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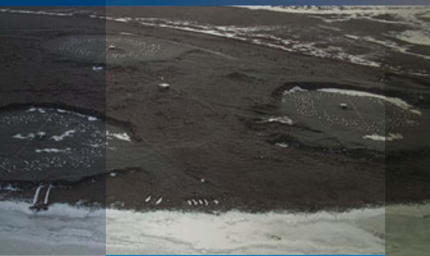

Infrasound Monitoring for Atmospheric Studies

Challenges in Middle Atmosphere Dynamics and Societal Benefits

Second Edition

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Foreword

Infrasound, sound at frequencies lower than the limit of human hearing, is generated by human activities that include nuclear-weapon testing and the use of explosives in mining, and by natural events and processes such as volcanic eruptions, thunderstorms and the interactions of ocean waves. Infrasound propagates through the atmosphere and can be refracted down to the surface far from its source. The refraction takes place primarily in the relatively warm regions that occur in the upper stratosphere and lower mesosphere, at heights close to 50 km, and in the thermosphere, above 100 km. The path taken by the infrasound depends also on the wind field, and is sensitive not only to the climatological average state but also to the presence of variations associated with planetary and gravity waves, and atmospheric tides.

Measurement of infrasound at the ground enables explosive events to be detected and longer lived sources to be monitored. Estimates may be made of the location and nature of the source if atmospheric conditions are sufficiently well known, usually from the analysis of observations employed routinely for numerical weather prediction and climate monitoring. This led to the establishment of a global network of infrasound measurement stations by the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) as one component of its system for detecting nuclear explosions. The routine monitoring provided by the 50 or so CTBTO infrasound stations that are now fully operational is supplemented for general purposes by regional and national networks of receivers. Prototype operational systems for remotely detecting and subsequently monitoring volcanic eruptions are also now being implemented, in support of civil aviation.

Conversely, if the location and nature of the source of detected infrasound are well known, inferences may be drawn as to the prevailing atmospheric conditions and how well they are known from other types of observation. Numerical weather predictions systems increasingly include representations of the upper stratosphere and mesosphere, but the operational global observing system at these heights comprises only satellite-based radiance measurements that have limited vertical resolution and are subject to biases that have to be estimated once instruments are in orbit. Moreover, the modelling on which data analysis and forecasting depend is subject to errors that are larger in the upper stratosphere and above than they are lower in the atmosphere. Addressing these issues is important because of the potential for improving weather forecasts that arises at certain times from the influence of middle and upper atmospheric conditions on the evolution of the lower atmosphere.

Complementary measurement techniques are vital for interpreting infrasound signals to gain insight into the dynamics of the upper stratosphere and mesosphere, and for supporting the improvement of modelling and routine observational analysis of the region. The latter could include bias correction of the operational radiance data from the higher sounding channels. These improvements should lead in turn to better characterization of infrasound sources. Both ground-based remote sensing using instruments such as lidars of different types, meteor radars, microwave wind radiometers and airglow spectrometers, and specialized satellite missions have roles to play. Related needs are for ready access to current and past data from these types of observation, with wide geographical coverage.

This book contains a comprehensive set of articles covering many aspects of infrasound detection and the uses to which measurements are put. It provides accounts of some of the important complementary types of observation and what has been learnt from them. It describes the substantial scientific and technological advances, developments in understanding the dynamics of the upper stratosphere and mesosphere, and progress towards wider societal benefit made since the first volume was published in 2010. This includes important contributions made within the ARISE and ARISE2 projects funded under successive European-Union programmes for research and technological development.

Reading, UK

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Preface

The publication of this book comes shortly after the Comprehensive Nuclear-Test-Ban Treaty (CTBT) marked its twentieth anniversary in 2016. This important milestone offered an opportunity for the global community to take stock of achievements in banning nuclear tests thus far, and to encourage new momentum in strengthening the global commitment to the Treaty and to further develop its verification regime. The Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) which is mandated to establish this verification regime in anticipation of the entry into force of the CTBT is constantly improving and upgrading its capacity in this regard. As the network of monitoring stations has grown over the past few decades, the technology has also improved to the effect that the system is now far more sensitive and accurate than was originally envisaged by its designers. Simultaneously, as we enhance the awareness of the benefits offered by the Treaty, we have also expanded the civil and scientific applications of the International Monitoring System (IMS) data to provide ever greater value for the international community. The scientific community and Member States have been reaping the benefits of this increased capacity and the development and prospects of the infrasound technology are an excellent example to illustrate this dynamic.

In many ways, the current state of infrasound technology as a science owes its existence to the CTBT, having been a marginal—and top secret—endeavour by a few states to keep an eye on atmospheric nuclear tests during the Cold War. When I joined CTBTO as Director of the International Data Centre (IDC) a decade ago, I realized the full potential of infrasound technology for explosion monitoring, but also for civil and scientific applications. I have witnessed the fast evolution of infrasound technology towards maturity, especially in terms of measurement systems, calibration capability, data processing and impact across numerous applications. In order to make it a more effective tool for explosion monitoring, CTBTO has pushed the technology forward by supporting the complete redesign of the IDC infrasound automatic and interactive review system between 2004 and 2010. These efforts ‘paid off’ not least with the contribution of the technology to the detection of the underground nuclear test announced by DPRK on 12 February 2013.

Beyond nuclear test detection, infrasound technology has also contributed to the detection of a number of significant events with global impact such as the 2011 Tohoku earthquake that triggered the Fukushima accident, large volcanic eruptions such as Calbuco in Chile in 2015 or Mount Kelud in Indonesia in 2014, as well as the largest ever infrasound recorded event: the meteor that broke up over Chelyabinsk, Russia in 2013 which was a 500 kT airburst.

Specificities of the technology have been integrated into the IDC software re-engineering efforts and remain a priority today in order to strengthen the technical and scientific credibility of the organization.

CTBTO also actively participates in international collaboration projects on infrasound technology, such as the European infrastructure project ARISE (Atmospheric dynamics Research InfraStructure in Europe) and with the International Civil Aviation Organization (ICAO) in investigating the usefulness of IMS data and IDC products for the international civil aviation community in identifying and characterizing volcanic eruptions. We have also strengthened our collaboration with the international metrology community to provide measurement traceability in the IMS frequency range and to ensure that the IMS needs were the main driver for the definition of primary standards for infrasound technology.

As of June 2017, 82% of the IMS infrasound network is certified and our objective is to reach 90% completion level by 2019. There is a good momentum as illustrated by the recent installation of the station I16CN in Kunming, China in January 2017 and I20EC in Galapagos Islands, Ecuador in June 2017. While sustainability of the IMS network is a day-to-day challenge, innovative engineering solutions are being developed to optimize our systems and make them more robust.

Over the 20 years of its existence, the CTBT has resulted in an almost complete stop to nuclear testing. At the same time, our detection—and deterrence—capabilities continue to improve. The infrasound community has played an important role in this and as a result we have seen the renaissance of infrasound technology as a science that has been brought to maturity to support credible operations. We need to continue our endeavour to further optimize its implementation, to maintain the level of excellence and to make it accessible to a larger base of users in the service of the international community.

Vienna, Austria

Dr. Lassina Zerbo
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Introduction

The establishment of the global infrasound network of the International Monitoring System (IMS), one of the four technologies supporting the Verification Regime of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) contributed to the renaissance of infrasound research. Since then, infrasound, the science of low-frequency acoustic waves, has developed into a broad interdisciplinary field, encompassing academic disciplines, such as geophysics and meteorology. We are now approaching an era where time windows of several decades will benefit from continuous data acquisition. The increased number of operating IMS infrasound stations and the establishment of regional infrasonic arrays have evidenced an unprecedented potential of such enhanced network in terms of detection capability, in particular for the monitoring of extreme atmospheric events at global scale. Recent thorough analyses of infrasound records from natural events, such as the 500 kT meteor which exploded over Chelyabinsk (Russian Federation) on 15 February 2013, have also confirmed the potential of this technology to detect, locate and characterize natural hazards with high societal benefits.

Infrasonic waves propagate over broad spatial scales, sampling on their paths the lower, middle and upper atmosphere along the source-to-receiver path. In recent years, systematic investigations of low-frequency acoustic signals have evidenced quantitative relationships between infrasound observations and atmospheric dynamical parameters over a range of altitudes where measurements are sparse and rare. Since atmospheric specifications are routinely used in a large variety of atmospheric sciences and applications, the validation of their values and main features is relevant to a broad scientific community, which by now uses infrasound as a consolidated verification technique.

The volume *Infrasound Monitoring for Atmospheric Studies* published in 2010 by Springer (IBSN 978-1-4020-9507-8) reviewed the most important areas of theory and application of infrasound, offering also a state of the art of infrasound studies applied to atmospheric measurements. Since 2010, a number of worldwide institutions have engaged in active research programmes based on infrasound technology. Significant technical and scientific advances have thus been achieved in various fields, spanning through engineering, signal processing and propagation modelling. Going beyond the mandate of verification of compliance with the CTBT, these studies promote the potential benefits of infrasound monitoring techniques for civil and scientific applications. The global character of the observed phenomena and the level of knowledge reached today in this science encourage the broadening of our current areas of research which, in turn, require a closer cooperation with upper atmosphere physicists and meteorologists.

The Middle Atmosphere (MA, including the stratosphere and mesosphere) is a dynamical region: the vertical and meridional structure of its temperature and its zonal wind are sensitive to atmospheric waves, which carry energy and momentum flux between different atmospheric layers. In the stratosphere, the propagation and the breaking of large-scale planetary waves are the cause of very spectacular stratospheric warming events that can destroy the polar vortex and reverse the zonal wind in mid-winter, leading to summer-like conditions with prevailing easterly winds. In the mesosphere, the amplitude of gravity waves originating from solar thermal tides increases with altitude due to the exponential decrease of the atmospheric density, until reaching a critical level where the gravity waves break. The MA mean state and variability is, as of today, poorly constrained in Numerical Weather Prediction (NWP) models due to lack of satellite observations to be incorporated in such models. In the stratosphere, the temperature is measured by thermal infrared and microwave sounders, but with a very poor vertical resolution (about 10 km). In the mesosphere, neither temperature nor wind data are assimilated above the top altitude of radiosonde (around 30 km). Validation of atmospheric analysis and forecast products, in particular in regions above 30 km altitude, are important for NWP applications, since the interaction between stratosphere and troposphere cannot be neglected. Several studies have indeed demonstrated that the quality of medium-range weather forecasts depends on the quality of the representation of the MA. In order to better capture the stratospheric–tropospheric interactions, weather and climate forecasters are thus moving towards a more comprehensive representation of the atmosphere. There is, therefore, a strong need for high-quality temperature and wind data in this region.

In recent years, the development of complementary ground-based observational platforms in several observation sites, including infrasound and innovative atmospheric remote sensing methods, have provided new scientific insight into the understanding of geophysical source phenomenology and related atmospheric processes. These platforms include Rayleigh lidars and airglow spectrometers for the measurements of the vertical temperature profile, Doppler lidars, radars and microwave radiometers for wind measurements. Such instruments provide additional integrated information on the structure of the stratosphere where data coverage is sparse. Until now, the instruments were operated independently from each other: one of the main achievements of the European Commission (EC)-funded ARISE Project has been to coordinate the observations from these technologies in three main sites around the ALOMAR Observatory in Northern Scandinavia, the Haute-Provence Observatory in Southern France and the Maïdo Observatory in Reunion Island. At these sites, each instrument maintains its independent level of accuracy, altitude range, vertical and time resolution. The synergy between the respective measurements provides a higher degree of information on the atmospheric state and evolution than what would be obtained through independent measurements. The vertical profiles derived from the measurements of these instruments are now used to simulate the propagation of infrasound waves and to compare such simulations with the observations recorded by co-located microbarometers. In reverse, the observed characteristics of infrasound detections can be used to better constrain atmospheric wind and temperature profiles. In addition, new studies using lidar and mesospheric airglow observations complemented by satellite measurements help to determine with a higher degree of precision the interaction between atmospheric layers and the influence of large-scale waves on the atmospheric dynamics: this constitutes a first step towards their assimilation in NWP models. The new infrastructure reinforces collaborations among scientists while developing and integrating a large set of complementary networks: through the integration of different independent MA measurement techniques currently not assimilated in NWP models, it provides a quantitative understanding of the stratosphere–troposphere dynamical coupling, which will contribute significantly to several NWP applications.

The first impact of these technical developments and researches concerns the development of innovative and robust methods, capable of generating high societal benefits, to remotely monitor extreme events, such as volcanoes or severe weather. A second impact concerns the development of refined weather forecasting and climate models through the quantification of uncertainties and biases in the MA wind and temperature. It is expected that a better representation of gravity waves in stratosphere-resolving climate models and forcing on the troposphere will improve the accuracy in short- and medium-range weather forecasts. It can be expected that such investigations will be of considerable value for NWP applications, since climate science including monthly and seasonal predictability requires an improved quantitative understanding of the dynamical coupling between the MA and the troposphere. Besides the atmospheric science community, the evaluation of NWP models is essential for the future verification of the CTBT, since improved atmospheric models are extremely helpful to assess the IMS network performance at higher resolution, reducing source location errors and improving characterization methods. Capitalizing on such scientific and technical advances should reinforce the potential benefit of a routine and global use of infrasound for civil applications and enlarge the scientific community interested in the operational aspects of infrasound monitoring.

This comprehensive volume reviews the latest researches, developments and applications performed by experts in instrumentation, propagation, sources and observations, putting an emphasis on relevant contributions for middle-upper atmospheric dynamics. It offers both a state-of-the-art assessment of infrasound technology and relevant complementary observations and associated models, addressing new perspectives on key issues and challenges for climate related studies and civil applications.

The first part of this volume presents an overview on strategies that have been developed and implemented to increase data availability and network detection capability of the IMS network, opening new perspectives for a growing number of civil and scientific applications. This part reviews the latest advances in the design and optimization of sensitive infrasound sensors and wind-noise reduction techniques. Non-traditional infrasound sensors such as maritime and free-flying infrasound sensors hosted by balloons are now being under study: the challenges and potential of such technologies to improve the existing network detection capability are discussed. A framework for evaluating the detection algorithms and the hypotheses developed for their operation is proposed. The standardization of both signal and noise models motivates the elaboration of alternative approaches to advance in the performance of detection and feature extraction algorithms. In the context of the future verification of the CTBT, the development and implementation of improved detection and location procedures now offer efficient tools to provide a realistic measure of the network performance and better characterize, at local, regional and global distances, the source at the origin of the detected signals.

The second part illustrates the potentiality of dense regional networks to detect local and regional small-magnitude surface explosions and to discriminate between natural and anthropogenic phenomena. The global IMS network has been designed to detect atmospheric explosions with an equivalent yield of 1 kiloton (1 kT) or more worldwide. Since the yield of anthropogenic sources generally remains much below 1 kT, most of events associated to such sources are only reported in single-station detection lists. Combining dense regional seismic and infrasound networks like the ones operated by the Institute of Geoscience and Mineral Resources (KIGAM) in South Korea or by the Norwegian Seismic Array (NORSAR), allows the development of more detailed source and propagation studies. Another example is the deployment of the USArray Transportable Array (TA), with an average interstation spacing of 70 km, which has demonstrated its capability to detecting and identifying sources of smaller energy than the ones which would have been observed by using a more sparse station distribution. In this new era of massive datasets, there is a unique opportunity to examine geophysical phenomena in more detail than before: the analyses of long-term collected signals from well identified sources, covering a wide range of distances and directions, highlight the existence of strong spatio-temporal variations in the waveform characteristics. Systematic assessments of the variability of the recorded infrasonic wave field at regional and global scales, on a broad range of timescales thus provide essential input data for studies of the middle-upper atmosphere.

Over the last decade, there have been significant improvements in global data assimilation capabilities of the lower, middle and upper atmosphere: the third part reviews operational and scientific research on atmospheric models that are available for the calculation of infrasound propagation. Full-wave numerical modelling techniques are now capable of describing the combined effects of the source and the atmosphere that influence propagation predictions in realistic conditions, by accounting for diffraction and scattering effects by atmospheric inhomogeneities. Conducting consistent analyses on a routine-basis provides an extensive database for help quantifying the relationship between infrasonic observables and atmospheric specifications, thus opening new areas of investigations in inverse problems. Inversion procedures are proposed to delineate the vertical structure of the wind field, in a range of altitude inaccessible to operational ground-based weather stations and meteorology satellites. Such studies benefit from an infrastructure that integrates various MA measurement techniques and provide independent measurements.

The fourth part explores the utilization of infrasound, large-scale gravity and planetary waves to improve the spatio-temporal resolution of the middle-upper atmosphere dynamics and to better understand the physical processes controlling the interaction between atmospheric layers. With the increasing number of ground-based atmospheric observation networks deployed around the globe, the validation of analysis products in NWP models is relevant for a wide variety of applications. Characterizing large-scale atmospheric disturbances and simulating the variability of the atmosphere from ground to the ionosphere remain a challenge for all climate models. In particular, the lack of stratospheric variability in the low-top models has an impact on the stratosphere–troposphere coupling: these models do not produce long-lasting tropospheric impacts which are observed. Thus, correctly predicting the evolution of large-scale atmospheric perturbations like sudden stratospheric warming events (SSWs) can provide useful information on the longer term influences of the MA dynamics on the troposphere and lead to improved medium-range weather forecasts.

The infrasound monitoring system also offers a unique opportunity to provide in near-real time continuous relevant information about natural hazards, like severe thunderstorms, tornadoes or large volcanic eruptions. These phenomena produce large-scale waves over a broad range of time and spatial scales. The chapters in the fifth part discuss the potential benefits of infrasound measurements for detecting, locating and providing reliable source information and chronology of such events. In particular, these investigations are of considerable value for monitoring eruptive processes of active volcanoes. With the advent of civil aviation and the exponential growth in the air traffic, the problem of a volcanic ash encounter has become an issue, which needs to be addressed in real time. Infrasound observations can complete satellite detection of hazardous volcanic clouds, which is limited in time and can suffer from the cloud cover over large areas, leading to a more efficient mitigation of the risk of volcanic ash encounters and of ash cloud impact on aviation. This part of the volume provides a detailed status of the art in volcano monitoring at local, regional and global scales using infrasound technology and highlights the need for an integration of the IMS infrasound network with local and regional infrasound arrays capable of providing a timely early warning to the Volcanic Ash Advisory Centers (VAACs).

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This book is dedicated to the memory of Dr. Jocelyn Guilbert, scientific expert and head of Laboratoire de Détection et de Géophysique at CEA, who died on 21 August 2016 after a courageous battle with cancer. Eminent seismologist, interested in source rupture process and propagation, and the development of high-resolution array techniques applied to dense networks, Jocelyn has earned an international recognition for his contribution in volcano seismology and innovative seismoacoustic approaches to model earthquake-generated infrasound. He inspired and shared his passion for fundamental and applied research in geophysics through stimulating discussions, encouraging explorative studies on emerging scientific problems.

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Part I
Instrumentation, Network and Processing: Instrumentation

Chapter 1
The IMS Infrasound Network: Current Status and Technological Developments

Julien Marty

Abstract The International Monitoring System (IMS) comprises 337 globally distributed facilities for seismic, hydroacoustic, infrasound, and radionuclide monitoring. This chapter focuses on the infrasound component of the IMS, often referred to as the IMS infrasound network. The chapter begins with an overview of the network and of the main challenges associated with its establishment, sustainability, and detection capability. It follows with a general description of IMS stations as well as with a review of the latest advances in array geometry, wind-noise reduction systems, infrasound sensors, calibration, meteorological data, data acquisition systems, and station infrastructure. This chapter is intended for researchers and engineers who are interested in the specifications, design, status, and overall capabilities of the IMS infrasound network or in the construction of state-of-the-art infrasound stations.

1.1 Introduction

The Comprehensive Nuclear-Test-Ban Treaty (CTBT) prohibits States Parties from carrying out, encouraging, or in any way participating in the execution of a nuclear explosion. The Treaty was adopted by the United Nations General Assembly on September 10, 1996 and opened for signature in New York on September 24, 1996. Twenty years later, it enjoys near-universality with 183 States Signatories and 166 ratifying States. Even with this high level of adherence, the CTBT has not yet entered into force. It still awaits ratification from 8 States out of the 44 specific nuclear technology holder States listed in Annex 2 to the Treaty. In the meantime, the Preparatory Commission (PrepCom) for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) is responsible for promoting the CTBT and establishing a verification regime. The objective of the verification regime is to ensure compliance with the Treaty. It is composed of four elements, one of them being the International Monitoring System (IMS). The IMS comprises 337 globally distributed facilities for seismic, hydroacoustic, infrasound, and radionuclide monitoring as well as

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respective means of communication between these facilities and the International Data Centre (IDC) located in Vienna, Austria. This chapter focuses on the infrasound component of the IMS, often referred to as the IMS infrasound network. The main objective of the IMS infrasound network is the monitoring of atmospheric nuclear explosions although this network can also contribute to the monitoring of near-surface underwater explosions and shallow underground explosions. The most recent examples of such a contribution are the detection by two IMS infrasound stations of clear infrasound signals generated by the subsurface nuclear tests announced by the Democratic People's Republic of Korea (DPRK) on February 12, 2013 and September 3, 2017 (CTBTO 2013d, 2017b).

The development of the infrasound monitoring technology began soon after the first atmospheric nuclear explosions were carried out in 1945. The technology evolved rapidly over the following decades with advancements in measurement systems as well as in propagation and source models (Thomas et al. 1971). These advancements began to slow after the Partial Test Ban Treaty, prohibiting the testing of nuclear weapons in the atmosphere, underwater, and in the outer space, was signed in 1963. The last atmospheric nuclear explosion was conducted in 1980 and it is estimated that, between 1945 and 1980, 520 nuclear tests were carried out in the atmosphere for a total yield of 545 Mt (Pavlovski 1998). When CTBT negotiations started in 1994, research in the field of infrasound had made little progress over the preceding decades (Evers and Haak 2010). The urgent need to define requirements for the IMS infrasound network revitalized research on this technology (Dahlman et al. 2011). Whereas global seismological networks were already operational as the Treaty opened for signature, the IMS infrasound network was a first attempt at establishing a global infrasound network. Most specifications for this new network were, therefore, defined based on studies carried out during the Treaty negotiations and shared similarities with the seismic technology. In 2001, continuous and high-quality data started flowing in near real time from the first IMS infrasound stations to the IDC. The processing of this unique set of data quickly led to studies on station performance and brought about optimizations in infrasound station design and specifications (Christie and Campus 2010). Research also focused on global network detection capability, demonstrating through modeling that any atmospheric explosion with a yield greater than 1 kT TNT equivalent would be detected by the IMS infrasound network anywhere on Earth at any time (Le Pichon et al. 2009; Green and Bowers 2010). These theoretical results were confirmed through ground truth calibration experiments (Fee et al. 2013) and by the detection of explosion-like events, such as the breaking up of meteors in the atmosphere (Le Pichon et al. 2013).

Beyond explosion monitoring, data from the IMS infrasound network was rapidly found beneficial in the study of a number of natural (volcanoes, tornadoes, meteorites, lightning, calving of icebergs and glaciers, large earthquakes, auroras, etc.) and man-made (industrial activities, quarry blasts, rocket launches, supersonic aircraft, etc.) sources (Campus and Christie 2010). It has been known since the 1883 explosion of the Krakatoa volcano that natural sources can produce low-frequency sounds capable of propagating several times around the globe (Symons 1888). However, the continuous recording of global infrasound data has allowed civil and scientific applications such as volcano information systems (Marchetti et al. 2019), the detection of near-Earth objects impacting the atmosphere or the better modeling of the middle atmosphere dynamics (Le Pichon et al. 2015). Furthermore, it was recently demonstrated that IMS infrasound data were not only accurate in the IMS frequency band (0.02–4 Hz) but also as down to 1-day period, paving the way to the global monitoring of atmospheric acoustic-gravity and gravity waves (Marty et al. 2010). Since the last atmospheric nuclear test occurred well before the establishment of the first IMS infrasound station, these growing civil and scientific applications based on IMS infrasound data are essential for supporting the sustainability of the IMS infrasound network and ensuring that the infrasound technology remains at the state of the art for Treaty verification purposes.

This chapter begins with an overview of the IMS infrasound network (Sect. 1.2) and of IMS infrasound stations (Sect. 1.3). The latest advances in array geometry (Sect. 1.4), wind-noise reduction systems (Sect. 1.5), sensors (Sect. 1.6), calibration (Sect. 1.7), meteorological data (Sect. 1.8), data acquisition systems (Sect. 1.9), and station infrastructure (Sect. 1.10) are then reviewed in the framework of the IMS specifications for infrasound stations.

1.2 The IMS Infrasound Network

1.2.1 Overview

The IMS infrasound network is composed of 60 globally distributed stations, whose locations are defined in Annex 1 to the Protocol to the Treaty (Fig. 1.1). Each of these stations is composed of an array of infrasound measurement systems capable of recording the micro-pressure changes produced at ground by the propagation of infrasonic waves. IMS infrasound stations continuously transmit these pressure fluctuation data together with state-of-health information to the IDC through the Global Communication Infrastructure (GCI). The data are then processed in near real time, with IDC automatic detection algorithms extracting infrasonic wave parameters from pressure fluctuation measurements for each station independently (Mialle et al. 2019). These wave parameters, together with station processing information from the seismic and hydroacoustic monitoring technologies, are used as inputs to IDC automatic source localization algorithms. The output of the IDC automatic processing of seismo-acoustic data includes event parameters, which are collected in Standard Event Lists (SELs). SELs are reviewed by IDC seismo-acoustic analysts within 2 days and the resulting events recorded in Reviewed Event Bulletins (REBs) (CTBTO 2011b). Natural events are automatically screened out from REBs within a few hours and the final results are published in Standard Screened Event Bulletins (SSEBs). The automatic and interactive processing of infrasound data has been operational since 2010 in the IDC. States Signatories have the right of full access to all IMS data and IDC products.