Assessment of a Physics Based UQ Method for the Application of CFD

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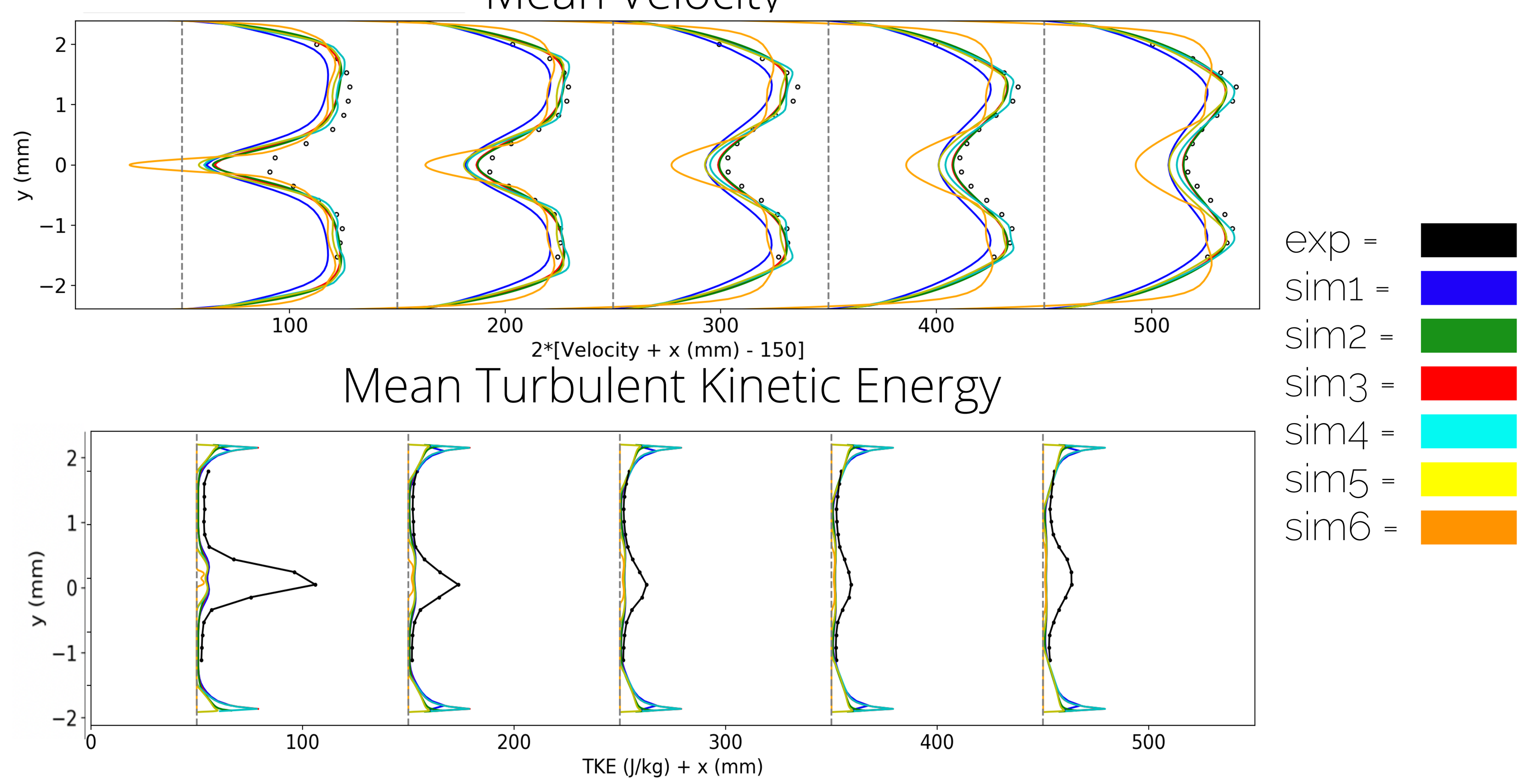
1 Introduction

- Nuclear Energy is a carbon free energy source and an attractive alternative to fossil fuel
- Computational fluid dynamics can characterize the turbulent flow in nuclear reactors with greater accuracy than other methods
- Uncertainty quantification of computer simulations will drive the practicality of sourcing clean energy from boiling water reactors
- The Standard k-ϵ model was used for the computer simulations

Standard k-ε	
2-layer [all y+]	
meshing	state
coarse	steady(1)
medium (2x)	steady(2)/unsteady(4)
fine (4x)	steady(3)
resolved	steady(5)
low re [all y+]	
resolved	steady(6)

2 Discretization Study

- Discretization is a numerical method used to employ simpler equations to approximate solutions of separate elements in a system
- A discretization study was utilized to determine the best suitable model to use for UQ
- To compare to experimental data, three profiles were graphed of the 6 computed simulations



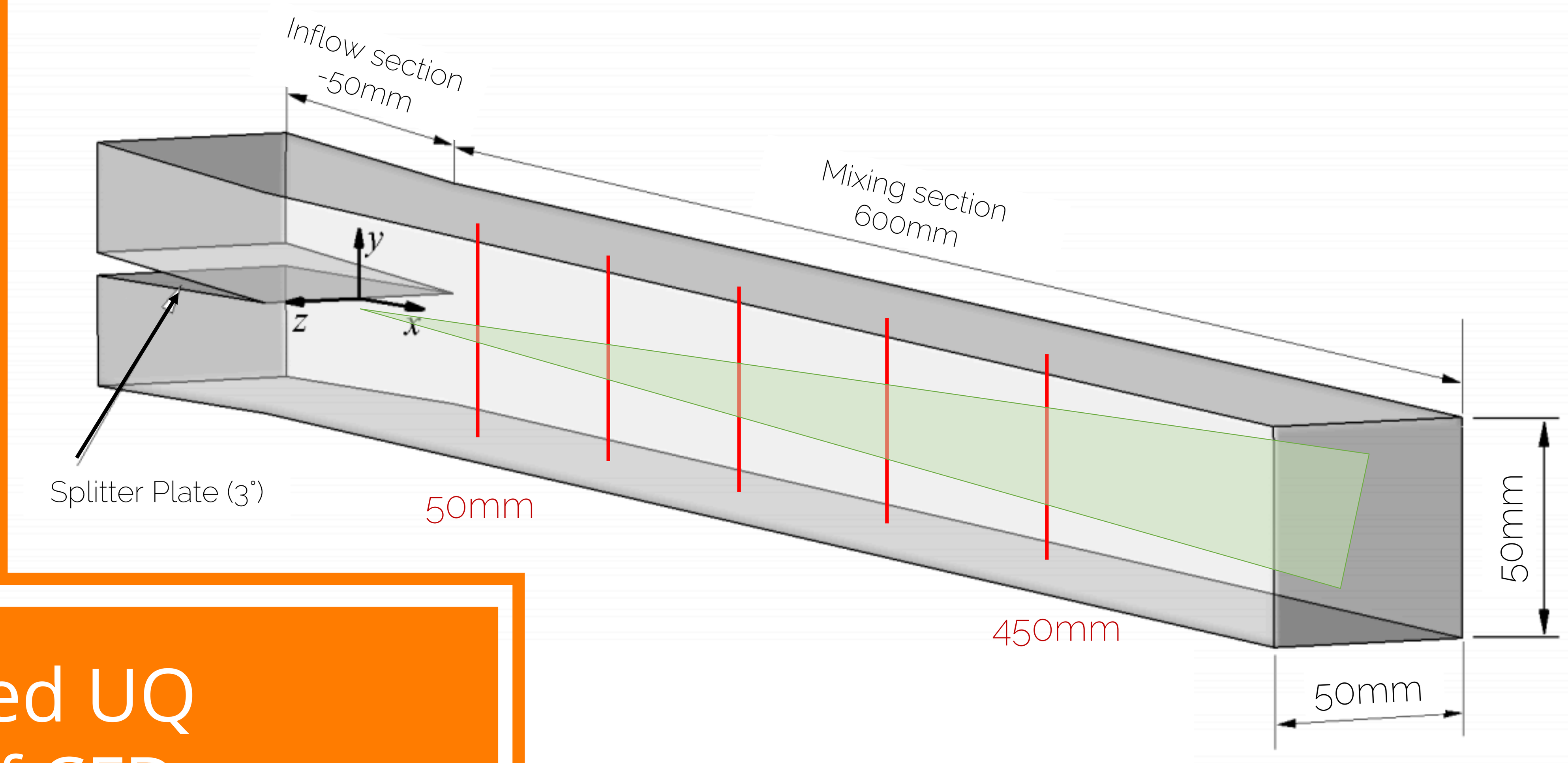
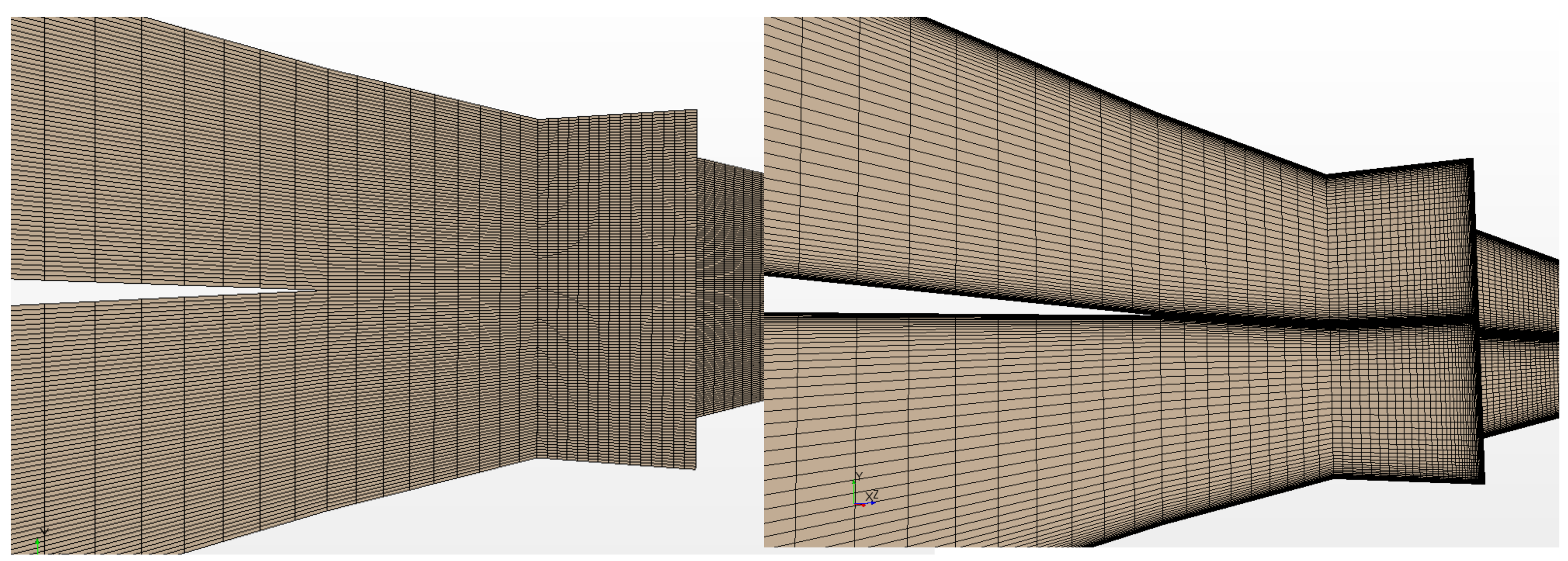


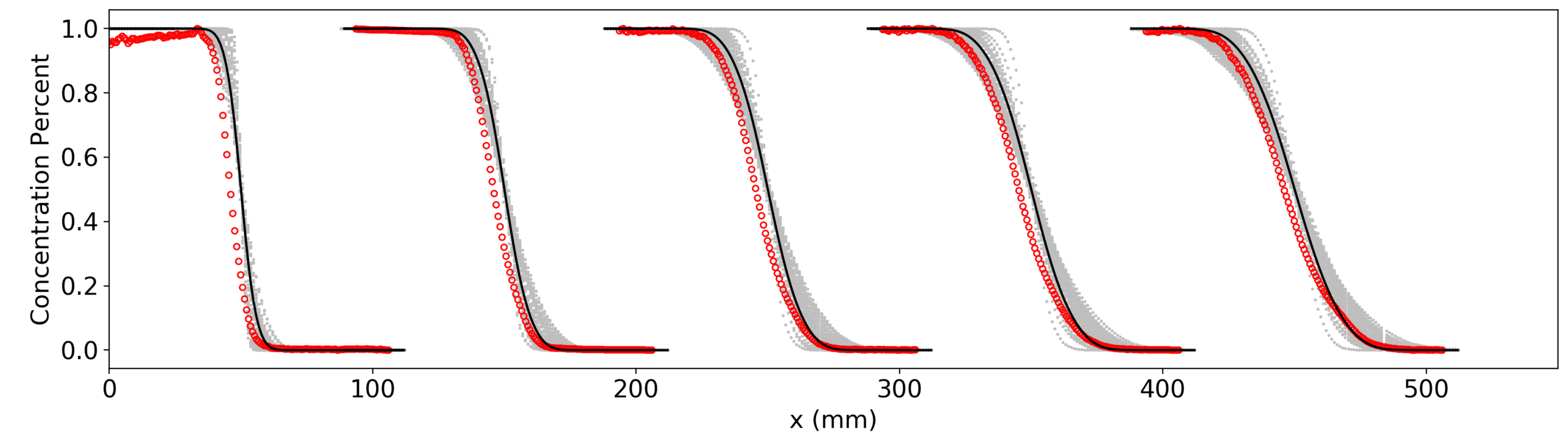
Fig 1. GEMIX Geometry[1]

Fig 2. Constant Mesh (left),Hyperbolic Mesh (right)

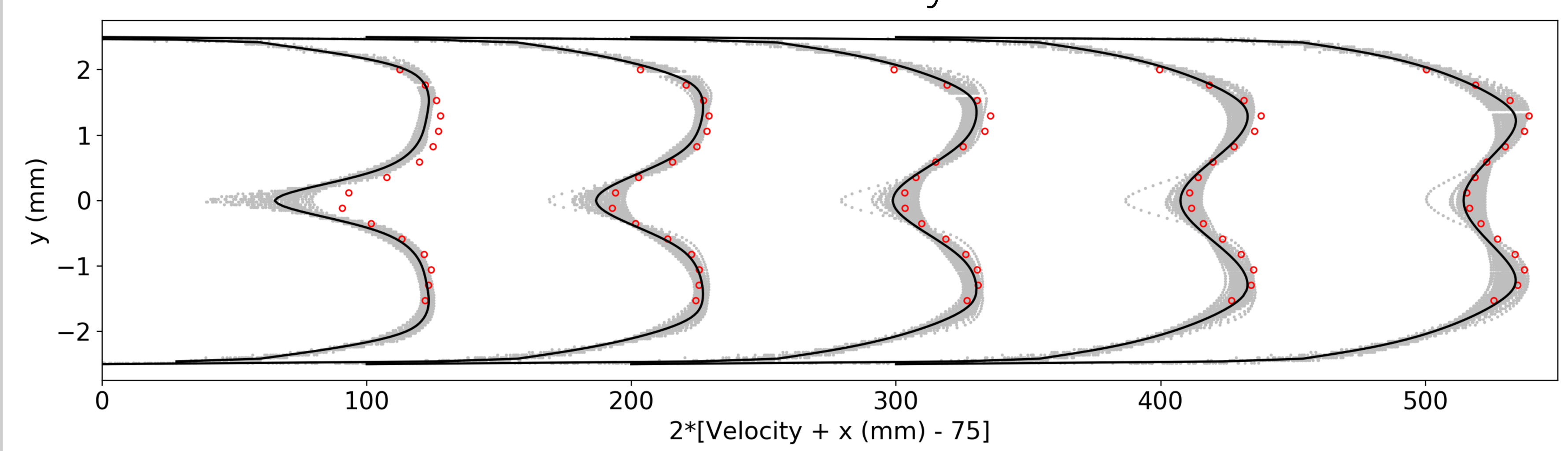


3 Uncertainty Quantification

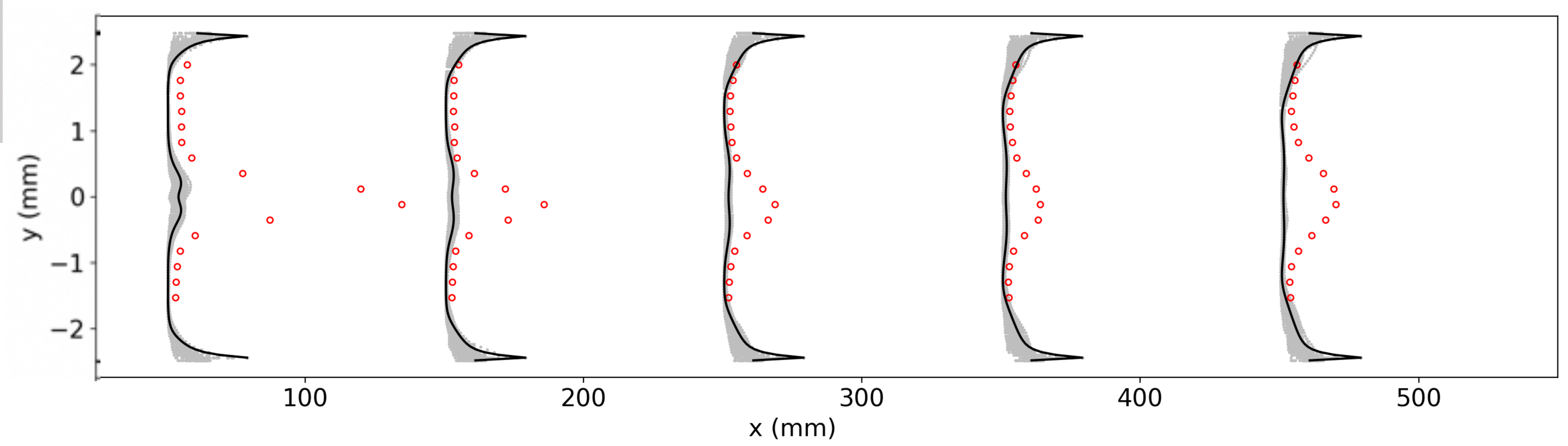
Mean Concentration



Mean Velocity



Mean Turbulent Kinetic Energy



exp - sim - UQ -

$$TKE = \frac{1}{2}\left(\langle u'^2\rangle + \langle v'^2\rangle + \langle w'^2\rangle\right)$$

- Source of uncertainty : model
- RANS Momentum Equation

$$\frac{\partial(\rho\bar{u}_i)}{\partial t} + \rho\bar{u}_i\frac{\partial(\bar{u}_i)}{\partial x_j} = -\frac{\partial\bar{p}}{\partial x_i} + v\frac{\partial\bar{u}_i}{\partial x_j x_j} - \frac{\partial}{\partial x_i}\rho\overline{u_i'u_j'}$$

- Boussinesq assumption

$$\overline{u_i'u_j'} = \mu_t\left(\frac{\partial\bar{u}_j}{\partial x_i} + \frac{\partial\bar{u}_i}{\partial x_j}\right) - \frac{2}{3}k\delta_{ij}$$

4 Summary & Future Work

- The UQ method has successfully bounded experimental data
- The UQ method is a new implantation of modeling uncertainty was characterized in CFD. This quantification will allow for CFD use in nuclear reactor safety analysis
- The UQ method has been designed for single phase flow. Boiling and pressurized water reactors frequently experience two phase flows
- Future work includes developing a UQ method for two phase flow
- Employ this UQ method in code, scaling, applicability, & uncertainty (CSAU) during reactor licensing[2]

Acknowledgements & References

[1] Barthet,A, Camy,R. “Participation of EDF to the OECD/NEA CFD-UQ benchmark: GEMIX.” 2016. PDF File
[2] Acton, M.; Nureth 2019, 1-14

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