The Influence of Cycle-to-Cycle Variation on Cross-Flow Turbine Performance

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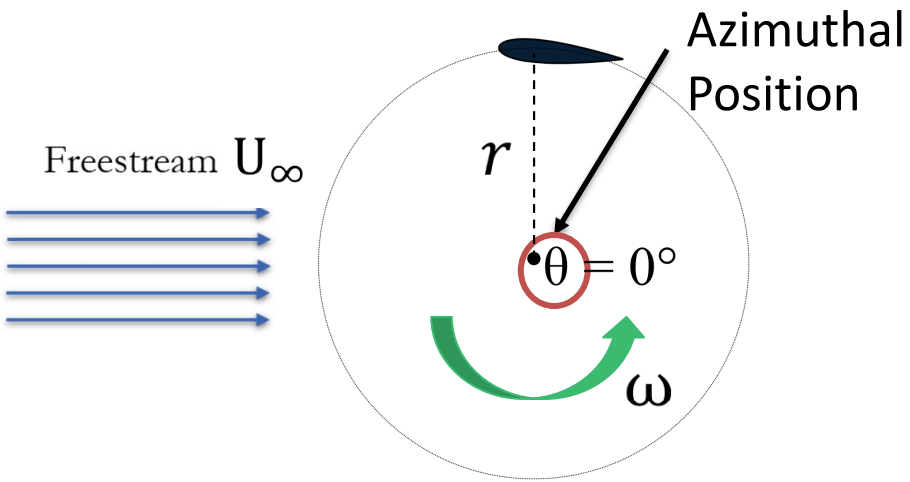
Cross-flow Turbines



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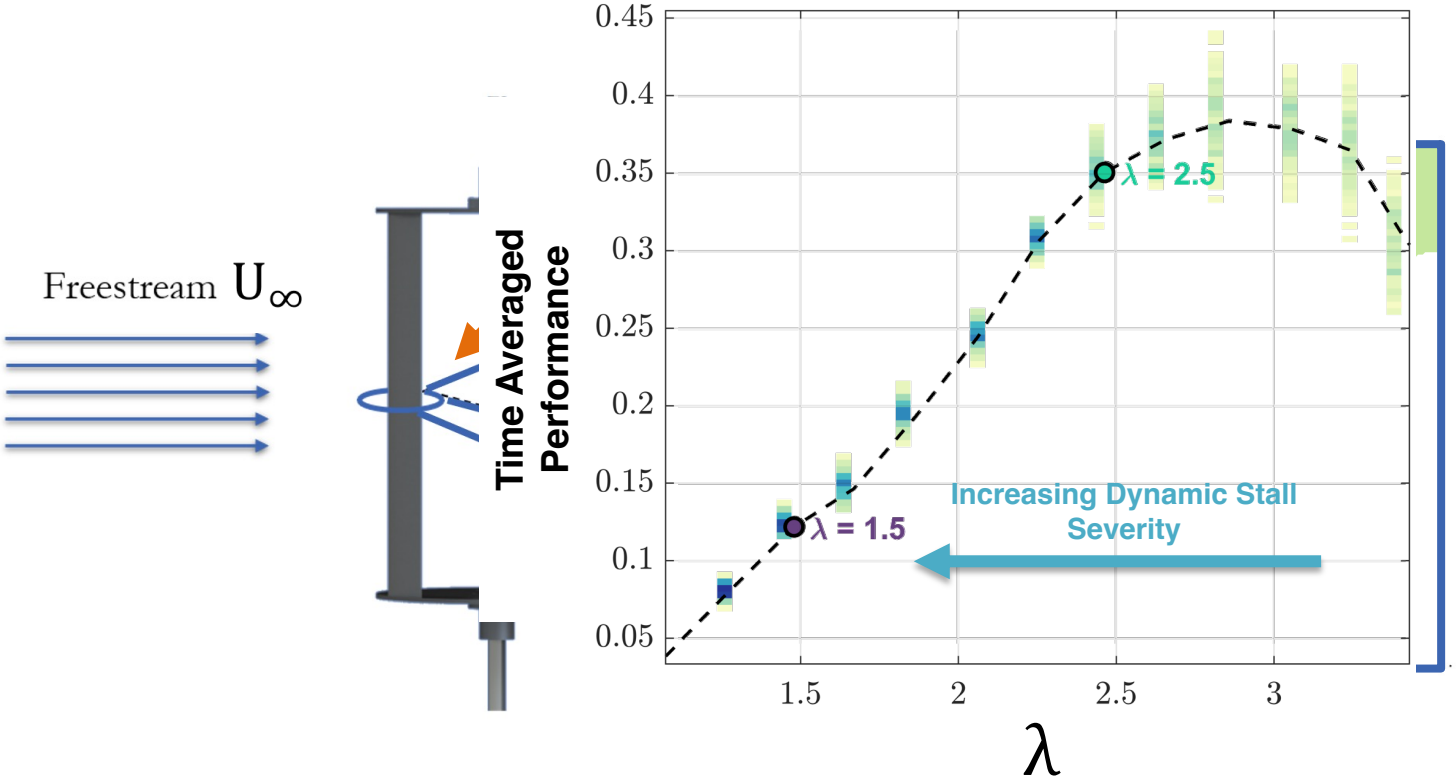


TIP SPEED RATIO

$$\lambda = \frac{r\omega}{U_\infty}$$

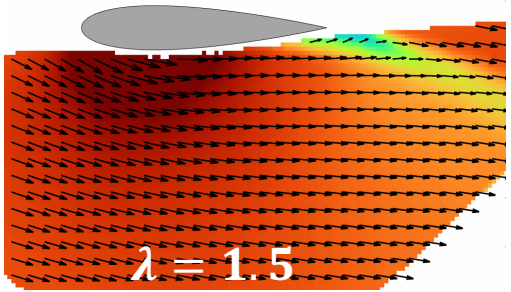
COEFFICIENT OF PERFORMANCE

$$C_P = \frac{P}{\frac{1}{2}\rho U_\infty^3 A}$$

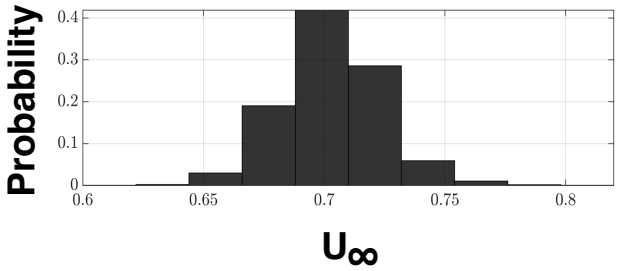
Frontal Area

Sources of Variability

Dynamic Stall's Sensitive and Stochastic Nature

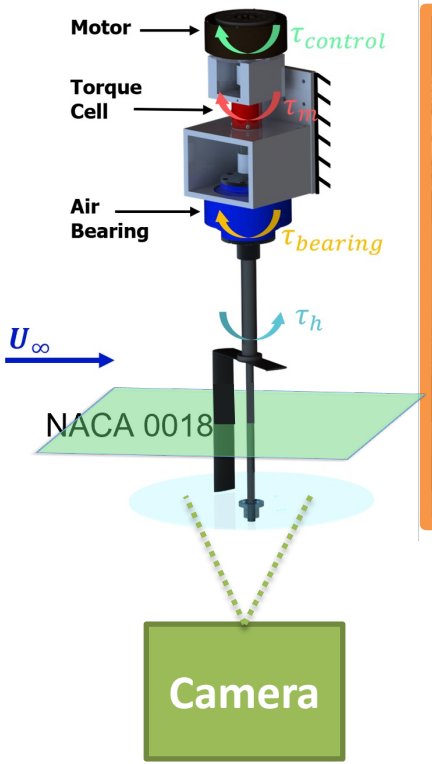


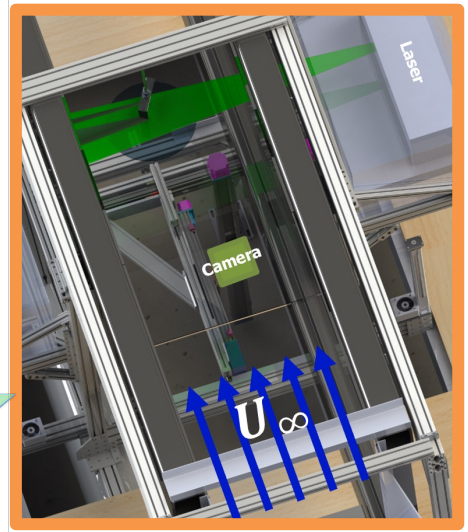
Inflow Perturbations

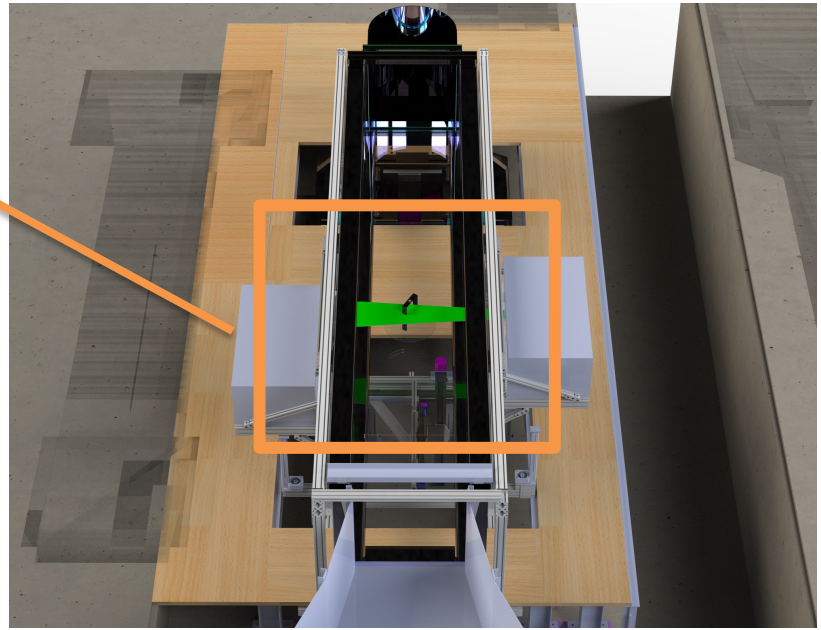


Hysteresis

PIV Acquisition

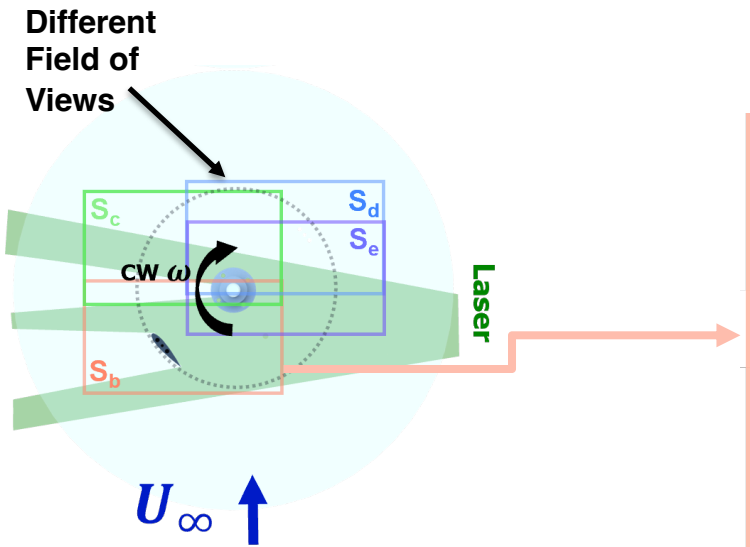


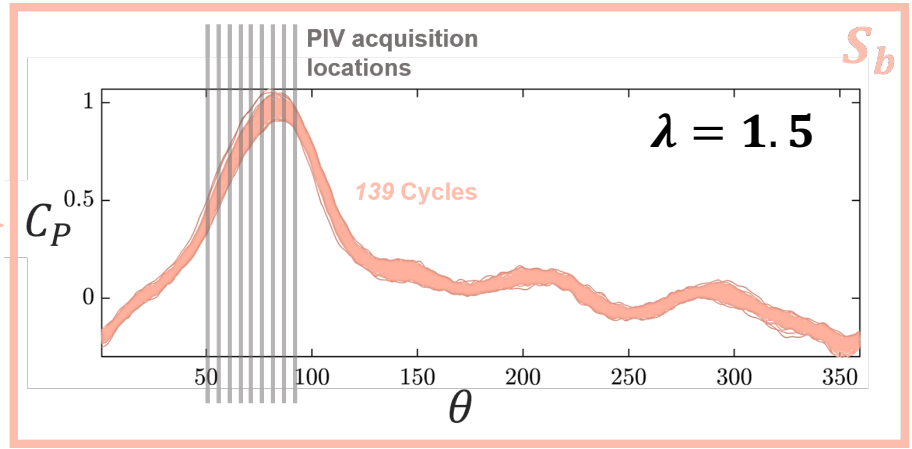




2D planar PIV in the Alice C. Tyler Flume at the University of Washington

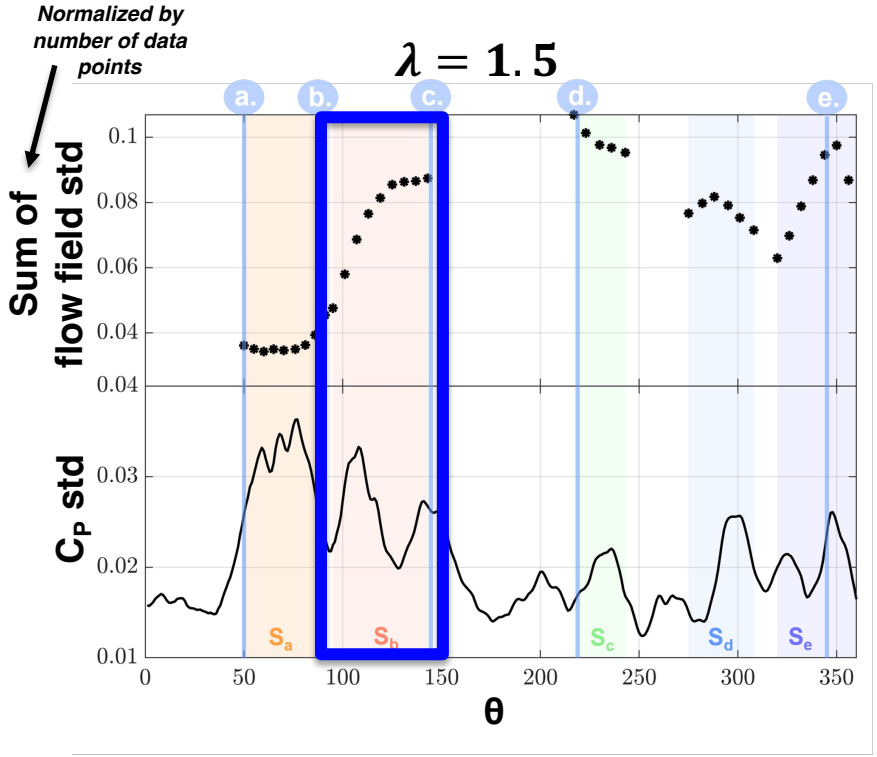
PIV Acquisition

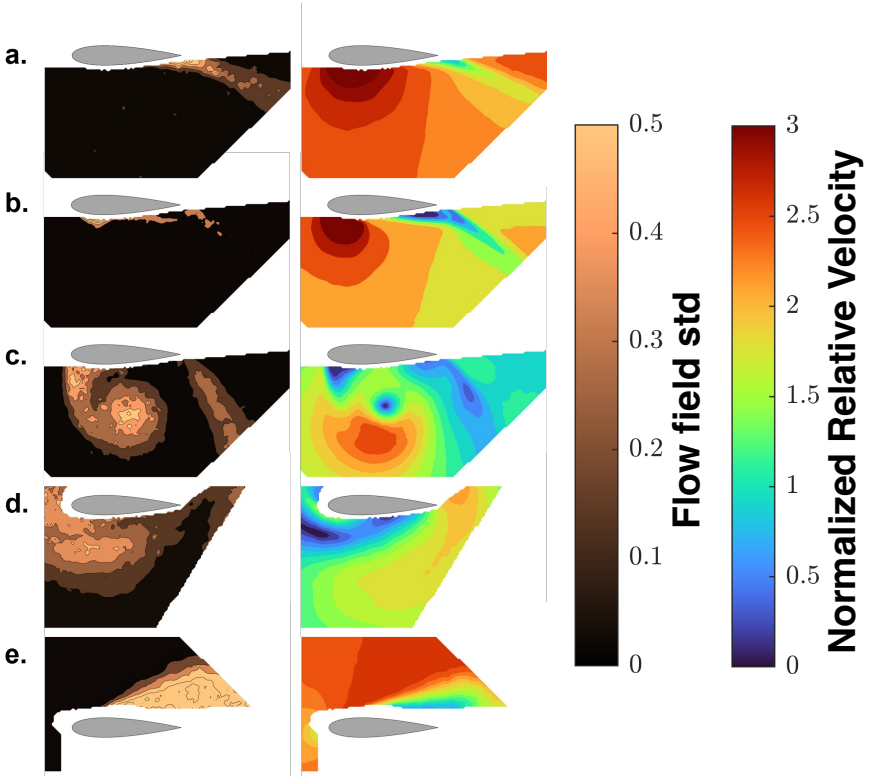




Discrete flow field acquisitions, continuous performance measurements

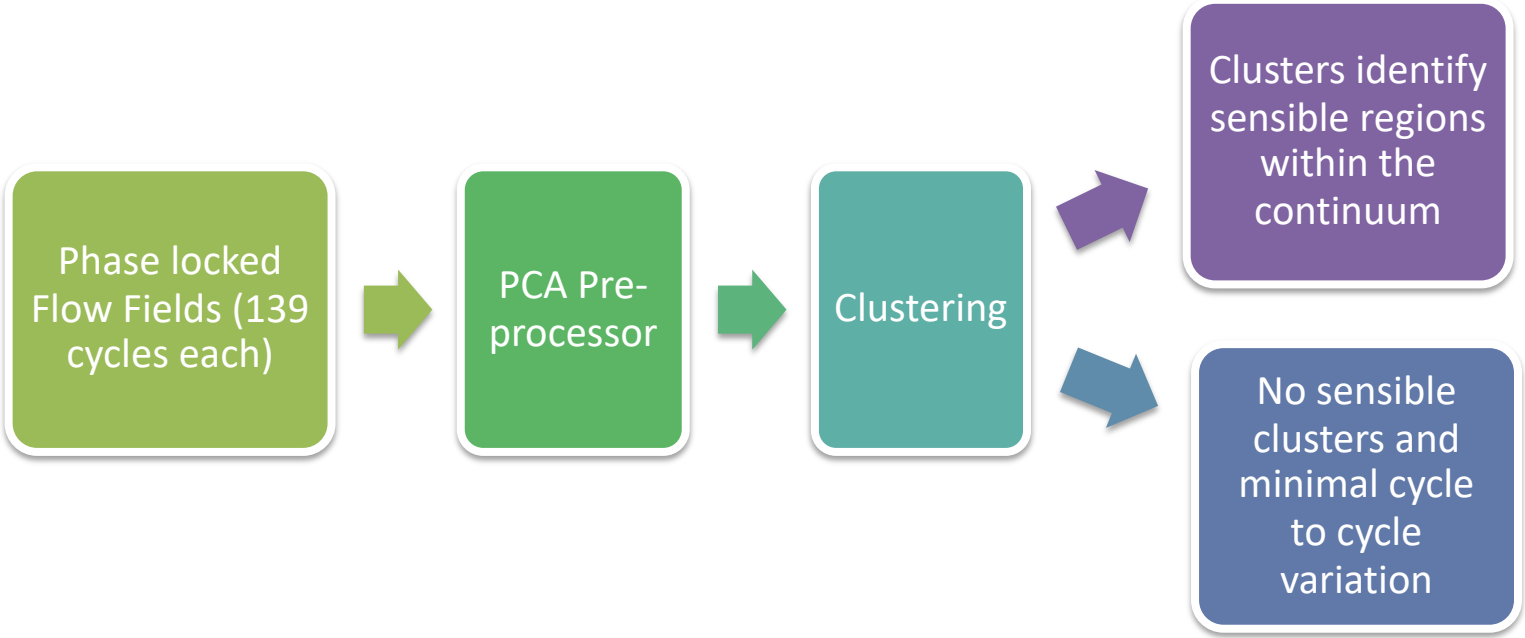
Performance and Flow Field Variability



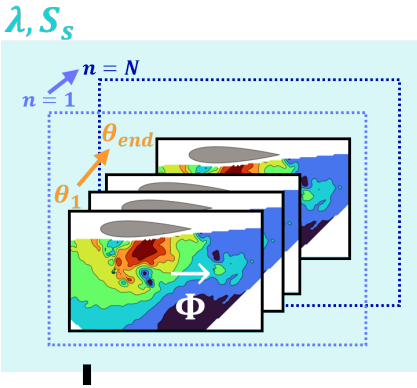


Opposing trends in flow field and performance variability

Investigation of Cycle-to-Cycle Variation with Flow Field Clustering

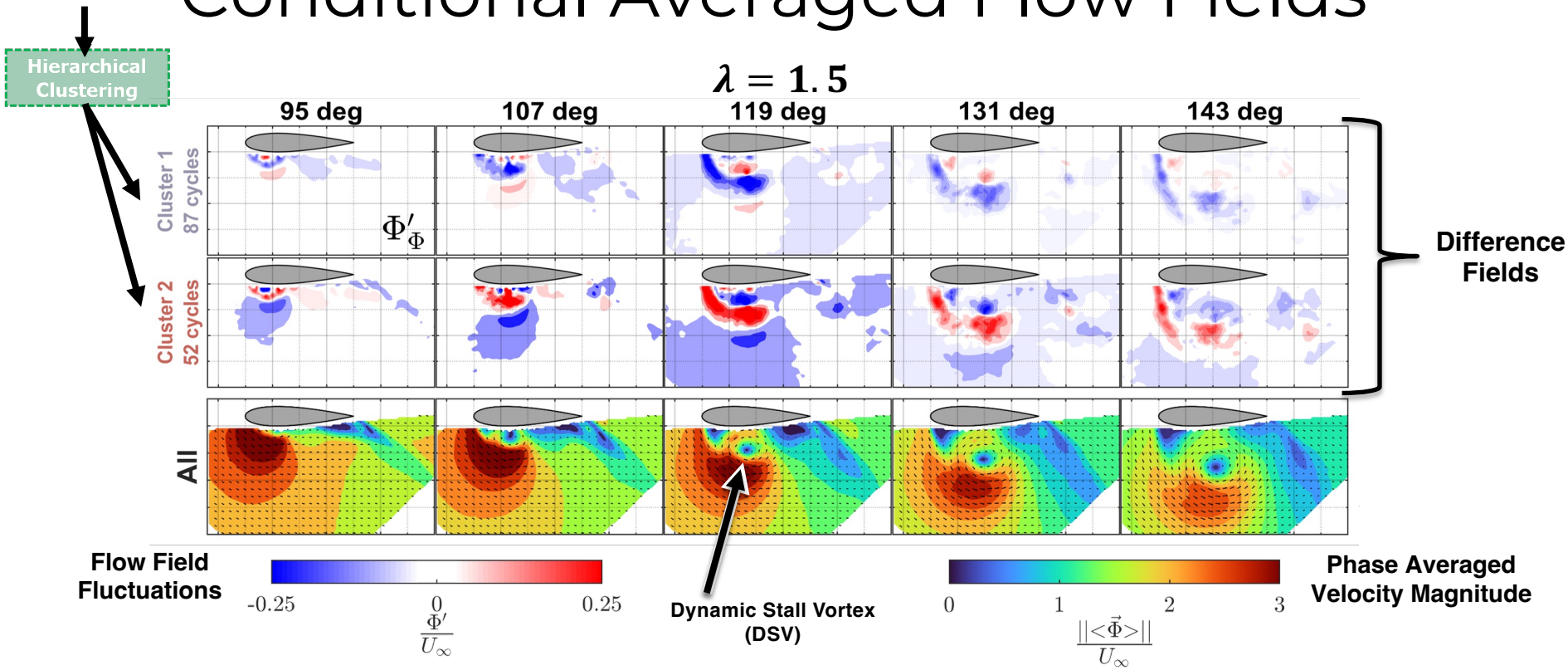


Are these clusters correlated with performance?

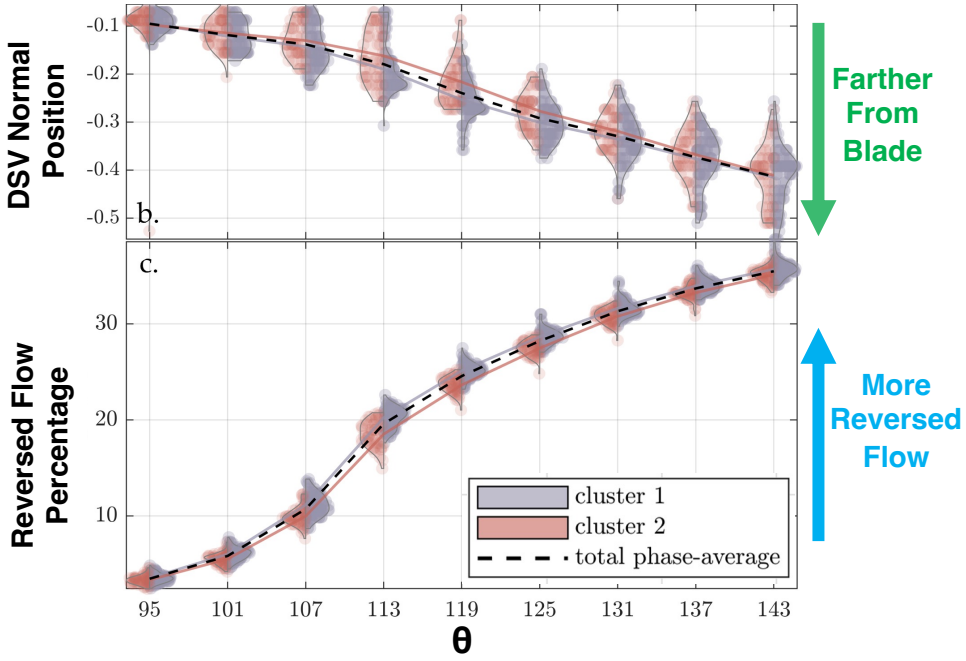


1) Rotate and crop flow field into blade centric reference frame.

Conditional Averaged Flow Fields



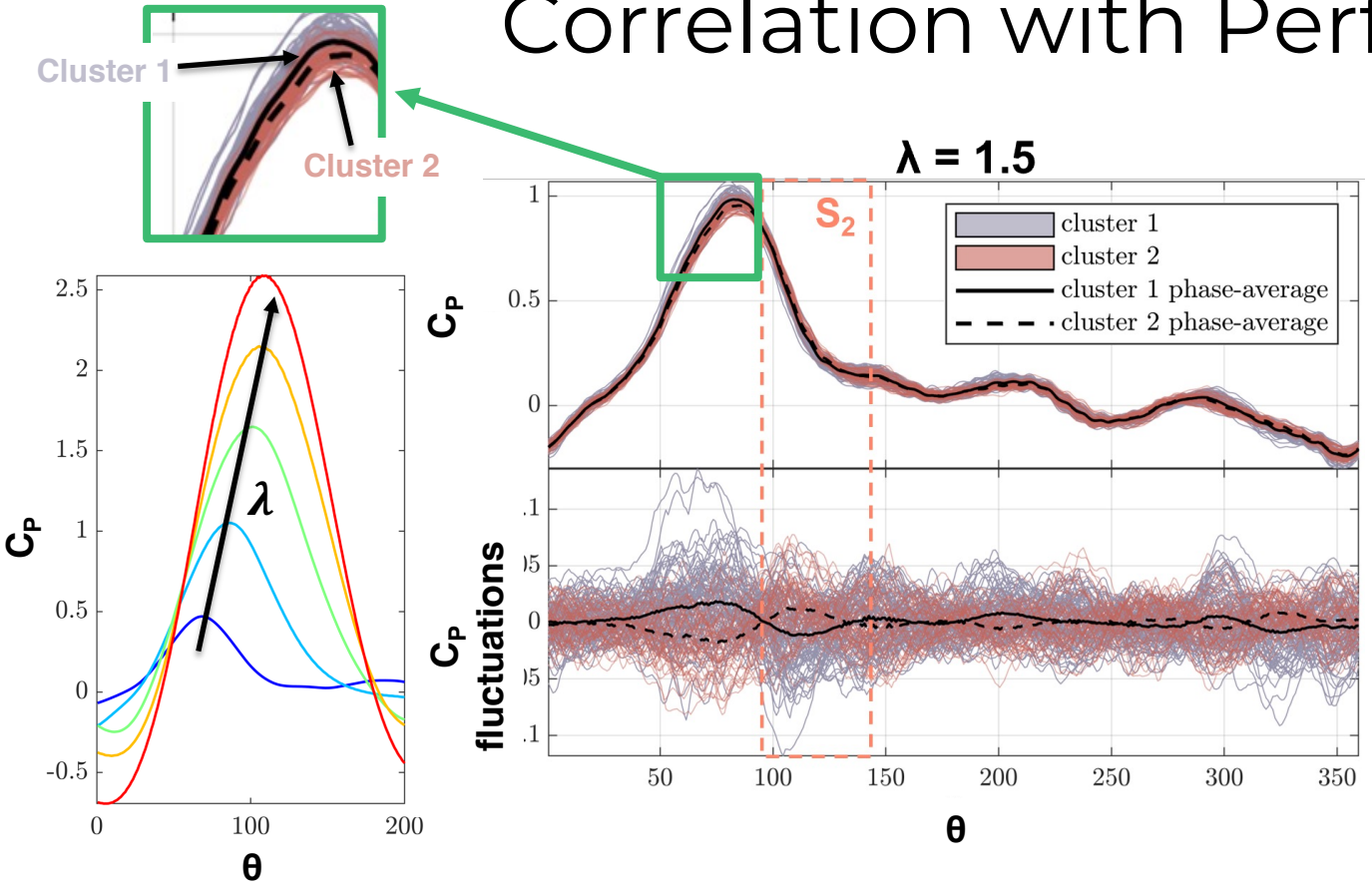
Flow Field Metrics



Cluster 1's **DSV is farther away from the blade and there is more reversed flow**

Suggesting Cluster 1 experiences earlier and/or stronger stall

Correlation with Performance



Cluster 1 outperforms Cluster 2 in a time-averaged sense by 1.5%

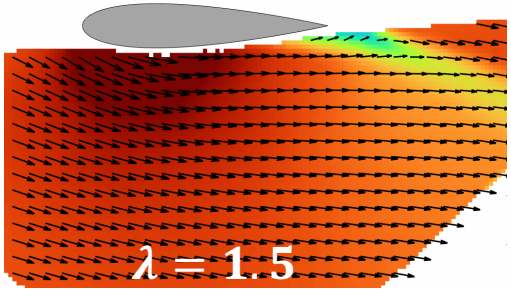
Sources of Variability

We have seen how the flow fields exhibit evidence of ***cluster 1*** experiencing ***earlier and/or stronger stall*** …..Yet ***cluster 1 outperforms cluster 2*** ….

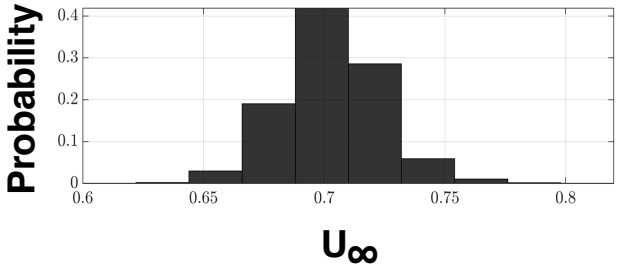
….And ***cluster 1*** sees a ***higher*** performance ***peak occurring earlier*** in the cycle opposing the normal trend….

- Surprising

Dynamic Stall's Sensitive and Stochastic Nature

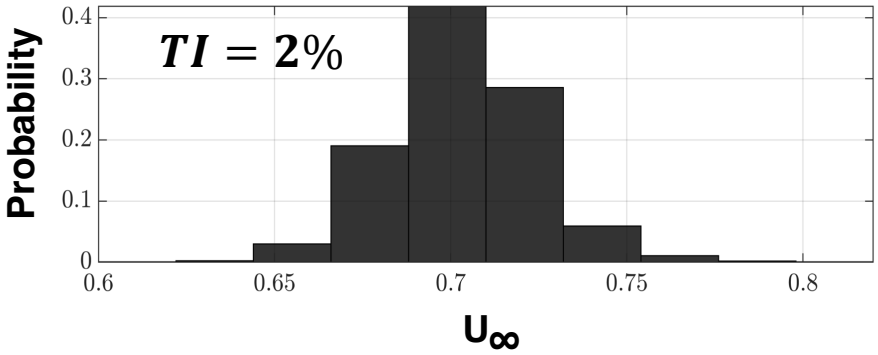


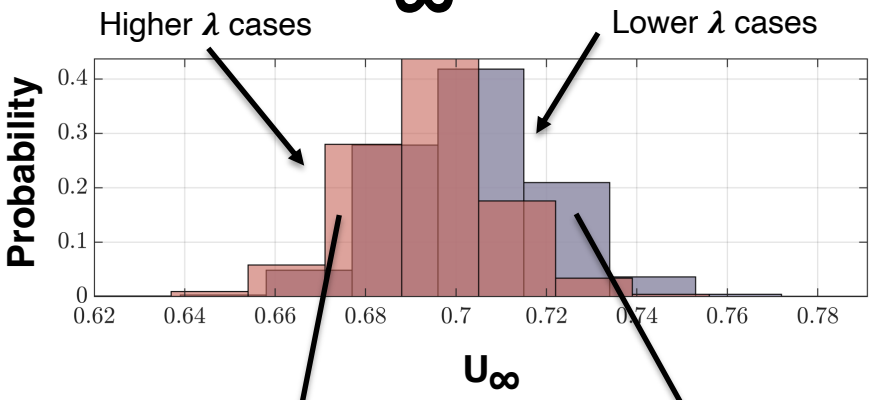
Inflow Perturbations



$\lambda = 1.5$

The Influence of U_∞





$$C_P = \frac{P}{\frac{1}{2}\rho < U_\infty^3 > A}$$

$$C_P^* = \frac{P}{\frac{1}{2}\rho < U_\infty^3 > A}$$

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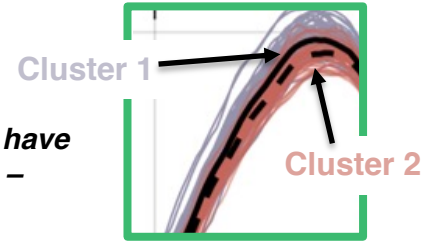
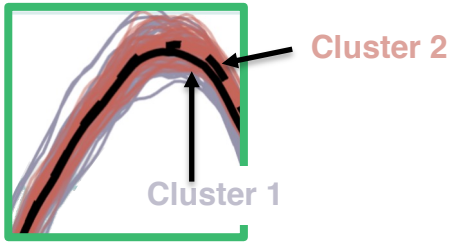


Lower λ cycles have higher peak Cp – Surprising!

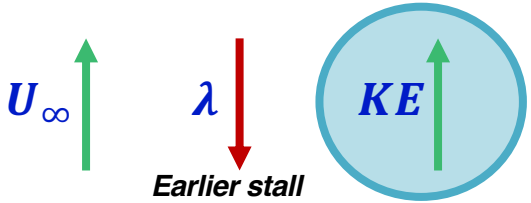
we see good collapse between the two clusters. Now only 0.24% different



Conclusions

Results show a clear power and hydrodynamic dependence on assigned cluster…

... even though the differences in time averaged performance (for this case) between the clusters is small, on the order of 1.5%.



Peak Performance variability occurs in a region of the low flow field variability. This suggests the relevant flow variability is confined close to the blade.

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Aidan Hunt- *University of Washington*
Andrew Witt- *University of Washington*

NATIONAL PHYSICAL SCIENCE CONSORTIUM

Questions?

If you are interested in learning more, look out for a publication coming soon!