

**भारत सरकार**  
**GOVERNMENT OF INDIA**  
**भारत मौसम विज्ञान विभाग**  
**INDIA METEOROLOGICAL DEPARTMENT**  
**LONG RANGE FORECAST**  
**FOR**  
**2009 SOUTHWEST MONSOON**  
**SEASON (JUNE-SEPTEMBER) RAINFALL**

**1. Background**

India Meteorological Department (IMD) issues operational long range forecasts for the southwest monsoon rainfall in two stages. First stage forecast is issued in April and the second stage forecast is issued in June. This year, the first stage forecast for the southwest monsoon rainfall over the country was issued on 17<sup>th</sup> April, 2009. IMD has now prepared the second stage forecasts.

**2. First Stage Forecast issued on 17<sup>th</sup> April, 2009**

*“IMD’s long range forecast for the 2009 southwest monsoon season (June to September) is that the rainfall for the country as a whole is likely to be Near Normal. Quantitatively, monsoon season rainfall is likely to be 96% of the long period average with a model error of  $\pm 5\%$ . The Long period average rainfall over the country as a whole for the period 1941-1990 is 89 cm.”*

**3. Second Stage Forecasts**

The following forecasts are being released now:

- a) Forecast update for the southwest monsoon season (June-September) rainfall over the country as a whole using a 6-parameter ensemble statistical model with a model error of  $\pm 4\%$ .
- b) Forecast for the monthly rainfall over the country as a whole for the months of July & August using separate principle component regression models with a model error of  $\pm 9\%$ .

c) Forecasts for the southwest monsoon season (June-September) rainfall for the following four broad geographical regions of India using separate multiple linear regression models with a model error of  $\pm 8\%$ :

**Northwest India** – Jammu and Kashmir, Himachal Pradesh, Punjab, Rajasthan, Haryana, Chandigarh, Delhi, Uttaranchal and Uttar Pradesh.

**Northeast India** – Arunachal Pradesh, Meghalaya, Assam, Nagaland, Manipur, Mizoram, Tripura, Sikkim, West Bengal, Bihar and Jharkhand.

**Central India** – Gujarat State, Madhya Pradesh, Chattisgarh, Maharashtra, Goa and Orissa.

**South Peninsula** – Andhra Pradesh, Karnataka, Tamil Nadu, Kerala, Lakshadweep and Andaman and Nicobar Islands.

#### **4. Details of the Operational Statistical Models**

##### **New Statistical Forecasting System for the Seasonal Rainfall over the Country as a Whole**

The 6 predictors used in the new statistical ensemble forecast model are: North Atlantic Sea Surface Temperature (December + January), Equatorial SE Indian Ocean Sea Surface Temperature (February + March), East Asia Mean Sea Level Pressure (February + March), Central Pacific (Nino 3.4) Sea Surface Temperature Tendency (MAM-DJF), North Atlantic Mean Sea Level Pressure (May) and North Central Pacific Zonal Wind at 850hPa (May).

In the ensemble method, instead of relying on a single model, all possible models based on all the combination of predictors are considered. With 6 predictors, 63 different models can be developed. Out of these 63 models, few best models were selected based on its skill in predicting monsoon rainfall during a common period and ensemble mean was computed as the weighted average of the forecast from the selected models. The weights are proportional to the multiple correlation coefficients of the models during the training period. For developing the models, two different statistical techniques namely, Multiple Regression (MR) and Projection Pursuit Regression (PPR) were considered. Verification of the results with the past data

showed that the ensemble method performed better than the individual models. The model error of the ensemble forecasting system is  $\pm 4\%$ .

#### **4.2. Principle Component Regression Models for Monthly (July & August)**

##### **Rainfall over the Country as a whole**

For the forecast of July rainfall over the country as a whole, a principal component regression model with 5 predictors was used. The predictors used are: East Asia mean sea level pressure (February), North Atlantic sea surface temperature (December of previous year), north America mean sea level pressure (January), North Atlantic mean sea level pressure gradient (March) and North Central Pacific zonal wind at 850hPa (May). The model was trained using data of 1958-2000 and the independent verifications were made using the data of 2001-2008. The model error of the model for July rainfall is  $\pm 9\%$ .

For the forecast of August rainfall over the country as a whole, a principal component regression model with 6 predictors was used. The predictors used are: South Atlantic mean sea level pressure (April), Southeast Pacific sea surface temperature (May), NINO 3.4 sea surface temperature tendency (MAM-DJF)), South Pacific zonal wind at 850hPa (April), outgoing long wave radiation over tropical North Atlantic (March), and outgoing long wave radiation over sub tropical North Atlantic (June). The model was trained using data of 1975-2000 and the independent verifications were made using the data of 2001-2008. The model error of the model for August rainfall is  $\pm 9\%$ .

#### **4.3. Multiple Linear Regression Models for the Seasonal Rainfall over the four**

##### **Broad Geographical Regions of India**

For the forecasting of Southwest monsoon season rainfall over the four broad geographical regions of India (NW India, Central India, South Peninsula and NE India), multiple regression (MR) models were developed using 4, 5, 5 and 4 parameters respectively.

The 4 parameters used in the model for NW India are; North Atlantic surface mean sea level pressure gradient (May), South Atlantic surface mean sea level pressure (January), East Asia surface mean sea level pressure (February + March) and North Central Pacific Zonal Wind at 850hPa (May).

The 5 parameters used in the model for Central India are; Equatorial Indian Ocean surface mean sea level pressure (November of previous year), Northwest Europe surface mean sea level pressure (January), North Atlantic sea surface temperature (December +January), North Atlantic surface mean sea level pressure gradient (May) and North Atlantic surface mean sea level pressure (March).

The 5 parameters used in the model for South Peninsula are; Southeast Indian Ocean mean sea level pressure (May), Southeast equatorial Indian Ocean sea surface temperature (October of previous year), Northwest Europe land surface air temperature (January), Southeast Pacific surface mean sea level pressure (May), Northwest Pacific zonal wind at 850hpa (February).

The 4 Parameters used in the model for the North-East India are: South Atlantic mean sea level pressure (January), North Atlantic mean sea level pressure Pressure (April), Southwest Pacific sea surface temperature (March) and Central Pacific sea surface temperature (May).

All the four multiple linear regression models have model errors of  $\pm 8\%$  of LPA.

## **5. Experimental Dynamical Model Forecast**

In 2004, a dynamical forecasting system was installed at IMD Pune. The seasonal forecast model (SFM) of Experimental Climate Prediction Center (ECPC), USA was adopted for this purpose. This model was used to prepare the seasonal monsoon forecasts for the period 2005-2008. For the preparation of experimental dynamical model forecast for 2009 monsoon season, persisting May sea surface temperatures were used as the boundary conditions. Ten ensembles were obtained using the initial conditions corresponding to 00Z from 21<sup>st</sup> May to 30<sup>th</sup> May 2009. The model climatology was prepared using the observed SSTs during the period 1985-2004. The hindcasts during the period 1985-2004 suggested satisfactory performance of the model over the Indian region.

*The experimental ensemble forecast for the 2009 Southwest monsoon season rainfall suggests normal rainfall is likely over most of parts of the country except some parts of west coast where the below normal rainfall is likely and northeastern most parts of the country where the above normal rainfall is likely. For the country as a whole the dynamical model suggests normal rainfall.*

## **6. Forecast from Other Institutes**

IMD has taken into account the experimental forecasts prepared by the national institutes like Indian Institute of Tropical Meteorology (IITM), Pune, Indian Institute of Science (IISc), Bangalore, Space Applications Centre (SAC), Ahmedabad, National Aerospace Laboratories (NAL), Bangalore, Centre for Mathematical Modelling and Computer Simulation (CMMACS), Bangalore, National Centre for Medium Range Weather Forecasting (NCMRWF), Noida and Centre for Development of Advanced Computing (C-DAC), Pune and operational/experimental forecasts prepared by international institutes like World Meteorological Organization (WMO)'s Lead Centre for Long Range Forecasting - Multi-Model Ensemble (LRFMME), the National Centers for Environmental Prediction (NCEP), USA, International Research Institute for Climate and Society (IRI), USA, Meteorological Office, UK, the European Center for Medium Range Weather Forecasts (ECMWF), UK, the Experimental Climate Prediction Center (ECPC), USA, and Asian-Pacific Economic Cooperation (APEC) Climate Centre, Korea.

*In general, the experimental forecasts based on both statistical and dynamical models suggest below normal to normal monsoon season rainfall over the country as a whole.*

## **7. Conditions over the equatorial Pacific and Indian Oceans**

The recent La Nina event that started in early December 2008 has ended. Since the middle of April, 2009, ENSO neutral conditions are prevailing with positive SST anomalies observed over the equatorial Pacific from the beginning of May. The latest observations and forecasts from both dynamical and statistical models suggest high probability (about 60%) for El Nino conditions to appear during the monsoon season. The probability for ENSO neutral conditions is about 40% and that for La Nina is negligible.

It is important to note that other factors such as the Indian Ocean Sea surface temperatures also influence the monsoon rainfall over India in addition to El Niño and La Niña events. Forecasts from few climate models suggest possibility of the development of a weak positive Indian Ocean Dipole event during the 2009 monsoon season, which may not have much impact on the Indian monsoon. However, IMD is carefully monitoring the possible evolution of El Nino conditions over Pacific and the Indian Ocean Dipole.

## 8. Summary of the Second Stage Forecasts

### i) South-West Monsoon Season Rainfall

IMD's long range forecast update for the 2009 south-west monsoon season (June to September) is that the rainfall is likely to be below normal. Quantitatively, monsoon season rainfall for the country as a whole is likely to be 93% of the long period average with a model error of  $\pm 4\%$ . The Long period average rainfall over the country as a whole for the period 1941-1990 is 89 cm.

### ii) Monthly (July & August) Rainfall

Rainfall over the country as a whole in the month of July 2009 is likely to be 93% of its LPA and that in the month of August is likely to be 101% of LPA both with a model error of  $\pm 9\%$ .

### iii) Rainfall over Broad Geographical Regions

Over the four broad geographical regions of the country, rainfall for the 2009 South-West Monsoon Season is likely to be 81% of its LPA over North-West India, 92% of its LPA over North-East India, 99% of its LPA over Central India and 93% of its LPA over South Peninsula, all with a model error of  $\pm 8\%$ .

The long period average and coefficient of variation of rainfall based on the 1941-1990 data for all India and 4 broad geographical regions are given below along with the forecast:

Area	Long period Average (mm)	Coefficient of variation (%)	Forecast (% of LPA)
All India (June to September)	890	10	93
All India (July)	293	13	93
All India (August)	262	14	101
NW India	612	19	81
Central India	994	14	99
NE India	1429	8	92
South Peninsula	725	15	93

**New Delhi**  
**The 24th June 2009**  
**3rd Asadha 1931 (SE)**

**AJIT TYAGI**  
**Director General of Meteorology**