Authors' Response to Reviews of

AFPD-DTW: An Adaptive Flex Power Detection Method for in Post-processing and Real-time Applications

GPS Solutions, `Submission ID d30c8c20-9d96-4903-b3d3-046b5bf9a9be`

RC: ***Reviewers' Comment***, AR: Authors' Response, ☐ Manuscript Text

Dear Editor-in-Chief and Reviewers,

We would like to sincerely thank the Editor-in-Chief and the anonymous reviewers for their thorough and constructive evaluation of our manuscript. Their insightful comments and detailed suggestions have greatly helped us to identify weaknesses in the presentation, clarify the description of our method, and further highlight the contributions of this study.

We have carefully considered each of the raised concerns and revised the manuscript accordingly. In particular, we polished the language throughout the manuscript, clarified methodological details, reorganized certain sections for improved readability, and incorporated new analyses where necessary. For clarity, we reproduce each reviewer's comment below (marked as **RC**) followed by our detailed author's response (marked as **AR**). We believe these revisions have substantially improved the quality of our work.

The satellite flex power detection has drawn attention in recent years for its importance in bias estimation, positioning convergence, and even military operations. Since confirming the research direction, our team has conducted systematic research on the mechanism of cn0 variations as well as the previous detection methods.

Overall, we contribute in the following three aspects. First, we propose a new detection method, AFPD-DTW, which combines inter-day difference with DTW for flex power detection. Second, we provide a five-year comprehensive demonstration of multi-constellation and multi-frequency detection results from 2020 to 2025. Third, we deliver a detailed examination of flex power mechanisms through visual analyses of C/N0 time series and satellite trajectories. In addition, we decided to open the source code on GitHub (https://github.com/BlackiePiggy/AFPD.git).

We hope you understand the importance we attach to this manuscript and our responsible attitude, as well as to express our sincerity in actively cooperating with the revision work.

0.1. Line 219

RC: ***Why did you select these stations? Is this a random selection? Are you sure that the detection of Flex Power depends on the antenna and receiver type? Include references to support your argument, or remove this from the revised manuscript.***

AR: We appreciate this important comment raised by the Editor-in-Chief.

Regarding the first question, the selection of stations was not random but followed a systematic strategy to ensure both the reliability of C/N0 observations and the robustness of flex power detection. The essential requirement for detecting flex power is continuous C/N0 time-series tracking. Since most satellites operate in Medium Earth Orbit (MEO), in theory only three well-distributed stations could provide global coverage (cf. Monaghan (2025)). However, in practice, relying on only a few stations may lead to missed events due to radio-frequency interference, hardware malfunctions, or temporary data outages. Therefore, our station selection followed two guiding principles.

(1) Geographical distribution and redundancy. Station distribution was carefully considered for both post-processing and real-time experiments. For real-time detection in particular, the analysis is performed at a much higher-resolution temporal scale, which makes the method more vulnerable to short-term data interruptions. To mitigate this risk, we intentionally selected a larger number(ten) of well-distributed stations to provide redundancy. In this way, even if one station experiences a temporary outage, other stations can still supply valid observations, ensuring continuity in C/N0 monitoring and robustness in flex power event detection.

(2) Data integrity and hardware reliability. Not all IGS stations provide stable C/N0 data, as some record only pseudorange and carrier phase data. We first evaluated the data completeness from CDDIS products and retained only those stations with long-term stable C/N0 availability. In addition, receiver and antenna types were cross-verified using IGS metadata (RINEX headers and SINEX files) to ensure that no known hardware anomalies were present. This step is important because the absolute level and stability of C/N0 data can indeed be influenced by receiver model and antenna characteristics.

Through this strategy, the selected stations provide both full coverage of GPS satellite visibility arcs and sufficient redundancy to avoid missed detections. Furthermore, in the **Method of AFPD-DTW** section of revised manuscript, we now include a detailed list of the receiver and antenna types for each station. In the revised **Datasets** section, we have added the following clarification to briefly illustrate our station selection strategy :

> The stations were selected based on two main criteria. The first is the continuous availability of reliable C/N observations. The second is a broad geographical distribution to ensure adequate spatial coverage and redundancy. Hardware consistency was additionally verified using IGS metadata.

Regarding the second question, we confirm that different receiver–antenna combinations do have a important impact on the detection results. This issue is discussed in detail in the section **Different Lift Patterns of Different Receivers and Antennas**. By comparing C/N0 data from different receiver–antenna combinations during the same flex power event, we observed significant differences in mean lift values: an average difference of 1.53 dB-Hz, with a maximum of 2.56 dB-Hz. Similar conclusions were also reported by Wu et al. (2025), which further supports our findings. Therefore, we decided to retain this perspective in the manuscript. To ensure clarity, we have additionally included the receiver and antenna types of the selected stations in Table 1 of the revised **Datasets** section.

0.2. Line 245

RC: ***How did you determine the number 8? How about 7, or 10? The abstract says: "The method requires data from as few as 8 stations for reliable detection" . Therefore, number 8 is the minimum limit, and is inconsistent with your text below. Discuss in detail how many stations are needed.***

AR: We appreciate the Editor-in-Chief' s careful observation. This issue is indeed related to Comment 0.1 concerning our station selection strategy. The number of stations (eight) was not arbitrarily chosen, but determined empirically through comprehensive experimental testing. Specifically, we evaluated different subsets of IGS stations to identify the minimum configuration that could ensure continuous and uninterrupted tracking of GPS Block IIR-M and IIF satellites for flex power detection.

Our experiments demonstrated that, with fewer than eight stations, gaps in satellite visibility or data interruptions could lead to missed flex power events. By contrast, using at least eight well-distributed and reliable stations provided sufficient redundancy to guarantee uninterrupted coverage and robust detection. Therefore, in the abstract we state that "as few as 8 stations" are required for reliable detection, which is consistent with our experimental findings.

We acknowledge that our original wording regarding the number of stations (e.g., "less than 8") was inaccurate and may cause confusion. To avoid ambiguity, we have revised the text to consistently use the phrasing "as few as 8 stations" throughout the manuscript. Additionally, we provide a detailed list of the selected stations, together with their geographical distribution and hardware information, to clarify how this number was determined in Table 1 in the manuscript.

0.3. Line 266 and figure 9

RC: ***How do you verify the flex power events? Show evidence of the flex power events other than the detection result. Is it publicly available from the authority office?***

AR: We thank the Editor-in-Chief for raising this critical question. The verification of detected flex power events is indeed a key issue, as GPS operates with limited transparency and authoritative event reports are not publicly accessible. The only official documentation we are aware of is the GPS Interface Specification Anthony Flores (2021), which describes flex power as follows:

> "In addition, due to programmable power output capabilities of Block IIR-M and IIF SVs, under certain operational scenarios, individual signal components of Block IIR-M/IIF SVs may exceed the previously stated maximum but are not expected to exceed −150 dBW."

Since the exact activation times of flex power are not disclosed in official sources, we adopt two complementary strategies to validate our detection results and ensure that the identified events are genuine flex power activations rather than noise-induced artifacts:

(1) Cross-validation with related works. We compare our detected events with results reported in prior researches. For instance, Esenbuğa, Hauschild, and Steigenberger (2023) summarized GPS flex power activities between 2017 and 2021, while Liu et al. (2024) investigated Beidou flex power events from 2021 to 2024. Agreement with these independently reported events provides additional confidence in the validity of our detections. Nevertheless, we acknowledge that relying solely on prior works is insufficient, since those studies themselves are not based on official disclosures.

(2) Geometrical validation using satellite ground tracks. We developed a visualization tool to plot satellite trajectories during detected flex power intervals. Examples are shown in Figs. 12 and 13 of the revised manuscript. When a detected event corresponds to a well-structured activation region—such as a single-center, dual-center, or longitude-bounded pattern—this provides strong evidence that the event is indeed caused by flex power. By contrast, spurious C/N0 fluctuations induced by noise or other effects do not exhibit such clear geometrical patterns.

In the revised manuscript , we have added the following clarification:

> Line 136：
>
> To validate the spatial consistency of detected events, satellite ground tracks are also examined to identify distinct activation regions and centers.

1. Response to reviewer #1's comments

1.1. Whole manuscript

RC: ***The language needs significantly polishing, as well as the format. A lot of space is not necessary. Please follow the guideline of GPSS. In addition, a lot of inappropriate expressions should be avoided.***

AR: We sincerely thank the reviewer for this valuable comment related to language and formatting. In response, we have carried out a thorough polishing of the manuscript to remove inappropriate expressions and to improve the overall clarity.

Regarding the formatting issue, we would like to clarify that the manuscript was originally prepared with double line spacing, as required by the *Submission guidelines | GPS Solutions* 2025. Nevertheless, to accommodate the reviewer' s concern about spacing compactness, we have additionally prepared a version with 1.5 line spacing and attached it as supplementary material for your reference. We believe that the revised manuscript now better conforms to the style and expectations of the journal. Should the reviewer identify further instances that require refinement, we will be glad to make additional revisions.

1.2. Line 20

RC: **"*achieving 0.9983 and 0.9988 accuracy, respectively*" *, would be better to use percentage.***

AR: We appreciate the reviewer' s helpful suggestion. Following this advice, we have revised the manuscript to express accuracy values in percentage form at this location and throughout the entire text for consistency (e.g., 99.83% and 99.88%).

1.3. Line 33

RC: "*EIRP (Effective Isotropic Radiated Power)*" *, only used once. The abbreviation is not necessary.*

AR: We thank the reviewer for pointing this out. Since the term is mentioned only once, we have removed the abbreviation "EIRP" and now use the full expression "Effective Isotropic Radiated Power" directly in the revised manuscript.

> Line 35:
>
> Furthermore, flex power affects the measurement and estimation of GPS transmitter ~~(EIRP)~~ effective isotropic radiated power, which impacts the accuracy of satellite-based wind speed retrieval.

1.4. Line 33

RC: "*use more than 200 stations' data for accurate judgment*" *, what is* "*accurate judgment*" *?*

AR: In the **Introduction** section, "accurate judgment" refers specifically to the ability to correctly identify all true flex power events, i.e., the event-level recall (true positive rate). It should be noted that Esenbuğa, Hauschild, and Steigenberger (2023) did not directly provide explicit performance metrics. To clarify, we re-examined their reported events (Tables 1–2) and compared them with the full set of flex power events during 2020–2021. Out of 144 known events, 140 were detected by Flex Power Detector(FPD), corresponding to an event-level recall of 97.2%. This demonstrates that FPD is indeed reliable and can reasonably be described as "accurate" at the event-detection level. However, compared to our AFPD-DTW method and also the results of Yang et al. (2022) and Meng, Ge, and Li (2024), the recall performance is still lower.

1.5. Line 100

RC: "*sustained C/N0 enhancement until the Rx endpoint*" *, what is Rx endpoint? I cannot find the definition.*

AR: We apologize for the lack of clarity in our original wording. Here, "Rx endpoint" was intended to denote the endpoint of the satellite's visibility arc as observed from a station, i.e., the receiving endpoint. To avoid ambiguity, we have replaced "Rx endpoint" with "FoV endpoint," referring to the station's Field of View endpoint. We believe this revised terminology is clearer and more intuitive for readers, as shown in Fig. 1.

1.6. Figure 2

RC: ***What is "FP ON area" ? what is "RX area" ?***

AR: We thank the reviewer for pointing out this ambiguity. In the original manuscript, "FP ON area" referred to the *flex power activation area*, and "RX area" denoted the *area where a station can receive signals from satellites*. Although the term "Rx" had been defined earlier (Line 93), we agree that its usage here was not sufficiently clear. To improve clarity and consistency, we have revised both the text and the figure captions:

- "FP ON area" has been replaced with **Flex power activation area**.
- "Signal RX area" has been replaced with **Station field of view**.

We believe these changes make the terminology more transparent to readers. The updated figure with the revised annotations is included in the revised manuscript, as shown in Fig. 1.

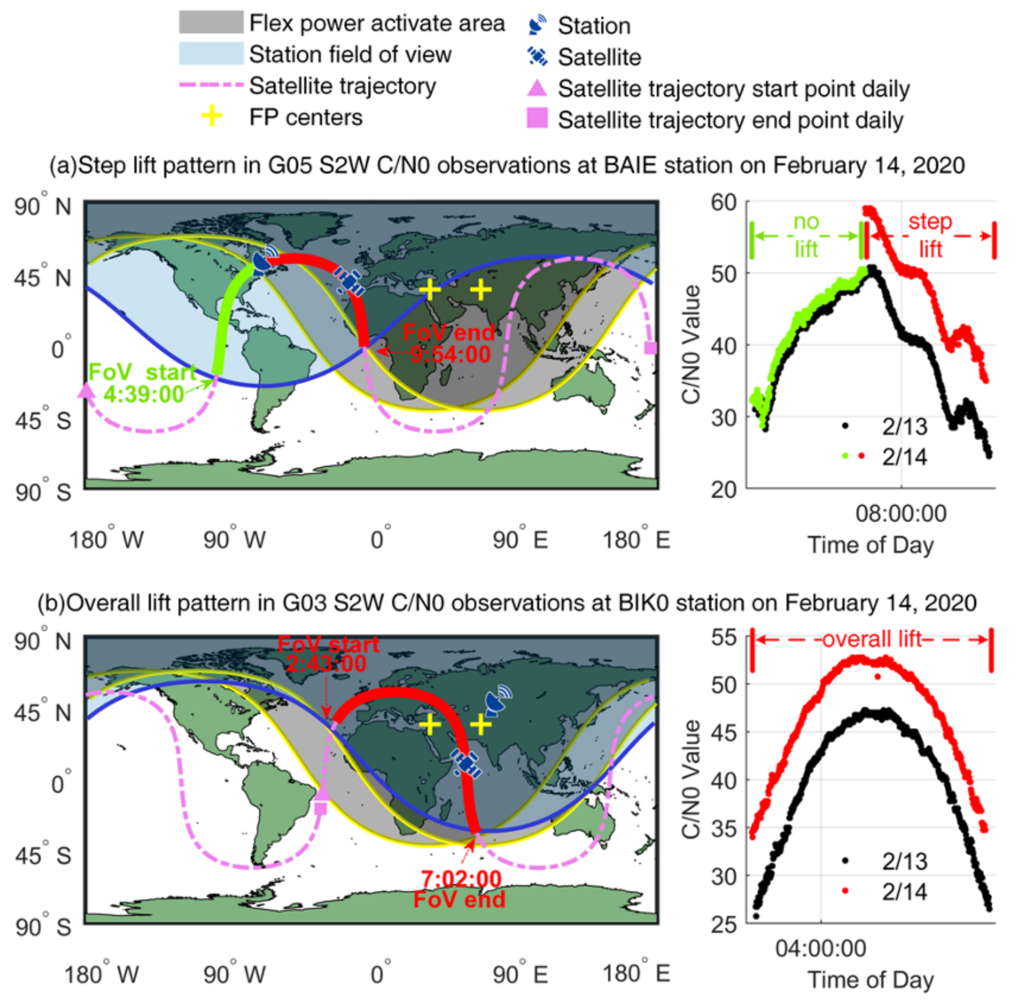

Fig. 1 Revised Figure 2

1.7. Line 130

RC: ***What is "snx data" ?***

AR: We appreciate the reviewer' s question. In brief, "SNX data" refers to the *Station Position Products*, which provide station coordinate information and are distributed by NASA (2025). More specifically, SNX files (Solution/ SINEX, i.e., Solution Independent Exchange Format) are standardized product files provided by the IGS for the exchange and storage of GNSS station solutions and related parameters. The IGS routinely publishes several types of SINEX products on a daily or weekly basis, including Final, Rapid, and Ultra-rapid SINEX files, Weekly Combined SINEX, as well as Earth Orientation Parameters (EOP) SINEX and Reprocessing SINEX. In our study, we adopted the IGS Final SINEX product.

1.8. Line 206

RC: ***The format is wrong.***

AR: We sincerely thank the reviewer for the careful observation. We have corrected the formatting issue at this location (regarding the usage of "around") and have also carefully checked the entire manuscript to ensure that all similar formatting inconsistencies have been revised accordingly.

1.9. Line 219

RC: ***Why those stations? Do you choose the station randomly? In addition, the antenna and receiver type should be added if the detection of flex power is related to this factor.***

AR: This point has already been addressed in our response to Comment 0.1. We kindly refer the reviewer to that section for details.

1.10. Line 245

RC: **"*could be determined using very few stations (less than 8)*". *How do you determine the number? In addition, it is not consistent with* "*The method requires data from as few as 8 stations for reliable detection*" *in the abstract. Please discuss in detail how many stations are needed.***

AR: This point has already been addressed in our response to Comment 0.2. We kindly refer the reviewer to that section for details.

1.11. Line 266 and figure 9

RC: ***How do you verify the flex power events? Do you have any evidence about the flex power event other than the detection result? Is it publicly available from the authority office?***

AR: This point has already been addressed in our response to Comment 0.3. We kindly refer the reviewer to that section for details.

1.12. Line 293

RC: “***Detection accuracy is consistently high, ranging from 0.9973709 to 0.9996528*****” *, too many digits are kept and they are not necessary.***

AR: We thank the reviewer for this comment. As mentioned in our response to Comment 1.2, we have rounded the reported accuracy values to two decimal places (percentage format) throughout the manuscript to improve readability and consistency.

1.13. Line 333 and table 7

RC: ***The performance of your method is very similar to that of the other method. The difference of 0.9983, 0.9994, 0.9986 is very small.***

AR: We thank the reviewer for this important remark. In Table 8 of the manuscript, we compared the performance of AFPD-DTW with other existing approaches. Here it is necessary to clarify the distinction between **post-processing accuracy** and **real-time accuracy**.

- Post-processing accuracy refers to event detection at the *daily level*, i.e., whether a flex power event occurred on a specific date. This evaluation framework has been widely used in previous works such as Esenbuğa, Hauschild, and Steigenberger (2023).
- Real-time accuracy, in contrast, is assessed at the *data-point level* (30-second sampling intervals), as adopted in Meng, Ge, and Li (2024) and Yang et al. (2022). This allows for detection of the precise time of event activation and deactivation within a day.

Both perspectives serve different purposes in practice:

- Daily post-processing accuracy is particularly useful for cataloging events and conducting long-term monitoring.
- Real-time accuracy enables precise identification of event onset times, which is valuable for analyzing the dynamics of flex power operations.

We also note that extremely high data-point-level accuracy values (e.g., $> 99\%$) can be somewhat misleading. Since flex power events are rare (e.g., only 41 event days during 2020–2021), the vast majority of data points correspond to “no-event” samples. As a result, even small detection errors at event boundaries may have negligible influence on the overall accuracy, leading to artificially inflated values.

Therefore, while existing machine learning–based and model–based approaches already achieve very high true positive rates at the sample level (99.83% and 99.94%, respectively), the marginal improvement in numerical accuracy is naturally limited. The true novelty and strength of AFPD-DTW lies not in pushing accuracy from 99.8% to 99.9%, but in its **plug-and-play adaptability**: it requires only minimal historical data (e.g., one prior day of observations) to construct a baseline model, and can thus achieve robust detection without the need for large-scale training datasets or complex constellation-specific modeling.

RC: ***The study is based solely on GPS data. Is it applicable to multi-frequency, multi-system scenarios?***

AR: We thank the reviewer for raising this important question. Yes, AFPD-DTW is inherently designed to be transferable to multi-frequency and multi-constellation scenarios, since it does not rely on baseline models but rather on the intrinsic day-to-day similarity of C/N0 time series. To further demonstrate this generalizability, we conducted additional experiments beyond GPS S2W signal.

For GPS, we extended the evaluation to the S1W signal during the same experimental periods reported in the manuscript. For BDS, we applied AFPD-DTW to S2I, S6I, and S7I signals during the years 2023–2025 (up to July 2025). The results consistently show that AFPD-DTW maintains high detection accuracy and robustness across different frequencies and constellations, including both GPS and BDS.

These new results have been incorporated into the revised manuscript in Section **Multi-constellation and Multi-frequency Detection**, with a summary in Table 6 and illustrative examples in Figure 14 in the manuscript. In addition, the performance parameters reported in Section **Comparison and Analysis** have been updated to reflect the comprehensive results of AFPD-DTW across GPS and BDS multi-frequency scenarios.

1.14. The novelty of the method should be improved.

RC: ***It looks like some engineering tricks, instead of original method. Therefore, it is recommended to add more information and focus on the novelty of the method.***

AR: We sincerely thank the reviewer for this valuable suggestion. We recognize that in the original submission, more emphasis was placed on describing the characteristics and mechanisms of flex power, while the methodological section did not sufficiently highlight the originality of AFPD-DTW. This may have led to the impression that our contribution is primarily engineeringoriented. In the revised manuscript, we have condensed Section 2 **Flex power characterization based on C/N0** and explicitly linked the identified limitations of existing approaches to the motivation for our method. Furthermore, we have substantially expanded Section 3 **Method of AFPD-DTW**, providing a clearer and more detailed explanation of the full pipeline and the core algorithmic innovations of AFPD-DTW.

The novelty of AFPD-DTW lies first in proposing a new detection paradigm. Previous approaches depend on empirical baseline models constructed from long-term historical data, such as azimuth/elevation-dependent C/N0 models or sliding-window thresholds. In contrast, AFPD-DTW leverages the inherent day-to-day similarity of C/N0 time series under nominal conditions. By aligning consecutive daily sequences with Dynamic Time Warping (DTW), we can identify flex power activations as structural deviations, eliminating the need for prior model training. This represents a fundamentally different principle from earlier methods.

Second, AFPD-DTW introduces DTW as a means of temporally aligning daily C/N0 patterns, ensuring that true flex power deviations are distinguished from orbital misalignments. The cumulative nature of DTW distances allows anomaly scores to accumulate gradually, and when combined with the adaptive interquartile range (IQR) thresholding strategy, flex power events can be robustly separated from normal variations even under noisy conditions. This approach provides both methodological novelty and practical robustness.

Finally, the method demonstrates strong efficiency and transferability. Because AFPD-DTW capitalizes on intrinsic signal properties rather than sliding-window differencing, it does not require hundreds of stations to capture power transitions. Our experiments show that reliable detection can be achieved with as few as eight high-quality stations, enabling both daily post-processing detection and near real-time point-level detection. This design yields an approximately twenty-fold speed-up over existing methods, while maintaining accuracy above 99.8%. These qualities—plug-and-play adaptability, robustness across constellations and frequencies, and computational efficiency—together establish AFPD-DTW as a genuinely novel detection framework rather than an incremental engineering trick.

2. Response to reviewer #2's comments

2.1. Paragraph 2

RC: ***There are many published literatures that can achieve relatively accurate detection of elastic power, such as the C/N0 epoch differential detection method in Yang***

et al. 2022; Meng et al. 2024; Zhang et al. 2025. Using C/N0 epoch differential data from multiple globally distributed stations, the jump of C/N0 of a certain satellite at the same time can also be quickly detected. Since the model estimation parameter is only the jump amount, more stations will not significantly increase the time consumption, but will be beneficial to the processing of outliers. Therefore, it does not make much sense for this article to emphasize that reliable detection can be achieved with fewer stations. The author mentioned that the post-processing speed is 20 times faster than the FPD method, which does not make much sense for the post-processing mode. Therefore, the author needs to further summarize the advantages and innovations of the AFPD-DTW method in this article.

Meng G, Ge H, Li B (2024) A real-time detection method for GPS flex power. GPS Solutions 28(3). doi:10.1007/s10291-024-01653-3 Yang X, Liu W, Huang J, Xiao W, Wang F (2022) Real-time monitoring of GPS flex power based on machine learning. GPS Solutions 26(3). doi:10.1007/s10291-022-01257-9

Zhang Z, Gong X, Gu S, Zheng F, Lou Y (2025) Analysis of GPS satellite flex power in 2023 and its effects on differential code bias variations. GPS Solutions 29(3). doi:10.1007/s10291-025-01849-1

AR: We appreciate the reviewer' s insightful comment and the references to related work. Indeed, C/N0 epoch-differential methods (e.g., **zhang2025analysis**; Yang et al. 2022; Meng, Ge, and Li 2024) can effectively detect flex power jumps. However, not all detection approaches are based on epoch differencing. For example, the early FPD method proposed by DLR is built on sliding-window differencing of C/N0 within ±5 minutes Esenbuğa, Hauschild, and Steigenberger 2023. While this method requires no prior modeling, it depends on a very large number of stations (>200) to ensure that at least one station captures the jump when a satellite crosses the flex power activation boundary, and its computational cost grows significantly with station number. Our 20-fold speed-up claim is based on direct experimental benchmarks against such sliding-window approaches.

Moreover, using more stations is not always beneficial. First, hardware diversity introduces systematic differences: as discussed in our manuscript and in Wu et al. 2025, different receiver–antenna pairs may exhibit different C/N0 lift magnitudes during the same flex power event. Threshold-based differential methods therefore require station-specific baseline models and thresholds, which incur very high data and time costs. By contrast, AFPD-DTW leverages day-to-day similarity and DTW alignment, allowing error accumulation and robust separation

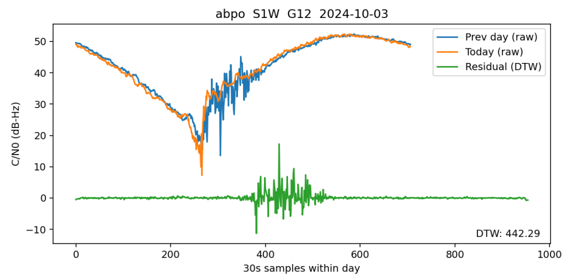

Fig. 2 The C/N0 time series of some stations are highly noisy

of flex and non-flex states using only a simple adaptive IQR threshold, without any historical model training. Second, data quality varies across stations: as illustrated in Fig.2, some stations produce very noisy C/N0 series. In such cases, direct epoch differencing leads to highly unstable residuals and false detections, whereas DTW accumulates mismatches within a window. This results in DTW scores for noisy traces that remain an order of magnitude smaller than true flex power events (see Fig. 5 in the manuscript), thereby ensuring robust detection even with fewer, high-quality stations.

Regarding the reviewer’s concern that the 20-fold speed-up in post-processing has limited meaning, we would like to clarify that the gain is not confined to offline analysis. Because AFPD-DTW requires only 8–10 stations and avoids historical model training, the same computational efficiency translates directly into real-time detection, which is critical as the size of GNSS constellations and station networks continues to grow. Faster throughput in both post-processing and real-time detection has clear value for research and operational applications.

To further highlight these advantages, we have revised the “Comparison and Analysis” section of the manuscript. The updated text now reads:

> Line 352:
>
> The comprehensive performance of the AFPD-DTW method, along with previous methods (FPD, random forest-based, and baseline modeling), is presented in Tables 7 and 8. We manually verified multi-constellation and multi-frequency flex power states through C/N0 time series and satellites’ trajectories, and it achieves a post-processing accuracy of 99.94%. For real-time detection, AFPD-DTW achieved 99.87% on TPR, maintaining high detection accuracy of 99.89% and precision of 99.98% using only 10 stations, with the potential for further improvement by incorporating more station data.

In terms of data requirements, the AFPD-DTW requires no historical data and only 8-10 stations. Thus, it enables rapid and simplified deployment across multiple constellations and frequency bands. In contrast, FPD requires more than 200 stations, and the RF-based method demands extensive labeled training datasets. Also, model-based approaches rely on large prior datasets and specific equipment configurations. Regarding detection, AFPD-DTW shows a 20-fold improvement over FPD since it uses only a few stations' data. This acceleration enables rapid post-processing and real-time detection, which is crucial as the number of stations and satellite constellations grows.

In summary, by leveraging satellite diurnal C/N0 difference and using DTW to correct period mismatches, the AFPD-DTW achieves efficient and reliable flex power detection. It significantly improves speed while maintaining high accuracy in both real-time and post-processing detection, with minimal data requirements and without any pre-trained baseline model.

2.2. Paragraph 3

RC: ***The keyword "flex power detection" contains flex power. The article proposes detection methods for step lift and overall lift, but the physical meanings of step lift and overall lift are not clearly explained. If they are named artificially because of daily data processing, they do not have universal significance. Is the jump in Figure 1 caused by turning on or off the elastic power? Are there only these two types of effects of the switch on C/N0?***

AR: We sincerely thank the reviewer for pointing out the need for a clearer explanation. In the revised manuscript, we have added further clarification in the section **Step and overall lift of the C/N0**. The terms "step lift" and "overall lift" are not physical mechanisms of flex power, but rather observational categories introduced from the perspective of a single station observing a single satellite within one day.

Flex power is activated within a certain geographical region. When a satellite crosses the boundary of this activation region, a C/N0 discontinuity occurs. If such a transition moment happens outside the visibility arc of a station, the jump cannot be captured by methods like the Flex Power Detector (FPD), which rely on sliding-window analysis. This is why the FPD approach typically requires a very large number of stations (more than 200) to ensure that at least one station records the C/N0 jump when a satellite crosses the activation boundary. An alternative solution has been to use differential approaches, i.e., subtracting the measured C/N0 from a pre-built baseline model and applying a threshold. However, such model-based methods require extensive historical data for model construction and station-specific thresholds, which limits their general applicability.

To address these limitations, we proposed the concepts of “step lift”and “overall lift”as a way to illustrate why existing methods struggle and to motivate our day-to-day differential approach. By leveraging the high similarity of C/N0 patterns between consecutive days, AFPD-DTW can detect flex power events without the need for long-term historical modeling and with only a small number of stations. This framework overcomes both the requirement for massive station networks (FPD) and the reliance on empirical baseline models (model-based approaches).

Regarding Figure 1, all illustrated cases are indeed caused by the **turning on or turning off of flex power**. From the observational perspective of ground stations, only two distinct effects have been identified so far: stepwise lifts when satellites enter or exit the activation region, and overall lifts when satellites are already inside the activation region at the start of the visibility arc. No additional modes have been observed in practice.

2.3. Paragraph 4

RC: ***The design and arrangement of the chapters in the article are unreasonable. The article needs to discuss your innovations and carry out necessary experimental demonstrations for the proposed AFPD-DTW method. There is no need to elaborate on the characteristics of C/N0 changes caused by elastic power because they have been discussed in some articles. The key points in Figure 4 are not prominent enough, for example, the data input, data processing and result fusion parts exceed the core method AFPD-DTW. Figures 7 and 8 are similar and a bit repetitive. The author needs to condense the key information. Tables 1-4 give a lot of digital information, which is not easy to read, like a project report. Table 5 has very little information and is not necessary to give it. It can be summarized in one or two sentences.***

AR: We sincerely thank the reviewer for these constructive suggestions on the structure and presentation of the manuscript. We agree that the initial arrangement placed disproportionate emphasis on background material, which may have obscured the methodological innovations of AFPD-DTW. The original structure was partly inspired by related works Meng, Ge, and Li 2024; Yang et al. 2022; Liu et al. 2024; Esenbuğa and Hauschild 2020, but we acknowledge that our emphasis required adjustment.

Regarding the section on "Flex power characterization based on C/N0" , we respectfully emphasize that this part is not a repetition of existing studies. We introduced two novel observational patterns—*step lift* and *overall lift*—from the station–satellite–daily perspective, and further explained their mechanisms using a combination of C/N0 time-series plots and satellite trajectory plots, which to the best of our knowledge has not been addressed before. This explanation is essential to motivate our method: it illustrates why the FPD approach requires a large number of stations to capture transition points, and why AFPD-DTW can achieve reliable detection with far fewer stations. In addition, we presented evidence of receiver- and antenna-dependent C/N0 variations during the same flex power event. This highlights the limitation of empirical baseline modeling methods, which require station-specific thresholds and extensive historical data. By contrast, AFPD-DTW leverages day-to-day similarity and DTW alignment, enabling plug-and-play detection without prior model building. These aspects directly connect the background characterization with the novelty of our method.

Concerning Figure 4, we have revised the design to highlight the AFPD-DTW pipeline more clearly. In the updated version, the data preprocessing steps are condensed, while the details of the AFPD-DTW algorithm, including both post-processing and real-time procedures, are emphasized to better demonstrate the methodological innovations.

Regarding Figures 7 and 8, they respectively present DTW anomaly scores for 2020 and 2021, with outliers marking detected flex power event days. Because these years correspond to periods where reference events are available from Esenbuğa, Hauschild, and Steigenberger (2023), we believe it is important to present the full-year detection results to enable transparent comparison. Although the visual styles are similar, the events occur on different days, and we have revised the text to explicitly highlight the differences between the two figures to guide the reader.

For Tables 1–4, we note that the style follows the precedent of Esenbuğa, Hauschild, and Steigenberger (2023), providing a comprehensive record of detected events. We regard this information as important not only to validate our method but also as a valuable reference dataset for future research. Nevertheless, we agree that such large tables may interrupt the flow of the main text, and in further revisions we are prepared to move the full event lists to an Appendix or Supplementary Material, while keeping summarized results in the main body.

Finally, Table 5 has been removed, and the information it contained is now summarized in the text as follows:

Line 312:

During the detection period, two modes were observed. Mode 1 was active during part of the day on June 1–3 and June 7, whereas Mode 2 was active throughout the entire day on June 4–6.

We believe that these revisions significantly improve the balance between background, methodology, and results, and make the manuscript more concise and reader-friendly.

2.4. Paragraph 5

RC: ***In summary, this article has defects in both the innovative summary of methods and the experimental analysis. The quality of the paper has not yet reached the journal standards and needs further revision before it can be published.***

AR: We acknowledge that the original manuscript did not fully highlight the innovation of our method. In response to this, we have expanded the **Method of AFPD-DTW** section to provide a more detailed explanation of our approach. Additionally, we have included new experiments demonstrating its effectiveness across multiple constellations and frequencies. Further details of our analysis can be found in the response to Comment 1.14.

References

Anthony Flores (Apr. 2021). *NAVSTAR GPS Space Segment/Navigation User Interfaces*. Interface Specification IS-GPS-200M. RFC-00413 Incorporation of IRN-IS-200L-001 and IRN-IS-200L-002, Rev. M. El Segundo, CA, USA: Space and Missile Systems Center (SMC). URL: `https://www.gps.gov/technical/icwg/IS-GPS-200M.pdf` (visited on 08/23/2025).

Esenbuğa, Özge Gizem and André Hauschild (2020). "Impact of flex power on GPS Block IIF differential code biases". In: *GPS Solutions* 24.4, p. 91.

Esenbuğa, Özge Gizem, André Hauschild, and Peter Steigenberger (2023). "Recent flex power changes". In: *GPS Solutions* 27.3, p. 104.

Liu, Tianjun et al. (2024). "Characteristics of Beidou-2 flex power and its impact on precise point positioning with ambiguity resolution". In: *GPS Solutions* 28.4, p. 152.

Meng, Guanlong, Haibo Ge, and Bofeng Li (2024). "A real-time detection method for GPS flex power". In: *GPS Solutions* 28.3, p. 111.

Monaghan, Heather (May 2025). *What is the Deep Space Network?* URL: https://www.nasa.gov/directorates/somd/space-communications-navigation-program/what-is-the-deep-space-network/?utm_source=chatgpt.com.

NASA, CDDIS (2025). *Station Position Products.* https://www.earthdata.nasa.gov/data/space-geodesy-techniques/gnss/station-position-products. Accessed: 2025-8-12.

Submission guidelines | GPS Solutions (2025). URL: https://link.springer.com/journal/10291/submission-guidelines (visited on 08/29/2025).

Wu, Zhou et al. (2025). "A novel real-time GPS flex power detection method based on the linear relationship between carrier-to-noise ratios". In: *GPS Solutions* 29.4, pp. 1–15.

Yang, Xin et al. (2022). "Real-time monitoring of GPS flex power based on machine learning". In: *GPS Solutions* 26.3, p. 73.