South Asian Climate Outlook Forum (SASCOF)

1. Some Climate Features of South Asia

South Asia is home to about one fourth of the world's population and occupies only 3% of the global land area, making it both the most populous and the most densely populated geographical region in the world. The annual climate of south Asia is dominated by two monsoons; summer or southwest monsoon (May to September), which is also the main agricultural season for the region and winter or northeast monsoon (October to February), which coincides with the second major agricultural season for the region. In summer, due to heating of the Asian continent faster than its neighboring oceans, the relatively warm and moist air from the oceans flows towards the continent leading to onset of southwest Monsoon. Subsequent to southwest monsoon, the flow of air reverses. The drier and colder air of the continent blows towards oceans leading to northeast monsoon*.* The northeast winds over the Bay of Bengal pick up moisture prior to reaching southern parts of the south Asia leading to considerable rains over the region.

Fig.1 shows the annual cycle of mean monthly rainfall of all the south Asian countries. As seen that for most of the south Asian countries the most of the annual rainfall is received during the 4 months of the summer monsoon season or southwest monsoon season (June to September). Many parts of South Asia also receive significant amounts of rainfall during the winter Monsoon Season (October to February). However, Afghanistan experience mainly dry climate during the summer monsoon season. It receives better rainfall during the winter season (December to February). For Sri Lanka, though the country receives good amount of rainfall during the summer monsoon season (May to September for Sri Lanka), the peak rainfall are received on either side of the summer monsoon season; First inter-monsoon season (March –April) and second inter monsoon season (October – November). Table-1 shows the various rainfall seasons over each of the south Asian countries.

The summer monsoon plays a crucial role in the entire socio-economic fabric of South Asia, highly influencing all walks of life. Almost 70-80% of the total annual rainfall occurs during the southwest monsoon season and the monsoon greatly affects the socio-economic sectors of the countries of this region. During this season, the most intense rainfall activity is seen over the northeastern parts of the region over Bangladesh, India and adjoining Myanmar (Fig.2). The influence of the Southwest monsoon diminishes towards both extreme north and south of the South Asian region, as the winter season rainfall bearing currents gains predominance. During the post monsoon and early winter months, substantial rainfall descends on the region, covering the southern tip of India and Sri Lanka as the prevailing northeasterly trade winds over the region gain strength. This season (October to December) has come to be known as the "North East" monsoon season.

a. Factors influencing South Asian seasonal climate

The two most important ocean-atmosphere phenomena identified as having large influence on the interannual variability on the south Asia monsoon is the El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD). Southern Oscillation or "SO" is a "see-saw" in the surface air pressure between eastern and western tropical Pacific. El Niño and La Niña are oceanic manifestation of opposite phases of SO, which is an atmospheric phenomena. El Niño is characterized by the warmer than normal sea surface temperatures in the central and eastern equatorial Pacific Ocean. This is called the warm phase of the SO. The cold phase of the SO, called "La Niña" is characterized by high pressure in the eastern equatorial Pacific, low in the west, and by colder than normal seas surface temperatures in the central and eastern Pacific. ENSO (El Niño Southern Oscillation) is an acronym designed to stress the fact that the El Niño and SO are components of the same global Ocean-Atmosphere coupled phenomena. In general, El Niño (La Niña) years are associated with the below (above) normal rainfall over most of south Asia except some east and northeast parts of the region (see Fig.3, which shows the composite rainfall anomaly map of south Asia during the south monsoon season).

A significant predictive relationship exists between ENSO and south Asia monsoon rainfall. While the ENSO influence on the monsoon is very important, recent experience indicates that it is not enough to rely entirely on El Niño or La Niña for prediction of the monsoon. The two great ENSOs of the century, 1982/83 and 1997/98 are good examples. The 1982/83 episode produced a devastating drought in south Asia, while the 1997/98 episode produced normal rainfall. This leads to the hypothesis that seasonal monsoon conditions in the region are very sensitive to details of the regional pattern of sea surface temperature (SST) as well as the global ENSO phenomenon.

Indian Ocean Dipole (IOD) is a coupled ocean-atmosphere phenomenon that occurs in the tropical parts of the Indian Ocean. IOD has two phases; positive and negative. A positive IOD period is characterised by cooler than normal water in the tropical eastern Indian Ocean and warmer than normal water in the tropical western Indian Ocean. A positive (negative) IOD SST pattern is associated with above (below) normal rainfall over central parts (monsoon trough zone) of south Asia (Fig.4). In spite of a noticeable association between IOD and monsoon rainfall over south Asia, a predictive relationship between IOD and Indian summer monsoon rainfall could not be identified mainly because the IOD pattern generally develops during the middle of the monsoon season. However, the IOD has been found to play an important role as a modulator of the Indian monsoon rainfall and influences the association between the ISMR and ENSO. It is observed that during the period when the ENSO-ISMR correlation is low (high), the IOD-ISMR correlation is high (low).

Other factors that are known to impact monsoon are winter and spring snow cover over Eurasia, northern hemisphere surface air temperature during spring season, sea surface temperature patterns over Atlantic Ocean, mid latitude flow pattern north of India etc.

2. Monsoon Prediction & Predictability over South Asia

Predictability of a climate system such as the south Asia summer monsoon system depends upon our ability to understand and model the mechanisms causing its variability. The seasonal mean climate is affected by the changes in the slowly varying boundary conditions such as sea surface temperature (SST), snow cover, soil moisture etc. through changes in the large scale organized convection. It has been theoretically shown that the evolution of these slowly varying boundary forcing is predictable beyond two-weeks, the limit of atmospheric predictability. It is hypothesized that the predictability of the boundary forcings are potentially translated to predictability of the seasonal atmospheric circulation and associated climate and this forms the scientific basis for seasonal climate prediction.

In case of summer monsoon over Asia, the year to year variation of the seasonal summer monsoon rainfall due only to the boundary conditions represents the potentially predictable component, which is of the order of ~50%. The remaining variance is driven largely by fast varying day-to-day weather or intra seasonal variations (ISV), which are difficult to predict with long lead time. The predictable component of the monsoon variability is often stronger in the extreme years (i.e. excess or deficient) that are also the years of interest for society at large. For example, model were able to capture the signal about the 2015 deficient SW monsoon over south Asia from February itself as the signature of the strong 2015-2016 El Nino event was evident in the subsurface and sea surface temperature over equatorial Pacific and in the atmospheric circulation above it from March 2015. On the other hand during 2016, La Nina conditions over Pacific and negative IOD conditions over Indian Ocean lead to normal monsoon prediction over south Asia.

For the seasonal prediction of monsoon, two main approaches are used. These are empirical statistical and dynamical. The statistical approach uses the historical relationship between the predictand (eg. seasonal rainfall averaged over a country) and predictor series derived from either the global atmosphere-ocean parameters representing slowly varying boundary forcing or their proxies. However, the statistical approach has been found to have relatively limited skill for seasonal forecasts at smaller spatial scales such as state, subdivision, district etc. The dynamical approach uses Coupled General Circulation Models (CGCMs) for prediction of monsoon circulation and associated rainfall. The improvements made by the CGCMs in forecasting the evolution of anomalous SSTs over equatorial Pacific (i.e. ENSO phenomena) during the last few ENSO events reflect a general improvement in the skill of CGCMs to simulate the boundary forcing (eg. SSTs). This has been possible mainly due to the improved knowledge of the phenomenon's nature, more and more powerful computers, and a very good operational observation system over the Pacific. As the ENSO is the main source of interannual variability of monsoon, the improvement in the ENSO forecasting should lead to the improvement in the monsoon seasonal forecasting also. However, epochal variation of ENSO-Monsoon relationship and inability of dynamical models in realistic simulation of the interaction between boundary forcing and the atmosphere (eg. SST-Rainfall relationship) contribute to uncertainties and deteriorated skill. Further improvements in the model physics leading to reduced biases is necessary for these models to be used for operational forecasting.

One of the important developments in recent times with a positive implication for the seasonal monsoon forecasting is the noticeable improvement shown by the coupled models in forecasting the monsoon ISVs, which were thought to be nearly unpredictable till recently. This has helped in issuing extend range forecast which act as bridge in the gap between weather and climate forecasts leading to development of seamless forecasting system. As discussed earlier, the ISVs cause substantial part of monsoon seasonal variance and therefore, any improvement in the skill of ISV prediction should help in improving the seasonal monsoon prediction over south Asia. This finally should help in generating better forecasts of monsoon on smaller spatial and temporal scales. On the other hand, the possible projected impacts of the global warming on the mean monsoon circulation and rainfall patterns, and on the monsoon teleconnections throw up new challenges in the monsoon prediction and these calls for continued efforts in improving the global observational networks and the models as well.

3. Importance of Monsoon Rainfall for South Asia: India as a Case Study

3.1 Impact of Monsoon Rainfall on Indian Agriculture

The agricultural practices in India have traditionally been tied strictly to the annual cycle of rainfall. The summer monsoon accounts for almost 78% of the gross cropped area. About a third of the cropped area is still rain fed. The most significant feature of the annual cycle of the Indian summer monsoon is its regularity. However, the very regularity of the monsoon makes agriculture susceptible to the changes in the annual cycle of the rainfall. The total monsoon rainfall during the season has a statistically significant relationship with the crop yield over the country. In general, a weak monsoon year with significantly low rainfall can cause a low crop yield. On the other hand, a strong monsoon is favorable for abundant crop yield, although sometimes too much rainfall may cause devastating floods. Fig.5 a & b respectively shows the relationship of ISMR with all India major crops production during the concurrent Kharif season and that during the subsequent Rabi season for the period 1966-2017. The crop production time series were first detrended to remove the technology trend from the series and anomalies were computed using normal computed for the base period of 1971-2000. It is seen that there is in phase relationship between the rainfall and the detrended crop production anomalies of the both Kharif and Rabi seasons. This indicates that above normal monsoon rainfall in addition to providing favourable condition for Kharif crops, helps in maintaining improved soil moisture during the subsequent winter season which is vital for the crops during the Rabi season. However, the relationship between ISMR and Kharif crop production is stronger (C.C. = 0.73) than that between ISMR and Rabi crop production (0.44).

3.2 Impact of Monsoon on Indian Economy

In India, agriculture and allied sectors like forestry, logging and fishing accounts for 17% of the GDP (2014 estimate) and employs 49% of the total workforce. Despite a steady decline of its share in the GDP, is still the largest economic sector and a significant piece of the overall socio-economic development of India. Further a great deal of electricity in the region is produced by hydroelectric power plants, which are driven by water collected during the monsoons. Electricity powers hospitals, schools, and businesses that help the economies of these areas to develop. This is the major reason for the economic growth of India to depend on Monsoon season. If the monsoon is good, it boosts up the economy of the country and helps in maintaining GDP growth. A good rainfall tends to increase the productivity of vegetables and fruits, rice, sugarcane, millet, oil seeds and cotton. This reduces the price and thus calms down the inflation. This also encourages the government to ease the edges on the export of wheat and rice. A good rainfall can also increase the ground water level and replenishes the reservoirs. This helps in good irrigation system and better hydroelectricity power output. However, the floods associated with the stronger than normal monsoon can cause inundation of low lying areas and cities leading great damage to crops, property and life.

A recent analysis of the variation of the GDP and the monsoon has revealed that the impact of severe droughts on GDP is about 2 to 5% of GDP. The large impact of droughts on GDP (despite the substantial decrease in the contribution of agriculture to GDP) is attributed to the indirect impact on the purchasing power of the large fraction of the population dependent on agriculture. Hence if the monsoon turns out to be a ‘normal’ monsoon, the nation heaves a sigh of relief and carries on with business as usual. If it turns out to be a drought, there is a significant impact on agriculture and the economy, and major drought relief programmes are launched.

3.3 Drought Situation and Its Management

Drought is a natural hazard that differs from other hazards since it has a slow onset, evolves over months or even years, affects a large spatial extent, and cause little structural damage. Its onset and end and severity are often difficult to determine. Like other hazards, the impacts of drought span economic, environmental and social sectors and can be reduced through mitigation and preparedness. Because droughts are a normal part of climate variability for virtually all regions, it is important to develop plans to deal with these extended periods of water shortage in a timely, systematic manner as they evolve. Drought in India occurs in areas with high as well as regions with meagre rainfall. There are three types of drought: meteorological, agricultural and hydrological. Meteorological drought is defined as a situation when there is significant decrease from normal precipitation over an area. Hydrological drought results from prolonged meteorological drought resulting in depletion of surface and sub-surface water resources. Agricultural drought is a situation when soil moisture and rainfall are inadequate to support healthy crop growth. Drought is also classified on the basis of time of onset as early season, mid-season and late season.

Basic to drought management in the Indian context is the delineation of drought prone areas. Next step is the monitoring of the indicators of drought (like rainfall and associated weather parameters, crop health, available ground water and surface water resources etc.). Drought assessment basically starts with rainfall measurement. The spatial and temporal variability of rainfall is very high in the semi-arid and arid areas prone to drought. The availability of real/near real time rainfall/ weather data makes it possible to develop early warning systems. The digital data obtained from telemetric rain gauges enables not only efficient data base management but also in developing and operationalizing early warning systems and development of meteorological, agricultural and hydrological models which provides decision support tools. The forecasting of the drought is another important part of the drought management. Accurate forecasts at various spatial and temporal scales are necessary.

Drought prevention and preparedness involve water supply augmentation and conservation (e.g. rainwater harvesting techniques), expansion of irrigation facilities, effective dealing with drought, and public awareness and education. Transport and communication links are a must to ensure supply of food and other commodities during and just after a drought. Successful drought management requires community awareness on the mitigation strategies, insurance schemes for farmers, crop contingency plans, etc.

Mitigation actions, programs, and policies are implemented during and before drought to reduce the magnitude of risk to human life, property, and productive capacity. Emergency response is a part of drought management, because it is unlikely that government and others will anticipate, avoid, or reduce all potential impacts through mitigation programs. A future drought event may also exceed the “drought of record” and the capacity of a region to respond. Given the severity of drought in dry areas, a central challenge for researchers is to devise technologies that lend greater resilience to agricultural production under this stress system. One way in which they have responded successfully to the challenge is by developing varieties of major food crops that are drought tolerant or escape drought through early maturity.

In drought prone areas rainwater is the main source of surface and ground water recharge. Because of more intense use of ground water in most parts of the country during the last few years, recharge of ground water did not take place. Immediate steps are needed to make efficient use of available surface and groundwater in drought prone areas - resorting to drip and sprinkler practices wherever possible, particularly for commercial crops including fruit orchards. Construction of water shed structures at the right place where water recharge can be enhanced will be used for life saving irrigation at critical stages of crop growth and during drought situations.

3.4 Other Dimensions/ Related Issues of Monsoon and Drought in India

The direct impact of drought is generally classified under four categories, viz. physical, social, economic and environmental. The relative and absolute magnitudes of each impact will however, depend on specific regional characteristics. Droughts cause a loss of assets in crops, livestock and productive capital as these are immediate consequences of water shortage. The lingering impact is felt in the lack of quality seeds in the subsequent season.

In the industrial sector, agro-based industries are directly affected. Lower domestic production of agriculture based inputs for agro processing units reduces non-agricultural production and employment opportunities. Availability of water for domestic consumption also diminishes. This has implications for health and household activities, including substantial increase in the time spent on collecting water. As water becomes scarce, competition among and within sectors usually increases. Droughts have other important implications for government policies, as it reduces tax revenues through declines in income, employment and exports. On the expenditure side, the government is faced with increased expenditure on relief, social welfare, health and water supplies, consumption-related subsidies on food distribution, and the logistical costs of drought related imports. The law and order structure is put under greater pressure by a rise in crime, in turn associated with temporary unemployment, migration and increased destitution.

In addition, there are likely to be pressures for the increased provision of subsidies and credit to the affected productive sectors, including public utilities. Increased budgetary pressures, resulting from lower revenues and higher expenditure, are usually met by either external and internal borrowings, higher taxes or the imposition of new taxes. Also, reallocation of planned government expenditure might occur, within or among sectors and also, between capital and recurrent spending with attendant opportunity costs. Droughts have a range of indirect, secondary effects as well. Generally, the secondary impact is on regional inequality, employment, trade deficits, external debt and inflation. The micro level impact at village and household levels, are equally important. Drought may result in a considerable intensification of household food insecurity, water related health risks and loss of livelihoods in the agricultural sector.

4. Background of SASCOF and User Involvement

In Asia, China has been coordinating a Regional climate outlook forum (RCOF) called 'Forum on Regional Climate Monitoring, Assessment and Prediction for Regional Association II (FOCRA II) since 2005, covering the entire Asian continent. Asia being a vast continent with large differences in the climatological settings on a sub-regional scale, Regional Association II (Asia) of World Meteorological Organization (WMO) recommended the establishment of sub-regional RCOFs devoted to specific needs of groups of countries having similar climatic characteristics. South Asia with its unique climate dominated by monsoons and an agrarian society is a natural choice for such an RCOF. A proposal regarding separate RCOF for south Asia first came up during a meeting of the Directors Generals of the National Meteorological and Hydrological Services (NMHSs) in South Asia and Permanent Representatives (PRs) of the respective countries with WMO convened by WMO at the Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy, on 6 August 2009. In this meeting, the PRs of south Asian nations with the WMO unanimously agreed to establish the South Asian Climate Outlook Forum (SASCOF) with a specific focus on the climate information needs of nations affected by the Asian summer monsoon climate. Looking into the importance of SASCOF for south Asia, PRs of all the participating nations also decided to conduct the first session of SASCOF in 2010. India volunteered to host the first three SASCOF sessions, in India.

The main objectives of SASCOF set during the meeting were the following:

1. To review the progress made in understanding and long range prediction of summer monsoon both regionally and globally;
2. To make available detailed information on climate variability in South Asia for dissemination along with the seasonal outlook;
3. To provide a platform for the stakeholders of SASCOF to share and exchange experience and knowledge on summer monsoon and its prediction;
4. To initiate capacity building/human resource development activities for the South Asian region, particularly in seasonal prediction;
5. To build collaboration and partnerships among the members of SASCOF for mutual benefit;
6. To identify needs of user sectors through a dialog among different groups.

SASCOF, co-sponsored by WMO is coordinated by India Meteorological Department (IMD). The Climate Research & Services Division of IMD, Pune is currently working as the WMO Regional Climate Centre (RCC) for South Asia (RCC, Pune). RCC, Pune also takes lead role in the preparation of consensus forecast. The main participants in the forum are representatives/ experts from the National Meteorological and Hydrological Services (NMHSs) of the South Asian countries (Afghanistan, Bangladesh, Bhutan, India, Maldives, Myanmar, Nepal, Pakistan and Sri Lanka). Other participants are climate experts from global and regional climate research/service institutions like Indian Institute of Tropical Meteorology (IITM), Pune, Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES), Bangkok, Japan Meteorological Agency (JMA), Korean Meteorological Administration (KMA), China Meteorological Administration (CMA), International Research Institute for Climate and Society (IRI), National Centers for Environmental Prediction (NCEP), Meteo-France, Met Office, UK, Asia-Pacific Economic Cooperation Climate Centre (APCC) etc. Prior information provided by the forum about the performance of the summer monsoon is helpful for the different sectors – crop production, the hydroelectric power generation and drinking water requirement – that are highly dependent on the rainfall in planning risk management strategies. For example, during the SASCOF-05 and 6 sessions held in Pune, India (2014) and in Dhaka, Bangladesh (2015) respectively featured a Water Forum that brought together water resources experts with SASCOF experts and participants. The purpose of the Water Forum is to bring better synergy between the water and climate community within the South Asian countries, with the long-term objective of making the best use of the climate services and information provided through SASCOF efforts. Water managers are invited to attend the forum where the climate consensus outlook and seasonal hydrological prediction available in the South Asian region are presented to them. In addition, they are exposed to ways of using climate information effectively in water management operations.

5. The Present SASCOF Process

During the first 5 years (2010 to 2014), SASCOF sessions were held only for southwest monsoon season (June to September). From 2015 onwards, SASCOF session dedicated to northeast monsoon season (October to December) was started in addition to the existing session for southwest monsoon season. Each year, the session for southwest monsoon season is held in April and that for northeast monsoon season is held in September. In addition to these physical sessions for the preparation of consensus forecasts for southwest and northeast monsoon seasons, online session for preparing consensus forecast for winter season (December to February) was started from 2015 onwards. The online session for preparing consensus forecast for winter season is generally held in November.

The main forum meetings of SASCOF are generally conducted for a period of 2-3 days. In these meetings, experts from south Asian countries join other regional and international climate experts to assess the skills of available seasonal forecasting systems over south Asia and develop a consensus climate outlook statement for south Asia. The consensus outlook is reached based on the prevailing large scale global climatic patterns (like ENSO, IOD, Snow Cover etc.) and seasonal forecasts for the relevant season from both statistical and dynamical models. These forecast information are derived from the participating National Meteorological Services (NMSs) of the region, WMO GPCLRFs and RCCs, and other climate research centers like IRI, IITM, APEC Climate Center etc. At least 50% of the forecast information is derived from various dynamical models.

The main forum meeting is generally followed by a joint meeting of climate experts, and practitioners & decision-makers from various user sectors and stake holders from the region. These sectors include Agriculture and food security, health, energy, water resources, disaster risk reduction and response etc. These joint meetings review various issues related to the use of climate information to sector specific applications, sharing the experiences and lessons learned from the applications of previous SASCOF products etc. The meeting also encourage sector experts to develop detailed sector specific risk information including warnings based on the SASCOF products, and communicate to decision-makers and the public. Special outreach sessions involving media experts are also conducted to develop effective communication strategies.

In addition to the above, capacity building training workshops are also conducted. Currently training workshops are conducted only during the April SASCOF sessions. The workshop is generally conducted as a pre-COF session for the experts from NMHSs to improve understanding of the regional climate processes, access and interpret global and regional climate prediction products, and gain skills in long range forecasting and communication of the climate information to user community. The capacity building training workshops are generally designed to impart theoretical and practical knowledge on the seasonal prediction and its applications to the participants.

First three meetings of SASCOF were held in Pune, India jointly hosted by India Meteorological Department (IMD), Indian Institute of Tropical Meteorology (IITM) with the support of WMO. The participants in SASCOF-1, April 2010, agreed that more collaboration among operational long range forecasters of South Asia and research institutes in the region are required to improve the prediction skill of the models. The Forum also agreed on the importance of maintaining an active interaction with relevant global and regional experts. SASCOF-1 strongly recommended the introduction of a capacity building/human resource development plan for the South Asian nations, particularly for seasonal prediction. Accordingly, from SASCOF-2 onwards, capacity building training workshop for participants from the South Asian countries have been conducted prior to Forums for summer monsoon. SASCOF-2 was held during 13-15 April 2011 and the first training workshop on seasonal prediction was held immediately prior to it (8-12 April 2011). The SASCOF-3 training workshop and Forum were held during 16-20, April 2012.

SASCOF-4 training workshop and Forum were held at Kathmandu, Nepal during 15-19 April 2013; and SASCOF-5 training workshop and Forum were held at Pune, India during 14-23 April 2014. In conjunction with SASCOF-5, a Climate Services User Forum for the Water Sector (CSUF-Water) was coordinated by the International Commission on Irrigation and Drainage (ICID) and was held during 23 - 25 April 2014. SASCOF-6 was held during 21-22 April 2015 in Dhaka, Bangladesh along with CSUF-Water. Following the success of SASCOFs for summer monsoon rainfall and associated training workshops during the first six years (2010-2015), there was demand from participating South Asian countries for extending SASCOF for northeast monsoon season (October to December) and winter seasons (December to February). As a result, the first Forum (SASCOF-7) that focused on the northeast monsoon was held in Chennai, India during 14-15 Oct 2015, in conjunction with the first CSUF-Agriculture. During the SASCOF-7, it was decided to conduct separate SASCOF for northeast monsoon in September in addition to SASCOF for summer monsoon season conducted in April every year. During the SASCOF-7, it was also decided to issue a consensus forecast for the rainfall and temperature for the winter season prepared through online discussions among the experts from south Asian countries.

SASCOF-8 was held during 25-26 April 2016 in Colombo, Sri Lanka. CSUF-Water and CSUF-Health was organized in parallel sessions during 27-28 April. In addition, a joint CSUF session was held with SASCOF on 26 April 2016. SASCOF-8 was also preceded by a Capacity Building Training Workshop on Seasonal Prediction for the operational climate experts of the South Asian countries during 19-23 April 2016. The Training Workshop was focused on operationalizing the long-range forecasts. SASCOF-9 for winter monsoon was held in Nay Pyi Taw, Myanmar during 27-29 September 2016, in conjunction with the second CSUF-Agriculture. The tenth session of the South Asian Seasonal Climate Outlook Forum (SASCOF-10) was held in Thimphu, Bhutan from 24-26 April 2017. The event was hosted by the National Center for Hydrology and Meteorology (NCHM), Government of Bhutan. SASCOF-10 was preceded by a Capacity Building Training Workshop (Pre SASCOF) as a part of the 9th International Training Workshop on Climate Variability and Prediction (9ITWCVP), organized by NOAA-USAID-WMO and IITM, and hosted by IITM from 13-21 April 2017 in Pune, India.

The SASCOF consensus statement consists of the following parts:

- Summary providing highlights of the consensus forecast outlook in a brief.
- Introduction about the concerned SASCOF like venue, participation, inputs used for preparing the forecast outlook, the current methodology/approach adopted for preparing the seasonal predictions and consensus outlook, including the global/regional/national technical inputs for the process, contents of the consensus forecast outlook statement etc.
- Current status of the large global climate anomalies like ENSO, IOD, snow cover over Northern Hemisphere that have some influence on the monsoon rainfall over the region. The forecast outlook for ENSO and IOD during the concerned season is also presented.
- Consensus forecast outlook over south Asia for the relevant season along with a probability forecast map for rainfall over the region. Though a brief statement on the temperature forecast outlook for temperature is included for OND and DJF seasons, probability forecast map for temperature is not presented.
- Verification of consensus forecast issued for the relevant season of previous year. The practice of including the verification part in the consensus forecast was started from 7th session of the SASCOF held in Colombo, Sri Lanka.

Once the regional consensus forecast is issued, most of the NMHSs of the region conduct National Climate Outlook Forums (NCOFs) in the country as well as sub-country scales in local languages.

As the SASCOF consensus forecast process does not cover all the seasons, RCC, Pune issues forecast outlook for the rainfall and temperature for the next two three month moving seasons (i.e.,for next four months period) over the region, The outlook is updated every month. The forecast outlook is prepared based on the high resolution climate forecasting system (CFS) model. RCC, Pune also provides forecast anomaly maps of rainfall and temperature over the region for the next 9 months and the anomaly maps are for monthly and 3 month moving seasons. RCC, Pune also provides latest status of the ENSO and IOD and its forecasts for next 9 months and issues ENSO and IOD bulletin updated every month.

6. Verification of the Consensus Forecasts

Since the first SASCOF session in 2010 to till date, there have been some changes in the content, methodology and presentation of the consensus forecast outlook for the south Asia. In the first year (2010), the consensus forecast outlook did not present probability forecast map and the forecast consisted of only rainfall forecast for the south Asia as a whole and no mention about the spatial distribution of season rainfall was made. Subsequently, from 2011 onwards probability forecast map and statement indicating probability forecast for regional rainfall distribution. During 2011-2015, the probability forecast map depicted areas of most likely rainfall categories (below normal, normal and above normal using yellow, green and blue colour shades) over the region, as well as the probabilities for each tercile categories over broad areas of same colour shade. From 2016 onwards the probability forecast map depicted grid wise most likely tercile category as well as its probability for each of the 1^{o} latitude x 1^{o} longitude spatial grid boxes over the region. The box-wise tercile probabilities were derived by synthesis of the available information and expert assessment. It was derived from an initial set of gridded objective forecasts and modified through a consensus building discussion of climate experts.

The verification of the consensus forecast maps for seasonal rainfall issued during the last six years (2011-2016) is given in the Annexure-I. It can be seen that in most of the cases, the performance of the large scale rainfall anomaly over the region during the season was correctly indicated by the consensus forecasts. However, some differences were noticed in the forecast for the regional rainfall distribution. It may be mentioned that consensus forecasts were able to correctly indicate the below normal southwest monsoon season (June to September) rainfall over the region during the years 2014 & 2015 as well as the above normal northeast monsoon season (October to December) rainfall over the southern part of the region.

7. SWOT Analysis

SWOT (Strengths, weaknesses, opportunities and Threats) analysis of the SASCF activities are presented below.

(S) Strengths:

- Countries of the region with nearly similar climatic characteristic and large agrarian community have nearly similar requirements of seasonal and sub-seasonal forecast outlook,
- NMHSs of the region have long experience in providing weather services and have started extending climate services. Most of the countries have density (spatial) of the observational network is in accordance with WMO standards
- Three RCCs in the Asia region (Beijing, Tokyo and Pune).
- Seasonal and sub-seasonal forecast products are readily available from WMO RCCs, GPCs of LRF, and other climate research cetenrs.
- SASCOF activity has been conducted every year since 2010
- Being tropical region, potential predictability of large scale climate features (like monsoon) over the region is relatively good
- Significant improvement in the understanding and predictability of the climate variability (particularly that of the monsoons, which are the most dominating climate feature) of the region due to long global and regional research efforts.
- Have expertize and essential techniques that are required to prepare the consensus forecast
- Opportunity to create new products to comply with the end users requirements
- Collaboration among met services and climate research centres/ institutiions has created incentives for development and advancing the services
- New/updated technologies for preparation and presentation of consensus forecasts and their dissemination
- Demand for NCOF in the country and sub country scales from local governments and user sectors.

(W) Weaknesses

- Climate services activity is new area for some countries and there is lack of general awareness about the existing of such services.
- Lack of funding from government (because not sure of benefits)
- Limited infrastructure and expertise (particularly in respect of seasonal prediction, which either absent or require further development) in some countries for extending the climate services.
- Non availability of long period, high resolution, and quality data bases.
- Low model skill for seasonal prediction as smaller spatial scale.
- Lack of coordination with end users (from various sectors like water, agriculture, energy, transport, sports etc,); messages also might not be understood by the end users.
- Lack of clear guidelines for fine tuning of RCOF products for sector specific uses.
- Appropriate tools for verification of consensus products yet to be developed.

(**O) Opportunities**

- Keen interest from the NMHS and user sectors is an opportunity to develop sustainable SASCOF services
- Success in providing reasonably correct climate forecast outlook in previous years (like deficient southwest monsoon rainfall over the region during 2014 & 2015) has given confidence in our ability to provide forecasting information/climate services about extreme events

- Raising awareness can create new opportunities
- Opportunities to develop sector specific SASCOF products.
- The SASCOF activities are beneficial for the NMHSs for improving climate services at national level (Success in RCOF activities will help NMHSs to demand more funding from government)

(**T) Threats**

- Lack of high resolution, long period and quality data reduces opportunities to develop tools for better understanding and prediction of the climate variability at various spatial scale
- Maintaining weather stations and expanding its scope to include climate observations.
- Defining met services institutions in all countries is different
- Rules and legislation might hinder development of climate service and data direct sharing
- Legal responsibility issues often unclear when weather/climate information is disseminated (is the situation different for probabilistic vs deterministic information?)
- Entry of private companies in the met. Services.

8. Sustainability of SASCOF

Prior to the implementation of the SASCOF, though the region is prone to climate extremes like droughts, floods, heat and cold waves etc. many NMHS from south Asia were not having either dedicated division for issuing seasonal or sub seasonal forecasts or capacity and infrastructure to generate these forecasts. Therefore, the proposal to conduct SASCOF was well received by these NMHS. After 8 years of existence of SASCOF and associated capacity building training workshop in seasonal prediction, now these NMHSs have not only gained some capacity to generate seasonal forecasts but also have started to issue seasonal forecast for the respective countries regularly. So this enhanced interest in the seasonal forecast has resulted in the active participation of all NMHS from the region in the SASCOF activities. For example, IMD took initiative to conduct five of the first seven SASCOF forum meetings, other five forum meetings were keenly hosted by other five NMHS from the region. Next SASCOF forum meeting (SASCOF-11) for the northeast monsoon season will be hosted by Maldives, the only island NMHS of the region in the last week of September 2017. Thus importance given by the NMHSs to the SASCOF activities and their active participation in the meetings form the most important basis for sustenance of SASCOF. Recognition of Climate Research & Services Division of IMD at Pune as WMO RCC for south Asia is another important step towards the sustenance of SASCOF as RCC Pune has been taking responsibility of technical co-ordination of the SASCOF forum meeting and associated training workshops including drafting of the consensus forecast outlooks. To further support climate services activities in the region, as mentioned earliest, RCC, Pune is also making available a suit of climate products and other climate information relevant to the region through a dedicated website (http://www.imdpune.gov.in/Clim_RCC_LRF/Index.html). In fact the probability forecast from the coupled forecasting system (CFS) model regularly run by RCC, Pune to generate LRF products for the region forms main input for the consensus forecast outlook.

Currently there is no regional group of country focal points to co-ordinate SASCOF activities. As per the present practice, the local arrangement for conducting the main forum user forum meetings and training workshop is done by the host NMHS in consultation with WMO and IMD. For conducting forum meetings for NE monsoon, RIMES takes important role as one of the coordinators. In addition, user forum meeting are conducted with support of various stake holders from user sectors. Financial support for the conducting SASCOF activities mainly come from WMO through its various funding agencies like The United States Agency for International Development (USAID), Department of the Environment, Government of Canada etc. Participation of the experts from IMD and IITM, Pune is funded by the respective institutions. IMD has earmarked funds (for local hospitality) to RCC, Pune for conducting SASCOF main forum meeting once in a year in India. However, funds may be necessary for participation of experts in the SASCOF activities from other NMHS from the region and invited experts from RCCs, GPCs etc.

9. The way forward

Based on the discussions among the climate experts, experts from user sectors and other participants of the main forum and user forum meetings of SASCOF during the last 8 years (2010-2017), following points are important for further acceptability and usability of the SASCOF products.

- Development of high resolution and quality data bases over the region for better climate monitoring as well as bias correction and verification of climate forecasts.
- Make the process of preparing the consensus forecast map from various forecast inputs to be objective as much as possible.
- Skill map of such objective methods available for improving confidence in using the consensus forecast products
- Standard tools for verification of consensus forecasts
- Mechanism to update the consensus forecast regularly (say every month). An expert team of focal points from each NMHS lead by RCC can generate the forecast.
- The seasonal forecast to be supplemented by sub-seasonal/monthly climate forecasts.
- Conduct capacity training workshops on other topics such as the construction of long time series of gridded climate data over the region, extended range prediction, climate applications and climate impact assessment
- Increased interaction with the user community and generation of tailored climate products for the users.
- Specialised capacity building workshops for user community,

Table-1. Major rainfall seasons of the south Asian countries

S. No.	Country	Main rainfall periods
1	Afghanistan	Winter (DJF), Spring (MAM)
2	Bangladesh	Pre-monsoon (MAM), summer Monsoon (JJAS)
3	Bhutan	Winter (DJF), JJAS (summer monsoon)
4	India	Winter (JF) for north India, pre-monsoon for south peninsula and northeast India (MAM), SW Monsoon (JJAS) for most parts fo the country and post monsoon (OND) for south Peninsula.
5	Maldives	May to October
6	Myanmar	Pre-monsoon (AM), summer monsoon (JJAS), post monsoon (ON).
7	Nepal	Winter (DJF), JJAS (summer monsoon)
8	Pakistan	Winter (DJF), JAS (summer monsoon)
9	Sri Lanka	First inter-monsoon (MA), SW Monsoon (MJJAS), second inter-monsoon (ON)

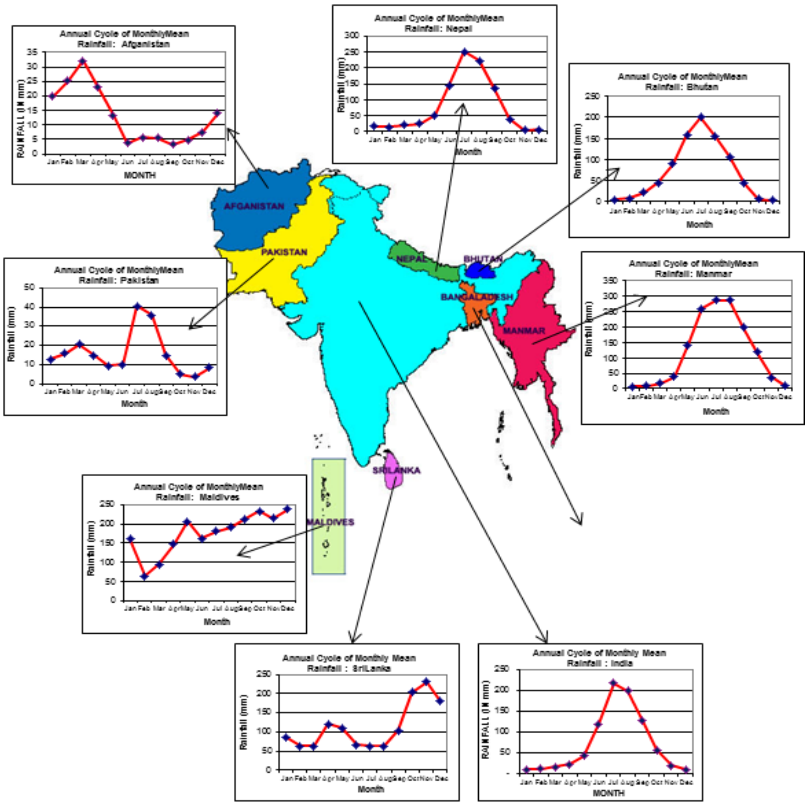


Fig.1. Annual cycle of monthly mean rainfall over eight south Asian countries. The mean was computed using data for the period 1951-2000. (Data Source: For countries except Maldives: APHRODITE's Water Resources Home page: http://www.chikyu.ac.jp/precip/english/index.html. For Maldives mean was prepared based on 1980-2007 data of 5 land stations).

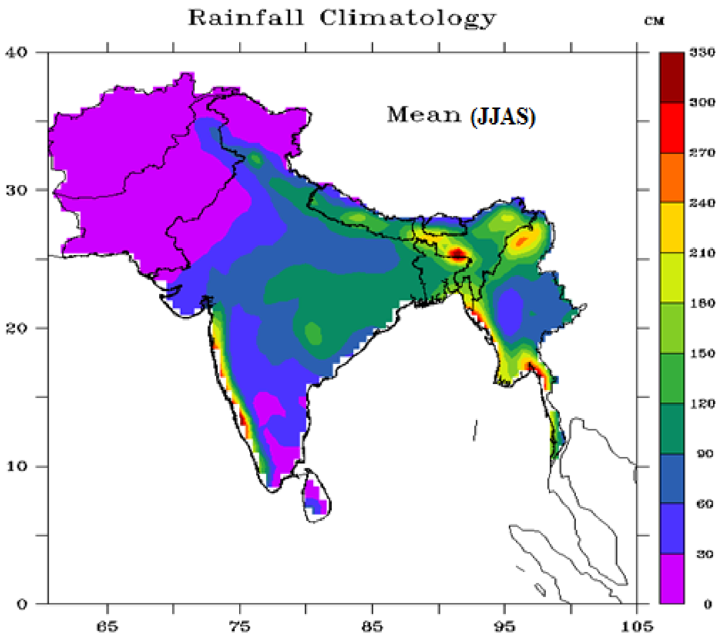


Fig.2. Rainfall Climatology for the period 1951–2007 over South Asia.

(Data Source: APHRODITE's Water Resources Home page: http://www.chikyu.ac.jp/precip/english/index.html)

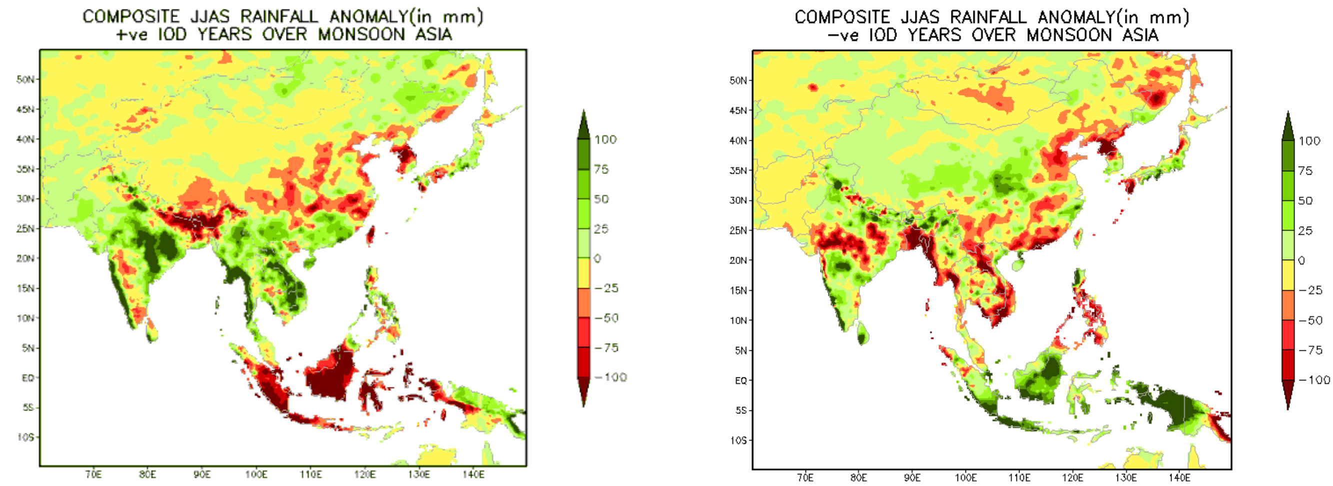


Fig.3. Composite rainfall anomaly patterns over south Asia during **(a)** El Niño years and **(b)** La Niña years. (Data Source: APHRODITE's Water Resources Home page: http://www.chikyu.ac.jp/precip/english/index.html).

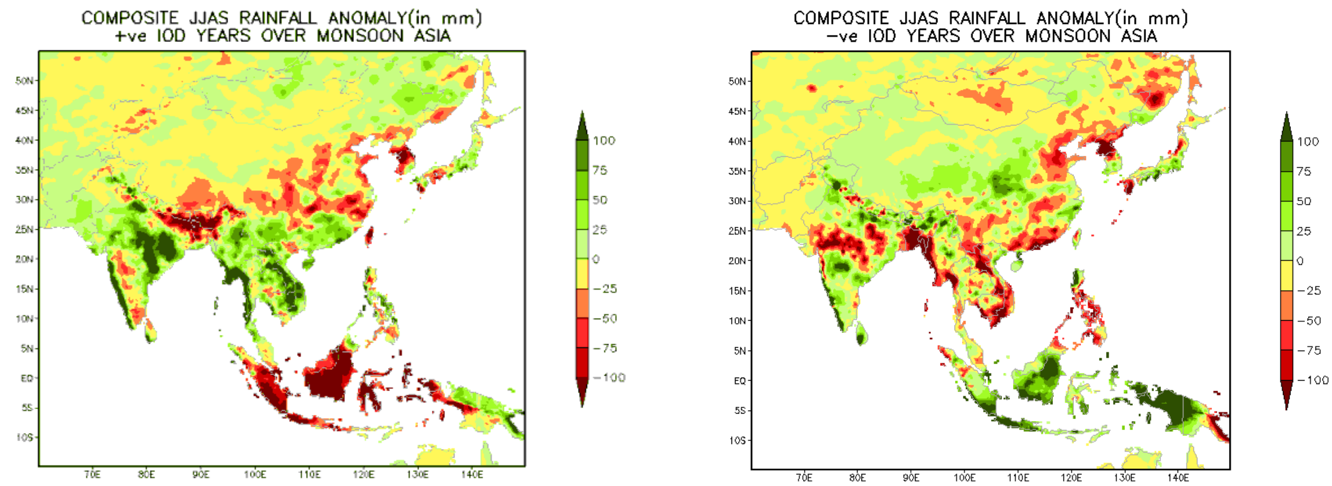


Fig.4. Composite rainfall anomaly patterns over south Asia during **(a)** positive IOD years and **(b)** negative IOD years. (Data Source: APHRODITE's Water Resources Home page: http://www.chikyu.ac.jp/precip/english/index.html).

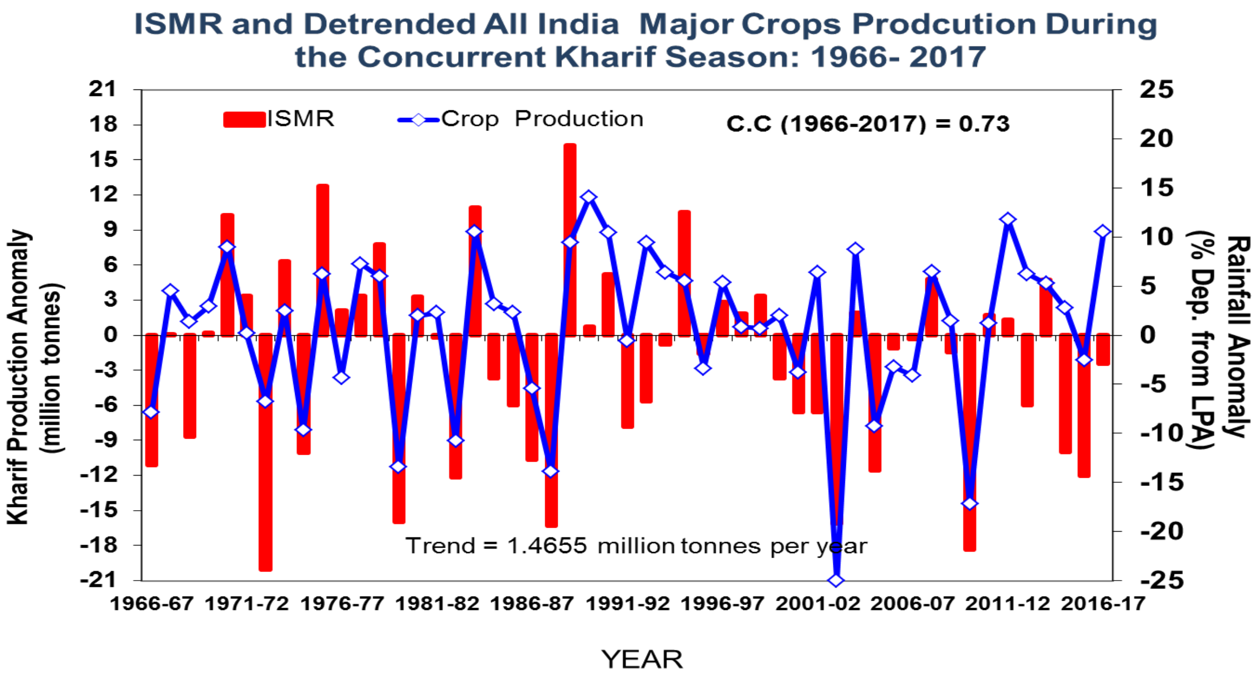


Fig.5a. Relationship between the year to year variation of all India southwest monsoon season (June – September) rainfall anomaly and detrended all India major crops production anomaly during the Kharif season for the period 1966-2017.

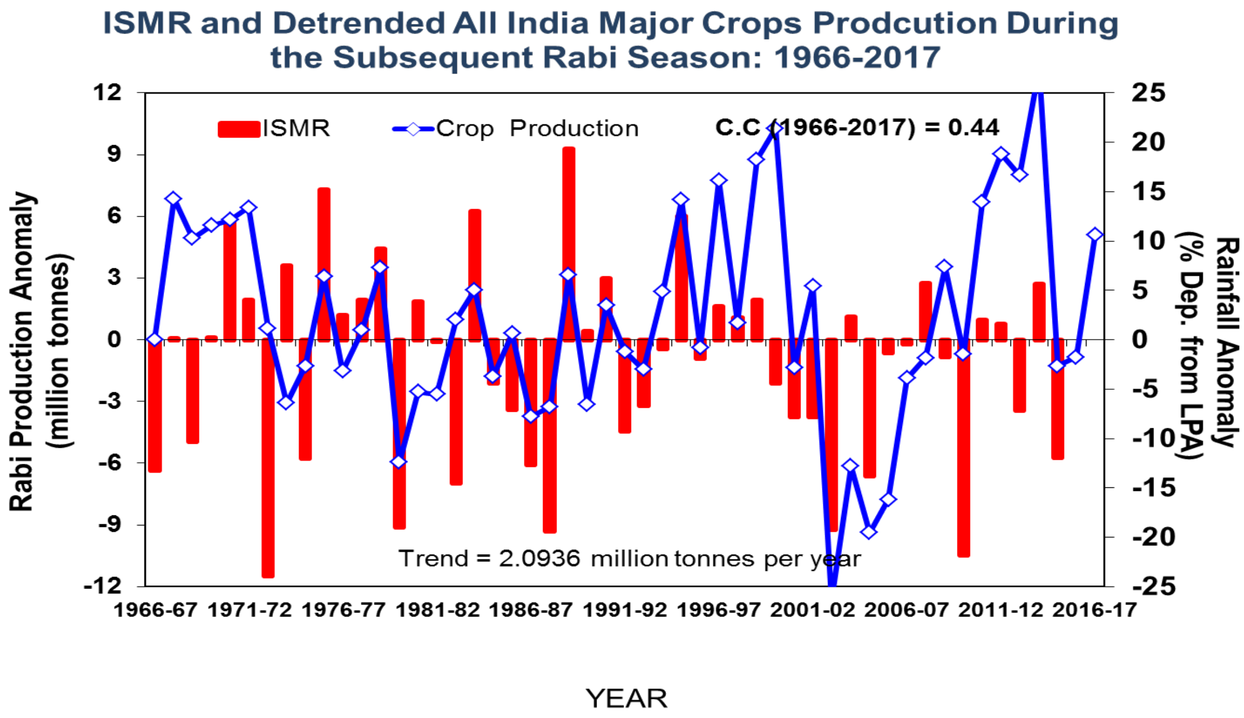
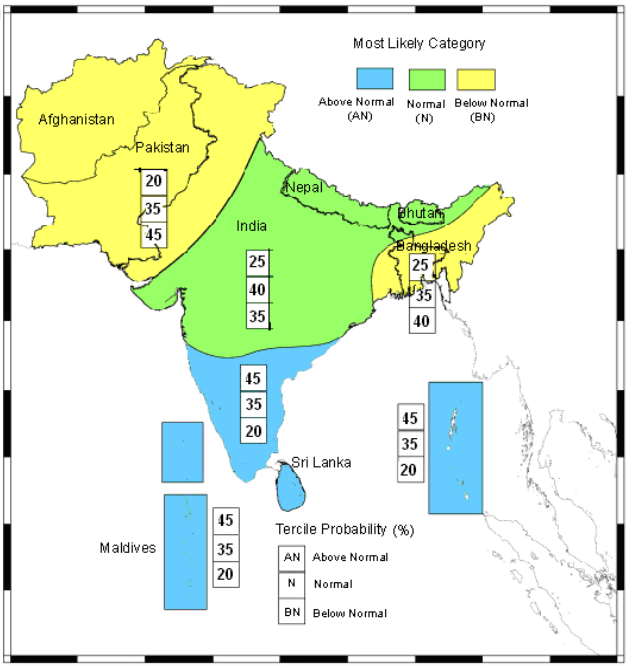
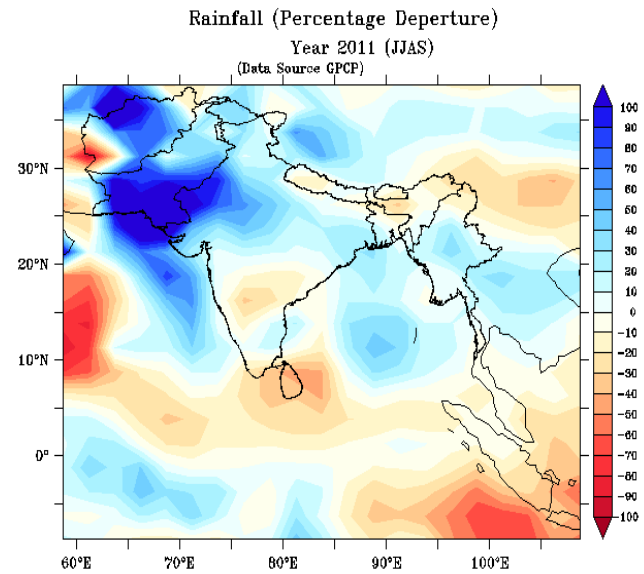


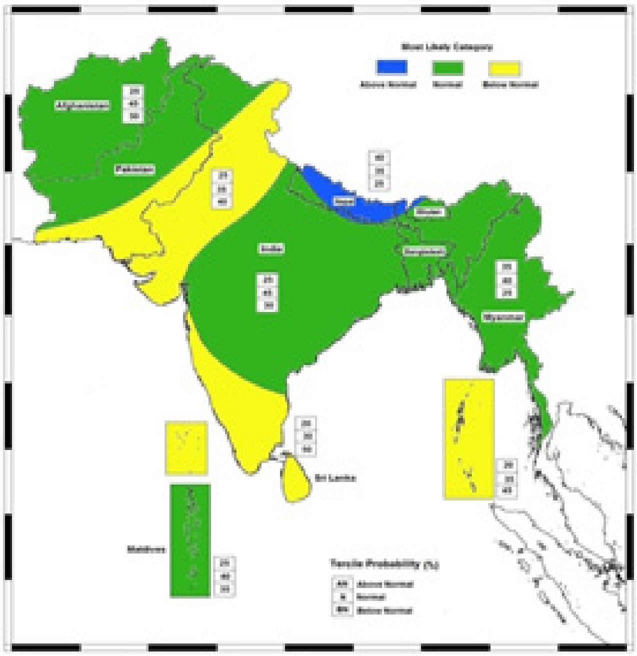
Fig.5b. Relationship between the year to year variation of all India southwest monsoon season (June – September) rainfall anomaly and detrended all India major crops production anomaly during the Rabi season for the period 1966-2017.

a) JJAS 2011





b) JJAS 2012



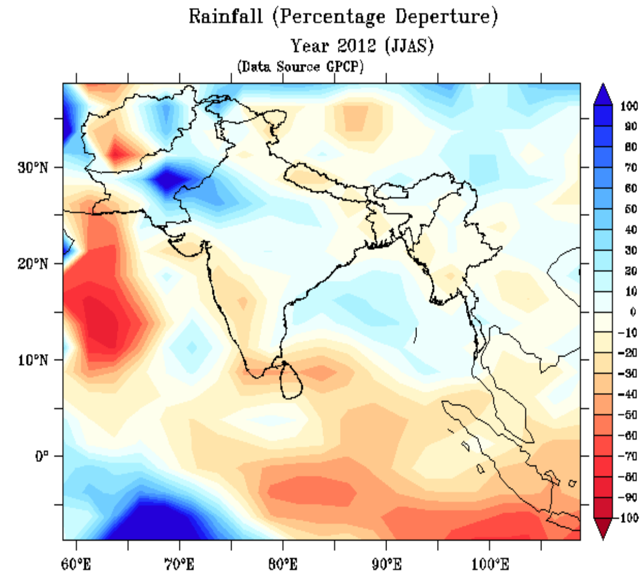
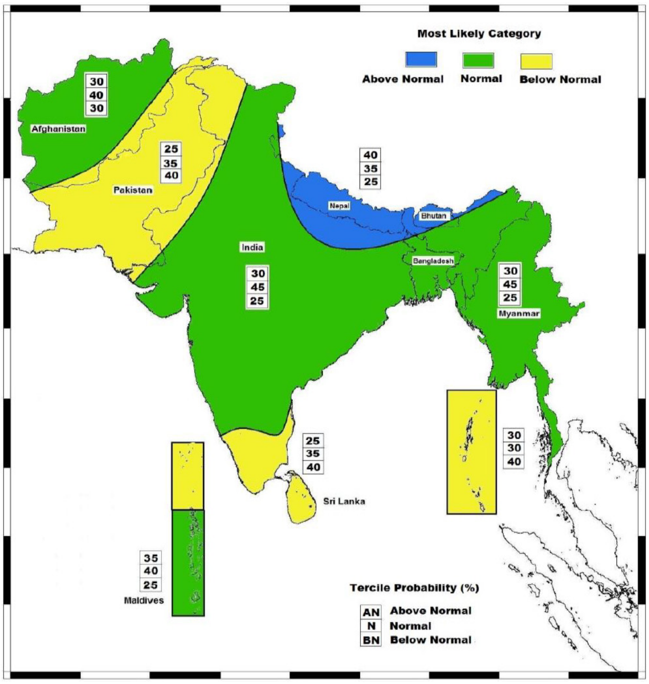
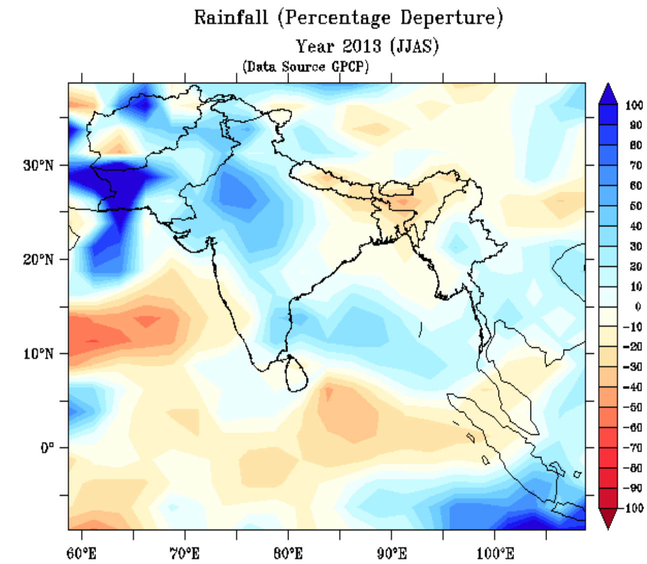


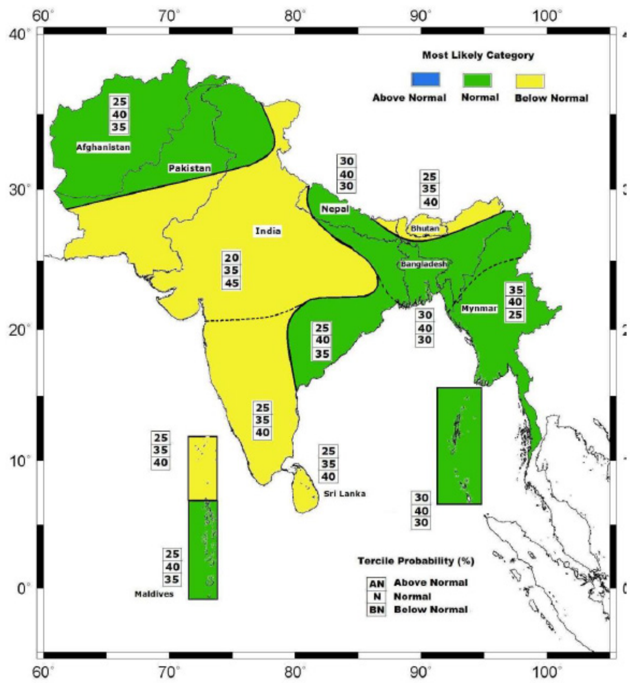
Fig.6 a to j. Verification of the consensus forecasts for season rainfall issue by SASCOF forums during the period 2011-2016 is given below. Consensus probability forecast maps issued for each season is presented along with the observed rainfall. The observed rainfall is expressed as the percentage departure from long period average (1981-2010). Source of the observed rainfall is the GPCP Version 2.3 Combined Precipitation Data Set (Data source: https://iridl.ldeo.columbia.edu/SOURCES/.NASA/.GPCP/.V2p3/.CDR/).

c) JJAS 2013





d) JJAS 2014



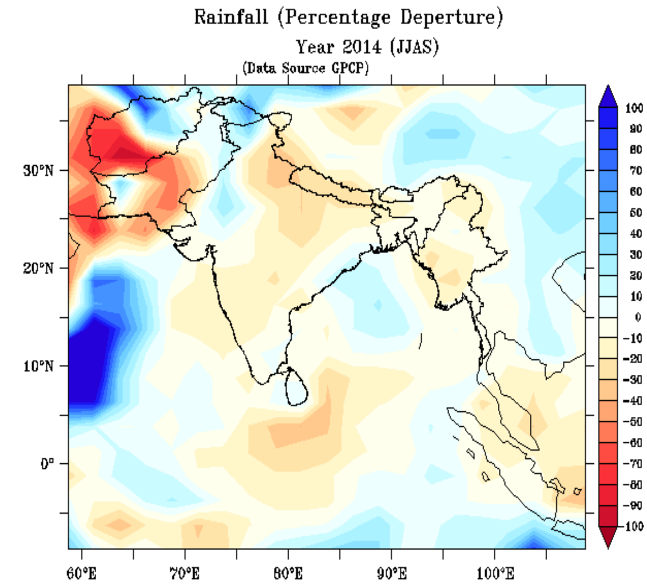
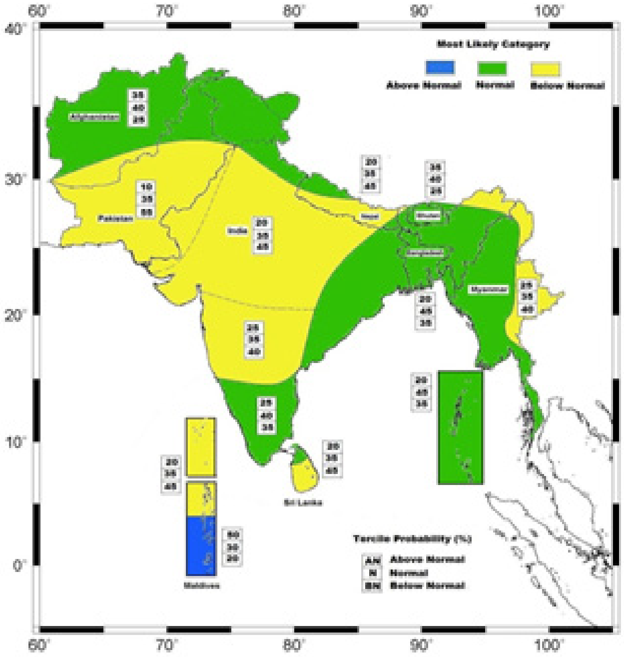
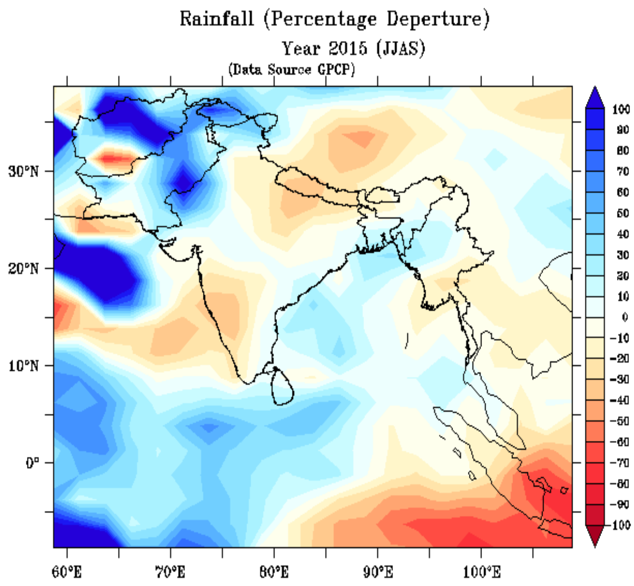


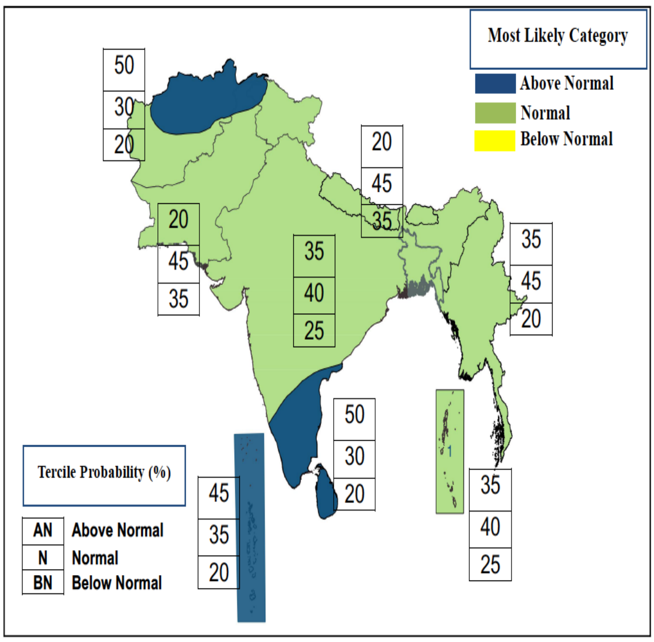
Fig.6 Continued …………

e) JJAS 2015





f) OND 2015



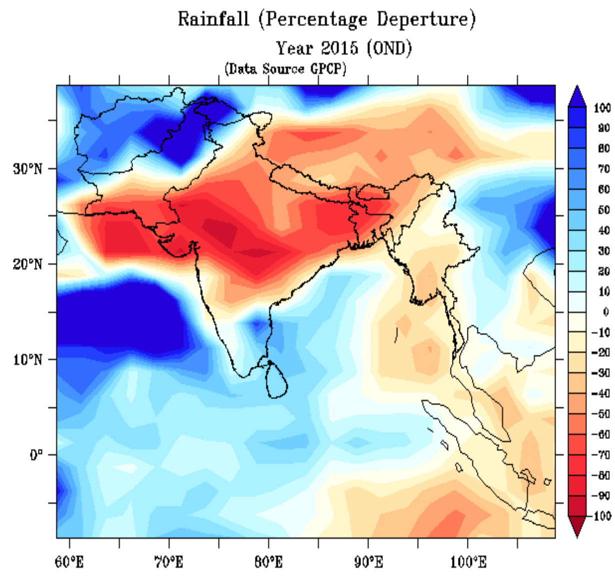
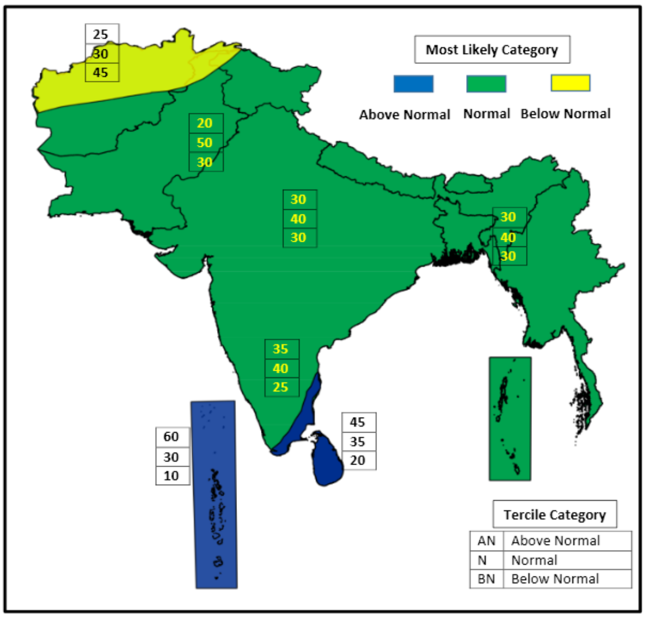
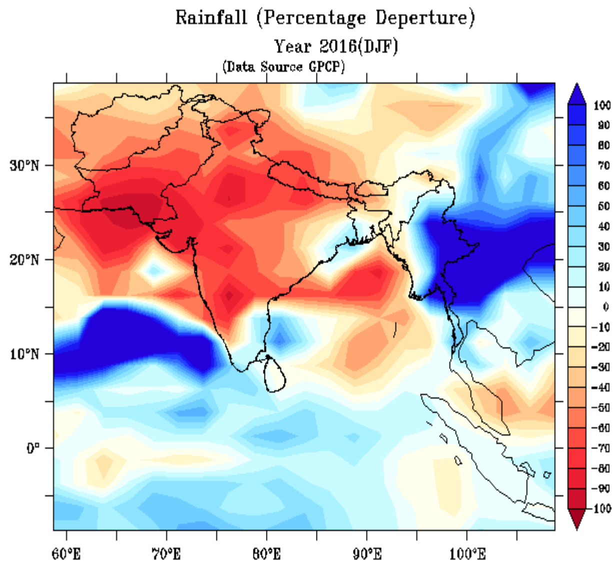


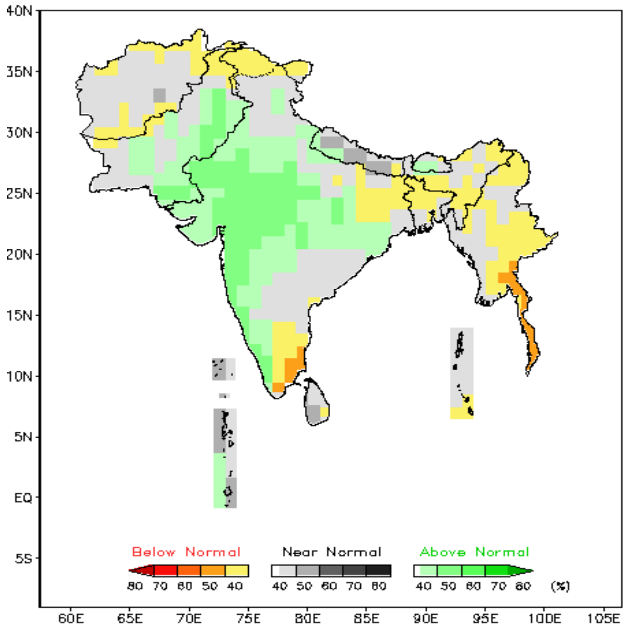
Fig.6 Continued …………

g) DJF 2015-16





h) JJAS 2016



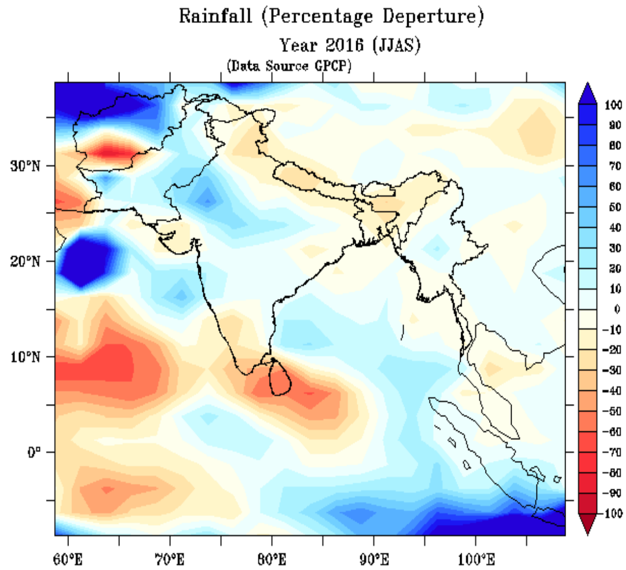
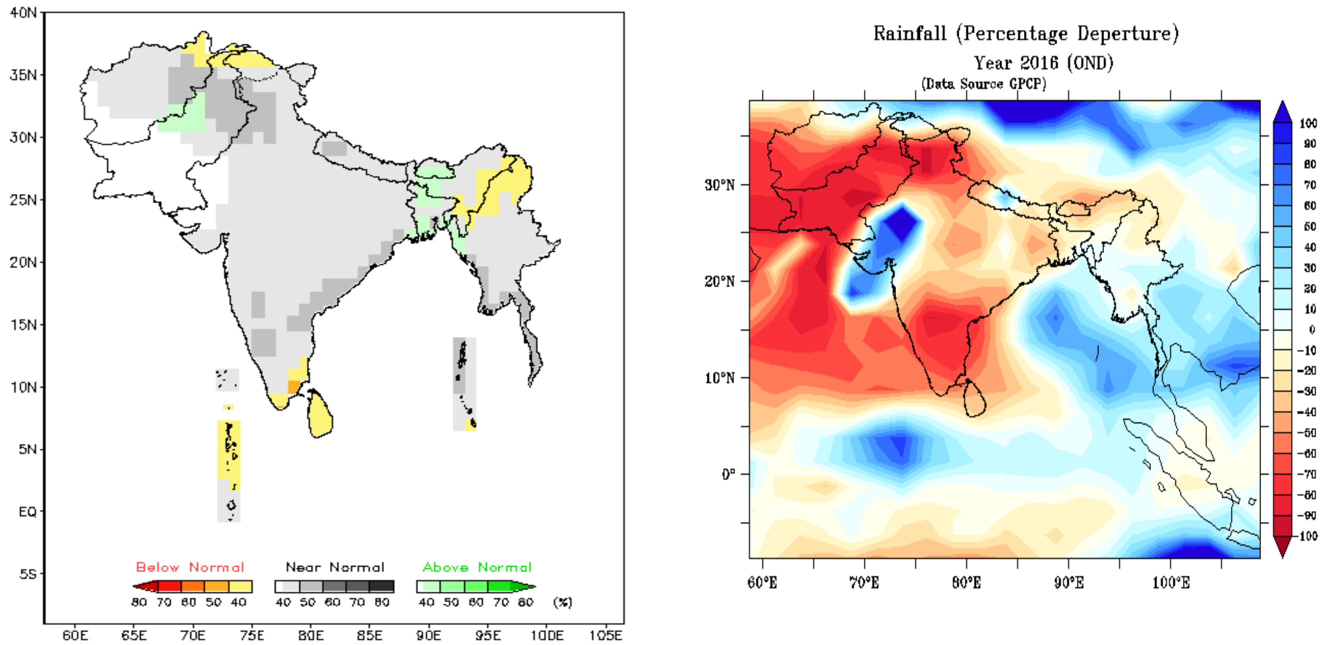


Fig.6 Continued …………

i) OND 2016



j) DJF 2016-17

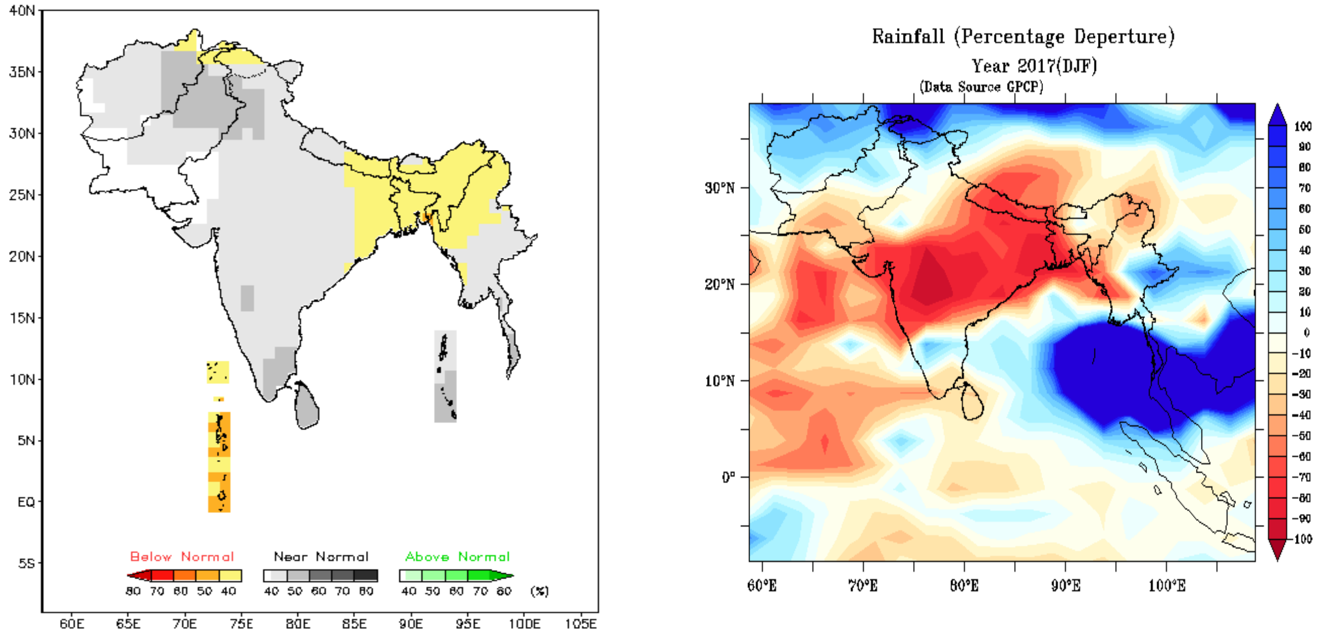


Fig.6 Continued …………