Reply to “Timing errors in global sea level observations” (Pan et al., 2025)

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Abstract

Pan et al (2025) claim to uncover numerous timing and datum errors in the University of Hawai‘i Sea Level Center Research Quality dataset and declare that the dataset is “less reliable than previously assumed”. We argue that Pan et al. overstate the scientific implications of unresolved issues in the dataset and demonstrate that Pan et al. have failed to consider the extensive metadata accompanying the observations, which already document most of the issues Pan et al. claim to expose. We also clarify the nature of the Research Quality dataset, which is not guaranteed to be free of errors, and assert that when data and metadata are used together as intended, the dataset remains a reliable basis for scientific research.

1 Introduction

Sea-level measurements from tide gauges provide invaluable observations of numerous oceanographic and geodetic processes spanning extreme events (e.g., tsunami and storm surges) to long-term trends (e.g., those associated with climate change and glacial isostatic adjustment). The most widely cited collection of hourly tide-gauge sea levels is the University of Hawai'i Sea Level Center (UHSLC) Research Quality (RQ) dataset, also known as the Joint Archive for Sea Level (JASL; Caldwell et al, 2001). As with any collection of historical in-situ observations, working with this dataset requires careful consideration of errors and inhomogeneities that can arise due to many factors, including instrumentation changes over time; complexities introduced during station maintenance and repair; and mistakes or improvements in data processing (UNESCO/IOC, 2020).

In a recent publication, Pan et al (2025) claim to uncover numerous timing and datum errors in the RQ/JASL dataset and assert that the existence of these issues undermines the reliability and suitability of the dataset for scientific analysis. However, most of their conclusions are demonstrably false, and others are misleading at best, especially in regard to the importance of their findings for sea-level science and applications. Pan et al. fail to acknowledge the existence of comprehensive metadata accompanying the RQ/JASL dataset, which provide the necessary context for responsible scientific use and explicitly document known issues, including most of those that Pan et al. claim to uncover. The authors also fundamentally misunderstand the nature and purpose of the RQ/JASL dataset, which is to facilitate robust scientific analysis through objective quality assessments and documentation, not to guarantee that the data is free of errors.

2 UHSLC Research Quality Dataset

The UHSLC advances global sea-level research through participation in the Global Sea Level Observing System (GLOSS), which was established by the UNESCO Intergovernmental Oceanographic Commission (IOC) in 1985. GLOSS coordinates global and regional in-situ sea-level observing networks, with the voluntary participation of more than 90 nations, to produce high-quality observations that support diverse research and operational needs (UNESCO/IOC, 2012). The RQ/JASL dataset is a core activity of the GLOSS program and is co-produced by the U.S. National Centers for Environmental Information (NCEI) and the UHSLC. Production of the dataset relies heavily on international participation—both in regular submission of collected sea-level data and in collaboration to investigate and correct errors uncovered during the RQ/JASL quality assurance process. At the time of writing, RQ/JASL holds nearly 170 million hourly sea level values—more than 19,000 years of data—from 548 sites in 92 countries.

The most important feature of the RQ/JASL dataset is the reciprocal quality-assurance effort undertaken between NCEI and the data originators (i.e., those operating tide gauges and submitting data to RQ/JASL). Note that this collaborative process is not designed to guarantee that data are free of errors. Rather, the goal of the quality assurance is to identify problems in data submitted to RQ/JASL and—whenever possible—work with the data originator to assess the history of the station (e.g., natural events, changes in instrumentation, leveling records, etc.) and have the originator rectify errors at the source when possible. When errors cannot be addressed by the originator, they are documented in the metadata accompanying each record so that researchers are aware of potential issues and can decide how to treat problematic data based on their desired application. Preserving the unaltered data in cases where the exact cause and/or effect of an observational error is not certain allows researchers to choose the best approach for mitigating the impact of errors given their specific application. Each sea-level record in the RQ/JASL database has an associated metadata file that describes potential problems and flags questionable data. The metadata files can be found online here: https://uhslc.soest.hawaii.edu/data/?rq.

3 False and Misleading Claims in Pan et al. (2025)

Pan et al. make a number of dubious claims about the RQ/JASL dataset, but the two most egregious are:

> *Our research unequivocally demonstrates that the 'research quality' sea-level data provided by the UHSLC may not be as reliable as previously assumed.*

and

> *Despite [quality-assurance efforts], considerable observation errors persist within global tide gauges, posing potential interference to related scientific studies.*

Not only do these statements discount the role of existing metadata that previously documented the issues highlighted by Pan et al., they also cast unwarranted doubt on the body of peer-reviewed scientific research based on the RQ/JASL dataset (e.g., https://uhslc.soest.hawaii.edu/publication-tracker/). In support of the credibility of the RQ/JASL dataset, we reproduce portions of the table of "significant timing errors" in Pan et al. and add an additional column containing relevant statements from the RQ/JASL metadata (Table 1). Note that in almost every case, the metadata explicitly document the issues that Pan et al. claim to expose and/or flag the same stretches of data as questionable. Furthermore, even if all the timing issues Pan et al. claim to have uncovered were previously unknown, the 54 years highlighted by the authors represent a minuscule fraction (<0.3%) of the 19,000 years of data in the RQ/JASL dataset. The actual fraction of affected data is even less given that the durations of significant timing issues are generally much shorter than a year. Along with timing issues, Pan et al. claim that "datum shifts and other exceptions are also uncovered in the UHSLC database" as a result of their effort. This claim is similarly flawed, as three of the four highlighted issues were already rectified or documented in the RQ/JASL metadata when Pan et al. was published (Table 2).

As for impacts on scientific studies, the comprehensive RQ/JASL metadata epitomized here provide clear means for responsible researchers to mitigate the influence of observational errors on their results. Even in the absence of metadata, the scientific implications of the issues highlighted by Pan et al. are minimal. For example, most of the unresolved timing issues occur during the 20th century and do not affect calculations of modern tidal datums. Otherwise, the scientific implications of isolated timing problems are confined to specific applications (e.g., Zaron and Jay, 2014) and do not affect critical scientific conclusions about long-term trends in mean sea level and sea-level extremes (e.g., Fox-Kemper et al, 2021). Thus, statements made by Pan et al. about the scientific reliability of the RQ/JASL dataset and the body of literature it supports are naive and misguided hyperbole.

Another recurring theme in Pan et al. is the contributions of "developed" and "developing" nations to the RQ/JASL dataset. The authors state:

> *Concerns on property and security often result in the majority of hourly tide gauge records from developing countries being inaccessible to the public. Generally, developed countries, particularly the US, contribute substantially more to the construction of the UHSLC database than developing countries.*

While the authors' motivation for making such statements is unclear, we aim to correct any misconceptions they introduce into the scientific literature. To do so, we will assign the terms "developed" and "developing" to the groups of nations defined by the International Monetary Fund as having "advanced economies" and "emerging and developing economies", respectively (IMF, 2024). First, although it is true that certain developing nations (including China, the affiliated nation of Pan et al.) withhold hourly sea-level data from public databases, it is not the norm. The majority of developing coastal nations do contribute when possible to the RQ/JASL dataset (and other GLOSS repositories), either by submitting data collected by their own national agencies or by supporting the collection of data by foreign entities. The UHSLC, in particular, takes a leadership role in ensuring the availability of sea-level data by operating >70 tide-gauge stations in developing nations, which are distributed across >30 unique countries. Second, while developed nations have contributed greater overall data volume to the RQ/JASL dataset due to denser tide-gauge networks and longer histories of sea-level observation, Pan et al. exaggerate the disparity in modern participation. Over the last decade, 54 developing nations have contributed data from more than 130 unique sites to the RQ/JASL dataset, which constitutes approximately 40% of the unique sites to have been updated during this time. The mission of GLOSS (and hence the UHSLC) is to facilitate a truly global in-situ sea-level observing network, and GLOSS and the UHSLC welcome contributions from all nations willing to support the Global Ocean Observing System and the international scientific enterprise.

4 Conclusions

The RQ/JASL dataset remains a reliable and "science-ready" basis for scientific research across numerous disciplines. The philosophy of the dataset's construction is rooted in international collaborations that facilitate identification and correction of observational errors at the originator level whenever possible. Not all data problems can be solved in this way, however, and it is essential to acknowledge that the RQ/JASL dataset, while rigorously curated, is not guaranteed to be free of errors. As such, the accompanying metadata is essential to allow users to navigate remaining errors or questionable data and make informed analysis decisions that mitigate impacts to their results. The combination of global scope, high-quality data, and comprehensive metadata make the RQ/JASL dataset a foundation of global sea-level research that will continue to foster scientific progress.

We conclude by encouraging any user of GLOSS datasets (and the RQ/JASL dataset in particular) to reach out directly to dataset curators and/or data originators when they believe unknown errors in the data have been detected. A collaborative approach allows curators and originators to investigate potential causes and either address the issues directly or update the metadata. This approach provides the greatest benefit to the scientific community as a whole and allows researchers to focus on technical or scientific advances instead of critiquing public datasets. In the case of Pan et al., a collaborative approach would have allowed the curators of the RQ/JASL dataset to provide the authors with the relevant metadata, which would have prevented false and misleading claims from entering the scientific literature.

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Data Availability. All RQ/JASL data and metadata are freely available at https://uhslc.soest.hawaii.edu/data/.

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Table 1 Tide-gauge sites and years from Table 1 in Pan et al (2025) with relevant notes from the RQ/JASL metadata.

UHSLC ID	Station Name, Country	Years with Timing Errors	Relevant Metadata Notes
h729	Mar del Plata, Argentina	2019	Period in question is labeled as "Fast Delivery" data in the UHSLC database, not "Research Quality".
h139a	Khepupara, Bangladesh	1992	Metadata notes timing errors of unclear origin.
h715a	Madeira, Brazil	1997	Metadata describe the location of the station "near a wide, strong river" with implications for tides/timing and flag a stretch of questionable data during 1997.
h716a	Santana, Brazil	1971	Short record. Metadata describe the location of the station "near a wide, strong river" with implications for tides/timing. Questionable data for 1971 says to see comments about site location.
h716b	Santana, Brazil	1975, 1976	Short record. Metadata describe the location of the station "near a wide, strong river" with implications for tides/timing. Questionable data for 1975 and 1976 says to see comments about site location.
h274	Churchill, Canada	1967	Metadata states, "It is estimated that the timing is off occasionally by about fifteen-minutes." Various stretches of data during 1967 are identified as questionable.
h287a	Puerto Williams, Chile	1997	Metadata states, "Except for a few periods with timing errors and short gaps, the data are of good quality."
h085a	Buenaventura, Colombia	1988, 2006-2009	Metadata states, "The residuals of the hourly data show a large amount of periodic fluctuations due to both the inability of the tidal analysis to resolve completely all the tidal constituents and to phase drifts caused by a variety of possible technical causes. The timing is exceptionally poor during 2005-2010."
h303a	Tumaco, Colombia	1970, 1973, 1999, 2000, 2006, 2007	Metadata states, "Timing drifts and data gaps occur throughout the record, especially poor in 1952, 1969-1970, 1999-2000 and 2004-2007."
h244a	Gibara, Cuba	1987	Metadata flag multiple stretches of bad and/or questionable data during 1987.
h003	Baltra, Ecuador	1989	Metadata states, "The hourly data contain significant timing errors in 1988-1990 as noted below."

Continued ⟶

Table 1 Continued

UHSLC ID	Station Name, Country	Years with Timing Errors	Relevant Metadata Notes
h160a	Surabaya, Indonesia	1993	Metadata notes a number of issues with the time series, including multiple stretches of bad or questionable data during 1993.
h140a	Kelang, Malaysia	2004	Metadata states, "The residual series are very noisy which is probably due to shallow water tides that are not resolved by the harmonic analysis."
h389a	Sandakan, Malaysia	2009	Metadata flag questionable data during 2009.
h108	Male, Maldives	2020	Period in question is labeled as "Fast Delivery" data in the UHSLC database, not "Research Quality".
h302	Balboa, Panama	1908	Metadata flag the entire year of 1908 as questionable. Quality improves in subsequent years.
h304b	Puerto Armuelles, Panama	1991, 2000	Metadata notes that "The timing is poor during 1983-84 and 1996-2001."
h096a	San Juan, Peru	1982, 1990	Metadata states, "The timing is questionable during select periods prior to 1993."
h683b	Pisco, Peru	2010	Metadata flag multiple stretches of bad and/or questionable data during 2010.
h370a	Manila, Philippines	1985	Metadata notes timing offsets of less than an hour during multiple stretches of data, including many such questionable stretches during 1985.
h371	Legaspi, Philippines	1985	Metadata states, "A timing offset of 30 minutes exists from 16Z 31 Jan - 15Z 11 Feb 1985. The timing has small offsets of 5-10 minutes during various periods throughout the record. 2014 has timing offset of -30 min to one hour."
h699	Tanjong Pagar, Singapore	2017, 2018	Metadata states, "The residual series are very noisy, which is due to shallow water tides that are not resolved by the harmonic analysis or due to timing drifts of less than 15 minutes."
h187	East London, South Africa	1971, 1972, 1991	Metadata states, "The timing of the gauge appears to be off by a fraction of an hour in some instances as noted below in the questionable fluctuations."
h221	Simon's Town, South Africa	2004	Metadata flag a stretch of questionable data lasting 13 days during 2004 and a variety of stretches of missing data.

Continued ⟶

Table 1 Continued

UHSLC ID	Station Name, Country	Years with Timing Errors	Relevant Metadata Notes
h702	Luderitz, South Africa	1978	Metadata flag 15 days of questionable data during 1978.
h703	Saldahna Bay, South Africa	1986-1989	Metadata notes poor timing quality during 2005-2007, which does not match the period questioned by Pan et al. Metadata flag multiple stretches of generally questionable data during 1986-1989.
h830	La Coruna, Spain	2017	Metadata flag multiple stretches of bad or questionable data during 2017.
h328	Ko Lak, Thailand	2002	Metadata states, "The residuals show considerable fluctuations of more than 30 cm with periods from 1 to 3 days", and multiple stretches of data are flagged as bad or questionable during 2002.
h294	Newlyn, UK	1938	Metadata states, "The timing improves in 1985 onward after installation of a new tide gauge. Prior to 1985, many time spans have questionable timing quality."
h240a	Fernandina Beach, US	2012	Metadata states, "The residual series are very noisy which are probably due to shallow water tides that are not resolved by the harmonic analysis."
h253	Newport, US	1978	Metadata flag a stretch of questionable data lasting 47 days during 1978.
h554	La Jolla, US	1926	Metadata flag 46 days of questionable data during 1926.
h556	Crescent City, US	1950	Metadata flag a stretch of questionable data lasting 31 days during 1950.
h565a	Port San Luis, US	1969	Metadata states, "Major timing problems are evident in 1969."
h572a	Astoria, US	1983, 1984	Metadata flag stretches of questionable data lasting 32 days during 1983 and 20 days during 1984.

Table 2 Tide-gauge sites and examples of "datum shifts and other exceptions" described by Pan et al (2025) with relevant notes from the RQ/JASL metadata.

UHSLC ID	Station Name, Country	Exception	Relevant Metadata Notes
h716a	Santana, Brazil	Temporary datum shift during 1971	Metadata states, "The data have been linked to tide staff zero by the originators. However, time segments of data for 1975-76, 1984-85, 1996-97, 2006 each appear to have independent datums; thus, the series are broken into unique pieces." While the brief stretch of data highlighted by Pan et al. is not mentioned explicitly in the metadata, it is clear that vertical control is a problem at this station, and analysis that requires vertical control should proceed with caution.
h266a	Cristobal, Panama	Long-term datum shift before and/or after 2000	This station has been moved multiple times throughout its history and is composed of three primary segments (Historic Cristobal, Coco Solo, and Limon Bay). Every effort has been made to work with the originator to link the segments together via leveling to common benchmarks, which is described in detail in the metadata. The metadata also directly address the issue Pan et al. claim to uncover and caution that "The linking of Coco Solo series, 1981-1996, to the [Primary Level Datum] for the Cristobal/Coco Solo/Limon Bay time series appears suspiciously high on the order of 60 mm."
h825a	Cuxhaven, Germany	Large negative outliers during 2015	These outliers were identified and addressed by the originator and were removed from the database prior to publication of Pan et al (2025).
h285a	Buenos Aires, Argentina	Local non-tidal oscillations	Metadata states, "The residuals contain large fluctuations with periods of 14-72 hours. These fluctuations are due to the inability of the tidal analysis routines to resolve the many nonlinear harmonic components of the shallow water/river environment."