Multi-GNSS trials: a note on software comparison and campaign GNSS measurements

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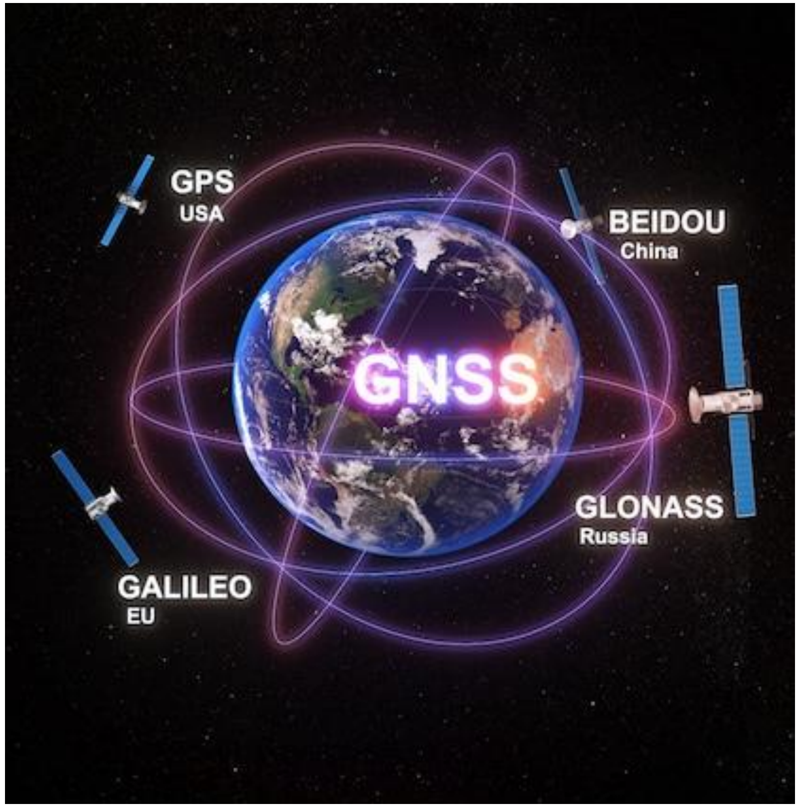
G 1.2

Motivation

- Model MULTI-GNSS positioning accuracy
- Do it as accurate as possible (PPP-AR)
- Make inferences for campaign measurements
- Are there any differences in the performance of GNSS software from different vendors?



Accuracy is assessed from many GPS and GNSS experiments

GNSS ones starting from:

Montenbruck et al. (2014)

and recently;

Chen et al. (2021)
Ogutcu et al. (2021)
Akpinar (2021)

The upcoming two have modeled coordinate components using GPS!

Accuracy of GPS from relative positioning (Eckl et al. 2001)

$$S_n(L,T) = [a_n/T + b_n L^2/T + c_n + d_n L^2]^{0.5}$$

Modelling the error of local topocentric coordinates n, e, u

Regional experiments used

Accuracy of GPS from PPP (Saracoglu and Sanli 2021)

The latest GPS model

Global assessment

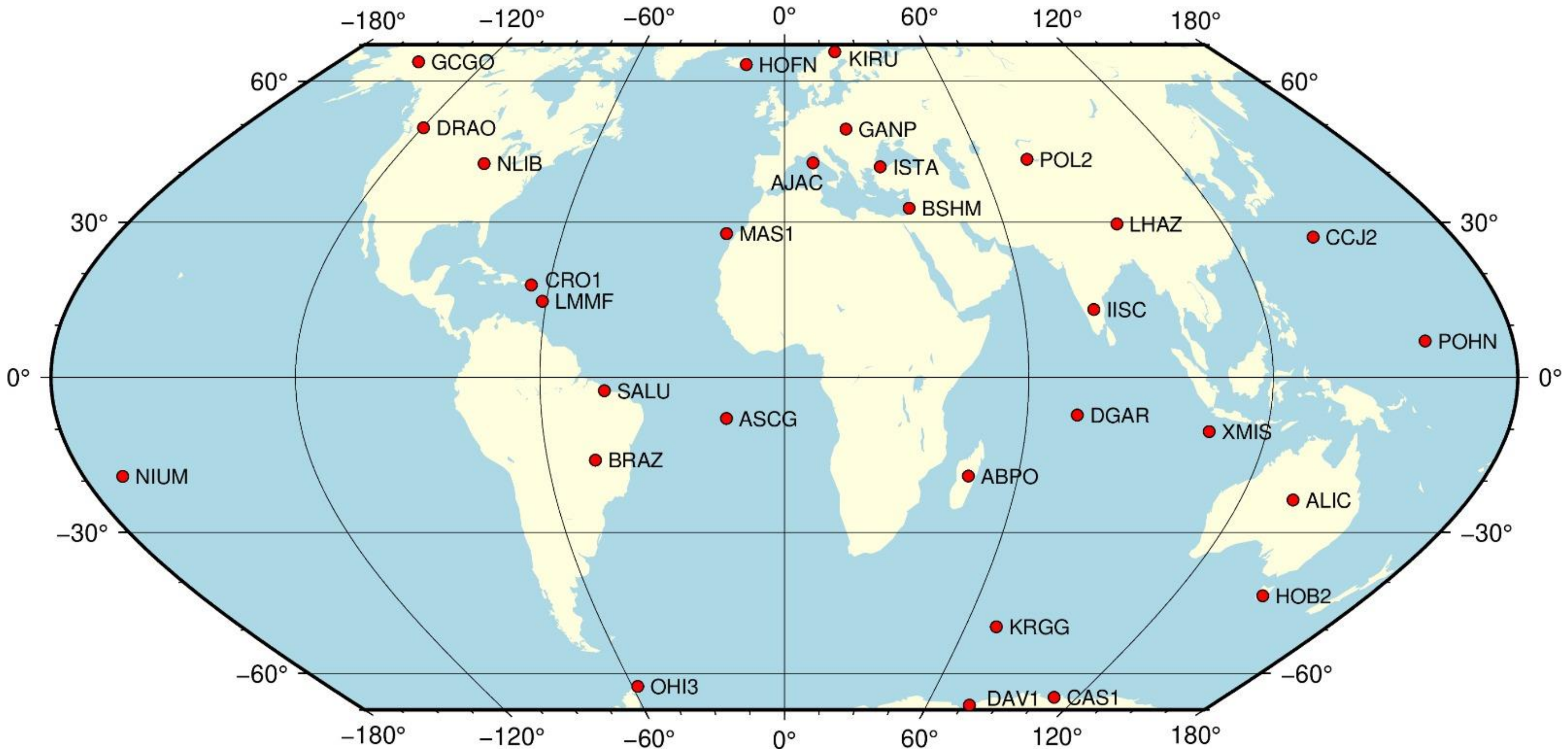
Climate taken into account

$$S_n(\varphi, T) = \sqrt{\frac{a_n}{T} + \frac{b_n\varphi^2}{T} + c_n + d_n\varphi^2}$$

$$S_e(\varphi, T) = \sqrt{\frac{a_e}{T} + \frac{b_e\varphi^2}{T} + c_e + d_e\varphi^2}$$

$$S_u(\varphi, T) = \sqrt{\frac{a_u}{T} + \frac{b_u\varphi^2}{T} + c_u + d_u\varphi^2}$$

IGS-MGEX stations used in this study (+15 stations to 2022 experiment)



NASA JPL's 2019 experiment

- AR provided (Sibthorpe et al. 2020)
  - IGS's 102 MGEX stations used
  - Performance of GR, GE, GRE and G
  - In IGSR3 frame
  - Various POD products

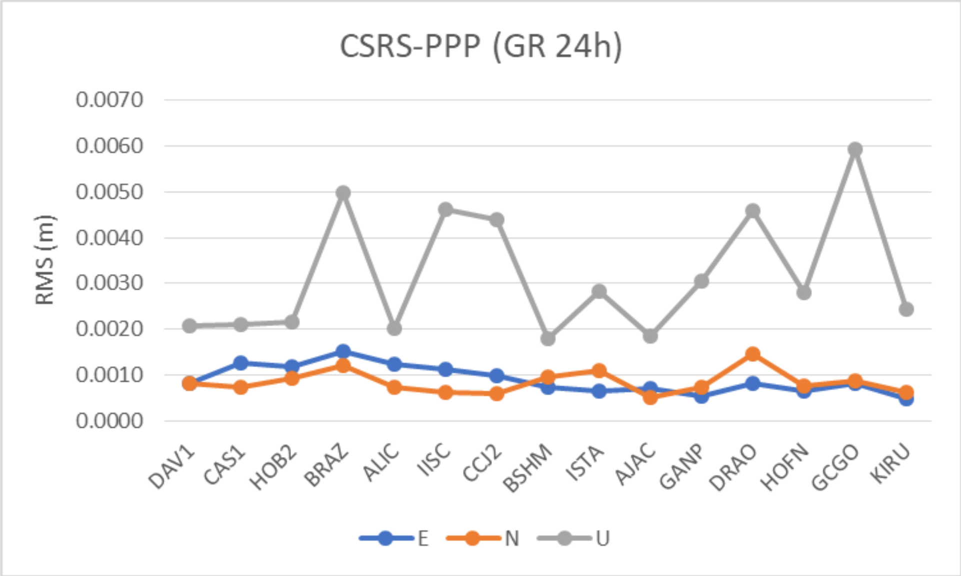
This study

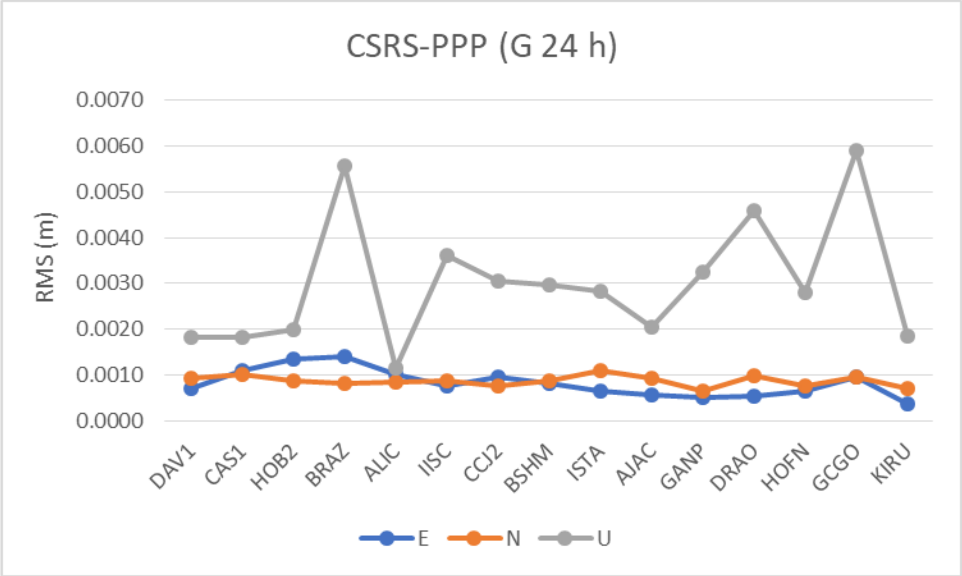
- Asses the positioning accuracy of GNSS combinations from GPS, GLONASS, and GALILEO
  - Derive mathematical model for n,e,u
- Compare GPS solutions with those of the GPS+GLONASS (GR), GPS+GALILEO (GE), and GPS+GLONASS+GALILEO (GRE)
- Software packages: CANADIAN CSRS-PPP vs. NASA/JPL GIPSY-X
- Use 24-h data (10 consecutive days starting from 1st Apr 2019)
- Also assess accuracy from synthetic GPS campaigns sampled 8-h per day using the continuous data of the IGS

Accuracy meant in this study

- Not
  - Compare GNSS results with those of;
    - VLBI, SLR etc
    - IGS weekly solution
- But
  - Take the mean of 24 h solution as the truth
  - Find the RMS of shorter spans
  - This has been adopted by;

Eckl et al. 2001, Soler et al. 2006, Sanli and Engin 2009, Wang and Soler 2012 etc.


CSRS-PPP (GR 24h)
RMS (m)
0.0070
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
DAV1 CAS1 HOB2 BRAZ ALIC IISC CCJ2 BSHM ISTA AJAC GANP DRAO HOFN GCGO KIRU
E N U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0.0010
0.0000
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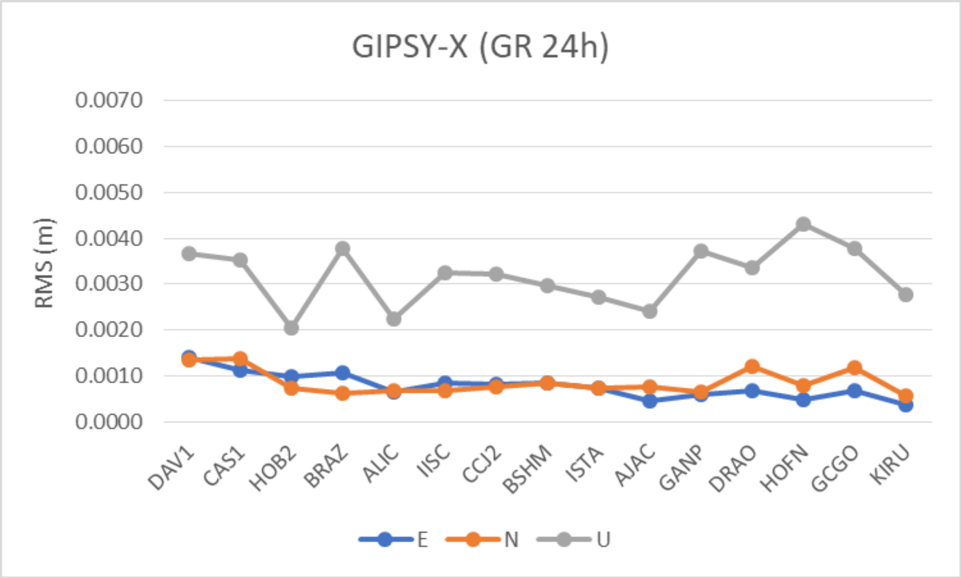
GIPSY-X (GR 24h)
RMS (m)
0.0070
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
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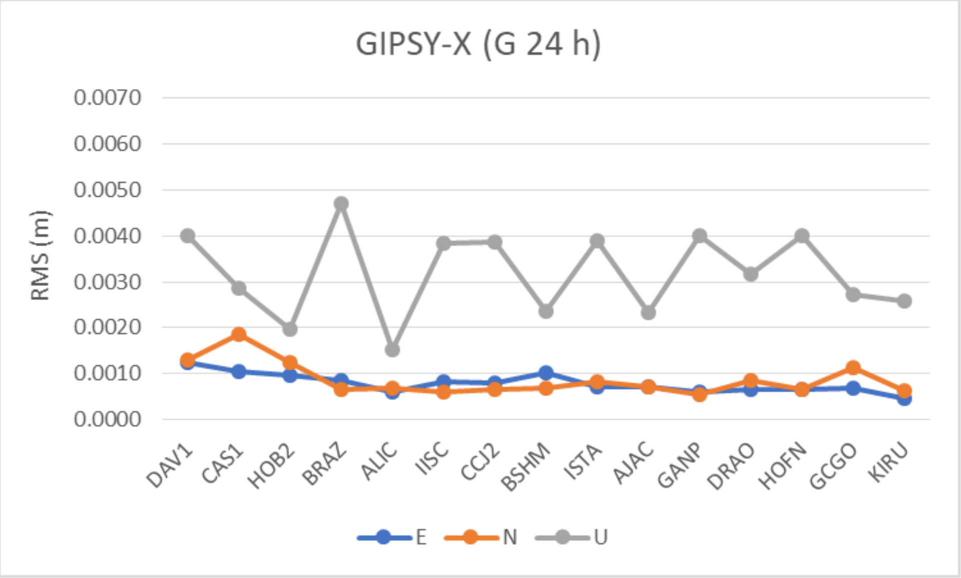
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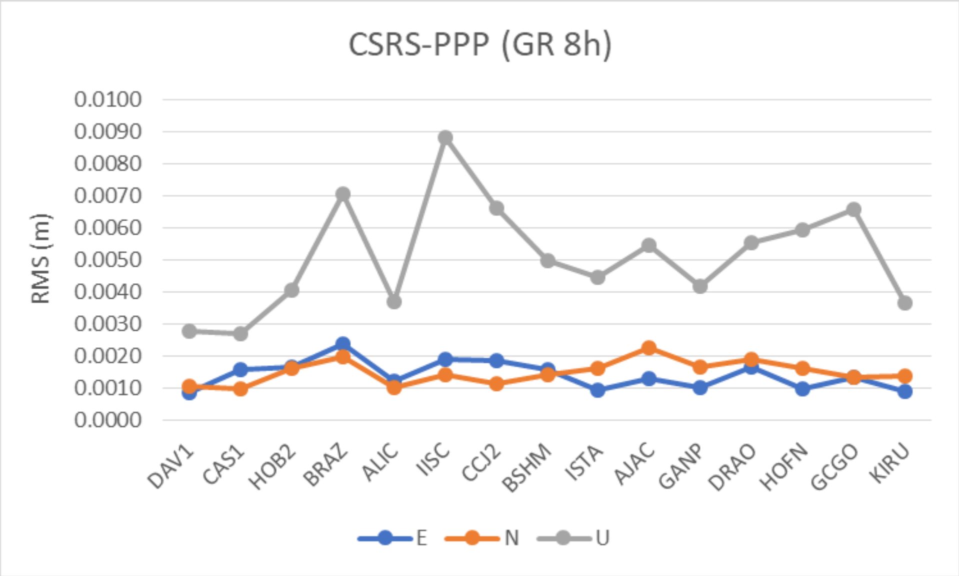
CSRS-PPP (GR 8h)
RMS (m)
0.0100
0.0090
0.0080
0.0070
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
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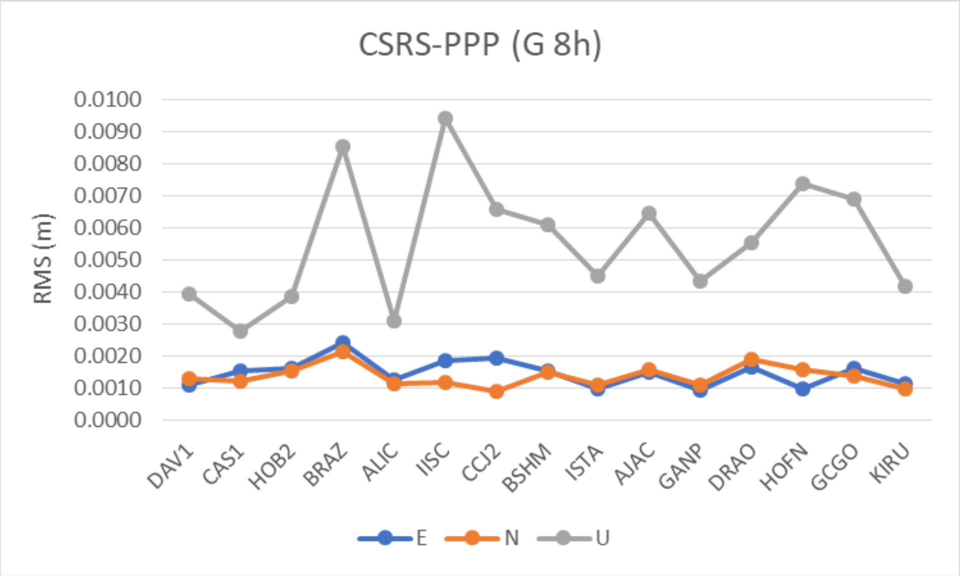
E N U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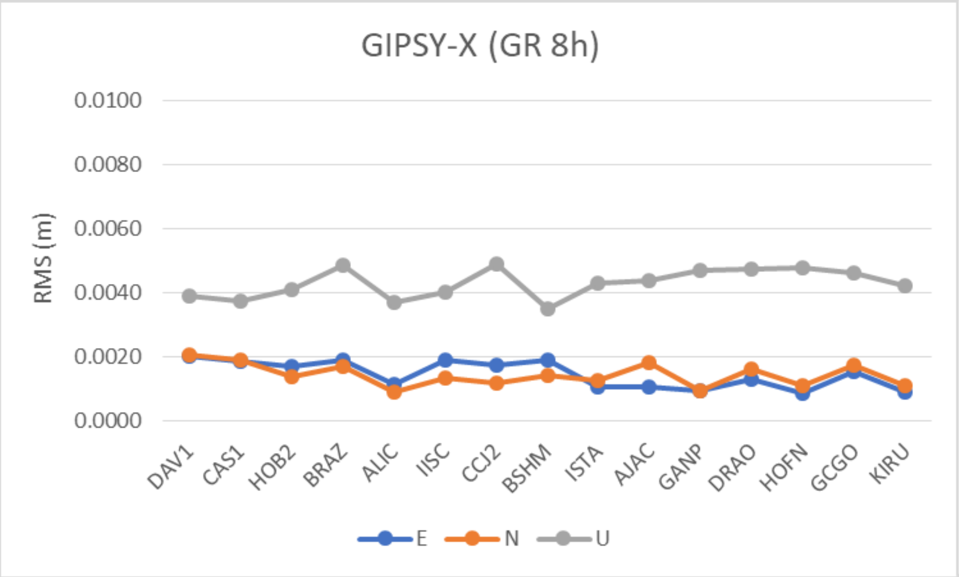
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RMS (m)
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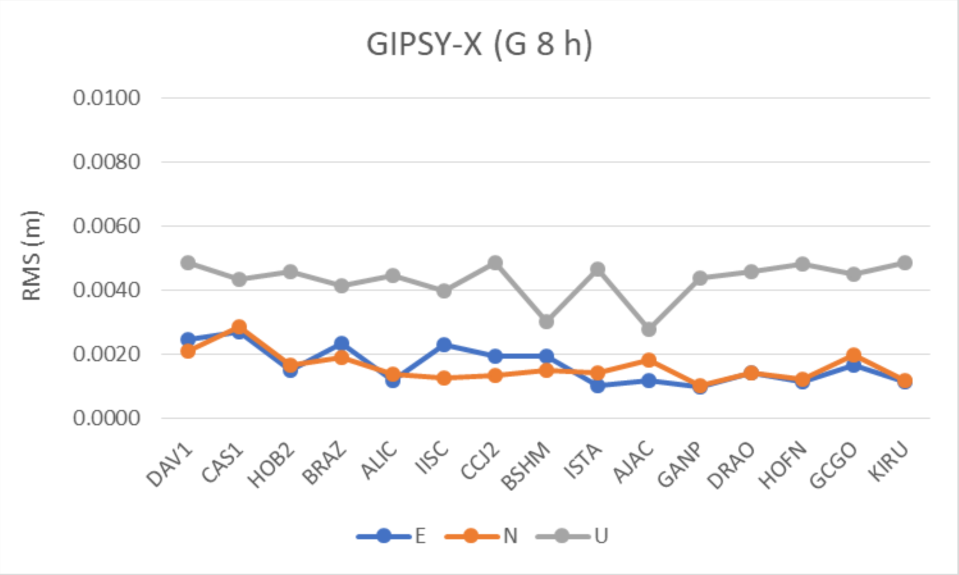
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RMS (m)
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
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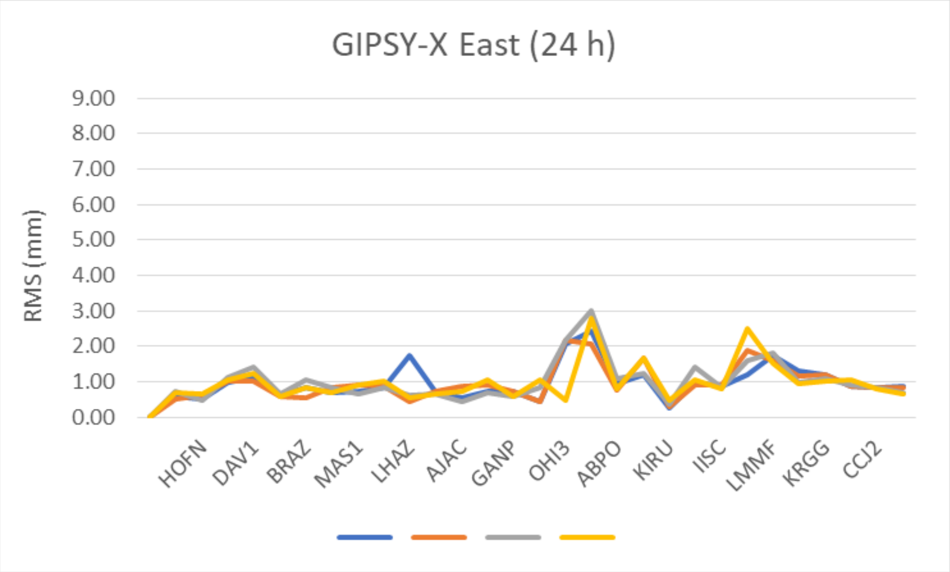
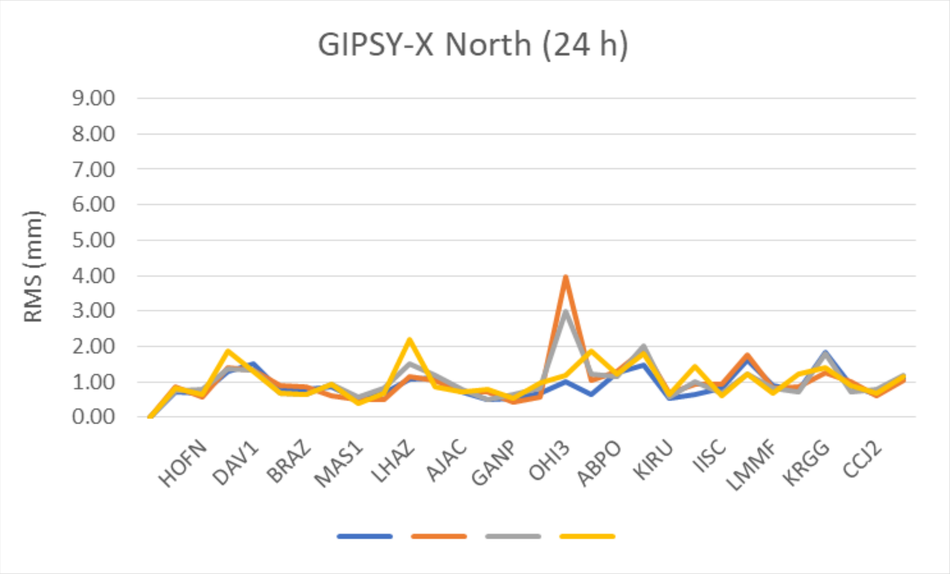
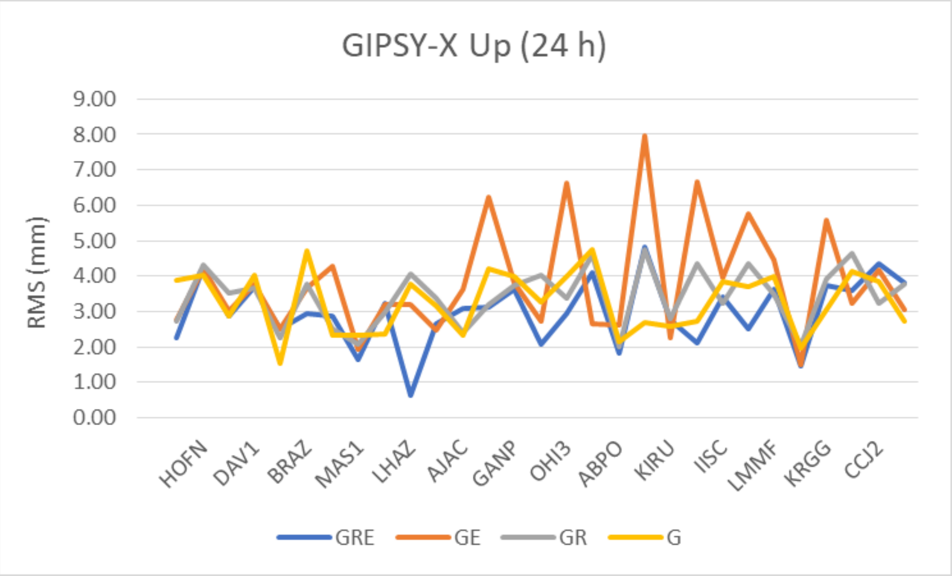
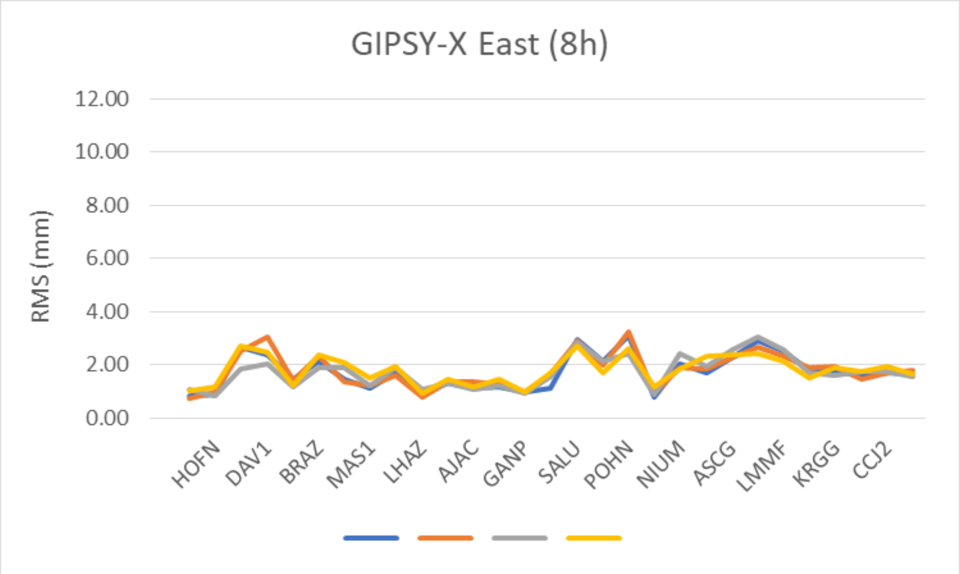
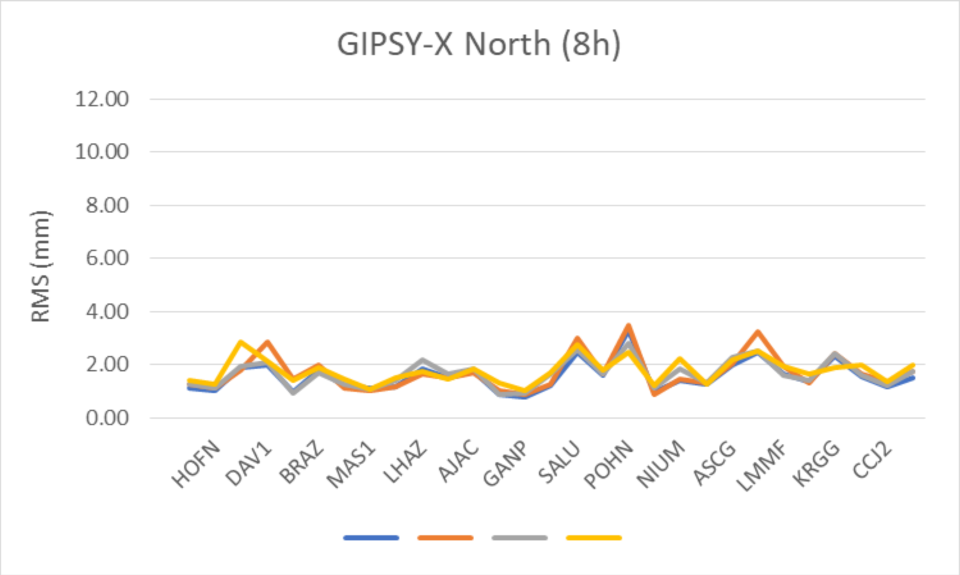
E N U


GIPSY-X East (24 h)
RMS (mm)
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
HOFN
DAV1
BRAZ
MAS1
LHAZ
AJAC
GANP
OHI3
ABPO
KIRU
IISC
LMMF
KRGG
CCJ2


GIPSY-X North (24 h)
RMS (mm)
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
HOFN
DAV1
BRAZ
MAS1
LHAZ
AJAC
GANP
OHI3
ABPO
KIRU
IISC
LMMF
KRGG
CCJ2


GIPSY-X Up (24 h)
RMS (mm)
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
HOFN
DAV1
BRAZ
MAS1
LHAZ
AJAC
GANP
OHI3
ABPO
KIRU
IISC
LMMF
KRGG
CCJ2
GRE
GE
GR
G


GIPSY-X East (8h)
RMS (mm)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
HOFN
DAV1
BRAZ
MAS1
LHAZ
AJAC
GANP
SALU
POHN
NIUM
ASCG
LMMF
KRGG
CCJ2


GIPSY-X North (8h)
RMS (mm)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
HOFN
DAV1
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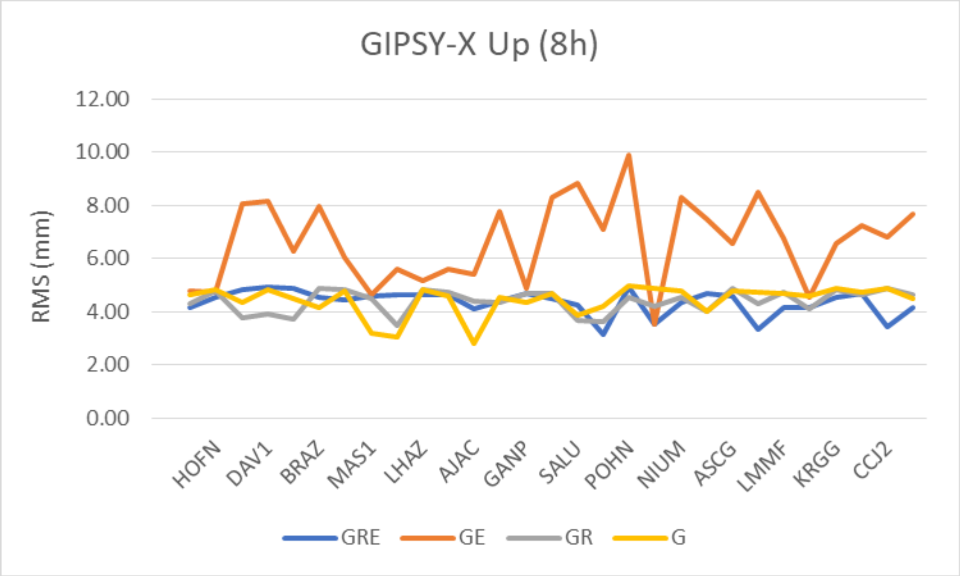
GIPSY-X Up (8h)
RMS (mm)
12.00
10.00
8.00
6.00
4.00
2.00
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G

GIPSY-X PRODUCTS USED FOR MODELLING

GPS+GLONASS

$$S_n = \frac{5.0}{\sqrt{T}}$$

$$S_e = \frac{5.5}{\sqrt{T}}$$

$$S_u = \left[\frac{81.1}{T} + 9.3\right]^{1/2}$$

GPS+GALILEO

$$S_n = \frac{5.1}{\sqrt{T}}$$

$$S_e = \frac{5.0}{\sqrt{T}}$$

$$S_u = \left[\frac{351.4}{T}\right]^{1/2}$$

GPS+GLONASS+GALILEO

$$S_n = \frac{4.9}{\sqrt{T}}$$

$$S_e = \frac{5.4}{\sqrt{T}}$$

$$S_u = \left[\frac{106.3}{T} + 5.4\right]^{1/2}$$

GPS

$$S_n = \frac{4.9}{\sqrt{T}}$$

$$S_e = \frac{4.6}{\sqrt{T}}$$

$$S_u = \left[\frac{87.8}{T} + 8.0\right]^{1/2}$$

Dependency on latitude in the latest GPS model

Saracoglu and Sanli (2021)

$$S_n(\varphi, T) = \sqrt{\frac{113,4173}{T} - \frac{0,0117\varphi^2}{T}}$$

$$S_e(\varphi, T) = \sqrt{\frac{60,1717}{T} - \frac{0,0044\varphi^2}{T}}$$

$$S_u(\varphi, T) = \sqrt{\frac{478,7246}{T} - \frac{0,0343\varphi^2}{T}}$$

?

Conclusions

- An independent sub-network produced similar results to JPL's 2019 experiment
- Sofware comparison yields differences especially for campaign GNSS: exact comparison in the same ref frame is essential!
- The positioning accuracy of GNSS dependent on 'session duration'
- Combination with FOC gives the signal of better accuarcy
  - Well at least for the up component in this study!
- The user will eagerly await the required AR infrastructure to produce improved/accurate solutions