INDIAN INSTITUTE

OF

TROPICAL METEOROLOGY

ANNUAL REPORT

1975-76

RAMDURG HOUSE, UNIVERSITY ROAD, POONA-5.

INDIA

C O N T E N T S

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 1.4.71, to enable it to pursue its scientific objectives in an atmosphere of academic freedom, entered its fifth year of activity on April 1, 1975. During the year under review, the scientists of the Institute continued their 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 present report reviews the progress made in these areas of study during the year under consideration. It also reviews the progress made in other areas of its activity, such as participation in and contribution to national and international seminars/symposia/conferences, co-operation with universities and other scientific and research institutions and recruiting research scientists at all levels to strengthen the ongoing and planned research activities of the Institute.

2. RESEARCH AND DEVELOPMENT

2.1 Synoptic and Dynamic Meteorology

2.1.1 Prognostic Models

(a) Primitive Equation Barotropic Model

A primitive equation barotropic model using quasi-Lagrangian advection scheme for integration has been successfully developed. The model was used to predict the flow patterns and movement of tropical disturbances. The forecast fields are found to be very satisfactory upto 24 hours. The study is being extended to predict the movement of disturbances upto 72 hours. A numerical experiment to use satellite data as input to the model over data sparse region is also being conducted.

(b) Multi-level Primitive Equation Model

A five-level limited-area fine-mesh primitive equation model for short range weather prediction was under development. The model was successfully tested based on frictionless and adiabatic framework. The results of 24 hours integration showed that the model is computationally stable. Further work to incorporate diabatic heating and friction has been taken up in hand.

2.1.2 Medium Range Forecasting

(a) 5-day mean flow at 700 mb

5-day mean flow at 700 mb was classified in broad categories for each monsoon month. Their evolution and persistence were studied. Certain statistics of sub-divisional rainfall like mean and standard deviation, for each category and each month were computed and compared with the statistics of 5-day rainfall in that month. Frequency distribution of subnormal, normal and abnormal rainfall were determined for each type in each month. Different charts show clear distinction in nature of rainfall for the regions covered by Gujarat, Maharashtra, Madhya Pradesh, Kerala and Andhra Pradesh.

(b) Power spectrum of daily sub-divisional rainfall

Power spectra of daily sub-divisional rainfall series of monsoon precipitation were computed for 33 sub-divisions of India for 19 years after removing seasonal effect from the series. Dominant peaks with 4-and 10-day periods were found.

(c) Regression equations between rainfall and parameters at mean sea level, 700-mb level and 500-mb level

Regression equations between rainfall and pressure/height parameters from each of the different pressure levels (Mean Sea Level, 700 and 500 mb) were computed separately for each monsoon month. Performance of the regression equations was found to be the best for 700-mb level. The experiment was repeated by increasing the data coverage at each level. This also showed that 700 mb level is the best single level for prediction. Hence more data at 700 mb level were collected for deriving stable regression equations. The same experiment was repeated for January month also.

(d) Prediction of 5-day rainfall on the basis of position of monsoon trough at 700-mb level

Position of monsoon trough at 700 mb was used to predict 5 day rainfall in July by developing regression equations. The equations were verified on independent data. The use of these equations shows a modest improvement over climatological forecast.

(e) Conditional and unconditional probabilities of rainy days during monsoon months

Unconditional and conditional probabilities of rainy days were computed for 219 stations of India for each month of the monsoon season. These charts can be

utilised as an additional tool either in 24 hour prediction or as a standard for verification of more sophisticated techniques. The unconditional probabilities so determined were compared with those determined from normals based on data upto 1940. This showed an increase in unconditional probability over the last 20 years.

(f) Concurrent relationship between 5-day mean 700-mb height anomaly and 5-day mean subdivisional rainfall

Concurrent relationship between 5-day 700 mb height anomaly and 5-day mean sub-divisional rainfall were established. This showed better relationship for Maharashtra and Gujarat region than that for any other area.

2.1.3 Diagnostic Monsoon Studies

(a) Water vapour flux across the West coast of India during the summer monsoon season

The computations regarding water vapour fluxes across the west coast of India for different years during the southwest monsoon season were made. It is found that the major contribution to the moisture flux is due to mean motion.

The departures from the nine years' mean flux for the south sector (Trivandrum to Bombay) were negative during years 1965, 1966, 1972 (drought years) and positive during 1967, 1968, 1970, 1971 (good monsoon years). The departures for 1964, 1969 (normal monsoon years) were negligible.

The average contribution to the total moisture flux from north sector (Bombay to Jodhpur) is about 29 percent of the sum of the total fluxes of the two sections.

The coefficient of correlation between the seasonal (June to September) total flux of water vapour across the west coast section (combined north and south sectors) and the average total seasonal rainfall over the west coast region in different years from 1964 to 1972, is 0.81 which is significant at 1 percent level. The south sector shows correlation coefficient of 0.87 whereas for the north sector there does not appear to be any relation between water vapour flux and rainfall in the sector.

The high correlation also exists between the moisture flux across the south sector and the rainfall over the Peninsular India. The correlation is 0.85 which is significant at 1 percent level.

(b) ISMEX 1973 Studies

The data from Indo-Soviet Summer Monsoon Experiment 1973 (ISMEX 1973) were utilised to study the moisture structure of the monsoon over the Arabian sea during an active and weak phase of the monsoon. The vertical distribution of moisture is seen to be intimately linked to the distribution of cyclonic vorticity and the vertical velocity fields associated with synoptic-scale motion.

In another study using the same data, long-wave water vapour radiation fluxes were computed at different levels using a numerical model. The results indicate that the clouds are very important modulators of the long wave radiation fluxes. The computed large horizontal differences in radiation fluxes during active monsoon as compared to the weak monsoon over the Arabian sea are hypothesised to have important feed-back effects on the synoptic scale disturbances.

(c) Diagnostic study of monsoon depression

A diagnostic study of a monsoon depression during 4 August 1968 to 7 August 1968 was completed. The study examines structural features like the (i) zonal flow, (ii) meridional flow, (iii) radial components,

(iv) tangential components, (v) divergence, (vi) vorticity, (vii) moisture, (viii) temperature, etc., of the depression and its environment. Vertical motion field using dynamical equations was computed including the effect of parameterisation of cumulus convection. The study shows that the depression which has a wave-length of about 2000 km, is cold-cored to the west of 80°E but the thermal structure was quite complicated when the depression lay to the east of 80°E. Bulk of the moisture convergence is in the boundary layer. The influence of cumulus convection on the dynamically computed vertical velocity field is substantial at 700 and 500 mb whereas the frictionally induced vertical velocity is dominant at 900 mb.

(d) Influence of orography of Indian peninsula on the Lower tropospheric monsoon flow

The role played by the topography of the west coast of India and the peninsular India on the lower tropospheric monsoon flow was investigated in a theoretical framework. Quasi-geostrophic equations of flow of a homogeneous fluid in the presence of obstacles in a rotating system are applied to identify two features of the low level circulation, viz. the orientation of isobars with reference to the peninsula and the trough in the Bay of Bengal. The suggestions put forth are that (i) the southward turning of the isobars on the peninsula and (ii) the trough in Bay of Bengal arise as a result of the interaction between the westerly current and the topography of the west coast and peninsula.

(e) Energy Aspects of the Asian Summer monsoon circulation

In this study, the seasonal monsoon circulation is considered to be the standing eddy embedded in the general circulation. The disturbances such as monsoon depressions are considered as transient eddies. The available potential energy (A.P.E.) and kinetic energy of the mean zonal flow of the standing eddy and of the transient eddy and the conversions between the various

energy terms have been computed. The generation of APE and the dissipation of kinetic energy in three forms are also computed.

Besides the above investigations, comprehensive reviews on the 'monsoon depression' and the importance of Tibetan Plateau to the weather and circulation over India were completed.

(f) Hydrodynamic Instability of Tropical Zonal flow

The barotropic instability problem was formulated and solved for some typical southwest monsoon cases.

The quasi-geostrophic mixed instability problem was also formulated and programmed on Dec-10 computer system. The model is in an advanced stage of development and is being tested now.

2.1.4 Theoretical Studies

(a) General Circulation Spectral Model

Barotropic divergent spectral model is being developed to study the Indian summer monsoon as a global phenomenon. The model is intended for the simulation of mean monsoon circulation over India, and its fluctuations.

In the course of finalising the model, generation of legendre polynomials for parallelogram truncation Gaussian Quadrature, fast Fourier transformation and spherical summation programmes were incorporated. Initial geopotential field for the model input was prepared by using non-linear balance equation corresponding to wave number 4 in stream function moving west with a velocity 20° /day. Initial testing and standardisation of the programme is completed. To evaluate the functioning of the model and to study the changes of initial input, spherical harmonic analysis programme was completed and tested with Newman's method.

(b) Annual Temperature Oscillation in the Northern Hemisphere.

The annual variation of meridional flux of sensible heat and that of its divergence field is calculated. In the annual mean, the meridional transport of sensible heat by the eddies show double maxima in the vertical over middle and high latitudes and a counter-gradient transport in the tropical mid-troposphere. The annual oscillation is also maximum over middle and high latitudes, occurring during January. Divergence field of meridional transport of sensible heat shows largest heating by the eddies over 60 -70 N latitude belt during April. The heating is more due to standing eddies than transient eddies.

(c) Spherical harmonic analysis

Spherical harmonic analysis of isobaric heights of 700 mb and 300 mb surfaces for strong monsoon (1967) and weak monsoon (1972) was done for the months of April to August. This analysis has been used in computation of momentum and heat transport as well as non-linear energy exchange amongst different wave numbers.

(d) The momentum and heat transport in the weak and strong monsoon years

The computation of the momentum and heat transport by standing eddies for the weak monsoon (1972), strong monsoon (1967) and the mean period (1951-60) in the various wave numbers for the months April to August in the northern hemisphere is being continued.

(e) The non-linear energy exchange between various wave numbers

The non-linear energy exchange between the wave numbers in the northern hemisphere for the weak monsoon (1972), strong monsoon (1967) and the mean period (1951-60) for the months April to August is being computed.

2.2 Climatological Studies

2.2.1 Objective rainfall forecasting over Gujarat region

Correlation fields relating the features of the 700-mb pressure heights over an area extending from Lat. 5°N to 35°N and Long. 60°E to 100°E and rainfall over Gujarat region have been used to specify the influence of 700-mb topography on rainfall. By means of the screening method of multiple regression, a prediction equation for objective quantitative precipitation forecast 5-days ahead in July over Gujarat region is derived. The prediction equation is not able to forecast intense rainfall.

2.2.2 Possible influence of sunspots on monsoon depressions

The number of monsoon depressions, annual mean maximum temperature at Port Blair and annual sunspots for a period of 80 years from 1891-1970 have been examined by fitting of orthogonal polynomials. Smooth polynomial curve of annual mean maximum temperature at Port Blair shows decreasing trend from the start of the present century to 1940s, and rising trend afterwards. Trends in monsoon depressions and annual mean maximum temperature at Port Blair show good resemblence from 1891 to 1920, whereas trends of monsoon depressions and annual sunspots except from 1920 to 1940, show striking resemblence. This indicates that there is decreasing trend in monsoon depressions with increasing trend in sunspots.

2.2.3 Climatic changes over Indian region : Rainfall - A review

In this review the studies carried out on climatic change from the time of Blanford (i.e. 1886) to present times have been reviewed. This review has shown that the mean annual rainfall of the Indian area is 118.8 cms on the basis of about 3000 rainfall stations

whose data are available for the 60-year period from 1901 to 1960. Other noteworthy findings are: (i) Generally, increasing trend in rainfall is observed in the rainfall at stations on the west coast of India, (ii) Increasing trend is noticed in sub-divisions of Maharashtra and Karnataka regions and decreasing trend, in south Assam, (iii) The normal mean annual rainfall of India as a whole was 5 percent more during 1931-60 when compared to that during 1901-30 period, (iv) A cycle of about 8 to 12 years (i.e. Sunspot cycle) is seen in some parts of India.

2.3 Hydrometeorological studies

2.3.1 A study of depth-area-duration statistics of the severemost rainstorms over different meteorological divisions of north India

This study has shown that during the last 60 to 80 years about 43 severemost rainstorms occurred over the different meteorological divisions of north India. These rainstorms were picked out from published rainfall data and analysed by depth-area-duration (DAD) method with a view to obtain envelope rain depths for different size of areas and durations for each of the meteorological divisions of north India.

This study has shown that although for each meteorological division in north India there are different severemost rainstorms which can be used for working out spillway design flood for river basins in these divisions, yet, considering the north Indian plains as a whole, the following are the severemost rainstorms which have caused record rain depths over different size areas in one, two and three-day durations during the last 60 to 80 years :

(a) September, 1880 rainstorm over northwest Uttar Pradesh,

(b) July, 1927 rainstorm over north Gujarat,

(c) October, 1955 rainstorm over north Punjab,

(d) July, 1927 rainstorm over Orissa, and

(e) Sept., 1926 rainstorms over Madhya Pradesh.

It was also observed that average rain depths obtained in the September, 1880 rainstorm over northwest Uttar Pradesh and in July, 1927 rainstorm over north Gujarat were unprecedented. These two rainstorms can be considered amongst the severemost rainstorms of the world.

2.3.2 Review of hydrometeorological studies of Indian rainfall

In this review an attempt has been made to provide up-to-date information on important hydrometeorological studies on rainfall of Indian river basins carried out in this country from 1891 to the present times. After the attainment of independence, the country has embarked on a number of multi-purpose river valley projects for the development of water resources. This review is intended to give an idea of what type of rainfall studies have so far been carried out for the benefit of the planners, design engineers and hydrologists. Results obtained from various studies have also been briefly mentioned with a view that these may prove useful to those who are engaged in the development of water resources of this country.

2.3.3 Estimation of probable maximum precipitation for stations along and near the Himalayas

In this study an attempt has been made to estimate probable maximum precipitation (PMP) for about 100 stations in and near the Himalayas from longitude 75°E to 96°E. Only those rainfall stations have been selected for this study whose daily rainfall data are continuously available for the last 60 to 70 years. Although Hershfield's latest statistical technique has been used for this purpose, the values for the frequency factor in the Hershfield's equation have been picked up from the frequency factor curve which has been

prepared on the basis of north Indian extreme rainfall data. It has been observed that if Hershfield's frequency curve, based upon world extreme rainfall data, were used, it would have given very high estimates of rainfall which are not likely to occur over these stations. This type of study will be quite helpful for flash flood warnings in the foothill areas of the Himalayas during the monsoon months.

2.3.4 Distribution of rainfall across the Kosi region of the Himalayas

With the existing network of rainfall stations in the Kosi Himalayas, the distribution of rainfall across this part of the Himalayas from the foot hills to the great Himalayan range has been studied. This study has shown that rainfall is maximum at stations just before the foot hills and starts decreasing in the lee side of the Siwalik range where stations have elevations between 0.6 to 0.8 kms. Rainfall thereafter starts increasing with altitude up till 2.0 to 2.4 kms. Beyond this elevation in the Kosi Himalayas, rainfall steadily decreases till the great Himalayan range is reached. Rainfall in the trans-Himalayan region could not be studied as there are no rainfall stations in the Kosi region of the trans-Himalayas.

2.3.5 A catalogue of the highest ever recorded floods in Indian rivers : A preliminary appraisal

On the basis of available river gauge data at different sites, a catalogue of highest ever recorded floods in the Indian rivers has been prepared. The river gauge data of selected gauge sites on different rivers for the period 1941 to 1974 have been utilised. The highest ever recorded flood heights at each of the selected sites have been compared with their respective danger levels. This study has shown that on majority of occasions, highest ever recorded floods have been 3 to 15 feet above their respective danger levels. However,

on three occasions it was observed that gauge heights were 50 feet and above of their respective danger levels. These were in the case of Brahmaputra at Saikhowa in August, 1962, Teesta at Anderson Bridge in October, 1968 and Narmada at Garudeshwar in September, 1970. In the case of Brahmaputra, the flood level height was more than 180 feet above the danger level at Saikhowa which is a record flood height for any Indian river on the basis of available river gauge data. The attendant meteorological situations which caused the above unprecedented floods in the rivers of Brahmaputra, Teesta and Narmada have been briefly touched upon and possible reasons have been advanced which were responsible for causing such high flood levels in these three rivers.

2.3.6 Spatial Distribution of Normal Rainfall over India and Adjacent seas

Pentadwise spatial distribution of normal rainfall over India and adjacent seas comprising of about 260 stations is being studied.

2.4 Cloud physics and Weather Modification

2.4.1 Cloud physics

Cloud droplet size distributions were obtained for maritime (Bombay), modified maritime (Poona) and well-inland (Rihand) regions during two summer monsoons of 1973 and 1974. Aerosol measurements in the giant size range were also made at cloud base level during the above periods. The analysis pointed out some association between the cloud micro-structure, aerosol state of the air and rain activity. These features suggest the importance of the aerosol state of air and the micro-structure of the clouds in facilitating rainfall in Poona and Rihand regions by the warm process. However, in the case of Bombay region no definitive conclusion could be drawn due to lack of sufficient data.

The frequency of occurrence of clouds in the two categories deficient and rich in micro-structure was evaluated on the basis of cloud droplet size spectra in Bombay, Poona and Rihand regions. The study pointed out that, for facilitating natural rain in the modified maritime and continental clouds, it is the number of droplets in the higher size range which matters rather than the width of the spectrum. Examination made of synoptic situations associated with rich and deficient cloud micro-structure in the three regions pointed out that the nature of the cloud micro-structure was closely associated with the synoptic situation. However, it was not found depedent on the stability condition.

2.4.2 Weather Modification

The analysis of the results of the cloud seeding experiments in the Poona area which were conducted on 11 pairs of seedable days in 1974 revealed positive results in 6 pairs, negative results in 2 pairs and inconclusive results in 3 pairs. The results were not statistically significant. Two scientists of the Institute participated in the cloud seeding operations conducted by the Karnataka State Electricity Board over Sharavati catchment area during the monsoon of 1975.

A scientist of the Institute participated in the operational cloud seeding experiment conducted by an American team hired by the Tamil Nadu Government during August-October, 1975.

Results of the cold cloud seeding experiments carried out at Delhi in the winter season during the period 1968 to 1975 were analysed. These results were found to be inconclusive.

Study of percentage frequency of occurrence of shower type echoes extending to a height of 15 km and above at Delhi during each monsoon season using radar data was in progress.

Mock cloud seeding experiments were carried out during the winter season of 1975-76.

2.5 Environmental Studies

2.5.1 Atmospheric Diffusion

A plume of the mixture used in warm seeding of clouds was released from an aircraft flying at cloud base levels. The plume was sampled from the aircraft flying across the plume at different levels and different distances. An expression for the expected value of the sample strength was derived. The expected values of sample strength computed using Pasquill's stability categories were compared with measured values.

2.5.2 Measurement of SO_2 in atmosphere

Measurement of SO_2 concentration and aerosols at Delhi in connection with study of atmospheric pollution was carried out.

2.5.3 Atmospheric Electricity

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

2.6 Development of Meteorological Payload for rockets

2.6.1 Testing of payload on rockets

Four meteorological payloads were tested at Thumba with Menaka II rockets. The tests failed as ejection system of rockets did not work properly.

2.6.2 Improvements carried out in circuits

Some improvements in sensing circuit as well as timer circuit of rocket payload were carried out.

2.7 Meteorological Instrumentation for boundary layer studies

i) An eddy correlation instrument to measure the sensible heat flux was designed.

ii) One hot wire anemometer to measure instantaneous wind vector was designed and constructed.

3. PUBLICATIONS

3.1 Papers published/accepted for publication in Journals

Sr. No.	Title of the paper	Author(s)	Journal in which published
1.	Temperature measurements from aircraft using vortex thermometer.	K.G. Vernekar and Brij Mohan	Ind.J.Met. Hydrol. Geophys., Vol.26, No.2, 1975.
2.	Semi-annual oscillation of constant pressure surfaces (1000-100 mb) in the northern hemisphere.	G.C. Asnani and R.K. Verma	Ind.J.Met. Hydrol. Geophys., Vol.26, No.3, 1975.
3.	Rossby wave and pure rotational wave.	G.C. Asnani	Ibid.
4.	Annual pressure oscillation from sea level to 100 mb in the northern hemisphere.	G.C. Asnani and S.K. Mishra	Ibid.
5.	Vertical motion in the Indian summer monsoon.	S.T. Awade and R.N.Keshavamurty	Ibid.
6.	Forecasting the movement of tropical storms in the Indian seas by non divergent barotropic model.	D.R. Sikka	Ind.J.Met. Hydrol. Geophys., Vol.26, No.3, 1975.
7.	Computation of vertical velocity incorporating release of latent heat of condensation	K.V. Rao and S. Rajamani	Ibid.

Sr. No.	Title of the paper	Author(s)	Journal in which published
8.	A study of trends and periodicities in the seasonal and annual rainfall of India.	B.Parthasarathy and O.N. Dhar	Ind.J.Met. Hydrol. Geophys., Vol.27, No.1, 1976.
9.	An exploratory study by radar of the effect of seeding two maritime cumulus clouds	K. Krishna, R.N.Chaterjee, S.Rajamani, K.K. Kanuga, L.T.Khemani, B.K.Mukherjee, S.K. Paul, R.Vijaykumar, S.K.Mishra, Brij Mohan and Bh.V.Ramana Murty	Ibid.
10.	Interdependence between surface potential gradient and rainfall in monsoon rains.	A.M.Selvam, G.K.Manohar, and Bh.V.Ramana Murty	Ibid.
11.	A comparative study of thermistor response time between ground and 80 km's.	K.G. Vernekar	Accepted for Ind.J.Met. Hydrol. Geophys.
12.	Recent trends in monsoon depressions and sunspots	H.N. Bhalme	Vayu Mandal, Vol.5, No.1, 1975.
13.	Vagaries of the Indian summer monsoon during the last ten years.	D.A. Mooley	Vayu Mandal, Vol.5, No.2 and 3, April-Sept. 1975.

Sr. No.	Title of the paper	Author(s)	Journal in which published
14.	Relationship between Central rainfall and its areal extent for severemost rainstorms of north Indian plains	O.N.Dhar and B.K.Bhattacharya	Accepted for Irrigation and Power CBI and P, New Delhi.
15.	Time distribution of intense rainfall associated with depressions/cyclonic storms over North Indian plains	O.N.Dhar and B.K.Bhattacharya	Indian J., Power and River Valley Development, Calcutta, Vol. 25, No.6, 1975.
16.	Climatology of the Asian Summer Monsoon Rainfall-(2) Patterns of monthly monsoon activity and their geographical distribution.	D.A. Mooley	Geog. Rev. of India, Vol.38,No.1, March 1976.
17.	A catalogue of the highest ever recorded floods in Indian rivers - a preliminary appraisal	O.N. Dhar, B.K.Bhattacharya and G.C.Ghose	Indian J. Power and River Valley Development, Calcutta, December, 1975.
18.	Variation of rainfall with elevation in the Himalayas - a pilot study	O.N. Dhar and B.K.Bhattacharya	Accepted for Ind.J.Power and River Valley Development, Calcutta, Vol. 26, No.6, 1976.

Sr. No.	Title of the paper	Author(s)	Journal in which published
19.	A study of aridity and its fluctuations over Andhra Pradesh	P. Rakhecha and O.N. Dhar	Accepted for Ind.Nat. Sc.Academy, New Delhi.
20.	Studies of trends and periodicities of rainfall over Madhya Pradesh.	B.Parthasarathy and O.N.Dhar	Ibid.
21.	Does the absence of tropical disturbances cause deficient rainfall in north Indian sub-divisions during the monsoon months ?	O.N. Dhar and P.Rakhecha	Ibid.
22.	A study of incidence of droughts in Gangetic West Bengal.	B.N. Chanda and O.N. Dhar	Ibid.
23.	Feature of Rainfall of stations within 200 kms of a Steel Industry.	T.Ramana Rao and Bh.V.Ramana Murty	Ind.Nat.Sc. Academy, New Delhi, 1976.
24.	Worst Summer Monsoon Failures over the Asiatic Monsoon Area	D.A. Mooley	Ibid.
25.	On some rainfall features of August 1973 rainstorm over Rajasthan	O.N. Dhar, P.Rakhecha and B.N. Mandal	IHD Newsletter, Nos.23,24, 25 and 26, 1974

Sr. No.	Title of the paper	Author(s)	Journal in which published
26.	Measurements of cloud droplet size distributions in seeded warm cumulus clouds.	R.K.Kapoor, S.K. Paul, A.S.R.Murty, K.Krishna, S.K.Sharma and Bh.V.Ramana Murty	Pure and Applied Geophys., Switzerland, Vol.114, 1976.
27.	A note on mean thermodynamic instability of northern tropical atmosphere.	S.S. Singh	Ibid.
28.	Summary of observation indicating dynamic effect of salt seeding in warm cumulus clouds.	A.S.R.Murty et.al.	J.Appl.Met., U.S.A., Vol.14, No.4, 1975.
29.	Reply to 'comments on 'The Role of Electricity forces in charge separation, by falling precipitation in Thunder clouds' by R.F.Griffth'	A.K. Kamra	J.Atmos.Sci., U.S.A., Vol. 32, No.2, 1976.
30.	Reply to 'comments on 'The Role of Electrical forces in charge separation by falling precipitation in thunder clouds' by W.D.Scott'	A.K. Kamra	Accepted for J.Atmos.Sci., U.S.A.
31.	Dynamic effect of salt seeding in warm cumulus clouds	A.S.R.Murty, A.M.Selvam, and Bh.V.Ramana Murty	J.of Weather Modification, Vol.7, No.1, 1975.

Sr. No.	Title of the paper	Author(s)	Journal in which published
32.	Study of drop size distribution in warm clouds subjected to repeated seedings.	R.K.Kapoor, S.K.Paul, A.S.R.Murty, K.Krishna and Bh.V.Ramana Murty	J.of Weather Modification, Vol.7, No.1, 1975.
33.	The influence of cross-equatorial flow over Kenya on the rainfall of western India.	K.Raghavan, D.R.Sikka and S.V.Gujar	Quart.J.Roy. Met.Soc., U.K., Vol.101, No.428, 1975.
34.	Trend analysis of annual Indian rainfall	B.Parthasarathy and O. N. Dhar	Hydrological Sciences Bulletin, U.K., Vol.20, No.2, 1975.
35.	Spherical harmonic analysis of the normal constant pressure charts in the northern hemisphere	S.T.Awade, G.C.Asnani and R.N.Keshavamurty	Archieves for Met.Geophys. and Bio-climatology, Ser.A., Vol.24, No.2, 1975.
36.	Atmospheric Pollutants and rainfall	L.T.Khemani, G.A.Momin, and Bh.V.Ramana Murty	J.of Radio and Space Physics, 1976.

3.2 Prepublished research reports

Sr. No.	Title of the Research Report	Author(s)	Research Report No.
1.	A study of trends and periodicities in the seasonal and annual rainfall of India.	B.Parthasarathy and O.N. Dhar	RR-023
2.	Southern Hemisphere influence on Indian rainfall	K. Raghavan, D.K.Paul and P.U.Upasani.	RR-024

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

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

Sr. No.	Seminars/Symposia/Meetings	Name(s) of scientists who attended
1.	Second Annual Convention of Poona Chapter of Computer Society of India, held at Poona on 12th and 13th June 1975.	Shri D.R.Sikka Shri S.S.Aralikatti
2.	Workshop on Monsoon Meteorology, Indian Institute of Science, Bangalore, 8-18 July, 1975.	Shri D.R. Sikka Shri S.S. Singh Shri S.K. Mishra Shri H.N. Bhalme Shri B.Parthasarathy
3.	International Conference on 'Climatic Fluctuations' held at Norwich (U.K.), 17-25 August, 1975.	Dr. K.R. Saha
4.	National symposium on Hydrology held at Roorkee University from 13th to 16th November 1975.	Dr. O.N. Dhar Shri P.P. Kamte Shri A.K.Kulkarni
5.	International Conference on 'Climatic Changes and Variability with particular reference to the southern hemisphere' held at Melbourne, Australia from 7 to 12 December 1975.	Dr. D.A. Mooley
6.	Second World Congress on Water Resources held at New Delhi from 12 to 16 December 1975 under the auspices of the Central Board of Irrigation and Power, New Delhi.	Dr. O.N. Dhar Shri P.R. Rakhecha

Sr. No.	Seminars/Symposia/Meetings	Name(s) of scientists who attended
7.	International Course on Acquisition and Transmission of Hydrometeorological and Oceanographic data for storm prediction and automation of flood control measures - held under the auspices of CWPRS Poona from 5th to 31st January 1976.	Shri P.R. Rakhecha
8.	Seminar on 'Weather Modification' held at New Delhi on 10th and 11th Feb. 1976 under the auspices of the Indian Meteorological Society.	Dr. K. R. Saha Dr. D. A. Mooley Dr. A. K. Kamra Shri R.N.Chatterjee
9.	Results of ISMEX 1973, Poona, February 1976.	Shri D. R. Sikka
10.	Annual Cyclone Review Meeting Bombay 29-30 March 1976.	Shri D. R. Sikka
11.	Annual Meeting of the Marathi Vidnyan Parishad, 25-27 December 1975.	Dr. D. A. Mooley

4.2 Papers contributed to Seminars/Symposia/Meetings

(A) National Symposium on 'Hydrology' held at Roorkee, in November 1975.

i) A study of depth-area-duration statistics of the severemost rainstorms over different meteorological divisions of north India.

ii) Estimation of probable maximum precipitation for some selected stations in and near the Himalayas.

iii) An objective rainfall forecasting over Gujarat region.

(B) Second World Congress Symposium on 'Water Resources' held in New Delhi, in December 1975.

i) A review of hydrometeorological studies of Indian rainfall

ii) Oscillations in monsoon trough.

(C) ISMEX 1973 Seminar, Meteorological Office, Poona February, 1976.

Numerical computation of long wave radiation flux due to water vapour including cloudiness.

(D) Symposium on Monsoon Meteorology Workshop, Indian Institute of Science, Bangalore, July 1975.

i) Monsoon depressions - A review in two parts.

ii) A diagnostic study of the monsoon depression.

iii) The influence of the topography of the Indian Peninsula on the low level circulation of the summer monsoon.

iv) Large scale rainfall over India during the summer monsoon and its relation to lower and upper tropospheric vorticity field.

v) Importance of Tibetan Plateau to the weather and circulation over India.

vi) Monsoon over the seas.

5. COLLABORATION WITH UNIVERSITIES AND OTHER SCIENTIFIC INSTITUTIONS

5.1 Collaboration with Universities :

(a) On a request from the central University of Hyderabad, a syllabus for Meteorology and Hydrology for M.Sc. and M.Phil Geoscience courses was prepared and sent to the University.

(b) Shri O.N.Dhar, Senior Scientific Officer, Gr.I., was awarded Ph.D. degree by the Jadavpur University, Calcutta, for his thesis entitled 'On some hydrometeorological aspects of rainfall distribution over north India'.

(c) During the year Shri L.T. Khemani was awarded M.Sc. degree of the Bombay University for his thesis on 'Some aspects of Atmospheric Chemistry as applied to cloud physics'.

5.2 Collaboration with other scientific institutions

(a) Shri D.R. Sikka, Senior Scientific Officer was an invited speaker in the workshop on Monsoon Meteorology organised by Indian Institute of Science, Bangalore during July 1975.

(b) The commandant Air Force Administrative College, Coimbatore requested the Institute for help in delivering a few lectures to the participants in their Senior Forecaster's course. In response to this, Shri D.R. Sikka, Senior Scientific Officer, delivered a series of 12 lectures during November-December 1975 on various aspects of Tropical Meteorology covering recent advances.

(c) Shri D.R. Sikka visited the centre of Theoretical Studies, Indian Institute of Science, Bangalore during December 1975 in connection with some studies on summer monsoon.

(d) On invitation from the Marathi Vidnyan Parishad, Dr. D.A. Mooley gave a talk in Marathi on 'Artificial Rainfall' before the delegates at its Annual Session held at Hyderabad from 25-27 December 1975.

(e) Shri D.R.Sikka, Senior Scientific Officer delivered a series of lectures to the participants of Advanced Refresher course on 'Tropical Cyclones' held in the Meteorological Office, Poona during February 1976.

(f) This Institute has been enrolled as an Institutional member of the Indian Association of Hydrologists, Roorkee and will be represented at annual general meetings of this association by Dr. O.N. Dhar and Shri P.R. Rakhecha.

(g) The Institute continued to be a recognised Institution of the University of Poona for research in atmospheric science for award of M.Sc. and Ph.D. degrees. It also continued to be recognised as a center for advanced research in Physics (meteorology) by the Universities of Banaras, Nagpur, Bombay, Andhra, Bangalore, Kerala and Baroda.

6. FACILITIES FOR RESEARCH EXTENDED TO OTHER INSTITUTIONS

6. Air India Research Fellowship

Air-India instituted two Fellowships for research in tropical meteorology at the Institute about ten years ago. Shri Shrinivas Moorthi and Kumari P.G. Kulkarni to whom the Fellowships were awarded during 1974-75 continued their research studies in the Institute.

7. VISITORS

7. The following visited the Institute during the period of the report :

i) Seven Meteorological Officers from Air Force Administrative College, Coimbatore, 6th and 7th May 1975.

ii) Four Indian Statistical Service probationers from Central Statistical Organization, New Delhi, 12th May 1975.

iii) Shri C.V. Gole, Member, Water Resources, Central Water and Power Commission, New Delhi, 16th June 1975

iv) Dr. N. Sundaraman of Climatic Impact Assessment Programme, Washington, U.S.A., 24th July 1975.

v) Dr. Charles Weiss, Jr., Scientific Advisor to World Bank, 3rd August 1975.

vi) Dr. T. Nitta, Scientific Officer, GARP Activities Officer, WMO, Geneva, 18th September 1975.

vii) Prof. P.R. Sengupta of the Institute of Applied Man Power, New Delhi, 9th October 1975.

viii) Dr. J.I. Schweitzer, Assistant Education Adviser (Science), British High Commission, 26th November, 1975.

ix) Dr. Alland, Director, Plant Division, Food and Agricultural Organisation, United Nations, 11th December, 1975.

x) Shri D.S. Upadhyay, Senior Scientific Officer, Snow and Avalanche Study Establishment, Ministry of Defence, 31st December 1975.

xi) Prof. Subhash Chandra, Head of Civil Engineering, Department, Indian Institute of Technology, New Delhi, 28th January, 1976.

xii) Prof. Satish Chandra, Professor and Cordinator of International Course in Hydrology, University of Roorkee, Roorkee, 24th February 1976.

xiii) Prof. A.B.Rao, Head of the Department of Mathematics and Statistics, B.M. College of Commerce, 10th February, 1976.

xiv) Prof. M.J. Deodhar, Prof. K.S. Sastarkur and Prof. A.S. Kale of the College of Engineering, Karad, on 17th February, 1976.

xv) Shri S.P. Adhikari, Chief of the Nepal Met. Service, Kathmandu, Nepal, 25th March, 1976.

xvi) Shri Y.P. Rao, Chairman, Governing Council, Indian Institute of Tropical Meteorology, 31st March 1976.

8. GENERAL

8.1 The Governing Council

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

8.2 Facilities

8.2.1 Library, Information and Publication

The Library, Information and Publication 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 84 books were added to the Library, 49 Indian and foreign journals were subscribed to and 2 research reports were issued.

8.2.2 Computer

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

Investigation and Research	:	1814 hrs.
Data Processing	:	1927 hrs.
Break-down/maintenance	:	261 hrs.
Computer time sold	:	113 hrs. and 30 mts.

8.2.2.2 Twentytwo special night runs (187 hrs.) of the computer were arranged during the year for the urgent data processing work of DDGC's office.

8.2.2.3 A three-week course in FORTRAN Programming with application to Numerical Analysis was conducted.

Following offices deputed candidates to the course :

	Organisation	No. of participants
a)	National Institute of Oceanography, Panaji	2
b)	Office of the DDGF, Poona	5
c)	Office of the DDGC, Poona	4
d)	Office of the Director, Agrimet, Poona	2

8.2.3 UNDP Fellowship training

i) Shri K.G. Vernekar, Senior Scientific Officer, Gr.II, completed the U.N.D.P. fellowship training in the field of Boundary Layer Meteorology and returned to the Institute on December 29, 1975.

ii) Dr. A.S.R. Murty, Senior Scientific Officer, Gr.II completed the U.N.D.P. fellowship training in the fields of Weather Modification Techniques and returned to the Institute on 1st April, 1976.

iii) Shri H.N. Bhalme, Senior Scientific Officer, Gr.II, proceeded on deputation to the U.S.A. on 15th September, 1975 for U.N.D.P. fellowship training for a period of eight months in the field of Climatology.

iv) Shri S.K. Mishra, Senior Scientific Officer, Gr.II, proceeded on deputation to U.S.A. on 15th September 1975 for U.N.D.P. fellowship training for a period of seven months in the field of General Circulation studies.

v) Shri S. Sinha, Senior Scientific Officer, Gr.II proceeded on deputation to U.S.A. on U.N.D.P. fellowship training on 29.12.1975 in the field of Numerical Modelling for a period of six months.

8.2.4 Seminars

During the year the Institute held 71 seminars covering the topics of Numerical Weather Prediction, Medium Range forecasting, Statistical Weather Prediction, Climatic change and fluctuation, Numerical Climatic Models, Hydrometeorology, various aspects of monsoon problems, Cloud Physics and Weather Modification, Air Pollution, Crop and Weather environment, Structure of Atmosphere, Monex and Rocket Payload.

8.3 Budget, Accounts and Audit

The Institute received from the Government of India grants totalling Rs. 35,71,389.46 including the unspent balance of the previous year and other receipts like Computer charges, Interest on Fixed Deposit etc. Out of this an amount of Rs. 26,89,447.57 (approximately) was spent during the year 1975-76. Audit of the Institute accounts for the year 1974-75 was conducted by M/s Kirtane and Pandit, Poona-2.

8.4 Important Staff Changes

8.4.1 Appointments

i) Dr. A.K. Kamra and Dr. Punyatma Singh assumed charge of their posts as S.S.O. Gr.I. with effect from 27.11.75 and 31.1.76, respectively.

ii) S/Shri S.S.Singh and Shyamvir Singh, assumed charge of their posts as S.S.O. Gr.II, with effect from August 8, 1975.

iii) Shri A.C.Mahanti and Shri R.N. Sengupta assumed charge of their posts as Junior Scientific Officers with effect from 26.8.75 and 7.11.75, respectively.

iv) Shri D.W.Kshirsagar assumed charge as Administrative Officer on 5th March, 1976.

v) Shri A.N. Limaye assumed charge as Junior Administrative Officer on 15th May, 1975.

vi) Shri A.T. Desai assumed charge as Purchase and Stores Officer on 10th March, 1976.

8.4.2 Review Promotions

i) Four Senior Scientific Officers, Gr.II were promoted to the Grade of Senior Scientific Officer, Gr.I. Out of four, three of them have joined.

ii) Four Junior Scientific Officers, were promoted to the grade of Senior Scientific Officer, Gr.II. All of them have joined.

iii) Five Senior Scientific Assistants were promoted to the grade of Junior Scientific Officer. All of them have joined.

iv) Four Scientific Assistants were promoted to the grade of Senior Scientific Assistant. All of them have joined.

8.4.3 Relief

i) Shri M.C. Juneja, Administrative Officer, was relieved on September 26, 1975 (A.N.) on reversion to the Ministry of Information and Broadcasting, New Delhi.

ii) Shri S.T.Balankhe, Purchase and Store Officer, was relieved on 31.5.1975 on repatriation to his parent department.

iii) Dr. Murari Lal, Junior Scientific Officer, was relieved on July 16, 1975 on acceptance of his resignation.

8.4.4 Staff Position

Appendix II gives the names of research scientists and administrative officers as on 31.3.1976.

APPENDIX - I

Names and Addresses of Members of Governing Council during 1975-76

1. Shri Y.P. Rao, — Chairman (Ex-officio)
Chairman, Governing Council,
C/o The Observatory,
Lodi Road, New Delhi-110 003.

2. Dr. P.K. Das, — Member
Deputy Director General of Observatories,
(S.S. and A.), C/o The Observatory,
Lodi Road, New Delhi-110 003.

3. Shri A.S. Bhatnagar, — Member
Joint Secretary,
Ministry of Tourism and Civil Aviation,
Sardar Patel Bhavan,
Parliament Street,
New Delhi-110 001.

4. Prof. R. Narasimha, — Member
Indian Institute of Science,
Department of Aeronautical Engineering,
Bangalore 560 012.

5. Shri P.R. Krishna Rao, — Member
Retired D.G.O.,
No. 70, Gayatri Devi Park Extension,
Bangalore 560 003.

6. Dr. Hari Narayan, — Member
Director,
National Geophysical Research Institute,
Hyderabad-7.

7. Dr. D. Lal, — Member
Director,
Physical Research Laboratory,
Ahmedabad-380 009.

8. Shri C.K. Vohra, — Member
Assistant Financial Adviser (CA),
Ministry of Finance,
C/o Ministry of Tourism and Civil
Aviation, Sardar Patel Bhavan,
Parliament Street, New Delhi 110 001.

9. Dr. K. R. Saha, — Member
Director,
Indian Institute of Tropical Meteorology,
Poona-411 005.

APPENDIX - II

(a) Research Scientists as on 31 March 1976 :

Director	:	Dr. K.R. Saha, M.Sc., D.Phil.
Assistant Directors	:	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	:	Dr. O.N.Dhar, M.Sc., Ph.D. Dr. D.A. Mooley, M.Sc., Ph.D. Shri R.Suryanarayana, M.Sc. Dr. P.Singh, M.Sc., Ph.D. Shri D.R. Sikka, M.Sc. Dr. A.K. Kamra, M.Sc., Ph.D. Shri K.Krishna, M.A. (Econ), M.A.(Maths) Shri R.K.Kapoor, M.A. (Maths)
Senior Scientific Officers, Grade II	:	Dr. R.V.Godbole, M.Sc., M.S., Ph.D. Shri K.G.Vernekar, M.Sc. Shri S.K. Mishra, M.Sc. Dr. A.S.R. Murty, M.Sc.(Tech), Ph.D. Shri R.N.Chatterjee,M.Sc.(Tech) Shri S.Sinha, M.Sc. Shri H.N.Bhalme, M.Sc. Shri Shyamvir Singh, M.Sc. Shri S.S.Singh, M.Sc. Dr.(Mrs) A.M.Selvam, M.Sc., Ph.D. Shri P.N.Sharma, M.A., Grad.ITE. Shri S.Rajamani, M.Sc. Shri R.K.Verma, M.Sc.
Junior Scientific Officers	:	Shri R.K. Gupta, M.Sc. Shri S.Sivaramakrishnan, M.Sc. Shri L.K.Sadani, M.Sc. Shri B.Parthasarathy, M.Sc.(Tech) Shri S.N.Bavadekar, M.Sc. Dr. D.Subramanayam, M.Sc.(Tech), Ph.D. Shri A.C. Mahanti, M.Sc. Shri P.P. Kamte, M.Sc. Shri D.K. Paul, M.Sc. Shri R.N. Sengupta, M.Sc. Shri S.T.Awade, M.Sc. Shri P.R. Rakhecha, M.Sc. Shri L.T. Khemani, M.Sc.

(b) Administrative Officers

Administrative Officer	:	Shri D.W.Kshirsagar, M.A., M.Com.LL.B.
Accounts Officer	:	Shri J.A. Kulkarni, B.A., B.Com.
Purchase and Stores Officer	:	Shri A.T. Desai, D.C.E.
Junior Administrative Officer	:	Shri A.N. Limaye, M.A. (Econ).