Climatology reflected by infrasound travel-times sampling the stratosphere in its transition between summer and winter

Ismael Vera Rodriguez*[1], Sven Peter Näsholm[1], Antoine Turquet[1]
* ismael@norsar.no; [1] NORSAR

Background

Similar to seismic waves traveling through the solid earth, infrasound waves travel through the atmosphere sensing its properties and carrying this information along to the ground-based stations where they are recorded. Therefore, there is great potential in developing ways to exploit this source of information to characterize the atmosphere, especially in regions where other measurement technologies provide sparse data. In this work, we investigate the climatology of the north of the Scandinavian peninsula as reflected by the variation in travel-times for a set of explosion-generated infrasound observations.

Explosions at Hukkakero, Finland

The infrasound dataset that we analyze spans a time range of 30 years from 1988 to 2018 and is the result of explosions conducted at a site named Hukkakero.

Hukkakero is a military site in Finland (67.94°N, 25.84° E), where explosions related to the destruction of ammunition happen regularly during the months of August and September (Figure 1). This period of time corresponds with the transition from a warmer summer atmosphere into colder temperatures that prelude the start of the winter season. Both seismic and infrasound waves generated by the blasts are regularly detected at the array station ARCES (69.53°N, 25.51°E) located in northern Norway.

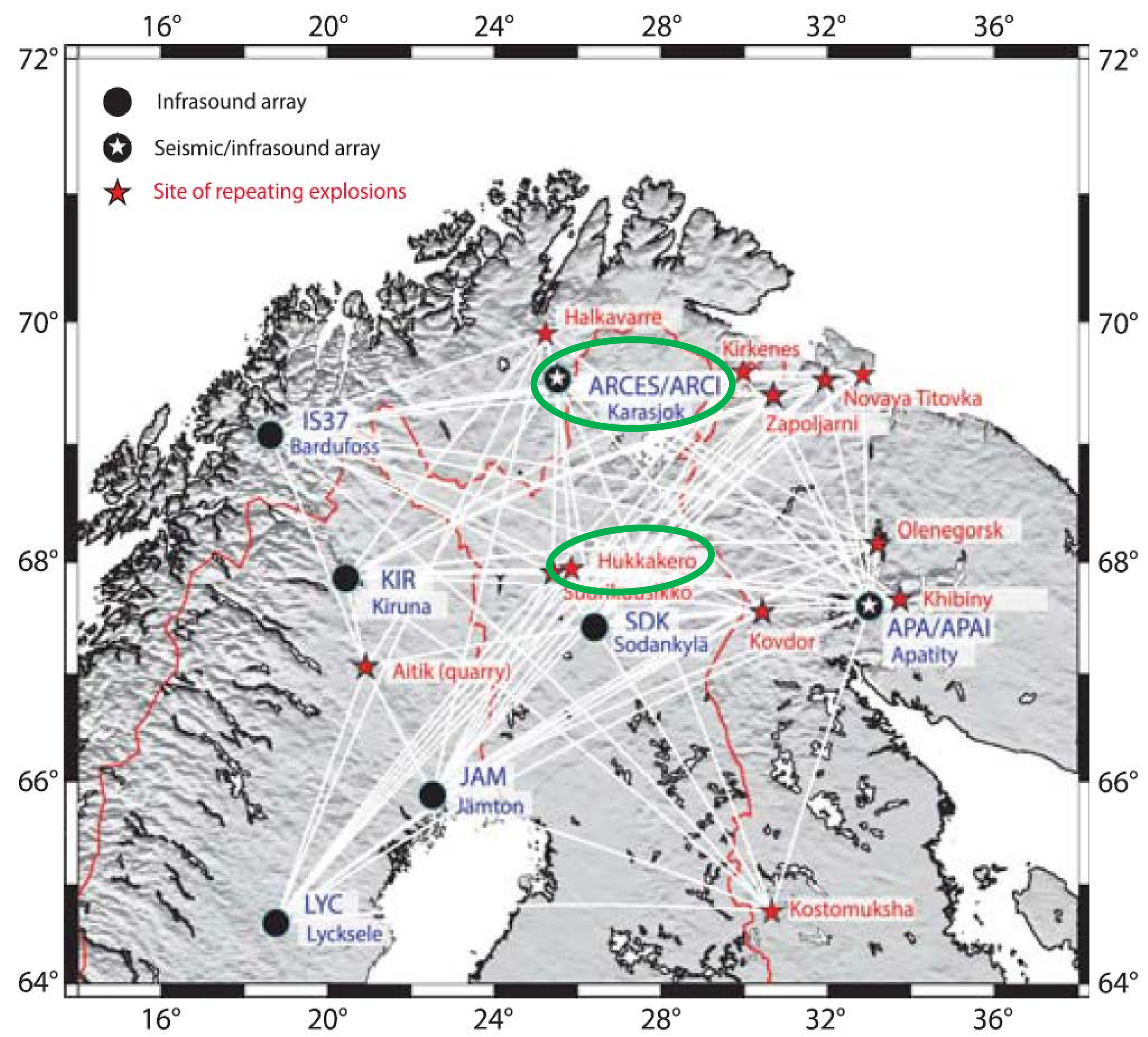

Figure 1*. Location of the Hukkakero military site and the seismic array ARCES in northern scandinavia. Figure after Gibbons et al. (2015).*

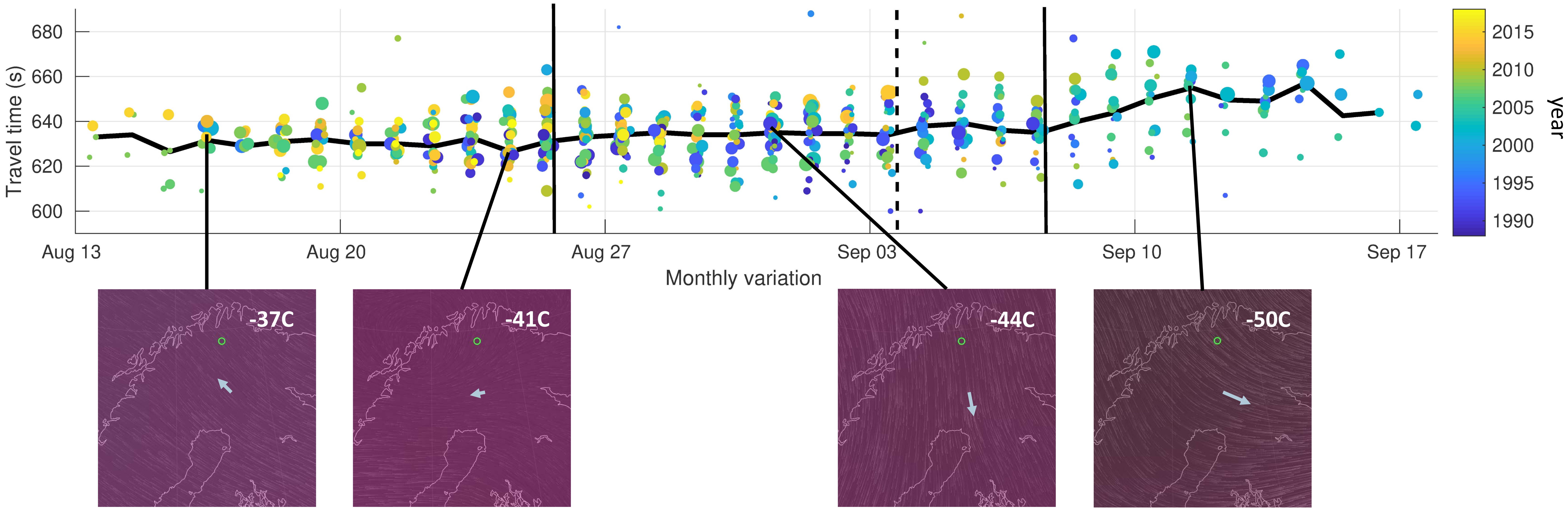

Figure 2*. Observed travel times of infrasound waves from explosions in Hukkakero detected at ARCES. The thick black line joins the medians from different dates, while vertical lines indicate changes in the median. The panels in the bottom are snapshots of stratospheric conditions showing temperature and wind (white arrows) near ARCES (green circle) for data points near the median. Bottom images obtained from earth.nullschool.net*

Time series of travel-times

Figure 2 presents the time series of travel times observed at ARCES from 1988 to 2018. The yearly seasonal change is clearly imprinted in the infrasound data. Travel times increase in two steps during this period of time. In both cases, the effect of the wind appears more significant compared to that of temperature (Figure 3). We observe that north-northwest winds coincide with shorter travel times. This is considering only stratospheric altitudes, where Blixt et al. (2019) hypothesized that the infrasound waves were reflected in this dataset. Clearly, changes in the lower atmosphere must also have an effect.

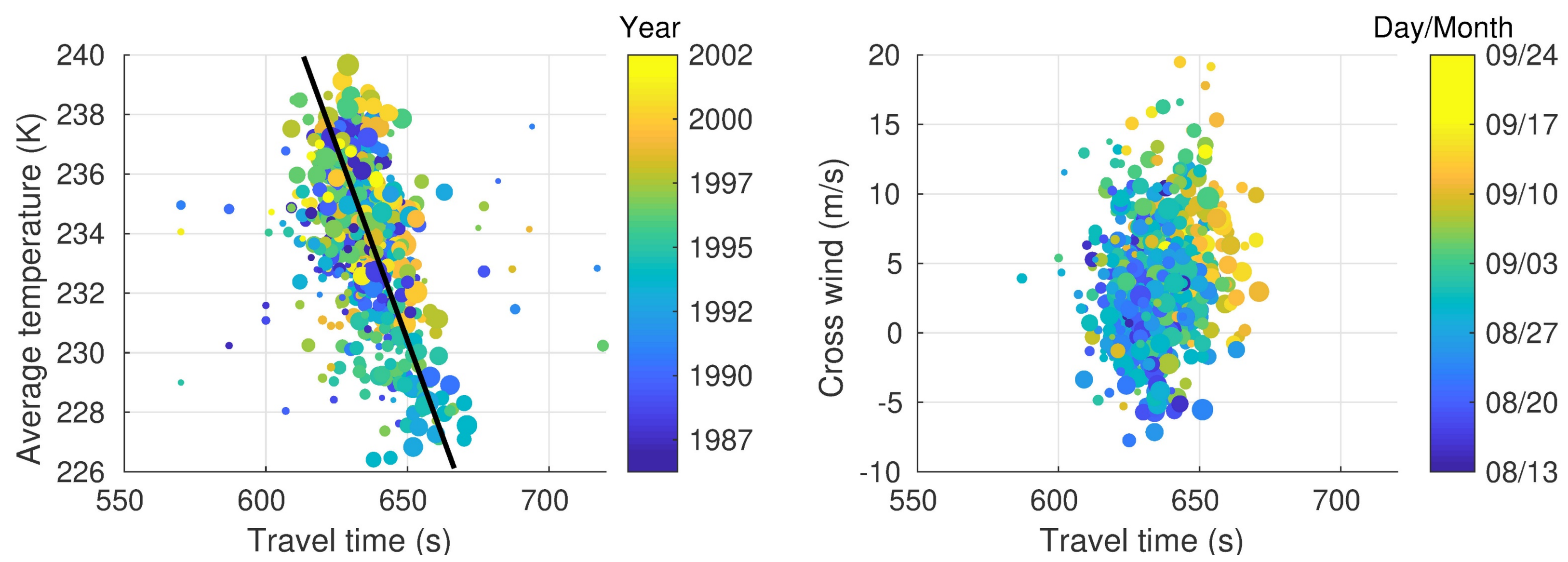

Figure 3*. Left: Crossplot of average temperatures in the altitude range 25-40km extracted from ERA reanalysis models and observed travel time for the complete explosion dataset. Right: Crossplot of crosswind computed following Blixt et al. (2019) and observed travel time for the complete explosion dataset.*

Comparing the travel times to (model) average-temperatures in the altitude range from 25 to 40 km (see Figure 3-left), a shift in the maximum average temperature in more recent years is accompanied by a consistent continuation of the linear trend followed by the two variables. On the other hand, comparing to average cross winds (see Figure 3-right), an increase in travel time also correlates with stronger eastward winds towards the month of September

Conclusions

Travel times from infrasound signals generated by explosions at Hukkakero reflect the transition from summer to winter in north Scandinavia. The effect of wind appears more significant compared to temperature in the reduction of travel time during the period of time that was analyzed. Travel times in more recent explosions correspond well with a warmer stratosphere in the same period of time reflected in the atmospheric models, although infrasound data variability does not allow the identification of clear trends.

References

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