

## 1. Introduction

• Since 2010, infrasound arrivals have been included in International Data Centre (IDC) analyst-reviewed bulletins of events detected across the International Monitoring System (IMS). Using five years (2010-2015) of data, we investigate Reviewed Event Bulletin (REB) entries to understand the following:

- The reliability of arrival identification ('detection').
- Which type of sources the IMS infrasound network is sensitive to.
- The geographical distribution of REB event locations.

• 4 large clusters of infrasound only events (IOE) in western Eurasia (Fig. 1) used in this study.

• Re-analysis of 20 randomly selected events from each cluster, using the F-detector in 3 overlapping 2-octave Butterworth 6-pole filters (0.5-2, 1-4 and 2-8 Hz).

• Time periods where the probability that the F-statistic indicates a coherent signal exceeded 95%, assuming a signal-to-noise ratio of 2 are identified as detections (Figs. 2 and 3).

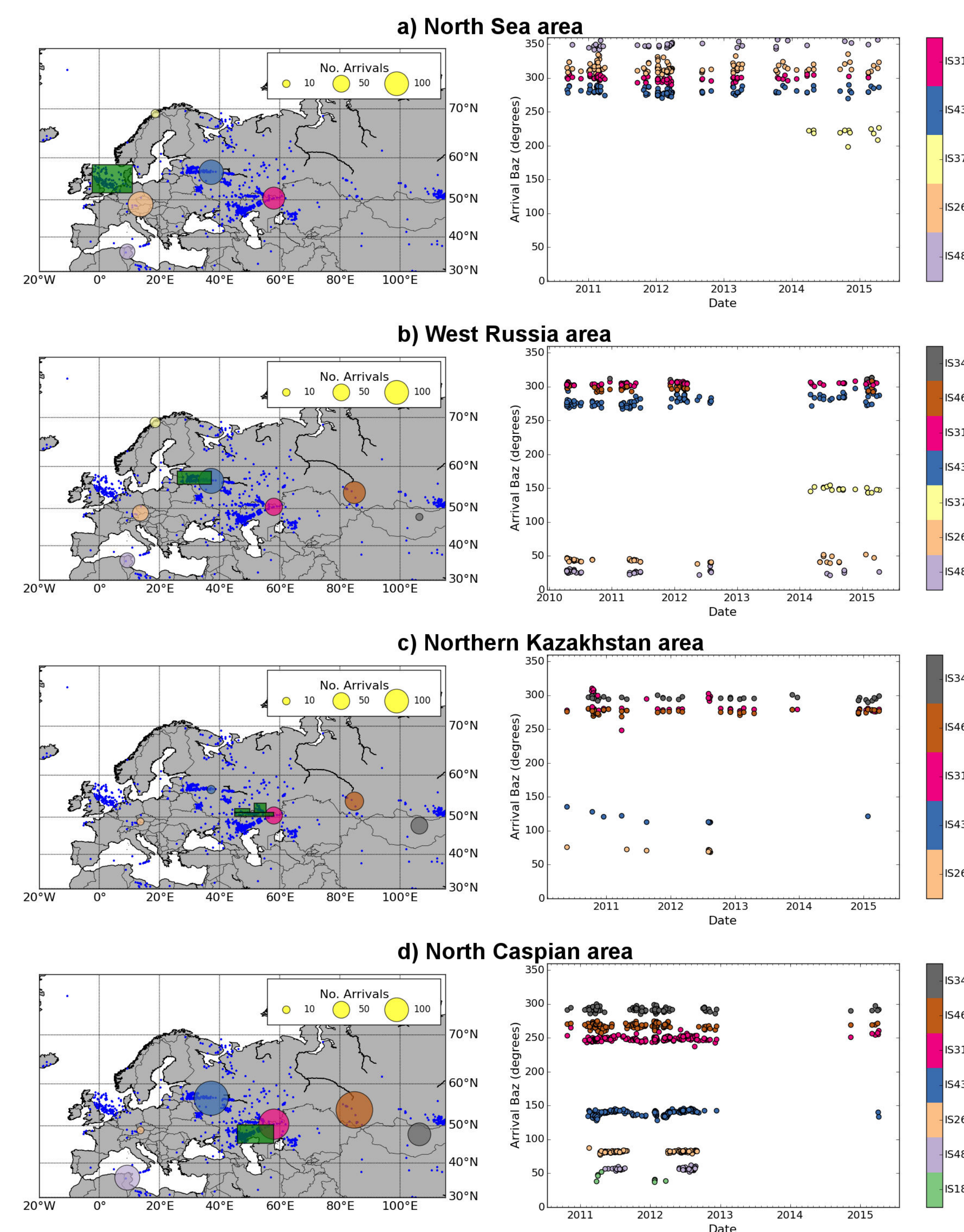


Figure 1. Geographical regions (green boxes) used to subset infrasound-only REB events (blue stars) in this study and the stations contributing to their location (see individual region's colour key). Number of REB arrivals per contributing station (left). Variation in arrival back azimuth with time for each of the four regions (right).

## 2. Reliability of REB arrival detection

- At least one arrival for each event always met our detection criteria.
- Only ~60% of the REB events re-analysed fulfil an event definition criteria of  $\geq 3$  station detections.
- The Northern Kazakhstan results agree once the station problems at IS46 have been taken into account (no H2 element data and coherence issues at H3).

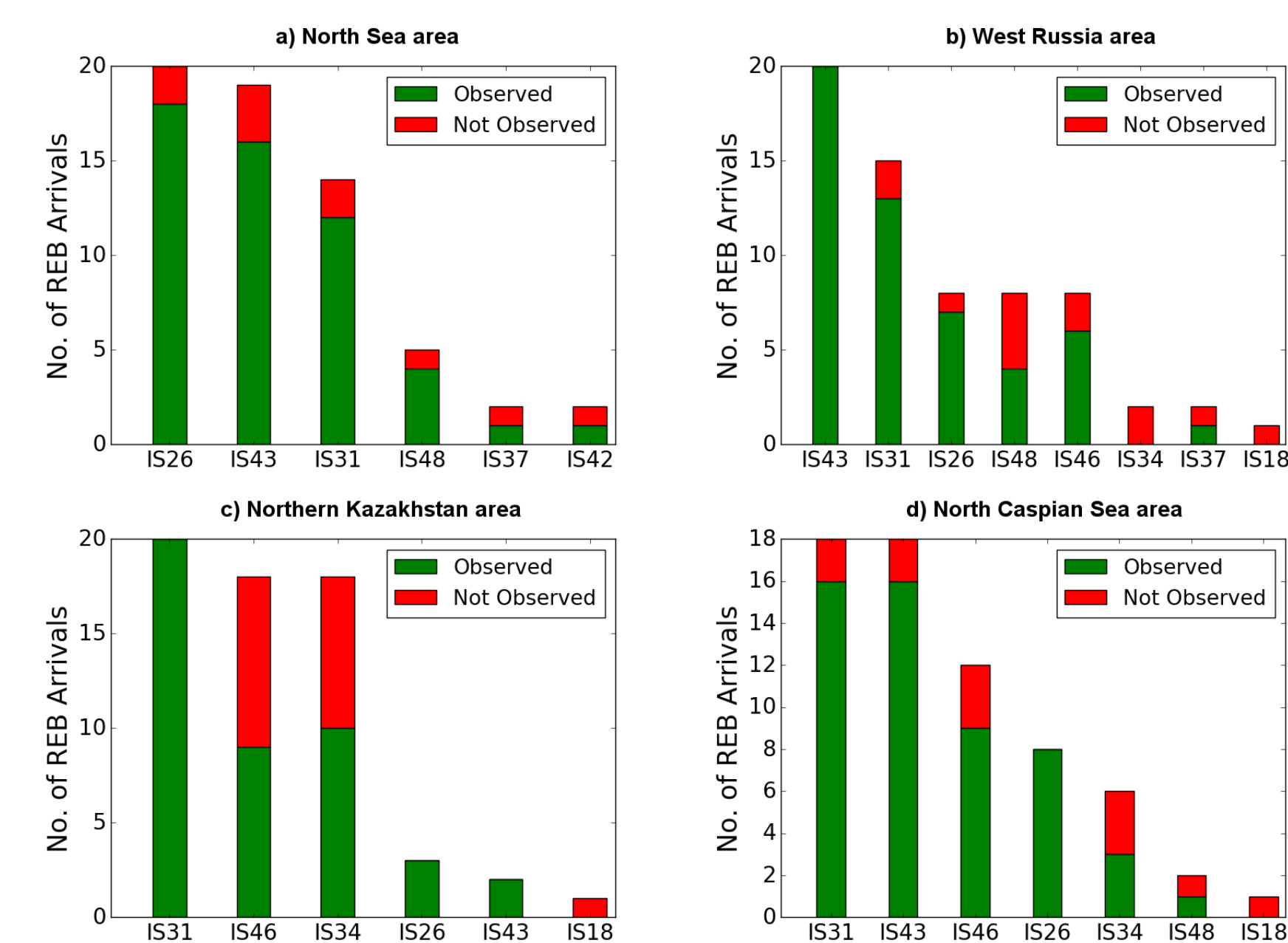


Figure 2. Number of REB arrivals that met our detection criteria (observed) versus those that did not (not observed).

## 3. IMS infrasound network sensitive to sonic booms

- Initial focus on North Sea cluster – known area of sonic boom activity and can supplement IMS data with Large Aperture Infrasound Array (LAIA) data from the Netherlands (available via ORFEUS).
- Common signal characteristics observed at LAIA (Fig. 4) and in the remaining three clusters: pulsed, high frequency arrivals (clearest in the 1-4 Hz passband), consistent with a sonic boom source (Gossard and Hooke, 1975; Evers et al., 2000; Le Pichon et al., 2002).
- Some arrivals are indicative of a moving source (e.g., Fig. 3, indicated by the variation in backazimuth through time).
- Event times indicative of anthropogenic activity (Monday to Friday and not in the early hours local time) and associated with areas of restricted (military) airspace.

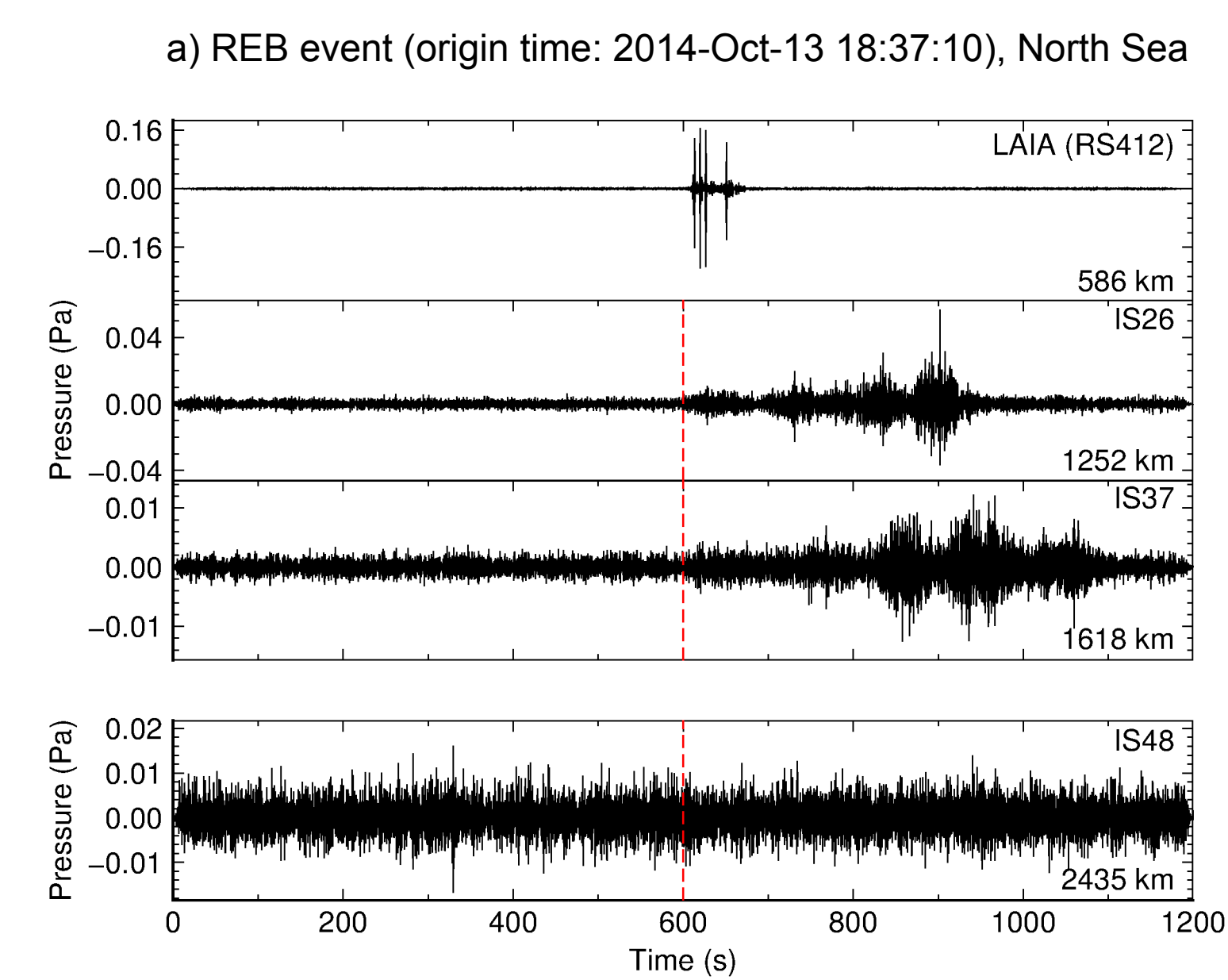


Figure 4. Example North Sea REB events reanalysed using our detection criteria. a) All but the detection at IS48 observed. b) All detections observed. All traces filtered 1-4 Hz. REB arrival time (red dashed line). Range to REB location (bottom right).

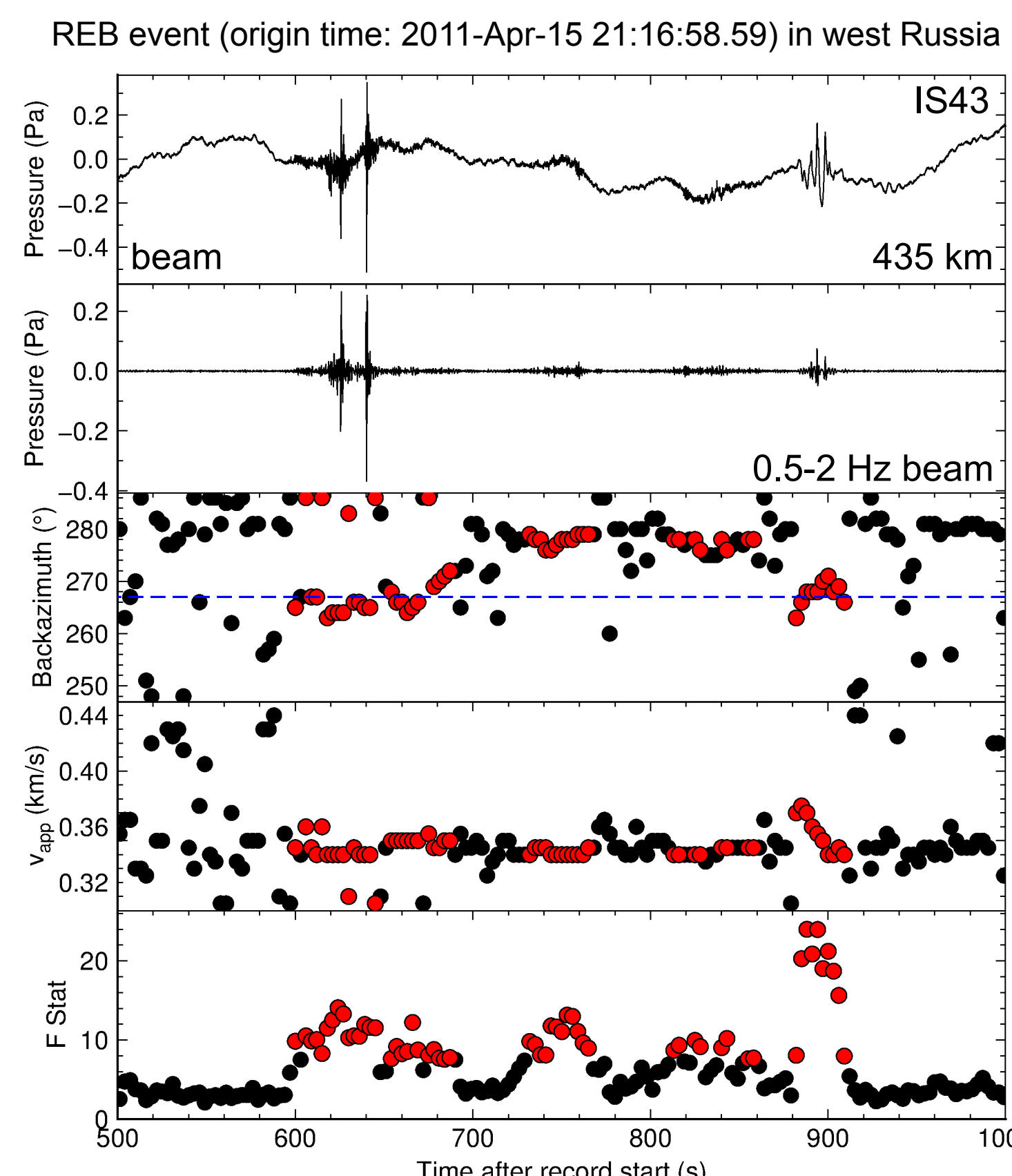


Figure 3. Example moving source likely to be a sonic boom. Bottom 3 panels: beamforming results over a combination of backazimuths (REB arrival detection backazimuth, blue line) and apparent velocities in the 0.5-2 Hz bandpass to determine the maximum F-statistic. Red rather than black circles indicate that the probability of a signal is >95% assuming a SNR of 2.

## 4. Seasonal REB event distribution

- Summertime – constrained clusters of events due to detections at stations to both the east and west of the source, i.e., propagation both with and against the prevailing westward stratospheric wind (episodic upwind propagation), e.g., Fig. 5a.
- Wintertime – elongated lines of events due to detections at stations all to the east of the source, e.g., Fig. 5b.
- Numerical acoustic modelling using the climatology models HWM07 and NRLMSISE-00, illustrates that elevating a source at any time of year increases the possibility of stratospheric returns through the reduction in at-source effective sound speed related to the reduction in temperature (e.g., Fig. 6).

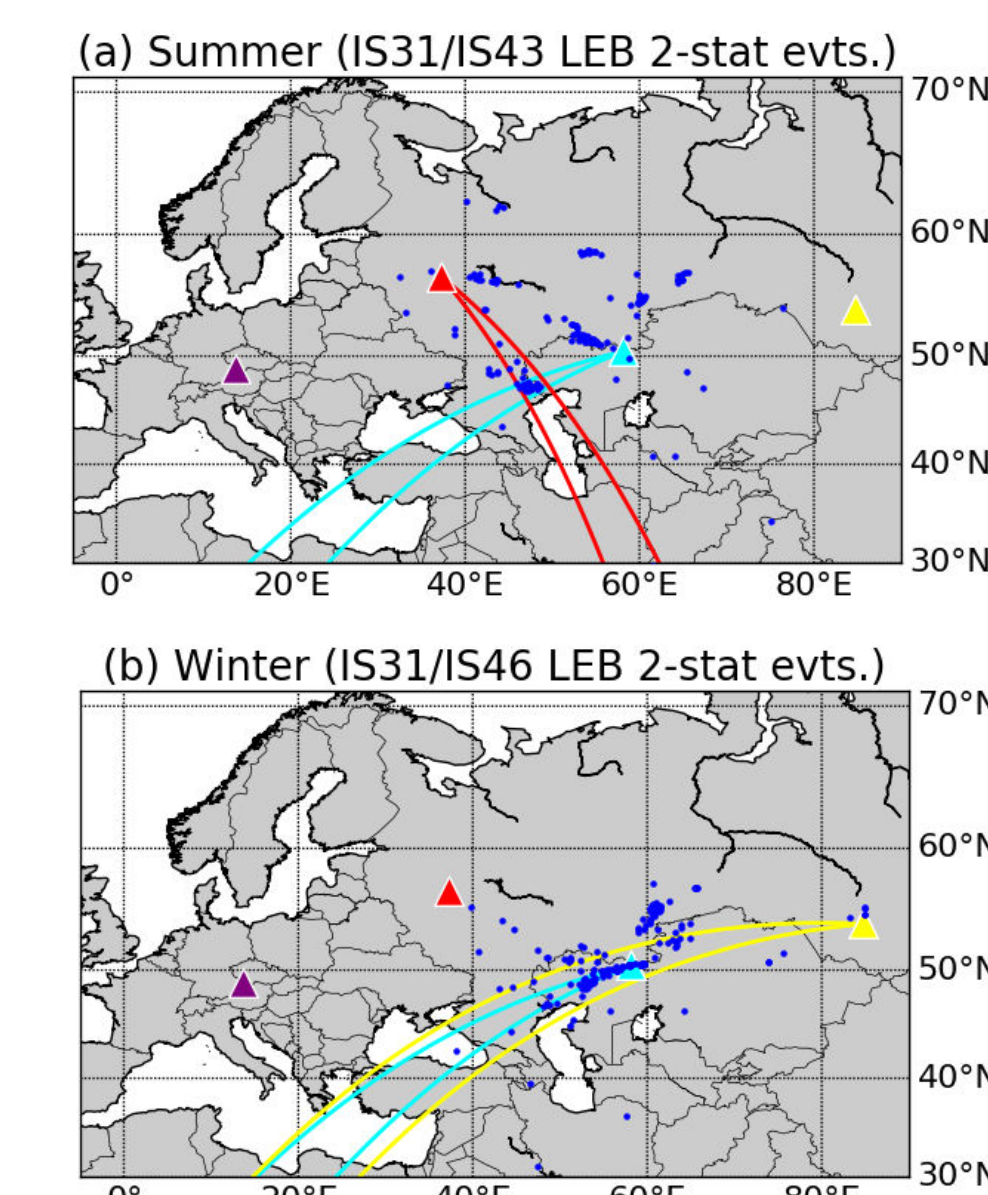


Figure 5. Summer (a) and winter (b) variations in REB event distribution. The backazimuthal segments coloured to match the IMS station are great circle paths at  $\pm 5^\circ$  of the backazimuth to an example REB event approximately at the centre of the cluster.

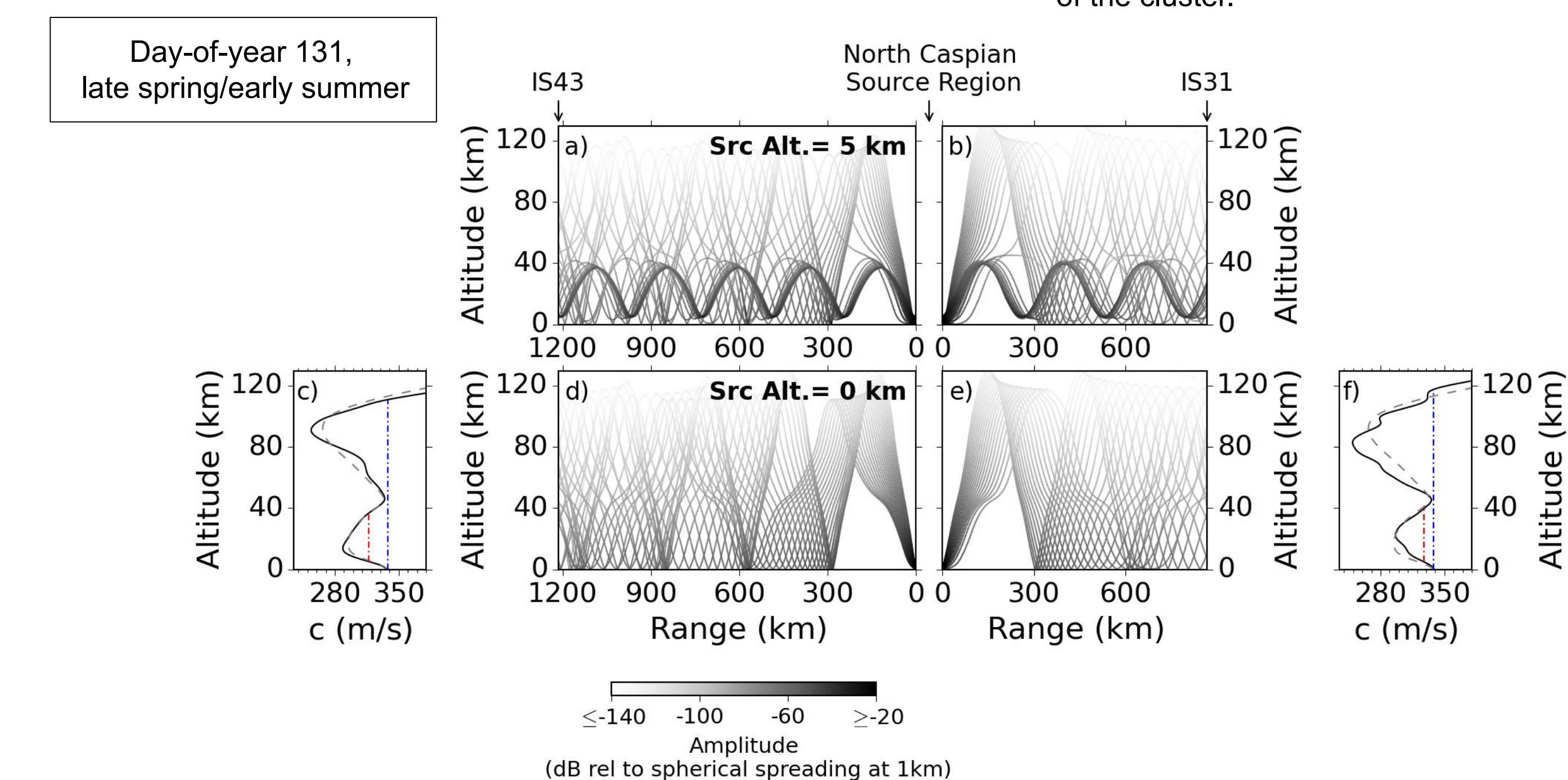


Figure 6. Numerical acoustic modelling for a source at an altitude of 0 km (Panels d and e) and an altitude of 5 km (Panels a and b) for propagation from the north Caspian source region towards stations IS43 (Panels a and d) and IS31 (Panels b and e). The shading of the rays represent the signal amplitude in decibels relative to the amplitude at 1 km from the source (assuming near-field spherical spreading).

## 5. Summary

- Only ~60% of the re-analysed REB events in the four largest IOE clusters in western Eurasia fulfil an event definition criteria of at least three station observations (the REB event definition criteria) meeting our detection criteria.
- IMS infrasound network highly sensitive to elevated sources, due to increased availability of a weak upwind stratospheric waveguide leading to episodic upwind propagation.
- Elevated sources are anthropogenic (majority are during the working week) and suggested to predominantly be sonic boom activity associated with military airspace.
- Seasonal features of REB IOE epicentre distribution must be viewed with caution in terms of representing genuine changes in event location; these features appear to be a consequence of the sparseness of the IMS network and its geometry, combined with the source elevation leading to observations of episodic upwind propagation.

References  
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