Towards a Multi-Constellation combination

Pierre Sakic [1], Gustavo Mansur [1,2], Benjamin Männel [1]

1 : GFZ Deutsches GeoForschungsZentrum
Space Geodetic Techniques Section, Potsdam, Germany
2 : Technische Universität Berlin, Germany

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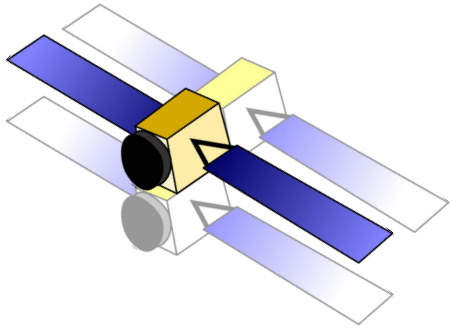
Combination Software

- Combination software based on the method developed by Springer & Beutler (1993), and Kouba et al. (1994)

- The current IGS final products are GPS-only
- A strong limitation for end users who want to perform Multi-GNSS processing

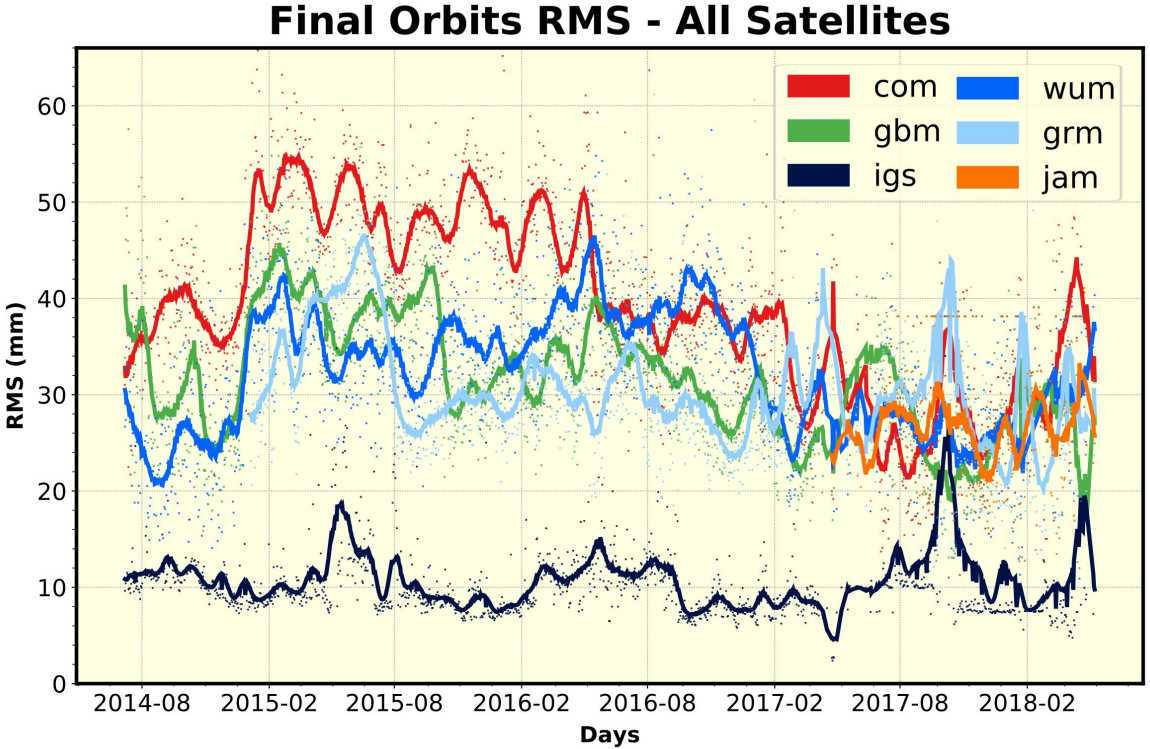


$$x, y, z, \delta t \quad ?$$

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)
wum	Wuhan University	China	G,R,E,C,J	w1722 (2013/01)

RMS for Orbit Combination



NB : No pole alignment for some ACs

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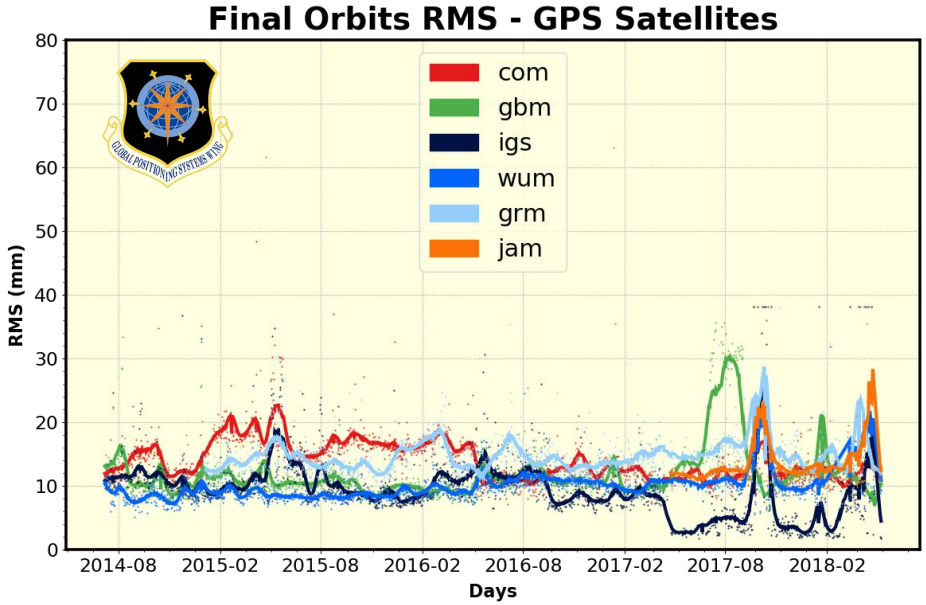
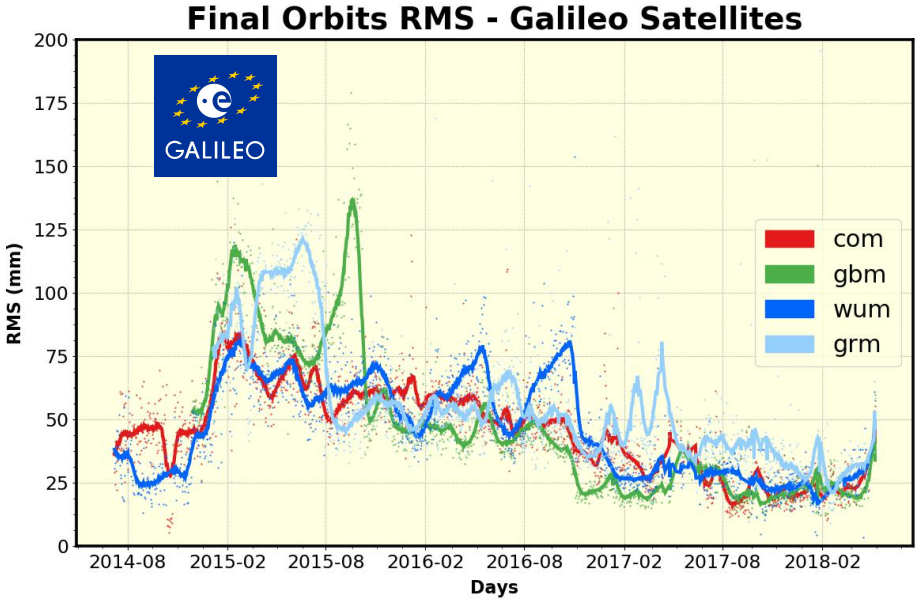
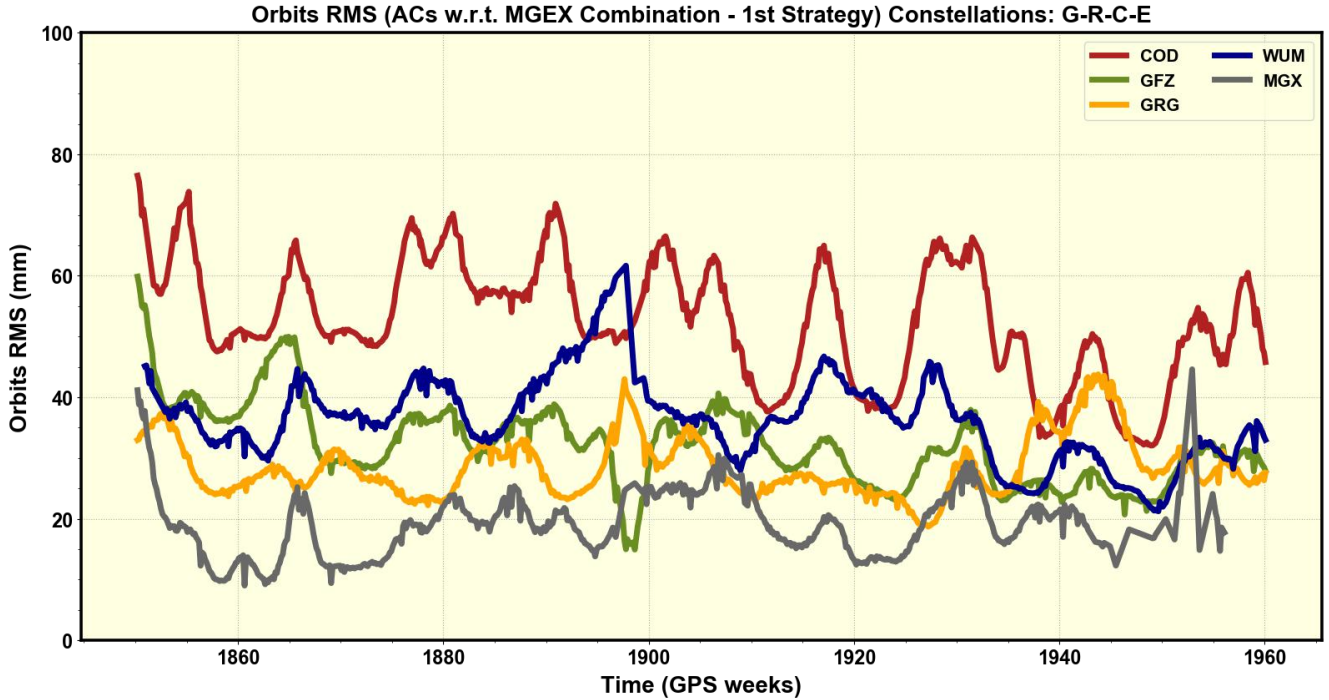




Prototype for a new combination strategy

- Developed in *Python 3*
- Based on the same theory so far
- Designed to add easily new functionalities

RMS for Orbit Combination



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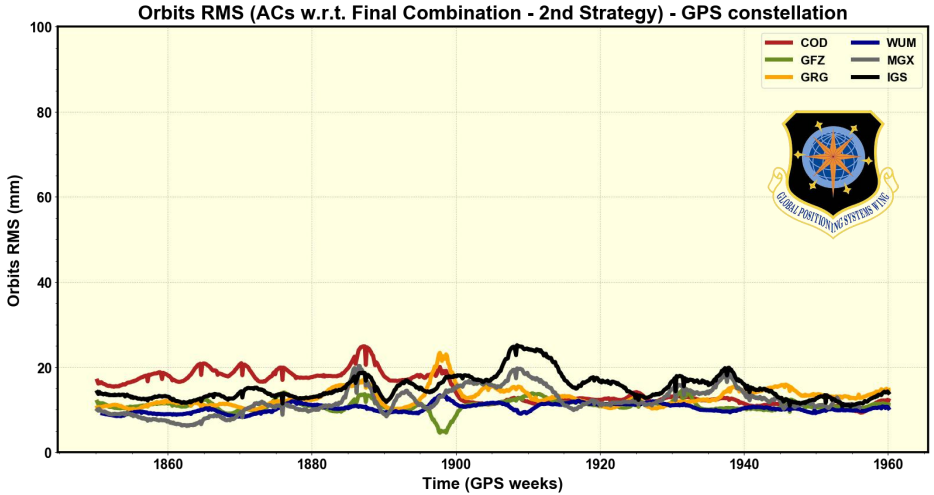
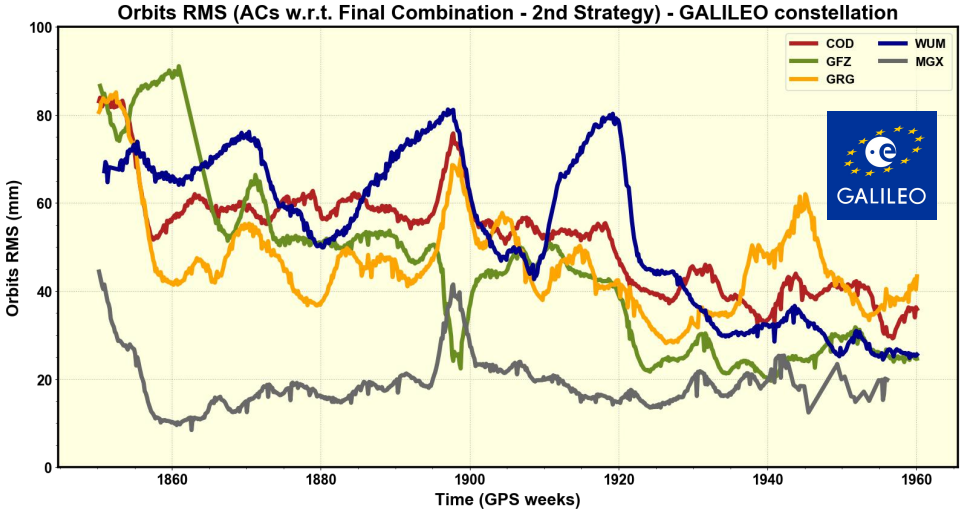


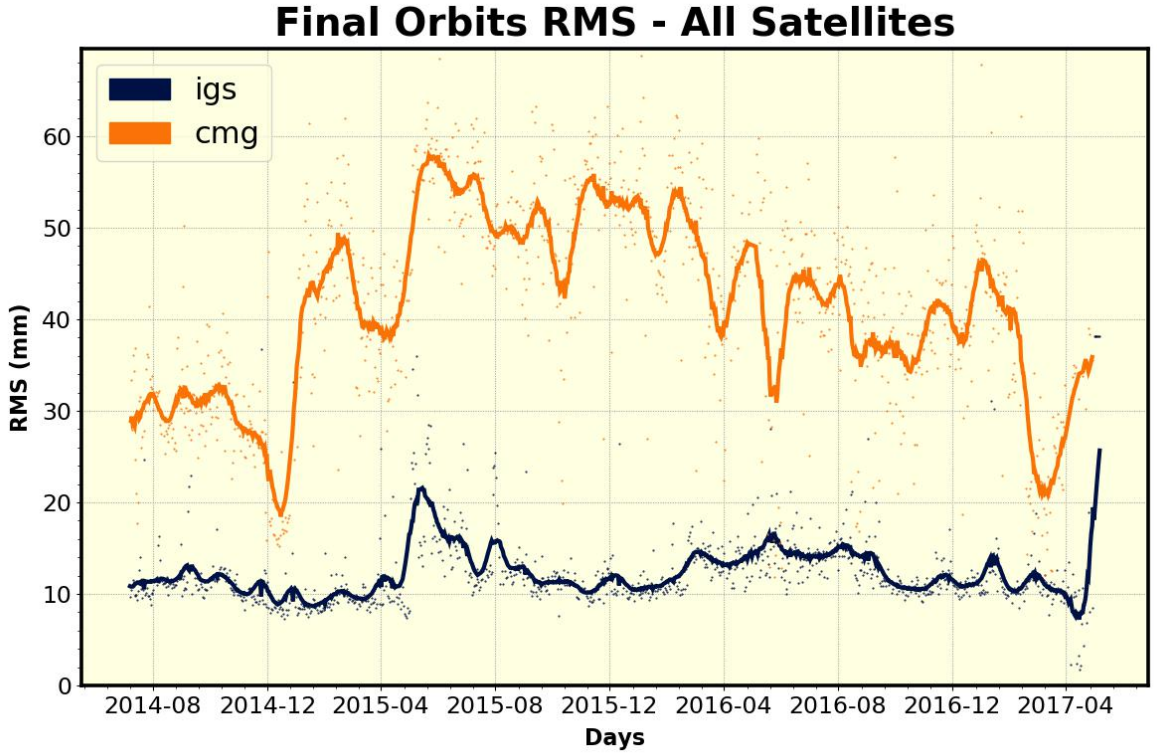


Further developments

- Weights according to the constellations
- Considering the different ACs' processing parameters (Orbit modeling ...) as annex weight information.
- Alignment to the ITRF based on ground station coordinates (Needs of SINEX)

- Combination of clocks

New combination software



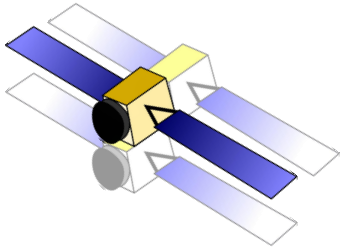
Preliminary results

cmg = Combination Multi-GNSS

reference :
Multi-GNSS Combination produced with the official software

Summary & Perspectives

- Orbit combination : ~30mm RMS w.r.t individual ACs
  ~10mm 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

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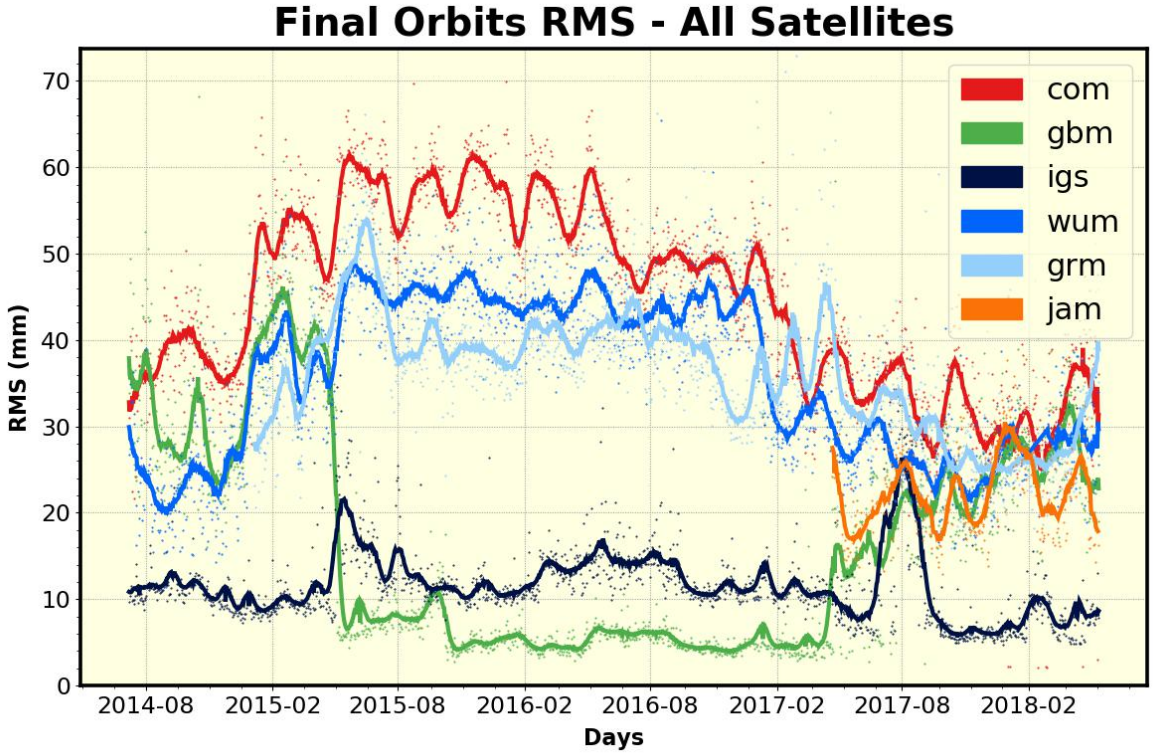
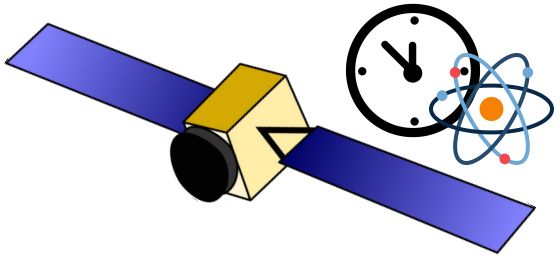
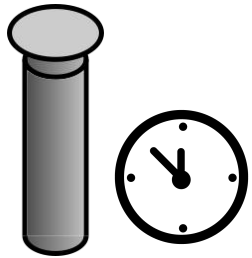


Clock offsets Combination Summary

- ***Step 1 :*** Radial correction (Ferland, 1999)
- ***Step 2 :*** Alignment to a reference AC clock
- ***Step 3 :*** Combination (weighted mean)
- ***Step 4 :*** Outlier detection & weight computation
  - Iterative process : back to Step 3 while there is still outliers





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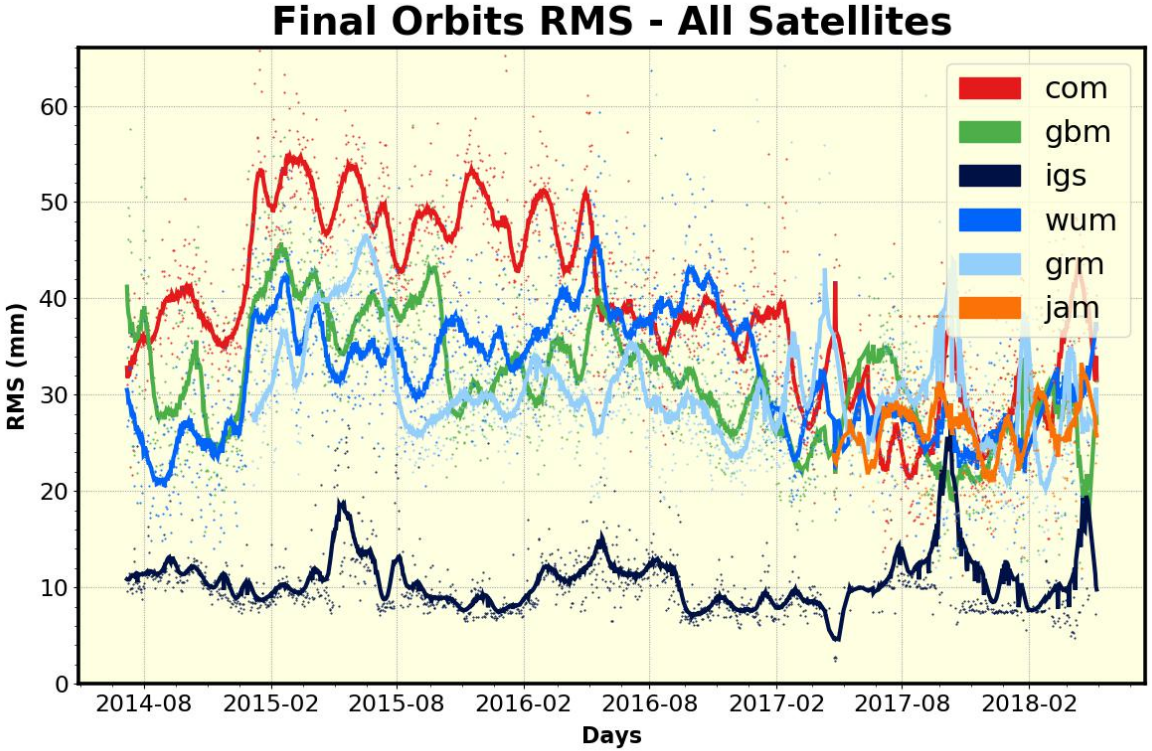

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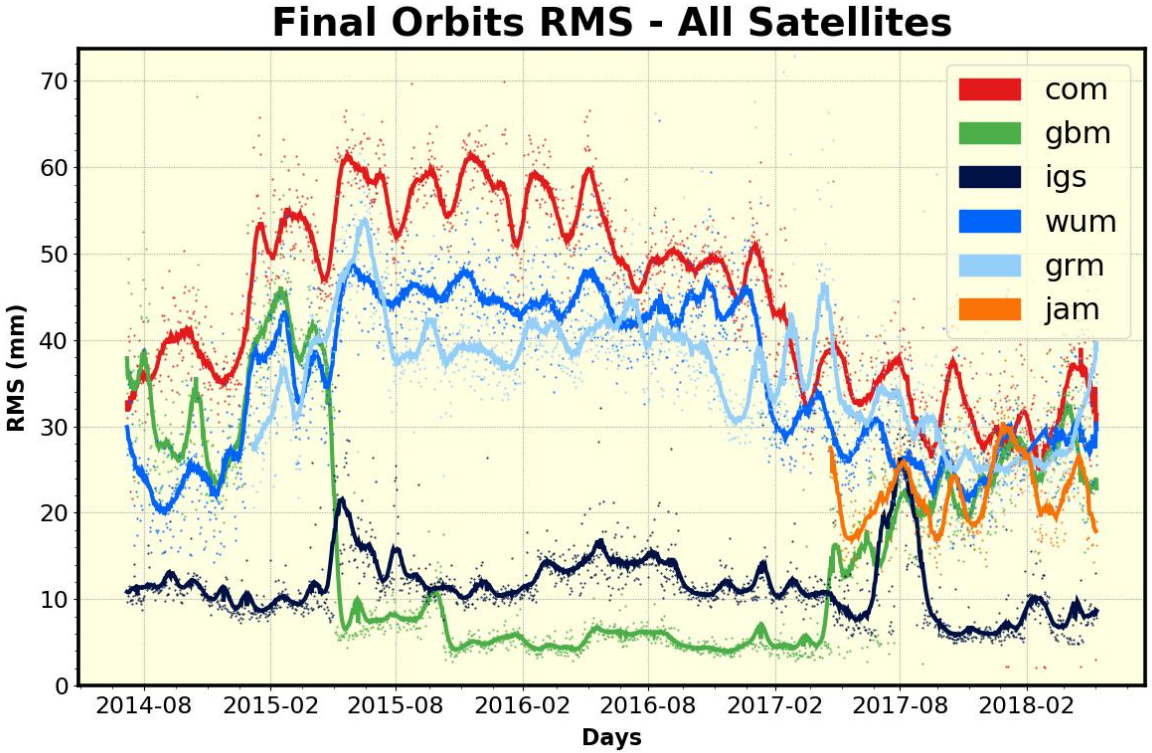

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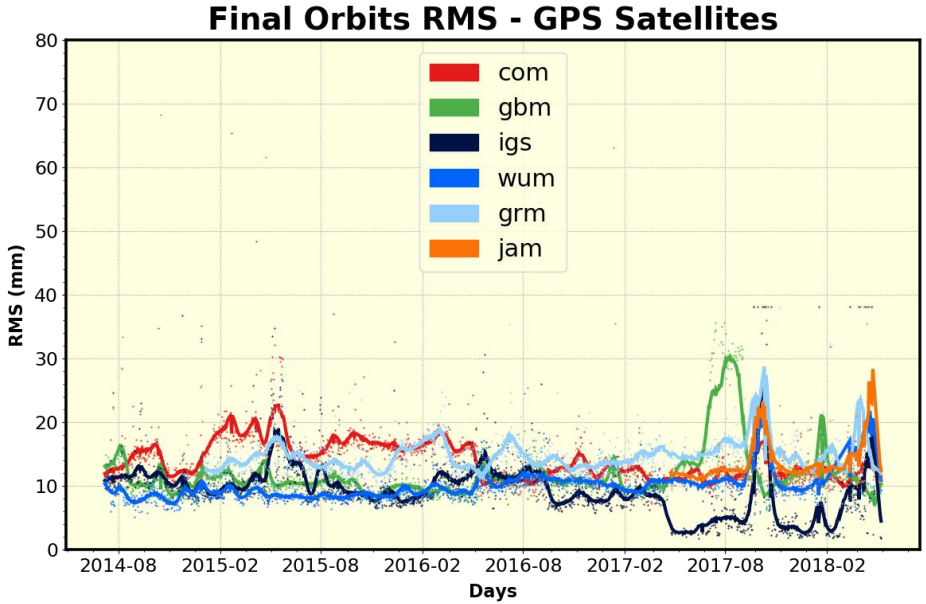

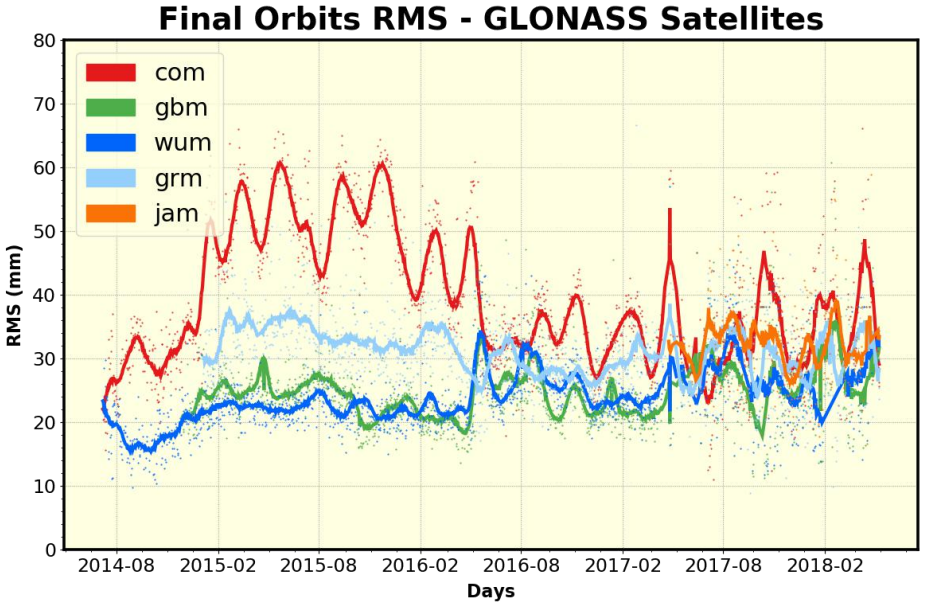

"historical" constellations

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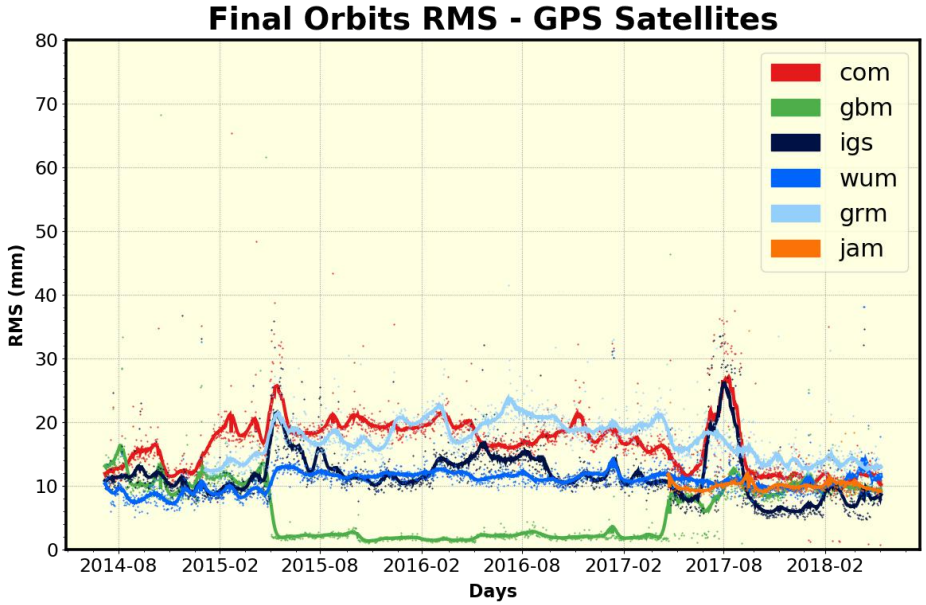
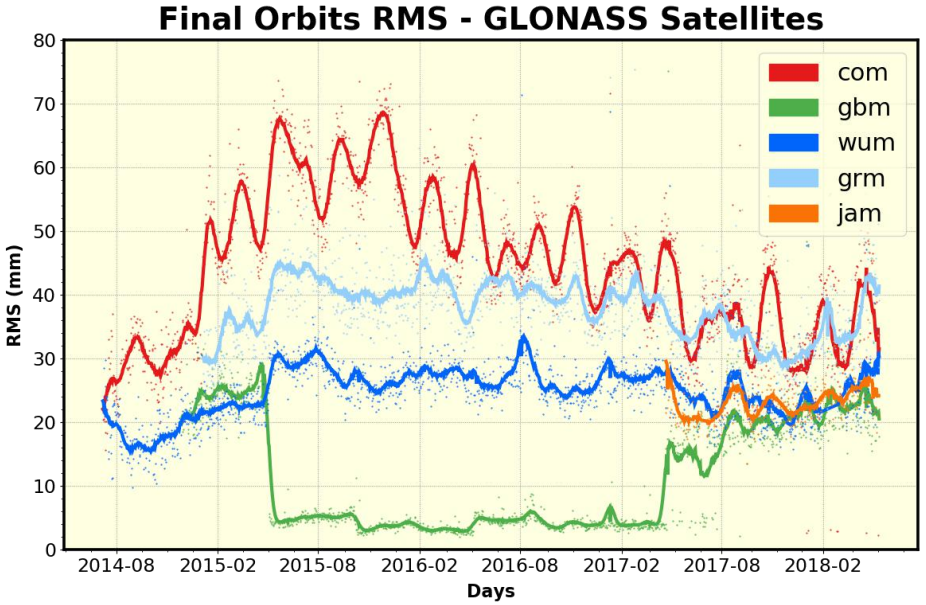
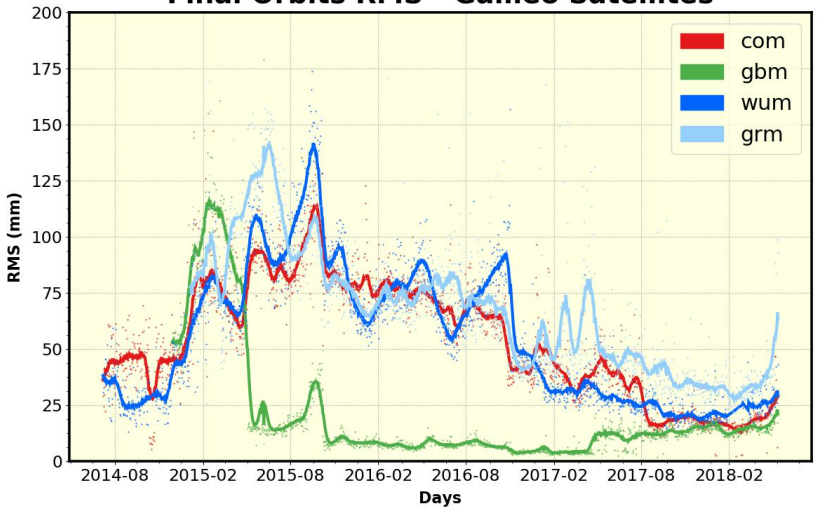


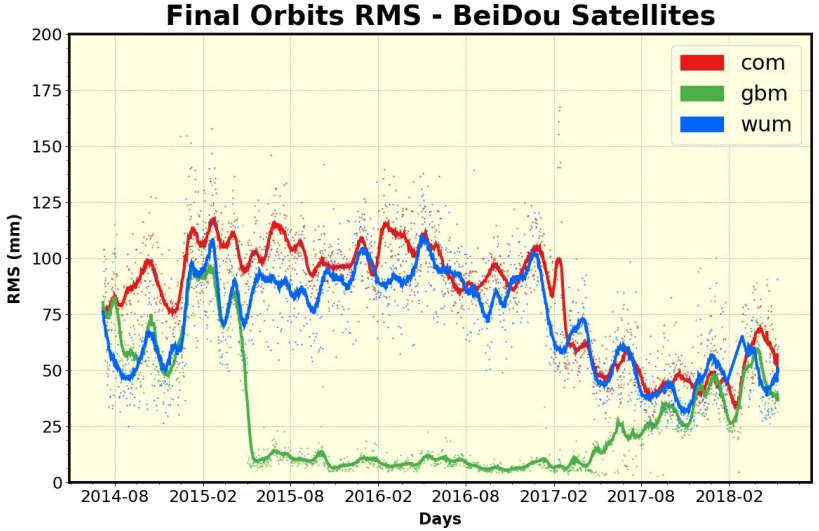


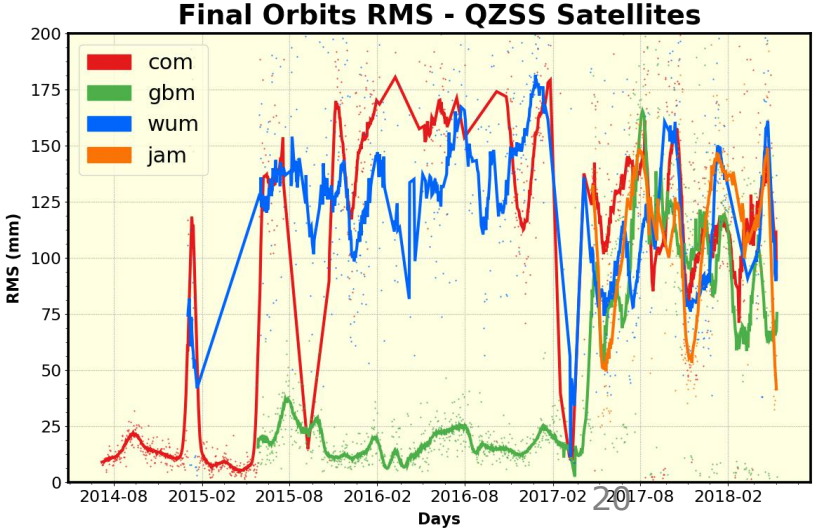
"historical" constellations

RMS for Orbit Combination

"New" constellations







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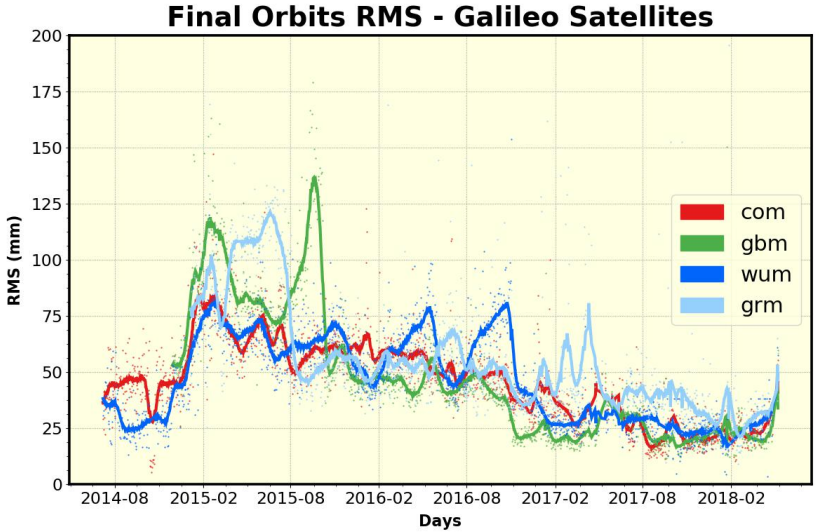
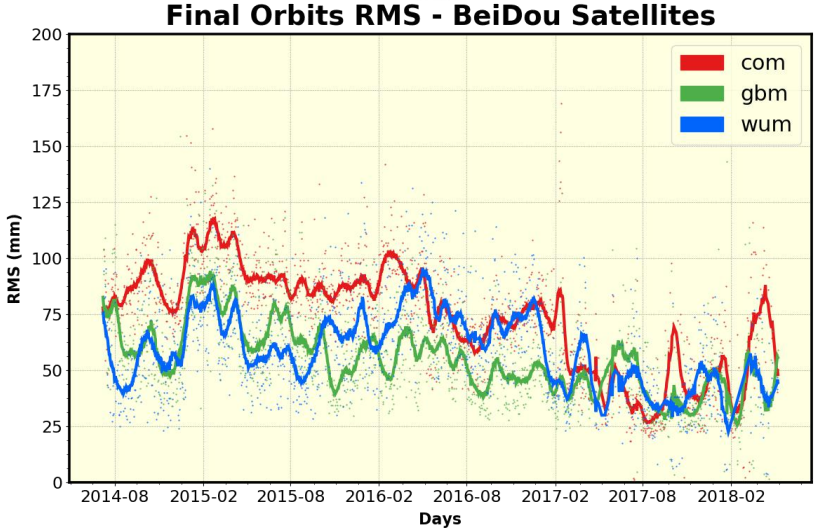
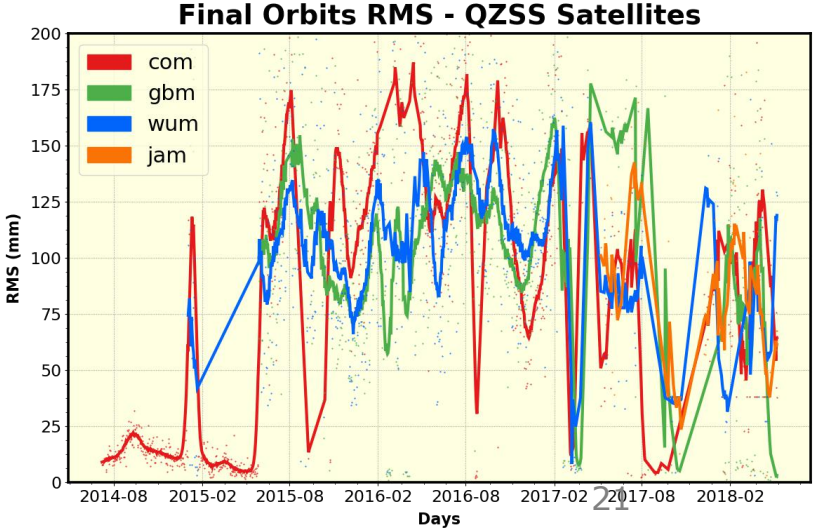




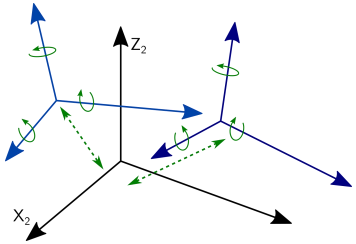


Orbit Combination Summary

- ***Step 1 :*** Alignment of each AC pole to the ITRF Combination Center one

- ***Step 2 :*** First unweighted combination
  - Get a mean position for each satellite & epoch
  - Perform an Helmert Transformation b/w the mean and each AC
  - Compute **weights for** each **AC & Satellite,** based on differences between mean and the Helmert-transformed AC

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



- ***Step 3 :*** weighted combination
  - Compute a new mean based on the weights
  - Perform an Helmert Transformation b/w the weighted mean and each AC, using the satellite weights
  - Compute a final mean based on the 2nd Helmert-transformed AC and AC weights

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