GREYBLS: modelling GREY-zone Boundary LayerS

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- The convective boundary layer (scales 1-3 km) is partially resolved, but not a full Large-eddy simulation (LES).
- Wyngaard (2004) called this "terra-incognita" but also called the "grey zone".
- Currently little theoretical and numerical modeling basis for representing the boundary layer in the grey zone.

The grey zone

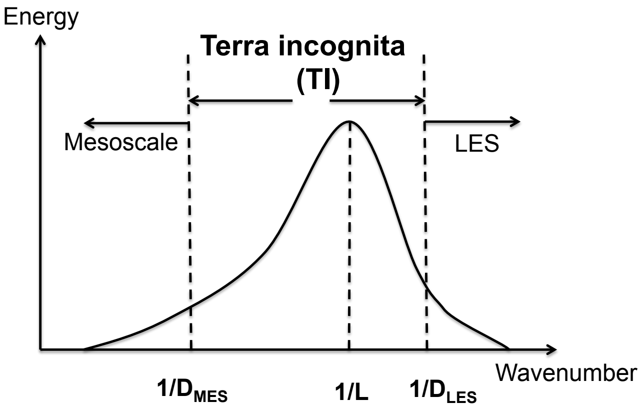

Figure: Schematic illustrating the terra-incognita. Plotted is the energy spectrum against total horizontal wavenumber. L is the length scale of the boundary layer turbulence, and D_{MES} and D_{LES} are the grid-lengths associated with a Mesoscale and LES simulation respectively.

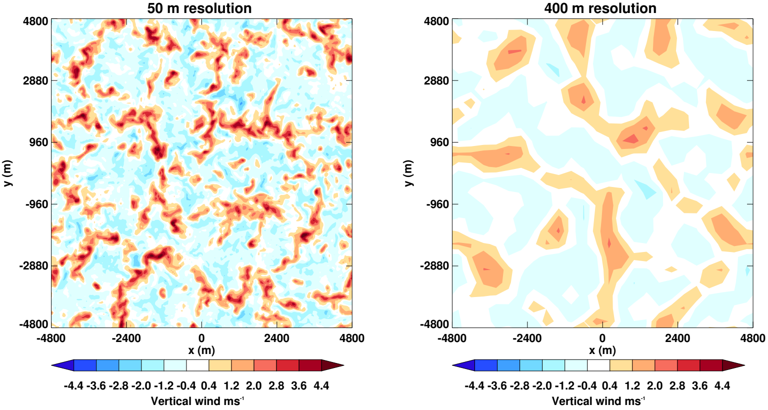

Figure: Horizontal cross-sections of vertical velocity from convective boundary layer simulations at a height 500 m for horizontal grid lengths of 50 m (left) and 400 m (right). For this boundary layer (depth 1 km), the 400 m grid length is in the grey zone. Taken from Beare (2014).

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- Aim: devise a scaling which accounts for *both* the sub-grid model *and* the advection scheme.

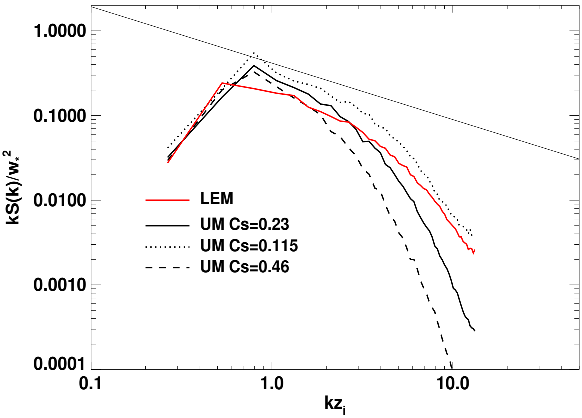

Figure: Normalised vertical velocity power spectra (averaged between hour 1 and 2) at height 1 km for 50 m horizontal resolution dry convective boundary layer runs. Thin line is the inertial subrange -2/3 power law. The wavenumber (k) is defined as 1/wavelength. $z_i = 1325m$ is the inversion height of the control simulation and w_* is the convective boundary layer velocity scale. Beare et al 07 MetO internal report.

Dissipation length scale- Beare (2014)

- The dissipation associated with an infinite spectrum with molecular viscocity, ν, is

$$\epsilon = 2\nu \int_0^\infty k^2 S_e(k) dk. \tag{1}$$

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- Using this insight, we define a dissipation wavenumber (k_d) for a finite spectrum which also scales with this integral.

$$k_d^2 = \frac{\int_{k_0}^{k_1} k^2 S_e(k) dk}{\int_{k_0}^{k_1} S_e dk}, \tag{2}$$

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- The dissipation length scale is then

$$l_d = \frac{2\pi}{k_d}, \quad (3)$$

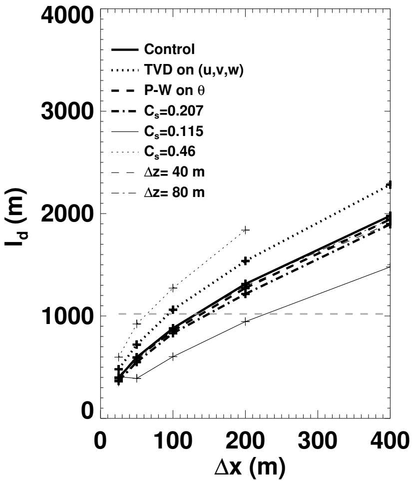

Figure: The dissipation length scale (l_d) plotted against horizontal grid length, evaluated at height 500 m. Beare (2014).

WP2: Novel sub-grid models

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WP3: A grey-zone boundary-layer scheme for the MetUM

The findings of WP1 could lead to a blending scheme of the form:

$$\frac{D\theta}{Dt} = \overbrace{[1-\alpha(\Delta)]\frac{\partial}{\partial z}\left(K_h\left[\frac{\partial \theta}{\partial z} - \gamma\right]\right)}^{\text{COLUMN}} + \overbrace{\alpha(\Delta)\frac{\partial \mathcal{H}_j}{\partial x_j}}^{\text{SMAGORINSKY}} \quad (4)$$

From WP2- A prototype hybrid dynamic/stochastic scheme of the form:

$$\frac{D\theta}{Dt} = \overbrace{\frac{\partial \mathcal{H}_j}{\partial x_j}}^{\text{DYNAMIC}} + \overbrace{\mathcal{B}_\theta,}^{\text{BACKSCATTER}} \quad (5)$$

where $\mathcal{B}_\theta$ is the stochastic back scatter.

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- Met Office partners: Adrian Lock and Humphrey Lean

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