Regional Workshop on Climate Monitoring and Analysis of Climate Variability:
Implementation of Climate Watch System in RA II with focus on Monsoon affected areas

(Beijing, China, 10–13 November 2009)
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General Executive Summary and Recommendations
Implementation of Climate Watch Systems in RA II with focus on Monsoon affected areas
General Summary and Recommendations

Introduction
Congress-XV requested WMO to support the organization of regional workshops on climate monitoring and issued a resolution on future climate monitoring priorities which include: To enhance climate monitoring capabilities for the generation of higher quality and new types of products and services. EC-LX, Geneva, 18 to 27 June 2008, noted the urgent need for NMHSs and regional climate institutions to make use of best practices in delivery, provision and evaluation of climate watches, and in managing efficiently and seamlessly the interaction among the three involved parties: Regional Institutions, the NMHSs and the end users. The WMO series of regional workshops on climate monitoring including the implementation of climate watches constitute a WMO supporting mechanism to the Members in achieving these objectives by strengthening the role of the National Meteorological and Hydrological Services (NMHS) and the Regional Climate Centres to produce operational climate advisories and timely delivering them to the various sectors, decision makers and end users. This is required to help these communities in taking anticipatory measures to reduce the negative impacts of climate anomalies and related extremes. The monsoon affected area of the Asian region records frequent extreme weather and climate related events such as droughts, dry spells, heat waves, cold waves, flooding, cyclones, wind storms, severe thunderstorms/lightning, land slides, costal erosions, salinity intrusion etc. In addition, the high density of the population exposes the sub-region to high climatic risks. These factors together require a cross-boundary and cross sectors collaboration to establish a sound climate watch system to deliver high quality climate monitoring products and watches. To stimulate the inception of this system in RA-II WMO organized in collaboration with China Meteorological Administration (CMA) a workshop on climate monitoring including the implementation of a climate watch system in RA-II with focus on monsoon affected areas, Beijing China, 10-13 November 2009. The objectives of the workshop are:

1. To identify the need for climate watches in the region,
2. To Review the status of climate monitoring and long range forecasting capabilities at global, regional and national levels,
3. To build on successful showcases in the region and from abroad in producing useful climate advisories;
4. To work on tailoring the WMO guidelines on climate watches to the region needs,
5. To recommend best practices for the region in issuing climate watches,
6. To recommend strategies towards users of climate watches,
7. To develop an action plan to implement climate watches at national and regional level,
8. To recommend a follow-up mechanism on the implementation of climate watches.
Definition, Format, Content, Dissemination and Verification of climate watches

- A climate watch was defined in the WMO guidelines on climate watches, 2005 (WMO-TD No. 1269 / WCDMP-No.58) as an advisory issued by the NMHSs to heighten awareness amongst the users on a particular state of the climate. It serves as a mechanism for initiating preparedness actions. Participants agreed that the WMO guidelines should be the basis for organising a Climate Watch System in RA-II and for the delivery of related products and advisories at regional and national levels. A climate watch should be agreed with users and should include a standard format to be kept consistently used and avoid changing it. When feasible, and when it is within the responsibility of an NMHS, or of some national committee, the content of a climate watch should include information on expected impacts which should be assessed with the help of the sectors and provide guidance on how to behave, or what to do to reduce negative consequences. RCCs should assist NMHSs by providing guidance on regional climate anomalies based on regional climate monitoring and long range forecasting products and services. Participants emphasized that user requirements and needs are best identified when there is a permanent structure including NMHS, governmental agencies and other users. This fits well with the WCC-3 outcome recommending the set up a User Interface. The participants were informed that the Espoo conference on Living with climate variability and change (LWCVC) provided a good reference in this matter as it conveyed useful users input from various sectors. The proceedings of the conference therefore provide good guiding recommendations on user requirements and needs.

- Socio-economic data is a key for implementing an efficient climate watch system in the region. Therefore there is a need for designing standard and inter-operable data base systems on socio-economic data using GIS. These data can for example help better target climate watches; thus becoming with less risk of negative side effects; as in some cases issuing a climate watch could trigger negative reactions in the local economic activities if the climate watch do not consider users socio-economic concerns. It is therefore advised that when such risk arises, climate watches should be sector-specific with time-space resolution as high as possible. RCCs with the assistance of the WMO Disaster Risk Reduction Programme (DRR) are well placed to lead the development of such data bases. In addition National statistical Institutions / Bureaux, insurance and reinsurance companies provide good sources of such data. Show-cases and success stories can be used to promote the exchange of socio-economic data between sector agencies and NMHSs.

- In disseminating climate watches we should take advantage of the existing national structures to customise the information according to the recipient’s requirements and needs. In many cases the information should target primarily high and/or medium level only to support contingency planning and actions. However field operation level should be always kept informed during the progress of the climate watch including on the end of the watch. Media should be handled carefully and delicately to avoid the risk of a misuse or misinterpretation of the content of a climate watch. Different countries have different policies in managing climate related hazards. Positive engagement of the media is therefore also important to ensure an efficient CWS with a proper use of the information by the users and particularly when the general public is also concerned by the watch. NGO’s should be considered in designing an end to end climate watch system, in the sense they have good interactions with end users and the population and they might have fast
reaction during disasters; therefore they can help heightening awareness among
the population and get data from the field. They may also have a good access to
information on socio-economic aspects. The use of cell phone technology could
become an effective mean in several cases to help reach out remote areas in
disseminating climate watches.

- The establishment of a regional/national databases on extreme events is required
  for an objective verification of climate watches. However it should be noted that a
good dissemination mechanism is crucial to ensure an end-to-end operational
climate watch system. In some cases despite good and timely advisories the lack of
an efficient dissemination can lead to unsuccessful climate watches.

**Basic infrastructure requirements and needs for climate watches in the region**

- It is required to have a solid data foundation based on high quality data sets with
timely exchange to ensure an operational climate watch system in the region. In
this regards, efforts should be made by NHMSs for the generation of a good quality
climate data. Countries having large gaps in the data bases need to accelerate the
digitization of the data which are available in paper form. WMO can further
strengthen data archival and rescue (DARE) programme over the RAII region
particularly for the NHMSs where only limited data is available. WMO would help by
organizing workshop/training programmes for the member countries to improve
climate data management including handling missing data, data quality and
homogeneity, etc. Climate data which are readily available at different NMHSs (like
gridded data and some stations data) need to be shared within the data policy
framework to ensure better operation of the RCCs. Data available from
international bodies such as NCDC, GPCP etc. can also be used as a complement.
RCCs (BCC and TCC) and NMHS should strengthen links for exchanging the
required climate and real time data for the operation of climate watch system in the
region.

- Global climate information including climate analysis and LRF products which are
routinely made available through websites by various global centres should serve
to provide the global context when appropriate on an ongoing global climate
anomaly and its future evolution. This is the case for monitoring the ENSO event for
example. Regional climate monitoring and forecast products which are routinely
made available by the Regional Climate Centres in RA-II should serve as regional
guidance on climate anomalies and their evolving stages at regional scale.
Therefore they provide input for developing climate watch advisories which should
be further refined, targeted and adapted based on climate information and
expertise existing at national level. The forecast information from BCC and TCC
can be provided to NMHSs either through their web sites or through ftp servers.
The Korean Meteorological Agency (KMA) is a WMO designated lead centre for
Multi-Model Ensemble (MME) long range forecasting. KMA forecast products and
MME-LRF data can therefore be made easily available to the NMHSs.

- NMHS have also direct access to information and tools related to the analysis of
climate extremes and indices; these are provided by the Joint CCl/WCRP-
Clivar/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI)
using their website.
• Close coordination at national level between NMHSs and other scientific organisations and institutes should be established or strengthened. Interactions with the user communities should be developed by NMHSs when designing and operating climate watch system. There is a continuous need for capacity building for both users and providers to better understand each other and effectively cooperate in operating CWS. Also outreach and education programs need to be promoted for raising population awareness;

• At regional level, RCCs (at present BCC and TCC) should play an increased role in providing training to NHMSs about their existing capabilities in climate monitoring and LRF. There are also new capabilities developed by these Centers such as ClimatView, ITACS and extreme event data bases. There are also a number of specific requirements for NMHS to implement a climate watch system at national level; especially in developing countries. These include particularly upgrading climate infrastructure and strengthening the manpower; and the establishment of improved collaboration with other national organisations and institutes. Real opportunities exist in the region and should be used including participation in FOCRA-II meetings and other workshops and seminars; taking benefit of the visiting scholar and exchange programmes which are being promoted for example by BCC. At national level NMHSs can also easily organize national workshop for the users and the media.

Conclusions and recommendations
The main elements of climate watches were discussed during the plenary sessions of the workshop based on WMO guidelines on climate watches (WMO-TD No.1269 / WCDMP No. 58) and the existing capabilities at regional and national levels. The participative approach through working groups, involving climate experts and some participants from user sectors was very useful in developing a common vision on climate watches in the sub-region. Participants agreed on the urgent need for the establishment of a Climate Watch System as part of the implementation of the proposed GFCS. Collaboration between regional and national institutions in data exchange including historical data, databases for extreme events, climate products delivery, tools and capacity building were identified to be essential requirements for implementing a sound CWS. The implementations of a CWS in the sub-region should start soon and should be based on the existing regional institutions (RCCs) and NMHSs in close collaboration with sectors and users.

I- Recommendations for actions to be undertaken in the short term (1-3 months)

- Publication of the proceedings of the workshop (Participants to submit paper of their presentation within one month);
- Presentations and soft copy of the proceedings will be put in RCC websites (BCC/TCC);
- The RCC websites will give announcement about the upcoming meetings and other events relevant to the topic taking place in the region.
II- Recommendations for actions to be undertaken in the medium term (1 year)
- Participants from NMHSs in RAII are welcome to take part to FOCRAII which is organised in April each year. The organisers will send formal invitation to NHMSs. TCC is planning to have a meeting about how to use the GPCs products over the region;
- Pakistan Meteorological Department offered to establish a web-based discussion forum to follow-up on the implementation of climate watch system in RA-II;
- Dr Azmat Hayat Khan from PMD, Pakistan and Dr. Dushmanta Ranjan Pattanaik from IMD, India offered to coordinate with the RA-II RCCs to develop a project proposal for funding by APN on climate watches implementation in the sub-region.

III- Recommendations for regional mechanisms for collaboration on climate watches
- Use the existing WMO working group structure and focal points to further raise the needs and identify difficulties in implementing CWS and propose solutions; and inform on the progress made. The WMO working Group on climate will be the main WMO mechanism for this purpose;
- NMHSs in the region are encouraged to benefit from some existing programmes at BCC and TCC;
- The Regional Association will be informed about the need for data exchange within the region and with the RCCs (including historical and extreme events data) as part of the implementation plan of CWS.
1. Global and Regional Aspects
Summary of Session II:
International and Regional Projects and Activities relevant to Climate Watch Systems

Session Chair: Dr T C Lee, Hong Kong Observatory

Speakers:
Mr Omar Baddour, World Meteorological Organisation
Mr Norihisa Fujikawa, Climate Prediction Division, Japan Meteorological Agency
Dr Fumin Ren, Beijing Climate Center, China Meteorological Administration
Mr D. R. Pattanaik, India Meteorological Department
Ms Jeonghee Choi, Climate Prediction Division, Korea Meteorological Administration

Summary
Mr Baddour presented the rationales and requirements for implementing a Climate Watch System. In short, a Climate Watch System provides an integrated mechanism based on climate observations, data management, climate monitoring and assessment, medium and long range forecasts, and dissemination of climate information, products and advisories for sectors and end users. It is based on a set of guidelines and procedures which NMHSs can use in delivering climate advisories for national users (climate watches) aiming at heightening their awareness on an ongoing or expected climate anomaly and its negative impacts. The implementation of the system should be based on existing infrastructures and capabilities of NMHSs and regional climate institutions, particularly the Regional Climate Centers (RCCs). He referred to the WMO El-Nino update providing global climate watch/guidance which can be used by countries to develop national climate watches.

On behalf Dr Michelle L'Heureux from The NOAA Climate Prediction Center (CPC), Mr Baddour presented the CPC ENSO Alert System which has become operational in February 2009 as a showcase example of a national Climate Watch System.

Mr Fujikawa gave a summary of the improvement of the predictability of long range forecast utilizing coupled general circulation model (CGCM) and statistical methods and presented the model forecast products available from Global Producing Centers (GPCs) and WMO Lead Centre for Long-Range Forecast Multi-Model Ensemble (WMO LC-LRFMME) for implementing climate watches. He also reported that JMA will innovate a CGCM with higher predictability in 2010. Moreover, JMA has developed two web-based analysis tools, namely the ClimatView and the Interactive Tool for Analysis of Climate System (ITACS), to assist NMHSs in monitoring climate conditions and analyzing extreme climate events.

Mr Ren briefed the participants on a wide variety of climate related services conducted by BCC of China Meteorological Administration (CMA), including climate monitoring, long range forecast, regional climate center network, visiting scholar programme, FOCRAII, EAMAC, etc. He also stressed that a good coverage of historical climate data is very important for climate monitoring and assessment and the current data coverage in some parts of Asia needs to be improved. BCC proposed to set up a “Center for Monitoring and Assessment of Extreme Weather and Climate Events in Asia”. The purpose of the project is to develop a climate monitoring and assessment system and a data center for extreme weather and climate events in Asia.
Mr Pattanaik talked about the climate monitoring and long range forecast services provided by India Meteorological Department, including the use of NCEP Climate Forecast System (CFS) for Monthly and Seasonal Prediction. The importance of monsoon monitoring and forecasting to the economy and agriculture production in India were highlighted. The main challenges for seasonal forecast, in particular the prediction of monsoon precipitation over land, were also discussed.

Ms Choi presented the background and goals of the WMO Lead Centre for Long-Range Forecast Multi-Model Ensemble (WMO LC-LRFMME). She also introduced the website and available products of LC-LRFMME to the participants. The future development of LC-LRFMME and expected multi-model ensemble products were also discussed.

Issues related to the climate data exchange and sharing were discussed during the Session. Participants opined that climate data exchange/sharing in the region should be further strengthened via collaborative efforts between NMHSs and regional climate centres (TCC and BCC). Moreover, it was suggested that NMHSs could be involved in the analysis and verification of the skill of CGCMs in different regions.
INTRODUCTION

Climate Variability refers to variations in the mean state and other statistics (such as standard deviation, percentiles, occurrence of extremes, etc…) of climate, at all spatial and temporal scales beyond that of individual weather events. Such variability may result from natural internal processes within the climate system (internal variability), or variations in natural or anthropogenic external forcing (external variability).

Climate Change refers to a change in the state of climate that can be identified by changes in the mean and/or the variability of its properties, and that persist for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

However: the UN Framework Convention on Climate Change (UNFCCC) defines Climate Change as « a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods ». So UNFCCC makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.

Most recent findings on Climate Variability and Change come from the IPCC 4th Assessment Report (AR4), which represents the state of the art synthesis of peer-reviewed relevant literature. The IPCC website (http://www.ipcc.ch) gives access to several documents:

- AR4 Synthesis Report
- Summary for Policymakers
- WG1 Report: the Physical Science basis
- WG2 Report: Impacts, Adaptation and Vulnerability
- WG3 Report: Mitigation of Climate Change

OBSERVED CHANGES IN CLIMATE AND THEIR EFFECTS AND CAUSES

1. Robust findings

1.1 Warming of the climate system is unequivocal and illustrated by a large number of facts, e.g. the increase in global average air/ocean temperatures, the widespread melting of snow and ice, the rising global average sea level, etc…)

1.2 It is likely that the rate and duration of global warming during the 20th century exceeds natural variability of the past 1000 years.

1.3 Global total annual anthropogenic greenhouse gases (GHG) emissions have grown by 70% between 1970 and 2004. As a result, atmospheric concentrations of:
   - N₂O now far exceed pre-industrial values spanning many thousands of years;
CH4 and CO2 now far exceed the natural range over the last 650,000 years.

1.4 Many natural systems on all continents and in some oceans are being affected by regional climate changes.

1.5 Most of the global average warming over the past 50 years is very likely due to anthropogenic GHG increase, and it is likely that there is a discernable human-induced warming averaged over each continent, except Antarctica.

2. Key uncertainties

2.1 Climate data coverage remains limited in some regions and there is a notable lack of geographic balance in data and literature on observed changes in natural and managed systems, with marked scarcity in developing countries.

2.2 Analysing and monitoring changes in extreme events, including drought, tropical cyclones, extreme temperatures and the frequency and intensity of precipitation, is more difficult than for climatic averages as longer data time-series of higher spatial and temporal resolutions are required.

2.3 Effects of climate changes on human and some natural systems are difficult to detect due to adaptation and non-climatic drivers.

2.4 Difficulties remain in reliably simulating and attributing observed temperature changes to natural or human causes at smaller than continental scales. At these smaller scales, factors such as land use change and pollution also complicate the detection of anthropogenic warming influence on physical and biological systems.

DRIVERS AND PROJECTIONS OF FUTURE CLIMATE CHANGES AND THEIR IMPACTS

1. Robust findings

1.1 Model simulations that include estimates of natural and anthropogenic forcing are now able to reproduce large scale aspects of the observed surface warming over this past century. Details on the scenarios, variables and models can be found at the following web page: http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php

1.2 Model projections based on a range of possible scenarios suggest that climate changes over this century will be larger than what has been observed up until now.

1.3 The pattern of future warming where land warms more that the oceans and more in northern high latitudes is seen in all scenarios (Fig.1).
1.4 With current practices, global GHG emissions will:
   - continue to grow, even if GHG emissions were to be reduced sufficiently for
     GHG concentrations to stabilize,
   - cause further warming and sea level rise,
   - induce many changes in the global climate system that would very likely
     be larger than those observed during the 20th century.

Equilibrium climate sensitivity is very unlikely to be <1.5°C.

1.5 Some systems, sectors and regions are likely to be especially affected by climate change:
   - The systems and sectors are some ecosystems (tundra, boreal forest, mountain, Mediterranean-type, mangroves, salt marshes, coral reefs and the sea-ice biome), low-lying coasts, water resources in some dry regions at mid-latitudes and in the dry tropics and in areas dependent on snow and ice melt, agriculture in low-latitude regions, and human health in areas with low adaptive capacity.
   - The regions are the Arctic, Africa, small islands and Asian and African mega-deltas.
   - Within other regions, even those with high incomes, some people, areas and activities can be particularly at risk.


1.6 Impacts are very likely to increase due to increased frequencies and intensities of some extreme weather events. Recent events have demonstrated the vulnerability of some sectors and regions, including in developed countries, to heat waves, tropical cyclones, floods and drought, providing stronger reasons for concern as compared to the findings of the TAR.

2. Key Uncertainties

   - Uncertainty in the equilibrium climate sensitivity creates uncertainty in the expected warming for a given CO2-equilibrium stabilisation scenario.
Uncertainty in the carbon cycle feedback creates uncertainty in the emissions trajectory required to achieve a particular stabilisation level.

Models differ considerably in their estimates of the strength of different feedbacks in the climate system, particularly cloud feedbacks, oceanic heat uptake and carbon cycle feedbacks, although progress has been made in these areas since the TAR.

The confidence in projections is higher for some variables (e.g. temperature) than for others (e.g. precipitation), and it is higher for larger spatial scales and longer time averaging periods.

Aerosol impacts on the magnitude of the temperature response, on clouds and on precipitation remain uncertain.

Future changes in the polar ice sheets mass, particularly due to changes in ice flow, are a major source of uncertainty that could increase sea level rise projections. The uncertainty in the penetration of the heat into the oceans also contributes to the future sea level rise uncertainty.

Large-scale ocean circulation changes beyond the 21st century cannot be reliably assessed because of uncertainties in the melt water supply from the Greenland ice sheet and model response to the warming.

Projections of climate change and its impacts beyond about 2050 are strongly scenario- and model-dependent, and improved projections would require improved understanding of sources of uncertainty and enhancements in systematic observation networks.

Impacts research is hampered by uncertainties surrounding regional projections of climate change, particularly precipitation.

Understanding of low-probability/high-impact events and the cumulative impacts of sequences of smaller events, which is required for risk-based approaches to decision-making, is generally limited.

Several natural modes of climate variability have been identified and described, but their predictability is uncertain.

Do not yet have confident assessments of the likelihood of abrupt climate changes.

Insufficient understanding of effects of climate variability and change on extreme events.

Limited capabilities at regional scales.

Need better means for identifying, developing, and providing climate information required for policy and resource management decisions.

**MAIN IPCC AR4 FINDINGS ON ASIAN MONSOON VARIABILITY AND CHANGE**

South Asian monsoon variability occurs over a range of temporal scales from intra-seasonal to inter-decadal, dominated by inter-annual variations, sometimes associated with ENSO, and 30-60 day intra-seasonal oscillations.

Some broad aspects of Asian climate change show consistency amongst AOGCMs simulations: e.g. increased meridional tropospheric temperature gradients, likely weakening of monsoonal flows and of the tropical large-scale circulation, greater variability via warmer mean state giving more variability in atmospheric moisture. However, the effect of enhanced moisture convergence in a warmer, moister atmosphere dominates over any such weakening of the circulation, resulting in increased monsoonal precipitation.
There are substantial inter-model differences in representing monsoon processes, and a lack of clarity over changes in ENSO further contributes to uncertainty about future regional monsoon and tropical cyclones behavior. Annamalai et al. (2007) reported that just 6 of the 18 AOGCMs in the PCMDI MMD realistically simulated the seasonal cycle of monsoon rainfall for the 20th century, and only 4 exhibited robust ENSO-monsoon contemporaneous teleconnection. Lin et al. (2006) found in most AOGCMs intra-seasonal variance of precipitation smaller than observed; speed of the equatorial waves too fast, and persistence of precipitation too long. Key uncertainties are the role of aerosols, the interaction with decadal variability, and changes to monsoon extremes.

**CURRENT STATUS ON EXTREMES**

Several definitions of extremes can be found in literature:
- High impact events
- Exceedence of a given threshold (e.g., 95th percentile of daily precipitation amounts)
- Rare events (long return period)
- Unprecedented events (in the available record)

Extremes cover a wide range of space and time scales: from very small scale (e.g. tornadoes) to large scale (e.g. drought). One must recall the difficulty to determine statistically significant trends of very rare events (Frei and Schär, 2001).

Recent trends, assessment of human influence on the trend and projections for extreme weather events for which there is an observed late-20th century trend, have been summarized in the IPCC AR4 (Table 1).

<table>
<thead>
<tr>
<th>Phenomenon and direction of trend</th>
<th>Likelihood that trend occurred in the late 20th century (typically post 1980)</th>
<th>Likelihood of a human contribution to observed trend</th>
<th>Likelihood of future trends based on projections for 21st century using SRES scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warmer and fewer cold days and nights over most land areas</td>
<td>Very likely</td>
<td>Likely</td>
<td>Virtually certain</td>
</tr>
<tr>
<td>Warmer and more frequent hot days and nights over most land areas</td>
<td>Very likely</td>
<td>Likely (nights)</td>
<td>Virtually certain</td>
</tr>
<tr>
<td>Warm spells/heat waves. Frequency increases over most land areas.</td>
<td>Likely</td>
<td>More likely than not</td>
<td>Very likely</td>
</tr>
<tr>
<td>Heavy precipitation events. Frequency (or proportion of total rainfall from heavy</td>
<td>Likely</td>
<td>More likely than not</td>
<td>Very likely</td>
</tr>
</tbody>
</table>

Increases in the amount of precipitation are
<table>
<thead>
<tr>
<th>Event</th>
<th>Likelihood 1</th>
<th>Likelihood 2</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area affected by droughts increases</td>
<td>Likely in many regions since 1970’s</td>
<td>More likely than not</td>
<td>Likely</td>
</tr>
<tr>
<td>Intense tropical cyclone activity increases</td>
<td>Likely in some regions since 1970’s</td>
<td>More likely than not</td>
<td>Likely</td>
</tr>
<tr>
<td>There is less confidence in projections of a global decrease in numbers of tropical cyclones</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased incidence of extreme high sea level (excludes tsunamis)</td>
<td>Likely</td>
<td>More likely than not</td>
<td>Likely</td>
</tr>
<tr>
<td>Extra-tropical cyclones - Changes in frequency and position - Change in storm intensity and winds</td>
<td>Likely (consistent in AOGCM projections) Decrease in the total number of extra-tropical cyclones Slight poleward shift of storm track and associated precipitation, particularly in winters</td>
<td>Likely (consistent in most AOGCM projections, but not explicitly analysed for all models) Increased number of intense cyclones and associated strong winds, particularly in winter</td>
<td></td>
</tr>
</tbody>
</table>
over the North Atlantic, central Europe and Southern Island of New Zealand

More likely than not

Increased windiness in northern Europe and reduced windiness in Mediterranean Europe

Likely
(based on projected changes in extratropical storms)

Increased occurrence of high waves in most mid-latitude areas analysed, particularly the North Sea.

Table 1: Recent trends, assessment of human influence on the trend and projections for extreme weather events for which there is an observed late-20th century trend (IPCC, 2007).

The joint CCI/CLIVAR/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI):

i) has been coordinating an international effort to develop, calculate, and analyse a suite of 27 climate indices (http://cccma.seos.uvic.ca/ETCCDMI/list_27_indices.shtml), including indices of extremes with a view towards detection of external influence on extremes. Indices approach is the basis of ETCCDI strategy, and Fig. 2 illustrates the type of outcomes provided.

A user friendly workshop software has been written by Xuebin Zhang of Environment Canada, which uses the free statistical package “R”, does QC, homogeneity testing, creates the 27 different indices, and produces a variety of high quality graphs (available from: http://cccma.seos.uvic.ca/ETCCDMI/)

The software user guide is available in English and Spanish.

Very important: these indices have also been computed from GCMs used in IPCC AR4 for future climate (see Fig. 3).

ii) has been organising a series of regional workshops on Homogenization of time series, Climate Change detection, and assessment of Extremes (Peterson, T.C. and M.J. Manton, 2008) ((http://cccma.seos.uvic.ca/ETCCDMI/workshops.shtml)
Fig. 2: Trends (in days per decade, shown as maps) and annual time series anomalies relative to 1961–1990 mean values (shown as plots) for annual series of percentile temperature indices for 1951–2003 for (a) cold nights (TN10p), (b) warm days (TX90p). The red curves on the plots are nonlinear trend estimates obtained by smoothing using a 21-term binomial filter (Alexander et al., 2006).

Fig. 3: Changes in precipitation indices based on multi-model simulations from nine global coupled climate models (Tebaldi et al., 2006).
IPCC-AR4 states that “confidence has increased that some extremes will become more frequent, more widespread and/or more intense during the 21st century”. This is well illustrated by the heat wave that stroke Western Europe in Summer 2003, and killed more that 50,000. Fig. 4 allows to estimate the return period of such an event in Switzerland, which appears to amount to several thousand years, a result comparable to data derived for France.

Fig. 4: Evaluation of return periods of Summer temperatures for an average of 4 Swiss stations (Zürich, Basel, Berne, Geneva) (Schär et al., 2004)

According to climate modelling using the French ARPEGE global climate model, summer temperatures like those registered in 2003 will have a return period of typically 2-3 years by 2070-2080 (Fig. 5).

Fig. 5: Observed and projected summer temperatures for France. Green squares: observations; Yellow triangles: modeled values.

This means that there is a clear need to consider climate change when trying to assess large return period quantiles, especially when these values are used for
designing long-lived installations such as nuclear power plants, or any other large installation of this kind (big buildings, bridges, harbours, dykes, …).

Currently, design criteria for (safety of) infrastructure are traditionally based on historical observations and rely on return periods of extreme events, assuming a stationary climate. Several reference methods, e.g. Peak Over Threshold (POT), Generalized Extreme Value distributions (GEV), Gumbel, are used to fit extreme value distributions to selected observations of extremes.

Alternative approaches for estimating return periods of extremes in that way include the following:

- It is possible to account for non-stationary conditions, e.g. use statistical approaches that account for changes in extremes by making the parameters of the corresponding statistical models time-dependent (Parey et al., 2007), but the best way to do this is still under debate;
- Formal Climate Change detection studies on extremes using climate models and predicted probability density functions (Fig. 6) begin to appear, despite challenges, e.g. Kharin and Zwiers, 2005; Kharin et al., 2007 (Fig. 7), which probably already allow to assess modifications of return periods of extremes at regional level.

Fig. 6: Probability density functions from different studies for global mean temperature change for the SRES scenarios B1, A1B and A2 and for the decades 2020 to 2029 and 2090 to 2099 relative to the 1980 to 1999 average (IPCC, 2007).
Fig. 7: Boxplots of relative changes (%) in the waiting times for late-twentieth-century
P20 (averaged 20-yr return values of 1981–2000 annual extremes of 24-h
precipitation amounts) as simulated by 14 IPCC AR4 models in 2046–65 relative to
1981–2000 with the SRES B1 (blue), A1B (green), and A2 (red) emission scenarios.
The boxes indicate the central 50% inter-model range and the median. The whiskers
extend to the lower and upper model extremes (Kharin et al., 2007)

The ETCCDI recently organized a dedicated Workshop on “Extremes in a changing
Climate” (see http://www.knmi.nl/samenw/ensembles_rt5/etcddi/debiltmeeting/), and
published a guidance document WCDMP-72 (WMO TD-100) entitled “Guidelines on
Analysis of extremes in a changing climate in support of informed decisions for
adaptation” available at http://www.wmo.int/pages/prog/wcp/wcdmp/wcdmp_series/
documents/WCDMP_72_TD_1500_en_1.pdf
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Climate Change and Environmental Management issues in South Asia with special focus on Bangladesh

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Abstract
Climate change related adverse impacts are affecting all South Asian countries including Bangladesh. The intensity and frequency of severe and recurrent floods, erratic rainfall, cyclones, storm surges and droughts are increasing in the recent years causing loss of lives and properties, increasing fresh water scarcity, destroying infrastructures, damaging food security and creating severe socio-economic and health problems for the people of these countries. Bangladesh are considered as one of the most vulnerable countries of the world to the adverse impacts of global warming and climate change for its low and flat topography, low natural resource base, high population density, extreme poverty and its low capacity to adapt to the natural disasters. During the last 25 years Bangladesh has experienced six severe floods and three devastating cyclones. During the last 40 years 15 major cyclones hit different coastal districts of Bangladesh of which 11 cyclones caused human deaths. The 1970, 1991 and 2007 and 2008 were the most devastating with major death toll of about 300000, 138000, 3363 and 200 with several billion dollars of damage cost. Besides droughts, salinity intrusion and sea level rise are also deteriorating the socio-economic condition of the country. Bangladesh should build adaptive capacity to climate change and managing climate risks through mainstreaming of climate risk into sustainable development strategies. Countries of South Asia need to strengthen the coordination, cooperation, networks and information flows for proper disaster management to reduce climate risks and effectively adapt to the effects of disasters.

INTRODUCTION
Climate change is a global issue. The climate of our planet has been changing continuously and rapidly. The scientists believe that the emissions of carbon dioxide, methane and nitrous oxide and other gases form energy, industry, agriculture and land use change and forestry and waste sectors have caused global warming in the troposphere, which subsequently caused irreversible change of global climate. The present global mean temperature has increased by about 0.7°C during the last 100 years with respect to 1990. Precipitation patterns have changed, glaciers retreated and the arctic ice cap and the Greenland ice sheets have been melting. As a result sea level has risen by 1.8 mm/yr during the period 1961-2003 which has been accelerated to a much faster rate of 3.1 mm/yr in the recent decade (1993-2003). The sea level rise is caused by the volumetric thermal expansion of the sea water and melting of the polar ice. In the present paper, the climate change and environmental management issues in South Asia are focused with special emphasis on Bangladesh case.

CLIMATE CHANGE IMPACTS IN SOUTH ASIA
All South Asian countries are experiencing climate related disasters more frequently than earlier. Specially eastern Himalayan glaciers are melting at faster rates bringing too much water for Bangladesh, India, Nepal, Bhutan and Pakistan causing devastating floods and landslides, worsening fresh water scarcity, damaging food
security and creating severe social, economic and health problems for the people of these countries.

On the other hand the South Asian countries may face severe water crisis if full loss of glaciers happen in the coming decades. In that case crop yield would decrease up to 30% in central and South Asia by the mid-21st century. It is projected that the number of deaths, diseases and injury due to floods, cyclones, storm surges, droughts, cold spells and heat waves will increase as a result of climate change included enhancements of disasters in South Asia. Severe and recurrent floods in Bangladesh, Nepal and India in 2002-2003, 2004 and 2007 caused heavy loss of lives and property. Erratic rainfall in Mumbai, India (944mm in 2 days in 2005) led to loss of over 1000 lives with loss of resources more than US $250 million. 730mm rainfall in Sri Lanka on 17 May 2003 caused floods in Southern province of Sri Lanka and 408mm rainfall in Chittagong in Bangladesh on 11 June caused landslide, killing 124 people in 12 hours, 438mm rainfall on 28 July 2009 caused heavy drainage congestion in the capital city Dhaka, Bangladesh are also due to the adverse impacts of climate change. Consecutive droughts occurred in 1999 and 2000 in Pakistan, in 2000, 2002 and 2006 in India in1951,1957, 1958, 1961, 1986, 1972, 1979, 1989, 1995 and 2007 in Bangladesh caused crop failures, mass starvation due to sharp decline in water tables in some parts of these South Asian countries among others. The frequency and intensity of cyclones is also increasing in South Asia in the recent years.

**BANGLADESH’S VULNERABILITY TO CLIMATE CHANGE**

Bangladesh is considered to be one of the most vulnerable countries to the adverse impacts of the climate change because of its geographical location and physiographic conditions and low capacity to adapt to climate change related disasters.
Bangladesh with an area of about 147,570 sq.km is located in the tropics between 20°34´ and 26°38´ north latitude and 88°01´ and 92°41´ longitude in South Asia and is bounded by India on the west, north and north east and Mymanmar on the south-east and the Bay of Bengal in the south. The Himalayas is close to the northern border of Bangladesh. Except the hilly regions in the northeast and the south east (about 12 percent), some areas of highlands in the north and north western part (about 8 percent) of the country. The rest areas of country mainly the flood plain consists of low and flat land. Thus two third of the country is less than 5 meters above mean sea level. Three major rivers-The Ganges, the Brahmaputra and the Meghna meet inside Bangladesh before discharging to the Bay of Bengal through a single outfall.

Bangladesh is a country with low natural resource base, high population density (1045/km²), low average income (less than US$1 per day 29%, less the $ 2 a day 84%). The economy of the country is mainly dependant on agricultural resources.

Bangladesh has a tropical monsoon climate. The climate of Bangladesh is influenced by the Himalayan monsoon chain and the Indian Ocean. The climate is controlled by the summer and winter winds and partly by pre monsoon and post monsoon circulation. In general the climate is characterized by high temperature (up to 43°C), heavily rainfall (average annual rainfall is about 2,200mm), often excessive humidity (over 80%) during monsoon (June to September) (Salehin, M et al, 2009).

The mean annual temperature is about 25°C within the country. The country has hot and humid summer during March to February. The mean monthly temperatures range between 18°C in January and 30°C in the months from April to May. The highest and lowest temperatures throughout the year range between 43°C and 4°C with the exception in the areas near the coast where the range is narrow.

Table 1. Trends of country average seasonal and annual mean maximum and minimum temperature (°C/decade) of Bangladesh for the period 1948-2004.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Winter</th>
<th>Pre-monsoon</th>
<th>Monsoon</th>
<th>Post monsoon</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>T.Max</td>
<td>-0.048</td>
<td>-0.1</td>
<td>0.133</td>
<td>0.23</td>
<td>0.046</td>
</tr>
<tr>
<td>T.Min</td>
<td>0.16</td>
<td>0.053</td>
<td>0.052</td>
<td>0.13</td>
<td>0.094</td>
</tr>
</tbody>
</table>

The annual mean temperature and rainfall exhibits increasing trends during the last few decades. (Source: Quadir, 2008; personal communication)
Table 2 Trends of seasonal and annual rainfall (mm/decade) using the data for the period 1948–2004 (57 years).

<table>
<thead>
<tr>
<th>Seasonal Trends of rainfall (mm)</th>
<th>mm/decade</th>
<th>% /decade</th>
<th>Change of rainfall (mm) in 50 years</th>
<th>R2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>5.6</td>
<td>16.1</td>
<td>27.9</td>
<td>0.025</td>
</tr>
<tr>
<td>Pre-monsoon</td>
<td>21.4</td>
<td>5.0</td>
<td>107.2</td>
<td>0.065</td>
</tr>
<tr>
<td>Monsoon</td>
<td>21.2</td>
<td>1.3</td>
<td>106.1</td>
<td>0.030</td>
</tr>
<tr>
<td>Post-monsoon</td>
<td>-0.5</td>
<td>-0.2</td>
<td>-2.4</td>
<td>0.000</td>
</tr>
<tr>
<td>Annual</td>
<td>50.3</td>
<td>2.2</td>
<td>251.4</td>
<td>0.065</td>
</tr>
</tbody>
</table>

From the trend analysis of rainfall data for the period 1948-2004 it has been revealed that the rate of rainfall has increased by 5.6, 21.4, and 21.2 mm/decade for the winter, pre-monsoon and monsoon seasons respectively. (Source: Quadir, 2008, personal communication)

Climate Change Scenarios
For Bangladesh in early stages researchers have used expert judgments to come up with climate scenarios. With the proliferation of computer assisted Atmosphere Ocean Global Circulation Models (AOGCM), scientifically more acceptable scenarios have been developed in the second stage. Only in recent times, with further development of regional models as well as strengthening of computational capabilities, scenarios have been developed by using Regional Climate Models.

Table- 3: The climate change projections for 2050 and 2100 with the year 2000 as the reference years based on AOGCM results using MAGIC 5.3 of NCAR are shown here. (Quadir, 2008, personal communication)

<table>
<thead>
<tr>
<th>Year</th>
<th>Parameter</th>
<th>DJF</th>
<th>MAM</th>
<th>JJA</th>
<th>SON</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>2050</td>
<td>Temp (C)</td>
<td>1.7</td>
<td>1.9</td>
<td>1.4</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>2100</td>
<td></td>
<td>3.6</td>
<td>3.5</td>
<td>2.6</td>
<td>3.1</td>
<td>3.3</td>
</tr>
<tr>
<td>2050</td>
<td>Rainfall (%)</td>
<td>10.5</td>
<td>15</td>
<td>11</td>
<td>7.5</td>
<td>10.4</td>
</tr>
<tr>
<td>2100</td>
<td></td>
<td>25</td>
<td>25.4</td>
<td>22.5</td>
<td>13</td>
<td>18.4</td>
</tr>
</tbody>
</table>

DJF: December, January and February; MAM: March, April and May; JJA: June, July and August and SON: September, October and November

Impacts of climate change in Bangladesh
Global warming and climate change has intensified the frequency and intensity of the natural disasters in Bangladesh causing recurrent floods, flash floods, sea level rise, salinity intrusion, coastal erosion, river bank erosion, draughts, heat waves, cold spells, diarrhea and vector borne diseases particularly dengue that are affecting our
country frequently. These disasters have adverse impacts on communication, water logging and drainage congestion, bio-diversity and forestry, fisheries, human health and on fresh water availability (Hossain, S.M.2008).

The country’s geographical location, high dependence on the overall GBM regional hydrology, spatial and temporal distribution of water resources-all contribute to the high degree of susceptibility of Bangladesh to water related extreme events (Ahmed et al., 1998). In order to appreciate the future vulnerabilities to climate change, it is necessary to understand the interrelationship between climate regime and associated risks in the form of water related disasters. A combination of upstream inflows and runoff generated from rainfall within the country feed all the rivers, canals, creeks, natural and man made seasonal and/or perennial reservations and all other forms of water bodies which constitute the natural surface water resources of Bangladesh (Ahmed, 2009). Thus the huge inflow of water from upstream catchments areas coinciding with heavy monsoon rainfall in the country, a low flood plain gradient, congested drainage channels, the major rivers converging inside Bangladesh, tides and storm surges in coastal areas, and polders that increase the intensity of floodwater outside protected areas. Different combinations of these various factors give rise to different types of flooding (Ahmed and Mirza, 2000).

Floods

Flood affected about 80% of land in Bangladesh and the four main types of floods are: flash caused by overflowing of hilly rivers, inflow of water from upstream catchments (river floods), rain floods caused by drainage congestion and heavy rains and coastal floods due to storm surges.

In the last 25 years, Bangladesh has experienced six severe floods. In 2007, two successive and damaging floods inundated the country in the same season. These floods caused heavy loss of human and animal lives, and substantial damage to infrastructure, housing, agriculture and livelihoods (Hossain, S.M.2008)

Fig. 3: Flood prone areas of Bangladesh
Severe floods in the last 25 years
Estimated damages caused by the severe floods in the last 25 years are given below:

<table>
<thead>
<tr>
<th>Flood</th>
<th>Estimated Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td>US$ 300 million, more than 500 deaths</td>
</tr>
<tr>
<td>1987</td>
<td>US$ 378 million, 2055 deaths</td>
</tr>
<tr>
<td>1988</td>
<td>US$ 1.2 billion, 2000-6500 deaths</td>
</tr>
<tr>
<td>1998</td>
<td>US$ 2.8 billion, 1100 deaths</td>
</tr>
<tr>
<td>2004</td>
<td>US$ 52 million, 700 deaths</td>
</tr>
<tr>
<td>2007</td>
<td>US$ Over 1 billion, 649 deaths</td>
</tr>
</tbody>
</table>


Cyclones
In every three year, a severe tropical cyclone hits Bangladesh coast. These storms generally form in the months just before and after the monsoon and intensify as they move north over the warm waters of the Bay of Bengal. They are accompanied by high winds of over 150 km/hr and can result in storm surges up to seven meters high, resulting in extensive damage to house and high loss of life to humans and livestock in coastal communities (Climate Change Strategy and Action Plan, 2008).
During the last 38 years (from 1970 to 2008) about 85 cyclones were formed in the Bay of Bengal. 15 major cyclones hit different coastal districts of Bangladesh of which 11 cyclones have caused human deaths.

The cyclones of 1970, 1991 and 2007 were the most devastating with major death toll of 300000 in 1970, 138000 in 1991 and 3363 in 2007. The damage costs of these three catastrophic cyclones were about US$ 86.4 million, 1.5 billion and 3 billion respectively ((Hossain, S.M.2008 & Disaster Management Bureau). More than 200 people were killed by the recent Cyclone “Aila” which hit Bangladesh on 25 May, 2009. About 2 million people were severely affected by this cyclone with huge damages of crops, properties and infrastructures.

Photographs of the devastation caused by Cyclones “Sidr”&“Aila”(Source: S.M.Hossain)
DROUGHT

It is prognosticated that, under climate change scenario evapo-transpiration will increase significantly, especially during the post-monsoon and pre-monsoon seasons, in the backdrop of diminishing rainfall in winter and already erratic rainfall variability over time and space (Karim et al.1998). Bangladesh experiences long spells of dry weather and moderate to severe droughts spreading over a region of 5.46 million ha (Salehin. M et al.,2009). Drought most commonly affected the north-western part of Bangladesh which generally has low rainfall than the rest of the country. The drought areas of Bangladesh are shown in the figure.

Fig. 4: Drought prone Areas of Bangladesh

SALINITY INTRUSION
The effect of saline water intrusion is highly seasonal in Bangladesh. Saline water intrusion is minimum as the salinity front in estuarine and flood plains greatly push back during the monsoon (June-September) when the river discharge about 80% of the annual fresh water flow. Environmental degradation caused by salinity intrusion is a major problem in south western Bangladesh. The reduced flow of the river Ganges in the dry season has exacerbated the process of northward movement of the salinity front, thereby threatening the environmental health of the region (Ahmed, A. U, 2009).
Fig. 5: Salinity affected areas of Bangladesh

According to soil Resource Development Institute the salinity affected area of the country was 0.833 million hectors in 1973 where as the area has extended up to 1.20 million hectors by 2000.

Sea Level Rise
The rate of sea level rise is increasing during the last few decades (4-7.8mm/yr) along the coastal belt that would not only inundate low-lying areas along the coast, it would also create a favorable condition for saline water to overtop the flood protecting coastal embankments, specially when induced by strong winds. The trends of sea level rise are 4.0 mm/year at Hiron point, 6.0 mm/year at Char Changa and 7.8 mm/year at Cox's Bazar of Bangladesh

Fig. 6: Trends of sea level rise at different points, mm/year
Climate Change activities in Bangladesh

The first climate change study in Bangladesh was initiated under United States country study programme over the period 1994 -1996 to prepare greenhouse gas emission inventory for the year 1990 and assess vulnerability of water, coastal resources and partially agriculture sectors.

The second project “Asia Least-Cost Greenhouse Gas Abatement Strategy” (ALGAS) was implemented with 12 other participating countries during 1995-1997 for updating greenhouse gas inventory for 1990 and least cost mitigation strategies for the energy and forestry sectors.

Bangladesh as a signatory to the United Nations Framework Convention on Climate Change (UNFCCC) and pursuant to Article 4.1 and 1.2.1 of UNFCCC has prepared its Initial National Communication (INC) and submitted to UNFCCC in 2002.

Bangladesh was also among the first countries to prepare and submit its National Adaptation Programmes of Action (NAPA) with the UNFCCC secretariat in November 2005. NAPA provides a process to identify priority activities that respond to its urgent and immediate needs with regard to adaptation to climate change.

Bangladesh Climate Change Strategy and Action Plan, 2008 has been recently approved by the Cabinet which have six pillars:

1. Food security, social protection and health;
2. Comprehensive disaster management;
3. Infrastructure development;
4. Research and knowledge management;
5. Mitigation and low-carbon development; and
6. Capacity building and institutional development

The Action Plan will be an integral part of national development policies, plans and programmes.

Second National Communication

Bangladesh is now preparing its Second National Communication (SNC). There are 5 activities (components) in the SNC:

- National Circumstances
- Green House Gas Inventory
- Programmes containing measures to mitigate climate change
- Programmes containing measures to facilitate adaptation to climate change
- Plans and programmes considered relevant towards achieving the objectives of the UNFCCC and prepare the report and submit to the CoP

Climate Risk Management & Adapting to climate change

The People of Bangladesh have adapted over generations to the risks of floods, droughts and cyclones. Government has also taken various steps to adapt the adverse impacts of climate change.

Bangladesh has developed comprehensive Disaster Management System where the government machineries, community and the stakeholders participate hand to hand to adapt and cope the impacts of disasters. The floods of 1988 and 1998 and the cyclone “Sidr” of 2007 may be cited as examples. During cyclone “Sidr” the cyclone preparedness programme (CPP) with the help of local administration, community leader and NGO workers mobilized its 44000 volunteers for immediately start to implement a community based warning system utilizing megaphones and other devices. Bangladesh has 2400 cyclone shelters in high risk areas. Over 1.5 million people were moved to shelters during this cyclone (Source: Bangladesh
Meteorological Department). Hence the loss of lives and damage to properties were less than the past. Otherwise it could exceed all the past records. During the floods the Govt. had also taken initiatives to issue timely and accurate warning to protect and prevent loss of lives and properties.

The other activities where the government had the prime contributions are as follows.

Bangladesh Government has undertaken initiatives to build new embankments where necessary and repair the old ones to protect its people from flood and also taken initiatives for dredging rivers to make rivers navigable and to remove drainage congestions.

Bangladesh Government has also undertaken initiatives for necessary drainage to flush out the water; imposed appropriate land use / fisheries activities in the water logged areas, constructed about 2400 cyclone shelters and planning to construct more cyclone shelters with minimum facilities of water and sanitation for gents and ladies.

Bangladesh Government has already constructed 6000 km of embankments to resist the floods and storm surges. Adequate numbers of strong embankments with regular maintenance are needed to fight the floods and storm surges.

Government has already developed a large belt of mangroves which are helpful to mitigate the cyclones and storm surges. More areas are to be afforested so that the strong coastal green belt guards the coastal zone against the tropical cyclone and storm surges.

We should take necessary initiatives to strengthen the national warning and forecasting techniques to ascertain reliable and timely forecast, provide training to community leaders and provide facilities of radio and mobile telephone connectivity for listening the weather forecast.

Bangladesh Government has created Climate Change Fund in 2009, with an allocation of about 142 million US$.

- Made climate change an integral part of the new draft Poverty Reduction Strategy Paper (PRSP)
- Established Climate change Cell at Department of Environment
- Developed Future climate change scenarios (temperature, rainfall) using climate prediction model PRECIS
- Conducting research on:
  - Future impact of climate change on flooding
  - Climate resilient crop varieties
  - Salt and drought tolerant crop varieties
  - Early maturing crop varieties
  - Flood resilient housing, improved fishing boat etc.

Meanwhile Bangladesh has already developed some salt and early maturing crop varieties. At the same time Bangladesh has already undertaken initiatives to build a climate resilient Bangladesh. For this purpose the country has started to construct climate resilient infrastructure:

- Housing and settlement
- Roads and highways (Raising current plinth level)
- Coastal polders (Increase height, better drainage system)
Conclusions and Recommendations
Bangladesh has experienced most of the common problems of climate change such as atmospheric warming, enhanced floods, river bank erosion, droughts, tropical cyclones, storm surges and inundations of the coastal zone due to sea level rise. So protecting Bangladesh and solving its problems will show the tracks for other nations to solve their problems of climate change impacts.

It is true that Bangladesh is one of the highly disaster prone countries of the world with extremely limited resources. Its real development is not possible without the integration of climate risk management policies in the development processes. Now Bangladesh is marching forward to establish a well coordinated disaster management to reduce climate risk and mitigate the effect of disasters.

Bangladesh and South Asian countries should strengthen national weather and climate service, increase regional climate cooperation and enhance capacity of SAARC Climate Office and SAARC Meteorological Research Centre (SMRC).

At the same time we should strengthen the technical and institutional capacity of the government, private organizations, NGOs and other stakeholders in mainstreaming climate change concerns into country’s sectoral and national development planning priorities and ascertain national, regional and global cooperation and coordination to reduce overall vulnerability of the country to climate change related adverse impacts, facilitate to efficiently adapt to climate change and ensure a climate resilient development in all spheres of life in our country.
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1.3 The poor weather early warning system in Tohoku District, Northern Japan, for agriculture

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The purpose of the presentation is to present an early warning system which is based on meteorological observation and forecast data, and provides agricultural warning information for farmers.

Tohoku District is located in the northern part of Japan. It lies to the south of Hokkaido and occupies the northern part of Honshu. Its climate zone is classified as temperate rainy climate (Cfa), but in winter there is a lot of snow. Tohoku district has a cool climate, abundant water resources, and has a lot of farming. The major industry in Tohoku is agriculture. The rice productivity is high: 28% of rice production in Japan comes from Tohoku District.

The agricultural history of Tohoku District is as follows; Rice has been planted since the Middle Ages. During the Medieval Warm Period (10-14th century), rice was well harvested. However, during the Little Ice Age (14-19th century), Tohoku District frequently suffered cool weather damage to crops. Farmers have experienced terrible famines, in particular in the Tenmei famine in 1783, several hundred thousand people died. Recently, cool summers have frequently occurred again and rice crops in Tohoku District are sometimes damaged by cool weather.

The time series of summer temperature indicates that the magnitude of year to year variation in summer temperature differs before and after the late 1970s (Fig.1). From the 1960s to the early 1970s, the year-to-year variation was small, but after the late 1970s, year to year temperature fluctuations were large, generating a cycle of cool and hot summers. Since rice production in the Tohoku District is principally determined by temperature, its harvest also fluctuates with greater magnitude after the regime shift. From the late 1970s, Tohoku District frequently experienced cool summers. Summers in 1980, 1993 and 2003 were the particularly damaging years, and especially in case of 1993, caused big social problems related to food supply. On the other hand, hot summers have also frequently appeared after the regime shift, and sometimes rice has been damaged by high temperatures. So, in northern Japan, temperature variations after the regime shift have had a strong effect on agriculture. In 2003, the rice production index in Tohoku District was 80 and the total amount of the crop damaged was 29.4%. Breaking down the damage rate, 23.3% was caused by sterility due to low temperatures and 5.3% was due to rise blast disease. Therefore, low rice yield is produced by two major factors in Tohoku District: low temperatures and disease in cool summers.

To reduce the agricultural damage by cool weather, the Early Warning System for Rice (ver.1) was developed in 1996 by National Agricultural Research Center for Tohoku Region (NARCT). That system was primary operated based on the meteorological observation data and produced information about the rice growing stage, low temperatures, and diseases warnings. Following the cool weather damage
in 2003, Early Warning System (ver.2) was developed in 2006. This new system is using meteorological forecast data (GSM) and produces information several days in advance.

The current early warning system uses two kinds of meteorological data: One is numerical simulated forecast data and the second is meteorological observation data. In regards to the forecast data, daily GSM data is sent from JMA to Japan Weather Association (JWA) and then the first downsizing process is performed using a local numerical simulation model, reducing the data from the 20 km to a 5 km square mesh size. Next, a second downsizing process is performed from the 5 km to a 1 km square mesh size. This process is statistical, as opposed to dynamical, and uses an interpolation formula in proportion to the distance. In regards to the observation data, we are able to use the Japanese meteorological observation network (Automated Meteorological Data Acquisition System: AMeDAS). In this network system, meteorological observation stations are located with about 20 km density all over Japan. The meteorological station data is interpolated using statistical formulae from ca. 20 km to 1 km square mesh size.

Through those processes, we have available 1 km square mesh data for both forecast and observations. Next, these 1 km mesh data are applied in a crop growing model and rice blast forecasting model. The resulting agricultural information data is expressed on the web site.

The agricultural information now produced is: Rice crop growth estimation for two major varieties: Akitakomachi, Hitomebore, and two planting styles: direct seeding and transplant, low temperature warning for rice sterility (Fig.2), high temperature warning for rice quality drop (Fig.3), and rice blast disease warning (Fig.4).

Rice blast is the most serious crop disease in Japan. The right photo shows rice blast on the leaf and left photo is on the ear of the rice plant. The hyphae of rice blast infects the plant from leaf to ear and the rice yield is decreased. Rice blast usually spreads in cool summers and sometimes decreases rice yield. The suitable conditions for rice blast are: temperature from 20 to 25°C, cloudy with fog or drizzle, and humid. Agricultural chemical spraying when rice blast grows on the leaf is effective against its growth. So, we forecast conditions conducive to rice blast growth using meteorological data and inform farmers of the best timing for chemical spraying.

We call the rice blast forecast model ‘BLASTAM’. BLASTAM needs 5-day mean temperature and two days of hourly temperatures, wind speed, sunshine duration, and precipitation data. In former studies, only past observation data were used, however, the current system uses numerical simulation data which extends the rice blast forecast from today to several days in the future.
Fig. 1: Time series of summer temperature anomalies and rice production indices of Tohoku District from 1950 to 2009

Fig. 2: Forecast of low temperatures caused by the Yamase wind over three days

Fig. 3: High temperature warning for rice quality drop. Milky rice possibly occurs in cases when the minimum temperature is over 24°C about 20 days after heading
Fig. 4: Rice Blast warning. Users can see map information: city name, railway, river and road, and then easily to find the 1 km mesh including their paddy field.
I. Introduction: Inter-annual variations can affect global and regional atmospheric and oceanic circulation. Many of these variations are recurrent and are usually depicted with well known climatic patterns such as the El Nino Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO), warming/cooling of Sea Surface Temperatures (SST) in the tropical oceans, strengthening/weakening of the upper level Jets, etc. They correlate significantly with the departures from the mean state of climate parameters at monthly, seasonal and annual time scales and with the onset of extreme climate and weather events leading to direct and indirect consequences on lives, goods, properties and the well being of societies. Droughts, heat waves, cold waves, flooding, extreme wind storms, land slides, bush and forest fires, costal erosions to list just these are the most popular induced impacts which may be triggered by one or several of such anomalies. In the context of global warming these extremes are expected to become in the future more frequent, more severe and gaining more geographical extend than usually known (IPCC 4AR). Some of the observed increase in climate extremes already fit in these projections.

Setting up an efficient warning system against climate anomalies and related extremes has been for more than a decade a focus of the WMO and the NMHSs to improve climate risk management capabilities among nations. Such climate warning system e.g. climate watch systems are designed to provide advisories (climate watches) to inform the users, particularly those involved in natural hazards preparedness, mitigation and response on ongoing, pending and/or expected climate anomalies and their negative impacts. To this effect, National Meteorological and Hydrological Services (NMHSs) should be adequately equipped and prepared to continuously monitor and assess the state of the climate, evaluate available long range forecasts, and where conditions warrant provide to the users concise and understandable climate early warning information at weekly, 10-day, monthly, and seasonal time scale.

II. System components and requirements
Climate Monitoring
The availability of quasi-real-time and historical climate observations is necessary for an efficient monitoring and forecasting of extreme climate events. Monitoring climate extremes usually requires high-quality and high resolution data. Therefore a good quality observation network able to capture the space and time features of climate events is necessary. At national level, such network should be manageable in an integrated way including central real time data collection system and robust climate data management facilities. This infrastructure should enable a quick access and retrieval of current and historical data along with adequate applications to perform climate analysis to the required accuracy. Climate data bases and users data bases need to be set up together to analyze climate hazards and related impacts; the use of GIS helps integrating both data bases in an efficient manner and allows customized criteria for climate watches. Climate monitoring has been strengthened by using
space based observations which provide useful environmental information needed to assess the intensity and the extent of climate related hazards.

**Long range forecasting**
The System uses also long range forecasting products which are provided by Global Producing Centres, Regional Climate Centres; and consensus forecasts provided by regional climate outlook forums should be considered whenever made available. Adaptation and downscaling of these products at the scale pertinent to the geographical scope covered by climate watches are also required and should be based on scientifically sound techniques and methods.

**Outputs**
The outputs of a climate watch system include initial climate watches outlining the ongoing and/or expected climate anomaly; updating statements at users-agreed time intervals informing them on the progress of the anomaly; and final statements stating the expiration of the warning. The content, format and dissemination plan of climate watches should consider specific purposes and geographical scope as required by the target users. It is also important that the system includes a verification procedure of its performance and that verification should be carried systematically as an integral part of the system operation. Users should be informed on the verification results on regular basis. This enables building a trust between the issuing organization and the users and to assess the effectiveness of the criteria which were jointly set up with them. On the long term the verification allows a knowledge asset needed for performance improvement.

**III. System requirements**
The issuing organization (NMHS) needs to meet a minimum set of requirements for operating climate watch. It should be able to run the following climate functions on operational basis:

- Provide timely observations of current climate conditions for their areas of responsibility and adequate historical climate data;
- Perform timely monitoring and analyses of current climate anomalies;
- Access to current global climate forecasts and the technical capabilities to interpret and downscale them to their region;
- Deliver probabilistic climate forecast products that are understandable by the user community;
- Continuously update records of past forecasts and analyses of past forecast performance;
- Employ effective methods for the routine dissemination of climate information to user groups and sectors;
- Develop active collaboration and feedback mechanism with the user community to provide guidance for the design of climate watches and evaluate their effectiveness.

If some aspects of these requirements are lacking, they need to be developed. There are two aspects to consider simultaneously when planning for building capacity in climate watch systems. One aspect includes those activities required to ensure that NMHS personnel have the capabilities to operate climate watch system. The second is building capacity of the users which requires dedicated and sustained efforts that are best achieved by regular interaction and partnership. This aspect
needs a parallel outreach program to ensure an adequate use of the system outputs and understand its limitation and where improvements are expected to be made.

IV. Supporting programs and activities
At global level, the WMO World Climate Data and Monitoring Program (WCDMP) facilitate the international efforts in Climate Data and Climate Monitoring. It produces the WMO annual statements on the status of the global climate which highlight major global and regional climate anomalies occurring during the year. This publication and others provide users which operate at global, regional and national level useful information with respect to the geographical extent and time frame of various climate extremes such as droughts, heat waves, flooding, heavy precipitations and tropical cyclones. In parallel, efforts have been taken to build NMHSs capacities in Climate Data Management, Data Rescue and, currently in implementing climate watches in developing and least developed countries.

Since 1997 WMO has been issuing the “El Niño Update”, it is the fruit of cooperation between WMO and the International Research Institute for Climate and Society, with contributions from many meteorological services and regional centres and organizations. The El Niño updates are coordinated by the WMO World Climate Applications and Services Program (WCASP). On another hand, WMO has established procedures and guidelines for the designation of WMO Regional Climate Centers (RCCs). These Centres are the main regional WMO operational climate institutions which provide regional products e.g. climate analysis, long range forecasts as well as regional data sets and maps. These products serve as input to operate climate watch systems by NMHSs at national levels. RCC designation process has already started in region II and VI.

In Africa, the monthly Climate Watch Africa bulletin is developed by the African Centre of Meteorological Applications for Development (ACMAD). The bulletin provides comprehensive analysis of the current state of the African climate, including, monitoring the Inter-Tropical Convergence Zone (ITCZ), monsoon winds, rainfall, and temperature and soil moisture. It includes as well, seasonal climate outlooks and possible related impacts at continental and sub-regional scales. The International Research Center on El Niño (CIIFEN) in Guayaquil, Ecuador, uses climate information from the Global Producing Centres as the basis for El Niño outlooks in South America. The Center also contributes to the Regional Climate Outlook Forums in the region.
Areas of serious to severe rainfall deficiencies across South Australia and western Victoria are likely to persist during the coming season. Most of SA and western Victoria have recorded rainfall totals in the lowest decile range for the thirteen-month period from 1st June 2007 to 30th June 2008. The outlook for the next three months, July to September, derived from the Bureau of Meteorology's statistical forecast model, shows that the chance of exceeding the median rainfall is only between 30 and 40% for these areas affected by rainfall deficits. Outlook confidence for this forecast is moderate over northern and central SA, with a skill level of around 60%. The confidence level for western Victoria low, although in several areas the July to September rainfall total would need to be decile 8 or higher for the deficits to be removed.

These figures meet or exceed the criteria for a rainfall deficit Climate Watch for this region, being:

- Rainfall for the past three or more months: decile one or lower.
- Chance of rainfall being greater than the median: 40% or lower.
- Forecast skill score: 55% or greater.

Climate situation: Sea surface temperatures in the central equatorial Pacific have gradually increased over the previous two months and are now generally close to average. The final remnants of the 2007/08 La Niña event continue to linger in the western Pacific, although the overall ENSO state is rated as neutral. A majority of computer models in a recent survey indicated that neutral conditions are likely to persist for the next three to six months. However, these same models show that a positive dipole of Indian Ocean temperatures (IOD) may persist for a few more months. This phase of the IOD has been linked with reduced rainfall over central and southeastern Australia.

This Climate Watch is expected to be updated on or before 4th August 2008. For further information please contact Grant Beard (03) 9669 4527
## BOX 2 Example of sectors applications

<table>
<thead>
<tr>
<th>Sectors</th>
<th>Climate extremes</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Health</strong></td>
<td>Heat wave or cold wave</td>
<td>Cardiovascular, respiratory and heat stroke mortality</td>
</tr>
<tr>
<td></td>
<td>Flood, landslide, windstorm</td>
<td>Deaths and injuries, infectious diseases and mental disorders</td>
</tr>
<tr>
<td></td>
<td>Drought</td>
<td>Starvation, malnutrition and diarrhea and respiratory diseases; strain on health due to poorer drinking water quality and availability</td>
</tr>
<tr>
<td></td>
<td>Temperature and excess of rainfall</td>
<td>Mosquito, tick-borne diseases; rodent-borne, waterborne and food-borne diseases</td>
</tr>
<tr>
<td><strong>Agriculture</strong></td>
<td>Flood, heavy rainfall, hailstorm</td>
<td>Effects on early seedling, damage to crops and submergence, inefficiency of applied fertilizers; food and shelter for livestock; diseases such as cholera, worm infestation</td>
</tr>
<tr>
<td></td>
<td>Drought</td>
<td>Early establishment in high lands, low plant stand, damage to crops; outbreak of diseases such as black quarter, anthrax in cattle</td>
</tr>
<tr>
<td><strong>Transport</strong></td>
<td>Flood, heavy precipitation</td>
<td>Flooding of roadways, rail lines, subterranean tunnels and runways, road washout, damage to rail-bed support structures, damage to pipelines</td>
</tr>
<tr>
<td></td>
<td>Heat wave</td>
<td>Compromised pavement integrity, deformation of rail lines, thermal expansion of bridge joints, heat buckling of runways</td>
</tr>
<tr>
<td></td>
<td>Drought</td>
<td>Increased susceptibility to wildfires, decreased visibility at airports located in drought-prone areas</td>
</tr>
<tr>
<td>Water resources</td>
<td>Heavy rainfall</td>
<td>Increased river discharge, inundation, dam management</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------</td>
<td>------------------------------------------------------</td>
</tr>
<tr>
<td>Dry spell</td>
<td>Lower water quality, reduction of water resources, effect on reservoir management and fresh water distribution in urban areas</td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td>Heat/cold wave</td>
<td>Increase of energy heating or cooling demand, reduced energy supply, affects gas and fuel pipelines</td>
</tr>
<tr>
<td></td>
<td>Precipitation deficiency</td>
<td>Reduction of hydropower energy production</td>
</tr>
</tbody>
</table>

**List of References** Precise references will provide on:
- WMO guidelines on climate watches
- WMO guidelines on RCCs
- Publications on ENSO, NAO, SST, etc.
- IPCC forth assessment report
- Some recent publications in the WMO bulletin
- Link to WMO statements and EINino Updates
1.5 Long Range Forecasting Methodologies and Available Products

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Abstract
From the late 19th century to the early 20th century, northern Japan often experienced cool summer which caused cold damage of paddy and other crops. After active researches and deployment of observational network, the central meteorological observatory launched a long range forecast (LRF) in 1942. However, operational LRF was forced into suspension because of the big failure of the cold season outlook in 1949 when a climate jump occurred. LRF fortunately restarted in 1953, but this history tells us the needs and requirements of LRF to a society.

To estimate predictabilities of LRF, we often use the potential predictability index $R$ (Rowell et al. 1995). By the state-of-the-art CGCM, potential predictabilities in the tropics and sub-tropics are large enough to issue a skillful long range forecast, while in the extra-tropics they are still small unfortunately.

Because of these circumstances, operational LRF is built by consolidating some signals such as results of CGCM, OCN and CCA. In particular, in recent years, temperature warming trend is too large to be ignored and OCN is one of the important methods though it is a very simple method. As CGCM doesn’t have skill enough to build an outlook by itself, MLR and CCA are also useful for building an outlook in case that relationships in each method are well understood climatologically such as ENSO impacts.

A relationship between analyzed SST and precipitation at each grid shows a negative correlation over much of warm pool areas. This relationship is not produced in AGCM but produced in CGCM. To improve predictabilities of Asian monsoon system and ENSO, it is very important that an air-sea interaction over the warm pool is realistically described. Recently, operational CGCM becomes compassable with the advancement of computer power. The advancement of computer power also enables operational EPS. To estimate potential predictabilities, to avoid uncertainties, to estimate reliabilities of each initial and to express a forecast with probabilities, EPS must be a powerful tool. Furthermore, MME can help to reduce systematic errors of each model.

Some GPCs and WMO Lead Center for LRF MME provide GPVs of EPS and some kinds of useful products via the Internet. In the use of products, at first we need to check their skills and should avoid saying about unpredictable climate. Verification results are also provided by GPCs and unified verification results are provided by WMO Lead Center for LRF verification system. As pointed out above, probabilistic products by the state-of-the-art CGCM have meaningful skills in the tropics and the sub-tropics. We should try to find the best way which is easy for users to understand and use them.

1. Introduction
Figure 1 shows a relationship between sterile rates of paddy “Mutsuhomare” and 30-day mean temperatures before paddy ear up. According to this relationship,
sterile rates become larger in the case of the temperature below 19.5 degree Celsius. Monthly mean temperatures at Miyako in northern Japan were often below 19.5 degree Celsius in July that is to say “northern Japan is located at the northern limit of paddy” (Fig. 2). From the late 19th century to the early 20th century, northern Japan often experienced cool summer which caused cold damage of paddy and other crops. The central meteorological observatory in Japan, the predecessor of Japan Meteorological Agency, began to develop active researches for cool summers in 1900’s (shown as a green two-headed arrow in Fig. 2) and deployed observational network including mountain and ocean in 1930’s (shown an aqua blue two-headed arrow in Fig. 2). In 1942, the central meteorological observatory launched a long range forecast (LRF) using statistical lag relationships between SSTs and temperatures. However, operational LRF was forced into suspension because of the big failure of the cold season outlook in 1949 when a climate jump occurred (shown as a red arrow in Fig. 3). A LRF fortunately restarted in 1953 by strong backing of farmers, but this history tells us the needs and requirements of LRF to a society. For a long time, only statistical methods such as period analysis and lag correlation had been used. In 1990, a new age using a dynamical method dawned.

2. Predictabilities

In a temporal scale of climatic phenomena, a LRF targets monsoon and ENSO variability. Because these phenomena are aspects of an ocean-atmosphere or an ocean-atmosphere-land interaction system, a coupled GCM is more preferable to an atmospheric GCM. Brushing up on a nature of predictability in Lorenz system, because atmospheric circulations are chaotic phenomena, slight different initial conditions grow in time. This is called as a predictability of the first kind. While in case of Lorenz system with a forcing, time averaged status can be predicted even after a long time. This is called as a predictability of the second kind. A LRF targets this signal. In the earth climate system, major forcing are boundary conditions such as sea surface temperatures, snow coverage, sea ice condition and soil wetness. Interannual variations of these conditions work on atmospheric circulation differently.

Well, it must be emphasized here that targets of a LRF should have certain predictabilities. How to estimate predictability? We often use the potential predictability index R (Rowell et al. 1995) which is calculated from a ratio of signal to total variance using many cases of ensemble predictions based on an assumption that used CGCM is a perfect model. Figure 4 shows distributions of square root of R which means maximum anomaly correlation based on a perfect model assumption. R for precipitation in summer (JJA) is large over the warm pool region and around India while small in the mid-latitude around Japan. R for temperature is
quite large in the tropics and the sub-tropics. These results show that potential predictabilities by the new JMA-CGCM are large enough to issue a skillful long range forecast in the tropics and the sub-tropics, while they are still small in the extra-tropics unfortunately.

3. Methodologies
According to an excerpt from operational prognostic discussion by CPC/NOAA, as the main factors, ENSO, trends, MJO, NAO, PNA, PDO and Soil, Snow Ice anomalies are listed. With these points in mind, operational LRF is built by consolidating some signals such as results of CGCM, OCN and CCA.

As statistical methods, global warming trends and decadal oscillation signals affect a portion of interannual variations. In particular, in recent years, temperature warming trend is too large to be ignored and an optical climate normal (OCN) is one of the important methods though it is a very simple method. For example, western Japan has experienced eight warm springs and never cold springs in recent 10 years. A multiple linear regression (MLR) is a classical statistical method and a canonical correlation analysis (CCA) is an advanced type of a MLR. Because these methods are based on lag correlations between predictant and predictor, boundary conditions which work as memories are adopted as predictors. As a CGCM given later doesn’t have skill enough to build an outlook by itself, MLR and CCA are also useful for building an outlook in case that relationships in each method are well understood climatologically such as ENSO impacts. As a more simple method, tendencies during ENSO events are often used.

For a while after a debut of dynamical method in a LRF, due to an insufficient computer power, an AGCM has been operationally used for a LRF. Recently, an operational CGCM becomes compassable with the advancement of computer power. The advancement of computer power especially a multi nodes supercomputer also enables an operational ensemble prediction system (EPS). By the way, why is a GCM necessary for a LRF? Figure 5 shows correlation coefficients between SST and precipitation at each grid in summer. A relationship between analyzed SST and precipitation at each grid is a negative correlation over much of warm pool areas. This relationship is not produced in an AGCM but produced in a CGCM. To improve predictabilities of Asian monsoon system and ENSO as main targets of a LRF, it is very important that an air-sea interaction over the warm pool is realistically described.
Well, what is the merit of EPS? By giving small perturbation to the initial value, each member runs in a different way and forecasted values spread around the expected true solution. An ensemble mean forecast is near the expected true solution compared to each forecast statistically. If an initial climate status is chaotically unstable, a spread of ensemble forecast tends to be large. A distribution of ensemble forecast is easy to translate into a probability density function. In this way, to estimate potential predictabilities, to avoid uncertainties, to estimate reliabilities of each initial and to express a forecast with probabilities, an EPS must be a powerful tool. However, even in an EPS, all of model biases cannot be removed due to an insufficient number of hindcast cases. That’s where a multi model ensemble (MME) comes in (Fig. 6). A MME has a large potential of being the best tool by avoiding each model inherent bias. The WMO Lead Center for LRF MME collects GPVs from each GPC and is going to provide the results of some customized MME methods.

Fig. 6 Schematic charts of ensemble prediction system (EPS) and multi model ensemble (MME)

Even in the latest Global Circulation Model, a resolution is too coarse to express phenomena affected by local topography. One of methods to avoid this problem is a dynamical downscaling. In a dynamical downscaling, a Global Circulation Model provides initial and boundary conditions to a region model which has fine mesh. The other method is a statistical downscaling. Model outputs are translated into more user friendly variables at each city using statistical methods such as a MLR. Because of this point and statistical methods need less computer power, statistical
downscaling is preferable to dynamical downscaling for an operational LRF.

4. Available Products

In using products, at first we need to check their skills and should avoid saying about unpredictable climate. For example, Figure 7 shows a distribution of ROC area and area mean ROC curves for seasonal precipitation in summer (JJA) by the new JMA-CGCM. According to this figure, it can be said that probabilistic products for summer monsoon rainfall by the new JMA-CGCM have meaningful skills. For comparison of each model, unified verification results are provided by WMO Lead Center for LRF verification system.

![Fig. 7 Verification results of 1-month lead seasonal precipitation in the 28-year hindcast of JMA-CGCM](image)

Upper: ROC area in case of above normal, Bottoms: Averaged ROC curves for each area

Some kinds of products, not only figures but also grid point values (GPVs), are provided by Global Producing Centers (GPCs) whose mission is to operate seasonal to inter-annual prediction system routinely and to provide the products with verification results for NMHSs on the website. Currently, 11 GPCs have been designated worldwide. Figure 8 is one kind of the typical probabilistic products. The upper panels show most likely probabilities with white area where this product has no skill and the bottoms show probabilities for each category for each grid.

![Fig. 8 Sample of most likely probabilities provided by TCC/JMA](image)
5. Summary

- Skillful LRF is much-needed by a society.
- Predictabilities in the tropics and sub-tropics are improved by a state-of-the-art CGCM.
- However they are still small in the mid-latitudes because of a chaotic nature of atmosphere.
- EPS and MME are useful not only for a deterministic forecast but also for a probabilistic forecast.
- GPCs in RAII (BCC, TCC, Seoul) and WMO-LC for LRFMME provide useful products.
- Keep in mind that forecast skills never exceed predictabilities.

References

2. Regional Institutions in RA II and climate activities
2.1 Activities of TCC and Climate Service in JMA

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Abstract

Regional Climate Centre (RCC) is a WMO-designated regional institution with capacity to develop high-quality regional-scale climate products based on global products incorporating regional information. RCC is responsible for providing necessary supports to NMHSs in the region in order to strengthen their operational climate information and prediction services. The first RCCs, Beijing Climate Centre (BCC) and Tokyo Climate Centre (TCC), were formally designated in June 2009. RCCs aim to mitigate hazards due to climatic variability by making full use of these activities.

Recently, by an advancement of climate monitoring and prediction technique, an accuracy of climate information has been improving more and more. And now, how to disseminate climate information including climate watches and early warnings is becoming the high barrier. The Tokyo Climate Conference: Better Climate Information for a Safe and Sustainable Society, was held in July 2009 and discussions were conducted to facilitate the provision and application of user-oriented climate information through enhanced collaboration between climate service providers and users. In the WCC-3, to implement these functions, establishments of the Global Framework for Climate Services (GFCS) and the task force for advancing GFCS were decided. RCCs are promoting their activities in line with the policy of GFCS.

TCC is a counter section for abroad in Climate Prediction Division of JMA, which also serves as some other international centres. On the TCC website, almost all fields of climate information are available now. GPVs and related forecast figures are provided as a GPC's function and downscaled probabilistic products are also provided. For monitoring climate, useful climate database tool “ClimatView” and useful climate analysis tool “ITACS” are available with good reputations. Furthermore, the reanalysis dataset (JRA-25) are provided to researchers. JMA is going to replace an EPS system for seasonal forecasts in February 2010. The new system is a state-of-the-art CGCM which perform better skills for the tropics and the sub-tropics in the hindcast, in particular for Asian summer monsoon. JMA is also executing a longer period reanalysis with the state-of-the-art assimilation system and it will be completed in 2012.

As in many other countries, JMA is making every effort to provide a society with better climate information, in particular dissemination of probabilistic products. In 2007, JMA started issuing the “Early Warning Information” targeting at extremely high or low temperature events beyond a week up to two weeks ahead. Through the website, probabilistic products are also provided to advanced users who are expected to use them in a cost loss model for example.
1. Introduction

JMA has five departments in the headquarters and climate related one is Global Environment and Marine Department. Climate Prediction Division (CPD) is a technically core division in the department. There are eight sections and four international or regional centres in CPD. Tokyo Climate Centre (TCC) is not only a Regional Climate Centre (RCC) but also a counter section for abroad in CPD, which also serves as some other international centres such as Global Producing Centre (GPC), GSN Monitoring Centre and CBS Lead Centre.

2. Activities of Tokyo Climate Centre

Regional Climate Centre (RCC) is a WMO-designated regional institution with capacity to develop high-quality regional-scale climate products based on global products incorporating regional information. RCC is responsible for providing necessary supports to National Meteorological and Hydrological Services (NMHSs) in the region in order to strengthen their operational climate information and prediction services. Mandatory functions of RCC are,

- Operational activities for LRF, climate monitoring and data services
- Training in the use of operational products and services.

Establishment of RCCs will be initiated by regional associations based on regional needs and priorities.

The first step of RCC network in Region II started in 2004. Then, through some procedures in WMO, the first RCCs, Beijing Climate Centre (BCC) and Tokyo Climate Centre (TCC), were formally designated in June 2009. In addition to BCC and TCC, Russia, India, Iran and Saudi Arabia are announcing their candidacy for RCC in Region II. To support NMHSs' activities, RCCs operationally started four active domains such as the climate database, the climate analysis, the climate monitoring and the climate prediction. RCCs and each NMHS aim to mitigate hazards due to climatic variability by making full use of these activities together.

Recently, by advancement and development of climate monitoring and prediction technique, accuracy of climate information has been improving more and more. And now, how to disseminate climate information including climate watches and early warnings is becoming the high barrier. The Tokyo Climate Conference: Better Climate Information for a Safe and Sustainable Society, was held in July 2009 and discussions were conducted to facilitate the provision and application of user-oriented climate information through enhanced collaboration between climate service providers and users (Fig. 1). In the WCC-3, to implement these functions, establishments of the Global Framework for Climate Services (GFCS) and the task force for advancing GFCS were decided. GFCS consists of four interactively linked sections, (1) User Interface Programme, (2) Climate Services Information System, (3) Observations and Monitoring, and (4) Research and Modelling (Fig. 2). RCCs are promoting their activities in line with the policy of GFCS.
TCC was established in April 2002 at the headquarters of JMA. The main activities of TCC are a provision of climate information to NMHSs and TCC is now responsible for “Support of climate services of NMHSs in Asia and Pacific region as an RCC in Region II” and “Provision of LRF products from GPC Tokyo”. The main route of services is the TCC Website. Almost all fields of climate information are available on it (Fig. 3). TCC newsletter are also published online every season to share an activity of TCC and climate information. In this section, some major products are noted. At first, GPVs and related forecast figures are provided as a GPC’s function with verification products. In addition to general LRF products, downscaled probabilistic products in Southeast Asia are available (Fig. 4). For monitoring global climate, weekly, monthly, seasonal and annual temperatures or precipitations are monitored and hazardous climatic events are reported. For monitoring climate system, various kinds of figures are provided and the results of diagnosis of current climate status are issued as the Monthly Highlights on Climate System every month. For monitoring and forecasting the ENSO which is one of the largest climatic events in the world, the Ocean Data Assimilation System and the Coupled GCM are routinely operated. “El Niño Monitoring and Outlook” is issued every month. JMA has conducted global warming experiment toward the year 2100. A series of “Global Warming Projection” was published to provide scientific estimation. As capacity-building activities, training modules are provided on the web. TCC also held a training seminar every year and “Training Seminar on Climate Analysis using Reanalysis Data” will be held in December 2009.
3. Climate Monitoring and Data Management

Now, JMA is in charge of one of the GSN Monitoring centres and the CBS lead centre for GCOS. The reception rate of CLIMAT bulletin on the GTS is monitored in the GSN Monitoring Centres and report the monitoring result to CBS lead centres. Each CBS lead centre tries to contact with NMHSs to identify a problem such as a telecommunication relay error and a CLIMAT bulletin format error (Fig. 5). According to these centres’ activities, the reception rate of CLIMAT bulletin in Region II is nearly 90% which is larger than the global mean 80%. Monthly climatic observational data such as monthly mean temperatures, monthly precipitation amounts and so on, are historically archived into the database and updated every month. To handle these climatic data, a useful visualization tool “ClimatView” based on SVG (Scalable Vector Graphic) is available on the TCC website (Fig. 6).

As one of the climate databases, long-term reanalysis data are most useful for analyzing mechanisms of climate system. JRA-25 is the third full-fledged reanalysis in the world and evaluated as expressing the most realistic precipitation. To diagnose current climate system, JMA continuously operates the same system as JRA-25 which is called
JCDAS. The detail and how to get data of JRA-25 and JCDAS are described on the webpage, http://jra.kishou.go.jp/JRA-25/index_en.html. A very useful and powerful tool for analyzing a climate system by using JRA-25 and JCDAS data is also available on the TCC Website. This tool is named as the interactive tool for analysis of climate system, “ITACS”. Not only drawing general figures but also various temporal-spatial cross section and statistical analysis such as regression analysis, FFT analysis, EOF analysis and SVD analysis are able to be done easily by the ITACS (Fig. 7). TCC will hold a training seminar on “Climate Analysis using Reanalysis Data” focusing on how to use “ITACS” in December 2009.

Fig. 7 Sample images of functions in the ITACS

4. Upcoming Seasonal Forecast Model Upgrade and the 2nd Reanalysis (JRA-55)

JMA is going to replace an EPS for a seasonal forecast in February 2010. The new system is an atmosphere-ocean coupled model (CGCM). The resolutions are TL95L40 for the atmosphere model and 1 degree in longitude, 0.3 - 1.0 degree in latitude and 50 levels for the ocean model. The ensemble size is 51 same as the current system and ensemble members are build with a combination of a bleeding of growing mode (BGM) method and a lagged averaged forecasting (LAF) method. To estimate model systematic errors, we run a hindcast for past 30 years with 10 ensemble members. According to an improvement of air-sea interaction over the warm pool, a forecast skill of precipitation by the new CGCM is higher than that by the current system in the western north Pacific monsoon region and it is greatly improved in the Indian monsoon region (Fig. 8).

JMA is also executing a longer period reanalysis with the state-of-the-art assimilation system which is called JRA-55. This system will provide a fundamental data set for various climate related sectors. The resolution of atmospheric model is TL319L60 and the assimilation scheme is 4D-Var. It will be calculated from 1958 to 2012 and will be completed in 2012.
5. Domestic Dissemination of Climate Information in JMA

Same as in many other countries, JMA is making every effort to provide a society with better climate information, in particular dissemination of probabilistic products. Most of products issued by JMA are provided as probabilistic products. However, they tend to be translated into deterministic forms when they are broadcasted on a mass media.

As the first step of promoting advanced use of probabilistic products, JMA started issuing the “Early Warning Information” targeting at extremely high or low temperature events beyond a week up to two weeks ahead in 2007. Figure 9 is an example of the product provided through the website. The left figure shows a time sequence of predicted probabilities for 7-day mean temperature starting from every day. The probabilities of extreme low temperature are represented by deep blue bars. The right diagram indicates forecasted probabilistic density for 7-day mean temperature with one-week lead time. The pink and green lines show distributions of probabilistic density for climatology and this case, respectively. On this website, users are able to get more detail products not only as a chart but also as raw data with selecting an arbitrary period and a threshold value they want to know. An agricultural sector and an energy sector are the most expected field for using a cost loss model which is one of the effective methods for advanced use of probabilistic products.

As one of other efforts for dissemination of climate information, advisory panel on extreme climatic events are running in cooperation with Japanese lead researchers. They provide advanced analysis tools to the executive office at CPD and the executive office reports the monitoring results to the panel. In the case of extreme climatic event, the panel issues a climate watch including their causes and outlooks.

6. Summary

- RCCs (BCC and TCC) are going to promote the GFCS.
- TCC provides skillful, useful and user-friendly products of LRF as a GPC.
- Powerful climate monitoring tools, “ClimatView” and “ITACS”, are available on the TCC website.
- TCC regularly promotes capacity-building activities.
- JMA innovates a new CGCM which has more predictabilities and better skills in Feb.
JMA operates the early warning information based on probabilistic products and is trying to make best practices in some user sectors.
2.2 Center for Monitoring and Assessment of Extreme Weather and Climate Events in Asia

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The Beijing Climate Center (BCC)/East Asian Monsoon Activity Center (EAMAC) at CMA proposes to conduct a project to establish a monitoring and assessment system and data center on extreme weather and climate events in Asia. These events are mainly associated with the multi-scale Asian monsoons and result in very high-cost impacts to the society due to the disasters they often cause. BCC proposes to establish an unified database and monitoring platform so that it can help organizing and disseminating real-time and post-time monitoring and assessment information on extreme weather and climate events in Asia, thus contributing to the goal of research on high impact monsoon weather for disaster reduction of WMO programs, including the WCP and the WWRP-TMR.

1. Background

Asia, with 60% of the world’s population most of which is in the developing countries, suffers more extensively than any other regions from natural disasters due to extreme weather and climate events. These include droughts, floods, heat waves, cold spells, snow storms, tropical cyclones, etc., which are mostly manifestations of variability and anomalies of the Asian summer and winter monsoons. In the past few decades, high intensity and high frequency extreme weather and climate events have been occurring at an alarming rate with the increase of extensive damages including property and life losses, which are the results of the rapid economical development and the influence of climate variations as evidenced by the occurring of record breaking events.

There are plenty of examples of damages occurred during the Asian summer monsoon. For example, from 2001 to 2005, the average annual death toll in South Asia due to heat wave alone reached 622, with the death exceeding 1,000 in both 2002 and 2003. The maximum temperature of heat wave events reached 50°C every year in these five years, and reached 53°C in 2003 that caused 1,700 deaths. In the summer of 2006, high temperature and drought in Chongqing, China caused severe damages when the maximum temperature reached 44.5°C, breaking the century-old historical record. In 1998, severe floods occurred in the Yangtze River basin, the Songhuajiang River basin and the Nenjiang River basin in China. In 2007, serious flood in the Huaihe River basin in China created the second highest water level in the history.

The most dramatic extreme weather and climate events during the Asian summer monsoon are associated with tropical cyclones, and their effects are far beyond the tropics and extend deeply into the entire summer monsoon region. For example, a landfall typhoon caused rare torrential rain in Henan Province of China in August 1975. As a result, several reservoir dams breached, causing a death toll of at least 30,000 people. In addition, 102 kilometer railways between Beijing and Guangzhou were
destroyed by flooding, causing a traffic break for 18 days. In 2004, the number of typhoons from the Northwest Pacific landed in Japan reached 10, far more than the former historical record of six. In 2005, the average intensity of typhoons from the Northwest Pacific landed in China also set a historical record. In 2006, tropical storm Bilis and super typhoon Saomai set many records in the history of China’s typhoon disasters, among which super typhoon Saomai set the record of having the highest intensity of typhoons landed on the mainland. Recent most noteworthy extreme events involving tropical cyclones also include the event in June 2007, when Oman and Iran of the Arabic Gulf in the Indian Ocean were hit by the strongest storm (the intensity reaching category-5 hurricane) in record. In November of the same year, Bangladesh was hit by a super-strong tropical storm Sidr, resulting in more than 5,100 lives lost or missing. In May 2008 during the onset of the summer monsoon, tropical cyclone Nargis from the North Indian Ocean swept across the delta area of Burma, caused at least 130,000 deaths including lives missing.

Extreme weather and climate events during the Asian winter monsoon also cause serious damages. In early 2005, worst snowfall in two decades blanketed northwest Asia and killed hundreds of people in Tajikistan, Pakistan, India and Afghanistan. The resultant melting in early spring flooded large areas, with over 110,000 residents affected in the Xinjiang region of northwest China alone. The strong late winter cold surges caused damages all over Southeast Asia. In January, 2006, unusually cold weather appeared in the western part of Russia, and minimum temperature in Moscow set the lowest record of the same period since 1927; minimum temperature in some areas of Siberia was close to -60°C; nearly at the same time, continuous snowfall occurred in large areas of Hokkaido Island of Japan, and the depth of accumulated snow created the deepest record in history in many areas. At the beginning of 2008, a widespread ice storm rampaged in southern China that broke all records. In the winter of 2008/2009, all 12 provinces in northern China suffered from serious drought at the probability of once per 30-50 years. Tropical cyclone also struck during winter monsoon and transition seasons. In Bangladesh, tropical storms killed more than 300,000 people in November 1970 and nearly 140,000 people in April of 1991.

At present the most comprehensive work in the operational monitoring of global extreme weather and climate events is being carried out at the US NOAA Climate Prediction Center (CPC) and National Climate Data Center (NCDC). Although some Asian countries such as China, Japan and Korea have set up their own climate monitoring system, they are all done with different emphases, coverage, and formats, and are in various stages of development. A lot of information and descriptions on many extreme weather and climate events still come from news media reports, which lack consistency in formats, contents, coverage, and methodology for interpretation and assessments, and are difficult as data source for vigorous research.

2. Purpose

The purpose of this project is to develop a monitoring and assessments system and data center for extreme weather and climate events in Asia that is systematic, comprehensive
and consistent, and provide a data base that is as complete as possible with high space and time resolutions to monitor and archive extreme weather and climate events in Asia. The goal is to provide the highest quality data for assessment, analysis and research of extreme weather and climate events therefore contributing to the goal of improved forecast and disaster prevention as well as mitigation efforts.

Recent progresses at BCC in the development of infrastructure, facility and capability have now enabled BCC to launch this project, which will establish a comprehensive database and monitoring platform through effective cooperation among NMHSs and other operational services in Asia. The system will organize and disseminate both real- and post-time monitoring and assessment information on extreme weather and climate events to serve the needs of the NMHSs and other operational and research agencies in Asia. BCC will provide necessary infrastructure and human resources and work with cooperating agencies and organizations to ensure the success of this project. The database established and the associated assessments of individual events will be very valuable to the research of severe monsoon weather and climate impacts, thus contributing to the goal of research in high impact weather for disaster reduction and mitigation of relevant WMO programs, in particular that of the Monsoon Panel of the WWRP-TMR. In this regard the project will also serve as a focus in BCC’s dual role as the East Asian Monsoon Activity Center.

3. The plan

The monitoring of extreme weather and climate events in Asia will include two main categories of data. The first category is the monitoring of the extremity of meteorological key elements in individual stations. At present, relevant monitoring techniques for this purpose are relatively mature, and various indexes have been adopted in the present preliminary monitoring work of global extreme weather and climate events at BCC. In this project, the application and methods will be further refined and enhanced as experience is accumulated and revised and new tools tested. The second category is the monitoring of case events which will be defined by a range of the relevant intensity of each type of events. The work in this aspect has not been launched at BCC yet; the main reason is that a suitable corresponding monitoring technical index system has not been identified. Therefore, research needs to be conducted on the monitoring technical index system for this category. The current status at BCC and future plans for each category are described below:

3.1 Refining and enhancing the monitoring system for extreme events based on data from individual stations

Current status
Currently, the operation in monitoring for extreme weather and climate events within China by BCC includes the monitoring of droughts, sandstorms, high temperatures, rainstorms, floods, snowfalls, heavy fog and typhoons, all at daily intervals.

For the monitoring of the whole Asia and the world, BCC has set the preliminary thresholds of extreme events according to their definitions and developed graphics that
can reflect extremely high and low temperatures, and extremely intense precipitations and droughts. At present, the graphics include mainly spatial distribution maps such as daily maximum, minimum and mean temperature, daily maximum temperature exceeding the threshold and its departure, daily minimum temperature under the threshold and its departure, and daily precipitation exceeding the threshold and its departure percentage. These graphics are for the purpose of projecting intuitively and effectively an image of the intensity in different regions reflected by extreme events. An example is given in Figure 1, which shows the distribution of the minimum temperature beyond the threshold in the extensive area from western Russia to Eastern Europe on January 20, 2006.

![Figure 1: The distribution of minimum temperature (unit: °C) below threshold value on January 20, 2006](image)

**Technical support for monitoring**

The development of the technologies for differentiating and monitoring extreme events based on meteorological elements of individual stations is relatively mature. For example, in 2004 the Expert Team on Climate Change Detection and Indices (ETCCDI) developed a set of index system on extreme climate events with the software available at the website [http://cccma.seos.uvic.ca/ETCCDI/software.shtml](http://cccma.seos.uvic.ca/ETCCDI/software.shtml). BCC/CMA recently developed additional indices after conducting research on monitoring index on several kinds of extreme events such as drought and high temperature. Each of these indices includes three parameters: absolute threshold index, extreme index based on percentile, and frequency (once-in-how-many-years) index based on probability distribution statistics.

**Future plan**

Currently key element products, such as frost, freezing, warm nights and hot days, etc are each treated as the same index used year-around without differentiation with respects to seasonality and weather system regimes. In 2009 this system will be...
improved by adopting multiple indices based on seasonal variations and time periods adjustable according to weather and climate regimes. Historical data and statistical methods and experiments will be used to find the best index and thresholds for each index.

In 2010, the real-time monitoring of daily variation time sequences will be enhanced. Asia will be divided into East Asia, Southeast Asia, South Asia, West Asia, Central Asia and Russia. Daily variation time series of individual stations in various areas will be provided aiming at different key elements. The data retrieval system of global station database will be established. Attention will be made to ensure that the system will possess suitable and convenient procedures for data interface, which is important to meet the needs of various statistic tasks and to provide extremity historical series and assessment information for individual stations.

3.2 Development of monitoring system based on the cases of extreme events

·Research on monitoring technology
Historical data will be used to develop monitoring technology. From 2009 to 2010, the research will be aimed at the cases of five types of extreme weather and climate events i.e., droughts, floods, heat waves, cold spells, tropical storms/typhoons within China. This includes the study of their definition, temporal and spatial variations, index system (extreme intensity, impact coverage, persistence and comprehensive intensity), and such study will evaluate the suitability of different ways of indexing them with existing technologies and develop possible revisions and conducting experiments to find the most suitable methods.

From 2011 to 2013, the research will be aimed at the cases of five types of extreme weather and climate events i.e., droughts, floods, heat waves, cold spells, tropical storms/typhoons for the entire Asia. The same tasks of 2009-2010 for the area of China will be carried out for the expanded area of Asia, with additional consideration relative to possible different characteristics between sub-regions of Asia.

·Future plan
From 2009 to 2011, a case-based database of the above-mentioned five types of extreme weather and climate events within China will be constructed, which will provide such information as spatial and temporal distribution characteristics of extreme climate events i.e., droughts, floods, heat waves, cold spells, tropical storms/typhoons within China, and also provide the inquiry, searching and downloading of relevant data and graphs. In the process of constructing the database the system will be able to realize the real-time monitoring and historical extremity assessment for all cases of the five types of extreme weather and climate events within China.

From 2011 to 2013, the work will be extended to the cases of all Asia. Namely, the study on their definition, temporal and spatial variation, index system (extreme intensity, impact coverage, persistence and comprehensive intensity) and corresponding monitoring technology will be carried out to construct the all-Asia database and establish an operational monitoring and assessment system that can be updated in real time or near
real time.

3.3 Information sharing and service among Asian countries

International cooperation will be most crucial to develop the operational monitoring and assessment system and data center of extreme weather and climate events in Asia and realize its potential as a valuable tool for research in high-impact monsoon weather and disaster reduction and mitigation. The cooperation will include data exchange, research, and technical training. The project will construct product websites and develop routines to strengthen service product exchanges among Asian countries. Based on the present website of BCC, the independent webpage for the monitoring and assessment operational products of extreme weather and climate events in Asia will be established to allow timely uploading and display of the above-mentioned monitoring and assessment products, and provide information and data services to meteorological services government departments of various countries, and relevant international agencies. Meanwhile, a user list for Asian countries will also be established to facilitate the timely exchange of relevant information.

In addition to regular interval meetings such as the annual FOCRAII which will provide opportunities for external inputs, BCC plans to organize a small advisory panel consisting of invited international experts for consultation on technical issues and to facilitate the international cooperation of the project.

4. Funding

BCC is currently conducting the monitoring and assessment system within China under both BCC’s internal development funding and the research project funding from the Chinese government. Both types of fundings will be utilized to support this project.

5. Relevancy to WMO programs

The proposed plan is relevant to two missions related to WMO programs. BCC is a WCP climate center in Regional Association II (Asia) and will work with all members of RCC-II to facilitate cooperation in the exchange of climate information and the efforts in climate monitoring and prediction, development of relevant technologies, and capacity building. In BCC’s role as the East Asian Monsoon Activity Center, which was established by WMO Tropical Meteorological Research Program in 2005 and now incorporated under the Monsoon Panel of the WMO WWRP-TMR, the project will contribute to the overall strategy of developing data infrastructure for research on severe monsoon weather and climate impacts on monsoon weather under WWRP/TMR. In this regard the project is complementary to the two other activities proposed by the WWRP/TMR Monsoon Panel, the Center for Monsoon Field Campaign Legacy Data Sets in the U.S. and the Monsoon Radar Meteorology Data Information Center in Japan. This crosscut of efforts related to the two WMO programs, WCP (a network of operational NMHSs) and WWRP (a network of severe weather and climate impact researchers), will facilitate and strengthen the cooperation of the two communities in advancing the common goal of disaster reduction in Asia.
2.3 Regional Climate Activities of India Meteorological Department

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1. Introduction
Due to its unique geo-climatic conditions Indian subcontinent experiences a variety of weather systems with two monsoons, two cyclone seasons, severe thunderstorms, snowstorms, heat waves and cold waves. The region is also affected by a number of natural hazards like tropical cyclones, floods, droughts, earthquakes, landslides, avalanches etc. Past records show that 60% of Indian landmass is prone to earthquakes of various intensities, 40 million hectares prone to floods, 8% of the total area prone to cyclones and 68% of the area is susceptible to drought. Hence, reliable weather forecasts and timely warnings are very important, especially in combating various natural hazards and minimizing the damages to the society. India Meteorological Department (IMD) has dedicated networks for climatic observations and has been providing climate services for more than a century. The main observational network includes 559 surface observatories, 39 RS/RW, 62 pilot balloon, 10 GPS based upper air systems, 5 Doppler Weather Radar, 55 Seismological observatories, 2500 District wise Rainfall Monitoring (DRM) network, 45 radiation observatories, number of Ozone observatories etc. In addition 125 Automatic Weather Station (AWS) have been installed across India (including one at Antarctica) during the year 2006-07. Under the ongoing modernization program of IMD, it is planned to establish a network of 1000 AWS and 3600 Automatic Rain Gauge Stations (ARG) across the country in a phased manner.

Being the National Meteorological Service (NMS) agency, IMD has the responsibility to monitor, forecast and provide weather warnings about the impending hazards and give climatic change information so that effective measures could be undertaken by disaster mangers to prevent/minimize loss of life and damages to property.

2. Climate Related Activities of IMD

2.1 Climate Monitoring and Analysis
The real time rainfall monitoring is carried out and rainfall summary is prepared based on about 2300 rainfall stations.

- Daily/weekly/monthly/seasonal/ annual rainfall summary prepared for sub division wise / district wise/ state wise/ region wise and for the country. Fig. 1 shows the real time monitoring of all India monsoon rainfall during the monsoon season 2009.
- Several rainfall statistics like rainfall normal, normal rainy days, extreme rainfall climatology are also being prepared and are supplied to the users.
- Prepares and publishes monthly, seasonal and annual climate diagnostic bulletins for Indian region regularly. Detailed special monsoon reports are also being published every year.
2.2 Data Services and Climate Data Products

IMD has long time series of various climate data in its archive. Data rescue and data services are mainly provided by National Data Center (NDC) at Pune (http://www.imdpune.gov.in). About 15 types of data comprising surface, rainfall, upper-air, agro-met, radiation, autographic, marine, and special observations data such as Ozone, OLR, Rocket Sonde, precipitation chemistry, turbidity, expedition (Antarctica, Sagar Kanya Cruise) and experiment (MONEX, BOBMEX, ARMEX, etc.) projects and programmes constitute the source of data on permanent archival at NDC Pune. Some of the important data set that is presently available in NDC is listed below:

- Daily, Monthly and Annual Rainfall 1847-2008
- Sub-Divisional Rainfall 1875-2008
- Climatological Normal 1901-1990
- Daily Synoptic Hour Data 1969-2008
- Monthly Mean Synoptic Data 1901-2008
- Indian Daily Weather Reports 1928-2008
- Upper Air Data 1951-2008
- Ozone Data 1957-2008
- Radiation Data 1957-2008
- Depressions and Cyclones 1891-2008
- Satellite Data 1984-2008

Fig. 1: Daily actual and normal rainfall for the country as a whole during the monsoon season of 2009 (May to September).
In addition to the climate data available in NDC, the National Climate Centre (NCC) at IMD Pune generates many climate data products for smaller spatial and temporal scales for the user community. These data products include high resolution daily gridded rainfall & temperature data over Indian region, district wise normal for various surface parameters, marine climate summaries for Indian Ocean region etc. (http://www.imdpune.gov.in/E_%20Products%20of%20NCC.pdf).

In addition, IMD has also brought out an electronic version of the hard copy editions of its widely referred atlas “Tracks of Storms and Depressions in the Bay of Bengal and the Arabian Sea”, which were published by IMD in the years 1964, 1979 and 1996. The electronic version named Cyclone e-Atlas – IMD, which has been released in the year 2008 is an integrated package providing substantial information on the Tracks of Cyclones and Depressions that occurred over Indian Seas during the period 1891–2008. The e-Atlas which could be installed in a personal desktop computer with Microsoft Windows Operating System would prove to be handy to Tropical Cyclone forecasters, researchers and disaster managers. (http://www.imdchennai.gov.in/cyclone_eatlas.htm).

2.3 Long Range Forecasting
India was the first country to start operational Long Range Forecasts, since 1886 by Sir H. F. Blanford. Mainly statistical/empirical methods have been used to prepare these forecasts. Forecasts during the initial years were subjective and qualitative. The forecasting based on objective techniques such as correlation and regression analysis was first (1909) introduced by Sir Gilbert Walker. At present, the operational long range forecasts for the rainfall during Southwest Monsoon Season (June to September) are issued in two stages (1st stage in April and updated in June).

IMD also issues forecasts for winter (January-March) precipitation over Northwest India and northeast monsoon (October-December) rainfall over Southern Peninsula.

In addition to its existing operational forecasting system based on statistical models, IMD has also established an experimental prediction system based on General Circulation Model (GCM) and some empirical methods developed using coupled model outputs from leading climate prediction centers outside India.

2.4 Climate Change vis-à-vis Global Warming
IMD also monitors change in surface air temperature from its network of observatories. Like the increasing tendency of global mean surface air temperature the annual mean temperature have also increased on regional scale and over India the increase is by 0.5°C over last 100 years (Fig. 2). Most of the increase is due to increase in winter & post monsoon seasons. Systematic analysis of climate data and model predictions/projections are very important for planners and managers. The climate change is going have wide ranges of implications in future.
2.5 Research and Development

Research projects on climate variability and predictability studies for the Indian region have been carried out by different institutes in India and also by different offices of IMD. Major emphasis has been given to monsoon, which contributes 75-90% of the annual rainfall over most parts of the country. Studies have also been conducted on the links of regional climate variability with ENSO, Indian Ocean Dipole (IOD) and global circulation features and climate change issues over the Indian region. Many research papers are published by scientists working in the organization and it also brings out research reports regularly.

![Image of temperature anomalies]

Fig. 2: All India mean temperature anomalies (a) annual for the period from 1901 to 2008 shown as vertical bars. The solid blue curve had sub-decadal time scale variations smoothed with a Binomial filter (Departures from the 1961-1990 average) : Source Annual climate summary, 2008 published by NCC, IMD Pune.

2.6 Weather and Climate Publications

The department also publishes regularly many research reports, bulletins etc. It is summarized below:

- Climate diagnostics bulletins:- Monthly, - Seasonal and Annual
- Monsoon reports
- Met monographs and Atlases
- Cyclone e-Atlas
- Climatic normals
- Forecasting manuals
- Technical reports
- Annual meteorological disaster reports
- Pre-published scientific reports
- Daily, weekly, seasonal and annual weather reports
- Journals- Mausam and Vayu Mandal
- Books

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• The data products include high resolution daily gridded rainfall and temperature data over Indian region, district wise normal for various surface parameters, marine climate summaries for Indian Ocean region etc.

• World Weather Records-Decadal Normals of 1991-2000 for RA II countries which is the fourth in the series of WWR publication

2.7 **Web Services**
The IMD and its regional websites provide various information such as:

Daily weather information, real time satellite pictures and products, Doppler radar pictures and products, numerical model forecasts, short range forecasts, weekly rainfall maps, agricultural advisories for farmers, details of surface instruments, air pollution monitoring, cyclone tracks over Indian Ocean, climate normals, monsoon reports, seasonal forecasts and climate diagnostic bulletins etc.

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<td>Regional web sites :</td>
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3. **Climatological Data Management System (CliSys)**
The proposed Climatological Data Management System (CliSys) by IMD is designed to fit the following objectives of climate data.

• Ensuring the collection and storage
• Protecting
• Quality controlling
• Giving easy access
• Providing tools for the data analysis and statistics
• Creating custom-tailored and adapted climate products
• Interface Climate Data Management to overall NMS Information System

The key features of CliSys are:

• Unified data storage structure built around a RDBMS.
• Dynamic data structure based on an underlying data model
• Flexible and open data import system, which can ingest all kinds of climate data.
• Web based architecture allowing regionalization
• Compliant to WMO recommended practices for data processing
• Compliant TDCF (Table Driven Code Form)
• Compliant to WIS (WMO Information System)
• Supports large number of concurrent users
• Allows different types of computers and operating systems to share climate information across networks.
• Maintains the features presented above with a high degree of overall system performance. Database users do not suffer from slow processing performance.
• Powerful climatological production environment.
• Climate products driven through the CliSys web interfaces

CliSys provides a set of tools and procedures that allow all data relevant to climate studies to be properly stored and managed. The CliSys climate data model is designed to get high performance in data retrieval and to optimize climate data storage. The parameter stored can be fully customized to fit the department requirements (historical data sets current and future data sets) even if CliSys proposed a first generic stored data set as a standard model.

4. Proposal for Regional Climate Centre (RCC)
IMD through its National Climate Centre (NCC) at Pune has submitted a proposal for capacity building towards development of a WMO recognized RCC for South Asia by upgrading the NCC at IMD, Pune.

WMO-RCC - A multifunctional centre (under a NMS) that fulfils certain mandatory functions (e.g. long-range forecasting (LRF), climate monitoring, climate data services, training) for an entire region, or for a sub-region to be defined by the regional association (RA).

WMO RCC-Network - A group of centres (under more than one NMSs) performing climate-related activities that collectively fulfill all the required functions of an RCC

WMO RCC-Network Node -
• a centre in a designated WMO RCC-Network
• a node will perform, for the region or sub-region defined by the regional association, one or several of the mandatory RCC activities

Under this program the NCC will have four Divisions

• Climate Prediction Division - for Operational Activities for LRF
• Climate Monitoring and Analysis Division – for Operational Activities for Climate Monitoring and Assessment
• Climate Research Division - for Operational Data Services to support operational LRF and climate monitoring, research studies on regional climate variability, prediction and climate change impacts etc.
• Scientific Secretariat (SS) for coordinating entire work of the centre and will also co-ordinate with HQs and focal points of other countries in conducting regional climate forums, training activities of RCC, public relation, Collaboration with other centres in achieving the operational objectives of the centre etc.

5. Centre for Climate Change Research (CCCR)
The Ministry of Earth Sciences, Government of India has established Centre for Climate Change Research at Indian Institute of Tropical Meteorology (IITM), Pune (http://www.tropmet.res.in), which is the sister organization of IMD. The Centre will generate climate change scenarios and predictions and will establish research networks
of leading National research groups and research centers involved in allied areas by supporting collaborative research on important issues.

6. **Other Services Provided by IMD**

6.1 **Public Weather Forecasting Services**
IMD through its effective weather monitoring network and forecasting tools provide weather forecasting services on different temporal scale. At present IMD is augmenting its observational infrastructure with automatic monitoring and forecasting systems. IMD’s operational weather observation and forecasting systems has 4 components such as observations, dedicated communication, analysis and forecasting and dissemination. The forecasting components includes:

- **Short Range Weather Forecast (including City Forecast)**
- **Medium Range (District Level Forecast)**
- **Extended range and Seasonal (Sub-division / National Level Forecast)**

6.2 **Cyclone Warning Services**
IMD is the nodal agency for monitoring and prediction of cyclones over the north Indian Ocean and also works as a Tropical Cyclone Advisory Centre (TCAC) for international civil aviation.

Regional Specialized Meteorological Centre (RSMC) at IMD New Delhi, provides the advice to the Members of World Meteorological Organisation (WMO) / Economic and Social Cooperation for Asia and the Pacific (ESCAP) Panel countries viz. Pakistan, Oman, Bangladesh, Sri Lanka, Thailand, Maldives and Myanmar.

All data pertaining to cyclonic disturbances viz. wind, storm surge, pressure, rainfall, damage report, satellite and Radar derived information etc archived and exchanged with Panel member countries. The observational network for cyclone monitoring consists of land-based surface and upper-air stations, observations from Doppler Weather Radars/Cyclone Detection Radars and data from geo-stationary satellites. In addition, observations from ships and also from buoys are of immense importance for the analysis and forecasting of cyclones.

The cyclone forecasting aims at monitoring and providing information to the public on (i) current location and intensity of the cyclone, (ii) forecasting the intensity, direction and speed of the cyclone, (iii) time and location of landfall and coastal areas likely to be affected by the gale force wind, (iv) estimated height of tidal waves/storm surge and the part of the coast likely to be affected by tidal waves/storm surge and (v) likely area to be affected by heavy/very heavy/extremely heavy rainfall. Apart from the synoptic analysis, various climatological, statistical and numerical weather prediction (NWP) including global models like National Centre for Medium Range Weather Forecasting (NCMRWF) global model (T254), regional models like MM5, WRF and cyclone track forecasting model like QLM (Quasi Lagrangian Model) are used for the above purpose. Also for the
cyclone intensity prediction statistical dynamical model is used.

RSMC, New Delhi imparts training on cyclone warning to the WMO sponsored forecasters of various countries every year. RSMC, New Delhi has two annual publication on regular basis viz, (i) ‘RSMC- Report on Tropical cyclone over north Indian Ocean’ and (ii) WMO/ESCAP Panel on Tropical Cyclone Annual Review. Apart from these publications, Met monographs on important cyclones are published. (http://www.imd.gov.in/section/nhac/dynamic/cyclone.htm).

6.3 Ocean Services
The Indian National Centre for Ocean Information Services (INCOIS) under the Ministry of Earth Sciences (MoES), has a mission i.e. to provide the best possible ocean information and advisory services to the society, industry, government and scientific community through sustained ocean observations and constant improvement through systematic and focused research (http://www.incois.gov.in).

- Ocean and Coastal State Forecast
- Early Warning System for Tsunami and Storm Surges
- Ocean Modelling
- Satellite Coastal and Oceanographic Research
- National and Regional Oceanographic Data Centre
- Web-based Ocean Data, Information and Advisory Services
- Value Added Services
- Ocean Observing System
- Coastal Geospatial Applications
- Indian Ocean and Global Ocean Observing System

6.4 Hydrometeorological services (Rainfall monitoring, flood forecasting & drought monitoring)
Hydrometeorological services are mainly provided for development & management of water resources through rainfall monitoring, quantitative precipitation forecast (QPF)/flood forecasting and design storm projects for construction of hydraulic structures.

Several rainfall statistics like rainfall normal, normal rainy days, extreme rainfall climatology are also being prepared and are supplied to the users. IMD maintains a national network of Flood Met Offices, which are located in the flood prone river basins for issuing (QPF) which are used by Central Water Commission & other agencies for flood forecasting. In addition, IMD also monitors meteorological drought, preparation of drought climatology, delineation and identification of drought prone areas and monitoring Agricultural drought conditions during Southwest and northeast monsoon seasons by preparing aridity anomaly maps. Weekly rainfall departure over met subdivisions during 10 to 16 September 2009 and the aridity anomaly during the period from 16 to 29 July, 2009 is shown in Fig. 3.
6.5 Environmental Monitoring Services
Environmental monitoring in IMD is carried out through dedicated measurement of Radiation, Ozone, Aerosol, Green house gas, Air quality, precipitation chemistry etc at different locations of the country. The main functions are to take these observations, archive and disseminate the environmental data, carry out research and application on environmental issues.

Fig. 3: Weekly rainfall departure (left) over meteorological subdivisions during 10 to 16 September, 2009 and aridity anomaly (right) during the period from 16 to 29 July, 2009

6.6 Agricultural Meteorology Services
Forecast and advisories for farmers are issued at district level by Agrometeorological Field Units at State Agricultural Universities, Indian Council of Agricultural Research Centres, IMD’s forecasting offices of State capital and National Agromet Advisory Service (AAS) Centre, Pune. IMD initiated district level quantitative forecasts in the operational mode weather forecast for meteorological parameters up to 5 days in quantitative terms for 612 districts of the country since 1 June 2008. (http://www.imdagrimet.org).

6.7 Meteorological Services to Aviation
IMD provides a crucial service to the national and international civil aviation sector in fulfillment of the requirements prescribed by the International Civil Aviation Organisation (ICAO) and the Director General of Civil Aviation of India (DGCA). These services are provided through 17 Aerodrome Meteorological Offices (AMO) and 51 Aeronautical Meteorological Stations (AMS) located at various national and international airports of the country.

6.8 Seismological Service
IMD is the nodal agency of Govt. of India, responsible for providing information, on 24X7 basis, relating to occurrence of earthquakes in and around the country to various state and central government agencies including those dealing with relief and rehabilitation
measures and other user agencies including, press, media etc. The information is also posted on IMD's Website (http://www.imd.gov.in).

6.9 Meteorological Training
Human resource development has always been one of the prime thrust areas of the IMD for capacity building and to keep pace with latest trends in various activities of the Department. The Central Training Institute (CTI) of the IMD is a World Meteorological Organization (WMO) rated Regional Meteorological Training Centre (RMTC), situated in Pune, India. Facilities for meteorological training at Pune and New Delhi have been recognized by the WMO to function as RMTC in all the four main disciplines namely, General Meteorology, Radio-meteorology, Telecommunication and Agro-meteorology. (http://www.imdpune.gov.in/training/training_index.html).

7. Summary
- IMD provides services to different sectors such as general public, Agriculture, Aviation, Power, Environment, Climate, Marine, Shipping etc. It takes meteorological observations on real time basis and provides current and past observations for operational and research community.

- IMD at present is involved in India specific climate related activities like Climate Monitoring and Analysis, Climate Data Management, Climate Research and Climate Prediction (extended range and Seasonal Forecasts).

- In order to enhance our climate related activities, in addition to resources within the department, IMD will make use of R & D support, expertise, latest and best available scientific knowledge and methods in performing the responsibility etc. from other institutes in India (such as IITM, NCMRWF etc.) and abroad, (such as NCEP, IRI, UKMO, ECMWF, Beijing Climate Centre (BCC, CMA), Tokyo Climate Centre (TCC, JMA), KMA and APCC etc.) as per the requirements.

- As a part of recent major modernization activities undergoing in IMD, efforts are going on to widen the climate services/activities so that in the near future it can cater the needs of the entire south Asian region.

Acknowledgement
First of all the author is very much thankful to Dr. (AVM) Ajit Tyagi, Director General of Meteorology, India Meteorological Department and the Ministry of Earth Science (MoES) for nominating to participate in the WMO workshop held in Beijing from 10-13 November, 2009. Thanks are also due to the National Climate Centre (NCC) in general and Dr. D.S. Pai, IMD Pune in particular for providing some input. Thanks are also due to WMO, BCC and CMA for making this event a success.
2.4 Report on regional climate applications in RA II

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WMO fosters the effective application of climate knowledge and information for the benefit of society in various sectors. Regional climate change and climate variability have various impacts on the socio-economic activities in the region. Recent climate fluctuations have demonstrated to many decision makers in weather-sensitive industries that climate variability has significant economic impacts. The impacts increase as the socio-economic activities become varied, complex and active. One major challenge to the NMHs is to provide the weather sensitive industries with timely and accurate forecasts and warnings of hazardous weather. The need for improving longer-term forecasting systems, particularly, to predict flood and droughts that could lead to disasters is a high priority in the region.

The advanced seasonal climate prediction can be enormously beneficial in national planning, e.g., in the areas of water resources management, disaster management, and agricultural planning and food production. The availability of improved models for seasonal climate prediction, and the development of ensemble prediction techniques, may provide the potential for the practical application of seasonal prediction.

One of the WMO roles, is to ensure that GPCs’ products are fully used to provide prediction data to WMO Member Countries, through their national meteorological services, to contribute to disaster prevention and mitigation (like severe climatic conditions), and to contribute to better socio-economic planning that accounts for variable climatic conditions. Towards achieving this goal, enhanced cooperation among GPCs is highly necessary. The fifteenth WMO Congress in 2007 agreed that some GPCs could serve as collectors of global LRF data to build Multi Model Ensemble (MME), and requested standards for MME products be developed. Congress requested also that the global LRF products be made available to as many Regional Climate Centres and National Meteorological Centres as possible for purpose of enabling them to perform their tasks. CBS-DPFS/ET-LRF recommended to CBS that KMA/NCEP be designated as a Lead Centre for LRFMME with responsibilities that include maintenance of a web portal of GPC and MME products.

Activities as Regional Climate Centres

The Climate Centres in Regional Association II have seriously developed and improved its LRF system and could deliver many various seasonal products for climate applications. Climate Applications Performed by Centres in various sectors.

Tokyo Climate Center (TCC) was established in April 2002 in the Headquarters of the Japan Meteorological Agency (JMA). TCC has conducted climate-related services with
the main purpose of assisting National Meteorological and Hydrological Services (NMHSs) in Asia and Pacific regions in the long-range forecast and climate monitoring. JMA has provided consolidated climate information to the public, decision makers and researchers through publication of the “Monthly Highlights on Climate System”. This report contains diagnostic information on current climate conditions with emphasis on climate in Japan, world climate, extra-tropical circulation, tropical circulation and convection, oceanographic conditions, and snow/ice coverage with the time scales from 5 days to decades. As one of the new services via TCC website, an online web-based interactive climate database called “ClimatView” was made available, enabling users to view and download data of monthly mean temperatures and monthly total precipitation derived from CLIMAT reports.

Beijing Climate Center (BCC) was established in March 2003, based on the National Climate Centre (NCC) of China Meteorological Administration (CMA), which was founded in January 1995, in order to meet the increasing requirements of social-economic activities on natural disaster mitigation related to climate anomalies and extreme climate events from domestic relevant communities to other National Meteorological and Hydrological Services (NMHSs) in Asia as well. Since its establishment, BCC has been engaged in its capacity building on provision of climate-related services and issuance of operational products of monitoring, diagnostics, long range forecast and assessments on regional and global climate to Asian communities through its websites (http://bcc.cma.gov.cn in English and http://ncc.cma.gov.cn in Chinese). BCC also provides operational data services to support climate monitoring, analysis and prediction in the web-based interactive way or on requirements of users.

North Eurasia regional Climate Centre (NEACC) was established by the Intergovernmental Council for Hydrometeorology of the Commonwealth of Independent States (CIS - Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, the Russian Federation, Tajikistan, Turkmenistan, Uzbekistan and Ukraine) at its 18th Session held in Dushanbe, Tajikistan, 4-5 April 2007, with the aim to provide regional climate related services to CIS countries. The 19th Session of CIS Intergovernmental Council for Hydrometeorology held in Obninsk, Russian Federation, 16-17 October 2007, adopted the Status of North Eurasia regional Climate Centre. At the current stage NEACC is a virtual multi-institutional centre comprising several institutions from Roshydromet:

National Climate Centre (NCC), Pune of the India Meteorological Department (IMD) has been functioning since 1995, carrying out many India specific climate related activities like Climate Monitoring and Analysis, Climate Data Management, Climate Research and Climate Prediction (Seasonal Forecasts). NCC is bringing out climate diagnostic bulletins regularly and different climate data products are prepared for the user community. Operational Seasonal forecast for rainfall over the country is another important activity of the NCC. As a part of recent major modernization activities undergoing in IMD, efforts are going on to widen the activities of the centre so that in the near future it can cater the needs of the entire south Asian region. Brief information regarding the present activities, future plans and needs of the center provided here.
The APEC Climate Center (APCC), established officially in Nov. 2005, has been issuing climate diagnostics and seasonal forecast guidance every month based on the climate multi-model ensemble (MME) methods. These MME predictions are the result of multi-institutional co-operation within the APEC region; 15 Tier-2, and 2 Tier-1 dynamical seasonal forecasts are made available to the APCC from 15 National Hydro-Meteorological Centers/Research Institutes of eight APEC member economies to facilitate the APCC MME forecasts. The ongoing development projects at APCC for future needs include an MME-based drought prediction system, and a user-friendly online climate information tool kit (CLIK) that can be used for customized applications such as regional downscaling or generating a customized MME online. These activities at APCC are directed towards the sustainable development of APEC economies through enhancement of human security against extreme weather and climate, and shed light on the adaptive measures for inadvertent climate change.
3. Countries Capabilities
3.1 Variability of monsoon rainfall and its impacts on socio-economic activity in Bangladesh

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Abstract

Bangladesh is a playground of natural calamities due to its geographical position. As a disaster prone area, Bangladesh experiences floods, droughts, flash flood, landslides etc. almost every year, causing heavy loss of lives and damages to properties. As the economy of Bangladesh is mainly agriculture oriented, crop failure either by the drought or flood and deficit/ or excess rainfall comes as a significant strain to its socio-economic structure. But the excess or deficit of rainfall depends on the behavior of monsoon as well as monsoon variability. An attempt has been made in this study to find out the monsoon rainfall variability and its associated hydrological impact in Bangladesh. It is found that monsoon rainfall of Bangladesh is quasi-biennial in nature with the intra-seasonal variability of 5-7 days. The variability of rainfall in June, July, August and September are within ±40%, ±30%, ±30% and ±30% respectively but the annual variability of monsoon rainfall is ±20%. The high amount of rainfall with short duration is responsible for the occurrence of flood situation in 1987, 1988, 1991, 1998 and 2007. It is also found that the high temporal and spatial variability of monsoon rainfall triggered landslide and flash flood situation over Chittagong (a city located in the south-eastern part of Bangladesh).

1. Introduction

Bangladesh is the most vulnerable to several natural disasters and every year natural calamities upset people’s lives in some part of the country. The major disasters concerned here are the occurrences of flood, cyclone and storm surge, flash flood, drought, tornado, riverbank erosion, and landslide. These extreme natural events are termed disasters when they adversely affect the whole environment, including human beings, their shelters, or the resources essential for their livelihoods. The geographical setting of Bangladesh makes the country vulnerable to natural disasters. The mountains and hills bordering almost three-fourths of the country, along with the funnel shaped Bay of Bengal in the south, have made the country a meeting place of life-giving monsoon rains, but also make it subjected to the catastrophic ravages of natural disasters. Its physiography and river morphology also contribute to recurring disasters. Since Bangladesh is a disaster prone country, it is subject to colossal damages to life and property almost every year.

Heavy rainfall can trigger superficial slope instabilities, such as landslides, debris flows and other related instability phenomena in hilly areas. These phenomena are a threat to settlements and infrastructure. Intense rainfall has a great potential to trigger landslides resulting in casualties and property damage across the world. Early results show that the landslide occurrences are closely associated with the spatial patterns and temporal
distribution of rainfall characteristics. Particularly, the number of landslide occurrences and the relative importance of rainfall in triggering landslides rely on the influence of rainfall attributes (e.g. rainfall climatology, antecedent rainfall accumulation, and intensity-duration of rainstorms) (Yang Hong et al., 2006).

Landslides are one of the most widespread natural hazards (Bryant, 2005) and cause billions of dollars in damages and thousands of deaths and injuries each year around the world (International Federation of Red Cross and Red Crescent Societies, 2003). Landslides are a significant component of many major natural disasters and are responsible for greater losses than is generally recognized. For rainfall-induced landslides, the effect can occur in many forms such as snow melt, change in groundwater levels, and water level changes along coastlines, reservoirs, and riverbanks; however, extreme rainfall of high intensity and/or long duration is among the most common landslide-triggering mechanisms (Dai et al., 2002).

2. Methodology and Data used

Data used in this study has been collected from Bangladesh Meteorological Department. 54 years (1951-2004) rainfall data for 31 stations Bangladesh during 01 June to 30 September have been considered for temporal variability. The missing data for some months of a few stations have been overcome by considering spatial or temporal averages and monthly normal of the stations. For finding out the recent situation of monsoon rainfall temporal and spatial analysis has been done during monsoon season of 2004-2009 with the data sets of 34 stations.

For understanding the flash flood situation on 11 June 2007 over Chittagong city three hourly rainfall data of Chittagong region namely Patenga (lat. 22.22°N and long. 91.23°E), Ambagan (lat. 22.35°N and long. 91.82°E), Sitakunda (lat. 22.58°N and long. 91.70°E), Sandwip (lat. 22.48°N and long. 91.43°E), and Rangamati (lat. 22.53°N and long. 92.20°E) during 09-11 June 2008 has been analyzed. As the rain gauge network has limited coverage, the Tropical Rainfall Measuring Mission (TRMM) 3B42 rainfall data with resolution of 0.25°x 0.25° for the same time and duration has been considered to estimate the rain rate and compare the result found from the BMD rain gauge rainfall for better explanation.

3. Results and discussion

3.1 Variability of monsoon rainfall

3.1.1 Daily rainfall pattern of Bangladesh in monsoon season
Based on the observed periodic rain gauge rainfall, daily average monsoon rainfall of Bangladesh is calculated. It is found that the pattern of it is quasi-biennial in nature with the peak values of 20.6 mm/day and 21.1 mm/day on 16 June and 10 July respectively. Daily average rainfall increases sharply from the onset of the season and maintains its high value (over or near 17 mm/day) during 14 June to 31 July. After that it is decreased with the progress of season and finally its value goes down to 7mm/day during the last
decade of September. The observed periodicity of the intra-seasonal variability is 5-7 days with the changing value of 3-5 mm/day and the details are given in Fig. 1.

### 3.1.2 Daily rainfall pattern of June, July, August and September in Bangladesh

From the analysis it is found that the daily average rainfall of June increases sharply during 01-16 June from 10.8 - 20.6 mm/day and then decreases to 13.0 mm/day on 27 June. After that it goes up 17.2 mm/day on 29 June but the higher values are found in between 11- 25 June. The pattern of it is biennial in nature with the peak values of 20.6 mm/day and 18.7 mm/day on 16 June and 29 June respectively and is shown in Fig. 2.

The average rainfall pattern of July is also biennial in nature with the peak values of 21.1 mm/day and 18.1 mm/day on 10 July and 21 July respectively. It varies from 13.9 - 21.1 mm/day but the higher values are found between 05-15 July and the details are shown in Fig. 3. The average rainfall pattern of August is also biennial in nature with the peak values of 17.0 mm/day and 16.1 mm/day on 02 August and 14 August respectively. It varies from 9.8-17.0 mm/day but the higher value is found in between 01-05 August and 12-16 August and is shown in Fig. 4. In September, average rainfall pattern is also biennial in nature with the peak values of 12.3 mm/day and 13.2 mm/day on 10 and 26 September respectively. It varies from 7.0- 13.2 mm/day during the month and is shown in Fig. 5.

### 3.1.3 Temporal variation of monthly monsoon rainfall

For better understanding the temporal variation of rainfall of June, July, August and September are analyzed separately and then temporal variation of seasonal rainfall is analyzed. In June, the country average rainfall varies within 234 mm and 785 mm and observed respectively in 1998 and 1954. Analysis shows that the variation of country average rainfall of June is high and varies normally from -40% to + 40%. But the most of the higher variation is found in 1954 (+89%), 2001(+61%), 1984 (+55%), 2003 (+49%), 1975 (-44%) and 1997 (-49%). The variation spectrum of rainfall of June is shown in Fig. 6.

In July, the country average rainfall varies within 337 mm and 856 mm and observed respectively in 1972 and 1987. The variation of it is mostly within ±30% but the higher variation are observed in 1974 (+42%), 1987 (+59%) and 1998 (+43%). The variation spectrum of rainfall of July is shown in Fig. 7. In August, the country average rainfall varies within 182 mm and 637 mm and observed respectively in 1987 and 1998. The variation of it is mostly within ±30% but the higher variation observed in 1998 (+53%), 1983 (+46%), 1969 (+44%), 1987 (+40%), 1956 (+38%), 1965 (+36%), 1975 (-32%), 1957 (-34%), 2001 (-35%), 1990 (-37%) and 1989 (-57%). The variation spectrum of rainfall of August is shown in Fig. 8.

In September, the country average monsoon rainfall varies within 143 mm to 606 mm found in 1972 and 2004 respectively. The variation of it is also within ±30%. The higher variations are found in 1986 (+60%), 1991 (+45%), 1997 (+42%), 1967 (+40%), 1953 (+31%), 1962 (-34%), 1981 (-36%), 1955 and 1968 (-38% each), 1976 (-43%), 1994 (-47%) and 1972 (-55%). The variation spectrum of rainfall of August is shown in Fig. 9.
3.1.3 Temporal variation of seasonal monsoon rainfall during

The country average monsoon rainfall during the observed period varies from 1272 to 2223 mm and found respectively in 1957 and 1987. The variation is almost within ±20%. The higher variation is found in 1987 (+26%), 2004 (+25%), 1984 (+21%), 1992 (-21%), 1958, 1972 and 1994 (-22% each), 1957 (-23%), 1980 (-27%). The variation spectrum of monsoon rainfall is shown in Fig. 10.

Figure 1: Daily average rainfall pattern of Bangladesh during monsoon season

Figure 2: Daily average rainfall pattern of Bangladesh in June

Figure 3: Daily average rainfall pattern of Bangladesh in July

Figure 4: Daily average rainfall pattern of Bangladesh in August

Figure 5: Daily average rainfall pattern of Bangladesh in September

Figure 6: Annual variation of rainfall in June in Bangladesh
3.1.4 Temporal variation of recent seasonal monsoon rainfall during

In June the highest positive deviation of 20.2% is observed in 2007 but the lowest negative deviation of -37.1% is observed in 2009. In July the highest positive deviation of 30.7% is observed in 2007 followed by 23.5% in 2008 but the lowest negative deviation of -19.4% is observed in 2006. In August the highest positive deviation of 23.2% is observed in 2009 but the lowest negative deviation of -34.3% is observed in 2006 followed by -26.3% in 2007. In September the highest positive deviation of 45.4% is observed in 2004 followed by 36.5% in 2006 but the lowest negative deviation of -16.7% is observed in 2009. Seasonal analysis shows that the highest seasonal rainfall deviation of 11.3% is observed in 2007 and the lowest negative deviation of -16.0% is observed in 2009. The details are given in Table 1 and shown in Figs. 11 and 12.

Table 1: Monthly and seasonal rainfall in Bangladesh during 2004-2009

<table>
<thead>
<tr>
<th>Month or season</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td>+8.1</td>
<td>-24.4</td>
<td>-23.6</td>
<td>+20.2</td>
<td>-4.4</td>
<td>-37.1</td>
</tr>
<tr>
<td>July</td>
<td>+1.4</td>
<td>-2.6</td>
<td>-19.4</td>
<td>+30.7</td>
<td>+23.5</td>
<td>+12.5</td>
</tr>
<tr>
<td>August</td>
<td>-17.8</td>
<td>+17.9</td>
<td>-34.3</td>
<td>-26.3</td>
<td>-0.5</td>
<td>+23.2</td>
</tr>
<tr>
<td>September</td>
<td>+45.4</td>
<td>+0.0</td>
<td>+36.5</td>
<td>+23.7</td>
<td>-15.6</td>
<td>-16.7</td>
</tr>
<tr>
<td>Monsoon</td>
<td>+10.0</td>
<td>-3.0</td>
<td>-16.0</td>
<td>+11.3</td>
<td>+2.9</td>
<td>-3.7</td>
</tr>
</tbody>
</table>
Fig. 11a: Temporal variation monsoon rainfall in 2004

Fig. 11b: Temporal variation monsoon rainfall in 2005

Fig. 11c: Temporal variation monsoon rainfall in 2006

Fig. 11d: Temporal variation monsoon rainfall in 2007

Fig. 11d: Temporal variation monsoon rainfall in 2008

Fig. 11e: Temporal variation monsoon rainfall in 2009
3.2 Hydrological impact of monsoon rainfall in Bangladesh

3.2.1 Impact of monsoon rainfall on floods in Bangladesh
The actual average rainfall, normal rainfall and percentage of deviation from the normal over Bangladesh during some floods are given in Table 2. It is seen from the table that the average rainfall over Bangladesh during the monsoon period of 1987 was excess by 19.77 to 77.43% as compared to the normal rainfall. In 1988, the rainfall was above normal by 13.18%, 2.11% and 27.01% in June, July and August respectively whereas it was below normal by 11.55% in September. In 1991, the average rainfall was above normal by 42.86% and 69.96% in June and September respectively, whereas the average rainfall over the country was almost normal in July and August respectively. The average rainfall was below normal by 43.64% in June 1998 and above normal by 52.95% in July.

<table>
<thead>
<tr>
<th>Month</th>
<th>Normal</th>
<th>Actual</th>
<th>% dev</th>
<th>Actual</th>
<th>% dev</th>
<th>Actual</th>
<th>% dev</th>
<th>Actual</th>
<th>% dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td>440</td>
<td>527</td>
<td>19.77</td>
<td>498</td>
<td>13.18</td>
<td>589</td>
<td>33.8</td>
<td>248</td>
<td>-43.64</td>
</tr>
<tr>
<td>July</td>
<td>474</td>
<td>841</td>
<td>77.43</td>
<td>484</td>
<td>2.11</td>
<td>444</td>
<td>-6.3</td>
<td>725</td>
<td>52.95</td>
</tr>
<tr>
<td>Aug.</td>
<td>385</td>
<td>566</td>
<td>47.01</td>
<td>489</td>
<td>27.01</td>
<td>385</td>
<td>5.0</td>
<td>604</td>
<td>56.88</td>
</tr>
<tr>
<td>Sept.</td>
<td>277</td>
<td>431</td>
<td>55.60</td>
<td>245</td>
<td>-11.55</td>
<td>476</td>
<td>71.896</td>
<td>282</td>
<td>1.81</td>
</tr>
</tbody>
</table>

The excessive rainfall over the country in the above mentioned years was responsible for the occurrence of floods in Bangladesh.

3.2.2 Flash flood situation over Chittagong City and adjoining area
Temporal analysis of rain gauge rainfall shows that from 06 UTC of 10 June 2007 rainfall started over Chittagong and adjoining areas and with the progress of time the rainfall rate was increasing and it was higher during 00-06 UTC on 11 June. During this time the highest rainfall of 315 mm was recorded at Ambagan, which is located in the city centre. After that the rainfall was continuing up to 06 UTC of 12 June with lower rate and very short break. This continuous and high rate of rainfall helped to trigger land slide and flash flood situation over the city. The details are given in Fig. 13.

Analysis of TRMM 3B42 rainfall data reveals similar pattern and high rainfall rate during 00-06 UTC on 11 June over Chittagong and adjoining areas with the rainfall of 461 mm at point 1 (lat. 22.50°N and long. 91.50°E), 435 mm at point 2 (lat. 22.00°N and long. 91.75°E), 395 mm at point 3 (lat. 22.25°N and long. 91.75°E), 412 mm at point 4 (lat. 22.50°N and long. 91.75°E), 381 mm at point 5 (lat. 22.50°N and long. 91.25°E) which are located over the city. The temporal variations of five higher rain rate points are shown in Fig. 14.

Spatial distribution of rainfall during 96 hours commencing 00 UTC of 09 June 2007 shows that due to high convection this heavy rainfall event was concentrated over Chittagong city and adjoining area only and is shown in Fig. 15. Similar distribution pattern is also observed for TRMM data with higher amount and the details are shown in Fig. 16.
4. Conclusions
Temporal and spatial variability of monthly and seasonal rainfall in monsoon is high and sometimes responsible for flood situation or drought condition in Bangladesh. But its diurnal or less periodic variability often created water logging; flash flood and or landslide and hamper socio-economic activities of the people. Though monsoon rainfall has a large contribution in agriculture and economic activities but it may create havoc if some social factors are added with the monsoon behaviour. To get clear understanding about monsoon variability and its hydrological impact further studies are required.

Reference


3.2 Climate Monitoring, Climate Change Research
and Long Range Forecasting
in Hong Kong, China

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Extended Abstract

Introduction

For over 120 years, the Hong Kong Observatory (HKO) has been monitoring various meteorological elements in Hong Kong and providing a large variety of climate information and services for different sectors of the community. In recent years, HKO has also been actively carrying out research and studies on climate change in Hong Kong and sparing no effort in its public education activities to reach out to the public, especially the younger generation. Moreover, HKO has been providing the public with seasonal forecasts services and the annual outlook on rainfall anomaly and tropical cyclone activities affecting the territory.

Climate Monitoring and Climate Change Researches

HKO has been conducting meteorological observations in Hong Kong since its establishment in 1883. From the 20th century onwards, apart from a break due to the Second World War, the frequency of observations, the number of weather stations and the number of meteorological elements observed have increased through the years. The meteorological coverage of Hong Kong was further enhanced with the establishment of an automatic weather station network since the mid-1980s. The meteorological data collected over the years serve as an important basis for monitoring the climate and studying the climate change in Hong Kong.

Scientific studies to evaluate the observed climate trends in Hong Kong due to global warming and urbanization effects were carried out in recent years. Significant changes in the climate in Hong Kong were observed in the last century, including the increase in average temperatures and total rainfall as well as the rise of mean sea level (Wong *et al.*, 2003; Leung *et al.*, 2004). Studies of past occurrences of extreme temperature and rainfall in Hong Kong have also been carried out. It is observed that cold episodes have become rarer while very hot days and heavy rain events are becoming more frequent (Wong and Mok, 2009).

Starting in 2004, HKO conducted studies on the possible future trends of temperature and rainfall in Hong Kong up to the end of the 21st century based on the latest available Intergovernmental Panel on Climate Change (IPCC) assessments of global climate change. In the light of the revised global projections of the 2007 IPCC’s Fourth Assessment Report (AR4), HKO updated its projections for the temperature and rainfall in Hong Kong in the 21st century in 2008 and 2009 respectively. It is found that
the mean temperature of Hong Kong will continue to rise in the 21st century (Leung et al., 2007). The annual rainfall in Hong Kong is also expected to rise by the end of the 21st century, so is the year-to-year variability (Lee et al., 2009). The results of the temperature and rainfall projections for Hong Kong in the 21st century will provide the scientific basis for further studies on the subject, particularly on the assessment of Hong Kong's vulnerability, adaptation and mitigation in connection with climate change. These projections are also of interest to the public and help raise the awareness of climate change and its impact in the community. Further studies on the projections of extreme weather events for Hong Kong in the 21st century is being carried out using daily projections of global climate models of IPCC. Initial results in respect of climate extremes suggest that, in the 21st century, extremely high temperature events will become more frequent while that of extremely low temperature events will become rarer in Hong Kong.

Furthermore, HKO has carried out climatological researches on topics of public interest such as urban climate and relationship between weather and health (Wu et al., 2008; Leung et al., 2008 Chan et al., 2009). Joint research projects with tertiary institutions have also been conducted to enhance research capability and broaden the scope of scientific investigation.

![Figure 1 Annual mean temperature recorded at the Hong Kong Observatory (1885-2008). Data was not available from 1940 to 1946 because of World War II. There was an average rise of 0.12°C per decade in the annual mean temperature from 1885 to 2008. The rate of increase in average temperature became faster in the latter half of the 20th century.](image)

**Long range forecasting**

In 2001, HKO started to provide annual outlook to the general public of Hong Kong based on the forecast ENSO status produced by major climate centres and the empirical statistical relationship between ENSO status and local climate. The annual outlook includes a tercile category rainfall forecast of Hong Kong and a forecast on the
tropical cyclone activity affecting the territory. Recently, dynamical model outputs from WMO Global Producing Centres (GPC) for Long-range Forecast have been adopted in formulating the rainfall forecast in a bid to improve performance of the annual outlook.

In 2006, HKO launched its seasonal forecast service which comprises of seasonal temperature and rainfall forecast, both in terms of tercile category (http://www.hko.gov.hk/wxinfo/season/season.htm). Currently HKO operates a suite of global-regional climate model adapted from the Experimental Climate Prediction Center (ECPC), US, to support seasonal forecasting (Hui and Shum, 2005). Apart from operating the model suite, HKO is also looking at statistically downscaling of digital forecast data from WMO GPC with a view to improving the skill of its long-range forecast.

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3.3 Status and priority needs of monitoring and predicting climate anomalies and extremes over the Indian region

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1. Introduction

India is frequently affected by extreme weather and climate events and related disasters such as droughts, dry spells, heat waves, cold waves, flooding, cyclones, wind storms, severe thunderstorms/lightning, land slides, coastal erosions, salinity intrusion etc. Also as the Agriculture output primarily depends on rainfall the variability in monsoon (rainy season) that occurs over a range of temporal scales from intra-seasonal (30-60 day intraseasonal oscillations) to inter-decadal, dominated by interannual variations can have adverse impacts due to crop failures. India receives about 75 to 90% of its annual rainfall during this period and hence, prediction of various phases of monsoon (like its onset & advance, active and break cycle of monsoon) is very crucial to the farming community. Prediction of rain producing monsoon systems like monsoon depressions and lows and the monsoon rainfall pattern in different time scales is important for various sectors, like agriculture, water management, power industry etc. Monsoon rainfall prediction in long range (On seasonal scale) is very useful for planners, especially when a large deficient rainfall scenario is foreseen. More importantly, the rainfall forecast on smaller spatial scale on intra-seasonal (active and break cycle) time scale is very crucial for the farming community. The onset, withdrawal and active and dry spell of monsoon is also very crucial for the country like India. A failure in monsoon rainfall leads to drought conditions and can affect the economy of the country. In addition to that the population density is very high over this part of the world as a result the risk arises due to these adverse climatic conditions are also very high. Thus having an effective climate watch system (CWS) is the need of the hour.

To meet the requirements of a variety of users, IMD issues weather forecasts in different time scales, from short range (including now casting) to long range. The present short range forecasting technique is primarily synoptic based, a subjective method, but the forecaster makes use of the valuable guidance available by different numerical models (regional as well as global) in addition to the various products from radars and satellites. Medium range forecasts are issued mainly making use of the predictions available by global models. IMD issues long-range forecasts in respect of monsoon rainfall using statistical methods. Very recently, it has introduced dynamical models for seasonal forecasting of monsoon rainfall in experimental mode.

A major concern in recent decades is the issue of climate change vis-à-vis global warming. Questions have risen about the change in monsoon rainfall pattern, trends in the occurrence of extreme rainfall events/droughts, increase in the frequency of severe cyclones, glacier melting and flooding in addition to rise in the sea level and coastal submerging. Systematic analysis of climate data and model predictions/projections are very important for planners and managers.
A number of national centers and institutions are also engaged in meteorological studies and development of suitable models for the prediction of weather systems affecting Indian region. IMD has strong linkages with these institutions as well as international operational/research centers for improving the understanding of tropical weather systems as well as prediction capabilities. Routinely seminars and brainstorming meetings are conducted by IMD and other national agencies to exchange and update the recent advances in meteorology.

2. Variability and Prediction of Climate Anomalies and Extremes

2.1 Monsoon

India being predominantly an agriculture country is dependent on the monsoon (June to September) rainfall. Prediction of monsoon rainfall in different time scales is a major challenge for operational meteorologists. Broadly, following aspects of monsoon are needed high priority:

a) Seasonal prediction of monsoon rainfall
b) Prediction of active-break monsoon spells
c) Role of Indian Ocean and other forcing in understanding monsoon variability
d) Extreme rainfall events - their trends and prediction

IMD utilizes a statistical model (8 to 10 parameters) for issuing the long-range prediction of monsoon rainfall, which has very large spatial non-homogeneity with lowest rainfall over northwest parts of India and highest rainfall over the west coast and parts of northeast India (Fig. 1). The details of the statistical model that is being used is available in Rajeevan et al., 2004 and Rajeevan et al., 2006a. The all India area weighted mean rainfall during June to September is about 89 cm with a coefficient of variability of 10%. Sahai et al., 2003 have developed a SST based long lead prediction of all India summer monsoon rainfall. These statistical models although have shown good promise, but has limitation in providing useful prediction in smaller spatial scale. Predictions by the dynamical models also are not encouraging as of now. Research work is to be focused on how to improve seasonal prediction capabilities and sub regional scale predictions of rainfall pattern.

A major advance in our understanding of the year-to-year variation of the monsoon rainfall occurred in the 80s, with the discovery of a strong link with El Nino - Southern Oscillation (ENSO), the dominant signal of interannual variation of the coupled atmosphere–ocean system over the Pacific (Shukla et. al., 2000). It was shown that there is an increased propensity of droughts during El Nino or the warm phase of this oscillation (e.g. 1982, 1987) and excess rainfall during the opposite phase, i.e. La Nina (e.g.1988) as seen from the interannual variability of monsoon rainfall (Fig. 2). Some recent studies have shown weakening of the classical relationship between ENSO and AISMR (Kripalani and Kulkarni 1997) and it was proposed that it might be due to global warming (Krishna Kumar et al. 1999). The experience of 1997 (strongest El Nino but positive rainfall departure) and 2002 (not a very strong El Nino but large negative
departure of rainfall) suggests that we yet to understand adequately, the response of the monsoon to El Nino.

Fig. 1: Rainfall during the Southwest monsoon season (June to September) contributes about 70-90% of annual rainfall (Source: Gridded rainfall data prepared by National Climate Centre (NCC), IMD Pune.

All India Summer Monsoon Rainfall (1875-2009)

Fig. 2: Departure of All India summer monsoon rainfall during 1875-2009 with mean = 89 cm and SD=10%.
The role of the Indian Ocean in understanding the interannual variability of the Indian Summer Monsoon Rainfall (ISMR) has also become very important in the light of the weakening of ENSO-monsoon relationship (Saji et al., 1999). It is also found that the convective activity over northwest Pacific is more pronounced associated with typhoon activity during the dry spell of monsoon over India as seen in case of July 2002 (Pattanaik and Rajeevan 2007). They have shown that there exists inverse relationship between Indian monsoon rainfall and typhoon activity over Northwest Pacific. Gadgil et al., 2003 have found that the enhancement of deep convection in the atmosphere over the western part the equatorial Indian Ocean is generally associated with suppression over the eastern part and vice versa and the oscillation between these two states, which is reflected in the pressure gradients and the wind along the equator, is called as the Equatorial Indian Ocean Oscillation (EQUINOO). The excess and deficient rainfall can be explained in terms of favourable/unfavourable phase of either this oscillation or the ENSO or both. In particular, in the monsoon season of 2002 while the ENSO phase was unfavourable but weak, the phase of the EQUINOO was highly unfavourable and a large deficit occurred in the monsoon rainfall. Even the evolution of convective anomalies over Indo Pacific region to Bay of Bengal from winter to pre-monsoon season (Jan to May) prior to a deficient and excess monsoon shows contrasting patterns (Pattanaik et al., 2005). As shown by them, before an ensuing excess monsoon year convection anomalies from winter moves in a west-north-west direction from western Pacific region and established over the eastern Indian Ocean and adjoining southeast Asia region by the month of May associated with a gradual reversal of anomalous rising motion over western Pacific in January to anomalous sinking motion in May. However, during a deficient monsoon year the convection anomalies established over the equatorial warm pool region of western Pacific east of around 150°E during the northern winter (January) almost remain active over the same region till the month of May and consequently there is persistent presence of anomalous rising motion over the western Pacific region from Jan to May as seen in case of deficient monsoon of 2002 and 2004. Hence, focused research required to understand the role of Indian Ocean and the convection anomalies vis-a-vis interannual variability of ISMR.

Analysis of seasonal monsoon rainfall shows intra seasonal variations. There are a few active spells and weak/break spells within the season. Prediction of such active and break phase of monsoon is very important for the agriculture sectors and water management and research on this issue need to be encouraged and supported. The convective activity over the monsoon trough region and that over the equatorial south Indian ocean oscillates with sea-saw relation with one active and other inactive and vice versa. These influence the monsoon activity over Indian region (Gadgil 2000, Pattanaik 2007) on intra-seasonal scale. The phenomenon of ‘break monsoon’ is of great interest because long intense breaks are often associated with poor monsoon seasons. Such breaks have distinct circulation characteristics (heat trough type circulation) and have a large impact on rainfed Agriculture. Anomalous southward intrusion of troughs in the mid-latitude westerlies into the Indo-Pak region in the middle and upper troposphere (Ramaswamy 1962) are often associated with break in monsoon condition. Although interruption of the monsoon rainfall is considered to be the most important feature of the break monsoon, traditionally breaks have been identified on the basis of the surface pressure and wind patterns over the Indian region. The rainfall criteria are chosen so as
to define the breaks period Ramamurthy (1969) and De et al (1998). The phase and magnitude of MJO has direct influence on intra-seasonal oscillation of monsoon rainfall over India (Pai et al., 2009). The prolonged break during July 2002 and the very active cycle of monsoon during 1988 is shown in Fig. 3.

**Fig. 3:** All India area weighted daily rainfall (mm) during the monsoon season of (a) 1988 and (b) 2002 along with the normal.

Although the IMD is operationally using the statistical model for long range forecasting the use of statistical models are somewhat problematic because of:

- Secular variations in the predictor-rainfall relationships and predictability
- Role of intra-seasonal variations (ISOS) on monsoon rainfall – MJO prediction
- Non-linear relationships of predictors with rainfall

Thus, there are efforts simultaneously to adopt dynamical model.
Dynamical Model

India was the first country to start operational Long Range Forecasts, since 1886 by Sir H F Blanford. The main approach used for this purpose was based on the statistical models. However, looking at the potential of dynamical models for providing seasonal forecasts for tropical region, IMD, Pune in collaboration with Indian Institute of Science (IISc) has also implemented an experimental dynamical model forecasting system in 2003. The experimental forecasting system established at the National Climate Centre (NCC), Pune is based on the Seasonal Forecast Model (SFM) of the Experimental Climate Prediction Center (ECPC). Preparation of experimental dynamical model forecasts for the monthly and seasonal southwest monsoon rainfall was started in 2005. The SFM model was originally developed at the National Centers for Environmental Prediction (NCEP) to provide regional details for the Global Spectral Model (GSM). The details of the model are described in Kanamitsu et al. (2002).

Empirical-Dynamical model for monthly and seasonal prediction

Different climate prediction centers around the globe (Like NCEP, ECMWF, UKMO, JMA, APCC etc. are presently producing real time seasonal forecast over the globe using coupled models. In order to use these forecast for operational purpose the skill of these models are to be evaluated. To evaluate the performance of the Climate Forcasting System (CFS) for the simulation of summer monsoon rainfall over Indian monsoon region during June to September (JJAS) against the verification rainfall analysis (Xie-Aarkin), the NCEP’s CFS model hindcasts are used for 25 years period from 1981 to 2005. The model initialized during March, April and May and integrated for a period of 9 months with 15 ensemble members during each month to generate the model hindcasts. The details of the analysis is published in a recent paper by Pattanaik and Kumar (2009). The model configuration of NCEP “climate Forecast System (CFS)” can be obtained from Saha et al., (2006).

The CFS’s hindcast climatology during JJAS for March (lag –3), April (lag –2) and May (lag-1) initial conditions show mostly the identical patterns of rainfall like that of verification climatology with both the rainfall maxima (one over the west-coast of India and the other over the head Bay of Bengal region) simulating well. The pattern correlation between verification and forecast climatology over the global tropics and Indian monsoon region (IMR) bounded by 50°E-110°E and 10°S-35°N shows significant correlation coefficient (CCs). The skill of the CFS as measured from Anomaly CC (ACC) to forecast the year-to-year variation of SST over the Nino3 and Nino3.4 regions are found to be highly significant. The maps of Anomaly CC (ACC) between forecast and verification rainfall during JJAS shows identical patterns with March, April and May forecast with higher ACCs particularly over the southern and eastern parts of the country (more than 0.4) and it is comparatively less over the northeastern and western parts of the country. The corresponding Root Mean Square Error (RMSE) is of the order of 1 mm/day almost over the entire Indian region except over the northeastern parts of the country and some isolated pockets of west coast of India. Hence the skill of the CFS for monsoon forecast is reasonably good over the Indian region particularly on seasonal
scale during JJAS. It is also seen (Saha et al., 2006; Pattanaik & Kumar 2009) that the CFS has better predictive skills for El Nino as well the monsoon circulation features. However, there is still some problem with prediction of Indian Ocean Dipole (Pattanaik and Kumar 2009). The CFS forecast rainfall anomaly during JJAS during the good monsoon year of 1994 as shown in Figs. 4b-4d with March, April and May initial conditions are slightly matching with the corresponding observed anomaly as shown in Fig. 4a, although the magnitude of the anomaly is different.

Fig. 4: Seasonal (June to September; JJAS) observed rainfall anomalies (positive anomalies are shaded) for 1994 in mm/day valid for a) observation (Xie-Arkin). (b), (c) and (d) Corresponding CFS forecast with March, April and May initial conditions.
Fig. 5: Seasonal (June to September; JJAS) observed rainfall anomalies (positive anomalies are shaded) for 1994 in mm/day valid for a) observation (Xie-Arkin). (b), (c) and (d) Corresponding CFS forecast with March, April and May initial conditions.

On the other hand in case of a drought year 2002 the negative anomaly as seen in the observed anomaly (Fig. 5a) is not very well captured in the CFS forecast anomaly (Figs. 5b-d). Thus, although the model could capture many features of Indian monsoon reasonably well there is a further need to enhance its skill by developing empirical models out of the forecast variables having higher skill.

Based on the regions of significant CCs between the All India Summer Monsoon Rainfall (AISMR; only the land observations) with the CFS forecast variables during JJAS at each grid point with March to May initial conditions, number of linear regression equations are developed for the prediction of AISMR (Pattanaik and Kumar 2009). It is found that the predicted mean AISMR and actual AISMR shows highly significant CCs (99% or more significance level) during March, April and May initial conditions. It is also observed that during most of the years the predicted and actual AISMR are in phase even in the test period of 2001 to 2005. Hence the calibrated CFS forecast could be used as a better tool for the real time prediction of AISMR (Pattanaik and Kumar 2009). In a similar manner efforts are needed to evaluate the skill of other climate models over the Indian region so that it can be used operationally by IMD.

Many statistical models have been developed to forecast monsoon rainfall on intraseasonal time scale (Xavier and Goswami 2007; Chattopadhyay et al., 2008 etc). Also some of the climate prediction centers generates extended range forecast up to one month using climate model (NCEP, ECMWF, JMA, KMA, CMA etc). Considering
2.2 Drought

The interannual variability of monsoon rainfall over India as shown in Fig. 2 indicates many drought years and also excess years. The recent drought years are 1972, 1974, 1979, 1982, 1986, 1987, 2002, 2004 and 2009. During these years different parts of the country faced drought conditions with rainfall departures varies from one-year to other. Many districts of the states Gujrat, Maharashtra, Rajasthan, Madhya Pradesh, Haryana, Uttar Pradesh, Bihar, Orissa, West Bengal, Andhra Pradesh, Karnataka and Tamilnadu are drought prone areas. During the 2009 monsoon season most parts of India experienced drought conditions as a result of very less rainfall as shown in Fig. 6. Non availability of proper drinking water and also the malnutrition during the drought years can create favourable conditions for the disease transmission. Indication of the drought like condition well in advance will be very useful. Thus, a better climate watch system can give indication of impending drought condition.

Fig. 6: Met subdivision wise departure of summer monsoon rainfall during the southwest monsoon season from June to September 2009.
2.3 Heavy rainfall

Another important operational and research problem is the occurrence of extreme rainfall events. For example, Santacruz observatory at Mumbai, the commercial capital of India had experienced unprecedented 24 hr rainfall of 94.4 cm recorded at 0300 UTC of 27 July, 2005, an all-time highest record for the city. There is a station near “Vihar Lake” which received 104.5 cm of rainfall on same day. Colaba Station recorded only 7.3 cm rain on that day. There are many unsolved questions such as what really happened in Mumbai on 26th July that caused such as unprecedented rain and can we predict such events?

Present day meso-scale model (Like WRF-ARW and MM5) are although capable of capturing genesis and movement of the synoptic scale system (like the monsoon depression), which contribute heavy to very heavy rainfall over India reasonably well the magnitude of observed heavy rainfall on some occasion is underestimated in the model. As seen in Fig. 7, forecast track of monsoon depression of September 2008 using WRF-ARW meso-scale model is reasonably good based on 16th and 17th initial condition particularly with Kain-Fritsch (KF) scheme of cumulus parameterization. Similarly the observed heavy rainfall on 18th September associated with the depression as shown in Fig. 8a is also well captured by WRF-ARW model with KF scheme in its 48hr forecast (Fig. 8b).

![Fig. 7](image-url) Observed and forecast track of monsoon depression for 3 days using WRF-ARW mesoscale model at 20 km resolution with Grell-Devenyi (GD) scheme, Kain-Fritsch scheme, Betts-Miller-Janjic (BMJ) scheme with initial condition of 16th (left) and 17th (right) September.
Easterling et. al., (2000) have found that changes in mean precipitation are insignificant while changes in heavy/very heavy precipitation are statistically significant. Pattanaik and Rajeevan (2009) have done a detailed analysis of spatial and temporal distribution of different category of daily rainfall during the southwest monsoon season during the period from 1951 to 2005 using the IMD’s gridded rainfall data (Rajeevan et al., 2006b). As per the classification when 1 day rainfall (R) exceeds 64.4 mm and upto 124.4 mm (64.4 < R ≤ 124.4) it is called heavy rainfall and when the one day rainfall satisfy the condition (124.4 < R ≤ 244.4) it is termed as very heavy rainfall and when it exceeds 244.4 mm in a day it is termed as exceptionally heavy rainfall. As it is seen from the study by Pattanaik and Rajeevan (2009) that the average frequency of heavy and extreme (very heavy + exceptionally heavy) rainfall area distributed over many parts of the central India, west coast of India, parts of northern India and entire northeast India with the highest frequency over the west-coast of India, northeast parts of India and also some isolated pockets over central parts of India. Thus, it is seen that the highest frequency of extreme rainfall event is mainly observed over west-coast region extending upto Gujrat coast, northeast parts of the country and some parts of central India associated with movement of synoptic scale systems from the Bay of Bengal. Some recent studies have indicated (i) significant rising trends in the frequency and the magnitude of extreme rain events and (ii) a significant decreasing trend in the frequency of moderate events over India during the monsoon seasons (Goswami et al., 2006; Pattanaik and Rajeevan 2009). The assimilation of non-conventional data with proper physics in the model can improve the heavy rainfall forecasting. In the light of global warming and climate change scenario, prediction of extreme rainfall events is a major challenge and needed priority research.

Fig. 8: Observed one day rainfall valid for 18th September, 2008 and 48hr forecast rainfall valid for the same day with WRF-ARW model using Kain-Fritsch scheme.
2.3 Tropical Cyclone

The tropical cyclones (TCs) are one of the most dangerous natural disasters throughout the globe. Over the Indian Seas the system with maximum sustained 3 minutes surface winds of 34 knots or more is called as cyclonic storm and when it exceeds 63 knots it is identified as Very Severe Cyclonic Storm (VSCS) and so on. India has a vast coastline, which is prone to very severe cyclone formations in the Arabian Sea and the Bay of Bengal. These occur during the pre monsoon (April-May), early monsoon and post monsoon (September-November) periods. Strong winds, heavy and torrential rains and the cumulative effect of storm surges and astronomical tides are the three major elements of tropical cyclone disaster. This is also the basin where TCs do the most damage due to the combined affect of terrain and the Geography.

The current emphasis of international tropical cyclone research is to achieve greater accuracy of tropical cyclone track and intensity prediction, especially in the short range (48-72 hr in advance), by maximizing the use of non-conventional data, meso-scale analysis, use of synthetic data for vortex specification, and the physical parameterization in non-hydrostatic environment at higher model resolution. High priority needs to be given to generate more quality data (both conventional and non-conventional), improved data assimilation technique and reliable model predictions (in respect of track and intensity). Recent studies have shown an increasing trend in the occurrence of severe cyclones over north Indian Ocean basin (Singh et al., 2001). It is important to investigate this issue in relation to the global warming scenario for giving suitable advices/guidelines to the national management agencies on this disturbing trend.

2.4 Heat Wave and Cold wave

Extremely hot weather is common in India during late spring preceding the climatological onset of the monsoon season in June. During summer, most areas of India experience episodes of heat waves almost during every year causing sunstroke, dehydration and death. Many authors have made detailed studies of heat waves over India in recent times (De et. al., 2005 Bhadram et. al., 2005 etc.). As reported the death tolls that were recorded over an entire summer some 10 years ago over India now routinely occur in just one week (Larsen 2003). The global climate anomalies have indicated that 1998 was the warmest year in last century (Jones & Briffa 1992) with more than 1000 people have died over India due to scorching temperatures over Orissa, Coastal Andhra Pradesh, Rajasthan and Tamilnadu during May/June. Similarly, in May 2003 the heat wave claimed over 1,600 lives throughout the country with some 1,200 individuals died in the state of Andhra Pradesh alone. Like in 2003, during 2005 also India was under the grip of severe heat wave towards the third week of June and about 200 people died in the eastern parts of the country covering the state of Orissa and neighbourhood Bhadram et al., (2005). During the period from 14-22 June, 2005 the maximum temperature anomaly reported was of the order of 5 to 6°C (Fig. 9) in some of the eastern states of India, where the maximum death were reported during this period. The heat wave during the middle of June in 2005 was due to the stagnation in monsoon progress over the region (Pattanaik and Hatwar 2006).
3. Climate Change vis-à-vis Global Warming

Like the increasing tendency of global mean surface air temperature the annual mean temperature have also increased on regional scale and over India the increase is by $0.52^\circ C$ over last 100 years. Most of the increase is due to increase in winter & post monsoon seasons. Systematic analysis of climate data and model predictions/projections are very important for planners and managers. The climate change vis-à-vis is going have wide ranges of implications in future. Many issues are of major challenges in this regard as given below :-

- Change in monsoon rainfall pattern
- Increasing trends in the occurrence of extreme rainfall events/droughts
- Increase in the frequency of severe cyclones
- Glacier melting and flooding in addition to rise in the sea level and coastal submerging.
- Increase in frequency of heat wave/cold wave etc.
- Enhanced thermal stress on crops and animals, especially during periods of rain failure.

3.1 Important points emerging from the Met. Observations of 20th Century

- No long-term trend in all India mean Monsoon Rainfall since 1871
• Epochs of above/below normal monsoon activity with a periodicity of approximately 3 decades— the current below normal epoch is still continuing (Kripalani and Kulkarni 1997)
• Some changes are taking place in the monsoon rainfall character (Rupa Kumar et. al., 2002)
• Increase in the frequency and intensity of heavy rainfall events at the expense of low rainfall events (Goswami et al., 2006; Pattanaik & Rajeevan 2009)
• Substantial decline in monsoon depressions and increase in low pressure systems (Pattanaik and Rajeevan 2009)
• Increasing trend of SST over the Indian Ocean (Rajeevan et al., 2000; Pattanaik 2005)
• Increasing frequency of severe cyclonic storm over Indian Sea (Singh et al., 2001)
• Restricted westward movement of the monsoon depression from Bay of Bengal (Pattanaik et al., 2004)
• All India mean annual temperatures during 1901 -2007 show an increasing trend of 0.52C/100yrs with an accelerated warming of 0.21C/10yrs after 1970s (IMD 2008).
• Flattening of trends during the current decade with a warming of 0.1C/10yrs
• Temperature trends in India are slightly lower compared to Global trends – probably due to large aerosols presence in the Indo Gangetic region

3.2 Future Climate Change

Climate scientists say a rise of up to two degrees Celsius more than pre-industrial global temperatures could be manageable, with people only in specific, vulnerable regions suffering catastrophic environmental effects. Any larger temperature increase puts the whole planet's population at risk. But sticking to this limit seems impossible. The Intergovernmental Panel on Climate Change (IPCC) predicts that if emissions continue (under different emission scenarios) to rise unchecked — they are already 38 per cent higher than in 1990 — the world could warm by as much as four degrees Celsius by 2100 (IPCC 2007).

As documented in chapter 10 of working group –II of 4th Assessment report of IPCC the other likely impacts of climate change over Asian region (Cruz et. al., 2007) are :

• An increase of 10 to 20%in tropical cyclone intensities for a rise in sea-surface temperature of 2 to 4°C (Knutson and Tuleya, 2004).
• In coastal areas of Asia, the current rate of sea-level rise is reported to be between 1 to 3 mm/yr which is marginally greater than the global average (Woodworth et al., 2004).
• As a consequence of the combined influence of fertilisation effect and the accompanying thermal stress and water scarcity (in some regions) under the projected climate change scenarios, rice production in Asia could decline by 3.8% by the end of the 21st century (Murdiyarso, 2000).
- Over-exploitation of groundwater in many countries of Asia has resulted in a drop in its level, leading to ingress of sea water in coastal areas making the subsurface water saline. India is also susceptible to increasing salinity of their groundwater as well as surface water resources, especially along the coast, due to increases in sea level as a direct impact of global warming (Han et al., 1999).
- The gross per capita water availability in India will decline from about 1,820 m3/yr in 2001 to as low as about 1,140 m3/yr in 2050 (Gupta and Deshpande, 2004). India will reach a state of water stress before 2025 when the availability falls below 1000 m3 per capita.
- Increases in coastal water temperature would exacerbate the abundance and/or toxicity of cholera in south Asia.

4. Climate and Health

Future climate change is likely to continue to adversely affect human health in Asia. Increases in endemic morbidity and mortality due to diarrheal disease primarily associated with climate change are expected in South and South-East Asia including most parts of India and the relative risks for these conditions for 2030 is expected to be also the largest (McMichael et al., 2004). Climate change will have a major influence on the dynamics of human diseases in the years to come. Different climatic conditions create favourable conditions for the transmission of disease such as temperature related illnesses, vector borne diseases, health impacts related to extreme weather events, and health effects due to food insecurity. These changes will require more emphasis to be placed on planning for health facilities, as well as increased capacity of the medical community to cope with these changes. The poor, as well as the elderly, children, and the disabled are likely to be most vulnerable to these extreme climatic conditions, as they already face limited access to health facilities.

"Human beings are at the centre of concerns for sustainable development, and that they are entitled to a healthy and productive life, in harmony with nature. The Goals of sustainable development can only be achieved in the absence of a high prevalence of debilitating diseases, while obtaining health gains for the whole population requires poverty eradication. The Energy Research Institute (TERI) in India has taken some initiatives to address these issues and very shortly bringing out a book entitled “Climate Change and Disease Dynamics in India” Edited by Nitish Dogra and Sangeet Srivastava to be available through TERI Press, Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi, India. This book brings together specialists from the field of climate, public health, medical, environmental and social science. The contributors, in a refreshing interdisciplinary spirit have synthesized the evidence to date, analysed policy, and suggested a way forward. This edited compilation is expected to provide a beacon for the looming ‘climate epidemic’, especially as it will play out in developing countries.

For most vectors of malaria, the temperature range of 20ºC – 30ºC is optimal for development and transmission and a relative humidity higher than 55% is optimal for vector longevity. Pattanaik and Mukhapadhyay (2009) also recently analysed over the 41 districts of India the seasonal and spatial variations of frequency of two transmission windows (TWS) considered favourable for vector borne diseases and enteric diseases.
The two windows are TW1 (T_{max} \leq 35^\circ C; T_{min} \geq 20^\circ C; RH \geq 55\%) and TW2 (25^\circ C \leq T \leq 30^\circ C; 60 \leq RH \leq 80\%), which are favourable for transmission of vector borne diseases and enteric diseases. As shown by Pattanaik and Mukhapadhyay (2009) for the vector borne disease and also the enteric disease mostly the monsoon season and early part of post monsoon season creates favourable conditions.

5. Summary

- India is frequently affected by extreme weather and climate events and related disasters such as droughts, dry spells, heat waves, cold waves, flooding, cyclones, wind storms, severe thunderstorms/lightning, land slides, costal erosions, salinity intrusion etc. Thus, having an effective climate watch system (CWS) is the need of the hour.
- The current generation CGCMs are capable of simulating monsoon circulation, ENSO, surface air temperature etc reasonably well, thus can be used in best possible way for the deterministic/probability forecasts on seasonal scale and intra-seasonal forecast up to one month.
- There is urgent need for further improvements in forecasts of precipitation over land. Thus, need to assess impacts of land surface initialization, air-sea interaction on the skill of seasonal and monthly forecast using a multi-model framework.
- Assimilation of non-conventional data from satellites, radar etc in the high resolution meso-scale models can improve the forecasting of heavy rainfall event and also the extreme weather events like cyclones.
- Other than Agriculture, there are many more sectors like health, tourism, power etc. where an effective climate watch system will be very useful.
- Considering the implications of observed and future climate projections (likely increase of extreme events such as heavy rainfall, heatwave, intense tropical cyclone,etc) better monitoring and prediction of climate anomalies and extremes by National Met Service is very essential.
- Regional co-operation through collaborative work will strengthens the National Met Service to provide better climate services over the region.

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3.4 “Climate View” and “ITACS”, Powerful tools for climate monitoring

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Abstract

Tokyo Climate Centre (TCC), which is one of regional climate centres in RA-II, provides various kinds of climate monitoring products on the website for support of climate services of NMHSs in Asia. Monthly climatic observational data such as monthly mean temperatures, monthly precipitation amounts and so on, are historically archived into the database and updated every month. To handle these climatic data, a useful visualization tool “ClimatView” based on SVG (Scalable Vector Graphic) is available on the TCC website. A very useful and powerful tool for analyzing a climate system by using JRA-25/JCDAS data and SST etc. is also available on the TCC Website. This tool is named as the interactive tool for analysis of climate system, “ITACS”. Not only drawing general figures but also various tempo spatial cross section and statistical analysis such as regression analysis, FFT, wavelet, EOF and SVD analysis are able to be done easily by the ITACS.


“ClimatView” is a web-based interactive climate database utility which provides monthly climate data of the world. “ClimatView” enables users to view or download monthly mean temperature and monthly total precipitation derived from CLIMAT reports which have been received and monitored by two GCOS Surface Network Monitoring Centers, JMA and the Deutscher Wetterdienst (DWD), since 1982 and 1999, respectively. By using "ClimatView", users can see and get monthly mean temperature, monthly total precipitation and its anomaly or ratio at all available stations. Monthly means of daily maximum/minimum temperatures are also available. These data are derived from CLIMAT messages via the GTS line from the WMO Members in the world. Climatological normals for monthly mean temperature and monthly total precipitation are based on the period 1971-2000. The data sources for the normals are based on CLIMAT messages received at JMA and the GHCN data distributed by the NCDC of NOAA. This website is expected to help not only all NMHSs but also other institutions and individuals in monitoring and analysis of surface climate and its variations for specific observation stations as well as the globe.

To view ClimatView graphics, Adobe-SVG Viewer is required.

1) Click on the area of interest

On the top page of ClimatView, a global map is shown. Clicking on an area of interest shows another map of the area with the distribution of monthly mean temperatures. The month and year are selected on the top page (the default value is the most recent month).

2) Distribution map

Users can choose the indicated area, month/year and element (monthly mean
temperature, monthly total precipitation, monthly mean of daily maximum/minimum temperature, monthly mean temperature anomaly, monthly total precipitation ratio, normal of monthly mean temperature and normal of monthly total precipitation). Hovering over a station on the distribution map page shows the data of the chosen element and the name of the station in a pop-up balloon. Data at all stations in the selected area can be shown as a table by clicking the "Data list" button.

3) Historical graph and data

A time-sequential graph for two years can be displayed by clicking on the station. The period of the graph can be changed (1 year, 2 years, 5 years and all years are available). The list of data used for the graph is indicated below it, and can be download as a text file by clicking the "Download" button.

Fig. 1 Distribution map of monthly mean temperature in Sep. 2007.

When a mouse is hovering on the location of Tokyo, a popup dialogue shows the station name and data.
2. ITACS  [http://jra.kishou.go.jp/itacs-info/tcc/conditions.html]

Interactive tool for analysis of climate system (ITACS) developed in JMA is available for a useful and powerful tool for climate monitoring on the TCC website. ITACS are opened only for registered users who belong to NMHSs. However, due to the limitation of users, a large benefit of its good performance with no stress is expected. ITACS consists of archived climatic dataset, statistical calculation or analysis methods, a drawing tool which is based on the GrADS and a user interface through a web browser. The outline of ITACS is described below.

1) Archived climatic dataset

[ Atmospheric circulation data ]

- Source : JRA-25 and JCDAS.
- Contents : 24 elements, 24 vertical levels, 2.5 x 2.5 deg horizontal grid.
- Temporal average : Annual mean, monthly mean, pentad-day mean and daily mean.

[ Sea Surface Temperature ]

- Source : COBE-SST
- Contents : SST and Ice concentration.
- Period : 1891 – present, the base period for normal and standard deviation is 1971 – 2000.
- Temporal average : Annual mean, monthly mean, pentad-day mean and daily mean.

---

**Fig. 2** Time sequence (upper) and table (bottom) of monthly mean temperatures and monthly precipitation amounts with normals for recent two years.
[ Outgoing Longwave Radiation ]
- Source: OLR by the courtesy of CPC/NOAA
- Contents: OLR.
- Temporal average: Annual mean, monthly mean, pentad-day mean and daily mean.

[ Index ]
- Source: COBE-SST
- Contents: El Nino monitoring indices (NINO.1+2, NINO.3, NINO.3.4, NINO.4, NINO.WEST).
- Period: 1900 – present, the base period for normal and standard deviation is 1971 – 2000.
- Temporal average: Annual mean, monthly mean and pentad-day mean.

[ Climat ]
- Source: CLIMAT bulletin and GHCN dataset
- Contents: Temperature (mean, maximum, minimum) and precipitation at each station.
- Period: 1951 – present, the base period for normal and standard deviation is 1971 – 2000.
- Temporal average: Monthly mean.

[ ODAS ]
- Source: Previous generation version of JMA's Ocean Data Assimilation System
- Contents: Temperature (mean, maximum, minimum) and precipitation at each station.
- Temporal average: Annual mean, monthly mean and pentad-day mean.

[ User Input ]
- Input: Type in the input field or upload the text
- Format: CSV text in the specific form.

2) Statistical functions
- Time average.
- Subtract data-1 from data-2
- Composite data-1 in case that data-2 satisfies specified condition.
- Significance test with the t-test.
- Lagged regression analysis of data-1 to data-2.
- Lagged correlation analysis of data-1 to data-2.
- Empirical orthogonal function (EOF) analysis for single value or multiple variables.
- Singular value decomposition (SVD) analysis.
- Fast Fourier transform (FFT) analysis.
- Wavelet analysis.

3) Drawing options
- Area: Arbitrary area by specifying latitudes and longitudes.
- Cross section: Arbitrary 2-D cross section by making other dimensions reduction.
- Map projection: Mercator and polar stereographic.
- Logarithmic coordinate: For vertical axis.
- Contour: Only contour interval and drawing range can be specified.
- Vector: Only vector scale can be specified.
- Graph axis: Reverse and flip are available.

4) Sample charts
Fig. 3 Monthly mean 850hPa stream function (contour) and its anomaly (shade) in Aug. 2007

Fig. 4 Vertical-Longitude cross section for vertical pressure velocity anomaly (shade) and zonal-vertical flow anomaly (vector) in Sep. 2007

Fig. 5 Time-Longitude cross section for 5-day running mean OLR anomaly

Fig. 6 500hPa geopotential height anomaly (contour) and surface temperature anomaly at each observatory station in Sep. 2007

Fig. 7 Regression coefficients of 850hPa stream function with respect to NINO.3 in JJA

Fig. 8 Lagged correlation coefficients of SST with respect to area mean OLR around the Philippines in August
Fig. 9 Composite of 850hPa stream function anomaly in case of La Nina years

Fig. 10 Significance test of 850hPa stream function anomaly for El Nino events in DJF

Fig. 11 Distribution of the first eigen values and time sequence of its score in EOF analysis of 500hPa geopotential height in January

Fig. 12 Power spectra of NINO.3 index by wavelet analysis

Fig. 13 Distribution of heterogeneous correlation coefficients (left panel for 500hPa geopotential height, right panel for SST) and time sequence of their scores in SVD analysis of 500hPa geopotential height and SST in December
3.5 Republic of Korea capabilities

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Current capabilities for seasonal prediction

In operational Global Climate Model
The operational extended forecasts system is based on the global spectral model, GDAPS, with a horizontal resolution of T106 and 21 vertical levels of hybrid sigma-pressure coordinates. For Ensemble forecasts, we utilize 20 ensemble members with a lagged average method with about a 15-day forecast lead time. The specifications for the model are summarized in Table 4.4.

Table 4.4 Detailed description for global climate model

<table>
<thead>
<tr>
<th>Major Physics</th>
<th>GDAPS (Operational model)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud Convection</td>
<td>Kuo</td>
</tr>
<tr>
<td>Land Surface &amp; PBL</td>
<td>SiB, Yamada-Meller</td>
</tr>
<tr>
<td>Radiation</td>
<td>Lacis &amp; Hansen for SW Roger &amp; Walshaw Glodman &amp; Kyle Houghton for LW</td>
</tr>
<tr>
<td>Large scale condensation</td>
<td>Kanamitsu et al.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dynamics</th>
<th>Three-dimensional global spectral model with hydrostatic primitive equations Hybrid sigma-pressure coordinate Semi-implicit method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>T106L21</td>
</tr>
<tr>
<td>Ensemble size</td>
<td>20 members</td>
</tr>
<tr>
<td>Sea Surface Temperature</td>
<td>Predicted SST anomaly</td>
</tr>
<tr>
<td>Land Surface Initial Condition</td>
<td>Observed Climatology</td>
</tr>
<tr>
<td>Model Climatology</td>
<td>SMIP2/HFP simulation (1979 to 2008)</td>
</tr>
<tr>
<td>Forecast range</td>
<td>1-month forecast 3-month forecast 6-month forecast</td>
</tr>
</tbody>
</table>

Global sea surface temperature forecasting system
The El Nino prediction system (Kang and Kug, 2000) is based on an intermediate ocean and statistical atmosphere model. The ocean model differs from the Zebiak and Cane (1987) model in the parameterization of subsurface temperature and the basic state. The statistical atmosphere model is developed based on the singular value decomposition (SVD) of wind stress and SST.
To reduce the uncertainty of the initial field on the ENSO model, the breeding technique is applied. In the case of an ideal experiment, this would contribute to better predictability, while for our El Nino prediction model, its effect is not as clear because of its weak nonlinearity. Our study thus suggests some possibilities for coupled GCM to contribute to the improvement of predictability for complicated future ENSO prediction.

In order to improve the western Pacific SST prediction, KMA introduced a heat flux formula and vertical mixing parameterization to its ocean model. The model is initialized by combining observed SST and wind stress. Wind stress is calculated by using the 925hPa wind of the NCEP/NCAR reanalysis data. The method with calculated wind stress for initialization has shown a better forecast skill than that with FSU wind stress in recent predictions (Kug et al. 2001). In addition, the present prediction is attended with random noise thought to be weather noise, and generates many sets of prediction. Our approach for random noise is similar to that of Kirtman and Schopf (1998).

A statistical model is also applied to correct the systemic error in the prediction model. The Coupled Pattern Projection Model (CPPM, Kang et al. 2004) used is a pointwise regression model, and the main idea of the model is to generate realization of predictions from projections of covariance patterns between the large-scale predictor field and regional predictions onto the large-scale predictor field of the target year. By applying this model to the dynamic model results and compositing the results from both the dynamical and statistical models, the predictability over the tropical Pacific is improved from before.

To predict the entire global SST, a statistical global SST prediction system is being developed by combining the Coupled Pattern Projection Model (CPPM), the Lagged Linear Regression Method (LLRM), the El Nino prediction model, and the persistence method. In the tropical Pacific, predictions produced by the El Nino prediction model are used, whereas in other regions the best results from CPPM, LLRM, and persistence are used. LLRM is a pointwise statistical model based on the lag relationship between the global SST and ENSO index; the optimal lag is selected using the hindcast process in the model. This development is for determining the Indian SST prediction. Using this global ocean forecasting system, boundary conditions for the global climate model are also produced.

**Long-range forecasts (LRF) (30 days up to two years)**

The long-range forecast system is identical to the extended range forecast system described in section 4.6, except for the forecast range. The official products of extended range forecasts are 3-categorical forecasts of temperature and precipitation over Korea for the upcoming 3 months (see 4.7.3).

For long-range forecasts, we also utilize the multi-model ensemble (MME) technique developed and operated at APEC Climate Center (APCC) and a WMO Lead Centre for Long-Range Forecast Multi-Model Ensemble (LC-LRFMME). The APCC collects the historical and real-time forecast data of 15 different models from 8 countries and the LC-LRFMME collects the historical and real-time forecast anomaly data from 11 Global
Producing Centres (GPCs) for its automatic MME input data producing system. The APCC and LC-LRFMME have developed various MME techniques for deterministic and probabilistic seasonal predictions. For deterministic forecast, three kinds of linear MME techniques are used, namely biased and unbiased simple composite, weighted combination of multi-models based on SVD, and MME with statistical corrections. For probabilistic forecast, three ranges are determined by a ranking method based on the percentage of ensemble members from all the participating models in those three categories. A regional version of the APCC for the MME system, MME I-IV, has been developed for the Asian Monsoon region.

**Operationally available EPS LRF products**

<table>
<thead>
<tr>
<th></th>
<th>1-month forecast</th>
<th>3-month forecast</th>
<th>Seasonal climate outlook</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issue Date</td>
<td>3rd, 13th, and 23rd day of each month</td>
<td>23rd day of each month</td>
<td>23rd day of Feb., May, Aug., and Nov.</td>
</tr>
<tr>
<td>Forecast type</td>
<td>Three-category forecast: Above, below and near normal</td>
<td>The anomalies are based on model’s climatologies obtained from a 30 year database (1979 to 2008).</td>
<td></td>
</tr>
<tr>
<td>Contents</td>
<td>10-day mean temperature and precipitation</td>
<td>1-month mean temperature and precipitation</td>
<td>30-day mean temperature and precipitation</td>
</tr>
<tr>
<td></td>
<td>1-month mean temperature and precipitation *1Asian dust outlook</td>
<td>seasonal temperature and precipitation</td>
<td></td>
</tr>
<tr>
<td>Forecast area</td>
<td>Korea</td>
<td>Korea</td>
<td>Korea</td>
</tr>
</tbody>
</table>

*1Asian dust outlook is issued in late February including the number of days of Asian dust expected to affect Korea for the upcoming spring.

*2 Typhoon outlook is issued in late May and Aug. regarding the number of Typhoon expected to affect Korea for the upcoming summer and autumn.

**Lead Centre for Long-Range Forecast Multi-Model Ensembles**

The CBS in November 2006, and the Fifteenth WMO Congress noted that related to LRF, a number of issues needed to be studied and discussed, including the role of some GPCs of LRF, which might serve as collector of global LRF data to build multi-model ensembles. The need for a Lead Centre for LRF Multi-Model Ensembles was subsequently indentified, and GPC Seoul (Republic of Korea) and GPC Washington (USA) have been jointly designated by WMO as a Lead Centre for Long-Range Forecast Multi-Model Ensembles (LC-LRFMME) with responsibility for a web portal of GPC and multi-model ensemble (MME) products. Provision of a single portal for GPCs information addresses current difficulties experienced by users in merging GPCs output into a consolidated forecast for their region. Data formats and forecast visualization products have been developed.
independently at different centres. Consequently GPCs forecasts are currently available in varying digital formats and visualized on GPCs websites using a wide variety of graphical approaches with no consistent contouring intervals or colour shading conventions and no consistent set of geographical domains. This makes inter-comparison of forecast signals from different GPCs difficult, and there is evidence that this discourages users from making collective use of GPCs output. The data sets provided by GPCs are standardized by LC-LRFMME, which makes it available to users including NMHSs, RCCs and RCOFs. Given the anticipated improvements in skill of LRF by using a multi-model ensemble approach, LC-LRFMME will thus provide a much needed conduit for GPCs information.

Structure of LC-LRFMME. GPCs are providing an agreed set of data to LC-LRFMME. The provided data are standardized by lead centre and disseminated to users through data exchange system of LC-LRFMME.

Functions of LC-LRFMME
The functions of LCs-LRFMME have been developed and refined by the Expert Team on Extended and Long-Range Forecasting (ET-ELRF), and are as follows:
1) Maintain a repository of documentation for the system configuration of all GPC systems;
2) Collect an agreed set of forecast data from GPCs;
3) Display GPCs forecasts in standard format;
4) Promote research and experience in MME techniques and provide guidance and support on MME techniques to GPCs, RCCs and NMHSs;
5) Based on comparison among different models, provide feedback to GPCs about the models performance;
6) Generate an agreed set of Lead Centre (LC) products;
7) Provide web pages to satisfy requirements for regional display of Lead Centre products (e.g. for RCOF coordinators);
8) Where possible verify the LC products using SVSLRF;
9) Redistribute digital forecast data for those GPCs that allow it;
10) Handle requests for the password for the Website and data distribution; maintain a database recording users who have requested access to data/products and the frequency of access;
11) Maintain an archive of real-time GPC and MME forecasts.

Core information available from LC-LRFMME
A website providing much of the recommended functionality of the LC-LRFMME has been developed (http://www.wmolc.org). GPCs digital products, where authorized by the provider, are available from LC-LRFMME. Monthly mean anomalies for individual ensemble members and ensemble mean for at least each of three months following the month of submission are provided. Global fields of forecast anomalies supplied by lead centre are Surface (2m) temperature, Sea Surface Temperature, Total Precipitation rate, Mean Sea Level pressure, 850hPa temperature, and 500hPa geopotential height. Various graphical products, indexes, consistency plots, ensemble plumes of Niño indices and energetics are displayed in common format on the LC website, for the variables listed above and for interactively selectable regions where appropriate.

Additional information and access to LC-LRFMME data
These additional products are distinct from the core products listed above. As part of research and development, the Lead Centre may make available products based on forecast and hindcast data from the subset of GPCs that are able to supply them. These products are additional information to help GPCs, RCCs and NMCs to further develop MME techniques and their application.
Access to GPC data and graphical products from LC-LRFMME websites will be by password. Recognized GPCs, RCCs, NMHSs, and institutions hosting RCOFs such as ACMAD, ICPAC are eligible for access to information held and produced by the LC-LRFMME.
The GPC Seoul and GPC Washington LC-LRFMME is fully functional and meets the requirements set by the "Expert Team on Extended and Long-Range Forecasts (ET-ELRF)" and makes GPCs forecast products available to users and has already entertained requests from the RCOFs. Lead Centre makes an important contribution to increasing the resources available for disaster prevention and mitigation, and for better social-economic planning and would be a valuable asset to the seasonal climate forecast community.
3.6 Abstract of climate Monitoring in LAO P.D.R

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Laos People's Democratic Republic (Lao PDR) is a land-locked country in the Indochina Peninsula, sharing a border with Cambodia, China, Myanmar, Thailand and Viet Nam. It has a land area of 236,800 square kilometres. About 88% of the country lies in the Mekong River drainage basin, with the river itself flowing about 1,700 km along the western border of the country or through its territory.

The climate regime is divided into two seasons, with a dry season dominated by the northeast monsoon (mid-October to mid-May) and a wet season dominated by the southwest monsoon (mid-May to mid-October).

The department of Meteorology and Hydrology, like many other National Meteorological and Hydrological Services (NMHSs) in developing countries, is poorly resourced, with a small budget to meet operational and development costs. The country has a small population and proportionally a small meteorological service. Manpower is thus another serious constraint in the operation, maintenance and development of facilities and services.

The surface observing network of DMH is in a poor state of maintenance, and requires rehabilitation to ensure a minimum amount of data is available to support weather monitoring, forecasting and warning, climatological monitoring/assessment, prediction and applications and international data exchange.

**Data processing, Analysis, archiving system**

In headquarter of DMH, there is data storage and data processing centre. The main activity is to process all climatic data in accordance to Climate computing (Data Base) and for the hydrological data, DMH use HYMOS modeling for processing and analysis the stream flow data.

- Weather situation use Synergies and Wedis software for analyzing the surface, Upper air chart and tropical cyclone forecast from TC web site Project under WMO (As JMA, KMA …)

  *All data processing computers are standalone, with no sharing of data.*

Meteorology and hydrology have an important role to play in the national strategy, as virtually all-human activities are influenced by weather, climate and water. The services provided by the Department of Meteorology and Hydrology (DMH) can contribute to the protection of life and property, mitigation of natural disasters, and the development of different sectors of the economy such as agriculture, forestry, civil aviation, urban development, water management, energy production, tourism, and others. Observations and predictions of the weather and climate with higher level of accuracy and lead-time can radically improve people's chances of living in relative
safety, building more comfortable lives and protecting precious natural resources more effectively.

Floods and drought are the main natural hazards to which the country is exposed. Floods usually occur in the alluvial plains of the Mekong and its tributaries between May and September. On average, there is one major flood every two to three years. The area most affected, namely the central and southern regions, is also the most populated and economically active area of the country. There are also flash floods and landslides in mountainous areas, which have become more frequent in recent years because of increasing human settlement and deforestation.

For the 24-hour and weekly forecasts, synoptic reasoning based on surface and upper-air charts produced by other centres and accessible from the GTS or the Internet is the primary method of forecasting. The forecasting of the remnants of tropical cyclones which might enter the country is additionally based on tropical cyclone warnings and marine forecasts issued by the Regional Specialized Meteorological Centre (RSMC) in Tokyo and by the Hong Kong Observatory.

Monthly and three-monthly climate outlooks (rainfall only) are prepared once a month, and that for the annual rainfall once a year using statistical empirical relationships between local rainfall climatology and ENSO forecasts.

Public weather services

DMH issues weather forecasts and outlooks to the public through television, radio, and newspapers. Newspaper carries the seven-day weather outlook. However, with one outlook issued per week, it becomes out of date as the week progresses.

Main users of Long – range Forecast and Dissemination System.

The diagram for the demand of Long – range Forecast is shown in the following
3.7 Maldives Country Report on Status and Priority needs of Monitoring and Predicting Climate Anomalies and Extremes

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Location
The Maldives located south of Lakshadweep islands and 700 km south west of Sri Lanka.

Maldives is an island nation consisting of a group of atolls in the Indian Ocean. 1190 islands are separated over 26 atolls, ring like coral formation enclosing lagoon. They stretch for about 820km from north to south, 130km at the widest point and 2 meters above sea level.

Two hundred and fifty islands are inhabited, the rest include 87 resorts and uninhabited islands.

Climate
In a nation with less than one percent land and over 99 percent sea, the weather obviously plays a significant role in day-to-day life.

The Maldives weather is determined largely by the two monsoons namely NE and SW monsoon. Northeast monsoon Dec - March (Dry season) During NE monsoon wind flows from Indian region and Indonesia region. Rain is less during this period and most hot days are observed during these months.

Hottest days are experienced during April which is the transition month. Southwest monsoon May to Oct (Wet season) is when the ITCZ moves from south to north. This season brings most of the rain during the year, strong winds and rough seas are experienced.

The warm tropical climate results in relatively minor variations in daily temperature throughout the year. The hottest month on average is April and the coolest is December.

The temperature in Maldives ranges between 26°C and 31°C all throughout the year. There is a significant variation in the monthly rainfall levels. February is the driest with January to April being relatively dry, May and September records the highest average monthly rainfall. The yearly rainfall averages 2200mm in the south and 1800mm in the north.

Present status.
Data is collect from 5 synoptic stations and 16 AWS and seven rain gauge stations. The data is provided to users in a usable format and is offered to the public through either official website of, printed formats or on CD-ROMs. The products
including year books, reports (weekly, monthly, annual), climatic normals, graphical reports (charts, wind rose, etc.) are prepared.

Most common users of data are the construction companies, insurance companies, fishing industry, and tourism industry and government ministries.

Using these data climate anomalies and extreme monitoring is done by the climate section of the Maldives Met Service. It has been noticed from these findings that days with maximum temperature 32 deg Celsius or more is increasing in central Maldives. It also shows a decreasing trend in rainfall anomalies for the central Maldives.

Long range forecasting is not done in Maldives at present.

Monsoon monitoring and onset of SW monsoon is predicted using the IMD monsoon criteria. Monsoon advancement across the country is monitored and predicted. ECMWF, EFS models and WRF and some other regional models are used for forecasting weather over the country.

Flash floods and strong monsoon activities are observed in Maldives Islands, the local people are warned and informed about these activities prior to the activity. The local people and other users (like tourist from the resorts) are also very keen and interested to get more information during bad weather days. They have great interest in the TV forecast presentation and the radio broadcast which given every hourly.

Awareness programs on weather and climate have been conducted in 15 islands in 6 atolls. Due to these and the people are aware of the climate now and would inquire more information on weather, when we get our dry period during February and March, also why we are getting high temperature during these months with no rainfall. Heat waves, cold waves, drought and dry spells are not observed in Maldives islands.

Needs

Installing AWS was started very recently. Due to budget constrains the project was halted by mid of this year, 10 more AWS was planned to be installed during this year. It is also planned to install over 150 AWS in over 5 years in most on the uninhabited islands in funds are available. Need more trained personals in climate monitoring sector.

For climate monitoring and LRF Maldives need help and training from other countries with their software and programs to be downscaled and used in Maldives.

Though 1 DWSR – 8501S is installed in National Met. Centre, we need at least one more radar in order to cover the whole country.
Abstract:

Persistent departures from long-term average climatic conditions are causing significant societal impacts. Drier-than-average conditions may lead to drought, affect agriculture and water resource management, lead to crop loss / failure, restricted water usage, and reduction in hydel power generation. The other side of the coin; excessively wet conditions may cause river flooding / urban flooding endanger people’s lives and destroy infrastructure. The impacts of such anomalies are much larger in RA II region, due to multiple reasons comprising high population density, poverty, weak adaptation to climate change and ineffective response mechanism to disasters. All these indicators stress the need for timely preparation and dissemination of climate watch to vulnerable communities and disaster management units to mitigate disasters in effective manner.

Introduction:

Pakistan is a disaster prone country. The country has a long latitudinal extent stretching from the Arabian Sea in the south to the Himalayan mountains in north. It is located in sub-tropics and partially in temperate region. Climatologically, most parts of Pakistan are arid to semi-arid with significant spatial and temporal variability in climatic parameters. Important climatic features are;

- 59% of the annual rainfall is due to monsoon rains; a dominant hydro-meteorological resource for Pakistan
- Greater Himalayan region above 35°N receives winter precipitation mostly in the form of snow and ice.
- The snow melt contribution keeps the rivers perennial throughout the year
- The coastal climate is confined to a narrow strip along the coast in the south and southeast, while the north is dominated by the mountain climate. In between the climate is broadly of typical continental nature.

Pakistan Meteorological Department (PMD) is the focal agency providing services in meteorology and allied fields. Main areas of operations are:
1. AVIATION METEOROLOGICAL SERVICES
2. HYDRO-METEOROLOGICAL SERVICES AND FLOOD FORECASTING
3. AGRO-METEOROLOGICAL SERVICES
4. RESEARCH ACTIVITIES ON CLIMATE & EVOLVING ISSUES
5. GEOPHYSICAL AND SEISMIC MONITORING / TSUNAMI WARNING CENTRES
6. WEATHER FORECASTING SERVICES TO PUBLIC THROUGH ELECTRONIC & PRINT NEWS MEDIA
7. DROUGHT MONITORING AND EARLY WARNING SERVICES
8. MARINE FORECAST AND TROPICAL CYCLONE WARNING CENTRES
9. ASTRONOMICAL INFORMATION SERVICES
10. MET-FORECAST FOR MOUNTAINEERING EXPEDITION

MARINE METEOROLOGICAL SERVICES

Case studies:

Damage already done to climate by the greenhouse gas emissions will effect us for the next millennium (Hadley Centre, 2002). As global warming takes hold, soils will emit more natural CO₂ which multiplies to man made emissions, accelerating climate Change –CCPF (Carbon-Cycle-positive-feedback).

In Pakistan, impacts of climate change are already being faced in various sectors of society. It has increased the value of climate watch and water, energy, tourism and agriculture sectors are being benefited by the dissemination of climate watch from PMD.

Water is the primary medium through which early climate change impacts are being experienced by various sectors and affecting sustainable development and jeopardize poverty reduction efforts. As the fundamental drivers of the hydrological cycle are affected by increasing climate variability and climate change, they will have large impacts on water resources availability and demand. PMD is issuing ten days/fortnightly inflows outlook to help water management authorities to manage releases from main reservoirs for power and irrigation purposes. During dry years and period with less snowfall, this outlook becomes very vital to overcome shortfall in water availability.

Increased water related risks associated with the changes in frequency of extreme events, such as flash floods, storm surge and land slides, droughts and floods...
are being faced every year in some parts of the country. PMD is provides regular climate outlooks on drought, dry and wet spells and makes efforts to sensitize the vulnerable communities and disaster managers for timely response.

Climate data and information underpin the planning and management of surface freshwater supplies and mitigation of damage from high and low water flows. Good design of storage reservoirs and water supply systems for cities is based on the water availability and how the supply fluctuates in space and time.

Climate and data information from weekly to seasonal to annual timescales at national, regional and local levels are essential gradi ents for effective management of natural resources. PMD has Climate Data Processing Centre that provides all related information to interested users. Following publications are readily available for end users.

- "Climatic Normal of Pakistan 1931-1960" (i.e., a thirty-year summary of the climate of Pakistan covering 80 parameters and 65 stations).
- "Monthly Climatic Summary of Pakistan" is issued by 10th day of following month.
- Climatic Normal of Pakistan 1971-2000
- 5-days Rainfall Normal of Pakistan

Energy Sector

Energy is at the heart of economic and social development and the correct use of historical climate data can help to locate and design better energy infrastructure.

Most humans are comfortable in a relatively narrow temperature range from about 15°C to 25°C. This comfort zone is reflected in energy usage patterns of modern cities. Energy companies are using the link between climate variability and energy demand for supply planning to guard against shortages during the most critical times. For this reason, energy companies were one of first users of climate outlooks/forecasts and continue to use these products in their energy demands to power producers.
Tourism Sector

For many countries, tourism has become a fundamental contribution to the local economy and one of the principal options for them to combat poverty. However, the increasingly important travel and tourism sector is highly vulnerable to the effects of climate variability and change. Favourable climatic conditions at destinations are key attractions for tourists. Mountain tourism or winter sports are highly dependent on specific climate and weather conditions.

Pakistan Meteorological Department provides a variety of extended forecasts and climate outlooks to support tourist's activities and contribute in their safety during expeditions to high mountains. The Below is the screen shot from website of EverestNews.com who acknowledged the value of PMD advisories being issued for mountaineers in Karakorum region.

Conclusion:

Impacts of climate change are being felt in Pakistan as increased frequency of climate extremes;

- Urban flooding; Karachi 2009, Hyderabad 2007, 8
- Cyclone Yemyen 2007
• 26 % below monsoon 2009 rainfall.
• Dry post monsoon 2009 period that is hampering winter crop sowing etc.

There is dire need for reliable climate forecasts for sustainable socio-economic development.

Recommendations:

Pakistan Meteorological Department is making all efforts to integrate climate watch and outlook to socio-economic activities in the country. Effective integration is being established with other sectors like agriculture, water & power, tourism, small industries etc to better use of climate information. Based on past exercises, it is proposed that effective sector-specific climate products and services may be developed to cater the needs of diversified users in a timely fashion.

Threat of Climate Change can be coped by identifying and quantifying its impacts on various socio-economic sectors. To address this aspect, it is proposed that Research groups may be made on region basis for;
• Prediction for urban flooding and impact assessment
• Prediction for soil moisture availability to crops at critical levels and yield
• Seasonal prediction models may be tuned to crop seasons
• Developing Climate Extreme Indices and quantification of impacts e.g. Extreme weather events affect agricultural productivity and may raise the price of staple foods causing increase in extreme poverty.
Sri Lanka is a tropical island situated just south of south India. It has the highland in the south-central parts with the highest being the 2524m above mean sea level. The mountains are surrounded by relatively flat terrain especially towards the north. The total area of the island is 65,610 km².

The island has four seasons; the southwest monsoon (from mid May to September), the Northeast monsoon (from December to mid March) and the two intermediate periods which are called as inter-monsoons.

Basically, the two monsoons by the names themselves the winds are mainly from the respective directions and the rainfall is mostly confined to the windward parts and slopes of the mountains. The remaining parts do not receive significantly heavy rainfall especially during the southwest monsoon as the southwest monsoon winds are stronger than northeast monsoon wind.

The annual rainfall varies between 950 and 6000mm and the average annual island wide precipitation is 1860mm of which 60% accounts for southwest monsoon (May-September) and 2nd inter-monsoon (October-November) totally, with 30% each. 26% of annual rainfall is received from Northeast monsoon (December – February). Since the southwest monsoon rain is mostly confined in to the southwestern parts, the most important season is 2nd inter-monsoon period as almost every where receive rain predominantly by convective activity and cyclonic systems within inter tropical convergence zone.

The average temperature in low land is 27.5°C. Attitudinally the temperature decreases. The seasonal variation of temperature is also low.

The collection of climatological data has been commenced from 1867 in Sri Lanka, and thus, it has the data for longer than 100 years. Today, the socio-economical implications of weather changes are becoming important thus, the demand for climate data and services is increasing.

At present, Sri Lanka department of Meteorology maintains 22 meteorological stations, 39 agro meteorological stations and about 350 rainfall stations manned by voluntary organizations.

The climate data management is done through CLICOM which commenced in 1987 and now CLIMSOFT also runs in parallel to CLICOM.
The climatological data is provided to various sectors such as project planning, agriculture, water supply, electricity generation, plantation and various other kinds and present days, insurance purposes as well.

As far as the major paddy cultivation season, Maha, (commencing in October) is concerned; the rainfall is very important and any low rainfall results in severe paddy production deficit and the prices of rice increases. The southwest monsoon brings significant amount of rainfall to the western slopes of the hills where most hydropower catchments are located, thus, the failure of southwest monsoon affects the hydro power generation and also the tea industry etc.

The global phenomena such as El Nino and outlook from various centres are being watched, with regard to future climate. The Madden Julian Oscillation has also been paid attention and the convective systems developing to the west of the island is also watched, especially setting-on period of southwest monsoon period where the possibility of developing convective activity is very high over the island.

Using CPT, seasonal rainfalls have been attempted to predict, however, it is still not reliable enough to use as operational forecast. Further, research is very much needed for seasonal rainfall prediction.

The extreme events such as heavy rainfalls, droughts, tropical cyclones, strong winds and strong lightning activity are observed in the island and therefore forecasting them with longer lead time reduces disaster risk. On the other hand, the weather or climate affects the group of society differently. Therefore, the long range prediction of extreme events and climate is much more important if the effect of the society is also considered.

Long range forecast or climate forecast for a small tropical island like Sri Lanka have been observed as difficult as it also has inhomogeneous parts. Therefore, downscaling of a reliable regional or global climate forecast products is a vital need. As the climate affects on different parties in different way, it is useful to have a cooperative work with the users. Since, Sri Lanka is now facing the problem of data missing due to unsettled situation during the past, the training in data management to construct the missing data is also very essential.
1. Climatic Condition of Thailand

Geographical Condition

Thailand is located in the tropical area between latitudes 5°37’N to 20°27’N and longitudes 97°22’E to 105°37’E. The total area is about 513,115 square kilometers or around 200,000 square miles. It can be divided into 5 regions i.e. Northern, Northeastern, Central, Eastern and Southern region. The population is about 65 million.

General Climatic Conditions

The climate of Thailand is under the influence of monsoon winds of seasonal character i.e. southwest monsoon and northeast monsoon. The southwest monsoon which starts in May brings a stream of warm moist air from the Indian Ocean towards Thailand causing abundant rain over the country. Rainfall during this period is not only caused by the southwest monsoon but also by the Inter Tropical Convergence Zone (ITCZ) and tropical cyclones which produce a large amount of rainfall. May is the period of first arrival of the ITCZ to the Southern Part. It moves northwards rapidly and lies across southern China around June to early July that is the reason of dry spell over upper Thailand. The ITCZ then moves southerly direction to lie over the Northern and Northeastern Parts of Thailand in August and later over the Central and Southern Part in September and October, respectively. The northeast monsoon which starts in October brings the cold and dry air from the anticyclone in China mainland over major parts of Thailand, especially the Northern and Northeastern Parts which is higher latitude areas. In the Southern Part, this monsoon causes mild weather and abundant rain along the eastern coast of the part. The onset of monsoons varies to some extent. Southwest monsoon usually starts in mid-May and ends in mid-October while northeast monsoon normally starts in mid-October and ends in mid-February.

2. Climate Center is under the Meteorological Development Bureau, Thai Meteorological Department (TMD) and provides climatic information to the public members as well as the related institutes that need concerning data and information to apply in their planned projects and decision-making procedures. The function and responsibilities of Climate Center are as follow:
- To continuously monitor and produces the climatological data and information,
- To provide climatological services to public and stakeholders,
- To studies, researches and update the knowledge in climatology including climate variability and climate change
- Provide the Long Range weather forecast and Climate Prediction to the public and related organization
- Fulfill any missions regarded as the responsibilities of the Department, or assigned by Director General or Director.
3. Weather & Climate Observation
Nowadays, there are 120 synoptic stations altogether in all regions of Thailand. They can be divided into 71 surface weather stations, 33 agro-meteorological stations and 16 hydrological stations. Observed data from these stations are transmitted to the Headquarter to prepare a database, analyze data in various forms and disseminate to the public. Additionally, there are 87 automatic weather stations in nationwide and 820 automatic stations for the hydrological purposes are carried out throughout 24 hours by the staffs.

4. Climate Monitoring
Climate data at the TMD are dated back since 1951. The parameters include air temperature, precipitation, relative humidity, atmospheric pressure, wind speed and direction, visibility etc. Additionally, the weekly, monthly and annually weather reports as well as the climatic technical documents are issued on the regular basis too.

- Variability of Rainfall and Temperature
  For mean maximum Temperature, over the whole period of observations, the markedly increasing trend is found in all parts of Thailand especially eastern, southern east coast and southern west coast, and less increase appear in northern part. Besides, for all parts of Thailand, annual mean minimum surface temperature rise markedly above normal especially during the last decade. For annual rainfall, decreasing trend in rainfall for the whole period of observations occur in all parts of Thailand. The prominent decreasing trend experience in eastern part, whereas a very slight decreasing trend occur in northern part.

- El Nino/La Nina watch
  TMD tracks the ENSO-SOI forecast from the Climate Prediction Center, NOAA

- Extreme Rainfall and Temperature over Thailand
  Using daily rainfall and max/min temperature during 1955-2007 period, it indicated that the extreme temperature indices show statistically significant increasing trends, with larger values for the index describing variations in the lowest minimum temperature. In general, warming trends in minimum temperature indices are greater magnitude than those of maximum temperature and most rainfall indices show non-significant change.

5. Long range weather forecast
There are 4 kinds of the long range weather forecasts provided by climate center, TMD. Monthly, seasonal, four week and three month weather forecasts are produced and based on the combination of information extracted from many different Weather Prediction Center, such as ECMWF, CPC, Met UK, IRI, TCC, APCC etc. and on Normal:1971 -2000. These information are consolidated into a final forecast. Furthermore, the predictions of the numbers of dry days and seasonal rainfall totals are regularly analyzed by the Climate Predictibility Tool (CPT) which based on the outputs of Global Climate Model Prediction from IRI. At present, the Global Spectral Model (GSM)
has been developed and experimentally applied to regional predictions for 1 month and 3 months periods.

In addition, we have studied the probability forecasting using the 3 month rainfall averaged 1951 - 2008 data to predict the probability of the 3 monthly rainfall in each area of Thailand based on the historical El nino and La nina composite analysis and CPC Nino 3.4 forecast.

6. Dissemination of climate Information and Long Range Forecast

The climate information such as the weekly, monthly and annually weather reports as well as the climatic technical documents are issued to users and stakeholders via website. Long range weather forecasts are released not only on website but also directly to the government agencies responsible for preparing to mitigate in case the severe weather affect the public e.g. the Department of disaster Prevention and Mitigation, media and local government.

7. Conclusion

TMD, the governmental agency that owns the meteorological stations and takes climate monitoring as its assignment, regards it as a duty to provide accurate climate data which are useful to the society. In case of climate monitoring task, the meteorological stations have continuously increased in number throughout Thailand. In addition, automatic weather stations have been installed countrywide. Besides, the Climate Data Management system (CDMS) is a tool used to speed up data transmission from the local stations to the Department’s Headquarters. For long range weather forecasts, TMD has more method than in the past. Nowadays we use the products provided by weather forecast models from various weather forecasting centers as the guidance to prepare the weather forecasts with high confidence to the public. However, the users, particularly for the agencies using such information in water usage planning, still expect the higher accuracy of the long range weather forecasts.
Abstract of “Long range weather forecast in Viet Nam and its perspectives”

The talk consists of three parts. The first part will introduce Viet Nam geographical position and its climatic distributions. In this part, we also give some extreme records on natural disaster. The second part tends to give briefly on operational works in National Center of Hydro-meteorological Forecastings of Viet Nam including methods and kinds of bulletins for long range weather forecasts. The observational network system also has been given as an overview about the challenge in data collection and the need to improvement current system towards a more dense, automatic and higher quality data system. Last part addresses some NHMS’s priorities for developing the long range weather forecast through joining in WMO/RA II projects such as upgrade the database management system, digitalize the raw-database and enhance the Climate Monitoring System.

I. Introduce about Vietnam

Vietnam is located in the centre of the southeast Asian region. It lies in the eastern part of the Indochinese peninsula, bordering China to the north, Lao and Cambodia to the west and the East sea and Pacific to the east and south. Vietnam’s coastline is 3,260 kilometres long and its inland borderline measure is 3,730 kilometres. The country’s total length as the bird flies is 1,650 kilometres from the northern most point to the southernmost. It with stretching from the eastern coast to the western border, continental shelf area is not included is 600 km at the widest point to the north and 50 at the narrowest part in the QuangBinh province on the central coast.

- Vietnam’s Area: approximately 330.000 km2
- People: 86 millions with 75% of population living in rural areas.

II. Climate characteristics of Vietnam:

Vietnam is located in the monsoon tropical region and divides two areas: The North and the South.

In the North:
- From May to September: Weather systems dominate this area usually are trough of low pressure, southeastern part of Indian low pressure, tropical cyclones (storm or tropical depression), ITCZ (Intertropical cyclone zone), western of subtropical high pressure, etc…. The weather is hot and rains a lot
- From October to April: The weather system dominates this area is the ridge of high pressure continental (come from China continental) with NE wind monsoon system is prevailing over this area. The weather is cold and dry.
In the South:
From May to September: Weather systems dominate this area usually are ITCZ, southeastern part of Indian low pressure, with SW wind monsoon system. The weather is hot and rains a lot.
From October to April: NE wind monsoon system is prevailing over this area, the weather is hot and dry.

Summary:
* Vietnam located in the tropical monsoon area: winter: cold, dry NE monsoon in North and Central; summer: hot, wet SW monsoon (esp. in the South).
* Affected systems: monsoons, tropical cyclones, ITCZ, heavy rain spells, cold surges, ENSO

III. Some Statistics about average data and extreme data such as:

- Average annual rainfall: 1500 - 2500mm.
- Total sun hour: 1800 sun.hrs
- Max. daily rainfall: 978mm (Hue, 3Nov1999);
  569mm (Hanoi (Vietnam’s capital), May 1926)
- Severe drought: Oct.2004-Apr.2005, rainfall lower than average in whole country, many regions: 30% lower, special in the Highland and Southern: 50% - 70% lower than average cause is ENSO impacts.
- Tropical cyclones: Approximately 9-10 typhoons or storms (Ty or Ts) & 2-3 tropical depression (TD) in East Vietnam Sea with 3-4 typhoons or storms & 1-2 tropical depression landing.
- 20 heavy rain spells (duration of more than 2 days): 8-9 spells in the north; 7-8 spells in the central and 5-6 in the south.
- 30 cold air invasion spells (dominate in the North).

IV. Operational forecasts: issue three kinds forecast
* 10 days forecasts: weather tendency, including rainfall amount, temperature (including: maximum, minimum, and average) for specific regions (including 7 regions).
* Monthly forecasts: we forecast temperature tendency and rainfall amount for specific regions.
* Seasonal forecasts: tendency of tropical cyclone activity, NE and SW monsoon activities.

V. Methods forecast:
* Synoptic: Circulation analyst. (geop. height at 500mb in EastAsia trough and Subtropical high)
* Statistics: Multi. Regressions equations (forecast tendency of temperature, rain of winter-spring season and rainy season)
* Dynamics: Simple ensemble from APEC Climate Center (APCC – Korea)
* Guidance from Medium range Numerical Weather Prediction products (ECMWF, NCEP, TCC-Japan, ..)
• Except, we used some methods such as: Similar method or Common experiences

VI. Hydro-meteorological & environmental station network:
• 171 climate station.
• 173 surface meteorological stations, in which 26 belong to Global Observing System, 41 synoptic stations make 8 observations each day with all elements: atmospheric pressure, temperature, humidity, rainfall, wind speed and direction, cloud, sunshine, vision and weather phenomena
• 396 Raingauge point operated by people.
• 13 sun radiation observation stations.
• 232 Hydrological stations, in which 67 for water level and discharge measurements, 165 water level stations
• 3 automatic upper air stations in Hanoi, Danang and Ho Chi Minh city. The element of upper air observation incluye: atmospheric pressure, temperature, humidity, wind speed and direction. In Hanoi, observations are made twice a day while in other places once a day.
• 8 pilot station measuring wind by theodolite.
• 3 stations make observations on ozone and ultraviolet radiation in Sapa, Hanoi and Ho Chi Minh city.
• 6 Weather radars to monitor typhoons, and other phenomena.
• 17 Marine Meteo. Stations make observations on meteorological as well as oceanographical elements: wave, sea level, tide…etc.
• 1 Marine Research vessel and 4 buoys.

VII. Long-range forecast bulletins
- 10-day forecast: issue daily
- Monthly: issue monthly
- Seasonal: issue 4 times per year

VIII. Development Priorities and towards proposals:
• Improvement on long range forecast and clim prediction are the most concerning issues in National Center Hydro-meteorological Forecasting.
• Upgrade the Climate Monitoring System (more dense, automatic and higher quality station) with the consultation from WMO/RA II.
• Digitalize raw-database kept in primitive method: paper, maps.
• Switch database system from CLICOM to a more cohesive management system.

* Towards proposals
• Encourage close cooperation with SEA countries in sharing climatological data.
• Propagate WMO projects products (such as CLiPAS) via localizations. (e.g.: develop tools for point scale seasonal prediction, separate level of user and build plan for each, translations documents to local language..)
• Participate in WMO projects on: Implementation of CMDS (a replacement of CLICOM), DARE and Enhance climate observation networks.
Working Group Session

Group I: Format, Content, Dissemination and Verification of climate Watches

Chair: Mr Panmao Zhai, CMA China  
Rapporteur: Mr Azmat Hayat Khan, PMD Pakistan

1.1 Identify issues relevant to the format, content, dissemination and verification of climate watches

- **Definition**: (use WCDMP guidelines WCDMP No58, available on the WMO website). A *climate Watch is an advisory with the following characteristics*: Issued to heighten awareness in the user community concerning a particular state of the climate to serve as a mechanism for initiating preparedness activities by users. Based on real-time monitoring (current status) of conditions and on climate outlooks;

- **Format**: The format should be agreed with users and should include a standard format which to be kept consistently used and avoid changing it. It should include time of issuing and its validity as well as the date of next update.

- **Content**: When feasible, and when it is within the responsibilities of NMHSs, or of some national committee (e.g. Pakistan), climate watch should include information on expected impacts (which might be assessed with the help of other communities e.g. agricultural sector), and advices on how to behave, or what to do to reduce negative impacts.

- **Dissemination**: NMHS have the responsibility to issue and disseminate climate watches. RCCs assist NMHSs by providing guidance on regional climate anomalies, including climate monitoring and long range forecasting products.

The use of Cell phone technology

1.2 Advise on defining user requirements and identifying their needs

- Best done when there is a permanent structure including NMHS, governmental agencies, and other users.

- WCC-3: build up interface between users and providers.

- The Espoo conference on *Living with climate variability and change* (LWCVC), where there was a strong input of the user sectors about their needs. The upcoming proceedings of the conference would provide a good guiding material on user requirements and needs.

- There is a continuous need for capacity building for both users and providers to better understand each other and effectively cooperate in operating CWS. Also
outreach and education program need to be promoted for raising population awareness. Media can help in these aspects.

1.3 Provide suggestions on inclusion of socio-economic data, how to get useful data and how to make use of it, at regional and national level. How Regional and International institutions could help NMHSs

- There is a need for designing a standard and inter-operable data base system based on GIS for managing and exploiting such data. RCCs and WMO DRR are best placed to provide the needed assistance on this aspect. Data will be input by NMHSs, and need to be exchanged for use by CWS components and RCCs.

- National statistical Institutions / Bureau are good source to get some of such data. Insurance and reinsurance companies provide also good source of data.

- Exchange of sectors specific amongst NMHSs and sectors agencies. Showcases and success stories can be used to promote the exchange of these data.

- We should be careful on to whom climate warning should be provided to avoid negative side effects on the local economical activities.

1.4 Identify mechanisms to consider for interactions with users and dissemination of climate watch advisories to various levels of decision-making,

- High level: State level: Government, Parliament, High level councils and Committees, etc. (Nation wide contingencies measures) Report into single words, on the expected impacts; in order government can organize response.

- Intermediate level: Public and private agencies, Early warning units, Civil defense agencies, NGOs, etc. (Early preparedness)

- Field operation users: Civil defense units, Hospitals, Aid units, NGO’s, etc. (Action on the ground)

- Media

- Take advantage of existing national structures at various levels. Customise the information according to the recipient of the information. In many cases the information should target high and/or medium level only to support contingency planning and actions. However filed operation level should be kept informed during the progress of the climate watch and informed on the end of the watch.

- Media should be handled carefully and delicately to avoid negative consequences. Different countries have different policies in managing climate related hazards. Positive engagement of Media is a key to ensure efficient CWS.

- NGO’s are an important component of a CWS, in the sense they have good interactions with end users and the population and a fast reaction during disaster, they can help heightening awareness among the population and get data from the field. They can also be involved in capacity building for the
verification of climate watches. They may have good information on the socio-
economics.

- Issue of uncertainty, especially as regards to LRF which in some case is not
  very skilful. Need for education and capacity building in that case

1.5 Recommendations on the verification of climate watch advisories and how to
improve the system

- CW should provide the scope: time and space
- Capabilities/skill of climate prediction, and related uncertainties
- Better knowledge of user needs: users feedback
- TV channels, cell phone, etc... to reach users
- Database of extreme events for objective verification,
- Need for guidelines for verification
- There is a need for a good dissemination mechanism. In some case despite
good warning, the lack of an efficient dissemination can lead to disastrous
consequences

1.6 Cross-cutting issues
Provide information and recommendations on the following cross-cutting issues
(and any other issue that seems appropriate in the region):

- **Research and Development** - BCC-TCC-KMA good opportunities, it might be
  useful that countries be associated in R&D with these institutions

- **Resource mobilization and funding opportunities** - Develop projects
  proposal to existing mechanisms such as APN

- **Regular climate related meetings** - It is important to benefit from these
  meetings, including RCOFS, Monsoon meetings which take place regularly in
  the region. Combining with these meeting CWS is cost-effective.

- Promotional activities through existing channels in the region.
2.1 Needs for climate watches in the region

- These parts of the world are affected by extreme weather and climate events and related disasters such as droughts, dry spells, heat waves, cold waves, flooding, cyclones, wind storms, severe thunderstorms/lightning, land slides, costal erosions, salinity intrusion etc.
- As most of the countries in this parts primarily depends on rainfall for Agriculture purpose the variability in monsoon (rainy season) that occurs over a range of temporal scales from intra-seasonal (30-60 day intraseasonal oscillations) to inter-decadal, dominated by interannual variations can have adverse impacts due to crop failures.
- As the population density is very high the risk arises due to these adverse climatic conditions are very high.
- Global warming can lead to change in frequency of extreme events i.e. droughts, heat waves, cold waves, heavy rainfall, cyclones and associated systems etc. These changes are also reflected in the observed climatic data.
- In addition to the Agriculture sector Climate watch and services can provide useful guidance to some other sectors such as Health, Energy, Tourism, etc.

2.2 Issues related to climate data availability, management and exchange in the region and how to improve the situation

- To have a better climate watch system over the region, efforts should be made by NHMSs for the generation of missing climate data (for the country having large missing data) and digitization of the data which are available in paper form. In this regard, in addition to the existing programmes of WMO for data archival, WMO can further strengthen data archival and rescue (DARE) programme over the RAII region particularly for the NHMSs where only limited data is available.
- WMO to organize workshop/training programmes for the member countries to improve the climate data management such as missing data, data quality and data in homogeneity problem etc.
- To have a better Climate Watch System over the region there is a need to share and exchange the historical data amongst the members country as per the requirement.
- The climate data which are readily available at different NMHSs (like gridded data and some stations data) may also be shared within the data policy of respective NMHS for the benefit of RCC and NMHSs with regard to climate
watch. WMO may further discuss this matter in an appropriate forum (Working group meeting of RA-II).

- Data available from international bodies such as NCDC, GPCP etc. can also be used by RCCs and NMHSs over the region

- RCCs (BCC and TCC) and NMHS should strengthen links by providing the data for collaborative work to improve the capability of NMHS in Climate Watch.

2.3 Existing methodologies, tools and source of climate information at global and Regional level in providing climate monitoring and prediction products for use by NMHSs to develop climate watches.

- Climate information available through websites from various global centres such as Climate Prediction Centre at NCEP, ECMWF, UKMO etc can be utilised directly by NHMSs for providing climate watches over their region.

- Climate monitoring and forecast products available through Regional Climate Centres in RA-II region such as Beijing Climate Centre (BCC) and Tokyo Climate Centre (TCC) can also be utilised directly by NHMSs for providing climate watches over their region.

- The BCC and TCC will provide the forecast products and also the forecast data to the NHMSs members to develop their own climate forecast over their region. The forecast data from BCC and TCC can be provided to NHMS members either through web site or through ftp server.

- Since the KMA is closely working with the research team of APCC and also as it is designated as WMO lead centre for multimodel ensemble (MME) long range forecasting, the forecast products and data from MMELRF can be made available to the NHMSs members.

- NHMSs members can make use of the information/tools provided by ETCCDI (Expert Team on Climate Change Detection and Indices) web site jointly established by WMO/the Climate Variability and predictability Project and the Joint Commission for Oceanography and Marine Meteorology (CCI/CLIVAR/JCOMM).

2.4 How to make best use of the existing capabilities at national and regional level, including GPCs and RCCs, FOCRA-II, etc.

- At national level close co-ordination between NHMSs and other scientific organisations/institutes

- Role of RCCs (here BCC and TCC) in giving training to NHMSs members about their existing capabilities and also the new capabilities (ClimatView, ITACS etc).
• WMO LC-LRFMME and APCC can give training programme about the MME technique and any other tools available. WMO can arrange this type of training programme.

• Participation in FOCRA-II meeting

2.5 Identify specific requirements for NMHS to implement climate watch systems at national level

• Up-gradation of infrastructure
• Manpower requirement
• Close collaboration with other organisations/institutes in the respective country
• Capacity building and training
• Technology transfer (Regional climate models)

2.6 Make recommendation on capacity building and training for NMHSs, Users, and Media.

• Target oriented training like for data management, interpretation of climate forecast products
• Participation in FOCRA-II and other workshop/seminars
• Visiting scholar and exchange programmes between RCCs (BCC and TCC) and NHMSs members
• Visiting scholar programmes in WMO-LC LRFMME (or in APCC) for other NHMSs members
• NHMSs will hold workshop/interactions with users and media

2.7 Cross-cutting issues

• Research and development - (improvement of physical processes in models, improvement in downscaling techniques, climate research etc)
• Resource mobilization and funding opportunities - WMO, RCCs and others
• Regular climate related meetings - Regional workshop for climate watch (monitoring, prediction) over RA-II region in every 2 years with participation from NHMSs members, experts from GPCs, forecasters, end users etc.
• Promotional activities through existing channels in the region – close interactions between NHMSs with RCC (BCC & TCC) and LC of WMO LRFMME
Structure of the Action Plan

a) Key issues for the general summary of sessions

1) Climate change in the region,

2) Monsoon, typhoons, drought, thunderstorms, floods, heat waves and cold waves constitutes major climate concerns in the region having strong socio-economic consequences.

3) Existence of excellent regional infrastructure and institutions for the generation of global and

4) Need for establishing CWS as part of Climate Risk Management.

5) Implementing CWS is an essential contribution of RCCs, NMHSs and Sector Agencies in the Global Framework for climate services (GFCS).

6) Regional collaboration is essential, for sharing data and products and capacity building.

7) Regional climate monitoring and prediction products including LRF-MME,

8) Climate activities in various countries, issues related to Observations, Data Management and Data rescue remain of high priority in the region.

9) Interaction with users is essential to build a sound CWS.

10) Statistical and dynamical downscaling and verification, guidelines.

11) Training for NMHS on using climate products.

b) General statement

Participants agreed on the urgent need for the establishment of climate watch system in the participating countries based on WMO guidelines and as part of the implementation of the GFCS. Collaboration between regional and national institutions in data exchange including historical data, database for extreme events, climate products delivery, tools and capacity building is essential for the success of CWS. The implementations of the CWS will be based on the existing regional institutions (RCCs) and NHMSs in close collaboration with sectors and users.
c) **Specific actions to be undertaken in short term (1-3 months)**

i. Bring out the Proceedings (Participants to submit paper of their presentation with in one month)

ii. The presentations and soft copy of the proceedings will be put in RCC websites (BCC/TCC)

iii. The RCC websites may also give announcement about the upcoming events over the region.

d) **Specific actions to be undertaken in Medium term (1 year )**

iv. Participants from NMHSs in RAII may join the programme FOCRAII organised in April each year starting from 2010. The organiser may send formal invitation to NHMSs.

v. TCC is planning to have a meeting about how to use the GPCs products over the region.

*e-Forum discussion?*

vi. To have a discussion forum PMD will establish web-portal for this purpose with all the participants of this workshop as users.

*Project proposal?*

vii. Dr. Azmat Hayat Khan from PMD, Pakistan and Dr. Dushmanta Ranjan Pattanaik from IMD, India can coordinate with RCC for submitting project proposal to APN.

e) **Regional mechanisms for collaboration on climate watches, WMO WGs**

*WMO WGs?*

viii. Working group on climate and Agrometeorology and DRR focal points of WMO RA-II be informed about the regional activities on CWS.

*Visiting scientist programs?*

ix. There are some existing programmes in BCC and TCC and participants and members of NMHSs over the region are encouraged to take benefit from this using the existing mechanism.

*Data exchange?*

x. Regional Association be informed about the need for data exchanges within the regions and with the RCCs (including historical and extreme events data) as part of the implementation of CWS and GFCS.
Data Bases?

xi. Socio-economic data base using GIS - BCC will explore the design of the data base

xii. Project proposal for extreme events by BCC – on going action by BCC for China, which will be expanded for the whole region.

xiii. The proposal of BCC on climate extreme events can be considered as showcase project within CCL activities.

xiv. The outcome of this project by BCC could serve as model for similar initiatives by other parts of the world.

The Role of BCC, TCC, others..., in leading some actions
Inter-agencies partnerships at regional and national levels (SAARC, ADPC, APCC, APN etc.)

xv. The proceedings of this workshop may be sent to these bodies (SAARC, ADPC, APCC, APN etc.) in addition to the RA and WMO bodies.
Regional Workshop on Climate Monitoring and Analysis of Climate Variability: Implementation of Climate Watch System in RA II with focus on Monsoon affected areas

(Beijing, China, 10–13 November 2009)