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The European Infrasound Bulletin

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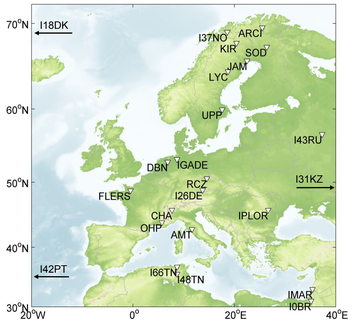
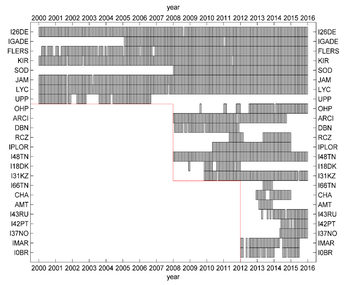
European infrasound network

A total of **24 infrasound arrays** in and around Europe is considered within this study to detect and to locate infrasound activity by mostly anthropogenic sources.
Infrasound recorded by stations from nine different national institutions (**BGR, CEA, IRF, NORSAR, KNMI, UNIFI, UFA, NIEP, SOREQ**) and the International Monitoring System (IMS) of the Comprehensive nuclear-Test-Ban Treaty Organization (**CTBTO**) is used to generate an European Infrasound Bulletin of HF-infrasound activity. Infrasound recordings and data contributions by international partners were collected in the course of the **ARISE project**.

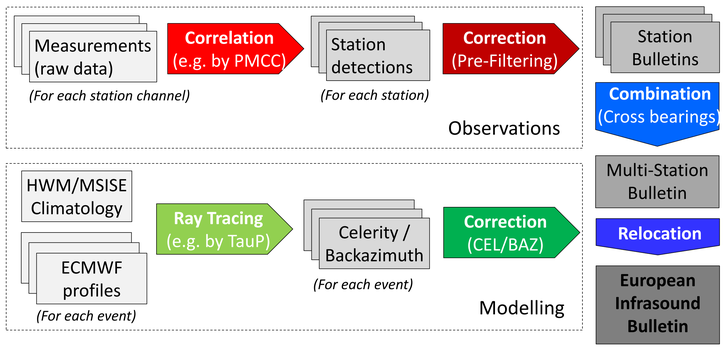


Data availability for the 24 infrasound arrays contributing to the European Infrasound Bulletin during **16 years (2000-2015)** of operation is presented on the right.
Grey rectangles reflect station data from a station used at least once for the bulletin in the given month. The dashed red line borders the **three stages of data processing** brought together for the bulletin: 2000-2008 *Le Pichon et al. (2008)* study. 2008-2012 data collection for the pre-ARISE time. 2012-2016 data collection during the ARISE project.



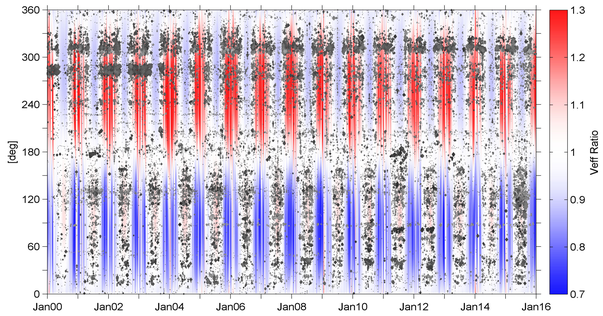
Methods

Station data are processed using **correlation** methods as e.g. PMCC. A **pre-filtering** is performed on the data to exclude detections by e.g. local sources and ambient noise. Data from all stations are then combined using **cross-bearings** and signal similarities to identify source regions in a multi-station bulletin.
A relocation of the events within this bulletin is performed using **ray-tracing** as e.g. TauP with corresponding background values for temperature and wind from climatologies (seasonal) and/or ECMWF (event-based). **Celerity/backazimuth corrections** from this modelling are implemented in the **relocation** to derive the final bulletin.



Single station (I26DE) detections

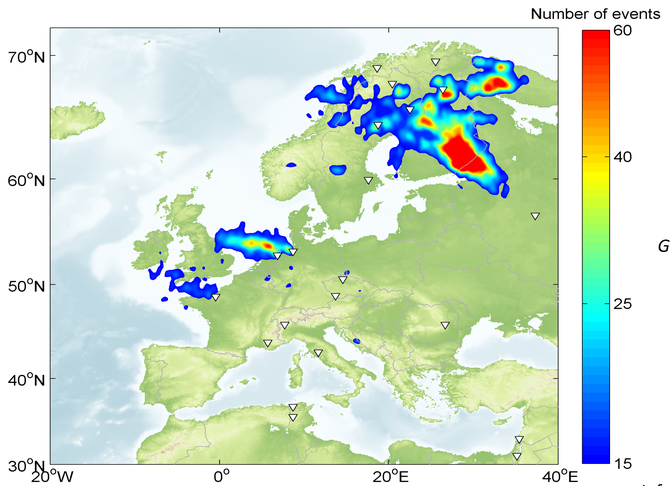
The seasonal distribution of high frequency infrasound signals from all 360 degree back-azimuth directions for the **infrasound array I26DE** clearly shows the correlation between the prevailing wind speeds and directions and the detectability of infrasound signals from different sources, directions and time periods.
The variability of arrivals matches the dominant stratospheric wind directions and thus the corresponding variation of the effective sound speed ratio between stratosphere and surface, indicating that the existence of a stratospheric duct is needed to enable infrasound propagation in the atmosphere over thousands of kilometers.

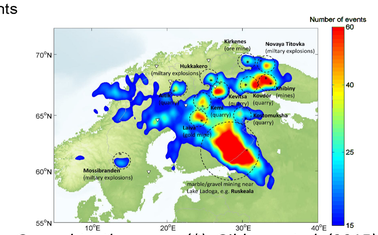


During wintertime transient signals at high frequencies with arrivals at 280 deg were generated by the **Concorde** supersonic airplane at the flight from New York to Paris or London until its operation was ceased on 24 October 2003. Furthermore signals from **supersonic flights** over the North Sea are regularly recorded from 300-330 deg. In summer high frequency signals from 30 – 150 deg are observed which can be associated with **quarry blasts**. In summer 2001 and 2011 arrivals from nearly 180 deg were generated by persistent **Etna eruptions**.
The number of detections from certain directions strongly depends on the seasonal trends and can be biased by dominant local wind patterns. Symbol color represents frequency from 0.7 Hz in black to 4 Hz in light grey, symbol size represents signal family size, red and blue color backgrounds represent ECMWF derived effective sound speed.

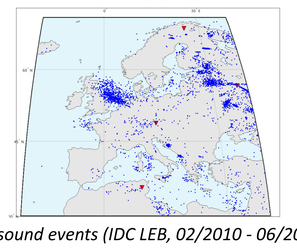
Source regions

The combination of cross bearings from all 24 infrasound arrays and relocation using ECMWF profiles for each event results in a color-coded **event detection density map** as presented below. Event clusters related to industrial activity mainly in Northern Europe, to the Concorde and to supersonic flights mainly in the North Sea can be identified and compared to **ground truth information** and **infrasound event localization** of the International Data Center (IDC) of the CTBTO.
Detections in Northern Europe dominate the given results, since most of the data and times of operation of participating stations in this study are situated in the north. Adequate filtering also highlights sources in Central and Southern Europe as e.g. Etna volcano, NATO airbases and large industrial activity.





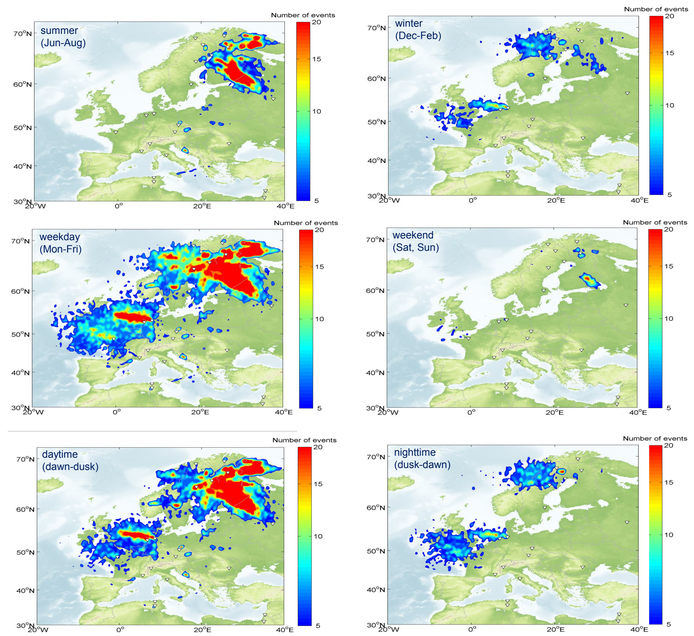
Ground-truth sources (*), Gibbons et al. (2015)



Infrasound events (IDC LEB, 02/2010 - 06/2017)

Seasonal, weekly and diurnal variation

There is a clear **seasonal variation** in the detection of infrasound signals due to the semi-annual change of the stratospheric wind direction: during summer, infrasound arrays predominantly detect sources from the east (e.g. mining blasts in Northern and Eastern Europe), during winter from the west (e.g. supersonic flights west of the arrays).
The **weekly variation** clearly highlights the anthropogenic origin of most sources: nearly all of the activity is during weekdays, only very few sources (including some Concorde flights) are during weekend.
Considering the **diurnal variation** of infrasound sources: Most events are recorded during daytime and again reflect man-made activity (working hours, e.g. in industry), while only supersonic sources also include nocturnal activity (night-flights or dusk and dawn starts).



Conclusions

- **Source regions** of anthropogenic infrasound activity in Europe are identified within the European Infrasound Bulletin with 10 partners, 16 years of data, 24 stations, 50.000 events
- **Ground truth information** (e.g. sites of quarry blasts, mining activity, air traffic) helps to confirm the methods and results
- **Infrasound detection and localization** in Europe is strongly season-dependent, sources show a strong weekly and diurnal variation (due to their mostly man-made origin)

References:

Le Pichon, A., J. Vergoz, P. Herry, and L. Ceranna (2008), Analyzing the detection capability of infrasound arrays in Central Europe, J. Geophys. Res., 113, D12115, doi:10.1029/2007JD009509

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BGR Bundesanstalt für Geowissenschaften und Rohstoffe