# Instruments for Physical Environmental Measurements

with special emphasis on atmospheric instruments

VOLUME I

Second Edition

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# FOREWORD

During the preparation of this book, numerous environmental modeling techniques for the prediction and control of the geosphere were developed. Although not all models are useful, their objectives are rational. Since these models attempt to simulate natural mechanisms with the aid of mathematical and statistical formulations, they serve as a guide for field instrument operations. Today, instrumentation consists of a complete data acquisition system instead of a single device to sense an environmental parameter at a locale. In other words, modern instrumentation may include data collection, storage, processing, and dissemination involving information retrieval and communication. Strictly speaking, instrumentation is developed according to the modeling design. For example, in the recent Global Atlantic Tropical Experiment Program, known as GATE, several new instruments and platforms including electronic communication systems were developed. The GATE field investigation covered a 20 million square mile area of the tropical land and sea. Instruments on 40 ships, more than 60 buoys, 13 aircraft, 6 types of satellites, and at nearly a 1000 land stations observed and recorded weather and ocean phenomena from the top of the atmosphere to about 5000 feet below the sea surface. This gigantic program was possible only because of the well designed modeling system.

Over the past decades, instrumentation has progressed from a piecemeal to an interdisciplinary approach, as can be seen in the literature. And yet, to the best of our knowledge, few books were organized to cover the measurement techniques in the atmosphere, hydrosphere, and lithosphere in a single volume. In this book, the author attempts to stress a total environmental approach by giving an in-depth description of some basic scientific techniques as they apply to the various systems of the geosphere. In writing this, much effort was expended in the collection of up-to-date information on instruments and instrument systems from many sources.

The first volume of this book will focus on the fundamental knowledge pertaining to the measurement of the atmosphere, hydrosphere, and lithosphere of the earth. It covers the requirements and specifications as well as the data acquistion systems and basic principles and mechanisms of instruments, with emphasis on atmospheric measurement. The second volume will discuss environmental monitoring techniques and devices, such as those utilized in pollution measurement, radioactivity and noise monitoring, and earth and space environmental inventory.

This publication is intended to be a textbook in physical environmental instrumentation for the upper division and graduate levels of universities and colleges. It can also be used as a reference work for engineers and scientists who are interested in the practical aspects of geoscience instrumentation. Therefore, the primary intent of the author is to give the reader sufficient knowledge of basic instruments in terms of their principles and mechanisms. The secondary intent is to provide the necessary assumptions and theories, mainly expressed in mathematical and statistical formulations. Recognizing the vast dimensions of instrumentation in geoscience applications, this publication cannot encompass them all. As a remedy, characteristics of each instrument category are summarized, and pertinent references provided.

This book is a result of the combined efforts of many individuals and groups whose help and encouragement provided the author with the incentive to persevere. To express his gratitude, the author has made a list of names appearing in the Appendix (Volume II), in which the contributions of individuals and organizations are listed. Especially, the author wishes to thank Mr. Milt Silverstein of Milieu Information Service for his contributions and participation in various stages of manuscript editing and preparation. Appreciation is also extended to Mr. Arthur Bayce for his contribution related to diffusion monitoring, and a portion of geological measurements, and of environmental systems; and to Mr. Ballard W. George for his assistance in noise measurement. The author is deeply indebted to the staff and students of the Department of Meteorology at San José State University for their valuable assistance and encouragement on the various aspects of this book.

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## FOREWORD TO 2ND EDITION

By the end of the third year following its publication, all copies of the first edition had been sold out. Meanwhile, the author had received comments from several scientists and engineers in the United States and abroad, in addition to improvements he made on the text while using it in his classes. Also, additional information became available to the author with respect to innovations and improvements of geoscience instrumentation since the first edition.

To incorporate all of this new information, the publisher requested that the author revise the manuscript and, in so doing, convert it from syllabus to book format.

The original outline of the first edition was preserved, but numerous changes were embodied. This included the addition of new materials on the technologies of instruments and measurements. Also, improvements were made on the text, illustrations, and data source selections.

Last but not the least, the contributions made by Dr. Catherine M.M. Felton as co-author enhanced the quality of this new edition significantly. The competent work of Ms. Nancy E. Burns as editor, Ms. Nobuko Ishigaki as graphic artist and typist, and Ms. Sandy Batey and Ms. C.M. Mancino as typists are gratefully acknowledged.

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## VOLUME II





INSTRUMENTS FOR PHYSICAL ENVIRONMENTAL MEASUREMENTS
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# CHAPTER 1 INSTRUMENTATION IN THE GEOSPHERE

Air, water and land comprise the physical surroundings of man. Collectively, they may be called the geosphere or the earth's environment, which includes three systems: atmosphere, hydrosphere, and lithosphere. The gaseous envelope of the earth is the atmosphere and the entire watery envelope of the earth is the hydrosphere. The solid crust and the cool, upper mantle of the earth are the lithosphere.

In order to understand the behavior of the geosphere, instruments are required for making observations and measurements of its physical and chemical properties. The dynamics and complexities of these properties are still not fully understood. The demand for more instrumental surveillance is obvious. Fortunately, the tendency toward research and development in new instruments is increasing and a huge inventory of instruments and instrumentation is now available. The reader, therefore, must familiarize himself with both the prototypic and commercial instruments for his own interests.

The first part of the present chapter will provide some fundamental information on instruments and instrumentation in general. The remainder of the chapter will deal with measurements in the atmosphere, hydrosphere and lithosphere, with special emphasis on the scope, characteristics and problems of these three systems.

## 1.1 Instruments and Instrumentation.

An instrument is a device for making observations and measurements[1] and for the control of energy and mass of its immediate or distant surroundings, while instrumentation refers to the use and application of an instrument or instruments. Instrumentation may encompass one or more instruments in addition to the instrumental platform, communications and data acquisition facilities in order to make it practical. We shall examine the general functions of an instrument first and then discuss the general characteristics of instrumentation.

An instrument is a mechanical, electrical, optical, chemical or even biological device for measuring the atom, the world or the universe. It can be a combination of two or more of these devices. It can also be a controlling device, to an appreciable extent, of the human physical environment. Measurements are accomplished by sensing the signal from the environment represented by either energy or mass, or both, arriving at the sensing element (or sensor) of an instrument. The response or interaction of a sensor to a signal defines the

[1] While observations are usually made by direct human "vision," measurements are conducted through the use of tools or instruments. However, these terms are used quite loosely and alternatively.