IPID4all Doctorate Research Exchange with University of Wyoming
Feedback report

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Stochastic-based Turbulence Modeling in CFD to Improve the accuracy of Site Assessment	

Introduction

My PhD topic's goal is to achieve a stochastic based hybrid turbulence model which can accurately simulate the atmospheric boundary layer in large and complex terrains. The motivation of simulating such a flow is estimating the wind turbine performance in the real situations. Also a RANS-LES hybrid method helps reducing the computational cost while having accurate results in the specific parts of the domain.

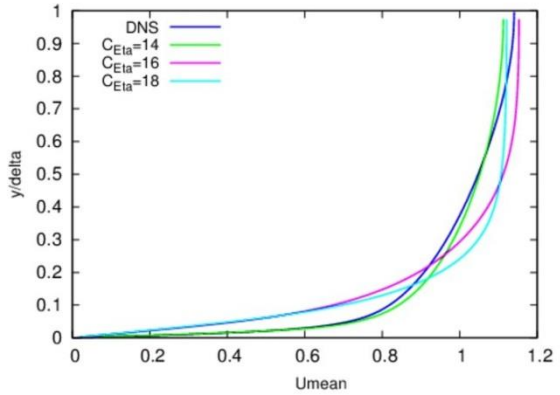
Prof. Stefan Heinz and his research group in University of Wyoming have developed such a hybrid RANS-LES turbulence model based on stochastic theories. This turbulence model has shown a very promising performance in modelling turbulence in channel flow and also flow over a hill with flow separation. This approach still needs some improvement and further study in high Reynolds flow and complex terrain. Some of the most important concepts which still need to be reviewed are as below:

1- Using the unified model to simulate flow with very high Reynolds numbers and in complex terrains.
2- Validation and modification of wall damping function in RANS mode which models turbulence viscosity as a function of distance from wall in RANS regions.
3- Computing coefficients of the Generalized Langevin Model (GLM) for turbulence from CFD simulations.

The second and third concepts were discussed with Dr. Heinz's research group during this research stay in University of Wyoming.

Research Undertaken

The improvement in damping function is planned to be achieved via channel flow RANS simulations to study the performance of the unified model in channel flow in different Reynolds numbers. The results will be compared to existing DNS data for channel flow and other reliable RANS wall damping functions. The first sets of results have been extracted from simulations with different values for damping function coefficient.



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To investigate the coefficients of Generalized Langevin Model, high resolved large eddy simulation (LES) will be used. GLM reads:

$$\frac{dX_i}{dt} = U_i \tag{1}$$

$$\frac{dU_i}{dt} = -\frac{1}{\rho}\frac{\partial \langle p_{ij} \rangle}{\partial x_j} + G_{ij}[U_j - \langle u_j \rangle] + B_{ij}\frac{dW_j}{dt} \tag{2}$$

Where Capital letters refer to Lagrangian properties of the flow.

GLM gives the same equations for mean velocity as RANS. A comparison between Reynolds stress equations in the usual RANS and ones achieved from stochastic based theory gives us an approximate relation between G and B and velocity-acceleration statistics as below:

$$G_{ik}\langle u_k' u_j' \rangle + \frac{1}{2}B_{ik}B_{jk} \approx \left\langle \left(\frac{Du_i}{Dt}\right)' u_j' \right\rangle.$$

On the other hand, estimating G and B from Kramers-Moyal coefficients gives us:

$$\left(G_{ij}\langle u_j' u_k' \rangle\right)(\boldsymbol{x}, t) = \lim_{\Delta t \to 0} \frac{1}{\Delta t}\left\langle \left[U_i(t+\Delta t) - U_i(t)\right] U_k'(t) \;\middle|\; \boldsymbol{X}(t) = \boldsymbol{x} \right\rangle,$$

$$U_k'(\boldsymbol{U}, \boldsymbol{X}, t) = U_k(t) - \langle U_k(t) \mid \boldsymbol{X}(t) \rangle,$$

To use this relation to compute G, Lagrangian particle tracking is needed to be implemented in OpenFoam.

Personal Experience

Participating in Prof. Heinz Seminars gave me a good opportunity to deepen my knowledge about the model and also ask my questions about the vague parts of his publications on this subject. Furthermore, in this time I could work with the rest of his team e.g. his PhD students, and got to know what their research subjects. The idea of designing the LES simulations to compute the GLM coefficients happened as a result of the mutual work with Grigory Sarnitskii.

Conclusions

IPID4all program funding gave me a great opportunity to exchange knowledge and ideas with the research group in University of Wyoming. My PhD thesis could benefit from this exchange in many different ways.

Outlook

- A co-supervision of my PhD thesis with Dr. Heinz is planned
- To continue the work and to exchange more ideas Grigory Sarnitskii is planning to apply for IPID4all research exchange funding to visit our research group in university of Oldenburg in 2017.
- Publication on both concepts are planned for the time when the simulations are done and the results are post processed.

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