Dear Editor,

We thank you and the reviewers for this evaluation.

We addressed the final concern of Reviewer #1 (see below)

We have now submitted all files required for production.

On behalf of all authors,

Wouter Berghuijs

Comment Reviewer #1

I appreciate the authors' efforts in revising the manuscript. All my comments have been addressed in this version. However, I still have some minor concerns regarding the robustness of the metrics. Based on the updated Figure 3, which illustrates the ranges of each metric, it appears that, except for IS2, the other three metrics are not highly sensitive to the binning choice. For instance, IS1 is 34.1% of its maximum when using 15-minute data and decreases slightly to 33.1% when using monthly data, which corresponds to 97.1% of the value calculated with 15-minute data. Similarly, for the directional metric, the corresponding ratio is 98.6%, only slightly higher than that of IS1, indicating that its sensitivity is only marginally weaker than IS1. I am not questioning the usefulness of the directional metric; rather, I believe that the differences among the various metrics should be conveyed more accurately. At the very least, I do not think IS1 and IS3 "strongly depend on the binning choice." Furthermore, instead of providing absolute values and potential ranges, I suggest presenting the relative values directly, as this would facilitate a clearer understanding of the differences among the metrics.

We changed the text and figure as follows:

3.2 Robust seasonality strength

Streamflow seasonality analyses using directional statistics assess the strength of seasonality based on the original temporal resolution of the dataset. For instance, when daily flow rates are provided, the timing and concentration can be derived from this daily data resolution. In contrast, most metrics that quantify the strength of seasonality (Eq. 3-5) require binning the data into a longer time interval, typically per month (e.g., Feng et al., 2013; Wang et al., 2024; Oliver, 1980; Han et al., 2024). However, these approaches that rely on binning come with several limitations. First, the theoretical range of seasonality values depends on the binning timescale. Second, Eqs. 3-5 do not account for the sequential nature of the (binned) timeseries, which prevents unambiguous differentiation between short-term variability and seasonal variations. Third, selecting a binning interval length is inherently arbitrary, and, as just stated, this decision impacts both the attainable range of seasonality values and the degree to which the method captures short-term versus seasonal variations.

We exemplify such limitations based on a 15-minute hydrograph for one year. For this hydrograph, we aggregate data to daily, weekly, and monthly resolution and calculate the strength of seasonality using traditional methods (Eqs. 3-5) and using directional statistics (Eq. 8) (Fig. 3). We also highlight the potential range of the seasonality indices based on a constant flow regime and a flow regime where all flow occurs at one single time interval (indicated in parentheses in Fig. 3) and the seasonality compared to its theoretical maximum value (expressed in percentage). Note that for the entropy-based measure, stronger seasonality is associated with lower entropy values. A timeseries binned into longer intervals loses a part of its temporal variability and shifts its potential seasonality range (Fig. 3). As a result, the absolute and the relative inferred seasonality strengths shift depending on the binning. For some methods, these changes are very large (e.g., Eqs. 4), whereas for other methods changes are smaller (e.g. Eqs. 3 and 5). However, also in these latter cases, inferred seasonality strengths do not unambiguously differentiate between short-term variability and seasonal variations. Directional statistics are insensitive to these problems (and do not require binning) and thereby have relatively constant absolute seasonality and potential seasonality ranges, and quantify seasonal variations without the degree of short-term variations substantially affecting the inferred seasonality strength.

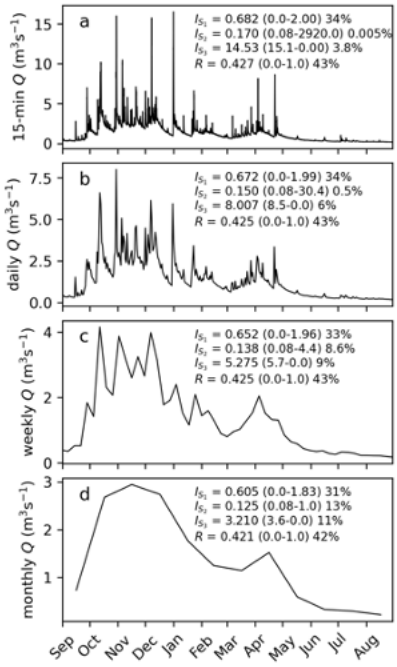

Figure 3. Effects of binning interval on inferred seasonality strength. An example hydrograph, given at 15-min (a), daily (b), weekly (c), and monthly (d) resolution and the values of the associated seasonality metrics (Eqs. 3-5, and Eq. 8) with their possible range indicated in parentheses (constant regime – most seasonal regime) and the seasonality compared to its theoretical maximum value (expressed as a percentage). This indicates that traditional seasonality metrics tend to be more sensitive to the binning process than directional statistics are. This sensitivity is present in the absolute value of seasonality strength, the values relative to their potential minimum and maximum, and the reference values determining the possible seasonality range. Note that binning is not required for directional statistics.