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Imaging the lithosphere and upper mantle of the North Atlantic region using massive seismic waveform datasets

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The North Atlantic Ocean and the neighbouring North America and Europe are now sampled with a densest coverage of seismic stations, providing us with massive amounts of seismic waveforms. Together with the continuing development of waveform tomography techniques, this presents us with an opportunity to resolve the structure of the underlying lithosphere and upper mantle at a new level of detail. Dynamics of the North Atlantic Ridge and the Iceland Hotspot, evolution of the passive margins on both sides of the ocean, and the shape and extend of the cratonic cores of Europe and North America are some of the important fundamental problems that we can make progress on using new, more detailed and accurate models of seismic structure and anisotropy within the lithosphere and underlying mantle. We assemble a very large waveform dataset including all publicly available data in the region, from both permanent and temporary seismic networks and experiments. The resulting very dense sampling of the area allows us to push our tomographic inversion to a very fine 130 km grid spacing. Our model is constrained by over 1.2 million vertical-component waveform fits, computed using the Automated Multimode Inversion of surface, S and multiple S waves. Each seismogram fit provides a set of linear equations describing 1D average velocity perturbations with respect to a 3D reference velocity model within an approximate sensitivity region between the source and receiver. The equations are then combined into a large linear system and jointly inverted for a model of shear- and compressional-wave speeds and azimuthal anisotropy within the lithosphere and underlying mantle. Finally, we carefully isolate and discard the outliers that pollute the data, mainly derived from station timing errors and event mislocations, which become a relevant problem when dealing with large datasets on fine grids. On the continents, we are able to image the fine scale structures of the North American, Greenland and East European Cratons, previously detected only by local studies, and now benefitting from our very large data coverage. We similarly image the low-velocity anomalies of the Eifel Hotspot and Pannonian Basin and the high-velocities associated to the Alpine, Calabrian and Vrancea slabs. In the North Atlantic Ocean, we retrieve a detailed low-velocity structure along the Mid-Atlantic Ridge all the way to the Arctic Ocean, with pronounced velocity minima in close proximity to the Iceland Hotspot and Azores triple junction, as well as smaller, more localized anomalies underpinning the Canary and Bermuda Islands.