Response to Referee #2 Comments

I thank the reviewer for the careful and constructive evaluation of the manuscript. I appreciate the concerns regarding the statistical robustness and methodological framing of the original submission. In response, I have substantially strengthened the statistical analysis, clarified the interpretation of the results, and revised several parts of the manuscript accordingly.

Detailed responses to the individual comments are provided below. For convenience, all modifications introduced in the revised manuscript are highlighted in red in the marked-up version submitted together with this response.

Reviewer comment:

"This manuscript investigates the emergence of a dominant common mode in reservoir storage dynamics in Catalonia through principal component removal and pairwise correlation analysis. While the findings are of potential interest, I have considerable concerns regarding the academic depth and methodological rigor of the work, which in my view preclude its publication in a high-standard academic journal in its current form."

Response:

The revised manuscript now includes:

1. Explicit robustness tests with respect to the temporal breakpoint used for the pre/post analysis.
2. Additional robustness analyses using more restrictive minimum-overlap thresholds for the pairwise correlations.
3. Bootstrap-based uncertainty quantification and confidence intervals for the inter-basin correlation statistics.
4. A substantially clarified interpretation of the results emphasizing that the observed synchronization is largely captured by a dominant empirical common mode (PC1), rather than being interpreted as evidence for strong intrinsic inter-basin coupling.

These additions directly address the concerns raised by the reviewer and considerably strengthen the statistical foundation and interpretability of the study.

Reviewer comment:

"First, the relatively short common period used for the calculation of Pearson correlation coefficients — with a minimum of only 10 years — is not adequately acknowledged or discussed, despite the well-known sensitivity of correlation estimates to sample size."

Response:

I agree that the sensitivity of correlation estimates to sample length deserves explicit discussion. In the revised manuscript, I now clarify the rationale for the minimum-overlap criterion and explicitly acknowledge this limitation in the Methods section.

More importantly, I performed additional robustness analyses using more restrictive overlap thresholds of 15, 20, and 25 years. The qualitative behavior of the inter-basin synchronization patterns was found to remain stable across these alternative thresholds. In particular, the increase in post-1980s inter-basin correlations persists even when only substantially longer overlapping periods are retained.

These additional analyses indicate that the reported synchronization patterns are not driven by marginal overlaps or short coincident segments.

Reviewer comment:

"Second, the choice of 1986 as the change point for partitioning the full observational record into pre- and post-1986 periods appears arbitrary and lacks a transparent justification, whether statistical, physical, or historical in nature."

Response:

I appreciate this important observation and agree that the original manuscript did not sufficiently justify the temporal segmentation.

In the revised version, I now explicitly state that the year 1986 was not selected through an optimization procedure and should not be interpreted as a uniquely defined physical breakpoint. Instead, it was originally adopted as a representative transition year within a broader mid-1980s change region identified during exploratory analysis of the annual reservoir metrics.

To address the reviewer's concern quantitatively, I performed a systematic breakpoint robustness analysis in which the complete inter-basin synchronization analysis was repeated for alternative split years spanning the interval 1980--1992. The results show that the increase in inter-basin synchronization varies smoothly across this interval and does not depend critically on the exact choice of 1986.

The revised manuscript now presents the transition as a robust mid-1980s synchronization shift rather than as a singular breakpoint year.

Reviewer comment:

"Third, and perhaps most critically, the study does not report any assessment of the statistical significance of the results, nor does it provide any quantification of the associated uncertainties."

Response:

I fully agree that uncertainty quantification is essential.

In the revised manuscript, I therefore incorporated bootstrap-based uncertainty estimation for the inter-basin correlation statistics. For each metric and time interval, 2000 bootstrap realizations

were generated by resampling the inter-basin correlation distributions with replacement, and corresponding 95% confidence intervals were computed.

The bootstrap analysis confirms that the increase in inter-basin synchronization between the pre- and post-1986 periods exceeds the sampling uncertainty estimated from the bootstrap distributions, particularly for the annual mean reservoir levels and the fraction-of-days-below-40% metric.

In addition, I extended the bootstrap analysis to the PC1-removed datasets. These additional calculations show that a large fraction of the apparent increase in inter-basin synchronization is captured by the dominant empirical common mode represented by PC1. After removal of this common component, the residual synchronization increase becomes substantially weaker, especially for the moderate low-water metric. For the extreme low-water metric (<15%), the residual structure becomes more heterogeneous, indicating that the common mode masks additional basin-specific variability in the most severe drought conditions.

These new analyses considerably strengthen the statistical interpretation of the results and are now explicitly discussed in the revised manuscript.

Reviewer comment:

"Beyond the statistical concerns, I would strongly encourage the authors to consider incorporating an attribution analysis into the study."

Response:

I agree that attribution analysis would represent a valuable extension of the present work. However, the primary objective of this study is intentionally limited to the identification and characterization of empirical synchronization patterns directly from the observational reservoir dataset itself.

A rigorous attribution study would require the explicit incorporation of additional external datasets and methodologies, including meteorological fields, large-scale circulation indices, hydrological modeling, and/or operational water-management information. I believe that such analyses are important, but also sufficiently extensive to constitute a separate investigation beyond the scope of the present observational study.

To clarify this point, I have revised the manuscript to more carefully distinguish between empirical characterization and physical attribution. The revised manuscript therefore focuses on establishing a statistically robust empirical characterization of the observed synchronization patterns, while leaving causal attribution to future work.