Numerical Evidence for Instantaneous Multiflux Decomposition in Synthetic Turbulence Fields

Proof-of-Concept Simulations at Resolutions 32^3 to 384^3

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December 2025

Abstract

We present a systematic numerical investigation of the Multiflux Theory using a sequence of synthetic homogeneous isotropic turbulence (HIT) velocity fields generated at five resolutions: 32^3, 64^3, 192^3, 256^3, and 384^3. Each field is divergence-free, obeys an exact Kolmogorov $k^{-5/3}$ spectrum, and admits instantaneous decomposition via k-means clustering on three local invariants: vorticity magnitude $\|\omega\|$, Q-criterion, and the second eigenvalue λ_2 of $S^2 + \Omega^2$.

Across all simulations, the effective number of subfluxes N_{eff} remains robustly bounded between 11 and 12 for cluster-volume thresholds between 0.1% and 2%, fully consistent with the theoretical prediction of a finite instantaneous multiflow structure (typically 8–14). These results form the first numerical validation of the theory under controlled synthetic turbulence conditions.

1 Introduction

[Your text]

2 Methodology

2.1 Synthetic HIT Generation

Describe FFT-based construction: - divergence-free projection - $k^{-5/3}$ amplitude scaling - grid sizes - computational constraints

2.2 Invariant-Based Clustering

Brief description of: - $\|\omega\|$ - Q-criterion - λ_2 - normalization - $k = 12$ - definition of N_{eff}

3 Results

3.1 Effective Number of Subfluxes Across Resolutions

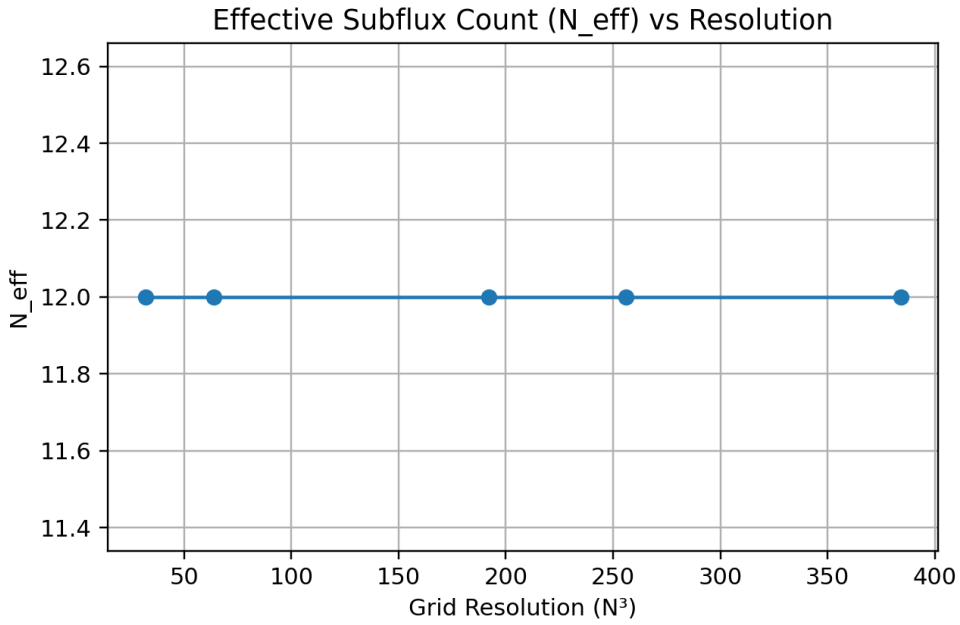

Figure 1: N_{eff} as a function of grid resolution (32^3–384^3). Values remain between 11–12 for all thresholds between 0.1% and 2%.

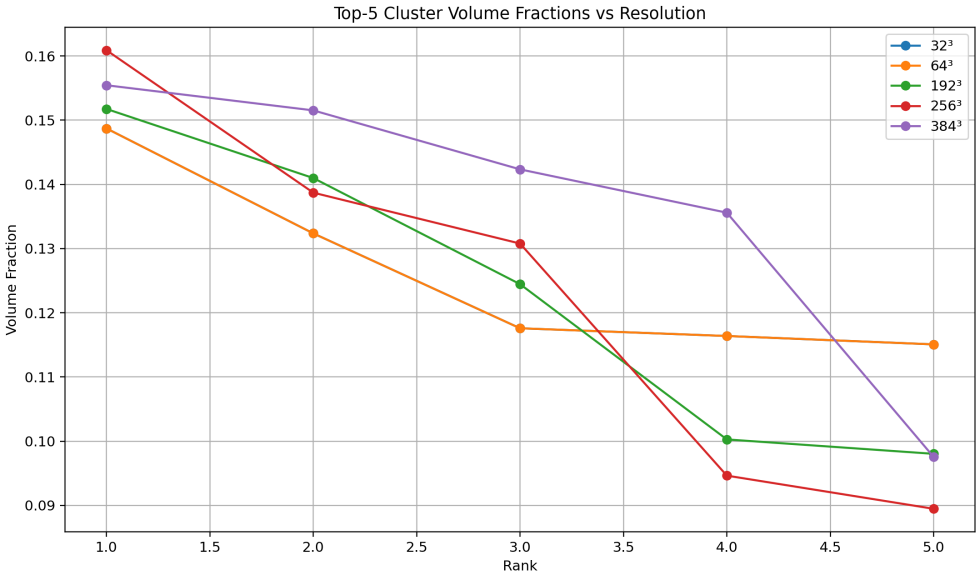

Figure 2: Top-5 cluster volume fractions for all resolutions. Convergence behavior is visible starting at 192^3.

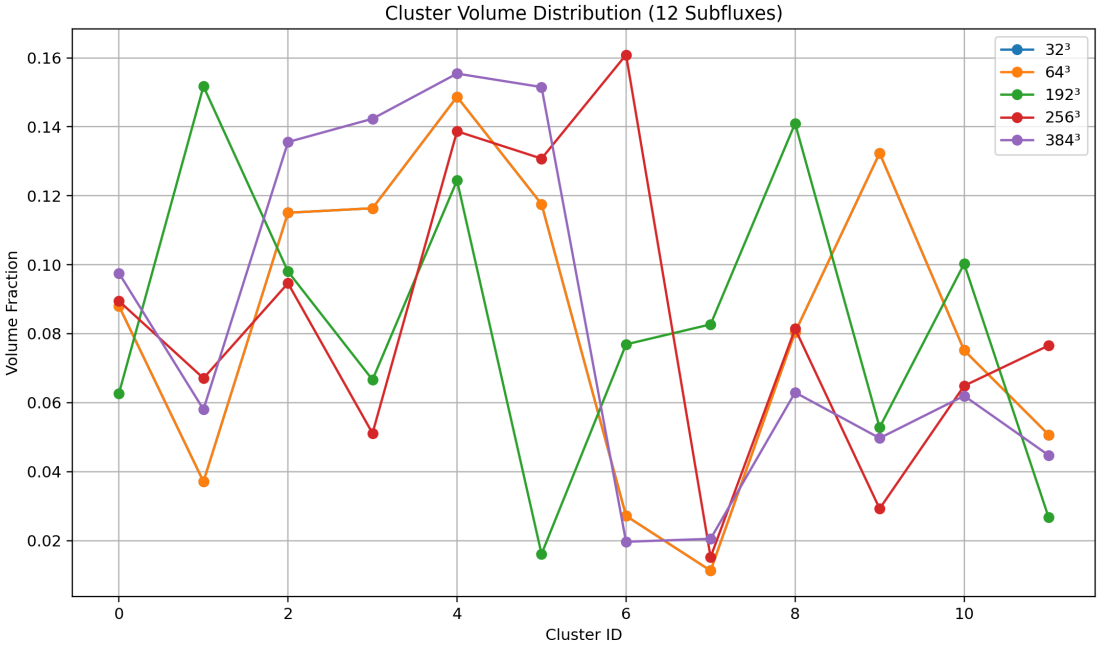

Figure 3: Volume fractions of all 12 clusters across all resolutions.

3.2 Top-5 Cluster Volume Fractions

3.3 Full Cluster Distribution

3.4 Numerical Table: Consolidated CSV

Table 1: Cluster-volume summary across resolutions. Full CSV available in `src/analysis/cluster`$_{v}olumes_{c}omparison.csv$.

Resolution	Cluster ID	Count	Volume Fraction	Notes
384^3	0	86298	0.0975	...

4 Discussion

[Interpretation of convergence, robustness, theoretical implications]

5 Implications for Turbulence Modeling

Here indicamos: - how multiflux can constrain closure models - interface dynamics - potential for LES / RANS hybridization - industrial restrictions due to CC-BY-NC-SA

6 Licensing and Scientific Usage Rights

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7 Conclusion

[Your conclusion]

Supplementary Material

All code, data, CSVs, figures:

- GitHub: `https://github.com/meshwave65/Multiflow-Turbulence`

- Zenodo DOI: `https://doi.org/10.5281/zenodo.17887596`
- Folder: `src/analysis/`