

Disclaimer

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Global Infrasound Association algorithms are an important area of active development at the IDC. These algorithms are incorporated into the automatic processing system for verification technologies, with a focus on enhancing association and signal characterization. The overall objective is to reduce the number of associated infrasound arrivals that are rejected from automatic bulletins when generating the Reviewed Event Bulletins (REB), and hence reduce IDC analyst workload. The proposed model is a fusion of seismic, hydroacoustic and infrasound processing built on a unified probabilistic framework incorporated into NETVISA, a Bayesian approach to network processing.

In this work, the focus is on infrasound specific efforts aimed at optimizing association criteria based on knowledge acquired by IDC over 7 years, and on seismo-acoustic events specificity.

The performances of the association algorithms are discussed in comparison with IDC bulletin production at automatic stage and after review process. IDC results for the European region are also compared with the European Infrasound Bulletin (EIB) [Pilger et al, SnT2017]. The EIB focuses on infrasound activity recorded over Europe and collected during the ARISE project (Atmospheric dynamics Research InfraStructure in Europe). Data from the EIB were recorded since 2000 by 24 European infrasound arrays including IMS stations.

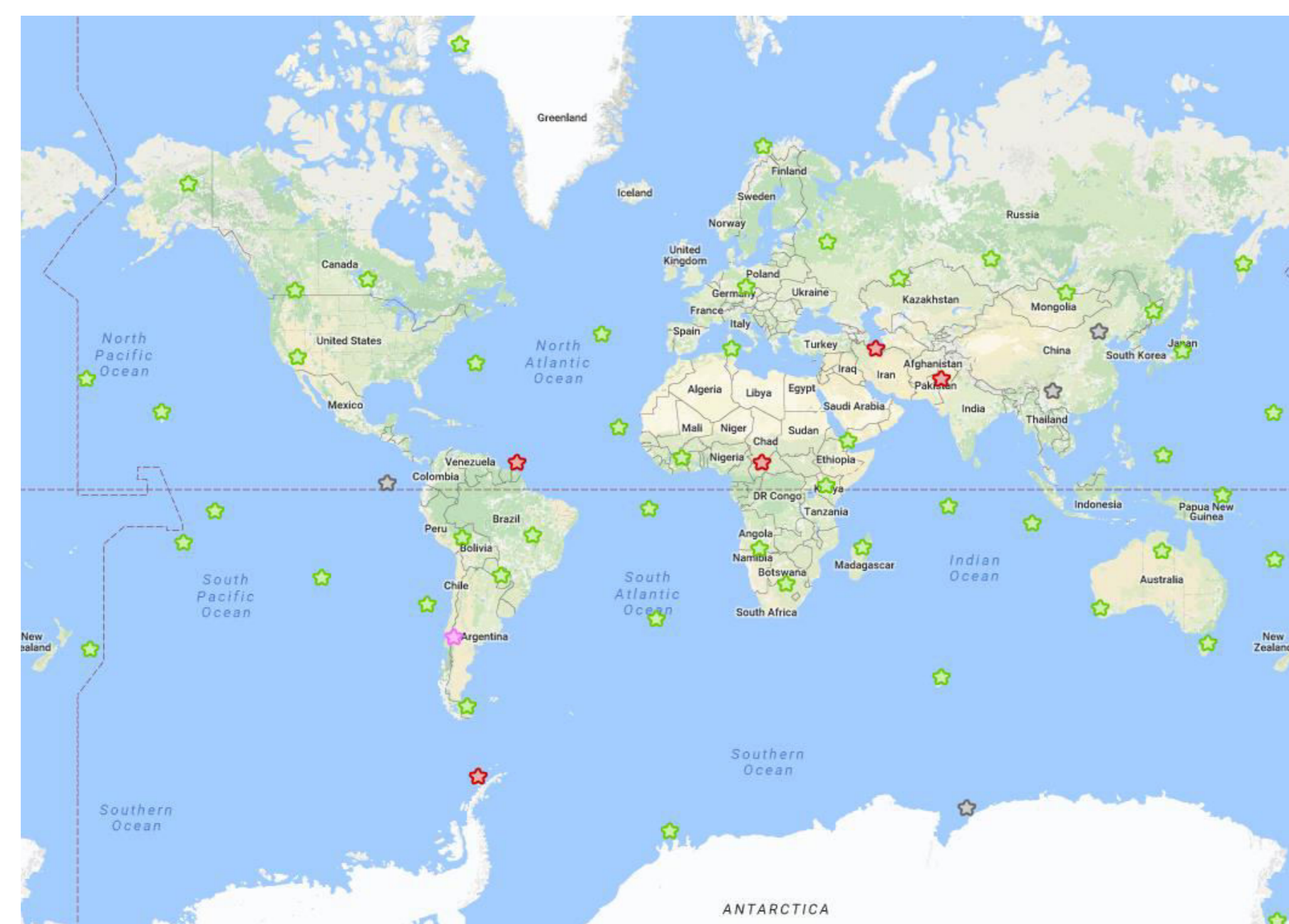


Figure 1. Status of the IMS infrasound network in April 2017
 - Network construction 2001 – 2017
 - Sustainment of assets
 - Infrasound component 80% complete (50 of 60 station installed)

7 years of Infrasound in IDC Operations

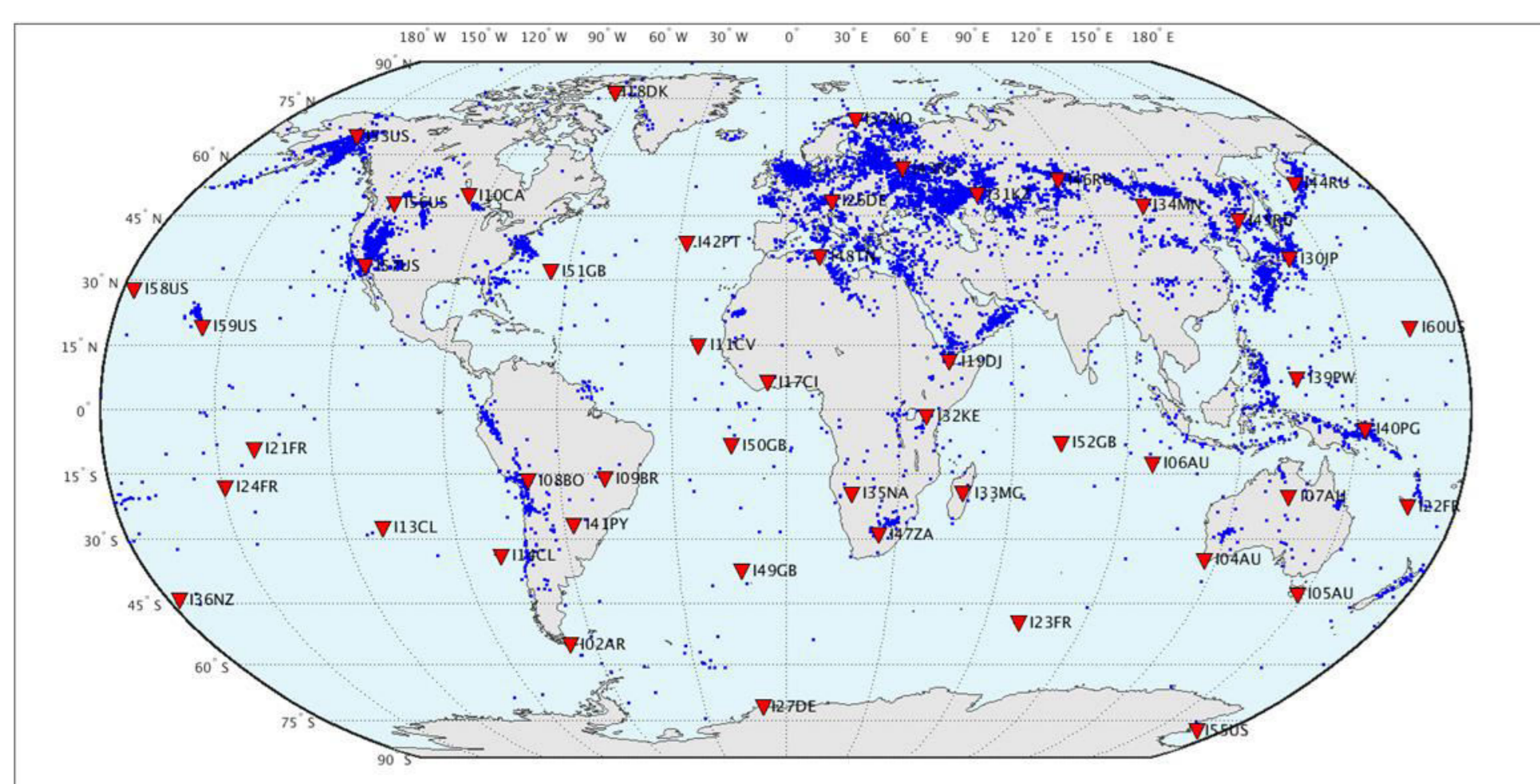


Figure 2. Map with over 21.000 infrasound LEB for period February 2010 to June 2017.
 Note: The IDC REB contains over 550.000 events since 2000.

CTBTO Mid Term Strategy (CTBTPTS/INF.1249): Enhancement of IMS Technology Monitoring Capabilities “As part of its re-engineering effort, the IDC Division will deploy new signal processing, event association and analyst tools to increase valid events detected and reduce the analyst workload.”

→ **Mandate for IDC to enhance and improve station and network processing algorithms.**

References

NETVISA: Network Processing Vertically Integrated Seismic Analysis. N. S. Arora, S. Russell, and E. Sudderth. BSSA 2013
 T1.1-P22 The European Infrasound Bulletin, C. Pilger, L. Ceranna, J.O. Ross, J. Vergoz, A. Le Pichon, P. Mialle

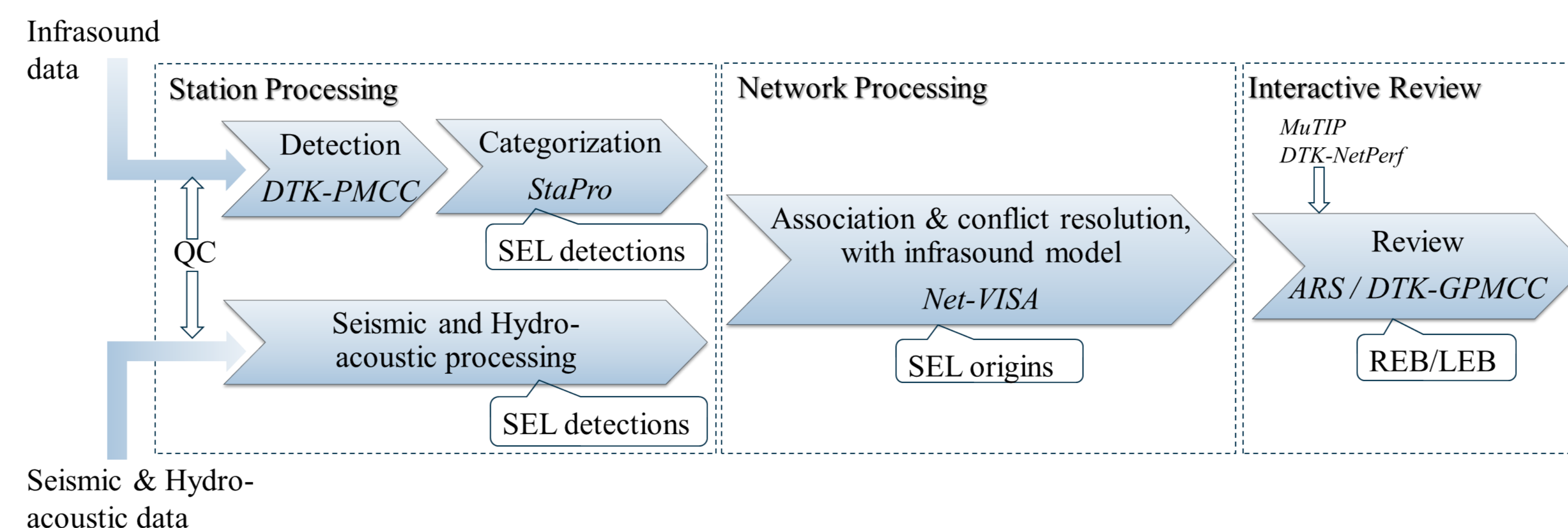


Figure 3. Development IDC processing pipeline

Major improvement to Net-VISA infrasound model

Static prior using a whole year's worth of data

- Clutter model to avoid building events from long duration nuisance source (gas flare...)
- Disentangling seismic-acoustic versus pure infrasound associations
- Identified minimal set of infrasound detection features
 - kept - azimuth, celerity, trace velocity, energy, frequency
 - dropped - consistency, family size, and duration

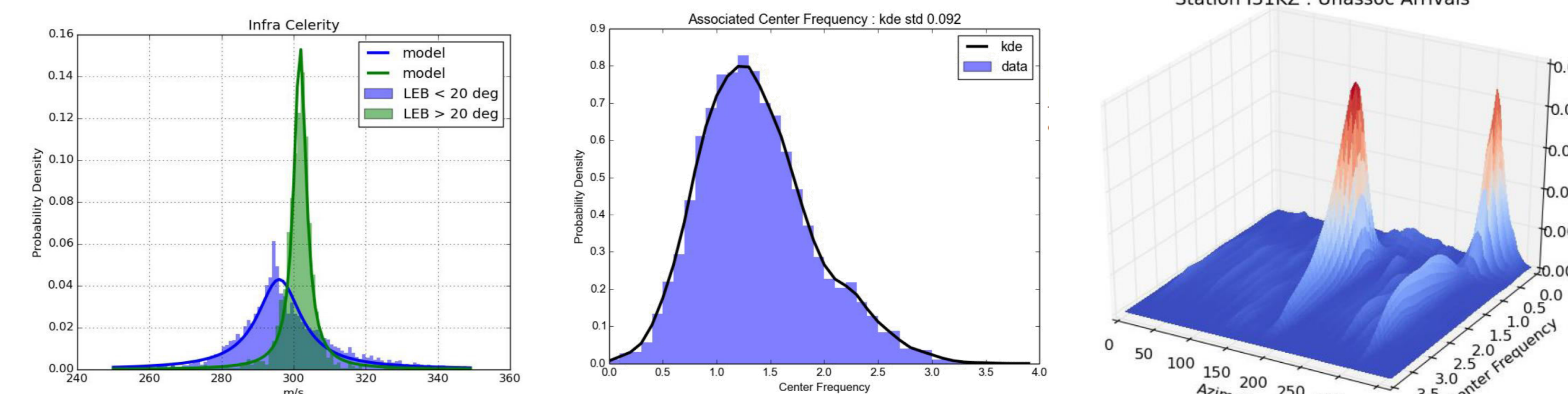


Figure 4. Distributions in IDC LEB for 2013 for: celerity, noise phases proportion and centre frequency of associated phases ; and infrasound clutter model, example of I31KZ a typical station

NET-VISA Event Formation Criteria

An event is real if the probability of the event occurring and generating its associated detections and mis-detections is higher than the probability of those same detections being generated by noise (including repetitive clutter) sources.

Inference - main idea

- Propose events along backazimuth of detection at 0.5 degree interval up to 60 degrees. Plus additional events with 2 degree perturbation of backazimuth
- Existing algorithm (from seismic) for associating proposed events to detections:
 - Reassociation i.e. find the best event for a detection.
 - Relocation i.e. changing location of an event to best explain associated detections.
 - Kill events not justified by model
- Infra events have preference for associating with infra detection (i.e. at infra station)

Reducing spurious seismic-acoustic associations

- Highlights:
 - LEB overlap from 24.7% to 46.5%
 - 90% reduction in spurious seismic-acoustic associations
- Update of association criteria:
 - seismic-acoustic association criteria updated to avoid unreasonable residuals for infrasound associations
 - small event association update based on GA rule, to reduce false alarm rate

Infrasound Evaluation

Two events in two different bulletins are identical if they share two similar arrivals where the arrivals are

- are detected at the same station
- within 500 seconds in time of each other
- point to a back azimuth within 5 degrees of each other

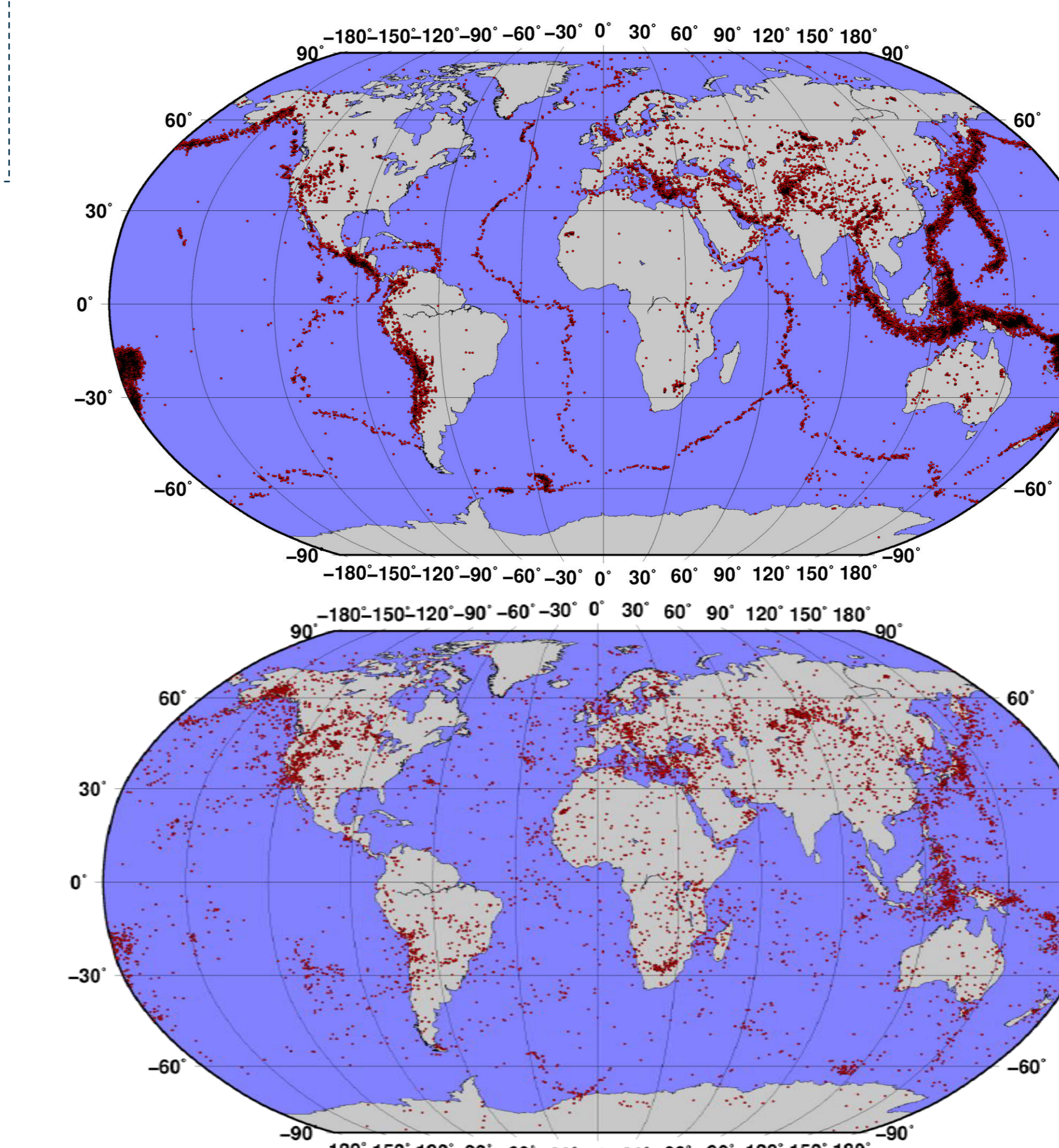


Figure 5. LEB bulletin 2013 42,782 events (baseline bulletin)

Figure 6. NETVISA bulletin 2013 Events with infrasound phases 7,374 events
 Note: model tuned in October to enhance results, helped to reduce false alarm rate

With the 2016 update, the pure-infrasound-event overlap remain stable and the infrasound inconsistency has gone down significantly from 91.2% to 85.3%. Over 2013, Net-VISA are producing 700 fewer false events and 5 fewer real events

Further integration and evaluation

Bulletin comparison for 2013

- Events with at least one associated infrasound station
- Net-VISA results obtained in IDC environment with version 2.2.44

REB	921 events	2.5 events/day
LEB*	1767 events	4.8 events/day
SEL3 (GA)	5517 events	15.1 events/day
Net-VISA	3383 events	9.3 events/day

*LEB used for technology improvement given lack of prior global infrasound knowledge and sparsity of IMS infrasound component

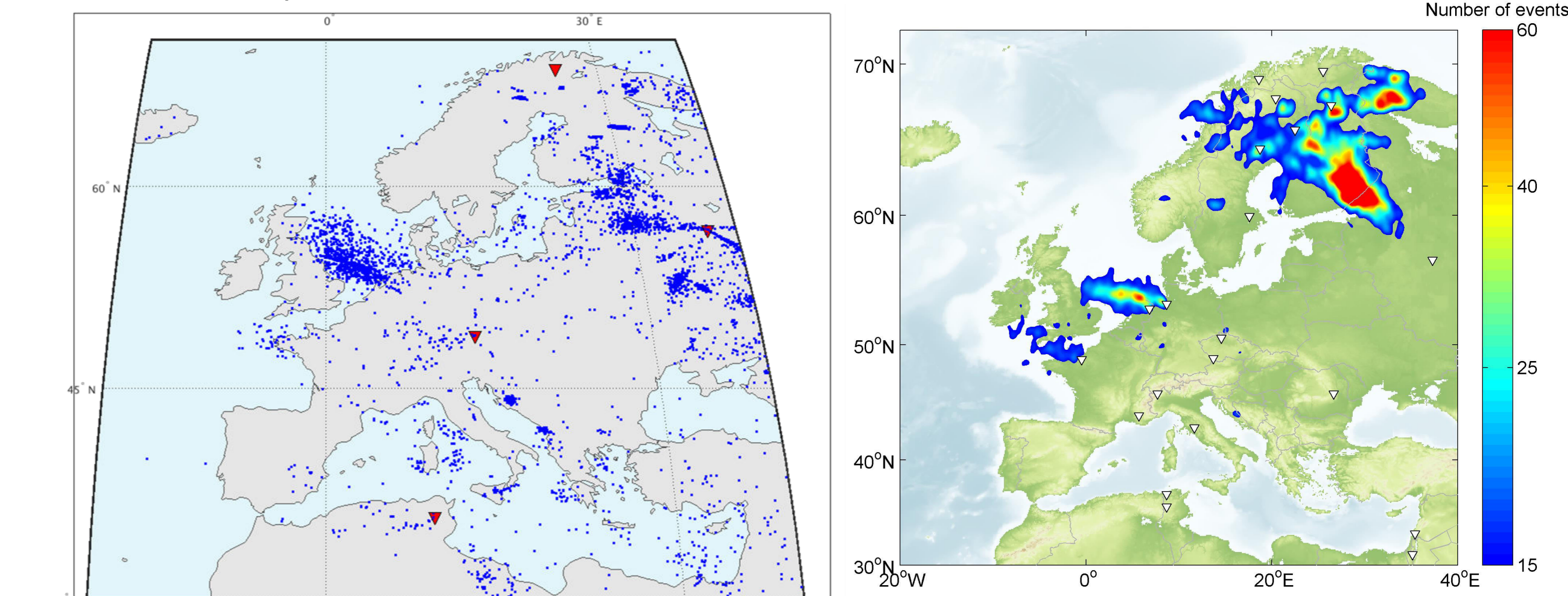


Figure 7. Left: LEB for infrasound event over European region ; right: European Infrasound Bulletin

Further comparison with infrasound bulletins available: the European Infrasound Bulletin [Pilger et al., 2017]