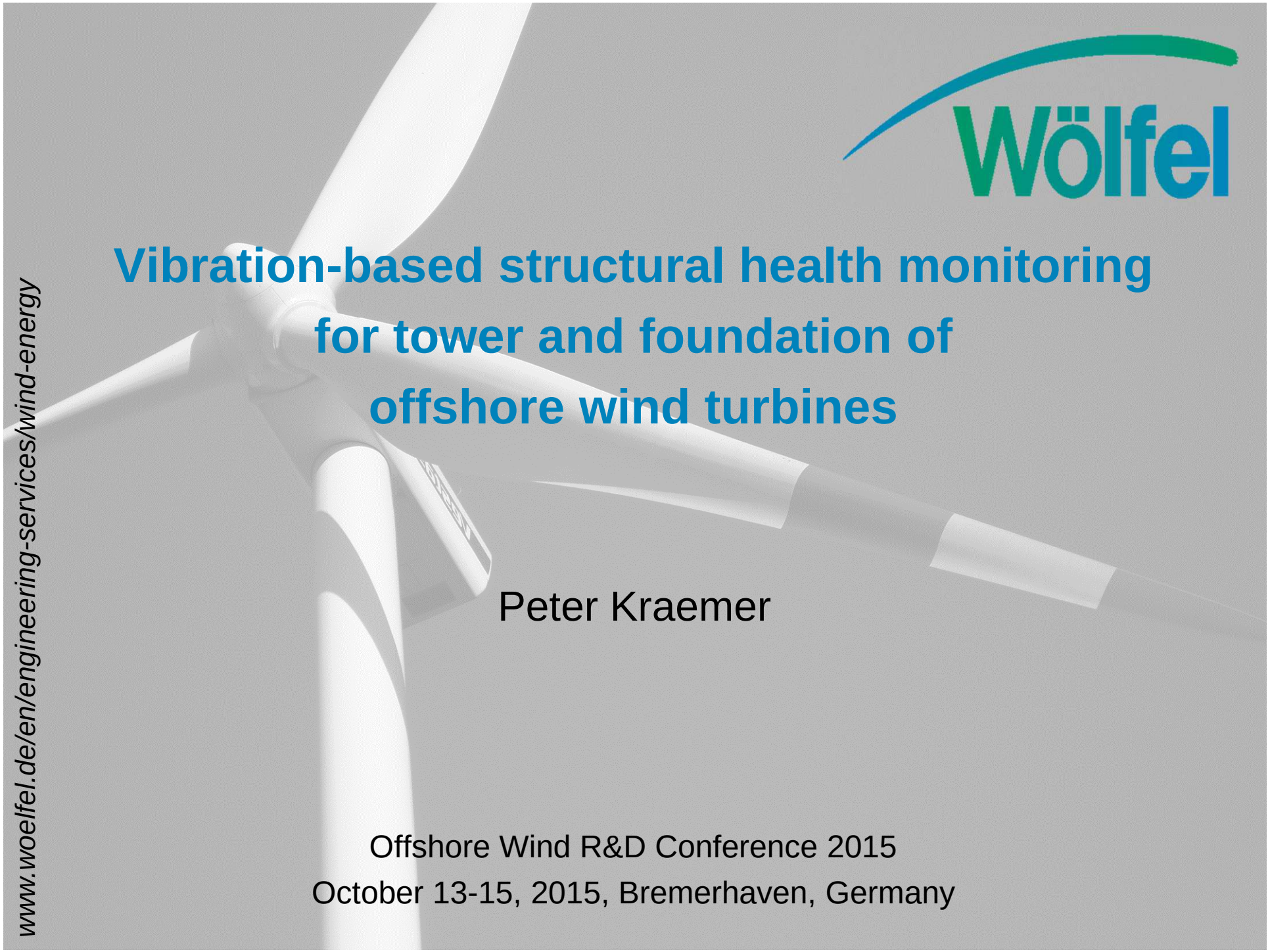
Wölfel

www.woelfel.de/en/engineering-services/wind-energy

Wind Energy



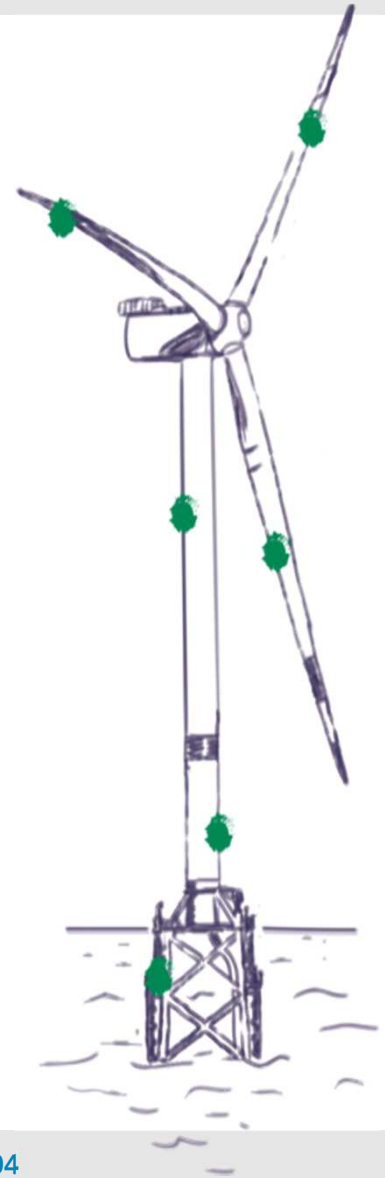
Vibration-based structural health monitoring for tower and foundation of offshore wind turbines

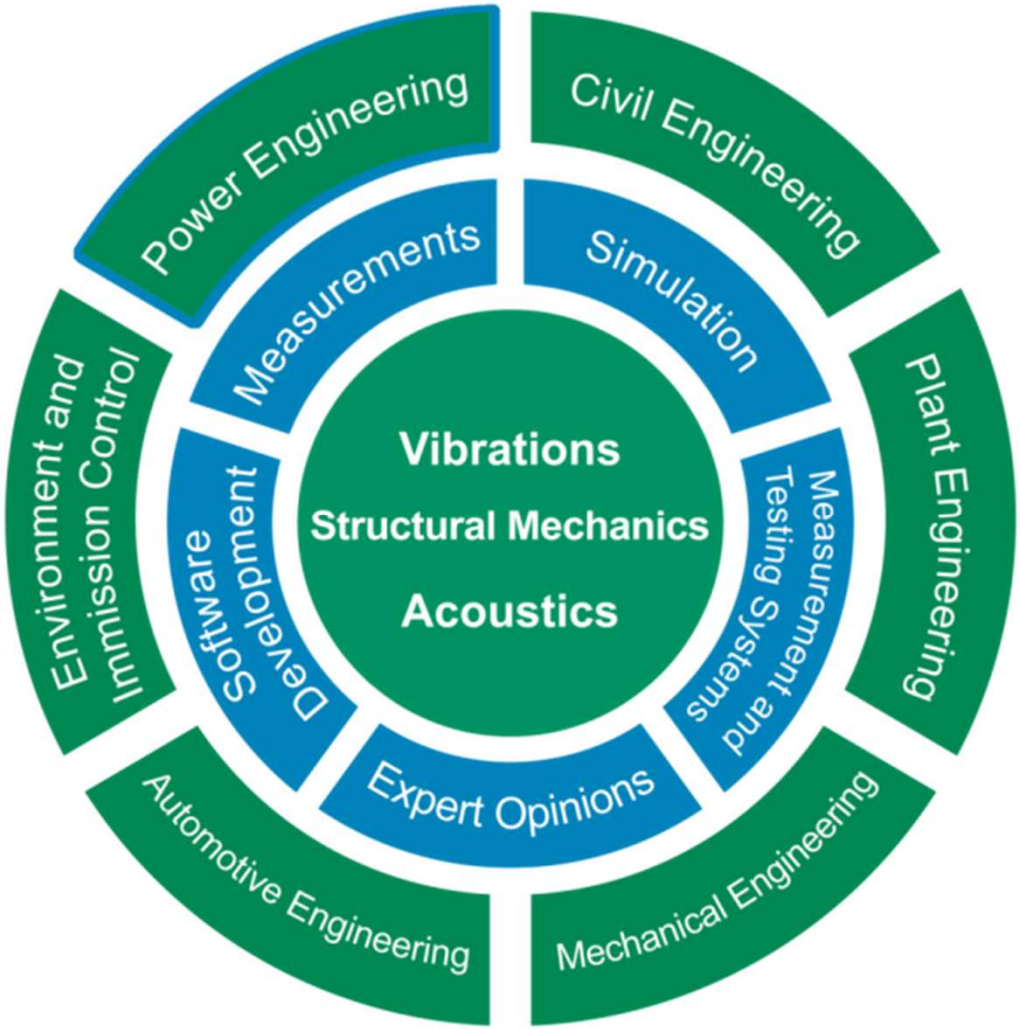
Peter Kraemer

Offshore Wind R&D Conference 2015
October 13-15, 2015, Bremerhaven, Germany

Vibrations experts

Vibration experts





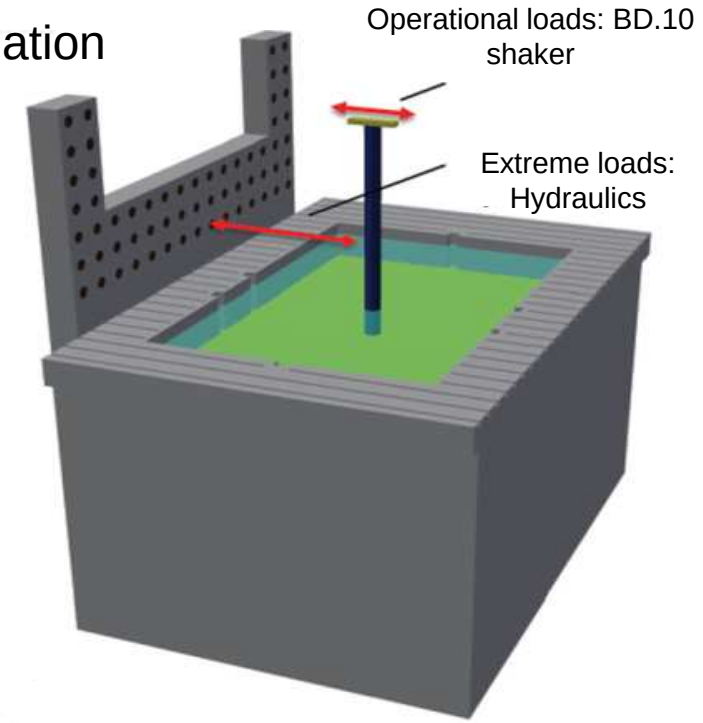
Projects / Systems – a selection: Foundation / Tower monitoring

- RWE Innogy – Nordsee Ost:
  - Measurement systems
  - Data analysis (online / offline) and decision making
  - Reports
- Iberdrola
  - Measurement systems
  - Data analysis (online / offline) and decision making
  - Reports
- WindMW
  - Data analysis
- EnBW
  - Measurement systems for Baltic 2
  - Data analysis for plant certification (Modal analysis: eigenfrequencies and modal damping)
- Nordex / Onshore:
  - Development of analysis software for calculation of tower bending moments and remaining lifetime by means of measured acceleration data

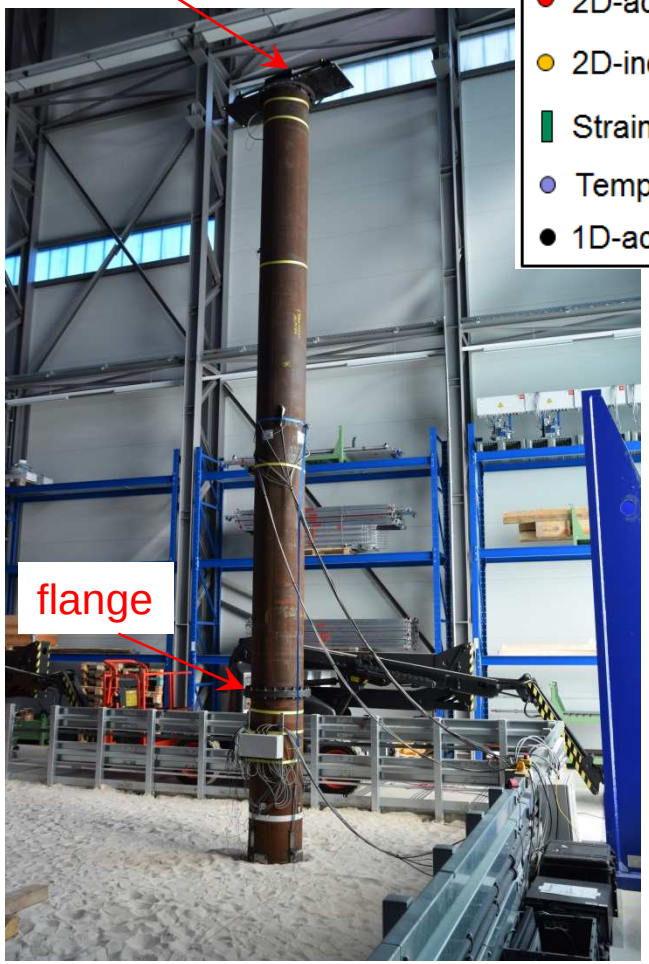
Purpose of the presentation

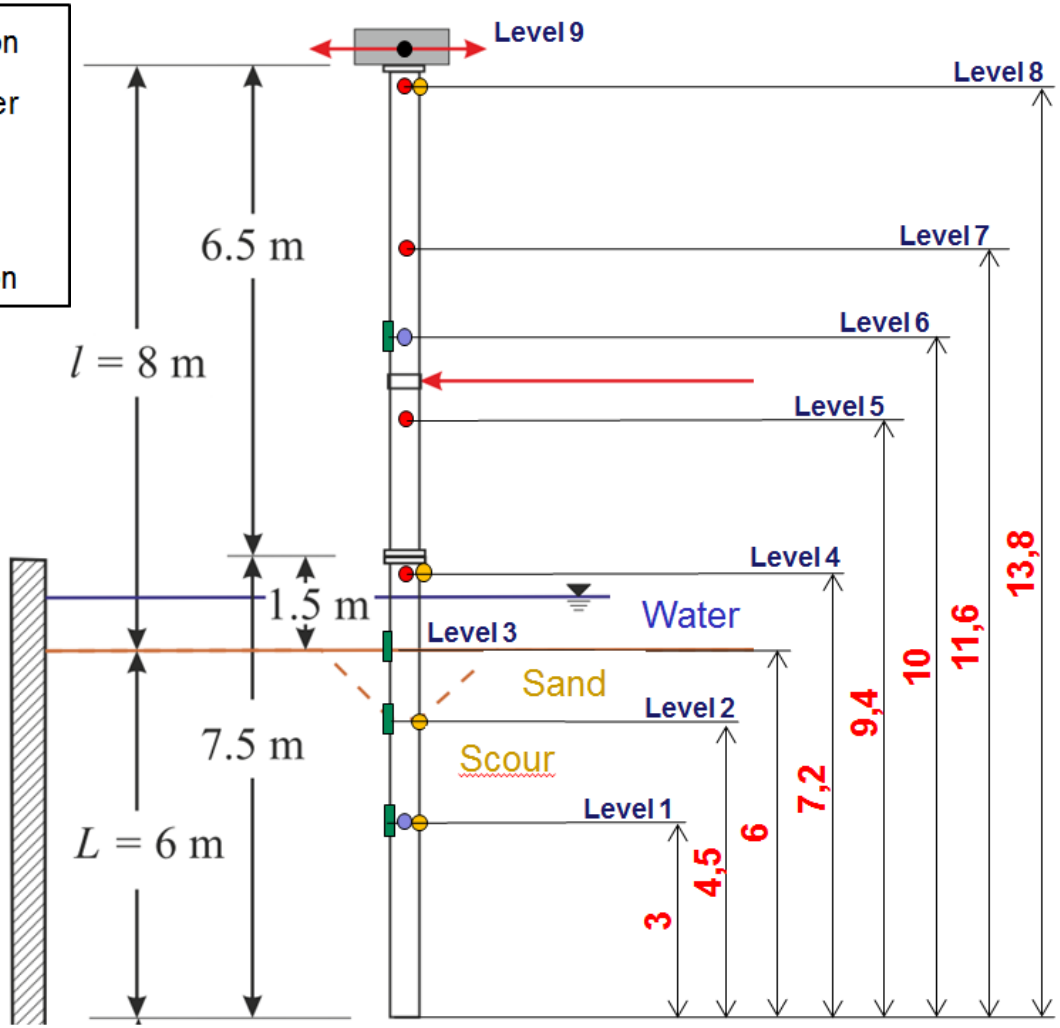
Preliminary results of the project UnderwaterINSPECT

- Test facilities: test hall and sand basin of TTH - Leibniz Universität Hanover (together with Fraunhofer IWES)
- Test rig: model of a plant with monopile foundation
- Sensors and hardware
- Purposes of the tests
- Preliminary results of data analysis
- Technical findings
- Further investigations



Experiments (test rig at TTH)





Scope of measurements & data analysis tools

Measurement of following structural states:

- References (no changes of the structure)
- Soil degradation
- Loosened screws at the flange
- Additional masses
- Scouring
- Inclined structure

Scopes:

→ Learning of unchanged state
→ Detection of soil degradation
→ Detection of loosened screws
→ Detection of fouling
→ Detection of scouring
→ Detection of inclination

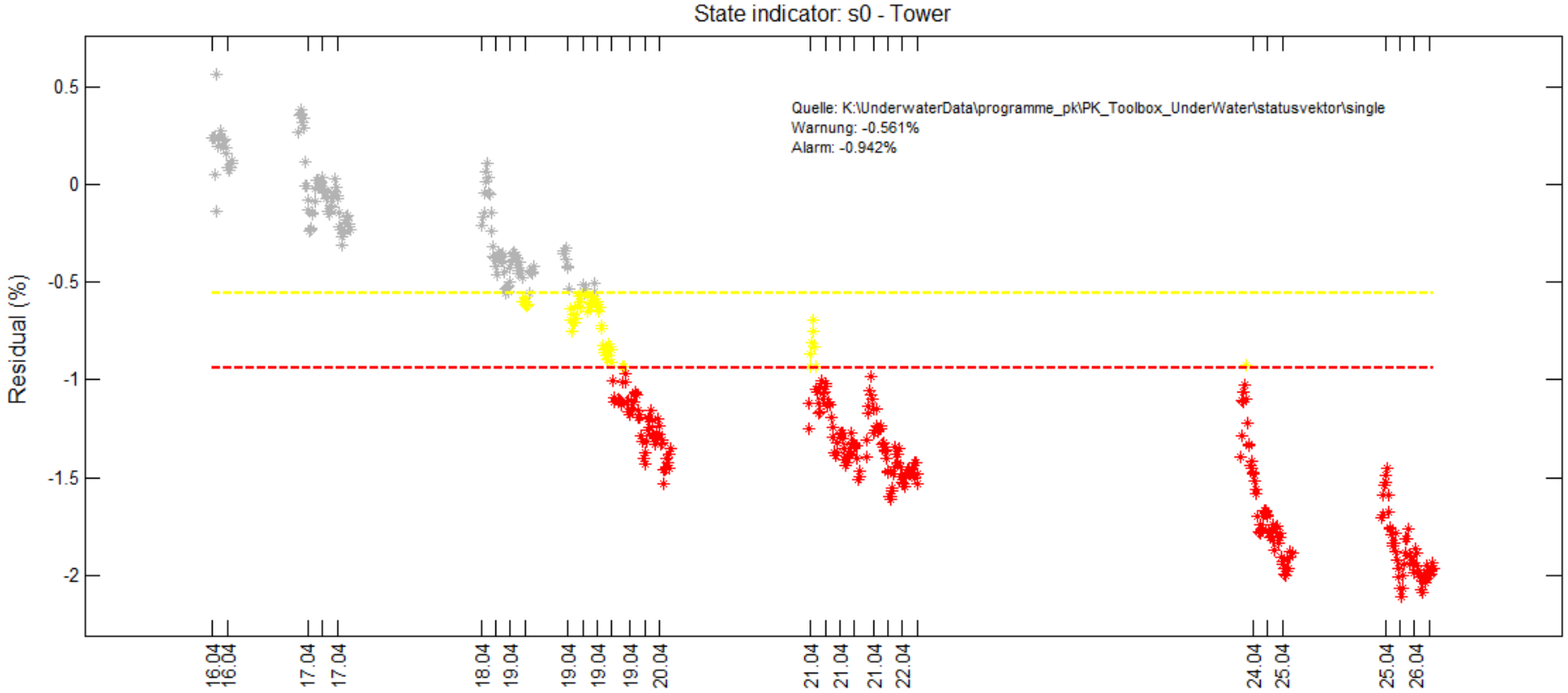
Excitation: Stochastic loads (assumed as unknown) by means of BD.10 shaker

Data analysis tools (only preliminary data-driven algorithms):

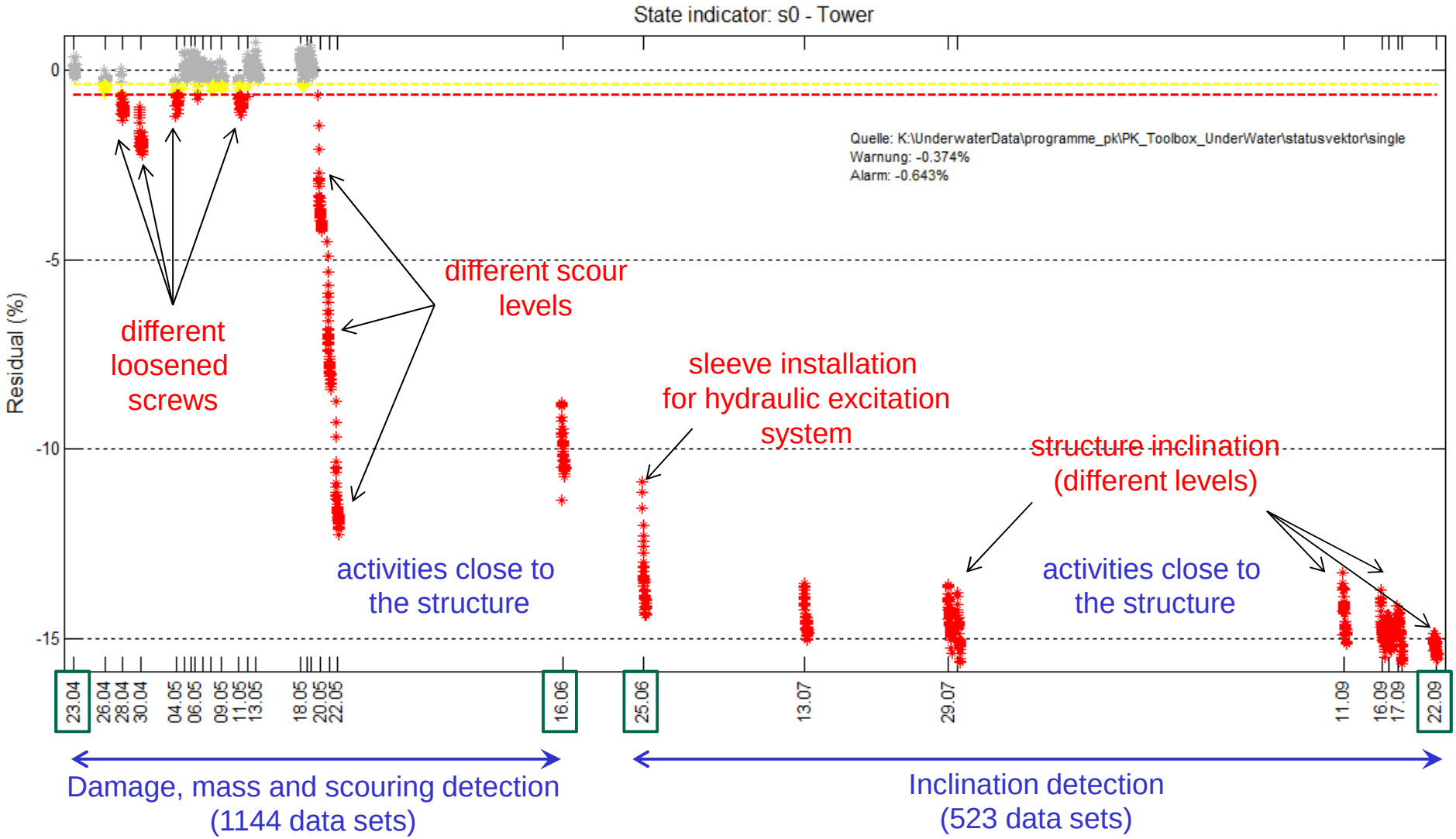
- Operational Modal Analysis (OMA)
- Stochastic Subspace Fault Detection (SSFD)
- Time series models (ARMA family)
- Statistical properties of the data
- Pattern recognition algorithms

Soil degradation

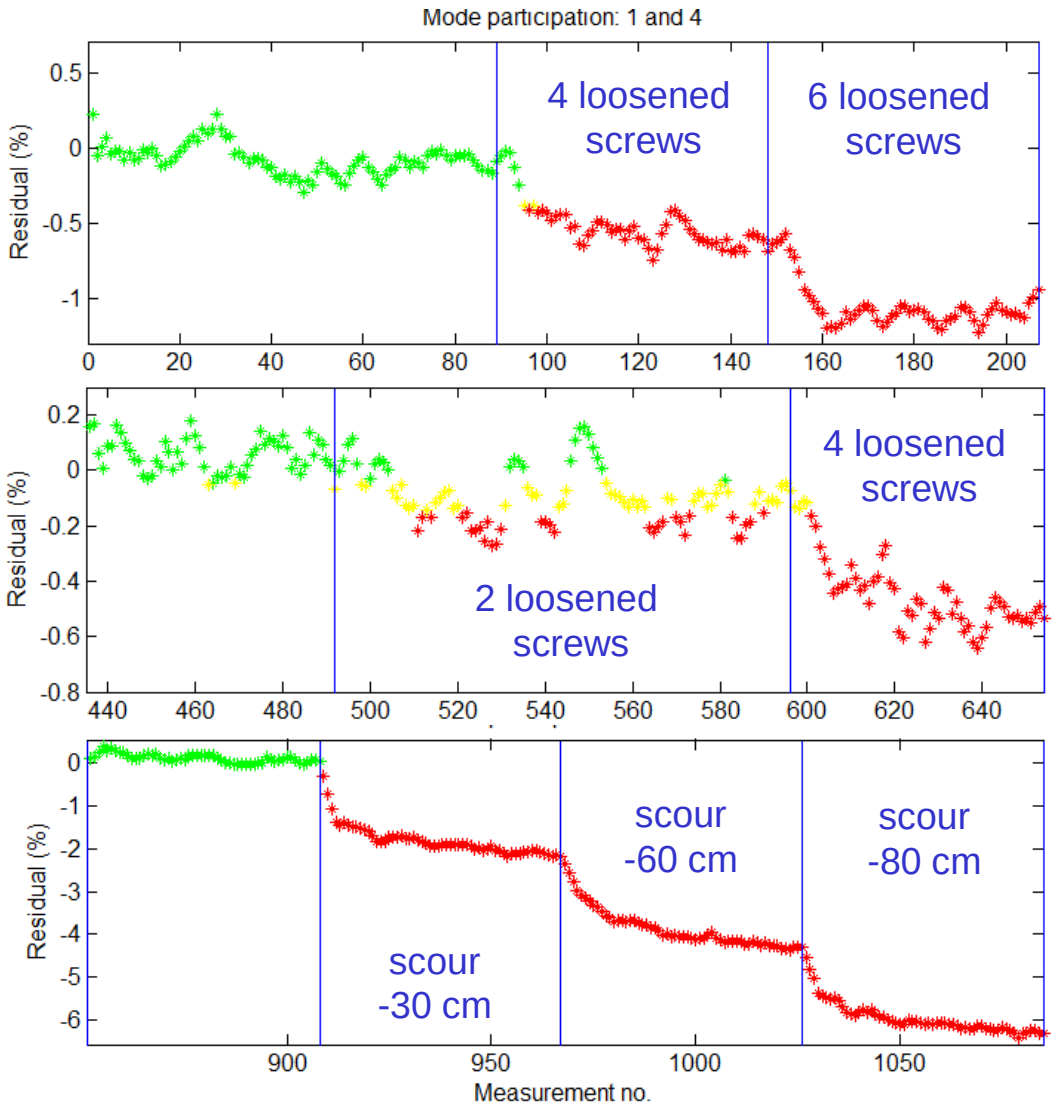
- Change of the state indicator (here based only on the changes of 1st eigenfrequency)
- Probable cause of change: soil degradation
- Excitation: Random within frequency range of 2-50 Hz; RMS of excitation: 350 N
- Measurement time / data set: 10 min; sample rate: 500 Hz

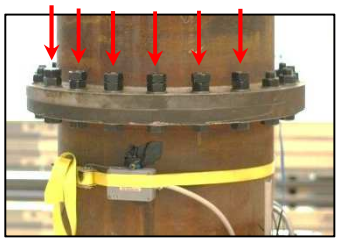


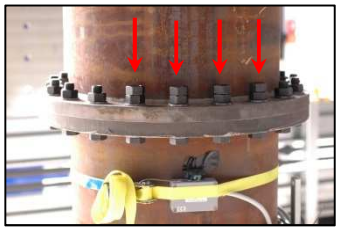
Changes of 1st eigenfrequency during the measurements; RMS of excitation: 250 N

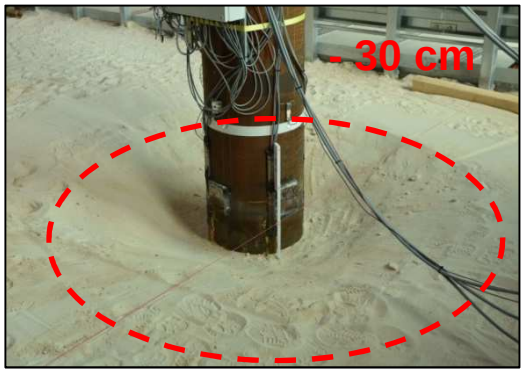


Loosened screws and scouring: Indicators based on OMA

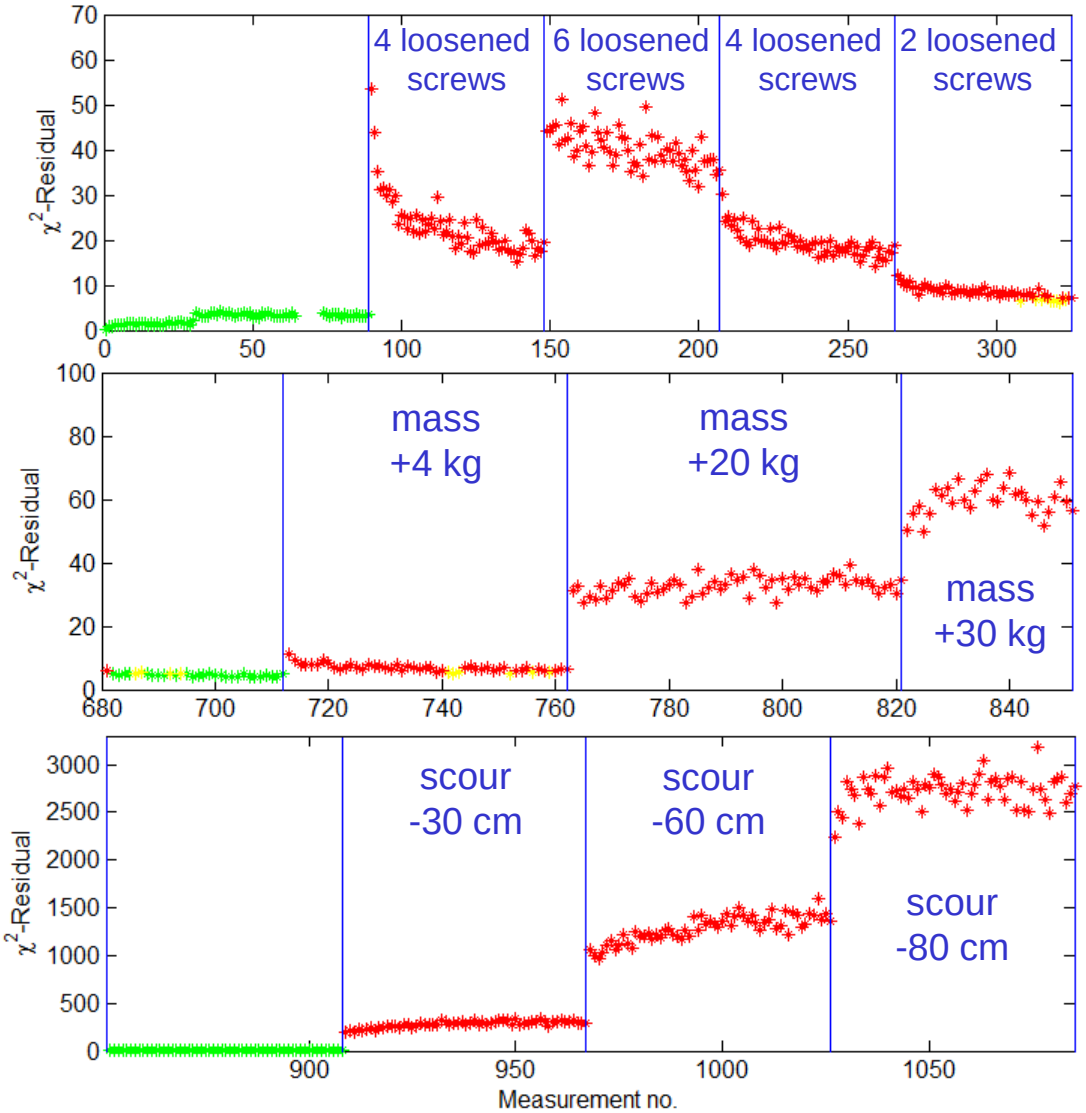


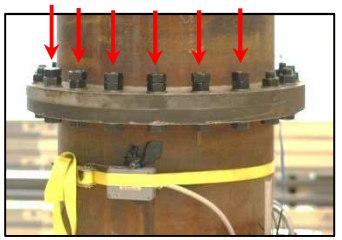


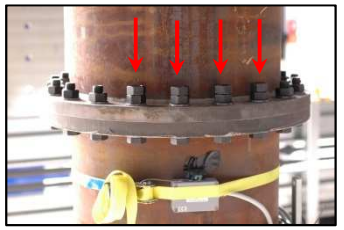


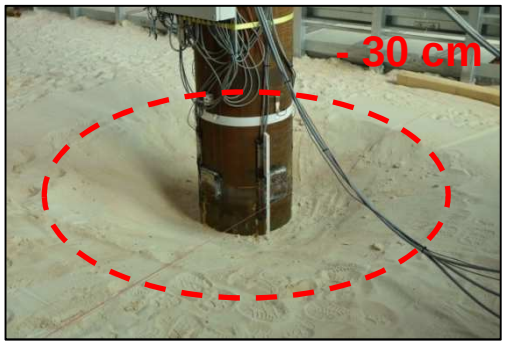


Loosened screws and scouring: Indicators based on SSFD

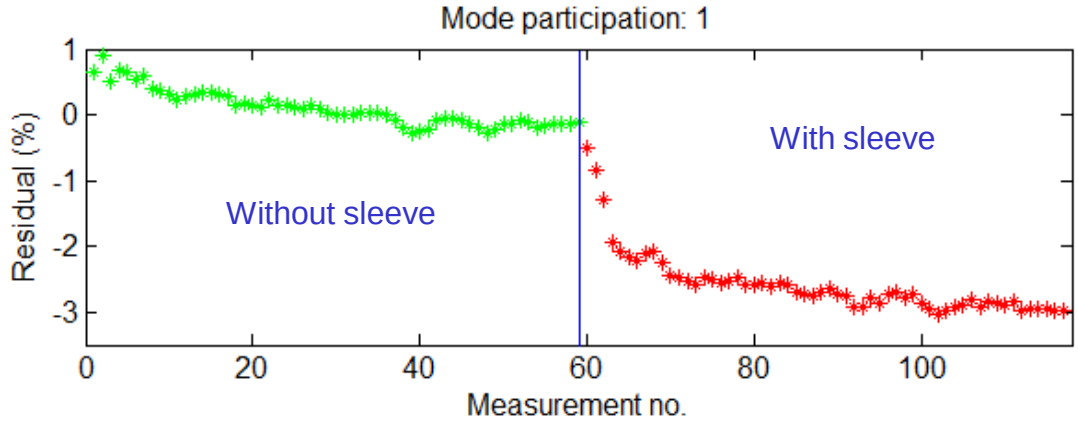


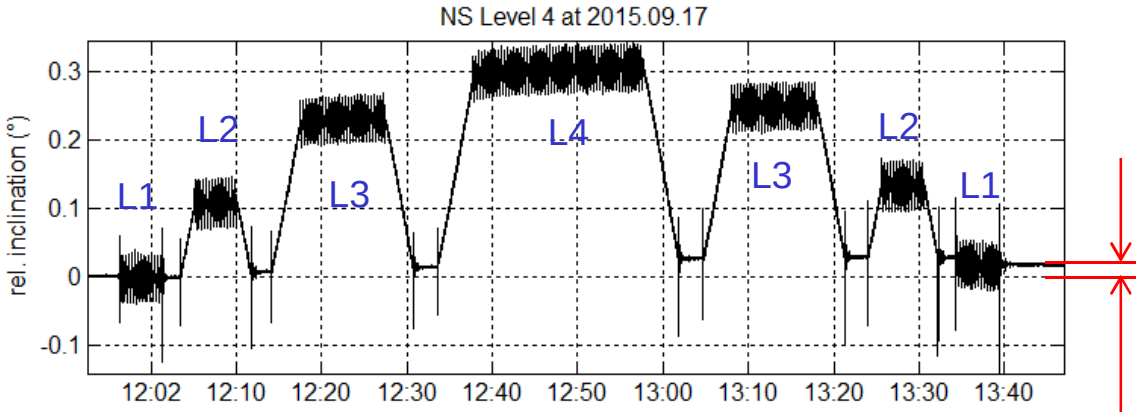




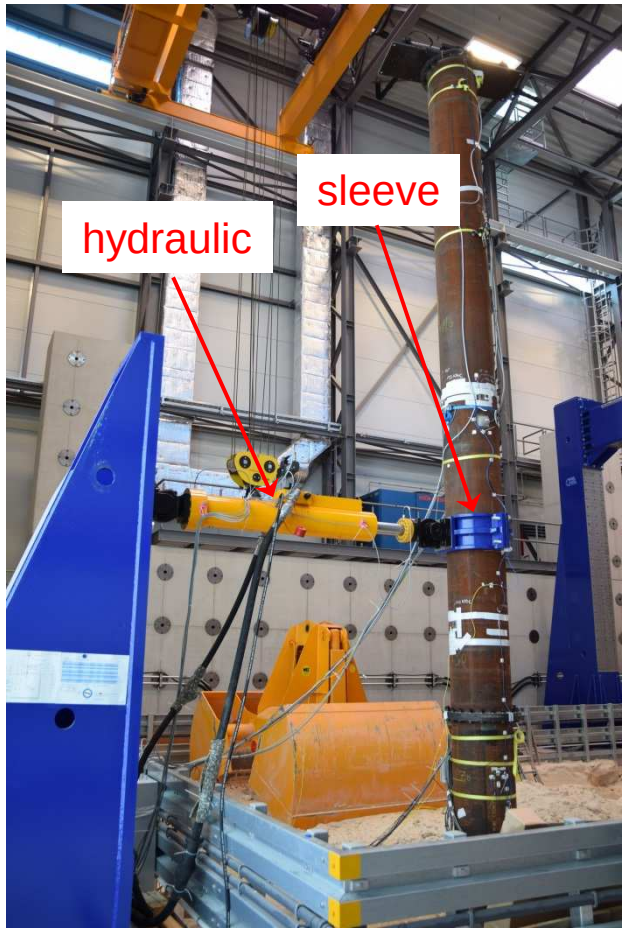


Installation of hydraulic system → periodical eccentric loads





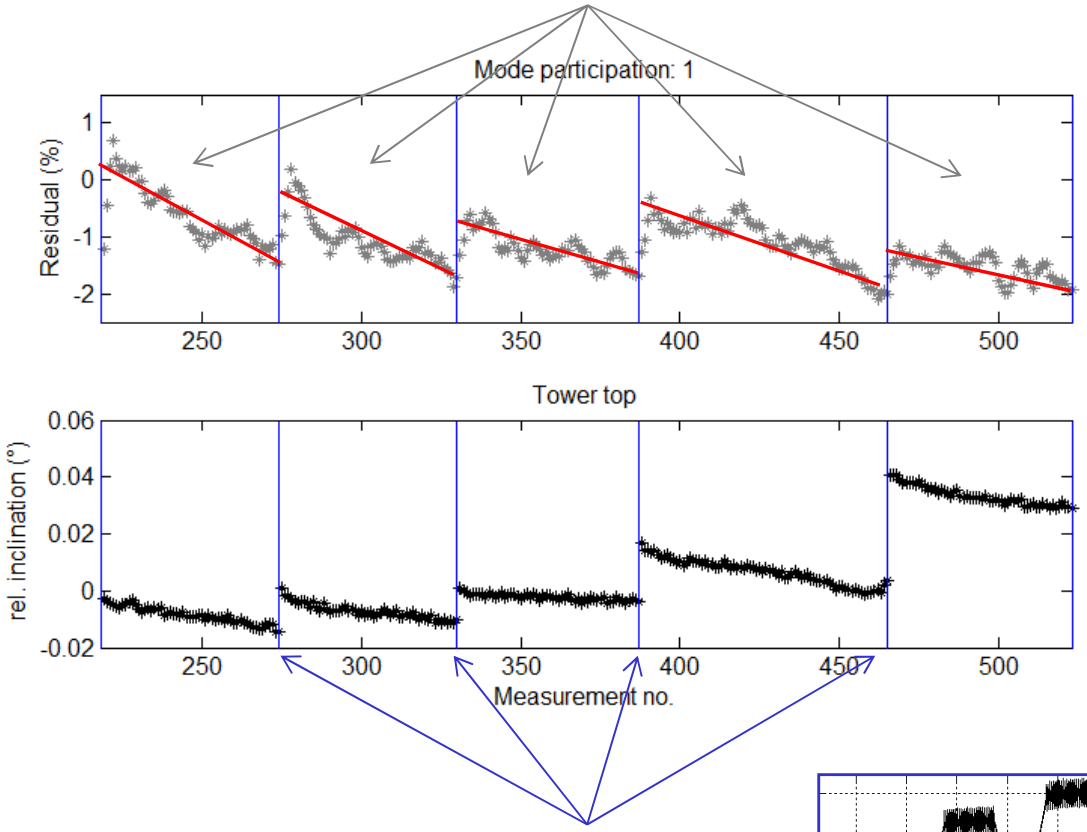
Inclination during loads from hydraulics

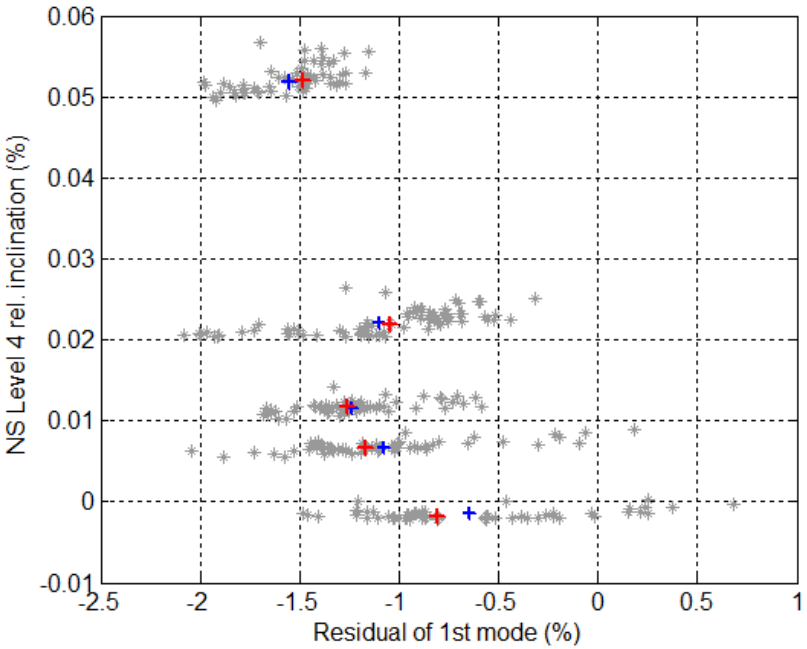


Remaining inclination

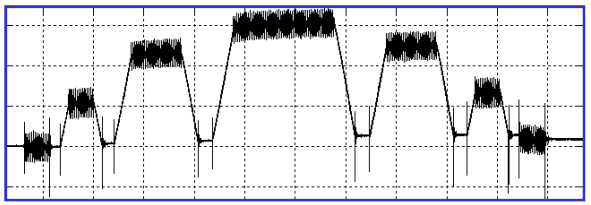
Structure inclination after eccentric loading by hydraulics

Measurements during shaker excitation → OMA





Loads from hydraulics
→ inclination



Conclusion and further work

- Strong changes of the soil during the measurements
- Loosened screws can be well detected
- The effects of structure inclination are covered by the effects of soil changes
- The effect of the scouring on the dynamical properties is very strong → could cover effects caused by damage, etc. → additional sensors only for scouring monitoring?
- In the future the data from UnderwaterINSPECT will be analyzed by means of further mathematical data-driven and model-based approaches
- Measurements for the purposes of cut loads and remaining lifetime estimation will be used for the development of appropriate approaches
- Effects of grout damage will be examined during the QS-M Grout project
- Further environmental and operational effects on the plant dynamics observed in situ are considered in our monitoring algorithms

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Thank you for your attention !

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