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Effect of gravity wave induced small-scale perturbations in the atmosphere on infrasound arrival times at a high-altitude floating sensor system

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INTRODUCTION

A high-altitude helium-filled balloon carrying a sensor was launched with the aim to capture infrasound generated by three pairs of controlled ground explosions in New Mexico, USA (Jul 2020).

METHODS/DATA

One of the signal arrivals detected while the balloon was in the predicted acoustic shadow zone. We examined the role of small-scale perturbations induced gravity waves on infrasound propagation.

START

RESULTS

Implementation of gravity wave perturbations to the stratospheric wind field explained the signal detection and correctly predicted infrasound travel times.

CONCLUSION

The influence of small-scale stratospheric perturbations can be substantial, even at regional distances. Our results demonstrate the importance of accounting for fine-scale structures in modeling efforts.

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Introduction

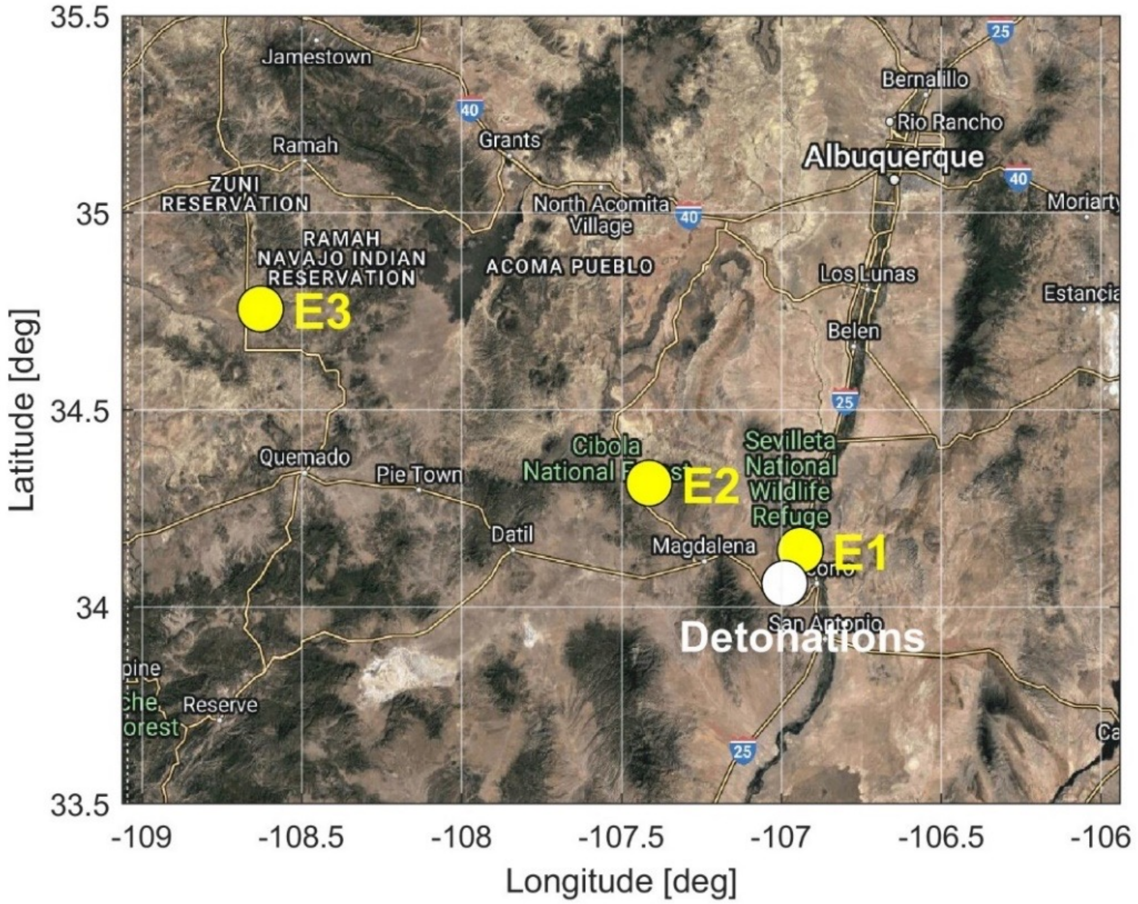


Figure 1: Map [4] showing the event and balloon geographical locations. The event (a pair of detonations) location is denoted with the white circle. Yellow circles show the locations of the balloon when Events 1 – 3 (E1 – E3) detections were made. The balloon was drifting in the northwest direction.

- In recent years, high-altitude floating platforms with a microbarometer payload have been utilized towards infrasound detection and source characterization [1].
- The stratospheric locale is presumed to be less noisy, thus facilitating better signal detection compared to ground-based sensors [2].
- A high-altitude balloon carrying a sensor payload was launched in early morning on July 10, 2020, with the aim to capture infrasound generated by a series of three pairs of controlled ground chemical explosions (New Mexico, USA) [3].

INTRODUCTION
OBJECTIVES
METHODS/DATA
RESULTS
CONCLUSION

Objectives

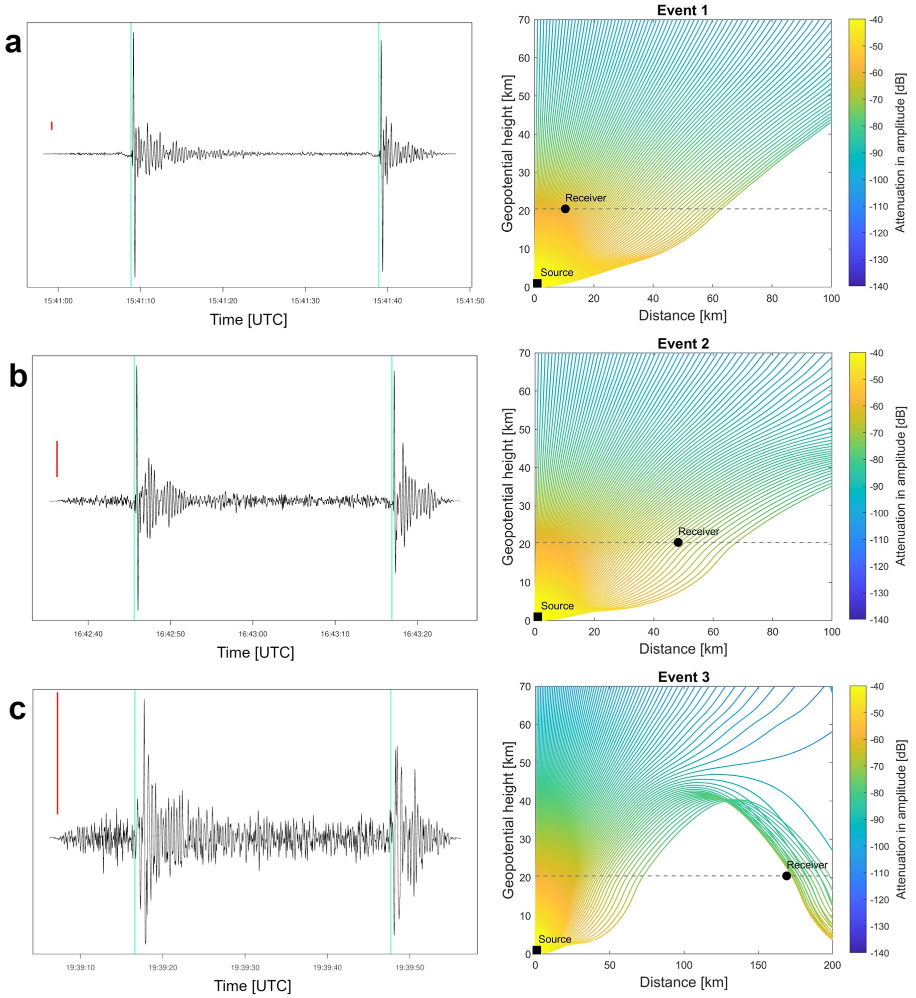


Figure 2: Left: Filtered (0.5–8 Hz bandpass Butterworth) waveforms with time picks for the three explosion pairs. The red bar is the amplitude (0.25 Pa). The green bars show time picks for each arrival. **Right:** Raytracing results.

- All three pairs of explosions were detected (Fig. 2, left). Raytracing [5] showed that the balloon was within the acoustic shadow zone when the third pair of shots (Event 3) was detected (Fig. 2, right).
- We ran raytracing using three different atmospheric specification (temperature, wind speed) profiles (G2S [6], radiosonde) to examine propagation paths and derive airwave arrival timing for Event 3.
- While arrivals for Events 1 and 2 were readily reproduced, none of the raytracing results were consistent with the observations for Event 3.
- The analysis of the horizontal motion of the balloon indicated the presence of small scale perturbations [7].
- Therefore, for Event 3, we aimed to ***investigate the effect of gravity wave perturbations*** to the wind field on infrasound propagation between a free-floating high-altitude sensor and the ground source.

INTRODUCTION
OBJECTIVES
METHODS/DATA
RESULTS
CONCLUSION

Methods

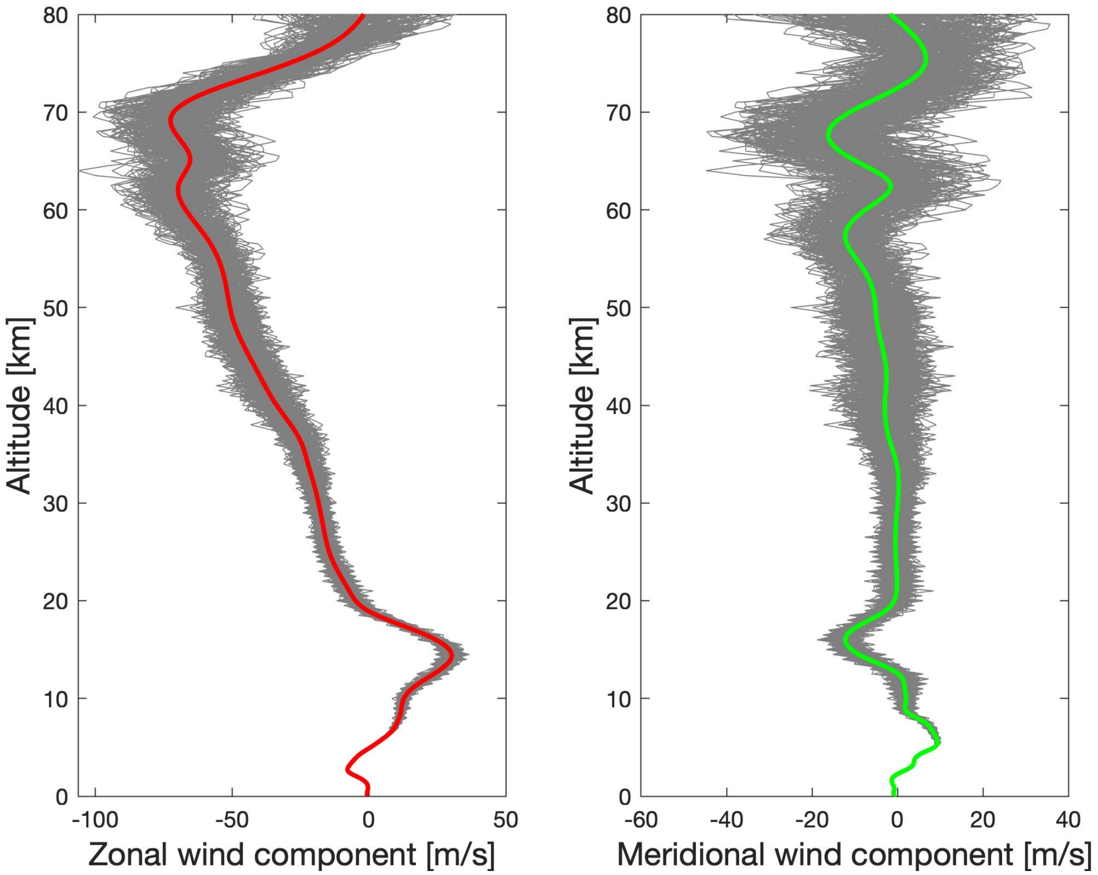
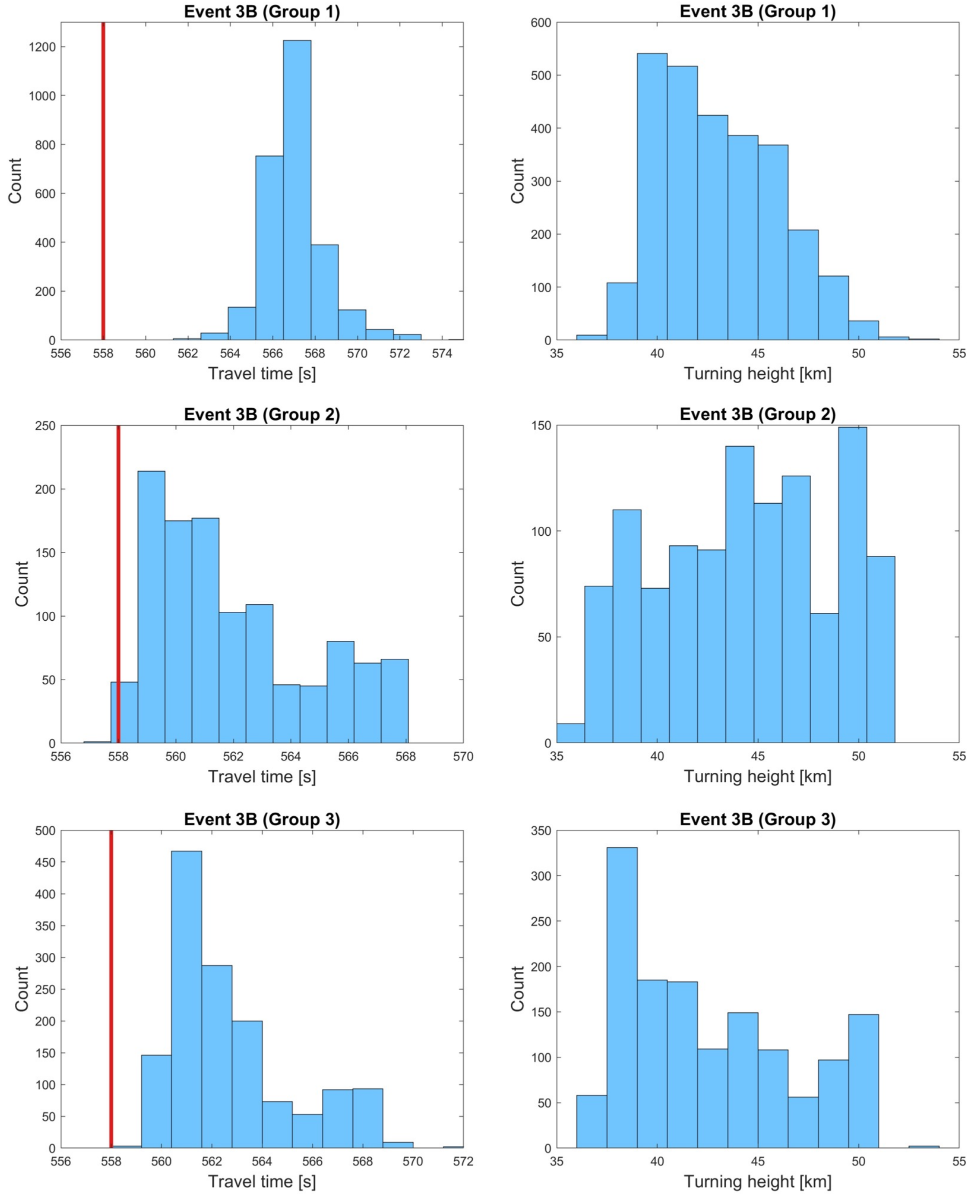


Figure 3: Example of perturbation realizations (grey lines). Green and red lines represent the model atmosphere.

- Small-scale perturbations were implemented following the Monte Carlo-type approach [8].
- We applied gravity wave perturbations to the wind speed of each one of the three atmospheric specification profiles (G2S, radiosonde).
- This resulted in three groups of several hundred new atmospheric profiles.
- A representative set of perturbed profiles, split into zonal and meridional wind components, is shown in Fig. 3.
- We ran raytracing in the eigenray search mode [9] for each perturbed atmospheric profile to examine the viability of propagation paths and derive airwave arrival timing.

Results



- Histograms with eigenray travel times and ray turning heights for the three groups of perturbed atmospheres are shown in Fig. 4.
- Even though eigenrays might exist, it does not necessarily follow that any of the predicted signal travel times would appropriately describe that observed, adding another layer of complexity.
- The acoustic wave underwent upward refraction before reaching the receiver, thereby spending enough time in the stratosphere where gravity waves amplitudes are non-negligible.
- Our findings are consistent with previous studies that also mention gravity wave perturbations as an important factor behind signal detections in an acoustic shadow zone [10-12].

Figure 4: Histograms for travel times (left) and turning heights (right). Red line denotes the observed travel time.

INTRODUCTION
OBJECTIVES
METHODS/DATA
RESULTS
CONCLUSION

Conclusions

- We investigated the effect of gravity wave perturbations to the wind field on infrasound propagation between a free-floating high-altitude sensor and a ground source, consisting of three pairs of chemical surface explosions. This is the first such study to date.
- One of the signal arrivals, detected when the balloon was in the acoustic shadow zone, could not be predicted via propagation modeling using a realistic atmosphere.
- Implementation of gravity wave perturbations to the stratospheric wind field explained the signal detection and correctly predicted infrasound travel times.
- The knowledge of atmospheric specifications is of great importance, especially at altitudes where gravity wave perturbation amplitudes might be dominated by other effects.
- However, the influence of small-scale stratospheric perturbations can be substantial, even at regional distances (<200 km).
- Our results demonstrate the complexities surrounding infrasound wave propagation at short ranges and the importance of accounting for fine-scale structures in modeling efforts.

INTRODUCTION
OBJECTIVES
METHODS/DATA
RESULTS
CONCLUSION

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INTRODUCTION
OBJECTIVES
METHODS/DATA
RESULTS
CONCLUSION