Influence of pitch motion on the wake of floating wind turbine models

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- tripods and monopiles feasible in shallow water

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Experimental investigation of wake development

Objectives - Approach

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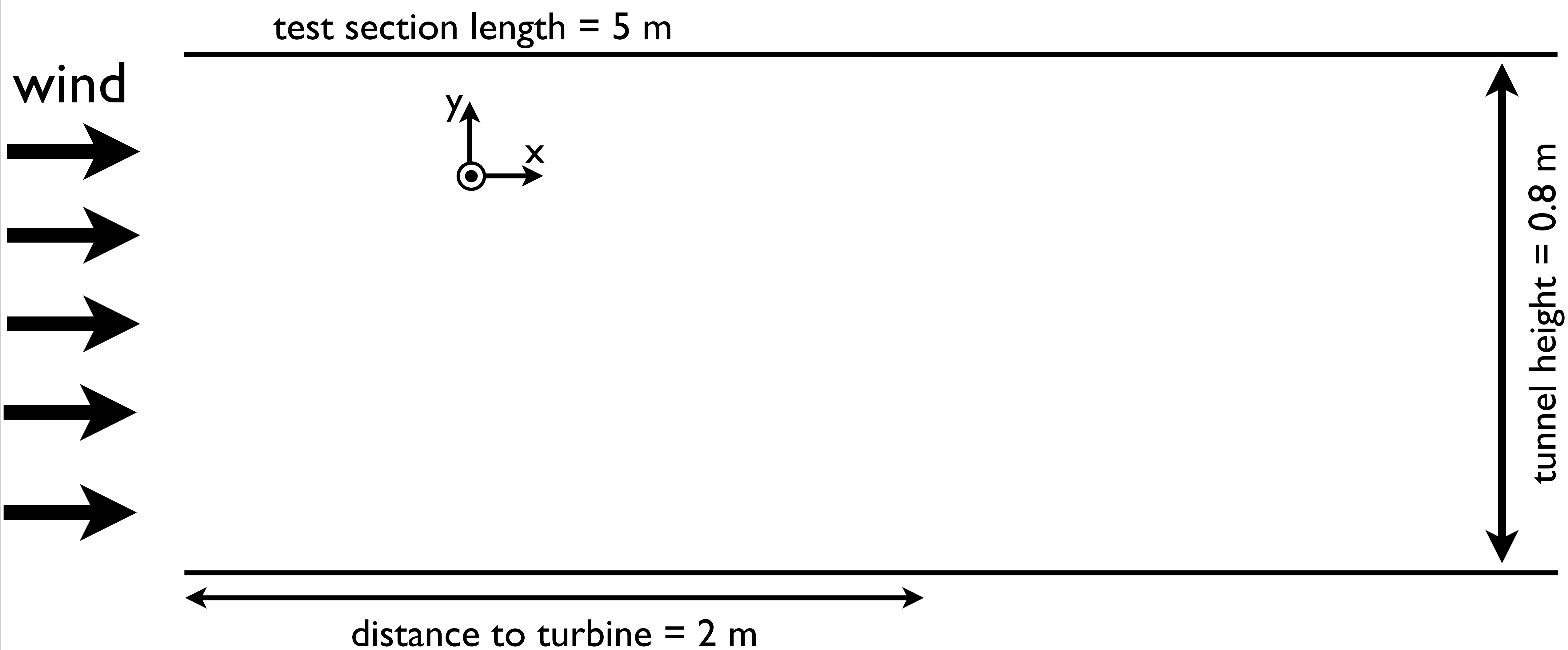
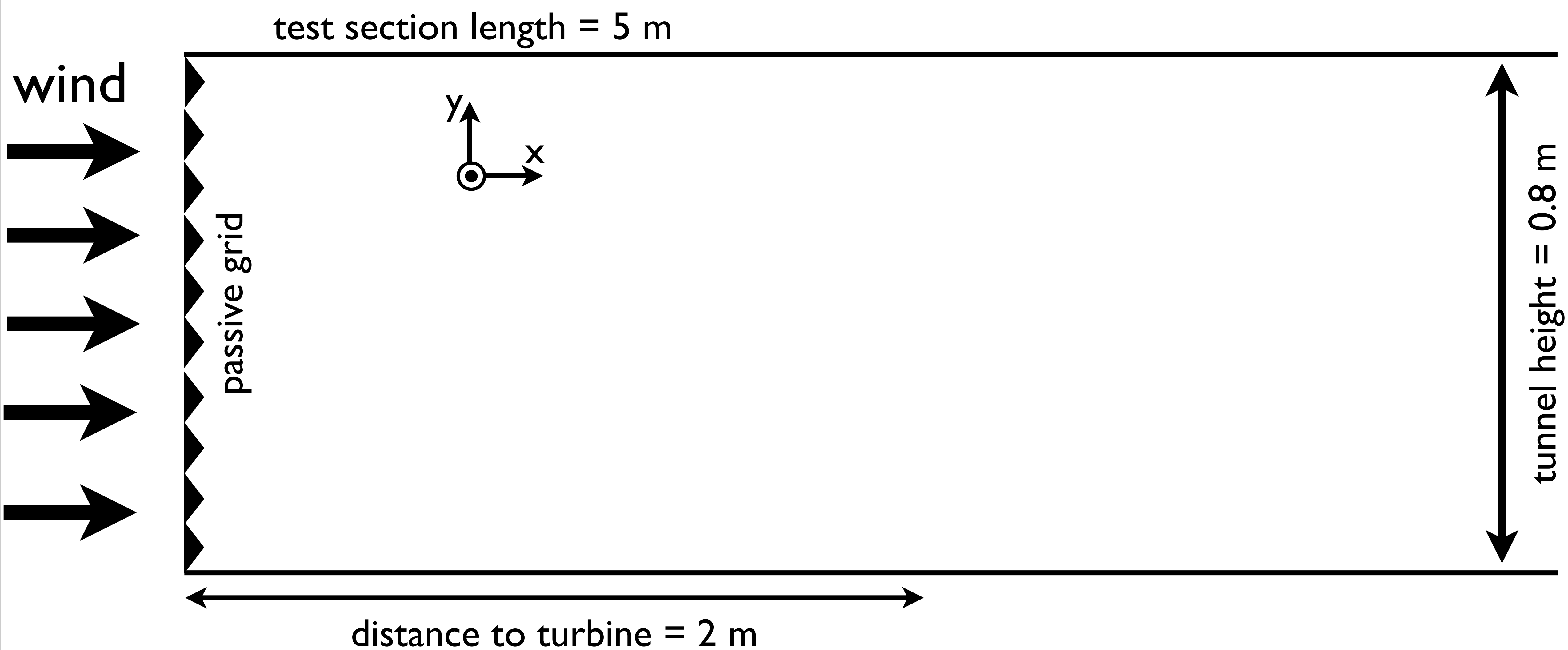
- comparison of inflow and wake development
  - near wakes of up– and downstream turbines

Experimental setup



wind tunnel at Portland State Univ.

Experimental setup



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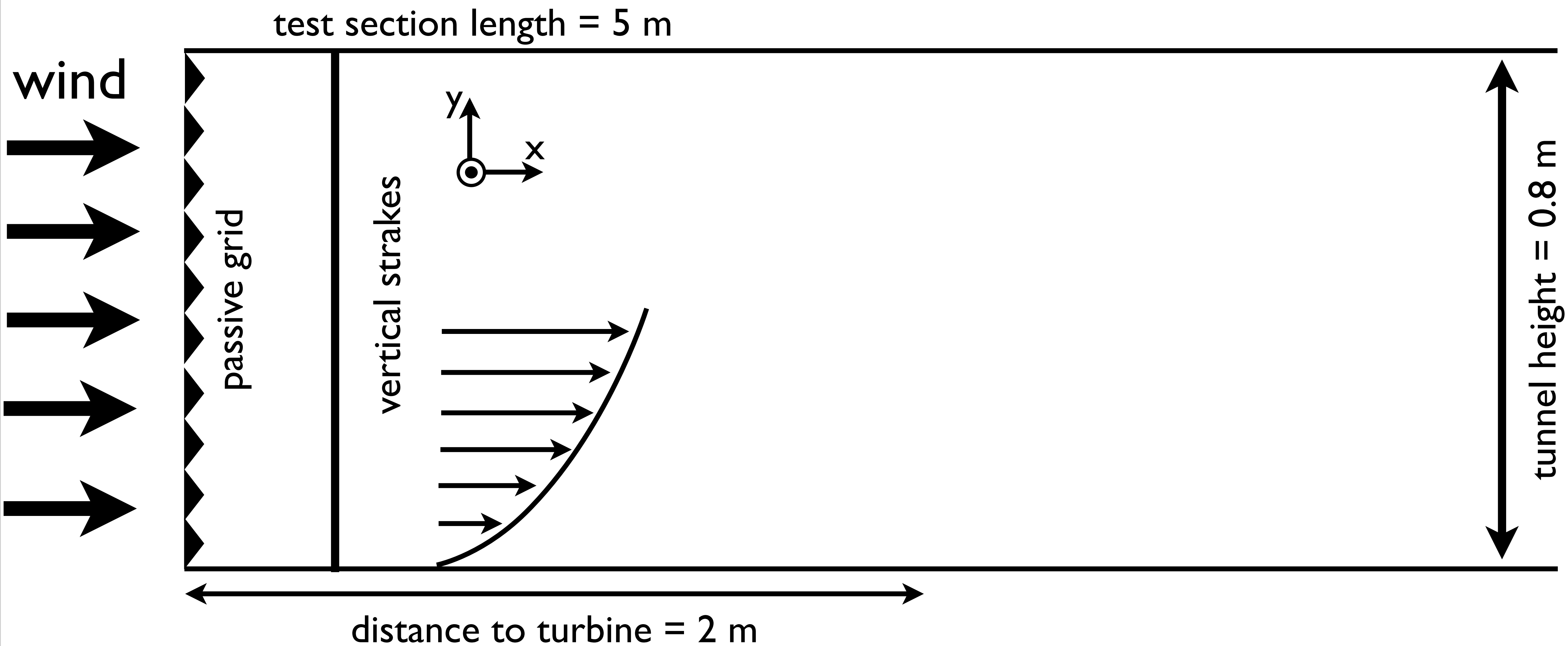

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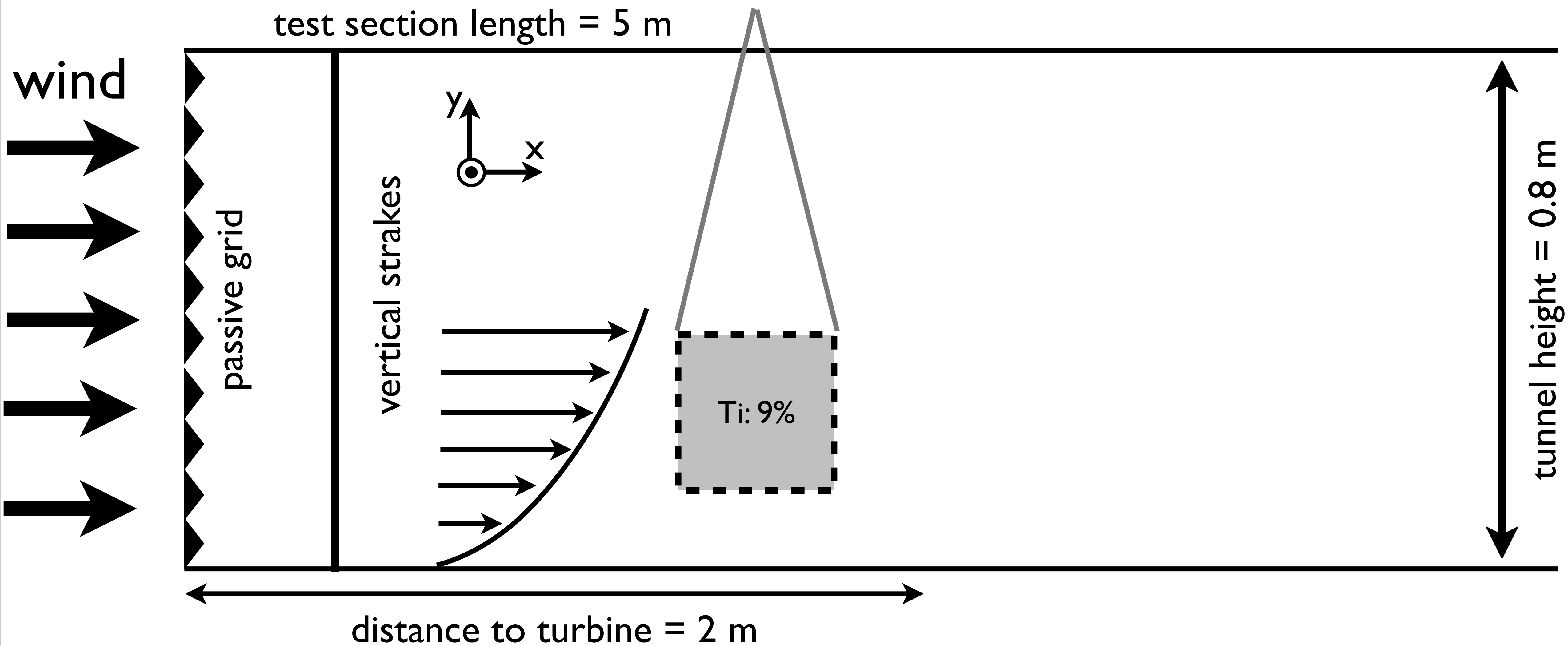

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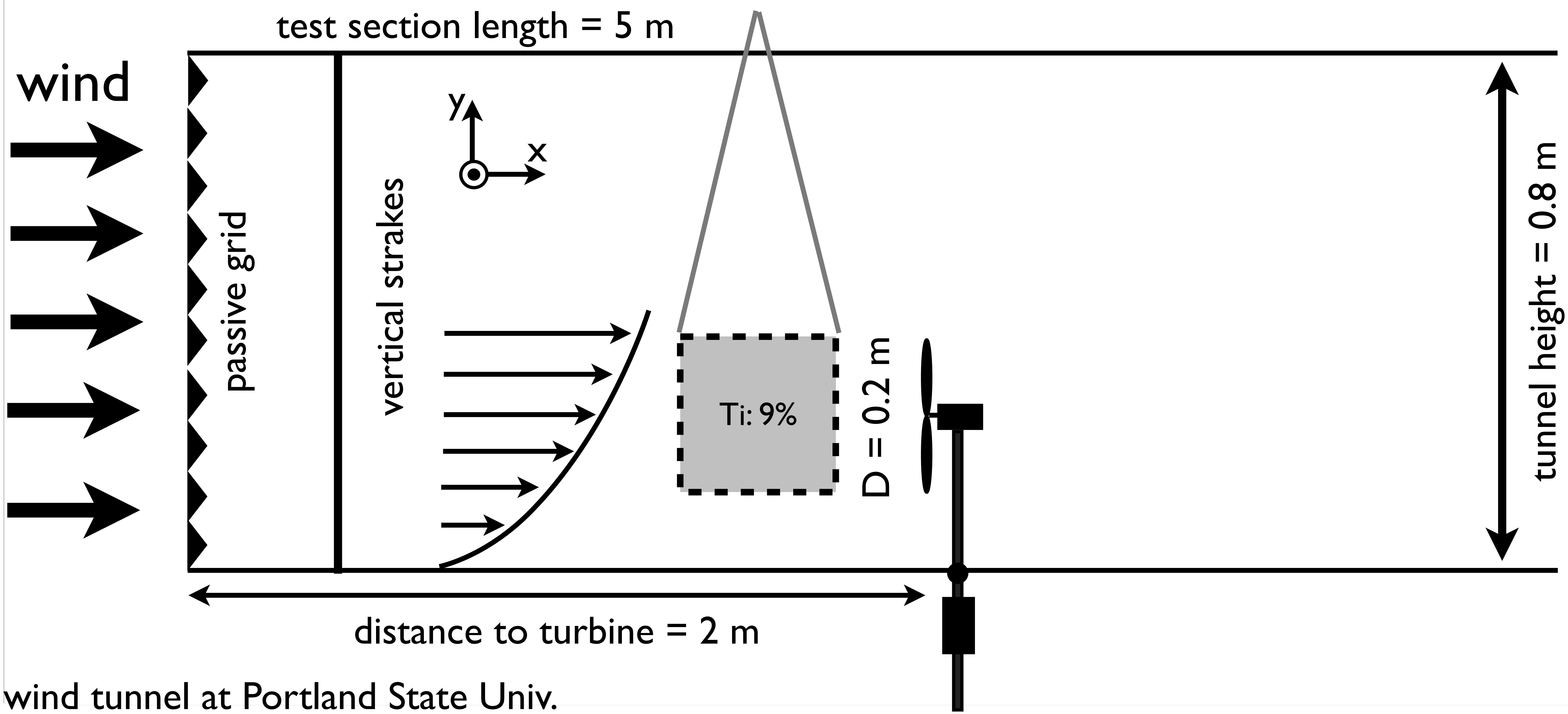
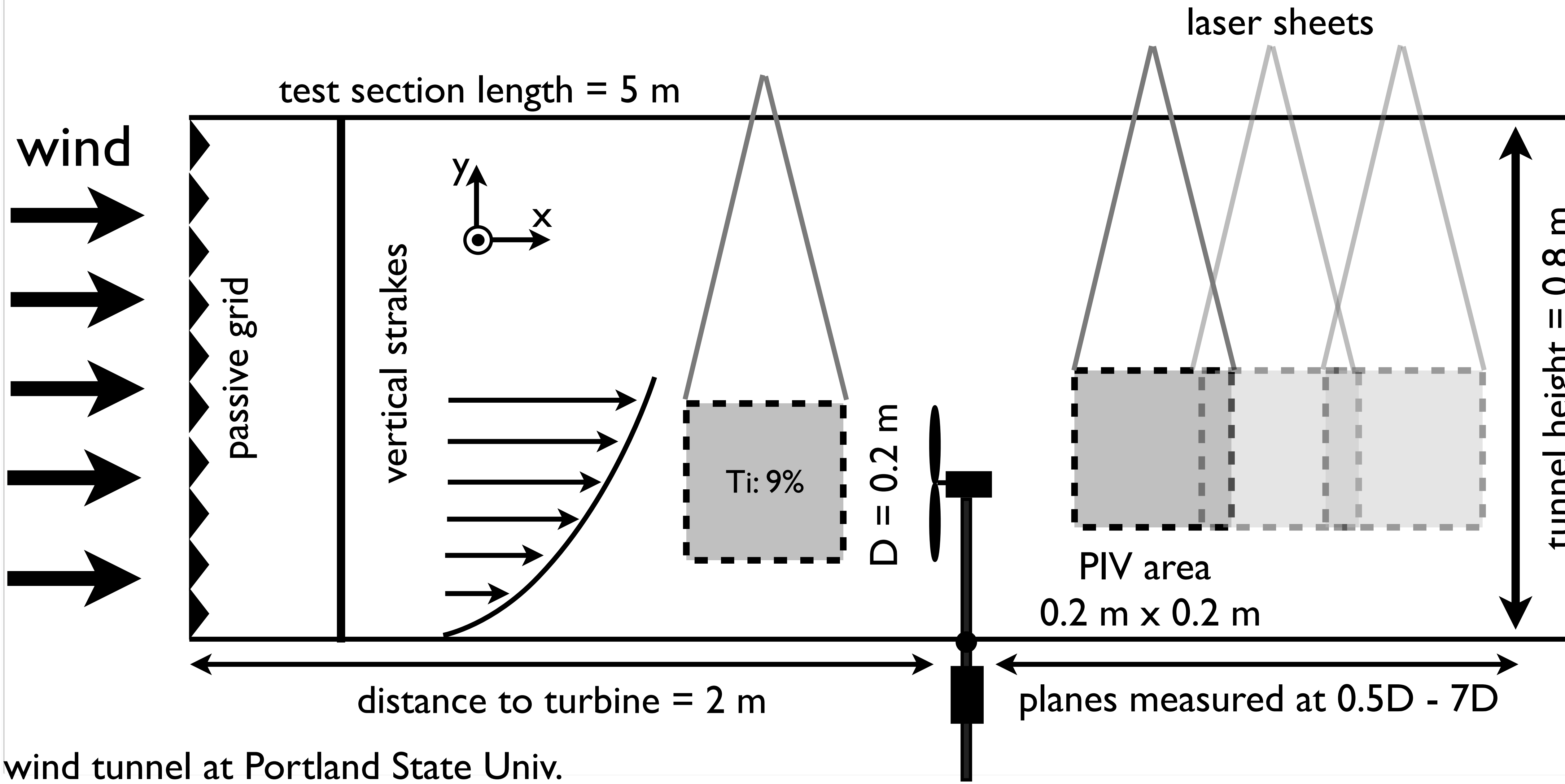


wind tunnel at Portland State Univ.

Experimental setup

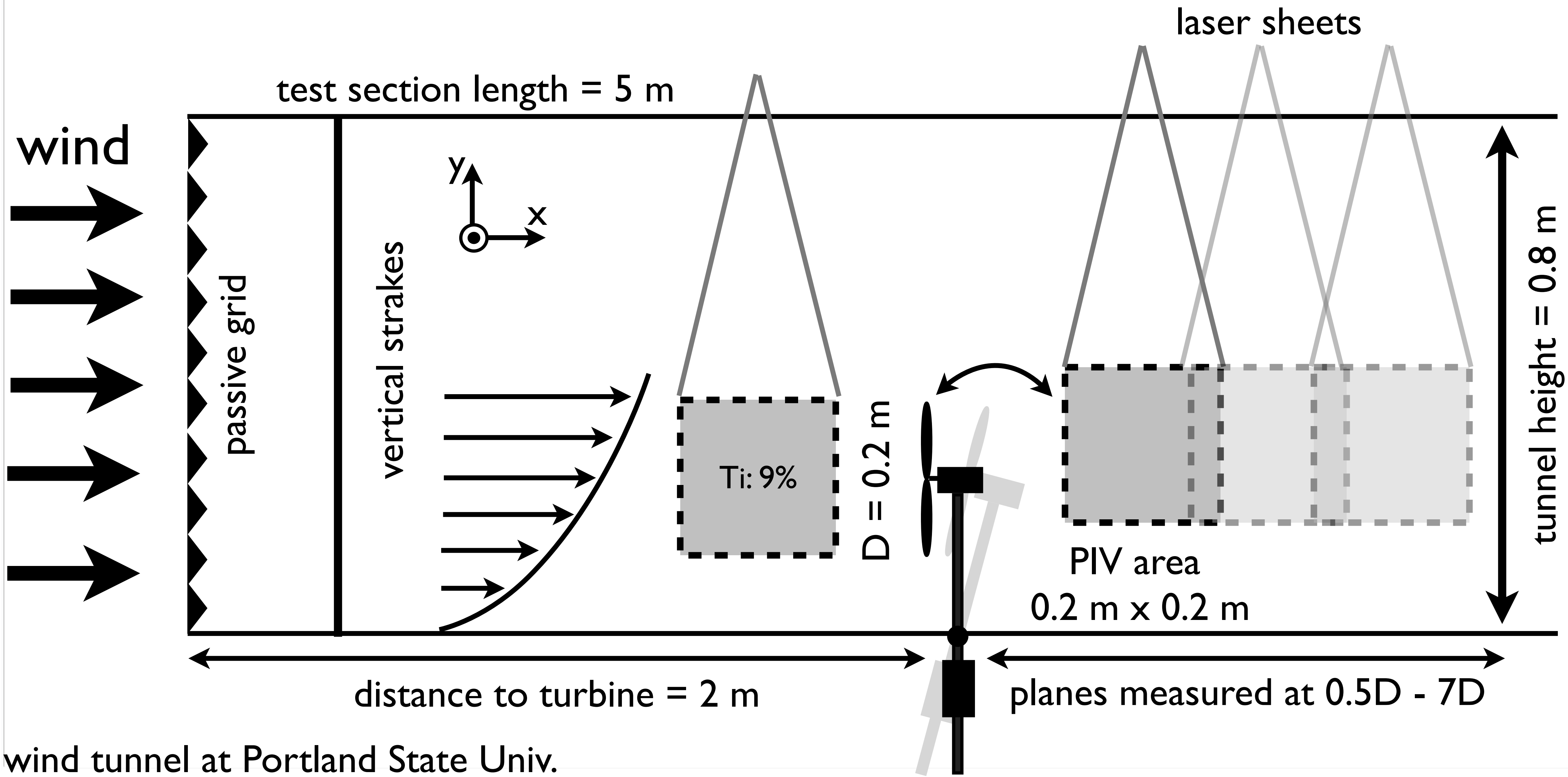
- *SPIV: optical flow measurements 2D-3C*
- *planes: center of tower*
- *fixed case data @1Hz*



wind tunnel at Portland State Univ.

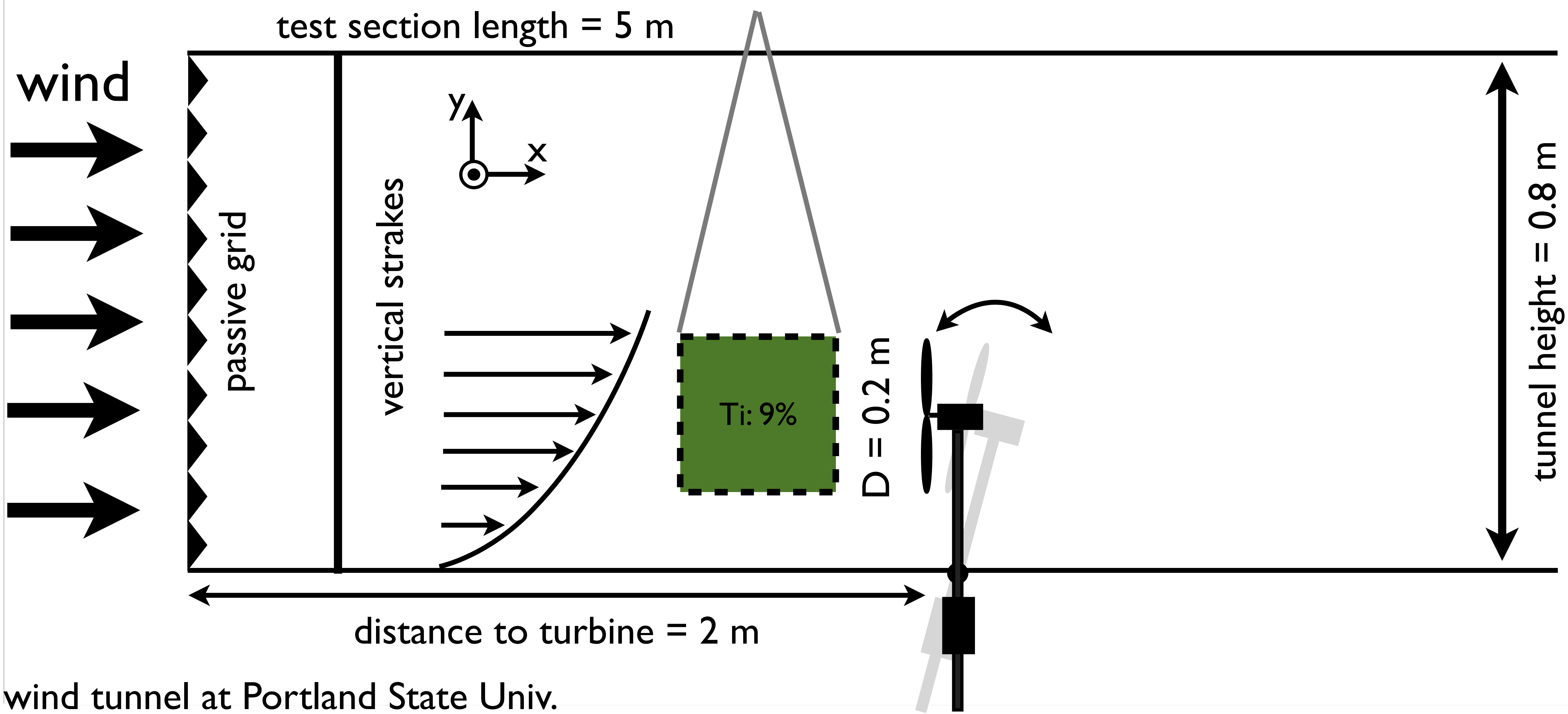
Experimental setup

- *SPIV: optical flow measurements 2D-3C*
- *planes: center of tower*
- *fixed case data @1Hz*
- *floating condition: 1D streamwise oscillation*
- *floating case PIV triggered on turbine position*
- *2500 images / plane*



wind tunnel at Portland State Univ.

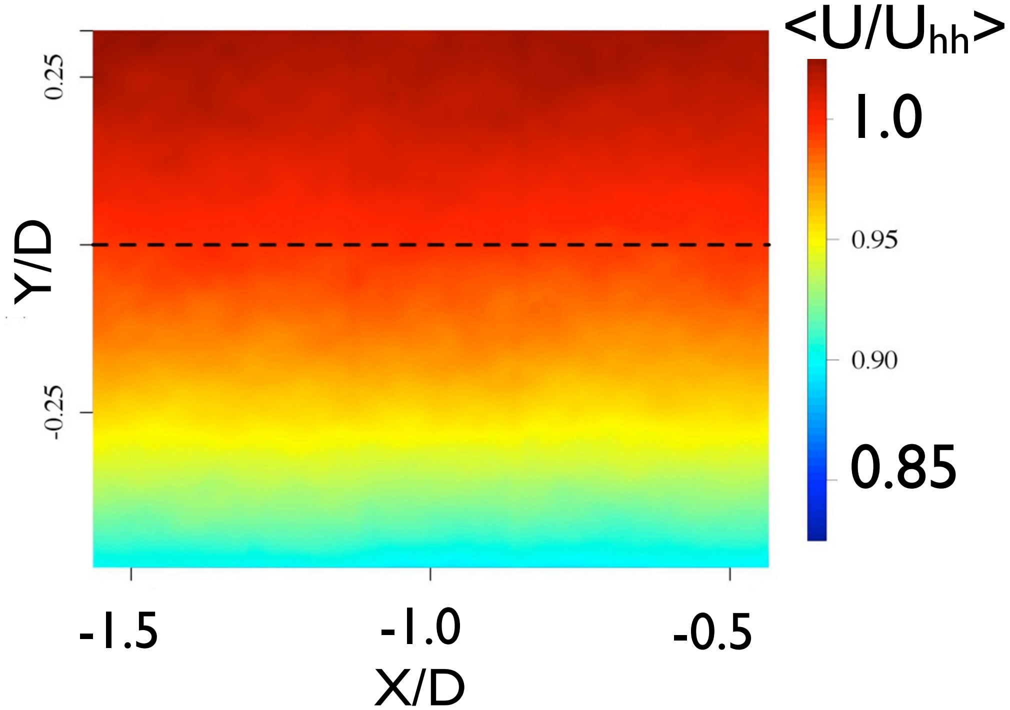
Inflow setup



wind tunnel at Portland State Univ.

Inflow: averaged streamwise component $\langle U/U_{hh} \rangle$

free inflow



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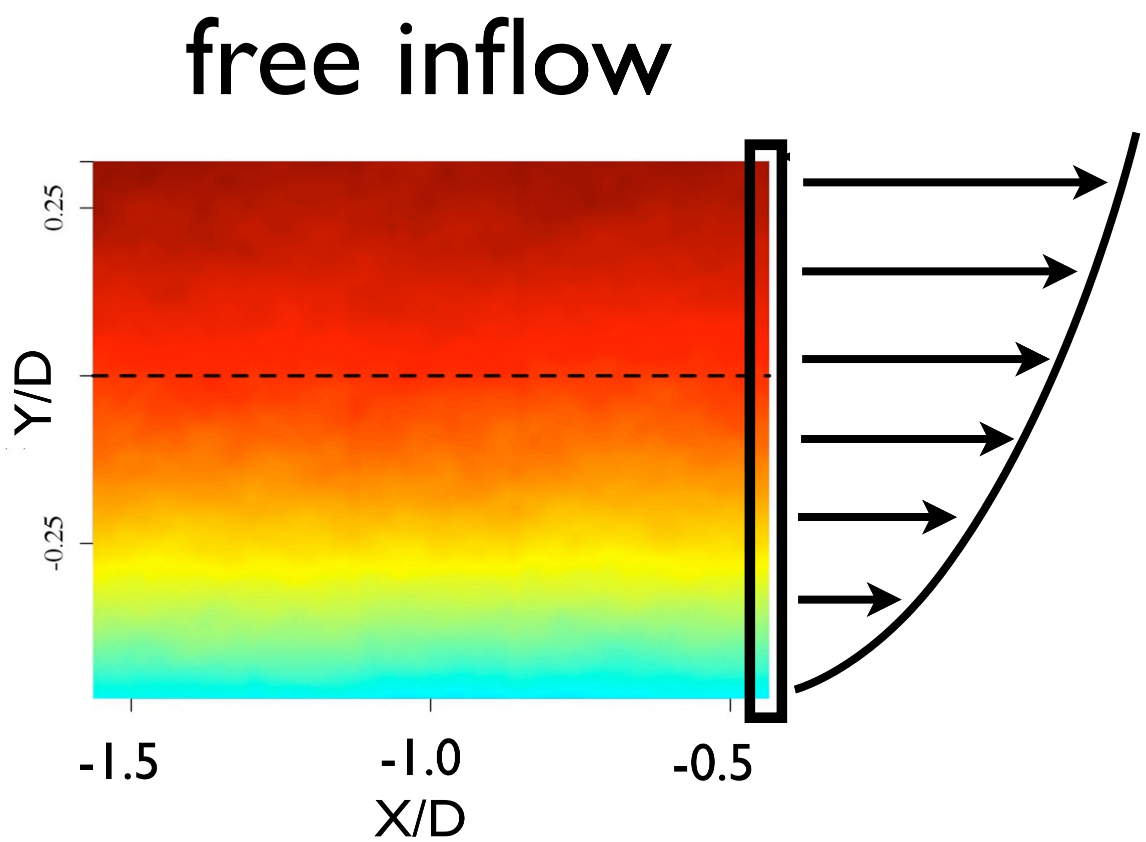

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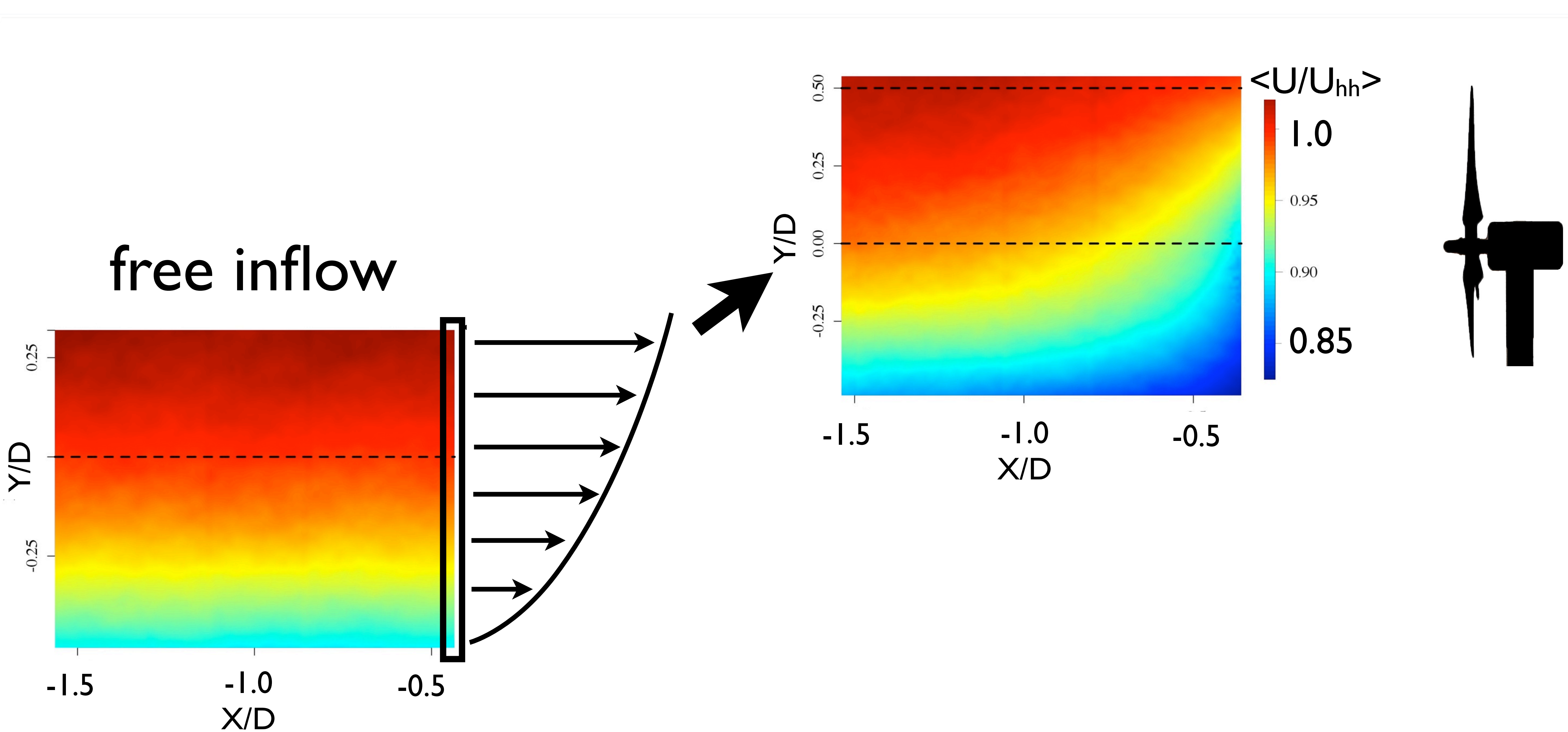

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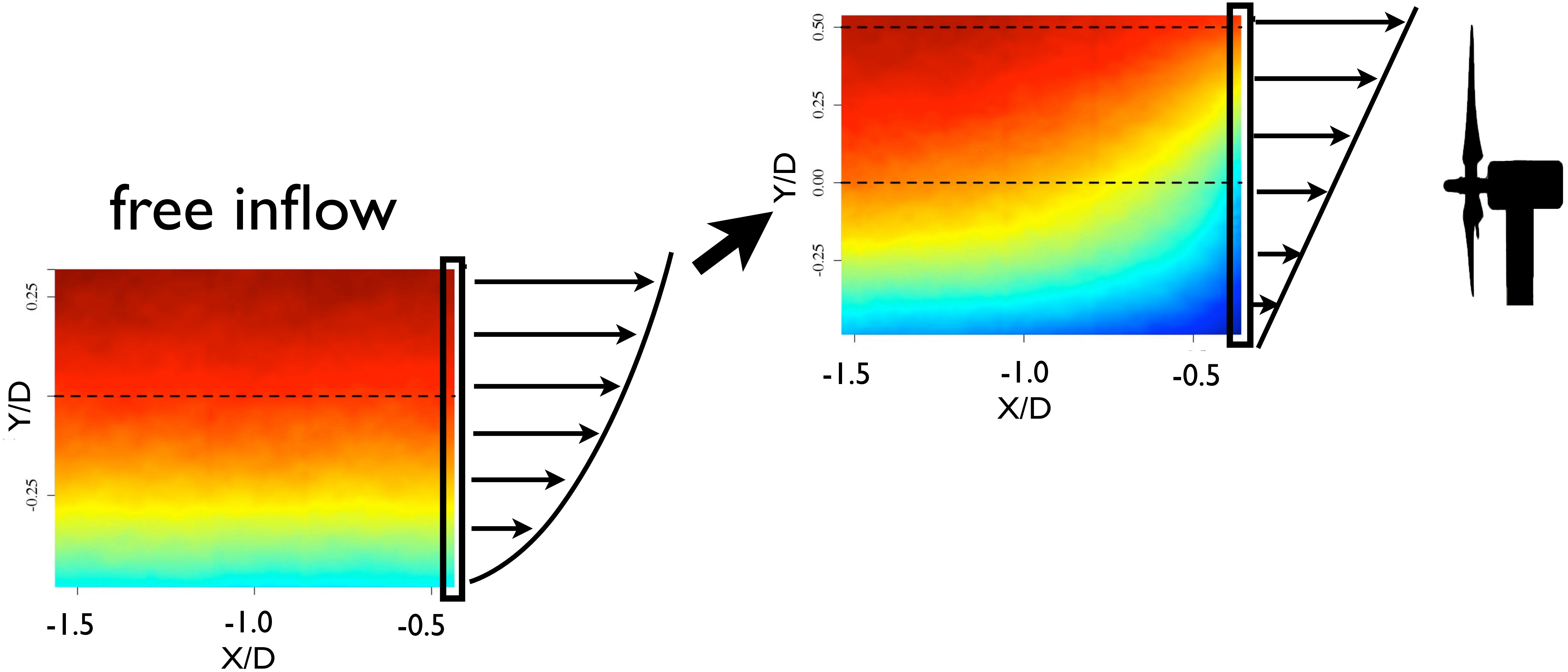

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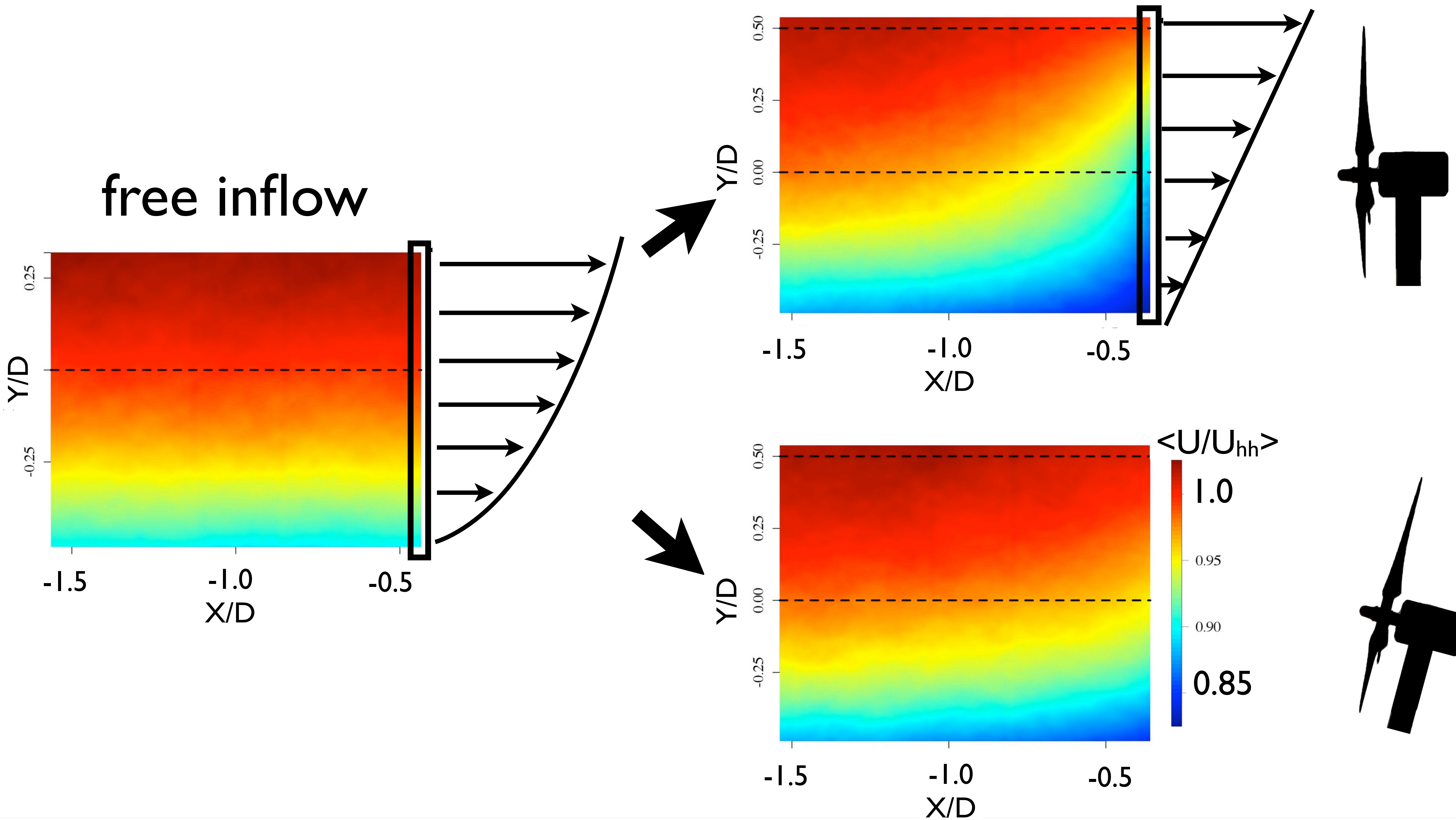
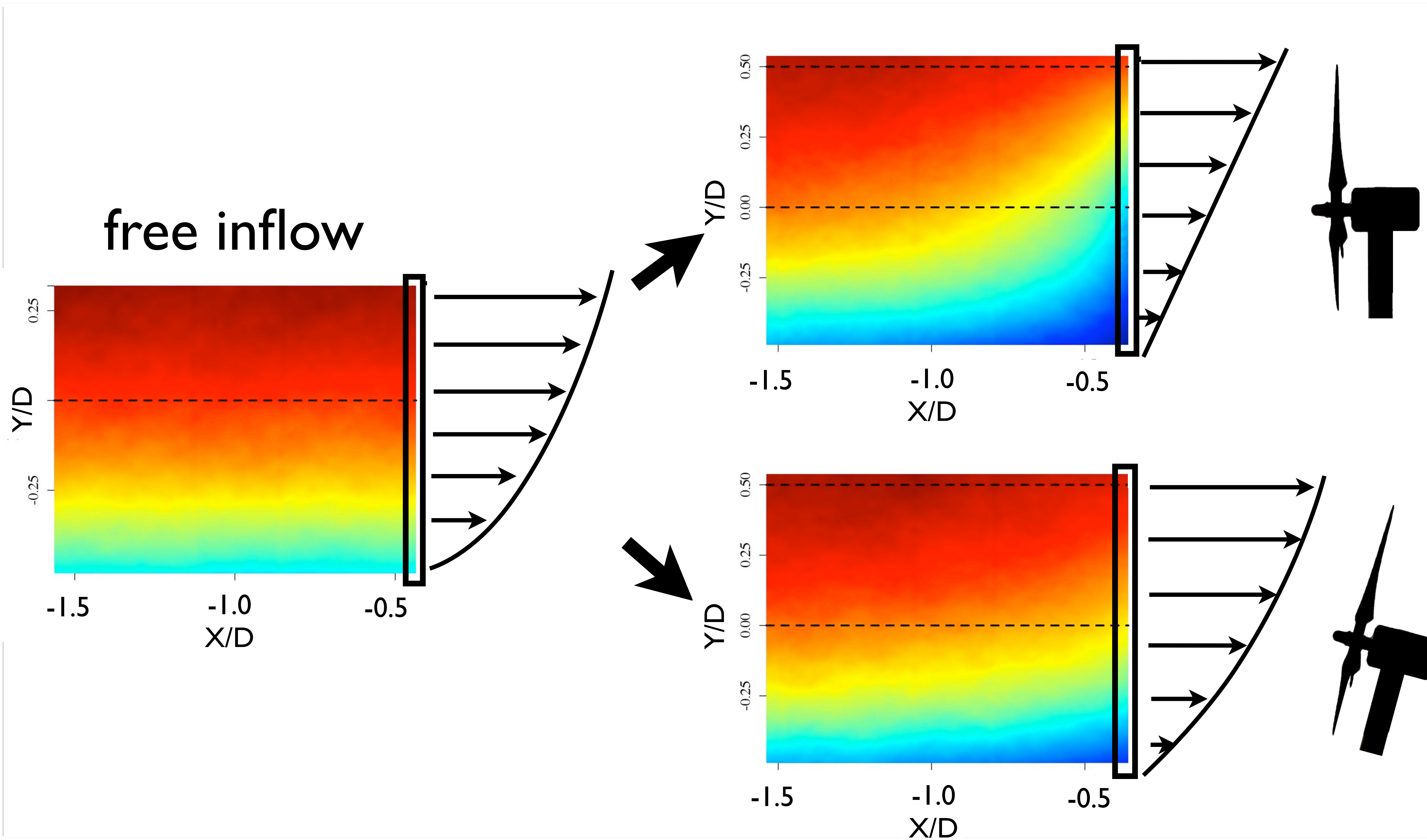
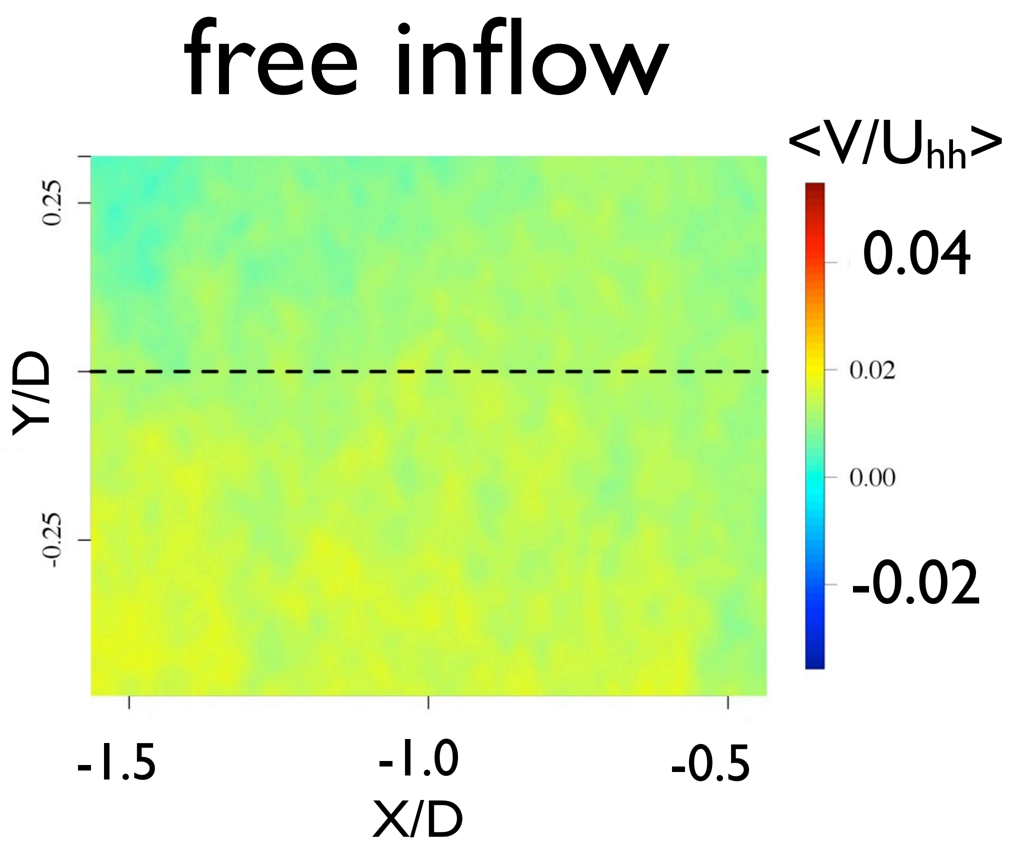


Inflow: averaged streamwise component <U/U_{hh}>



Inflow: averaged vertical component <V/U$_{hh}$>



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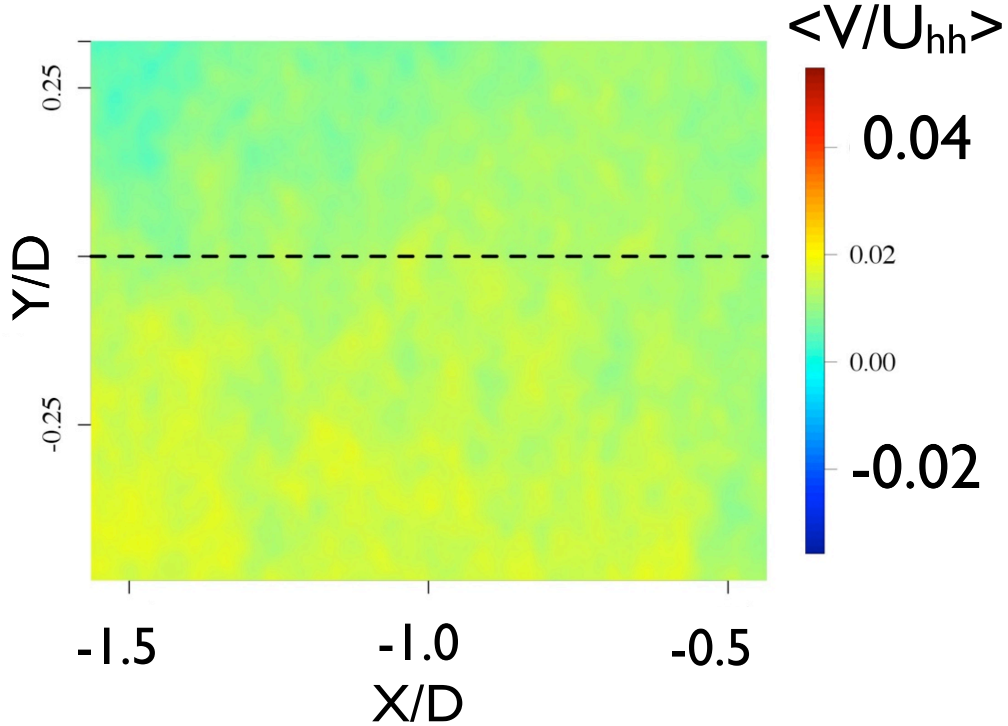

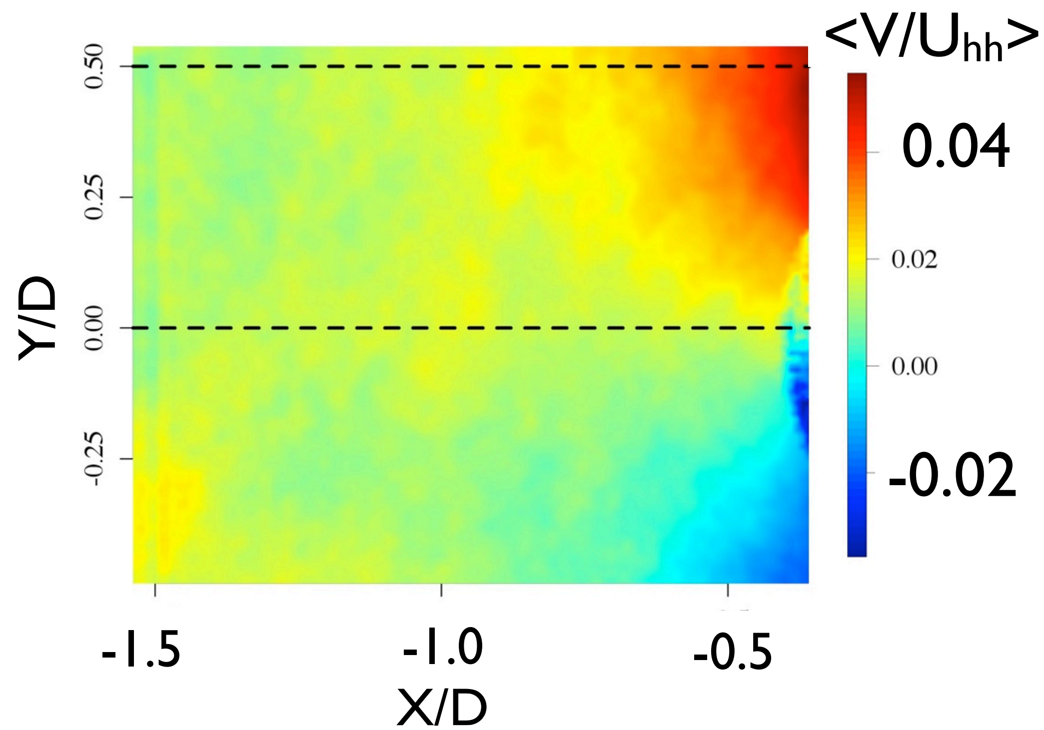

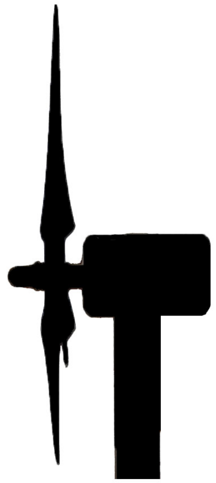

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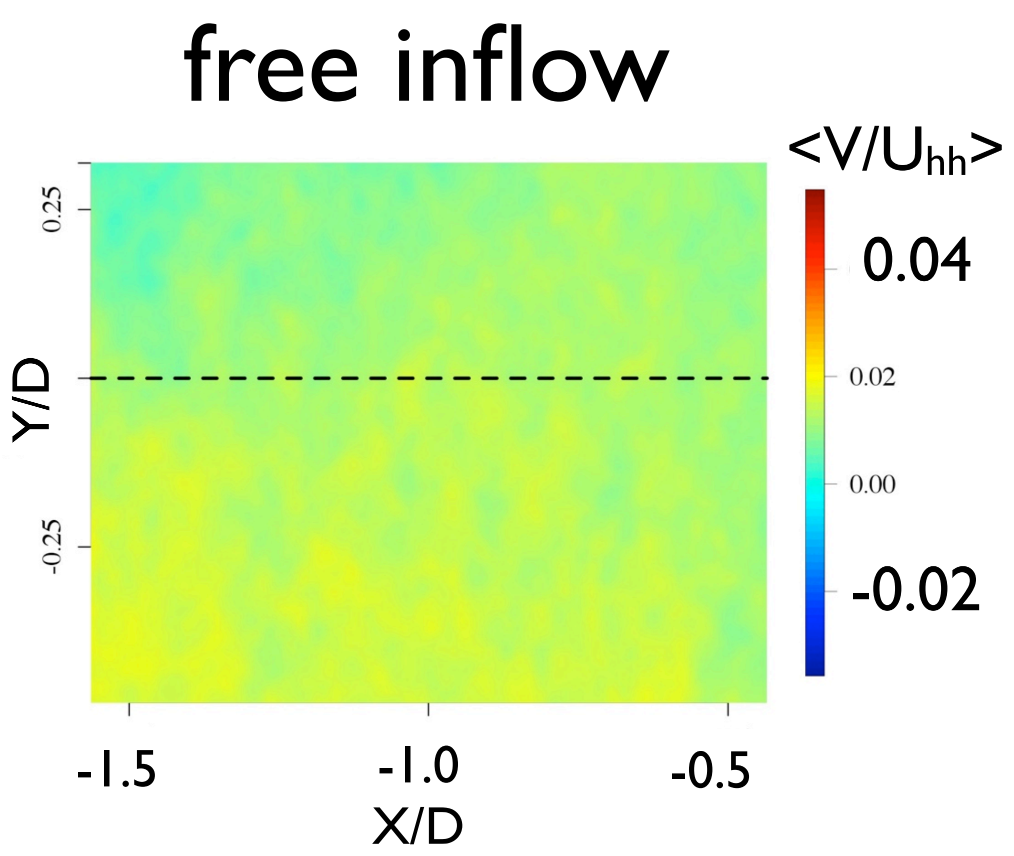
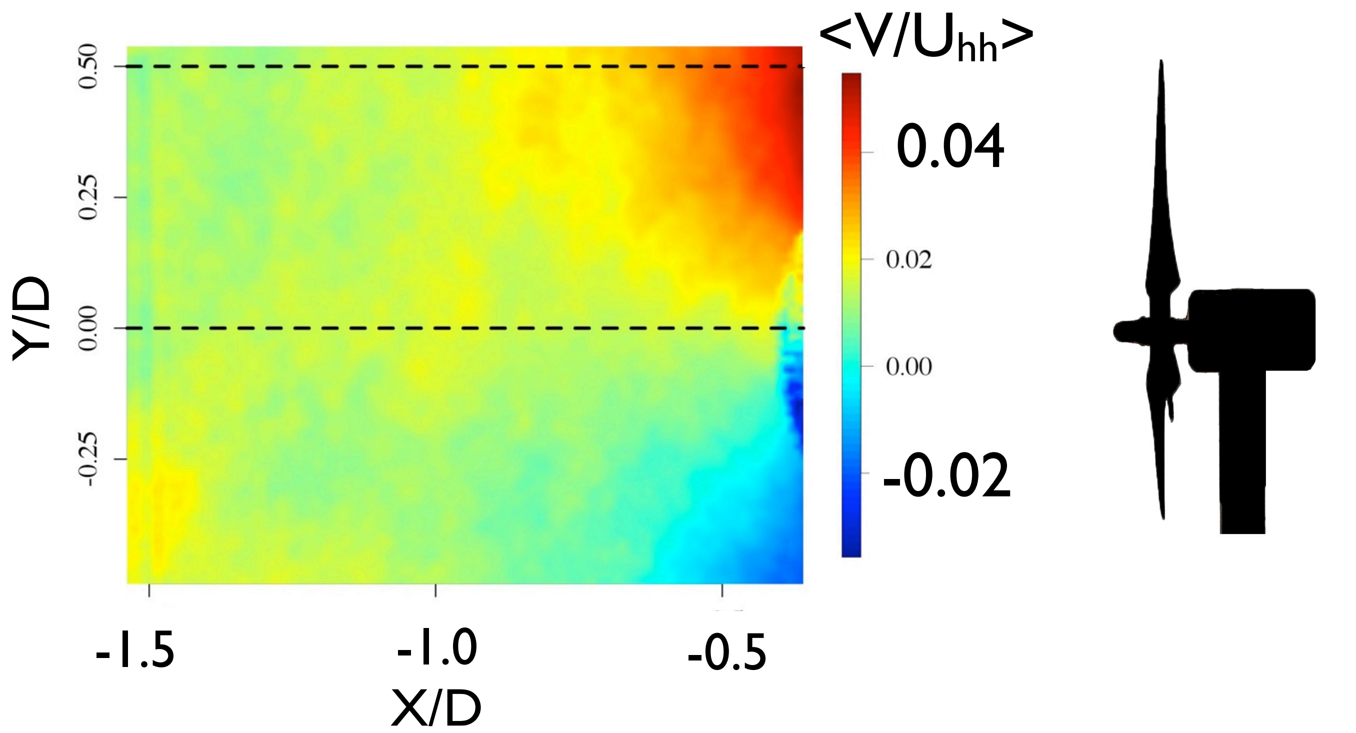
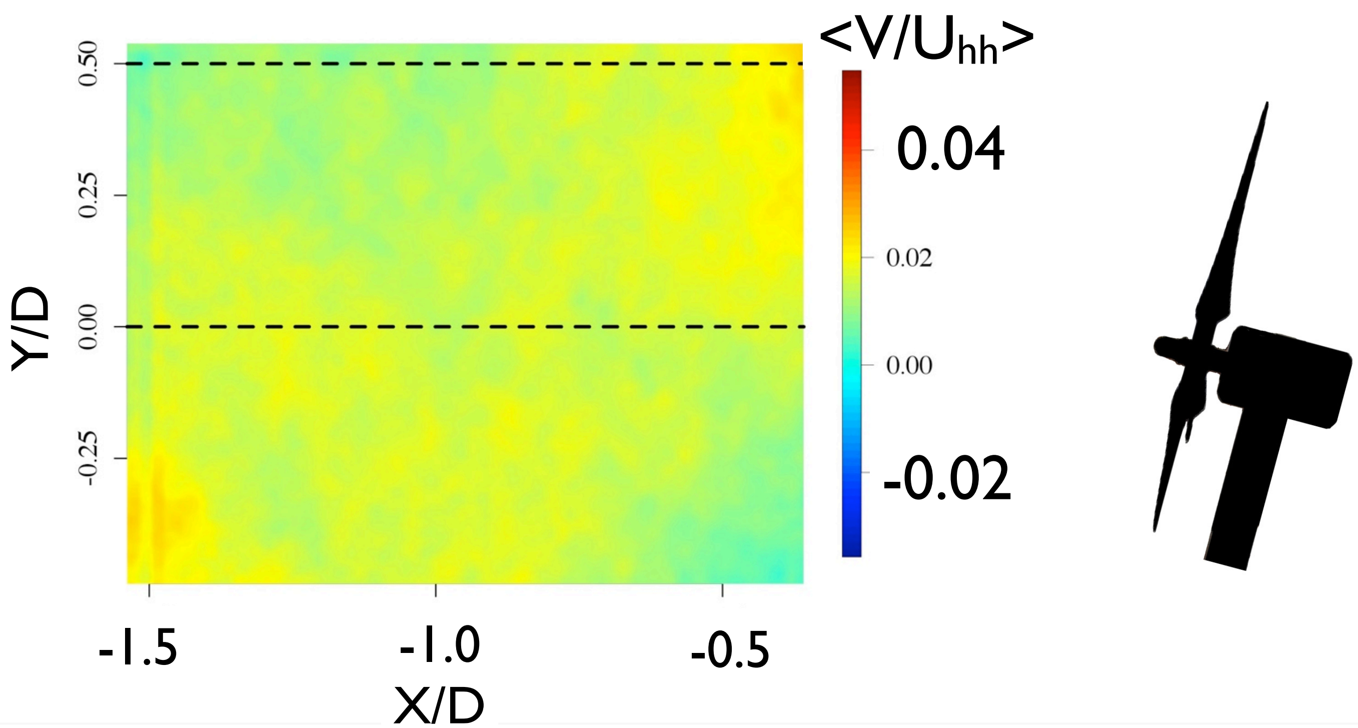
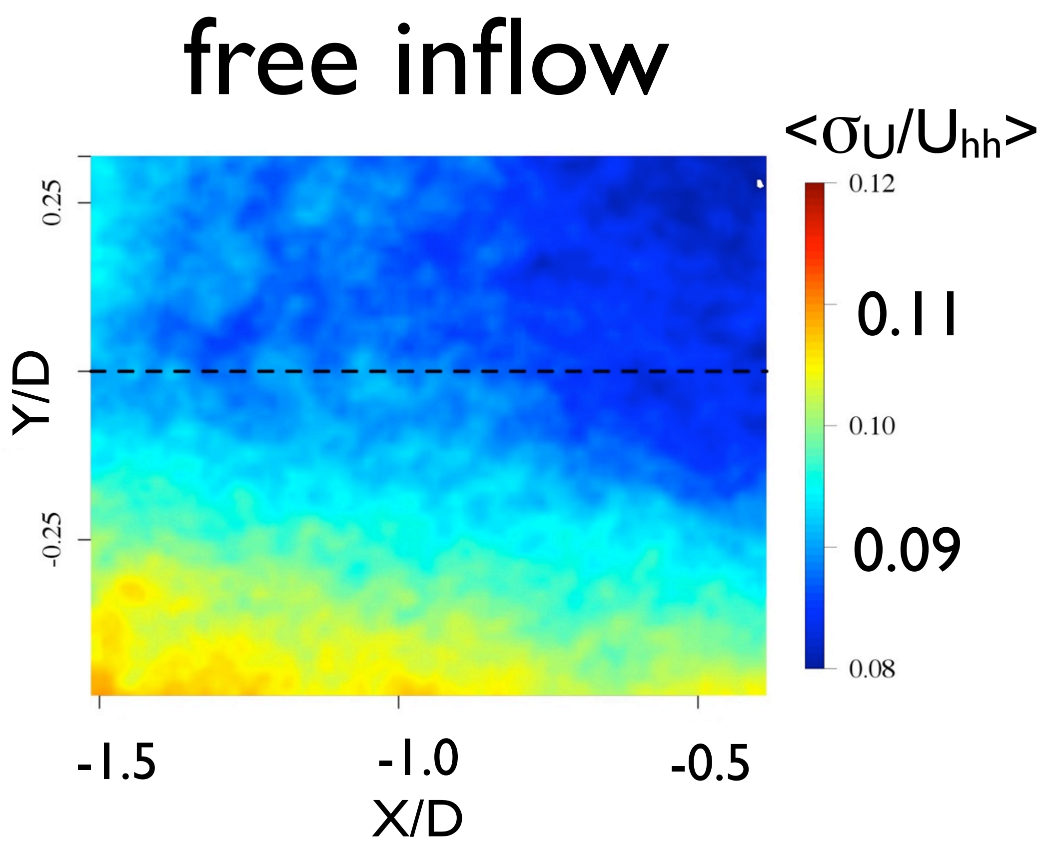






Inflow: averaged turbulence intensity $<\sigma_U/U_{hh}>$



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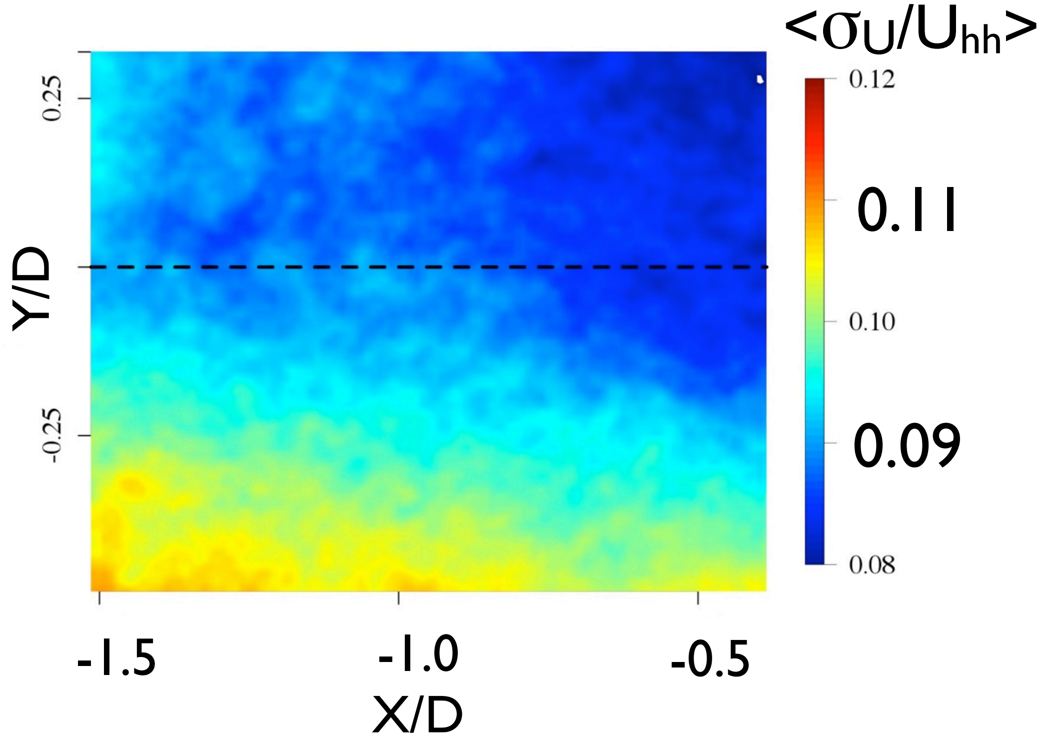

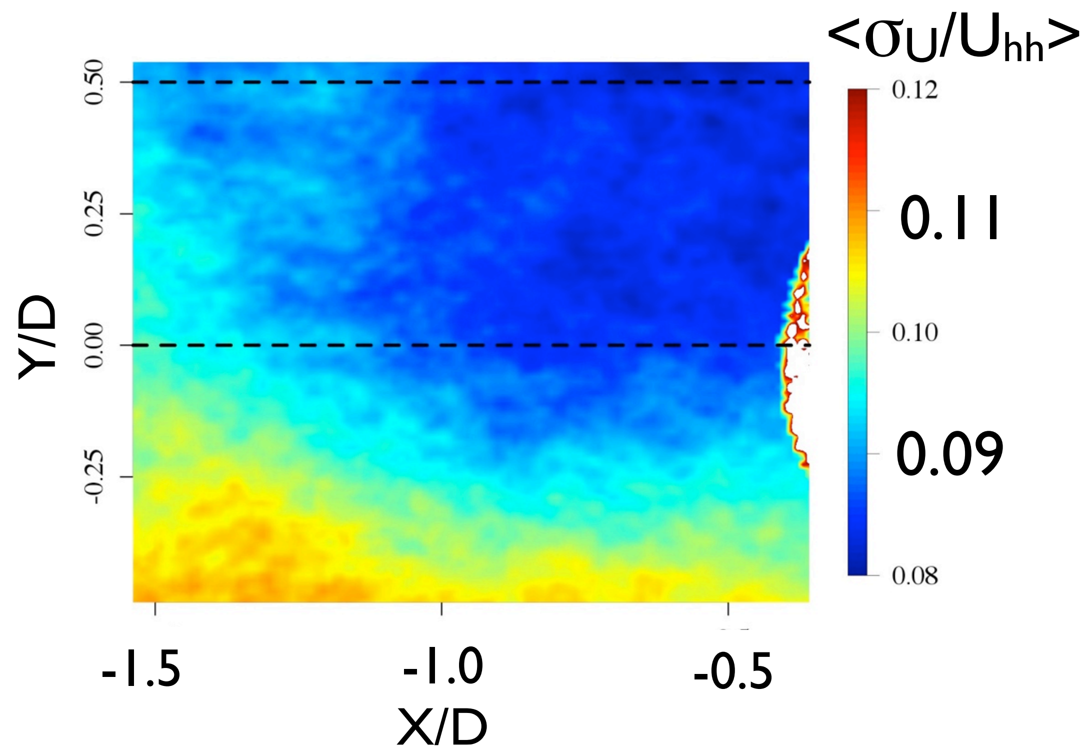

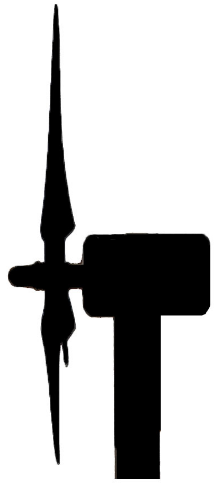

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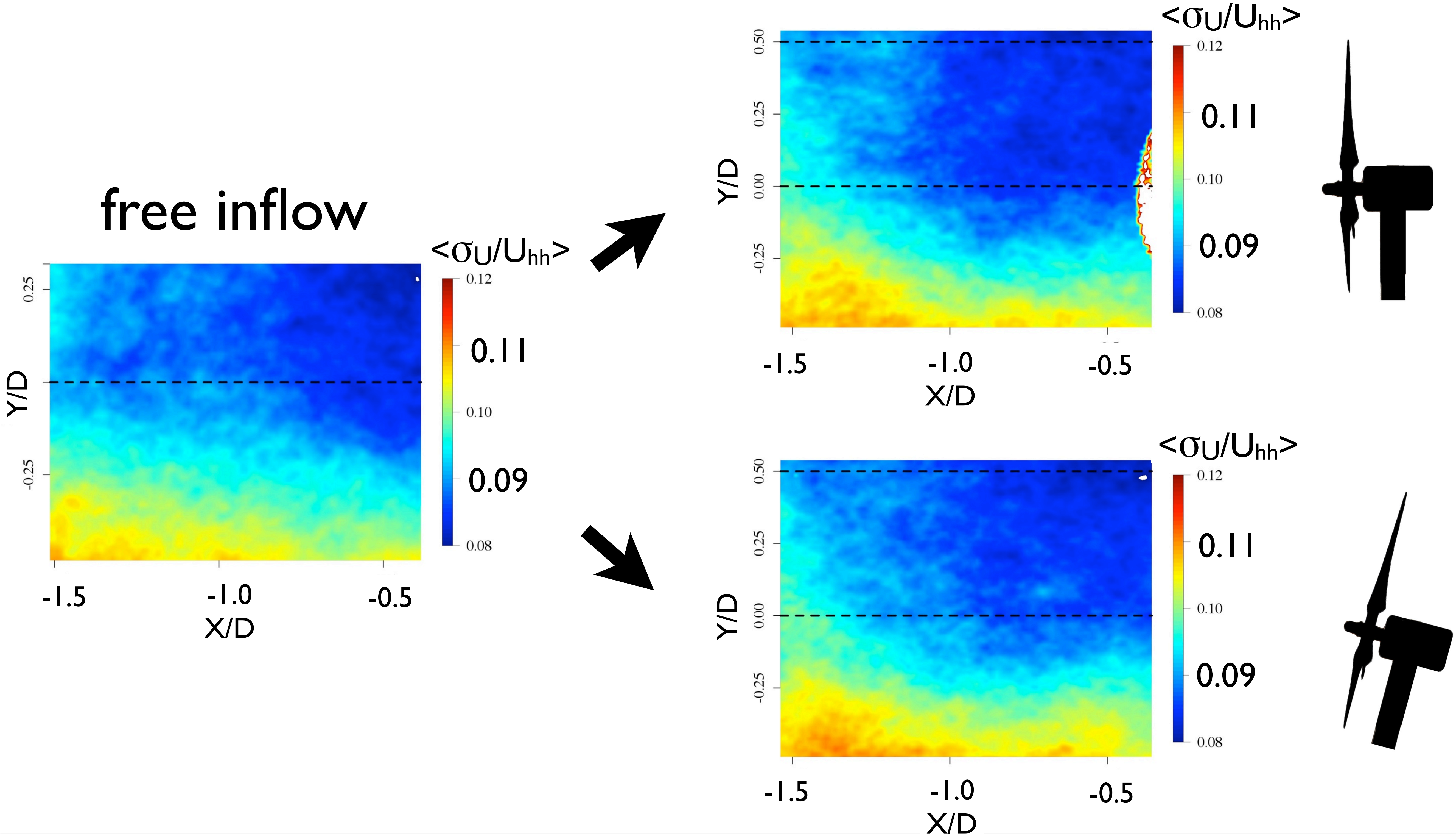
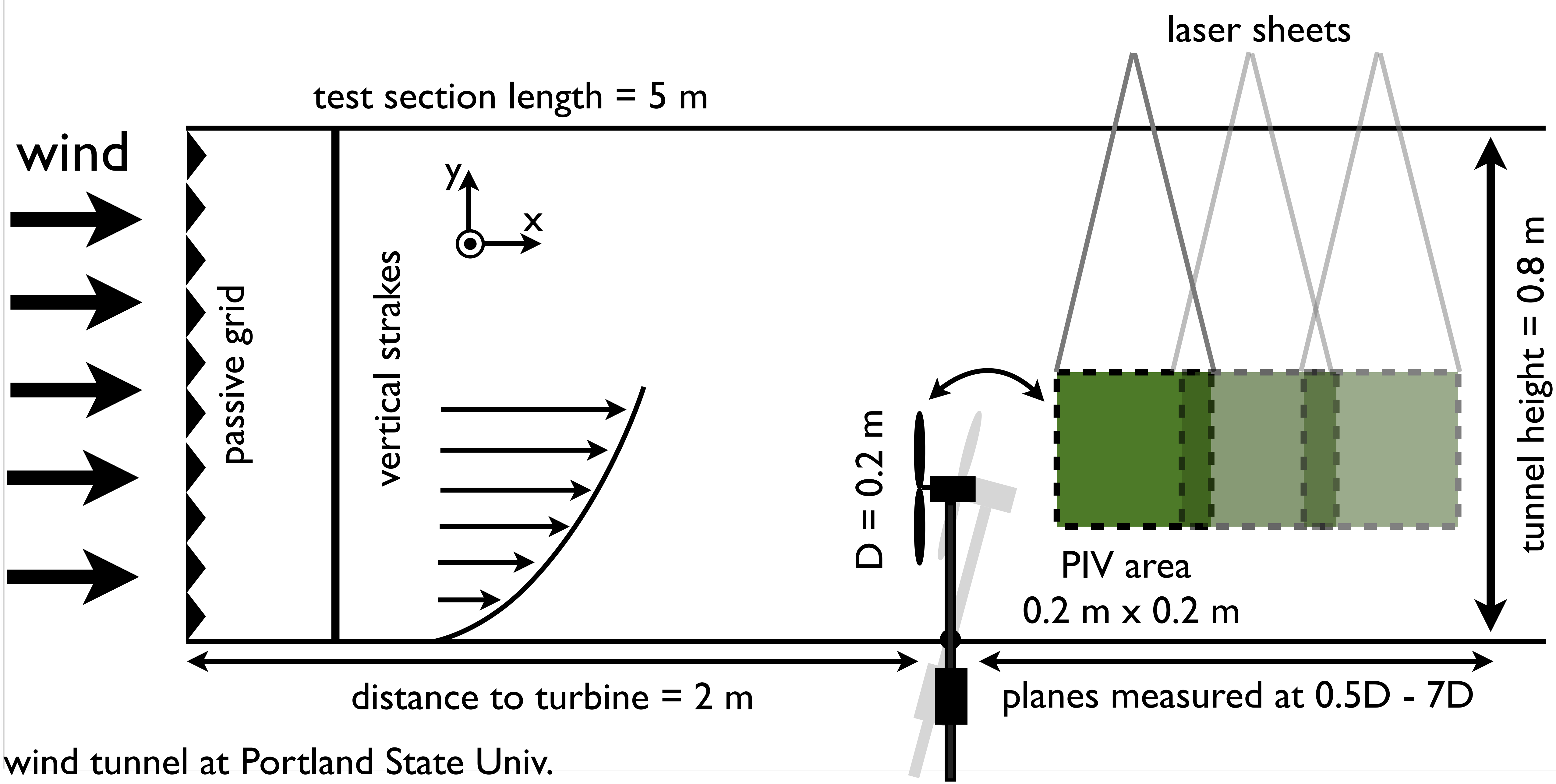
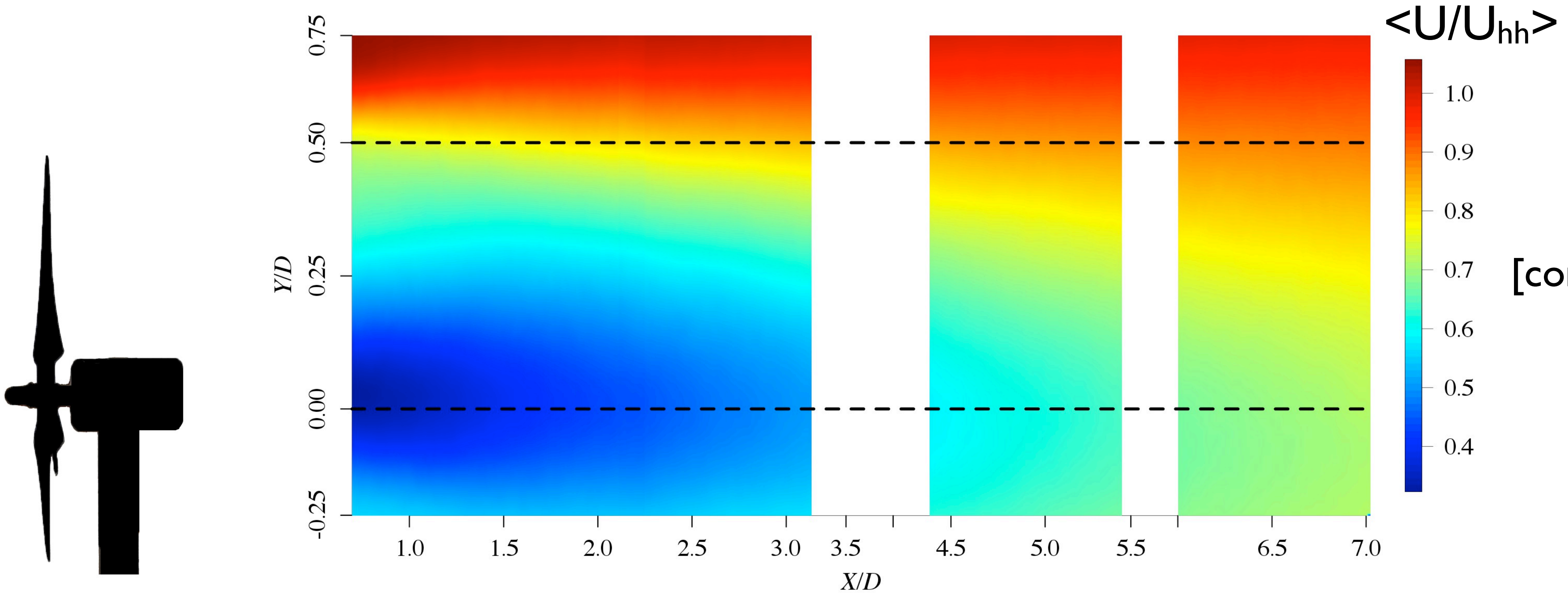


Wake of turbine 1



wind tunnel at Portland State Univ.

Averaged streamwise velocity <U/Uhh>



[comp. Vermeer, 2003]

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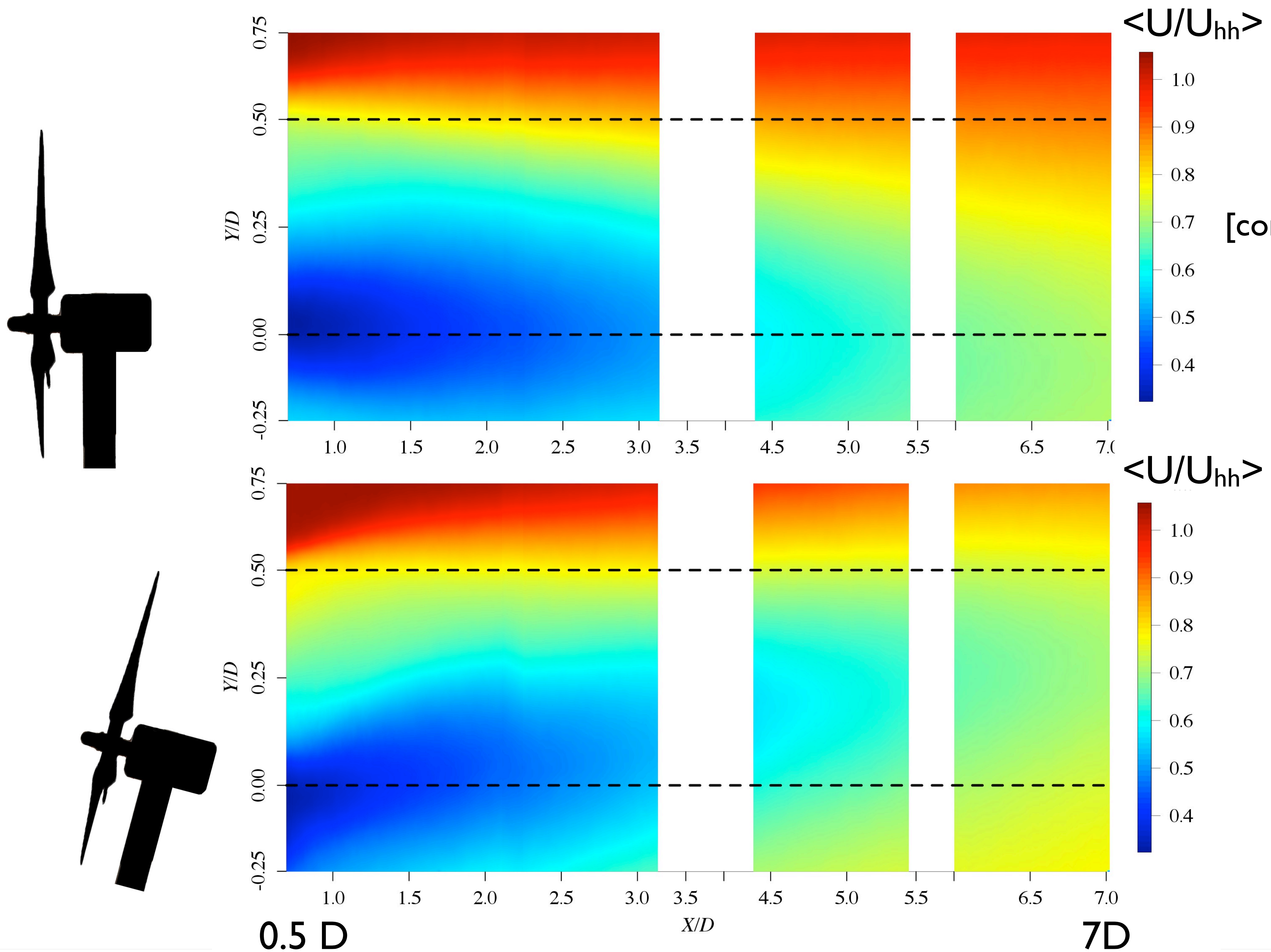

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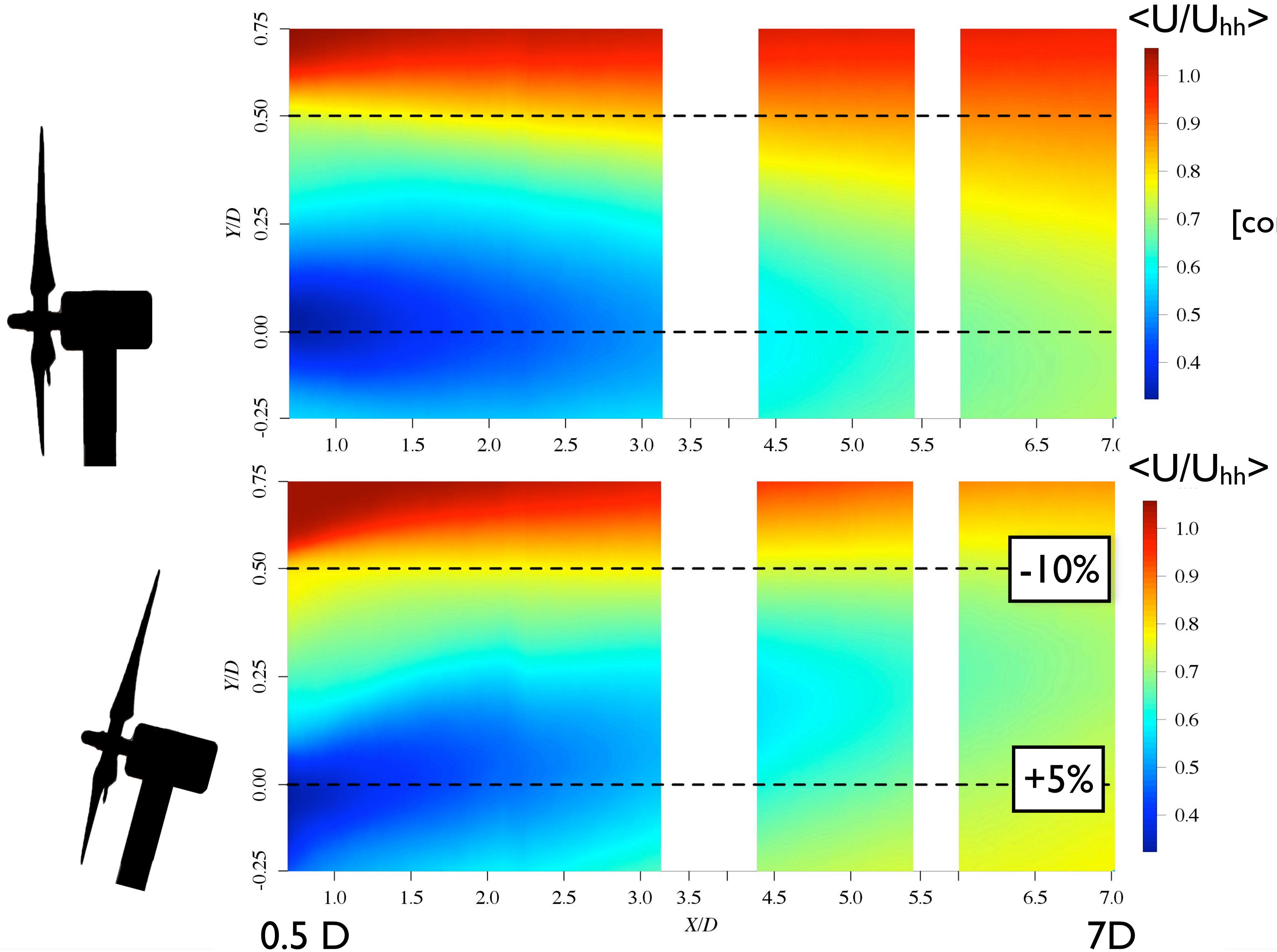

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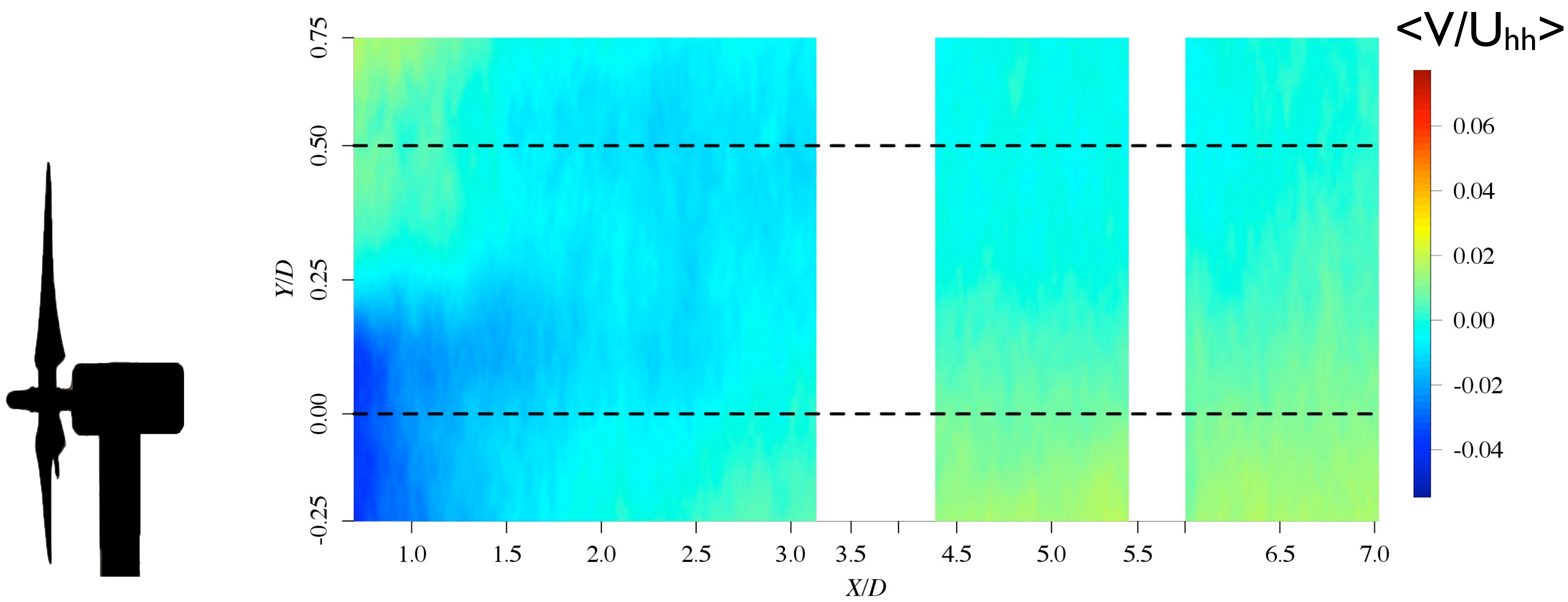

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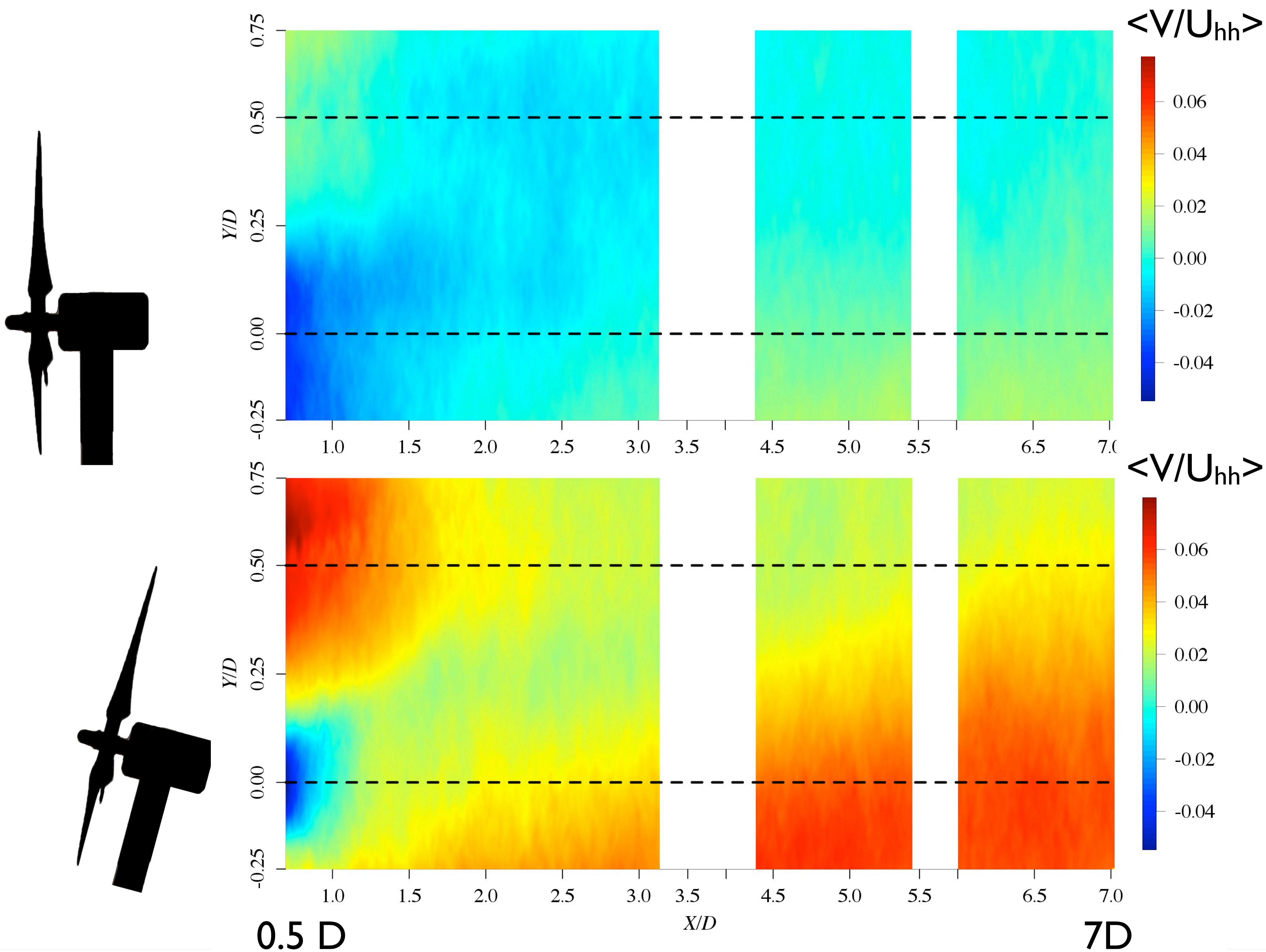

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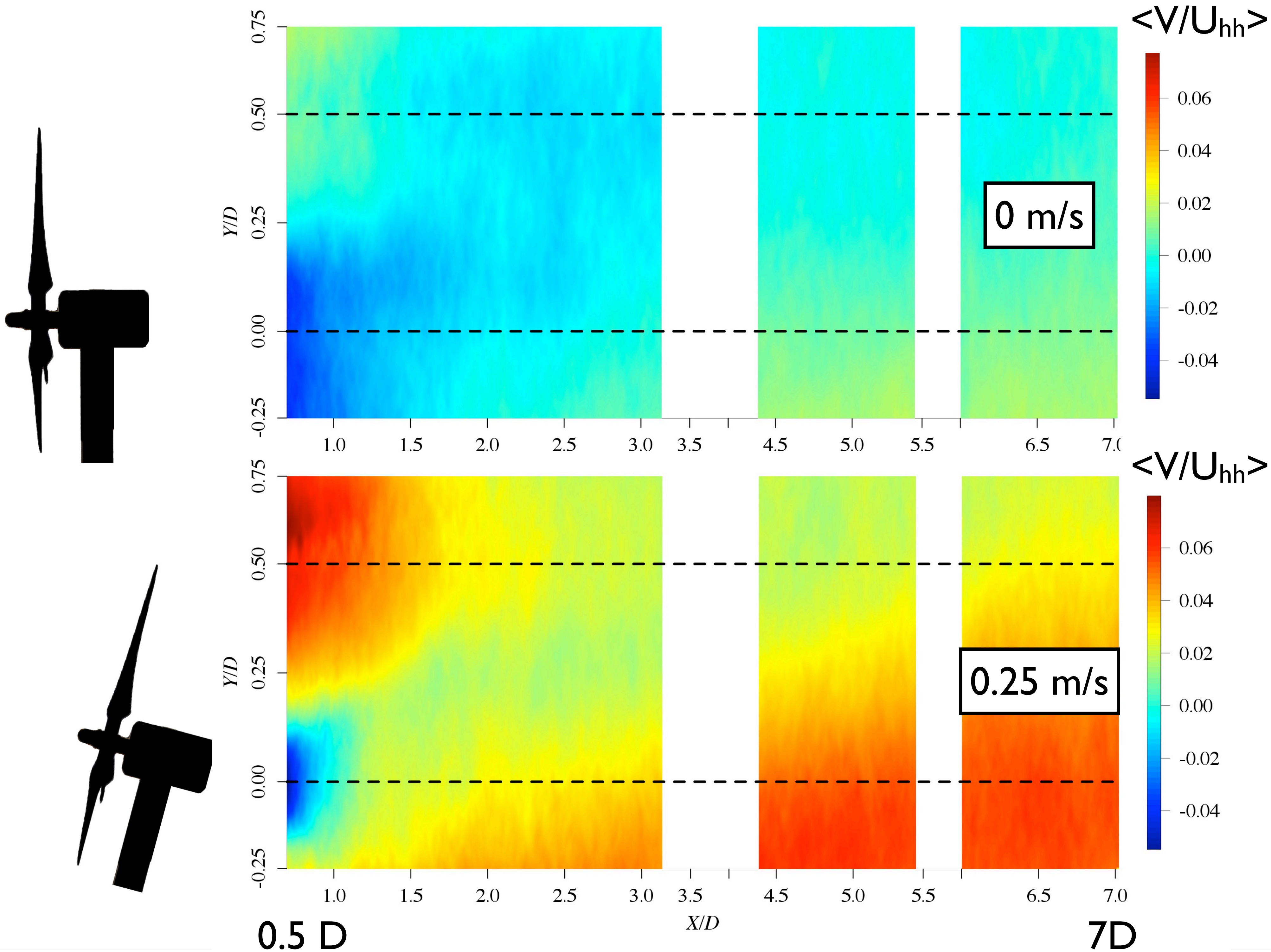

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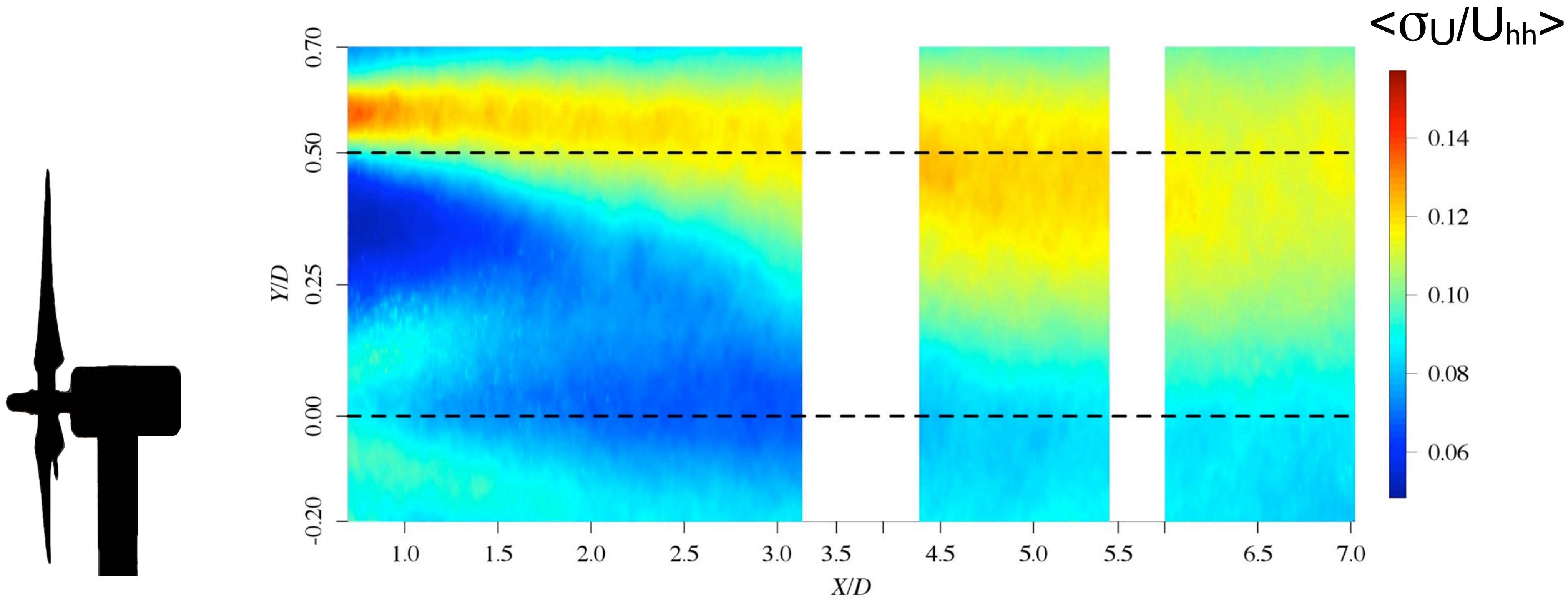

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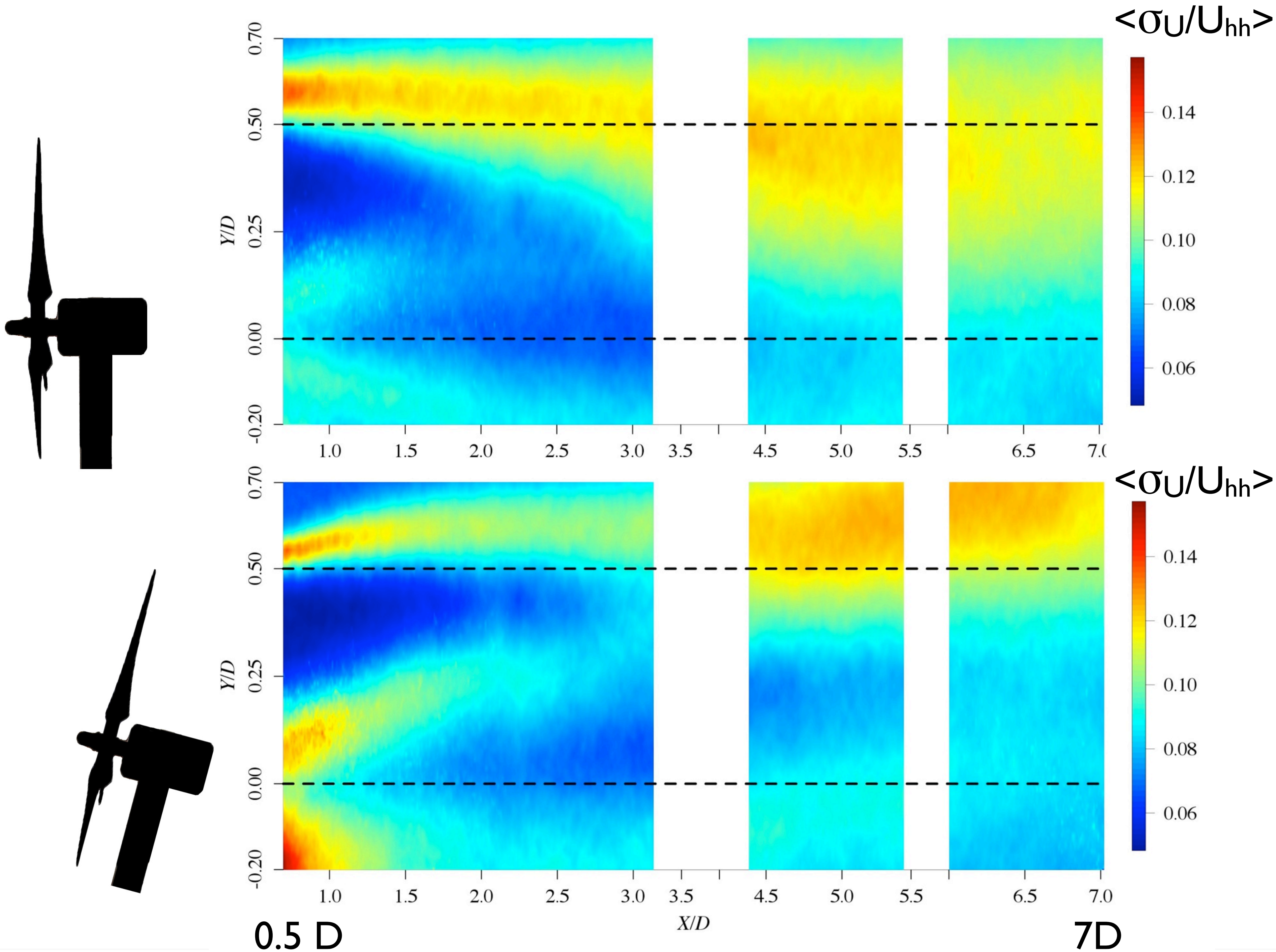
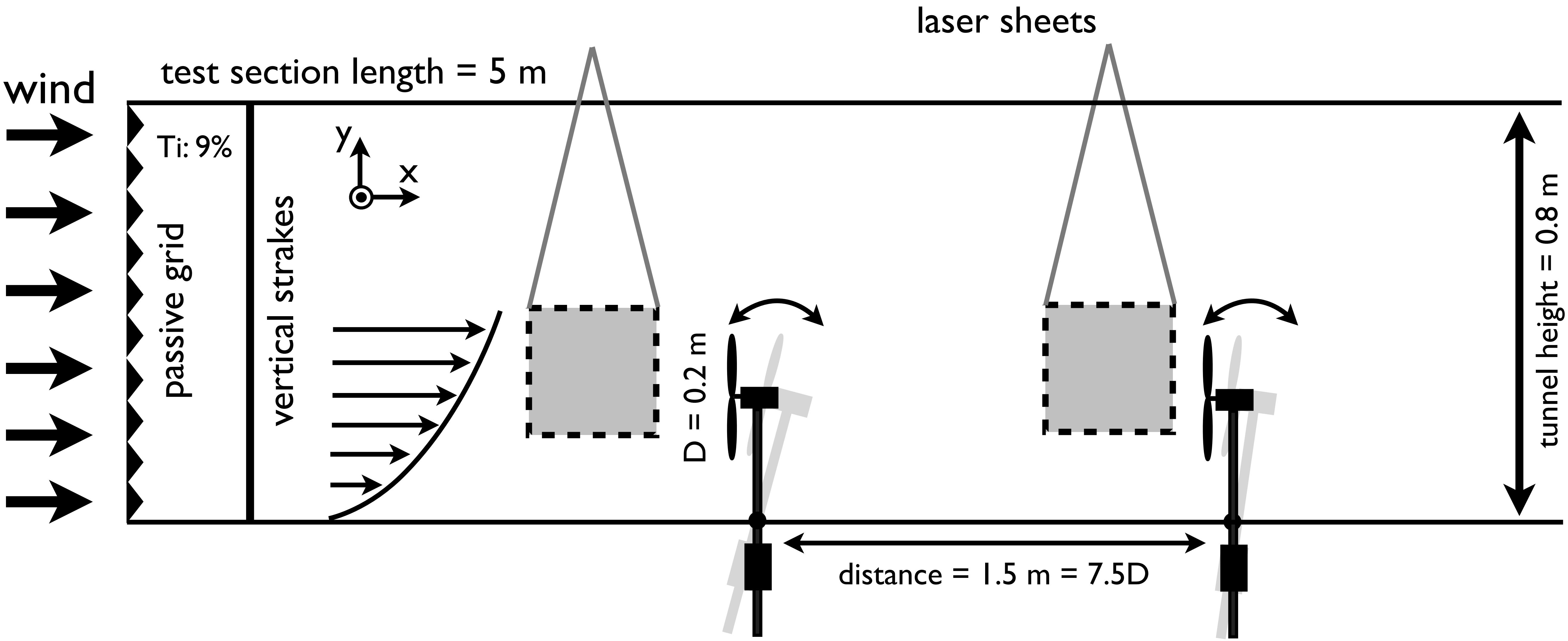


Setup: two turbines



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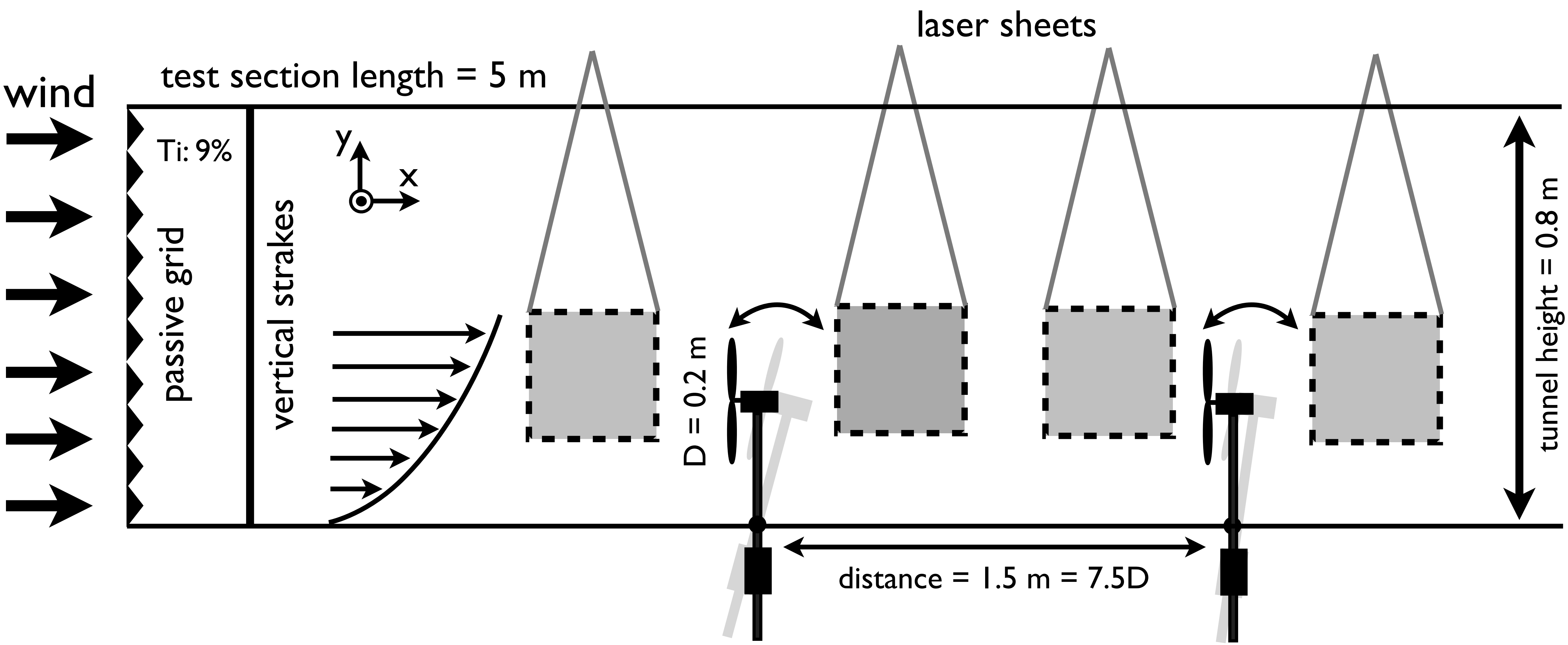

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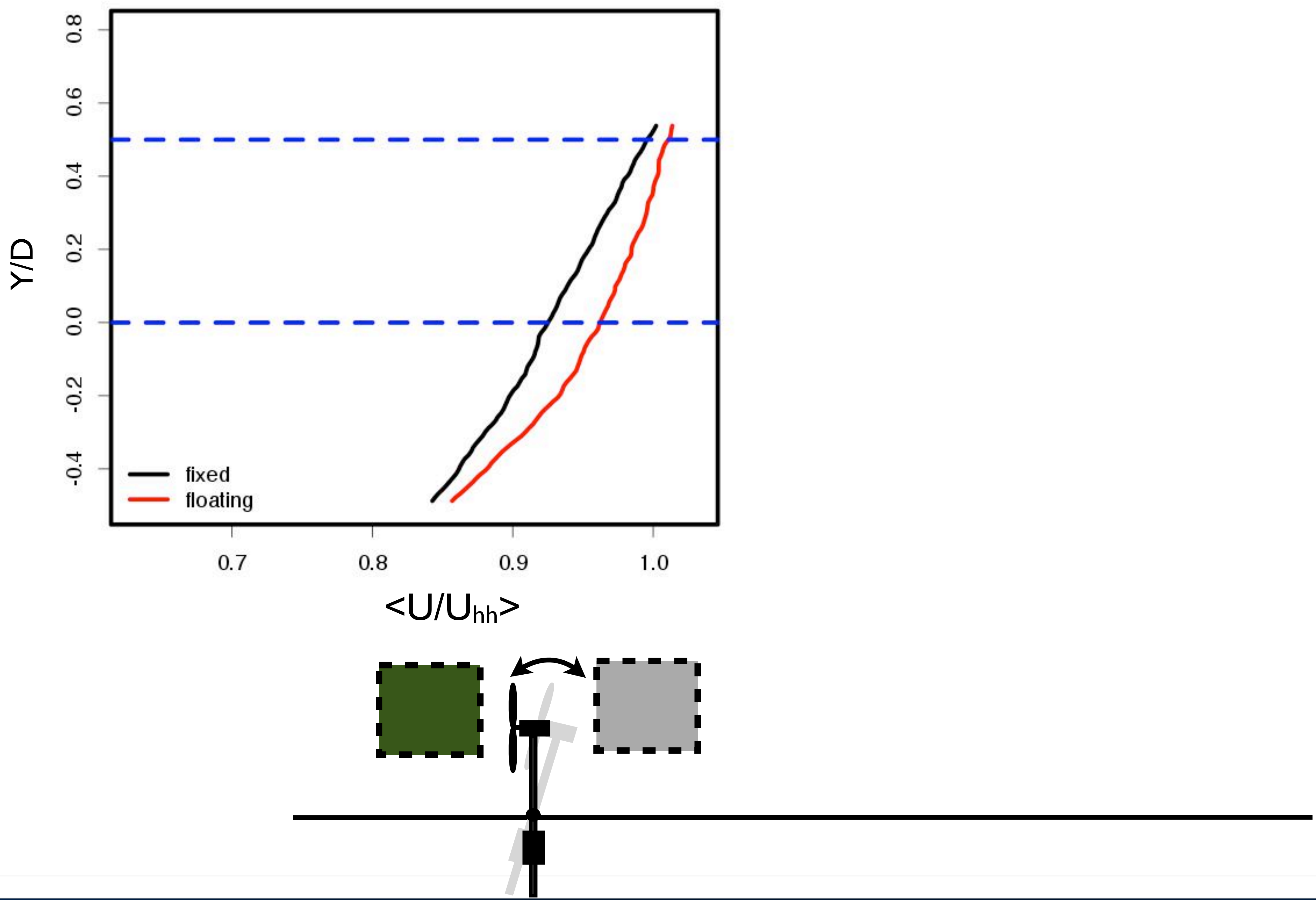
Inflow profiles <U/U_{hh}> at 0.5D upstream



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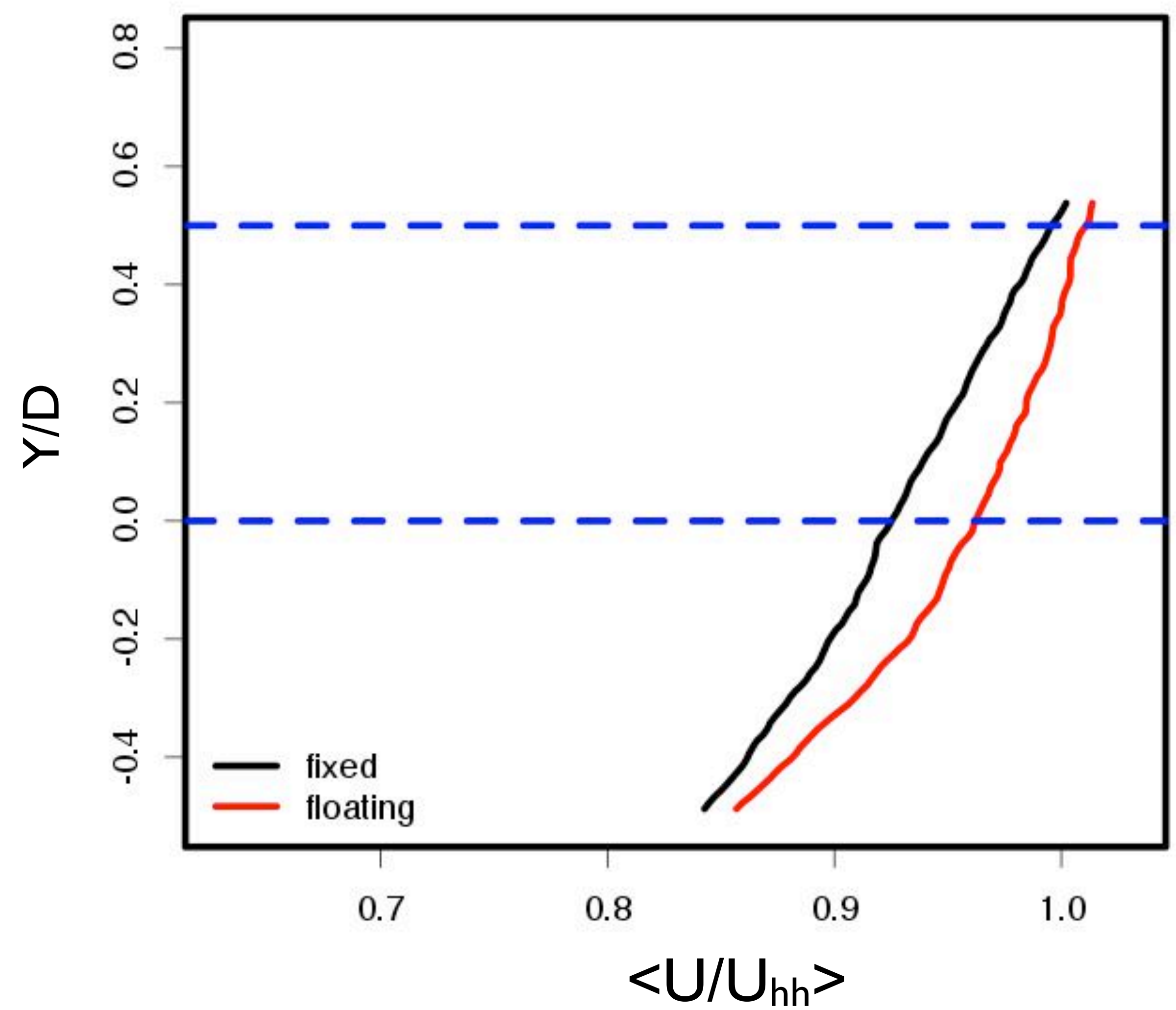
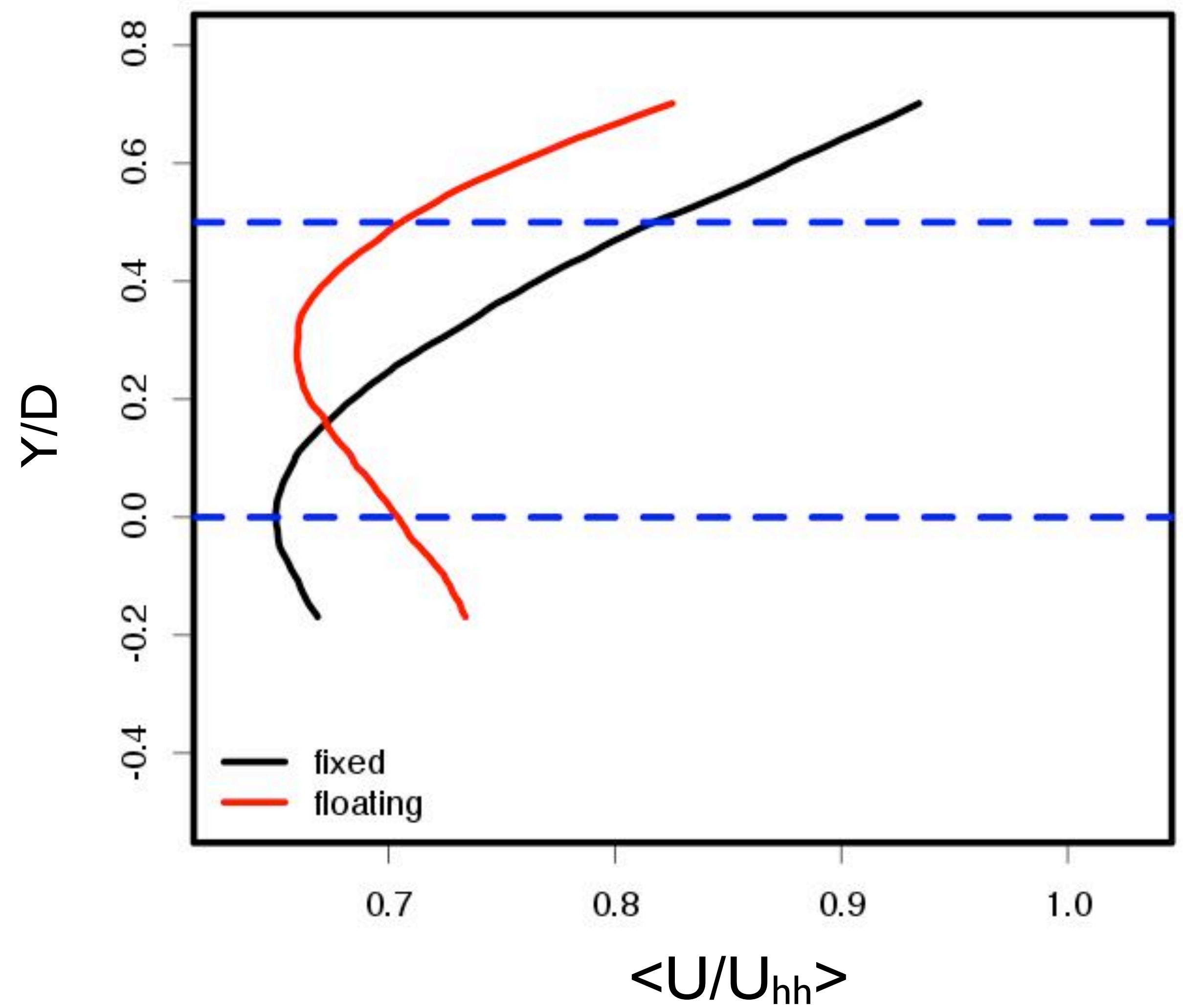
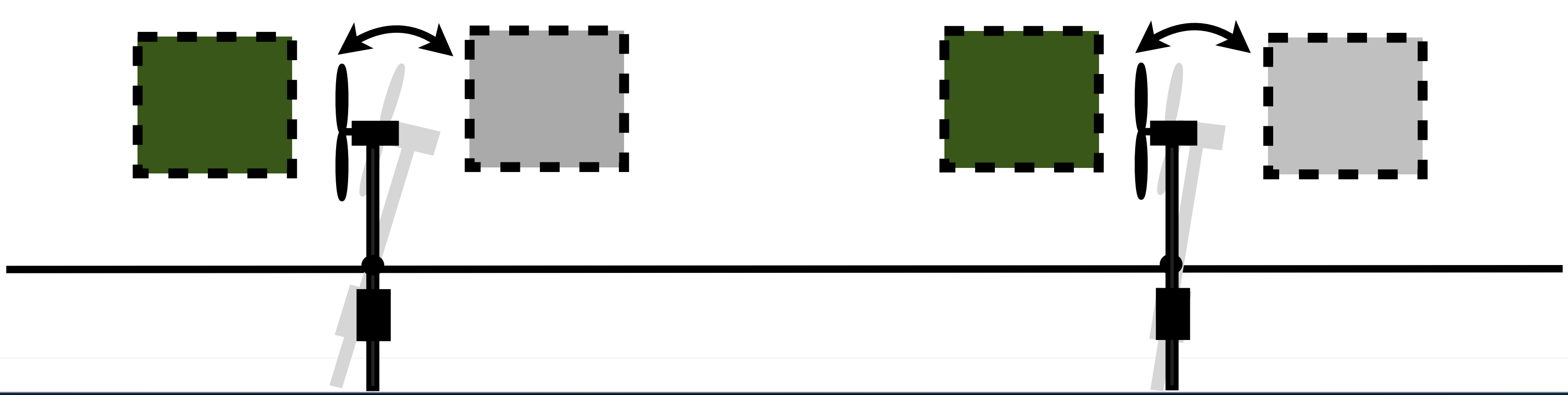
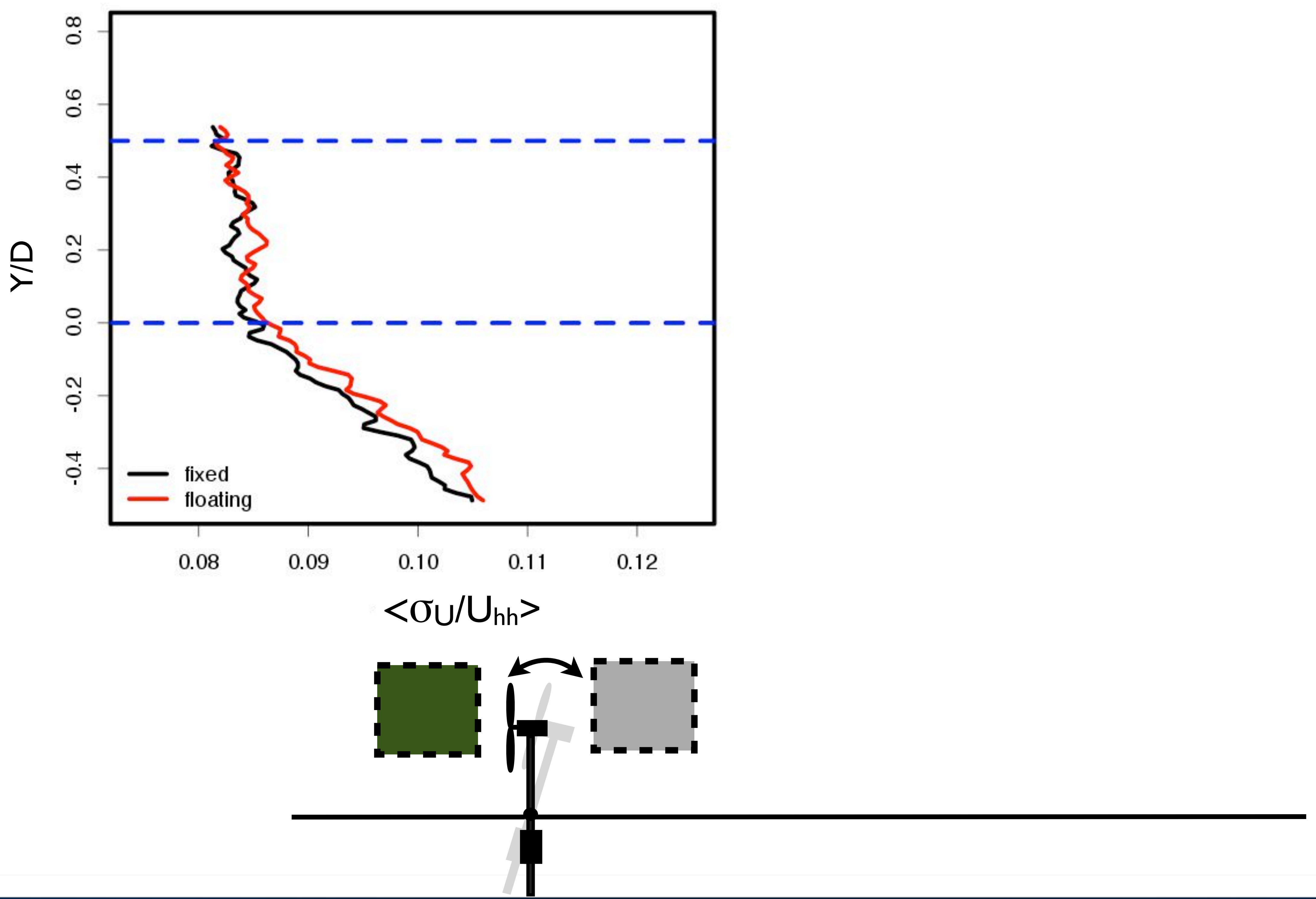






Turbulence intensity profiles $<\sigma_U/U_{hh}>$ at 0.5D upstream



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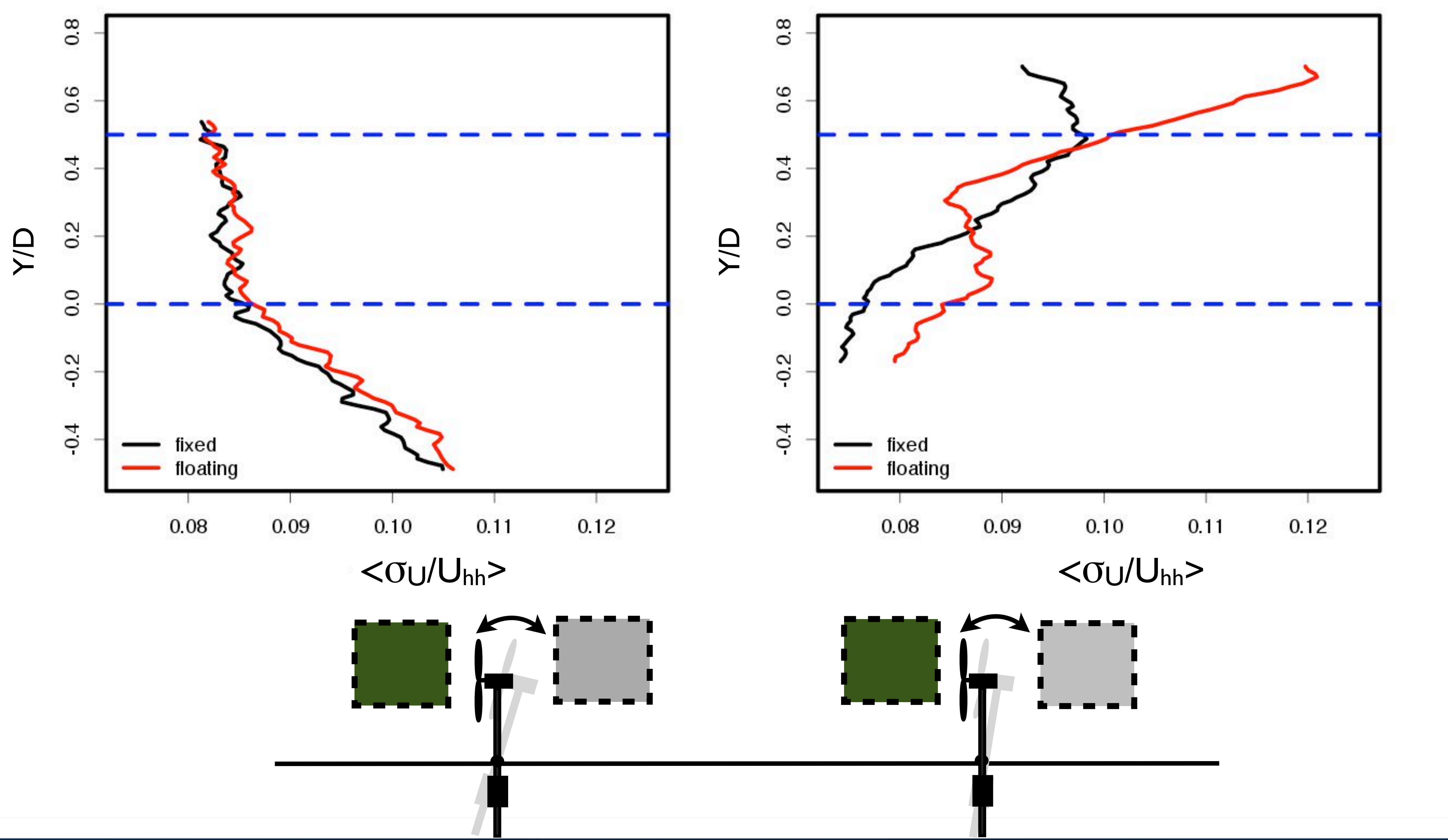
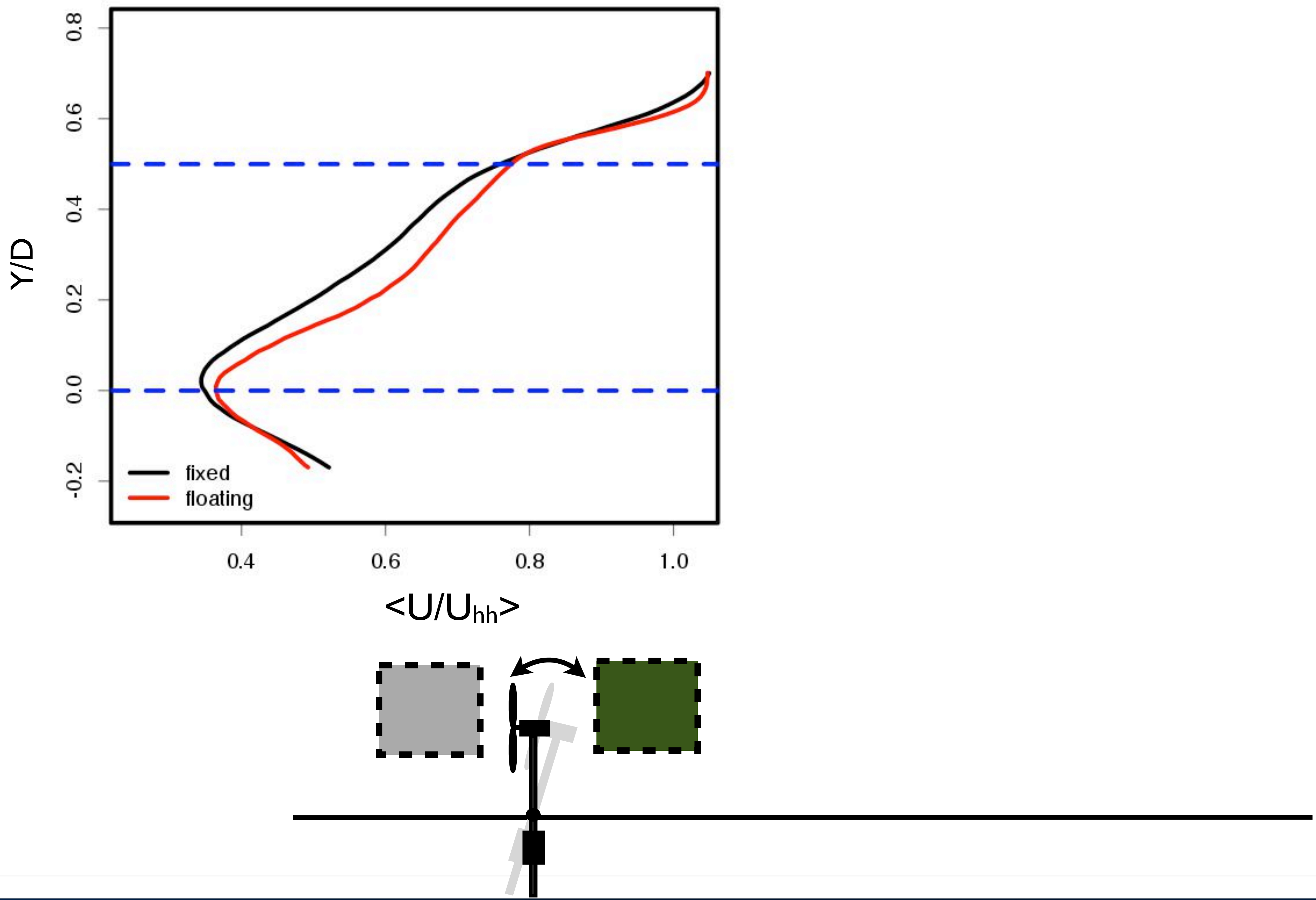
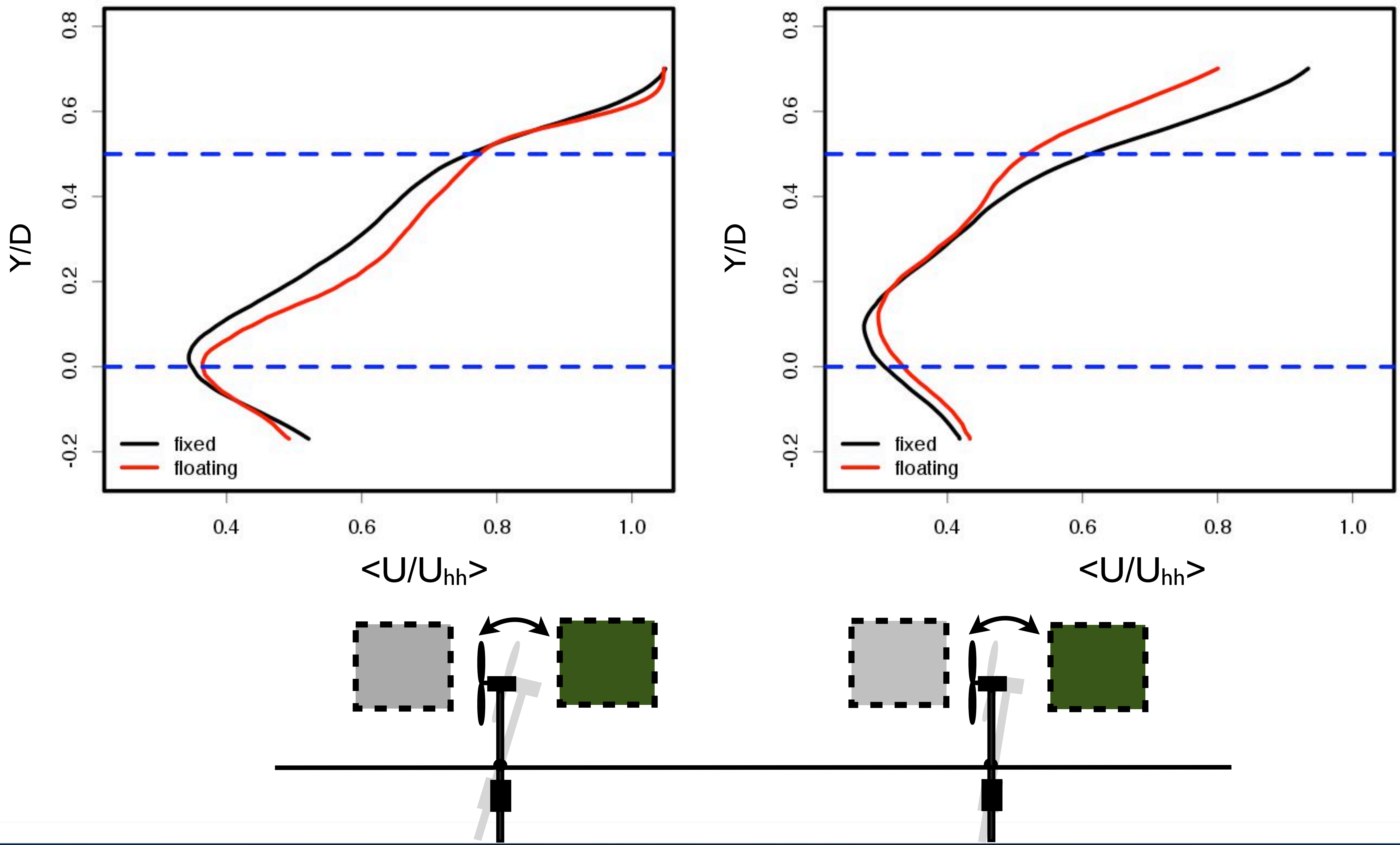


Near wake profiles <U/U$_{hh}$> at 1D downstream



Near wake profiles $\langle U/U_{hh} \rangle$ at 1D downstream



Summary & Conclusions

- Blockage changes inflow profile

- Pitch motion has strong impact on wake
  - Vertical trend in all quantities
  - Increased vertical flow

- Reduced turbulence intensity in far wake

- Changed inflow profile for downstream turbine has no influence on near wake

Thank you!

Questions?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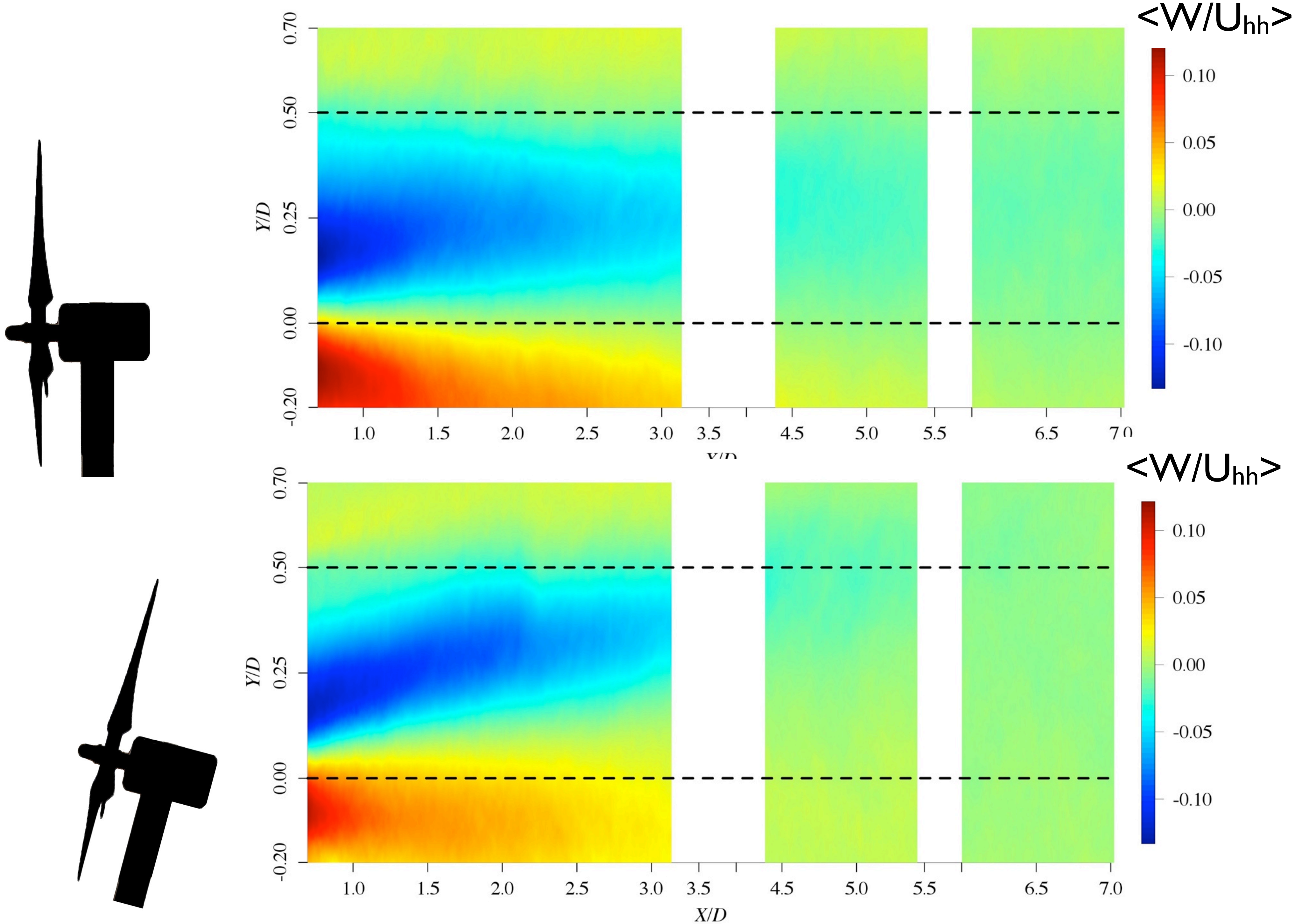
Acknowledgements:

- Elizabeth Camp
- German Environmental Foundation

„Experimental study on influence of pitch motion on the wake of a floating wind turbine model", Rockel et al., *Energies, submitted 2013*

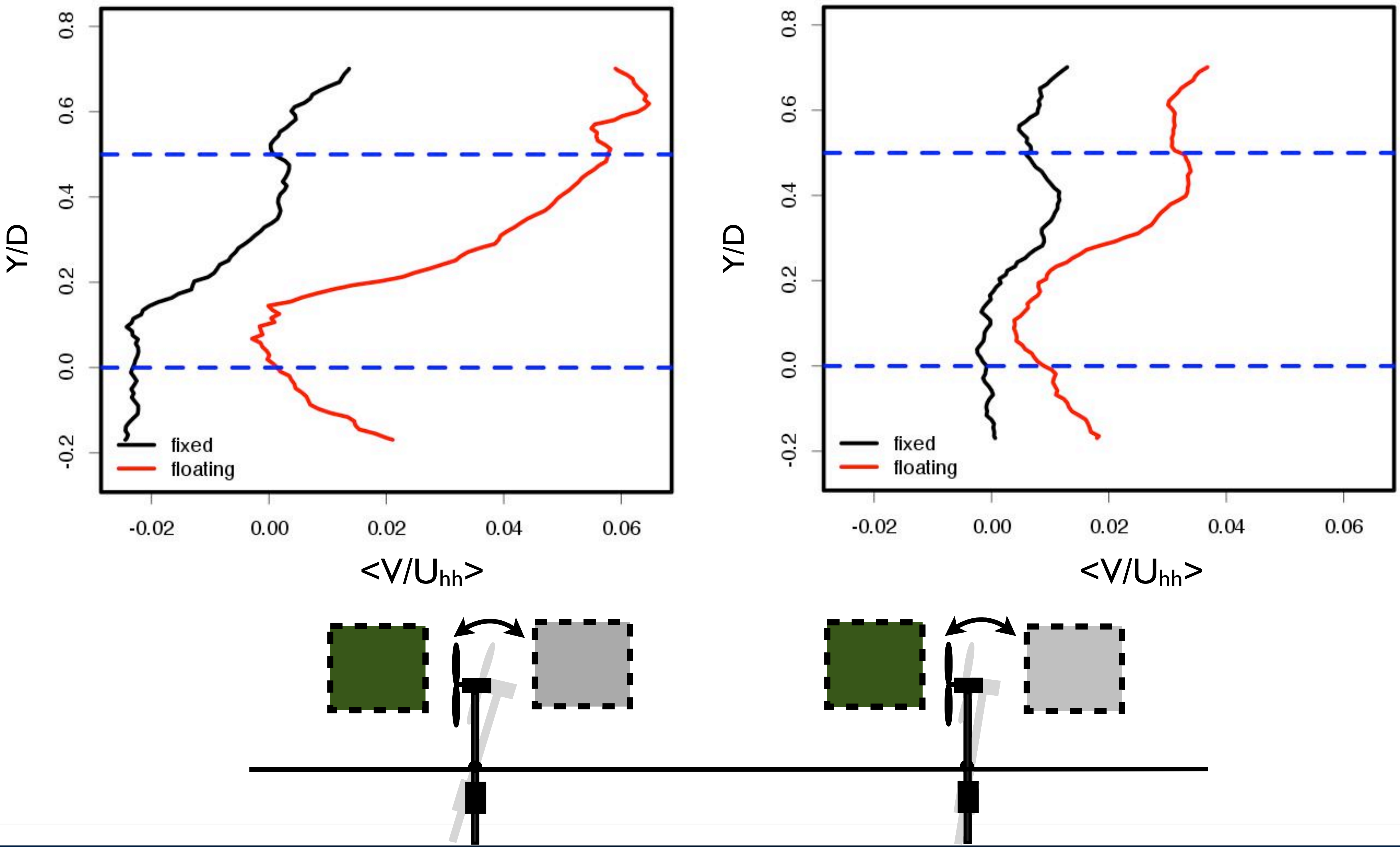
spanwise velocity



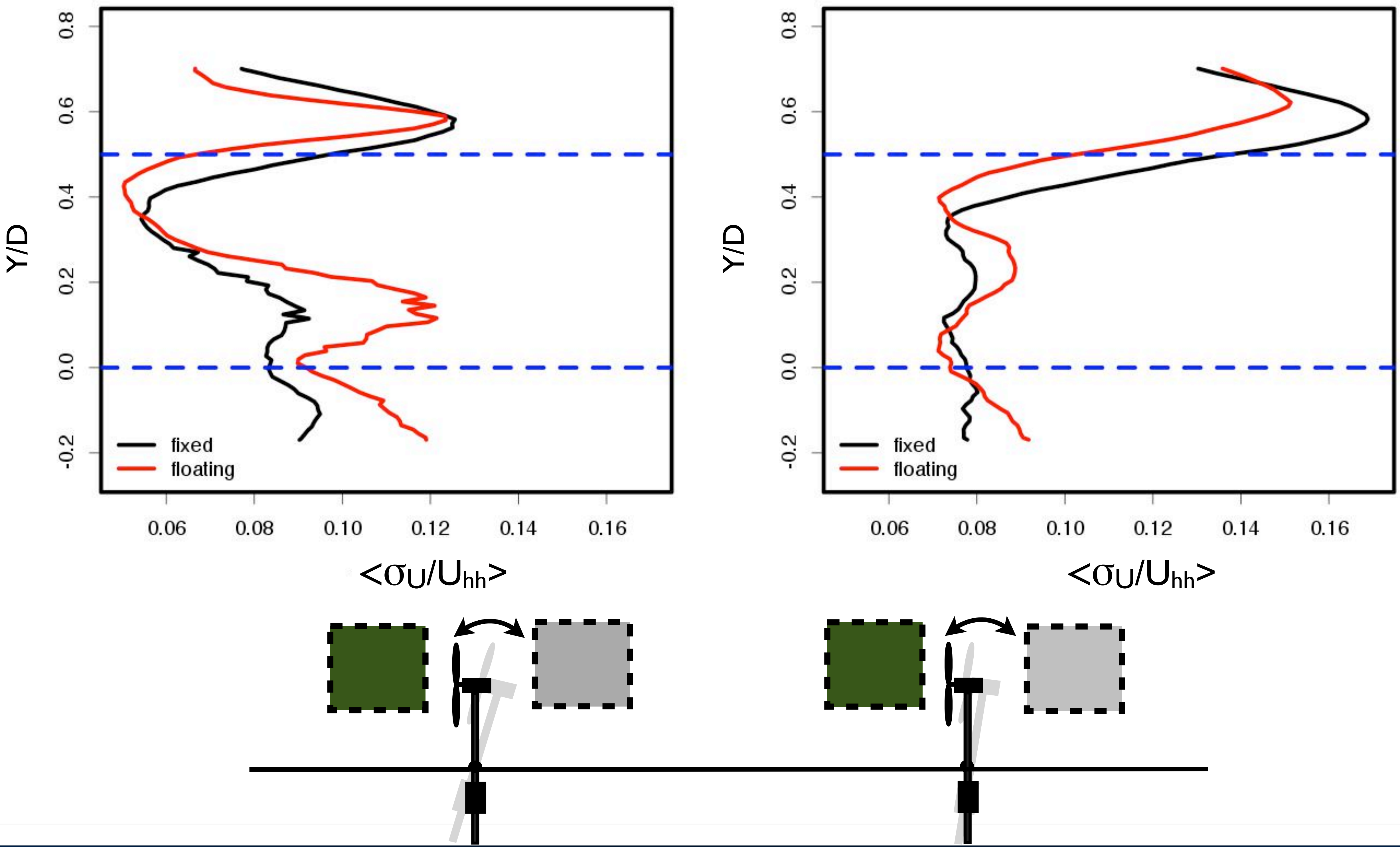
0.5 D

7D

Near wake profiles $\langle V/U_{hh} \rangle$ at 1D downstream

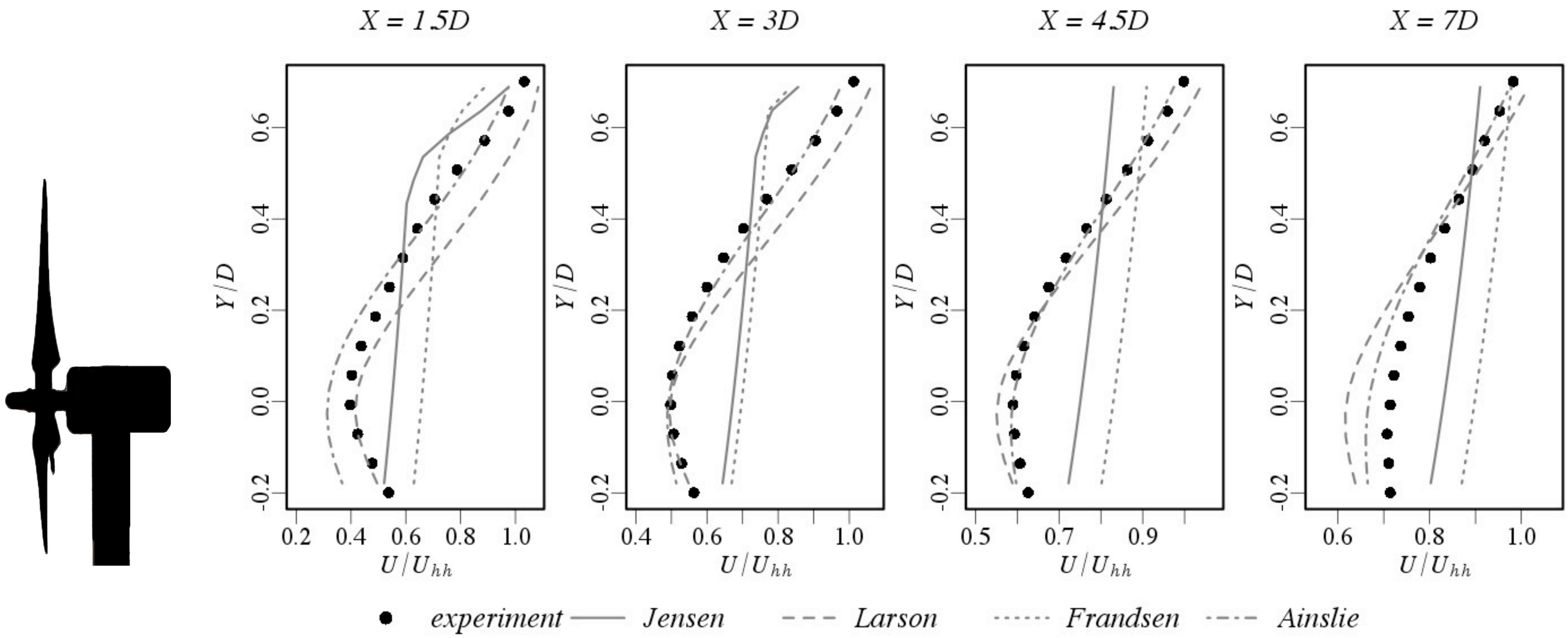


Near wake turbulence intensity $\langle \sigma_U / U_{hh} \rangle$ at 1D downstream



Comparison with wake models: fixed

- shape and magnitude of deficit predicted for X = 3D and 4.5D



Comparison with wake models: floating

- vertical displacement NOT captured