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AsiaFlux Newsletter

Contents

A Step toward a Breakthrough in Understanding Terrestrial Ecosystems

- A Letter from Professor Oikawa -

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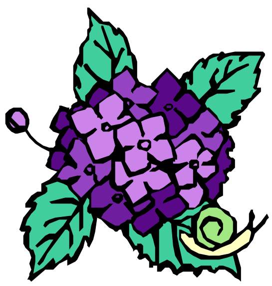
The 6th International Symposium on Plant Responses to Air Pollution and Global Changes was held in Tsukuba, Japan, from October 19 to 22, 2004. At this symposium, Professor Takehisa OIKAWA from the University of Tsukuba presented a lecture titled "Our Challenges towards Integrated Terrestrial Carbon Study of Asia in the 21st Century". In this lecture, he described the major trends in research on the carbon balance of terrestrial ecosystems for the past few decades. He began the lecture by introducing his own research on a carbon balance model for tropical rainforests, which he conducted about 20 years ago. After reviewing more recent research topics, he closed the lecture by summarizing research efforts for elucidating the carbon balance in Asia, which is currently being conducted as the "Integrated Study for Terrestrial Carbon Management of Asia in the 21st Century Based on Scientific Advancements" under the Global Environment Research Fund of the Ministry of the Environment. Listening to this lecture, I imagined the great challenges that Professor Oikawa must have faced in his research on the carbon balance of tropical rainforests 20 years ago. Back then, our knowledge and techniques for this topic were limited compared to today. I asked him what he considered to be the biggest advancement in this field over the last 20 years. Because of the limited time at the symposium, we were unable to discuss this matter adequately. I was thinking how unfortunate it was, then I one day received a polite letter from Professor Oikawa summarizing his own thoughts on the subject. The content of the letter was highly thought-provoking. I was convinced that it should be shared with researchers in carbon balance studies, and offer its full translation here with the writer's consent.



As I mentioned the other day, recent advancements in science and technology are remarkable: computer power is improving by leaps and bounds, and the availability of satellite data is increasing rapidly. Our research on the global environment can now use these tools as highly effective means. Obviously, research which can make good use of all these advancements is becoming increasingly important. One good example of such an attempt is the development of the Earth Simulator. We have a hope that creating models which integrate the atmosphere, oceans, and terrestrial areas will improve our understanding of the basic mechanisms controlling the global environment.

At the same time, researchers could overlook important processes in this kind of massive research. To remind researchers of this danger, I ventured to describe my old research from 20 years ago in my talk the other day. In this research, I developed a forest model which has three physiologically differentiated strata (upper, middle and lower) to simulate the dynamics of a tropical rainforest. This research originated from my opportunity to work as a member of the Global Carbon Cycle Research Group. This group, headed by Masayuki TANAKA, was initiated as a part of the Ministry of Education's Environmental Sciences Research, which started in 1979. My role in this research project was to assess how terrestrial ecosystems respond to rising concentrations of atmospheric CO_2.

To achieve this goal, I developed a forest ecosystem model which could reproduce reality reasonably well. Using this model, I attempted to predict how a forest ecosystem would respond when atmospheric CO_2 concentration was gradually raised; that is, the magnitude of CO_2 fertilization effects. Therefore, at the outset, I had no intention at all of dividing a forest into strata, but the earliest single-stratum model did only a poor job of reproducing the actual measurements (which were obtained by a research group led by Tatsuo KIRA in the IBP*). The Kira group made detailed measurements not only of various kinds of biomass, but also of various kinds of carbon flux. My modeling results did not match all these measurements even though many different parameters were tested. I was stumped and racked my brain for a solution.

Suddenly, it occurred to me that tropical rainforests in particular have a layered structure. I immediately adopted the above-mentioned three-strata concept. The resulting model could reproduce all the variables measured by the Kira group. [1]

Having achieved a tool to simulate the dynamics of an actual tropical rainforest, I next performed a simulation by varying the annual growing period, which was one of the model parameters (this simulation was to investigate the influence of the dry season). As expected, the longer the dry season, the slower the growth rate of the forest. At the same time, I found that the tropical rainforest system remained stable and could survive as long as the dry season was no longer than four months (In other words, if the dry season lasted for five months, this forest system collapsed). This result was consistent with the actual geographical distribution of tropical rainforests. [2]

What especially surprised me was that a longer dry season inhibited tree growth only in the upper stratum, whereas it enhanced tree growth in the middle and lower strata, which occurred as a result of the suppressed tree growth in the upper stratum. The positive effect of more available light exceeded the negative effect of the shortened annual growing period due to a longer dry season. I checked to see if this could occur in nature and learned such cases had been actually observed (see *Tropical Ecology* [3] by Fusato OGAWA, a member of the Kira group).

Since the dry-season effect on the tropical rainforest model coincided with the facts known to date, I gained more confidence in my model. Through this experience, I truly appreciated the importance of proper data sets. My model would never have been completed without the tropical rainforest data-set compiled by Tatsuo KIRA and others. Acquiring this kind of data set requires significant efforts and

* International Biological Programme (1965-1974)

is perhaps considered as the greatest achievement of the IBP between 1965 and 1974. In actuality, after the passage of 30 years, it is now more difficult to obtain such a comprehensive data set. Although global LAI data estimated from satellite observations are useful for some applications, I must say that the currently available versions need to be further improved.

As an individual involved in ecology, I find it gratifying that the Kyoto Protocol has served to attract much attention to the carbon-absorbing ability of forests. This development will encourage people to achieve a proper understanding of the functions of forests, grasslands and other terrestrial ecosystems. At the moment, the carbon-absorbing ability of forests is generally the only focus of attention. I believe it is a big mistake as I always point out. In my opinion, grasslands are a far superior production system of organic matter when they are compared to forests. Trees grow their branches for a few tens of meters high and conduct photosynthesis. Growing leaves high up above the ground requires supporting tissues such as stems and branches, which entails considerable costs. To allow leaves to conduct photosynthesis properly, trees must transport enough water from the soil to their leaves. They provide water through vessels (hardwoods) and tracheids (conifers), and there is always a time lag between the supply and consumption of water. Furthermore, trees must transport photosynthate for a long distance to develop their stems and roots at the cost of great respiratory consumption. Grass, on the other hand, is at most about 2 m high, and therefore it lives on far smaller costs than trees in terms of both water transport and stem maintenance. This is my basic perspective of forests and grasslands from a standpoint of organic matter productivity.

If we proceed with the above-mentioned view of forests and grasslands, we come to understand the difference in responses to unfavorable environments between forests and grasslands. Using a different model for grasslands, I simulated the response of a grassland by varying the length of the dry season. Even if the dry season lasted for about 10 months, the grassland survived as a sound system although the overall biomass and productivity did decline. This is very different from the result of the tropical forest model, which yielded only four months for the maximum drought-tolerance period. Grasslands can survive after a longer dry season because they have small non-photosynthetic organs. Thus, they require much less respiratory consumption compared to forests, which need to maintain their large stems. It is my understanding that this fact is the ecological basis that distinguishes tree-climates from treeless climates in the Köppen climate classification. I believe this is the reason that grasslands can continue to exist in harsh environments (while also feeding very many animals) such as tropical savannas, temperate steppes, and the polar tundra, which are too dry or too cold for forests. Finding some evidence for my hypothesis is one of the reasons for conducting research on terrestrial ecosystems including grasslands as well as forests in the aforementioned research project supported by the Ministry of the Environment.

Although the Earth Simulator has been attracting the attention of the world, I wonder if there are elements missing in the Earth Simulator. If there are, I wish to see if they are of great importance. I would like to achieve a breakthrough and pin down such elements in the current project of the Ministry of the Environment.

Pondering on the Earth Simulator, I came to realize an ironic reality. Phenomena in the natural world involve a large number of various processes intertwined with one another, and it is not easy to grasp the essence of any phenomena in this complex system. Therefore, we have been building a model by formulating interrelationships among all fundamental elements involved in this system. However, since it is a model which simulates the interactions among the atmosphere, oceans, and land, the model itself is extremely complex. Although we built the model in an attempt to resolve the complexity of the natural world, we now have to struggle with the complexity in the modeled natural world. Since many researchers have been taking part in developing the model, each researcher works on only a very small piece. A concern springs to my mind is whether we can truly get to the essence of phenomena under such circumstances.

Acknowledgement

I am grateful to Professor Takehisa OIKAWA for generously allowing me to publish his personal letter in AsiaFlux Newsletter. I wish to acknowledge Dr. Reina NAKAMURA for her assistance with the English translation of this letter.

References

In preparing this manuscript I had Professor Oikawa cite these references:

1. Oikawa, T. (1985): Simulation of forest carbon dynamics based on a dry-matter production model. I. Fundamental model structure of a tropical rain forest ecosystem. *Bot. Mag.* Tokyo, **98**, 225-238.
2. Oikawa, T. (1986): Simulation of forest carbon dynamics based on a dry-matter production model. II. Effects of dry season upon a tropical rain-forest ecosystem. *Bot. Mag.* Tokyo, **99**, 213-223.
3. Ogawa, F. (1974): *Tropical Ecology I*: Forests. Ecology Lectures No. 30, Kyoritsu Publishing (p. 52, Table 3.5) (in Japanese).

Carbon Flux Observation in the Tropical Seasonal Evergreen Forest in Sakaerat, Thailand

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Introduction

Our knowledge of the sources and sinks of CO_2 is not sufficient in the tropical area where sequestration of CO_2 by forests seems to be large. Generally, there are two types of forests in the tropical humid areas, rain forests and seasonal forests. The tropical seasonal forests disappear more rapidly and deteriorate much faster than that of rain forests, because seasonal forests are easier accessible and human population pressure is much stronger than that of rain forests. In Southeast Asia, the tropical seasonal forests mainly prevail in Thailand, Myanmar, Cambodia, Laos, and Vietnam.

The tropical seasonal forests can be divided into three types: 1) dry dipterocarp forest (DDF; deciduous, coral color), 2) mixed deciduous forest (MDF; deciduous, red), and 3) dry evergreen forest (DEF; green, Fig. 1).

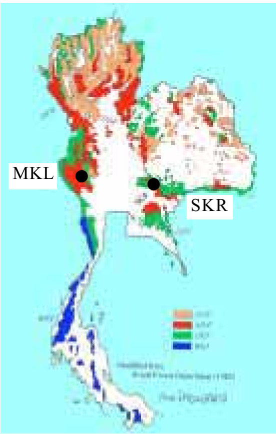

Fig. 1 Forests in Thailand
SKR:Sakaerat
MKL:Maeklong

According to statistics by the Royal Forest Department (RFD) in 1998, forests excluding plantation, occupy 25% of total land of Thailand. Ratio of DDF and MFD is 21% and 34%, respectively. The tropical evergreen forests, including dry evergreen forest (DEF) and wet evergreen forest (WEF) occupy 40% of the forests in Thailand. If we assume that the evergreen forest in the central and north regions belongs to DEF, then DEF occupies 32% of total forests.

Site Description

Sakaerat site is located in the Sakaerat Environmental Research Station (SERS) of Thailand Institute of Scientific and Technological Research (TISTR), on the east side of Kaoyai National Park. The vegetation is DEF that is predominated by the Hopea ferrea (Dipterocarpaceae). Canopy height is about 35m. The micrometeorological observation tower (14°29'29"N, 101°55'05"E, 535 m asl.) is located in a comparatively flat top with inclination of 6m/100m. There is a cliff in the southeast direction. Distance between the tower and the cliff is about 0.7 km. CO_2 flux measurements have been carried out from March 2001. Acquisition rate of

CO_2 flux was 34%, 86%, 82%, and 87% in 2001, 2002, 2003, and 2004, respectively. The data gap filling was made by parameterization that described in the *Parameterization* session.

Results and Discussion

Fig. 2 shows the daily trends of meteorological and biological parameters for the four years. Precipitation (PRCP) clarified dry and wet seasons. Therefore, soil water content (SWC) could be a good guide for classifying dry and wet seasons. Leaf area index (LAI) was 3-4. In spite of the evergreen forest, there was a seasonal change in LAI with the maximum value in the beginning stage of dry seasons (December), and minimum value toward the end of March just before onset of the wet season.

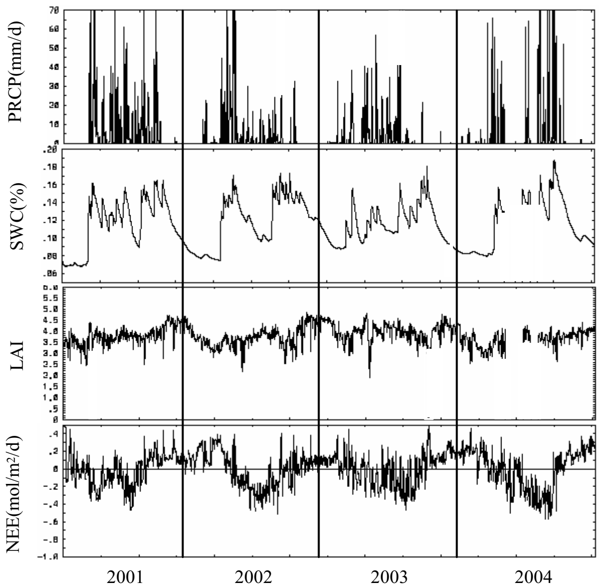

Fig. 2 Daily trends of meteorological and biological parameters at Sakaerat site. PRCP: daily precipitation, SWC: soil water content at 10cm depth, LAI: leaf area index, NEE: net ecosystem exchange in the case when yearly accumulated NEE is assumed to be zero for each year.

Annual net ecosystem exchange (NEE) was -13.5, -12.7, -14.9, and -13.0 t C ha^{-1} in 2001, 2002, 2003, and 2004, respectively. Tree census data (Kanzaki et al, 1995, Vegetation Science in Forestry, pp. 495-513, Kluwer Academic Publishers) showed that this site was a mature forest. One of the reasons caused large negative NEE for this forest was probably due to the under estimation of ecosystem respiration (R_{ec}), the sum of plant and non-plant respiration. Fig. 3 shows the relationship between NEE and friction velocity u_* during the nights. NEE increased with the increasing in u_*, and did not maintain a constant value at large u_*. We estimated R_{ec} in the case when annual NEE became zero. In that case, R_{ec} at night was 9.6, 10.2, 11.3, and 9.9 μmol $m^{-2}s^{-1}$ and annual gross primary production (GPP) was 22.2, 25.7, 26.7, and 24.6 t C ha^{-1} in 2001, 2002, 2003, and 2004, respectively.

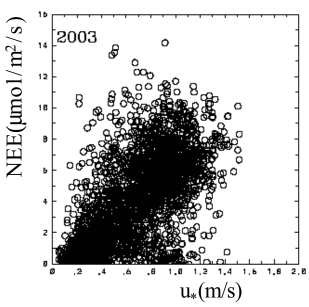

Fig. 3 Dependency of NEE on u during the nights

Parameterization

There are three benefits to the parameterization of CO_2 flux data. Firstly, the parameterization clarifies the structure of canopy. Secondly, the parameterization is useful for estimating the productivity by the combination of satellite vegetation index with routine meteorological data. Thirdly, the parameterization is used as a method of gap filling of observed data.

As shown in Fig. 4, the photosynthetic light response curve (*I-P*) for an individual leaf can be expressed by the quantum yield (ϕ, the initial slope of curve), maximum rate of photosynthesis (P_{max}), efficiency of absorption (θ, the parameter of non-rectangular hyperbola) , and dark respiration (*R*). (Hikosaka: http://hostgk3.biology.tohoku.ac.jp/Hikosaka/Photosyn-home.html):

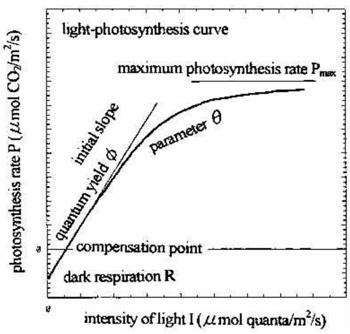

Fig. 4 Schematic graph of photosynthetic light (I-P) curve.

$$P = (\phi I + P_{max} - ((\phi I + P_{max})^2 - 4\phi I \theta P_{max})^{0.5}) / 2\theta - R$$

We applied the characteristics of photosynthetic light curve at individual leaf level to the canopy level, since we considered the photosynthetic light curve of canopy as an analogy of that of individual leaf. In this case, *P*, *I* and R at individual leaf level were replaced with GPP, APAR, and R_{ec0}, respectively. R_{ec0} was the ecosystem respiration that extrapolated GPP at the point where APAR equaled zero. Hourly R_{ec} was assumed as the following equation,

$$R_{ec} = 2^{\frac{T-T_0}{10}} R_{ec0}$$

where T_0 was the temperature at sunrise or sunset. It seems that parameterization by using the rectangular hyperbola leads to overestimation of ϕ and GPP_{max}. Non- rectangular hyperbola was applied in a similar manner by Hirano et al. (2005: J. Agric. Meteorol. 60(5): 737-740) and Takanashi et al. (2005:Ecol.Res. 20: 313-324).

Monthly changes of the four parameters, GPP_{max}, ϕ, R_{ec0}, and θ for GPP-APAR curves are shown in Fig. 5. Comparison between estimated GPP and observed GPP is shown in Fig. 6. Parameters of ϕ and θ were similar to the individual leaf level. GPP_{max}, ϕ and R_{ec0} showed the similar tendency, with ϕ/GPP_{max} was about 1/100 and R_{ec0}/GPP_{max} was between 1/7 and 1/13.

GPP_{max} is the most important parameter for estimating productivity of ecosystem. Dependency of GPP_{max} on soil moisture (SWC) is shown in Fig. 7. This tendency is quite different with that in mid- and high-latitude forests where GPP_{max} increases with increase of soil temperature. More accurate survey showed GPP_{max} increased linearly with SWC in the transition periods from dry to wet season. However, GPP_{max} remained constant in the beginning stage of next dry season (from October to December).

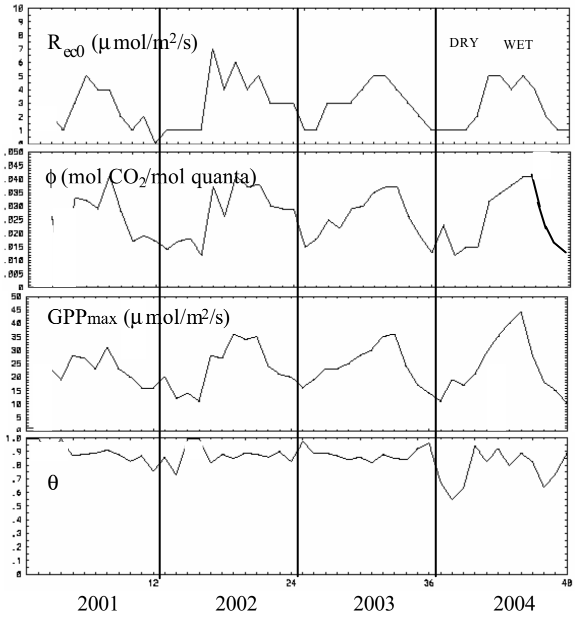

Fig. 5 Monthly values of 4 parameters for GPP-APAR curve

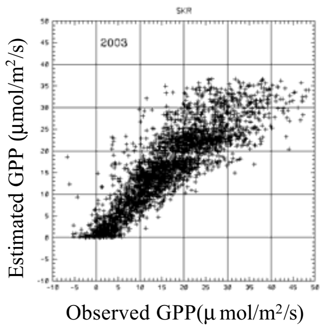

Fig. 6 Relationship between observed and estimated GPP

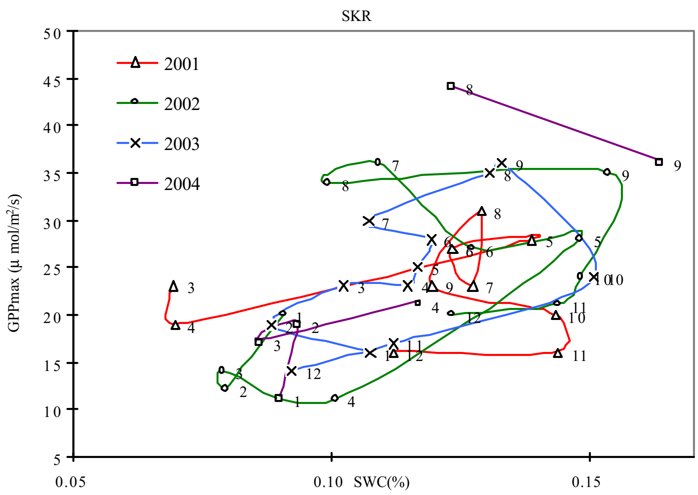

Fig. 7 Relationship between GPP_{max} and SWC

Acknowledgement

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AsiaFlux Workshop 2005

"AsiaFlux Workshop 2005" (4th AsiaFlux Workshop) will be held in this summer on the foothills of Mt. Fuji, Japan. The workshop provides an excellent opportunity to improve our understanding on carbon cycle in terrestrial ecosystems. Topics will include tower flux measurement, carbon cycle process models, remote sensing, general flux research, and others in related to terrestrial carbon cycle. Special session, "Flux measurements on complex topography" will be held in this workshop.

Organized by:	AsiaFlux Steering Committee
Jointly Organized by:	Forestry and Forest Products Research Institute (FFPRI), Japan National Institute for Environmental Studies (NIES), Japan
Date:	24-26 August 2005
Venue:	Hotel Highland Resort (Fujiyoshida, Yamanashi, Japan)
Registration Fees	Printed materials: JPN 2,000 (USD20) Banquet: JPN 5,000 (USD50) / JPN 3,000 (USD 30) for student * Note: Cash only at the registration desk

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Schedule

Date

24 Aug. (Wed.):

Morning	Invited Presentation Special Session
Early-afternoon	Poster Presentation
Late-afternoon	Oral Presentation
Evening	Banquet

25 Aug. (Thurs.):

Morning	Oral Presentation
Early-afternoon	Poster Presentation
Late-afternoon	Oral Presentation Country Report Summery and General Discussion

26 Aug. (Fri.):

Morning	Post-Conference Field Trip

Important Deadlines

15 July (Fri.):	Registration (Presentation)
29 July (Fri.):	Registration and Abstract Submission (One page, size A4)

* Check up-to-date information on the web: http://www.asiaflux.net/workshop2005

Contact to:

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MEETINGS & EVENTS

Date	Place	Title	Information
July 25-27, 2005	Xiamen, China	4th International Conference on Environmental Informatics	http://www.iseis.org
August 2-11, 2005	Beijing, China	Carbon Cycle and Climate session for the 2005 IAMAS meeting	http://www.iamas2005.com
August 7-12, 2005	Montreal, Canada	IX INTECOL International Congress of Ecology joint with the Ecological Society of America	http://www.intecol.net/IX-Montreal/9-montreal.htm
August 22-25, 2005	Jakarta, Indonesia	MAP ASIA 2005	http://www.mapasia.org
August 24-26, 2005	Fujiyoshida, Japan	AsiaFlux WS 2005	http://www-cger2.nies.go.jp/asiaflux/
September 15-16, 2005	Paris, France	Reduction of Emissions and Geological Storage of CO_2	http://www.globalcarbonproject.org/meetings.htm
September 25-30, 2005	Boulder, CO, USA	7th International CO_2 Conference	http://www.cmdl.noaa.gov/info/icdc7
October 8-9, 2005	Tsukuba, Japan	Regions, Cities, Carbon, Climate Change and Consequences	http://www.globalcarbonproject.org/meetings.htm Contact:Penelope Canan
October 25-27, 2005	Canmore, AB, Canada	Sixth Fire and Forest Meteorology, Symposium/19th Interior West Fire Council Meeting	http://www.ametsoc.org/meet/fainst/fireandforest.html
November 13-17, 2005	Melbourne, Australia	Greenhouse 2005: Action on climate change	http://www.greenhouse2005.com/
November, 15-28, 2005	Taiwan	Advanced Training Workshop on Southeast Asia Regional Carbon and Water Issues	http://www.globalcarbonproject.org/meetings.htm
December 5-9, 2005	San Francisco, CA, USA	American Geophysical Union (AGU) Fall Meeting	http://www.agu.org/
January 21-26, 2006	Boulder, CO, USA	1st iLEAPS Science Conference	http://www.atm.helsinki.fi/ILEAPS/
January 26-28, 2006	Boulder, CO, USA	Workshop on Flux Measurements in Difficult Conditions	http://www.atm.helsinki.fi/ILEAPS/
January 29 - February 2, 2006	Atlanta, GA, USA	86th American Meteorological Society (AMS) Annual Meeting	http://www.ametsoc.org/meet/annual/index.html

Editor's Note

I am looking forward to meeting you at the AsiaFlux Workshop 2005 in Fuji-Yoshida city.

The editor of AsiaFlux Newsletter No.14:
Nobuko SAIGUSA
(National Institute of Advanced Industrial Science and Technology)

The editor of AsiaFlux Newsletter No.15 will be Kentaro TAKAGI (Hokkaido University).

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