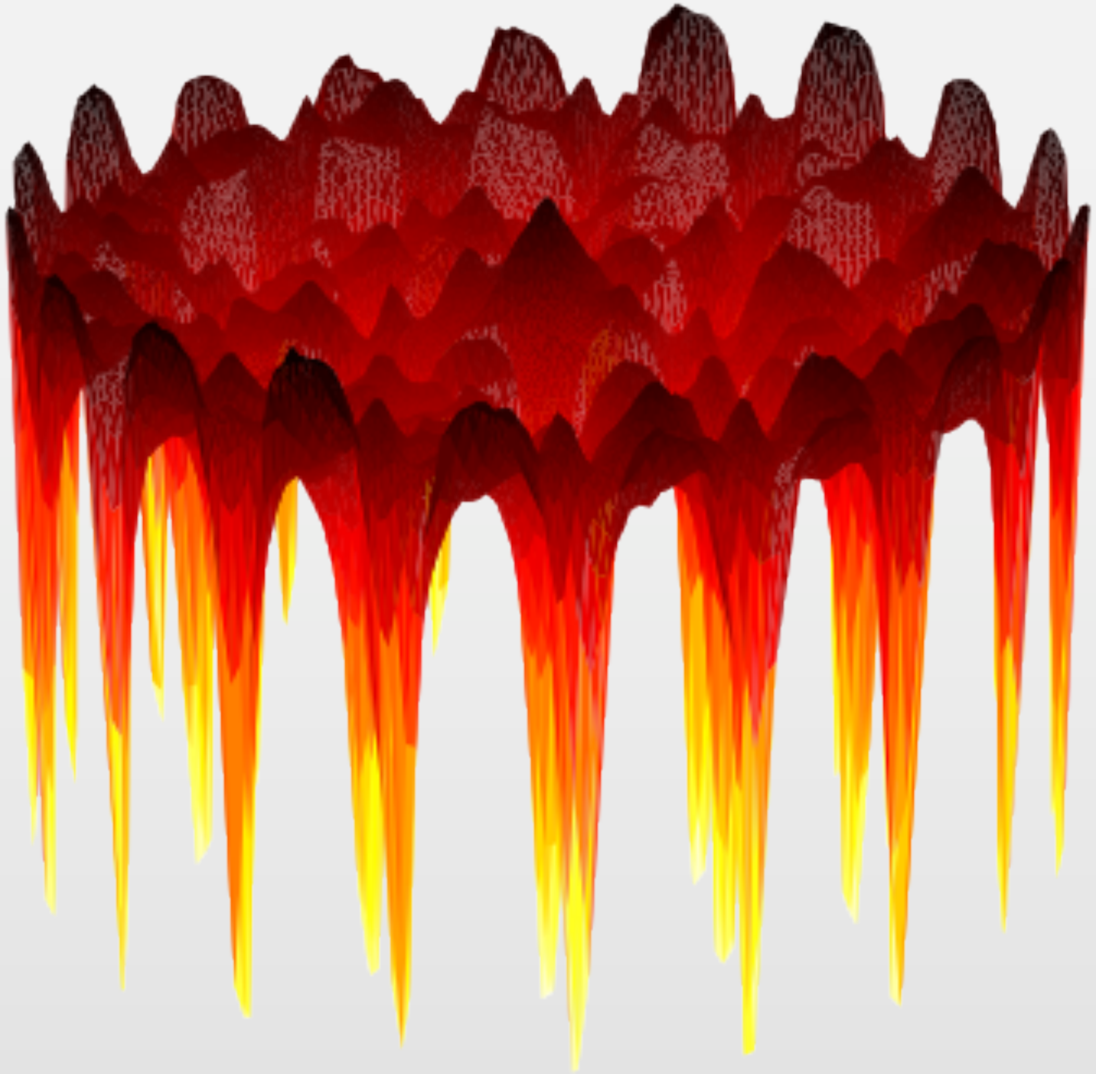

Large Scale Optimization of Wind Energy Systems

Oct 3, 2019

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Brigham Young University

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BYU Mechanical Engineering

NREL Transforming ENERGY

NSF

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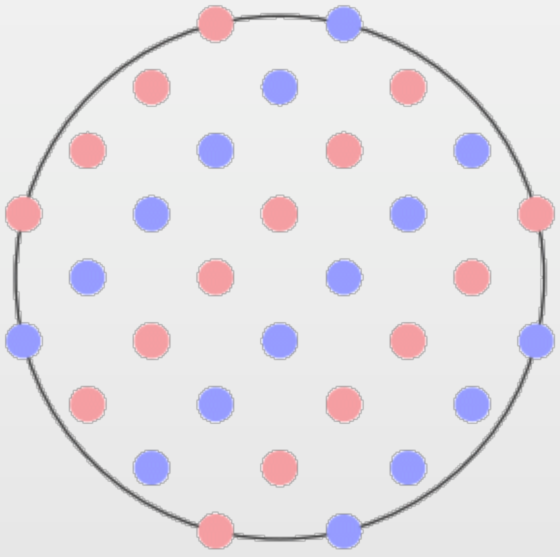
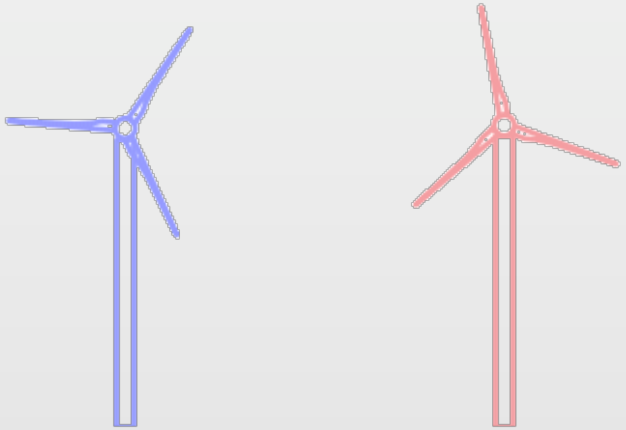
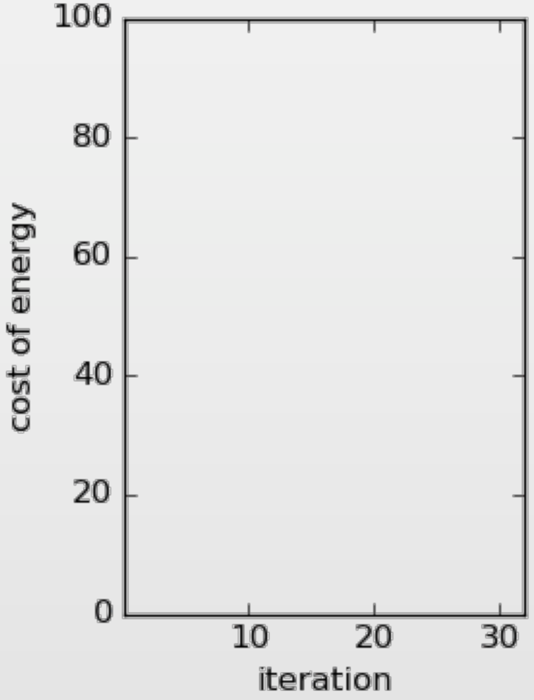
Eduardo Alvarez (PhD)

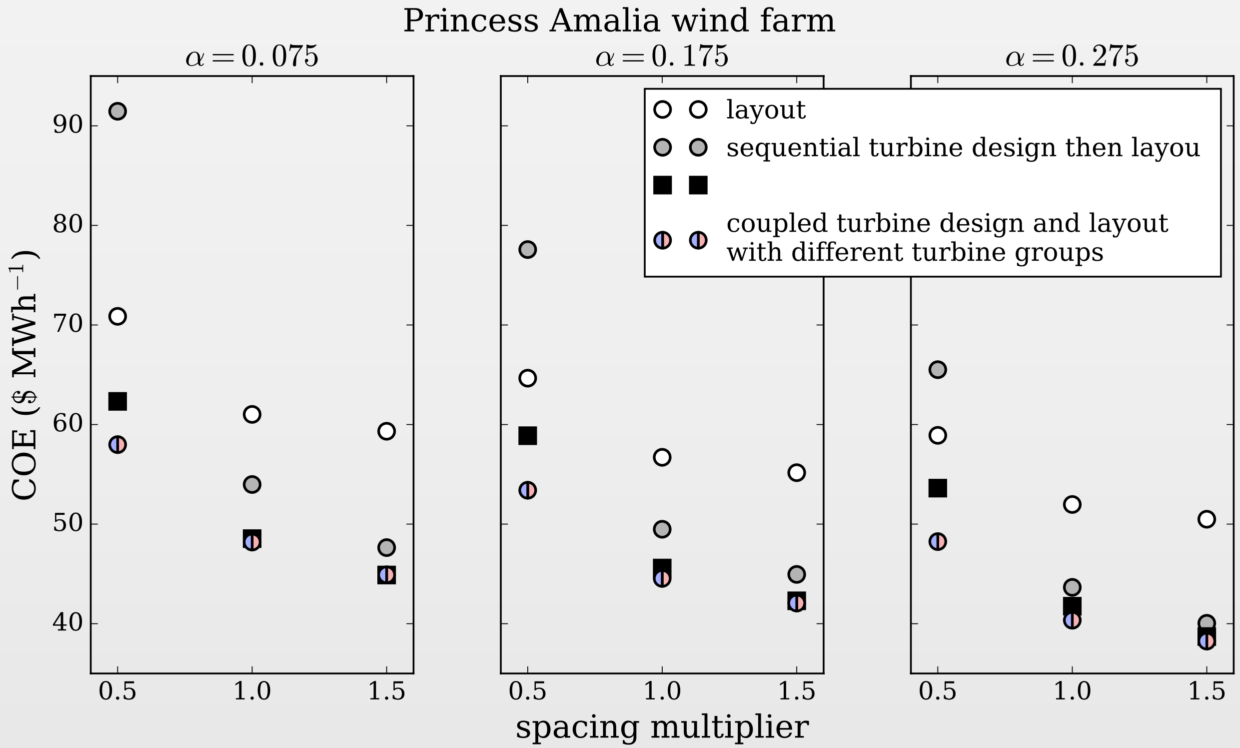
Jennifer King
Katherine Dykes
Garrett Barter
Paul Flemming

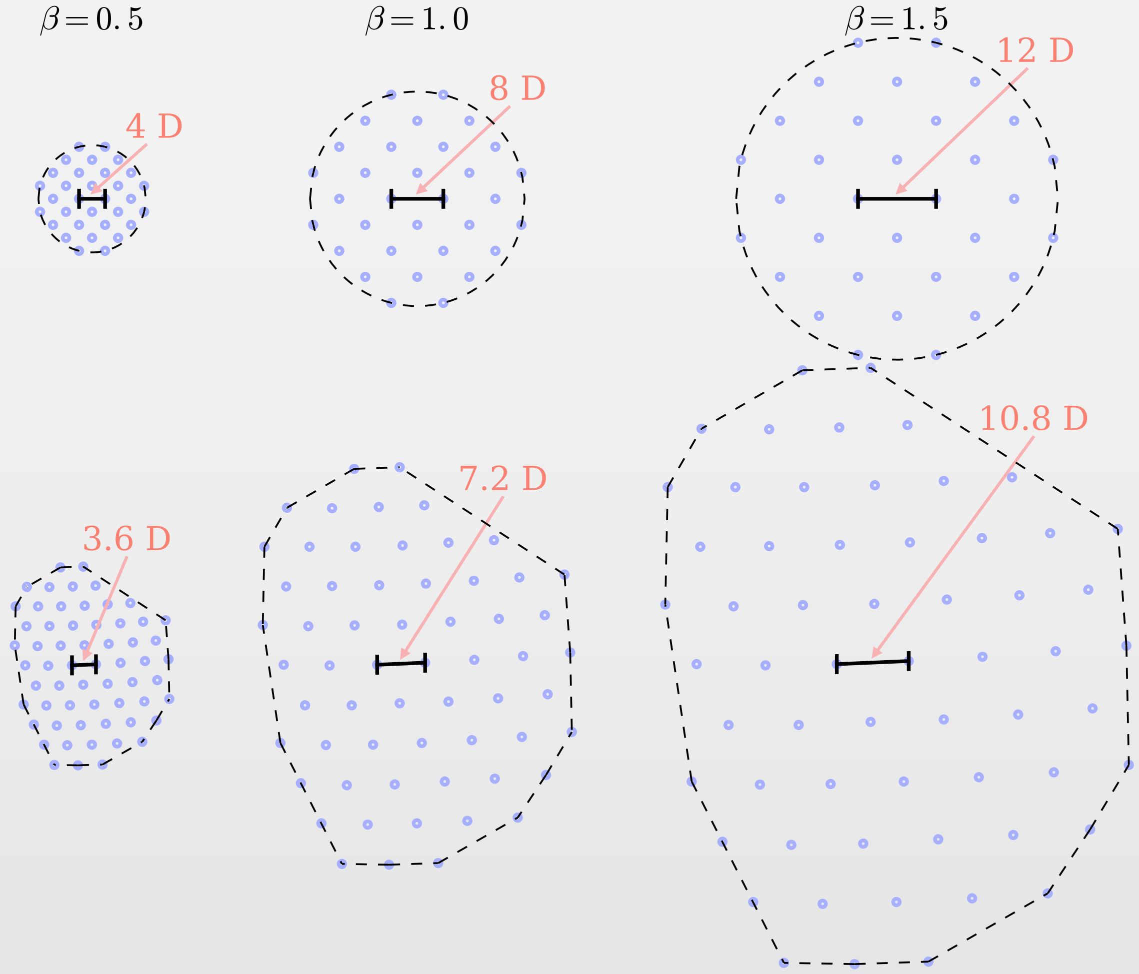
Coupled Wind Turbine Design and Layout Optimization











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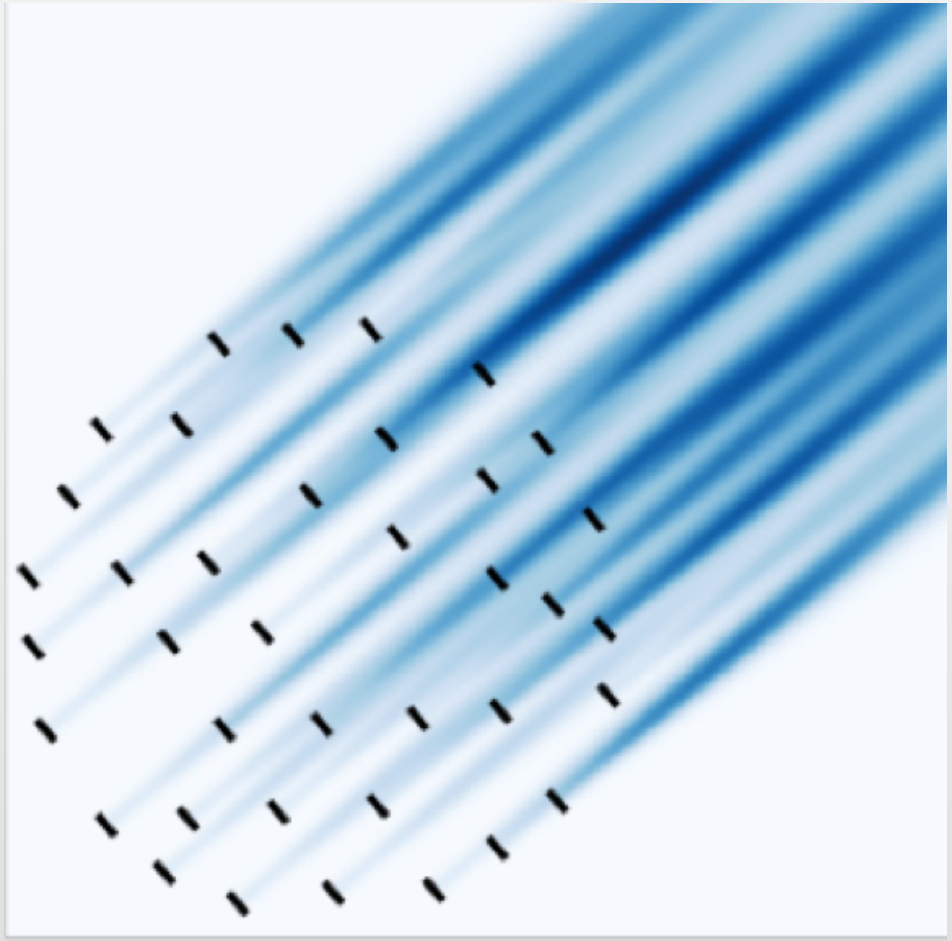
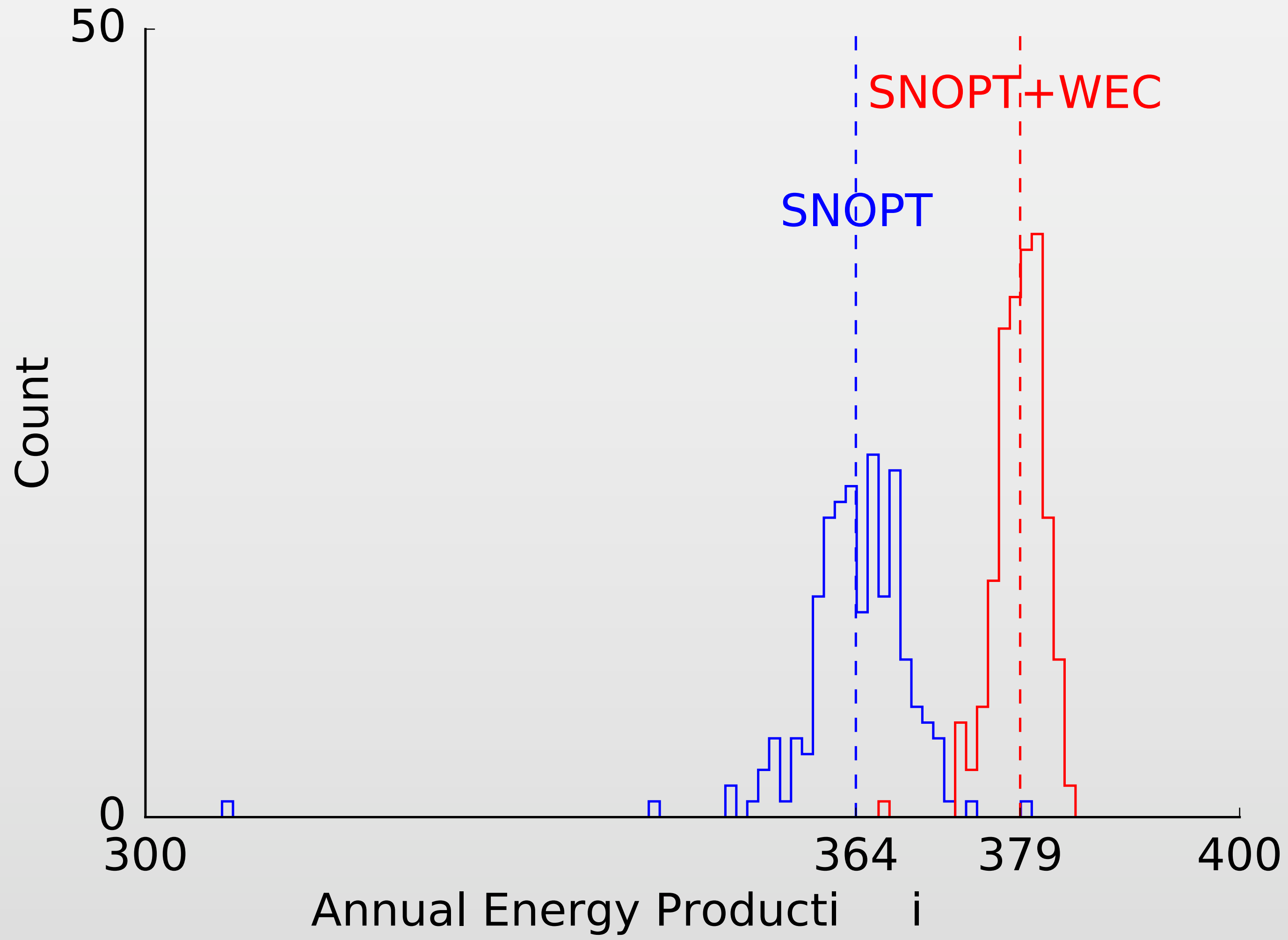
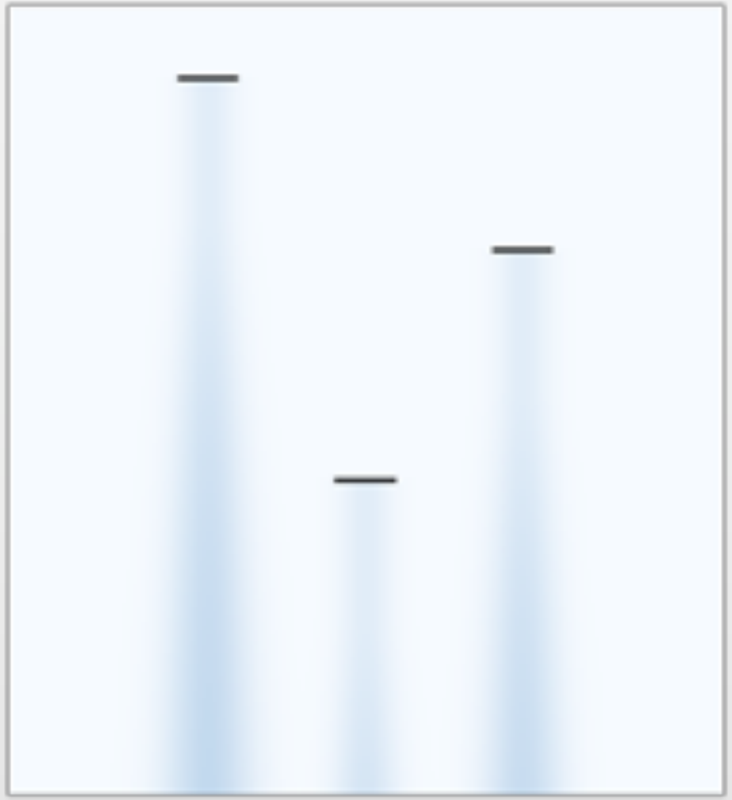
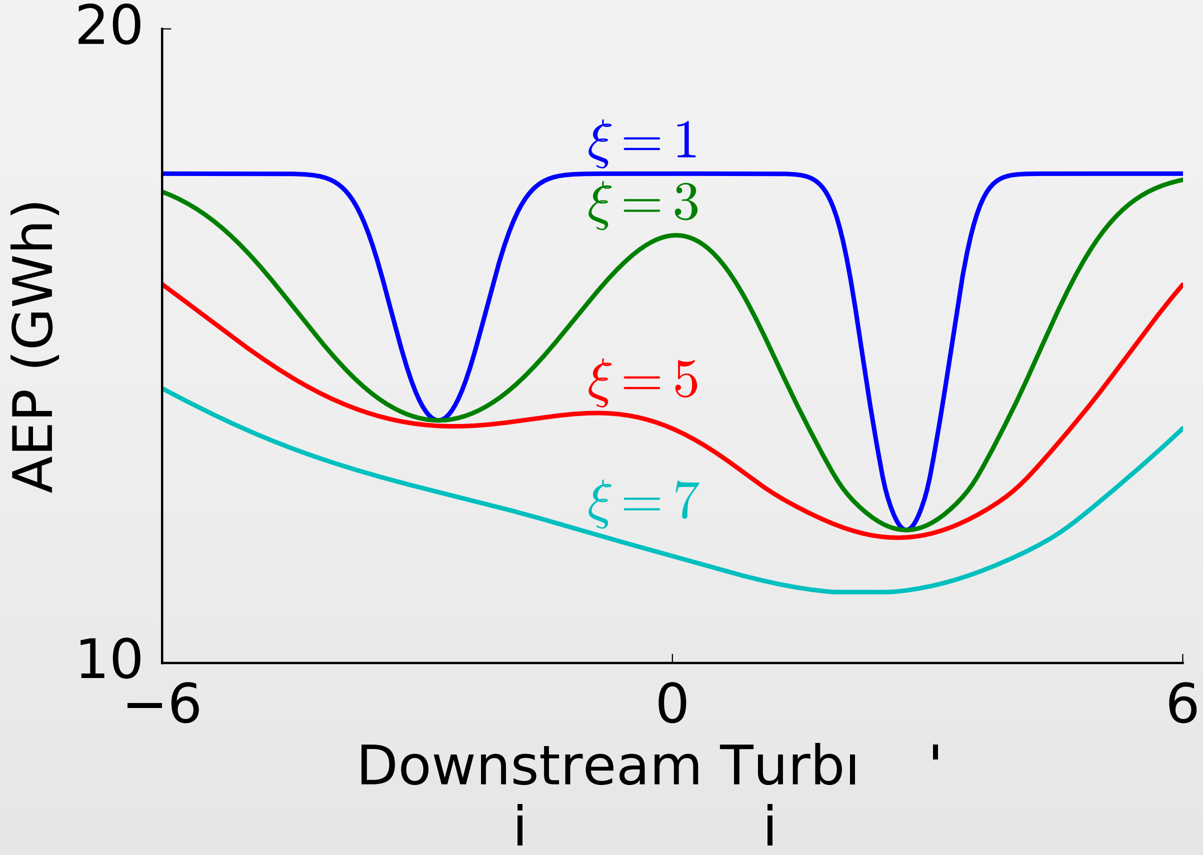
Searching a Highly Multimodal Design Space









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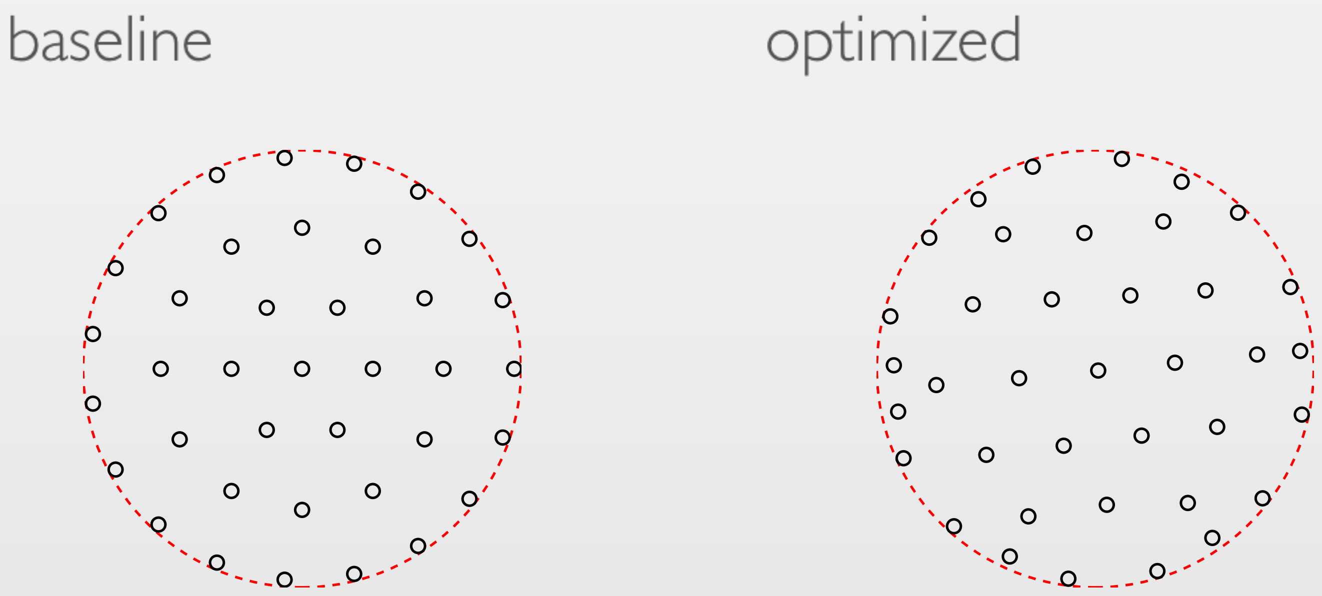
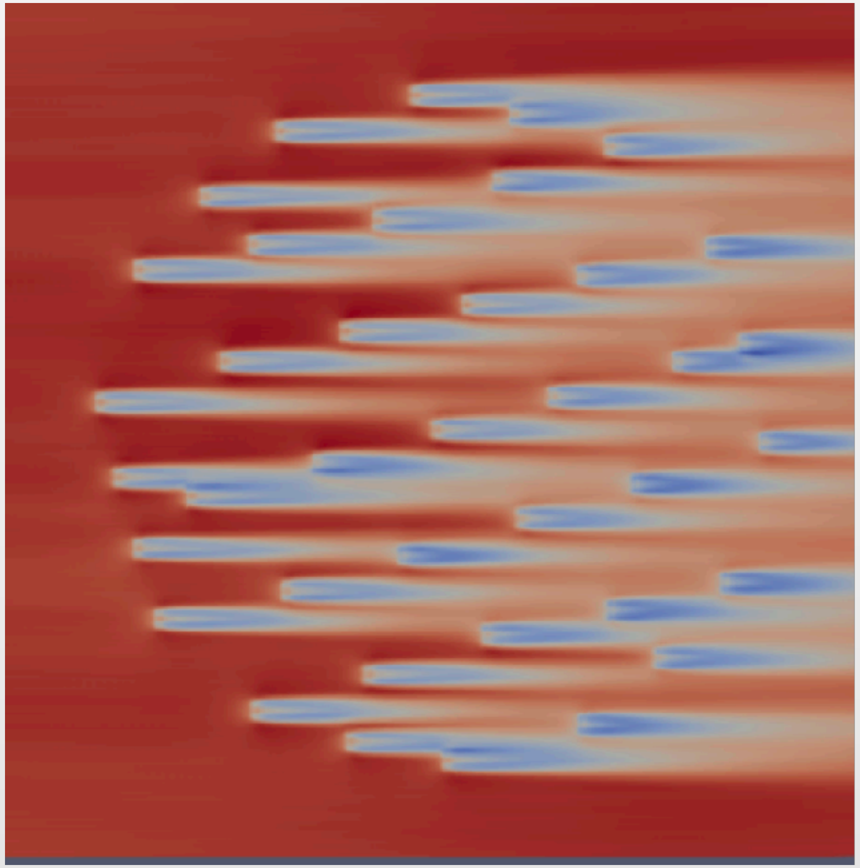
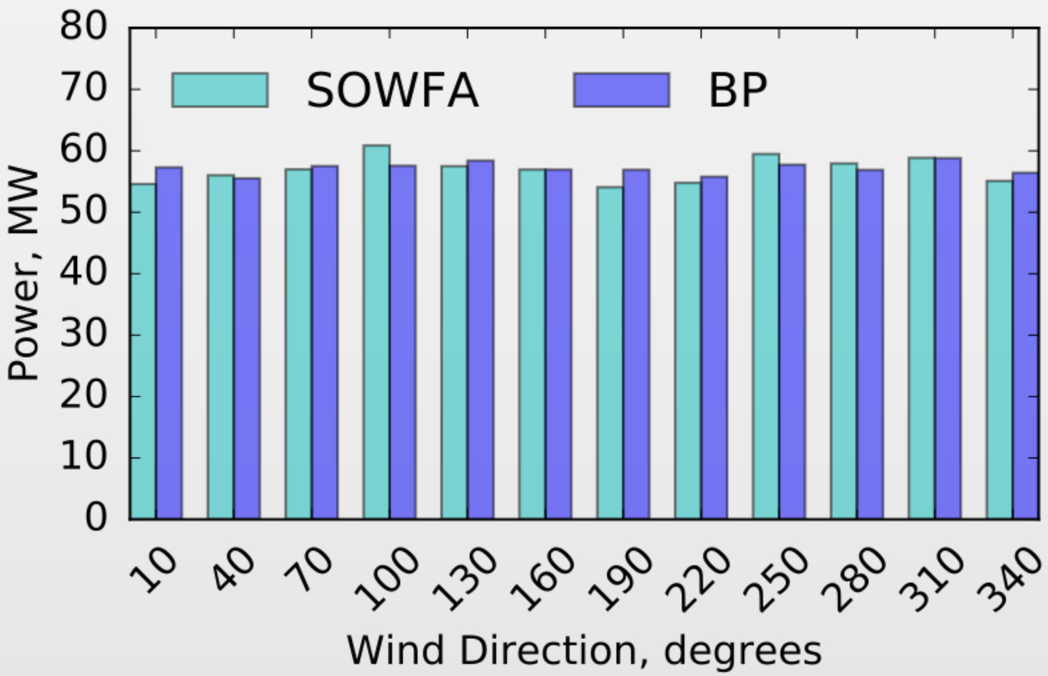
Optimization Comparison to LES



AEP improvement	
Model	7.5%
LES	9.9%





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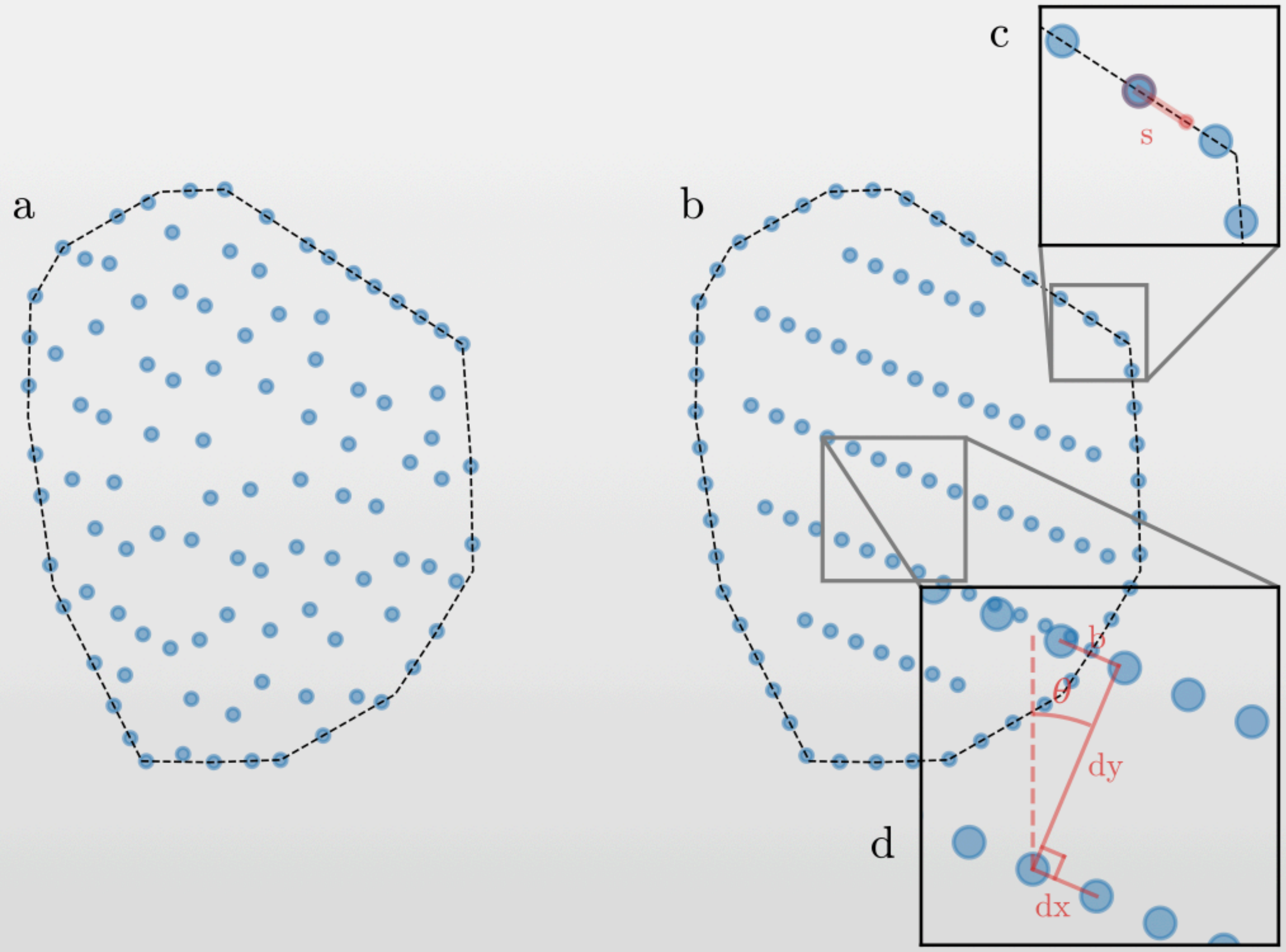
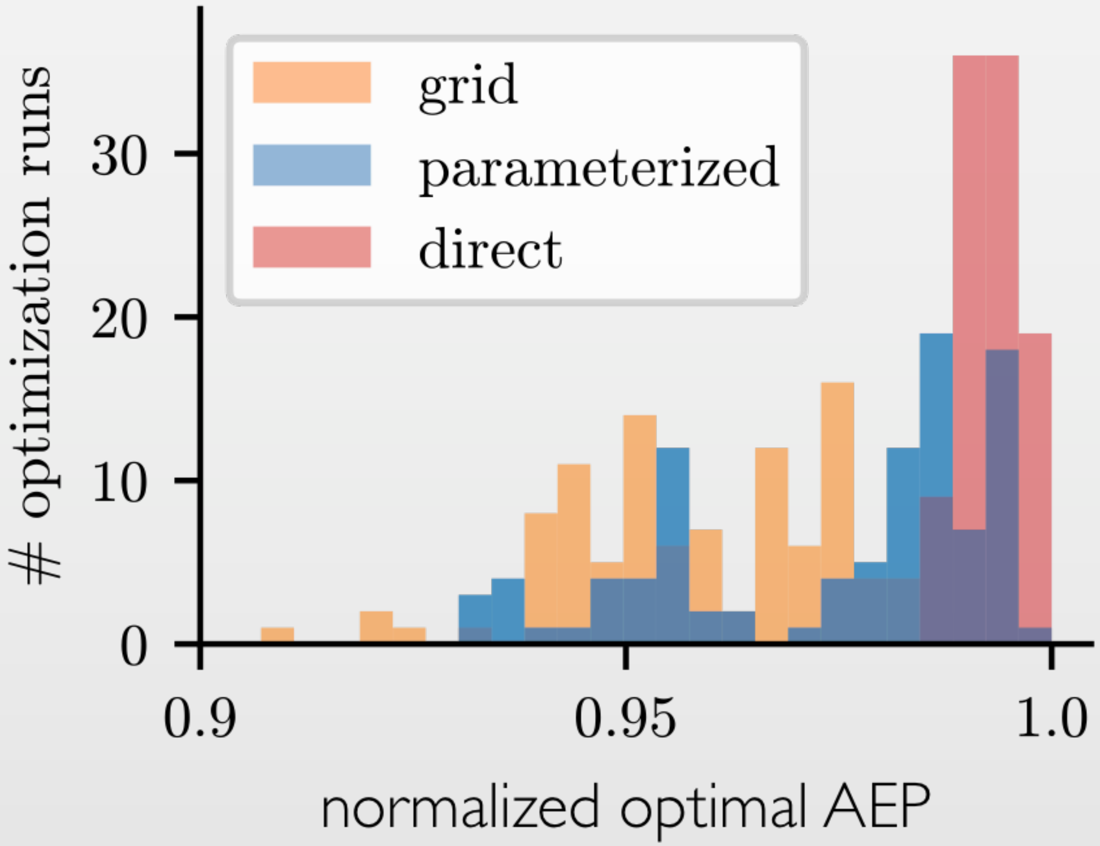
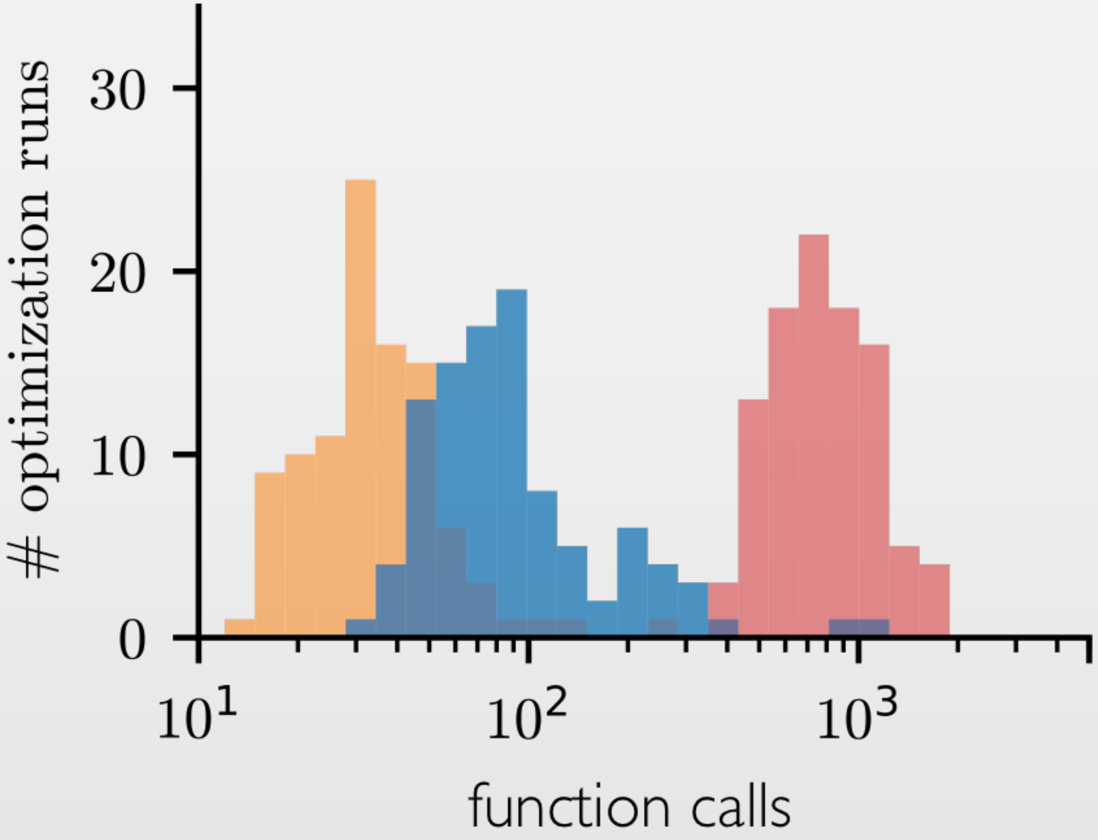
Reducing Dimensionality of Design Space







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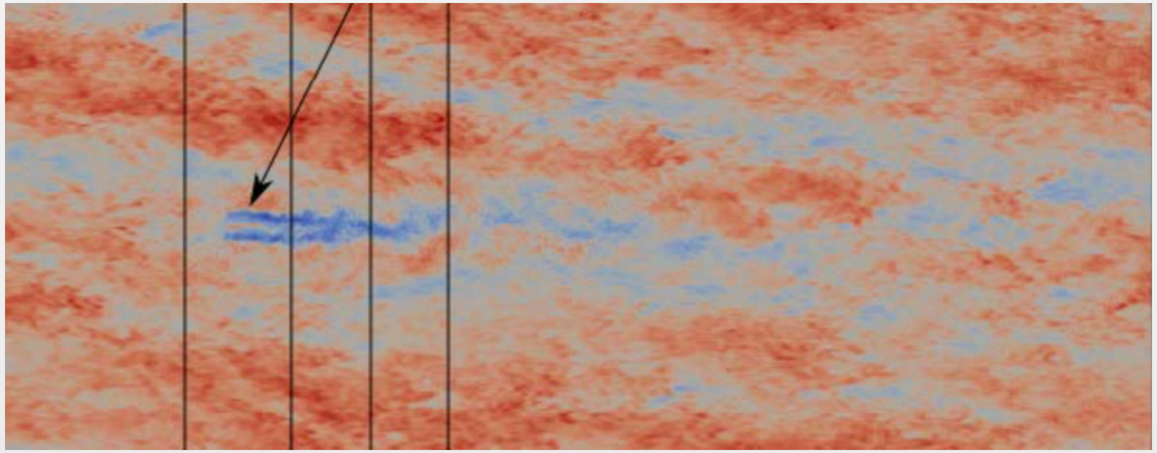
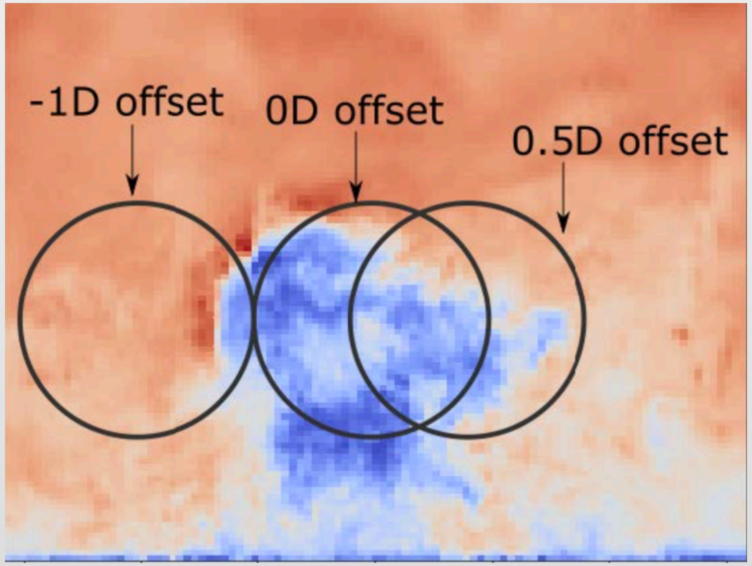
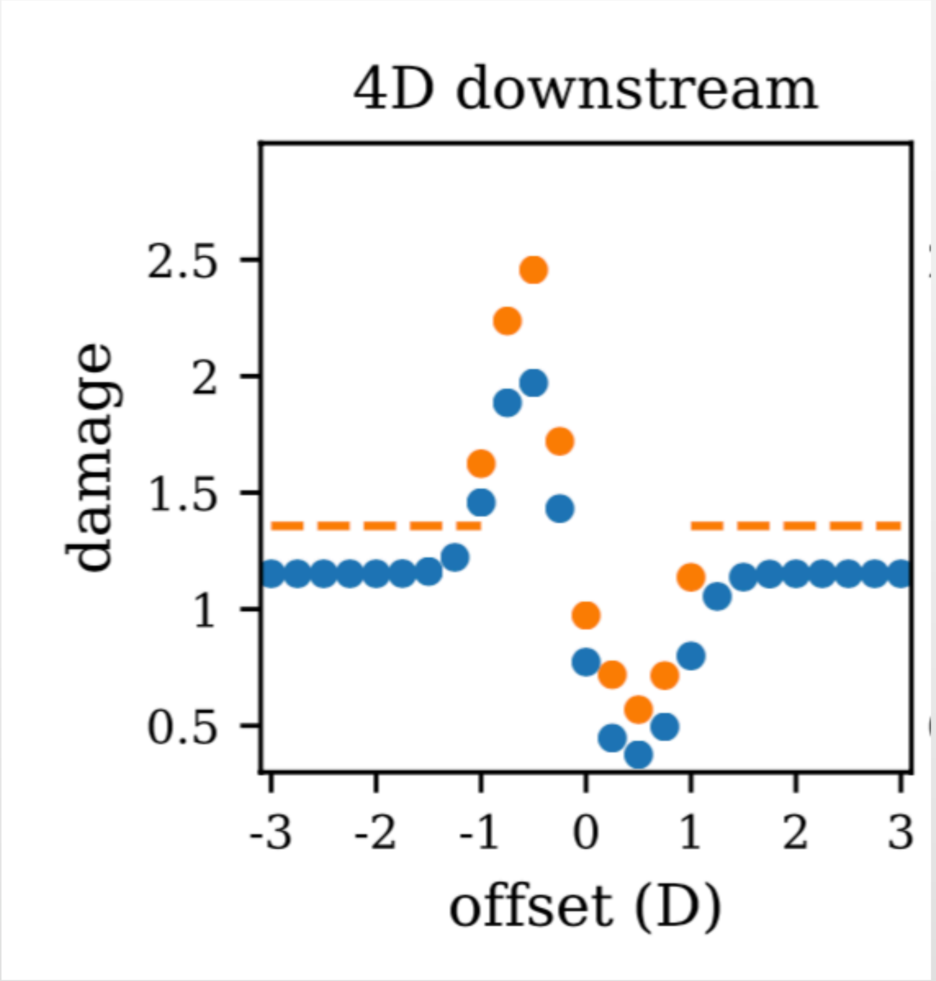
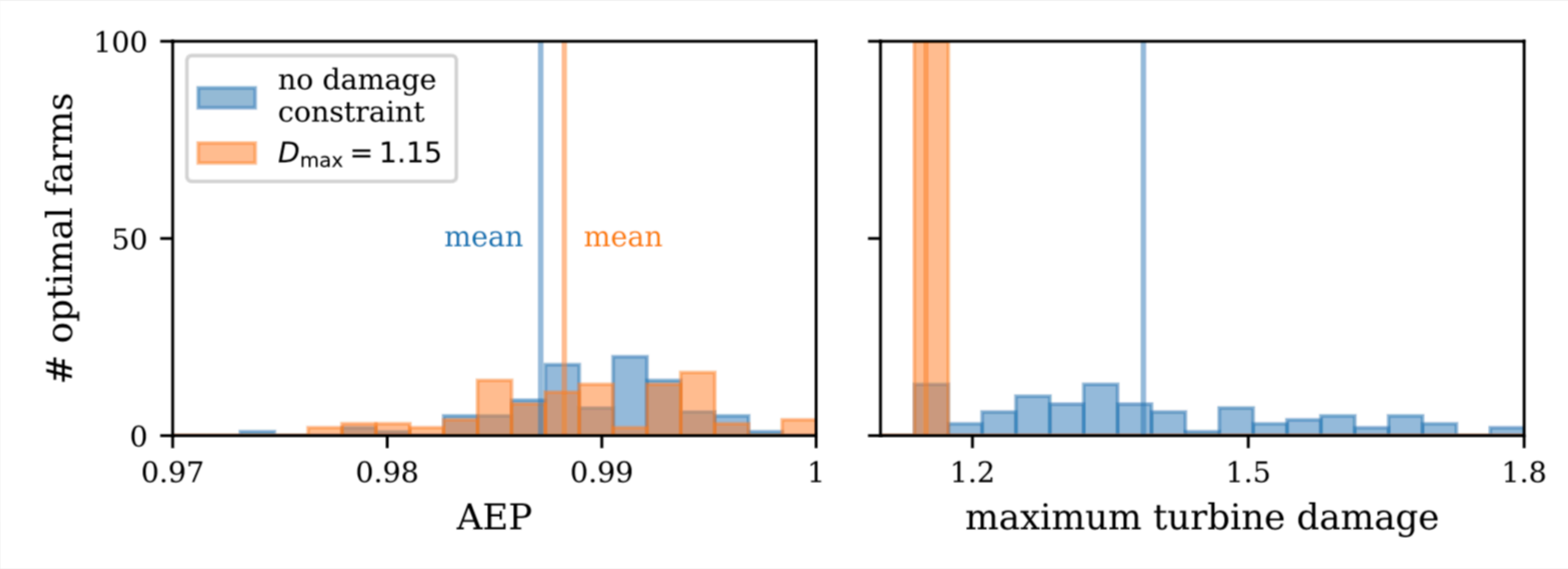
Including Loads in Layout Optimization









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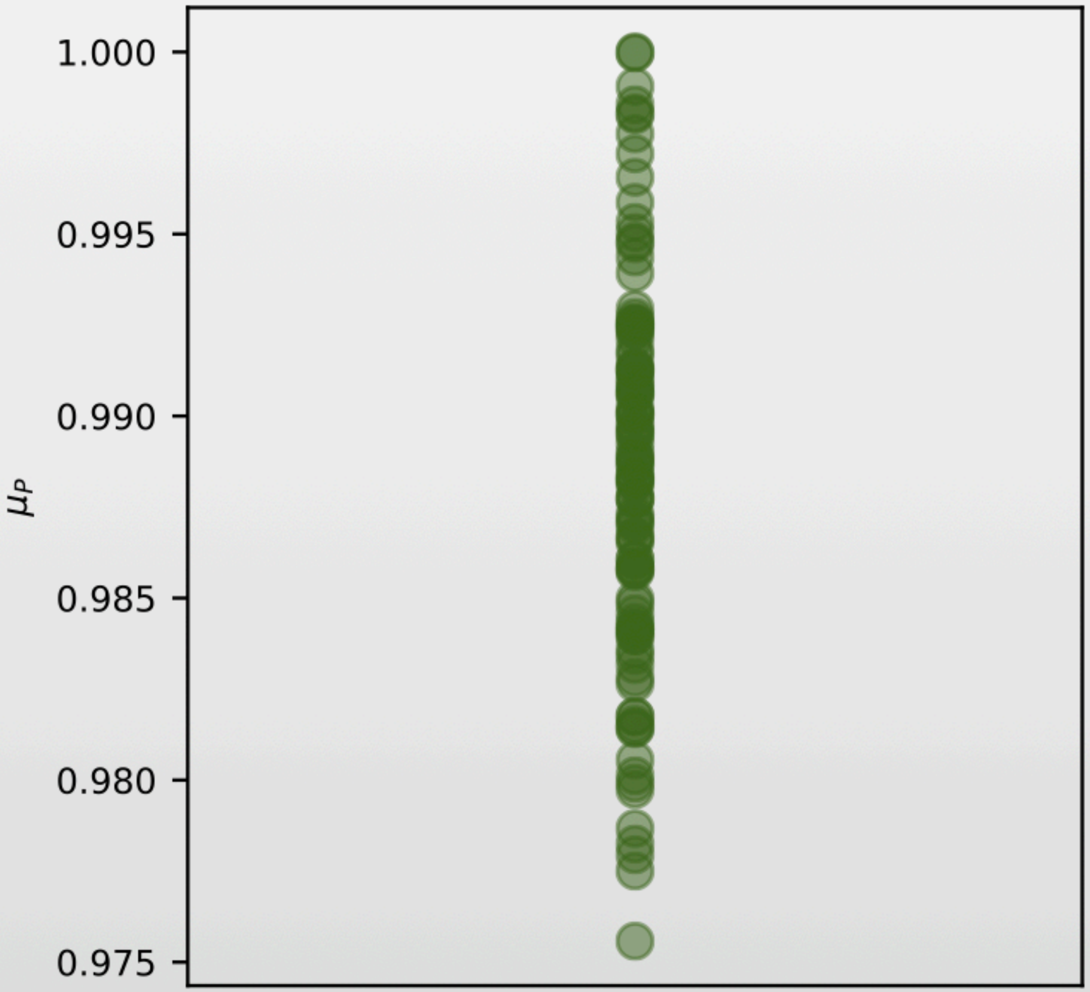
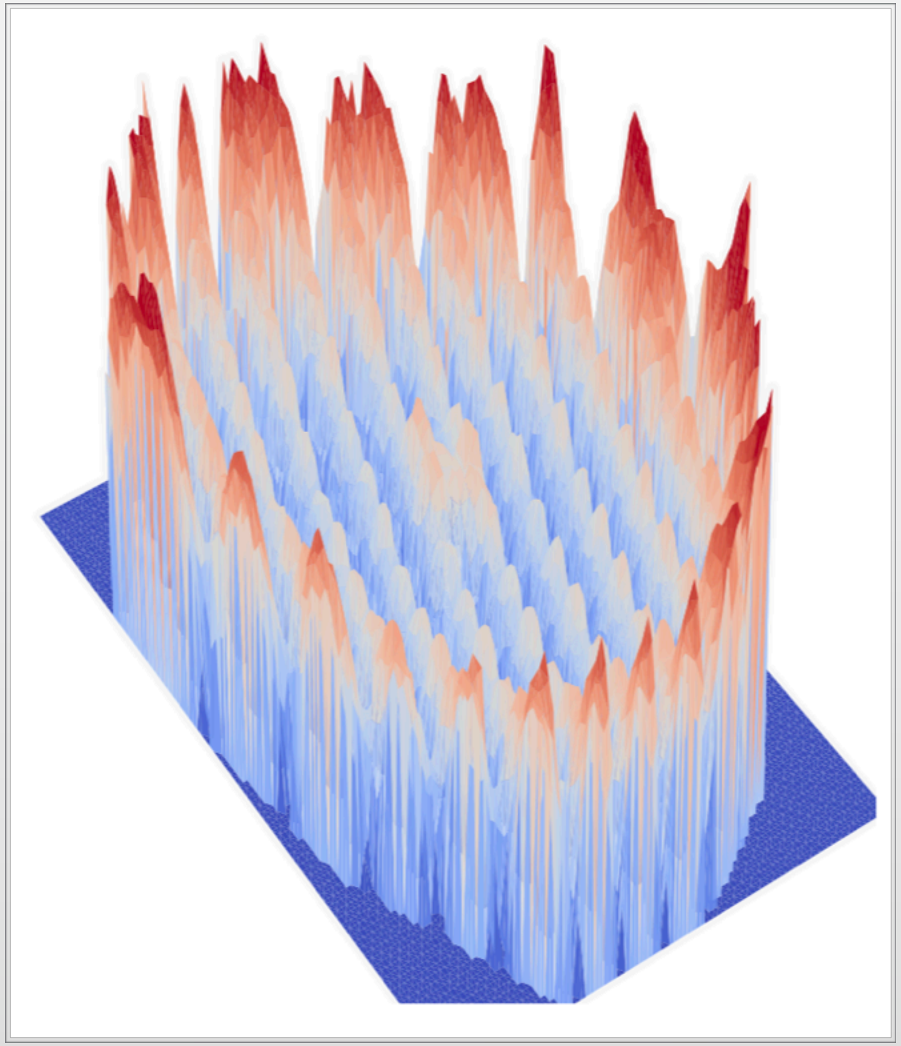
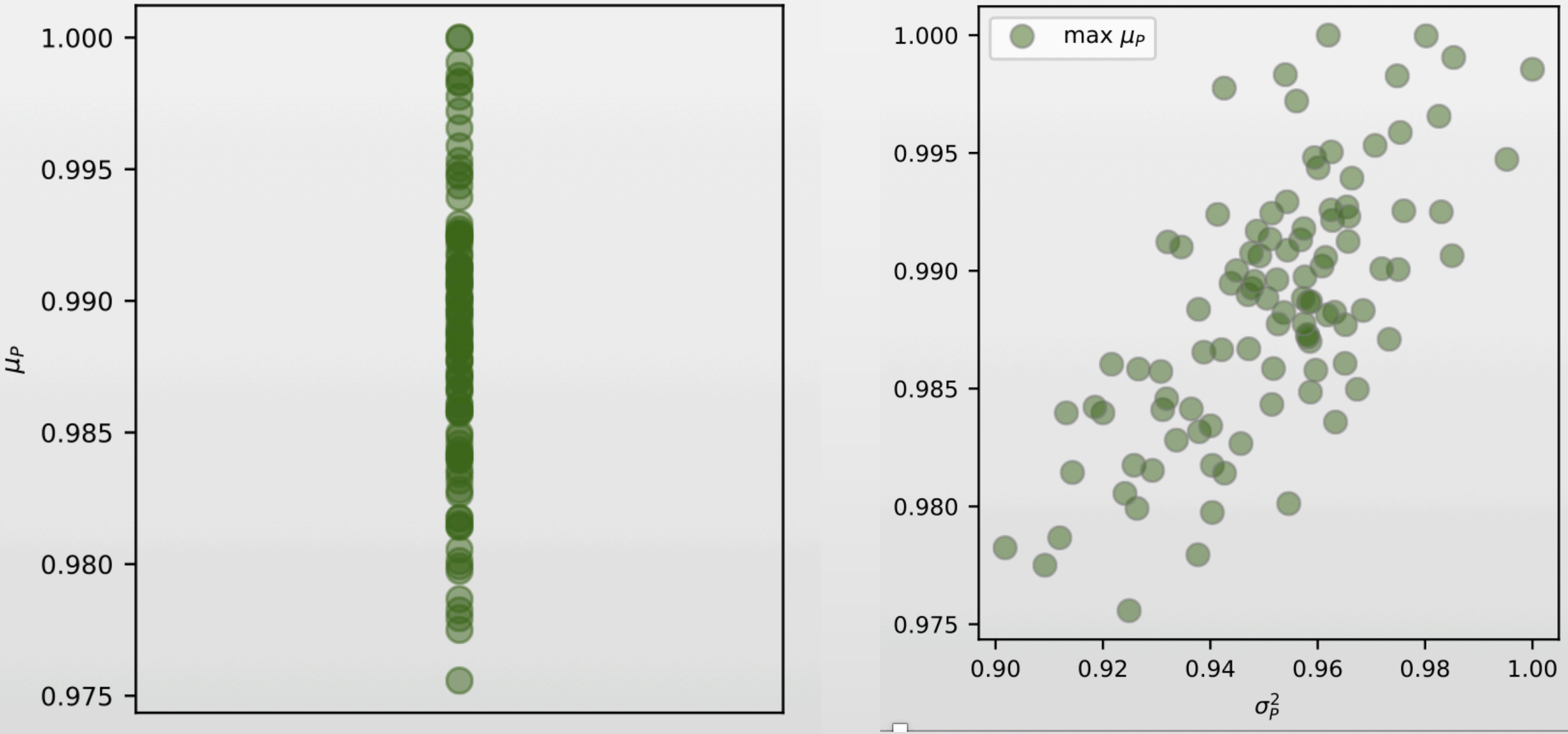
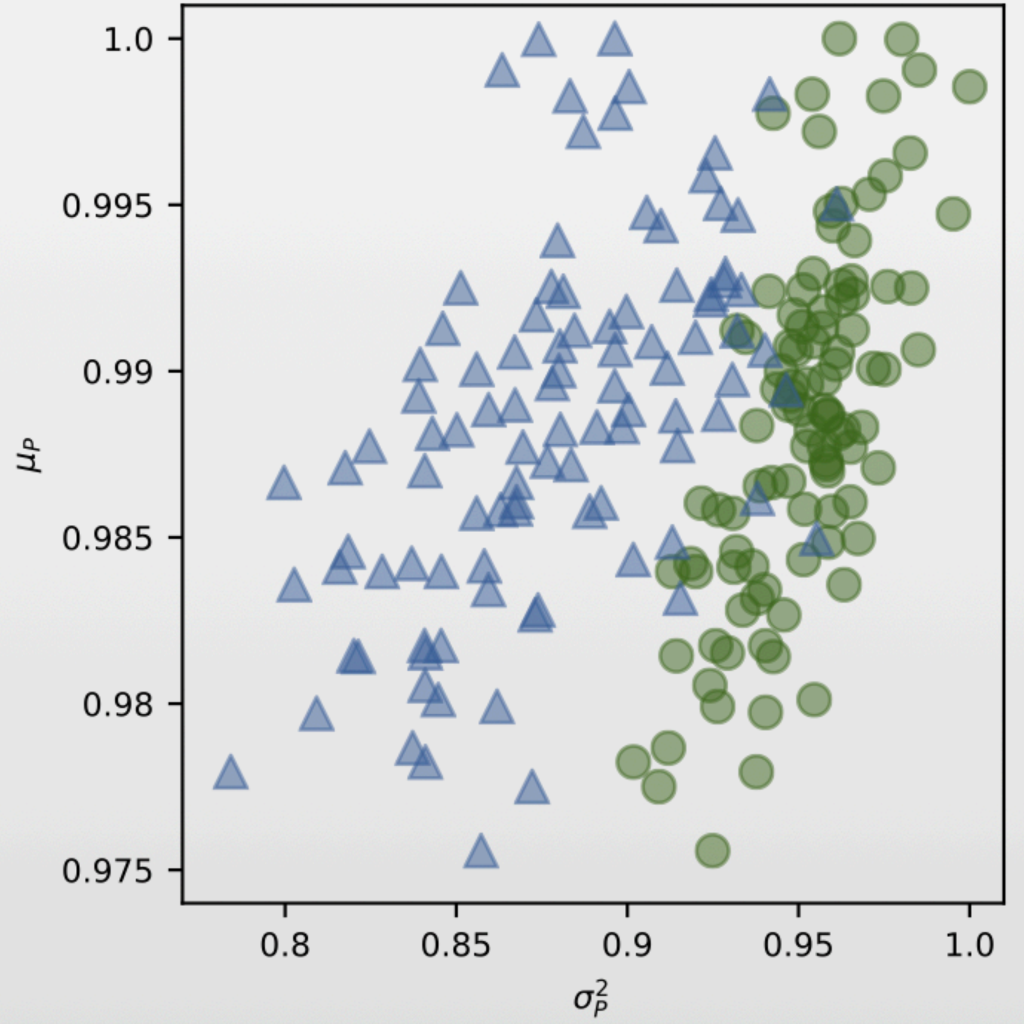
Reducing Variance



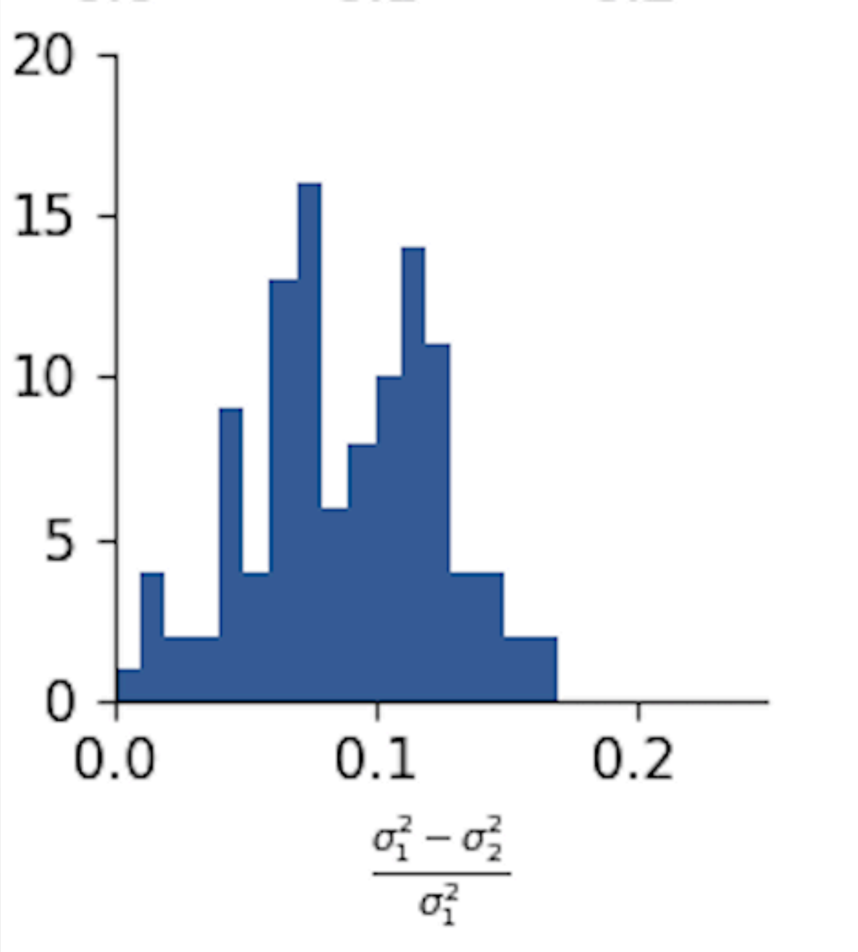




1.000
0.995
0.990
0.985
0.980
0.975
μ_P
max μ_P
0.90
0.92
0.94
0.96
0.98
1.00
σ_P^2

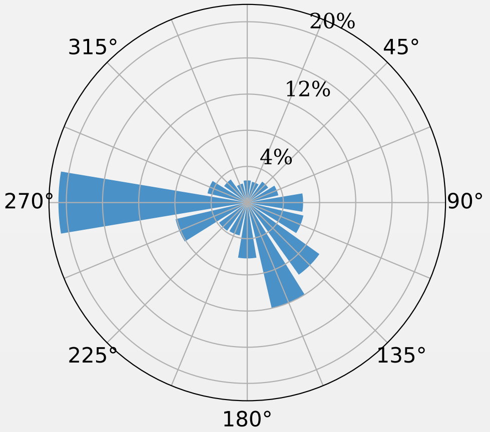


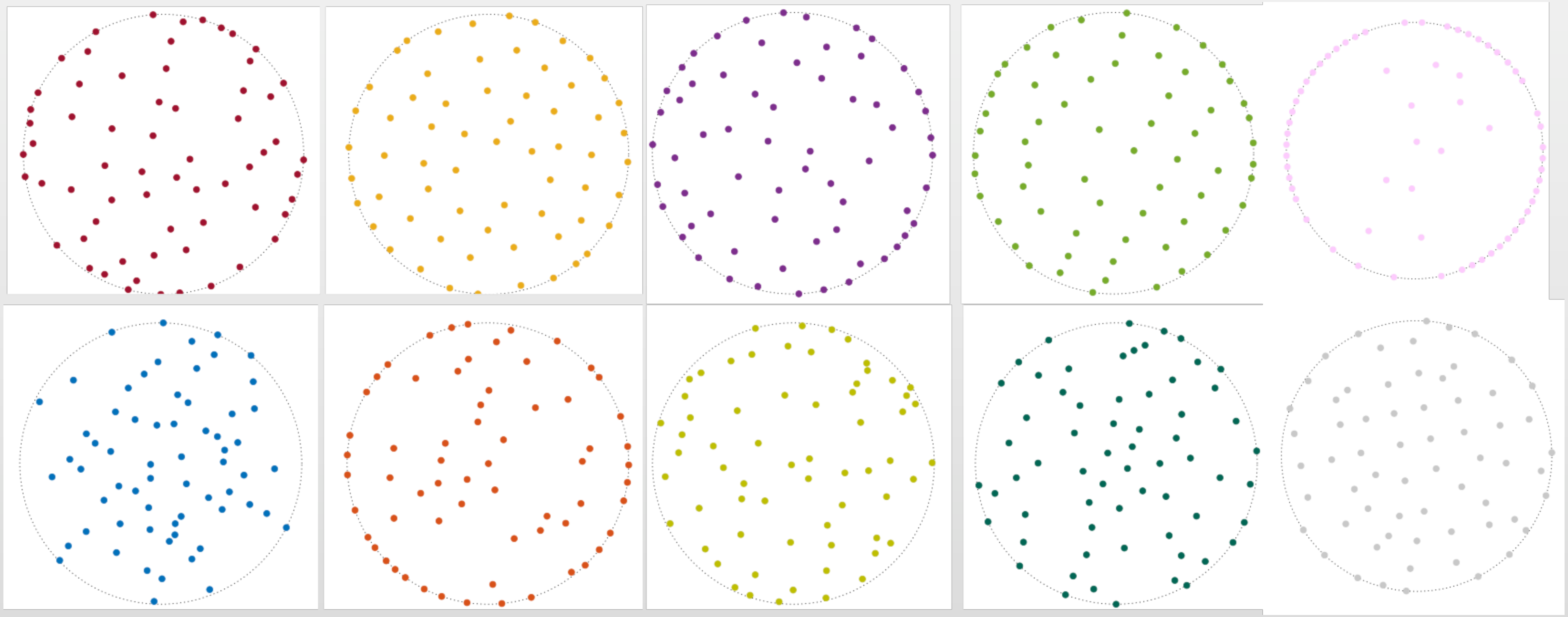
Amalia, 64 turbines

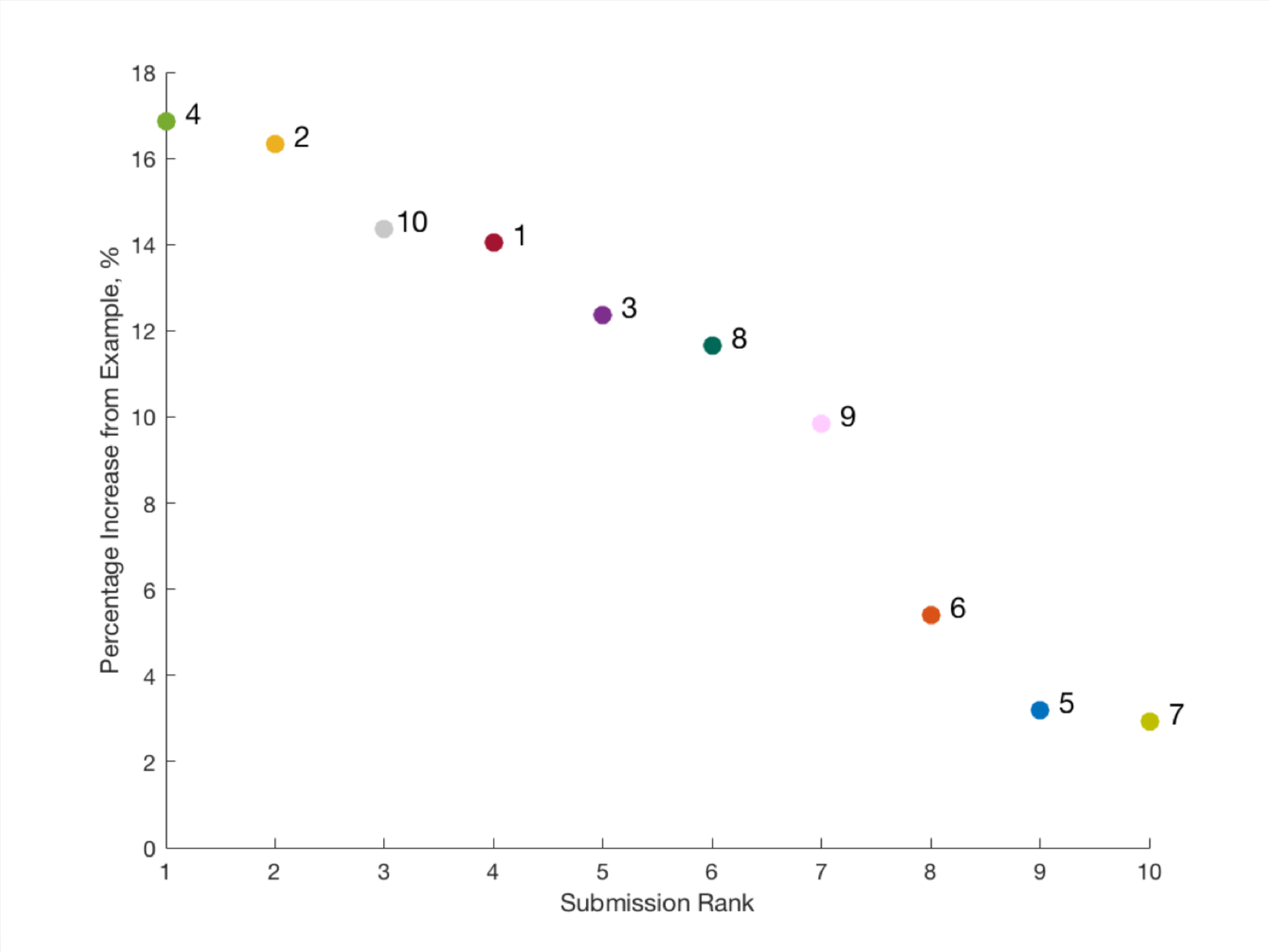


preprint: this week

IEA Task 37 Wind Farm Optimization Case Study







Baker, N. F., Stanley, A. P. J., Thomas, J. J., Ning, A., and Dykes, K., "Best Practices for Wake Model and Optimization Algorithm Selection in Wind Farm Layout Optimization," AIAA Scitech 2019 Forum, San Diego, CA, Jan. 2019. doi:10.2514/6.2019-0540

Wind Farm Layout Optimization Case Studies 3 & 4
IEA Task 37 on System Engineering in Wind Energy

Nicholas F. Baker, Andrew P. J. Stanley, and Andrew Ning
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Katherine Dykes
Technical University of Denmark, Kongens Lyngby, Copenhagen, Denmark

June 4, 2019

1 Introduction

Two major factors that affect wind farm layout optimization are 1) the optimization method and 2) the wake model. We have thus far conducted two case studies to analyze differences in these variables, this document defines a third and fourth case study to further research these factors when given a more realistic wind farm boundary and wind resource. Case study 3 (cs3) presents a scenario with a concave boundary. Case study 4 (cs4) presents a scenario with boundaries that are discontinuous and contain concavities. For cs3 a wake model is provided, participants need only optimize turbine locations. For cs4 users are free to choose both optimization approach and wake model.

Participants will 1) optimize turbine locations to maximize annual energy production, 2) submit details regarding their optimization convergence history and methodology. After all submissions are received, participants of cs4 will be expected to perform a cross comparison of other participant solutions. Data will be consolidated, processed, and made available to all participants.

2 Problem Definition

Objective

The objective of each scenario is to maximize annual energy production (AEP), which we define simply as the expected value of aerodynamic power multiplied by the hours in a year. In other words:

$$AEP = 8760 \frac{\text{hrs}}{\text{yr}} \sum_{i=1}^{n} \sum_{j=1}^{m} f_i w_{i,j} P_{i,j}$$

where $P_{i,j}$ is the power produced for wind direction i at wind speed j, n is the number of wind directional bins, f_i is the corresponding wind direction probability, m is the number of wind speed bins for each direction, and $w_{i,j}$ is the probability each speed bin will occur at each direction. Participants are free to use any optimization method.

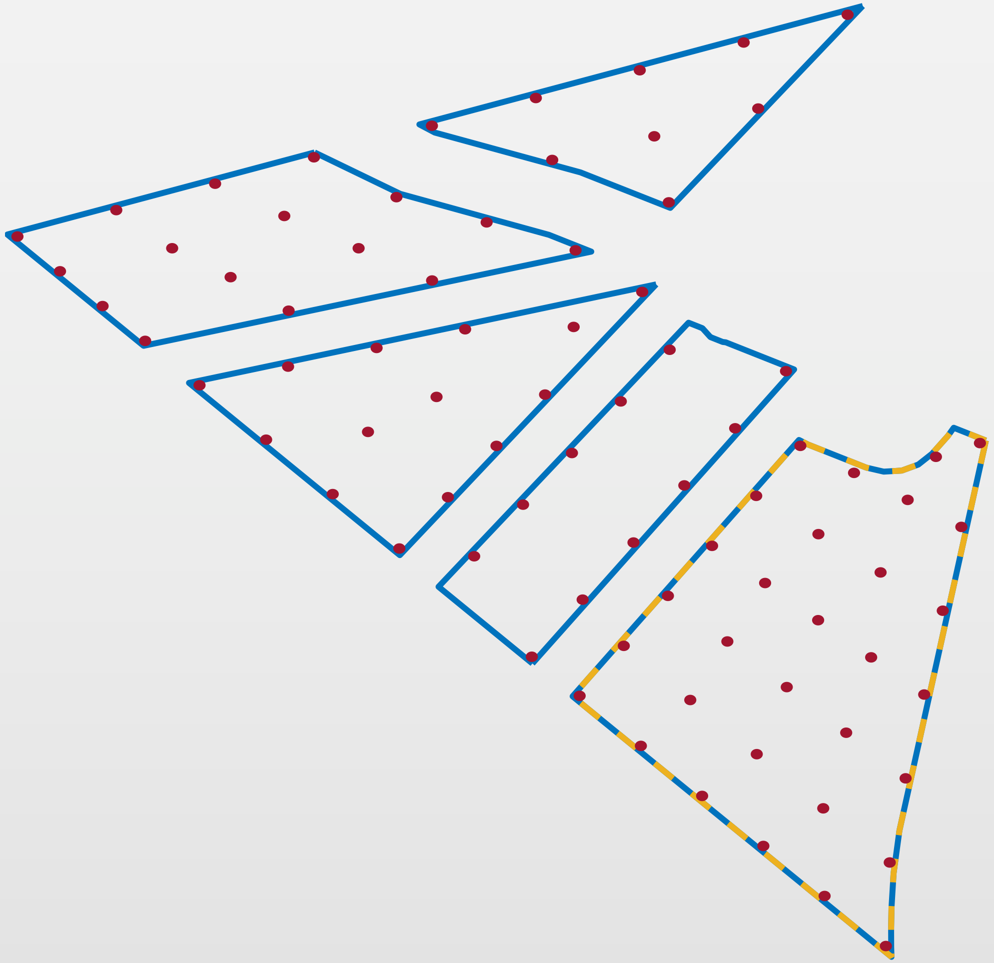
Variables

The final reported designs will be in terms of the (x, y) locations of each turbine, although participants are free to parameterize the turbine positions using any design variables they choose (e.g., pre-selected grid locations, grid spacing parameters, etc.). Note that every turbine is identical and defined below in Parameters.

Constraints

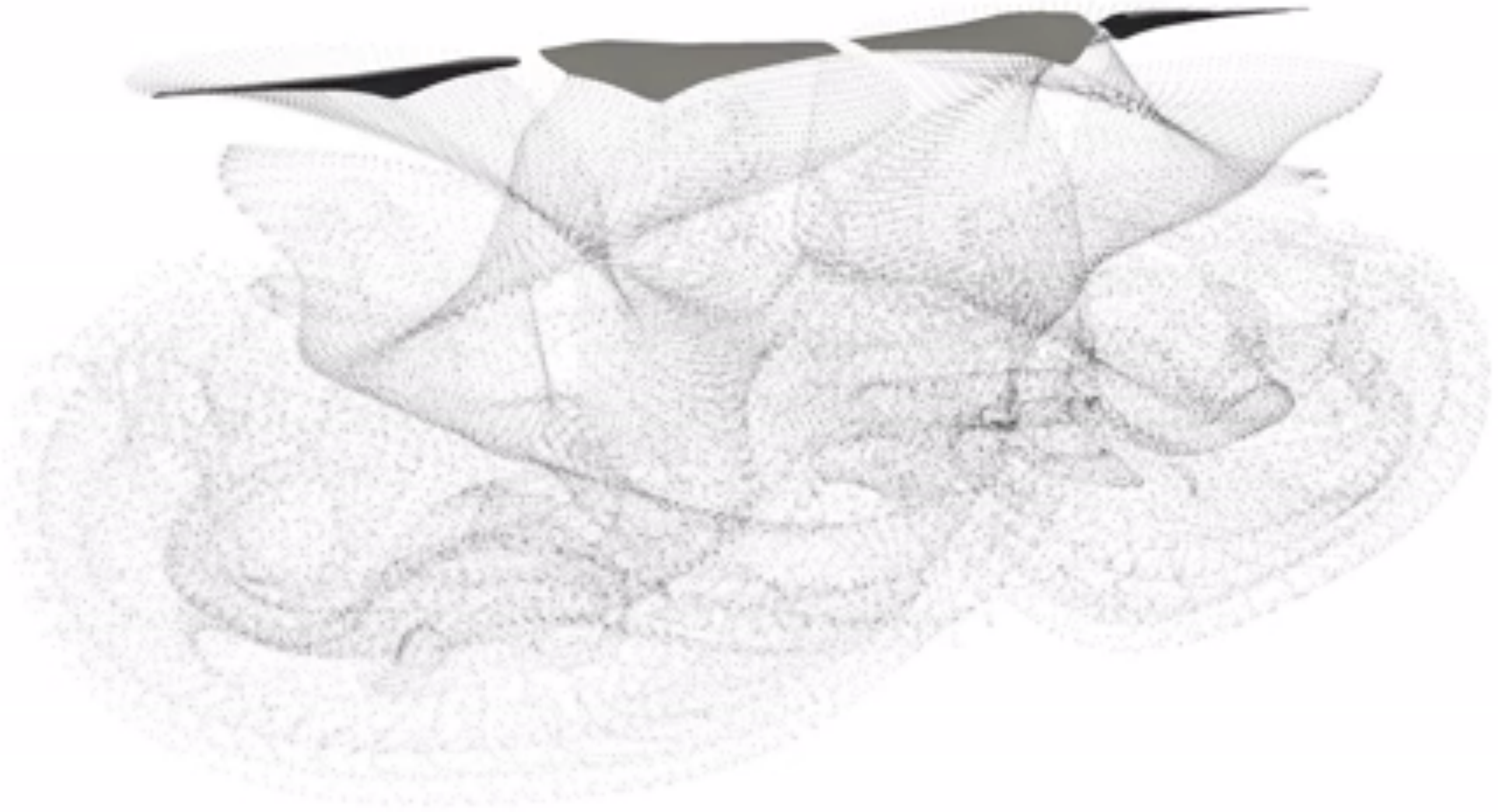
In case studies 1 and 2, all farm boundaries were circular. To make cs3 and cs4 more realistic, all boundaries are non-uniform. The cs3 and cs4 boundaries are based on the Borselle III and IV wind farms, our version is depicted graphically in Figure 1. The coordinates for the boundary vertices are given in `iea37-boundary-cs3.yaml` and `iea37-boundary-cs4.yaml`. All turbine hub coordinates must remain on or within these boundaries. The turbines are further constrained such that no hub can be less than two rotor diameters from any other hub, and for these farms scenarios all hub heights (z values) will be the same.

1



https://github.com/byuflowlab/iea37-wflo-casestudies

Vortex Particles



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Alvarez, E. J., and Ning, A., "Development of a Vortex Particle Code for the Modeling of Wake Interaction in Distributed Propulsion," AIAA Applied Aerodynamics Conference, Atlanta, GA, Jun. 2018. doi:10.2514/6.2018-3646

FLOW Lab

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