On the Challenges of Analysis and Design of Turret-Moored FPSOs in Squalls (2)

Presented by: Amir Izadparast

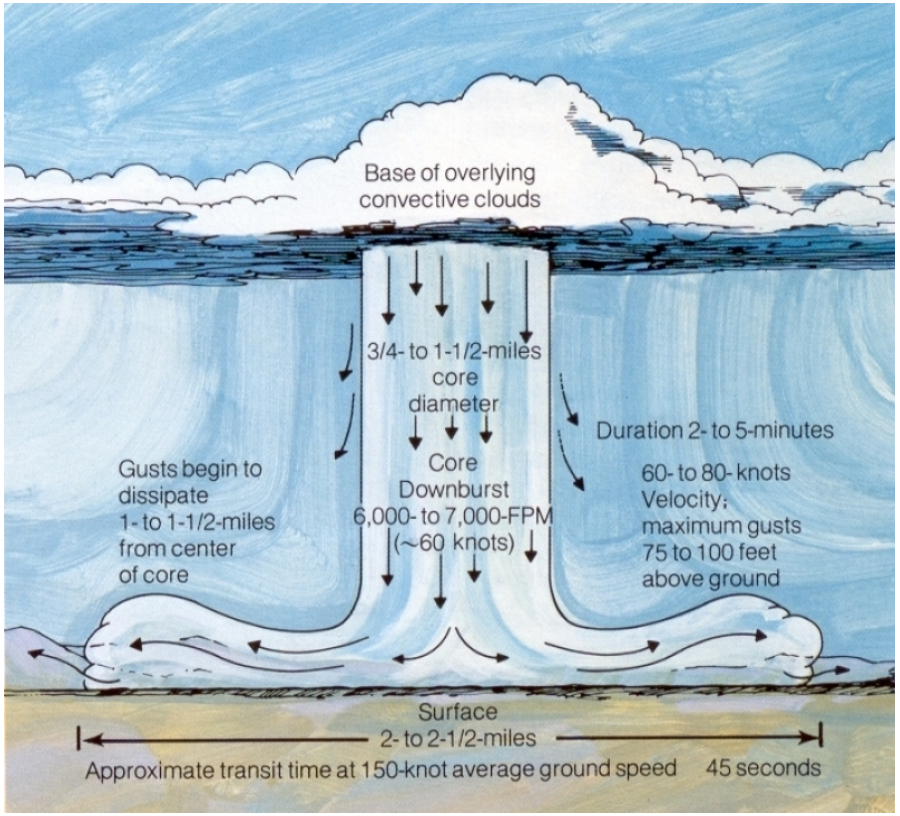
Co-Authors: Arun Duggal

Overview

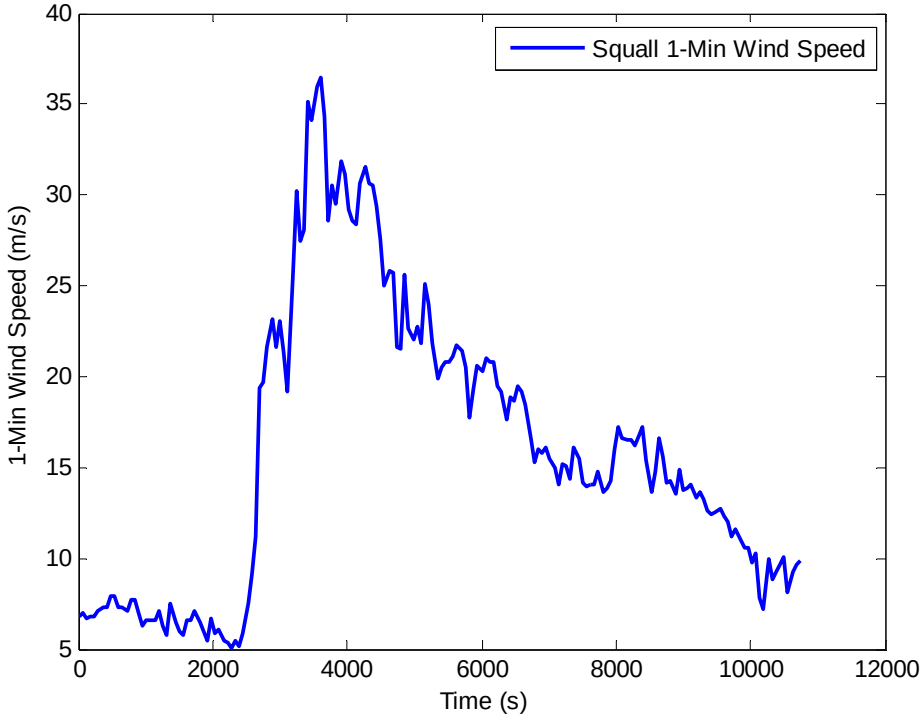
- Background –
  - Squalls Yet Another Environmental Phenomena
  - Current Design Practice
  - Our Proposal (previous paper)
- Further Discussion on Design Value

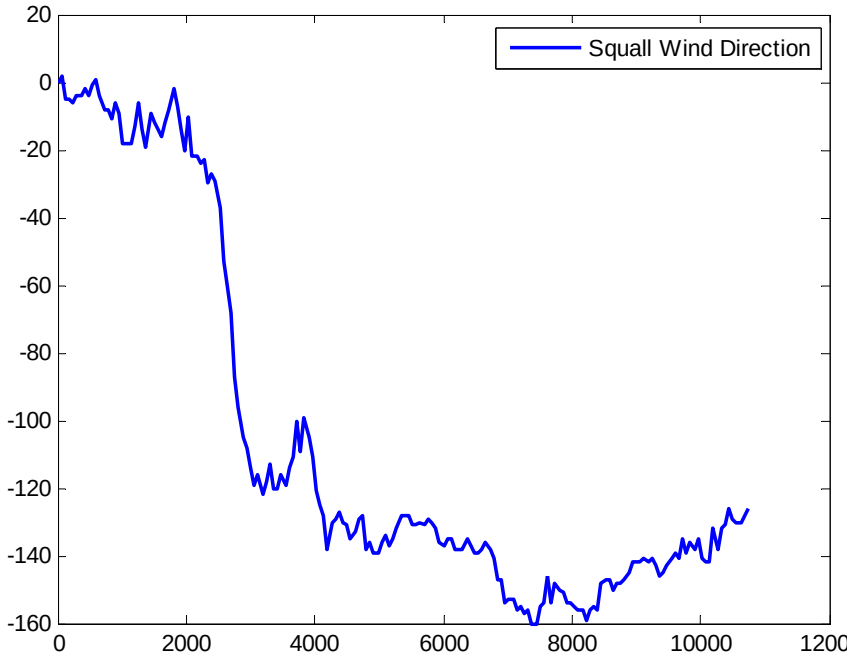
Background – Squall Characteristics

- Squall: A sudden onset of **Strong Winds** with speeds increasing to at least 8 m/s and sustained at 11 m/s for at least 1-minute. The **Intensity and Duration** is longer than that of a Gust.



Background – Squall Characteristics





Background – Analysis

- Analysis For Squalls
  - Scale the measured squalls (from 9 to 100+ timeseries) to 100yr RP wind speed (commonly up to 36m/sec) – Scale the time as well?
    - Run squalls from all plausible headings.
      - **Squall Heading** is commonly defined as the heading at peak velocity
    - Various vessel loading conditions
    - Various ambient wave and current combinations (zero wave and current!)
    - Various riser arrangements

Background – Design Value (Class Society)

- DNV-OS-E301 (Oct. 2010):
  - The extreme value of the mooring line tension and offset shall be taken as the **maximum value** for the time series of the actual responses.

- DNV-OS-E301 (Oct. 2013):
  - "As a minimum the **maximum tension from at least 20 representative squalls** is required."…
  - "If a much better basis in data is available a **95% fractile** as the characteristic load may be accepted. The set of scaled squalls considered shall be much larger than 20 representative cases (e.g. **100 representative squalls**)."

- NR 493 DT R02 E (April 2012):
  - "Design response (of tension, offset,...) is the **maximum responses** obtained over all the squall cases **except otherwise agreed**."

Background – Design Value (Argument)

- From a Designer Perspective:
  - Most critical value is the most sensitive estimate
    - Input squalls (scaling, quality of measurements, etc.)
    - Numerical modeling
  - Most critical value is the most unreliable (uncertain) statistics
    - Could significantly change in time
    - Tends to increase with sample size increase

Background – Design Value (Argument)

From a Designer Perspective

- Maximum overall response is the most sensitive estimate
  - Input squalls (scaling, quality of measurements, etc.)
  - Numerical modeling
- Maximum overall response is the most unreliable (uncertain) statistics
  - Sample size effect
  - Could significantly change in time
  - Tends to increase with sample size increase

- Most critical expected maximum response of large enough sample is not significantly sensitive to input uncertainties.
- Most critical expected maximum response of large enough sample is significantly less uncertain and less sensitive to sample size.

Background – Design Value (our proposal)

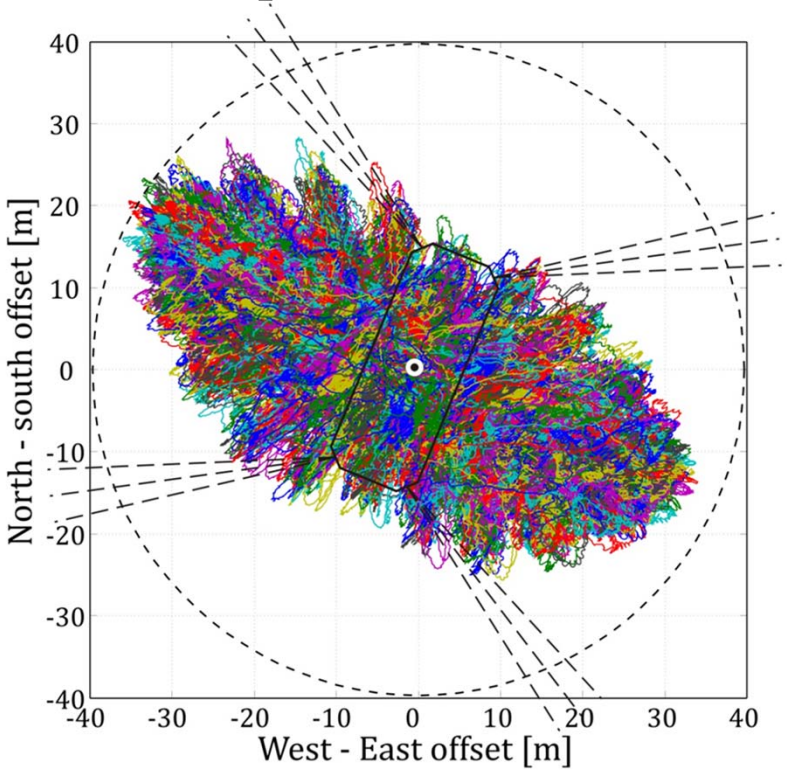
- 19th SNAME TX Offshore Symposium Feb. 2014:
  - Choose ~ 35 squalls that require minimal "scaling" for desired return period
  - Run simulations changing other variables (loading condition, ambient environment, squall heading, riser arrangements, etc.)
  - Treat the squalls as independent realizations of the same phenomena and estimate the **Expected Maximum** of the 35 observed maxima
    - The only random variables are squall intensity and directionality
  - The design value is the most critical **Expected Maximum**

Question?

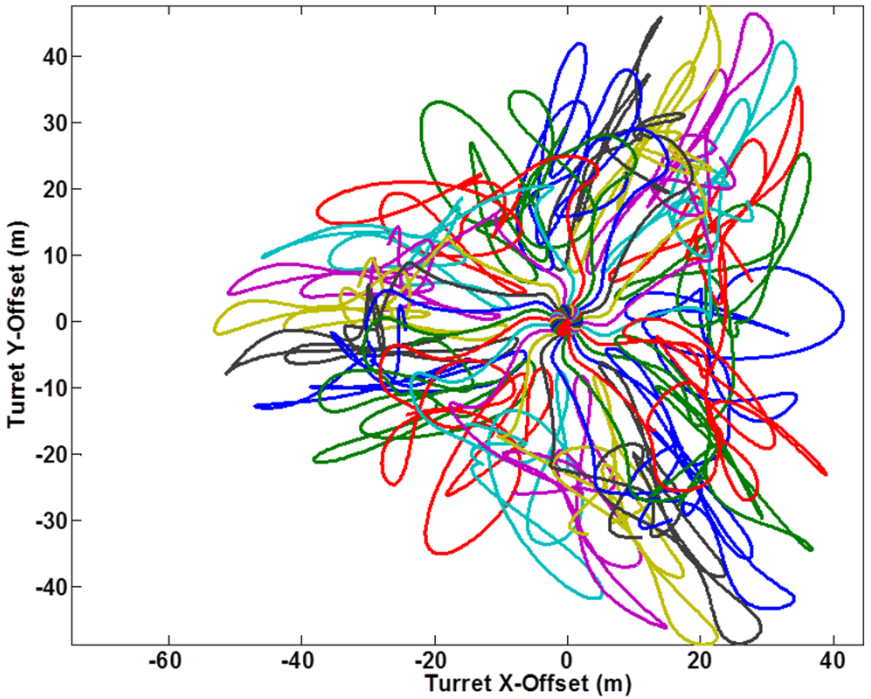
- "Are we fair to spread moored FPSOs?"
  - The design value for spread moored FPSOs is estimated as the expected value of response to squalls approaching the vessel from a certain angle (e.g. beam on).
  - The design value for turret moored FPSOs is estimated as the expected value of response to squalls approaching the vessel with a specific heading but individual maximum response could happen at different relative headings.

Spread Moored vs. Turret Moored

Spread-Moored



Turret-Moored

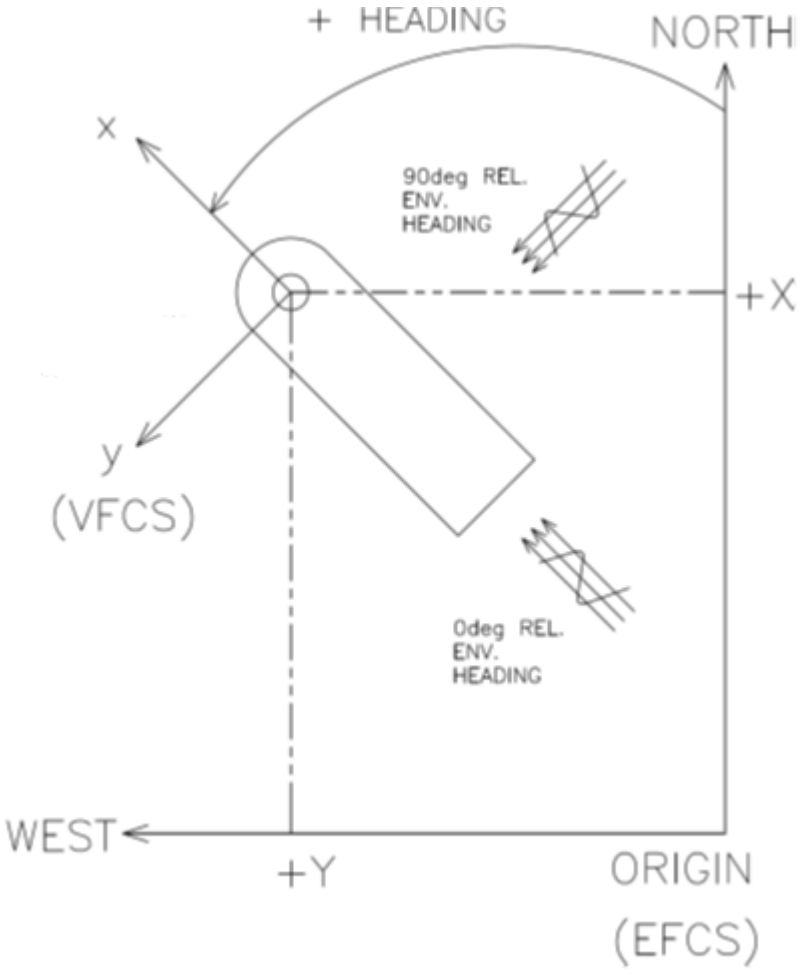


Response – First Reaction

Spread-Moored

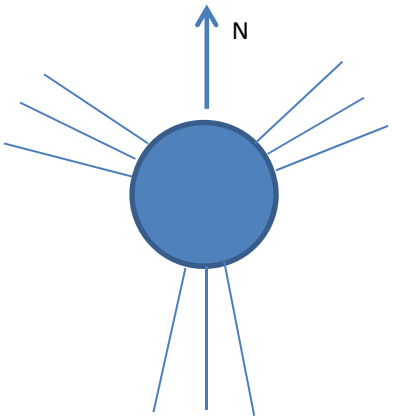
Turret-Moored

Earth Fixed vs Vessel Fixed Angles

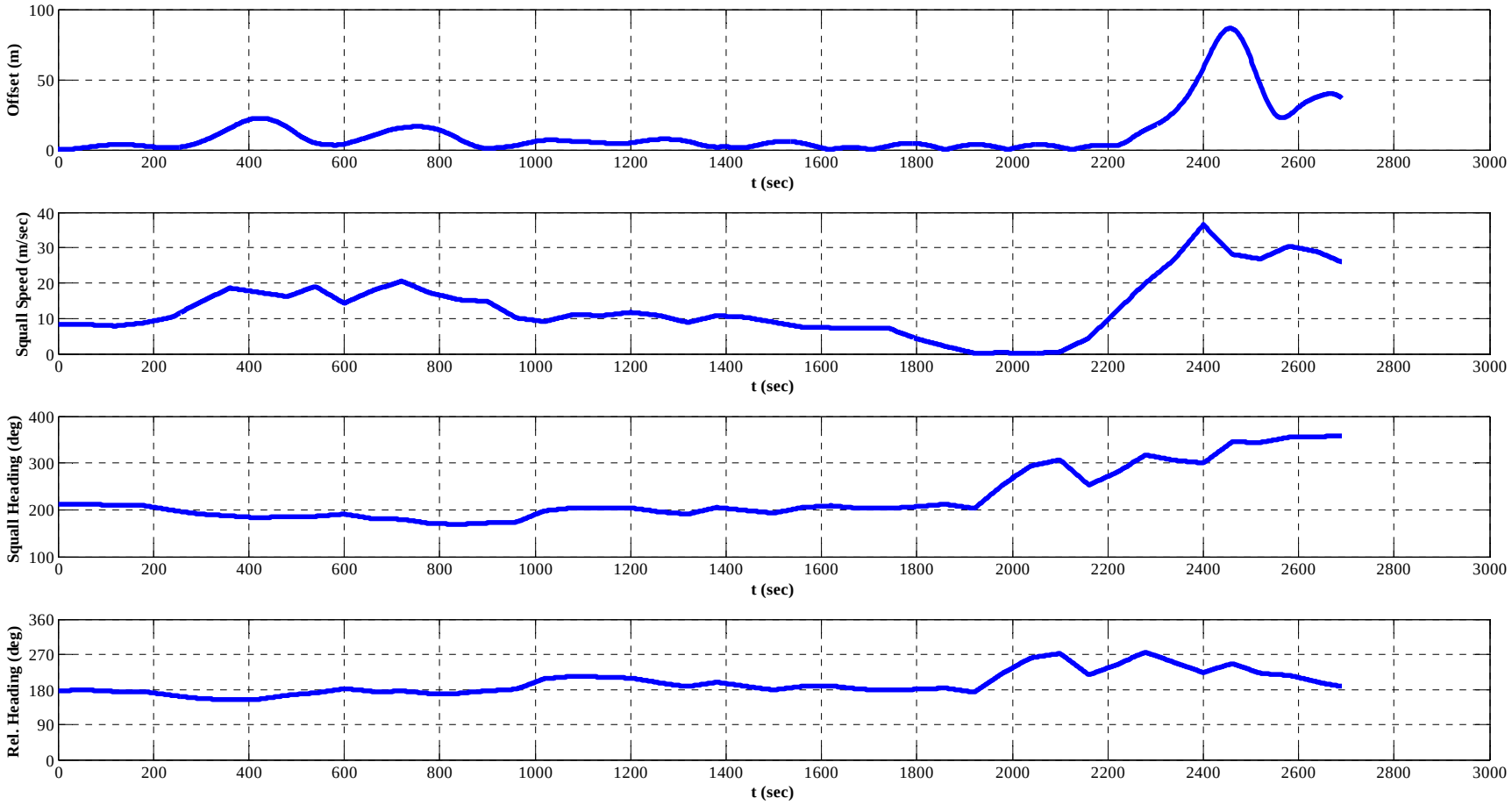


Further Discussion on Design Value

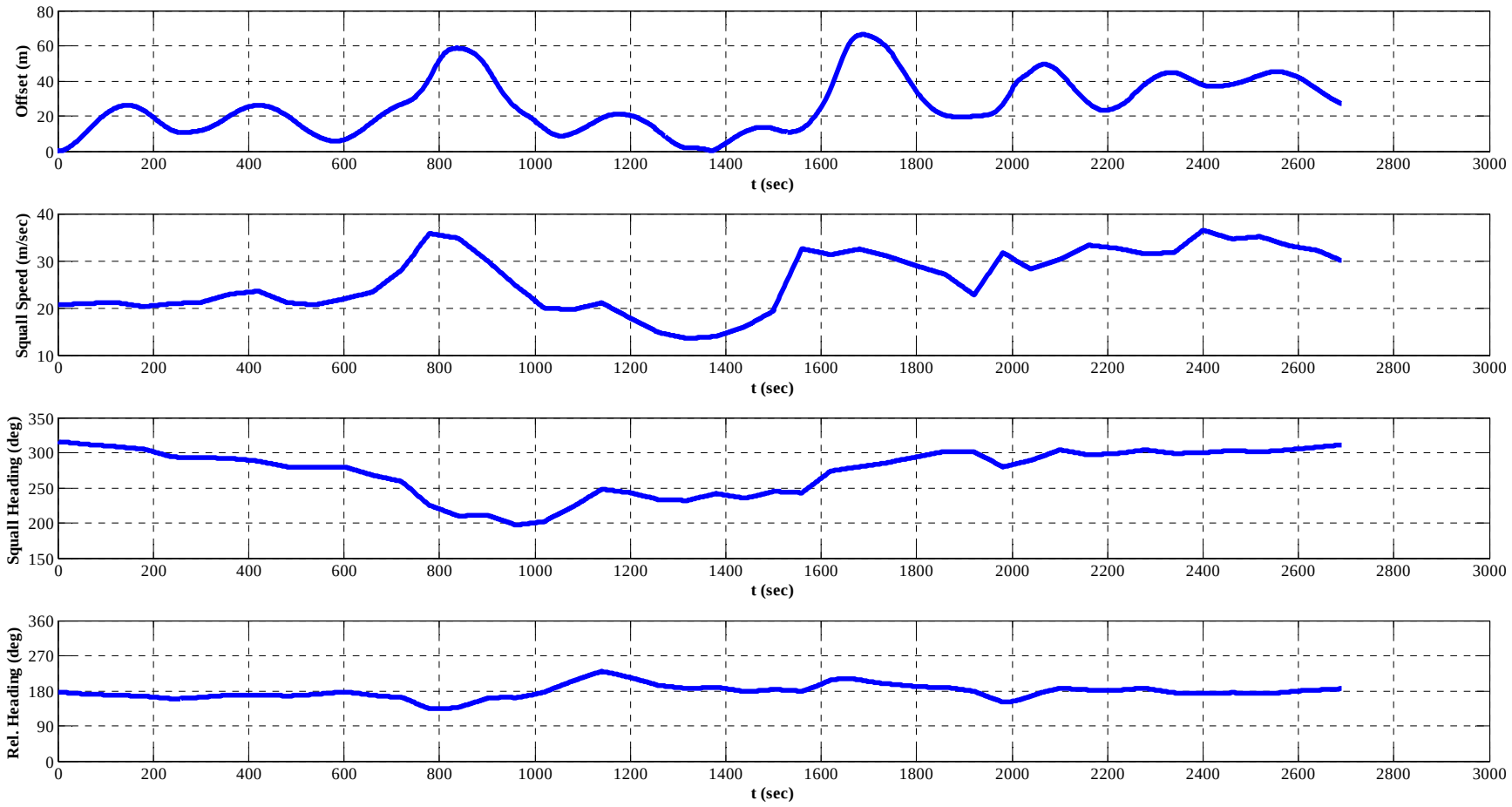
- Case Study
  - A typical deep-water turret moored FPSO designed for West Africa environment
  - Taut chain-polyester-chain mooring legs
  - 3G*3L mooring leg arrangement
  - 73 squalls, 24 headings (360deg, 15deg resolution)
    - Most critical draft
    - Most critical riser arrangement
    - Most critical ambient environment
    - 1752 cases



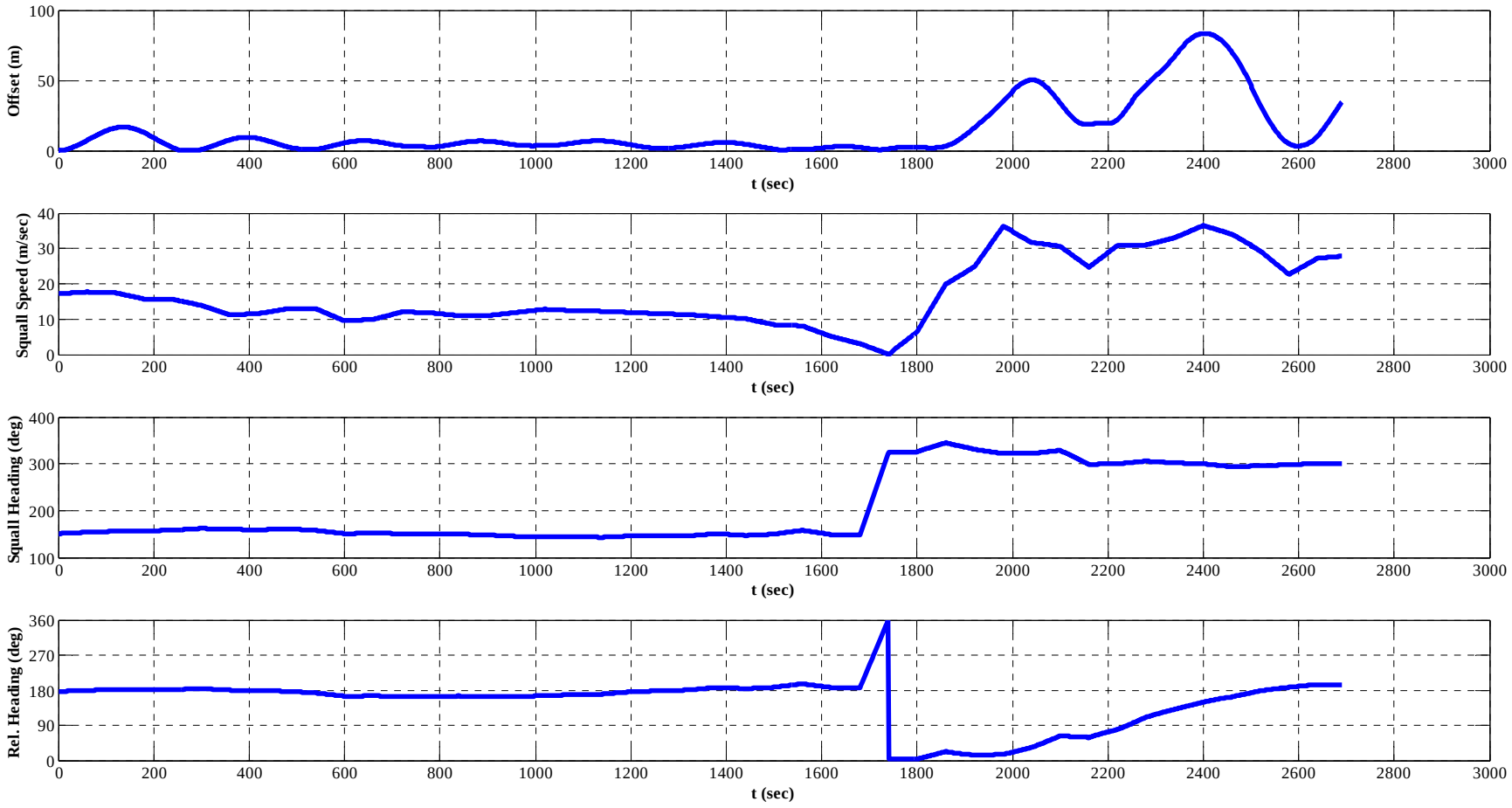
A More Careful Look at Offset



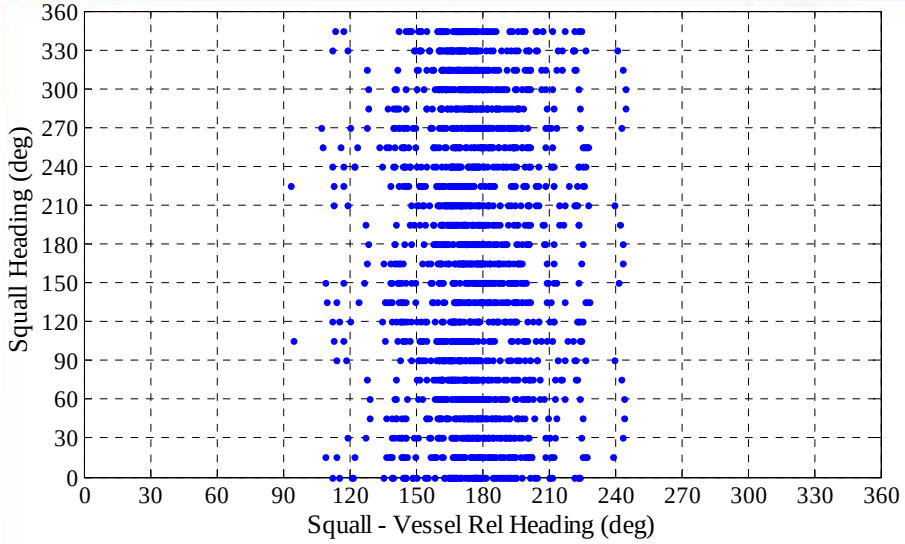
A More Careful Look at Offset

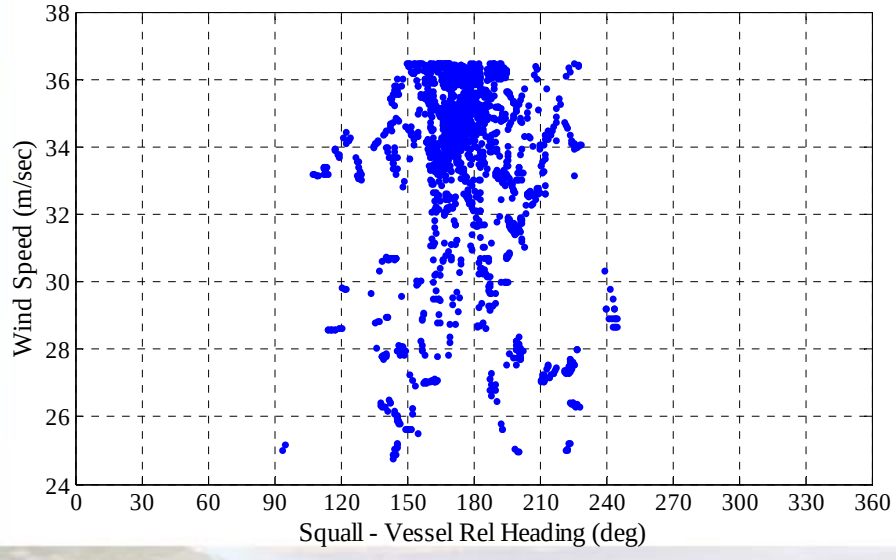


A More Careful Look at Offset

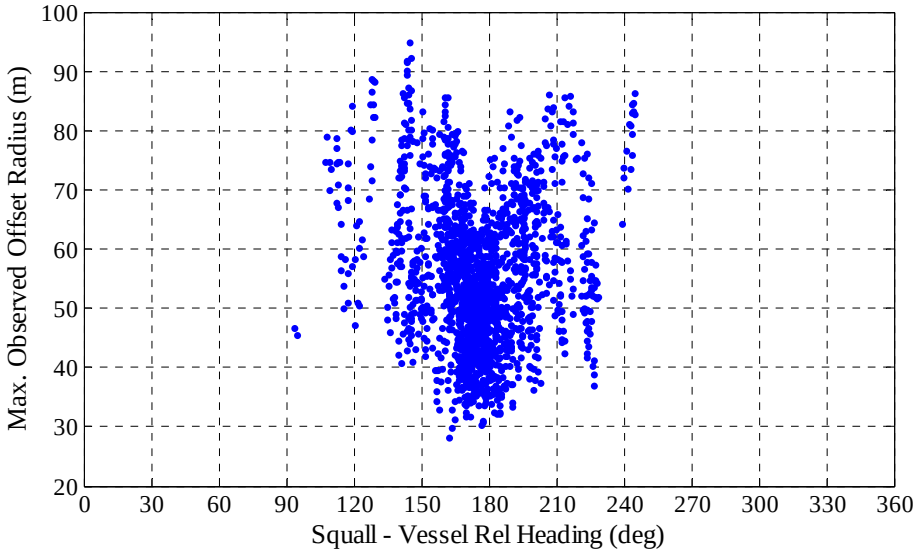


A More Careful Look at Offset

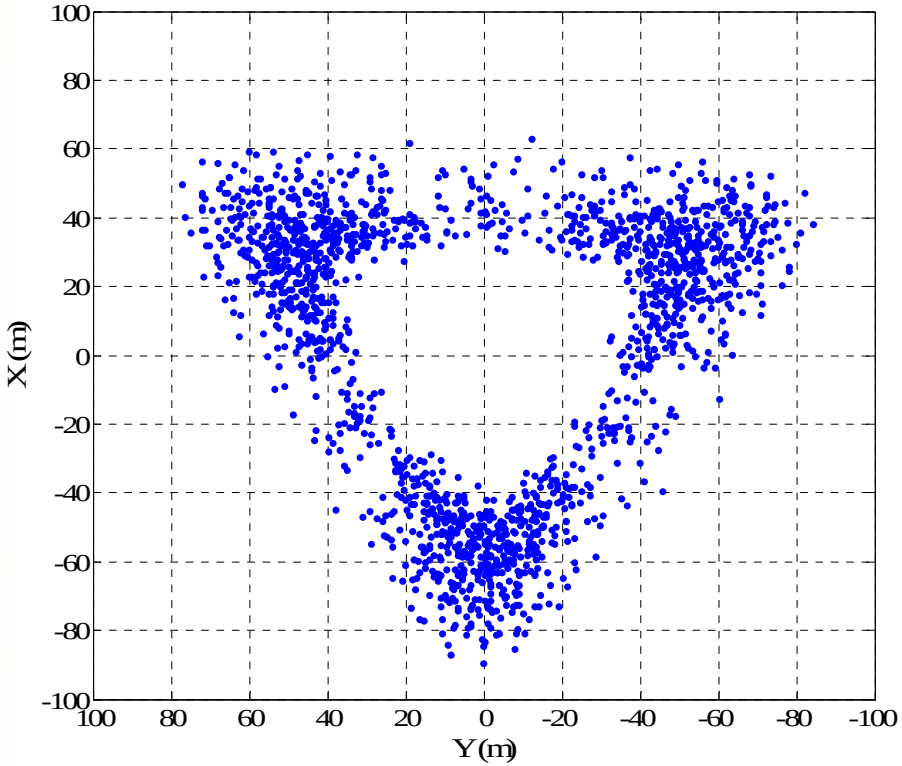


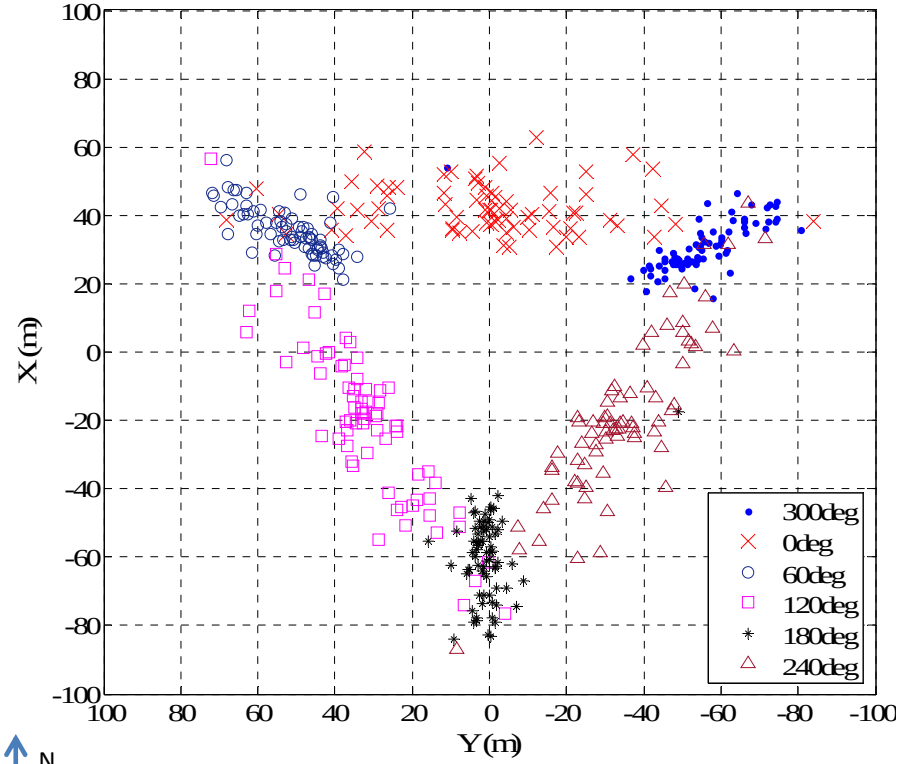


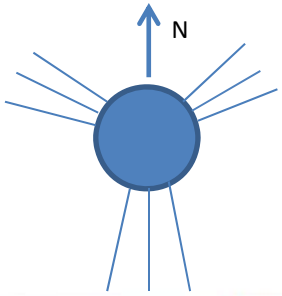
At the time of Max Offset



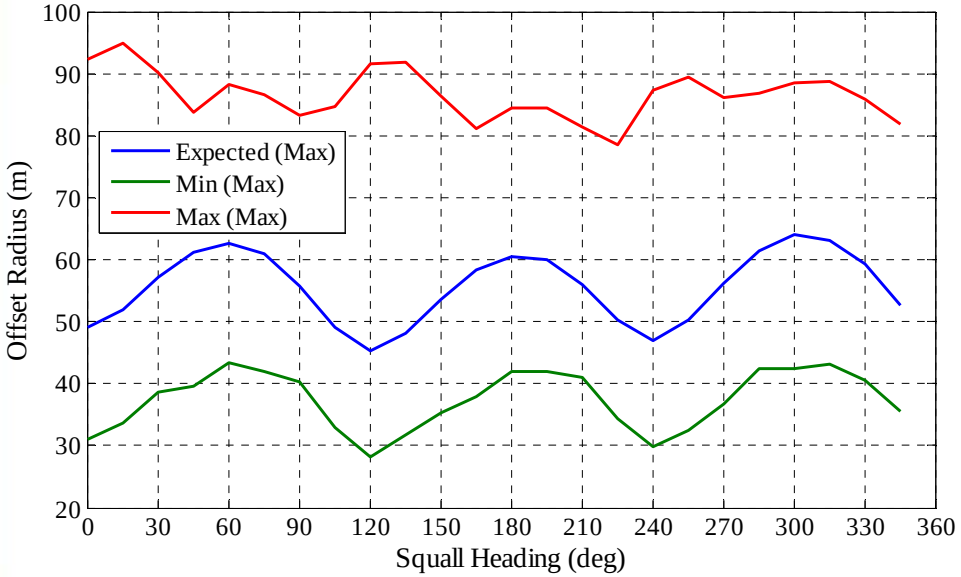
A More Careful Look at Offset

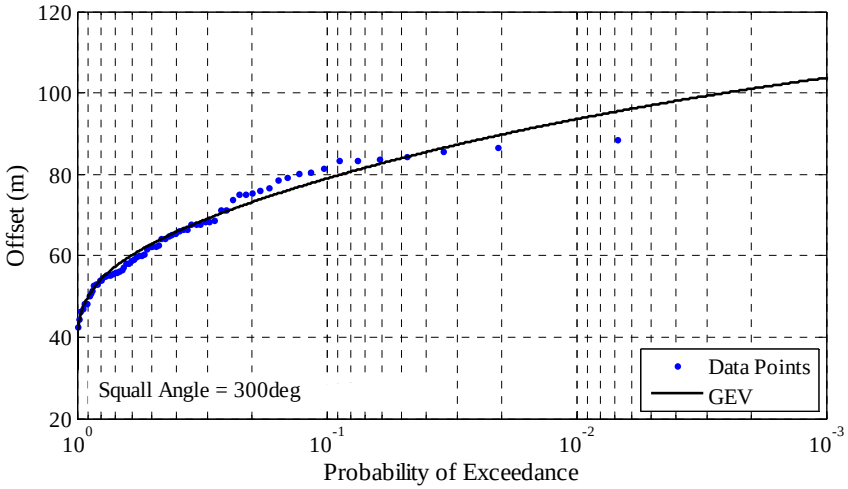


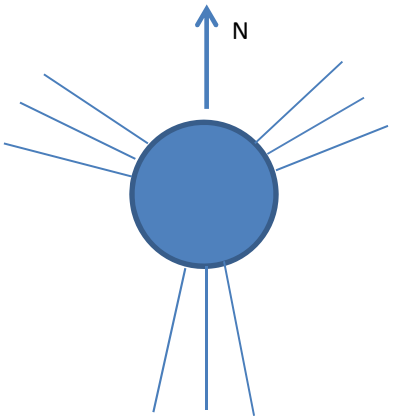




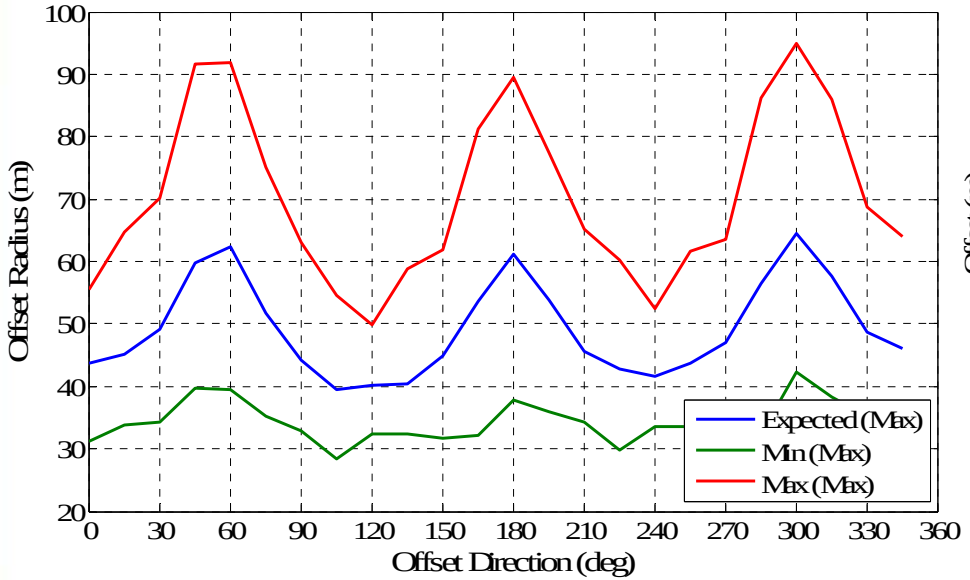
Offset Design Value – Original Proposal

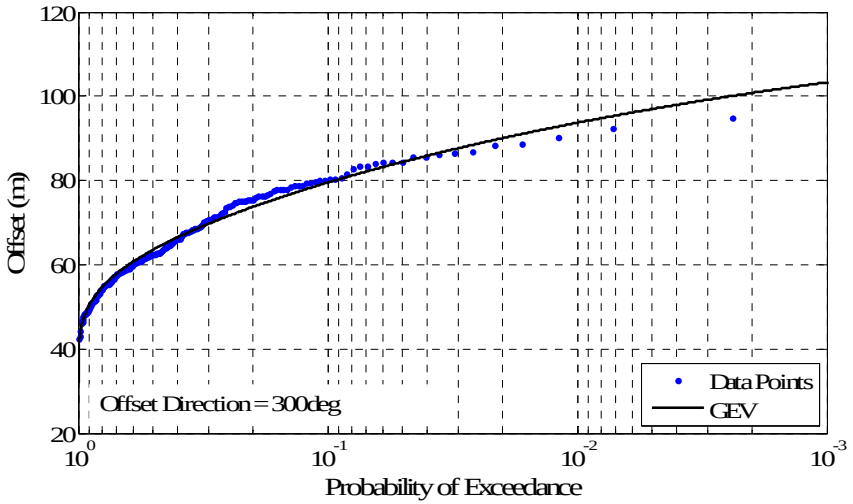


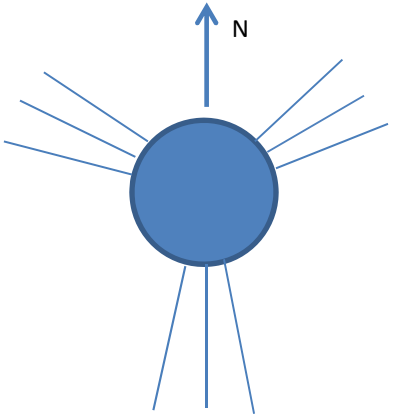




Offset Design Value – Offset Direction

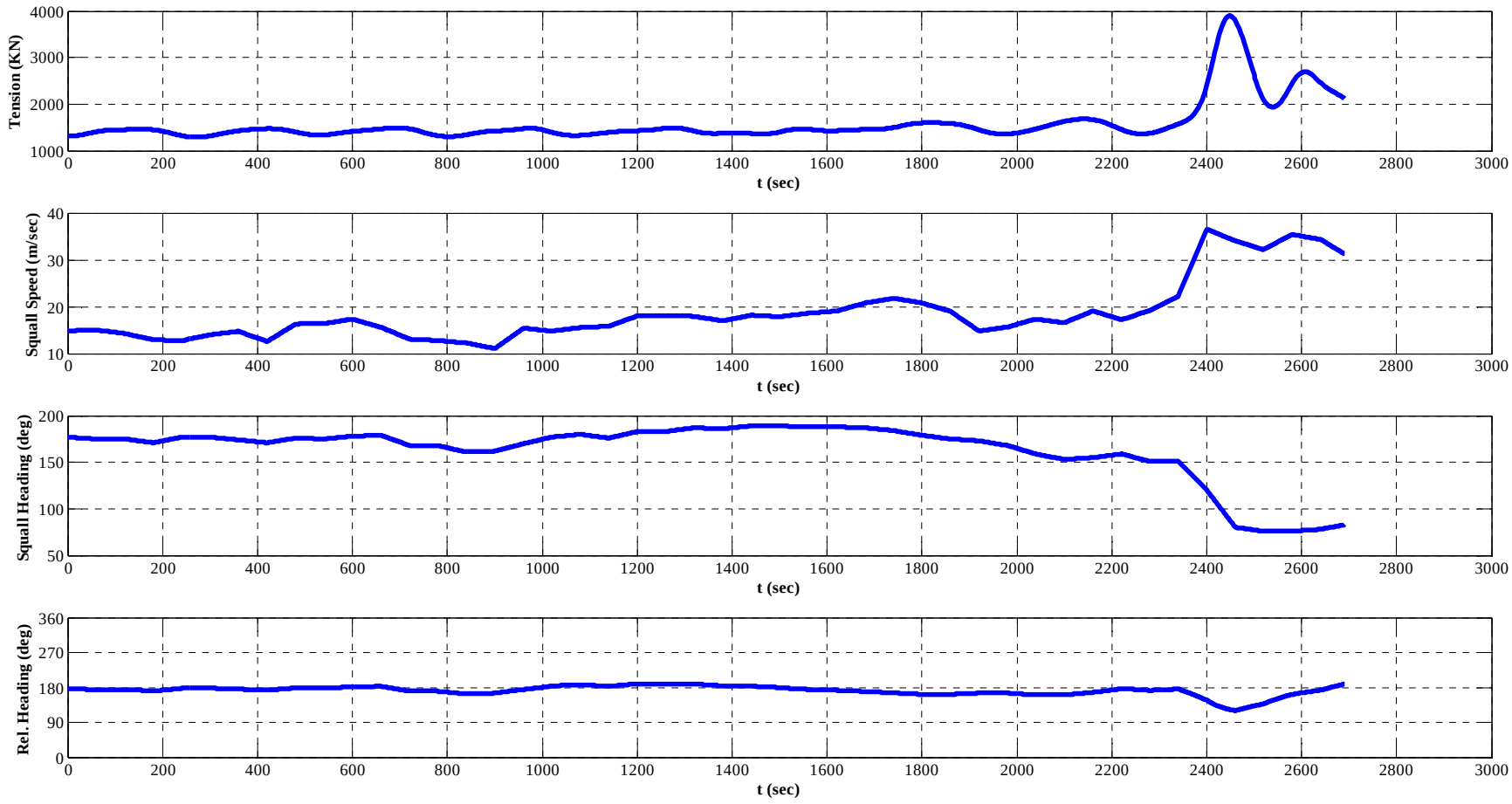




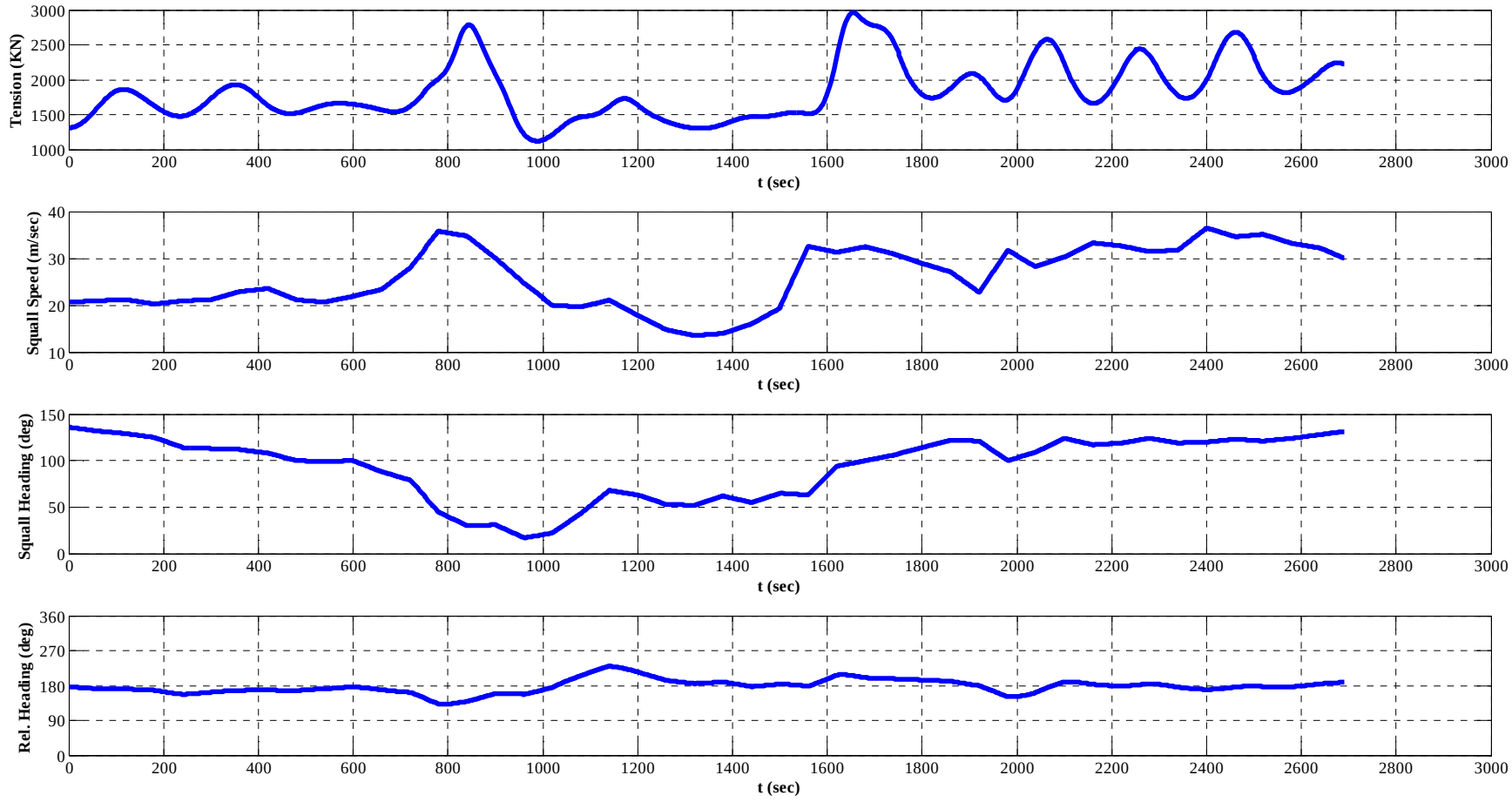


Method	E [Max Offset] (KN)
Expected Value – Squall Heading	63.9
Expected Value – Offset Direction	64.4

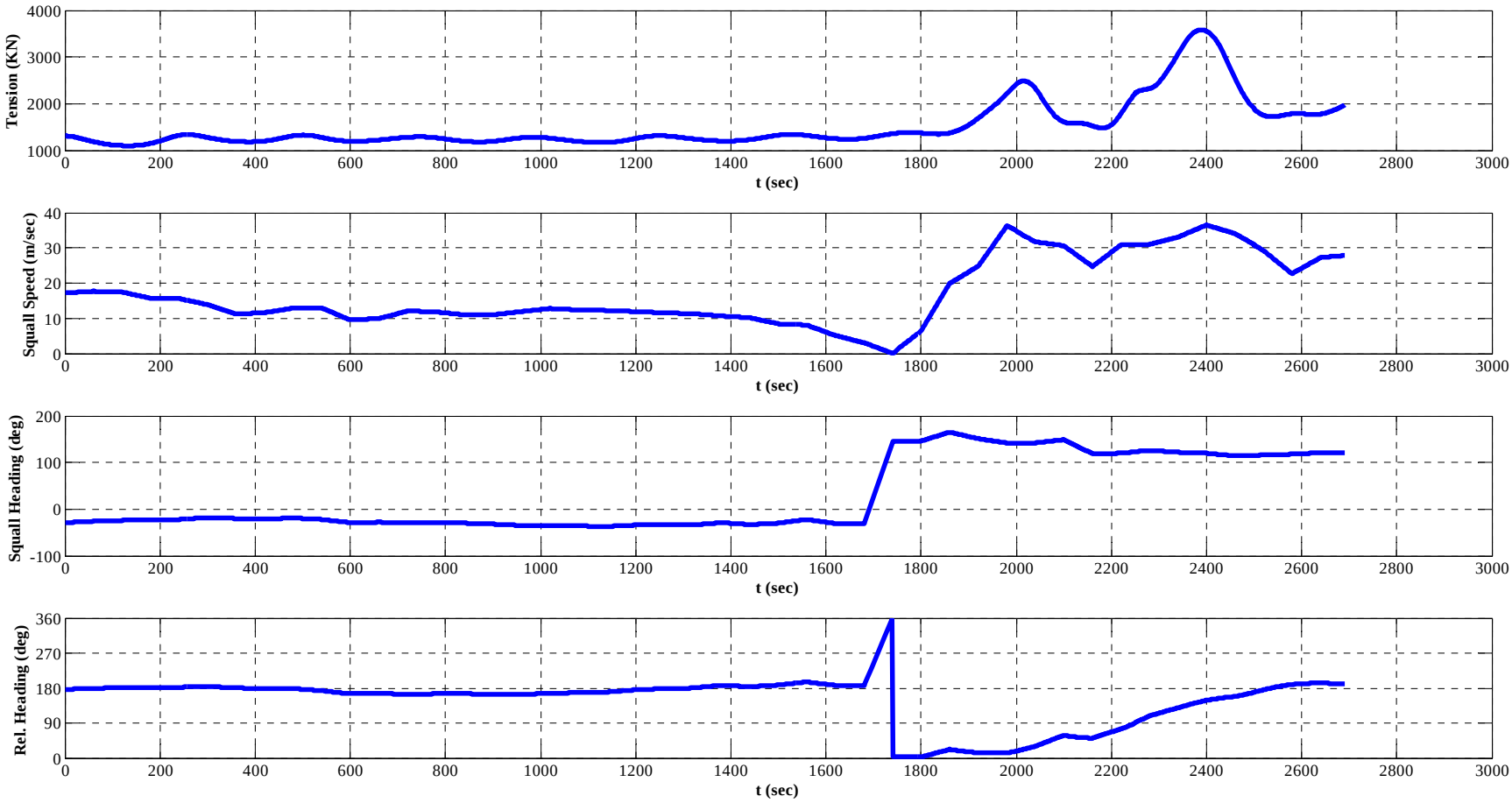
A More Careful Look at Tension



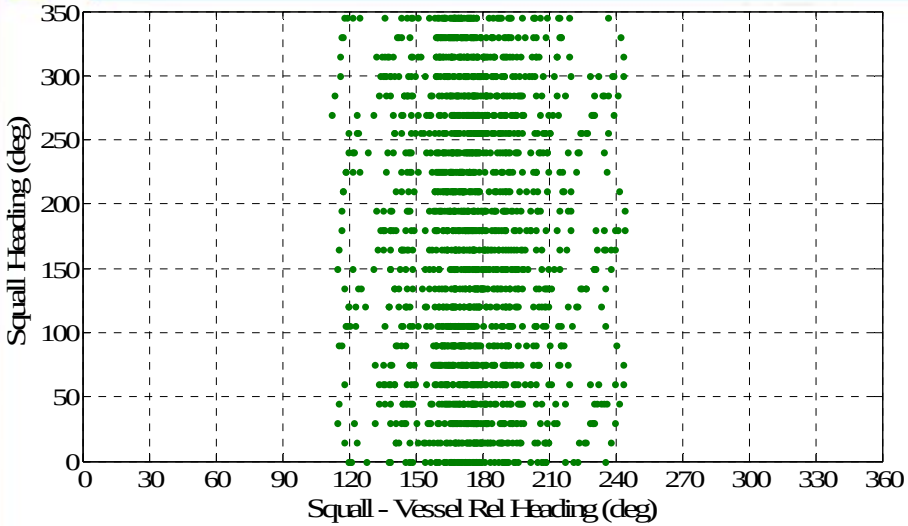
A More Careful Look at Tension



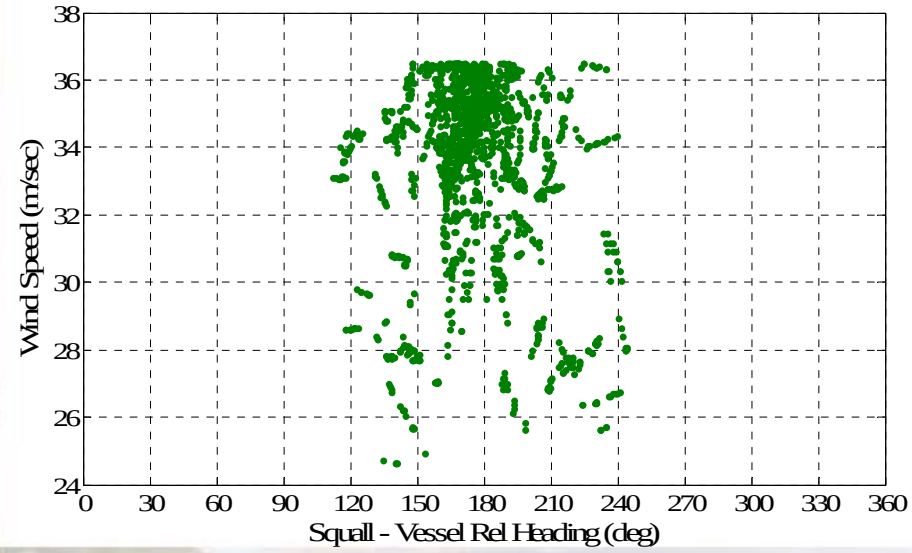
A More Careful Look at Tension

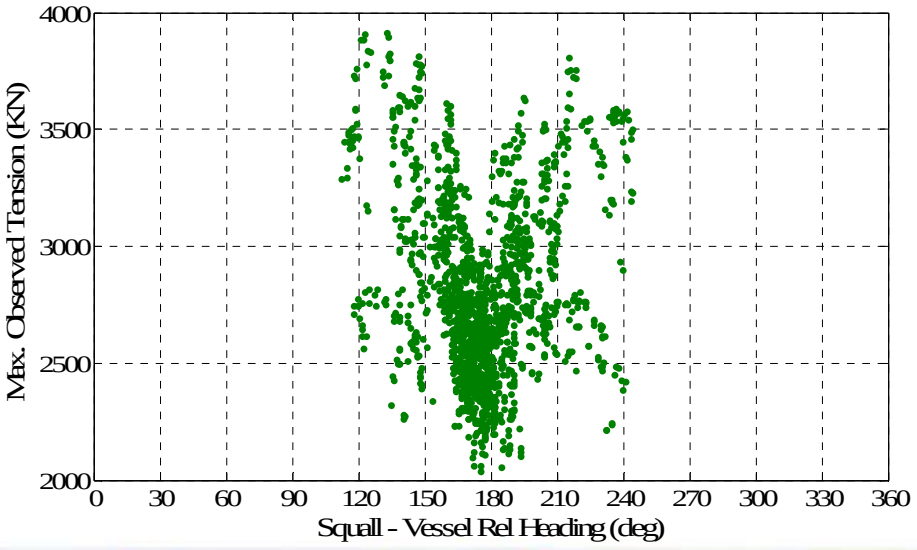


A More Careful Look at Tension

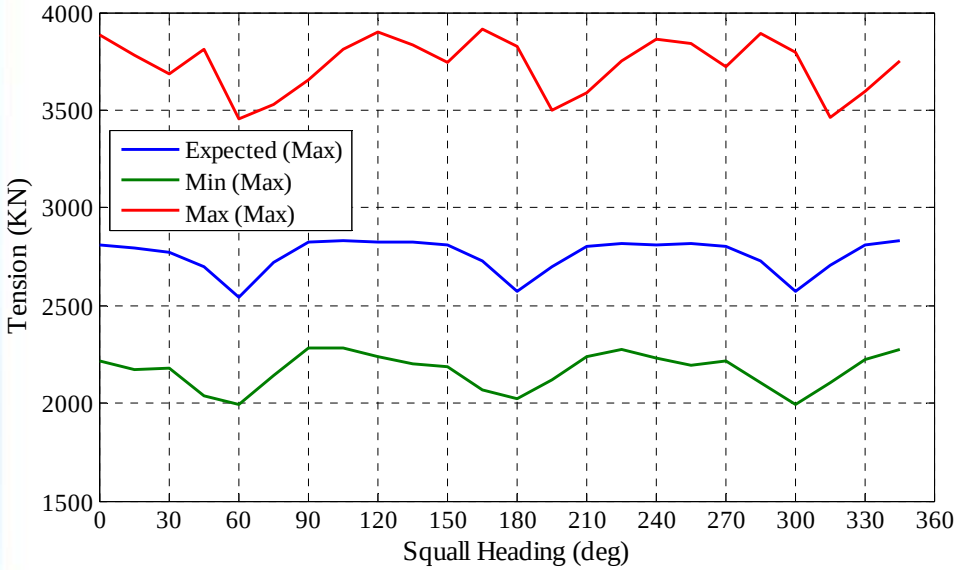


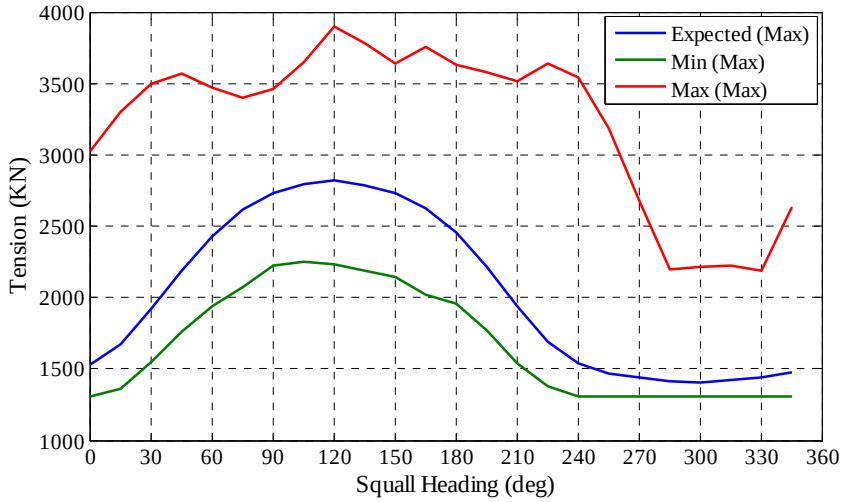
At the time of Max Tension in Most Critical Line

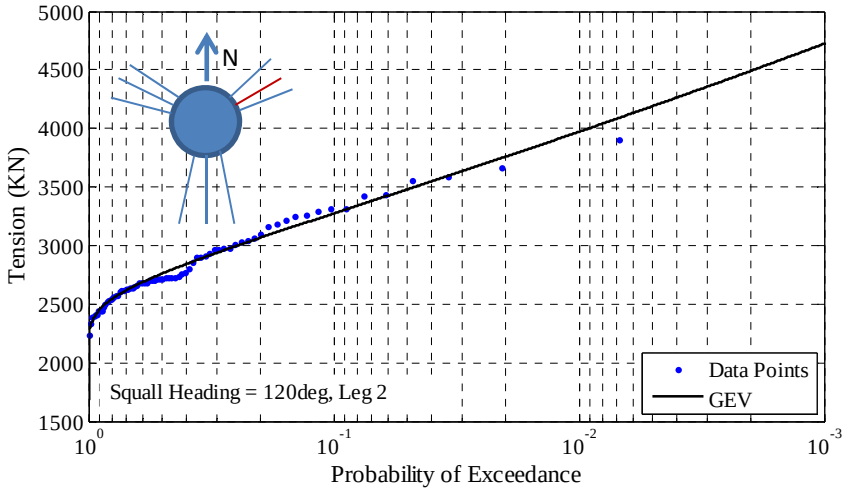




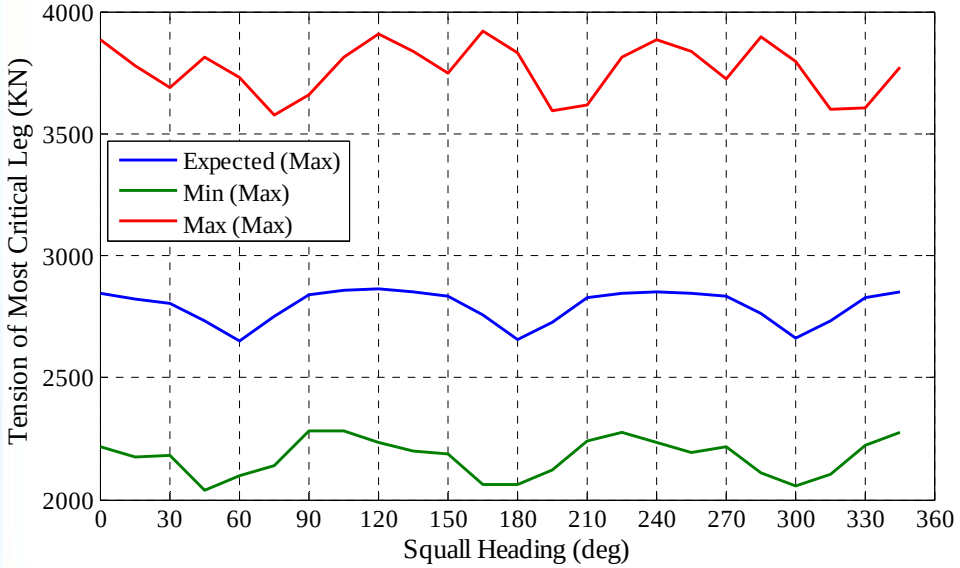
Tension Design Value – Original Proposal

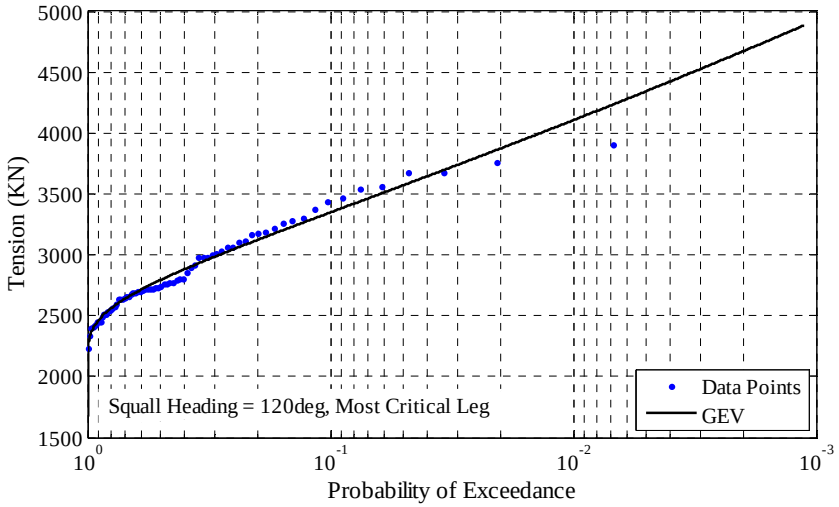




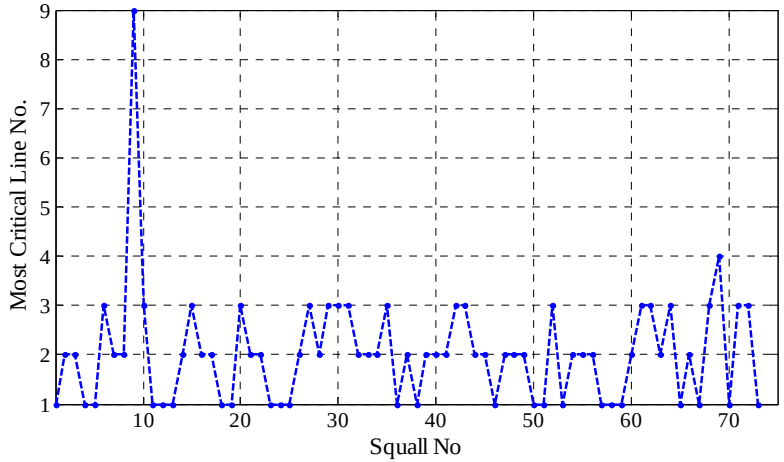


Tension Design Value – Most Critical Line





Method	E [Max Tension] (KN)
Expected Value – Individual Leg	2835
Expected Value – Most Critical Leg	2863



Next Steps

- Response – Based Analysis of Turret Moored FPSOs in Squalls
  - Challenges
    - Scaling Issues
    - Synthetic Squalls (intensity and directionality)
    - Extrapolating Inputs or Responses


Thank You!