Non-linear Inversion of Noise Cross-correlations Using Probability Density Functions of Surface Waves Dispersion

Ianis Gaudot [1] *, Éric Beucler [1], Antoine Mocquet [1], Mélanie Drilleau [2], Mathieu Le Feuvre [3]

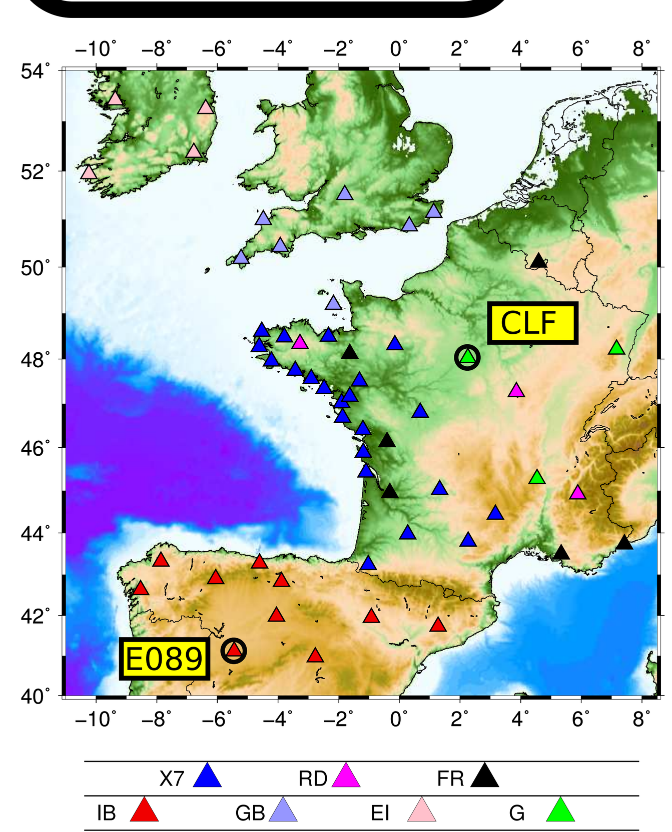
[1] Laboratoire de Planétologie et de Géodynamique, UMR CNRS 6112, Nantes, FRANCE
[2] Institut de Physique du Globe, Paris, FRANCE [3] Laboratoire Auscultation et Imagerie, IFSTTAR, Nantes, FRANCE

* Contact : ianis.gaudot@univ-nantes.fr

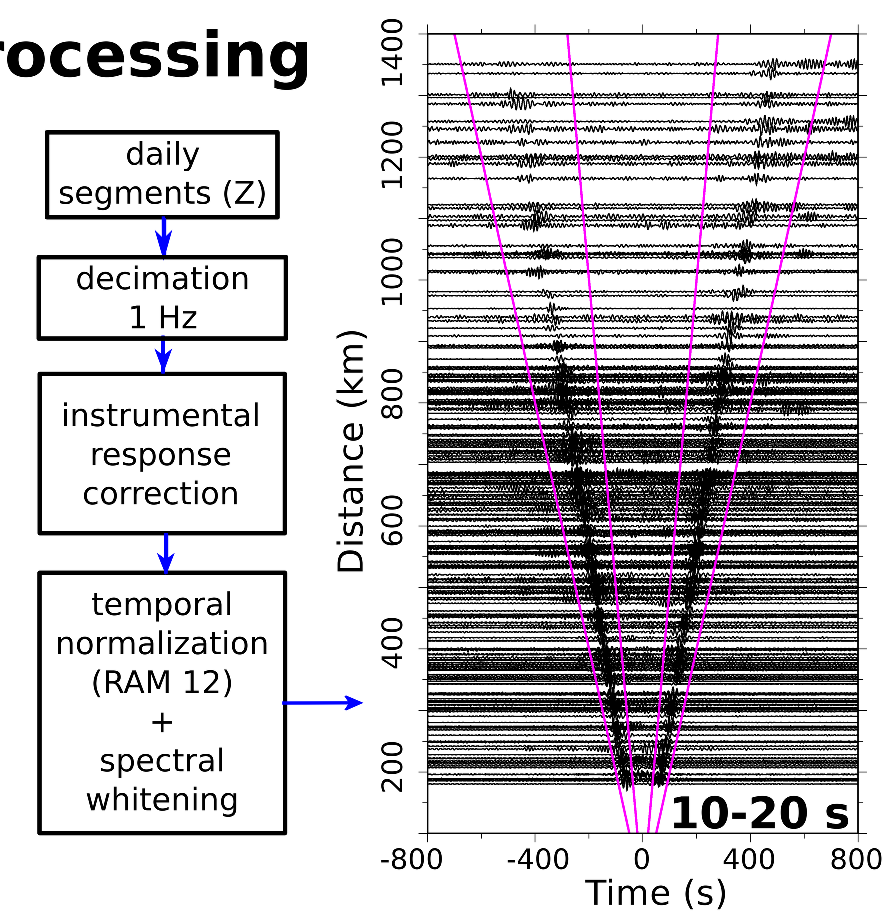
Abstract

Correlations of ambient seismic noise are widely used to retrieve the information of the medium between pairs of stations. For periods between 1 and 50 s, the wavefield is dominated by surface waves energy. Therefore, information about the structure are obtained using dispersion analysis, i.e computing phase or group velocities. Classical group velocity determination relies on tracking the maximum energy in the dispersion diagrams in order to get a unique dispersion curve. This procedure may often present problems due to the presence of several maxima. Moreover, the estimation of associated measurement errors usually depends on ad hoc user's criteria. We handle the non-unicity of the problem by inverting the whole dispersion diagram using a non-linear inversion scheme. For each frequency, the seismic energy is mapped into a time-dependent probability density function. The resulting map is inverted for the S-wave velocity structure using a Monte Carlo Markov chain algorithm.

Data

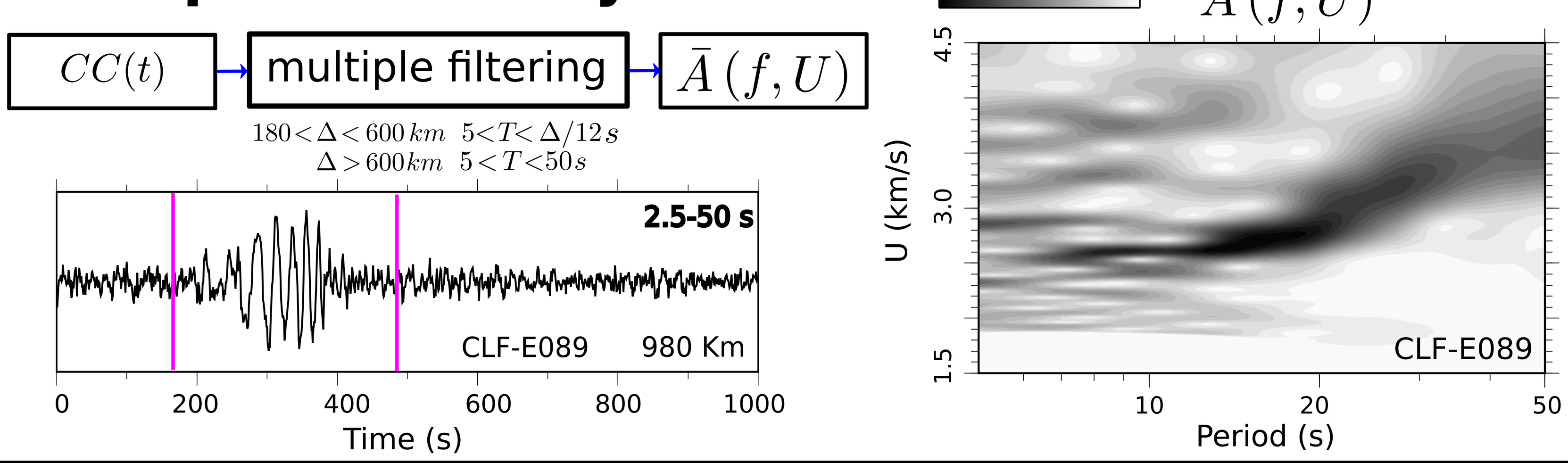


Processing

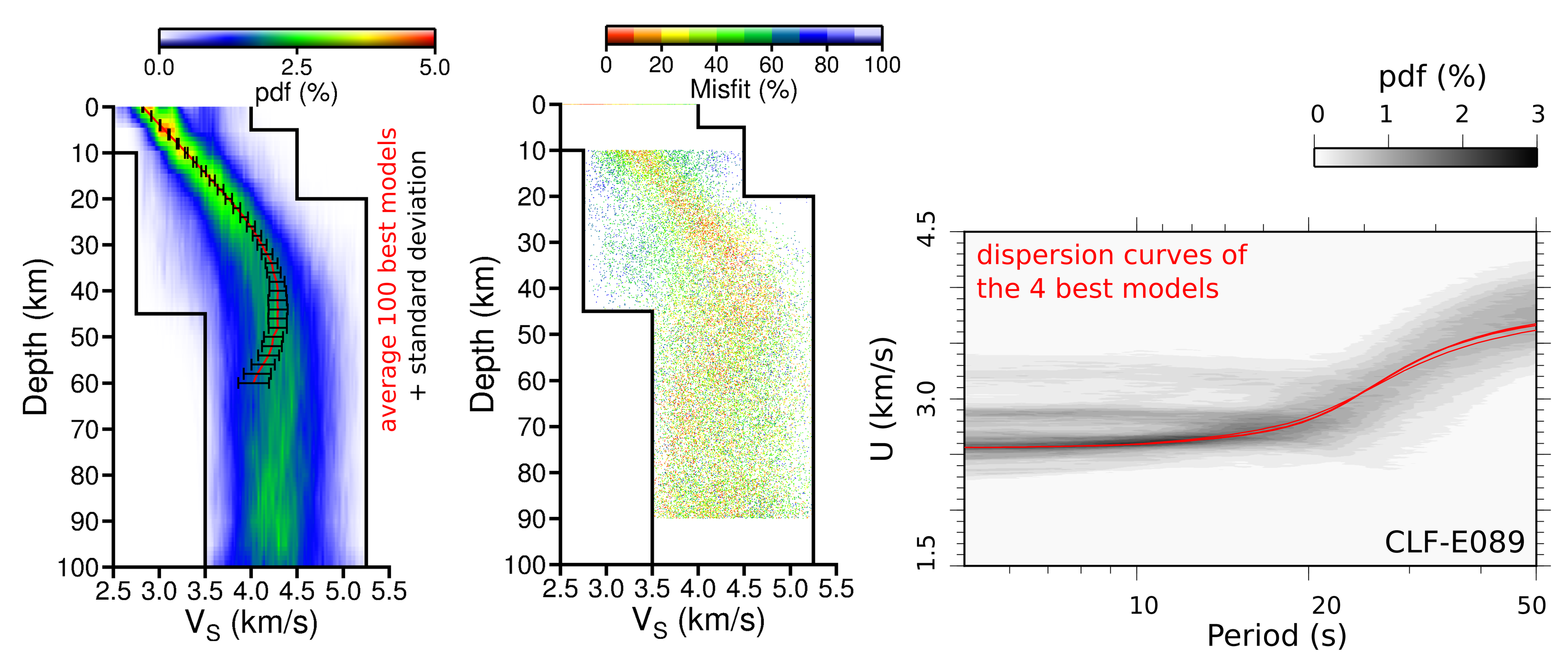


CLF-E089 station pair used as real data example

Dispersion analysis

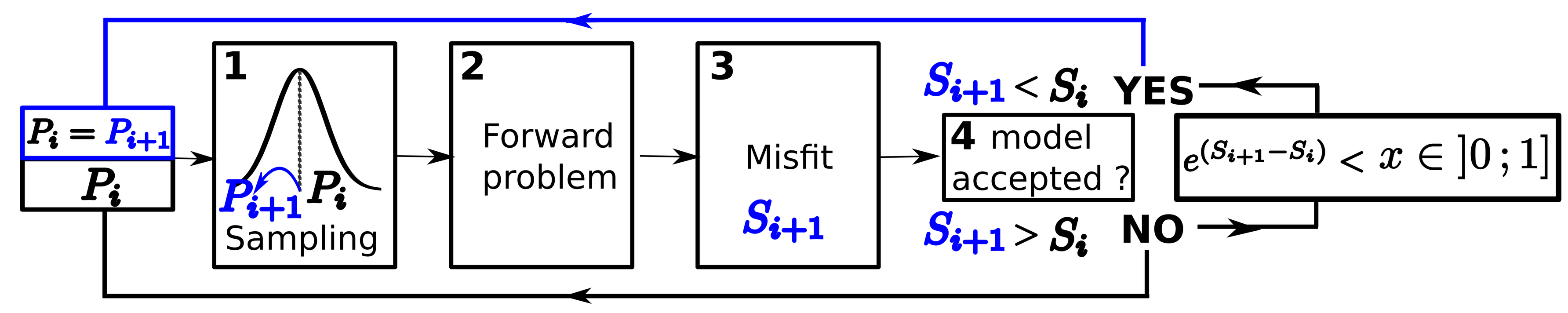


Real data example



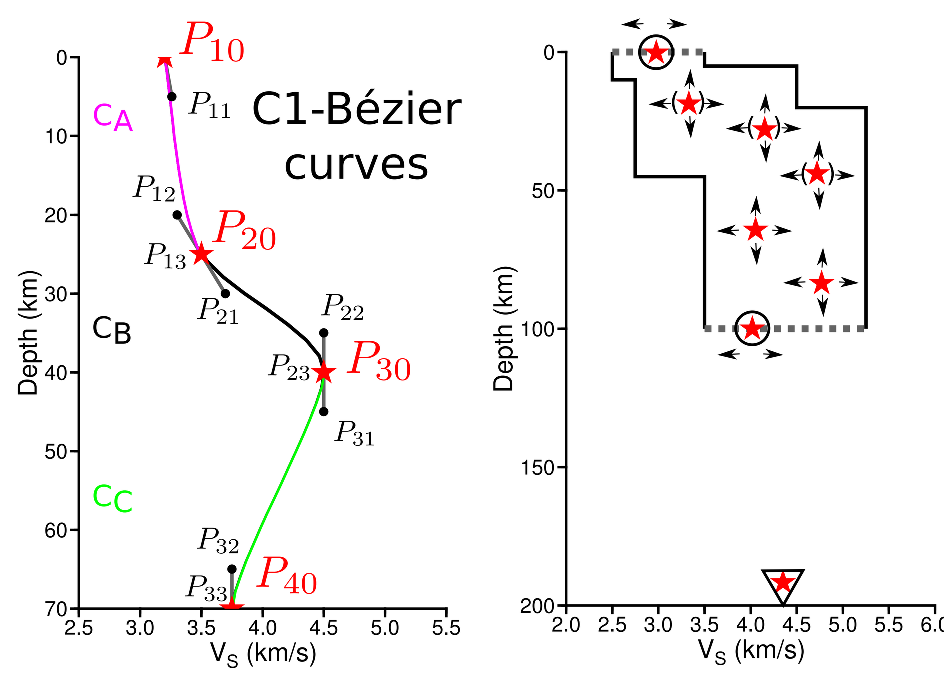
Non-linear depth inversion

McMC inversion scheme

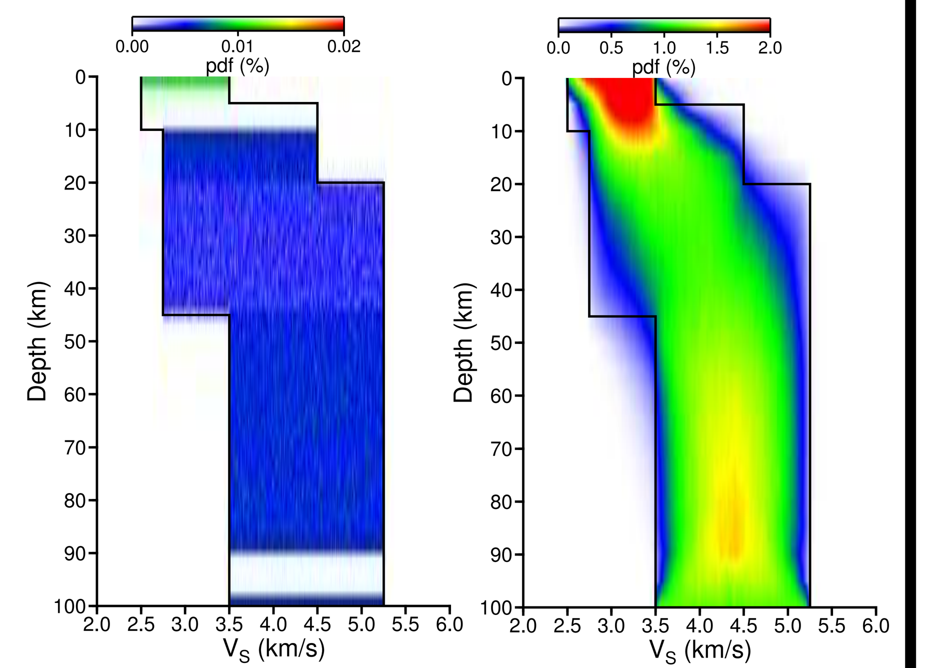


Parametrization

(Drilleau et al., 2013)



Prior information



Forward problem

Computation of group velocity dispersion of fundamental mode Rayleigh wave (Herrmann, 2013)

$U_{th}(i)$ for $i = 1, nf$

Misfit

Computation on dispersion map

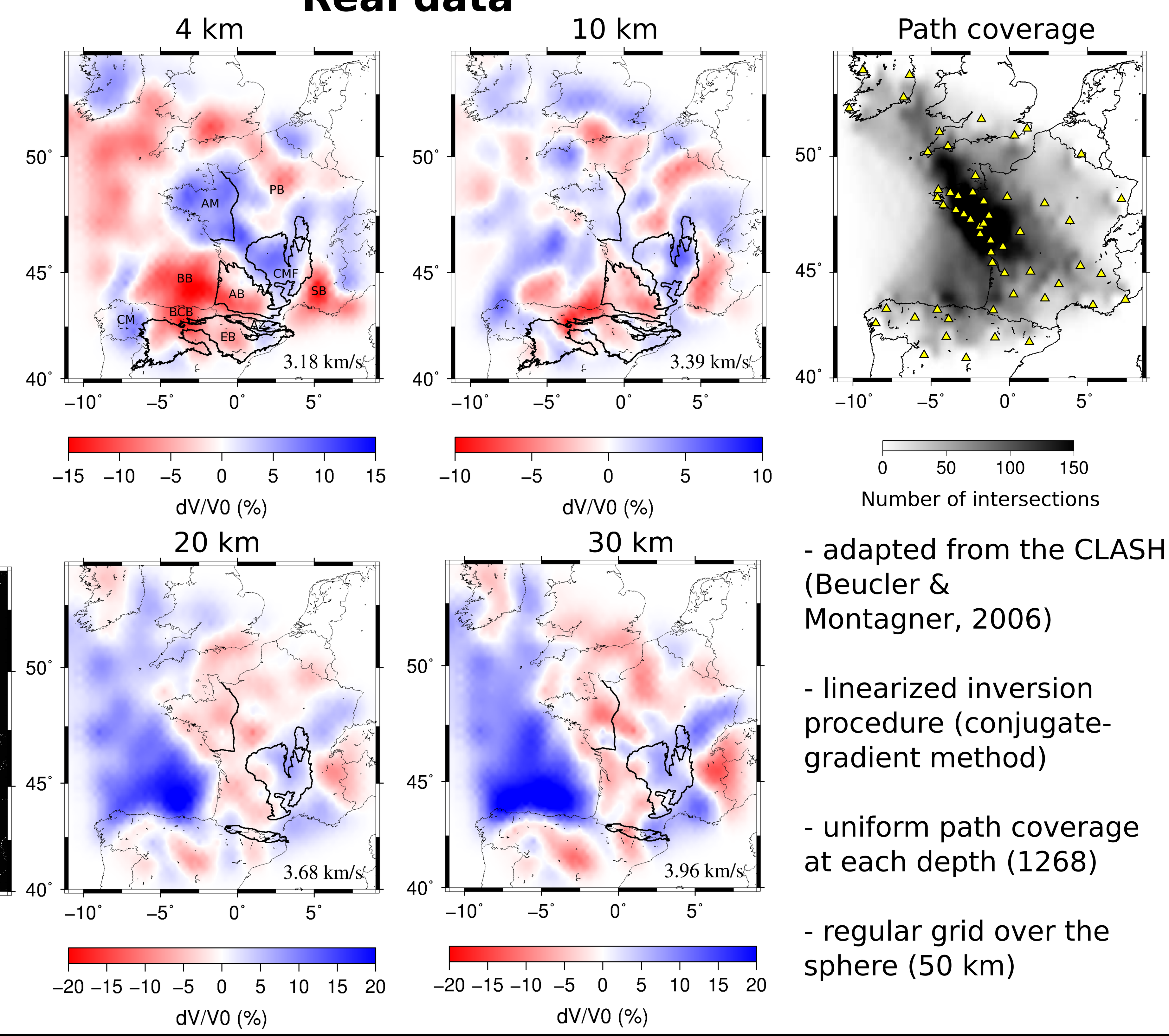
$$S = \sum_{i=1}^{nf} \bar{A}(f(i), U_{th}(i))$$

S-wave velocity maps

EB : Ebro basin
BCB : Basque Cantabrian basin
BB : Bay of Biscay
AB : Aquitain basin
PB : Parisian basin

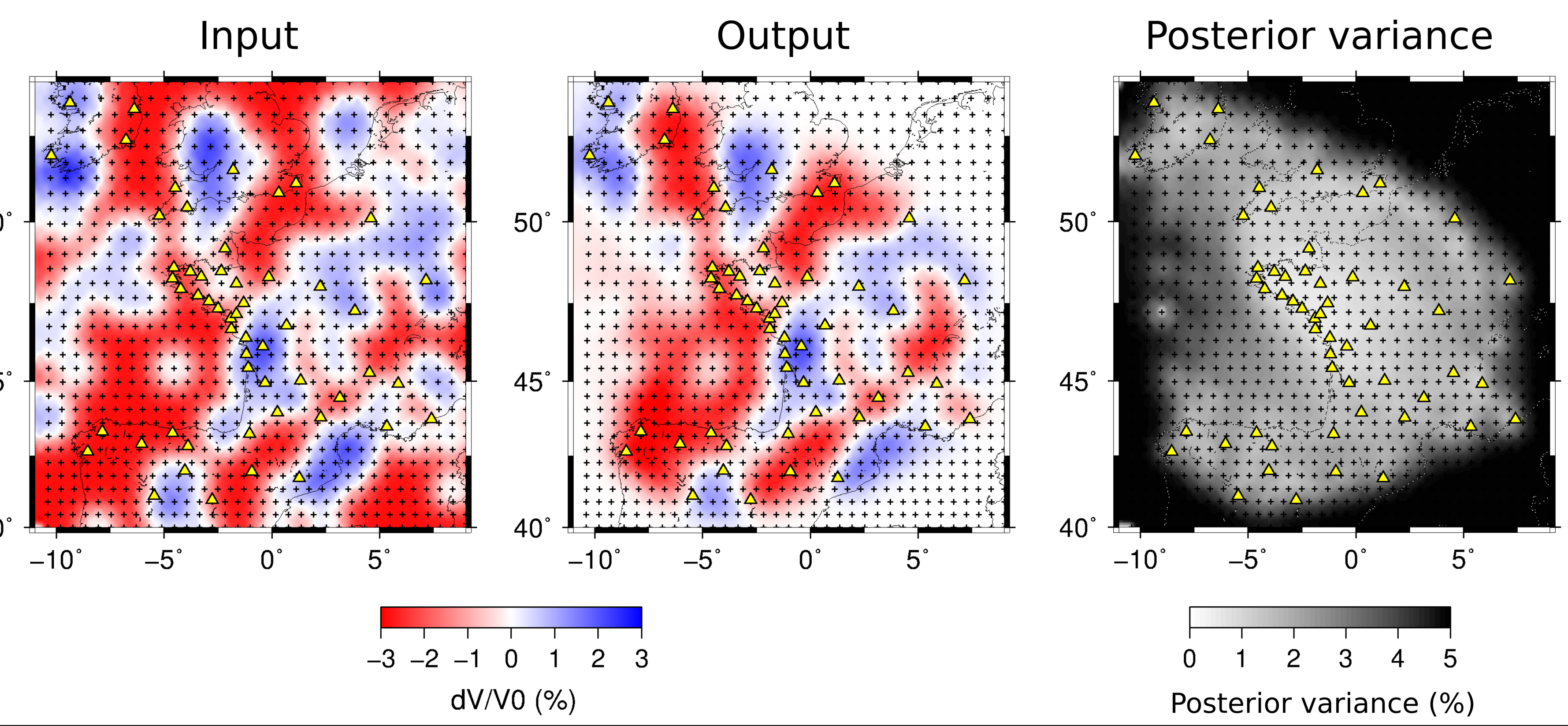
AM : Armorican Massif
CMF : Central Massif
AZ : Axial zone of the Pyrenees
CM : Cantabrian moutains

Real data



- adapted from the CLASH (Beucler & Montagner, 2006)
- linearized inversion procedure (conjugate-gradient method)
- uniform path coverage at each depth (1268)
- regular grid over the sphere (50 km)

Synthetics



Conclusion

The use of probability density functions of ambient noise correlation dispersion coupled to a non-linear inversion scheme allow us to successfully build a 3D Vs model of western France and the surrounding area. A careful analysis of the velocity maps and comparisons with previous studies (Macquet et al, 2014 ; Chevrot et al, 2014) are required in order to interpret the observed seismic structures in term of geodynamics. Due to high path coverage, the Armorican massif area is well resolved. This region will be analyzed in details since very few pictures of the crustal structures exist beneath this area.

Drilleau M. et al. (2013), A Bayesian approach to infer radial models of temperature and anisotropy in the transition zone from surface wave dispersion curves. **Herrmann R.B.** (2013), Computer programs in seismology : an evolving tool for instruction and research. **Macquet M. et al.** (2014), Ambient noise tomography of the Pyrenees and the surrounding regions: inversion for a 3-D Vs model in the presence of a very heterogeneous crust. **Chevrot S. et al.** (2014), High-resolution imaging of the Pyrenees and Massif Central from the data of the PYROPE and IBERARRAY portable array deployments. **Beucler and Montagner**, (2006), Computation of Large Anisotropic Seismic Heterogeneities. Thanks to S.Chevrot for the geological contours and M. Haugmard for fruitful discussions.

This work is part of I. Gaudot Ph.D thesis, in the framework of the VIBRIS project sponsored by the Région des Pays de la Loire in collaboration with IFSTTAR.