C. LECTURE

Hydrology and Water Resources in Monsoon Asia

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Hydrology and Water Resources in Monsoon Asia

- A Consideration of Necessity to Establish a Standing Research Community of Hydrology and Water Resources in Asia Pacific Region -

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Abstract

Hydrological and water resources issues appear very differently, region by region, strongly affected by geographical conditions, and hydrological knowledge and methodologies which are obtained in a specific region can not be necessarily adopted to other regions. The purpose of this paper is to clarify the way to address adequately regional characteristics of hydrology and water resources in monsoon Asia, especially in "too much water" problems in the region. For the purpose, geomorphological factor, climatic factor and human intervention to the natural environment are taken into consideration as three major factors governing regional characteristics of the hydrology-water resources system. To identify geomorphological features macroscopically between the Asia Pacific region and other continental regions, "tectonic zone" and "stable region", which are two major subdivisions of continental masses in the world, are introduced. Also, a new climatic sub-division "warm-humid" is proposed to express the abundant precipitation due to the Asian monsoon. Then, hydrological characteristics common or similar in "warm-humid tectonic zones" in the Asia Pacific region, contrasted to those in stable regions, are enumerated together with the human intervention corresponding to the characteristics, and research targets peculiar to warm-humid tectonic zones are discussed. Finally, the establishment of a standing research community called "Asia Pacific Association of Hydrology and Water Resources" is proposed to promote the exchange of operational knowledge and experience in water resources management, cooperative research activities and professional education in the Asia Pacific region.

KEY WORDS comparative hydrology, hydrology - water resources system, hydrological region, climatic region, geomorphology, monsoon Asia, Asia monsoon, tectonic zone, floodplain management

INTRODUCTION

"The basic concepts of investigating hydrological processes were developed in Europe and refined and further improved in North America. It is quite natural, therefore, that the methods usually applied to describe the continental branch of the hydrological cycle are fitted to the geographic and climatic conditions prevailing in those areas. Both Europe and North America - at least their greater parts - belong to the temperate zone, large areas having humid or semi-humid climates and undulating topography. Therefore the conventional hydrology in those

continents is based on the determination of catchment-response to precipitation. ------- When the development of hydrological sciences became linked to a large international program, the limitations to the application of conventional methods in areas with different characteristics were immediately recognized -------."

This is referred from a paper entitled "Proposal to construct a coordinating matrix for comparative hydrology" written by G. Kovac (Kovac, 1984) who served the President of IASH at that time. The above description expresses very well the background of the development of hydrological sciences and their limitations. The purpose of his paper was to provide a framework for comparative hydrology by defining " specific regions" in which common hydrological conditions take place. By combining morphological and climatic conditions, he proposed a new systematic categorization of specific hydrological regions. In this categorization, morphological conditions are classified into three sub-divisions such as flat lands, sloping terrains and mountainous regions according to the gradient of the land slope. The categorization proposed by Kovac is systematic and overall, and might be useful for huge continental river basins. It is partly used as sub-topics for "hydrological problems of specific regions" in the IHP research projects. However, it is too detailed to be applied for relatively small-scale river basins like those in Asia Pacific region.

Usually we consider hydrological characteristics for a start in a river-basin scale in which a series of mountainous areas, sloping terrains and flat lands are included. The purpose of this paper is to propose more macroscopic hydrological regions that enable to express hydrological characteristics common in a river-basin scale especially for the monsoon-Asian region.

THREE MAJOR FACTORS GOVERNING HYDROLOGY – WATER RESOURCES SYSTEM

Generally in the past study on the classification of hydrological regions including Kovac's one, the morphology of terrain and the climate are considered as decisive factors characterizing regional hydrology. We adopt two similar factors, geomorphology in place of morphology and climate, in this paper. These factors represent natural conditions for hydrology. However, the hydrological features in the river basin are different not only by natural conditions, but also considerably modified by human activities such as land use, water utilization, flood control measures etc.. Especially, more than 60% of the earth's population live in the humid climate region influenced by Asian monsoon, different from arid, semi-arid and semi-humid regions, and an appreciate number of human beings live even in mountainous areas in the region. Therefore, we have to take various effects of human activities into account as an important decisive factor modifying the hydrological features. Then, we introduce this decisive factor as "human intervention to the natural environment".

In other words, the human intervention to the natural environment is closely related to water resources management components in a wide sense (including water utilization, flood disaster mitigation, environmental conservation and protection, etc..), while the former two factors represent hydrological components. Therefore, we define the interdependency of these components as "hydrology – water resources system" as shown in Fig. 1. Regional characteristics of hydrology and water resources issues should be considered in a dynamic interaction among these three factors.

Geomorphological factor

The term "geomorphology" means the form and structure of terrain, or both topography and geology. The geomorphological factor, associated with land cover conditions, has predominant effects on every hydrological processes on the ground such as surface runoff and stream flow, infiltration and percolation, groundwater storage and runoff, sediment yield and transport, etc.. In addition, the factor is a decisive factor for human beings to determine the land use.

What can we adopt to express the geomorphological factor characterizing the Asian region?

From a global point of view, the continent masses consist of two basic subdivisions: one is an active belt of mountain making and another is an inactive region of old rocks (Strahler et al, 1992). The mountain-making activity on the earth is caused by plate tectonic motion and the belts are called "tectonic zones". The inactive region is called "stable region" hereafter in this paper.

There are two principal tectonic zones: one is Alpine-Himalayan zone and another is circum-Pacific zone (Fig.2). The Alpine-Himalayan zone runs from Alps and Mediterranean coast, through Middle and Near East, to Himalayas and then to Malay peninsula, Sumatra and Java islands. The circum-Pacific zone runs from New Zealand, through New Guinea, Philippines, Taiwan, Japan and Aleutian islands, and also along eastern fringe of Asian continent like Vietnam, southern and eastern China, Korea and northeastern Russia, then to west coasts of both north and south American continents. Land (topographical and geological) conditions in these tectonic zones are remarkably different from stable regions, and consequently characteristics of river basins from the hydrological point of view are distinctly distinguished between tectonic zones and stable regions.

Hydrological characteristics in river basins along tectonic zones are summarized below:

- Most of all high mountains in the world are located in tectonic zones.
- The land is structurally unstable as a result of tectonic plate motion over the past 200,000,000 years, and the motion is still taking place.
- The tectonic zones are characterized by seismic and volcanic activities, and have similar geological components such as igneous rocks, volcanic products, Tertiary formations, fractured zones, etc.
  - Basin geology greatly affects the hydrological regime, the river configuration and the feature of alluvial plains.
- The steep slope and fragile geology bring about high sediment yield, slope failure, landslide and debris/mud flow in mountainous areas.
- The scale of plains is relatively small in tectonic zones. Large plains in the world face mainly Atlantic and Arctic Coasts.
- Plains in tectonic zones are mainly alluvial plain, formed up by flooding of rivers, while those in stable regions are mainly structural plain, of which the surface is composed of residual soils.
- In general, the alluvial plain in tectonic zones is composed of three topographical units; alluvial fan, natural levee area and delta. On the other hand, most portions of the river course in stable regions are erosive valley, and the alluvial plain is usually limited in the delta area near the river mouth.

As a conclusion of the above discussion, it can be said that two basic categories based on geological structure, namely tectonic zones and stable regions (inactive regions of old geology), are quite suitable to express primary characteristics of geomorphology on the earth. The tectonic zones cover large parts of Asia and have great influences on hydrological processes in almost of all river basins in Asia.

Climatic factor

Most common approach to the classification of the climate from the hydrological point of view is a combination of two parameters, namely aridity and latitude. The aridity index (α) is defined as the ratio of potential evapotranspiration (ETP) to precipitation (P) given by

$$\alpha = ETP / P$$

Here, ETP and P both represent annual average values. If α less than unity, the region is classified as humid, whereas if it is greater than unity, the region is classified as arid. If α greater than 1 on annual basis but become less than 1 during some part of year, the region is classified as semi-arid, whereas the regions for opposite case where α is less than 1 for annual average but becomes greater than 1 during some part of year are termed as semi-humid.

Usually five zones are distinguished according to latitude: arctic, sub arctic, temperate, subtropical and tropical. Their borders can be defined basically by given values of latitude, although may be modified due to oceanic effects as well as orographic conditions.

The combination of two climatic parameters makes twenty possible categories, but twelve categories out of twenties exist actually on the earth as follows; humid arctic, humid sub arctic, humid temperate, humid tropic, semi-humid sub arctic, semi-humid temperate, semi-humid tropic, semi-arid temperate, semi-arid sub tropic, semi-arid tropic, arid temperate and arid sub tropic (Kovac, 1984).

Then, what climatic regions are East, Southeast and South Asian regions classified into ?

Let us take the Chao Phraya river basin in Thailand as an example. The basin is classified into semi-arid according to the conventional definition of aridity index, since the annual precipitation is about 1,200mm and the potential evapotranspiration about 2,000mm. However almost of all annual precipitation appears during the rainy season from May to October when it is quite humid and everywhere of flat lands are inundated with heavy rainfall. It is not fitted for our feeling that Thailand is defined as semi-arid. In a large part of monsoon Asia, there is plenty of rainfall during the rainy season. In such a case, we should consider not only the ratio of ETP to P, but also the absolute value of P. Tentatively, if the annual precipitation is greater than 1,000mm, then the region is defined as humid. Thus almost of all East and Southeast Asian regions are involved in humid climate (Fig. 3).

As for the latitudinal categorization, the summer in East Asian countries like Japan, Korea and part of China located in temperate zone has high temperature similar to Southeast and South Asia located in the tropical zone. Therefore, from a macroscopic point of view, we put temperate and tropic together in the same category, which is defined here as "warm" zone.

The combination of "warm" and "humid" both defined here makes a new climatic region named "warm-humid". The wan-humid climates cover a large part of Asian regions.

Proposal of a new hydrological region "warm-humid tectonic zone"

By combining geomorphological and climatic factors discussed above, "warm-humid tectonic zone" is proposed as a new macroscopic hydrological region. The warm-humid tectonic zone covers widely island countries in the Pacific Ocean and the south-eastern fringe of Asian continent. Similarly, we will be able to define "warm-semi-humid tectonic zone", "warm-semi-arid or arid tectonic zone", etc., taking "tectonic zone" as a primary geomorphorogical factor. The definition of these hydrological regions should be examined and discussed in the future.

We can observe many types of human activities particular to the warm-humid tectonic zone, such as paddy cultivation, slope agriculture, location of urban areas in alluvial flood-plains, protection of alluvial plain from inundation, etc.. The interrelationship between human activities and natural conditions in the zone are discussed in the following section.

HYDROLOGY AND WATER RESOURCES CHARACTERISTICS COMMON IN WARM-HUMID TECTONIC ZONE

Hydrological characteristics in the tectonic zone, contrasted to those in stable regions, are enumerated together with the human intervention corresponding to the characteristics below:

- The hydropower potential is high in mountain areas associated with the abundant precipitation.
- The mountain slope cultivation can be carried out on slopes composed of the fragile geology such as volcanoes, fractured zones, Tertiary formation and weathered granite areas. Therefore, an appreciate number of people live even in mountainous areas. On the other hand, the fragile geology, associated with the steep slope, bring about high sediment yield, slope failure, landslide and debris/mud flow in mountainous areas. It is necessary to apply Sabo engineering works (debris control, landslide and slope failure prevention works) in order to prevent or mitigate damages caused by them.
- Catchment areas of rivers in the tectonic zone are generally smaller than those in stable regions, because of relatively short distance from the mountain to the seashore.
  - ➢ The size of river basins in the zone is suitable for the integrated river basin management.
- The alluvial plain is the most important place for people's lives and industrial activities in the tectonic zone, while the major human activities in stable regions are placed on relatively high lands located in the structural plain with gentle and undulating topography.
- Since the alluvial plain is low-lying and wet land, it is used for paddy cultivation if the high temperature and sufficient water can be obtained. The paddy cultivation has special water management technologies different from other field crop cultivation in stable regions.
- It is the most densely populated area in the tectonic zone; big cities, towns and villages are located in the low-lying alluvial plain, while, in stable regions, they are located generally in the undulating high structural plain.
- Alluvial plains, formed up by flooding, have a nature vulnerable to be flooded.
  - ➢ Therefore, flood control and flood disaster mitigation measures are much more important in the tectonic zone than in stable regions.

- The concept of flood plain management is remarkably different between tectonic zone and stable regions;
  - In case of flood plains along the erosive valley in stable regions, they apply mainly non-structural measures such as land use restriction without the construction of flood control facilities like embankment.

Regional characteristics of hydrology – water resources system in the warm-humid tectonic zone are summarized and illustrated in Fig. 4.

DIFFERENCES IN RESEARCH SUBJECTS OF HYDROLOGY AND WATER RESOURCES BETWEEN TECTONIC ZONE AND STABLE REGIONS

Physical, chemical and biological principles governing the hydrological phenomena are general and common in the world. However, the phenomena themselves appear very differently, region by region, strongly affected by geographical conditions. Usually, researchers and practitioners in the field of hydrology and water resources deal with subjects surrounding them. It is difficult even for an excellent researcher to develop the study on hydrological phenomena which does not exist surrounding him. In this sense, hydrological studies tend to be site-specific. Therefore, scientific concepts and/or methods developed in a specific region are not necessarily applicable to other regions. Also, targets of research in a specific region may differ from those in another region. Some examples representing those differences between warm-humid tectonic zone and stable regions are listed up below:

- The original version of SHE (Systéme Hydrologique Européenne) Model, one of the most sophisticated distributed hydrological models, does not have a component of lateral sub-surface flow, since it was developed in gently undulating terrains. Therefore it is very difficult to simulate the stream runoff in river basins with steep gradient and thick surface soil of mountain slope (Jha et al, 1995).
- SiB2 (Simple Biosphere Model 2), one of the latest Land Surface Models, does not have the scheme for paddy fields. The scheme was developed in the research related to the GEWEX Asian Monsoon Experiment (GAME), and using it, the results of simulation were much improved (Kim et al, 2001).
- The source of sediment yield in stable regions is mainly soil erosion, and the soil erosion process is formulated as Universal Soil Loss Equation (Wischmier and Smith, 1965), Revised Soil Loss Equation (Weltz et al., 1987), etc.. We have other major sources of sediment yield particular to tectonic zones, such as landslide, mountain-slope collapse, debris/mud flow and volcanic eruption. Although the estimation and prediction of sediment yields from these sources are very difficult due to their discontinuous nature, systematical studies on them should be organized in our region.
- In Europe, "karst hydrology" becomes a specific field of hydrology, since limestone areas which have special hydrological conditions are widely distributed. Volcanic areas located in tectonic zones also have special conditions, but we do not establish yet a specific research field of "volcanic hydrology".
- The awareness of flood plains seems to be considerably different between warm-humid tectonic zone and stable regions. Generally in stable regions, most of river reaches are erosive and in those reaches the bottom of valley is flood plain, which is relatively only limited areas. Most of population lives on undulating terrains above the valley. On the other hand, in the tectonic zones we have large alluvial flood plains along the middle and down reaches of river, where a lot of people live and human activities are most active. Therefore the idea of flood-plain management is basically different between two regions.
- The awareness of river basin is somewhat different between arid/semi-arid and humid regions. In the arid/semi-arid region where the water resources depend mainly on the ground water, the awareness of river basin is very weak. On the other hand, in the humid region where the water resources depend mainly on the river water and the flood inundation often takes place in the alluvial plain, we have much concern to the

river basin.

These are only limited examples relating to the author's research subjects. We can find out a lot of other specific research topics particular to the Asia Pacific region. Some examples are as follows:

- Precipitation mechanism in Asian monsoon, influences of ENSO/El Nino on monsoon rainfall, etc.
- Irrigation and drainage technologies and water management peculiar to the paddy cultivation
- Flood disaster mitigation measures for urbanizing areas located in the low-lying alluvial plain
- Integrated water resources management for river basins where there are "too much water" and "too little water" issues at the same time.

SUMMARY – TOWARD THE ESTABLISHMENT OF ASIA PACIFIC ASSOCIATION OF HYDROLOGY AND WATER RESOURCES

In this paper, the main focus is placed on how to recognize the "too much water" problems in monsoon Asia, which are not adequetely addressed in the world–wide international societies led by western people. For this purpose, the author introduced a new macroscopic hydrological region defined as "warm-humid tectonic zone", indicating that geomorphological conditions peculiar to the tectonic zone should be considered together with abundant precipitation due to Asian monsoon, and discussed water resources issues and research subjects particular to the zone. Using the macroscopic classification of tectonic zone and stable region, differences in "too much water" problem between two regions may be more clearly recognized.

On the other hand, there are also arid, semi-arid and semi-humid areas in monsoon Asia. Although the "too little water" problems were not discussed in this paper for the above-mentioned reason, we have many research and practical subjects to be solved for the water scarcity due to the imbalance between supply and demand in a geographical region of monsoon Asia.

In order to encourage and promote the exchange of operational knowledge and experience in water resources management and cooperative research activities in monsoon Asia, Japan Society of Hydrology and Water Resources (JSHWR) proposed to establish a standing research community at " International Symposium on Innovative Approaches for Hydrology and Water Resources Management in Monsoon Asia" (JSHWR, 2001) held in 13-14 December 2001, Tokyo, Japan. At a consultation meeting during the Symposium, the Preparatory Committee for Asia Pacific Association of Hydrology and Water Resources was organized to discuss and decide the terms of reference describing the framework of the Association's activities. After finalizing the terms of reference, the Association will launch on 1 September 2002, and will hold the "First International Conference on Hydrology and Water Resources in Asia Pacific Region" in 13-15 March 2003 (just before the Third World Water Forum), Kyoto, Japan (the conference web site: http://www.wrrc.dpri.kyoto-u.ac.jp/~aphw/APHW2003/WWW/index.html).

Although the Association deals mainly with water issues particular in the Asia Pacific region, the membership is open for individuals and institutes of every country in the world. We expect that the Association will be grown up by the active participation of many researchers and practitioners.

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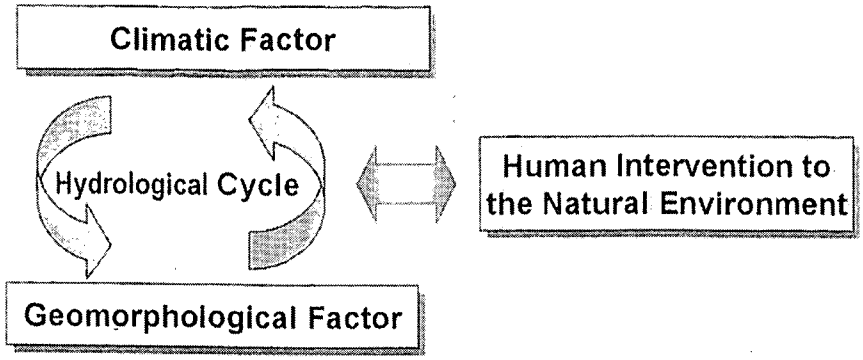

Fig.1 Three major factors governing hydrology–water resources system

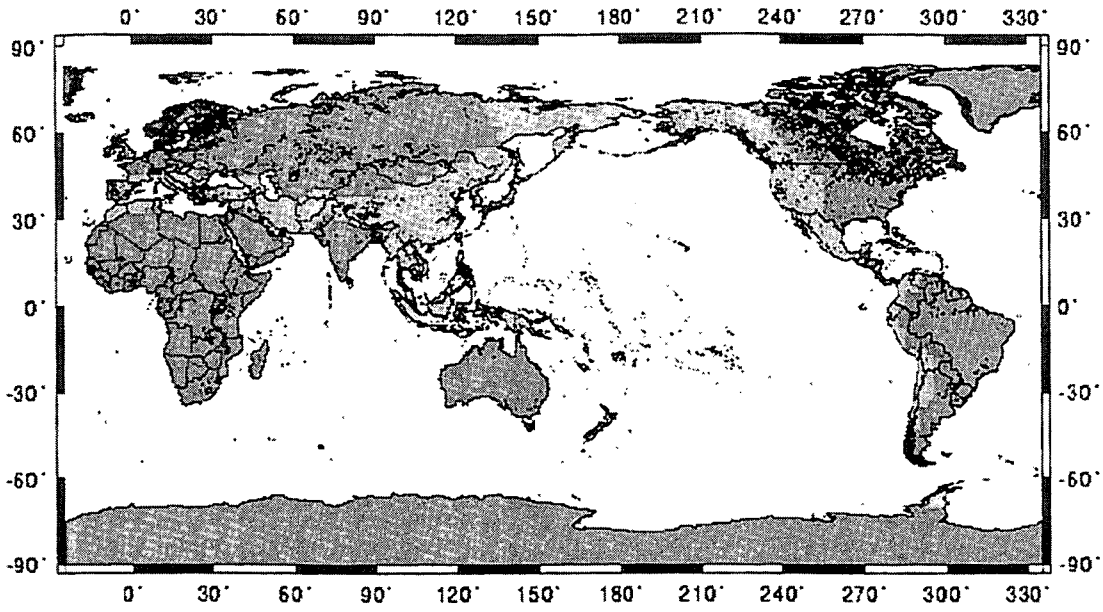

Fig. 2 World distribution of tectonic zones

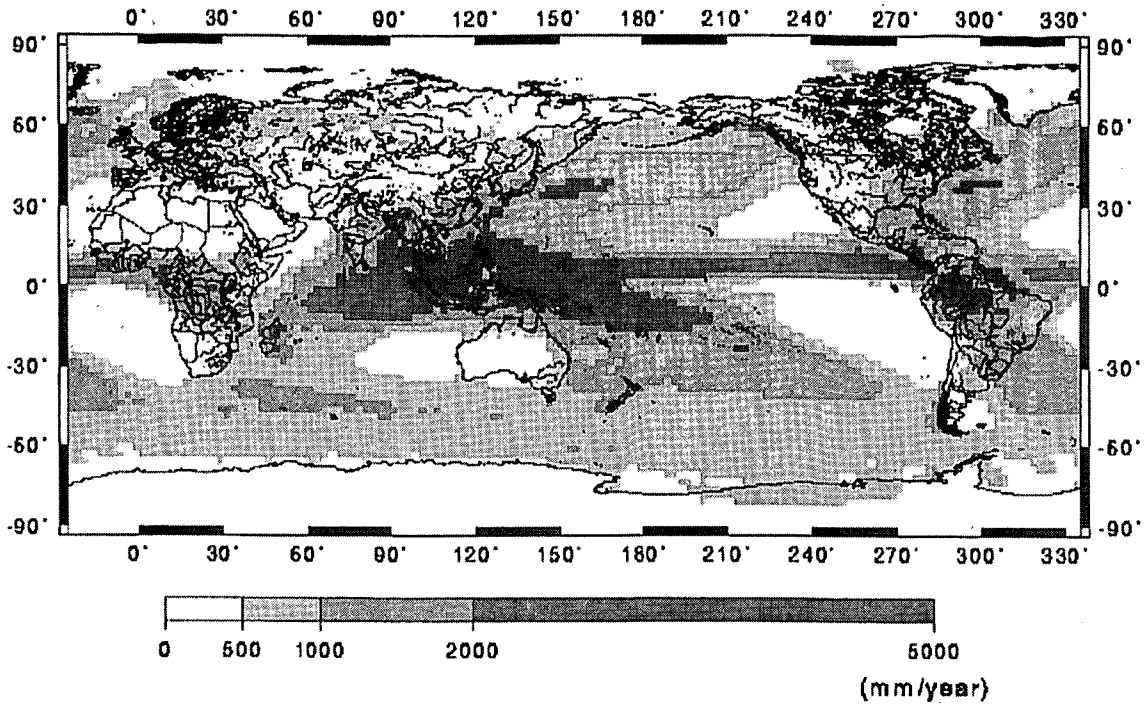

Fig. 3 World distribution of annual precipitation

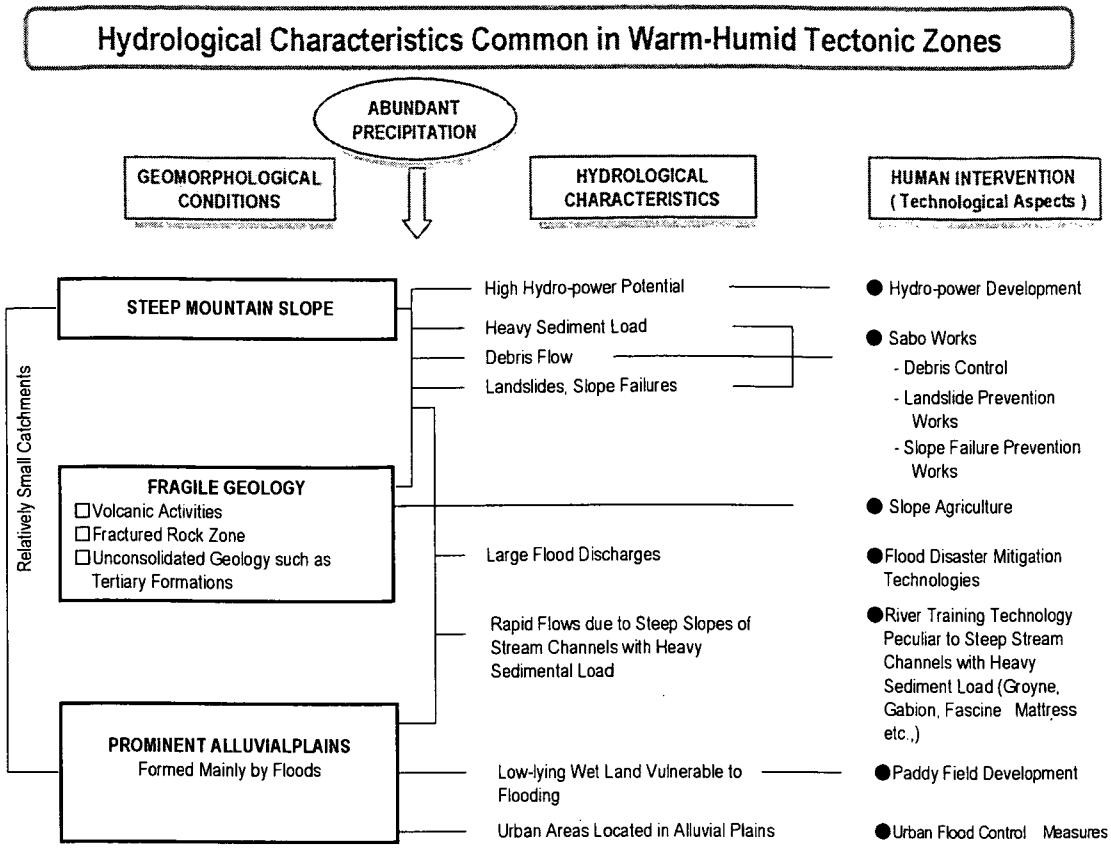

Fig. 4 Hydrological and water resources characteristics common in warm-humid tectonic zones

Hydrology and Water Resources In Monsoon Asia

A Consideration of Necessity to Establish a Standing Research Community of Hydrology and Water Resources in Asia Pacific Region

Katumi Musiake
Former President, Japan Society of Hydrology and Water Resources
IIS, University of Tokyo

Purpose of My Talk

- **" Asia Pacific Association of Hydrology and Water Resources (APHW)" just launched on 1 Sept. 2002 after discussions in the international Preparatory Committee since Dec. 2001.**
  The First International Conference on Hydrology and Water Resources will be held in 13-15 March 2003 (just before the Third Water Forum), Kyoto, Japan.
- **Why do we need to establish the APHW ?**
  – That is the purpose of my talk

Contents

- Motivation for proposing to establish a standing research community in Asian region
- Regionality of hydrological phenomena and their studies
- How to categorize regional features of hydrology and water resources in monsoon Asia, from a macroscopic or global point of view
- Proposal of a hydrological region, "warm-humid tectonic zones", to represent hydrological characteristics in East, Southeast and South Asian Regions
- Research subjects particular to the Asian Region
- Introduction of newly established "Asia Pacific Association of Hydrology and Water Resources"

Motivation

Ideas from Asia region are rarely reflected to world-wide international societies related to hydrology and water resources

- **A Typical Case : "World Water Vision" presented by World Water Council in 2000**

- **Its major focus is placed on water issues appearing in arid and semi-arid regions such as north and west Africa, Middle East etc., which are of interest mainly to Western countries**
- **Almost no description about "too much water" issues (flood problems) from which most of Asian countries suffer seriously**
- **Why western people show little concern about "too much water" issues ? ⇨ The weight of them is comparatively very low.**
- **We should appeal water issues particular to Asian region more systematically and more effectively to the world**

For this, we have to recognize regional characteristics of hydrology and water resources in our region

Major Disasters around the World, 1963-1992
- Those which cause 100 or more of deaths -

Type \ Region	Asia			America			Europe	Mid.East/Africa			Caribbean	Pacific
	EAS	SAA	SAS	NOA	CAM	SAM		MEA	CAF	SAF		
Floods	130			35			10	19			2	6
	43	10	78	5	3	27		9	1	9		
Tropical Storms	84			13			0	5			11	40
	41	1	43	8	4	1		1	0	4		
Storms, Other	27			10			1	4			0	4
	8	0	19	9	0	1		3	1	0		
Landslides	28			20			3	3			1	1
	9	5	12	1	1	18		0	0	3		
Drought	6			0			0	15			0	0
	2	4	0	0	0	0		0	11	4		
Food Short -ages/ Famine	1			0			0	3			0	4
	0	1	0	0	0	0		0	1	2		
Earthquakes	34			20			22	22			0	4
	10	10	13	4	5	11		19	2	1		
Epidemics	41			16			1	74			0	0
	4	3	34	0	2	14		3	49	22		
Other	31			21			7	5			1	7
	6	5	20	14	2	5		2	2	1		

- The number of disasters which caused 100 or more of deaths in one event
- Aggregated country-base statistics for 30 years from 1963 to 1992

(Source: Disaster around the World – A Global and Regional View, World Conf. on IDNDR, Yokohama, Japan, May 1994)

Disasters related to "too much water" such as floods, storms and landslides are much more serious in Asia than in North America/Europe or in Mid. East/Africa.

Roughly speaking, the frequency of serious flood disasters in North America/ Europe or in Mid. East/Africa is one order less compared to that in Asia.

Regional classification for the above table

EAS(Eastern Asia): Japan, Democratic Republic of Korea, Republic of Korea, People's Republic of China, Republic of China, Mongolia, Hong Kong Macao, Vietnam, Laos, Kampuchea, Thailand, Myanmar

SAA(Southeastern Asia/Australia): New Zealand, Australia, Papua New Guinea, Indonesia, Malaysia

SAS(Southern Asia): Bangladesh, Nepal, India, Sri Lanka, Maldives, Pakistan, Afghanistan

NOA(North America): Canada, United States, Mexico

CNA(Central America): Belize, Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica, Panama

SAM(South America): Venezuela, Guyana, Suriname, Colombia, Ecuador, Brazil, Peru, Bolivia, Paraguay, Uruguay, Argentina

MEA(Middle East/North Africa): Iran, Iraq, Syria, Lebanon, Israel, Jordan, Bahrain, Saudi Arabia, United Arab Emirates, Oman, Yemen, Egypt, Libya, Tunisia, Algeria, Morocco

CAF(Central Africa): Somalia, Djibouti, Ethiopia, Sudan, Chad,Central Africa, Cameroon, Niger, Nigeria, Benin, Togo, Burkina Faso, Ghana, Mali, Cote d'Ivoire, Liberia, Sierra Leone, Guinea, Guinea Bissau, Senegal, Gambia, Mauritania, Cape Verde

SAF(Southern Africa): Mauritius, Madagascar, Comoros, Kenya, Uganda, Rwanda, Burundi, Tanzania, Mozambique, Malawi, Zimbabwe, Swaziland, Lesotho, Congo, Zambia, Botswana, South Africa, Namibia, Angola, Gabon, Equatorial Guinea, Sao Tome & Principe

How to Express Regionality of Hydrology

- **There are some proposals of hydrological regions in the context of comparative hydrology such as arid/semi-arid regions, humid tropics, marsh-ridden areas, fractured rock areas, etc.**
- **A systematic approach to classify hydrological regions : "*Proposal to construct a coordinating matrix for comparative hydrology*" by G. Kovac (1984) who served the President of IAHS**
- **The purpose of his paper is to provide the framework of comparative hydrology for IHP Phase 4, and some of his proposal have reflected for setting research themes in "hydrological problems of specific regions" of IHP**

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比較水文学のためのコーディネーティング・マトリックス構成案

Proposal to construct a coordinating matrix for comparative hydrology

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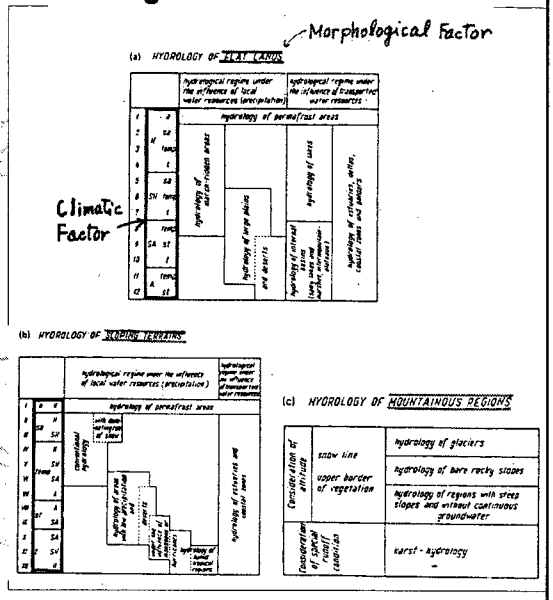
INTRODUCTION

The basic concepts of investigating hydrological processes were developed in Europe and refined and further improved in North America. It is quite natural, therefore, that the methods usually applied to describe the continental branch of the hydrological cycle are fitted to the geographic and climatic conditions prevailing in those areas. Both Europe and North America – at least their greater parts – belong to the temperate zone, large areas having humid or semi-humid climates and undulating topography. Therefore the conventional hydrology in those continents is based on the determination of catchment-response to precipitation.

When the development of hydrological sciences became linked to a large international programme, the limitations to the application of conventional methods in areas with different characteristics were immediately recognized.

Outline of Kovac's Categorization

- Kovac proposed a new systematic categorization by combining morphological and climatic conditions.
- In this categorization, morphological conditions are classified into three sub-divisions such as flat lands, sloping terrains and mountainous regions according to the gradient of the land slope.
- It is partly used as sub-topics for "hydrological problems of specific regions" in the IHP research projects. However, it is too detailed to be applied for relatively small-scale river basins like those in Asian regions.



View-Point of My Proposal

- Usually in Asian region, we consider hydrological characteristics for a start in a river-basin scale in which a series of mountainous areas, sloping terrains and flat lands are included.
- The purpose of my proposal is to provide more macroscopic hydrological regions which enable to express hydrological characteristics common in a river-basin scale especially for Asian region.

Decisive Factors to be Adopted to Express Regional Characteristics in Hydrology and Water Resources

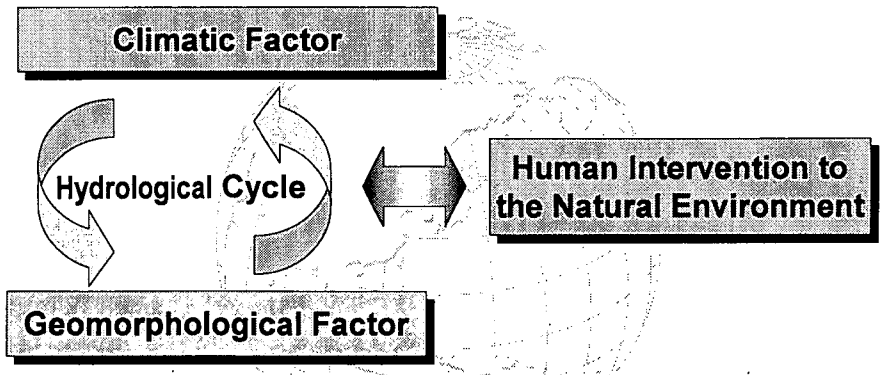
- Generally in the conventional study on the classification of hydrological regions including Kovac's, the climate and the morphology of terrain are considered as decisive factors characterizing regional hydrology

- We also adopt the climate, and not the morphology but the geomorphology of terrain, here in this discussion
- These two factors, climatic and geomorphologic factors, represent natural conditions for hydrology

- However, the hydrologic features in the river basin are determined not only by natural conditions, but considerably modified also by human activities. Especially, more than 60% of the world population live in monsoon Asia, and an appreciate number of human beings live in plain areas and even in moutain areas as well.
- We have to take various effects of human activities into account.

- Therefore, in addition to the above two factors, we introduce the artificial factor as " human intervention to the natural environment"

Three Major Factors Governing Regional Characterization in Hydrology-Water Resources System



- Hydrology-water resources system in the river basins should be considered in a dynamic interaction among these three factors

What Characterizes each of Factors for Hydrological Features in River Basins in East, Southeast and South Asian Region (or Asia-Pacific)?

Climatic Factor ; Warm Humid Climates ➡ Monsoon Climates (Temperate Humid + Humid Tropics)

Geomorphological Factor ; Tectonic zones

Human Intervention to the Natural Environment ; Paddy Cultivation, Irrigation and Drainage, Flood Control Measures, etc.

Geomorphological Factor

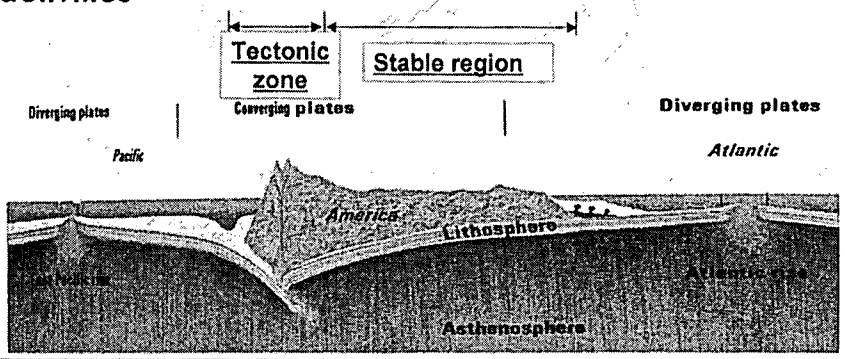
- **Geomorphology: Topography + Geology**
- The geomorphological factor, associated with land cover conditions, has predominant effects on every hydrological processes on the ground such as surface runoff and stream flow, infiltration and percolation, ground water storage and runoff, sediment yield and transport etc.
- In addition, the factor is a decisive factor for human beings to determine the land use

- **How to Classify the Factor from a Global Point of View**
- **Two basic subdivisions of the Continent Masses**
  - Tectonic Zones (Active Belts of Mountain Making)
  - Inactive Regions of Old Rocks ➡ "Stable Regions"

Two Major Divisions of the Earth's Crust

- Tectonic Zones and Stable Regions -

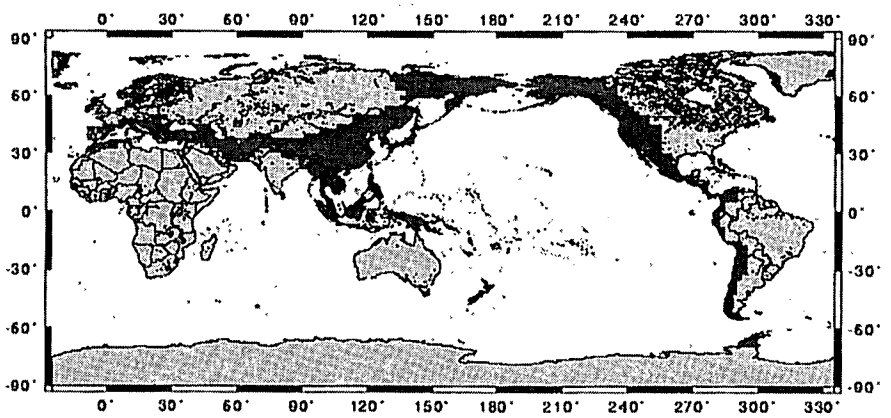
- Tectonic zones: zones where mountain-making activities take place due to tectonic plate motion
- Stable regions: regions which are composed of old geology and not affected by seismic and/or volcanic activities



There are two tectonic zones in the world

-Alpine-Himalayan Zone : Alps -- Mediterranean Coast -- Middle and Near East -- Himalaya -- Sumatra – Java

-Circum-Pacific Zone : New Zealand – New Guinea – Philippines – South-western fringe of Asian continent -Japan Archipelago– Aleutian Islands – West Coasts of both North and South America



TECTONIC ZONES

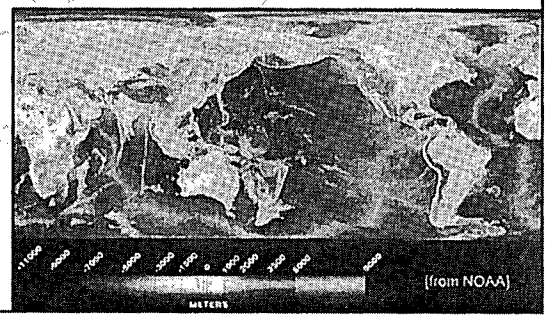
Land Conditions particular to Tectonic Zones(1)

• Most of all high mountains in the world are located in tectonic zones.

•The land is structurally unstable as a result of tectonic plate motion over the past 200,000,000 years, and the motion is still taking place.

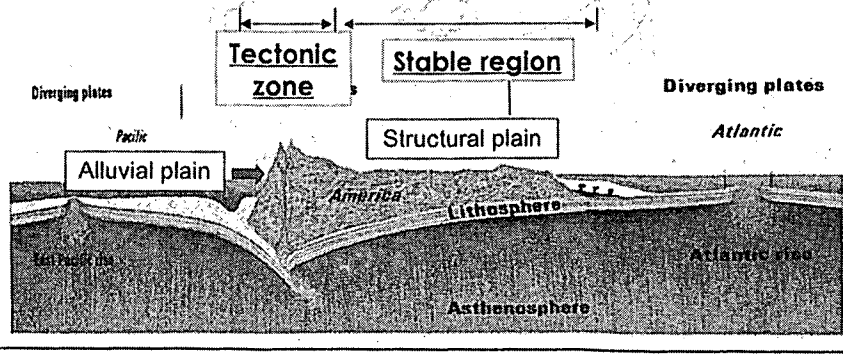
• The tectonic zones are characterized by seismic and volcanic activities, and have similar geological components such as igneous rocks, volcanic products, tertiary formations, fractured zones, etc..

--- Basin geology greatly affects the hydrological regime, the sediment yield, the river configuration and the feature of alluvial plains.



Land Conditions particular to Tectonic Zones(2)

- The scale of plains is relatively small in tectonic zones. Large plains in the world are located in stable regions which face mainly Atlantic or Arctic Oceans
- Plains in tectonic zones are mainly alluvial plains, formed up by flooding of rivers, while those in stable regions are mainly structural plains, of which the ground surface is composed of residual soils
- Alluvial plains are a nature vulnerable to be flooded, while structural plains have almost no risk of flooding from rivers



Catchment areas of rivers in tectonic zones are generally smaller than those in stable regions, because of relatively short distance from the mountain to the sea shore.

Large Rivers of the World in order of Catchment Area

: River in Tectonic Zones, Flowing into Pacific or Indian Oceans

Others : River in Stable Regions

No.	River	Country at Mouth	Catchment Areas (10^3km^2)	No.	River	Country at Mouth	Catchment Areas (10^3km^2)
1	Amazonas	Brazil	5710	16	Ganges	Bangladesh	1100
2	Congo	Rep. Congo	3970	17	Nelson	Canada	1060
3	Mississippi	America	3170	18	Murtay-Darling	Australia	1060
4	Lena	U.S.S.R	2990				
5	Nile	Egypt	2940	19	Indus	Pakistan	950
6	Ob	U.S.S.R	2880	20	Brahmaputra	Bangladesh	920
7	Yenisey	U.S.S.R	2660	21	Yukon	America	900
8	Parana	Argentina	2270	22	Tokantins	Brazil	900
9	Chang Jiang	China	1800	23	Mekong	Vietnam	890
10	Amur	U.S.S.R	1790	24	Danube	Romania	830
11	Mackenzie	Canada	1780	25	Orinoko	Venezuela	750
12	Volga	U.S.S.R	1440	26	Huang He(Yellow)	China	
13	Zambezi	Mozambique	1310	27	S. Francisco	Brazil	660
14	Niger	Nigeria	1100	28	Kolyma	U.S.S.R	630
15	Shatt al Arab	Iraq	1100	29	Dnepr	U.S.S.R	500
				30	Irrawaddy	Myanmar	420

➡ The size of river basins in these zone are suitable for the integrated river basin management

Climatic Factor : Combination of Aridity Index and Latitudinal Climate Classification

	ETP / P < 1.0 (yearly average)		ETP / P > 1.0 (yearly average)	
	ETP / P < 1.0 (for each season or month) humid	ETP / P > 1.0 (for some season or month) semi - humid	ETP / P < 1.0 (for some season or month) semi - arid	ETP / P > 1.0 (for each season or month) arid
arctic	Humid - arctic	X	X	X
sub - arctic	humid/ - sub - arctic	semi – humid - sub - arctic	X	X
temperate	Humid - temperate	semi – humid - temperate	semi – arid - temperate	Arid - temperate
sub - tropic	X	X	semi – arid - sub - tropic	Arid - sub - tropic
tropic	Humid - tropic	semi – humid - tropic	semi – arid - tropic	X

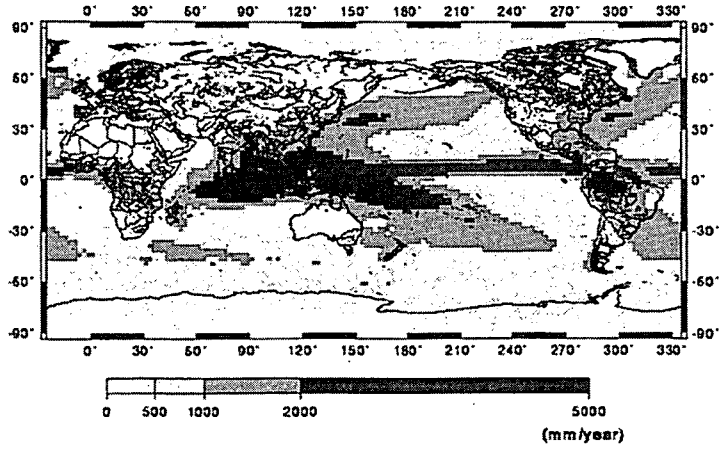
Climatic Factor (Aridity and Latitude)
- Aridity -

- According to the aridity index, the Chao Phraya basin in Thailand (P ≒1200 mm, ETP ≒2000 mm)
  →Semi-Arid (not compatible with our feeling)
- Can we express the wetness only by the ratio of ETP to P ?
- We should consider the absolute value of P, too.

- Modified definition in Monsoon Asia:
  e.g. Humid if P > 1000 mm
  Then, Thailand → Humid

- Humid Climate defined here covers large part of Asia.

Humid Climate defined here
(areas with annual precipitation of more than 1000mm) covers large part of Asia



Mean Annual Precipitation (Average of 1979-1999)

Climatic Factor (Aridity and Latitude)
- Latitude -

- As for the latitudinal categorization, the summer in East Asian countries like Japan, Korea and part of China located in temperate zone has high temperature similar to Southeast and South Asia located in tropical zone
- Therefore, from a macroscopic point of view, we put temperate and tropic together in the same category, which is defined here as "warm" zone.

- Aridity and Latitude -

- The combination of "warm" and "humid" both defined here makes a new climatic region named "warm-humid".
- The warm-humid climates cover large part of Asian region.

Proposal of a New Hydrological Region : "Warm-humid Tectonic Zone"

- Based on the above discussions, by combining geomorphological and climatic factors, "warm-humid tectonic zones" is proposed as a new macroscopic hydrological region.
- The warm-humid tectonic zone covers wide parts of Asia, island countries in the Pacific Ocean and the south-eastern fringe of Asian continent.
- Similarly, we will be able to define "warm-semi-humid tectonic zone", "warm-semi-arid/arid tectonic zone" and so on, taking "tectonic zone" as a primary geomorphological factor. (The definition of those hydrological classification should be discussed in the future)

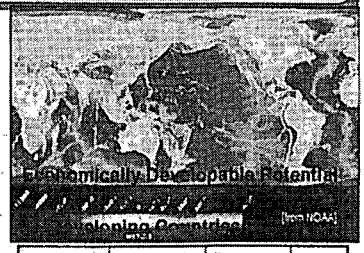
Human intervention to the Natural Environment in monsoon Asia

- In monsoon Asia, there are a variety of human activities under geomorphological conditions of tectonic zone and climatic conditions of Asian monsoon which cover from humid to arid climates.
- However, we will focus on warm-humid tectonic zone here in the discussion, to clarify "too much water" issues in monsoon Asia.
- We can observe many types of human activities particular to the warm-humid tectonic zone, such as paddy cultivation, slope agriculture, location of urban areas in alluvial flood-plains, protection of alluvial plain from inundation, etc..

Hydrological and Water Resources Characteristics Common in River Basins along WHT zone in Asia

<u>High Potential of Hydro-power Generation</u>

- (High mountains + Abundant Precipitation) provides "high potential of hydro-power"
- In developed countries along tectonic zones, such as France, Italy, Switzerland, Japan, west coast of Canada and USA, etc., almost of economically developable hydro-power potentials had been developed before the middle of 20th century.
- On the other hand, in developing countries of Asia, most of hydro-power potentials are remained for the future energy development.



	Developable H-Power (MW)	Developed H-Power (MW)	Ratio (%)
Indonesia	7500	3012	40
China	378000	70000	19
Thailand	15000	3900	26
Malaysia	29000	2058	7
Philippine	12310	2230	18
Vietnam	9000	3343	37
India	94000	22448	24
Pakistan	33572	4825	14
Sri Lanka	——	1137	——
Bangladesh	600	230	38

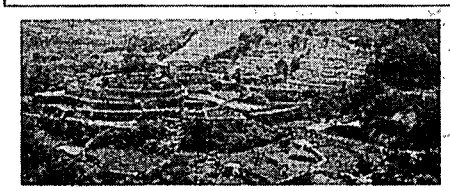
(Source: Electric Power Industry in each country (JEPIC 2000), APEC ENERGY DATABASE)

Hydrological and Water Resources Characteristics Common in River Basins along WHT zone in Asia

Mountain slope cultivation

- Fragile mountain lands formed up due to mountain making activities, such as slopes of volcanoes, fractured zones, Tertiary formation and weathered granite areas, can be cultivated, if they have necessary temperature and water. ⟹ mountain slope cultivation in WHT zones
- On the other hand, they are disaster-risk areas vulnerable to slope failure, landslide, debris/mud flow, etc..
- "Land productivity" and "Disaster risk" are both sides of coin.

Terrace fields on pene-plain of weathered granite – views from Malaysia and Japan



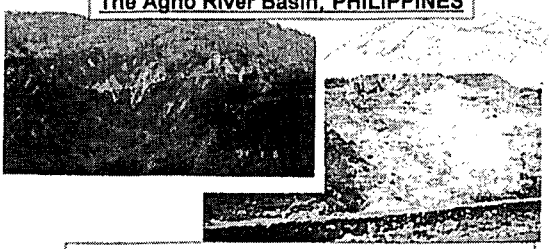
Terrace fields on the slope of Cameron Highlands, MALAYSIA

Terrace paddy fields on the pene-plain in Chugoku district, JAPAN

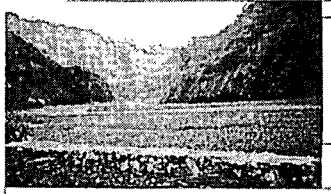
Hydrological and Water Resources Characteristics Common in River Basins along WHT zone in Asia

Slope failure due to earthquake and sediment runoff

The Agno River Basin, PHILIPPINES



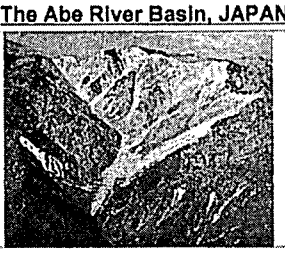
Landslide/slope failure due to Bagulo Earthquake (Magnitude: 7.8) in 1990



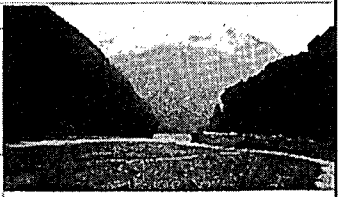
30-50m riverbed aggradation due to storms after the Earthquake

Geology of both basins is Mesozoic/Paleozoic formations with fractured zones

The Abe River Basin, JAPAN



Landslide/slope failure due to big earthquake (Genroku-zisin) in 1702



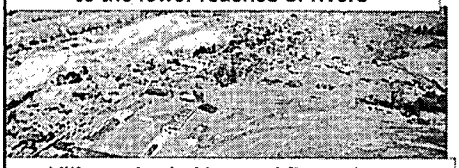
Partially, riverbed aggradation of more than 100m after the earthquake

Hydrological and Water Resources Characteristics Common in River Basins along WHT zone in Asia

Volcanic eruption and sediment yield/ runoff

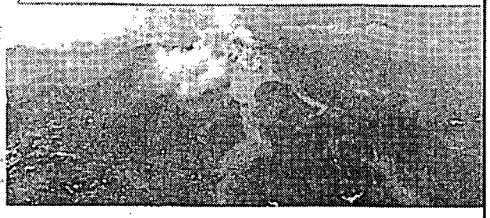
Eruption of Mt. Pinatubo, PHILLIPINES, in July 1991

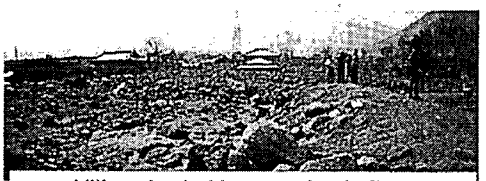
A great quantity of sediment flows down to the lower reaches of rivers



Villages buried by mud flows due to storms after the eruption

Eruption of Mt. Unzen-fugendake, Nagasaki, JAPAN, in Augaust 1991





Village buried by pyroclastic flow

Effects of a volcanic eruption on the river basin last for a very long time

Hydrological and Water Resources Characteristics Common in River Basins along WHT zone in Asia

Debris/mud flow and drifting fallen tree disaster

Debris/mud flow with drifting fallen trees in Ban Nam Kor, Petchaboon (located along the upper reaches of the Pasak River), THAILAND, in 11 August 2001.
The river catchment is composed of Mesozoic formation with limestone.

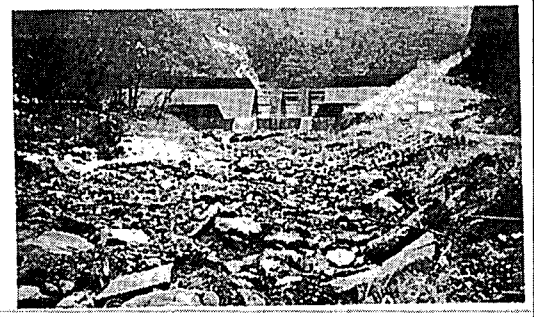
Debris flow with drifting fallen trees in Kawauchi-cho, Ehime Pref. JAPAN, in 15 September 1999.
The river catchment is composed of Mesozoic/Paleozoic formations.

Hydrological and Water Resources Characteristics Common in River Basins along WHT zone in Asia

Sabo engineering works

- The steep slope and fragile geology bring about high sediment yield, slope failure, landslide, volcanic eruption and debris/mud flow in mountainous areas.

- Sabo engineering works (debris control, landslide and slope failure prevention works) are applied to prevent or mitigate damages caused by them.

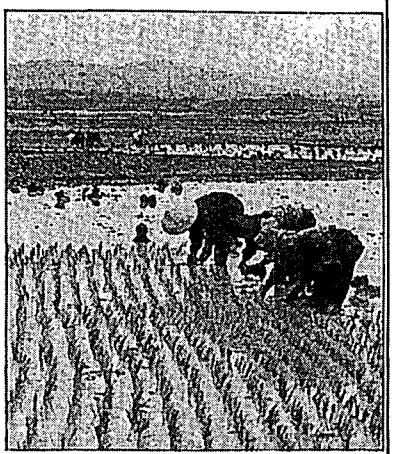


A debris control dam constructed in the upper reaches of the Ade river, JAPAN

Hydrological and Water Resources Characteristics Common in River Basins along WHT zone in Asia

Paddy cultivation in the alluvial plain

- Since the alluvial plain is low-lying and wet land, it is used for paddy cultivation if the high temperature and sufficient water can be obtained.
- The paddy cultivation is the most suitable crop for the low-lying wet alluvial plain.
- It has a special water management with irrigation/drainage technology different from dry crop cultivations.



Vietnam

- Cấy lúa (Bắc bộ)
- Planting young rices
- La plantation du riz

Hydrological and Water Resources Characteristics Common in River Basins along WHT zone in Asia

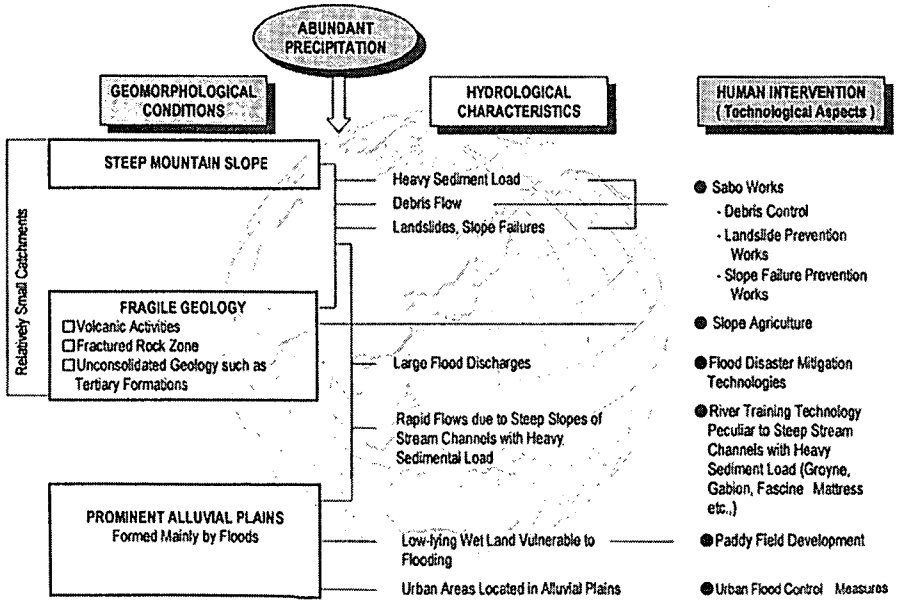
Urban areas located in the alluvial plain

- The alluvial plain is the most densely populated area in tectonic zones ; big cities, town and villages are located in the alluvial plain.
- Alluvial plains, formed up by flooding of rivers, have a nature vulnerable to be flooded. Therefore, flood control and flood disaster mitigation measures are much more important in tectonic zones than in stable regions.

Jakarta, INDONESIA

Flooding in Jakarta city

Hydrological/Water Resources Characteristics Common in Warm-Humid Tectonic Zone



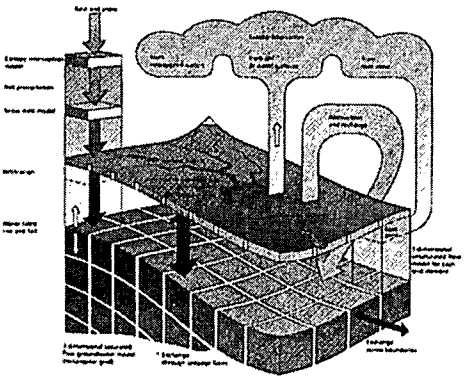
Differences in Hydrological and Water Resources Issues between Warm-Humid Tectonic Zone and Stable Regions

- Physical principles controlling the hydrological phenomena are general and common in the world.
- However, methods developed in a specific region are not necessarily applicable to other regions since the phenomena themselves are strongly affected by geographical conditions.
- Also, targets of research in a specific region may be different from those in another specific region.

Differences in Research Subjects of Hydrology and Water Resources between Warm-Humid Tectonic Zone and Stable Regions

Physically-based distributed hydrological modeling

SHE Model, one of the most sophisticated DHM:
No component of lateral sub-surface flow
→ Not applicable to river basins with steep gradient and thick surface soil on mountain slopes (Jha et al, 1995)



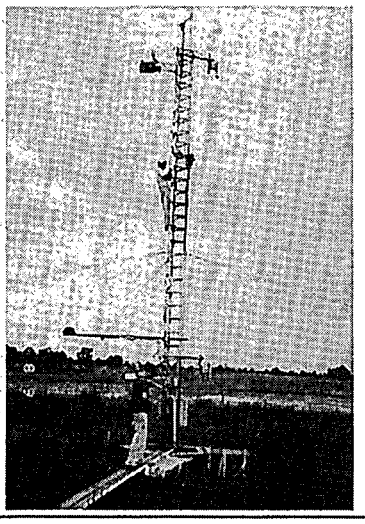
Differences in Research Subjects of Hydrology and Water Resources between Warm-Humid Tectonic Zone and Stable Regions

Land surface scheme for climate models

SiB2, one of the latest Land Surface Model developed in NASA: No scheme for paddy field.

→ By paddy scheme developed in GAME-T, the results of simulation were much improved (Kim et al, 2001)

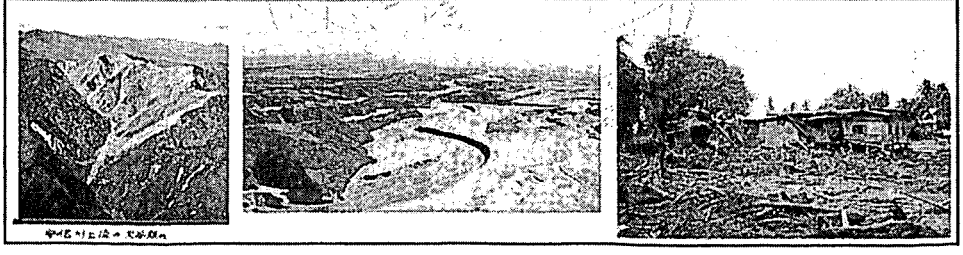
Heat/water flux observation in the paddy field station at Sukhothai, Thailand, carried out in GEWEX Asian Monsoon Experiment- Tropics (GAME-T)



Differences in Research Subjects of Hydrology and Water Resources between Warm-Humid Tectonic Zone and Stable Regions

Sediment yield and runoff

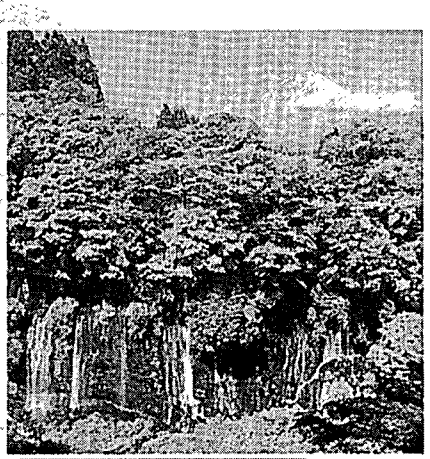
- **The source of sediment yield in stable regions is mainly soil erosion. The soil erosion/runoff processes formulated as Universal Soil Loss Equation (USLE) and Revised Universal Soil Loss Equation (RUSLE).**
- **We have other major sources of sediment in WHT zone in Asia, such as landslide, slope failure, volcanic eruption, debris/mud flow, etc..**
- **Although the estimation and prediction of sediment yield/runoff are very difficult due to their discontinuous nature, we should carry out systematical studies on them.**



Differences in Research Subjects of Hydrology and Water Resources between Warm-Humid Tectonic Zone and Stable Regions

Volcanic hydrology in Asian tectonic zone

- In Europe mainly composed of old geology, "Karst (limestone area) hydrology" becomes a specific field of hydrology.
- However, we do not establish yet a specific research field of "volcanic hydrology" in Asian tectonic zone.

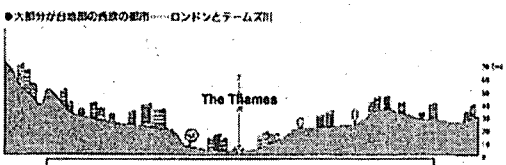


Mt. Fuji and its springs

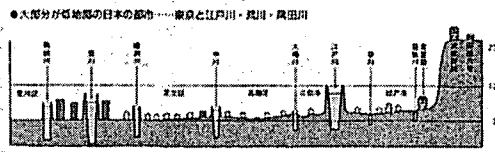
Differences in Research Subjects of Hydrology and Water Resources between Warm-Humid Tectonic Zone and Stable Regions

Flood plain management

- The awareness of flood plains seems to be considerably different between warm-humid tectonic zones and stable regions.
- Generally in stable regions, almost of river reaches are erosive and in those reaches the bottom of valley is flood plain , which is relatively only limited areas. Most of population lives on undulating terrains above the valley.
- In tectonic zones, we have large alluvial flood plains along the middle and down reaches of river, where a lot of people live and human activities are most active.
- Therefore the idea of flood-plain management is basically different between two regions.



The Thames River and London City Area : Flooding areas are so limited



Cross Section of Down Town Tokyo Metropolitan Area: Flooding areas are so large

In stable regions, they apply mainly non-structural measures such as land use restriction without the construction of flood control facilities like large-scale embankment, while we cannot help applying structural measures in tectonic zones.

Differences in Research Subjects of Hydrology and Water Resources between Warm-Humid Tectonic Zone and Stable Regions

Other research subjects particular to the warm-humid tectonic zone

- Precipitation mechanism and water resources variability in Asian monsoon climate, effects of ENSO/EL Nino on monsoon rainfall, etc..
- Irrigation/drainage technologies and water management peculiar to the paddy cultivation.
- Flood disaster mitigation, water supply and environmental conservation measures for urbanizing areas located in the low-lying alluvial plain.
- Water scarcity issues due to imbalance between water supply and demand (Although the WHT zone receives "too much water", it has "too little water" issues due to "too much water demand", especially for growing big cities like Bangkok, Manila, Jakarta, etc..).
- Dam construction harmonized with societal and natural conditions in Asia.
- *You can find out a lot of other research topics to be solved in Asia Pacific region.*

What Makes Regional Differences in Hydrology and Water Resources Research ?

- Physical, chemical and biological principles governing the hydrological phenomena are general and common in the world.
- However, researchers in the field of hydrology and water resources deal usually with research subjects surrounding them. (e.g. It is difficult even for an excellent researcher to develop the study on phenomena which does not exist surrounding him)
  In this sense, hydrological studies tend to be site- specific.
- Therefore, scientific concepts and/or methods developed in a specific region are not necessarily applicable to other regions since the phenomena themselves are strongly affected by geographical conditions.
- Also, targets of research in a specific region may be different from those in another specific region.
- In this sense, research subjects and results have considerable differences region by region, especially between tectonic zones and stable regions.

Summary

- In my talk, the main focus is placed on how to recognize the "too much water" problems in monsoon Asia, which are not adequately addressed in the world-wide international societies led by western people.
- For this purpose, a new macroscopic hydrological region, "warm-humid tectonic zone", is introduced, and water resources issues particular to the zone are discussed.
- On the other hand, there are also arid and semi-arid areas, and we should address many research and practical subjects to be solved for the water scarcity in Asian-Pacific regions.
- We can find out a lot of specific research topics particular to our region.

Summary - Introduction of "Asia Pacific Association of Hydrology and Water Resources (APHW)"-

- In order to encourage and promote the exchange of knowledge/experience in water resources management and cooperative research activities in our region, "Asia Pacific Association of Hydrology and Water Resources (APHW)" just launched 1st Sept. 2002.
- The First International Conference on Hydrology and Water Resources in Asia Pacific Region will be held in 13-15 March 2003 (just before the 3rd World Water Forum) Kyoto, Japan.
  (web site: http://www.wrrc.dpri.kyoto-u.ac.jp/~aphw/APHW2003/WWW/index.html)
- The membership is open for individuals and institutes of every country in the world. We expect that the Association will be grown up by the active participation of many researchers and practitioners in Asia Pacific region

Thank you very much

for your kind attention