CHAPTER

1

Aim and Scope of the IASPEI New Manual of Seismological Observatory Practice (NMSOP)

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1.1 History of the Manual

Most of what we know today about the internal structure and physical properties of the Earth, and thus about the internal forces which drive plate motions and produce major geological features, has been derived from seismological data. Seismology continues to be a fundamental tool for investigating the kinematics and dynamics of geological processes at all scales. With continued advances in seismological methods we hope to better understand, predict and use our geological environment and its driving processes with their diverse benefits as well as hazards to human society.

Geological processes neither know nor care about human boundaries. Accordingly, both the resources and the hazards can be investigated and assessed effectively only when the causative phenomena are monitored not only on a local scale, but also on a regional and global scale. Moreover, geological phenomena typically must be recorded with great precision and reliability over long time-spans corresponding to geological time-scales. Such data, which are collected in different countries by different research groups, have to be compatible in subtle ways and need to be widely exchanged and jointly analyzed in order to have any global and lasting value. This necessitates global co-operation and agreement on standards for operational procedures and data formats. Therefore, it is not surprising that the international seismological community saw the need many decades ago to develop a Manual of Seismological Observatory Practice (MSOP). This matter was taken up by the scientific establishments of many nations, finally resulting, in the early 1960s, in a resolution of the United Nations Economic and Social Council (ECOSOC). In response, the Committee for the Standardization of Seismographs and Seismograms of the International Association of Seismology and Physics of the Earth's Interior (IASPEI) specified in 1963 the general requirements of such a Manual as follows:

- act as a guide for governments in setting up or running seismological networks;
- contain all necessary information on instrumentation and procedure so as to enable stations to fulfil normal international and local functions; and
- not to contain any extensive account of the aims or methods of utilizing the seismic data, as these were in the province of existing textbooks.

The first edition of the Manual of Seismological Observatory Practice was published in 1970 by the International Seismological Centre (ISC) with the financial assistance of the United

Nations Educational, Scientific and Cultural Organization (UNESCO). A sustained demand for copies and suggestions for new material prompted the Commission on Practice of IASPEI in 1975 to prepare a second edition. The authors worked to achieve balance between western and Soviet traditions of seismological practice. This resulted in the 1979 version of the Manual, edited by P. L. Willmore, in which the basic duties of seismological observatories were envisaged as follows:

- maintain equipment in continuous operation, with instruments calibrated and adjusted to conform with agreed-upon standards;
- produce records which conform with necessary standards for internal use and international exchange; and
- undertake preliminary readings needed to meet the immediate requirements of data reporting.

The "final" interpretation of seismic records was considered to be an optional activity for which the Manual should provide some background material, but not attempt a full presentation. On the other hand, the Manual did provide more detailed guidance for observatory personnel when they are occasionally (but most importantly) required to collect and classify macroseismic observations. In general the international team of authors "... sought to extract the most general principles from a wide range of world practice, and to outline a course of action which will be consistent with those principles."

Even as the 1979 Edition of the Manual was published, it was obvious that there existed significant regional differences in practice and that the subject as a whole was rapidly advancing. Since this implied the need for continuous development it was decided to produce the book in loose-leaf form and to identify chapters with descriptive code names so as to allow for easy reassembling, updating and insertion of new chapters. This useful concept was not achieved, however, and no updating or addition of new chapters happened after the 1979 edition. Nevertheless, the old MSOP is still a valuable reference for many seismologists, especially those who still operate classical analog stations, and for those in developing countries where the MSOP is a valuable text for basic seismological training.

The general aims of the MSOP are still quite valid, although the scope of modern practice has broadened significantly and old analog stations are now being rapidly replaced by digital ones. Fortunately, in conjunction with the preparations for the IASPEI Centennial publications such as the International Handbook on Earthquake and Engineering Seismology (2002), the complete 1979 edition of the MSOP has now been made available as a pdf-file (images of each page) on CD-ROM and on the Internet. It can be viewed and retrieved from the website http://www.216.103.65.234/iaspei.html via the links “Supplementary Volumes on CDs”, “Literature in Seismology” and then “MSOP”). Major parts of the 1979 Edition of the Manual are also available at the website http://www.seismo.com/msop/msop_intro.html in which the Manual has been converted to text by optical character recognition, so that the text is searchable and can be cut and pasted.

Since the last edition of the MSOP, seismology has undergone a technological revolution. This was driven by cheap computer power, the development of a new generation of seismometers and digital recording systems with very broad bandwidth and high dynamic range, and the advent of the Internet as an effective vehicle for rapid, large-scale data exchange. As the seismological community switches from analog to digital technology, more and more sections of the 1979 Manual have become obsolete or irrelevant, and the old MSOP provides no guidance in many new areas which have become of critical importance for modern seismology.

In a workshop meeting organized in late 1993 by the International Seismological Observing Period (ISOP) in Golden, Colorado, entitled "Measurement Protocols for Routine Analysis of Digital Data", it was acknowledged that existing documents and publications are clearly inadequate to guide routine practice in the 1990s at seismological observatories acquiring digital data. It was concluded that a new edition of MSOP is needed as well as tutorials showing examples of measuring important seismological parameters (Bergman and Sipkin, 1994). This recommendation prompted the IASPEI Commission on Practice (CoP) at its meeting in Wellington, New Zealand, January 1994, to establish an international MSOP Working Group (WG) entrusted with the elaboration of an IASPEI New Manual of Seismological Observatory Practice (NMSOP). Peter Bormann was asked to assemble and chair the working group and to elaborate a concept on the aims, scope and approach for a new Manual.

The first concept for the NMSOP was put forward at the XXIV General Assembly of the European Seismological Commission (ESC) in Athens, September 19-24, 1994 (Bormann, 1994) and at the meeting of the IASPEI CoP on the occasion of the XXI General Assembly of the International Union of Geodesy and Geophysics (IUGG) in Boulder, Colorado. The concept was approved and both an IASPEI and an ESC Manual WG were formed. Most of the members met regularly at ESC and IASPEI Assemblies (ESC: 1996 in Reykjavík, 1998 in Tel Aviv and 2000 in Lisboa; IASPEI: 1997 in Thessaloniki, 1999 in Birmingham and 2001 in Hanoi) while others corresponded with the group and contributed to its work via the Internet. At these assemblies the Manual WG organized special workshop sessions, open to a broader public and well attended, with oral and poster presentations complemented by Internet demonstrations of the Manual web site under development. With a summary poster session at the IASPEI/IAGA meeting in Hanoi, 2001, the work of the IASPEI Manual WG was formally terminated and the WG chairman was entrusted with the final editorial work and the preparations for the publication of the Manual. IASPEI offered to attach a pre-publication CD-ROM version of the NMSOP to volume II of the International Handbook of Earthquake and Engineering Seismology and provided some financial support for a printed Manual version. The latter is scheduled for publication by the end of 2002. Part of the material contained in the NMSOP has already been made available piecewise since 1996 on the website of Global Seismological Services (http://www.seismo.com). Some of the contributions are still in a pre-review stage. The NMSOP website will be updated and completed (in a "first edition" sense) during 2002 and 2003.

1.2 Scope of the NMSOP

1.2.1 Historical and general conceptual background

Emil Wiechert (1861-1928), professor of geophysics in Göttingen, Germany, and designer of the famous early mechanical seismographs named after him, had the following motto carved over the entrance to the seismometer house in Göttingen: “Ferne Kunde bringt Dir der schwankende Boden - deute die Zeichen.” (“The trembling rock bears tidings from afar – read the signs!”). He also considered it as the supreme goal of seismology to "understand each wiggle" in a seismic record. Indeed, only then would we understand or at least have developed a reasonable model to explain the complicated system and “information chain” of seismology with its many interrelated sub-systems such as the seismic source, wave propagation through the Earth, the masking and distortion of "useful signals" by noise, as well as the influence of the seismic sensors, recorders and processing techniques on the seismogram (see Fig. 1.1).

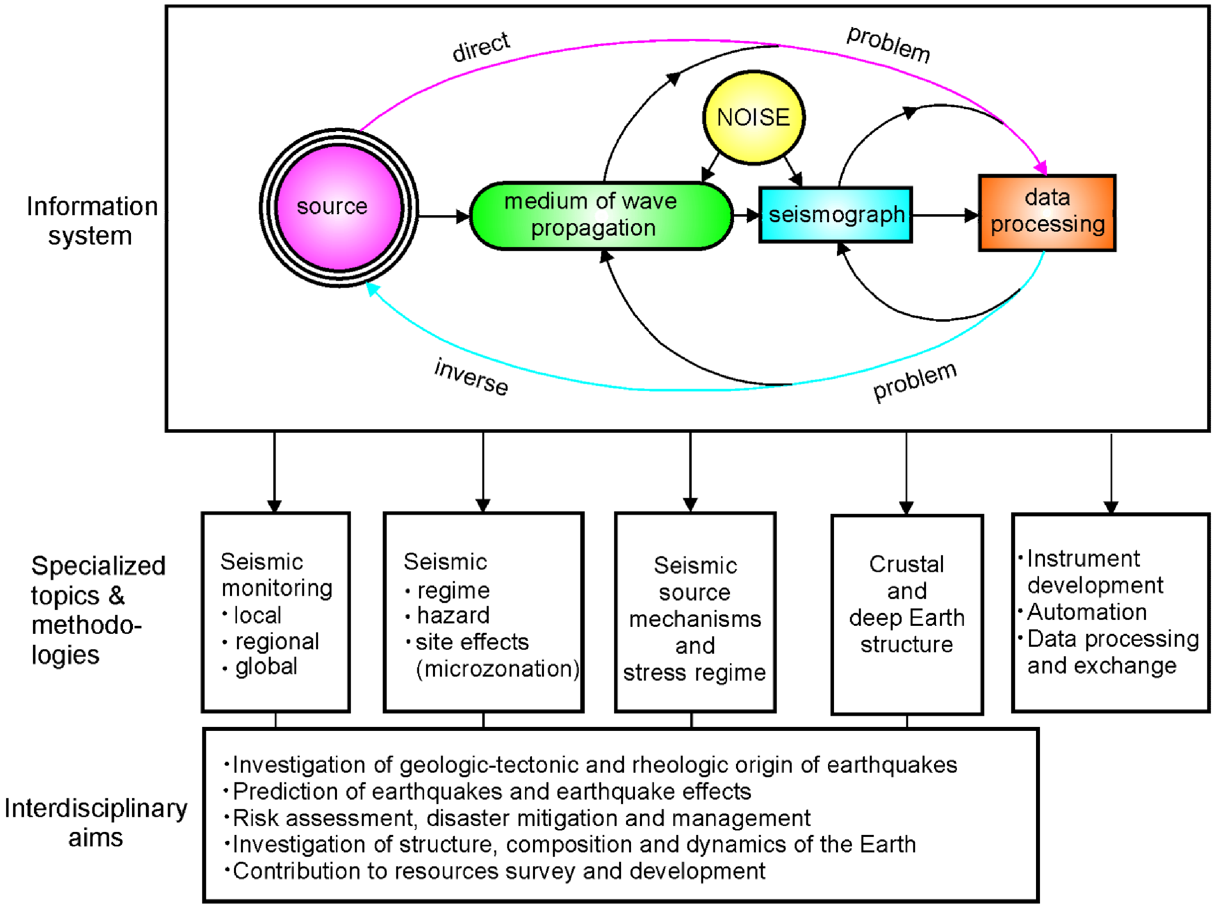

Fig. 1.1 Diagram illustrating seismology as the analysis of a complex information system linked to a diversity of specialized and interdisciplinary task of research and applications.

Despite the tremendous progress made since Wiechert in understanding the most prominent features in seismic records, long-period ones in particular, we are still well short of reaching the goal he set. In fact, most operators and analysts at seismological observatories, even those who work with the most modern equipment, have not advanced much beyond the mid 20th century with respect to their capability to "understand each wiggle" in a seismic record. There are several reasons for this lack of progress in the deeper understanding of seismogram analysis by station operators. Early seismic stations were mostly operated or supervised by broadly educated scientists who pioneered both the technical and scientific development of these observatories. They took an immediate interest in the analysis of the data themselves and had the necessary background knowledge to do it. After World War II the installation of new seismic stations boomed and rapid technological advance required an increasing specialization. Station operators became more and more technically oriented, focusing on equipment maintenance and raw data production with a minimum of effort and interest in routine data analysis. Thus, they have tended to become separated from the more comprehensive scientific and application-oriented use of their data products in society. Also the seismological research community has become increasingly specialized, e.g., in conjunction with the monitoring and identification of underground nuclear tests. This trend has often caused changes in priorities and narrowed the view with respect to the kind of data and routine analysis required to better serve current scientific as well as public interest in earthquake seismology, improved hazard assessment and risk mitigation.

Hwang and Clayton (1991) published a revealing analysis of the phase reports to the International Seismological Centre (ISC) by all the affiliated seismological stations of the global seismic network. Most of them, even those equipped with both short- and long-period or broadband seismographs, reported only the first P-wave onset even though later energy arrivals in teleseismic records of strong events are clearly discernable. Even secondary phases with much larger amplitudes than P (e.g., Figs. 1.2 and 1.4, Fig. 2.23 in Chapter 2 and Figure 10c in DS 11.2) are usually not analyzed.

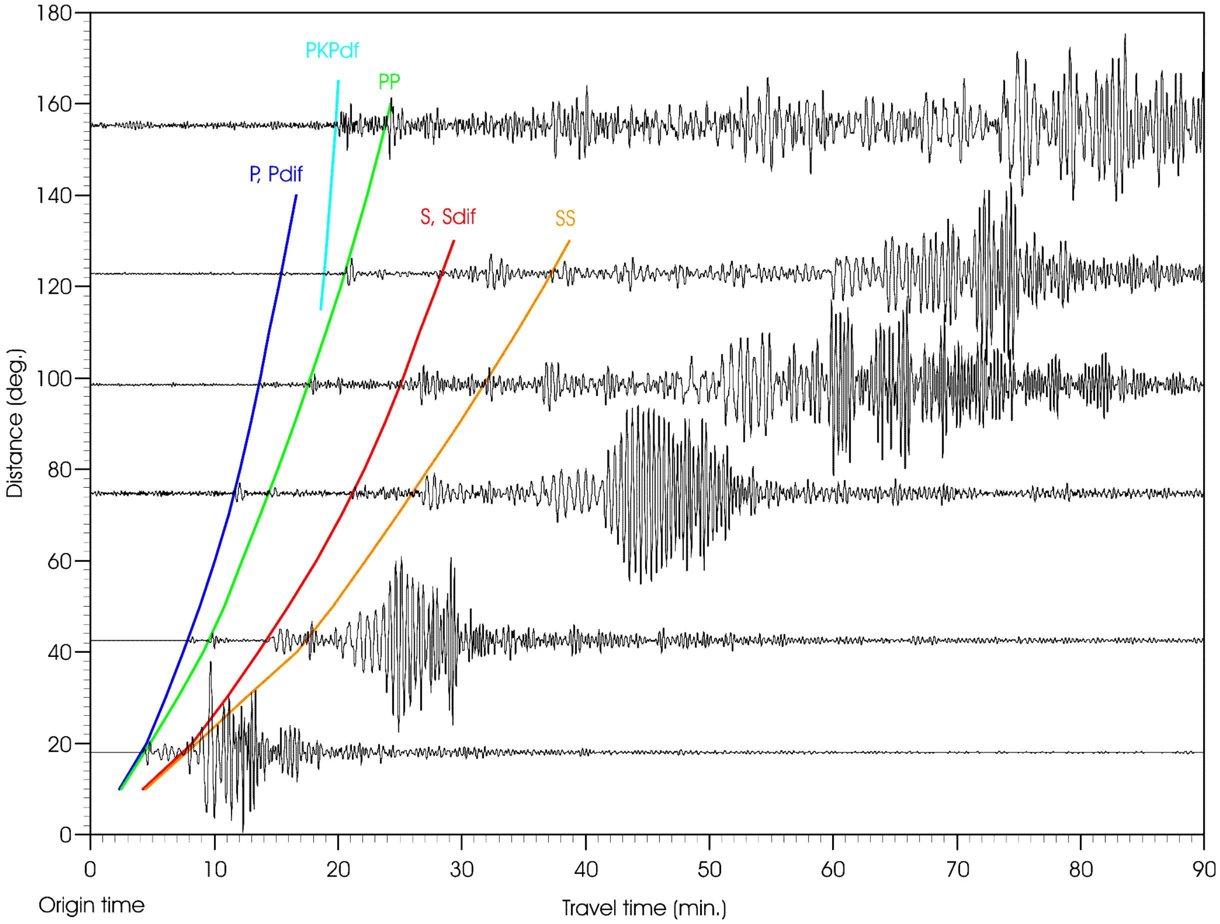

Fig. 1.2 Long-period filtered vertical-component broadband records of station CLL, Germany, of shallow earthquakes in the distance range 18° to 157°. Note the strong later longitudinal (PP) and transverse energy arrivals (S, SS) that are recognizable in the whole distance range, and the dispersed surface wave trains with large amplitudes. The record duration increases with distance (courtesy of S. Wendt, 2002).

Between 1974 and 1984, the first S-wave arrivals were reported on average to the ISC about twenty times less frequently than P, and other secondary phases are reported hundreds to thousands of times less often (Bergman, 1991). These differences reflect operations practice at least as much as the observability of secondary phases. For example, U.S. stations reported very few S phases in this period because the USGS National Earthquake Information Center (NEIC) did not normally use them in its routine processing and station operators knew that such readings would be "wasted". Conversely, a heavy proportion of all S readings came from European stations, especially those in former Soviet Bloc countries, where standards of practice included an emphasis on complete reading of seismograms.

The "classical" seismological observatory, for example, Moxa (MOX) in former East Germany, is now an endangered species. They depended on a social and political system that was prepared to devote relatively large numbers of personnel and other resources to station operation and analysis, with the goal of extracting the maximum amount of information out of a limited number of recordings. One can think of this as the "observatory-centered" model for observational seismology. Beginning in the 1960s, seismology in the west favored deployment of global networks (e.g., the WWSSN - World-wide Standard Seismograph Network) with relatively less attention given to individual stations or records, making up in quantity what they gave away in quality. This "network model" of observational seismology now dominates global seismology, but some balance between quantity and quality must still be found. This Manual is explicitly intended to support the side of quality in the acquisition, processing, and analysis of seismic data.

The accelerating advancement of computer capabilities during the last few decades is a strong incentive to automate more and more of the traditional tasks that need to be performed at seismological observatories. Despite significant progress made in this direction, automated phase identification and parameter determination is still inferior to the results achievable by a well-trained analyst. For this reason, and because this is more an area of research than of operational considerations, automated procedures are not considered in the Manual. Of course it will be easy to add such material to the web-based Manual whenever it is appropriate. The Manual focuses on providing guidance and advice to station operators and seismologists with less experience and to countries which lack specialists in the fields that should be covered by observatory personnel and application-oriented seismologists.

In designing the Manual for a global audience, we have tried to take into account the widely varying circumstances of observatory operators worldwide. While in developing countries proper education and full use of trained manpower for self-reliant development has (or should have) priority, highly advanced countries often push for the opposite, namely the advancement of automatic data acquisition and analysis. The main reasons for the latter tendency, besides the desire to limit personnel costs in high-wage countries, are:

- special requirements to assure most rapid and objective data processing and reporting by the primary (mostly array) stations of the International Monitoring System (IMS) in the framework of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) (see 8.6.9.1) or
- coping with the huge data rates at dense digital seismic networks and arrays in areas of high seismicity.

Seismologists in highly industrialized countries can usually address their special concerns with national resources. They typically need no guidance with respect to high-tech developments from a Manual like this. Even so, specialists in program development and automation algorithms in these countries often lack the required background knowledge in seismology and/or the practical experience of operational applications in routine practice. A similar argument applies to young scientists, beginning careers in seismological research, who often remain ignorant of the long history of operational seismology that produces the data available for their research. A typical graduate program in seismology gives scant attention to the historical development of measurement standards, which can lead either to neglect of valuable older data, or its misuse. In this sense, the NMSOP also aims at addressing the educational needs of this advanced user community with a view to broaden both their historical perspective and their ability to contribute to interdisciplinary research.

1.2.2 Creation of awareness

The subject of standards of practice at seismological observatories normally stays well below the active consciousness of most seismologists, yet it sometimes plays a central role in important research and policy debates.

1.2.2.1 The magnitude issue

Earthquake magnitude is one of the most widely used parameters in seismological practice, and one that is particularly subject to misunderstanding, even by seismologists. Examples of the way in which changing operational procedures have contaminated a valuable data set have recently been put forward and discussed in the Seismological Research Letters. After re-examining the earthquake catalogue for southern California between 1932 and 1990, Hutton and Jones (1993) concluded:

- ML magnitudes (in the following termed Ml with l for “local”) had not been consistently determined over that period;
- amplitudes of ground velocities recorded on Wood-Anderson instruments and thus Ml were systematically overestimated prior to 1944 compared to present reading procedures;
- in addition, changes from human to computerized estimation of Ml led to slightly lower magnitude estimates after 1975;
- these changes contributed to an *apparently higher rate of seismicity* in the 1930’s and 1940’s and a later decrease in seismicity rate which has been interpreted as being related to the subsequent 1952 Kern County (Mw = 7.5) earthquake;
- variations in the rate of seismic activity have often been related to precursory activity prior to major earthquakes and therefore been considered suitable for earthquake prediction;
- the re-determination of ML in the catalogue for southern California, however, *does not confirm any changes in seismicity* rate above the level of 90% significance for the time interval considered.

Similar experiences with other local and global catalogues led Habermann (1995) to state: "... the heterogeneity of these catalogues makes characterizing the long-term behavior of seismic regions extremely difficult and interpreting time-dependent changes in those regions hazardous at best. ... Several proposed precursory seismicity behaviors (activation and quiescence) can be caused by simple errors in the catalogues used to identify them. ... Such mistakes have the potential to undermine the relationship between the seismological community and the public we serve. They are, therefore, a serious threat to the well-being of our community."

Another striking example of the consequences of neglecting changes in observatory practice (and mixing in some political priorities as well) is the following: Classical seismology was based on the recordings of medium-period instruments of relatively wide bandwidth such as Wiechert, Golizyn, Mainka, and Press-Ewing seismographs. Gutenberg’s (1945 b and c) and Gutenberg and Richter’s (1956 a-c) work on earthquake body-wave magnitude scales for teleseismic event scaling and energy determination was mainly based on records of such seismographs. Then, with the introduction of the WWSSN short-period instruments, body-wave magnitudes were determined routinely in the United States only from amplitude-measurements of these short-period narrowband records, which have better detection performance for weaker events than medium- and long-period seismographs and yield a better discrimination between earthquakes and underground nuclear explosions on the basis of the mb-Ms criterion (see 11.2.5.2). However, American seismologists calibrated their amplitude measurements with the Gutenberg-Richter Q-functions for medium-period body waves. This resulted in a systematic underestimation of the P-wave magnitudes (termed mb). In contrast, at Soviet "basic" stations, the standard instrument was the medium-period broadband Kirnos seismometer (displacement proportional between about 0.1 s to 10(20)s). Accordingly, Russian medium-period body-wave magnitudes mB are more properly scaled to Gutenberg-Richters mB-Ms and logEs-Ms relations. It happens that the corresponding global magnitude-frequency relationship logN-mB yields a smaller number of annual m = 4 events than the U.S. WWSSN-based mb data (Riznichenko, 1960). Accordingly, in the late 1950s at the Geneva talks to negotiate a nuclear test ban treaty, the US delegation assumed a much more frequent occurrence of non-discriminated seismic events when only teleseismic records were available. This prompted them to demand some 200 to 600 unmanned stations on Soviet territory at local and regional distances as well as on-site inspections in case of uncertain events (Gilpin, 1962). Thus, a biased magnitude-frequency assessment played a significant role in the failure of these early negotiations aimed at achieving a Comprehensive Nuclear-Test-Ban Treaty (CTBT); underground testing continued for several more decades.

In 1996 the CTBT was finally agreed upon, and signed by 71 States as of 2002. The United Nations CTBT Organization in Vienna runs an International Data Centre (IDC) which also determines body-wave magnitudes from records of the International Monitoring System (IMS). However, in the interest of best possible discrimination between natural earthquakes and underground explosions by means of the body-wave/surface-wave magnitude ratio mb/Ms, they measure P-wave amplitudes after filtering the broadband records with a displacement frequency-response peaked around 5 Hz instead of around 1 Hz or 0.1 Hz. However, they calibrate their amplitude readings with a calibration function developed for 1 Hz data. Finally, they measure the maximum amplitudes for mb determination not, as recommended by IASPEI in the 1970s, within the whole P-wave train but within the first 5 seconds after the P-wave onset. These differences in practice result in systematically smaller mb(IDC) values as compared to the mb(NEIC). Although this difference is negligible for explosions it is significant for earthquakes. The discrepancy grows with magnitude and may reach 0.5 to 1.5 magnitude units. Nonetheless, the IDC magnitudes are given the same name mb, although they sample different properties of the P-wave signal. Users who are not aware of the underlying causes and tricky procedural problems behind magnitude determination, may not realize this incompatibility of data and come to completely different conclusions when using, e.g., the mb data of different data centers for seismic hazard assessment. In order to throw light onto the fuzzy practice of magnitude determinations and to push for standardization of procedures of magnitude estimation and unique magnitude names, the new Manual goes into great detail on this crucial issue. As a consequence, the magnitude sub-chapter 3.2 covers more pages than two of the smaller main Chapters.

1.2.2.2 Consequences of recent technical developments

When assembling the NMSOP we took into account that:

- modern seismic sensors, in conjunction with advanced digital data acquisition, allow recording of seismic waves in a very broad frequency band with extremely high resolution and within a much larger dynamic range than was possible in the days of analog seismology (see Fig. 1.3 below and Fig. 7.48);
- modern computer hardware and versatile analysis software tremendously ease the task of comprehensive and accurate seismogram analysis. This allows one to determine routinely parameters which were far beyond the scope of seismogram analysis a few decades ago;
- precise time-keeping and reading is much less of a problem than it was in the pre-GPS (Global Positioning System) and pre-computer era;
- the rapid global spread of high-speed communications links largely eliminates any technical barrier to widespread data exchange of full waveform data in near real time.

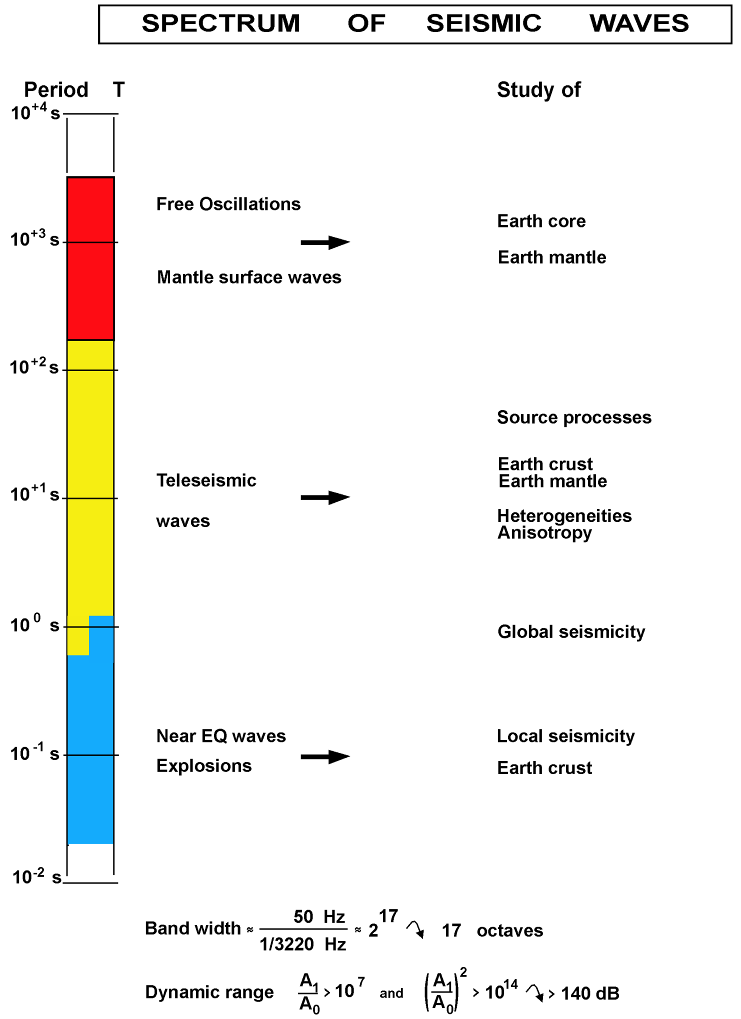

Fig. 1.3 Frequency range, bandwidth and dynamic range of modern seismology and related objects of research. The related wavelength of seismic waves vary, depending on their propagation velocity, between several meter (m) and more than 10,000 kilometer (km). The amplitudes to be recorded range from nanometer (nm) to decimeter (dm).

At the same time, these new possibilities carry new risks:

- analysts who only use ready-made computer programs for solving a diversity of tasks, by feeding in the data and pressing the button, tend to lose a deeper understanding of the underlying model assumptions, inherent limitations and possible sources of error so that the quality of the results may be judged by the attractiveness of the graphic user interface;
- readily calculated and displayed standard deviations for all conceivable solutions often seem to indicate a reliability of the results which is far from the truth. Therefore, an understanding of the difference between internal, computational and also model-dependent *precision* on the one hand, and *accuracy* of the solutions with reference to reality on the other hand, has to be encouraged;
- specialist are increasingly required to operate and properly maintain modern seismic equipment and software. They usually lack a broader geoscientific background and thus an active interest in the use of the data which could result in declining concern for long-term data continuity and reliability, which is the backbone for any geoscientific observatory practice.

In consideration of these factors, the authors took as prime aims of the new Manual the creation of:

- interdisciplinary problem understanding; and
- motivation of observatory personnel to overcome boring routines by developing curiosity and an active interest in the use of the data they produce both in science and society.

1.2.2.3 The need for secondary phase readings

The currently dominant practice of reporting mainly first-arriving seismic phases, together with the inhomogeneous distribution of seismic sources and receivers over the globe, results in a very incomplete and inhomogeneous sampling of the structural features and properties of the Earth's interior. The consequences are not only ill-constrained Earth models of inferior resolution but also earthquake locations of insufficient accuracy to understand their seismotectonic origin and to identify the most likely places of their future occurrence. In the late 1980s, this prompted seismologists (e.g., Doornbos et al., 1991) to conceive a plan for an International Seismological Observing Period (ISOP) aimed at:

- maximum reporting of secondary phases from routine record readings aimed at improved source location and sampling of the Earth (see, e.g., Fig. 1.4);
- taking best advantage, in the routine analysis, of the increasing availability of digital broadband records and easy-to-use data preprocessing and analysis software;
- improved training of station operators and analysts;
- improved communication, co-ordination and co-operation between the stations of the global and regional seismic networks.

Ultimately, the ISOP plan for an international observational experiment focused on expanded reporting of secondary body wave phases collapsed in the face of entropy and inertia, but the issues raised in the ISOP project have remained important to many seismologists. The need for the NMSOP grew out of discussions within the ISOP project, and many seismologists who were active in ISOP went on to contribute to the NMSOP which has been developed in the spirit of ISOP It is largely based on training material and practical exercises used in international training courses for station operators and analysts (see Bormann, 2000).

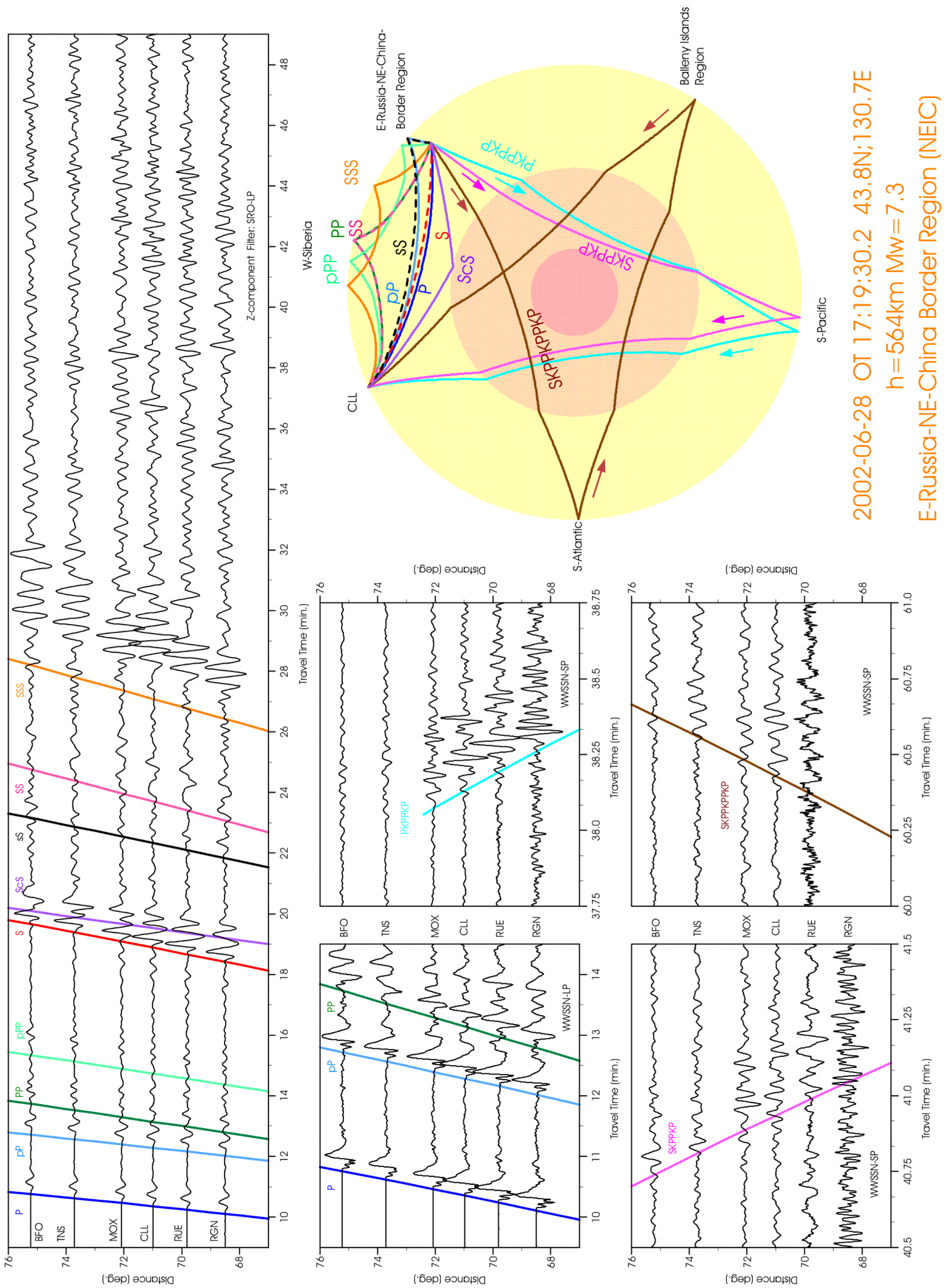

Fig. 1.4 Detailed interpretation of long-period (LP) and short-period (SP) filtered broadband records of the stations of the German Regional Seismic Network (GRSN). Note the clearly recognizable depth phases pP, pPP and sS, which are extremely important for more accurate depth determination of the event, and the rare but well developed multiple core phases PKPPKP, SKPPKP and SKPPKPPKP which sample very different parts of the deep Earth's interior than the direct mantle phases (courtesy of S. Wendt).

Accordingly, Chapter 11 on Data Analysis and Seismogram Interpretation (101 pages) is, together with its extended annexes with seismogram examples (79 pages), event location and related software (45 pages), and several exercises on magnitude determination, event location and phase identification (40 pages) the most extensive part of the NMSOP.

1.2.2.4 New seismic sensors and sensor calibration

Modern broadband seismographs record ground motions with a minimum of distortion and it is possible to restore true ground motion computationally with high accuracy. Seismic waveforms carry much more information about the seismic source and wave-propagation process than simple parameter readings of onset times, amplitudes and prevailing periods of seismic phases. Therefore, waveform modeling and fitting has now become a major tool both of advanced seismic research and increasingly also of routine processing and analysis. Seismic waveforms and amplitudes, however, strongly depend on the transfer function and gain of the seismograph, which must be known with high accuracy if the full potential of waveform analysis is to be exploited. Also reliable amplitude-based magnitude estimates, most of them determined from band-limited recordings, require accurate knowledge of the recording system's frequency-dependent magnification. Consequently, instrument parameters that control the instrument response must be known and kept stable with an accuracy of better than a few percent. Unfortunately, at many seismic stations the seismographs have never been carefully calibrated, the actual gain and response shape is not precisely known and their stability with time is not regularly controlled. Some station operators rely on the parameters given in the data sheets of the manufacturers or those determined (possibly) by the primary installer of the stations. However, these parameters, instrumental gain in particular, are often not accurate enough. Therefore, station operators themselves should be able to carry out an independent, complete calibration of their instruments.

Long-period seismographs are strongly influenced by changes in ambient temperature and ground stability. However, for modern feedback-controlled broadband seismographs the basic parameters, eigenperiod and gain, are rather stable, provided that the seismometer mass is kept in the zero position. This should be regularly controlled, more frequently (e.g., every few weeks) in temporary installations and every few months in more stable permanent installations.

Although short-period instruments are generally considered to be much more robust and stable in their parameters, experience has shown that their eigenperiod and attenuation may change with time up to several tens percent, especially when these instruments are repeatedly deployed in temporary installations. Parameter changes of this order are not tolerable for quantitative analysis of waveform parameters. Therefore, more frequent control and absolute determination of these critical sensor parameters are strongly recommended after each re-installation.

Therefore, the NMSOP presents a rather extensive chapter on the basic theory of seismometry and the practice of instrument calibration and parameter determination, which is complemented by exercises and introductions to freely available software for parameter determination and response calculations. Additionally, in other chapters, the effects of different seismograph responses, post-record filtering or computational signal restitution on the appearance of seismograms and the reliability and reproducibility of parameter readings is demonstrated with many examples.

1.2.2.5 What has to be considered when installing new seismic networks

More and more countries now realize the importance of seismic monitoring of their territories for improved seismic hazard assessment and the development of appropriate risk-mitigation strategies. Installation and long-term operation of a self-reliant modern seismic network is quite a demanding and costly undertaking. Cost-efficiency largely depends on proper project definition, instrument and site selection based on a good knowledge of the actual seismo-tectonic and geographic-climatic situation, the availability of trained manpower and required infrastructure, and many other factors. Project-related funds are often available only within a limited time-window. Therefore, they are often spent quickly on high-tech hardware and turn-key installations by foreign manufacturers without careful site selection and proper allocation of funds for training and follow-up operation. If local people are not involved in these initial efforts and capable of using and maintaining these new facilities and data according to their potential, then the whole project might turn out to be a major investment with little or no meaningful return. These crucial practical and financial aspects are usually not discussed in any of the textbooks in seismology that mostly serve general academic education or research. Therefore, the NMSOP dedicates its largest chapter (108 pages) to just these problems.

What can be achieved with modern seismological networks, both physical and virtual ones, and how they relate with respect to aperture, data processing and results to specialized seismic arrays, is extensively dealt with in complementary chapters of the NMSOP.

1.3 Philosophy of the NMSOP

The concept for the NMSOP was developed with consideration of the benefits and drawbacks of the old Manual, taking into account the technological developments and opportunities which have appeared during the last 20 years, as well as the existing in-equalities in scientific-technical conditions and availability of trained manpower world-wide (Bormann, 1994).

Seismological stations and observatories are currently operated by a great variety of agencies, staffed by seismologists and technicians whose training and interests vary widely, or they are not staffed at all and operated remotely from a seismological data or analysis center. They are equipped with hardware and software ranging from very traditional analog technology to highly versatile and sophisticated digital technology. While in industrialized countries the observatory personnel normally have easy access to up-to-date technologies, spare parts, infrastructure, know-how, consultancy and maintenance services, those working in developing counties are often required to do a reliable job with very modest means, without much outside assistance and usually lacking textbooks on the fundamentals of seismology or information about standard observatory procedures.

To ensure that data from observatories can be properly processed and interpreted under these diverse conditions, it is necessary to establish protocols for all aspects of observatory operation that may effect the seismological data itself. In addition, competent guidance is often required in the stages of planning, bidding, procurement, site-selection, and installation of new seismic observatories and networks so that they will later meet basic international standards for data exchange and processing in a cost-effective and efficient manner.

1. Aim and Scope of the IASPEI New Manual of Seismological Observ. Practice

One drawback of the old Manual appeared to us to be that its chapters were organized purely according to components or tasks of observatory practice, namely:

- Organization of station networks;
- Instruments;
- Station operation;
- Record content;
- The determination of earthquake parameters;
- Reporting output;
- Macroseismic observations;
- International services.

A consequence of this structuring was that the seismological fundamentals required to understand the relevance and particulars of the various observatory tasks were sometimes referred to in various chapters and dealt with in a fragmented manner. This approach makes it difficult for observatory personnel to comprehend the interdisciplinary problems and aims behind observatory practice and to appreciate the related, often stringent requirements with respect to data quality, completeness, consistency of procedures etc. Further, this approach puts together in the same chapters basic scientific information, which is rather static, with technical aspects which evolve quickly. This makes it difficult to keep the Manual up-to-date without frequent rewriting of entire chapters.

The IASPEI WG on MSOP agreed, therefore, to structure the new Manual differently:

- the body of the Manual should have long-term character, outlining the scope, terms of reference, philosophy, basic procedures as well as the scientific-technical and social background of observatory practice. It should aim at creating the necessary awareness and sense of responsibility to meet the required standards in observatory work in the best interests of scientific progress and social service.
- this main body or backbone of the NMSOP (Volume 1) should be structured in a didactically systematic way, introducing first the scientific-technical fundamentals underlying each of the main components in the "information chain" (see Fig. 1.1) before going on to major tasks of observatory work.
- the core Manual should be complemented by annexes of complementary information (Volume 2) which can stand alone. Some of these topics are too bulky or specific to be included in the body of the Manual while others may require more frequent updating than the thematic Manual chapters. Therefore, they should be kept separate and individualized. Some annexes give more detailed descriptions of special problems (e.g., event location or theory of source representation); others provide data about commonly-used Earth models, shareware for problem solving, seismic record examples, calibration functions for magnitude determination, widely-used sensors and their key parameters, or job-related exercises with solutions for specific observatory tasks such as phase identification, event location, magnitude estimation, fault-plane determination, etc.

With this structure it is hoped to produce a new Manual which is a sufficiently complete, self-explanatory reference source ("cook and recipe book") with an aim to provide awareness of complex problems, basic background information, and specific instructions for the self-reliant execution of all common "routine" or "pre-research" jobs by the technical and scientific staff at seismological stations, observatories, and network centers. This includes system planning, site investigation and preparation, instrument calibration, installation, shielding, data acquisition, processing and analysis, documentation and reporting to relevant national and international agencies, data centers or the public, and occasionally, also assessing and classifying earthquake damage.

The NMSOP will not cover the often highly automated procedures now in use at many international seismological data centers. These normally neither record nor analyze seismic records themselves but rather use the parameters or waveforms reported to them by stations, networks or arrays. Such centers usually have the expertise and the scientific-technical environment and international connections needed to carry out their duties effectively. Rather, the NMSOP should mainly serve the needs of the majority of less experienced or too narrowly specialized operators and analysts in both developing and industrialized countries, so as to assure that all necessary tasks within the scope and required standards for national and international data acquisition and exchange can be properly performed. Worldwide there is no formal university education or professional training available for seismic station operators and data analysts. Observatory personnel usually acquire their training through "learning by doing". The formal educational background of observatory personnel may be very different: Physicists, geologists, electronic or computer engineers, rarely geophysicists. Accordingly, the NMSOP tries to be comprehensible for people with different backgrounds, to stimulate their interest in interdisciplinary problems and to guide the development of the required practical skills. The method of instruction is mainly descriptive. Higher mathematics is only used where it is indispensable, e.g., in the seismometry chapter.

The NMSOP should, however, also be a contribution, at least in part, to public, high school and university education in the field of geosciences. It is hoped that many components, practical exercises in particular, will be useful for students of geophysics. The NMSOP will therefore be made available in different forms:

- as a loose-leaf collection of printed chapters and annexes, which can easily be updated and complemented in accordance with changing job requirements and new developments without the need to re-edit and re-print the whole Manual. Also, these updates and complements can be disseminated to Manual owners as E-mail attachments and some Manual users may order only those parts which are relevant for them.;
- on a website with hyperlinks for convenient searches, linking external complementary resources, and easy extraction of problem-tailored educational modules (see 1.4.2);
- as a CD-ROM which will be affordable for everybody.

1.4 Contents of the NMSOP

1.4.1 The printed Manual

The IASPEI and ESC Working Groups for the NMSOP agreed on the following topical Manual chapters (for details see List of Contents):

Chapter 1: Aim and scope of the IASPEI New Manual of Seismological Observatory Practice (NMSOP)
Chapter 2: Seismic Wave Propagation and Earth Models
Chapter 3: Seismic Sources and Source Parameters
Chapter 4: Seismic Signals and Noise

Chapter 5: Seismic Sensors and their Calibration
Chapter 6: Seismic Recording Systems
Chapter 7: Site Selection, Preparation and Installation of Seismic Stations
Chapter 8: Seismic Networks
Chapter 9: Seismic Arrays
Chapter 10: Data Formats, Storage, and Exchange
Chapter 11: Data Analysis and Seismogram Interpretation
Chapter 12: Intensity and Intensity Scales
Chapter 13. Volcano Seismology

These chapters form Volume 1 of the printed NMSOP and cover either the fundamental aspects of the main sub-systems of the "Information Chain of Seismology" as presented schematically in Fig. 1.1, or related specific tasks, technologies or methodologies of data acquisition, formatting, processing and application.

Volume I is complemented by Volume 2. The latter contains annexes in the following categories:

- **Datasheets (DS):** Lists of sensor parameters; record examples, travel-time curves, Earth models, calibration functions, etc.;
- **Information Sheets (IS):** They contain more detailed treatments of special topics or condensed summaries of special instructions/recommendations for quick orientation, present the standard nomenclature of seismic phase and magnitude names, give examples for parameter reports and bulletins, etc.;
- **Exercises (EX):** Practical exercises with solutions on basic observatory tasks such as event location, magnitude estimation, determination of fault-plane solutions and other source parameters, instrument calibration and response construction. For educational purposes, most of these exercises are carried out Manually with very modest technical and computational means, however links are given to related software tools;
- **Program Descriptions (PD):** Short descriptions of essential features of freely available software for observatory practice and how to access it;
- **Miscellaneous:** Contains a list of acronyms, an extensive index, the list of authors with complete addresses and the list of references for Volume 1. Other items may be added later.

1.4.2 The NMSOP website

Very early in the discussions about a New Manual of Seismological Observatory Practice, it was decided that the usefulness and longevity of the project could be maximized by adapting it to the World Wide Web, which was only then becoming widely appreciated as a medium for exchanging information among scientists. Working scientists, especially older ones, are more oriented to the discipline of paper publication, with near-total control and permanence. The flexibility and unpredictability of the hyperlinked experience of a large technical document such as the NMSOP would require a different attitude on the part of the author, the editor, and the reader. The web-based Manual should be experienced more like a conversation than a prepared lecture; the reader must always evaluate the material for self-consistency and use common sense to evaluate apparent discrepancies as in electronic (e-)learning tools.

Compared to the printed version, the main advantages of a web-based Manual should be the ease with which it can be updated and expanded, navigation via hyperlinks (both within the Manual and to external data and information resources), and the ease with which the user may copy portions of the Manual for use in other computer-based documents, lecture notes, etc.

Regrettably, this ambitious original concept for the NMSOP could not yet be achieved because no person or institution has been found so far which felt able to produce, maintain and permanently update in the long run such has hyperlinked web-based Manual. Therefore, as an alternative, the GeoForschungsZentrum Potsdam, which had financed the printing of the hard-copy version of the first edition of the NMSOP, has agreed to put corrected and gradually updated and complemented pdf-versions of the Manual, after approval by the editor and/or the Commission on Seismic Observation and Interpretation (CoSOI) of IASPEI, on its website. The GFZ is willing to maintain and propagate the availability of this NMSOP website for the foreseeable future and strive to modernize it, as resources and upcoming new technologies will permit, into a tool of e-learning according to the original concept.

1.5 Outreach of the NMSOP

The authors and the webmaster of the NMSOP will strive to keep both the printed Manual and the NMSOP home page in tune with the most recent developments and needs. It is intended that the maintenance and regular updating of the NMSOP be a permanent obligation of the IASPEI Commission on Seismological Observation and Interpretation (CoSOI) and its relevant Working Groups. Production of an inexpensive printed loose-leaf collection of the Manual, complemented by a CD-ROM, will assure general availability of the Manual at every manned seismological station, network center, seismological institution or geoscience department at universities all over the world.

It is expected, therefore, that the user community of the NMSOP will not be limited to observatory personal. Many chapters and sections will be of general interest to lecturers and students in seismology, geophysics or geosciences in general. They will find both suitable lecture and exercise material. With the NMSOP on the Internet, special training institutions in the field of applied seismology may make use of this resource. They can retrieve self-tailored training modules from it according to their specific requirements, provided that the data source and the individual authors of the related Manual contribution are properly cited. The copyright rests with IASPEI (see Editorial remarks). We hope that the NMSOP will be of long-term and far-reaching benefit to a rather diverse user community.

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Recommended overview readings (see References under Miscellaneous in Volume 2)

Aki and Richards (2002)
Båth (1979)
Bolt (1982, 1993, 1999)
Havskov and Alguacil (2004)
Kennett (2001 and 2002)
Kulhánek (1990)
Lay and Wallace (1995)
Lilie (1998)
Scherbaum (2001)
Shearer (1999)
Udias (1999)
Willmore (1979)