2nd European Fluid Dynamics Conference (EFDC2)
26 – 29 August 2025, Dublin, Ireland

Global improvement and performance evaluation of two-dimensional progressive data-augmented turbulence models

Mario J. Rincón[*] [†], Martino Reclari[†], Xiang Yang[‡], and Mahdi Abkar[*].

The consistency of *a posteriori* results and the generalisability of models are critical challenges in data-driven turbulence modelling [1]. This study employs multi-case surrogate modelling and Bayesian optimisation to enhance the predictive capabilities of the k–ω Shear Stress Transport (SST) turbulence model, specifically for Prandtl's secondary flows of the second kind and flow separation in two dimensions. Two key modifications are introduced: (1) a non-linear explicit algebraic Reynolds stress term to improve secondary flow predictions[2], and (2) a separation correction factor incorporated into the turbulent specific dissipation rate (ω) transport equation to address the model's underestimation of turbulent viscosity in flow separation scenarios[3]. The proposed model is optimised using a diverse set of training cases, including periodic hills, a curved backward-facing step, and duct flows, with channel flow simulations incorporated to preserve the baseline k–ω SST performance in the absence of separation. Validation is conducted on unseen cases with varying Reynolds numbers and geometries. Results demonstrate significant improvements in predicting streamwise vorticity, recirculation zones, velocity profiles, and friction coefficient distributions for both training and testing cases (Figures 1, **??**). Furthermore, the model retains the robust performance of the original k–ω SST in scenarios without flow separation, ensuring broader applicability and reliability.

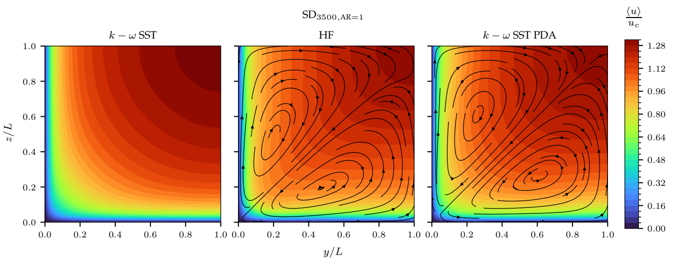
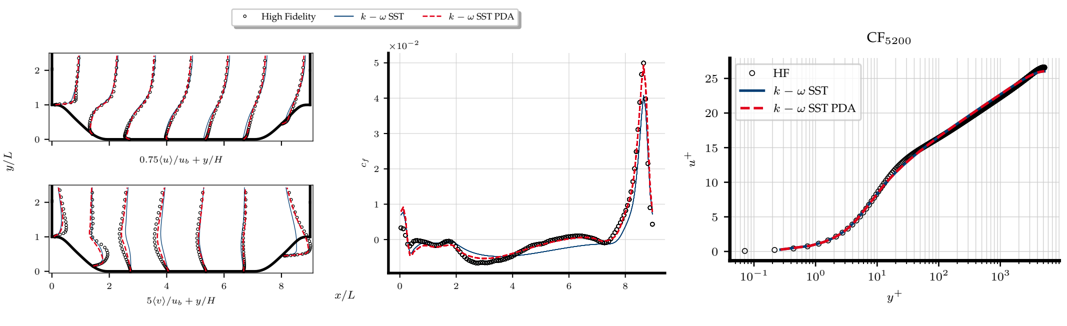


Figure 1: Streamwise velocity contour results with off-plane stream function for square duct case at $\mathrm{Re}_b = 3500$.



(a) Velocity components and friction coefficient results for periodic hills at $\mathrm{Re}_b = 2800$.

(b) Velocity profiles of the channel flow case at $\mathrm{Re}_\tau = 5200$.

Figure 2: Velocity profiles of diverse tested cases.

[*]Department of Mechanical and Production Engineering, Aarhus University, 8200 Aarhus N, Denmark
[†]Quality & Sustainability Department, Kamstrup A/S, 8660 Skanderborg, Denmark
[‡]Pennsylvania State University, State College, Pennsylvania 16802, USA

[1]Duraisamy et al., *Annual Review of Fluid Mechanics, 2019*
[2]Rincón et al., *International Journal of Heat and Fluid Flow., 2023*
[3]Amarloo et al., *Physics of Fluids, 2023*