Underestimation characteristics of TRMM 2A25 V7 near surface rain over and around the Meghalaya Plateau

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Utilizing our original tipping bucket raingauge network over Bangladesh and northeast India (Fig. 1), we have detected underestimation of the near surface rain in TRMM 2A25 V7 dataset over and around the Meghalaya Plateau. This underestimation was prominent especially in the monsoon season. Such underestimation of TRMM PR sensor was detected in other mountaneous areas also (Prat and Barros 2010; Wilson and Barros 2014; Terao et al. 2017).
In the present study, we further analyzed the characteristics of underestimation utilizing TRMM 2A25 V7 and raingauge dataset. In TRMM 2A25 dataset, rain type is defined for each ray to distinguish stratiform and convective rainfalls. We evaluated the contribution to the underestimation from different types of rainfall (Figs. 2 and 3) for two regions, Meghalaya and Sylhet-Barak areas, with different orographic situation. In these figures, we evaluated the averaged contribution ratio and their 95 % confidence intervals for each rain type. These confidence intervals were evaluated by the boot-strap method. The Meghalaya area is the hill area in India, and Sylhet-Barak area is the northeastern part of the Bengal Plain, which consists of both Sylhet Division in Bangladesh and Barak Basin in Assam, India.
Figure 2 shows that the underestimation has been highly contributed by stratiform rain over the Meghalaya Plateau. Averaged for the stratiform rain cases, rainfall intensity detected by raingauges was greater than 6 mm h^{-1}, with more than 50 % negative bias ratio. Most notable result was the high contribution of the no-rain detected cases. We detected tipping of raingauge more than 5 % out of TRMM 2A25 no-rain detected cases. For other areas, this ratio was much less than 0.5 %. Over the Sylhet-Barak area, underestimation was explained mainly only by the convective rain (Fig. 3). Thus, although the areas of underestimation in TRMM PR sensor were geographically adjacent to each other, the cause of the underestimation was largely different.
For near nadir cases, the clutter free bottom height (CFB height) of the ray tends to be lower. Therefore, we checked the impact of the angle of ray to check its impact on the underestimation (not shown), but we found no clear tendency.

Keywords: TRMM, PR, underestimation, northeastern Indian subcontinent

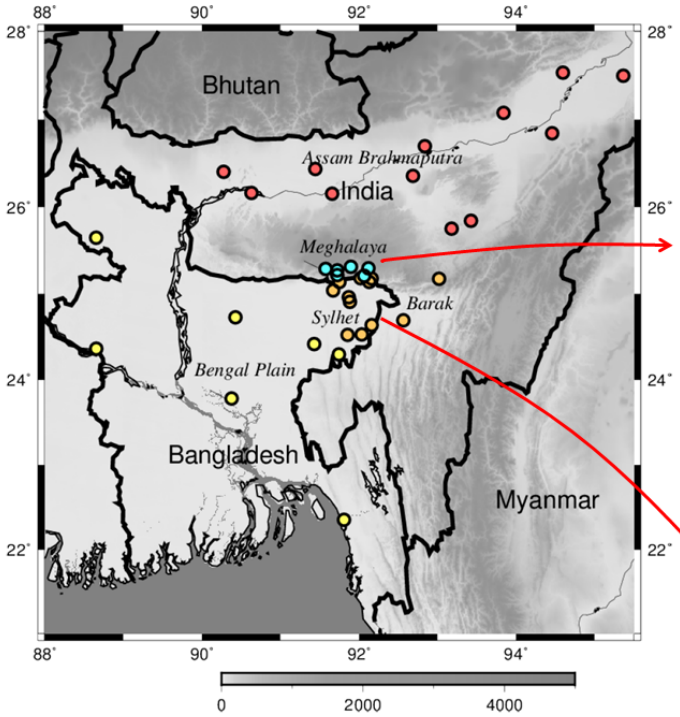

Fig. 1: Raingauge network

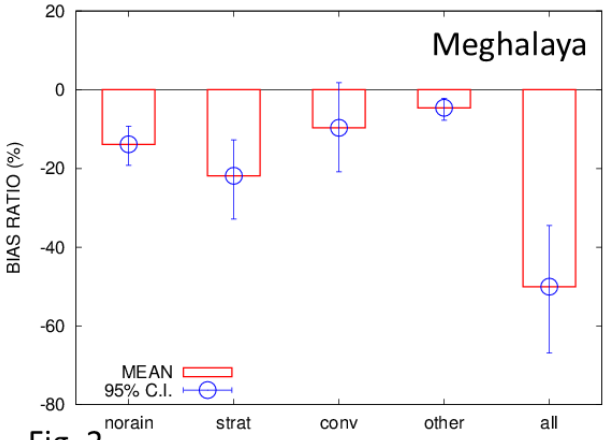

Fig. 2

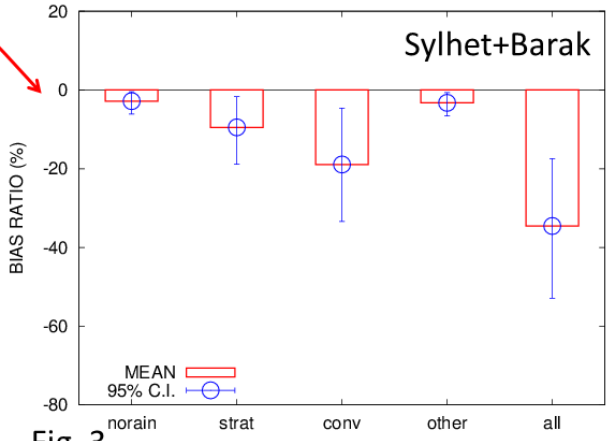

Fig. 3

Impact of land-use change on terrestrial water balance in the Chao Phraya River Basin

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Deforestation in the mountainous upper-reaches of the Chao Phraya river has been worried to enhance floods in the lower reaches. To cope with this issue, afforestation is expected to reduce the risks of floods by increasing water holding capacity and slowing the response of discharge. On the other hand, afforestation has impacts not only on the terrestrial water balance and the water resources/uses, but also on the social and economical issues, e.g., reduction in income due to decreases in croplands. Thus, the impacts of deforestation/afforestation should be carefully assessed. The water resource assessment has been conducted by a global hydrological model (H08; Hanasaki et al., 2008ab) in this region, but effects of land-use change have not explicitly examined since a bucket-type model without an explicit consideration for vegetation type is used for the land surface scheme of H08. Then, another land surface model, MATSIRO (Takata et al, 2003; Nitta et al., 2014) that includes processes of vegetation canopy is used to examine the impacts of vegetation change on the terrestrial water balance in the Chao Phraya river basin. In the numerical experiments, near surface meteorological conditions were given, and the results with the present and cultivated vegetation distributions were compared. The preliminary experiments were conducted at a horizontal resolution at 1°×1° from 1 January, 1979 to 31 December, 2007 with the meteorological data by Kim et al., (2009).
The calculated river discharge in the northwestern upper-reaches of the basin, where natural vegetation is broad-leaf evergreen forest, has been compared with the observed inflow of the Bhumipol dam, and that in the northeastern upper-reaches where natural vegetation is mixed forest has been compared with the observed inflow of the Sirikit dam. The observed seasonal change of river discharge, that shows an increase from July to September and a decrease in October, has been roughly presented by the calculation on the northwestern point, but the observed small peaks in May and June has not appeared. Besides, the calculated discharge was concentrated in August on the northeastern point where observed one showed a gradual increase in July and a decrease in September. Moreover, the calculated annual discharges were smaller by a few factors than observed ones. As for the calculated differences due to the land-use change, the beginning time of river discharge was later and the annual discharge was smaller for broad-leaf evergreen forest than cropland, implying the mitigation effect for floods by forest. In contrast, the beginning time of discharge did not show a significant difference and the annual discharge was larger for mixed forest than cropland.
A high-resolution experiment will be conducted using a 5'×5' meteorological data in the Chao Phraya river basin (Kotsuki et sl., 2013). The model and its settings will be improved for better representation of the observed river discharge. The reason for different response to land-use change for different types of forest will be examined, to understand and quantify the impacts of land-use change on the terrestrial water balance and the water resources.

Acknowledgements: We acknowledge Dr. Tomoko Nitta at University of Tokyo and Dr. Shunji Kotsuki at RIKEN as to help conducting the offline MATSIRO experiments. This research is supported in part by Science and Technology Research Partnership for Sustainable Development (SATREPS) program by Japan Science and Technology Agency (JST) and Japan International Cooperation Agency (JICA).

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Keywords: Land-use change, Terrestrial water balance, Chao Phraya river basin

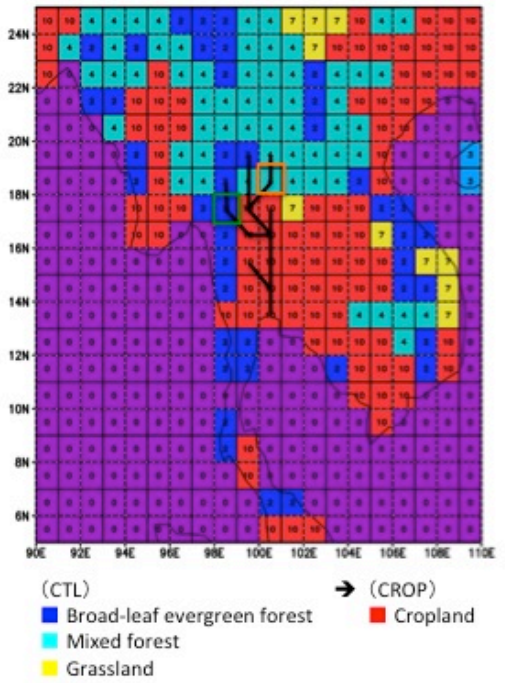

Figure Land-use distribution used in the preliminary experiment. Black lines indicate river route of the Chao Phraya river. Boxes (orange and green) are the grid points compared with observed river discharge.

An analysis of the atmospheric circulation around the Tibetan Plateau revealed by the stable isotope in precipitation—A case study of GEWEX-GAME/Tibet in 1998

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Data of stable isotopes obtained from glaciers and tree rings on the Tibetan Plateau are useful in restricting the paleoclimate. It is important to meteorologically analyze stable isotopes in precipitation over the Tibetan Plateau, which are affected by complicated atmospheric circulation processes, because the ratio of stable isotopes in precipitation based on the transport process is affected by atmospheric circulation. However, this approach has not yet been well implemented.
Data of temporally and spatially stable isotopes in precipitation were obtained over the Tibetan Plateau and Nepal during a field campaign of the Global Energy and Water Experiment Asian Monsoon Experiment/Tibet in 1998. The data reveal a relationship between stable isotopes in precipitation over the Tibetan Plateau and active/break variations of the Indian monsoon.
During a break phase, low $\delta^{18}O$ values and low d-excess values were observed at all observational sites. Transportation in this phase was an upslope process in which an air parcel gains altitude near the Himalayas. This trend can be explained by air parcels crossing over the Himalayas.
During an active phase, a characteristic trend of stable isotopes in precipitation over Tibetan Plateau was observed. Low $\delta^{18}O$ and low d-excess values were observed around the south of the Tibetan Plateau (hereinafter called region 1) while high $\delta^{18}O$ and high d-excess values were observed around the north of the Tibetan Plateau (hereinafter called region 2). The phase of region 1 coincided with the break phase, and transport might be an upslope process. However, the phase of region 2 was different because of the inland effect. To interpret the high $\delta^{18}O$ values, we used the forward trajectory from convective cloud over central India, and examined the top height of convective cloud around region 2 over the Tibetan Plateau using measurements made by the precipitation radar onboard the Tropical Rainfall Measuring Mission satellite. Results showed that air parcels at an altitude exceeding 8,000 m in convective cloud around central India were transported to the Tibetan Plateau, and high $\delta^{18}O$ values between 8,000 and 10,000 m in convective cloud around central India might be associated with precipitation around region 2 over the Tibetan Plateau.
To interpret the characteristics of stable isotopes in precipitation around the Tibetan Plateau, it is important to consider the active/break phase and trajectory of air parcels of the Indian monsoon. Clarifying the vertical distribution of stable isotopes in precipitation in convective cloud can improve our knowledge of the paleoclimate and help determine an isotope model in future work.

Keywords: stable isotope in precipitation, the Tibetan Plateau, atomospheric circulation

Heavy rain prediction applying satellite-based cloud data assimilation over land

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For accurate flood prediction, warning systems, and optimized dam control, information of positional relationship between rain areas and river basins is crucial. This requires very fine precision in the prediction of rainfall areas. Assimilation of satellite-based microwave observation of cloud has great potential to improve precipitation areas because it can directly obtain information on rainfall locations as well as amount of cloud. However, it is difficult to observe clouds over land using satellite microwave remote sensing, because land emissivity is much stronger and more heterogeneous than that of cloud. To overcome this challenge, appropriate representation of heterogeneous land emissivity is needed. Thus, We developed a Coupled Atmosphere and Land Data Assimilation System with the Weather Research and Forecasting model (CALDAS-WRF), which can assimilate soil moisture, cloud water content over land, and heat and moisture within clouds simultaneously. Results of application of CALDAS-WRF to heavy rain events show that the system effectively assimilated cloud signals and produced very accurate cloud and precipitation distributions with appropriate intensity. Also, the local atmospheric fields are modified appropriately around the area of assimilated clouds. Furthermore, by using operationally analyzed dynamical and moisture fields as initial and boundary conditions, the system improved prediction of precipitation duration. The results demonstrate the method’ s promise in dramatically improving predictions of heavy rain and consequent flooding.

Keywords: cloud assimilation, remote sensing, heavy rain prediction

Regional seasonal marches of precipitation and their long-term variations in India for 1901-2013

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Regional characteristics of climatological seasonal marches of precipitation and their long-term variations have been examined for the period 1901-2013 in India using a high resolution (0.25˚×0.25˚) daily gridded precipitation dataset provided by the Indian Meteorological Department.
Cluster analysis (Ward’ s method) was applied for the 30-year climatological 5-day precipitation (1981-2010) at each grid box, and nine regions were divided. Then changes of seasonal precipitation characteristics, including onset, peak, and retreat of rainy season were examined for the 113-year period from 1901-2013 in a regional basis. As a result, for example, in the west coast area where typical monsoonal seasonal changes are observed, a prominent precipitation peak appeared in July prior to 1940, while precipitation in the subsequent rainy season in August has increased during the 20th century, and the degree of concentration of precipitation in July has decreased after the 1940s.

Keywords: India, precipitation, climatic variation

Predictable and unpredictable monsoons

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MAHASRI renewed GAME both in scientific and non-scientific aspects of monsoon-related issues. The infrastructures for hydro-climatological observations have been improved by economic growth and public needs. Now we can distinguish the predictable and unpredictable parts of monsoons, and must do it. The monsoonal or rainy-seasonal cycles are originated from the insolation varying astronomically with season and latitude, and are amplified geographically mainly with the solid (land) - liquid (sea) heat capacity contrast on the Earth's surface. The former astronomical process is completely predictable as described in a classical agricultural calendar which might have been changed gradually by the recent global warming. In addition, most of geographical variabilities of Asia monsoon have been revealed by GAME-MAHASRI periods. At first we must perfect to archive them, to let everybody know them, and to apply them for agricultural application, disaster prevention, and so on. Those parts might be still supported by so-called developed countries including outside of the monsoonal Asia, but are not so many in my view. At last we will recognize the truly unpredictable parts, which may be varying dynamically or even indeterministically due to nonlinear or multivariate processes. These remainder parts are so truly pioneering/challenging and/or domestic that any advanced countries can never support them. In this meaning now we are entering into indeed a qualitatively new era.

Keywords: monsoon, science and society, international collaboration

Dynamics of changing impacts of tropical Indo-Pacific variability on Indian and Australian rainfallDynamics of changing impacts of tropical Indo-Pacific variability on Indian and Australian rainfall

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A positive Indian Ocean Dipole (IOD) and a warm phase of the El Niño-Southern Oscillation (ENSO) reduce rainfall over the Indian subcontinent and southern Australia. However, since the 1980s, El Niño’s influence has been decreasing, accompanied by a strengthening in the IOD’s influence on southern Australia but a reversal in the IOD’s influence on the Indian subcontinent. The dynamics are not fully understood. Here we show that a post-1980 weakening in the ENSO-IOD coherence plays a key role. During the pre-1980 high coherence, ENSO drives both the IOD and regional rainfall, and the IOD’s influence cannot manifest itself. During the post-1980 weak coherence, a positive IOD leads to increased Indian rainfall, offsetting the impact from El Niño. Likewise, the post-1980 weak ENSO-IOD coherence means that El Niño’s pathway for influencing southern Australia cannot fully operate, and as positive IOD becomes more independent and more frequent during this period, its influence on southern Australia rainfall strengthens. There is no evidence to support that greenhouse warming plays a part in these decadal fluctuations.

Keywords: Monsoon, ENSO, IOD

Dominant synoptic disturbance in the extreme rainfall at Cherrapunji, northeast India, based on 104 years of rainfall data (1902-2005)

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The characteristics of active rainfall spells (ARSs) at Cherrapunji, northeast India, where extreme rainfall is experienced, and their relationships with large-scale dynamics were studied using daily rainfall data from 1902 to 2005 and Japanese 55-year reanalysis from 1958 to 2005. Extreme daily rainfalls occur in association with ARSs. The extremely large rainfall amounts in the monsoon season are decided by a cumulative rainfall during ARSs. ARSs start when anomalous anticyclonic circulation (AAC) at 850-hPa propagates westward from the South China Sea and western North Pacific, and covers the northern Bay of Bengal. The AAC propagates further westward and suppresses convection over central India during ARSs at Cherrapunji, and continues for 3 to 14 days. Consequently, a northward shift of the monsoon trough during the 'break' in the Indian core region occurs. The westerly wind, which prevails in the northern portion of the AAC, transports moisture toward northeast India and enhances moisture convergence over northeast India with southerly moisture transport from the Bay of Bengal, and greatly intensifies the orographic rainfall. In the upper troposphere, the Tibetan high tends to extend southward with the onset of ARSs. A linear relationship can be seen between the length and total rainfall of an ARS. Longer ARSs tends to result in greater total rainfall. AACs with a greater zonal scale tend to produce longer and more intense ARSs. This study provide a certain evidence for the effect of AACs in the western North Pacific on the Indian summer monsoon.

Keywords: extreme rainfall , Indian summer monsoon, intraseasonal variability, orographic rainfall

Characteristics of the Rainfall over Luzon during the Summer Monsoon of the Philippines

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The changes in rainfall over Luzon Island during the summer monsoon of the Philippines are investigated using averaged pentad rainfall data from 1981-2010. A monsoon break (P32 to P34; Jun. 5 to Jun. 19) after the climatological onset (P29, May 21 to May 25) was identified. The break is associated with the southwestward extension of the subtropical high during the seasonal evolution of the Western North Pacific Monsoon (WNPM). The break is obvious in stations located over the north and central Luzon. The average rainfall distribution reveals the impact of intra-seasonal oscillations in the summer monsoon rainfall of the Philippines.

Keywords: summer monsoon, Philippines, monsoon break, Intra-seasonal Oscillation

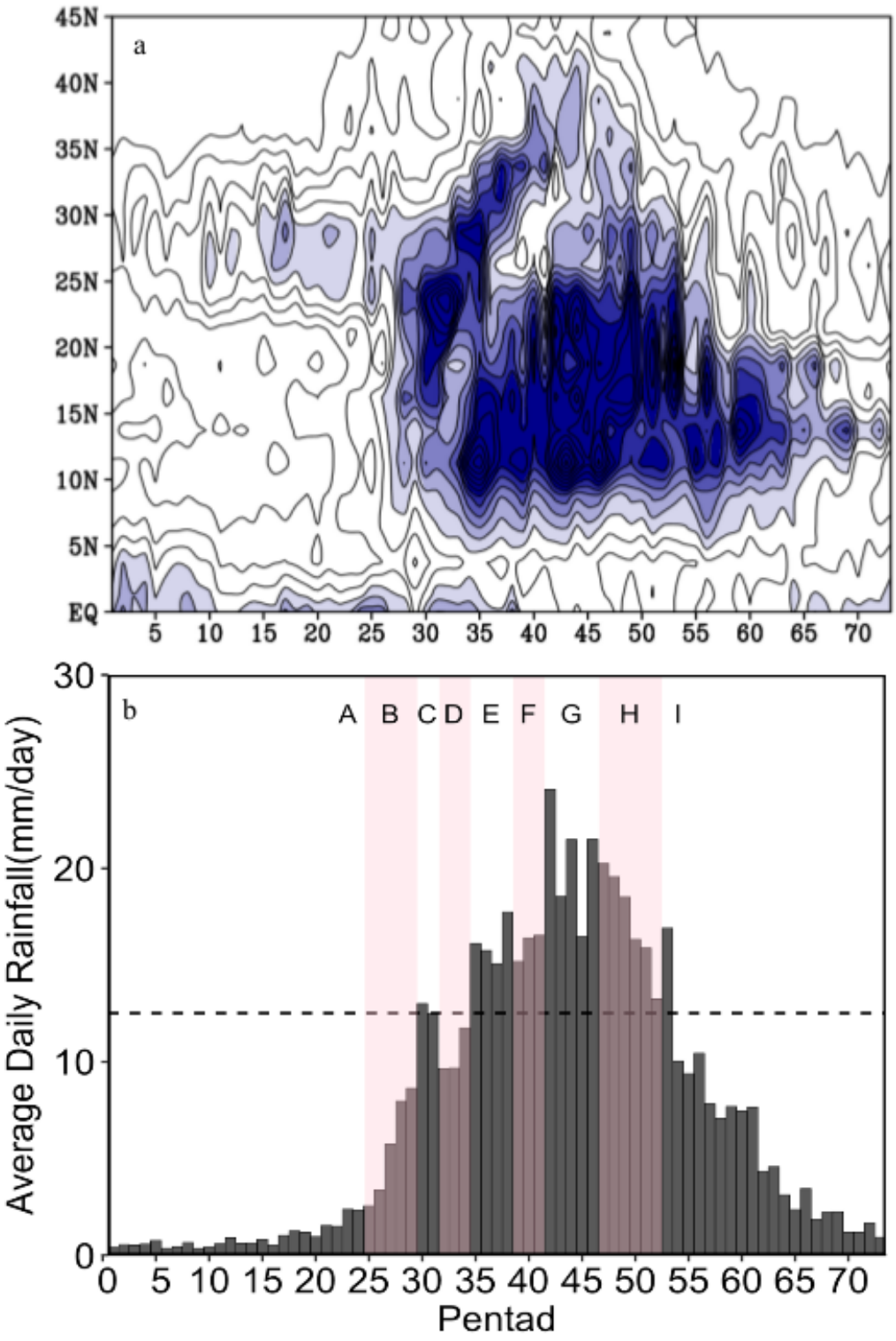

Figure 3 Rainfall distribution from a). CMAP data set averaged from 119E to 121E, and b). averaged across the nine PAGASA stations. Shaded contours are for rainfall greater than 5 mm/day. The dashed line is the rainy seasonal mean (12.52mm/day) averaged from P29 (onset) to P67 (withdrawal).

Records of the East Asian Monsoon from Beibu Gulf since Last Deglaciation

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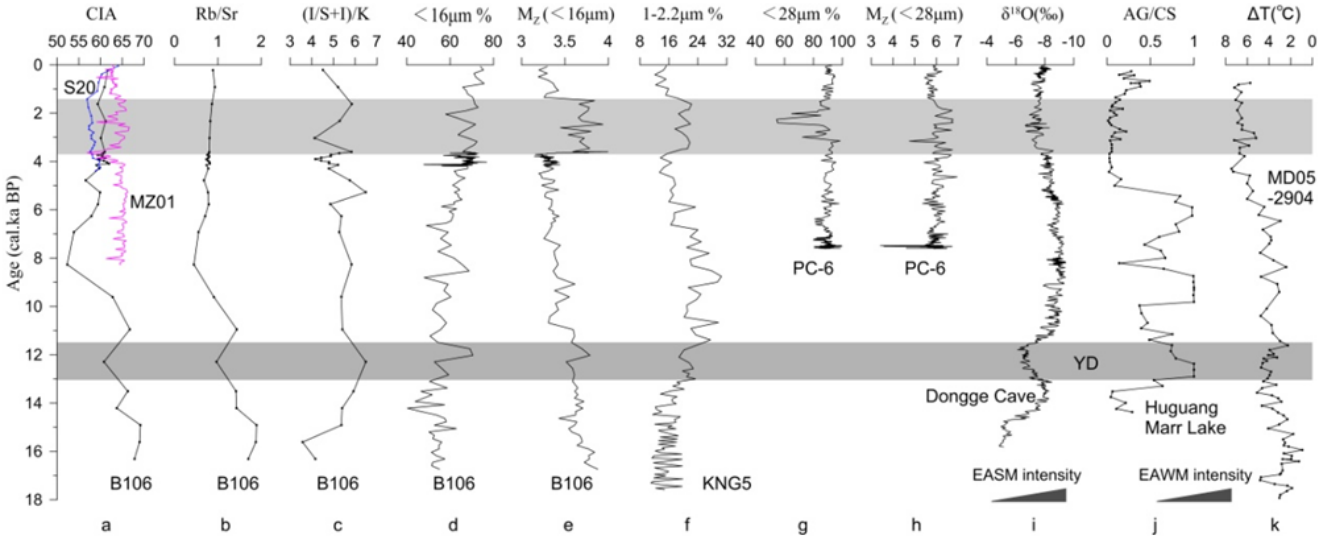
The East Asian Monsoon is one of the most active components in the global climate system. Many researchers have found that the intensity of East Asian Summer Monsoon (EASM) quickly increased in the early Holocene, characterized by strengthened precipitation and humid climate, while gradually decreased during the middle and late Holocene, characterized by decreased precipitation and dry climate. But due to the difficulty of constructing substitute indexes, the evolution of East Asian Winter Monsoon (EAWM) through Holocene was debatable.In this paper we studied the East Asian Monsoon records in core B106 recovered from the Beibu Gulf (the Gulf of Tonkin) in northwestern South China Sea.The 300cm long core was located in 108°36′02″E,19°54′04″N with a water depth of 62 m, and the grain size, chemical and clay mineral component,and AMS^{14}C age of this core was analyzed. The results show that before 13ka BP, the location of B106 was in continental sedimentation environment, with sedimentation source mainly from south China paleo-rivers, and the sediments was characterized by coarser grain size and high ΣHREE/(ΣLREE+ΣMREE), TiO_2/Al_2O_3 and C/N. From about 13 ka BP to 7ka BP, B106 located in marine environment with increasing water depth and fading influence of south China paleo-rivers. Since the formation of loop current in Beibu Gulf at about 7ka BP, the sediments of core B106 came from mixed sources but with little contribution of Red River or Pearl River.The fluctuation of CIA, Rb/Sr, (I/S+I)/K and the content and mean grain size of less than 16μm grain size population of core B106 were influenced by the evolution of East Asian monsoon.By synthesizing these indexes, the warm and humid climate in early Holocene was revealed, and also the cold event around 8.2, 5.4 and 4.8ka BP in middle Holocene, the drought climate during 3.6-1.6ka BP in late Holocene were revealed, reflecting a regional response to global climate change. But more attention should be paid in using CIA and mean grain size of fine environmental sensitive population as the substitution indexes of EAWM intensity, as they may be influenced by EASM too. In middle and late Holocene, the content of less than 16μm grain size population of core B106 can reflect the strength of EAWM to some extent, while the mean grain size of less than 16μm population was insensitive to EAWM and the increasing of which was closely linked with the weakening of EASM. When extracting grain size index to study the evolution of East Asian Monsoon, the restriction of sedimentation source and dynamics should be defined firstly.

Keywords: Beibu Gulf, East Asian Monsoon, Last Deglaciation



(a)CIA records of core B106(this study),S20 (Xu et al.,2010) and MZ01 (Liu et al.,2010a); (b)Rb/Sr of B106;(c)clay mineral proxy-(illite-smectite interstratified clay minerals + illite) vs.kaoline of B106 (Wu et al.,2011); content(d) and mean grian-size(e) of fine grain-size population(<16μm) of B106;(f)fine grain-size population(1-2.2μm) content of core KNG5 (Huang et al.,2011); content(g) and mean grain size(h) of fine grain-size population(<28μm) of core PC-6 (Xiao et al.,2006);(i)records of the stalagmite $\delta^{18}O$ from Dongge Cave,South China (Dykoski et al.,2005);(j)relative abundance ratio of two diatom species(*A.granulate* vs. *C.stelligera*) recorded in Huguang Marr Lake (Wang et al.,2012);(k) the temperature differences between sea surface (based on alkenone) and thermocline (based on thermocline-dwelling planktonic foraminifera *Pulleniatina obliquiloculata*) recorded by core MD05-2904 (Steinke et al.,2011).

Characteristics on the seasonal march of rainfall at Manila for the late 19th century - the early 20th century

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Rainfall is one of the most important climatic elements in Monsoon Asia, including the Philippines, because the seasonal change of rainfall is larger than that of temperature and is closely related to the water resources. Therefore, we aim to clarify longer-term variability in seasonal march of rainfall and its causes in the Philippines. To achieve our purpose, as the first step, we have collected and digitized the older meteorological observation records of the Philippines before the late 20th century under the data rescue projects in Japan. As the meteorological observations in the Philippines had been conducted by Spanish Jesuits for the late 19th century and by U.S. administration for the early 20th century, those data were found in the different places (e.g. UK, Spain and Japan). By connecting those data, we made the historical rainfall dataset in the Philippines for the period.
From the dataset, we used daily rainfall data at Manila where has the longest records of the observation in the Philippines. Based on daily rainfall at Manila from 1868 to 1940, we calculated pentad rainfall to study the seasonal change excluding daily rainfall variations. There are no data in 1875, 1877 and 1889. Manila has distinct dry season for February-April and wet season for May-October. Thus, to investigate the long-term changes in the seasonal march of rainfall at Manila, we determined the onset and withdrawal pentads of the rainy season: the onset (withdrawal) pentad corresponds to the first pentad when the pentad rainfall exceeds (falls below) 25mm since April. As results, the inter-annual variability in the onset of the rainy season since 1914 was small and the delayed withdrawal frequently appeared compared to the period before 1914. The durations of the rainy seasons for 1914-1940 were longer than those for 1950-2012. We will discuss these characteristics on the seasonal march of rainfall at Manila for the late 19th century-the early 20th century and its relation to the long-term variability in the Asian summer monsoon.

Keywords: Manila, rainfall, seasonal march, long-term change, data rescue

Projections of the duration of low-precipitation season in the Chao Phraya river basin based on the output from CMIP5 GCMs

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The duration of low-precipitation season under climate change was projected in the Chao Phraya river basin based on the output from all 31 CMIP5 GCMs which is available for both historical (1951-1981) and RCP8.5 (2070-2100) emission scenario. We estimated the length of the continuous days in each year that total precipitation during preceding 30days below a threshold which defines low-precipitation season, 15, 30, 45, and 60 mm/30days in this study (the annual average is 82.4 mm/30days). The result indicates that the top 10 percentile of long duration becomes much longer under climate change while the average duration slightly decrease. This tendency is valid for each thresholds. In the case of 15 mm/30days threshold, the occurrence of 10^{th} longest duration in historical period (1951-80 in this study), which corresponds almost 0.1% (ones in ten years), becomes 3.79 times as frequent under climate change from the estimation using 31 GCMs. The range of changing ratio estimated without highest and lowest 2 GCMs, which corresponds almost 90% confidence level, is 1.00 to 6.33. The fact suggests that the severe low-precipitation will happen more often under climate change.

The result of projection is significantly different between with and without applying bias correction method. For the average duration, an increase trend calculated without bias correction changes to a decrease trend after bias correction. It is well known that precipitation simulated by GCMs generally have considerable bias, thus it is common to correct bias before the application. This is true for the projections of the duration of low-precipitation season. To the best of our knowledge, there is no specific correction method for this purpose. Hence, we developed a method that correct the duration of low-precipitation season directly by changing threshold of precipitation for GCMs so that a duration of GCM low-precipitation season calculated by corrected threshold is agree to that of observation by original threshold in historical period. The developed method is different from common bias correction method in terms of the characteristic that not a precipitation itself but a threshold is corrected. This approach used in the correction of low-precipitation amount, which correct low-precipitation below a threshold as 0 considering the characteristic of GCM that there are significantly larger number of low-precipitation than observation.

It is important to understand the change of the duration of low-precipitation season because not only it has some impact on hydrology but also it affects the accuracy of bias correction for the amount of precipitation especially for pre- and post-monsoon season because many of bias correction methods adopt the approach that low-precipitation and others are separately corrected. Due to this reason, it is known that the error of bias correction generally large in these seasons. The results of this study can contribute to the improvement of bias correction as well as understanding the characteristics of the projections of precipitation among GCMs in monsoon regions.

Keywords: Climate change, Precipitation, Chao Phraya river basin

Uncertainty from climate forcing of glacier projection for High Mountain Asia

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Current model-based projections in glacier runoff are affected by considerable uncertainties. One of the largest uncertainties originates from climate forcing especially precipitation data. Underestimation of input precipitation data due to poor gauge network in mountainous regions is serious problem. Climate model driven information on climate change is also needed for future projection of glacier but often deemed unreliable. Those hamper effort to simulate the glacier runoff peak timing and magnitude. This research aims at an assessment of the major uncertainties from climate forcing in the modeling of future glacier runoff.

The glacier runoffs were calculated by a glacier model (HYOGA2) forced by two precipitation data and observed temperature data over historical period. Future glacier runoff was projected forced by eight climate models under the RCP4.5 and RCP8.5. The glacier model was calibrated using two precipitation date-sets. Bias correction of climate models were also done by comparing against two precipitation data-sets. The uncertainty of glacier runoff projection from input precipitation datasets and climate model spread will be discussed.

Keywords: Glacier, Precipitation, GCM

Seasonal Responses of Pacific Japan Teleconnection on Indo-China Peninsula

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Summer monsoon precipitation provides a valuable support to the livelihood of the people live in Southeast Asia where the population density is very high. But monsoon precipitation shows high variation in seasonal and yearly time scales affecting daily life of the people in the regions such Indo-China Peninsula where most of the countries depend on agricultural economy. Tropical cyclones (TCs) and westward-propagation disturbances (WDs) are some of the major summer precipitation providing weather systems of this region. Pacific-Japan (PJ) teleconnection is a meridional teleconnection pattern which dominate the summer in Western North Pacific (WNP). TC locations were identified by TC best track dataset and WDs were detected subjectively using reanalysis dataset. PJ pattern timeseries is represented as 1st principle component seasonal average of relative vorticity at 850 hPa. High interannual and interseasonal variation of occurrence frequency was observed in Indo-China Peninsula which is not understood well enough. TC occurrence and genesis showed increasing trend in PJ pattern whereas it is negative for WDs. TCs and WDs have positive correlation with landfall in Indo-China Peninsula.

Keywords: Pacific Japan teleconnection, westward-propagating disturbance

Influence of global warming on Eurasian snow cover teleconnection to the Indian monsoon rainfall using a large ensemble AGCM experiment

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Relationship with Eurasian snow cover (ESC) and Indian summer monsoon rainfall (ISMR) is an extensively discussed aspect in terms of monsoon forecasting. Previous studies have found a strong negative correlation with the winter snow cover of western Eurasian region and ISMR. A weakening of this negative correlation has been observed recently but the reasons behind this are inconclusive, especially due to the limited observational record of snow amount. Influence of global warming on the change in snow-monsoon teleconnection has been widely discussed and suggested to have impacts on typical monsoon behavior such as the inverse relationship with ENSO. Therefore, this study was carried out to investigate the influence of anthropogenic global warming on the snow-monsoon relationship using a large ensemble experiment with and without human influence on the climate, using MRI-AGCM.

Carefully conducted correlation and composite analysis showed that the global warming has a possible weakening effect on the ESC-ISMR inverse relationship. This impact seems to be inflicted upon the ISMR with a modulation in the summer walker circulation anomaly over the South/South-East Asian region. Based on the correlation analysis, the impact of the global warming was shown to be less than the change observed from the observation-based analysis. Therefore, recent (after 1990) and past (before 1990) time slices were analyzed using correlation and composite based methods to observe any apparent deviations. Both ensemble simulations with and without human influence showed a similar decrease of the negative relationship with a westward shift of the rising anomalies associated with Indian ocean walker circulation during recent heavy snow years. This result was consistent with observations, suggesting a low-frequency variation of the circulation patterns associated with the ESC-ISMR relation due to the stochastic nature of the processes occurs from the natural variability, independent from global warming. Based on these results, we speculate that although an apparent weakening impact from global warming has occurred, more dominant low-frequency variability might be the reason for the significant reduction of ESC-ISMR correlation during recent decades.

Keywords: Indian monsoon, Eurasian snow cover, Teleconnections, Global warming

