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# Revisiting Global Response of FPSOs in Shallow Water and the Riser Analysis Requirements

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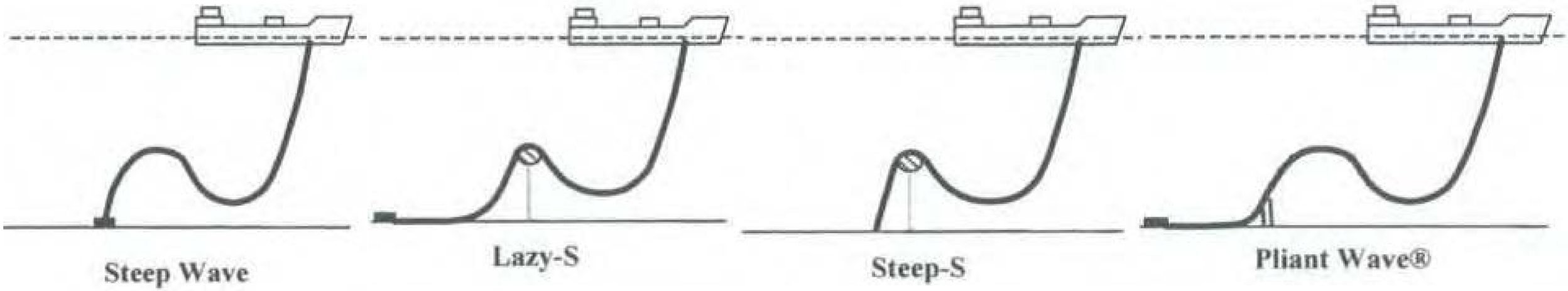
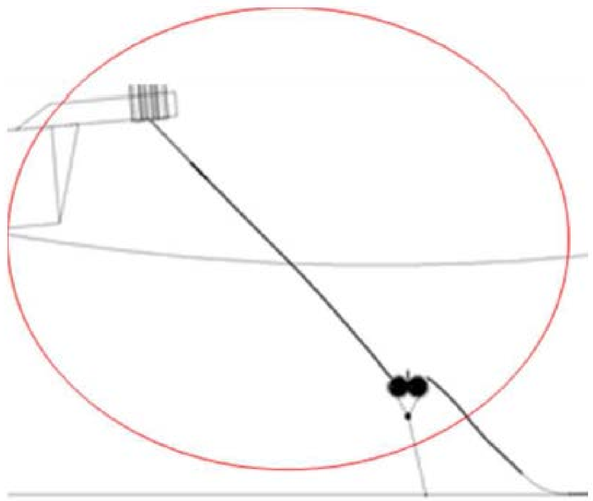
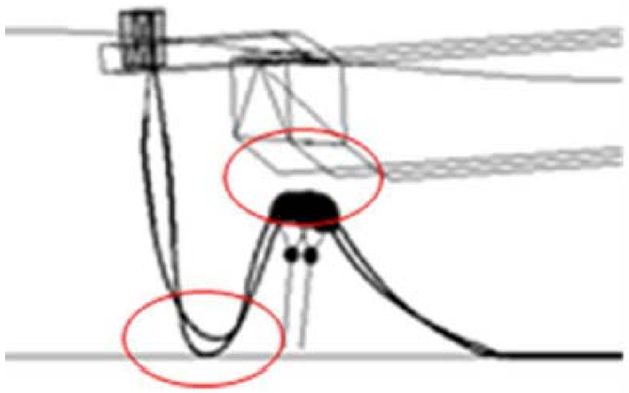
# Motivations

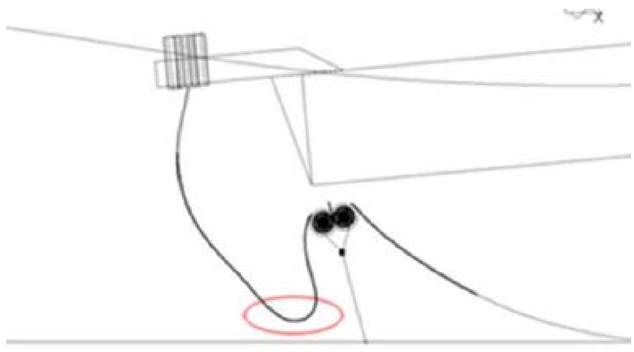


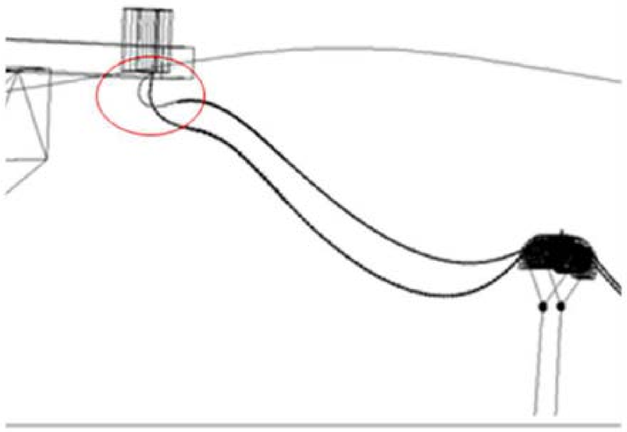

- Highly nonlinear mooring system response in shallow water systems (WD < 150m)
- Complex nature of shallow water hydrodynamics
- Water depth limitations
- Proximity of risers with other structures (vessel, mooring lines, other structures)

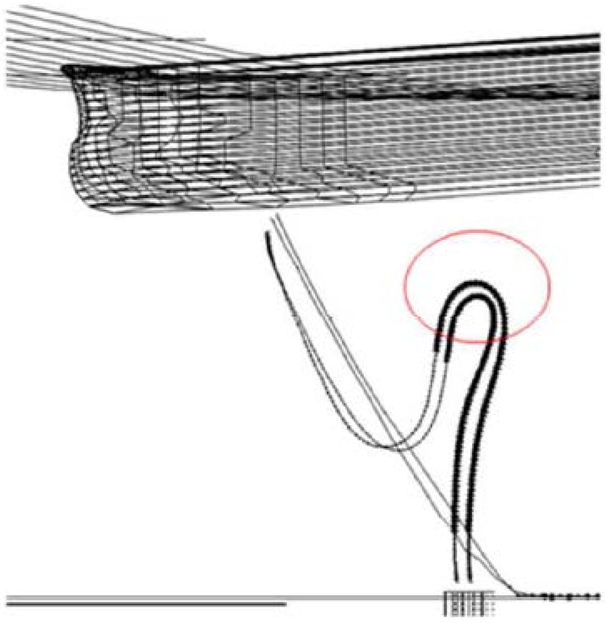
# Motivations











Ref: AOG • Innovative Riser Configurations for Shallow Water • Claus Dencker Christensen • Emad Libis

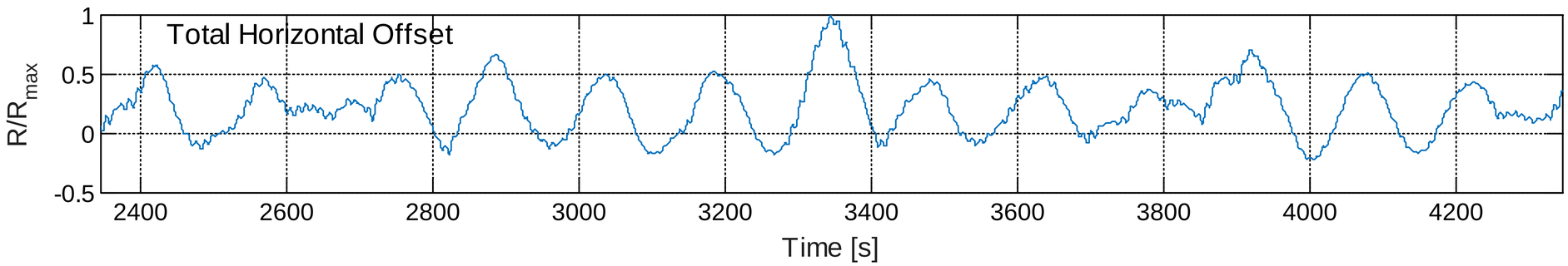
# Motivations

- Complex nature of the problem + Conservative Assumptions:
  - Complex riser configurations (e.g. restricted S)
  - Heavier riser structures
  - Added ballast
  - Added stiffness layers
  - …. Cost

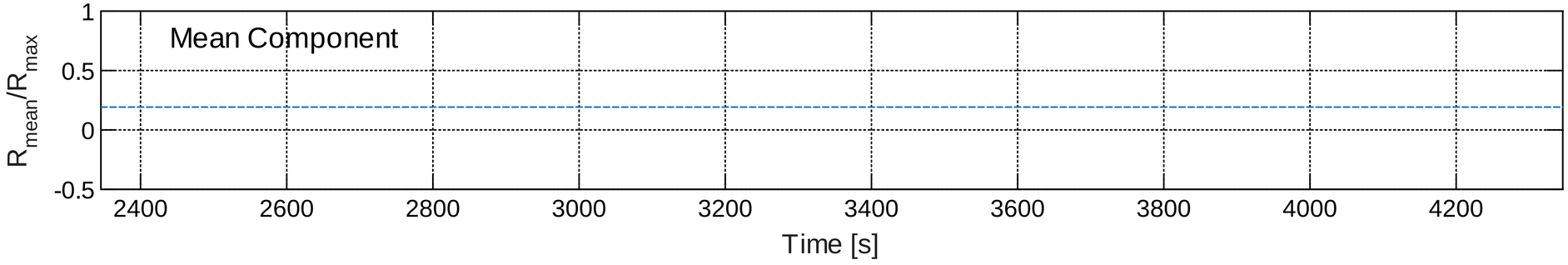
# Presentation Structure

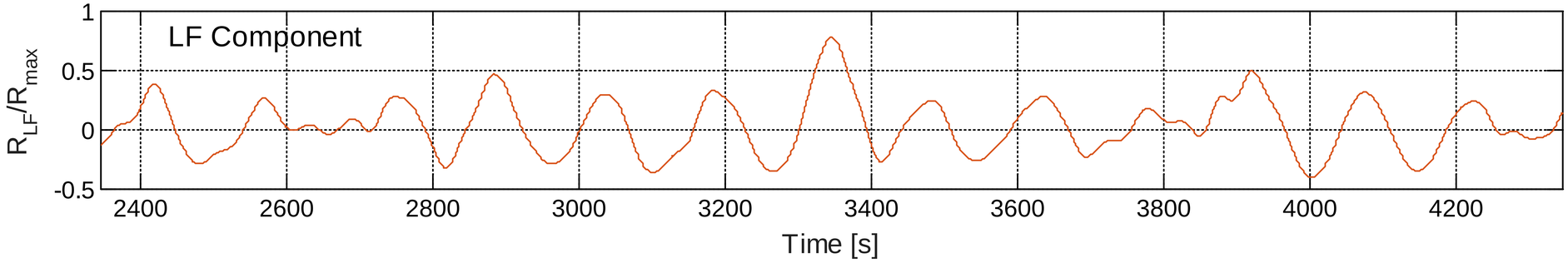
- Global Response of FPSOs in Shallow Water
  - Focus on horizontal offset
- Application of Global Responses in Riser Analysis
  - Uncoupled Riser Analysis
- Case Study
  - Global Response of mooring system
  - Statistical Analysis of Extreme Offset and Extreme Wave Height
- Concluding Remarks

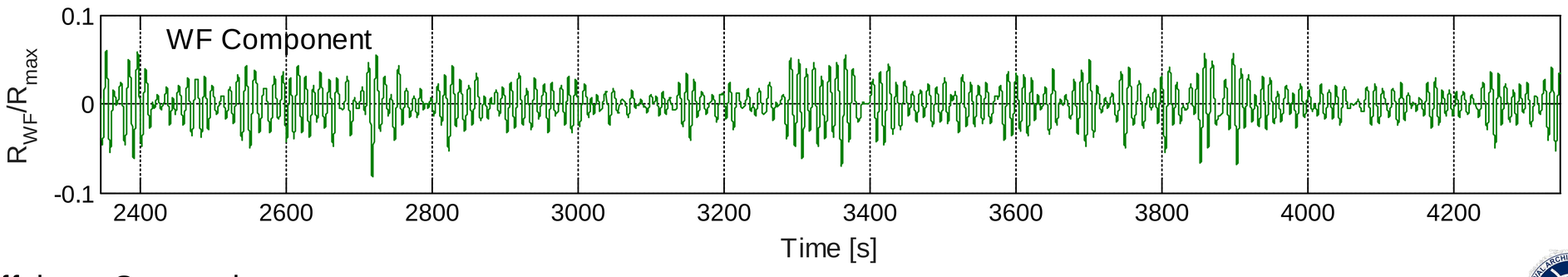
# Global Response of FPSOs in Shallow Water




Quasi-Static Offset



# Riser Analysis

- Coupled Riser Analysis
  - Modeling mooring legs/risers/vessel and their contribution to the response
  - Simulation considers vessel LF and WF responses (simultaneously)
  - Irregular wave analysis for 3hr duration (multiple seeds)
  - Usually done for global analysis purposes
  - Difficult to model all the riser details (and the devil is in the details)
  - Limited to few critical cases

# Riser Analysis

- Uncoupled Riser Analysis
  - The vessel is placed at a “representative” extreme LF offset
  - Vessel WF response is captured by vessel motion RAOs
  - Regular wave analysis or Irregular wave analysis of a short duration (~200-300sec)
  - Model includes all riser details
  - Suitable for large analysis matrix

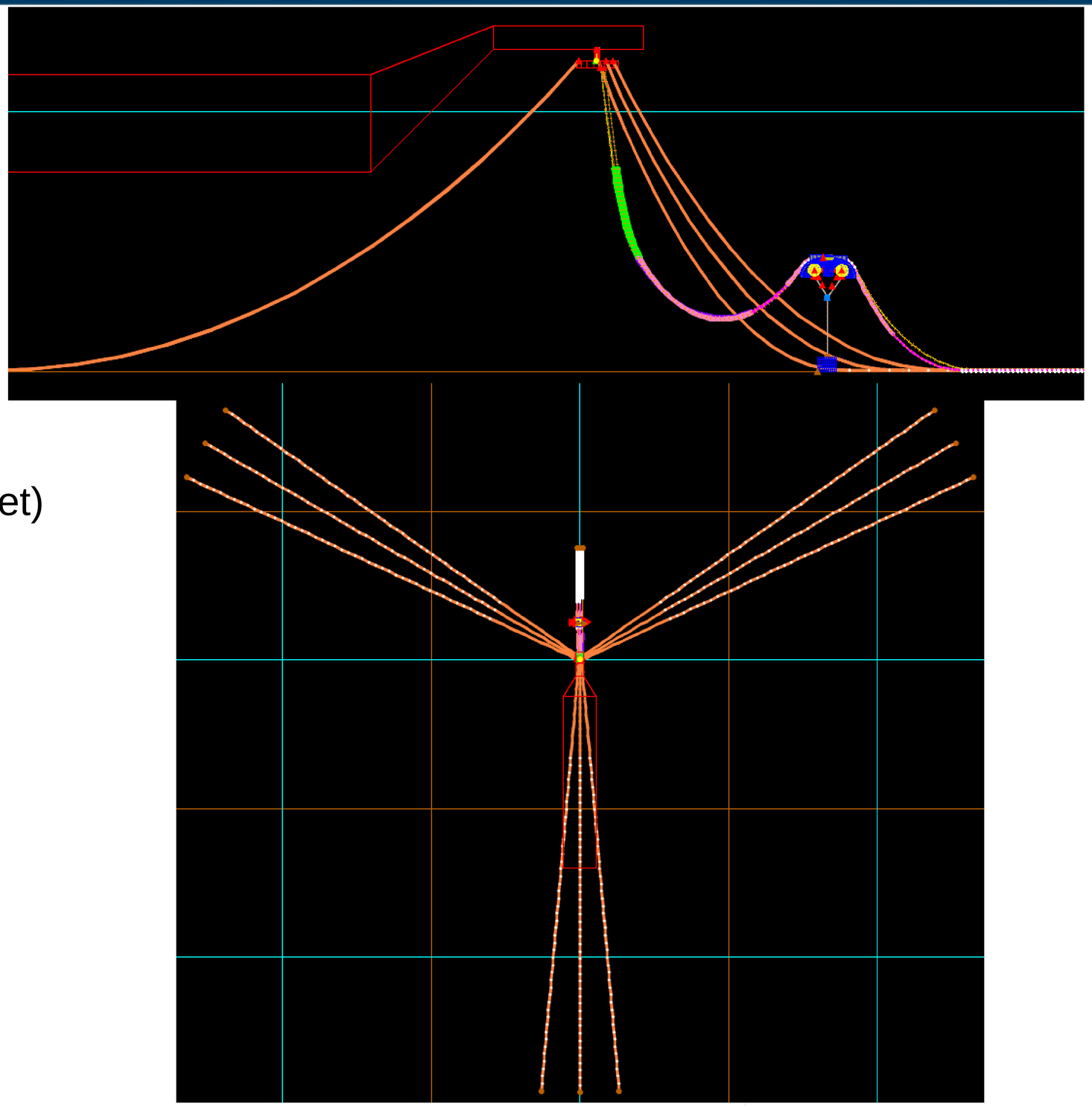
# Riser Analysis

- Challenge (problem definition)
  - New codes rely heavily on coupled riser analysis
    - Not used very frequently in actual design process
  - The “representative” extreme LF offset to be used for uncoupled analysis is not clearly defined in riser codes
    - Some texts in previous rev of codes and standards are removed (e.g. API RP 17-B)
  - Some requirements have been adopted from deepwater systems
  - Mooring codes definition of total design offset (Frequency Domain)
    - **Design Offset = max [Mean Offset + MPM (LF Offset) + Significant (WF Offset), Mean Offset + Significant (LF Offset) + MPM (WF Offset)]**
  - Conservative solution used in riser analysis:
    - **MPM Quasi-Static Offset happens with Hmax**

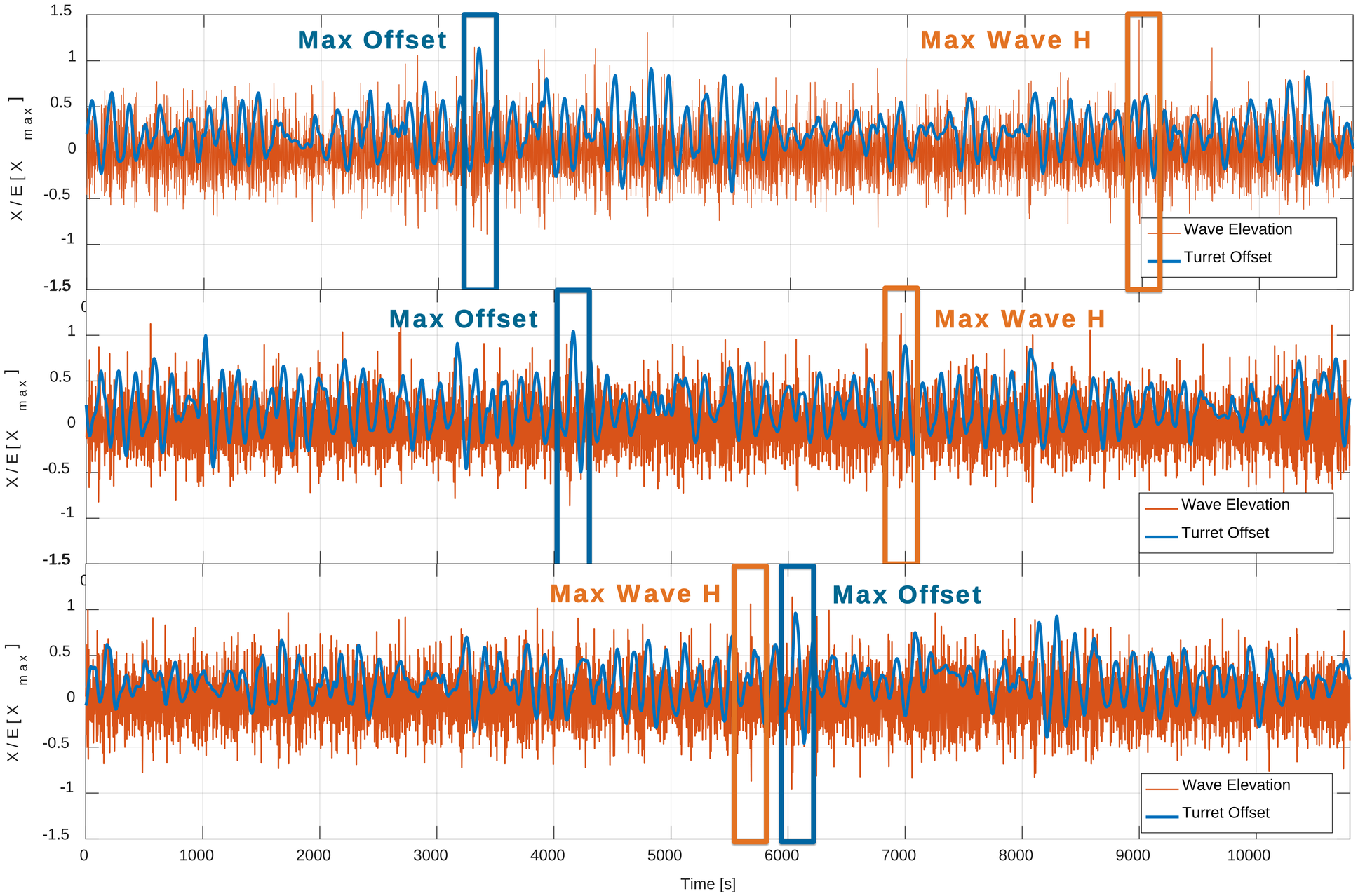
# Case Study

Water Depth: ~ 60m
Mooring System: External Turret
Anchor Legs: 3 legs in 3 groups (all chain)
Vessel: Aframax size (small topside)
100yr Hs: ~ 7.0m
Riser: Lazy S (midwater arch)

Model test and Numerical Simulation:
Environment: 100yr Design case (critical offset)
Seeds: 5 random seeds (3hr each)

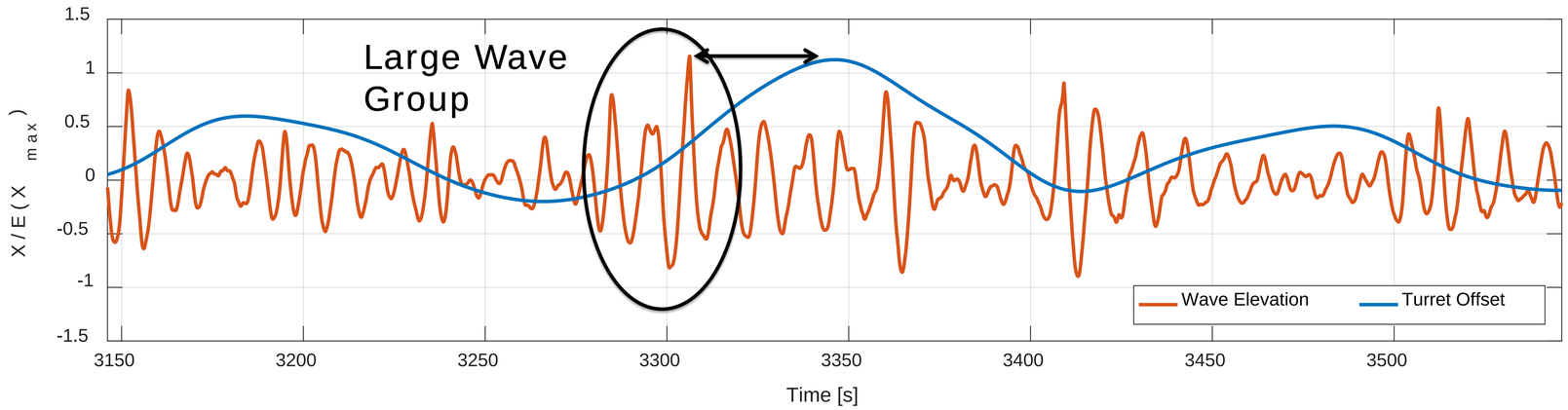


# Global Response of the Mooring System

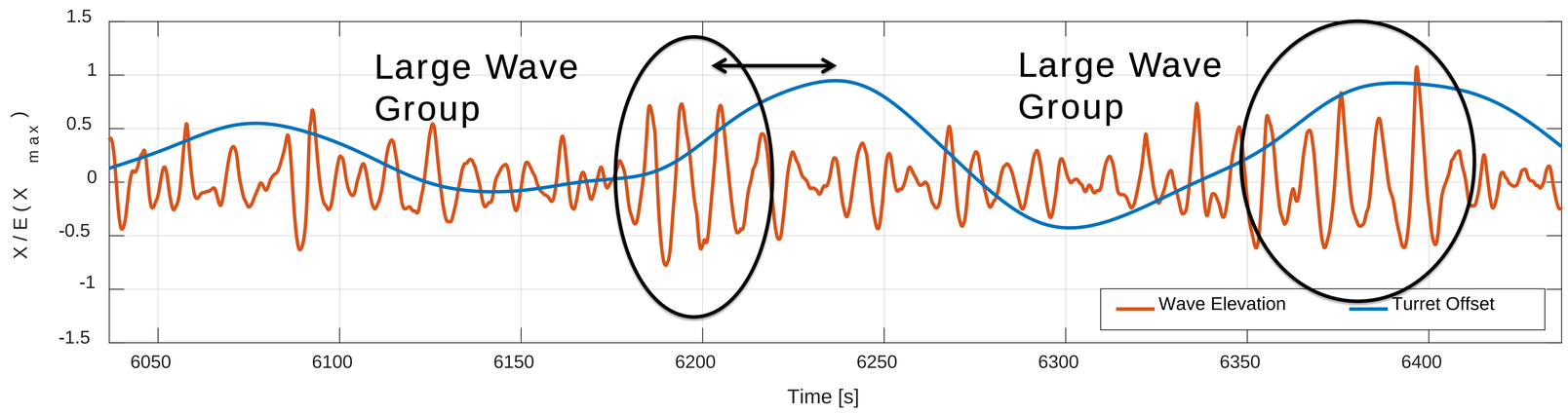


# Global Response of the Mooring System

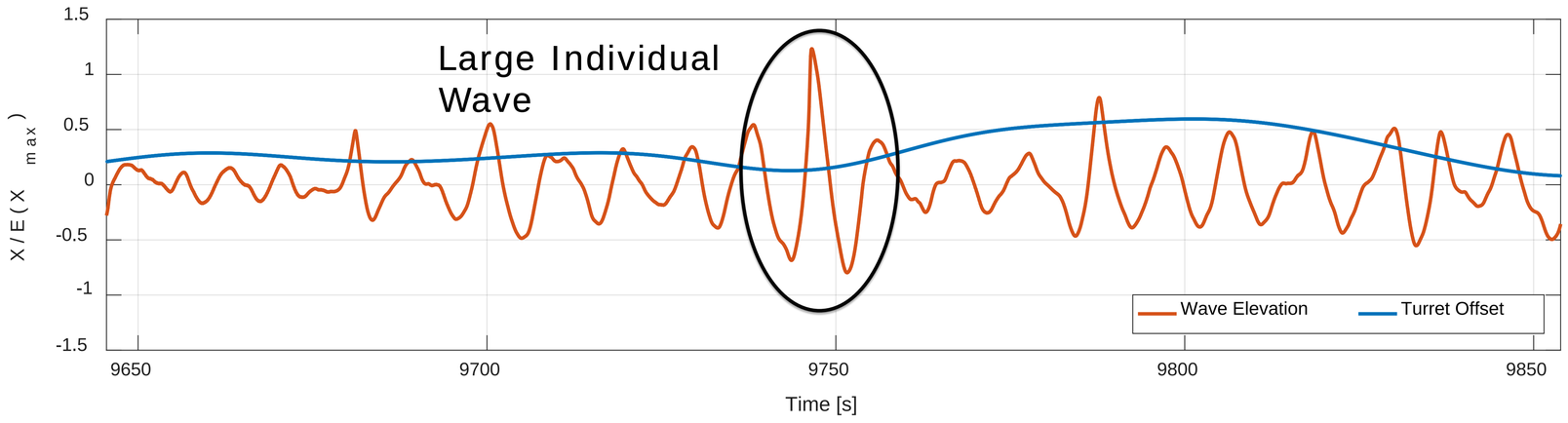
Example 1:
Max Offset




Example 2:
Max Offset




Example 3:
Max Wave H

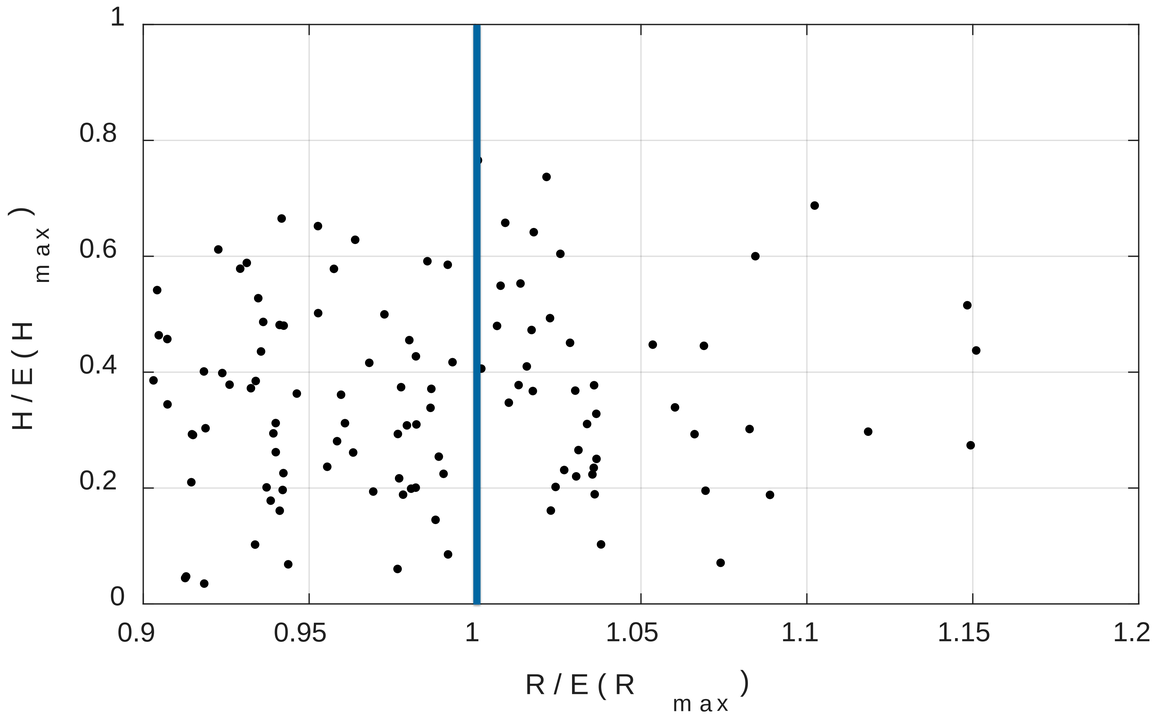


# Statistical Analysis of Extreme Offset and Extreme Wave Height

- Time domain simulations
  - Same system with same initial setup
  - Model verified with model test results
  - 50 seeds (3 hr each)
  - Same environmental condition as the model test

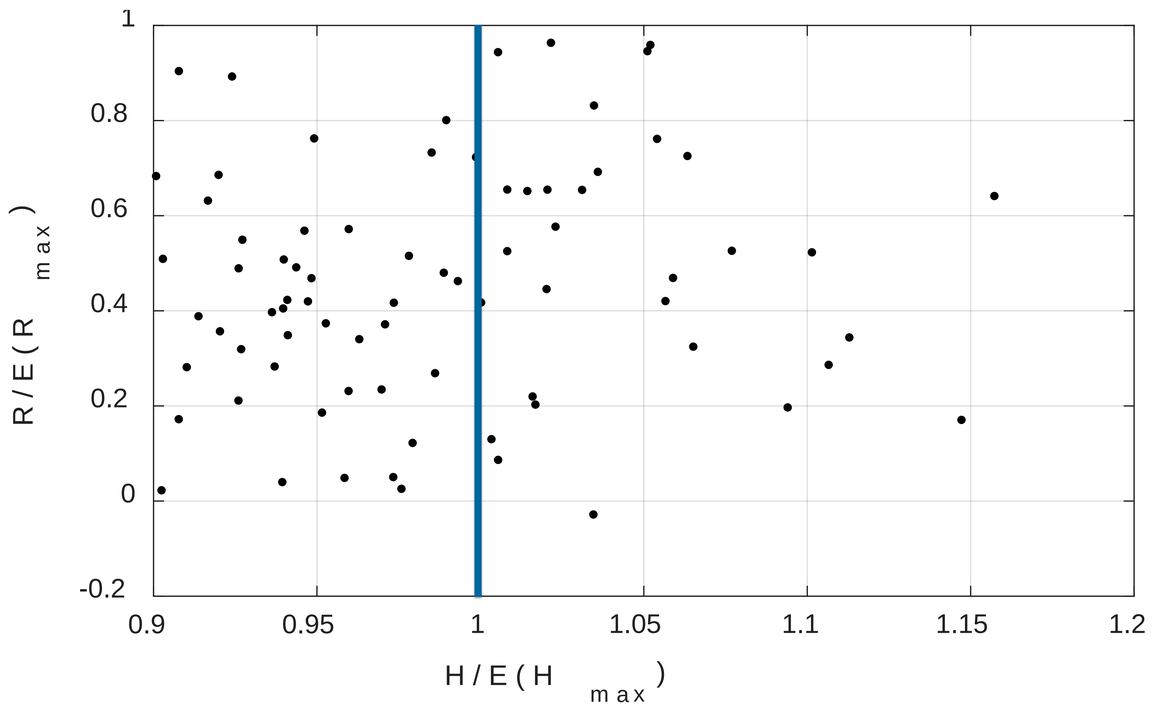
# Statistical Analysis of Extreme Offset and Extreme Wave Height

## Maximum Offset and Associated Wave Height




| At Maximum Offset | Average of Associated Wave Height | |
|---|---|---|
| | E (H) / E (Hmax) | E (H) / Hs |
| | 0.36 | 0.65 |

## Maximum Wave Height and Associated Offset

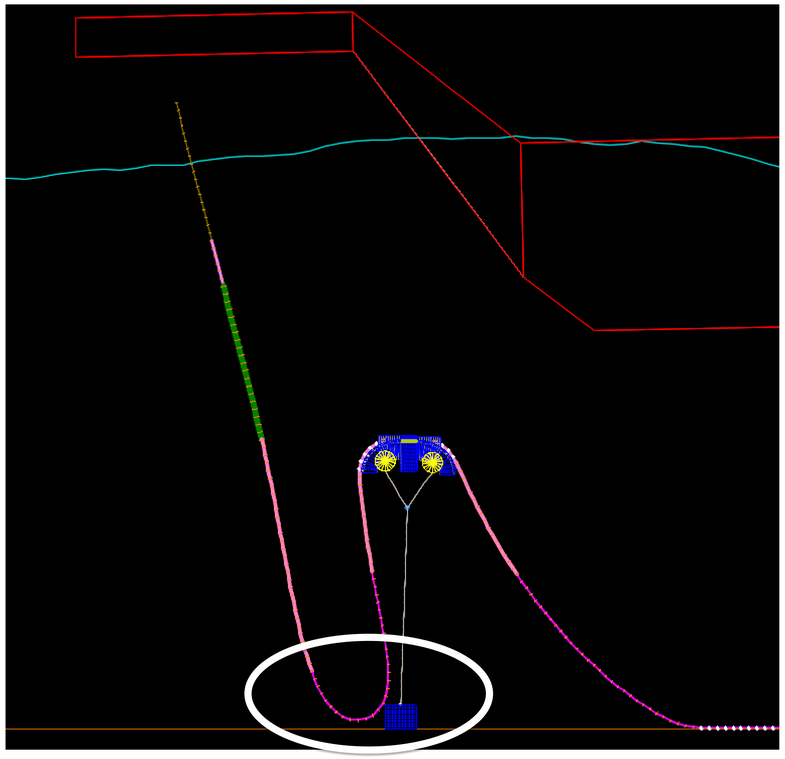



| At Maximum Wave Height | Average of Associated Offset | |
|---|---|---|
| | E (R) / E (Rmax) | E (R) / Rs |
| | 0.48 | 0.62 |

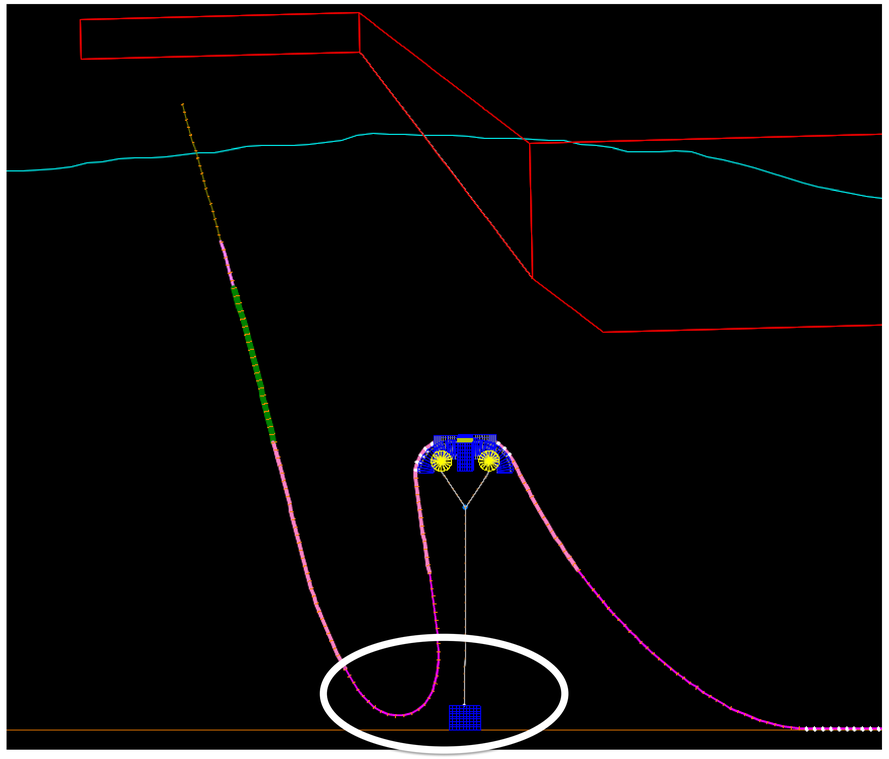
# Concluding Remarks

- The comments made here are based on one example. However, based on our experience they can be extended to other systems.
- Maximum wave height and maximum quasi-static offset are not correlated and they do not coincide.
- The natural vessel response causes a gap between the large individual wave in the group and the large corresponding offset. The gap depends on the vessel response.
- The assumption used in riser design that MPM quasi-static offset and Max wave height coincide is very conservative.
- An approach similar to that used in mooring design (Max Offset + Sig Wave, Sig Offset + Max H) seems to be more representative and is recommended for uncoupled analysis purposes.

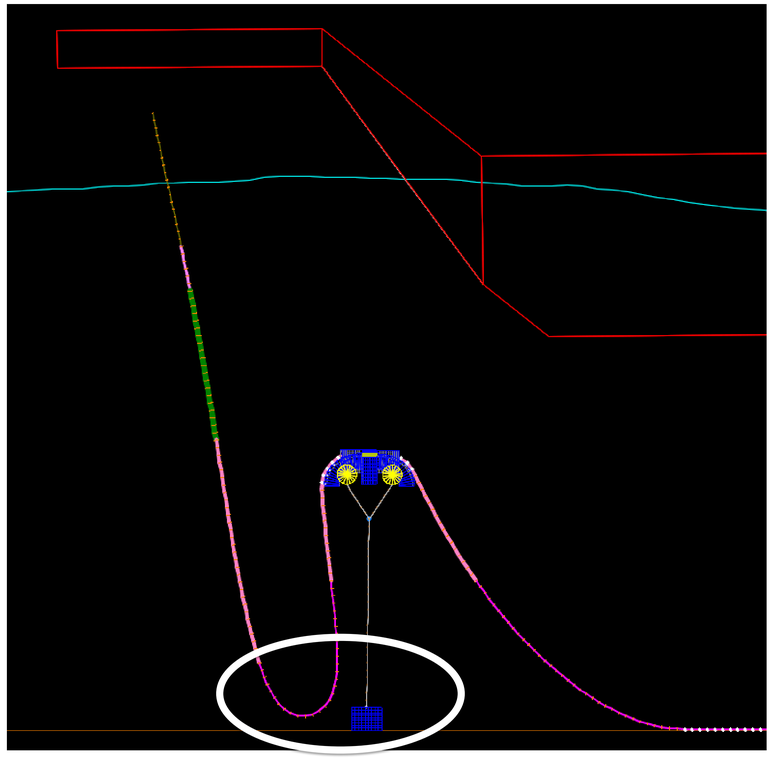
# Concluding Remarks



MPM Offset + Hmax



Sig Offset + Hmax



MPM Offset + Hs