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

Project Leader:
Won-Tae Kwon, Korea Meteorological Administration, Republic of Korea

Collaborator:
Kyung-On Boo, Yu-Mi Cha, Gwangyong Choi, JaYeon Moon, Jae-Cheol Nam (Korea), Blair Trewin, Dean Collins (Australia), Guoyu Ren (China), Yoshikazu Fukuda (Japan), Norlisam Lias (Malaysia), Purevjav Gomboluudev (Mongolia), Marina Baldi (New Zealand), Muhammad Afzaal (Pakistan), Theeralux Pianmana (Thailand), Pham Thi Thanh Huong (Viet Nam)
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Final Report submitted to APN
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 +2.5 days/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 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.

References

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 99\textsuperscript{th}
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 6\textsuperscript{th} 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 6\textsuperscript{th} 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

<table>
<thead>
<tr>
<th>Country</th>
<th>NO of weather stations</th>
<th>Base data period</th>
<th>First year (Max)</th>
<th>Last year (Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pakistan</td>
<td>12</td>
<td>1961-2006</td>
<td>1964</td>
<td>2006</td>
</tr>
<tr>
<td>Thailand</td>
<td>7</td>
<td>1955-2007</td>
<td>1955</td>
<td>2005</td>
</tr>
</tbody>
</table>

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 5th percentile) and cold/warm duration indicator (upper and lower 10th percentiles). Similarly, percentile-based extreme precipitation indices include very wet days (95th percentile) and extremely wet days (99th percentile). In contrast, summer days (Tmax>25 °C), tropical nights (Tmin>25 °C), ice days (Tmax<0 °C), and frost days (Tmin<0 °C) 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

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Names</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>su25</td>
<td>Summer days</td>
<td>Annual count when TX(daily maximum)&gt;25°C</td>
</tr>
<tr>
<td>id0</td>
<td>Ice days</td>
<td>Annual count when TX(daily maximum)&lt;0°C</td>
</tr>
<tr>
<td>tr20</td>
<td>Tropical nights</td>
<td>Annual count when TN(daily minimum)&gt;20°C</td>
</tr>
<tr>
<td>fd0</td>
<td>Frost days</td>
<td>Annual count when TN(daily minimum)&lt;0°C</td>
</tr>
<tr>
<td>su30</td>
<td>Strong summer days</td>
<td>Annual count when TX(daily maximum)&gt;35°C</td>
</tr>
<tr>
<td>id5</td>
<td>Weak ice days</td>
<td>Annual count when TX(daily maximum)&lt;5°C</td>
</tr>
<tr>
<td>tr25</td>
<td>Strong tropical nights</td>
<td>Annual count when TN(daily minimum)&gt;25°C</td>
</tr>
<tr>
<td>fd5</td>
<td>Weak Frost days</td>
<td>Annual count when TN(daily minimum)&lt;5°C</td>
</tr>
<tr>
<td>gsl</td>
<td>Growing season Length</td>
<td>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&gt;5ºC and first span after July 1 (January 1 in SH) of 6 days with TG&lt;5ºC</td>
</tr>
<tr>
<td>txx</td>
<td>Max Tmax</td>
<td>Monthly maximum value of daily maximum temp</td>
</tr>
<tr>
<td>txn</td>
<td>Max Tmin</td>
<td>Monthly maximum value of daily minimum temp</td>
</tr>
<tr>
<td>tnx</td>
<td>Min Tmax</td>
<td>Monthly minimum value of daily maximum temp</td>
</tr>
<tr>
<td>tnn</td>
<td>Min Tmin</td>
<td>Monthly minimum value of daily minimum temp</td>
</tr>
<tr>
<td>tx10p</td>
<td>Cool nights</td>
<td>Percentage of days when TN&lt;10th percentile</td>
</tr>
<tr>
<td>tx90p</td>
<td>Cool days</td>
<td>Percentage of days when TX&lt;10th percentile</td>
</tr>
<tr>
<td>tn10p</td>
<td>Warm nights</td>
<td>Percentage of days when TN&gt;90th percentile</td>
</tr>
<tr>
<td>tn90p</td>
<td>Warm days</td>
<td>Percentage of days when TX&gt;90th percentile</td>
</tr>
<tr>
<td>wsdi</td>
<td>Warm spell duration indicator</td>
<td>Annual count of days with at least 6 consecutive days when TX&gt;90th percentile</td>
</tr>
<tr>
<td>csdi</td>
<td>Cold spell duration indicator</td>
<td>Annual count of days with at least 6 consecutive days when TN&lt;10th percentile</td>
</tr>
<tr>
<td>dtr</td>
<td>Diurnal temperature range</td>
<td>Monthly mean difference between TX and TN</td>
</tr>
</tbody>
</table>

#### Extreme Precipitation Indices

<table>
<thead>
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<th>Abbreviation</th>
<th>Names</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>rx1day</td>
<td>Max 1-day precipitation amount</td>
<td>Monthly maximum 1-day precipitation</td>
</tr>
<tr>
<td>rx5day</td>
<td>Max 5-day precipitation amount</td>
<td>Monthly maximum consecutive 5-day precipitation</td>
</tr>
<tr>
<td>sdii</td>
<td>Simple daily intensity index</td>
<td>Annual total precipitation divided by the number of wet days (defined as PRCP&gt;=1.0mm) in the year</td>
</tr>
<tr>
<td>r10mm</td>
<td>Number of heavy precipitation days</td>
<td>Annual count of days when PRCP&gt;=10mm</td>
</tr>
<tr>
<td>r20mm</td>
<td>Number of very heavy precipitation days</td>
<td>Annual count of days when PRCP&gt;=20mm</td>
</tr>
<tr>
<td>R30mm</td>
<td>Number of extremely heavy precipitation days</td>
<td>Annual count of days when PRCP&gt;=30 mm</td>
</tr>
<tr>
<td>cdd</td>
<td>Consecutive dry days</td>
<td>Maximum number of consecutive days with RR&lt;1mm</td>
</tr>
<tr>
<td>cwd</td>
<td>Consecutive wet days</td>
<td>Maximum number of consecutive days with RR&gt;=1mm</td>
</tr>
<tr>
<td>r95p</td>
<td>Very wet days</td>
<td>Annual total PRCP when RR&gt;=95th percentile</td>
</tr>
<tr>
<td>r99p</td>
<td>Extremely wet days</td>
<td>Annual total PRCP when RR&gt;99th percentile</td>
</tr>
<tr>
<td>prcptot</td>
<td>Annual total wet-day precipitation</td>
<td>Annual total PRCP in wet days (RR&gt;=1mm)</td>
</tr>
</tbody>
</table>
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 show 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.

<table>
<thead>
<tr>
<th>Country</th>
<th>Australia</th>
<th>China</th>
<th>Japan</th>
<th>Malaysia</th>
<th>Mongolia</th>
<th>New Zealand</th>
<th>Pakistan</th>
<th>Republic of Korea</th>
<th>Thailand</th>
<th>Vietnam</th>
<th>APN</th>
</tr>
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<tbody>
<tr>
<td>Total</td>
<td>36</td>
<td>32</td>
<td>15</td>
<td>8</td>
<td>6</td>
<td>10</td>
<td>12</td>
<td>14</td>
<td>7</td>
<td>5</td>
<td>145</td>
</tr>
<tr>
<td>95%</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
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<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>su25</td>
<td>18</td>
<td>18</td>
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<td>15</td>
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<td>4</td>
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<td>2</td>
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<td>4</td>
<td>32</td>
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11
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 5th upper or lower percentile-based indices including cool/warm days/night, 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 20 days/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 magnitude 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°S. 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.

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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 show 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 show 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.

References


## Appendix A

### Workshop Programme and Participants List

#### A1. Programme

**20 February 2008 Yoido Hotel**

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<td>Opening Address</td>
<td>Man-Ki Lee, KMA Administrator</td>
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<td>10:30-11:20</td>
<td>Current Research on Climate Change in Korea</td>
<td>Won-Tae Kwon, KMA, Korea</td>
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<td>11:20-12:10</td>
<td>Climate Statistics on Eigen Analysis including CSEOF</td>
<td>Young-Kwon Lim, Florida State Univ.</td>
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**Chair: Guoyu Ren (13:30-14:50)**

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<td>Previous APN and other regional climate workshop</td>
<td>Blair Trewin, National Climate Center, Australia</td>
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<td>Observed trends in New Zealand climate over 1951-2007</td>
<td>Marina Baldi, New Zealand Meteorological Service, New Zealand</td>
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<td>14:30-14:50</td>
<td>Preliminary study on changes of present climate extremes in Mongolia</td>
<td>P. Gomboluudev, Mongolia</td>
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**Chair: Blair Trewin (15:20-16:20)**

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<td>15:40-16:00</td>
<td>Recent Progresses in Studies of Regional Temperature Changes in China</td>
<td>Ren Guoyu, National Climate Centre, China</td>
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<td>Trend in Extreme Climate Indices for Thailand</td>
<td>Pianmana Theeraluk, Thailand</td>
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<td>An uncertainty assessment of surface temperature and precipitation variability in the IPCC AR4 GCMs over East Asia</td>
<td>Jinho Shin, KMA, Korea</td>
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<td>Application of CSEOF to monsoon climate analysis and prediction</td>
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<td>Precipitation changes in future climate: Extreme events and constraints</td>
<td>William J. Gutowski, Jr., Iowa State Univ., USA</td>
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**Chair: Marina Baldi (13:30-14:50)**

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<td>14:10-14:30</td>
<td>Trends in climate extremes in Japan</td>
<td>Yoshikazu Fukuda, Japan</td>
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<td>Trend of climate index of Vietnam</td>
<td>Pham Thi Thanh Huong, Vietnam</td>
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<td>Changes in climate extremes in Australia</td>
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### 23 February 2008

Science Tour (Seoul Meteorological Observation Station)
## A2. Participants List

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<tr>
<td>1 Blair Trewin</td>
<td>National Climate Centre, Bureau of Meteorology, Australia</td>
<td><a href="mailto:B.Trewin@bom.gov.au">B.Trewin@bom.gov.au</a> 61-3-9669-4623 61-3-9669-4673</td>
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<tr>
<td>2 Dean Collins</td>
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<tr>
<td>3 Guoyu Ren</td>
<td>National Climate Centre, China Meteorological Administration, China</td>
<td><a href="mailto:guoyoo@cma.gov.cn">guoyoo@cma.gov.cn</a> 86-10-6840-6408 86-10-6217-6804</td>
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<td>4 Marina Baldi</td>
<td>National Institute of Water &amp; Atmospheric Research Ltd., New Zealand</td>
<td><a href="mailto:m.baldi@niwa.co.nz">m.baldi@niwa.co.nz</a> 64-9-375-4537 64-9-375-2051</td>
</tr>
<tr>
<td>5 Muhammad Afzzal</td>
<td>Pakistan Meteorological Department, Pakistan</td>
<td><a href="mailto:afzaalkarori@yahoo.com">afzaalkarori@yahoo.com</a> 92-51-925-0360 92-51-925-0368</td>
</tr>
<tr>
<td>6 Norlisam Lias</td>
<td>Kuching Regional Meteorological Office, Malaysia</td>
<td><a href="mailto:norlisam@met.gov.my">norlisam@met.gov.my</a> 82-45-2454 82-45-3527</td>
</tr>
<tr>
<td>7 Pham Thi Thanh</td>
<td>Institute of Meteorology and Hydrology, Viet Nam</td>
<td><a href="mailto:huonkhk@vkttv.edu.vn">huonkhk@vkttv.edu.vn</a> 84-4-773-3090 84-4-835-5993</td>
</tr>
<tr>
<td>8 Purevjav Gomboluudev</td>
<td>Institue of Meteorology and Hydrology, Mongolia</td>
<td><a href="mailto:p_gombo@hotmail.com">p_gombo@hotmail.com</a> 976-11-326606 976-11-326614</td>
</tr>
<tr>
<td>9 Theeralux Pianmana</td>
<td>Thai Meteorological Department, Thailand</td>
<td><a href="mailto:tpianmana@yahoo.com">tpianmana@yahoo.com</a> 662-3991423 662-3838827</td>
</tr>
<tr>
<td>10 Yoshikazu Fukuda</td>
<td>Japan Meteorological Agency, Japan</td>
<td><a href="mailto:y-fukuda@met.kishou.go.jp">y-fukuda@met.kishou.go.jp</a> 81-3-3211-8406 81-3-3211-8406</td>
</tr>
<tr>
<td>11 Yong-Kwon Lim</td>
<td>Center for Ocean-Atmospheric Prediction Studies, Florida State University, USA</td>
<td><a href="mailto:yklim0503@yahoo.co.kr">yklim0503@yahoo.co.kr</a> 850-644-9138 850-644-4841</td>
</tr>
<tr>
<td>12 Won-Tae Kwon</td>
<td>Korea Meteorological Administration, Korea</td>
<td><a href="mailto:wonta@metri.re.kr">wonta@metri.re.kr</a> 82-2-6712-0300 82-2-836-0688</td>
</tr>
<tr>
<td>13 Young-Hwa Byun</td>
<td>Korea Meteorological Administration, Korea</td>
<td><a href="mailto:yhb@metri.re.kr">yhb@metri.re.kr</a></td>
</tr>
<tr>
<td>14 Kyung-On Boo</td>
<td>Korea Meteorological Administration, Korea</td>
<td><a href="mailto:bko@metri.re.kr">bko@metri.re.kr</a></td>
</tr>
<tr>
<td>15 Hyun-Suk Kang</td>
<td>Korea Meteorological Administration, Korea</td>
<td><a href="mailto:hyunsuk@metri.re.kr">hyunsuk@metri.re.kr</a></td>
</tr>
<tr>
<td>16 Suhee Park</td>
<td>Korea Meteorological Administration, Korea</td>
<td><a href="mailto:suhee@metri.re.kr">suhee@metri.re.kr</a></td>
</tr>
<tr>
<td>17 Hyo-Shin Lee</td>
<td>Korea Meteorological Administration, Korea</td>
<td><a href="mailto:hyolee@metri.re.kr">hyolee@metri.re.kr</a></td>
</tr>
<tr>
<td>18 Yu-Mi Cha</td>
<td>Korea Meteorological Administration, Korea</td>
<td><a href="mailto:finedrop@metri.re.kr">finedrop@metri.re.kr</a></td>
</tr>
<tr>
<td>19 Johan Lee</td>
<td>Korea Meteorological Administration, Korea</td>
<td><a href="mailto:johan.lee@metri.re.kr">johan.lee@metri.re.kr</a></td>
</tr>
<tr>
<td>20 Young-Ah Kwon</td>
<td>Korea Meteorological Administration, Korea</td>
<td><a href="mailto:yakwon71@metri.re.kr">yakwon71@metri.re.kr</a></td>
</tr>
<tr>
<td>21 Jinho Shin</td>
<td>Korea Meteorological Administration, Korea</td>
<td><a href="mailto:jshin@metri.re.kr">jshin@metri.re.kr</a></td>
</tr>
<tr>
<td>22 Gwangyong Choi</td>
<td>Korea Meteorological Administration, Korea</td>
<td><a href="mailto:tribute@metri.re.kr">tribute@metri.re.kr</a></td>
</tr>
<tr>
<td>23 Gyo-Sook Koo</td>
<td>Korea Meteorological Administration, Korea</td>
<td><a href="mailto:geogen@metri.re.kr">geogen@metri.re.kr</a></td>
</tr>
<tr>
<td>24 Han-Cheol Lim</td>
<td>Korea Meteorological Administration, Korea</td>
<td><a href="mailto:hclim99@metri.re.kr">hclim99@metri.re.kr</a></td>
</tr>
<tr>
<td>25 Moon-Hyun Kim</td>
<td>Korea Meteorological Administration, Korea</td>
<td><a href="mailto:mhhkim@metri.re.kr">mhhkim@metri.re.kr</a></td>
</tr>
<tr>
<td>26 Da-Hee Choi</td>
<td>Korea Meteorological Administration, Korea</td>
<td><a href="mailto:dhchoi@metri.re.kr">dhchoi@metri.re.kr</a></td>
</tr>
<tr>
<td>27 Yoon So Kang</td>
<td>Korea Meteorological Administration, Korea</td>
<td><a href="mailto:yskang@metri.re.kr">yskang@metri.re.kr</a></td>
</tr>
<tr>
<td>28 Minji Kim</td>
<td>Korea Meteorological Administration, Korea</td>
<td><a href="mailto:minji@metri.re.kr">minji@metri.re.kr</a></td>
</tr>
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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

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<th>Organization</th>
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<td>The Applications of Regional Climate Change Scenario for the National</td>
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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

Won-Tae Kwon
Korea Meteorological Administration

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°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°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°C. In East Asia, temperature will rise by 3-4°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°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

Young-Kwon Lim
Florida State Univ.

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**

Blair Trewin
National Climate Centre, Australian Bureau of Meteorology

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.
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

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**Preliminary Study on Changes of Present Climate Extremes in Mongolia**

Purevjav Gomboluudev, Luvsan Natsagdorj and Lamjav Oyunjargal
Institute of Meteorology and Hydrology, National Agency for Meteorology, Hydrology and Environmental Monitoring, Ulaanbaatar, Mongolia

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.

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

Norlisam Lias
Kuching Regional Meteorological Office,
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 relimdex 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, 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

Ren Guoyu
Lab for Climate Studies, China Meteorological Administration, National Climate Center, Beijing 100081

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°C/10 yr. and 0.08°C/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°C in period of 1961-2000, with an increasing rate of temperature of 0.11°C/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°C/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°C/10a and -0.22°C/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

**Theeraluk Pianmana**  
Thai Meteorological Department, Thailand

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 temperature and rainfall indices.

The analysis results of trend in temperature indices have been showed that summer days (number of days with Tmax > 30°C) and tropical night (number of days with Tmin > 25°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 change 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

**J.H. Shin, H.S. Lee, W.T Kwon, and M.J. Kim**  
National Institute of Meteorological Research, Korea

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, $T_n(t)$;

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

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

Precipitation Changes in Future Climate: Extreme Events and Constraints

William J. Gutowski, Jr.
Department of Geological and Atmospheric Sciences
Iowa State University
Ames, Iowa USA

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

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

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

Muhammad Afzaal
Pakistan Meteorological Department
Research & Development Division
Sector H-8/2, P. O. Box 1214
Islamabad - Pakistan

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

**Yoshikazu Fukuda**  
Climate Prediction Division, JMA, Tokyo, Japan

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).

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### Trend of Climate Index of Vietnam

**Author Pham Thi Thanh Huong**  
National Institute of Meteorology Hydrology and Environment, Ha Noi, Vietnam

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

Dean Collins and Blair Trewin
National Climate Centre, Bureau of Meteorology, Melbourne, Victoria, AUSTRALIA

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


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

Frozen period of Han River (1997-2007)

Changes in Natural Season

Frequency of Heavy Rainfall

Natural Disasters in Korea

Typhoon Rusa in 2002

Land slides in 2006

Precipitation changes at Inje
2. Climate Statistics on Eigen Analysis including CSEOF
Physical Decomposition
- Systematic reduction of complex data into dominant modes: \( B(t,t') \), with their amplitude time series, \( S(t) \).

\[
P(t,t') = \sum_{i=1}^{n} S_i(t) B_i(t,t')
\]

- \( B(t,t') \): Independent climate signals (e.g., Seasonal cycle, ISO mode, El Niño mode)
- \( S(t) \): 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 equation in consideration of time dependency in covariance matrix:

\[
C(t,t') = \lambda(t) \delta(t-t')
\]

An example of decomposition
- Space-time dependent mode (a climate signal)

Data set for CSEOF analysis on the variation of Asian summer monsoon (ASM)
- Jie-Arkin precipitation pentad data (1979-2001)
- National Center for Environmental Prediction (NCEP) reanalysis data for 44 years (1958-2001)

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.

The first several modes identified

<table>
<thead>
<tr>
<th>Mode</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>6th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Components</td>
<td>Seasonal cycle</td>
<td>ISO</td>
<td>ENSO mode</td>
<td>95</td>
<td>90</td>
<td>80</td>
</tr>
<tr>
<td>% variance</td>
<td>15</td>
<td>14</td>
<td>7</td>
<td>4</td>
<td>3.7</td>
<td></td>
</tr>
</tbody>
</table>

(for climatological)
3. Previous APN and other regional climate workshop

A summary of previous APN workshops and international workshop activities in Vietnam
Blair Trwin
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 95th percentile (hot days/warm nights)
- Number of days with maximum/minimum temperature below 1st percentile (cool days/cold nights)
- Frequency of days with extreme hourly average temperature
- Number of days with extreme wind speed

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

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 broader climate influences (e.g. ENSO)

Several major papers also produced — e.g.
- Nason et al. (2001), Griffiths et al. (2005), Mcloughlin et al. (2005)

Expert Team on Climate Change Detection and Indices (ETDCI)

- Co-sponsored by CCI, CLIVAR and JCOMM
- Has supported numerous regional climate workshops
- Has also fostered development of relevant software (originally NASH, now ROIDindex and RMT/ESC)

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

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

- Warming has occurred across all New Zealand.
- Temperatures increased by 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 143M
  - Apples overheated, worthwhile
  - Significant losses from native and planted trees
  - Floods on the West Coast

**Mean climate shifts**

- NZ mean temperatures have warmed 0.4°C in the period 1981-2006.
- 1961-1978 saw more E winds. Mean rainfall increased in NH of NZ, decreased in SE of NZ.
- 1976-1998 saw stronger S winds. Mean rainfall increased on the West Coast, became drier in eastern districts.
- Since 1998, a climate shift towards more E winds (6 record warmest for NZ) was observed.

**Climate core indices**

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

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

**Stations in New Zealand**

<table>
<thead>
<tr>
<th>Station</th>
<th>Lat</th>
<th>Lon</th>
<th>Height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campbell Is</td>
<td>-43.59</td>
<td>177.70</td>
<td>30</td>
</tr>
<tr>
<td>Invercargill</td>
<td>-46.12</td>
<td>169.34</td>
<td>0</td>
</tr>
<tr>
<td>Chatham Islands</td>
<td>-41.85</td>
<td>178.57</td>
<td>48</td>
</tr>
<tr>
<td>Lincoln</td>
<td>-43.65</td>
<td>172.44</td>
<td>38</td>
</tr>
<tr>
<td>Botanic</td>
<td>-42.72</td>
<td>176.09</td>
<td>38</td>
</tr>
<tr>
<td>Blanket Research</td>
<td>-42.40</td>
<td>171.60</td>
<td>4</td>
</tr>
<tr>
<td>Hawke's Bay, New Zealand</td>
<td>-41.58</td>
<td>174.97</td>
<td>130</td>
</tr>
<tr>
<td>Christchurch</td>
<td>-39.06</td>
<td>172.00</td>
<td>2</td>
</tr>
<tr>
<td>Endeavour</td>
<td>-37.58</td>
<td>172.31</td>
<td>43</td>
</tr>
<tr>
<td>Nelson</td>
<td>-39.23</td>
<td>177.00</td>
<td>0</td>
</tr>
</tbody>
</table>

**Temperature (TN10p)**

- General decrease of the index
Temperature:
TN10p
General increase of the index

Temperature:
TX90p
General (small) increase of the index

Temperature:
Number of frost days - FD90
Minor decrease in NL and offshore

Rain:
Ni: general decrease

Rain:
Annual total: PCLP
Minor decrease in NL 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 Holitsa
5. Preliminary study on changes of present climate extremes in Mongolia
Present Climate Change

- Precipitation Trends
- Geographical pattern of trends
- Temperature: warming is observed across the country, with increases in temperature and decreases in precipitation in some areas.

Local Anthropogenic Factors

- Number of extreme events is increasing, with more severe and longer-lasting heatwaves and droughts.

Extreme Indices Change

- Used software and selection criterion
- The software is RStudio, which provides various tools for data analysis and visualization.

Projection of Extreme Climate

- Regional Climate Projection using RCM (Dynamic Downscaling)
- Projected temperature and precipitation changes for different regions of the country.
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 deforestation are negatively influenced feedback to the regional climate of the pattern of global warming.

Extreme temperatures indices are shown increasing of both daily maximum and minimum temperature. Their warm and cool tail of 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.
6. Climate Change and Extreme Weather Events in **Malaysia**

### Climate Change and Extreme Weather Events in Malaysia

**Norhuan Lias**

**Outline**

1. Climate of Malaysia
2. Location of the stations
3. Annual temperature variations and trend comparison
4. Extreme Events in Malaysia
   - Frequency and intensity increasing?

#### 1. Climate of Malaysia
- Uniform temperature
- High humidity (70 – 90 %)
- Copious rainfall (> 2000 mm)
- Winds are generally light
- 2 monsoon seasons (2 Inter-monsoon period in between)

#### 1.1 Monsoon in Malaysia
- **i) Northeast Monsoon**
  - November – March
  - Steady easterly and northeastely winds (10-20 knots)
  - Cold surges from Siberia (> 30 knots)
  - Causing floods in East Coast of Peninsula and the state of Sarawak in East Malaysia
- **ii) Southwest Monsoon**
  - May – September
  - Winds are southwesterly and light (< 15 knots)
  - Drier season except for state of Sabah
  - Stable atmospheric condition in the Equatorial region
  - Sabah is wetter due to the tail effect of typhoons

#### ii) Inter – Monsoon
- April and October
- Winds are light and variable
- Clear sky in the morning favors thunderstorm activities in the afternoon
- West coast of Peninsula gets the maximum mean monthly rainfall during this season

#### 2. Location of the stations
2.1 Station informations

Penang
- Latitude: 5.39° N, Longitude: 100.27° E
- Height: 2.6 m above MSL.
- In Penang, a Free Industrial Zone, where activities of many multinational companies are located.
- Penang has a population of about 190,000 people. Bayan Lepas is now the offshoot from development in Penang. Many new condominiums, housing estates are all currently under construction in that area.

Kuantan
- Latitude: 3.78° N, Longitude: 103.72° 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 hardcrackles, bakul, terongkak (fried fish crackers) and salted fish. Kuantan is the administrative and commercial capital of Pahang.

96411, 96413, 96421 and 96449
- All located in the state of Sarawak.
- 96413 and 96421 inland stations.
- 96411 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
- 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.

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.

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 48691 is the largest.

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 48691 on 26th May 1998 during extreme El Niño condition.

Station 96471 has the largest trend in TXx caused the forest fire in Kota Kinabalu region in 1996.
3.4 Trend comparison for TX10p, TX90p, TN10p and TNN90p.

Analysis of TX10p, TX90p, TN10p and TNN90p indicated that the number of warm days/nights increase but the number of cold days/nights 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 46657 has the largest trend which is related to number of flood events increasing at this region during north-east monsoon season.

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 46647 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 and R99p indicated largest trend in station 46647 and station 48647 respectively.
Analysis of R95p, R99p and PRCPTOT indicated almost the same trend pattern, of which station 86421 (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
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.


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).

Location of Beijing Station (34°41')
- The station underwent 10 times of warming in the past 30 years but understanding it is still not well understood.

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 1970-2004 period.
- Significant difference exists between the surface and upper air temperature trends.

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 effect.
8. Trend in Extreme Climate Indices for Thailand
9. An Uncertainty Assessment of IPCC AR4 GCMs Temperature and Precipitation Variability over East Asia

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

Juhn Shin
National Institute of Meteorological Research
Korea
February 23, 2006

Motivations

- Global warming causes the current and future climate change.
- To prepare for the future climate change, the hydrological longer term planning using the GCMs is required.
- However, uncertainty of PCP is caused generally by incomplete physical and dynamical processes to determine PCP.
- Based on identified uncertainty, we can provide useful information about model improvement.

Outline

- Motivations
- Goals and objectives
- Data
  - Observational and reanalysis
  - GCMs participating in IPCC AR4
- Analysis methods
- Result
  - 20th century
  - Uncertainty of surface air temperature (T2m) and precipitation (PCP) over East Asia
  - Annual cycle of PCP for East Asia summer monsoon
- Conclusion

(To be continued)

Insufficient consideration of topography effect caused by coarse resolution in GCMs underestimates rainfall resulting from the summer monsoon 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°x5° latitude-longitude grid.
  - Period: January 1961-December 1990 (30 yrs).
- CPC Merged Analysis of Precipitation (CMAP) data
  - Monthly means of precipitation.
  - Global 2.5°x2.5° latitude-longitude grid.
  - Period: January 1979-December 1999 (21 yrs).
- ECMWF data
  - Monthly mean of surface and pressure level; wind, moisture.
  - Global 2.5°x2.5° latitude-longitude grid.

IPCC AR4 SRES and Models

Regidding process of IPCC data

Analysis methods

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

Regression method (especially for the third goal)

\[ T(t) = \beta_0 + \beta_1 P(t) + \epsilon(t) \]

where \( P(t) \) is the PC time series of pressure, and \( \beta_0, \beta_1 \) are regression coefficients.

Regression pattern of predictor. \( \psi(t) \) is obtained from:

\[ \psi(t) = \sum c_{ij} x(t) \]

where \( c_{ij} \) is pattern of the target.

Geographical domain for this study

74
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 is winter and T2m in spring.

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

PCP and 850hPa moisture convergence

Low level moisture transport

- Summer Monsoon period
  1) Positive OBS anomalies appear over Northwest China in spring, positive Moisture transport anomalies and northerly wind over north China
  2) Further northeast and monsoon rain falls in the northern China
  3) Positive anomalies in east China in spring (observed).
  4) Blue shaded region (positive anomaly) is located over the south China in spring (MME7 model ensemble average).
  5) Center of positive anomaly over east China is located in the Northwest China in spring (MME7 model ensemble average) and northern China.

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
Conclusions

1. Prominent physical modes (Seasonal cycle, ISO, and ENSO) contributing to the ASM are successively separated from the observed precipitation data using CEEOF technique.
2. Monsoon evolutions over the entire monsoon domain, and for the entire ASM period are easier to understand.
3. How significantly each physical mode explains the total variance can be assessed.
4. PC time series explains the amplitude variation of each mode on an interannual time scale.
5. Climate prediction of ASM precipitation

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 interdecadal 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).

EOOF assumes stationarity, which means the moment statistics is independent of time.

Acknowledgements

This research was supported by the National Science Foundation (ATM-0817243) and the Department of Energy (DE-F12-03Y01564).


Climate prediction algorithm (idea)

Basic idea:

\[ P(t) = \sum_{k=1}^{p} \beta_k \Delta P_{k}(t) + \epsilon(t) \]

The underlying idea is to predict \( P(t) \), the temporal fluctuations of the amplitude of the individual climate signals.

Predictability can be improved in the sense that \( \Delta P_{k}(t) \) is easier to predict than raw data, which contains significant amount of high-frequency fluctuation.

Once the \( \Delta P_{k}(t) \) of each mode is predicted, ENSO forecast field is obtained by constructing data using the above equation. \( \Delta P_{k}(t) \) are the predicted value of the respective PC time series.

( Climate prediction model (Kim and North 1998) )
11. Precipitation Changes under Global Warming

Precipitation Changes under Global Warming

W. J. Gutowski
Iowa State University
Ames, Iowa, USA

Two Parts

1. Simulating the Synoptic Climatology of Extreme Precipitation Events under Global Warming
   S. S. Wilks, J. C. Patton, B. R. Schweizer, R. W. Arritt, E. S. Takte and Z. Pan

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

Analysis of Extremes

Societal Importance, esp. for climate change

Key Question: Do climate models behave like observations?

Diagnosis of physical mechanisms
- Necessary for model vs. obs. comparison
- Basis for developing confidence in projections
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 0.65% of events

Simulations

<table>
<thead>
<tr>
<th>Model</th>
<th>Observed</th>
<th>GCM-control</th>
<th>GCM-Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>RegCM2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NCEP Reanalysis (1979-1998)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hadley Centre (1980)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hadley Centre (2000-2050)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HRH4AM (JFM)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

1981-1983 Cold season October - March

Precipitation Frequency vs. Intensity

Cumulative Precipitation vs. Intensity

Simultaneous Extreme Precipitation Events

- OBS: 6 Events
- NCEP: 7
- CTRL: 8
- SCN: 5

Widespread 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

---

NCEP-Driven: 500 hPa Heights - Day of Event

- 27 Nov 1983

NCEP-Driven: 500 hPa Heights - Sequence

- 24 Nov 1983
- 28 Nov 1983

---

CTRL-Driven: 500 hPa Heights - Day of Event

- 21 Jan 82
- 29 Mar 84

---

83
Two Parts

1. Simulated precipitation extremes
   - Low vs. observations (resolution-limited)
   - For cool-season "widespread events"
   - Model's large-scale dynamics - observed
   - Scenario's dynamics - contemporary climate

2. A Possible Constraint on Regional Precipitation Intensity Changes under Global Warming
   - K. A. Lau, R. W. Pielke, J. H. Christensen, J. C. Piton, E. S. Takle and Z. Pan

Suite of 10-year Simulations

<table>
<thead>
<tr>
<th>Model</th>
<th>Observed</th>
<th>GCM Control</th>
<th>GCM Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRHAM (GME)</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>

Observations

Precipitation:
- NCDC Cooperative Observing Network
  - Quality controlled (Clark & Hay 2004)
  - Missing obs. <3 months for 1936-1999
  - No gauge undercatch adjustment
12. Observed Climate Change over **Korea**

**Long-term change of temperature and precipitation**
- Data: 1912-2005, 4 stations
- Temperature: rising gradually during the past 10 years by -1.3 °C
- Precipitation: increasing trend with decadal variation
  - Warmer and wetter trend in 20th century

**Recent observational Climate change**
- **Annual mean Temperature**
  - **1971-2000** | **1971-2000** | **0.6 °C**
  - Spring: Winter: 0.7 °C, Autumn: 0.6 °C, Summer: 0.4 °C
- **Annual precipitation**
  - **1971-2000** | **1971-2000** | 10%
  - Average: 765.7 mm, 765.9 mm, 11%
  - Summer: 16%, Autumn: 12%, Spring: 18%

Data: 35 stations
Summary and Conclusion

• Over the past 10 years (1995–2004), significant changes in extreme temperature events have occurred across South Korea regardless of urban and rural locations within the nation. Average temperature has increased, exceeding long-term trends. The autumn season has experienced the largest warming trends (maximum increase of 1.2°C), exceeding long-term warming trends. Daytime maximum temperatures have increased the most, exceeding 1.0°C, while nighttime temperatures have increased by 0.6°C.

• The winter season has experienced the largest warming trends, reaching a maximum increase of 1.3°C compared to long-term warming rates. The winter season has experienced the largest warming trends, exceeding 1.0°C. Cold nights have also increased, exceeding long-term trends and reaching a maximum increase of 1.3°C. Cold days have increased by 0.6°C.

• No significant warming trends were observed for the summer season, with an increase of 0.3°C and an increase in cold nights by 0.3°C. Cold nights have increased by 0.3°C.

• Significant warming trends have been observed during the past 10 years, exceeding long-term warming trends of 0.9°C. Maximum temperature has increased by 1.3°C, exceeding long-term warming trends. Maximum temperature has increased by 0.9°C, exceeding long-term warming trends.

• Significant warming trends have been observed during the spring season, exceeding long-term warming trends of 0.9°C. Maximum temperature has increased by 1.3°C, exceeding long-term warming trends. Maximum temperature has increased by 0.9°C, exceeding long-term warming trends.

• The general increase in nighttime temperature will contribute to the increase in heavy precipitation events. More detailed research and additional observations are needed to understand the complex relationship between temperature and precipitation.
13. Changes in Temperature and Precipitation Trends over Pakistan
14. Trends in Climate Extremes in **Japan**

**Trends in Climate Extremes in Japan**

Yoshitaka Fukuda (JMA)

1. The characteristics of distributions of trends for 6 extreme indices in Japan

**Climate in Japan**

- Existence of long-term observation record
- No significant change in meteorological stations
- Relatively uniform warming trend
- Matsuda or urban city temperature

**Data for analysis**

JMA uses 17 stations for temperature and 51 stations for precipitation to monitor long-term trend in Japan
Data for analysis

17 stations for temperature

Azateria, Namie, Fujisawa, Kamogawa, Fujimura, Nagaoka, Minami, Iida, Chiba, Saku, Hamamatsu, Hitome, Miyazaki, Yatomi, Naka and Ishigakina

In this research, the 17 stations are used. Miyazaki moved in 2006 (no significant change on the data).

Indices of Tokyo are also calculated for the reference.

Maximum Temperature

Minimum Temperature

Precipitation

Summary

Temperature

SUJIS, TR05: Increase trend at almost all stations
PDEQG-5: Decrease trend in the northeastern area

Precipitation

R010: Decrease trend at almost all stations
R010: Increase trend in the southern area
RSPF/RGFP: Increase trend around East Japan

TCC webpage

http://tcc.jma.go.jp/tcc/j Respiratory Review
Thank you!
15. Trend of Climate Index of Vietnam

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

The whole country is divided into 3 parts: North (northern mountains 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 decreasing in almost areas except in the plain in the North and South
   - Max Tmx: almost places have Tmx increasing but Tmn increasing light decreasing
   - Min Tmx: increasing in the Northern and Southern fastest raising occurs in the mountain areas, but decreasing in the Middle

   ![Temperature Trends Diagram](image)

<table>
<thead>
<tr>
<th>Station</th>
<th>Tmax</th>
<th>Tmin</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCM</td>
<td>0.005</td>
<td>0.002</td>
</tr>
<tr>
<td>DVN</td>
<td>0.010</td>
<td>0.003</td>
</tr>
<tr>
<td>HCM</td>
<td>0.006</td>
<td>0.002</td>
</tr>
<tr>
<td>HCM</td>
<td>0.017</td>
<td>0.006</td>
</tr>
<tr>
<td>HCM</td>
<td>0.004</td>
<td>0.002</td>
</tr>
<tr>
<td>HCM</td>
<td>0.006</td>
<td>0.002</td>
</tr>
<tr>
<td>HCM</td>
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</tr>
<tr>
<td>HCM</td>
<td>0.003</td>
<td>0.001</td>
</tr>
</tbody>
</table>

   ![Min Tmax Temperature Chart](image)

<table>
<thead>
<tr>
<th>Station</th>
<th>Tmin</th>
<th>Tmax</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCM</td>
<td>0.003</td>
<td>0.002</td>
</tr>
<tr>
<td>HCM</td>
<td>0.001</td>
<td>0.003</td>
</tr>
</tbody>
</table>

   ![Max Tmax Temperature Chart](image)

   Cool days: decreasing in all most country, except a station in the southern high land

   ![Cool Days Chart](image)

   Warm days and Warm spell duration indicator: increasing in all most country, except use in the southern high land and one in the middle near by the Mekong river delta

   ![Warm Days Chart](image)
Max Twins: increasing in all most country, except in Da Nang.

Min Twins: increasing in all most country, TNN of 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 CSN spell duration indicators: 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

National Institute of Meteorology, Hydrology and Environment (NIMHE)

National Institute of Meteorology, Hydrology and Environment (NIMHE)

National Institute of Meteorology, Hydrology and Environment (NIMHE)

And many others...

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 area have decreasing trend, in the high land increasing and lowland decreasing.

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 8 day precipitation amount; increasing fast in the Southern and mountain areas.

Consecutive day days: increasing lightly in the Northern and decreasing in the Middle and Southern

**CONCLUSION**

* The temperatures have the increasing trend with rate very 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 climate trend for 7 climate areas of Vietnam
* Impact on main sectors: Water resources, Agriculture, transportation, Human health...
* Predict the extreme weather and climate

**THANK YOU VERY MUCH**
16. Changes in Climate Extremes in **Australia**
17. Trends of Extreme Climate Events in the Asian-Pacific Network (APN) Region

Outlines
- Global trends and models of changes in extreme climate
- Objectives/Methods
- Extreme climate indices suggested by the RCI/Irr/Dec
- Results: trends of extreme temperature and precipitation events across the APN region
- Summary and conclusions
- Suggestions
- Appendix: How to use the scripts for a homogenously test and for calculations of extreme climate indices

Objectives
- To examine the coherences and differences in trend and magnitude of extreme temperature and precipitation events across the APN region
- To evaluate currently used climate indices in detecting fingerprints of current and future changes in extreme climate events along the western Pacific Rim
- To suggest the directions of future steps for the workshop

Geographical Coverage of 10 Countries Participating in the 6th Asian Pacific Network (APN) workshop
- Australia
- China
- Japan
- Malaysia
- Mongolia
- New Zealand
- Pakistan
- Republic of Korea
- Thailand
- Vietnam

Methods: Extreme Climate Indices
Linear trends in the time series of indices since the mid-1950s (1951) based on 107 1/2000 climatology and their significance levels using rCummax (Zhang & Yang, 2006)

DATA: The distribution of weather stations included in the 6th Asian Pacific Network (APN) workshop
- Daily maximum temperatures as well as daily precipitation observed at more than 100 weather stations since the mid-1950s
- The number of weather stations where significant (5% or more) trends are observed across the APN region:
  - 60% or more
  - 45-60%
  - 60% or more
An overview of changes in extreme climate events over the APN region

**Temperature**
- Both winter & summer
- Very significant: Frequency & Scale
  - Relative threshold (percentile) indices
    - Cold/Cool
    - Warm/Hot
  - Days

**Precipitation**
- Regionally-varying
- Extreme, Frequency, & Intensity
- Drier patterns:
  - e.g., Mongolia
  - Southern Island of NZ
- Intermediate significant: Frequency
  - Fixed threshold indices
- Wetter patterns:
  - e.g., Republic of Korea, Malaysia, Northwestern Australia, Southern Island of NZ

Summary and Conclusions

- The frequency of warm extremes 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, spells, and coldness-related indices in winter has decreased.
- The magnitude of changes in extreme temperature events is greater at nights (daily minimum temperatures) than during the daytime (daily maximum temperatures).
- However, trends of extreme precipitation events are not significant in the greater than regional scale, showing spatially-varying trend and magnitude.
- For instance, dry patterns have been observed in Mongolia, northern Australia, and the northern part of NZ. While wet patterns have been detected in the southern part of NZ, Malaysia, northern Australia, the southern Island of NZ.

Suggestions

- A consistent data period should be used for collaboration (e.g., 1960-2007 or 1960-2007).
- A metadata should be collected such as available data in each APN countries (digital and non-digital data and naming 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 occur locally 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 nongeological data.
- An example of metadata

Three steps to finish the homogeneity test

1. **Step 1.** Use FindJ to find undocumented changepoint(s);
2. **Step 2.** Use FindJ to find documented changepoint(s);
3. **Step 3.** Use available metadata sources to delete or change actual data about each changepoint, 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 (RTestV2)...
  - "Start GUI"... at 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 this function to adjust the inhomoageneous time series in the RHtestV2 package.
How to get the adjusted data for indices

- Once all the coefficients are determined, you use them to get adjusted time series. If a coefficient is determined to be not significant, delete it from the time series. This is the data selection and modification. Then, the adjusted time series should be used to calculate the adjusted indices.
- Repeat the procedure above until each and every coefficient remains in the final example series is determined to be significant.
- If you will only focus on large mean shifts, you may stop the 2 step.
- After the step 1, you will get a plot of "Graph 3", and the true index is in the original series. Fourth column is the index of 5, and the fifth column is the adjusted time series when you would like to examine indices.
- However, if you can be further details, we refer to the information of "How to get the extended data for indices" in this chapter. To modify the above data, we would refer to the relevant section and modify the original data file.

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

- Run R and open R script source (PClimDex) (debug of 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)
- Index calculation: default period is 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 suggest user-defined thresholds as follows but I would like to claim to your suggestions:
  1)SU/30°, 2)FD/0°, 3)TR/25°, and 4)FD^°/6°.

Acknowledgements

Participants

Support
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