Repercussions of available long offset, random noise and impedance contrast on AVO analysis

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30/Oct/2015

Outline

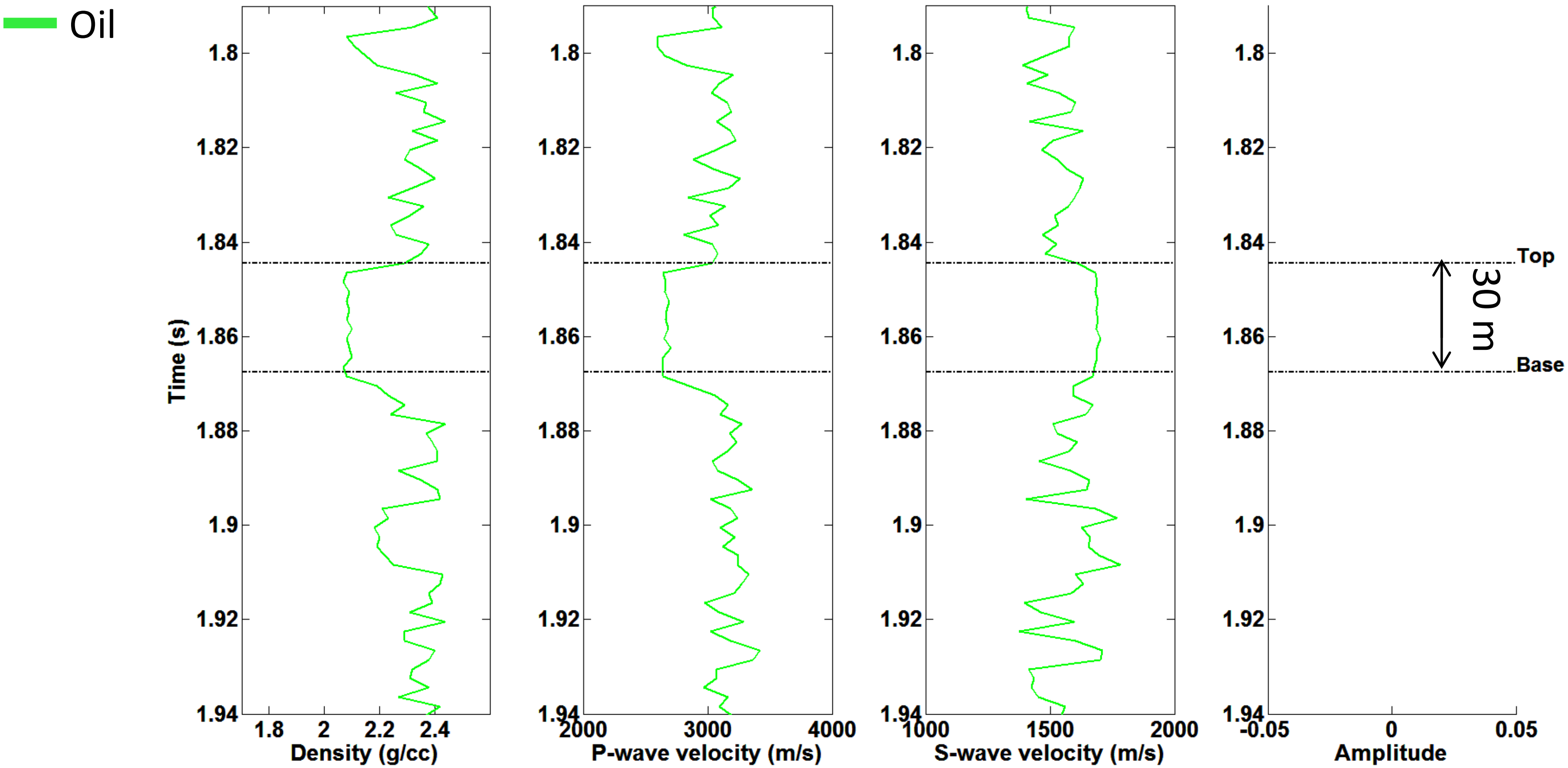
- ✓ Introduction
  - Motivations
  - Geological target
  - Fluid replacement modelling
  - Vertical seismic resolution
  - AVO modelling using Zoeppritz equations
- ✓ Effect of random noise keeping maximum offset constant
- ✓ Quantifying the error
- ✓ Effect of reducing offset keeping noise constant
- ✓ Simultaneous effect of reducing offset and varying level of noise
- ✓ Conclusions and future work

Motivations

- How to meet the large offset requirement when designing a seismic survey for AVO analysis

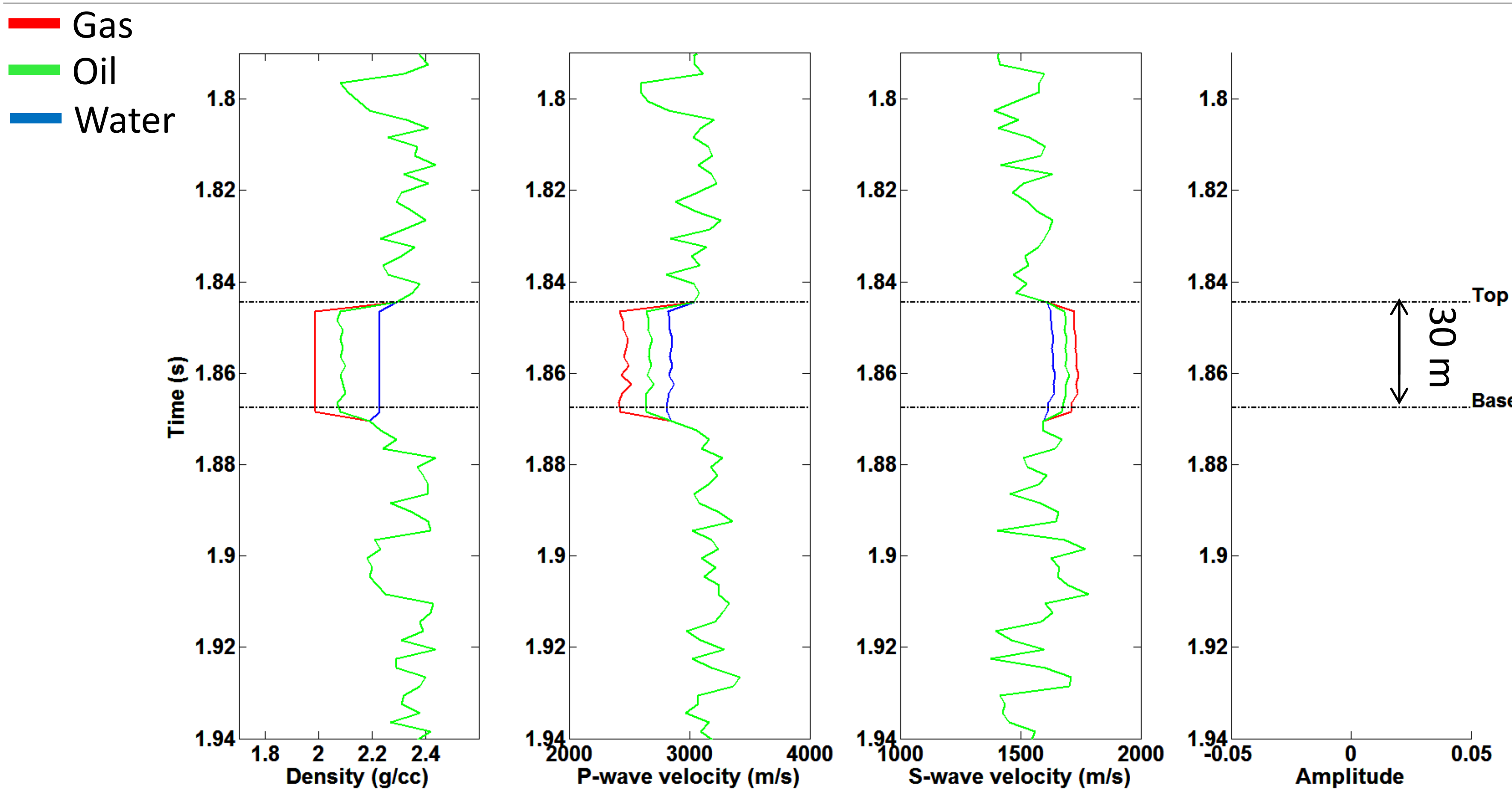
- If we already have a seismic data set, is it suitable for AVO analysis?

Geological target



Depth of reservoir =2280 m

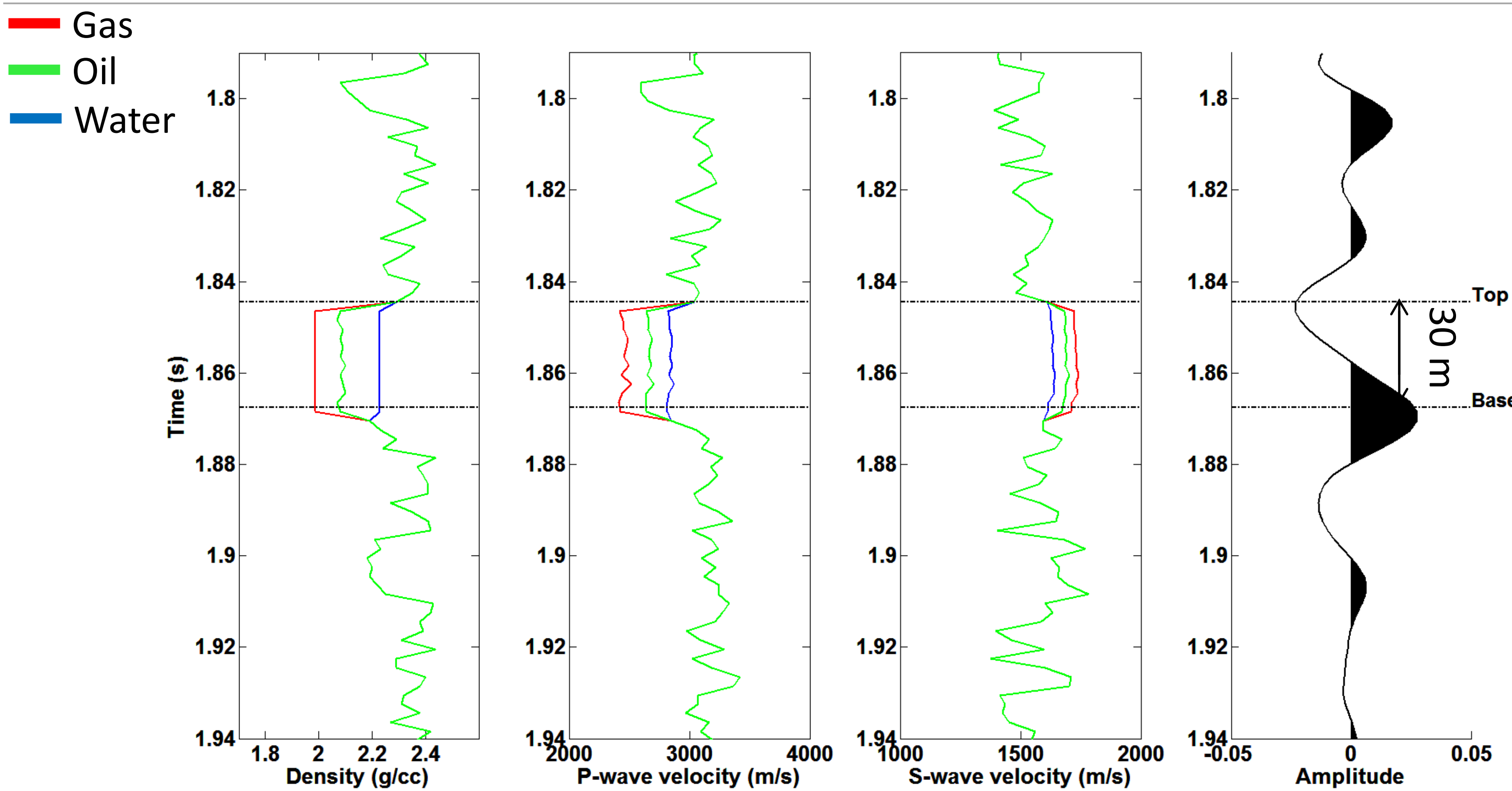
Light oil (38 api)

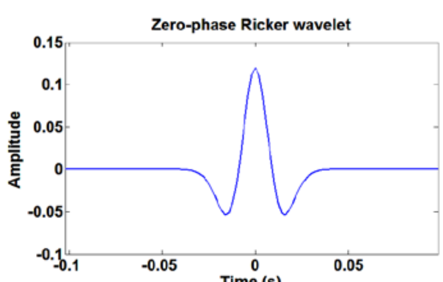


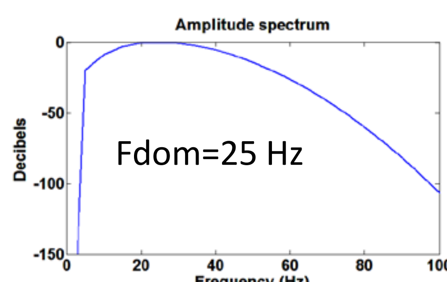
Gas produces a significant decrement of P-wave velocity and density , and a subtle increase in S-wave velocity.

Water produces the opposite change; P-wave velocity and density rise, while S-wave velocity slightly falls.

Vertical seismic resolution

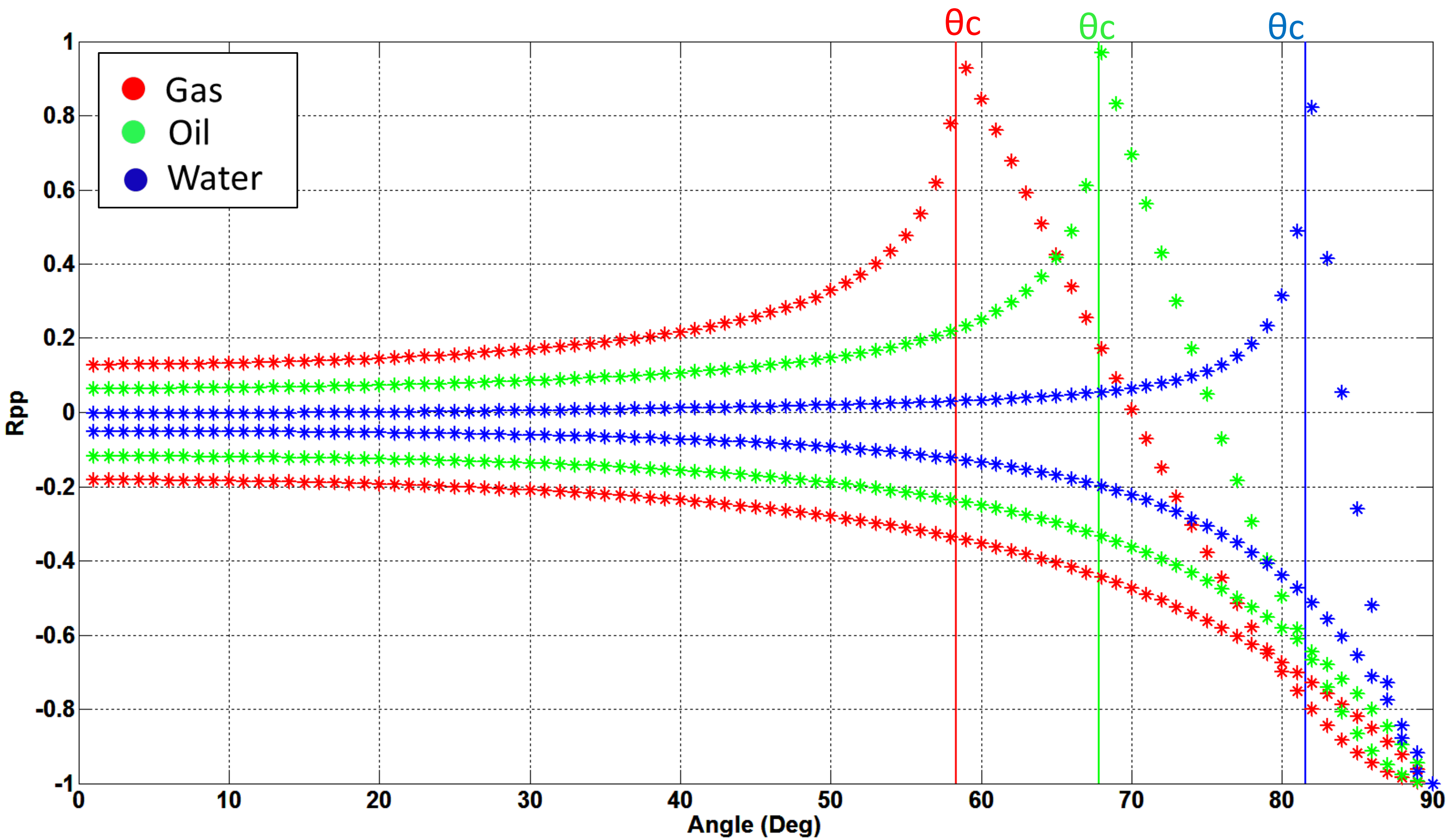






Reflection coefficient vs angle of incidence
Zoeppritz equations

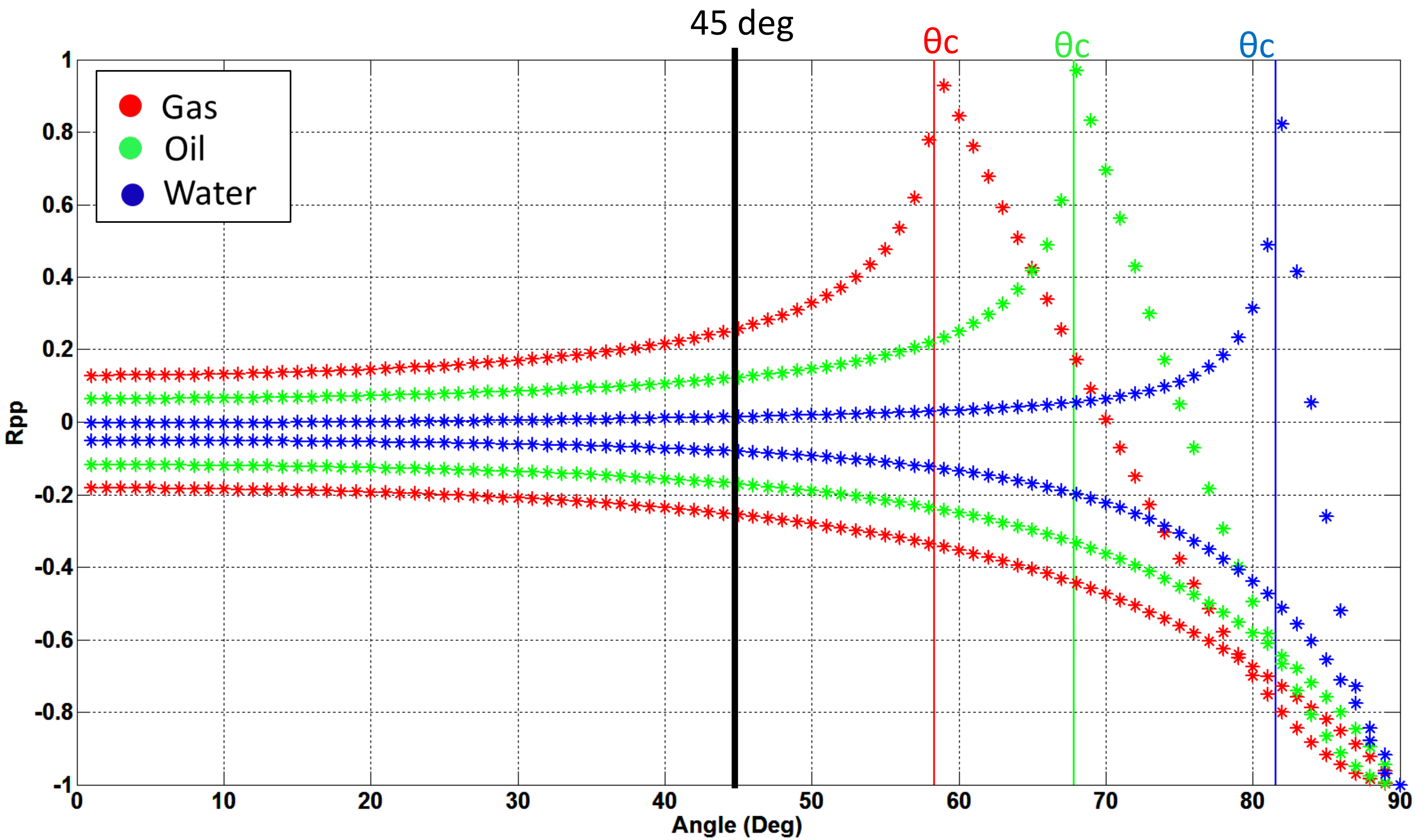
Introduction



Θc=critical angle

Reflection coefficient vs angle of incidence
Zoeppritz equations

Introduction



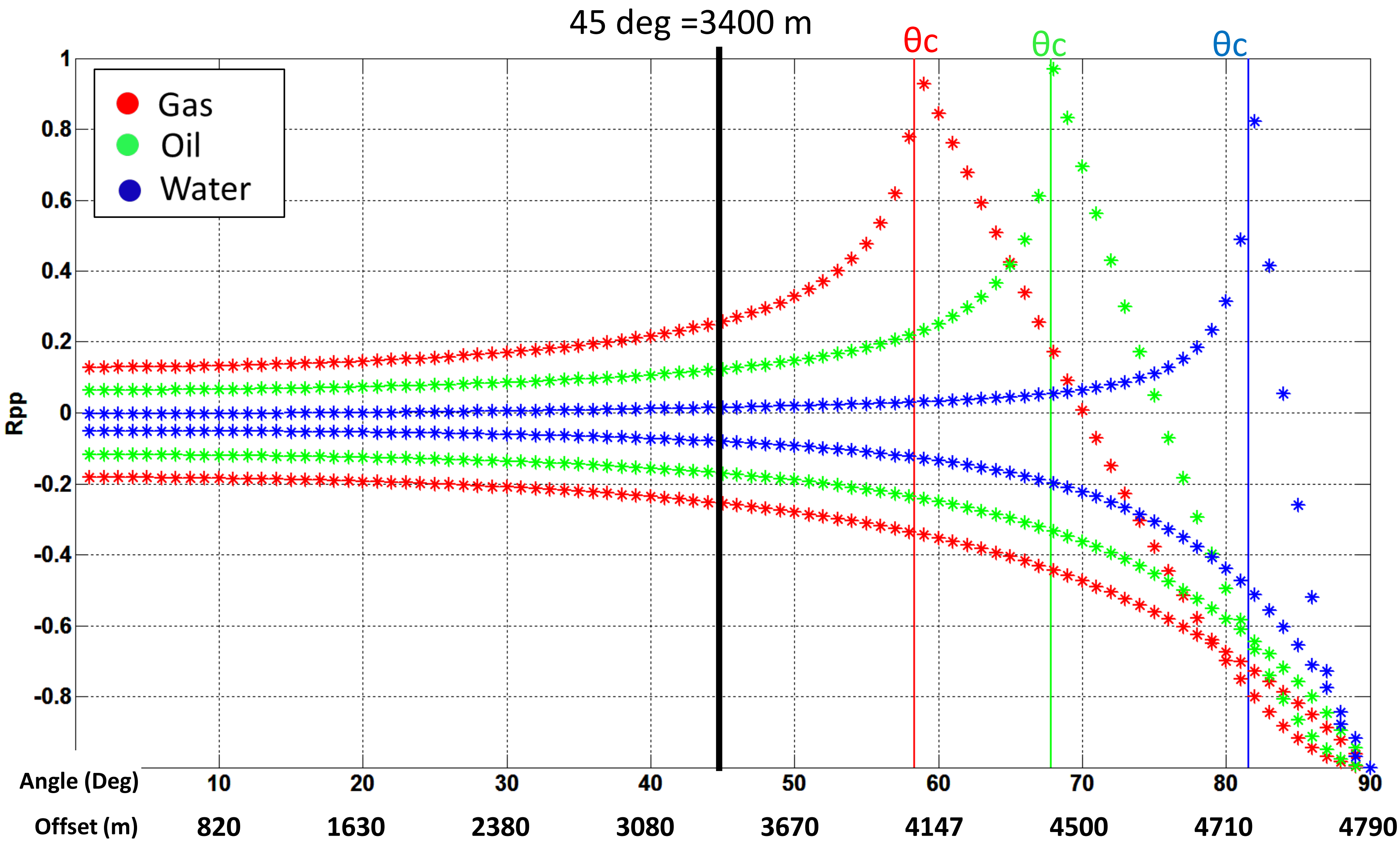
Pre-critical angles up to 45 degrees were used for this experiment

Θc=critical angle

Reflection coefficient vs angle of incidence

Zoeppritz equations

Introduction



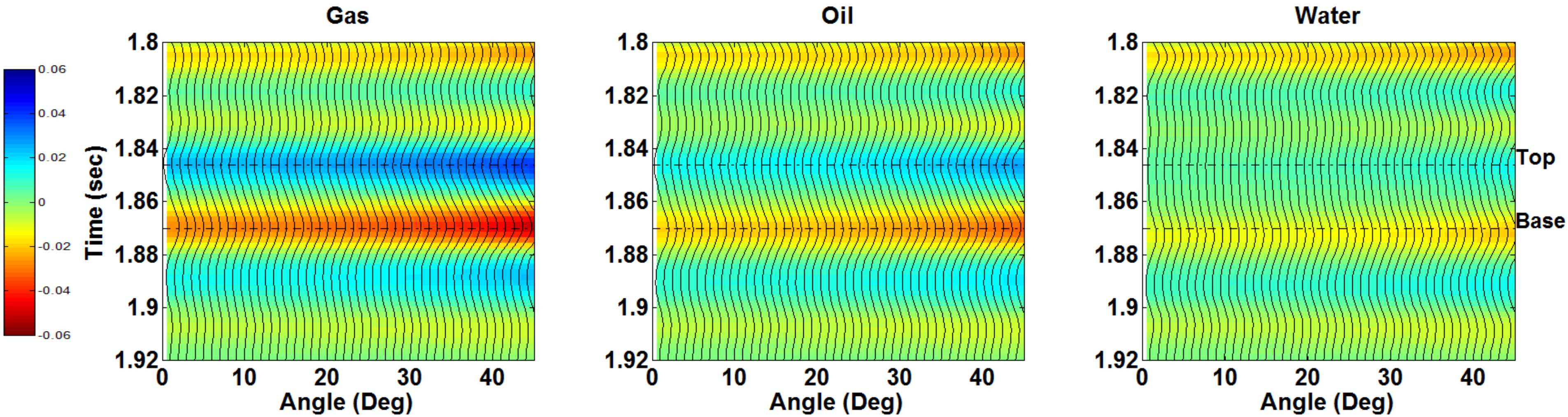
$$\sin\theta = \frac{X\,V_{int}}{t\,V_{rms}^2}$$

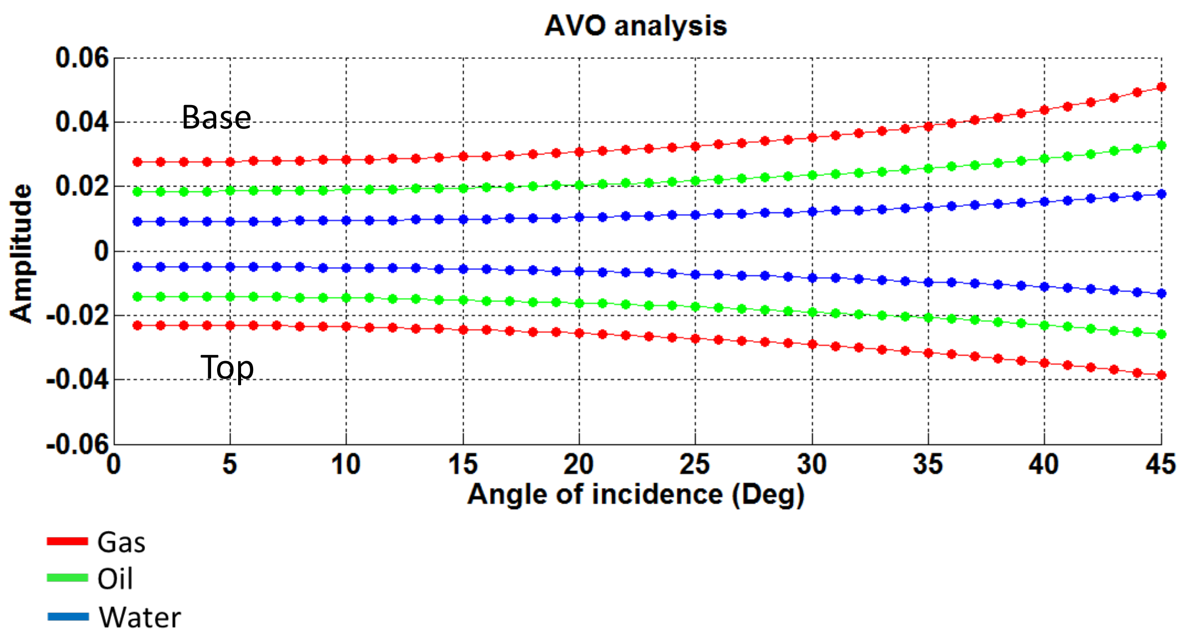
Top

Θc=critical angle

AVO modelling
Amplitude vs angle of incidence

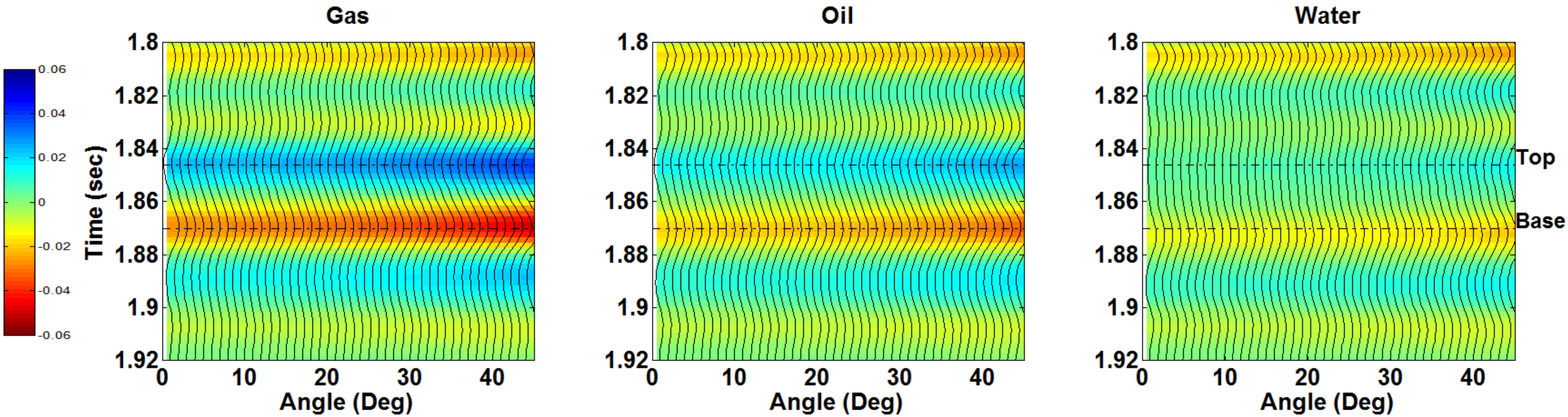
Introduction

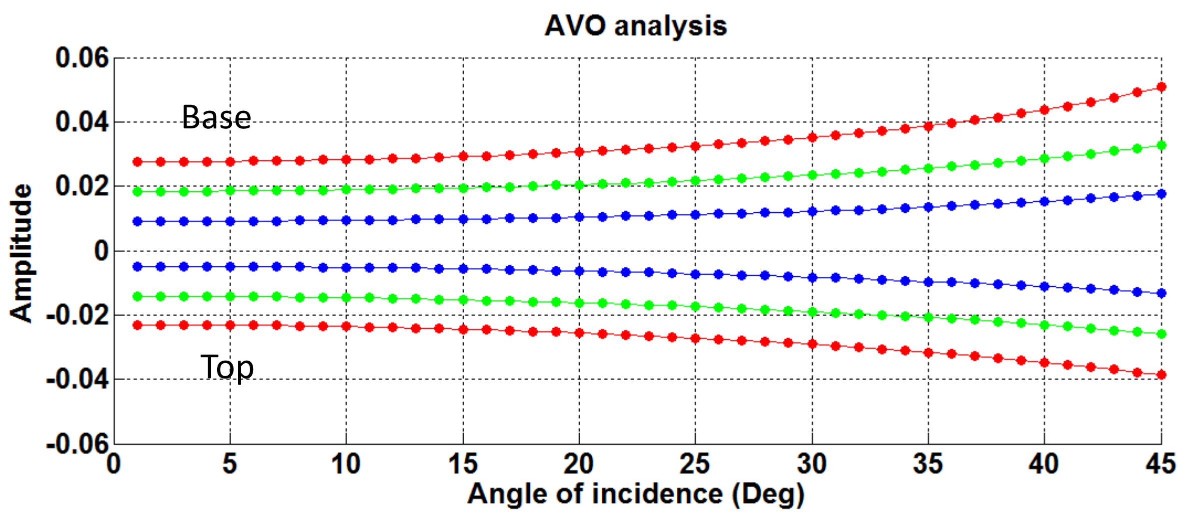


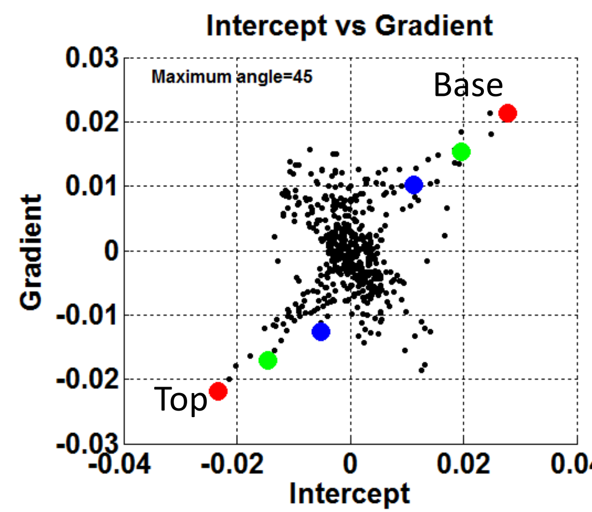


AVO modelling
Amplitude vs angle of incidence

Introduction







Gas
Oil
Water

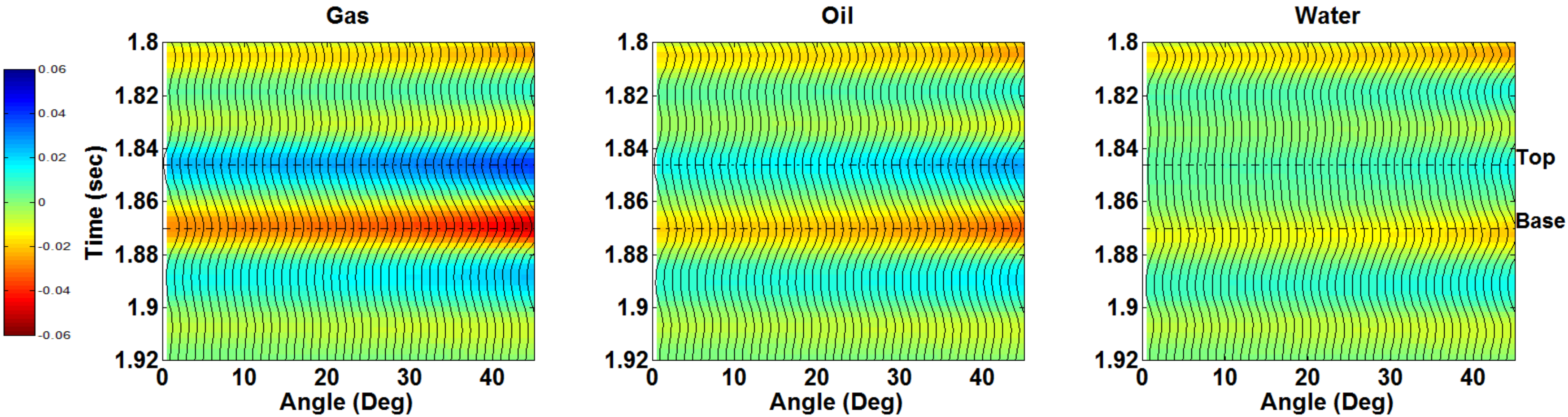
$$R_P(\theta) = R_{AI} + G\sin^2\theta + R_{VP}\sin^2\theta\tan^2\theta$$

Intercept Gradient Curvature

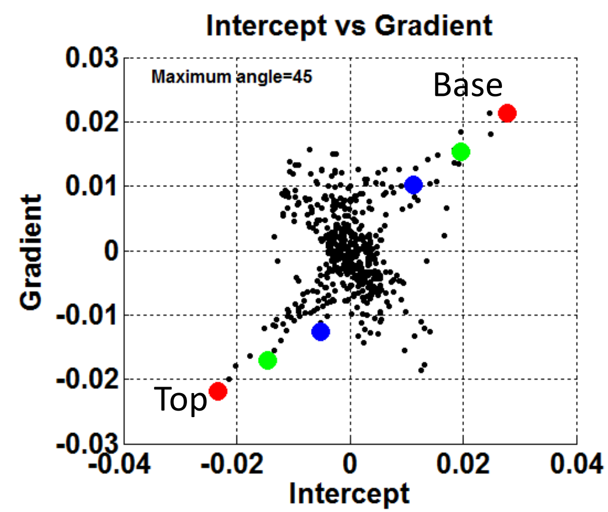
Wiggins et al (1983)

Max. Angle=45
No noise

Introduction



	TOP			BASE		
	Intercept	Gradient	Curvature	Intercept	Gradient	Curvature
GAS	-0.023	-0.021	-0.010	0.028	0.022	0.024
OIL	-0.014	-0.017	-0.007	0.018	0.016	0.013
WATER	-0.005	-0.012	-0.004	0.009	0.010	0.007



$$R_P(\theta) = R_{AI} + G\sin^2\theta + R_{VP}\sin^2\theta\tan^2\theta$$

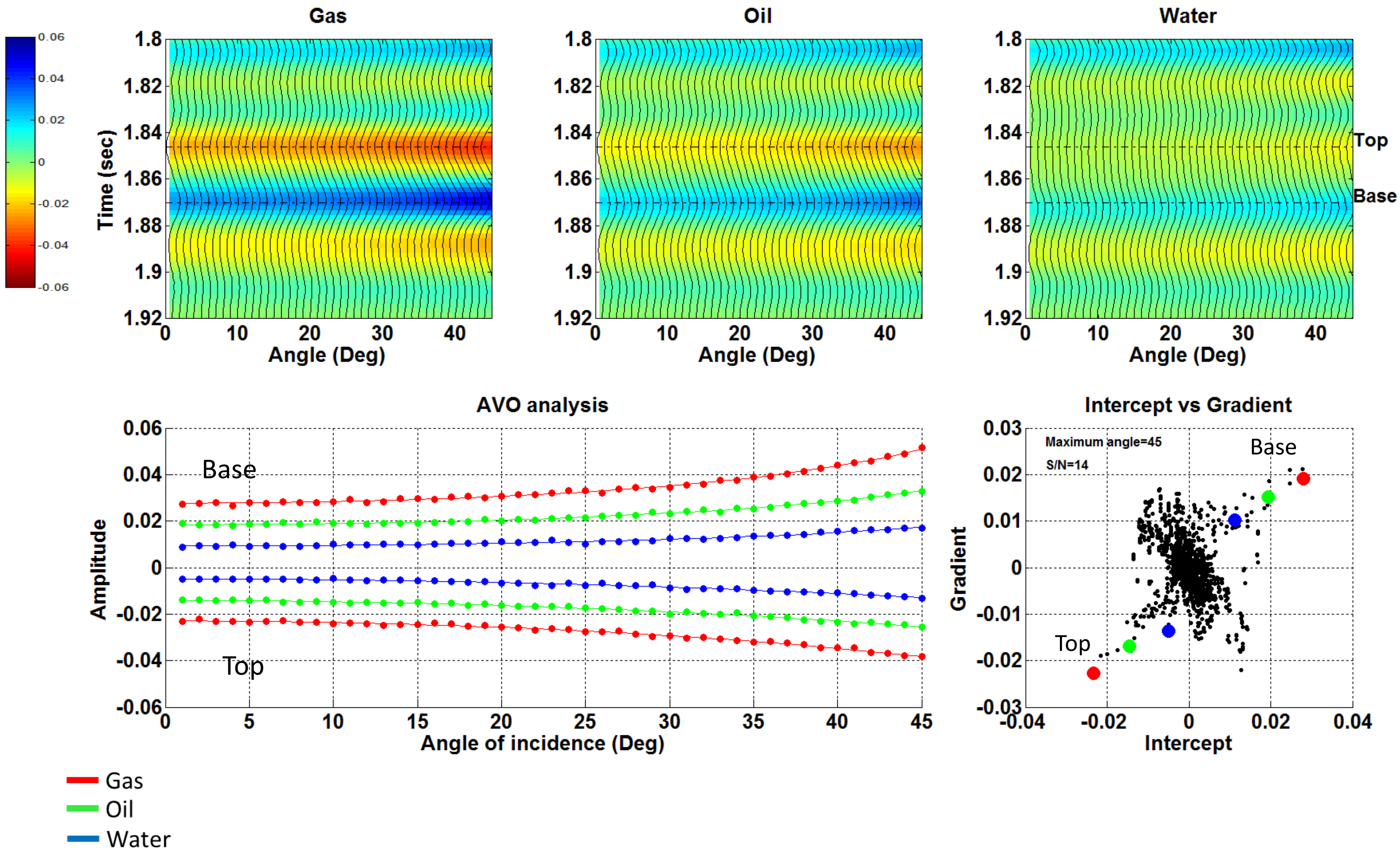
Intercept Gradient Curvature

Wiggins et al (1983)
Russell and Hampson(2006)

Effect of varying level of noise keeping maximum angle constant

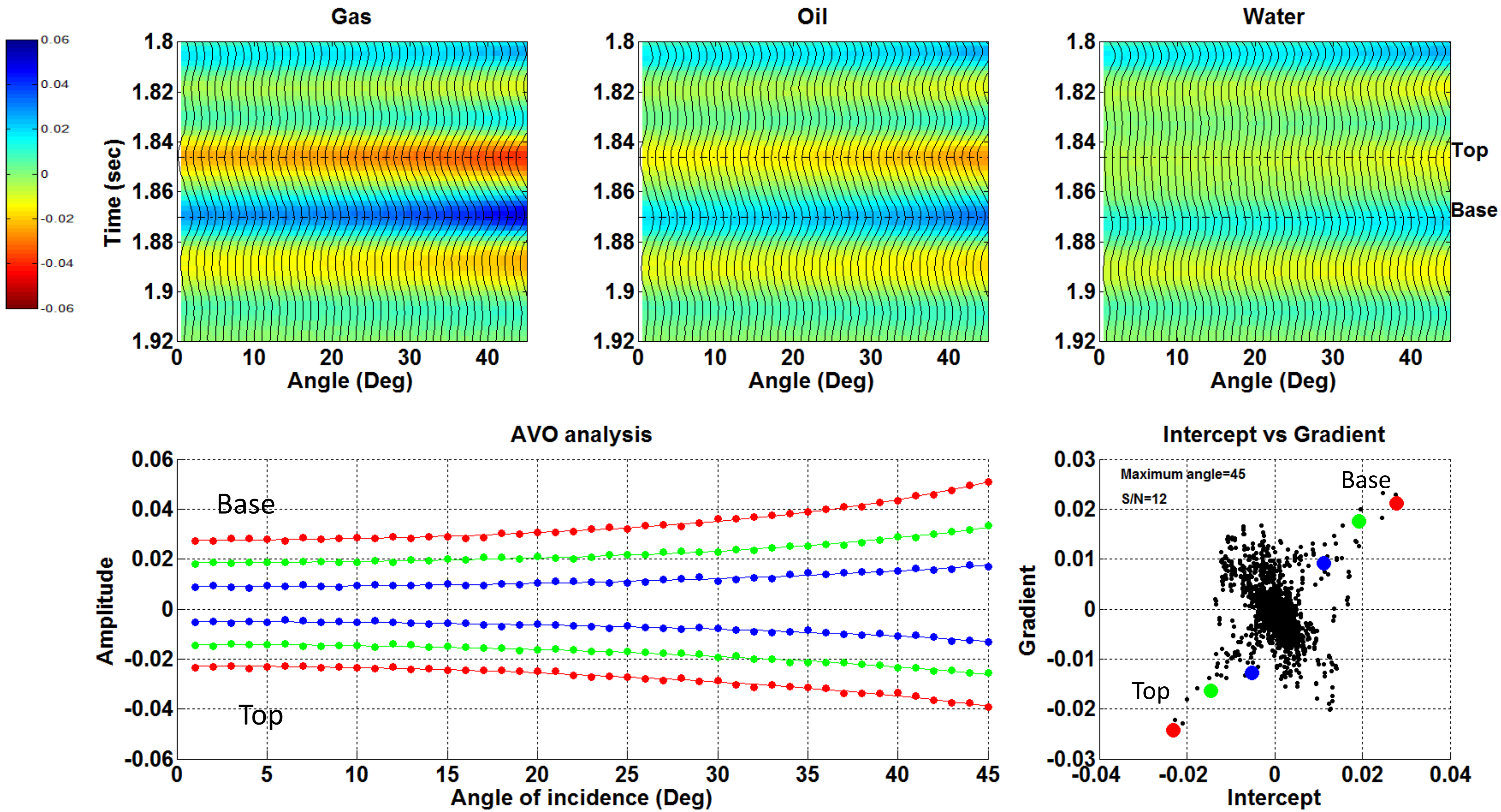
Max. Angle=45
S/N=14

Effect of reducing angle of incidence
Keeping maximum angle constant



Max. Angle=45
S/N=12

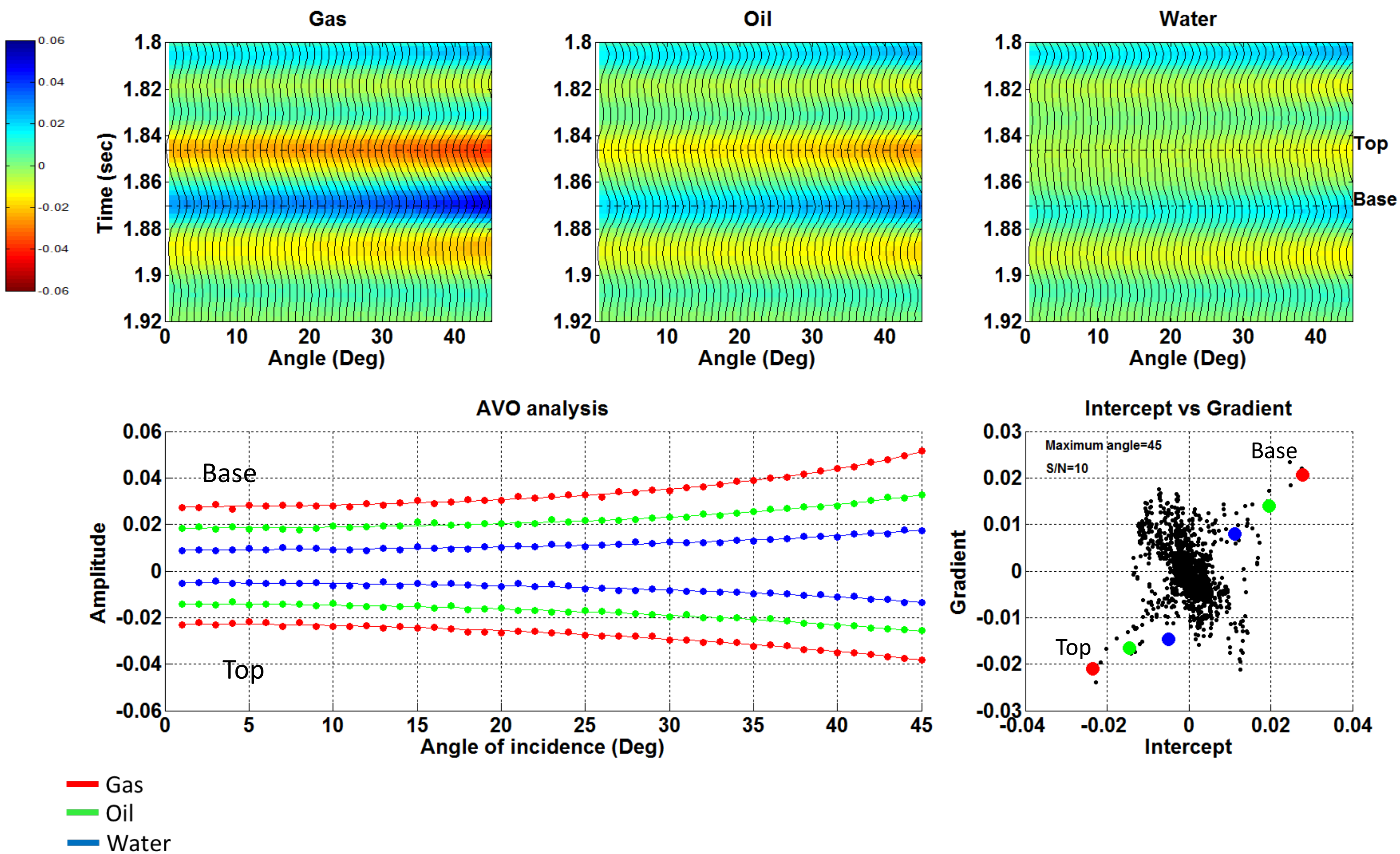
Effect of reducing angle of incidence Keeping maximum angle constant



Gas
Oil
Water

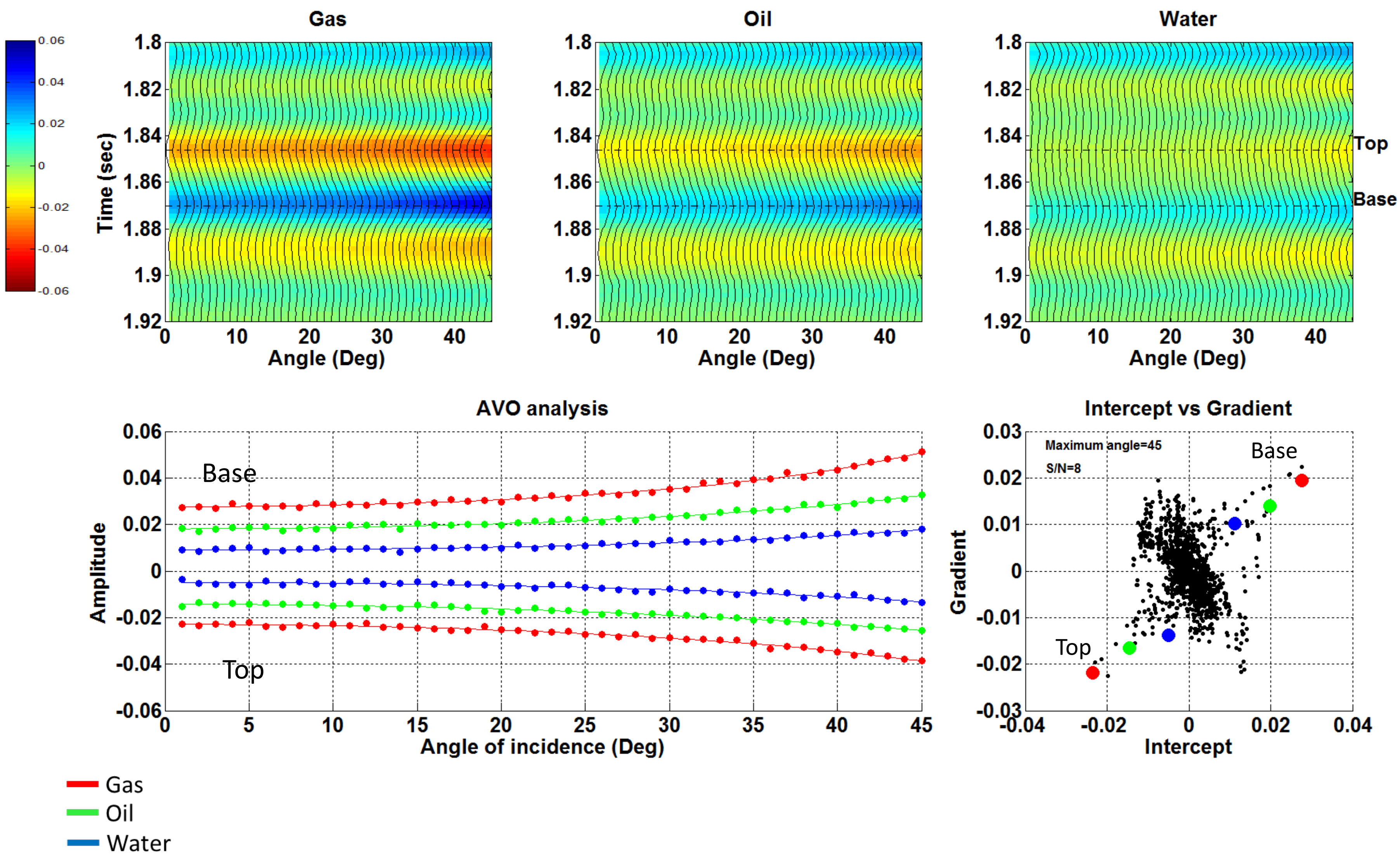
Max. Angle=45
S/N=10

Effect of reducing angle of incidence Keeping maximum angle constant



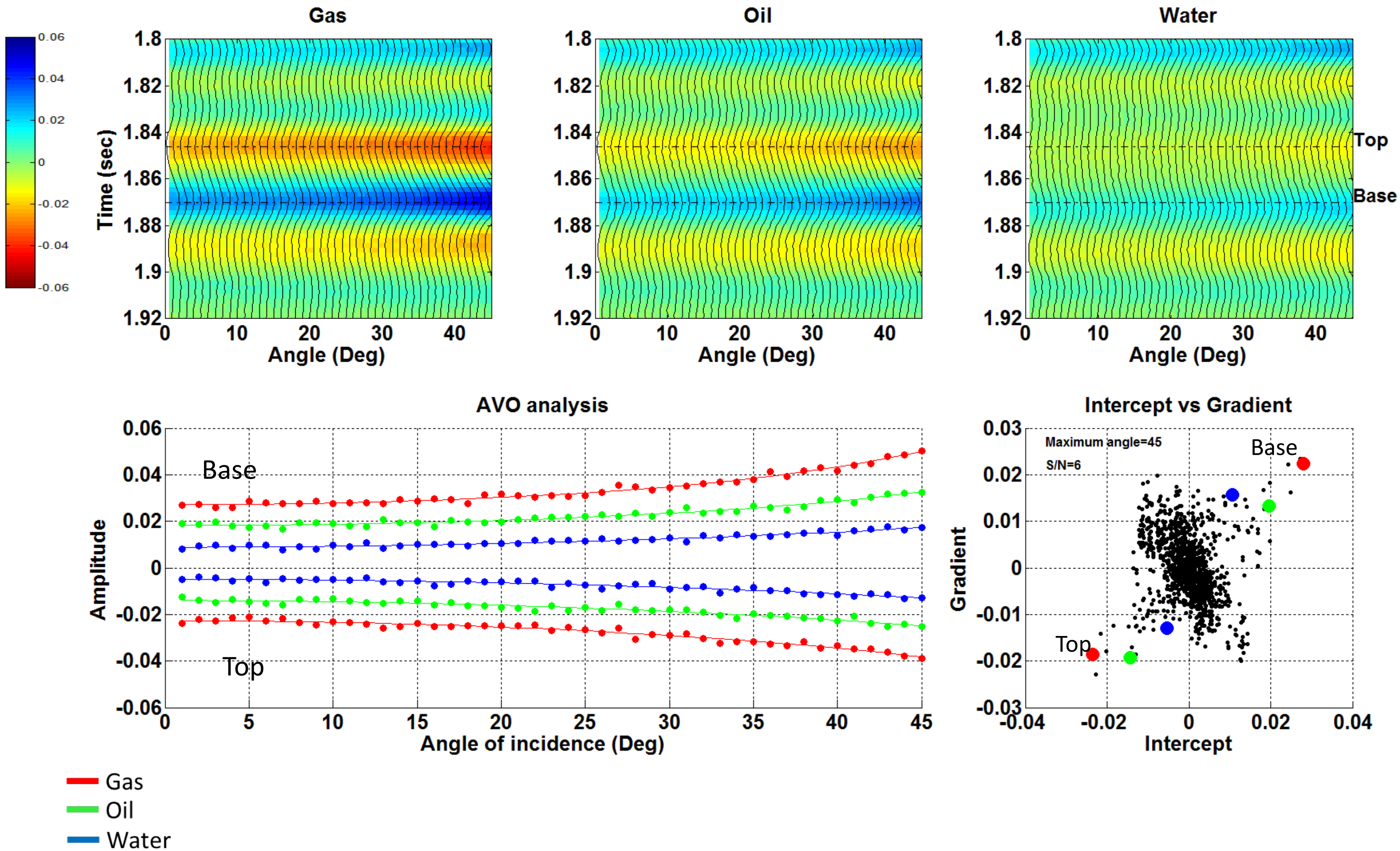
Max. Angle=45
S/N=8

Effect of reducing angle of incidence Keeping maximum angle constant



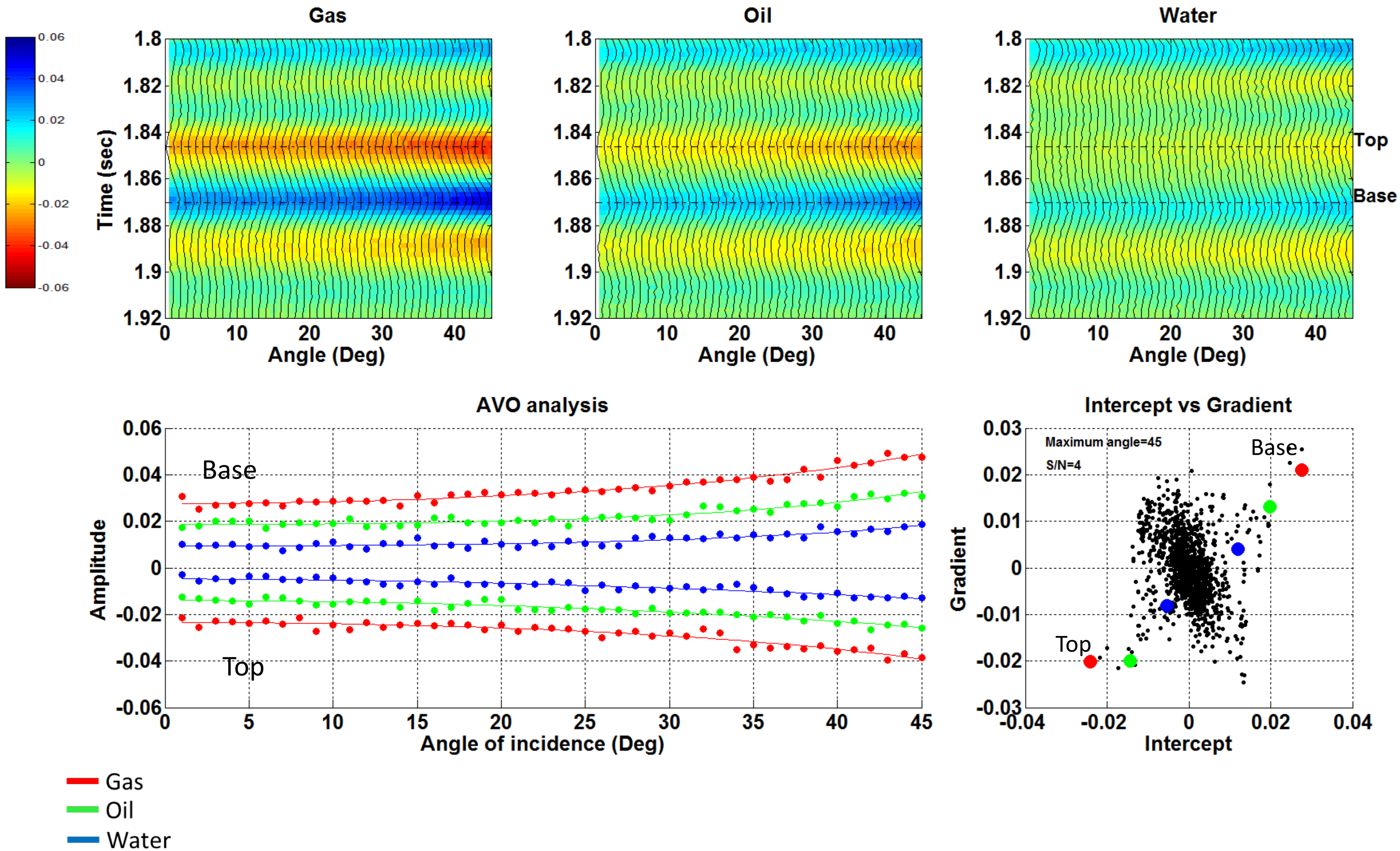
Max. Angle=45
S/N=6

Effect of reducing angle of incidence
Keeping maximum angle constant



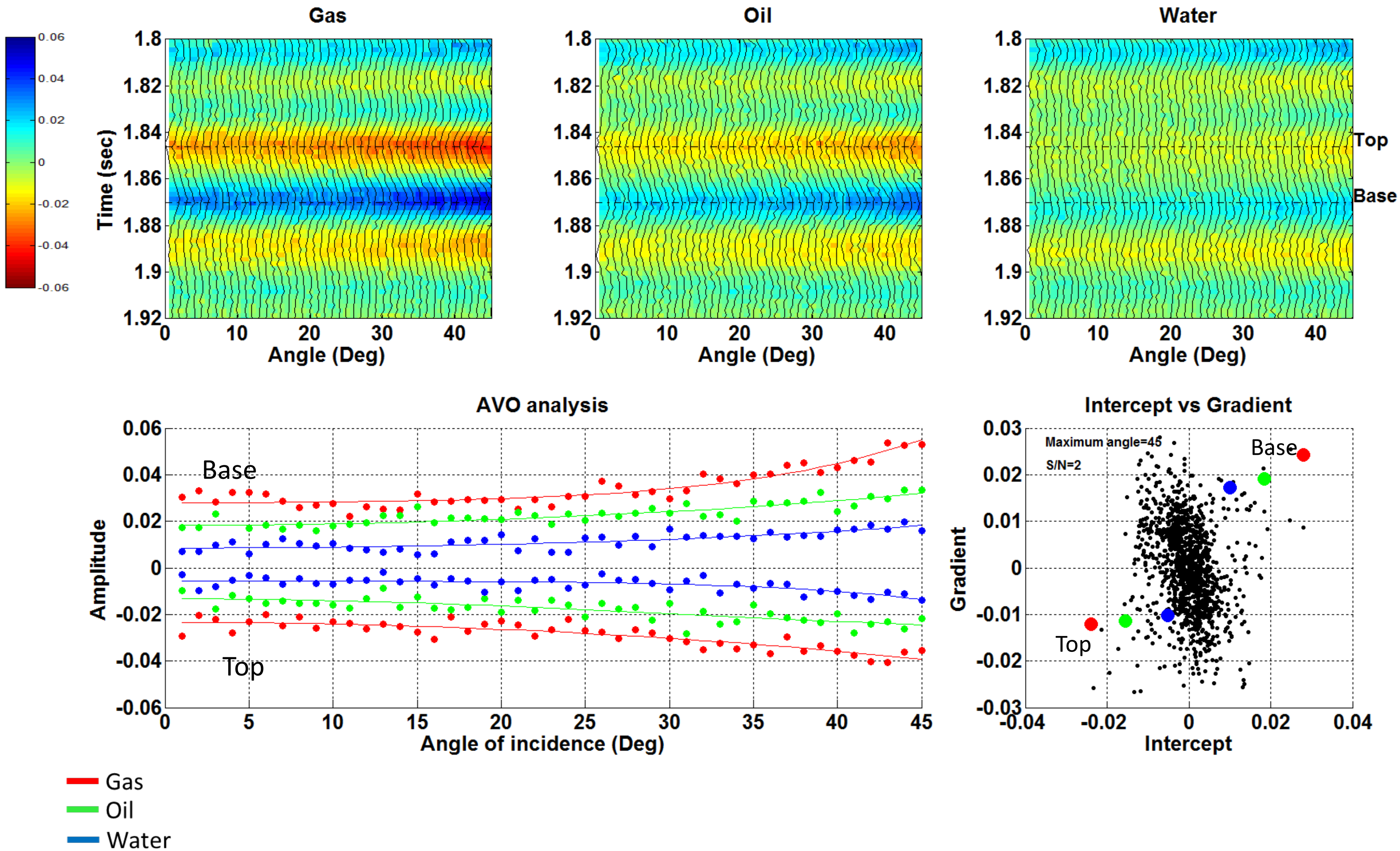
Max. Angle=45
S/N=4

Effect of reducing angle of incidence
Keeping maximum angle constant



Max. Angle=45
S/N=2

Effect of reducing angle of incidence
Keeping maximum angle constant

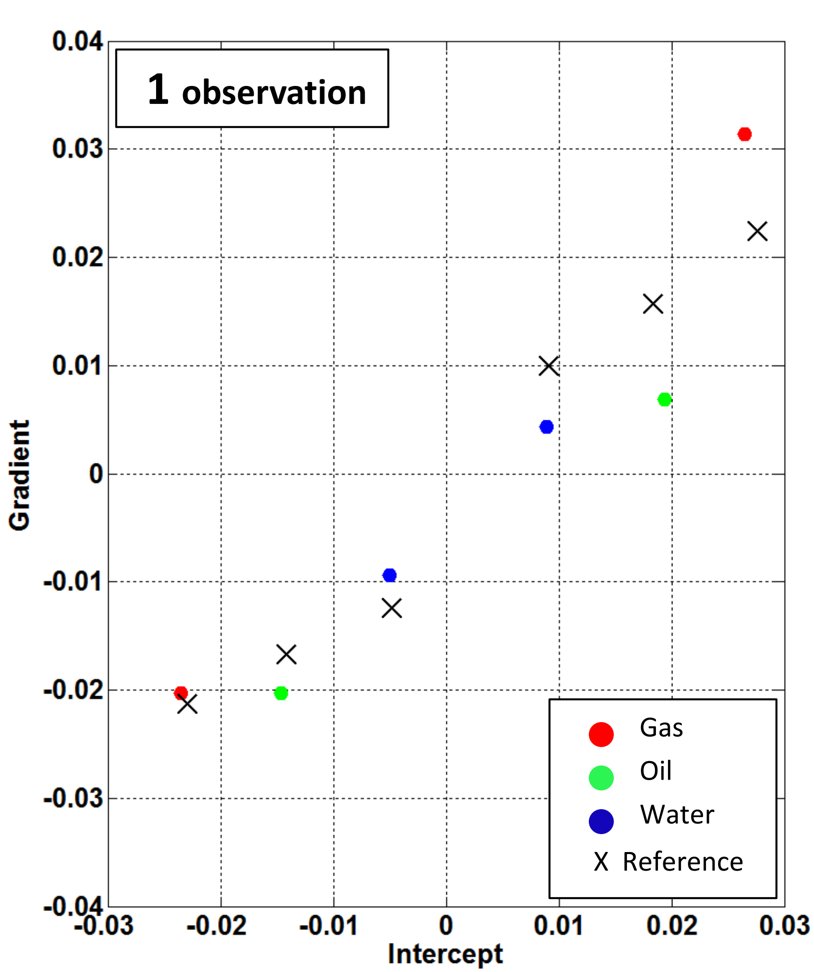


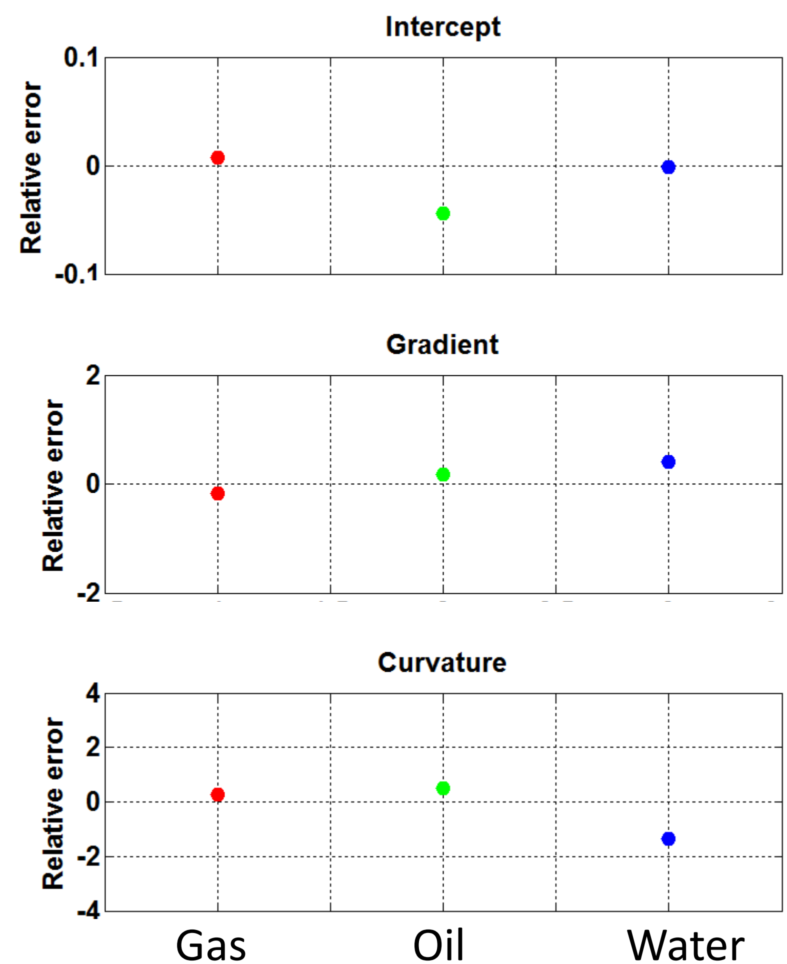
Measuring error and standard deviation

S/N=2

Max. Angle=45 deg.

Measuring error and standard deviation





Reference to measure the error

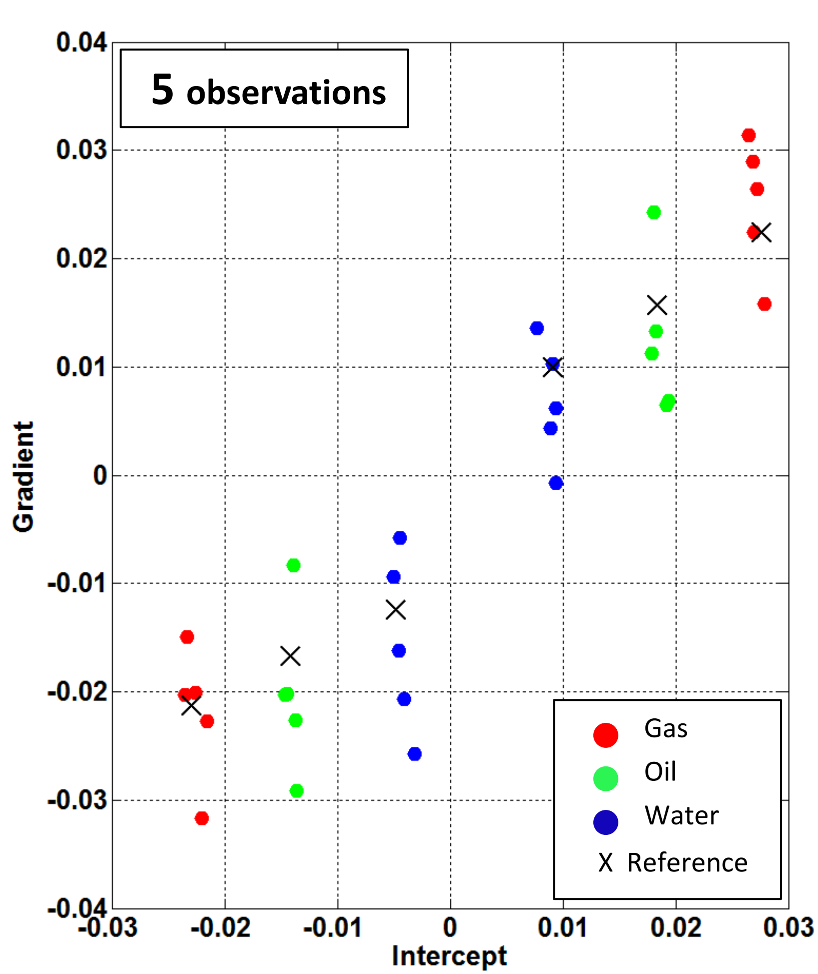
No noise

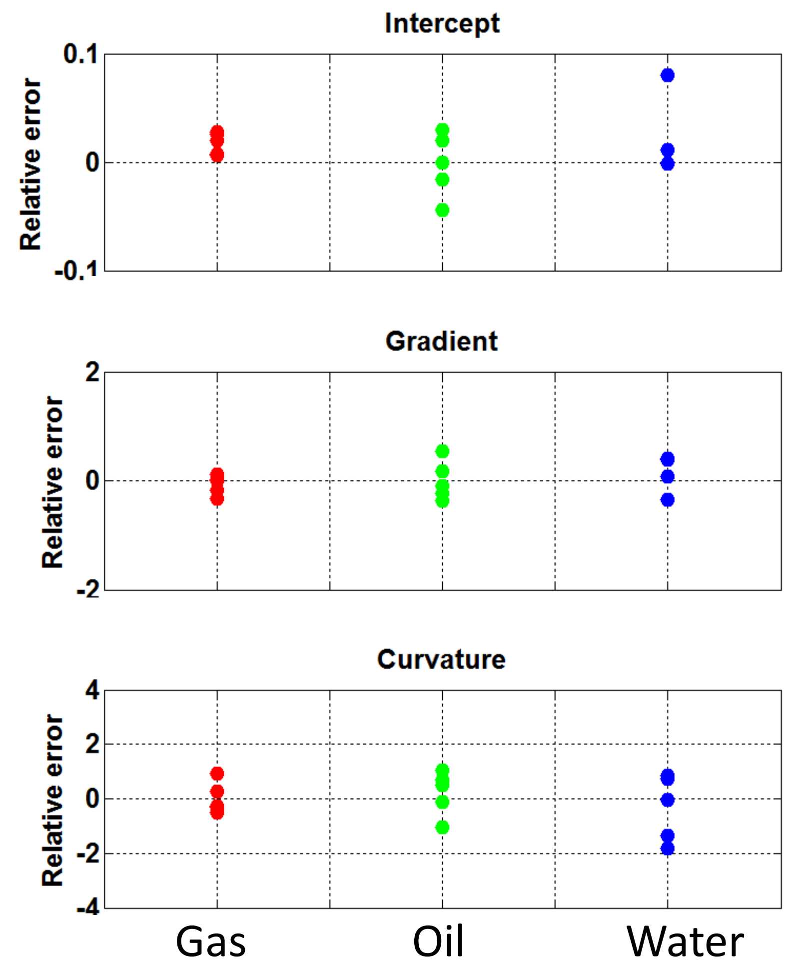
Max. angle: 45 deg

	TOP			BASE		
	Intercept	Gradient	Curvature	Intercept	Gradient	Curvature
GAS	-0.023	-0.021	-0.010	0.028	0.022	0.024
OIL	-0.014	-0.017	-0.007	0.018	0.016	0.013
WATER	-0.005	-0.012	-0.004	0.009	0.010	0.007

S/N=2
Max. Angle=45 deg.

Measuring error and standard deviation





Reference to measure the error

No noise

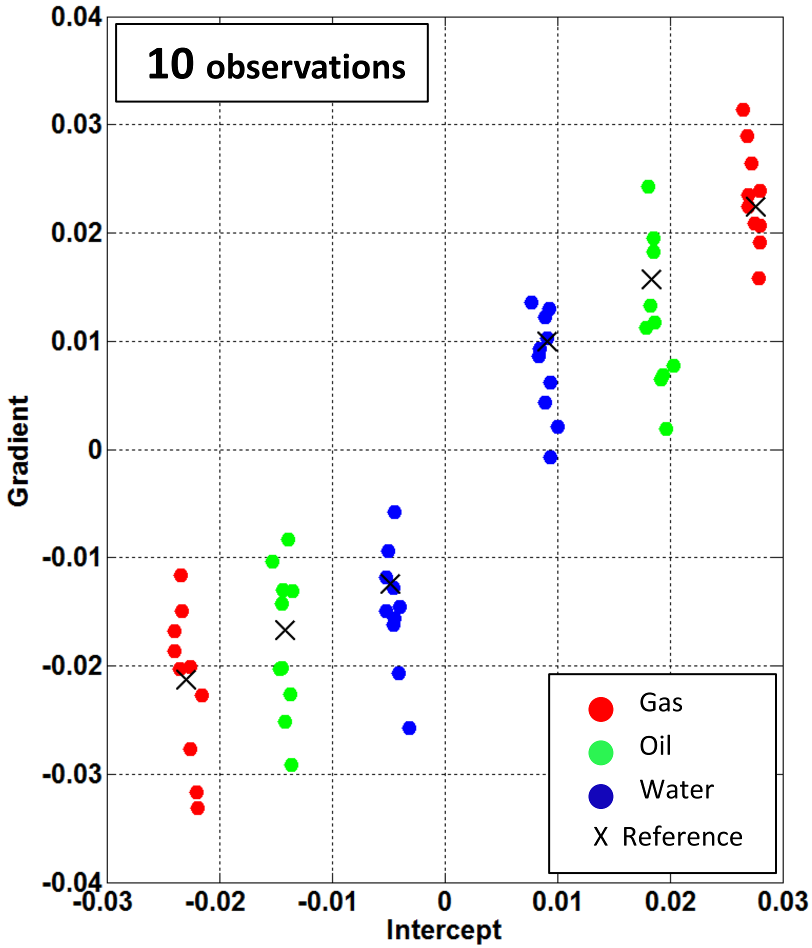
Max. angle: 45 deg

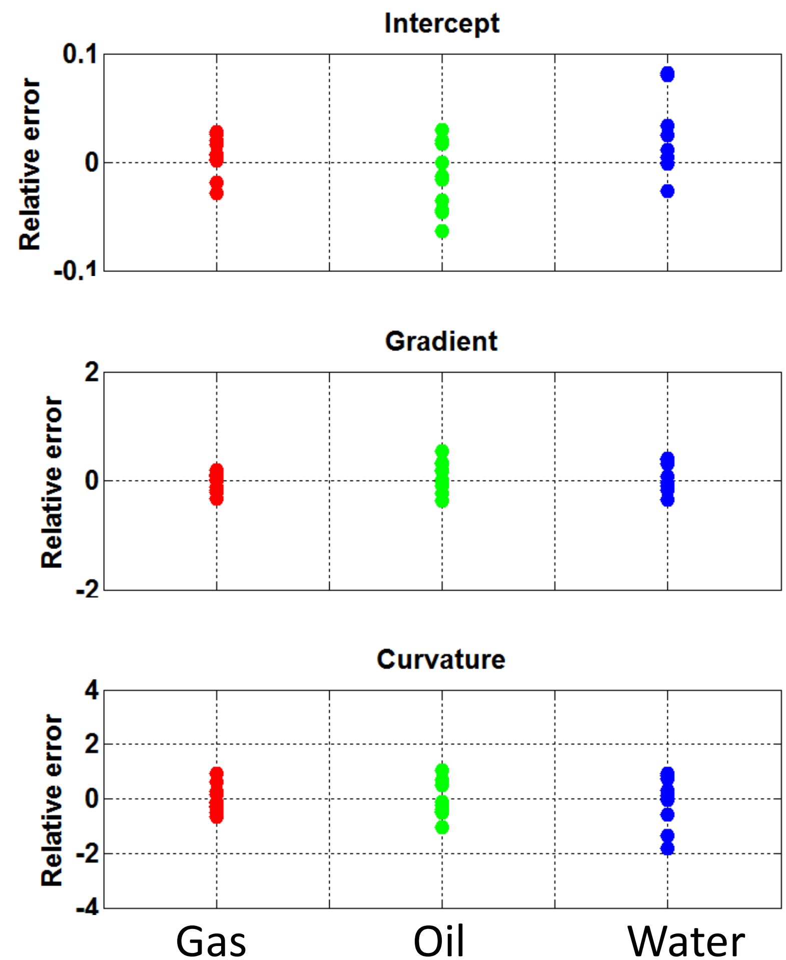
	TOP			BASE		
	Intercept	Gradient	Curvature	Intercept	Gradient	Curvature
GAS	-0.023	-0.021	-0.010	0.028	0.022	0.024
OIL	-0.014	-0.017	-0.007	0.018	0.016	0.013
WATER	-0.005	-0.012	-0.004	0.009	0.010	0.007

S/N=2

Max. Angle=45 deg.

Measuring error and standard deviation





Reference to measure the error

No noise

Max. angle: 45 deg

	TOP			BASE		
	Intercept	Gradient	Curvature	Intercept	Gradient	Curvature
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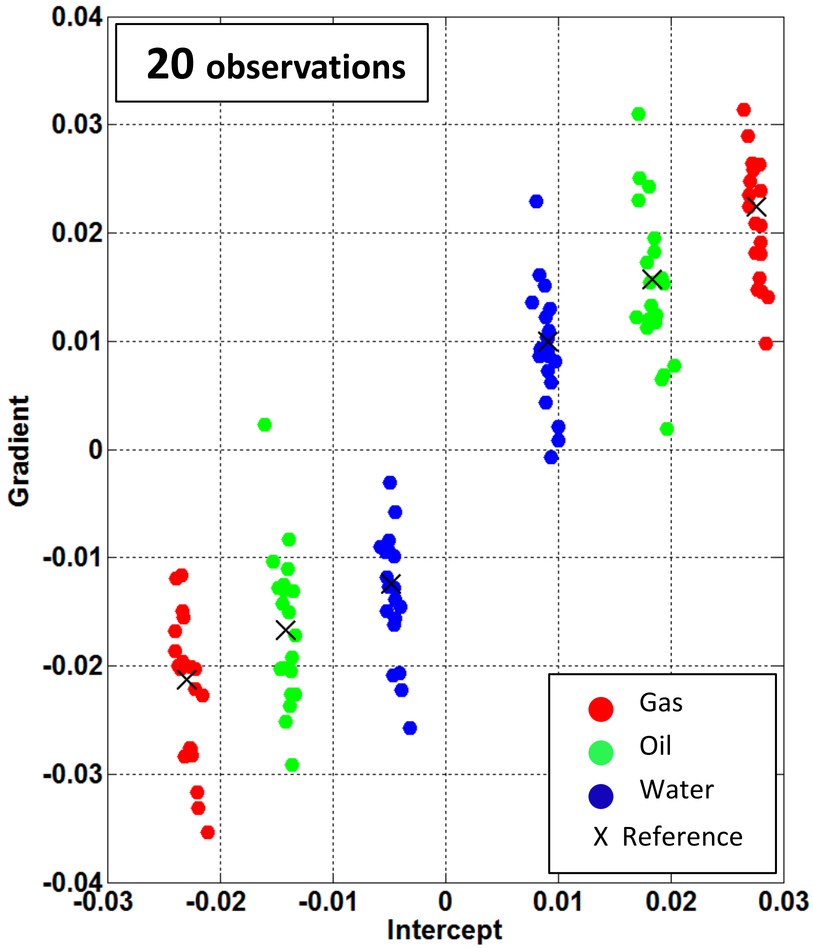
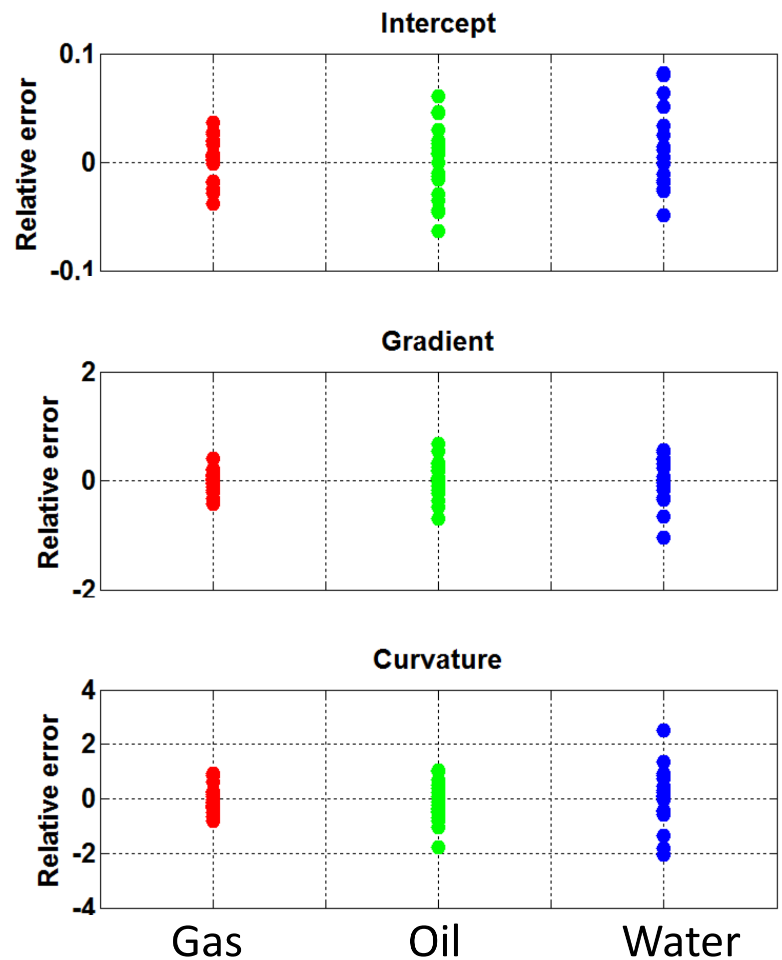
WATER	-0.005	-0.012	-0.004	0.009	0.010	0.007

S/N=2
Max. Angle=45 deg.

Measuring error and standard deviation





Reference to measure the error

No noise

Max. angle: 45 deg

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	Intercept	Gradient	Curvature	Intercept	Gradient	Curvature
GAS	-0.023	-0.021	-0.010	0.028	0.022	0.024
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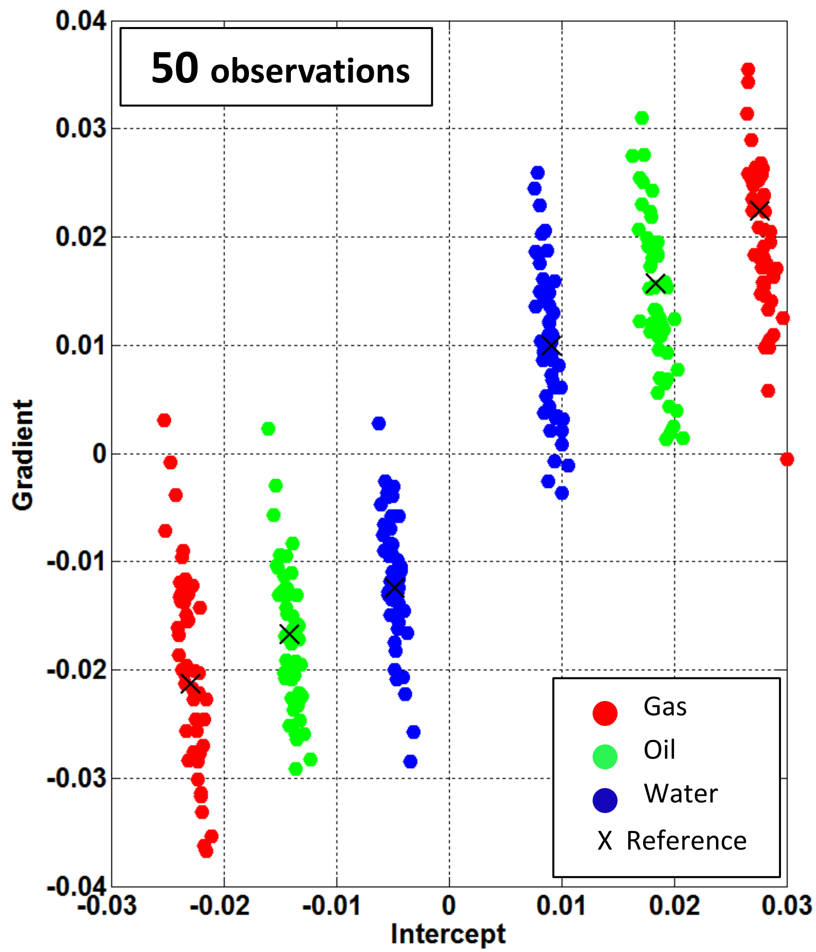
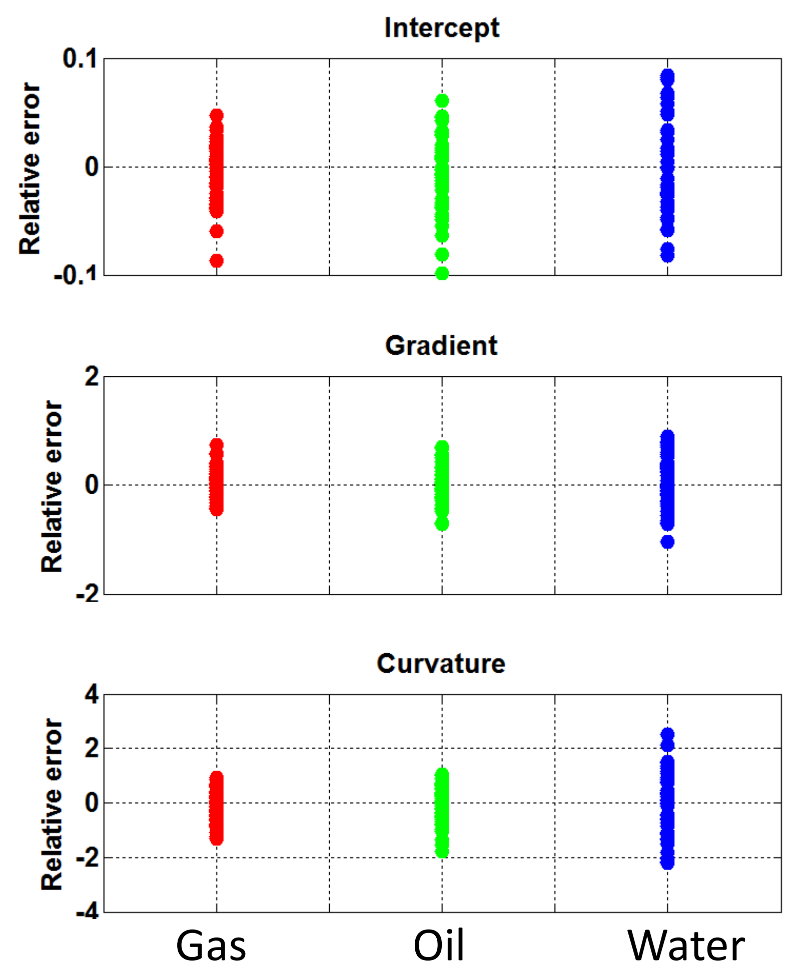
S/N=2
Max. Angle=45 deg.

Measuring error and standard deviation





Reference to measure the error

No noise

Max. angle: 45 deg

	TOP			BASE		
	Intercept	Gradient	Curvature	Intercept	Gradient	Curvature
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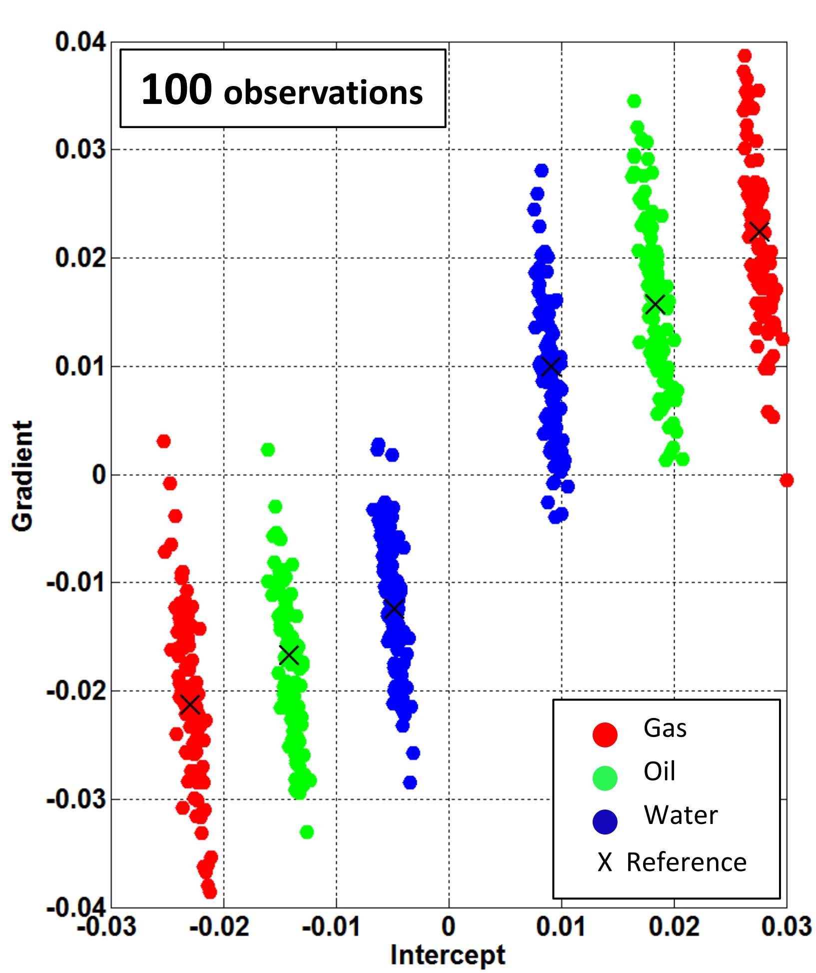
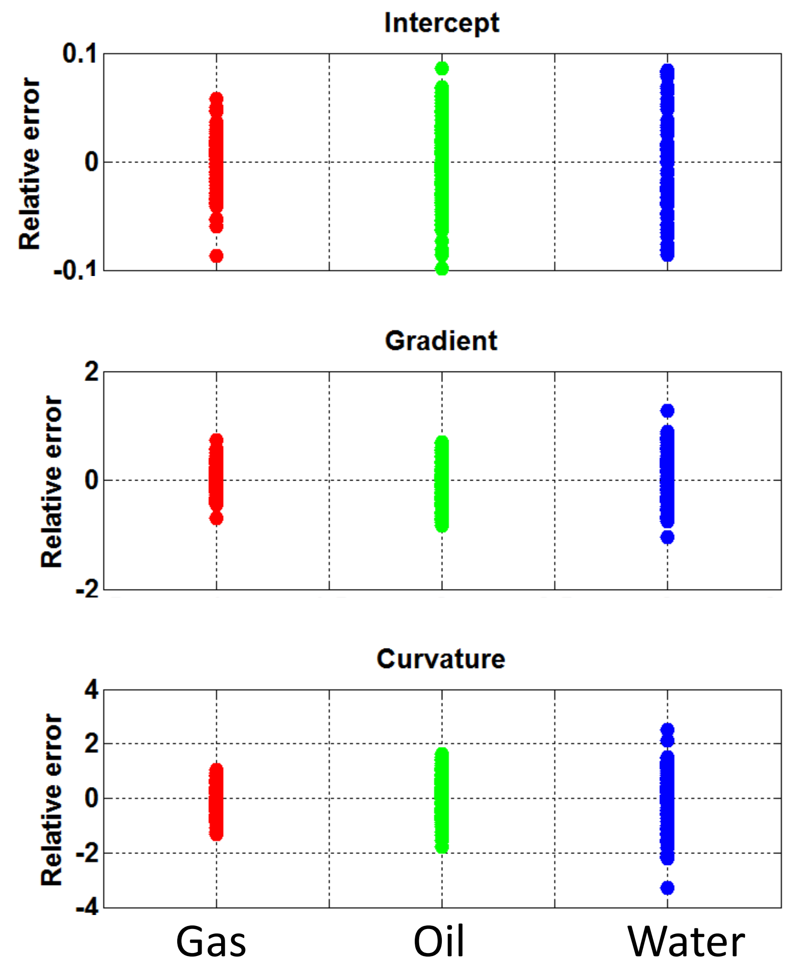
S/N=2
Max. Angle=45 deg.

Measuring error and standard deviation





Reference to measure the error

No noise

Max. angle: 45 deg

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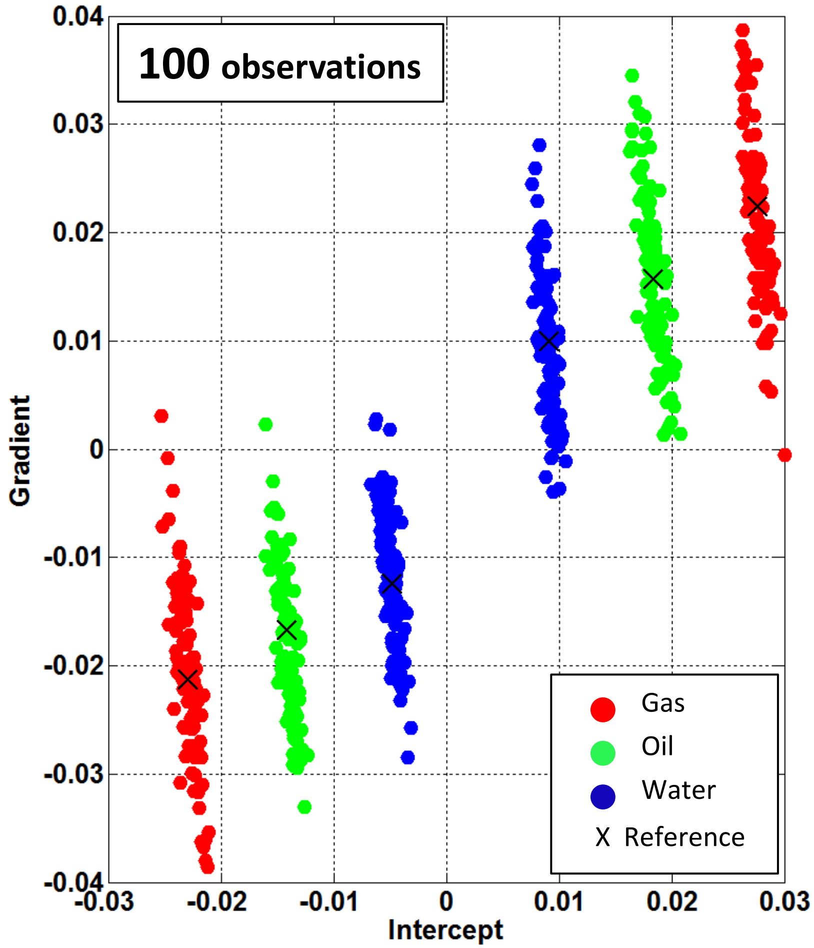
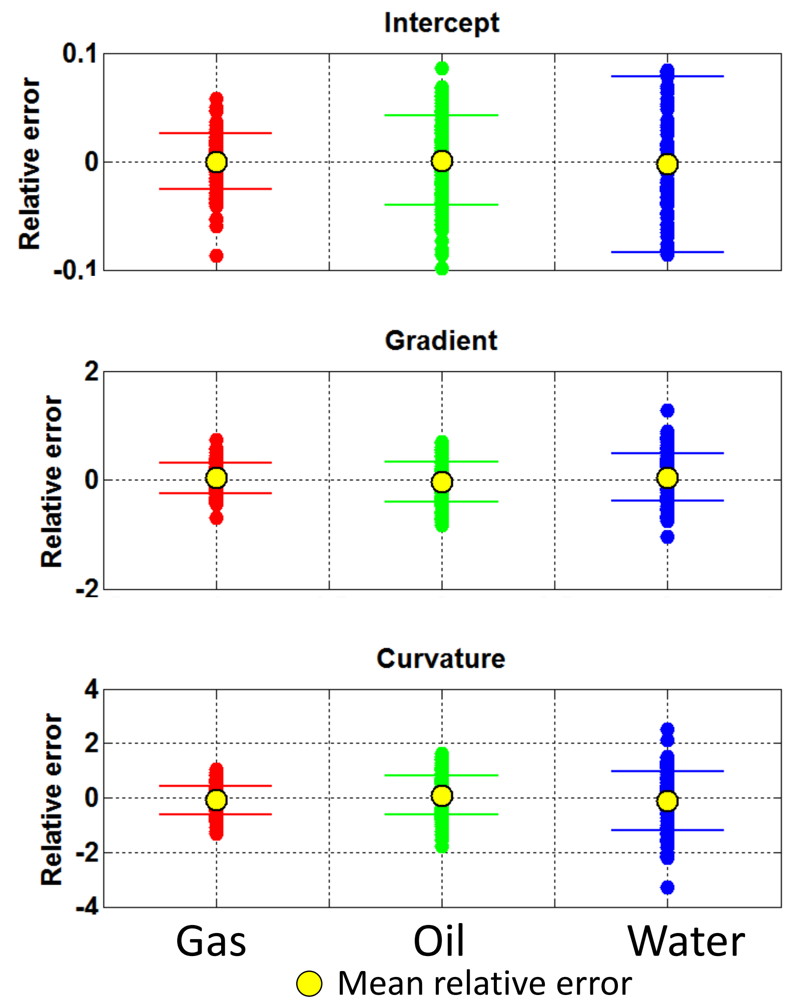
	Intercept	Gradient	Curvature	Intercept	Gradient	Curvature
GAS	-0.023	-0.021	-0.010	0.028	0.022	0.024
OIL	-0.014	-0.017	-0.007	0.018	0.016	0.013
WATER	-0.005	-0.012	-0.004	0.009	0.010	0.007

S/N=2

Max. Angle=45 deg.

Measuring error and standard deviation





Reference to measure the error

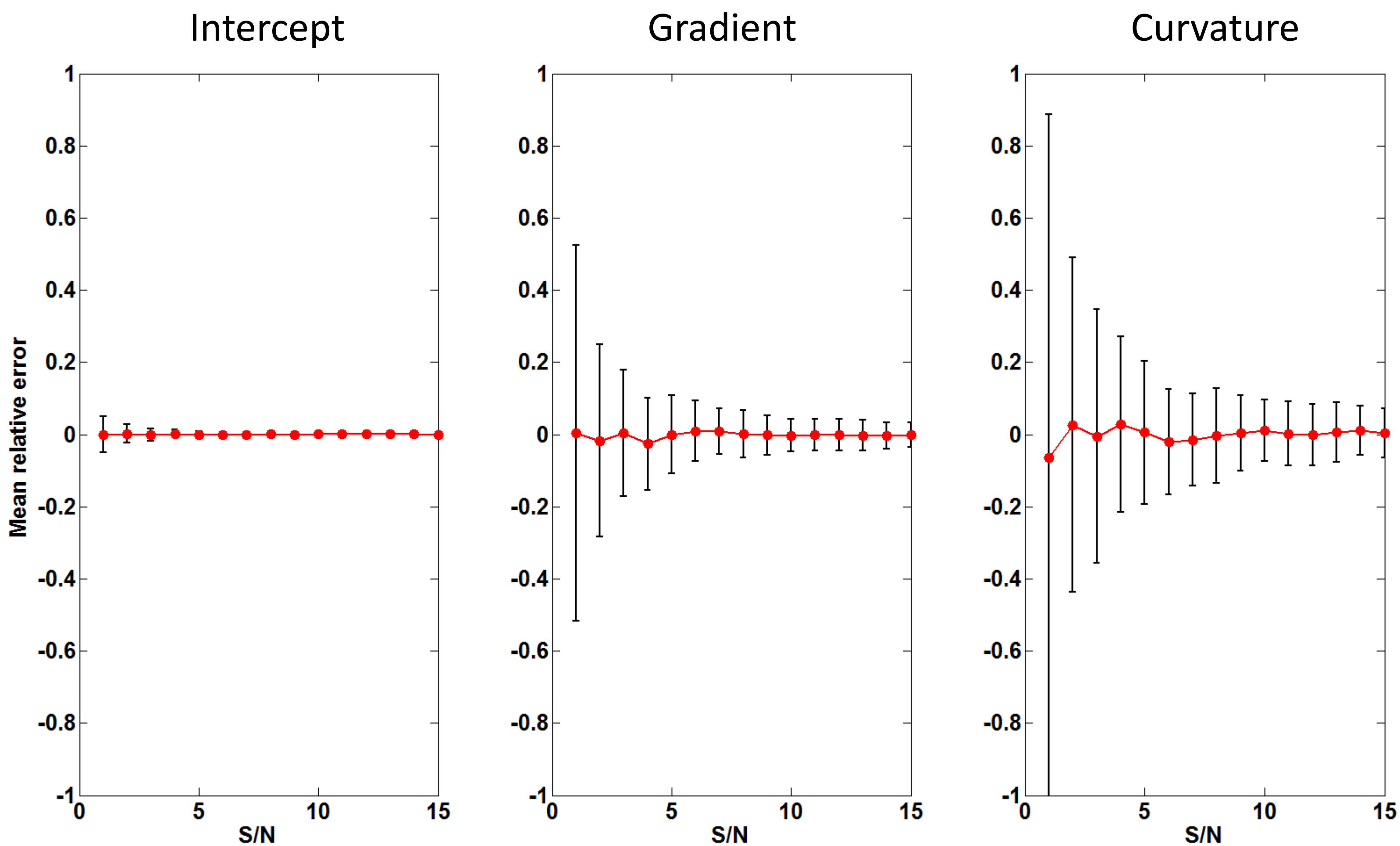
No noise

Max. angle: 45 deg

	TOP			BASE		
	Intercept	Gradient	Curvature	Intercept	Gradient	Curvature
GAS	-0.023	-0.021	-0.010	0.028	0.022	0.024
OIL	-0.014	-0.017	-0.007	0.018	0.016	0.013
WATER	-0.005	-0.012	-0.004	0.009	0.010	0.007

Max. Angle=45

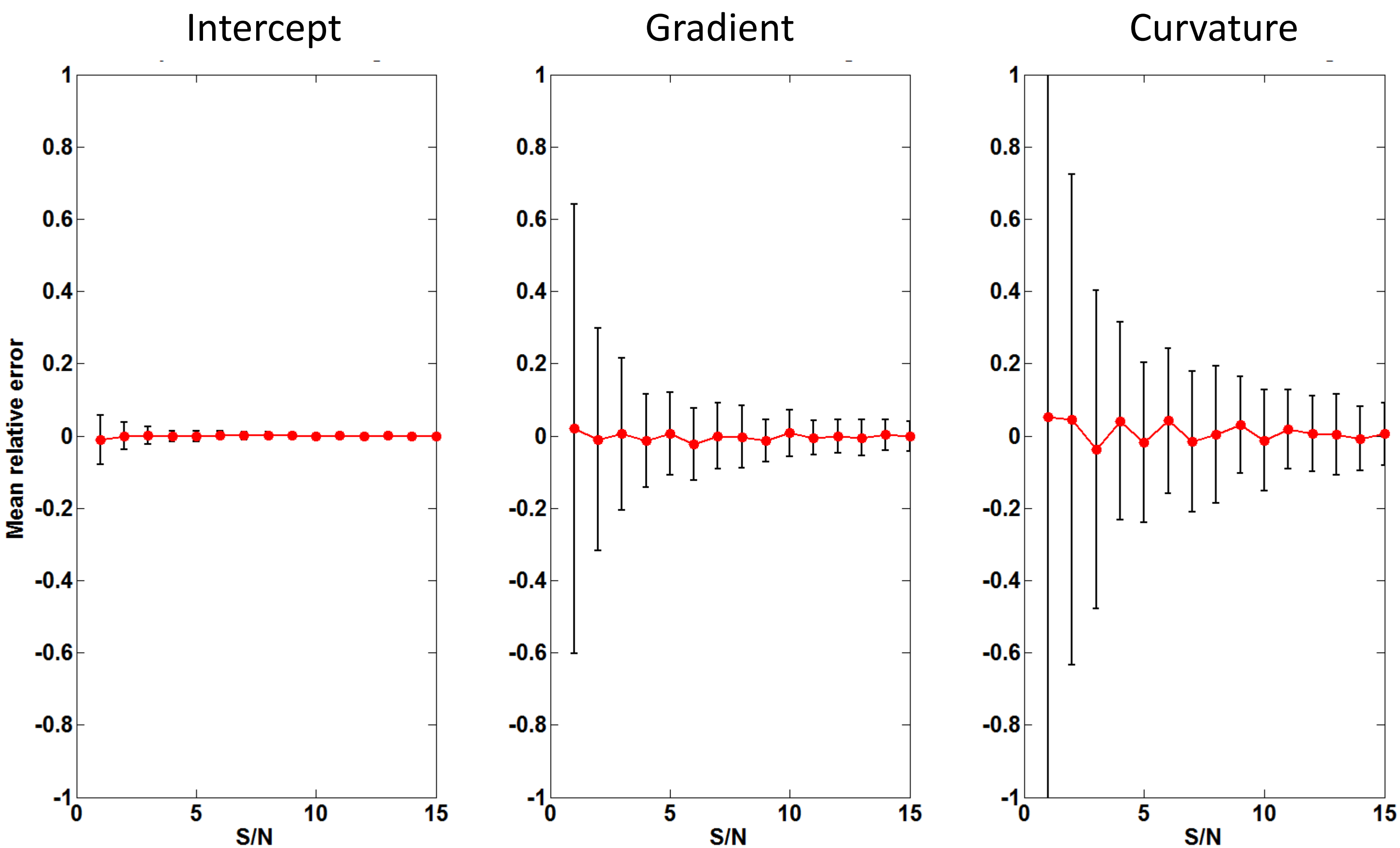
GAS-error



Max. Angle=45

Effect of reducing angle of incidence
Keeping maximum angle constant

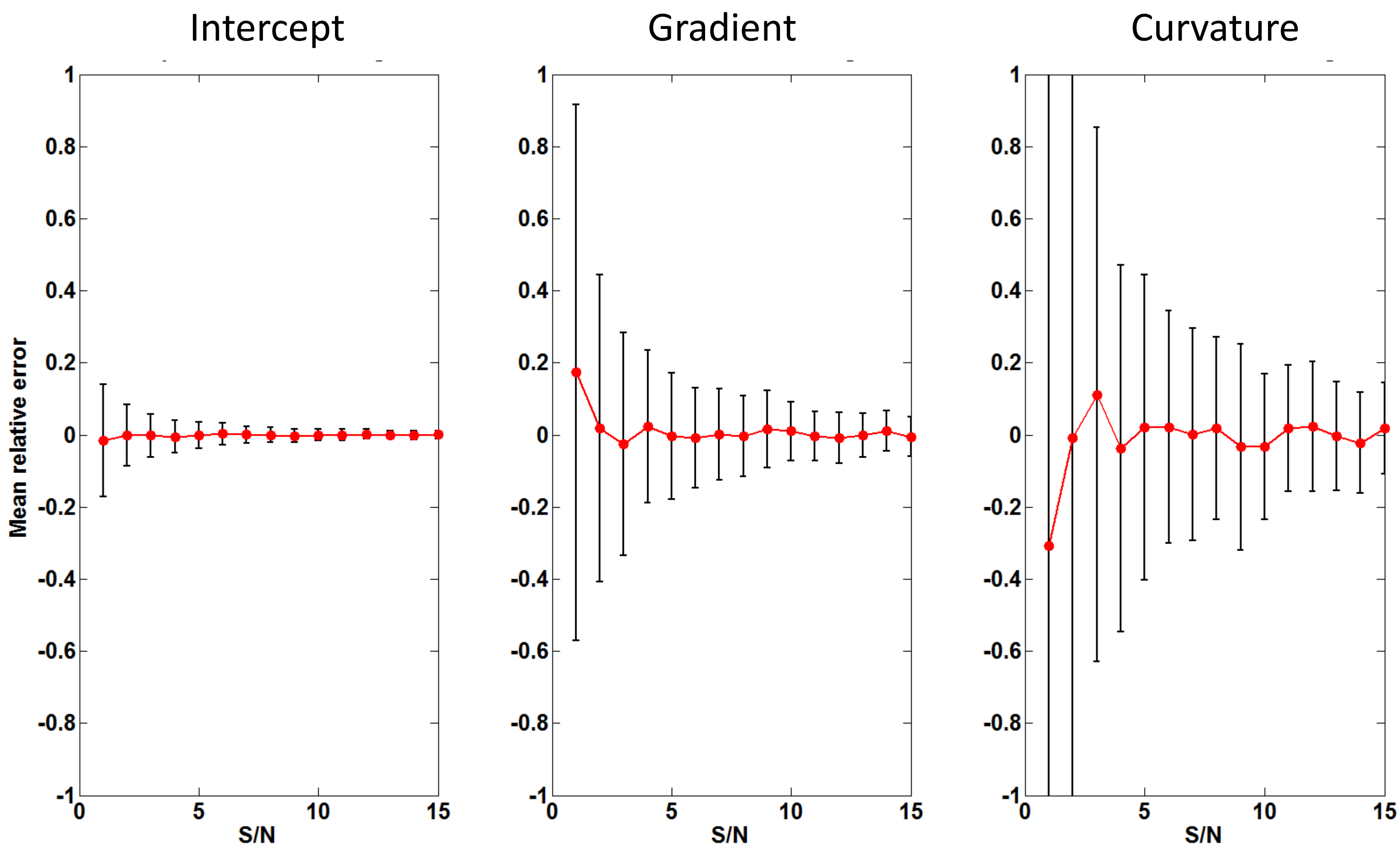
OIL-error



Max. Angle=45

Effect of reducing angle of incidence
Keeping maximum angle constant

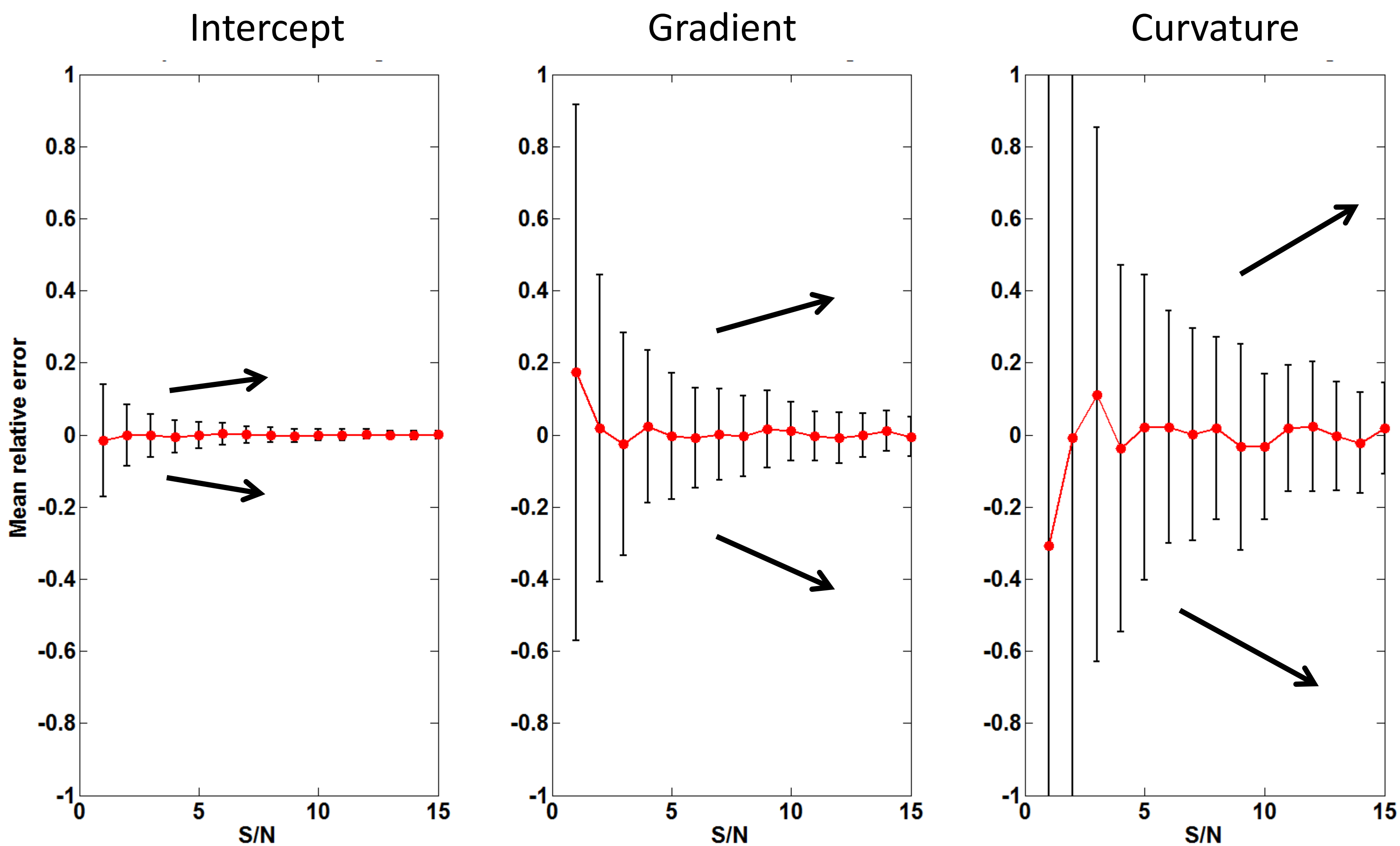
WATER-error



Max. Angle=45

Effect of reducing angle of incidence
Keeping maximum angle constant

WATER-error

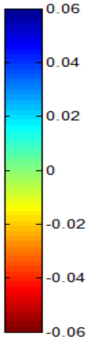


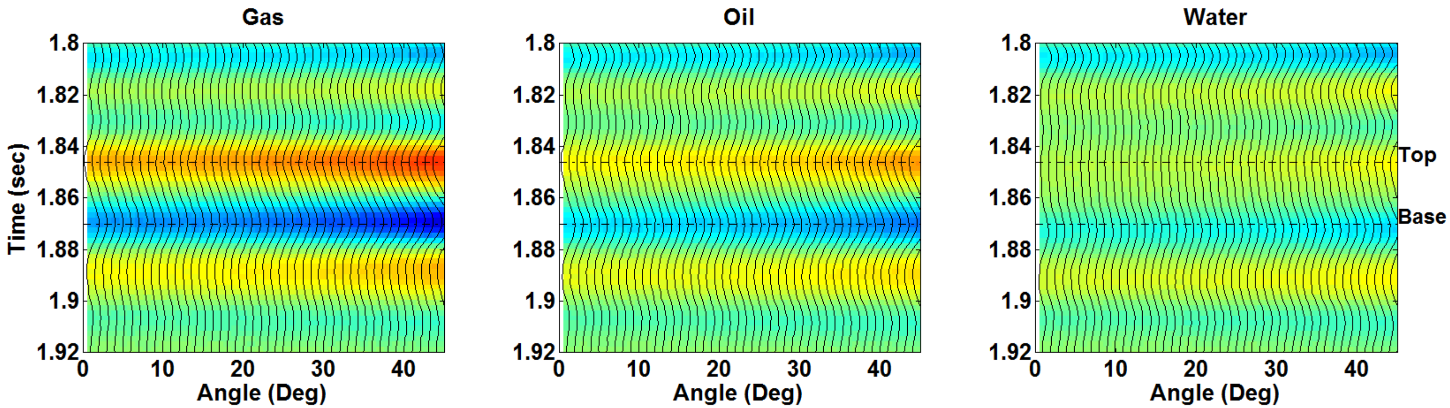
The error increases as the impedance contrast decreases

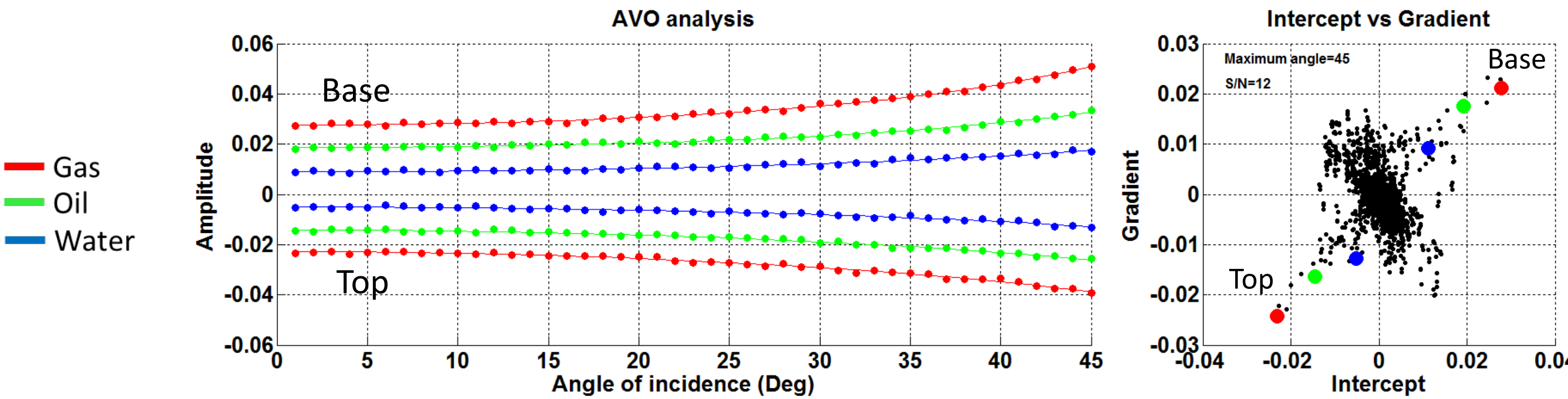
Effect of reducing angle of incidence keeping noise constant

Max. Angle=45
S/N=12

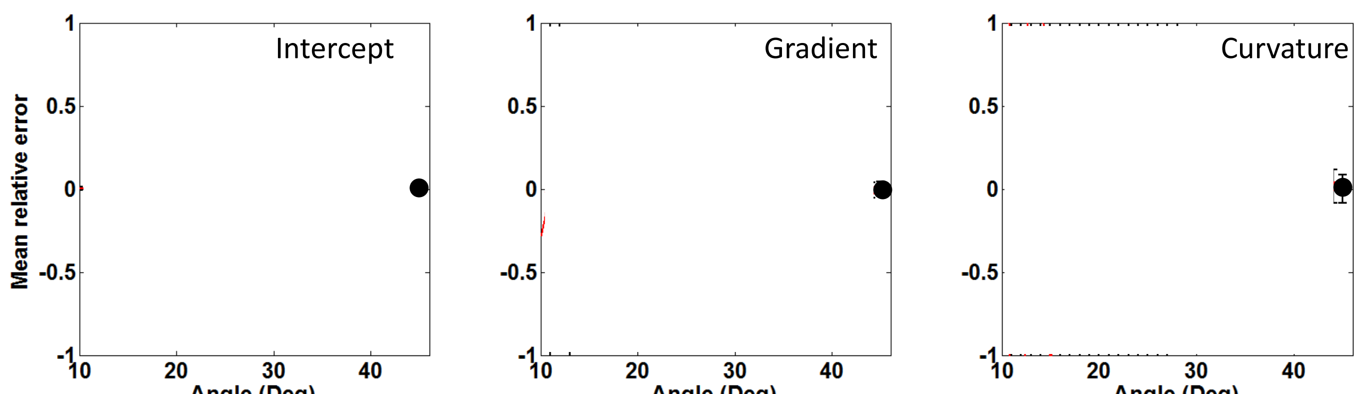
Effect of reducing angle of incidence keeping noise constant





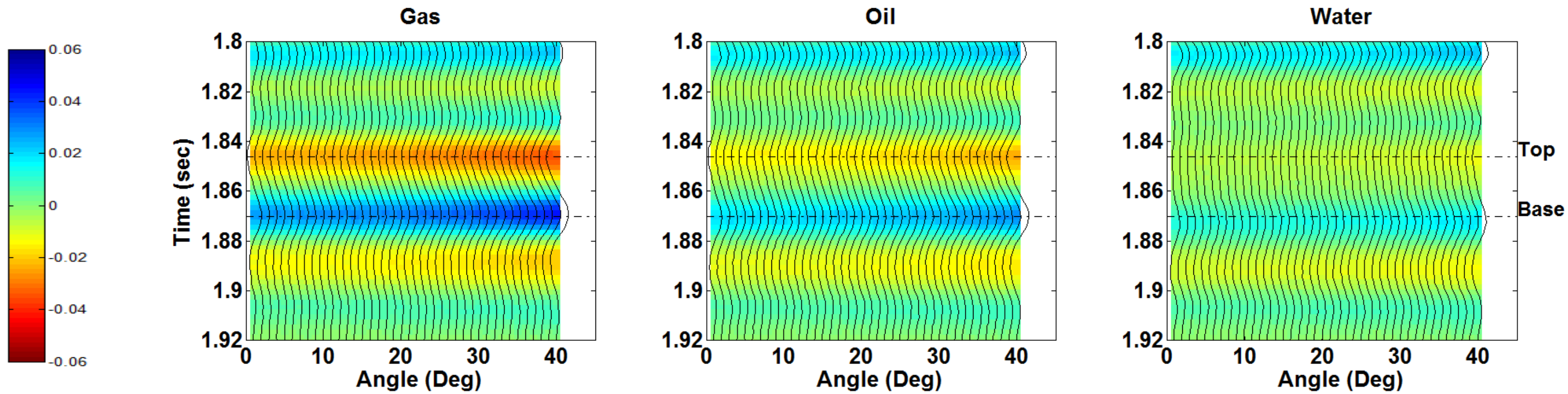


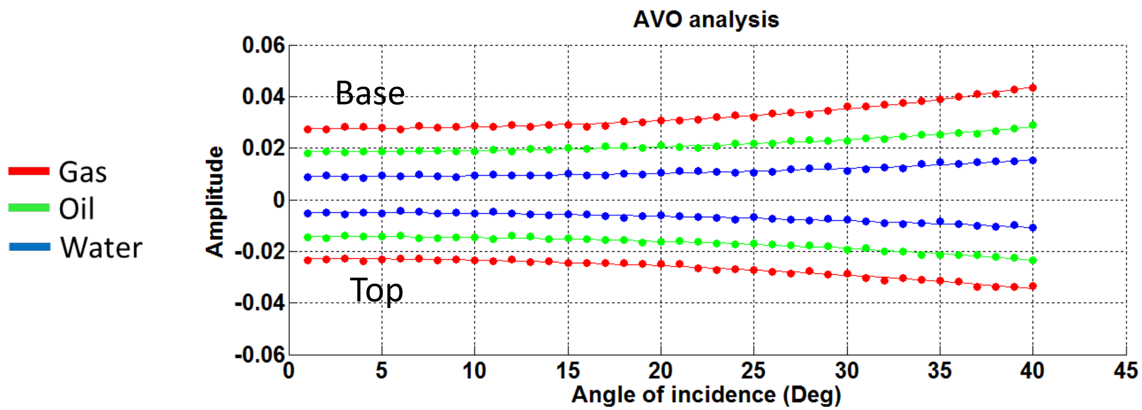
GAS error

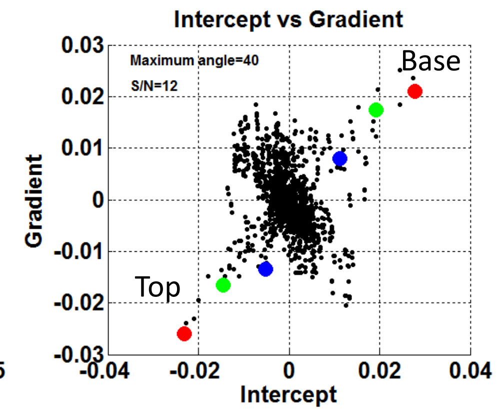


Max. Angle=40
S/N=12

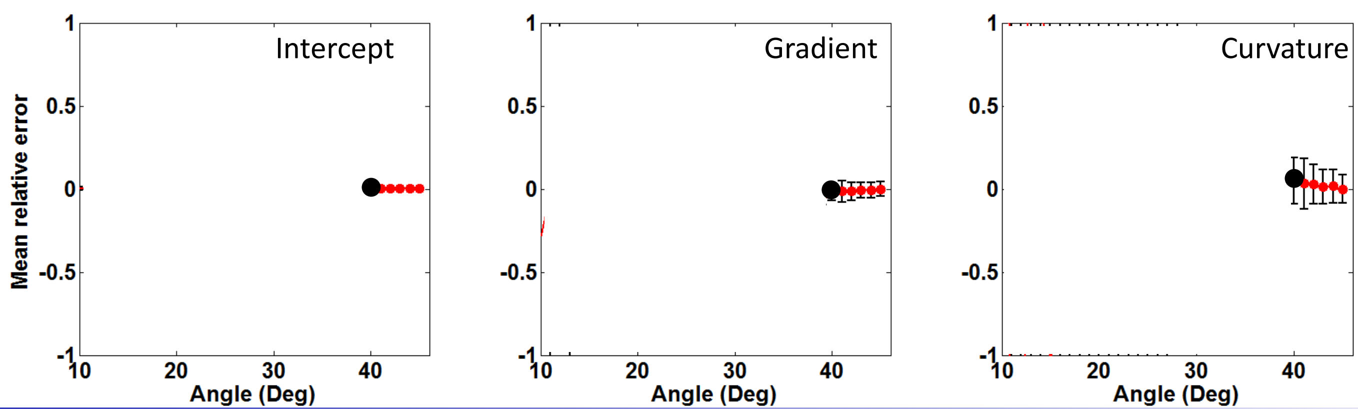
Effect of reducing angle of incidence keeping noise constant





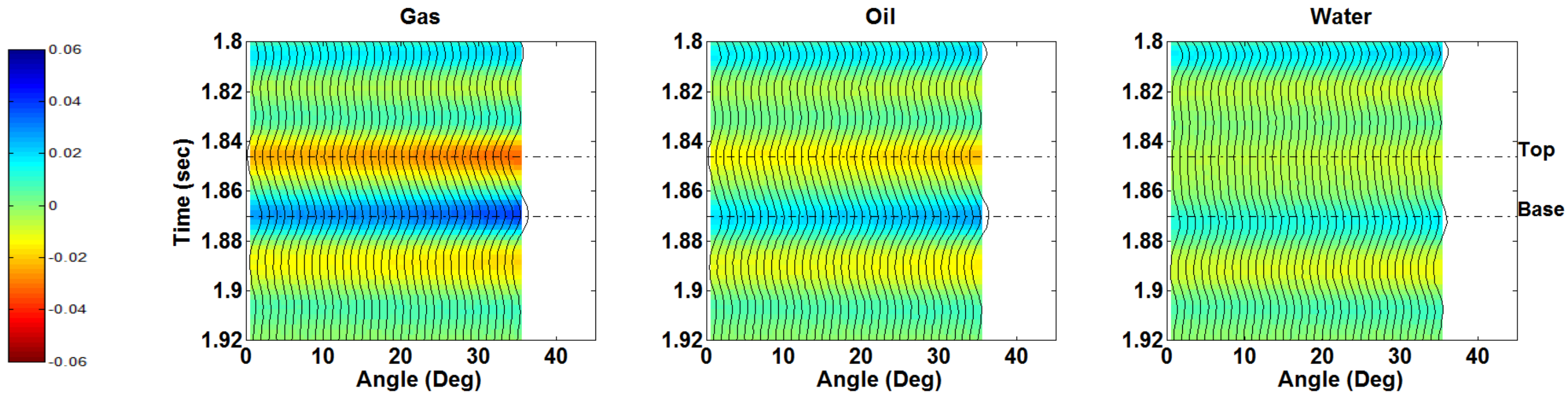


GAS error

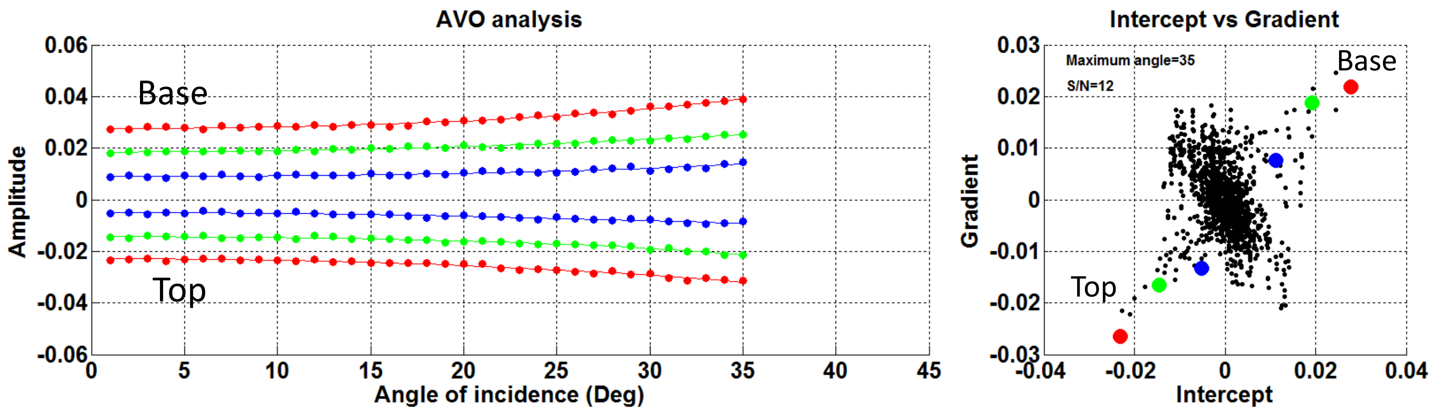


Max. Angle=35
S/N=12

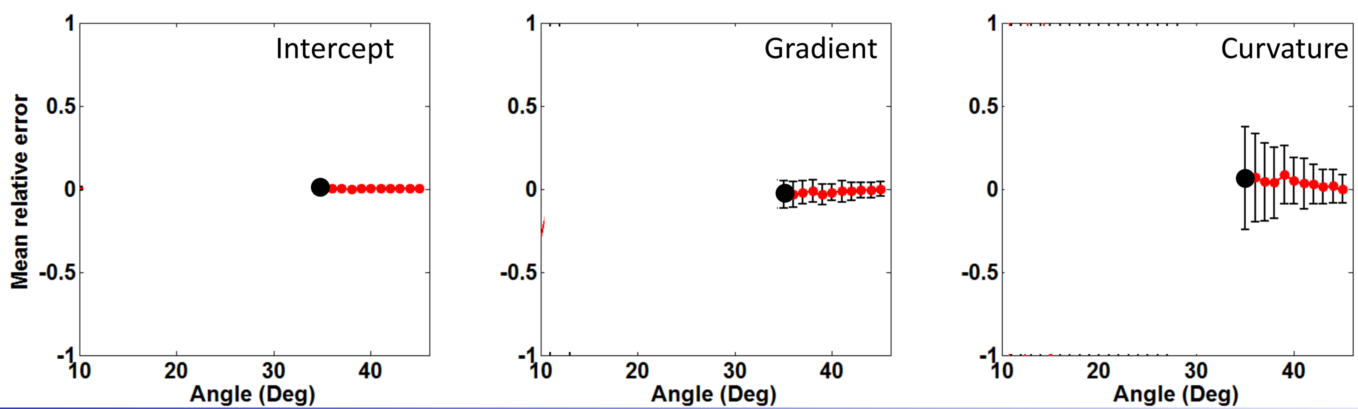
Effect of reducing angle of incidence keeping noise constant



Gas
Oil
Water

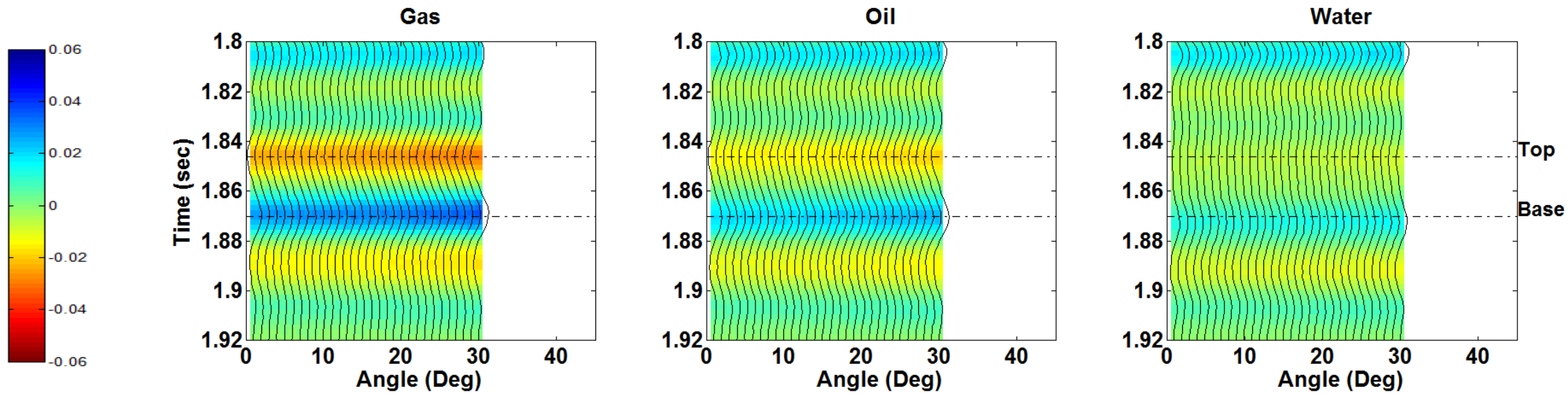


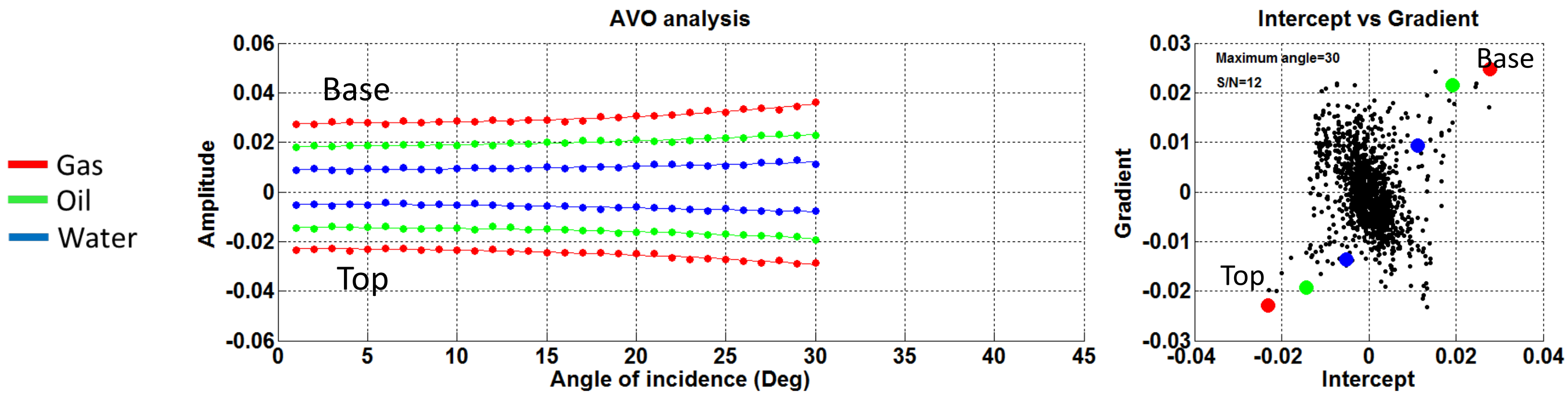
GAS error



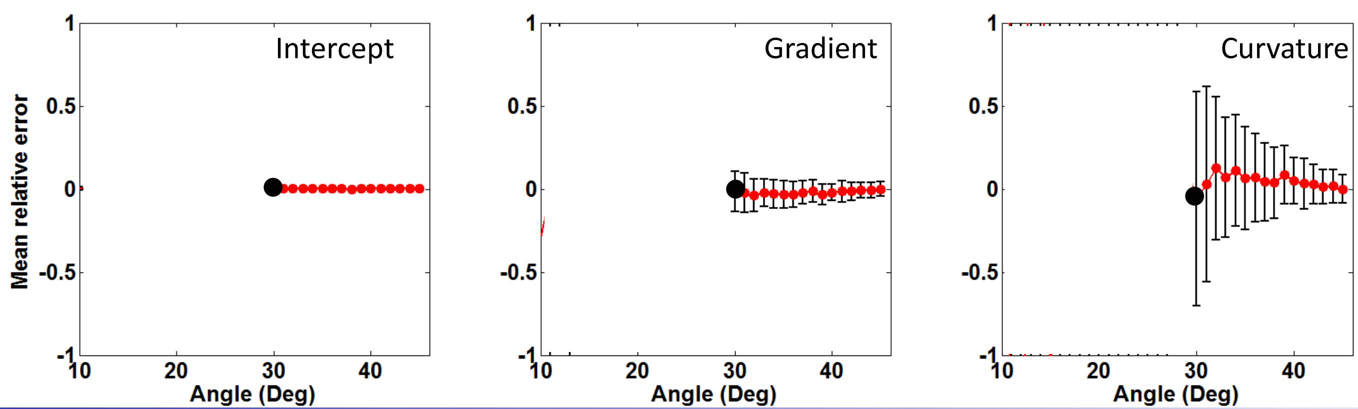
Max. Angle=30
S/N=12

Effect of reducing angle of incidence keeping noise constant



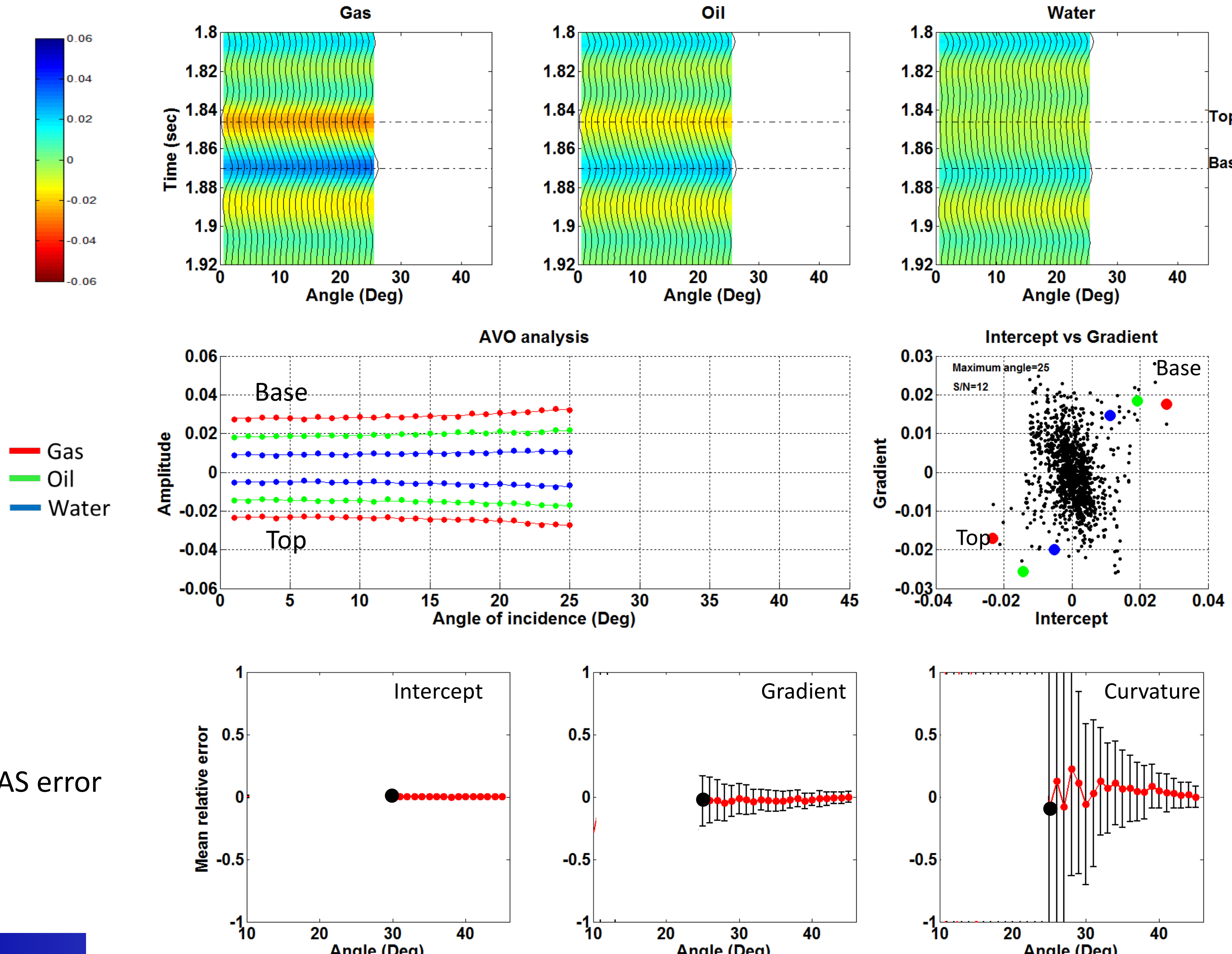


GAS error



Max. Angle=25
S/N=12

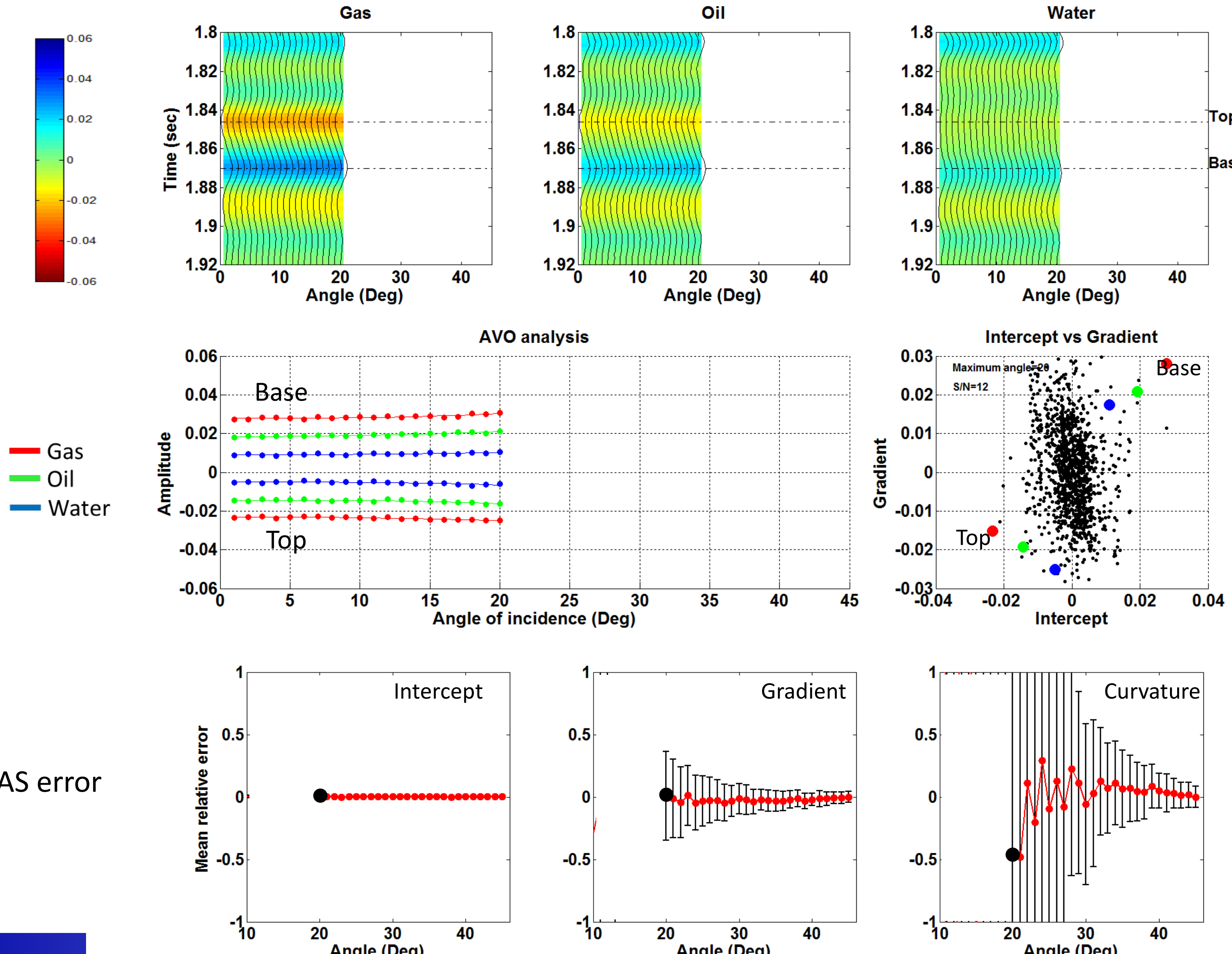
Effect of reducing angle of incidence keeping noise constant



GAS error

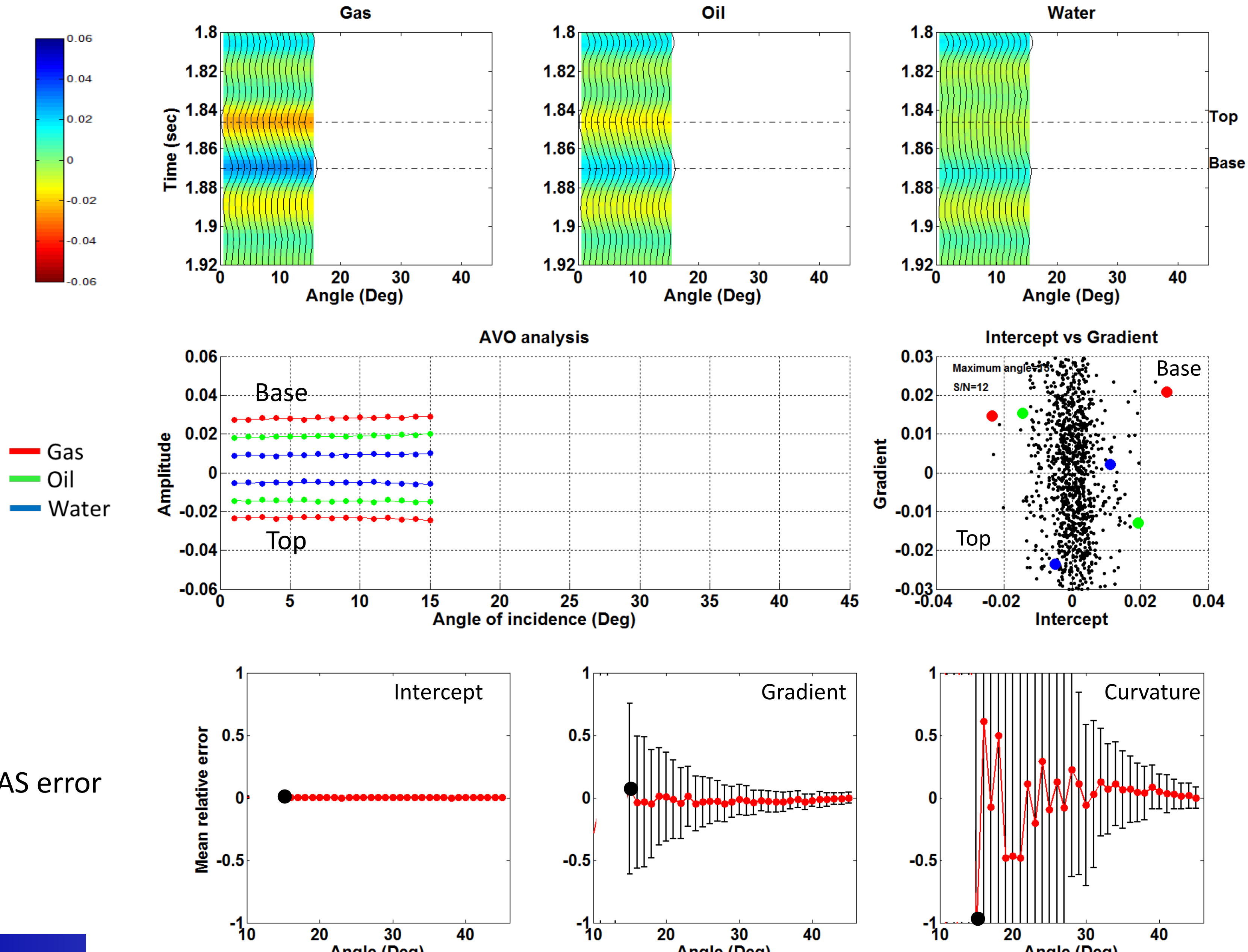
Max. Angle=20
S/N=12

Effect of reducing angle of incidence keeping noise constant



Max. Angle=15
S/N=12

Effect of reducing angle of incidence keeping noise constant

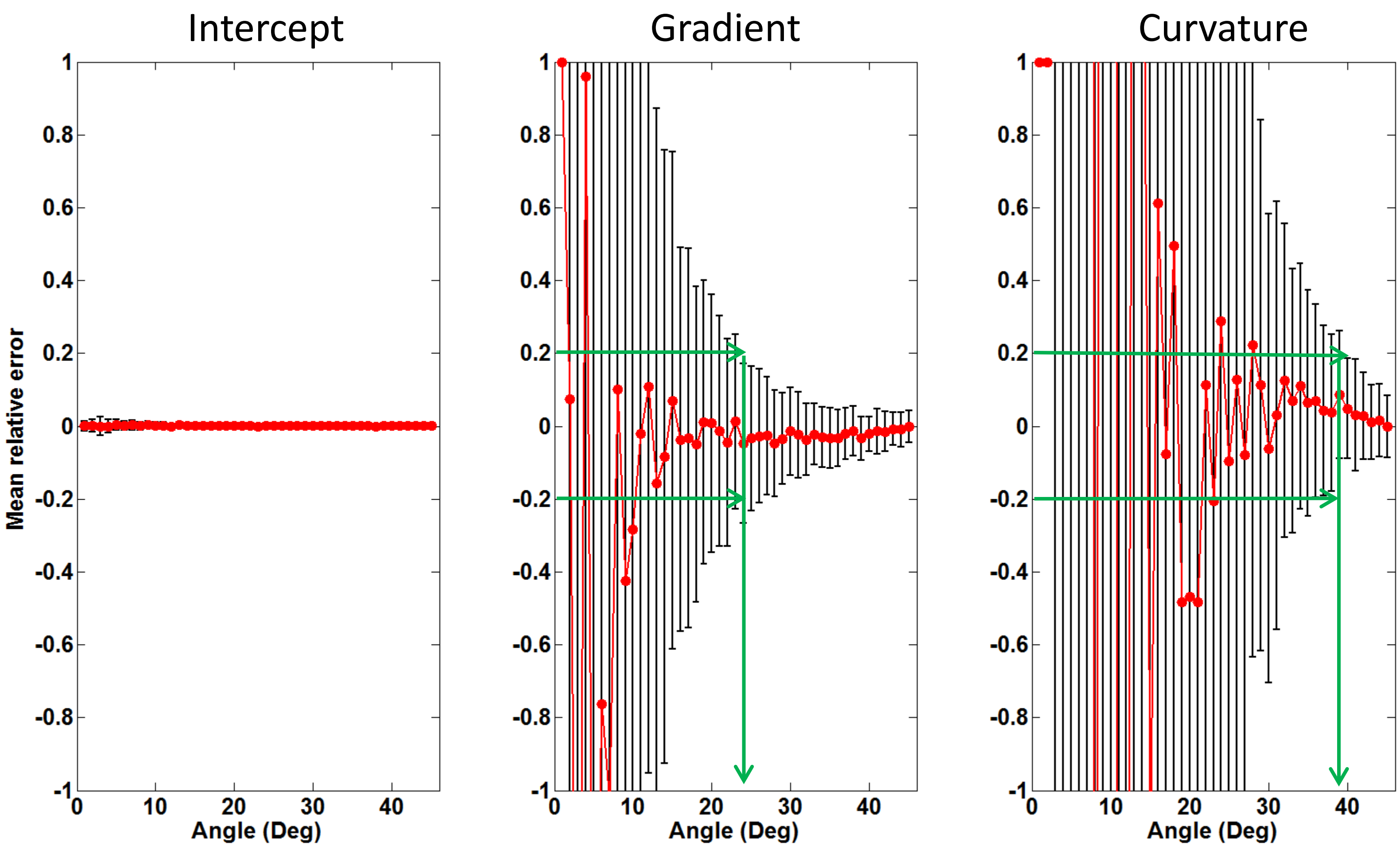


GAS error

S/N=12

Effect of reducing angle of incidence
keeping noise constant

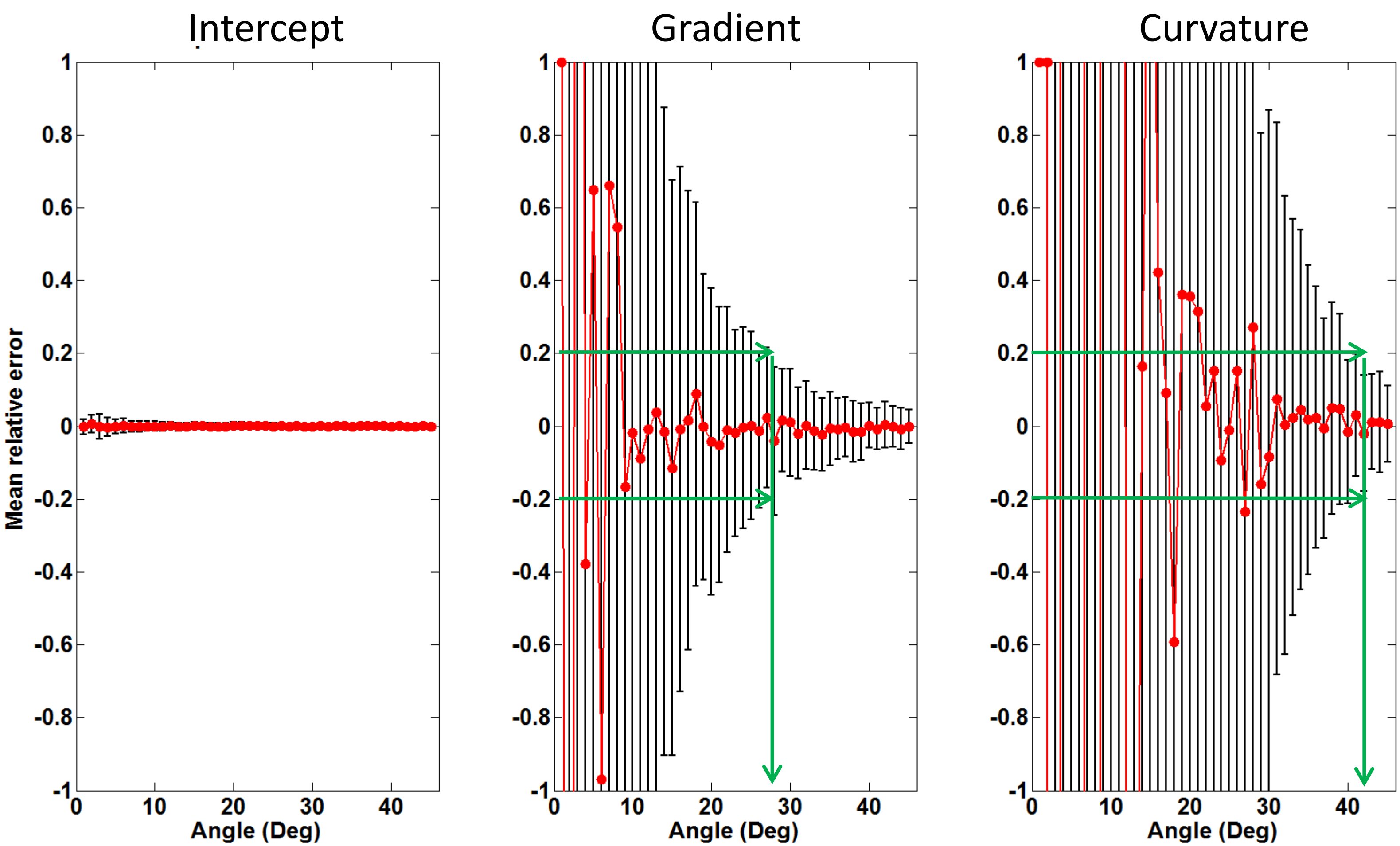
GAS-error



The parameter estimation becomes unstable with errors higher than 20%

Effect of reducing angle of incidence keeping noise constant

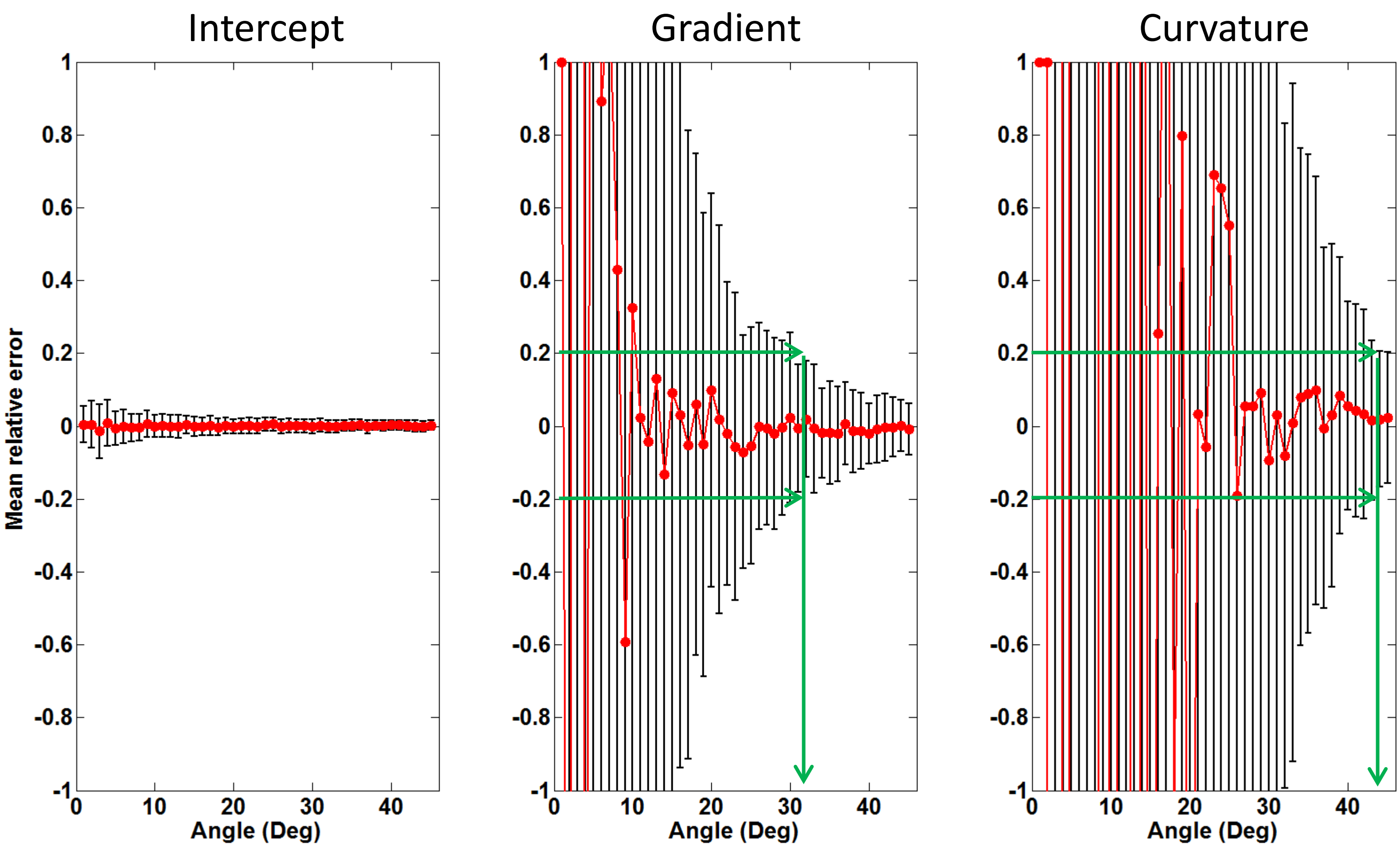
OIL-error



S/N=12

Effect of reducing angle of incidence keeping noise constant

WATER-error

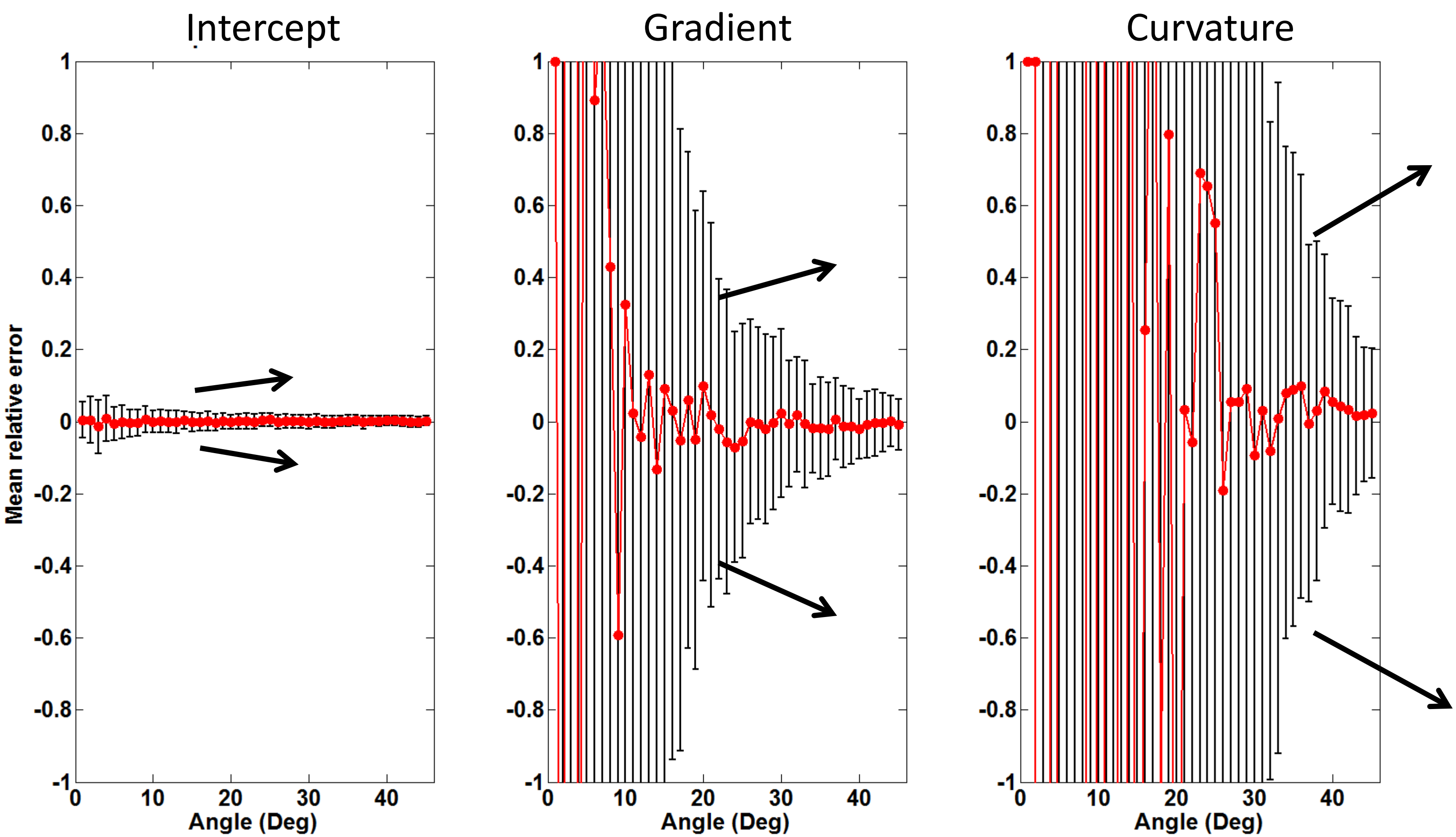


The parameter estimation becomes unstable with errors higher than 20%

S/N=12

Effect of reducing angle of incidence keeping noise constant

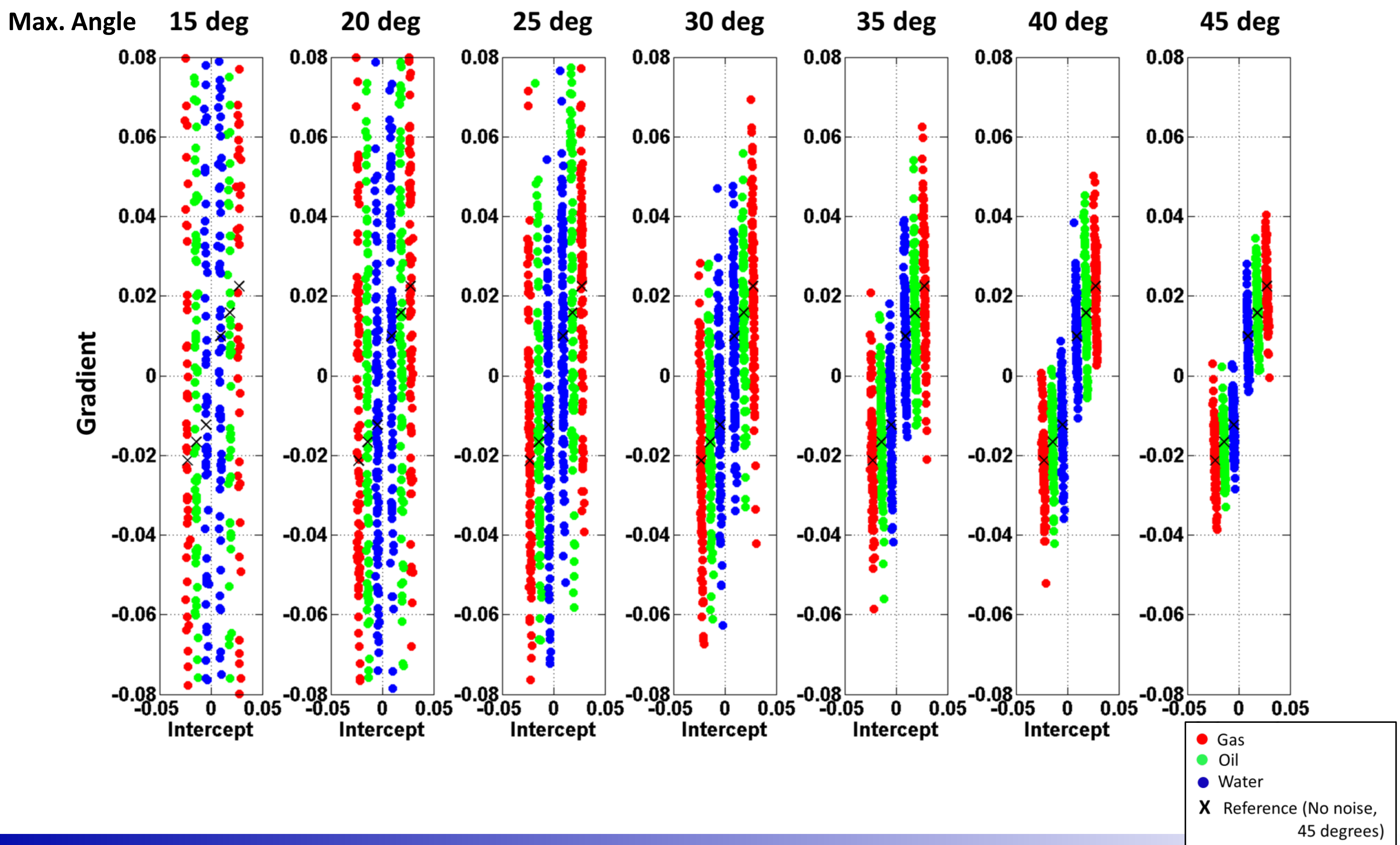
WATER-error



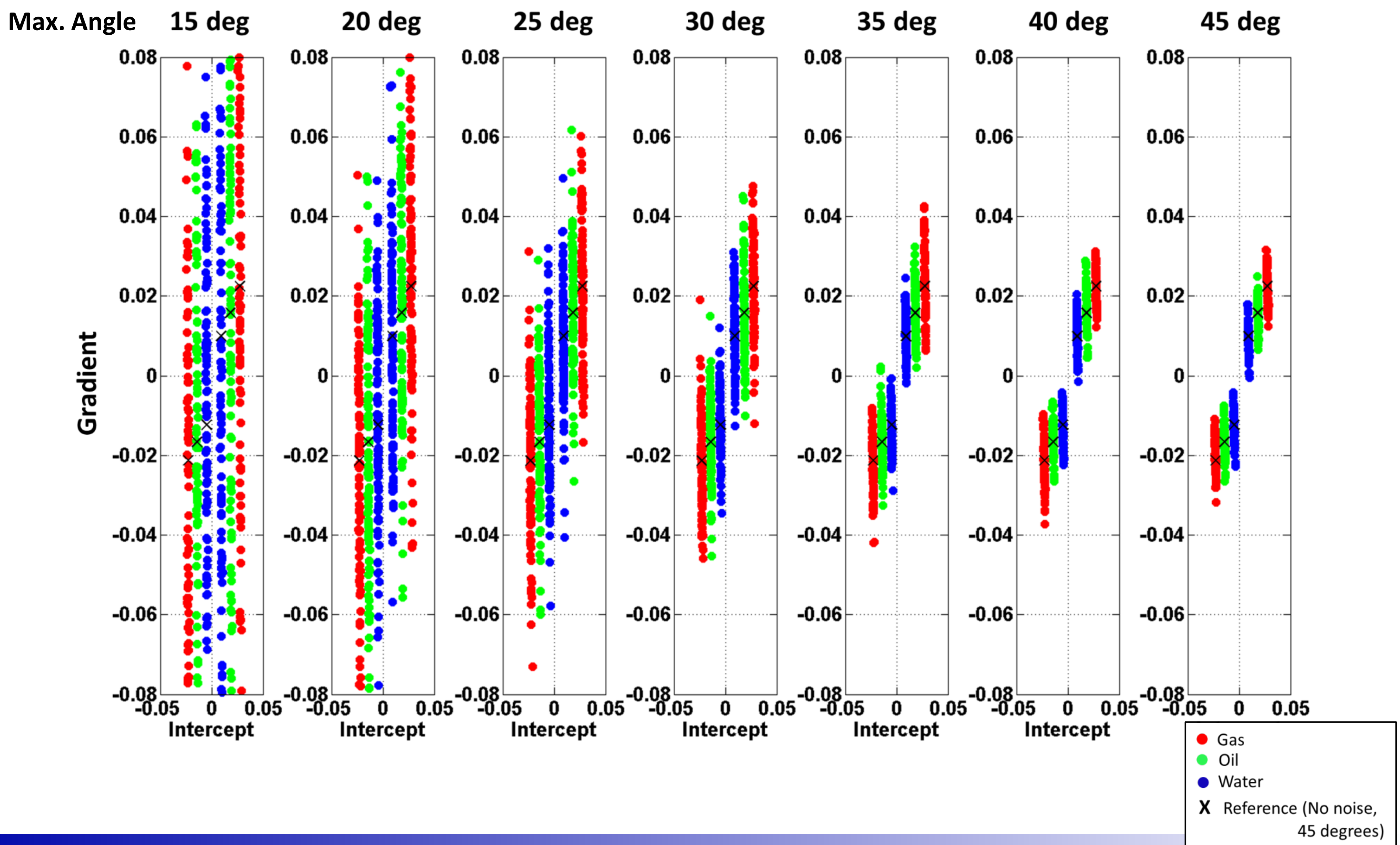
The error increases as the impedance contrast decreases

Simultaneous effect of reducing angle of incidence and varying level of noise

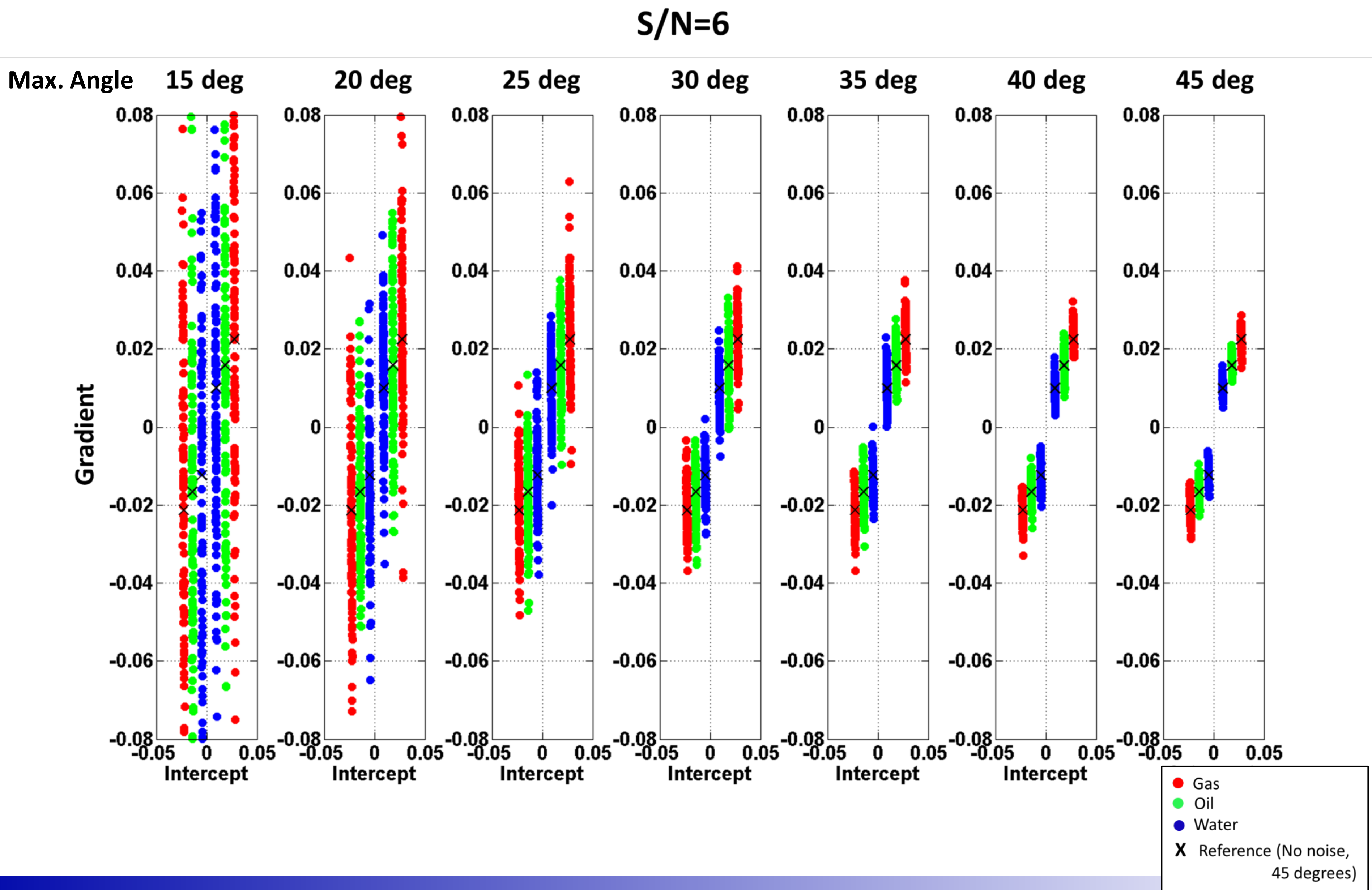
S/N=2


Max. Angle
15 deg
20 deg
25 deg
30 deg
35 deg
40 deg
45 deg
Gradient
Intercept
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.05
0
0.05
Gas
Oil
Water
X Reference (No noise, 45 degrees)

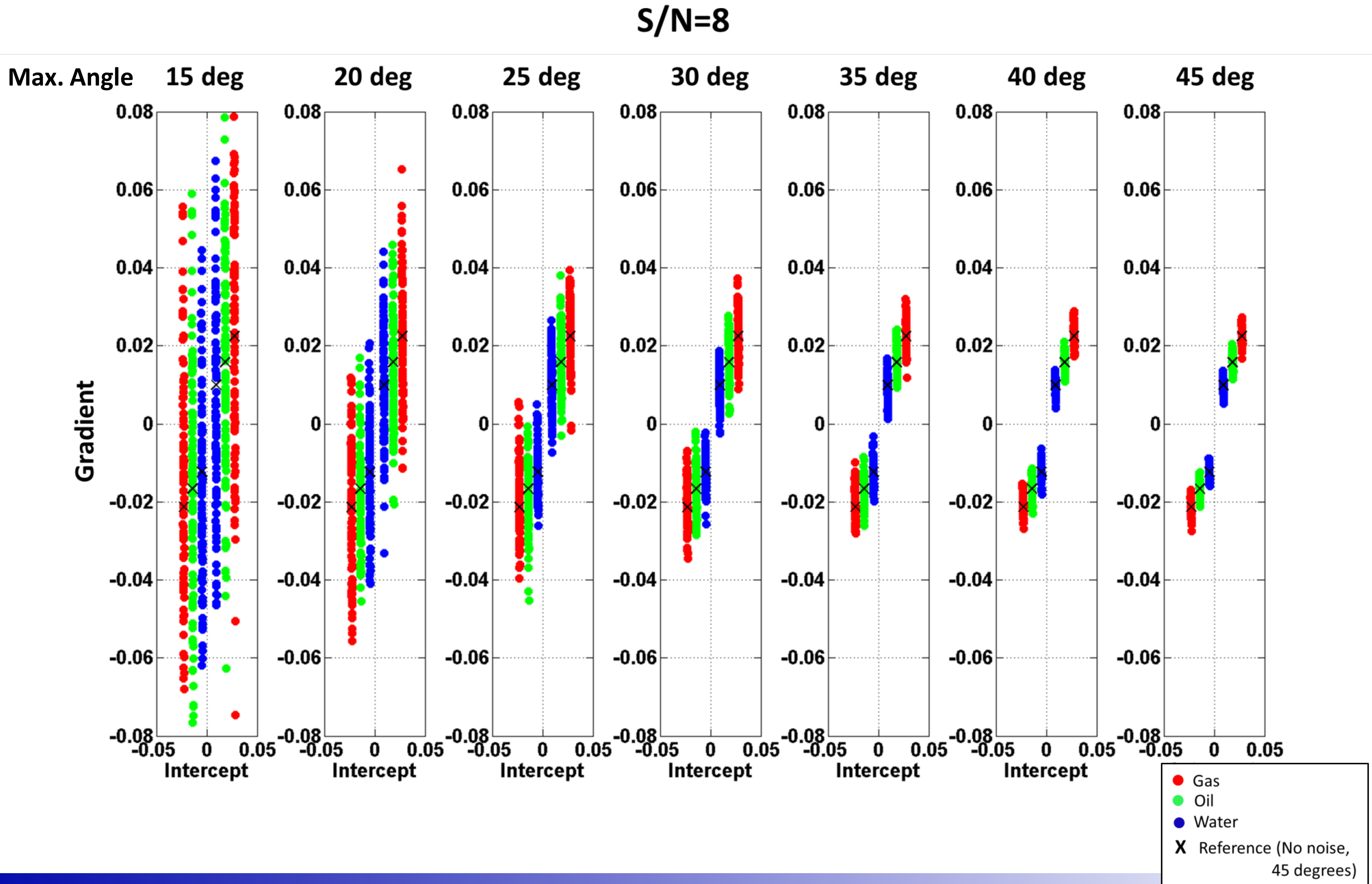
S/N=4


Max. Angle
15 deg
20 deg
25 deg
30 deg
35 deg
40 deg
45 deg
Gradient
Intercept
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.05
0
0.05
Gas
Oil
Water
X Reference (No noise, 45 degrees)

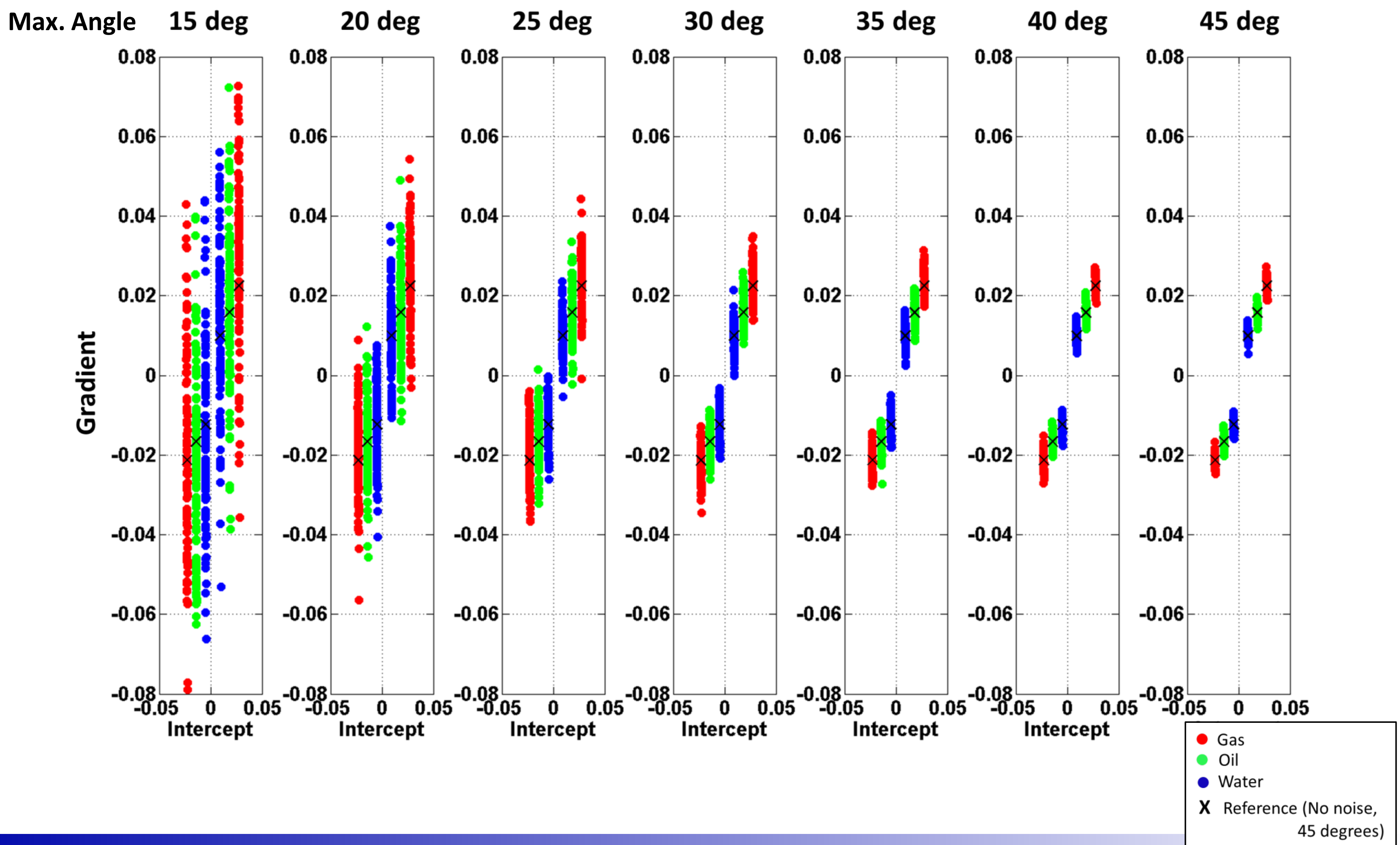
Effect of angle of incidence and noise



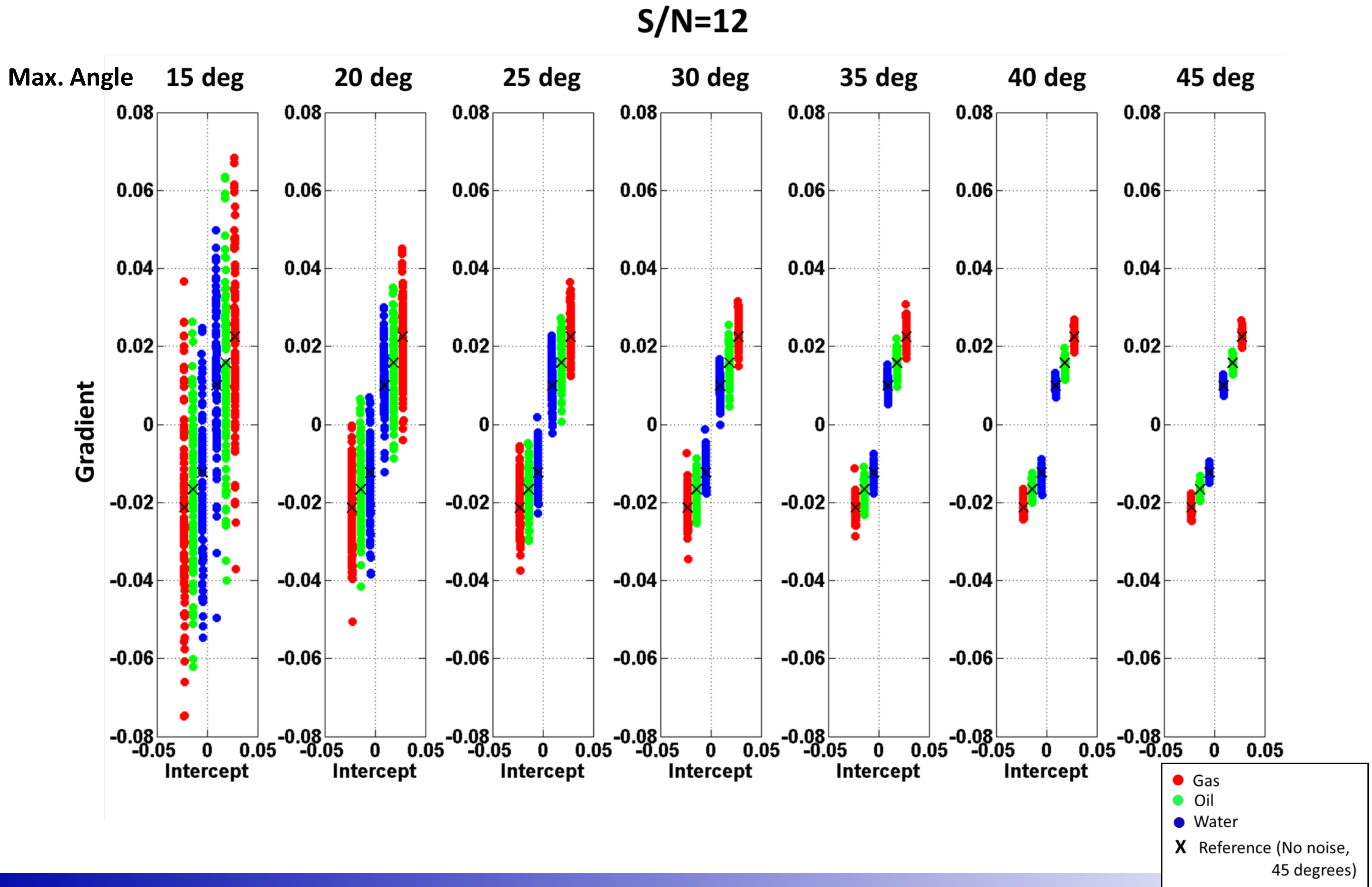
Effect of angle of incidence and noise



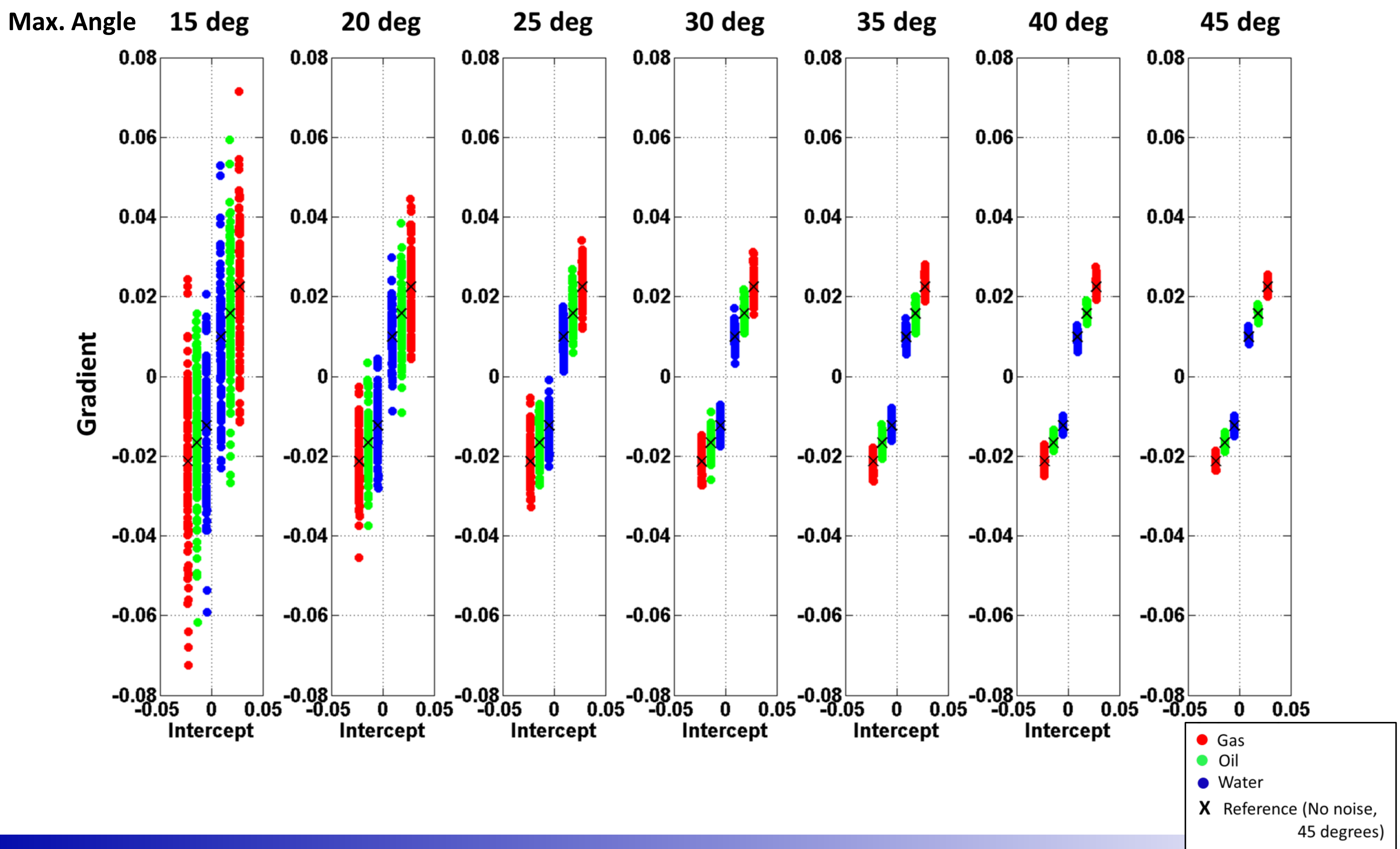
S/N=10


Max. Angle
15 deg
20 deg
25 deg
30 deg
35 deg
40 deg
45 deg
Gradient
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.05
0
0.05
Intercept
Gas
Oil
Water
X Reference (No noise, 45 degrees)

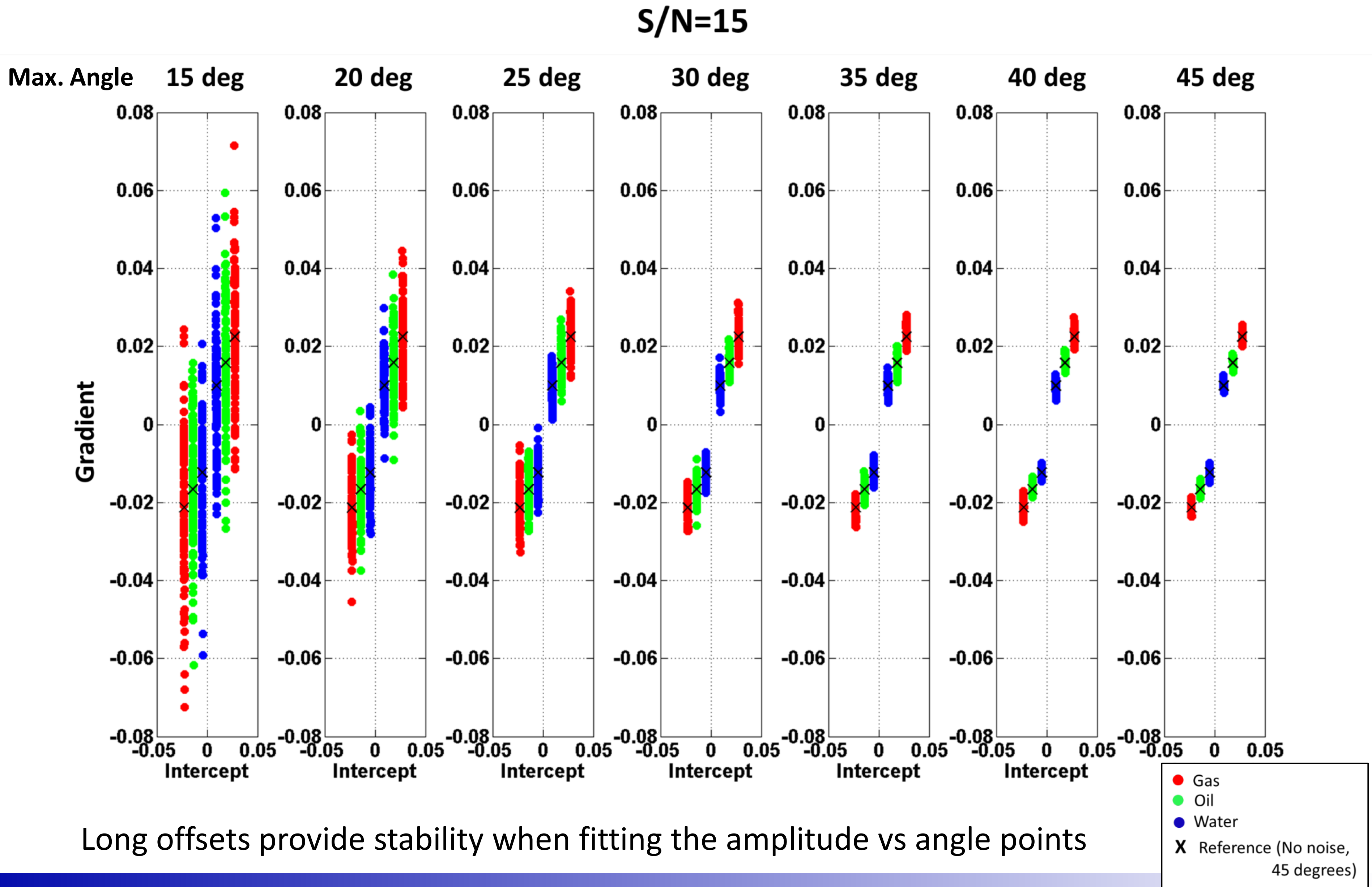
Effect of angle of incidence and noise



S/N=15

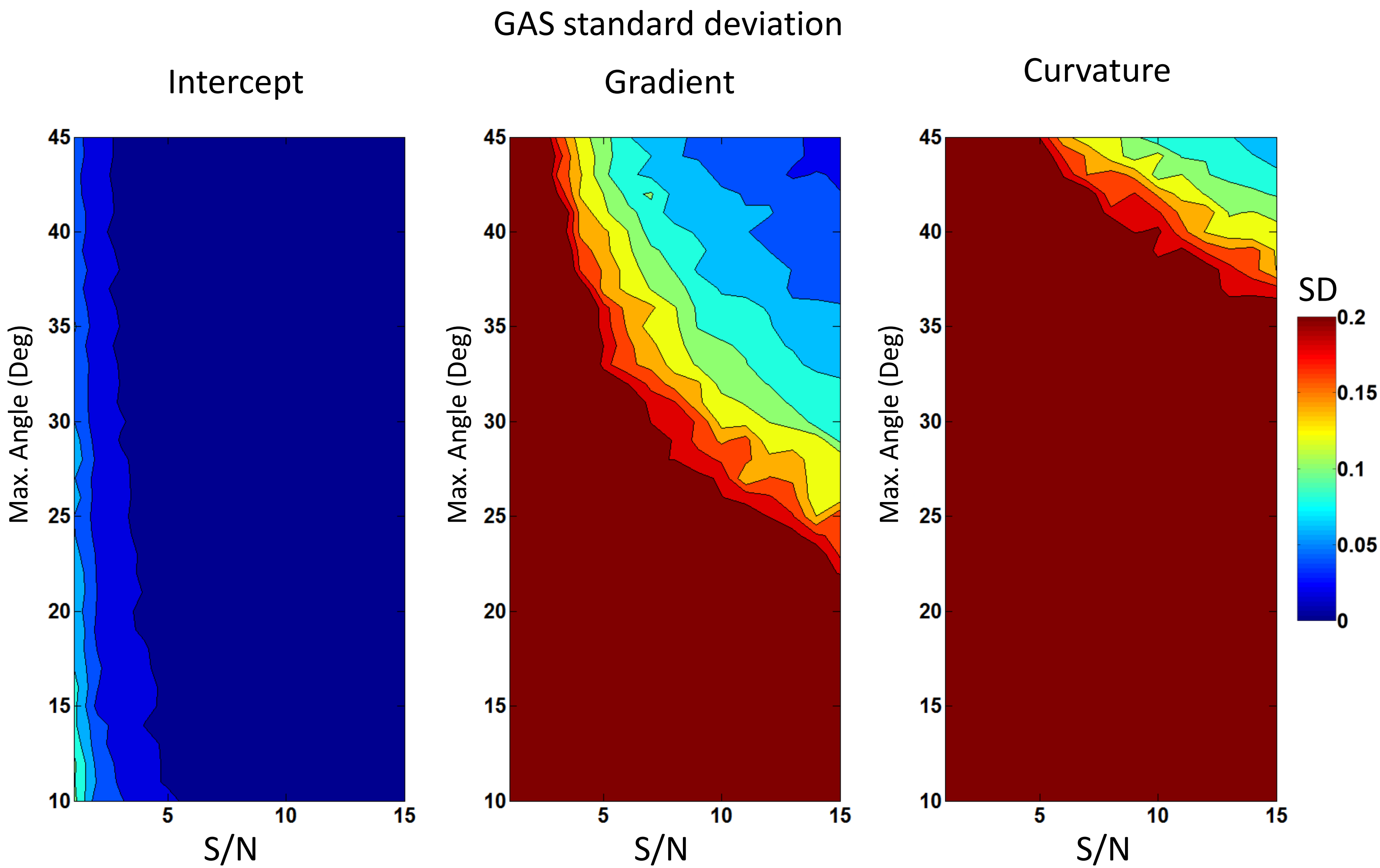

Max. Angle
15 deg
20 deg
25 deg
30 deg
35 deg
40 deg
45 deg
Gradient
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.05
0
0.05
Intercept
Gas
Oil
Water
X Reference (No noise, 45 degrees)

Effect of angle of incidence and noise

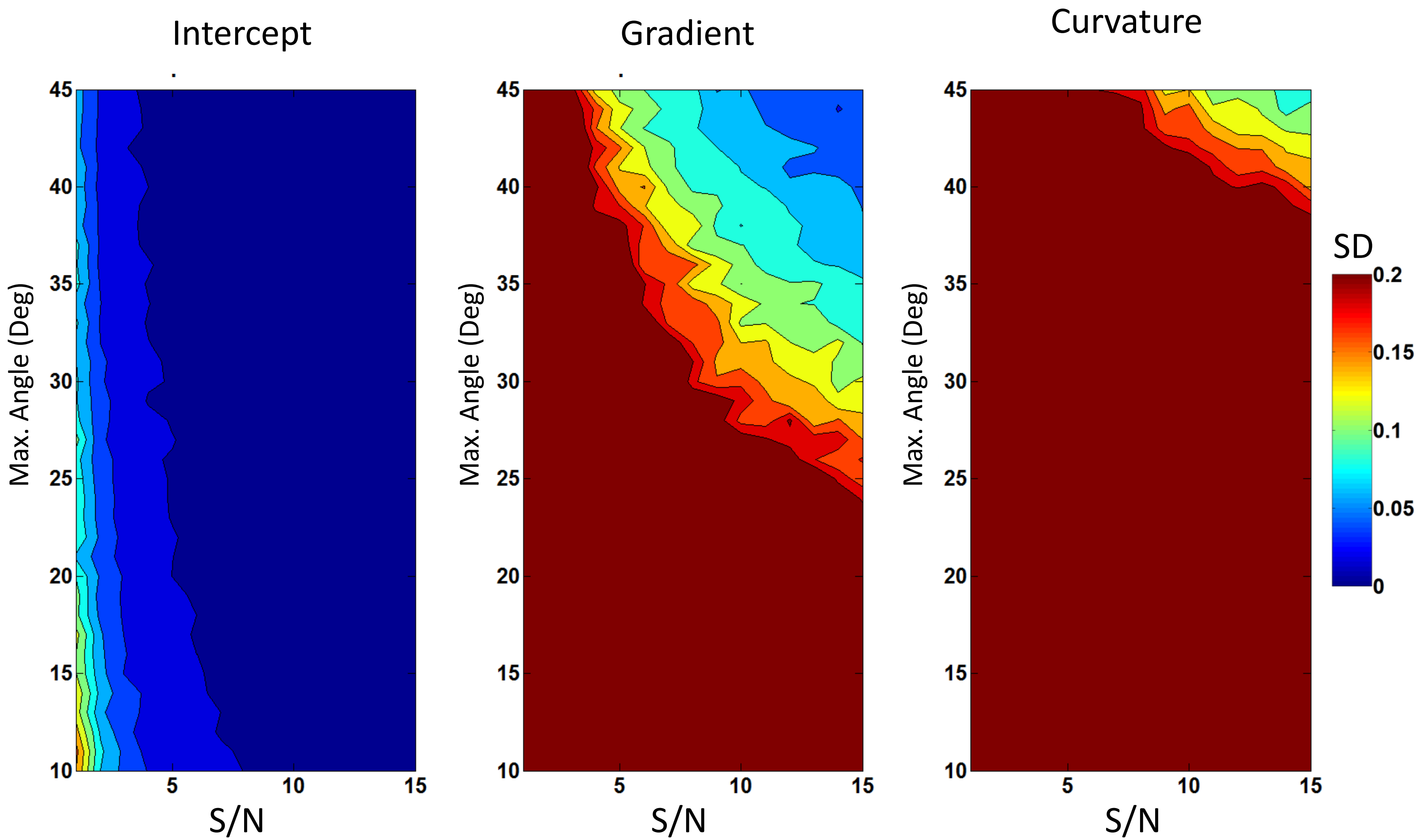


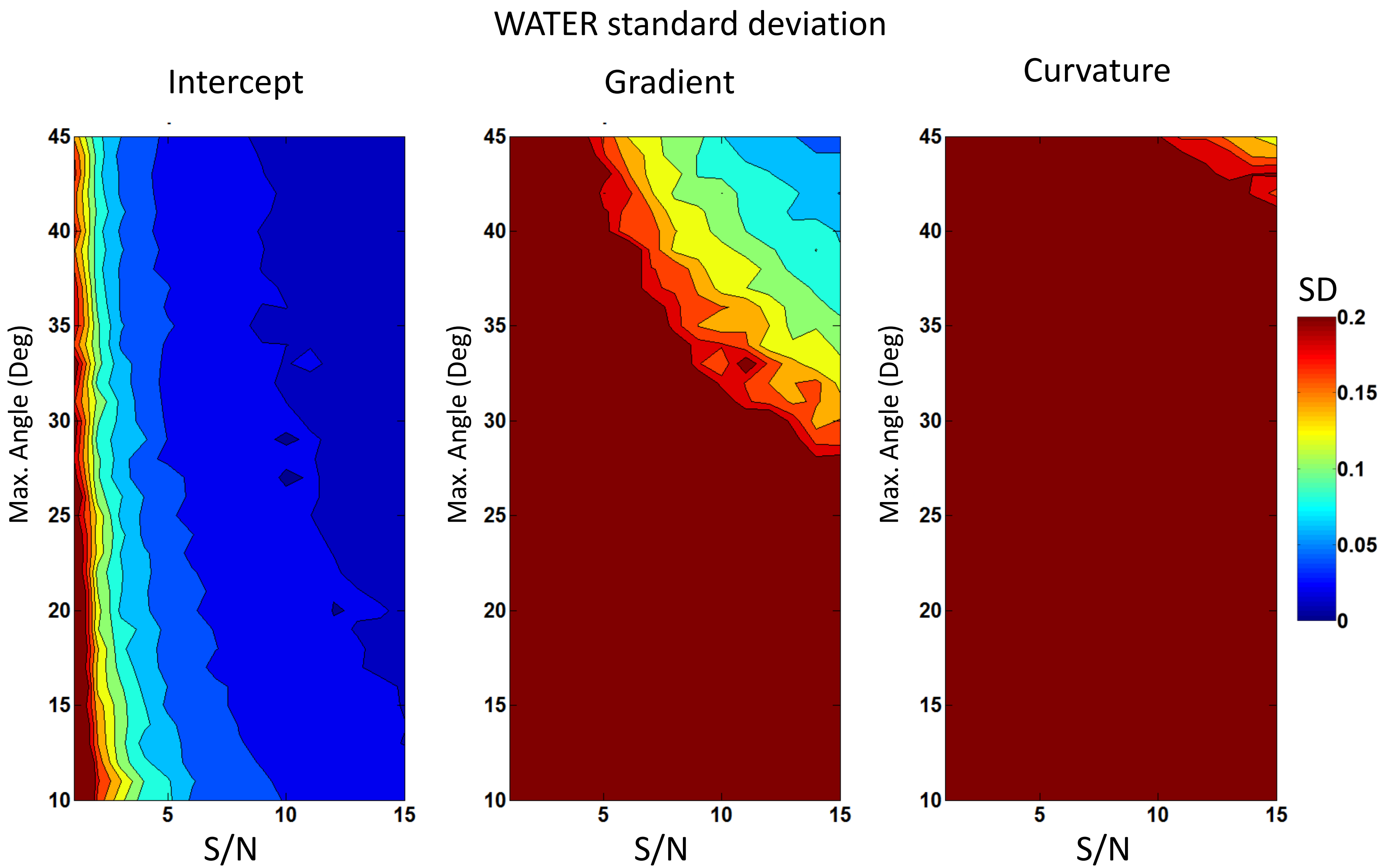
Long offsets provide stability when fitting the amplitude vs angle points

Effect of angle of incidence and noise



OIL standard deviation



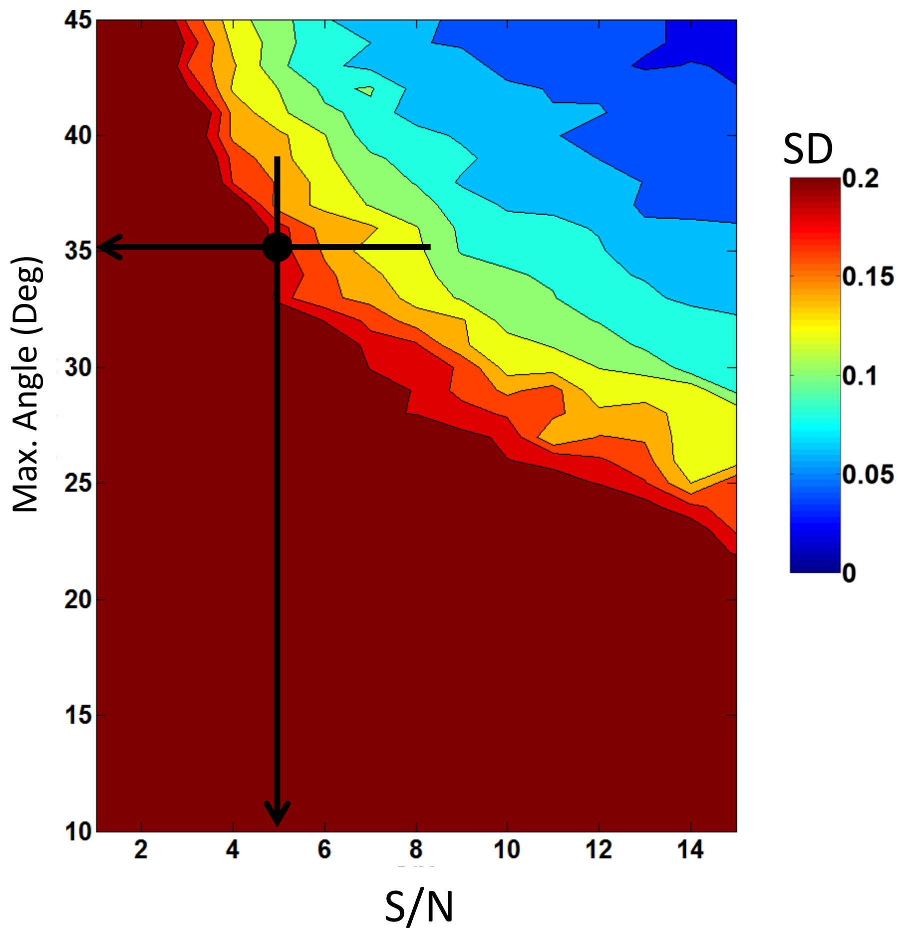

WATER standard deviation
Intercept
Gradient
Curvature
Max. Angle (Deg)
S/N
SD
0.2
0.15
0.1
0.05
0
45
40
35
30
25
20
15
10
5
10
15

GAS standard deviation

Target depth=2280 m

Offset=2600 m

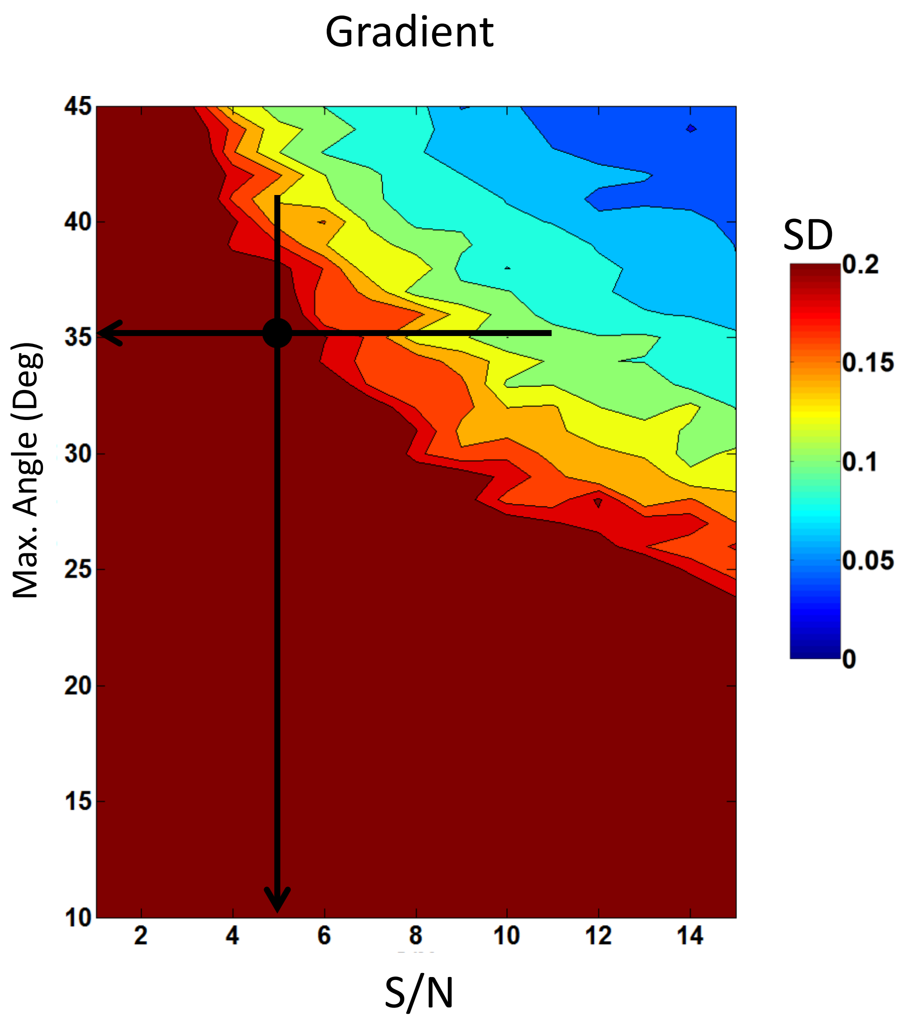
Gradient



OIL standard deviation

Target depth=2280 m

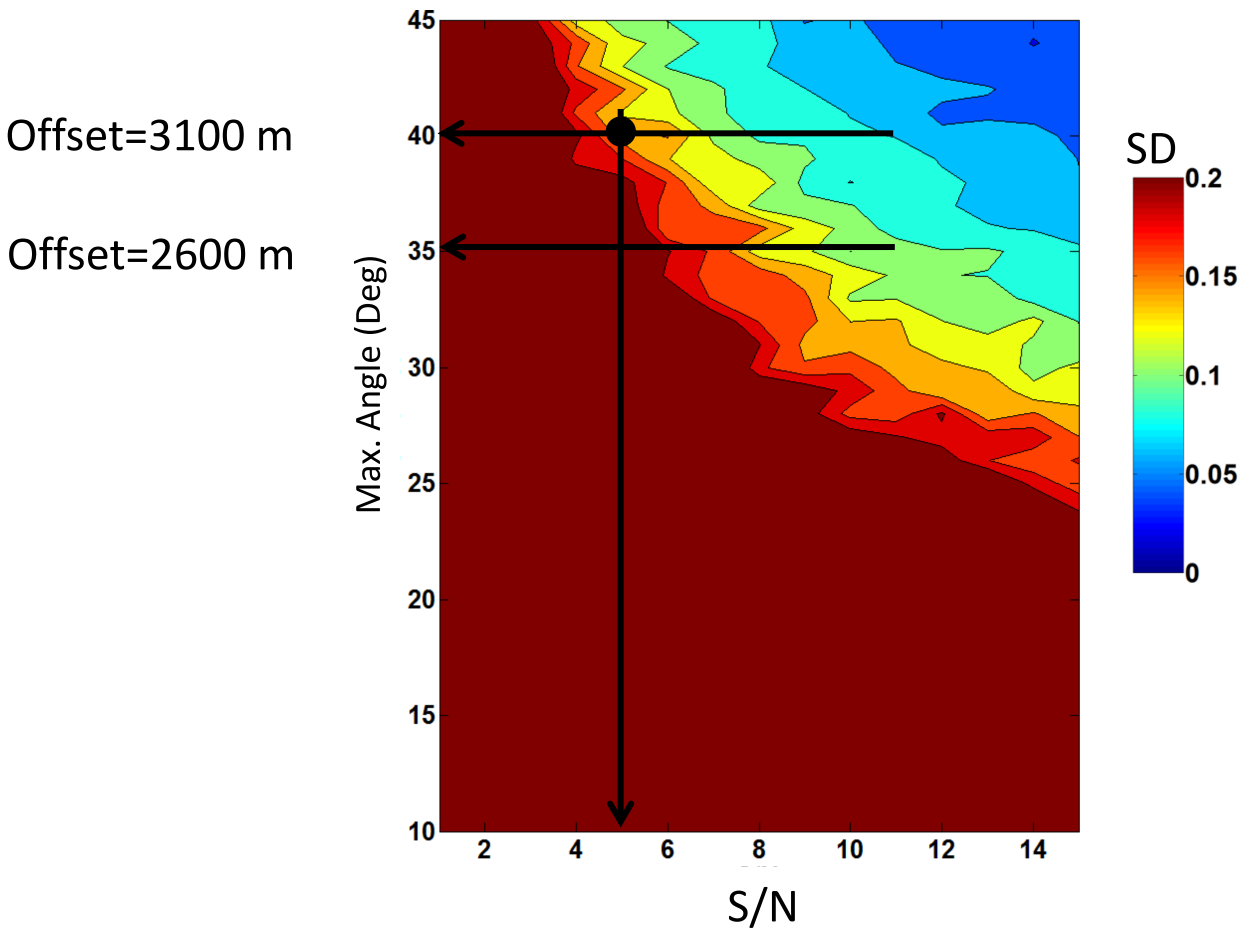
Offset=2600 m



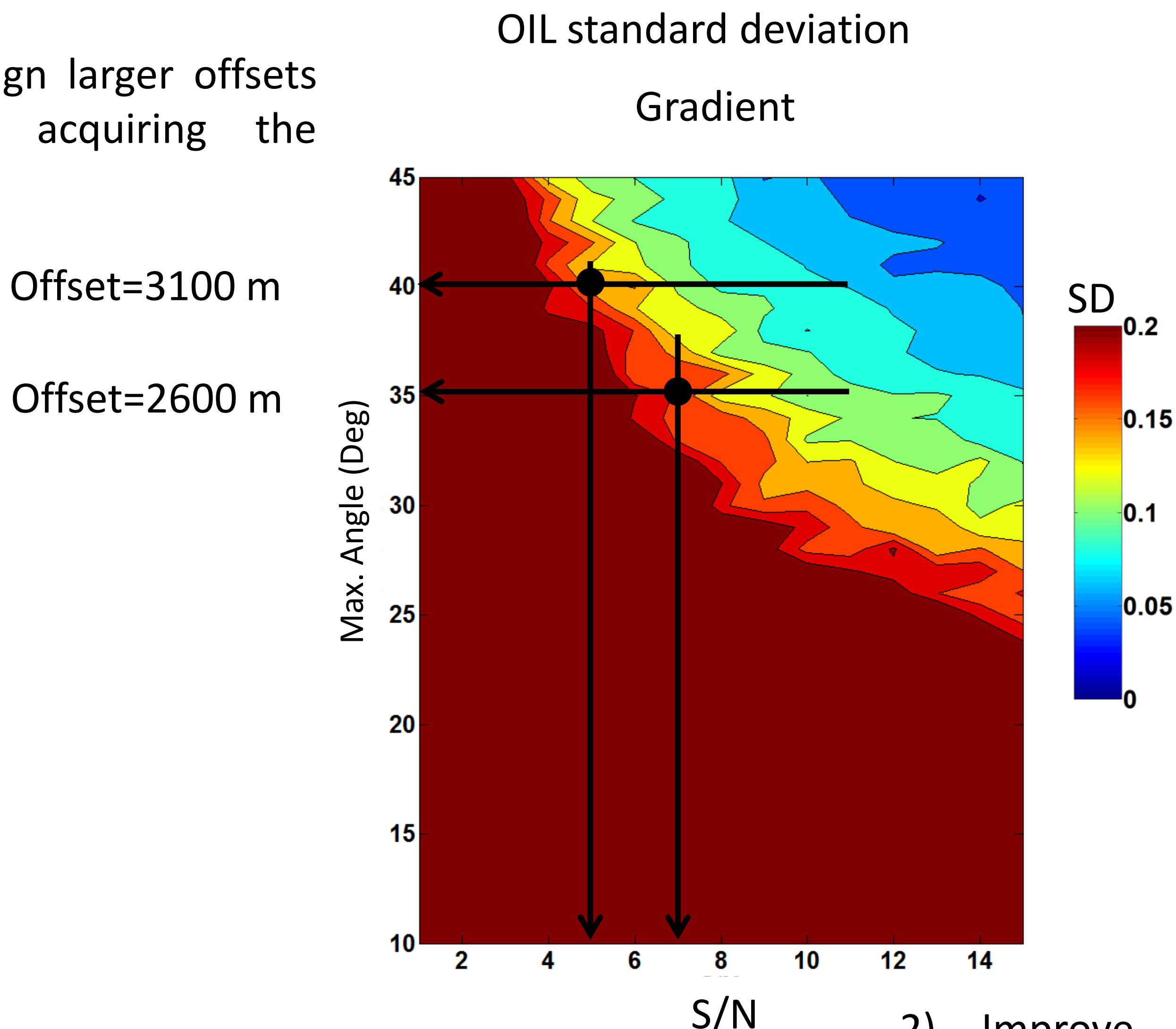
1) Design larger offsets before acquiring the data

OIL standard deviation

Gradient



1) Design larger offsets before acquiring the data



2) Improve the S/N when processing the data

Conclusions

- Random noise and available long offset are variables that affect the estimation of AVO-parameters.
- The intercept is practically not affected by reducing offset and slightly affected by random noise.
- The gradient and curvature are strongly impacted by both noise and maximum available offset.
- The error tends to be higher if the target has low impedance contrast.
- Long offsets provide stability when fitting the amplitude vs angle points in the presence of noise
- This methodology can be used to check the feasibility of applying AVO analysis with old seismic data or for deciding the maximum offset in new seismic surveys . This information may be useful when designing a seismic survey for monitoring changes of fluids in time-lapse studies.

Future work

- Investigate the effect of other factors such as: different noise distributions, changing the thickness of the reservoir and attenuation
- Incorporate AVO information in full waveform inversion

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CREWES staff and students
PEMEX

END