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A Trends Review of Geophysics Research

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Introduction

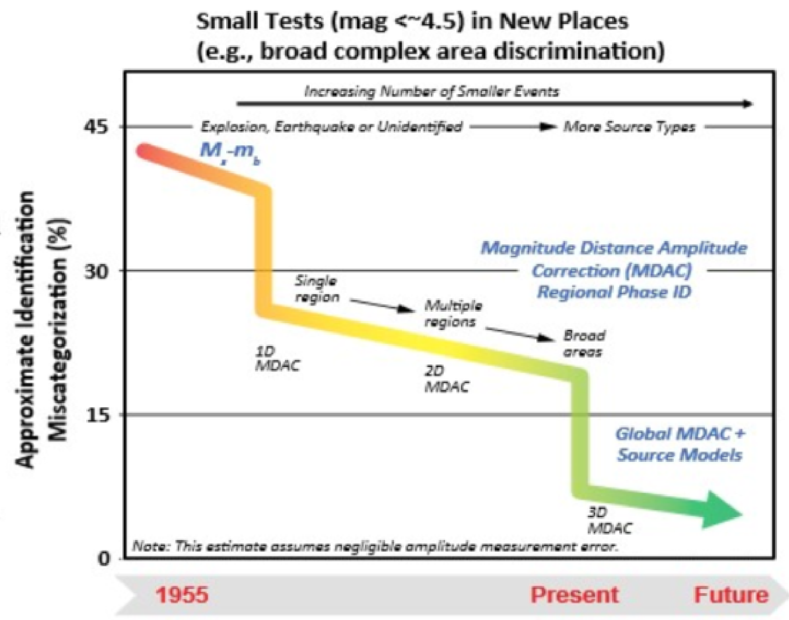
In the 20 years since the CTBT first opened for signature, tremendous progress has been made in monitoring capabilities. This poster previews work in an upcoming monograph which seeks to review and summarize the research trends critical to improving detection, location, and discrimination of nuclear tests. As researchers striving to continuously expand our collective knowledge and capabilities, it is valuable to occasionally pause and observe the arcs of progress. Our monograph provides a summary of such trends, includes tutorials and links to key journal articles, and guides the reader through the world of monitoring research. Trends are organized using a physics-based approach with chapters on source, signal propagation, sensors, signal analysis, and cross-cutting trends. This poster shows the list of trends discussed in each chapter of the book, and highlights a sample trend.

Source Physics – What happened at Ground Zero

Source physics research focuses on improving our ability to understand what happened at the source, based on the observed signals recorded by sensors. Of critical importance is our ability to deduce whether an event was a nuclear explosion, chemical explosion, or earthquake.

The table of contents for each chapter shows the complete list of trends reviewed in the monograph.

Sample Trend: From surface-to-body-wave magnitude ratios to corrected regional phase amplitude ratios



Progress chart for broad tectonic regional discrimination of small tests.

"Near the beginning of the atomic age a key challenge was distinguishing seismic waves caused by underground nuclear explosions from those of earthquakes (Leet, 1962). Combining teleseismic amplitude measurements made at variable frequencies initially solved the discrimination problem. The most popular of these measurements was the ratio of long-period surface-wave magnitude, Ms, to short-period body-wave magnitude, mb, as initiated by Brune and Pomeroy (1963). The success of this discriminant led Evernden (1969) to summarize, "Therefore, the basic problem for differentiating earthquakes and underground explosions of magnitude 4¾ or greater by seismic criteria has been solved."… "

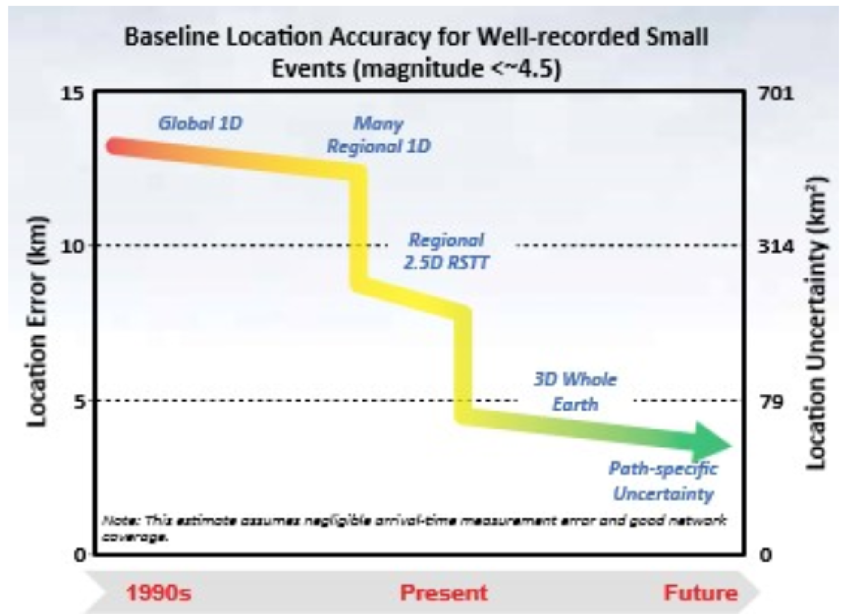
"….Future R&D will focus on improvements to the explosion and earthquake source models and calculation of their uncertainties so that an explosion discriminant can be used in a new test location and a confidence can be assigned to the event identification"

Signal Propagation - Getting the Signals Out to Distances

The event source is generally not directly observable. Consequently, in the observed signal, one must account for degradation as it propagates before it is observed at recording stations. Signal propagation research has improved our understanding of seismic, infrasound, hydroacoustic, and radionuclide signals.

Sample Trend: From 1D to 3D models

Improvement in location error and location uncertainty by moving from 1D to 3D models



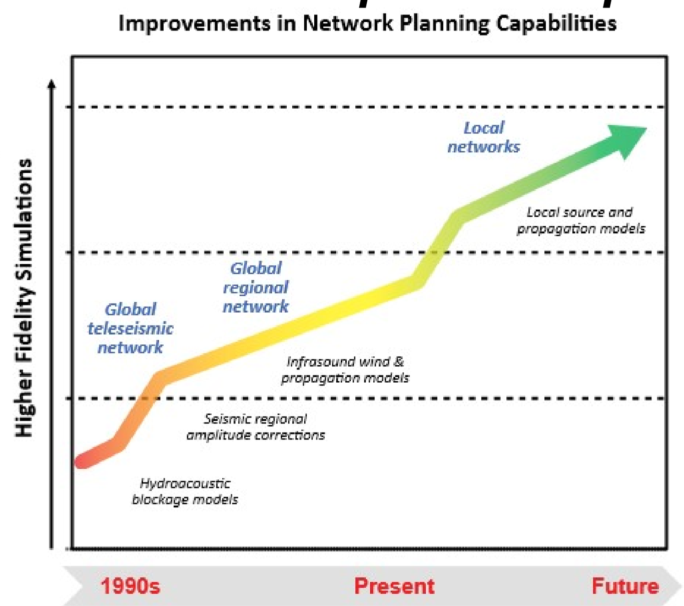
"Traditionally the earth models used to predict P and S travel times for seismic event locations have been one-dimensional (1D), radially symmetric models where seismic velocities and density vary only as a function of depth. Examples of such models are the Preliminary Reference Earth Model (PREM) (Dziewonski and Anderson, 1981), iasp91 (Kennett and Engdahl, 1991), or ak135 (Kennett et al., 1995). Even though travel times predicted using these models vary only as a function of source-receiver distance and source depth…"

Sensors – Recording the Signals

Sensors come into play at the operational stage after signal propagation. Sensors collect the continuous data (waveforms and radionuclides) that will be processed to detect, locate, and categorize events of monitoring interest. Waveform sensor systems take seismic, hydroacoustic and infrasonic signals and archive those data acquired along with their metadata.

Sample Trend: From simple to complex sensor deployment planning

Improvement to simulation fidelity through time, as the modeling ability improves

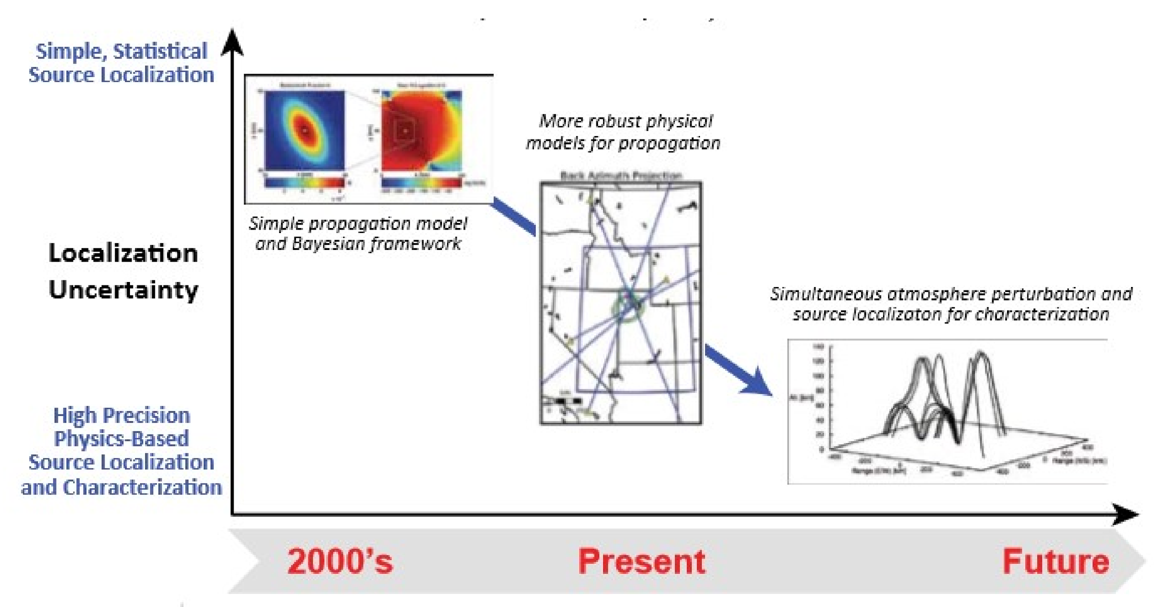


"The establishment of a global monitoring network requires the commitment of significant resources in order to build the stations, construct a reliable communications infrastructure, and establish a data analysis center. System planners hypothesize the performance of the individual stations and use that information in order to evaluate station location options based on projections of the performance of the overall network. In addition, this deployment planning capability would be useful in assisting decision makers understanding the impact of station outages as well as maintaining and upgrading existing networks."

Signal Analysis - Processing the Observed Signals

Signals created by sources, propagated through the solid earth, oceans, or atmosphere, and recorded by the sensors must be processed to form hypotheses of possible nuclear events. We refer to this final processing step as Signal Analysis.

Sample Trend: From simple, statistical location algorithms to physics-informed algorithms for infrasonic analysis



"Source localization is a key component of network-level analysis in nuclear explosion monitoring because further analysis (estimation of source energy, height-of-burst/depth-of-burial, etc.) is dependent on the relative locations of the source and receivers. Correctly quantifying the uncertainty in the localization estimate is required in order to quantify uncertainties in the results of this continued analysis. Although seismic localization estimates are typically more robust and precise, infrasonic contributions…"

Summary

We identified over 40 key research trends related to nuclear explosion monitoring. An associated book is planned for release by June, 2017, which discusses the past, present, and future for these trends. Each trend covers key research developments and links to references. Moreover, chapters are enhanced by tutorials to aid the non-expert reader. The book focuses on trends related to source physics, signal propagation, sensors, and signal analysis, as well as cross-cutting trends, and covers seismic, infrasound, hydroacoustic, and radionuclide signals. We hope this upcoming publication will be a help to all researchers in the monitoring arena, and, in particular, to new researchers and those looking to branch into new areas of research.

For further information, or to be notified when the book is released, contact leslie.casey@nnsa.doe.gov

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