Asia-Pacific Network for Global Change Research

Development of Indices and Indicators for Monitoring Trends in Climate Extremes and its Application to Climate Change Projection

Final report for APN project: ARCP2007-20NSG

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Final Report submitted to APN

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Overview of project work and outcomes

Non-technical summary

The trends in climate extremes based on surface observation data are analyzed to monitor significant changes in climate extremes across ten western Pacific countries (Australia, China, Japan, Malaysia, Mongolia, New Zealand, Pakistan, Republic of Korea, Thailand, Viet Nam). The 20 extreme temperature indices and 10 extreme precipitation indices are examined for the period of 1955-2007. To synthesize the observed changes in climate extremes, the 6th Asian-Pacific Network workshop was held in Seoul (February 20-23, 2008). According to the workshop results, the number of summer warm days/nights based on upper/lower 5th percentile thresholds has increased, while the number of winter cool days/nights has decreased. The numbers of frost and ice days have decreased and those of tropical nights and summer days have increased. On the other hand, trends and intensity of extreme precipitation events are highly variable in regional scale. This workshop contributed to enhance the close collaboration between APN member countries and allowed for increasing recognition of the importance of monitoring and understanding climate extreme in relation to global change in Asia-Pacific region.

Objectives

The main objectives of the project were:

1. Develop and compute indicators of trends in climate extremes for the Asia-Pacific region
2. Build regional capacity in systematic handling and analyzing of climate data
3. Promote the application of climate trend indicators for government policy development

By obtaining the indices and indicators of climate extremes, we can provide useful information and support the government taskforces in establishing one of the comprehensive countermeasures in the Climate Change Convention.

Amount received and number years supported

2007/08: US$ 10,000

No. of Years: One

Activity undertaken

The main activity is holding the 6th APN climate extremes workshop to collect climate data from ten countries over Asia-Pacific region. State-of-the-art climate extreme analysis techniques of ETCCDI (Expert Team on Climate Change Detection and Indices), RClimDex and RHtestV2 are applied for monitoring trend in climate extremes during the period of 1955-2007. The region of data coverage extends from Mongolia (46°N, 105°E) to New Zealand (41°S, 174°E). The data observed at approximately 145 weather stations since the mid-1950s were collected from Australia (36 stations), China (32 stations), Japan (15 stations), Malaysia (8 stations), Mongolia (6 stations), New Zealand (10 stations), Pakistan (12 stations), Thailand (7 stations), Vietnam (5), and the Republic of Korea (14 stations).
Debugged software scripts for testing homogeneity of the data and calculating the trends of each extreme climate index have been disseminated to each APN country representative. At the 6th APN workshop on February 20-23, each representative presented a national report. These reports were synthesized to examine the trends in the entire APN region. In the workshop, the data period for the consistent analysis,

and significant indices to monitor extreme climate events in the APN region were determined and future plan for a publication was discussed to be a continued success.

Results

The 20 extreme temperature indices and 10 extreme precipitation indices are investigated during the period of 1955-2007 using 145 observations in ten APN countries. The number of summer warm days/nights based on upper/lower 5th percentile thresholds has increased, while the number of winter cool days/nights has decreased. The APN average trends of cool nights and warm nights are -6.7 days/decade and +6.2 days/decade, respectively, and those of cool days and warm days are -3.5 days/decade and +4.5 days/decade, respectively. Cold events based on fixed thresholds including frost days and ice days have decreased, while hot events such as tropical nights and summer days have increased. The APN average trend of frost days is -1.5 days/decade but its less magnitude than expected is caused by zero trends at tropical weather stations, where there is no record of frost days. The APN regional average trend of strong summer days is +2.5days/decade.

Compared with extreme temperature indices, the weather stations which show significant trends of extreme precipitation events is less than 15% among all weather stations. Moreover, locations of these stations that show significant trends are scattered without coherent clustering patterns across broad regions. The results concluded that trends and intensity of extreme precipitation events are highly variable in regional scale so that further studies are needed in the future.

Relevance to APN's Science Agenda and objectives

Anthropogenic climate change is currently recognized as one of the important global changes that threaten future human society and ecosystems. More frequent and intense climate extremes, such as heat waves and flooding, are predicted so that international efforts to reduce the expected serious damage are needed to protect humans and environment such events. This project shows an example of the importance of international collaboration in the APN region. This project is a continuation of the five APN workshops previously led by Australia. The workshops will develop adaptation strategies for, and reduce uncertainty regarding occurrence of extreme climate events in the APN region.

Self evaluation

This project strengthened regional scientific links through collaboration between scientists from 10 countries of Mongolia (46°N, 105°E) to New Zealand (41°S, 174°E) and contributed to integrate climate extreme changes over the Asia and western Pacific region. Every task had been carried out as scheduled. The selection of indices and evaluation of trends across the APN countries was carried out at the 6th APN workshop in February 2008. Results from the 5th APN workshop have been updated by the 6th APN workshop.

The results can be used to extend the scope over the wide area when it is connected to the other workshops using the methodology and software developed from ETCCDI.

This project enhances understanding of the climate of the Asia Pacific region, as countries work together using common techniques to analyze and compare national climate data.

To achieve the goal of this project, additional funding in addition to the APN was needed. The support of the Korea Meteorological Administration to meet the needs contributed to carry out the project successfully.

Potential for further work

Outcome in this project deals with climate extremes as one of the key climate issues. So it can be used to provide the scientific basis to support policy decision and measures a in the APN region. It can increase public understanding of climate extremes.

This project established an effective network of scientists who can work together to develop appropriate climate indices for their country. The national results are brought together to provide information on variations and trends over the whole region.

Publications

Not available now, but an scientific journal article will be submitted in which all the participants would be involved.

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Acknowledgments

We are very grateful to the Asian Pacific Network (APN) for their financial support and to all participants for their collaboration. The 6th APN workshop is also partially supported by the National Institute of Meteorological Research at Korea Meteorological Administration under the project of “The Application of Regional Climate Change Scenario for the National Climate Change Report”. This project used RClimDex and RHtest from ETCCDMI (Expert Team for Climate Change Detection Monitoring and Indices).

Technical Report

Preface

As climate extreme events such as heat waves, drought, and flooding occur more frequent, intense, the threats posed by climate change demand serious, integrated action by the international community. Monitoring and Evaluation of changes in extreme climate events is an essential task which should be carried out to prepare for adaptation and mitigation plans which can minimize the potential damages from those events. So this project is initiated to extend the understanding climate extremes in relation to global change in the Asian-Pacific Network (APN, hereafter) region as a continuation of the previous APN workshop activities. Scientists from ten countries (including Australia, China, Japan, Malaysia, Mongolia, New Zealand, Pakistan, Republic of Korea, Thailand, Vietnam), collaborated to examine the long-term trends of extreme temperature and precipitation events in the APN region over the past several decades. This report is on the outcome of the collaboration and summarizes spatial and temporal coherences and differences of recent extreme climate trends in the APN region.

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1. Introduction

The global scientific communities, as represented by the IPCC, have sent a clear message that warming of the climate system is unequivocal and most of the observed warming is attributable to human activities (IPCC, 2007). Climate change will seriously influence various sectors. The impacts could be large and vary significant from region to region. Therefore climate change is the biggest challenge in this century. To meet the challenges and get insights for the possible consequences of climate change, Korea Meteorological Administration contributes to provide scientific basis for the climate change and provides them to assess climate change impact and develop adaptation measures. As the relevant effort, international collaboration of the 6th APN workshop is planned to detect long-term trends in climate extremes over the Asian Pacific region.

Future climate projections demonstrated that global warming due to increases of greenhouse gas emission will give more favorable condition for more frequent, intense extreme climate events, extending to broader regions in the 21st century. In fact, unprecedented extreme events have been already reported in recent decade worldwide. Recent studies project increases of intense hurricanes with the warmer sea surface temperature and amplify the importance of monitoring extreme climate events such as tropical cyclones accompanying heavy rainfall. When abrupt extreme climate events occur, the diverse ecosystem, society and economy may be more vulnerable to extreme climate changes.

Several efforts have been made to examine trends of extreme climate indicators by collaborating local data on regional (Manton et al., 2001; Peterson et al., 2002; Klein Tank & Konnen, 2003; Griffiths et al., 2005; New et al., 2005; Vincent et al., 2005; Moberg & Jones, 2005; Klein Tank et al., 2006) or global scales (Frich et al., 2002; Alexander et al., 2006) through international workshops. Alexander et al. (2006) examined the most extensive trends of extreme climate indices based on grid data which were produced through assimilating point observations on the globe. However, grid data can attenuate characteristics of spatially-varying extreme climate indices within averaged areas. In particular, precipitation extreme events are highly localized so that the grid data may not be able to capture the locality of extreme climate events. Thus, it is also important to examine the trends of individual weather stations.

In the Asian Pacific regions, there have been workshops on extreme climates. One of reported documents after the workshop is Manton's et al (2001) which examined trends of eight extreme temperature and precipitation indices based on the 99th percentile thresholds for Southeast and South Pacific for the period, 1961-1998. This project is an extended effort to monitor the extreme climate trend with more numbers of indices and to develop better applicable extreme climate indices for the Asian-Pacific network regions including East Asia. The purpose of this project is to examine spatial and temporal changes in 20 extreme temperature indices and 10 extreme precipitation indices in broad western Pacific region which covers from Mongolia to New Zealand over the 1955-2007 period. This work is collaborated through the 6Th APN workshop on extreme climates in ten APN countries, which was held on February 20-23, 2008 in Seoul, Republic of Korea.

2. Data and Methodology

2.1 Preparing climatic Data

Ten countries in the APN region, including Australia, China, Japan, Malaysia, Mongolia, New Zealand, Pakistan, Republic of Korea, Thailand, and Vietnam, have participated in this project. Total number of weather stations included in the data analyses is 145. These weather stations relatively well cover the Asian Pacific regions including East Asia, South Asia, and South Pacific (Figure 1). In particular, Australia and China provided 36 and 32 weather station data sets, respectively, which relatively homogeneously cover the extensive regions by selecting the most regional standard weather station.

Through a discussion at the 6th APN workshop, it is revealed that the available long-term data period can date back to the mid 1950s, even though several countries have the non-digital format data before 1960. For example, Mongolia manually digitized the pre-1960 data for the second data analyses after the Workshop. Overall, the data sets from 145 weather stations cover last 53 years from 1955 to 2007 (Table 1). The data from Pakistan and Vietnam covers a little short period between 1961 and 2000 because the pre-1960 data exist as non-digital paper archive. At individual weather station, the first and last year for data period vary, but only data which date back to at least the early 1960s are included in data analyses. The ending year of most data is 2007 except some countries.

Table 1. Data collaborated across ten APN countries

Country	NO of weather stations	Base data period	First year (Max)	Last year (Min)
Australia	36	1955-2007	1955	2005
China	32	1955-2007	1961	2007
Japan	15	1955-2007	1955	2007
Malaysia	8	1955-2007	1961	2007
Mongolia	6	1955-2006	1950	2006
New Zealand	10	1955-2007	1955	2007
Pakistan	12	1961-2006	1964	2006
Republic of Korea	14	1955-2007	1955	2007
Thailand	7	1955-2007	1955	2005
Vietnam	5	1961-2006	1961	2006
Overall	145	1955-2007		
Variables	Daily maximum and minimum temperatures & daily precipitation			

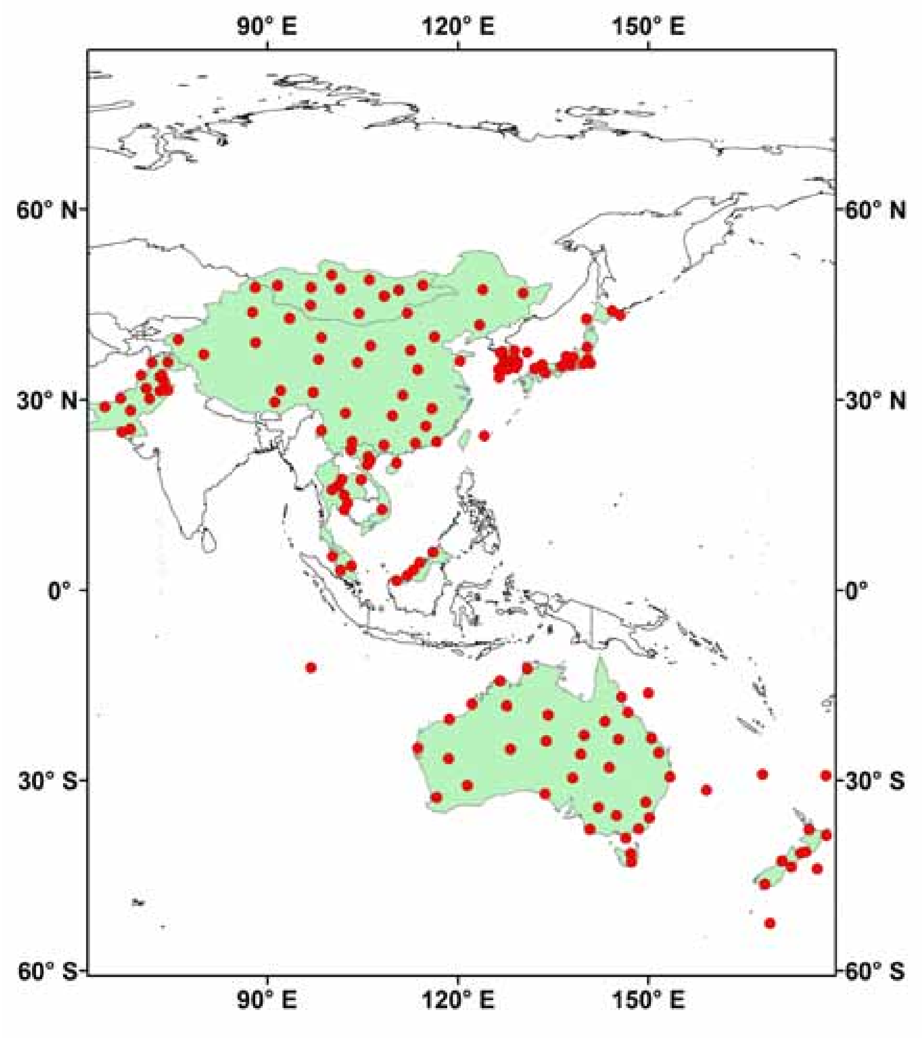


Figure 1. Distribution of weather stations across ten APN countries

Daily maximum and minimum temperatures as well as daily precipitation data are used in this study. Weather station data with more than 20% data missing record in a given year during more than 5 years are excluded in the analyses. Data homogeneity is checked using the RHTestV2 software (Wang and Feng, 2002). The homogeneity test can detect changing points in the time series which are caused by unrecorded changes in observational practices, devices, locations, and land use in the surroundings. The package provides an adjustment method but it was not used in this study because extreme climate indices may be sensitive to the artificial adjustment so that it may produce unrealistic records. However, the test at least helps the elimination of weather station data with many significant changing points at the early stage of data selection.

2.2 Extreme Climate Indices

20 extreme temperature indices and 10 extreme precipitation indices are used in this study (Table 2). These indices are classified into three groups: percentile-based indices, fixed-threshold-based indices, and others. Percentile-based extreme temperature indices include cool/warm nights/days (upper and lower 5^{th} percentile) and cold/warm duration indicator (upper and lower 10^{th} percentiles). Similarly, percentile-based extreme precipitation indices include very wet days (95^{th} percentile) and extremely wet days (99^{th} percentile). In contrast, summer days (Tmax>25 ºC), tropical nights (Tmin>25 ºC), ice days (Tmax<0ºC), and frost days (Tmin<0 ºC) are examples of extreme temperature indices based on the fixed absolute thresholds regardless of regional variations of climate averages. Others including Max/Min Tmax/Tmin used absolute values at individual weather stations. Extreme precipitation indices which use fixed thresholds include the number of heavy/very heavy/extremely heavy precipitation days as well as consecutive dry/wet days. Others are annual total wet-day precipitation, simple daily intensity index, and Max 1 or 5 day precipitation.

30 year (1971-2000) average values are used to calculate each extreme index from daily maximum/minimum or precipitation data at individual weather station. A simple linear regression line in the time series of extreme climate indices for each weather station over the 1955-2007 period are fitted and significance levels of their slope values are calculated using the RClimDex software (Zhang and Yang, 2004). The minimal units for daily temperature and precipitation data are degrees Celsius and millimeters, respectively. T-test provides P values for the linear trends. Slope values of linear regression line whose p-value is less than 0.05 (which indicate more than 95% of significance) are considered as a statistical significant trend. In the process of data load, the package checked outliers or wrong records of daily records before deriving annual time series of extreme climate indices from daily climatic data. To detect the outlier, 4 standard deviations of daily temperature records based on long-term values. When outliers are found, it should be manually checked the possibility of data reality and if needed, the record should be eliminated from the analyses. To detect wrong data, several methods (e.g. Tmax should be greater than Tmin) are applied. In this case, we should compare the data with original paper archive to correct the errors or eliminate it from the analyses.

The calculated trends and their significance level are put together in a dbf file and represented in a GIS system. In this process, latitude and longitude records are used to coordinate the locations of weather stations along with all other trend records. Automatically point entities, which locate each weather station, are linked to the attribute table, which contain all other information for each location including lat/long as well as trend values. Then, the sign and magnitude of trends are represented using symbols. In this study, triangles/reversed triangles are used for increasing/decreasing trends. Significance levels are represented by whether each symbol is filled with color or not. Open symbols indicate its trends are not significant at the 95% level. The size of symbols indicates the magnitude of trends.

Table 2. Extreme temperature and precipitation indices used in this study

Extreme Temperature Indices		
Abbreviation	**Names**	**Definition**
su25	Summer days	Annual count when TX(daily maximum)>25ºC
id0	Ice days	Annual count when TX(daily maximum)<0ºC
tr20	Tropical nights	Annual count when TN(daily minimum)>20ºC
fd0	Frost days	Annual count when TN(daily minimum)<0ºC
su30	Strong summer days	Annual count when TX(daily maximum)>35ºC
id5	Weak ice days	Annual count when TX(daily maximum)<5ºC
tr25	Strong tropical nights	Annual count when TN(daily minimum)>25ºC
fd5	Weak Frost days	Annual count when TN(daily minimum)<5ºC
gsl	Growing season Length	Annual (1st Jan to 31st Dec in NH, 1st July to 30th June in SH) count between first span of at least 6 days with TG>5ºC and first span after July 1 (January 1 in SH) of 6 days with TG<5ºC
txx	Max Tmax	Monthly maximum value of daily maximum temp
txn	Max Tmin	Monthly maximum value of daily minimum temp
tnx	Min Tmax	Monthly minimum value of daily maximum temp
tnn	Min Tmin	Monthly minimum value of daily minimum temp
tx10p	Cool nights	Percentage of days when TN<10th percentile
tx90p	Cool days	Percentage of days when TX<10th percentile
tn10p	Warm nights	Percentage of days when TN>90th percentile
tn90p	Warm days	Percentage of days when TX>90th percentile
wsdi	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX>90th percentile
csdi	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN<10th percentile
dtr	Diurnal temperature range	Monthly mean difference between TX and TN
Extreme Precipitation Indices		
Abbreviation	**Names**	**Definition**
rx1day	Max 1-day precipitation amount	Monthly maximum 1-day precipitation
rx5day	Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation
sdii	Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as PRCP>=1.0mm) in the year
r10mm	Number of heavy precipitation days	Annual count of days when PRCP>=10mm
r20mm	Number of very heavy precipitation days	Annual count of days when PRCP>=20mm
R30mm	Number of extremely heavy precipitation days	Annual count of days when PRCP>= 30 mm
cdd	Consecutive dry days	Maximum number of consecutive days with RR<1mm
cwd	Consecutive wet days	Maximum number of consecutive days with RR>=1mm
r95p	Very wet days	Annual total PRCP when RR>95th percentile
r99p	Extremely wet days	Annual total PRCP when RR>99th percentile
prcptot	Annual total wet-day precipitation	Annual total PRCP in wet days (RR>=1mm)

3. Results & Discussion

3.1. Trends of extreme temperature events

The trends of 20 extreme climate indices with 95% or more of significance vary by country (Table 3). For instance, trends of summer days in Australia are significant at the half of weather stations, while other countries show different features. Across ten APN countries, the top five indices that shows significant trends at more weather stations are cool night (tn10p), warm night (tn 90p), warm day (tx90p), and Min Tmin(tnn), and cool days (tx10p). These are significant at approximately 70% of weather stations across ten APN countries (Table 4). In contrast, the bottom five indices with insignificant trends at many weather stations are ice days (id0), Max tmax (txx), weak ice days (id5), growing season length (gsl), and warm spell duration indicator. These bottom indices are significant only at less than 25% of weather stations. These patterns indicate that percentile based indices are free from different regional climatology so that it is more applicable to a broad region.

Table 3. The number of weather stations with significant (S) or insignificant (IS) linear trends (at 95% level) during the analysis period for extreme temperature indices.

Country	Australia		China		Japan		Malaysia		Mongolia		New Zealand		Pakistan		Republic of Korea		Thailand		Vietnam		APN	
Total	36		32		15		8		6		10		12		14		7		5		145	
95%	S	IS	S	IS	S	IS	S	IS	S	IS	S	IS	S	IS	S	IS	S	IS	S	IS	S	IS
su25	18	18	17	15	5	10	4	4	5	1	1	9	5	7	5	9	2	5	3	2	65	80
id0	0	36	16	16	1	14	0	8	1	5	0	10	1	11	13	1	0	7	0	5	32	113
tr20	17	19	17	15	6	9	4	4	4	2	2	8	8	4	6	8	7	0	3	2	74	71
fd0	4	32	24	8	9	6	0	8	5	1	6	4	6	6	12	2	0	7	0	5	66	79
su30	12	24	13	19	2	13	8	0	6	0	1	9	5	7	1	13	6	1	3	2	57	88
id5	0	36	12	20	3	12	0	8	4	2	0	10	3	9	14	0	0	7	0	5	36	109
tr25	16	20	11	21	6	9	8	0	2	4	0	10	6	6	4	10	7	0	4	1	64	81
fd5	19	17	25	7	7	8	0	8	5	1	9	1	7	5	10	4	2	5	0	5	84	61
gsl	3	33	12	20	2	13	0	8	4	2	2	8	2	10	11	3	0	7	0	5	36	109
txx	7	29	7	25	5	10	6	2	3	3	1	9	4	8	0	14	0	7	1	4	34	111
txn	9	27	24	8	5	10	5	3	3	3	2	8	3	9	14	0	1	6	1	4	67	78
tnx	12	24	17	15	6	9	7	1	6	0	1	9	4	8	2	12	5	2	2	3	62	83
tnn	16	20	28	4	12	3	7	1	3	3	5	5	6	6	13	1	7	0	2	3	99	46
tx10p	24	12	23	9	7	8	8	0	5	1	3	7	5	7	14	0	6	1	3	2	98	47
tx90p	23	13	22	10	10	5	8	0	6	0	5	5	7	5	12	2	6	1	3	2	102	43
tn10p	20	16	28	4	13	2	8	0	5	1	6	4	8	4	11	3	7	0	4	1	110	35
tn90p	20	16	25	7	6	9	8	0	6	0	9	1	7	5	11	3	7	0	5	0	104	41
wsdi	7	29	14	18	7	8	4	4	6	0	2	8	4	8	5	9	4	3	3	2	56	89
csdi	14	22	23	9	2	13	8	0	3	3	5	5	7	5	9	5	7	0	2	3	80	65
dtr	15	21	20	12	11	4	5	3	4	2	8	2	7	5	8	6	7	0	2	3	87	58

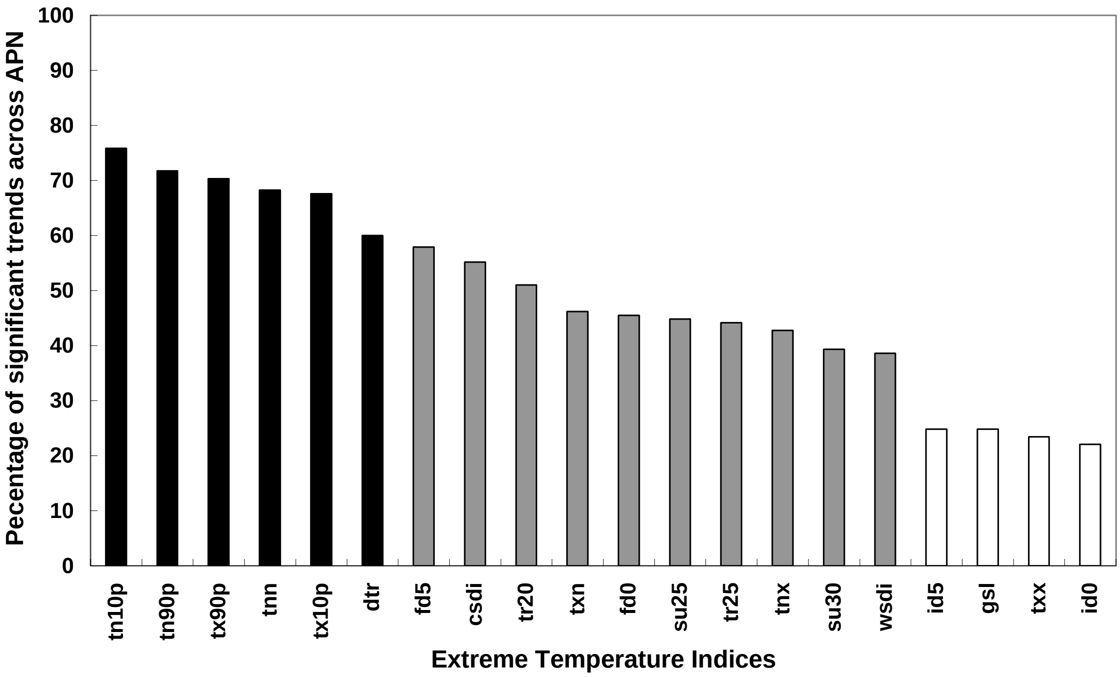


Figure 4. Percents of weather stations with significant (95% or more) trends across ten APN countries for 20 extreme temperature indices

The average trends regardless of their significance levels at individual weather stations are depicted in Figure 5. The APN average trends of cool nights and warm nights are -6.7 days/decade and +6.2 days/decade, respectively, and those of cool days and warm days are -3.5 days/decade and +4.5 days/decade, respectively. Tropical night (tr25), strong summer days (su30), weak tropical nights (tr20), and summer days (tr25) show increasing trends at the rate of 2-3 days/decade. In contrast, frost days (fd0) and week frost days (fd5) show decreasing trends at the rate of 1-2 days/decade. Trend values of all other indices are less than 1 degrees Celsius/decade or days/decade.

The maximum and minimum values of statistically-significant trends for each indice are illustrated in Figure 5. The max trend of warm nights exceed 40 days/decade and similarly the max trend of tropical nights also exceed 35 days/decade, indicating that the increasing trends of summer nighttime warm events show high local variations. Max trends of warm days and strong summer days shows relatively high values exceeding 30 days/decade and 25 days/decade, respectively. In contrast, both the highest positive and negative trends of cool nights are greater than 10 days, even though overall patterns are negative trends as mentioned above. Both ends are also similar in cases of frost days, weak frost days, and cold spell duration indicator.

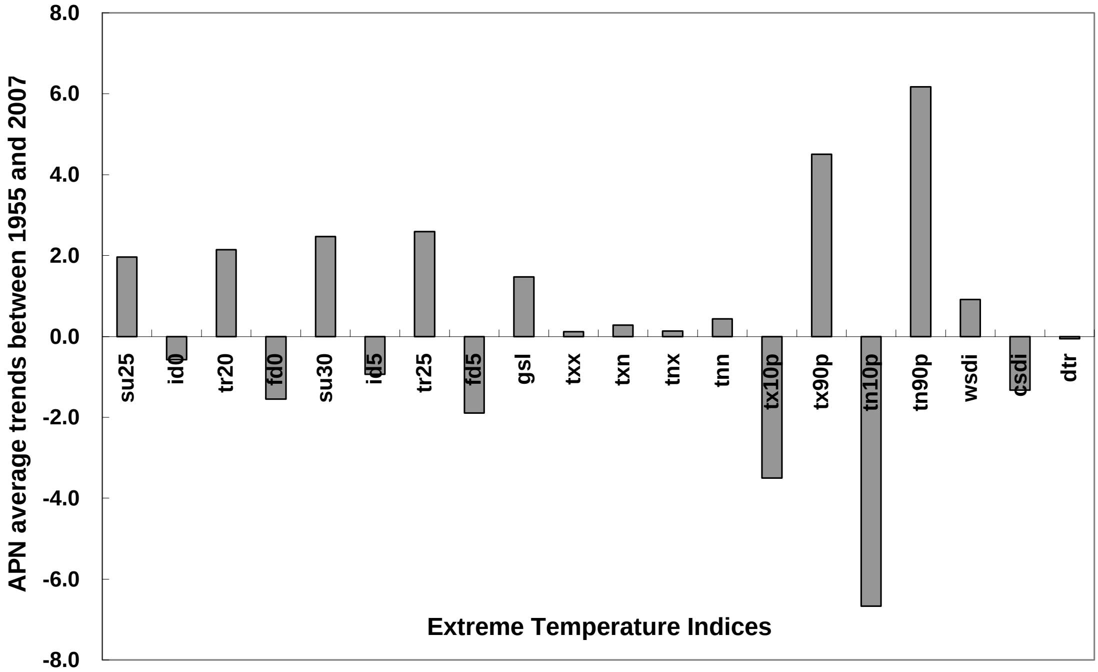


Figure 5. Average trends (unit per decade) across ten APN countries for individual extreme temperature indices.

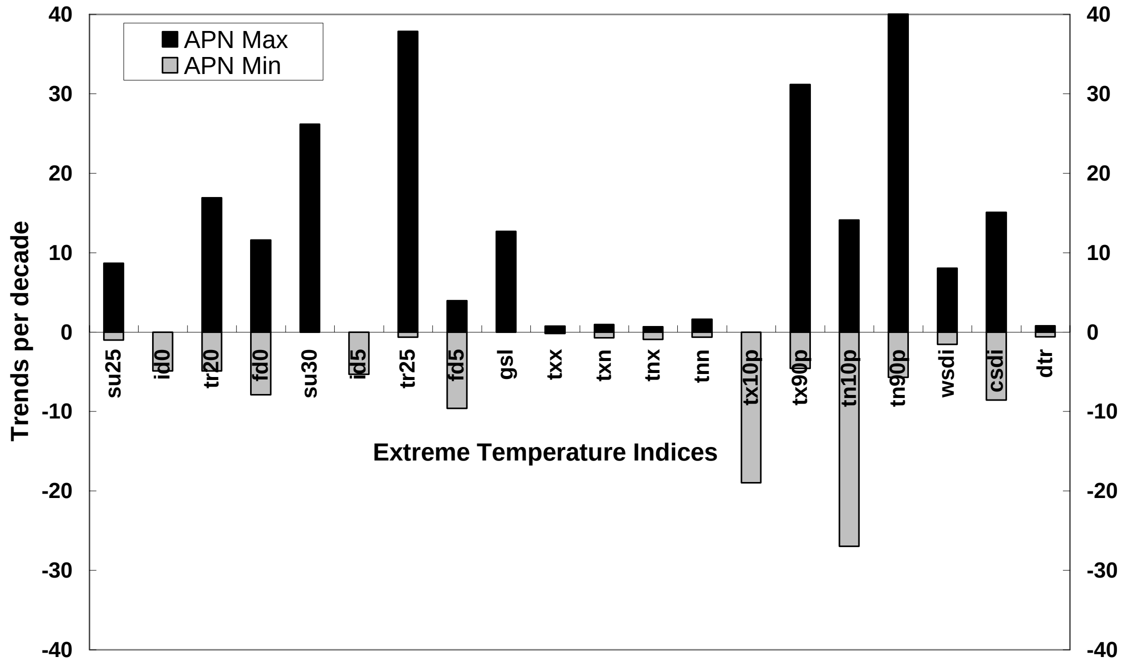


Figure 6. Significant (95% or more) maximum and minimum trends of extreme temperature indices within ten APN countries

Figures 7-10 show spatial patterns of linear trends of extreme climate indices over the 1955-2007 period from one weather station to another. Among 5^{th} upper or lower percentile-based indices including cool/warm days/nights, magnitude of changes in cool nights are greatest at both low- and mid-latitude regions. As shown in Figure 7, cool nights have decreased most in Southeast Asia at the rate of 20days/decade or more. In the midlatitude regions above 30°N, cool nights have decreased at the rate of 0-10 days/decade. In central Australia, the trends are not statistically significant and also show reversed signs. In Pakistan, significantly-increasing trends of cool nights are found, but it needs further study because of prevailing decreasing trends at all other weather stations across ten APN region.

Spatial patterns and magnitude of warm night trends are similar to those of cool nights as described above. Highest increasing trends exceeding at least 20 days/decade are found in Southeast Asia near the equator, while in the midlatitude regions, the trends are less than 15 days/decade. The difference is that they show increasing trends. On a regional scale, they are not significant in western Australia, while many significant increasing trends are observed in eastern Australia. Warm day trends show a similar spatial pattern to warm night trends. At most of weather stations except for central China and northwest Australia, warm days show increasing trends. The increasing trends vary from 0-10 days in the midlatitude region. The magnititude of cool day trends is smallest among 5th upper or lower percentile-based indices. The magnitude varies within the range of 0-10 days/decade in most APN regions

Significant trends of cold spell duration indicator (csdi) appear in most ten APN countries except for some regions (Figure 9). Its magnitude varies in the range of 0-5 days/decade. The number of weather stations with 95% or more of significance are smaller in the case of warm spell duration indicator (wsdi) compared with cold spell duration indicator (csdi). They are clustered as northern and eastern East Asia, southeast Asia, and northeastern Australia. Their magnitude varies at the rate of 0-10 days/decade. Not significant but the decreasing trends of warm spell duration indicator (wsdi) are found in several stations.

Frost days do not occur in the tropical regions between 30°N and 30°S (Figure 10). Regions where frost days do not occur extend to more southward in the Southern Hemisphere compared with the northern limit of no frost days. For instance, southern limit of no frost days occur in New Zealand (midlatitude), while the northern limit is located in the southern China (subtropical region). In many regions in the midlatitude of the Southern Hemisphere, frost day is not observed. In contrast, over the continents including China and Mongolia, the number of frost days has decreased at the rate of 0-8 days/decade. Compared with frost days, significant trends of summer days are observed in both 50°N and 50°N. In several locations on the Tibetan Plateau and in New Zealand, summer days are not observed.

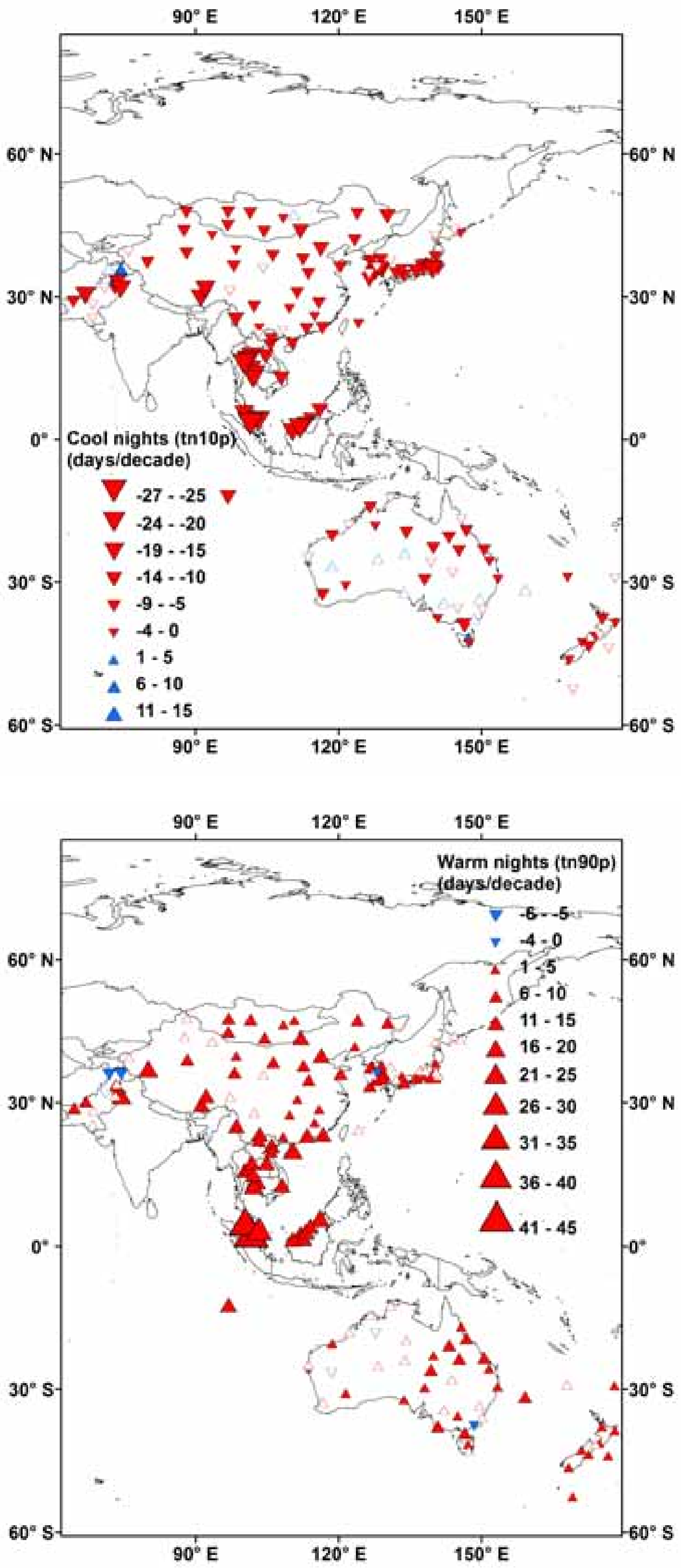


Figure 7. Linear trends (days/decade) of cool nights (tn10p) and warm nights (tn90p) over the 1955-2007 period across ten APN countries. Color-filled symbols indicate that the linear trend is significant at the 95% level.

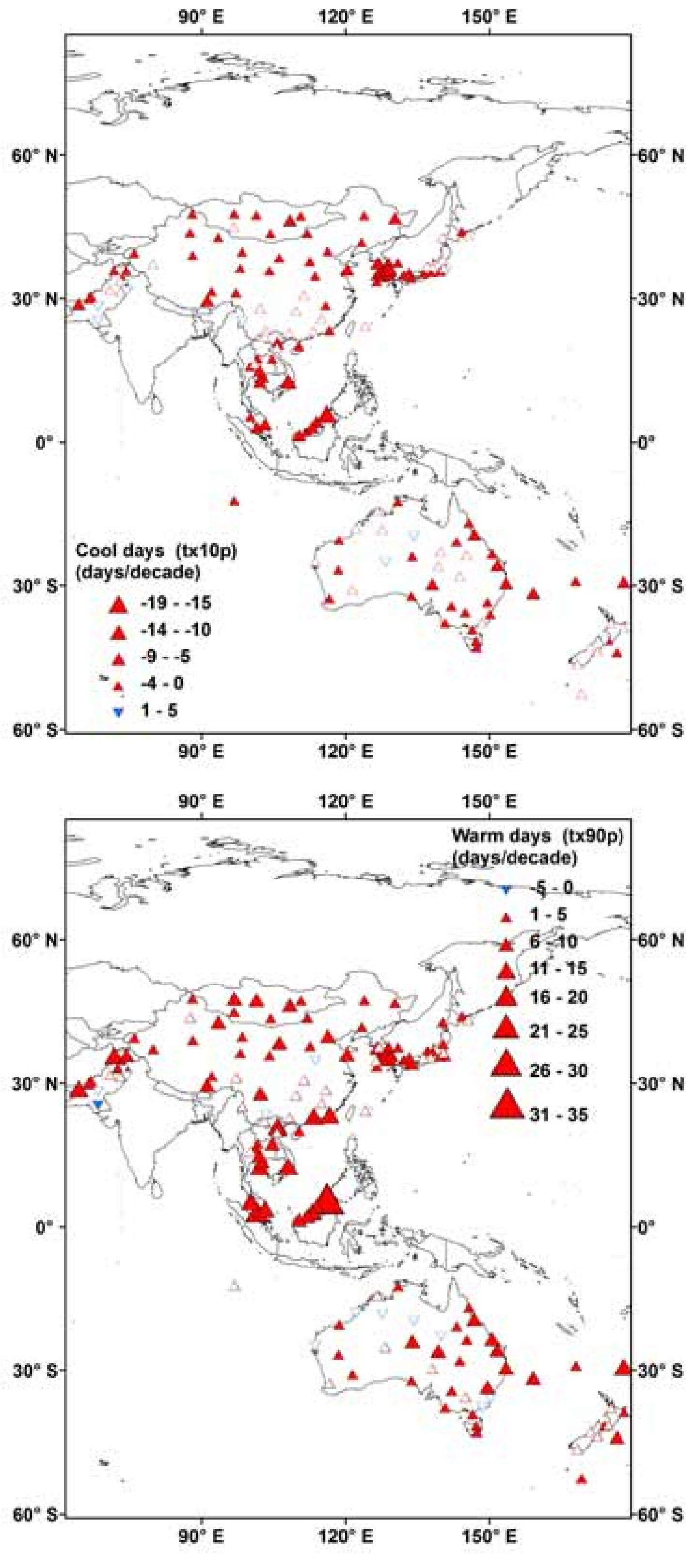


Figure 8. Same as in Fig. 7, but for cool days (tx90p) and warm days (tx90p).

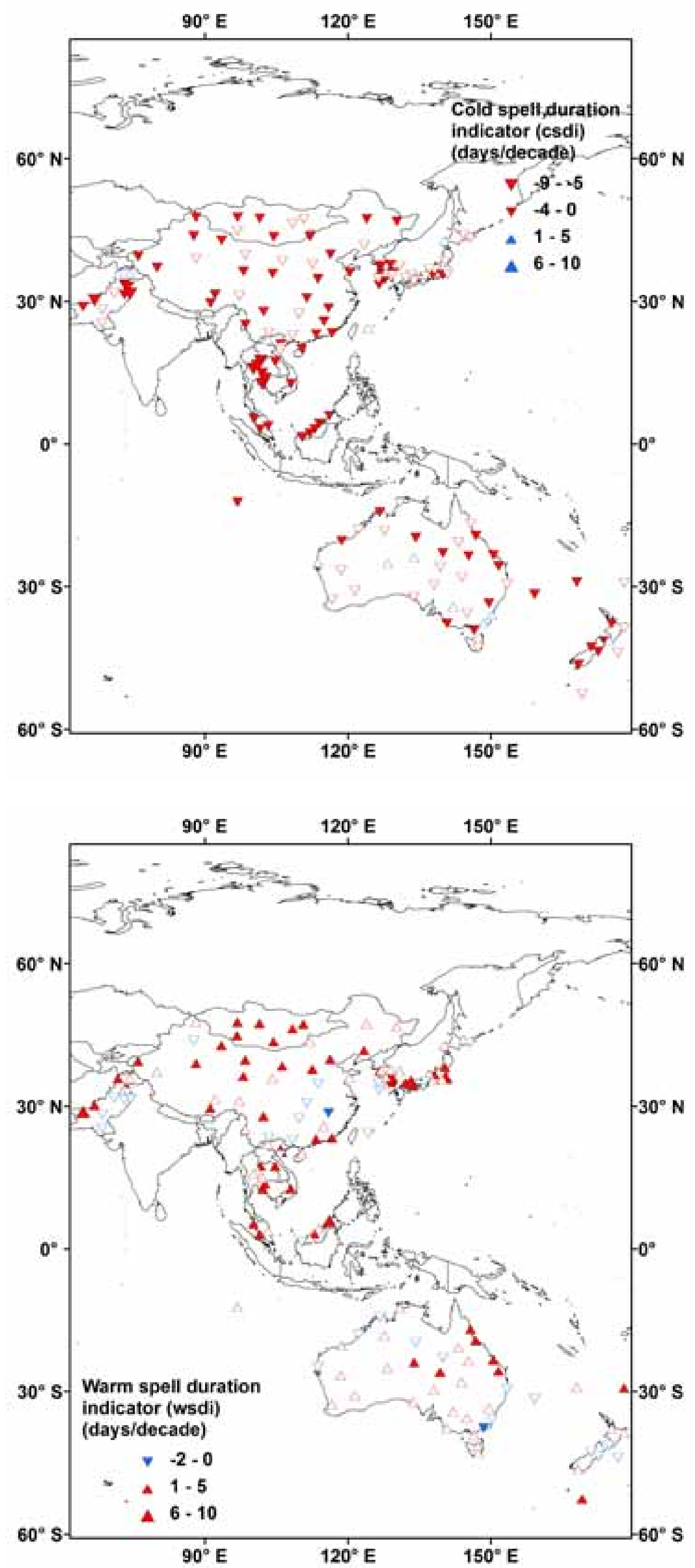


Figure 9. Same as in Fig. 7, but for cold spell duration indicator (csdi) and warm spell duration indicator (wsdi).

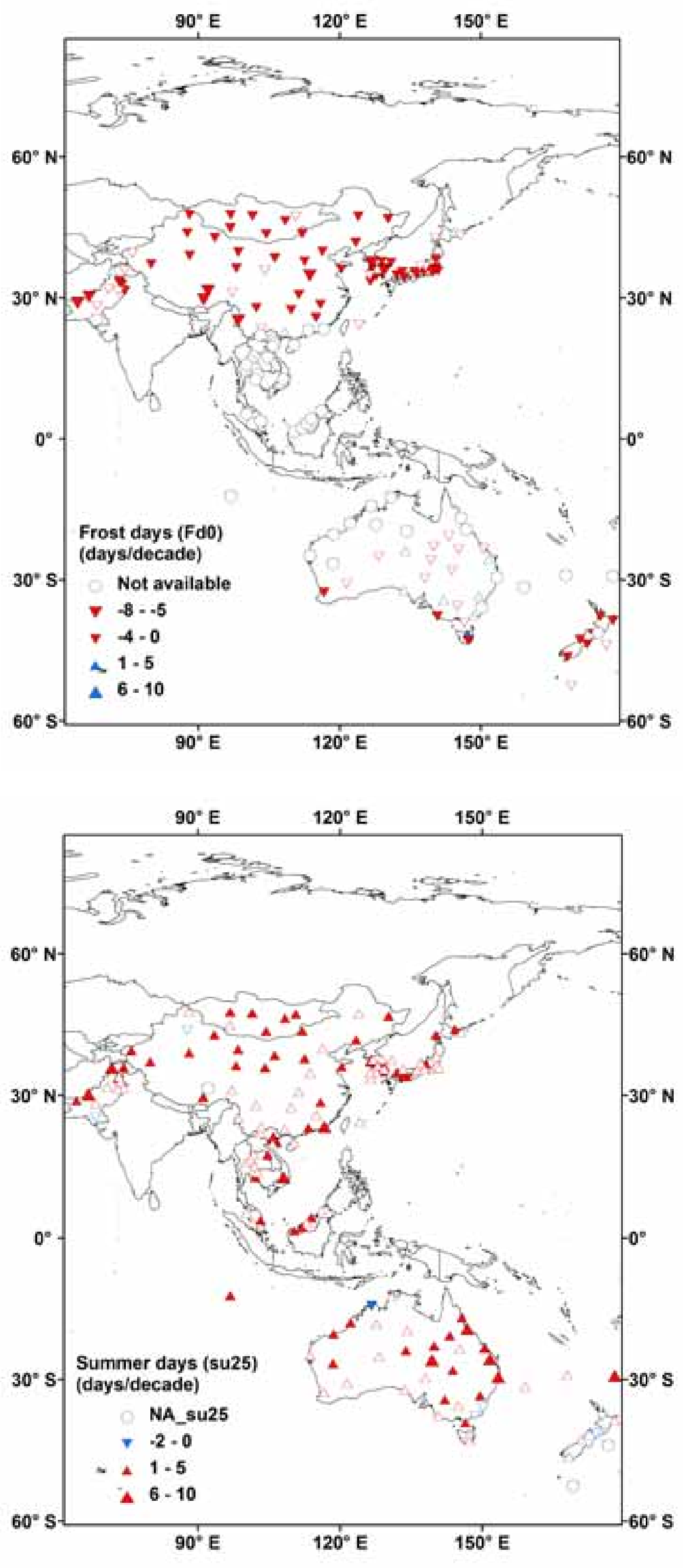


Figure 10. Same as in Fig. 7, but for frost days (fd0) and summer days (su25).

3.2. Trends of extreme precipitation events

The number of weather station with significant trends of extreme precipitation indices is much smaller than that for extreme temperature indices (Table 4). Significant trends of any individual extreme precipitation indices are not observed at more than 120 weather stations. In particular, the trend of very heavy precipitation days (r20mm), and extremely heavy precipitation days (r30mm) are not significant at 136 weather stations. The number of weather stations with significance of annual total wet-day precipitation (prcptot) and maximum 5-day precipitation amount (rx5day) are relatively more than other indices. However, the percentage of weather stations with significant extreme temperature trends is less than 15% (Figure 11).

The average trends of 10 extreme precipitation indices are quantified in Figure 12. The APN regional average trend of very heavy day precipitation (r95p) and extremely heavy day precipitation (r99p) are 5.4 mm/decade and 2.9 mm/decade, respectively. The regional average trend of maximum 5-day (rx5day) precipitation amount is 1.3 mm/decade. The magnitude for all other trends is less than 1 mm or 1 days/decade. The max and min values of significant trends of extreme precipitation indices at individual weather stations show two extremes of trends (Figure 13). The magnitude of positive precipitation extreme trends are slightly greater than the negative one in the cases of very heavy precipitation day and extremely heavy precipitation day, annual wet day precipitation, as maximum 1-day and 5-day precipitation amount. In particular, annual total wet day precipitation varies between +75 mm/decade and -70 mm/decade, indicating that precipitation trends are highly variable from one location to another. The numbers of very heavy precipitation day and extremely heavy precipitation day also show large difference between two extreme, implying that trends of extreme precipitation events is highly localized. Maximum and minimum extremes of all other index trends are less than 10 mm or 10 day/decade.

Spatial patterns of linear trends of annual total precipitation amount (prcptot) are illustrated in Figure 14. Overall, the trends vary from one location to another neighboring location. It is difficult to identify regionally-coherent significant trends. However, if insignificant trends are also considered, the overall decreasing trends of annual total precipitation amount are observed in northern China and southeastern Australia, while the increasing trends are found in Tibetan plateau, southeast Asia, Republic of Korea and northwestern Australia, implying that summer monsoon system may be intensified in these regions. As shown in Figure 15, similar patterns are observed in the case of trend maps of very wet days and 5-day maximum precipitation. Strong increasing trends of two indices are observed in Southeast Asia, and Republic of Korea, where heavy rainfall events occur during the monsoon period. In contrast, the phase is reversed into decreasing trend in northern China and southeastern Australia. In terms of duration, consecutive wet days and dry days are examined as illustrated in Figure 16. However, there is no noticeable regionally-clustered pattern. The magnitude and sign of their trends are highly localized, varying from one location to neighboring location.

Table 4. The number of weather stations with significant (S) or insignificant (IS) linear trends (at 95% level) over the analysis period for extreme precipitation indices.

Country	Australia		China		Japan		Malaysia		Mongolia		New Zealand		Pakistan		Republic of Korea		Thailand		Vietnam		APN	
Total	36		32		15		8		6		10		12		14		7		5		145	
95%	S	IS	S	IS	S	IS	S	IS	S	IS	S	IS	S	IS	S	IS	S	IS	S	IS	S	IS
rx1day	2	34	6	26	0	15	2	6	1	5	2	8	1	4	0	12	2	12	0	7	16	129
rx5day	2	34	7	25	0	15	2	6	2	4	2	8	2	3	0	12	4	10	1	6	22	123
Sdii	0	36	5	27	3	12	3	5	1	5	1	9	1	4	0	12	4	10	0	7	18	127
r10mm	5	31	4	28	2	13	2	6	3	3	2	8	0	5	1	11	0	14	2	5	21	124
r20mm	2	34	4	28	0	15	1	7	1	5	0	10	0	5	0	12	0	14	1	6	9	136
R30mm	2	34	3	29	0	15	1	7	0	6	1	9	1	4	1	11	0	14	0	7	9	136
Cdd	2	34	2	30	1	14	0	8	0	6	2	8	0	5	0	12	0	14	1	6	8	137
Cwd	4	32	7	25	2	13	3	5	1	5	0	10	0	5	1	11	0	14	1	6	19	126
r95p	4	32	5	27	1	14	2	6	0	6	1	9	1	4	1	11	6	8	0	7	21	124
r99p	3	33	3	29	0	15	2	6	0	6	2	8	1	4	1	11	5	9	0	7	17	128
prcptot	9	27	6	26	2	13	1	7	1	5	3	7	1	4	0	12	1	13	1	6	25	120

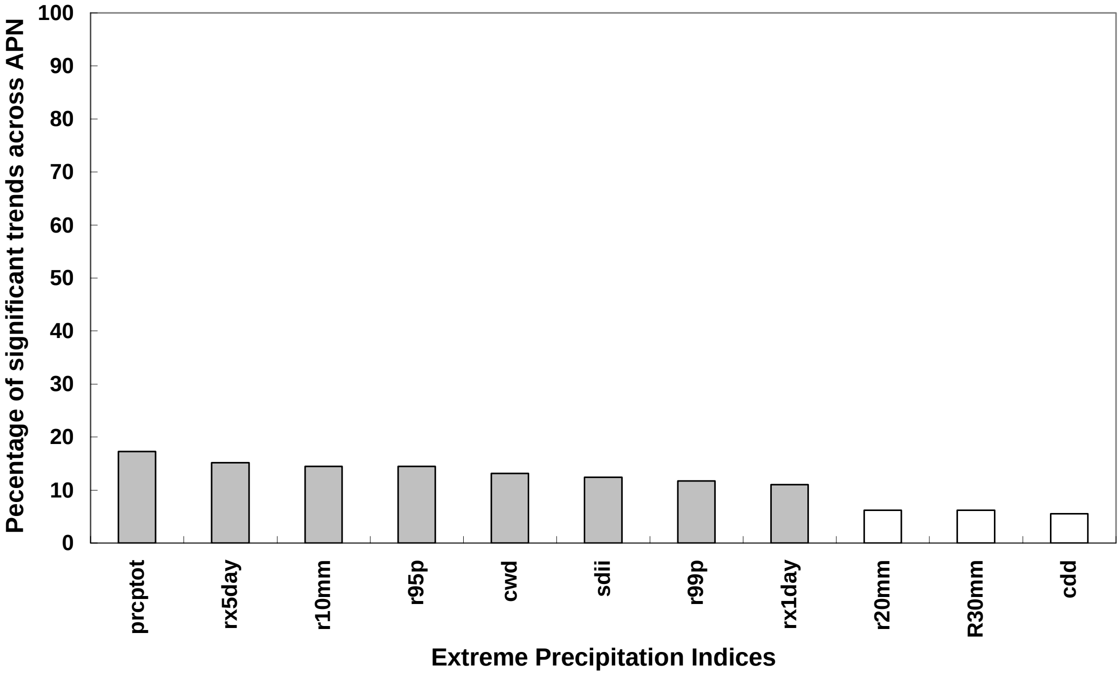


Figure 11. Percents of weather stations with significant (95% or more) trends across ten APN countries for individual extreme precipitation indices

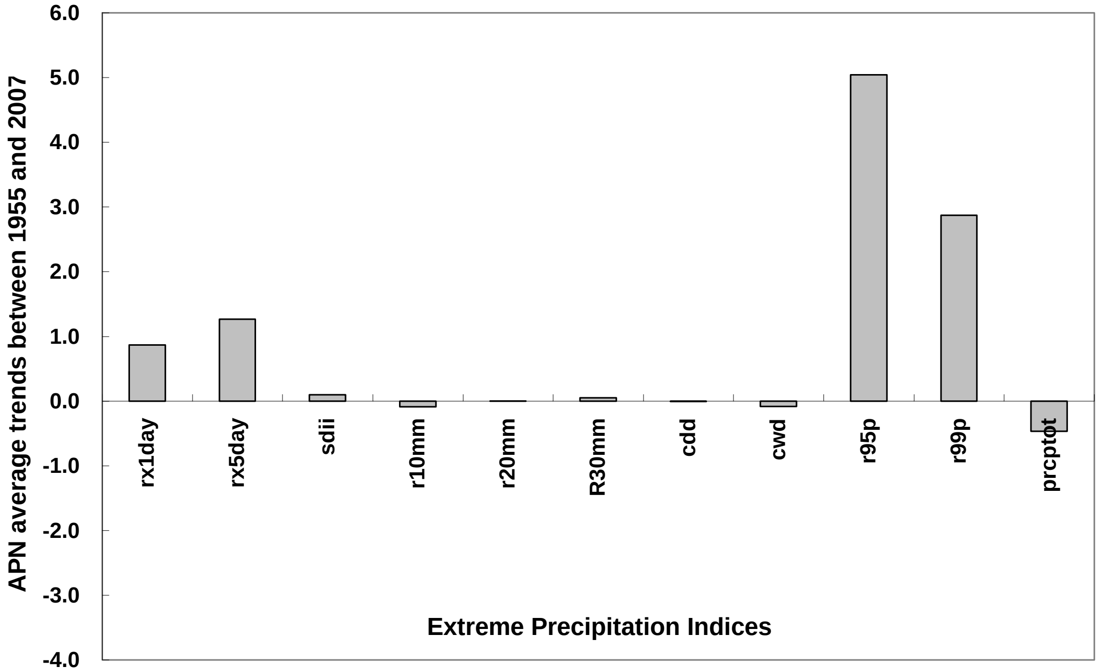


Figure 12. Average trends (unit per decade) across ten APN countries for individual precipitation indices.

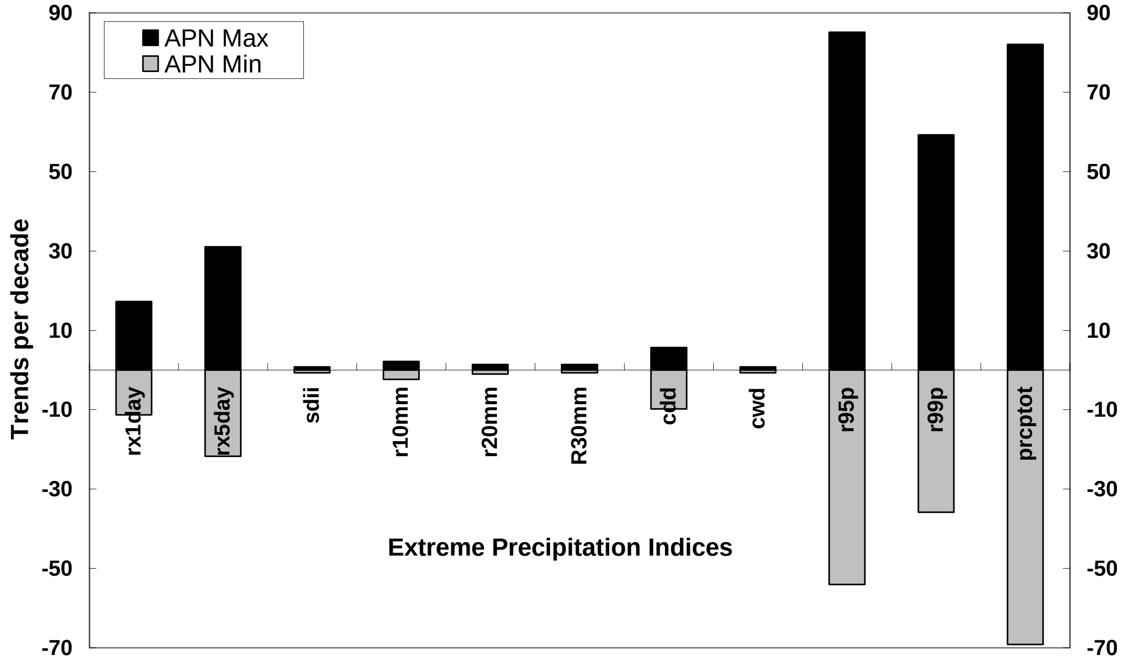


Figure 13. Significant (95% or more) maximum and minimum trends of extreme precipitation indices within ten APN countries

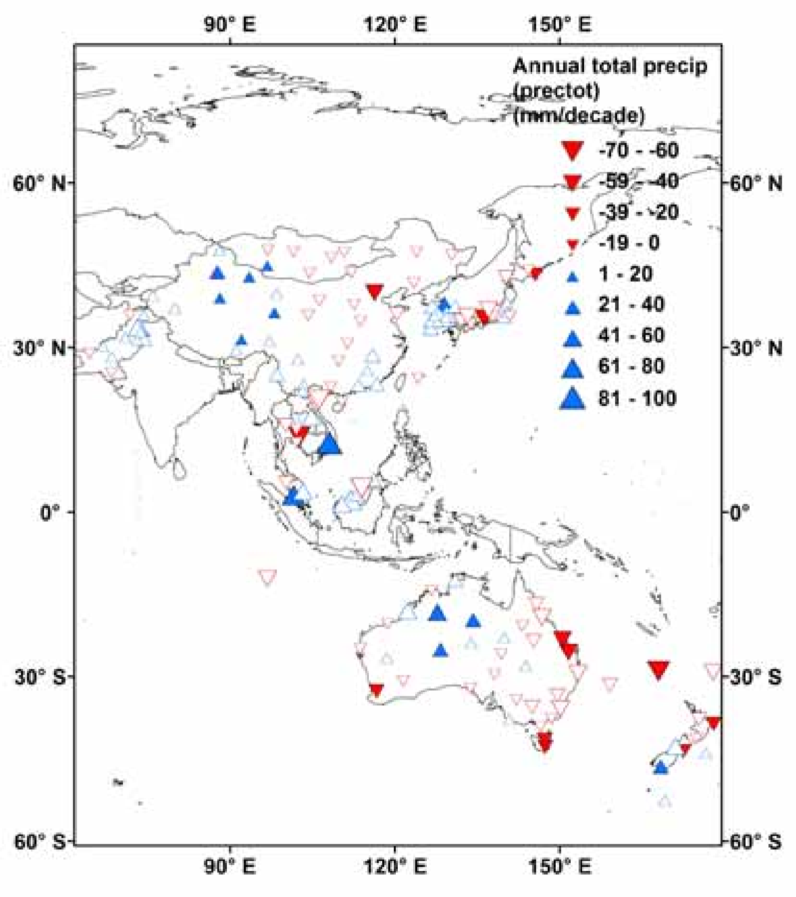
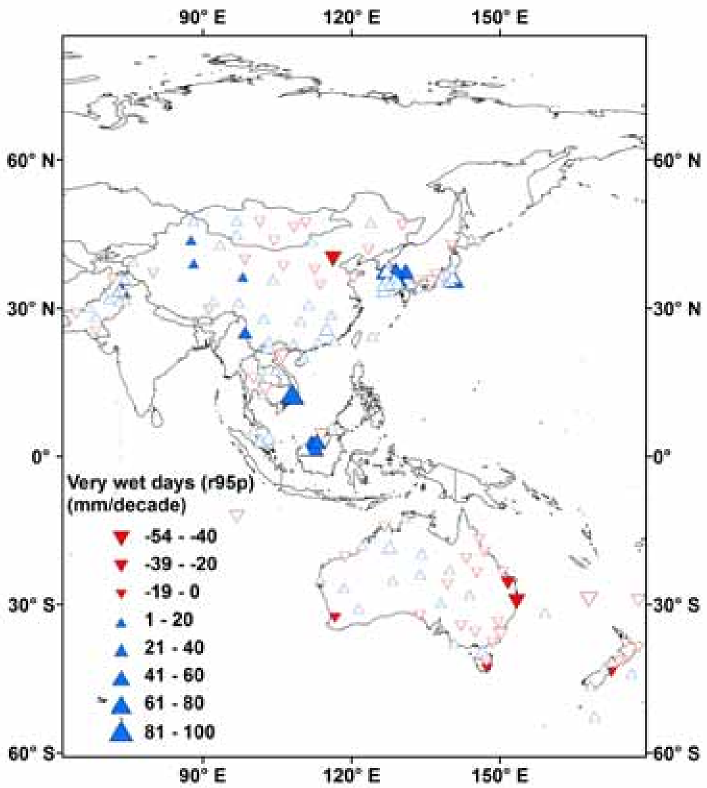


Figure 14. Linear trends (mm/decade) of annual total precipitation day amount (prcptot) over the 1955-2007 period across ten APN countries. Color-filled symbols indicate that the linear trend is significance at the 95% level.



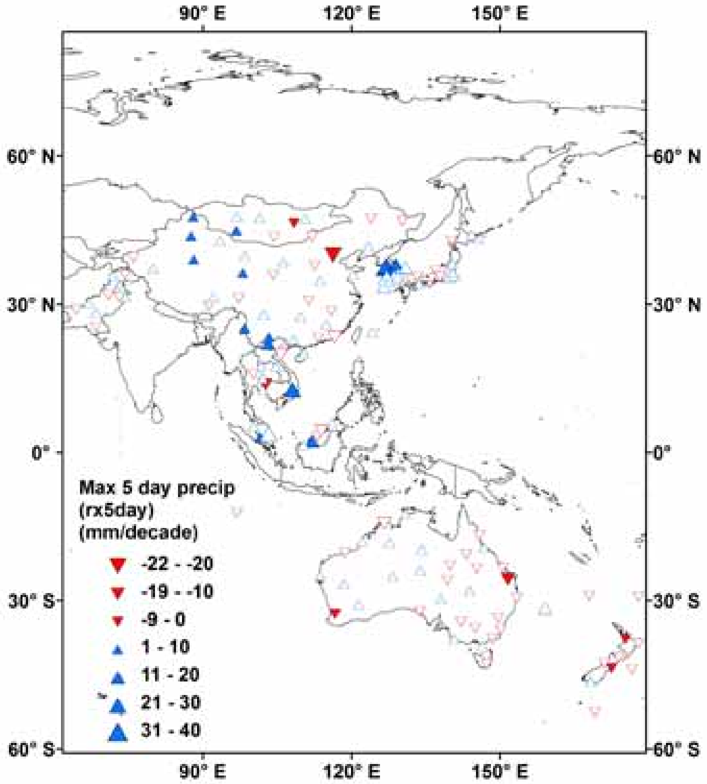


Figure 15. Same as in Fig. 14, but for very wet days (r95p) and 5 day maximum precipitation (rx5day).

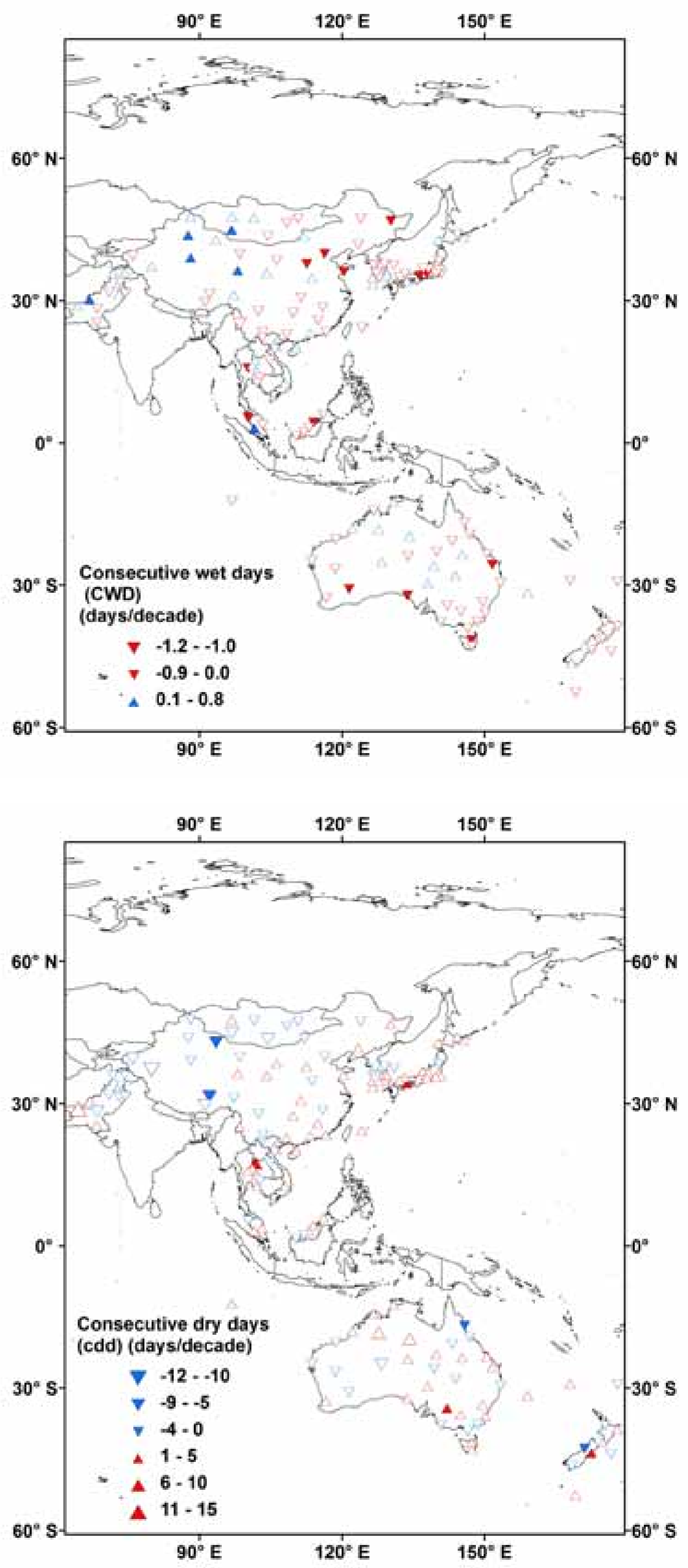


Figure 16. Same as in Fig.14, but for consecutive wet days (cwd) and consecutive dry days (cdd).

4. Conclusions

This study intended to develop appropriate indicators to monitor extreme temperature and precipitation across more than 140 weather stations in the APN region based on long-term daily climatic data. Collaborated results indicate that the number of summer warm days/nights based on upper/lower 5th percentile thresholds has increased across the study region, while the number of winter cool days/nights has decreased. The trends of cool nights and warm nights in the APN region are -6.7 days/decade and +6.2 days/decade, respectively, and those of cool days and warm days are -3.5 days/decade and +4.5 days/decade, respectively. Cold events based on fixed thresholds including frost days and ice days have decreased, while hot events such as tropical nights and summer days have increased. The trend of frost days in the APN region is -1.5 days/decade but its less magnitude than expected is caused by zero trends at tropical weather stations, where there is no record of frost days. The trend of strong summer days in the APN region is +2.5 days/decade.

These results shows that percentile-based temperature indices captured statistical significance in their trends better and at more numbers of weather stations compared to the fixed-threshold indices. The 95th percentile-based temperature indices show significant linear trends at more than 70% of weather stations in the APN region, while fixed-threshold indices such as ice days shows the significant trends only at less than 20% of weather stations. Larger magnitude of significant trends at more weather stations are detected by the order of cool nights, warm nights, warm days, and cool days. In contrast, some of fixed-threshold indices such as ice days are not applicable in the tropical regions because lower temperature events rarely occur.

Compared with extreme temperature indices, the weather stations which show significant trends of extreme precipitation events is less than 15% among all weather stations. Moreover, locations of these stations that show significant trends are scattered without coherent clustering patterns across broad regions. Linear trends of frequency and intensity of extreme rainfalls are not significant in many stations and regionally vary. These results concluded that extreme precipitation events are highly localized so that fine-scale approach is needed in the future studies.

5. Future Directions

Several future works should continue to make sure whether the magnitude of trends derived from current data set represents regional trends of extreme climate indices attributable to current global warming.

First, many weather stations used in this study are currently located near or within regions where fast urbanization occurs in Asian and Pacific large regions with economic developments. However, observation environments are not documented well so that the bias of local urbanization is still contained in the quantified magnitude of trends calculated in this study. One option to justify the trends is to classify stations into several groups (e.g. rural, small towns, and urban) based on observational environments (e.g. percentage of pavements within 100m radius areas).

Second, it is needed to develop a synthesized database system that allows scientists to share the data and update their digital data based on paper archive data. In some countries in the APN regions, there are many paper-archived data which are hardly accessible. Thus, continuous support to update the data is needed to construct long-term data.

Third, future climate projection simulated by regional climate models may have potential to compare the observation data with modeled data and later use the model output to fill the spatial gap between observation sites. Furthermore, the validation through the comparison allow us to project future directions of extreme climate events using climate model simulations from regional to global scales.

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Appendix A

Workshop Programme and Participants List

A1. Programme

20 February 2008 Yoido Hotel

Time	Title	Speaker
09:30-10:00	Registration	
10:00-	Opening Address	Man-Ki Lee KMA Administrator
10:30-11:20	Current Research on Climate Change in Korea	Won-Tae Kwon KMA, **Korea**
11:20-12:10	Climate Statistics on Eigen Analysis including CSEOF	Young-Kwon Lim Florida State Univ.
12:10-13:30	Lunch	
Chair: Guoyu Ren (13:30-14:50)		
13:30-14:10	Previous APN and other regional climate workshop	Blair Trewin National Climate Center, **Australia**
14:10-14:30	Observed trends in New Zealand climate over 1951-2007	Marina Baldi New Zealand Meteorological Service, **New Zealand**
14:30-14:50	Preliminary study on changes of present climate extremes in Mongolia	P.Gomboluudev **Mongolia**
14:50-15:20	Coffee Break	
Chair: Blair Trewin (15:20-16:20)		
15:20-15:40	Climate Change and Extreme Weather Events in Malaysia	Norlisam Lias Kuching Regional Meteorological Office, **Malaysia**
15:40-16:00	Recent Progresses in Studies of Regional Temperature Changes in China	Ren Guoyu National Climate Centre, **China**
16:00-16:20	Trend in Extreme Climate Indices for Thailand	Pianmana Theeraluk ,**Thailand**
16:20-16:50	Coffee Break	
16:50-18:00	Discussion	

21 February 2008

Time	Title	Speaker
Chair: Gwangyong Choi (09:30-12:00)		
09:30-10:10	An uncertainty assessment of surface temperature and precipitation variability in the IPCC AR4 GCMs over East Asia	Jinho Shin KMA, **Korea**
10:10-10:50	Application of CSEOF to monsoon climate analysis and prediction	Young-Kwon Lim Florida State Univ.
10:50-11:20	Coffee Break	
11:20-12:00	Precipitation changes in future climate: Extreme events and constraints	William J. Gutowski, Jr. Iowa State Univ., **USA**
12:00-13:30	Lunch	
Chair: Marina Baldi (13:30-14:50)		
13:30-13:50	Trends of extreme climate events in Republic of Korea 1955-2004	Kyung-On Boo KMA, **Korea**
13:50-14:10	Changes in temperature and precipitation trends over Pakistan	Muhammad Afzaal **Pakistan**
14:10-14:30	Trends in climate extremes in Japan	Yoshikazu Fukuda, **Japan**
14:30-14:50	Trend of climate index of Vietnam	Pham Thi Thanh Huong **Vietnam**
14:50-15:10	Changes in climate extremes in Australia	Dean Collins National Climate Center, **Australia**
15:10-15:40	Coffee Break	
15:40-16:00	On the Indices and R-ClimDex, RH-test	Gwangyong Choi KMA, **Korea**
16:00-18:00	Group Discussion Data Analysis using R-ClimDex, RH-test	

22 February 2008

Time	Title	Speaker
10:00-10:30	Trends of Extreme Climate Events in the Asian-Pacific Network(APN) Region	Gwangyong Choi KMA, **Korea**
10:30-12:00	Discussion Future Plan for the Final Report	Kyung-On Boo KMA, **Korea**
12:00-13:30	Lunch	
14:00-17:00	Visiting KMA	

23 February 2008

Science Tour (Seoul Meteorological Observation Station)

A2. Participants List

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28	Minji Kim	Korea Meteorological Administration, Korea	minji@metri.re.kr

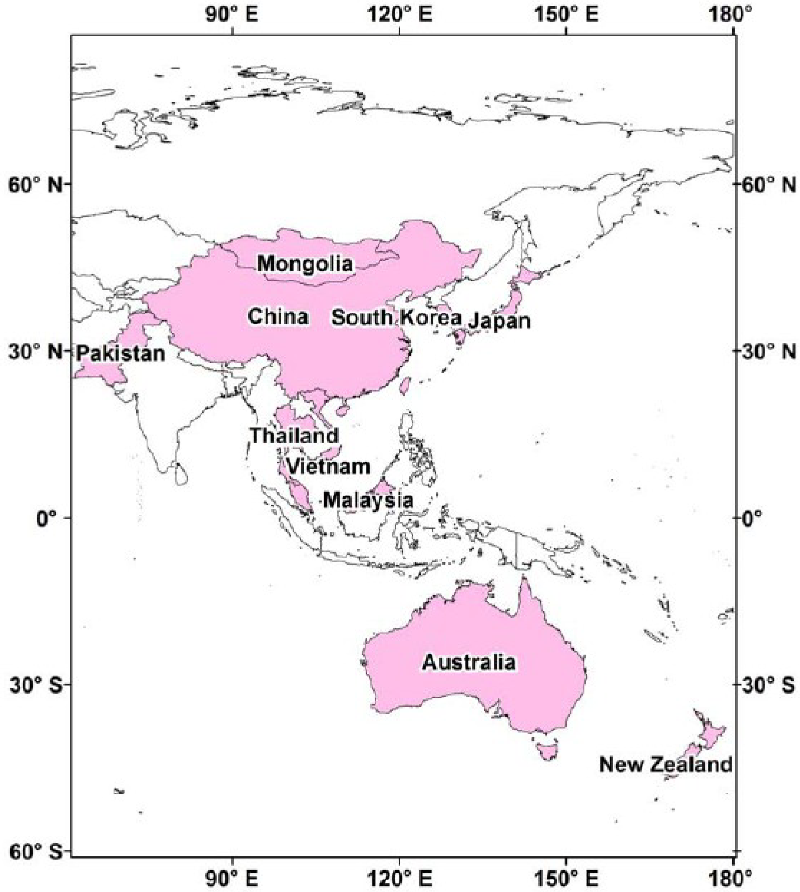

Figure A1. Ten countries participating in the 6th Asian Pacific Network workshop (Australia, China, Japan, Malaysia, Mongolia, New Zealand, Pakistan, Republic of Korea, Thailand, Vietnam).

A3. Funding sources outside the APN

Table A1. Funding source for 6th APN workshop

Organization	Project	*Contribution*
APN	ARCP2007-20NSG	US$10,000
National Institute of Meteorological Research / Korea Meteorological Administration	The Applications of Regional Climate Change Scenario for the National Climate Change Report	US$16,000

A4. Glossary of Terms

APN: Asian-Pacific Network

ETCCDI: Expert Team on Climate Change Detection and Indices

Appendix B

Abstracts of Workshop

Current Research on Climate Change in Korea

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The global scientific communities, as represented by the Intergovernmental Panel on Climate Change (IPCC), have sent a clear message that warming of the climate system is unequivocal and most of the observed warming is attributable to human activities. For the next two or three, a warming of about 0.2^{o}C per decade is expected for a range of SRES emission scenarios. At the end of 21st century, global mean surface temperature is projected to increase by 1.1-6.4^{o}C due to the projected increases of greenhouse gas concentrations in the atmosphere.

Climate change will seriously influence various sectors, including agriculture, forestry and fisheries, the coastal and marine environment, natural disasters, health, etc. The impacts could be large and vary significant from region to region. therefore climate change is the biggest challenge in this century. To meet the challenges and get insights for the possible consequences of climate change, METRI/KMA contributes to provide scientific basis for the national Report for the United Nations Framework Convention on Climate Change and provides them to assess climate change impact and develop adaptation measures in Korea.

At first, observed climate change are analyzed and future projections are produced. To understand possible future surface climate change over East Asia, global climate change projections are produced from the coupled climate model ECHAM4/HOPE-G simulation based on the IPCC SRES scenarios (A1B, B1, A2). To capture the regional features, we have produced the dynamically downscaled data from a long-term simulation with the NCAR/PSU Mesoscale Model version 5 (MM5) that is based on the IPCC SRES A1B scenario. The regional projection is useful to evaluate the regional impact of climate change over Korea because of regional details due to its complex topography.

The result of long-term scenario simulation shows that at the end of the 21st century, the global mean temperature will rise by approximately 2-3^{o}C. In East Asia, temperature will rise by 3-4^{o}C and projected rainfall shows more extreme events such as droughts and heavy rainfall event associated with global warming.

Large-scale forcing arising from global warming may locally change the precipitation distribution over complex terrain regions such as the Korean Peninsula. Therefore, in regional projection, temperature will increase by 4^{o}C over the Korean Peninsula in the end of 21st century (A1B). Hot extremes and heavy rainfall events will continue to become more frequent.

The above results contribute to improve understanding of climate change in global and regional scale and assess the impacts of the climate change to formulate sectoral and regional adaptation strategies.

Climate Statistics on Eigen Analysis including CSEOF and Application of CSEOF

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My presentations for two days focus on the new perspective of eigen analysis on climate variability, and its application to climate prediction. An objective of this study is to better understand the prominent climate variations with an emphasis on the possible coupling among dominant climate signals. For this purpose, observational dataset is viewed as a combination of climate signals (e.g., seasonal cycle, dominant intraseasonal oscillations including MJO, and ENSO-associated evolution, etc.) and their interannual intensity variations. Cyclostationary Empirical Orthogonal Function (CSEOF) method is employed for this decomposition of observational data into the complete evolution cycle of independent climate signals and their amplitude variation time series (PC time series). In this study, we applied CSEOF method to the analysis on the Asian summer monsoon (ASM) variations.

Precipitation and other synoptic variables during the prominent life cycle of the ASM are used to show the detailed evolution features of dominant modes, which are identified as the seasonal cycle, the ISO defined by the 40-50 day intraseasonal oscillation, and El Niño-related monsoon evolution. The CSEOFs quite successfully describe the evolution pattern of these modes over the entire monsoon domain throughout the ASM period. CSEOF also identifies how strength of these modes varies on interannual time scale and how significantly they play a role in determining the monsoon precipitation amount and the observed intraseasonal or interannual rainfall variations.

Based on the modal decomposition of the ASM variability, a new paradigm for climate (one month and longer) prediction is developed and is applied to the 5-day averaged ASM precipitation. The foundation of the method is to predict the interannual amplitude variation (stochastic components) of individual climate signals (deterministic components) that constitutes the ASM system. Prediction is much facilitated by forecasting this slowly undulating amplitude time series. The present method extends the predictability of the ASM pentad precipitation event to six months in certain regions with correlation greater than 0.4. Also, ISO propagation is successfully predicted 60 days ahead of time with correlation greater than 0.4. The performance of the new prediction method using CSEOF technique is significantly better than persistence and that of conventional methods in which raw data should be predicted directly.

The results from this study demonstrate improved prediction and physically sound interpretation of the ASM variability. Based on improvements presented in this study, it reveals that CSEOF has many applications not only for numerous climate analyses on variability, change, and extremes, but also for the statistical climate predictions.

Previous APN and other regional climate workshops

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APN has supported a series of climate workshops over the last 10 years, hosted by Australia and New Zealand. The first of these workshops took place in 1998 in Melbourne, and there were a total of 8 workshops (5 in Australia, 3 in New Zealand). While the countries involved have changed between workshops, most countries in the South Pacific and eastern Asia (north to Japan and Korea and west to Myanmar) have attended at least one of the workshops, with the New Zealand workshops concentrating more directly on the South Pacific islands.

The original workshop concentrated on analyses of observed climate change in the region (both means and indices of extremes). The use of indices, and the carrying out of analyses at the workshop, overcame difficulties with the exchange of historical daily data between countries, as each participating country brought their own data for analysis at the workshop. Later workshops, as well as updating the results from the first workshop, extended into other important areas, such as data quality control and homogeneity, data rescue and metadata, and relationships between climate indices and other broadscale climate indicators such as ENSO.

The original APN workshop series provided a model for other similar workshops to take place in many other parts of the world, under the auspices of the WMO. Since 2001, such workshops have taken place covering northern Africa, southern Asia, western and central Asia, central Africa, the Caribbean and Central America, and South America. The results from this series of workshops formed an important part of the global analysis of climate extremes reported in the recently-released 4th Assessment Report of the IPCC.

The most recent WMO-sponsored workshop took place in Vietnam in December 2007 and included representatives from 12 countries, Vietnam, Cambodia, Laos, Thailand, Australia, Timor-Leste, Myanmar, Nepal, Bhutan, Sri Lanka, Fiji and the Maldives. Several of these countries had not previously been involved in such a workshop. The capacities of the various countries, and the amount of data they had available, varied considerably, with some countries (especially those badly affected by conflict in recent decades) having only 5-10 years of data, but many useful results were still obtained. As has been the case with many of the other regional analyses, the results from the Vietnam workshop show a general increasing trend in indices of warm extremes (especially those relating to overnight minimum temperatures), a decreasing trend in indices of cold extremes, and mixed results for rainfall.

In addition to the scientific results obtained, the workshops which have taken place to date have been very useful in building links between developed and developing countries, and for raising awareness of issues affecting various countries – in particular, in raising awareness in developed countries of the difficulties facing meteorological services in many small developing countries. The links which have been developed have also provided a framework for other projects, such as an Australian-sponsored project to improve capacity for seasonal climate prediction by South Pacific countries.

Observed trends in New Zealand climate over 1951-2007

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It is well accepted nowadays the fact that climate is changing, through global warming and natural climate shifts. As a consequence, wind patterns will be affected by climate change, and warmer temperatures can affect evaporation, clouds and rain. Parts of the country will get drier or wetter, stormier or calmer and generally there will be a change in the extremes of temperature and rainfall.

This study is devoted to analyze changes in the mean climate in New Zealand over the period 1951-2007 with as main intent to find out if the changes in climate now being observed are having any effect on extreme weather events, and if changes in the mean climate are paralleled by changes in extreme temperatures and rainfall.

Between 1951 and 2007, mean, maximum and minimum surface temperatures have warmed in the New Zealand region, and the climate patterns in the Pacific region have shifted around 1950, and again in the mid 1970s and also in 1998, with resulting changes in average wind patterns, mean temperature and mean rainfall across New Zealand.

Daily maximum and minimum temperature and rainfall data from 10 stations around New Zealand were analyzed which are representative of the two main Islands (North and South) and of the islands located well off the Mainland in the Pacific Ocean.

We then analyzed extreme indices over the period 1951-2007. The extreme indices are based on percentiles, as opposed to a threshold amount because an arbitrary threshold would not be appropriate for all of the stations used, which come from climatically diverse regions around New Zealand. The analysis of several annual indices of extreme temperature and rainfall show a general increase of maximum and minimum temperatures and a general decrease of daily temperature range and of frost days, which are in any case rare events in New Zealand except for the mountainous regions and the southern tip of the Country. The analysis of hot days and cold nights doesn't show remarkable trends, although in some of the stations there is an increase of hot days and hot nights over the period. While total rainfall shows different trends in different parts of the Country, there is a slight increase in dry spells and a little decrease in the wet spells.

In conclusion, in the period 1951-2007 significant trends have been observed in some of the core indices analyzed, although differences have been detected between the six climate regions of New Zealand. It also seems that some extremes respond differently to the mean climate, and are affected by shifts in climate patterns around New Zealand. Further work is required to confirm and quantify the results.

KEY WORDS: New Zealand, temperature extremes, rainfall extremes, climate trends

Preliminary Study on Changes of Present Climate Extremes in Mongolia

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In order to define the changes of present climate extremes are considered on basis of daily maximum, minimum temperature and precipitation which were observed at the 10 meteorological stations over the Mongolia from 1961 to 2006. Stations are selected in the different natural zones as much as possibly to represent typical location of the country and have been checked homogeneity test as well.

Extreme temperatures indices are shown increasing of both daily maximum and minimum temperature. However, intensity of the minimum temperature higher than maximum and it is consistent with decreasing of the diurnal range over the Mongolia. Their warming and cold tail of the distribution has been warmed.

About precipitation, generally there is decreasing trends except the south-western region, especially relative high intensity decreasing is might be observed in the central region of the country. Same feature corresponds to indices of wet extreme condition also. But it is needed to study precipitation type or percentage of heavy precipitation in the total amount in terms of place where land degradation is going on.

Climate Change and Extreme Weather Events in Malaysia

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This paper presents an overview of climate change and trends of extreme weather events occurrence in Malaysia. The climate in Malaysia is basically dominated by a cycle of two monsoon regimes i.e. the northeast monsoon and southwest monsoon. However, being an equatorial country, Malaysia has uniform temperature throughout the year. The eight stations are chosen for analysis using rclimdex and excel based on sufficient length of climate data as possible from 1955 to the present and with some criteria such as medium industrial zone (48601), commercial zone with high density population (48647), flood prone area (48657), tourism zone (96471) and oil & gas area (96441 & 96449). Analysis indicates the annual variation is less than 3°C. The diurnal temperature range is large, being from 6.3°C to 8.7°C at the coastal stations and from 7.9°C to 10.3°C at the inland stations but the excessive day temperatures, which are found in continental tropical areas, are never experienced. It may be noted that air temperature of 38°C has very rarely been recorded in Malaysia. Although the days are frequently hot, the nights are reasonably cool everywhere. Over the Maritime Continent, the signal is weakened and becomes disorganized due to the presence of orographic lands. Analysis of eight stations in various parts of Malaysia indicated warming trends. Generally, the overall correlation analysis of annual mean temperatures has the largest trend over station 48647 followed by station 48657, 48601, 96471, 96441, 96421, 96449, and 96413. The rates of increase are about 0.8°C to 4.5°C per 100 years. There is strong evidence to link the local warming trends to urbanization process and also global trends. Similarly, in some stations long-term trends in precipitation since mid-1970s are also present. Most stations in the west coast of Peninsular Malaysia show upward trends of annual rainfall and seasonal rainfall during northeast and southwest monsoons since mid-1970s. In most cases the upward trends appears to be due to the increasing trends of maximum daily rainfall. At the same time the maximum length of dry spell also seems to be showing an upward trend during the period.

Recent Progresses in Studies of Regional Temperature Changes in China

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An overview of recent studies of temperature changes over China will be presented. The studies come mainly from studies on observed changes of surface air temperature of the last 55 years and 100 years, and of free atmospheric temperature of the last 50 years, and on effect of rapid urbanization on site temperature records and regional average temperature series. Based on a data set of national basic and reference stations, which have been quality-controlled and adjusted for in-homogeneity dominantly induced by relocation of stations, updated surface air temperature time series of the past 55 years and 100 years are established. The new temperature series show a generally more rapid warming than those obtained before, with the rates of change of annual mean temperature reaching 0.22℃/10 yr. and 0.08℃/10 yr. respectively for the past 55 year and 100 years. The current warming is more significant in Northeast China, North China, Northwest China and the Qinghai-Tibet Plateau, and the largest increase in temperature occurs in wintertime and springtime. It is found, however, that significant effects of urbanization on recorded trends of temperature for single stations as well as for region averaged temperature series exist in a few regions investigated so far. In North China which experiences the most remarkable warming in the country, increase of annual mean temperature induced by urbanization for national basic and reference stations reaches 0.44℃ in period of 1961-2000, with an increasing rate of temperature of 0.11℃/10a, accounting for 38% of the total warming rate as recorded by these stations. The effects of urbanization might have remained in the other regional changes in annual mean temperature. Regardless the remarkable warming of the surface, mid-to lower troposphere (850-400hPa) witnesses no significant change in temperature, with a rate of change of only 0.05℃/10a for the period of 1961-2004, and upper troposphere (300-150hPa) and lower stratosphere (100-50hPa) are experiencing a significant decrease in temperature at rates of -0.17℃/10a and -0.22℃/10a respectively. A slight decrease in temperature is found for the entire troposphere in the period investigated. However, mid-to lower troposphere temperature is increasing in the past 20 years at a much higher rate than before, and the difference of change between surfaces and mid-to lower troposphere is getting smaller. It is still premature to answer the question of what cause the observed warming on the surface in China. Some evidence support the claim that it has mainly been induced by the increased concentration of greenhouse gases in atmosphere, but the influences of other factors like solar activities and the low-frequency

oscillations of ocean-atmospheric system could not be ruled out.

Key Words Temperature Change, Urbanization Effect, Upper Air Temperature, Mainland China

Trend in Extreme Climate Indices for Thailand

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Extreme climate events having major impacts on large loss of human life and properties. This study based on the analysis of trend in extreme climate indices in Thailand would be one that increased ability for monitoring and detecting our changed climate. In this study, the fifty-three years of daily temperature and rainfall record from 1955 to 2007 are used to calculate trends in extreme indices. Based on the homogeneity testing and quality control, data for 7 stations i.e. Petchabun, Loei, Nakhon Phanom, Nakhon Ratchasima, Nakhon Sawan, Aranyaprathet and Chanthaburi were prepared for analyze trends in tempearture and rainfall indices.

The analysis results of trend in temperature indices have been showed that summer days (number of days with Tmax > 30^{o}c) and tropical night (number of days with Tmin > 25^{o}c) has significantly increased in most stations. Trends in warm days and warm nights have significantly increased as well. On the contrary, trends in cool days and cool nights have significantly decreased.

For trend in rainfall indices, no significant changed at most stations. However, a few stations displayed significantly decreased in rainfall, Loei experienced rainy day (days with rain ≥ 0.1 mm) decreased, Nakhon Ratchasima decreased in number of rainy day and heavy precipitation days. In particular, Aranyaprathet has significantly decreased in the annual total wet day corresponding to the negative trend in the number of rainy day, heavy precipitation and very heavy precipitation days.

From this study, it showed that trend in temperature indices has significantly changed with more changed in minimum temperature than maximum temperature and no significant trend in rainfall indices in several stations.

An Uncertainty Assessment of Surface Temperature and Precipitation Variability in the IPCC AR4 GCMs over East Asia

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An uncertainty assessment of surface temperature (T2m) and precipitation (PCP) variability over the East Asia is practiced using T2m and PCP simulated by general circulation models (GCMs) participating in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). Comparisons between observation and simulation are carried out by statistical methods including bias and root mean square error (RMSE). Since large uncertainty of PCP over East Asia is caused by summer monsoon contributing to heavy rainfall, the cyclostationary Empirical Orthogonal Function (CSEOF) analysis [1] is employed to investigate the annual cycle of PCP in this region. The CSEOF analysis calculating eigenfunctions of a periodic and time-dependent covariance statistics is a proper tool to understand the PCP variability with physical mode and its undulation. The space-time data, $T(r,t)$ are represented in terms of the cyclostationary loading vectors (CSLVs), $B_n(r,t)$ and their corresponding principal component (PC) time series, $T_n(t)$;

$$T(r,t) = \sum_n T_n(t) B_n(r,t) \qquad (1)$$

Through the CSEOF analysis, the evolution of PCP anomalies can be investigated. Figure 1 represents the first mode (annual cycle) of observed (OBS) and multi-model ensemble (MME) PCP anomalies from spring to summer over East Asia. Positive OBS PCP anomalies (more PCP) occur in spring (April-May, Fig. 1a-b) over southeastern China. They expand northeastward in June (Fig. 1c), in which rainfalls from Changma system (the monsoon over northeast Asia) start over Korea and Japan. As positive anomalies prevail during the Changma period from July to August (Fig. 1d-e), torrential rainfalls outbreak over Korea.

Compared with the evolution of the OBS PCP anomalies, that of MME PCP anomalies [2] cannot explain properly increasing PCPs by the Changma system. The disagreement between OBS and MME PCP anomalies represents from simulated PCP uncertainty over Korea. Temporal-spatial patterns of PCP anomalies are strongly associated with lower and upper circulations, in which the lower-level moisture transport from the warm pool and corresponding moisture convergence is important.

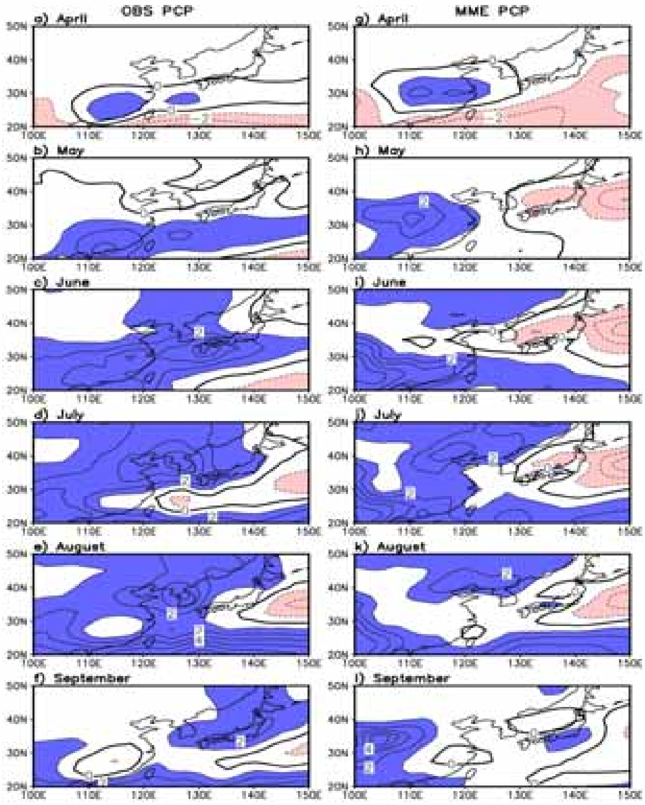

Figure 1. OBS and MME PCP anomalies extracted by the CSEOF analysis from April to September over the Eastern Asia region. The unit of the contour lines is mm/day; positive values greater than 1.0 are blue shaded and negative values less than -1.0 are pink shaded.

References

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Precipitation Changes in Future Climate: Extreme Events and Constraints

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This paper considers two aspects of precipitation change under global warming: synoptic behavior of extreme events and a possible constraint in precipitation-intensity changes. Although the analyses focus on U.S. simulations, the results appear to apply more generally.

The first part presents analysis of regional climate model (RCM) simulations of extreme regional precipitation in the U.S., using observations from the U.S. co-operative network observing sites and model results from 10-year RCM simulations of present and future-scenario climates. An Upper Mississippi River Basin region is analyzed for daily precipitation events during the cold half of the year (September-March) that have intensities in the top 0.05% and that cover several observation sites or model grid points. For both observed and simulated contemporary precipitation, nearly all such extreme regional events occur when a slow moving, cut-off-low system develops over the Rockies and U.S. Great Plains and steadily pumps moisture into the Upper Mississippi region from the Gulf of Mexico. The model shows similar circulation behavior for similar extreme events in its future scenario. However, the magnitude of daily precipitation in extreme events increases substantially in the future scenario, by 26%, compared to the

16% increase in average daily precipitation. The results suggest robust circulation behavior for such extremes, even in the face of climate variability.

The second part presents diagnoses of changes in daily precipitation versus intensity under global warming in two RCM simulations of the U.S. Both show a well-recognized feature of more intense precipitation. More important, by resolving the precipitation-intensity spectrum, the changes show a relatively simple pattern for nearly all regions and seasons examined whereby nearly all daily precipitation above the 70th percentile contributes a larger fraction of the total precipitation, and nearly all precipitation below the 70th percentile contributes a reduced fraction. Further analysis suggests that this consistent response in precipitation intensity may be a consequence of the intensity spectrum's adherence to a gamma distribution.

Trends of Extreme Climate Events in Republic of Korea, 1955-2004

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In this paper, temporal trends of extreme temperature and precipitation events in Republic of Korea over the past 50 years (1955-2004) are examined. The time series of 30 extreme climate indices are extracted from daily minimum and maximum temperatures as well as daily precipitation observed at 14 weather stations.

Significant changes in winter and summer extreme temperature events have occurred across South Korea regardless of urban and rural regions. Cool days (with Tmax < 10th percentile) and nights (with Tmin < 10th percentile) have decreased since the late 1980s compared to the previous period. The decreasing rate of cool nights is greater than those of cool days. In contrast, warm days (with Tmax > 90th percentile) have increased, and monthly maximum values of daily minimum temperatures also show significantly-increasing trends. Moreover, the frequency of ice days (Tmax < 0°C) and frost days (Tmin< 0°C) has decreased. The frequency of summer days as well as the length of growing seasons has increased. Precipitation extreme indices averaged across South Korea show significantly-increasing trends since the late 1990s, even though significance levels vary from one weather station to another. The significant increases of heavy rainfall events are detected particularly in the eastern and southeastern regions of the Korean Peninsula. Extreme precipitation indices which show these significant increases include the extremely wet days (r99p), monthly maximum consecutive 5-day precipitation (rx5day), the number of days above 80mm (r80mm), and very wet days (r95p).

These temporal patterns suggest that mitigation plans to reduce damages of summertime extreme climate events including flooding and heat waves are needed. In future studies, nonlinear trends in the time series of extreme climate indices as well as local urbanization effects in temperature data should be considered to reduce uncertainty in quantifying the magnitudes of changes in extreme climate events.

Changes in Temperature and Precipitation Trends over Pakistan

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Changes in the indices of temperature and precipitation extreme have been studied on the basis of daily data from 18 meteorological stations in Pakistan. In comparison with normal (1971-2000), over all, warming trend has been observed for both night time and day time temperatures in the country for the period from 1960 – 2006. Stations with data period 1974 – 2006 also showed the same trends. Precipitation indices showed little changes in this period with mixed positive and negative trends. There was a significant increasing trend of heavy precipitation indices at 2 out of 18 stations and one station showed the decreasing trend of extreme precipitation indices and amount of total precipitation.

Trends in Climate Extremes in Japan

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Using the tool RClimDex, indices were calculated such as Annual count when daily maximum temperatures are more than 30 degree (SU30), annual count when daily precipitation amounts are more than 20 mm (R20mm). 17 stations are selected in this research. These stations are similar to the stations used to calculate long-term temperature trends in Japan considered not to have been highly influenced by urbanization and have continuous records from 1898 onwards. The indices of Tokyo are also calculated for reference.

Fig 1 shows the trends of SU30. In almost all stations SU30 have increased. As supposed, ID0 have decreased at many stations. Similar results are also shown about minimum temperature. (Not shown)

Fig 2 and 3 shows the trend of R10mm (annual count when daily precipitation amounts are more than 10 mm) and R20mm respectively. R20mm have increased at some stations while R10mm have decreased at all stations except for Tokyo. R25mm have increased at more stations (not shown).

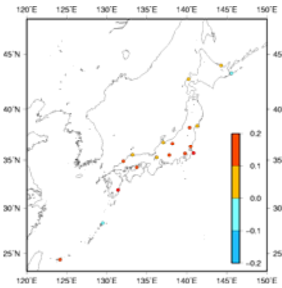
Fig 1 Trends of SU30

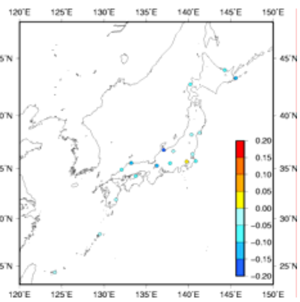
Fig 2 Trends of R10mm

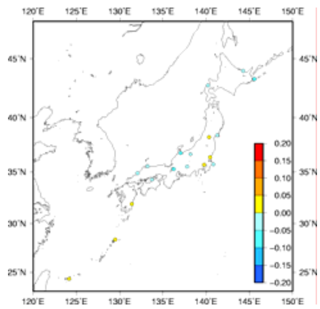
Fig 3 Trends of R20mm

Trend of Climate Index of Vietnam

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The daily data of 11 chosen stations representing for all regions of country were calculated by RclimDex software to determine the trends of indices.

The whole country is divided into 3 parts: North (northern mountain and Red river plain), Middle and South (Mekong river delta and high land). Here is a brief the trends of indices:

1/ Temperature:

- Diurnal temperature range: fast increasing in the southern and mountain areas but light decreasing in Red river plain
- Max Tmax: almost places have Txx increasing (Ha Noi: 0.35 and Phan Thiet: 0.32) but Txx of some places have trend light decreasing (Da Nang, Quy Nhon, Bao Loc, Can Tho)
- Min Tmax: increasing in the Northern and Southern, fastest raising occurs in the mountain areas, but decreasing in the Middle
- Cool days: decreasing in all most country, except in the southern high land
- Warm days and Warm spell duration indicator: increasing in all most country, except in the southern high land and coast in the middle
- Max Tmin: increasing in all most country, except in Da Nang
- Min Tmin: increasing in all most country, TNN of the South increases faster than in the North
- Warm nights and Tropical nights: increasing in plain areas, faster in the southern, but decreasing in the mountain areas
- Cool nights and Cold spell duration indicator: decreasing in whole country
- Summer days and Hot days (SU30): increasing in all most country, except in the Southern part
- Growing season Length: very slightly increasing
- Frost days and Ice days have not observed in the collected data set

In general, the temperatures have the increasing trend with more significant in the South.

2/ Precipitation:

- Annual total wet-day precipitation and Simple daily intensity index: the trend doesn’t consistent, increasing in the South and decreasing in the North: almost areas have increasing trend, in the high land increase faster than lowland

- Number of heavy precipitation days: increasing in the high land and Middle and decreasing in the Red River plain.
- Number of very heavy precipitation days: increasing fast in the North and South while in the Middle it is decreasing clearly
- Max 1-day precipitation amount is quite same Max 5-day precipitation amount: increasing fast in the Southern and mountain areas
- Consecutive dry days: increasing in the Northern and decreasing in the Middle and Southern

In general, the extreme event concern of precipitation have the increasing trend in the South and mountain areas.

Changes in climate extremes in Australia

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Changes in indices of extreme temperature and rainfall have been analysed over the 1955-2007 period for 37 Australian observation stations using the *RClimDex* software. Most of the records are included in high-quality datasets used to monitor climate change in Australia and therefore data homogeneity is considered relatively good.

Changes in the extreme temperature indices tend to reflect the warming observed through most of Australia since mid-20th Century. The frequency of Summer Days (Su25, Su30) has generally increased since 1955, with the strongest increases in the northeast. The frequency of Tropical Nights (Tr20, Tr25) has mostly increased across the north, while changes in frost frequency (FD0) across the south are weak and mixed, suggesting that more frequent dry and cloudless nights in recent years have offset the influence of a warmer atmosphere. The majority of stations show increases in the highest and lowest daytime and nighttime temperatures of the year (Txx, Txn, Tnx, Tnn), with almost all stations showing a rise in the lowest daytime temperature (Txn). Results for the percentile based indices predominantly show an increase in the percentage of warm days and nights throughout the year (Tx90p, Tn90p) and a decline in the percentage of cool days and nights (Tx10p, Tn10p). Most stations also show an increase in the duration of warm spells (WSDI) and decline in the duration of cold spells (CSDI). Highlighting the difficulty of using fixed-threshold definitions across wide regions, the indices for Growing Season Length (GSL), Ice Days (ID0) and Frost Days less than -5°C (FD-5) are not meaningful in Australia.

Strong declines in total rainfall (PRCPTOT) are evident across southern and eastern Australia since 1955, with marked increases in the northwest. Changes in rainfall intensity (SDII), heavy rainfall frequencies (R10, R20, R25) and heavy rainfall totals (R95p, R99p) generally mirror these changes in total rainfall. Changes in Consecutive Wet Days (CWD) also reflect the total rainfall changes but changes in consecutive dry days (CDD) are more mixed. Interestingly, the CWD and CDD indices have both increased in the northwest, suggesting a trend toward a shorter, but more continuous, wet season in the region. Overall, the indices provide little evidence that Australian rainfall has become more extreme, except in regions where total rainfall has increased.

Trends of Extreme Climate Events in the Asian-Pacific Network (APN) Region

Choi, G., B. Trewin, D. Collins, G. Ren, Y. Fukuda, N. Lias, T. Pianmana, M. Baldi, P. Gomboluudev, M. Afzaal,, P.T.T. Huong, and W.-T. Kwon

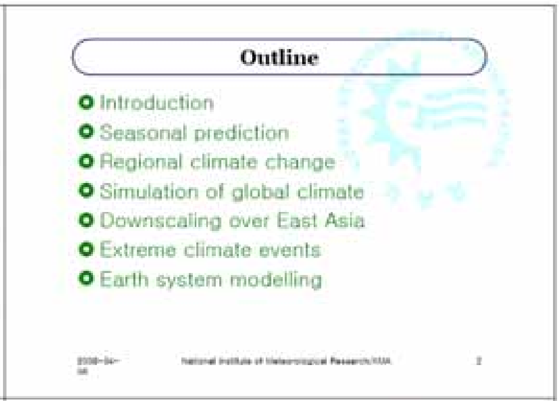
In this paper, national reports for the 6th Asian Pacific Network (APN) Workshop (Seoul in Republic of Korea; Feb. 19-24, 2008) on spatial and temporal trends of extreme temperature and precipitation events since the mid-1950s in the Asian Pacific Network (APN) region are synthesized. 31 extreme climate indices are extracted from daily maximum and minimum temperatures as well as daily precipitation observed at more than 100 weather stations across ten APN countries (including Australia, China, Japan, Malaysia, Mongolia, New Zealand, Pakistan, Republic of Korea, Thailand, and Vietnam). Linear trends and their significance in the time series of extreme climate indices are calculated using the *RClimDex* (Zhang and Yang, 2004) and mapped using the Geographic Information System (GIS). Collaborated results indicate that the number of warm days/nights (upper 90th percentile of Tmax and Tmin) in summer has increased across the study region, while the number and duration of cool (lower 10th percentile of Tmax and Tmin) days/nights or coldness-related indices in winter have decreased. However, trends of extreme precipitation events are not significant with spatially-varying trend and magnitude. For instance, the frequency and intensity of extreme rainfalls have decreased in many parts of Mongolia and Australia but increased in Japan and Republic of Korea. Regarding the selection of indices applicable to all APN countries from Mongolia to New Zealand, significance tests suggest that the use of relative percentile-threshold indices is more desirable compared to the fixed-threshold indices.

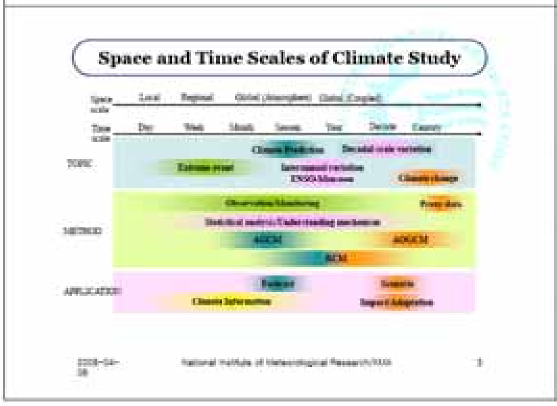
Keywords: Asian Pacific Network (APN), extreme climate indices, climate change

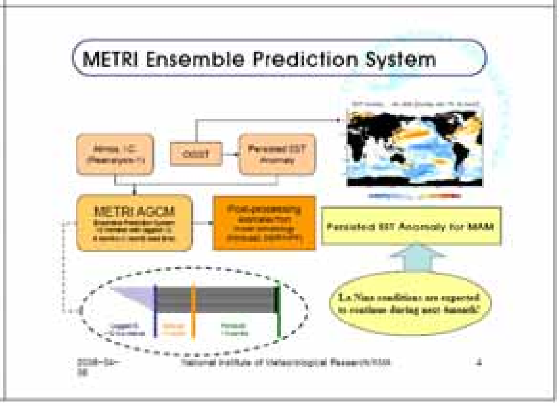
Appendix C

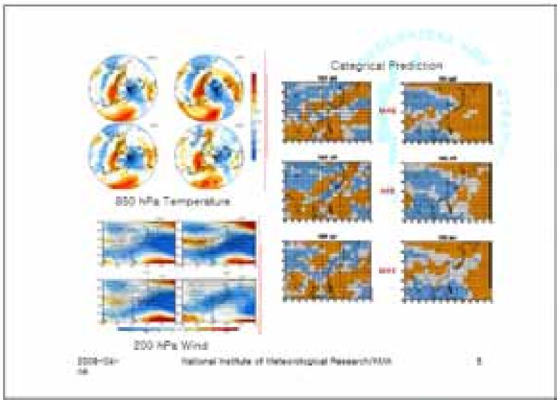
Power Point Slides of Workshop Presentations

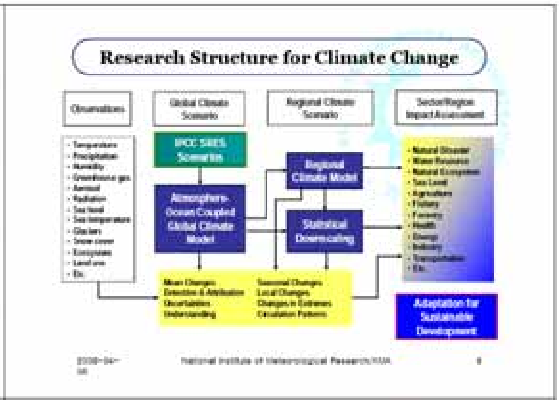
1. Current Research on Climate Change in **Korea**

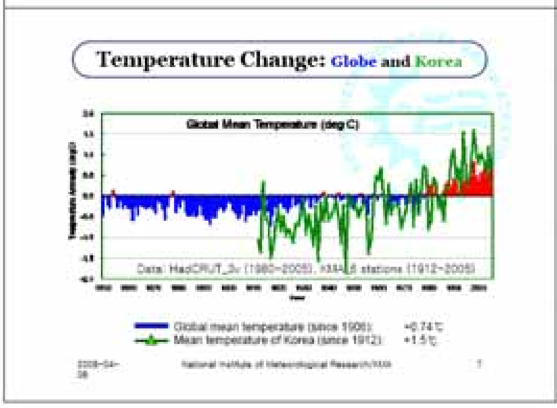


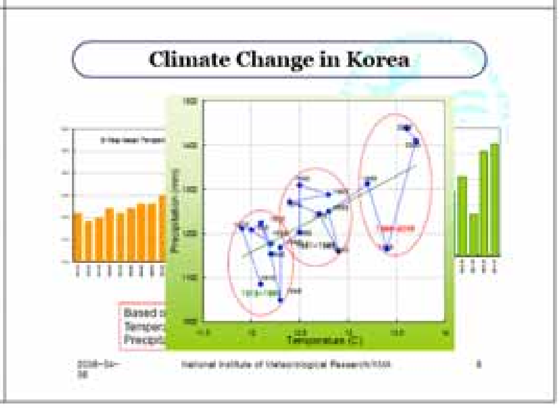


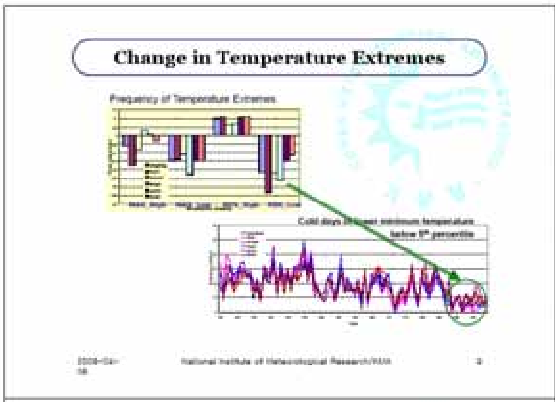


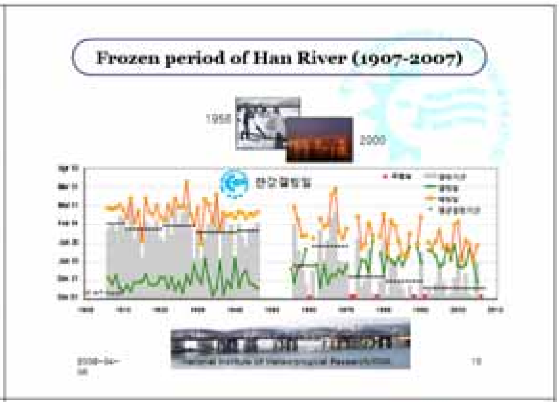


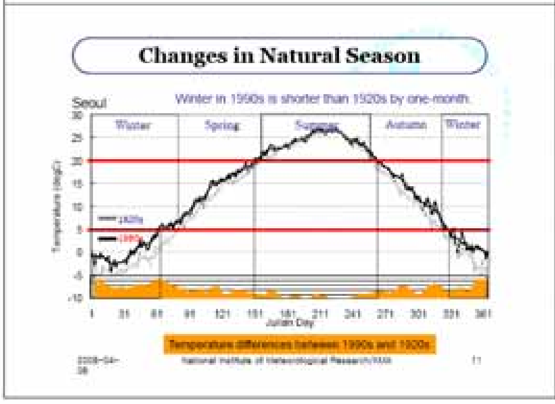


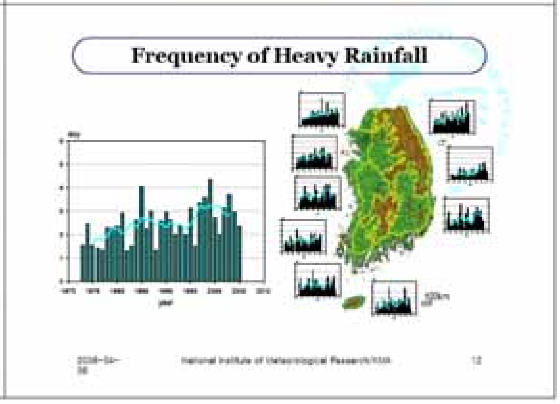


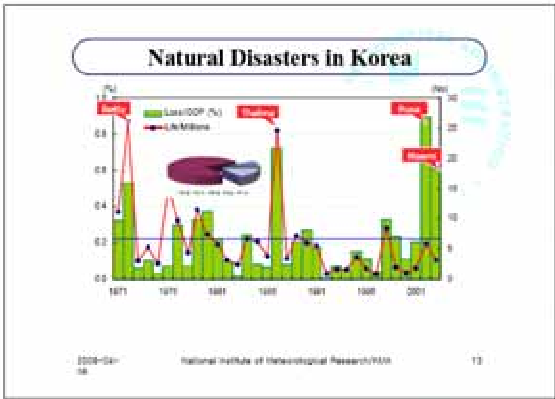



Change in Temperature Extremes
Frequency of Temperature Extremes
Cold days (Daily minimum temperature below 5th percentile)
National Institute of Meteorological Research/KMA


Frozen period of Han River (1907-2007)
1958
2000
한강결빙일
National Institute of Meteorological Research/KMA

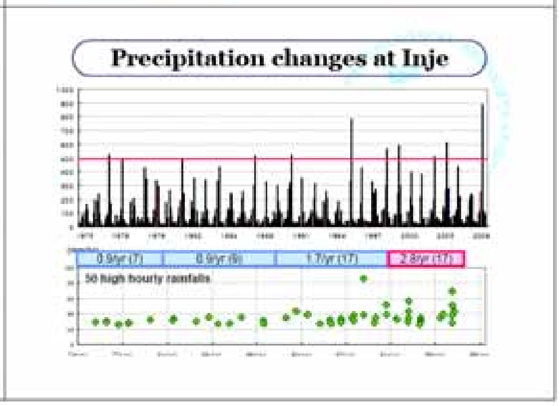

Changes in Natural Season
Seoul
Winter in 1990s is shorter than 1920s by one-month.
Winter
Spring
Summer
Autumn
Winter
Temperature (degC)
1920s
1990s
Julian Day
Temperature differences between 1990s and 1920s
National Institute of Meteorological Research/KMA
11

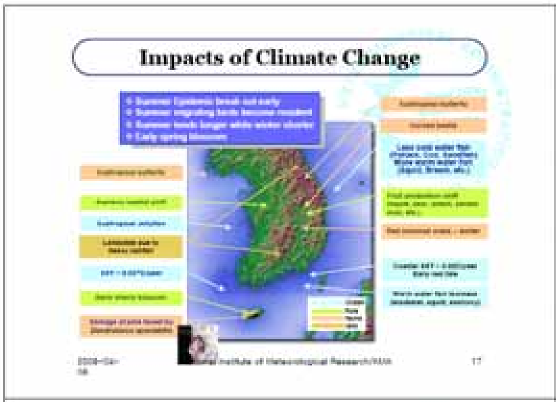

Frequency of Heavy Rainfall
year
100km
National Institute of Meteorological Research/KMA
12

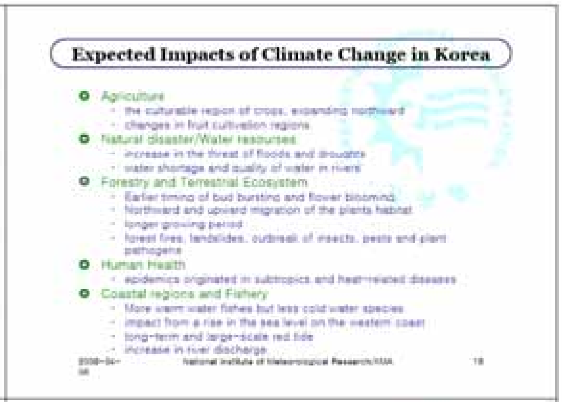

Natural Disasters in Korea
Betty
Loss/GDP (%)
Life/Millions
Thelma
Rusa
Maemi
National Institute of Meteorological Research/KMA
13


Typhoon Rusa in 2002
Life loss: more than 250 people
Property loss: More than 6 billion US dollars
Daily rainfall record: 870 mm


Land slides in 2006


Precipitation changes at Inje
0.9/yr (7)
0.9/yr (8)
1.7/yr (17)
2.8/yr (17)
50 high hourly rainfalls


Impacts of Climate Change
(IPCC, 2007)
National Institute of Meteorological Research/KMA
17


Expected Impacts of Climate Change in Korea
Agriculture
- the culturable region of crops, expanding northward
- changes in fruit cultivation regions
Natural disaster/Water resources
- increase in the threat of floods and droughts
- water shortage and quality of water in rivers
Forestry and Terrestrial Ecosystem
- Earlier timing of bud bursting and flower blooming
- Northward and upward migration of the plants habitat
- longer growing period
- forest fires, landslides, outbreak of insects, pests and plant pathogens
Human Health
- epidemics originated in subtropics and heat-related diseases
Coastal regions and Fishery
- More warm water fishes but less cold water species
- impact from a rise in the sea level on the western coast
- long-term and large-scale red tide
- increase in river discharge
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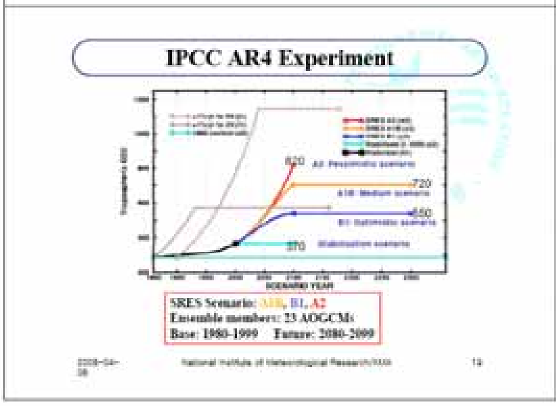
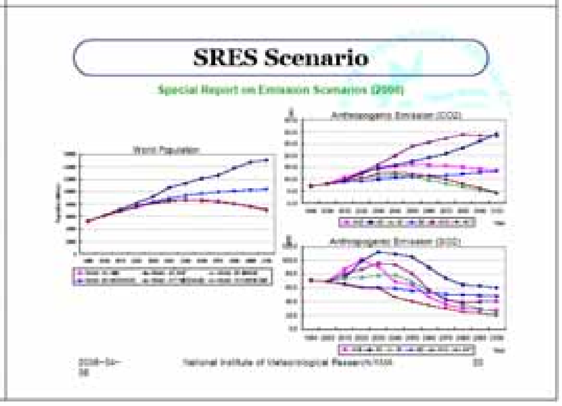
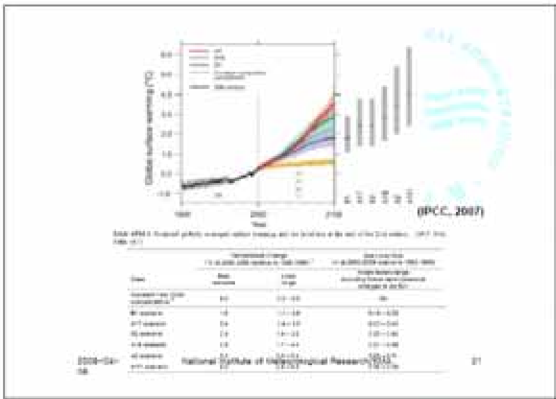
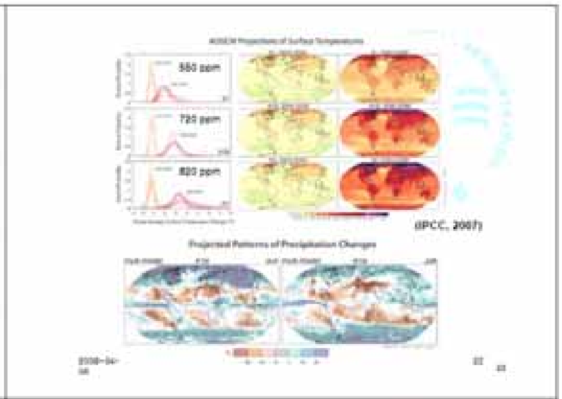
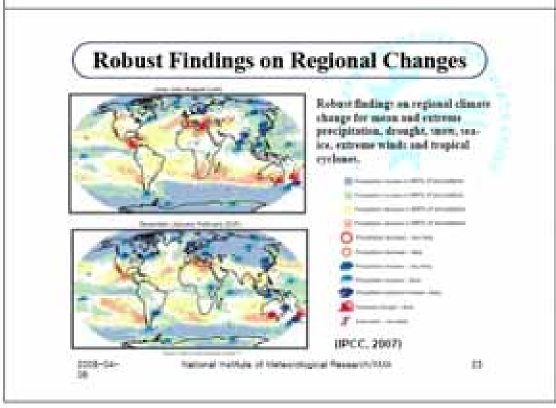
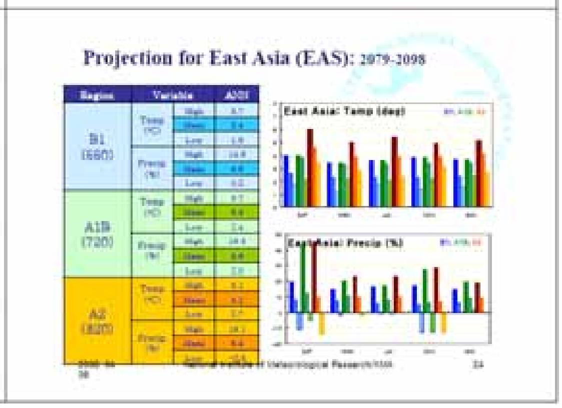

IPCC AR4 Experiment
820
A2: Pessimistic scenario
720
A1B: Medium scenario
550
B1: Optimistic scenario
370
Stabilization scenario
SCENARIO YEAR
SRES Scenario: A1B, B1, A2
Ensemble members: 23 AOGCMs
Base: 1980-1999 Future: 2080-2099
National Institute of Meteorological Research/KMA
19

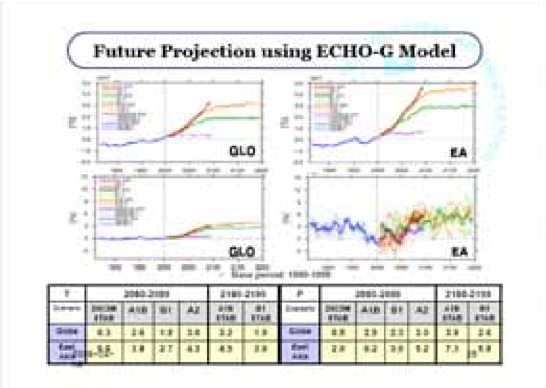

SRES Scenario
Special Report on Emission Scenarios (2000)
World Population
Anthropogenic Emission (CO2)
Anthropogenic Emission (SO2)
National Institute of Meteorological Research/KMA
20

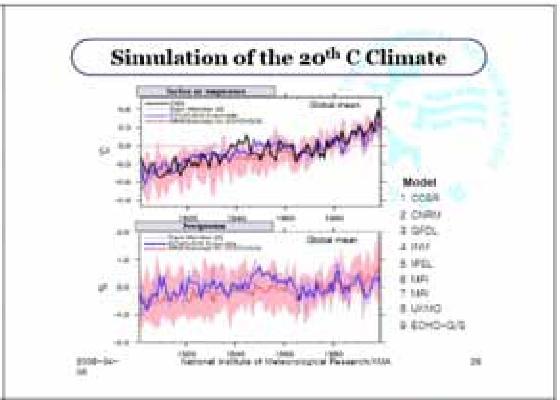

(IPCC, 2007)
National Institute of Meteorological Research/KMA
21

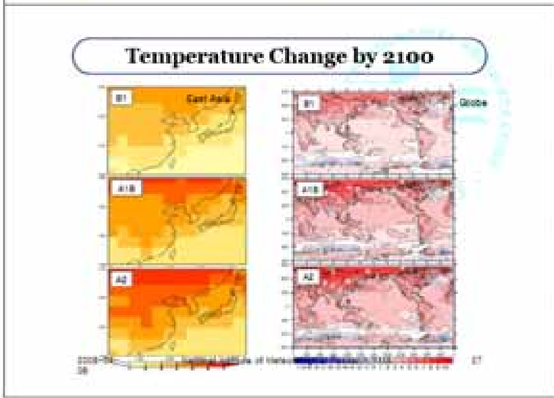

550 ppm
720 ppm
820 ppm
(IPCC, 2007)
Projected Patterns of Precipitation Changes
22

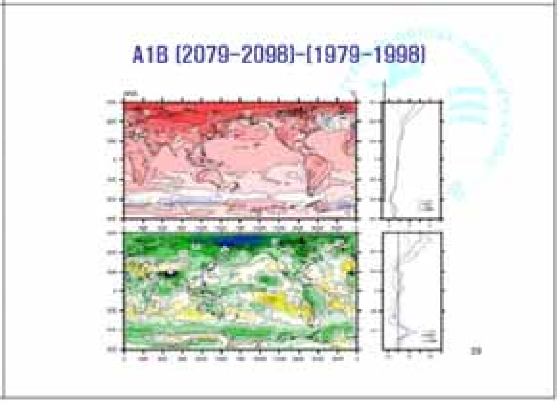

Robust Findings on Regional Changes
Robust findings on regional climate change for mean and extreme precipitation, drought, snow, sea-ice, extreme winds and tropical cyclones.
(IPCC, 2007)
National Institute of Meteorological Research/KMA
23

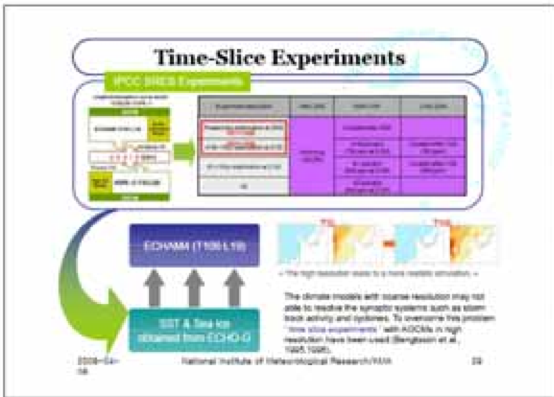

Projection for East Asia (EAS): 2079-2098
Region
Variable
B1 (550)
A1B (720)
A2 (820)
East Asia: Temp (deg)
East Asia: Precip (%)
National Institute of Meteorological Research/KMA
24

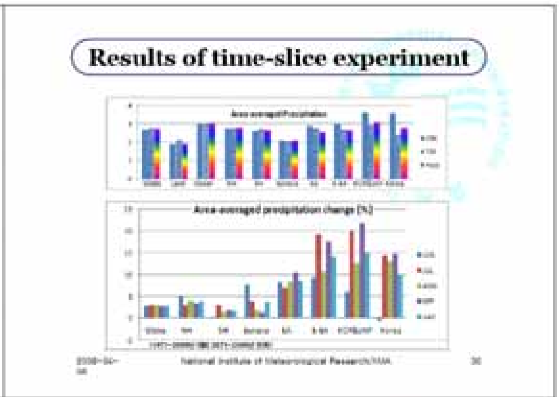

Future Projection using ECHO-G Model
GLO
EA
GLO
EA

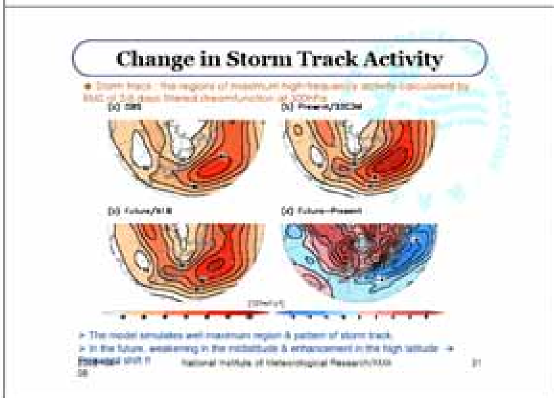

Simulation of the 20th C Climate
Global mean
Model
1 CCSR
2 CNRM
3 GFDL
4 INM
5 IPSL
6 MPI
7 MRI
8 UKMO
9 ECHO-G/S
National Institute of Meteorological Research/KMA

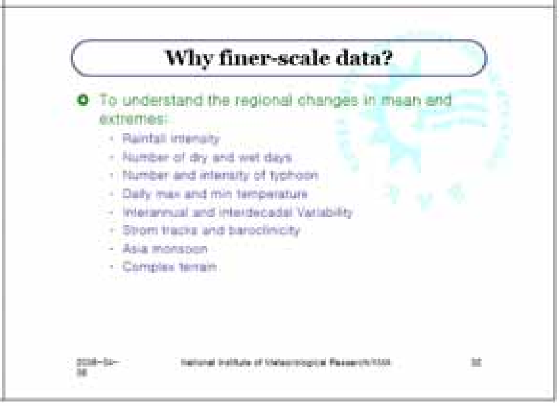

Temperature Change by 2100
B1
East Asia
Globe
A1B
A2

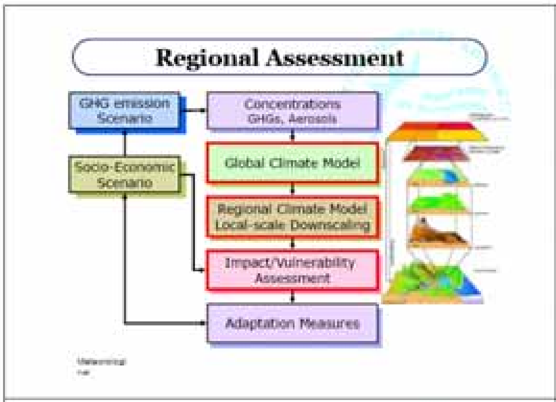

A1B (2079-2098)-(1979-1998)

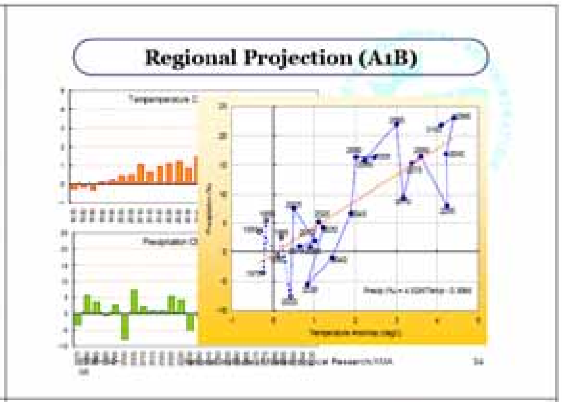

Time-Slice Experiments
IPCC SRES Experiments
ECHAM4 (T106 L19)
SST & Sea ice obtained from ECHO-G
National Institute of Meteorological Research/KMA

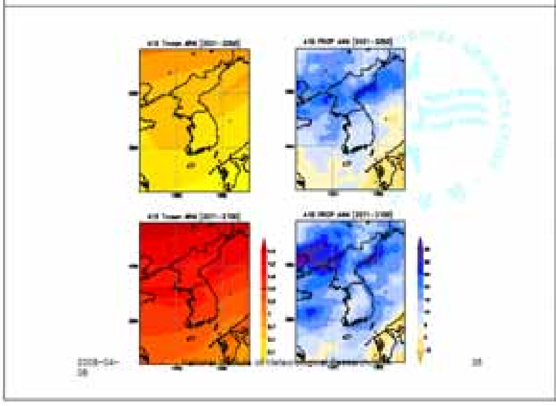

Results of time-slice experiment
Area averaged Precipitation
Area-averaged precipitation change (%)
National Institute of Meteorological Research/KMA

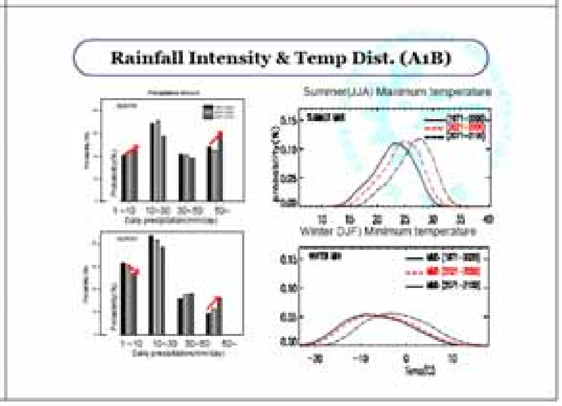

Change in Storm Track Activity
National Institute of Meteorological Research/KMA

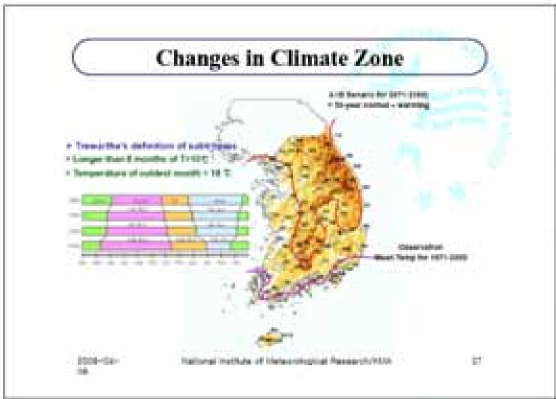

Why finer-scale data?
To understand the regional changes in mean and extremes:
Rainfall intensity
Number of dry and wet days
Number and intensity of typhoon
Daily max and min temperature
Interannual and interdecadal Variability
Strom tracks and baroclinicity
Asia monsoon
Complex terrain
National Institute of Meteorological Research/KMA

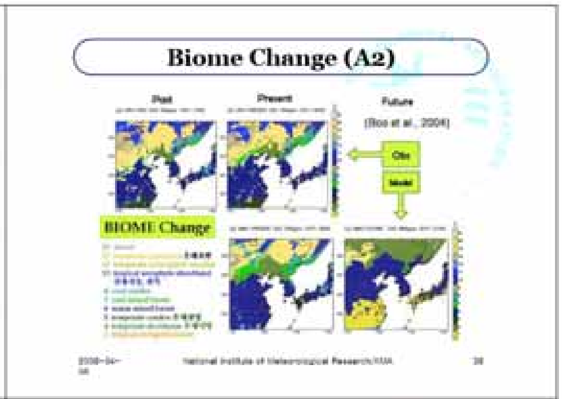

Regional Assessment
GHG emission Scenario
Concentrations GHGs, Aerosols
Socio-Economic Scenario
Global Climate Model
Regional Climate Model Local-scale Downscaling
Impact/Vulnerability Assessment
Adaptation Measures

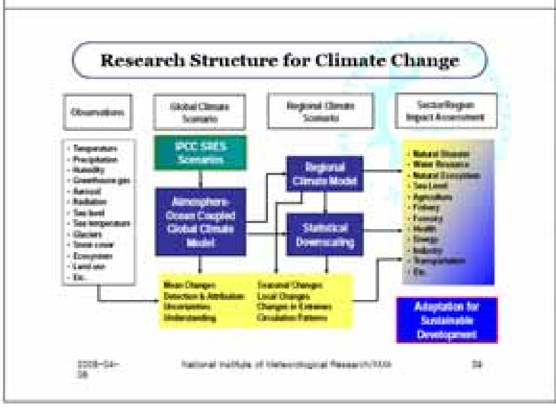

Regional Projection (A1B)

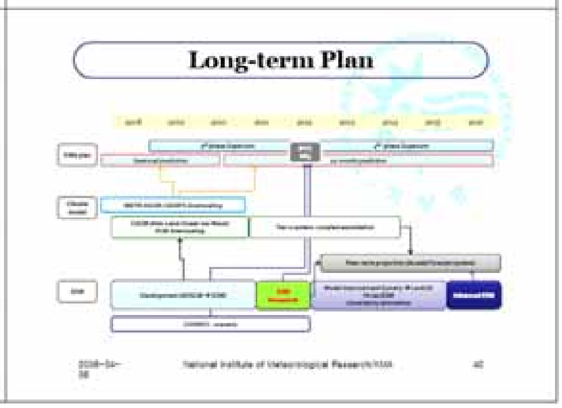



Rainfall Intensity & Temp Dist. (A1B)
Summer(JJA) Maximum temperature
Winter DJF) Minimum temperature


Changes in Climate Zone


Biome Change (A2)
Past
Present
Future
Obs
Model
BIOME Change


Research Structure for Climate Change
Observations
Global Climate Scenario
Regional Climate Scenario
Sector/Region Impact Assessment
IPCC SRES Scenarios
Regional Climate Model
Atmosphere-Ocean Coupled Global Climate Model
Statistical Downscaling
Adaptation for Sustainable Development


Long-term Plan

Eigen Techniques for Climate Analysis : Cyclostationary Empirical Orthogonal Function (CSEOF)

Young-Kwon Lim
Center for Ocean-Atmospheric Prediction Studies
The Florida State University, Tallahassee, FL

Eigen technique ?

- Eigen technique is the climate analysis method to decompose raw data into a set of empirical orthogonal functions (EOFs), and their principal component time series.
- EOFs are orthogonal spatial patterns that can be thought of as empirically derived basis functions.
- Principal component (PC) time series are obtained by projecting the observed (or modeled) field onto the EOFs. PC time series are uncorrelated each other.

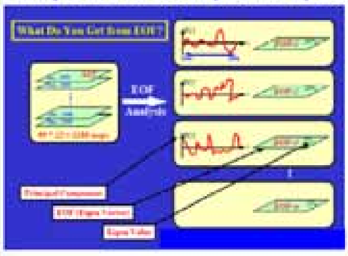
Why useful for climate analysis?

- The low-order EOFs can be interpreted as natural modes of variation of the observed (or modeled) system.
- PC time series represent the temporal variability of each EOF spatial pattern.
- Eigen technique is, therefore, very useful for understanding the prominent climate signals that constitute the complex natural system, and their spatial patterns and variations in time.

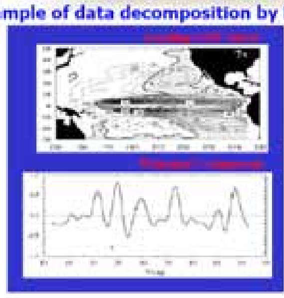
Primarily used eigen techniques

- Regular EOF: EOFs and PC
- Rotated EOF: find EOFs by coordinate transform
- Extended EOF: temporal lag, produce moving patterns
- Complex EOF: imaginary (by Hilbert transform of the real part) represents the phase shift (1/4 of a period).
- SVD: correlated patterns between two variables
- CCA: maximized correlated fields within two bases
- Cyclostationary EOF (CSEOF): Reduction of complex data by physical decomposition

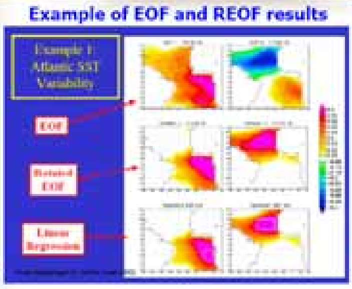
Example of data decomposition by EOF



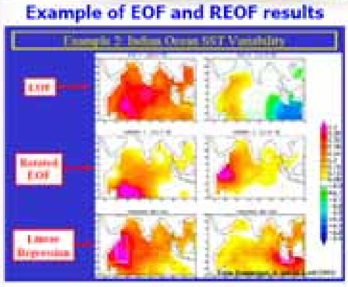
Example of data decomposition by EOF



Example of EOF and REOF results



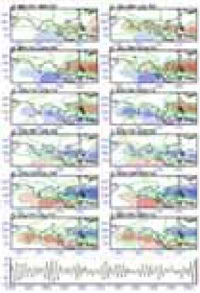
Example of EOF and REOF results



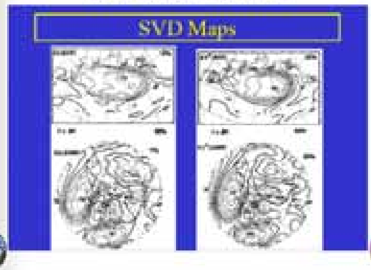
Example of EEOF result

Space-time evolutions
(-max. lag ~ +max. lag)

PC time series



Example of SVD result



Physical Decomposition

- Systematic reduction of complex data into **dominant modes**, $B_i(r,t)$, with **their amplitude time series**, $S_i(t)$.

$$P(r,t) = \sum_{i=1}^{n} B_i(r,t)\, S_i(t)$$

$B_i(r,t)$: Independent climate signals
(e.g., Seasonal cycle, ISO mode, El Niño mode)

$S_i(t)$: Amplitude time series of each climate signals (Principal component time series)

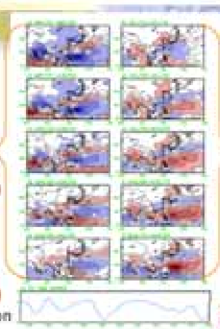
Basic concepts of cyclostationary process

- **Cyclostationary**: The moment statistics of variable are dependent of time with cyclic nature.
- **Time dependency is considered in covariance matrix**: CSEOFs are, computationally, the solutions of K-L eqution in consideration of time dependency in covariance matrix.

$$\int C(r,r',t)\psi_n^{(i)}(r')dr' = \lambda_n \psi_n^{(i)}(r)$$

An example of decomposition

$B_i(r,t)$
Space-time dependent mode (a climate signal)



$S_i(t)$
Amplitude fluctuation

Motivation

- Better understanding of observed climate variability is possible **if we successfully extract dominant components** (e.g., seasonal cycle, ENSO-related spatio-temporal evolution, ISO) from data.
- Clearer separation of prominent climate signals is expected to **improve the predictability** of the climate variation and change.

Data set for CSEOF analysis on the variation of Asian summer monsoon (ASM)

- Xie-Arkin **precipitation** pentad data (1979-2001)
- **National Center for Environmental Prediction** (NCEP) reanalysis data for 44 years (1958-2001)
- **Variables**:
  1) surface level : SLP
  2) wind (850, 200hPa level), humidity (850), geopotential height (850, 200), temperature (850)

The first several modes identified

Analysis domain : Asian monsoon area (50°-180°E, 10°S-60°N)

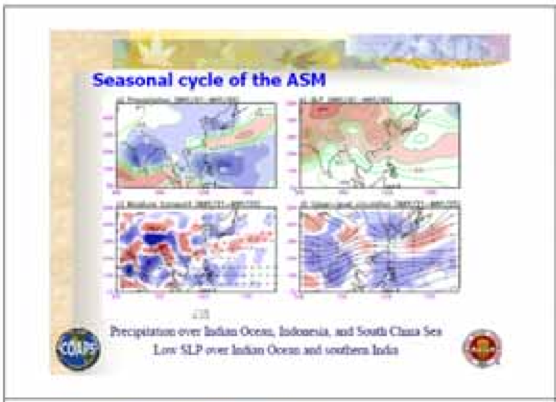
Analysis period : May/21-Sep./17, 1979-2001

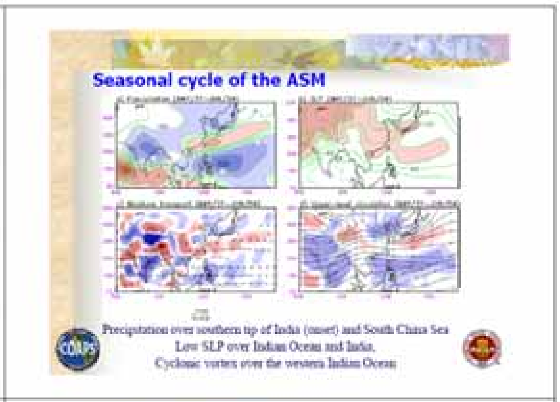
Variables : Prcp., SLP, wind (850,200), moisture transport, streamfunction (200), etc.

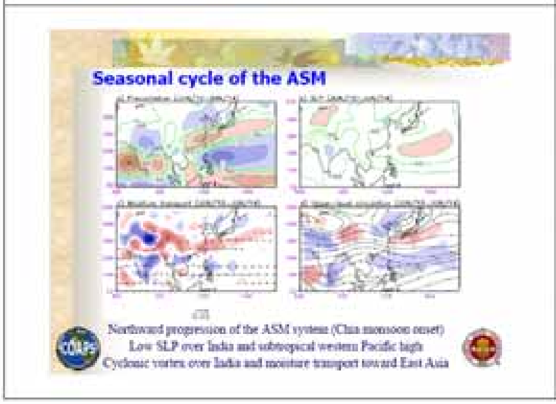
Mode #	1st	2nd	3rd	4th	5th	6th
Components	Seasonal cycle	ISO	ISO	ENSO mode	ISO	ISO
% variance	16	14		7	4	3.7

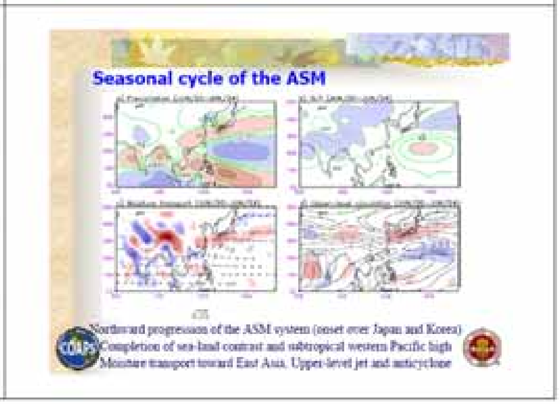
(for precipitation)

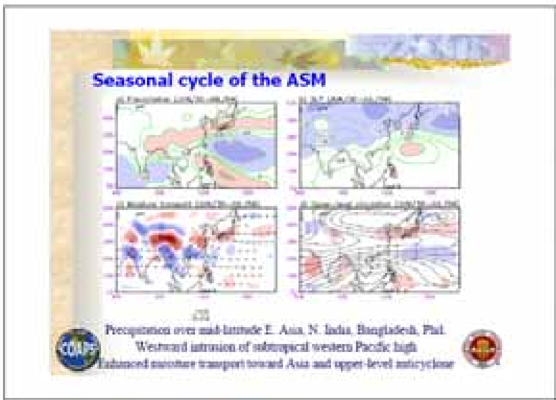
2nd–3rd: 90° out of phase


Seasonal cycle of the ASM
Precipitation over Indian Ocean, Indonesia, and South China Sea
Low SLP over Indian Ocean and southern India

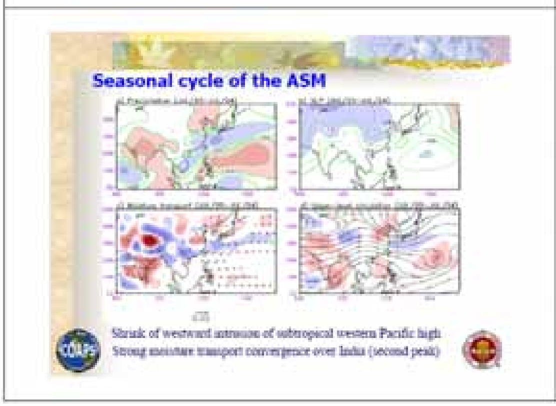

Seasonal cycle of the ASM
Precipitation over southern tip of India (onset) and South China Sea
Low SLP over Indian Ocean and India
Cyclonic vortex over the western Indian Ocean

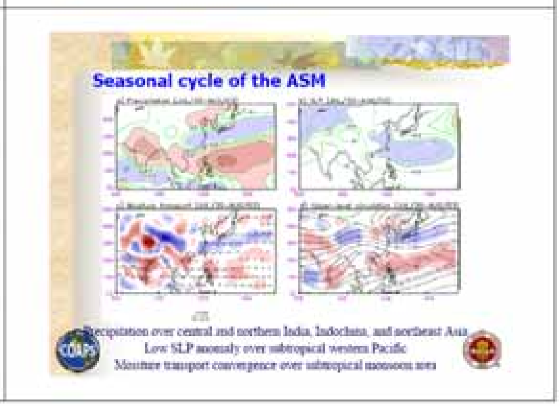

Seasonal cycle of the ASM
Northward progression of the ASM system (China monsoon onset)
Low SLP over India and subtropical western Pacific high
Cyclonic vortex over India and moisture transport toward East Asia

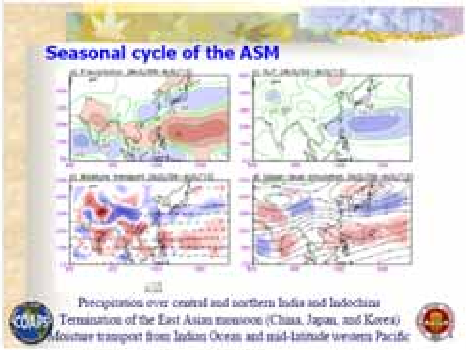

Seasonal cycle of the ASM
Northward progression of the ASM system (onset over Japan and Korea)
Completion of sea-land contrast and subtropical western Pacific high
Moisture transport toward East Asia, Upper-level jet and anticyclone

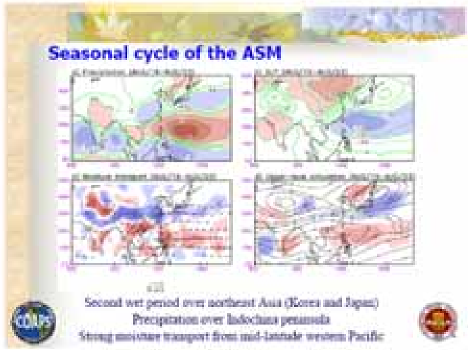

Seasonal cycle of the ASM
Precipitation over mid-latitude E. Asia, N. India, Bangladesh, Phil.
Westward intrusion of subtropical western Pacific high
Enhanced moisture transport toward Asia and upper-level anticyclone

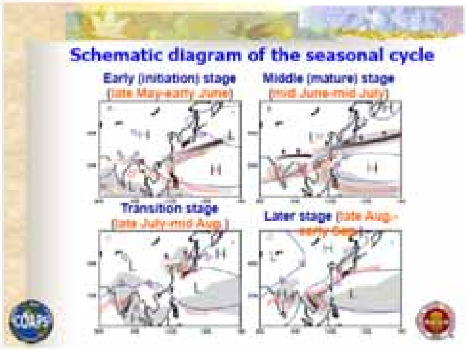

Seasonal cycle of the ASM
ndia (East Asia) : moisture transport from Indian (western Pacific) Ocean
pper-level divergence over India and mid-latitude (Japan and Korea)

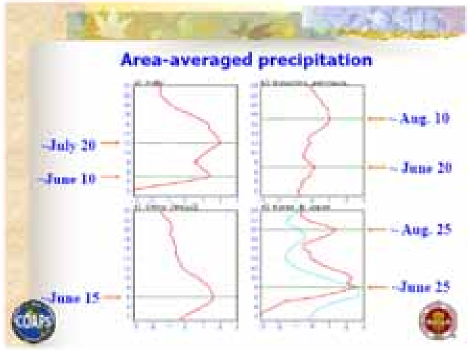

Seasonal cycle of the ASM
Shrink of westward intrusion of subtropical western Pacific high
Strong moisture transport convergence over India (second peak)


Seasonal cycle of the ASM
ecipitation over central and northern India, Indochina, and northeast Asia
Low SLP anomaly over subtropical western Pacific
Moisture transport convergence over subtropical monsoon area









3. Previous APN and other regional climate workshop

A summary of previous APN workshops and international workshop activities in Vietnam

Blair Trewin
National Climate Centre
Australian Bureau of Meteorology

The 'APN' workshops

- 8 workshops backed by the Asia-Pacific Network for Global Change Research (APN) between 1998 and 2004 (5 in Australia, 3 in New Zealand)
- Involved a wide range of countries from the South Pacific and East Asia (more than 20 across 5 Australian workshops)

Original goals of the APN workshops

- To provide regional information to assist in determining 'has the climate become more variable or extreme?' (originally for IPCC TAR)
- To encourage regional participation in global studies to monitor and detect changes in climate extremes

The workshops concept

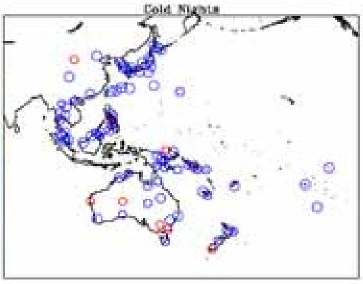
- Representatives from each participating country meet for a period of ~1 week
- Representatives bring relevant data to subject to common analysis methods during workshop
- By end of workshop, one or more papers are drafted presenting key results from the workshop
- Also forum for presentations on various aspects of climate science

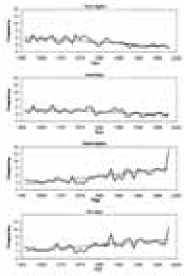
The original APN indices

- Number of days with maximum/minimum temperature above 99th percentile (hot days/warm nights)
- Number of days with maximum/minimum temperature below 1st percentile (cool days/cold nights)
- Frequency of daily rainfall exceeding the 99th percentile (extreme frequency), average intensity of these events (extreme intensity), and % of total annual rainfall from these events (extreme proportion)
- Number of days with 2mm or more of rain (rain days)

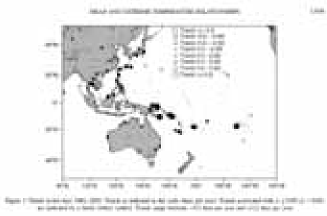
Original station selection criteria

- High-quality and well-maintained
- Preferably non-urban
- As long a record as possible, including 1961-90 standard reference period
- Good metadata
- At least 80% data completeness in each year





From Manton et al. (2001)



From Griffiths et al. (2005)

Areas addressed during past APN workshops

- Analysis of data and production of indices relevant to climate change
- Data homogenisation
- Metadata and data rescue
- Relationships between surface climate variables and broadscale climate influences (e.g. ENSO)

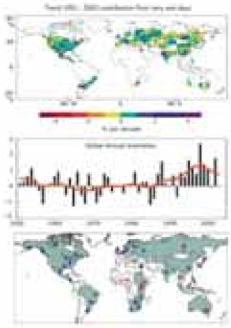
Several major papers also produced – e.g. Manton et al. (2001), Griffiths et al. (2005), Nicholls et al. (2005)

Expert Team on Climate Change Detection and Indices (ETDDCI)

- Co-sponsored by CCI, CLIVAR and JComm
- Has supported numerous regional climate workshops
- Has also fostered development of relevant software (originally MASH, now RClimdex and RHTest)

Further regional climate workshops (under WMO auspices), 2001-07

- Caribbean
- North Africa
- West and central Africa
- Southern Africa
- South America
- West/Central Asia
- South Asia



Workshop results have fed into IPCC assessments

Additional Pacific region climate projects

- Capacity building in seasonal climate prediction
- Data rescue/preservation in the Pacific region

What positives have we gained from the earlier APN projects?

- Pioneering a model for analysis of climate indices which circumvented barriers to exchange of raw data
- Allowing cross-border analyses on a common basis
- Building links between Australia/New Zealand and Asia/Pacific countries, assisting further (non-APN) climate projects
- Raising awareness of issues such as metadata, data rescue, data quality and completeness
- Developing data analysis/management technology appropriate to locally available infrastructure

Issues of concern

- Very wide range of capacity - very small and often poorly-financed meteorological services in places
- Loss of expertise as key personnel move on

The 2007 Vietnam workshop

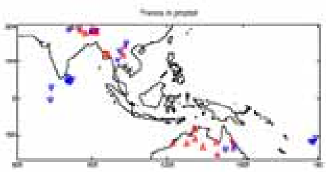
- Hanoi, December 2007
- Covered south/southeast Asia and parts of the Pacific
- Countries: Maldives, Sri Lanka, Nepal, Bhutan, Myanmar, Thailand, Laos, Cambodia, Vietnam, East Timor, Fiji, Australia

Very wide range in capacity and data availability

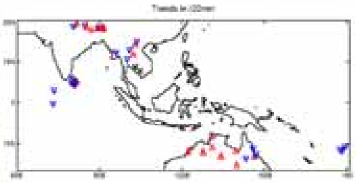
- Some countries had 50-100 years of good quality, digitised daily data
- Some had only 5-10 years of data from a few stations
- Still a lot of undigitised data
- Many data gaps in war zones 1960s to 1990s

Precipitation

Total precipitation

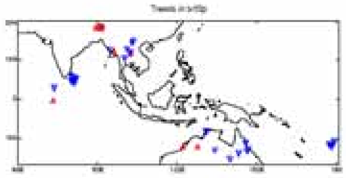


Days over 20mm precipitation

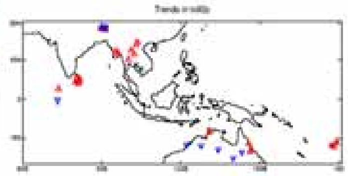


Temperature

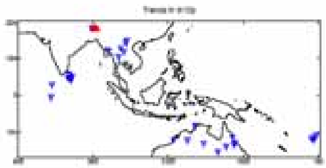
Cold days



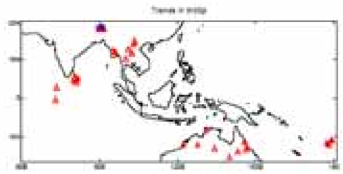
Warm days



Cold nights



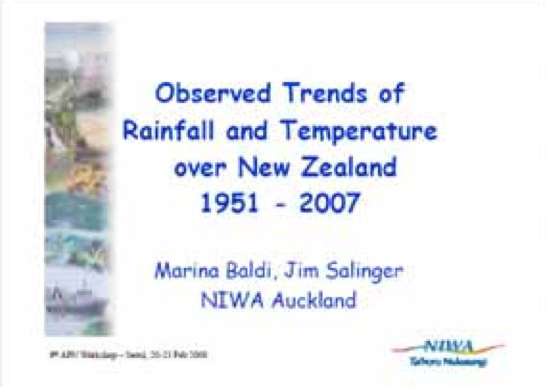
Warm nights

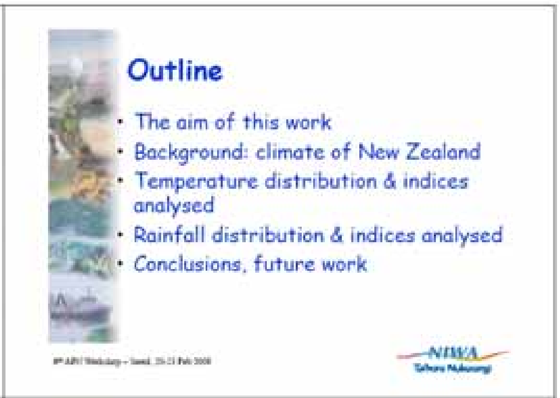


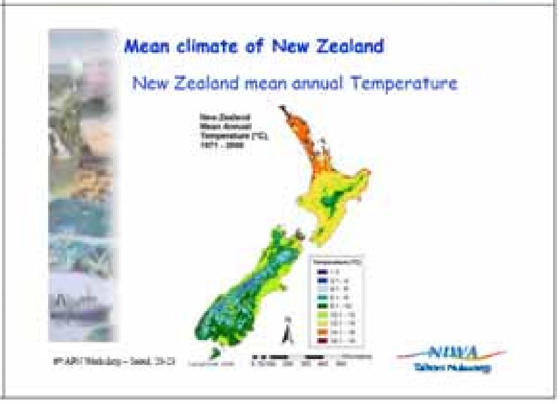
Major outcomes from the Vietnam workshop

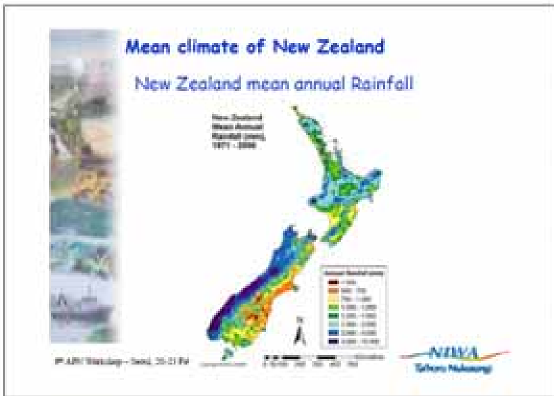
- Regional results: more warm extremes, fewer cold extremes, strong signals for minima, mixed picture for rainfall extremes
- Some countries with short records couldn't contribute to trends, but still useful info (e.g. effect of 1997-98 El Niño)
- Filled some key gaps in regional analyses

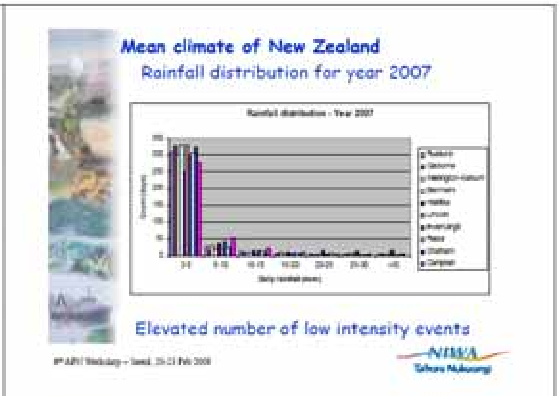
4. Observed trends in **New Zealand** climate over 1951-2007

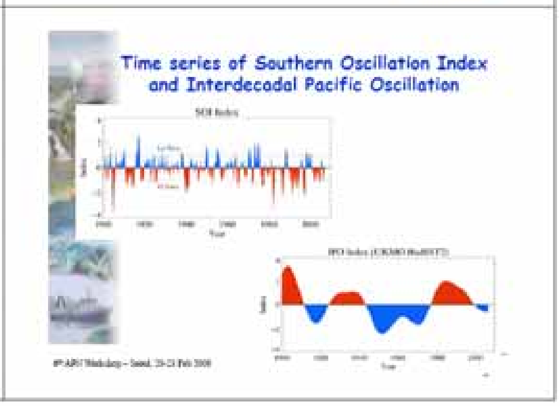




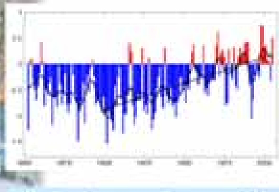








New Zealand Temperature: current trend

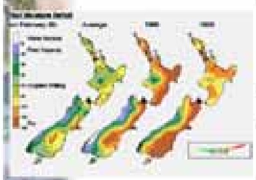


Mean annual temperature over New Zealand, from 1855 to 2005 inclusive. The blue and red bars show annual differences from the 1971 - 2000 average, the solid black line is a smoothed time series, and the dotted line is the linear trend over 1900 to 2005.

- Warming has occurred across all New Zealand
- Temperatures increased +1°C during 20th century

The cost of extremes

The 1997/98 El Niño



- Loss of pastures, reduced animal numbers, production down in meat, wool, dairy, grain by $425M
- Apples overheated, sunburnt
- Significant losses of native and planted trees
- Floods on the West Coast

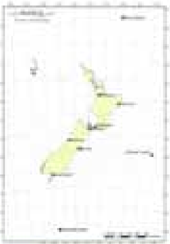
Mean climate, climate shifts

- NZ mean temperatures have warmed 0.4°C in the period 1951-2005.
- 1951-1975 saw more E winds. Mean rainfall increased in N of NZ, & decreased in SE of NZ.
- 1976-1998 saw stronger W winds. Mean rainfall increased on the West Coast, it became drier in eastern districts.
- Since 1998, a climate shift towards more E winds (& record warmth for NZ) was observed.

Climate core indices

- Daily Temperature Range - DTR
- TN10p, TN90p, TX90p
- Number of frost days - FD0
- Annual rainfall PRCP
- Annual total PCRP when RR > 95p
- Dry/wet spells CDD/CWD

How did they change in the last 50 years, relative to 1971-2000?



Map of New Zealand showing the stations used including the offshore islands: Raoul (29° 15' S, 177° 55'W) Chatham (43° 57' S, 176° 34'W), Campbell (52° 33' S, 169° 9'W)

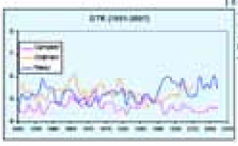
The climate regions of New Zealand

Stations in New Zealand

Station	Lat	Lon	Height (m)
Campbell Is	-52.55	169.15	19
Invercargill	-46.42	168.34	0
Chatham Island	-43.95	176.57	48
Lincoln	-43.65	172.48	18
Hokitika	-42.72	170.99	38
Blenheim Research	-41.49	173.96	4
Wellington, Kelburn	-41.29	174.77	125
Gisborne	-38.66	177.99	5
Ruakura	-37.78	175.31	43
Raoul Island	-29.23	177.93	49

Temperature:

Daily Temp Range
(monthly mean difference between TX and TN)

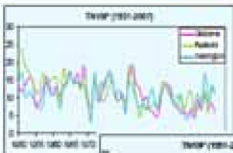


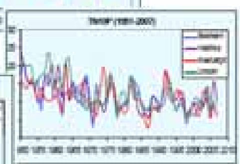
General decrease of the index except for Raoul Is

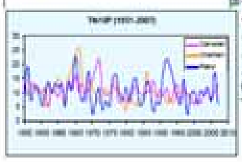
Temperature:

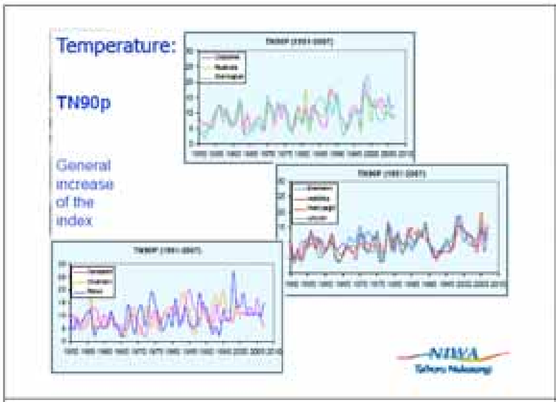
TN10p

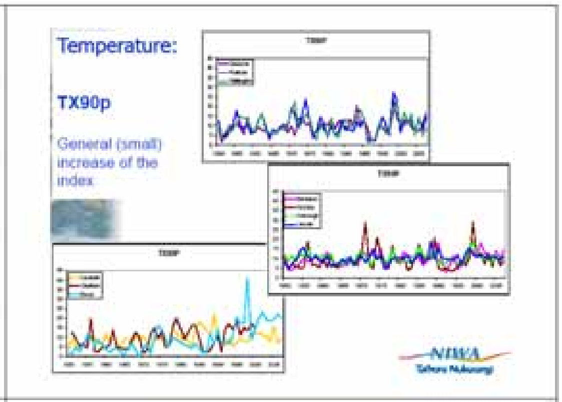
General decrease of the index

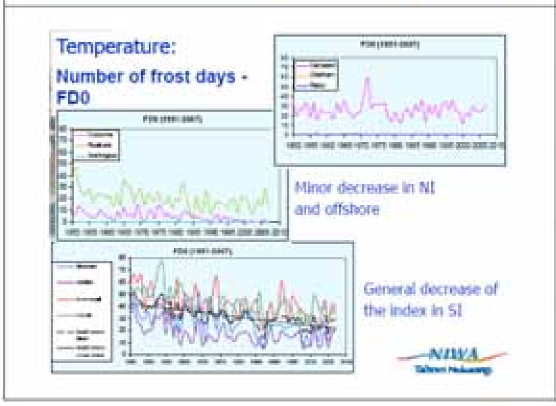


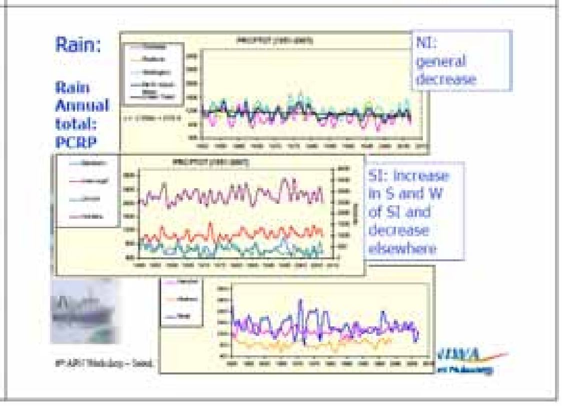


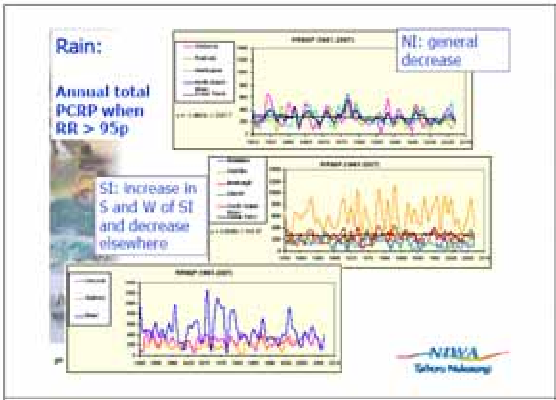


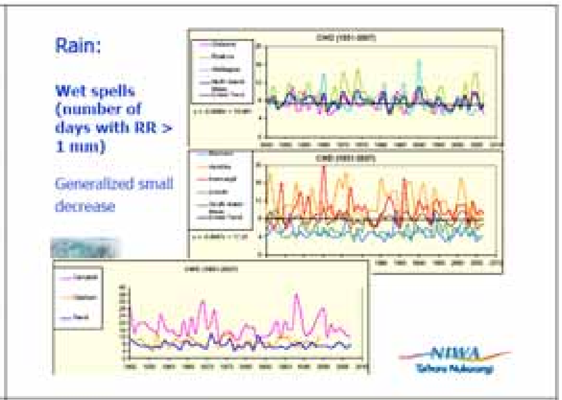

Temperature:
TN90p
General increase of the index


Temperature:
TX90p
General (small) increase of the index

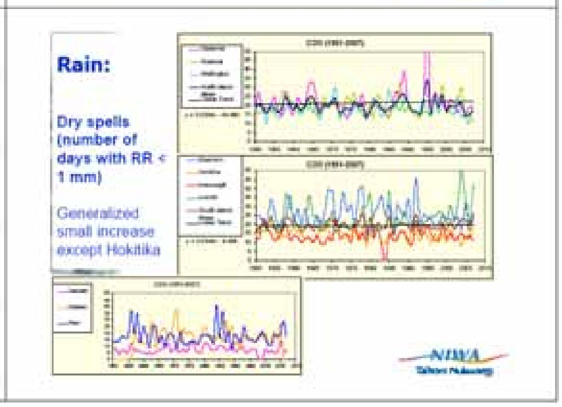

Temperature:
Number of frost days - FD0
Minor decrease in NI and offshore
General decrease of the index in SI

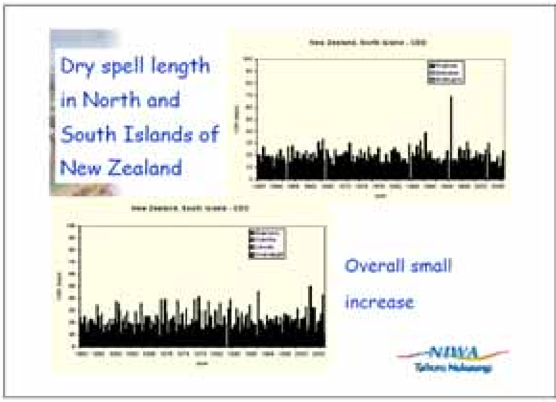

Rain:
Rain Annual total: PCRP
NI: general decrease
SI: increase in S and W of SI and decrease elsewhere


Rain:
Annual total PCRP when RR > 95p
NI: general decrease
SI: increase in S and W of SI and decrease elsewhere

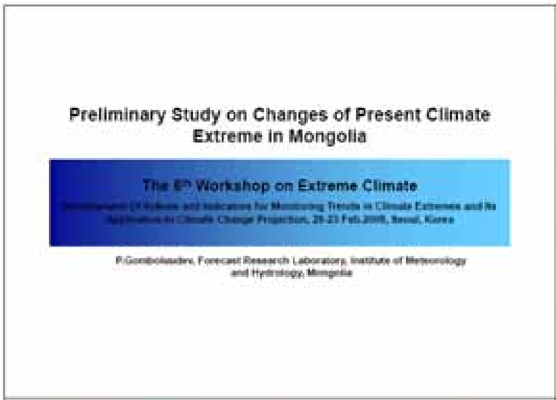

Rain:
Wet spells (number of days with RR > 1 mm)
Generalized small decrease

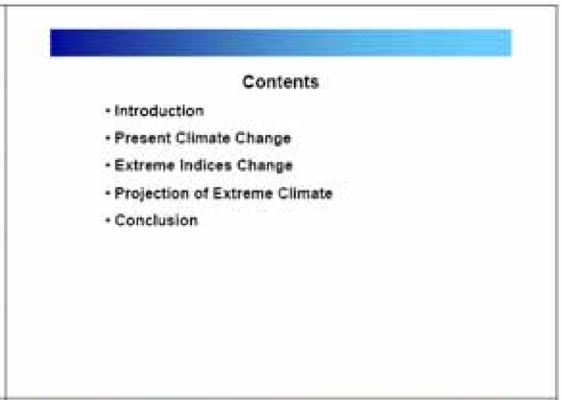

"Dry Spell Length"
Is the maximum number of consecutive dry days per year
(Where a 'dry' day is defined here to be a day with <1 mm rainfall)

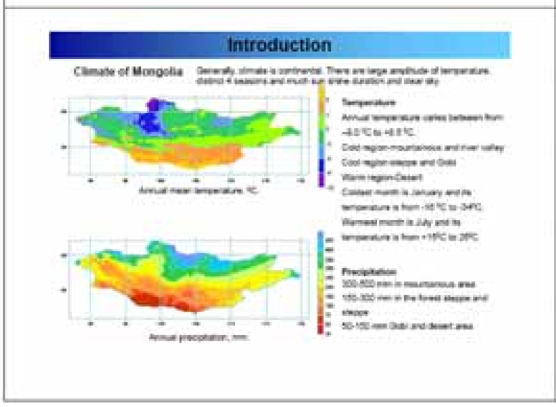

Rain:
Dry spells (number of days with RR < 1 mm)
Generalized small increase except Hokitika

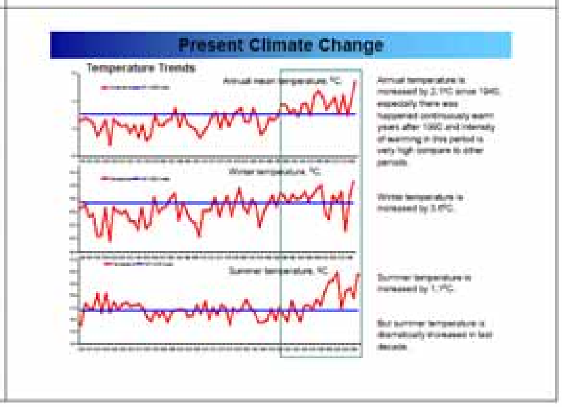


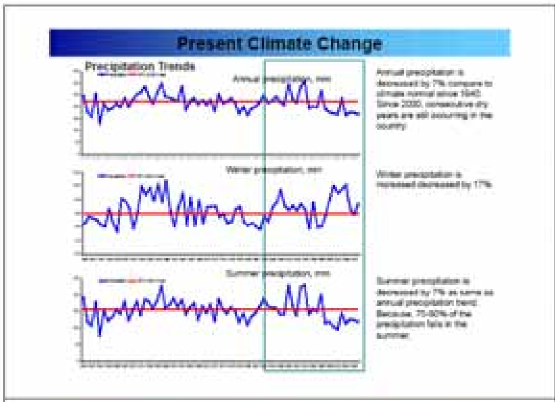
5. Preliminary study on changes of present climate extremes in **Mongolia**

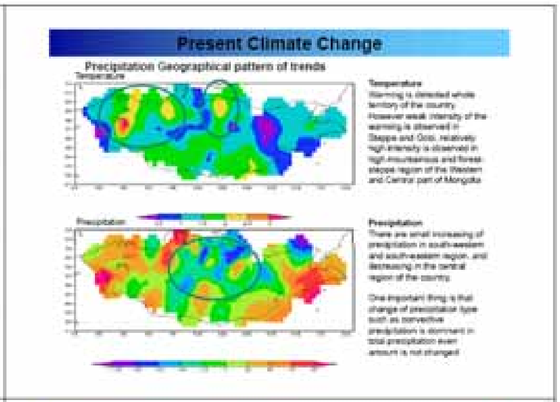


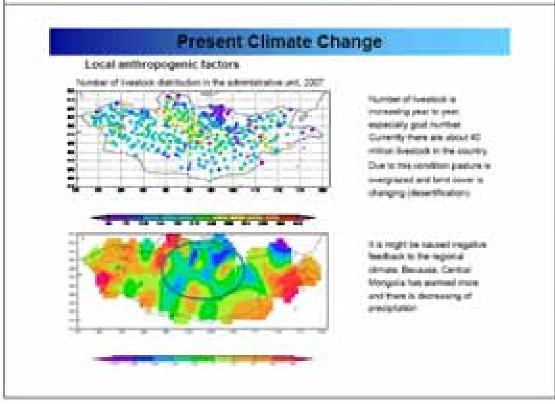


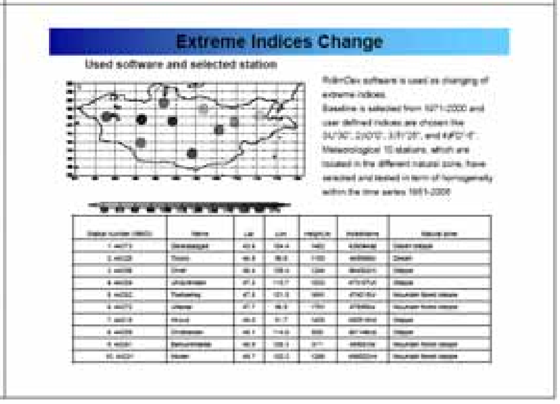


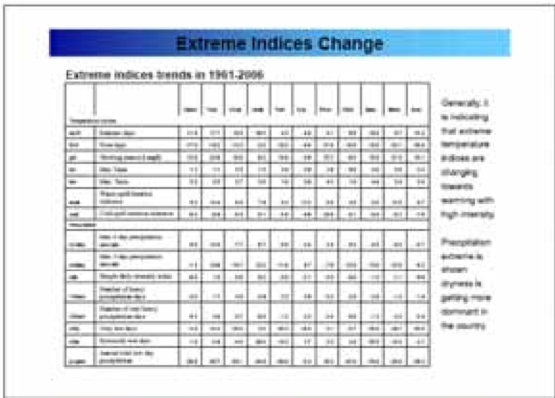


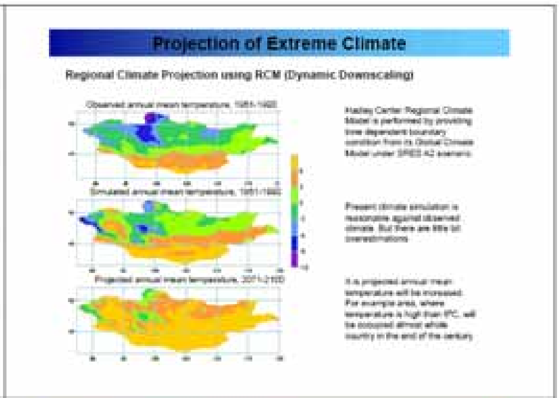

Present Climate Change
Precipitation Trends
Annual precipitation, mm
Annual precipitation is decreased by 7% compare to climate normal since 1940. Since 2000, consecutive dry years are still occurring in the country.
Winter precipitation, mm
Winter precipitation is increased decreased by 17%
Summer precipitation, mm
Summer precipitation is decreased by 7% as same as annual precipitation trend. Because, 75-80% of the precipitation falls in the summer.

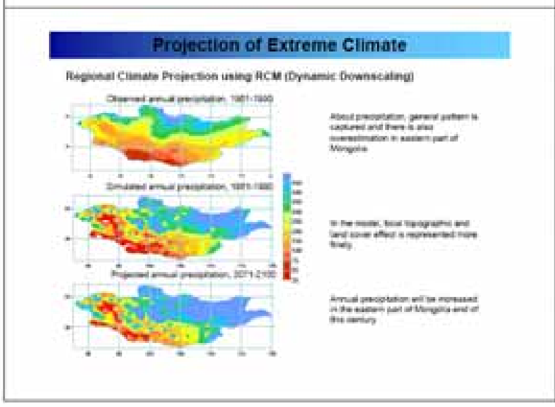

Present Climate Change
Precipitation Geographical pattern of trends
Temperature
Temperature
Warming is detected whole territory of the country. However weak intensity of the warming is observed in Steppe and Gobi, relatively high intensity is observed in high mountainous and forest steppe region of the Western and Central part of Mongolia
Precipitation
Precipitation
There are small increasing of precipitation in south-western and south-eastern region, and decreasing in the central region of the country.
One important thing is that change of precipitation type such as convective precipitation is dominant in total precipitation even amount is not changed

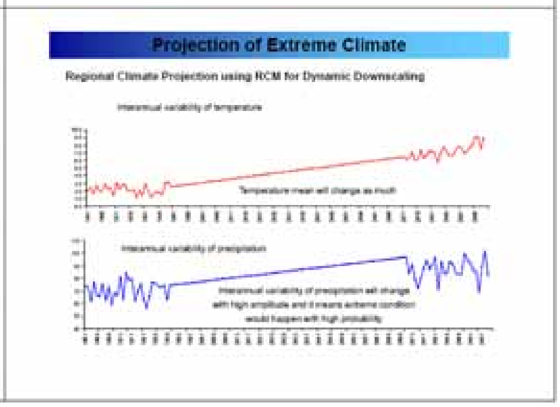

Present Climate Change
Local anthropogenic factors
Number of livestock distribution in the administrative unit, 2007
Number of livestock is increasing year to year especially goat number. Currently there are about 40 million livestock in the country. Due to this condition pasture is overgrazed and land cover is changing (desertification)
It is might be caused negative feedback to the regional climate. Because, Central Mongolia has warmed more and there is decreasing of precipitation

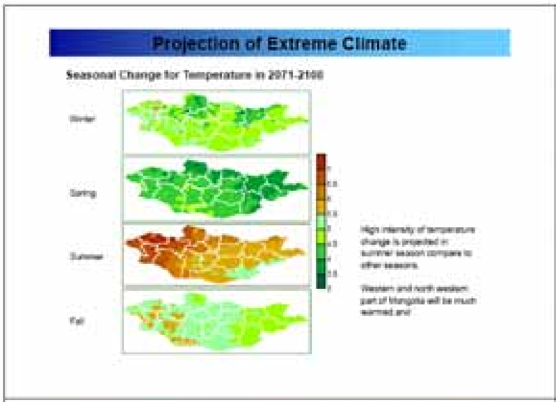

Extreme Indices Change
Used software and selected station
RclimDex software is used as changing of extreme indices.
Baseline is selected from 1971-2000 and user defined indices are chosen like
Meteorological 10 stations, which are located in the different natural zone, have selected and tested in term of homogeneity within the time series 1961-2006

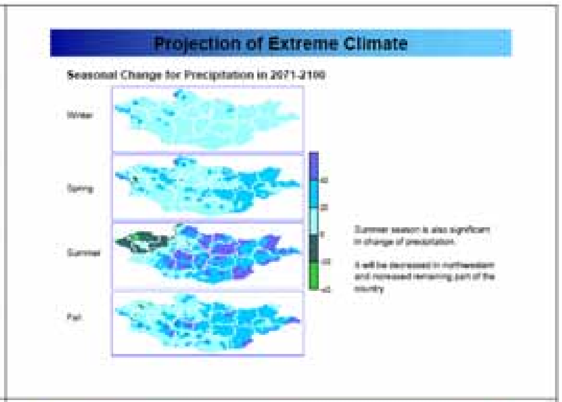

Extreme Indices Change
Extreme indices trends in 1961-2006
Generally, it is indicating that extreme temperature indices are changing towards warming with high intensity
Precipitation extreme is shown dryness is getting more dominant in the country

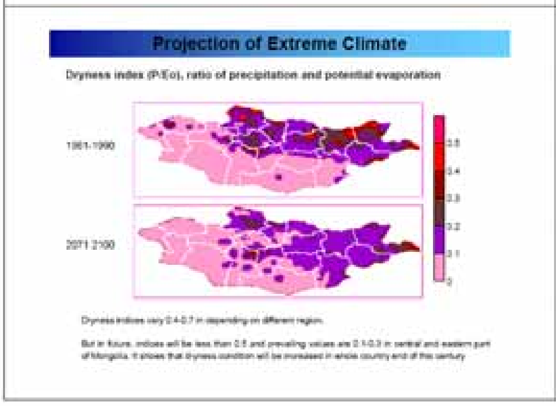

Projection of Extreme Climate
Regional Climate Projection using RCM (Dynamic Downscaling)
Observed annual mean temperature, 1961-1990
Simulated annual mean temperature, 1961-1990
Projected annual mean temperature, 2071-2100
Hadley Center Regional Climate Model is performed by providing time dependent boundary condition from its Global Climate Model under SRES A2 scenario.
Present climate simulation is reasonable against observed climate. But there are little bit overestimations
It is projected annual mean temperature will be increased. For example area, where temperature is high than 0°C, will be occupied almost whole country in the end of the century

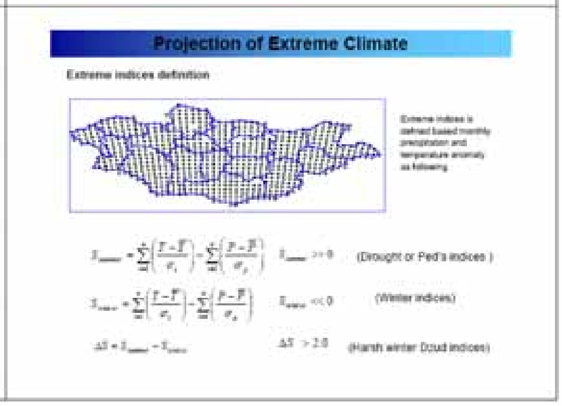

Projection of Extreme Climate
Regional Climate Projection using RCM (Dynamic Downscaling)
Observed annual precipitation, 1961-1990
Simulated annual precipitation, 1961-1990
Projected annual precipitation, 2071-2100
About precipitation, general pattern is captured and there is also overestimation in eastern part of Mongolia
In the model, local topographic and land cover effect is represented more finely
Annual precipitation will be increased in the eastern part of Mongolia end of this century

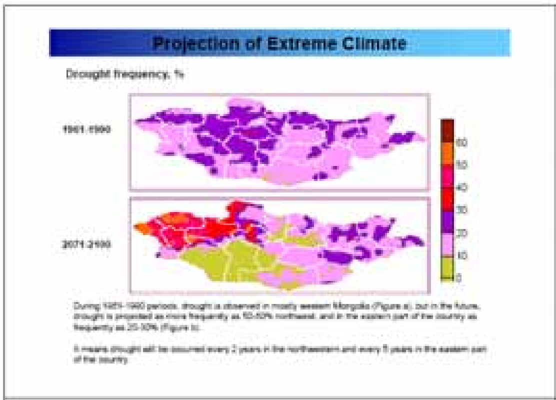

Projection of Extreme Climate
Regional Climate Projection using RCM for Dynamic Downscaling
Interannual variability of temperature
Temperature mean will change as much
Interannual variability of precipitation
Interannual variability of precipitation will change with high amplitude and it means extreme condition would happen with high probability

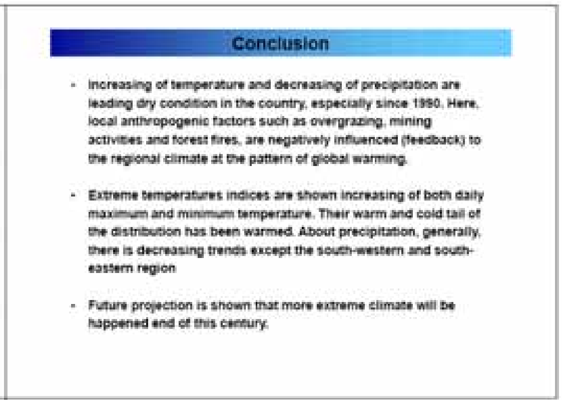

Projection of Extreme Climate
Seasonal Change for Temperature in 2071-2100
Winter
Spring
Summer
Fall
High intensity of temperature change is projected in summer season compare to other seasons.
Western and north western part of Mongolia will be much warmed and

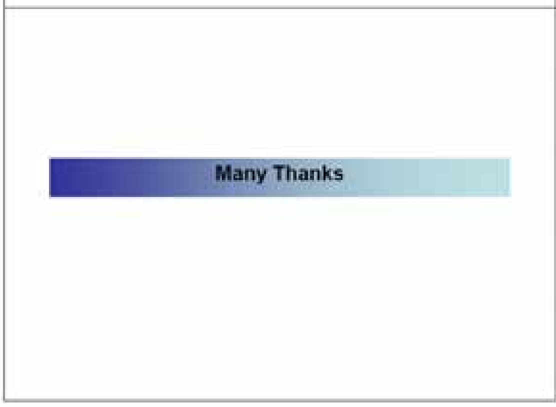

Projection of Extreme Climate
Seasonal Change for Precipitation in 2071-2100
Winter
Spring
Summer
Fall
Summer season is also significant in change of precipitation.
It will be decreased in northwestern and increased remaining part of the country.


Projection of Extreme Climate
Dryness index (P/Eo), ratio of precipitation and potential evaporation
1961-1990
2071-2100
0.5
0.4
0.3
0.2
0.1
0
Dryness indices vary 0.4-0.7 in depending on different region.
But in future, indices will be less than 0.5 and prevailing values are 0.1-0.3 in central and eastern part of Mongolia. It shows that dryness condition will be increased in whole country end of this century

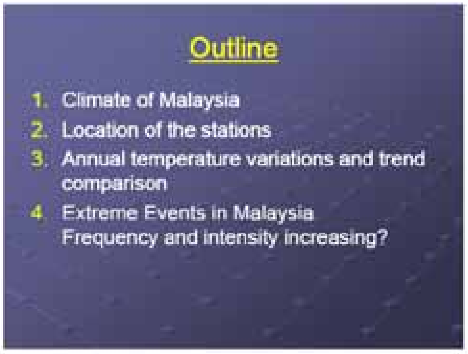

Projection of Extreme Climate
Extreme indices definition
Extreme indices is defined based monthly precipitation and temperature anomaly as following
(Drought or Ped's indices)
(Winter indices)
(Harsh winter Dzud indices)


Projection of Extreme Climate
Drought frequency, %
1961-1990
2071-2100
60
50
40
30
20
10
0
During 1961-1990 periods, drought is observed in mostly western Mongolia (Figure a), but in the future, drought is projected as more frequently as 50-60% northwest, and in the eastern part of the country as frequently as 20-30% (Figure b).
It means drought will be occurred every 2 years in the northwestern and every 5 years in the eastern part of the country.


Conclusion
Increasing of temperature and decreasing of precipitation are leading dry condition in the country, especially since 1990. Here, local anthropogenic factors such as overgrazing, mining activities and forest fires, are negatively influenced (feedback) to the regional climate at the pattern of global warming.
Extreme temperatures indices are shown increasing of both daily maximum and minimum temperature. Their warm and cold tail of the distribution has been warmed. About precipitation, generally, there is decreasing trends except the south-western and south-eastern region
Future projection is shown that more extreme climate will be happened end of this century.


Many Thanks

6. Climate Change and Extreme Weather Events in **Malaysia**



2.1 Station informations

- 48601
  - Latitude: 5.3⁰ N, Longitude: 100.27⁰ E
  - Height: 2.8 m above MSL.
  - In Penang, a Free Industrial Zone, where factories of many multinational companies are located.
  - Penang has a population of about 100,000 people. Bayan Lepas is now the off-shoot from development in Penang. Many new condominiums, housing estates are all currently under construction in that area.

- 48647
  - Latitude: 3.12⁰ N, Longitude: 101.55⁰ E
  - Height: 16.5 m above MSL.
  - Located in Subang, a district in the middle of the Klang Valley with a population of 1,418,700 people over a 484.32km² area for year 2005.
  - A commercial zone where hotels, restaurants, hypermarkets and etc thrives.

- 48657
  - Latitude: 3.78⁰ N, Longitude: 103.22⁰ E
  - Height: 15.3 m above MSL.
  - It is situated near Kuantan River mouth that faces the South China Sea.
  - Known as a tropical getaway, Kuantan's main economic activity is tourism. Domestically, it is famous for the production of handicrafts, batik, *keropok* (dried fish crackers) and salted fish. Kuantan is the administrative and commercial capital of Pahang.

- Trade and commerce are also important economic activities.The timber industry and the fishing industry also play vital roles in the local economy.
- Other than tourism and commerce is the strong presence of the petrochemical industries, mostly located in Gebeng, an industrial area about 25 km north of Kuantan.

- 96413, 96421, 96441 and 96449
  - All located in the state of Sarawak.
  - 96413 and 96421 inland stations.
  - 96441 and 96449 coastal stations.
  - It is situated north-west of the Borneo Island and is the largest state in Malaysia.
  - The state population was 2,404,200 in 2007.
  - Sarawak is blessed with an abundance of natural resources. LNG and petroleum have provided the mainstay of the state's economy for decades.

- Sarawak is also one of the world's largest exporters of tropical hardwood timber, which is the major contributor to Malaysian exports. This has led to wide-scale deforestation of Sarawak's rainforest. The last UN statistics estimated Sarawak's sawn timber exports at an average of 14109000 m³ between 1996 and 2000.

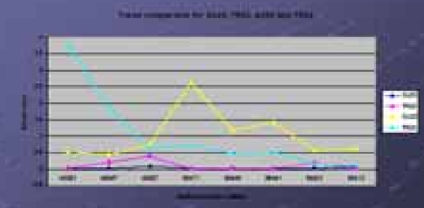
- 96471
  - Latitude: 5.93⁰ N, Longitude: 116.05⁰ E
  - Height: 2.3 m above MSL.
  - With an estimated population of 532,129 in the city and 700,000 in the urban area, it is the largest urban centre in Sabah and the sixth largest in Malaysia.
  - The economy is dominated by the primary industrial sector. Historically, the secondary sector, commerce, dominated the economy, but due to rapid urbanisation and economic development, this sector of economy is slowly diminishing. More recently, a move towards a more tertiary based industry has become more apparent, especially with regards to the boom in the tourism industry.

3. Annual temperature variations and trend comparison.

- Being an equatorial country, Malaysia has uniform temperature throughout the year. The annual variation is less than 2°C except for the east coast of Peninsular Malaysia which are often affected by cold surges originating from Siberia during the northeast monsoon. Even then, the annual variation is below 3°C.

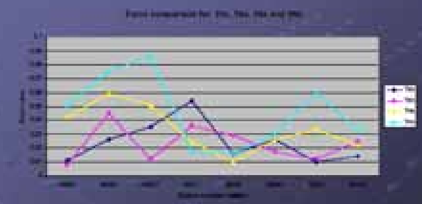
- It may be noted that air temperature of 38°C has very rarely been recorded in Malaysia. Although the days are frequently hot, the nights are reasonably cool everywhere.

3.1 Trend comparison for SU30 and TR25.

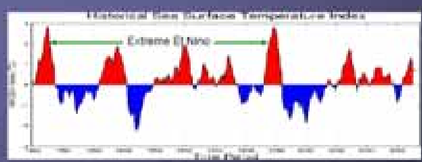


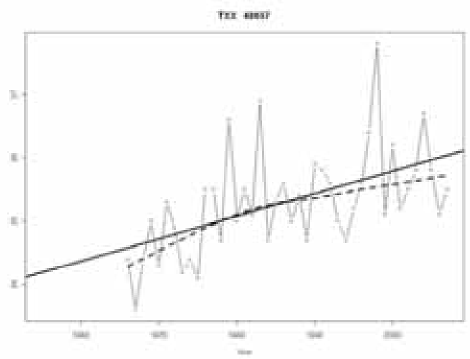
- Analysis of SU30 indicated that all coastal stations facing South China Sea has the larger trend than inland stations, of which station 96471 is the largest.
- Analysis of TR25 indicated that stations located in West Peninsular Malaysia has the larger trend than other stations, of which station 48601 is the largest.

3.2 Trend comparison for TXx, TXn, TNx and TNn.



- Analysis of TXx, TXn, TNx and TNn indicated warming trends.
- TNx and TNn has showed almost the same trend pattern but different in TXx and TXn.
- The highest maximum temperature, TXx, is 37.8 • C which occurred in station 48657 on 26th May 1998 during extreme El Nino condition.



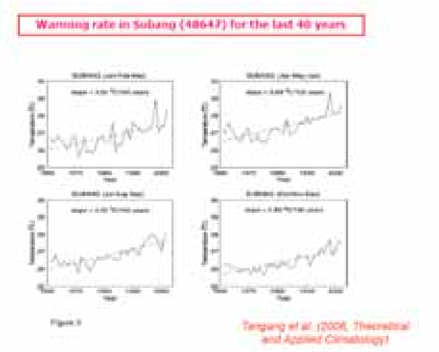


- Station 96471 has the largest trend in TXx caused the forest fire in Kota Kinabalu region in 1998.

Forest Fires in Klias and Beaufort Areas, SPOT Satellite from CRISP

3/3/1998

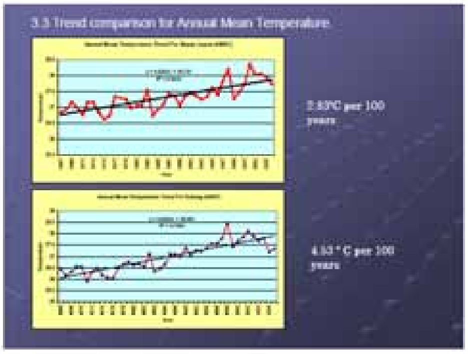
7/4/1998

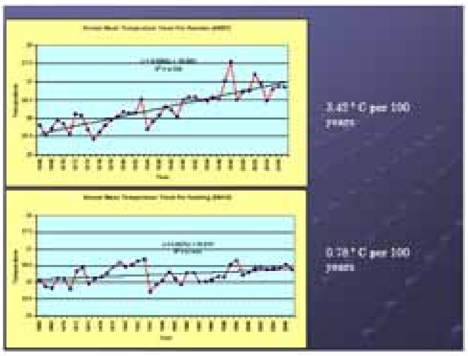

Warming rate in Subang (48647) for the last 40 years
Figure 3
Tangang et al. (2008, Theoretical and Applied Climatology)


Warming rates in other cities in Malaysia

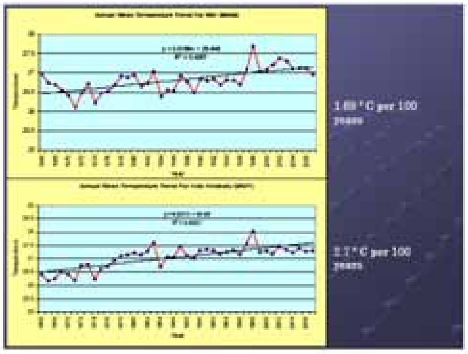
	Stations	Slope β (in °C/100 years)			
		JFM	AMJ	JAS	OND
1.	Sandakan	2.20	2.78*	2.14	2.06
2.	Kota Kinabalu	3.98*	3.39	2.97	2.98
3.	Miri	0.08	0.29*	0.2	−0.47
4.	Bintulu	(1.32)*	(0.83)	(0.75)	−0.1
5.	Kuching	1.40*	1.47	(1.00)	(0.91)
6.	Mersing	2.41*	(1.54)	1.27	2.00
7.	Kuantan	3.37	3.72*	3.36	2.83
8.	Kota Bharu	2.15*	1.98	1.77	2.04
9.	Melaka	2.87	2.98	3.07*	2.7
10.	Subang	3.53	3.98	4.02*	3.49
11.	Penang	2.39*	2.28	2.28	2.09

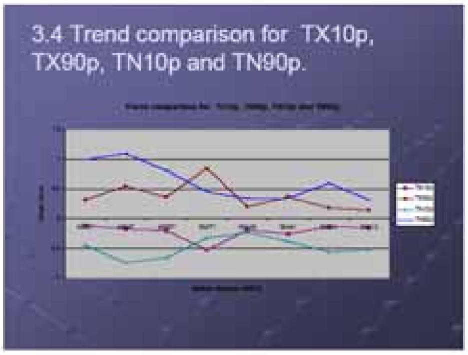
Increases of between 0.5 – 1.5°C for the last 40 years
IPCC AR4: Linear trend for global average temperature increase for the last 100 years (1906 – 2005) = °C/100 years. For the last 50 years = °C/100 years.

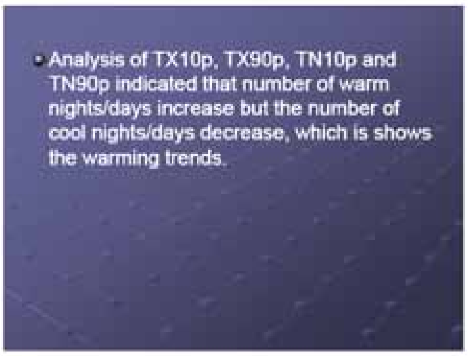

3.3 Trend comparison for Annual Mean Temperature
2.83°C per 100 years
4.53 °C per 100 years


3.45 °C per 100 years
0.78 °C per 100 years

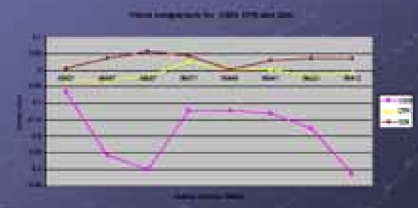

1.77 °C per 100 years
1.87 °C per 100 years


1.69 °C per 100 years
2.7 °C per 100 years


3.4 Trend comparison for TX10p, TX90p, TN10p and TN90p.


Analysis of TX10p, TX90p, TN10p and TN90p indicated that number of warm nights/days increase but the number of cool nights/days decrease, which is shows the warming trends.

3.5 Trend comparison for CSDI, DTR and SDII.



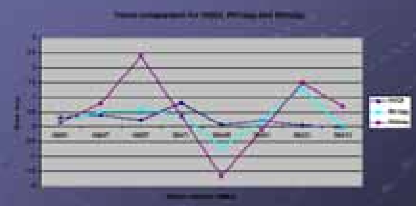
- Analysis of CSDI indicated the decreasing value which is related to number of cool nights, TN10p, decreasing.
- The diurnal temperature range, DTR, is large, ranging from 6.3°C to 8.7°C at the coastal stations and from 7.9°C to 10.3°C at the inland stations but the excessive day temperatures which are found in continental tropical areas are never experienced.

- Analysis of Simple Daily Intensity Index, SDII, indicated station 48657 has the largest trend which is related to number of flood events increasing at this region during north-east monsoon season.

HIGH WATER ... aerial view of the outskirts of Kuantan. (Picture from the Star)

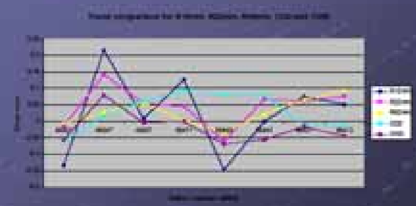
FAST-FLOWING WATERS ... the Lembing River overflows (Picture from the Star)

3.6 Trend comparison for WSDI, RX1day and RX5day.



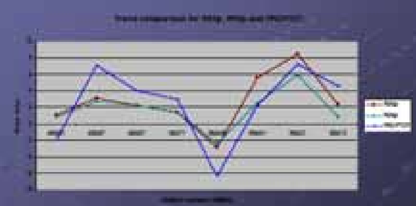
- Analysis of warm spell duration indicator, WSDI, indicated region of Sabah (96471) and Peninsula has the larger trend than region of Sarawak. This is related to local urbanization process is frequently active at this two region.
- Analysis of RX1day and RX5day indicated almost the same trend pattern, which is flood prone area (48657 and 96421) shows the larger trend.

3.7 Trend comparison for R10mm, R20mm, R50mm, CDD and CWD.



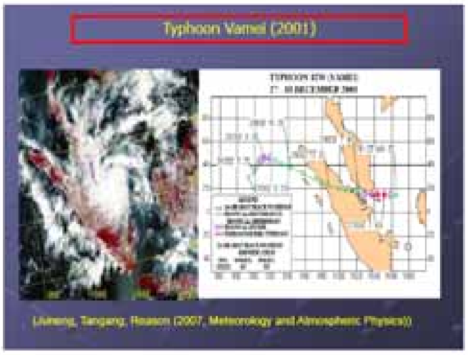
- Analysis of R10mm and R20mm indicated largest trend in station 48647 but for R50mm indicated largest trend in station 96413 that usually cause flash flood in this region.
- Analysis of CDD and CWD indicated largest trend in station 96471 and station 48647 respectively. Only station 48647 indicated increasing trend in CWD.

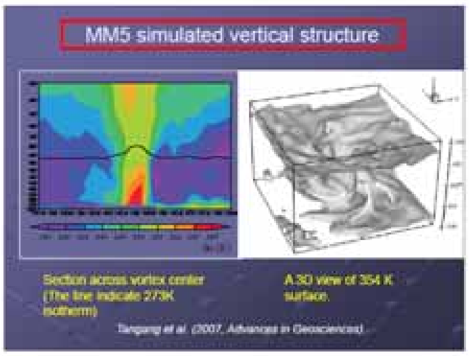
3.8 Trend comparison for R95p, R99p and PRCPTOT.

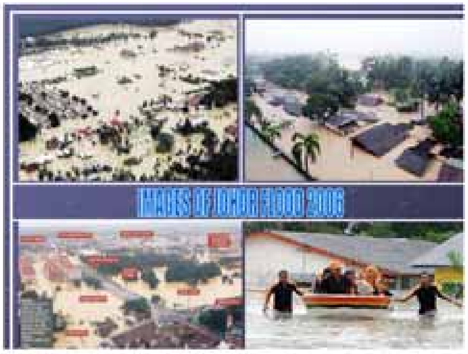


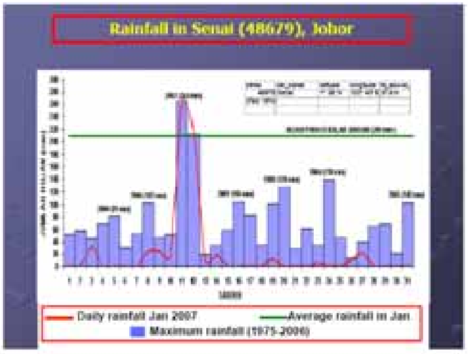
- Analysis of R95p, R99p and PRCPTOT indicated almost the same trend pattern, of which station 96421(flood prone area) is the largest.
- Station 96449 indicated decreasing trend in R95p, R99p and PRCPTOT, which is linking to CWD indicator.

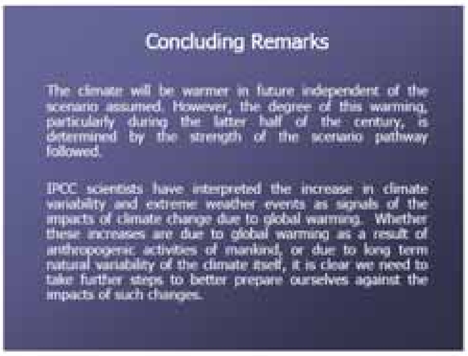
4. Extreme Events in Malaysia: Frequency and intensity increasing?



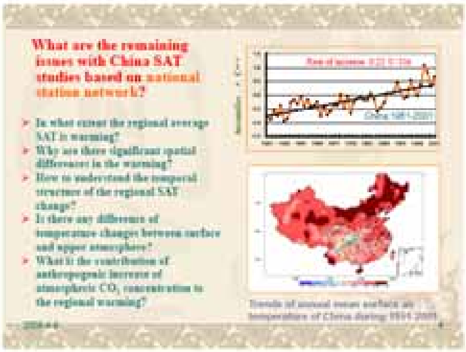


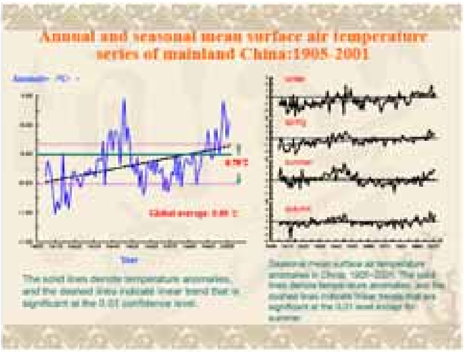


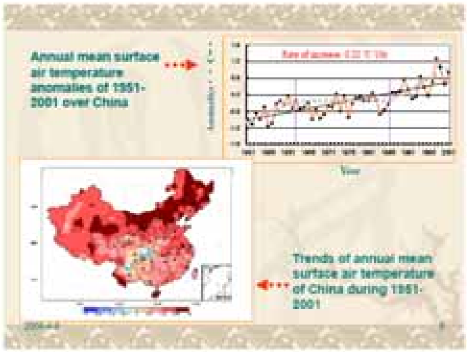


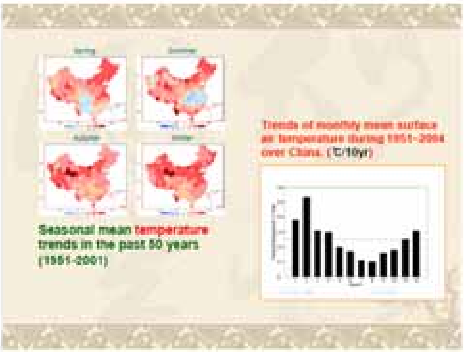


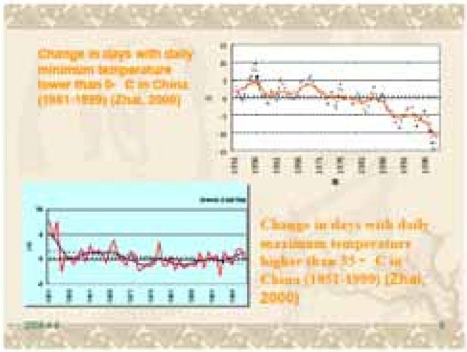
7. Air temperature change over **China**



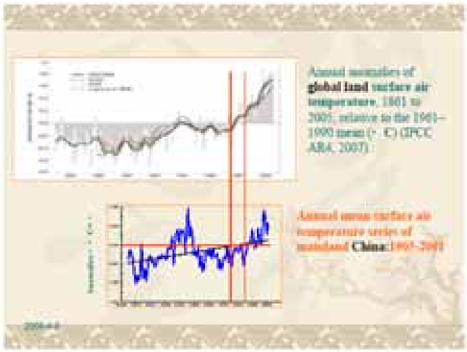

Annual and seasonal mean surface air temperature series of mainland China:1905-2001
Global average: 0.60 ℃
The solid lines denote temperature anomalies, and the dashed lines indicate linear trend that is significant at the 0.01 confidence level.

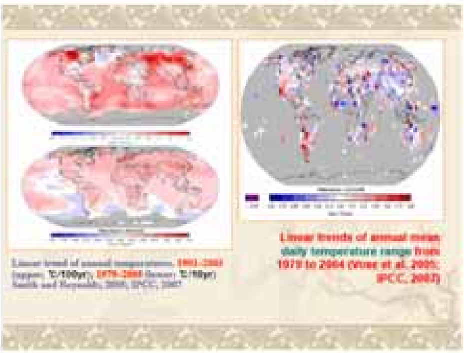

Annual mean surface air temperature anomalies of 1951-2001 over China
Trends of annual mean surface air temperature of China during 1951-2001

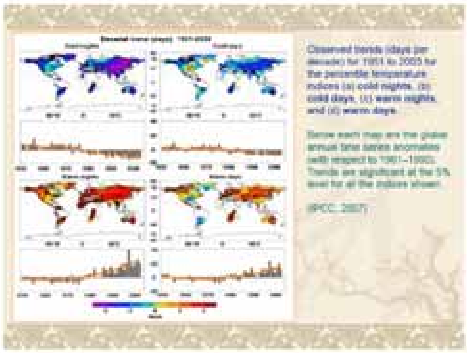

Seasonal mean temperature trends in the past 50 years (1951-2001)
Trends of monthly mean surface air temperature during 1951-2004 over China. (℃/10yr)


Change in days with daily minimum temperature lower than 0 ℃ in China (1951-1999) (Zhai, 2000)
Change in days with daily maximum temperature higher than 35 ℃ in China (1951-1999) (Zhai, 2000)


Characteristics of China SAT change as obtained from national station network
Rapid warming over the past 100 years, especially over the last 25 years;
More evident warming in north than in south;
A few areas undergoing a cooling, in particular in summertime and springtime;
Larger increase of SAT in cold seasons;
Significant drop in annual and daily SAT ranges nationwide.

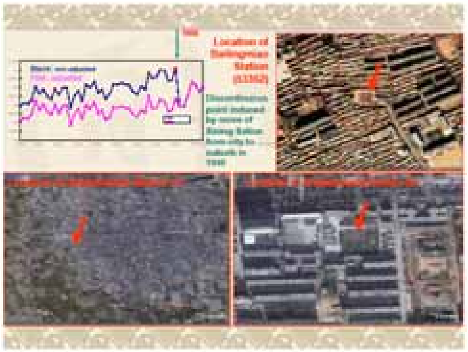

Annual anomalies of global land surface air temperature, 1861 to 2005, relative to the 1961–1990 mean (℃) (IPCC AR4, 2007)
Annual mean surface air temperature series of mainland China:1905-2001

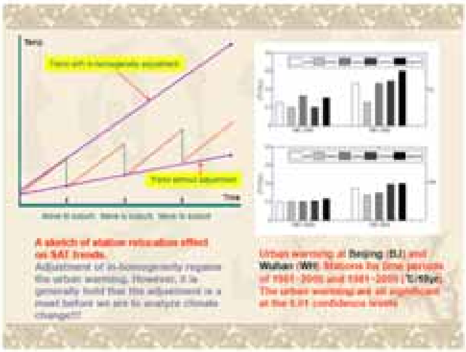

Linear trends of annual mean daily temperature range from 1979 to 2004 (Vose et al. 2005; IPCC, 2007)

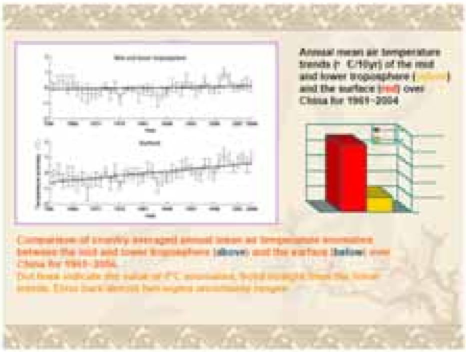

Observed trends (days per decade) for 1951 to 2003 for the percentile temperature indices (a) cold nights, (b) cold days, (c) warm nights, and (d) warm days.
Below each map are the global annual time series anomalies (with respect to 1961–1990). Trends are significant at the 5% level for all the indices shown.
(IPCC, 2007)

Difference from the global change:

- More rapid warming in China, even more in NC;
- More significant warming in 1930s-1940s;
- A delayed warming of about ten-years behind global average in the recent warm period;
- More significant warming in cold seasons and nighttime;
- The most obvious drop in daily temperature range (DTR).

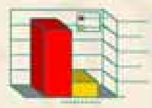






Characteristics of upper air temperature change

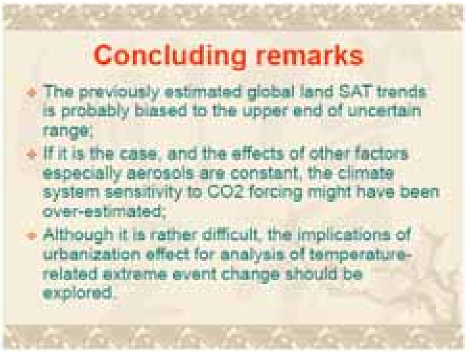
- No significant warming in the past 40-50 years for troposphere as a whole;
- warming in mid-to lower troposphere is also weak for the entire period analyzed, but significant for 1979-2004 period;
- **Significant difference exists between the surface and upper air temperature trends.**



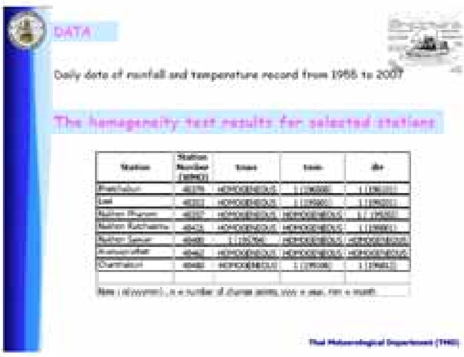
Mid and lower troposphere (yellow) and the surface (red): which one is in error???

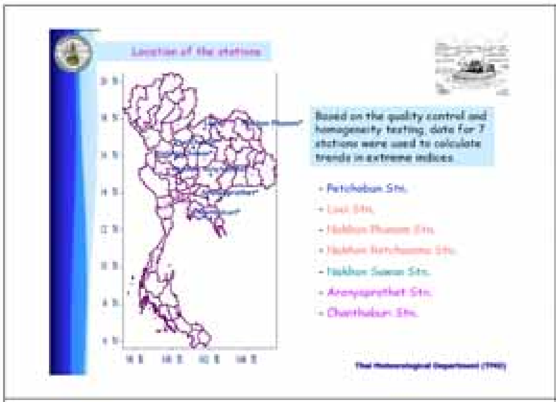
Possibility One: upper air data not reliable;
Possibility Two: surface data significantly contaminated;
Possibility Three: both upper and surface data incorrect.

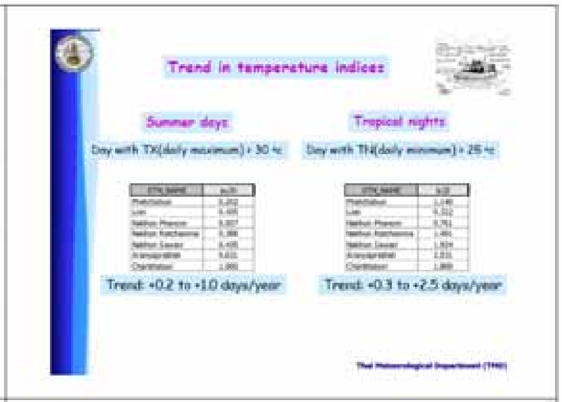
The second possibility – partly urbanization affect

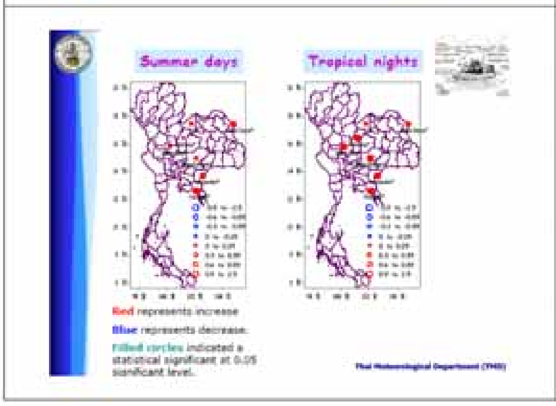


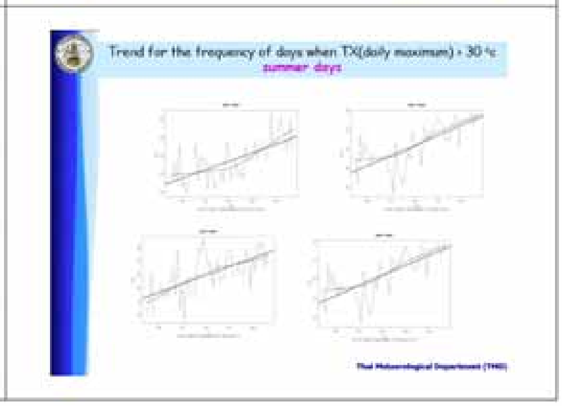
8. Trend in Extreme Climate Indices for **Thailand**

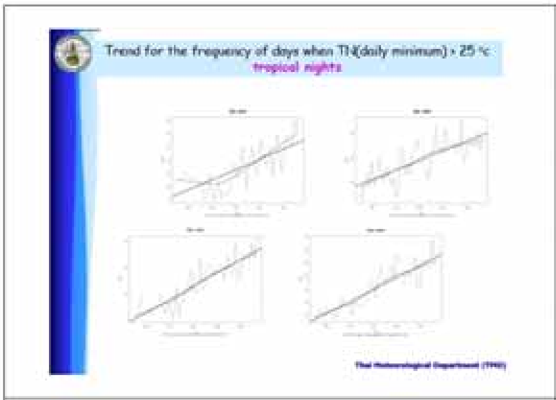



Location of the stations
Based on the quality control and homogeneity testing, data for 7 stations were used to calculate trends in extreme indices
- Petchabun Stn.
- Loei Stn.
- Nakhon Phanom Stn.
- Nakhon Ratchasima Stn.
- Nakhon Sawan Stn.
- Aranyaprathet Stn.
- Chanthaburi Stn.

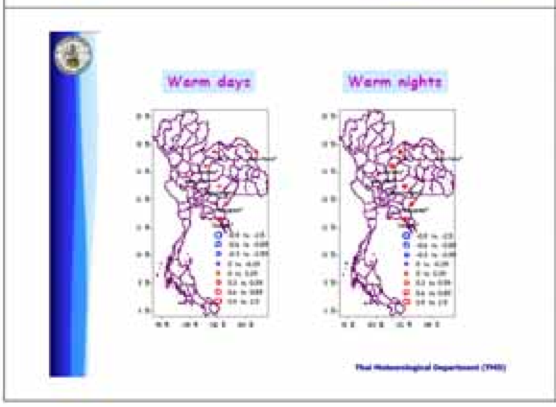

Trend in temperature indices
Summer days
Tropical nights
Day with TX(daily maximum) > 30 °c
Day with TN(daily minimum) > 25 °c
Trend: +0.2 to +1.0 days/year
Trend: +0.3 to +2.5 days/year


Summer days
Tropical nights
Red represents increase
Blue represents decrease.
Filled circles indicated a statistical significant at 0.05 significant level.
Thai Meteorological Department (TMD)

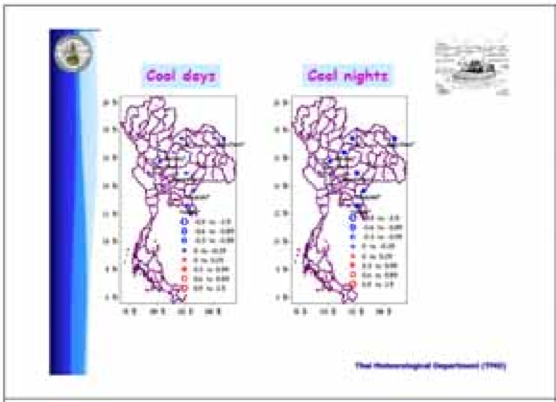

Trend for the frequency of days when TX(daily maximum) > 30 °c
summer days
Thai Meteorological Department (TMD)


Trend for the frequency of days when TN(daily minimum) > 25 °c
tropical nights
Thai Meteorological Department (TMD)

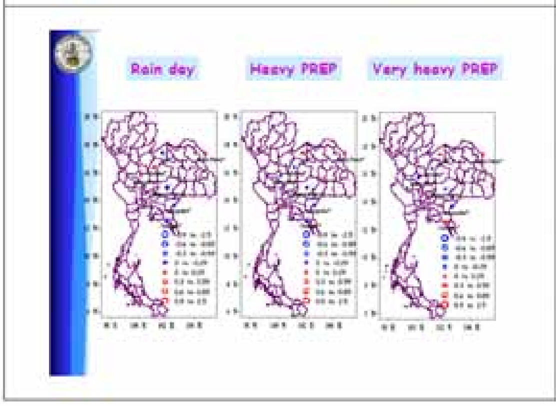

Trend in temperature indices
Warm days
Warm nights
Percentage of day when TX(daily maximum) > 90 percentile
Percentage of day when TN(daily minimum) > 90 percentile
STN_NAME | tx90p
Phetchabun | 0.101
Loei | 0.124
Nakhon Phanom | 0.220
Nakhon Ratchasima | 0.016
Nakhon Sawan | 0.143
Aranyaprathet | 0.242
Chanthaburi | 0.321
STN_NAME | tn90p
Phetchabun | 0.369
Loei | 0.349
Nakhon Phanom | 0.288
Nakhon Ratchasima | 0.372
Nakhon Sawan | 0.298
Aranyaprathet | 0.475
Chanthaburi | 0.419
Trend: +0.1 to +0.3 days/ year
Trend: +0.3 to +0.5 days/ year
Thai Meteorological Department (TMD)

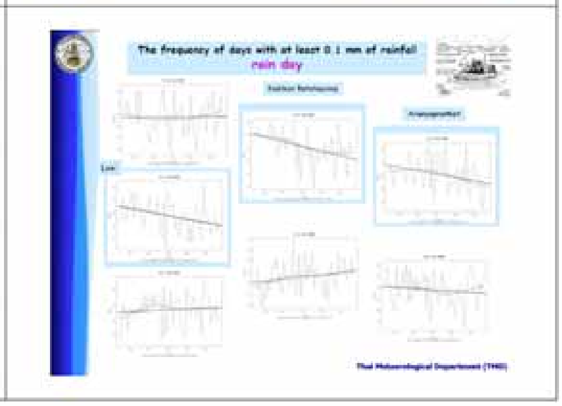

Warm days
Warm nights
Thai Meteorological Department (TMD)

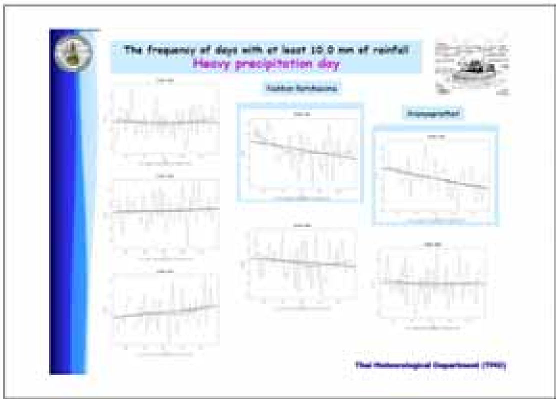

Trend in temperature indices
Cool days
Cool nights
Percentage of day when TX(daily maximum) < 10 percentile
Percentage of day when TN(daily minimum) < 10 percentile
STN_NAME | tx10p
Phetchabun | -0.052
Loei | -0.071
Nakhon Phanom | -0.107
Nakhon Ratchasima | -0.111
Nakhon Sawan | -0.106
Aranyaprathet | -0.178
Chanthaburi | -0.198
STN_NAME | tn10p
Phetchabun | -0.503
Loei | -0.462
Nakhon Phanom | -0.362
Nakhon Ratchasima | -0.595
Nakhon Sawan | -0.376
Aranyaprathet | -0.498
Chanthaburi | -0.510
Trend: -0.1 to -0.2 days/ year
Trend: -0.3 to -0.6 days/ year
Thai Meteorological Department (TMD)

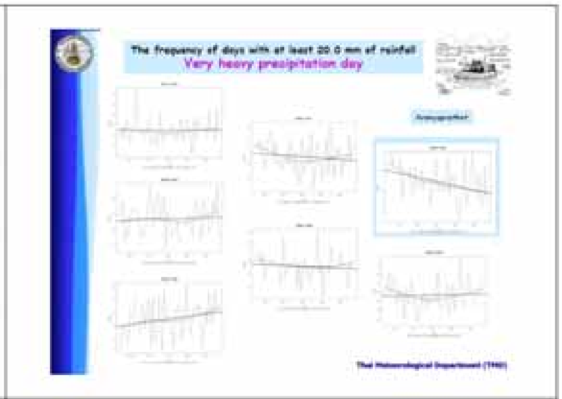

Cool days
Cool nights

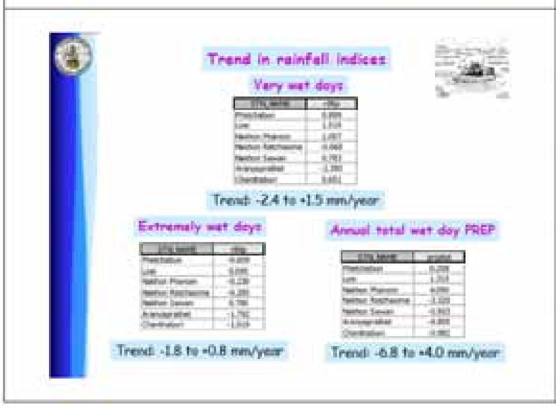

Trend in rainfall indices
Rain day
Trend: -0.4 to +0.2 days/year
Heavy PREP days
Very heavy PREP days
Trend: -0.2 to +0.1 days/year
Trend: -0.1 to +0.1 days/year

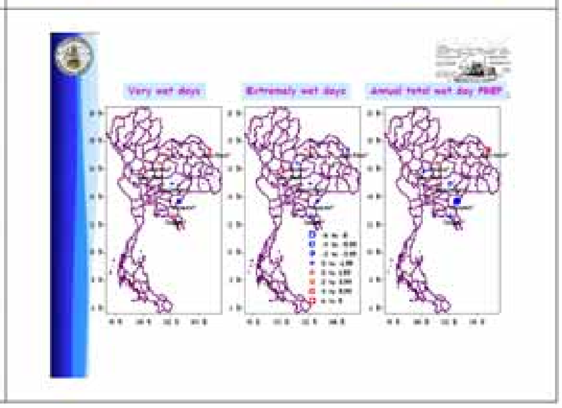

Rain day
Heavy PREP
Very heavy PREP

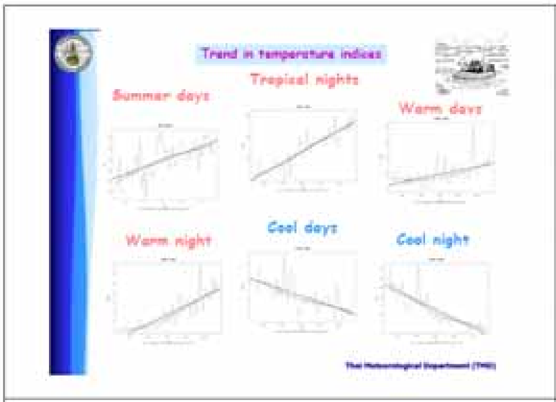

The frequency of days with at least 0.1 mm of rainfall
rain day


The frequency of days with at least 10.0 mm of rainfall
Heavy precipitation day

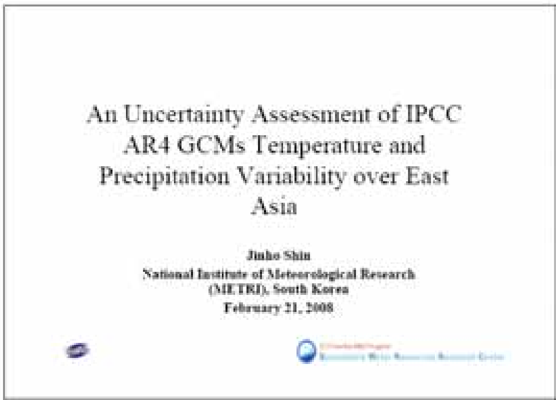

The frequency of days with at least 20.0 mm of rainfall
Very heavy precipitation day

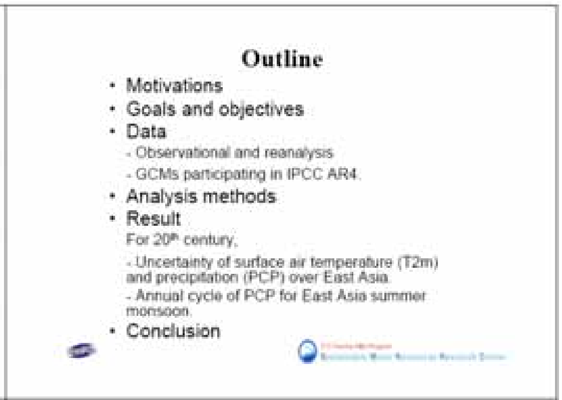

Trend in rainfall indices
Very wet days
Trend: -2.4 to +1.5 mm/year
Extremely wet days
Annual total wet day PREP
Trend: -1.8 to +0.8 mm/year
Trend: -6.8 to +4.0 mm/year

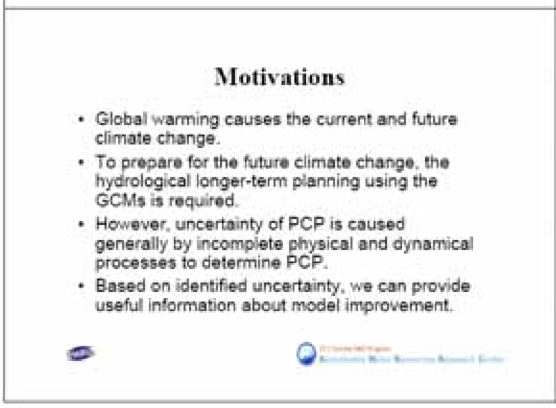

Very wet days
Extremely wet days
Annual total wet day PREP

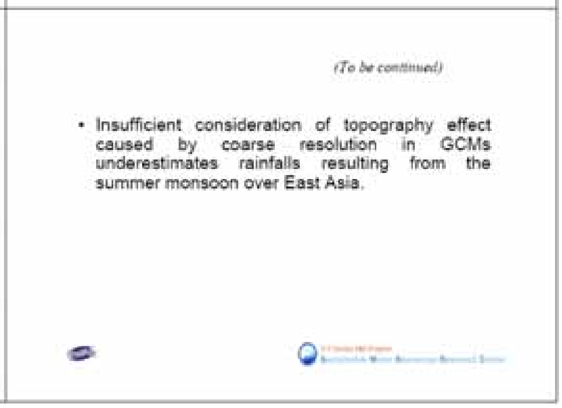


9. An Uncertainty Assessment of IPCC AR4 GCMs Temperature and Precipitation Variability over East Asia









Goals and objectives

- 1) assess an uncertainty of T2m and PCP over East Asia using statistical methods.
- 2) examine the spatio-temporal evolutions of PCP for the summer monsoon period.
- 3) investigate the interaction between PCP and lower-level circulation in the annual cycle.

Observational and reanalysis data

- **Climate Research Unit (CRU) data**
  - Global 5°×5° latitude-longitude grid.
  - Period: January 1961-December 1990 (30 yrs).
- **CPC Merged Analysis of Precipitation (CMAP) data**
  - Monthly means of precipitation.
  - Global 2.5°×2.5° latitude-longitude grid.
  - Period: January 1979-December 1999 (21 yrs).
- **ECMWF data**
  - Monthly means of surface and pressure level; wind, moisture.
  - Global 2.5°×2.5° latitude-longitude grid.
  - Period: January 1979-December 1999.

IPCC AR4 SRES and Models

Regriding process of IPCC data

20c3m	B	[illegible]	[illegible]	[illegible]	[illegible]
	A	[illegible]	[illegible]	[illegible]	[illegible]
A1B	B	[illegible]	[illegible]	[illegible]	[illegible]
	A	[illegible]	[illegible]	[illegible]	[illegible]
B1	B	[illegible]	[illegible]	[illegible]	[illegible]
	A	[illegible]	[illegible]	[illegible]	[illegible]
A2	B	[illegible]	[illegible]	[illegible]	[illegible]
	A	[illegible]	[illegible]	[illegible]	[illegible]

-Approximately 1.7TB of main surface variables (T2m, PCP, etc) stored in METRI

Analysis methods

- For reference period
  1) T2m : 1961-1990 (30 years)
  2) PCP : 1979-1999 (21 years)
- 1) Bias : difference between modeled and observed (OBS) T2m (or PCP) during each reference period.
- 2) Root Mean Square Error (RMSE) of T2m (or PCP) during each reference period.

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\mathrm{mod}_i - \mathrm{obs})^2}$$

- 3) Ratio of standard deviation (RSD) between modeled and OBS T2m (or PCP).

$$RSD = \frac{\sigma_{MME}}{\sigma_{obs}}$$

- 4) Pattern correlation between modeled and OBS T2m (or PCP).

(To be continued)

- Cyclostationary EOF (CSEOF) Analysis
  (specically for the second goal)
  - See Kim and North (1997).
  - Decomposition of observational data, $T(r,t)$ into physical modes and their amplitude histories

$$T(r,t) = \sum_{i=1} B_i(r,t)T_i(t)$$

$B_i(r,t)$: Physical modes (time-dependent spatial patterns)
i : mode number
$T_i(t)$: PC time series (evolution history of physical mode).

(To be continued)

- **Regression method** *(specically for the third goal)*
  -Physically consistent evolution between target and predictor.
  -PC times series of target, $T_i(t)$ is expressed by

$$T_i(t) = \sum_{k=1} a_k^{(i)} P_k(t) + \epsilon(t), t = 1,2,3$$

where $P_k(t)$: PC time series of predictor, and
$a^{(i)}_k(t)$: Regression coefficient.

-Regressed pattern of predictor, $\Psi_i(r,t)$ is found from

$$\Psi_i(r,t) = \sum_{k=1} a_k^{(i)} C_k(r,t), t = 1,2,3$$

where $C_k(r,t)$: Pattern of the target.

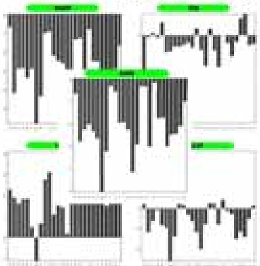
Geographical domain for this study

Result I :

Uncertainty Assessment of T2m and PCP over East Asia

using statistical methods (1) - (4)

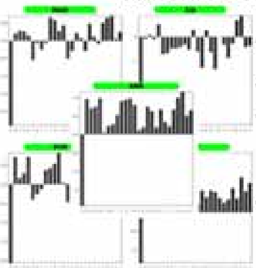
Seasonal T2m Bias



X axis: models(a-x), MME24(y) and MME9(z)

- Cold bias (model < OBS) in MAM,JJA,DJF for all or most of models.
- Warm bias (OBS< model) in SON for all models except GF0(g).
- Cold bias in ANN
  - All models underestimate the observed T2m.
  - MME24(y)~ -2.1℃c
  - Cold bias (~-2.8C) in MAM contributes tremendously to increase uncertainty of T2m.

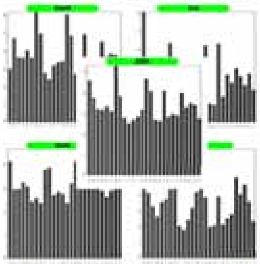
Seasonal PCP Bias



X axis: models(a-x), MME24(y) and MME9(z)

- Wet bias (model > OBS) in MAM,SON,DJF for most of models
- Dry bias (OBS > model) in JJA for most of models.
- Wet bias in ANN for all models except BCC.
  - MME24(y)~ 0.4mm/day
  - Wet bias (~0.6mm/day) in DJF contributes tremendously to increase uncertainty of PCP
- Totally, GCMs overestimated observed PCP by 20%.

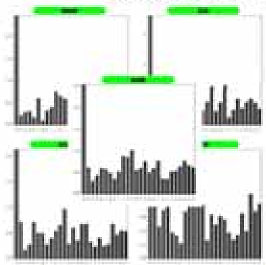
Seasonal T2m RMSE



X axis: models(a-x), MME24(y) and MME9(z)

- For MAM:
MP(2.11)<MME24(3.79℃)< GFD(5.18)
- For JJA:
MMG(3.23)< MME24(2.89℃)< BCC(5.04)
- For SON:
GFD(2.58)<MME24(3.17℃)< MPI(4.08)
- For DJF:
GIH(1.82)<MME24(3.82℃)<GFD(5.88)
- For ANN:
GIH(2.55)<MME24(3.43℃)<GFD(5.27)

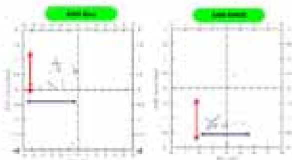
Seasonal PCP RMSE



X axis: models(a-x), MME24(y) and MME9(z)

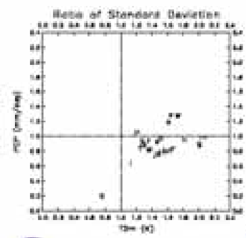
- For MAM:
GFD(0.11)<MME24(0.71mm/day)< BCC(2.45)
- For JJA:
BCR(0.17)< MME24(0.75mm/day)< BCC(3.50)
- For SON:
CCM(0.17)<MME24(0.54mm/day)< BCC(2.12)
- For DJF:
GFN(0.22)<MME24(0.73mm/day)<AP(1.59)
- For ANN:
CCM(0.30)<MME24(0.83mm/day)< BCC(2.63)

Comparison of inter-model Bias and RMSE



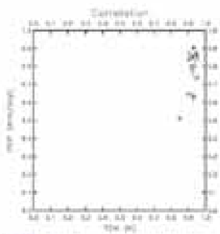
- It appears that cold bias value tends to increase with the decrease in wet bias value. However, the signal is not obvious yet.

Ratio of Standard Deviation (RSD)



- T2m RSD > 1
Model standard deviation (SD) is greater than OBS SD except BCC.
- PCP RSD < 1
- RSD of T2m is proportional to RSD of PCP → models with larger T2m variability simulated larger PCP RSD.

Pattern correlations of T2m and PCP



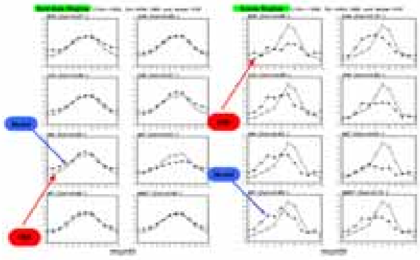
- Higher T2m correlation shows higher PCP correlation.

Summary

- Uncertainty assessment of T2m and PCP over East Asia

1) Cold T2m bias (~-1℃c) and wet PCP bias (~20%).
2) In seasonal variability, large uncertainty of PCP in winter and T2m in spring.

PCP annual time series

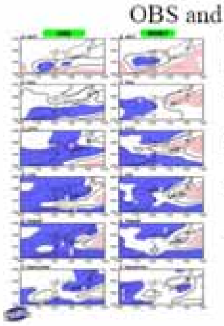


Next: It is necessary to study on spatio-temporal evolution characteristics of PCP (obs. and models) for summer monsoon period using CSEOF analysis

Result II : Comparison in evolution characteristics of PCP for summer monsoon period

using CSEOF analysis

OBS and MME7



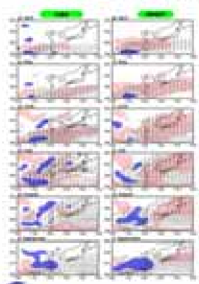
- CMAP (OBS) — in summer Monsoon period

1) Positive OBS anomalies appear over southeast China in spring (a).
2) Northeastward Expansion of positive anomalies and more rainfalls over Japan in June (c).
3) Further northward and more rainfalls over Korea in July-August (d)-(e).

- MME (7-model ensemble average)

1) Positive anomalies in east China in spring (April-May) (g)-(h).
2) Blue shaded region (positive anomaly) is divided in half in June (i). Dry bias signal is obvious for Korea and Japan region since June.
3) Center of positive anomaly over east Asia is located in northeastern China (north of Korea), indicating the clear difference between OBS and model.

Low level moisture transport



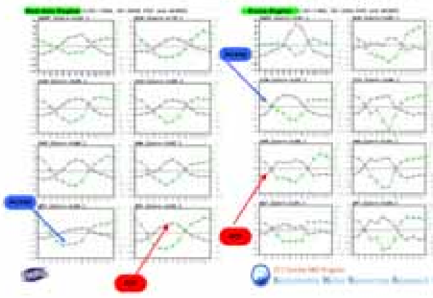
- ECMWF (OBS) — in summer Monsoon period

1) Moisture transport toward east Asia develops in spring and reaches maximum in July(a)-(d).
2) Same characteristic patterns for the moisture convergence.
3) Moisture transport comes from the tropical western Pacific. The transport vector is southwesterly by July, followed by southeasterly in August (e).

- MME (7-model ensemble average)

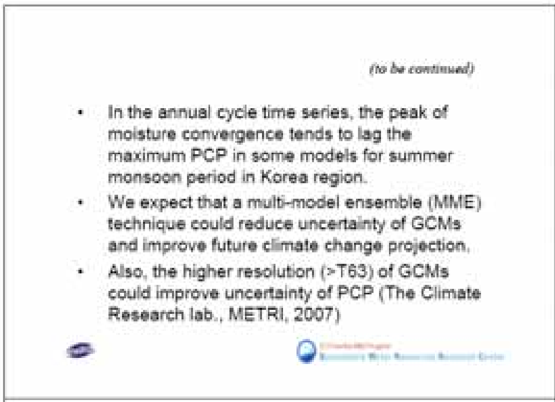
1) Earlier development in moisture transport than observation in spring (April-May) (g)-(h).
2) Underestimate of moisture transport in July and August.
3) The transport vector in July is southeasterly, while it is southwesterly in observation. Moisture source region over the Pacific shifts northward from the observed source region.

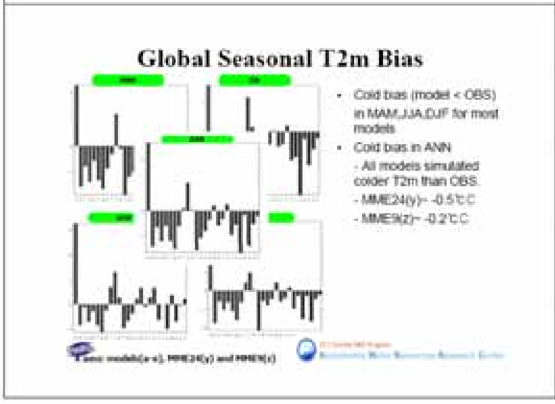
PCP and 850hPa moisture convergence

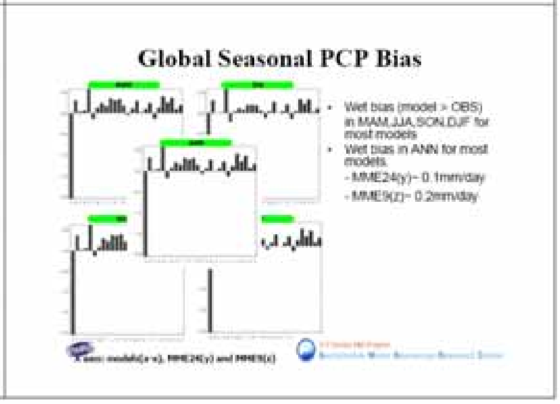


Conclusion

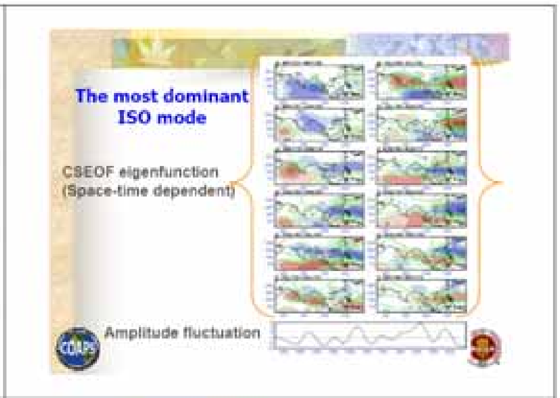
- For uncertainty assessment of IPCC A4 GCMs, GCMs simulated cold T2m bias (~-1℃c) and wet PCP bias (~20%).
- Comparison among seasons shows that the largest cold bias is found in spring, substantially contributing to the uncertainty of T2m over East Asia. The largest wet bias is found in winter. It plays a role in increasing the uncertainty of PCP.
- Evolution patterns of the modeled monthly PCP and moisture transport over Korea and Japan region give some information about why the PCP is underestimated in models.

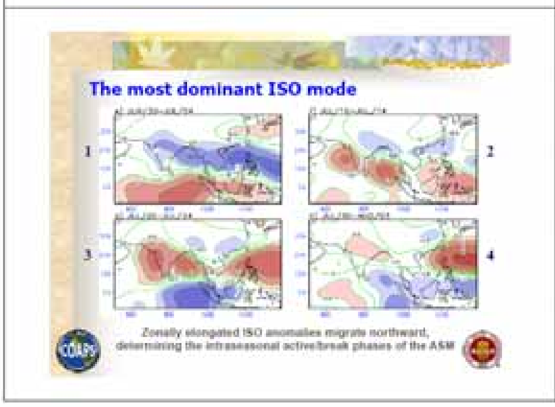


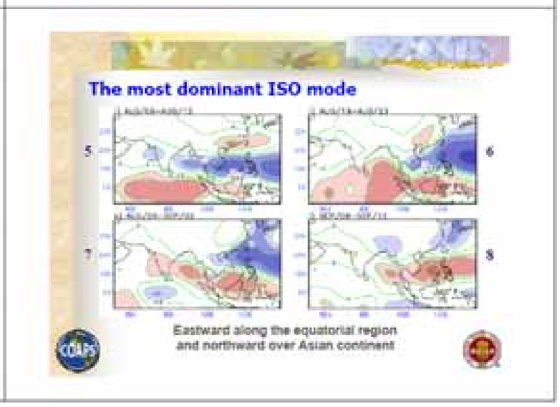


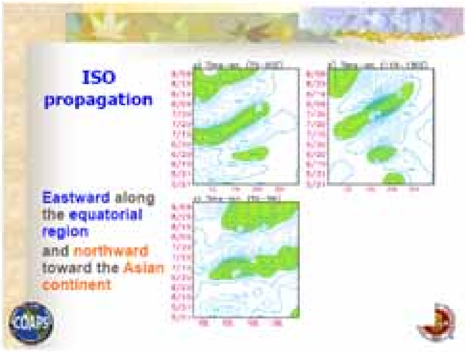


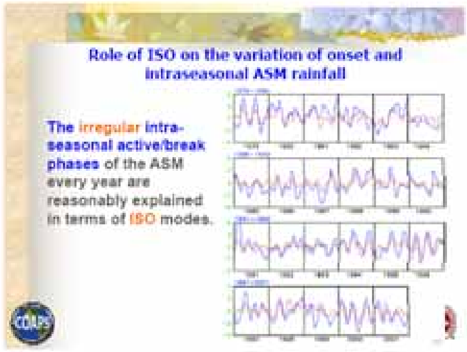
10. Application of CSEOF to Monsoon Climate Analysis and Prediction

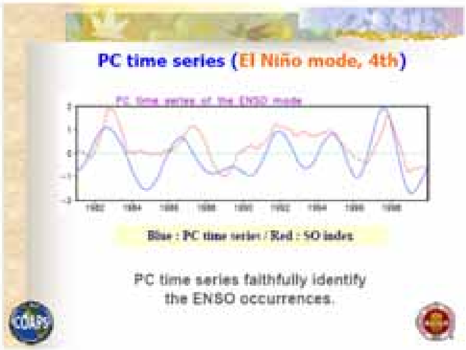


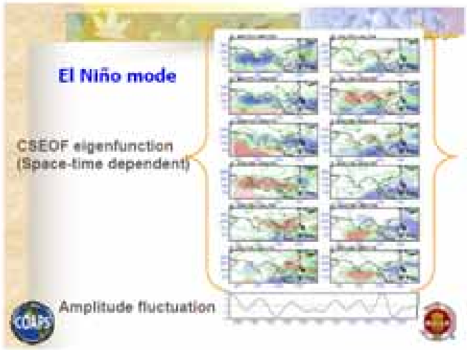


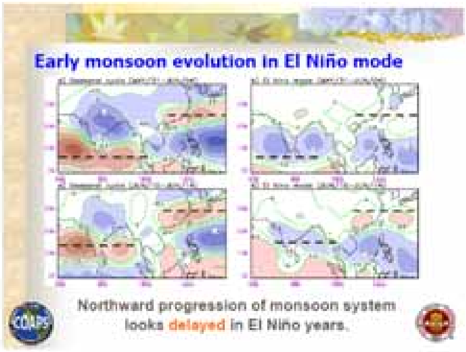


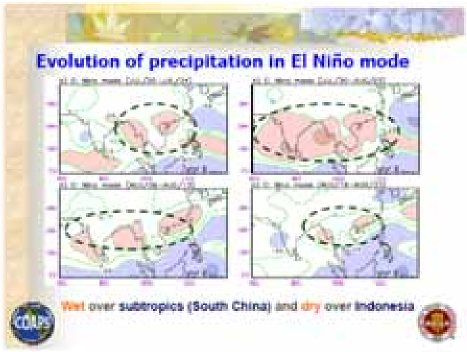

ISO propagation
Eastward along the equatorial region
and northward toward the Asian continent

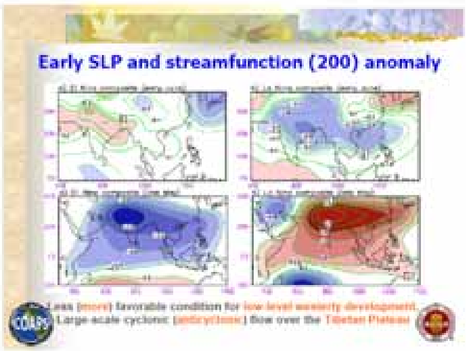

Role of ISO on the variation of onset and intraseasonal ASM rainfall
The irregular intra-seasonal active/break phases of the ASM every year are reasonably explained in terms of ISO modes.

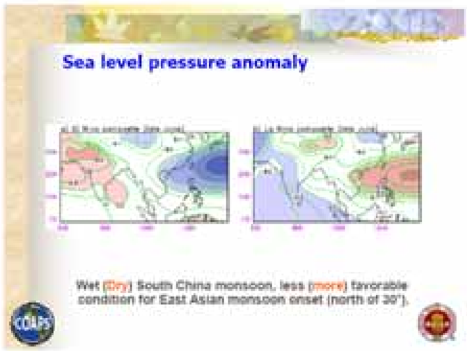

PC time series (El Niño mode, 4th)
PC time series of the ENSO mode
Blue : PC time series / Red : SO index
PC time series faithfully identify the ENSO occurrences.

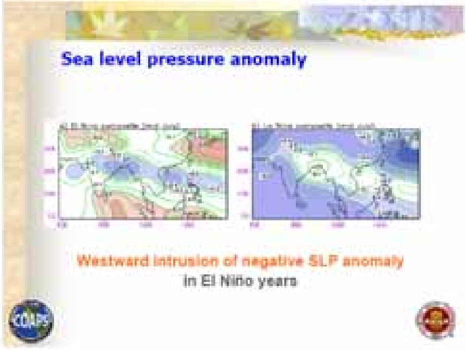

El Niño mode
CSEOF eigenfunction
(Space-time dependent)
Amplitude fluctuation

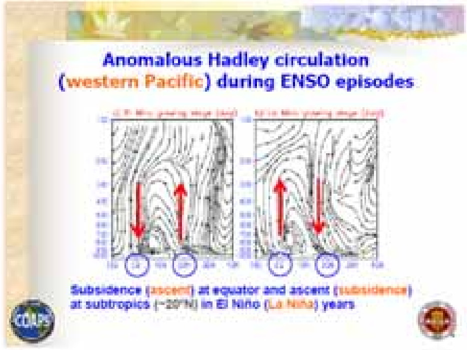

Early monsoon evolution in El Niño mode
Northward progression of monsoon system looks delayed in El Niño years.

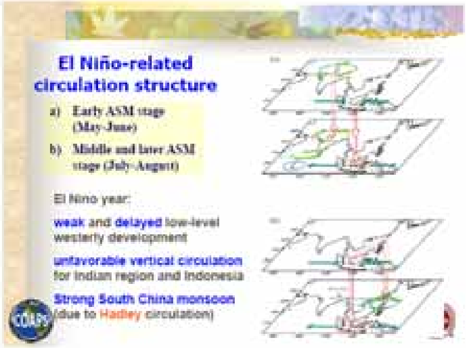

Evolution of precipitation in El Niño mode
Wet over subtropics (South China) and dry over Indonesia

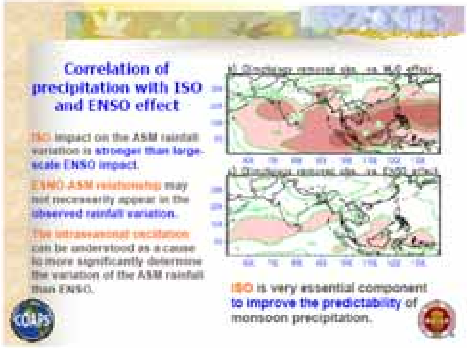

Early SLP and streamfunction (200) anomaly
Less (more) favorable condition for low-level westerly development.
Large-scale cyclonic (anticyclonic) flow over the Tibetan Plateau

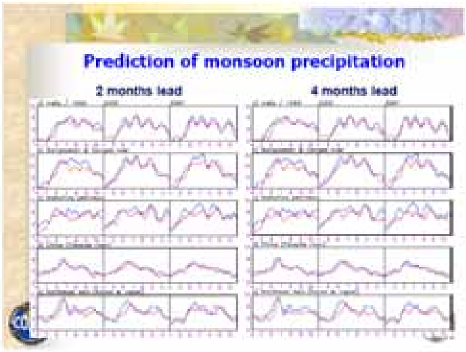

Sea level pressure anomaly
Wet (Dry) South China monsoon, less (more) favorable condition for East Asian monsoon onset (north of 30°).

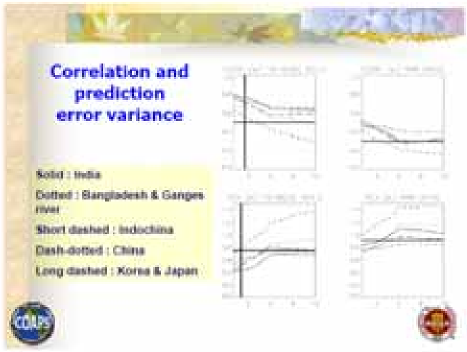

Sea level pressure anomaly
Westward intrusion of negative SLP anomaly
in El Niño years

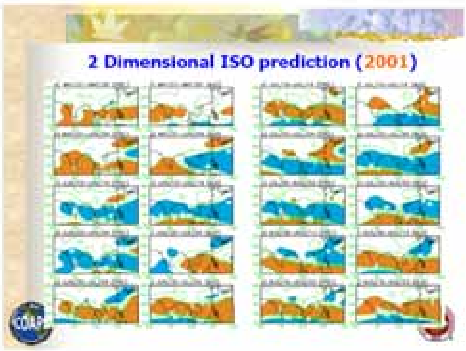

Anomalous Hadley circulation
(western Pacific) during ENSO episodes
Subsidence (ascent) at equator and ascent (subsidence)
at subtropics (~20°N) in El Niño (La Niña) years

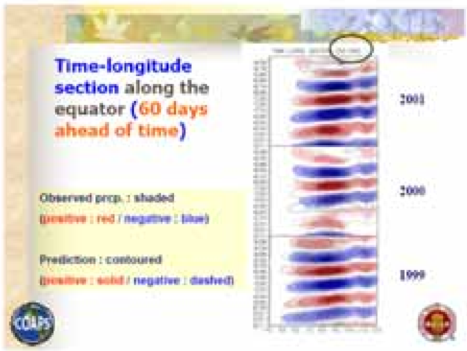

El Niño-related
circulation structure
a) Early ASM stage
(May-June)
b) Middle and later ASM
stage (July-August)
El Nino year:
weak and delayed low-level
westerly development
unfavorable vertical circulation
for Indian region and Indonesia
Strong South China monsoon
(due to Hadley circulation)

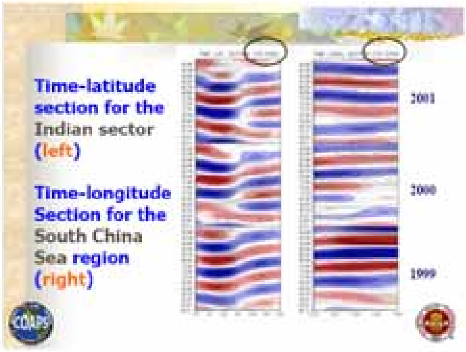

Correlation of
precipitation with ISO
and ENSO effect
ISO impact on the ASM rainfall
variation is stronger than large-
scale ENSO impact.
ENSO-ASM relationship may
not necessarily appear in the
observed rainfall variation.
The intraseasonal oscillation
can be understood as a cause
to more significantly determine
the variation of the ASM rainfall
than ENSO.
ISO is very essential component
to improve the predictability of
monsoon precipitation.

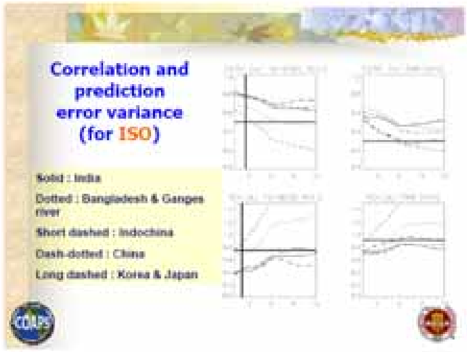

Prediction of monsoon precipitation
2 months lead
4 months lead

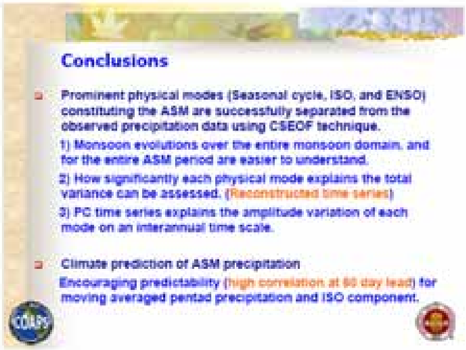

Correlation and
prediction
error variance
Solid : India
Dotted : Bangladesh & Ganges
river
Short dashed : Indochina
Dash-dotted : China
Long dashed : Korea & Japan


2 Dimensional ISO prediction (2001)

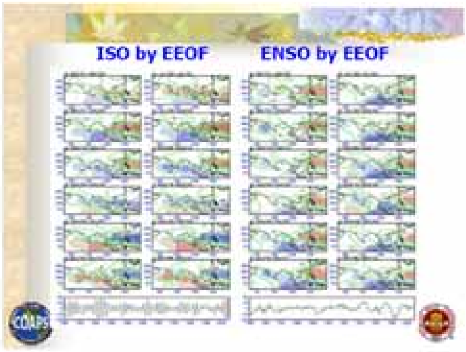

Time-longitude
section along the
equator (60 days
ahead of time)
Observed prcp. : shaded
(positive : red / negative : blue)
Prediction : contoured
(positive : solid / negative : dashed)
2001
2000
1999


Time-latitude section for the Indian sector (left)
Time-longitude Section for the South China Sea region (right)
2001
2000
1999

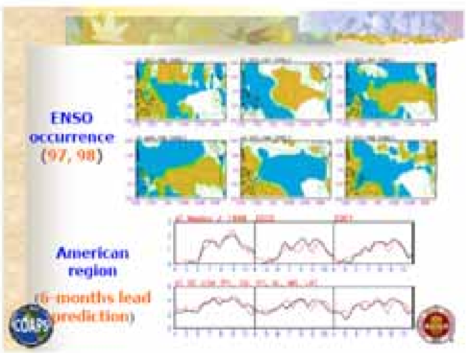

Correlation and prediction error variance (for ISO)
Solid : India
Dotted : Bangladesh & Ganges river
Short dashed : Indochina
Dash-dotted : China
Long dashed : Korea & Japan

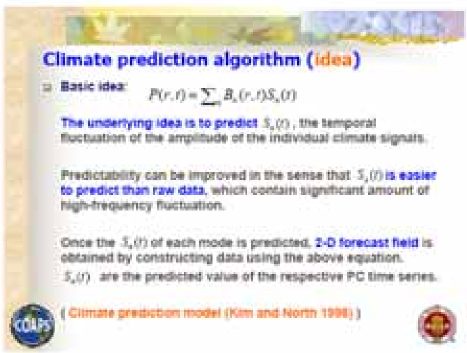

Conclusions
Prominent physical modes (Seasonal cycle, ISO, and ENSO) constituting the ASM are successfully separated from the observed precipitation data using CSEOF technique.
1) Monsoon evolutions over the entire monsoon domain, and for the entire ASM period are easier to understand.
2) How significantly each physical mode explains the total variance can be assessed. (Reconstructed time series)
3) PC time series explains the amplitude variation of each mode on an interannual time scale.
Climate prediction of ASM precipitation
Encouraging predictability (high correlation at 60 day lead) for moving averaged pentad precipitation and ISO component.

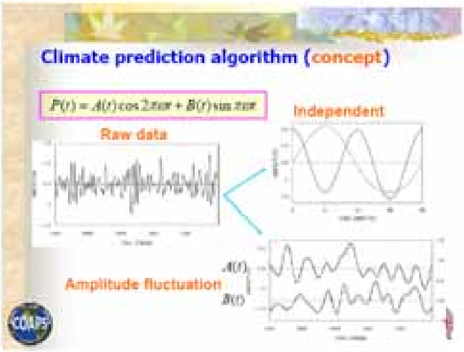

Discussion on how EEOF decomposes the precipitation data over the ASM domain?
Seasonal cycle is separated into 2 modes with 90 degree out of phase each other.
PC time series for ISO mode exhibits the high-frequent fluctuations. Interannual intensity variation of the ISO is relatively hard to understand.
The high frequent fluctuation of EEOF PC is not favorable for application to statistical climate prediction.
El Nino mode was not captured clearly by EEOF (8th mode).
EEOF assumes stationarity, which means the moment statistics is independent of time.


ISO by EEOF
ENSO by EEOF

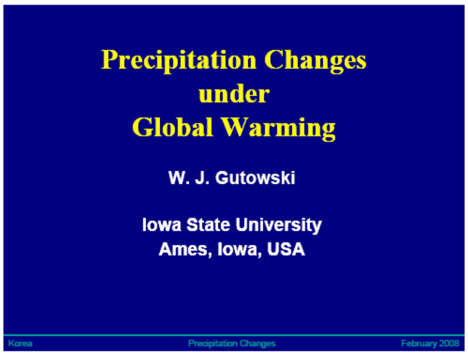

Acknowledgements
This research was supported by the National Science Foundation and the Department of Energy
Lim, Y.-K., K.-Y. Kim, and H.-S. Lee, 2002: Temporal and Spatial Evolution of the Asian Summer Monsoon in the Seasonal Cycle [illegible]. J. Climate, 15, 3630-3644.
Lim, Y.-K., and K.-Y. Kim, 2006: A New Perspective on the Climate Prediction of Asian Summer Monsoon Precipitation. J. Climate, 19, 4840-4853.
Lim, Y.-K., and K.-Y. Kim, 2007: ENSO Impact on the Space-Time Evolution of the Regional Asian Summer Monsoons. J. Climate, 20, 2397-2415.

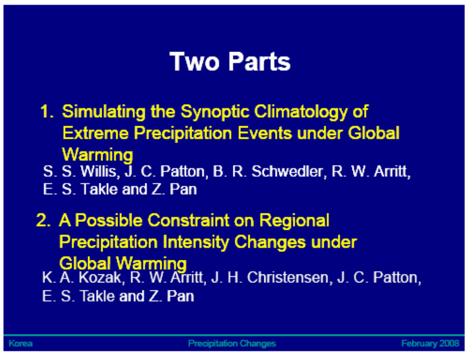

ENSO occurrence (97, 98)
American region
(6-months lead prediction)

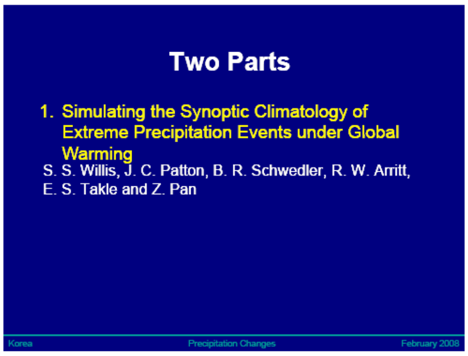

Climate prediction algorithm (idea)
Basic idea: $P(r,t)=\sum_n B_n(r,t)S_n(t)$
The underlying idea is to predict $S_n(t)$, the temporal fluctuation of the amplitude of the individual climate signals.
Predictability can be improved in the sense that $S_n(t)$ is easier to predict than raw data, which contain significant amount of high-frequency fluctuation.
Once the $S_n(t)$ of each mode is predicted, 2-D forecast field is obtained by constructing data using the above equation.
$S_n(t)$ are the predicted value of the respective PC time series.
(Climate prediction model (Kim and North 1998))

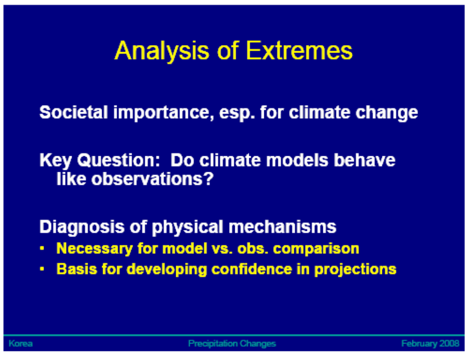


11. Precipitation Changes under Global Warming









Focus:
Extreme Precipitation by Synoptic Weather

Criteria:

- **Daily precipitation**
- **"Event" ⇒ Nonzero daily precip. at an observation site or grid point**
- **"Widespread" ⇒ Simultaneous extreme events at several locations**
- **"Extreme" ⇒ Upper 0.05% of events**

Simulations

Model	Observed	GCM-control	GCM-Scenario
RegCM2	NCEP Reanalysis (1979-1988)	Hadley Centre (~1990's)	Hadley Centre (2040-2050)
HIRHAM (DMI)	"	"	"

Simulations

Model	Observed	GCM-control	GCM-Scenario
RegCM2	NCEP Reanalysis (1979-1988)	Hadley Centre (~1990's)	Hadley Centre (2040-2050)
HIRHAM (DMI)			

Observations

Precipitation:

NCDC Cooperative Observing Network

- **Quality controlled (Clark & Hay 2004)**
- **Missing obs. < 3/month for 1950-1999**
- **No gauge undercatch adjustment**

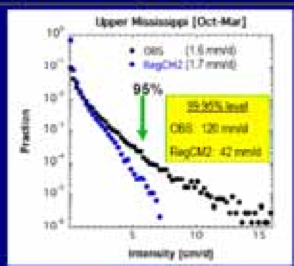
500 hPa Heights:

NCEP/DOE Reanalysis

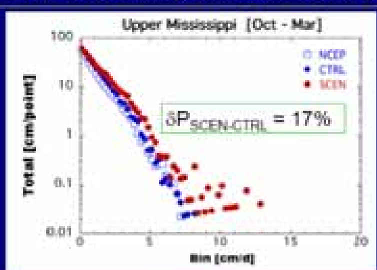
Domain & Analysis Region

1981-1988 Cold season (October - March)

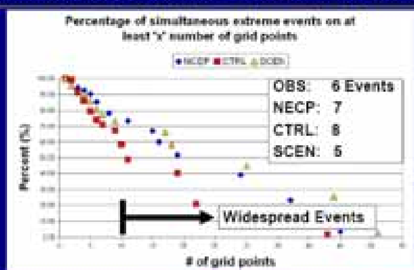
Precipitation Frequency vs. Intensity

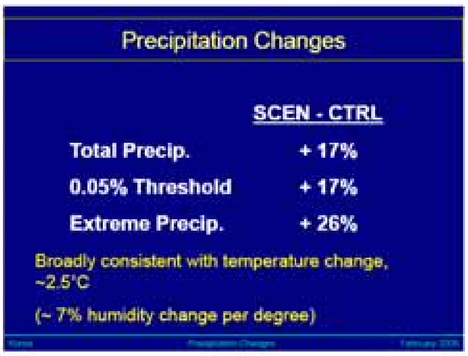


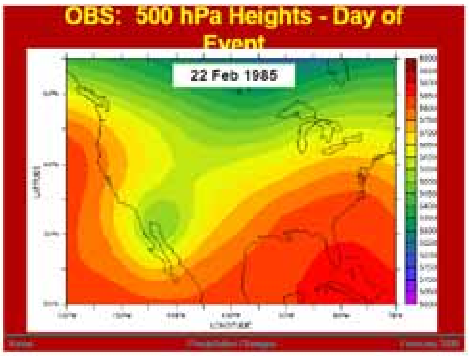
Cumulative Precipitation vs. Intensity

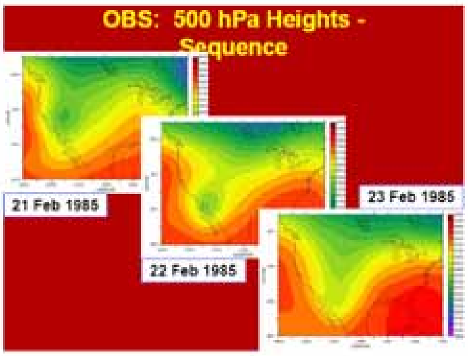


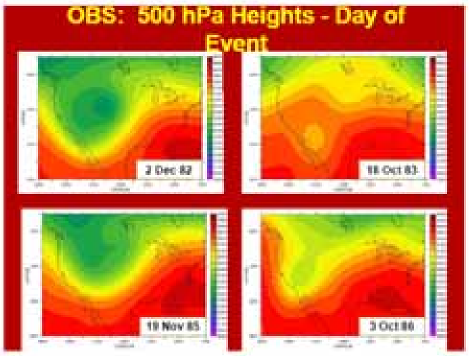
Simultaneous Extreme Precipitation Events

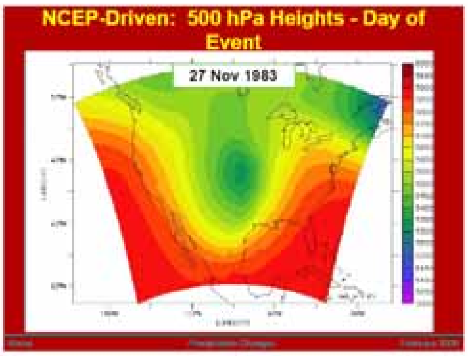


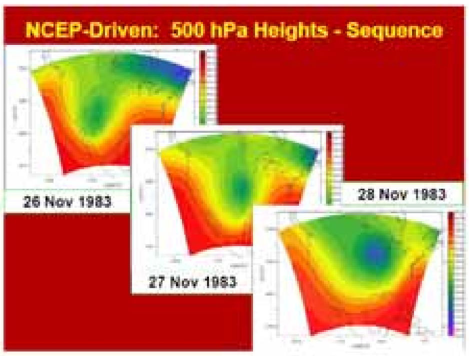

Precipitation Changes
SCEN - CTRL
Total Precip. + 17%
0.05% Threshold + 17%
Extreme Precip. + 26%
Broadly consistent with temperature change, ~2.5°C
(~ 7% humidity change per degree)

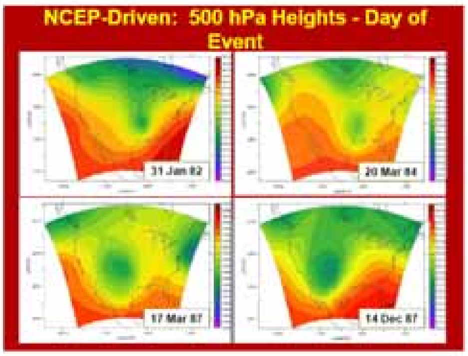

OBS: 500 hPa Heights - Day of Event
22 Feb 1985

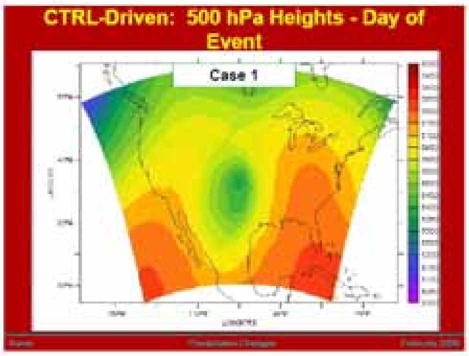

OBS: 500 hPa Heights - Sequence
21 Feb 1985
22 Feb 1985
23 Feb 1985

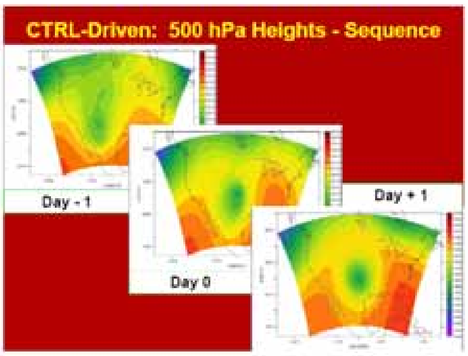

OBS: 500 hPa Heights - Day of Event

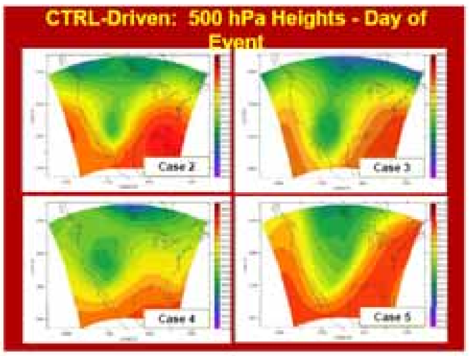

NCEP-Driven: 500 hPa Heights - Day of Event
27 Nov 1983

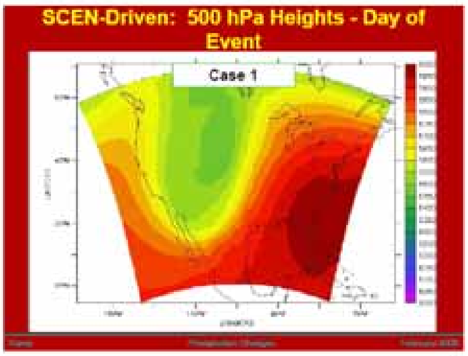

NCEP-Driven: 500 hPa Heights - Sequence
26 Nov 1983
27 Nov 1983
28 Nov 1983

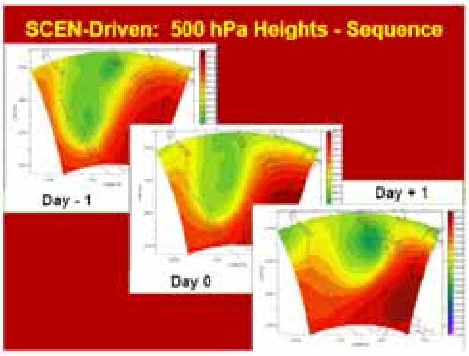

NCEP-Driven: 500 hPa Heights - Day of Event

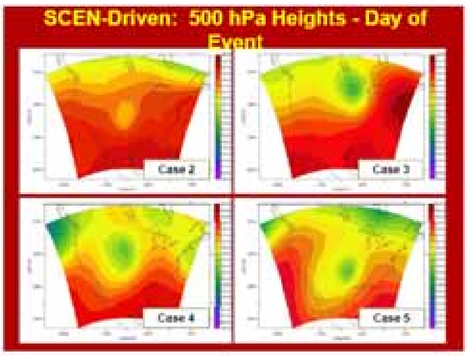

CTRL-Driven: 500 hPa Heights - Day of Event
Case 1









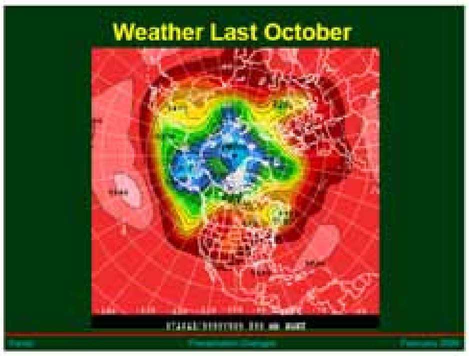


Timing

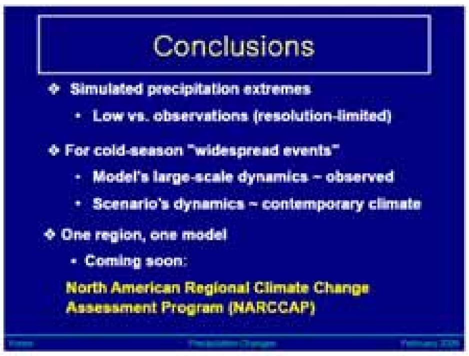
SOURCE	Oct	Nov	Dec	Jan	Feb	Mar
Observations	5	2	2		2	
NCEP	2	1	1	1		2
CTRL	2	1	3	1		1
SCEN	3	1				1

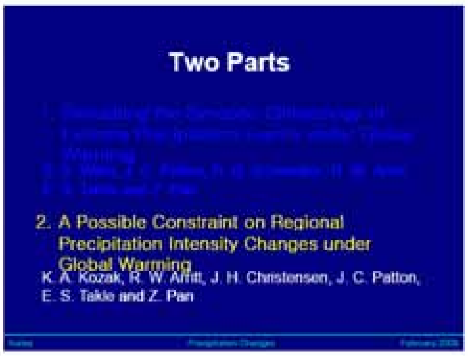
Two-day Episodes

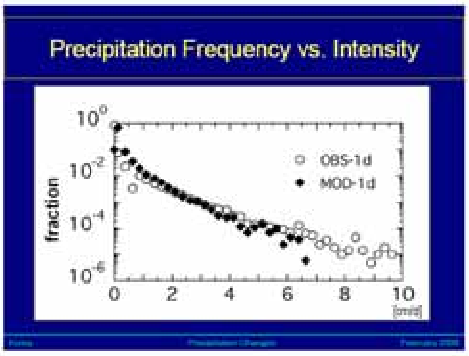
Observed: 10 out of 11 events

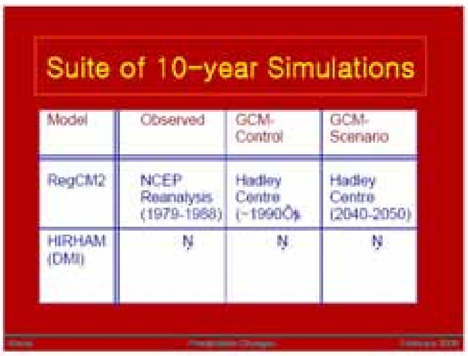


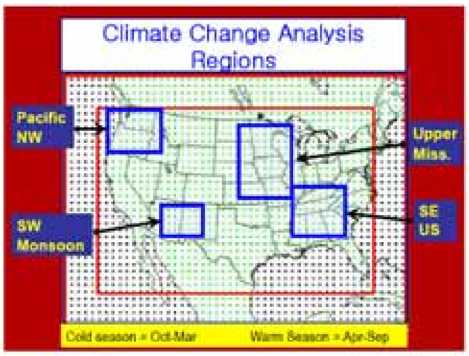

Weather Last October
99.95% level
OBS: 120 mm/d = 4.7 inches/day

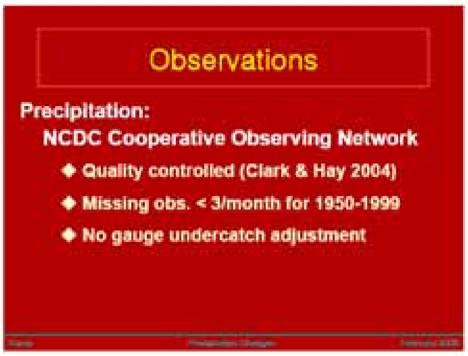

Conclusions
Simulated precipitation extremes
Low vs. observations (resolution-limited)
For cold-season "widespread events"
Model's large-scale dynamics ~ observed
Scenario's dynamics ~ contemporary climate
One region, one model
Coming soon:
North American Regional Climate Change Assessment Program (NARCCAP)

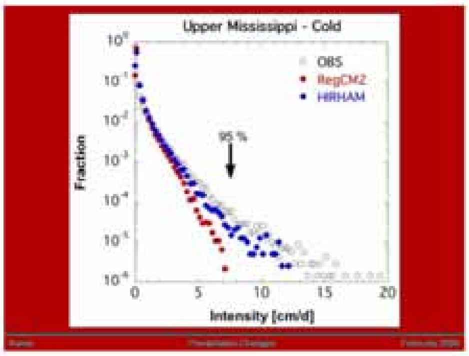

Two Parts
2. A Possible Constraint on Regional Precipitation Intensity Changes under Global Warming
K. A. Kozak, R. W. Arritt, J. H. Christensen, J. C. Patton, E. S. Takle and Z. Pan

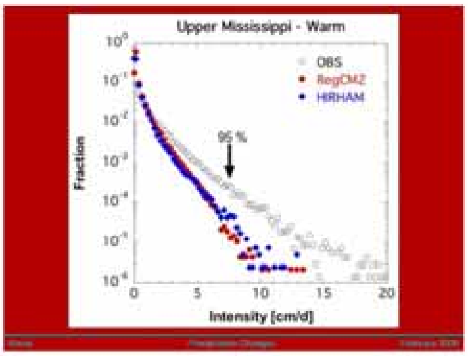

Precipitation Frequency vs. Intensity
OBS-1d
MOD-1d
fraction
[cm/d]

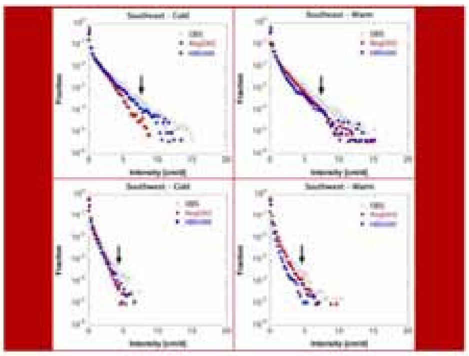

Suite of 10-year Simulations
Model
Observed
GCM-Control
GCM-Scenario
RegCM2
NCEP Reanalysis (1979-1988)
Hadley Centre (~1990's)
Hadley Centre (2040-2050)
HIRHAM (DMI)

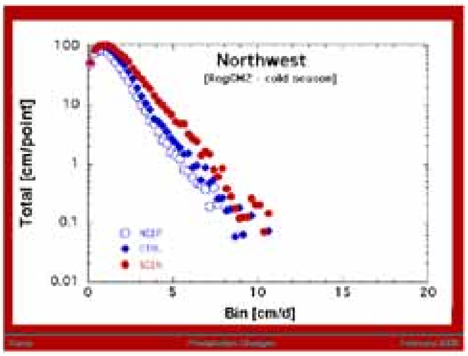

Climate Change Analysis Regions
Pacific NW
Upper Miss.
SW Monsoon
SE US
Cold season = Oct-Mar
Warm Season = Apr-Sep

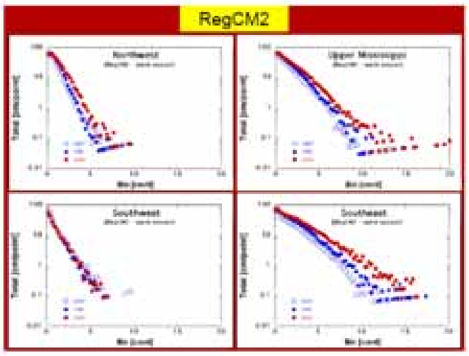

Observations
Precipitation:
NCDC Cooperative Observing Network
Quality controlled (Clark & Hay 2004)
Missing obs. < 3/month for 1950-1999
No gauge undercatch adjustment

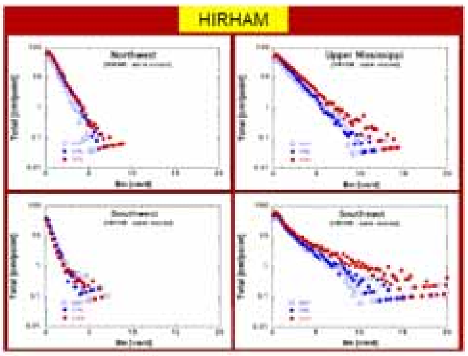

Upper Mississippi - Cold
OBS
RegCM2
HIRHAM
95 %
Fraction
Intensity [cm/d]

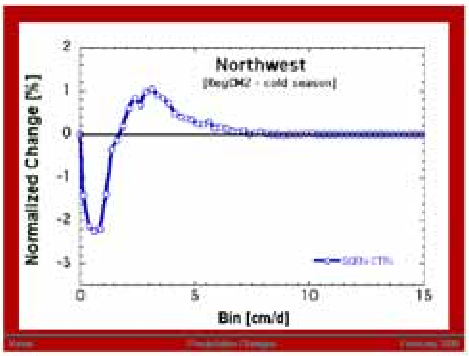

Upper Mississippi - Warm
OBS
RegCM2
HIRHAM
95 %
Fraction
Intensity [cm/d]

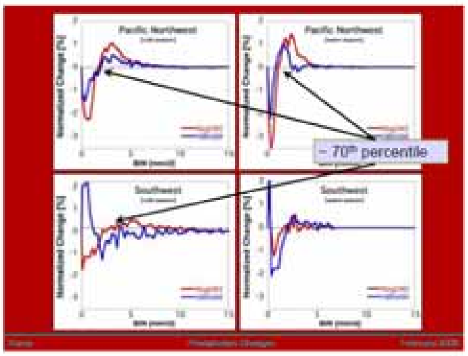


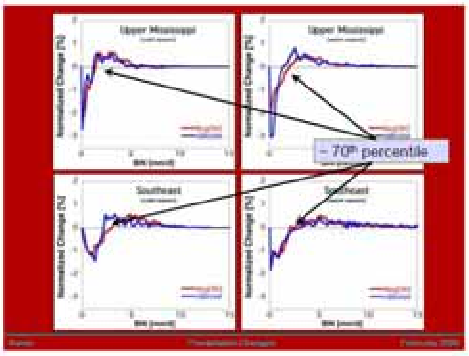

Northwest
[RegCM2 - cold season]
Total [cm/point]
Bin [cm/d]

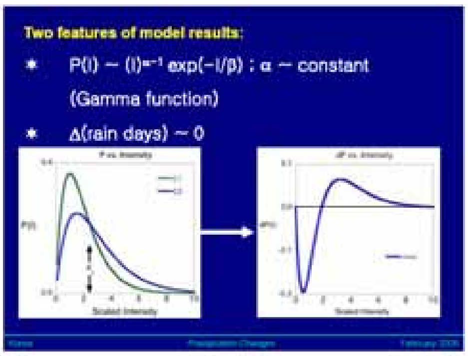

RegCM2

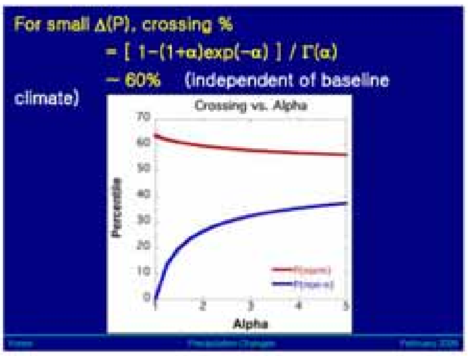

HIRHAM

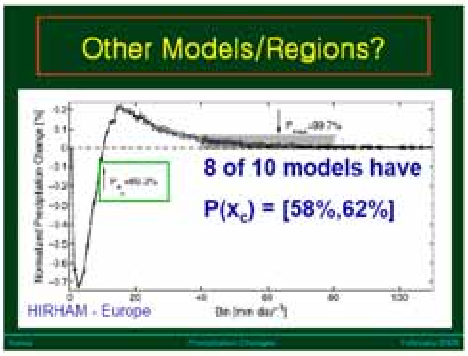

Northwest
[RegCM2 - cold season]
Normalized Change [%]
Bin [cm/d]


~ 70th percentile

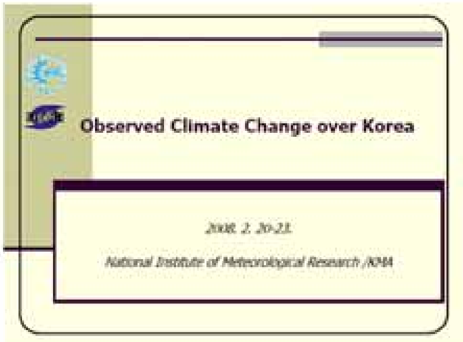

~ 70th percentile

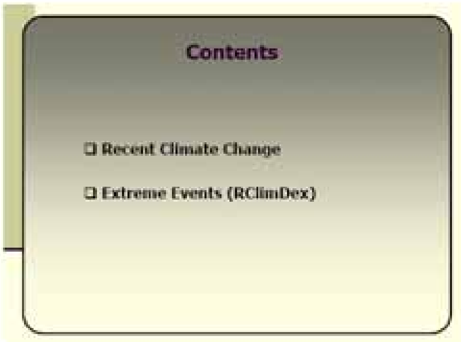


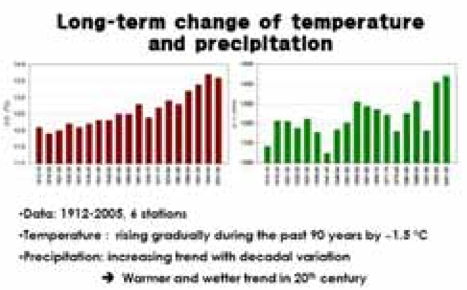


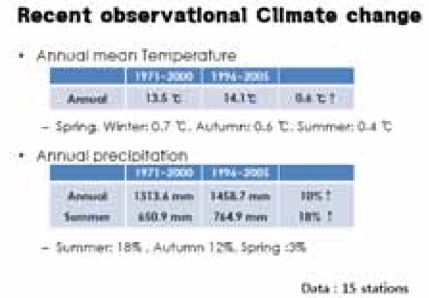


12. Observed Climate Change over **Korea**

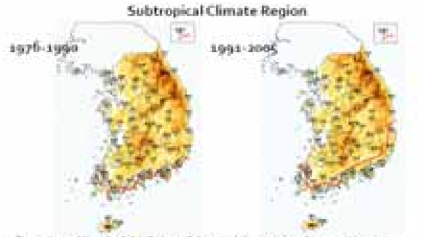








Subtropical Climate Region



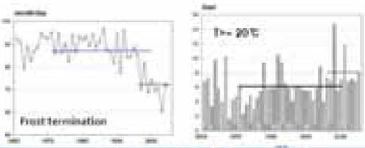
Trewartha and Horn (1980) definition : Subtropical climate is based on monthly mean temperatures above 10°C during the period from eight to 12 months, and the monthly mean temperature in the coldest month below 18°C.
(Kwon et al., 2007, Journal of the Korean Geographical Society)

Change in Duration of Natural Seasons

- Duration
  - Summer : longer
  - Winter : shorter
- Onset dates
  - Spring and Summer : earlier
  - Autumn and Winter : delayed

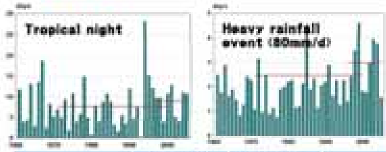
(Kwon et al., 2007, Journal of the Korean Geographical Society)

Spring



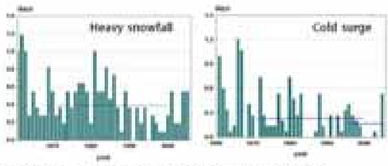
	1971-2000	1996-2005	
Frost day	6.5day/yr	4.0 day/yr	2.5day ↓
Frost termination	3. 28	3. 13	2week ↓
Yellow sand	8.9 day/yr	12.9day/yr	3day ↑
T >= 20℃	6.1 day/yr	8.1 day/yr	2day ↑

Summer



	1971-2000	1996-2005	
Tropical night	7.8 day/yr	9.2 day/yr	1.4 day ↑
Heavy rainfall (80mm/d)	2.0 day/yr	2.8day/yr	0.8 day ↑
Typhoon	2.3 /yr	2.5 /yr	
Tmax >= 35℃	2.0 day/yr	1.6 day/yr	0.4 day/yr ↓

Winter



- Heavy snowfall event (Snow depth>=20cm) : decreasing
- Cold surge(Tmin drop in one day >=10C) : decreasing
- Tmin<=-10 ℃ : 1.2day/yr decreasing

The 6th APN Workshop, Seoul in Korea (Feb 19-24, 2008)

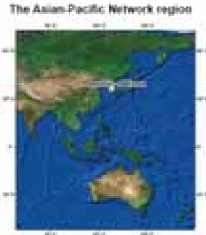
A National Report

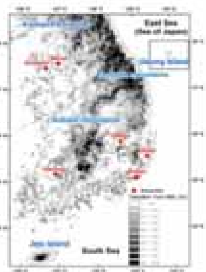
Trends of Extreme Climate Events in Republic of Korea,1955-2004

Gwangyong Choi, Kyung-On Boo*, Yu-Mi Cha, and Won-Tae Kwon
*Presenter
Climate Research Lab, National Institute of Meteorological Research, Korea Meteorological Administration,
Republic of Korea

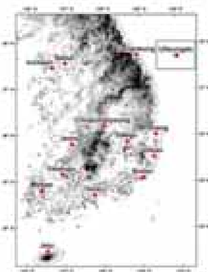
Geography of Korea

The Asian-Pacific Network region





Data and Methods



- 14 weather stations with the 50 years (1955-2004) data
- Daily maximum and minimum temperatures as well as daily precipitation
- 30 extreme climate indices
- Linear trends and their significance test (Climdex; Wang & Feng, 2007)

Extreme Climate Indices

20 Indices for Extreme Temperature Events
Summer days
Ice days
Tropical nights (high altitudes)
Frost days
Extreme summer days
Tropical nights (Mid-altitudes)
Extreme Frost days
Growing season Length
Max Tmax / Max Tmin
Min Tmax / Min Tmin
Cool nights / Cool days
Warm nights / Warm days
Warm spell duration indicator
Cold spell duration indicator
Diurnal temperature range

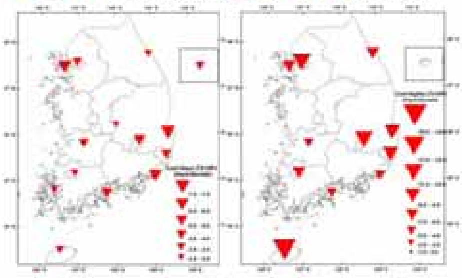
10 Indices for Extreme Precipitation Events
Max 1-day precipitation amount
Max 5-day precipitation amount
Simple daily intensity index
Number of heavy precipitation days
Number of very heavy precipitation days
Number of days above nn mm
Consecutive dry days
Consecutive wet days
Very wet days
Extremely wet days
Annual total wet-day precipitation

The number of Weather Stations with Significant (p-value <= 0.05) Trends of Extreme Climate

a) More than 75% of weather stations

Index	NO	%	Trends	Names	Definitions
tx10p	14	100	Decrease	Cool days	Percentage of days when TX<10th percentile
id0	13	93	Decrease	Ice days	Annual count when TX(daily maximum)<0ºC
txn	13	93	Increase	Max Tmin	Monthly maximum value of daily minimum temp
fd0	12	86	Decrease	Frost days	Annual count when TN(daily minimum)<0ºC
tx90p	12	86	Increase	Warm days	Percentage of days when TX>90th percentile
tnn	11	79	Increase	Min Tmin	Monthly minimum value of daily minimum temp
tn10p	11	79	Decrease	Cool nights	Percentage of days when TN<10th percentile

Trends (Days/decade) of Cool days (Tx10p) vs. Cool nights (Tn10p)

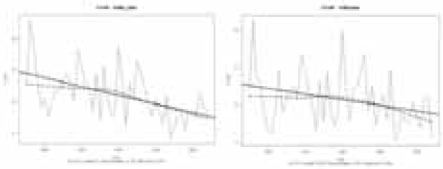


Decreasing Trends of Cool days (Winter Daytime)

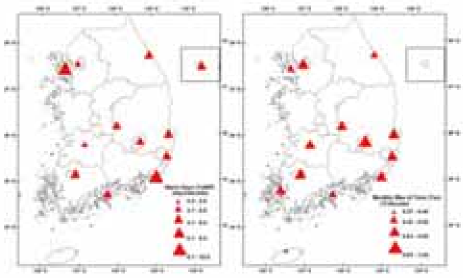
(Percentage of days when TX<10th percentile)

a) Seoul (Urban)
- 5.0 days /decade

b) Chupungryeong (Rural)
-2.8 days /decade



Trends (Days/decade vs. °C/ decade) of Warm days (Tx90p) vs. Monthly Max of Tmin (Txn)

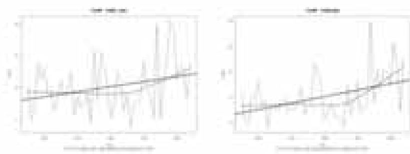


Decreasing Trends of Warm days (Summer Daytime)

(Percentage of days when TX>90th percentile)

a) Seoul (Urban)
+ 2.9 days /decade

b) Chupungryeong (Rural)
+4.7 days /decade



b) 25-75% of weather stations

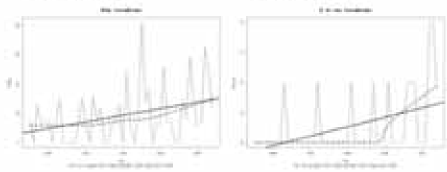
Cont.

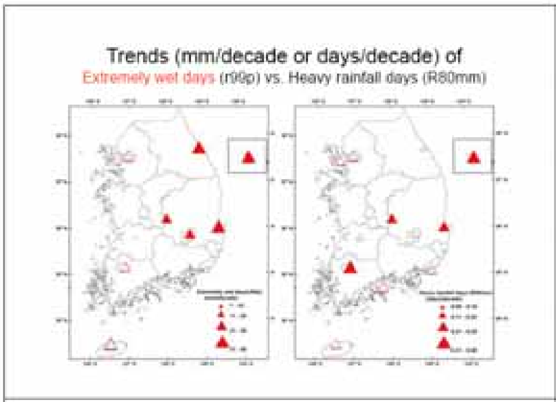
Index	NO	%	Trends	Names	Definitions
fd-10	10	71	Decrease	Extreme Frost days	Annual count when TN(daily minimum)<-10ºC
gsl	10	71	Increase	Growing season Length	Annual (1st Jan to 31st Dec in NH, 1st July to 30th June in SH) count between first span of at least 6 days with TG>5ºC and first span after July 1 (January 1 in SH) of 6 days with TG<5ºC
tn90p	10	71	Increase	Warm nights	Percentage of days when TN>90th percentile
csdi	8	57	Decrease	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN<10th percentile
dtr	8	57	Both	Diurnal temperature range	Monthly mean difference between TX and TN
su25	5	36	Increase	Summer days	Annual count when TX(daily maximum)>25ºC
tr20	5	36	Both	Tropical nights (High latitudes)	Annual count when TN(daily minimum)>20ºC
r99p	5	36	Increase	Extremely wet days	Annual total PRCP when RR>99th percentile
wsdi	4	29	Increase	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX>90th percentile
rx5day	4	29	Increase	Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation
R80mm	4	29	Increase	Number of days above nn mm	Annual count of days when PRCP>=nn mm, nn is user defined threshold
r95p	4	29	Increase	Very wet days	Annual total PRCP when RR>95th percentile

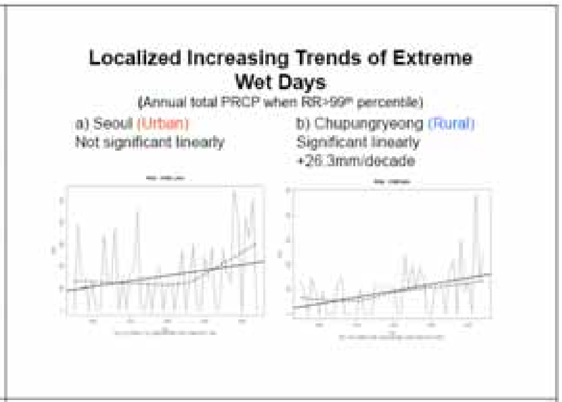
Trends (mm/decade or days/decade) of Averaged Across South Korea

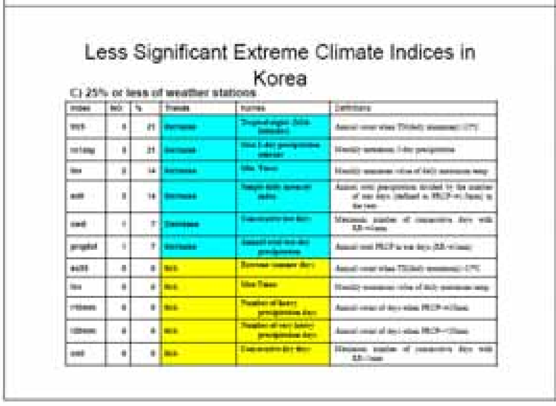
Extremely wet days (r99p)
Significant linearly
+22.8mm/decade

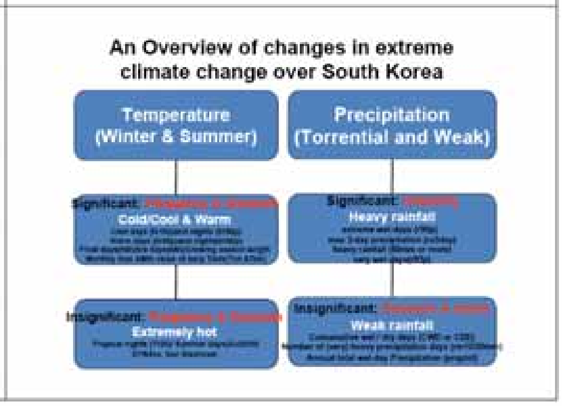
Heavy rainfall days (R80mm)
Significant linearly
+0.16days/decade

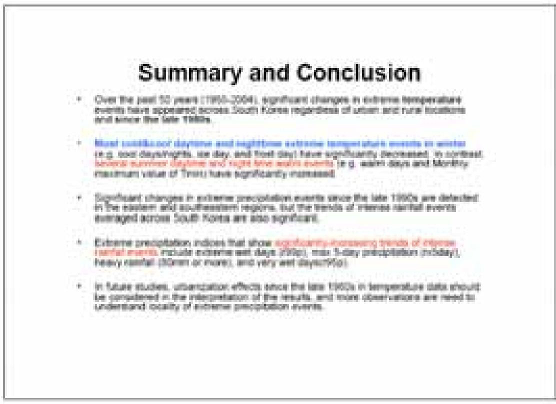



Trends (mm/decade or days/decade) of
Extremely wet days (r99p) vs. Heavy rainfall days (R80mm)


Localized Increasing Trends of Extreme Wet Days
(Annual total PRCP when RR>99th percentile)
a) Seoul (Urban)
Not significant linearly
b) Chupungryeong (Rural)
Significant linearly
+26.3mm/decade

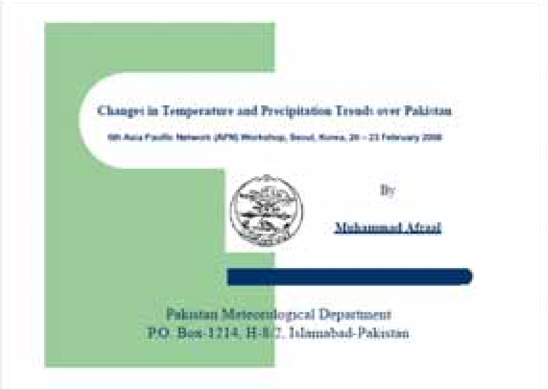

Less Significant Extreme Climate Indices in Korea
C) 25% or less of weather stations
Index
NO
%
Trends
Names
Definitions

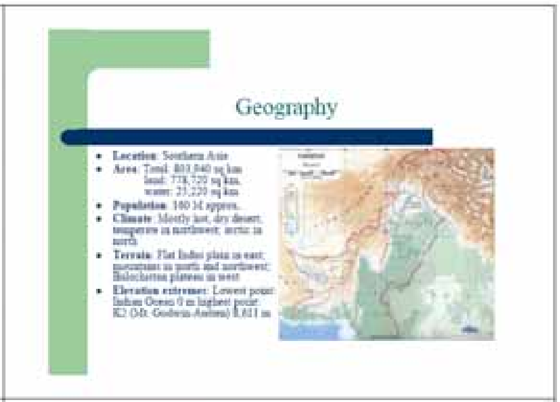

An Overview of changes in extreme climate change over South Korea
Temperature (Winter & Summer)
Precipitation (Torrential and Weak)
Significant:
Cold/Cool & Warm
Significant:
Heavy rainfall
Insignificant:
Extremely hot
Insignificant:
Weak rainfall

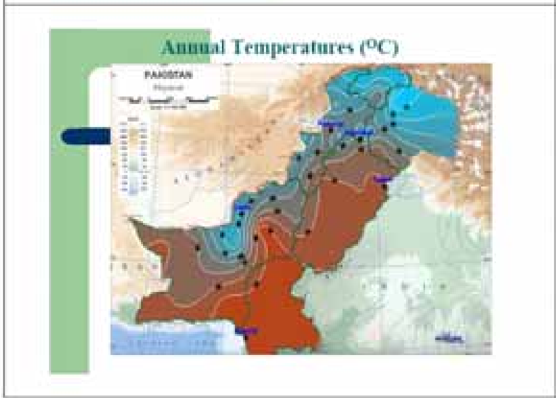

Summary and Conclusion
Over the past 50 years (1950-2004), significant changes in extreme temperature events have appeared across South Korea regardless of urban and rural locations and since the late 1980s.
Most cold/cool daytime and nighttime extreme temperature events in winter (e.g. cool days/nights, ice day, and frost day) have significantly decreased. In contrast, several summer daytime and night time warm events (e.g. warm days and Monthly maximum value of Tmin) have significantly increased.
Significant changes in extreme precipitation events since the late 1990s are detected in the eastern and southeastern regions, but the trends of intense rainfall events averaged across South Korea are also significant.
Extreme precipitation indices that show significantly-increasing trends of intense rainfall events include extreme wet days (r99p), max 5-day precipitation (rx5day), heavy rainfall (80mm or more), and very wet days(r95p).
In future studies, urbanization effects since the late 1960s in temperature data should be considered in the interpretation of the results, and more observations are need to understand locality of extreme precipitation events.

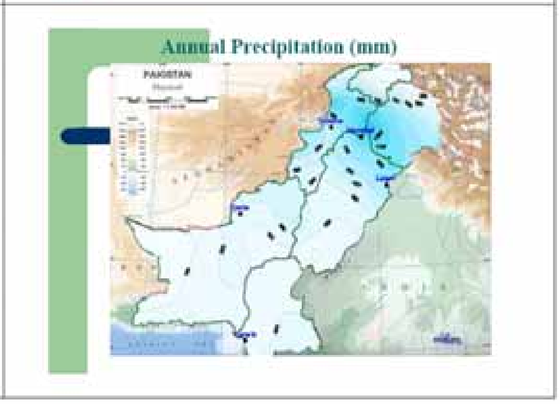

Thank You.

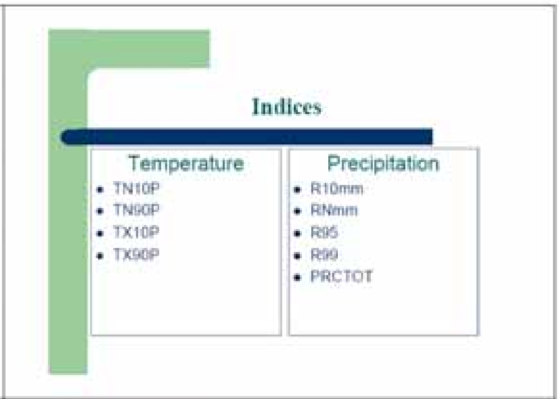
13. Changes in Temperature and Precipitation Trends over **Pakistan**

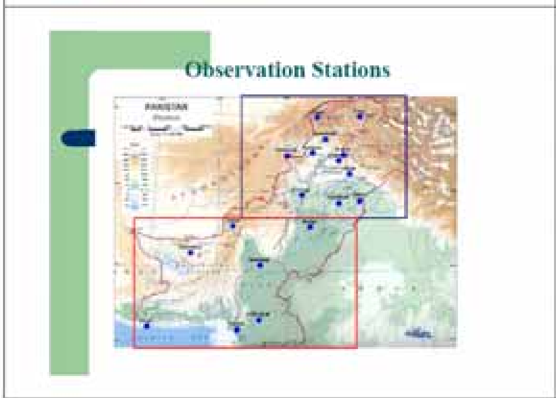


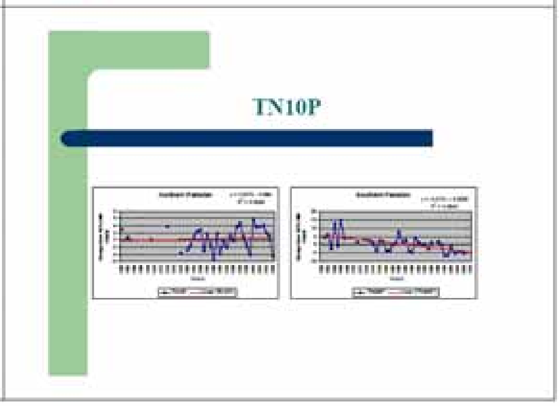


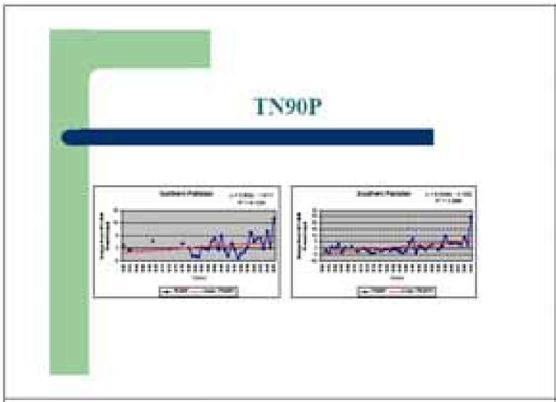


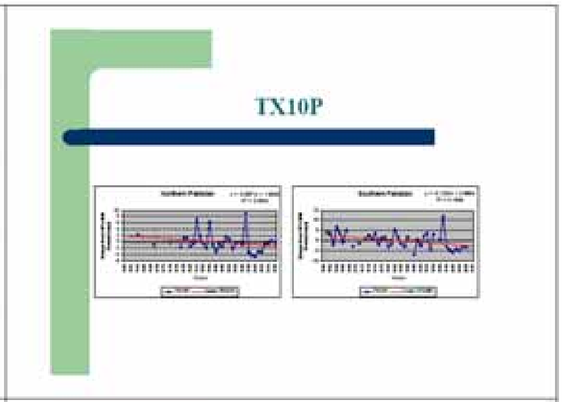


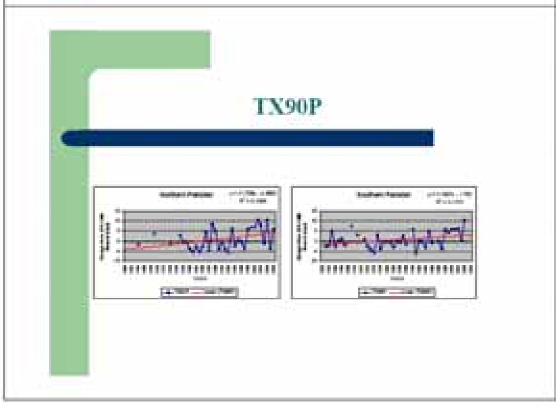


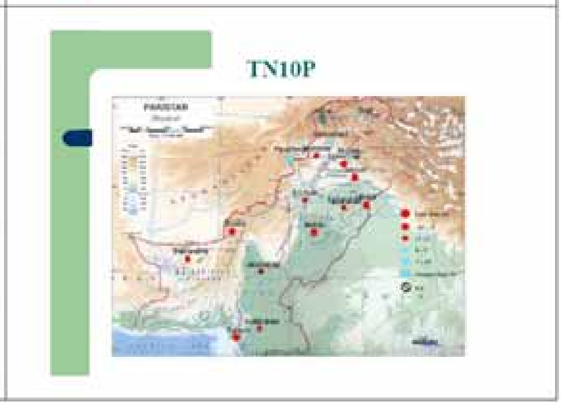


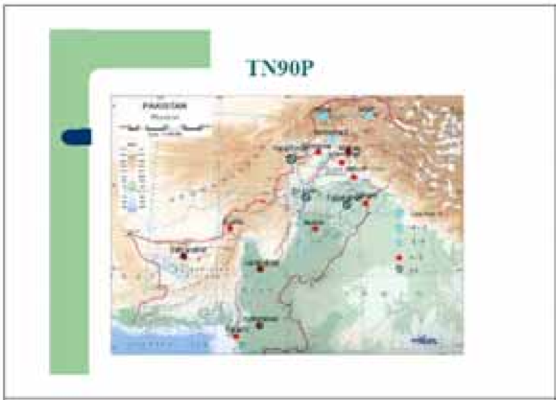


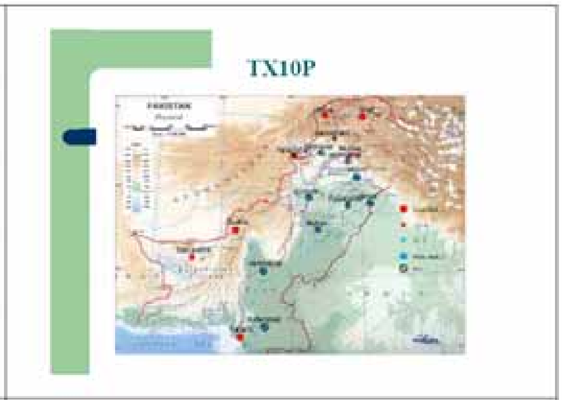

TN90P

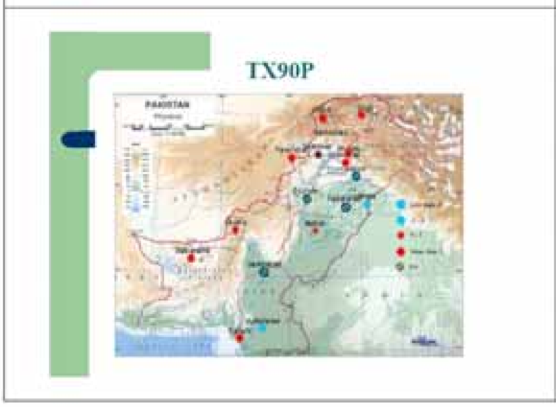

TX10P

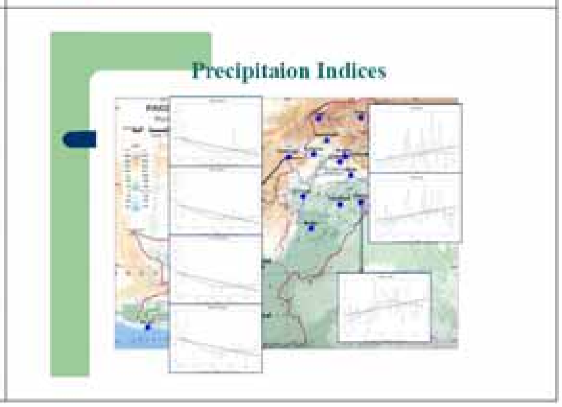

TX90P

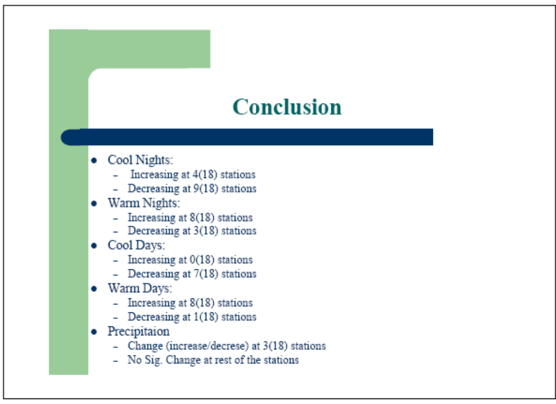

TN10P

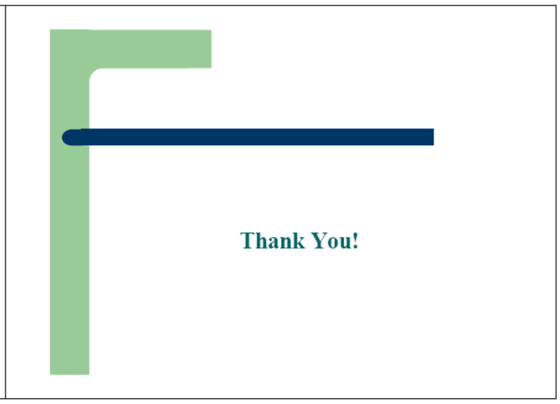

TN90P


TX10P

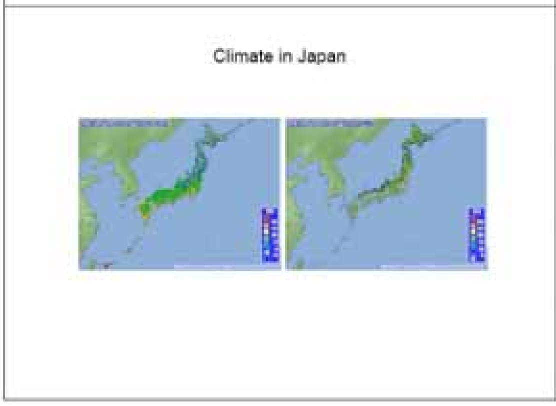

TX90P

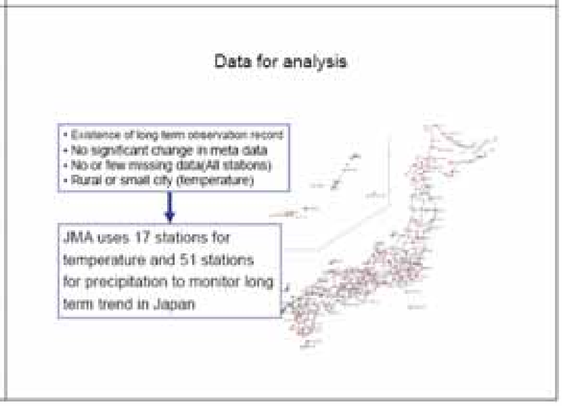

Precipitaion Indices





14. Trends in Climate Extremes in **Japan**





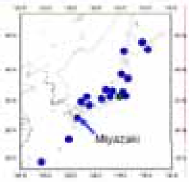
Data for analysis

17 stations for temperature

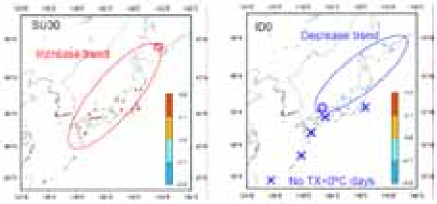
Abashiri, Nemuro, Suttsu, Yamagata, Ishinomaki, Fushiki, Nagano, Mito, Iida, Choshi, Sakai, Hamada, Hikone, Miyazaki, Tadotsu, Naze and Ishigakijima

In this research, the 17 stations are used.
Miyazaki moved in 2000 (no significant change on the data).

Indices of Tokyo are also calculated for the reference.

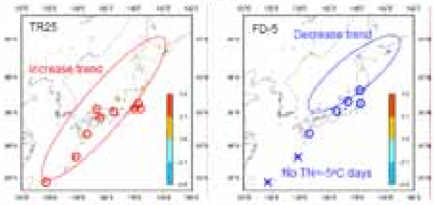


Maximum Temperature



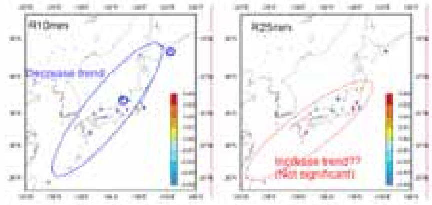
Annual count when TX (daily maximum) >30°C (left) TX<0°C (right)

Minimum Temperature



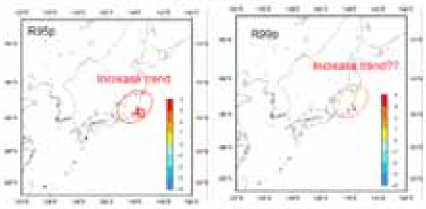
Annual count when TN (daily minimum) >25°C (left) TN<-5°C (right)

Precipitation



Annual count of days when PRCP>=10mm (left), PRCP>=25mm (right)

Precipitation



Annual total PRCP when RR>95th percentile (left), RR>99th percentile (right)

Summary

Temperature

SU30,TR25	Increase trend at almost all stations
FD0,ID-5	Decrease trend in the northeastern area

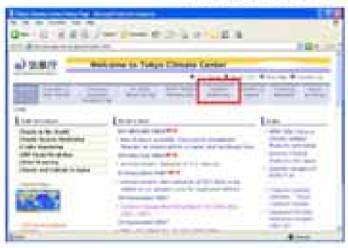
Precipitation

R10mm	Decrease trend at almost all stations
R25mm	Increase trend mainly in the southern area
R95P,R99P	Increase trend around East Japan

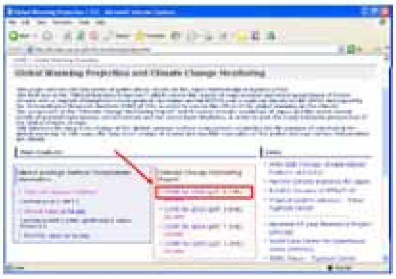
2.Introduction of TCC/JMA web page

TCC webpage

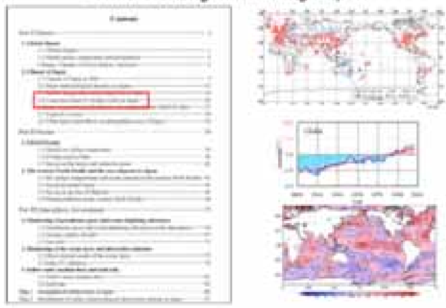
http://ds.data.jma.go.jp/gmd/tcc/index.html



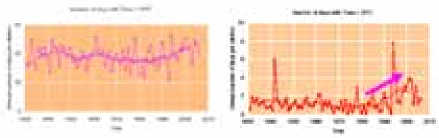
TCC web page



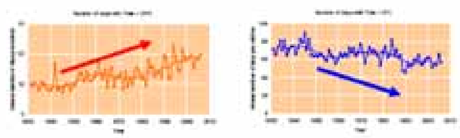
Climate Change Monitoring Report



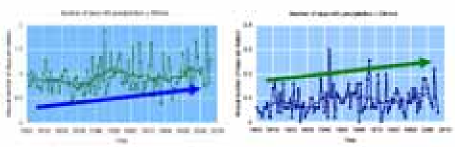
Maximum Temperature



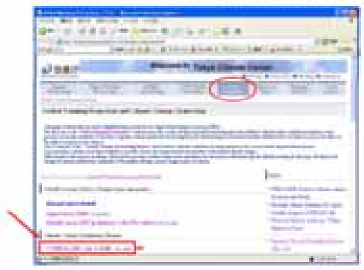
Minimum Temperature



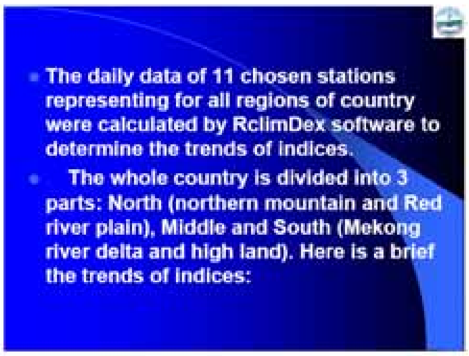
Heavy Rain

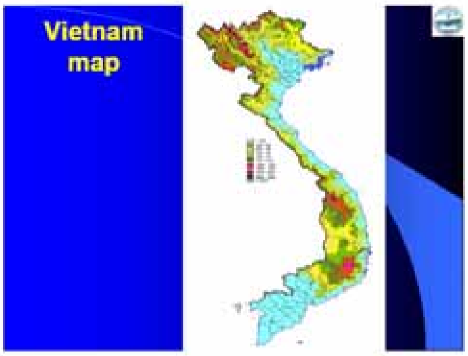


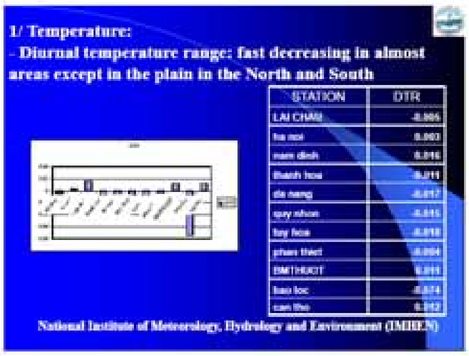
To get any more information, please access the TCC web page!



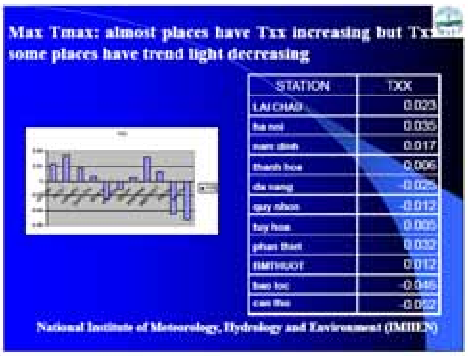
15. Trend of Climate Index of **Vietnam**



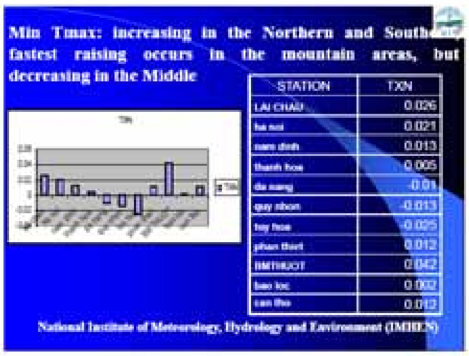




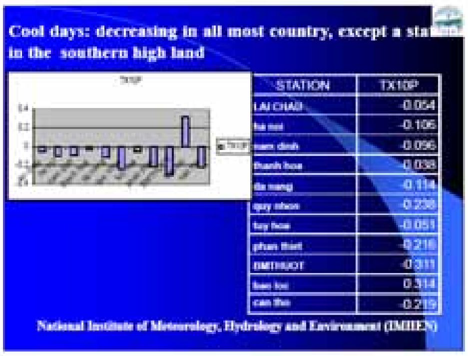
STATION	DTR
LAI CHAU	-0.005
ha noi	0.003
nam dinh	0.016
thanh hoa	0.011
da nang	-0.017
quy nhon	-0.015
tuy hoa	-0.018
phan thiet	-0.004
BMTHUOT	0.011
bao loc	-0.074
can tho	0.012



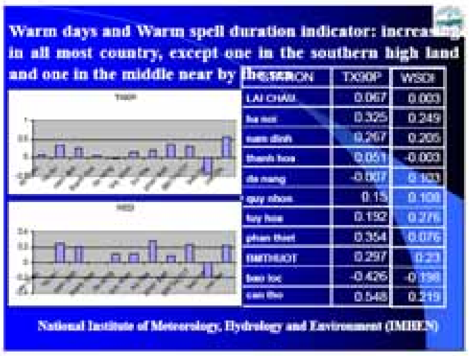
STATION	TXX
LAI CHAU	0.023
ha noi	0.035
nam dinh	0.017
thanh hoa	0.006
da nang	-0.025
quy nhon	-0.012
tuy hoa	0.005
phan thiet	0.032
BMTHUOT	0.012
bao loc	-0.046
can tho	-0.052



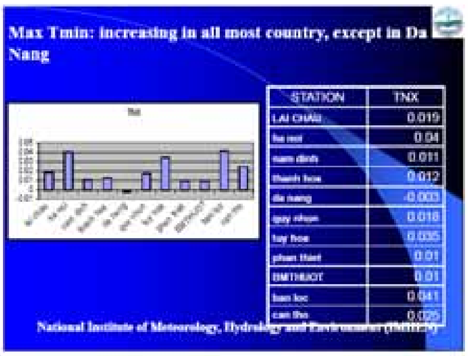
STATION	TXN
LAI CHAU	0.026
ha noi	0.021
nam dinh	0.013
thanh hoa	0.005
da nang	-0.01
quy nhon	-0.013
tuy hoa	-0.025
phan thiet	0.012
BMTHUOT	0.042
bao loc	0.002
can tho	0.012

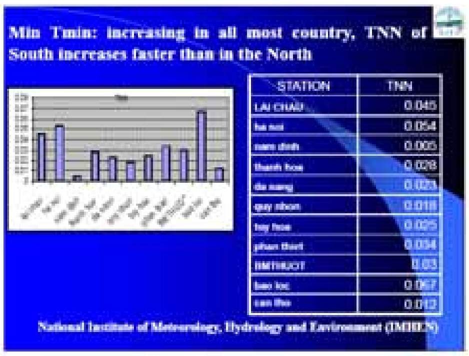


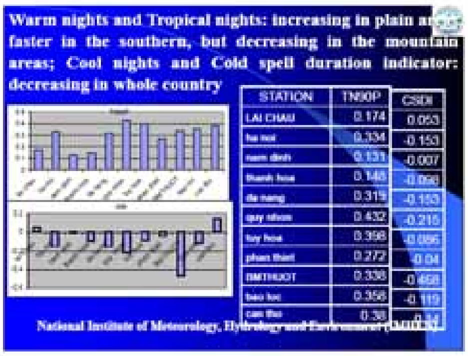
STATION	TX10P
LAI CHAU	-0.054
ha noi	-0.106
nam dinh	-0.096
thanh hoa	-0.038
da nang	-0.114
quy nhon	-0.238
tuy hoa	-0.051
phan thiet	-0.216
BMTHUOT	-0.311
bao loc	0.314
can tho	-0.219

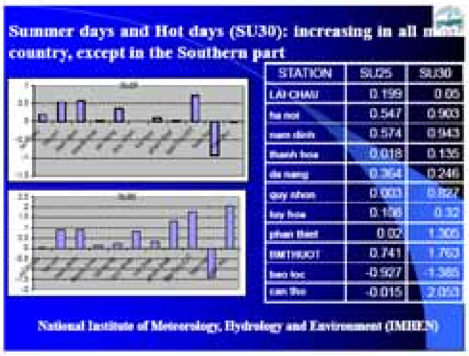


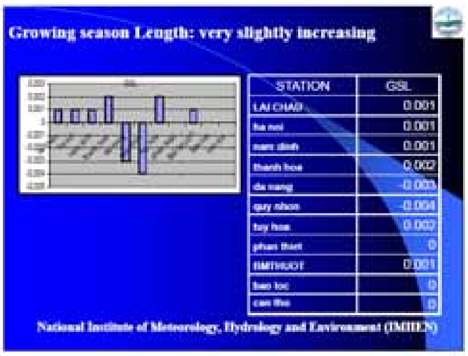
STATION	TX90P	WSDI
LAI CHAU	0.067	0.003
ha noi	0.325	0.249
nam dinh	0.267	0.205
thanh hoa	0.051	-0.003
da nang	-0.007	0.103
quy nhon	0.15	0.108
tuy hoa	0.192	0.276
phan thiet	0.354	0.076
BMTHUOT	0.297	0.23
bao loc	-0.426	-0.198
can tho	0.548	0.219


Max Tmin: increasing in all most country, except in Da Nang
STATION TNX
LAI CHAU 0.019
ha noi 0.04
nam dinh 0.011
thanh hoa 0.012
da nang -0.003
quy nhon 0.018
tuy hoa 0.035
phan thiet 0.01
BMTHUOT 0.01
bao loc 0.041
can tho 0.025
National Institute of Meteorology, Hydrology and Environment (IMHEN)

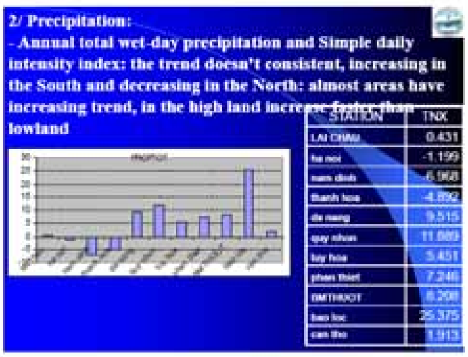

Min Tmin: increasing in all most country, TNN of South increases faster than in the North
STATION TNN
LAI CHAU 0.045
ha noi 0.054
nam dinh 0.005
thanh hoa 0.028
da nang 0.023
quy nhon 0.018
tuy hoa 0.025
phan thiet 0.034
BMTHUOT 0.03
bao loc 0.067
can tho 0.012
National Institute of Meteorology, Hydrology and Environment (IMHEN)

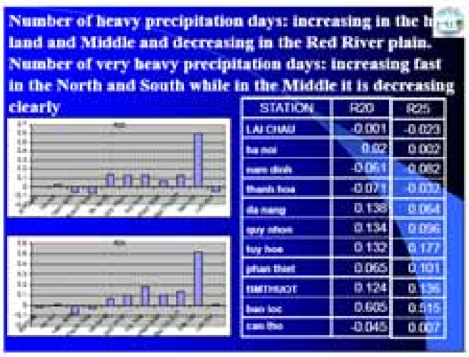

Warm nights and Tropical nights: increasing in plain and faster in the southern, but decreasing in the mountain areas; Cool nights and Cold spell duration indicator: decreasing in whole country
STATION TN90P CSDI
LAI CHAU 0.174 0.053
ha noi 0.334 -0.153
nam dinh 0.131 -0.007
thanh hoa 0.148 -0.098
da nang 0.319 -0.153
quy nhon 0.432 -0.215
tuy hoa 0.398 -0.086
phan thiet 0.272 -0.04
BMTHUOT 0.338 -0.458
bao loc 0.358 -0.119
can tho 0.38
National Institute of Meteorology, Hydrology and Environment (IMHEN)

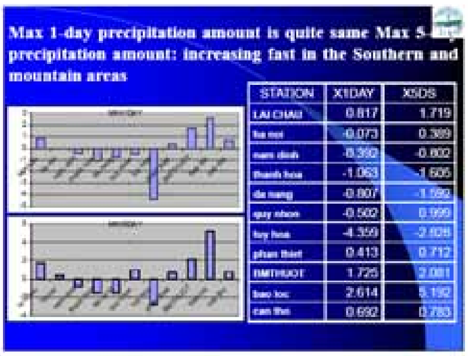

Summer days and Hot days (SU30): increasing in all most country, except in the Southern part
STATION SU25 SU30
LAI CHAU 0.199 0.05
ha noi 0.547 0.903
nam dinh 0.574 0.943
thanh hoa 0.018 0.135
da nang 0.364 0.246
quy nhon 0.003 0.827
tuy hoa 0.108 0.32
phan thiet 0.02 1.305
BMTHUOT 0.741 1.763
bao loc -0.927 -1.385
can tho -0.015 2.053
National Institute of Meteorology, Hydrology and Environment (IMHEN)

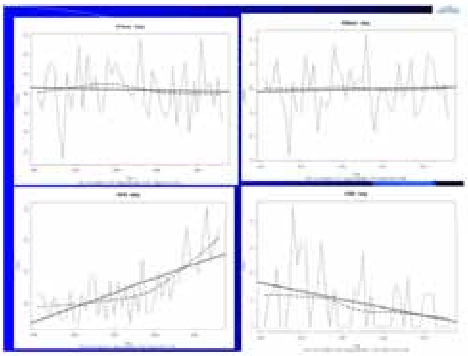

Growing season Length: very slightly increasing
STATION GSL
LAI CHAU 0.001
ha noi 0.001
nam dinh 0.001
thanh hoa 0.002
da nang -0.003
quy nhon -0.004
tuy hoa 0.002
phan thiet 0
BMTHUOT 0.001
bao loc 0
can tho 0
National Institute of Meteorology, Hydrology and Environment (IMHEN)

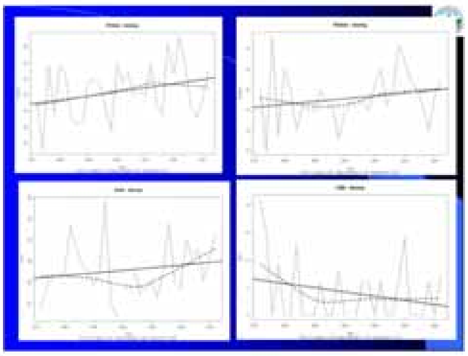

And many other…
In general, the temperatures have the increasing trend with more significant in the South.

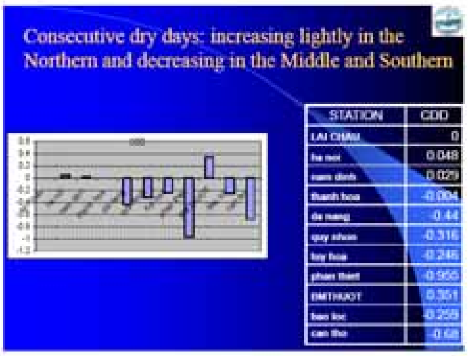

2/ Precipitation:
- Annual total wet-day precipitation and Simple daily intensity index: the trend doesn't consistent, increasing in the South and decreasing in the North: almost areas have increasing trend, in the high land increase faster than lowland
STATION TNX
LAI CHAU 0.431
ha noi -1.199
nam dinh -6.968
thanh hoa -4.892
da nang 9.515
quy nhon 11.889
tuy hoa 5.451
phan thiet 7.246
BMTHUOT 8.208
bao loc 25.375
can tho 1.913


Number of heavy precipitation days: increasing in the high land and Middle and decreasing in the Red River plain. Number of very heavy precipitation days: increasing fast in the North and South while in the Middle it is decreasing clearly
STATION R20 R25
LAI CHAU -0.001 -0.023
ha noi 0.02 0.002
nam dinh -0.061 0.082
thanh hoa -0.071 -0.032
da nang 0.138 0.064
quy nhon 0.134 0.096
tuy hoa 0.132 0.177
phan thiet 0.065 0.101
BMTHUOT 0.124 0.136
bao loc 0.605 0.515
can tho -0.045 0.007


Max 1-day precipitation amount is quite same Max 5-day precipitation amount: increasing fast in the Southern and mountain areas
STATION | X1DAY | X5DS
LAI CHAU | 0.817 | 1.719
ha noi | -0.073 | 0.389
nam dinh | -0.392 | -0.802
thanh hoa | -1.063 | 1.605
da nang | -0.807 | -1.592
quy nhon | -0.502 | 0.999
tuy hoa | -4.359 | -2.028
phan thiet | 0.413 | 0.712
BMTHUOT | 1.725 | 2.081
bao loc | 2.614 | 5.192
can tho | 0.692 | 0.783





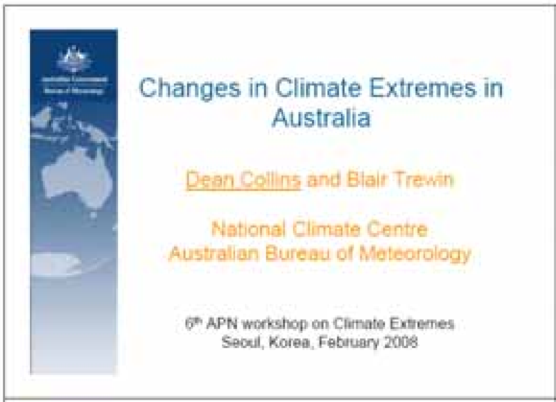

Consecutive dry days: increasing lightly in the Northern and decreasing in the Middle and Southern
STATION | CDD
LAI CHAU | 0
ha noi | 0.048
nam dinh | 0.029
thanh hoa | -0.004
da nang | -0.44
quy nhon | -0.316
tuy hoa | -0.246
phan thiet | -0.955
BMTHUOT | 0.351
bao loc | -0.259
can tho | -0.68

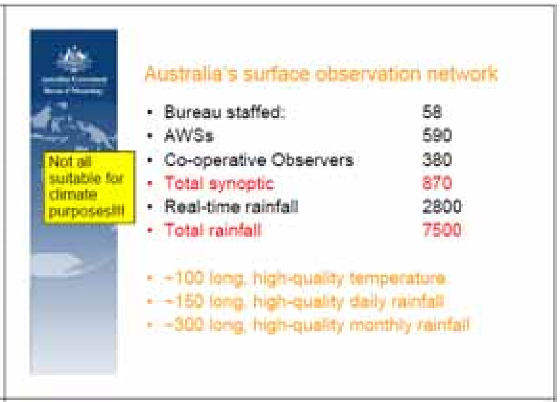

CONCLUSION
* The temperatures have the increasing trend with more significant in the South.
* The extreme event concern of precipitation have the increasing trend in the South and mountain areas.

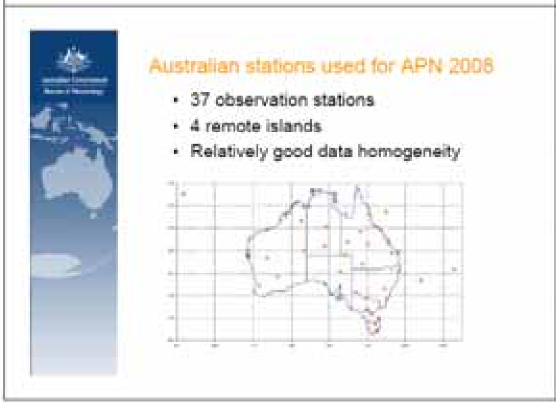

Next plan
Determine the extreme clim-dex trend for 7 climt areas of Vietnam
Impact on main sectors: Water resources, Agriculture, tranportation Human health …
Predict the extreme weather and clinate

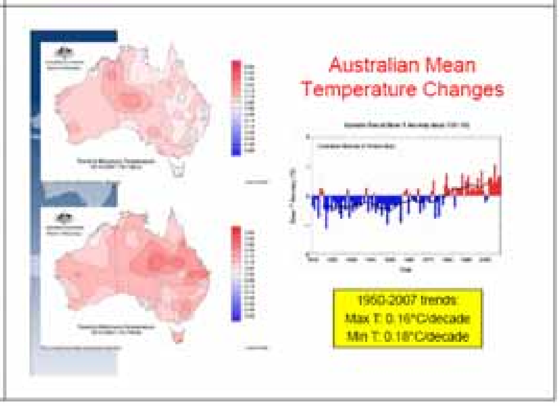

THANK YOU VERY MUCH

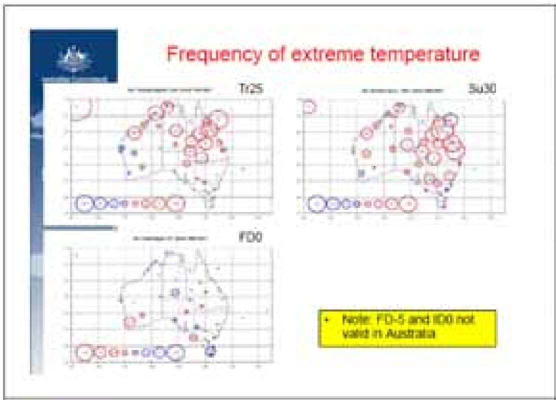
16. Changes in Climate Extremes in **Australia**

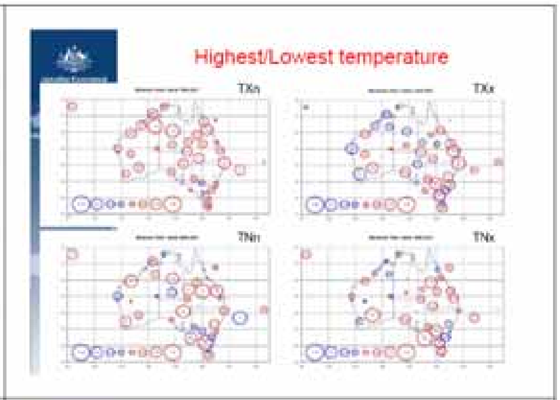


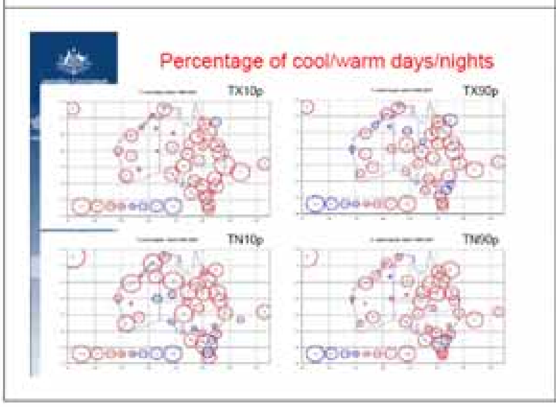


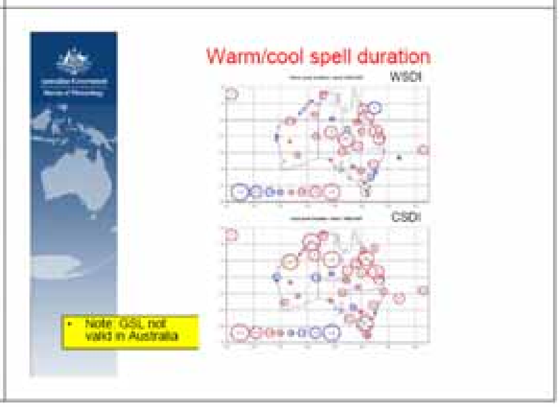


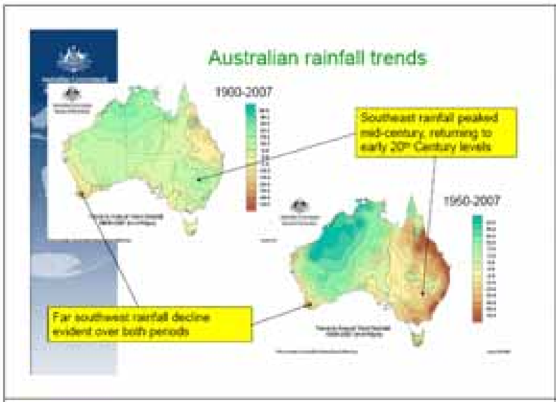


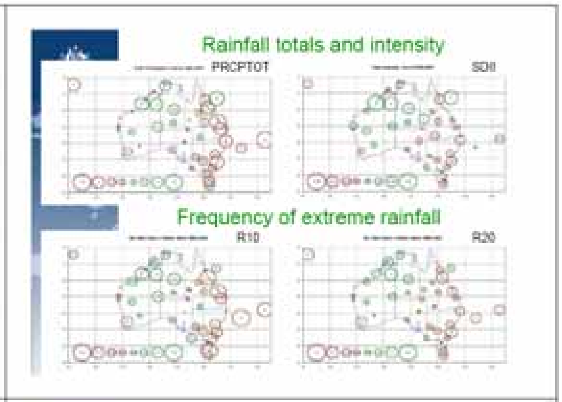


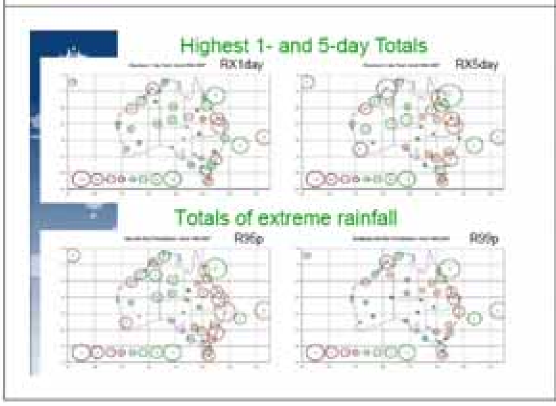


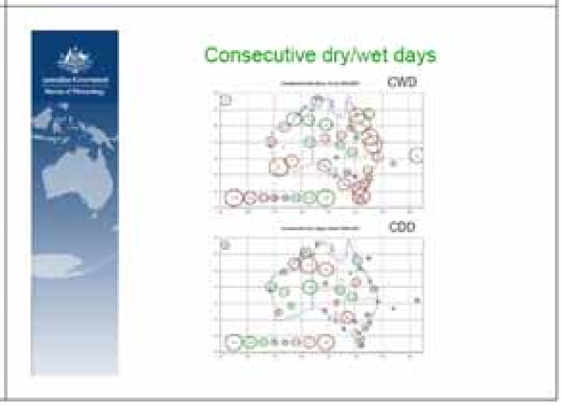


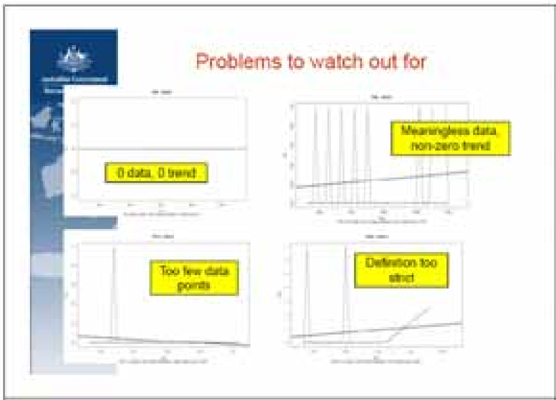


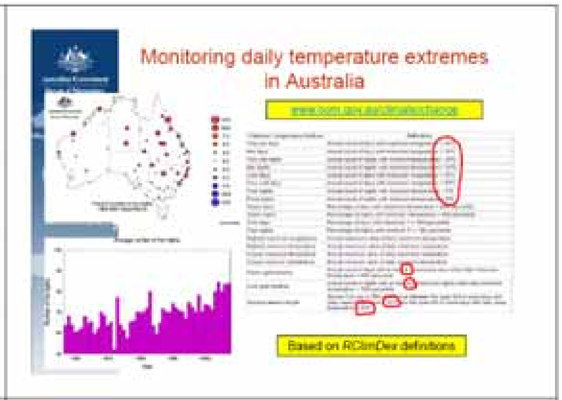

Australian rainfall trends
1900-2007
Southeast rainfall peaked mid-century, returning to early 20th Century levels
1950-2007
Far southwest rainfall decline evident over both periods

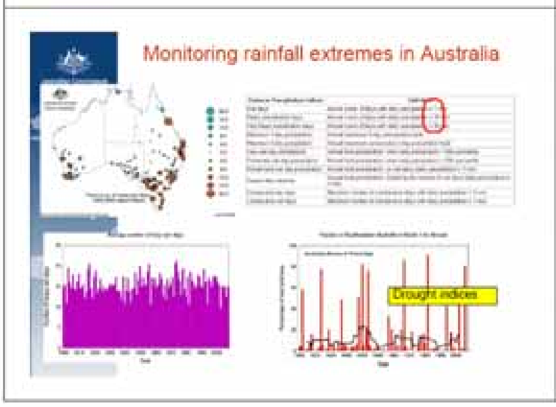

Rainfall totals and intensity
PRCPTOT
SDII
Frequency of extreme rainfall
R10
R20

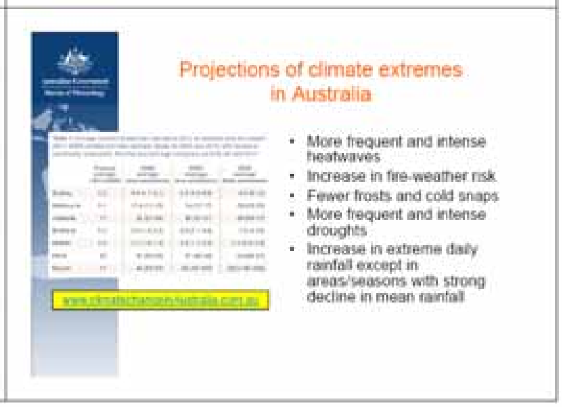

Highest 1- and 5-day Totals
RX1day
RX5day
Totals of extreme rainfall
R95p
R99p


Consecutive dry/wet days
CWD
CDD

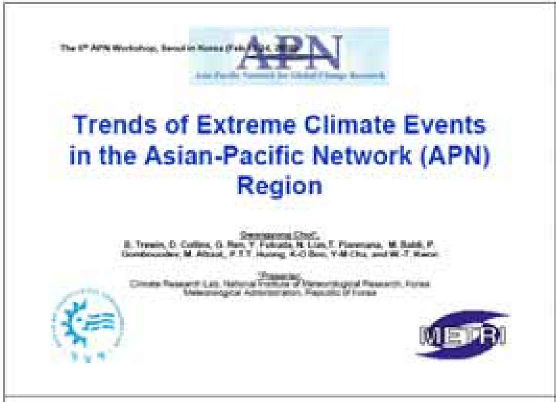

Problems to watch out for
0 data, 0 trend
Meaningless data, non-zero trend
Too few data points
Definition too strict

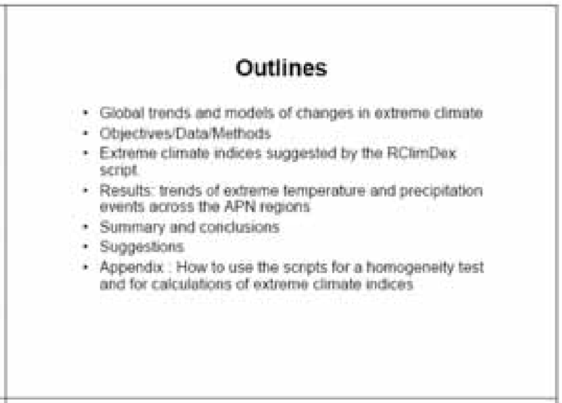

Monitoring daily temperature extremes in Australia
www.bom.gov.au/climatechange
Based on RClimDex definitions

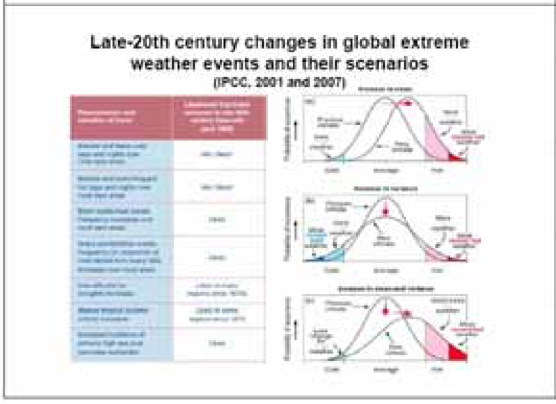

Monitoring rainfall extremes in Australia
Drought indices

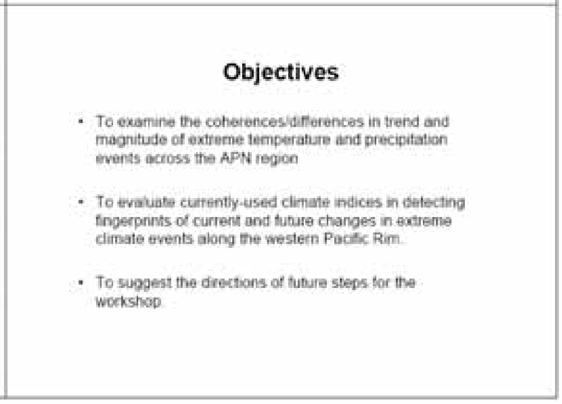

Projections of climate extremes in Australia
More frequent and intense heatwaves
Increase in fire-weather risk
Fewer frosts and cold snaps
More frequent and intense droughts
Increase in extreme daily rainfall except in areas/seasons with strong decline in mean rainfall
www.climatechangeinaustralia.com.au

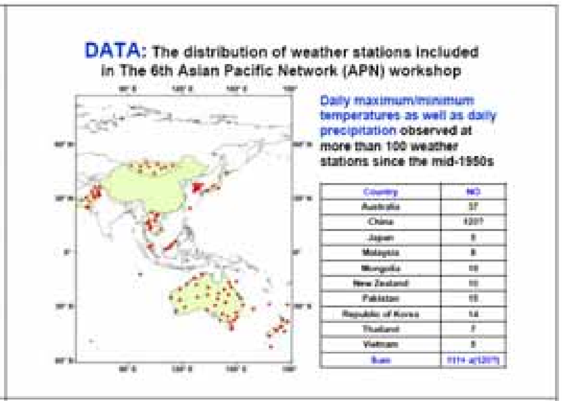
17. Trends of Extreme Climate Events in the Asian-Pacific Network (APN) Region

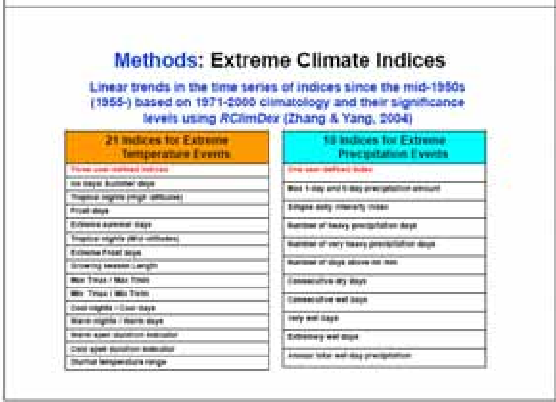


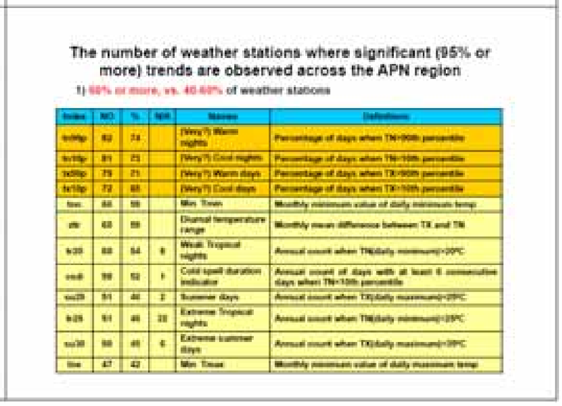




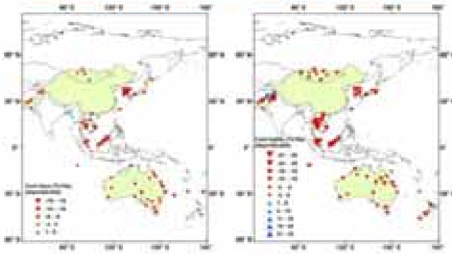




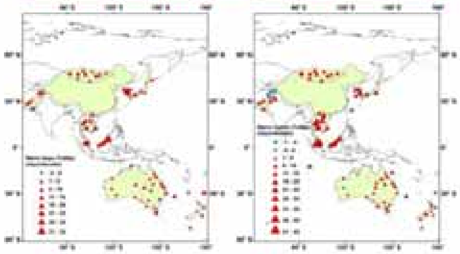




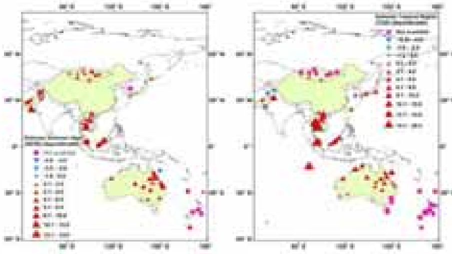
Trends (days/decade) of
Cool days(tx10p) and Cool nights (tn10p)



Trends (days/decade) of
Warm days (tx90p) and Warm nights (tn90p)



Trends (days/decade) of
Extreme summer days (Su30) and tropical night (Tr25)

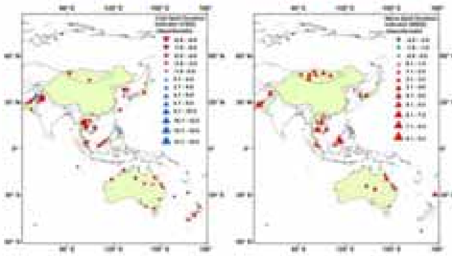


The number of weather stations where significant (95% or more) trends are observed across the APN region

2) 20-40% of weather stations

Index	NO	%	N/A	Name	Definition
fd0	40	35	41	Frost days	Annual count when TN(daily minimum)<0ºC
tnx	39	35		Max Tmin	Monthly maximum value of daily minimum temp
wsdi	36	32		Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX>90th percentile
fd-5	28	25	62	Extreme Frost days	Annual count when TN(daily minimum)<-5ºC
txx	27	24		Max Tmax	Monthly maximum value of daily maximum temp
gsl	21	19	37	Growing season Length	Annual (1st Jan to 31st Dec in NH, 1st July to 30th June in SH) count between first span of at least 6 days with TG>5ºC and first span after July 1 (January 1 in SH) of 6 days with TG<5ºC
prcptot	20	18		Annual total wet-day precipitation	Annual total PRCP in wet days (RR>=1mm)

Trends (days/decade) of
Cold Spell (CSDI) and Warm Spell (WSDI)

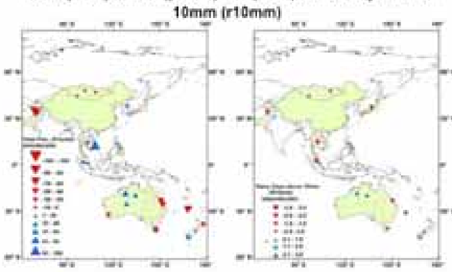


The number of weather stations where significant (95% or more) trends are observed across the APN region

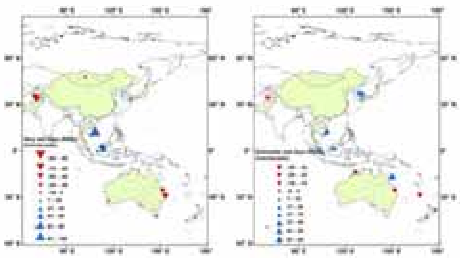
2) Less than 20% of weather stations

Index	NO	%	N/A	Name	Definition
id0	19	17	79	Ice days	Annual count when TX(daily maximum)<0ºC
rx5day	16	14		Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation
r10mm	16	14		Number of heavy precipitation days	Annual count of days when PRCP>=10mm
R00mm	16	14		Number of days above nn mm	Annual count of days when PRCP>=nn mm, nn is user defined threshold
r99p	16	14		Extremely wet days	Annual total PRCP when RR>99th percentile
r95p	15	14		Very wet days	Annual total PRCP when RR>95th percentile
rx1day	12	11		Max 1-day precipitation amount	Monthly maximum 1-day precipitation
sdii	11	10		Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as PRCP>=1.0mm) in the year
cwd	11	10		Consecutive wet days	Maximum number of consecutive days with RR>=1mm
r20mm	6	5		Number of very heavy precipitation days	Annual count of days when PRCP>=20mm
cdd	6	5		Consecutive dry days	Maximum number of consecutive days with RR<1mm

Trends (mm/decade or days/decade) of
Total precipitation (prcptot) and precipitation days above 10mm (r10mm)



Trends (mm/decade) of
Very wet days (R95p) and Extremely wet days (R99p)



An overview of changes in extreme climate events over the APN region

Temperature (Both winter & summer)

- Very significant: Frequency & Spells; Relative threshold (percentile) indices; Cool/Cold & Warm/Hot Days
- Intermediate significant: Frequency; Fixed threshold indices

Precipitation (Regionally-varying)
Amount, Frequency, & Intensity

- Drier patterns: e.g. Mongolia, Southeastern Australia, Northern Island of NZ
- Wetter patterns: e.g. Republic of Korea, Malaysia, Northwestern Australia, Southern Island of NZ

Summary and Conclusions

- The frequency of warm days/nights and warm spell (upper 90th percentile of Tmax and Tmin) in summer has increased across the APN region.
- The frequency of cool (lower 10th percentile of Tmax and Tmin) days/nights, cold spell, and coldness-related indices in winter has decreased.
- The magnitude of changes in extreme temperature events is greater at nights (daily minimum temperature) than during the daytime (daily maximum temperature)
- However, trends of extreme precipitation events are not significant on the greater than regional scale, showing spatially-varying trend and magnitude.
- For instance, dry patterns have been observed over Mongolia, southeastern Australia, and the northern island of NZ, while we patterns have been identified over Republic of Korea, Malaysia, northwestern Australia, the southern island of NZ

Differences in user-defined thresholds amongst APN countries

APN countries	User defined indices				
	Temperature				Precipitation
Australia	su30	id0	tr25	fd-5	R25mm
Japan	su30	id0	tr25	fd-5	R25mm
Malaysia	su30	id10	tr25	fd5	R50mm
Mongolia	su30	id0	tr25	fd-5	R30mm
New Zealand	su30	id0	tr25	fd-5	R25mm
Pakistan	su39	id23	tr30	fd15	R8mm
Republic of Korea	su35	id0	tr25	fd-10	R80mm
Thailand	su30	id0	tr25	fd-5	R0.1mm
Vietnam	su30	id0	tr25	fd0	R25mm

Suggestions

- A consistent data period should be used for collaboration (e.g. 1955-2007 or 1961-2007)
- A metadata should be collected such as available data in each APN countries (digital and non-digital data and missing data)
- The original data set should be shared amongst participating countries.
- The use of relative percentile-threshold indices is more desirable compared to the fixed-threshold indices.
- We should think of whether changes in extreme climate events occurs linearly or not.
- We should think of how we can remove local urbanization effects from temperature data in understanding the changes in extreme temperature events.
- Indices related to droughts and heat waves should be included in future studies.

We need agreements about targets and data collaboration!

- At least we need a collection of time series of indices at each location between 1955 and 2007.
- Metadata: all data available including indigital data

An example of metadata

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Lat	Long	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Appendix: On the data homogeneity test and calculation of extreme climate indices

using RHtestV2 (Wang&Feng, 2007)
and RClimDex (Zhang&Yang, 2004)

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Three steps to finish the homogeneity test

Step 1. use FindU to find undocumented changepoint(s);

Step 2. use FindUD to find documented changepoint(s);

Step 3. use available metadata sources to delete or change actual date about each changepoints, visual analysis would be also important at this step.

How to use the RHtestV2 package "without" a reference data to check the homogeneity of data

- Run R and open R script source (RHtestV2)
- "**Start GUI[ ]**" ....in the command line
- Click,,, "**Transforming data**",, from daily to monthly
- Click,,,, "**Find U**"..... To find changing points
- If you have detected a changepoint at the time series, you have to adjust the time series first.
- Actually, we have the function to adjust the inhomogenized time series in the RHtestV2 package

How to get the adjusted data for indices

- Once all the changepoints are determined, you use Stepsize to get adjusted time series. If it is determined to be not significant, delete it from the file Example_mCs.txt in the data directory and click the **StepSize** button to re-assess the significance and magnitudes of the remaining changepoints.
- Repeat the procedure above, until each and every changepoint retained in the file Example_mCs.txt is determined to be significant.
- If you will only focus on large mean-shift, you may skip the 2 step.
- After the step 3, you will get a file as "OutFile_F.dat", and the third column is the original series, fourth column is the model fit and the fifth column is the adjusted time series which you would use in calculating indices.
- **<u>However, it can be better idea if we refer to the information of changing points without data adjustments at this time. It is mainly because there is enormous uncertainty of how the adjusting function modifies the original daily data.</u>**

How to use the RClimDex package to calculate the trends of extreme climate indices

- Run R and open R script source (RClimDex; I debugged the original version due to "internal" function)
- Load the data and do outlier test (subjectively, you can include the record or delete it; based on 3 or 4 standard deviations)
- Indices calculation (based period: 1971-2000, though default is 1961-1990). Put the latitude and longitude information. Otherwise, you should provide the information as a separate metadata file.
- I suggested user-defined thresholds as follows but I would like to listen to your suggestions;

1)SU"30", 2)ID"0", 3)Tr"25", and 4)FD"-5".

Acknowledgements

Participants

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Support

http://www.apn-gcr.org/en/indexe.html

Appendix D
Workshop Photos

D1. Group Photo

Photo with M-K Lee, KMA Administrator, C-Y Choi, Director-General of National Institute of Meteorological Research, W-T Kwon, KMA and all the participants

D2. Visiting KMA

D3. Workshop