

# **North Sea Jacket Analysis: Dynamic Amplification and Wave-in-Deck Analysis**

*Abby Baca*

Graduating Senior

Civil & Environmental Engineering Department,  
Stanford University

*Steve Winterstein*

Independent Study Supervisor

Presented at the Annual RMS Industry  
Affiliates Mtg,  
May 31-June 1, 2001, Stanford CA

# The Jacket

**Name:** Kvitebjørn

**Location:** Northern North Sea  
(near Statfjord)

**Water Depth:**  $d \approx 200\text{m}$

**4 Legs, Spacing:**

$d \approx 40\text{m}$  at seafloor

$d \approx 25\text{m}$  at mean water level

**Natural Period:**  $T_n \approx 5\text{sec}$  (!)

**Concerns:** Dynamic amplification; waves-in-deck

# The Air Gap:

## Critical values of total water surface:

$\eta_{tot}=24.5\text{m}$  → wave impacts underside of cellar deck

$\eta_{tot}=26.0\text{m}$  → system failure  
(Basis: for smaller jacket, Haver and Dalane found  $\Delta\eta=2\text{m}$  submergence led to failure)

## Critical values of wave crest height:

Assume extreme (tidal level + storm surge) = 2m:

$\eta=22.5\text{m}$  → wave impacts underside of cellar deck

$\eta_{tot}=24.0\text{m}$  → system failure

# Crest models

**Narrow-band Gaussian**  $\eta(t)$ : Rayleigh crests

**Heideman-Haring:** Water depth dependent;  
becomes Rayleigh as  $d$  grows

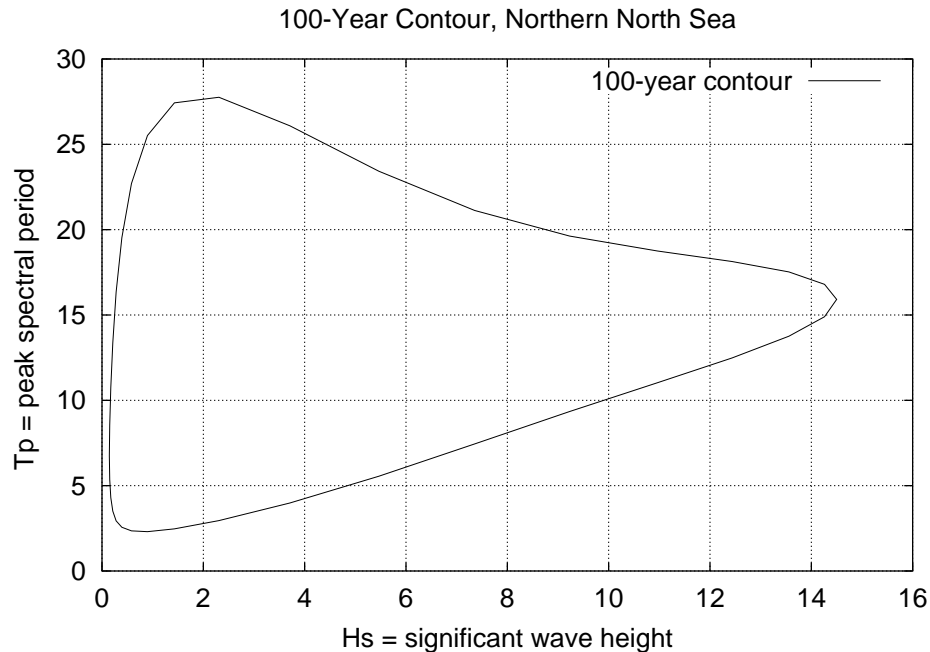
**Random 2nd-order:** Function of power spectrum, wave steepnesses (double Fourier sum).  
Algorithm: WAVEMAKER

**Hermite:** Function of assumed wave skewness  $\alpha_3$ , kurtosis  $\alpha_4$ . Here (from data, 2nd-order simulations):

$$\alpha_3 = 0.2$$

$$\alpha_4 = 3.1$$

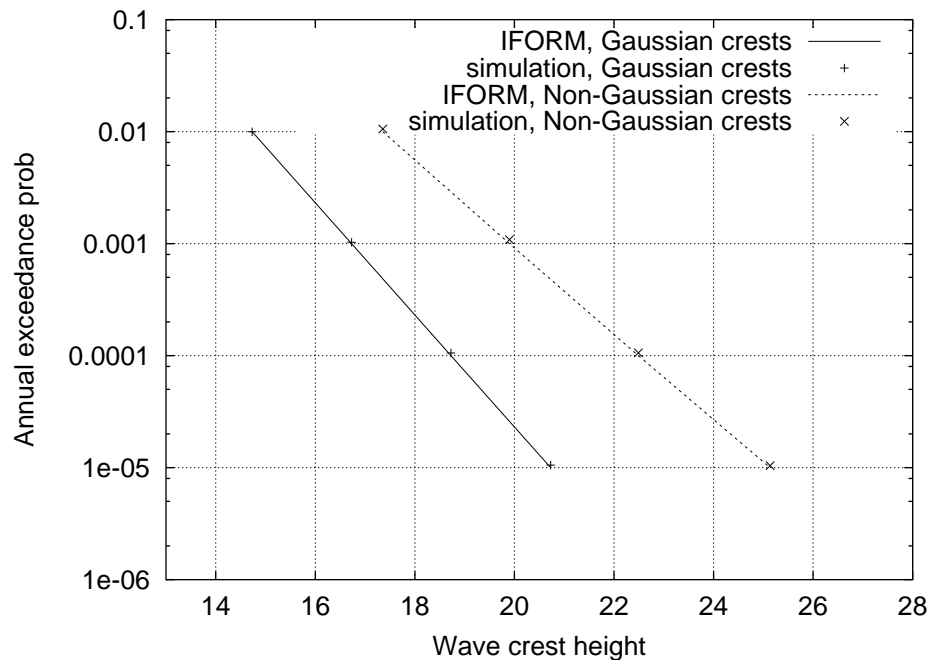
# Extreme crest estimates



SURFIT: Inverse FORM search for largest wave crest over 100-year  $H_s-T_p-C$  ( $C=\text{crest} | H_s, T_p$ )

Gauss vs Non-Gauss crests: read in different tables of  $m_X, \sigma_x, \alpha_3, \alpha_4$  as functions of  $H_s, T_p$  into SURFIT

# Extreme crest distributions



SURFIT characterizes non-Gaussian response (wave elevation) by  $(m_x, \sigma_x, \alpha_3, \alpha_4, \nu_0)$ ; response surface for each in terms of  $H_S, T_P$ .

Also permits simulation (importance sampling) to check FORM/IFORM solution.

# Wave crest conclusions

- Gaussian model quite non-conservative (no surprise)
- Non-Gaussian (Hermite) model suggests adequately low  $p_f$ :

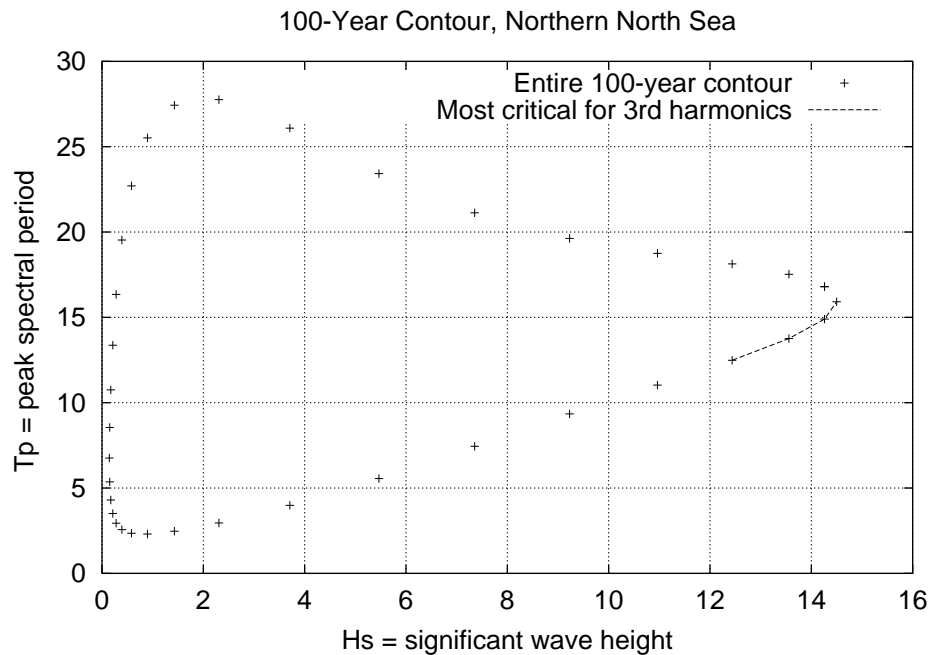
$$p_f \approx P[C > 24\text{m}] \approx 2 \times 10^{-5}$$

- Threshold  $C > 24$  m should be verified by pushover analysis
- Excellent agreement between IFORM and importance sampling simulation (also in SURFIT)

# Possible extensions

- Different wave power spectra as one goes around contour (e.g., double-peaked)
- Short-crested waves (non-coherent across structure)
- Lessen conservative combination of extreme wave crest with extreme (tide + surge) → joint statistics
- Freak waves?

# Jacket dynamics



- $E[X_{max}] = \text{max deck sway} = ?$
- $DAF = \text{Dynamic Amplification Factor} = ?$

$$DAF = \frac{E[X_{max}]}{E[X_{max,st}]} \approx E\left[\frac{X_{max}}{X_{max,st}}\right]$$

- Which seastates  $(H_s, T_p)$  give highest  $X_{max}$ ,  $DAF$  values?

# Methods and issues

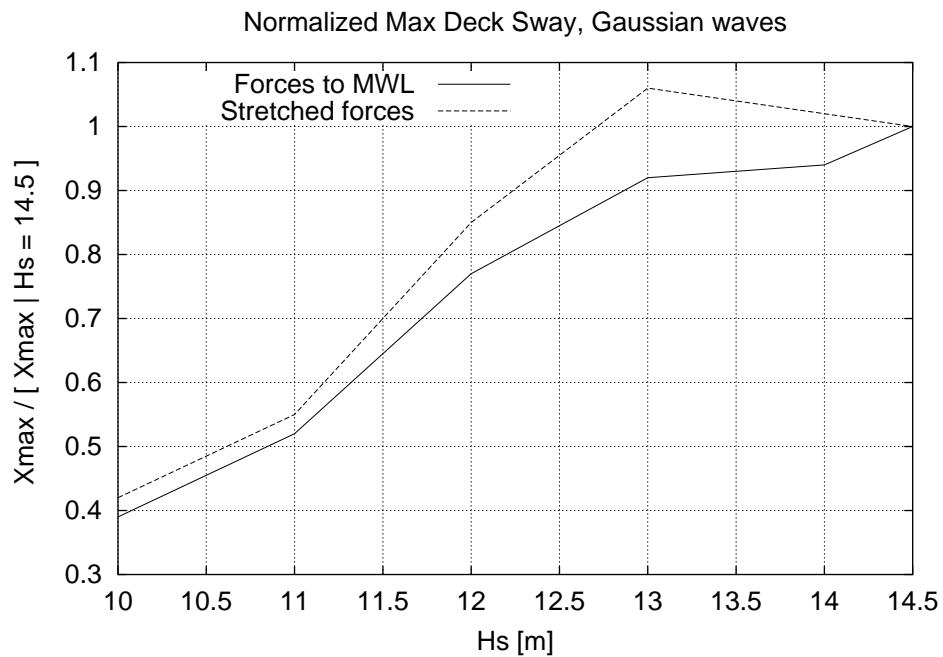
- Model jacket as system of piles; estimate  $F(t)$ =base shear under simulated  $\eta(t)$  (Gaussian or non-Gaussian)
- Model deck structure as 1DOF oscillator (with  $T_n$  between 1–5 sec); estimate  $x(t)$ =deck sway
- Consider effect of stretching: compare forces integrated to (1) MWL=mean water level and to (2) exact time-varying surface (constant extrapolation above MWL).

# Findings

**In all cases** (Gaussian vs Non-Gaussian; average versus stretched kinematics):

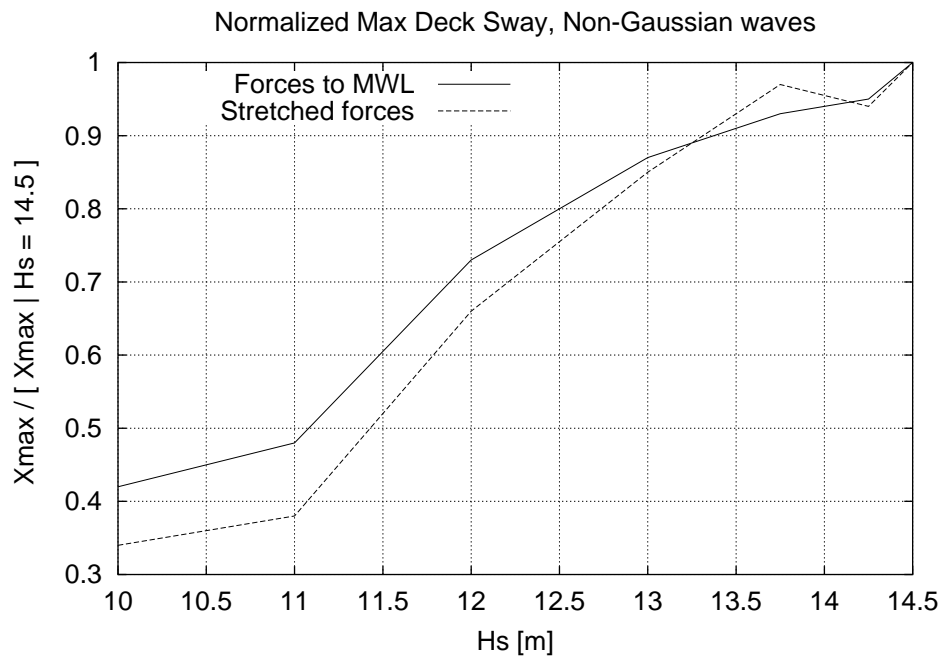
- Critical seastate well approximated by 100-year  $H_s$  condition (not true for floaters; e.g., slow drift problems)
- For  $T_n=5$  sec, DAF  $\approx 1.4$  over wide range of seastates

# Gaussian waves



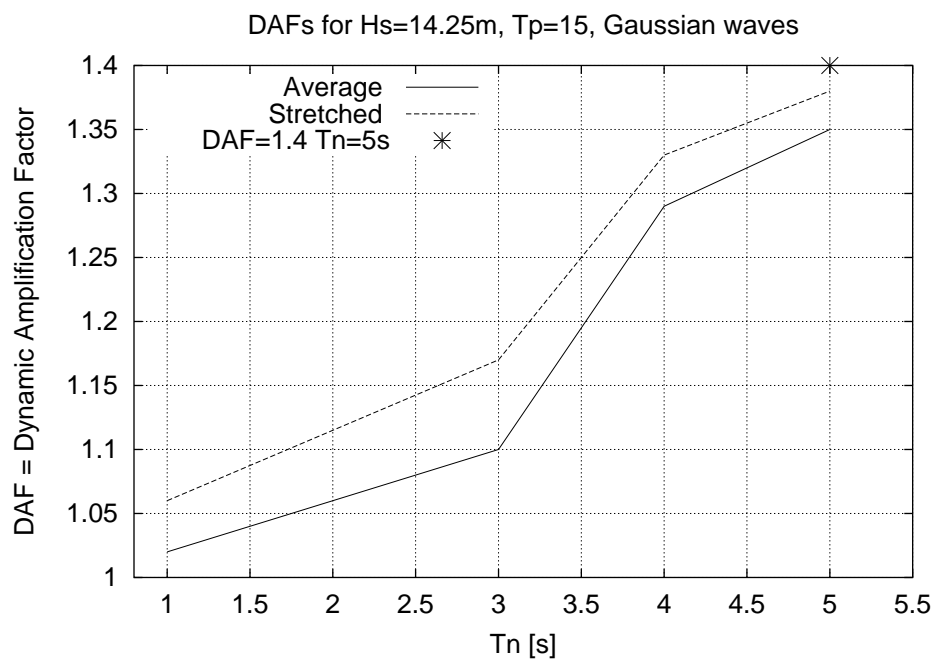
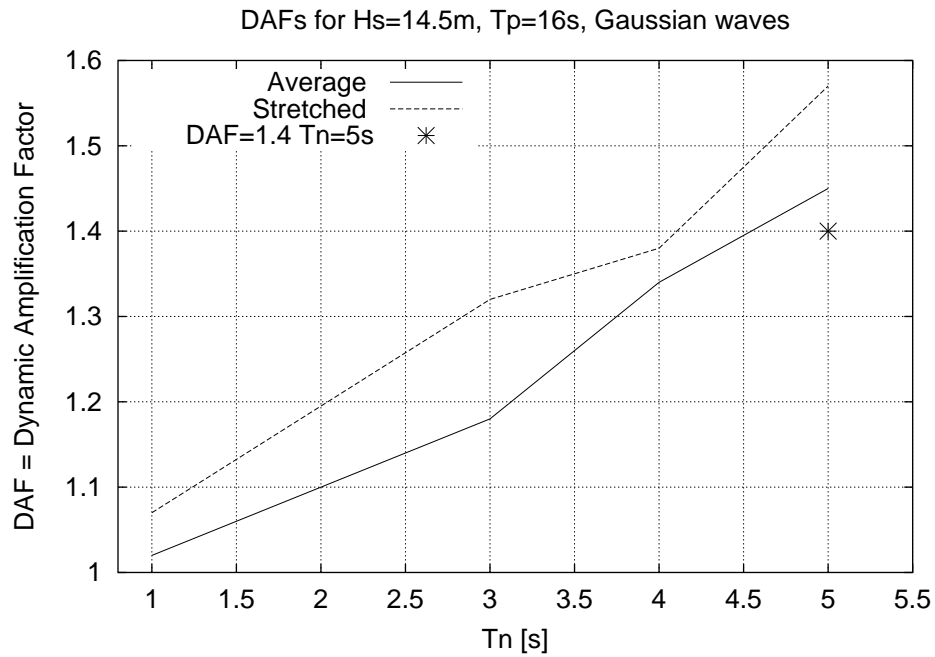
Critical seastate near  $H_S=14.5\text{m}$

# Non-Gaussian waves



Critical seastate always  $H_S=14.5\text{m}$

# Gaussian waves



# Gaussian waves

