COLLEGE OF ENGINEERING
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Numerical Modeling of Tidal Turbines: Comparison of Models with Different Complexity

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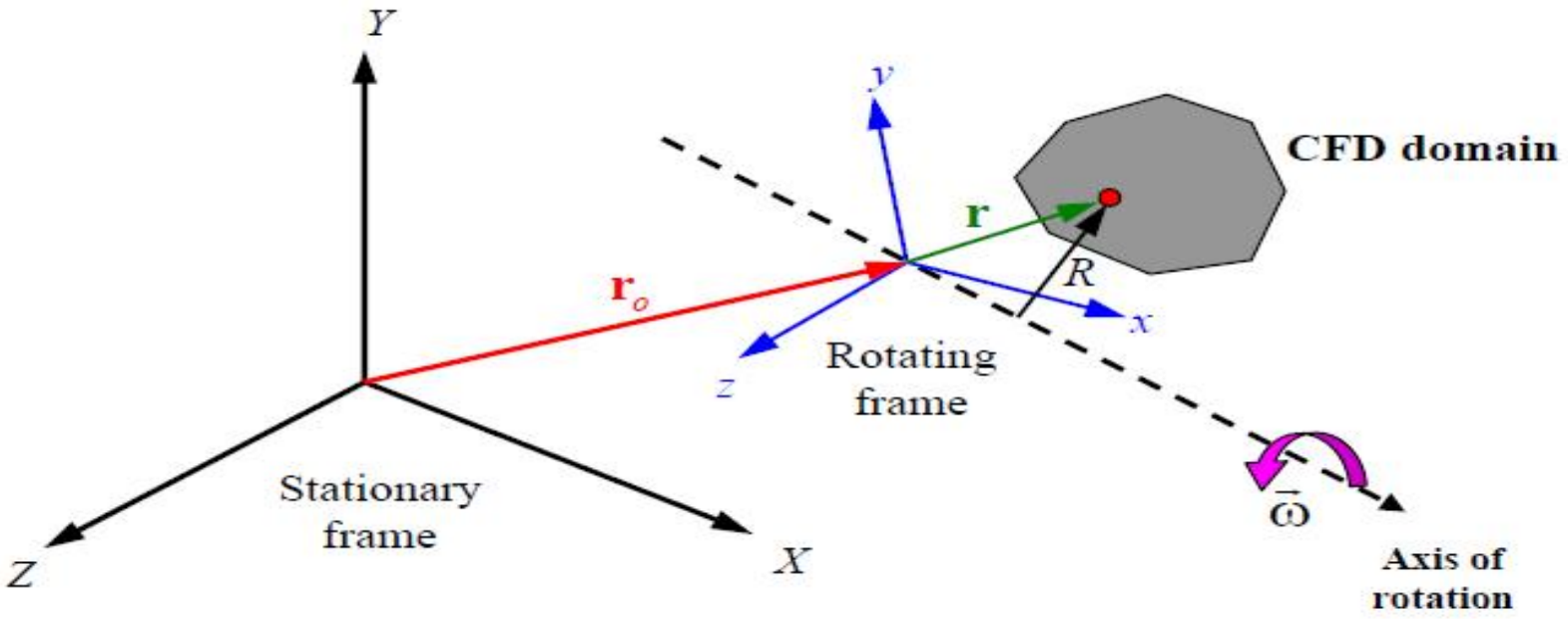
Introduction

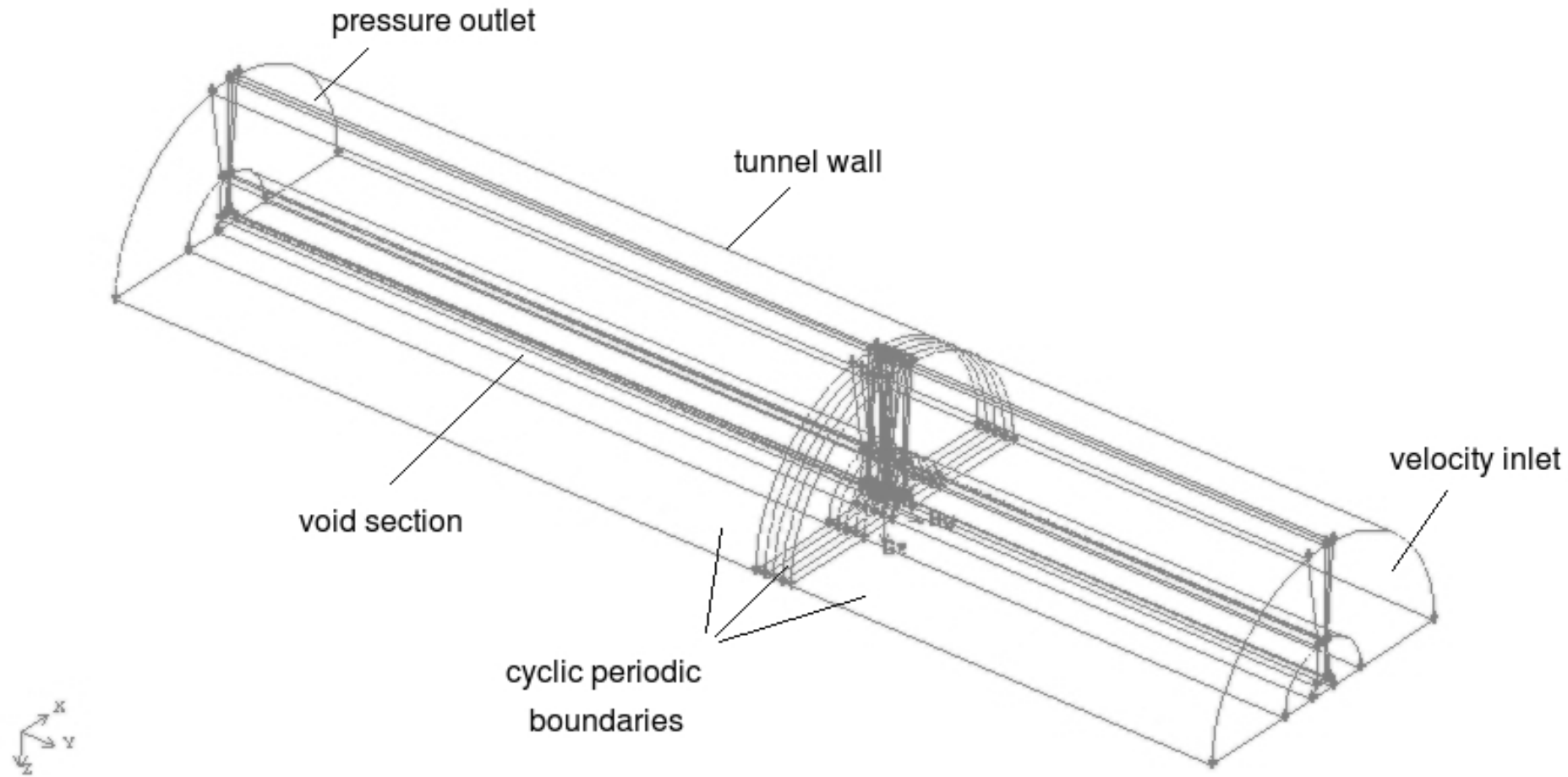
- NREL Phase VI turbine (Re = 2.6 10^6 , λ (TSR)= 6.13)
- Single Moving Reference Frame (SRF)
- Virtual Blade Model (VBM)
- Actuator Disk Model (ADM)
- Main focus is the far wake of the turbine.

Single Moving Reference Frame (SRF)

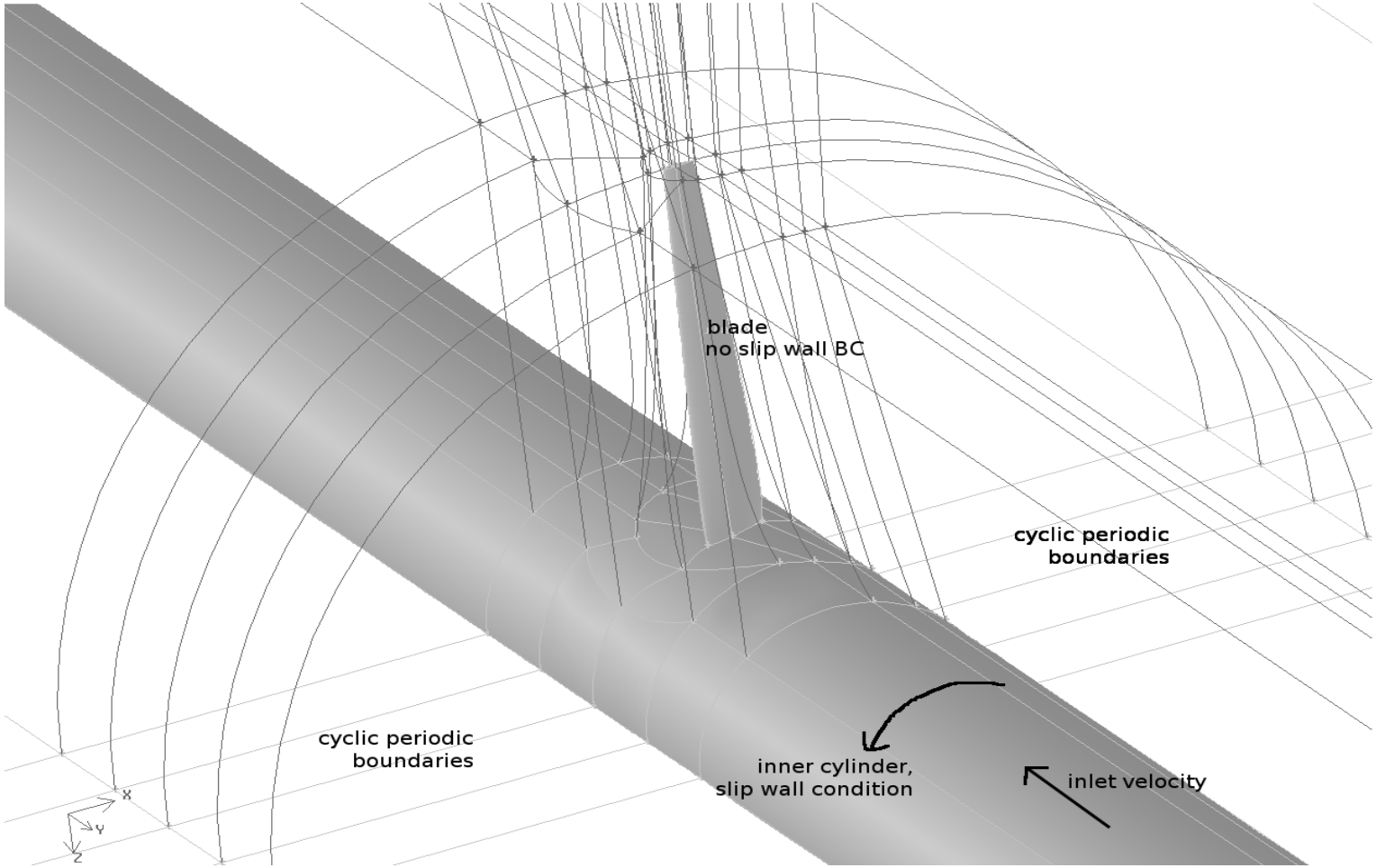
SRF is a model to simulate rotating flows with axisymmetric boundary conditions in a simplified environment.



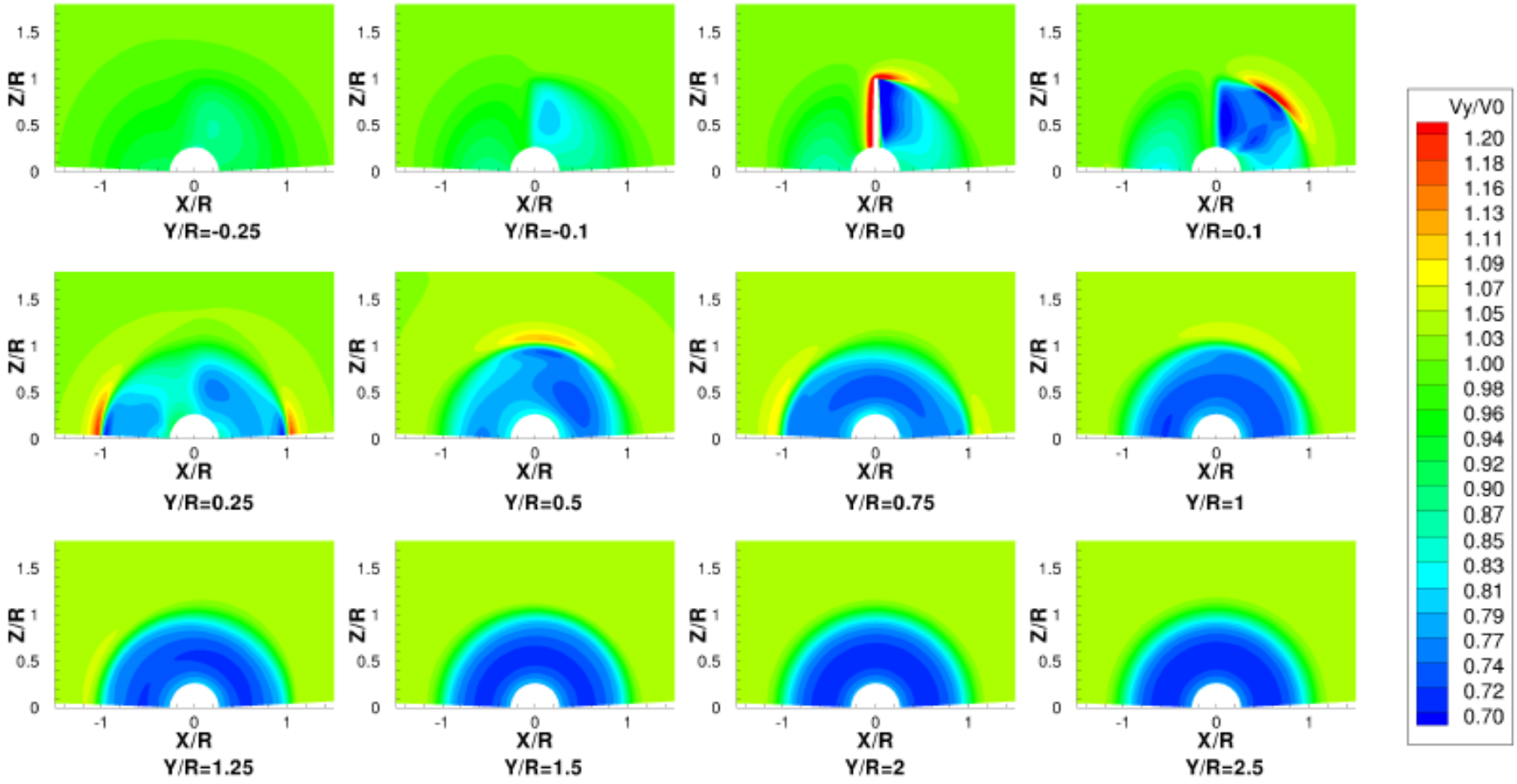
Single Moving Reference Frame (SRF)



Single Moving Reference Frame (SRF)



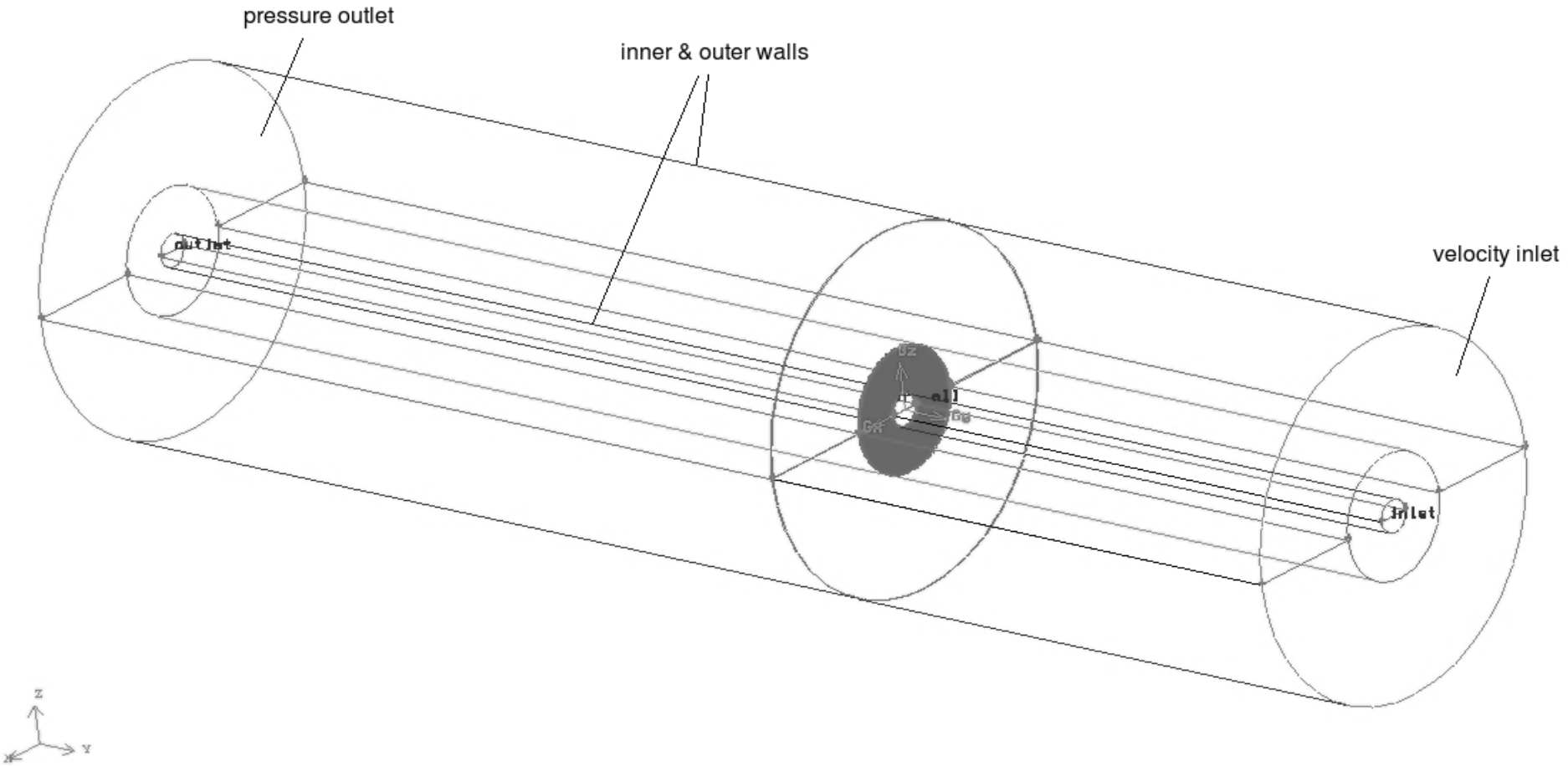
Characteristic Result from SRF

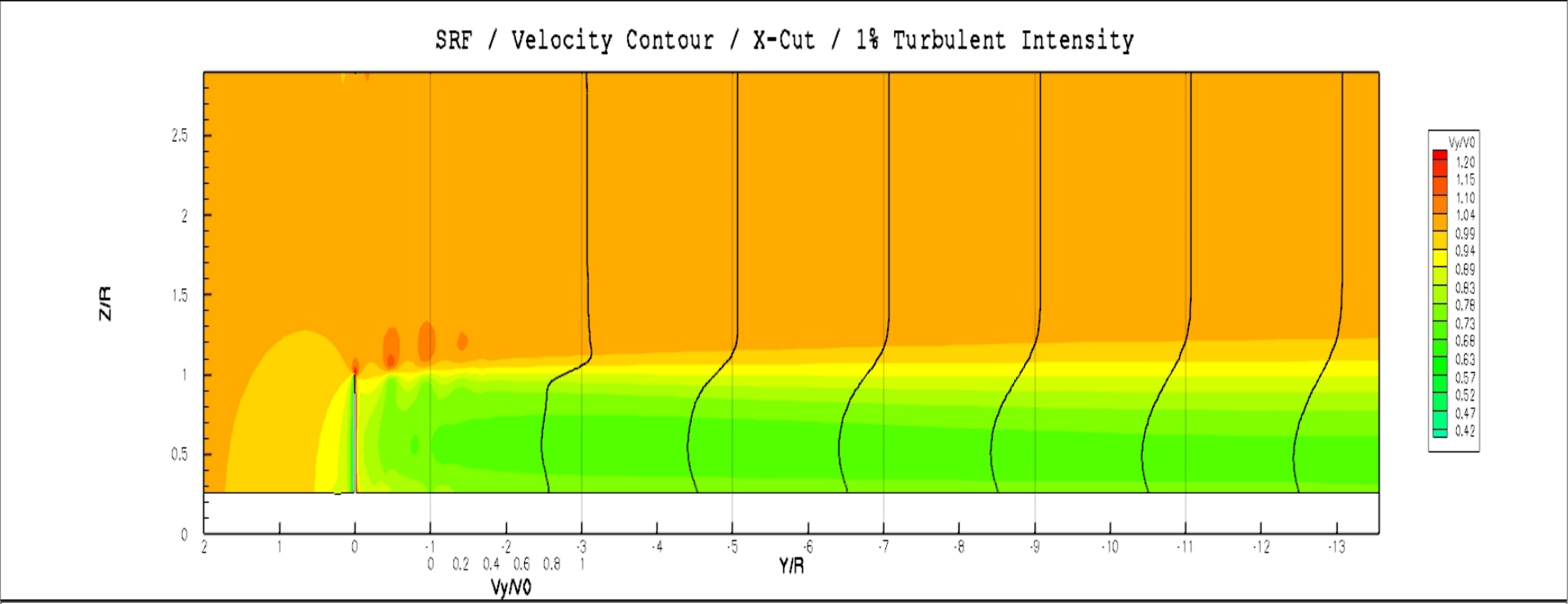


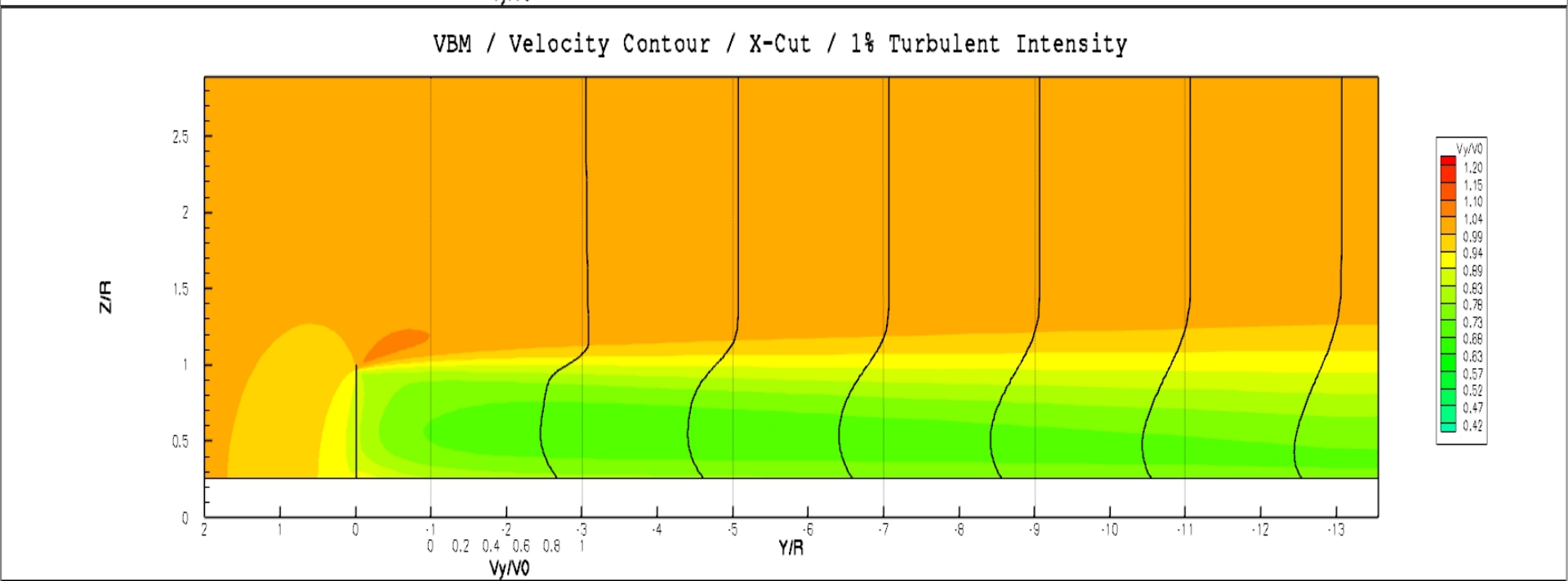
Virtual Blade Model (VBM)

- Effect of blades is modeled by body forces exerted on the fluid.
- These forces are calculated using the lift and drag coefficient for each section of the blade.
- The effect of the blades (body forces) is averaged over a whole revolution.

Virtual Blade Model (VBM) Mesh




SRF / Velocity Contour / X-Cut / 1% Turbulent Intensity
Z/R
Y/R
Vy/V0
Vy/V0
1.20
1.15
1.10
1.04
0.99
0.94
0.89
0.83
0.78
0.73
0.68
0.63
0.57
0.52
0.47
0.42


VBM / Velocity Contour / X-Cut / 1% Turbulent Intensity
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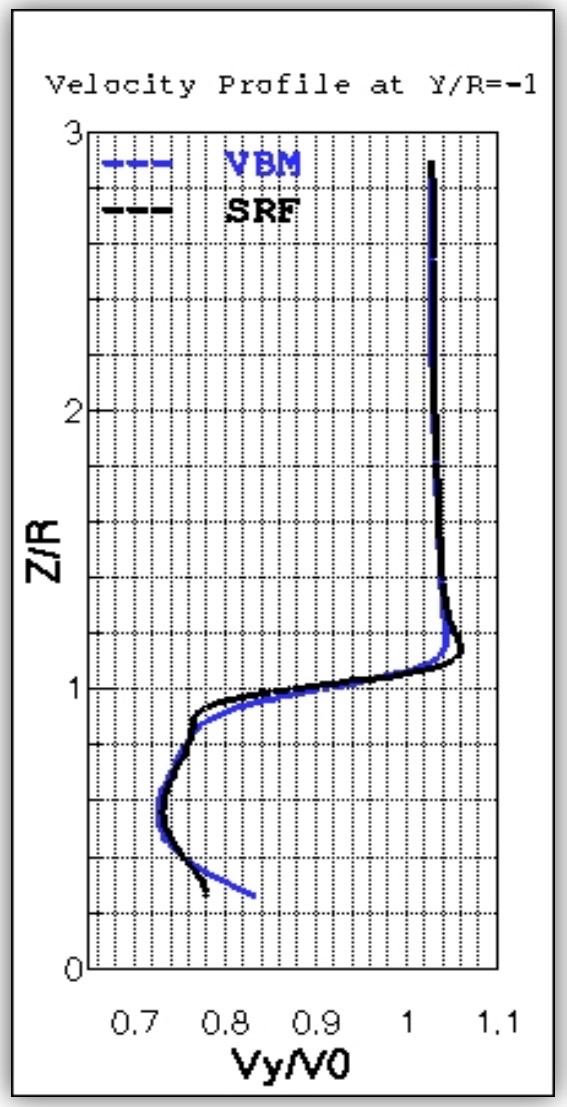
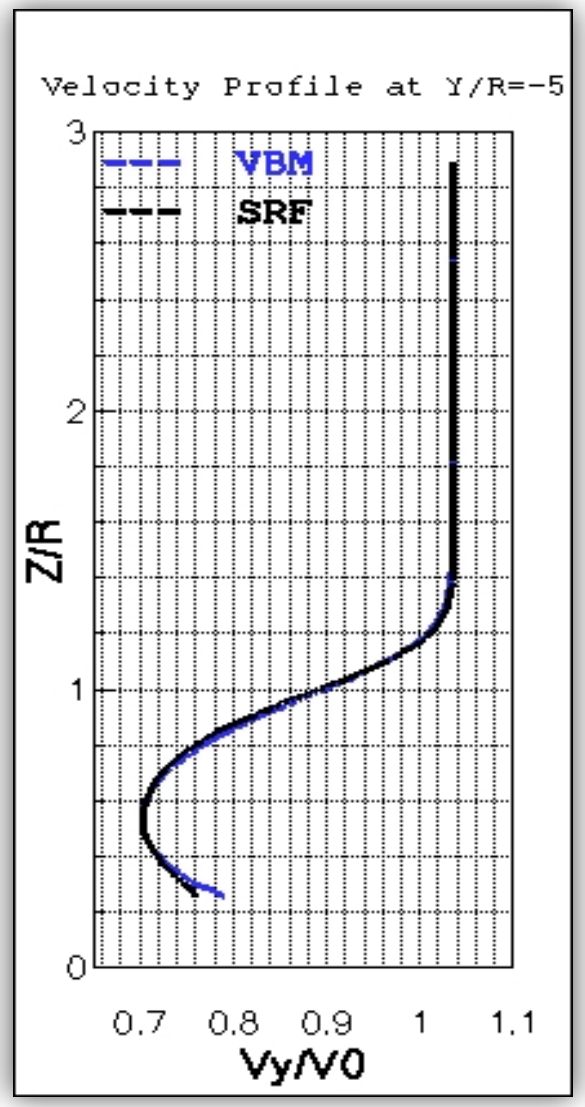
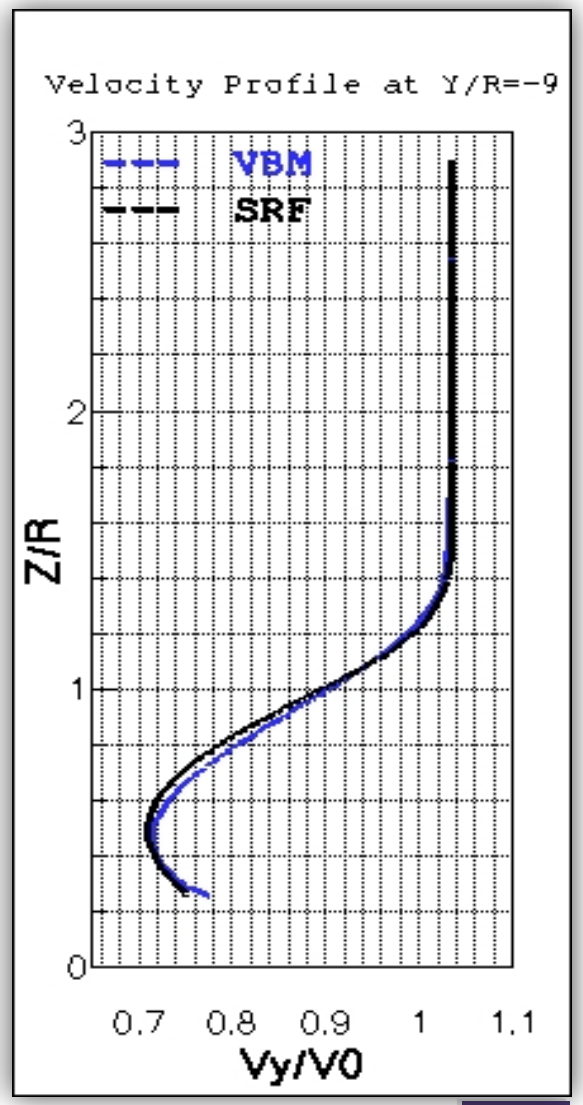
SRF vs. VBM


Velocity Profile at Y/R=-1
VBM
SRF
Z/R
Vy/V0
0
1
2
3
0.7
0.8
0.9
1
1.1


Velocity Profile at Y/R=-5
VBM
SRF
Z/R
Vy/V0
0
1
2
3
0.7
0.8
0.9
1
1.1

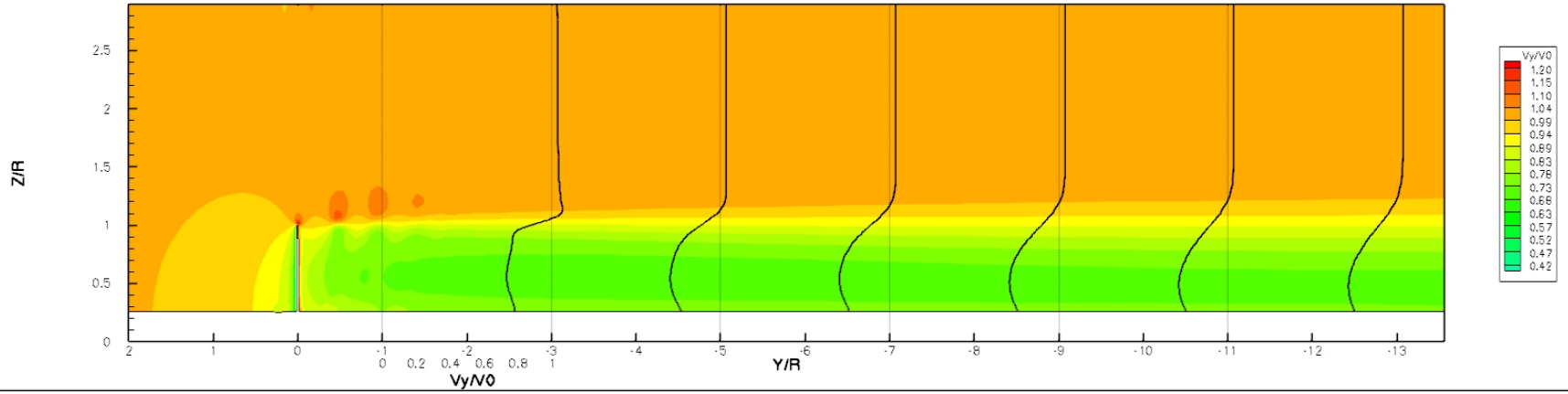

Velocity Profile at Y/R=-9
VBM
SRF
Z/R
Vy/V0
0
1
2
3
0.7
0.8
0.9
1
1.1

Actuator Disk Model (ADM)

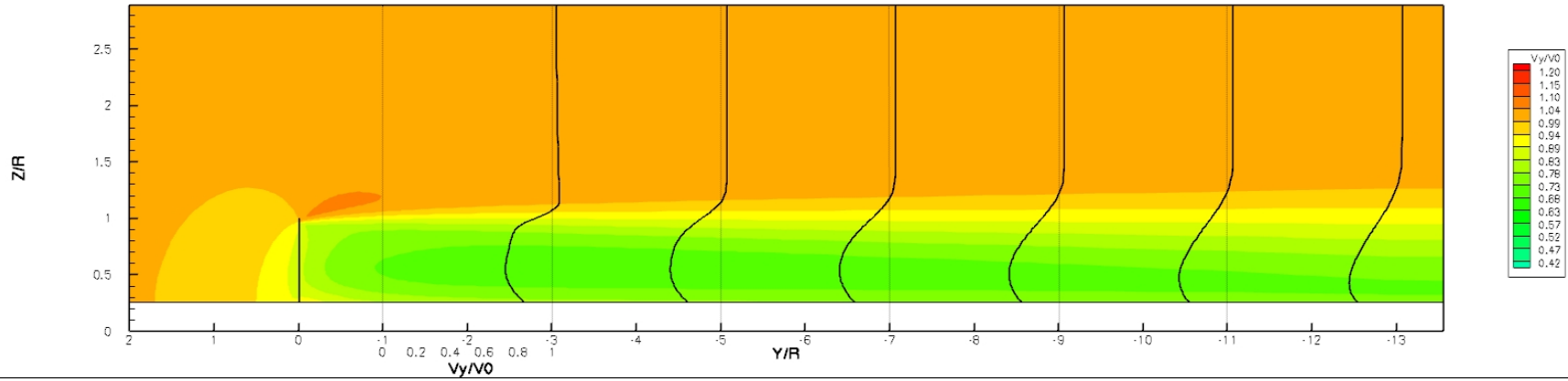
- Based on the actuator disk theory, turbine is modeled as a circular porous disk.

- Modeling the porous disk requires two porous coefficients, which are calculated based on actuator disk theory and the efficiency of the turbine.

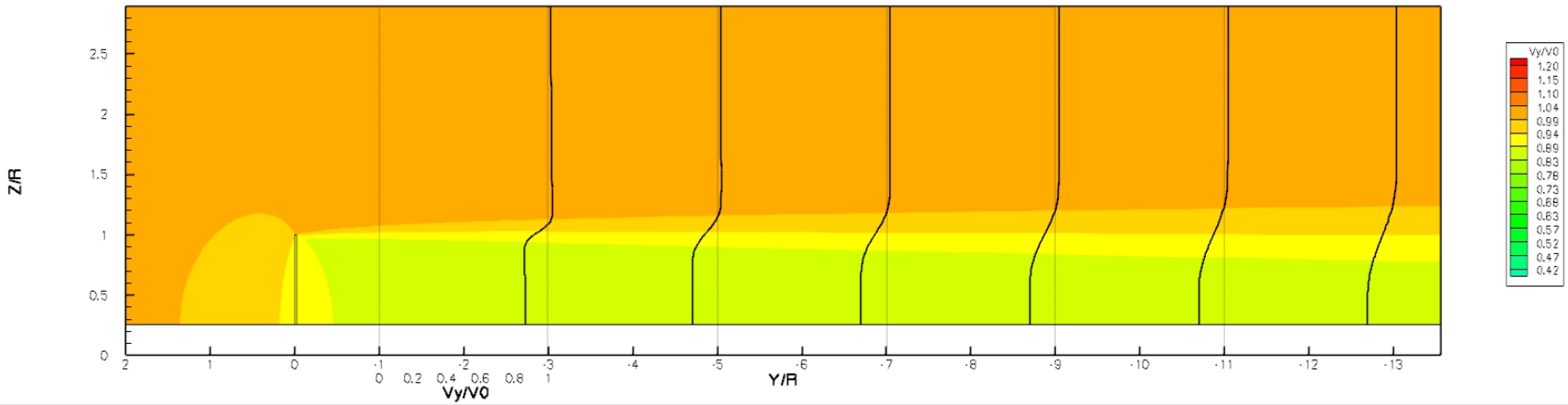
SRF / Velocity Contour / X-Cut / 1% Turbulent Intensity



VBM / Velocity Contour / X-Cut / 1% Turbulent Intensity



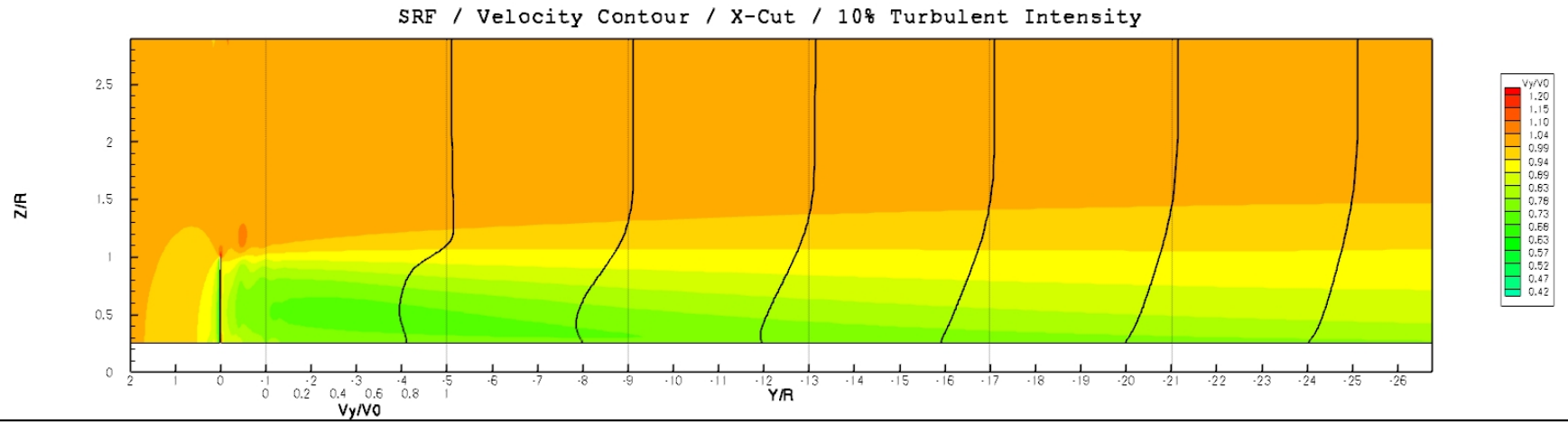
ADM / Velocity Contour / X-Cut / 1% Turbulent Intensity



Changing Turbulent Intensity (TI)

- Turbulent Intensity for the first set of simulation was 1% based on NREL test conditions in the AMES wind tunnel.

- To have more realistic simulations, the background turbulence intensity was changed from 1% to 10%.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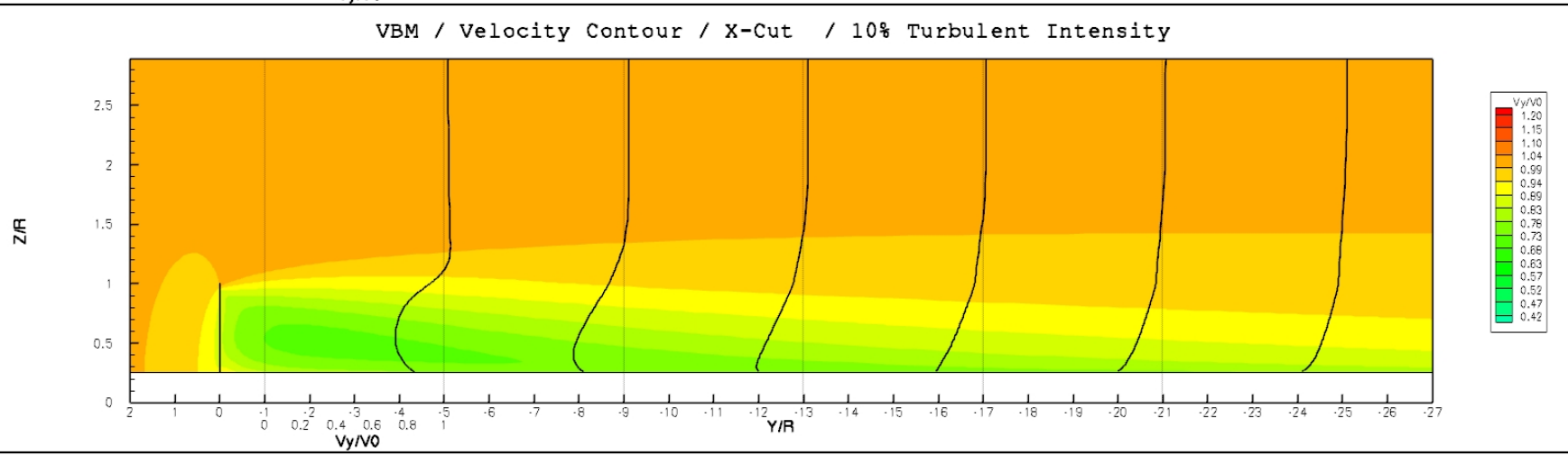
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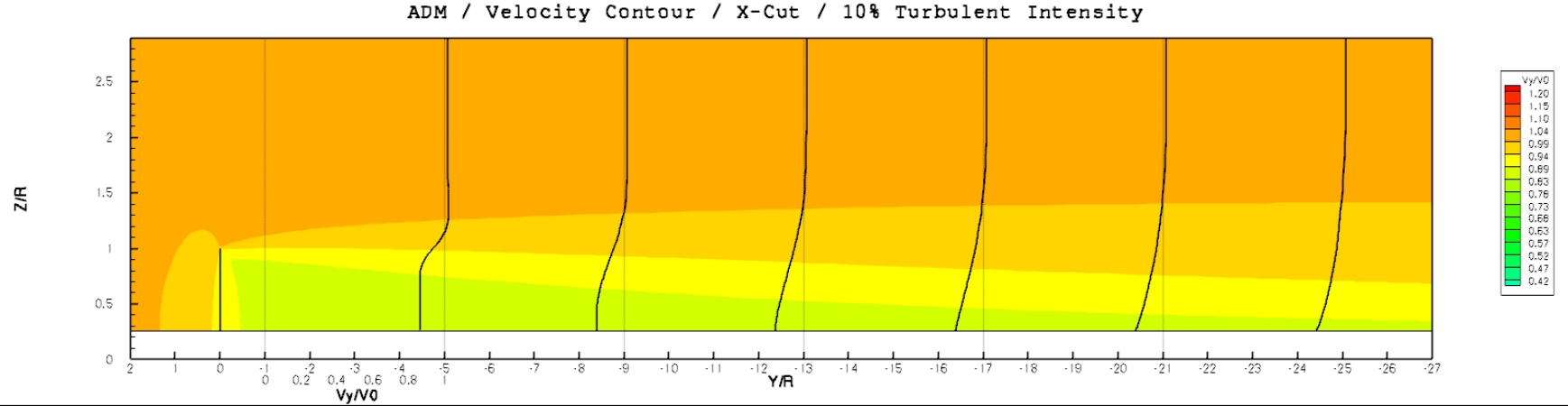
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Summary

- SRF was computed as a benchmark for other models. These results were validated with experimental results from literature (NREL).

- VBM has been compared to SRF both in the integral performance metrics (torque, power and thrust) and in detailed comparison of the far wake.

- ADM presents the opportunity of studying large turbine arrays with reasonable accuracy and computational cost.

Acknowledgement

Mr. Sylvain Antheaume
Mr. Joseph Seydel

Thank you for your time.