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Estimation of infrasound-consistent wind and temperature atmospheric profiles from model ensembles in North Scandinavia

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Atmospheric reanalysis models rely on the assimilation of direct and indirect measurements of different properties of the atmosphere. A better representation of the upper stratosphere in these models, especially for winds, can contribute to enhanced numerical weather predictions on weekly to monthly timescales. Infrasound waves provide complementary information to characterize the middle atmosphere. This is particularly valuable above 30 km altitude where few other currently available technologies provide direct measurements, especially for the dynamics.

In the current work, we update ensemble-averaged ERA5 atmospheric models to become consistent with sets of infrasound array observations of travel-time, backazimuth, and apparent velocity. The atmosphere is simplified to a layered, time-invariant representation, which is considered valid for infrasound propagation at regional distances (< 400km). The optimization is achieved via a heuristic solver derived from particle swarm optimization. The solver minimizes a mixed l1-l2 cost function that measures the distance between the infrasound observations and their prediction based on ray tracing through the updated atmospheric model. When the array station is situated within the classical shadow-zone range from the source, the infrasound observations are assumed to be stratospheric reflections, and the reflection altitude is included as part of the model parameters to estimate. The problem is highly ill-posed, which we alleviate by bounding the temperature and wind profile solution space to a region in the vicinity of the members of the ERA5 ensemble with 137-level reanalysis model product. The profiles are also smoothed using a length of the smoothing operator empirically adapted to match the constraint provided by the observations. The performance of the method is demonstrated using observations of infrasound waves produced by explosions that happen regularly during August and September at the site of Hukkakero in Finland and detected at the array station ARCES located in northern Norway. The updated atmospheric model profiles require corrections that are more

significant above the 30 km altitude to explain the infrasound observations. These results are consistent over the observations of multiple explosions.