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4D Turbulent Wake Reconstruction using Large Eddy Simulation based Variational Data Assimilation

Pranav Chandramouli¹, Dominique Heitz^{1,2}, and Etienne Mémin¹,

¹ INRIA, Fluminance group, Campus universitaire de Beaulieu, F-35042 Rennes Cedex, France

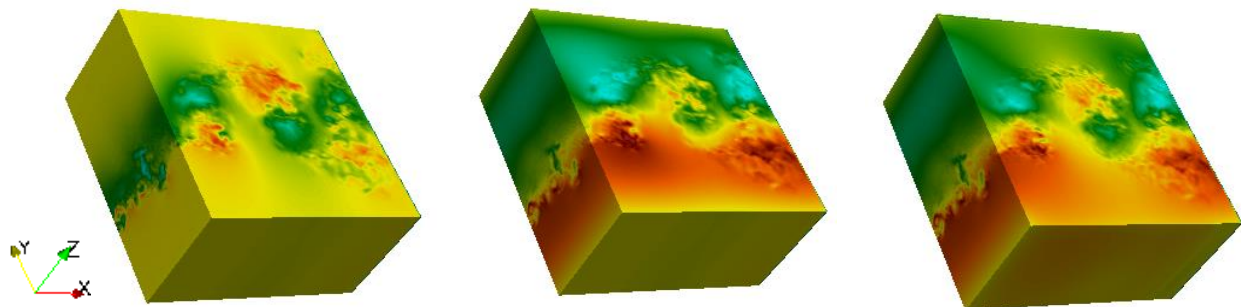
pranav.chandramouli@inria.fr

² Irstea, UR OPAALE, F-35044 Rennes Cedex, France

Abstract

Data Assimilation (DA) has been used as an effective tool for guiding simulations with observation data-sets for the better part of last few decades. However, DA has been mainly limited to applications within weather/meteorological studies with only recent excursions into conventional fluid dynamics. The limitations of computational fluid dynamics (CFD) due to complex or unknown boundary conditions and/or initial conditions can be alleviated using experimental observations through DA. Recent applications of such methodologies include [1] and [2] among many others. However, due to large computational power requirement, DA remains restricted to either 2D flows or to low Reynolds number (Re) 3D flows. A reduction in computational requirement is necessary to facilitate simulation of 3D higher Re flows. This can be achieved by using Large Eddy Simulation (LES) models within DA. This study proposes to perform Variational DA (VDA) with the adjoint of the Navier-Stokes equation using a LES model within DA to reduce computational cost.

An initial study of several sub-grid scale (SGS) models (see figure 1) have shown the newly developed Models under Location Uncertainty (MULC – StSp/StSm) to perform well for various turbulent flows [3]. In addition, these models can be shown to produce accurate results at just 0.46% the cost of performing a DNS making them ideal for performing DA with LES at reduced cost. In this work, the application of the MULC to VDA are analysed for the case of wake flow over a circular cylinder for a transitional Re of 3900. The 4DVar code (Incompact3d) of [2], who performed DNS based VDA for wake flow around a circular cylinder at Re 300, has been modified to include the SGS model. The adjoint is constructed using an auto-differentiation tool – tapenade [4]. Preliminary results are shown with synthetic data-sets and an optimal reconstruction is obtained using VDA with the MULC. Future studies include performing VDA using PIV data-sets as well as using DA to characterise the SGS model coefficient.



(a) Observation (b) Background (c) Assimilated
Figure 1. 3D vorticity contours at Re = 3900 for cylinder wake flow at the beginning ($t = 0$) of the assimilation window.

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