Frequently asked Questions (FAQs) on Monsoon

1. What is the all India monthly and seasonal rainfall?

All India monthly rainfall is the amount of accumulated rainfall received over India for a particular month. For example, All India monthly rainfall of June 2018 is 155.7mm. Similarly All India seasonal rainfall is the amount of accumulated rainfall received over India for a particular season. e.g. All India seasonal rainfall of South-West monsoon (JJAS) of 2018 is 804.1mm. These quantities are not constant; they vary from year to year.

2. What do we mean by long period average (LPA) of rainfall?

LPA of rainfall is the rainfall recorded over a particular region for a given interval (like month or season) average over a long period like 30years, 50-years etc. It acts as a benchmark while forecasting the quantitative rainfall for that region for a specific month or season. For example, LPA of south west monsoon rainfall over Kerala for the months June, July, August and September are 556mm, 659mm, 427mm and 252mm respectively. Current LPA of all India south west monsoon rainfall based on the average rainfall over the period 1961 -2010 is 880.6mm.

3. What is large excess, excess, normal, deficient, large deficient rainfall?

These are categories of rainfall used to describe realised rainfall averaged over various temporal scales like daily, weekly, monthly etc for spatial scales like districts, states operationally. Accordingly, when the realised rainfall is ≥60%, 20% to 59%, -19% to +19%, -59% to -20%, -99% to -60% of long period average (LPA), the rainfall is categorized as large excess, excess, normal, deficient, large deficient respectively.

4. What is below normal, normal and above normal rainfall for the country as a whole?

If ‘m” is the mean and “d” is the standard deviation of a long time series of any climate variable like rainfall, temperature etc. Assuming the time series is normally distributed, 68% of the observations fall within +/- 1 standard deviation (d) from the mean (d). Therefore, when a realised value of the variable falls between m-d to m+d, it is categories as normal. When the realised value is <(m-d), it is categorised as below normal and when the realised value is > (m+d), it is categorised as above normal.

In case of monsoon season (June to September) rainfall over India as a whole, the long period average (LPA) is 88 cm and standard deviation is 9cm (about 10% of mean value).Therefore, when the rainfall averaged over the country as a whole is within ±10% from its long period average (LPA) or 90% to 110% of LPA, the

rainfall is said to be “normal” and when the rainfall is <90% (>110%) of LPA, the rainfall is said to be “below (above) normal”.

5. What is the role of monsoon trough?

Monsoon Trough is an elongated low-pressure area which extends from heat low over Pakistan to Head Bay of Bengal. This is one of semi-permanent feature of monsoon circulation. Monsoon trough may be a characteristic of east west orientation of Himalayan ranges and north south orientation of Khasi-Jaintia Hills. Generally eastern side of monsoon trough oscillates, sometimes southwards and sometimes northwards.

Southward migration results in active/vigorous monsoon over major part of India. In contrast, the northward migration of this trough leads to break monsoon condition over major part of India and heavy rains along foothills of Himalayas and sometimes floods in Brahmaputra river.

6. What is heat low? What are its impacts on monsoon rainfall?

During the northward march of sun in northern hemisphere, the continent surrounding the Arabian Sea begin to receive large amounts of heat; not only in the form of radiation from sun, but also flux of heat from the earth’s surface into atmosphere (160 Watts/m2 for month of June over the arid zones of northwest India, Pakistan and middle eastern countries). As a result of this large input of power, trough of low pressure forms over this region. It is a semi-permanent feature of monsoon over India. The heat low is very shallow (extending up to 850 hPa (1.5 KM) level and there exist a well-marked ridge above heat low. In spite of occurrence of cloudiness, the precipitation is very small. Intense heat low (pressure departure is below normal) acts as suction devise for moist air along the monsoon trough and to some extend related to good monsoon over India. During weak heat low (pressure departure is above normal) monsoon rainfall over India is greatly affected and results in deficient or scanty rainfall over vast area of country (eg. In 1987, central pressure over heat low area was mostly above normal, which proved to be drought year). Satellite measured estimates of longwave radiation indicates that tropical /subtropical deserts are heat sinks.

7. What is monsoon low, how does it influence monsoon?

An area with pressure at the centre lowest one, closed in shape with winds blowing around in anti-clockwise direction in Northern Hemisphere is Low Pressure Area (LPA). The LPA is associated with a whirling motion of air, convergence and upward motion of air. In the low usually clouds and rainfall are present. LPA which seen during monsoon is monsoon low.

The monsoon lows may be intensified into monsoon depressions. The monsoon lows and depressions are the principal rain bearing systems of the south west monsoon period over India. Substantial amounts of rainfall are generated by the westward passage of monsoon depressions forming in the Bay of Bengal. These

are low pressure areas having wind speeds between 17 and 33 knots in their circulation.

On the average, 2 depressions form in each of the monsoon months (June-September). However, year to year variation in their number is quite large. Those that form in early June are responsible for the advance of the southwest monsoon, and are not strictly monsoon depressions. In July and August they usually form north of 18°N in the northwest Bay, and the site of genesis shifts in September southward in the Central Bay.

8. What is Tibetan High? How is it related with monsoon rainfall?

Tibetan High is a warm anticyclone (in this wind are changing in a clock-wise direction in the Northern Hemisphere and it will have always outflow of winds) located over Tibetan Plateau (centre latitude at 28ºN, longitude 98ºE) in the middle/upper troposphere during monsoon period. It is marked at 300 hPa level with centre 30ºN, 90ºE and extends 70ºE-110ºE.The outflow of winds from Tibetan High as the easterly flow concentrates into jet stream centred near about the latitude of Chennai at 150 hPa in July. The jet stream runs from the east coast of Vietnam to the west coast of Africa. Thusthe location of the Easterly Jetstream seems to influence the pattern of monsoon rainfall. Shifting its position east or west causes variation of monsoon activity over India. The Tibetan 'High' may sometimes shift much to the west of its usual position. In such a situation, the monsoon may extend further westward into Pakistan and in extreme cases into north Iran, though such a westward position of the Tibetan 'High' would be against its having origin in the heating effect of the Tibetan Plateau.

9. What is Mascarene high? How does it influence monsoon rainfall?

Mascarene High is a high-pressure area that is found around Mascarene Islands (in south Indian Ocean) during monsoon period. This is responsible for cross-equatorial flow through south Arabian Sea and it acts as southern hemispheric linkage. The variation in the intensity of High Pressure causes monsoon surges across equatorial flow. These surges are responsible for heavy rains along the west coast.

10. What is Somali jet?

Somali jet is low level (1 to 1.5 km asl) inter hemispheric cross equatorial flow of air, attains Jet speed at the west end of monsoon regime along the east coast of Africa. This Jet originates near Mauritius and northern part of Madagascar in the southern Hemisphere. This jet reaches Kenya coast (at about 3ºS) covers the plains of Kenya, Ethiopia and to Somali Coast at about 9ºN)

During May, it moves further into eastern Africa, then into Arabian sea and reaches west coast of India in June. It attains maximum strength in July. Short period (8-10 days) fluctuations are observed in Low Level Jet stream. Its strengthening gives rise to strong monsoon over peninsular India.

11. What is Tropical easterly Jet? How does it influence the rainfall?

South of the sub-tropical ridge over Asia, the easterly flow concentrates into jet stream centred near about the latitude of Chennai at 150 hPa in July. This is Tropical easterly jet. The jet stream runs from the east coast of Vietnam to the west coast of Africa. Over Africa, the location is at 10° N. Normally, the jet is at an accelerating stage from the South China Sea to south India and decelerates thereafter. The location of the Easterly Jetstream seems to influence the pattern of monsoon rainfall. TEJ weakens to less than 50 knots over India in September. During Break monsoon conditions TEJ moves northwards up to latitude 20ºN.

12. What is the difference between monsoon depression and depression forming in pre-monsoon season and post-monsoon season?

The depressions which form in the monsoon season are called the monsoon depressions. These are low pressure areas with two or three closed isobars (at 2 hPa interval), which cause most of monsoon rains. These can be of Bay origin, Land origin or Arabian Sea origin. Their shape is roughly elliptical and its horizontal extension is about 1000's of Kms of surface. Its vertical extension is about 6-9 kms. Monsoon depression is cold core system (central temperature colder than environment) over surface and in the lower levels and warm core in upper levels (central temperature warmer than environment). The Maximum wind strength and intensity can be noticed at the levels of 0.9km or 1.5 km. The monsoon depressions tilt southwards with height and if monsoon depression is moving westward, the heavy rainfall is mainly concentrated in the SW quadrant. Due to the high vertical wind shear present during South west monsoon season, monsoon depressions are generally do not intensify into cyclonic storms.

The depressions forming in pre-monsoon season and post-monsoon season intensify into a cyclonic storm. The average diameter of Post monsoon storms is about 1200 km whereas in pre-monsoon season it is about 800 km, however intensity does not depend on size. The cyclonic storm is a warm core phenomenon where the temperatures at the centre are warmer than the surrounding (areas) regions. The maximum warming occurs at the 300 hPa level.

13. Why don't we get cyclones during main monsoon months like July and August?

Tropical cyclogenesis requires several favourable precursor environmental conditions. Warm Ocean waters (of at least 26.5℃ throughout sufficient depth at least on the order of 50 m). Relatively moist layers near the height of 5 km. Non-negligible amount of Coriolis force, pre-existing near surface disturbance. Low values of vertical wind shear between the surface and upper troposphere.

In July and August winds on the surface are westerly/south-westerly to the south of monsoon trough and south easterly/ easterly to its north and are generally stronger over the seas than the Land areas. The upper winds are westerly/south-westerly to the south and south easterly/ Easterly to the north of this trough region. Westerly

winds increase with height and reach a maximum speed of 20-25 knots between 900 to 800 hPa levels. Easterly winds strengthen with height from 200 hPa reaching a maximum at 100 hPa. Speeds are between 60 to 80 knots over peninsula at 150 /100 hPa level or even at lower height (around 200 hPa) in the southern latitude. This results in high values of vertical wind shear which is unfavourable for Tropical cyclogenesis. So, we don't get cyclones during main monsoon months like July and August.

14. What is off shore trough?

During monsoon season a shallow trough of low pressure is observed (on sea level surface chart) along west coast of India. This is known as off-shore trough. This type of system quite frequently develops off the west coast of India, anywhere from north Kerala to south Gujarat, during the period of southwest monsoon, and is responsible for the strengthening of the monsoon in terms of rainfall, in the adjacent parts of the coastal belt.

15. What is off shore vortex?

West coast of India has an orographic barrier in the form of Western Ghats. These mountains are oriented in north south direction and approximately 1000 km in length and 200 km in breadth. When monsoon winds strikes the mountains, on many occasions they do not have enough energy to climb over Western Ghats. On such occasions they tend to be deflected round the mountains and return current forms the off-shore vortex. These vortices are responsible for the occurrence of heavy to very heavy rainfall over west coast during monsoon season.

16. How does rainfall vary during monsoon season? Is there any periodicity.

During monsoon, considerable variability in rainfall is seen with space and time. The following are reasons which contribute to this.

Onset, Advancement and Withdrawal of monsoon. They decide the duration, period of monsoon current at different places.

Position of monsoon trough: It can oscillate 5º to north and 5º to south within 24 hours. If this trough is in south of normal position, strong monsoon conditions are observed over India. If this trough is in north of normal position or if it runs to foothills of Himalayas or not seen at all, then break monsoon conditions are observed. Synoptic systems like cyclonic circulations, lows, depressions move along trough and contribute to rainfall.

Formation and movement of synoptic systems and number of days of systems:
Low frequency oscillations considerably change the rainfall distribution over different parts of India. 40-day mode or northward propagation of maximum cloud zone from equator to 30ºN. This mode is also seen as northward propagation of trough and ridges in wind field with periodicity of 0.75º of longitude per day.
Westward propagating biweekly oscillation of 14 to 15 days.

17. What is synoptic mode of variation? How does it influence rainfall?

Low frequency oscillations considerably change the rainfall distribution over different parts of India. Synoptic mode variation has a periodicity of 3-7 days. It is mainly due to the formation of low pressure systems and its movements over Indian land mass. Under its influence, central Indian region receives good amount of rainfall.

18. What is Quasi-biweekly oscillation or Monsoon intra-seasonal oscillation? How does it influence rainfall?

Westward propagating biweekly oscillation of 14 to 15 days. Trough lines and low-pressure systems, ridges and high-pressure systems propagate in sequence from east to west with a periodicity of 2 weeks (14 to 15 days). This is known as Quasi-biweekly oscillation. When a trough or low-pressure area propagates on a particular area that area will experience an enhanced precipitation and when ridge or high-pressure passes over particular area, it will lead to suppressed rainfall or no rainfall over a particular area.

19. What is Madden Julian Oscillation? How does it influence rainfall?

The Madden Julian Oscillation (MJO) is one of the most important atmosphere-ocean coupled phenomena in the tropics, which has profound influence on Indian Summer Monsoon. The MJO is the leading mode of tropical intra-seasonal climate variability and is characterized by organization on a global spatial scale with a period typically ranging from 30-60 days, which was discovered by Madden and Julian in 1971 in a published paper. It has the following characteristics: -

- MJO is a massive weather event consisting of deep convection coupled with atmospheric circulation, moving slowly eastward over the Indian and Pacific Oceans.
- MJO is an equatorial traveling pattern of anomalous rainfall that is planetary in scale.
- Each cycle lasts approximately 30–60 days. Also known as the 30-60 day oscillation, 30-60 day wave, or intra-seasonal oscillation (ISO).
- The MJO involves variations in wind, sea surface temperature (SST), cloudiness, and rainfall.

Based on the place of convective activity the period of MJO is divided into 1-8 phases with each phase roughly last for 7 to 8 days. Since the MJO is the most important mode of tropical intra-seasonal variability with potentially important influences on monsoon activity in the Asian regions on extended range time scale (beyond 7 days to on1 month), the capability of statistical or numerical models in capturing MJO signal is very crucial in capturing the active/break cycle of monsoon.

20. How does monsoon vary from year to year? Is there any periodicity?

Year to year variation of monsoon rainfall over the large number of years is known as the interannual variability of monsoon. Periodicity of monsoon is largely controlled by the global ocean atmospheric phenomena like El nino Southern oscillation (ENSO).

21. What are the main factors governing interannual variation of south west monsoon?

Interannual variations are the variations on the annual cycle of the monsoon producing anomalously wet or dry years. The major factors governing interannual variation of south west monsoon are El nino Southern oscillation (ENSO) and Indian Ocean Dipole (IOD). Other contributing factors are North Atlantic Oscillation (NAO) and Pacific Decadal Oscillations (PDO).

22. How do we monitor monsoon?

- Monsoon is being monitored by IMD using various techniques as given below.
- Continuous monitoring of surface and upper air meteorological observations
- Real time monitoring of the monsoon using remote sensing techniques like satellite and Radars.
- Analysis of the different meteorological charts.
- Guidance from various national and international weather forecasting models at different spatio-temporal scales.

23. What are the observational tools used for monitoring monsoon?

The observational tools used for monitoring monsoon are:

- Synoptic observations of various meteorological parameters plotted on appropriate charts viz., mean sea level pressure chart, wind observations at constant pressure levels, geopotential heights, temperature, etc.
- Auxiliary charts prepared out of derived parameters, for example, dew point temperature, pressure tendency, anomaly charts of pressure, maximum & minimum temperatures etc.
- Satellite imageries
- Satellite bulletins
- Various derived products from satellite observations, viz. Cloud Top Temperatures, Cloud Motion Vector (CMV) winds, water vapour derived winds, Outgoing Longwave Radiation (OLR), Quantitative Precipitation Estimates (QPE), divergence-convergence patterns of lower & upper levels, wind shear tendency, etc.

- The AWS plotted charts and other products of numerical weather prediction models available on the ftp server.
- Some more products of numerical weather prediction models available on Internet from IMD and NCRMWF and other worldwide centres such as UKMO, ECMWF, COLA, NOAA, NOGAPS, JTWC, etc.
- Ships and buoy observations
- Weather Radar and Doppler Weather Radar Observations.
- Current Weather Observations (CWOs), Aircraft Reports (AIREPs)

24. How do we predict monsoon in different spatial and temporal scale?

Prediction of monsoon is done by IMD in different spatial and temporal scales. It varies from country as a whole to district wise in spatial scales and from a seasonal forecast to nowcast in temporal scale.

Seasonal forecast for monsoon rainfall issued based on long range forecast (LRF)in the month of April for the entire country. This forecast update in the month of May for the entire country and also for its broad homogenous regions. LRF of monsoon will give a general picture of seasonal and monthly rainfall for the coming monsoon season.

Extended range forecast of IMD issued in every Thursday of the week give forecast for a period extending from about 10days to 30 days in advance for the entire country. This forecast helps in the forecasting of active-break cycle of monsoon, formation of monsoon lows and depressions.

IMD issues short to medium range forecast for 5 days based on various national and international weather forecasting model guidance and expertise from the scientists. This forecast is being used by various stakeholders for planning their routine activities.

Different meteorological centres issue nowcast for heavy rainfall during monsoon season with validity up to 6 hours.

25. What is long range forecast of monsoon?

As per the World Meteorological Organization (WMO) definition, long range forecast is defined as the forecast from 30 days' up to one season's description of averaged weather parameters. The monthly and seasonal forecast comes under long range forecast.

26. What is extended range forecast of monsoon?

Extended range Forecast is a forecast for a period extending from about 10 days to 30 days in advance. With regard to the extended range time scale it is the time scales between medium range (About a week in the tropics) and seasonal scale and extends up to a period of one month. The extended range time

scale of monsoon is also called the intra-seasonal time scale or active-break cycle of monsoon. The synoptic scales systems and other oscillations like Madden Julian Oscillation (MJO) influence the monsoon in this time scale. The monsoon forecast in this time scale is most difficult as it is neither a complete initial value problem (like the short to medium range prediction) nor a complete boundary value problem (like the seasonal forecast) but perhaps the most important of all time scales for economic and agricultural sectors. It makes difficult to predict in this time scale since the time scale is sufficiently long so that much of the memory of the atmospheric initial conditions is lost, and it is probably too short so that the variability of the ocean is not large enough.

27. What is forecast accuracy of ERF?

With regard to the skill of monsoon prediction in this time scale based on the operational coupled models runs at IMD it shows very useful guidance about the monsoon onset, monsoon withdrawal, active and break phases of monsoon and active-break transitions reasonably well. With regard to the quantitative verification, on average, it shows significant skill up to about three weeks for all India rainfall. Over the homogeneous regions of Indian it shows significant skill up to 2 to 3 weeks over Central India, monsoon zone of India & Northwest India. Over the south peninsula and northeast India it shows significant skill up to 2 weeks. On smaller spatial domain like meteorological subdivision level forecast skill it shows useful skill up to 2 weeks.

28. What is short to medium range forecast of monsoon?

Short range forecast is forecast valid for a period up to 3 days and the medium range forecast is valid for 3 to 10 days. This forecast is useful for planning agricultural activities, disaster management, town planning etc.

29. What is forecast accuracy of short to medium range forecast, especially heavy rainfall?

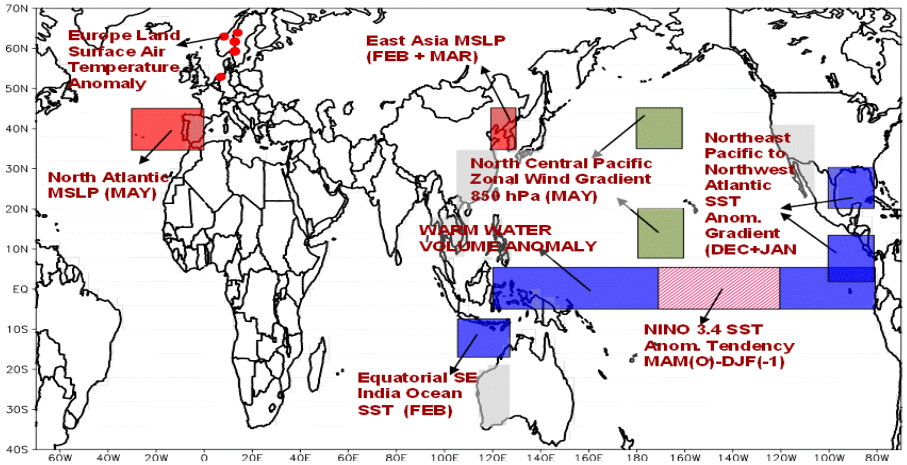
Accuracy of the short to medium range forecast is quite good in capturing the rainfall distribution, heavy rainfall events and formation of the synoptic systems up to 3-4 days in advance. Accuracy of the forecast decreasing beyond 5 days due to error propagation in initial condition.

30. What is SEFS?

SEFS stands for Statistical Ensemble Forecasting system. It is a statistical model used by IMD for the long range forecasting of South west monsoon season rainfall over the country as a whole. For this a set of 8 predictors (given in below Table) that having stable and strong physical linkage with the Indian south-west monsoon rainfall is used.

Details of the 8 predictors used for SEFS

No.	*Predictor*	*Used for forecasts in*	*Correlation Coefficient (1981-2010)*
1.	Europe Land Surface Air Temperature Anomaly (January)	April	0.42
2.	Equatorial Pacific Warm Water Volume Anomaly (February + March)	April	-0.35
3.	SST Gradient Between Northwest Pacific and Northwest Atlantic (December +January)	April and June	0.48
4.	Equatorial SE India Ocean SST (FEB)	April and June	0.51
5.	East Asia MSLP (FEB + MAR)	April and June	0.51
6.	NINO 3.4 SST (MAM+(MAM-DJF) Tendency)	June	-0.45
7.	North Atlantic MSLP (MAY)	June	-0.48
8.	North Central Pacific Zonal Wind Gradient 850 hPa (MAY)	June	-0.57



Geographical domains of the predictors used in the statistical ensemble forecasting system for the seasonal rainfall forecast

The geographical domains of the predictors are shown in the above figure. For the April SEFS, first 5 predictors listed in the Table are used. For June SEFS, the last 6 predictors are used that include 3 predictors used for April forecast. The standard errors of the 5–parameter and 6- parameter SEFSs were taken as ±5% and ±4% respectively. According to this forecasting system, the forecast for the seasonal rainfall over the country as a whole is computed as the ensemble average of best few models out of all possible models constructed using two statistical methods; multiple regression (MR) technique and projection pursuit regression (PPR) - a nonlinear regression technique. In each case, models were constructed using all

possible combination of predictors. Using 'n' predictors, it is possible to create (2n-1) combination of the predictors and therefore as many number of models. Thus with 5 (6) predictors respectively for April (June) SEFS, it is possible to construct 31 (63) models.

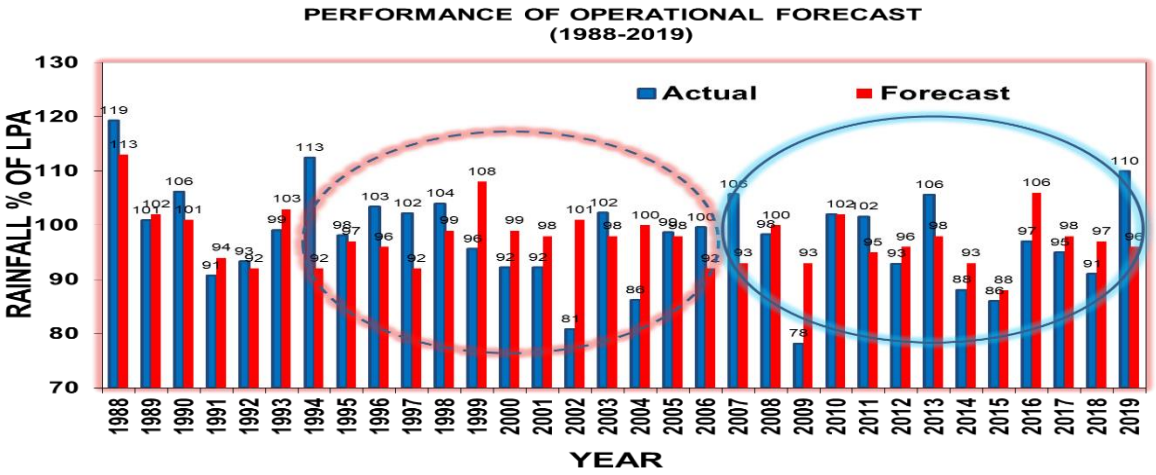
31. What is MMCFS?

MMCFS stands for Monsoon Mission Coupled Forecasting System. It is a coupled dynamical model developed under Monsoon Mission Project. The original model frame work of CFS was developed by the National Centers for Environmental Prediction (NCEP), USA. This model was modified to provide better forecast over Indian monsoon region for different spatial and temporal resolutions through mission mode research work by the Indian Institute of Tropical Meteorology (IITM), Pune in collaboration with various climate research centers from India and abroad. The latest high-resolution research version of the coupled model has been implemented in High Performance Computer (HPC) at Indian Institute of Tropical Meteorology (IITM), Pune. IMD uses Monsoon Mission Climate Forecast System (MMCFS) model for preparing operational forecast of rainfall and temperature along with statistical models. More model details are available at http://imdpune.gov.in/Clim_Pred_LRF_New/Models.html

32. What is forecast accuracy of LRF for the Southwest Monsoon Seasonal Rainfall over the country a whole?

The LRF for all India season rainfall was reintroduced in 1988 using 16 parameter power regression and parametric models. IMD introduced new state of art LRF models during 2003 & 2007 following review of old forecasting system in 2002. The performance of the operational long range forecast for the season rainfall over the country as whole for the period 1988-2019 is shown in Figure below. During the period the absolute error was ≥ 10% of LPA in 7 years with highest in 1994 (21%) followed by 2002 (20%).

The average absolute error (difference between forecast and actual rainfall) during the last 13 years (2007 -2019) during which forecast was prepared using new Statistical Ensemble Forecasting system (SEFS) was 6.25% of LPA compared to the average absolute error of 8.91% of LPA during the 13 years (1995 -2006) just prior to that period. During 1994-2006, the forecast within the ±8% of actual values during 8 years. Within these 8 years, forecast was within ±4% during 3 years. On the other hand, during 2007-2019, the forecast was within the ±8% of actual values during 8 years with forecast within ±4% during 5 years. This clearly indicates improvement made in the operational forecast system in the recent 13 years period compared to earlier 13 years period. It is not possible to have 100% success for forecasts based on statistical models. The problems with statistical models are inherent in this approach and are being faced by forecasters worldwide.



33. What is Monsoon Mission?

Monsoon Mission is a national programme launched by Ministry of Earth Sciences (MoES) with a vision to develop state-of-the-art dynamical prediction system for the monsoon rainfall in different time scales. The mission supports focused research by national and international research groups with definitive objectives and deliverables to improve models in the short, medium, extended and seasonal range scales through setting up of a framework for generating dynamical forecasts and improving skill of forecasts. It also supports observational programs which will helps the better understanding of the atmospheric processes related to monsoon. The main objectives of this mission are

- To improve Seasonal and Intra-seasonal Monsoon Forecast
- To improve Medium Range Forecast.

Indian Institute of Tropical Meteorology (IITM), Pune, India Meteorological Department (IMD), Indian National Centre for Ocean Information Services (INCOIS), Hyderabad and National Centre for Medium Range Weather Forecast (NCMRWF), Noida are the major participating institutions in Monsoon Mission.

34. How do we declare onset and advance of monsoon?

The onset of the broad-scale monsoon occurs in many stages and represents a significant transition in the large-scale atmospheric and ocean circulations in the Indo-Pacific region.

At present IMD uses a new-criteria adopted in 2016 for declaring the onset of monsoon over Kerala which was based on the daily rainfall of 14 stations over Kerala and neighbouring area along with wind field and Outgoing Longwave Radiation (OLR) over southeast Arabian Sea. The new criteria emphasize on the sharp increase in rainfall over Kerala along with setting up of large-scale monsoon flow and extension of westerlies up to 600 hPa. However, IMD declares monsoon onset/progress dates for other regions operationally in a subjective manner considering the sharp increase in rainfall and its characteristic sustenance for a few days and associated changes in the atmospheric circulation features.

The guidelines to be followed for declaring the onset of monsoon over Kerala and its further advance over the country are enlisted below:

a) Rainfall
If after 10th May, 60% of the available 14 stations enlisted*, viz. Minicoy, Amini, Thiruvananthapuram, Punalur, Kollam, Allapuzha, Kottayam, Kochi, Thrissur, Kozhikode, Thalassery,Kannur, Kasargode and Mangalore report rainfall of 2.5 mm or more for two consecutive days, the onset over Kerala be declared on the 2nd day, provided the following criteria are also in concurrence.

b) Wind field
Depth of westerlies should be maintained upto 600 hPa, in the box equator to Lat. 10ºN and Long. 55ºE to 80ºE. The zonal wind speed over the area bounded by Lat. 5-10ºN, Long. 70-80ºE should be of the order of 15 – 20 Kts. at 925 hPa. The source of data can be RSMC wind analysis/satellite derived winds.
c) Outgoing Longwave Radiation (OLR)

INSAT derived OLR value should be below 200 wm-2 in the box confined by Lat. 5-10ºN and Long. 70-75ºE. Further Advance of Monsoon over the Country a) Further advance be declared based on the occurrence of rainfall over parts/sectors of the sub-divisions and maintaining the spatial continuity of the northern limit of monsoon, further advance be declared.

The following auxiliary features may also be looked into:

b) Along the west coast, position of maximum cloud zone, as inferred from the satellite imageries may be considered.

c) The satellite water vapour imageries may be monitored to assess the extent of moisture incursion.

Northern Limit of Monsoon (NLM)
Southwest monsoon normally sets in over Kerala around 1st June. It advances northwards, usually in surges, and covers the entire country around 8th July (More details are available at http://www.imdpune.gov.in/Clim_Pred_LRF_New/Reports.html). The NLM is the northern most limit of monsoon up to which it has advanced on any given day.

35. How do we define withdrawal of monsoon?

Like the onset criteria, the criteria for the withdrawal of monsoon have also undergone changes. The current operational criteria used by IMD for declaring the withdrawal from extreme north-western parts of the country was adopted in 2006 and consist of the following major synoptic features which will be considered only after 1st September,

i) Cessation of rainfall activity over the area for continuous 5 days.
ii) Establishment of anticyclone in the lower troposphere (850 hPa and below)
iii) Considerable reduction in moisture content as inferred from satellite water vapour imageries and tephigrams.

Further withdrawal from the country is declared keeping the spatial continuity, reduction in moisture as seen in the water vapour imageries and prevalence of dry weather for 5 days. SW monsoon is withdrawn from the southern peninsula and hence from the entire country around 15th October, when the circulation pattern indicates a change over from the south-westerly wind regime. More details are available at http://www.imdpune.gov.in/Clim_Pred_LRF_New/Reports.html.

36. Is there any impact of climate change on monsoon?

Yes. Several studies have attributed the rising trend in the frequency and magnitude of the extreme rainfall events and decreasing trend in moderate rainfall events during monsoon season over central Indian region to climate change and natural variability.

37. What is its impact on monsoon rainfall over different parts of the country?

Based on recent studies it has been observed that the summer monsoon precipitation (June to September) over India has declined by around 6% from last fifty years, with notable decreases over the Indo-Gangetic Plains and the Western Ghats. It is also observed that there has been a shift in the recent period toward more frequent dry spells and more intense wet spells during the summer monsoon season. Over central India, the frequency of daily precipitation extremes with rainfall intensities exceeding 150 mm per day increased by about 75% during the recent decades.

38. How Climate Change does influences heavy rainfall activity?

Temperature of the earth is increasing rapidly due to anthropogenic greenhouse gas emissions. Thermodynamically, warm air holds more moisture as compare the dry air. According to Clausius-Clapeyron equation, the capacity of air to hold moisture increases by 7% for each degree of warming. Studies indicate that, in a changing climate, heavy rainfall events are expected to rise due to abundance of the moisture due to warming.

39. What is its impact on monsoonal low-pressure systems?

Several studies have shown significant decreasing trend in the frequency of Monsoon Depressions over the east coast of India in the recent decades. Some studies showed significant increasing trend in the frequency and duration of monsoon lows, whereas the number of lows intensifying into depressions are observed to be decreasing.

40. What are future projections on monsoon rainfall?

Simulations of Earth's climate in future decades (typically until 2100) based on assumed scenarios of the concentrations of greenhouse gases, aerosols, and other atmospheric constituents that affect the planet's radiative balance is called climate projections. Studies show that all-India summer monsoon mean rainfall is likely to increase moderately in future. It is also projected that the lengthening of the season due to late withdrawal. On interannual timescales, it is speculated that

severity and frequency of both floods and droughts might increase noticeably in future climate.

41. What are the vagaries of monsoon?

Monsoon brings relief to dry and parched land in the form of rain, and affects Indian agriculture in a very substantial measure. The impact of monsoon on Indian economy is more pronounced. The Indian farmer has to put up a temperamental nature a many occasion in past. Excessive rain leads to floods in certain areas, while little or no rain in other parts bringing drought and famine resulting in acute distress to millions. Such fluctuations in rainfall have engaged the attention of our people and to make considerable effort to avert these calamities. There are many legends in our land of worship to the rain God for averting famines, and prayers are offered for pacifying the turbulent rivers of India. The Indian poets have sung about the rainy season in prose and verse.

42. How do we define floods and droughts?

A great flow of water, especially, a body of water rise in, swelling and over flowing land usually thus covered. Generally, flood occurs due to heavy rainfall in the catchment area but some time it occurs due to upstream discharge/ dam failure.

A flood that occurs in a short time (Usually less than six hours) of heavy or excessive rainfall, dam or levee failure is called flash flood.

Drought:
Drought is the consequence of a natural reduction in the amount of precipitation over an extended period of time, usually a season or more in length, often associated with other climatic factors (viz. high temperatures, high winds and low relative humidity) that can aggravate the severity of the drought event.

There are four types of droughts:

i) Meteorological Drought
ii) Hydrological Drought
iii) Agricultural Drought
iv) Socio-Economic Drought

Meteorological Drought:

According to India Meteorological Department, meteorological drought over an area is defined as a situation when the seasonal rainfall received over the area is less than 75% of its long term average value. It is further classified as "moderate drought" if the rainfall deficit is between 26-50% and "severe drought" when the deficit exceeds 50% of the normal.

Hydrological Drought:

Hydrological Drought can be defined as a period during which the stream flows are inadequate to supply established use of water under a given water management system.

Agricultural Drought:
It occurs when available soil moisture is inadequate for healthy crop growth and cause extreme stress and wilting.

Socio-economic drought:

Abnormal water shortage affects all aspects of established economy of a region. This in turn adversely affects the social fabric of the society creating unemployment, migration, discontent and various other problems in the society.

Thus, meteorological, hydrological and agricultural drought often leads to what is termed as Socio-economic drought.

43. Which areas are mainly affected by heavy rainfall and dry spells?

Densely populated urban areas are mainly affected by the heavy rainfall due to chances of urban flooding. Land slide prone hilly areas are also affected by heavy rainfall. On the other hand rainfed areas of the agriculture sector are strongly affected by the dry spells.

44. Whether lightning occurs during monsoon season?

Lightening is mainly associated with the convective clouds. Monsoon clouds are mainly stratiform. Therefore, lightening generally do not occur during active phase of the monsoon season. However, the convective activity during break spell of the monsoon may lead to formation of convective clouds and hence the lightening.

45. How IMD does support flood management?

IMD provides real time rainfall situation and intensity as well as rainfall forecast for different temporal and spatial scales to support flood management.

46. What is cloud burst? Can it be predicted? Which area mainly gets cloud burst?

If 10 cm rainfall is received at a station in one hour, the rain event is termed as cloud burst. It is very difficult to predict the cloud bursts due to its very small scale in space and time. To monitor or nowcast (forecasting few hours lead time) the cloud burst, we need to have dense radar network over the cloud burst prone areas or one need to have a very high resolution weather forecasting models to resolve the scale of cloud burst. Cloud bursts do occur at plains, however, mountainous regions are more prone to cloud bursts due to orography.

47. What is break and active monsoon spells?

After southwest monsoon gets established over Central India in July, copious rainfall is received over large areas of the country with maximum over central India. During the peak monsoon rainfall months (July and August) of the season, the monsoon trough shifts north and south about its normal position causing large scale rainfall variation over the country both in terms of spatial and temporal scales. The intervals of dry monsoon conditions during which the large-scale rainfall over the monsoon trough zone (the zone between which the monsoon trough fluctuates north and south wards) is interrupted for several days in July and August are known as the breaks. On the other hand, the intervals between spells of dry monsoon conditions when the rainfall is higher than normal are known as active spells. Break in the monsoon rainfall was defined as the situations when the trough of low pressure was not seen on the surface chart and the easterlies were practically absent in the lower tropospheric levels up to about 1.5 km above sea level for more than 2 days.

48. What are the criteria used to declare active and weak monsoon condition?

Criterion for declaring active monsoon condition over a meteorological sub division is

i) Rainfall 1 ½ to4 times the normal.
ii) The rainfall in at least two stations should be 5 cm, if that sub-division is along the west coast and 3 cm, if it is elsewhere.
iii) Rainfall in that sub-division should be fairly widespread to widespread. (over the land area)
iv) Wind speed is between 23 to 32 knots(over the Sea)

Criteria for declaring weak monsoon condition over a meteorological sub division is

i) Rainfall less than half the normal (over the land area)Wind speed up to 12 knots (over the Sea)

49. What is rainstorm?

Rainstorm is a storm characterised by substantial heavy rainfall. It is an extreme rainfall event experienced over a particular area for a particular period, in association with various weather systems of different spatial scales (Monsoon, Thunderstorms, cyclonic storm etc.) A rainstorm of any considerable duration typically consists of spurts of high-intensity rain punctuated by variable periods of low-intensity rain. Many times it has been observed that rainstorms lead to floods and landslides.

50. How can a common man get information on monsoon?

Information on monsoon is readily available and updated daily on our website: https://mausam.imd.gov.in. Various mobile apps are available for users such as Meghdoot, Damini, Rainalarm and the weather information is also hosted on Umang app of Government of India. In addition to this farmers can get agro

advisories through sms. They can register for the service by registering on http://imdagrimet.gov.in/farmer/FarmerRegistrationFrontpage/welcome.php

51. What are the special forecasts provided for agriculture during monsoon season?

- India Meteorological Department (IMD) in active collaboration with ICAR, State Agricultural Universities and other institutes is rendering the weather forecast based Agromet Advisory Services (AAS), under Gramin Krishi Mausam Sewa (GKMS) scheme, to the farmers at district level.
- Under this scheme, medium range weather forecast at district level is generated for eight weather parameters, viz., rainfall, maximum temperature, minimum temperature, morning and evening relative humidity, wind speed, wind direction and cloud cover. Based on this forecast, Agromet Advisories are prepared by the Agromet Field Units (AMFUs) located at State Agricultural Universities, institutes of ICAR and IIT etc., in collaboration with State Departments of Agriculture and communicated to the farmers to take decision on day-to-day agricultural operations.
- Based on the past weather conditions and regular extended range forecasts (ERF), Agromet advisories are being prepared and issued on every Friday by ICAR-CRIDA in collaboration with IMD.
- In addition to above, IMD monitors weather aberrations and issues alerts and warnings to the farmers from time to time under GKMS scheme. SMS-based alerts and warning for extreme weather events like cyclone, floods, hailstorm, delayed arrival of monsoon, long dry spells etc. along with suitable remedial measures are issued to take timely operations by the farmers. Such alerts and warnings are also shared with State Department of Agriculture at State level and also with respective districts in various States for the effective management of calamity.

52. What are the forecast products provided for river in flood management?

In flood management India Meteorological Department is providing Quantitative Precipitation Forecast (QPF) for river sub basins of India for Day 1, Day 2 and Day 3. IMD also monitoring rainfall and volume of water for cumulative period of 1-week for 101 river sub basins of India and using Extended Range Forecast providing rainfall and volume of water for 101 river sub basins for week 1, week 2, week 3 and week4.

53. What does IMD do for monitoring and forecasting of urban flooding?

IMD is providing real-time rainfall situation and rainfall intensity with its highly dense AWS/ARG network at major urban cities. The AWS/ARG network is being increased to include more urban cities. Also with Doppler Weather Radar and nowcasting it is providing expected rainfall intensities and warning if any in the major cities of India to avoid urban flooding. In

addition to existing services on urban flooding, IMD is starting Impact based forecast (IBF) for major cities from monsoon-2020 onwards. However proper urban drainage system is the key issue in urban flood management.

54. What is IFLOWS? How does it work?

IFLOWS is a monitoring and flood warning system that will be able to relay alerts of possible flood-prone areas anywhere between six to 72 hours in advance. The primary source for the system is the amount of rainfall, but the system also factors in tidal waves and storm tides for its flood assessments.

The system has provisions to capture the urban drainage within the city and predict the areas of flooding. The system comprises seven modules- Data Assimilation, Flood, Inundation, Vulnerability, Risk, Dissemination Module and Decision Support System.

The system incorporates weather models from the National Centre for Medium Range Weather Forecasting (NCMRWF), India Meteorological Department (IMD), field data from the rain gauge network of 165 stations set up by Indian Institute of Tropical Meteorology (IITM), BMC and IMD. It has been launched for Mumbai city on 12th June 2020.

55. What are the gap areas in monsoon monitoring and forecasting?

Monsoon forecasting was a grand challenging problem for a very long time and significant progress is made after Monsoon Mission program was launched by Ministry of Earth Sciences, Government of India. Forecasts have improved significantly in recent decade with long lead times (short range forecasts -3 to 5 days, Extended range forecasts up to 3 weeks and long range forecasts 2 to 4 months lead time). Major gap areas of monsoon forecasting are

1. Systematic biases in mean state of monsoon in present day weather/climate models (Dry and cold bias in Coupled models and wet bias in atmospheric models).
2. If present day models get mean state correctly then they miss to capture reasonable interannual variability vice versa.
3. Interconnections of Indian summer monsoon and Indian Ocean SST is not correct in present day models.

Monitoring of boundary layer and upper air is very much essential to address the above gap areas and at present we have very few observations in the boundary layer and upper air. Enhancing the sampling in these areas over India will significantly reduce the systematic biases in the present day models. Extension and development of observational network will helpful for the better monitoring of monsoon especially for extreme rainfall events.

56. What are the science issues?

- How and why the interannual variability of monsoon is controlled beyond El Nino and Indian Ocean Dipole (Equinoo)?

- How to improve the synoptic variability (first building block of interannual variability of monsoon) in present day climate models?

- What is required to represent clouds accurately in the present weather forecasting and climate models?

57. What is the future plan of IMD for monsoon monitoring and forecasting?

- Operationalising the Impact Based Forecast (IBF) for major cities.
- Exploring the use of Artificial Intelligence and Machine Learning techniques (AIML) for weather services during monsoon season.
- Increasing the number of Automatic weather stations (AWS) and Automatic rain gauge stations (ARG).
- Enhanced and sustained observations in the monsoon region particularly in the boundary layer and upper air.
- Weather/climate models will be using very high resolution coupled models (Short range: 5km globally and 1 km locally; Extended and long range forecast: 25 km) with improved physics constrained by observations to improve the accuracy of weather/climate predictions including cyclones. The models also will employ Artificial Intelligence and Machine learning techniques to improve the accuracy of the forecasts.
- Multi-model ensemble forecasting for the short to medium range using various models of the MoES institutions.
- Monitoring of monsoon for South-Asia region.
- Operationalisation of Multi Model Ensemble (MME) technique for seasonal prediction.
- Development of integrated mobile app for weather information.
- Expansion of the Doppler Weather radar (DWR) network.
- Enhancement of the in-house research activities related to monsoon.