Modélisation de la précision bathymétrique en amplitude pour les sonars multifaisceaux

Accuracy modelling of bathymetry measurement by amplitude processing for multibeam echosounders

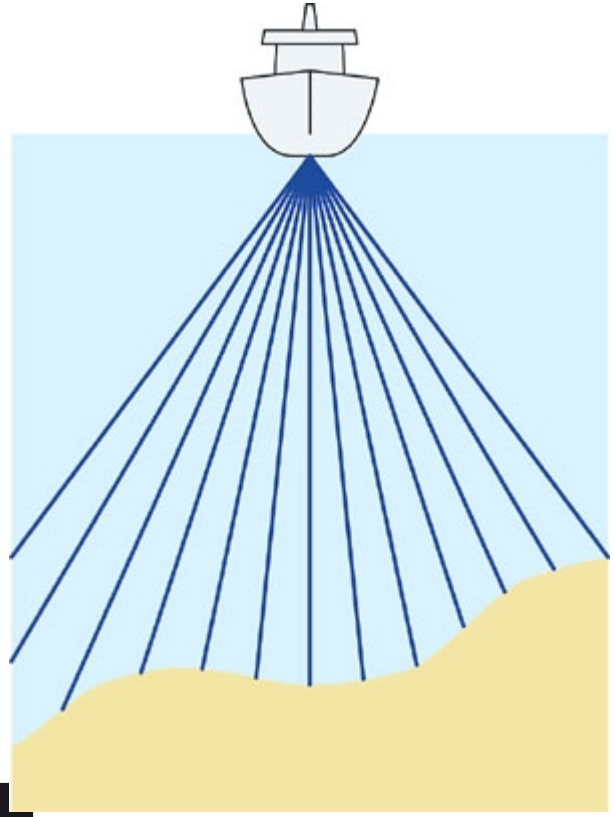
Yoann LADROIT*, Xavier LURTON, Jean-Marie AUGUSTIN, & René GARELLO**

Ifremer – Service Acoustique Sous-marine, Brest

* **Telecom-Bretagne, Dpt ITI, Brest*

* *DGA/D4S/MRIS, Bagneux*

Summary



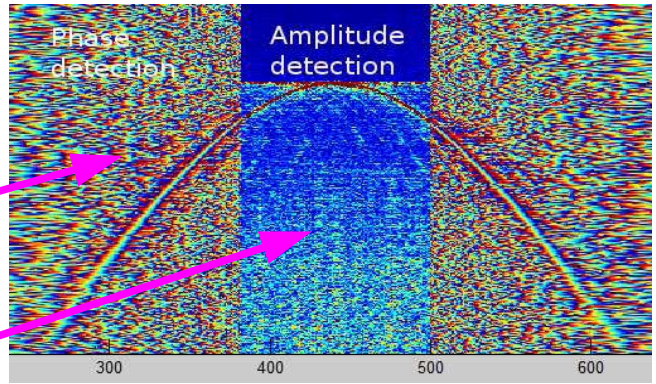
1. Amplitude processing for MBES
2. Evaluation of depth measurement
3. Definition of the amplitude QF
4. Application on real data

Introduction

Classical detection algorithm for MBES

Phase : zero crossing of phase difference

Amplitude : centre of gravity of the echo envelope



Phase detection algorithm :
-Robust and accurate
Amplitude detection algorithm :
-Accuracy modelling needed
-Further improvement expected in robustness and accuracy

Issues : Sounding validity ; Choice Amplitude vs Phase

Context

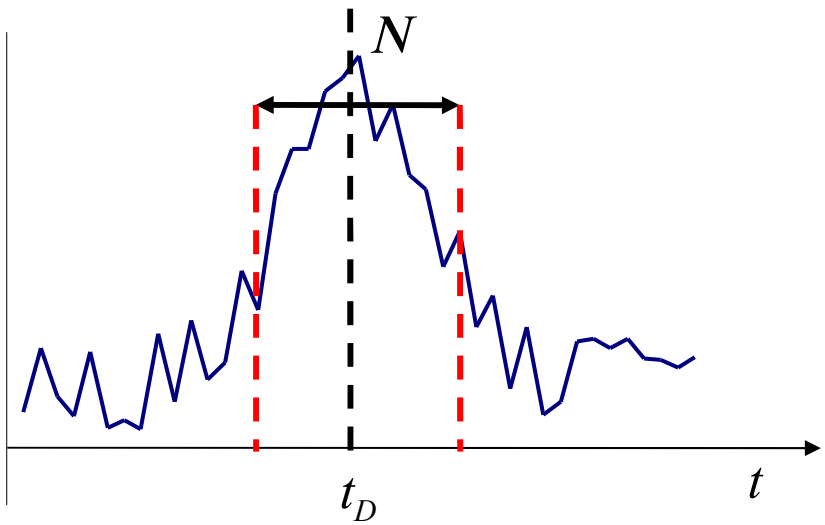
- **Definition and development** of a measurement Quality Factor (see paper by Xavier Lurton, this conf.)
- **PhD topic :**
  - Development of a model of accuracy for amplitude measurement
  - Proposition of advanced methods of amplitude detection

Amplitude processing for MBES(1/2)

- **Estimation of the Time of Arrival** t_D

Centre of gravity on the signal intensity *s(t)* in each beam

$$t_D = \int_{-\infty}^{+\infty} s(t).t.dt$$

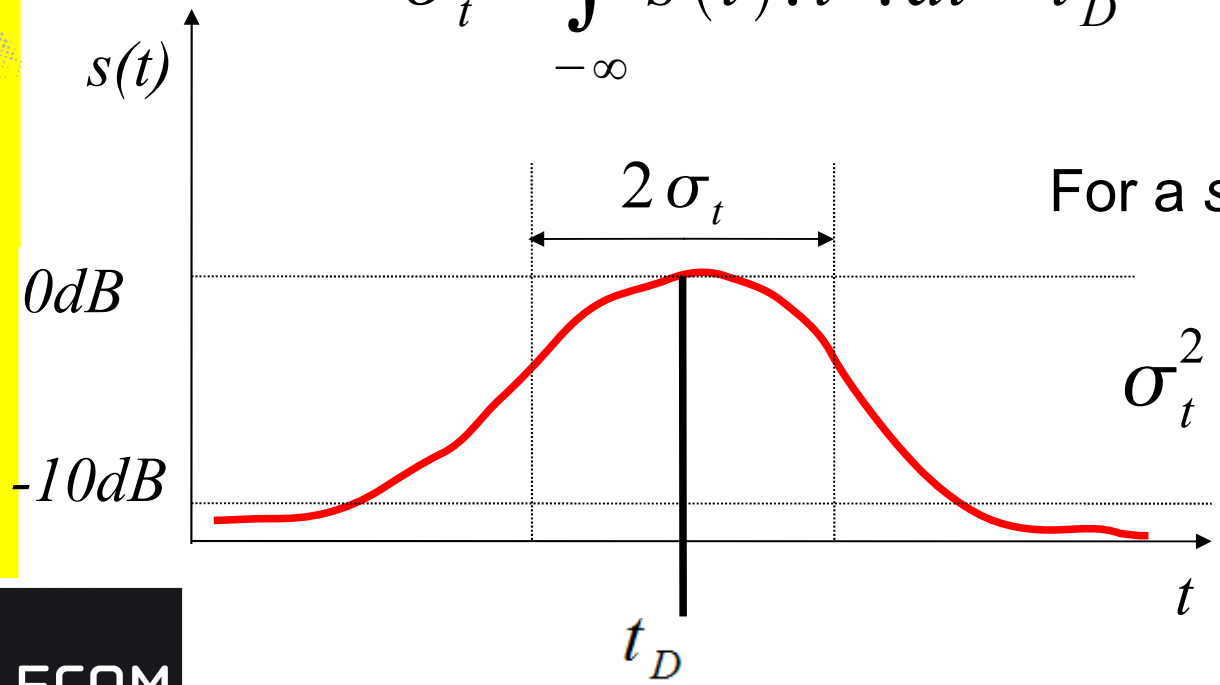


Next step : determination of the signal envelope width

Amplitude processing for MBES(2/2)

- Estimation of the envelope width

$$\sigma_t^2 = \int_{-\infty}^{+\infty} s(t).t^2.dt - t_D^2$$



For a *sinc* shaped envelope :

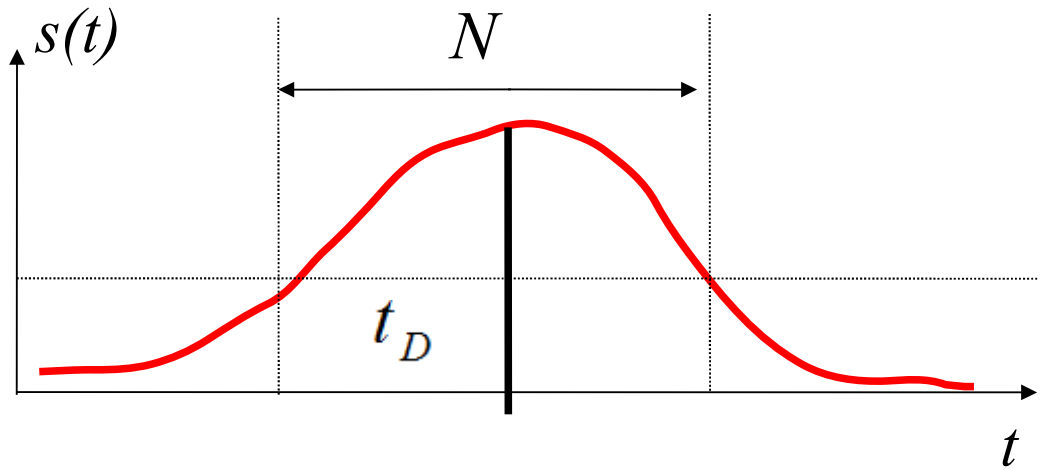
$$\sigma_t^2 = \pi / \cos(\theta_{beam})^2$$

TOA processed from this signal part

Evaluation of the depth uncertainty(1/3)

- **TOA :** Estimator of the centre of gravity :

$$\hat{t}_D = \frac{\sum_N s(t)t}{\sum_N s(t)}$$



- Determination of the estimator variance :

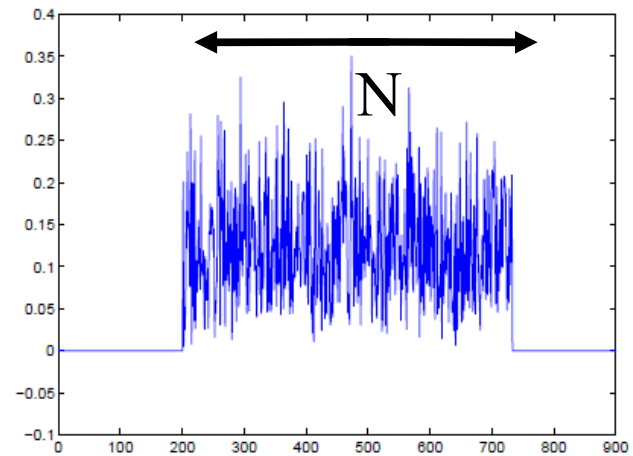
$$\delta t^2 = E\left[\left(\hat{t}_D - t_D\right)^2\right]$$

Analysis and simulation in a simple case

Evaluation of the depth uncertainty(2/3)

- **Hypothesis :** Speckle noise (m,σ^2), sampling frequency *fs.* Simple case of a step function.

$$\delta t_D^2 = \frac{\sigma^2}{12 m^2 fs^2} \frac{N(N+2)}{N+1}$$



Approximation :
Speckle noise : modulus Rayleigh distributed

$$\frac{\sigma^2}{m^2} = \frac{4-\pi}{\pi} \rightarrow \boxed{\delta t_D^2 = \frac{4-\pi}{12\pi\, fs^2} \frac{N(N+2)}{N+1}}$$

Evaluation of the depth uncertainty(3/3)

- Adaptation to a bell-shaped signal with a factor *B* :

$$\delta t = B.\delta t_D$$

$$B \approx 0.7$$

$$\delta t_D^2 = B^2 \frac{4-\pi}{12\pi\, fs^2} \frac{N(N+2)}{N+1}$$

Vertical uncertainty :

$$\frac{\delta z}{z} = \frac{\delta t}{t}$$

Shape	Cut	B
sinc	3 *dB*	0.92
	10 *dB*	0.78
	20 *dB*	0.70
$sinc^2$	3 *dB*	0.92
	10 *dB*	0.77
	20 *dB*	0.67
cos	3 *dB*	0.92
	10 *dB*	0.79
	20 *dB*	0.79

Simulation results

Definition of the amplitude QF (1/2)

QF definition :

$$q_F = \frac{N_D}{N_{Pulse}} \frac{2\sqrt{3(N+1)}}{B\left(\frac{4}{\pi}-1\right)\sqrt{(N+2)N}}$$

$$q_F = \frac{z}{\delta z} = \frac{t_D}{\delta t_D}$$

$$QF = \log_{10}(q_F)$$

$$q_F \approx \frac{N_D}{N_{Pulse}} \frac{12.7}{B} \frac{1}{\sqrt{N}}$$

$T_{Pulse} \nearrow$	$QF_{Amp} \searrow$
$H \nearrow$	$QF_{Amp} \nearrow$
$H \wedge T_{Pulse} \nearrow$	$QF_{Amp} \longrightarrow$
$\theta \nearrow$	$QF_{Amp} \searrow$

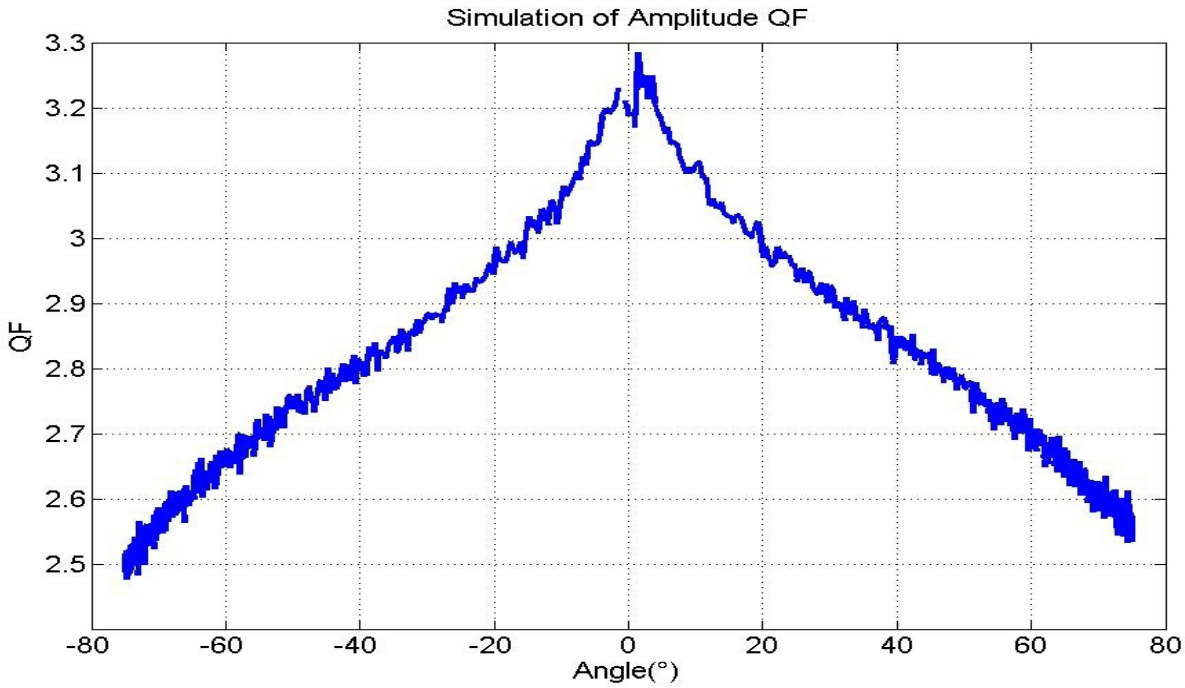
N: number of independent samples in the envelope

***N*$_{Pulse}$** : number of samples in the pulse of emission

***N*$_D$** : sample chosen as TOA

Definition of the amplitude QF (2/2)

- <u>Conditions of simulation :</u>
  - Flat sea-floor, depth : 2200m
  - MBES specifications : Reson Seabat 7150 (880 beams, equidistant, +/- 75°)



Validation by computation of a real δz (1/3)

Raw Data (I/Q) (uniform flat sea floor, at least 100 pings)

Bottom detection

PingBeam **Bathymetry**

PingBeam QF

Numerical model creation
- Filtering ping after ping
- Filtering on each beam

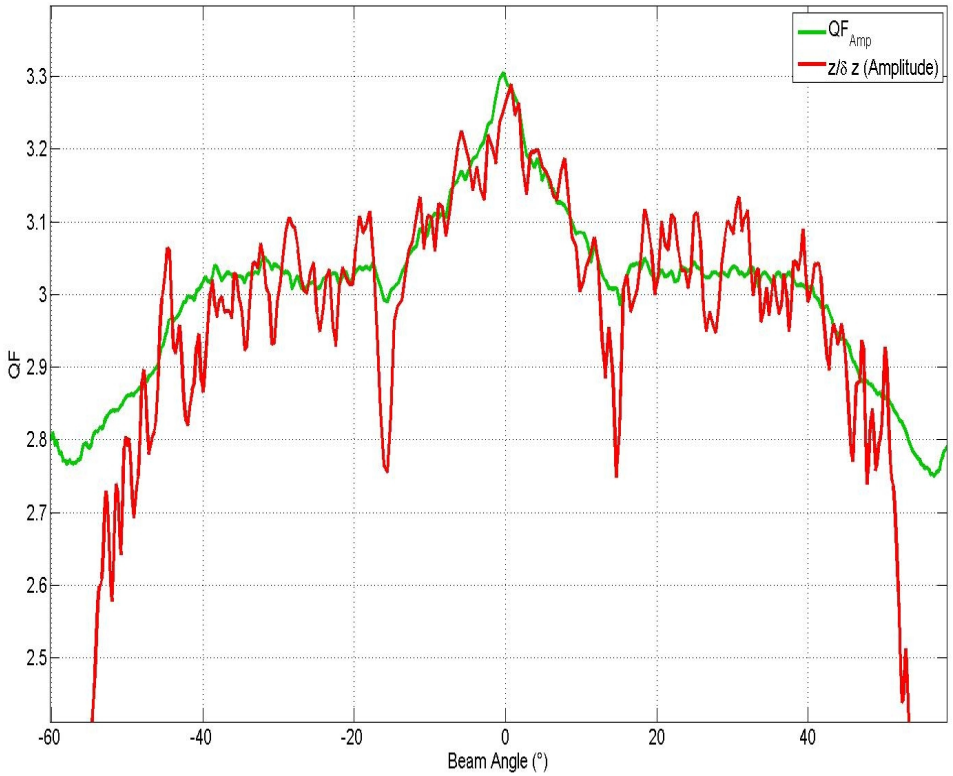
Subtraction to the bathymetry

δz processing for each beam

Global QF for the data

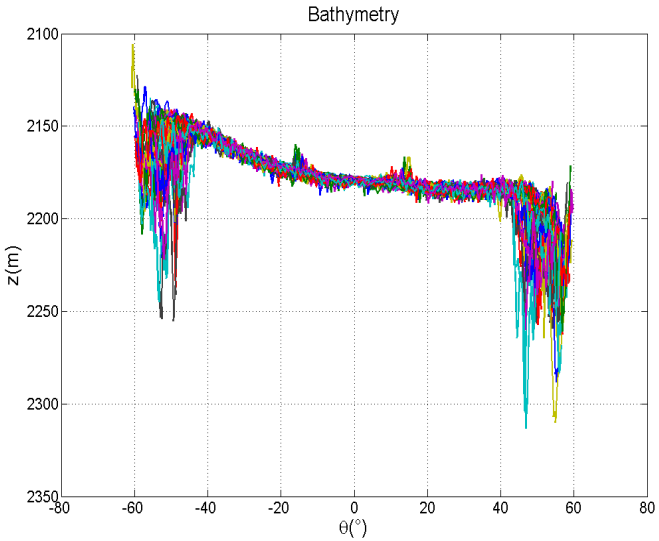
Comparison

Validation by computation of a real δz(2/3)



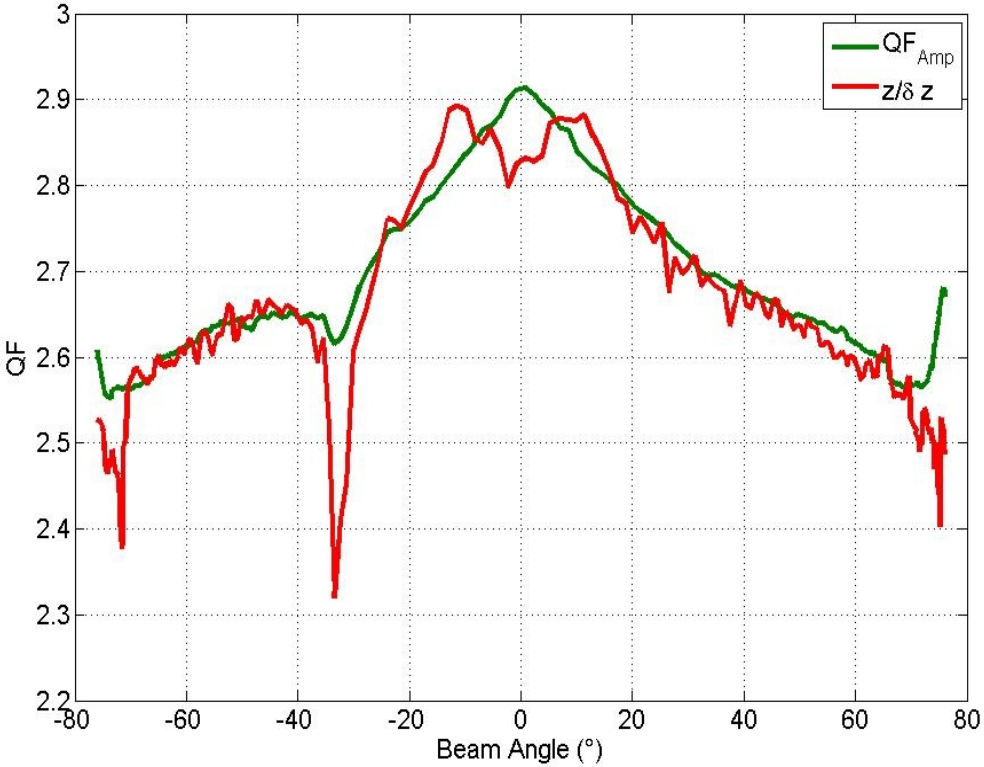
Data :

- Seabat 7150 24kHz 880 beams
- Flat seafloor 2200m
- Variance processed on 108 pings



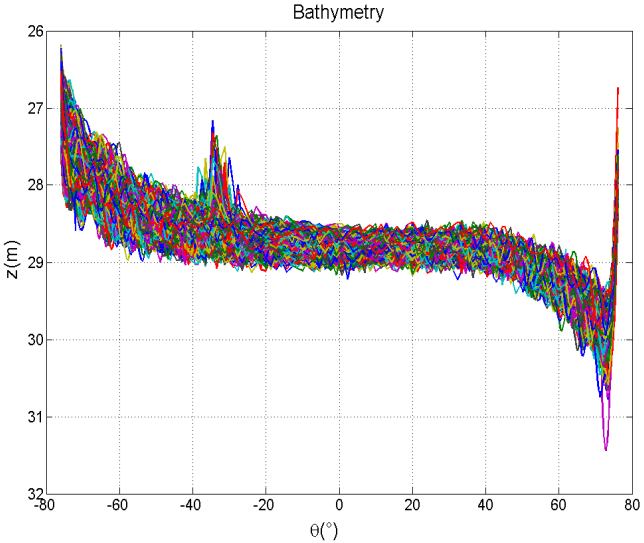
Relevance of the amplitude **QF** on sector -50°:50°.

Validation by computation of a real δz(3/3)

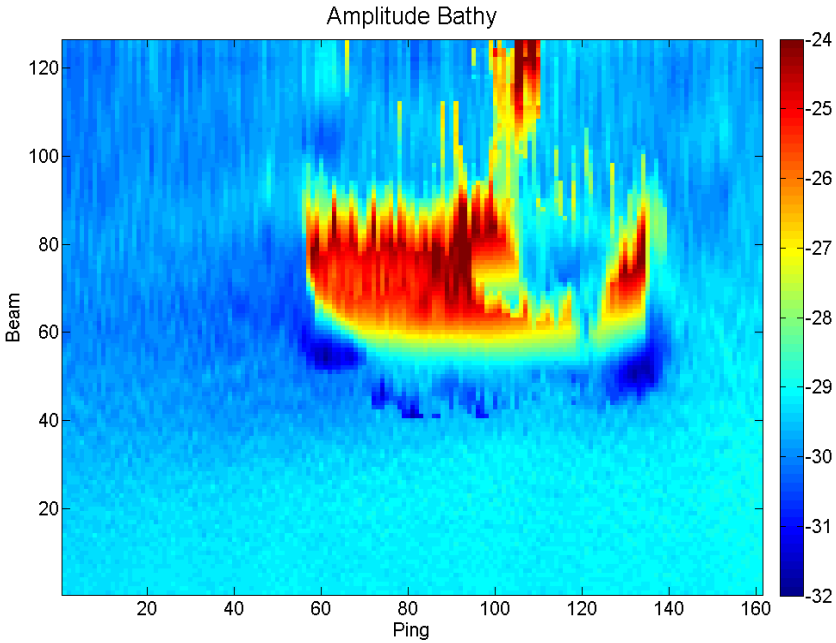


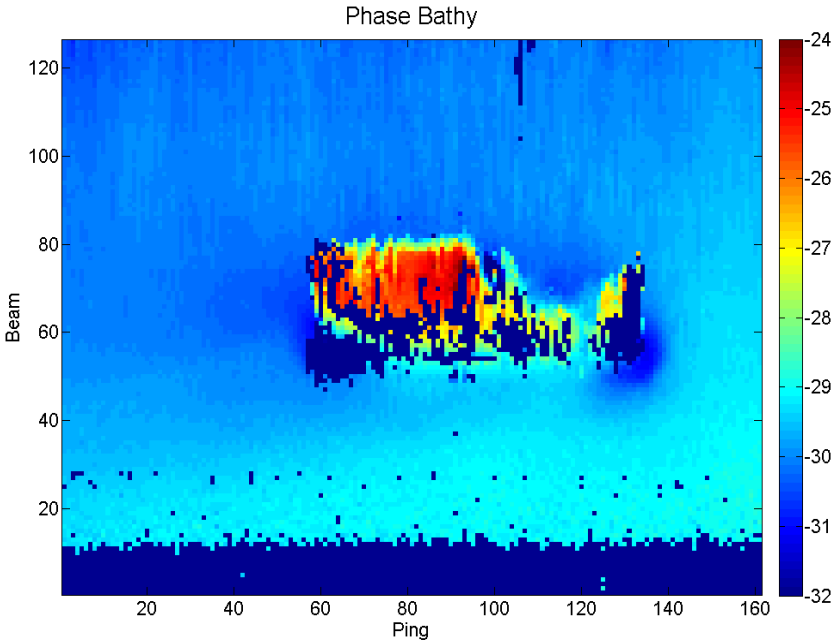
Data :

- Seabat 7111 201 beams (equi-angle)
- Flat seafloor 29m
- Variance processed on 675 pings

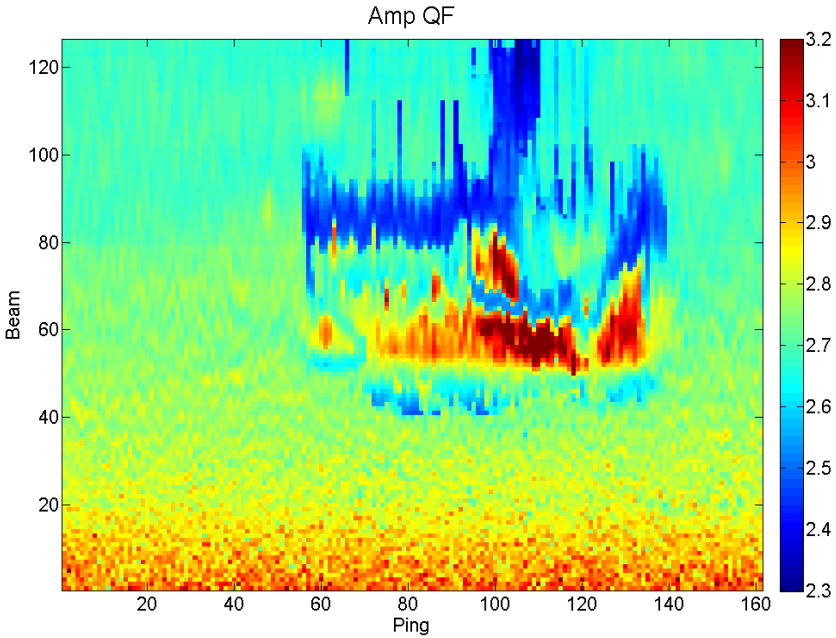


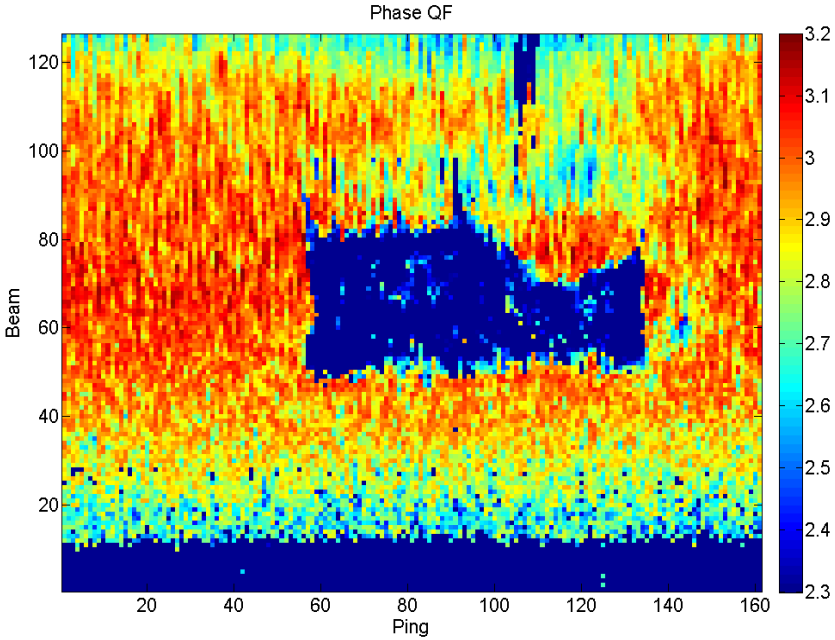
Relevance of the amplitude **QF** on sector -70°:70°.

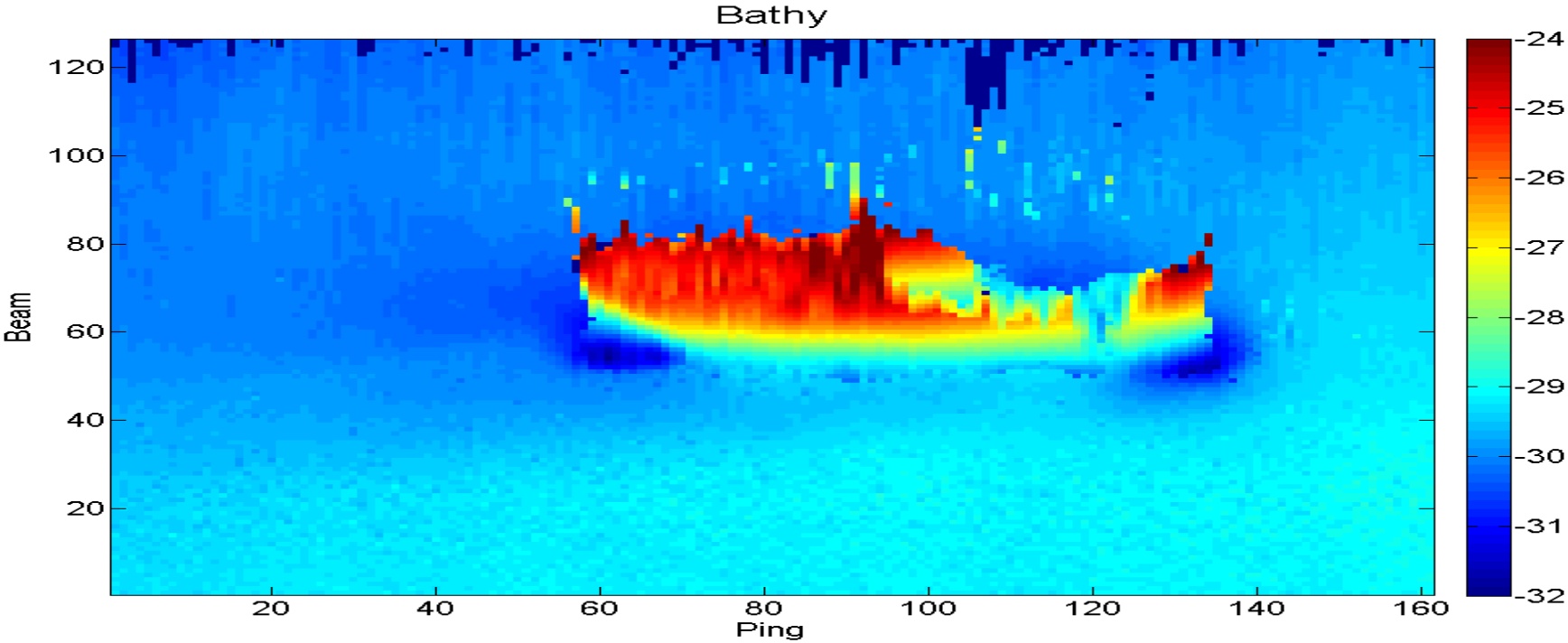


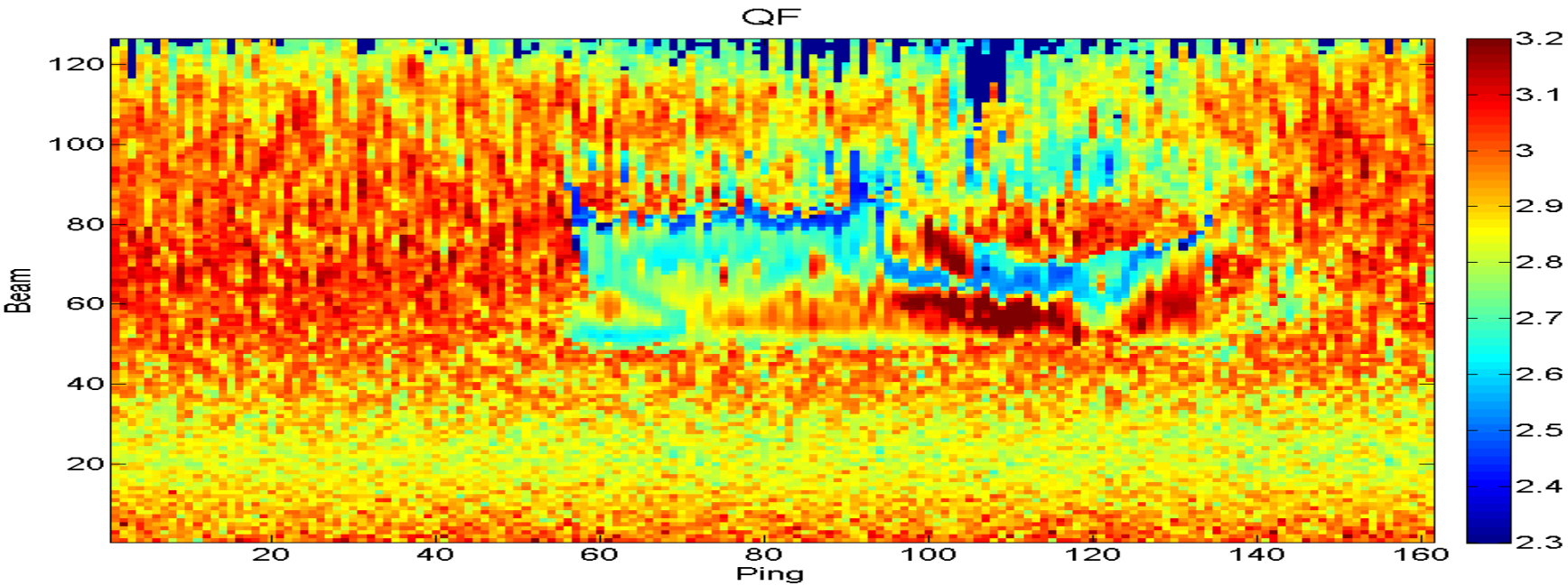


Detection choice with QF






Bathy
Beam
Ping
120
100
80
60
40
20
20
40
60
80
100
120
140
160
-24
-25
-26
-27
-28
-29
-30
-31
-32


QF
Beam
Ping
120
100
80
60
40
20
20
40
60
80
100
120
140
160
3.2
3.1
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3

Conclusions

- Successful definition of an **accuracy model** for **amplitude detection** by MBES
- Relevance of the Quality Factor for amplitude soundings : **confirmed by real data analysis**
- **Local depth quality** computed directly from the signal amplitude : **simple and robust**
- **Quality Factor** processed for **individual soundings** :
  - Useful **accuracy descriptor** for DTM cleaning
  - Well-adapted **input for algorithms** such as CUBE®

Questions?