

FPSO Station Keeping Systems - Issues & Experience

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FMC SOFEC Floating Systems

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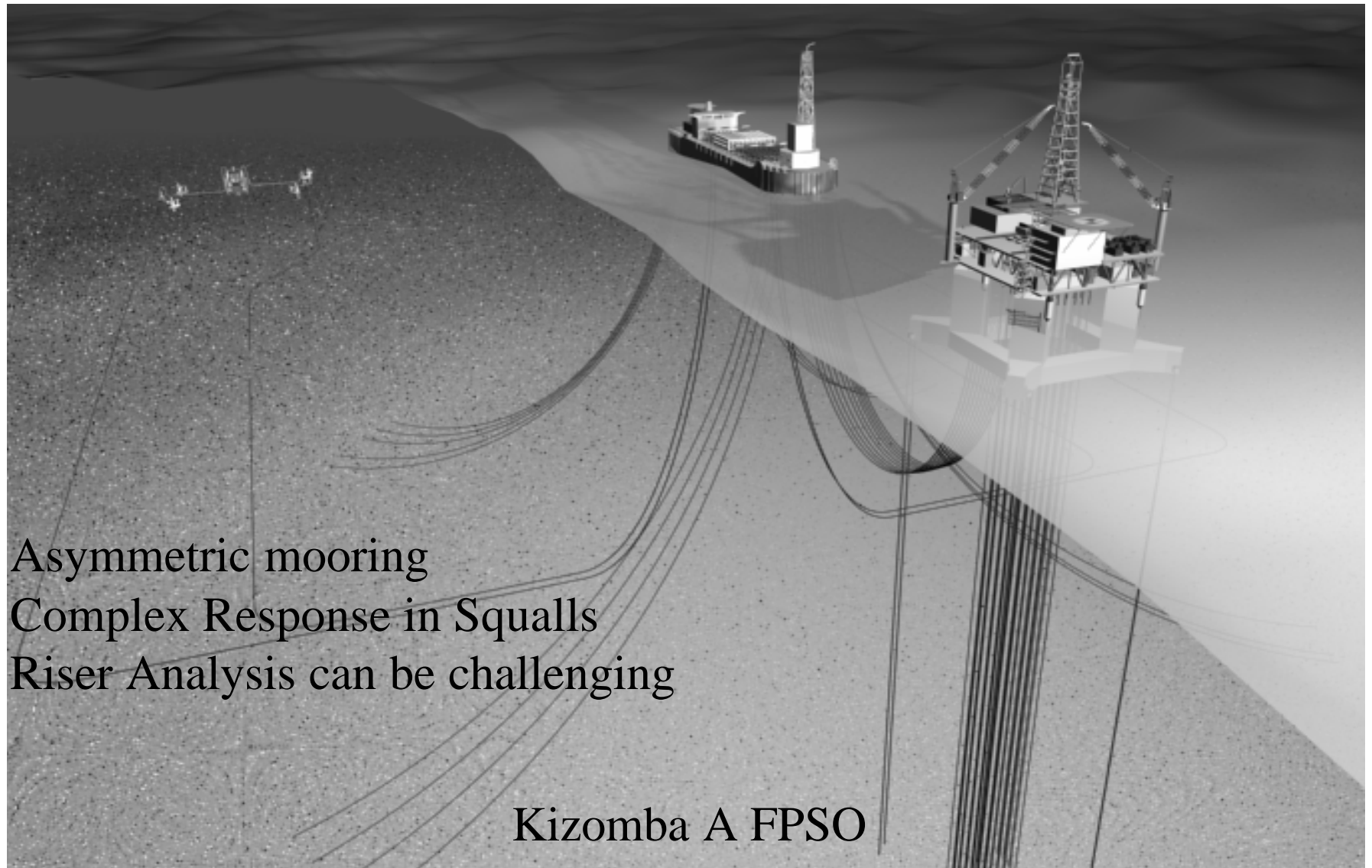
Outline of Presentation

- **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**

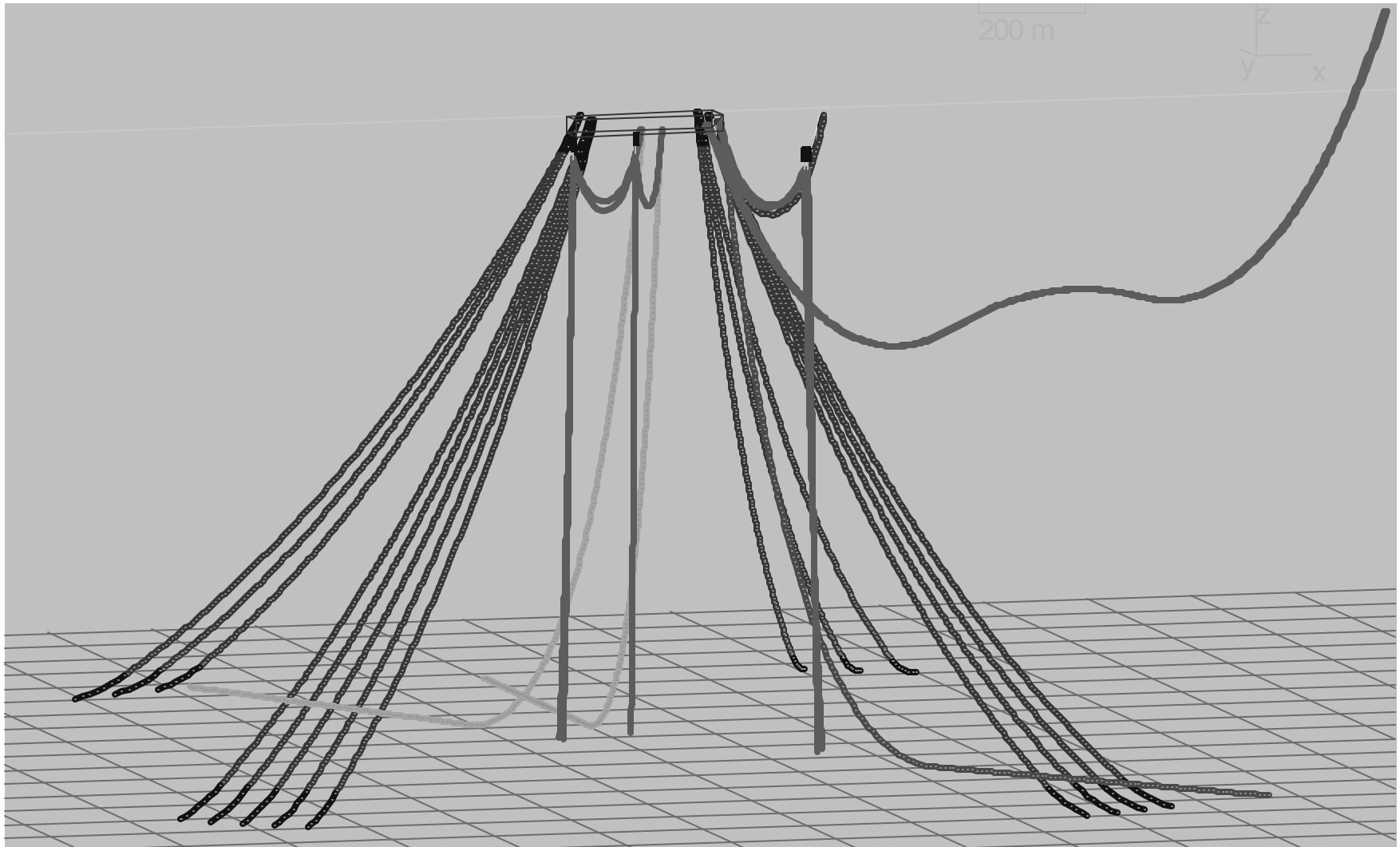
Spread-Moored FPSOs for Deep Water



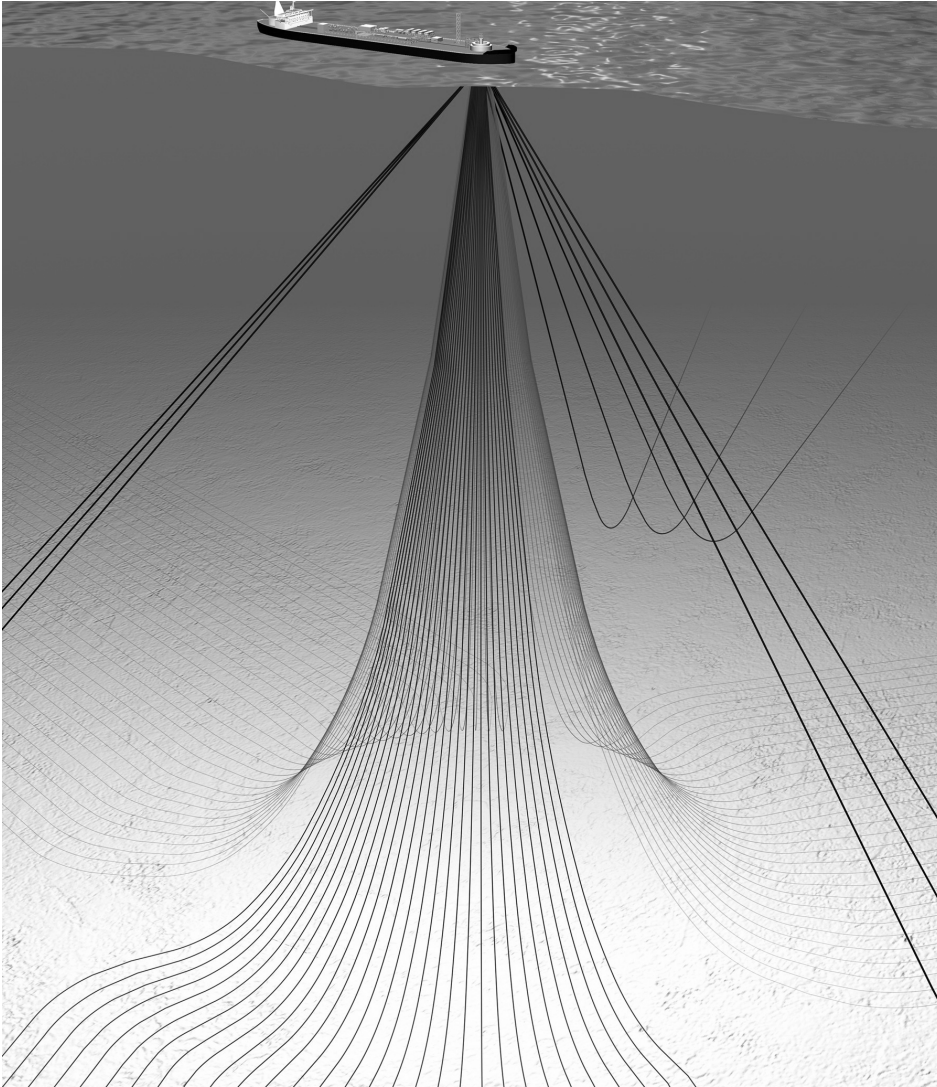
Asymmetric mooring
Complex Response in Squalls
Riser Analysis can be challenging

Kizomba A FPSO

Deep Water Spread Moored FPSO

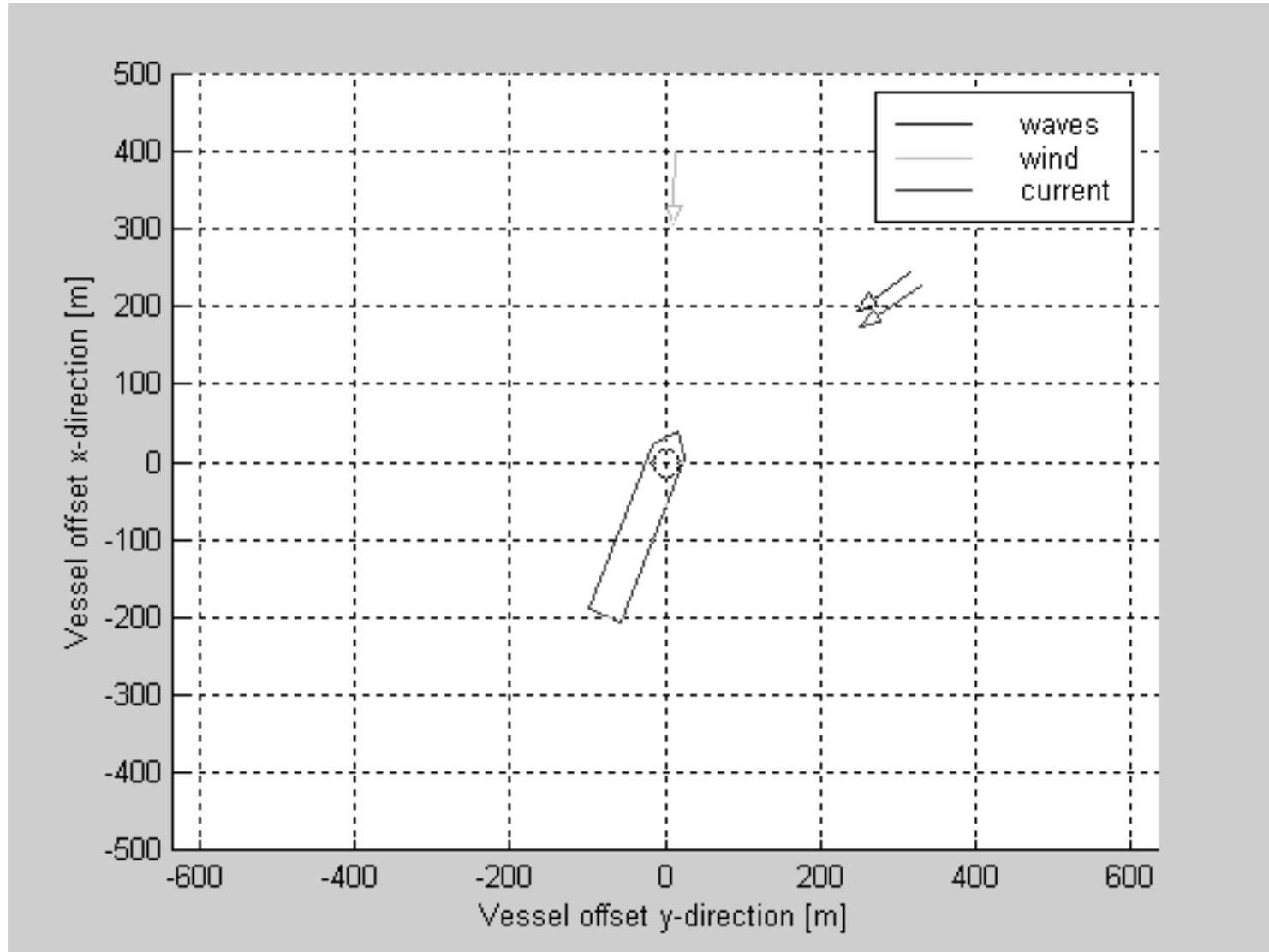


Turret Moored FPSOs for Deep Water



- 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



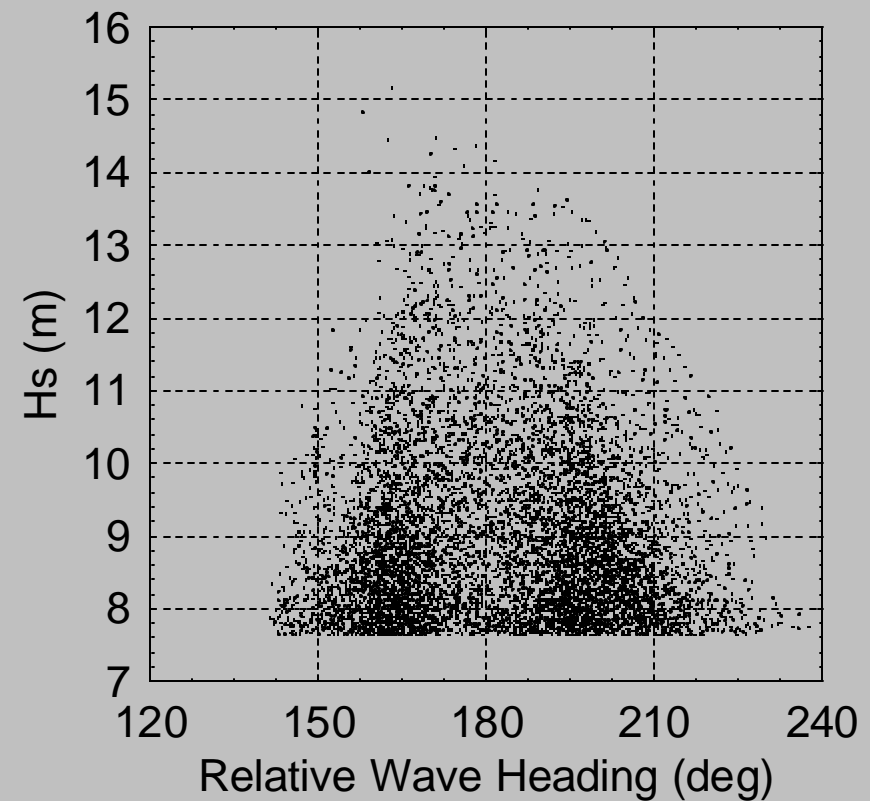
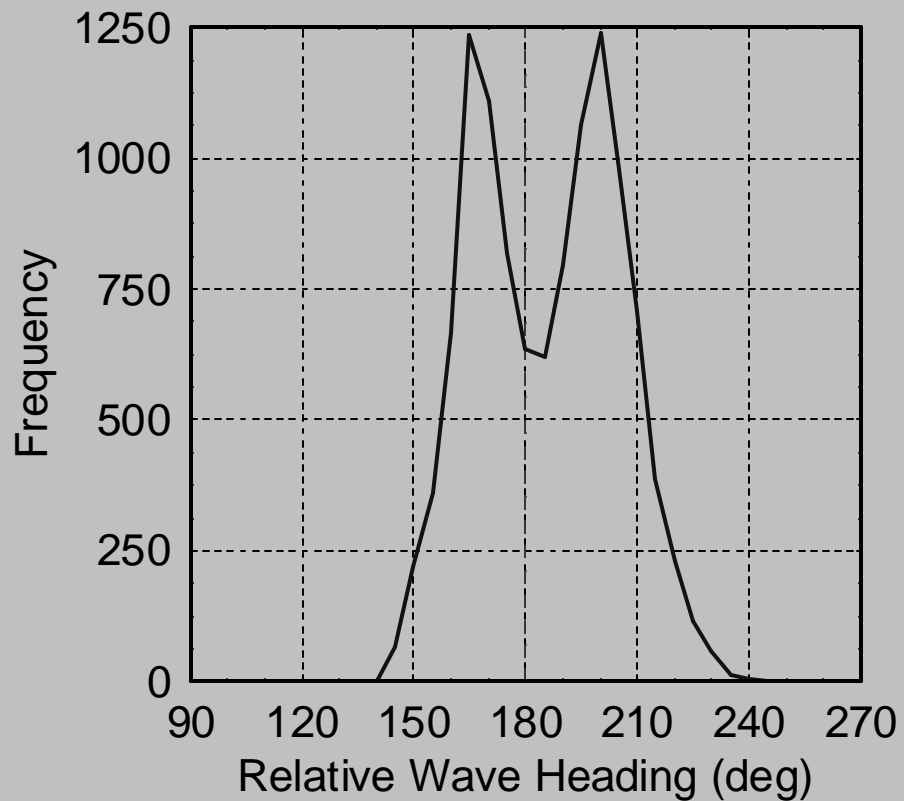
Specification of Environmental Conditions for Turret-Moored FPSO Design

- **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

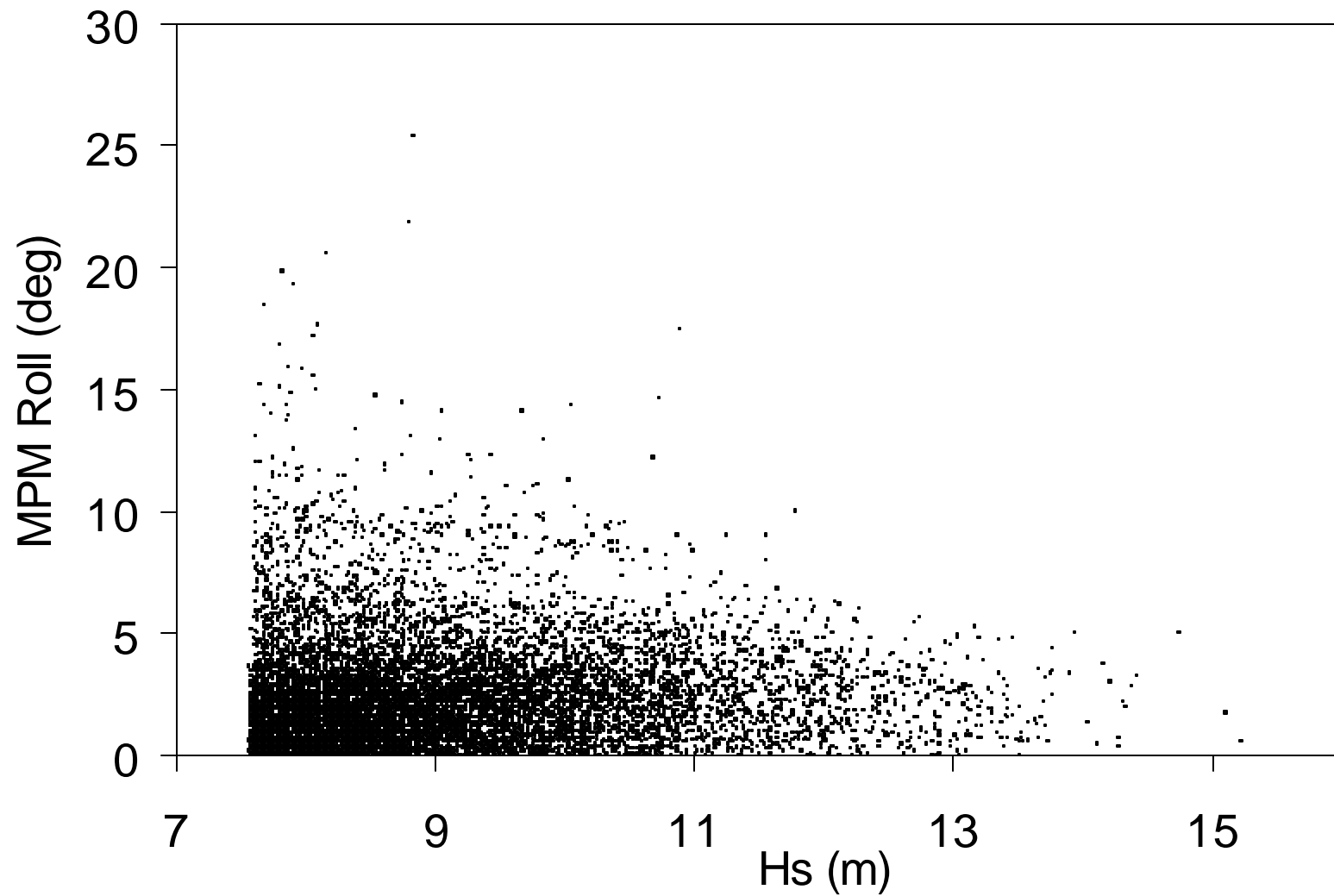
Long-term Response Analysis of FPSO Systems

- **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

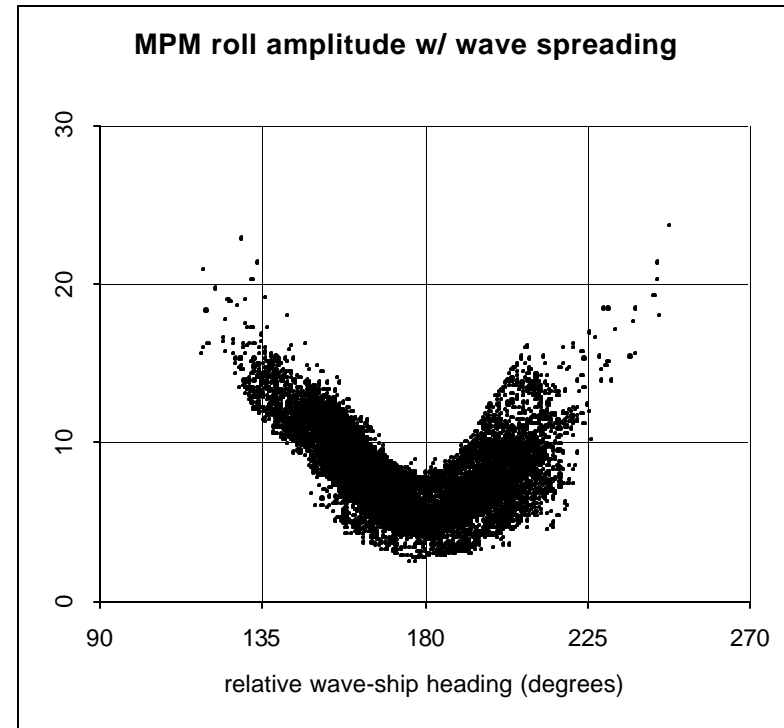
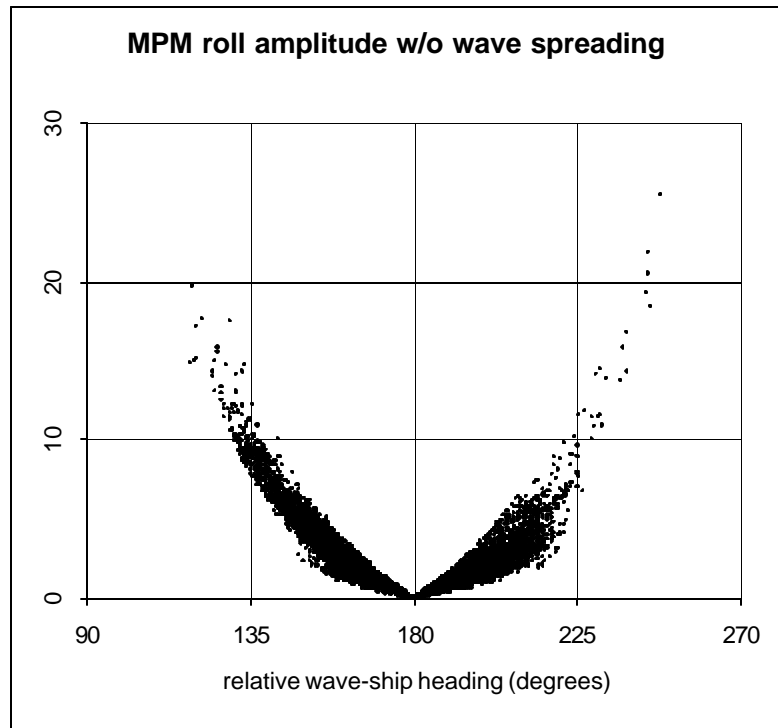
FPSO Relative Wave Heading



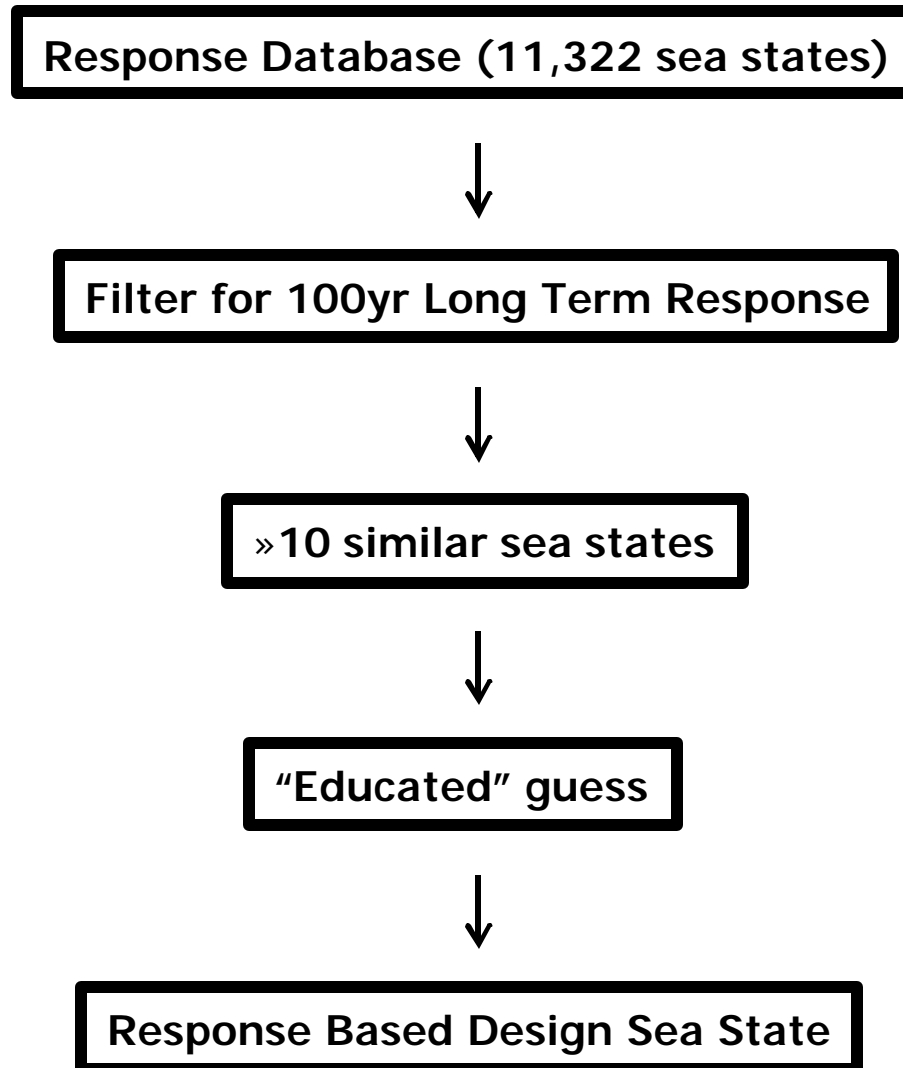
Roll vs Wave Height



Effect of Wave Spreading



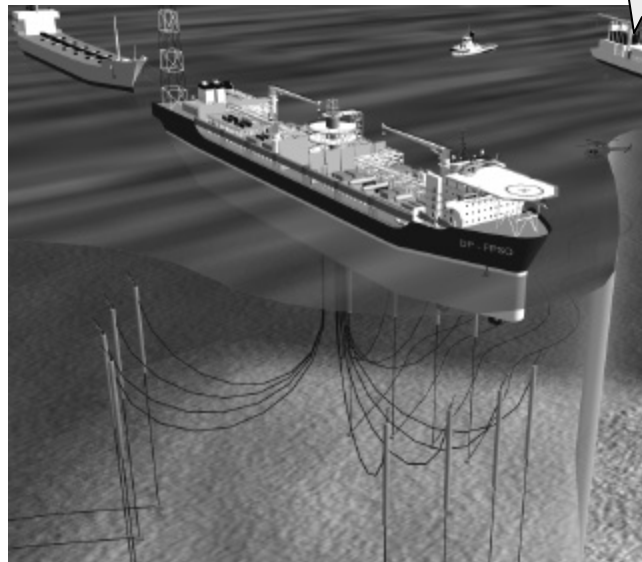
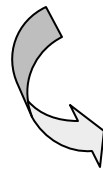
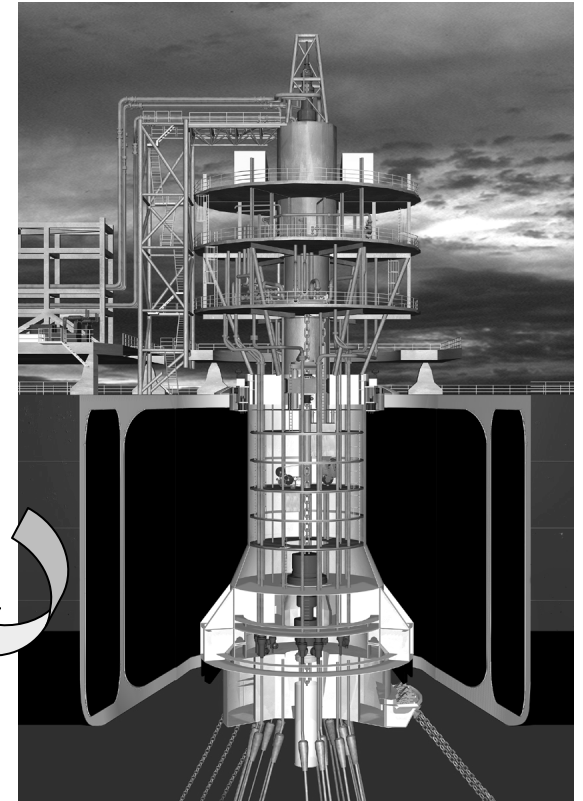
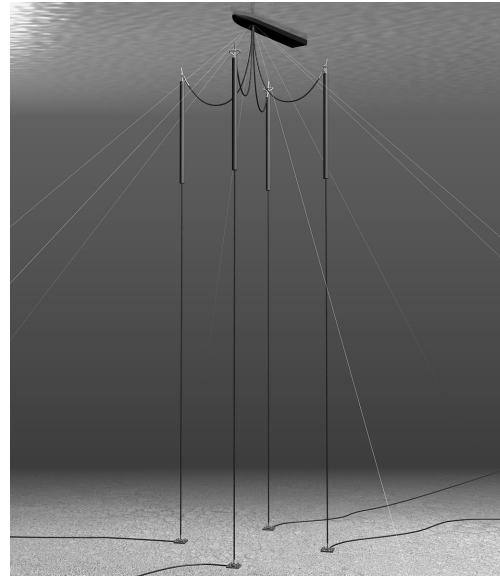
Design criteria - methodology



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



Innovative Technologies, Creative Solutions

FMC Energy Systems

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**
- **Disconnectability 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**