Simulation of Separated Turbulent Flows

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Abstract

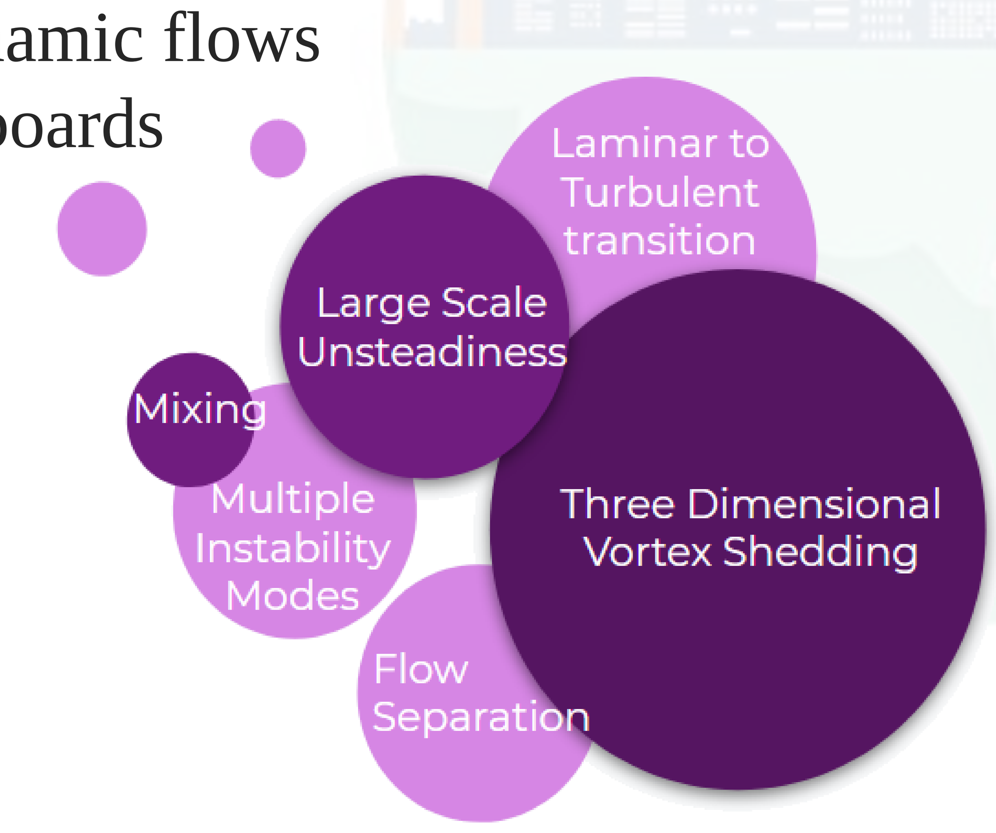
- ❖ Conventional approach (RANS) fails to capture essential flow physics in separated turbulent flows.
- ❖ Bridging methods (like PANS) are developed to overcome RANS' limitations.
- ❖ PANS demonstrate significant improvement in performance i.e. prediction of drag, friction coefficient, pressure and velocity profiles.

Introduction

High speed flow around bluff bodies involve concurrence of multiple phenomena.

Applications include:

- ➢ High speed aerodynamic flows
- ➢ Electronic circuits boards
- ➢ Cooling towers
- ➢ Heat exchangers
- ➢ Engines
- ➢ Power turbines



Equations

1) Continuity

$$\frac{\partial \langle V_i \rangle}{\partial x_i} = 0;$$

2) Momentum

$$\frac{\partial \langle V_i \rangle}{\partial t} + \langle V_j \rangle \frac{\partial \langle V_i \rangle}{\partial x_j} = -\frac{1}{\rho}\frac{\partial \langle p \rangle}{\partial x_i} + \frac{\partial}{\partial x_j}\left(\nu \frac{\partial \langle V_i \rangle}{\partial x_j}\right) - \frac{\partial \tau(V_i, V_j)}{\partial x_j};$$

3) Temperature

$$\frac{\partial \langle T \rangle}{\partial t} + \langle V_i \rangle \frac{\partial \langle T \rangle}{\partial x_i} = \frac{\partial}{\partial x_i}\left(\frac{\nu}{Pr}\frac{\partial \langle T \rangle}{\partial x_i}\right) - \frac{\partial \tau(V_i, T)}{\partial x_i}.$$

4) Turbulent Kinetic Energy

$$\frac{\partial k_u}{\partial t} + \langle V_j \rangle \frac{\partial k_u}{\partial x_j} = P_u - \varepsilon_u + \frac{\partial}{\partial x_j}\left(\left(\frac{\nu_u}{\sigma_{ku}} + \nu\right)\frac{\partial k_u}{\partial x_j}\right);$$

5) Turbulence Dissipation Rate

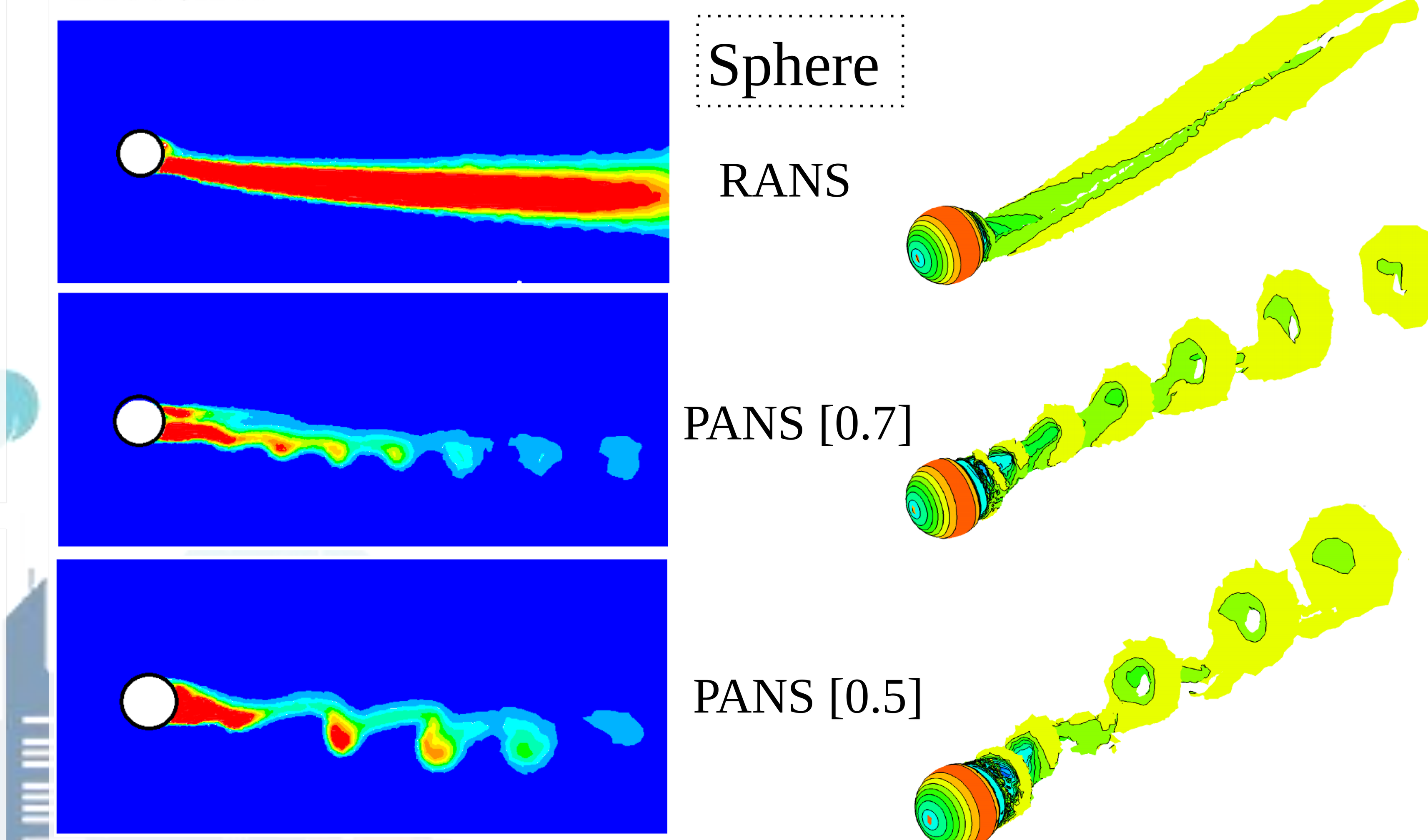
$$\frac{\partial \varepsilon_u}{\partial t} + \langle V_j \rangle \frac{\partial \varepsilon_u}{\partial x_j} = \left(C_{e1}\frac{P_u \varepsilon_u}{k_u} - C^*_{e2}\frac{\varepsilon_u^2}{k_u}\right) + \frac{\partial}{\partial x_j}\left(\left(\frac{\nu_u}{\sigma_{\varepsilon u}} + \nu\right)\frac{\partial \varepsilon_u}{\partial x_j}\right);$$

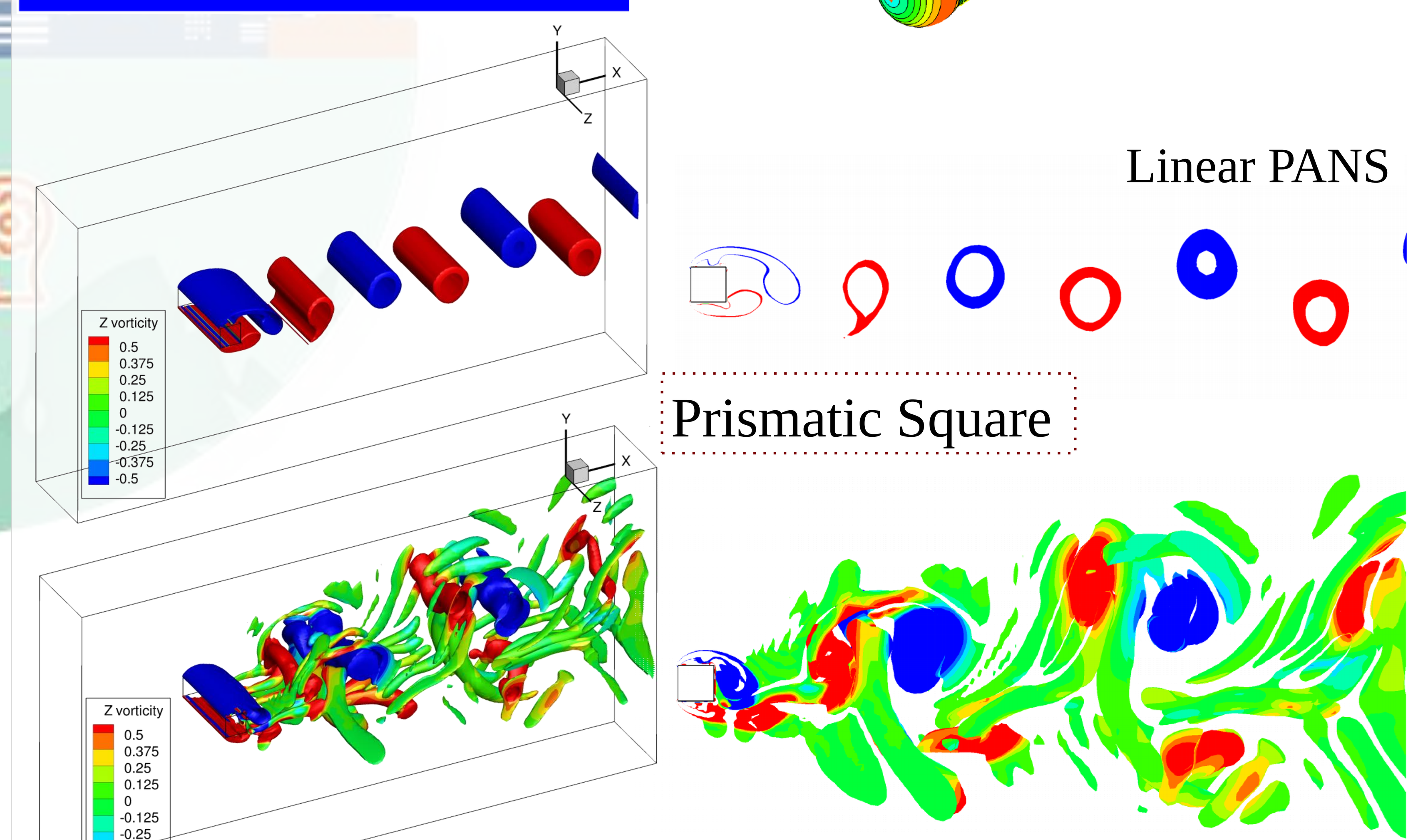
$$C^*_{e2} = C_{e1} + (f_k/f_\varepsilon)(C_{e2} - C_{e1})$$

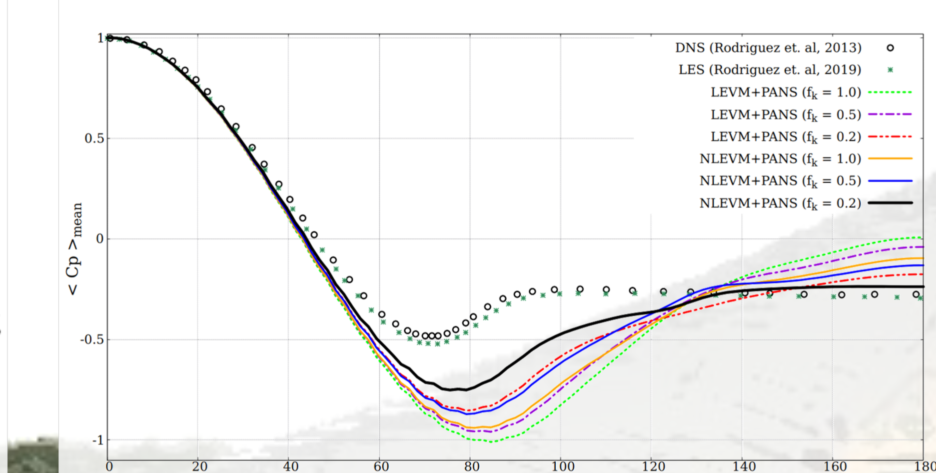
$$\sigma_{k_u} = \sigma_k \frac{f_k^2}{f_\varepsilon}; \sigma_{\varepsilon_u} = \sigma_\varepsilon \frac{f_k^2}{f_\varepsilon}$$

$$\boxed{f_k = \frac{k_u}{k};} \quad \boxed{f_\epsilon = \frac{\epsilon_u}{\epsilon};}$$

Results

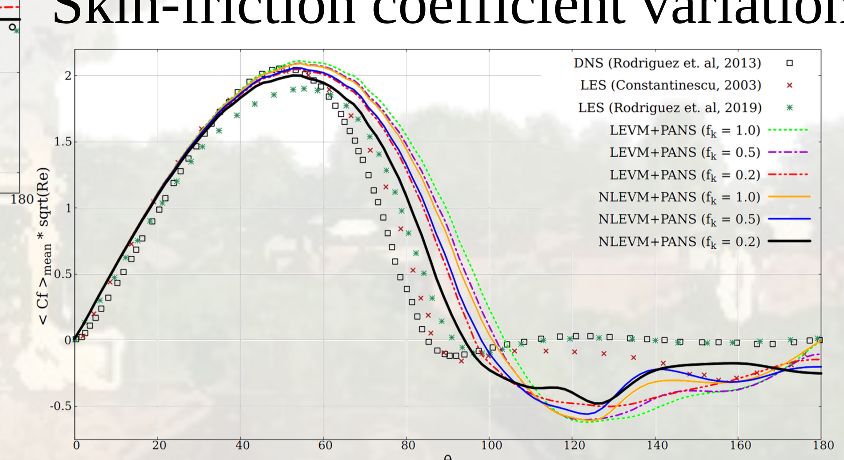






Pressure coefficient variation

Skin-friction coefficient variation



Conclusions

Non-linear PANS methodology exhibits inherent potential to perform better than RANS based turbulence model in case of separated turbulent flow fields.

Industrial Significance

This work is relevant to any industrial application and product involving high speed flow of fluids (even involving heat transfer).

Technology Readiness Level:

PANS model can be easily implemented in any fluid flow solver. With the help of user-defined scripts, we have tested it with ANSYS FLUENT and OpenFOAM solver packages.

References

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