Global Analysis of Shallow Water FPSOs

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Outline of Presentation

- Typical Shallow Water FPSO Systems
- Environmental Loading
- Example 1: External Turret Mooring System
  - Mooring Design and Global Analysis
  - Riser System Design
- Example 2: Tower Yoke Mooring System
- Summary and Conclusions

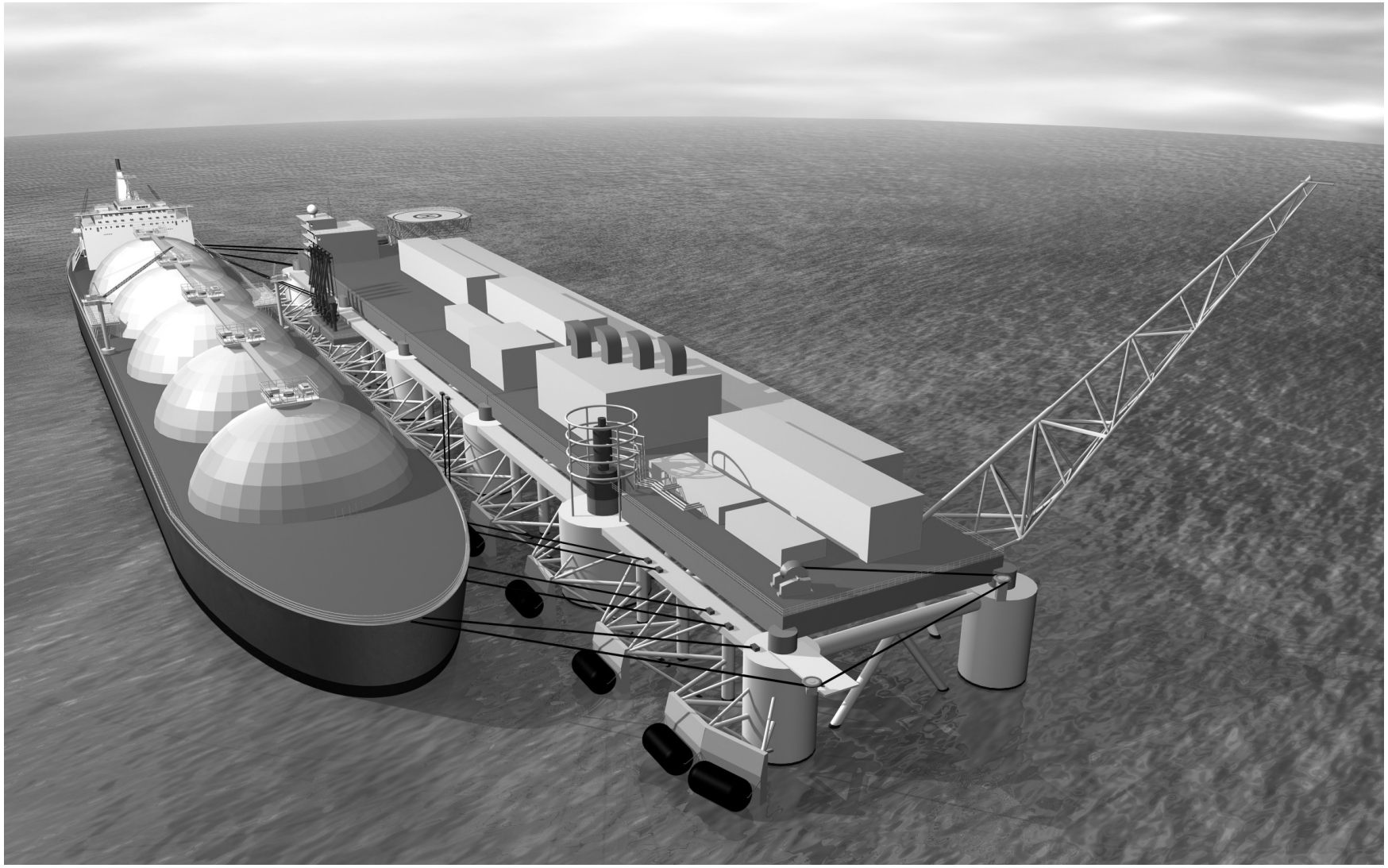
Challenges in Shallow Water Global Analysis

- **Shallow Water! – “Blockage” Effects**
- **Wave and Current Loading**
- **Hardening non-Linear Stiffness of Mooring Systems**
- **Low Level of Damping**
- **Design of Mooring-Riser Systems**

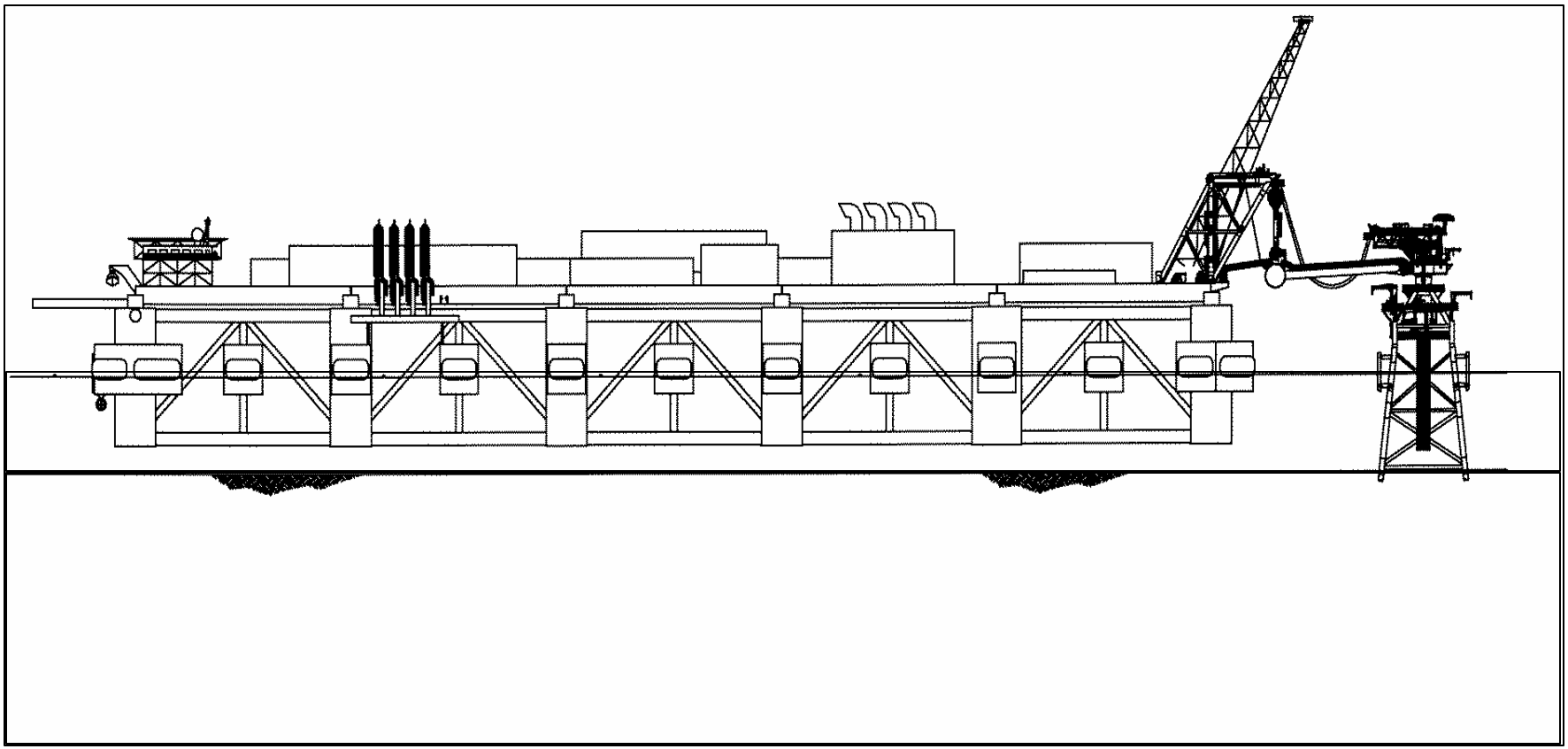
External Turret Moored FPSO

Tower Yoke Moored FPSO

Shallow Water LNG Offloading Terminal



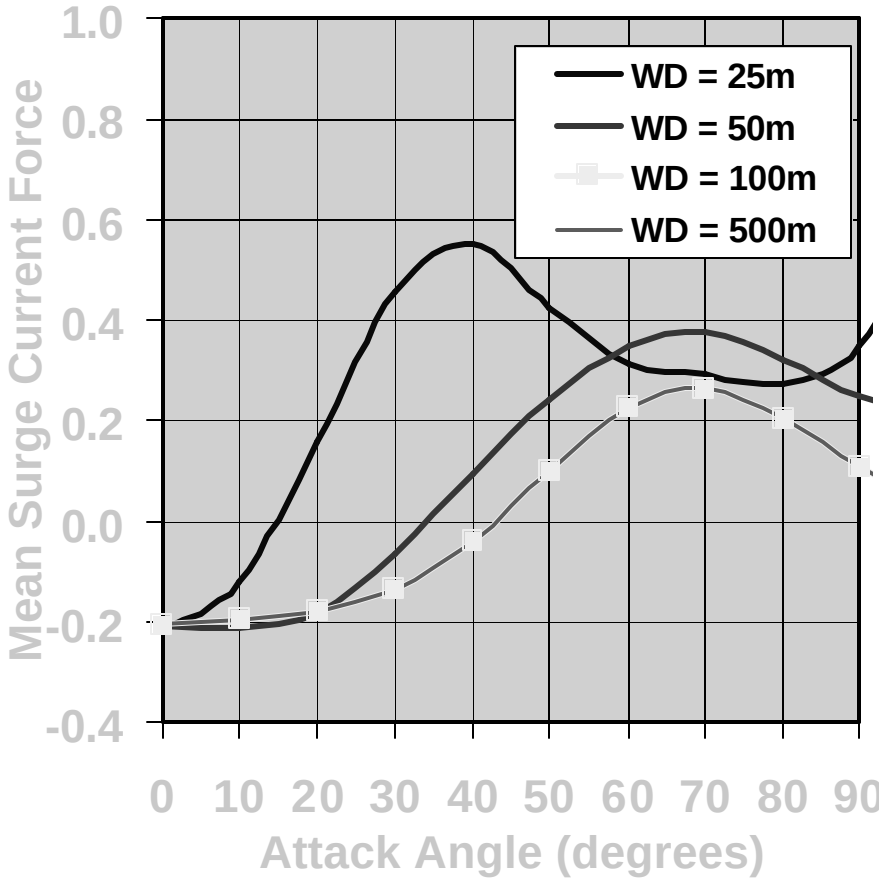
Shallow Water LNG Offloading Terminal

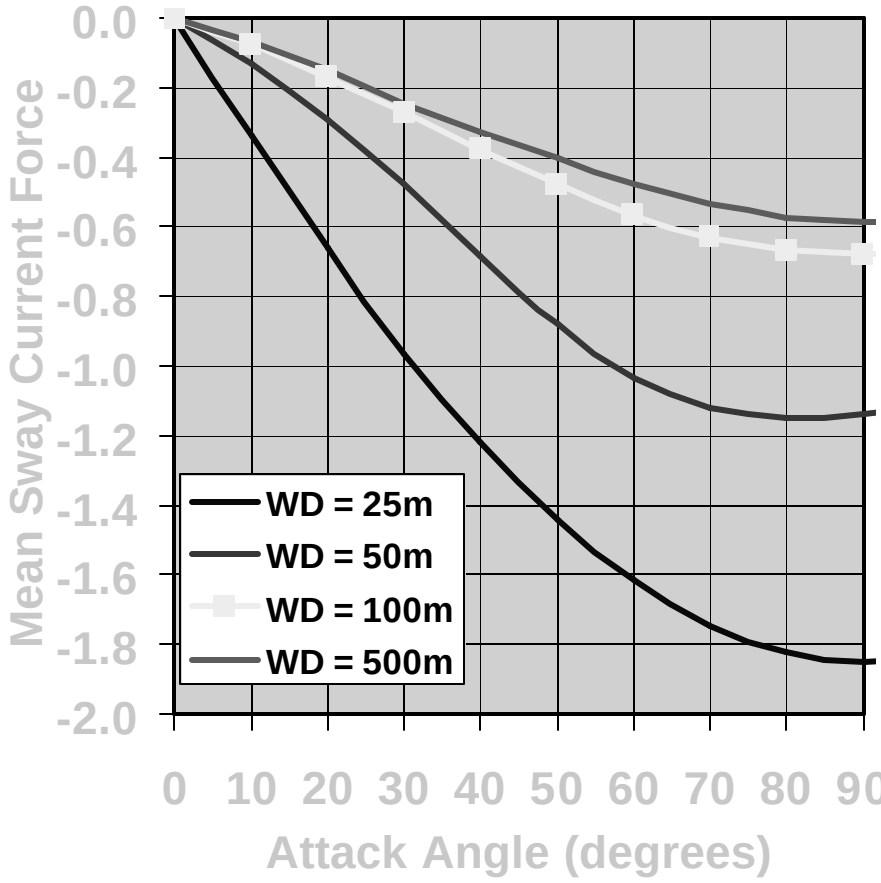


Metocean Issues for Shallow Water

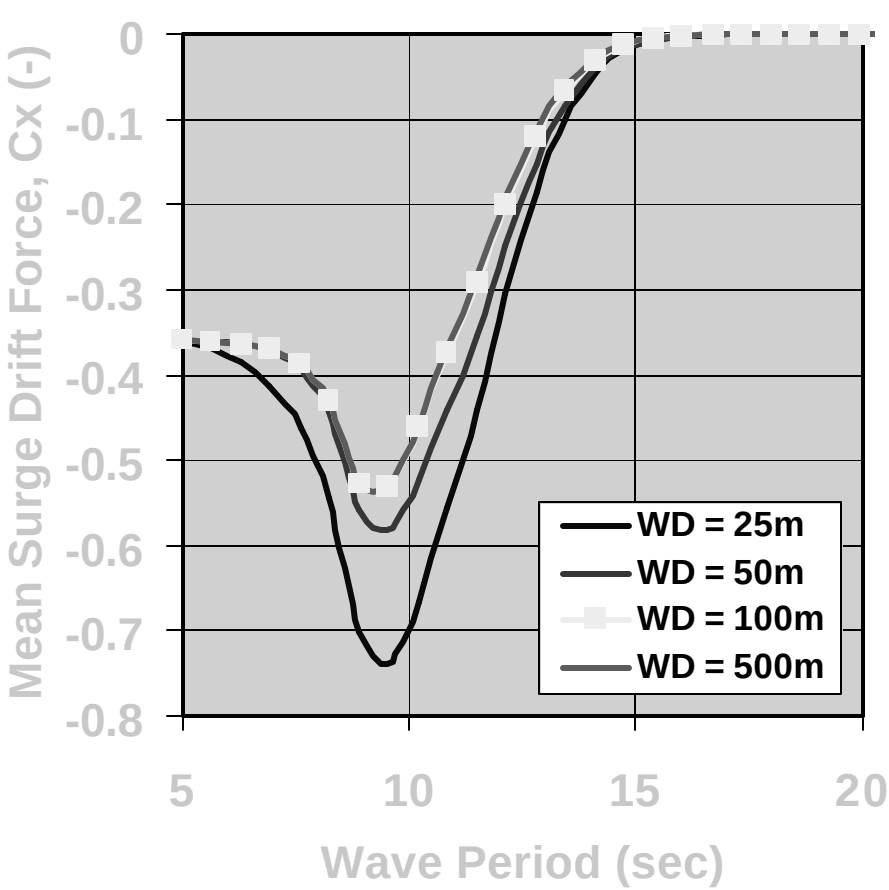
- **Seafloor Topography**
- **Definition of Metocean Conditions at Exact Location**
  - **Derivation of Metocean criteria from hindcast models**
  - **Joint distribution of wave and current intensity & direction**
  - **Tidal elevation and storm surge**
- **Current Loading on Floater**
- **Wave Loading on Floater**
  - **Shallow water wave characteristics**
  - **Mean and slowly-varying forces**

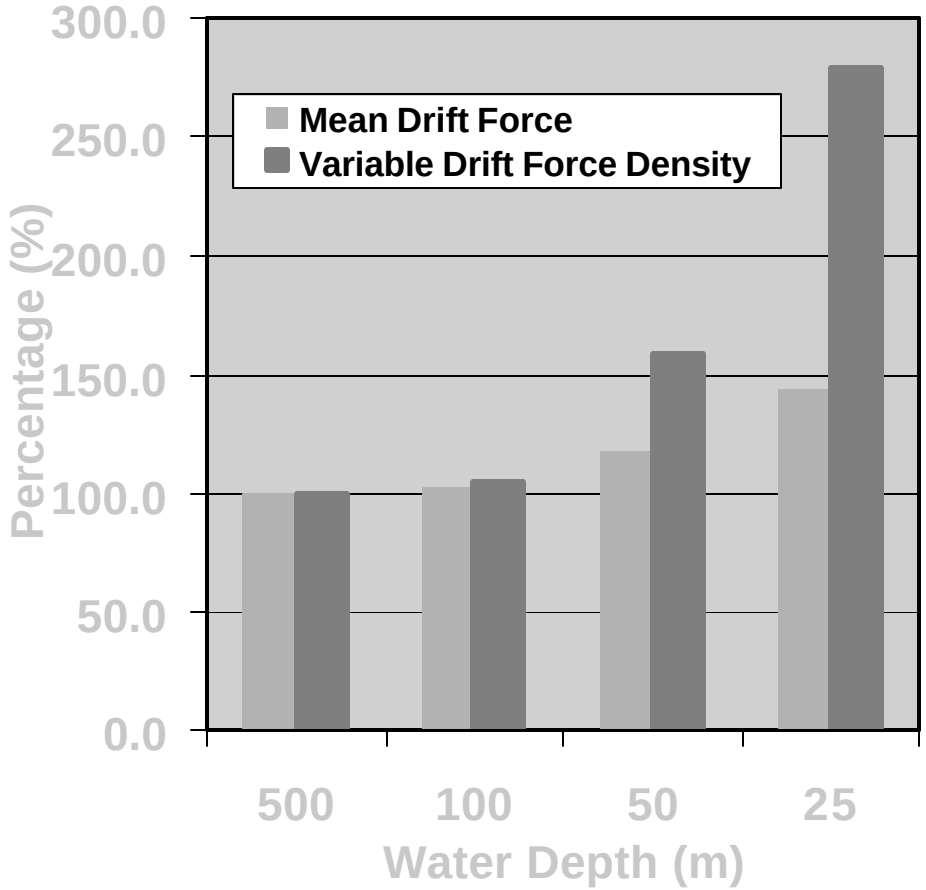
Current Loads as a function of Water Depth





Wave Loads as a function of Water Depth

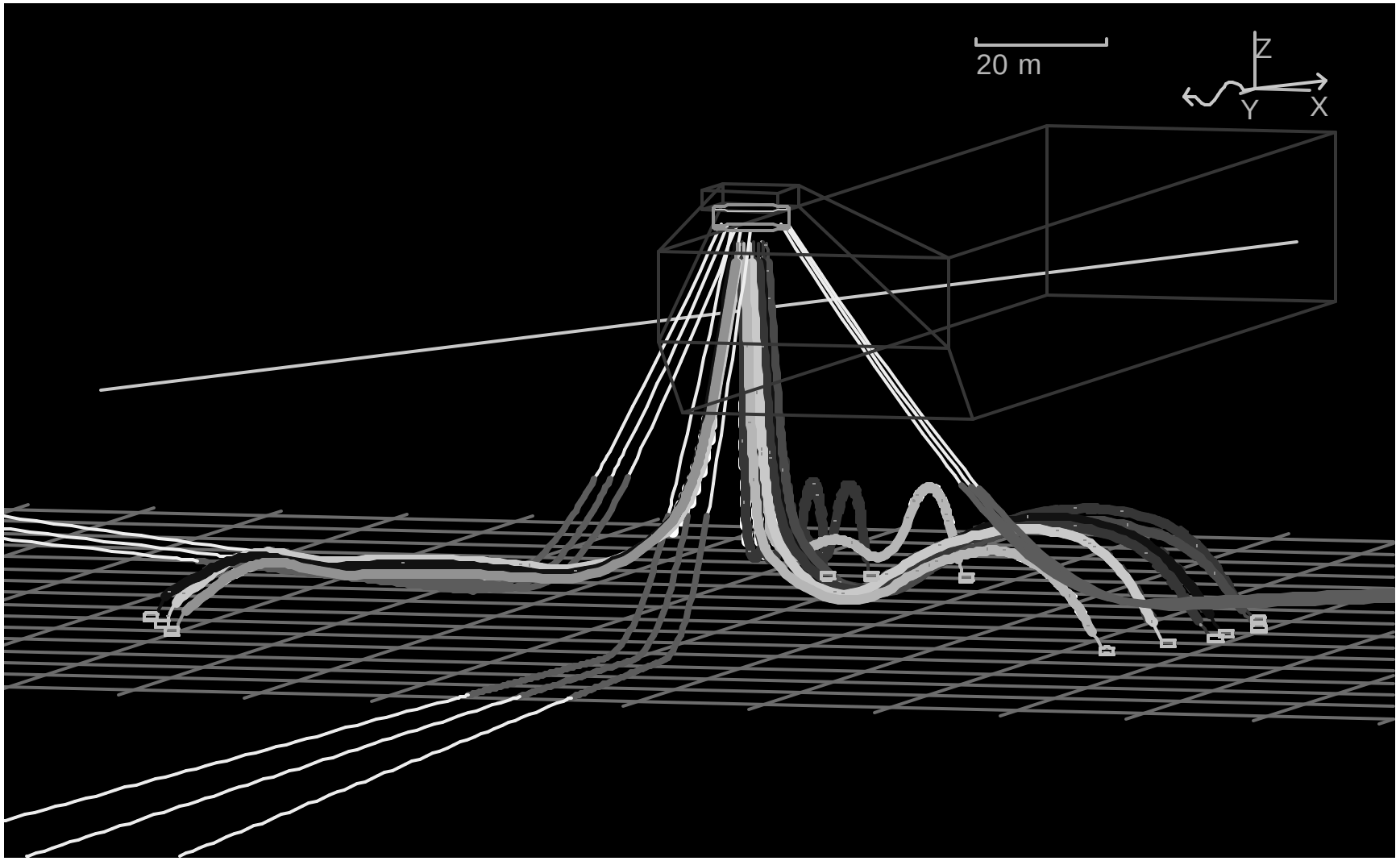




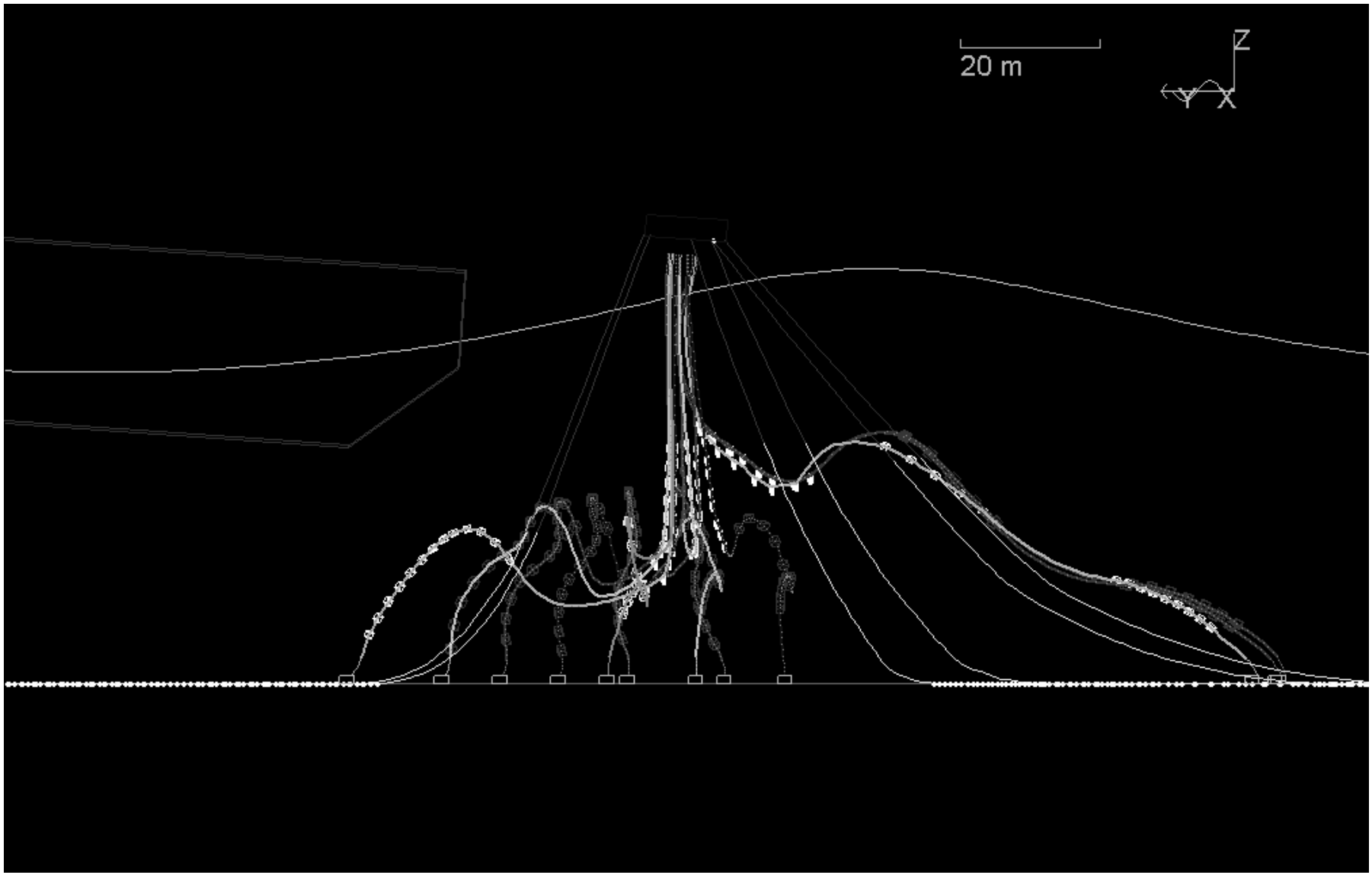
Example 1: External Turret Moored FPSO

- **Water Depth: 50 meters**
- **100-yr Wave: Hs=8.2m, Tp=14s**
- **Current: 1.5 m/s**
- **Wind: 30 m/s**
- **Risers: 11**

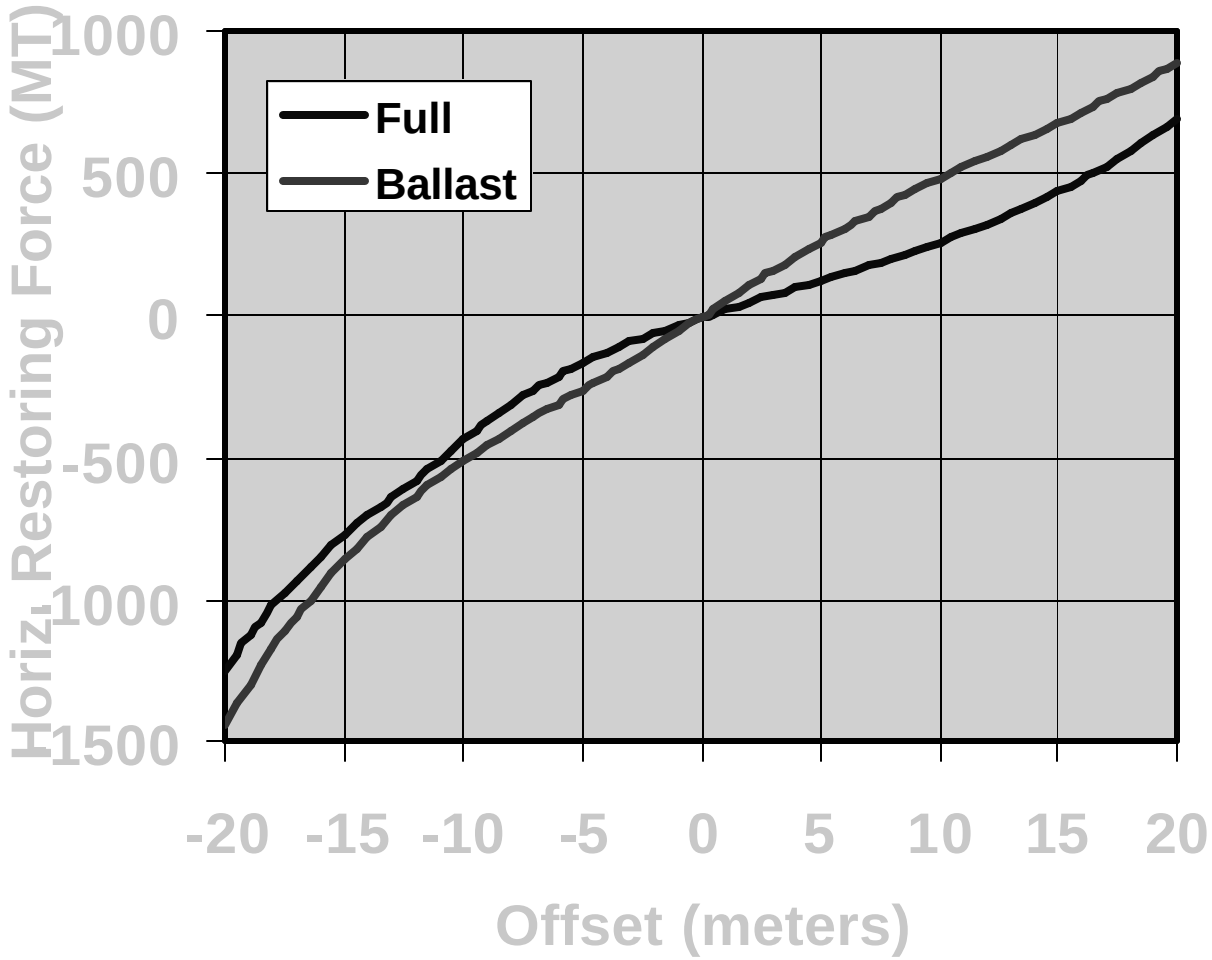
External Turret Moored FPSO



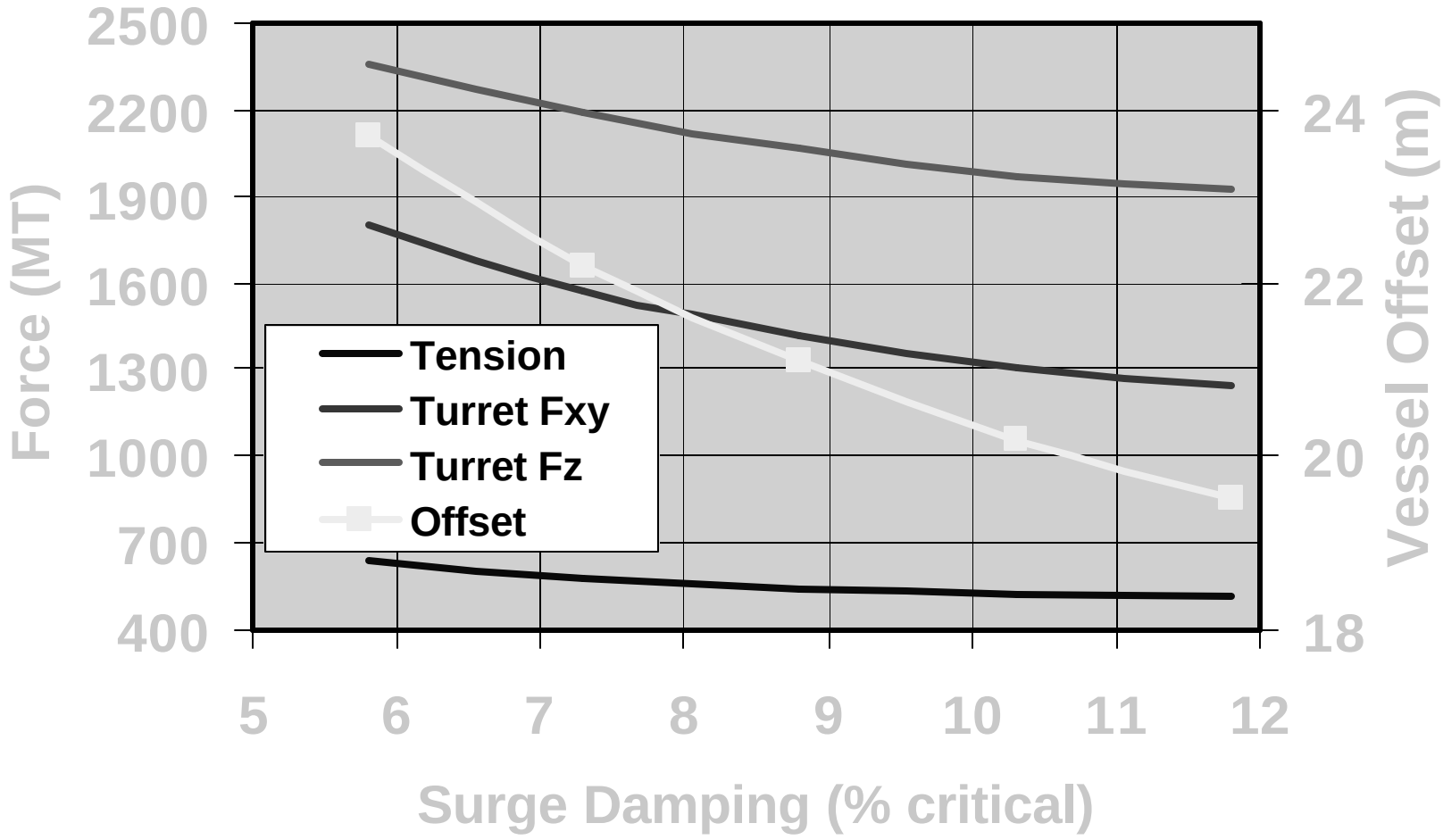
Example: Riser Extreme Response



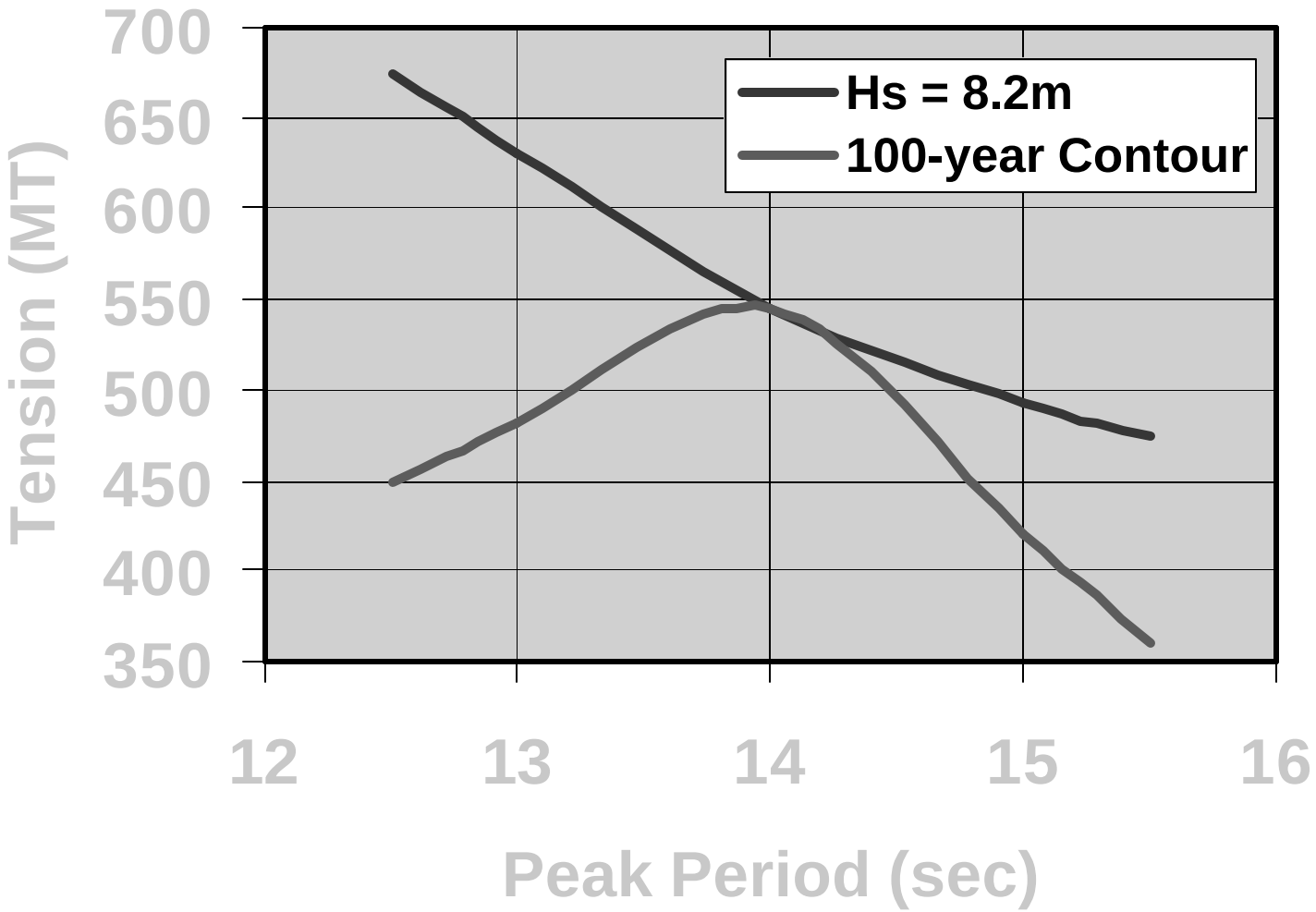
External Turret Mooring Stiffness



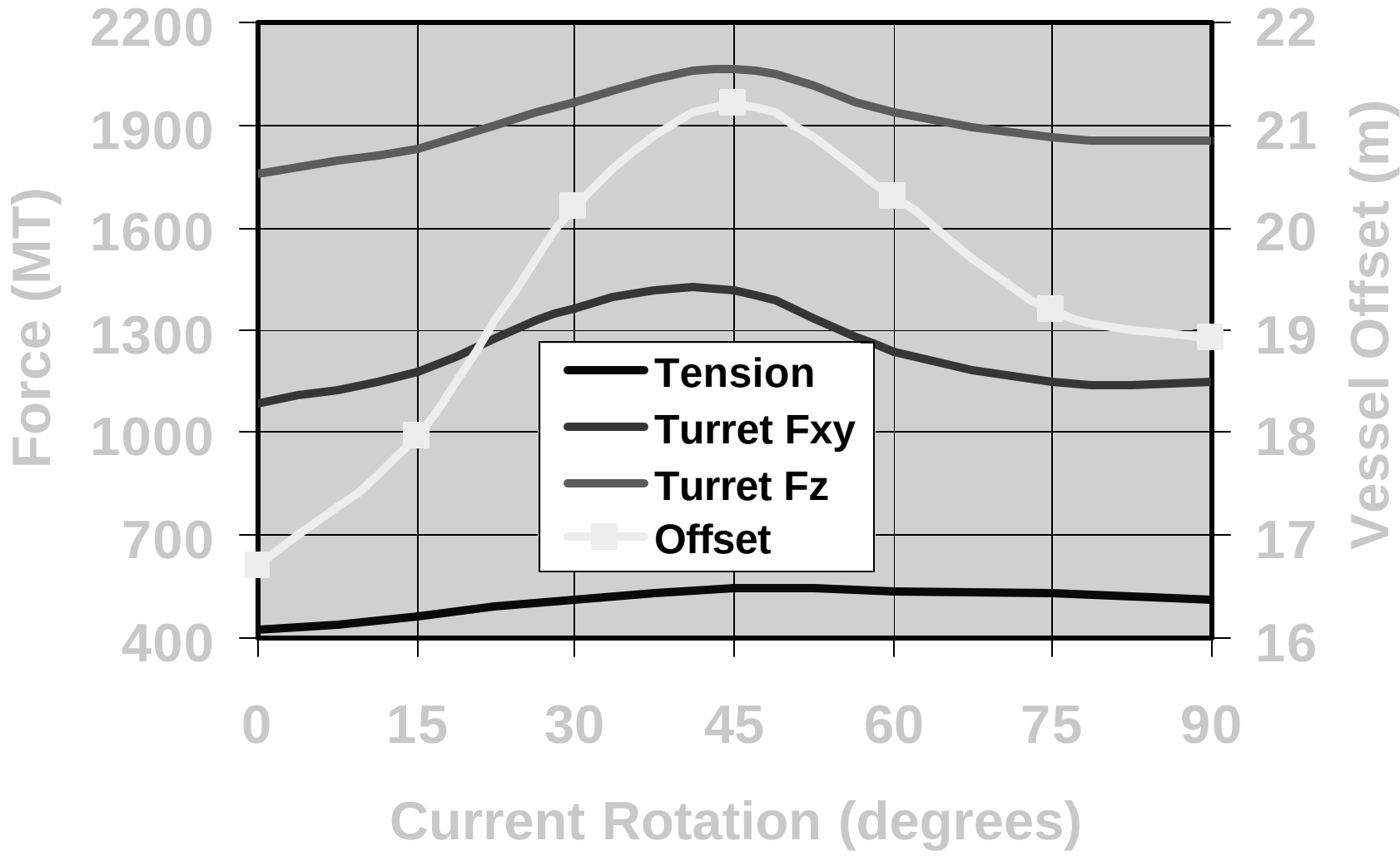
System Response as a function of Damping



Sensitivity to Hs-Tp Variation



Effect of Current Rotation



Time Domain Analysis: Sensitivity

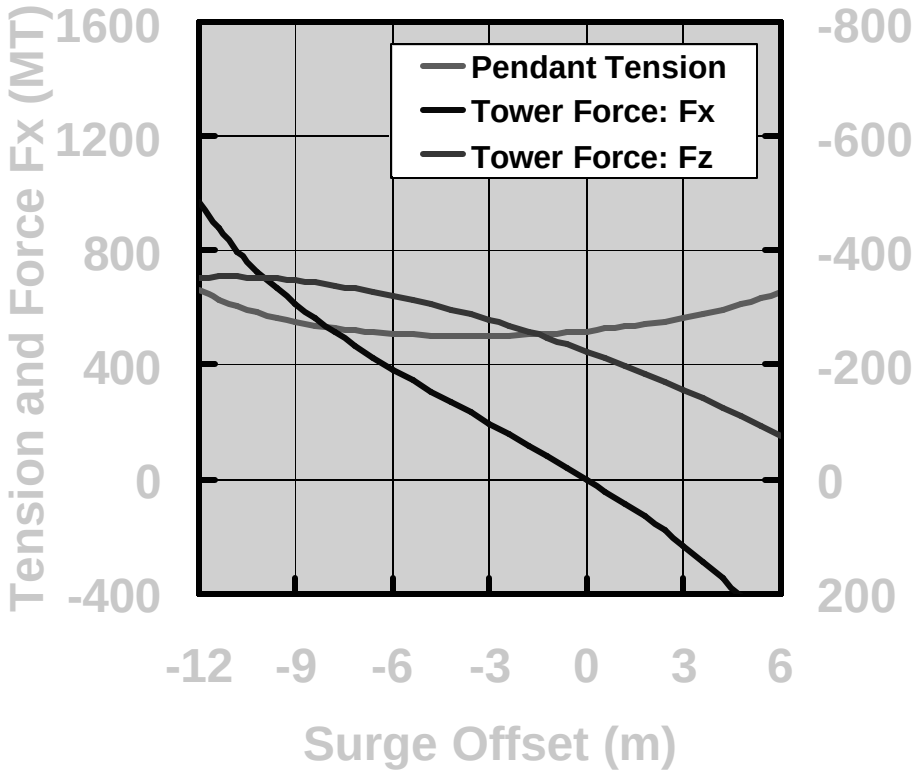
Simulation	Maximum Tension (MT)	Maximum Offset (m)
1	560	19.5
2	450	17.2
3	434	18.1
4	576	18.6
5	512	17.4
6	506	17.1
7	580	18.1
8	490	17.0
9	579	20.8
Mean	**521**	**18.2**
Std. Dev.	**56**	**1.3**

Example 2: Tower Yoke Moored FPSO

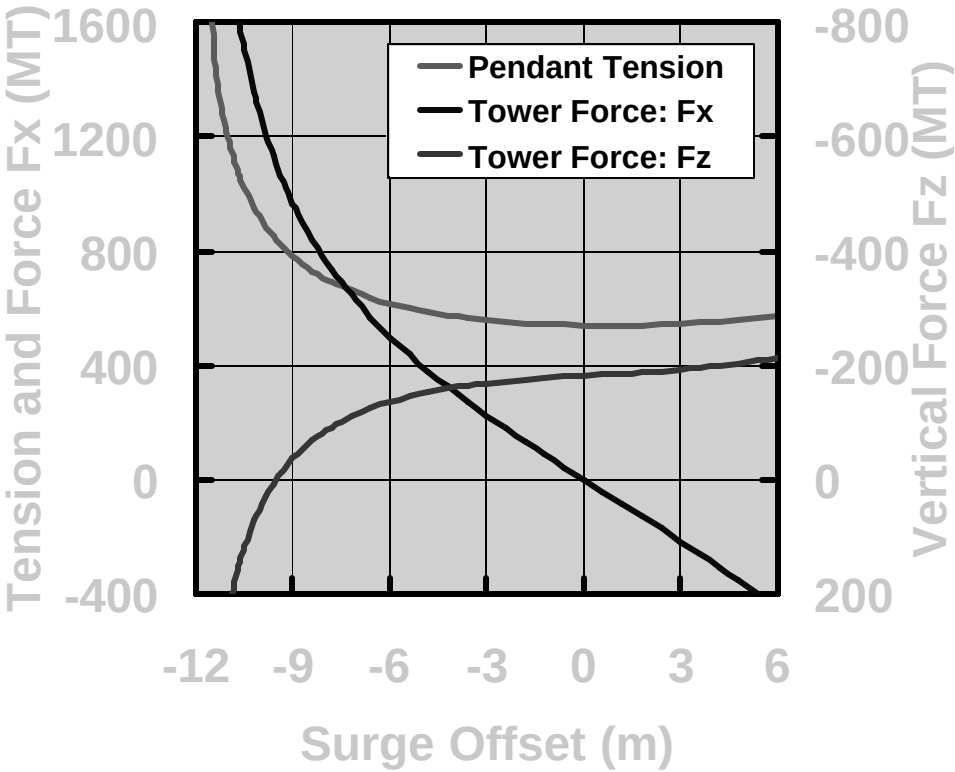
- **Water Depth: 25 meters**
- **100-yr Wave: Hs=5.0m, Tp=10s**
- **Current: 1.4 m/s**
- **Wind: 24 m/s**
- **Risers: 6 Risers**

Tower Yoke Mooring Stiffness

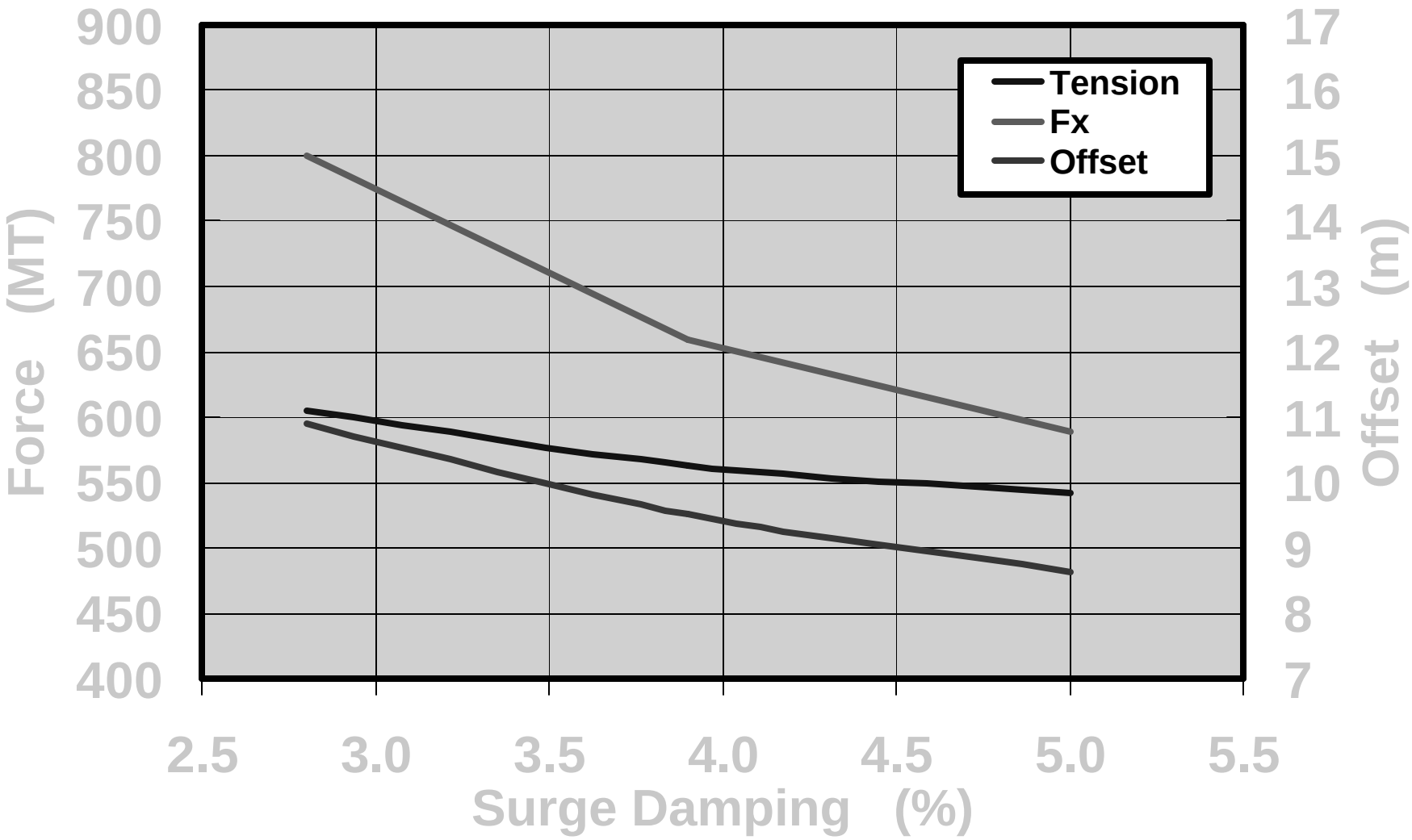
Full Load



Ballast Load



System Response as a function of Damping



Summary and Conclusions

- **Complex Interaction between**
  - **Environment**
  - **Seafloor**
  - **Vessel**
  - **Mooring**
- **Proper Specification of Metocean Criteria important for Shallow Water Systems**
- **Riser Design can Influence Mooring System Choice**
- **SPM Industry has an Excellent Track Record in Shallow Water**