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On the use of hybrid RANS/LES methods in applied aerodynamics.

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ABSTRACT

During the last decades, most of numerical efforts in the field of applied aerodynamics have been focused on the simulation of nominal operational configurations. As a consequence of the rules of design, most practical configurations exhibit only limited separated flow areas and smooth gradients. Therefore, steady methodologies for turbulent flow prediction are able to handle these flowfields with a sufficient degree of accuracy. New industrial needs in aerodynamics concern for example the control of noise as well as the capability to predict the dynamic loads so that the simulation of 3D unsteady turbulent flows in now required. Indeed, this need is becoming an especially pressing issue since a wide-range of unsteady phenomena that have serious implications in terms of achievable performance, acoustic environment or safety has to be considered, and therefore requires to be accurately predicted as soon as possible in the design cycle of flight vehicles or cars.
The primary obstacle to practical use of LES on industrial flows which involve wall boundary layers at high Reynolds number remain computational power resources. Indeed LES aims at capturing the scales of motion responsible for turbulence production which impose severe demands on the grid resolution near solid walls. Hybrid RANS/LES was invented to alleviate this resolution constraints in the near-wall regions. According to Sagaut, Deck and Terracol[1], hybrid methods can be categorized into two major classes corresponding respectively to global to zonal hybrid methods (see figure 1). The global hybrid methods are based on a continuous treatment of the flow variables at the interface between RANS and LES. These methods (like DES[2]) introduce a “grey-area” in which the solution in neither pure RANS nor pure LES since the switch from RANS to LES does not imply an instantaneous change in the resolution level. This can lead to unphysical outcomes like an underestimation of the skin friction. In order to get rid of this drawback, two methods have been developped, namely ZDES (Zonal-DES)[3] and DDES (Delayed DES)[4]. In the first approach, RANS and DES domains are selected individually while in the second approach a modification of the length scale delays the switch into LES mode to prevent “Modelled-Stress Depletion”.
Both approaches will be briefly presented. We then focus on a selected number of typical applications of industrial interest studied in the Applied Aerodynamics Department at ONERA: side-loads over launcher configurations, airfoil aerodynamics, mixing enhancement in a propulsive jet, supersonic inlet

buzz (see figure 2). For each example, validation through comparisons with adequate experimental data is available. As a conclusion, it is shown that hybrid techniques combining RANS and LES show an already quite interesting domain of application. The next foreseen challenge in applied numerical aerodynamics will be the capture of the boundary layer dynamics including transition and separation issues.

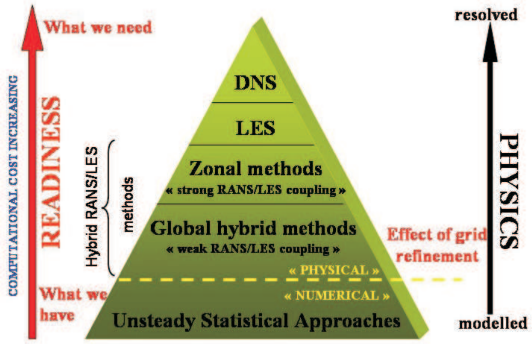

Figure 1: Classification of unsteady approaches according to levels of modelling and readiness.

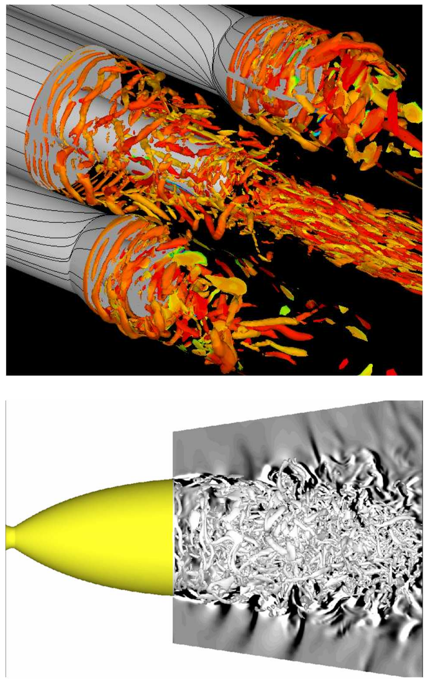

Figure 2: ZDES of transonic buffet on an Ariane V-type configuration and DDES of a restricted shock separation in a supersonic nozzle

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