Using ambient noise array techniques for site characterization::

results from a international benchmark (ESG2006)

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Why a noise blind test ?

- use of microtremors for deriving velocity structures exist for more than 20 years in Japan
- calibration of these techniques at borehole sites (especially in Japan)

- recent increase of these techniques world wide for deriving **Vs30** or **site transfer function** (especially at sites with moderate seismicity or developed countries)

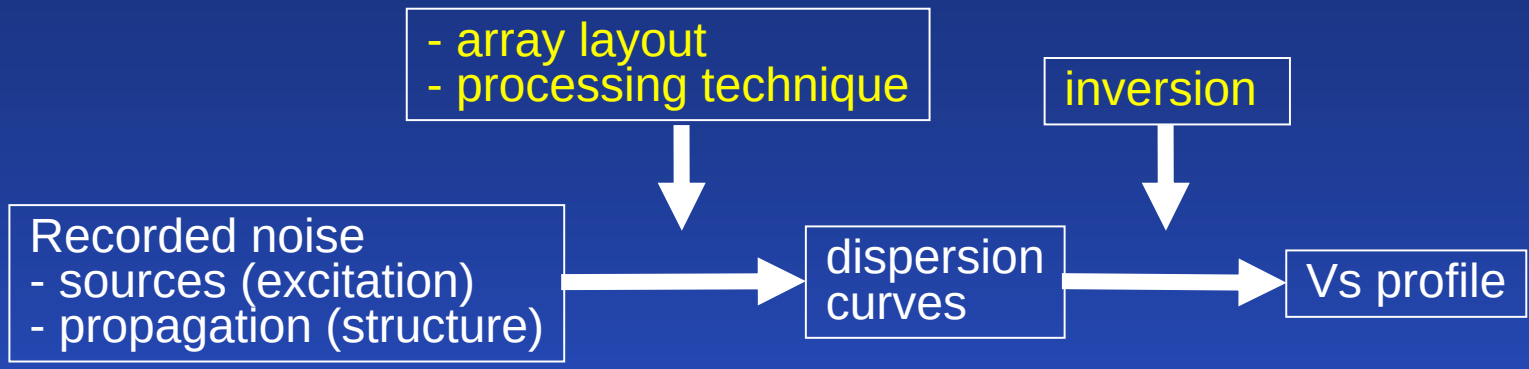
  ⇒ blind application : no (few) data to check reliability of estimates !

- recent increase of new techniques (dispersion curves, inversion, …)

  => no real comparison of techniques (except at peculiar sites)

- What is the reliability of the dispersion curves?
- What is the reliability of the inverted shear-wave profile?
- What is the reliability of the derived « amplification » factors (transfer function, Vs30, etc …)?

Objectives: how to manage ?



Blind experiment involving noise synthetics

FIXED

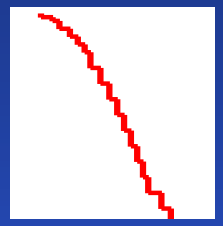
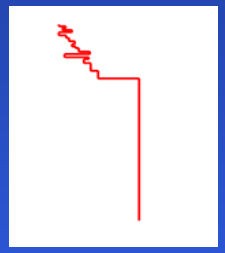
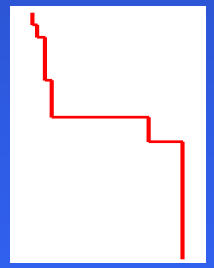
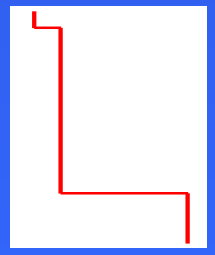
Recorded noise
- sources (excitation)
- propagation (structure)

Blind experiment involving real noise at well-known sites

FIXED

Recorded noise
- sources (excitation)
- propagation (structure)

Rough presentation of the data sets

	SYNTHETICS	REAL DATA
	gradient velocity	–
	complex shallow site	CCOC (California)
	deep site	NARITA (Japan)
	shallow + deep layers	–

Rules of the experiment

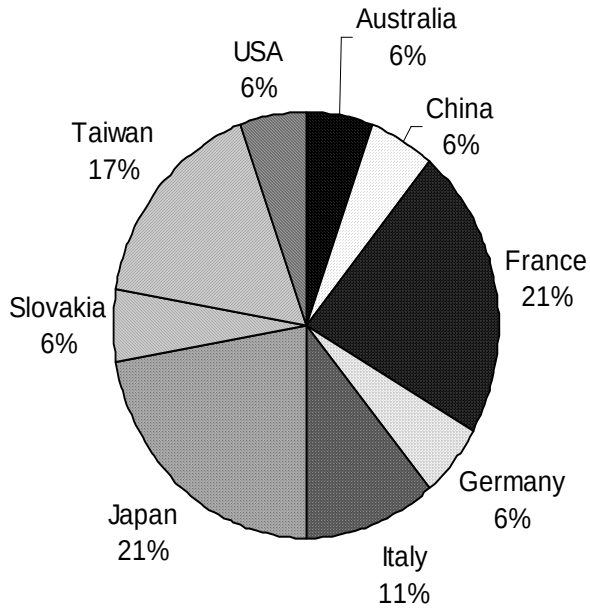
What was asked to participants ?

To provide:

- dispersion curves including standard deviation
- velocity profiles including standard deviation

Participants

Participants	Origin	N101	N102	N103	N104	N201	N202	N301	N302
M. Asten & J. Roberts	Australia								
L. Shi	China								
A. Roulle & A. Bitri	France								
H. Cadet	France								
P. gouedard, P. Roux & M. Campillo	France								
M. Wathelet	France								
A. Koehler	Germany								
G. di Giulio	Italy								
C. Comina, S. Foti, L. V. Socco & D. Boiero	Italy								
Toshiaki Yokoi	Japan								
S. Tsuno & T. Kanno	Japan								
H. Morikaw a & K. Sakai	Japan								
S. Higashi & H. Sato	Japan								
S. Bonnefoy-Claudet	Slovakia								
H. Havenith, D. Faeh, G. Stamm	Sw itzerland								
C. Lin	Taiw an								
C-H. Kuo	Taiw an								
C.-F. Wu	Taiw an								
J. Louie	USA								

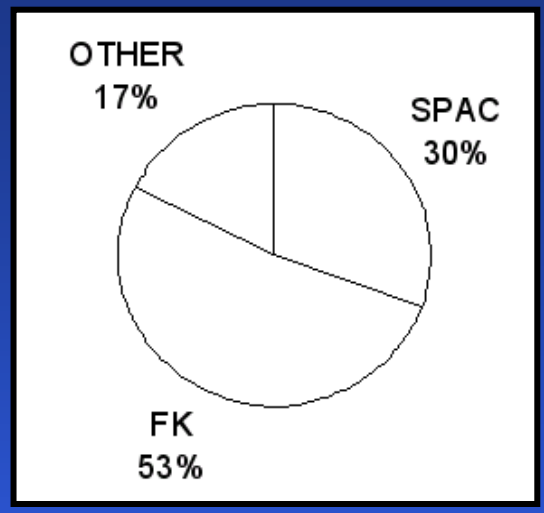


MANY THANKS !

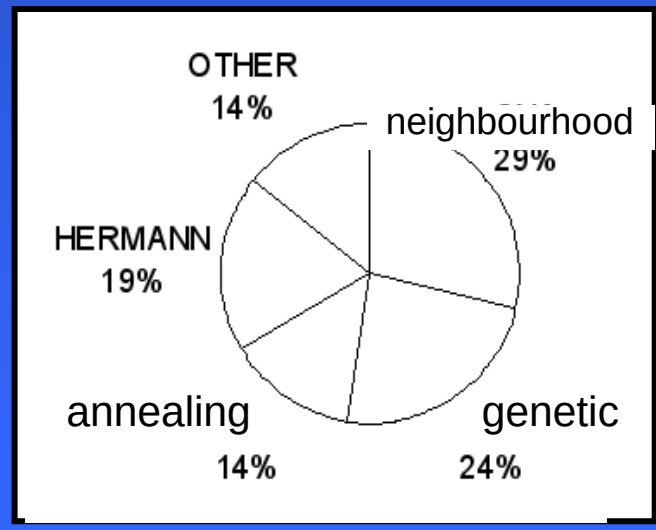
What were methods used by participants ?

Participants	Origin	Methods for DC estimation	Inversion methods
M. Asten & J. Roberts	Australia	MMSPAC	ITF
L. Shi	China	SPAC	GSA
A. Roulle & A. Bitri	France	slant-stack, FK	CNA Herrmann
H. Cadet	France	FK, SPAC	CNA
P. gouedard, P. Roux & M. Campillo	France	CORR	No inversion
M. Wathelet	France	SPAC/FK/CAPON	CNA
A. Koehler	Germany	SPAC FK	CNA
G. di Giulio	Italy	FK, CAPON	CNA
C. Comina, S. Foti, L. V. Socco & D. Boiero	Italy	FK	MC
Toshiaki Yokoi	Japan	LMM	FSA-DHS
S. Tsuno & T. Kanno	Japan	SPAC	GAA
H. Morikawa & K. Sakai	Japan	SPAC, 2sSPAC	GAA
S. Higashi & H. Sato	Japan	CAPON	SAA
S. Bonnefoy-Claudet	Slovakia	CAPON	CNA
H. Havenith, D. Faeh, G. Stamm	Switzerland	CAPON	GA
C. Lin	Taiwan	CAPON	GA-Herrmann
C-H. Kuo	Taiwan	CAPON	GA-Herrmann
C.-F. Wu	Taiwan	CAPON	Herrmann
J. Louie	USA	REMI	?

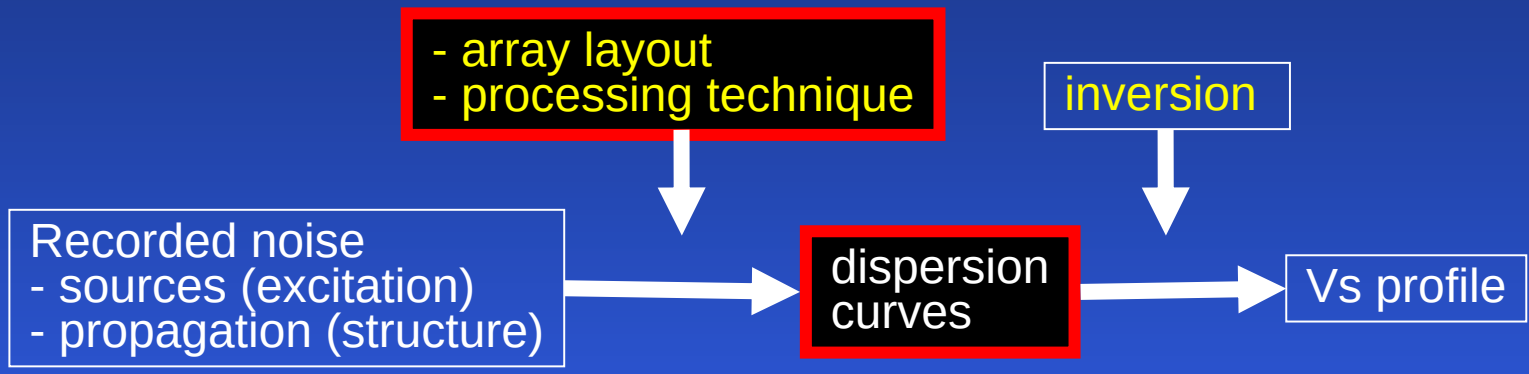
Dispersion curves



Inversion



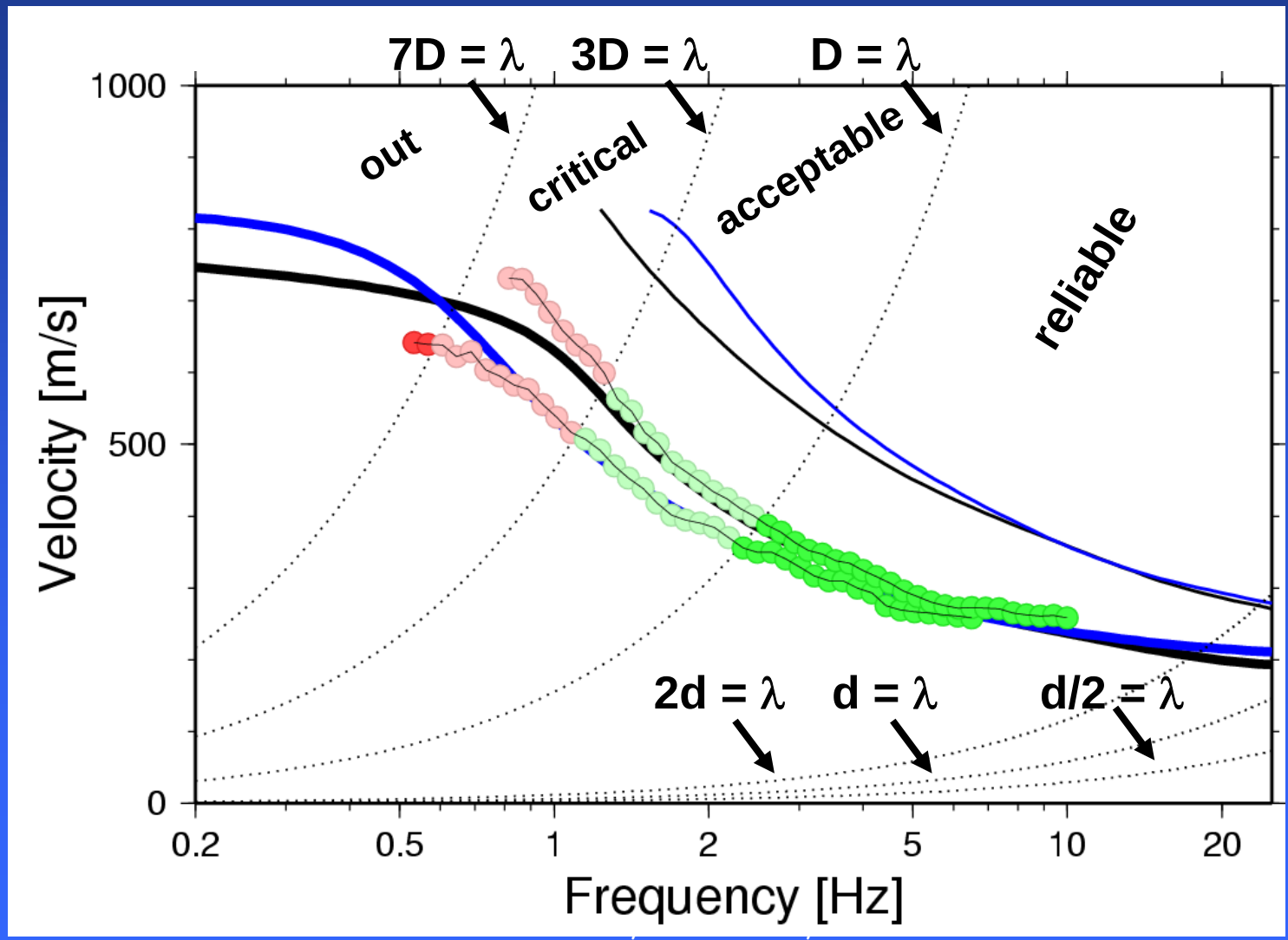
Estimation of dispersion curves



Steps:
1) Array geometry
2) Estimation of phase velocities

Dispersion Curves – Fair(?) Comparison

D = array aperture
d = minimal interstation distance



Results for dispersion curves estimates

	Main learnings	Comments
Estimation of phase velocities	No trend regarding the method used	
	SPAC seems performing better at low frequency	often reported in litterature
	Overestimation more pronounced for low frequency (array layout)	limitations: array size and related frequency band of interpretation
	Bias to higher velocities (for this experiment)	this experiment: higher modes effects ?

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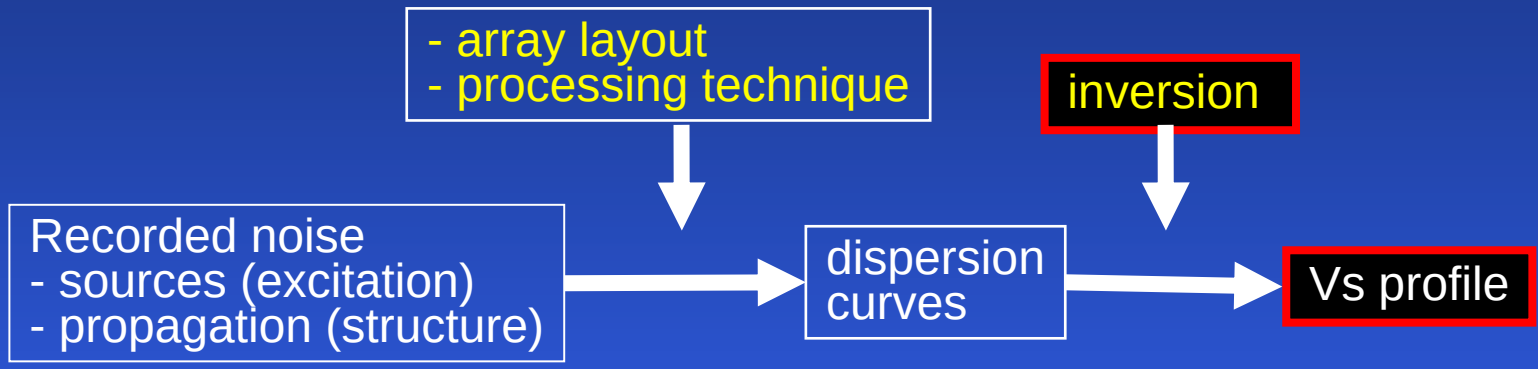
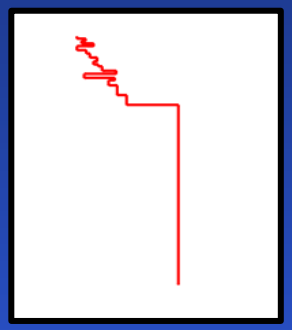
Derivation of velocity profiles

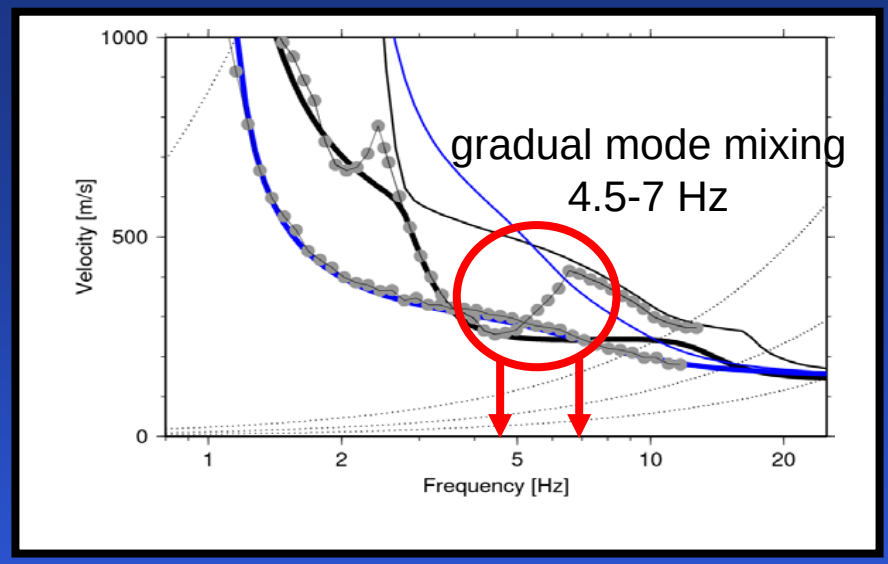


Steps:
1) Mode association
2) inversion

N102 & N104: Misinterpretation of modes

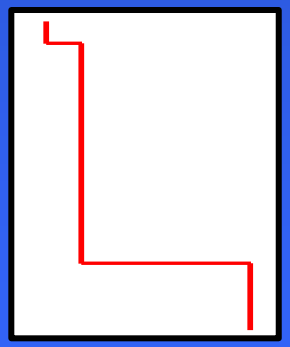
N102

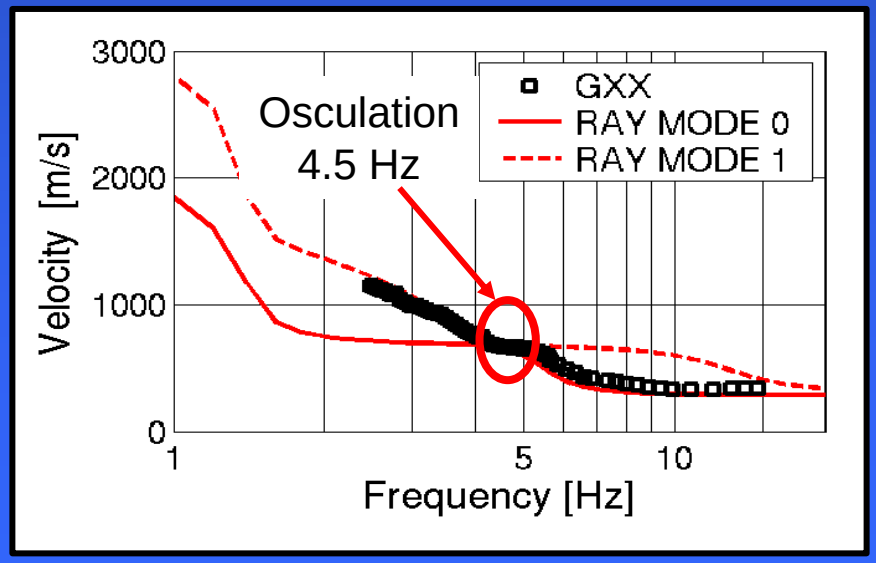




More complex model showing mixed mode conditions in the wavefield cause problems.
Individual phase velocity estimates are rather appropriate, problematic is the interpretation of results, i.e. mode identification.

N104





Correct mode identification seems to be even more difficult, as fundamental mode is observed at higher frequency band than first higher mode.

Model	Correct interpretation of modes	Incorrect interpretation of modes
N101: Simple gradient	100%	0%
N103: Deep site	100%	0%
N102 : Complex shallow site	63%	37%
N104: Shallow and deep layers	25%	75%
N201: Deep site (Narita)	100%	0%
N202: Complex site (CCOC)	100%	0%

Derivation of the velocity profiles

NOISE SYNTHETICS

MMSPAC	RAY + LOVE (+ higher mode)	ITF
SPAC	RAY	Genetic
FK/SLANT-STACK	RAY or LOVE	Neighboorhood Herrmann
FK, SPAC	RAY	Neighboorhood
SPAC/FK/CAPON	RAY (+ LOVE) (+higher mode)	Neighboorhood
SPAC/FK	RAY+LOV (+higher mode)	Neighboorhood
FK/CAPON	RAY	Neighboorhood
FK	RAY	Monte Carlo
LMM	RAY	Annealing
SPAC	RAY	Genetic
SPAC/2sSPAC	RAY	Genetic
CAPON	RAY	Annealing
CAPON	RAY	Neighboorhood
CAPON	RAY+LOV	Genetic + H/V
CAPON	RAY	Genetic
CAPON	RAY	Genetic
CAPON	RAY	Herrmann
REMI	RAY	?

No same input information (RAY, RAY+LOVE, higher modes, use of H/V, …)

No standard procedure for inversion + lack of information from participants (my fault!)

<u>As many as inversion procedures as number of participants !!!</u>

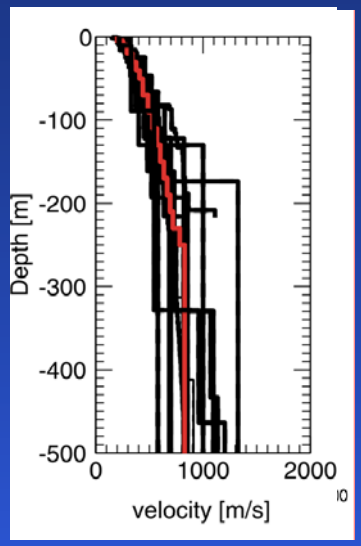
So far, inversion results do not show:

- any trend regarding inversion scheme
- Any clear quantitative improvement in final Vs when using « multiple » inputs RAY+LOV, RAY+HV, …

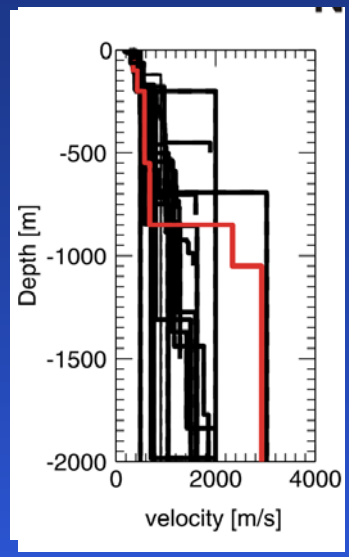
Summary for noise synthetics

NOISE SYNTHETICS

N101

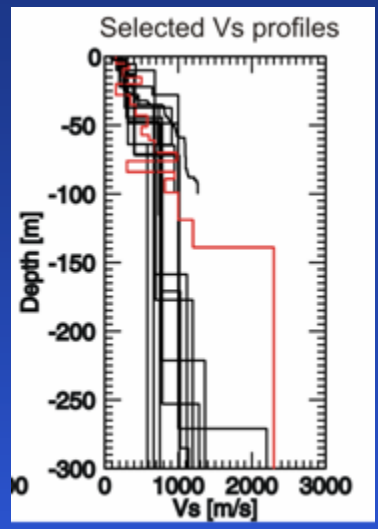


N103

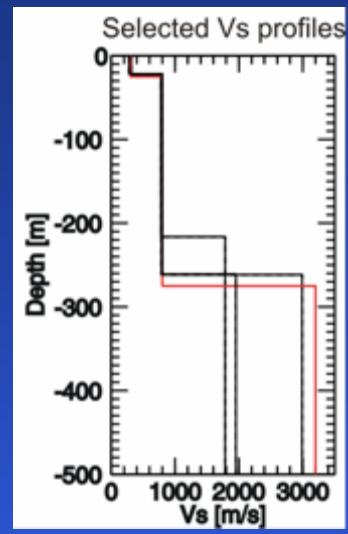


Fundamental mode

N102



N104



Mix of fundamental and higher modes

- Overestimation of the velocities (from 10% to 30% for the median on average velocity) within sediments, especially within the first 50 m
- Fine layering has never been retrieved !
- Large underestimation of velocities at depth
- No (few) participants could estimate the bedrock depth

Results for dispersion curves estimates

	Main learnings	Comments
Interpretation of modes	critical issue !!!	
Derivation of velocity profiles	no standard procedure	
	No systematic improvement by inverting simultaneously different quantities (Rayleigh + Love + higher mode + H/V)	lack of samples (bad statistics)
	Details in Vs profiles are not retrieved	average Vs profile is a most robust measure
	Bedrock depth and bedrock velocity have not been recovered	limitation: energy content of noise for lowest frequency + array size
	no uncertainties	

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	Bias to higher velocities (for this experiment)	this experiment: higher modes effects ?
Interpretation of modes	difficult issue !!!	
Derivation of velocity profiles	no standard procedure	
	No systematic improvement by inverting simultaneously different quantities (Rayleigh + Love + higher mode + H/V)	lack of samples (bad statistics)
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