The Myth of URANS

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In the 1990s, RANS modeling practitioners using finer grids and higher-order models began to observe cases for which simulations never reached a steady state. Instead, they observed the emergence of structures which were, at least qualitatively, similar to the turbulent structures observed in experiments.[1][2] These studies raise numerous questions. Fundamentally, it is not clear why some RANS simulations result in unsteady solutions, and other do not. And the results of these studies have a mixed record of quantitative accuracy when compared to experiments. Spalart[3] presents a systematic critique of what he refers to as the unsteady RANS (URANS) approach, notably, the lack of a theoretical justification.

The current work addresses this lacuna by demonstrating a theoretical model aimed primarily at asking answering the following question: in the absence of a model parameter to set the scale for the decomposition into resolved and modeled scales, from where does that scale arise and what value does it take? This is accomplished by treating the coarse scales of a URANS as a turbulent flow at lower Reynolds number and re-filtering the governing equations.

The pricniple result is that, in the absence of continous forcing, regardless of the initial conditions, URANS will eventually relax to a steady RANS solution. The trajectory of that relaxation may include regions where the mean flow evolution deviates substantially from the physically correct solution. For forced homogeneous turbulence, the asymptotic state is one where about 30% of the turbulent kinetic energy is modeled, regardless of the strength of the forcing. This comes about from a balance between the forcing and the model dissipation, and does not necessarily reflect the correct physics.

The proposed model shows both how URANS can fail, and why it sometimes produces, at least qualitatively, reasonable looking results.

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[1]Johansson et al., *Int. J. Num. Meth. Fld.* **16**, 859 (1993)

[2]Durbin, *AIAA J.* **33**, 659 (1995)

[3]Spalart, *Int. J. Heat Fld. Flow* **21**, 252 (2000)