Preface

Efforts to mitigate global warming at the societal level call for a rapid implementation of systems that quantitatively evaluate the carbon dioxide (CO_2) budgets for forests, croplands, grasslands, and other terrestrial ecosystems. For observational studies of carbon budgets for terrestrial ecosystems, tower-based micrometeorological CO_2 flux observations conducted at the interface between the atmosphere and terrestrial ecosystems have attracted attention as an approach that allows direct measurements of the amount of CO_2 absorbed by the terrestrial ecosystems from the atmosphere. Such CO_2 flux observations have been taking place at more than 200 locations worldwide. Furthermore, efforts to integrate studies from tower-based observations on CO_2 and energy fluxes and those on the carbon dynamics and energy budgets of terrestrial ecosystems are currently in progress with the goals of improving the parameterization of ecosystem models relevant to global warming research and elucidating the influences of natural and anthropogenic disturbances, e.g., typhoons and land use changes, respectively, on the dynamics of diverse terrestrial ecosystems.

With this background, four research institutes (Forestry and Forest Products Research Institute, National Institute for Agro-Environmental Sciences, National Institute of Advanced Industrial Science and Technology, and National Institute for Environmental Studies) which have conducted long-term tower observations within Japan agreed to conduct joint research and development in 2007 in order to promote shared use of observation data, for which the reliability has been ensured and quality-control has been performed. The observation data under consideration concern exchanges of energy and mass such as CO_2 between terrestrial ecosystems and the atmosphere, the exchanges for which worldwide observation networking has been promoted. A micrometeorological observation and analysis technique called the eddy covariance method has become very common in recent years as a result of the development of measuring instruments with a relatively high response time and improvements in computational processing speed. This technique has enabled continuous acquisition of ecosystem production data as well as ecosystem-atmosphere mass and energy exchange (flux) data, without damaging the ecosystem under observation. Data acquisition with the eddy covariance method has, in turn, allowed clear evaluations of the diurnal, annual, and inter-annual variations of energy and mass (e.g., CO_2) exchanges, contributing significantly to improved understanding of ecosystem carbon dynamics and energy budgets.

Unlike general surface observations of meteorological variables, the micrometeorological technique does not require uniform conditions for the observation site and instrumentation. Therefore, while the micrometeorological technique offers various advantages, the data acquired with this technique have been subject to measurement uncertainties associated with variations in the observation location, observation method, and analysis method since the initial adoption of this technique. Currently, the observation-data sharing that has been promoted by FLUXNET, AsiaFlux and other related programs aims to inter-compare data through direct means or through indirect means such as model validation and also to achieve an improved understanding of the regional-scale carbon budget. Therefore, great care has been taken in order to eliminate data uncertainties including those associated with the use of the micrometeorological technique. For example, in Europe and Canada, instrumentation and analysis techniques have been standardized by creating manuals since the beginning of the observational efforts (Aubinet *et al.*, 2000; Fluxnet-Canada, 2003), and tower observations have been implemented in a systematic manner. In Japan, under the leadership of the AsiaFlux Steering Committee, “Current Practice of CO_2 and Other Flux Observations in Measurements for Terrestrial Ecosystems“ (AsiaFlux Steering Committee (ed.), 2003 in Japanese, 2007 in English) was published, which has contributed to the improvement of observation and analysis standards and the establishment of an observation network by illustrating measurement and analysis techniques. In 2004, with FLUXNET as the nucleus of the project, a handbook with details on a wide variety of topics including the theory and technique of observation and analysis and examinations of factors affecting observation error was published (Lee *et al*. (ed.), 2004). With the manual and the handbook, a guideline has been created for handling factors which cause uncertainties in observation data. On the other hand, of the issues associated with uncertainties in observation data, errors induced by phenomena that depend heavily on the terrain conditions of the observation site, e.g., complex terrain, are fundamental causes of uncertainties in observation data and are rooted in the principle of measurements and analysis. This issue remains as a research topic which needs to be continuously addressed.

Accordingly, the number of literature references on observations by the eddy covariance method has increased compared to the time when such observations were initiated. However, when observations and analyses by the eddy covariance method are attempted in practice, detailed technical information that is not described in the existing publications becomes necessary for many of the tasks associated with the project such as starting a new observation site, deployment of the observation system, and analyses and quality control of the data. Given this circumstance, it has been proposed that data quality and distribution among researchers be increased by making the necessary technical information available on the internet and allowing researchers, who are aware of the necessity of standardizing the data, to share technical information. This proposal aims to contribute to the construction of a system that provides an improved estimate of the amount of CO_2 absorbed by terrestrial ecosystems, which is relevant in the mitigation of global warming. In the regions centered around Asia, tower-based observation sites within terrestrial ecosystems to be used for the purpose of validating various models remain scarce. Without detailed technical information such as that provided in this manual, it may be nearly impossible for a research team to start and operate a new observation site alone.

Because detailed technical information such as that described above is inseparably linked to the development of observation and analysis techniques, this information has been made available on the internet, which allows for relatively easy update of information – an advantage of the internet. Because the information included in this manual is published on paper at this time, the inability to easily update the information is one of the biggest concerns. Nonetheless, publication of the present manual is valuable in that it provides a record of the current state of observations and analyses from a technical point of view. It is our hope that the present manual will serve in transferring various techniques to the science communities in Asia and contribute to the efforts to mitigate global warming through the expansion of tower observation

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Preface to English edition

A half century ago, Dr. Eiichi Inoue, a pioneering scientist of turbulence in the atmospheric boundary layer and famous for his studies on “Honami” (waving plants), tried to measure carbon dioxide (CO_2) fluxes over crop fields by applying the aerodynamic method. He dreamed that a sensor similar to a heat flux plate could be developed in the future (he named the sensor the CO_2 flux plate), and that by merely setting the plate horizontally we could easily measure the CO_2 flux from the difference between the concentration of CO_2 at the upper side of the plate and that at the lower side of the plate. We may say that his dream “partially” came true with the development of the eddy covariance system consisting of a sonic anemometer, a fast-response infrared gas analyzer, and a data logger. Now, the eddy covariance system is used for monitoring fluxes of CO_2 as well as those of water vapor and sensible heat in various terrestrial ecosystems throughout the world.

However, the measurement of CO_2 flux using the eddy covariance system is not as easy as, and actually far different from that using the CO_2 flux plate which Dr. Inoue dreamed of a half century ago. It is certain that open- and closed-path infrared gas analyzers as well as sonic anemometers and data loggers have recently been much improved and have become more sophisticated so that we can operate those advanced instruments more easily than two decades ago. In addition, as the number of users of the eddy covariance system increases, manufactures and their agents are providing detailed instruction manuals, technical notes, and even training courses. However, these resources are not enough for someone who is going to start flux observations using the eddy covariance system because these materials and activities generally focus on how to use the individual instruments or the eddy covariance system at best, but do not discuss practical issues related to eddy covariance flux observation such as constructing an observation site including a tower and related facilities, setting up the eddy covariance instruments in the field, and conducting the micrometeorological observations that are inseparable from the eddy covariance flux observations. AsiaFlux has also had several training courses including lectures on the theory of flux observation, but could not spend much time on the above-mentioned practical issues, which are really required for newcomers, especially those without expertise in micrometeorology.

As shown by its title, the “Practical Handbook of Tower Flux Observation” focuses on the practical issues in eddy covariance flux observation and includes a substantial amount of useful knowhow and unique sections such as “lightning surge countermeasures” and “detection and reduction of noise”, which are rarely found in similar publications. All of the authors of this handbook have been engaged in long-term flux monitoring in forest or cropland sites and have expertise in eddy covariance flux observation. I sincerely appreciate the efforts of the authors to spend their valuable time to share their experiences and knowhow with the readers, and expect this handbook to be utilized as a practical reference by eddy covariance users and in training courses on eddy covariance flux observation. It is also my hope that another practical handbook, which focuses on the processing of eddy covariance data and is complementary to the present handbook, will be published in the near future.

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