Artifact Suppression and the Need for Cleaned Q(t)

To ensure that the Coherence Quotient $Q(t)$ accurately reflects physically meaningful structure, several types of diagnostic artifacts must be addressed. Below, we explain the origin and impact of each, and why they were removed in the refined Q(t) implementation.

1. Thin Spectral Elements

Also referred to as *high-frequency filamentary noise* or *spurious thin structures*, these are narrow, thread-like high-gradient features in the velocity gradient field ∇u that do not correspond to coherent flow dynamics.

They distort the Fourier transform by amplifying high-frequency spectral components that should be suppressed by the cutoff k_c. As a result, they introduce artificial misalignment between ∇u and its coherent projection $A = P_{k_c} \nabla u$, which leads to a depressed value of $Q(t)$ even when the underlying flow is physically coherent.

2. Boundary Interpolation Artifacts

These artifacts occur near the edges of the spatial domain (e.g., near `lat_min`, `lat_max`, etc.) where fewer neighboring grid points are available for interpolation.

The resulting velocity field gradients become unstable or biased at these boundaries, inflating $\|\nabla u\|$ or introducing directional distortion. This in turn shrinks the inner product $\langle \nabla u, A \rangle$, falsely lowering the value of $Q(t)$.

3. Vertical Level Projection Error

When extracting data at a fixed isobaric level (such as 925, 850, or 700 hPa), the actual slice may not align with the most coherent part of the vortex structure—especially in the presence of vertical shear.

This issue is compounded by limited vertical resolution in reanalysis datasets. Misalignment between the true vortex core and the sampled gradient field reduces the effectiveness of the spectral filter, causing $Q(t)$ to reflect a falsely incoherent flow structure.

Summary of Terms Used

Issue	**Descriptive Term**
Thin, noisy features in ∇u	Filamentary spectral artifacts
Interpolation instability	Boundary-induced aliasing
Misrepresentation by pressure slice	Vertical mismatch error or level bias