SECOND WMO WORKSHOP ON
OPERATIONAL CLIMATE PREDICTION
30 May - 1 June 2018, Barcelona, Spain

2.6 Operational Climate Prediction in RCC Pune: Good Practices on Downscaling Global Products

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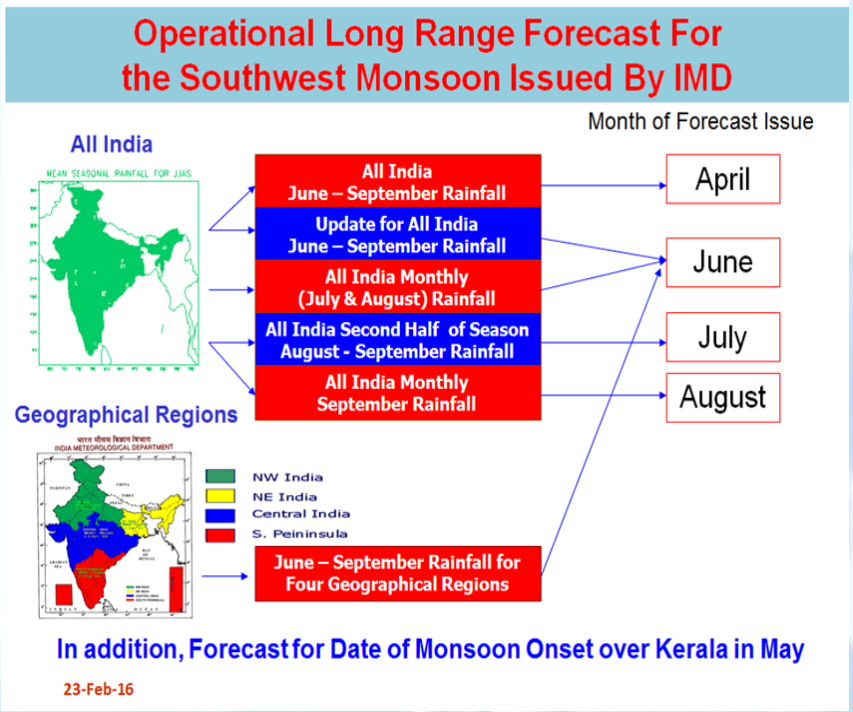
भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

India Specific Operational Monthly and Seasonal Forecasts

Sr. No.	Forecast for	Region for which forecast issued	Issued in	Method/ Model
1	Winter Season (Jan- March) Precipitation	Northwest India	December	Statistical, MMCFS
2	Hot Weather Season Temperature (March to May) & (April-June)	Subdivision wise	February & March	MMCFS
3	SW Monsoon Season (June to September) Rainfall	Country as a whole	April	Statistical, MMCFS
4	SW Monsoon Season (June to September) Rainfall	Country as a whole	June	Statistical, MMCFS
5	South-West Monsoon Onset	Kerala	May	Statistical
6	SW Monsoon Season (June to September) Rainfall	Four broad geographical regions: Northwest India, Northeast India , Central India and South Peninsula	June	Statistical, MMCFS
7	SW Monsoon Monthly Rainfall for July and August	Country as a whole	June	Statistical, MMCFS
8	SW Monsoon Second half of the Season (August- September) Rainfall	Country as a whole	July	Statistical, MMCFS
9	September Rainfall	Country as a whole	August	Statistical, MMCFS
10	NE Monsoon Season (October to December) Rainfall	South Peninsula	September	Statistical, MMCFS
11	Cold Weather Season (December - February) Temperature	Subdivision wise	November	MMCFS

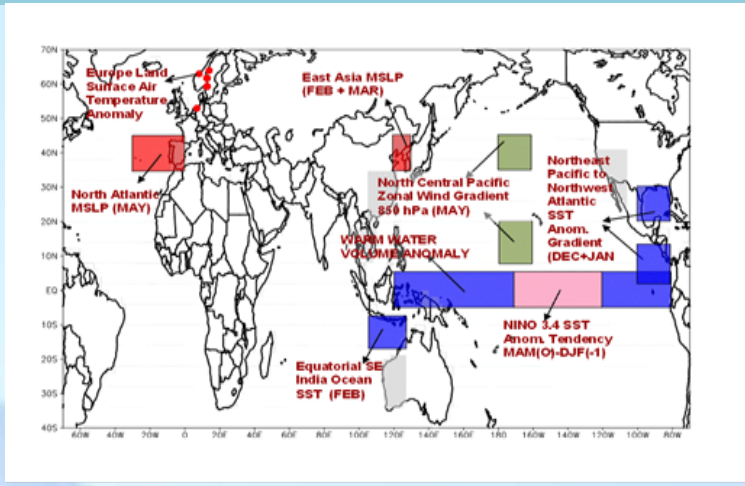
Skill of the statistical models currently used for the operational LRF of Monsoon Rainfall over India



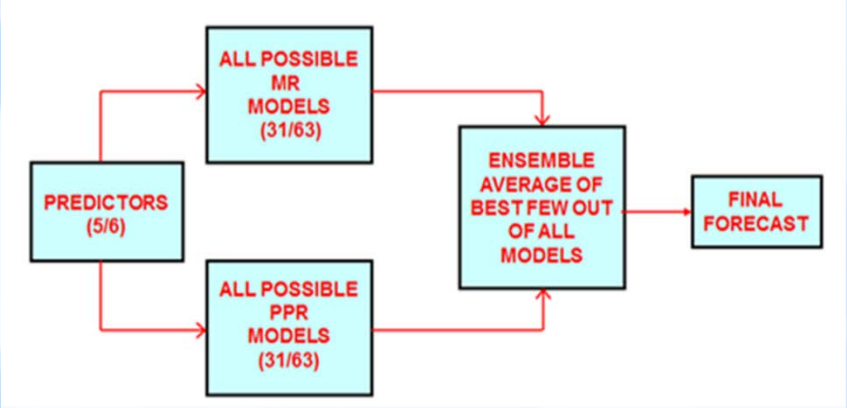
Forecast Period	Forecast Region	Model (Training Window Period)	CC. Actual Vs Forecast Rainfall (Period)	Root Mean Square Error (RMSE) in % of LPA (Period)
June to September	All India	5-P Statistical Ensemble Forecast System (SEFS) (23 yrs)	0.69 (1981-2015)	6.70 (1981-2015)
June to September	All India	6-P (SEFS) (23 yrs)	0.80 (1981-2015)	5.48 (1981-2015)
July	All India	6 –P Principal Component Regression (PCR) (23 yrs)	0.63 (1981-2015)	11.02 (1981-2015)
August	All India	5-P PCR (23 yrs)	0.34 (1998-2015)	11.36 (1998-2015)
September	All India	5-P PCR (23 yrs)	0.71 (1981-2015)	14.60 (1981-2015)
August-September	All India	5-P PCR (23 yrs)	0.53 (1981-2015)	11.40 (1981-2015)
June to September	Northwest India	5-P PCR (30 yrs)	0.63 (1988-2015)	12.5 (1988-2015)
June to September	Northeast India	5-P PCR (30 yrs)	0.54 (1988-2015)	10.75 (1988-2015)
June to September	Central India	5-P PCR (30 yrs)	0.37 (1988-2015)	12.4 (1988-2015)
June to September	South Peninsula	6-P PCR (30 yrs)	0.56 (1988-2015)	12.54 (1988-2015)

Statistical Ensemble Forecasting System (SEFS) for Seasonal Rainfall over Country as a whole

S.No	Predictor Used	Issued in
1	Europe Land Surface Air Temperature Anomaly (January)	April
2	Equatorial Pacific Warm Water Volume (February + March)	April
3	SST Gradient Between Northeast Pacific and Northwest Atlantic (December +January)	April and June
4	Equatorial SE Indian Ocean SST (February)	April and June
5	East Asia Mean Sea Level Pressure (February + March)	April and June
6	Nino 3.4 Sea Surface Temp (MAM + Tendency (MAM-DJF))	June
7	North Atlantic Mean Sea Level Pressure (May)	June
8	North Central Pacific Zonal Wind Gradient 850 hPa (May)	June



Schematic Diagram of the SEFS

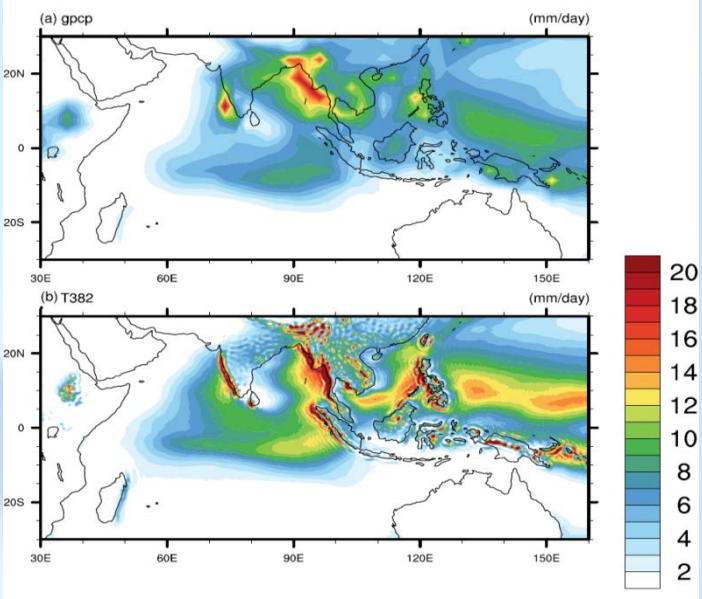


The average of the ensemble forecasts from best out of all possible MR (multiple regression) and PPR (projection pursuit regression) models gives the final forecast.

The Monsoon Mission Experimental MMCFS Model Forecasting System

- Under Monsoon Mission, the state-of-the-art Coupled Forecasting System (MMCFS) developed by NCEP, USA was implemented in 2012 at the ESSO-IITM, Pune.
- The latest high resolution research version of the MMCFS implemented at IMD, Pune in 2017.
- The model shows a moderate skill for both temperature and rainfall forecast.
- The rainfall forecast from MMCFS was used as an additional input to operational forecast from 2012.
- From 2016, used for generating operational subdivision wise temperature forecast for India and climate predicton services for South Asia

JJAS Climatology(1982-2008)



Forecast: probabilistic and deterministic

Model type and resolution: T382L64

Ensemble size: 12 members for hindcast and 40 members for forecast

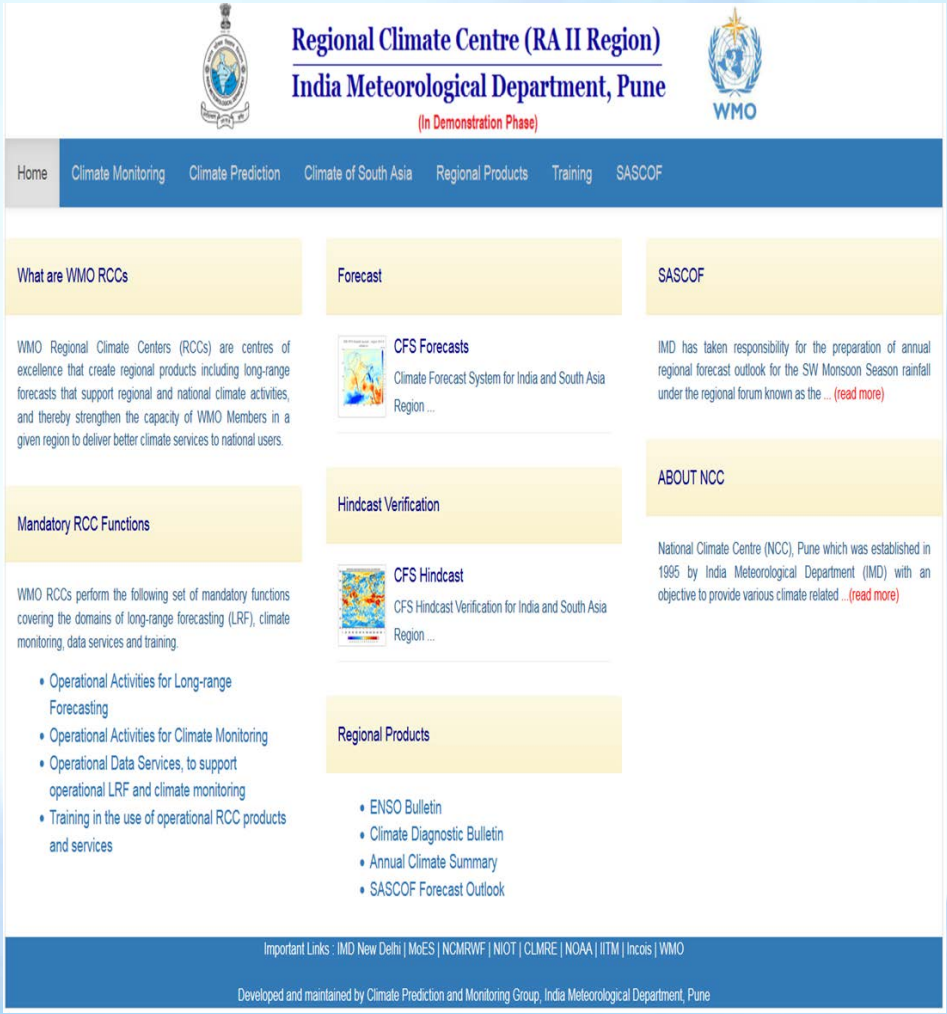
Initial Conditions (ICs): Atmospheric provided by ESSO-NCMRWF and the oceanic provided by ESSO-IITM & ESSO-INCOIS.

Hindcast period – 1982-2008

Forecast period: 9 months

Long Range Forecast Products Available from RCC, Pune Website Based on Monsoon Mission CFS

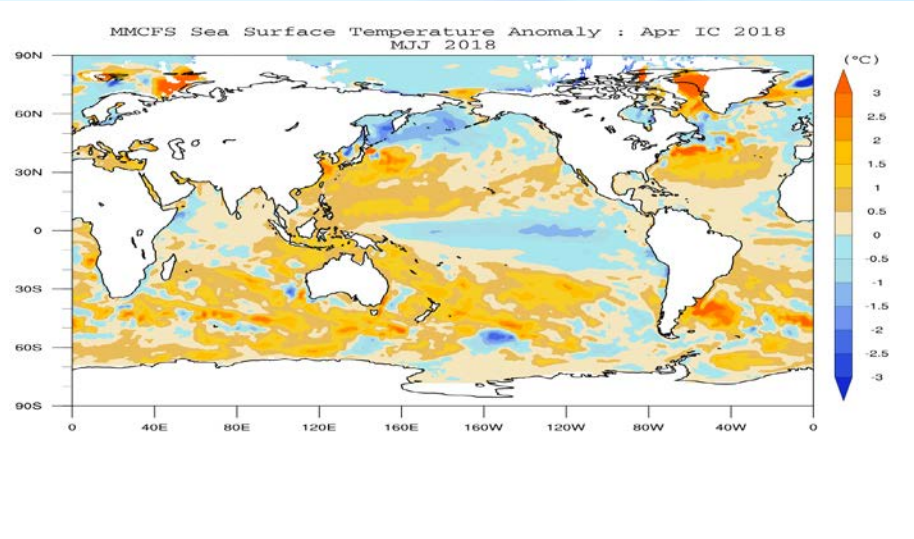
(http://www.imdpune.gov.in/Clim_RCC_LRF/Index.html).



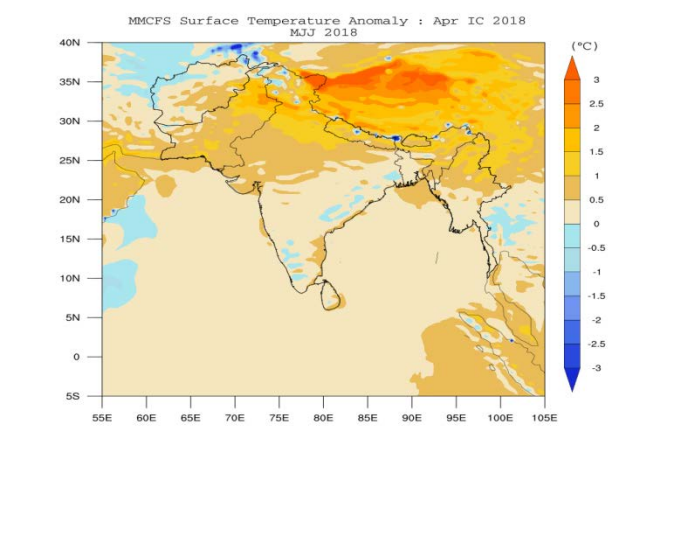
- **Global monthly and seasonal forecast anomaly maps of rainfall and Temperature for next 8 months (Every month)**
- **ENSO & IOD Forecast Bulletins (Every month)**
- **Seasonal Forecast Outlook of Rainfall and Temperatures over South Asia (updated every month)**
- **Consensus forecast for south Asia Under SASCOF**

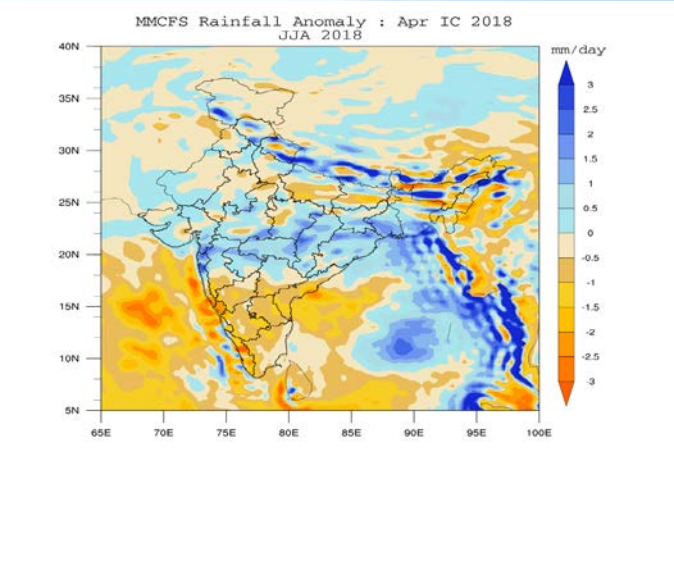
Products based on CFS: LRF Maps

Global SST Ano. Forecast



South Asia 2m Temp. Ano. Forecast





India Rainfall Ano. Forecast

ENSO & IOD Forecast Bulletin (Every month)

Earth System Science Organization (ESSO)
Ministry of Earth Sciences (MoES)
India Meteorological Department

El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) Bulletin

May 2018

Highlights:
Currently, ENSO neutral conditions are present over equatorial Pacific Ocean and the latest MMCFS forecast indicates that these conditions are likely to continue till the end of the forecast period.
Currently, neutral IOD conditions are prevailing over equatorial Indian Ocean. MMCFS forecast indicates that negative IOD conditions are likely to develop during the monsoon season and likely to turn to neutral IOD conditions by OND season.

1. Current Sea Surface Temperature (SST) Conditions over Pacific & Indian Oceans

During April 2018, cool SST anomalies were observed over central to eastern equatorial Pacific Ocean (Fig.1a) and warm SST anomalies were observed over west equatorial Pacific Ocean. Negative SST anomalies were also observed over parts of southeast subtropical Pacific Ocean close to west coast of South America. Positive SST anomalies were observed over northwest Pacific Ocean as well as most parts of the north and south subtropical Pacific Ocean. As compared to the last month, increase in cooling of SSTs is seen over the northwest Pacific Ocean. However, cool SSTs over equatorial Pacific Ocean turned into warm SSTs during the current month. Cool SSTs were also observed over south subtropical Pacific Ocean near international dateline as compared to the last month (Fig.1b).

Normal SST anomalies were observed in the most parts of Arabian Sea and Bay of Bengal. Positive SST anomalies were observed over parts of west equatorial Indian Ocean while negative SST anomalies were observed over parts of east equatorial Indian Ocean (Fig.1a). During April, cooling of SSTs was observed over most parts of the equatorial Indian Ocean as well as over Arabian Sea and Bay of Bengal and warming of SSTs was observed over south west subtropical Indian Ocean near 15°S (Fig.1b) as compared to the last month.

1.1. El Niño Southern Oscillation (ENSO) conditions over the Pacific Ocean

The monthly time series of Niño3.4 SST anomalies for the last 12 months i.e. from May 2017 to April 2018 (Fig.2a) suggests that ENSO neutral conditions persisted till October 2017. From November 2017 to March 2018 La Niña conditions were prevailed. During April 2018, Nino 3.4 SST anomaly value is within the threshold of La Niña condition and currently, ENSO neutral conditions are present. Negative subsurface temperature anomalies were seen (with stronger magnitude) over parts of eastern Pacific Ocean (around thermocline depth) (Fig.2 b) around 100°W. The strong positive subsurface anomalies were observed in the west to central equatorial Pacific Ocean within 140°E to 110°W.

1.2. Indian Ocean Dipole (IOD) conditions over the Indian Ocean

The DMI index for the last 12 months suggests that (Fig. 2c) prevailing positive IOD conditions turned to neutral IOD conditions in the month of September 2017 and continued up to April 2018. Negative subsurface temperature anomalies (Fig. 2d) (stronger magnitude) were seen spread over the parts of eastern equatorial Indian Ocean at around thermocline depth.

2. ENSO & IOD Forecast

The SST forecast were prepared using the high resolution Monsoon Mission Coupled Forecast System (MMCFS) (AGCM T382L64; 38 km and OGCM 25 km in tropics) based on the 2018 April initial conditions. The initial conditions for the model runs were obtained from ESSO-INCOIS and ESSO-NCMRWF analysis. Probability density function (PDF) bias correction was applied on the forecasts of Niño3.4 index (Fig.4a) and DMI (Fig.4b) based on hindcasts for the period 1999-2008 and anomalies were calculated based on 1982-2008 climatology.

The forecasted 3-month season averaged SST anomalies (Fig.3) indicate normal to slightly cooler than normal SST anomalies are likely to continue along the central to eastern parts of the equatorial Pacific Ocean up to JAS season. However, from ASO season onwards normal SST anomalies are likely over most parts of equatorial Pacific Ocean. North-western Pacific Ocean is likely to have normal to warmer than normal SST anomalies for most of the forecasted seasons. The latest forecast indicates that current ENSO neutral conditions are likely to continue till the end of forecast period (Fig.4a). In the Indian Ocean, during most of the forecasted seasons, normal SST anomalies are likely in Arabian Sea and Bay of Bengal (Fig.3). Currently, neutral IOD conditions are prevailing over equatorial Indian Ocean. MMCFS forecast indicates that negative IOD conditions are likely to develop during the monsoon season and likely to turn to neutral IOD conditions by OND season (Fig.4b).

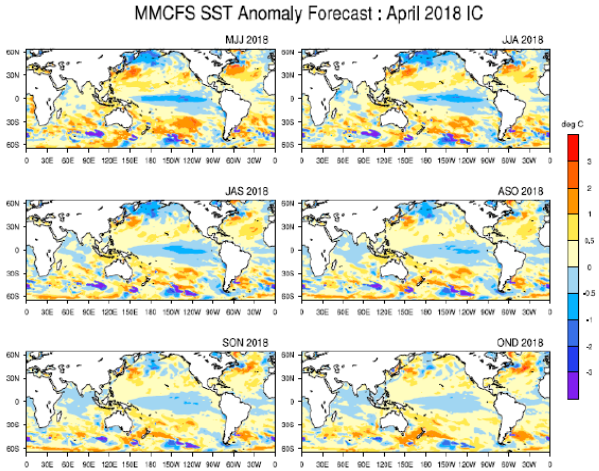


Fig.3: Forecasted Seasonal mean SST anomalies for 3 monthly seasons, (a) May to July (MJJ), (b) June to August (JJA), (c) July to September (JAS), (d) August to October (ASO), (e) September to November (SON), (f) October to December (OND) (Model bias correction base period: 1999-2010; Climatology base period: 1982-2010).

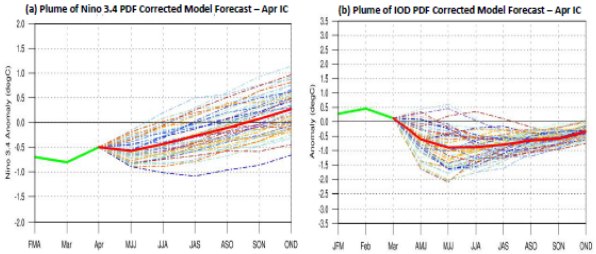


Fig.4: Plume of (a) Niño 3.4 SST anomalies, (b) Indian Ocean Dipole Mode Index forecasted by high resolution CFSv2. The forecasts were PDF corrected for bias and variance. The solid green line is the observed SST anomaly (ERSSTv5, NOAA) and solid red line is the ensemble SST anomaly forecast mean of 51 members (MMCFS). The individual ensemble member forecasts are shown in light dotted lines of different colours.

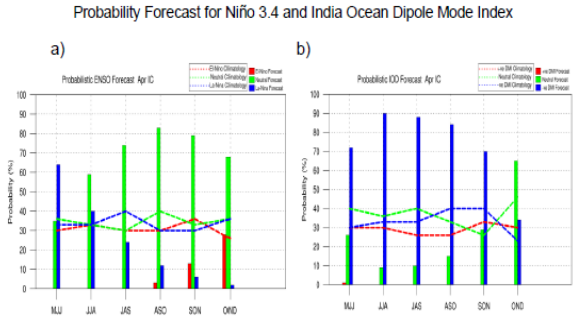


Fig.5: Probability forecast along with climatological probabilities of (a) Niño 3.4 and (b) Indian Ocean Dipole Mode Index from high resolution MMCFS. Data source for Climatology probabilities: NOAA Extended Reconstructed SST V5. Criteria used for Probabilistic ENSO Forecast: ≤ -0.5 La Niña, >0.5 to <-0.5 neutral, ≥ 0.5 El Niño. Criteria used for Probabilistic DMI Forecast: ≤ -0.2 negative DMI, >0.2 to <-0.2 neutral, ≥ 0.2 positive DMI.

The probability forecast for ENSO (Fig.5a) indicates maximum probability for ENSO neutral conditions is likely for most of the forecasted seasons.

The probability forecast for IOD (Fig.5b) indicates maximum probability for negative IOD conditions is likely during most of the forecasted seasons.

Seasonal Climate Outlook for South Asia

Earth System Science Organization (ESSO)
Ministry of Earth Sciences (MoES)
India Meteorological Department
WMO Regional Climate Centre
(Demonstration Phase)
Pune, India

SEASONAL CLIMATE OUTLOOK FOR SOUTH ASIA

(May to August 2018)

- Currently, ENSO neutral conditions are present over equatorial Pacific Ocean and the latest MMCFS forecast indicates that, these conditions are likely to continue till the end of the forecast period.
- The spatial pattern of forecasted precipitation anomalies using April initial conditions for MJJ and JJA 2018 seasons indicate normal to below normal precipitation is likely for Afghanistan, Pakistan, and Myanmar and normal to above normal precipitation is likely over the remaining south Asian region for both the seasons.
- In general, the country averaged monthly precipitation is likely to be normal to below normal for Afghanistan, Myanmar and Pakistan and it is likely to be normal to above normal for Bangladesh, Bhutan, India, Nepal and Sri Lanka during all the months from May to August.
- Temperature anomaly forecast for MJJ and JJA 2018 seasons indicates normal to above normal temperature anomalies are likely over most parts of the Afghanistan, Pakistan, Nepal, Bhutan, Myanmar and northern parts of Bangladesh and normal to below normal temperature anomalies are likely over the remaining South Asian region.
- The country averaged monthly mean temperature anomaly forecast indicates normal to above normal temperatures are likely during most of the forecasted months for all other South Asian countries except India and Sri Lanka where it is likely to be normal to below normal.

DISCLAIMER:
(1) The long range forecasts presented here are currently experimental and are produced using techniques that have not been validated.
(2) The content is only for general information and its use is not intended to address particular requirements.
(3) The geographical boundaries shown in this report do not necessarily correspond to the political boundaries.

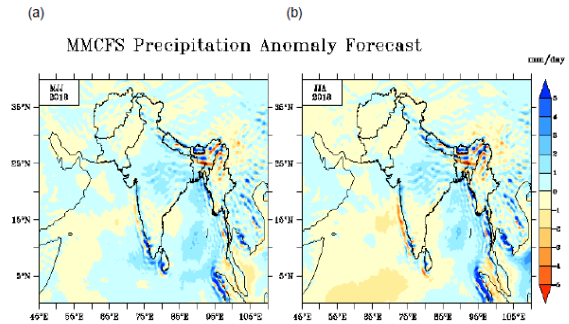


Fig.5: Seasonal forecasts of precipitation anomalies (mm/day) for (a) MJJ (left) and (b) JJA (right) based on Initial conditions of April 2018.

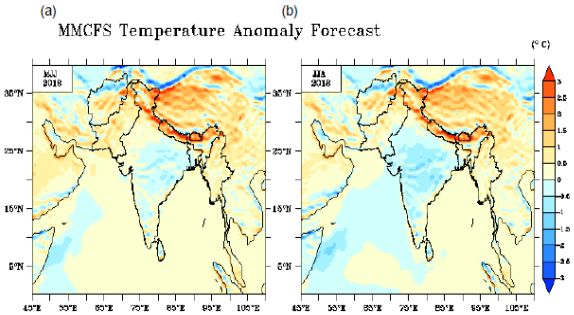


Fig. 6: Seasonal mean temperature anomalies (°C) for (a) MJJ (left) and (b) JJA (right) based on Initial conditions of April 2018.

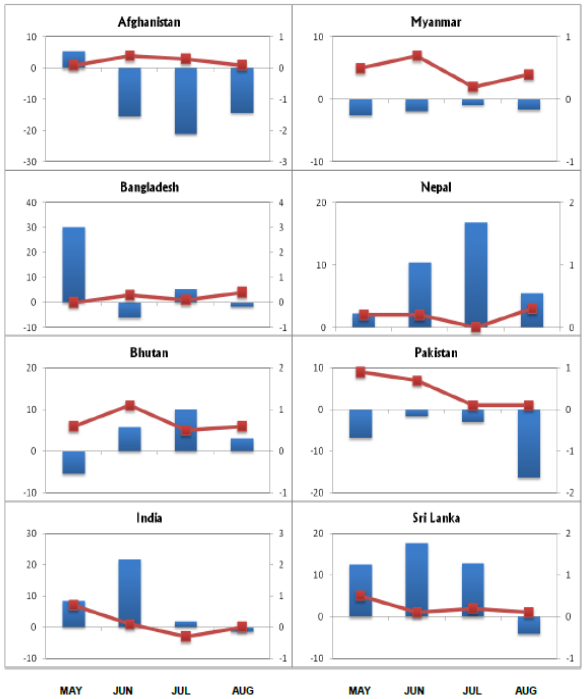


Fig.7: Monthly country averaged rainfall forecast expressed as percentage departures (%) during May to August, 2018. (The normal range for country averaged monthly precipitation is taken as -10% to +10%).
(Left Vertical Axis Scale)
PRECIPITATION

Fig.8: Monthly country averaged temperature anomaly (°C) forecast during May to August, 2018. (The normal range for country averaged monthly temperature is taken -0.25°C to +0.25°C).
(Right Vertical Axis Scale)
TEMPERATURE

SASCOF

Target Region: South Asia (9 countries)

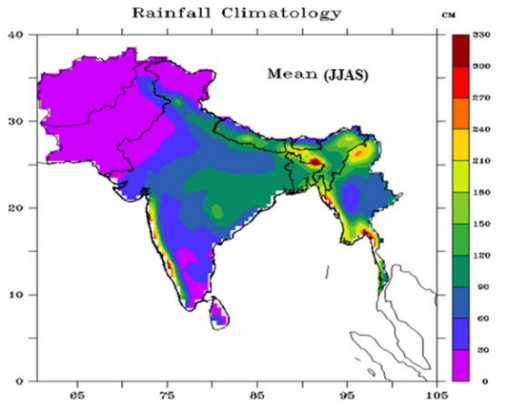
Co-ordinating Institution: India Meteorological Department (IMD)

Target Seasons: SW Monsoon (JJAS), NE Monsoon (OND), winter (DJF)

Parameters: Rainfall for all seasons. Temperature for OND and DJF

Major forcings on the regional climate: ENSO, IOD, Winter and spring Eurasian Snow Cover, Northern Hemisphere surface air temperature during spring season, sea surface temperature patterns over Atlantic Ocean, mid latitude flow pattern north of Asia etc.

Potential applications of seasonal outlooks: Agriculture (selection crops, crop yield forecast), Disaster preparedness and risk reduction (impact of floods and droughts), Public health (disease outbreaks like Malaria, cholera etc.), Energy sector (expected energy demand scenarios), water management (reservoir) etc.



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)

RCOF frequency: Physical sessions in April for SW Monsoon & in September for NE Monsoon. online session in November for winter season (December to February):

Sources of funding: Financial support for 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.

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 of the country and post monsoon (OND) for south Peninsula.
5	Maldives	May to September (summer Monsoon), October to January (winter monsoon)
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)

SASCOF Consensus Outlook for the 2017 JJAS over South Asia

This project was undertaken with the financial support of:
Ce projet a été réalisé avec l'appui financier de:
Environment Canada Environnement Canada

Tenth Session of

South Asian Climate Outlook Forum (SASCOF-10)

Thimphu, Bhutan, 24-26 April 2017

Consensus forecast for the 2017 Southwest Monsoon Season (June – September) Rainfall over south Asia

Summary

Normal rainfall is most likely during the 2017 southwest monsoon season (June – September) over much of South Asia. More specifically:

- **Below-normal rainfall is most likely over broad areas of north-western, central and south-eastern parts of South Asia.**
- **Above-normal rainfall is most likely over broad areas of eastern and the south-western parts of the region.**
- **Normal rainfall is most likely over the remaining areas.**

This consensus outlook for the 2017 southwest monsoon rainfall over South Asia has been developed through an expert assessment of the prevailing global climate conditions and forecasts from different climate models from the participating National Meteorological Services (NMSs) and from around the world. The weak La Nina conditions that prevailed over the Pacific during the latter part of the last year (2016) weakened and turned to neutral ENSO conditions in January 2017. Currently, warm neutral ENSO conditions are prevailing. There is strong consensus among experts that neutral ENSO conditions are likely to continue through the spring season and weak El Nino conditions are likely to develop in the second half of this year. However, it is recognized that there is uncertainty about the development and timing of El Nino conditions. There is also uncertainty about the impact of development of weak El Niño conditions on the southwest monsoon season rainfall over the region. Other regional and global factors that may affect the region were also considered in arriving at this consensus outlook.

For more information and further updates on the southwest monsoon outlook on national scale, the respective NMSs may be consulted.

Introduction:

The climate outlook for the 2017 southwest monsoon season (June to September) was finalized during the tenth session of the South Asian Climate Outlook Forum (SASCOF-10), held at Thimphu, Bhutan during 24–26 April 2017 attended by experts from the South Asian countries. The Forum deliberated on various observed and emerging climatic features that influence the performance of the southwest monsoon, such as the El Niño-Southern Oscillation (ENSO) conditions over the equatorial Pacific, Indian Ocean Dipole (IOD) conditions over the Indian Ocean, winter and spring Northern Hemisphere snow cover etc. The key features of these conditions are as follows:

ENSO Conditions over the Pacific Ocean

The El Niño/Southern Oscillation is one of the global scale climate phenomena that have a significant influence on the year-to-year variability of the monsoon over South Asia. The weak La Nina conditions over the equatorial Pacific prevailed during the second half the last year weakened to neutral ENSO level in the early part of 2017. At present warm neutral ENSO conditions are prevailing. Recent changes in atmospheric conditions over the Pacific reflect the border line La Nina to neutral ENSO conditions. Latest forecasts indicate neutral ENSO conditions are likely to continue through middle of the monsoon season. Weak El Niño conditions are likely to develop in the second half of this year.

Conditions over the Indian Ocean

In addition to ENSO conditions over the Pacific, other factors such as Indian Ocean surface temperatures have some influence on the South Asian southwest monsoon. At present, close to normal SSTs are prevailing in the equatorial and north Indian Ocean. In the subtropical south Indian Ocean, negative SST anomalies are prevailing over eastern part and positive SST anomalies are prevailing over western part. As a result, currently neutral Indian Ocean Dipole (IOD) conditions are prevailing. The recent forecasts from coupled models suggest the development of positive IOD conditions in the latter part of the monsoon season and continue to early part of the post monsoon season.

Snow Cover over the Northern Hemisphere*

The snow-covered area over northern hemisphere (NH) was above normal during December 2016 & Jan 2017 and close to normal in the recent two months (February & March 2017). Snow-covered area over Eurasia was above normal from December 2016 to February 2017 and was close to normal in March 2017. NH snow cover during winter and spring has a general negative relationship with the subsequent Asian summer monsoon. (*Data source: Rutgers University global snow cover (link: http://climate.rutgers.edu/snowcover/)

Consensus Outlook for the 2017 Southwest Monsoon Rainfall over South Asia:

A consensus outlook for the 2017 Southwest monsoon season rainfall over South Asia was prepared based on the expert assessment of prevailing large-scale global climate indicators mentioned above, experimental models developed during capacity-building workshops conducted for the South Asian countries in association with the previous and the current SASCOF sessions, and experimental as well as operational long-range forecasts based on statistical and dynamical models generated by WMO Global Producing Centers (GPCs) of long range forecasting, Regional Climate Centers (RCCs) and other climate research centers of the world.

There is strong consensus among the experts that the prevailing neutral ENSO conditions in the equatorial Pacific will develop into weak El Niño conditions during the second half of this year. However, uncertainty in the timing and intensity of the event was recognized. Analyses of historical observations indicate that developing El Niño though has a general negative impact on the monsoon rainfall over the region, there is no one to one association between El Nino and below-normal rainfall. Particularly during positive IOD years, impact of El Niño on the monsoon rainfall over the region was found to be significantly weakened. Therefore, it was recognized that there is some uncertainty in the impact of the developing weak El Niño conditions on the 2017 southwest monsoon over the region. It is also important to note that developing El Niño or positive IOD conditions are not the only factors that determine the performance of the Southwest monsoon over the region. Other relevant climate drivers such as the state of the tropical Atlantic temperatures, Eurasian land heating, intra-seasonal variability during the monsoon season are also important. The net impact of all these parameters determines the state of the monsoon over the region.

3

The outlook for southwest monsoon rainfall over South Asia is shown in Fig. 1. The figure illustrates the most likely tercile category[1] as well as its probability for each of the 1° latitude x 1° 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 adjusted through expert assessment and consensus-building discussion of climate experts.

The outlook suggests that during the 2017 southwest monsoon season (June – September), normal rainfall is most likely over much of South Asia. More specifically, below-normal rainfall is most likely over broad areas of north-western, central and south-eastern parts of South Asia and above-normal rainfall is most likely over broad areas of eastern and the south-western parts of the region. Normal rainfall is most likely over the remaining areas.

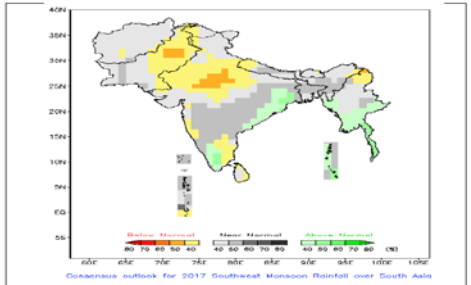


Fig.1. Probability of the most likely category for the 2017 Southwest Monsoon Rainfall over South Asia based on this consensus statement. The consensus-based probability forecast map was prepared based on model forecasts at global as well as national levels synthesized through subjective expert assessment.

[1]Tercile categories have equal climatological probabilities, of 33.33% each.

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Verification of consensus outlook statement of 2016:

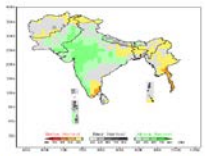


Fig.2 Consensus outlook map of SASCOF-8 for 2016 Southwest Monsoon Rainfall over South Asia.

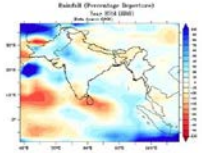


Fig.3 The observed rainfall anomaly (percentage departure) during the 2016 Southwest Monsoon Season over South Asia.

The consensus outlook map (Fig.2) for the southwest monsoon season (June to September) of 2016, developed in the eighth session of the South Asian Climate Outlook Forum (SASCOF-8) had indicated above-normal rainfall over South Asia as a whole during the 2016 southwest monsoon season (June – September). Region-wise, the forecast had indicated above-normal rainfall over broad areas of central and western South Asia, and below-normal rainfall over eastern parts of the region and the southeastern part of the peninsula. Normal rainfall predicted over the remaining areas.

The observed rainfall* (Fig.3) for the 2016 southwest monsoon season was normal over most parts of South Asia. However above normal rainfall was observed over some central and western parts of the region and below-normal rainfall over the southern and north and northeastern parts of the region. Thus the large scale spatial distribution of the observed rainfall was close to the forecasted rainfall pattern over the region.
(*Data source: https://iridl.ldeo.columbia.edu/SOURCES/.NASA/.GPCP/.V2p3/.CDR/)

5

The SASCOF-10 (24–26 April 2017) session was attended by participants from six of the eight South Asian countries, namely, Bhutan, India, Maldives, Myanmar, Nepal, Pakistan, and Sri Lanka. The session was also attended by experts from IMD, Indian Institute of Tropical Meteorology (IITM), WMO, Japan Meteorological Agency (JMA), National Centers for Environmental Prediction (NCEP), USA, and Regional Integrated Multi-hazard Early-warning System (RIMES). In addition, experts from various user sectors of Bhutan such as government, health, media, agriculture, and water resources took active part in the deliberations for assessing the available forecast information and for finalizing the consensus outlook for the southwest monsoon rainfall over South Asia. For preparing the consensus forecasts, the forecast products from various centers such as IMD, IITM, NCEP, Météo France, Met Office, UK, European Centre for Medium Weather Forecasting (ECMWF), Canadian Meteorological Centre (CMC), Bureau of Meteorology, Australia, IRI, JMA, Korea Meteorological Administration (KMA), China Meteorological Administration (CMA), Bureau of Meteorology, Australia, WMO's Lead Centre for Long Range Forecasting - Multi-Model Ensemble (WMO LC-LRFMME), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), and APEC Climate Center, APCC were also considered.

The long-term historical patterns of the southwest monsoon rainfall over South Asia (Fig.4), characterized by remarkable spatial variability, provide the general reference points at the respective locations for the rainfall anomalies indicated in the outlook.

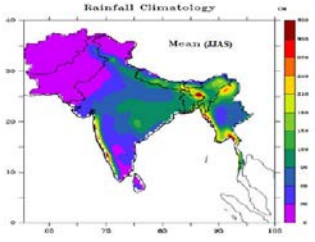
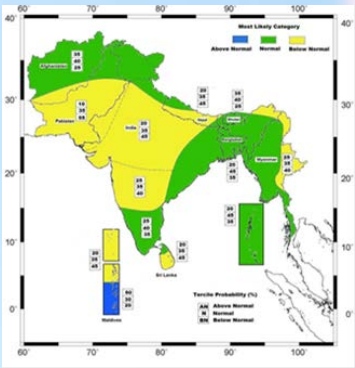


Fig.4. Rainfall Climatology for the period 1951–2007 over South Asia (Source: APHRODITE's Water Resources Home page: http://www.chikyu.ac.jp/precip/english/index.html)

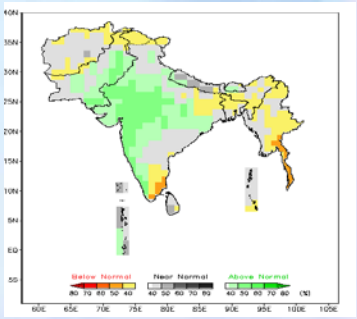
Preparation of the Consensus Forecast

- 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. At least 50% of the forecast information is derived from various dynamical models.
- Predictand data used in the statistical models are Grid point (GPCP) data from IRI data library & station data brought by the participating NMSs. Predictor data used are observed data (SST, precipitation, mslp, wind etc.) and model simulations (mainly NCEP CFS).
- Representatives from NMSs uses CPT to recalibrate the predictor data, assesses the skills of the methodology, and generate forecasts for the respective country.
- Forecast information derived from the participating NMSs of the region based on the exiting forecasting system, WMO GPCLRFs and RCCs, and other climate research centers like IRI, IITM, APEC Climate Center etc. is also used.
- During 2011-2015, the probability forecast map depicted areas of most likely tercile 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° latitude x 1° 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

Consensus forecast for JJAS 2015

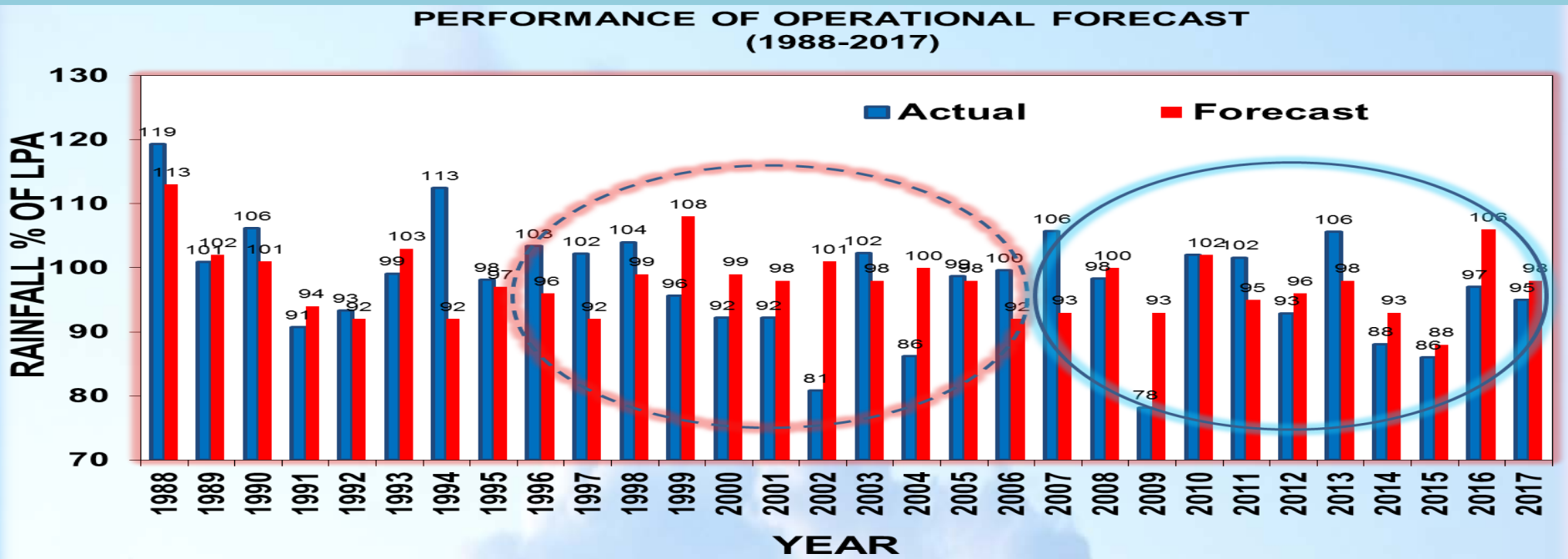


Consensus forecast for JJAS 2016



Recent Success in Predicting Extreme seasonal Events

Improved Performance of the Operational Forecast (Empirical Model) for All India Seasonal Rainfall (1988-2017):



- Error ≥ 10% in 7 yrs with highest in 2002 (20%) and 1994 (18%). Error in 2009 15%.
- Ave. absolute error during the last 11 years (2007-2017) was 5.95% of LPA compared to that of 8.56% of LPA during the 11 years (1996-2006) just prior to that period.
- C.C between the actual and forecast rainfall for (2007-2017) & (1996-2006) are 0.46 & -0.42 respectively.
- During 1996-2006, the forecast within the ±8% of actual values during 7 years. Within these 7 years, forecast was within ±4% during 2 years. On the other hand during 2007-2017, the forecast was within the ±8% of actual values during 8 years with forecast within ±4% during 5 years. *These clearly indicate improvement made in the operational forecast system in the recent 11 years period compared to earlier 11 years period.*

Successful forecasting of Successive Large Scale Deficient monsoons (2014 & 2015):
IMD Operational Forecast for 2014 Monsoon Rainfall & Verification

Region	Period	Forecast (% of LPA)			Actual Rainfall (% of LPA)
		24th April	9th June (1st Update)	12th August (2nd Update)	
All India	June to September	95 ± 5	93 ± 4	87 ± 4	88
Northwest India	June to September		85 ± 8	76 ± 8	79
Central India	June to September		94 ± 8	89 ± 8	90
Northeast India	June to September		99 ± 8	93 ± 8	90
South Peninsula	June to September		93 ± 8	87 ± 8	93
All India	July		93 ± 9		90
All India	August		96 ± 9	96 ± 9	91
All India	August to September			95 ± 8	98

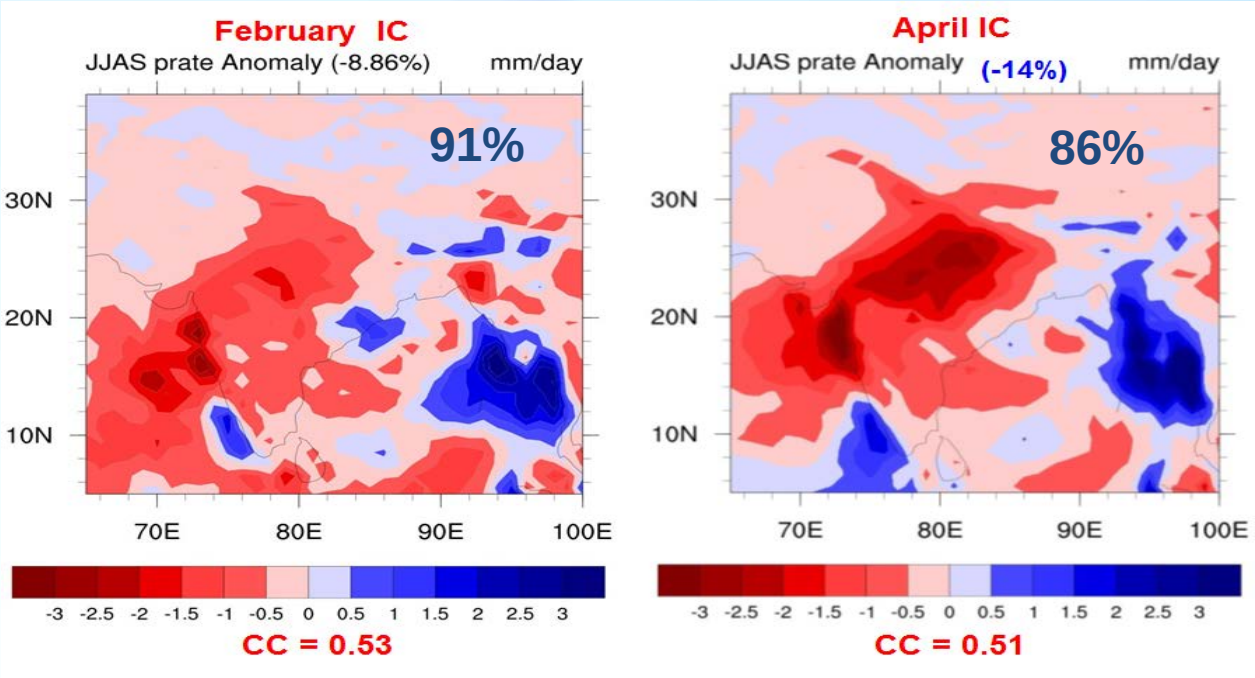
The season rainfall over the country as a whole and that over four broad geographical regions (northwest India, central India, northeast India and south Peninsula) were within the limits of the forecasts updated in August and accurate. Similarly, the forecasts for the monthly rainfall (for July and August) as well as that for the rainfall during the second half of the monsoon season over the country as a whole were also accurate.

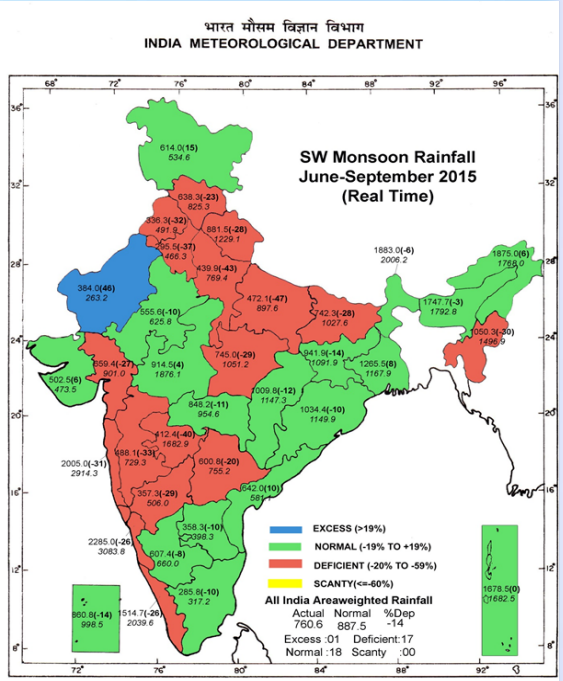
ESSO-IMD Operational Forecast for 2015 Monsoon Rainfall & Verification

Region	Period	Forecast (% of LPA)			Actual Rainfall (% of LPA)
		22th April	2th June (Update)	2nd August	
All India	June to September	93 ± 5	88 ± 4		86
Northwest India	June to September		85 ± 8		83
Central India	June to September		90 ± 8		84
Northeast India	June to September		90 ± 8		92
South Peninsula	June to September		92 ± 8		85
All India	July		92 ± 9		84
All India	August		90 ± 9		78
All India	August to September			84 ± 8	77

The operational forecasts for the 2015 season rainfall over the country as a whole and that over four broad geographical regions (northwest India, central India, northeast India and south Peninsula) were within the limits of the forecasts issued in June and accurate. Similarly, the forecasts for the July as well as that for the rainfall during the second half of the monsoon season over the country as a whole were also accurate. However, the August forecast was an overestimate to the realized rainfall and was not accurate. .

Rainfall anomalies Predicted by the MMCFS T382 (Initialized with Feb. & April Initial Conditions)



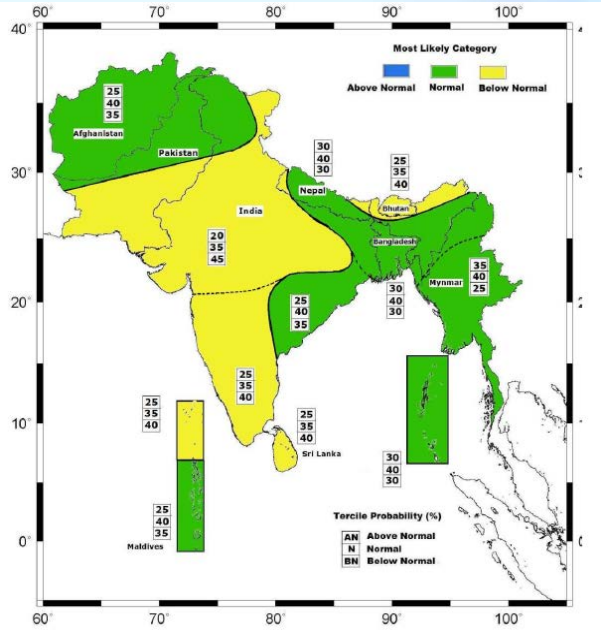


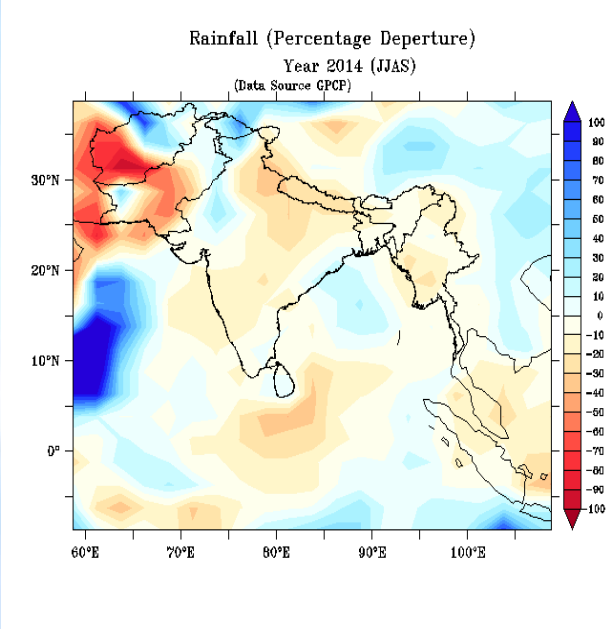
Category	Rainfall Range (% of LPA)	Forecast Probability (%) April	Climatol. Probability (%)
Deficient	<90	61	16
Below Normal	90 - 96	24	17
Normal	96 -104	13	33
Above Normal	104 -110	2	16
Excess	> 110	0	17

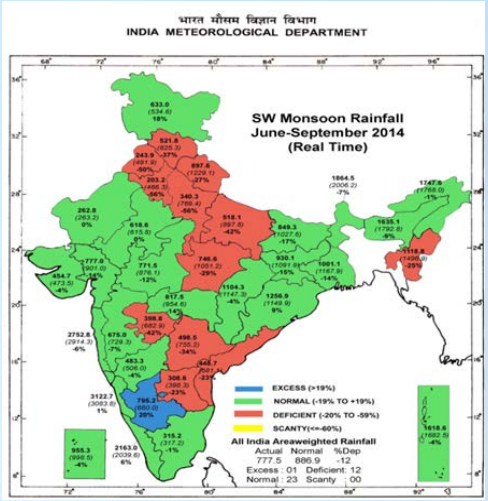
Initial conditions (IC) of	JJAS		Forecast for 2015 (% of LPMA)
	C.C (1981-2008)	Corrected RMSE (% of LPMA) (1981-2008)	
February	~ 0.55	7.4%	91%
April	~ 0.4	8.3%	86%

SASCOF:
Below normal Rainfall Consensus Forecast for South Asia – JJAS 2014

a) JJAS 2014



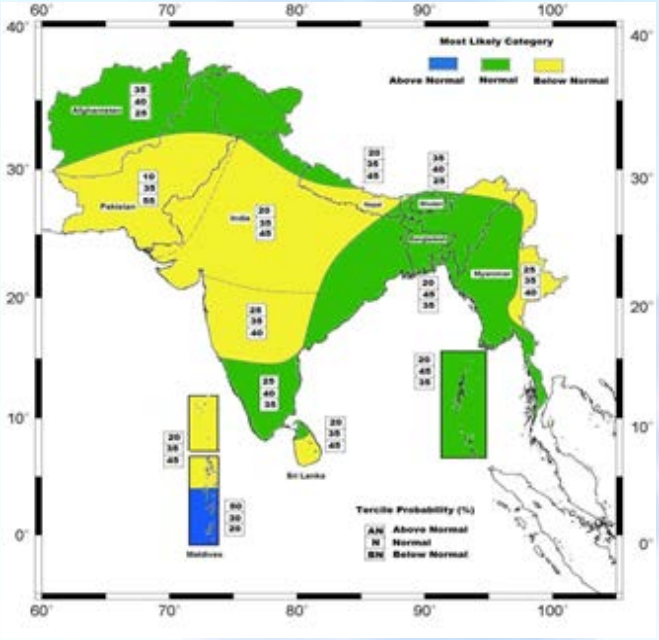


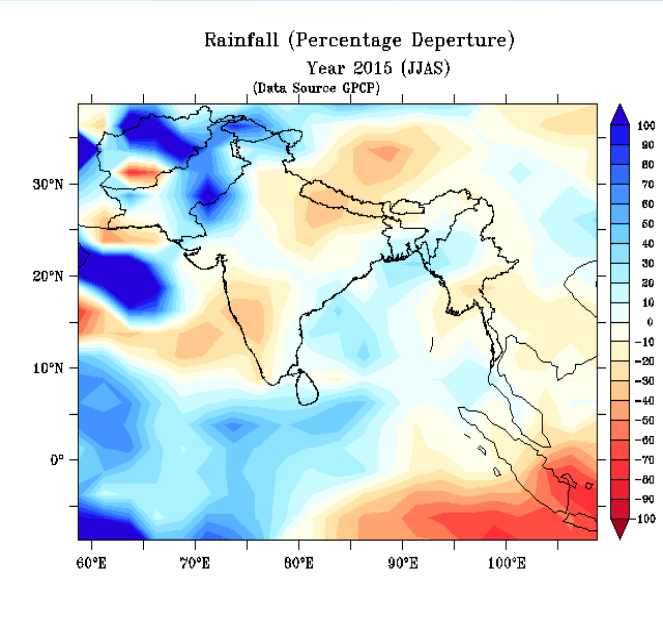


Below-normal to normal rainfall is most likely during the 2014 summer monsoon season (June – September) over south Asia as a whole. Below-normal rainfall is likely over broad areas of western, central and southwestern parts of South Asia and some areas in the northeastern-most parts of the region. Normal rainfall is likely over broad areas of northwestern and eastern parts and some island areas in the southernmost parts of the region.

SASCOF:
Below normal Rainfall Consensus Forecast for South Asia-JJAS 2015

a) JJAS 2015

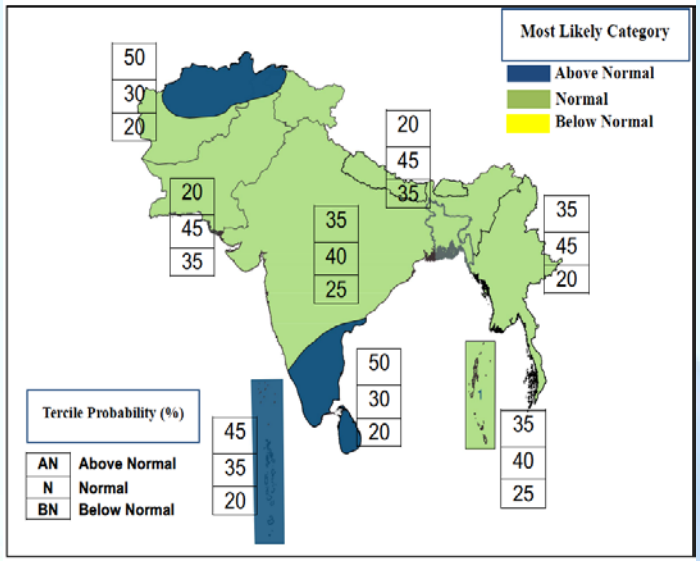


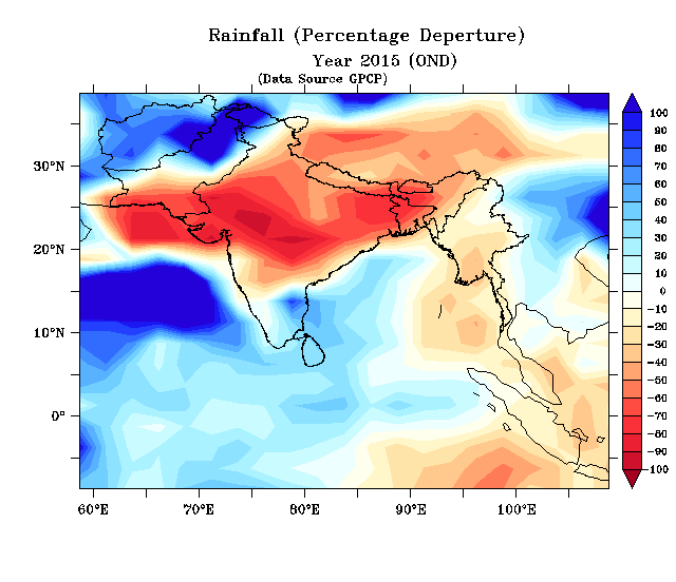


The observed rainfall for the 2015 southwest monsoon season was below normal over most parts of the south Asia except over some northeastern parts of region suggesting below normal rainfall over the region as whole in general agreement with the consensus forecast. However, there were some differences in the spatial distributions of the observed and forecasted rainfall over the region.

Above Normal Rainfall southern Parts of S. Asia: 2015 NE monsoon consensus Forecast

a) OND 2015





Normal to above normal rainfall is likely during the 2015 Northeast monsoon season (October–December)over southern parts of South Asia including southeast peninsular India, Sri Lanka and Maldives. Above normal rainfall is likely over northern most parts of the region. Other areas of the region that generally receive very little rain during the season are likely to receive normal rainfall. During the season, normal to above normal temperatures are likely,
over most parts of the region.

Downscaling

- At present, Global Climate Models (GCMs) are unable to provide information at the spatial scale required by many stakeholders. Hence, regionalisation/ downscaling methods are necessary for adapting the global-model predictions to smaller spatial scales, providing suitable products for a range of applications.
- Downscaling is the derivation of regular scale (10-100 km) information from large scale modelled or observed data. It can be carried out on spatial and temporal aspects of climate prediction
- Spatial downscaling - derives climate information at finer spatial resolution from coarser spatial resolution GCM output. The fundamental basis of spatial downscaling is the assumption that significant relationships exist between local and large-scale climate.
- Temporal downscaling - derivation of fine scale temporal data from coarser-scale temporal information (e.g., daily data from monthly or seasonal information). Its main application is in impact studies when impact models require daily or even more frequent information.

Downscaling Approaches

- Downscaling relies on the assumption that local climate is a combination of large-scale climatic/atmospheric features (global, hemispheric, continental, regional) and local conditions (topography, water bodies, land surface properties). Representation of the latter is generally a challenging job for the GCMs. There are two main approaches; dynamical downscaling and statistical downscaling.
- Dynamical downscaling (DD) relies on the use of a regional climate model (RCM), similar to a GCM in its principles but with high resolution. RCMs take the large-scale atmospheric information supplied by GCM output at the lateral boundaries and incorporate more complex topography, the land-sea contrast, surface heterogeneities, and detailed descriptions of physical processes in order to generate realistic climate information at a higher spatial resolution.

Since the RCM is nested in a GCM, the overall quality of dynamically downscaled RCM output is tied to the accuracy of the large-scale forcing of the GCM and its biases. Despite recovering important regional-scale features that are underestimated in coarse-resolution GCMs, RCM outputs are still subject to systematic errors and therefore often require a bias correction as well as further downscaling to a higher resolution.

- **Statistical downscaling (SD)** involves the establishment of empirical relationships between historical and/or current large-scale atmospheric and local climate variables. Once a relationship has been determined and validated, future atmospheric variables that GCMs predict are used to predict future regional/local climate. Statistical downscaling can produce site-specific climate prediction, which RCMs cannot provide since they are computationally limited to some specified spatial resolution. However, this approach relies on the critical assumption that the relationship between present large-scale circulation and local climate remains valid under different forcing conditions of possible future climates. It is unknown whether present-day statistical relationships between large- and regional-scale variables will be upheld in the future climate system
- e. Main advantage of SD is that they are computationally cheap, thus allowing to efficiently downscale the enormous ensembles of seasonal hindcasts. Moreover, statistical downscaling techniques directly incorporate observations into the method, so no further calibration/correction is needed for the resulting outputs

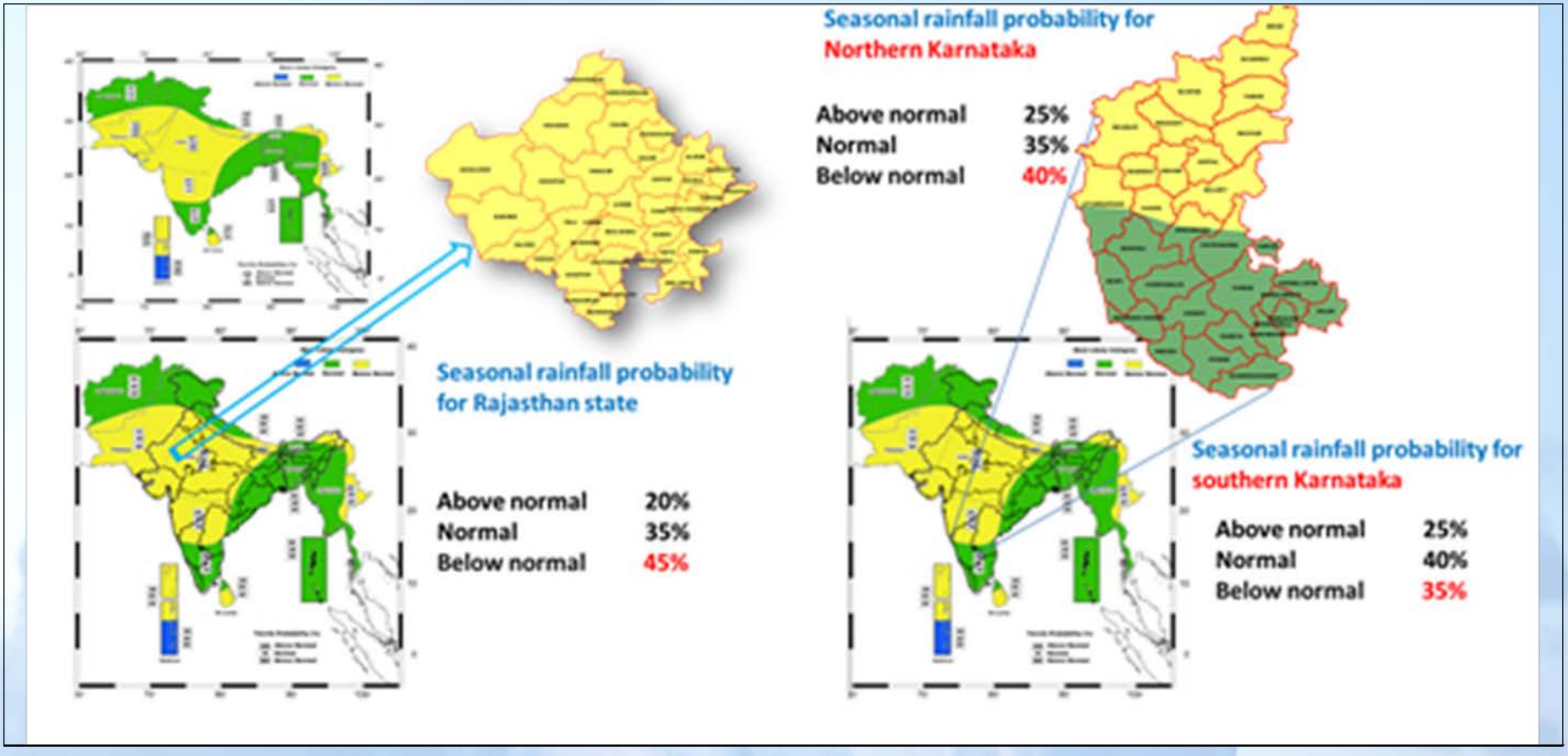
Selection of Downscaling Approaches

- The approach should be selected based on the information needs and also, importantly, on available resources (data, computing resources, expertise, and time-frames).
- For example, the dynamical downscaling has numerous advantages but is computationally intensive and requires large volumes of data as well as a high level of expertise to implement and interpret results, often beyond the capacities of institutions in developing countries.
- In contrast to the dynamical method, the statistical methods are easy to implement and interpret. They require minimal computing resources but rely heavily on historical climate observations and the assumption that currently observed relationships will carry into the future. However, high quality historical records often are not available in developing countries.
- Often, dynamical and statistical approaches are used in conjunction. *Dynamical-statistical downscaling* involves the use of an RCM to downscale GCM output before statistical equations are used to further downscale RCM output to a finer resolution. Dynamical downscaling improves specific aspects of regional climate modeling and provides better predictors for further statistical downscaling to higher-resolution output. *Statistical-dynamical downscaling* is a somewhat more complex approach but is less computationally demanding in comparison to dynamical downscaling.

THANK YOU

Interpretation of seasonal forecast at district level and organizing state level monsoon preparedness meetings

Seasonal rainfall forecast which has been overlaid by district map for Rajasthan and Karnataka



Southwest Monsoon Rainfall over South Asia
Consensus outlook for 2015 for Karnataka and Rajasthan state