Supporting Information for

Atmospheric wind and temperature profiles inversion using infrasound: an ensemble model context

I. Vera Rodriguez[1*], S. P. Näsholm[1] and A. Le Pichon[2]

[1]NORSAR, Department of Applied Seismology, Kjeller, Norway

[2]CEA, DAM, DIF, Arpajon, France

Description

The supplementary information contained in this document provides additional examples demonstrating the performance of the inversion methodology proposed in the article.

These inversion results used infrasound observations from 12 explosions that occurred at Hukkakero between the months of August and September 2007.

For each set of infrasound observations from one explosion the following processing was performed:

1. Interpolate an ERA5 ensemble for the time of the explosion.
2. Interpolate 2D models along the line that joins Hukkakero and ARCES for each ensemble member.
3. Average the 2D models along the horizontal direction to produce and ensemble of 1D models.
4. Average the 1D models to produce the starting model for the inversion.
5. Estimate standard deviations (for each altitude) in the 1D models.
6. Find eigenrays between Hukkakero and ARCES using the starting model and considering reflections from layers between 30km and 50km.
7. Select the reflection altitude above the layer with the smallest difference with respect to the observed travel time for the explosion under analysis to initialize the inversion.
8. Run inversion setting the solution space to be centered at the starting model profiles and spanning 3 times the estimated standard deviations. For reflection altitude the span of the solution space is the smallest between 1000 m or the distance to the next layer in the model.
9. If the inversion results are within the uncertainty of the infrasound observations, then repeat the inversion another 4 times.

10. If the inversion results are not within the limits of the infrasound observations, then increase the size of the solution space for the profiles in the 1D models and repeat the inversion.
11. If the inverted reflection altitude falls at the lower boundary of the solution space, then move the initialization point to one layer down.
12. Steps 10 and 11 are repeated until the inversion results are within the uncertainties of the infrasound observations and the inverted reflection altitude is not at the boundary of the solution space.
13. Once the solution space is adjusted to allow the inversion to find acceptable solutions, the inversion is repeated until 5 results are produced.

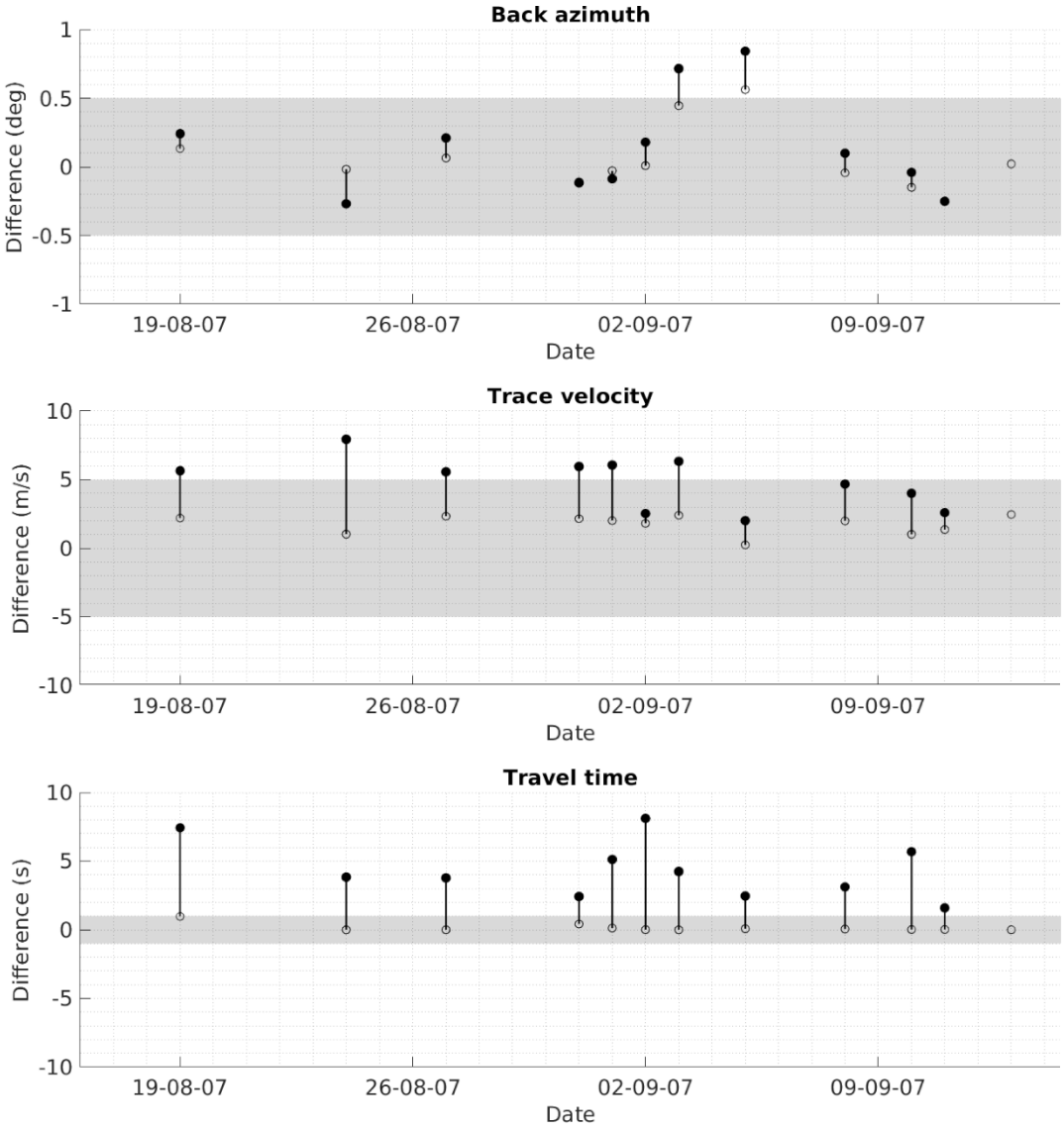

Figure SM1. Black-filled dots: Differences between observed infrasound-derived measurements (i.e., back azimuth, trace velocity and travel time) minus their forecast using the 1D starting models extracted from ERA-5 ensembles. Circles: Differences between observed infrasound-derived measurements minus their forecast using weighted averages of the inverted atmospheric models. The 5 inversion results were averaged using weights related to the misfit of the forecasts with the measurements. Shaded regions: Uncertainty of infrasound-derived measurements. Vertical lines join corresponding differences before and after inversion. The ray tracer could not find an eigenray for the last explosion (13-Aug) using the starting model, hence no filled dot is displayed.

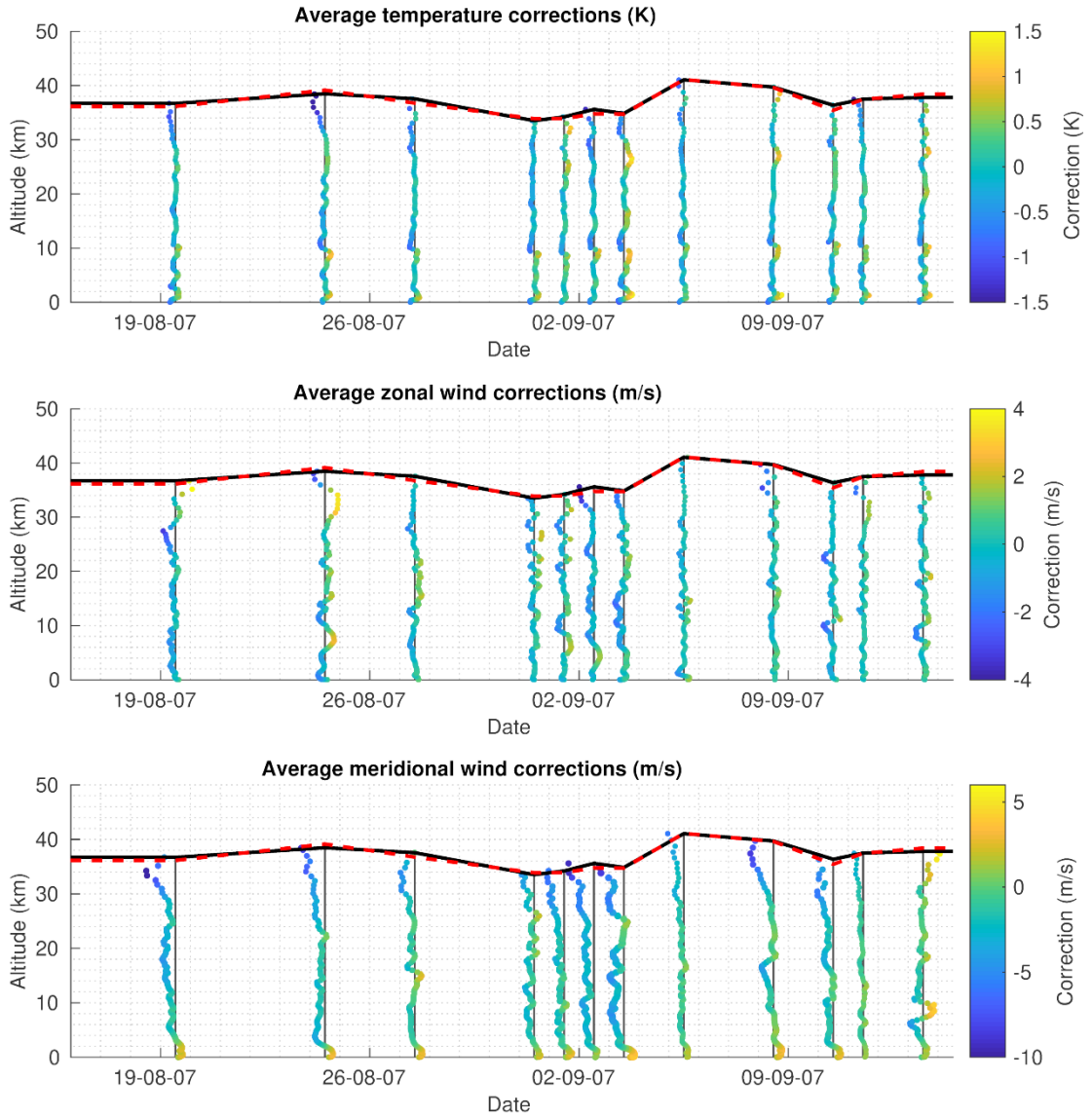

Figure SM2. Colored profiles: Averages of the cross differences between all 10 interpolated and averaged (1D) ERA-5 ensemble members minus all 5 profiles obtained from inversion for each explosion. Vertical black lines: corresponding zero axes presented for reference. The horizontal black line joins the inverted reflection altitudes (weighted averages of inverted results), while the red-dashed line joins the initialization points for the inversions. These corrections are meant to identify biases in the ERA-5 ensembles that must be corrected to be able to reproduce the infrasound observations. The consistent bias in meridional wind towards higher altitudes requires a correction in the negative direction, which is necessary mostly to reduce travel time (see Figure SM1).

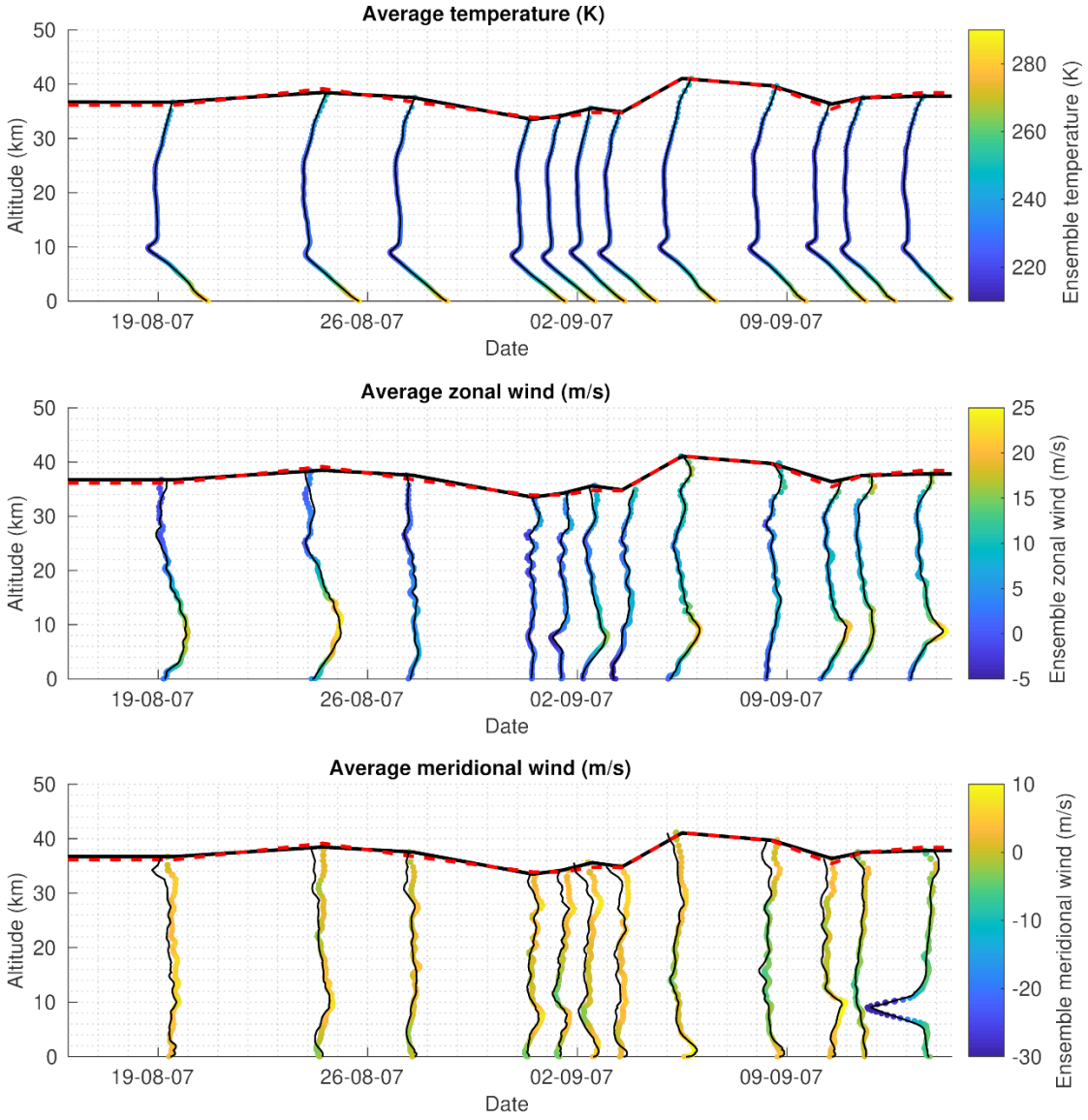

Figure SM3. Colored profiles: starting (1D) models extracted from ERA-5 ensembles. Vertical lines: (1D) models obtained from weighted averages of the 5 inversion results estimated for each explosion. The weights are related to the misfit of the forecasts with the measurements of infrasound data. The horizontal black line joins the inverted reflection altitudes (weighted averages of inverted results), while the red-dashed line joins the initialization points for the inversions. Notice the consistent separation between meridional wind profiles at higher altitudes.