§36. Localization of the Nonlinear Energy Transfer during Vortex Rolling-up Process

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Orthonormal divergence-free wavelet analysis of nonlinear transfer in some isolated vortices has revealed that the rolling-up process of vortices are relevant to the energy cascade to smaller scales though their detailed statistical features have not studied yet.[1)2)]

Comparison between the spatial distribution of wavelet *energy* spectrum $E_{j\vec{l}} = \frac{1}{2}\int |\boldsymbol{u}_{j\vec{l}}|^2 dV$ (Fig.1) and that of wavelet *nonlinear energy transfer* spectrum $\langle j'|\boldsymbol{u}|j\vec{l}\rangle = -\int \boldsymbol{u}_{j'} \cdot ((\vec{u}\cdot\nabla)\boldsymbol{u}_{j\vec{l}})dV$ (Fig.2) clearly shows that the latter has more localized features. This seems to suggest that the nonlinear transfer process of rolling-up vortices tend to enhance more and more localized or 'intermittent' features of coherent structures because the nonlinear transfer does not occur uniformly in coherent structures but in their small portions.

In order to evaluate the inhomogeneity of spatial distribution of nonlinear transfer intensity we plot the Lorenz curve of the ensemble of $\langle 5|\boldsymbol{u}|4,\vec{l}\rangle$ at the time t = 15.0, 17.5, 20.0 (see Fig.3). The curves tend to get close to the vertical line at $x = 1$ as the time goes. This implies that the nonlinear energy transfer is relatively more intensified in some narrow region. It is very interesting that the enhancement of inhomogeneity is more distinct for the nonlinear transfer distribution than the energy distribution.

1). K. Araki, H. Miura, "Orthonormal divergence-free wavelet analysis of nonlinear transfer process in rolling-up vortex sheets", Annual Report of National Institute for Fusion Science, April 2006-March 2007, p.382.

2). Keisuke Araki and Hideaki Miura, "Orthonormal divergence-free wavelet analysis of cascading/backscattering process around coherent structures", in ADVANCES IN TURBULENCE XI Proceedings of the 11th EUROMECH European Turbulence Conference, Springer, p.768.

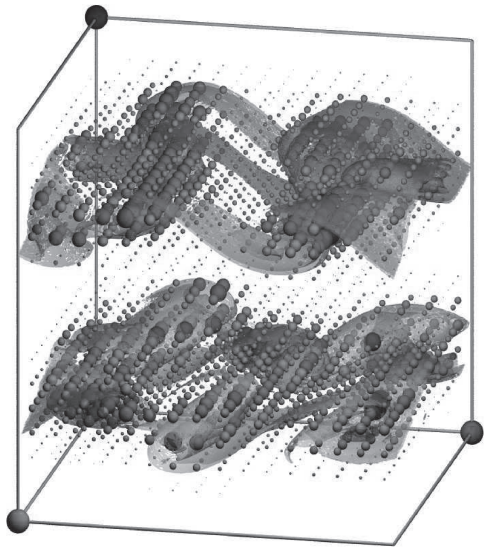

Fig.1. Distribution of scale-location wavelet energy spectrum $E_{4\vec{l}}$ together with enstrophy density isosurfaces.

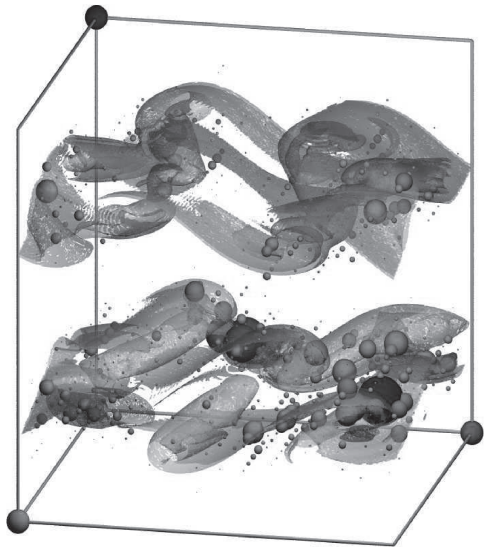

Fig.2. Spatial distribution of scale-location wavelet spectrum of the nonlinear energy transfer $\langle 5|\boldsymbol{u}|4\vec{l}\rangle$.

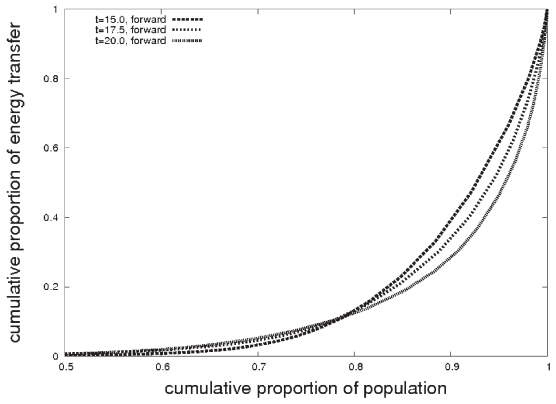

Fig.3. Lorenz curve of cumulative portion of $\langle 5|\boldsymbol{u}|4\vec{l}\rangle$ at t = 15.0, 17.5, 20.0.