FPSO Station Keeping Systems - Issues & Experience

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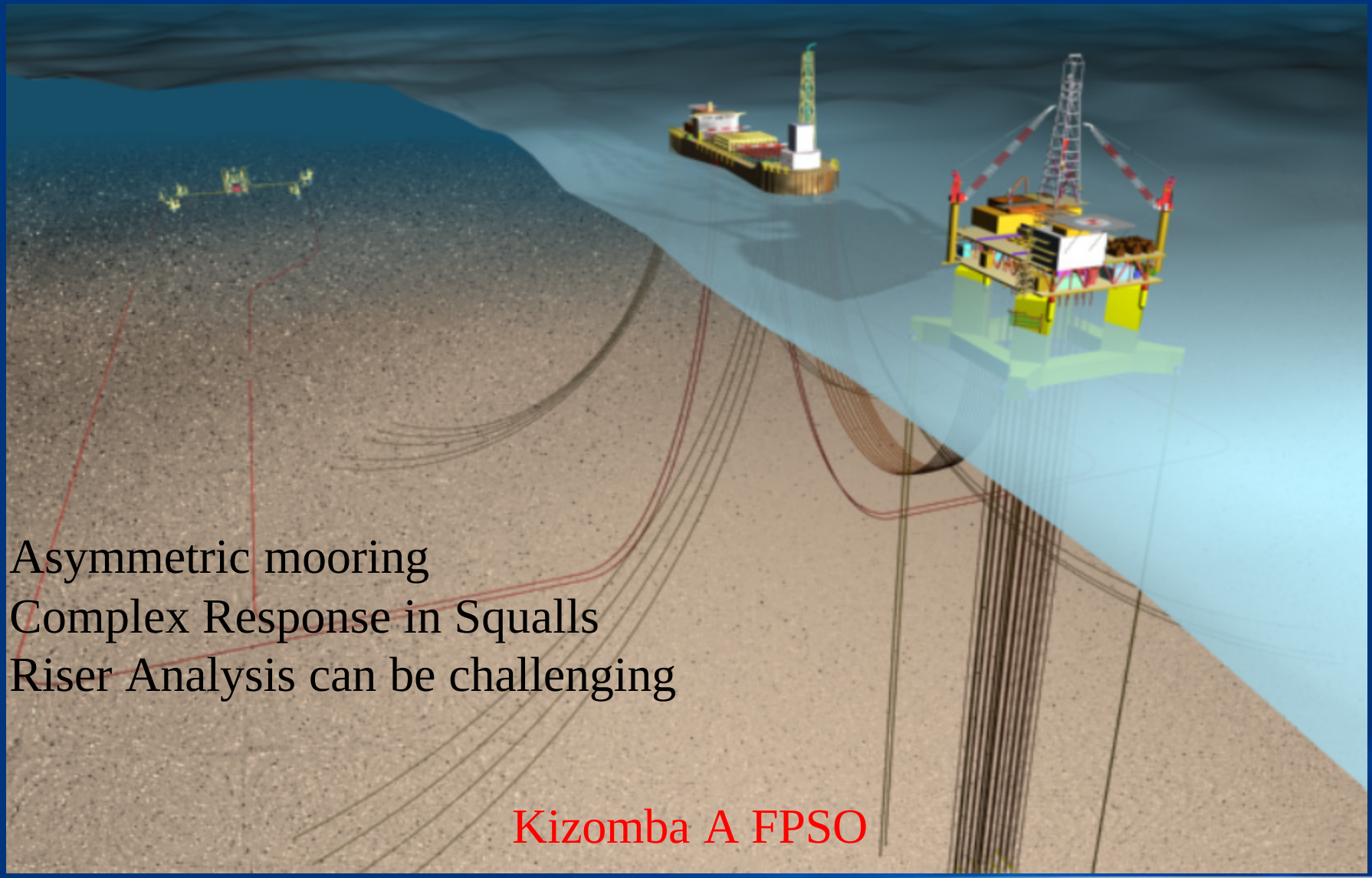
Outline of Presentation

- General Overview
  - Spread-Moored FPSOs
  - Turret-Moored FPSOs
- DP FPSO for Ultra Deep Water
- Some comments/issues based on personal experience

FPSOs are a Mature & Versatile FPS Technology

- Over 100 units in operation worldwide
- FPSO total > than all other FPS combined
- Water depth range <20 m to > 1,400 meters
- 1 to 100+ risers
- 10,000 bbl – 200,000 bbls/day
- Up to 2,000,000+ bbls storage
- Benign (West Africa) to Extreme Environments (North Atlantic)
- Various flavors:
  - Turret-moored
  - Spread-moored
  - Yoke-moored
  - Hawser-moored

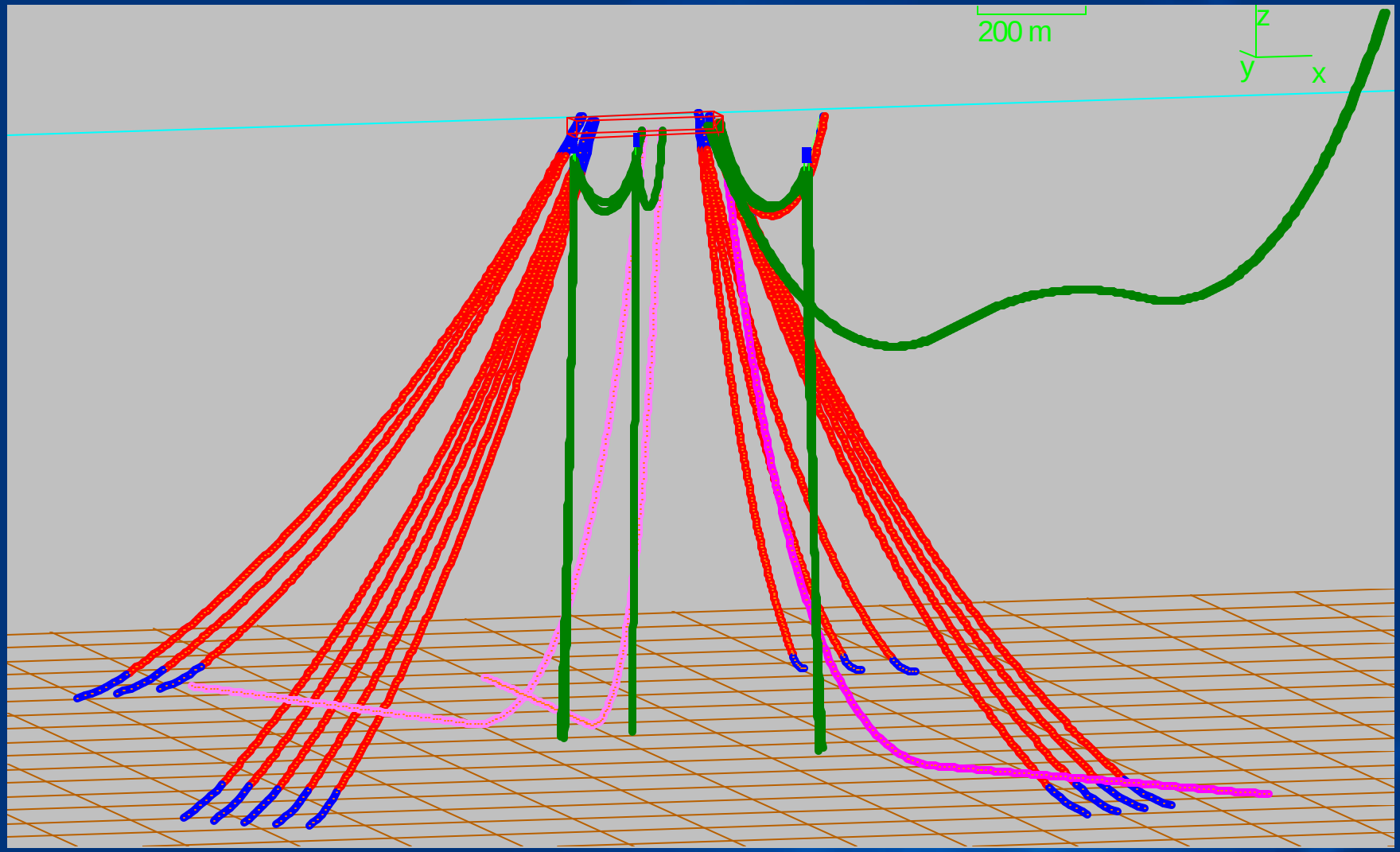
Spread-Moored FPSOs for Deep Water



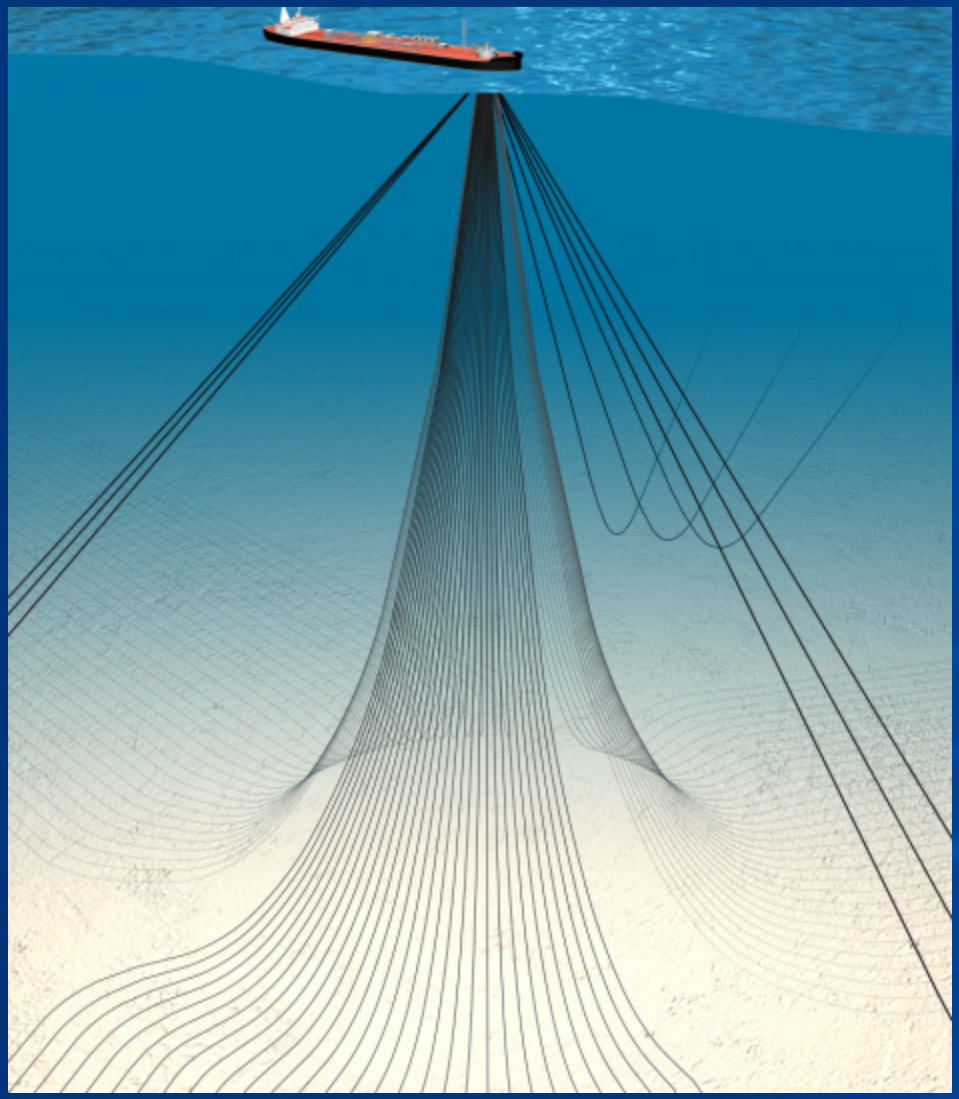
Asymmetric mooring
Complex Response in Squalls
Riser Analysis can be challenging

Kizomba A FPSO

Deep Water Spread Moored FPSO

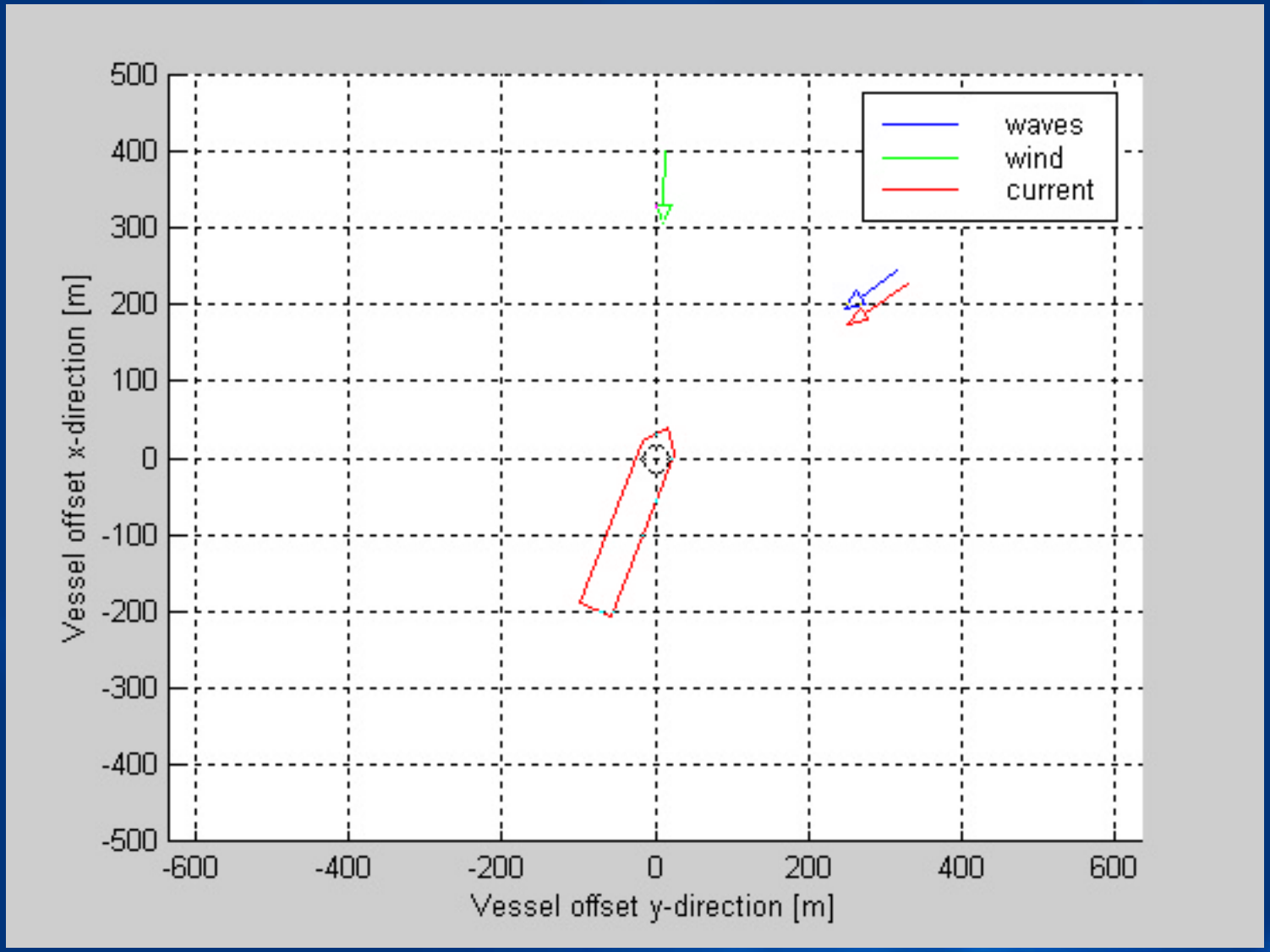


Turret Moored FPSOs for Deep Water



- Uses conventional turret-mooring technology
- Weathervaning ability provides efficient stationkeeping
- Typically 9 – 12 anchor legs sufficient
  - Wire/Chain: 7 – 10% WD
  - Polyester: 3 – 5% WD
- Readily adapts to deepwater riser systems
- From a Global Analysis Perspective – easier to analyze than shallow water systems

Response of a Turret-Moored FPSO in a Hurricane



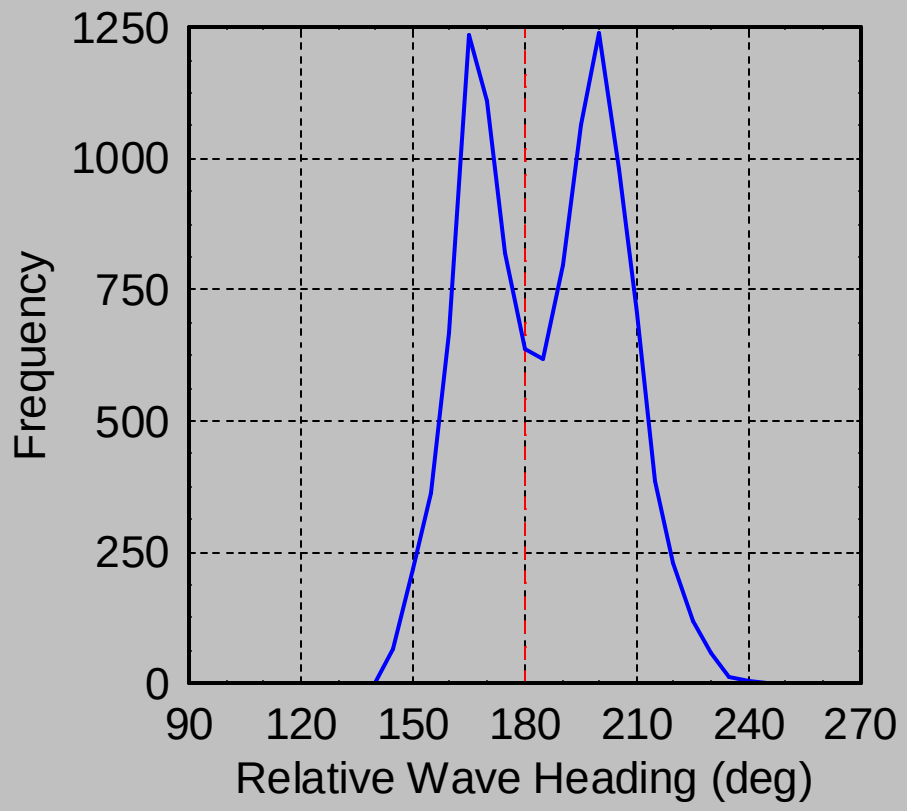
Specification of Environmental Conditions for Turret-Moored FPSO Design

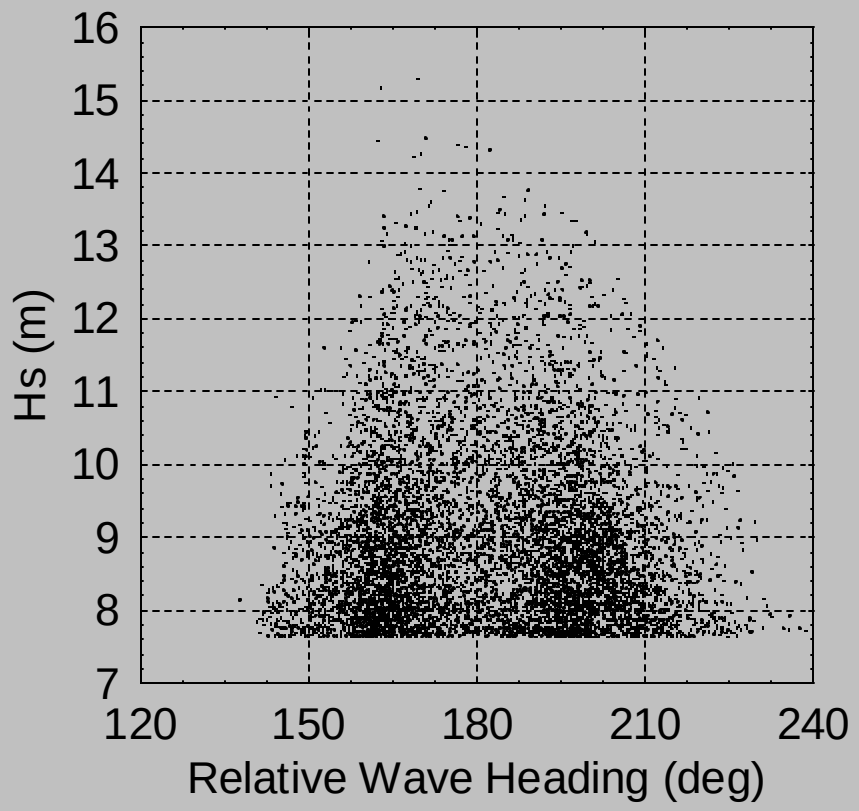
- Turret Moored FPSO Response is very sensitive to Crossed Environmental conditions
  - Requires definition of associated intensity and direction of wind, wave and current components for extreme and operational conditions
- Many ITT documents contain insufficient or non-specific definition of criteria
  - Standard metocean report for fixed/FPS systems issued
  - Metocean data simplified or incomplete
  - **Problem:** Is usually part of the contractual basis
- **Alternative:** Use Design Recipes based on experience (or inexperience!) or Class Society recommendations
  - May not result in accurate estimate of actual system performance and response

Long-term Response Analysis of FPSO Systems

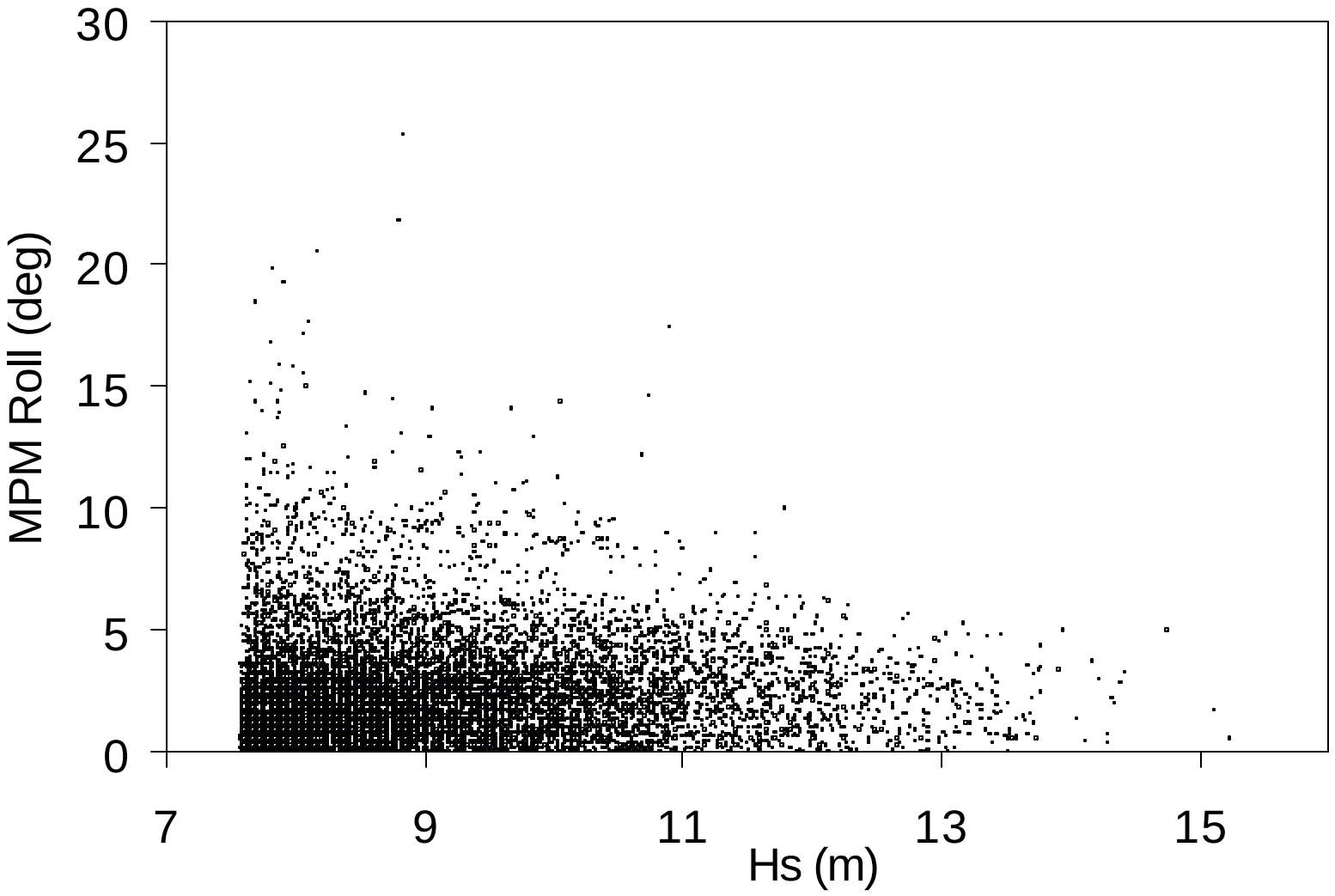
- **Goals**
  - Accurate prediction of long-term response levels
  - Identify responses that are sensitive to changes in environmental parameters
  - Develop design seastates to estimate 100-year response levels
- **Requirements:**
  - Joint probability of environmental parameters
  - Hindcast database (GUMSHOE, SEAMOS, etc)
  - Response model

FPSO Relative Wave Heading

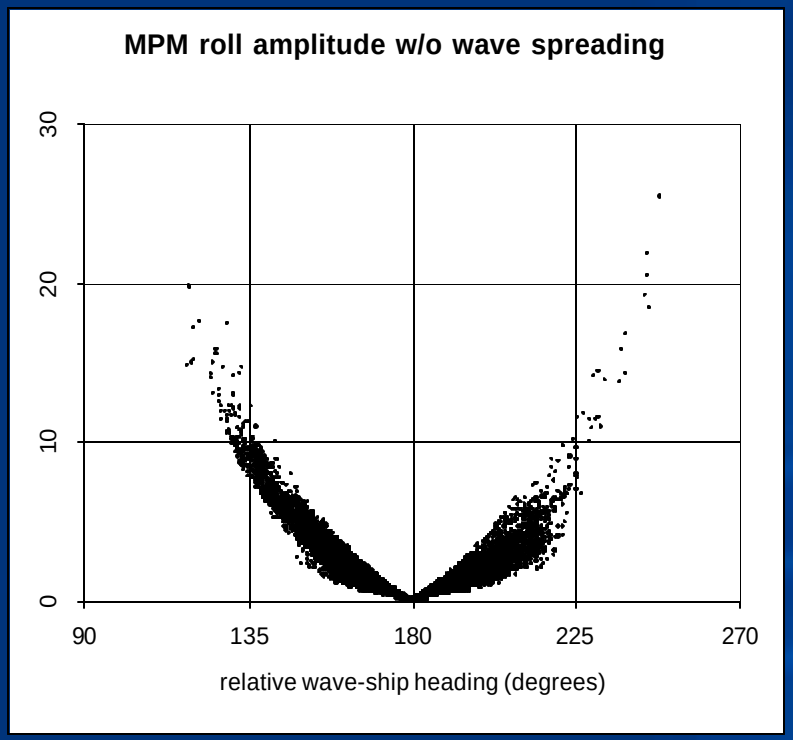


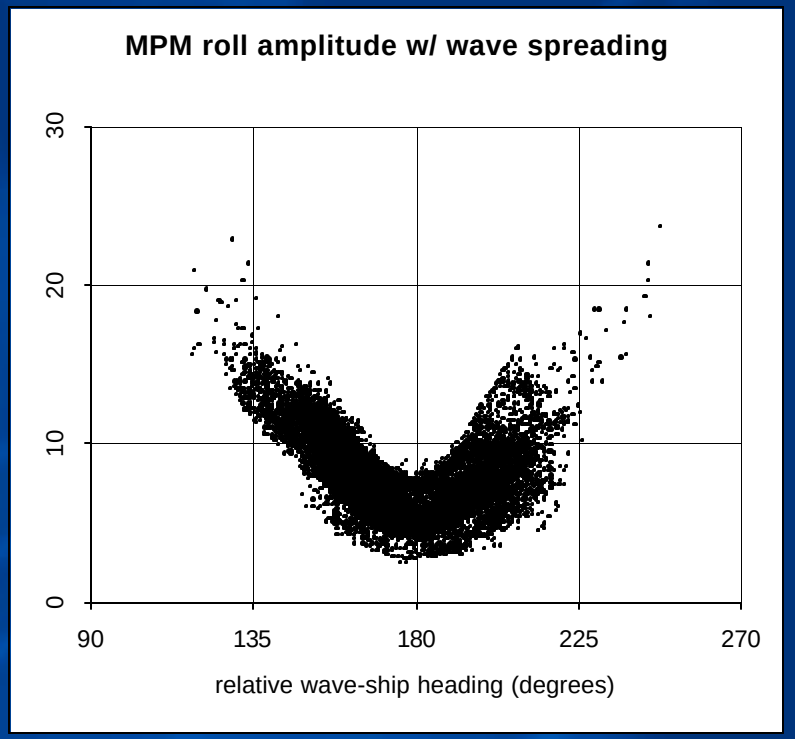


Roll vs Wave Height

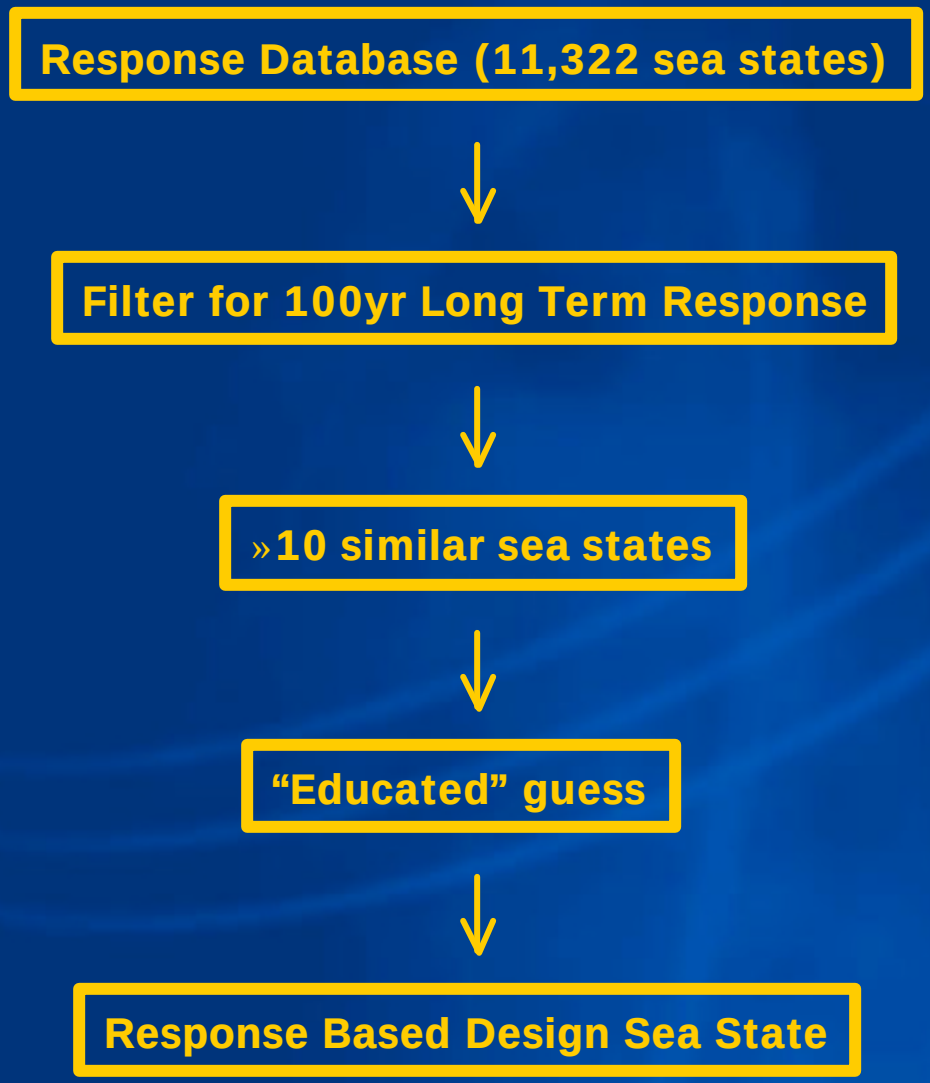


Effect of Wave Spreading





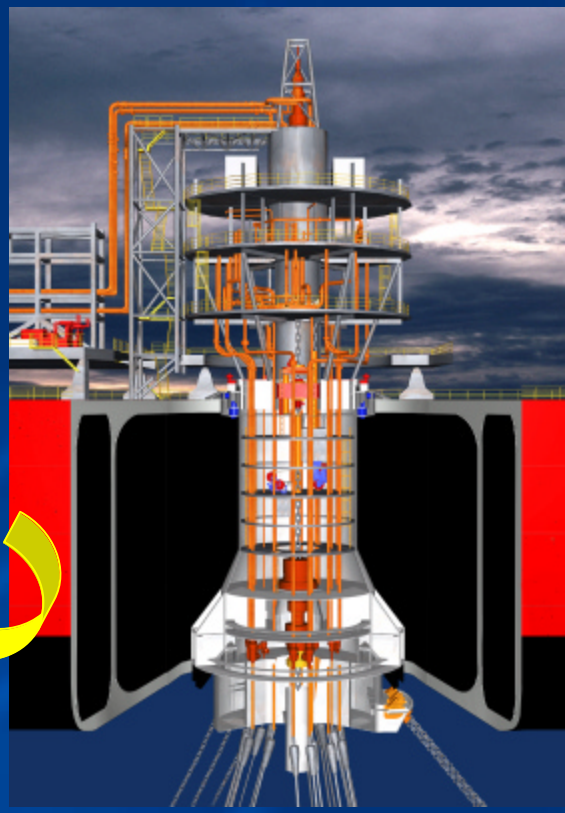
Design criteria - methodology

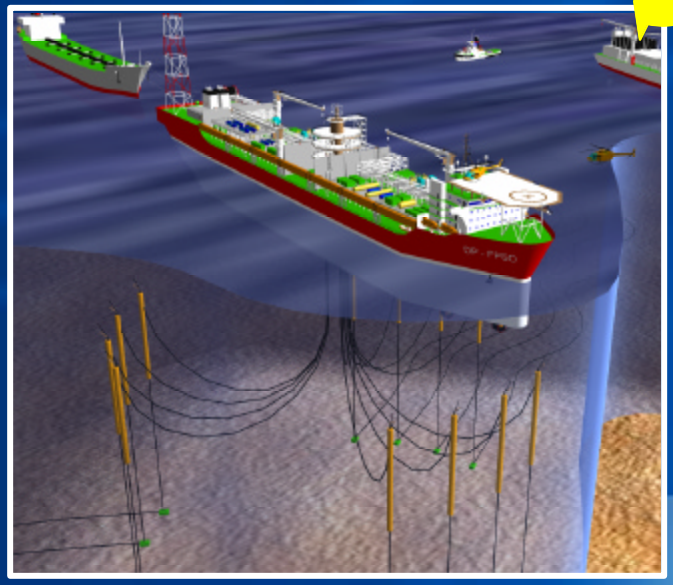


100-Year Designer Seastates

Parameter	Units	Offset	Tension	Heave	Roll	Pitch	Relative Wave		Design
							Bow	Side	
Hs	m	10.4	13.0	12.9	8.9	13.2	14.6	10.0	12.2
Tp	s	12.3	15.3	14.9	14.5	14.5	15.0	11.9	14.2
g		2.7	2.0	2.7	1.4	2.8	2.0	2.9	2.4
Heading	deg	45.0	130.0	162.0	134.0	165.0	175.0	220.0	?
Wind	m/s	30.9	38.1		27.5				36.5
Heading	deg	45.0	160.0		215.0				?
Current	m/s	2.2	1.8		0.8				1.8
Heading	deg	-25.0	140.0		147.0				?

DP FPSOs based on Proven Technology





DP FPSOs for Ultra Deepwater

- Joint Engineering Study
  - IZAR, Spain (Vessel, DP-Thruster Systems, etc.)
  - FMC SOFEC (Turret & Riser System)
  - Marin (Analysis & Model Testing)
  - DNV (Risk Assessment, Regulatory Requirements, Code Compliance)
- GoM FPSO
  - 2,500 meter water depth
  - 200,000 ton displacement FPSO, 6x5 MW thrusters
  - 16 risers
  - 125,000 bbl/day
  - Designed to stay on station for 10-year hurricane

DP FPSO: Pros & Cons

Advantages:

- Utilizes Proven Offshore Technology
- Adapts to Ultra-Deepwater
  - No anchor leg system
  - No interference with equipment on seabed
  - Deepwater allows large offsets – easier control
  - Hybrid riser system suited for ultra deep water
- Candidate for an Early Production System
- Diconnectability allows for Easy Evacuation during Hurricanes

Issues:

- Stationkeeping Reliability
  - Power generation system
  - Thrusters
  - Control system
  - Operators
- Disconnectable Riser System
- Maintenance
- Life of Field Costs

Other Issues – Personal Experience

- Installation Related
  - Suction pile landing speed and positioning
  - Mooring line twist – during installation and pull-in
  - Class society criteria for vertically loaded anchors (VLAs)
  - Correct specification of polyester rope lengths and expected stretch during installation
- Definition/Specification of Vessel Offset Criteria for Riser Design for Spread Moored vessels
- Estimation of Vessel Roll Motions
  - Metocean conditions specification
  - Viscous damping estimation
  - Bilge Keels

Conclusions

- FPSOs readily adaptable as a FPS for a variety of water depths worldwide
- Design of FPSO Stationkeeping Systems presents different challenges in Shallow versus Deep Water
- Proper specification of Metocean conditions essential for accurate performance and response prediction
- DP FPSO could be a technically feasible option for ultra deepwater developments
  - Will operators buy into the concept?
- Mooring Designers are faced with a much broader scope of work to help solve mooring related issues that were typically left to others