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Review of the Researches on Changma and Future Observational Study (KORMEX)

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ABSTRACT

Changma is the most important supplier of water resource in Korea. However, its interannual variation may cause either floods or droughts time to time in many regions of Korea. A number of studies on Changma have been done in many subjects, such as the on-set and retreat timing, duration of Changma, and its interannual variation, which may cause either wet or dry Changma, and the heavy rainfall phenomena associated with the Changma front. Also, the subjects covered the dynamical situation of Changma compared to that of Baiu and Mei-yu as a part of East Asian monsoon circulation, and relation between Changma and tropical Pacific sea-surface temperature (SST) through atmosphere-ocean interaction, etc.

A numerical study is presented in this paper to check the teleconnection between the behavior of Changma front and the variation of tropical Pacific SST. The difference in the lower level streamfunction between the El Niño event of 1987 and the La Niña event of 1988 illustrates that the cross-equatorial and westerly wind crossing over the India and Indo-China peninsula were weak during the summer of 1988 compared to 1987. This may cause the drought of 1988 in East Asia by reducing moisture supply from the Indian Ocean and the south-western Pacific.

Even though there are numerous research activities on the Changma, our knowledge on the Changma is still limited to explain the mechanism of interannual variation of Changma and to provide a proper prediction of precipitation due to both geographical location of Korea and its complex topography. In collaboration with the international field observational projects, such as GAME and SCSMEX, the Korea Monsoon Experiment (KORMEX) has been planned by several scientists in Korea to improve our knowledge on the atmospheric circulation and water cycle related to the East Asian monsoon and to provide necessary information to predict both short- and long-term variation of rainfall during the Changma season.

Key words: Korea Monsoon Experiment (KORMEX), Changma, GAME, East-Asian monsoon

I. INTRODUCTION

Rainfall is one of the most important climatic variables to affect a great influence on the human life and industrial activities. In Korea the Changma provides more than 40% of the annual precipitation. Therefore, the rainfall in this period is an indispensable source of water for farming, industry and even for the daily lives in Korea. By its variation, however, it causes floods and droughts in many parts of Korea. Due to the importance of precipitation the King Sejong (1397–1450), who was the third king of the Choson Dynasty (1392–1910), invented "Chuck-u-gi", the first rain gauge in the world and ordered to keep records in the king's diary. Although the monitoring of rainfall and related technology was started and developed almost 550 years ago (Kim, 1990) (Figure 1), our knowledge on precipitation mechanism associated with the monsoon circulation, particularly on interannual variation of precipitation, is still not enough to predict the precipitation with confidence.

Fig. 1. Measurement of precipitaion with the ancient Korean rain gauge, "Chuck-u-gi" invented in 1441 by King Sejong of Chosen Dynasty.

Regardless of the importance of long-term records of both rainfall amount and rainy days to study the climate variability, the regular precipitation monitoring has been operated only on the limited area of earth until recently. Basically, the rainfall monitoring remains only on the land with not enough historical records. Considering that the ocean covers about 70% of the earth's surface, many scientists assert the limited surface rainfall monitoring is one of the serious obstacles to understand the global energy and water cycle.

Recently, remote sensing technique from satellite has been developed and enhanced to overcome the obstacle of ground monitoring (Arkin and Ardanay, 1989). In the mean time, the World Climate Research Program (WCRP) sponsored jointly by the World Meteorological Organization (WMO), International Council of Scientific Union (ICSU) and International Oceanographic Committee (IOC) launched a challenging research program so called Global Energy and Water cycle Experiment (GEWEX) to improve our ability to understand and predict the key elements of the energy and hydrological cycle (WCRP, 1990). The scientific steering committee of WCRP, which has investigated quantitative understanding and forecast of global as well as regional climate change, recognized the importance of heavy rainfall, floods and drought as a part of water cycle and initiated GEWEX since 1987. GEWEX is to study the exchange of energy and water between the atmosphere and the surface including many important atmospheric physical phenomena, such as global radiation balance and cloud formation, etc. To do this, first of all it has been planned to obtain a scientific understanding and technical experience on the regional atmospheric phenomena and then, to expand into global-scale phenomena. As its first step, there are five on-going or planning observation plans, such as GCIP (GEWEX Continental-scale International Project) in U. S. A. MAGS (Mackenzie River GEWEX Study) in Canada, LAMBADA (Land-Atmosphere Moisture Budget Studied over the Amazon by the Four-dimensional Data Assimilation) in Brazil, GAME. (GEWEX Asian Monsoon Experiment) in East Asia, and BALTEX (Baltic Sea Experiment) in northern Europe. In relation to GEWEX, Yasunari (1994) put forward a field observational experiment plan named as GAME (GEWEX Asia Monsoon Experiment) for better understanding of continental-scale hydrometeorological phenomena.

As pointed out by Yasunari, it is essential to understand the atmospheric circulation and water cycle related to the East Asian monsoon to predict both short- and long-term variation of rainfall in the Korea peninsula. The atmospheric variation on the seasonal time-scale resides mainly on slowly varying sea surface temperature (SST) anomalies even though the snow cover and soil moisture may affect significantly (e. g., Webster and Yang, 1992; Barnett et al., 1989; Dickson, 1984). Furthermore, the role of biosphere on the variation of precipitation should not be ignored because the biosphere is one of the important components not to be treated properly in the climate system.

Since the monsoon is one of the large-scale thermally-driven atmospheric circulations it is largely governed by atmospheric heating and cooling distributions. The strong monsoon years are characterized by the enhanced meridional temperature gradients over the monsoon Asia. Then it can be expected that the westerlies over East Asia are increased because of the thermal wind relationship. Many scientists assert a strong linkage in the variation between rainfall and of SSTs in the tropics (e. g., Shukla and Fennessy, 1991; Smith and Gordon, 1992; Rasmusson and Arkin, 1993). Variation of Asian monsoon also has a strong connection to the changes of SST of tropical Pacific (Yasunari and Seki, 1992). Such impact studies of tropical SST variation on the atmospheric circulation and associated changes of either global or regional precipitation pattern became one of the popular research subjects recently. For example, Lau (1985), Kang and Lau (1986), and Kang et al, (1987) studied the impacts of SST variation on the global scale atmospheric circulation and rainfall. Regional scale studies associated with SST variation also have been performed by Smith and Gordon (1992) for the Australia region, Hunt and Gordon (1991) for the North America region, and Folland et al. (1986) for the Africa. These studies clearly supported the existence of teleconnection between tropical SST to temperature and rainfall of the remote area.

In this study, we reviewed the characteristics of Changma in Section 2. To check the teleconnection between the tropical Pacific SSTs and the strength of Changma a numerical study on the behavior of Changma front with the variation of tropical SST has been presented in Section 3. Finally, the summary of Changma researches and future observational research work in Korea has been presented in Section 4.

II. CHARACTERISTICS OF CHANGMA

The East Asian monsoon generally is accompanied with the quasi-stationary front along the northern and northwestern periphery of the subtropical anticyclone in the boundary zone of the polar cold air mass and the tropical warm air mass. The rainy season in Korea so-called Changma accompanied with a belt-like maximum rainfall zone begins with the influence of the quasi-stationary convergence zone between the tropical-maritime airmass from the south and both continental and maritime polar airmass from the north. This maximum rainfall zone progresses northward with time. Park et al. (1988) characterized Changma front as follows: It is similar to Baiu front at the beginning period of the rainy season in the southern part of Korea. At this time the quasi-stationary front extends from South China to southern

Japan. In the later part of Changma season, the precipitation is usually generated by the eastward propagating disturbances which originate at the Yangtze River region.

Kim et al. (1983) reported that the most important factor on the prediction of onset and retreat is the variation of moisture tongue from the southern China. Park et al. (1985) showed that the dry / wet seasons over Korea were accompanied by changes in the location of 850 hPa maximum wind zone which corresponds to the northwestern edge of subtropical Pacific high. Furthermore, Park et al. (1988) examined the relationship among the onset of Changma of 1985 over Korea, the change of large–scale circulations over East Asia, the intensification of the southwesterly low–level jet stream along the northern periphery of the Pacific anticyclone, and the Indian monsoon westerly wind. They concluded that the onset of Changma is likely to be identified with the rapid rise of geopotential height over Korea at both 500 hPa and 300 hPa levels related to the eastward extending of the Tibetan high and the arrival time of the moisture tongue from the southeastern foot of Tibetan Plateau to southern Korea accompanied by the southwesterly strong low–level jet stream just to the south of the moisture tongue.

The decision of the onset dates and retreat of Changma is ambiguous because of different viewpoints on the definition of Changma. These can be determined based on either daily variation of rain and cloudiness or large–scale movement of quasi–stationary front and associated large scale circulation pattern. Another difficulty is originated in the multi–scale interaction from global to mesoscale, movement of quasi–stationary front can abruptly jump and retreat within a few days.

The criteria of the onset of Changma by Korea Meteorological Administration (KMA) are the following: (a) the duration of precipitation is more than 3 days, and (b) the quasi–stationary front is located over Korean peninsula. And the retreat is defined: the duration of non–precipitation exceeds 3 days and the quasi–stationary front moves northward from the peninsula. Climatologically, the establishment of convection over Korea signals the earliest stage of the onset of Changma. Fig. 2 shows the progression of the onset dates of Changma, based on station rainfall records (Kim, 1992). In Fig. 2 the onset date of the Changma is between 30 June to 10 July. The interannual variation of the onset dates and retreat of Changma are very high (Fig. 3). Generally the Changma begins in the late June and ends in the middle of July. And the onset and retreat of the Changma season vary year to year significantly.

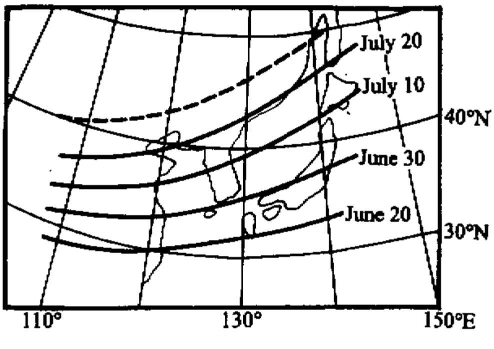

Fig. 2. Mean onset data of the summer monsoon in Korea (Kim, 1992).

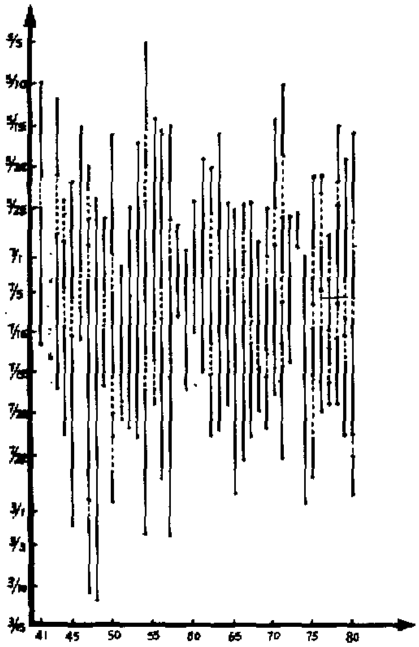

Fig. 3. Interannual variation of the onset dates and retreat of Changma (Lee and Kim, 1983).

Table 1. Character of the Changma for 10 years (1980–1989) (Ahn and Park, 1995)

year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Mean
onset date	6.16	6.19	7.10	7.14	6.16	6.23	6.23	7.2	7.2	6.24	
ending date	7.30	7.14	7.29	8.1	7.15	7.20	7.26	8.11	7.28	7.29	
Changma period (day)	45	26	20	19	30	28	34	41	27	36	30.6
850 hPa θ jump before the onset (°K / day)	2.5	1.6	1.9	5.7	1.8	2.7	2.6	1.7	2.9	5.5	2.9
Total precipitation amount during Changma period (mm / station)	407	336	161	190	300	377	308	514	286	353	323.2
Mean precipitation rate in Changma period (mm / day)	9.0	12.9	8.1	10.0	10.0	13.5	9.1	12.5	10.6	9.8	10.6
area mean 500 hPa Geopotential height at onset time (m)	5,820	5,820	5,825	5,825	5,800	5,820	5,810	5,820	5,830	5,800	5,817
500 hPa gph jump before the onset (m / day)	17	8	4	9	−2	10	12	10	5	15	9
area mean 200 hPa Geopotential height at onset time (m)	12,400	12,410	12,380	12,400	12,350	12,360	12,400	12,420	12,410	12,370	12,390

Table 1 summarizes characteristic features of the Changma phenomena in Korea (Ahn and Park, 1995). It can be observed in Table 1 that the Changma period varies from 19 days to 45 days and that the rainfall amount of Changma is directly related to the duration of Changma. The relative less rainfall during Changma is associated with short Changma period and the abundant rainfall is related to relatively long Changma period. Ahn and Park (1995) characterized the onset of the Changma by the abrupt jumps of the 850 hPa equivalent potential temperature of about 2.9 K / day and the 500 hPa geopotential height of about 9 m / day during 3–15 day period. They also did the ending of the Changma by the change of the zonal wind direction from westerly to easterly over Korea.

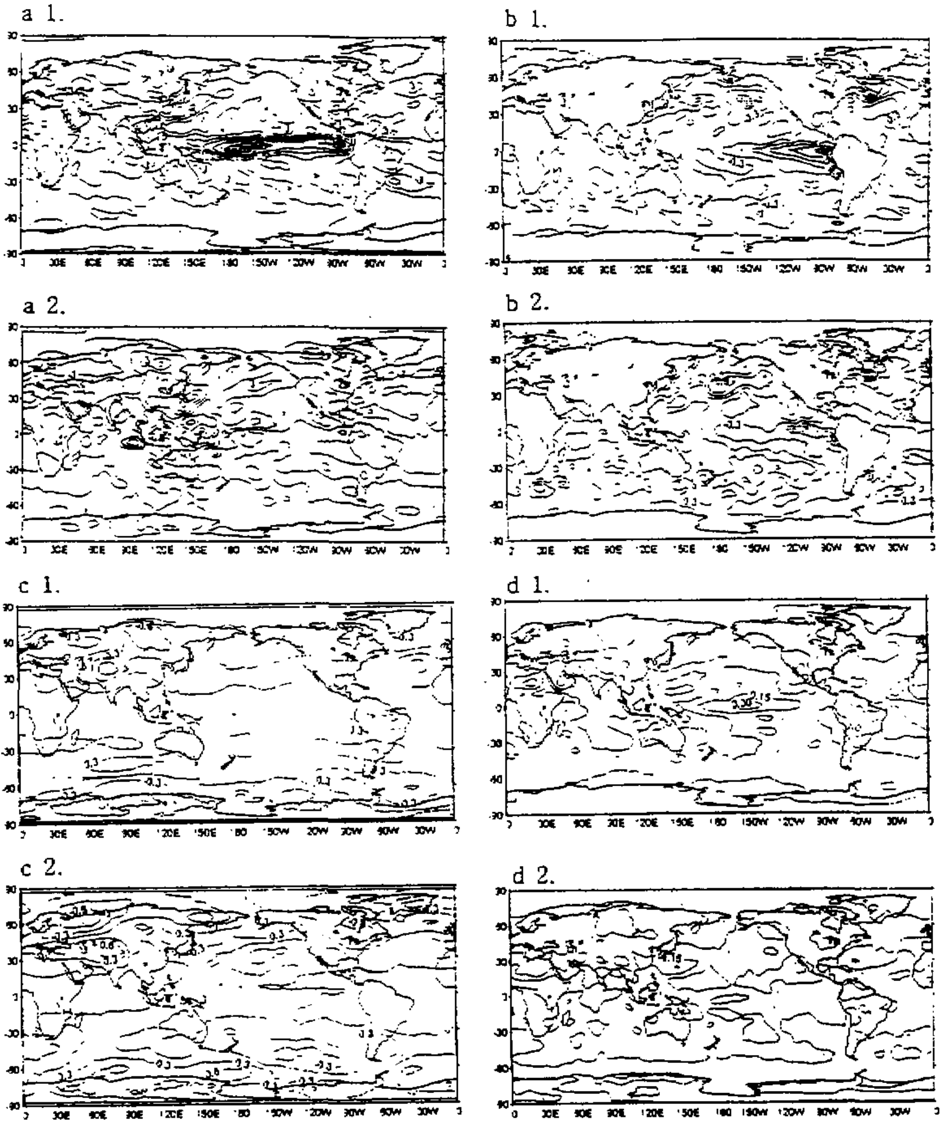

Fig. 4. Summer mean anomalies of (a) OLR, (b) SST, (c) MSU / BT, and (d) PW for the strong monsoon years and the weak monsoon years (Sohn and Han, 1985).

Lee (1989) examined the three-dimensional structure of the Northern Hemisphere summertime circulation for extreme summers (dry summer: 1982, wet summer: 1985) in Korea, and concluded that the dry / wet summer in Korea is characterized by the cold Arctic low and the low-level monsoonal southerly wind. For the wet summer, the low-level wind is much strong in East Asia than for the dry summer. Through the study of the characteristics of moisture transport during the Changma period and its role on the onset of Changma, Lim and Park (1991) found that the moisture transport in the southern China has been increased repidly about 4-5 days ahead of the onset of Changma. They reported that the moisture transportation in the southern China can be used as a predictor of the onset of Changma.

During the Changma season, the prevailing wind at the 850 hPa level is southwesterly, while there is no particularly significant prevailing wind at the surface. For the wet Changma season, the positive 500 hPa geoptential high anomalies are found over northern Pacific and the Okhotsk sea occasionally, while the negative over the middle latitude of East Asia. In contrast to the wet Changma, the reversed anomaly fields are observed during the dry Changma. The cross correlation between the monthly rainfall over Korea and the 500 hPa geopotential heights of Northern Hemisphere shows there is a positive correlation over the Northern Pacific and the Okhotsk sea, while the negative one is observed over the middle latitude of East Asia (Lee and Kim, 1983).

Recently, the low-frequency oscillation of the outgoing longwave radiation (OLR) and its anomaly were analyzed with respect to the variation of Asian monsoon (Lau and Chan, 1986). Since the Changma is a part of the monsoonal circulation in East Asia, this could be associated with the low frequency oscillation revealed in the OLR field. Sohn and Han (1995) used OLR over the East Asian monsoon domain (20°N-40°N, 115°E-150°E) as an index of overall convective activities and then, examined the interannual variability of the East Asian summer monsoon in relation to land-sea thermal contrast, convection, SST, and column precipitative water. The quasi-stationary front accompanying heavy-rain band is established over the South China Sea (SCS) and Taiwan during the period of mid May to mid June and then the front migrates northward to Korea and Japan area in mid June to mid July. They reported that East Asian summer monsoon area is located in the relatively small OLR regions, implying relatively strong convective activities and heavy rainfall, and the East Asian monsoon takes place in area showing large north-south gradients of the analyzed variables, i. e., the sea surface temperature (SST), Microwave Sounding Unit channel 2 brightness temperature (MSU / BT), and total precipitable water from TOVS estimates (PW) (Fig. 4). They reported that there is a certain relation between the strength of monsoon and the anomalies of OLR, SST, MSU / BT, and PW.

Climatologically, the regional heavy rainfall events over Korea are frequently produced by mesoscale disturbances developing on the Changma front. These disturbances are located in the domain between the north of low-level jet stream at 800-700 hPa and the south of upper-level jet stream near 200 hPa (Fig. 5) (Park et al., 1986).

The rainfall amount these events has a large portion of the annual rainfall amounts and often causes serious disaster in Korea. Thus, the variabilities of Changma rainfall is one of the most important problems because of is association with droughts and floods over Korean peninsula. There are several reports on the heavy rainfall mechanism associated with the Changma front with mesoscale model simulation. Lee and Hong (1991) tested the sensitivity of initialization procedures to mesoscale model simulation of heavy rainfall occurring in the

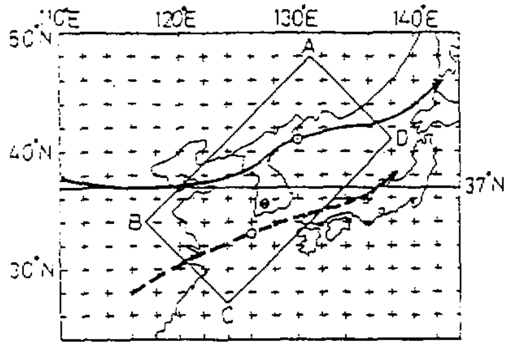

Fig. 5. Simple composite structure of the Changma front for the wet seasons. The mark +, ○ and ◉ stand for the grid point, the surface distribution center and the maximum wind center, respectively. The thick solid and dotted lines are jet axes at 200 hPa and 850 hPa, respectively (Chung and Kim, 1983).

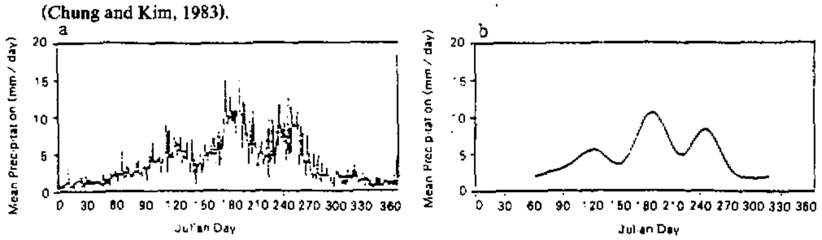

Fig. 6. (a) Annual distirbution and (b) its smoothed one of the daily precipitation amount obtained from 88–year daily observation at Pusan, Korea (Kwon and Park, 1995).

Korean peninsula, and Wee and Lee (1994) did the semi–prognostic tests for validation of underlying assumption and sensitivity concerning with internal parameters on heavy rain events over the Korea.

During wet season, the variability of daily rainfall distribution in Korea has a strong linkage with East Asia circulation since the Changma front is a part of the summer monsoon system in East Asia. Lee and Kim (1992) supported this strong linkage through the analysis of rainfall data over South Korea during the Changma period (June and July) from 1980 to 1989. Over the Pacific, the moisture moves slowly to the north until mid July, however, during early August the intensity of the transport is weakened (Kang et al., 1991). They reported that there is the largest climatological variation along the east coast of Asia. Sohn and Han (1995) suggested that the anomalous moisture over East Asian monsoon regions is more likely related to dynamically induced convergence or divergence of water vapor rather than direct air–sea interactions.

The annual distributions of daily precipitation amount, intensity, and probability over Korea are characterized by the three dominant peaks: the first spring peak is associated with synoptic system passing over Korea in early May, the second one is known as Changma in early July, and the last in early September is known as the 2nd Changma (Fig. 6). Kwon and Park (1995) found some distinguished features of these three peaks through the investigation of the variability of annual rainfall distribution, the maximum value and its occurrence date of the daily precipitation records at Pusan in the period of 1904 to 1992 and at Mokpo in the period of 1906 to 1992. For the 2nd Changma the maximum precipitation amount and intensity show statistically significant positive trends, while the maximum probability of precipitation occurrence shows a negtive trend. It may be explained by both influence of the typhoon and the variation of the East Asian monsoon. Meanwhile, a significant positive trend is observed in the maximum intensity at the spring peak and occurrence date of maximum probability at the lst Changma peak. Also, a negative trend has been observed in the occurrence date of maximum probability during spring peak in both stations.

III. IMPACTS OF TROPICAL SST ON THE CHANGMA

In order to study the strength of monsoon in conjunction with the variation of the large-scale atmospheric circulations, many researchers have categorized the monsoon years as either "strong" or "weak" monsoon (Meehl, 1987; Webster and Yang, 1992; Huang and Sun, 1992; Lee and Kim, 1992; Sohn and Han, 1995). The strong East Asian monsoon might be associated with the strengthened westerlies over East Asia. By contrast the increased north-south temperature gradient across the Indian sub-continent may lead to the weakening of the predominant upper-level tropical easterly jet which is considered as one of important elements maintaining the Indian summer monsoon. Since the reduced easterlies often indicate the weak Indian summer monsoon (Krishnamurti and Kanamitsu, 1981), these findings suggest an opposite characteristic between the East Asian and Indian monsoon.

One of great switching of weak monsoon and strong monsoon occurred during the late 1980s. The years of 1987 and 1988 were recorded as one of extremes of monsoon activity over both Asia and Africa. During the summer of 1987, rainfall over India was well below the long-term average, while that of 1988 was well above this average. These extremes in monsoonal rainfall are related to disruption of global SSTs which might be associated with the El Niño events. Recently, Misumi (1994) reported that Japan has less (more) monsoonal rainfall, when the convective activities become active (inactive) over the ocean near Philippines. Nitta (1986) named this teleconnection as the Pacific-Japan pattern. Kurihara and Tsuyaki (1987) summarized that sea-level pressure near Korea and Japan has a tendency of increase by propagation of the Rossby wave, which might be generated as a result of strong convective activities over the tropical ocean near Philippines.

The changes of atmospheric circulation and rainfall pattern of Changma have been investigated with the Meteorological Research Institute / Yonsei University general circulation model (METRI / YONU GCM) Tr 7.0 (Oh et al., 1994; Oh, 1996) through the Atmospheric Model Intercomparison Project (AMIP) (Gates, 1992). The detailed evolution of Asian monsoon of 1987 and 1988 are presented in Figs. 7 (a) and 7(b), respectively. In both figures there are six panels representing a sequence of monsoonal rainfall evolution during June. Each panel presents the mean precipitation field of five days in the order of top-lift panel for June lst to 5th, middle-left panel for June 6th to 10th, ..., and bottom-right panel for June 26th to 30th, respectively.

In both Figs.7(a) and 7(b), the basic pattern of rainfall consists of three major bands. The most dominant rain band is the tropical rain band along the inter-tropical convergence zone (ITCZ) from the south of Arabian peninsula the to equatorial Pacific with local precipitation maximum associated with strong convection over the ocean near Indonesia and Philippines. Another rain band is along the southern Pacific convergence zone (SPCZ) over the east of Australia. The other is the monsoonal quasi-stationary rain band over China to Korea which has been known as Changma in Korea, Mei-yu in China and Baiu in Japan.

Comparing the Figs.7(a) and 7(b), we may observe some details: first, the rainfall over India during 1988 is much more than that of 1987 except the first pentad. This feature of

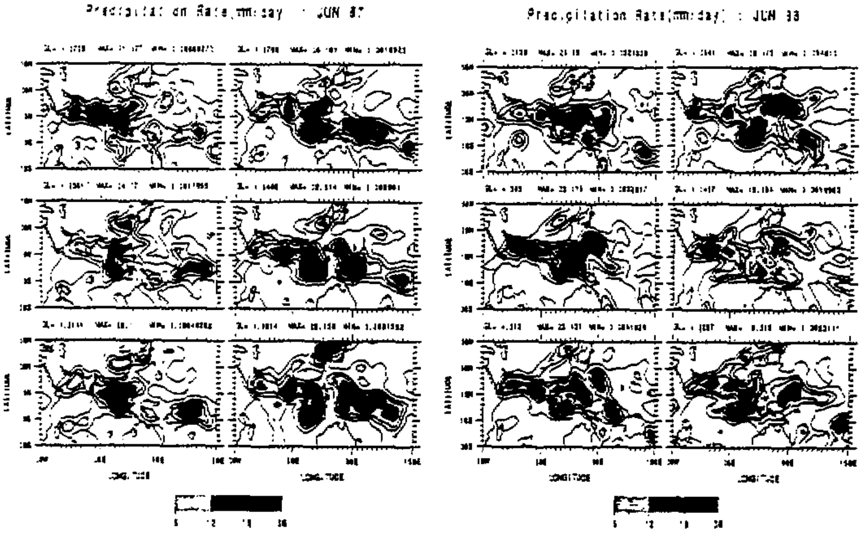

Fig. 7. Precipitation pentads during June 1987 (a) and June 1988 (b), respectively. The upper left pentads of (a) and (b) are for the mean of lst to 5th, the upper middle for 6th to 10th, ..., the right bottom for 26th to 30th. The unit is mm / day.

relative wet June of 1988 and dry June of 1987 is in good agreement with the observation. Another interesting feature observed in comparison of those figures is the behavior of quasi-stationary front over China and Korea. In both figures the individual local precipitation maximum pops out from the SCS and marches toward the sea Okhotsk along the quasi-stationary monsoon front. Note that this local precipitation maximum might be associated with the generation and movement of low pressure system during monsoon season in this region.

The characters of Asian summer monsoon is mainly determined either for wet or dry conditions by the fluctuation of quasi-stationary monsoon front instead of the behavior of individual low pressure system marching along the quasi-stationary front. One of the significant differences in the quasi-stationary front between 1987 and 1988 is in its northward movement. The quasi-stationary monsoon front is located to the south of Korea peninsula in mid-June, however, it moved slowly toward northward and reached Northeast China at the end of June as shown in Fig.7(a). From this figure we may characterize the simulated June of 1987 as a wet season in East Asia including Korea, China and Japan and a dry season in India. Different from 1987, the climate of 1988 can be conversely characterized as a dry season in East Asia with strong convective activities over the tropical ocean near Philippines and a wet season in India. The quasi-stationary monsoon front had been located at further north region compared to that in 1987 so that China, Korea and Japan have less rainfall with a short summer monsoon period. One of the reasons of this northward shift of quasi-stationary monsoon front during 1988 is strong convective activities over the SCS. The descending air at the mid-China, Korea and Japan, which may be occurred to compensate the ascending air over the SCS due to strong convection associated with relatively warm SST in this region, may prohibit the propagation of lows poked out from the SCS to this region and push the quasi-stationary front to further north.

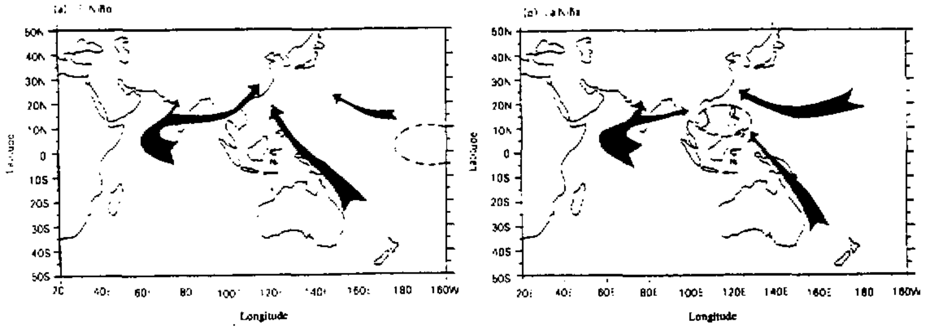

Fig. 8. Schematic illustration of difference in the moisture movement for the case of (a) El Niño and (b) La Niña. The active convective region is shaded.

From the comparison of summer monsoon between 1987 and 1988 known as a typical El Niña and La Niña period, the characteristics of monsoon can be determined either for wet or dry condition in East Asia mainly by the fluctuation of three major moisture supply routes (Fig.8). The variation of SSTs of the western Pacific disturbs the atmospheric circulation in the East Asia. The enhancing or vanishing of convective activities over the ocean near philippines by movement of warm pool causes a disturbance in the low monsoonal circulation in particular in the lower level wind fields. The enhancing of convective activities over the ocean near Philippines reduces the moisture supplies with cross–equatorial flow from the south western Pacific and westerly flow cross–over the India and Indo–China peninsula, even though it enhances the rotational flow associated with the northern Pacific high and Asian continental summer low as presented schematically in Fig. 8.

In contrast to above La Niña situation, for the El Niño case the eastward movement of convective activities to the central Pacific provides a condition of enhancing the supplies of moisture by increasing the cross–equatorial flow over the western Pacific as well as allowing the further eastward moisture advection from the Indian Ocean to the SCS and then, to the inner China. This enhancing low level moisture supplies may provide a wet summer monsoon in East Asia. The enhancing zonal westerlies over the India and Indo–China may cause less rainfall over India. Thus, the Indian monsoon and East Asia monsoon are under a kind of seesaw situation. The variation of tropical SSTs in the western Pacific may provide either a wet summer monsoon in East Asia, whilea dry summer monsoon in India at the same time or vice versa.

IV. SUMMARY OF RESEARCHES ON CHANGMA AND FUTURE OBSERVATIONAL STUDY (KORMEX)

1. *Summary ofResearches on Changma*

The characteristics of Changma have been analyzed in several ways: the climatological description, the case study of the synoptic situations, mesoscale numerical model, and GCM. The annual rainfall variation associated with Changma was analyzed by Moon (1981), Chung and Kim (1983), Park et al. (1989) and Lim et al. (1991). They investigated the characteristics of unusual rainfall variability and the role of Changma in the variation of total annual precipitation amount. In 1980's, several investigators employs the EOF analysis to seek the rainfall patterns in Korea (Seo et al., 1982; Ho and Kang, 1988). The synoptic patterns during Changma period were examined by many scientists (Kim et al., 1983; Park et al., 1985, 1986, 1988, 1989). Also, Oh (1996) reviewed the impacts of SST changes on the strength of Changma and found the rainfall variation in Korea is strongly related to the variation of tropical SST.

Since 1980's, the large scale features associated with the Changma heve been studied experimentally and analytically (e. g., Moon, 1981; Kang et al., 1991; Sohn and Han, 1995), and the charateristics of Changma system been also warmly studied by analyzing the mean structure of the dynamics and thermodynamics concerning Changma front during the flood / drought in Korea peninsula (Kim et al., 1983; Chung and Kim, 1983; Sohn and Han, 1995). There are several reports on the heavy rainfall mechanism associated with the Changma front based on mesoscale model simulation (e. g., Lee and Hong, 1991; Wee and Lee, 1994).

With such a number of research activities, however, our knowledge on the Changma is still not enough to provide a proper prediction. Also, the mechanism of the development of a heavy rain–producing disturbance along the Changma front has not been understood sufficiently, although it is an intriguing issue.

2. *Future Observational Study (KORMEX)*

The Korea located in the zone of mid–latitude westerlies is surrounded with ocean so that it is affected not only from the large contrast in heat capacity between land and ocean, but also from the local effects of its own complex topography. As a result of these effects there are very distinctive regional weather events and climate. The proper monitoring of large scale weather event is not a simple task, however, that of local extreme weather events is even more difficult task, due to their temporal and spatial scales. As a result, it is hard to expect a forecast with confidence.

Changma brings about 40% of annual total rainfall amount (1,300 mm) in Korea during the short transitional period of spring and summer and plays an important role as the major supplier of national water resource. Meanwhile, it causes a natural disaster related to water supply by its large interannual variation. Hong (1996) reported that the most frequent meteorological disaster in Korea is the heavy rainfall during the Changma season with 30% of occurrence among all natural disasters and the property losses due to this heavy rainfall reach 70% of total property loss in Korea. The 1995 winter drought in the southern part of the Korean peninsula was directly related to the relatively dry Changma of 1994. In the estimation of property losses due to natural disaster the impact of drought has been omitted due to the difficulty to be estimated quantitatively. However, total loss will grow into several times of the property damage by heavy rainfall alone.

To protect the human life and properties from the natural disaster it is absolutely necessary to monitor the causing severe weather events properly and to forecast with confidence. With this circumstance the reasonable prediction of seasonal and temporal precipitation might be one of the most urgent things to be done within near future. In order to achieve this goal, first of all, it is the most urgent task to monitor the extreme weather event precisely, to analyze the monitoring data carefully and to understand this event exactly.

The accurate prediction of the onset of the Changma with the evolutionary features of large scale circulation over East Asia is imperative for the preparation of natural disasters that may occur during Changma period over Korea. However, as the evolution features of summer monsoon system over East Asia, that of Changma system also is not well understood yet. Many scientists of East Asia and other countries including U.S.A. and Australia recognized the importance of understanding the atmospheric circulation and water cycle related to the East Asian monsoon to predict both short- and long-term variation of rainfall and set a plan to collaborate on the monitoring of the East Asian monsoon in China several years ago. The major planned projects are GAME and SCSMEX (South China Sea Monsoon Experiment) to improve the understanding on the role of East Asian monsoon in the energy transfer and water cycle of the global climate system and enhance the capability to forecast. To do this GAME has a plan to campaign four field experiments in the Asian continent in 1998 with preparation period of 1994-1997.

The participation of Korea in the GAME and SCSMEX project may provide a unique opportunity to establish a reasonable Changma monitoring system and to enhance the confidence of long-term precipitation forecast. To do this, the Korea Monsoon Study Panel (KMSP) has been organized in 1995 including the experts from KMA, universities and research institutions. KMSP provided a science plan of KORMEX (Korea Monsoon Experiment) in March, 1996. The practical purposes of KORMEX are to produce a data set of Changma and heavy rainfall, to understand the mechanism of Changma and heavy rainfall, and to improve the predictability. To achieve these goals successfully and systematically, the steering structure of KORMEX has been constructed as presented in Fig. 9.

There are two main distinguished tasks in KORMEX: The first task is to provide a system to produce, collect and manage the necessary data to study the interannual variation of Changma and to validate the simulation of seasonal situation of this variation. The second is to enhance the prediction capability through the dynamical and physical studies on Changma

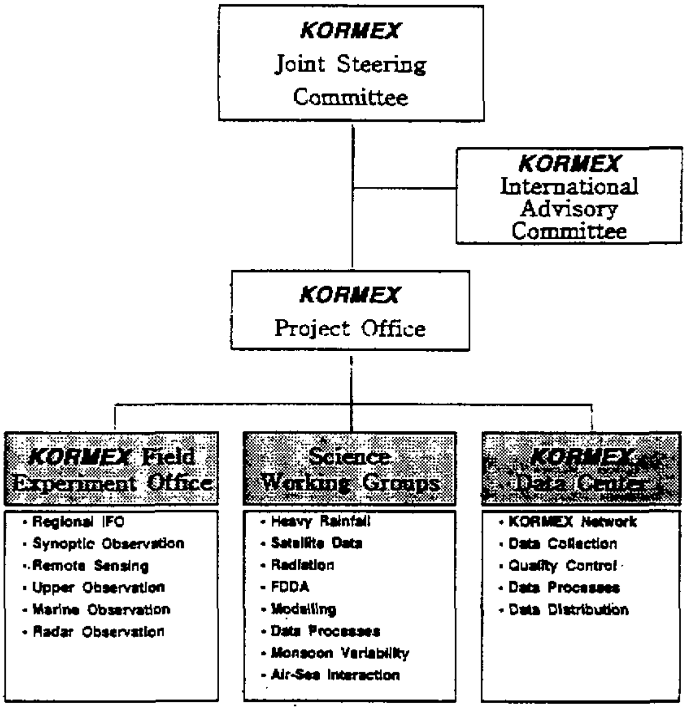

Fig. 9. Steering structure of KORMEX.

modelling based on the above data set.

The KORMEX data will be produced through both ground observation and satellite monitoring. The ground observation will utilize all available observing system in Korea, such as 400 AWS stations, 4 radiosonde stations, wind profilers, two NEXRADs, bi–static radar and regional intensive field observation campaign at the catchment of the mid–west part of Korea peninsula, etc. The satellite monitoring will be conducted by the remote sensing group with the data of GMS–5, TRMM and ADEOS–1. In KORMEX project the national climate data center will be set up to produce, collect, verify and distribute KORMEX archives data to users. Also, the verified data and 4–DDA data will be distributed to the researchers and operational personnel to assist estimation of mass circulation, energy and water distribution and variation near Korea peninsula. This climate data center will coordinate with GAIN (GAME Archives Information Network) to communicate the essential data to study East Asian monsoon with neighboring countries.

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