A Comparison of Hindcast and Measured Wave Spectra

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Acknowledgements

- Colin Grant (BP) for donation of West of Shetland measured wave data

- Vince Cardone (Oceanweather, Inc) for donation of AES40 hindcast data

Presentation Outline

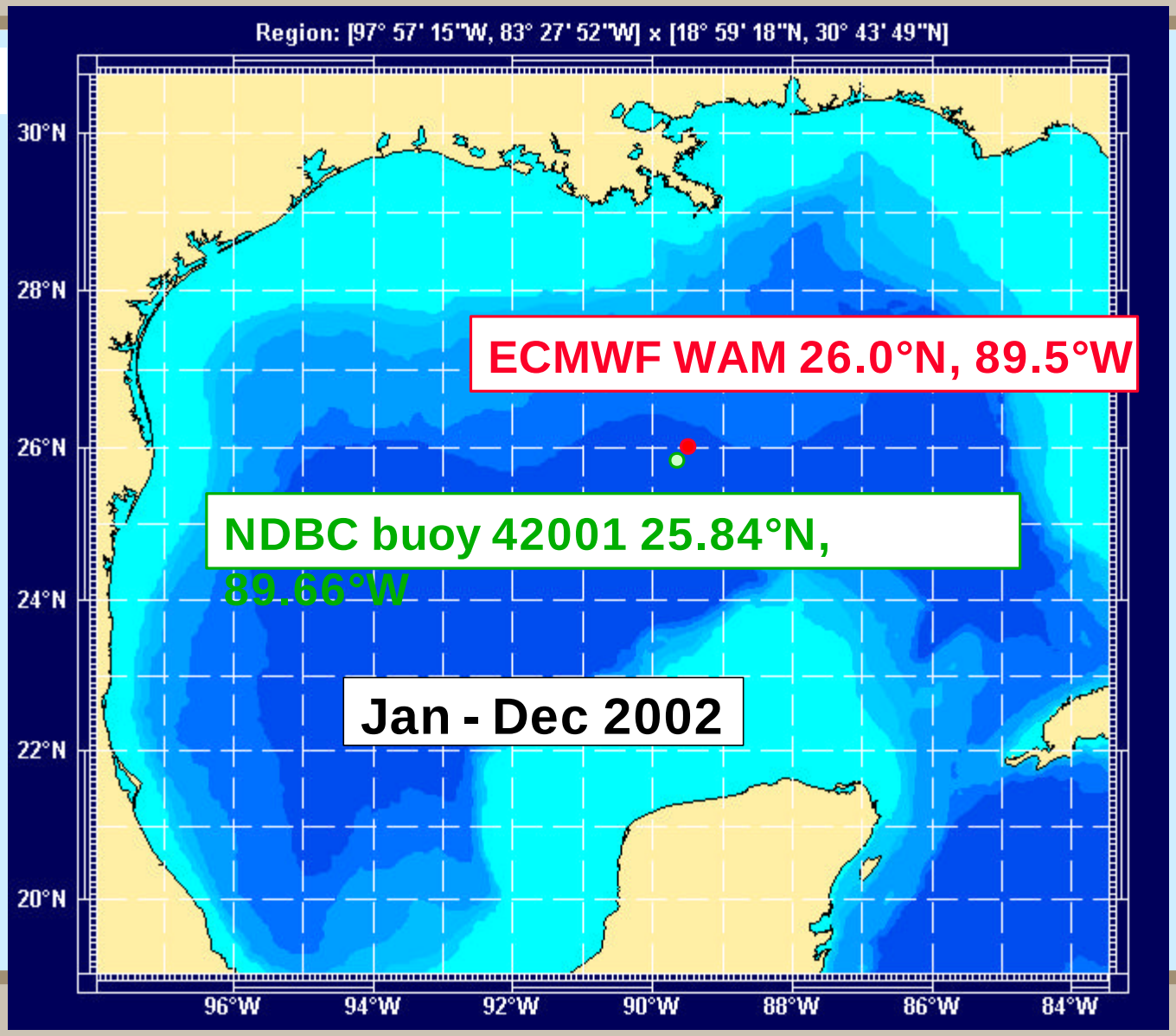
- Motivation
- Data sets
- Synthesis of measured directional spectra
- Total sea state parameter comparison
- Spectral analysis and partitioning
- Spectral parameterisation
- Comparison of spectral parameters
- Summary

Motivation

- Determination of spectral shapes has significance for both operability and design of floating structures
- To compare the spectral shape parameters between hindcast and measured wave partitions
- Identify any patterns in the comparison

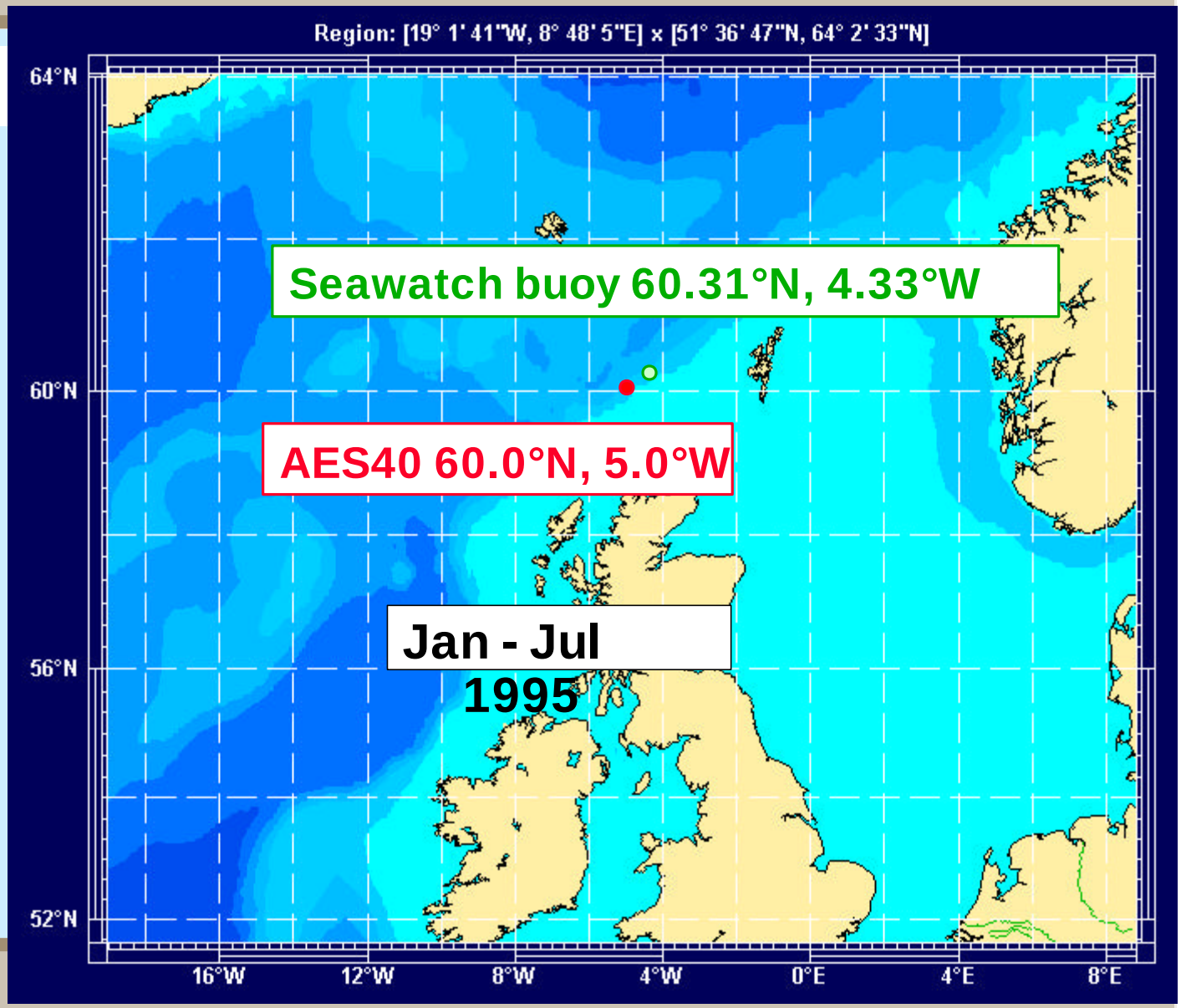
Selection of Data Sets

Gulf of Mexico



Selection of Data Sets

West of Shetlands



Reasons for Selection

- Co-locational and contemporary data available
- Directional information was available for all data sets
- Two very different locations:
  - Gulf of Mexico - a closed basin
  - West of Shetland - open ocean

Synthesis of Measured Directional Spectra

Gulf of Mexico

- **Parameters**

  S spectral energy density in m^2/Hz

  D mean wave direction, in degrees from true North

  r_1 $[(a_1^2 + b_1^2)^{0.5}]/a_0$

  r_2 $[(a_2^2 + b_2^2)^{0.5}]/a_0$

  a_1 $270 - \tan^{-1}(b_1/a_1)$

  a_2 $270 - (0.5*\tan^{-1}(b_2/a_2) + \{0 \text{ or } 180\})$

- **Weighted Fourier sum:**

$$S(f,q) = \frac{1}{p}\left(0.5 + \frac{2}{3} r_1 \cos(q - a_1) + \frac{1}{6} r_2 \cos(2(q - a_2))\right)$$

- **Spectra averaged over 6 hours**

Synthesis of Measured Directional Spectra

West of Shetland

- **Parameters**

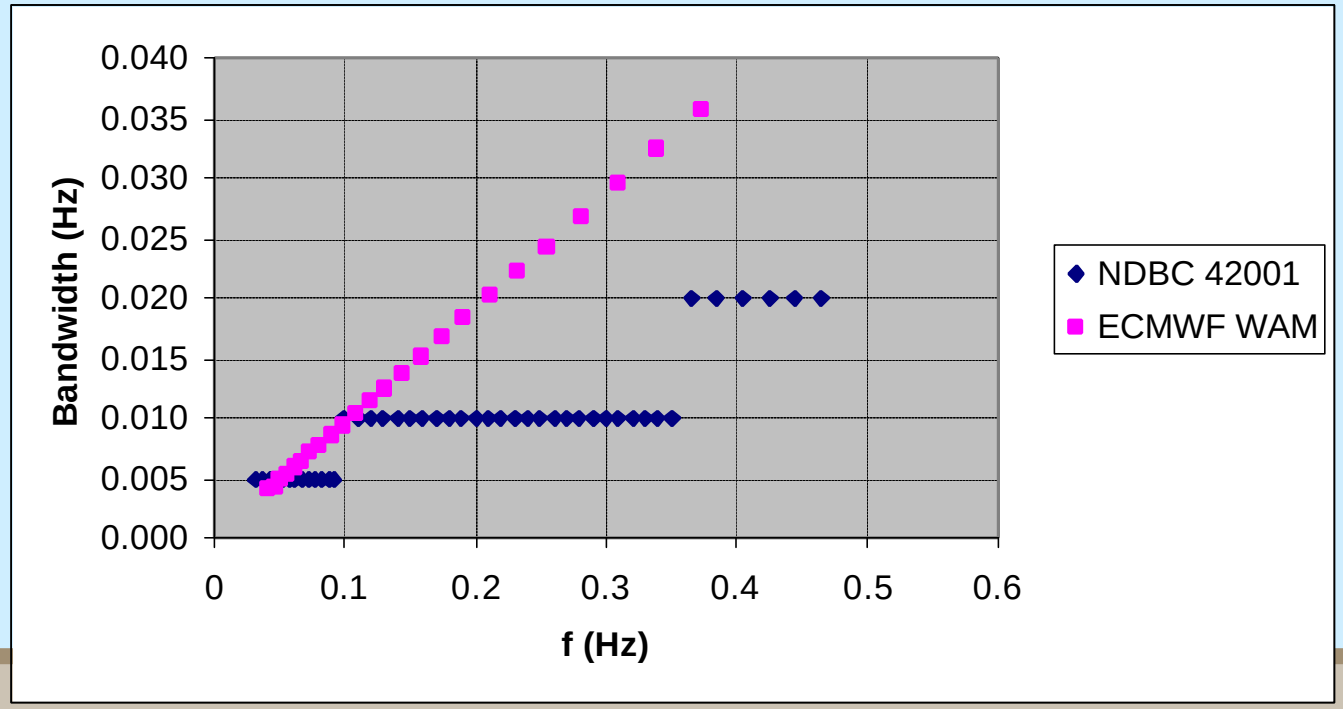
S	spectral energy density in m^2/Hz
a_1, b_1	first Fourier coefficients
a_2, b_2	second Fourier coefficients

- **Maximum Entropy Method**
- **9-point averaging**
- **Spectra averaged over 6 hours**

Data Characteristics

Gulf of Mexico

- "6-hour average"
- directional resolution 15°
- frequency resolutions



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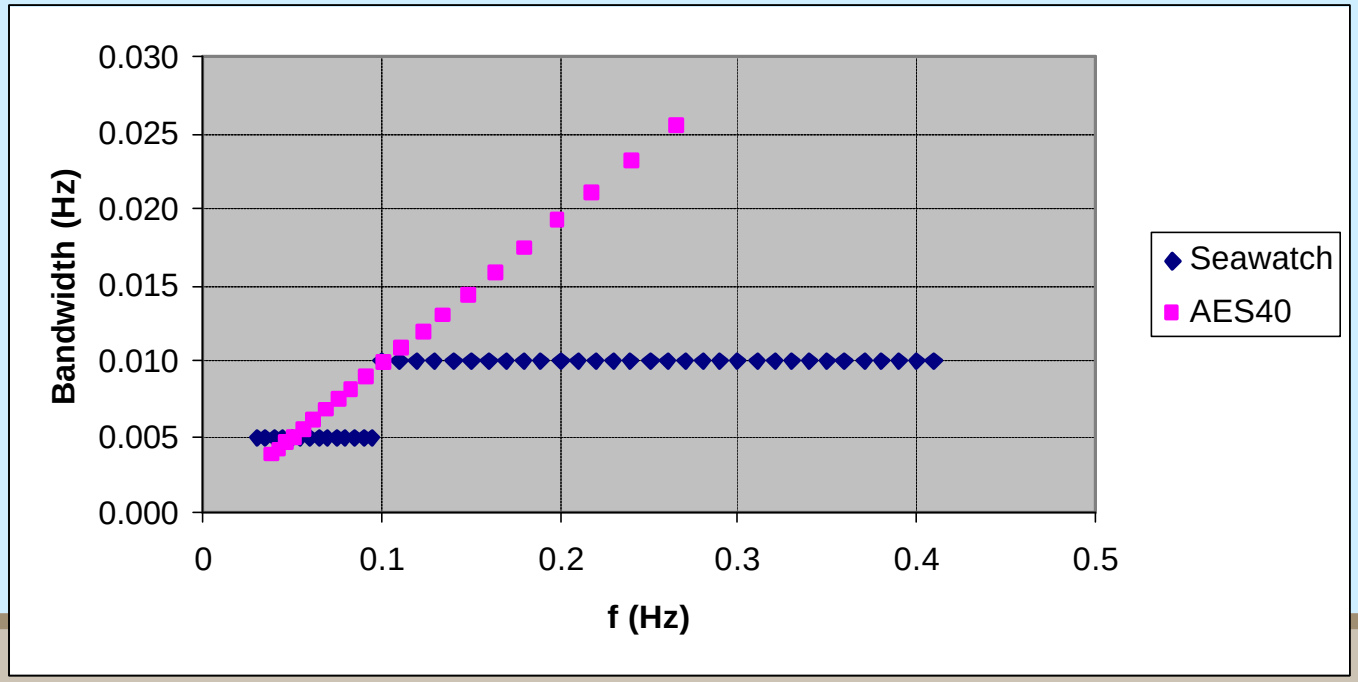
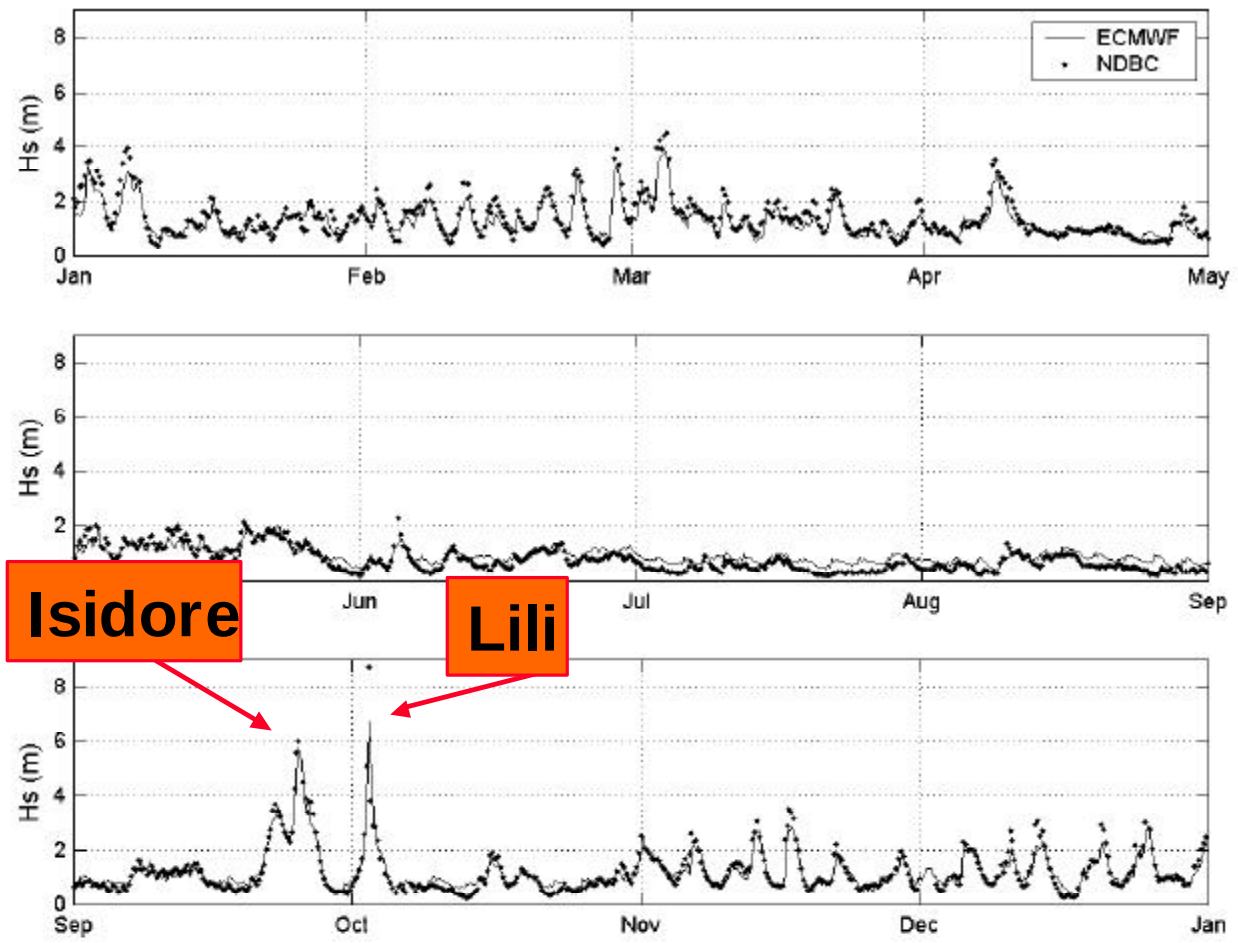


Total Sea State Parameter Comparison - Hs

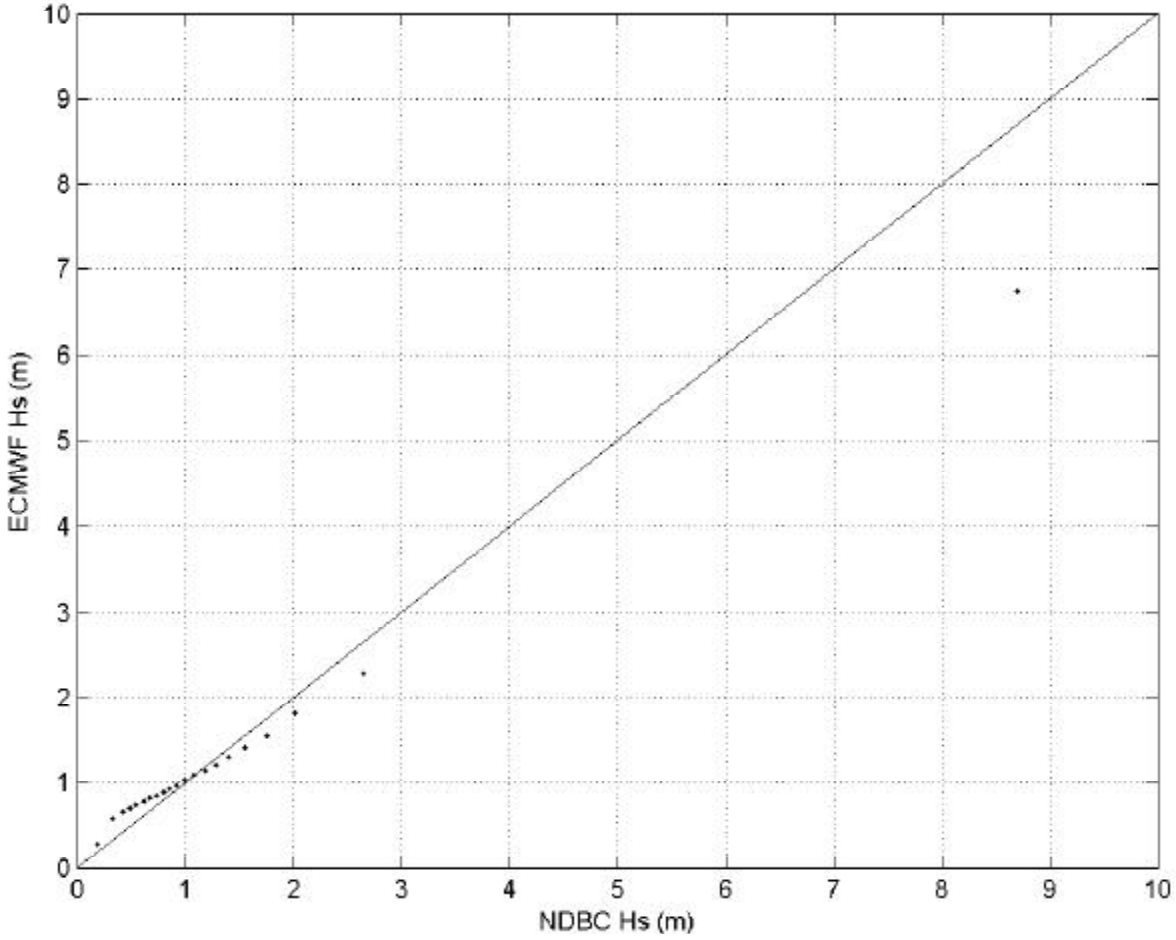
Gulf of Mexico
Jan - Dec 2002



Total Sea State Parameter Comparison - Hs

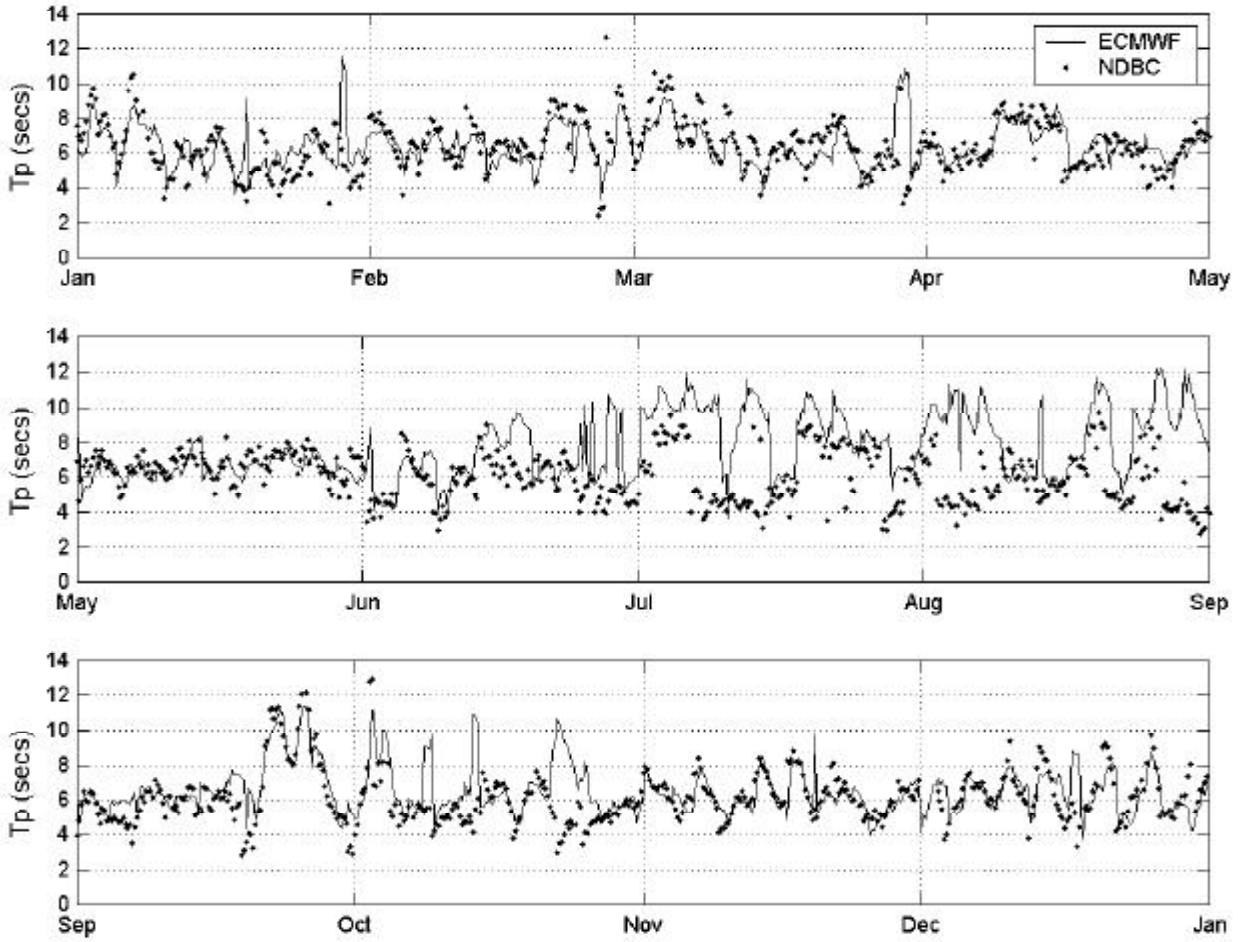
Gulf of Mexico
Jan - Dec 2002

Quantile-quantile plot



Total Sea State Parameter Comparison - Tp

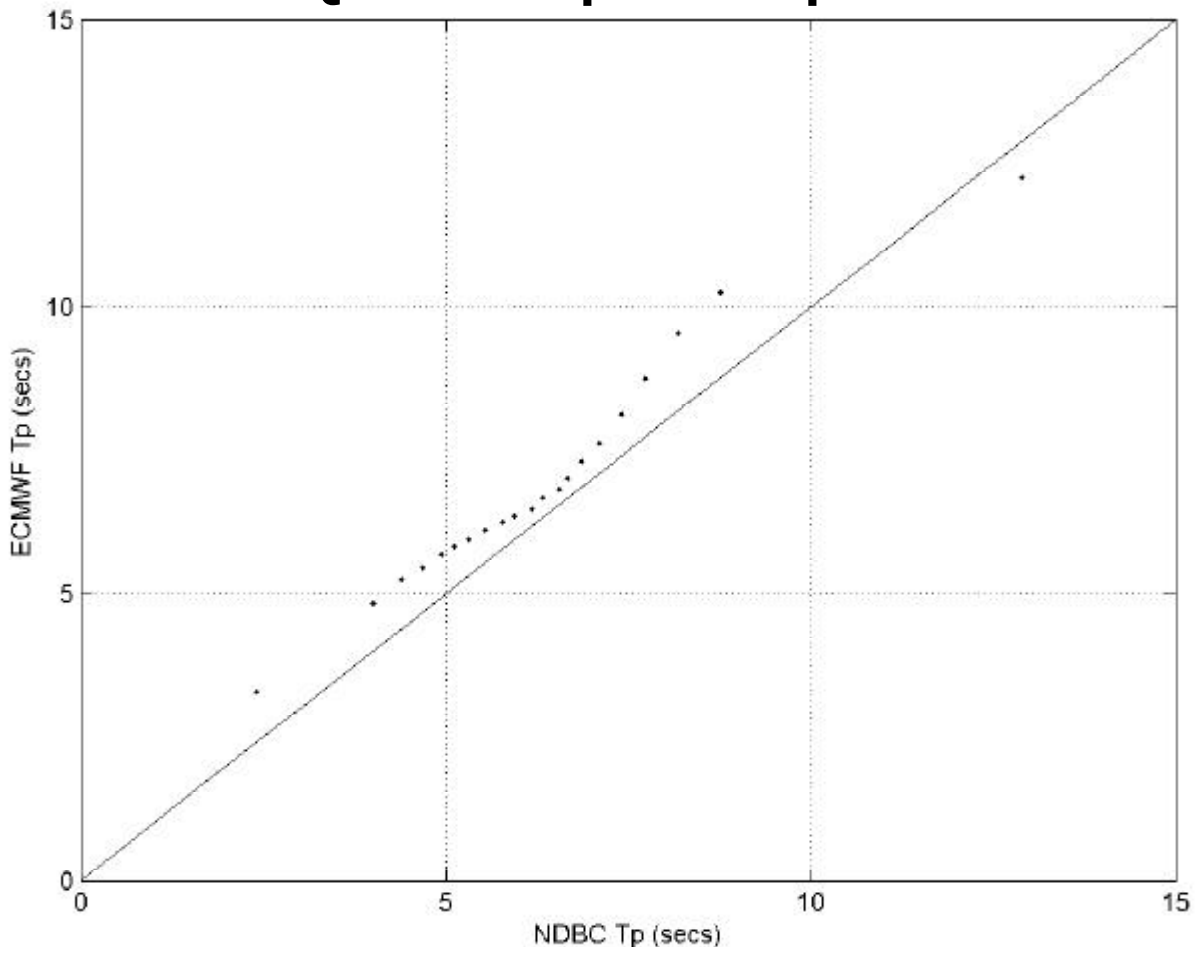
Gulf of Mexico
Jan - Dec 2002



Total Sea State Parameter Comparison - Tp

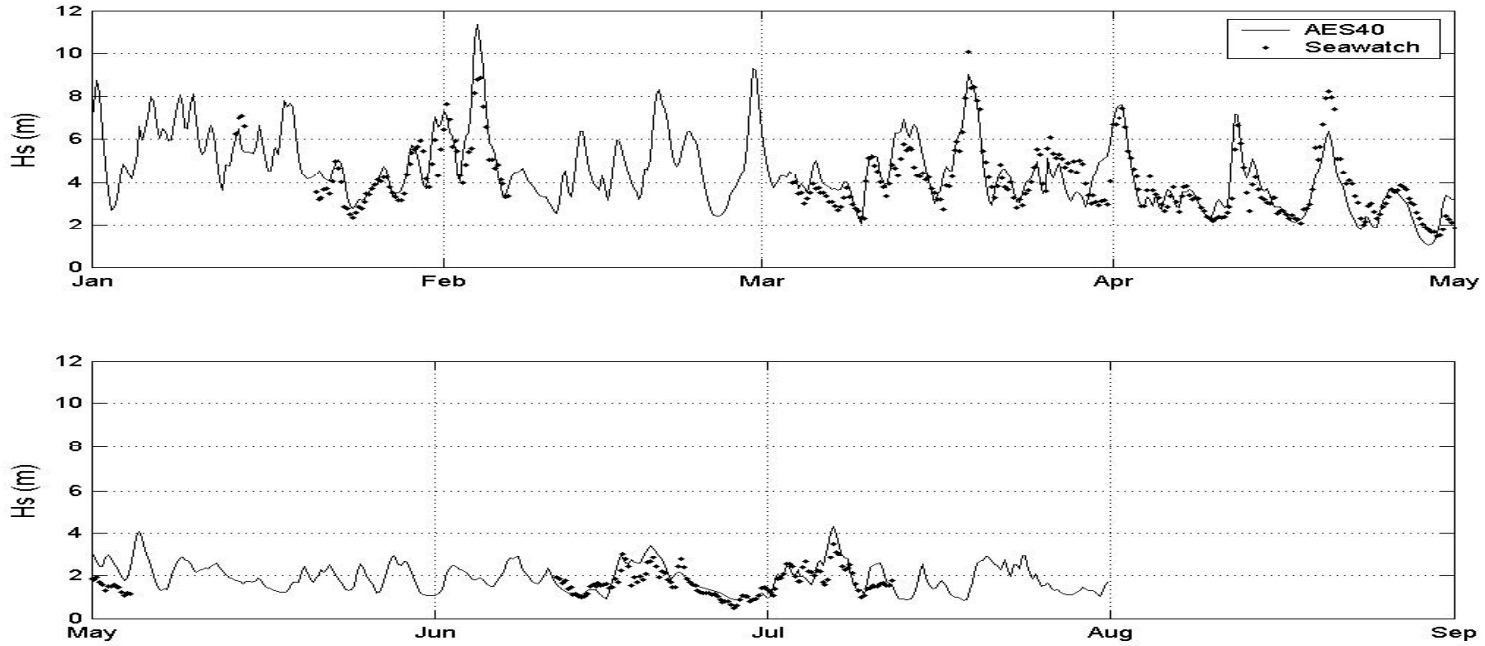
Gulf of Mexico
Jan - Dec 2002

Quantile-quantile plot



Total Sea State Parameter Comparison - Hs

West of
Jan - Jul 1995



Total Sea State Parameter Comparison - Hs

West of
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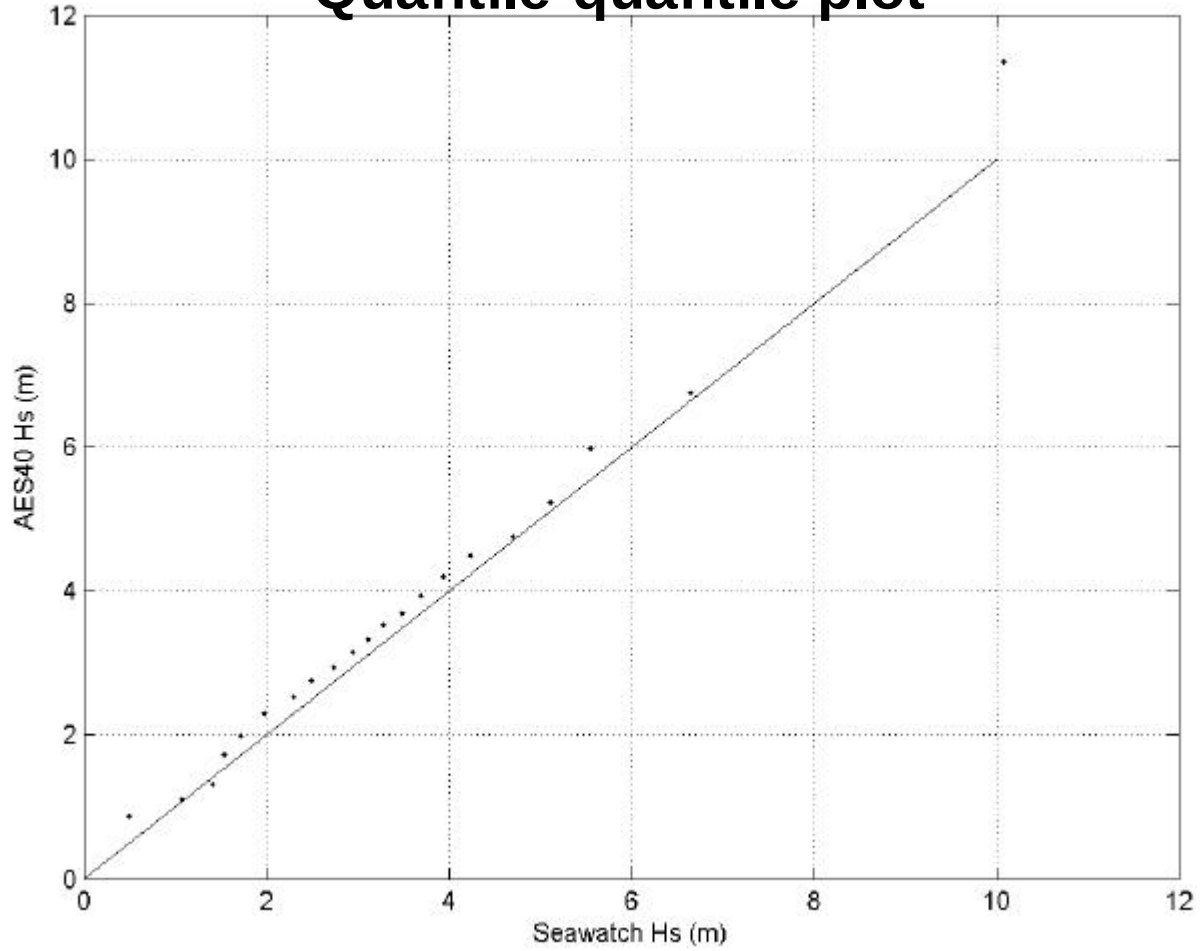
Quantile-quantile plot



Total Sea State Parameter Comparison - Tp

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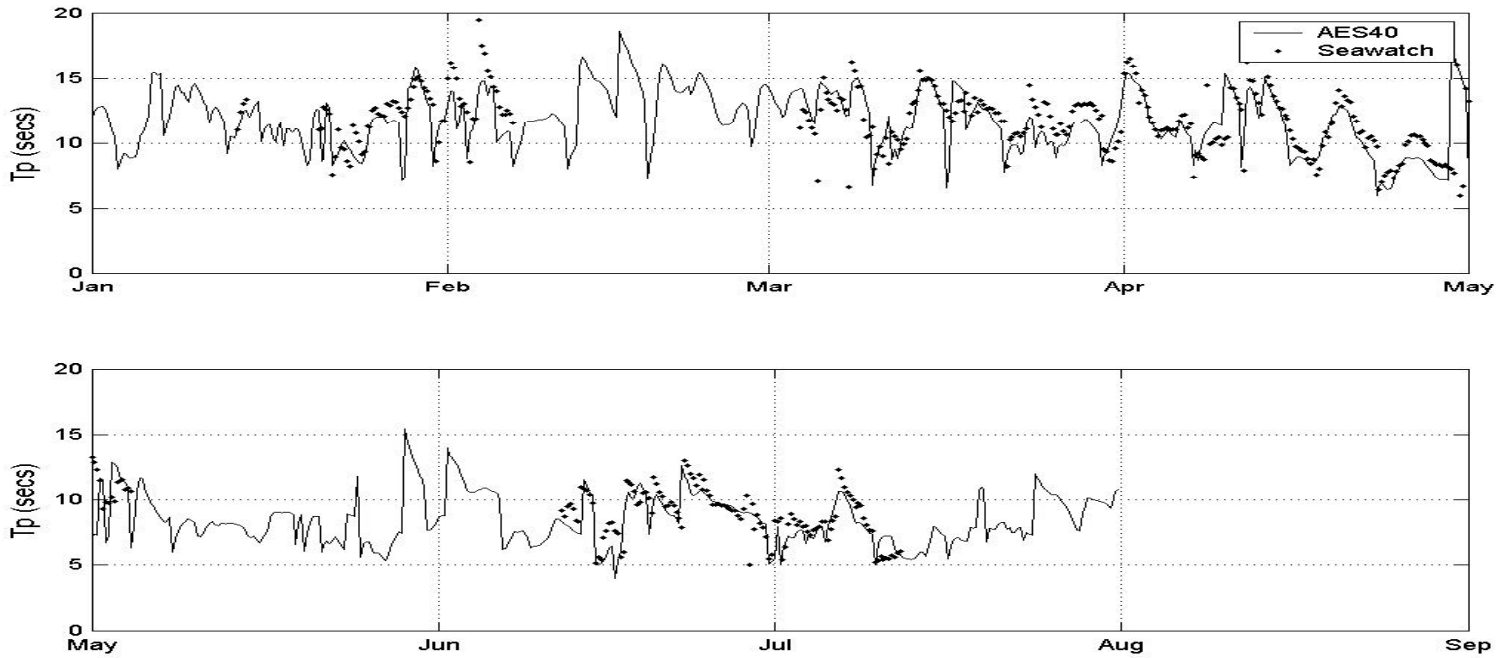

Total Sea State Parameter Comparison - Tp

West of
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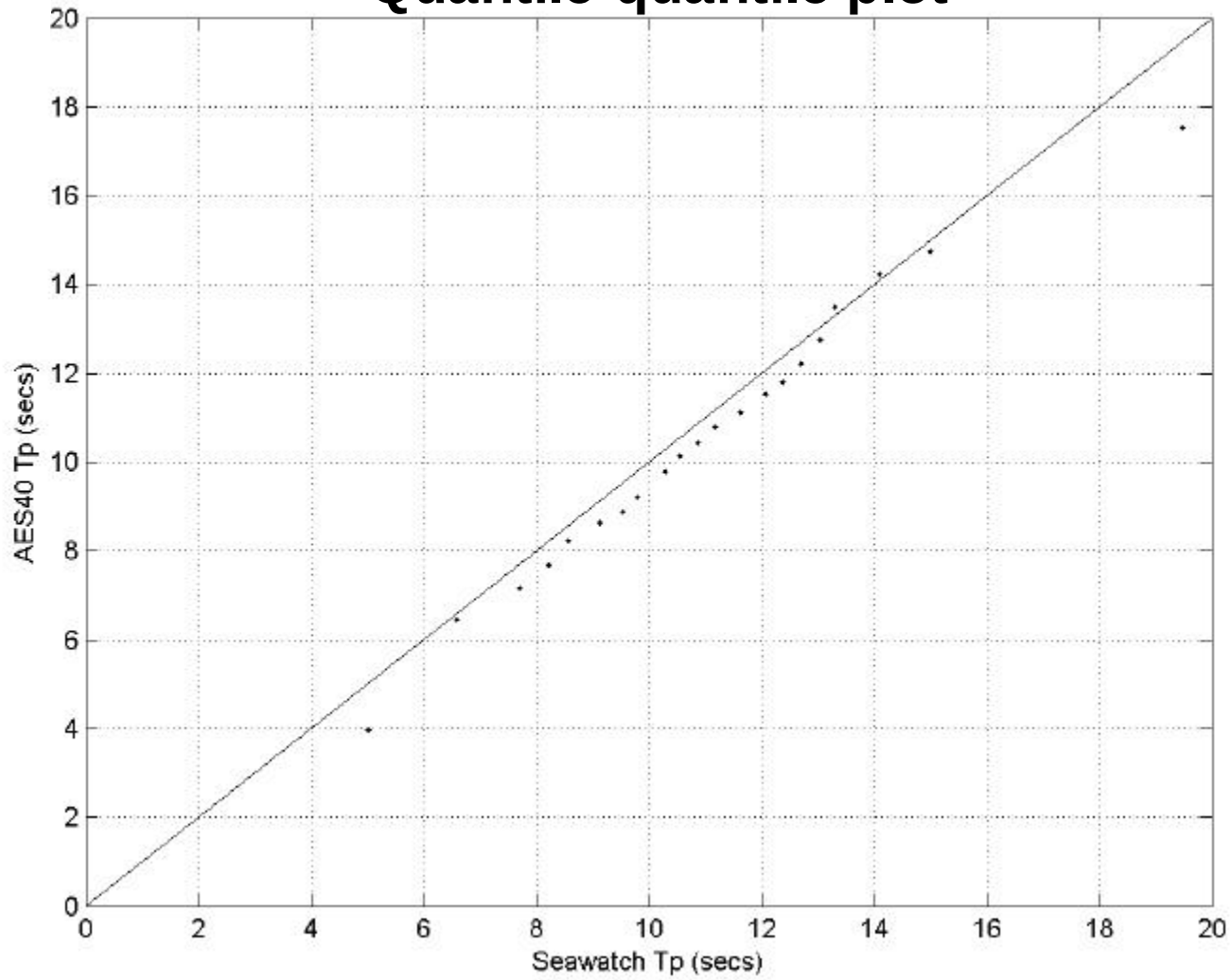
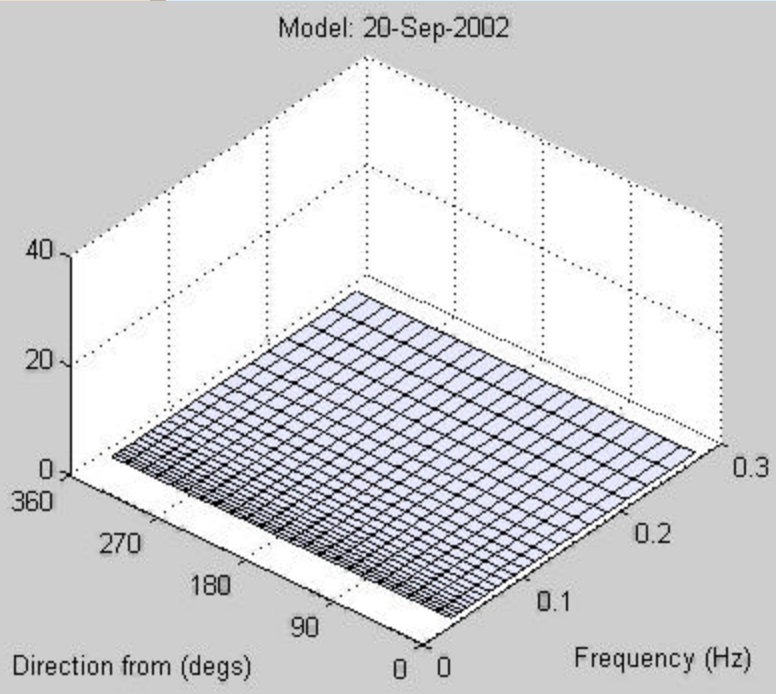
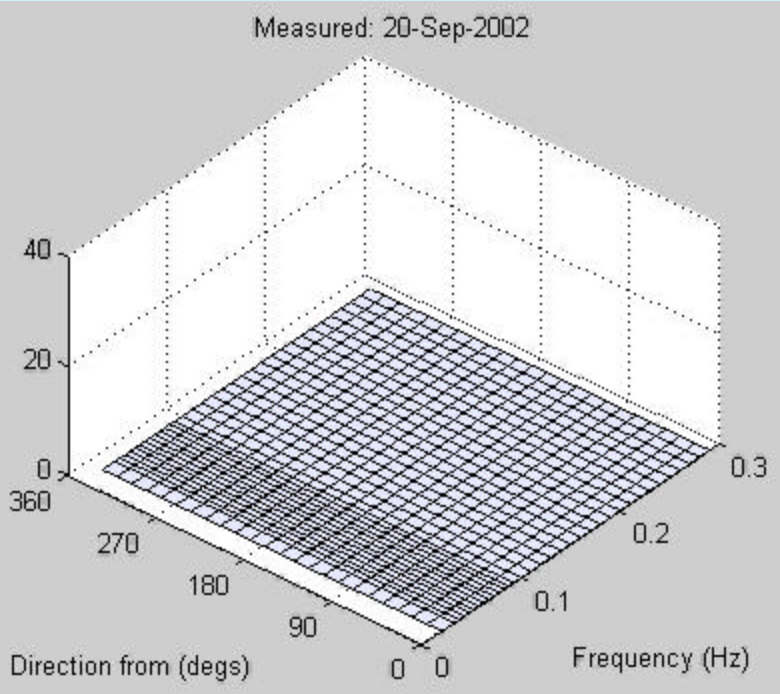
Quantile-quantile plot



Directional Wave Spectra

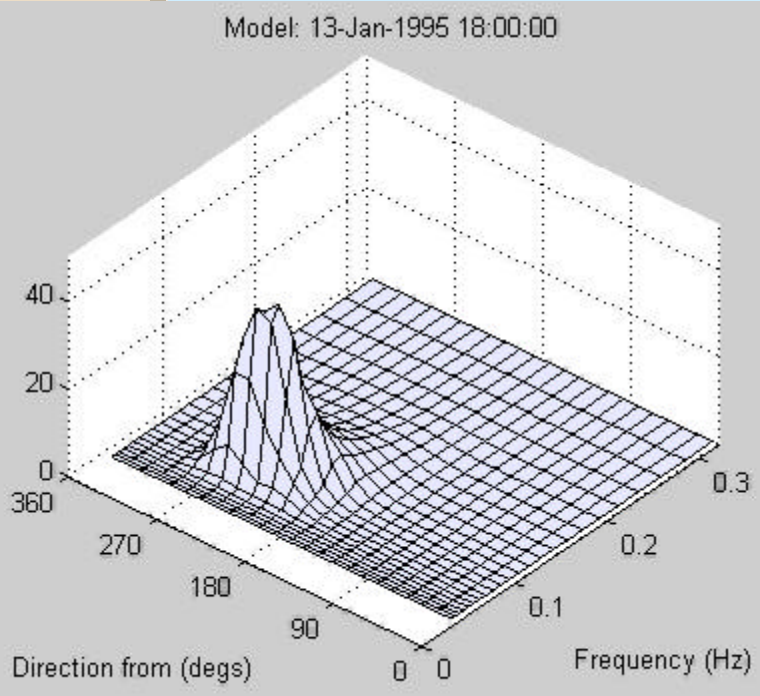
Gulf of Mexico

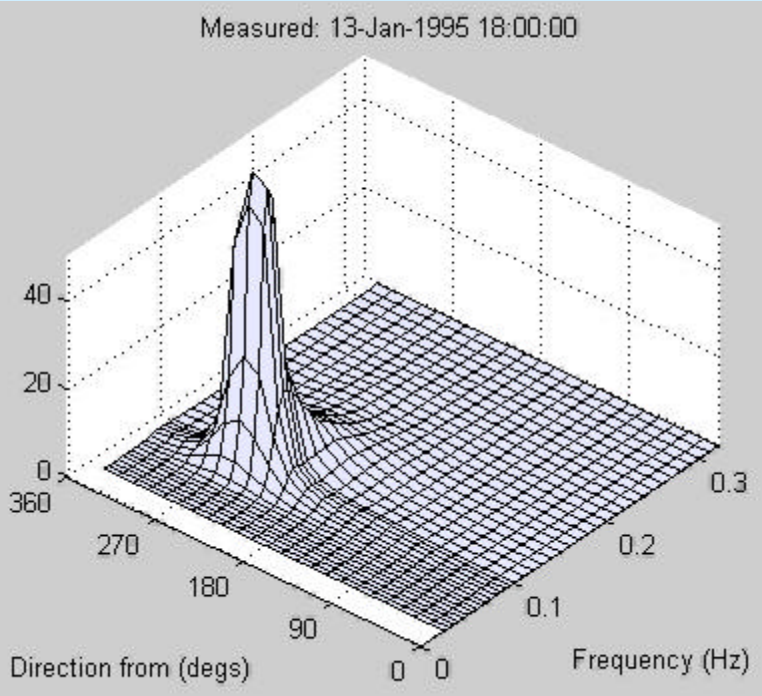




Directional Wave Spectra

West of Shetland





Spectral Analysis and Partitioning

- **Spectra partitioned on the basis of a steepest ascent matrix**

  (Hanson and Phillips, 2001, Aarnes and Krogstad, 2001)

- **Tunable splitting parameters:**

  identification of wind-sea

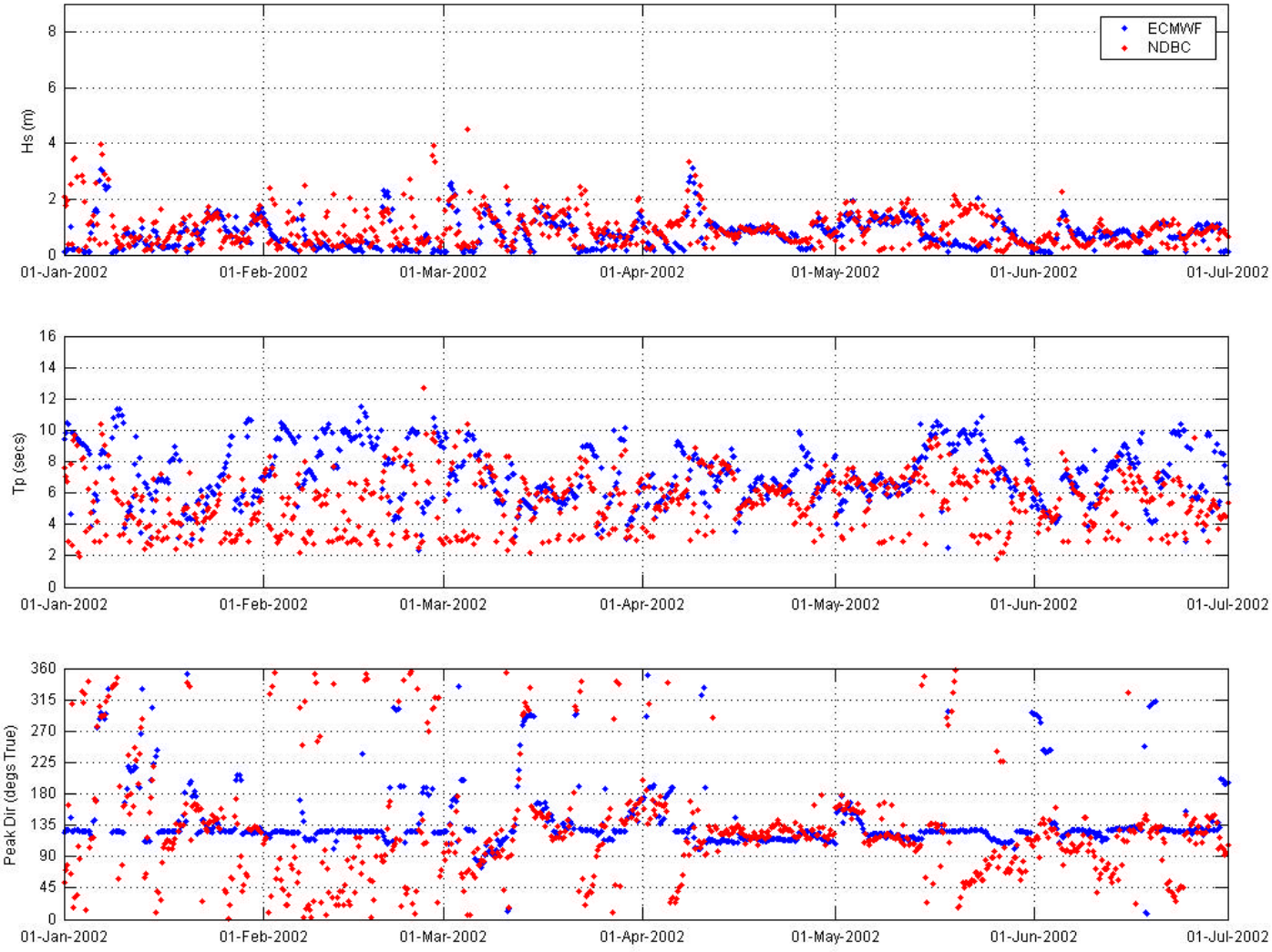
  distance between peaks *v* peak spread

  saddle point *v* peak energy

  partition energy

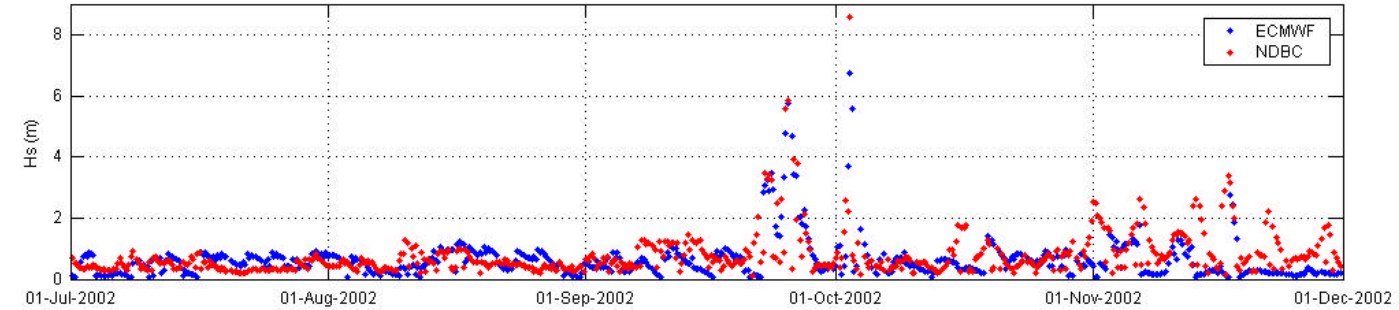
Partition Comparisons

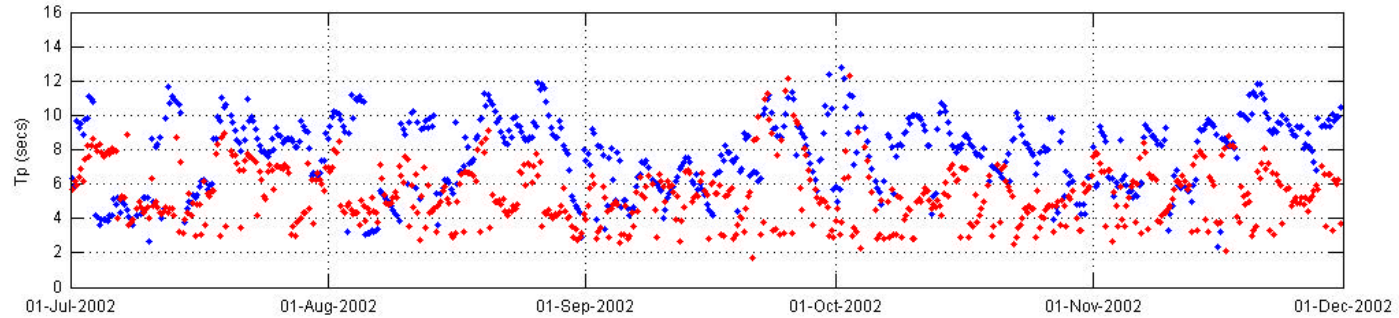
Gulf of Mexico - Part I

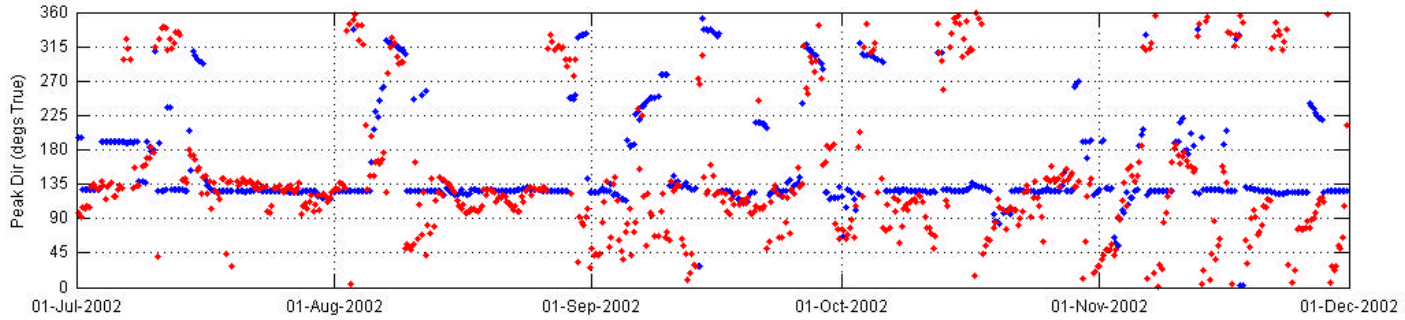


Partition Comparisons

Gulf of Mexico - Part II

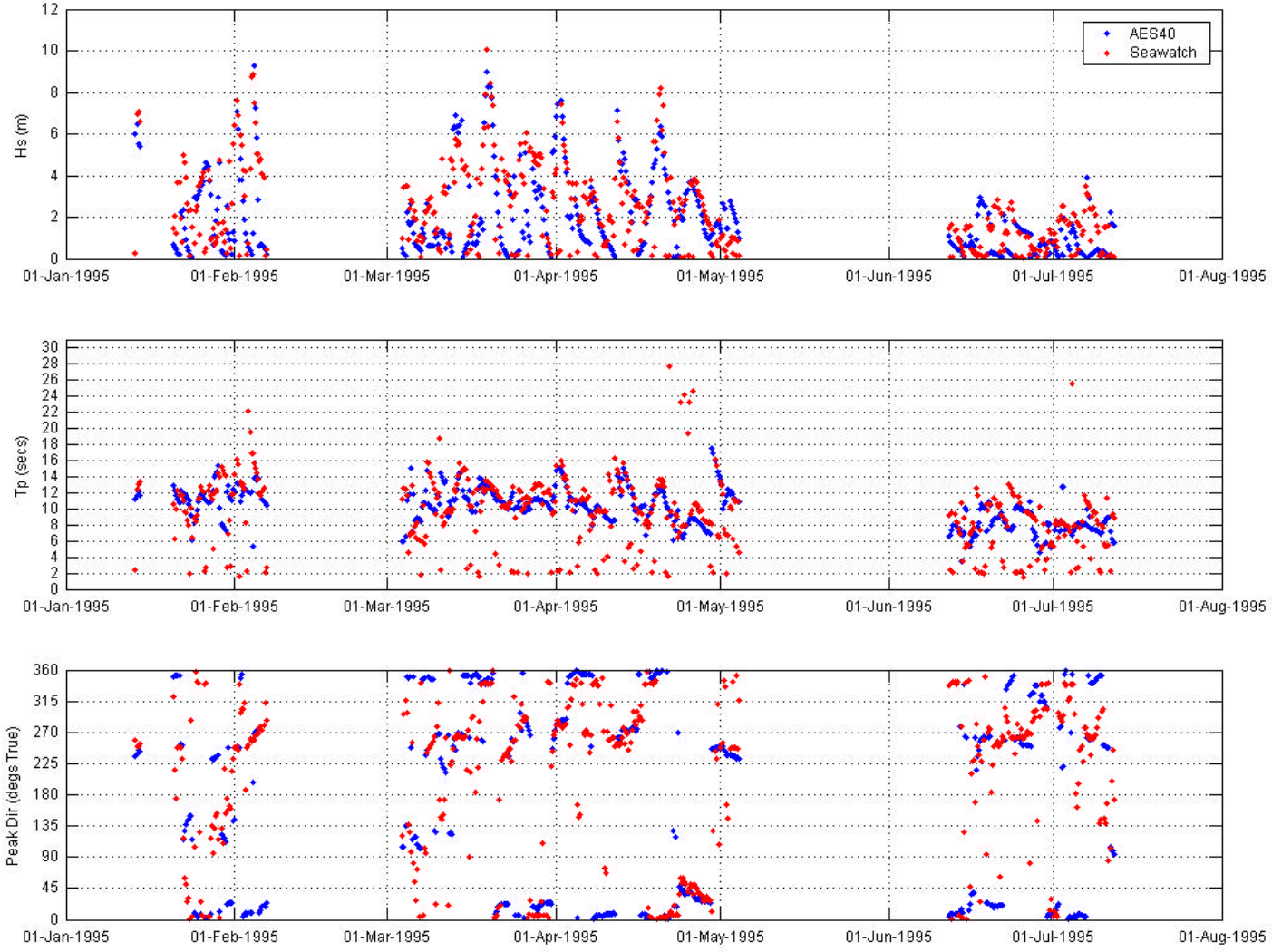






Partition Comparisons

West of Shetland



Spectral Parameterisation

Each spectral partition fitted using:

- **parabola around spectral peak to identify f_m**
- **α derived on the basis that 1.35 f_m to 2.0 f_m is as a P-M spectrum**
- **γ, σ_a and σ_b fitted by least squares**
- **for $\gamma < 1$ a P-M was assumed with least squares fit of f_m and α**

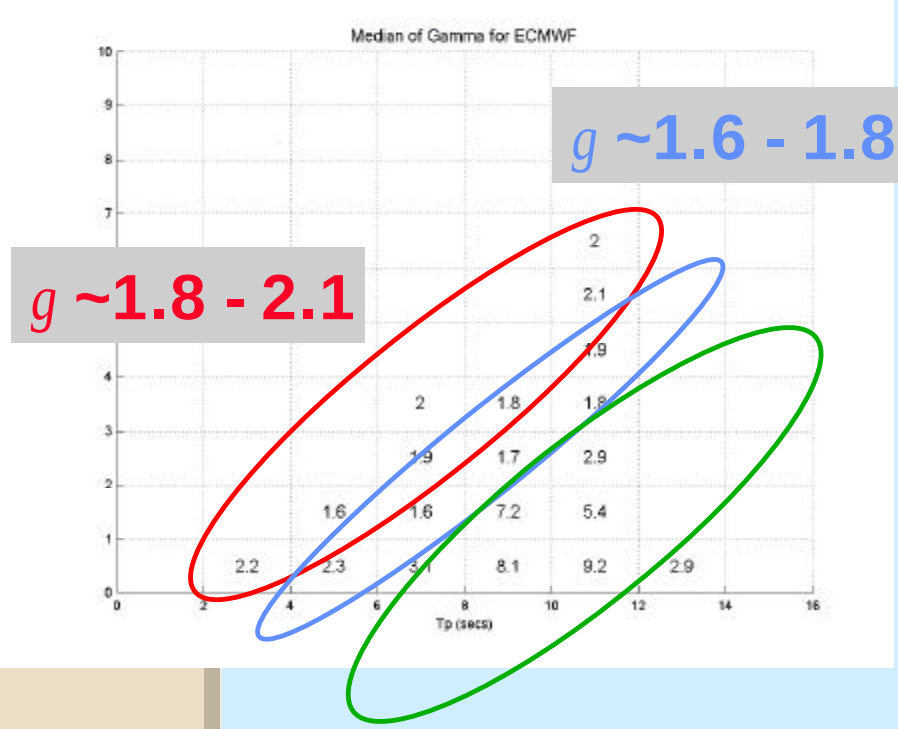
A normalised rms error and bias were calculated

Comparison of Spectral Parameters

- Spectra were chosen for comparison only if:
  - rms error < 5%
  - bias <5%
- Each fitted spectrum was placed in *Hs-Tp* bin of size 1m x 2secs
- Spectral parameters were aggregated in each bin

Gulf of Mexico Comparison

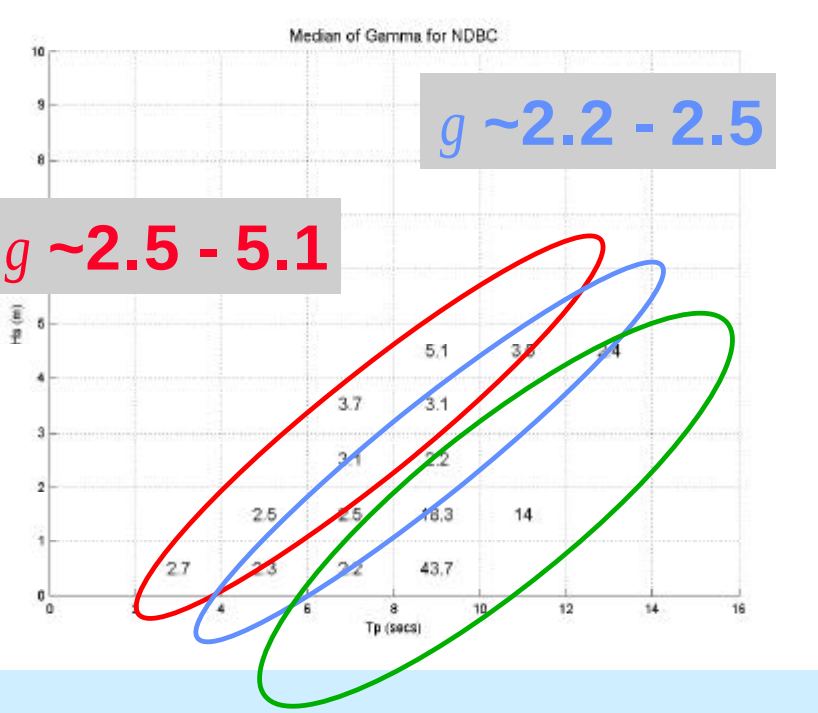
Comparison of median values of g



g ~1.6 - 1.8

g ~1.8 - 2.1

Large, scattered g



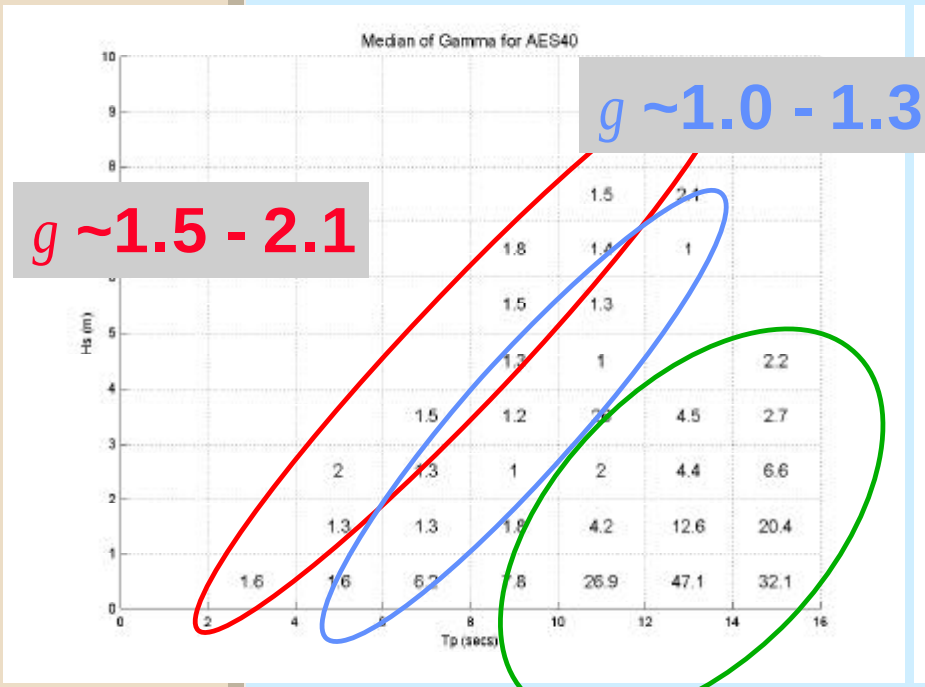
g ~2.2 - 2.5

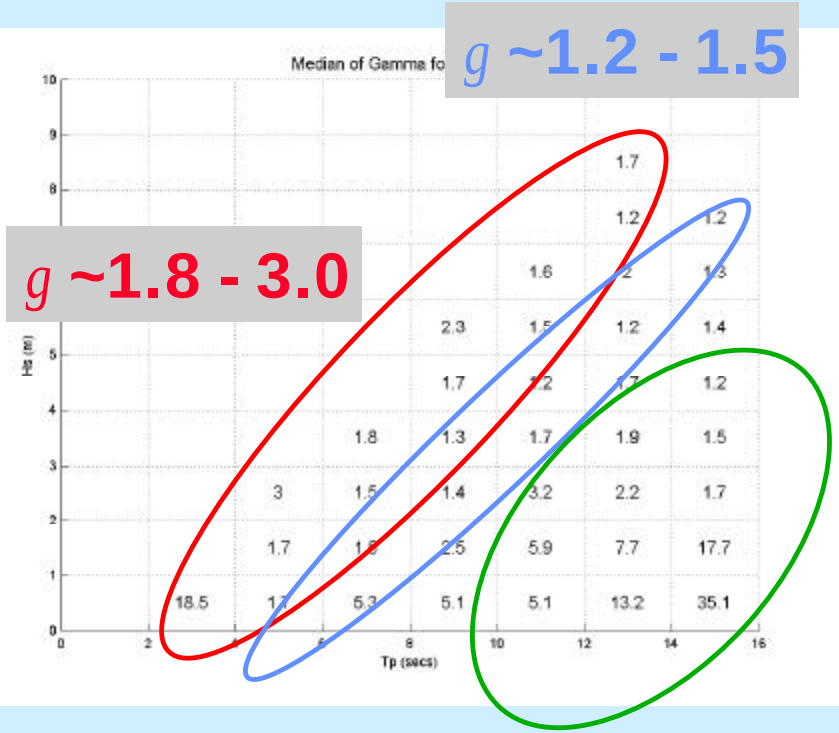
g ~2.5 - 5.1

Large, scattered g

West of Shetland Comparison

Comparison of median values of g





Large, scattered g

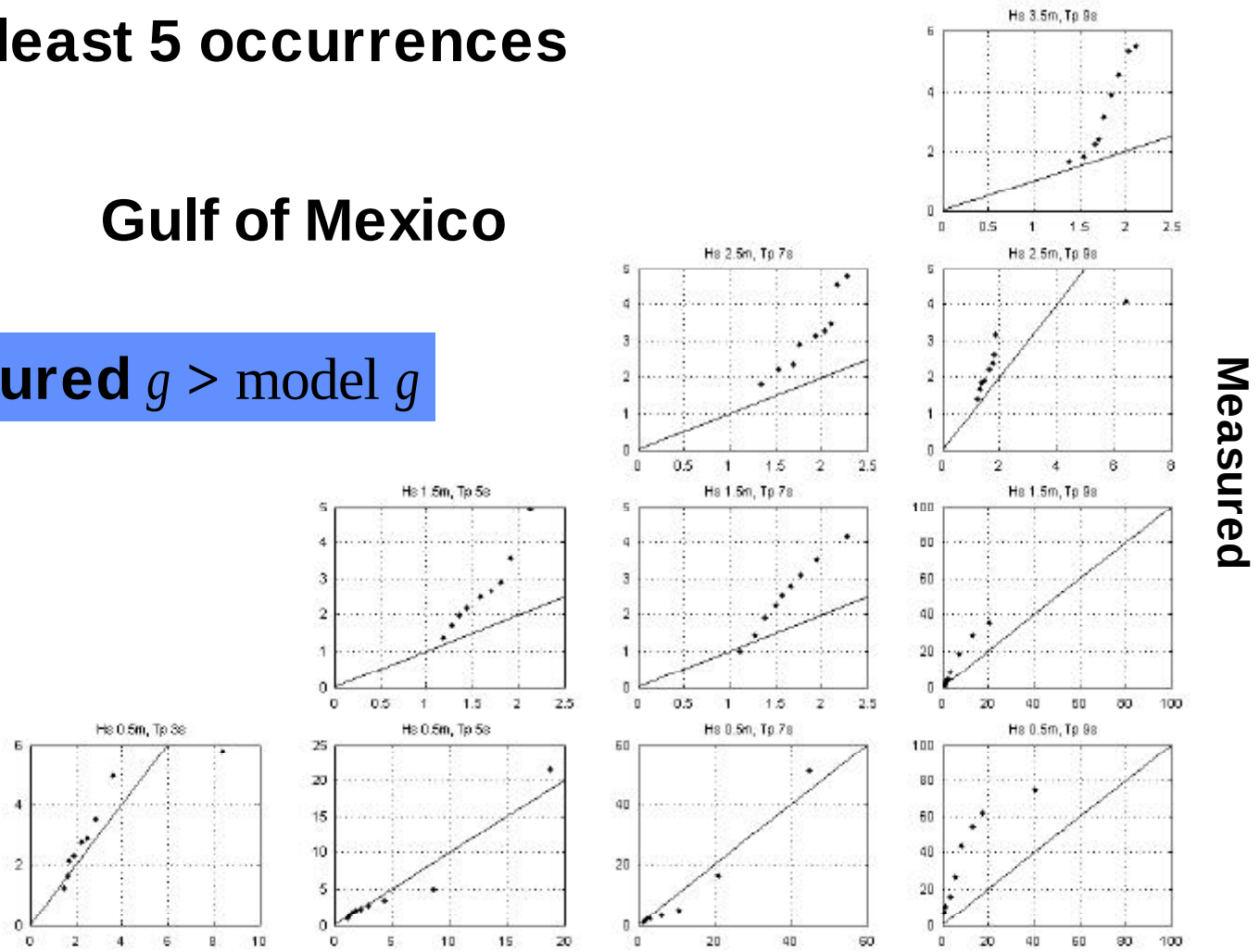
Large, scattered g

Quantile-Quantile Comparison of g

- **At least 5 occurrences**

Gulf of Mexico

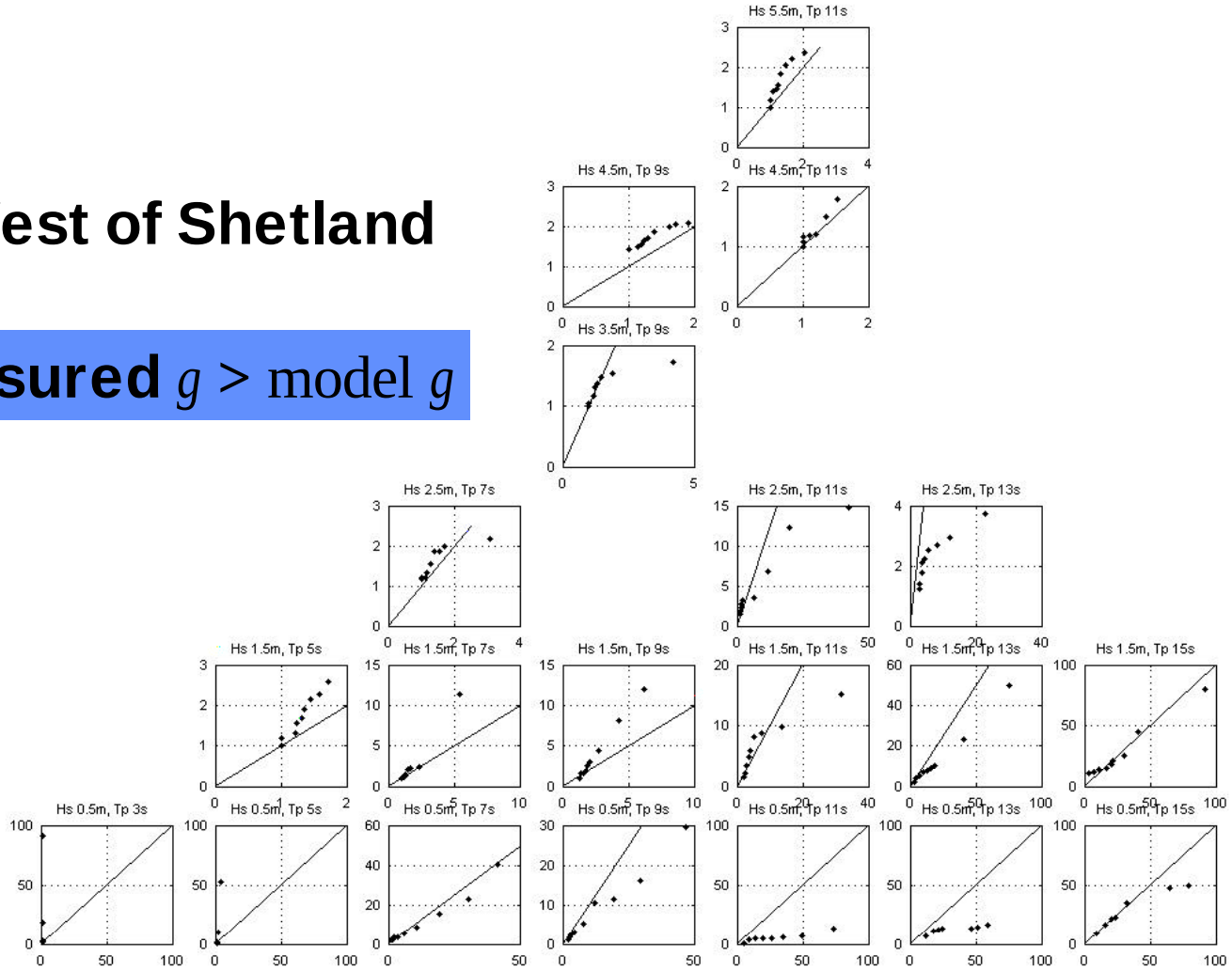
Measured g > model g



Quantile-Quantile Comparison of g

West of Shetland

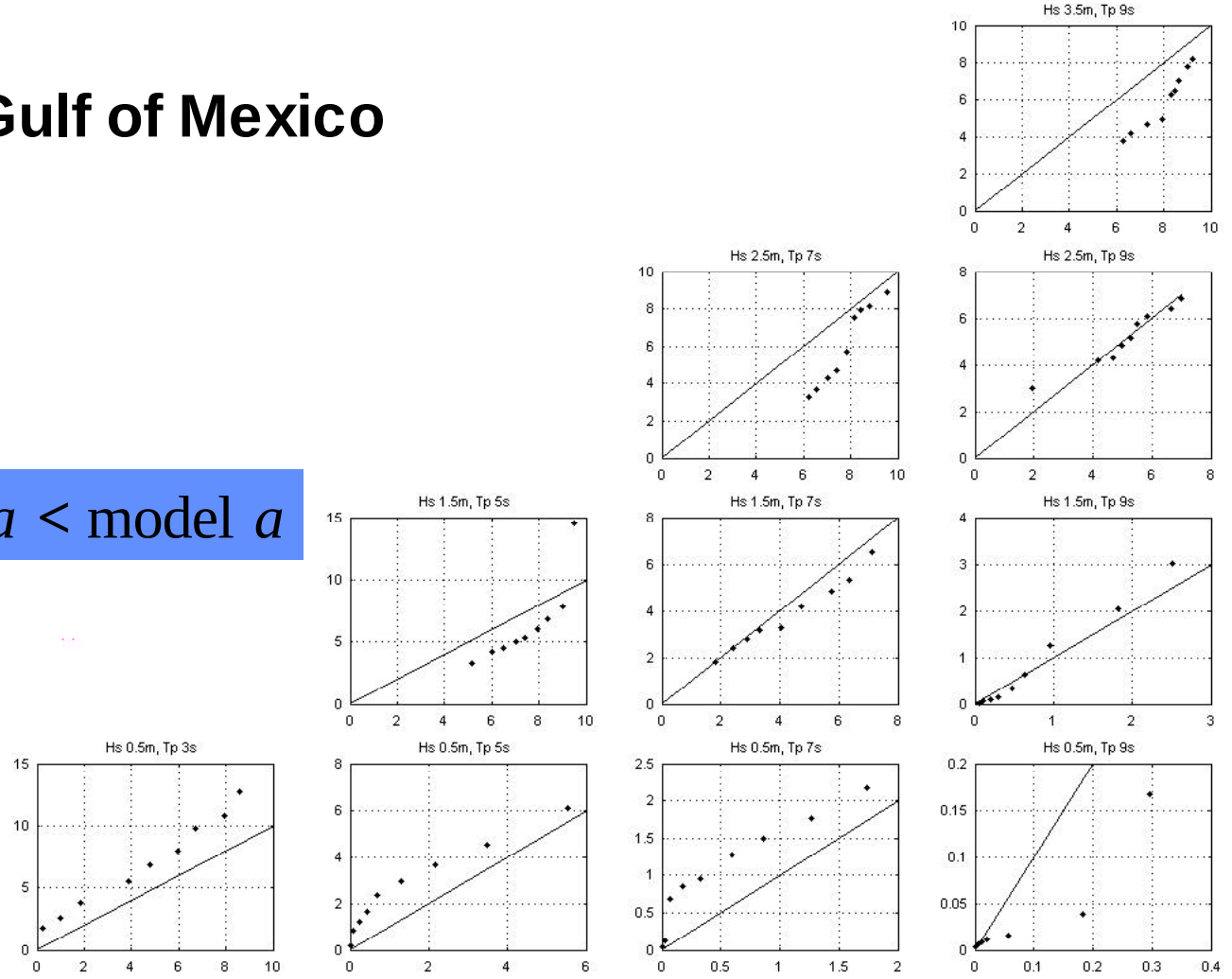
Measured g > model g



Quantile-Quantile Comparison of a

Gulf of Mexico

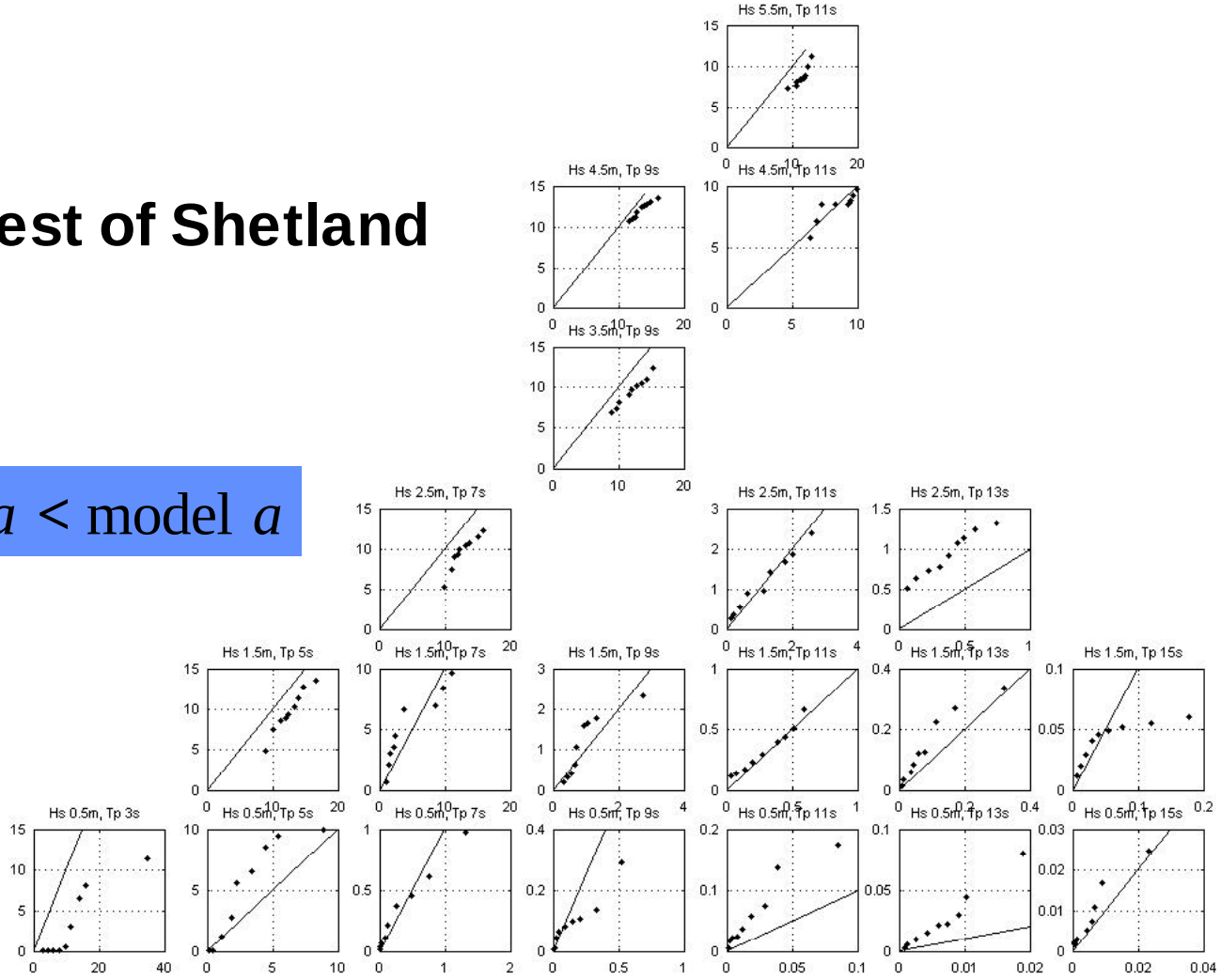
Measured a < model a



Quantile-Quantile Comparison of a

West of Shetland

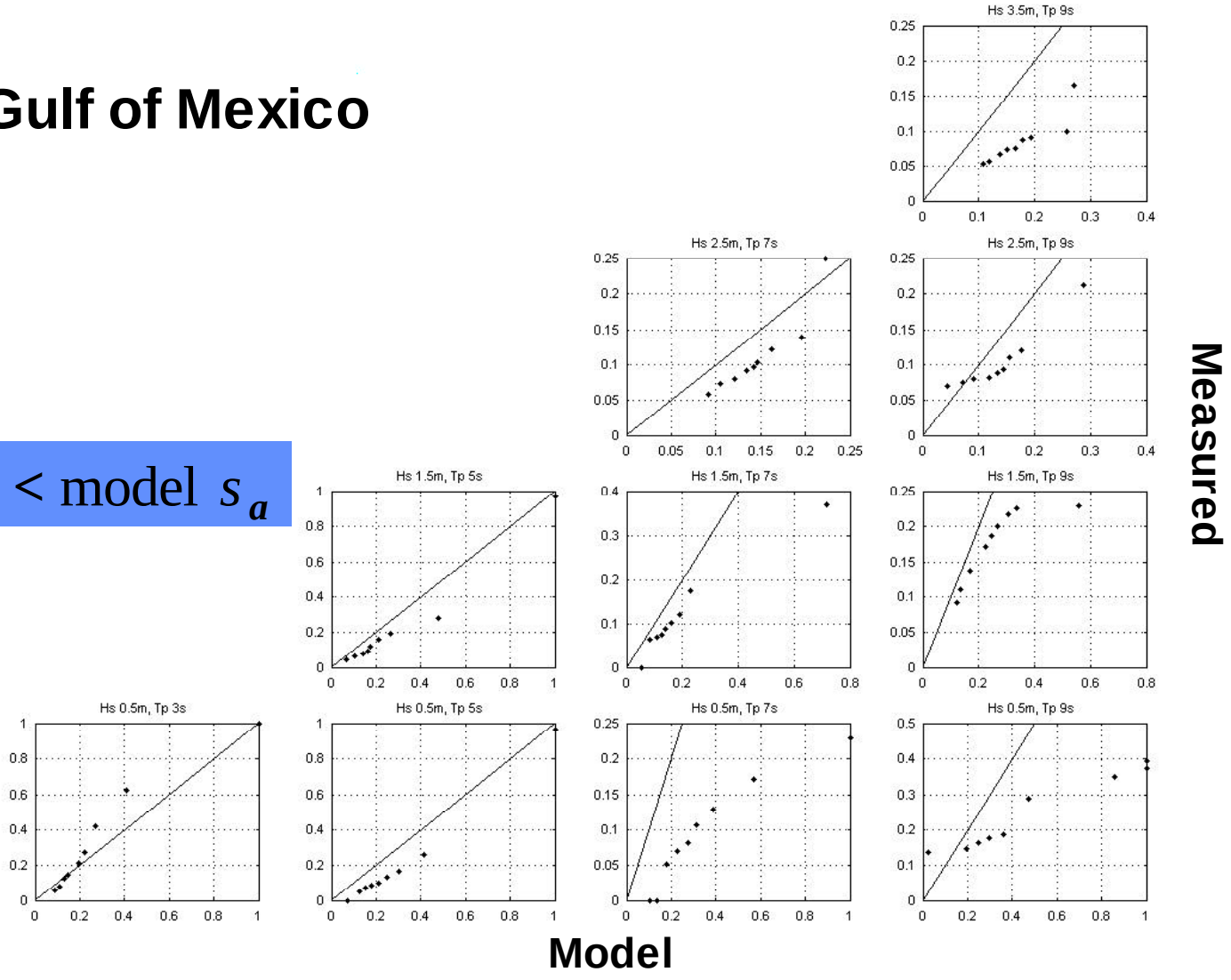
Measured a < model a



Quantile-Quantile Comparison of s_a

Gulf of Mexico

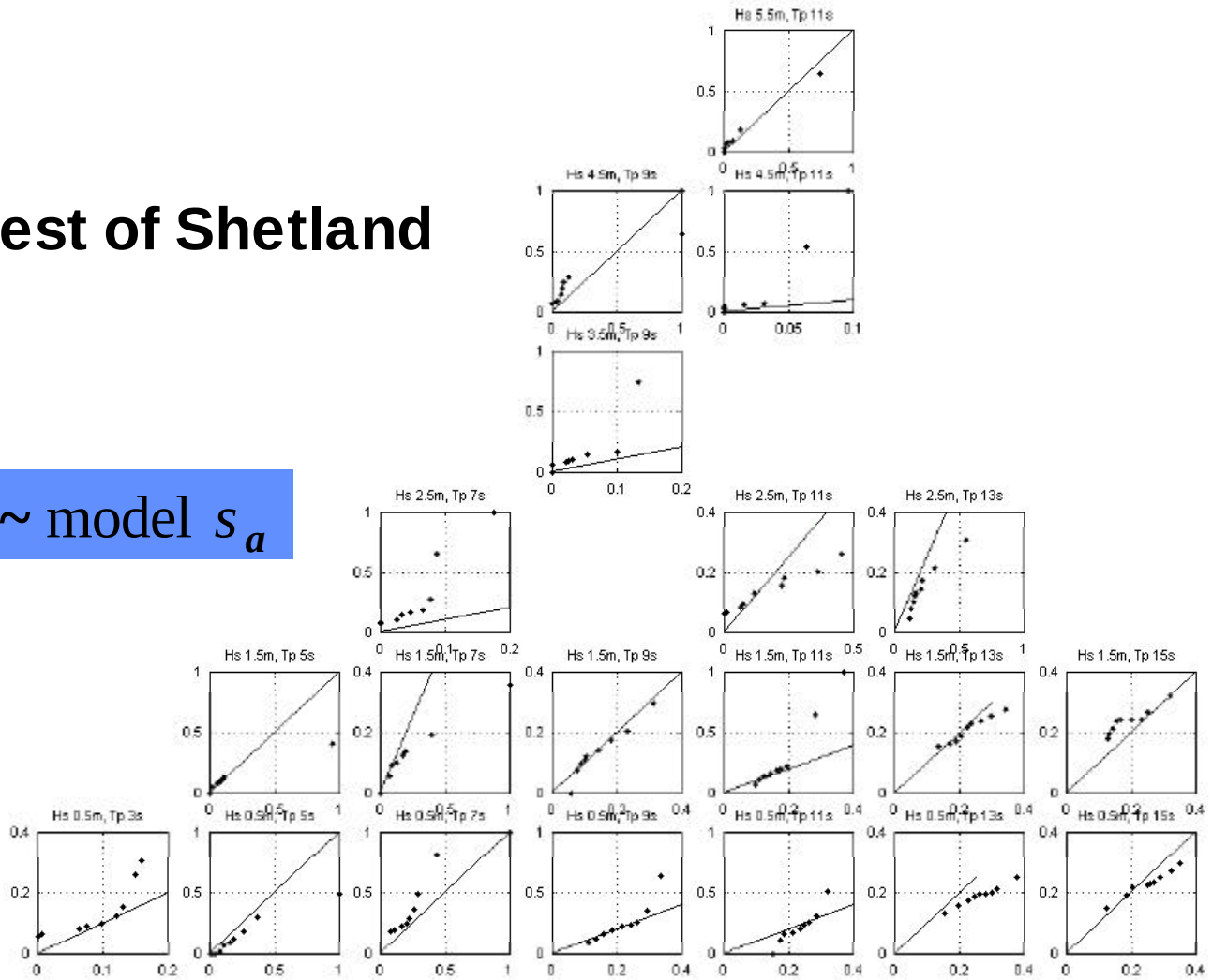
Measured s_a < model s_a



Quantile-Quantile Comparison of s_a

West of Shetland

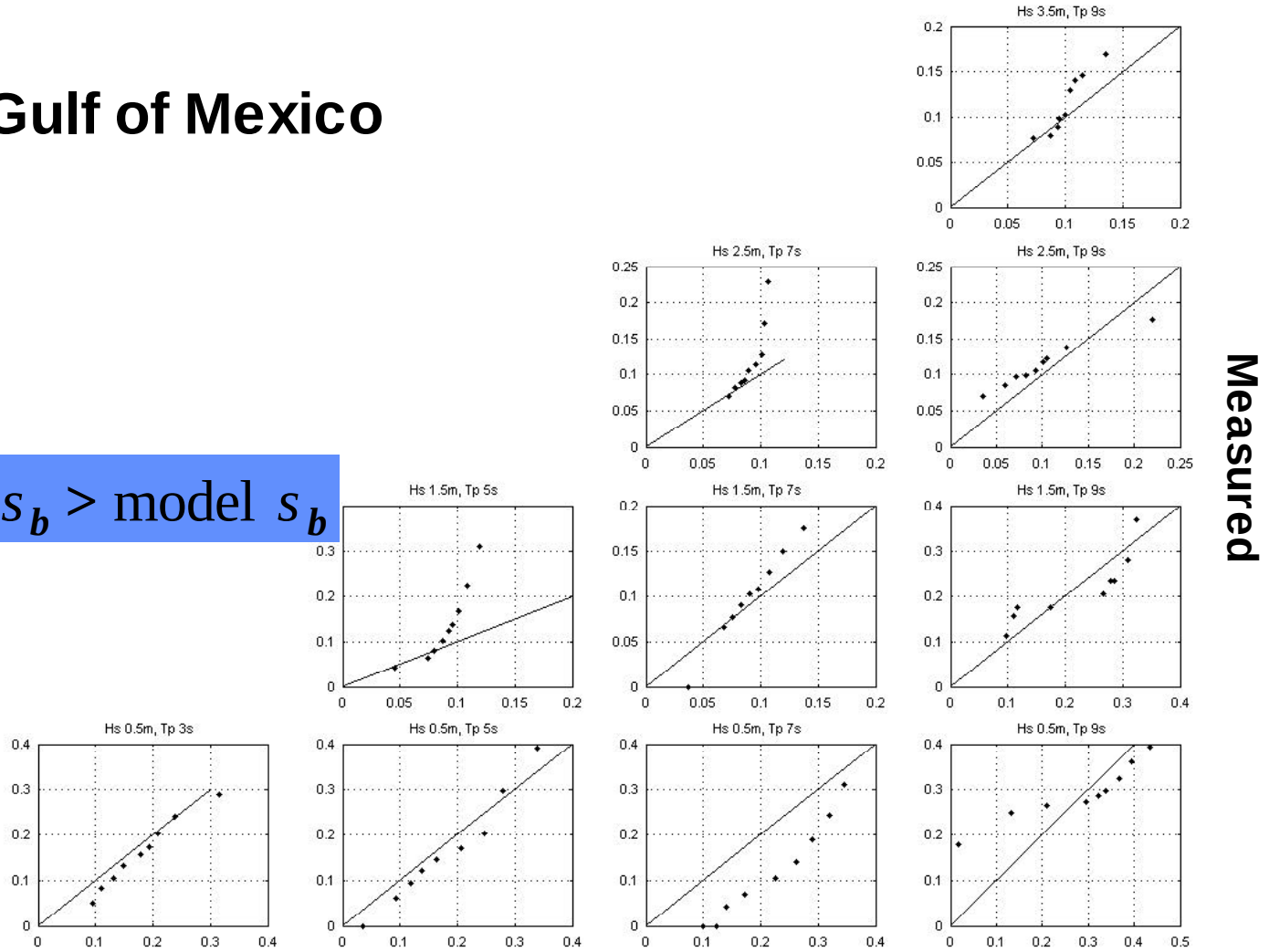
Measured s_a ~ model s_a



Quantile-Quantile Comparison of s_b

Gulf of Mexico

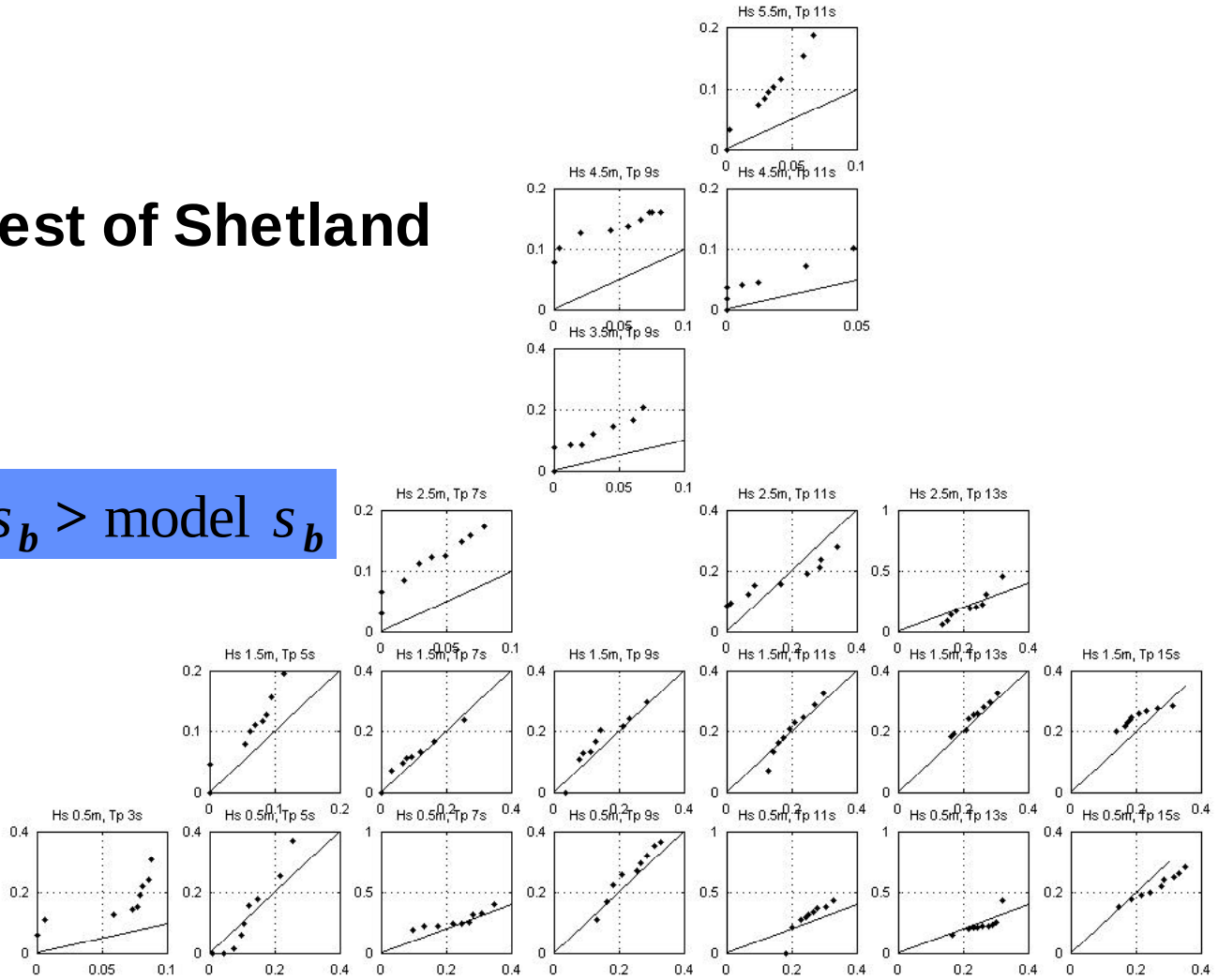
Measured s_b > model s_b



Quantile-Quantile Comparison of s_b

West of Shetland

Measured s_b > model s_b



Summary I

Overall model spectra were:

- **less peaked than the measured spectra (smaller g, larger a) - despite 6-hour averaging**
- **slightly more energy on lf side of peak than the measured spectra (larger s_a, smaller s_b)**

Summary II

- AES40 model performed very well, ECMWF WAM OK

With these data:

- median g values of steepest seas in range 1.5 - 3.0 (Gulf of Mexico measured data in range 2.5 - 5.0)
- Causes of differences:
  - by chance?
  - artefact of analysis methodology?
  - comparative frequency resolution?
  - duration of spectral averaging?
  - real differences?