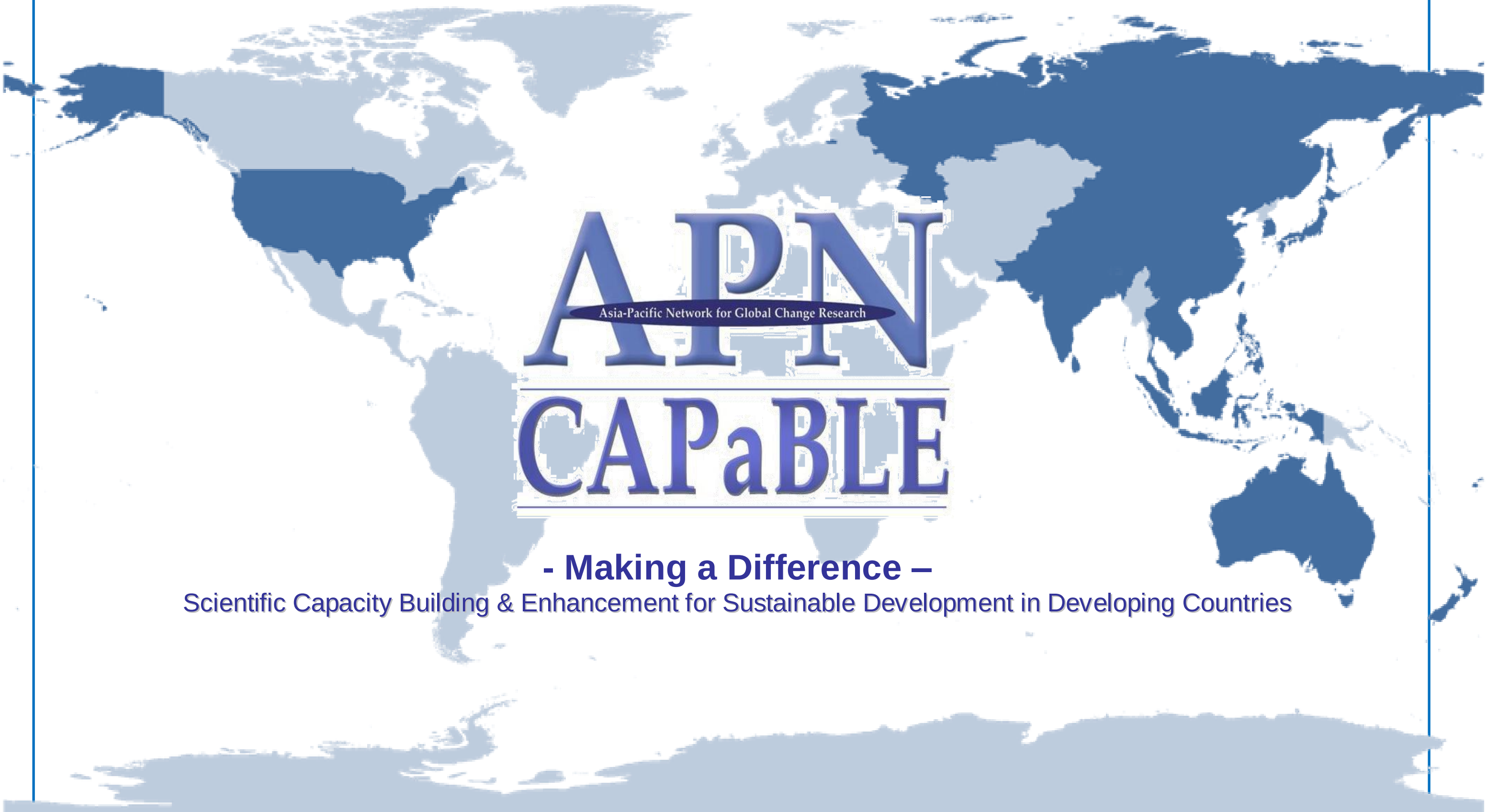
FINAL REPORT for APN PROJECT
Project Reference Number: CBA2011-02CMY-Kaihotsu

Drought monitoring system development by integrating in-situ data, satellite data and numerical model output



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Final Report submitted to APN

OVERVIEW OF PROJECT WORK AND OUTCOMES

Non-technical summary

Drought has a direct influence on agriculture, energy production, transportation, tourism and recreation, forest and wild land fires, urban water supply, environment and human health. As a precaution against drought, we investigated the establishment and development of an integrated system with in situ and satellite data, and numerical model outputs.

After addressing the definition of drought, we constructed a fundamental network of drought monitoring and research among project member countries. We shared and improved drought monitoring data and capabilities, and built a network data bank. Validation of Advanced Microwave Scattering Radiometer (AMSR-E) soil moisture data and its analysis were successfully done in certain target areas and member countries of the Asian Water Cycle Initiative (AWCI). We also proposed a numerical modeling concept for a drought early warning system. Based on these results, we held two useful training courses for drought and climate change studies in Tokyo during 2010 and 2011, in which numerous scientists and operators of AWCI member countries learned project results.

Objectives

The main objectives of this project were:

1) To share and improve the drought monitoring capability in various Asian countries, such as Bangladesh, China, Nepal, Mongolia, Philippines, Pakistan, Thailand, and Vietnam.
2) To set up a drought monitoring and research network in Asian countries.
3) To assist development of early warning systems of drought hazards in the countries.

Amount received and number years supported

The Grant awarded to this project was:

US $40,000 for Year 1
US $40,000 for Year 2

Activity undertaken

There were various activities, as follows:

1) Drought definition study
2) Building a data bank and data analysis for sharing and improving drought monitoring capabilities
3) Building a drought monitoring and research network
4) Developing an early warning system of drought hazard
5) Holding training courses for Asian scientists and operators

Results

Many countries or areas in Asia and worldwide have been using differing definitions of drought. It was necessary to investigate and then discuss the definitions used in AWCI member countries. China had drought indices from meteorological and agricultural points of view. In the central coastal part of Vietnam, because of a lack of observation data, a simple meteorological model to estimate drought index was used. In this project, although we obtained a few valuable results from the definitions used in some countries, we unfortunately could not arrive at a standard definition of drought. This was because of unclear definitions and lack of scientific data.

We built a fundamental network of drought monitoring and research within project member countries, and shared and improved drought monitoring data and capabilities. To construct a network of data bank, we collected data on soil moisture, certain soil physical properties, and meteorology/hydrology from routine in situ observations in member countries. Quality checking has been done since 2008, in cooperation with AWCI of the Global Earth Observation System of Systems (GEOSS) and the Coordinated Energy and Water Cycle Observations Project (CEOP) of the Global

Energy and Water-cycle Experiment (GEWEX). There are in situ soil moisture data from China, Bangladesh, Mongolia, and Pakistan from 2002 to 2008/2010 in the data bank.

To explore large-scale soil moisture conditions in Asia, AMSR-E soil moisture data were validated in some target areas. Validation results showed that AMSR-E accurately estimates daily surface soil moisture. Then, AMSR-E soil moisture data for Asia were analyzed for drought study and were provided to countries upon request. Only sample data were entered into the data bank, because the AMSR-E dataset is huge. All obtained data are available for APN CAPaBLE activities (Scientific Capacity Building/Enhancement for Sustainable Development).

We proposed a numerical model for a drought early warning system, called the Water and Energy Budget-based Distributed Hydrological Model (WEB-DHM). It includes observation and modeling. However, practical testing of this model in basins is still required.

Two useful training courses for drought and climate change studies were held in Tokyo during 2010 and 2011, in which many scientists and operators of AWCI member countries learned project results. They also learned methods of in situ and satellite monitoring data analysis, and numerical techniques for an early warning system of drought forecasting.

Relevance to the APN Goals, Science Agenda and to Policy Processes

As is well known, the program in developing countries (CAPaBLE) of APN enhances their scientific capacity to improve decision-making for issues directly linked to their sustainable development. We challenged to conduct one project that faithfully followed the policy of APN CAPaBLE for concerned scientists and operators in Asian developing countries. Specifically, we gave instruction on methods for studying the drought process, building a drought monitoring and research network, data analysis, and making in situ observations. This was done in cooperation with AWCI drought working group members and organizations concerned (e.g., the Institute of Meteorology and Hydrology, Pakistan Meteorological Department, and Bangladesh University of Technology). In addition, we held two training courses for acquisition of information about drought and climate change, as a part of capability activities. These courses were successful, according to the impressions of attendees. As a result, we believe that the project results were appropriate for APN capacity development.

Self evaluation

Since the objectives were basically achieved, our results should be evaluated. However, we should improve the quality of drought monitoring, and the research network and data bank. Furthermore, regarding objective 3 (aid development of early warning systems of drought hazard in the countries), it is very important to apply our prototype early warning system to basins of the AWCI member countries. We believe that the aforementioned issues will be solved in the future.

Potential for further work

We will continue with drought study in the AWCI Drought working group. One colleague, Dr. Rasul Ghulam of the Pakistan Meteorological Department, is applying a project (Impact of Climate Change on Glacier Melting and Water Cycle Variability in Asian River Basins) to the APN CAPaBLE program.

Publications

・I. Kaihotsu (Representative editor): Data book of Asia Drought Workshop 2011, APN, 150p, 2011

・JAXA: Data book of a Training Course on Analysis Techniques for APN/AWCI Drought Studies,APN, 37p, 2011.

・Jaranilla-Sanchez, P. A.,L. Wang, and T. Koike: Modeling the hydrologic responses of the Pampanga River basin, Philippines: A quantitative approach for identifying droughts, Water Resour. Res., 47, W03514, doi:10.1029/2010WR009702, 2011.

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・Yang, D., T. Koike, and H. Tanizawa: Application of a distributed hydrological model and weather radar observation for flood management in the upper Tone River of Japan, Hydrological Processes, 18, 3119-3132, doi:10.1002/hyp.5752, 2004.

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TECHNICAL REPORT

Preface

We initially investigated the definition of drought and collected data on soil moisture and meteorological elements. We built drought monitoring-research networks in AWCI member countries and validated the soil moisture measurement algorithm of AMSR-E. An early warning system for drought was developed, and a prototype numerical model with observation and modeling was proposed. It remains to conduct practical tests of this model within basins. Two training courses for drought and climate change studies were held for many Asian scientists and operators to learn project results.

Table of Contents

1.0 Introduction

2.0 Methodology

3.0 Results & Discussion

4.0 Conclusions

5.0 Future Directions

References

Appendix

1.0 Introduction

The Asian Water Cycle Initiative (AWCI) of GEOSS has organized cooperation among the 18 Asian countries. It focuses on convergence and harmonization of observation activities, interoperability arrangements for observed data and collected information, effective and comprehensive data management, and capacity building of participating countries as the most functional elements. The AWCI approaches water issues with global observations and local applications, via cooperation between research communities and operational sectors, and between different sectors of social benefit. We believe that AWCI can solve various real-world problems and lead the Group on Earth Observations (GEO) to realize societal benefits. Currently, AWCI has four components for capacity building: flood, drought, water quality and climate change.

As is well known, drought is one of the most serious disasters in many Asian countries, such as Mongolia and Thailand. In Mongolia, it is said that economic loss from drought is tremendous. Mongolian National Statistics (National Statistical Office of Mongolia, 2004) show a sudden great decrease of livestock number in 2002. Pasture conditions in all Mongolia in that year were much worse than in 2001 and 2003 (Munkhzul and Ramesh, 2007). Since there was severe drought in 2002, it is possible that it affected the livestock decrease and pasture condition changes. It is very difficult to predict drought because it is influenced by many factors, such as rainfall, air temperature, and water use. Drought that develops gradually and slowly is an unexpected creeping hazard of prolonged existence. Drought produces a complex web of impacts spanning many economic sectors, especially agriculture, energy production, transportation, tourism and recreation, forest and wildland fires, urban water supply, environment and human health.

Some scientists and a few countries have recently attempted to monitor drought using remote sensing technology, and to create an early warning system of drought disaster. Scientists and policy makers have a great opportunity to study and monitor drought, to improve drought management, and reduce socioeconomic losses. State-of-the-art tools and methods for inferring drought conditions are not operationally available in most developing countries. There is an urgent need to enhance development of drought monitoring and assessment systems. Satellite products furnish a great opportunity for scientists to improve the techniques and understanding of drought study, as does numerical model simulation. Model outputs will continue to be available and useful in this endeavor.

Drought is an important water issue in the GEOSS implementation plan, and is of increasing concern to the public and policy makers.

Given this background, this project focused on capacity building for drought monitoring and study, under the framework of the AWCI of GEOSS. The specific aims were: 1) To share and improve drought monitoring capabilities in various Asian countries such as Bangladesh, China, Nepal, Mongolia, Philippines, Pakistan, Thailand, and Vietnam; 2) to set up a drought monitoring and research network in participating Asian countries; and 3) to assist development of early warning systems of drought hazard in those countries. We made special efforts to study the effectiveness and use of satellite soil moisture data, and to develop a prototype numerical model for an early warning system of drought hazard in FY 2011. We then directly applied the results to capacity building (e.g., conducting training courses) for scientists and operators of AWCI member countries

2.0 Methodology

Drought study is mainly based on observation of precipitation, temperature and soil moisture, and now, various drought and moisture indices. Observation is fundamental and indispensable. For monitoring and studying drought, we need some type of drought index. These indices are based mainly on in situ observations of precipitation, temperature and soil moisture. However, standards of drought definition vary with country and region, because of different spatial and temporal resolutions of observation stations. Consequently, we investigated drought definitions in each country.

As mentioned above, it is fundamental and essential for drought studies to continue using in situ observation. Member countries of the AWCI Drought Working Group have been trying to build drought monitoring/research networks since 2006. The monitoring network is useful for validation of satellite soil moisture measurement algorithms, and for sharing or improving drought monitoring data and capabilities in various Asian countries. We therefore strove to augment these networks.

Satellite products have not been widely used in many Asian countries, because of a lack of capacity building. With support of the Japan Aerospace Exploration Agency (JAXA) and The University of Tokyo, a retrieved soil moisture dataset from satellite remote sensing and numerical model products were used. Collaborators from involved countries took part in validation of the soil moisture measurement algorithm of AMSR-E, using in situ observations of soil moisture, precipitation and temperature. The AWCI of GEOSS has been in charge of coordinating this regional activity, along with the flood, climate change and water quality groups.

Research on soil moisture remote sensing has been conducted for several decades, especially using early truck-based and airborne remote sensing retrievals. Estimates of soil moisture from satellite microwave remote sensing data have improved greatly in recent years. However, as there is still a remarkable difference between satellite microwave remote sensing and in situ data, we required more validation of satellite remote sensing-estimated soil moisture for complex land surfaces. Because of complex soil types, irrigation and vegetation types in the project area, soil moisture was a key indicator for drought monitoring, in addition to precipitation and temperature. The JAXA helped develop soil moisture datasets for specific regions of interest within the countries. Evaluation of satellite soil moisture products in a few specific areas was done by Professor Kaihotsu's team, using the AWCI drought network. Other collaborators led in validation and retrieval of the remote sensing data, in cooperation with JAXA.

We have been studying a predictive model of vegetation change in the pasture area of Mongolia since 2007, and have been attempting the promotion of an empirical predictive model considering meteorological data and AMSR-E soil moisture products. This model would be available for study of the drought early warning system. We thoroughly studied drought in a specific area using this model.

Numerical model simulation was done by Professor Koike's team to illustrate the mechanism of water cycle change in Asia using a Global Climate Model (GCM) over a considerable period. Their simulation products were useful to our drought studies, and contribute to formation of a drought early warning system. They indicated the strong possibility for obtaining simulated data of soil moisture, soil temperature, and others.

International meetings on drought study were organized for AWCI Asian participants. After discussion of analysis results and numerical model products, we delivered training courses for the involved Asian countries, sharing techniques and experiences in monitoring, understanding, and prediction of drought.

3.0 Results & Discussion

1) Drought definition

As is well understood, there are several definitions of drought. There are meteorological, hydrological, agricultural, and other types of drought. Since each country currently uses varying drought definitions, it is not easy to concretely discuss drought or conduct a cooperative project. Unfortunately, we could not present a standard definition of drought for all involved countries. However, we obtained some valuable results after investigation and discussion of the definitions in a few countries.

Chinese scientists have used drought indices, such as Standardized Precipitation Index (SPI), Palmer Drought Severity Index (PDSI), Crop Moisture Index (CMI), Surface Water Supply Index (SWSI) and Drought Frequency Index (DFI) (Endo et al., 2006). These indices are mainly based on ground observations of precipitation, temperature and soil moisture. Definition standards for these indices differ between countries and regions, because of variable spatial and temporal resolutions of observation stations.

Vietnam uses a meteorological drought definition. On the central coast of this country, because of a lack of observation data, it is difficult to apply meteorological methods to estimate the drought index generally used worldwide (e.g., Herbst et al., 1966). Therefore, two ways to estimate drought index are used, as follows:

a). Estimate a drought year as one with rainfall deficit > 20%;

b). Estimate a drought year with water balance K (Dry index – the rate of inflow and outflow).

$$K: \qquad K_n = E_n/R_n, \qquad (1)$$

where E_n is the amount of Piche evaporation in calculated period (n), and R_n is the rainfall amount in calculated period (n). We can easily assess the level of drought from the calculated value of K, as shown in Table 1.

Table 1 Drought level of K index

K index	K < 0.5	0.5 ≤ K < 1.0	1.0 ≤ K < 2.0	2.0 ≤ K < 4.0	K ≥ 4.0
Drought level	Very humid	humid	slightly dry	moderate dry	very dry

2) Data bank and data analysis for sharing/improving drought monitoring capability

There are several types of hydrological and meteorological data from Asian countries in the data bank. The data have been provided by member countries since 2006. Our own data bank has data of soil moisture, soil physical properties, and fundamental meteorological or hydrological elements from in situ observations in Mongolia, Pakistan, Bangladesh and China from 2002/2006 to 2008/2010. At present, the data are available to members of this APN CAPaBLE project and to people formally connected with the AWCI Drought Working Group. That is, we are sharing the data among member countries, and several members are trying to use such data for drought studies and climate change adaptation. All collected data shown in Table 2 will be provided to people connected with the AWCI community upon request only (Contact: kaihotu@hiroshima-u.ac.jp). We need registration before using the data. The AMSR-E dataset and the collected in situ data are extremely large, so only sample data are provided in our data bank. However, people connected with AWCI can visit the web site <https://gcom-w1.jaxa.jp> and download AMSR-E soil moisture data after registration (see data book of a training course on analysis techniques for APN/AWCI drought studies in the publications list above).

Table 2 List of the data collected in the data bank

Folder name of data	Period	Target country/ area	Others
SM MON	2006–2011	Mongolia	4 AWS
SM NAMHEM	2006–2011	Mongolia	More than 30 stations
SM SHANXI	2006–2009	China	More than 100 stations
SM PAKISTAN	2002–2009	Pakistan	4 stations
SM BD	2007	Bangladesh	9 stations
MET VEIT	2008–2009	Vietnam	3 stations
MET MON	2006–2011	Mongolia	4 AWS

Data in the data bank are very useful for studies of drought, climate change, and operation/control of grass and crop production. Of course, it is very important to validate or evaluate satellite soil moisture products.

The huge dataset of worldwide AMSR-E soil moisture estimates from 2002–2011 is now available. All downloadable data were also available to this APN CAPaBLE activity as mentioned above. To obtain accurate AMSR-E soil moisture data, we needed to carefully validate the soil moisture algorithm of AMSR-E across various areas in Asia. We have continued this validation using in situ monitoring data of AMSR-E in the data bank since 2006, for a study area on the Mongolian Plateau.

Figure 1 shows a sample of validation results in target area M1 (Fig. 2) of the MAVEX (Mongol AMSR-E/AMSR2/ALOS Validation Experiment), using in situ monitoring data of soil moisture (SM) in the data bank from 2011.

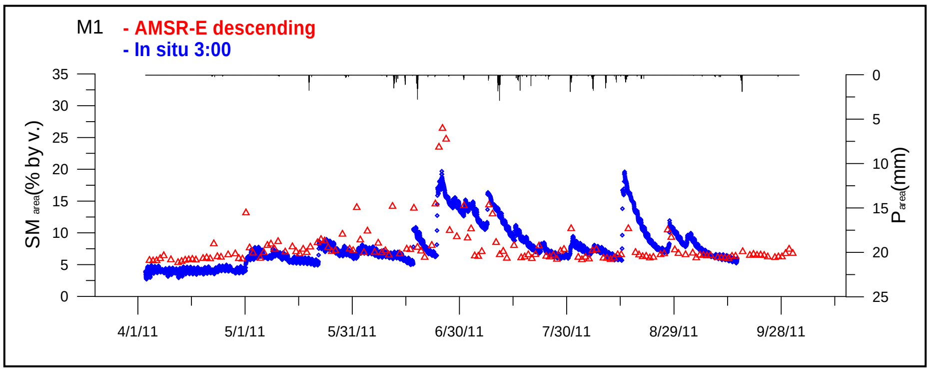

Fig. 1 A sample of validation results of the soil moisture measurement algorithm of AMSR-E in the target area M1 of the Mongolian plateau in 2011 (SM_{area}: area-averaged soil moisture, P_{area}: area-averaged rainfall)

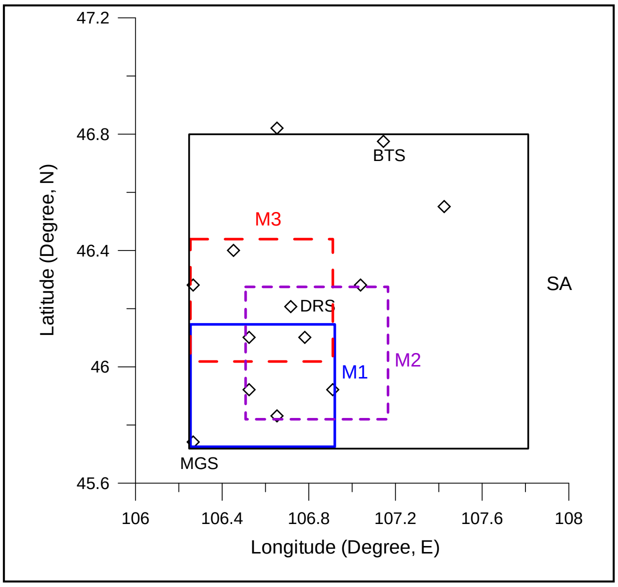

Fig. 2 Stations (◇) and target areas (M1, M2 and M3) in the study area of the Mongolian Plateau as of September in 2011

Figure 1 shows that there is not much difference between in situ and AMSR-E soil moisture. We see a good correlation between the two in Figure 3.

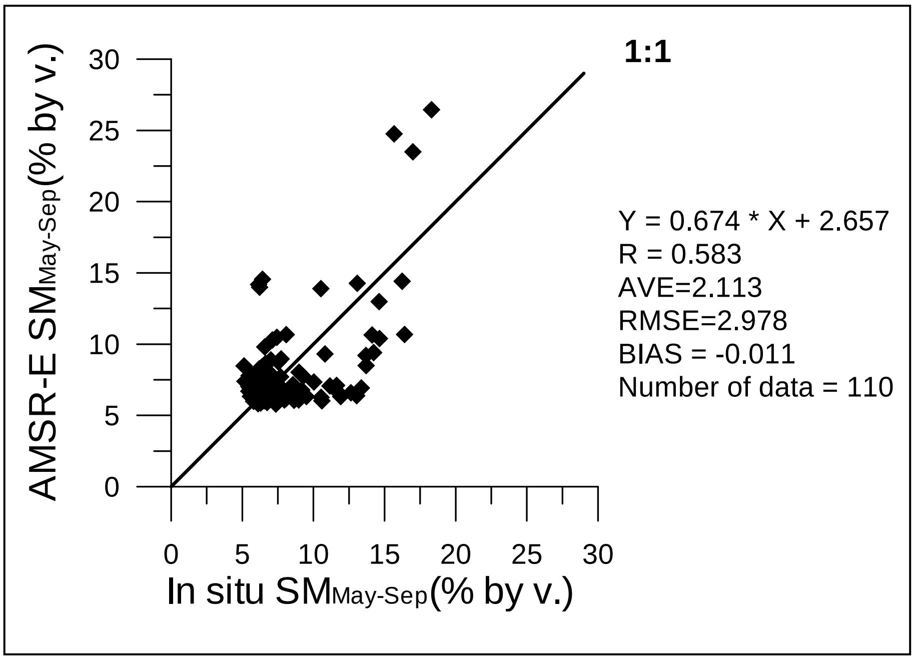

Fig. 3 Relationship between in situ soil moisture and AMSR-E one in 2011 of Fig. 1

Values of root mean squared error (RMSE) and bias are very small. The results of Figures 1 and 3 suggest that the measurement accuracy of AMSR-E is very good. The in situ data and stations used in the Fig. 1 are described in Kaihotsu et al. (2009).

It is more important to validate the soil moisture products of AMSR-E in a larger area than the aforementioned target area M1. A validation of AMSR-E soil moisture products was done using routine in situ soil moisture data of the National Agency for Meteorology Hydrology and Environmental Monitoring (NAMHEM), provided by the Institute of Meteorology and Hydrology of Mongolia. Unfortunately, this soil moisture was not measured daily. Data were collected every 10 days by the sampling and oven method at each 5-cm depth, from soil surface to 1-m depth. This was done at more than 30 sites across Mongolia. Figures 4 and 5 present Mongolian soil moisture estimates in the data bank from AMSR-E and NAMHEM, respectively.

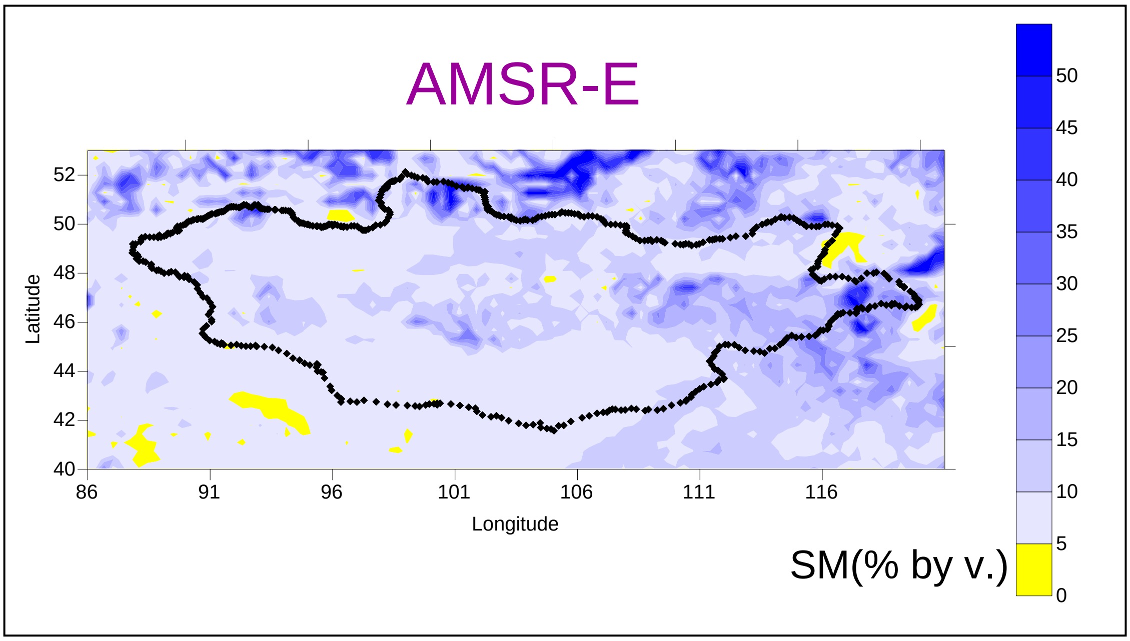

Fig. 4　AMSR-E soil moisture distribution in early-July in 2008 in the whole of Mongolia

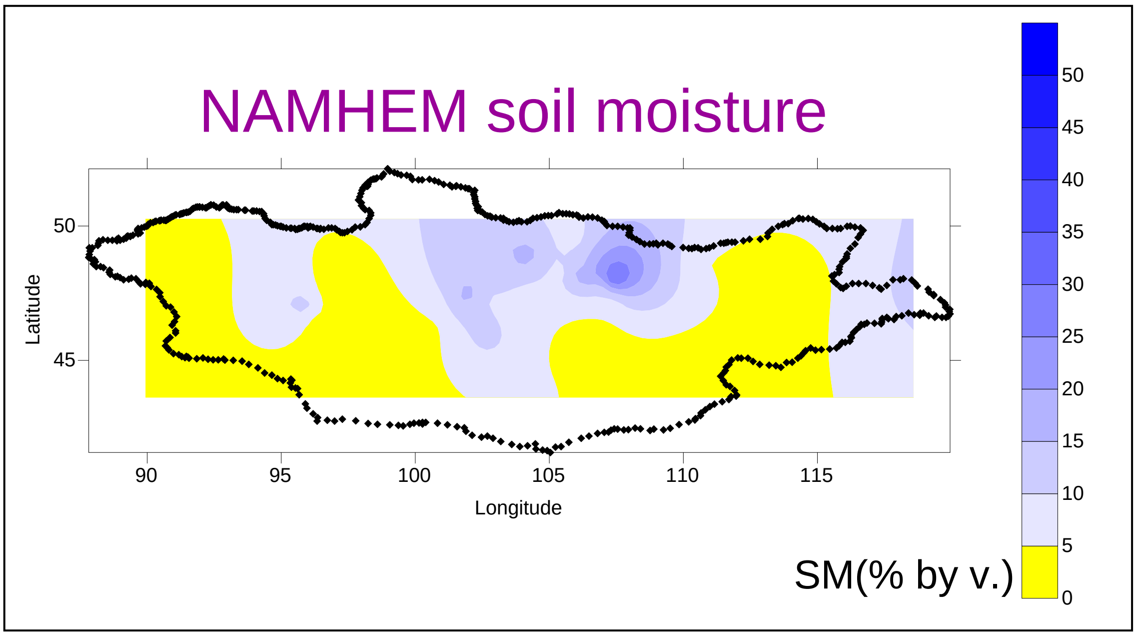

Fig. 5　NAMHEM soil moisture distribution at the 0-5 cm depth in early-July in 2008 in

the whole of Mongolia

NAMHEM soil moisture data from 21 stations were used to estimate the soil moisture distribution across Mongolia. The distributions from AMSR-E and NAMHEM were obtained using linear interpolation.

Figures 4 and 5 reveal a similar distribution pattern, albeit with some differences in value. Figure 6 shows the relationship between both soil moistures in 2008.

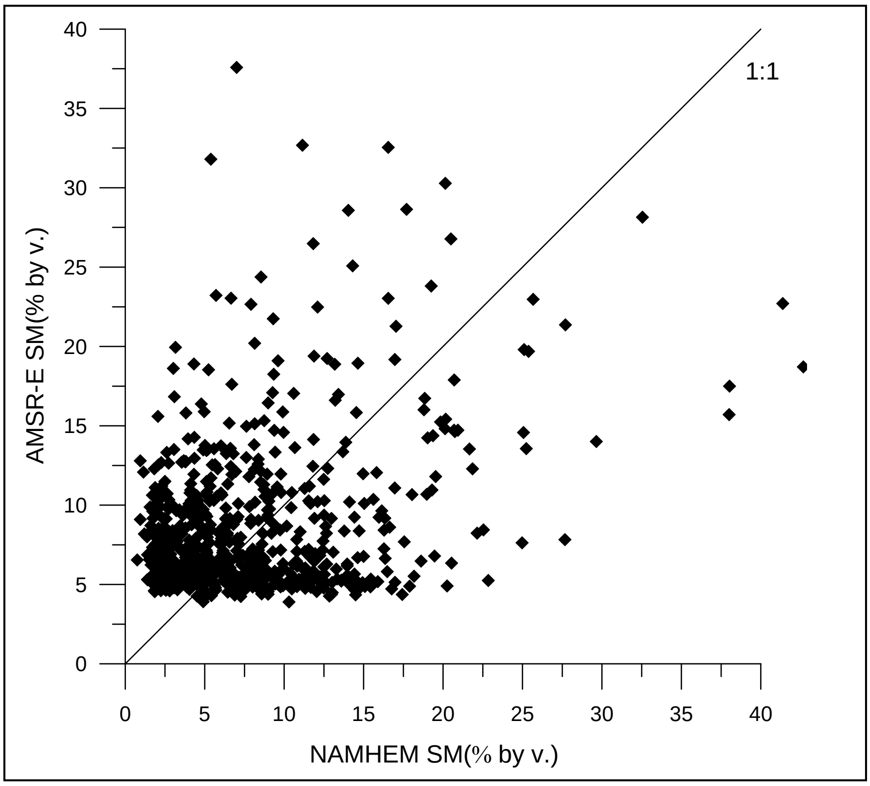

Fig. 6 Relationship between in situ soil moisture of NAMHEM and AMSR-E in 2008

We obtained a small RMSE value, less than 4.4, and found that AMSR-E slightly overestimates (Fig. 6). Although the number of the NAMHEM stations is not sufficient for validation, validation results are very good.

It is useful to have validations in different Mongolian surface and climate conditions. We attempted to validate the soil moisture measurement algorithm of AMSR-E, using routine in situ soil moisture data from the data bank for Bangladesh. Unfortunately, there were not much data. We procured in situ soil moisture data measured weekly by the sampling and oven method, for only nine stations of the Bangladesh Meteorological Department (Fig. 7).

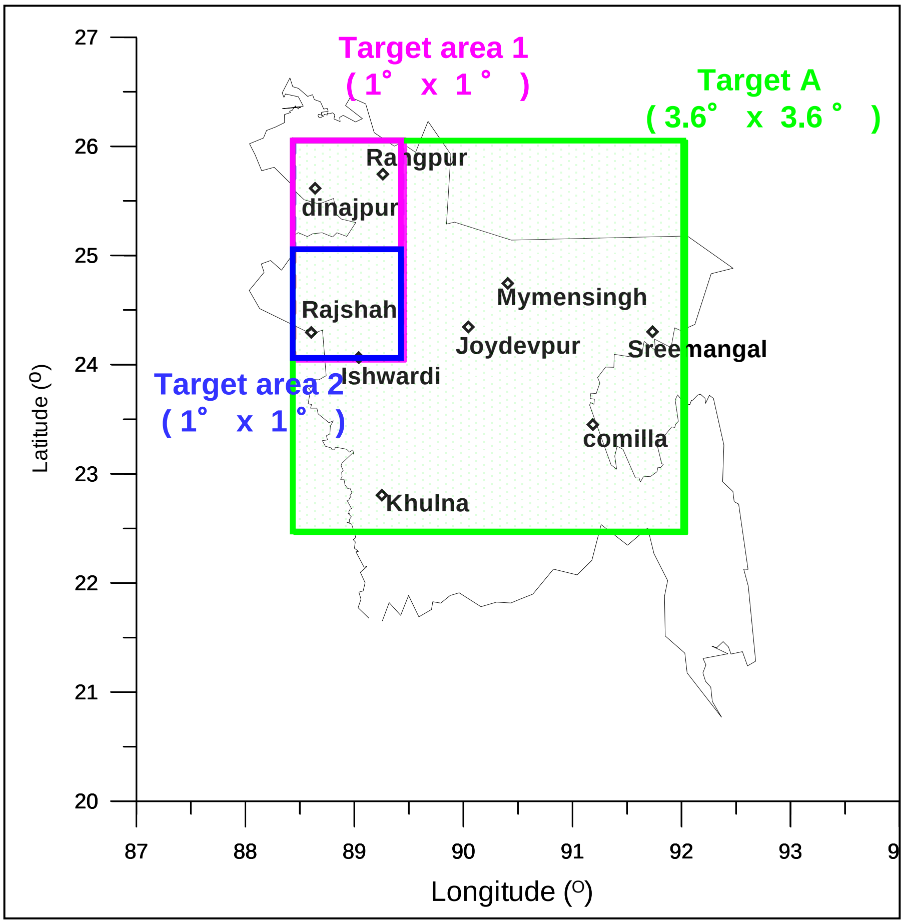

Fig. 7 Target areas and in situ stations (Agromet stations: SM (5cm depth) by weekly sampling) in Bangladesh for the evaluation

Comparisons of AMSR-E and in situ soil moisture are shown in Figures 8, 9 and 10. Since there are insufficient stations in target areas 1 and 2, there is not good matching between the soil moistures. However, Figure 10 shows a relatively improved validation for the dry season of October through April. In the rainy season from May to September, there is a clear difference between the soil moistures. This may be caused by rainwater storage on the ground and by free water on plants.

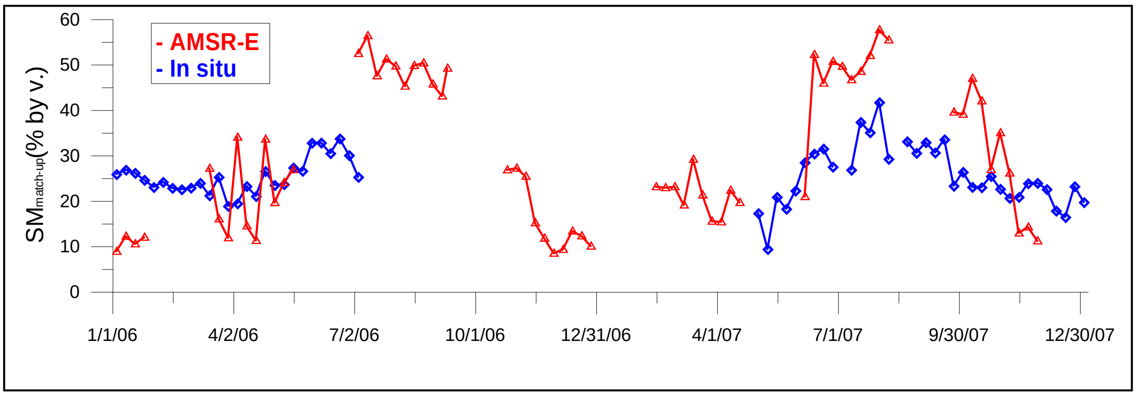

Fig. 8　Validation results in the target area 1 in Bangladesh (2006-2007)

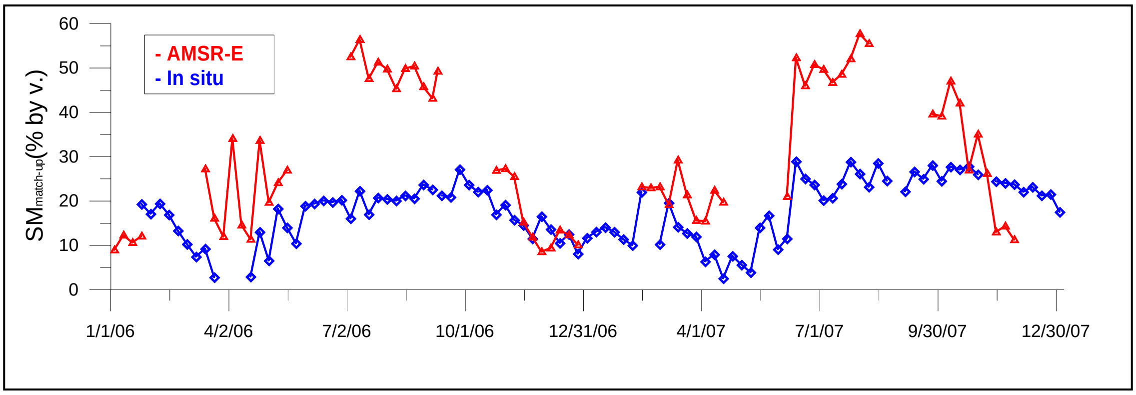

Fig. 9　Validation results in the target area 2 in Bangladesh (2006-2007)

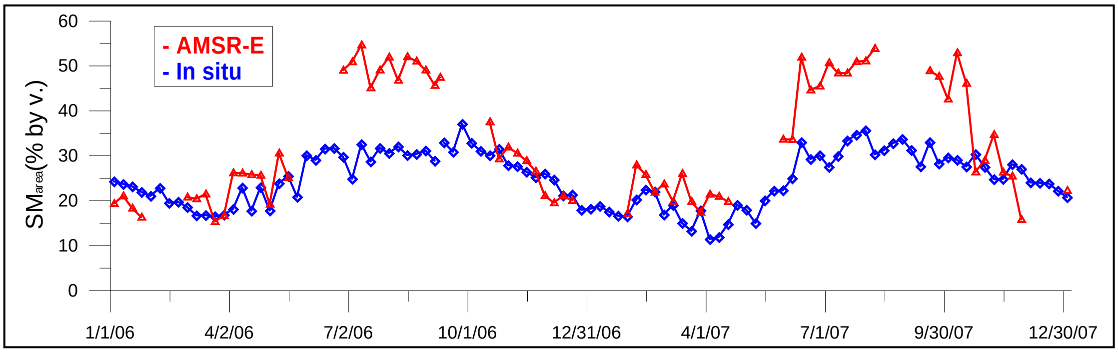

Fig. 10 Validation results in the target area A in Bangladesh (2006-2007)

The relationship of in situ and AMSR-E soil moisture in target area A is shown in Figure 11.

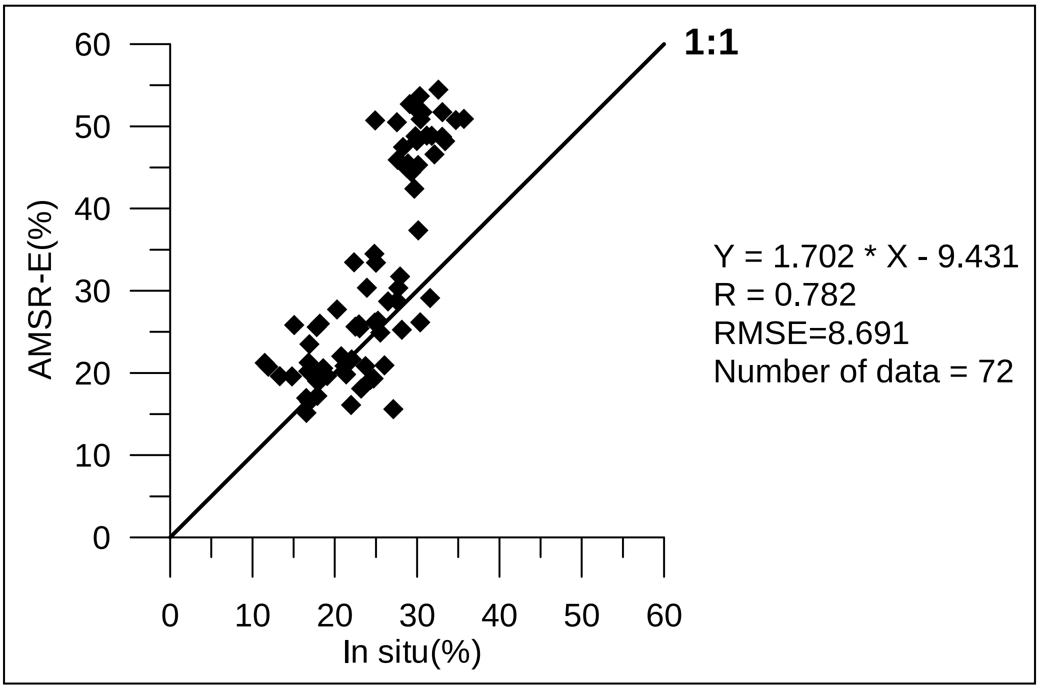

Fig. 11 Relationship between in situ soil moisture to the AMSR-E one in the target area A of Fig. 10

The figure shows a higher value of RMSE than in the Mongolian case, because of poorer matching in the higher soil moisture range (more than 30 % in situ). Despite these comparatively poorer results, AMSR-E may measure surface soil moisture during the dry season with high accuracy.

The validations in Mongolia and Bangladesh indicate a good possibility for accurate measurement of soil moisture by AMSR-E at large scales in Asia. This would provide a useful tool for studying droughts in Asia. Figure 13 shows monthly AMSR-E surface soil moisture in the target area of about 550 km by 550 km (Fig. 12) of Thailand (eastern part of Thailand and adjacent regions). In the middle of the dry season from January to March, surface soils are extremely dry. In contrast, they are very wet during the rainy season from May to October. The figure clearly reveals this remarkable change from wetting to drying.

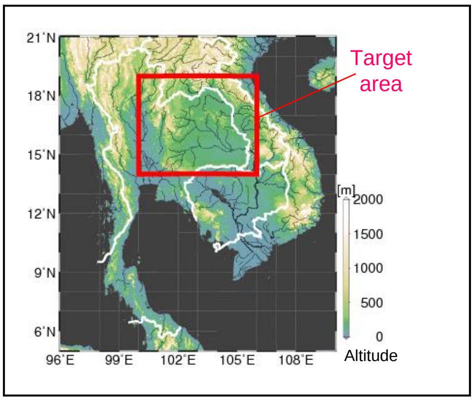

Fig. 12　Target area in Thailand

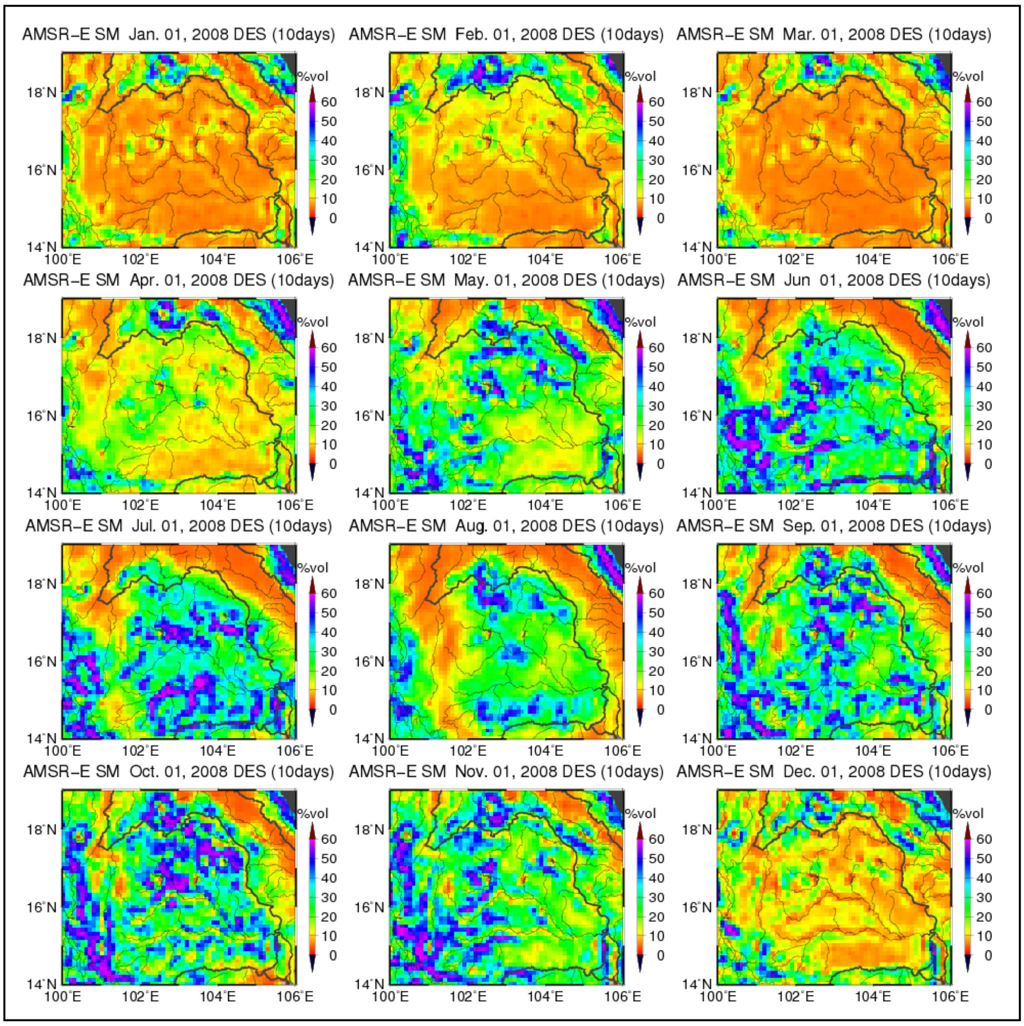

Fig. 13 Surface soil moisture change by AMSR-E in the target area of Fig. 12 in 2008

3) Drought monitoring and research network

We have been building a drought monitoring network since 2006. This network consists of two sub–networks: in situ sites and satellite.

At present there are two sites for monitoring soil moisture and water cycle elements during drought, and four specific study areas for AWCI drought studies (Fig. 14).

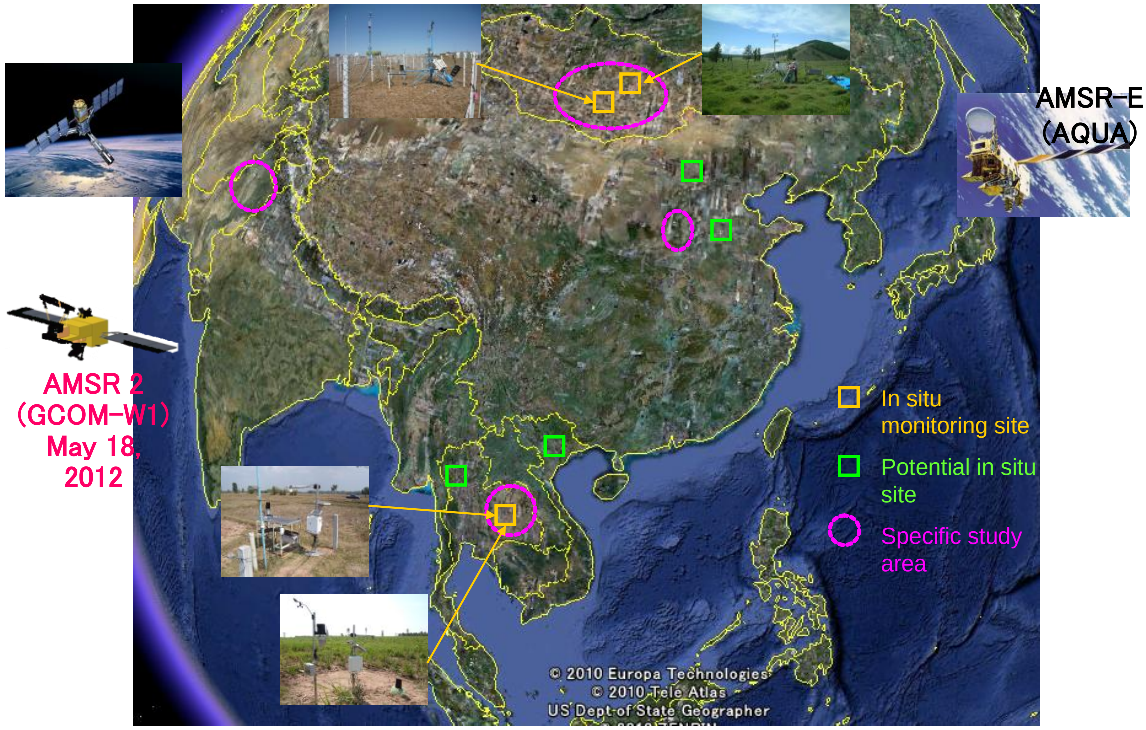

Fig. 14 Drought monitoring network

We are considering additional sites in Thailand, Vietnam, and China, pending funding.

A satellite observation network is also available for the drought monitoring network of AMSR-E, Soil Moisture and Ocean Salinity (SMOS) of the European Space Agency (ESA) and AMSR2. AMSR-E measured surface soil moisture from 2002 to 2011, except when it was down in October 2011. Now, SMOS is monitoring soil moisture globally. A new satellite of Global

Change Observation Mission 1st-Water (GCOM-W1), equipped with AMSR2 following on AMSR-E, will be launched in May 2012.

A drought research network among member countries of the AWCI Drought Working Group has been gradually assembled since 2006, with frequent data exchange and meetings. Current member countries of the drought research network are Mongolia, China, Vietnam, Nepal, Philippines, Thailand, Bangladesh, Japan, and Pakistan.

As part of activities of the AWCI drought research network, we held one formal Asia Drought Workshop in January 2011, and two training courses for climate change and drought study in March 2011 and January 2012, respectively. Many attendees learned various analysis techniques of drought and climate change.

4) Developing an early warning system of drought hazard

We attempted an empirical model of an early warning system of drought forecasting in Mongolia. However, because there were insufficient soil moisture data for model validation, we could not construct a model prototype. Because an empirical model is simple and convenient, further studies should be done.

Professor Koike's team has been working on a numerical model of an early warning system for drought for some time (Wang, 2007). They proposed a trial model prototype. Figure 15 shows the system concept.

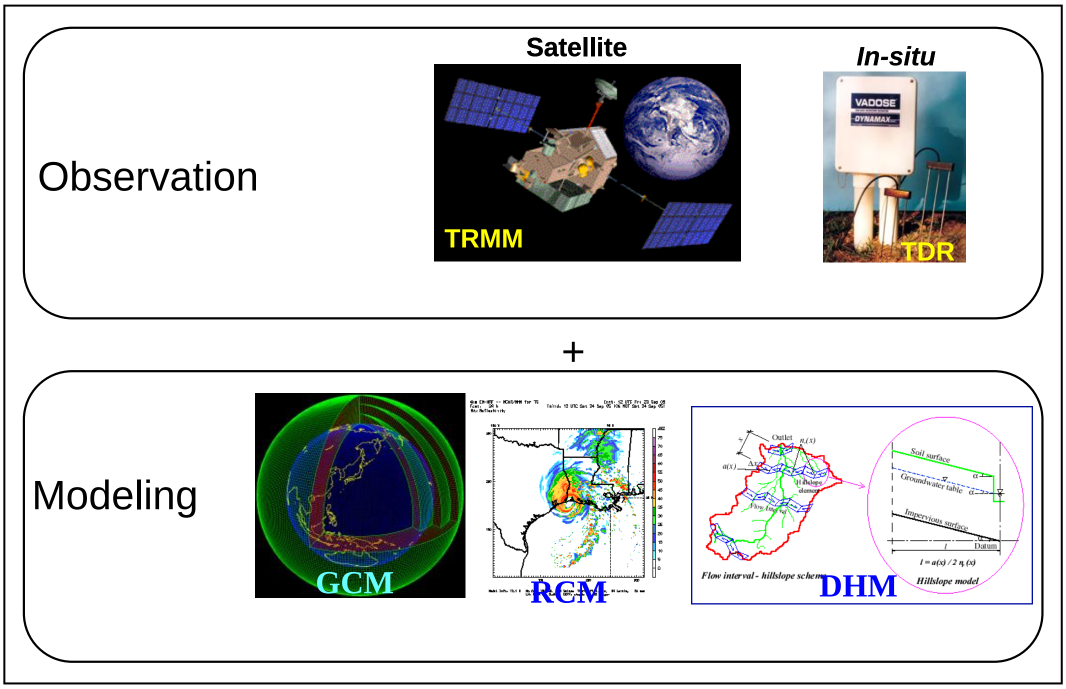

Fig. 15 Concept of a numerical model of an early warning system of drought

As shown in the figure, the system consists of two components: observation by satellites and in situ observations and modeling by GCM/RCM (Regional Climate Model)/DHM (Distributed Hydrological Model). This model is called the Water and Energy Budget-based Distributed Hydrological Model (WEB-DHM). It was developed by fully coupling a simple biosphere scheme SiB2 (Sellers et al., 1996) with a hillslope hydrological model GBHM (Yang et al., 2004) and was well validated using in situ data from Southern Great Plains Hydrology Experiments (SGP) 97 and SGP99 (Wang et al., 2009). Figure 16 presents the basic procedures of this model, which we use for data assimilation. Although there are large data requirements, we can run the model on a personal computer

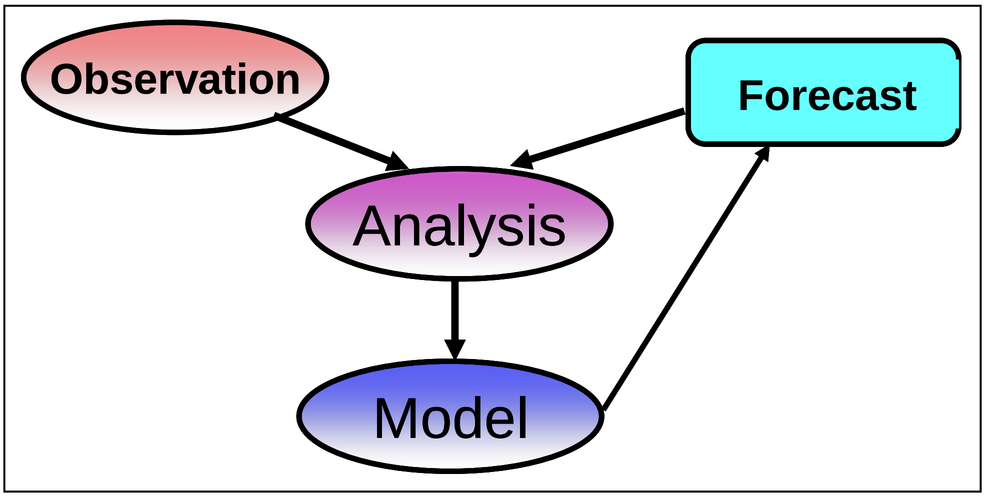

Fig. 16 Data assimilation of the proposed model of Fig. 15

Inputs to the model are as follows:

Meteorological parameters - JRA25

LAI/FPAR-AVHRR

DEM-Aster DEM/GDEM (large grid: 1 km × 1 km)

Rainfall (observed AWCI or other sources 1981–2000)

Soil: FAO

Land Use: USGS

Outputs are rain, discharge, soil moisture at the root zone, soil moisture at the surface, and groundwater level. These can be furnished as basin average values in text files or spatially distributed monthly values in binary files.

This model is being applied in a few basins for forecasting drought and flood, but so far there have been no results from application to basin drought forecasting.

4.0 Conclusions

Investigation of drought definitions used in AWCI member countries was done. Each country and area was using a different definition. China was using several drought indices from meteorological and agricultural points of view. On the central coast of Vietnam, because of a lack of observation data, a simple meteorological model for estimating drought index was being used.

Although we obtained a few valuable results after investigation and discussion of definitions from a few countries, unfortunately we could not achieve a standard definition of drought.

We built a fundamental network of drought monitoring and research among project member countries, and shared and improved drought monitoring data and capabilities. To construct a network data bank, we collected data on soil moisture, soil physical properties, and meteorology/hydrology, from routine in situ observations in member countries. Data quality checking was done beginning in 2008, in cooperation with the AWCI of GEOSS and Coordinated Energy and Water Cycle Observations Project (CEOP) of the Global Energy and Water-cycle Experiment (GEWEX). The data bank contains some in situ soil moisture data from China, Bangladesh, Mongolia, and Pakistan from 2002 to 2008/2010.

To investigate large-scale soil moisture conditions in Asia, AMSR-E soil moisture data was validated in certain target areas. Validation results showed that AMSR-E accurately estimates daily surface soil moisture. Consequently, AMSR-E soil moisture data from Asia were analyzed for drought study and provided to countries upon request. Only sample data were entered in the data bank, because the AMSR-E dataset is enormous. All obtained data are available for APN CAPaBLE activities.

We proposed a numerical model for a drought early warning system. The model is called Water and Energy Budget-based Distributed Hydrological Model (WEB-DHM), and consists of observation and modeling. However, we need to do practical testing of this model in basins.

Two training courses for drought and climate change studies were held in Tokyo in 2010 and 2011, and many scientists and operators from AWCI member countries learned the results of this project.

5.0 Future Directions

The following activities should be pursued in the future:

1) Continue in situ drought monitoring with the drought/water cycle monitoring network of AWCI and CEOP.

2) Develop drought monitoring techniques.

3) Conduct a practical international drought project, using results of this APN CAPaBLE project.

4) Apply the early warning system proposed in this project to basins in APN/AWCI member countries.

5) Regularly hold an international training course on drought study.

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Appendix

Asia Drought Workshop 2011

1) Agenda

APN

Asia Drought Workshop 2011*

(For APN CAPaBLE project (CBA2010-14NMY-Kaihotsu))

Tokyo Office of Hiroshima University (Room 408#, Campus Innovation Center, Shibaura, Tokyo: http://www.hiroshima-u.ac.jp/liaison/access/, Phone: 03-5440-9065) on the 20th (Thursday) in January, 2011

Objectives

To understand mutually the real conditions of drought in each country related in the APN CAPaBLE project (CBA2010-14NMY-Kaihotsu) and learn the recent study methods of drought To discuss planning a new international project of the drought scientific study in Asia in strong cooperation with the APN CAPaBLE project and AWCI Drought WG

Agenda

Thursday 20 January, 2011

9:30 Registration

Session I (Chair: Davaa Gombo)

9:40 WS Objectives (Ichirow Kaihotsu: HU)

9:50 Case studies of severe drought events in China (Likun Ai and Jie Wei: IAP)

10:10 Major drought events in Pakistan during this decade (Ghulam Rasul: PMD)

10:30 Recent MRI projects for climate projection - for Asian drought studies - (Masahiro Hosaka: MRI)

10:50 Drought indices and prediction capability (Toshio Koike: UTy)

11:10 – 11:40 Break

Session II (Chair: Likun Ai)

11:40 Atmospheric drought in Mongolia and its influence on agriculture (Erdenetsetseg Baasandai: IMH)

12:00 Hydrological droughts in Mongolia (Davaa Gombo: IMH)

12:20 Observation and modeling of interannual variability of surface hydrological budget over Mongolian steppe (Jun Asanuma: TERC-UTs)

12:40 – 15:30 Lunch

Session III (Chair: Ghulam Rasul)

16:00 Drought and orientation strategy for drought prevention in Vietnam (Khan Van Duong:

MRE)

16:20 Hydrological regions in Monsoon Asia and land characteristics related to human dimension of drought

(Akihiko Kondoh: CEReS)

16:40 Global soil moisture monitoring with AMSR-E satellite observation (Yukihide Fujii: EORC-JAXA)

17:00 Drought in Thailand – actual condition and countermeasure – (Taichi Tebakari: TPU)

17:20 Drought in Thailand: Impacts on agriculture and monitoring (Thaworn Onpraphai: CMU)

17:40 - 18:10 Break

Session IV (Chair: Jun Asanuma)

18:10 A new international project of the drought scientific study in Asia (Ichirow Kaihotsu: HU)

18:30 Total discussion and After WS function

20:30 Adjourn

CEReS: Center for Environmental Remote Sensing of Chiba University, Japan
CMU: Chiang Mai University, Thailand
HU: Hiroshima University, Japan
IAP: Institute of Atmospheric Physics, China
IMH: Institute of Meteorology and Hydrology, Mongolia
EORC: Earth Observation Research Center of JAXA (Japan Aerospace Exploration Agency), Japan
MRE: Center for Water Resources Planning and Investigation of Ministry of Resources and Environment, Vietnam.
MRI: Meteorological Research Institute, Japan
PMD: Pakistan Meteorological Department, Pakistan
TPU: Toyama Prefectural University, Japan
TERC: Terrestrial Environmental Research Center of UTs (The University of Tsukuba), Japan
UTy: The University of Tokyo, Japan

* This workshop is sponsored by APN and held in cooperation with JAXA and Hiroshima University.

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Funding sources outside the APN

- JAXA (USD 40,00)
- Hiroshima University (USD 22,00)

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Glossary of Terms

AMSR-E: Advanced Microwave Scattering Radiometer

APN: Asia-Pacific Network for Global Change Research

Aster: Advance Spaceborne Thermal Emission and Reflection radiometer

AVHRR: Advanced Very High Resolution Radiometer

AWCI: Asia Water Cycle Initiative

CEOP: Coordinated Energy and Water Cycle Observations Project

CEReS: Center for Environmental Remote Sensing of Chiba University, Japan

CMU: Chiang Mai University, Thailand

DEM: Digital Elevation Model

EORC: Earth Observation Research Center of JAXA

ESA: European Space Agency

FAO: Food and Agriculture Organization

FPAR: Fraction of PAR

GCOM-W1: Global Change Observation Mission-Water 1st

GDEM: Global Digital Elevation Model

GEO: Group on Earth Observations

GEOSS: Global Environmental Observation System of Sytems

GEWEX: Global Energy and Water-cycle Experiment.

HU: Hiroshima University, Japan

IAP: Institute of Atmospheric Physics, China

IMH: Institute of Meteorology and Hydrology, Mongolia

JAXA: Japan Aerospace Exploration Agency

JRA: Japanese Re-Analysis

LAI: Leaf Area Index

MRE: Center for Water Resources Planning and Investigation of Ministry of Resources and Environment, Vietnam.

MRI: Meteorological Research Institute, Japan

PAR: Photosynthetically Active Radiation

PMD: Pakistan Meteorological Department, Pakistan

RCM: Regional Climate Model

SiB2: Simple Biosphere Model 2

SMOS: Soil Moisture and Ocean Salinity

TERC: Terrestrial Environmental Research Center of UTs (The University of Tsukuba), Japan

TPU: Toyama Prefectural University, Japan

UTy: The University of Tokyo, Japan

WCRP: World Climate Research Programme

Other data concerned in this report are put in the attached CD.