

# Turbulent Flows

Stephen B. Pope

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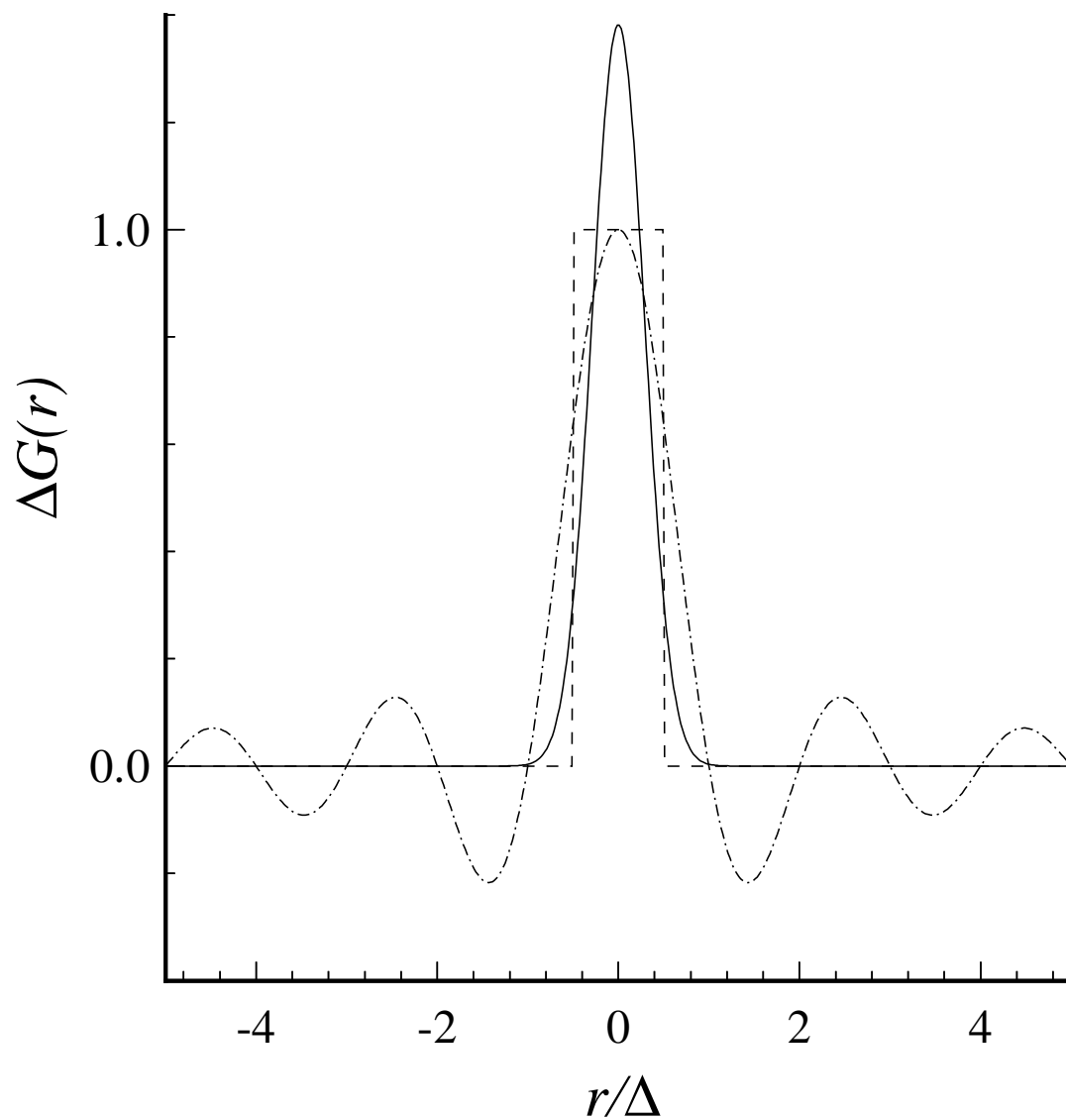


Figure 13.1: Filters  $G(r)$ : box filter, dashed line; Gaussian filter, solid line; sharp spectral, dot-dashed line.

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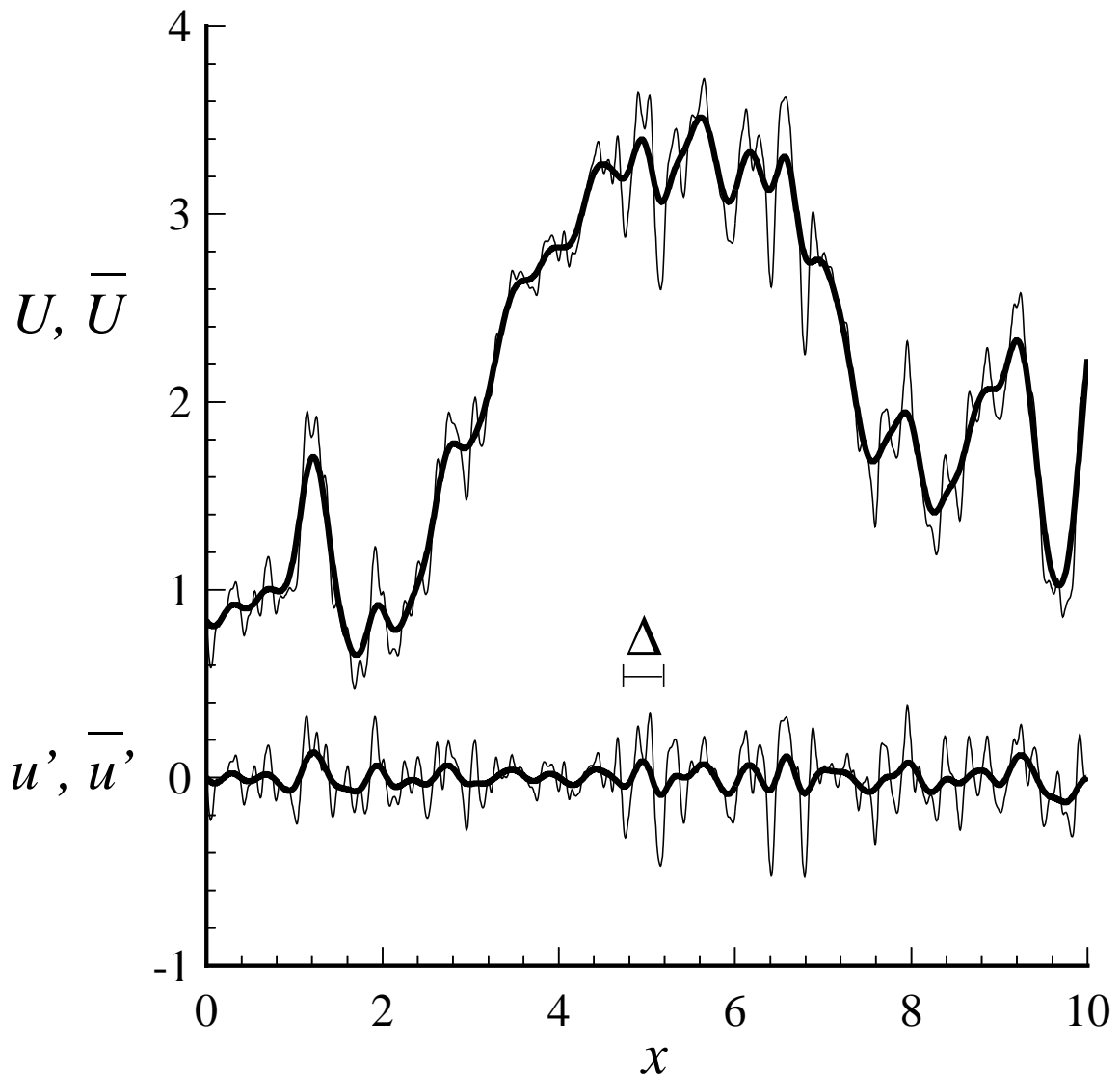


Figure 13.2: Upper curves: sample of velocity field  $U(x)$  and the corresponding filtered field  $\bar{U}(x)$  (bold line), using the Gaussian filter with  $\Delta \approx 0.35$ . Lower curves: residual field  $u'(x)$  and the filtered residual field  $\bar{u}'(x)$  (bold line).

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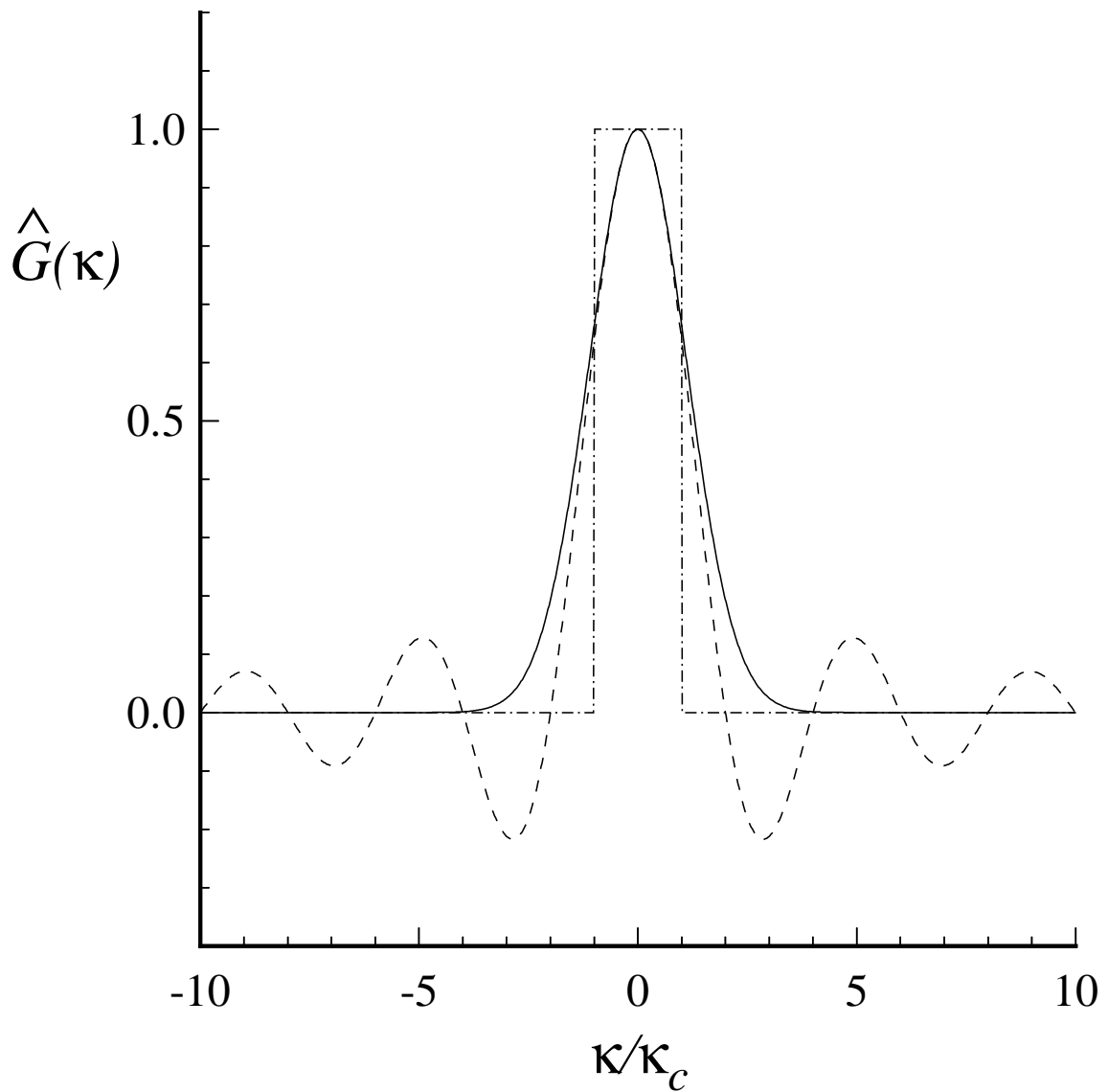


Figure 13.3: Filter transfer functions  $\hat{G}(\kappa)$ : box filter, dashed line; Gaussian filter, solid line; sharp spectral filter, dot-dashed line.

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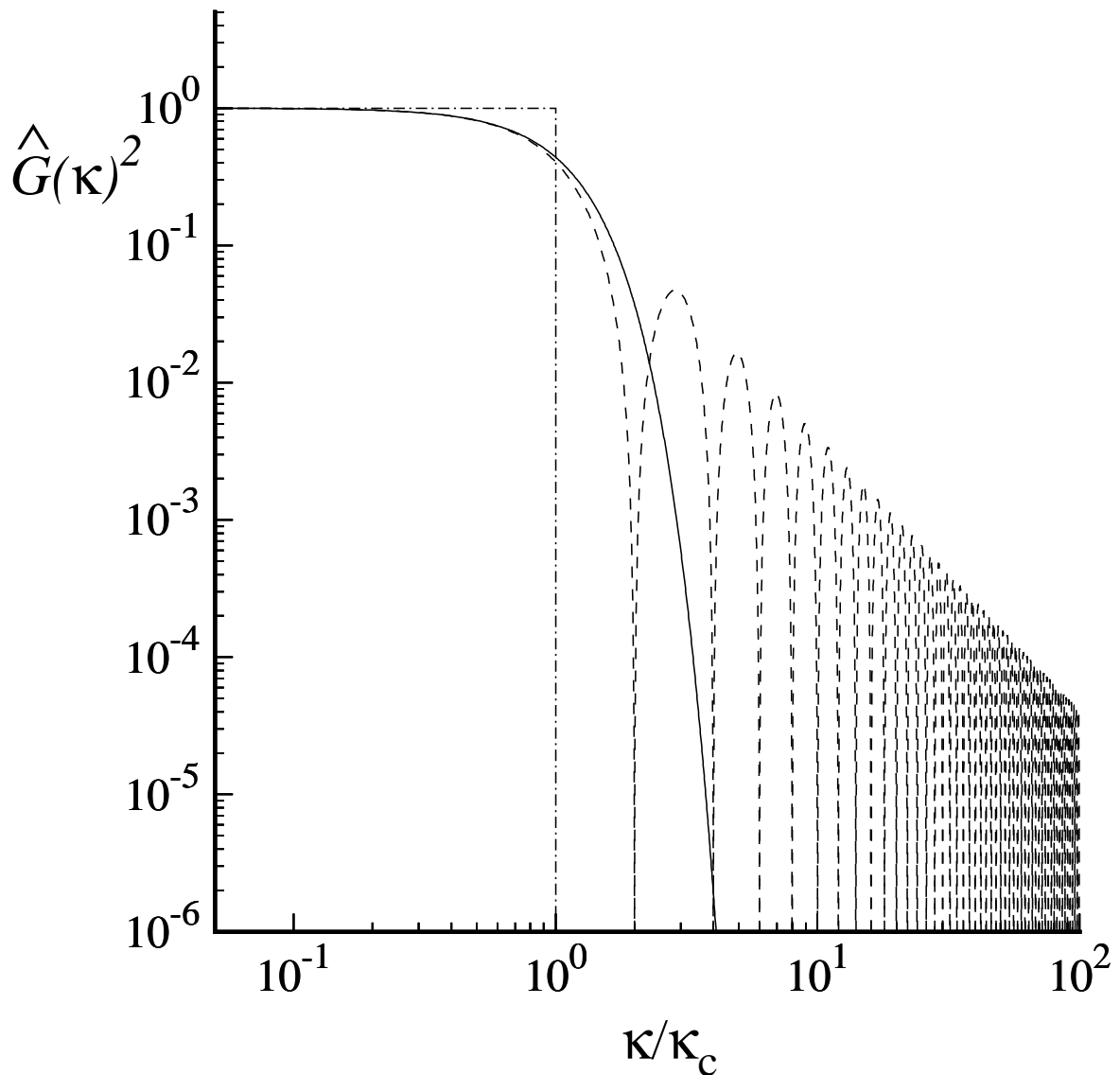


Figure 13.4: Attenuation factors  $\hat{G}(\kappa)^2$ : box filter, dashed line; Gaussian filter, solid line; sharp spectral filter dot-dashed line.

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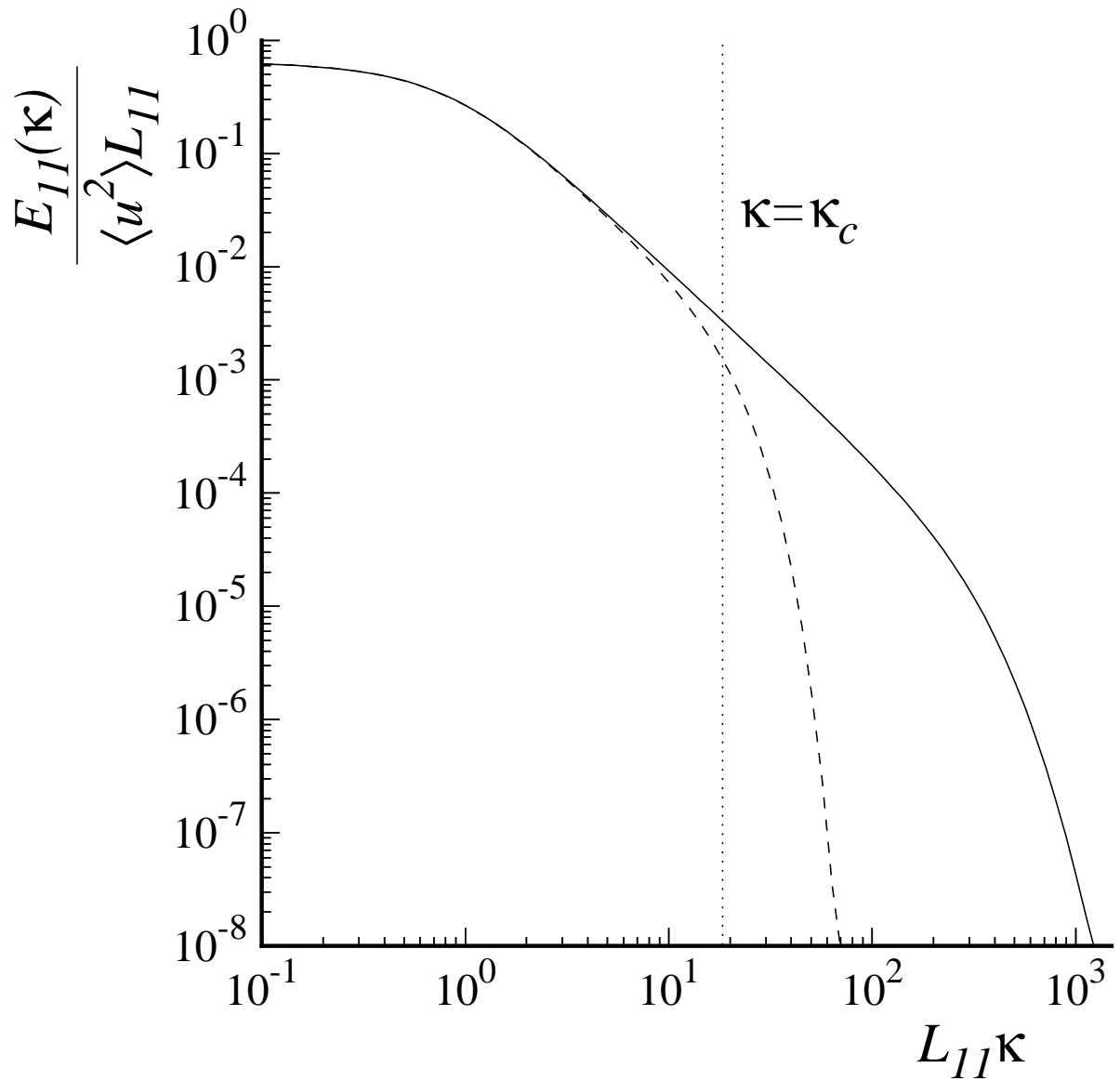


Figure 13.5: One-dimensional spectrum  $E_{11}(\kappa)$  (solid line) obtained for the model spectrum at  $R_\lambda = 500$ ; and the filtered spectrum  $\bar{E}_{11}(\kappa)$  (dashed line) obtained using the Gaussian filter with  $\Delta = \frac{1}{6}L_{11}$ .

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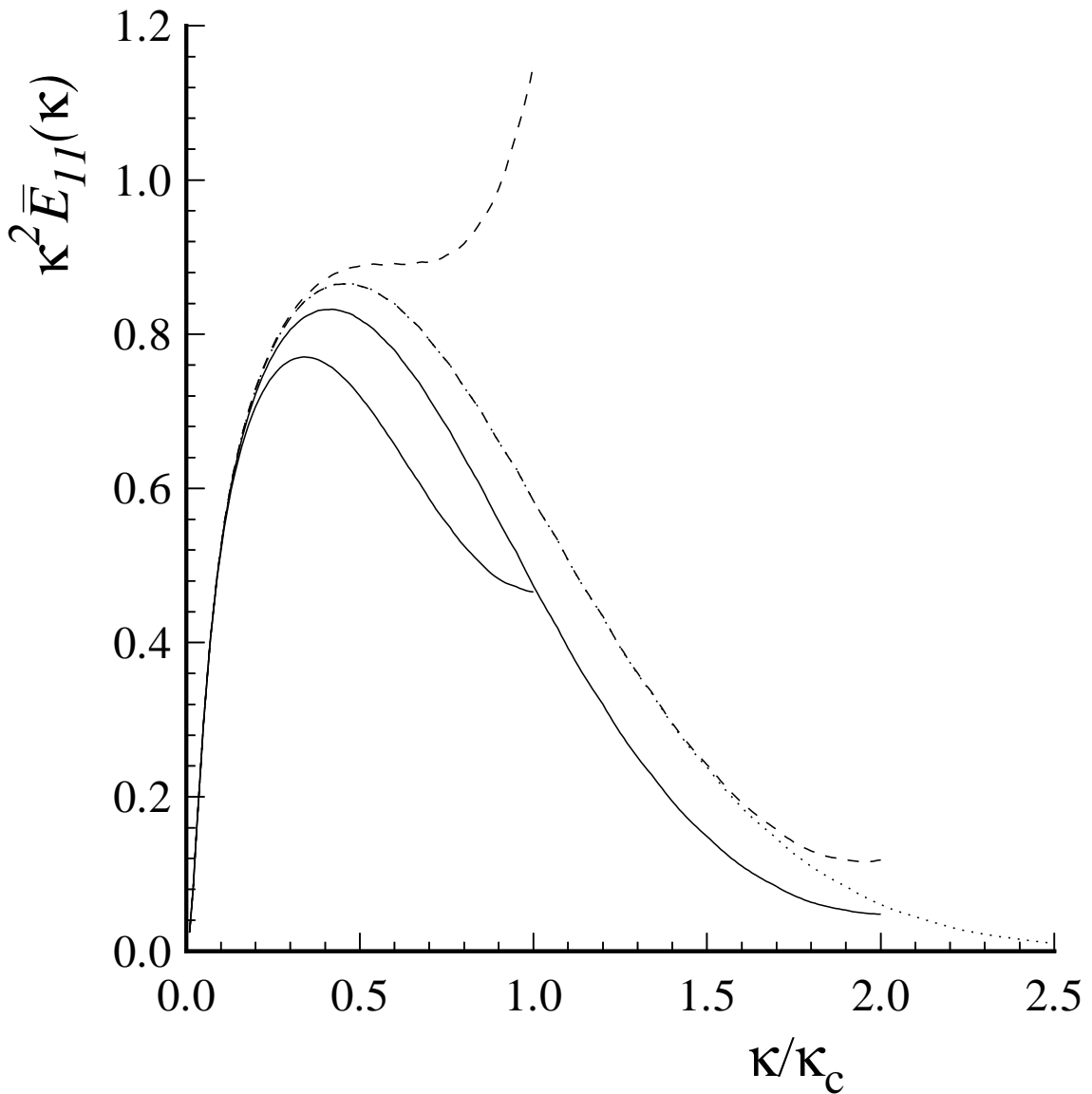


Figure 13.6: Spectrum of  $d\bar{u}(x)/dx$ ,  $\kappa^2 \bar{E}_{11}(\kappa)$  (dotted line); aliased spectra  $\kappa^2 \tilde{E}_{11}(\kappa)$  for  $h/\Delta = \frac{1}{2}$  and 1 (dashed lines); and the spectra  $\tilde{D}_h(\kappa)$  (Eq. 13.57) of the finite-difference approximation to  $d\tilde{u}/dx$  (Eq. 13.56) for  $h/\Delta = \frac{1}{2}$  and 1 (solid lines). For the model spectrum ( $P_{11} = 500$ ) and the Gaussian filter. (The spectra

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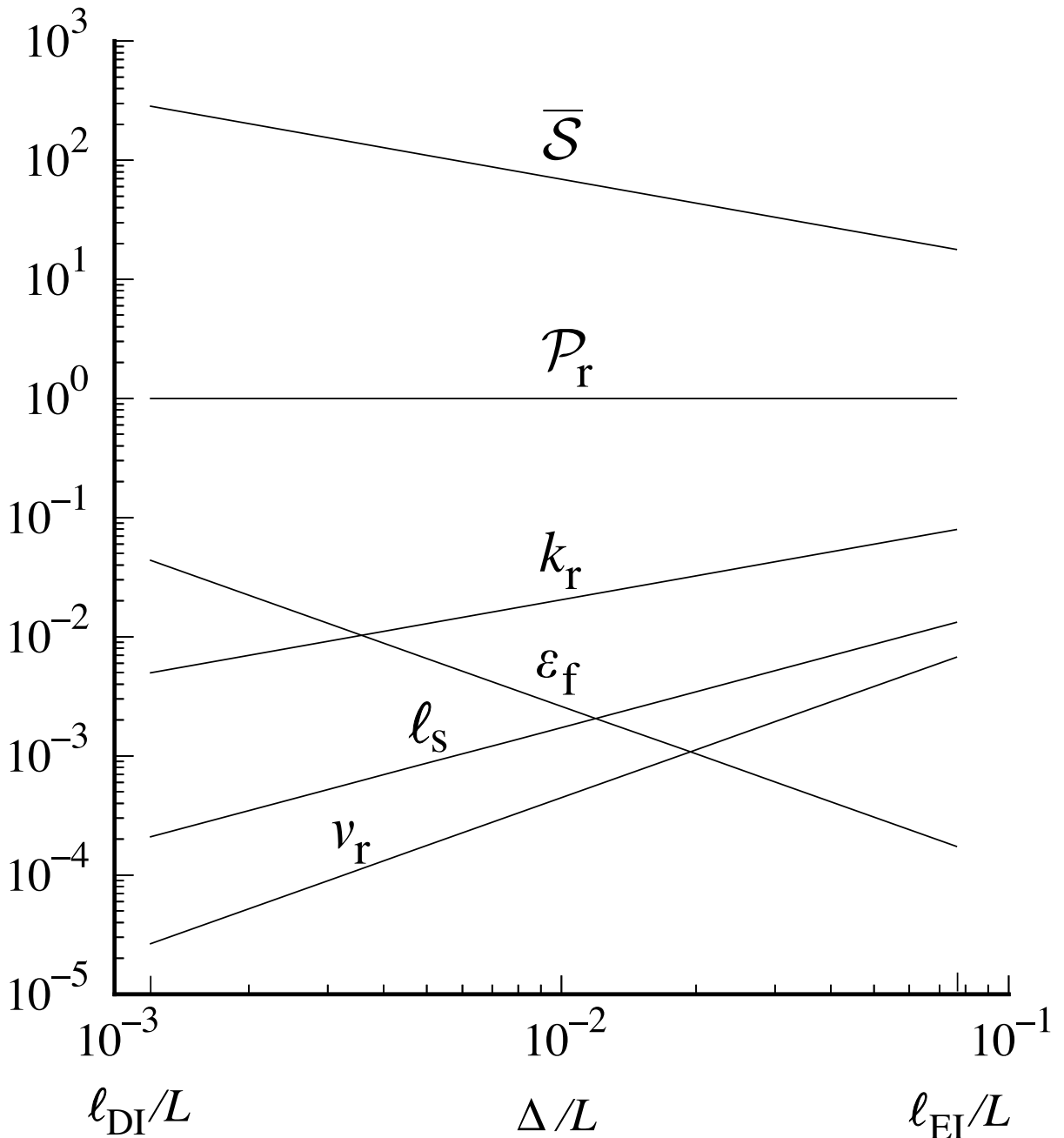


Figure 13.7: Estimates of normalized filtered and residual quantities as functions of filter width  $\Delta$  for the sharp spectral filter in the inertial subrange of high Reynolds number turbulence. The nor

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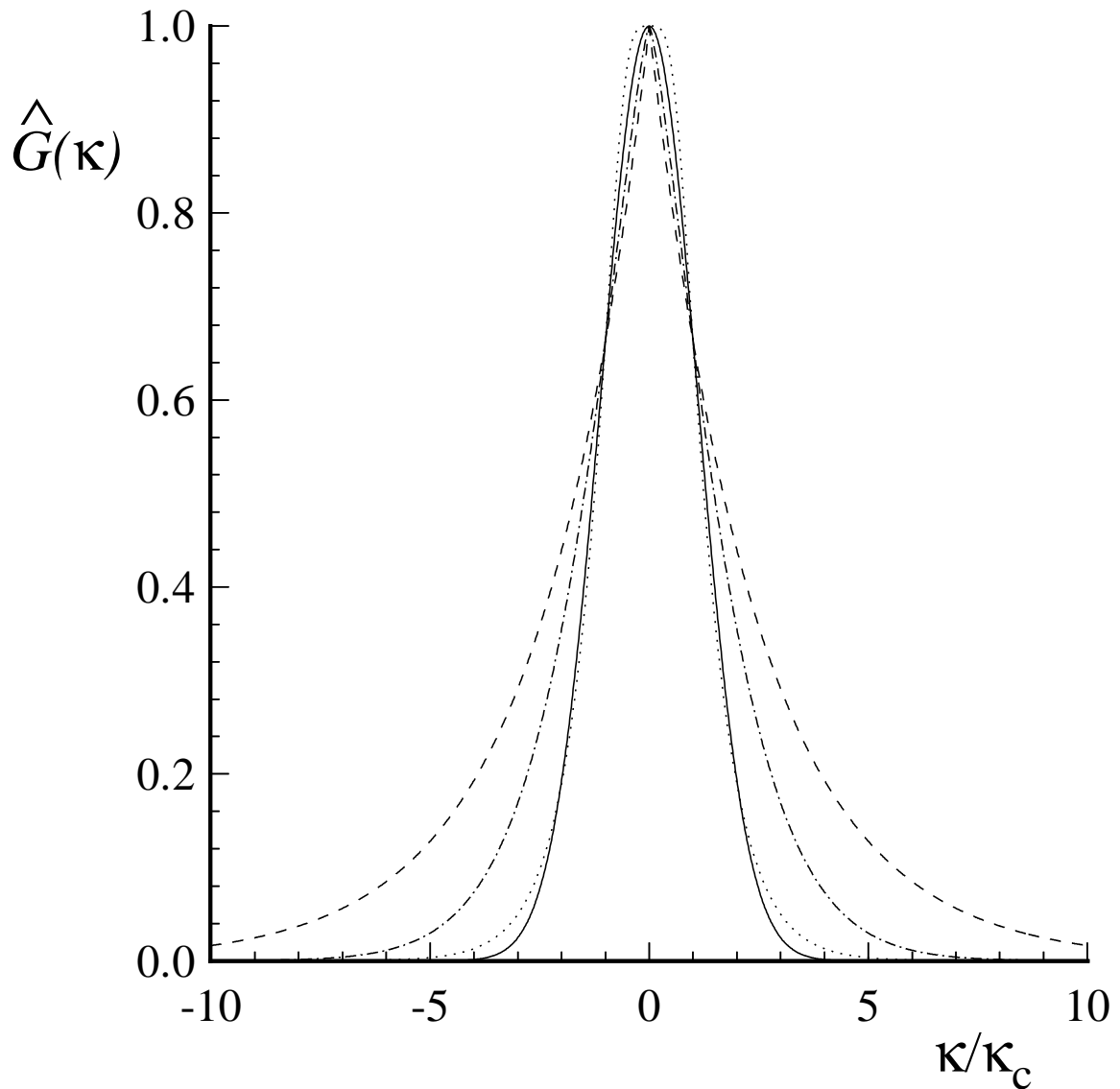


Figure 13.8: Filter transfer functions: Gaussian, solid line; Cauchy, dashed line; Pao, dot-dashed line; implied by model spectrum (Eq. 13.150), dotted line.



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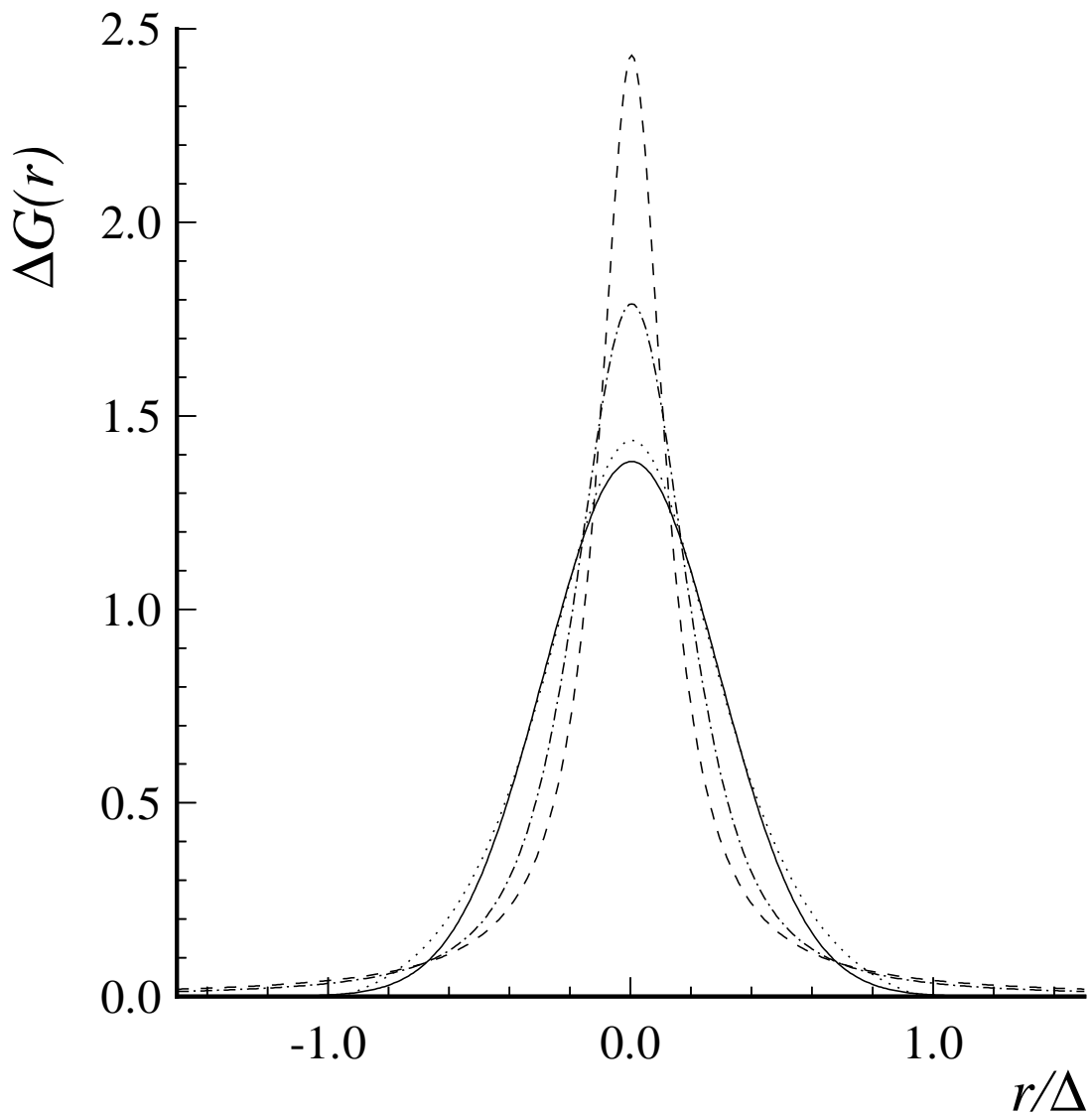


Figure 13.9: Filter functions: Gaussian, solid line; Cauchy, dashed line; Pao, dot-dashed line; implied by model spectrum (Eq. 13.150), dotted line.

CHAPTER 13: LARGE EDDY SIMULATION

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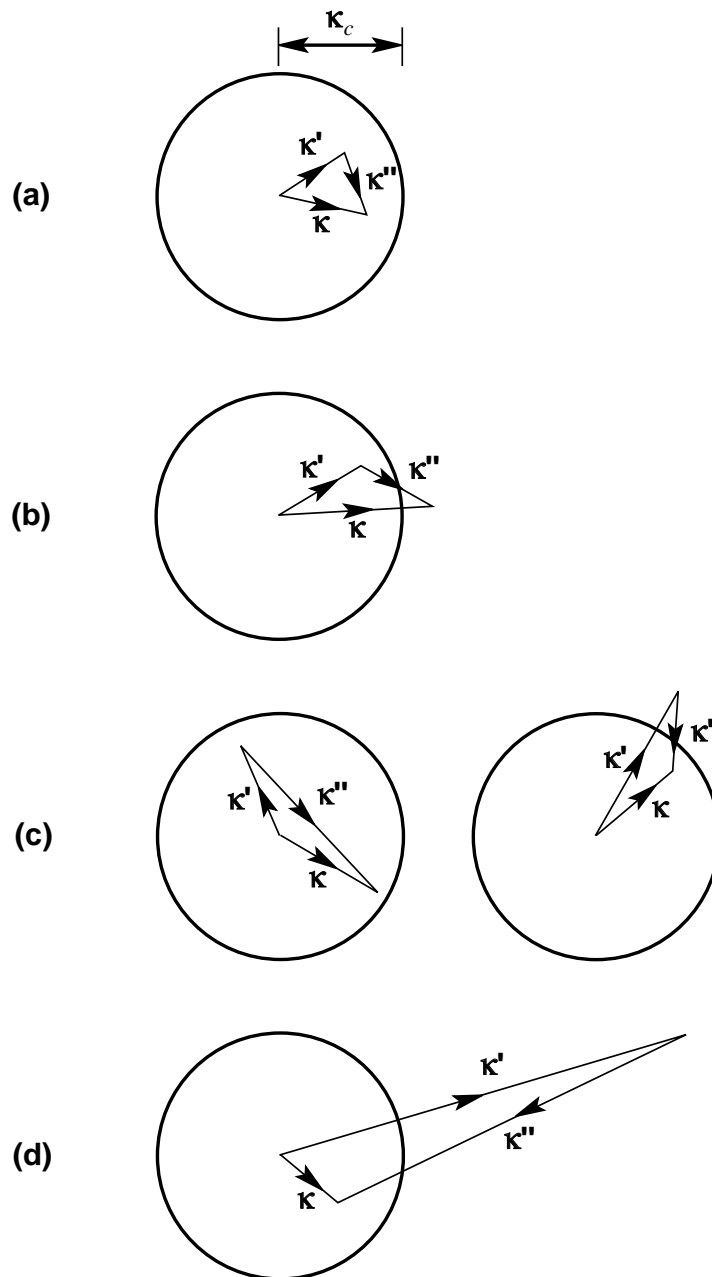


Figure 13.10: Sketch of the different types of wavenumber triad interactions defined in Table 13.4. (a) Resolved (b) Leonard (c) Cross (d) SGS.

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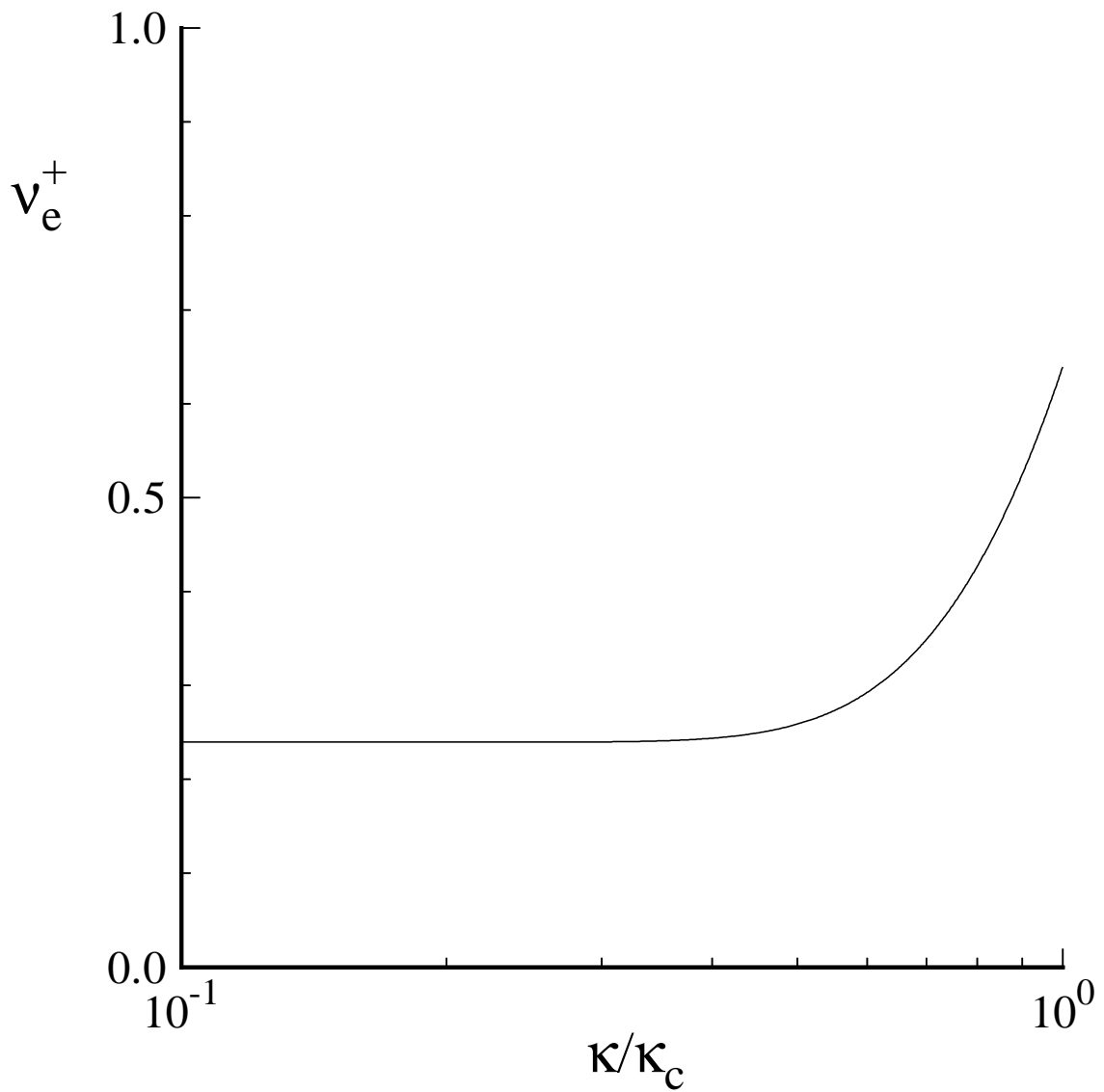


Figure 13.11: The non-dimensional spectral viscosity  $\nu_e^+(\kappa|\kappa_c)$ , Eq. (13.216).

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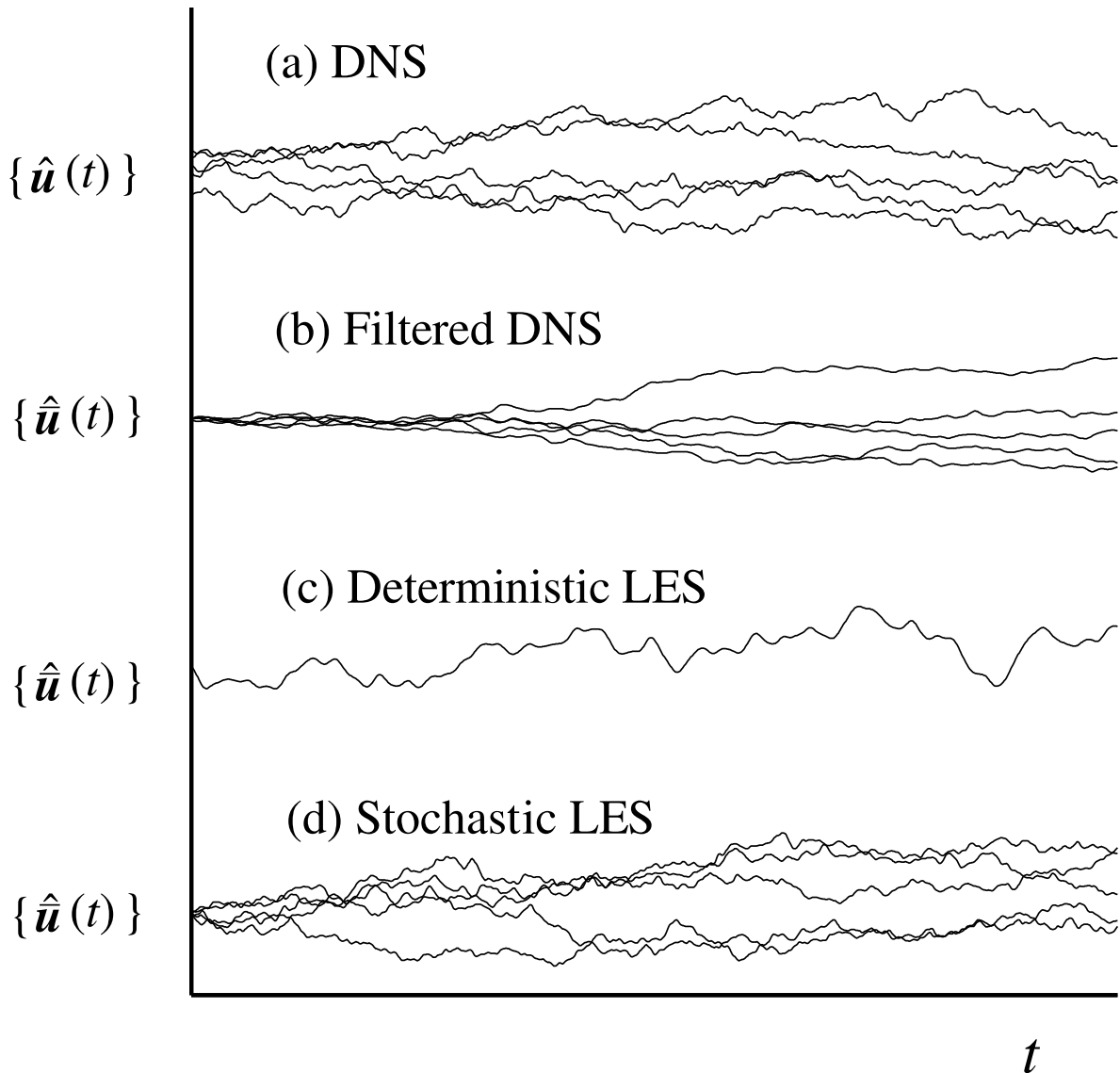


Figure 13.12: Sketch of DNS and LES sample paths for simulations of isotropic turbulence: (a) DNS,  $\{\hat{\mathbf{u}}(\boldsymbol{\kappa}, t)\}$  (b) filtered DNS,  $\{\hat{\mathbf{u}}(\boldsymbol{\kappa}, t)\}$  (c) LES with a deterministic residual-stress model,  $\{\hat{\mathbf{u}}(\boldsymbol{\kappa}, t)\}$  (d) LES with a stochastic backscatter model,  $\{\hat{\mathbf{u}}(\boldsymbol{\kappa}, t)\}$ . The paths in (a) are in the  $N_{SSDNS}^3$ -dimensional state space; those in (b)–(d) are in the  $N_{SSLES}^3$ -dimensional state space.

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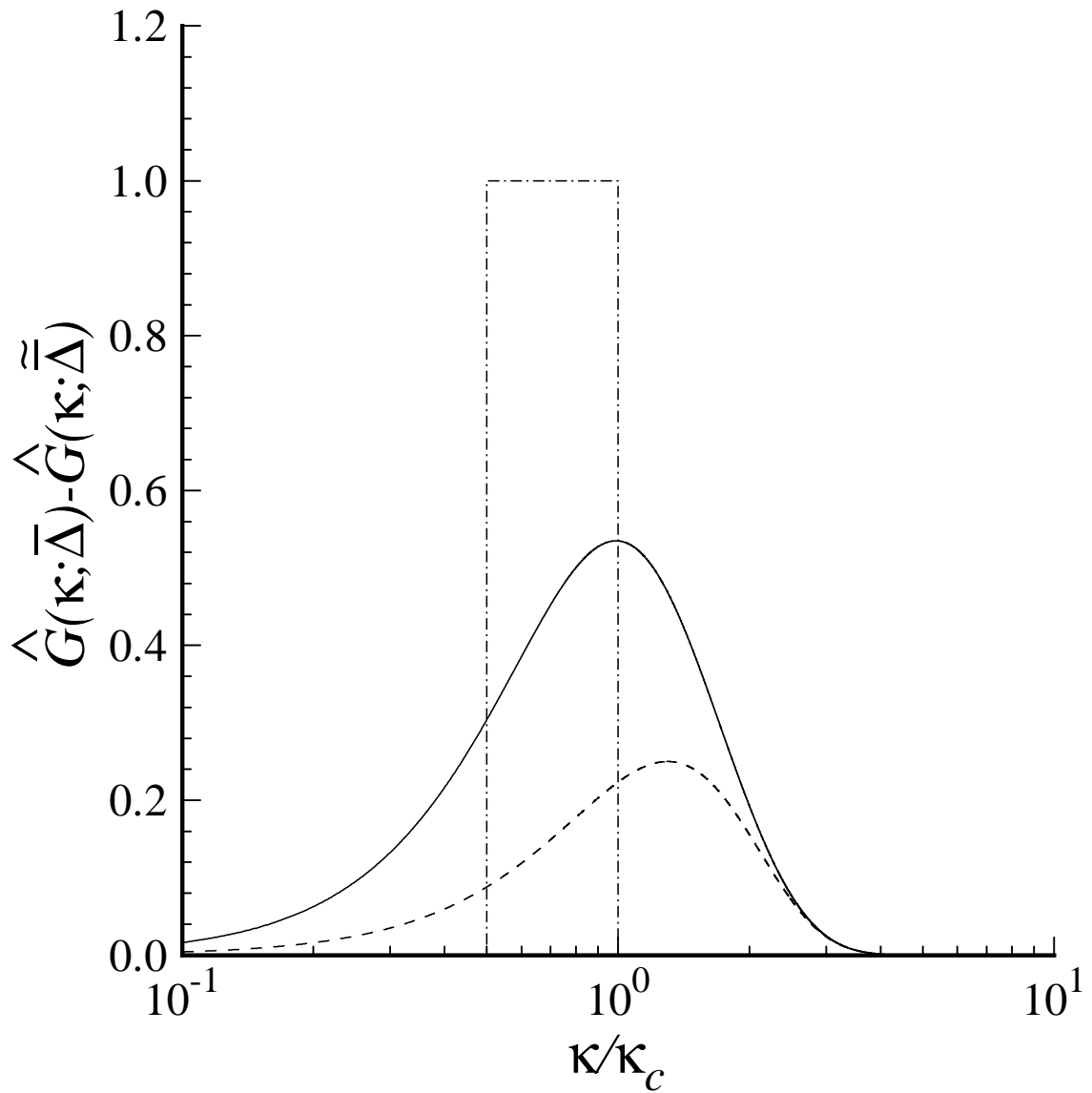


Figure 13.13: Filter transfer function differences corresponding to the smallest resolved motions. Solid line, Gaussian filter with  $\tilde{\Delta} = 2\bar{\Delta}$ ; dot-dashed line, sharp spectral filter with  $\tilde{\Delta} = 2\bar{\Delta}$ ; dashed line, Gaussian filter with  $\tilde{\Delta} = \bar{\Delta}$ .