Problem of Repro3 combined clock

We have analyzed the issues shown in your email last month about the IGS repro3 clock combinations. We reproduced the problem for day 199 of 2019 which are,

1. Satellite clocks have a huge jump at around mid-day in the repro3 solution;
2. There is higher epoch-to-epoch noise of the repro3 clock solution compared to the legacy solution.

Through a step-by-step analysis of the clock combinations software, we confirm that the reason for this phenomenon lies in the selection of reference clock solution. In the original combination algorithm, the most complete AC clock solution is selected as the reference, and the remaining AC clock solutions are aligned to it. Therefore, the temporal behavior of the reference clock solution will be translated into the combined clock consequently. For day 199 of 2019, the TUG clock is selected as the reference. But we recently have found that TUG satellite clock solutions have higher noise, and jumps sometimes, compared to other ACs' clock solutions.

We also counted how often this problem had happened for the whole repro3 period. The conclusion is that this problem happens for all days when the TUG clocks are selected as the reference. At the same time, this phenomenon does not only occur in GPS satellite clock, but also Galileo and GLONASS. Therefore, in the modified algorithm, we do not allow TUG to be selected as the clock reference to obtain a new combination product. Fig. 1 shows the situation of the previous combined clock solution and the modified results compared with legacy products after removing the linear trend.

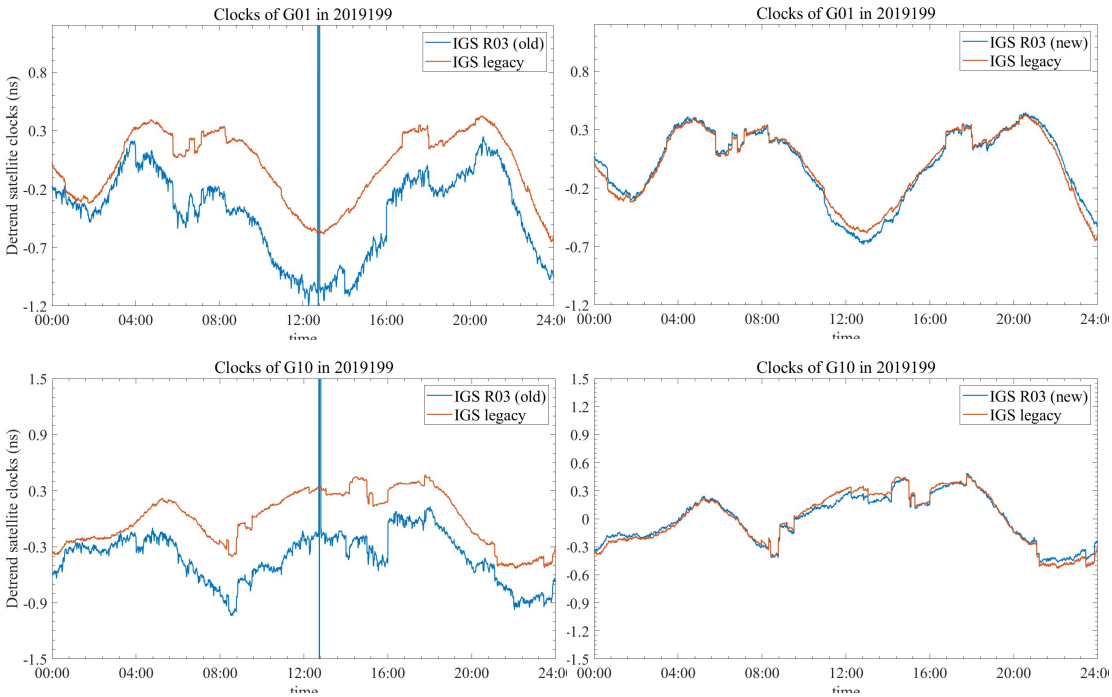

Fig. 1 Detrend clock image (Repro3 vs. legacy)
(The left side shows the previous combined clock solution, and the right side is the modified results)

We then combined IGS Repro3 clock/bias again for the period of 2000 to 2020 (NOTE: from 1995 to 1999, few ACs provided clock of *30s* sampling rate except TUG, so we don't recompute the combination for this period). Moreover, we calculated RMS (based on complete satellite clocks in common) of previous combined clocks and the recombined clocks relative to legacy clocks after removing the linear trend for each day, which are shown as Fig. 2. The relevant information about the products before and after is summarized as Tab. 1. It can be found that the recombined clock effectively solves the two problems existing in the previous combined product.

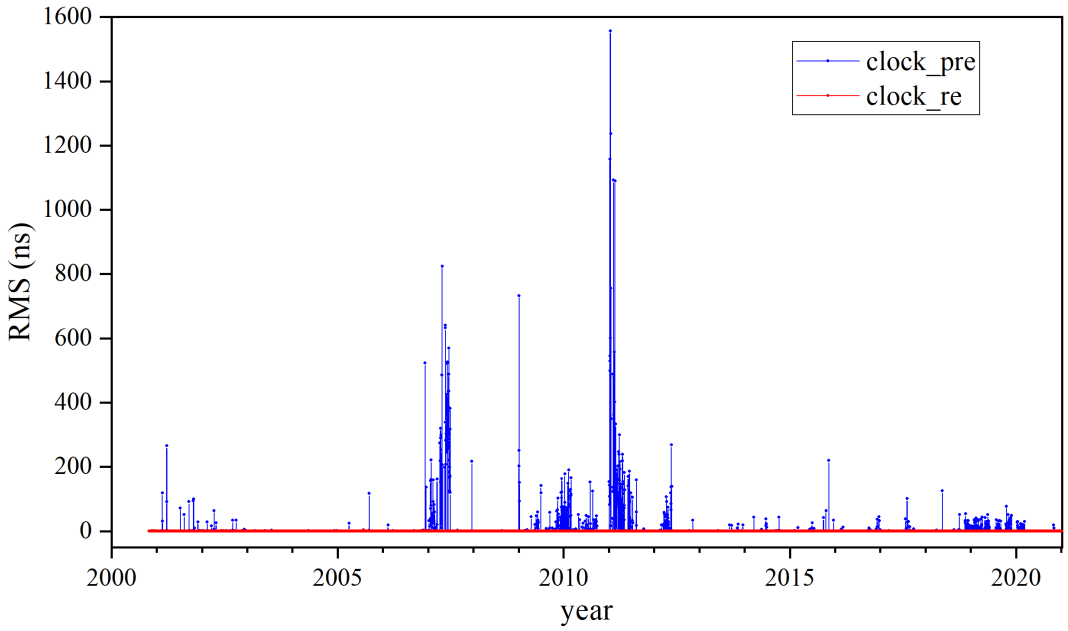

Fig. 2 daily RMS of combined clock compared to IGS legacy products after removing the linear trend (clock_pre: previous combined clocks; clock_re: recombined clocks)

Tab. 1 Statistical situation after the delinearization trend of clock

Item	Number of jumps	Overall RMS after removing jumps (ns)
clock_pre	711	0.0804
clock_re	15	0.0521

At the same time, PPP-AR tests were conducted on new combined products (once every ten days), and the statistical results of ambiguity fixing rate and positioning precision were shown in the Fig. 3 and Fig. 4. It can be found that the positioning results have even improved.

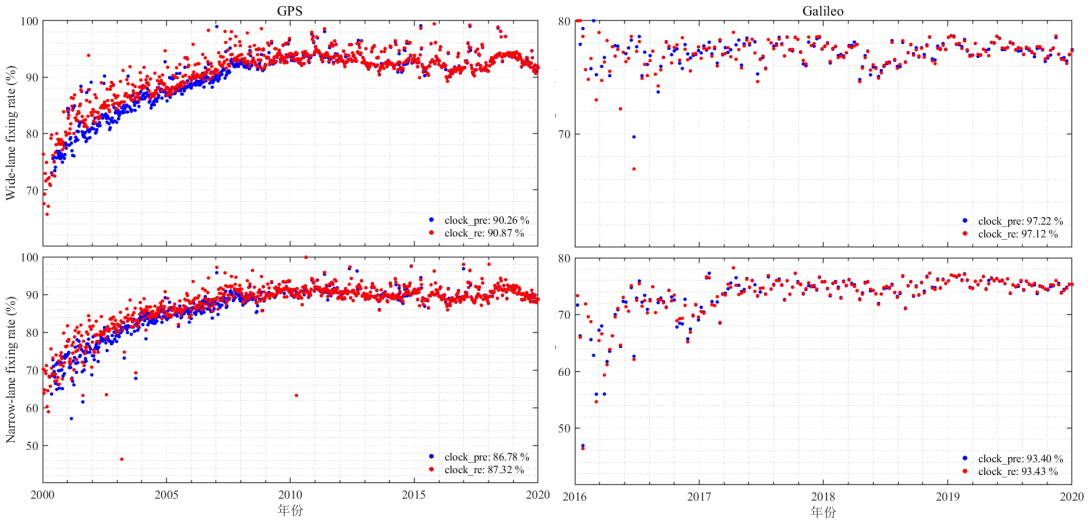

Fig. 3 Fixing rate of previous combined products and recombined products

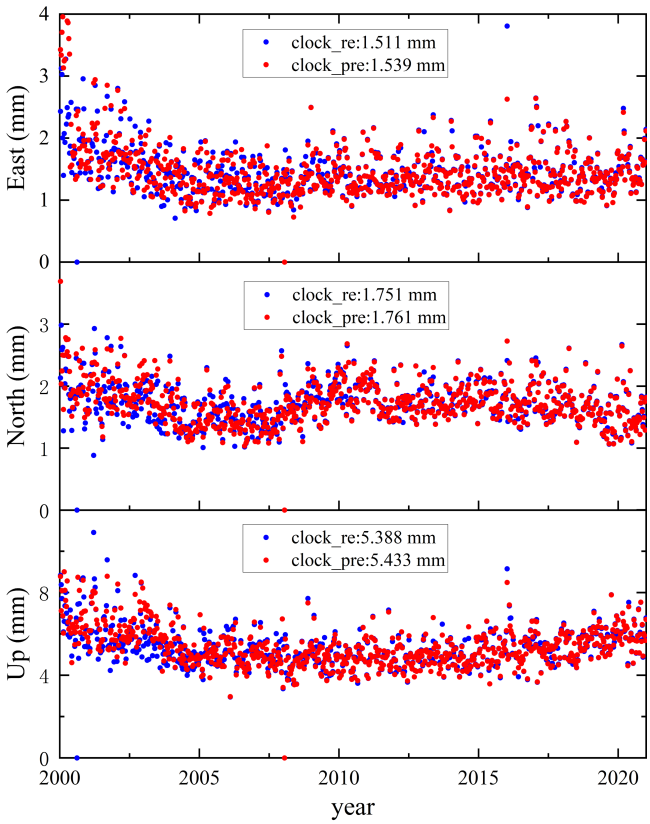

Fig. 4 PPP-AR precision of previous combined products and recombined products

The current solution to these problems is to prohibit the use of TUG clock as a reference datum, but this is not a long-term solution. In subsequent products combination testing, we will make more reasonable criterions on choosing the reference clock solution.