QUANTIFYING THE EFFECT OF ROCK ARMOUR SCOUR PROTECTION ON EIGENFREQUENCIES OF A MONOPILE SUPPORTED OHVS

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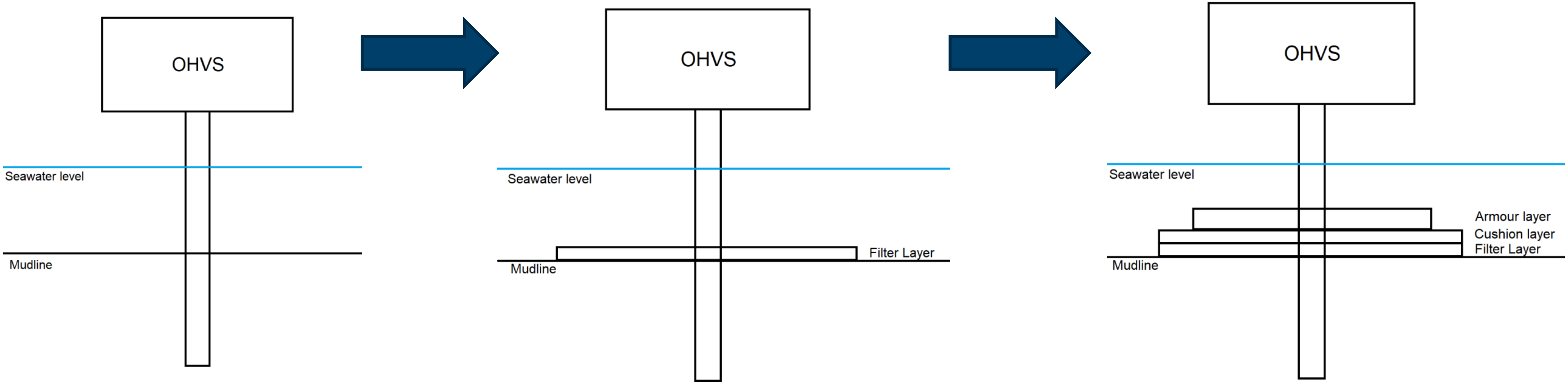
INTRODUCTION

- Scour protection increases stiffness of its structure which leads to increase in natural eigenfrequency

$f_{n,0} < f_{n,FL} < f_{n,AL}$



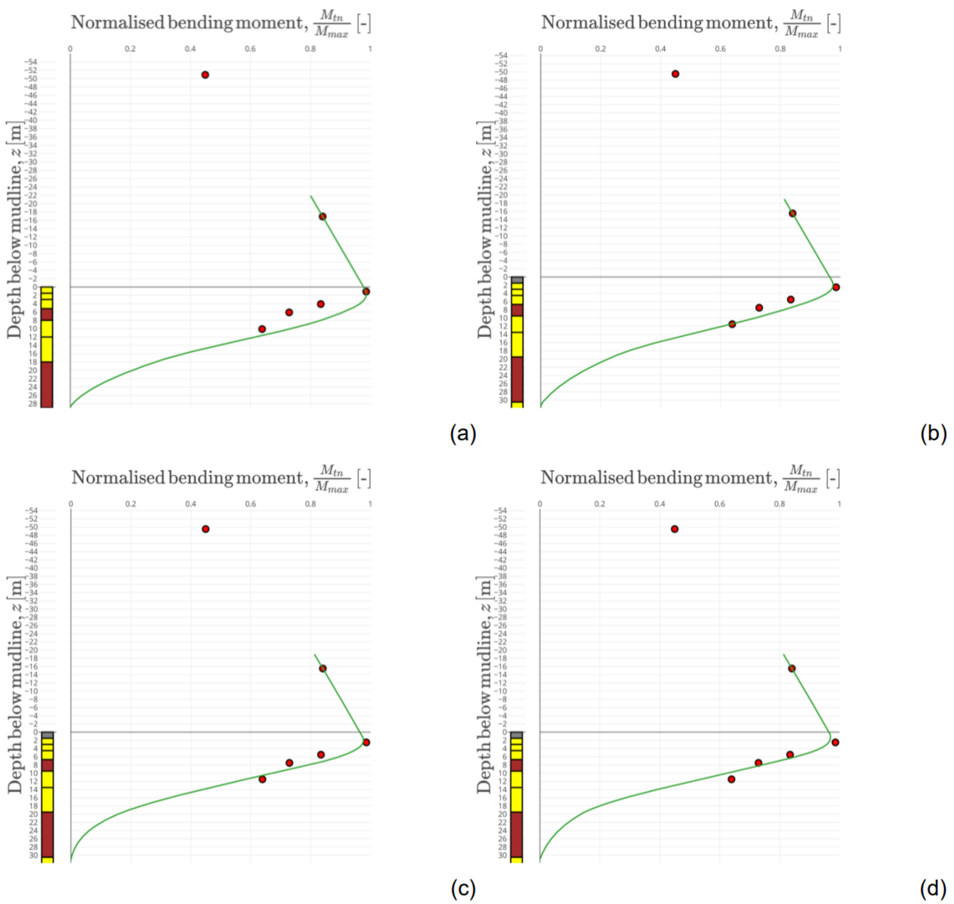
TRUE ?

HOW ?

WHY ?

INTRODUCTION

- Discrepancy between design and the build OWT-structures
  - Natural eigenfrequencies
  - Bending moments
  - Fatigue
- Affects overall cost and lifetime calculations
- Scour Protection needed to explain discrepancy
- Other sources confirm (e.g. Kallehave paper 2015)



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MEASUREMENTS

- Mobile DV box
  - Accelerometer
  - Every 10 minutes
- Natural frequencies
  - Fore-aft (FA) 1^{st} and 2^{nd} mode
  - Side-side (SS) 1^{st} and 2^{nd} mode
  - 1 torsional (OHVS only)
- Variability in Tidal level
  - Tidal level correction (0.5mLAT)

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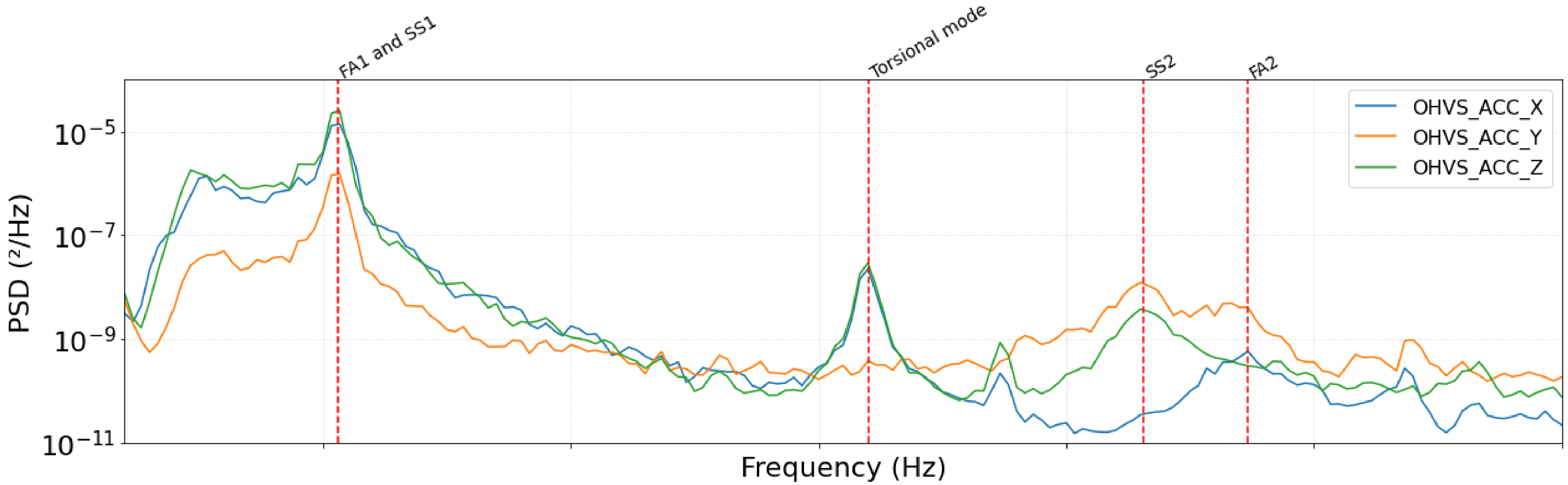
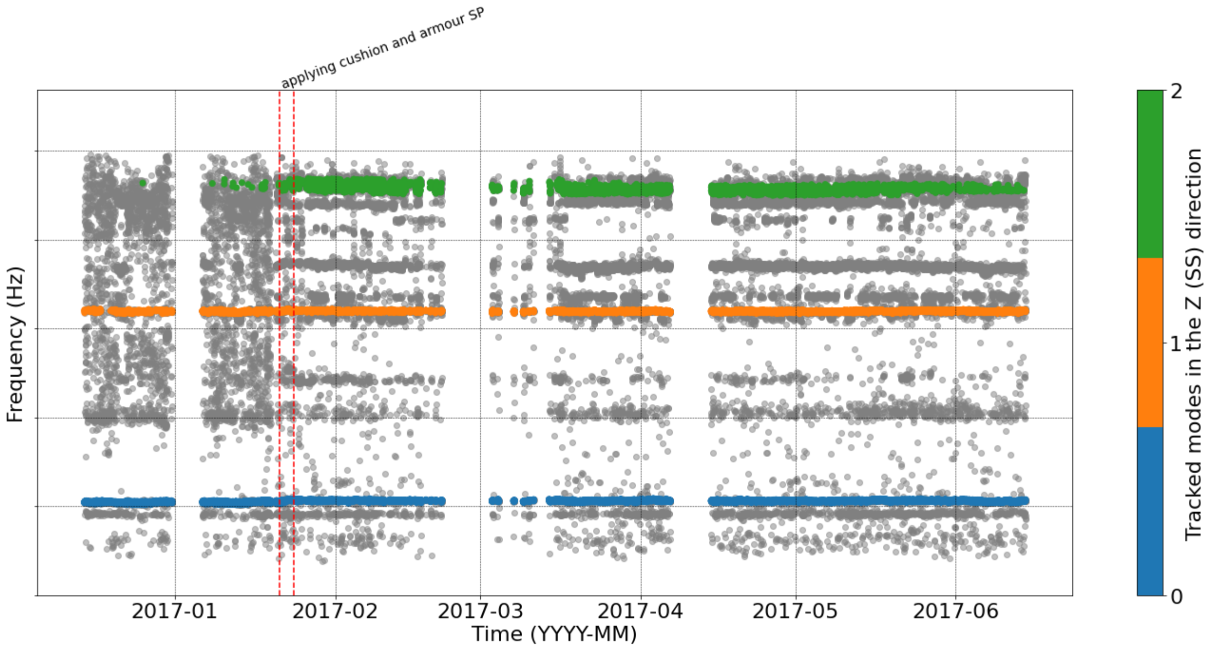
MEASUREMENTS

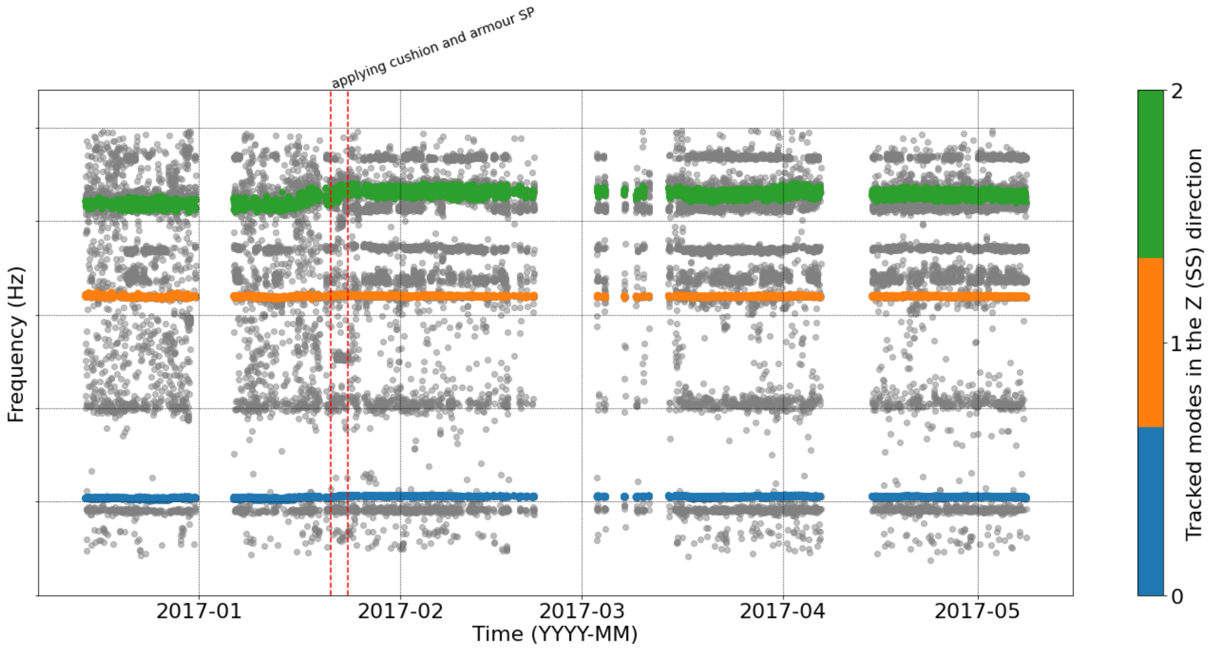
- 10 minutes of data represented with the power spectral density (PSD) method.
- Peaks correlate with:
  - 1st eigenfrequency
  - Torsional mode
  - 2nd eigenfrequency



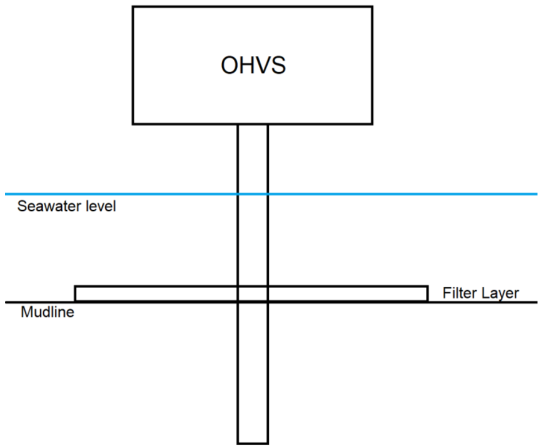
MEASUREMENTS

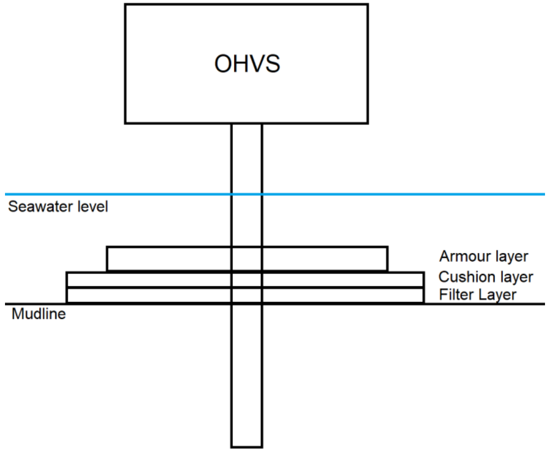
- Operational modal analysis (OMA) calculated with the least square complex frequency (LSCF) method
- Modes are tracked in an unsupervised manner
- Pre-installation 2nd FA frequencies could not be tracked

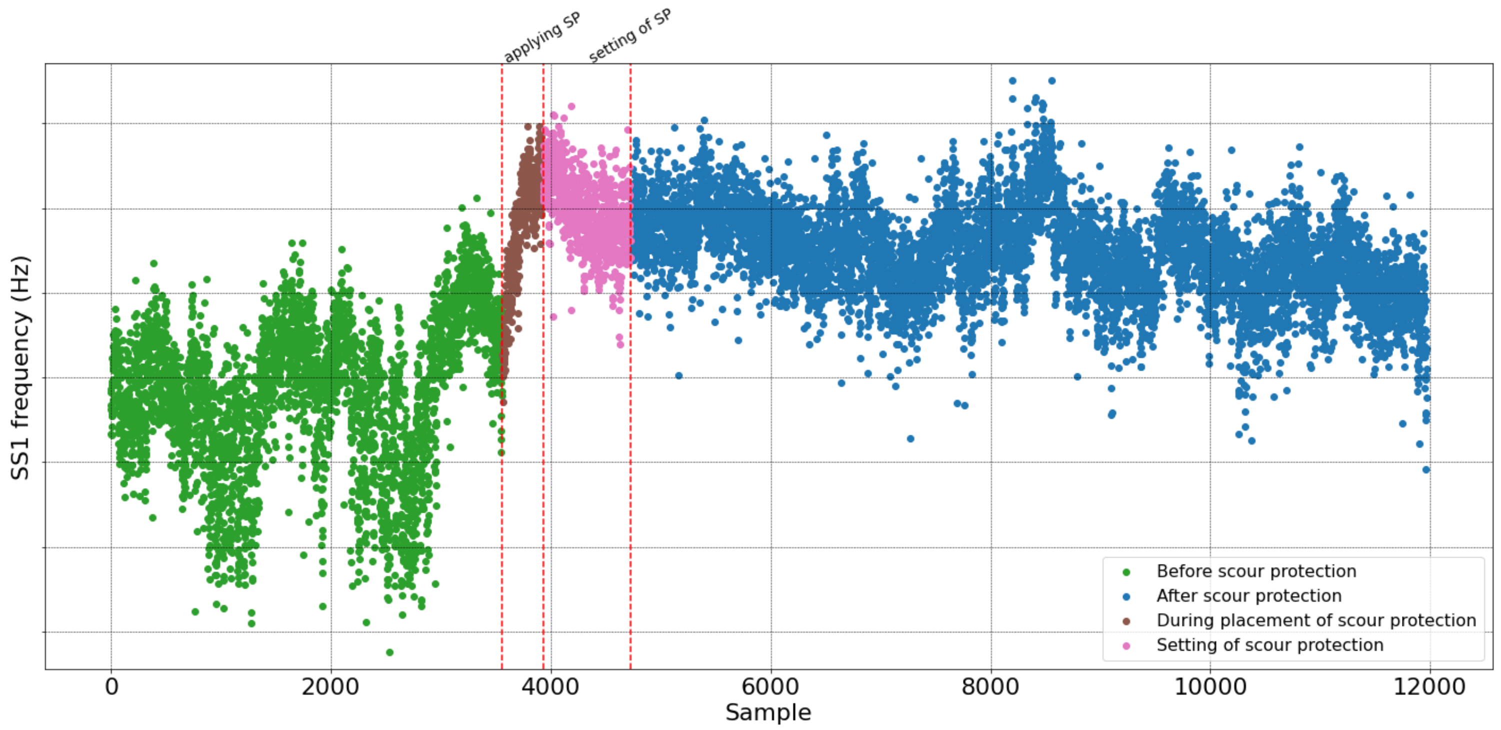




MEASUREMENTS



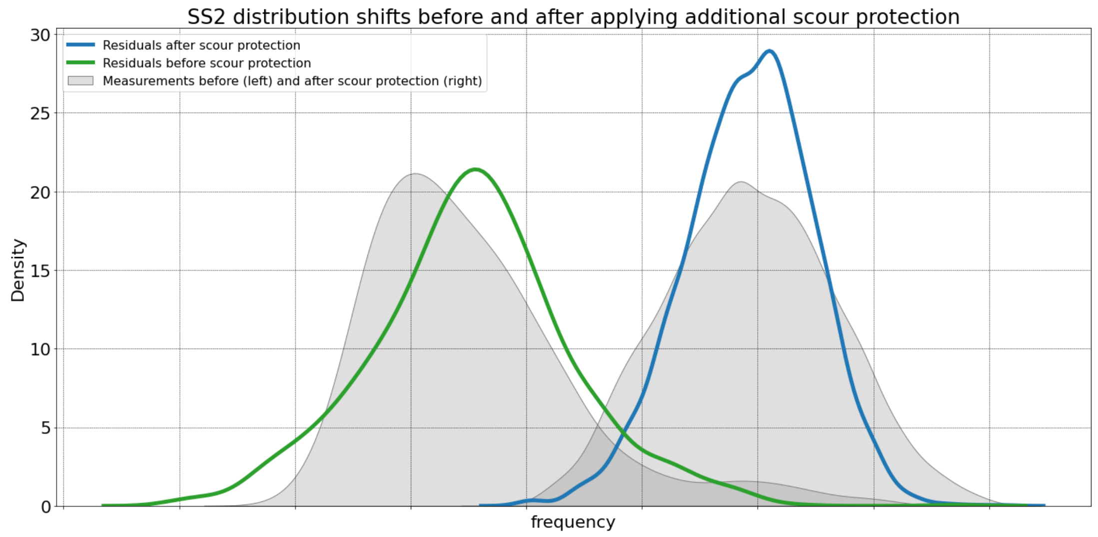


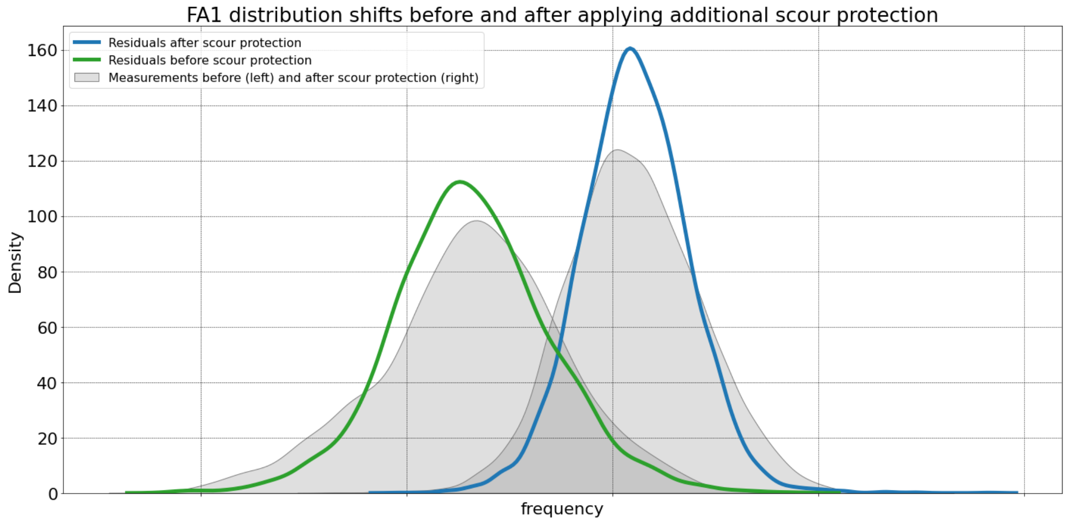


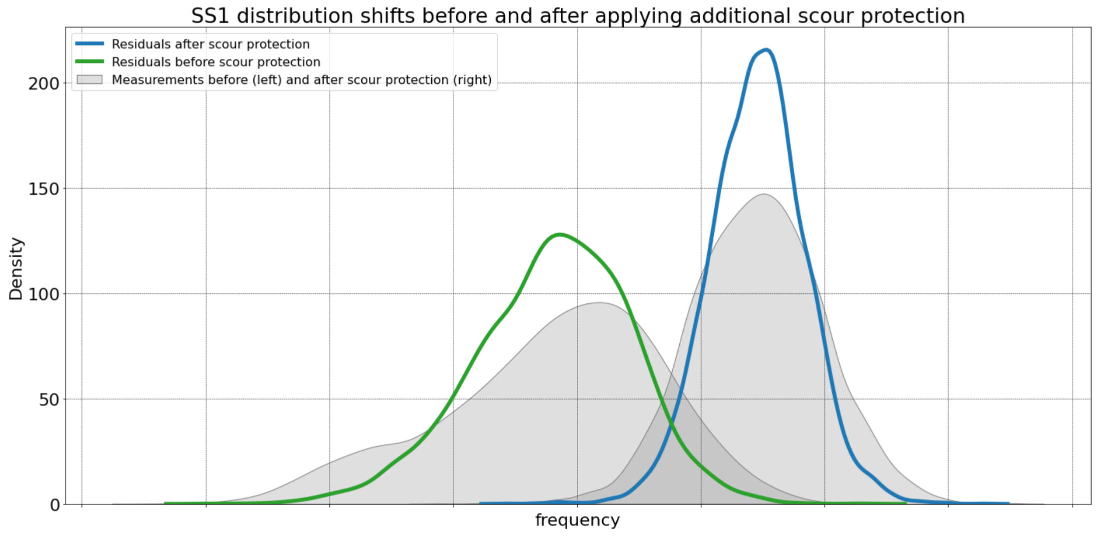
- Shift from filter layer (green) to full armour SP (blue)
- Just after installation of armour, an increase of eigenfrequencies (1-3days)
- Long term (3 months), still an increase from initial, but lower
- Variation on measurements is due to environmental conditions

MEASUREMENTS

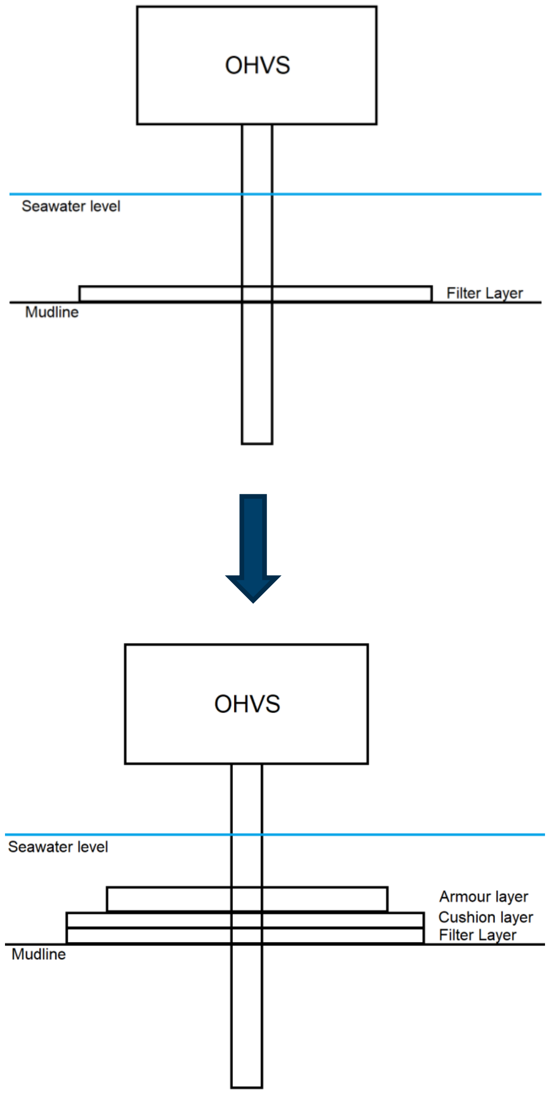
- Distribution of measurements
- Distribution after normalization for:
  - Temperature
  - Seawaterlevel
  - Waveheight
- Shift in mean value

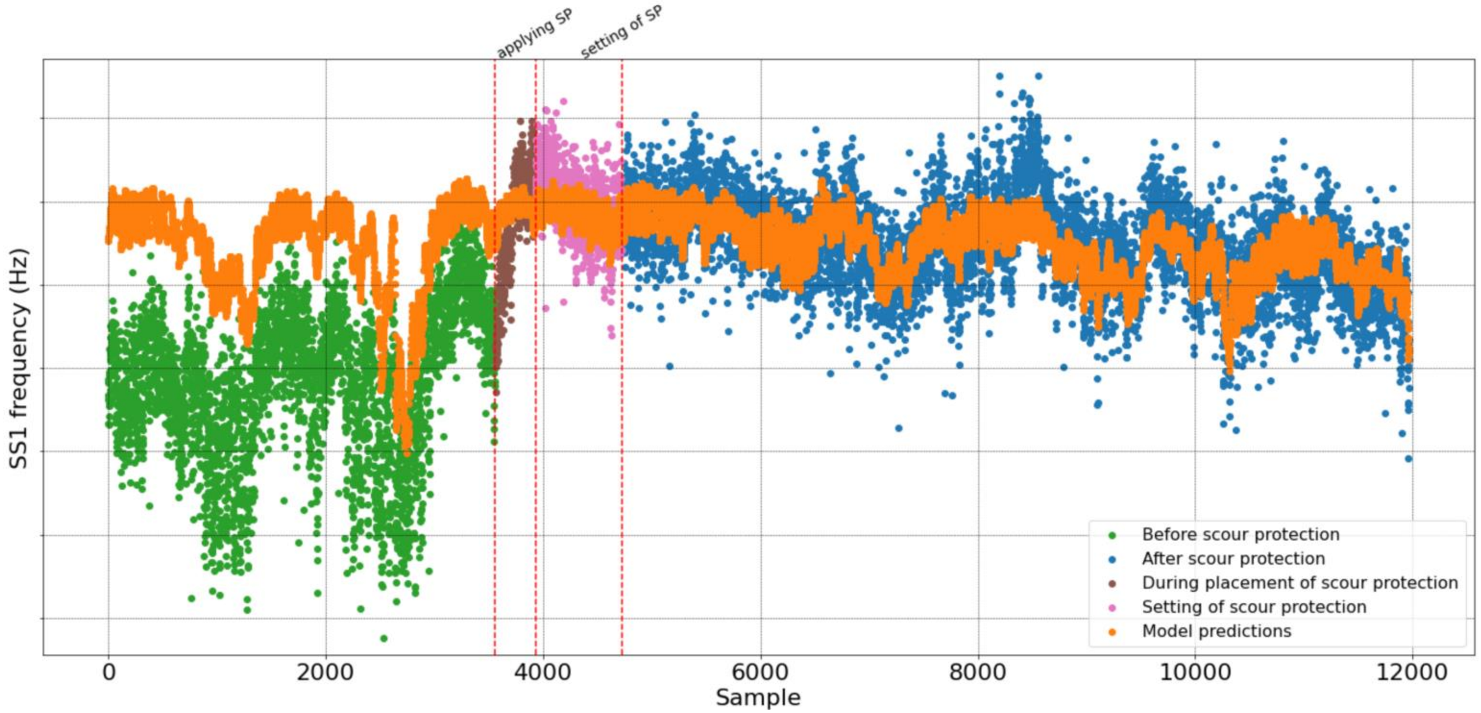






MEASUREMENTS

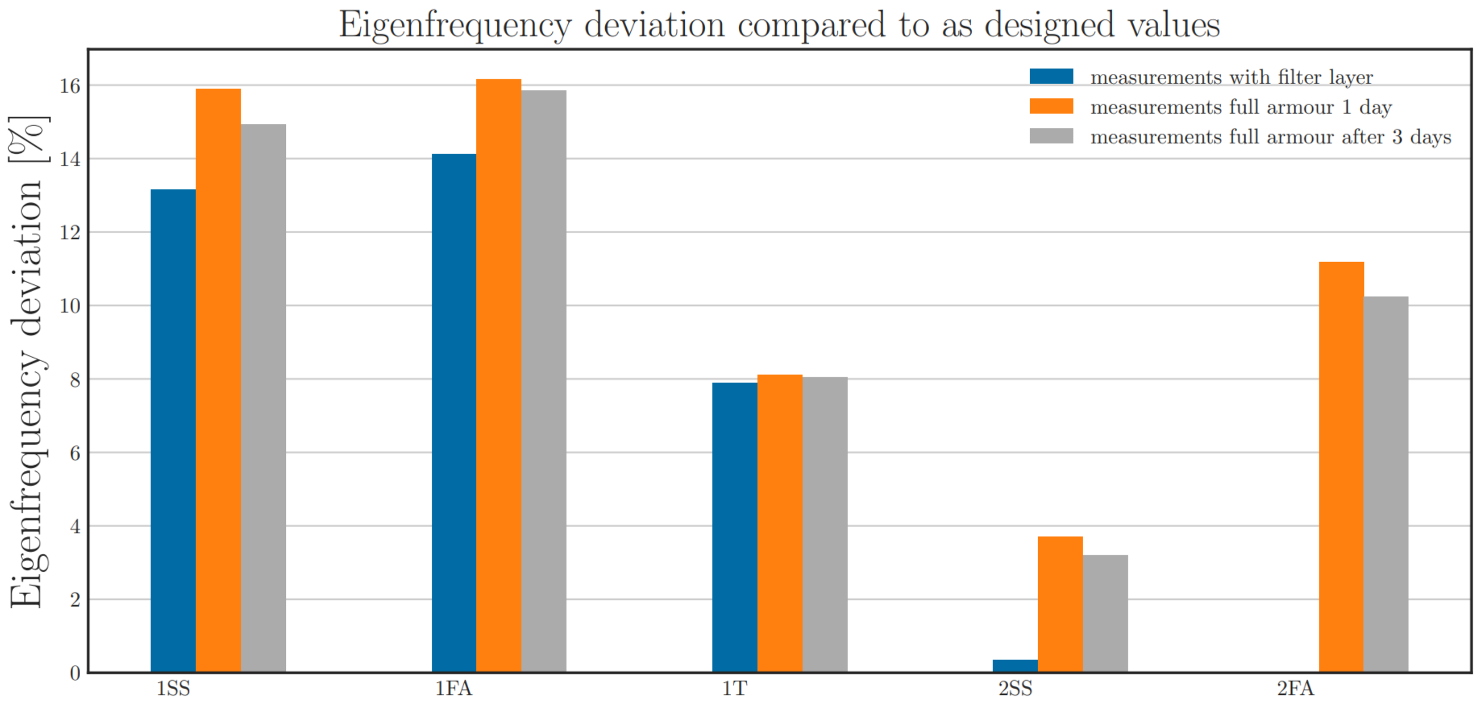




- Linear regression model to predict eigenfrequencies trained with blue data (long term, after full SP installation)
- based on parameters:
  - Sea water temperature
  - Wave height
  - Tidal level
- It predicts the shape of the preinstallation frequencies, but with offset

MEASUREMENTS

- Measurements compared to the design values
- Design underestimates the actual frequencies by upwards of 16%

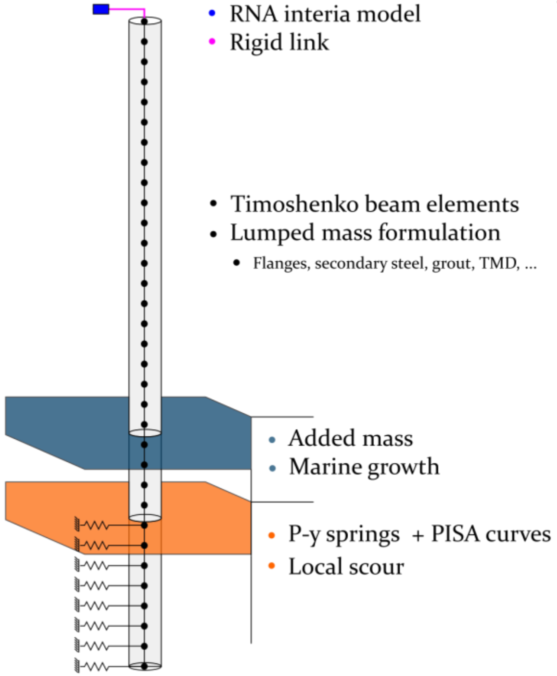


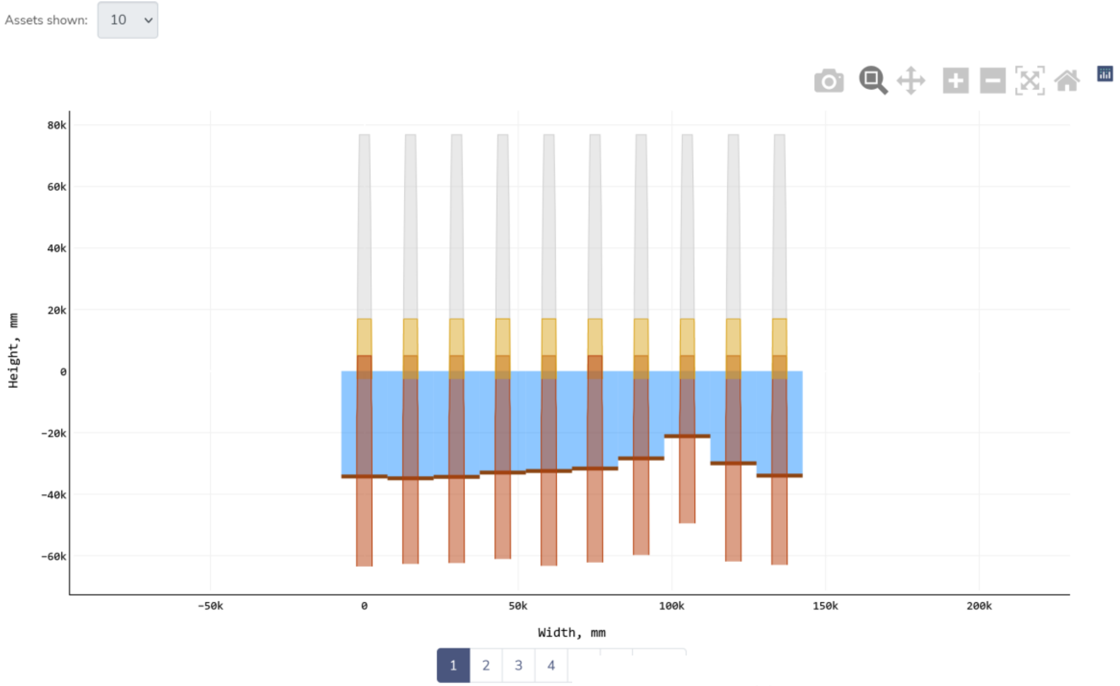
FIRST CONCLUSIONS

1. Natural Eigenfrequencies of monopile supported structures increase due to scour protection installation.
2. Measured eigenfrequencies are higher than the Design values.

MODEL

- <u>Integrated 1D FE model for OWT's</u>
  - Assumptions & detailed info designer
  - Individual, Farm wide or multiple farms
  - owi_meta_data_base
- Verification
  - Frequencies from designer
- Improved geotechnics
  - Stiffer soil
  - PISA method
- OHVS specific:
  - Top mass on transition piece
  - Specific added masses





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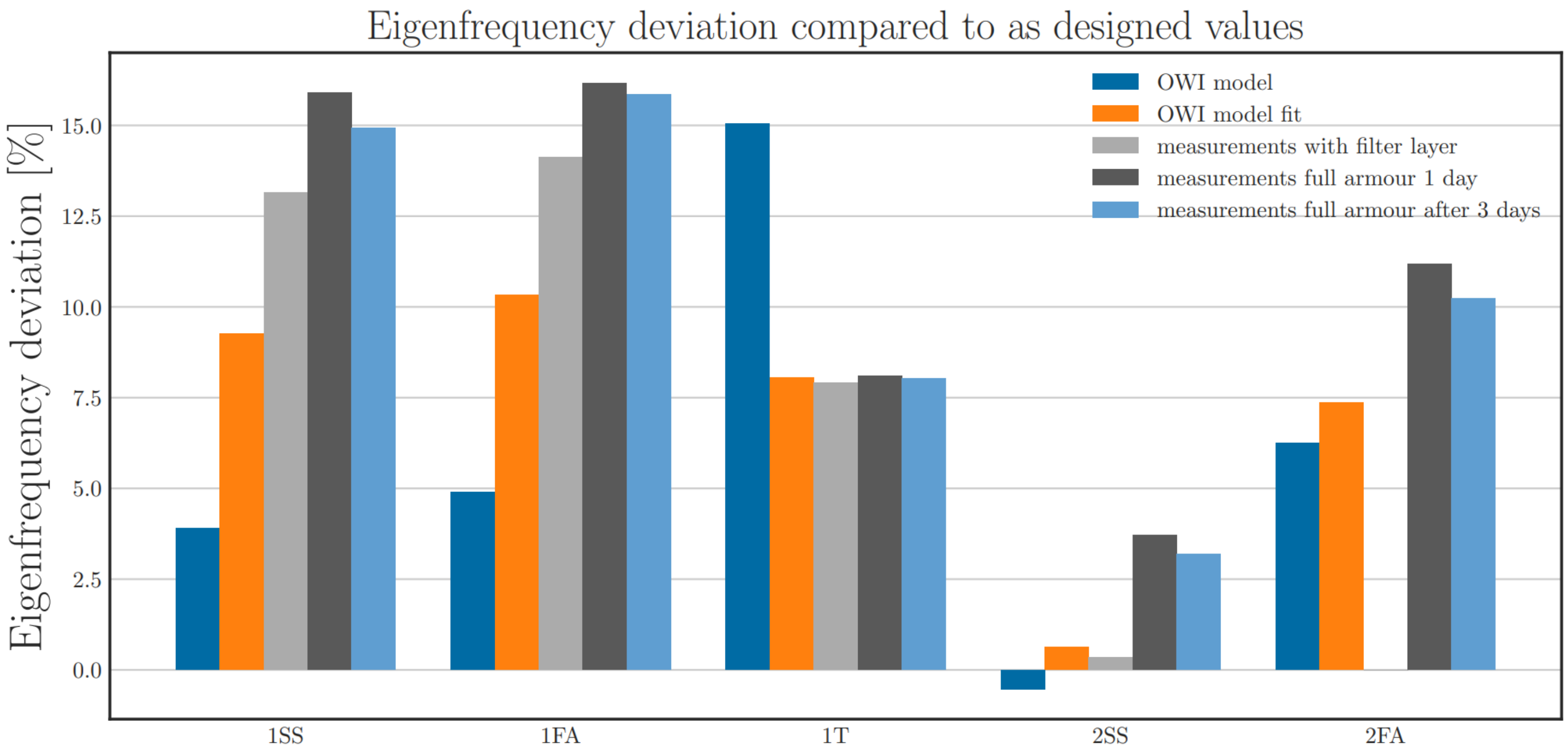
MODEL

- integrated 1D FE model compared to design and measured eigenfrequencies
  - Better than design
  - Can't bridge the gap completely



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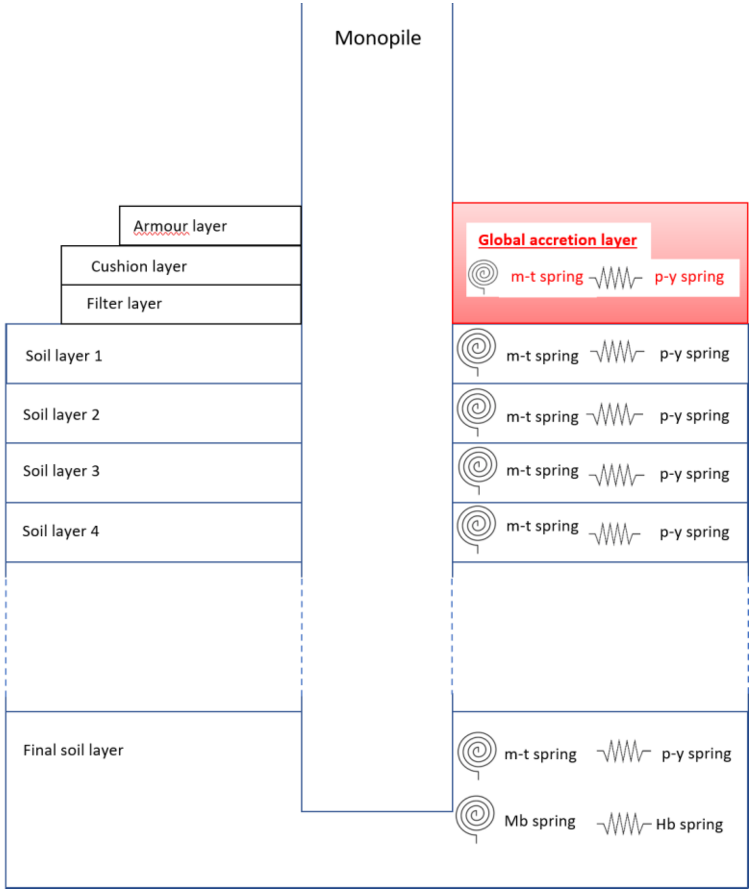
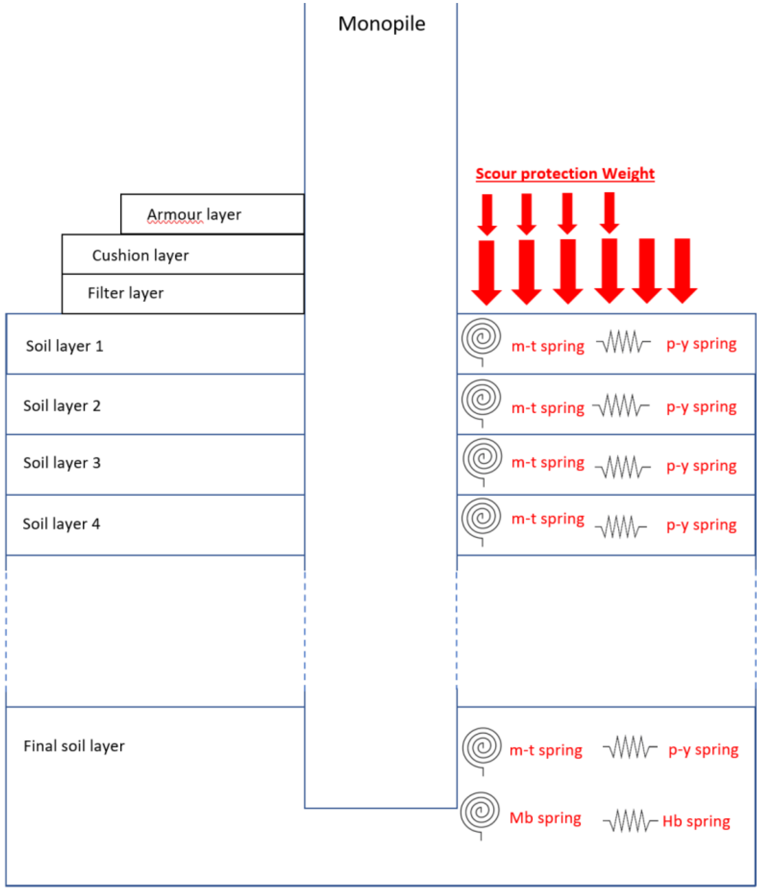
THIRD CONCLUSION

1. Natural Eigenfrequencies of monopile supported structures increase due to scour protection installation.
2. Measured eigenfrequencies are a lot higher than the Design values.
3. Models without Scour protection can't explain the measurements.

MODEL

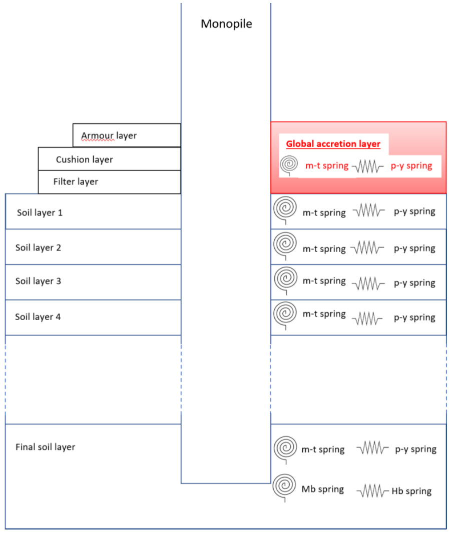
- Introducing 2 possible methods to model scour protection
  - Global accretion layer => extra soil layer with its own stiffness
  - Physics based model => overburden pressure that increases stiffness of the soil layers (G_{max})

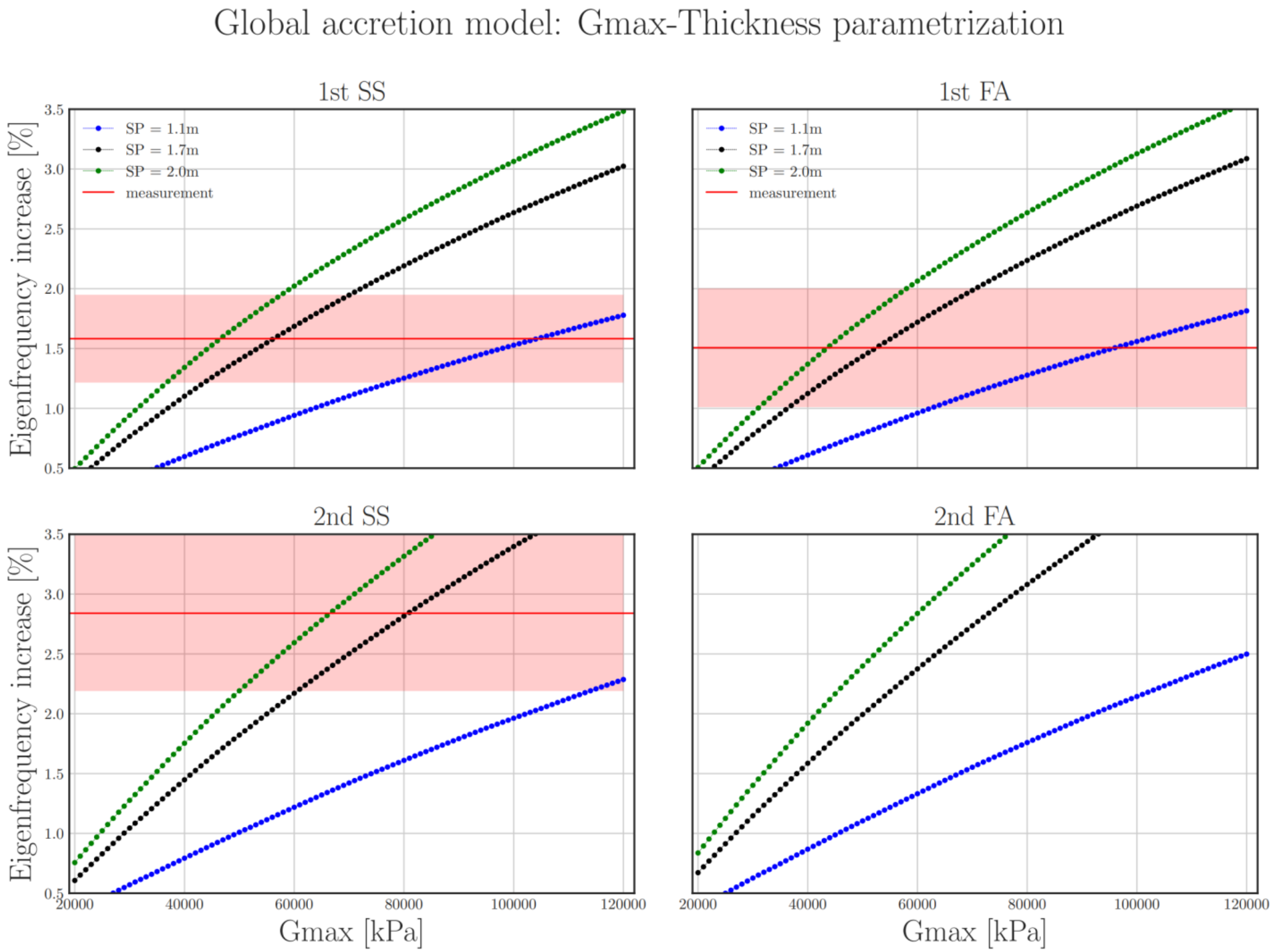




MODEL: GLOBAL ACCRETION MODEL

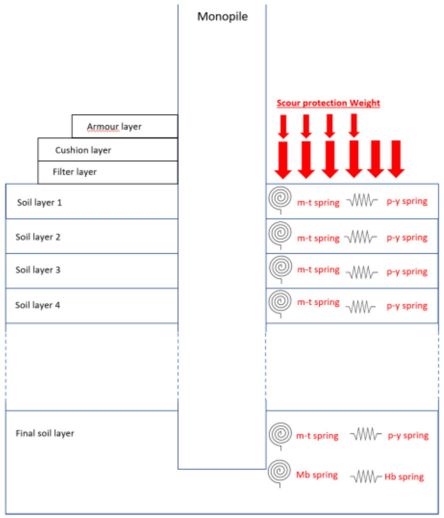
- Can bridge the gap
- No reference values for stiffness of a rock/pebble layer
- Cannot fit 1SS and 2SS at the same time

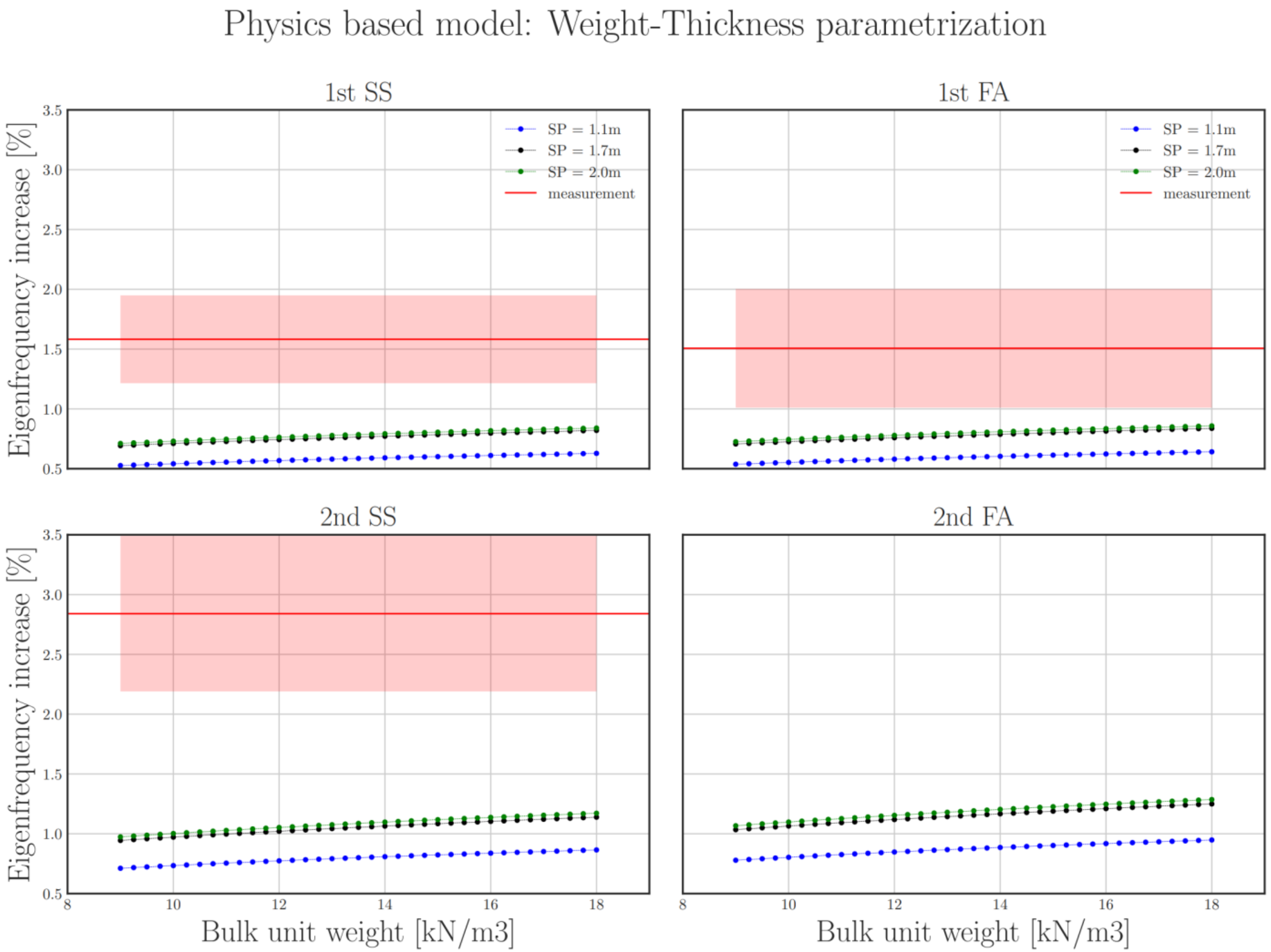




MODEL: PHYSICS BASED MODEL

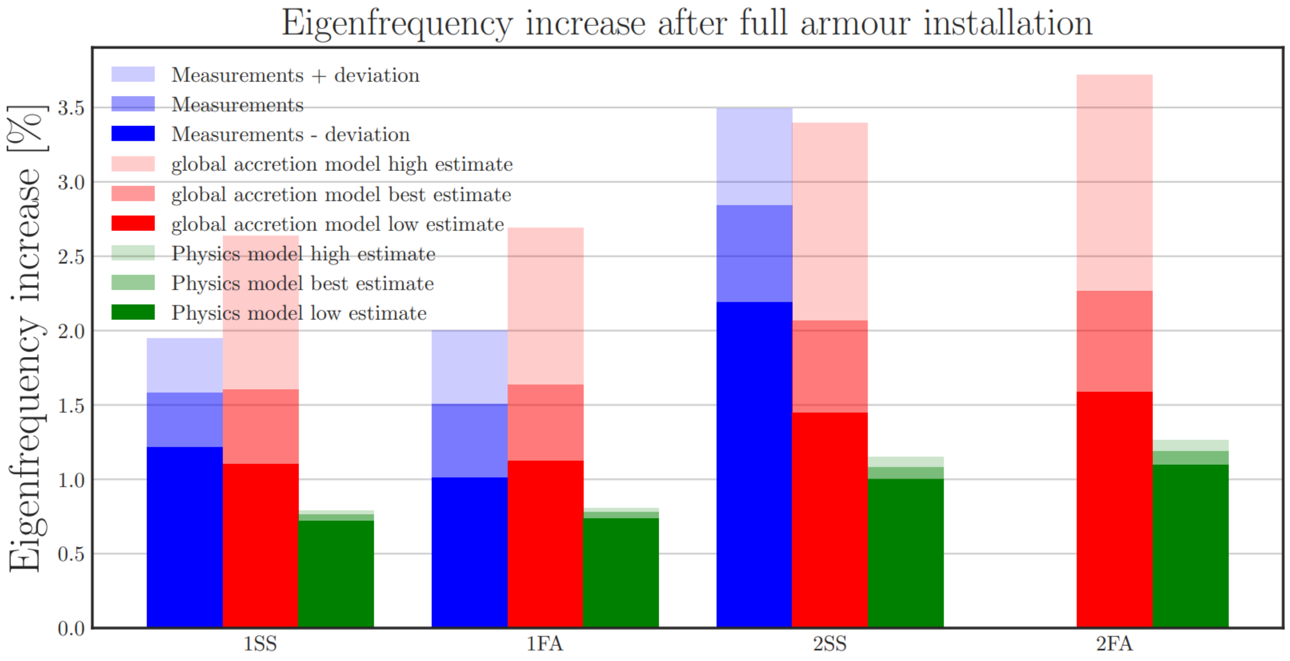
- Cannot bridge the gap
- There are references for weight and geometry of scour protection (e.g. design)
- Cannot explain the full effect, but has merit is a part of it
- Diminishing returns for increased thickness and weight => Filter layer will have the biggest effect





FINAL CONCLUSIONS

1. Natural Eigenfrequencies of monopile supported structures increase due to scour protection installation.
2. Measured eigenfrequencies are a lot higher than the Design values.
3. Models without Scour protection can't explain the measurements.
4. Global accretion layer model: can bridge the gap but no way to validate due lack reference values pebble/rock layer.
5. Physics based model: cannot bridge the gap but is credible due to easily understandable phenomenon.



FUTURE RESEARCH

- Verify results at different locations
- Improve models for scour protection (combination or something new)

QUESTIONS?

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