Fractal reconstruction of the subgrid scales in turbulence models in applications to cloud microphysics

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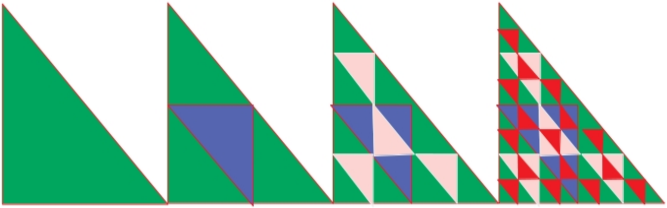
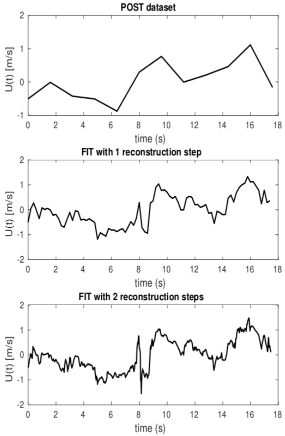
What is the fractal interpolation technique (FIT)?

Fractal interpolation is an iterative mapping procedure to construct the synthetic (unknown) small-scale field from its known large-scale structure, assuming self-similarity of the investigated field.



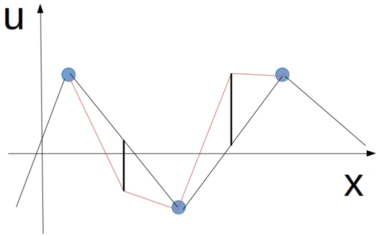
How the FIT can be applied in turbulence study?

FIT was applied by Scotti & Meneveau [Phys. Rev. Lett. 78, 86, 1997] to synthetically generate subgrid eddies in Large Eddy Simulation and to model their effect on resolved scales.



Stretching parameters.

A free parameter in the FIT method is the "stretching parameter" d which controls how the structures are rescaled into each other.



In Scotti & Meneveau (1997)

$$d = \pm 2^{-1/3}$$

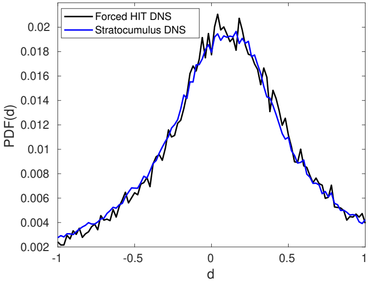
PDF of the stretching parameter in the inertial range is a universal function !

In Akinlabi et al.

[Flow, Turbulence and Combustion 103:293-322 (2019)]

values of stretching parameters were calculated directly from numerical and experimental data of startocumulus cloud.

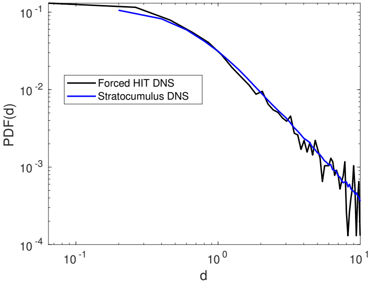
New result: comparison with Direct Numerical Simulation (DNS) of the forced isotropic turbulence and for wider range of *d* values.



PDF of the stretching parameter in the inertial range is a universal function !

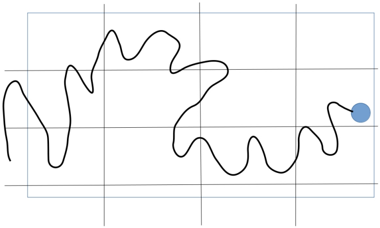
The PDF of the stretching parameter

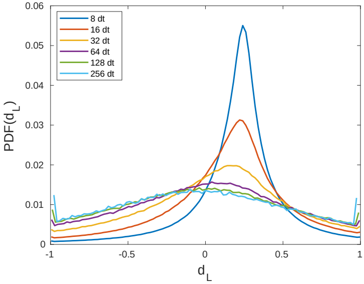
- is universal and indepedent of *Re*
- slightly skewed
- has non-Gaussian tails



PDF of the stretching parameter along Lagrangian particle tracks.

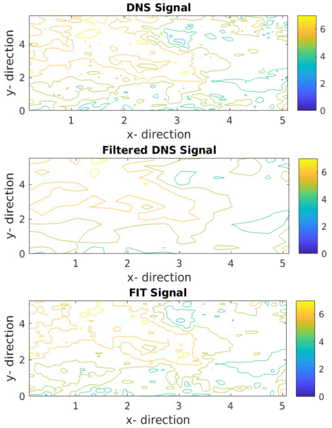
New result: Self-similarity of the PDF of the stretching parameter along Lagrangian particle paths in LES.



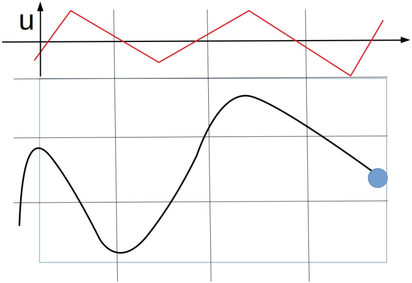


Fractal reconstruction of velocity field in stratocumulus cloud

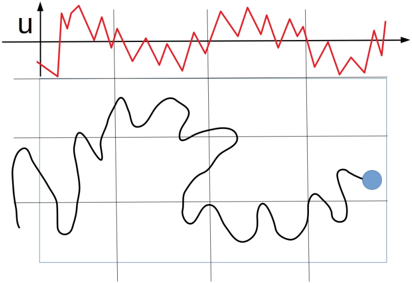
In the improved method the stretching parameters *d* are random numbers with prescribed PDF.



Tracking of Lagrangian particles in the FIT reconstructed field.



LES field



LES+FIT field

Tracking of Lagrangian particles in the FIT reconstructed field (LES of stratocumulus cloud)

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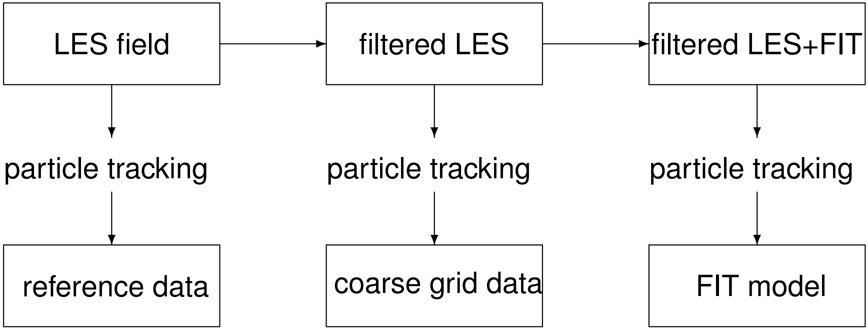


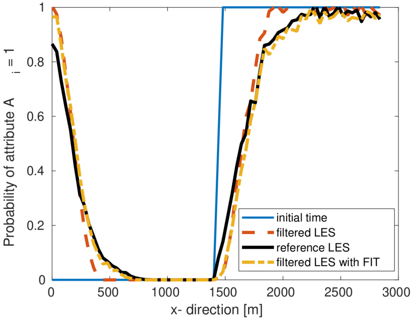
Tracking of Lagrangian particles in the FIT reconstructed field (LES of stratocumulus cloud)

Particle equations:

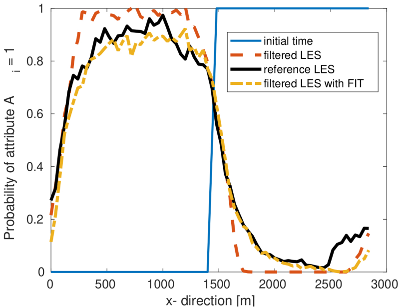
$$\begin{aligned} d\mathcal{X} &= \left(\mathcal{U}_{LES} + \boldsymbol{u}'_{FIT}\right)\, dt \\ d\Theta &= 0 \end{aligned}$$

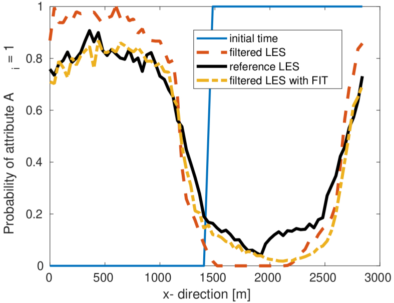
Initial conditions:

$\Theta = 0$ for $x < L/2$
$\Theta = 1$ for $x > L/2$



Tracking of Lagrangian particles in the FIT reconstructed field (LES of stratocumulus cloud)





Θ properties averaged over the *x*- and *y* directions in the in-cloud region only at (a) t = 30 minutes (b) t = 60 (c) 90 minutes of simulation time.

Perspectives

- Particle tracking in high-resolution LES of stratocumulus cloud with FIT
- Fractal reconstruction of the scalar fields (water vapor and potential temperature)
- Coupling with the super-droplet method of Shima et al. [Q. J. R. Meteorol. Soc., 135, 1307-1320, 2009]

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