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Investigating trade-offs in anelastic waveform tomography for global-scale models

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Introduction

What is attenuation?

Attenuation or intrinsic attenuation, $1/Q$, is the energy loss due to anelastic processes or internal friction during wave propagation.

- Intrinsic attenuation is strongly sensitive to temperature.
- Attenuation causes velocity dispersion, therefore constraining attenuation improves the accuracy of the velocity models.
- Intrinsic attenuation is a valuable parameter that may help to understand the dynamics of plate tectonics and the type of heterogeneities discovered in the Earth.

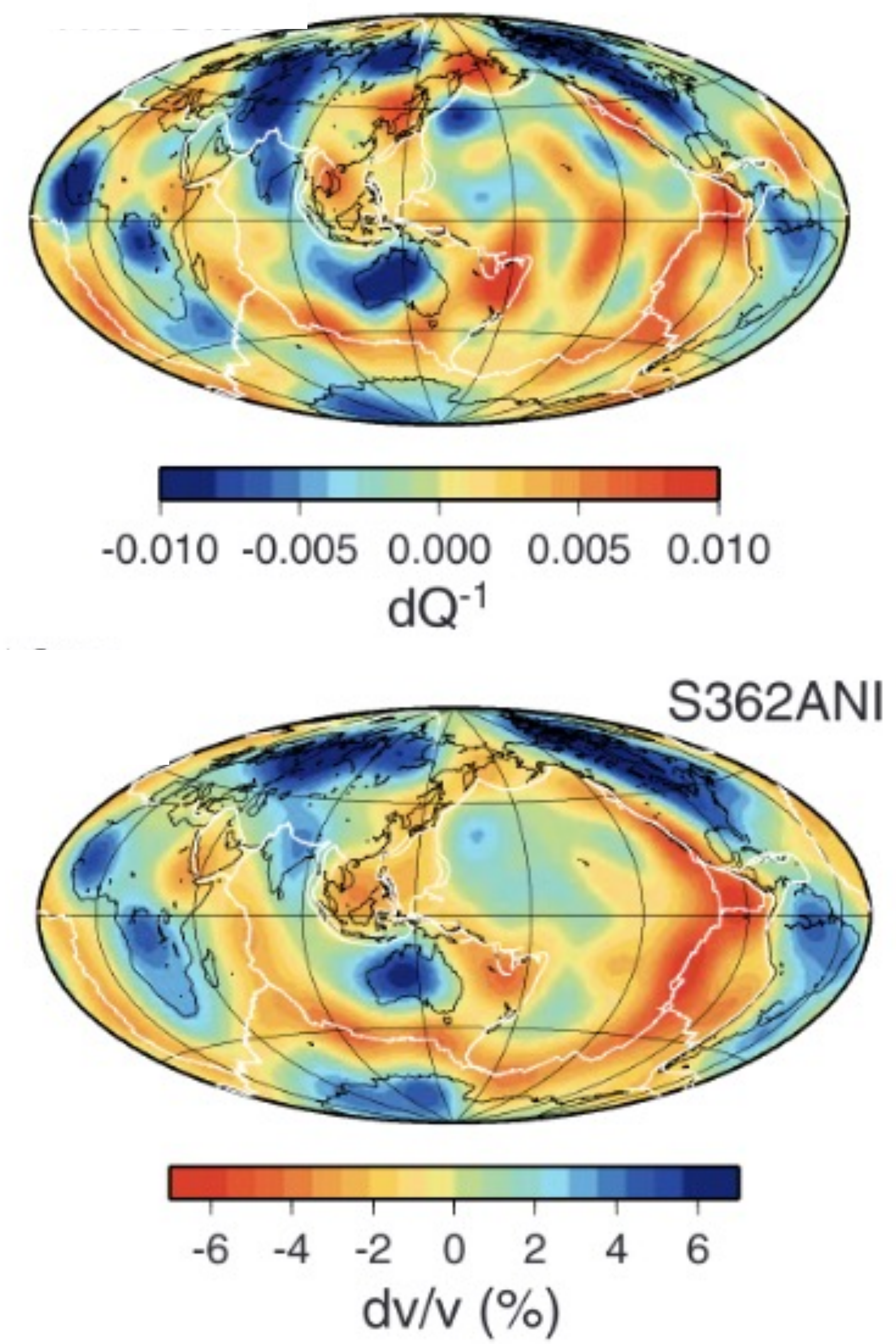


Fig. 1 Top: Global attenuation model. Bottom: Shear wavespeed model. Figure from Dalton et al., 2008

Introduction

Problem complexity:

- Amplitude measurements
  - Scattering/focusing effects
  - Anelasticity

- Uncertainties in sources
  - Source magnitude

- Phase measurements
  - Physical dispersion

- Workflow strategies
  - Sequential inversion
  - Joint inversion

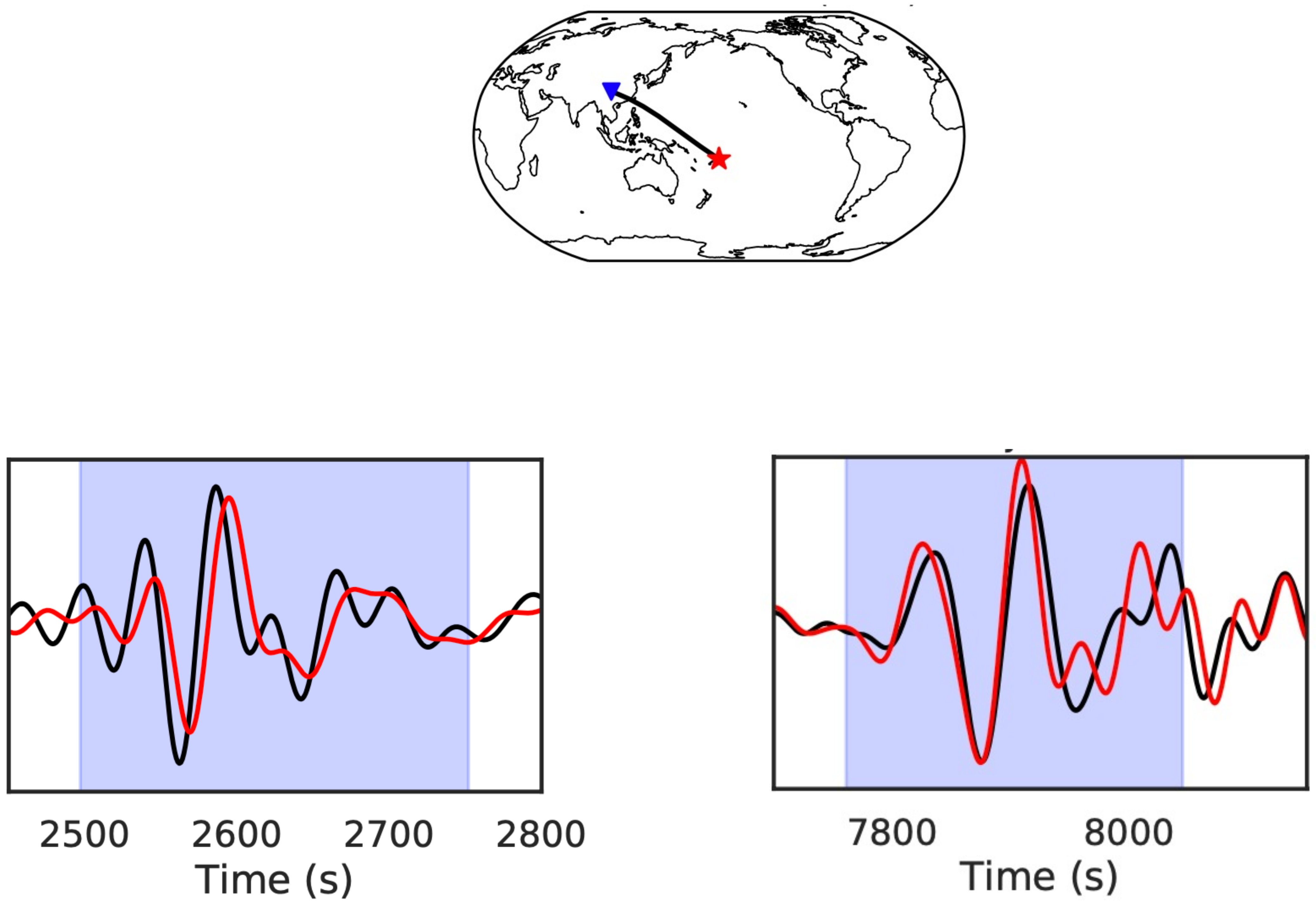
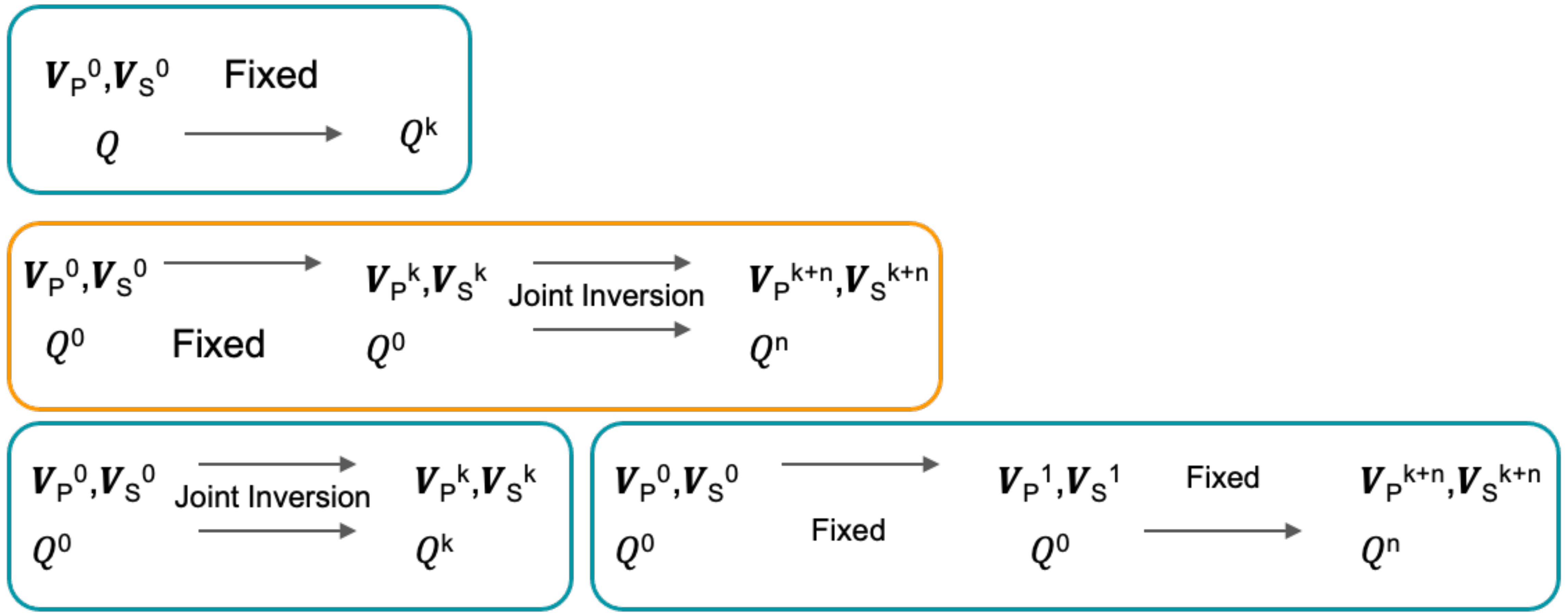


Fig. 2 Samples of seismic waves recorded. The blue background represents the selected window. The blue triangle depicts the station and the red start the source.

Methodology

We will perform three numerical experiments to find suitable inversion strategies to tackle the following challenges:

- Uncertainty in sources and receivers
- Inversion workflows (sequential and joint inversions)
- Optimal combination of observables to constrain attenuation $1/Q$
- Resolution capabilities from real source-receiver configuration.



K : Inversion iterations

Data

263 Earthquakes

> 500 Stations (3-component)

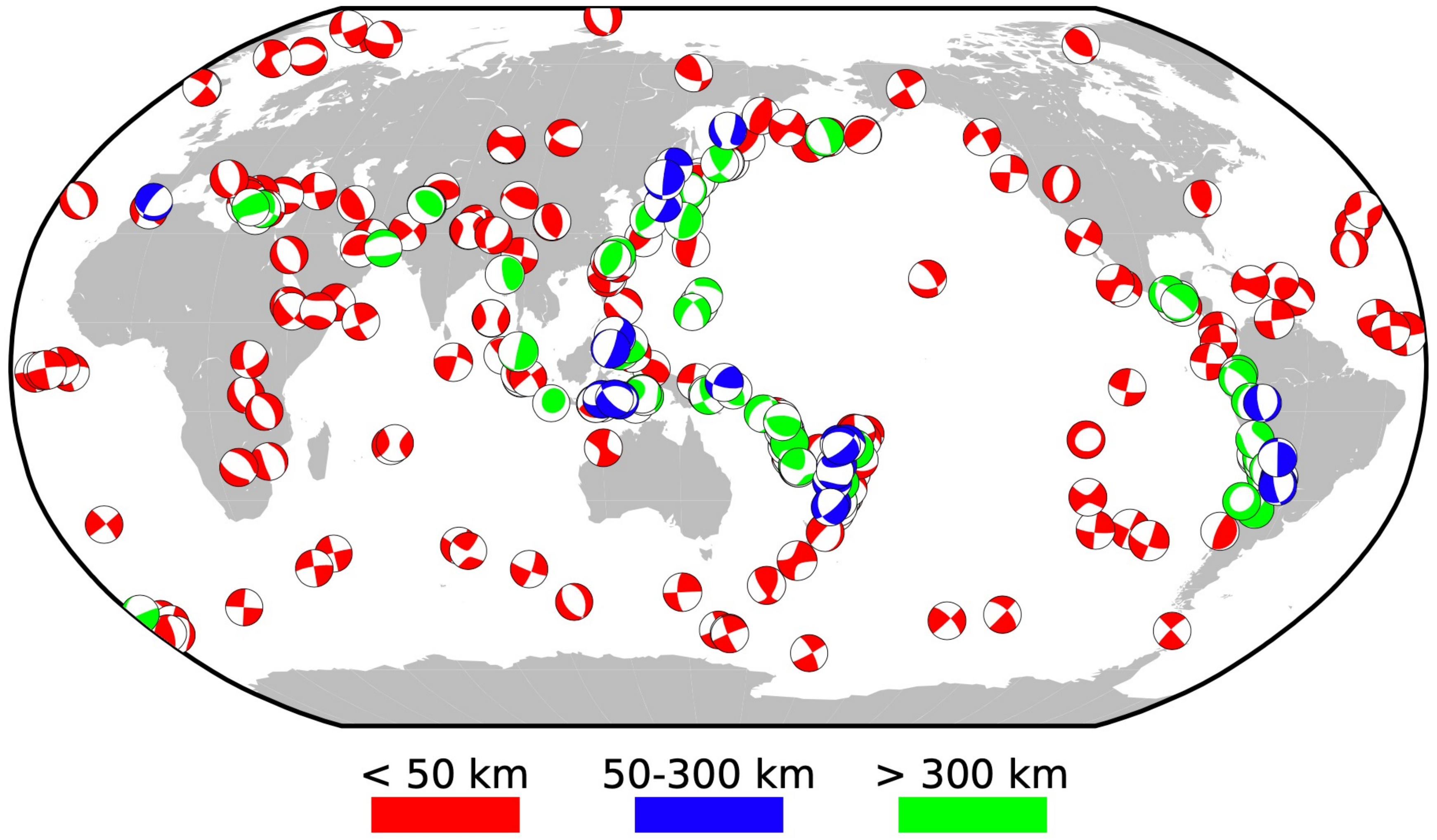


Fig. 3 Earthquake distribution

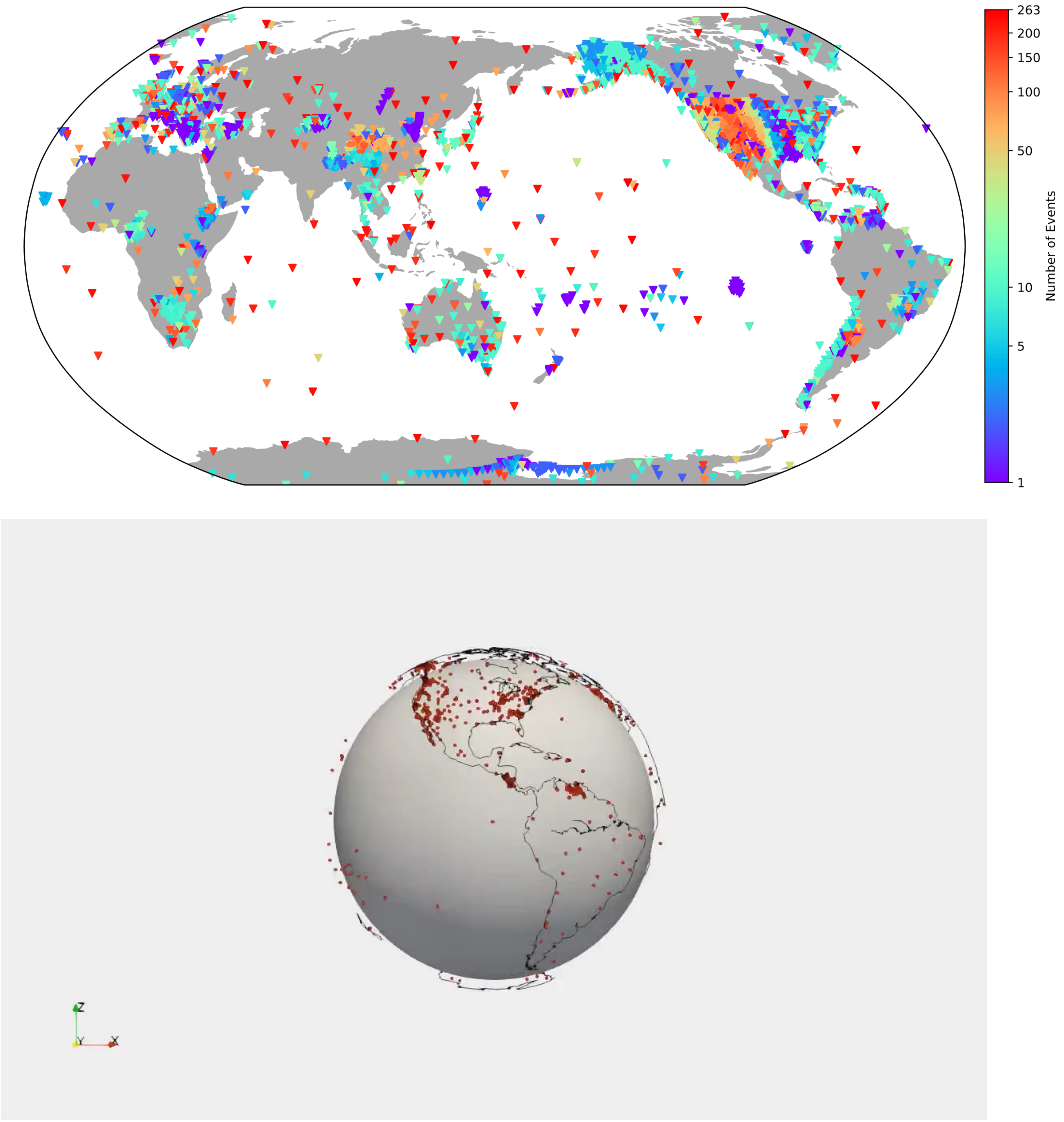
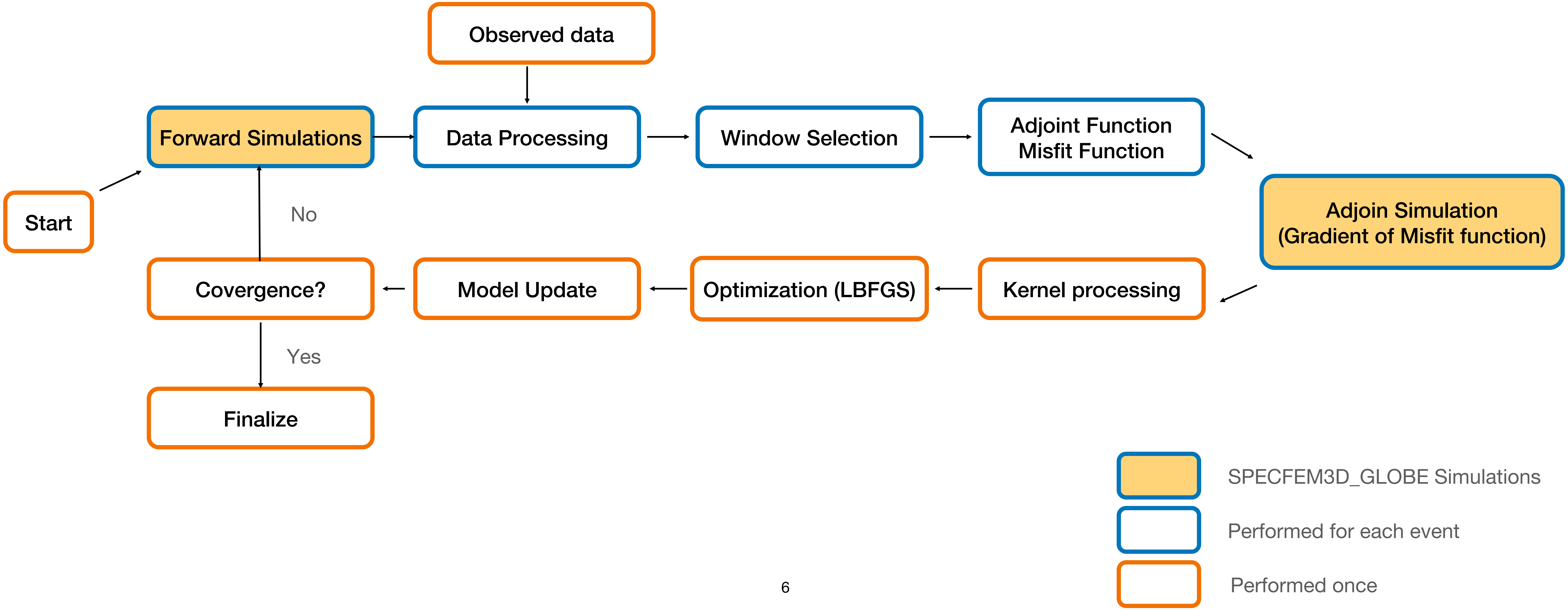


Fig. 4 Station distribution

Workflow


Observed data
Start
Forward Simulations
Data Processing
Window Selection
Adjoint Function
Misfit Function
Adjoin Simulation
(Gradient of Misfit function)
No
Covergence?
Model Update
Optimization (LBFGS)
Kernel processing
Yes
Finalize
SPECFEM3D_GLOBE Simulations
Performed for each event
Performed once

Simulations details

- The Earth is mapped to cubed-sphere and divided into six chunks:
- Space resolution:
  - 96 x 96 Spectral elements
  - 4th order Lagrange polynomials
- Minimum period resolved:
  - 60 s (0.167 Hz)
- Every chunk uses:
  - 4 processors
  - 4 GPUs
- Computational resources utilized per simulation:
  - 6 nodes (24 GPUs)
  - 3 minutes every forward simulation
  - 9 minutes every adjoint simulation (1 Forward and 1 Adjoint)

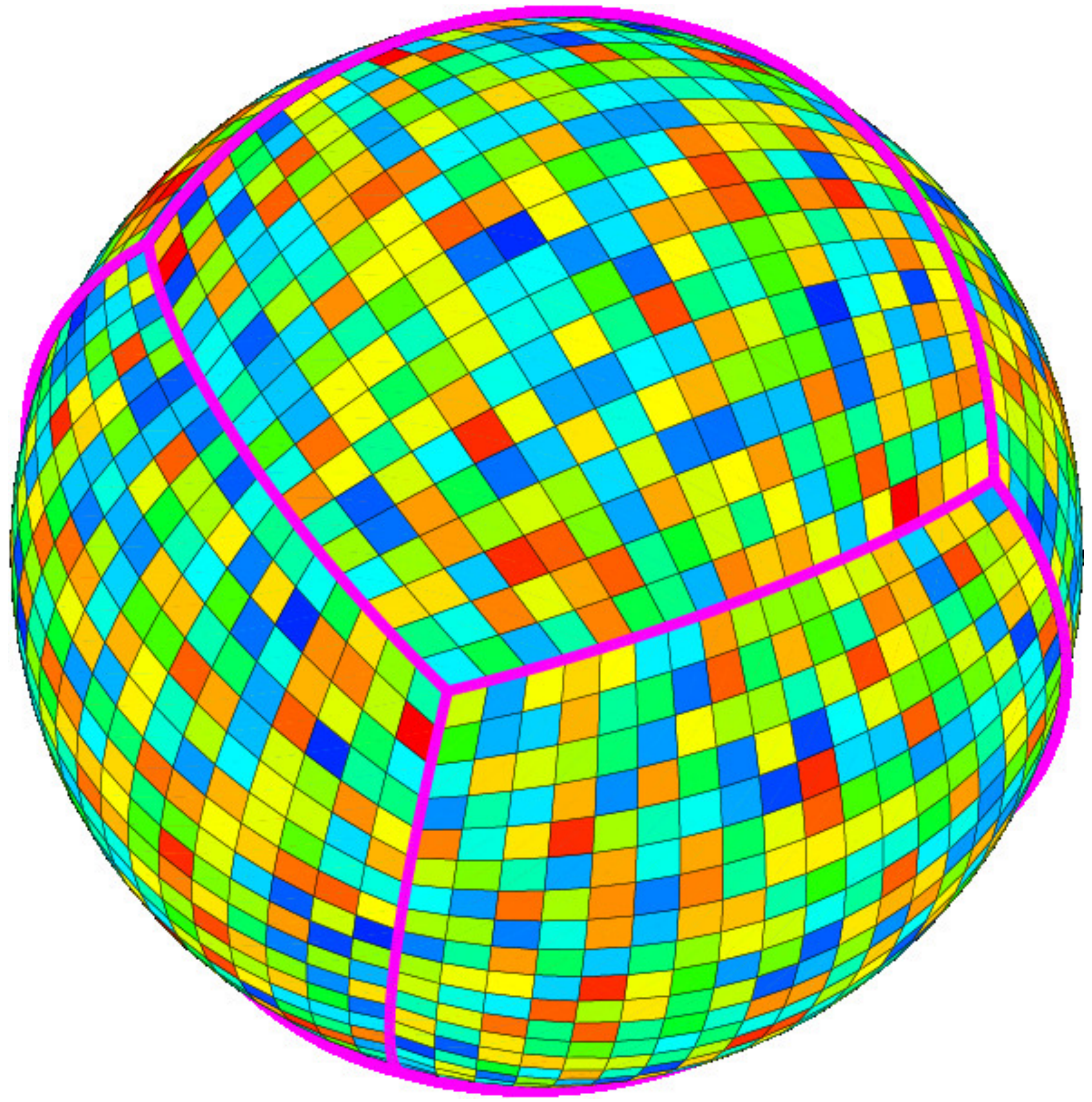


Fig. 5 Cubed-sphere mapping. The six chunks constitute the cubed-sphere.

Preliminary results

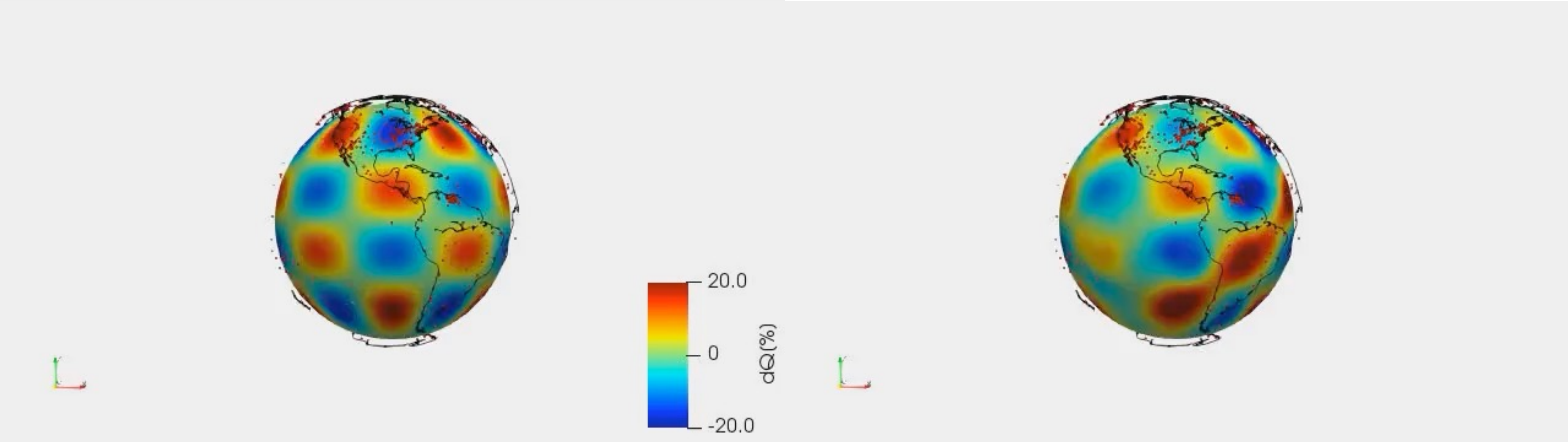


Fig. 6 (First numerical experiment) Map view of relative attenuation perturbations at depth 300 km. (Right) Target 3-D Q-model. (Left) Third iteration Q-model.

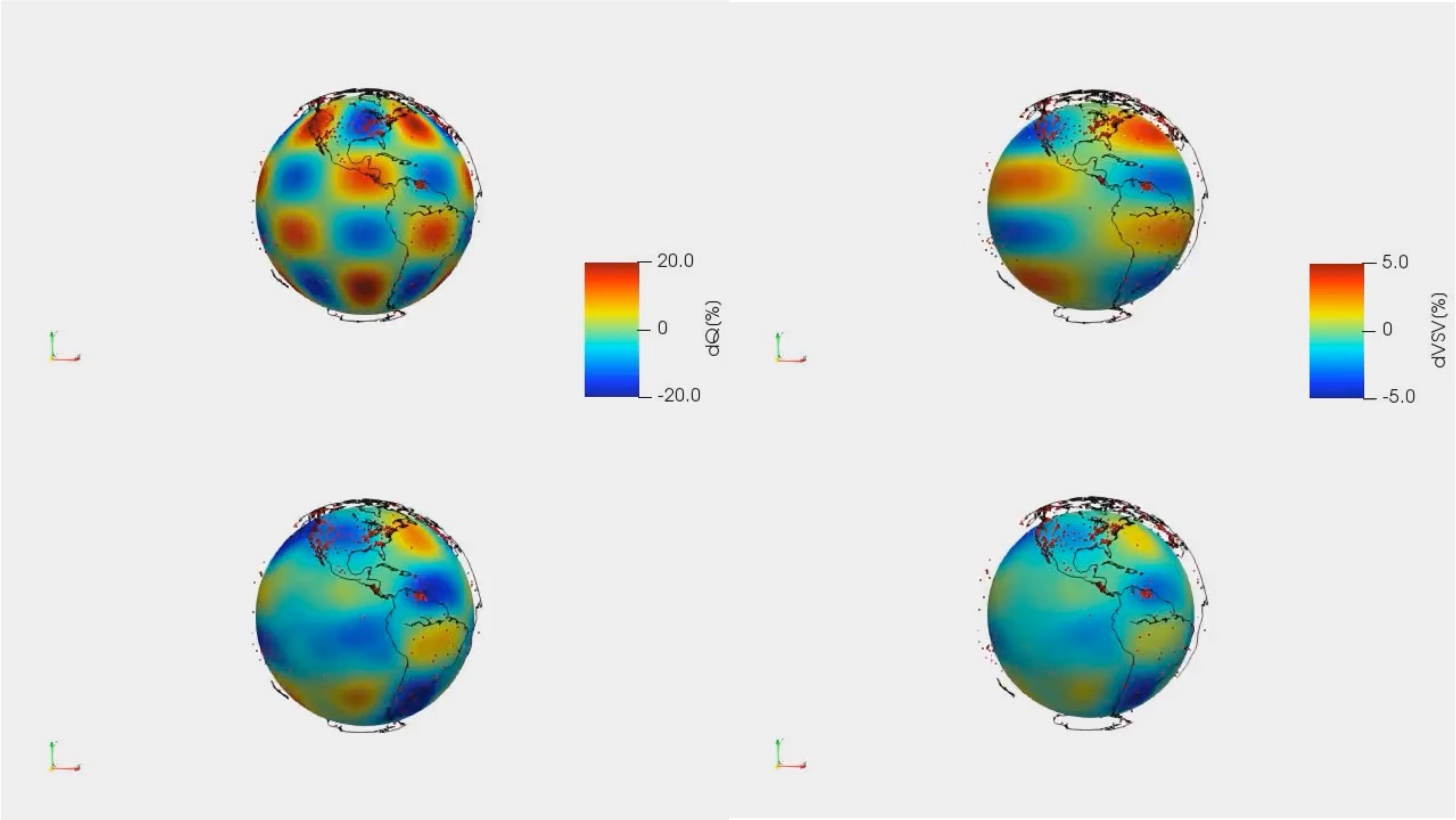


Fig. 7 (Second numerical experiment) Map view of relative attenuation perturbations at depth 300 km. (Left) 3-D Q-model relative perturbations. (Right) 3-D Vsv relative perturbations.

Remarks

1. For the first numerical experiment, we observe a perfect reconstruction of the perturbations. In areas where the station coverage is low we identify a small horizontal smearing in the reconstructed checkerboard anomalies as it was expected. But, despite this, a few inversion iterations are enough to reconstruct the checkerboard test (three iterations).

2. In the second hypothetical example, we observe an erratic behavior in the VSV model due to the trade-off between parameters and the high 3-D Q model perturbations (+- 30 %). High perturbations produce no-linearity and crosstalk between elastic and anelastic parameters.

3. The previous numerical examples show that is possible to constrain the 3-D Q model with the station coverage utilized, which is close to the number of stations employed in real global inversions.

Thank You

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