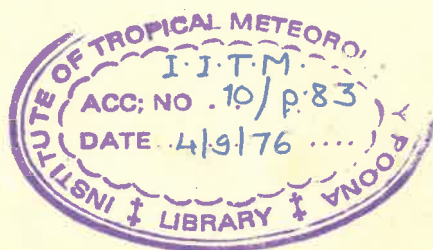


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**INDIAN INSTITUTE
OF
TROPICAL METEOROLOGY**

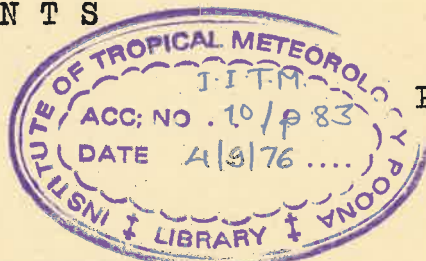


**ANNUAL REPORT
1974-75**

**RAMDURG HOUSE, UNIVERSITY ROAD, POONA-5.
INDIA**

C O N T E N T S

	Page
1. INTRODUCTION	1
2. RESEARCH AND DEVELOPMENT	5
2.1 Synoptic and dynamic meteorology	7
2.2 Climatological studies	15
2.3 Hydrometeorology	17
2.4 Weather Modification	22
2.5 Atmospheric Electricity	22
2.6 Development of Meteorological Payload	23
2.7 Meteorological Instrumentation	23
3. PUBLICATION	25
3.1 Papers published/accepted for publication in Journals	27
3.2 Prepublished research reports	31
4. PARTICIPATION IN SEMINARS/SYMPOSIA/MEETINGS AND CONTRIBUTION OF PAPERS	33
4.1 Participation in Seminars/Symposia/Meetings	35
4.2 Papers contributed	36
5. COLLABORATION WITH UNIVERSITIES AND OTHER SCIENTIFIC INSTITUTIONS	39
6. FACILITIES FOR RESEARCH EXTENDED TO OTHER INSTITUTIONS	43
7. VISITORS	47
8. GENERAL	51
Appendix I. Members of the Governing Council	
Appendix II. Officers of the Institute	



1. INTRODUCTION

The Indian Institute of Tropical Meteorology which was converted into an autonomous research organisation attached to the Ministry of Tourism and Civil Aviation, Government of India, with effect from 1.4.1971, to enable it to pursue its scientific objectives in an atmosphere of academic freedom, entered its fourth year of activity on April 1, 1974. During the year under review, the scientists of the Institute pursued studies on various aspects of synoptic and dynamic meteorology, climatology, hydrometeorology, cloud physics, weather modification, theoretical meteorology and meteorological instrumentation and made a number of research contributions as evidenced by published papers.

The Governing Council of the Institute at its eighth meeting held on October 17, 1974 decided that research work in the Institute should be organised on project basis and that instead of diversifying efforts by taking up a large number of research projects, only a limited number of specific research projects should be undertaken and studied in depth. Work on formulation of the specific research projects made considerable progress during the year under review.

Dr. K. R. Saha was appointed the Director of the Institute with effect from July 11, 1974.

2. RESEARCH AND DEVELOPMENT

2.1 Synoptic and dynamic meteorology

2.1.1 Prognostic models

(a) Divergent barotropic model

Divergent barotropic model with wind as input already developed in the Institute was successfully applied to predict the movements of a monsoon depression and a tropical cyclone. The vector-error was 55 km in a 24-hour prediction and 110 km in a 48-hour prediction in the case of monsoon depression whereas, the corresponding errors in the case of tropical cyclone were zero km, and 110 km respectively.

(b) Primitive equation barotropic model

Integration of primitive equation barotropic model using quasi-Lagrangian advective scheme with real time data developed instability after 9-12 hours of integration. It appeared that this instability might be due to improper smoothing or boundary specification. Suitable steps are being taken to remove the cause of this instability.

(c) Multi-level primitive equation model

Preparation of initial data for a limited-area 5-level primitive equation model is in progress.

A computer programme to incorporate cumulus scale heating in numerical models based on Kuo's formulation was tested.

(d) Storm Surge Prediction model

A fine-mesh linear barotropic storm surge prediction model including bottom friction and a coarse-mesh (grid length is 3 times the grid length of fine mesh) version of it excluding the bottom friction were formulated. The two models were tested independently for an idealised storm case, utilising the depth contour data of the Bay of Bengal. The work on coupling these two grid systems, with the fine-mesh along the sea coast and the coarse-mesh in the open sea is in progress.

2.1.2 Medium Range Forecasting

Certain characteristics of time and space averaged rainfall such as frequency distribution, persistence, and inter-correlation between different sub-divisions of India were studied. The mean 700 mb surface was classified in 3 categories for each monsoon month by visual examination as well as by fitting orthogonal surfaces. Correlations between certain basic parameters and rainfall were developed and attempts were made to correlate these parameters with the observed state. Orthogonal polynomials were fitted to a 700 mb contour surface covering wider area and these will be treated as parameters in forecasting. Data for two more levels (viz. mean sea level, 500 mb) have been collected to find their usefulness in precipitation forecasting on experimental basis.

2.1.3 Diagnostic monsoon studies

(a) ISMEX - 1973

The data collected during the Indo-USSR monsoon experiment 1973 (ISMEX 1973) were processed during the year. The Institute collaborated with the India Meteorological Department at Poona in the analysis of synoptic weather charts for the ISMEX period. The detailed structure of the boundary layer over the Arabian sea and its changes under different synoptic conditions are being investigated. In one of the studies, the ISMEX data were utilised to determine the structure of the moisture field during the active and weak monsoon conditions and the role of vertical motion in maintaining the typical moisture distribution in the horizontal and vertical directions was highlighted.

(b) Low-level jet over Western Indian ocean and monsoon rainfall over India

Low level wind field during the northern hemisphere summer season over the west Indian Ocean and the Arabian sea has been the subject of another study. It is brought out that the low level jet stream over these regions is not continuous in space from north Malgassy to the central Arabian sea, but the wind strengthening occurs at three distinct locations, viz., (i) near the northern tip of the Malagassy Republic, (ii) near Garissa over the equatorial belt of west Indian ocean,

and (iii) near Socotra island in the Arabian sea. It has been suggested that while orographic features may play dominant role in strengthening the air current over the first two regions, the winds near Socotra island in the Arabian sea is largely geostrophically controlled. The role of the east African mountains in causing the flow of the monsoon over the Arabian sea and towards India has also been highlighted. It has also been shown that while the pulsatory character of the cross-equatorial flow near the east African coast may be affecting the monsoon flow over the Arabian sea, it has no apparent predictive value for the rainfall over the west coast of India, the latter being controlled by the synoptic systems forming over the Indian region itself.

(c) Monsoon rainfall in relation to vorticity

A study on the large-scale rainfall over India in relation to changes in the lower tropospheric and upper tropospheric vorticity field over India has been completed. It has been shown that in the rainy spells, when the large-scale lower tropospheric vorticity over India is cyclonic, the lower troposphere and upper troposphere get vertically coupled and this coupling is very weak during the weak monsoon i.e. comparatively dry spell regime. A tentative model of this coupling is also suggested.

(d) Low pressure systems on the monsoon trough

The data collected for the categorisation of weather types during the southwest monsoon for over 20 years has been subjected to a detailed study of the pressure field such as the north-south pressure gradient over India, the position and intensity of the monsoon trough and the formation and dissipation of cyclonic systems in the monsoon region. It is shown that the low pressure systems in the monsoon trough over India which have a predominant separation of about 1500 km and a periodicity of about 3-8 days are very important in maintaining the activity of the rains over the central parts of the country.

- (e) Relationship between Fort Dauphin pressure and Indian rainfall

Lag correlations between the rainfall over different belts of the west coast of India and pressure over sub-tropical Indian ocean (Fort Dauphin) were worked out based on 30 years of data. It is found that the rainfall during August over Kerala coast is positively correlated with pressure during July at Fort Dauphin.

- (f) Monsoon flux divergence and rainfall over peninsula

The study regarding the behaviour of the moisture fluxes across the east coast of India has been taken up for the different years of the south west monsoon season. This study together with a similar study for the west coast of India, which is already completed, will be used to compute the water vapour budget for the Peninsular India.

- (g) Hemispheric anomalies associated with strong and weak monsoon conditions over India

Spherical harmonic analysis of the observed mean monthly geopotential charts of April to August at 700 and 300 mb levels for a few years representing normal, weak and active monsoon conditions over India has been completed.

The energy in different wave numbers and nonlinear interactions between various wave numbers are calculated for the above cases.

The hemispheric anomalies as depicted by the analysis are correlated with the rainfall anomalies over the Indian region during the monsoon season.

- (h) Dynamical parameters derived from analytical functions and the activity of the Indian monsoon

The July normal zonal winds along longitude $77\frac{1}{2}^{\circ}$ E and $87\frac{1}{2}^{\circ}$ E between latitudes 5° N and 25° N at isobaric levels 850 mb to 150 mb were fitted with parabolic curves.

Similar analysis is under progress for a few more years representing normal, weak and active monsoon conditions over India along longitude $77\frac{1}{2}^{\circ}\text{E}$. The different parameters are compared with the normal case and anomalies correlated with the activity of Indian monsoon.

- (i) Spherical harmonic analysis of the constant pressure charts in the northern hemisphere

On the spherical earth, the spherical harmonics constitute the most natural set of orthogonal functions for the study of the planetary scale meteorological system. It is believed that the large-scale anomalies in the behaviour of the Indian summer monsoon are dynamically related to the anomalies of the global flow patterns.

A first step in this direction would be to have qualitative representation of the global northern hemispheric charts for various levels so that one can then qualitatively work out the departure of the observed patterns from the normal patterns.

Monthly northern hemispheric constant pressure charts are subjected to spherical harmonic analysis for $m = 0, 1, 2, \dots, 18$ and $n-m = 0, 2, 4, \dots, 18$ where m is number of waves along latitude circle and $n-m$ is the number of nodal points between north pole and south pole excluding the poles. The features of normal contour pattern are studied in details. They have been compared with the corresponding charts for strong and weak monsoon conditions. The energy in different wave numbers and the nonlinear interaction between them are studied.

- (j) Oscillations in the monsoon trough

The area of low pressure over the Indo-Gangetic plain in the southwest monsoon season is commonly known as monsoon trough. The axis of monsoon trough is not stationary but oscillates to the north and south of Indo-Gangetic plain. The area of the rainfall also frequently shifts in association with changes in the location of monsoon trough. Hence the oscillations of monsoon trough have an important bearing on a short period prediction of

rain over India. The day to day variations in the position of monsoon trough across longitudes 75°E , 80°E and 90°E for the months of July and August of 1966-1970 were examined by means of power spectrum analysis to investigate quantitatively the period of oscillation of monsoon trough. The study reveals a mean period of ten-day oscillations in the monsoon trough. The power spectrum analysis of zonal component of surface wind at selected stations in the zone of monsoon trough lends strong support to the mean period of ten days oscillation in the position of monsoon trough.

- (k) Recent Trends in southwest monsoon rainfall of Arid and semi-Arid regions of northwest India

Winstanley's speculation on the contraction of meridional tropical circulation leading to low monsoon rainfall in recent years over northwest India and Sahel zone evoked considerable interest not only in India but also elsewhere. One would expect decreasing trend in the monsoon rainfall of stations of northern latitudes and increasing trend at some stations of lower latitudes if there is contraction in monsoon circulation. But the recent trends in southwest monsoon rainfall of New Delhi, Nagpur and Hyderabad which are located almost along the same longitude but different latitudes does not support the speculation on contraction of monsoon circulation. However, 500 mb-height along 40°N between 110°W and 70°E of October-May shows significant influence on subsequent monsoon rainfall of northwest Indian station of Arid and semi-Arid regions. The trend from 1950s to early 1960s was towards higher rainfall but the trend has since been completely reversed.

The decreasing trend in monsoon rainfall since 1960s appears to be due to restricted westward movement of monsoon storms/depressions which are the most important monsoonal circulation systems responsible for spreading rainfall. It is probable that the abnormal southward extent of the troughs in circum-polar westerlies has restricted the westward movement of monsoon storms/depressions controlling the monsoon rainfall of northwest India. Further it is found that annual sunspot number has high positive correlation with 500-mb height along 40°N , and with rainfall of northwest India and significant

negative correlation with westward extent of monsoon storms/depression. If this rainfall/sunspot cycle relationship continues then anticipating 1978 as the peak year of the next solar cycle we would expect southwest monsoon rainfall of northwest India to increase until about 1978-79 and then decline.

(1) Vagaries of the monsoon during the last ten years

A study was made to find out the percentage area of India under 'deficient' and 'scanty' rainfall during the summer monsoon season. It is seen from this study that (i) during the last ten years, there were as many as 5 years viz. 1965, 1966, 1968, 1972 and 1974 when 44 to 60 percent of the country's area was under the combined category of deficient and scanty rainfall, whereas during the preceding 18-year period, 1947-1964, there were only three occasions when percentage varied from 25 to 33, (ii) the minimum percentage area (generally 5 percent) under this category is found to recur with regularity every three years from 1958 onwards. This means that the good performance of the monsoon is being repeated every three years from 1958 onwards and that 1976 can be expected as a good monsoon year.

(m) Hydrodynamic Instability

The role played by the hydrodynamic instabilities of the tropical zonal flow in the generation and maintenance of tropical disturbances especially in the Indian ocean region is being explored. The work on the formulation of barotropic, baroclinic and mixed instability models has been started. An eigen-value approach of evaluating the instability structure and energy transformations of the zonal current is being adopted in the study.

2.1.4 Theoretical Studies

(a) General circulation spectral model

To study the monsoon as a global phenomenon and its role in the general circulation, simulation of mean monsoon circulation over India and oscillation in monsoon trough position has been undertaken. For this purpose, a multi-level primitive-equation spectral model is proposed

a
to be developed. As first step, the development of divergent barotropic spectral model has been undertaken. Formulation, computer programming and some initial testing have been completed for this barotropic model. For time integration of the spectral model, matrix inversion programme has been tested and results are verified. Now testing is going on for the time integration part of the spectral model. Computational time of the model is considerably reduced by using fast numerical algorithm for some of the subroutines.

(b) Mathematical studies connected with the spectral model

The iterative method of Oliver Aberth has been chosen, with some modifications to make it, particularly, applicable for finding out all zeros of Legendre polynomial simultaneously. It is noticed that Legendre polynomial expansion involving multiples of angle is very much suitable for calculating values and its derivatives in comparison to the power series expansion because the former has much less round-off error. The zeros of the Legendre polynomial upto degree sixty have been obtained; only two decimal places were lost in computation. Three different methods suitable for rhomboidal truncation have been chosen for generating associated Legendre polynomial. Round-off error, computation time and stability of each method are studied in detail in order to develop a method which will generate associated Legendre polynomial upto a high order of accuracy.

(c) Annual temperature oscillation in the northern hemisphere

Annual heating cycle on the global scale is shown by the thickness oscillations from the lowest layers to the top of the troposphere in the northern hemisphere. The study has revealed that the heat low which appears over southeast Asia during the summer monsoon is partly due to the permanent warm temperatures over the region. It is, therefore, suggested that the special features of the annual monsoon of southeast Asia are mainly due to special permanent features of temperature field over the

area rather than due to very special features of the annual temperature oscillation over the area. The three-dimensional analyses of phase and amplitude of the annual oscillation suggest that perhaps one and the same physical mechanism is responsible for the diabatic heating in the entire troposphere.

(d) Planetary Boundary Layer Studies -
Baroclinic Ekman Layer

The Ekman-Taylor solution for barotropic boundary layer in the atmosphere is well known. It is also known that second order differential equation for the Ekman layer is valid not only for a barotropic layer in which geostrophic wind is constant with height but also equally well for that baroclinic layer in which geostrophic wind is a linear function of height. It follows that if we can break up Ekman layer into a series of sub-layers such that one can reasonably assume geostrophic wind to vary linearly with height in each sub-layer, then the differential equation can be applied to an Ekman layer having any plausible and continuous distribution of geostrophic wind with height. This technique is applied in this paper with good success. The baroclinic model gives considerably better result than the equivalent barotropic model. The location for which the technique is illustrated is in southwest Arabian sea off Somali coast where strong upwelling of the sea during the summer monsoon causes strong horizontal gradients in the sea surface temperature as well as in the overlying atmospheric boundary layer.

2.2 Climatological studies

2.2.1 A study of trends and periodicities in the seasonal and annual rainfall of India

The seasonal and annual rainfall of India have been worked out for each year of the 60-year period from 1901 to 1960 by using the data of about 3,000 raingauges distributed uniformly all over the country. These time series of rainfall have been intensely studied by subjecting them to the latest statistical techniques. This analysis has brought out that the mean annual rainfall is 119 cm with a standard deviation of 9.5 cm. Fisher's

measures of skewness (g_1) and kurtosis (g_2) are not significantly different from those for the normal distribution. Chi-square test also generally confirms that the frequency distribution of these time series is normal for the seasonal and annual rainfall distributions. Significant increase of 5 percent in 30 years' mean is observed in the southwest monsoon and the annual rainfall. Power spectrum analysis has revealed the presence of 2.3 to 2.5 years' cycle and a weak cycle of about 10 to 15 years.

2.2.2 A study of human comfort at a few stations in India

A study of discomfort indices at 16 important stations spread all over India has been made by using Thom's (1950) formula. Hourly mean monthly temperature and relative humidity values for the 10-year period between 1957 to 1968 have been used to calculate discomfort indices for each hour of the day and separate figures have been drawn for each of the stations showing discomfort and comfort periods during the year. Such bio-climatological studies are helpful in planning airconditioning systems, in choosing health resorts and tourist centres etc.

The thermal comfort scale proposed by Parthasarathy and Rakhecha (1972) has been utilised in finding out comfort and discomfort regions of the country. This study has shown that the five-month period from October to February happens to be the best comfort period throughout the country excepting at a few north Indian stations. This study has shown that Bangalore is the place where most comfortable conditions exist almost throughout the year while June to September period is the best period so far as Srinagar is concerned.

2.2.3 Climatological Discontinuities in the monsoon activity in the neighbourhood of Western Ghats

The major climatological discontinuities in the monsoon activity from July to August and from August to September, as measured by rainfall, in the neighbourhood of the Western Ghats have been studied by utilising rainfall data for 1901-1950 from a close network of stations.

The criterion for major discontinuity is based on the quartiles of rainfall distribution. It is found that (a) from July to August, the major discontinuity exists, between 9°N to 18°N on the west coast, in the belts $16^{\circ} 30'\text{N} - 18^{\circ}\text{N}$ and $12^{\circ}\text{N} - 14^{\circ} 30'\text{N}$ just to the east of the Ghats and no discontinuity is observed further east of the Ghats and beyond some distance west of the west coast, (b) from August to September, the major discontinuity exists, between $11^{\circ} 30'\text{N}$ and $14^{\circ} 30'\text{N}$ on the west coast and at a few isolated stations only just east of the Ghats, (c) the Western Ghats appear to play a differential role, enhancing rainfall substantially under favourable conditions during July and decreasing rainfall substantially under unfavourable conditions thereafter with the advance of the season.

2.3 Hydrometeorology

2.3.1 A study of maximum one-day point rainfall of different return periods over north Indian plains taking district as a unit

A study has been made of maximum one-day point rainfall for different return periods from 2 to 100 years using the rainfall data of about 1000 long-period stations whose data are continuously available for the last 40 to 70 years in the plains of north India, roughly north of $\text{Lat. } 20^{\circ}\text{N}$. Gumbel technique as adopted by Chow has been used in the analysis of individual station's rainfall data. On the basis of this study, 2-year generalised rainfall chart for the entire north Indian area has been prepared. Considering a district as the smallest homogeneous unit, average district ratios of 2-year to 5, 10, 25, 50 and 100-year rainfall were obtained which can be used to obtain maximum point rainfall of different return periods for any station in north India knowing 2-year rainfall value and the average district ratio. These estimates of one-day point rainfall for different return periods can be helpful in the design of small hydraulic structures. This study has shown that for the entire north Indian plains, 100-year one-day rainfall is about 2.3 times the 2-year rainfall while in USA the ratio is of the order of 2.2. Similarly, the value of the frequency factor K_m in the equation $X_{100} = \bar{X} + K_m \cdot S$ was found to be of the

order of 3.35 instead of 3.50 as obtained by Hershfield on the basis of USA rainfall data.

2.3.2 Time distribution of intense rainfall associated with depressions/cyclonic storms over north Indian plains

Heavy rainfall associated with 54 severe rainstorms which occurred over the plains of north India in association with the passage of depressions/cyclonic storms was studied using the observational-day rainfall data of the period 1880 to 1971. Each rainstorm was first analysed by depth-area-duration method and maximum areal rain depths were obtained for areas of 500 (i.e. 1296 sq. km.), 1000 (2592 sq. km.), 3000 (i.e. 7776 sq. km.), 5000 (i.e. 12960 sq. km.) and 10,000 sq. miles (i.e. 25920 sq. km.) for first, second and third day of the storm. It was observed from this study that over an area, rainfall associated with depressions/cyclonic storms generally gave maximum rain depths for a duration of about three days and therefore, in this study, rain spells of 3-day duration have been considered. From these statistics, rain depths for each day of the rain spell were converted into percentiles of 3-day rain depths. Using this data, average time distribution models were prepared for different sizes of area. This study has, however, shown that area does not play any major part in affecting time distribution of rainfall in intense rainstorms.

2.3.3 A study of major rainstorms over and near Mahi basin upto Kadana dam site for the evaluation of probable maximum design storm

Mean monthly and annual rainfall of the Mahi basin upto Kadana dam site has been worked out by the isohyetal method on the basis of rainfall data of the period 1901 to 1950. Highest rain depths actually experienced by the Mahi basin upto Kadana dam site during the period 1902 to 1962 were also worked out for 1, 2 and 3-day durations on the basis of maximum rainfall experienced during these duration in each year of the above period.

Using frequency analysis technique, maximum basin rain depths for the return periods of 500, 1000 and 10,000 years were also worked out on the basis of 61-year data of basin rainfall for the use of design engineers and hydrologists.

The July, 1927 rainstorm over north Gujarat was found to be the severest rainstorm over this region; its transposed rain depths over this basin were determined. These were then maximized for moisture charge in order to obtain probable maximum rain depths over the Mahi basin.

2.3.4 Intense rainstorm relationships for north Indian plains

From the analysis of 42 most severe rainstorms over the plains of north India lying between the Himalayan foot-hills and north of Lat. 20°N , average ratios of rainfall over different size areas around the rain centre to the rainfall at the centre of the rainstorm have been worked out for 1, 2 and 3-day durations separately. The average percental ratios for different areas and duration have been fitted by the least square method to the empirical relationships of the form :

$$\text{i) } Y = 100 - KA^n \quad \text{and} \quad \dots \quad \text{(I)}$$

$$\text{ii) } Y = 100 \cdot e^{-KA^n} \quad \dots \quad \text{(II)}$$

where Y is the percentage ratio of the rainfall over an area A surrounding the rain centre to the maximum rainfall at centre of the rainstorm and K and n are the constants. This study has shown that the Equation (II) mentioned above, gives fairly accurate results when compared with the results obtained with the help of Equation (I).

The average ratios of one and two day rain depths as a percent of 3-day rain depths have also been worked out for the plains of north India so that 1 and 2-day rain depths can be estimated if the 3-day depths are known and vice-versa.

2.3.5 A comparative study of potential evapotranspiration over Andhra Pradesh

To compute the potential evapotranspiration, Thornthwaite (1948) and Leeper (1950) developed an empirical formula. An attempt has been made in this paper to get an idea of the magnitude of the difference in the potential evapotranspiration values computed by the two methods for a group of about 16 representative stations in Andhra Pradesh. It has been seen that the potential evapotranspiration values by Leeper's method are less by 2 to 8 cm for hot weather period and by 10 to 13 cm during monsoon period than those computed by Thornthwaite's method. However, there is a fairly close agreement between the values obtained by the above two methods for the winter and post monsoon seasons.

2.3.6 A study of intense recorded rainstorms over Subarnarekha basin upto Ghatsila Dam site and their respective water potentials

All the intense rainstorms which occurred over Subarnarekha basin upto Ghatsila Dam site were examined from the scrutiny of published rainfall records of the period 1902 to 1950. This scrutiny revealed that the following were the periods of the most intense rainstorms which caused heaviest rain depths over the basin upto Ghatsila Dam site :

7-9th July, 1904; 25-27th July, 1906; 5-7th August, 1920; 28-30th July, 1927; 9-11th July, 1942; 3-5th August, 1943 and 10-12th August, 1950.

The water potential generated by the above seven severemost rainstorms upto the above dam site was worked out for different durations of the respective rainstorms. This study has shown that each of the rainstorms of 1942 and 1943 were responsible in generating about 3180 million cubic metres of water. Next to this was the rainstorm of 1904 which generated about 3120 million cubic metres of water.

In the homogeneous region in and around this basin, it was found that the rainstorm of July, 1927 was the severest rainstorm which occurred during the 50-year period. This rainstorm was transposed over this basin and it was found that in the transposed position this storm would have generated a volume of water which was equivalent to 6515 million cubic metres of water had it occurred over the basin. This rainstorm has therefore been recommended as the design storm for the design of spillway capacity of the proposed dam at Ghatsila.

2.3.7 Water potential generated by the unprecedented rainstorm of August, 1973 over Rajasthan

In August, 1973, an intense rainstorm occurred over Rajasthan which caused severe floods in the rivers Luni, Sukri, Badi and Jawai as a result of which large areas in the districts of Jaisalmer, Barmer, Pali and Jalore were flooded for days together.

During this rainstorm, some stations received in one day rain amounts which equalled or exceeded their respective mean annual rain amounts. As an example, Jaisalmer town recorded as much as 20 cm of rain on 16th August 1973, when its mean annual rainfall is hardly of the order of 20 cm.

This study has revealed that during the storm period of 13 to 19th August, 1973 the total volume of water generated over Rajasthan was of the order of 32,293 million cubic metres. This is the first instance when such a huge volume of water was generated in one rainspell over this arid region.

Depth-area-duration analysis of this rainstorm has shown that although this rainstorm was not the severest rainstorm that occurred over the western India, its uniqueness lies in the fact that the entire rainfall yielded by this rainstorm was confined over Rajasthan region only. This was mainly due to the fact that the tropical disturbance which was responsible for causing this rainstorm had its track over Rajasthan region and even when the disturbance recurved, the track still remained over this region causing copious amounts of rainfall over the entire Rajasthan. The volume of rainfall obtained from other severe rain storms over this region in the past 80 years has also been compared

with the volume of water obtained from the August, 1973 rainstorm.

2.4 Weather Modification

Cloud Seeding experiments using aircraft were carried out for the second successive year at Poona during the monsoon season of 1974. During flights, cloud physics parameters such as liquid water content, cloud temperature, cloud dimension, cloud droplet size spectrum, cloud condensation nuclei, aerosols, etc. were measured.

The results of the cloud seeding experiments in Poona area which were conducted on 13 pairs of seedable days during the monsoon season of 1973 showed positive trend on 7 pairs, negative trend on 4 pairs and inconclusive trend on 2 pairs. The results were not statistically significant.

Operational cloud seeding by aircraft was carried out over the Rihand catchment area, for the second successive year. Along with the seeding the usual cloud physics observations were also collected for study.

Evaluation of cloud seeding experiments by radar was also attempted for the second successive year off Bombay coast.

2.5 Atmospheric Electricity

Aircraft instruments for measurement of atmospheric electric field, cloud drop charges and static discharge current during the cloud seeding flights were fabricated.

Measurements of the above parameters were made during seeding flights at Rihand and Bombay in September, 1974.

Continuous measurements of the surface atmospheric electricity parameters were made during fair weather and during disturbed weather, with instruments fabricated at IITM.

2.6 Development of Meteorological Payload

Ten payloads were made ready for flight test.

2.7 Meteorological Instrumentation

- i) For low level sounding few transmitters working on 403 mhz and 202 mhz were designed and tested.
- ii) A vane working on induction principle was designed and a prototype unit was made.
- iii) Timer circuits were designed for printing the acquisition time.
- iv) Different ways of linearisation of thermistors were studied.
- v) Vortex thermometer designed earlier was used again in this year's cloud seeding. One more vortex thermo-meter with direct recording facility was designed for use during aerial cloud seeding over Rihand catchment area.

3. PUBLICATIONS

3.1 Papers published/accepted for publication in Journals

Sr. No.	Title of the paper	Author(s)	Journal in which published
1.	Dynamical abnormalities associated with drought in the Asiatic summer monsoon	R.N.Keshavamurty and S. T. Awade	Ind.J.Met. Geophys. Vol.25, No.2, 1974.
2.	Generalized relationship between maximum raindepth, area and return period of major rainstorms	O.N. Dhar and P. Rakhecha	Accepted for Ind.J.Met. Geophys., Vol.25, No.3, 1974.
3.	A study of droughts by water balance methods over Andhra Pradesh	P. Rakhecha	Accepted for Ind.J.Met. Geophys., Vol.25, No.3,4, 1974.
4.	Results of operational cloud seeding experiment over Rihand catchment in Northeast India	R.K. Kapoor, K.Krishna, U.S. De, I.C.Talwar, K.G.S.Nair, S.K.Sharma and Bh.V.Ramana Murty	Accepted for Ind.J.Met. Geophys., Vol. 25, No. 3, 1974.
5.	Fluctuations in the pattern of distribution of SW monsoon rainfall over Rajasthan and their association with sunspot cycle	H. N. Bhalme	Accepted for Ind.J.Met. Geophys., Vol. 26, No. 1, 1975.
6.	5-6 days oscillations in the pressure gradients over India during SW monsoon	H. N. Bhalme and S.S.Parasnis	Ibid.

Sr. No.	Title of the paper	Author(s)	Journal in which published
7.	Some basic concepts about 'Unit Hydrograph'.	O.N. Dhar	Vayu Mandal, Vol.3, No. 3, 1973.
8.	A study of mean monthly and annual rainfall of contiguous Indian area	O.N. Dhar, B.Parthasarathy and G.C. Ghose	Vayu Mandal, Vol.4, No.2, 1974.
9.	The Pollution Encroching on us	M. Lal	Vayu Mandal, Vol. 4, No. 4, 1974.
10.	Glaciers and their contribution to water resources	O.N. Dhar	Accepted for Vayu Mandal, Vol. 4, No. 4, 1974.
11.	A hydrometeorological study of Sept., 1880 rain-storm which caused the greatest rain-depths over north-west Uttar Pradesh	O.N. Dhar, P. Rakhecha, and B.N. Mandal	Irrigation and Power; Jan., 1975 issue.
12.	A study of human comfort at a few stations in India	B.Parthasarathy and O. N. Dhar	National Geographical Journal, Varanasi, Vol. 20, Part 4, 1974.
13.	Climatology of the Asian Summer Monsoon Rainfall: Controls and Concentration	D. A Mooley	Geographical Review of India, Vol. 37, No. 1, 1975.

Sr. No.	Title of the paper	Author(s)	Journal in which published
14.	A study of major rainstorms over and near Mahi basin upto Kadana dam site for evaluation of Probable Maximum design storm	O.N. Dhar, P. Rakhecha and R.B. Sangam	Ind.J.Power and River Valley Development, Calcutta, Vol.XXV, No.1, 1975.
15.	A numerical study of mountain wave problem	S.M.T.Farooqui and U.S. De	Pure and Applied Geophysics, Switzerland, Vol. 112, (1974/II).
16.	Major Climatological Discontinuities in the Monthly Activity of the summer monsoon over Asia	D. A. Mooley	Pure and Applied Geophysics, Switzerland, Vol. 112 (1974/III).
17.	A Randomized cloud seeding experiment in the Deccan Plateau, India - Preliminary Results	K. Krishna, R.K. Kapoor, A.S.Ramachandra Murty, B.K. Mukherjee, A.M. Selvam, K.K. Kanuga, L.T. Khemani, S.K. Paul, R.Vijayakumar, and Bh. V. Ramana Murty	Weather Modification, U.S.A., Vol.6, No.1, 1974.
18.	Dynamic effect of salt seeding in warm cumulus clouds	A.S. Ramachandra Murty, A.M. Selvam and Bh. V. Ramana Murty	Weather Modification, U.S.A., Vol. VII, March 1975.

Sr. No.	Title of the paper	Author(s)	Journal in which published
19.	Study of dropsize distribution in warm clouds subjected to repeated seeding	R.K. Kapoor, S.K. Paul, A.S. Ramachandra Murty, K. Krishna and Bh.V.Ramana Murty	Weather Modification, U.S.A., Vol. VII March 1975.
20.	Computation of Non- divergent stream function and Irrota- tional velocity Potential from the observed winds	J. Shukla and K. R. Saha	Monthly Weather Review, American Meteorologi- cal Society, Vol. 1, No.6, 1974.
21.	Secular variations of regional rainfall over India	B.Parthasarathy and O.N. Dhar	Quart.J.Roy. Met. Soc., Vol. 100, No.424, 1974.
22.	A study of extreme point rainfall over flash flood prone regions of the Himalayan foothills of north India	O.N. Dhar, A.K. Kulkarni and R.B.Sangam	Hydrological Sciences Bulletin, U.K., Vol.20, No.1, 1975.
23.	Some aspects of the Arabian sea summer monsoon	K. R. Saha	Tellus, Vol.26, No.4, 1974.
24.	A boundary layer model for thermal effects of pollutants in the atmosphere	M. Lal	Archives for Met., Geophys. and Bioclima- tology, Series B, Vol. 23, No. 1 1975.

3.2 Prepublished research reports

Sr. No.	Title of the Research Report	Author(s)	Research Report No.
1.	Energy conversions during weak monsoon	R.N. Keshavamurty and S. T. Awade	RR-015
2.	Vertical motion in the Indian Summer Monsoon	S.T.Awade and R.N.Keshavamurty	RR-016
3.	Semi-annual pressure oscillation from sea-level to 100 mb in the northern hemisphere	G.C. Asnani and R.K. Verma	RR-017
4.	Suitable Tables for application of gamma probability model to rainfall	D. A. Mooley	RR-018
5.	Diabatic heating Model of the Indian Monsoon	G.C. Asnani and S.K. Mishra	RR-019
6.	Annual and semi-annual thickness oscillation in the northern hemisphere	G.C. Asnani and R.K. Verma	RR-020

4. PARTICIPATION IN SEMINARS/SYMPOSIA/
MEETINGS AND CONTRIBUTION OF PAPERS

4.1 The scientists of the Institute participated in the following Seminars/Symposia/Meetings

Seminars/Symposia/Meetings	Name of the scientist who attended
1. Annual Convention of Poona Chapter of Computer Society of India, Poona 14-15 June 1974.	Shri R.Suryanarayana Shri D.R. Sikka
2. National Committee on Global Atmospheric Research Programme, Bombay, 15 July 1974	Dr. K. R. Saha
3. Second informal planning conference on Monex, Singapore, October 28 - 1st November 1974.	Dr. K. R. Saha
4. Indian Science Congress New Delhi, Jan 3-7, 1975.	Dr. K. R. Saha Dr. D. A. Mooley
5. Symposium on climatic change and long range forecasting, Poona, 29-30 January, 1975.	Dr. K. R. Saha Dr. D. A. Mooley Shri H.N. Bhalme Shri K. Raghavan Shri D.K. Paul Shri S.T. Awade
6. Symposium on 'Recent development in the concept and use of water balance', Waltair, 21-22 February 1975.	Shri P. Rakhecha
7. Annual Cyclone Review meeting, Calcutta, 13-14 March 1975.	Shri D. R. Sikka

4.2 Papers contributed to Seminars/Symposia/Meetings

- (A) Annual convention of Poona chapter of computer Society of India, Poona, 14-15 June 1974.
Computer in Weather prediction.
- (B) Fourth Conference on Weather Modification Fort Laurderdale, Florida, U.S.A., 18-21 November, 1974.
Results of warm seeding experiments in three different regions in India during summer monsoon 1973.
- (C) Indian Science Congress, New Delhi, 3-7 January 1975.
 - i) Onset and advance of summer monsoon over Northern Indian Ocean and Indian sub-continent.
 - ii) Major climatological discontinuities in the monsoon activity in the neighbourhood of Western Ghats.
- (D) Symposia on Long Range Forecasting, Poona 29-30 January 1975.
 - i) Hemispheric anomalies associated with strong and weak monsoon conditions over India.
 - ii) Dynamical abnormalities associated with drought in the Asiatic summer monsoon and some dynamical features for long range forecasting.
 - iii) Vagaries of the monsoon during the last ten years.
 - iv) Possible influence of sunspots on monsoon depressions.
 - v) Southern hemispheric influence on Indian rainfall.
- (E) Symposia on Recent Developments in the concept and use of water balance, Waltair, 21-22 February 1975.
 - i) A comparative study of potential evapotranspiration over Andhra Pradesh.
 - ii) A study of intense recorded rainstorms over Subarnarekha basin upto Ghatsila dam site and their respective water potentials.

- iii) Water potential generated by the unprecedented rainstorm of August, 1973 over Rajasthan.
- (F) Second World Congress on water resources to be held in New Delhi during December 1975.
 - i) A review of the hydrometeorological studies of Indian rainfall.
 - ii) Oscillations in the monsoon trough.

5. COLLABORATION WITH UNIVERSITIES AND OTHER SCIENTIFIC INSTITUTIONS

5.1 Collaboration with Universities

- (a) Shri A.S.R. Murty, Senior Scientific Officer, Grade II was awarded Ph.D. degree by Andhra University, Waltair for his thesis entitled 'Ice Nucleation studies by drop freezing technique'.
- (b) Dr. D.A. Mooley, Senior Scientific Officer, Grade I has been recognised as a Post Graduate teacher (by research) by University of Poona in January 1975 for imparting instructions on behalf of the University in Physics.
- (c) Shri Y.S. Gondhalekar, Senior Scientific Assistant, was coopted as a member of the Board of Studies in Geography and Meteorology in February 1975 by Shivaji University, Kolhapur to work for a period of three years.

5.2 Collaboration with other scientific institutions

- (a) Dr. G.C. Asnani, Assistant Director, had discussions on theoretical aspects of monsoon problem with the theoretical physics group of TIFR, Bombay on 24th and 25th June, 1974.
- (b) Shri D.R. Sikka, Senior Scientific Officer, Grade II visited during December 1974 the National Institute of Oceanography (N.I.O.), Panaji to participate in Physical oceanographic data analysis of the Indo-Soviet monsoon experiment. Shri Sikka also gave a Scientific talk on 'Air-sea interactions in global meteorological experiments'.
- (c) Shri D.R. Sikka, also visited during January 1975 the Centre of Theoretical Studies at the Institute of Science, Bangalore on invitation in connection with some studies on the summer monsoon.
- (d) Shri D.R. Sikka delivered a series of lectures on different aspects of satellite meteorology to the participants in Advanced Refresher Course in Satellite Meteorology conducted by the Office of Deputy Director General of Observatories (Forecasting), Poona during March 1975.

6. FACILITIES FOR RESEARCH EXTENDED
TO OTHER INSTITUTIONS

6. Air India Research Fellowship

Shri Shrinivasa Murty was awarded the Air India research fellowship in Tropical Meteorology at the Institute. He joined the Institute in November 1974.

Kumari P.G. Kulkarni was selected for the award of Air India research fellowship in Tropical Meteorology.

7. VISITORS

7. Visitors

- i) Hon'ble Shri Raj Bahadur, Union Minister for Tourism and Civil Aviation and Shri B. Sivaraman, Member (Agriculture), Planning Commission, 29th January 1975.
- ii) Six Air Force Meteorological Officers from Indian Air Force Administrative College, Coimbatore, accompanied by their Instructor, 18th June 1974.
- iii) Shri R.K. Jain, Hydrometeorologist, Central Ground Water Board, Chandigarh, 17th July, 1974.
- iv) Shri V.V. Sinarkar, Associate Dean, College of Agriculture Engineering, Mahatma Phule Krishi Vidyapith, Rahuri, 3rd August 1974.
- v) S/Shri G.P. Kulkarni, V.B. Bhat, P. J. Namjoshi, Civil Engineers and Shri Shekhar, Trainee Engineer from Tata Electric Companies, Bombay, 24th September 1974.
- vi) Mr. M. Azin Zamil and Mr. Taher of Afghan Meteorological Service, 7th September 1974.
- vii) 15 members of Geographers' club of National Defence Academy, Khadakwasla, 25th September 1974.
- viii) Shri P.G. Mate of Omega Science Library, Otur, Dist. Poona, 4th and 5th November 1974.
- ix) Dr. H. Rakshit, Principal Scientific Officer, National Committee on Science and Technology, 19th November 1974.
- x) Dr. S.M. Seth, Reader in Hydrology, University of Roorkee alongwith twenty trainee officers of the 3rd International Hydrology Course of the training centre, 28th December 1974.
- xi) Mr. Fritz Larsoon from Air Force Meteorological Service from Stockhohm, Sweden, 2nd January, 1975.

- xii) Dr. S.O. Krichak, Hydrometeorological Centre of U.S.S.R., Moscow, 31st January, 1975.
- xiii) Prof. Dr. K.R. Ramanathan, Physical Research Laboratory, Ahmedabad, 28th and 29th May, 1974.
- xiv) Dr. (Miss) Durga Ray, visiting Scientists from Indian Institute of Technology, Powai, Bombay, 28th February, 1975.

8. GENERAL

8.1 The Governing Council

The Governing Council of the Institute which consists of nine members including the Director met thrice during the year. List of members is given in Appendix I.

8.2 Facilities

8.2.1 Library, Information and Publication Division

The Division continued the work of documentation, supply of scientific information, publication of research reports, maintenance of library and procurement of special meteorological data required by Institute scientists. During the year under review 41 books were added to the library, 48 Indian and foreign journals were subscribed to and 6 research reports were issued.

8.2.2 Honorary fellowship

The Governing Council of the Institute at its eighth meeting held on October 17, 1974, conferred honorary fellowship of the Institute on Dr. R. Ananthakrishnan, retired Director of the Institute.

8.2.3 Computer

8.2.3.1 Statistics of the working of the computer

The IBM-1620 computer worked during the year in two shifts per day and seven days a week as shown below:

Investigation and Research	:	1979	hours
Data Processing	:	1822	hours
Break-down/Maintenance	:	590	hours
Computer time sold	:	101	hr. 35 mts.

8.2.3.2 44 Special night runs (374 hrs.) of the computer were arranged during the year for the urgent data processing work of DDGC's office.

8.2.3.3 Proposal for a fast Computer

A proposal for the acquisition of a high speed computer by IITM made 3 years ago is still under consideration of the Government.

8.3 Training

8.3.1 Three Junior Scientific Assistants and two Junior Technical Assistants completed the Elementary Training Course in Meteorology conducted by the India Meteorological Department. One Scientific Assistant was deputed for training in Intermediate Course in Meteorology conducted by the same Department.

8.3.2 A FORTRAN Training course with application to Numerical methods was conducted from 10th March to 25th March, 1975. 28 Officers and staff of the Institute and I.Met.D. and 2 Officers of the National Institute of Oceanography, Goa, attended the course.

8.4 Meetings of Academic Council

The academic Council met six times during the year to discuss important matters.

8.5 Meetings of Staff Council

Six meetings of the staff council were held during the year.

8.6 Budget, Accounts and Audit

The Institute received from the Government of India grants-in-aid totalling Rs. 32,90,099 = 56 including the unspent balance of the previous year and other receipts like computer charges, etc. Out of this, an amount of Rs. 29,10,664 = 09 was spent during the year 1974-75.

1973-74 Audit of the Institute accounts for the year was conducted M/s S.N. Doshi and Co., Poona.

8.7 Important Staff changes

8.7.1 Dr. G.C. Asnani, Assistant Director, joined the University of Nairobi, Kenya, on World Meteorological Organisation assignment as Senior Lecturer in Meteorology.

8.7.2 Shri J.A. Kulkarni assumed charge as Accounts Officer on 1.8.1974 (F/N).

8.7.3 Shri V.S. Kamavisdar, Junior Administrative Officer, was relieved on August 31, 1974 (A/N) on reversion to Geological Survey of India.

8.7.4 Retirement

Shri H. Mitra, Assistant Director, retired from service on the afternoon of March 31, 1975 on superannuation.

Names and addresses of the members of the
Governing Council during 1974-75 :

- | | | |
|----|--|---------------------------------------|
| 1. | Dr. P. Koteswaram,
Director General of Observatories
Lodi Road, New Delhi 110 003. | Chairman ⁺
(Ex-officio) |
| 2. | Shri A.S. Bhatnagar,
Joint Secretary,
Ministry of Tourism and Civil Aviation,
Sardar Patel Bhavan, Parliament Street,
New Delhi 110 001. | Member |
| 3. | Shri C. K. Vohra,
Assistant Financial Adviser (CA),
Ministry of Finance,
C/o The Ministry of Tourism and
Civil Aviation, Sardar Patel Bhavan,
Parliament Street, New Delhi 110 001. | Member |
| 4. | Shri Y. P. Rao,
Deputy Director General of
Observatories, C/o The Observatory,
Lodi Road, New Delhi 110 003. | Member ⁺⁺ |
| 5. | Prof. D. Lal,
Director,
Physical Research Laboratory,
Ahmedabad 380 009. | Member |
| 6. | Dr. Hari Narayan,
Director,
National Geophysical Research
Institute, Hyderabad-7. | Member |
| 7. | Dr. S. R. Valluri,
Director,
National Aeronautical Laboratory,
Bangalore-17. | Member |
| 8. | Dr. C. Ramaswamy,
Ex-Director General of
Observatories, C/o The Observatory,
Lodi Road, New Delhi 110 003. | Member |
| 9. | Dr. K. R. Saha,
Director,
Indian Institute of Tropical
Meteorology, University Road,
Poona - 5. | Member |

⁺Retired as Director General of Observatories, on 24.3.1975.

⁺⁺Appointed Director General of Observatories w.e.f.
24.3.1975.

APPENDIX II

(a) Research Scientists as on 31 March 1975 :

Director	:	Dr. K. R. Saha, M.Sc., D.Phil.
Assistant Directors	:	Shri H. Mitra, M.Sc. Dr. Bh.V.Ramanamurty, M.Sc., Ph.D. Dr. G.C.Asnani, M.Sc., Ph.D. (on foreign service at Nairobi since 23.1.1975).
Senior Scientific Officers, Grade I	:	Shri O.N. Dhar, M.Sc. Dr. D.A. Mooley, M.Sc., Ph.D. Shri R. Suryanarayana, M.Sc.
Senior Scientific Officers, Grade II	:	Shri D.R. Sikka, M.Sc. Dr. R.V.Godbole, M.Sc., M.S., Ph.D. Shri K.Krishna, M.A.(Econ), M.A.(Maths) Shri R.K.Kapoor, M.A.(Maths) Dr. A.K.Kamra, M.Sc., Ph.D. Shri K.G.Vernekar, M.Sc., Dr. A.S.R.Murty, M.Sc.(Tech), Ph.D. Shri S.K.Mishra, M.Sc. Shri S.Sinha, M.Sc. Shri H.N.Bhalme, M.Sc. Shri R.N.Chatterjee, M.Sc.(Tech)
Junior Scientific Officers	:	Shri R.K.Verma, M.Sc. Dr. (Smt) Mary Selvam, M.Sc., Ph.D. Shri P.N.Sharma, M.A., Grad.ITE. Shri S. Rajamani, M.Sc. Shri Shyamvir Singh, M.Sc. Shri S.Sivaramakrishnan, M.Sc. Shri R.K. Gupta, M.Sc. Dr. M. Lal, M.Sc., Ph.D. <i>16/2/74 38-1</i> Dr. D.Subramanyam, M.Sc.(Tech), Ph.D. <i>55/5/73</i> Shri Shiva Sagar Singh, M.Sc. Shri S.N. Bavadekar, M.Sc. Shri L.K. Sadani, M.Sc. Shri B.Parthasarathy, M.Sc.(Tech)

(b) Administrative Officers

Administrative Officer	:	Shri M.C. Juneja, M.A., LL.B.
Accounts Officer	:	Shri J.A. Kulkarni, B.Com.
Purchase and Stores Officer	:	Shri S.T. Balankhe, B.Com.