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Editorial[‡]

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This special issue collects original research papers issued from the workshop dedicated to 'Industrial Applications of Low-order Models Based on Proper Orthogonal Decomposition' (POD) held in Bordeaux from March 31, 2008, to April 2, 2008. The presentations ranged from applied mathematics to fluid mechanics in engineering and environmental sciences. Some talks concerned approaches to model reduction different from POD. The presentations can be downloaded at http://www.ufr-mi.u-bordeaux.fr/WKSPOD/.

The aim of the workshop was to foster research in the direction of low-order models having an impact on real-life applications. The main subjects discussed were optimization and control in aerodynamics as well as real-time predictions and data assimilation in environmental flows. The open issues that were discussed and that are common to all these fields were: (i) system identification and closure models; (ii) accuracy for large regions of parameter variations; (iii) optimal sampling; and (iv) goal-oriented modal decomposition.

Although some successful examples of application of low-order models exist, the issues above need to be further investigated in order to make a step toward large-scale high Reynolds number flows. The seven papers that are collected here give a rather complete overview of these themes. The issue of low-order modeling in 3D is an open issue that remains to be addressed.

In particular Rempfer and Mokhasi [1] develop in their paper dynamical system models that are based on radial basis functions and discrete multivariate time series information. In order to demonstrate the effectiveness of the method they consider the 3D Lorenz model, the 9D Lorenz model, and a 5D in-house model.

Mathelin and LeMaître [2] propose an equation-free model reduction consisting in a mapping, over a coarse time-step, of the POD projection coefficients of the system state on the reduced basis. The mapping is expressed as an explicit polynomial transformation of the projection coefficients. An application of the method to the 2D flow past a circular cylinder is presented and both asymptotic state and transient stages are investigated.

Fang *et al.* [3] propose a method for mesh optimization that is based on a goal-oriented POD decomposition. Both the primal and dual solution are solved, thanks to the low-order model in

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order to compute mesh sensitivity. This approach was implemented within the Imperial College Ocean Model, to solve a barotropic wind-driven gyre problem.

Degroote *et al.* [4] investigate the parameter dependence of low-order models based on Galerkin projection. In order to derive models that are valid for cases not considered in the derivation of the POD basis, the authors propose to interpolate among reduced-order matrices as a means to obtain parameterized models. The interpolation approach is applied to a steady-state thermal design problem and probabilistic analysis via Monte Carlo simulation of an unsteady contaminant transport problem.

Noack *et al.* [5] propose a system reduction strategy for spectral and Galerkin models of incompressible fluid flows. Their approach leads to dynamic models of lower order, based on a partition in slow, dominant, and fast modes. In the reduced models, slow dynamics are incorporated as a non-linear manifold consistent with mean-field theory. Fast dynamics are stochastically treated and can be lumped in eddy viscosity approaches. Their system reduction strategy is numerically validated using to the cylinder wake as a benchmark.

Weller *et al.* [6] propose numerical alternatives that can be exploited to derive efficient low-order models of the Navier–Stokes equations showing that optimal solution sampling can be derived using suitable norms of the Navier–Stokes residuals. A classical Galerkin approach is then derived in the context of a residual minimization method similar to variational multiscale modeling. Finally, calibration techniques are reviewed and applied to the computation of unsteady aerodynamic forces. Examples pertaining to both non-actuated and actuated flows are used for illustration.

Finally Cordier *et al.* [7] investigate various methods of calibration that can be used in practice to improve the accuracy of reduced-order models based on POD. They use as a benchmark a two-dimensional flow around a cylinder for a Reynolds number of 200. They generalize to the first- and second-order the method of calibration. Finally, they show that for this flow configuration the proposed procedure is the most effective in terms of reduction of errors.

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