Dear Wenbin Tang,

Thank you for your insightful question regarding the impact of the information granule merging operation. This step is a crucial design choice in our feature engineering pipeline, fundamentally aimed at transforming fragmented, noisy trend segments into meaningful representations of complete trend cycles while significantly enhancing computational efficiency and model interpretability. Below, we elaborate on its specific impacts on the construction of the 4×h-D feature space and its role in capturing key dynamic characteristics of the time series.

The initial granulation based on monotonicity and concavity-convexity often results in a large number of fine-grained information granules due to noise or minor fluctuations (e.g., small convex/concave variations within an overall rising/falling trend). While these granules locally approximate the series, they introduce significant redundancy and fail to represent holistic trend behavior. Critically, we observed that natural periodic patterns (e.g., annual SST variations) consistently manifest as sequences of concave-convex or convex-concave sub-cycles within a sustained monotonic phase. For instance, a complete warming trend typically comprises an initial concave segment (accelerating increase) followed by a convex segment (decelerating increase). Merging adjacent granules with identical monotonicity but opposing concavity-convexity consolidates these physically related sub-cycles into unified "macrogranules." Each macrogranule now represents a complete acceleration-deceleration phase of a monotonic trend, aligning directly with the intrinsic dynamics of geophysical variables (Fig.1).

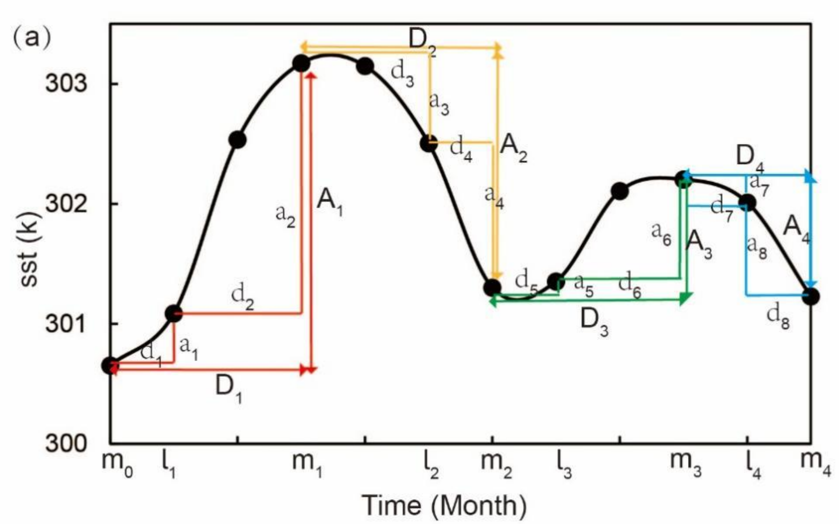

Fig.1 The interannual variation of monthly SST at 107.10°E, 17.45°N and the formation of its 4*h-D

feature space

This merging operation profoundly reshapes the $4 \times h$-D feature space. First, it achieves drastic dimensionality reduction: Each macrogranule replaces 2 or more original granules, substantially reducing the number of temporal units (h) per cycle (e.g., a 12-month cycle may yield 2 – 4 macrogranules instead of 4 – 8 initial segments). Consequently, the total feature dimensions ($4 \times h$) become far smaller than the original $3 \times N$ space (where $N>h$), mitigating the curse of dimensionality. More importantly, it enables feature semantic enrichment: The new features (A, D, C, F) derived from macrogranules encapsulate aggregate dynamic properties: Amplitude (A) represents the net change over the entire macrogranule (e.g., total SST rise/fall), quantifying cumulative trend strength. Duration (D) is the total time span, directly measuring trend persistence. Curvature (C) captures the global bending degree of the unified trend, distinguishing smooth (low |C|) vs. abrupt transitions (high |C|). Fluctuation (F) indicates the average rate of change (trend intensity).

These features replace redundant local descriptors (a, T, d) with holistic, physically interpretable metrics. The merging operation directly enhances the model ' s ability to capture key dynamic characteristics. First, it clarifies turning point identification: Macrogranule boundaries inherently align with true monotonicity reversal points (e.g., peak summer SST), as spurious splits from minor concavity changes are eliminated. Second, it explicitly quantifies trend persistence through D (long D = sustained trend) and characterizes trend shape through C and F. For example:A long-D, high-A, low-C macrogranule represents a sustained, near-linear trend. A short-D, high-C macrogranule signifies an abrupt nonlinear transition (e.g., rapid spring warming). Critically, the concave→convex (or convex→ concave) pattern within each macrogranule is abstracted into a single curvature metric (C), distilling acceleration-deceleration dynamics without fragmentation. Third, merging inherently suppresses noise by smoothing minor fluctuations that cause over-segmentation, enhancing feature robustness.

We sincerely thank you for this constructive suggestion. Your focus on the merging operation's rationale has allowed us to better articulate how it addresses fragmentation, reduces redundancy, and extracts physically interpretable descriptors (A, D, C, F). We will enhance it in revision, Thank you.