

Definition of Metocean Criteria for FPSO Systems

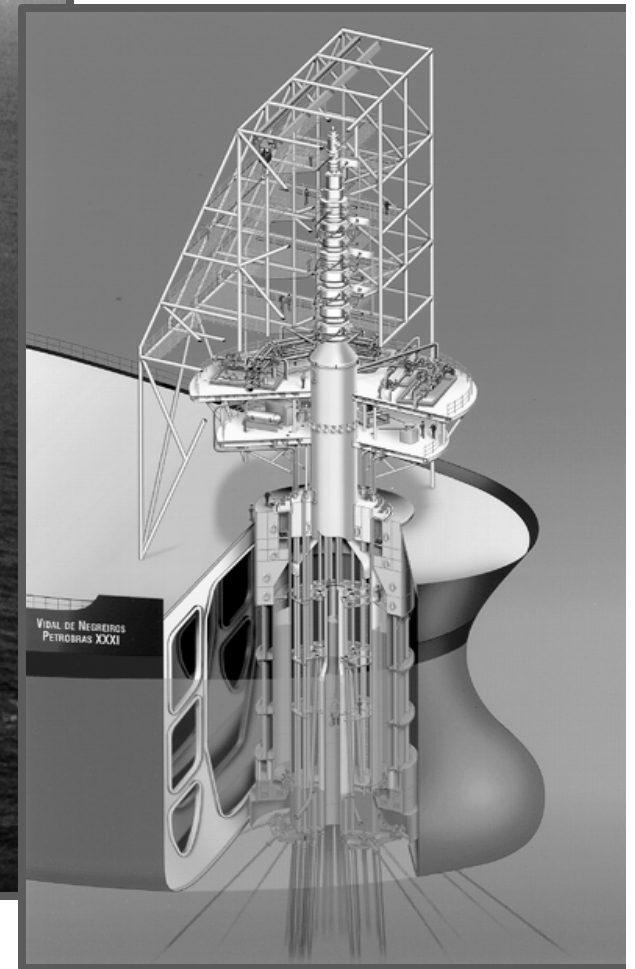
Deepwater Mooring Symposium, Houston

Arun Duggal

FMC SOFEC Floating Systems

3 October 2003

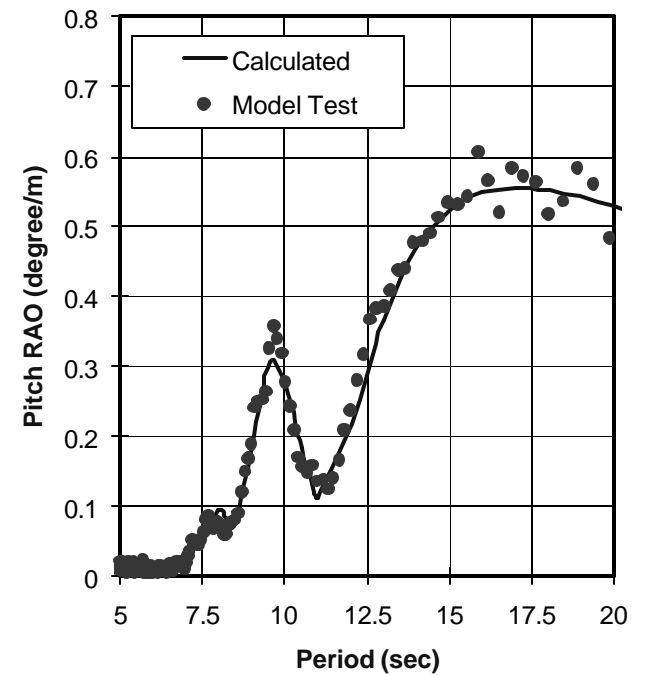
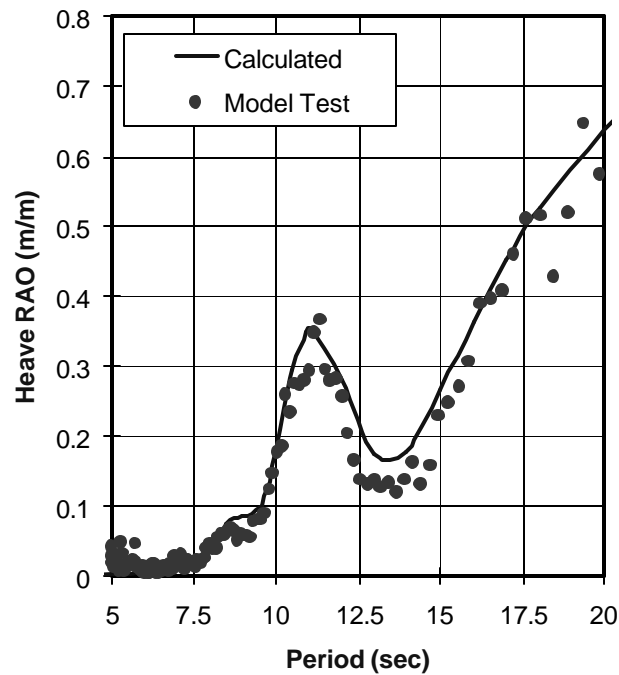
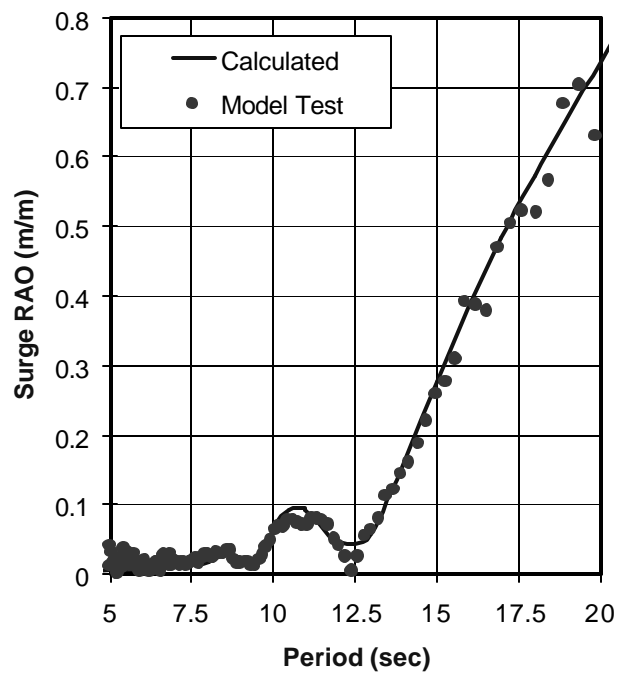
Deepwater Turret Mooring – P-31, Brazil



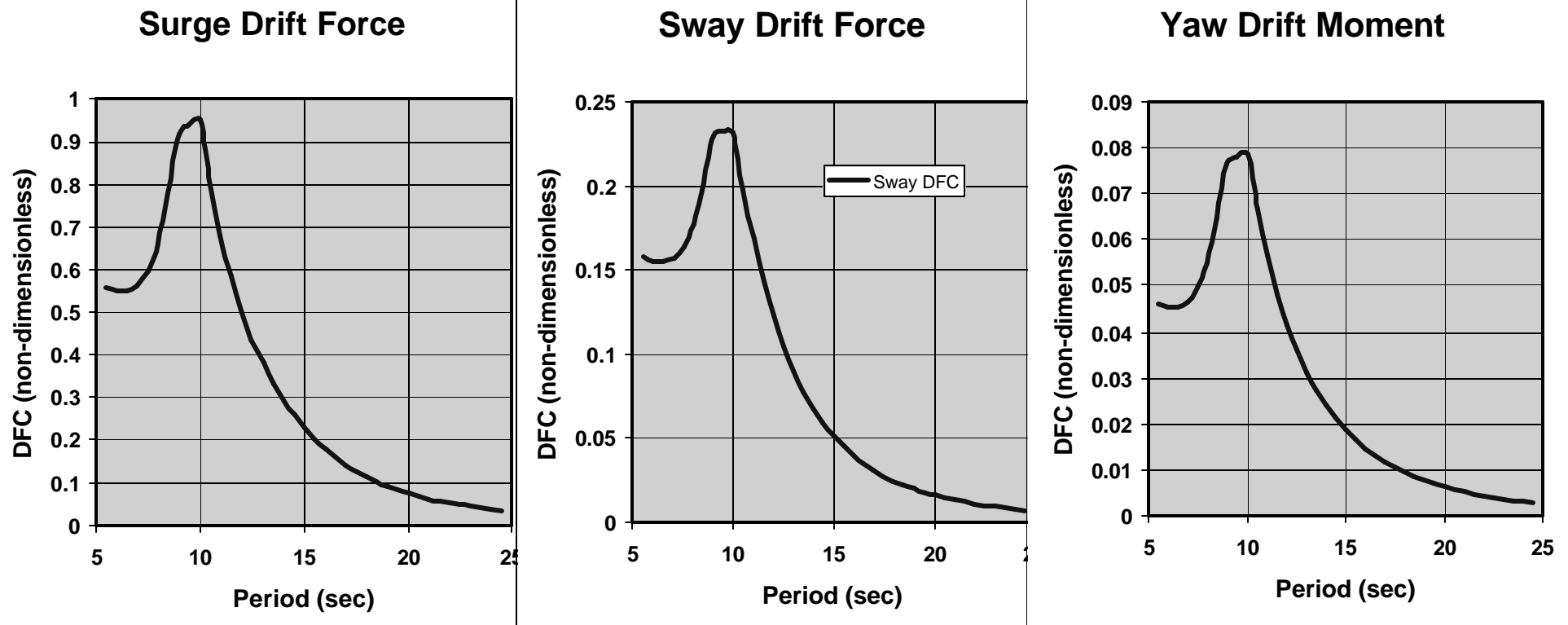
Innovative Technologies, Creative Solutions

FMC Energy Systems

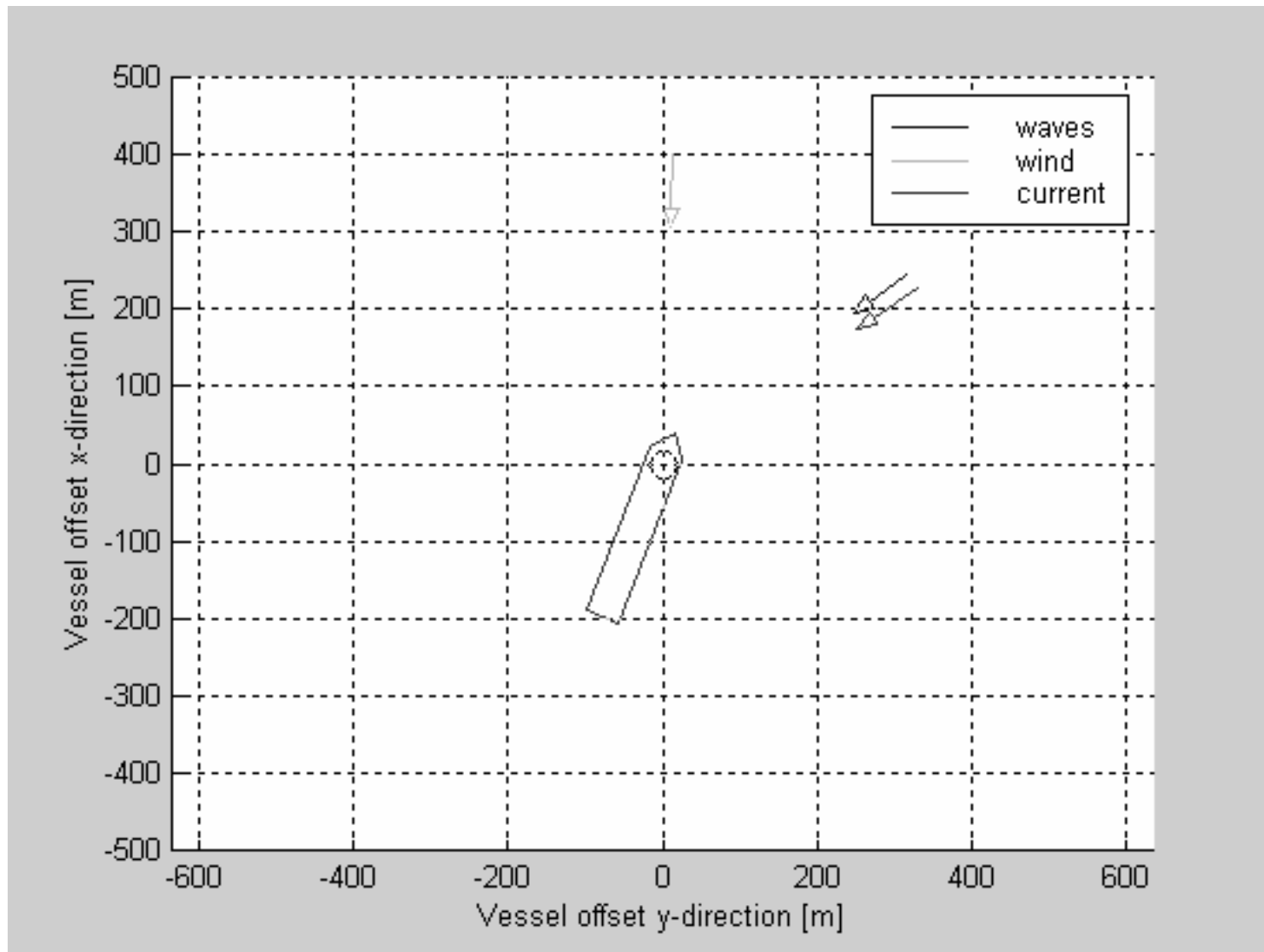
Sample FPSO RAOs – Terra Nova



Sample Drift Force Coefficients



Response of a T-M FPSO in a Hurricane



Specification of Environmental Conditions for Turret-Moored FPSO Design

- **Turret Moored FPSO Response is very sensitive to Crossed Environmental conditions**
- **Many ITT documents contain insufficient or non-specific definition of criteria**
 - **Standard metocean report for fixed/FPS systems issued**
 - **Metocean data overly simplified or incomplete**
 - **Return period values are estimated independently**
 - **Relative directionality between wind, wave and current not always presented**
- **Problem: Is usually part of the contractual design basis**

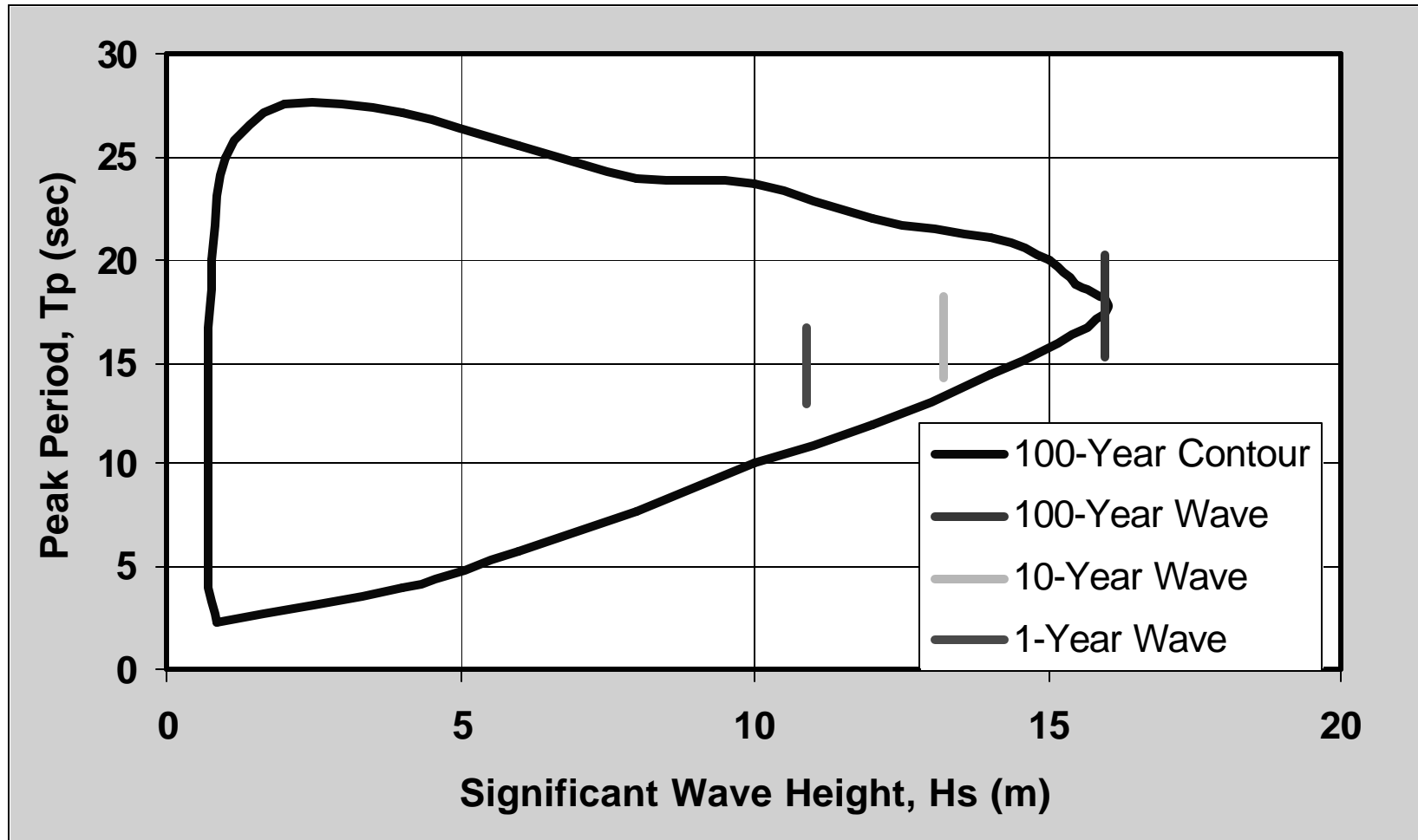
Specification of Metocean Criteria

- **Use Design Recipes based on experience (or inexperience!) and Class Society recommendations**
 - May not result in accurate estimate of actual system performance and response
 - Typically conservative for offsets and loads,
 - May not capture maximum value of some responses (roll, greenwater, etc.)
- **Response Based Environmental Criteria developed using long-term response based analysis of the system computed from hindcast database**

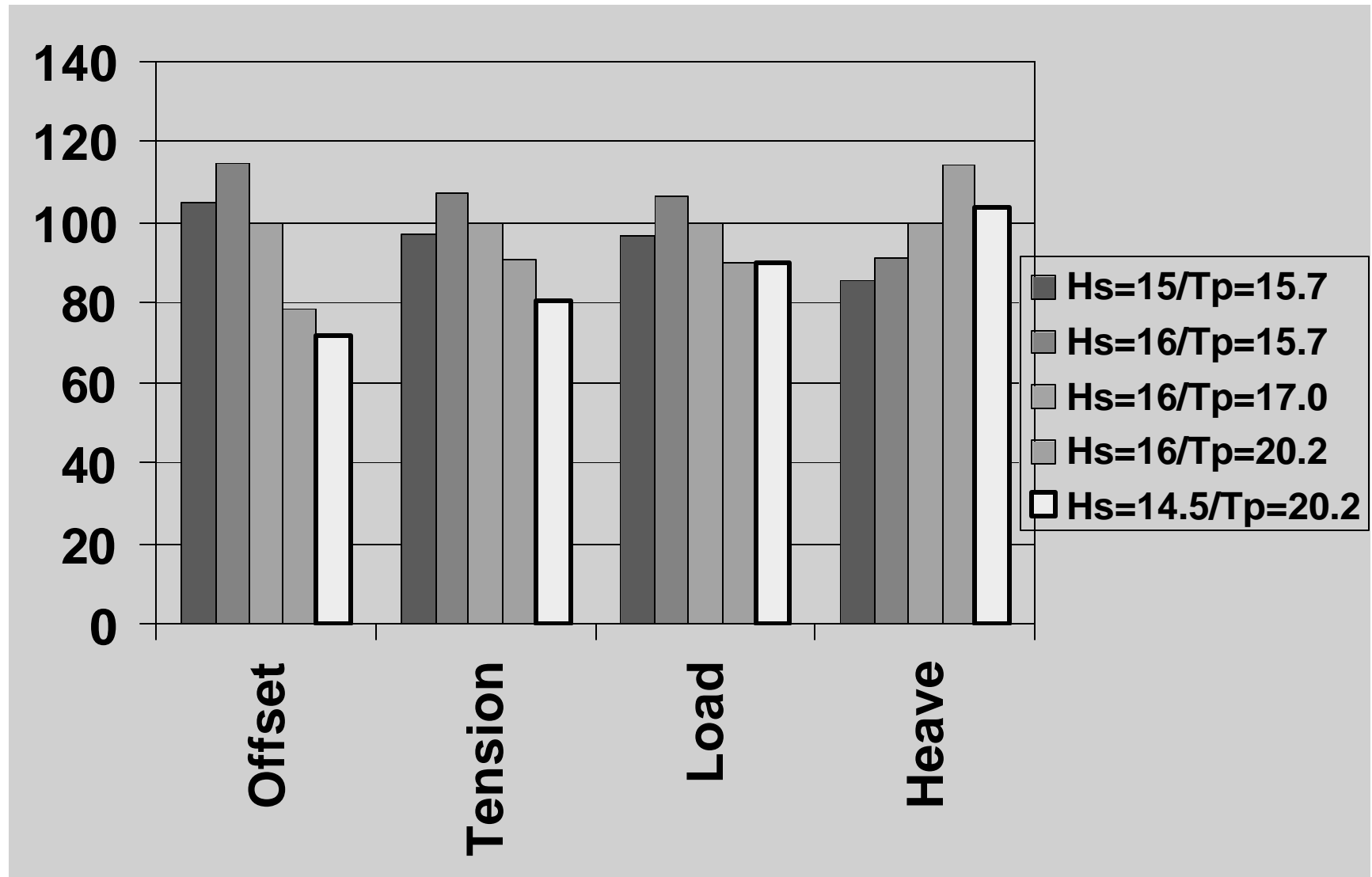
Class Society Guidelines if no site specific data available

- **ABS:**
 - 100-year waves with associated wind & current and combinations
 - Vary spectral peak period about 100-year Hs
 - Collinear, Crossed 30-30, Crossed 30-90
- **LR:**
 - 100-year wind + wave, 10-year current
 - 100-year waves + current, 10 year current
 - Use 100-year Wave Contour
 - Collinear, Crossed 30-30, Crossed 30-90 (only with 10-year current)
- **DNV:**
 - Use 100-year Wave Contour
 - Combine 100-year wind, 100-year waves, 10-year wind
 - Collinear, Crossed 30-45
- **API:**
 - No clear guidelines – consider directionality

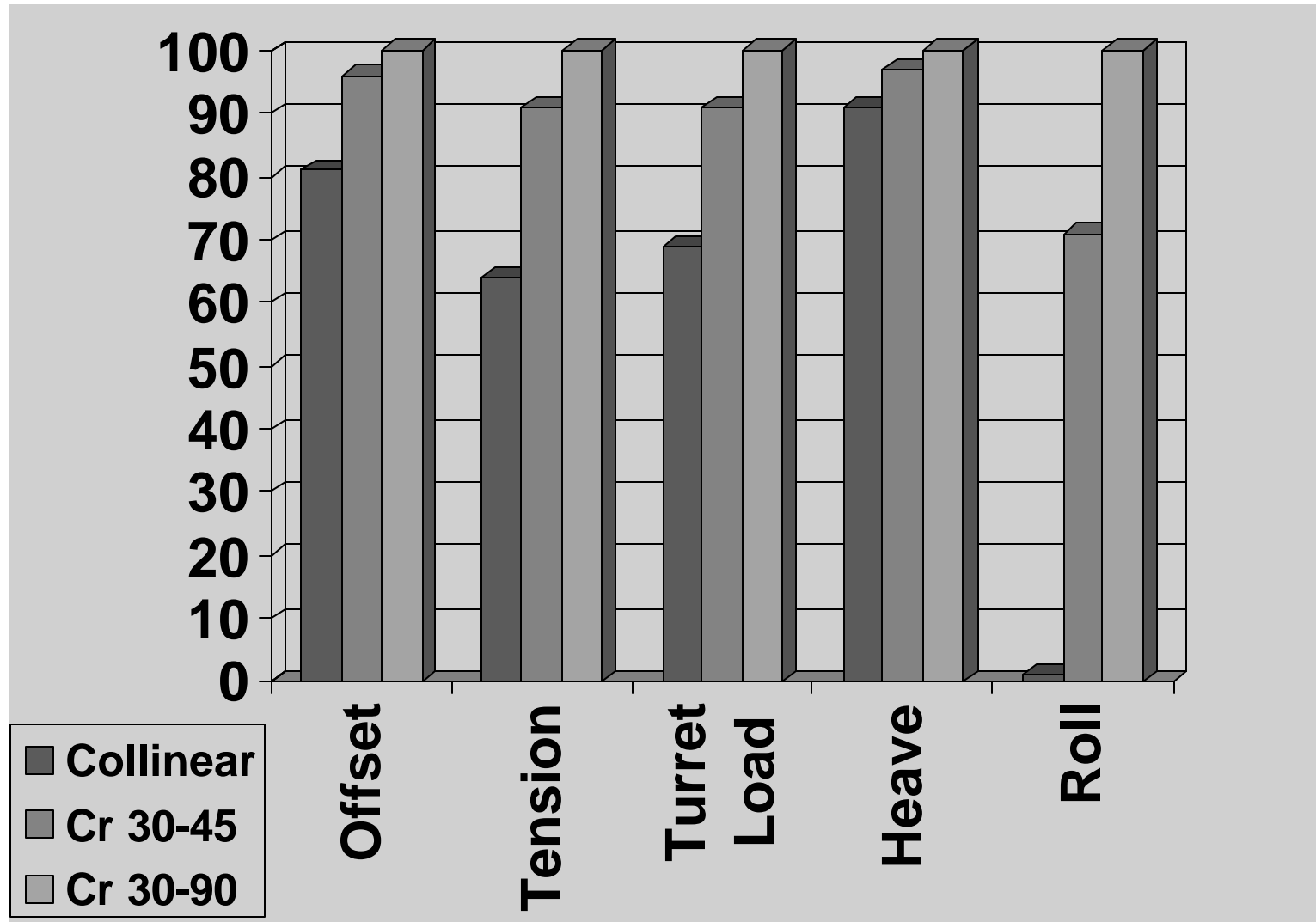
100-Year Wave Contour, Grand Banks



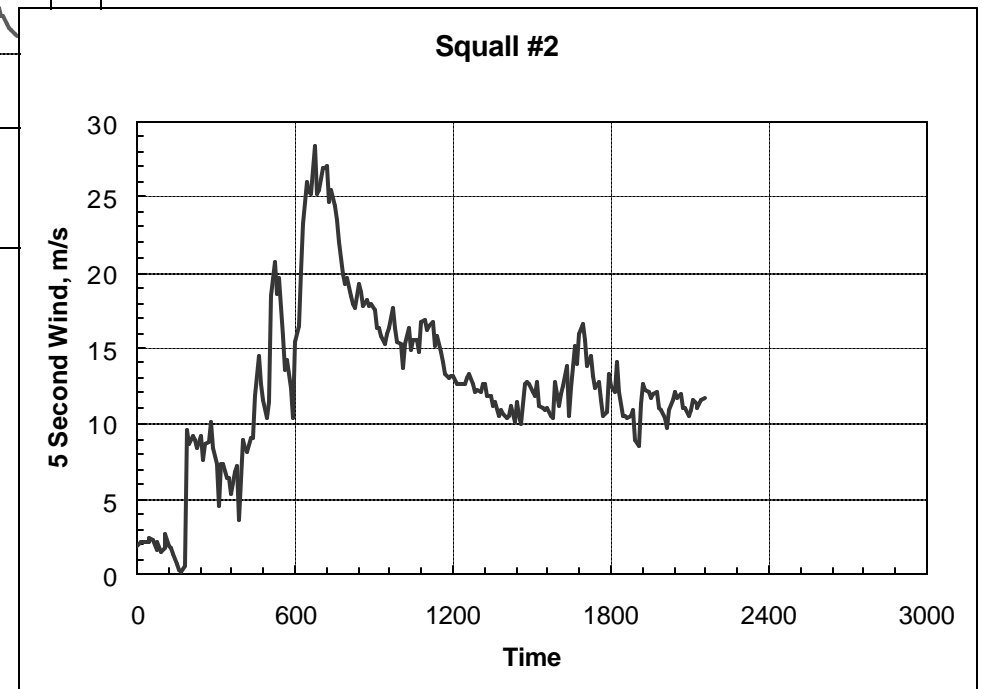
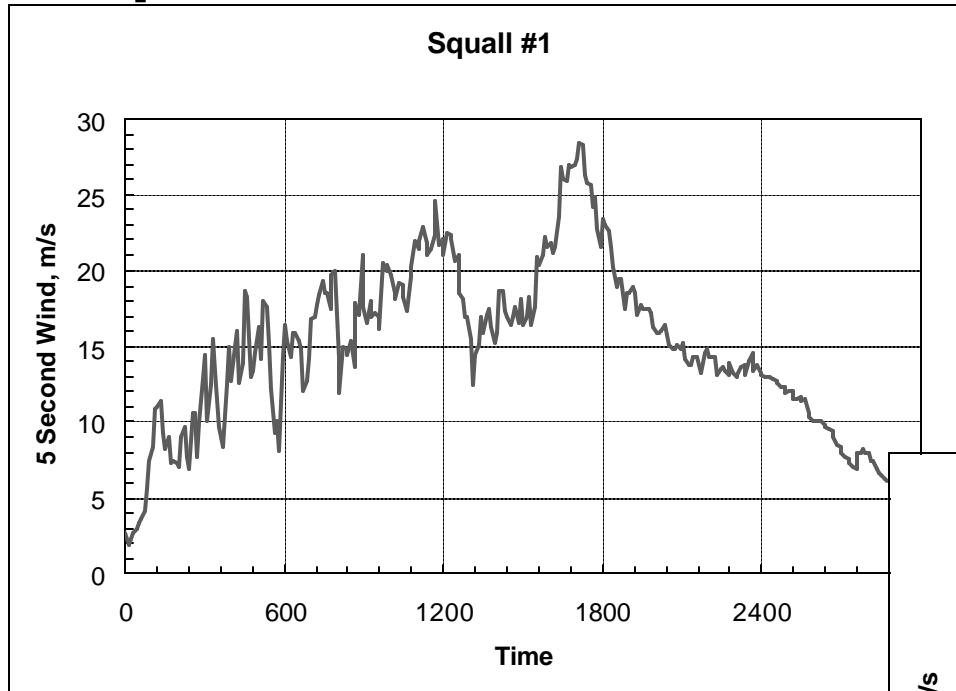
FPSO Responses to 100-Year Wave Climate



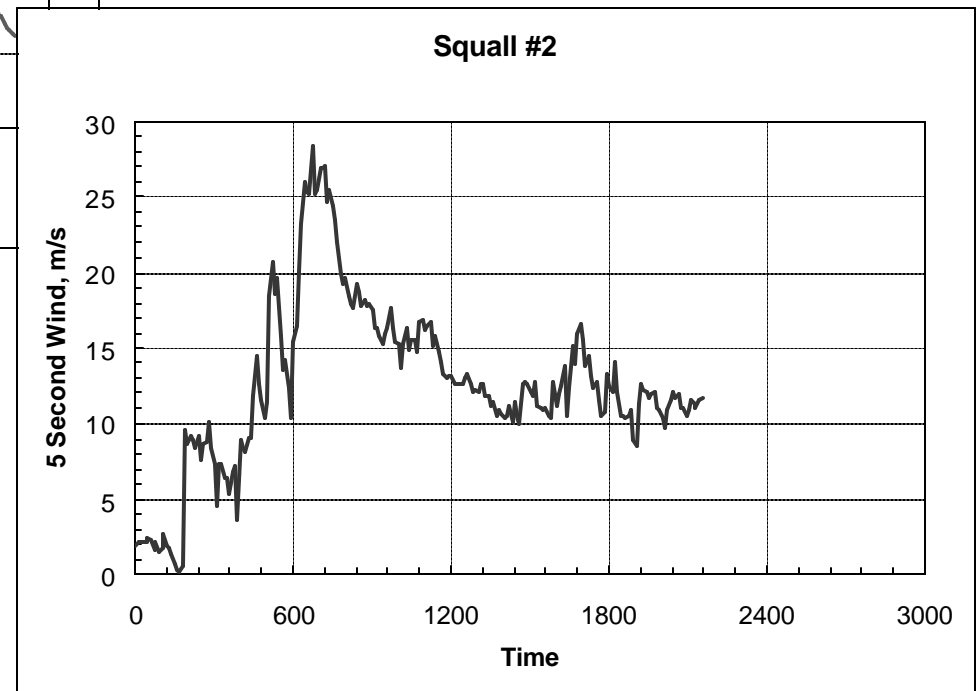
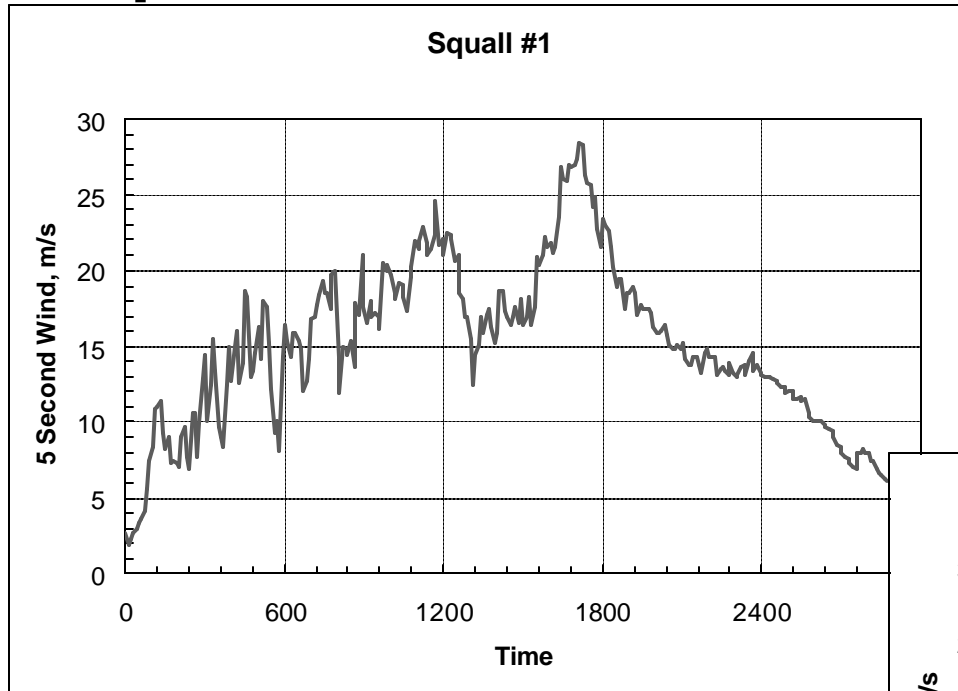
Deepwater GOM FPSO: Effect of directionality



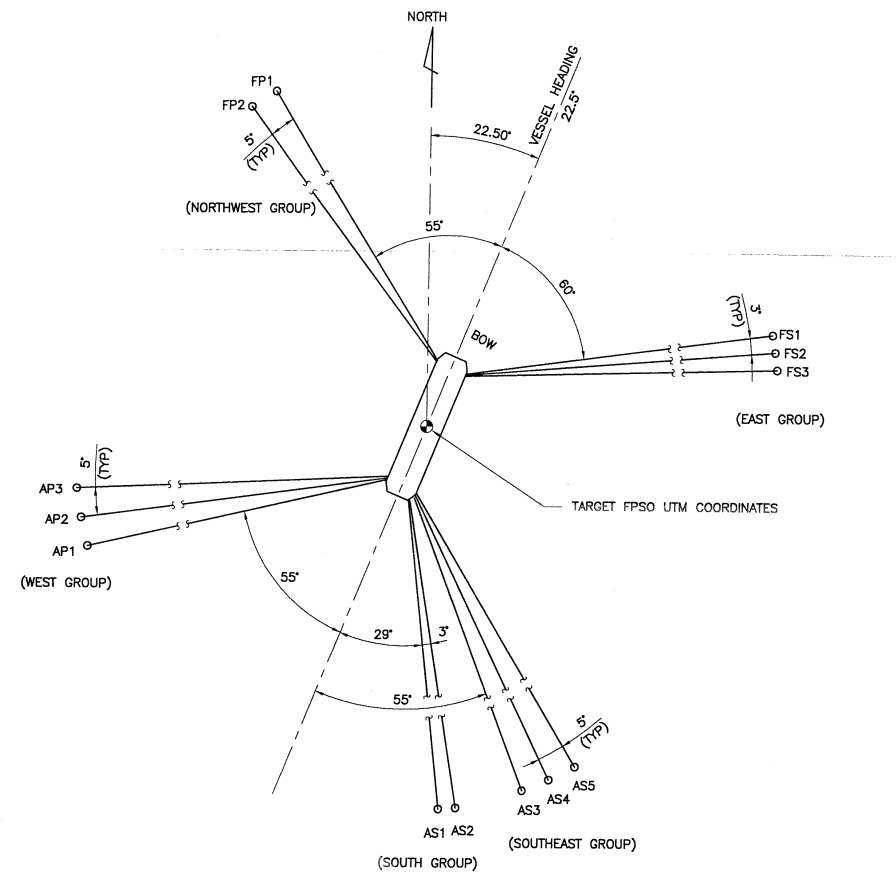
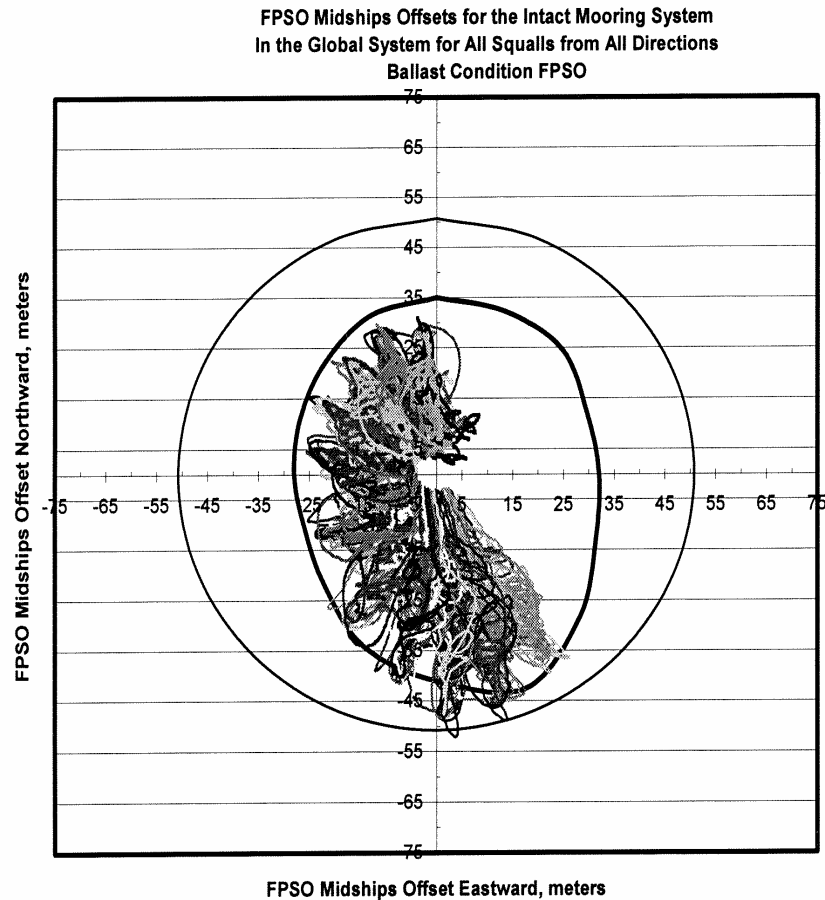
Squalls “Measured” off West Africa



Squalls “Measured” off West Africa



Squall Environment Response: SM FPSO



Offloading from FPSOs



Operational Environmental Conditions



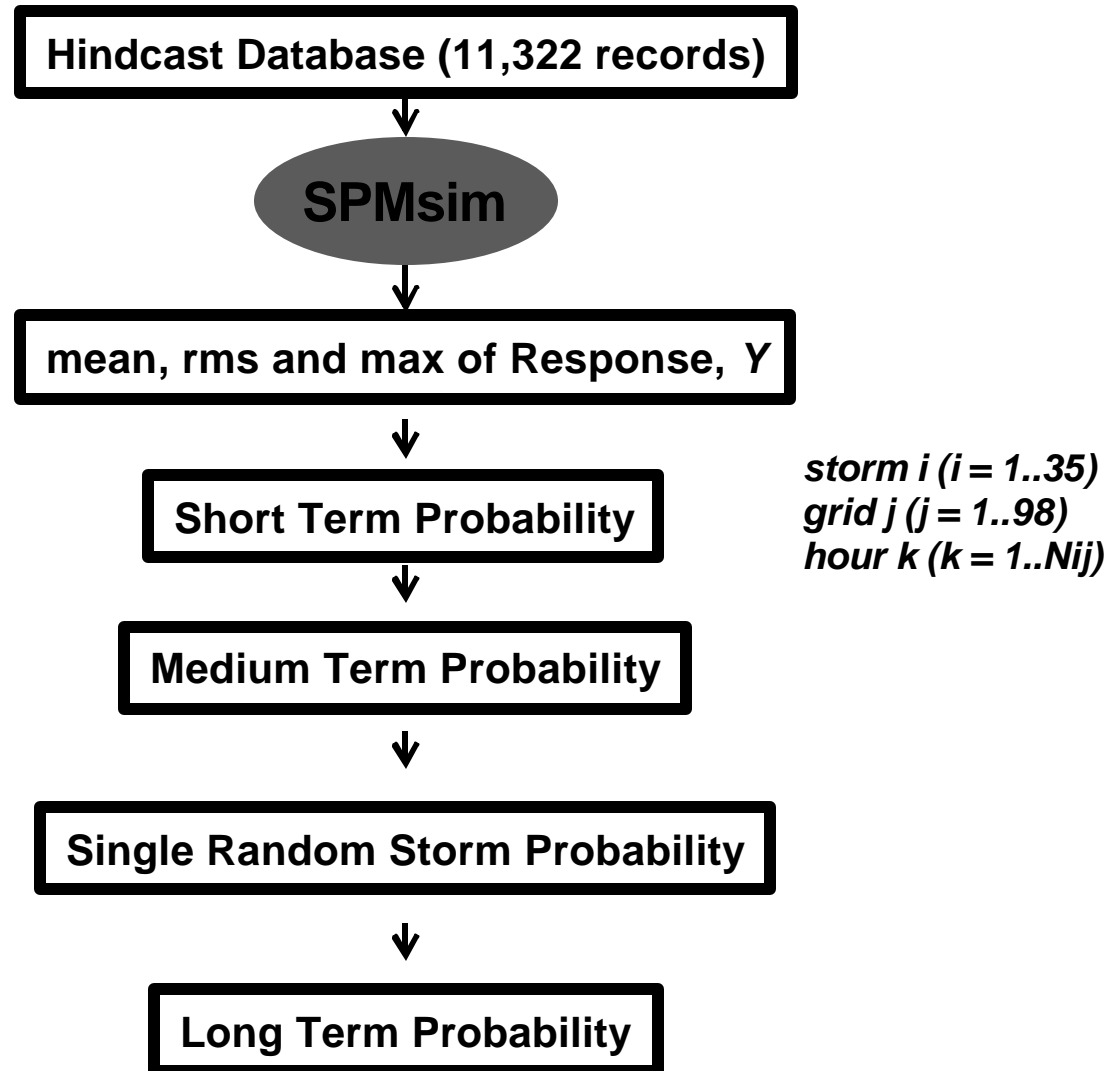
Long-term Response Analysis of FPSO Systems

- **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

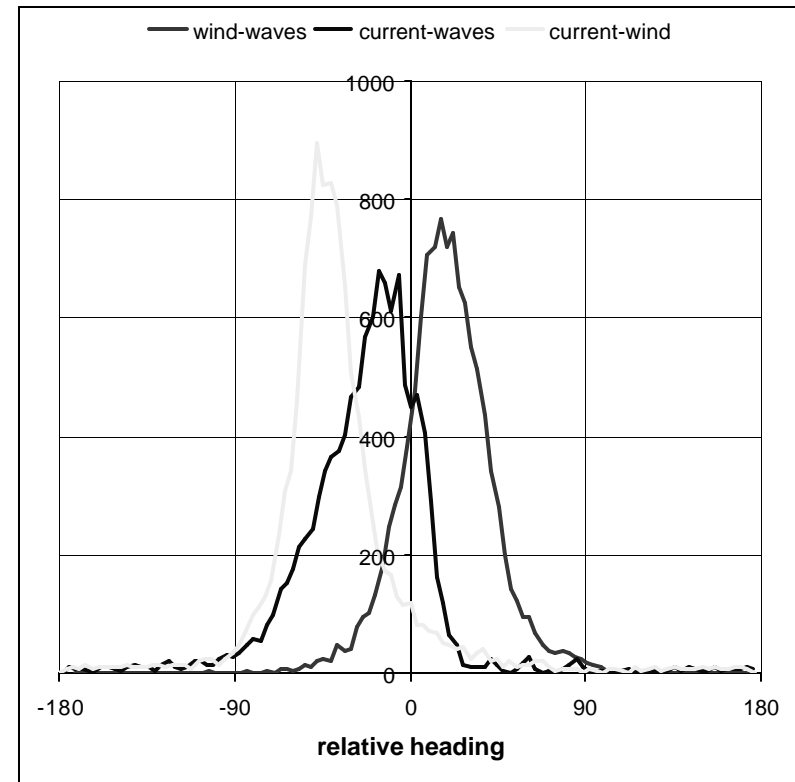
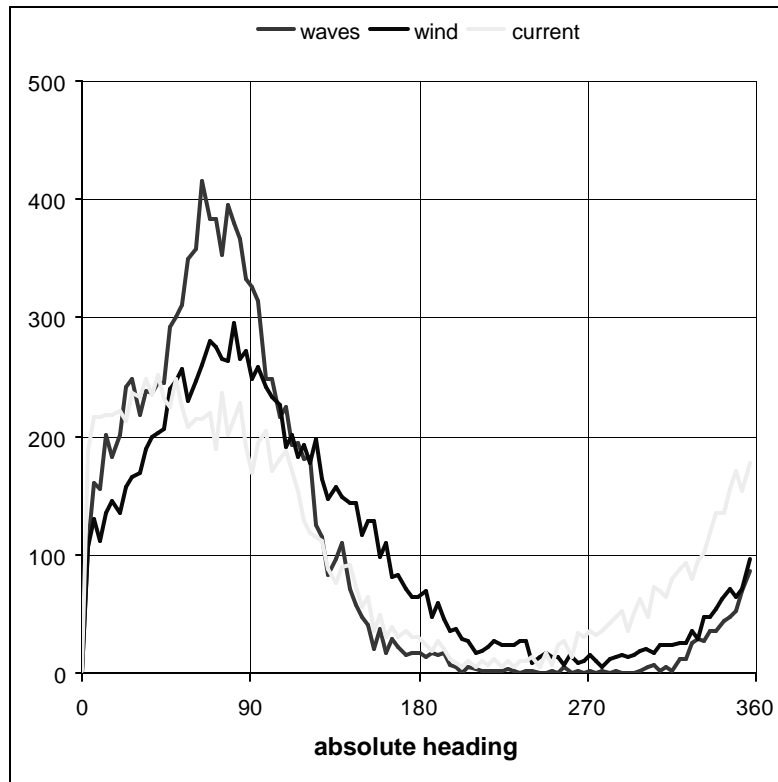
Long-Term Response Analysis (GOM) with Shell

- **Hindcast Hurricane Database (11,322 records)**
 - 85 year database
 - 35 storms over 98 grid-points
- **Dynamic Global Analysis Model of FPSO System**
 - FPSO and mooring
 - FPSO, mooring and risers
- **Develop Long-Term Response Statistics:**
 - Anchor leg and riser tensions
 - Turret loads and moments
 - Vessel offsets and motions

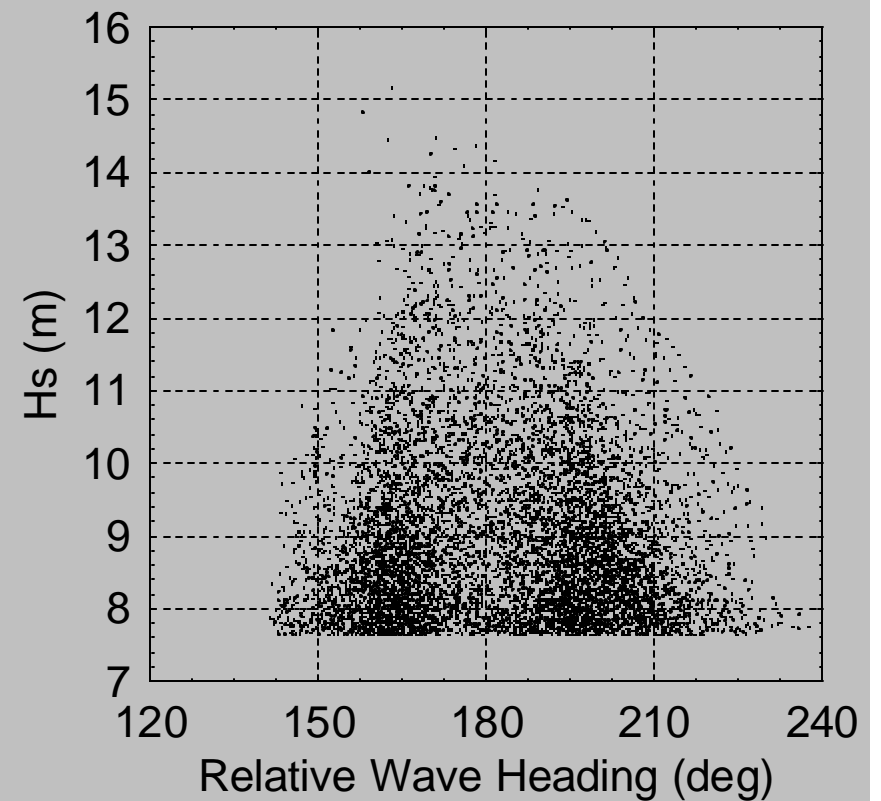
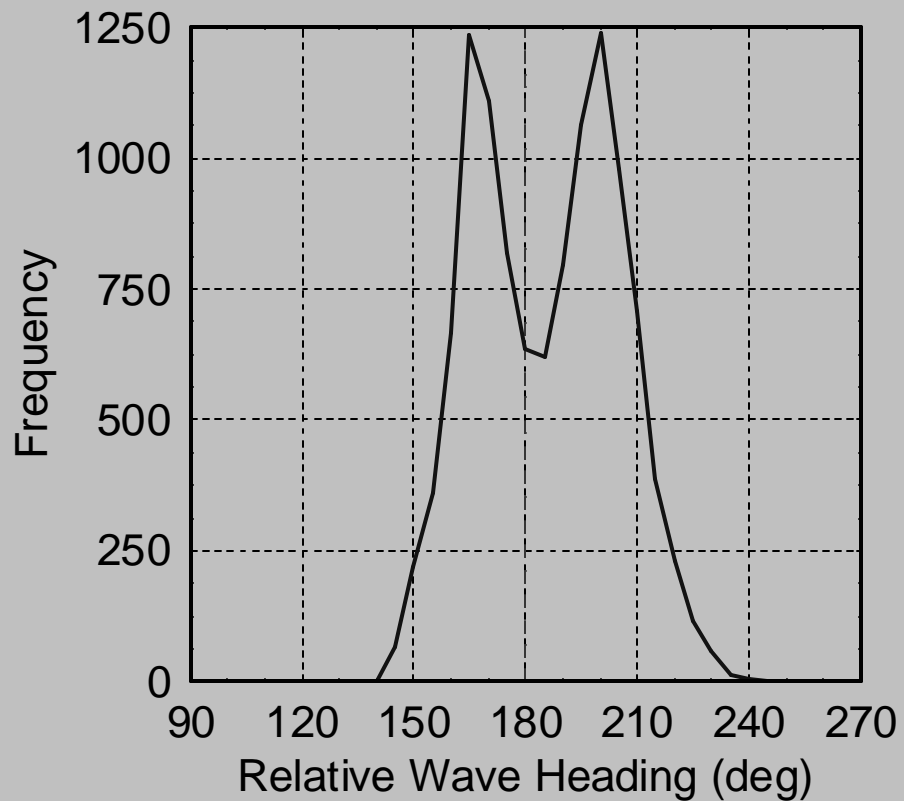
Long Term Response Analysis Methodology



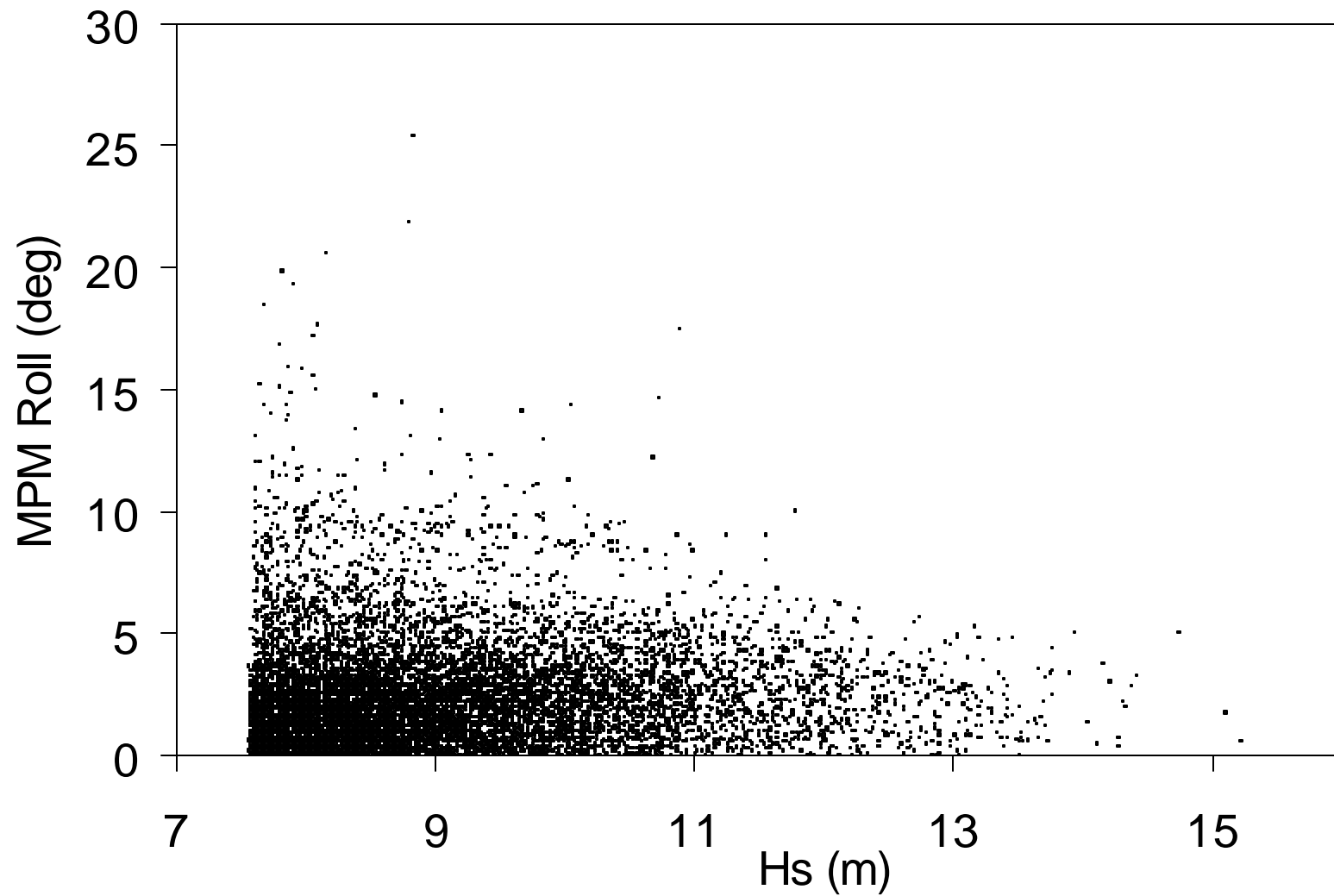
GOM Hurricane Hindcast Database: Environmental Alignment



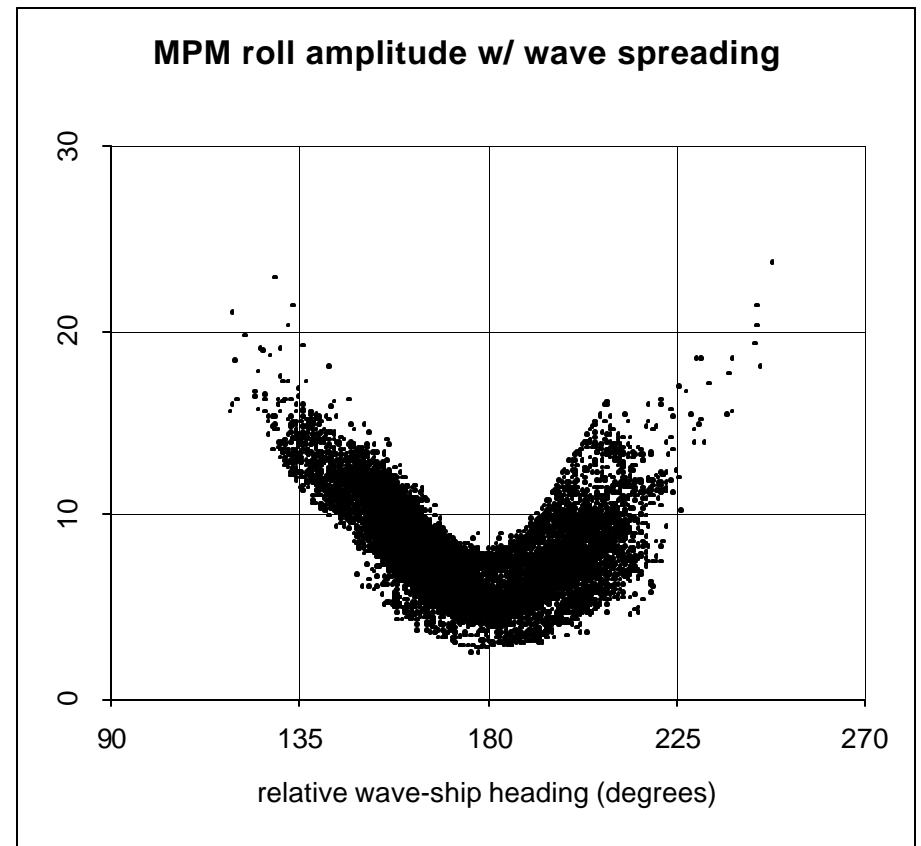
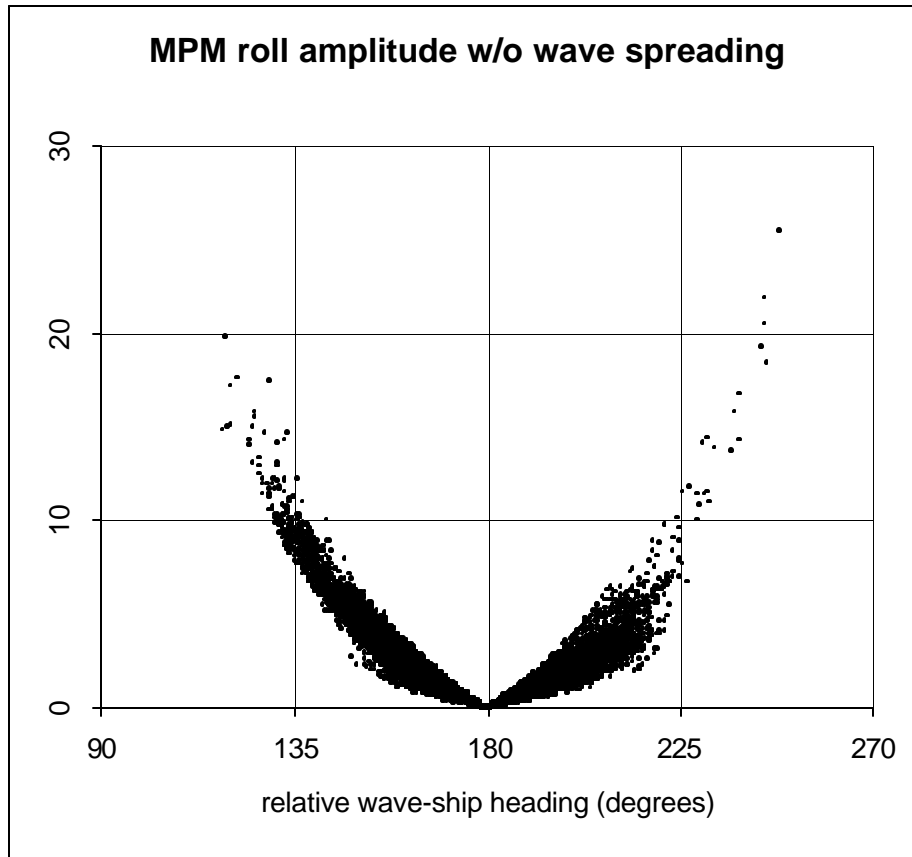
FPSO Relative Wave Heading



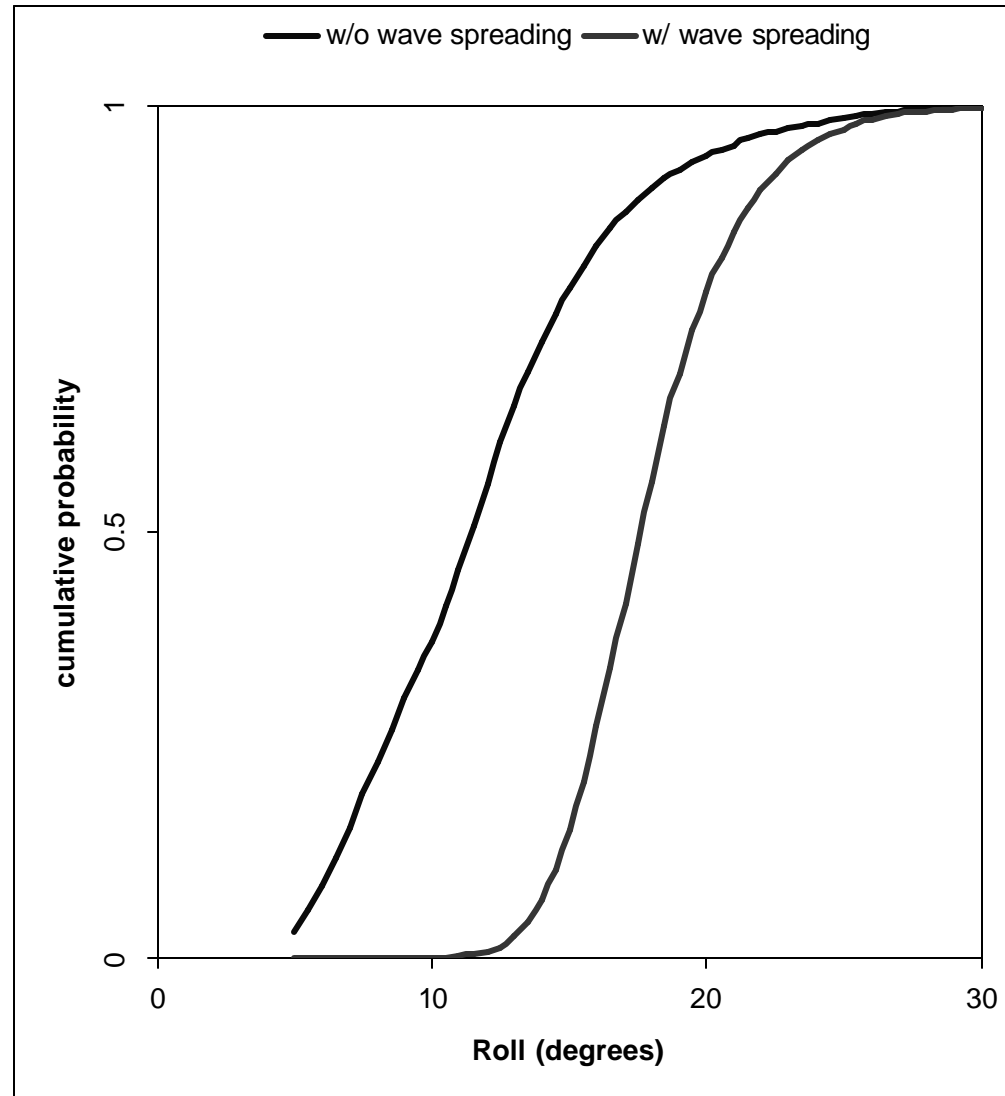
Roll vs Wave Height



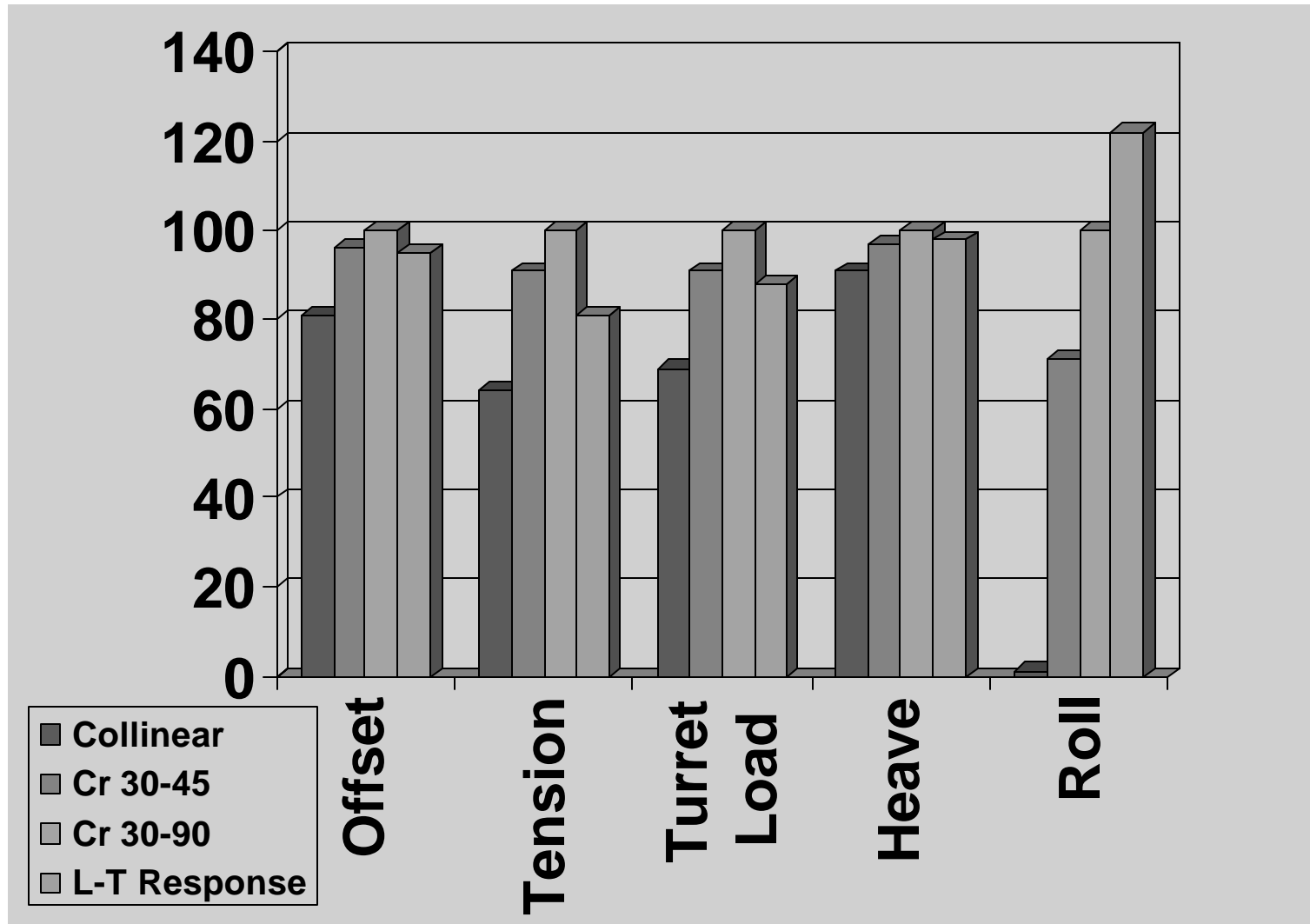
Effect of Wave Spreading on Roll Motions



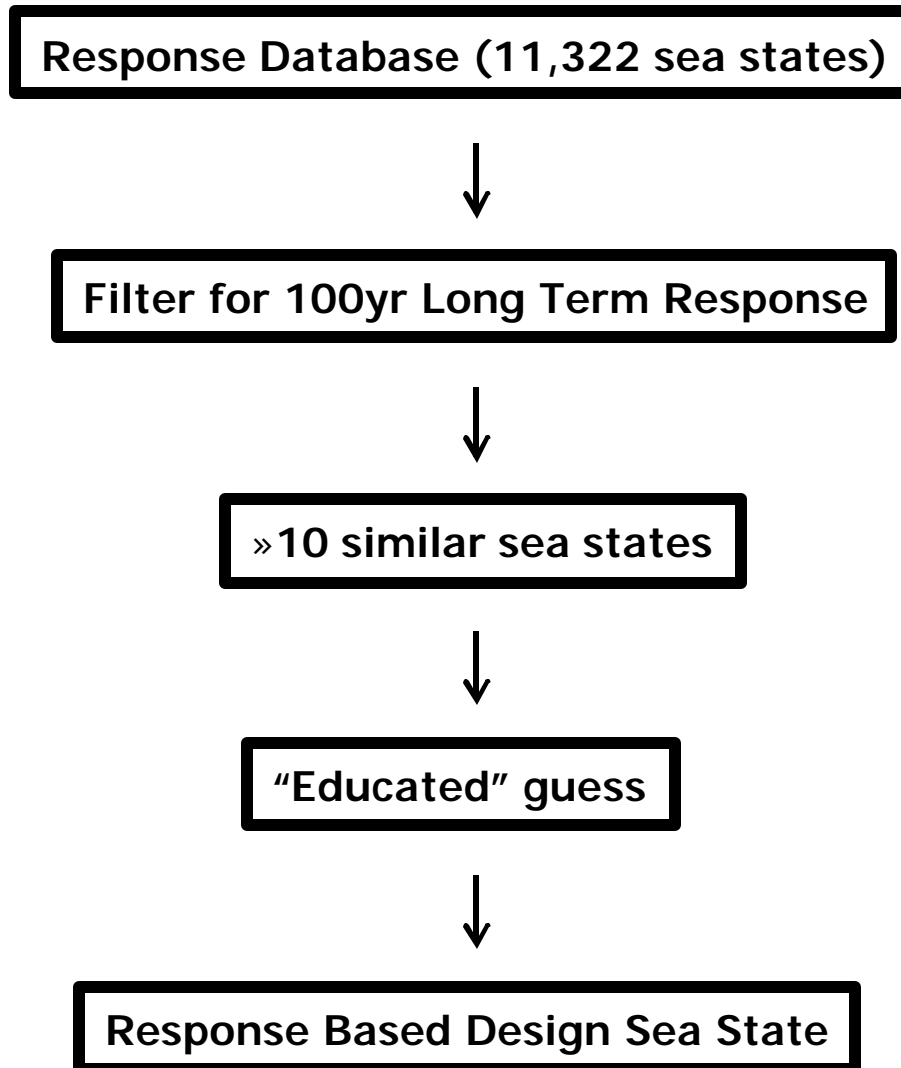
Long-Term Response Distribution - Roll



GOM FPSO Comparison: L-T Response



Design Environmental Criteria – L-T Responses



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				?

Conclusions & Recommendations

- **Quality of Metocean Conditions Specification has large impact on Turret-Moored FPSO responses**
 - Metocean data specification is a function of platform
- **TM FPSOs require definition of Joint Distribution of Wind, Wave and Current for various Return Periods.**
 - associated intensity and direction
 - Can be relatively easily extracted from hindcast databases
- **Provide a detailed description of the environment**
 - Mechanisms that create day-to-day seas and extreme storms
 - Anecdotal data, etc.
- **Response based analysis is a powerful tool for optimizing FPSO mooring and riser systems and for developing Environmental Criteria**
- **A large amount of published information is available to generate the appropriate data**
- **More communication required between Metocean Specialists and FPSO mooring designers**