Application of data assimilation to computational fluid dynamics: from isotropic turbulence to urban flows

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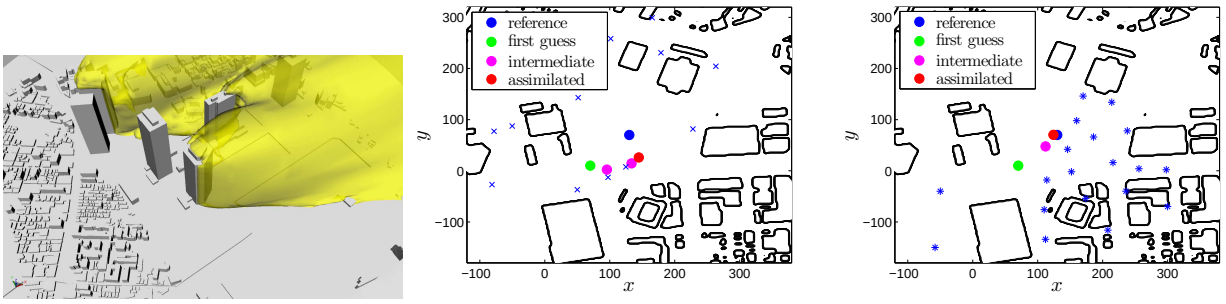
Summary

Turbulent flows are ubiquitous in engineering applications, and computational fluid dynamics (CFD) is a valuable tool to investigate such flows since it may provide detailed information about fluid phenomena that is not accessible through experimental or theoretical approaches. However, aside from possible errors arising during the physical modelling or discretization processes, uncertainties in the input quantities required by the CFD solver may prevent from an accurate estimation of the considered flow. For example, the numerical reproduction of the flow past an airfoil needs, among others, proper knowledge of the angle of attack and Mach number, which are rarely known with accuracy in real applications.

It is here proposed to employ data assimilation (DA) to address the above mentioned issue, with the ultimate goal of enhancing the prediction of real-world turbulent flows. DA consits in merging numerical predictions and experimental observations in order to improve the estimation of the CFD solver inputs. Three components are essential to the success of the DA procedure: a model that accurately reflects the physics of the flow, appropriate observations, and an efficient DA methodology that is adapted to both the considered flow and the available numerical solver. In this presentation, these three aspects will be illustrated with turbulent flows of increasing complexity, and both methodological aspects of DA and its application to the theoretical study of turbulence will be examined. Among others, new results dealing with the decay of grid turbulence obtained through DA will be discussed, and a first application of DA to the reconstruction of urban flows in conjunction with a Large Eddy Simulation (LES) solver will be exposed.



(a) (b) (c)

Figure 1: Application of DA to LES of full-scale urban flows: (a) typical concentration field, and reconstruction of the location of a pollutant source using either (b) a standard observation network (blue crosses) or (c) optimal sensors obtained from a global sensitivity analysis (blue stars). The reference source to be identified and the results of the DA procedure are depicted by blue and red dots respectively.