CTBT: SCIENCE AND TECHNOLOGY 2017 CONFERENCE

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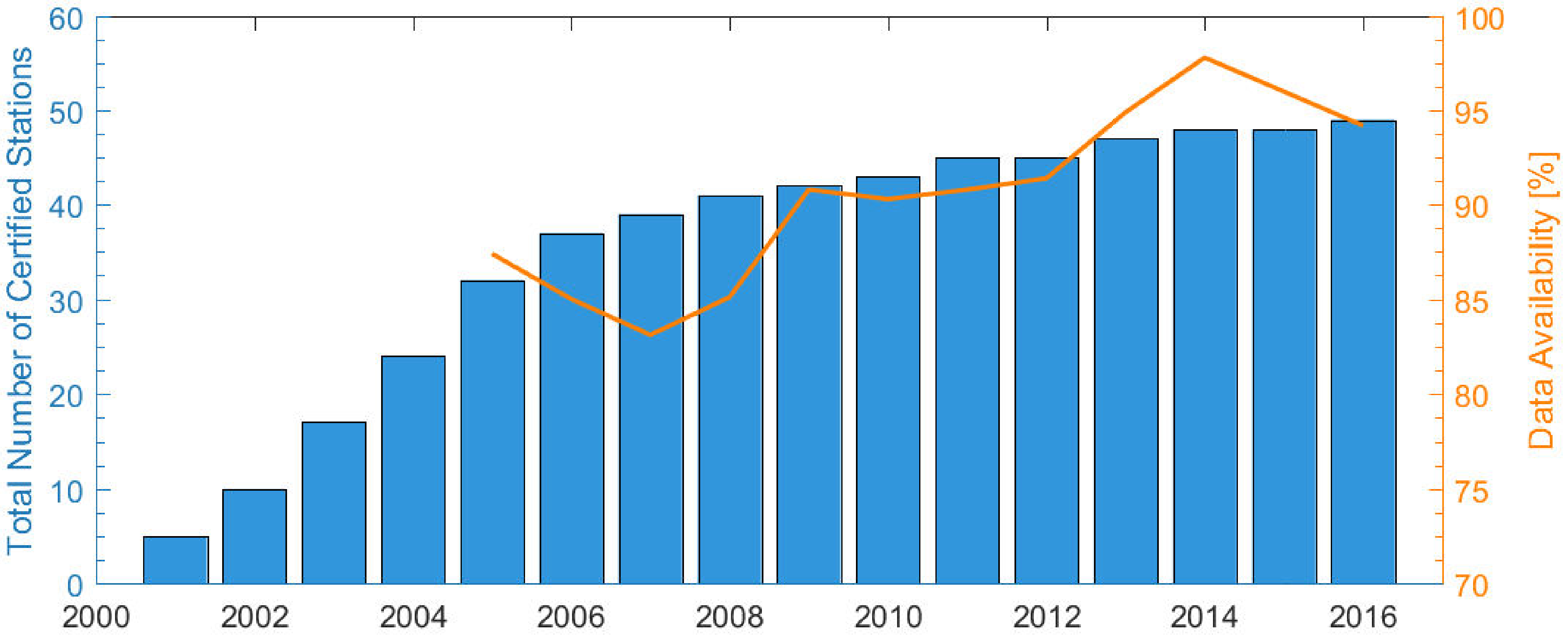
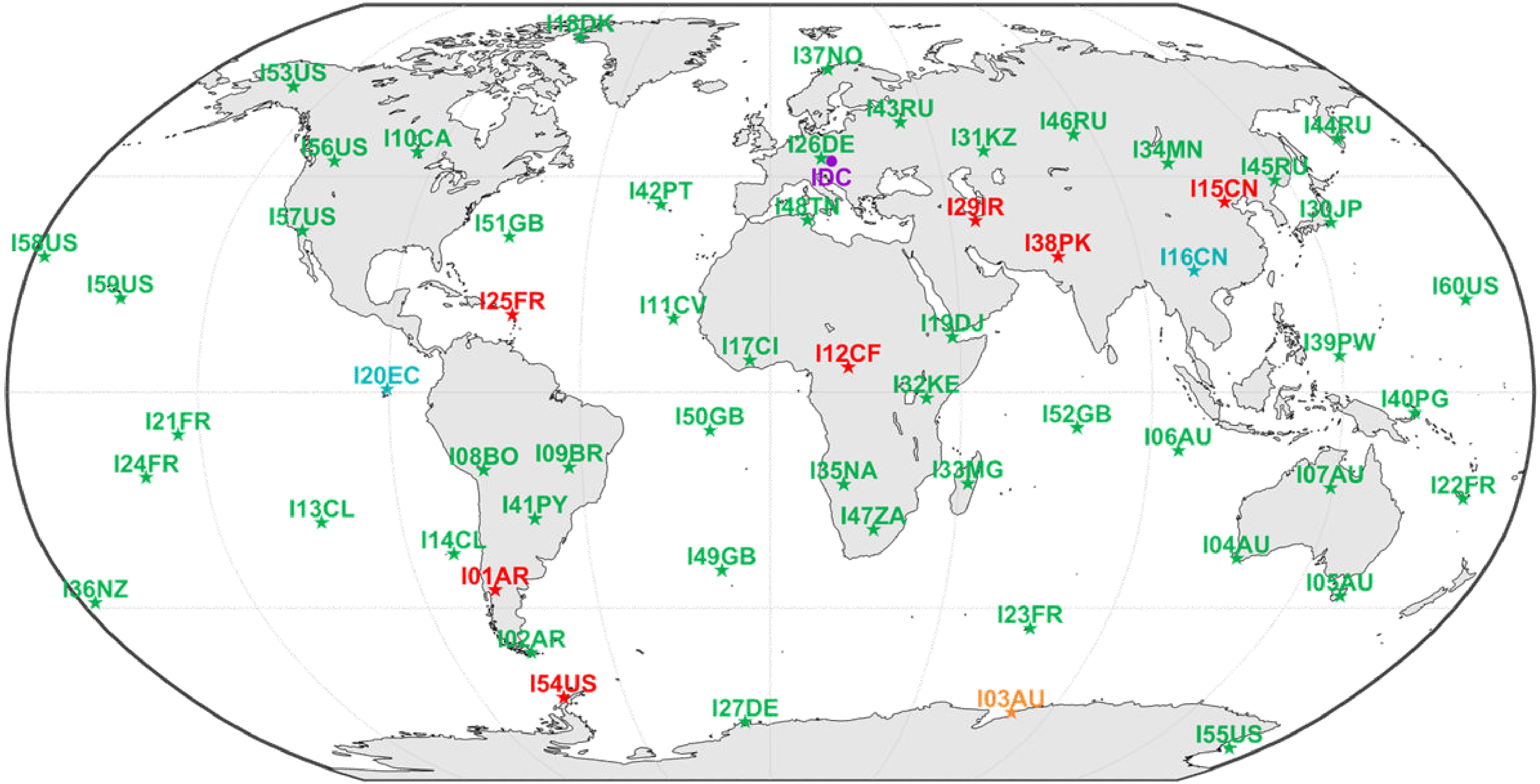
The IMS Infrasound Network: Status and State-Of-The-Art Design

IMS Infrasound Network – History



IMS Infrasound Network – Status



- certified
- installed
- under construction
- planned

Station Establishment – Status

- Planned station certifications
  - I01AR (2019): Site survey completed in 2016
  - I03AU (2018): Construction work started in 2016
  - I16CN (2017): Installation completed in January 2017
  - I20EC (2017): Installation completed in June 2017
  - I25FR (2019): Site survey carried out in 2017

85% minimum requirement for network completeness to support commissioning of the IMS to be reached by 2017

90% completeness to be reached by 2019

I01AR, Pilcaniyeu

I03AU, Davis Base

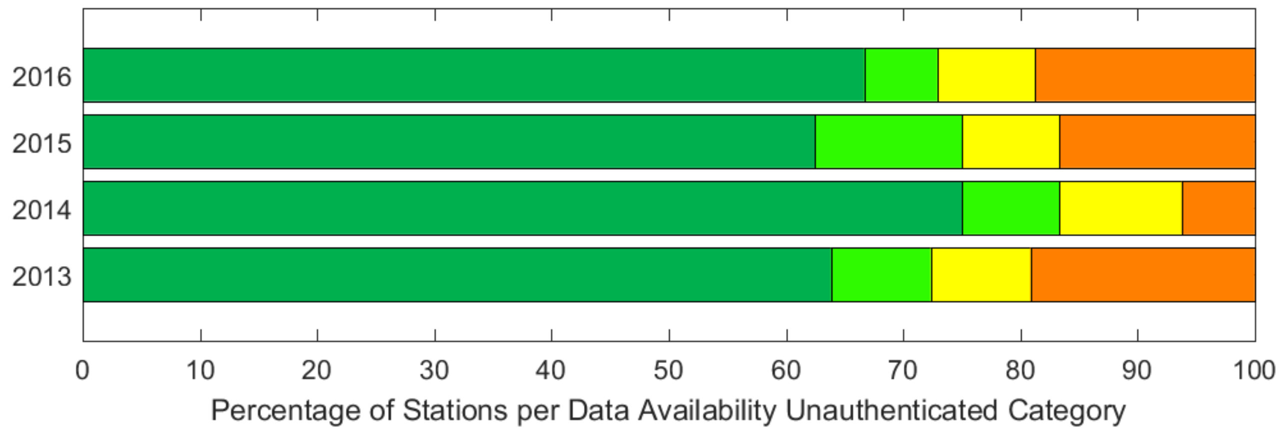
I16CN, Kunming

I20EC, Galapagos

I25FR, Guadeloupe

Data Availability

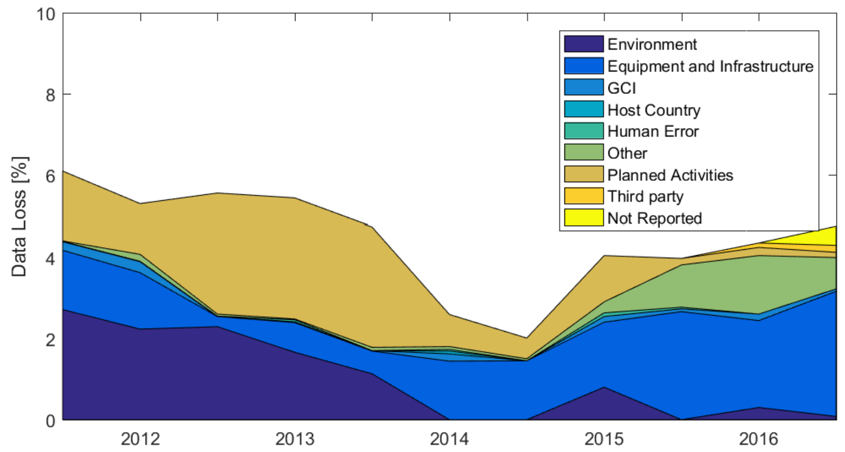
- Fulfilment of IMS DA requirements at all IMS Stations is a real challenge
- Proactivity, responsiveness and technical skills of Station Operators are key to achieve high DA
- Stations must also be designed to be as reliable and as resilient as possible within available resources
- Sustaining high DA also requires specific engineering activities dedicated to this objective



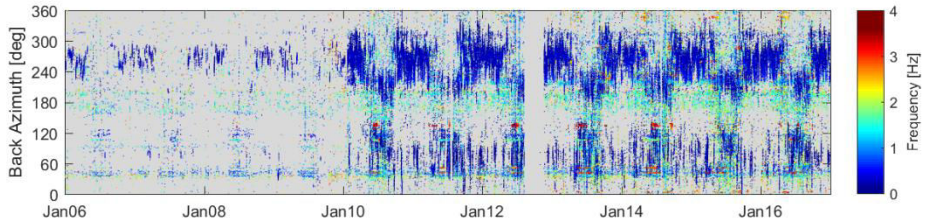
DA > 98%	IMS Operational Manual Minimum Requirement
96% < DA < 98%	Threshold for commissioning of the IMS
90% < DA < 96%	PTS Midterm Strategy objective 2014–2017
DA < 90%	

Station Sustainability

- Monitor station failures to trigger engineering projects and verify that implemented solutions lead to DA improvements
- Long term agreements put in place to provide timely and high quality engineering equipment and services
- Station upgrade are a good opportunity to improve station contribution to the network
- Major station upgrade can be much more challenging than new installations
  - Minimize station downtime to keep meeting DA requirements
  - Integration of new components with legacy components
  - Fulfilment of new IMS requirements (data surety, command and control, authentication, calibration, etc.)



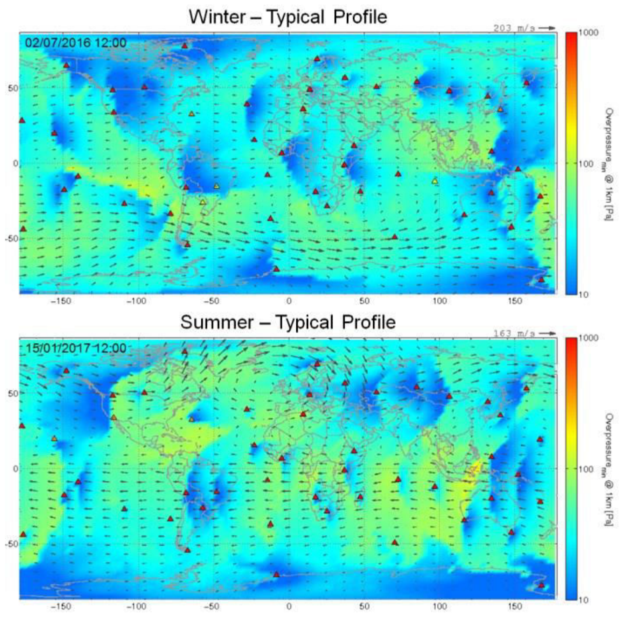
Causes of station failures (2011-2016)



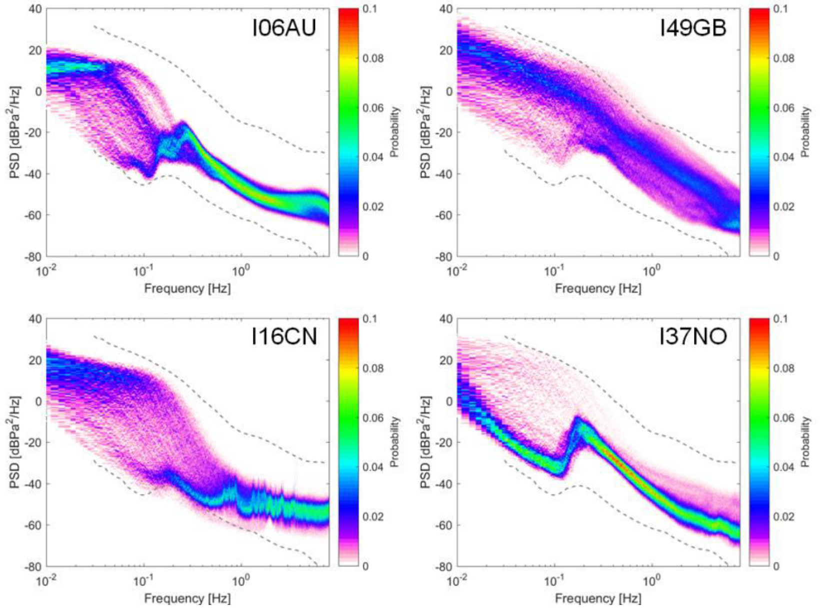
IDC SEL3 detections for station I56US (2006-2016)

Detection Capability

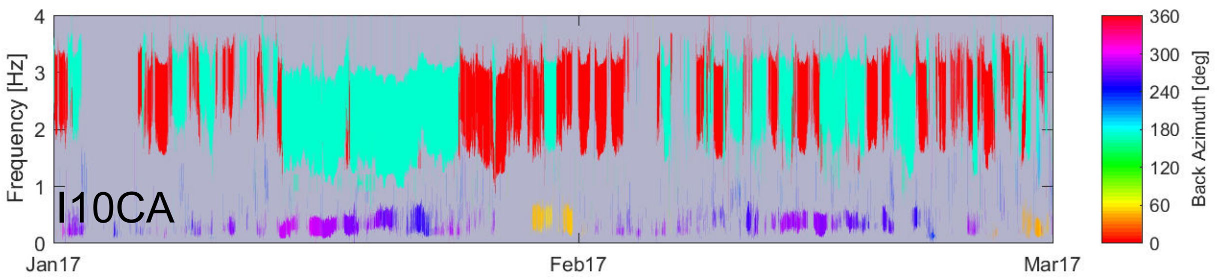
- Main challenge of technology: detection of signals with poor signal-to-noise ratios
- Models have demonstrated that network detection capability is below the 1 kT threshold
- Site identification is key (densely vegetated, away from local sources, sustainability, etc.)
- Essential to use efficient wind-noise reduction systems and adapted array geometries



Detectability maps (DTK-NetPerf)



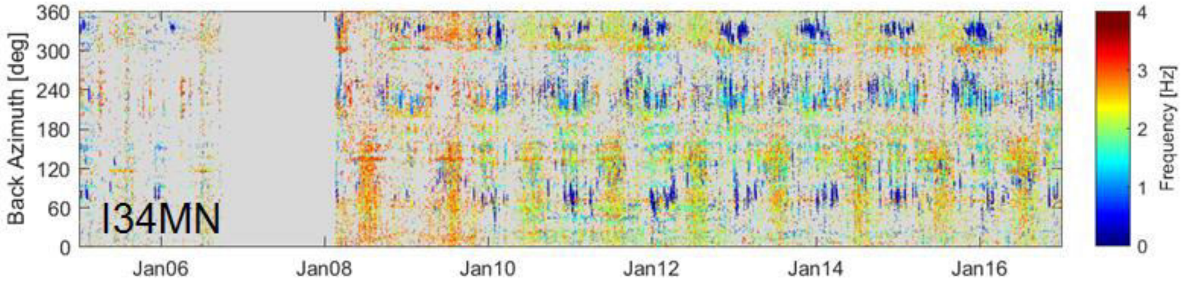
Probability density functions (Feb 2017)



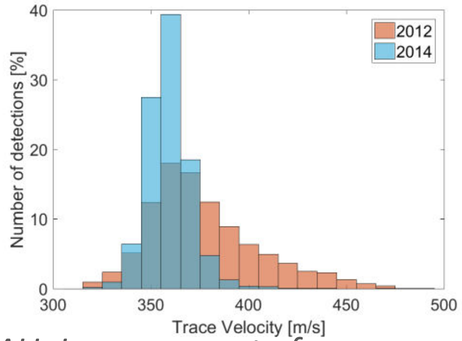
IDC SEL3 detections for station I10CA (Jan-Feb 2017)

Array Geometry

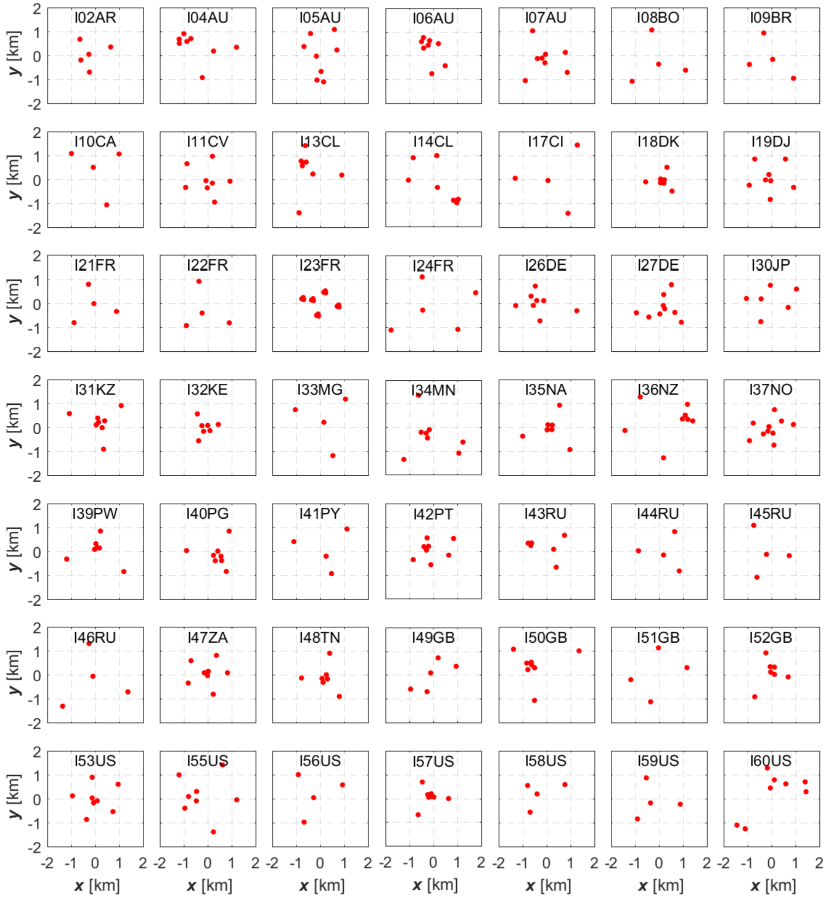
- Trade-off between detection and wave parameter estimation
- Mainly driven by coherence loss of infrasound signals with distance and background noise levels
- Absence of quantitative models
- Main criteria: land constraints, noise levels, minimum 8 elements, homogeneous distribution of elements, aperture adapted to noise conditions, resilience to mission capability loss, costs



I34MN: Improvement of detection capability after upgrade from 4 to 8 elements in 2007



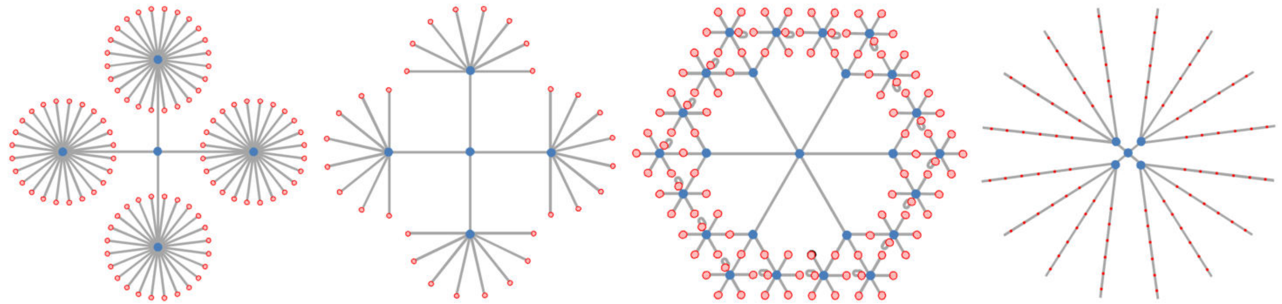
I07AU: Improvement of wave parameter estimation after moving of one element



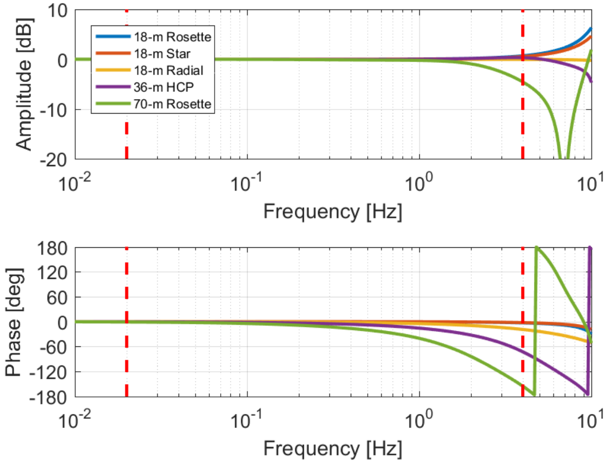
Array geometry of the 49 certified IMS infrasound stations

Wind Noise Reduction Systems

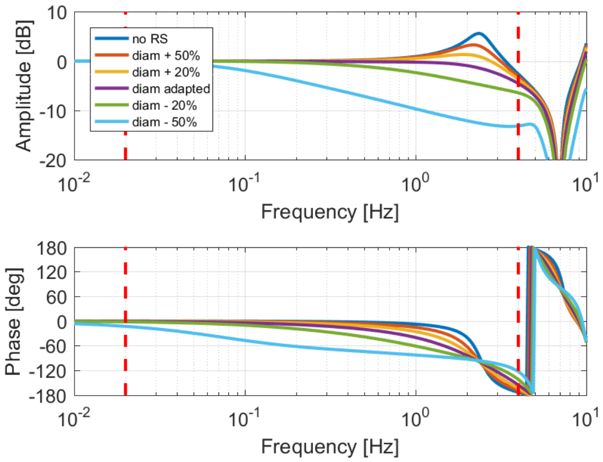
- Atmospheric turbulence is by far the main source of pressure fluctuations
- Pipe arrays installed at all IMS infrasound stations
- PTS standard 18-m rosette pipe array is a good compromise in terms of response stability and noise reduction
- New design with extended lifetime and possibility to be pressure tested and installed within dense forests
- Avoid components that introduced response instabilities (resonance suppressors, small holes, etc.)



Pipe array configurations installed at IMS infrasound stations



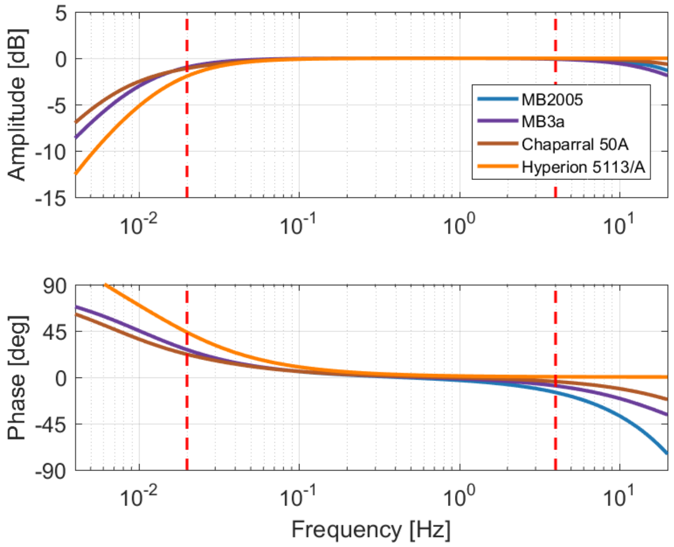
Acoustic responses of main types of IMS pipe arrays



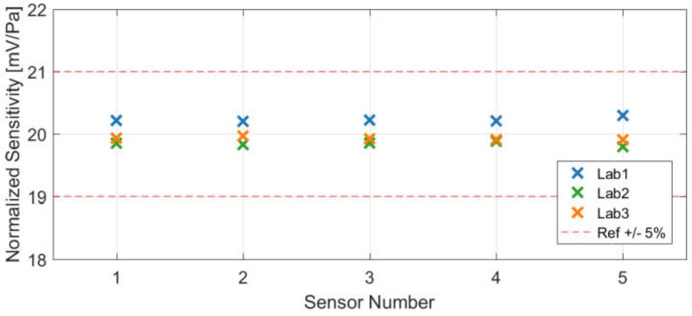
Sensitivity of acoustic responses to resonance suppressor diameters

Microbarometers

- Key piece of equipment → much attention given to design and testing
- MB2000/MB2005 deployed on most of the network due to very high stability of the response in all environments
- MB3a sensors include self-calibrating capability, which is a useful feature for performing remote quality checks
- Current state of the art for infrasound calibration has a lower limiting frequency of 2 Hz and suitable primary calibration methods are still under development by the National Measurement Institute community
- PTS leading Pilot Interlaboratory Comparison Studies on sensor acceptance testing with four infrasound expert laboratories
- PTS working with the international metrology community to provide measurement traceability



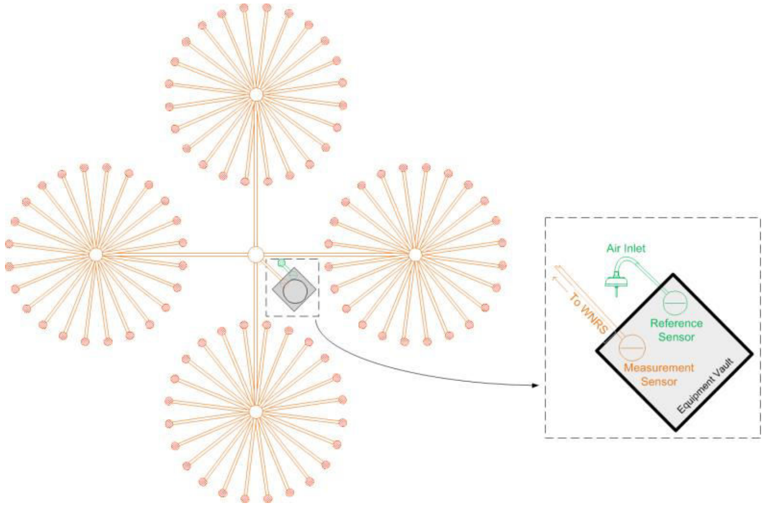
Theoretical responses of main infrasound sensors



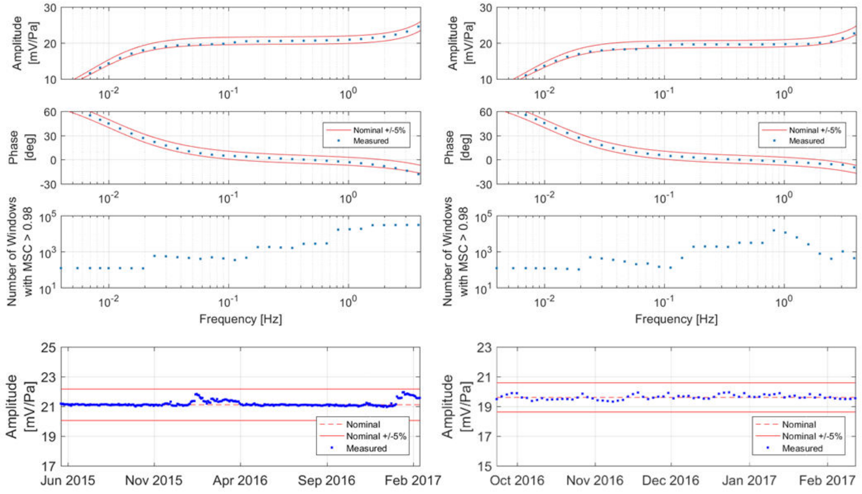
Results obtained during the Pilot Interlaboratory Comparison Study 1 for sensitivity at 1 Hz

Calibration

- Essential process to ensure data quality and trustworthiness
- Includes two processes: initial and on-site calibration
- Calibrations must include the wind-noise-reduction system response and be full frequency (0.02 – 4 Hz)
- Based on side-by-side comparison with background noise for low wind conditions used as a source
- Calibration equipment installed at 3 IMS stations
- Very high stability of the results through time → High stability of the method and of IMS infrasound measurement system responses
- Standard procedures being defined with the support of the expert community



Operational and reference systems for on-site calibration



On-site calibration results for station I26DE and I37NO

Conclusion

- The IMS infrasound network is the only worldwide infrasound network
- 82% of the network certified -> 90% to be reached by 2019
- Main challenges: fulfilment of IMS requirements for data availability and calibration
- Objective: reach compliance with IMS requirements at all stations to support preparation for the Entry into Force
- In parallel, stay at the forefront of scientific and technical innovation to ensure that the IMS infrasound technology stands at the state of the art for Treaty verification purposes

THANK YOU