Exploring sedimentary basins with Receiver Functions: the Dublin Basin case study

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The SIM-CRUST project

*"**S**eismic **I**maging and **M**onitoring of the upper **CRUST**: exploring the potential low-enthalpy geothermal resources in Ireland"*

Grant Number 11/SIRG/E2174

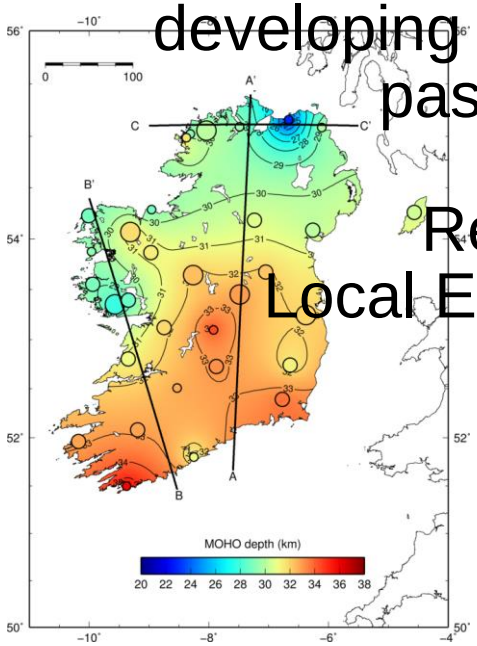
PASSIVE seismic methods applied to geothermal research

Goals:

- **Regional scale study (Moho depth and Vp/Vs ratio)**
- **Local scale studies focused on potential geothermal targets.**

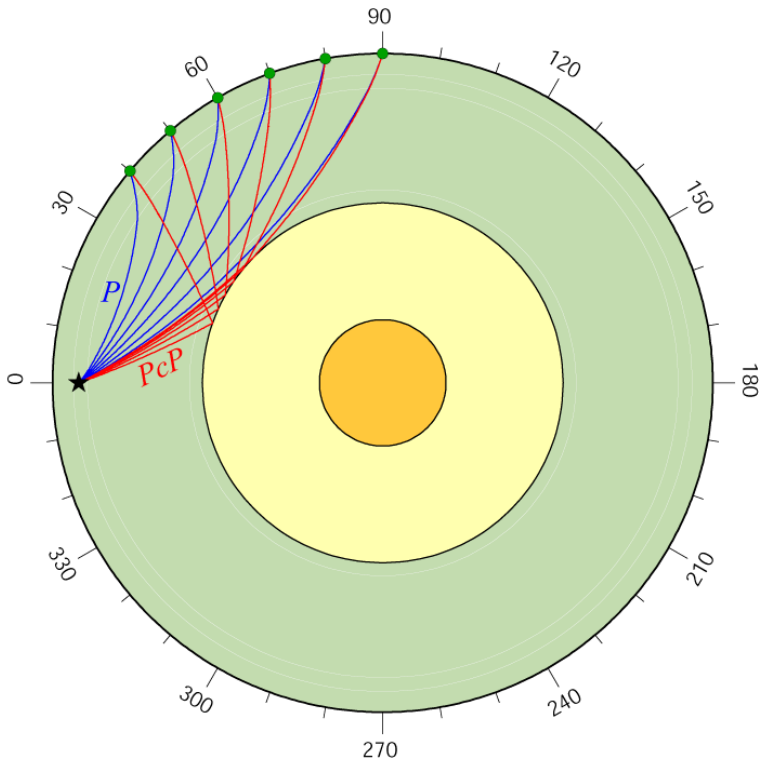
developing and testing **new techniques** for passive seismic exploration

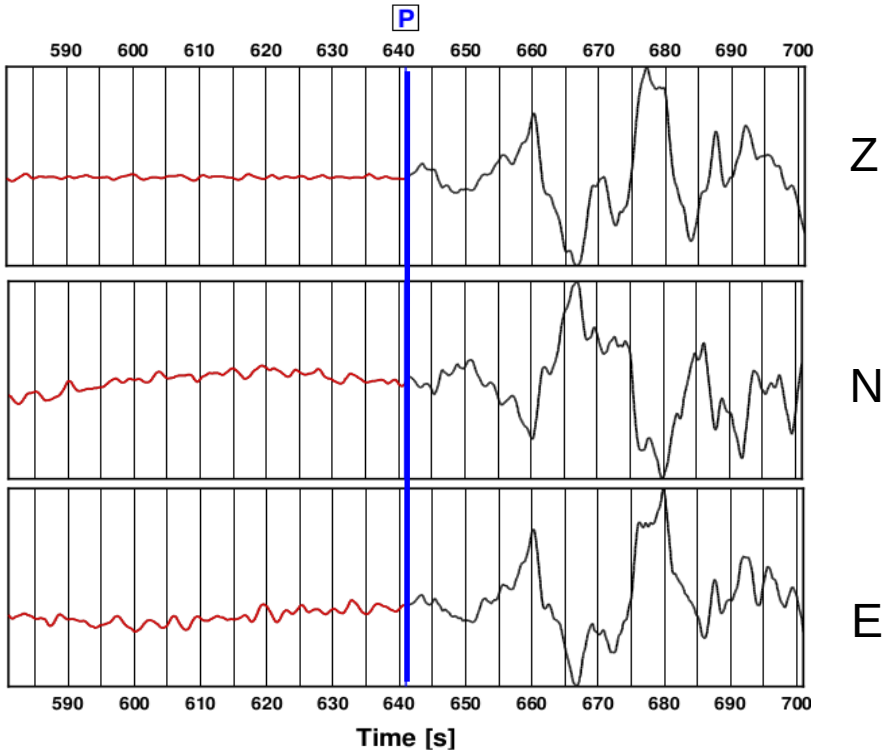
Receiver Functions (RF)
Local Earthquke Tomography (LET)



Licciardi et al. (2014)

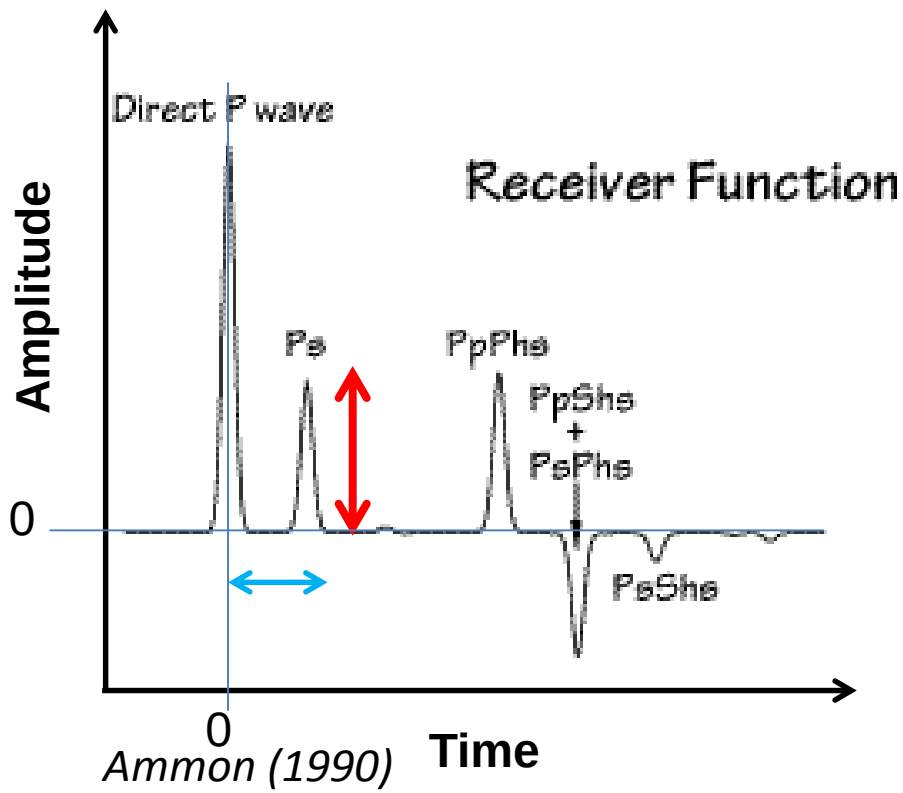
The Receiver Function (RF) method





- The **P-coda** of a teleseismic P-wave arrival contains the P-to-S conversion at **sharp velocity contrasts** in the Earth;
- Depth of the velocity contrast;
- Seismic velocities (Vs and Vp/Vs) within the Earth.
- **Single station** method (broadband, three component seismic station);
- Imaging tool for crust - upper mantle - Transition Zone

Amplitude and delay time

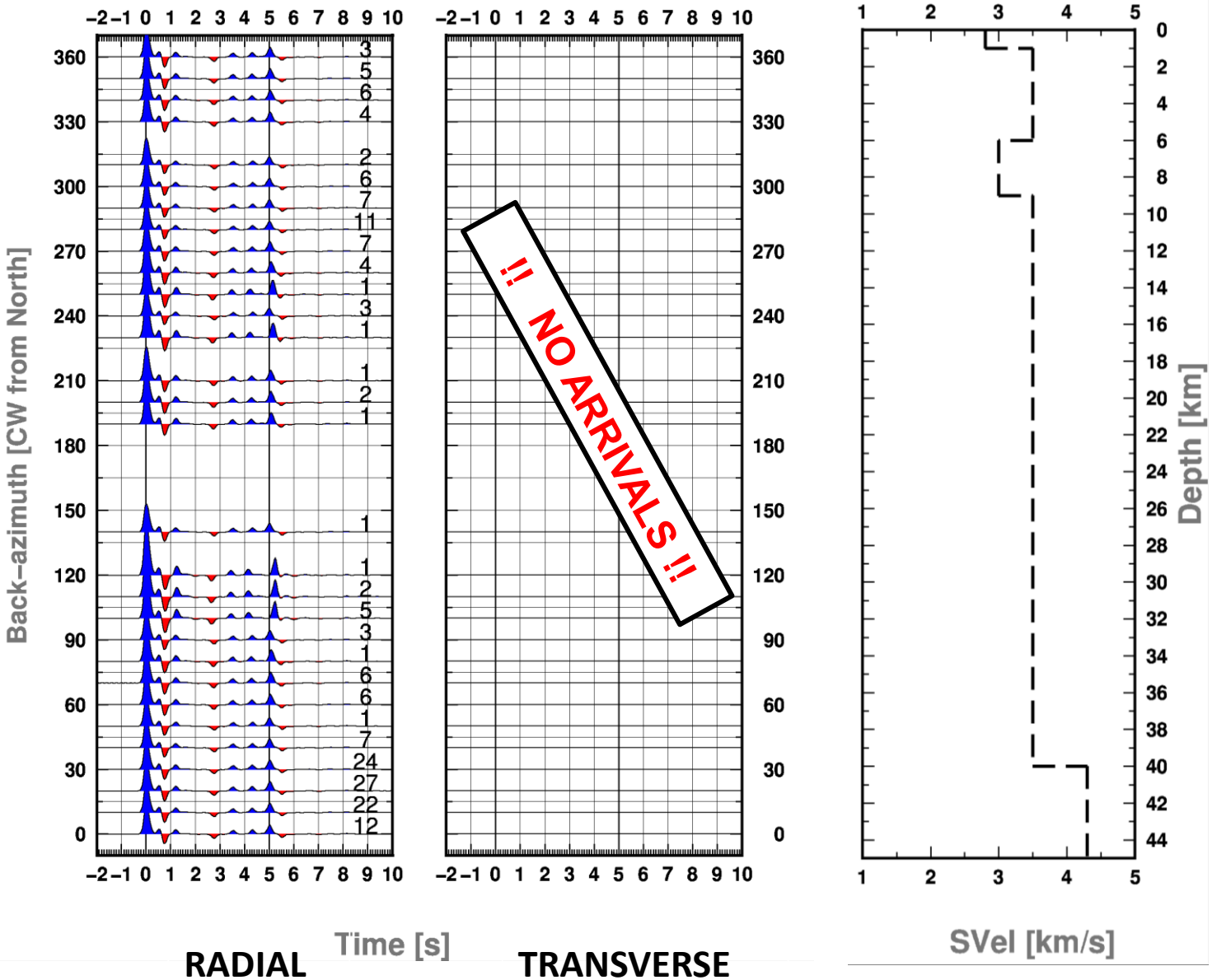


Ammon (1990)

- The **amplitudes** in the RF depend on the incidence angle and the intensity of the **velocity contrast** that generate each phase.
- The **delay time** of each phase (e.g. **Ps**) depends on the **depth** of the velocity contrast, the incidence angle and the **seismic velocities**.

Many RF are computed for one station from earthquakes coming from different directions and distances.

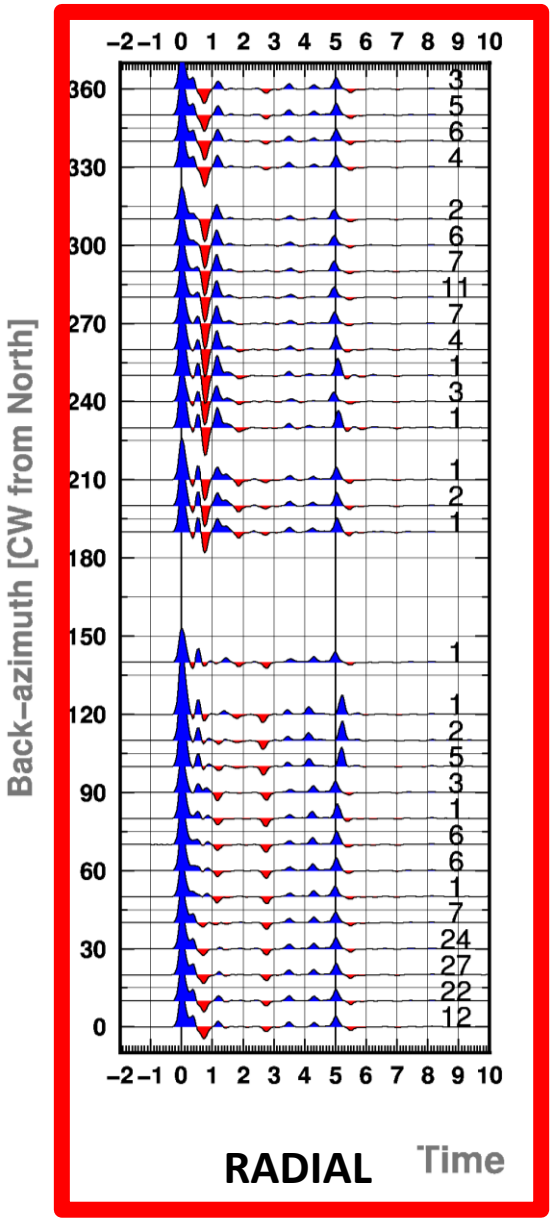
ISOTROPIC CASE – synth.

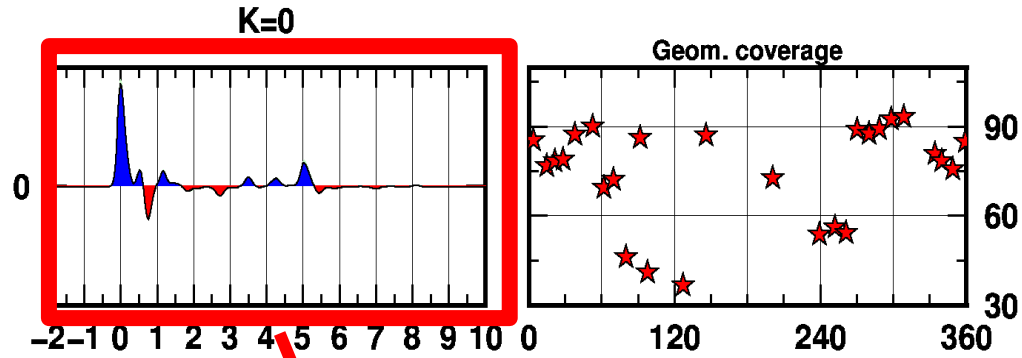


Blue pulses: positive velocity contrast (Vs is increasing with depth).

Red pulses: negative velocity contrast (Vs is decreasing with depth).

ANISOTROPIC CASE – synth.

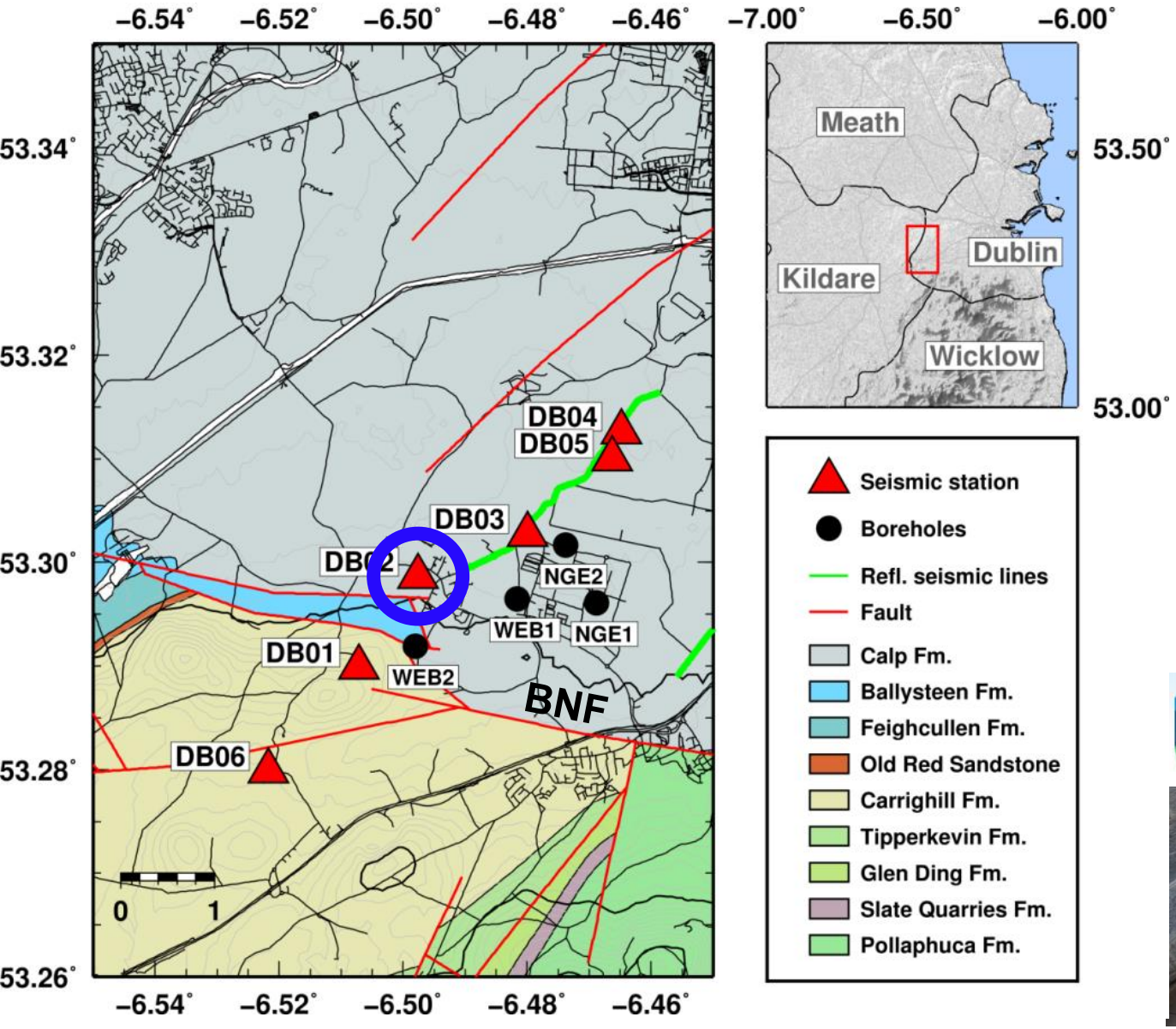




!! Focus on the ISOTROPIC structure !!

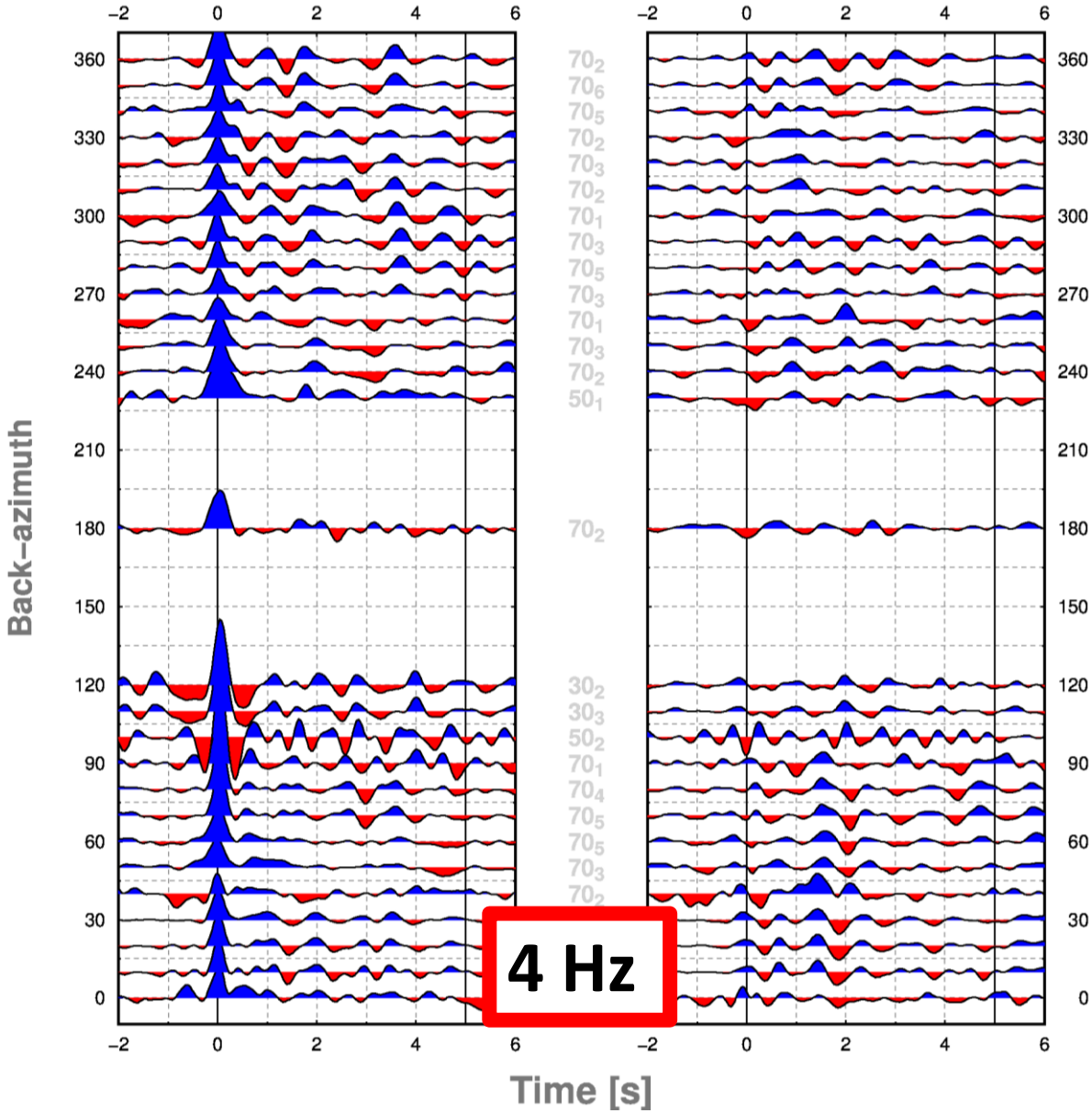
Inversion of multi-frequency k=0 to obtain 1D Vs profiles

The Dublin Basin experiment



- 6 broadband seismic stations
- Linear array
- Spacing ~ 1 km
- Crossing the Blackrock-Newcastle Fault (BNF)

RF examples station DB02



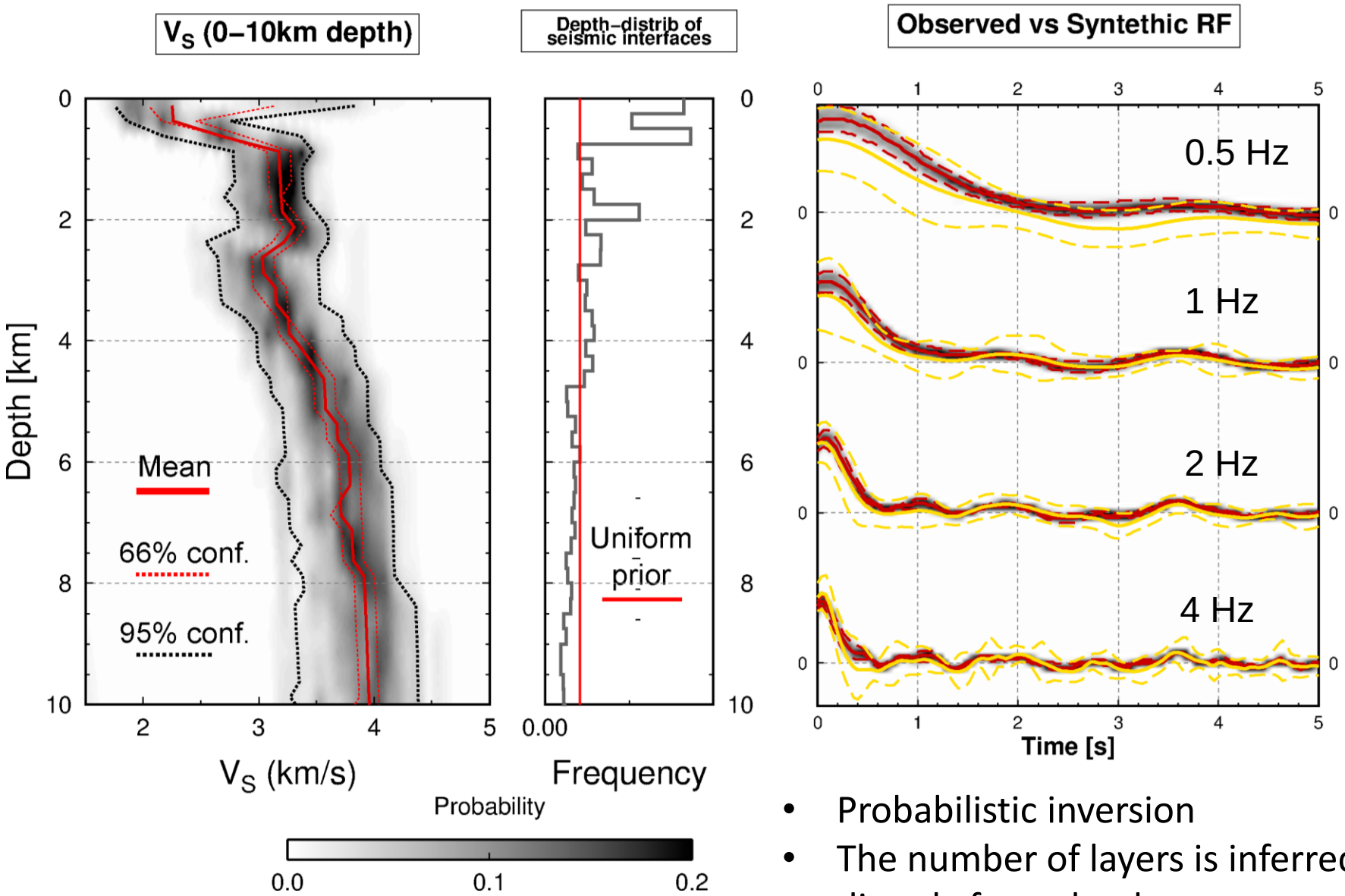
RF used for classical crustal and upper-mantle imaging: 0.5 – 1 Hz.

Progressively increasing the frequency content in the computed RF, highlight features in the upper crust and allows for better absolute velocities estimation.

This station is in the village of Newcastle. Surprisingly good data!

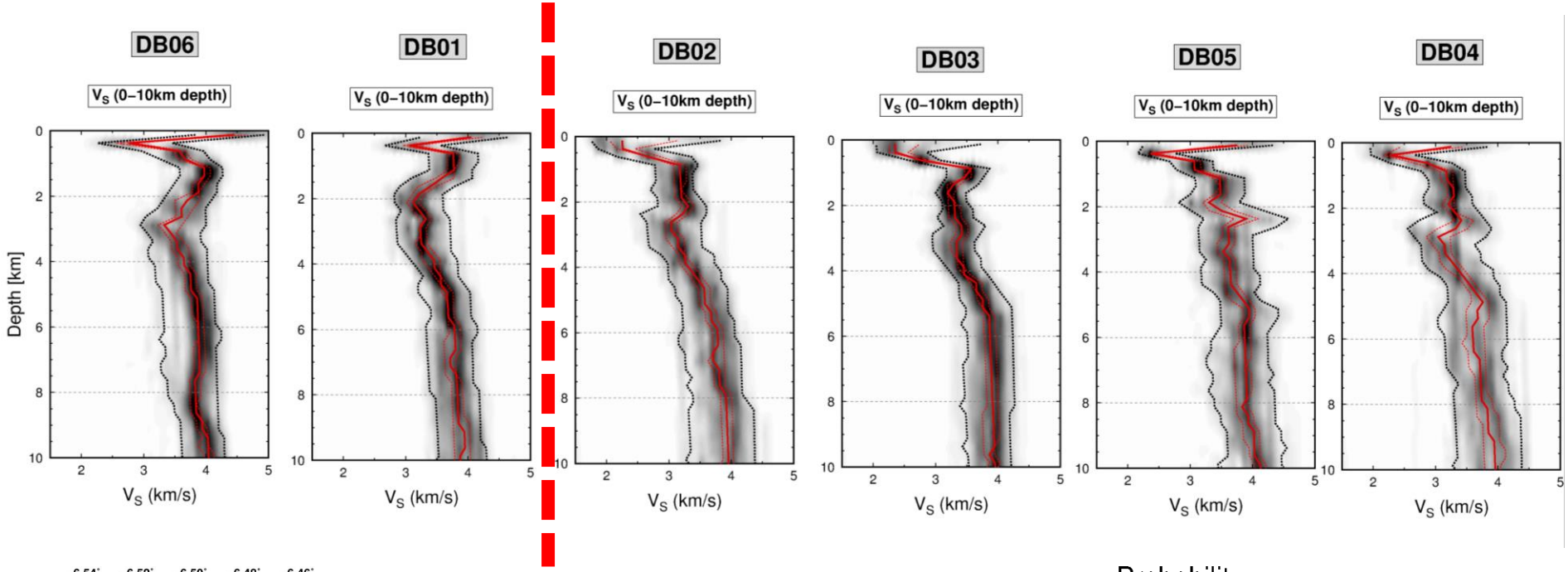
Backazimuthal coverage is good (nearly 2 years).

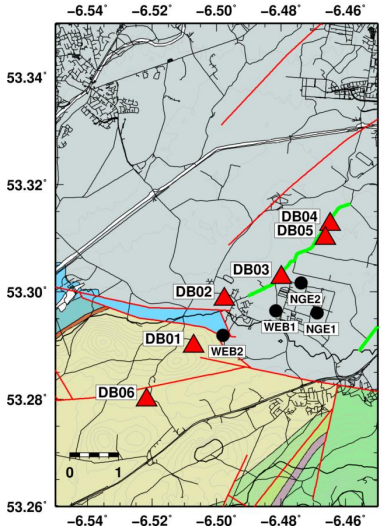
Bayesian inversion



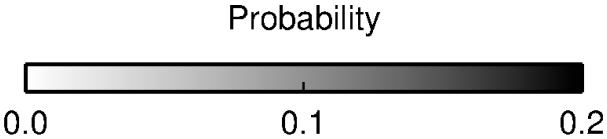
- Probabilistic inversion
- The number of layers is inferred directly from the data.

Results



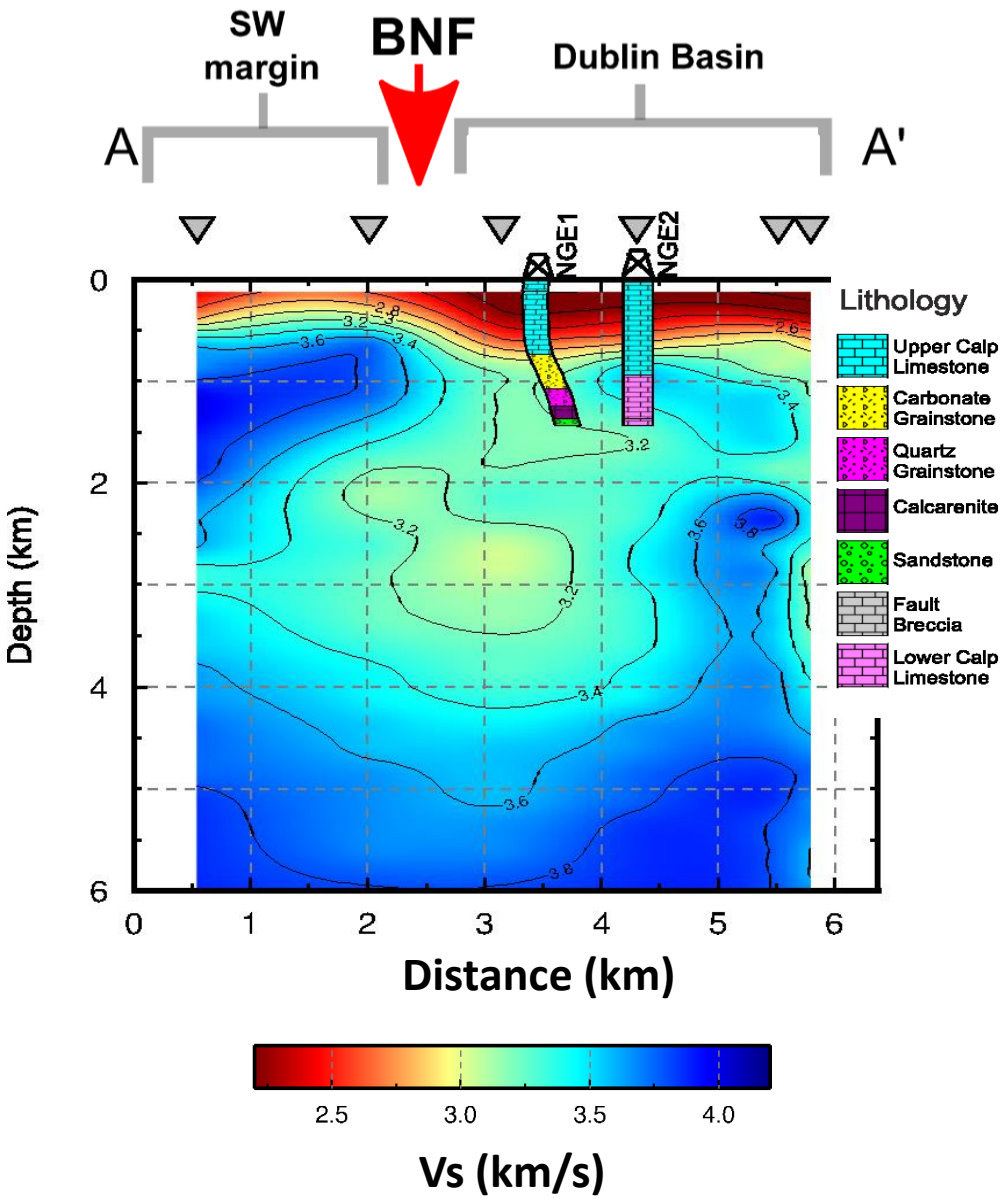


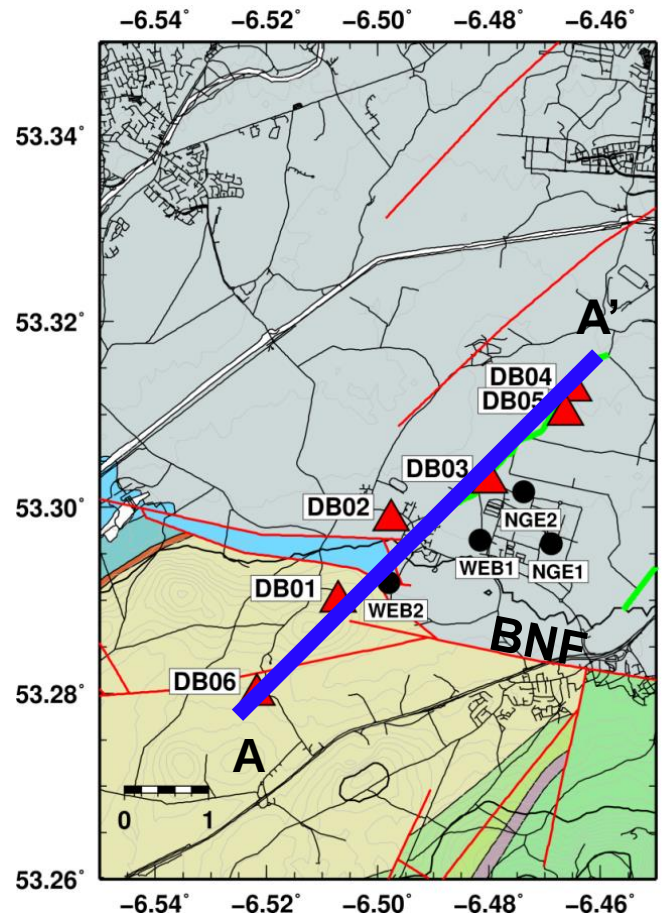
BNF



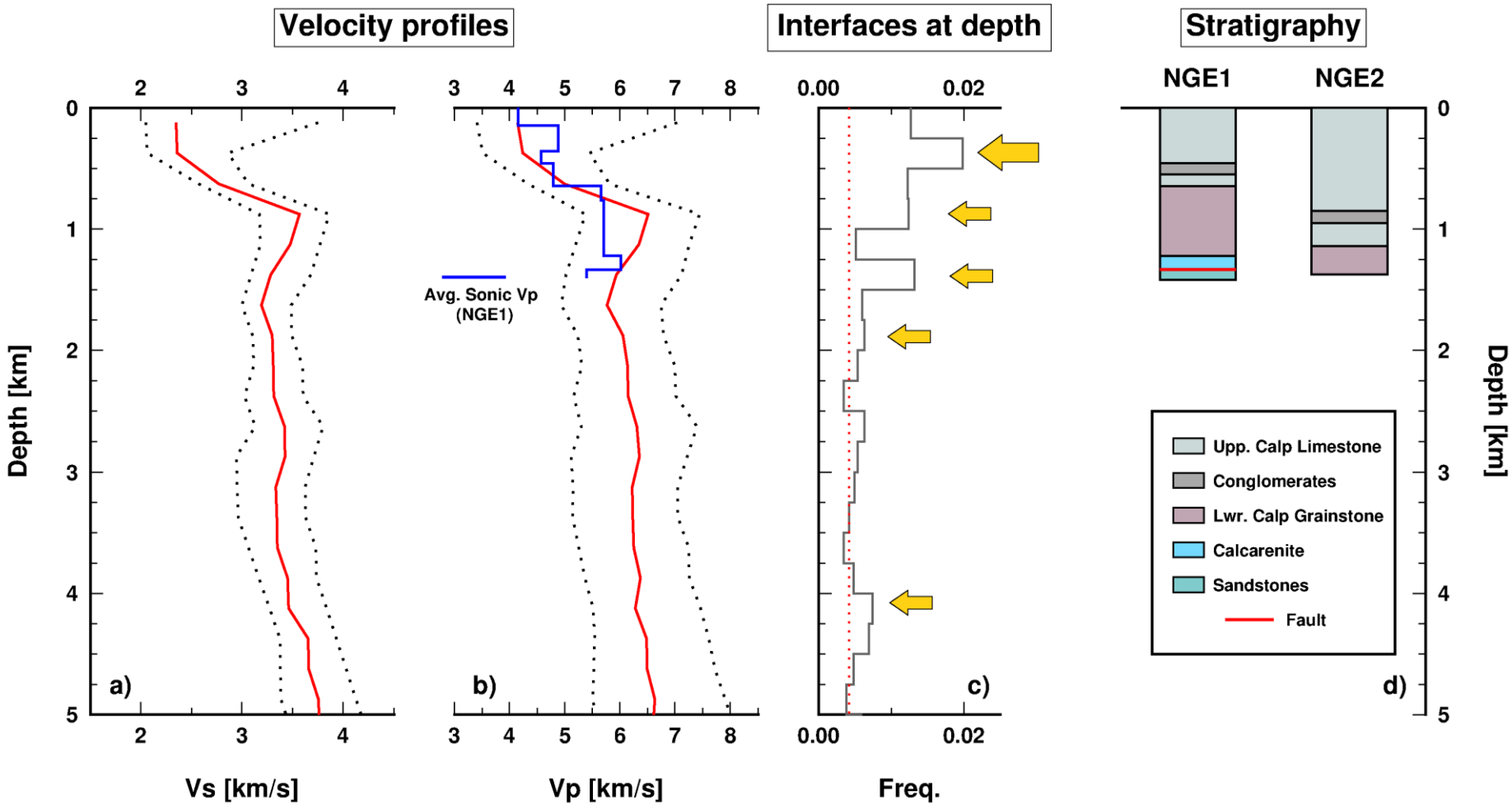
How do we put together single 1D marginal PPDs? An interpolation scheme that takes into account the full posterior uncertainties on the model parameters is needed. In the meantime …

Interpolated profile

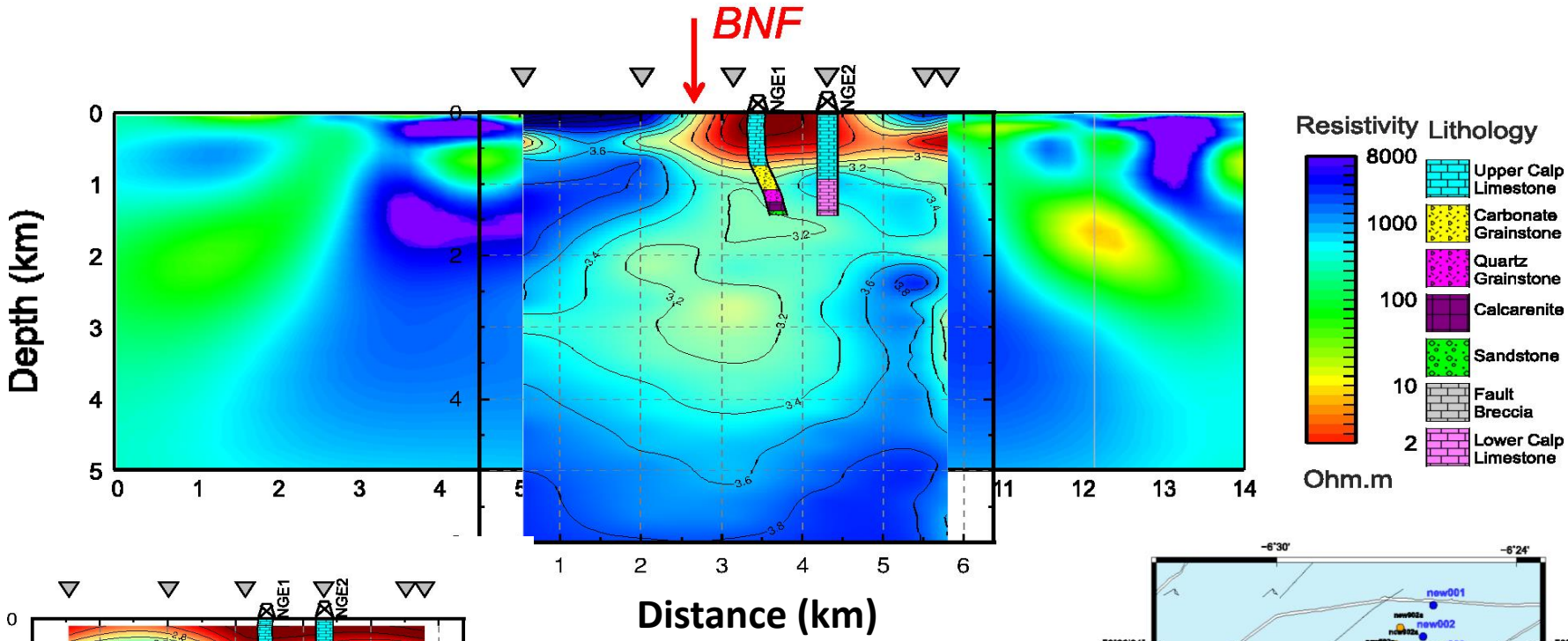


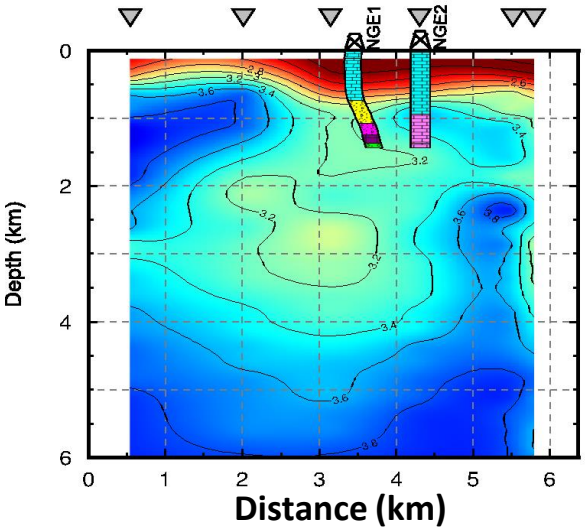


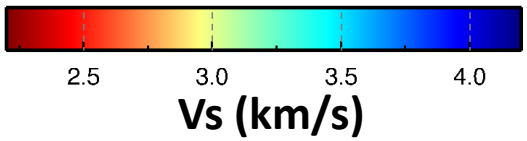
Comparison with borehole data

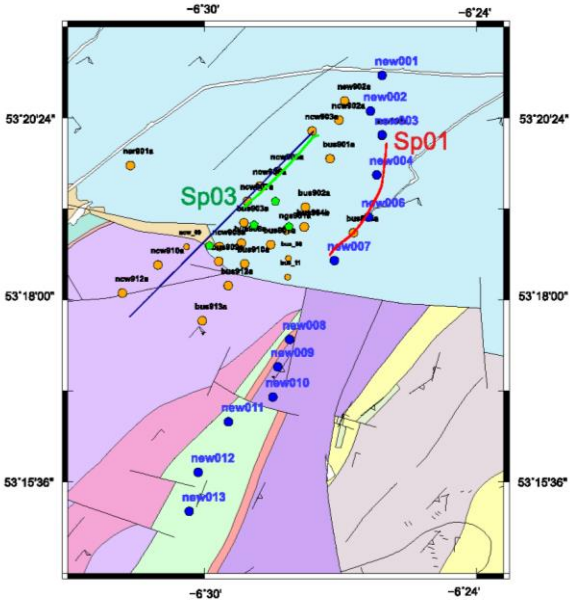


Comparison with MT

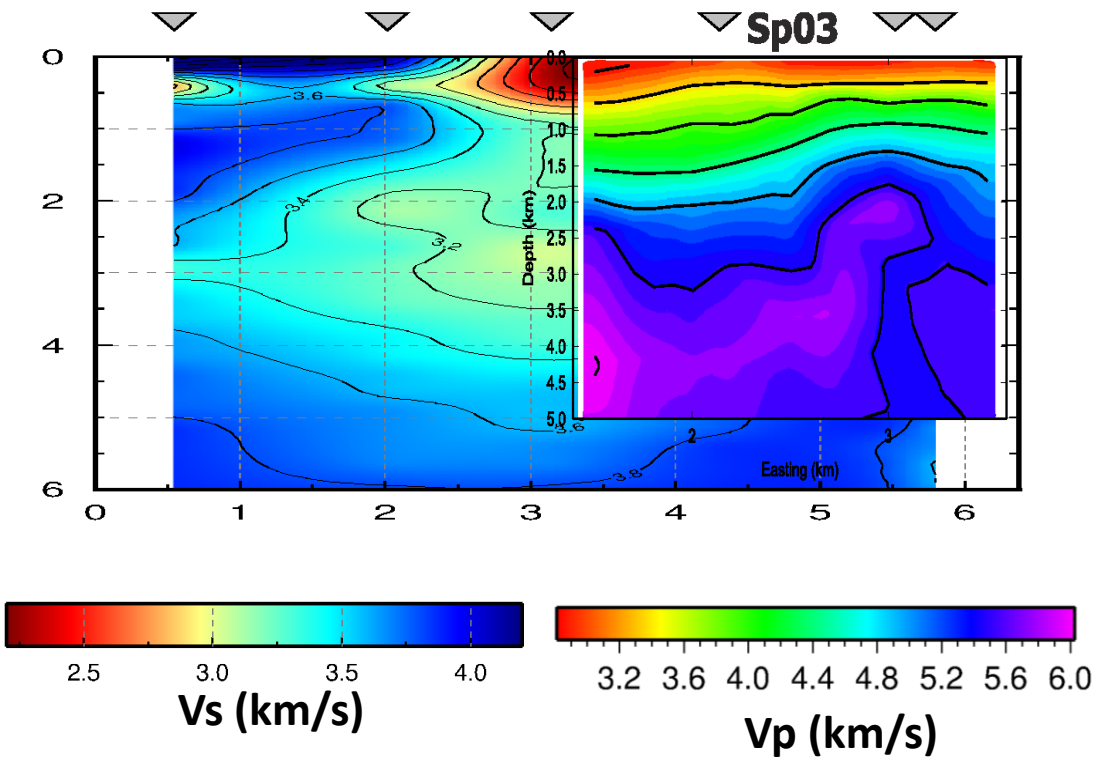


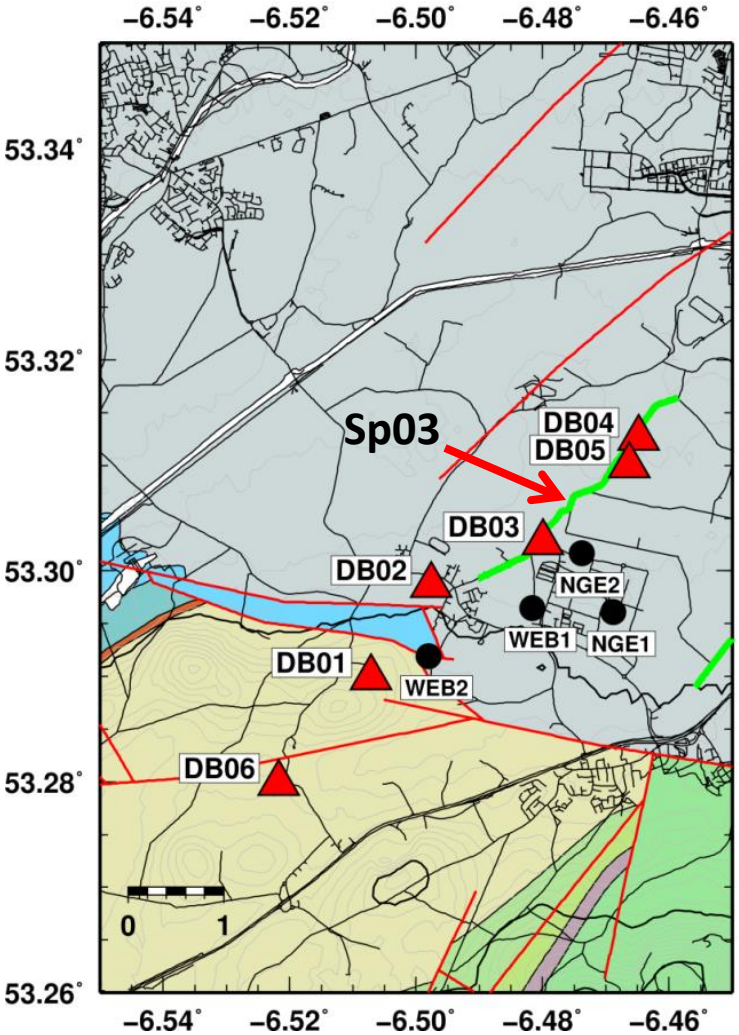






Comparison with seismic reflection profile



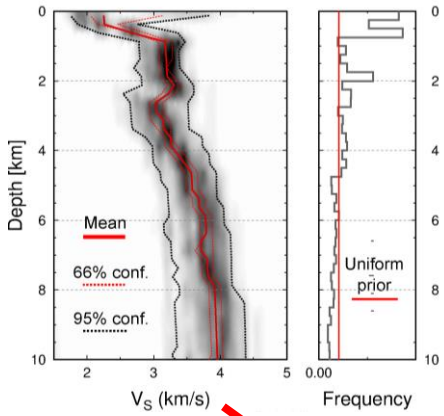


More information on this and previous slide @ Ján Vozár's poster:
"Magnetotelluric investigations in the Newcastle area (Dublin Basin)"

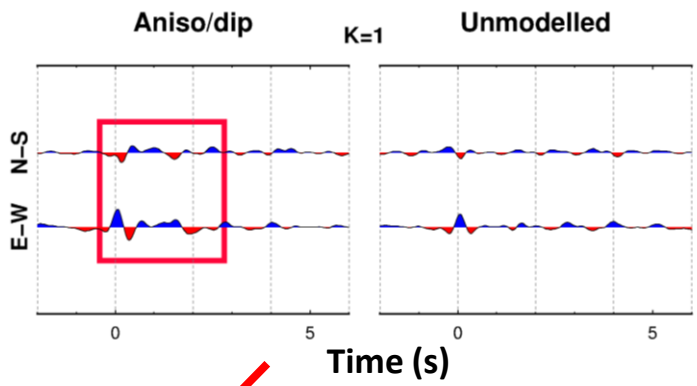
What's next?

Anisotropy is a critical parameter for geothermal potential assessment.

ISOTROPIC constraints

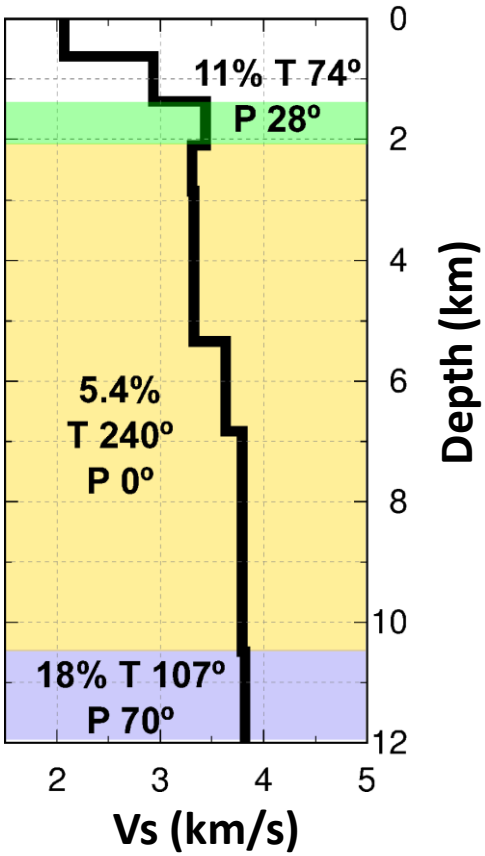


Anisotropy information (from harmonics)



Automatic parameterization (with uncertainties) for anisotropic parameters inversion.
(see Licciardi & Piana Agostinetti 2016, GJI)

Estimation of depth-dependent anisotropic properties

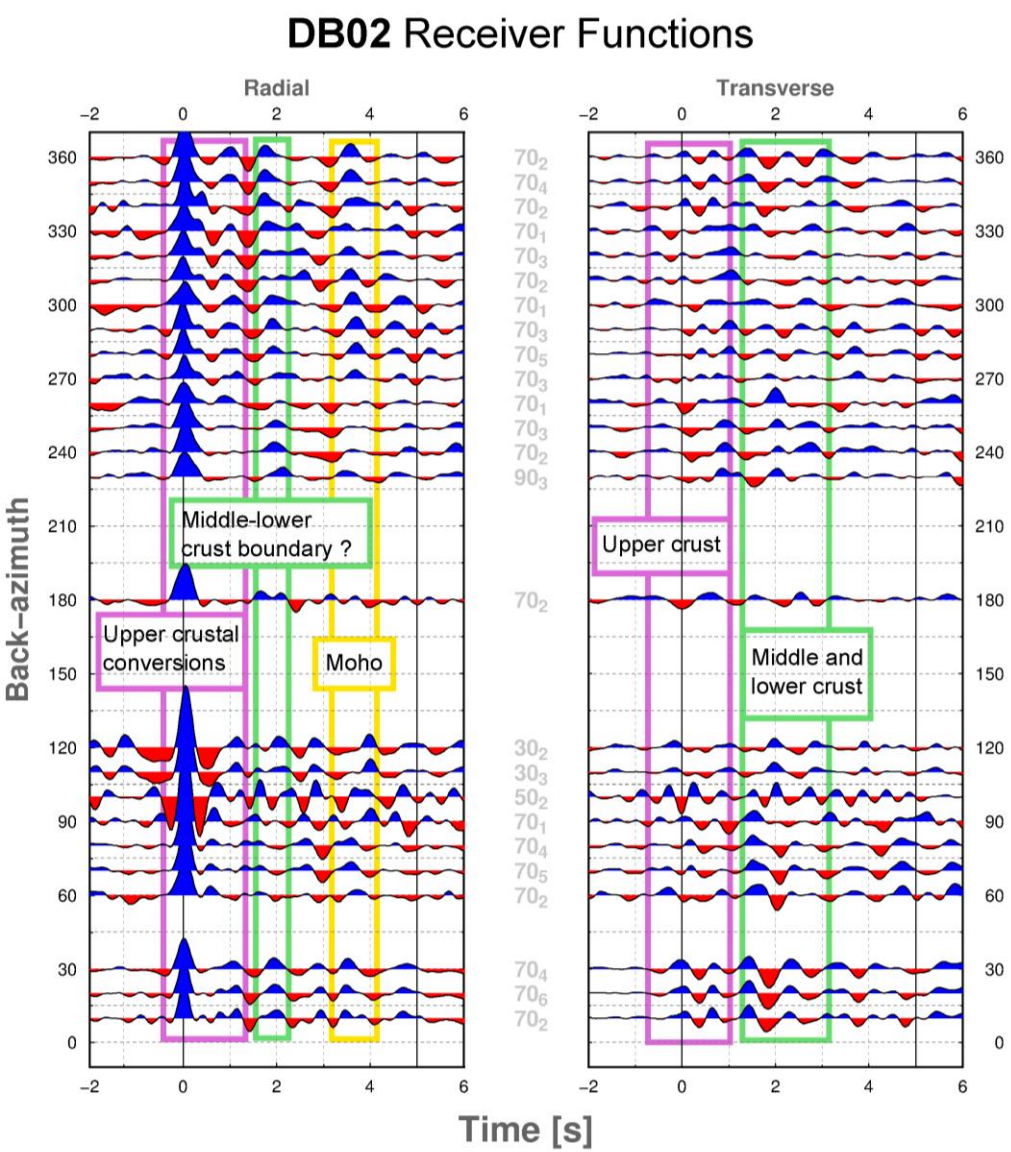


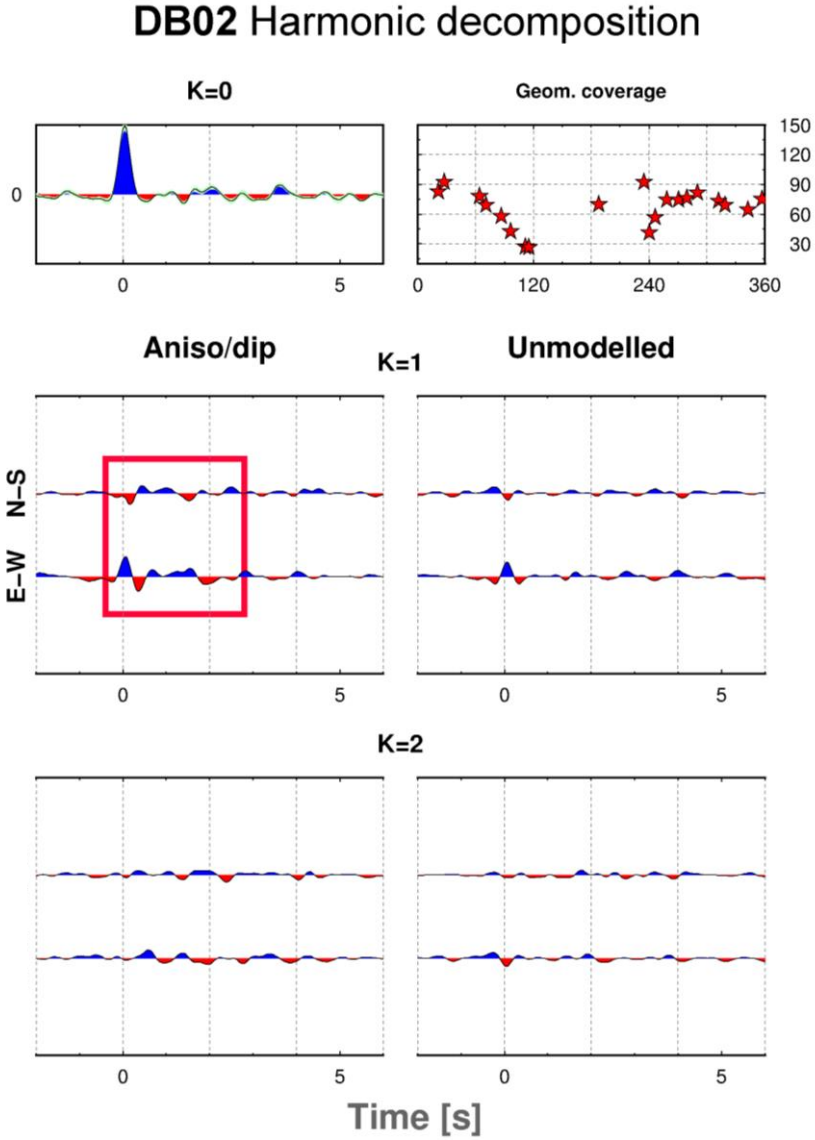
Conclusions and future work

- Receiver functions represents a powerful (and cheap!) tool to image the isotropic structure of sedimentary basins even in urban areas;
- Strong correlations of our Vs model with other geophysical and geological evidence (e.g. MT, seismic reflection and boreholes) ;
- Resolution can be further improved by adding higher frequencies;
- Future work will focus on the characterization of the "anisotropic" structure in the Dublin Basin, exploiting the information contained in the higher order harmonics.
- Ultimately, quantitative fusion of different data-set (with uncertainties)

Thank you

Harmonic decomposition DB02





Method

Following Bianchi et al., 2010

Inputs

Multi-freq. **harmonics**

Bayesian PPD of **Vs** and **depth of interfaces**

Automated choices

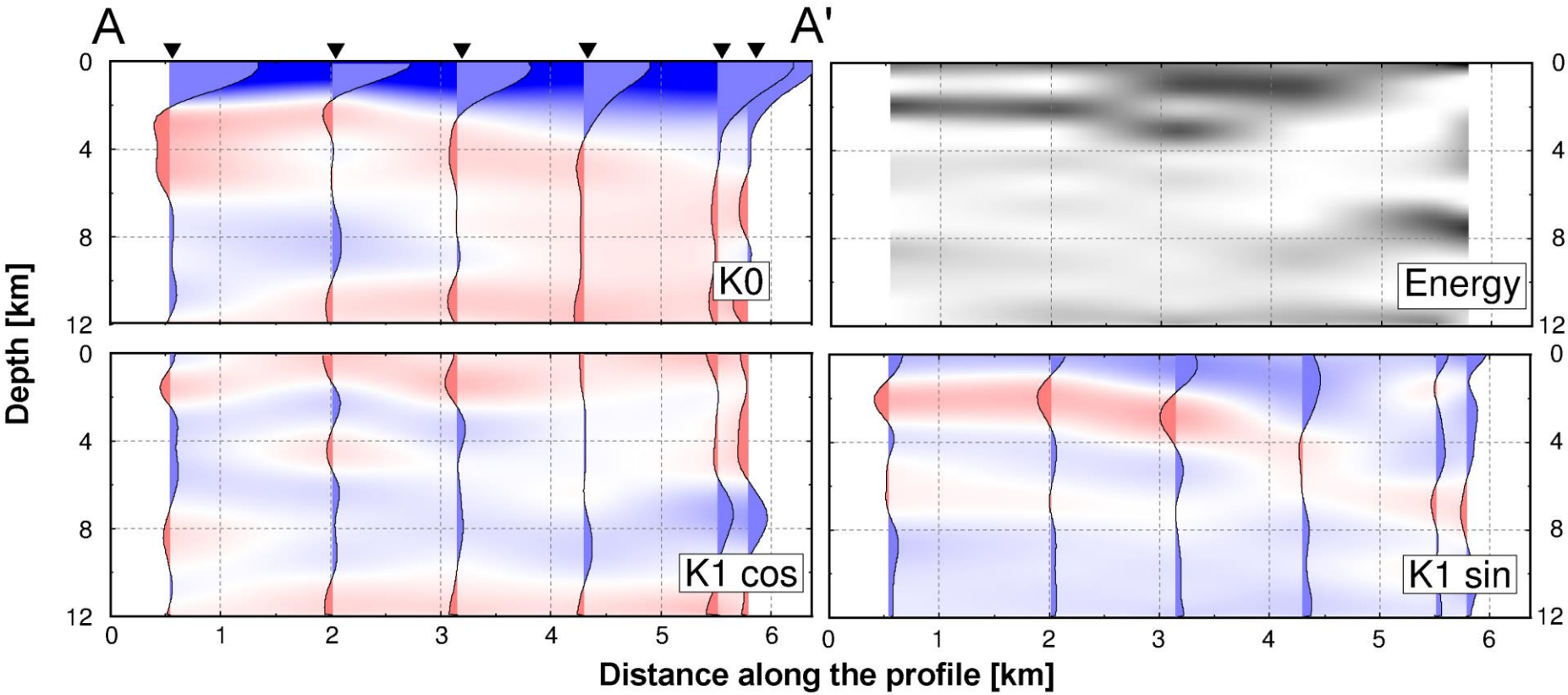
Select depth of **ANI** interfaces (+min/max)

Select depth of **ISO** interfaces (+min/max)

Build the parameter space for anisotropic inversion (+ Vs min/max)

Results

Anisotropic parameters through Neighborhood Algorithm (NA)


A
A'
K0
Energy
K1 cos
K1 sin
Depth [km]
Distance along the profile [km]
0
4
8
12
0
1
2
3
4
5
6