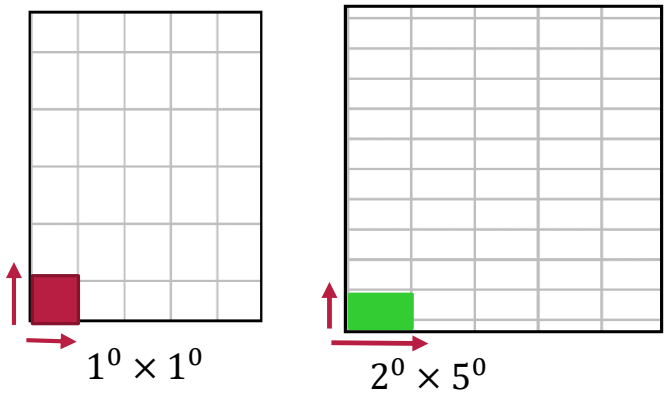
One-way phase residuals show differences in carrier-phase observations and estimated values after adjustment of parameters e.g. coordinates, ambiguities and tropospheric parameters.

This information contains non-modelled error sources which could be:

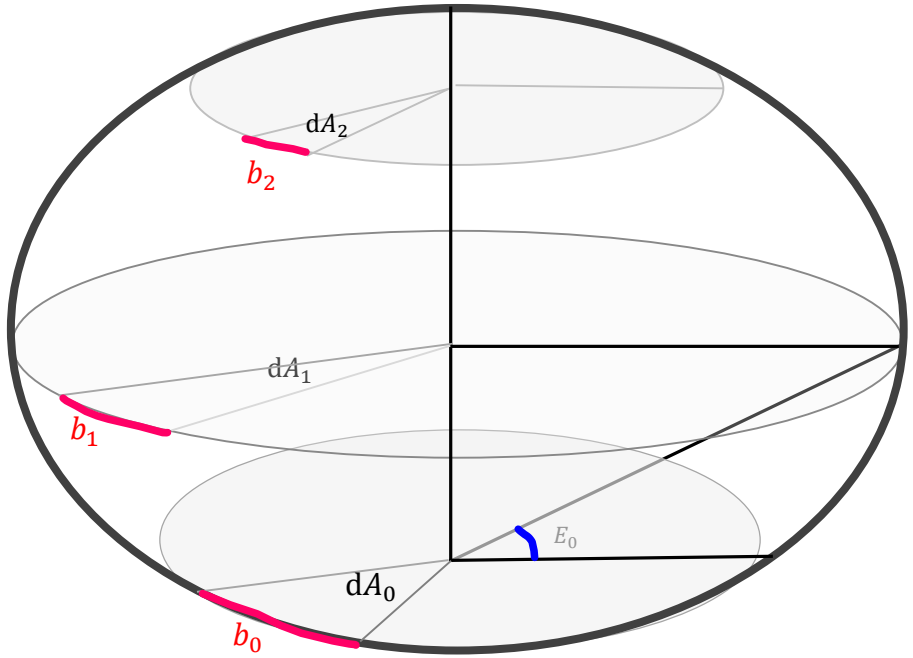


CONSTRUCTION OF MULTIPATH STACKING MAPS (MPS)

Currently residual stacked mapping uses a constant grid size (azimuth & elevation resolution): strongly depends on the number of residuals per cell.



With a fixed azimuth ⇨ size of the grids decreases with increasing elevation, leading to sparse post-fit residuals



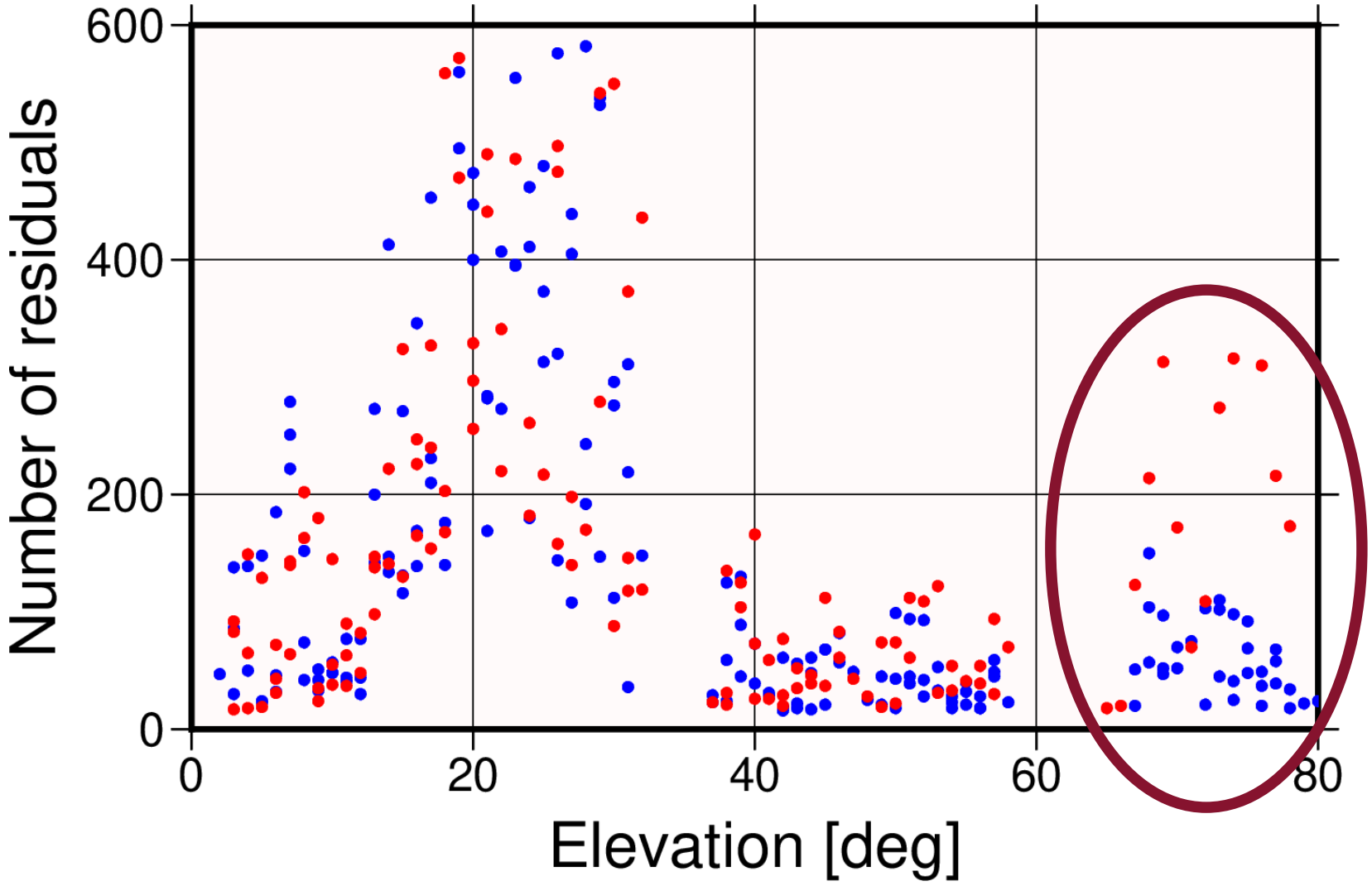
With fixed Azimuth: $dA_0 = dA_1 = dA_2 \Longrightarrow$

$b_0 > b_1 > b_2$

NUMBER OF RESIDUALS PER CELL FOR FIXED AND VARIABLE AZIMUTH

Fixed azimuthal resolution

Variable azimuthal resolution (congruent cell)



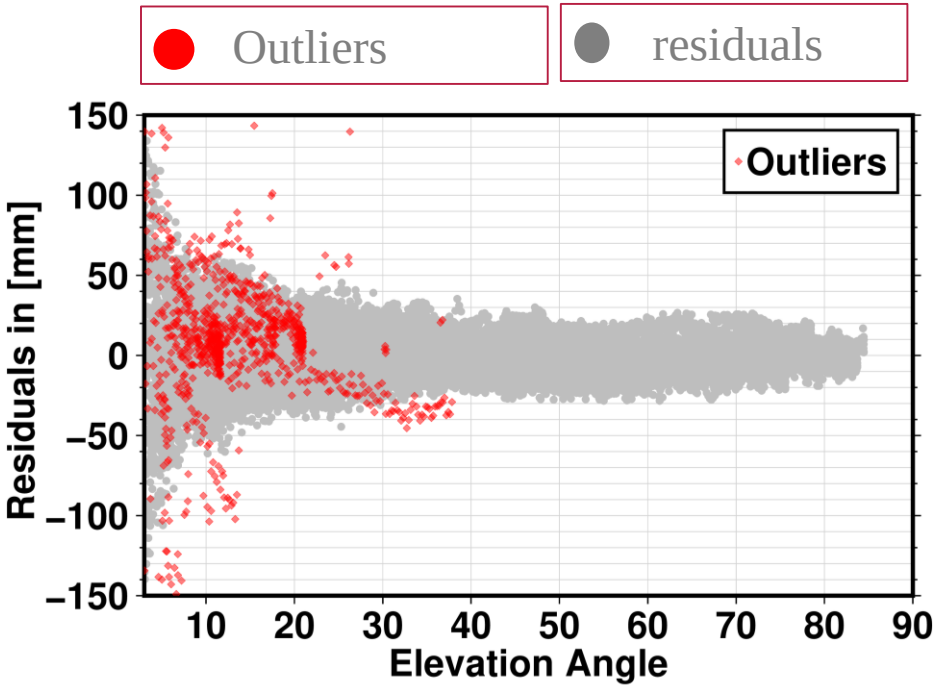
PROCEDURE FOR MULTIPATH STACKING MAPS (MPS)

Compute post-fit residuals using GAMIT-GLOBK GNSS processing engine

The site-specific MPS is estimated by averaging post-fit residuals in each congruent grid cell:

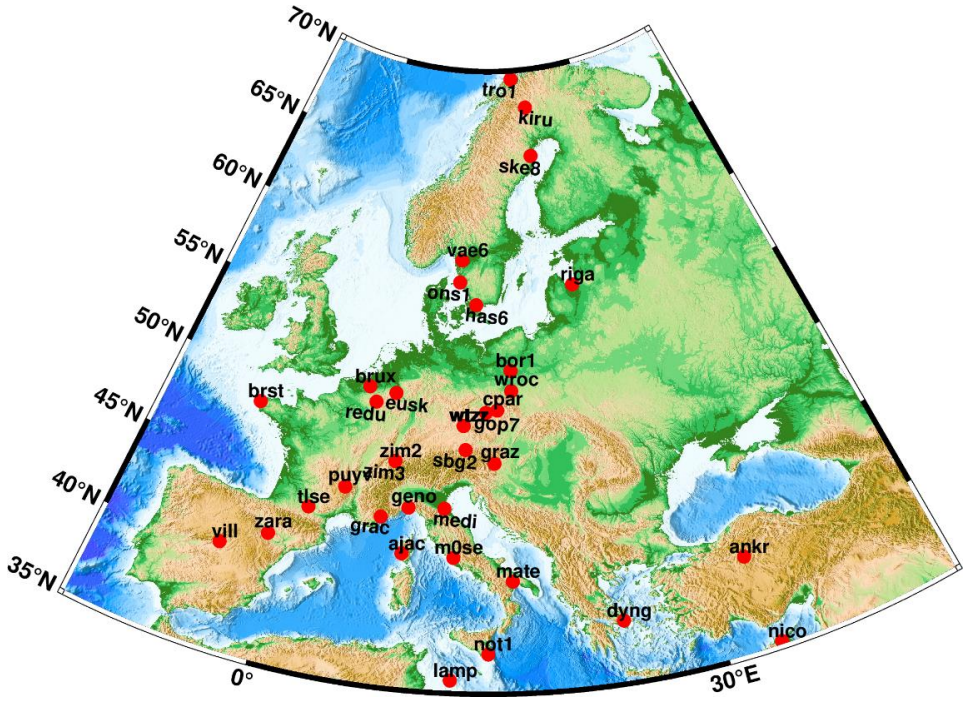
Outlying post-fit residuals are identified with 3-sigma rule.

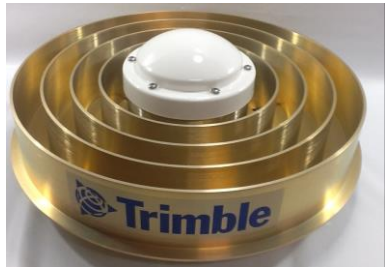
The resulting correction maps contain merged effects of multipath and insufficient modelled errors



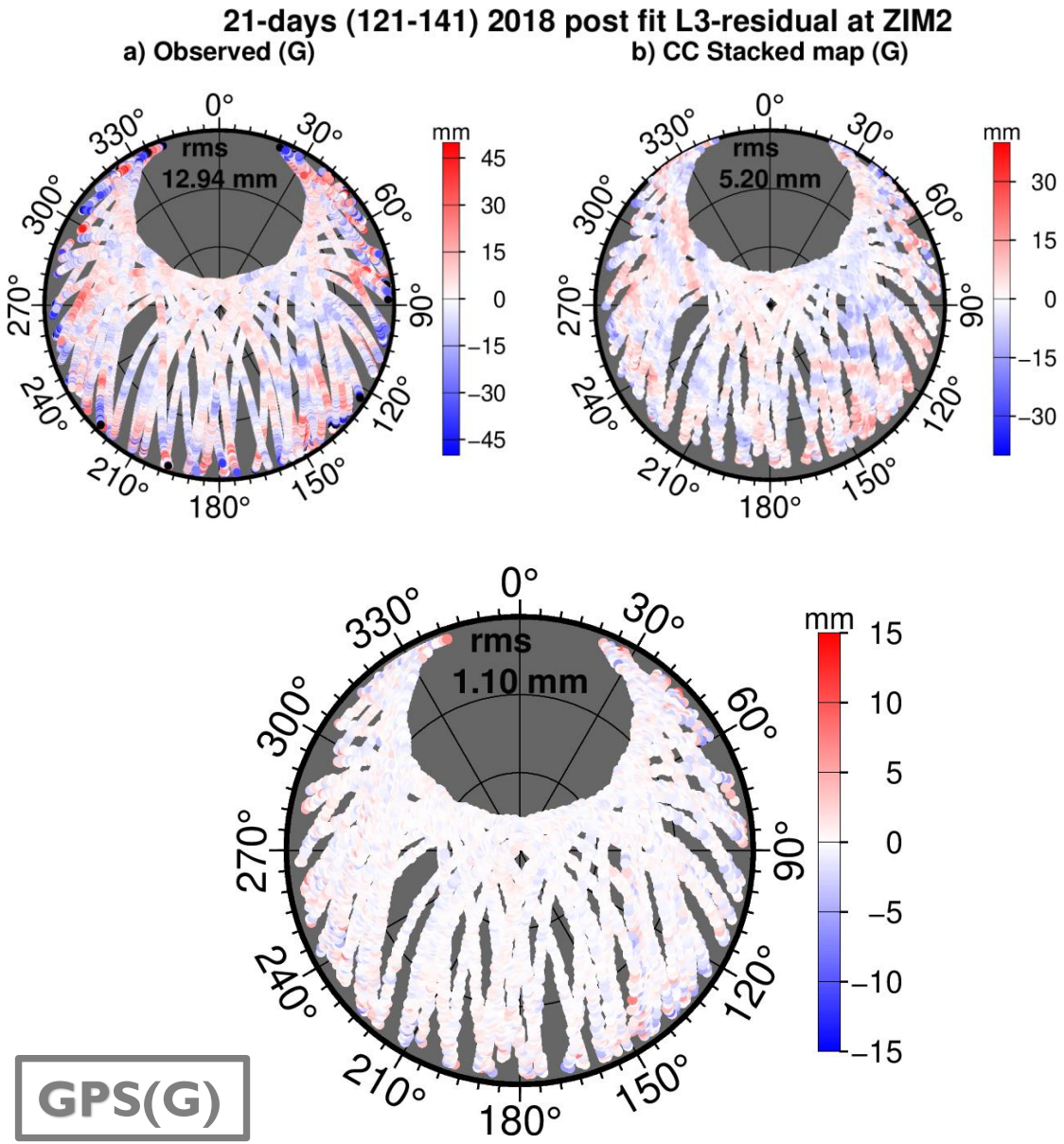
EXAMPLES OF MULTIPATH STACKING MAPS

- Station with larger post-fit residuals (ZIM2, Zimmerwald, Switzerland)
- TRACK: GPS+GLO+GAL+BDS
- INDIVIDUAL CALIBRATION PCV: GEO++ ROBOT-BASED
- Receiver: Trimble NETR9
- Antenna type: **TRM59800.00 NONE**

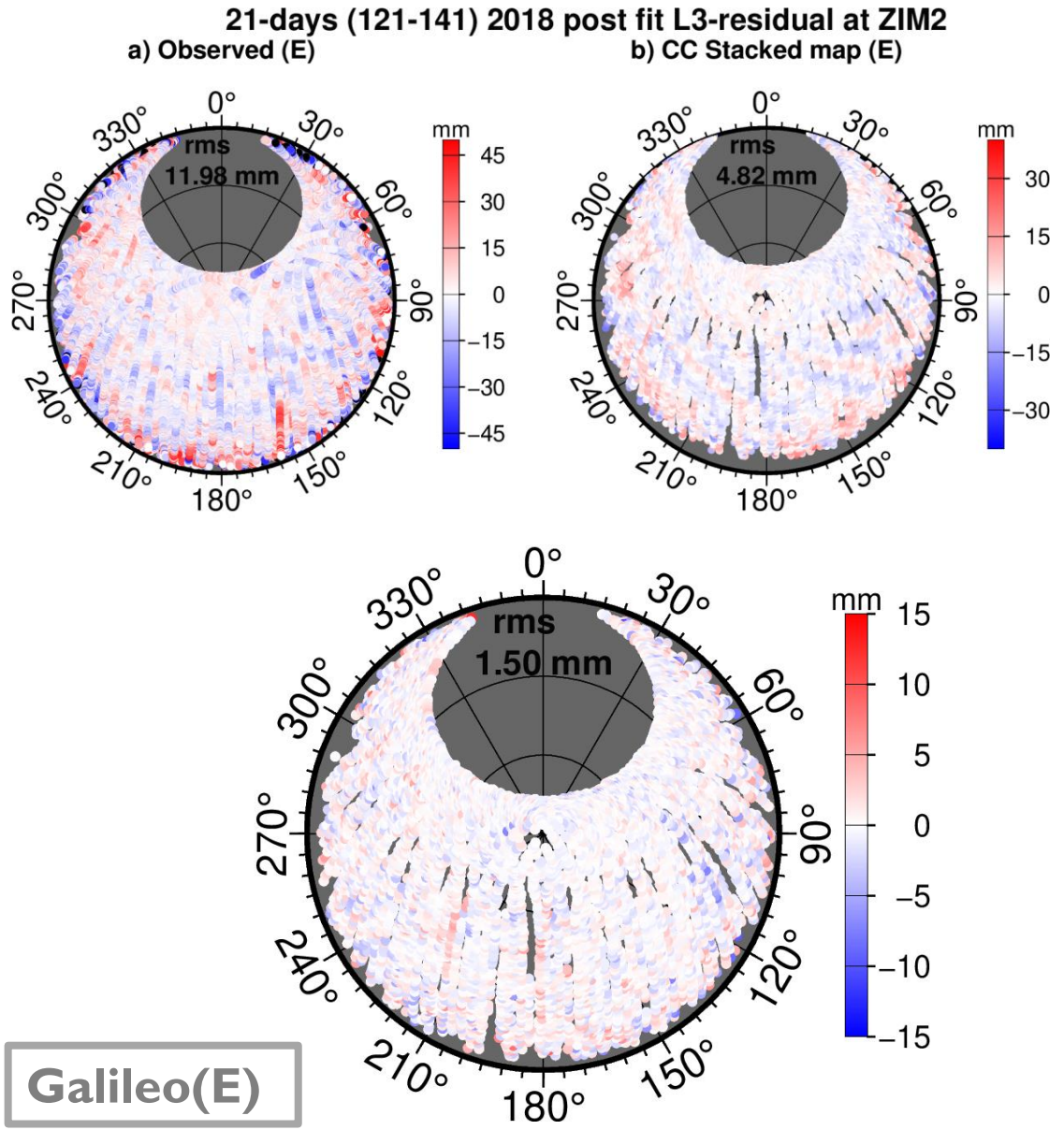




GPS(G) & GALILEO(E) POST-FIT RESIDUALS: ZIM2

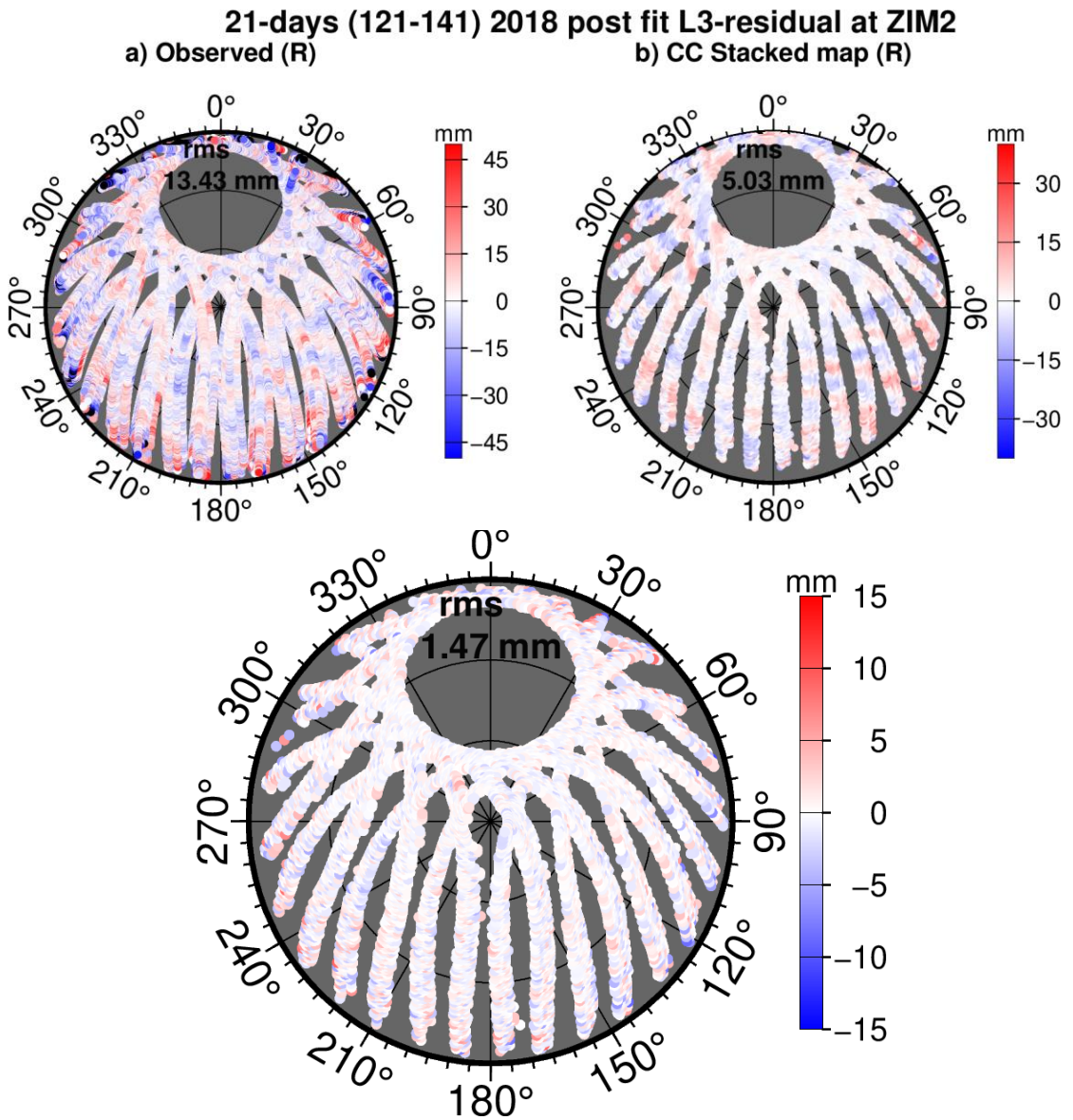


GPS(G)

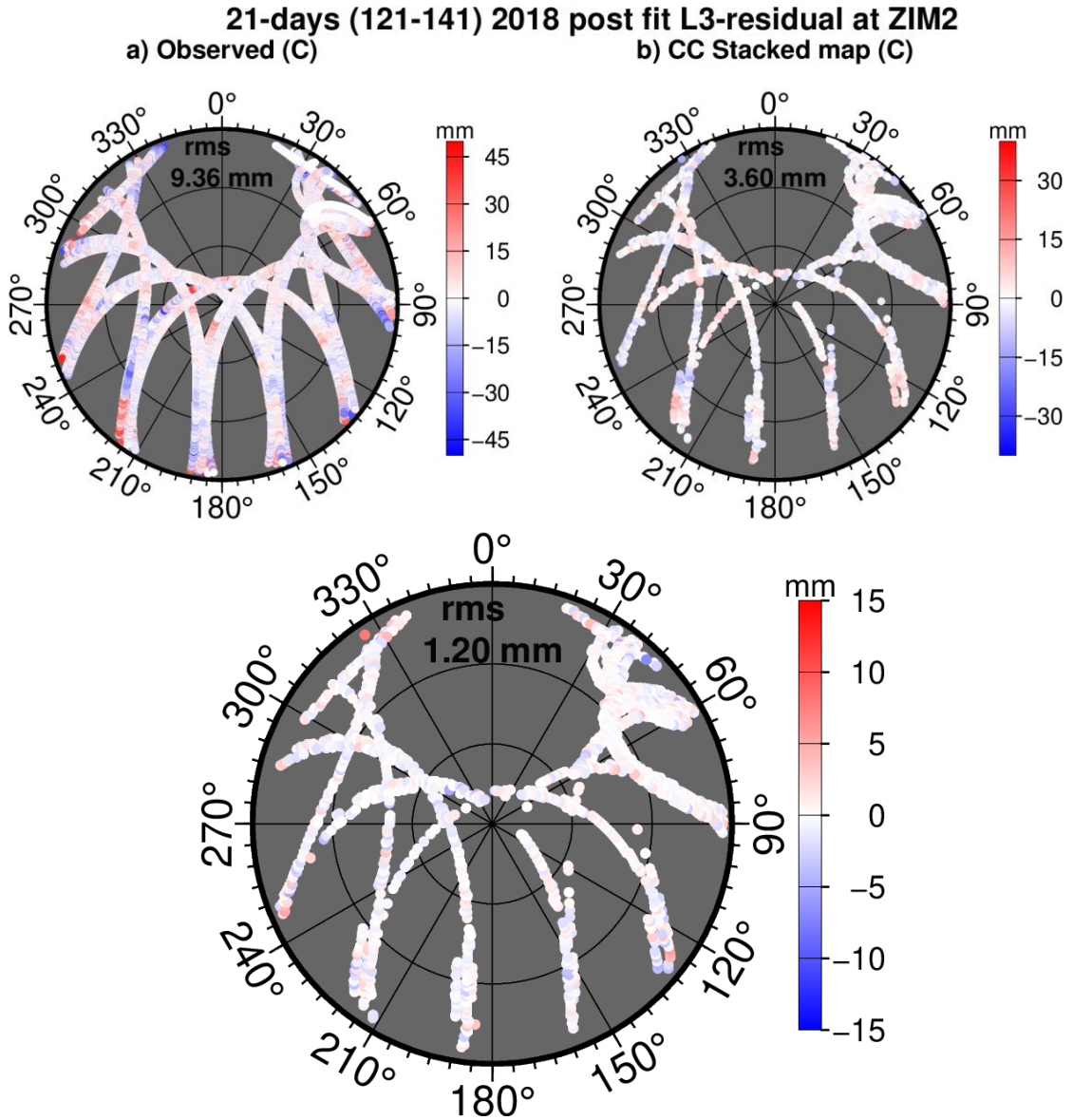


Galileo(E)

GLONASS(R) & BDS(C) POST-FIT RESIDUALS: ZIM2

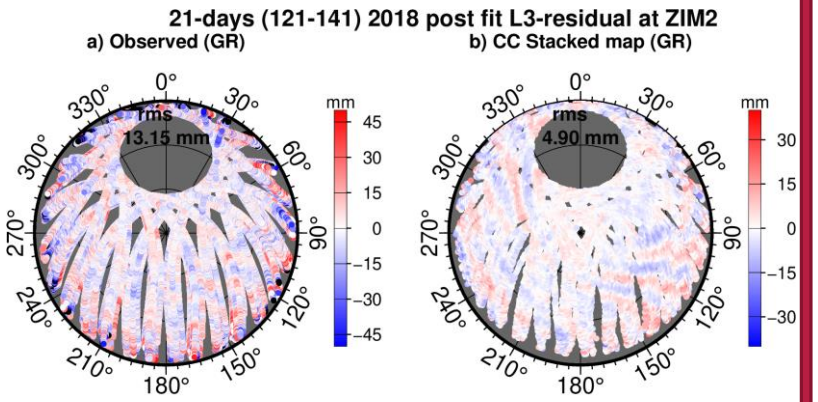


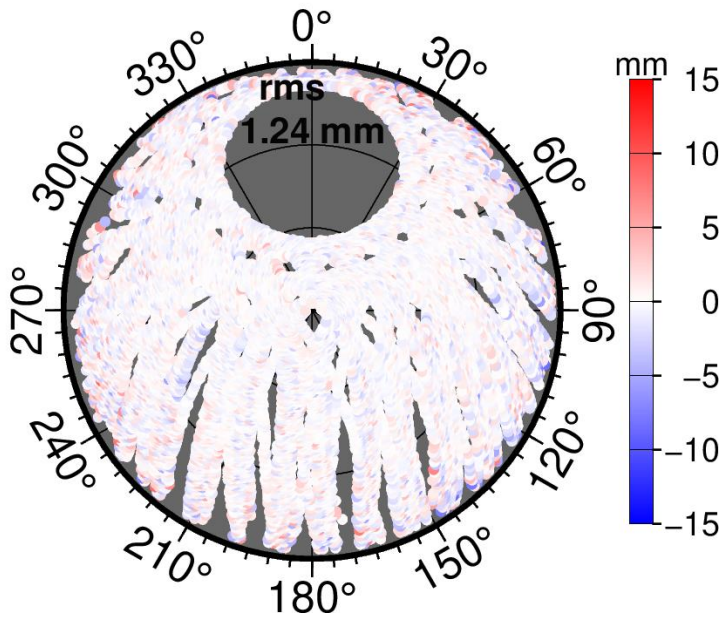
GLONASS(R)



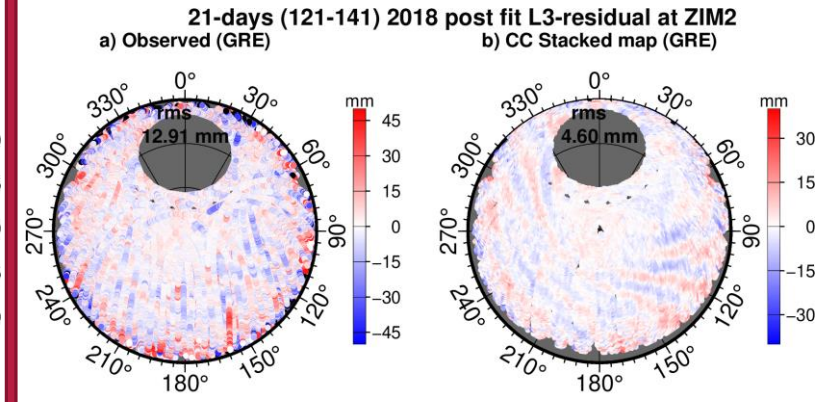
BDS(C)

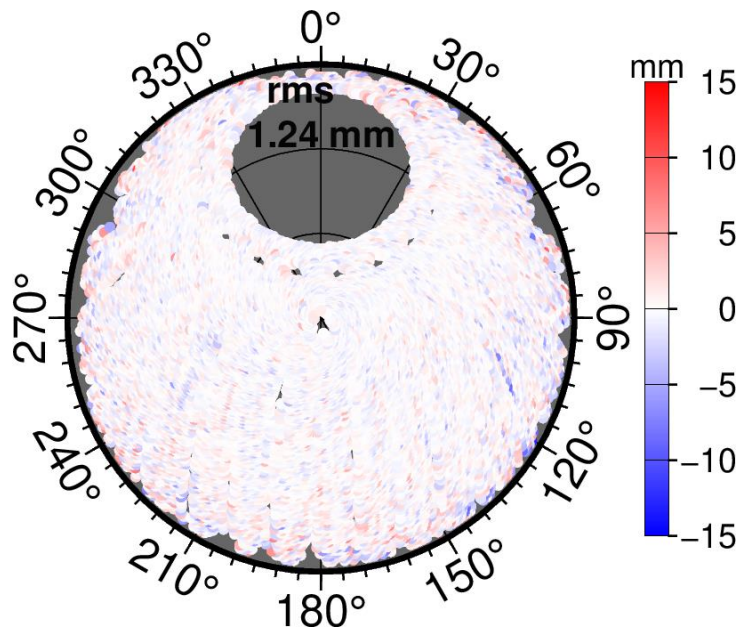
MULTI-GNSS COMBINATIONS: ZIM2



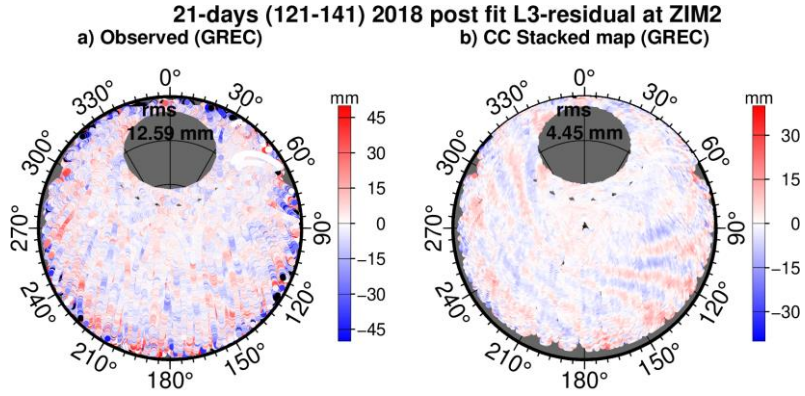


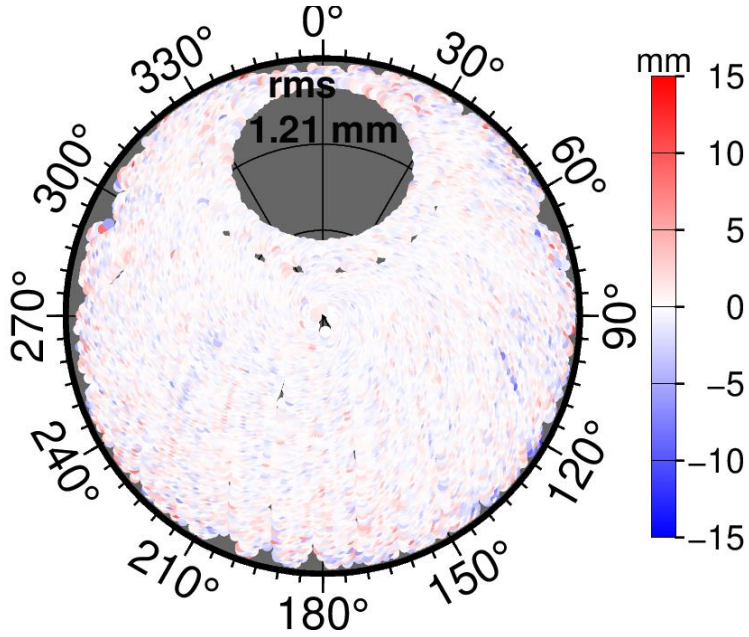
GPS+GLONASS





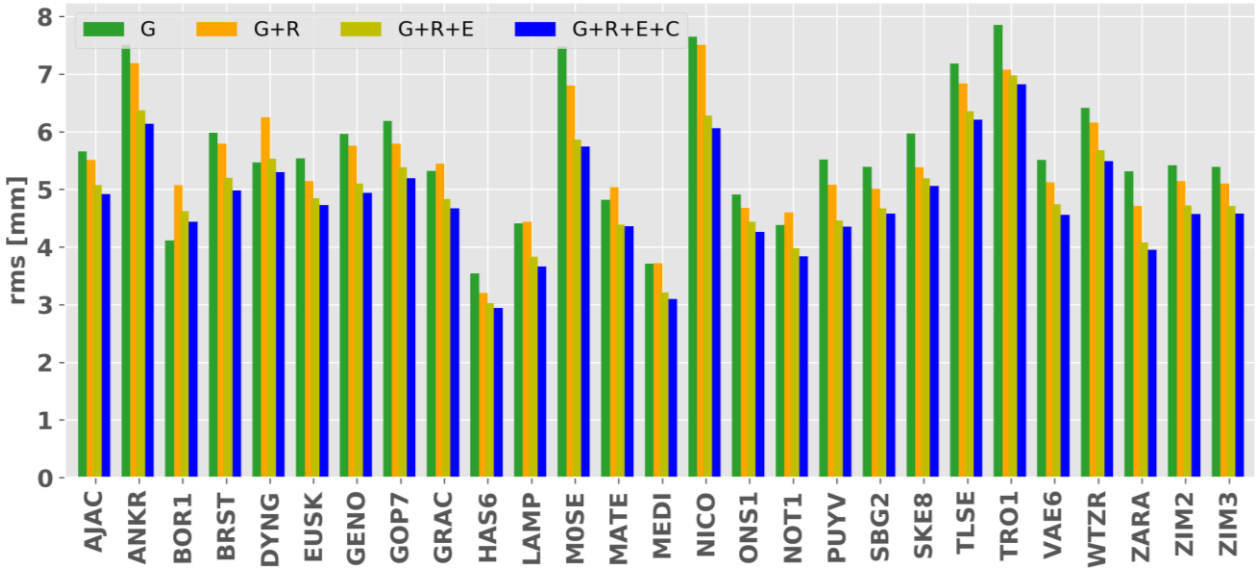
GPS+GLONASS+Galileo

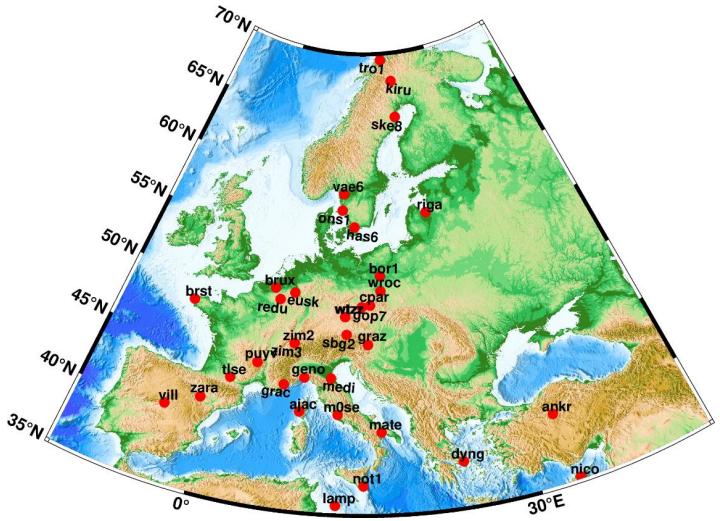




GPS+GLONASS+Galileo+BDS

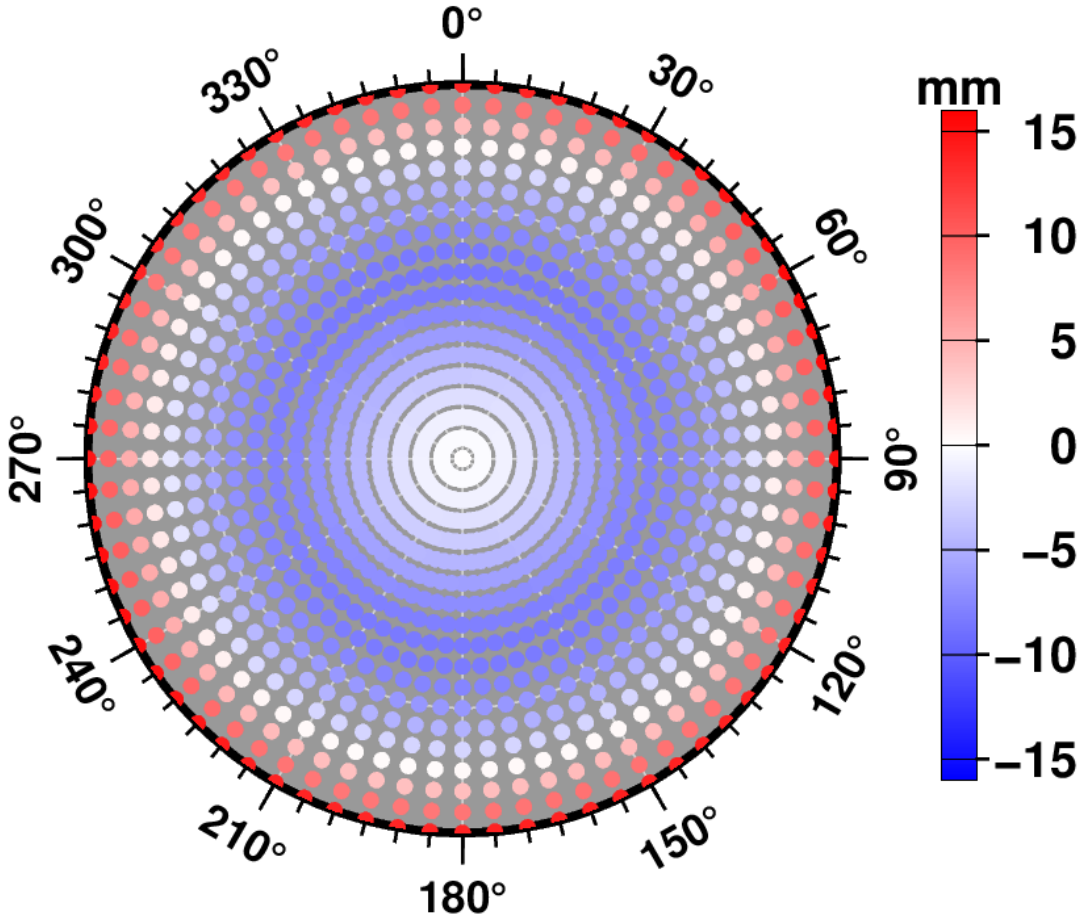
RMS FOR DIFFERENT MEGX STATIONS FOR MULIT-GNSS COMBINATIONS:



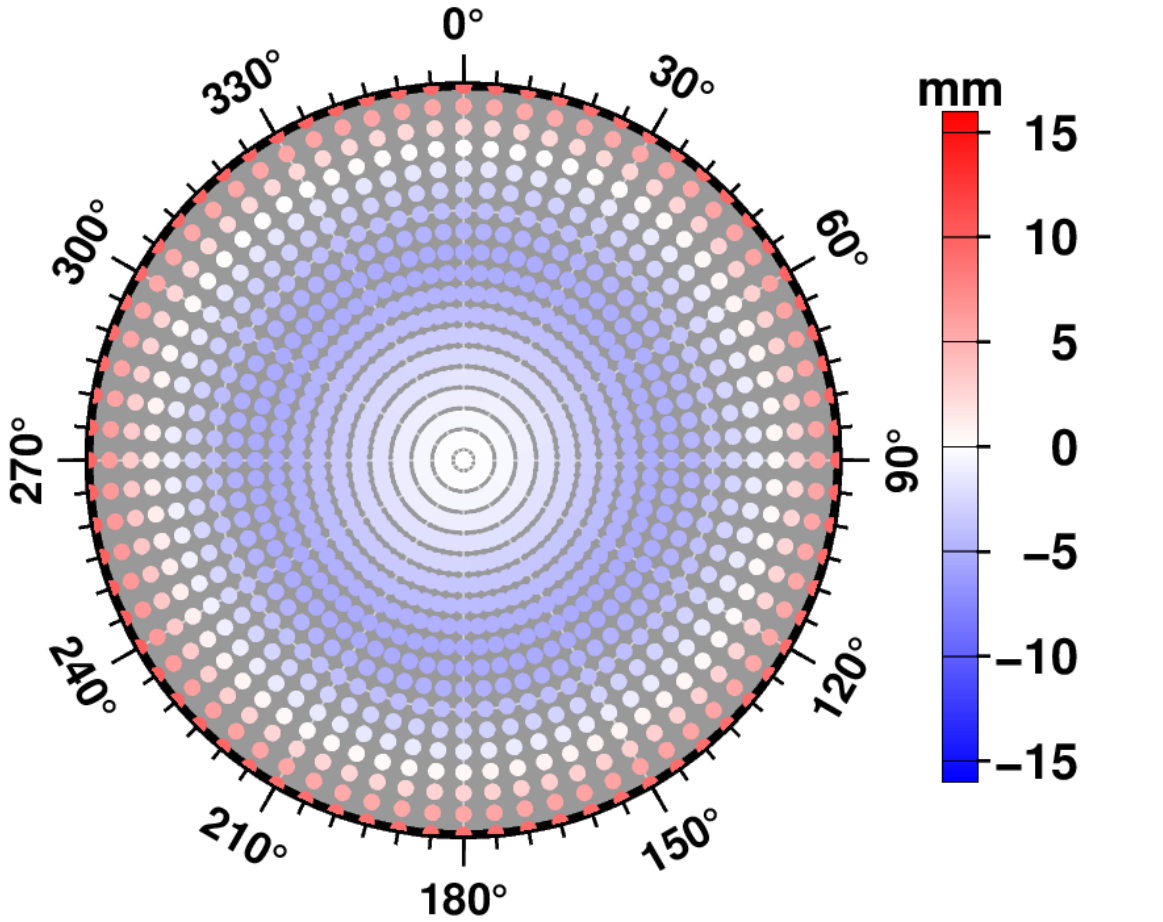


SITE	G	GR	GRE	GREC
AJAC	5.66	5.51	5.07	4.92
ANKR	7.51	7.19	6.37	6.14
BOR1	4.11	5.07	4.62	4.44
BRST	5.98	5.79	5.20	4.98
DYNG	5.47	6.25	5.53	5.30
EUSK	5.54	5.14	4.85	4.73
GENO	5.96	5.76	5.10	4.94
GOP7	6.19	5.79	5.38	5.19
GRAC	5.32	5.45	4.83	4.67
HAS6	3.54	3.20	3.03	2.94
LAMP	4.41	4.44	3.83	3.66
M0SE	7.48	6.80	5.86	5.74
MATE	4.82	5.04	4.39	4.36
MEDI	3.71	3.72	3.21	3.10
NICO	7.65	7.51	6.28	6.06
ONS1	4.91	4.68	4.44	4.26
NOT1	4.38	4.60	3.98	3.84
PUYV	5.52	5.08	4.46	4.35
SBG2	5.39	5.01	4.67	4.58
SKE8	5.97	5.38	5.19	5.06
TLSE	7.18	6.84	6.36	6.21
TRO1	7.85	7.08	6.98	6.82
VAE6	5.51	5.12	4.74	4.56
WTZR	6.41	6.16	5.68	5.49
ZARA	5.31	4.71	4.08	3.95
ZIM2	5.42	5.14	4.72	4.57
ZIM3	5.39	5.10	4.71	4.58

PCV CORRECTIONS FOR L1(GPS-ONLY) FOR STATION, AJAC ,FRANCE



PCV at station (ASH700936A_M NONE), @ AJAC



PCV after MPS corrections(ASH700936A_M NONE) @ AJAC

IMPLEMENTING PCV CORRECTIONS

GNSS RINEX files

IGS and external products

GAMIT network solutions Global/Regional

Post-fit residuals

Construct Congruent cells: R_i

Outlier detections

Multipath stacking maps: previous 21 days: $R_{(i-21)}$

$\mathbf{R_{(i-21)} - MPS}$

Reconstruct: L1 and L2 residuals

Corrected PCV

ANTEX FILE PCV model

CONCLUSIONS

- Raw (unfiltered) residuals manifest large fluctuations below ~15 degrees elevation
- Multi-GNSS stacking reduces multipath effects: the amount depends on severity of the site-specific multipath
- The MPS map RMS improves when GPS+GLONASS+Galileo+BDS are combined
- Galileo shows the smallest RMS
- There is potential to provide in-situ correction products for all IGS stations similar to those for the PCV correction tables