Department of Meteorology

The Hi-Fi project: a new turbulence scheme for Large-Eddy Simulation of grey zone parametrization

Yuqi Bai[1], Peter Clark[1], Bob Plant[1], George Efstathiou[2], Bob Beare[2], Dimitar Vlaykov[2]

1. Department of Meteorology, University of Reading
2. Department of Mathematics and Statistics, University of Exeter

What is “Hi-Fi” and why?

- The “novel closure for **Hi**gh-**Fi**delity Numerical Weather Prediction” project is a subproject under the NERC/Met office project: **Parachute**
- The Hi-Fi project’s objective is to develop an improved turbulent scheme for parameterising sub-km scale turbulence to provide more accurate forecasts of extreme weather events
- The outputs of the project will be implemented in the Met Office Unified Model (UM).

Large Eddy Simulation

- Turbulent scheme based on spatial filtering of fields; coherent structures are well resolved
- Spectra approach down to grid-scale + parametrisation at sub-grid-scale

“Terra incognita”: the grey zone

- In the “grey zone”, usually in sub-km range modelling resolution, neither of the traditional approaches for the treatment of unresolved motions is appropriate
- Evidence has shown that further grid refinement to sub-kilometric resolutions does not always result in a continued improvement in forecasting ability[1]
- The sub-grid scale turbulent properties needs to be parameterised appropriately

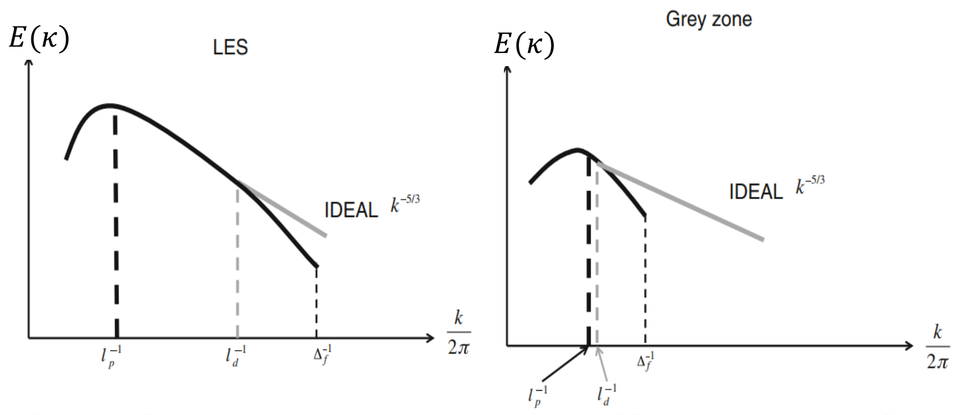
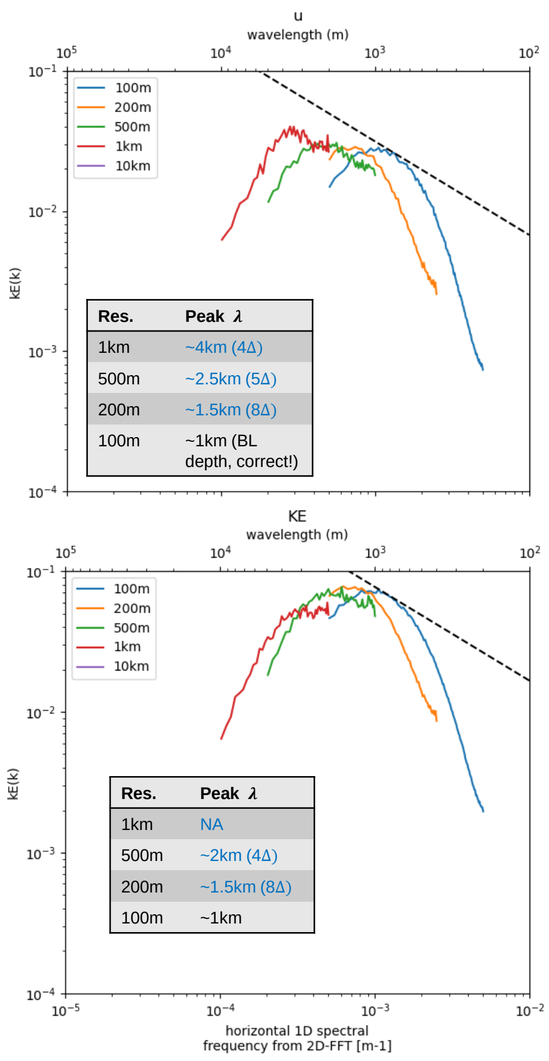


Figure 1. Schematics of turbulent energy spectra of LES and in the grey zone**[2].**

Exemplar Problem: Idealised CBL on L100 vert, LEM+ Smag



Res.	Peak λ
1km	~4km (4Δ)
500m	~2.5km (5Δ)
200m	~1.5km (8Δ)
100m	~1km (BL depth, correct!)

Res.	Peak λ
1km	NA
500m	~2km (4Δ)
200m	~1.5km (8Δ)
100m	~1km

Res. :	10 km	1 km	500 m	250 m	200 m	100 m
Timestep :	300 s	30 s	15 s	6s	6s	3 s
Pts. (x,y):	(64,64)	(128, 128)	(128,128)	(128,128)	(128,128)	(256,256)
Domain:	640 km	128 km	64 km	32 km	25.6 km	25.6 km

From Figure 2 Summary:

- Horizontal velocity shows typical grey-zone spectra with resolution higher than 1km; inertial subrange with -2/3 exponent
- 3-D total kinetic energy spectra, on the other hand, only shows inertial subrange in resolution higher than 500m;
- For high resolution (200m,100m), u-spectra is similar to KE spectra (isotropy?)

However from Figure 3:

- Buoyancy production of KE of all resolutions higher than 1km are same order of magnitude; 200m and 100m are identical
- Despite surface layer and cap improving, SGS TKE need better parametrisation than standard Smagorinsky even with 100m resolution

Note current UK NWP has 1.5 km resolution, global ~10 km!

Figure 2. Horizontal 2-D spectra of horizontal velocity (top) and explicit kinetic energy (bottom) at z=500m, averaged over 4h after 2h of spinning up.

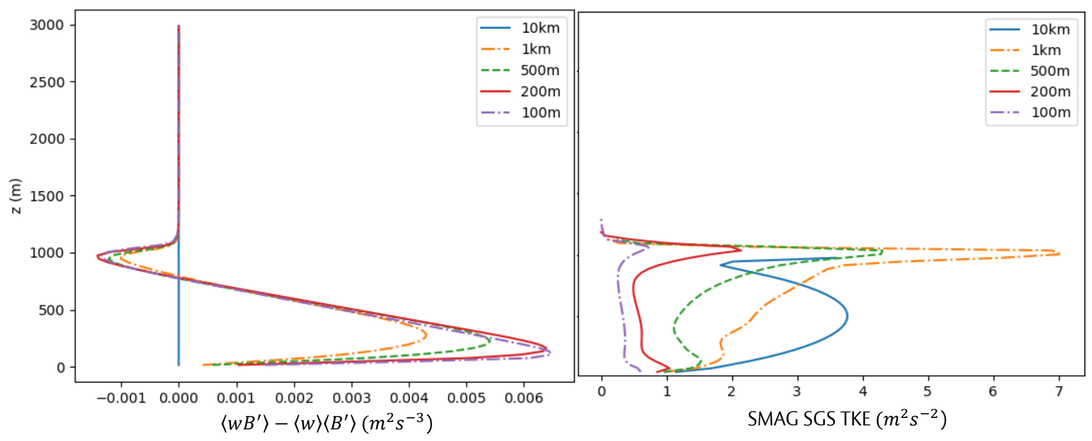
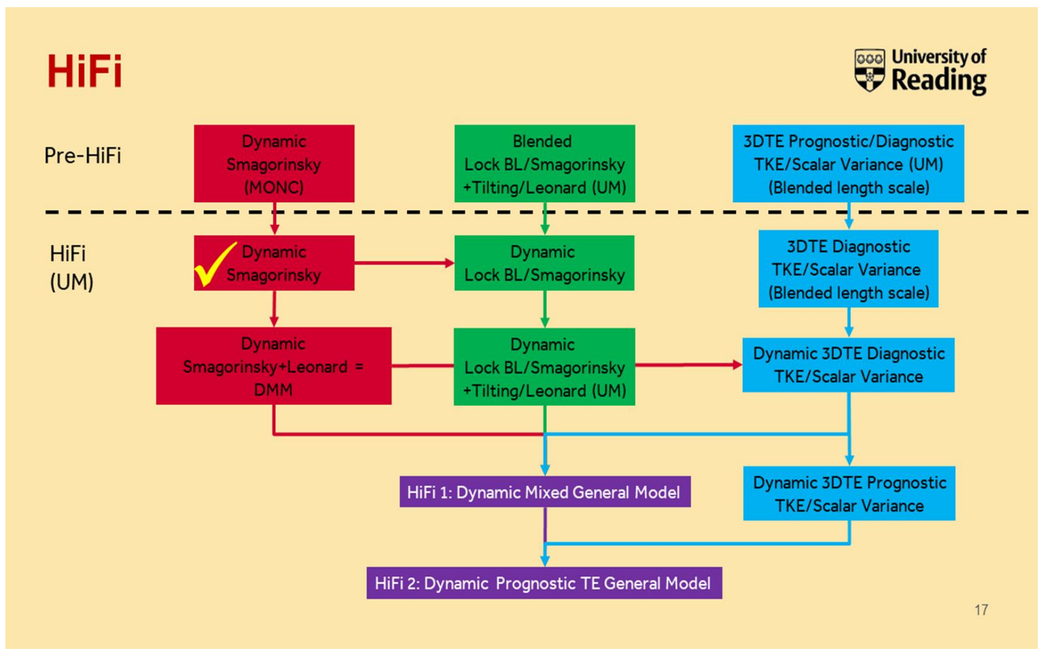


Figure 3. Horizontal profile of hourly mean, horizontal averaged buoyancy production rate of KE (left) and Smagorinsky sub-grid scale TKE (right) after 1h of spinning up.

References.

1. J. Ito, S. Hayashi, A. Hashimoto, et al. (2017). Stalled Improvement in a Numerical Weather Prediction Model as Horizontal Resolution Increases to the Sub-Kilometer Scale.
2. R. Beare (2014). A Length Scale Defining Partially-Resolved Boundary-Layer Turbulence Simulations

What Hi-Fi will unify



We currently have three incomplete approaches for parameterising grey zone, which **will be unified by Hi-Fi**:

- **Smagorinsky** with **dynamic** lengthscales.
- Ad-hoc **blending** of **Smagorinsky** with a **1D BL** scheme and 1D Tilting / Leonard paramaterisation
- An enhanced turbulence scheme based on **prognosed Turbulent Kinetic** and Potential **energy** scales (3DTE) developed by us in the ParaCon Programme. This includes down-gradient, non-local and tilting/Leonard terms