

# OTC2016

Offshore Technology Conference

**ENDLESS**INNOVATION

2-5 May 2016

HOUSTON, TEXAS, USA

NRG Park

## OTC-27039-MS

# Efficient Environmental and Structural Response Analysis by Clustering of Directional Wave Spectra

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S. Fan, Shell; G.Z. Forristall, Forristall Ocean Engineering Inc;  
Y. Li, Shell; R. Fratantonio, RPS ASA; P. Jonathan, Shell.

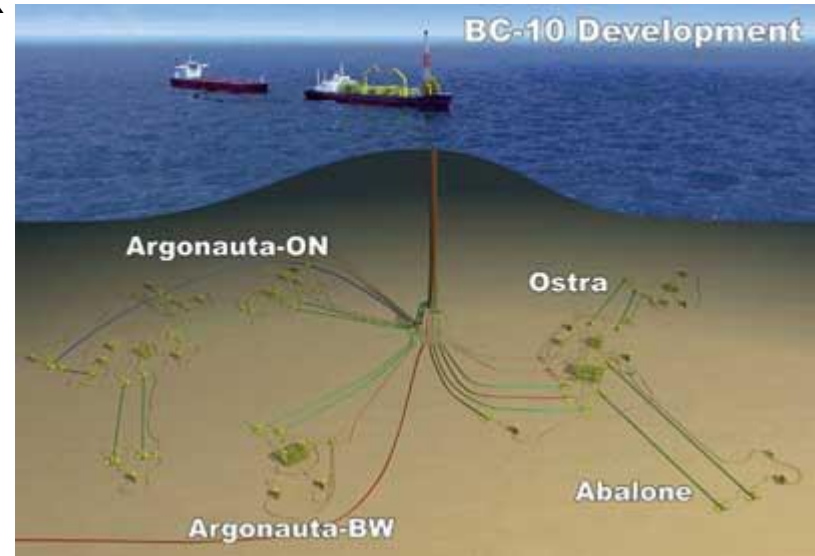


# OUTLINE

- Motivation
- Cluster Analysis Methodology
- Case study – BC-10 Offshore Brazil
- Discussion and Conclusions

## MOTIVATION

- Estimation of environmental and complex structural responses, such as fatigue for risers on deepwater floating production systems, is a critical and generally computationally intensive process.
- Long term damage estimates require the determination of host vessel motions used for riser stress calculations.
- In principle, riser stress could be calculated for each of a large number of directional sea states, a considerable computational burden.



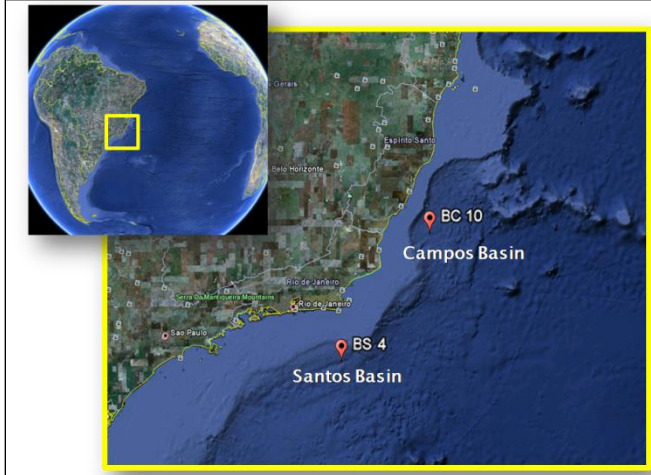
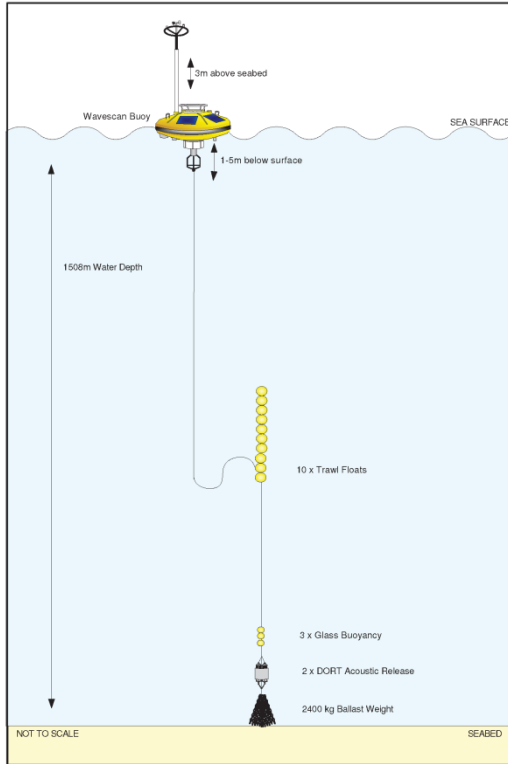
## CLUSTER ANALYSIS METHODOLOGY

- Cluster analysis provides a way of grouping a (typically large) number of individuals (such as directional spectra for consecutive sea states) into a (typically small) number of clusters.
- All members of the same cluster have similar characteristics.
- Each cluster has a cluster center, or centroid.
- All members of a given cluster are more similar to the cluster centroid for that cluster than to any other cluster centroid.

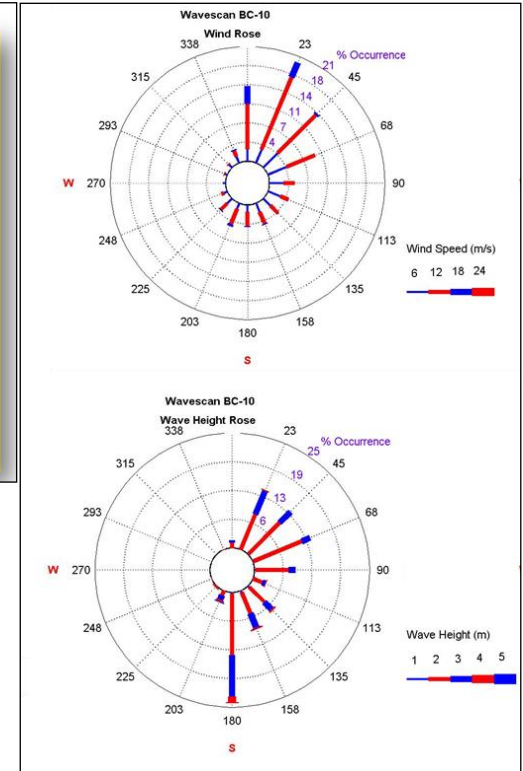
Non-hierarchical K-MEANS clustering: to find cluster allocations and centroid estimates such that the within-cluster sum of squares is minimized:

$$I_G^2 = \sum_{j=1}^m \sum_{X_i \in C_j} \|G(X_i) - G(\mu_j)\|^2$$

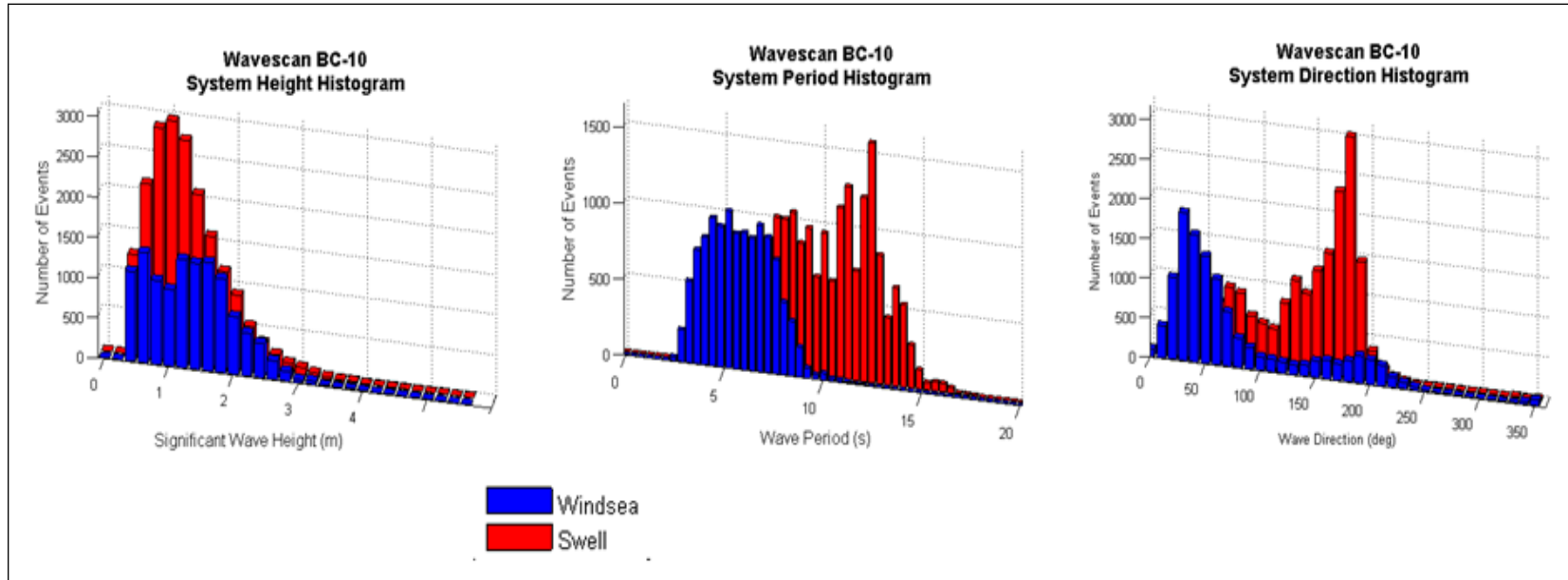
# WIND AND WAVE MEASUREMENT – BC10



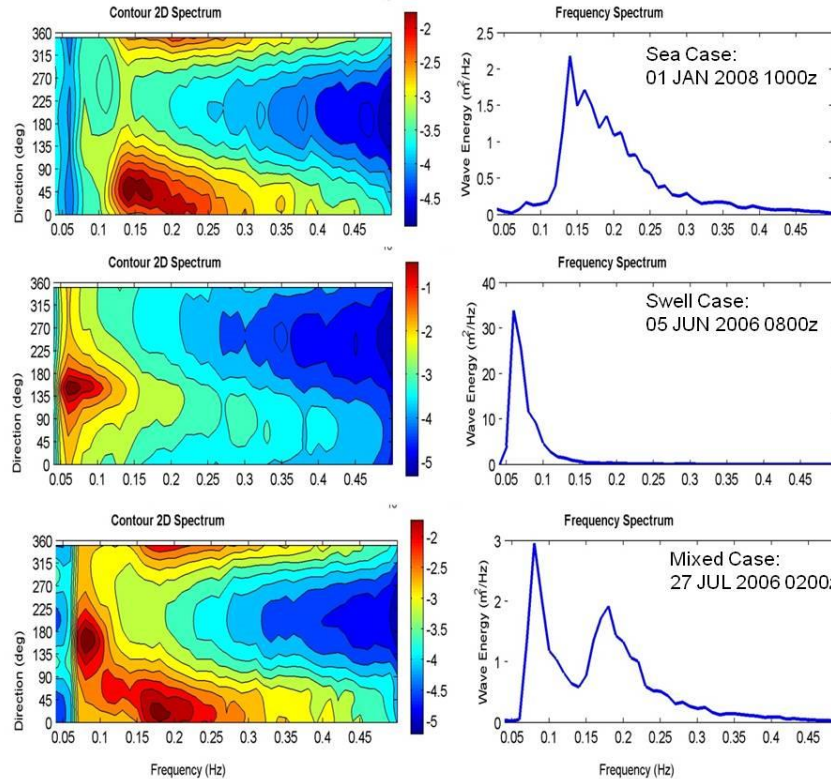
A total of 17,086 hourly wave records were obtained spanning an approximate two-year time period from 1 May 2006 to 17 June 2008



# OBSERVED WAVE CLIMATE

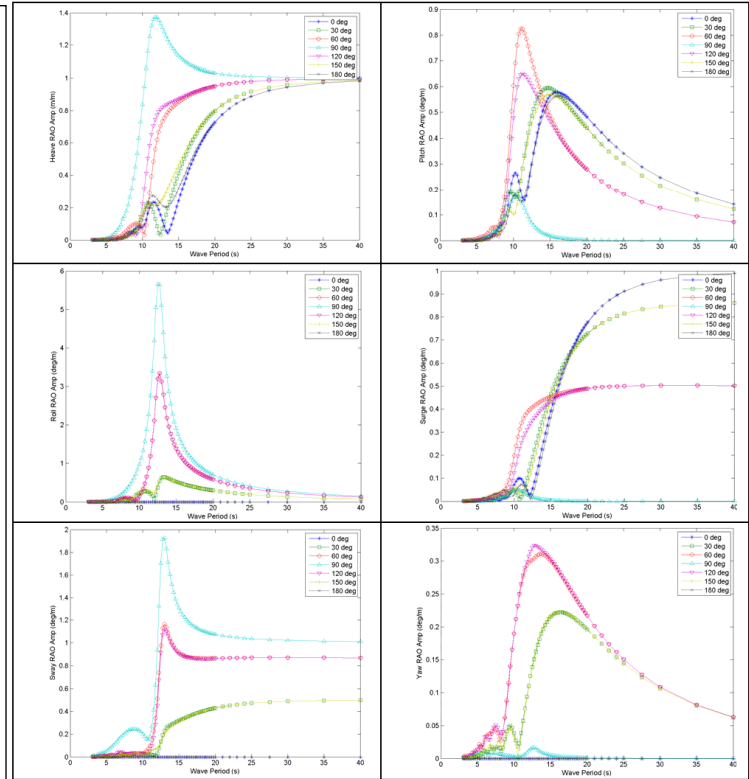
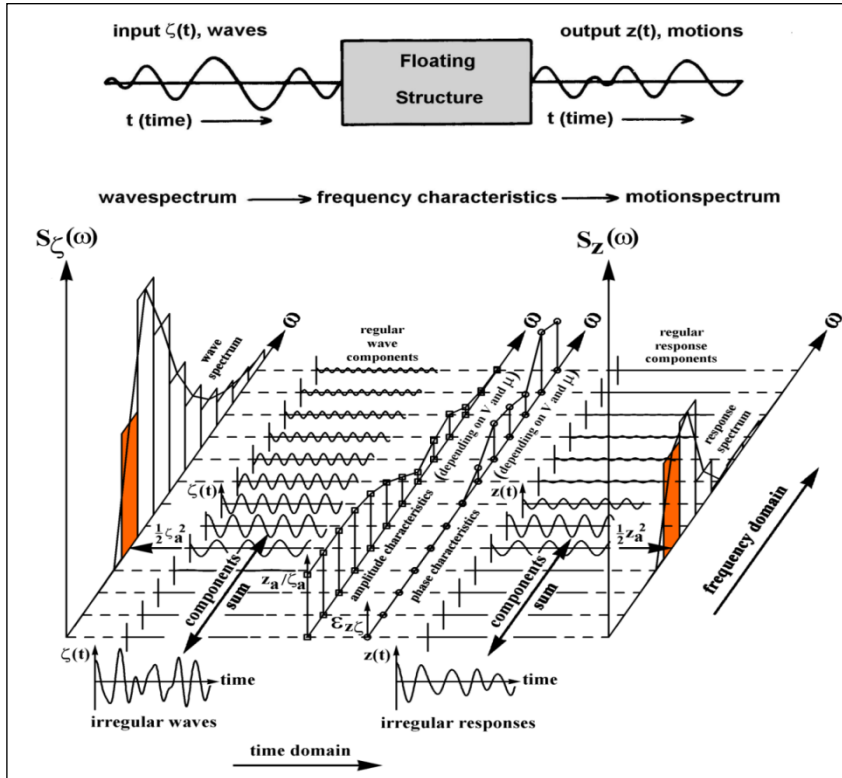


# OBSERVED WAVE CLIMATE – TYPICAL WAVE SPECTRUMS



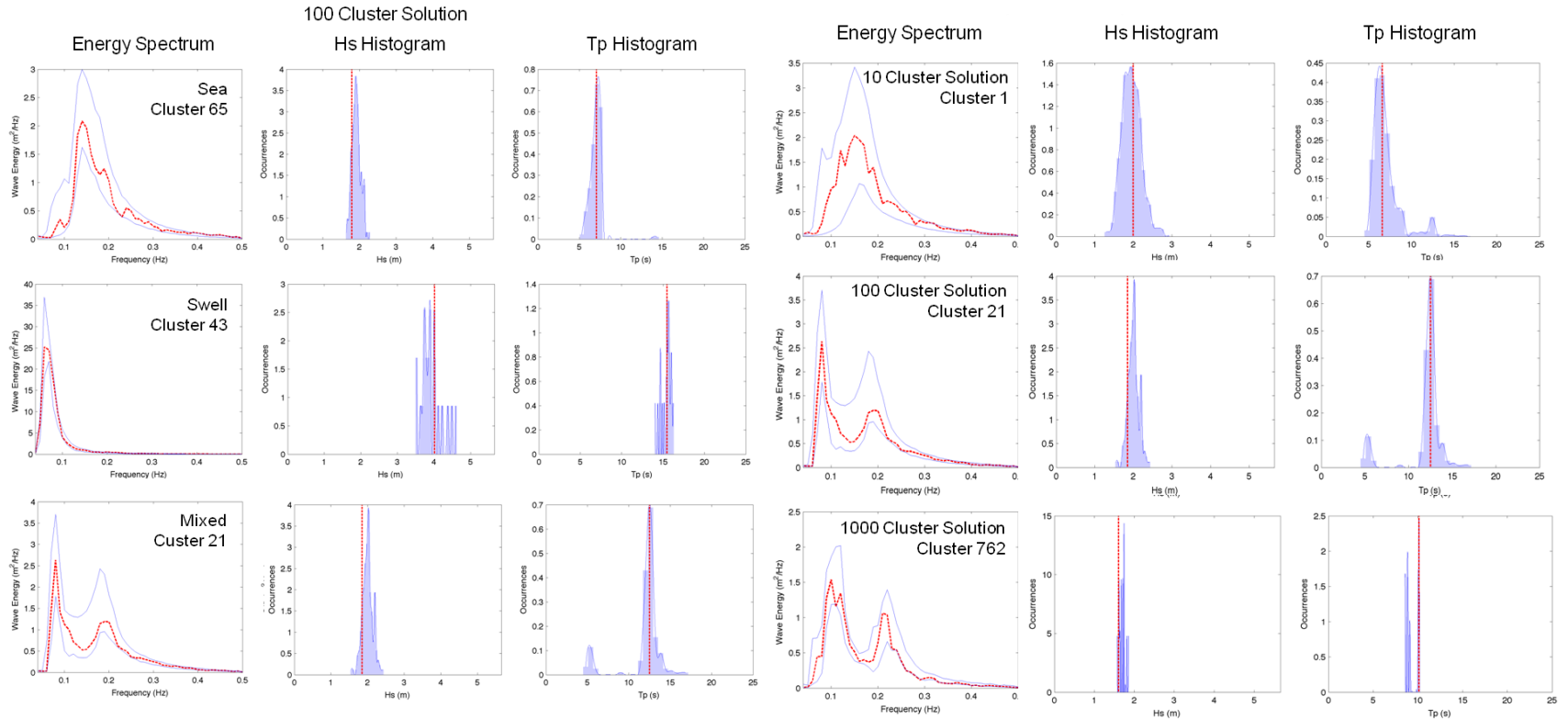


# RESPONSE ANALYSIS

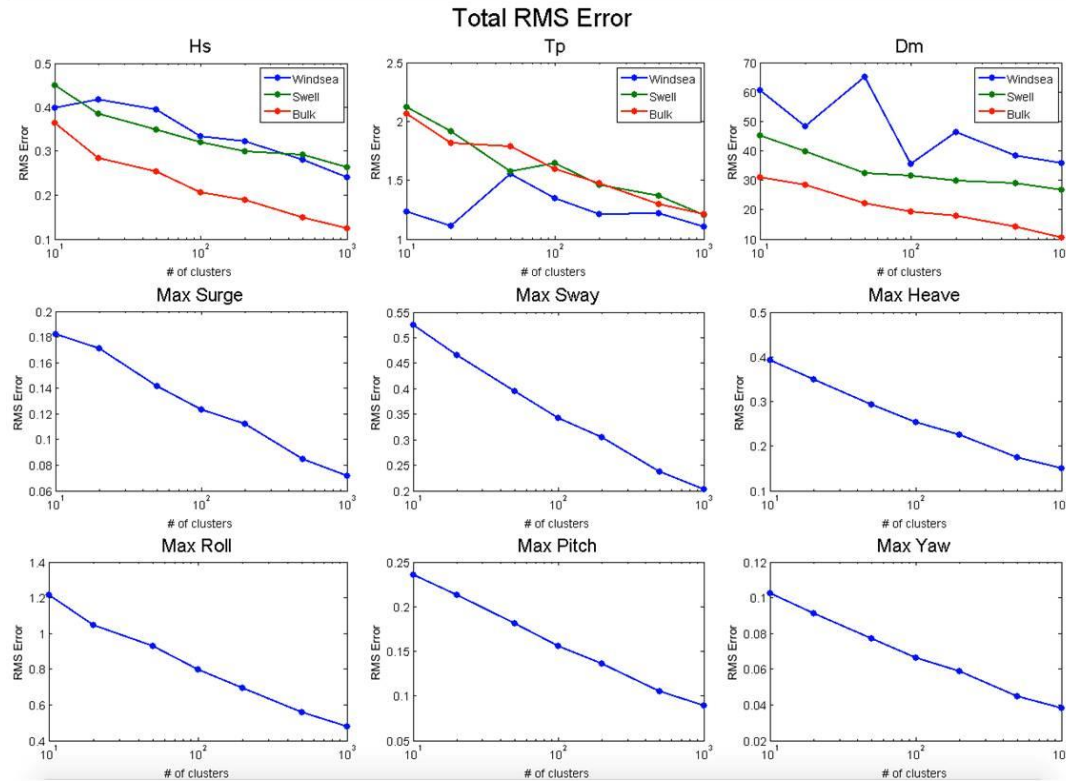




# CLUSTER ANALYSIS – WAVE SPECTRA

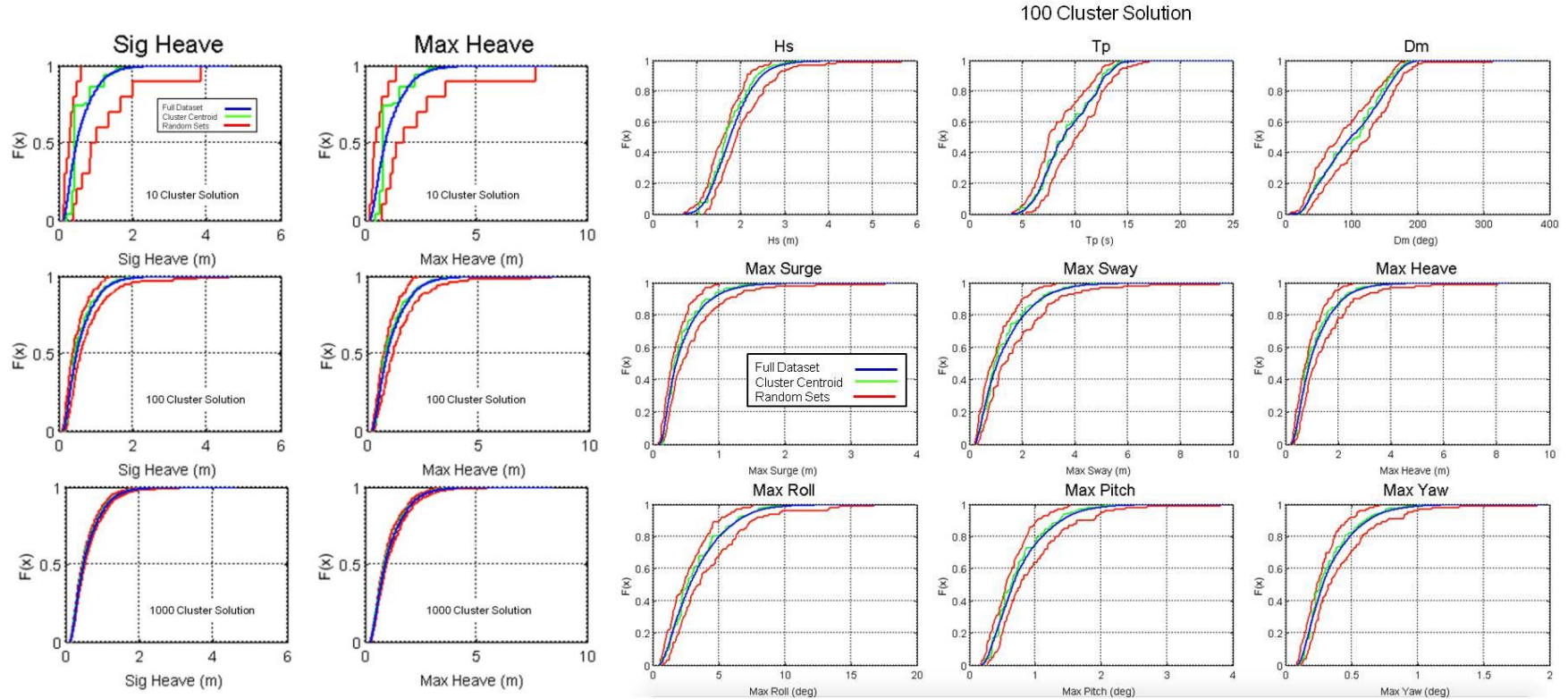


# CLUSTER ANALYSIS – WITHIN-CLUSTER TOTAL RMS

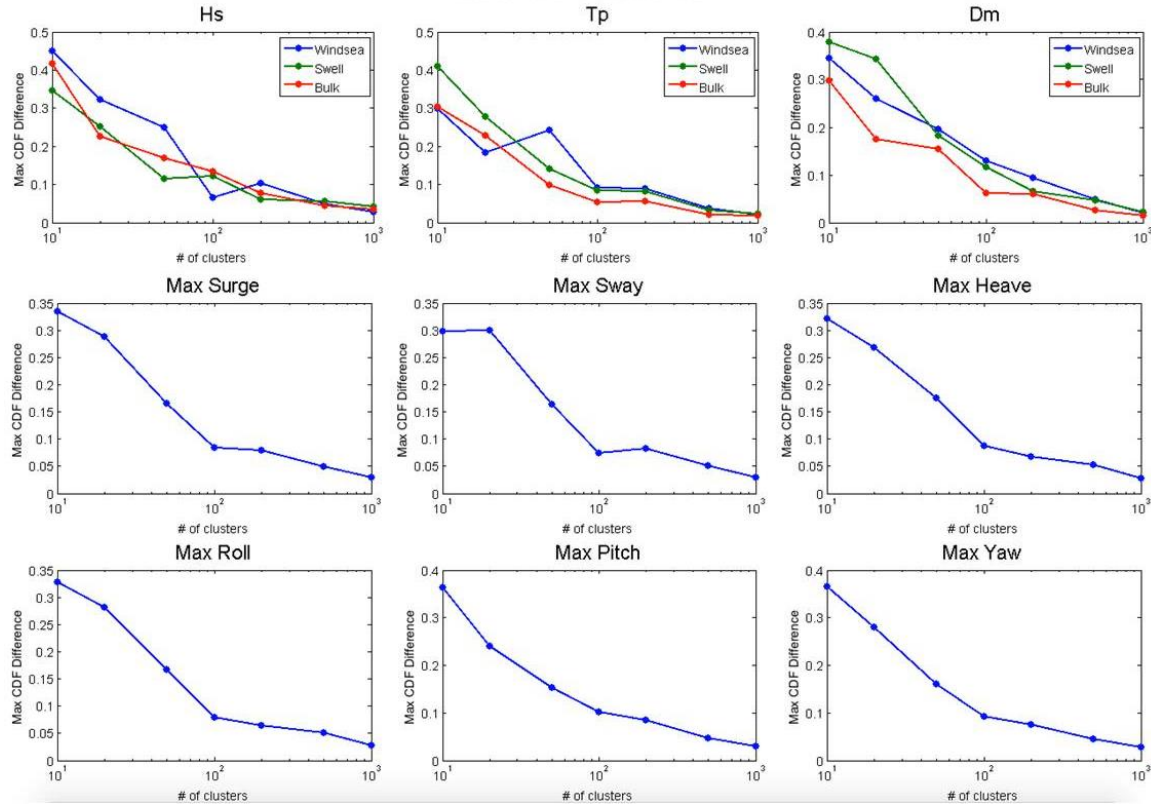


$$I_G^2 = \sum_{j=1}^m \sum_{X_i \in C_j} \|G(X_i) - G(\mu_j)\|^2$$

# CLUSTER ANALYSIS – EMPIRICAL CDFS



# CLUSTER ANALYSIS – MAX CDF DIFFERENCE



## DISCUSSION AND CONCLUSIONS

- For regions with dynamic and multi-modal seas, such as offshore Brazil, more sophisticated techniques are needed to identify a small yet relatively representative set of directional wave spectra.
- We demonstrated that the representative sea states provide an efficient basis for estimation of overall sea state bulk, wind sea and swell characteristics.
- K-MEANS is a computationally efficient algorithm.
- We evaluated the effect of cluster size on the performance of the representative sea states, 100-cluster solution provides a relatively good approximation at BC-10 area offshore Brazil.
- Guidelines for the application of the methodology are provided.
- The linear transfer function (RAOs) approach may not be as appropriate for extreme environmental conditions and highly non-linear systems, for which full time-domain hydrodynamic response analysis might be required.

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## Questions?

