Spar Global Responses

Prepared for OGP Workshop
The Metocean and Engineering Technology Requirements for Floatijng Systems
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Outline

- **Description of Spar**
- **Salient Response Characteristics**
- **Important Metocean Issues**
  - ➔ **Low Frequency Wave Energy**
  - ➔ **Current Turbulence**

Spar Technology

Oryx “Neptune”

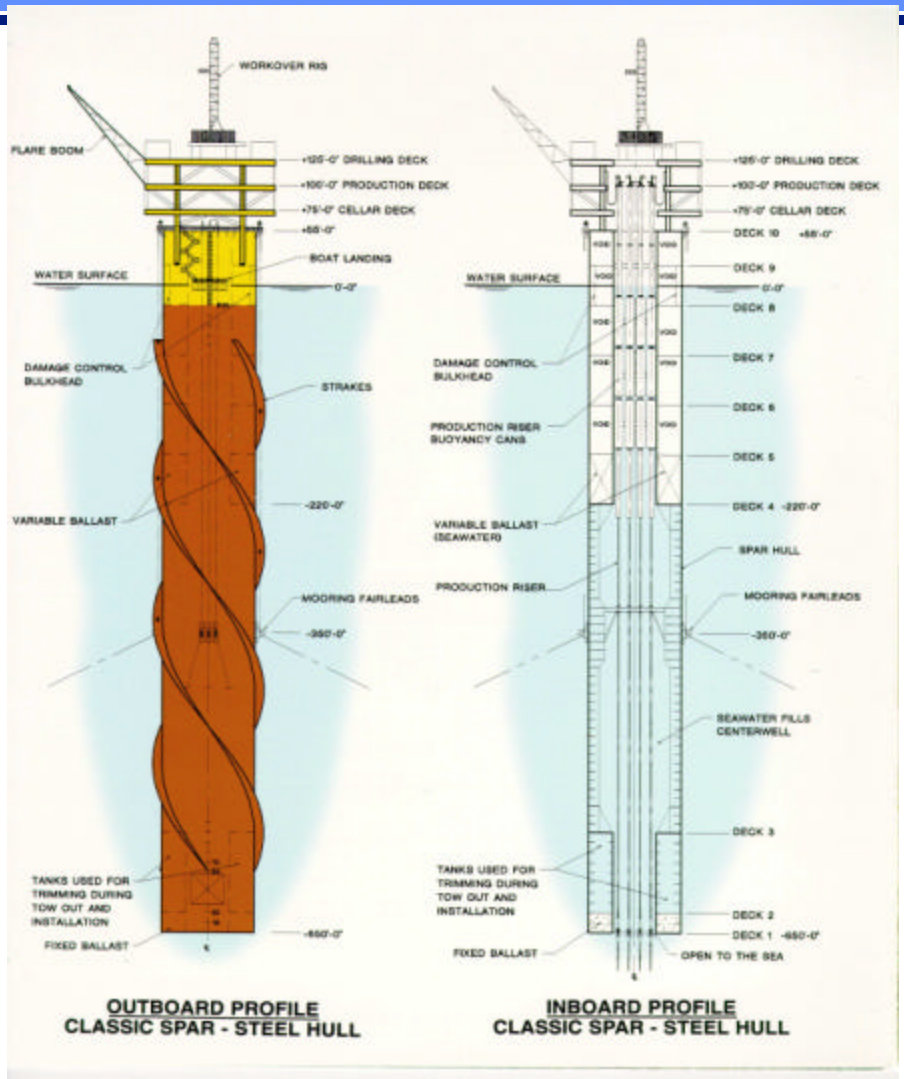
Spar Functions

- **Drilling**
- **Workover**
- **Production**
- **Wellhead**
- **Oil storage and offloading**
- **Any combination of the above**

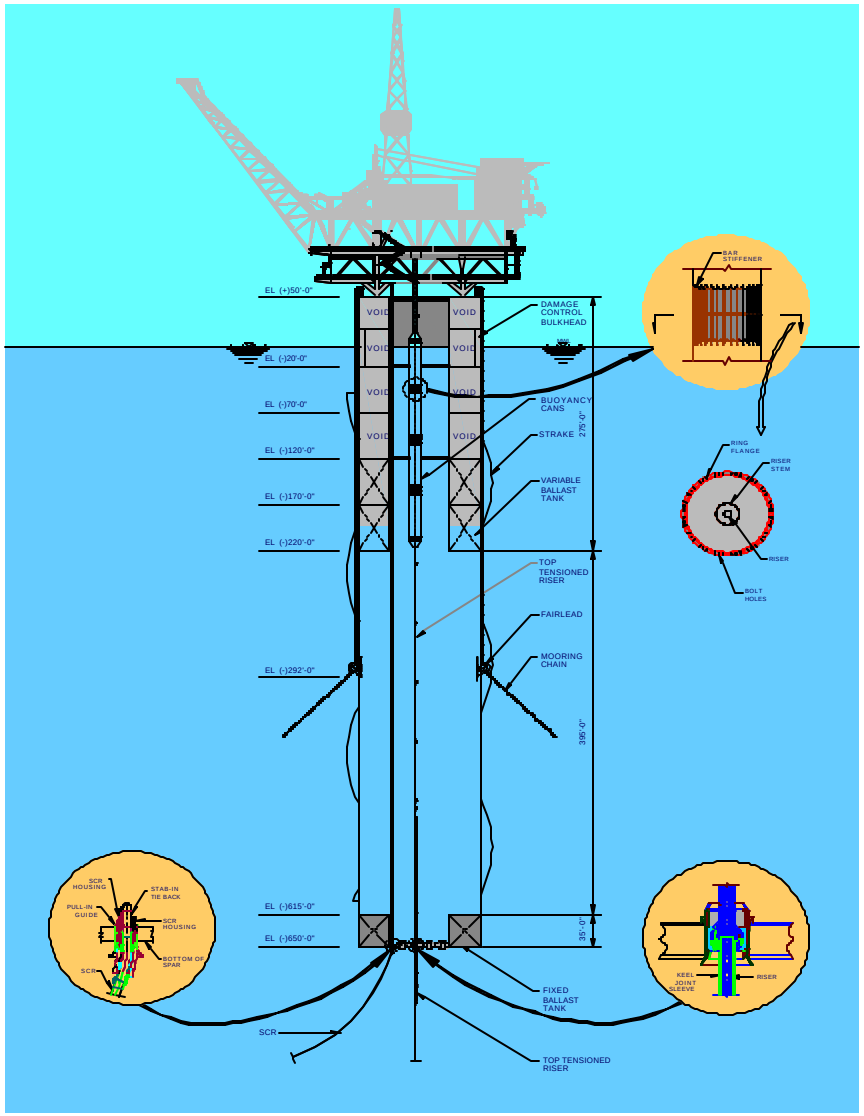
Classic Spar - Steel Hull

Spar Elements

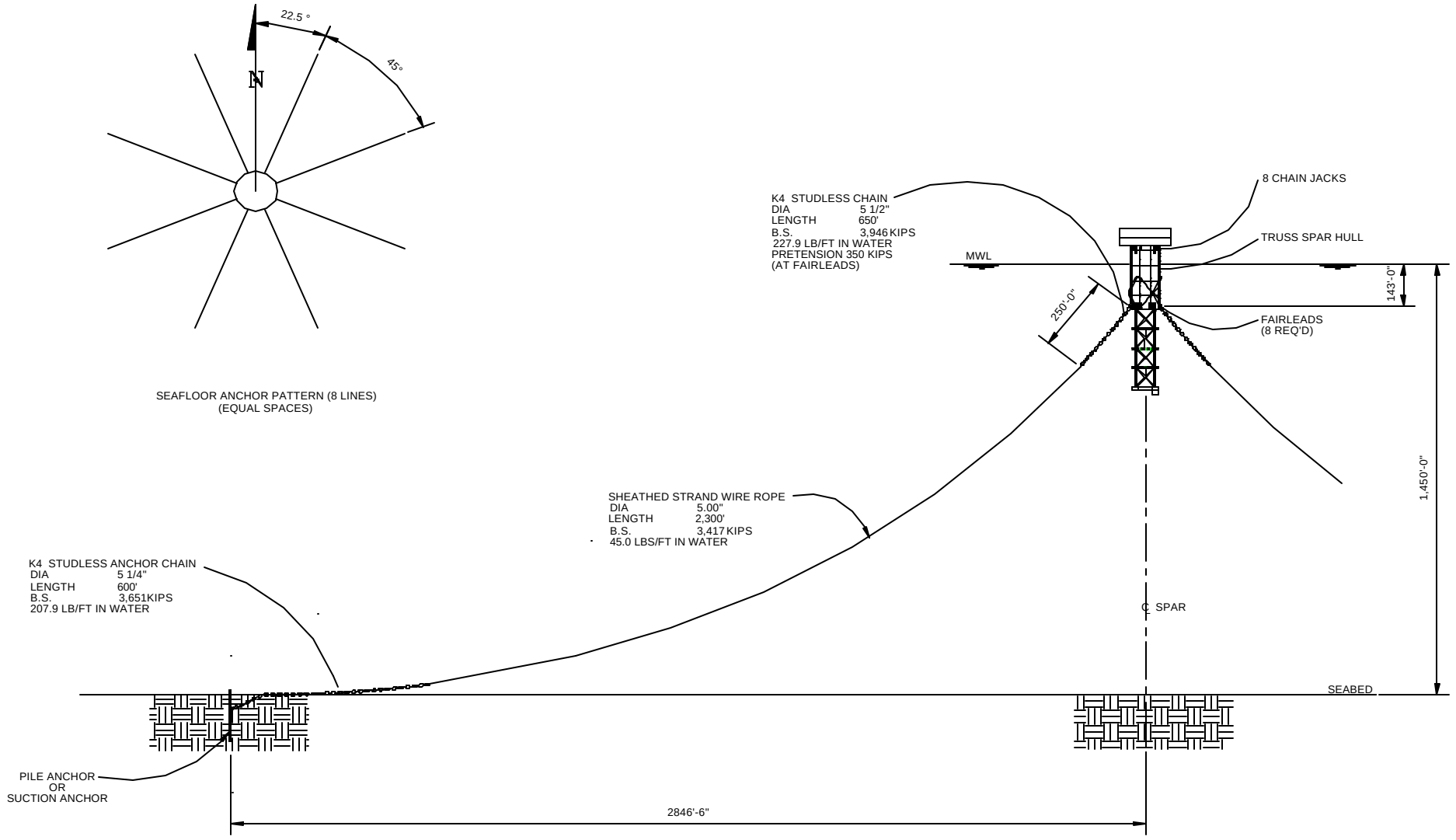
- Topside
- Hull Shell
- Buoyancy
- Centerwell
- Risers
- Mooring



Classic Spar In-Board Profile



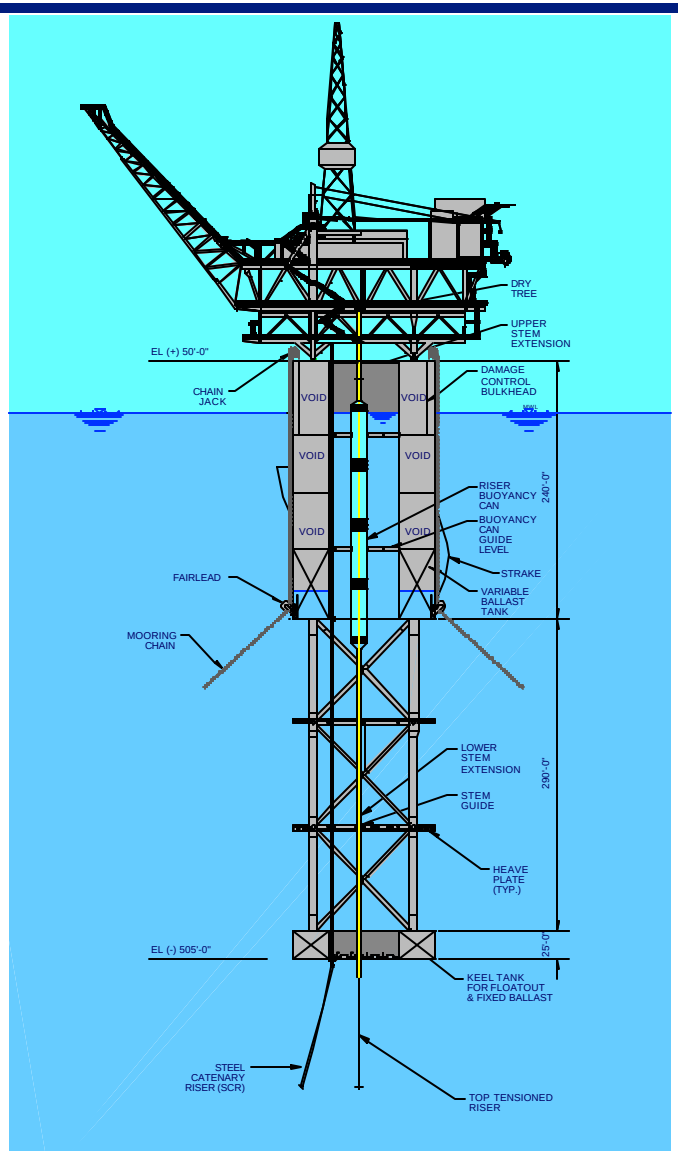
Taut Cantenary Mooring



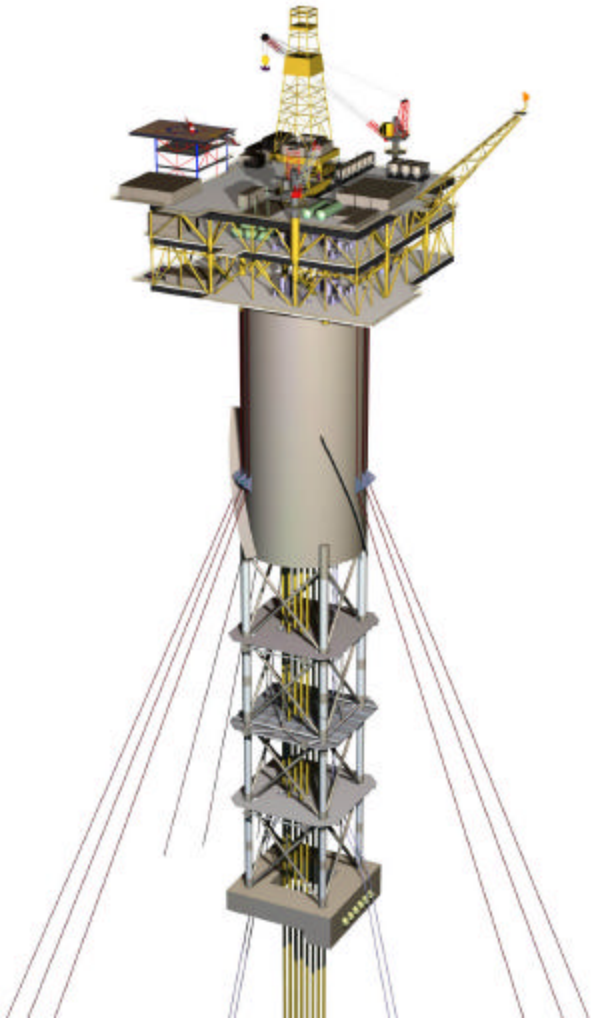
Installed Spars

	Spar Dia.	WD	Top Deck	Production	Well Slots	Payload
Neptune	72'	1,930'	Workover & Production	25 mbfpd 30 mmcfpd	16 Production	6,600 st
Genesis	122'	2,590'	Full Drilling & Production	55 mbfpd, 72 mmcfpd	20 Production, 1 Drilling	19,000 st
Hoover/ Diana	122'	4,300'	Full Drilling & Production	100 mbfpd, 325 mmcfpd	8 Production, 9 SCRs, 1 Drilling	29,500 st

Truss Spar


DRY TREE
UPPER STEM EXTENSION
EL (+) 50'-0"
CHAIN JACK
DAMAGE CONTROL BULKHEAD
VOID
VOID
VOID
VOID
VOID
VOID
RISER BUOYANCY CAN
BUOYANCY CAN GUIDE LEVEL
STRAKE
FAIRLEAD
VARIABLE BALLAST TANK
MOORING CHAIN
240'-0"
LOWER STEM EXTENSION
STEM GUIDE
200'-0"
HEAVE PLATE (TYP.)
EL (-) 505'-0"
25'-0"
KEEL TANK FOR FLOATOUT & FIXED BALLAST
STEEL CATENARY RISER (SCR)
TOP TENSIONED RISER

Nansen / Boomvang



Water Depth:	**3,450 feet**
Production:	**40 MBOPD**
	200 MMSCFG
Workover Rig	
Topside Weight:	**7,800 tons**
Risers:	**7 top tension**
	8 SCRs
Center Well:	**40x40 feet**
Hull Diameter:	**90 feet**
Hull Weight:	**12,200 tons**
Mooring:	**9 lines, 3x3**

Nansen Truss Spar

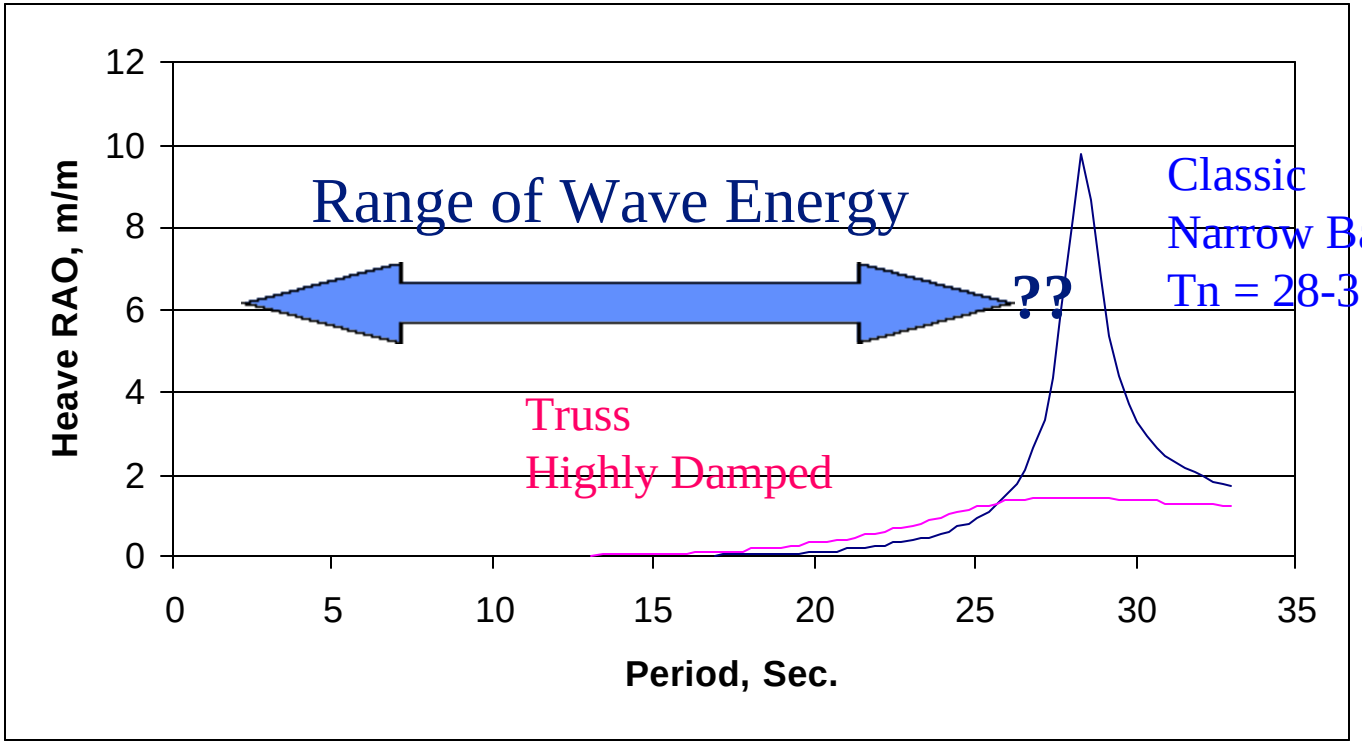
What is Important

- **Deck Accelerations**
  - → **Dominated by Pitch response**
- **Riser stresses and fatigue at keel**
  - → **Dominated by Pitch Response**
- **Riser stresses and fatigue at mudline**
  - → **Dominated by surge and sway**
- **Mooring line tensions**
  - → **Can be dominated by currents or wave/wind depending on environment**
- **Riser Stroke**
  - → **Dominated by drawdown (surge/sway) in ultra deep water**
  - → **Spar heave plays an important but not dominant effect**

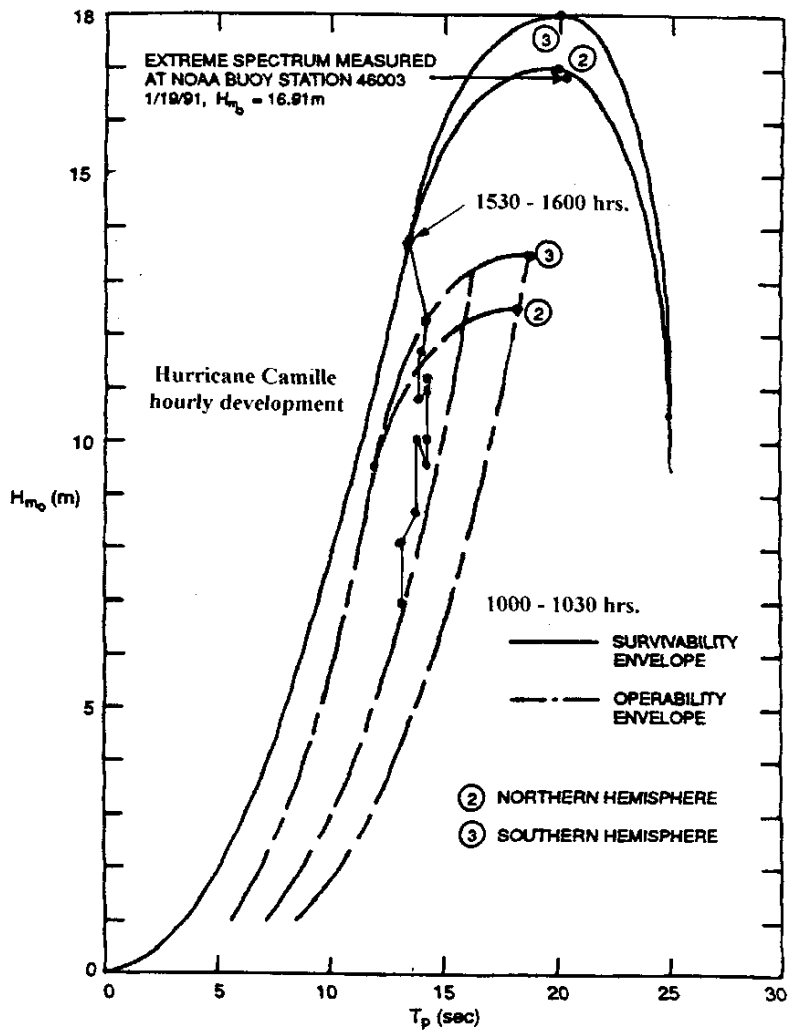
Spar Global Responses

- **Low heave motions due to deep draft**
  - ➔ **Wave excitation is filtered**
  - ➔ **Low frequency dominates heave response**
- **Surge and Sway Dominated by responses at Natural Periods (200 - 500 sec)**
  - ➔ **Higher order wave (drift)**
  - ➔ **Vortex Induced Motions (current)**
  - ➔ **Turbulence induced motions (wind and current)**
- **Pitch response includes equal parts of wave frequency and low frequency motions**
  - ➔ **Wave frequency center of pitch is at keel**
  - ➔ **Low frequency (60-90 sec) center is at CG**

Heave Response Comparison



Extreme Wave Envelope



Highest Measured:

Hs=16.9 m

Tp=20 sec

Buckley, W.H., "First Principles Methodology Applied to Loads and Motions of Offshore Platforms", unpublished manuscript received Jan. 1999

Measured Extreme Wave Profile

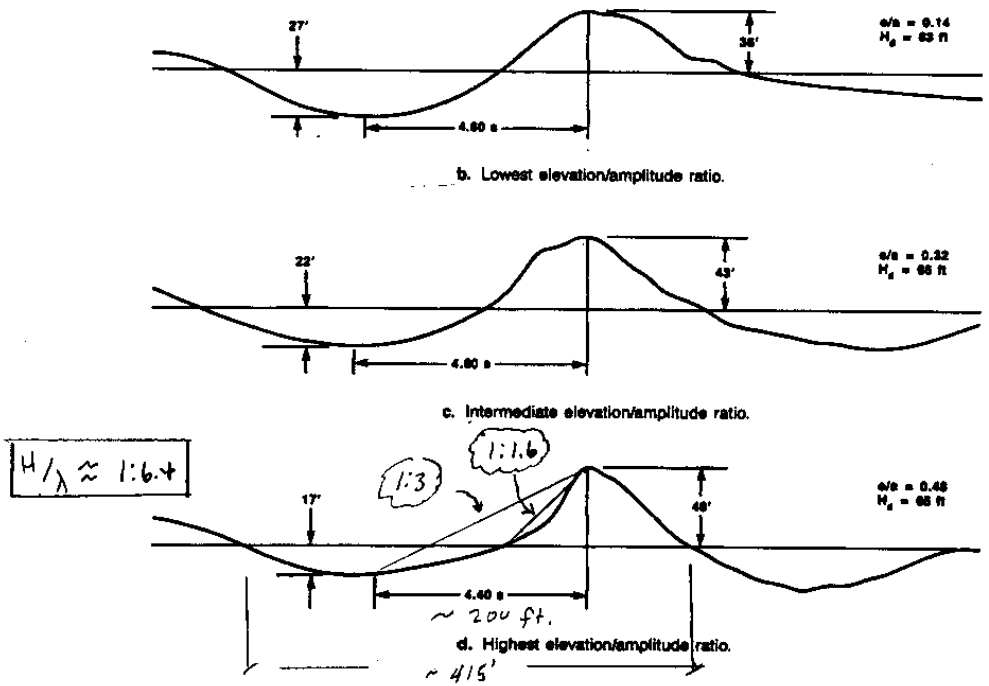
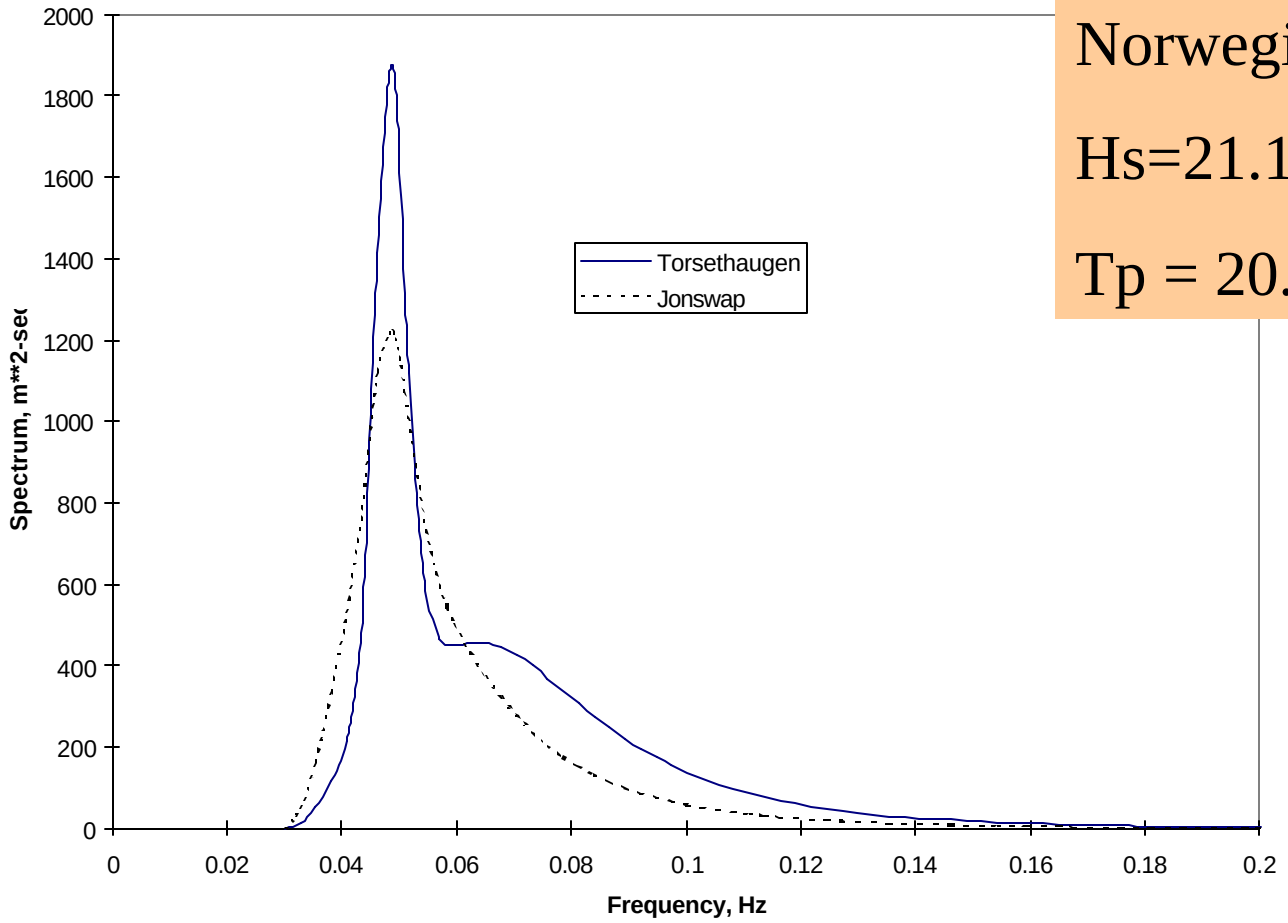


Fig. 27. Time Series Characteristics of Highest Waves — Hurricane Camille 1500-1530 Hours.

Jonswap vs. Torsethaugen Spectra

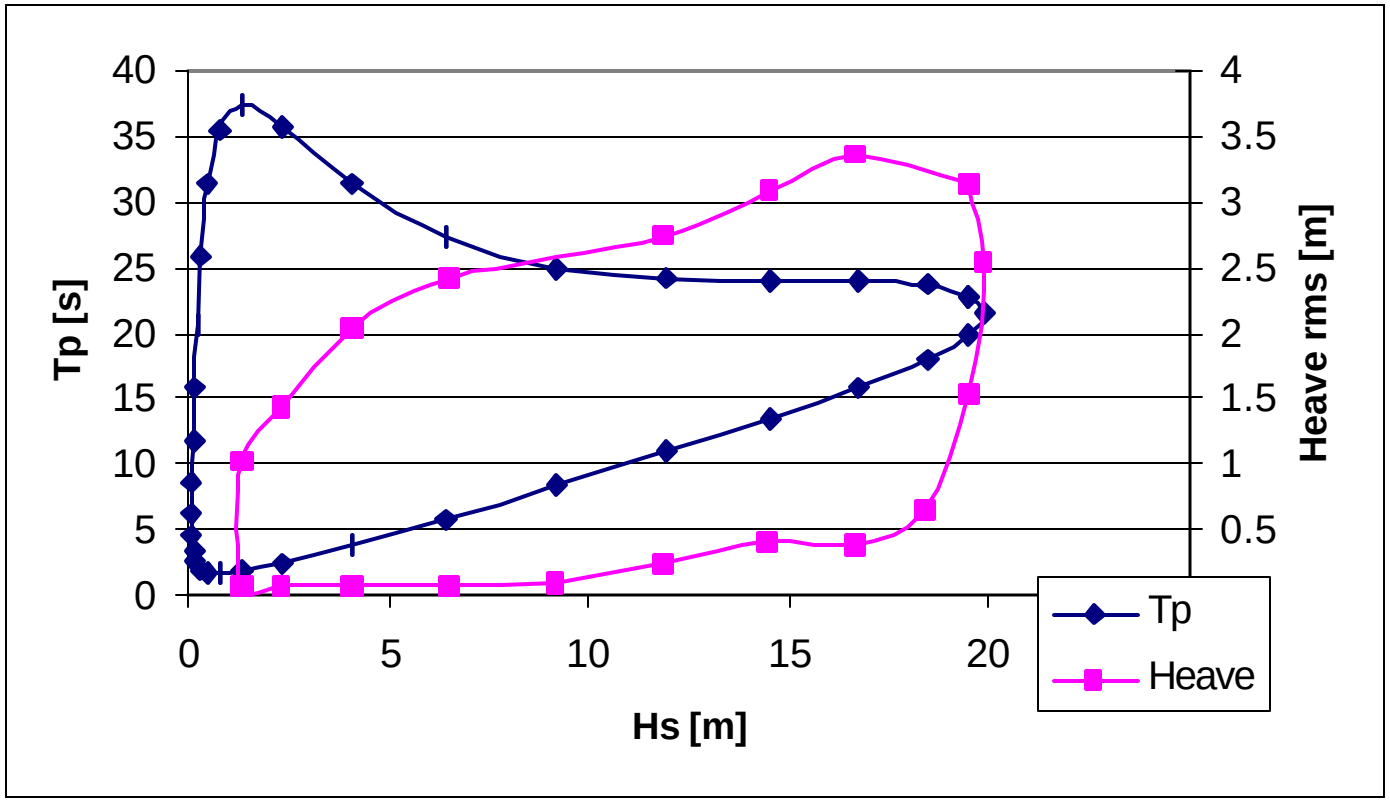


10000 Yr
Norwegian Sea

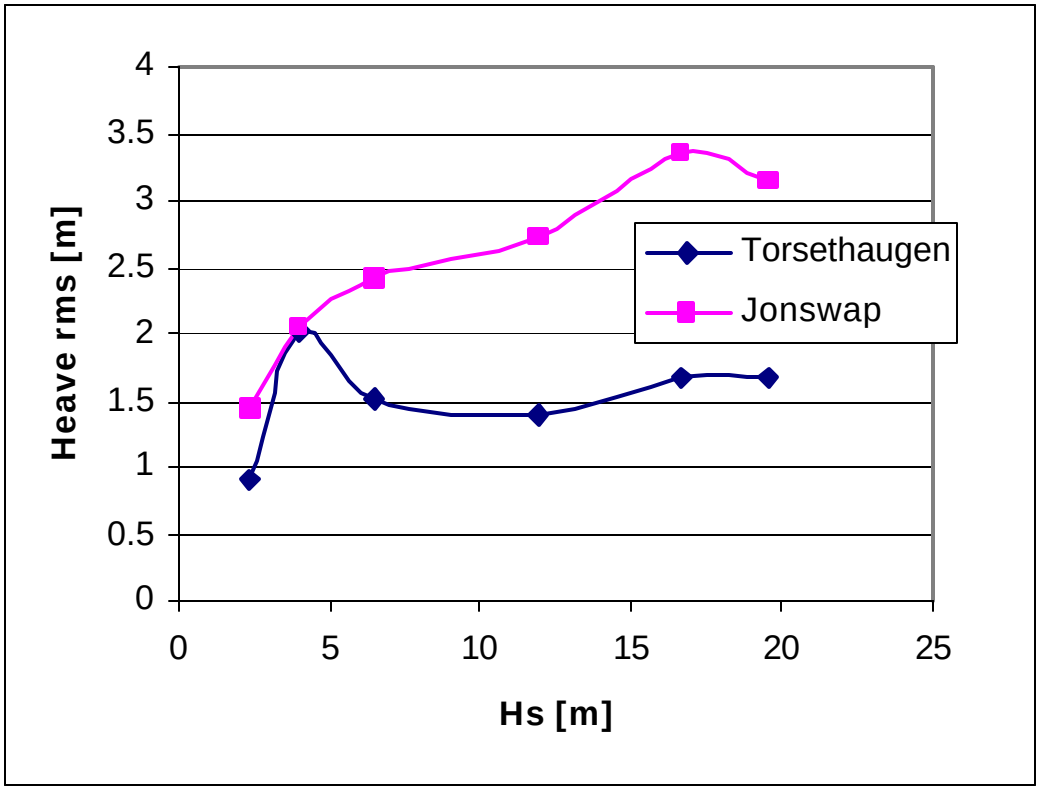
Hs=21.1 m

Tp = 20.8 sec

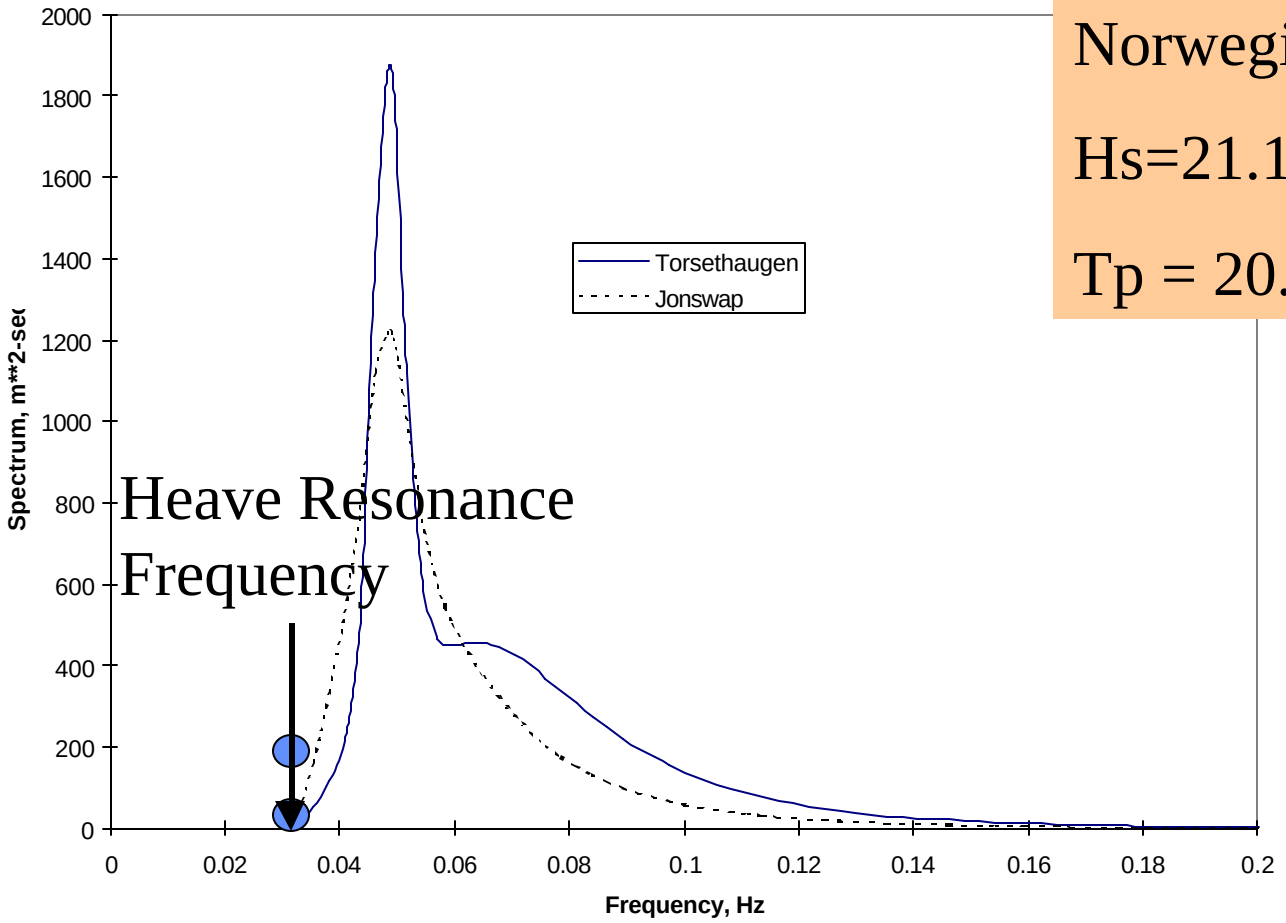
Classic Spar Heave Response Map



Heave Sensitivity to Spectral Shape



Jonswap vs. Torsethaugen Spectra



10000 Yr Norwegian Sea

Hs=21.1 m

Tp = 20.8 sec

Spectral Shape Conclusions re Heave Responses

- **Long period energy (>25 sec) can be important for spar responses**
- **Typical storm spectra (e.g. Jonswap) fits a theoretical curve to high frequency energy**
- **Low frequency shape is not accurately represented**
  - ➔ **Low frequency cutoff is ignored**
  - ➔ **Little if any data or hindcast results for >25 second period are available**
  - ➔ **Low frequency wave grouping is not represented**
- **Theoretical spar heave response predictions are probably overpredicted**

Recommendations

- **Use instruments that are sensitive to low frequency**
  - ➔ **Wave riders are not accurate for low frequency**
  - ➔ **Augment wave riders with subsurface pressure measurements**
- **There is a large body of archived data from bottom founded pressure gages in coastal areas**
  - ➔ **Examine data with eye toward better low frequency definition**

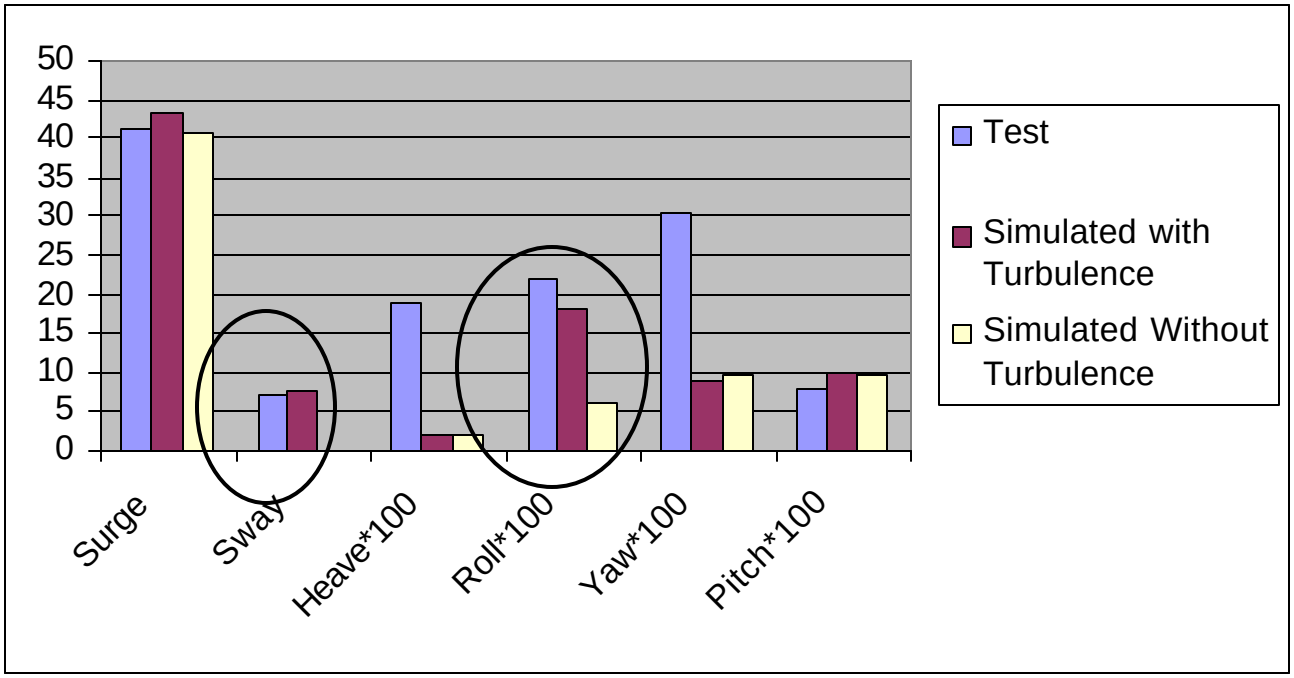
Low Frequency Surge and Sway Responses

- **Waves**
  - → **Governed by 2nd Order Spectrum**
- **Wind**
  - → **Turbulence excites surge, sway and pitch even in moderate environments due to low damping**
- **Current**
  - → **Causes Vortex Induced Motions**
  - → **Turbulence excites surge and sway**
- **All of the above important for mooring design and riser fatigue**

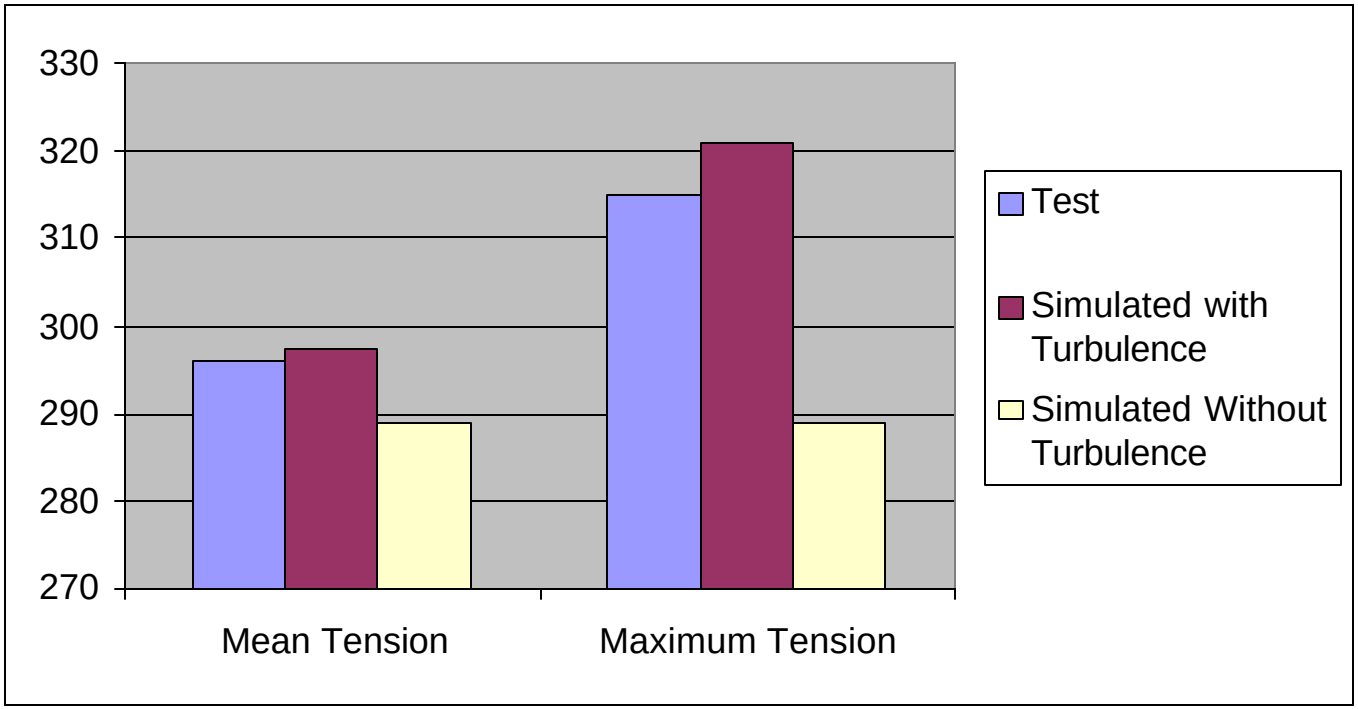
Current Turbulence

- **There is almost no full scale data on turbulence scales of interest**
  - **Spar Responses on 60 - 600 seconds are of interest**
  - **Associated Turbulence Scales are about 60 - 600 m**
  - **Current turbulence data typically is on the scale of 10s to 100s of km, or on very small (mm) scale.**
  - **15 min current averaging is standard.. All turbulence information of interest is lost!**
- **Ocean Model Basins have difficulty generating low turbulence currents**

Current Turbulence Effect on Motions

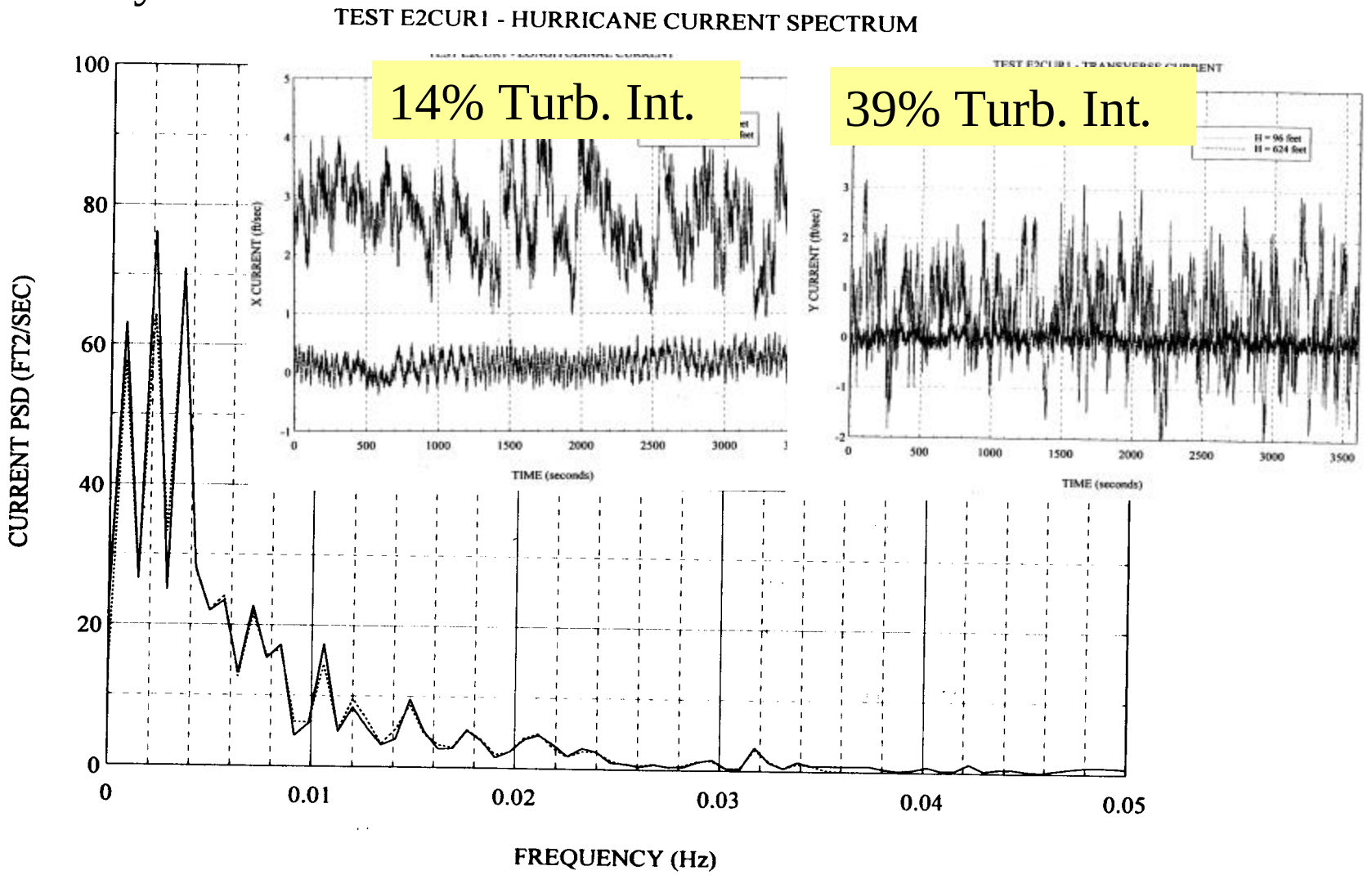


Current Turbulence Effect on Mooring Tensions

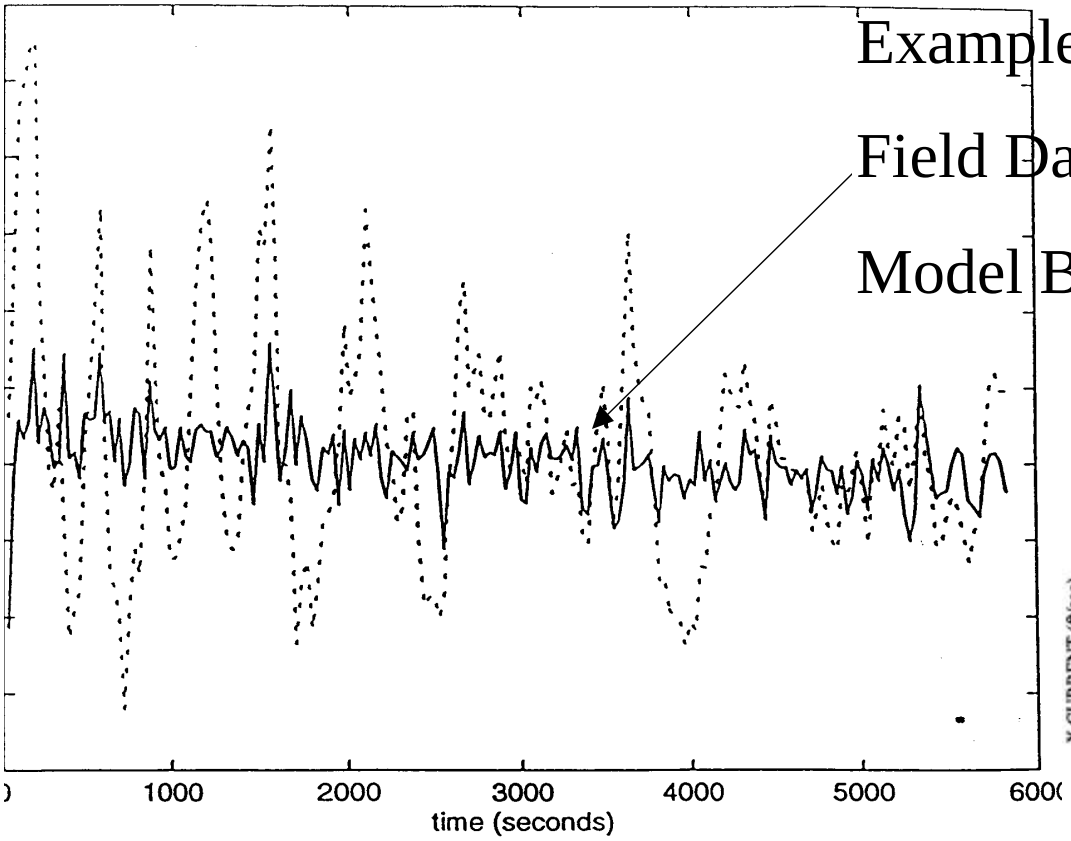


Current Spectra Measured in Wave basin

Turbulence Intensity = Urms/Uave



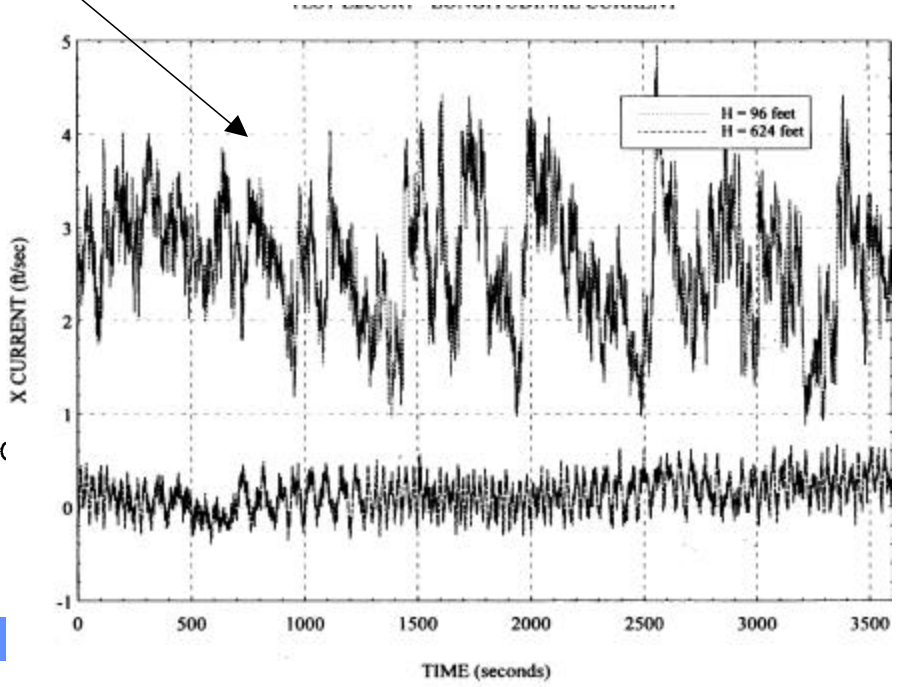
Data Comparison



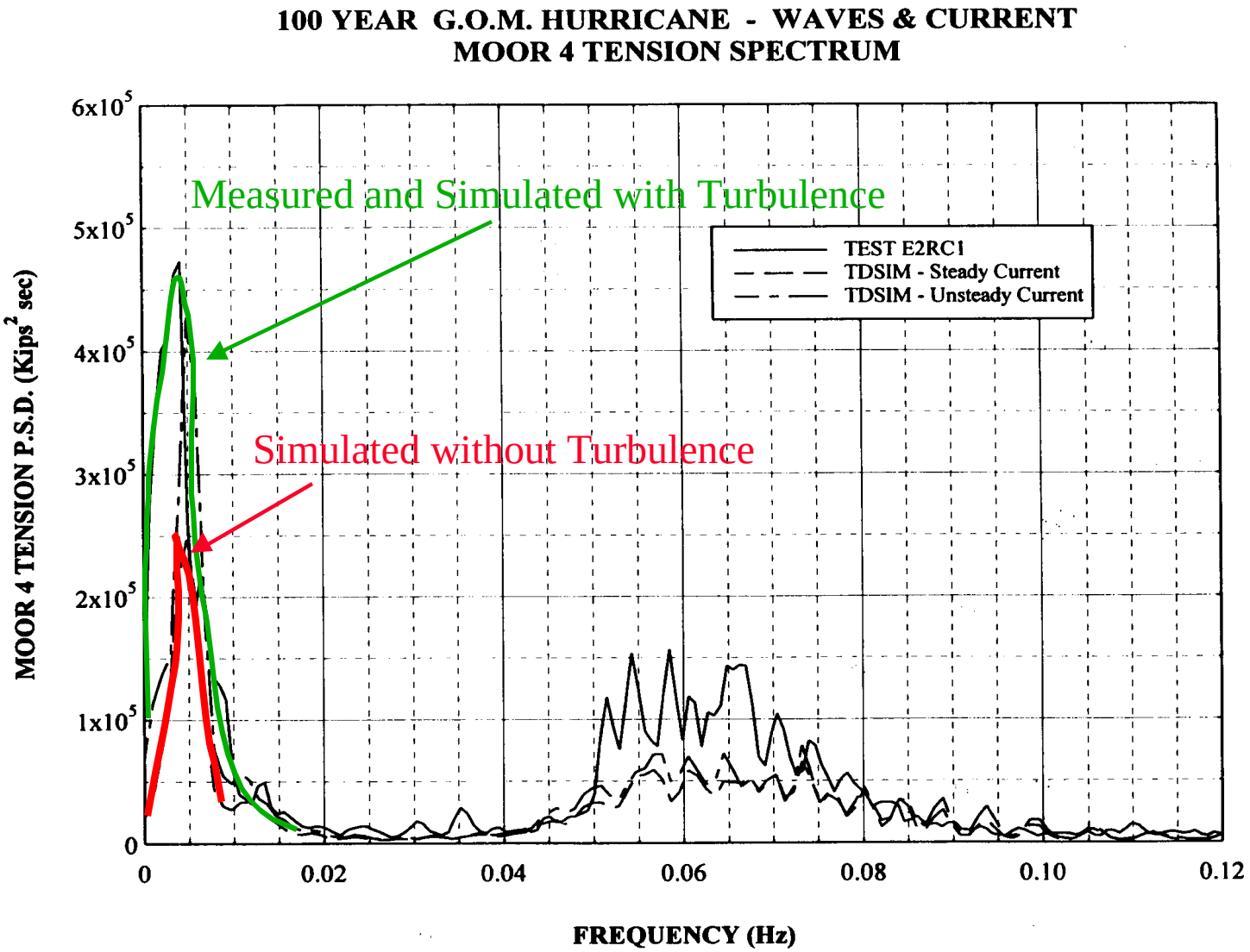
Example Turbulence Intensity:

Field Data - 1.8%

Model Basin - 14-39% !!



Current Turbulence Effect on Tension Spectrum



Overall Conclusions

- **Wave spectra for low frequencies should be defined and validated, including wave group effects**
- **Current Turbulence in the 60 - 600 sec. Period band should be measured**

Other Issue

- **Joint distribution of Waves and Current**
  - ➔ **Collinear events are not necessarily conservative**
  - ➔ **Heave and pitch may be worse if current opposes waves**