Σigma
SeIsmic Ground Motion Assessment

ISTerre
Institut des Sciences de la Terre

CASHIMA
CADARACHE SEISMIC HAZARD INTEGRATED MULTIDISCIPLINARY ASSESSMENT

Site characterization (soil classes, Vs30, Vs profile…):

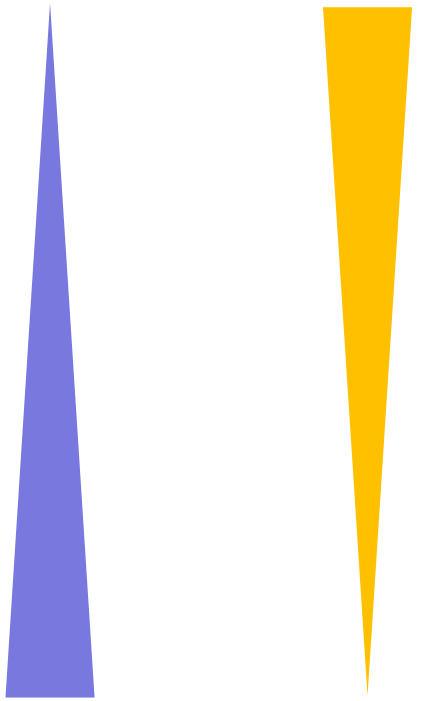
Review of existing methods and state-of-the-art of non-invasive approaches Presentation of upcoming work

Fabrice HOLLENDER, Cécile CORNOU, Pierre-Yves BARD and Cédric GUYONNET-BENAIZE

Deliverable D3-37 – Reviewers: A. Pecker & R. Paolucci

Improving Vs (profile, Vs30…) characterization methodologies: why?

- We need methods to characterize velocity profile (or V_S30 or soil class) in these frameworks:
  - characterization of site where large / important facilities had to be designed (or where facility safety has to be re-assessed)
    - ➔ *high quality characterization, with evaluation of spatial variability and uncertainties*
  - characterization of accelerometric network stations to complement station meta-data (and thus help to derive optimized GMPEs, true "reference"…)
    - ➔ *need of cost-effective methods (number of stations, restricted budget…)*
  - application of regulation (eg. EC8) for all kind of buildings
    - ➔ *budget even lower, but need to avoid bad quality works*



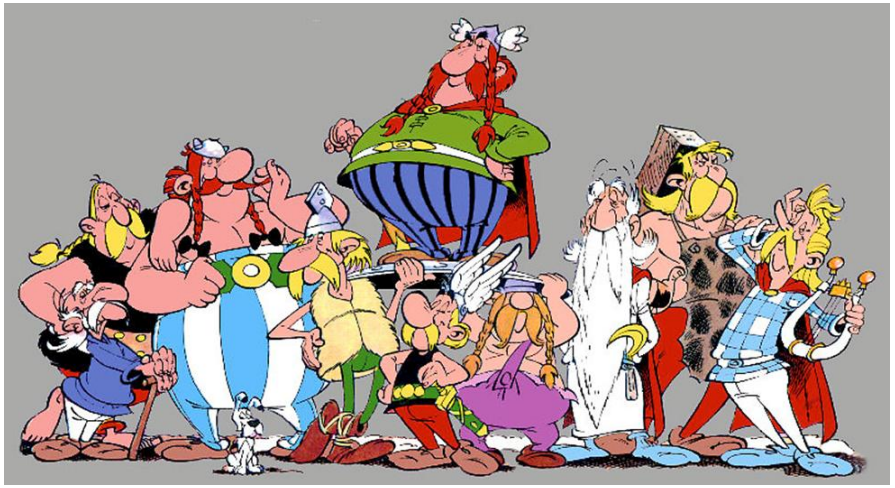
- Which approaches should we emphasize?

- Let’s listen at the position of a first group…

“Our approaches are based on surface wave dispersion phenomenon. They are using the frequencies of interest for seismic hazard! They perform an average of geological variability at the right scale… We don’t need to do boreholes, why continue to transform geological formation into emmental cheese?”

Let’s called this group, the “geophysicists”…

Sorry, the geophysiciX !

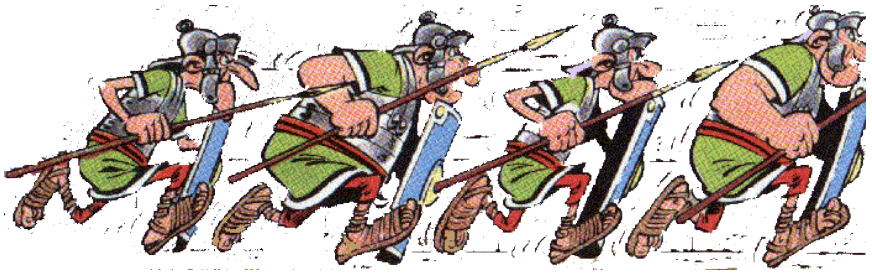


• Let’s listen at the position of a second group…

“Our approaches are the reference since the beginning of earthquake engineering. We are measuring soil properties in situ, not indirectly. No smoothing issues, no uniqueness problem… If you want quality, you must afford invasive tests !”

You have recognized the group of the “engineers in geotechnics”…

… specialized in Roman works !



- But there is a third group !

“If you want to assess site effect, measure it directly from seismological data, use generalized inversion technics, you will find the only truth!”

This new group in the debate is called “seismologists” …

… they are coming from the New World…

… and they took a hostage

… a dog that seismologists renamed “Kappa” (what a strange idea…)

- There is only one question…

“In such a complex situation how to avoid the fight?”

Before answering this question... let's present and comment the different approaches...

Scope

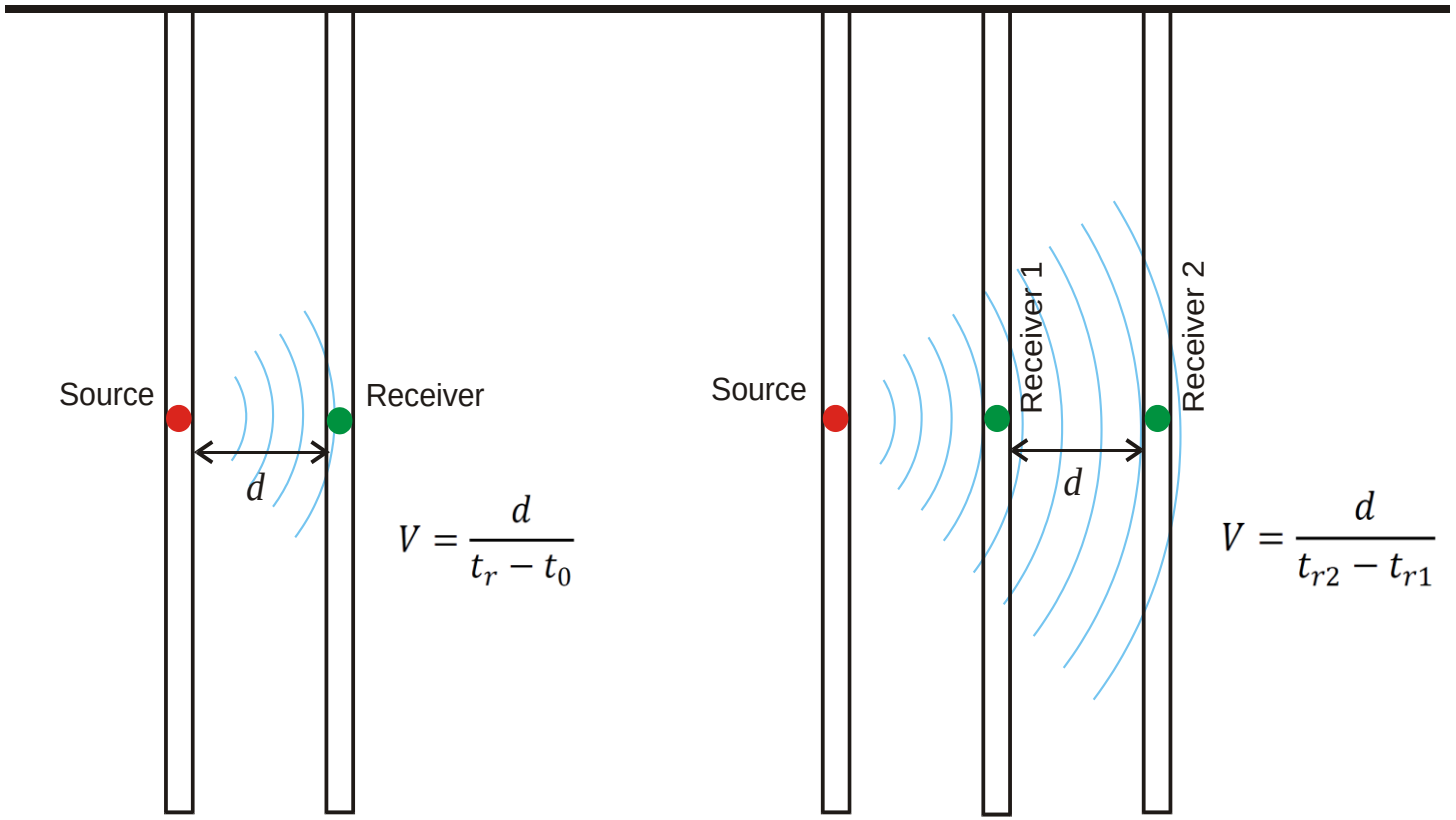
- Methods:
  - Invasive:
    - CH, DH, PSSL
  - Non-invasive:
    - passive and active methods based on surface wave analysis

- “Values” to be investigated:
    - S-wave velocity profile up to bedrock (and at least 30 m),
    - scalar macroscopic parameter : Vs30,…
    - soil class.

- Objective of surveys:
    - getting results for site effect analysis for different level of precision and for various applications

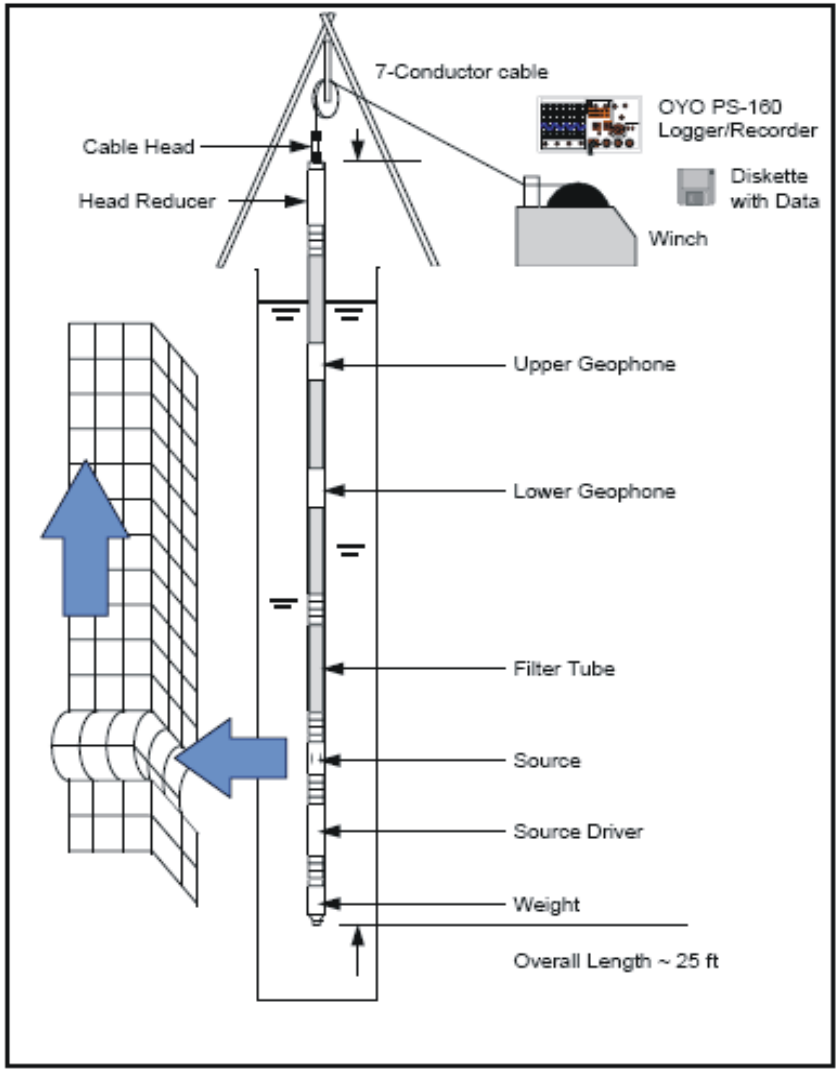
Invasive methods

- Cross-hole principles



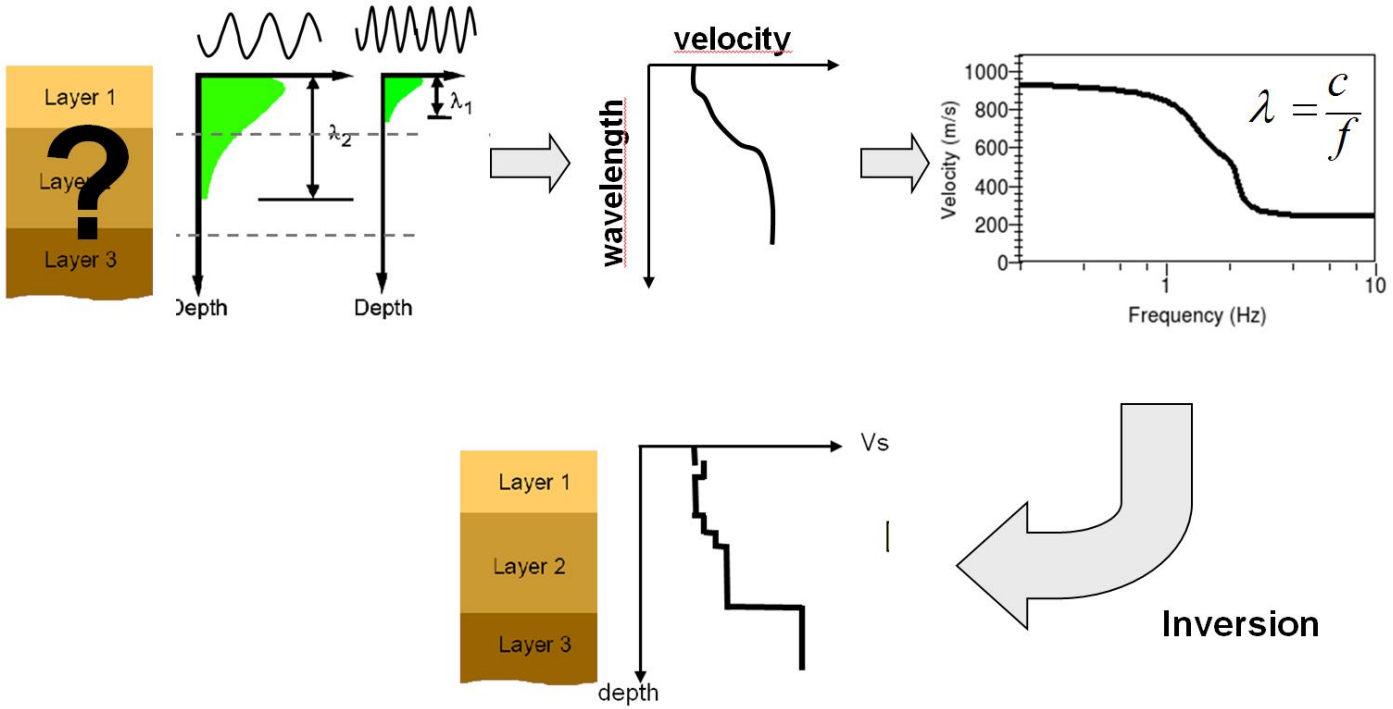
Invasive methods

- P-S suspension logging



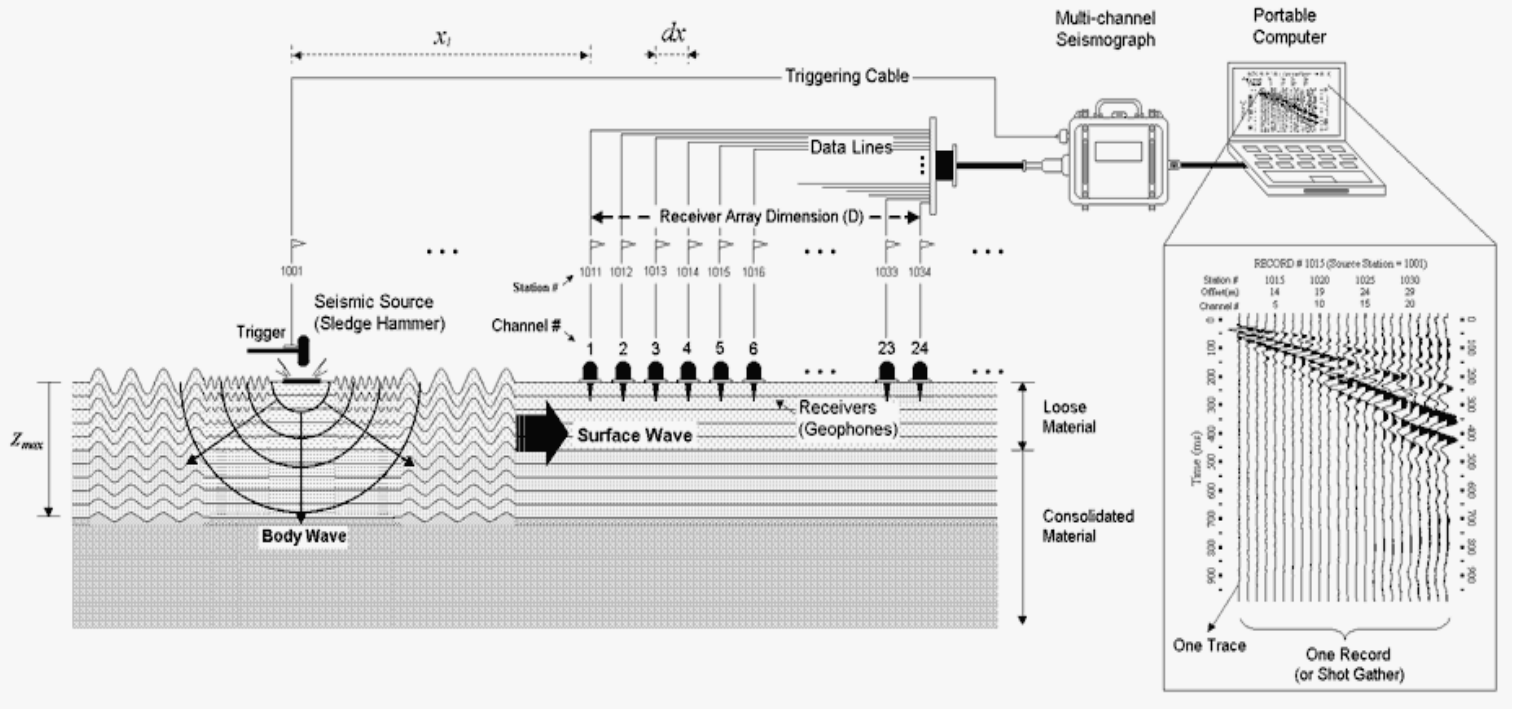
Non-invasive methods

- Surface-wave methods principles

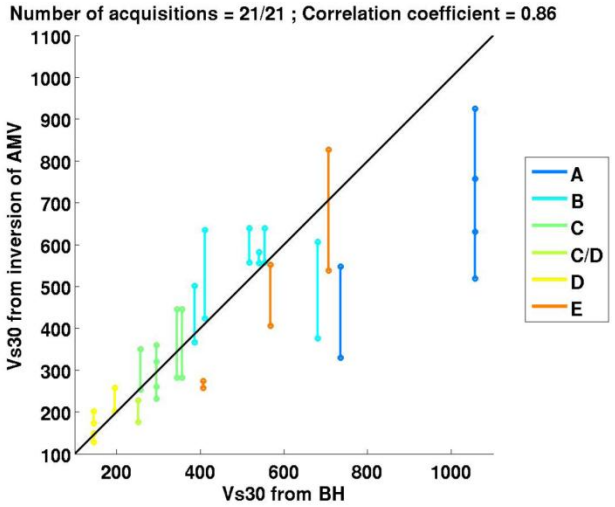


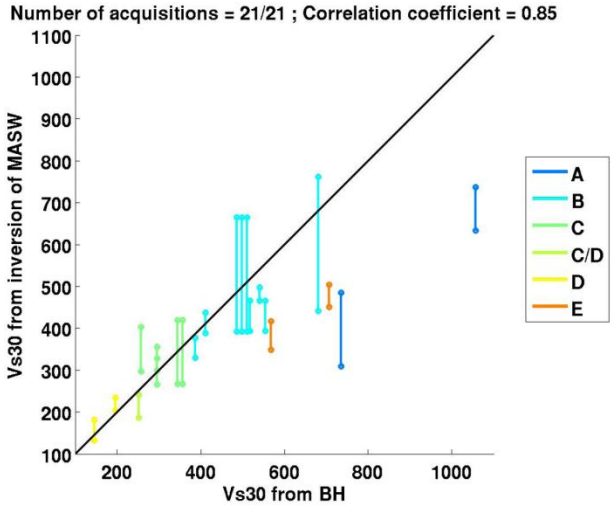
Non-invasive methods

- MASW (active)



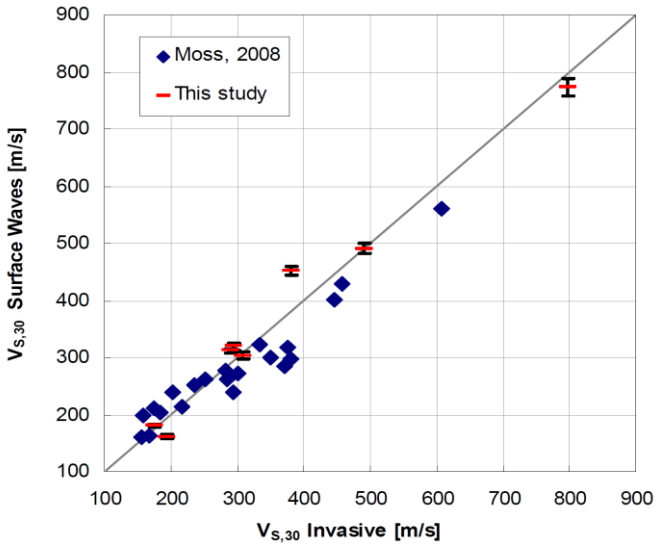
Testing non-invasive approaches: lots of works already done



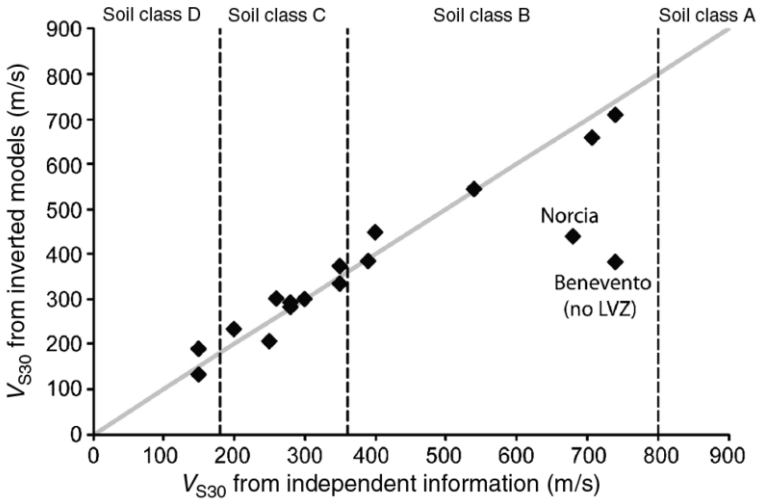


NERIES project (Renalier 2010, Renalier & Endrun 2009)

Moos (2008) and Comina et al. (2011)

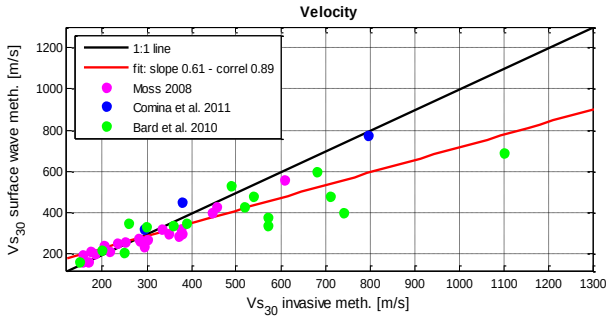


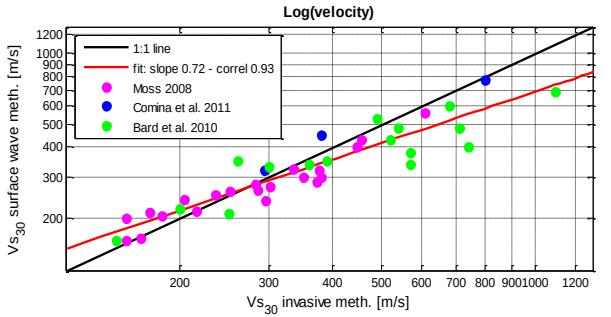
Di Giulio et al. 2012

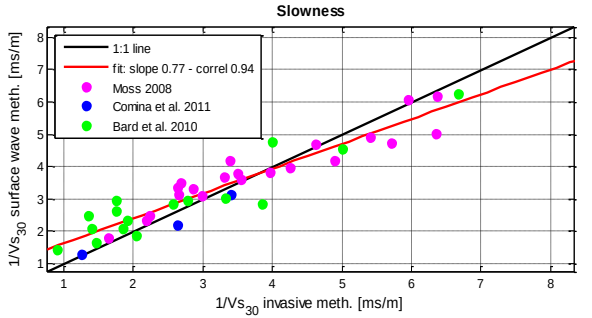


Testing non-invasive approaches: Vs30 synthesis

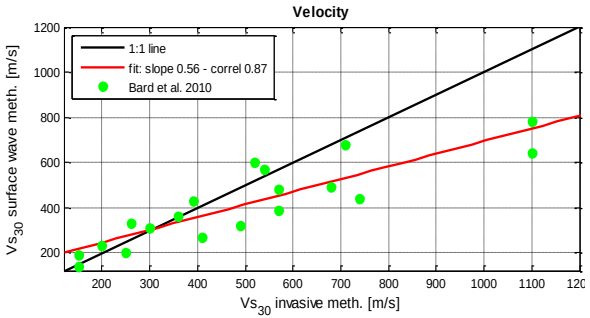
MASW only

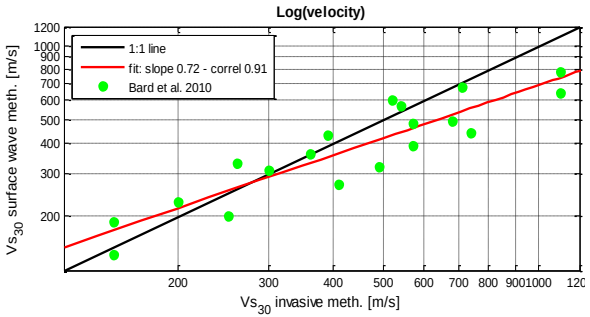


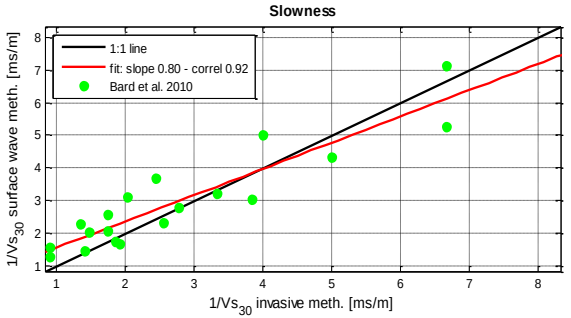




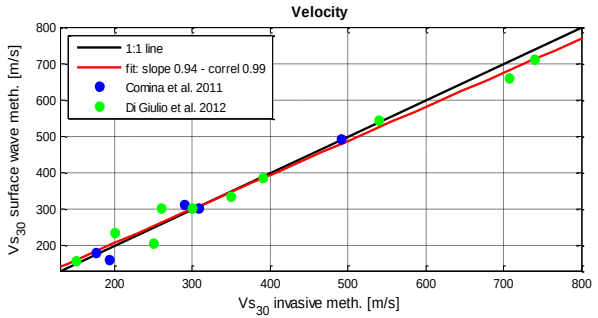
AMV only

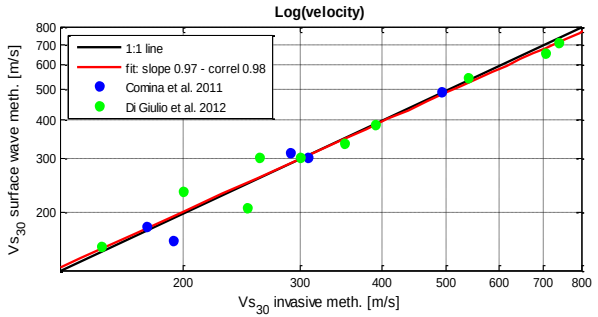


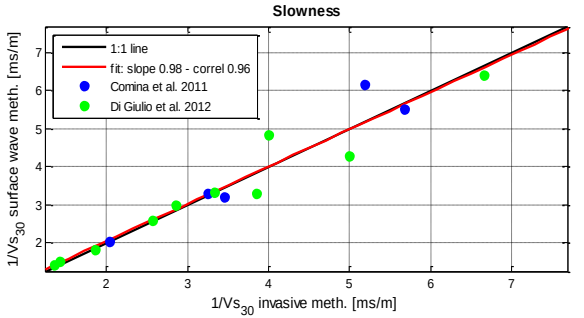




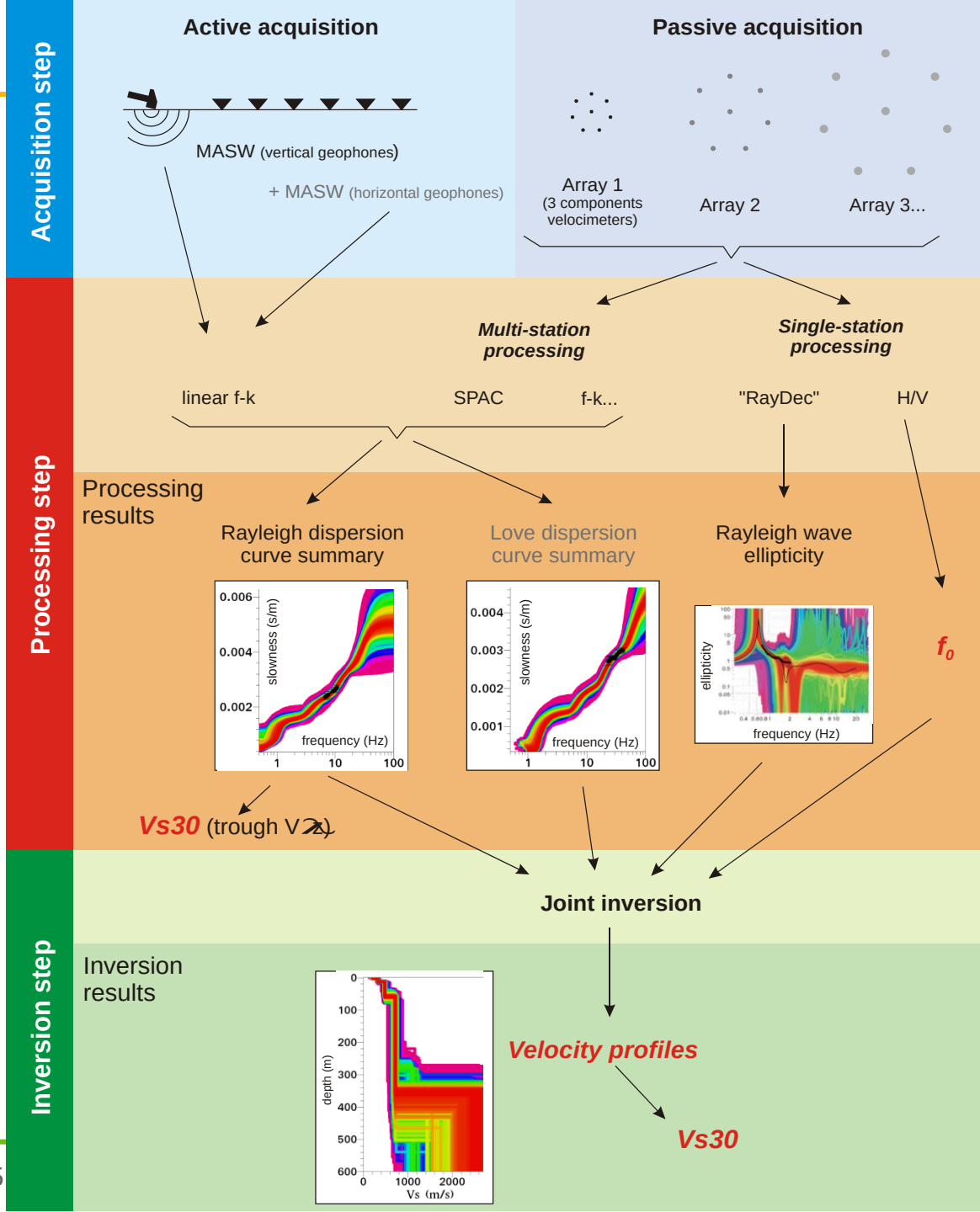
Joint inversion



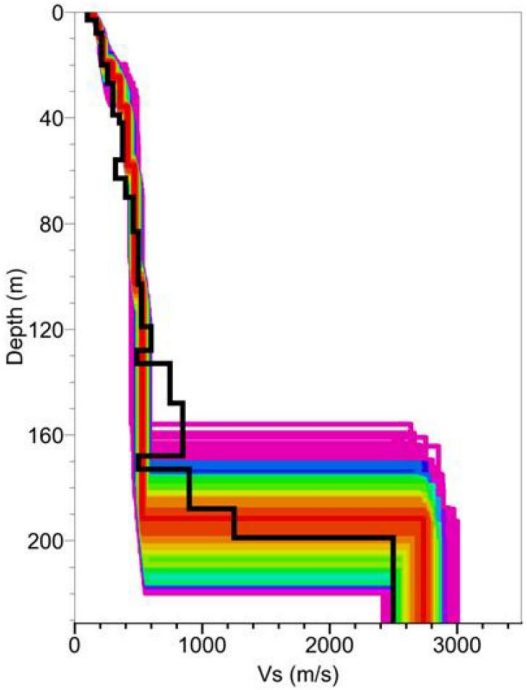




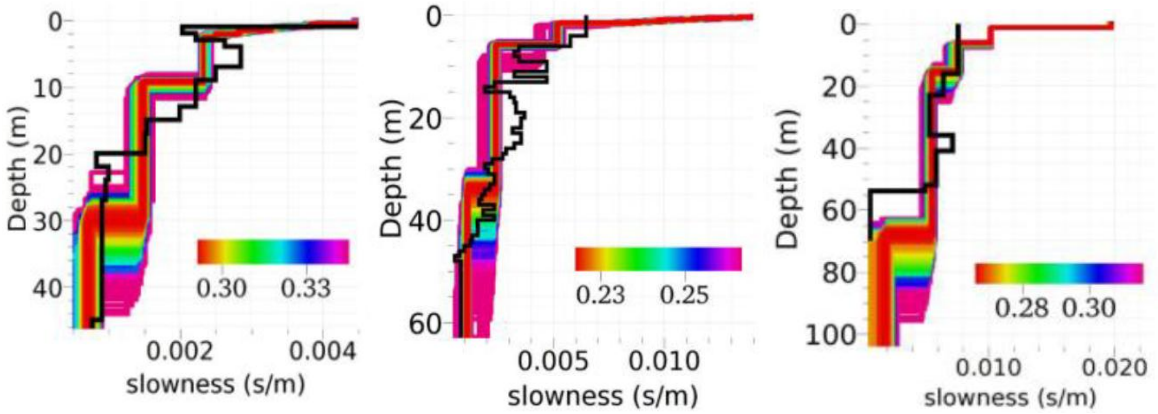
« state of the art »
of non-invasive surveys



Whole profile comparisson



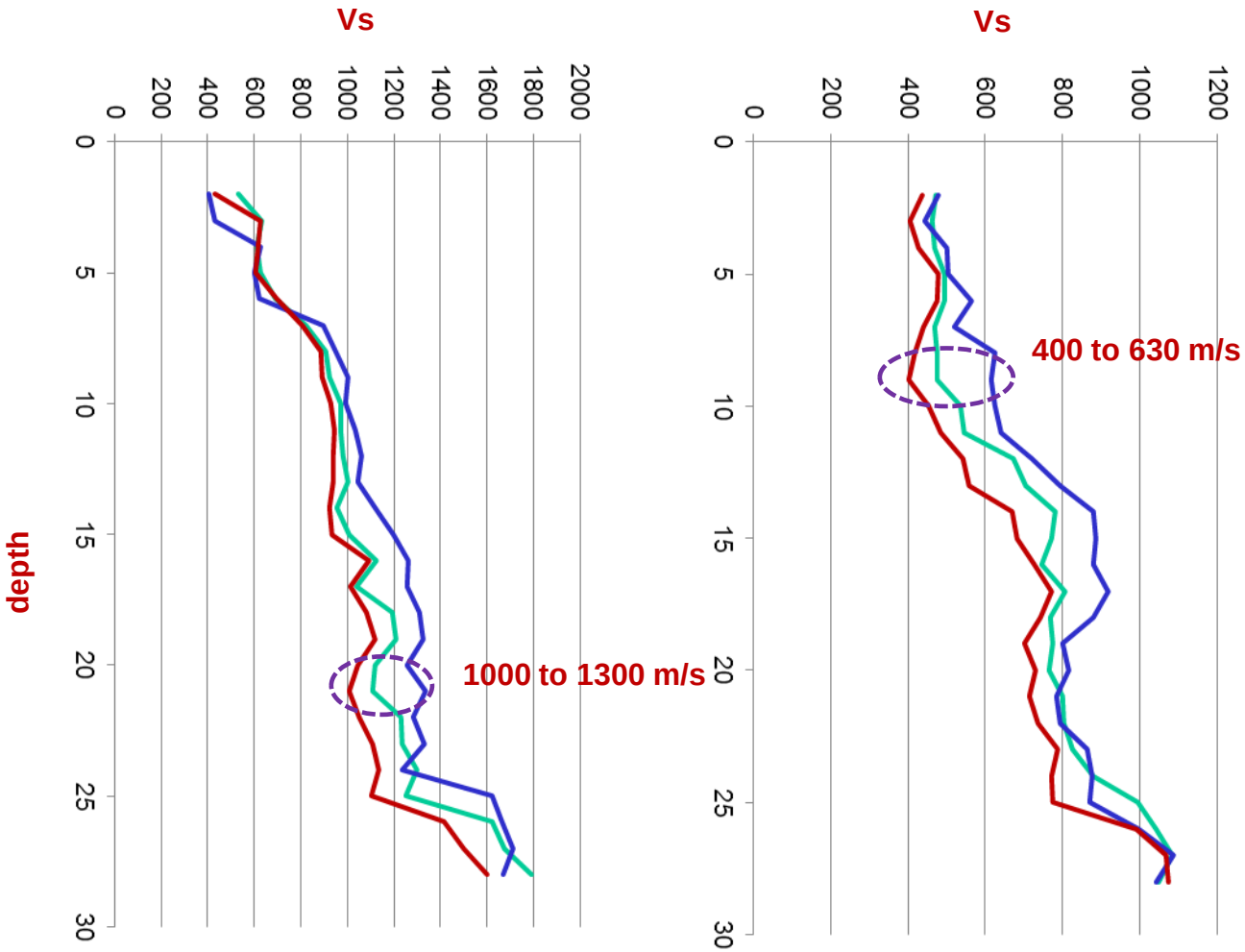
Renalier & Endrun (2009)



Di Giulio et al. 2012

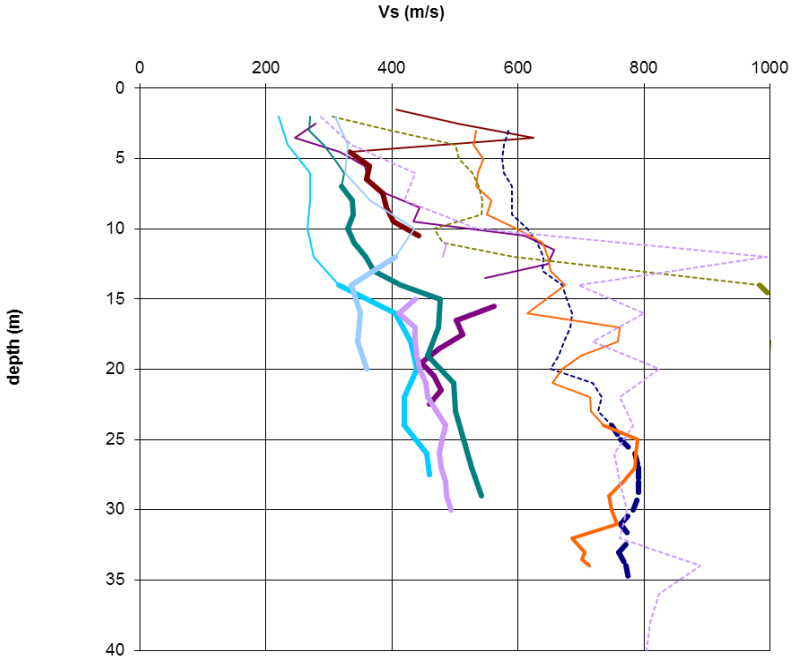
Are the cross-hole data (always) reliable?

- Site 1: same contractor, same campaign, CH carried out in triplets of boreholes (5 m spacing), velocity calculations by pairs.



Are the cross-hole data (always) reliable?

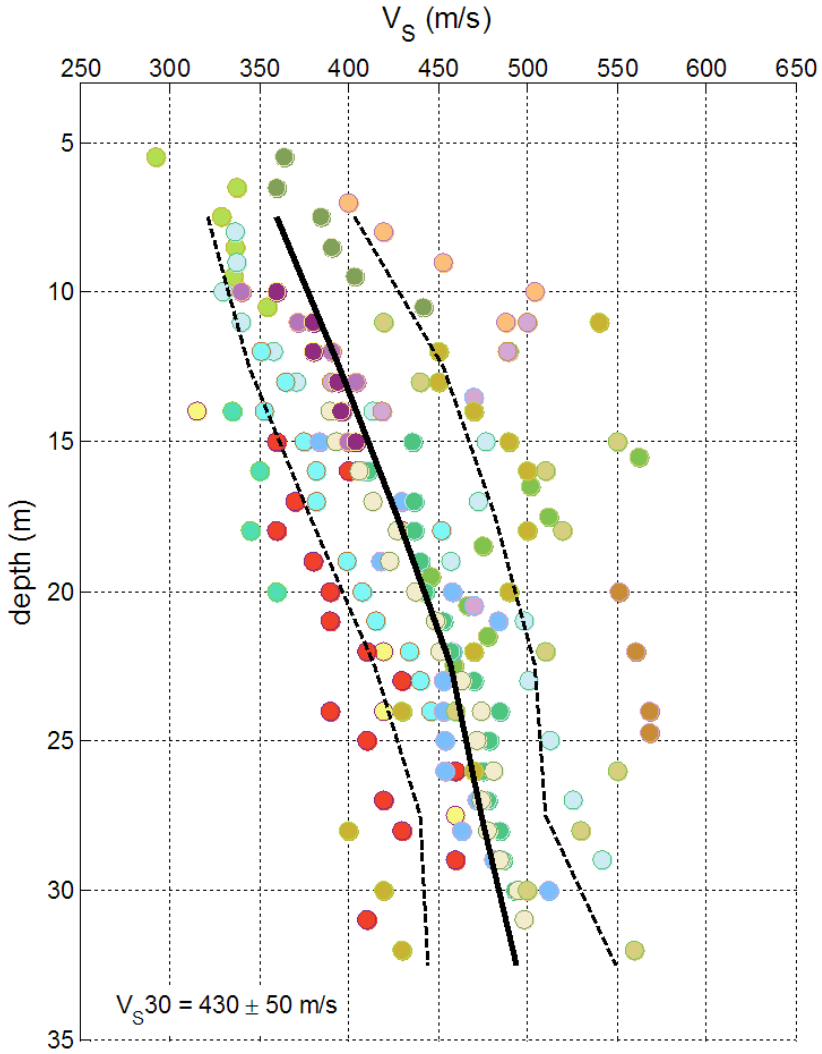
- Site 2 :



➔ two "populations" of cross-hole data non-correlated to the geology ... but contracting companies!

Are the cross-hole data (always) reliable?

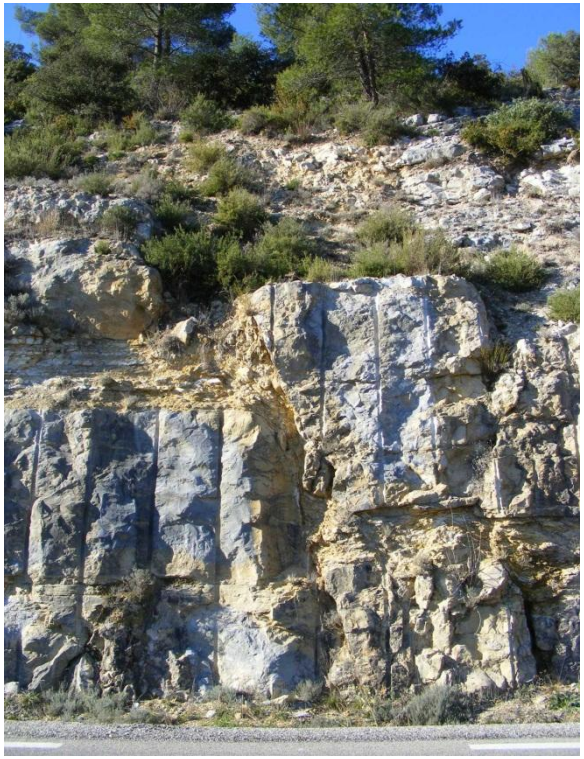
- Site 2: all measurements within the same geological formation (after rejecting abberent surveys)

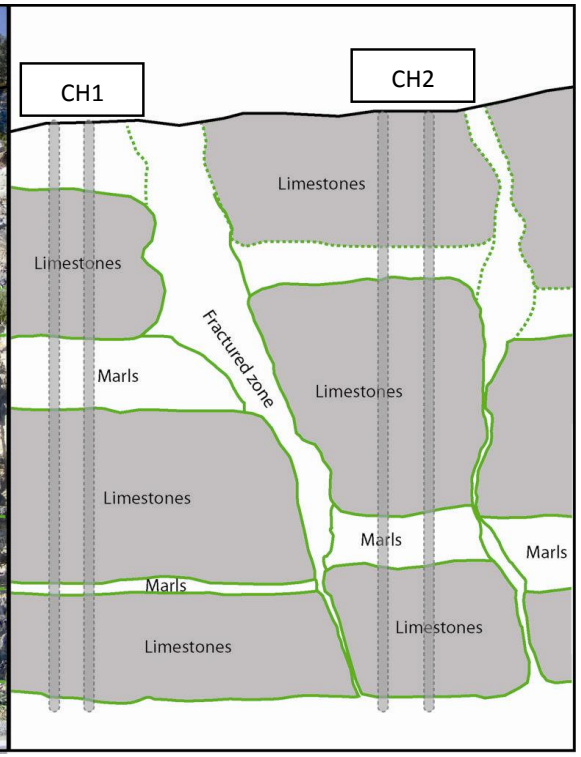


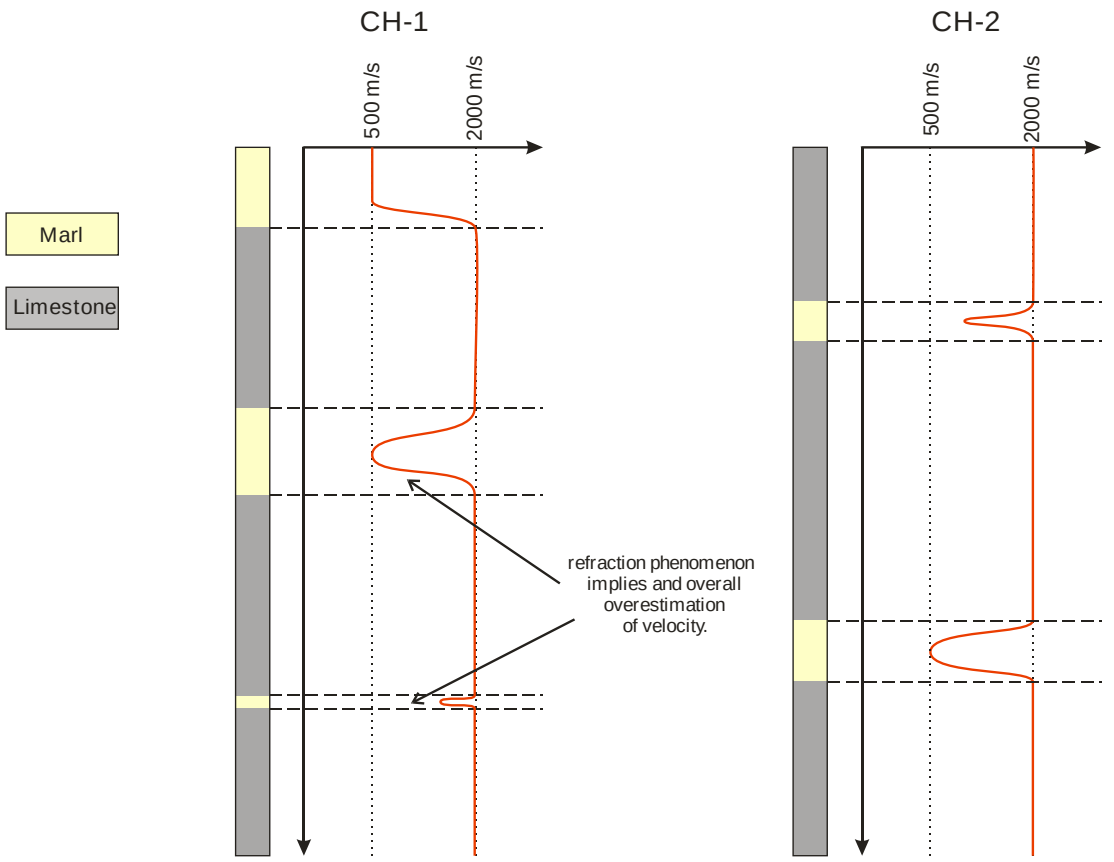
Are the results really comparable?

- Difference possible causes:
  - basic problem on a method of implementation in a given case,
  - anisotropy,
  - effects of frequency,
  - spatial variability,
  - damage produced by invasive methods.

« Virtual exercice » on variability

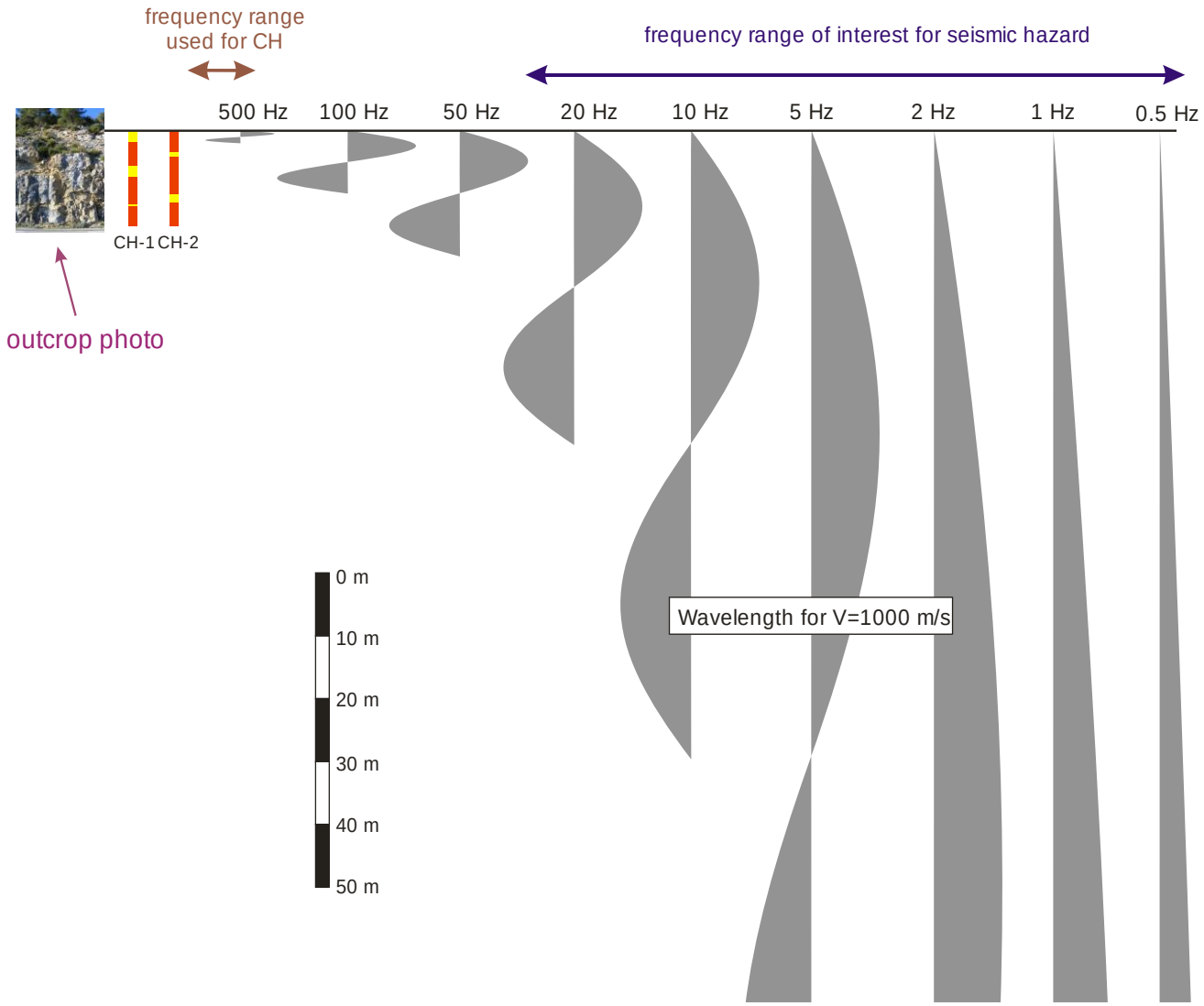






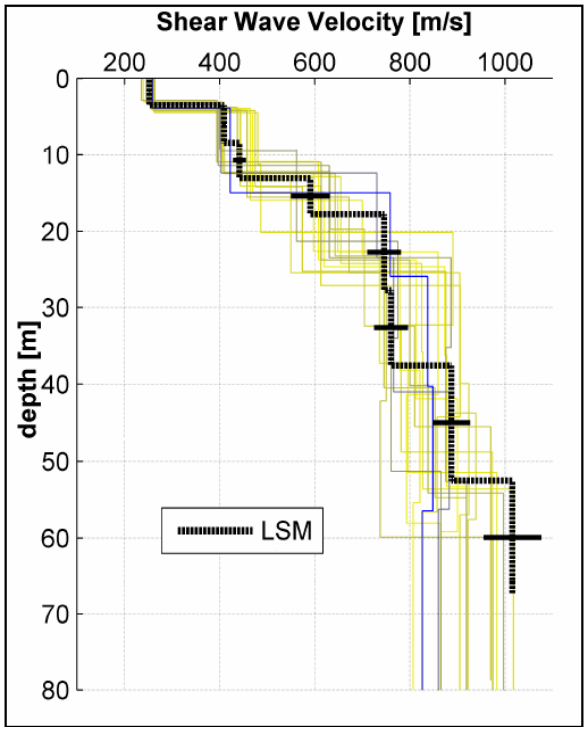
- Vs30 (CH1)
  - true: 1100 m/s
  - measuread: 1250 m/s
- Vs30 (CH2)
  - true: 1400 m/s
  - measuread: 1550 m/s
- Vs30 overall outcrop average:
  - 1000 m/s

Wavelengths

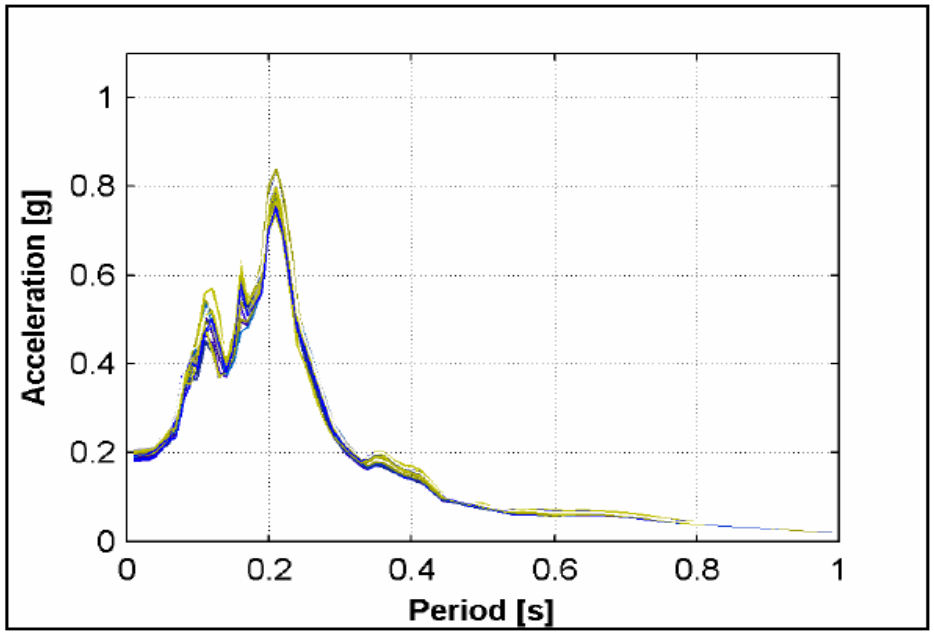


Is non-uniqueness an issue that disqualify non-invasive methods?

Numerous different profiles from one survey



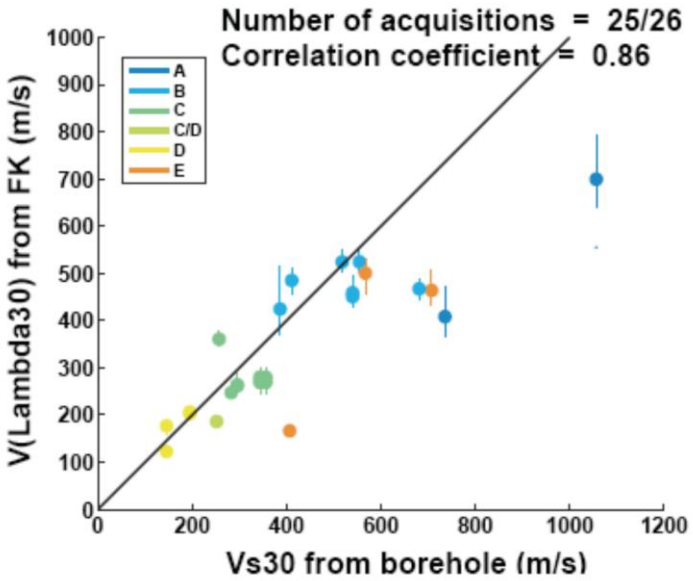
Similar 1D transfer function



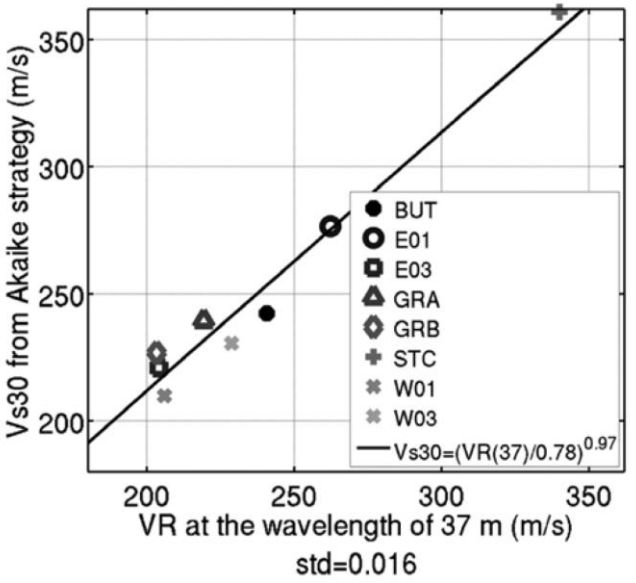
Foti et al. (2009)

Is non-uniqueness an issue that disqualify non-invasive methods?

- Retrieving Vs30 directly from dispersion curve (without inversion)



Comparison between Vλ30 and Vs30 derived from borehole measurements (Bard et al. 2010).



Comparison between Vλ37 and Vs30 derived from non-invasive measurements (Cadet and Savvaidis 2011).

Summary

- A lot of progress in non-invasive methods within the last few years, especially by the joint inversion of active/passive acquisition, Rayleigh/Love inversion etc.

- Invasive methods uncertainties probably underestimated.

- Choice of methods (in a real world):
  - depend on the objective
    - characterization for large / important facilities had to be

    ➔ *high quality characterization, with evaluation of spatial variability and uncertainties*

    ➔ ***Obviously, mix of invasive and non-invasive methods***
  - characterization of accelerometric network

    ➔ *need of cost-effective methods (number of stations, restricted budget…)*
  - application of regulation (eg. EC8) for all kind of buildings

    ➔ *budget even lower, but need to avoid bad quality works*

    ➔ ***Non-invasive method clearly a better alternative that "geological" or "slope" proxies***

- Now let's answer the previous question…

"In such a complex situation how to avoid the fight?"

… by an (inter-)pacification work!

“ Intercomparaison of methods for site parameter and velocity profile characterization”

(Inter-PACIFIC)

A benchmark to better understand differences and complementarities between invasive and non-invasive methods.

Main objectives

- “Confront” different characterization approaches (invasive and noninvasive) on a set of test-sites, with the following objectives:
    - better quantify the variability within and between-methods
    - better understand the phenomenological differences impacting the results between different methods
    - writing a "good practice guide" for non-invasive methods and testing this guide
- This project is open to teams that want to test their methods (acquisition on field and/or processing and inversion…)

Emphasized aspects

- In order to complement the previous benchmark / intercomparison projects, we will emphasize:
  - work on rock and hard-rock sites
  - sharing discussions with companies implementing invasive methods
  - writing “guidelines” for the use of invasive methods
  - “testing” the guidelines (blind-tests with end-users not involved in first phases of the project)

Test sites

- We target two categories of sites:
  - "Main" sites:
    - 3 to 4 sites with different features : soft soil / stiff soil / rock / hard rock
    - where we will perform :
      - new invasive measurements by at least two different contractors: crosshole, downhole, PS-suspension logging,
      - a whole set of non-invasive surveys : ambient vibration arrays with different geometries, active surface wave methods (MASW), ...
    - the sites will be left open (at least one year) to all contributing teams that want to perform their own experiments (including boreholes).
    - *could be linked to other projects in order to reduce respective costs*
  - "Complementary" sites:
    - ~ 10 sites, preferably from stiff soil to hard rock (to complement previous works),
    - where recent invasive measurements have already been done (and where results are available)
    - where we will perform a "standard" set of non-invasive surveys (to be defined : at least MASW and Ambient Vibration Array with a standard geometry)

Possible main test-sites (non invasive methods)

- Soft soil: (Vs30 ~ 200 m/s)
  - Casaglia (Italy)
- Stiff soil: (Vs30 ~ 400 m/s)
  - Grenoble (downstream valley) with an “inverted” velocity profile
- Rock site: (Vs30 ~ 800 m/s)
  - ➔ to be found, on a key accelerometric station (ITACA, RAP?)
- Hard rock site: (Vs30 > 1500 m/s)
  - Cadarache (France)

General schedule (proposition)

- Phase 1:
  - choice of sites,
  - realization of invasive and non-invasive measurements,
  - at least two “iterations” of data processing and inversion *(the first one in “blind” conditions, without having access to invasive surveys results?)*
  - at least two workshops of two days in order to exchange results and to discuss with participating team

- Phase 2:
  - results communication,
  - writing “guide-lines” for the use of surface-wave based noninvasive methods.

- Phase 3:
  - “testing” the “guide-lines” by involving possible further users, asking them to process and inverse in blind conditions, the previously acquired data.

Link with seismological approaches

- Surveys on accelerometric network stations (ITACA & RAP) in order to:
  - « test » on field constraints (time, etc.),
  - confront 1D computed response with transfer function computed with generalized inversion technics,

  - A mid term (within the next 12 months)
    - 6 to 10 stations in Pyrenees
    - 6 to 10 stations in North Italy

    (stations chosen with WP2 package)

… at the end of the project, perhaps that « kappa» will be set free?