Exascale Simulations of Waves with High-Performance Computing

using the spectral-element method

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The machines

The computing capacities of the Linux clusters available

1. Fionn @ ICHEC (Irish Center for High-Ending Computing)
   - peak performance: 140.4 TFlop (10^{12})
   - 320 cpu nodes x 24 cores per node = 7680 cpu cores
   - job size limitation: 1032 cores x 72 hours = 74304 core hours
   - 16 gpu nodes x 32 NVIDIA K20X
2. Gaia @ Earth Institute, UCD
   - 25 cpu nodes x 40 cores per node = 1000 cpu cores
   - job size limitation: 640 cores x 48 hours = 30720 core hours

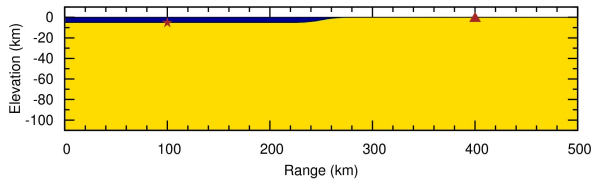
The simulators

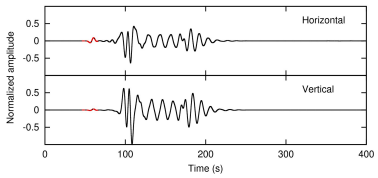
Open-source packages

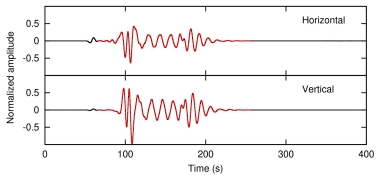
- forward simulation
  - coupled acoustic, elastic and poroelastic waves
- adjoint simulation
  - sensitivity kernels
- internal & external meshers

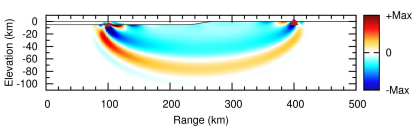
Sensitivities of microseism in ocean I

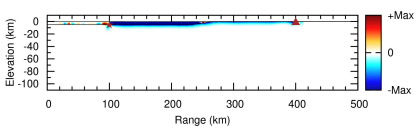
A very simple 2D ocean model, recording on land

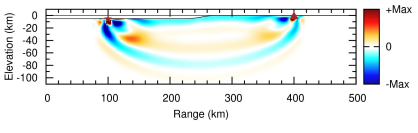


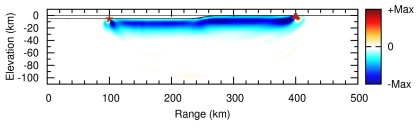






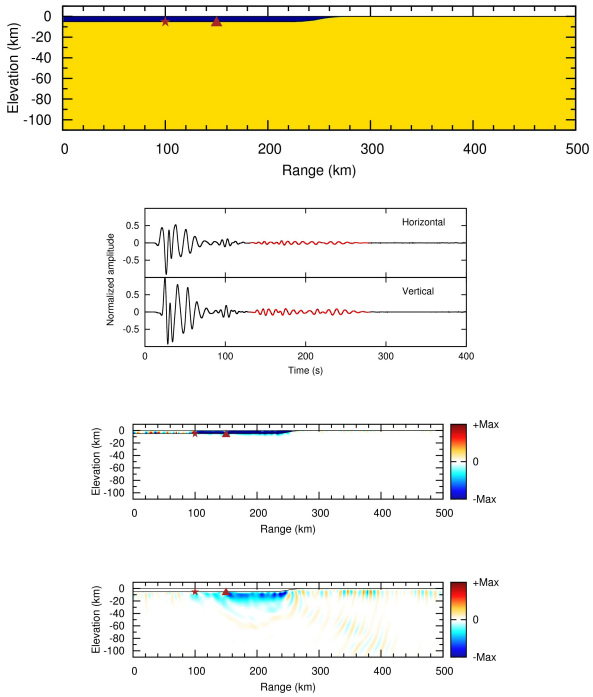






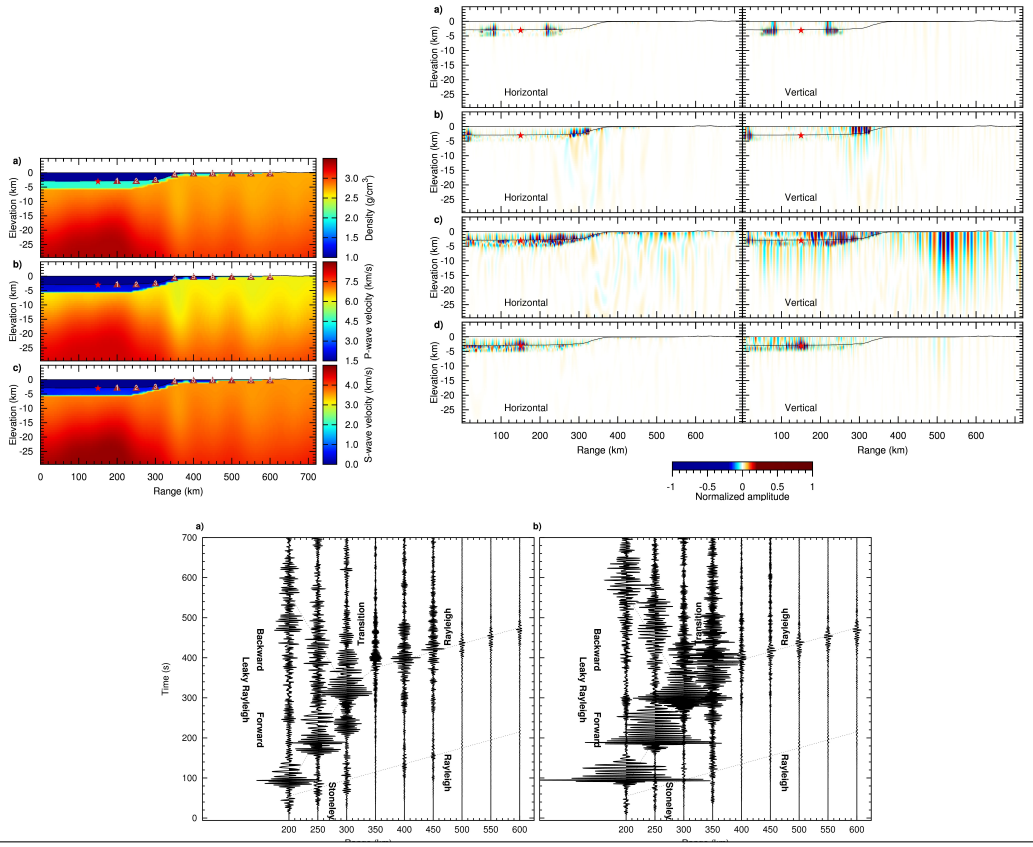
Sensitivities of microseism in ocean II

A very simple 2D ocean model, recording at ocean bottom



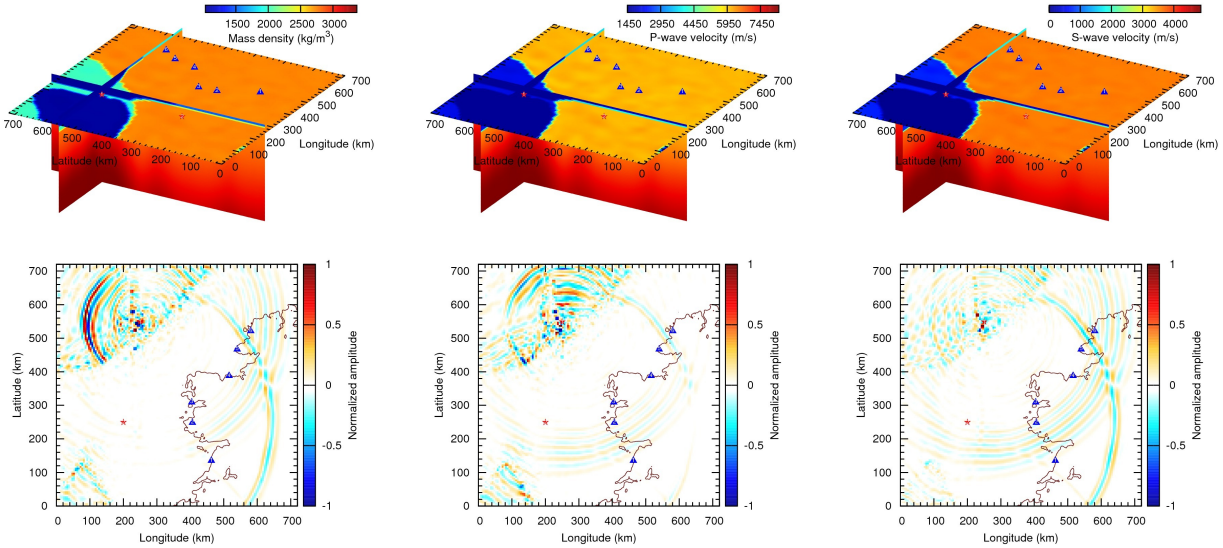
Propagation of microseism in ocean I

A more realistic 2D North-East Atlantic Ocean model



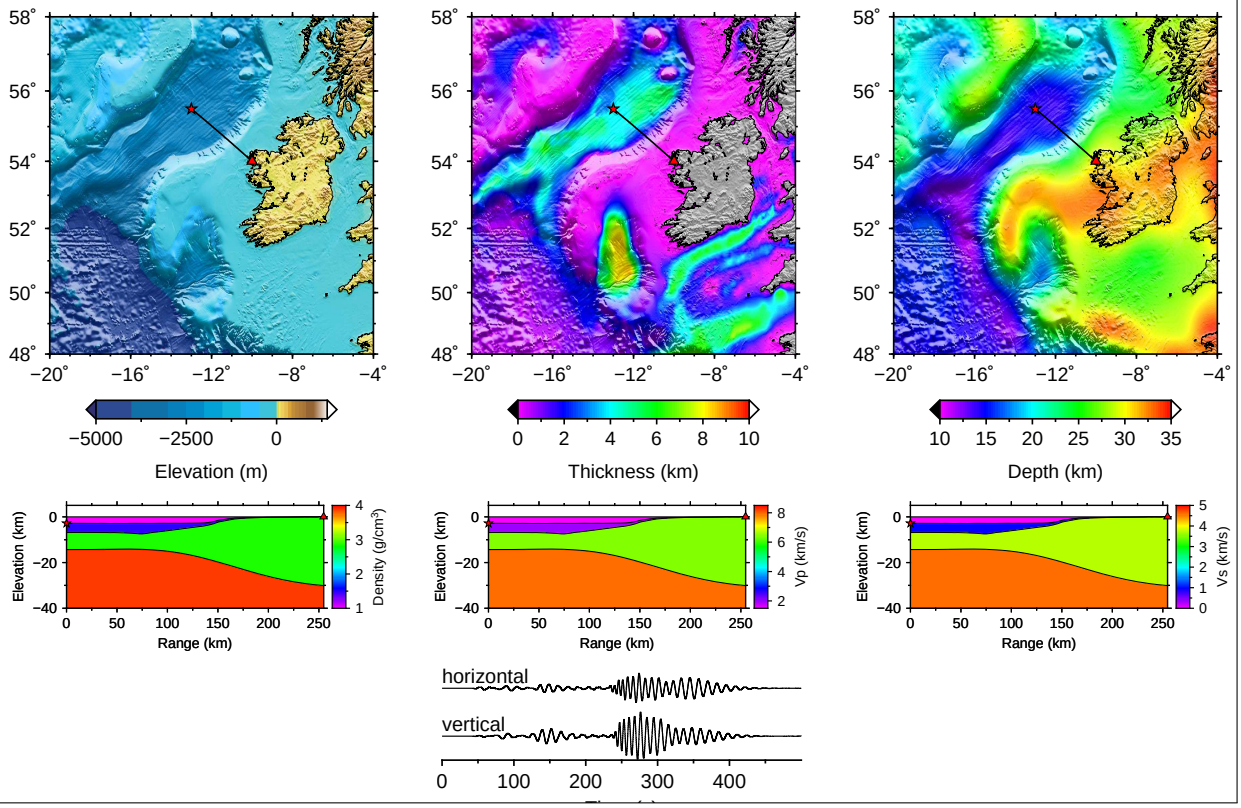
Propagation of microseism in ocean II

A more realistic 3D North-East Atlantic Ocean model



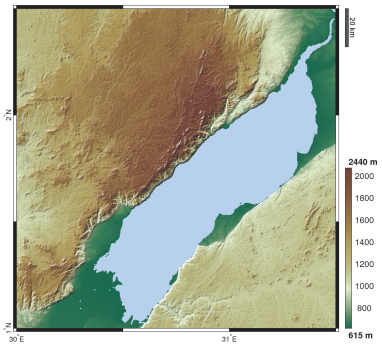
Propagation of microseism in ocean III

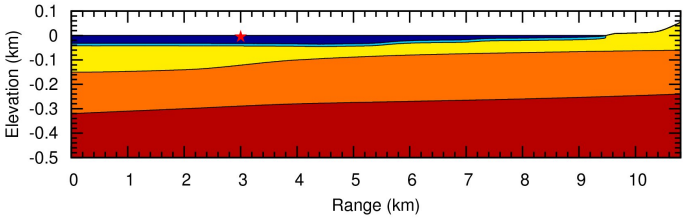
Another more realistic 3D North-East Atlantic Ocean model

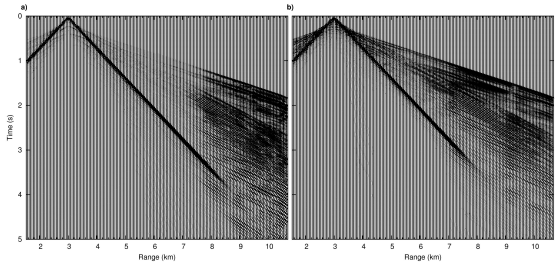


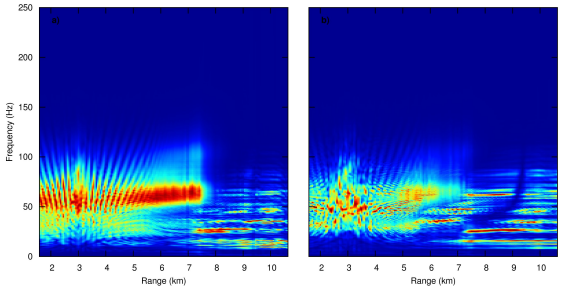
Seismic wave in Lake Albert I

Propagation



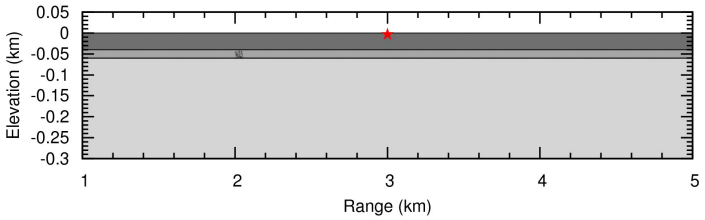


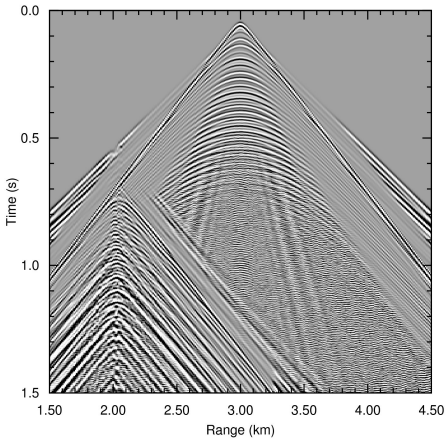


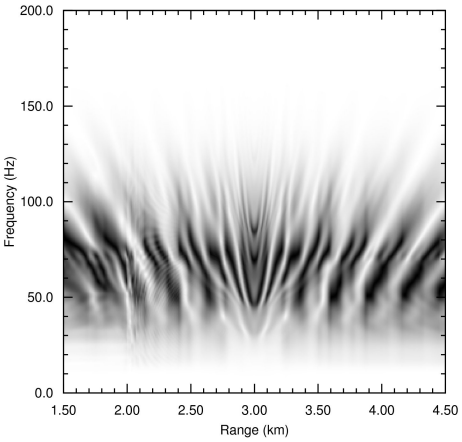


Seismic wave in Lake Albert II

Scattering

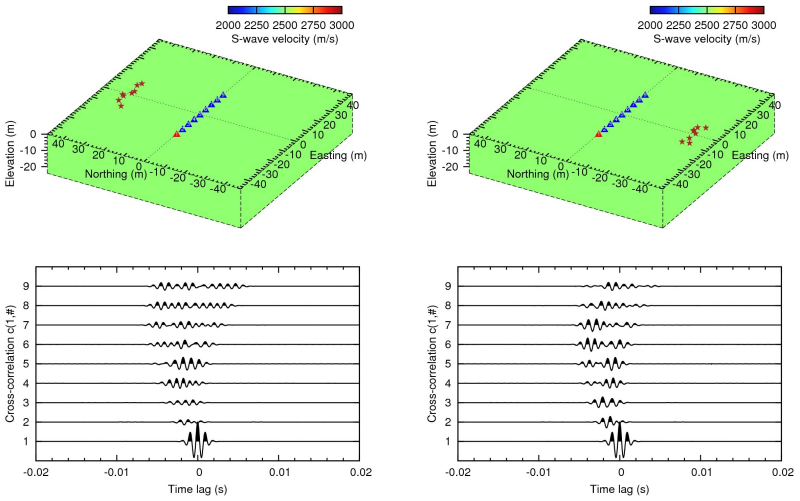






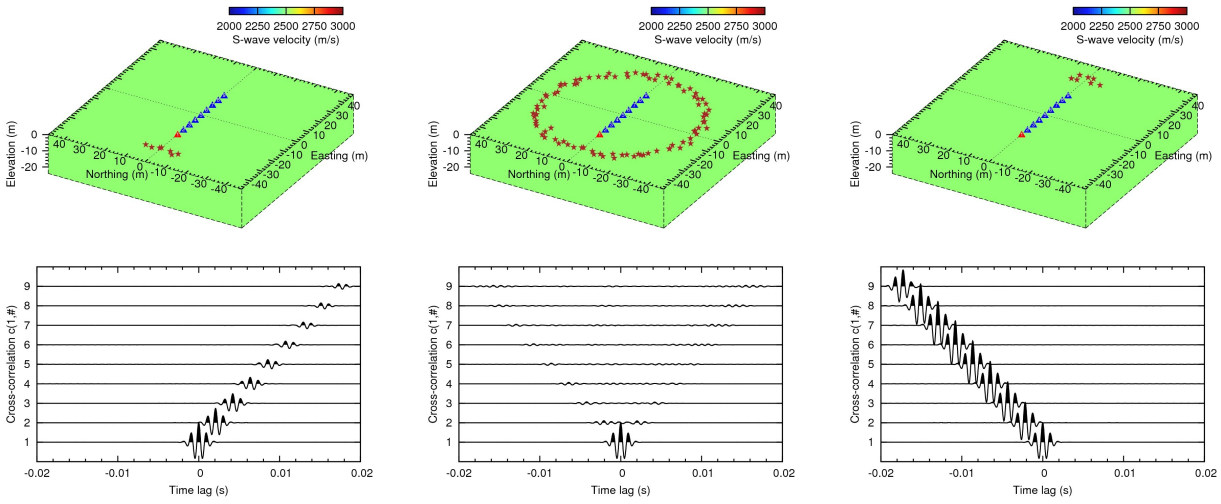
Interferometry pattern with noise distribution I

Synthetic ensemble-averaged interferograms: homogeneous halfspace



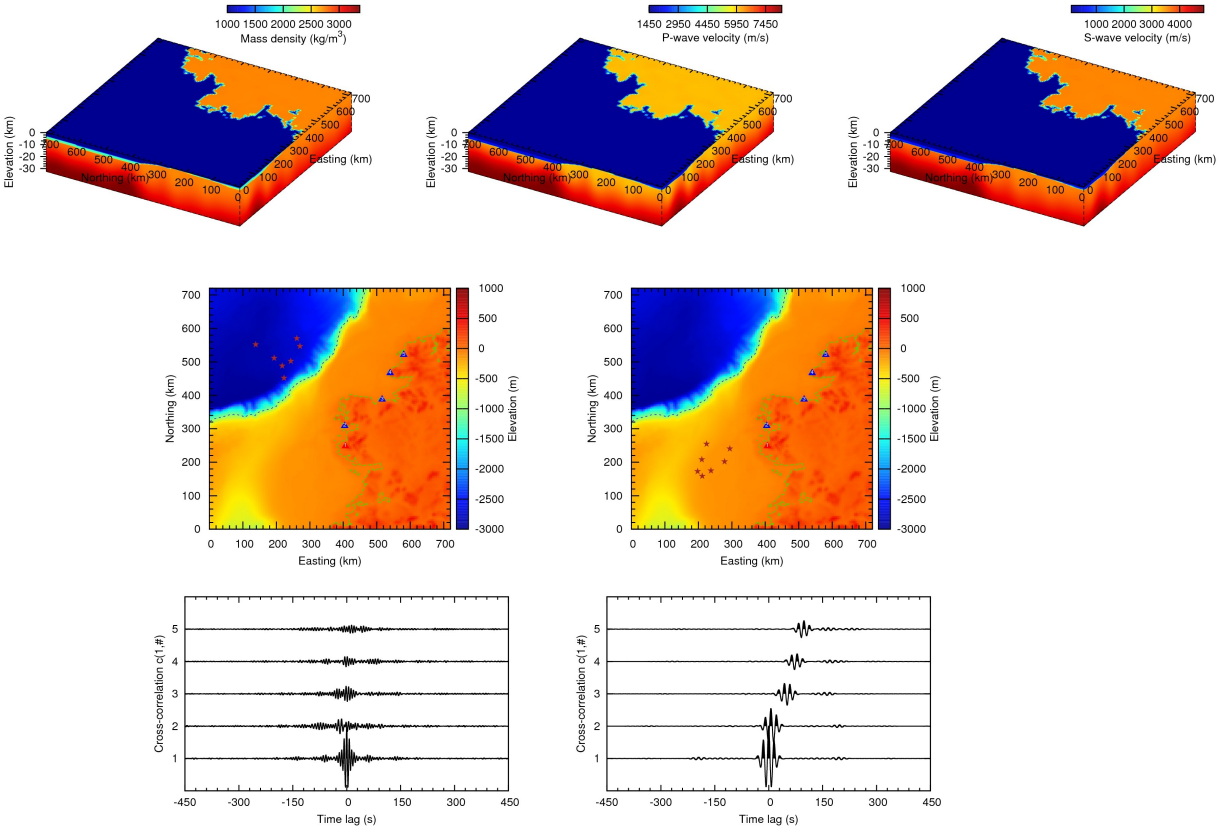
Interferometry pattern with noise distribution II

Synthetic ensemble-averaged interferograms: homogeneous halfspace



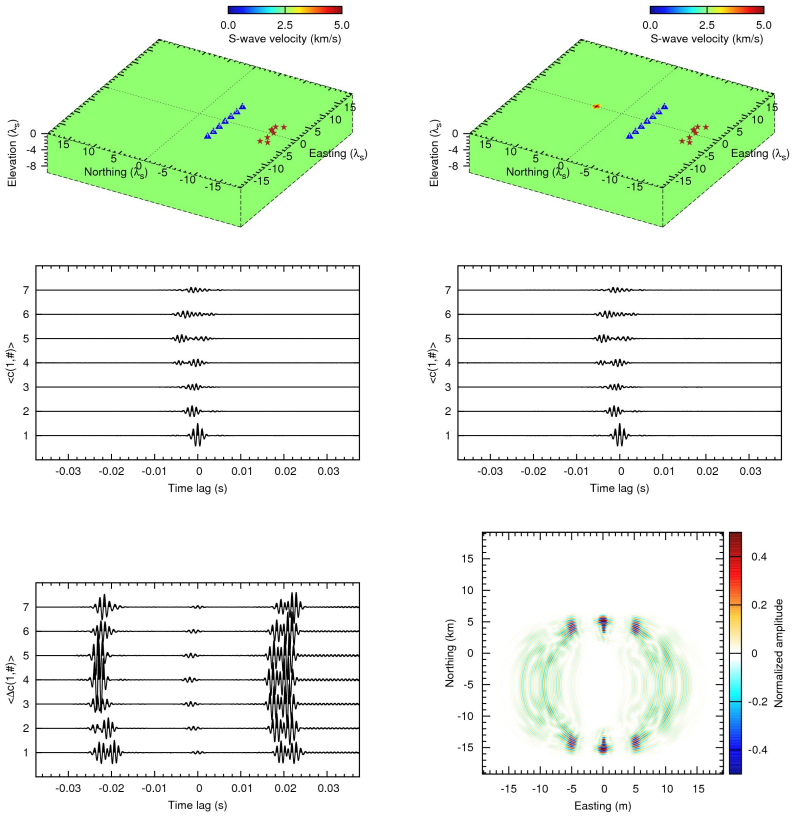
Interferometry pattern with noise distribution III

Synthetic ensemble-averaged interferograms: North-East Atlantic Ocean



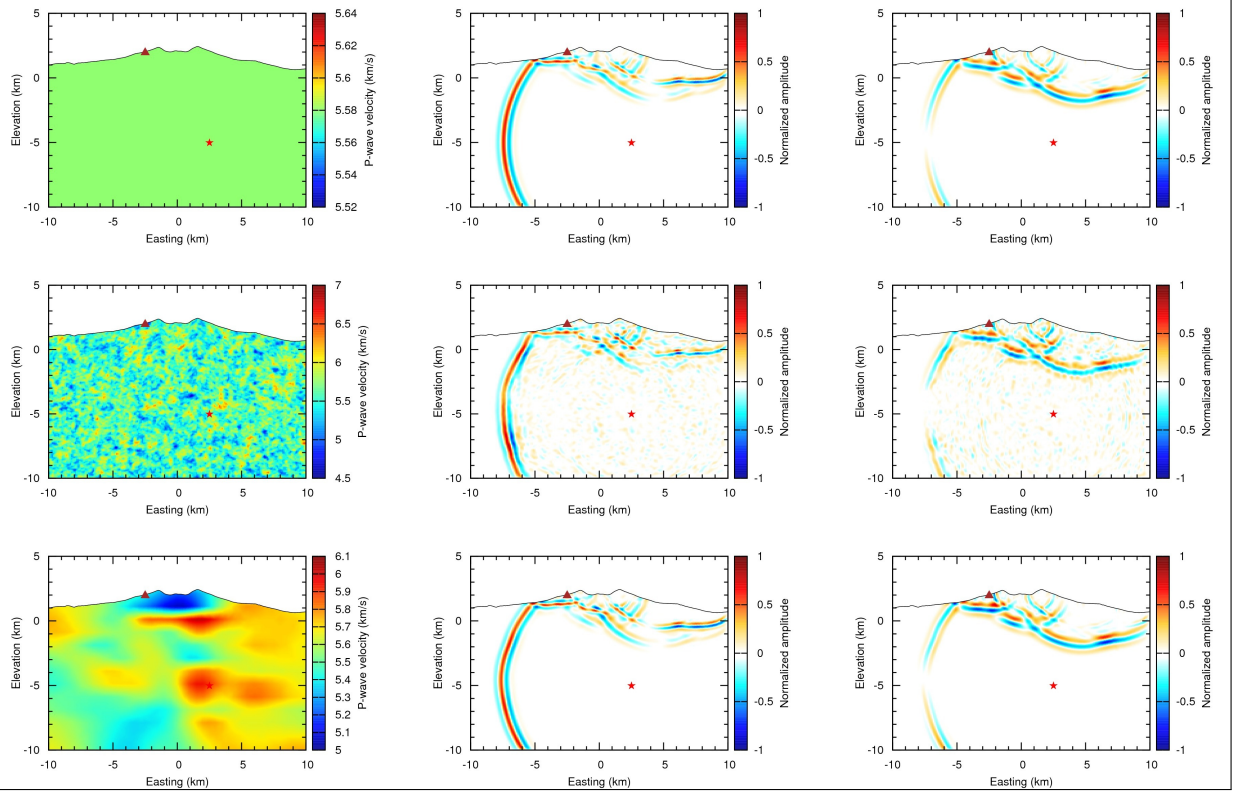
Noise interferometry

Traveltime migration of interferogram differences: daylight illumination



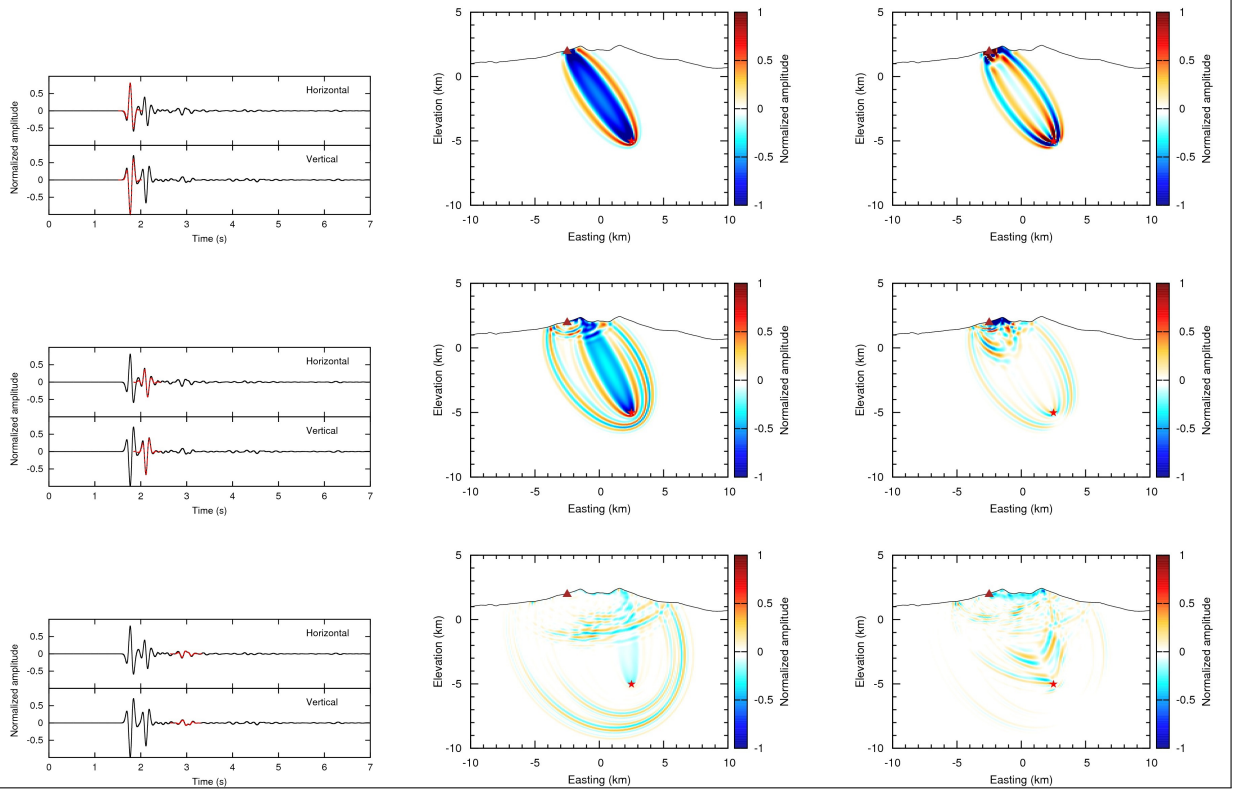
Seismic tremor in Mount St. Helens I

Snapshots in 3 different models



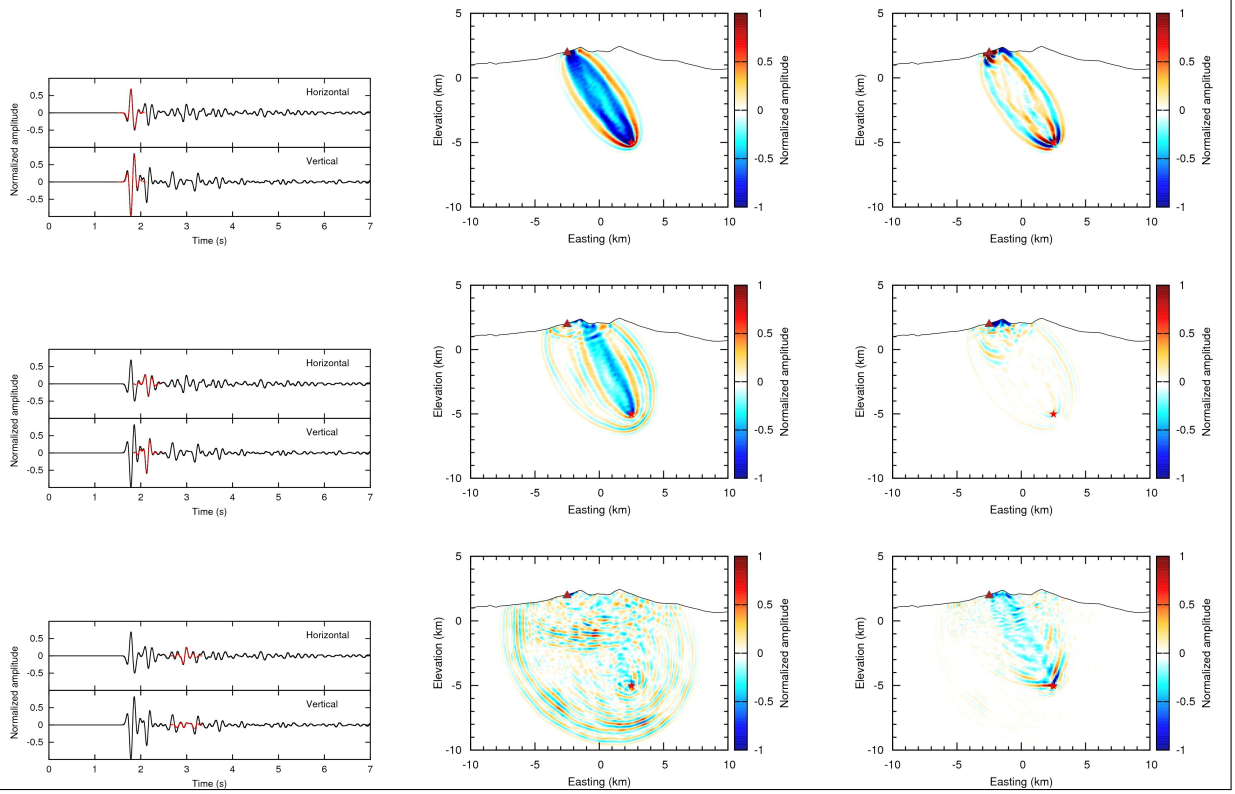
Seismic tremor in Mount St. Helens II

Sensitivities of the first model



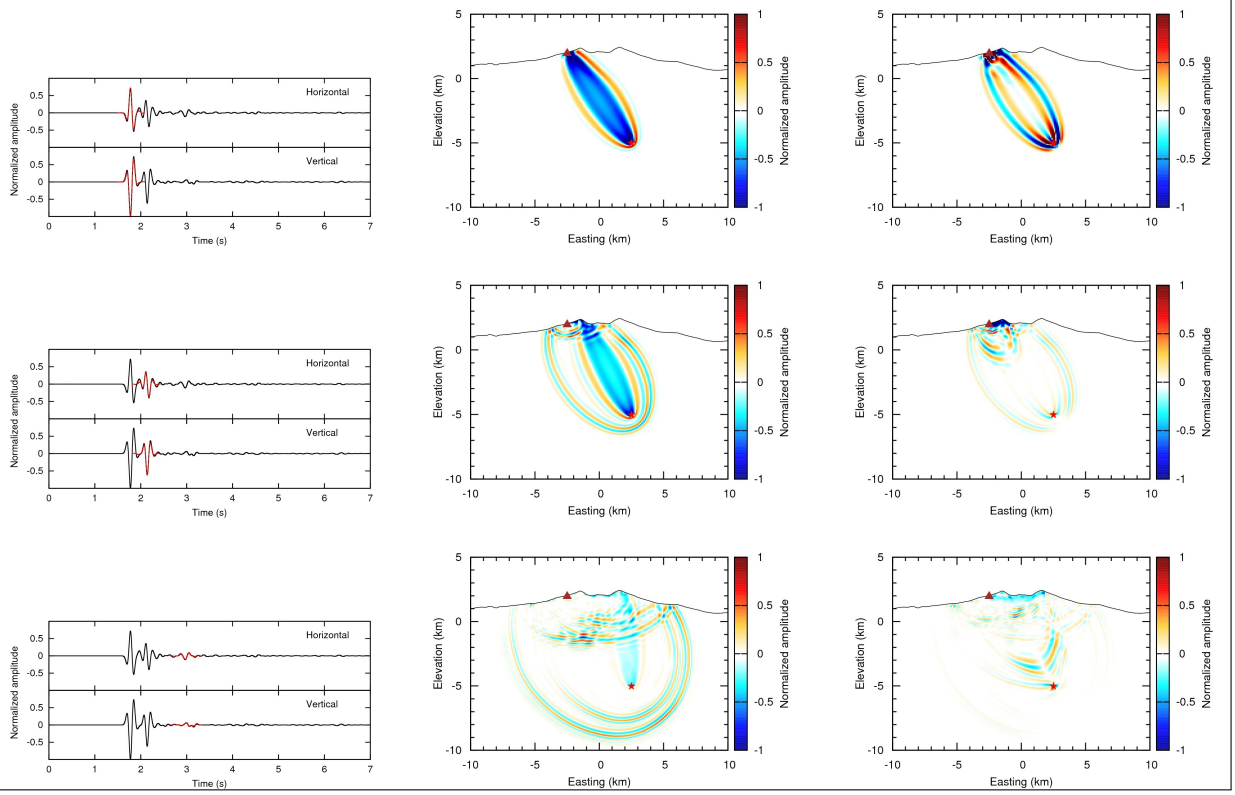
Seismic tremor in Mount St. Helens III

Sensitivities of the second model



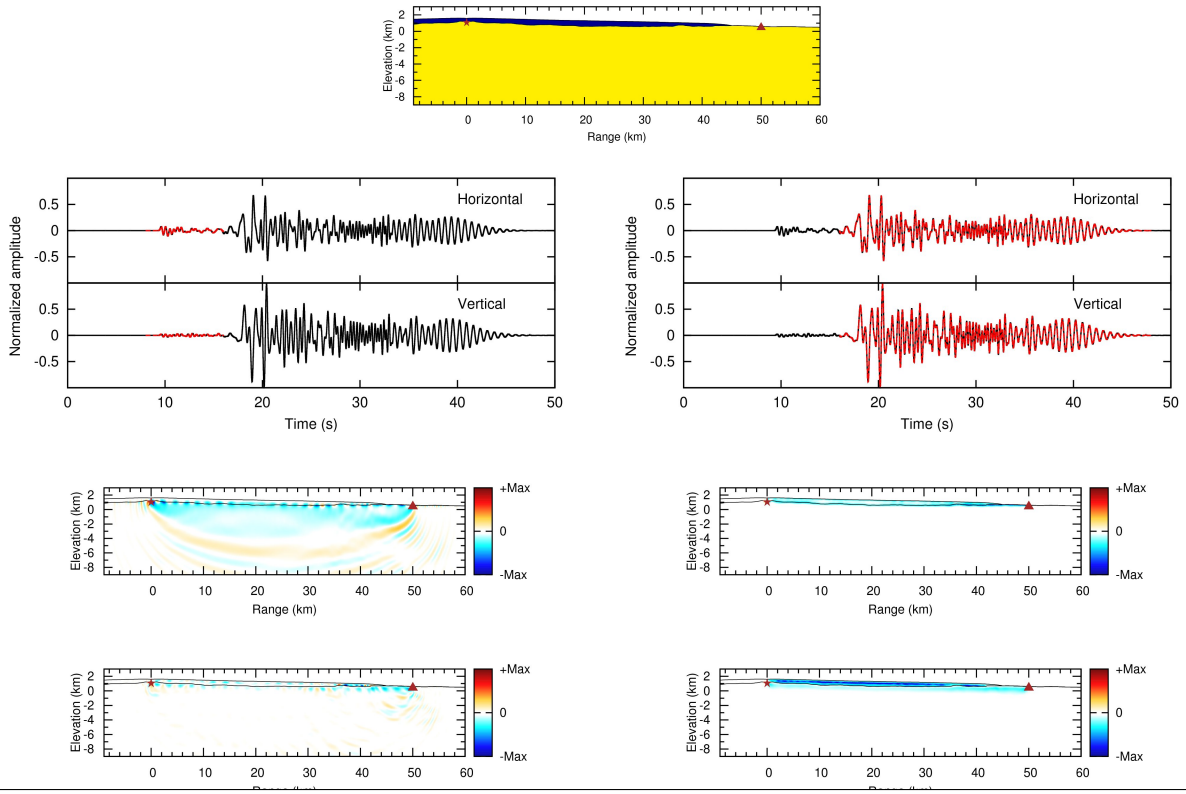
Seismic tremor in Mount St. Helens IV

Sensitivities of the third model



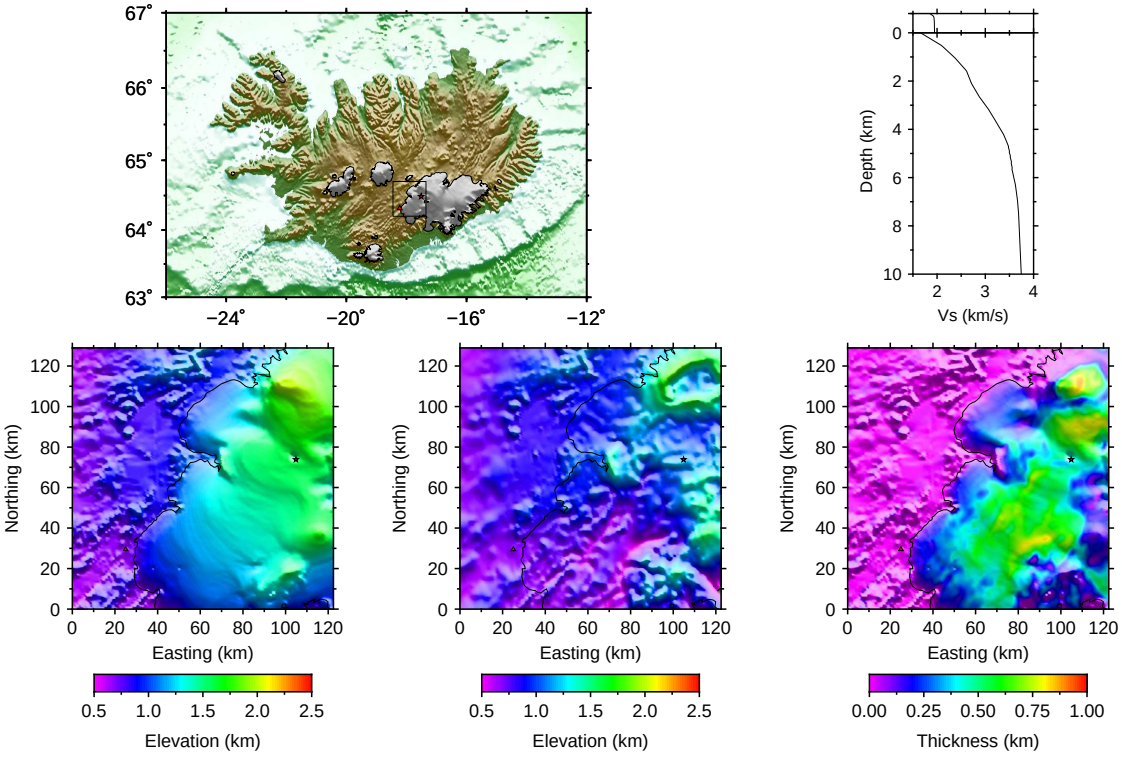
Seismic tremor under an icecap I

A very simple 2D model



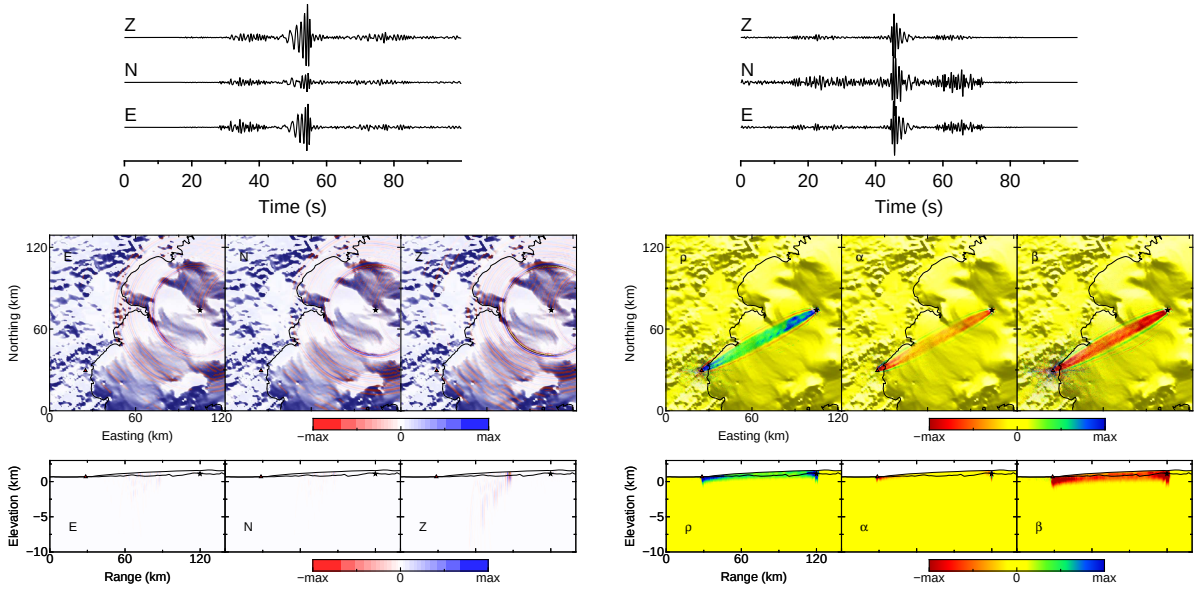
Seismic tremor under an icecap II

A realistic 3D model in Vatnajökull



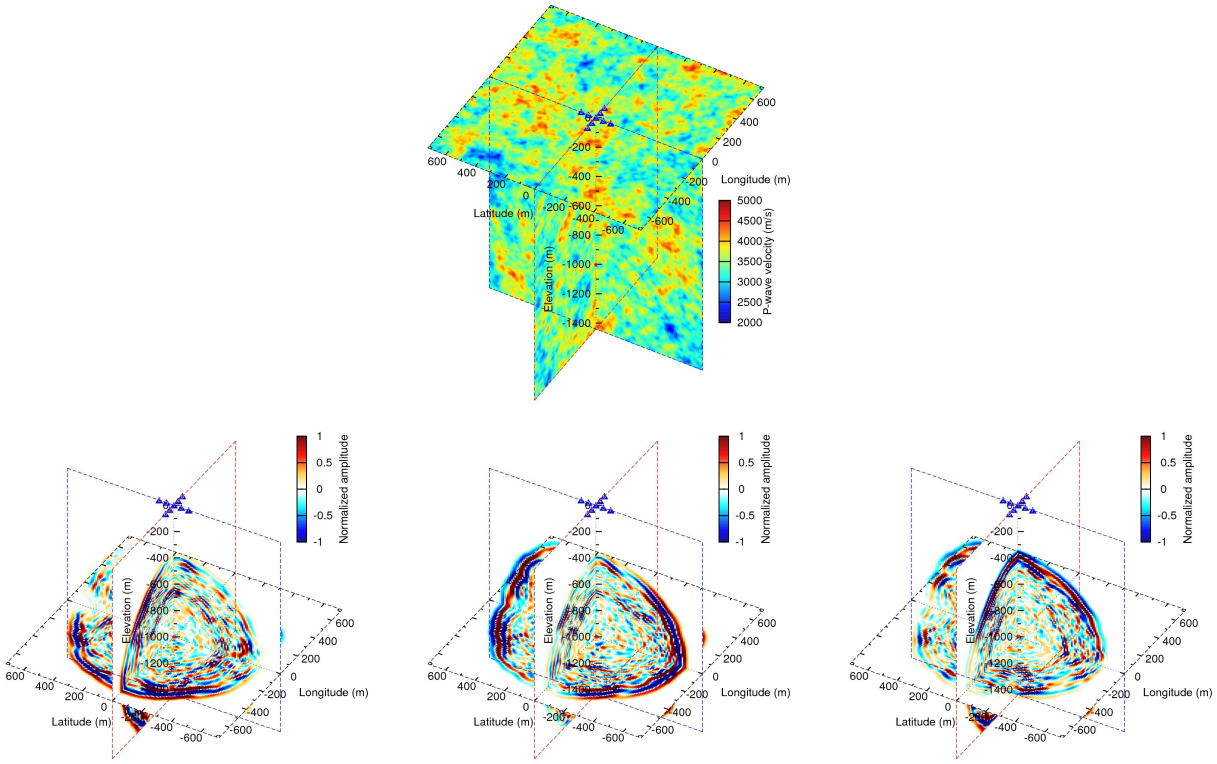
Seismic tremor under an icecap III

A realistic 3D model in Vatnajökull



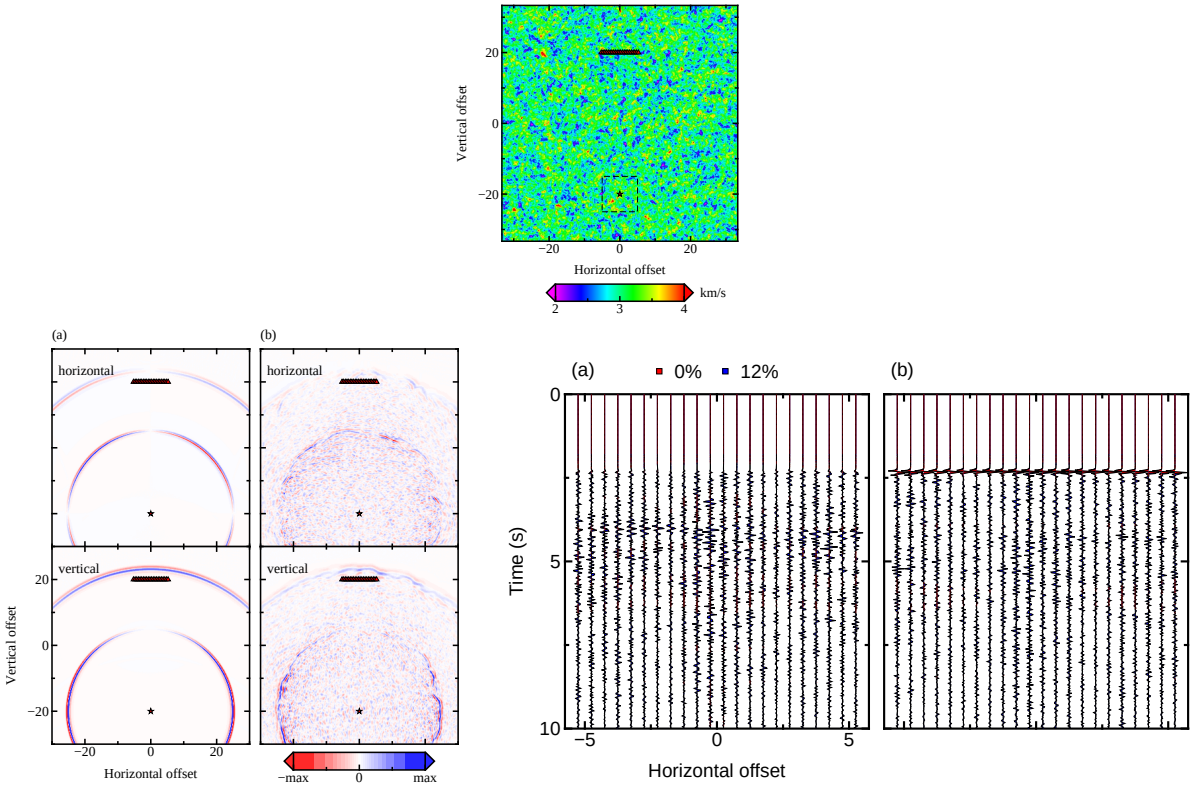
Seismic wave in 3D heterogeneous halfspace

Snapshots



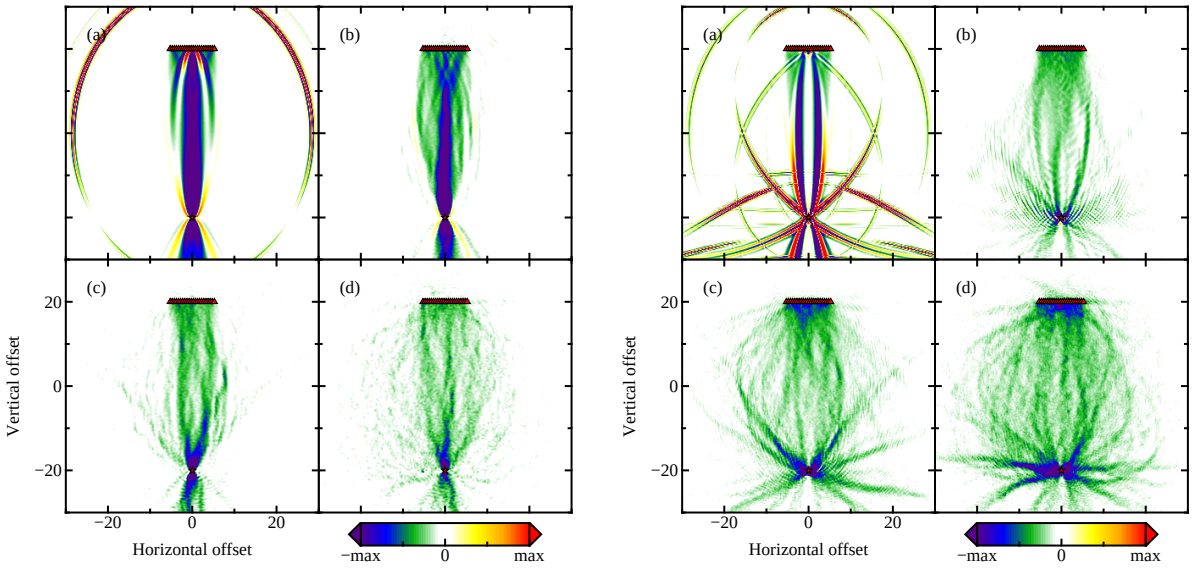
Seismic wave in 2D heterogeneous solids I

Distorted forward propagation



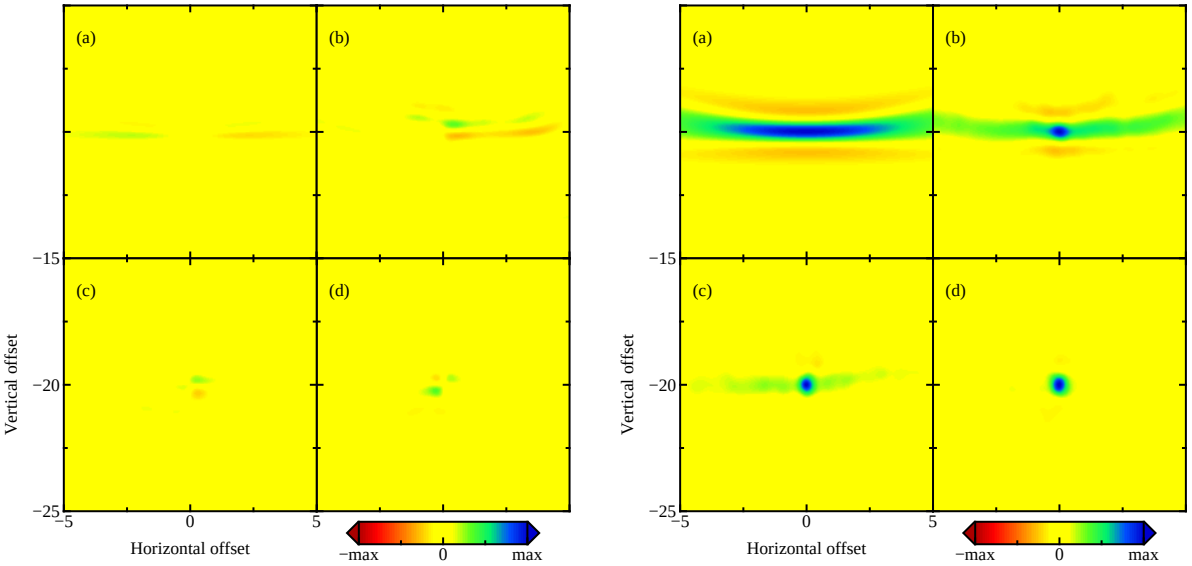
Seismic wave in 2D heterogeneous solids II

Dispersed sensitivities



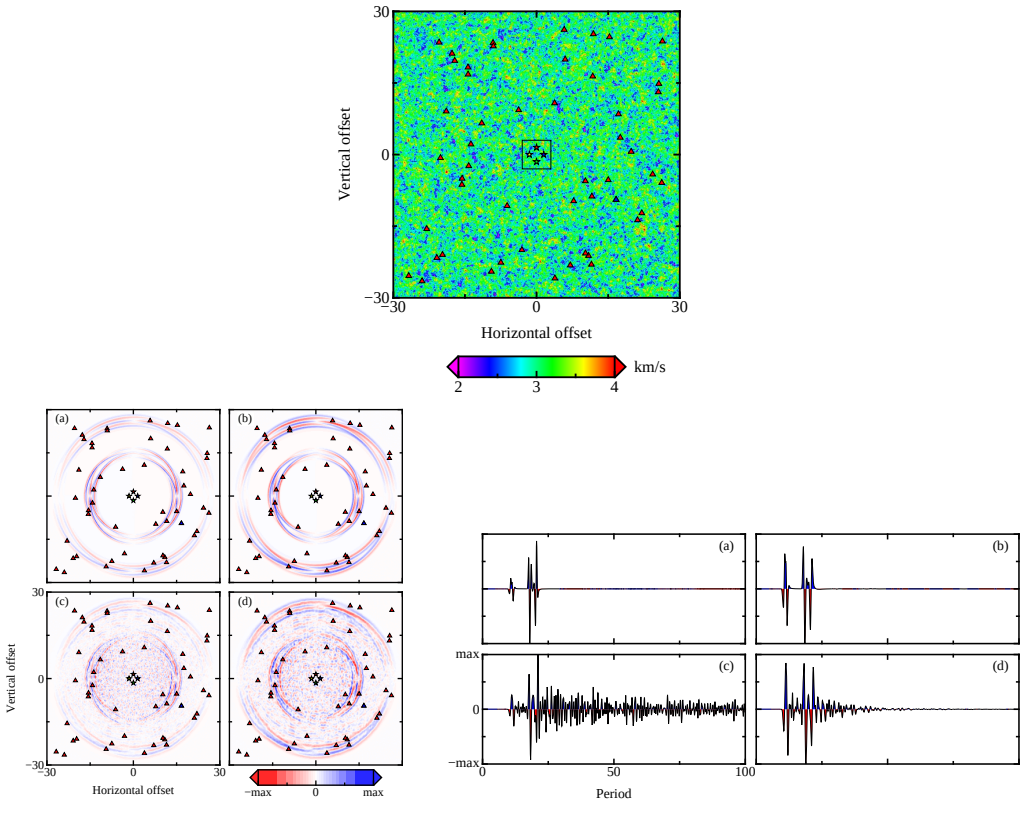
Seismic wave in 2D heterogeneous solids II

Enhanced refocusing



Relocation of seismic events in scattering solids I

Forward propagation



Relocation of seismic events in scattering solids II

Imaging result