

Multi-GNSS Positioning with the New M-PAGES Software

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Q&A doc

Q: Why are QZSS and IRNSS considered Global when they only function regionally?

A: QZSS and IRNSS are considered regional GNSS. We use the term “GNSS” in this case as an umbrella term to include all navigation satellite systems (global and regional augmentation systems).

Q: Why the change in plot at 12h duration? Slide 24

A: This is likely just the result of some poor solutions that slightly skew the results at the 12h duration for that baseline.

Q: You use a multiple of rms as rejection criteria. Why not Chauvenet's criteria?

A: Based on some reading, we essentially used Chauvenet's criterion except for the fact that we used RMS as opposed to standard deviation as part of the equation. One issue here is that we are working with an asymmetric (skewed) distribution (i.e., not a normal distribution) which breaks the assumptions of Chauvenet's criterion. Regardless, this worked well enough for our purposes to flag the most egregious outliers.

Q: Is it worth using the BeiDou network in North America?

A: Yes, the MEO BeiDou satellites are visible in North America. If your receiver tracks BeiDou it will be advantageous to use this data for positioning.

Q: Can a user select the desired constellations to include? Can I select GPS only and stay with a double differenced solution?

A: OPUS will allow the user to specify which systems to process. And no, when M-PAGES is integrated it will be processing only in single-difference mode.

Q: Hi. Thanks for the Webinar. Which datums does M-PAGES use? Can other datum be added? What is the datum epoch in M-PAGES?

A: M-PAGES does the processing in ITRF coordinates (currently we are using IGB14 with reference epoch of 2010). When NGS transitions to ITRF20 we will change this accordingly. Transformations to NAD83 (or in the future NATREF/PATREF/CATREF/MATREF) are done in OPUS, which is distinct from M-PAGES. OPUS currently provides two sets of coordinates; one in the ITRF and the other NAD 83.

Q: Are you focused on the PAGES being more accurate and that M-PAGES is the one with the most error in your testing?

A: For the OPUS-style testing we did, we generally assumed that PAGES solutions were accurate and compared the M-PAGES solutions to PAGES. These cases are challenging because we do not know what the “true” coordinates are for these submissions. In the future, we could run CORS data through OPUS and assess the PAGES/M-PAGES results by comparing to the MYCS coordinates for those stations.

Q: Great info. Can you estimate any improvements we might see once we start seeing L-5 from the GPS III constellation?

A: At this point, we have not really experimented with GPS L1/L5 processing in M-PAGES but we will explore that in the future. My hunch is that the modern L5 signal may be more reliable, but I’m not sure I would expect drastic improvements. We may see more benefit in processing three frequencies (L1/L2/L5) which may help correct for ionospheric delays. This is an open question that our team will have to investigate.

Q: Will M-Pages use baseline info from Benchmark data? Will M-Pages deliver a similar style opus solution report? What software, if any, is being used to splice, decimate, and QC observation files?

A: ***Will M-Pages use baseline info from Benchmark data?***

M-PAGES is a software suite capable of processing data collected simultaneously at two or more GNSS antennae. "Baseline info" from "Benchmark data" is not something that M-PAGES can "use."

Will M-Pages deliver a similar style opus solution report?

The M-PAGES software is the future processing engine to be used within OPUS. OPUS will use M-PAGES to produce the solutions. OPUS will construct an OPUS solution report from the M-PAGES outputs. More details about this will be provided in an upcoming OPUS User Forum.

What software, if any, is being used to splice, decimate, and QC observation files?

We use gfzrxn (<https://gnss.gfz-potsdam.de/services/gfzrxn>) for file splicing and editing operations and some QC. For more detailed QC, the ANUBIS software package (<https://gnutsoftware.com/software/anubis/>) can be used to handle RINEX 3/multi-GNSS data.

Q: Again about the time offset... Russia does not use UTC so there is a time offset there. I expect Galileo also uses UTC so no time offset. Comments

A: Luckily, RINEX obs files provide observations using a consistent time system (almost always GPS time) so this time system offsets do not have to be explicitly dealt with in obs files. The RINEX navigation files, however, require time system conversions. Beyond this, one thing M-PAGES must deal with are inter-system biases. These are timing biases between systems that we estimate. Generally, these are small ($\ll 1$ second) effects but they must be accounted for to obtain the best possible solutions.

Q: Slide 26.. the legend shows one line as FREO00USA NRC 100CAN... what does that refer to?

A: FREO00USA-NRC100CAN is the label for one of the baselines that was processed. In this case, FREO00USA was the station whose coordinates were held fixed and the coordinates for NRC100CAN were estimated.

Q: will it use ITRF2020?

A: Yes, we will adopt ITRF2020 coordinates for the NOAA CORS Network after Multi-Year CORS Solutions 3 (MYCS3) is complete.

Q: will it use 14 parameter Helmet time positioning?

A: M-PAGES does everything using ITRF coordinates at the epoch of the data. Transformations to different reference frames or epochs are done outside of M-PAGES using software tools like HTDP.

Q: support for Beidou-3 constellation signals?

A: Yes. The software is capable of distinguishing between BDS-II and BDS-III satellites and can process data from either (or both) generation.

Q: will it support RINEX 4.0 FILE import?

A: Yes. We currently support up to RINEX 3.05 but will soon update our libraries for RINEX 4.0. Note that the changes in RINEX 4 predominantly affect the RINEX navigation file format rather than the obs file format.

Q: triple and fourth frequencies supported?

A: We currently process dual frequency solutions as we rely on the ionosphere-free linear combination. Future research will be done to explore the usage of > 2 frequencies.

Q: Are you tracking efforts for Hybrid Satellite Networks (HSN) and the impacts their solutions (from NIST/DOD/others) for resilient use of Position Navigation and Timing (PNT) signals into the future? How may changes to leveraging technology impact the efforts into NCN?

A: Yes, DOC/NOAA is very engaged in this area as the leader for US Space Commerce. NOAA/NGS personnel have been directly involved in the evaluation of HSN operations on positioning tools. Impacts to the NOAA CORS Network, OPUS Solutions, and even RTN operations are all being evaluated with an eye to attribution and magnitude of this potential interference in transmission bands adjacent to GNSS broadcast frequencies.

Q: Do multi-satellite solutions have any implications/relevance for OPUS-RS?

A: Currently OPUS-RS is capable of GPS only and requires a more complicated processing strategy to enable such short occupations. It also uses a different baseline processing engine than OPUS-S named RSGPS. At this time, we do not have a plan to update OPUS-RS (RSGPS); instead, our future goal is to make M-PAGES capable of handling shorter occupations (perhaps using a similar baseline processing strategy as RSGPS for the short occupations). This is future work and it will be a while before it is ready.

Q: Could your test results reveal an optimum combination of constellations based on a certain longitude/latitude?

A: In general, I would expect that the inclusion of all available constellations would provide the optimal solution. As the tests showed, this is most noticeable when processing data for shorter durations.

Q: What are the sources for orbits for short term and processing after 14 days?

A: We either use the IGS rapid/final orbits or the MGEX orbits from a particular analysis center (e.g., GFZ, CODE) for multi-GNSS processing.

Q: I am interested in the 24 hr observations. The first dataset you showed had RMS of 4-8 mm and last set had RMS of 1cm? Is the difference only the dataset or processing

A: I am not sure which results are being referred to here. This could just be differences between different baselines that we processed.

Q: Brian, can you please repeat why you chose to only go with single difference solutions and not double difference solutions.

A: We chose a single difference strategy because we found it to be a bit more flexible for processing observations from multiple systems. Forming double differences with satellites that operate on different frequencies makes ambiguity resolution very challenging.

Q: what is the approximate timeline for m-pages to be live

A: M-PAGES development is ongoing as there is work to be done to improve performance and added functionality needed for applications like OPUS-Projects and orbit processing. Currently, the goal is to release a beta version of OPUS-S with M-PAGES integrated by the end of the calendar year.

Q: What is the delivery time frame for the final version?

A: See previous answer.

Q: Do we have rapid orbits available for other constellations too

A: At this time, there are multi-GNSS rapid orbits produced by several IGS analysis centers (ACs) that contribute to the MGEX working group. The following link shows which the range of MGEX orbit products (including the constellations/latency; https://igs.org/mgex/data-products/#orbit_clock).

Q: besides comparing PAGES to M-PAGES, have you compared solutions using PPP or Gypsy or other code?

A: We have occasionally spot checked results with PPP solutions but have not yet done any thorough comparisons to date. One alternative we have done with IGS data is a comparison to the weekly SINEX solutions.