Evaluating Combined IGS Orbit Products

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Rolf Dach[1], Elmar Brockmann[1], Salim Masoumi[2], Gustavo Mansur[3], Stefan Schaer[4]

[1]Astronomical Institute, University of Bern, CH
[2]Geoscience Australia, AU
[3]GFZ German Research Centre for Geosciences, Potsdam, DE
[4]Federal Office of Topography swisstopo, Wabern, CH

Description of the problem

The analysis centers contributing to the IGS use different force models to compute their orbit products. For that reason the related parameters of their orbit model are not compatible and cannot be directly used on a rigorous combination as it is done for instance for station coordinates.

The satellite positions in the Earth fixed frame (preferable IGSxx) are extracted from these force model-based trajectories. So, the relation of these satellite positions represent the force model. As long as all these positions are handled fully consistent, the characteristics of the force model is kept in a combined IGS orbit product (Beutler et al., 1995).

This principle is of course essential looking at the sequence of positions from one particular satellite. We have also to recognise that any GNSS receiver connects all satellites in view – even across the different GNSS – which is an argument for a rigorous consistent handling of all satellites from one analysis center solution.

If the weighting of the solutions in the orbit combination procedure shall reflect the performance of the contributing analysis center one weighting factor per analysis center might be adequate what is still in agreement with the above mentioned condition. With the growing number of different satellite types and characteristics, it can be expected that the performance varies from system to system (e.g., GPS orbits are better determined as BDS, in particular if they are not on MEO orbits).

If starting to apply different weights for satellites from different constellations, the logical next step is to apply weights individually for each satellite (e.g., because the eclipse handling of one analysis center performs better than for another).

The further the individual weighting is applied the more is the principle of consistent treatment of all satellites violated. The question is what is the optimal compromise between both contradictory conditions.

The input data

The ultra-rapid solutions for GPS week 2299 (28. January to 03. February 2024) have been used for applying various orbit combinations by both groups developed new multi-GNSS orbit combination software, namely at Geoscience Australia (GA, Zajdel, Masoumi, et al., 2023) and at GeoForschungsZentrum Potsdam (GFZ, Mansur et al., 2022). First, an assessment of the input orbits by the analysis centers is done.

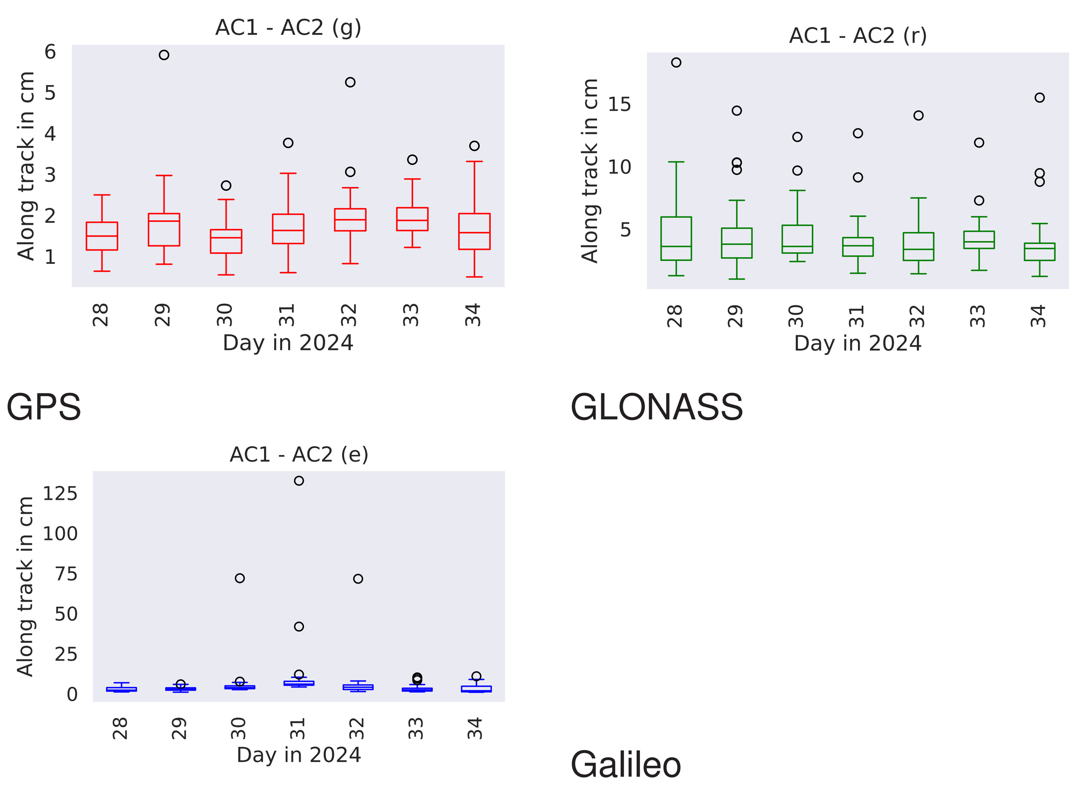

Figure 1: Boxplot from the RMS of the differences between AC orbits in along track direction.

The comparison between two analysis centers is shown in Figure 1 where the RMS per satellite is computed per component from the observed part. The along track component is shown as box-plot as the one with the biggest differences. For all three GNSS it is unfortunately not an extreme bad example: 2 to 2.5 cm for GPS; 4 to 5 cm for GLONASS; and for Galileo 5 to 10 cm (with some cases even up to 1 m for the satellites in the elliptic orbits E14 and E18). When GPS satellites perform repositioning events, we may also observe differences up on the meter level between the orbits from the analysis centers.

Comparing the weighting schemes

From the GA orbit combination, the three weighting schemes are available:

1. satellite-wise per analysis center
2. per constellation and analysis center
3. per analysis center

From the GFZ orbit combination, only to the following weighting schemes were provided:

1. satellite-wise per analysis center
2. per constellation and analysis center

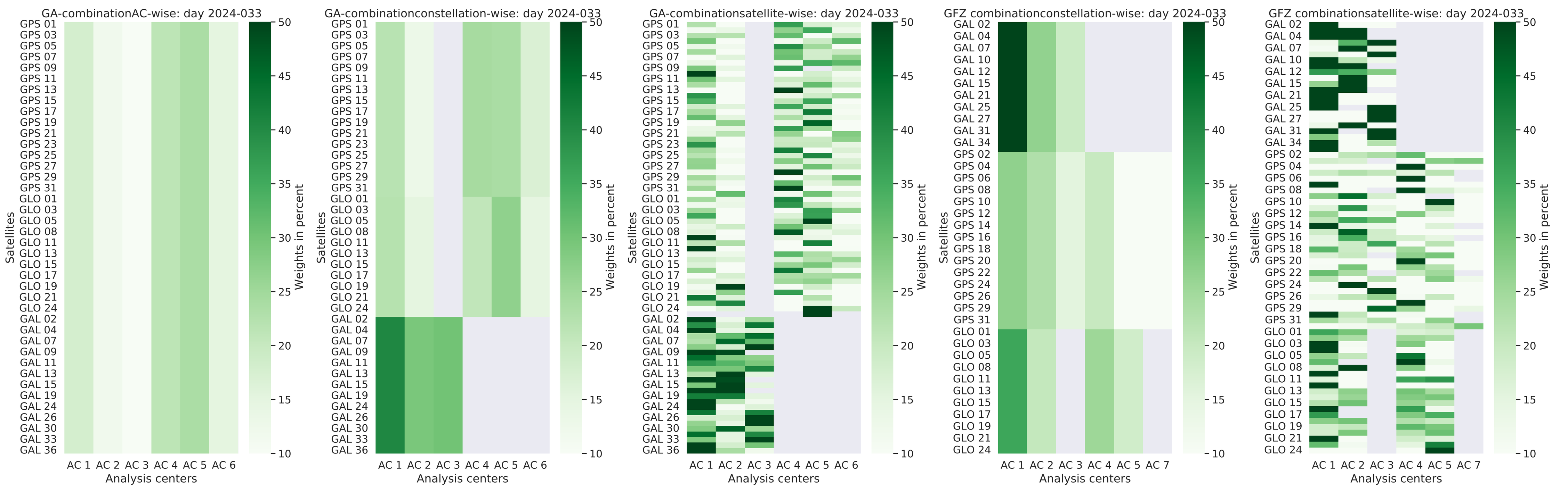

Figure 2: Different weighting applied in the different orbit combination setups for typical day February 2nd, 2024.

Conclusion for GA weighting:
The less ACs contribute to a satellite/constellation the less variations are found in the satellite-wise weighting scheme. In particular for GPS and GLONASS there is a high variablity from satellite to satellite.
Often one AC gets an extreme high weight of nearly 40 to 50% for a specific satellite whereas the other ACs get comparable low weights of only 10%. The "winning" AC is changing from satellite to satellite.

Conclusion for GFZ weighting:
The variations in the weights are dominated by the satellite exclusions that is extensively applied (about 10% of the satellites are excluded). There are also cases, where likely the exclusion algorithm did not identified a problematic satellite and the VCE procedure did set the weight to zero.
Whether all these exclusions are justified is not further investigated here.

Orbit comparison

Figure 3 shows the differences between the combined orbits applying the constellation- and satellite-wise weighting scheme (same procedure applied as for Figure 1).

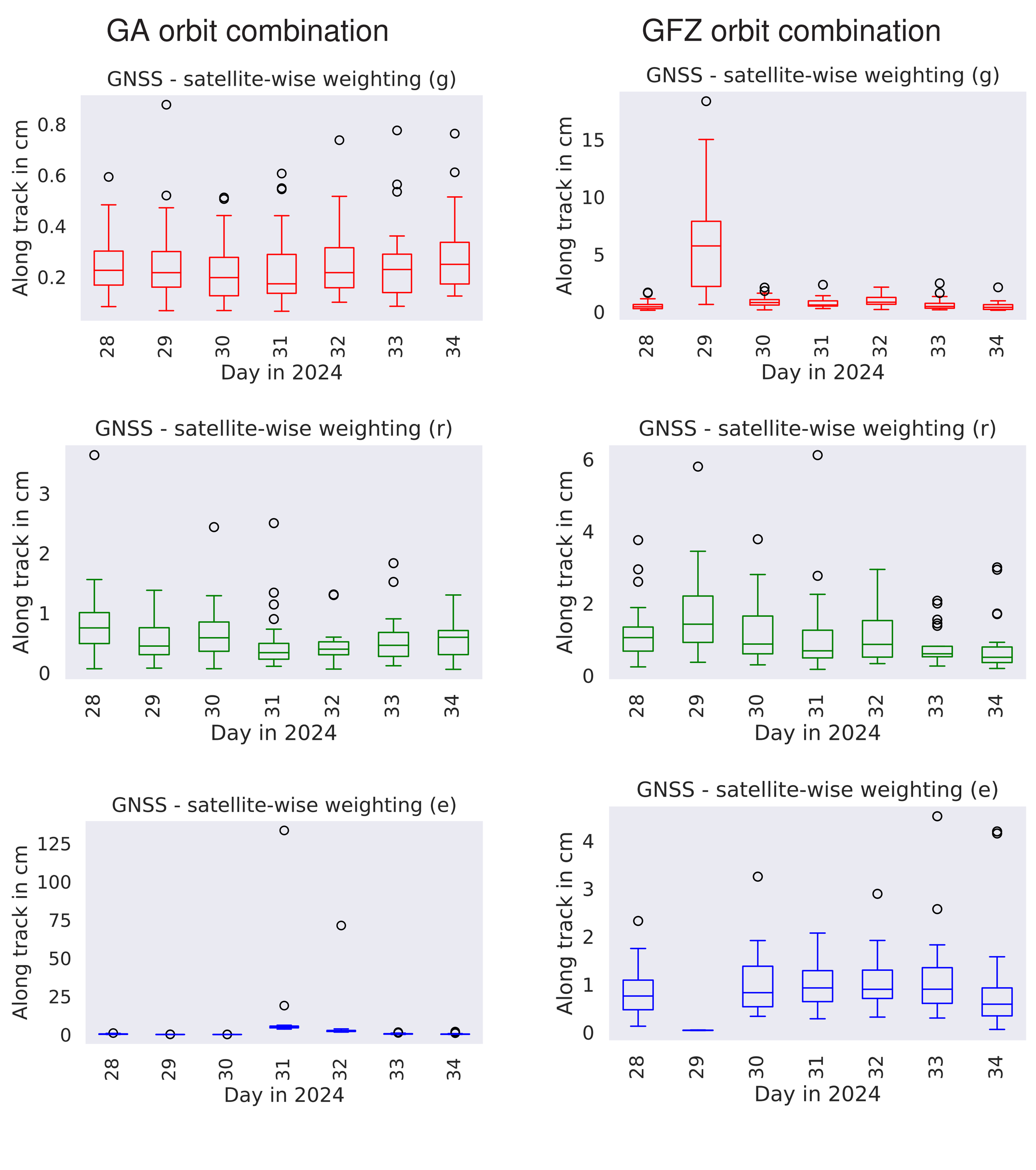

Figure 3: Boxplot from the RMS of the differences between the combined orbits in along track direction.

The comparison between the orbits from the analysis center versus constellation-wise weighting from the GA-combination is not shown because these orbits differ only on a few mm-level (below 0.5 cm).
The combined orbits resulting from the different weighting schemes do differ only on the 1 to 2 cm level for GLONASS and Galileo for GPS even below 1 cm (with the exception for day 029 in the GFZ combination).
The main difference between both combination solutions is that the GFZ-combination excludes a reasonable number of satellites from the combination. On one hand, one prefers products that are as complete as possible. On the other hand, with such a strategy the user gets only verified orbits in the combined products. It should anyhow a task of the ACs to ensure that it does not happen that orbits with such big differences go into the combination process.

Data processing

A more user-oriented evaluation of the combined orbits is to just generate a global solution with 140 stations from the IGS network. The orbits are just introduced without further corrections. Even if we have used the Bernese GNSS Software package for that purpose, the satellite positions in the precise orbit file is fitted with a big number of stochastic parameters allowing a representation of the inserted orbit of 2 to 3 mm.

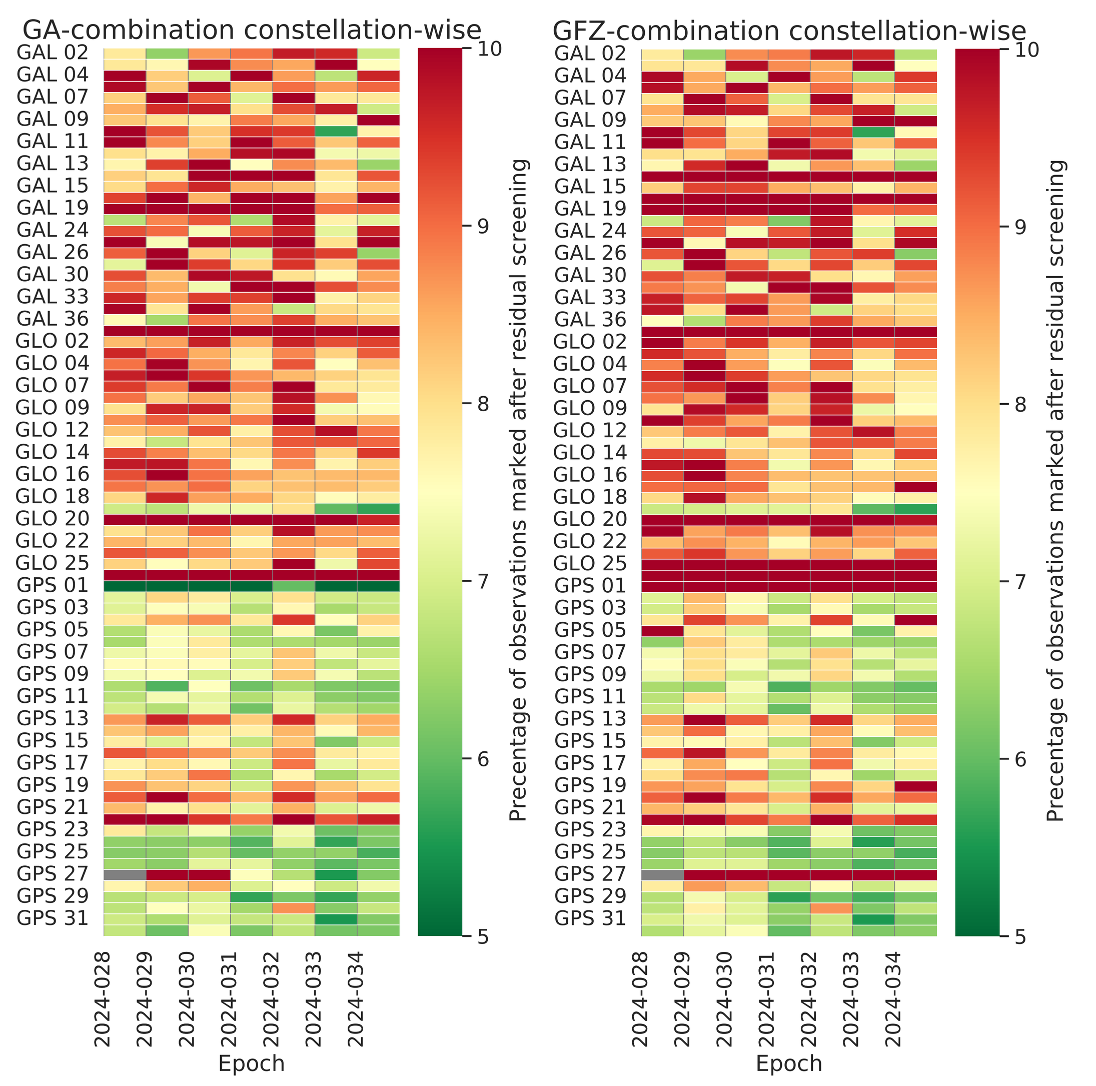

Figure 4: Percentage of observations exceeding a residual screening threshhold of 4 mm.

After the residual screening the constellation- and satellite-wise weighting schemes differ in both combination procedures by not more than 1000 observations (with a preference for the constellation-wise weighting). Regarding the total number of 8 000 000 processed observations this difference is marginal.
In the GFZ combination remain overall 3% less observations in the solution than in the GA combination due to the excluded satellites.
This result does not surprize regarding the consistency of the input orbits for most of the satellites. So the decision on the weighting scheme it primary a philosophic one.

Poster compiled by R. Dach, June 2024
Astronomical Institute, University of Bern
rolf.dach@unibe.ch

Contact address
Rolf Dach
Astronomical Institute, University of Bern
Sidlerstrasse 5
3012 Bern (Switzerland)
code@aiub.unibe.ch

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