Phase and Amplitude Rayleigh Wave Fields Measured by AlpArray

Tesch, M., Meier, T. (CAU Kiel), AlpArray Working Group

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- Modern station densities in the Alps allow to resolve the shape and inherent distortion of tele-seismic surface waves across the greater Alpine area at unprecedented resolution.

- Over 1500 available broadband stations within a 20° radius around the central Alps.

- Measuring surface wave phase and amplitude in the space-frequency domain to derive structural phase velocities corrected for possible dynamic effects.

- Correlation with synthetic fundamental mode signals for a spherically symmetric earth to suppress noise, higher modes, and coda waves.

- Dynamic contributions to the eikonal phase velocity are significant and need to be accounted for.

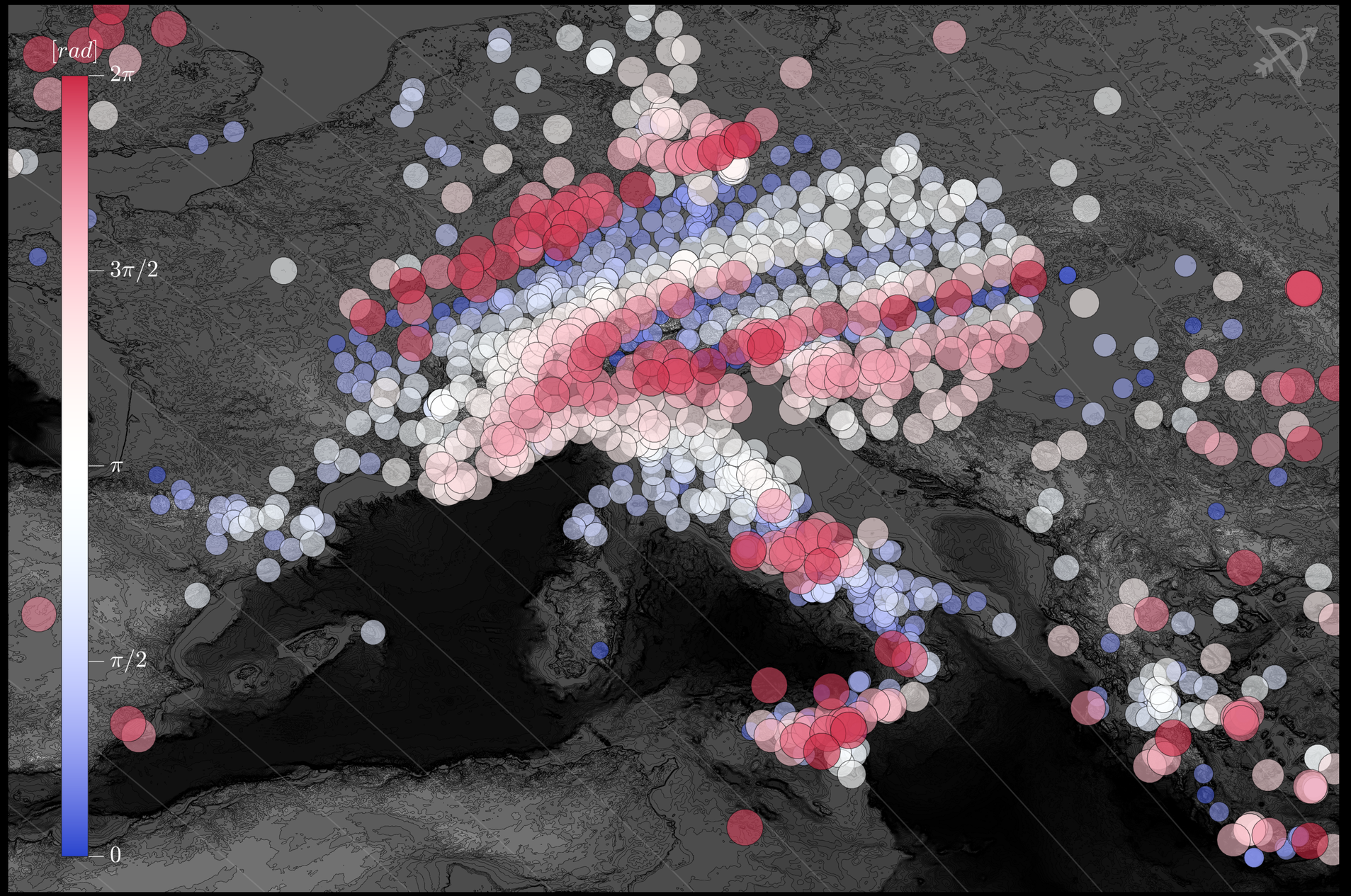
Phase Perturbations at 40s

Shown is an example of a relative phase measurement of a wave field for a tele-seismic event with magnitude 7.5. Phases are given as principle values, i.e. in the interval [0, 2π].

Clear deformations of the wave field are visible, with the phase gradient in part strongly deviating from the propagation direction. The shape of these deformations evolves over frequency and naturally becomes more chaotic at shorter periods.

Judging by the fact that some of the deformations span almost the entire width of the observed region, it stands to reason that they are at least in part induced (potentially far) outside of the array. The phase perturbations are however especially strong in the Alpine area.

Note the comparison to the regions directly adjacent to the AlpArray network, where an assessment of deformation becomes significantly more difficult due to lack of station density.



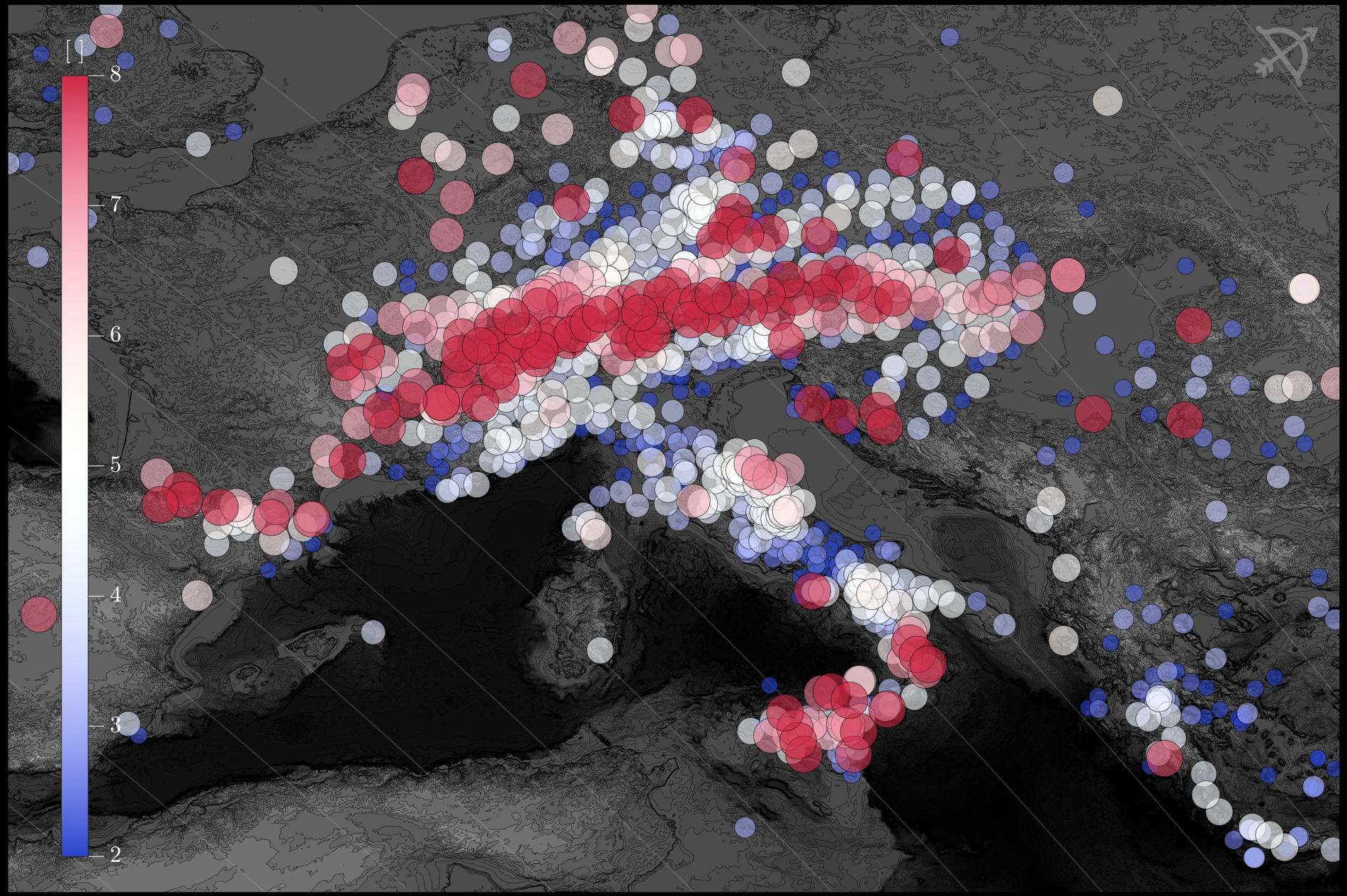
Event in Southern Chile on December 25th, 2016, propagating from the south-west to the north-east.

Amplitude Ratios at 40s

Shown are the ratios by which the wave field's amplitude at the given period compares to the to synthetic wave forms for a spherically symmetric earth.

Similar to the phase, the amplitude field is strongly deformed as well, forming a dominant stripe of high amplitudes across the array, roughly aligned with the central anomaly in the previous figure, deviating only slightly from the propagation direction.

Smaller local reverberations are particularly visible around Mount Etna and Vesuvius.



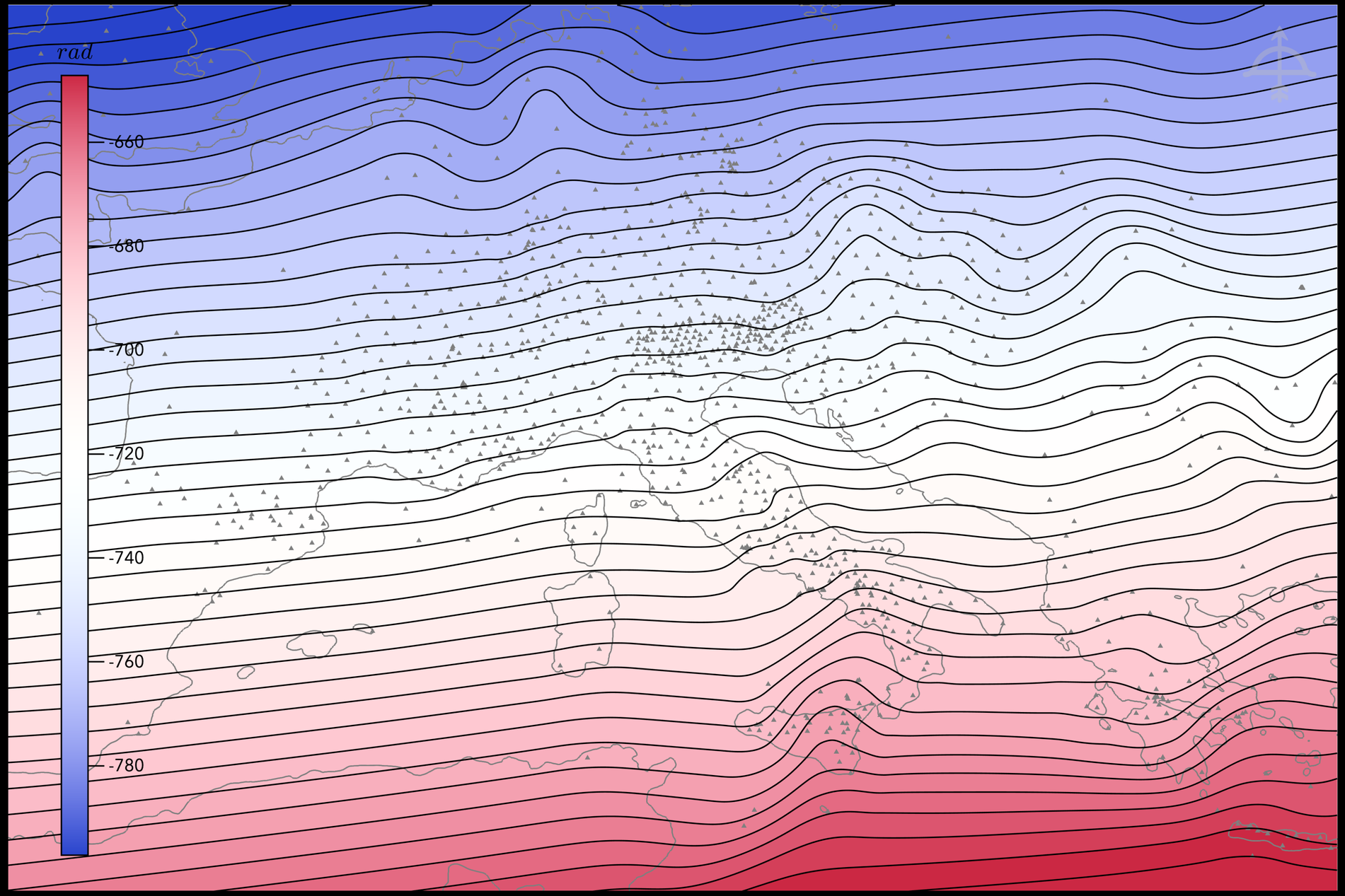
Event in Southern Chile on December 25th, 2016, propagating from the south-west to the north-east.

Phase Field at 25s

Combining the obtained phase differences with the known phase field of the synthetics allows for resolving the complexity of wave fronts of the incoming fundamental Rayleigh mode.

Phases are now given as absolute values, decreasing with distance to the source. (Note the negative sign on the labels of the colorbar.)

The shape of the wave fronts does locally differ quite significantly from the expected small circles around the source, due to scattering in- and outside of the array. Understanding and correcting for such deformations requires the consideration of amplitudes.



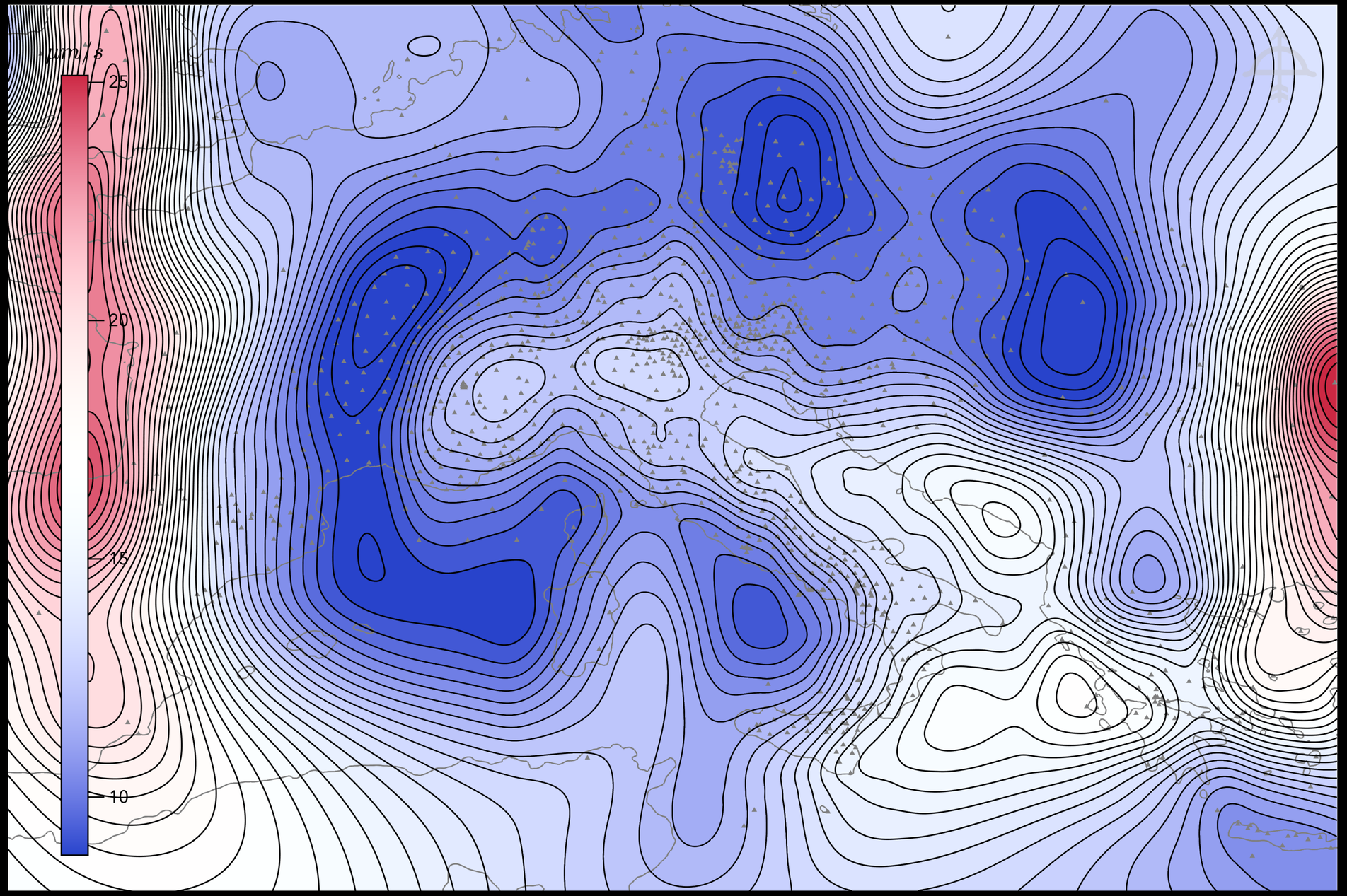
Event in the Southern Atlantic on January 28th, 2018, propagating from the south to the north.

Amplitude Field at 25s

Shown are the absolute amplitudes of the wave field, constructed from the measured ratios and the known synthetics.

The resulting image has no semblance with the expected decay with distance of an unperturbed wave, but rather features a collection of complex anomalies. At the choosen period a strong negative anomaly spans from the western Alps along the entire Alpine arc, up to the Pannonian Basin in the east.

These amplitude distributions encode a lot of useful information in regard to structural wave propagation and are essential in measuring well adjusted local phase velocities.



Event in the Southern Atlantic on January 28th, 2018, propagating from the south to the north.

- Rayleigh fundamental mode phase and amplitude fields can be determined using AlpArray data.
- Wave fields show high complexity with local and large-scale anomalies that vary greatly with frequency.
- Some large anomalies are likely induced outside the array and therefore need to be corrected when assessing local structure.
- Amplitudes give an indication of the dynamic nature of the wave field and can be used to derive structural phase velocities.