NREL
Transforming ENERGY

Tradespace Exploration of Floating Offshore Wind Mooring Systems

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EERA DeepWind Conference
January 18, 2024

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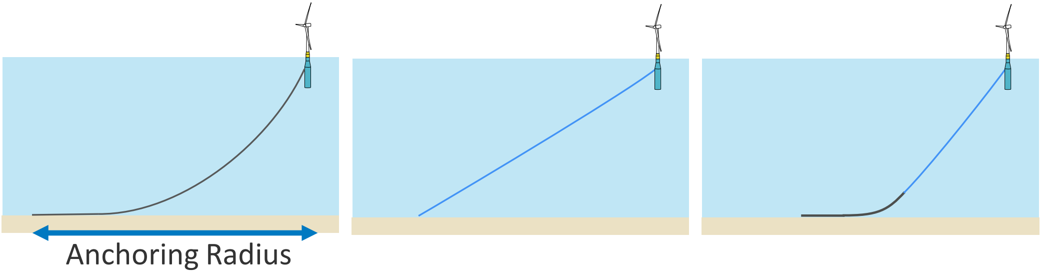
Contents

Methodology

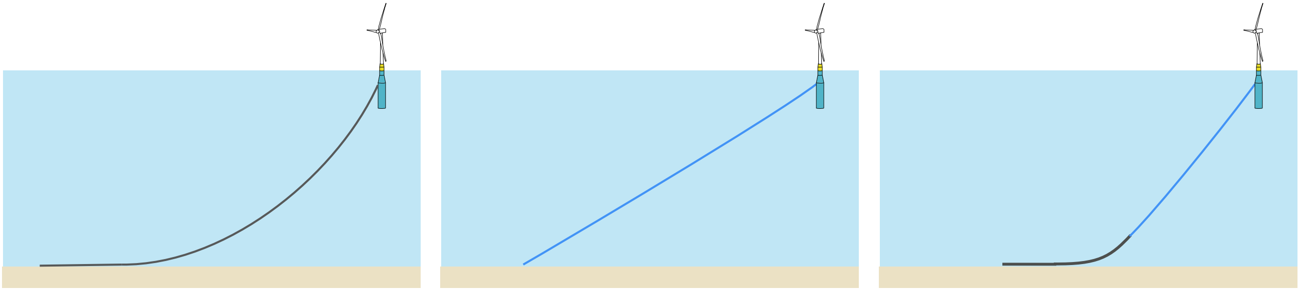
Goal: to design mooring systems across a range of depths and anchor spacings, allowing patterns in cost, optimal anchoring radius, and more to be mapped out

Three mooring system types:



Configuration	Line Type	Anchor Type	Water depth	Anchoring Radius
Catenary	Chain	DEA		
Taut	Polyester	Suction pile	100 to 1400 m	600 – 2400 m
Semi-taut	Chain and polyester	DEA		

Methodology

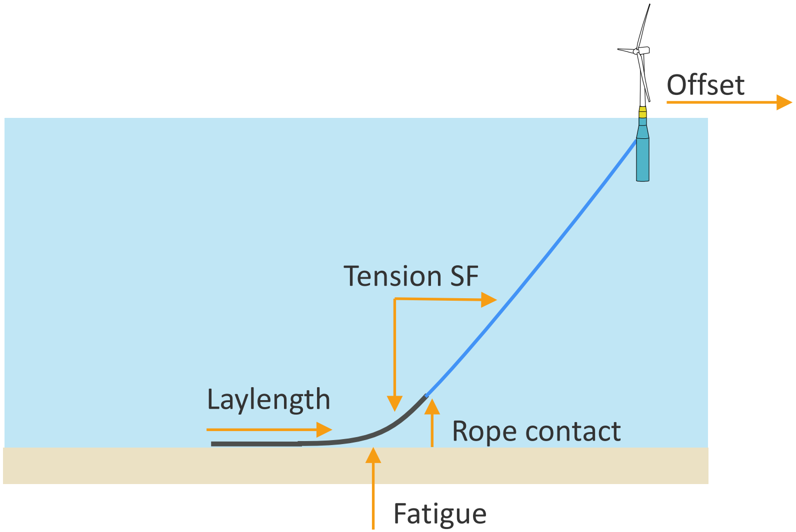


Tools:

- LineDesign: quasi-static mooring line optimizer
- MoorPy: quasi-static mooring line model
- OpenFAST: wind turbine simulation tool
- MoorDyn: lumped mass mooring line dynamics model

Design Constraints

Constraint	Catenary	Taut	Semi-taut
Tension safety factor	X	X	X
Fatigue damage	X		X
Platform offset	X	X	X
Chain laylength	X		X
Rope contact		X	X



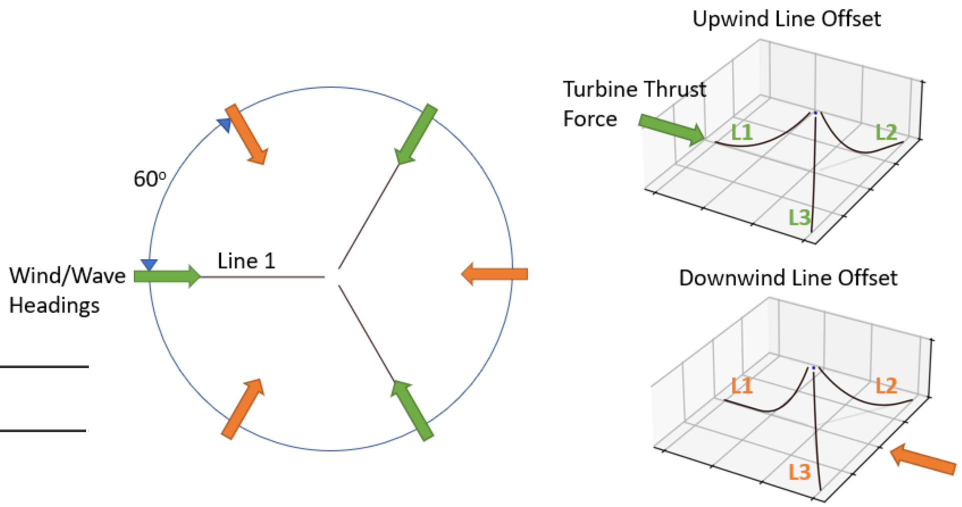
Environmental Conditions

Extreme load cases:

DLC	1.6
Wind speed (m/s)	10.59
Hs (m)	8.0
Tp (s)	12.7

Fatigue load cases:

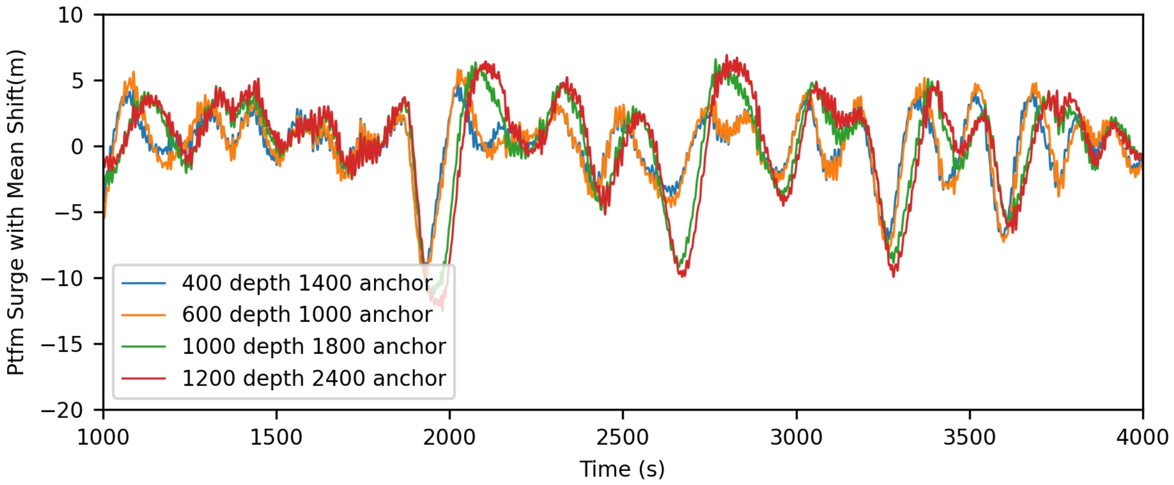
Load Case	1	2	3
Wind speed (m/s)	10	12	14
Hs (m)	1.54	1.84	2.19
Tp (s)	7.65	7.44	7.46
Probability	34.2%	35.4%	30.4%



Simulation Approach

~300 moorings x 7 load cases x ~5 iterations = 10500 simulations

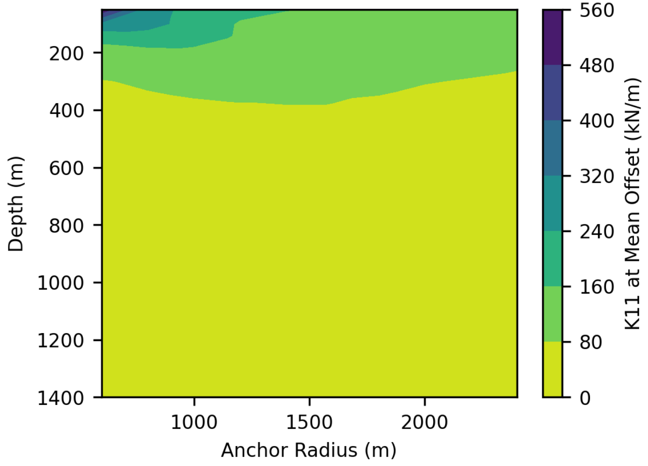
Simplification: platform oscillations are similar across mooring systems for a range of depths and anchor spacings

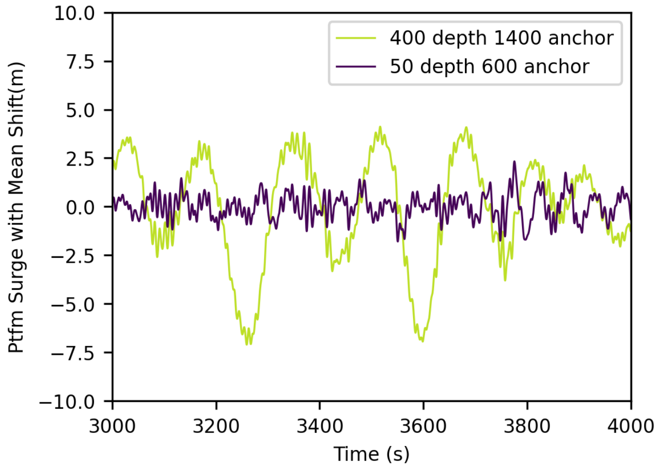


Simulation Approach

Simplification: platform oscillations are similar across mooring systems for a range of depths and anchor spacings

Except in shallow water!

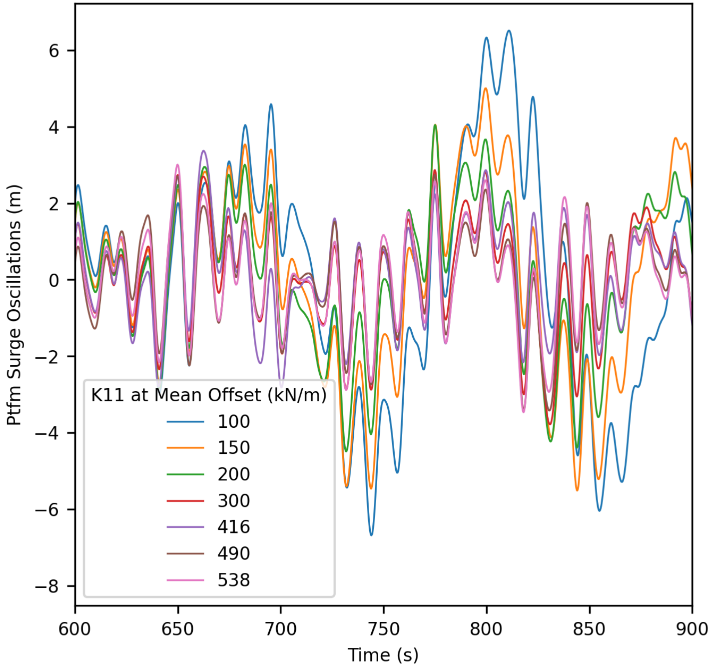




Overall Procedure

1. Optimize initial mooring designs
2. Simulate a subset in OpenFAST and extract platform motion time series (motions)
3. Apply turbine load in MoorPy to get mean offset (mean)
4. Simulate in MoorDyn driver with prescribed platform motions (mean + motions)
5. Evaluate tensions and fatigue damage
6. Reoptimize mooring designs with dynamic inputs

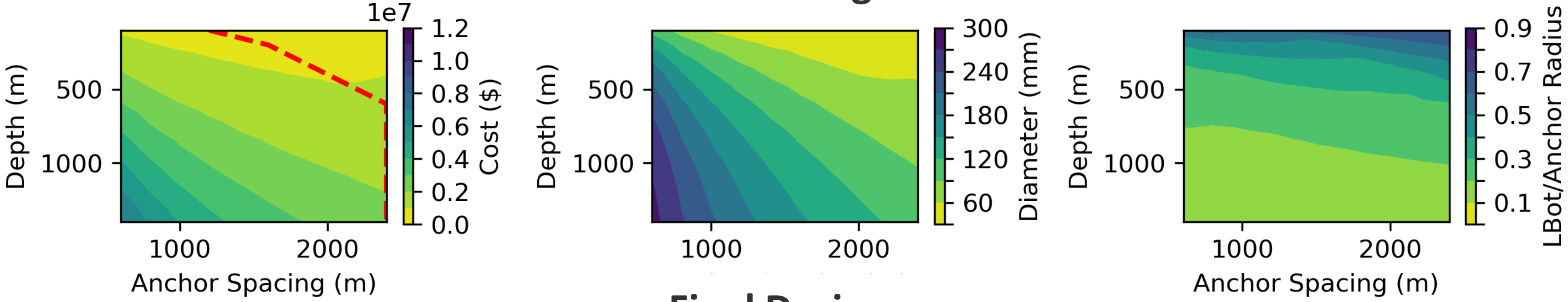
Platform Motions Library



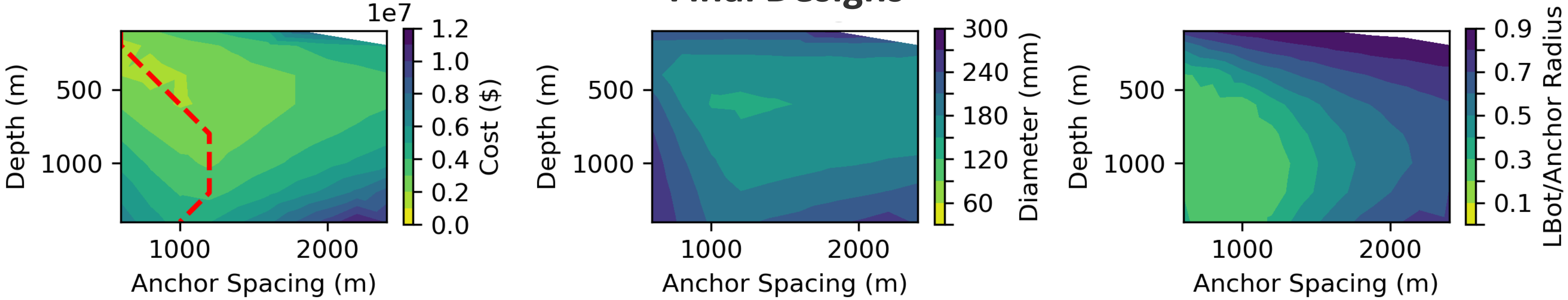
Results

Catenary Results

Initial Designs



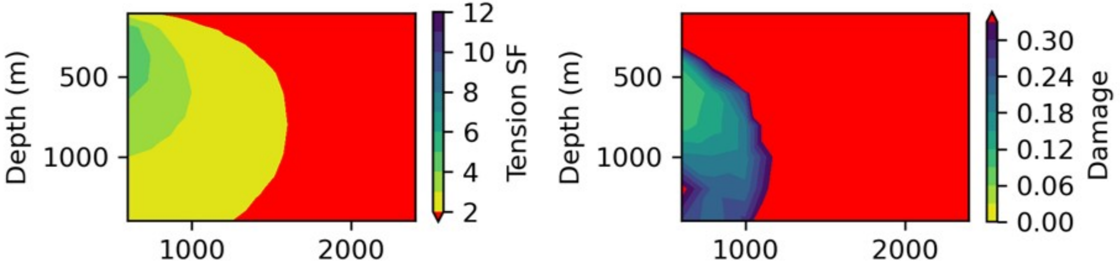
Final Designs



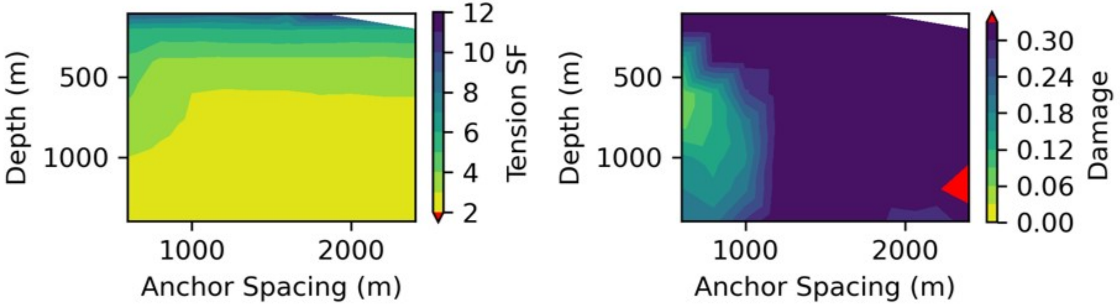
Least-cost spacing

Catenary Results

Initial Designs

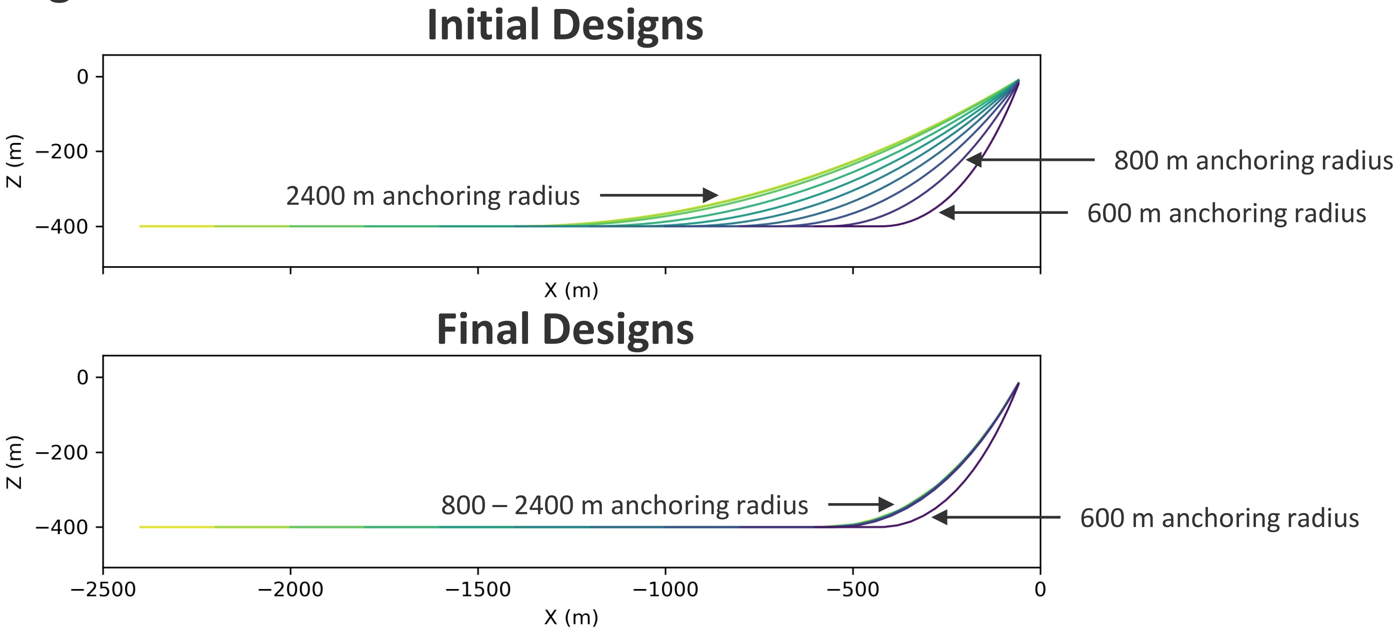


Final Designs



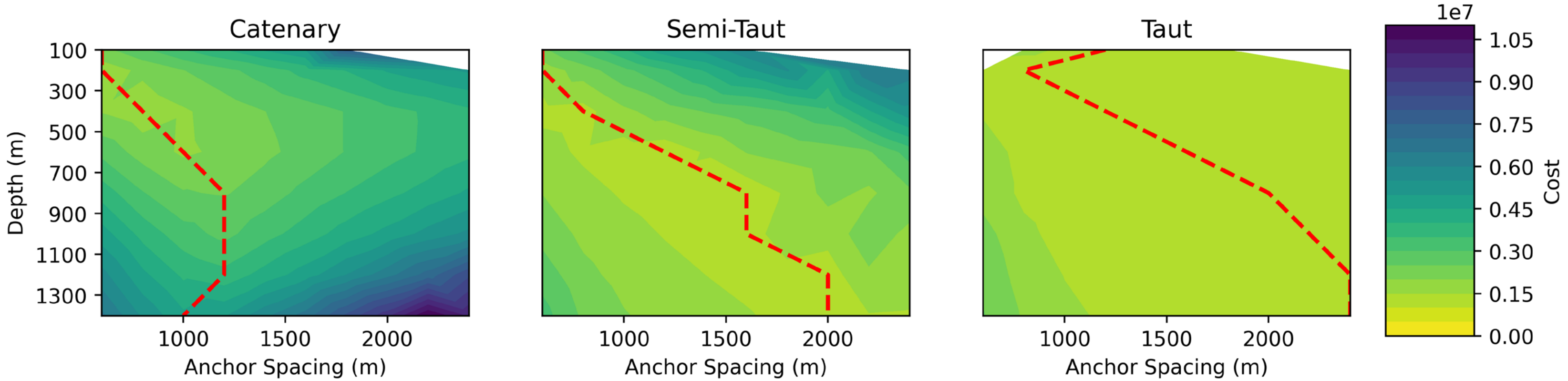
Catenary Results

Dynamic performance iterations significantly change the profile of the mooring designs



Conclusions

- Able to map patterns in optimal mooring systems and make comparisons
- Full design and performance for range of mooring systems
  - Mooring line lengths and diameters, anchor sizes, cost breakdown
  - System performance: mean and extreme offsets, tensions, line motions



Q&A

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This work was authored [in part] by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by [applicable Department of Energy office and program office, e.g., U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office (spell out full office names; do not use initialisms/acronyms)]. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

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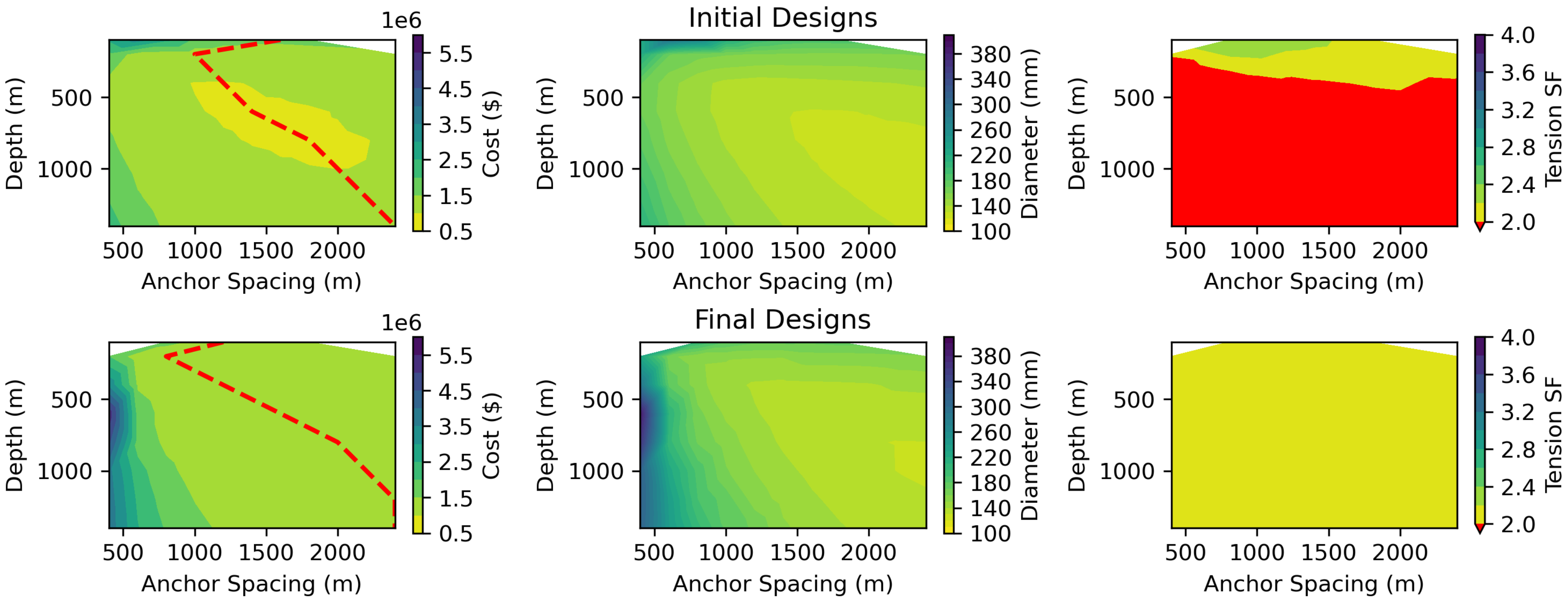
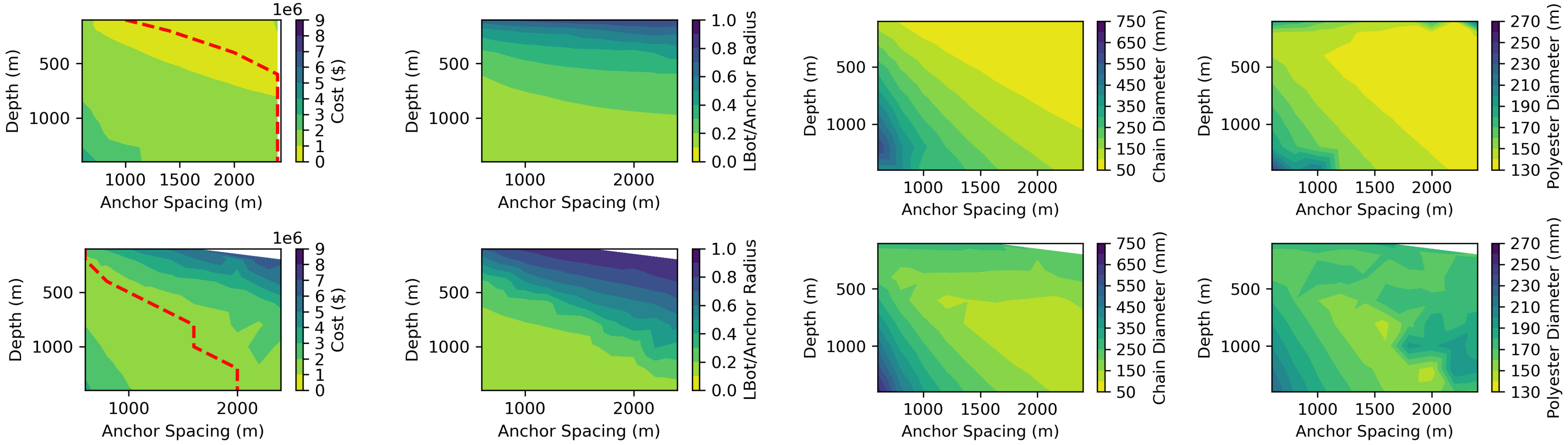
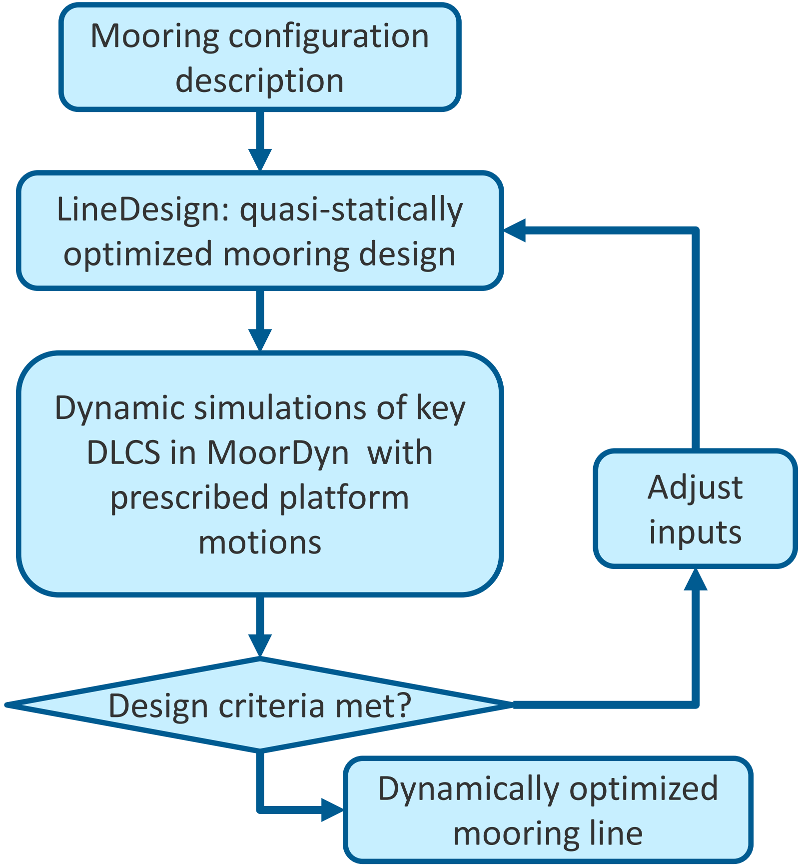
Taut Results



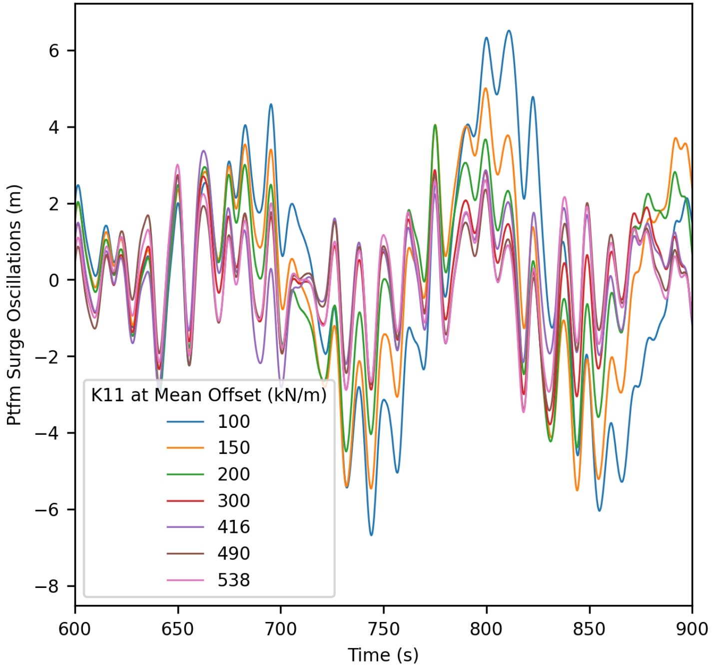
Semi-taut Results



Design and Analysis Procedure



Platform Motions Library



Allowable Platform Offset