

Towards a Multi-Constellation combination : Improving the IGS orbit & clock combination software for MGEX products.

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IGS Workshop 2018, Wuhan, China

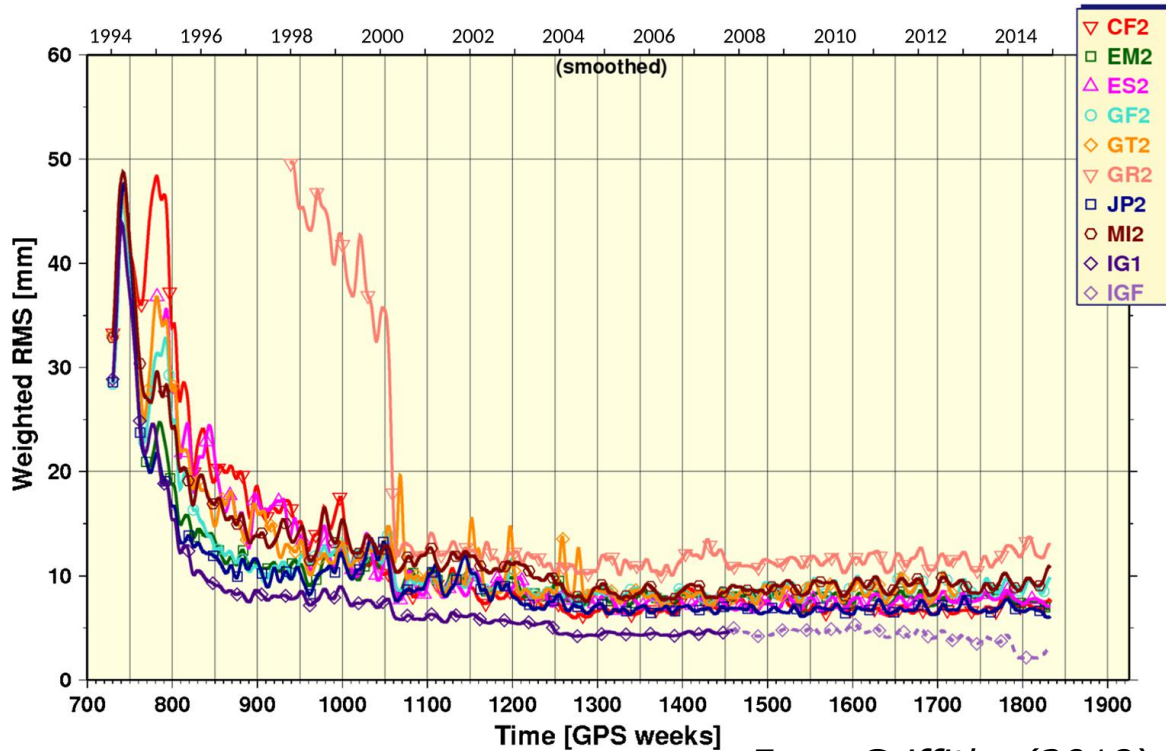
Current G/RNSSs

| Name | 1st Launch | Country | IGS ID | # of sats./ nominal |
|-------------|------------|------------------|--------|---------------------|
| GPS | 1978 | USA | G | 31/33 |
| GLONASS | 1982 | Russia (ex-USSR) | R | 24/26 |
| Galileo | 2005 | Europe | E | 26/30 |
| Beidou | 2007 | China | C | 23/35 |
| QZSS | 2010 | Japan | J | 4/7 |
| NAVIC/IRNSS | 2013 | India | I | 7/7 |



**= 115
satellites
in orbit**

IGS Orbit Combination



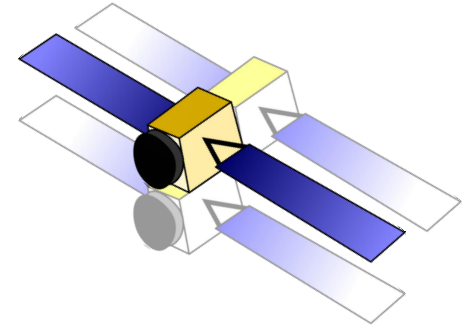
From Griffiths (2018)

WRMS difference for each Analysis Center w.r.t. IGS orbit combination

(Repro2 campaign)

Combination Software

- Combination software based on the method developed by Springer & Beutler (1993), and Kouba et al. (1994)
- Some improvements for clock combination (Kouba & Springer, 2001)
- Software is quite old, without significant improvement for almost 20 years
- The IGS official products are GPS-only
- A strong limitation for end users who want to perform Multi-GNSS processing

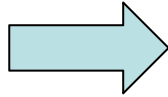


$x, y, z, \delta t$?

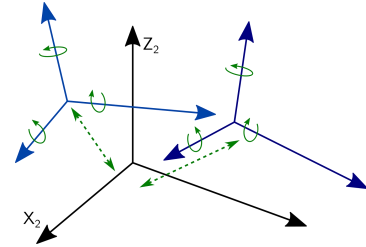
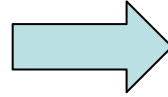
Orbit Combination Summary



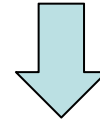
Step 1 :
Pole Alignment
to ITRF



$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

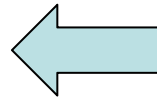


Step 3 :
Helmert transformation
of each AC \Rightarrow Mean

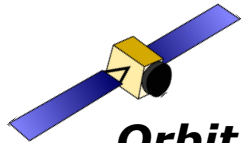
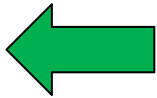
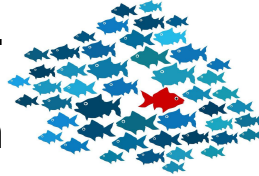


Step 4 :
coordinates
weighted
mean

$$\bar{x} = \frac{\sum_{i=1}^n w_i x_i}{\sum_{i=1}^n w_i}$$



Step 5 :
AC & sat.
outliner
detection



**Orbit
Combination**

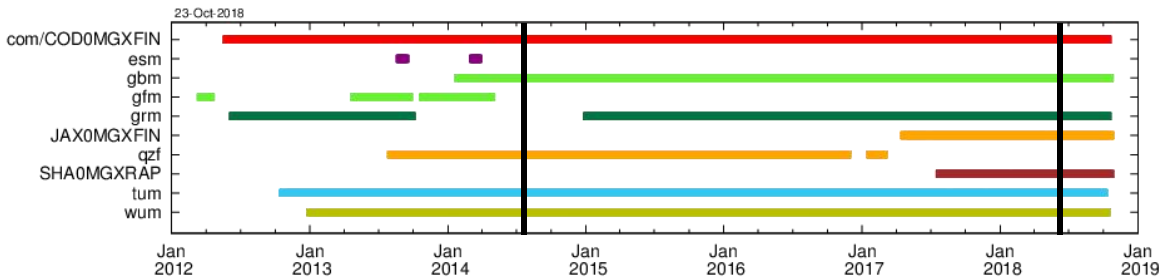
MGEX Analysis Centers Used

| intern. ID | Name | Country | GNSS processed | 1st epoch used |
|------------|------------------|-----------|----------------|-----------------|
| com | CODE | Swi./Ger. | G,R,E,C,J | w1690 (2012/05) |
| gbm | GFZ | Germany | G,R,E,C,J | w1777 (2014/01) |
| grm | GRGS/CNES/CLS | France | G,R,E | w1692 (2012/06) |
| jam | JAXA | Japan | G,R,J | w1945 (2017/04) |
| tum | TU Munich | Germany | E,J | w1711 (2012/10) |
| wum | Wuhan University | China | G,R,E,C,J | w1722 (2013/01) |



Improvements & Tests

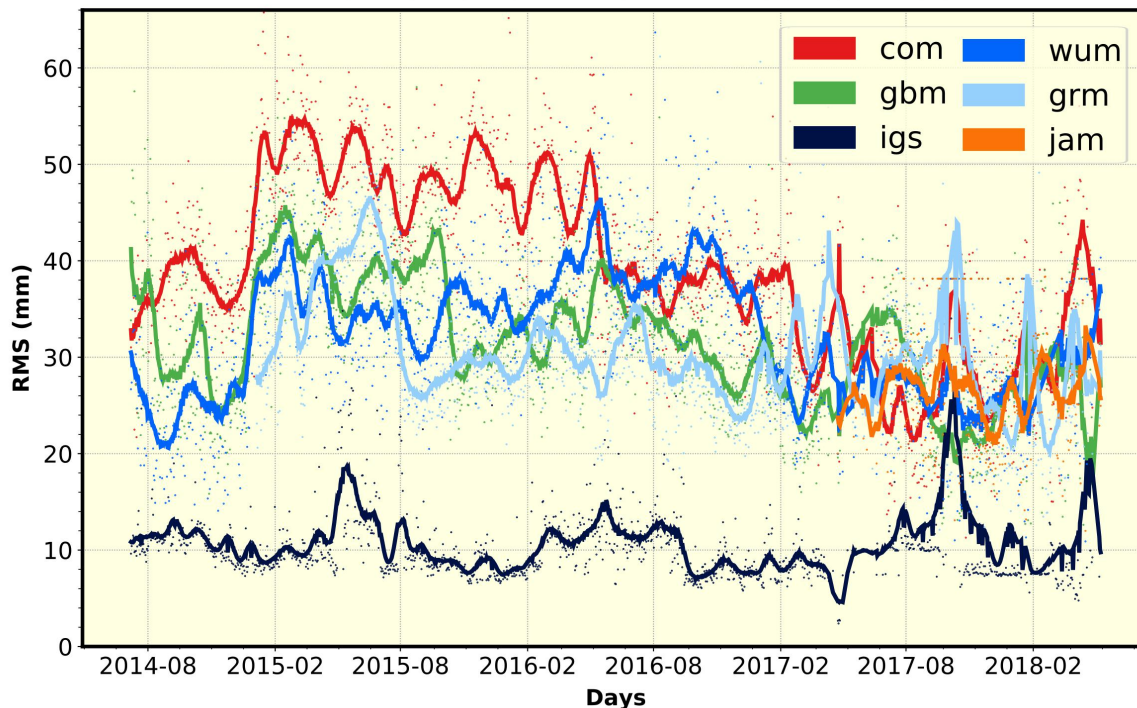
- Add modifications to manage Beidou & QZSS
- Make the software compatible with *sp3d* format (*sp3c* : limited to 85 satellites)
- Test period of 200 weeks
(GPS week 1800 \Rightarrow week 2000, 2014/07 \Rightarrow 2018/05)



From
IGS/MGEX
Website

RMS for Orbit Combination

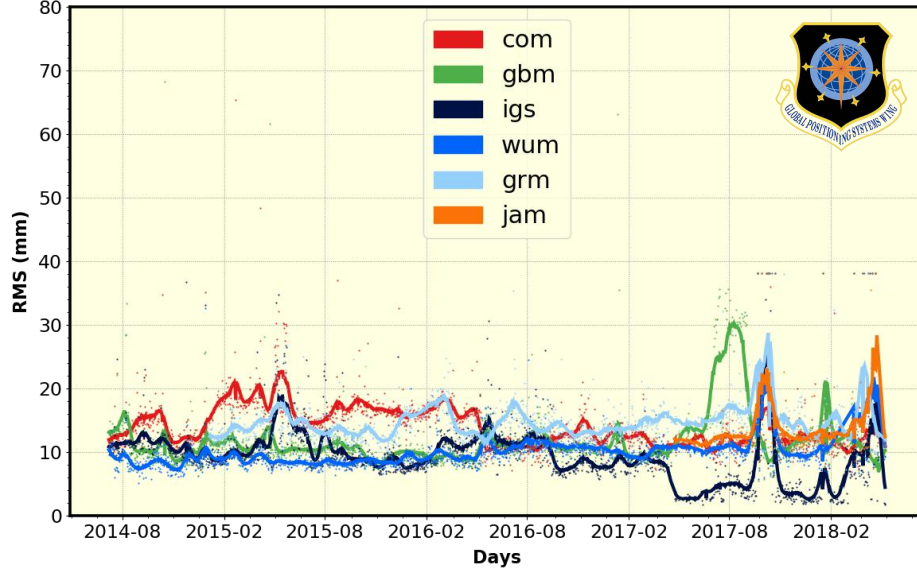
Final Orbits RMS - All Satellites



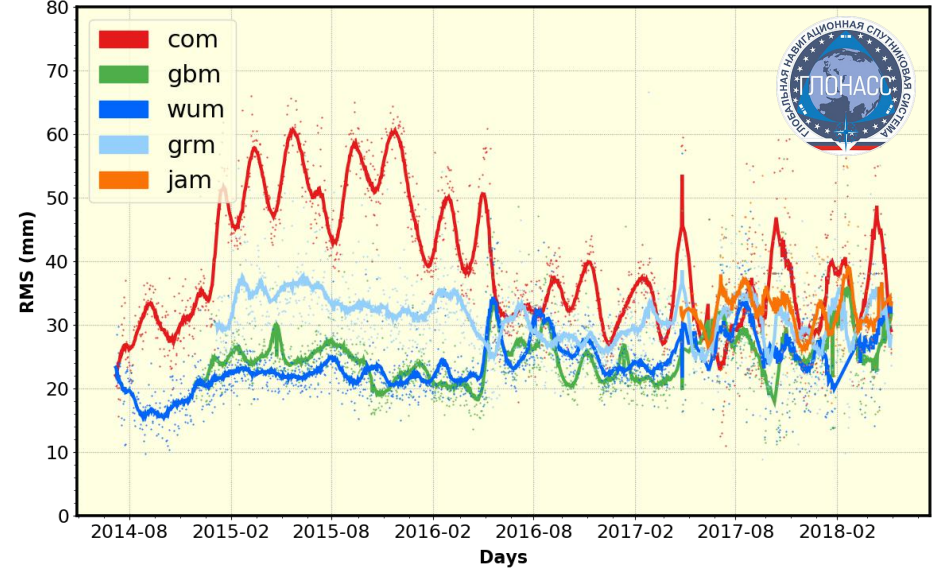
NB : No pole alignment for some ACs

RMS for Orbits Combination

Final Orbits RMS - GPS Satellites



Final Orbits RMS - GLONASS Satellites

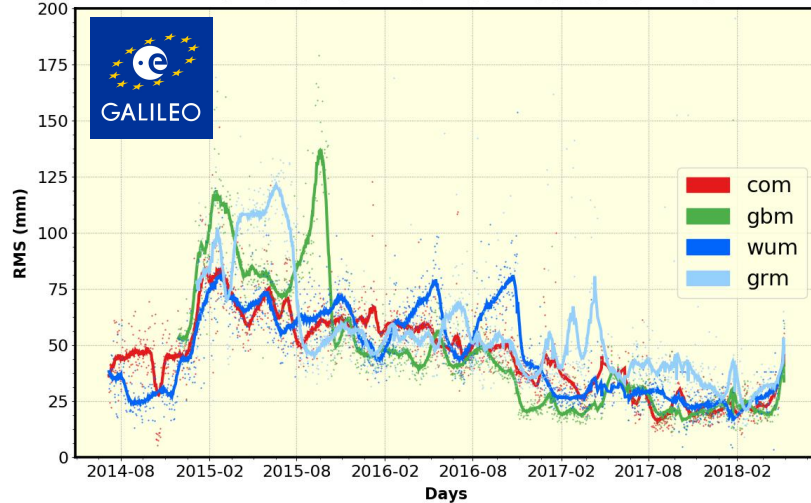


"historical" constellations

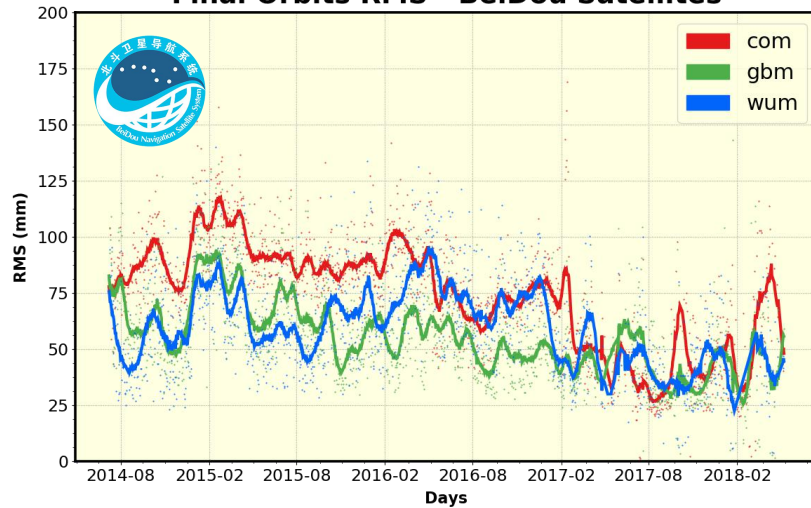
RMS for Orbit Combination

"New" constellations

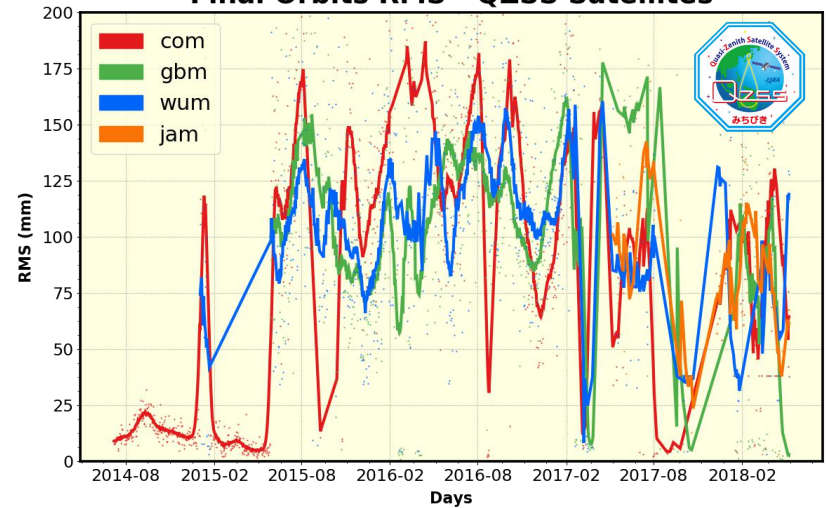
Final Orbits RMS - Galileo Satellites



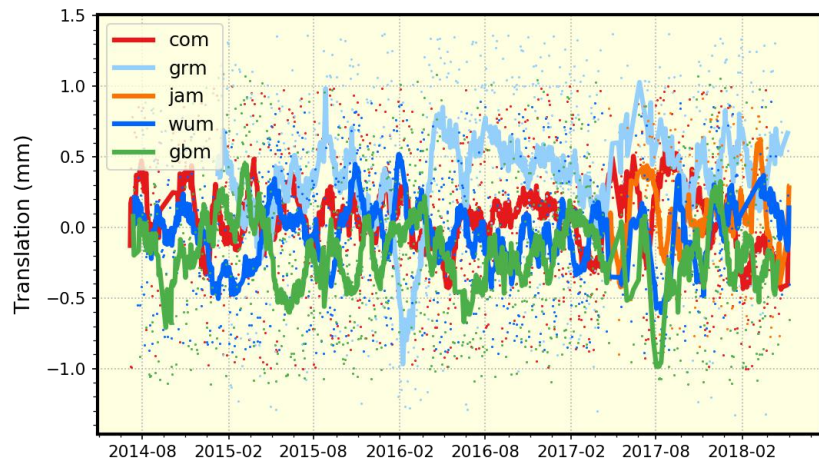
Final Orbits RMS - BeiDou Satellites



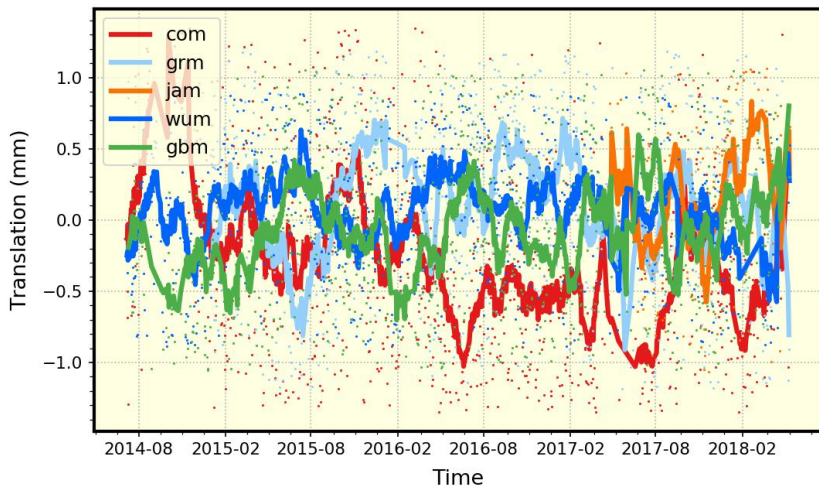
Final Orbits RMS - QZSS Satellites



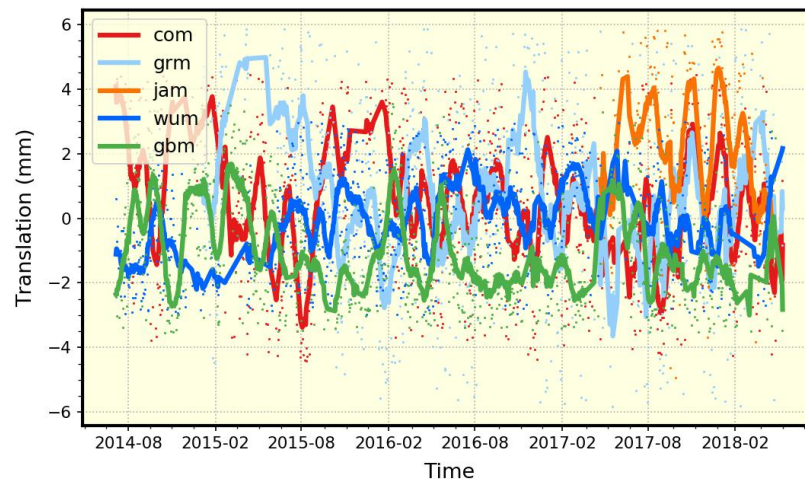
X-Translation



Y-Translation

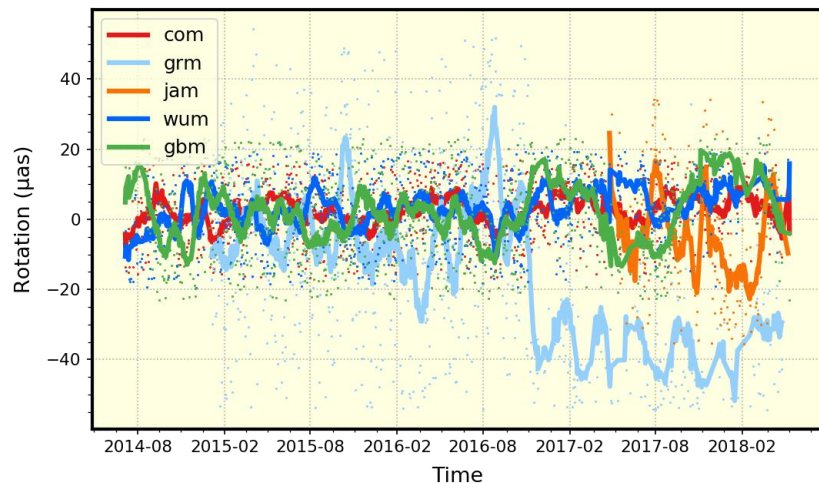
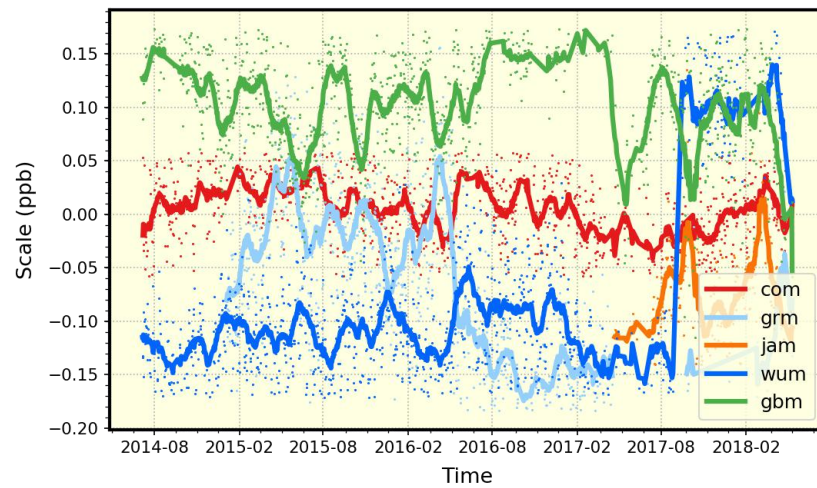
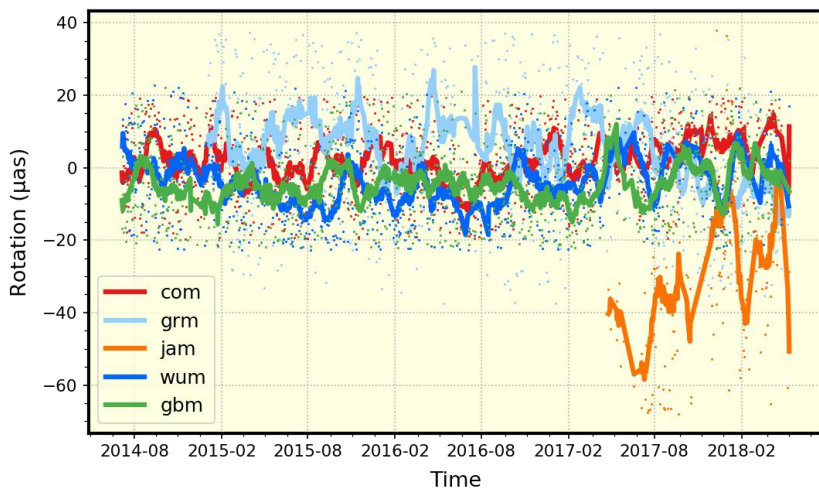
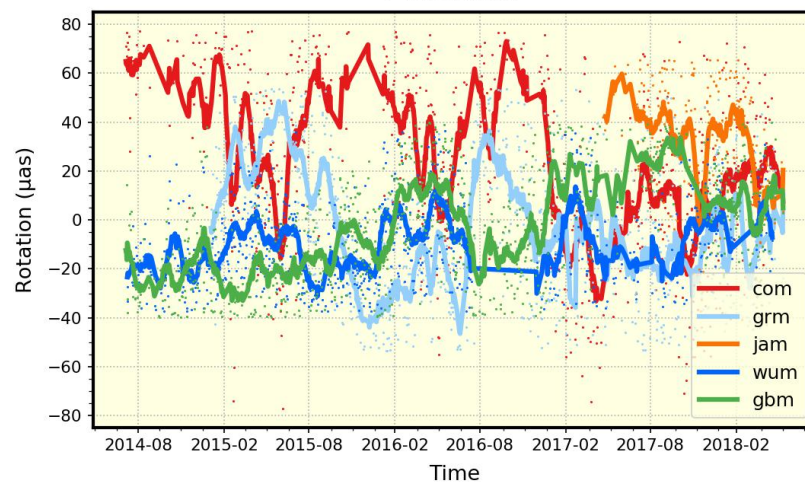


Z-Translation



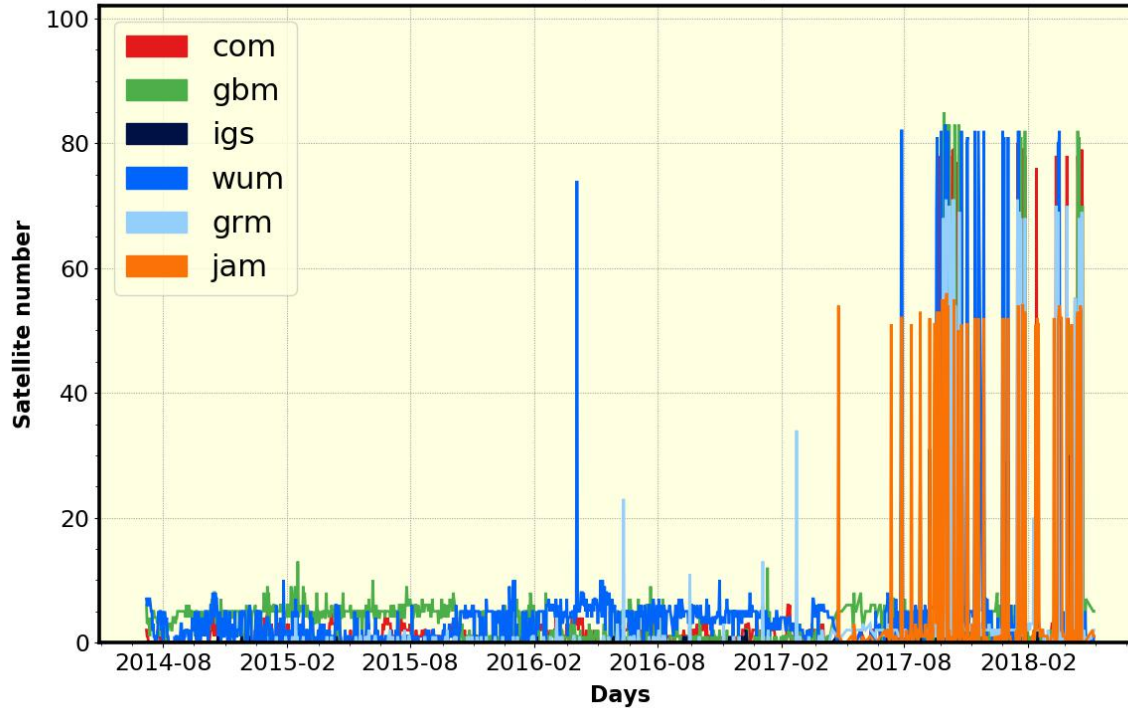
Transformation Parameters

*Consistency with IGS
GPS-only Combination*

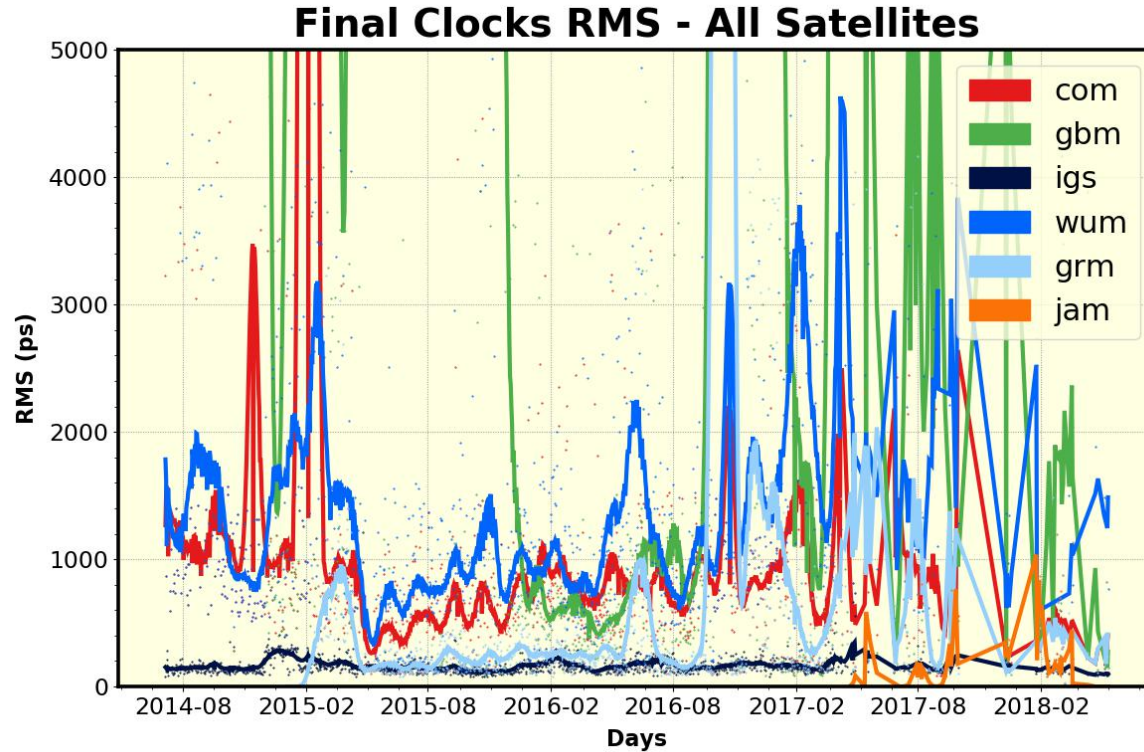
X-Rotation**Scale****Y-Rotation****Z-Rotation**

Satellites excluded

Satellites excluded (outliers) - All Satellites



RMS for Clock Combination



New combination software

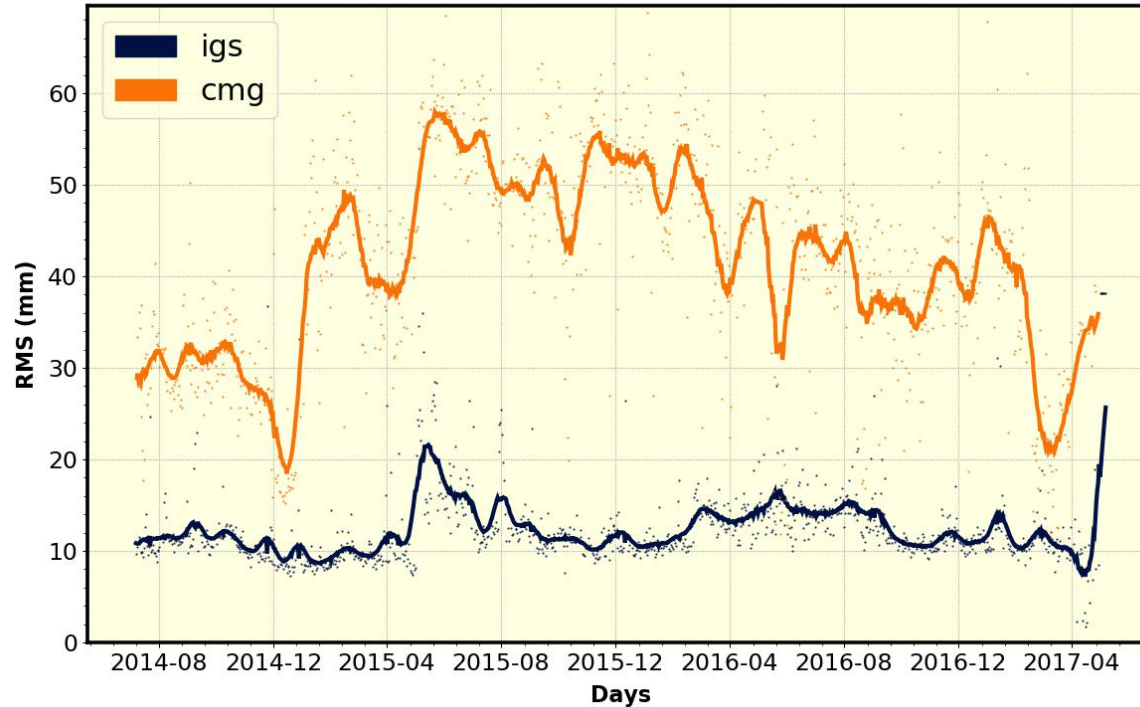
- Start from scratch
- Developed in *Python 3*
- Based on the same theory so far
- Designed to add easily new functionalities
- PhD student subject

Further developments

- Weights according to the constellations
- Alignment to the ITRF based on ground station coordinates
- SLR observation integration (?)

New combination software

Final Orbits RMS - All Satellites



Preliminary results

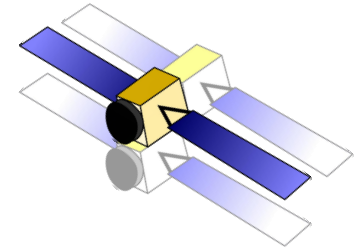
cmg = Combination Multi-GNSS

reference :
Multi-GNSS
Combination
produced with the
official software

Summary & Perspectives

- Orbit combination : $\sim 30\text{mm}$ RMS w.r.t individual ACs
 $\sim 10\text{mm}$ RMS w.r.t. IGS Final Combi.
- Can be improved with pole alignment for all ACs
- Clock combination is unstable so far
- Instabilities during recent weeks (lot of exclusions)

- A new software is under development,
for an easier implementation of new features



But ...

- What is the level of “emergency” ?
- Should be the result of a collective discussion