ISSN 0250-6017

Indian Institute of Tropical Meteorology

Pune 411 005 INDIA

ANNUAL REPORT
1988-89

Dr. S.K. Mishra, D.D., receiving SAARC Award.

Employees of the Institute giving the message of National Integration.

CONTENTS

Cover Page Photograph
Dr. Vasant Gowarikar, Secretary, DST delivering Inaugural Speech at the Int. Symp. on 'Monsoon : Understanding and Prediction'.

INTRODUCTION

The year 1988-89 was an eventful year for the Institute as it organised an international symposium on 'Monsoon Understanding and Prediction' to commemorate its Silver Jubilee, 25 years of the International Indian Ocean Expedition (I.I.O.E.), and a decade of the MONEX which was a sub-programme of the Global Weather Experiment. Dr. Vasant Gowarikar, Secretary, DST, Govt. of India inaugurated the Symposium. A large number of delegates from India and abroad participated in the Symposium and 52 papers were presented. The Institute also co-sponsored and hosted the first Annual Conference of the Indian Aerosol Science and Technology Association (IASTA), Bombay during 23-24 March 1989. The theme of the Conference was 'Aerosol Science : A perspective on Research and Development of India'.

The National Science day was celebrated in the Institute during the year from 24-28 February with a focus on Nehru's vision of Science to synchronise with the birth centenary celebrations of Late Pandit Jawaharlal Nehru, the first Prime Minister of independent India and the architect of scientific development in the post-independent India. Scientific Exhibition, lectures on popular science, Science Quiz and cultural programmes were arranged under this programme. A series of Nehru Centenary Lectures was also organised in the Institute during the current year. The Institute actively took part in the Scientific Exhibition organised during the 76th Session of the Indian Science Congress held at Madurai from 6-18 January 1989. An invited talk on 'Climate Modelling' was delivered by the Director during the session.

The Institute is actively taking part in several bilateral scientific programmes with the U.S.A. and the U.S.S.R. Director participated in the Indo-Soviet Seminar on 'Pressing problems of computing mechanics and mathematical modelling' held at Moscow from 19 May-01 June 1988. A delegation of Soviet Scientists visited the Institute during December 1988 — January 1989 under the Indo-USSR Integrated Long Term Programme of Collaboration in Science and Technology. Scientists from the Institute participated and presented papers at the Second Indo-USSR Symposium on Programmes and Projects under the Long Term Programme. Institute's scientists also actively participated in the deliberations of the joint Indo-USSR Scientists' meet held at PRL, Ahmedabad during 31 May-09 June 1988 under the ISRO-SCHENE Theme I Programme. Participation in cruise No. 43 of the research ship 'SAGAR KANYA' during the period 27 July - 16 September 1988 was also a part of the programme. The Institute also organised an informal meeting on 23 August 1988 to review the progress and recommend the future plan of work for the scientific projects formulated earlier in August 1987 under the Indo-US Sub-Commission programme on climate-related research. The Institute received a set of magnetic tapes containing Comprehensive Ocean Atmospheric Data (COADS) during the year from Dr. J.O. Fletcher, Assistant Administrator, NOAA, when he visited the Institute in November 1988 for participation in the international symposium.

To study the climate vegetation interaction in the Nilgiri Biosphere Reserve, in collaboration with the Centre for Ecological Studies, Indian Institute of Science, Bangalore, the Institute had set up last year a Field Observational Station at Masingudi, Karnataka. Field observational programmes were organised from 28 March 1988 to 10 April 1989 to study the interaction of atmospheric chemistry with the Nilgiri Biosphere Reserve. The programme is a pre-runner of the Institute's effort under the national programme on International Geosphere-Biosphere Programme (IGBP). Institute's scientists took part in the First National Workshop on IGBP, organised by the Indian National Science Academy (INSA), New Delhi during 12-15 August 1988.

The Institute is collaborating in a national programme sponsored by the Department of Science and Technology (DST) on the 'Monsoon Trough Boundary Layer Experiment (MONTBLEX)'. Scientists from the Institute actively participated in the MONTBLEX Pilot Experiment conducted at I.I.T., Kharagpur. The Institute is also undertaking a DST-sponsored project on climatic reconstruction for the past 1000 years over the Western and the Central Himalayan regions using dendroclimatic approach. Active support and co-operation continued to be extended to the National Centre for Medium Range Weather Forecasting (NCMRWF), New Delhi, which has been set up by the Government of India as a constituent unit of the DST.

At the instance of the DST, field observational programmes were carried out by the Institute during the period of 'Vrishti Yagna' for rain making conducted at Mathura from 24-31 May 1988 under the auspices of Vrishti-Vigyan Mandal. The analysis of the observations made during the period of the Yagna did not indicate any alteration in the environmental conditions leading to the formation of clouds and rain which could be attributed to the Yagna. Technical guidance was provided to the State Govt. of Andhra Pradesh through preparation of Planning document for the proposed cloud seeding operations in the catchment areas of the Osmansagar and Himayatsagar reservoirs in the Hyderabad region. The Institute had conducted warm cloud seeding experiments over certain parts of the state of Maharashtra for 11 summer monsoons during 1973-86. Incorporating the results of the said experiments, a Detailed Project Report (DPR) for operational Cloud Seeding Programme (CSP) was prepared by the Institute which was later revised and submitted to DST for funding. The DPR was recommended by the expert committee set up by the DST under the Chairmanship of Dr. Vasant Gowarikar, Secretary, DST.

The Institute continued to provide support to various Central and State agencies responsible for the management of water resources in the country. Technical guidance was provided to the Koyana Dam Maintenance Division, Govt. of Maharashtra regarding the estimation of Probable Maximum Precipitation (PMP) for the Koyana catchment. The Institute contributed its research findings in the field of hydrometeorological studies to the document on 'Achievements in hydrology since independence', being prepared by the National Institute of Hydrology (NIH), Roorkee. Sixteen maps showing the Probable Maximum Precipitation for the different states of the country were prepared in the form of PMP Atlas for the benefit of hydrologists and design engineers.

The Institute maintained its academic contact with a number of Universities in the country having teaching programmes in atmospheric sciences. It collaborated with the University of Poona and rendered academic support in offering a programme in Atmospheric Physics in the M.Sc. (Physics) curriculum as well as in teaching M. Tech. programme in Atmospheric Sciences.

The Institute continued to emphasise high standard in scientific research. Scientists of the Institute won the Second SAARC Regional Award for the paper entitled, 'A Primitive equation barotropic instability study of monsoon onset vortex, 1979' by S.K. Mishra, M.D. Patwardhan and Leela George published in the Quarterly Journal of the Royal Meteorological Society, Vol. 111, April 1985. The 13th Mausam Award for the two-year period 1984 and 1985 was won by the paper entitled, 'Energetics of the monsoon circulation over South Asia Pt. I : Diabatic heating and the generation of available potential energy, Pt. II : Energy terms and energy transformation terms' by S. Rajamani published in Mausam, Vol. 36, 1985. The University of Poona awarded Ph. D. (Physics) degree to Shri P.R. Rakhecha, SSO I for his doctoral thesis, 'On some hydrometeorological studies of the Indian rainfall'. Scientists of the Institute contributed 28 papers to scientific journals of national and international standing. 7 research papers were also published by them during the year in the Proceedings of national/international seminars/symposia relating to varied scientific topics. Besides, 53 papers were presented at national and international conferences/symposia. Two Research Reports were also published by the Institute.

Considerable progress was achieved in the progressive use of Hindi in the official work. A Hindi Workshop was conducted in the Institute for the benefit of scientific officers. Hindi week was celebrated in the Institute from 16-21 September 1988.

The Institute continued its research work with forward-looking vision and dynamism with focus on a few emerging thrust areas of research. The Institute prepared its 8th Five Year Plan programmes (1990-95) with emphasis on emerging areas in atmospheric sciences which are relevant to national and international programmes. It looks forward to future with confidence for continuing to play a dynamic role in the development of atmospheric sciences in the country.

Pune
September 1989.

D. R. SIKKA
Director

RESEARCH HIGHLIGHTS

The Institute organised an international symposium on 'Monsoon - Understanding and Prediction' during 22 November to 28 November 1988 to commemorate its Silver Jubilee, the completion of 25 years of the International Indian Ocean Experiment and a decade of MONEX which was a sub-programme of the Global Weather Experiment. The Symposium received enthusiastic response from the co-sponsoring organisations and the community of atmospheric scientists from India and abroad.

Analyses of ENSO episodes during 1935-1988 in relation to Indian Summer Monsoon suggest that a strong ENSO (El-Nino Southern Oscillation) may cause drier or wetter monsoon depending upon the phase-locking between the ENSO and the monsoon. Majority (about 65%) of extreme monsoons are linked with ENSO.

The average surface air temperature for six stations over the west central Indian region for the months of March-April-May was found to be a highly significant regional parameter in the prediction of all India Monsoon rainfall.

Sixteen maps showing the Probable Maximum Precipitation (PMP) for the entire country were published in the form of an Atlas.

Under the MONTBLEX programme, a 30 m tower was erected at IIT, Kharagpur by the IISc-IITM group. The tower was fitted with instruments to measure wind speed, direction, temperature and humidity at different levels. A pilot experiment was conducted during the monsoon period of August 1988. A field experiment was conducted during February-March 1989 at the College of Agriculture, Pune to study the structure and evolution of the Atmospheric Boundary Layer using kytoon and instrumented tower.

Atmospheric electric field, conductivity of both polarities and space charge at ground surface at Pune were measured during the partial solar eclipse of 18 March 1988. It was observed that inspite of no appreciable change in the atmospheric surface temperature, these electrical parameters show remarkable changes during the eclipse.

Studies on break-up of water drops freely suspended over a vertical wind tunnel in the laboratory have shown that breaking probability of a drop increases with the increasing diameter. Moreover, the number of droplets produced by breaking of water-drops increases with the diameter of the drop. Charge transfer by point discharge current occurring below dust storms can play an important role in the global electrical circuit. Some old data obtained at Roorkee were analysed to see the contribution of this component over a period of one year. It was found that contribution of point discharge current below dust storms may be comparable to that below thunderstorms.

In order to understand the possible mechanisms for the depletion of Antarctic Ozone, the analysis of the geopotential height, temperature and wind data at 30 hPa level for the high latitude station for the three months (Sept.-Nov.) for the period 1977-1986 were examined. The results suggested that the dynamical processes in the middle atmosphere could be associated with the depletion of Antarctic ozone.

2. RESEARCH

2.1 Forecasting Research

The Division is engaged in comprehensive research in weather forecasting and understanding of atmospheric processes.

Emphasis is to expand the scientific understanding of those physical processes which govern the behaviour of the atmosphere in general and monsoons in particular. The atmosphere can be modelled mathematically and its phenomenology studied by computer simulation methods. The thrust has been to develop a regional model for short-range prediction. Diagnostic studies are also conducted, in particular, towards understanding the predictability of large scale weather, the structure, variability and sensitivity of climate, Global and regional. The interaction of the atmosphere and oceans with emphasis on ENSO are also examined.

2.1.1 Numerical Weather Prediction

a) Regional models

Six level primitive equation model was tested for 13 days for the monsoon depression cases which formed in June to August, 1979. Forecast results in respect of flow patterns, movement of cyclonic circulations and area of precipitation were found to be satisfactory. Sensitivity of the model with respect to counter gradient effect in turbulent heat transport was also investigated. The precipitation rates associated with the cyclonic circulation were considerably increased with the inclusion of this effect and were found comparable with the actuals.

To incorporate the effects of radiation processes in the regional model, the long wave and short wave flux divergence (associated with water vapour only) and the corresponding cooling and heating rates in different layers of the atmosphere were computed. The preliminary results showed that the cooling/heating rates are of reasonable order.

A single level primitive equation model in flux form was used to study the impact of Kessel and Winninghoff sponge damping technique. The model was integrated upto 48 hrs with and without including the sponge damping scheme. The forecast results without sponge damping showed high divergence close to the boundaries. However, inclusion of the sponge damping does not improve the forecast results.

b) Objective Analysis

In connection with the development of Optimum Interpolation (O.I.) scheme of objective analysis of winds, geopotential heights and relative humidity, the autocorrelation functions and structure functions were earlier computed with the daily data of July months of the four years during 1976-1979. In order to carry out these computations for a longer period, the daily radiosonde data for the summer monsoon period over the Indian region for six more years (1980-1985) were processed. The computations were thus updated for six July months (1976-1981) period.

Relative humidity analysis was carried out for five days from 4 to 8 July 1979 at all standard levels upto 500 mb using the univariate Optimum Interpolation scheme. The analyses were found to be satisfactory with R.M.S. errors varying from 9 to 12%.

A scheme to estimate the upper air relative humidity from surface observations to augment radiosonde observations, particularly over the data sparse regions, was drawn up by developing a regression equation. The relative humidity at 700 mb was estimated from this regression equation and the analyses were made for six days from 4 to 9 July 1979. These analyses were found to be better when compared to those obtained through the radiosonde data only.

c) Numerical Modelling and study of the planetary boundary layer

The surface meteorological data collected during the cruises of the research ships, 'Gaveshani' from 21 May to 2 August 1979, 'Sagar Kanya' and 'Academic Korolev' from 3 August to 14 September 1988, were utilised to compute the following :

i) Fluxes of momentum, sensible and latent heat at the air-sea interface and (ii) incoming and outgoing longwave radiation, Bowen ratio and net heat flux at the air-sea interface, using two different approaches, viz., (a) Dynamical approach after Warsh, 1973 and (b) Stability stratification approach after Stevenson, 1982.

Comparison of the values obtained by each approach showed that the stability stratification approach gives more realistic values of the drag coefficient at low wind speeds and high air-sea temperature difference, specially in regions where atmospheric systems, like lows or depressions, have formed.

Various thermodynamic parameters have been computed from the radiosonde data of 20 stations in the region of the monsoon trough (20° - 30°N and 70° - 90°E) during the months May to September for the year 1979, for all data levels upto the height of 500 mb pressure level. These parameters have also been computed over the eastern Arabian sea with the FGGE, MONEX-79 data.

d) Utilization of satellite data for forecasting research

Multiple regression equations were developed using the satellite derived radiation parameters (albedo, OLR, absorbed solar radiation and net radiation) over the Arabian sea for the period 11-20 June 1979, to find out the relative humidity (R.H.) at different levels. Isohygric patterns obtained from regression equations were compared with the observed cloudiness. Results suggested that the satellite estimated R.H. field could be more useful than the R.H. field obtained from ECMWF analyses.

An empirical relation between the satellite observed HRC (Highly Reflective Cloud) and rainfall of island stations over the Indian Ocean for the period January 1971 through December 1983, was developed. Linear regression relationship between HRC and rainfall was found to be statistically significant at 1% level suggesting that HRC data can be utilised for monitoring rainfall distribution over the Indian Ocean.

Satellite derived winds obtained from INSAT-1B for a depression period, 15-23 July 1988, were decoded and a file was created on ND-560 computer for the purpose of analysis and prediction.

2.1.2 Extended Range Prediction

a) Statistical dynamical prediction

12 years of daily OLR data at 2.5° Lat./Long. grid were analysed to study the low-frequency intra-seasonal variations of convection over the Indian ocean and the adjoining Pacific region. The 30-60 day oscillations were found to be strong over the eastern Arabian sea (near 12.5°N, 70°E), equatorial Indian ocean near 85°E long. and the west Pacific region. The 10-20 day oscillations were found to be strong along the 25°N and 15°S latitudes. EOFS of 5-day OLR fields over the Indian region revealed coherent eastwest oriented bands of OLR between 0° to 10°N latitude with centre around 85°E longitude.

Three large scale parameters viz., (i) 500 mb ridge axis location during April across 75°E longitude, (ii) April to January Darwin surface pressure tendency and (iii) northern hemisphere surface air temperature, averaged for January and February were utilised for development of multiple regression equation for prediction of monsoon rainfall over all India, northwest India, Peninsular India and the 29 meteorological subdivisions. Data of 37 years (1951-87) were used. Predictions were verified against the observed values. The regression equations produced correct forecast for 57, 65 and 57% of the occasions for all-India, NW India and Peninsular India, when verified in three equiprobable categories. The equations for the subdivi-

sions showed comparatively poor results. The forecasts were better over the west and central India, being correct on 50 to 62% of the occasions.

b) Synoptic-Climatological Studies for Extended Range Prediction

A recent decreasing trend in mean Indian summer monsoon rainfall and an increasing trend in its variability, on two and three - decadal scales, were revealed since early 1960s. These trends are in association with the increasing trend in the frequency of extreme monsoons, particularly of droughts. The region most affected by this decreasing rainfall trend is more or less the contiguous east-west belt over central India.

Intra-seasonal low-frequency oscillations in the mean sea level pressure field over the Indian region during the Monsoon-1987 were examined with the help of spectrum analyses and Hovmoller diagrams. There was hardly any discernible zonal propagation of pressure anomaly field along the trough zone. Western half of the trough zone revealed lower frequency in the variations compared to that in the eastern half. Only two episodes of south-to-north wave propagation occurred.

Recent monsoon variability in the global climate perspective was examined. Monsoon variability in the present decade is the second largest during the century which is a manifestation of larger frequency of extreme-monsoons. This large variability appears to be mainly due to ENSO (El Nino-Southern Oscillation) episodes of 1982-83 and 1986-87 as the monsoon rainfall was deficient in the 1982, 1986 and 1987 seasons.

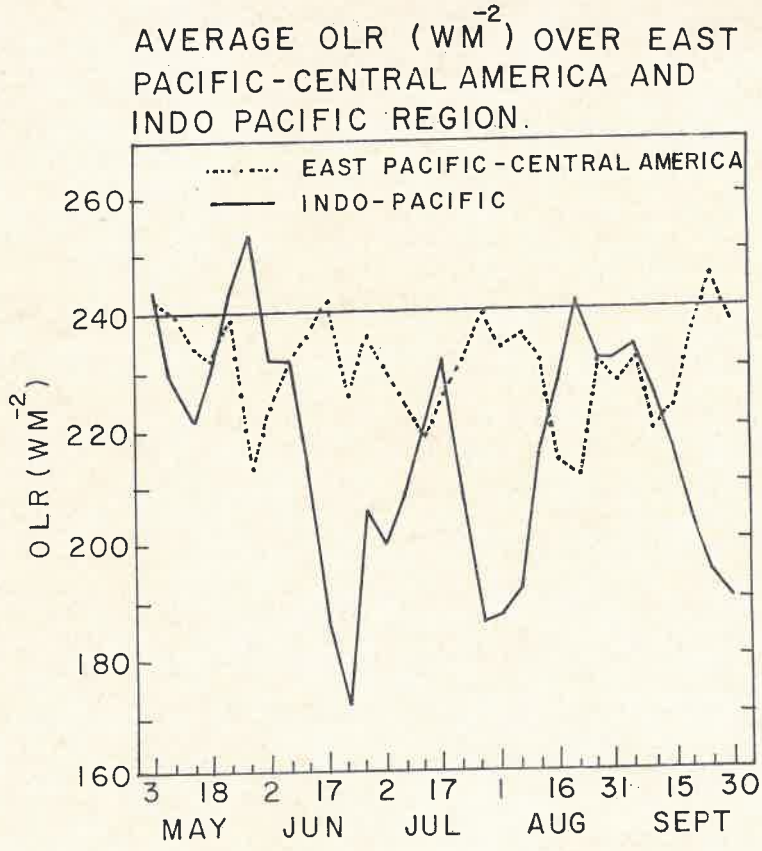


Fig. 1. Average OLR (WM^{-2}) over east Pacific - Central America and Indo Pacific region.

Analyses of ENSO episodes during 1935-1988 in relation to Indian Summer Monsoon suggest that a strong ENSO may cause drier as well as wetter monsoons depending upon the phase-locking between the two events. This is depicted in Fig 1 for the period 1980-88 in which during 1983 monsoon season, when the recovery to non-ENSO condition began in May-June 1988, the monsoon rainfall over India was in excess. About 65% of extreme monsoons are linked with ENSO.

The antecedent global and regional meteorological parameters which have revealed relationship with the Indian summer monsoon rainfall were examined to monitor the monsoon 1988. A good-to-excess of monsoon rainfall for the country was predicted. Fortnightly monitors of the prospects of Monsoon-1988 were regularly communicated to the India Meteorological Department (IMD).

2.1.3 Monsoon Studies and Forecasting

Analysis of the outgoing longwave radiation (OLR) data for the summer monsoon June-September 1979, over the Indo-Pacific (70°E - 140°E) and the Eastern Pacific Central American (140°W - 70°W) regions showed an out of phase relationship of the large scale convective episodes in the latitudinal belt of 5° - 15°N between the two regions (Figure 2).

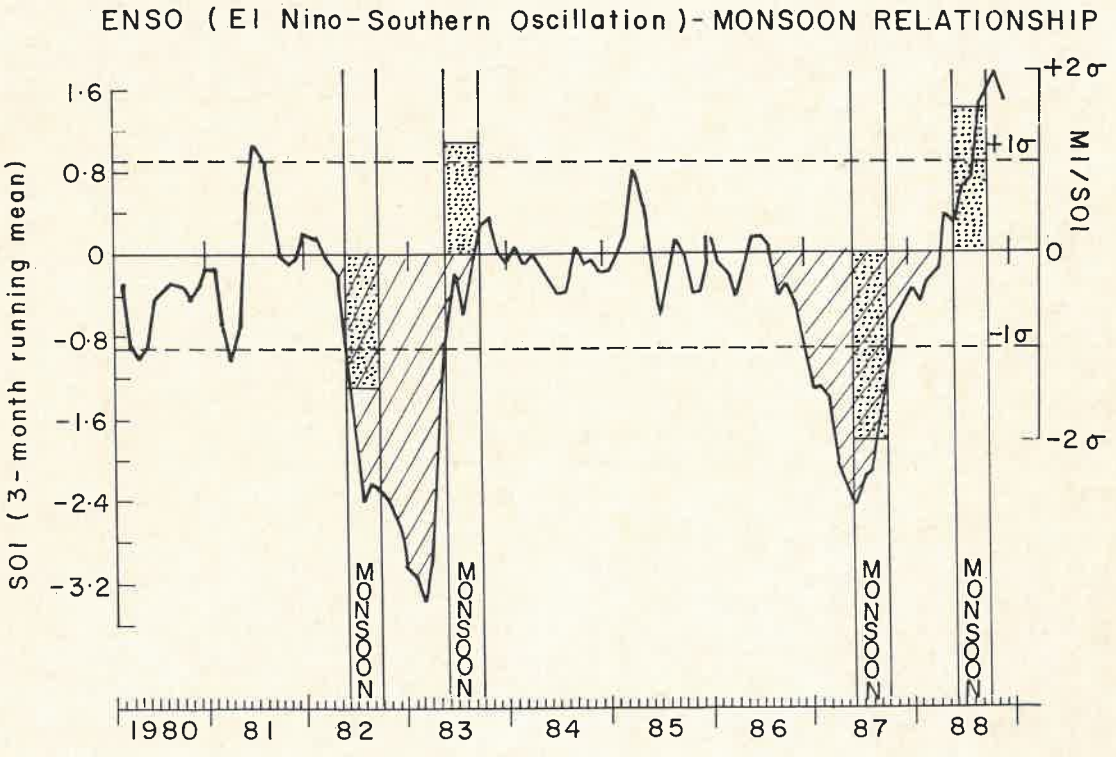


Fig. 2. ENSO - Monsoon relationship

Interannual variability of monsoon rainfall over India was studied in relation to fluctuation of the regional scale atmospheric features. The result showed that the failure of the monsoon rains over India during the years 1979 and 1987 were associated with presistent anomalous features of some of the regional scale parameters. Two low frequency oscillations in the time scale of 10-20 day and 30-50 day were noticed in the regional monsoon circulation. The higher period of oscillation (near 50-day) dominated the years of deficient monsoon rainfall (1979 and 1987) while the lower periodicity of 10-20 day or 30-day dominated the years of good monsoon activity in 1983 and 1988.

Relationship between the sea surface temperature (SST) and the fluctuation of near equatorial ITCZ was studied based on SST data obtained from the Geostationary meteorological satellite of Japan and the marine ship observations over the west Pacific ocean for the season 1979. The study showed that as the near equatorial ITCZ migrated northward, a cold sea surface progressively developed over the equatorial west Pacific in the meridional belt 130° -135°E as a result of upwelling and vertical mixing of the sea due to formulation of intense tropical disturbances.

The radiosonde data of monsoon 1979 were averaged over all active and break periods separately to study the characteristics of the data. The analysis revealed the presence of (i) strong (weak) westerlies over the peninsula, (ii) easterlies (westerlies) to the north of the normal position of the monsoon trough, (iii) northward (southward) shift of the upper tropospheric ridge line and that of high (low) moisture content in the lower troposphere during the active (break) phases of the monsoon.

The northwest (NW) India experienced below normal rainfall during the summer monsoon season of 1985 and 1987. The study of the circulation features for NW India during those two years showed that (i) the northern limit of monsoon along the westcoast of India remained stagnant near 20°N latitude for a prolonged period of over 5 weeks and that (ii) the upper tropospheric ridge line at 200 mb along the meridional belt 70° - 90°E remained south of its normal position during the period of stagnation.

The weekly frequencies of occurrence of the thunderstorms at four stations over the southernmost part of the westcoast of India (Trivandrum, Alleppy, Cochin and Kodaikanal) during the months of April to June for a period of 10 years (1978-1987) were studied. Two distinct peaks in the frequency of occurrence of the thunderstorms, one during the week of onset of monsoon and the other 5 to 7 weeks prior to the onset of monsoon were noted. This result may have some potential in issuing long range forecast of monsoon onset over Kerala.

Global upper tropospheric momentum transport for the latitudinal belt 28°N to 28°S were computed using the monthly mean wind data at 200 mb for the years 1970 and 1971 (good monsoon) and 1972 and 1979 (bad monsoon). The results showed contrasting variations in the momentum transport for good and bad monsoon years over India.

2.2 Climatology and Hydrometeorology

Large scale droughts/floods have a profound impact on many aspects of the economy of India, viz. agricultural production, hydroelectric power generation and on the development of the country as a whole. In view of the great importance of monsoon rainfall to the country, studies are carried out in this Division for improving knowledge and understanding of the physical and dynamical factors associated with the abnormalities in the behaviour of the monsoon such as intra-seasonal and inter-annual variability and long-term changes in the monsoon rainfall. One of the major aims of these studies is to use the knowledge acquired to do what is possible towards developing practical advice on monsoon performance, from seasonal monsoon rainfall forecasting to estimating probable trends of future climate over many decades.

2.2.1 Climate and Climatic Change

a) Intra-seasonal variations in all-India monsoon rainfall

The analysis of 18 monsoon seasons during the period 1971-88 revealed a variety of patterns in the daily all-India monsoon rainfall activity (e.g. Fig 3 for 1986, 1987 and 1988 monsoon seasons). The daily monsoon rainfall activity over the country fluctuates more or less simultaneously with the pressure gradient over the peninsular India signifying strength of southwesterly monsoon current. These intra-seasonal fluctuations are dominated by long periods of about 40-60 days and short periods of 10-15 and 3-5 days. The fluctuations in all-India rainfall particularly in drought years are characterized with a period of about 60 days. Long period fluctuation in rainfall seems to be linked with a northward propagation of the cloud zone from the equatorial region.

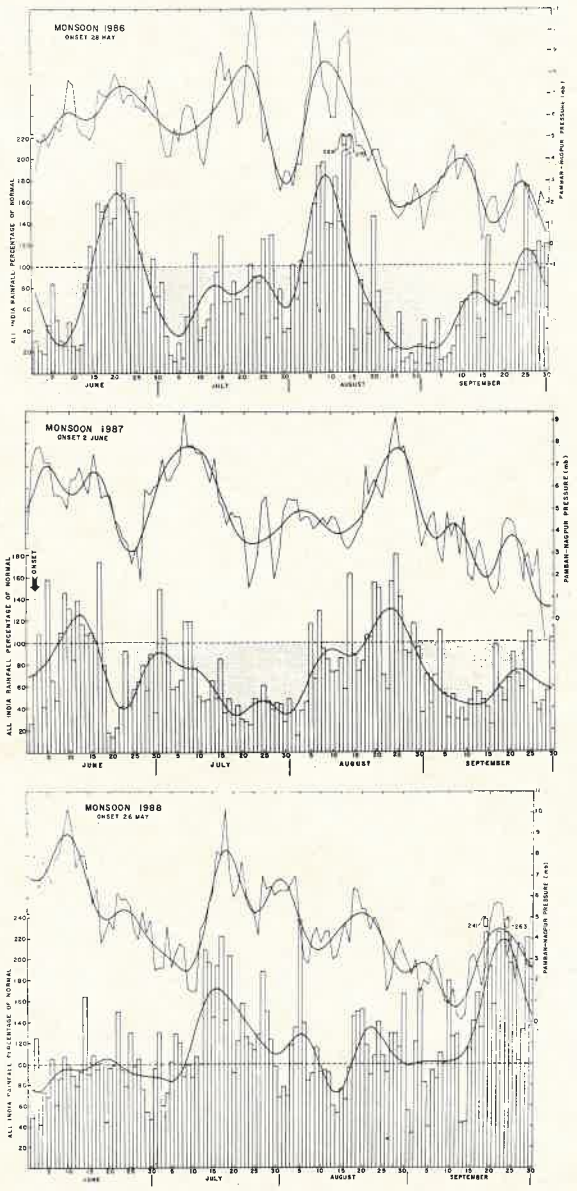


Fig. 3. Daily all India monsoon rainfall activity for 1986, 1987 and 1988 monsoons.

b) Long-range forecast for Monsoon 1988

Long-range Monsoon season rainfall forecast for 1988 based on different techniques developed at the Institute over the years were passed on to the India Meteorological Department. All the techniques gave an overall indication of good monsoon rainfall activity for the year 1988, which turned out to be correct.

Indian summer monsoon rainfall and surface air temperatures over the Indian region for the period 1951-80 and its spatial and temporal characteristics were made to identify a useful predictor for the monsoon rainfall. The average surface air temperature of six stations over the west Central India showed a highly significant correlation coefficient (C.C.) with the Indian monsoon rainfall (Fig 4). The suitability of this parameter for inclusion into the predictive regression model alongwith other parameters was assessed.

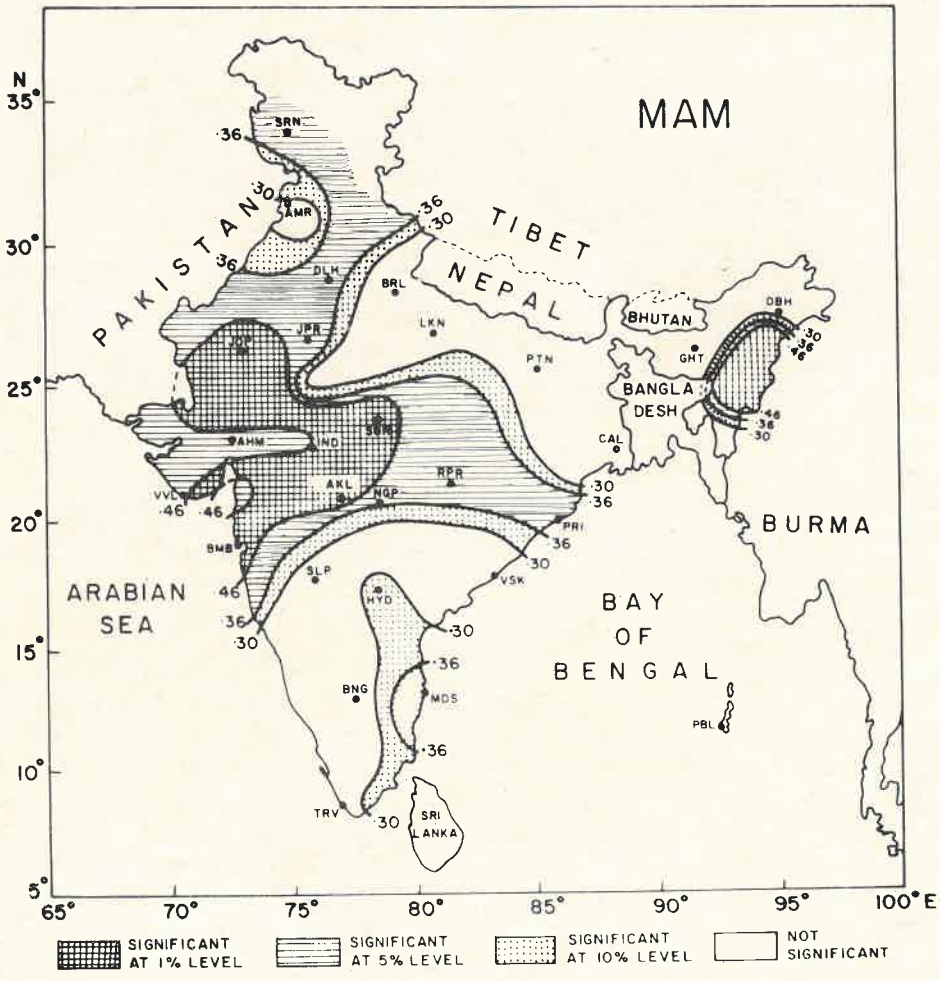


Fig. 4. Correlation coefficients between All India summer monsoon rainfall and surface air temperature for the summer (MAM) season of different stations over India for the period 1951-80.

c) Monsoon rainfall and food grain production

The C.C. between the percent departure of all-India summer monsoon rainfall from average (p) and total food-grain production index (F) is 0.82 for the period 1961-1988.The regression equation between the two series is

$$F = 0.58\ p + 101.05$$

It is possible to use this equation to estimate the food grain production of the country in advance.

d) Linear trends of monsoon rainfall in spatial domain

Linear trends of monthly, seasonal and annual rainfall were computed for 306 stations over India using data over the period 1871-1984, to understand the spatial and sub-seasonal patterns of long-term trends. Areas of both increasing and decreasing trends in the monsoon and annual rainfall were noticed, which probably answers the basically trendless characteristics of the all-India rainfall series. But, on a sub-regional scale, large areas of significant decreasing trend were seen in east Madhya Pradesh and adjoining parts of north-east India, parts of Gujarat and Kerala, while those of increasing trend were mainly along the west coast, north Andhra Pradesh and northwest India.

2.2.2 Hydrometeorological Studies

Depth-area relations associated with severe rainstorms are important to water resources designers for planning and design of hydraulic structures. Keeping this in view, Depth Area Duration (DAD) analysis of the severe rainstorms that had occurred since 1880 are being carried out under this research area. Estimates of probable maximum precipitation (PMP) are mostly used in the design of spillways for large dams in assessing the safety of dams. Applying meteorological principles, the PMP can be estimated from Depth-area values. For this purpose, the observed areal rainfall values are adjusted by the ratio of highest amount of moisture recorded in the specific area to that recorded during the rainstorm period. The highest value of atmospheric moisture is determined from the 24-hour persisting dew point values. In-depth studies have also been carried out regarding the incidence of maximum rainfall, variability in the rainfall and short duration rainfall related to water resources development.

a) Extreme persisting dew points

Based on the daily dew point data of 48 stations during the period 1961 to 1980, the extreme persisting 12-hr dew point monthly maps were prepared for June to September. It was found that during June to September the spatial range of extreme persisting 12-hr dew points, reduced to 100 mb, is 24°C to 30°C. The maps are useful for estimating the maximum moisture content at any location for moisture maximisation studies.

b) Analysis of rainstorms

DAD analysis of severe rainstorms that had occurred since 1880 over different meteorological sub-divisions of India were compiled to determine the greatest rainfall amounts for various size areas and durations ranging from 1 to 3 days. The analysis showed that the areas of the meteorological sub-divisions of Gujarat and West Uttar Pradesh recorded the most severe rainstorms which gave greatest rain-depths for each size of area and each duration. The DAD data would provide basic input for design flood studies of different river catchments where water resources projects are likely to be constructed.

c) Spells of maximum rainfall

The daily rainfall data from 1891 to 1980 for stations of Narmada basin upto Narmada Sagar dam site were used to determine the spells of maximum rainfall experienced by the basin in different durations. The analysis revealed that during the period of record, the basin experienced the greatest raindepths of 13, 18, 25, 29, 35 and 39 cm respectively in 1 to 6 day durations. The pro-

babilities of occurrence of two successive heavy rainspells with a time interval of 1, 2, 3 and 4-day durations were found to be 5, 13, 15 and 13 percent respectively.

d) Rainfall variability

i) Daily rainfall data of 365 stations of the Indian sub-continent for a period of 80 years were analysed to obtain the number of rain days, rainy days (rainfall $\geqslant$ 2.5 mm), intensity of rainfall in a rain day and the coefficient of variability of the daily rain intensities. Based on these data, a relationship between the cumulated rain amounts (x) and the cumulated rain days (y), both expressed in percentage, was developed as

$$x = y \; e^{-b\,(100-y)^c}$$

The constants 'b' and 'c' were found to be dependent on the coefficient of variability of the daily rain intensity. The analysis revealed that about 75% to 80% of the total rainfall at a station is realised just in 25 to 30% of the total rain days.

ii) The fluctuations in the annual maximum rainfall (1 to 10 days durations), seasonal rainfall (May to October) and precipitation concentration indices of the upper Narmada catchment were studied using 80-year rainfall data from 1901 to 1980. The analysis showed that there are some long-period oscillations in the series of individual annual maximum rainfall, seasonal rainfall as well as in precipitation concentration indices.

e) Analysis of stream flow data

The hourly observed values of stage/discharge data for 5-year period from 1980-84 of Karanja catchment were analysed. The hydrographs suitable for unit hydrograph derivation were identified by examining the plotted hydrographs. The hydrograph occurring during 21-23 Sept. 1983 was selected for unit hydrograph analysis. The peak and the base period of the unit hydrograph was worked out to be 37,000 cusecs and 48 hours respectively.

f) Short-duration rainfall analysis

The extreme value type I (EV_1) distribution was fitted to the annual maximum raindepths for 7 different duration between 1-hr and 48-hrs, recorded at Colaba observatory during the period 1924-1984, using five selected procedures such as maximum entropy method, method of moments, method of maximum likelihood, probability weighted moments method and mixed moments methods. The quality of the resulting fit was assessed and it was found that the maximum likelihood method is the most efficient method to derive the parameters of extreme value distribution.

g) Precipitation network design

At the request of the High Level Technical Committee on Hydrology (HILTECH), NIH, Roorkee, a review study on precipitation network design was carried out. The study revealed that the density of the rainfall stations in India as a whole at present is about 600 km^2/gauge which is in line with the recommended WMO standards (600-900 km^2/gauge).

2.3 Physical Meteorology and Aerology

The Division's work is organised in two areas : (i) Cloud Physics and Weather Modification and (ii) Environmental Physics.

The research is organised to study the various physical processes relating to atmospheric electrical parameters, mechanisms for the maintenance of atmospheric electric field, charge separation in clouds, interaction among cloud electrical, microphysical and dynamical parameters, mechanisms of formation of clouds and precipitation, warm cloud modification. Also, studies relating to atmospheric boundary layer, atmospheric chemistry, air pollution, dynamics of the middle atmosphere and the interaction between the physical processes taking place in the middle atmosphere and the troposphere vis-a-vis monsoon rainfall in the country, remote sensing of atmospheric aerosols and trace gases using LIDAR and spectrometer techniques are being continued.

2.3.1 Cloud Physics and Weather Modification

2.3.1.1 Studies in atmospheric electricity

The atmospheric electric field observation and selected meteorological parameters (temperature, pressure and humidity) recorded at Pune during 1930-38, 1957-58, 1964-65, 1973-74, 1987 and 1989 are being investigated for climatic scale variations over the period 1930-1987. Preliminary results indicated increase in atmospheric electric field of about 140 percent over the period.

The variations in the atmospheric electric field and aerosol concentration were studied using the observations collected in rural, urban, semi-urban and marine environments. The values of the atmospheric electric field recorded in the rural and marine environments were found to be low (60 Vm^{-1}). The aerosol concentrations also showed similar variations suggesting the influence of urban aerosols/pollutants on the atmospheric electric field.

2.3.1.2 Radar study of rain and rain-bearing clouds

The characteristics of frequency distribution of the convective clouds forming within 100 km around Delhi were studied using the radar observations of precipitation echoes of convective clouds obtained during the monsoon seasons of 1977 and 1978. The distributions computed using data relating to 2230 cloud cases showed log-normal characteristics.

Based on the radar data, a comparative study of the frequency of precipitation occurrence within 100 km around Delhi, their areal coverage and the percentage of convective clouds showing thunderstorm development was made for the two contrasting monsoon seasons, i.e., monsoon season of 1966 when the seasonal rainfall was deficient by 11% and 1971, when the seasonal rainfall was in excess by 38% of the normal. The study showed that the total number of precipitation echoes, observed during the monsoon season of 1971 and their average areal coverage are comparatively higher than those observed during the monsoon season of 1966. A similar result was also obtained in respect of the percentage of convective clouds showing thunderstorm development.

2.3.1.3 Warm cloud modification

At the request of the Government of Andhra Pradesh, planning and preparations for the cloud seeding operations proposed to be undertaken in the catchment areas of the Osmansagar and Himayatsagar reservoirs in the Hyderabad region were completed. Planning document for the above operations was prepared and submitted to the Govt. of Andhra Pradesh for further necessary action.

As desired by the Department of Science and Technology (DST), the Institute carried out field observational programme during the period of Vrishti Yagna for rain-making conducted at Mathura during 24-31 May 1988 by Shri Hariprasad Sharma, President of Vrishti-Vigyan Mandal. During the above field programme, measurements of atmospheric aerosols and meteorological parameters were taken. These were used to evaluate the possible effects of Yagna on Weather. No clouds were observed in the environment at the experimental site before and during the performance of Yagna (24-31 May 1988). The analysis of the observations made during the period of Yagna did not indicate any alteration in the environmental conditions leading to formation of clouds and rain which can be attributed to Yagna.

Action for acquisition of a 5-cm Doppler Weather radar for research in cloud physics and weather modification was initiated. Detailed technical specifications of the radar suitable for the research work of the Institute were formulated for acquiring a suitable radar.

2.3.2 *Environmental Physics*

2.3.2.1 *Studies in atmospheric boundary layer*

Spectral analysis of the high resolution aircraft cloud physical data obtained from NOAA aircraft at 500 mb level in the Arabian sea during MONEX-79 to study the characteristics of the atmospheric boundary layer was undertaken. The spectra of mixing ratio, wind and temperature exhibited slopes ranging from - 1.5 to - 6.0. These values are in agreement with those reported by other investigators. The spectra in the cloudy region showed a well marked peak corresponding to the convective scales.

Special aerological observations made at Pune during the summer monsoon seasons of 1980 and 1981 were used to study the convective activity in the sub-cloud layer. The stability of the sub-cloud layer computed, using the temperature data at the lifting condensation level, was used to investigate the convective activity at the cloud base level during weak and active monsoon conditions. The results indicated decrease/increase of convective activity on days of active/weak monsoon conditions.

Computations of saturation points at different levels from surface upto 500 mb were carried out using the special aerological ship observations made in the Arabian sea and the Bay of Bengal, Indian Ocean regions during June, July and August months of 1977. The mixing line constructions and the saturation pressure differences were also investigated utilising the above data. It is envisaged to study the variations in the mixing processes in the oceanic boundary layers during different weather conditions using the saturation point analysis technique.

2.3.2.2 *Studies in upper atmosphere*

The association between the stratospheric temperatures in the north pole regions during winter and the activity of the following summer monsoon in the Indian region was investigated. For this study, the mean temperatures at the 30 hPa level based on the data for the north pole region obtained from Free University of Berlin for 26 winter seasons (1955-56-1980-81) and the departures of rainfall for the 35 meteorological sub-divisions for the corresponding 26 year period (1956-81) were utilised. The results of the study indicated association between the warm anomaly in the north pole temperature during the winter and the years of active monsoon (rainfall more than + 10%) and vice versa.

The relationship between the equatorial lower stratosphere and the Indian monsoon activity was investigated considering the all-India rainfall as one index and zonal winds at 50mb over Balboa (9°N, 80°W) and Singapore (1°22'N, 103°59'E), during June to September, for the period 1950-86. The rainfall data were standardized and subjected to spectral analysis. The data were also composited according to the phases (westerly/easterly) of the equatorial QBO. Results of the analysis revealed a strong QBO signal in the inter-annual variability of the Indian monsoon rainfall. It was further revealed that excess rainfall (drought) activity is significantly more and the average rainfall is above (below) normal during the westerly (easterly) phase of the QBO.

Spectral analysis was performed in the geopotential height fields at levels 500, 300, 200, 100 and 50 hPa for an equatorial station Singapore (1°22'N, 103°59'E) for the two contrasting summer monsoons (June-September) 1972 (very weak monsoon year) and 1983 (very strong monsoon year). The preliminary analysis indicated the following :

i) Low frequency mode around 40-day period was active in the troposphere during 1972,
ii) Kelvin wave mode (10 to 20-day period) was active in the troposphere during 1983 and
iii) 4 to 5 day mode was active in both 1972 and 1983.

In order to understand the possible mechanisms for the depletion of Antarctic

ozone, the analysis of the geo-potential height, temperature and wind data at 30 hPa level for the high latitude station for the three months (Sept.-Nov.) for the period 1977-86 were examined. The results of the analysis indicated the decrease in heights and temperature during the period 1980-86 as compared to 1977-79. The variations showed in the above meteorological parameters are in association with the observed ones in the secular decline in ozone. The spectral analysis of the meteorological data showed weak oscillations in winds ranging from 6.3 to 12.5 days during the period 1980-86 when depletion of ozone was observed. However, no oscillations were noticed in winds during the year 1979 when the planetary wave activity followed by major stratospheric warming were observed. The above results suggest that the dynamical processes in the middle atmosphere could be associated with the depletion of the Antarctic ozone. The above hypothesis is further corroborated with the results of the study of the variations in the distribution of the nitric acid, trihydrate droplets in the polar stratospheric clouds and Cl and OH levels inside the cold vortex and aerosol at the stratospheric levels vis-a-vis planetary wave activity in the middle atmosphere.

The daily stratalert messages received from Berlin, during the winter, 1988-89 were analysed. The analysis revealed occurrence of major warming over the high-latitudes during the end of February 1989. The concurrent analysis of temperature data for Thumba, received up to 23 January 1989, also showed temperature variations up to 10°C in the lower mesosphere.

The effect of the high-latitude volcanoes on winter rainfall over Sri Lanka were being analysed.

Under the ISRO-SCHCNE collaborative programme, special launchings of M-100 rocket commenced from 9 January 1989 to define stratwarm events over tropics. The experiments could not however be completed due to non-availability of the additional rockets.

NESO (Northeast Summer Oscillation) is defined as the oscillation in the surface pressure field in the northeast region during the northern summer. The total effects of the sea-level pressure differences between Kwajalein (9°N, 167°E) and Minicoy (8°18'N, 73°09'E) and between Calcutta (22°39'N, 88°27'E) and Jodhpur (26°18'N, 73°01'E), which represent the areas of interest in the region of the Pacific high, basic monsoon flow, monsoon depressions and prominent heat flow were considered. The study of relationship of the NESO and the all-India rainfall during the summer monsoon for the period 1951-1986 revealed that about 60% of variability in rainfall could be attributed to the NESO phenomenon and 20% of variability to SO (Southern Oscillation).

A study was undertaken to examine the possible relationship between the stratospheric changes and the Antarctic ozone by looking into the heights, temperatures and winds at 30 hPa level, reported over a high-latitude station (Syowa, Antarctic) during the months September to November for the period 1977-1986. The study pointed out a significant decrease in heights and temperatures since 1980 as compared to the period 1977-1979. It corroborates with the observed secular decline in total ozone over Antarctica. The spectral analysis revealed weak oscillations in the zonal winds with the periodicities ranging from 6.3 to 12.5 days during the decline period of the ozone (1980-86). No oscillations in winds were noticed in 1979, when the planetary wave activity led to a major stratospheric warming and enhancement of ozone in the Antarctic.

2.3.2.3 Studies in air pollution

Field observational programme at Masingudi in the Nilgiri Biosphere Reserve was organised from 28 March 1988 to 10 April 1988 to study the interaction of atmospheric chemistry with Nilgiri Biosphere Reserve in Tamil Nadu. The measurements of trace gases (SO_2, NO_2, NH_3 and O_3) and aerosol were taken daily in the early morning, afternoon and eve-

ning hours. Also, rain water collection gadgets were installed for collection of rain water samples during the monsoon season. The concentration of NO_2 varied from 0.7 to 2.8 $\mu g/m^3$, and that of NH_3 from 0.2 to 4.3 $\mu g/m^3$. However, the average concentration of NO_2 (1.49) and NH_3 (1.94) were found to be within the range of background concentrations.

Rain water samples were collected at the Rain and Cloud Physics Research Centre of the Institute at New Delhi on 6 shower occasions during the month of August 1988. The number of samples collected during different showers varied between 1 and 21. pH values of all samples were found to be alkaline and varied between 5.8 and 8.3. Measurement of trace gases viz., sulphur dioxide, ammonia, nitrogen dioxide and total oxidant were made in the surface air-layer at the same site during the month of October 1988. Their mean concentrations were respectively 9.7, 26.3, 2.6 and 60.0 $\mu g/m^3$.

pH of 22 rain water samples collected at Muktsar (Punjab) during the monsoon season was found to vary between 6.4 and 8.1.

The pH analysis of rain water samples collected at Trivandrum during the monsoon season of 1987 showed that the average pH at this place was 5.8 which is near to the CO_2 — equilibrated value (5.70). However, the pH analysis of rain water samples collected during the monsoon season of 1988 indicated decrease in pH. The average H^+ ion concentration in rain water during 1987 was 1.58 μ moles per litre (pH = 5.80) which increased to 11.22 μ moles per litre (pH = 4.95) in rain water during 1988. This is being further investigated.

The chemical composition of fresh snow samples collected during the winter period of 1987 at Gulmarg indicated that sufficient amount of nitrate and sulphate is brought in the region by the western disturbances. However, these components were not in the form of acids but were present in the form of neutral salts. The most striking features of the Gulmarg snow were very high concentration of Ca and alkaline pH.

2.3.2.4 Lidar Probing of the Atmosphere

The association between the lidar-derived aerosol distributions in the lower atmosphere and the meteorological parameters was investigated. For the above study, the lidar observations of atmospheric aerosols collected during April-July 1987 and the aerological observations (temperature, humidity and wind) obtained from radiometersonde and pilot balloon ascents made at Pune during the corresponding period were utilised. The aerosol concentration in air layer between the surface and 800 m AGL showed a very rapid decrease and thereafter it showed a gradual decrease. A close association was found between the stability and wind conditions in the lower levels and the aerosol concentration. The humidity profile did not show any systematic association with the aerosols in the lower atmosphere. A transition zone was detected at about 1 km AGL where the concentration of aerosol below and above this layer showed marked changes. This transition zone corresponds with the capping inversion in the Atmospheric Boundary Layer (ABL).

The variations in the total column aerosol number density (N Cm^{-2}) in the lower layers of the atmosphere (50-1100 m AGL) were studied using the lidar observations made during the one year period (October 1986 to September 1987). The values of 'N' varied between 90 x 10^6 and 280 x 10^6 cm^{-2}. The concentration of aerosols in the winter months were higher by 78% than those observed during the monsoon months. These results suggest that the contribution of aerosol of soil origin (total suspended particulates) to the total dust load of the atmosphere is substantial particularly during the winter. During the monsoon months, the concentrations are lower possibly due to dispersion resulting from good mixing in the lower atmosphere caused by turbulence/convective processes.

A study was undertaken to investigate the suitable size index and refractive index for determining the aerosol size distribution applicable for the measuring site. For this purpose, Argon ion lidar observations obtained from a constant altitude (30 m AGL) in the atmosphere for different scattering angles were used. In this experiment, the laser-return signal strength was collected at 12 different scattering angles (from 90° to 175°) by reorienting the transmitter and receiver elevation angles. Analysis of the data collected on 9 clear days during April 1987 - November 1988 showed that the minimum value of normalised signal strength occurs between the scattering angles 105° and 110° which is in accordance with the Mie theory of scattering and also suggests the values of size index and real refractive index to be around 4 and 1.5 respectively for the measuring site.

Special observations of atmospheric aerosols at 30 m AGL using Argon ion lidar system and selected meteorological parameters (surface relative humidity and wind) were carried out on the evening of the lunar eclipse day (20.2.89). Analysis of the observations indicated that the concentration of aerosols started increasing rapidly from the commencement of totality, reaching a maximum around 21 : 15 hrs and thereafter decreasing slowly till the end of the eclipse. Also, the results showed an increase in relative humidity by about 10% and strong winds for a short period immediately after the beginning of total obscuration.

Atmospheric aerosol observations were made on 63 days during the Argon ion lidar system.

2.3.2.5 Spectroscopic measurement of atmospheric constituents

Spectrometric observations of total columnar density of NO_2 collected during May-June 1987, October 1987 - January 1988 were analysed. The results of analysis indicated that the density of NO_2 varied between 0.5×10^{16} and 6.0×10^{16} molecules/cm^2. The density of NO_2 observed during winter 1987 was found to be 4 to 5 times lower than that observed during the summer season.

2.4 Instrumental and Observational Techniques

The broad scope of the Division is to design and develop instruments and techniques of observations and to carry out field and laboratory experimental studies to understand the structure and dynamics of the troposphere and the stratosphere. Areas identified for research are :

The development of rocket payload to measure the temperature and wind structure in the 30-70 km altitude.

The development of instruments / techniques to study the structure of the atmospheric boundary layer.

The development of instruments / techniques to study the cloud electrification process.

Simulation techniques to study cloud physics under a controlled environment.

2.4.1 Development of Meteorological Rocket Payload for Rockets and Satellites

2.4.1.1 Development of rocket payload for upper atmospheric research and to carry out related physical studies.

Under this area, a project to develop rocket payload to measure the temperature and winds in the 30-70 km altitude using the Rohini-200 rockets of ISRO was under progress. During the year, four meteorological rocket payloads were tested at TERLS, Trivandrum for constant acceleration at RH-200 levels. Two payloads showed drift in carrier frequency and the others showed noise in modulation frequency. A final report on the project is under preparation.

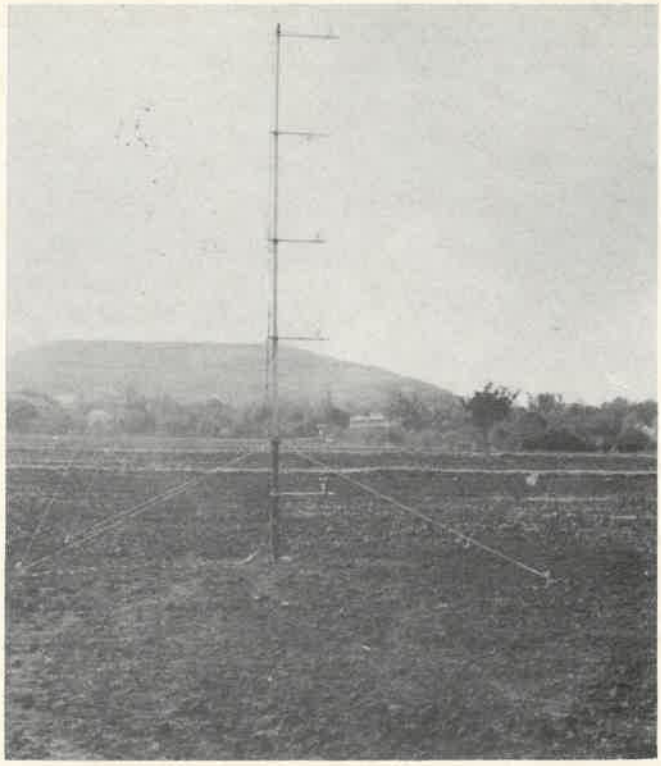


Fig. 5. A 9 meter instrumented tower for surface layer studies.

Fig. 6. A teethered Kytoon system ready for hoisting.

2.4.2 *Development of Instruments for Boundary Layer Studies*

2.4.2.1 *Development of instruments for the fluxes and profiles measurements in the atmospheric boundary layer and to carry out related studies*

To study the Atmospheric Boundary Layer (ABL) structure, various instruments were developed for field measurements of wind speed, temperature and humidity. Wind speed sensors are cup anemometers with an infrared chopping device to yield outputs in terms of frequency to voltage. Temperature sensors are fine wire thermocouples which yield an output of 10 mv/°C with an AD 594 chip. Lyman α hygrometer and an Infrared hygrometer were developed to measure humidity. The instruments were used in a field experiment conducted at the College of Agriculture, Pune during Feb-March 1989. Figure 5 shows cup anemometers and thermocouple sensors fitted to a 9 m tower for wind and temperature profile measurements in the surface layer. A kytoon (Fig. 6) with a payload having sensors to measure pressure, wind speed and direction and wet and dry bulb temperature was procured and used in the field experiment to probe the structure of ABL from ground to 800 m altitude. Data were collected using datalogger and a Personal Computer.

2.4.3 *Instrumentation for Cloud Physics and Weather Modification Studies*

2.4.3.1 *Cloud electrification studies*

Measurements of atmospheric electric potential gradient, conductivity of both polarities and space charge at ground surface were made at Pune during the partial solar eclipse of 18 March 1988. Inspite of no appreciable change in the atmospheric surface temperature, potential gradient showed an appreciable increase and conductivity of both polarities showed an appreciable decrease during the period of eclipse. Observations do not support either atmospheric boundary layer convective processes or upper atmospheric processes to be responsible for such changes in electrical parameters.

Charge transfer by point discharge current occurring below dust storms can play an important role in the global electrical circuit. Some old data obtained at Roorkee were analysed to see the contribution of this component over a period of one year. It was found that the contribution of point discharge current below duststorms is comparable to that below thunderstorms.

Atmospheric nuclei concentrations near the ground surface influence the electrical space charge near to ground. An experiment to investigate this problem was conducted during 1-15 April 1987, in which space charge was simultaneously measured at three different locations having different nuclei concentrations. Observations showed that space charge and potential gradient at locations having higher nuclei concentrations are larger, positive and fluctuating. Moreover, during night time, observations showed an increase in conductivity with height at location having larger nuclei concentrations as compared to a decrease in conductivity with height at locations having small nuclei concentrations.

An Observatory for making atmospheric electrical measurements was being set up. Measurements of different atmospheric electrical parameters at ground surface were made at this location irregularly on 2-3 fair-weather days every month for the last couple of years. Behaviour of diurnal variations of these parameters in different seasons was examined. Diurnal variations of space charge density at two different heights inside a Faraday cage were measured and compared to the values of space charge observed outside the cage.

Electrical charge brought down to ground by raindrops contributes to the maintenance of earth's negative charge and is important to study the precipitation electrification. With a Particle Charge measur-

ing apparatus, fabricated earlier, the charges on three different size categories of particles under a few rainshcwers were measured. Precipitation current was also measured simultaneously. Observations showed some interesting trends and are under analysis for rains under thunderstorms and monsoon clouds.

2.4.3.2 Simulation techniques for cloud Physics studies

Breakup of raindrop in clouds is important for understanding the development of rain in clouds. To simulate this process in laboratory, waterdrops were freely suspended over a Vertical Wind Tunnel. Breakup of these uncharged waterdrops and size distribution of fragments on breakup of these drops were studied for various drop sizes. It was observed that breakup probability of a drop increases with increasing diameter. Average lifetime for drops of sizes 4.5 - 8.3 mm were observed to decrease with the increasing diameter. It was also observed that the number of droplets produced by breaking of these waterdrops increases with the diameter of the drop.

To study the behaviour of waterdrops falling at their terminal velocity, one 12 m long Vertical tube was installed in which waterdrops of all sizes can attain their terminal velocities. This tube was fitted with two long internal electrodes to apply strong horizontal electric fields on falling drops. To study the scavanging of aerosol particles by waterdrops and to study the corona produced by splashing of raindrops on water surfaces, the instruments were being fabricated and assembled.

2.5 Theoretical Studies

Research studies are undertaken in order to understand the physical mechanism and energy source involved in the formation and growth of various synoptic scale disturbances during the southwest monsoon. The global spectral models are being developed for simulation of monsoon circulation and systems and also for investigating their error characteristics in order to develop the improved version. The Division also organises training course at different levels.

2.5.1 Simulation of Monsoon and Tropical Circulation Systems

2.5.1.1 Simulation of mean monsoon circulation and predictability of monsoon system.

A radiation package for parameterising the long wave radiation (infra-red) due to carbon dioxide and water vapour and short wave (visible) fluxes was prepared and was being tested to incorporate into 5-level primitive equation spectral model.

Computer routines for the preparation of input spectral coefficients from the observed grid point data fields and for the conversion of the forecast spectral fields from the primitive equation barotropic global spectral model into grid point values, were developed and tested. An experiment for five day forecasting of the monsoon depression on 7 July 1979 (700 mb level) with and without orography was performed and the results were found to be satisfactory.

Computations for the non-divergent part of wave-wave kinetic energy interaction due to advection and orography were performed in the latitudinal belt 3.5°S to 24.5°N at 700 mb for 7 July 1979, using FGGE III b level data. Results indicated a gain in KE (16.8×10^{13}J/sec) to the wave numbers 2 to 6 and a loss of energy (-8.6×10^{13}J/sec) for the wave numbers 7 to 11. Orographic effect was found to be more prominent than advection for synoptic scale waves. It was also found that the wave number 4 receives maximum kinetic energy from the zonal-wave interaction due to orography.

The set of equations for error available potential energy in the wave number domain was developed for a study of error propagation in different scales and variables.

The transformation equations for spherical co-ordinate system with the north pole located at a particular latitude and longitude were derived. These equations were used for analytical representation of symmetric cyclone whose centre is located anywhere on the globe.

The horizontal and vertical structure equations were derived in connection with normal mode initialisation for multilevel primitive equation global spectral model. Vertical structure equation was solved as an eigen value problem.

2.5.2 Studies on Dynamic Instability

2.5.2.1 Barotropic and baroclinic instability of the atmospheric flow

From the numerical experiments performed with barotropic global spectral model it was found that the inclusion of restoration process of basic zonal flow to the initial state restores the vacilation cycle,

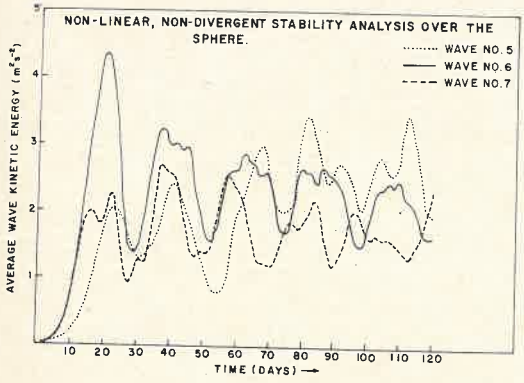


Fig. 7 The Oscillations of eddy Kinetic energy as observed during non-linear integration of barotropic global spectral model. The initial condition for the integration consists of unstable wave superimposed on mean monsoon tropical easterly jet.

suppressed by friction. The study on nonlinear development of wave numbers 5, 6 and 7 in the model showed a realistic maximum meridional wind of 6.2 ms^{-1} for wave number 6 during its evolution. Perturbation showed a small N-S tilt in the waves as compared to linear and quasilinear cases. Further, the nonlinear interactions lead to development of asymmetry in the intensities of highs and lows of the perturbation.

Average K.E. spectra during the growth and decay of nonlinear barotropic waves of the easterly jet are found to obey -5/3 power law of turbulence of inertial subrange in wave number domain $6 < m \leqslant 24$ and -1/2 power law for $m > 24$, where m is the zonal wave number.

The non-normal form of eigen value equation of linear equatorial balance model for the study of instability of monsoon zonal flow involved a singular matrix. The equation was manipulated into a normal form in such a way to avoid the inversion of singular matrix.

The un-initialised ECMWF data for the onset vortex over the Arabian sea during 10-19 June 1979 and the monsoon depression over the Bay of Bengal during 22-30 June 1979 for the area 15°S - 30°N and 30°E - 120°E were analysed for all levels and for each day using a computer routine in order to check the horizontal continuity of each field. Computer routines were developed to compute vorticity budget, heat sources and moisture sink and were included in the energetics study.

2.6 Computer

To manage the operations of the in-house Computer Centre.

To liaise with Computer Centres of Tata Institute of Fundamental Research (TIFR), National Informatics Centre (NIC), India Meteorological Department (IMD) and National Centre for Medium Range Weather Forecasting (NCMRWF).

To provide the necessary computational support, including training, to the Scientists of the Institute.

To collect, organise, store, retrieve and supply the meteorological data to the Scientists.

To organise data bank of global tropics.

Data collected during IIOE period were transferred from cards to magnetic tapes (10 lakhs). Monthly climate data (surface) for 125 stations for the period 1971-86, were transferred from card to magnetic tapes.

Ships data on 7 magnetic tapes were processed on ND-560 Computer System for I.Met.Dept., Pune. A Computer program for retrieving packed binary global FGGE-IIIb data was developed for use on ND-560 System. The data in the region of latitudes 15° S - 30° N and longitudes 30° E - 90° E (for 06 Z and 12 Z) for the period 10-19 June 1979 and 22-30 June 1979 were retrieved.

A mass storage file containing Monthly Climatic Upper Air Data for the ten standard levels in respect of the selected 80 tropical stations for the period 1984-86 was created. The data for the years 1984-85 were checked for consistency and transferred on to a magnetic tape for use by the Institute's Scientists. The data for the year 1986 were under scrutiny for consistency.

The work of preparation of Data Bank has been started. For this, the meteorological data on about 40 magnetic tapes from various Divisions were converted into ND-560 readable form on VAX 11/30 System at IMD, Pune.

A PC and a PC/XT with a Letter Quality Printer and 1.2 MB floppy drive have been acquired. PCs are connected to ND-560 Computer system to provide the facility of direct file transfer between PCs and main computer. Five dumb terminals emulating Tandberg terminals were also added to the computer system so that more scientists can work on computer simultaneously in inter-active mode.

3. SYMPOSIA ORGANISED/ CO-SPONSORED

3.1 Symposium organised

To commemorate the Silver Jubilee of the Institute's foundation and the Meteorological Programme of the International Indian Ocean Experiment (IIOE), an International Symposium on 'Monsoon : Understanding and Prediction' was organised in the Institute during 23-28 November 1988. Dr. Vasant Gowarikar, Scretary, Department of Science and Technology, Govt. of India, inaugurated the symposium. A large number of delegates from India and nine foreign countries participated in the symposium. 52 papers were presented by prominent scientists covering different aspects of Monsoon.

A talk in Marathi on 'Highlights of the scientific activities of the Institute' by Dr. H.N. Bhalme, AD and Shri S.S. Parasnis, SSO II was broadcast over AKASHVANI, Pune, on 21 November 1988 in connection with the symposium. Discussions on the concluding session of the symposium were also broadcast on 29 November 1988. Dr. G.B. Pant, AD, Shri K.G. Vernekar, AD, Shri S.K. Pradhan and Dr. R.R. Kelkar participated in it.

An Open House Exhibition depicting the Institute's activities and a cultural programme by the Institute's employees and their children were also arranged during the symposium period.

3.2 Symposium co-sponsored

The first Annual Conference of the Indian Aerosol Science and Technology Association (IASTA), Bombay was held at the Institute during 23-24 March 1989. The conference was co-sponsored by the Institute. Theme of the conference was 'Aerosol Science : A perspective on Research and Development in India'. Institute's scientists also participated in the same.

Fig. 8 Dr. Gowarikar, Secretary, DST, Shri D.R. Sikka, Director, IITM and Dr. Kulshreshtha, ADGM (I), India Met. Deptt. going for inauguration of Int. Symp. on 'Monsoon : Understanding and Prediction'.

Fig. 9 Section of the audience at the International Symposium

4. COLLABORATION WITH UNIVERSITIES AND OTHER SCIENTIFIC INSTITUTIONS

The Institute maintains contacts with the Universities and other Scientific Institutions in India and abroad. It has also collaborative research arrangements with different organisations. Highlights of these activities during the year are given below :

4.1 Collaboration with Universities

The Institute continued to collaborate with the University of Poona in teaching a course on Atmospheric Physics in the second year of M.Sc. (Physics) and M. Tech. degree programmes. Several scientists of the Institute delivered invited lectures on their respective areas of specialisation.

Dr. S.K. Mishra, D.D. was nominated by the Andhra University as a member of the Standing Committee for implementation of Post-M.Sc. Programme on Atmospheric Sciences. Dr. (Mrs) P.S. Salvekar, SSO I was co-opted as a Member of the Board of Studies in Mathematics of the University of Poona, Pune. Dr. D. Subramanyam, SSO I acted as External Examiner in M.Sc. Tech. examination of Andhra University, Visakhapatnam. Computer usage was permitted to the M.Tech. (Met.) and M.Sc. students of the University of Poona and those of the Cochin University of Science and Technology.

The following scientists worked as Examiners for M.Sc. and Ph.D. degrees of different universities. :

Name	Degree
1. Shri D.R. Sikka, Director	Ph.D.
2. Dr. A.S.R. Murty, DD	M.Sc.
3. Dr. H.N. Bhalme, AD	M.Tech.
4. Dr. P.C.S. Devara, SSO I	M.Sc.
5. Dr. L.T. Khemani, SSO I	Ph.D.
6. Shri R. Vijaykumar, SSO II	M.Sc.

Award of Ph.D. Degree

Shri P.R. Rakhecha, SSO I was awarded Ph.D. Degree in Physics by the University of Poona for his thesis entitled, 'On some hydrometeorological studies of the Indian rainfall'. He worked under the guidance of Dr. O.N. Dhar, Emeritus Scientist.

Shri C.K. Rajan, Lecturer in Meteorology, School of Marine Sciences, Cochin University of Science and Technology was awarded Ph.D. degree by the University of Cochin for his thesis entitled, 'Studies on some characteristics of Indian rainfall'. He worked under the guidance of Prof. R. Ananthakrishnan, Hon. Fellow of the Institute.

4.2 Collaboration with Institutions / Organisations

Bilateral Scientific Programmes

Indo-USSR Integrated Long Term Programme

Under the long term programme of Indo-USSR Collaboration in Science and Technology, 4 Scientists from the USSR visited the Institute during 19 Dec - 22 Jan 1989 and collaborated with its scientists in the area of Atmospheric and Oceanic Circulation. During the visits, studies on boundary layer parameterisation, boundary layer modelling and barotropic instability were initiated.

Institute scientists presented three papers at the Second Indo-USSR symposium on Programmes and Projects under the Long-term Programme, held at the National Aeronautical Laboratory, Bangalore, during 14-17 February 1989.

The numerical model program, for barotropic instability of an atmospheric zonally asymmetric zonal flow over a sphere of Dr. Yu. N. Skiba, Department of Numerical Mathematics, Academy of Sciences, USSR was loaded on the Institute's computer system. Some test runs were made utilising July mean 700 mb level data with his model and results were being analysed.

Research Projects under the Indo-US Sub-Commission

An informal meeting of the Principal Investigators (P.I.) and some of the Scientists involved in different research projects, formulated in August 1987 under the sponsorship of the Indo-US Sub-Commission, was held at the Institute on 23 August 1988. The meeting reviewed the progress of the projects and recommended the plan of work for the next year within the national plan.

ISRO-SCHCNE Theme-I Programme

A joint meeting of the Indian and the USSR scientists involved in the ISRO-SCHCNE Theme I Programme was held at the Physical Research Laboratory, Ahmedabad during 31 May to 9 June 1988. Dr. B.K. Mukherjee, SSO I and Shri J.R. Kulkarni, JSO participated in the meeting. It was decided that the results of 1985-86 joint stratwarm campaign based on M-100 rocketsonde data from Thumba, Volvograd and Heiss Island could be sent for publication by the Indian side. A joint publication would be planned after the next stratwarm campaign during 1988-89 on the basis of joint analyses. It was decided that studies relating to the climatology, waves and short period fluctuations of the middle atmosphere are to be undertaken as a part of the above programme.

Co-operation with the National Centre for Medium Range Weather Forecasting (NCMRWF)

DST continued to involve IITM in the implementation of mission-mode project for the establishment of the NCMRWF. For this purpose, support was rendered for the determination of the permanent location for NCMRWF and assessment of data requirements. Scientists of the Institute were awarded projects under the DST sponsorship, for conducting studies required towards the fulfilment of the work of the NCMRWF. Director attended different meetings at the DST for the scientific organisation of the centre. Shri R. Suryanarayana, DD also gave support in matters connected with the acceptance of the Super-computer.

National Workshop on the International Geosphere Biosphere Programme

Scientists of the Institute took part in the First National Workshop on the International Geosphere Biosphere Programme (IGBP), organised by Indian National Science Academy (INSA), New Delhi during 12-15 August 1988. The Institute was involved in all the five programmes recommended by the workshop for the implementation of a National Programme under the IGBP.

MONTBLEX Pilot Experiment

The Institute Scientists participated in the pilot experiment of MONTBLEX 1988 at IIT, Kharagpur. A 30 m tower was erected at the field site by a group of scientists of I.I.Sc. and IITM. Instruments like cup anemometer to measure mean wind speed, temperature sensors (fast and slow), humidity sensors and windvane to measure wind direction were installed at 1, 2, 4, 8, 15 and 30 m levels on booms projecting out from the tower. Sufficient care was taken so that the sensors are on the upwind side of the tower when the prevailing winds are on this sector most of the time. Propeller anemometers to measure the wind components, a hot wire probe to measure wind fluctuations at 15 m level and a solar radiometer (2 m level) to measure incoming radiation were installed. The outputs of these sensors were received at the base of the tower and transmitted through cables in a PCM mode to a nearby observation laboratory where the signals were fed to a Personal Computer. Parallel observations were also taken at the base of the tower using Micrologger Campbell 21-x system. Twentyfive channels record the output from slow sensors like cup anemometer, temperature and humidity sensors, wind vane and radiometer. The output scanned at every second were averaged over a minute. Fast sensors were scanned every tenth of a second and recorded on magnetic tapes, cartridge tapes, and 5½ inch floppy disks. Some sample data were printed out for examination.

Fig. 10 A young tree (45 years)

Fig. 11 An old tree (200 years)

Climatic Reconstruction

Department of Science & Technology sanctioned a research project entitled, 'Climatic reconstruction for the past 1000 years over the Western and Central Himalayan region using dendroclimatic approach' with Dr. G.B. Pant, Assistant Director, as Principal Investigator and Dr. K. Rupa Kumar, SSO I, as Principal Co-Investigator. The total project cost is Rs. 6,85,400/-. Work on the project commenced during the year. Major part of the equipment sanctioned was procured. Analysis of some samples collected from the Himalayan regions earlier was in progress. A field programme for tree ring sample collection has been drawn up for implementation during June 1989.

Technical Guidance to River Valley Projects

Technical guidance was provided to Koyana Dam Maintenance Division, Govt. of Maharashtra, regarding the estimation of Probable Maximum Precipitation (PMP) for the Koyana catchment during the period 9 to 29 March 1989. A report giving the estimates of maximum 1 day rainfall likely to be experienced during the months of September and October was made available to the Koyana Dam Authorities.

An up-to-date report on Hydrometeorological activities and research outcomes of the various hydrometeorological studies carried out in this Institute, was prepared and sent to the Director (Hydrometeorology), IMD, New Delhi. Another report giving the important findings of research in Hydrometeorological studies carried out in this Institute, was prepared and sent to the National Institute of Hydrology (NIH), Roorkee for inclusion in a document, 'Achievements in hydrology since independence' being prepared by them.

Research Applications Group

A Research Applications Group consisting of scientists from the Institute and the India Meteorological Department (I.M.D.) that had earlier been established by the Governing Council met on 25 April 1988 with the Director in the chair. It reviewed the work since its last meeting held in 1985, identified the application potential of the Institute's research work towards the service side and also laid down further plan of work.

Participation in the Exhibition

The Institute participated in the Exhibition arranged during the 76th session of the Indian Science Congress held at Madurai from 6 to 18 January 1989.

WMO Day Celebration

The Institute participated in the 29th World Meteorological Organisation (WMO) Day on 23 March 1989 at the India Meteorological Department, Pune.

Membership of Committees/Fellowships etc.

The following scientists of the Institute were elected/nominated to serve on different committees during the year :

Sr.No.	Name	Committee
1.	Shri. D.R. Sikka, Director	Executive Council of the Indian Meteorological Society for 1989-91
2.	Shri. R. Suryanarayana D.D.	a) Acceptance tests for Super Computer b) Procurement of Graphics package for installation on Cray-Vax Computer System
3.	Dr. A.S.R. Murty, D.D.	Int. Commission on Cloud Physics (ICCP) of the Int. Assn. of Meteorology and Atmospheric Physics (IAMAP) for 1988-92
4.	Dr. G.B. Pant, A.D.	a) Nat. Committee on World Climate Research Programme of the INSA for 1988-1991 b) Executive Council of the Indian Meteorological Society for 1989-91
5.	Shri. K.G. Vernekar A.D.	Expert Committee on Instrument/ Equipment for All India Co-ordinated programme on Himalayan Glaciology
6.	Dr. H.N. Bhalme, A.D.	World Meteorological Organisation (WMO) Commission on Climatology
7.	Dr. B. Parthasarathy, A.D.	Executive Committee of the Assn. of Hydrologists of India for 1989-90
8.	Dr. P.C.S. Devara, SSO I	Optical Society of India (OSI), Calcutta

Participation in cruise

Shri P. Seetaramayya, SSO II participated in cruise No. 43 of the research ship, 'Sagar Kanya' during the period 27 July - 16 Sept. 1988.

5. PARTICIPATION IN SYMPOSIA / CONFERENCES ETC AND PAPERS PRESENTED

Forecasting Research Division

Symp./Conf. etc. a) National workshop on 'Antarctic studies', National Physical Laboratory, New Delhi, 3-5 May 1988

Participant(s) — S.S. Dugam.

Paper(s) presented (i) Some climatic teleconnections of Antarctic

Author(s) : R.K. Verma, S.S. Dugam, K. Subramaniam and S.B. Kakade.

b) Int. Conf. on 'Tropical Meteorology', University of Queensland, Brisbane, Australia, 4-8 July 1988
— K.D. Prasad.

(i) Large-scale abnormalities of 1987 Indian summer monsoon and the associated Global/Regional anomalies
: D.R. Sikka and R.K. Verma.

(ii) Prediction of monthly and seasonal summer monsoon rainfall over India
: K.D. Prasad and S.V. Singh.

c) Seventh annual convention and Int. Sem. on 'Hydrology' and Colloquium on 'Water Resources Problems of South Asian Countries', Visakhapatnam, 20-23 October 1988
— V.R. Deshpande.

(i) Comparative study of stagnation of northern limit of monsoon and associated monsoon rainfall over northwest India during 1985 and 1987
: V.R. Deshpande, P.V. Puranik and V.R. Mujumdar.

d) SAARC Workshop on 'Numerical Weather Prediction', Mausam Bhavan, New Delhi, 2-3 Nov. 1988
— S.S. Singh.

e) 25th Annual convention and Sem. on 'Advances in Geophysical Research in India', National Geophysical Research Institute, Hyderabad, 8-10 Feb. 1989
— S. D. Dahale.

(i) On the relationship between satellite observed HRC and rainfall over the Indian Ocean
: P.N. Mahajan and S.P. Ghanekar.

(ii) Periodicity in pentad impulses during SW monsoon over Maharashtra
: S.D. Dahale.

f) Second Indo-USSR Symp. on 'Programmes and Projects for INDO-USSR Collaboration in Mechanics', National Aeronautical Laboratory, Bangalore, 13-17 Feb. 1989
— D.K. Paul, P. Seetaramayya and S.S. Vaidya.

(i) Inter-seasonal monsoon variability in relation to 30-50 and 10-20 day oscillations
: D.K. Paul, V.R. Mujumdar, S.P. Ghanekar and D.R. Sikka.

(ii) On composite structure of the prevailing weather over western Indian ocean during the third phase of monsoon-88
: P. Seetaramayya and S.G. Nagar.

(iii) Sensitivity of a regional model with respect to the counter gradient effect in turbulent transport
: S.S. Vaidya, V.N. Lykossov and S.S. Singh.

Symp./Conf. etc. g) 4th Int. Meeting on 'Statistical Climatology', Rotorua, New Zealand, 27-31 March 1989

Participant(s) — S.V. Singh (He chaired a session on invitation).

Paper(s) presented (i) Forecasting of seasonal monsoons rainfall over India and adjoining countries

Author(s) : S.V. Singh, R.H. Kripalani, K.D. Prasad and S.D. Bansod.

(ii) Low frequency intraseasonal variations of rainfall and outgoing longwave radiation over India
: R.H. Kripalani and S.V. Singh.

Climatology and Hydrometeorology Division

a) Quadrunnial Ozone Symp., Gottingen, Federal Republic of Germany, 8-13 August 1988
— L.S. Hingane

(i) On the reversal of total ozone gradient over India
: L.S. Hingane.

b) National Sem. on 'Environmental Issues, Problems and Solutions', University of Kerala, Trivandrum, 7-11 Oct. 1988
— G.B. Pant (He chaired a scientific session).

(i) Environmental conservations and climate
: G.B. Pant.

c) Seventh Annual Convention and Int. Sem. on 'Hydrology' and Colloquium on 'Water Resources Problems of South Asian Countries' Visakhapatnam, 20-23 Oct. 1988
— B. Parthasarathy and A.K. Kulkarni.

(i) Monsoon behaviour over homogeneous regions of India during last one hundred years
: B. Parthasarathy, N.A. Sontakke and A.A. Munot.

(ii) Rainstorms which contributed greatest areal raindepths in Andhra Pradesh
: O.N. Dhar, S. Nandargi and A.K. Kulkarni.

d) 76th Session of Indian Science Congress, Madurai, 7-12 January 1989
—A.B. Sikdar.

e) 25th Annual Convention and Sem. on 'Advances in Geophysical Research in India', National Geophysical Research Institute, Hyderabad, 8-10 February 1989
- A.K. Kulkarni.

(i) Analysis of most severe rainstorms of India
: O.N. Dhar, A.K. Kulkarni, B.N. Mandal and S. Nandargi

(ii) Some features of heavy rainfall distribution over Narmada Basin upto Narmada Sagar Dam site in M.P.
: O.N. Dhar, S.S. Mulye, S. Nandargi, and A.K. Kulkarni.

Symp./Conf. etc. a) Workshop on 'Antarctic studies', National Physical Laboratory, New Delhi, 3-5 May 1988

Participant(s) — V.N.R. Mukku.

Paper(s) presented (i) Ozone hole re-examined

Author(s) : V.N.R. Mukku.

b) First National Workshop on 'Indian Geosphere Biosphere Programme (IGBP)', Indian National Science Academy, New Delhi, 17-19 August 1988 — L.T. Khemani.

c) Seventh Annual Convention and Int. Sem. on 'Hydrology', and Colloquium on 'Water Resources, Problems of South Asian Countries', Visakhapatnam, 20-23 Oct. 1988
— R.S. Reddy.

(i) On the relationship between the equatorial lower stratosphere and Indian Monsoon activity
: R.S. Reddy, B.K. Mukherjee, M.L. Khandekar, V.R. Neralla and W.L. Godson.

d) Nehru Centenary Celebrations, Department of Science and Technology, New Delhi, 15-16 December 1988
— R.N. Chatterjee.

e) 76th Session of Indian Science Congress, Madurai, 7-12 January 1989
— R. Vijayakumar.

f) 25th Annual convention and Sem. on Advances in Geophysical Research in India, National Geophysical Research Institute, Hyderabad, 8-10 Feb. 1989.
—S.S. Parasnis, A.L. Londhe, C.S. Bhosale and S.S. Kandalgaonkar.

(i) Association of equatorial wave dynamics with Indian summer monsoon activity
: C.S. Bhosale, R.S. Reddy, and B.K. Mukherjee.

(ii) Diurnal and seasonal variations of surface atmospheric electric field and its associates with the meteorological parameters at Pune
: S.S. Kandalgaonkar, S.M. Sholapurkar and G.K. Manohar.

(iii) High resolution spectroscopic techniques for remote sensing of atmospheric constituents, oceanic mixed layer and land resources by satellite
: D.B. Jadhav and A.L. Londhe.

(iv) On the height time variation of aerosol layered structure in the lower troposphere
: P.C.S. Devara and P.E. Raj.

(v) On the mixing processes in the atmospheric boundary layer
: S.S. Parasnis and S.S. Goyal.

(vi) Point discharge current observations during two consecutive pre-monsoons
: G.K. Manohar and S.S. Kandalgaonkar.

(vii) Preliminary observations of total column density of Nitrogen dioxide over Pune
: A.L. Londhe, H.K. Trimbake, S.D. Bhonde and D.B. Jadhav.

(viii) Season thunderstorms of the years 1987 and 1988 at Pune
: S.M. Sholapurkar

Symp./Conf. etc. g) 1st Annual conf. of Indian Aerosol Science and Technology Association (IASTA) on 'Aerosol Sciences - A Perspective on Research and Development in India', IITM, Pune, 23-24 March 1989

Participant(s) —A.S.R. Murty, R.K. Kapoor, P.C.S. Devara, L.T. Khemani, D.B. Jadhav, P.E. Raj, M.S. Naik, G.K. Manohar, A.G. Pillai, G.A. Momin, A.L. Londhe, P.S.P. Rao, G. Singh, S.S. Kandalgaonkar and P.D. Safai.

Paper(s) presented (i) Association between giant hygroscopic condensation nuclei and meteorological parameters at a tropical station

Author(s) : A.G. Pillai and A.M. Selvam.

(ii) Chemical compositions of fresh snow over Gulmurg
: L.T. Khemani, G.A. Momin, P.S.P. Rao, P.D. Safai, R.K. Kapoor and Prem Prakash.

(iii) Influence of volcanically erupted atmospheric aerosols on climate
: B.K. Mukherjee and K. Indira.

(iv) Inter-monsoonal variability of natural and anthropogenic aerosol in rainfall chemistry within 10 km distance
: G.A. Momin, L.T. Khemani, P.S.P. Rao, P.D. Safai, G. Singh and M.S. Naik.

(v) Lidar investigations of atmospheric constituents at a tropical station
: P.C.S. Devara and P.E. Raj.

(vi) Nature of aerosols and their sources at Trivandrum
: P.S.P. Rao, L.T. Khemani, G.A. Momin, P.D. Safai and M.S. Naik.

(vii) Observations of aerosol and atmospheric electric parameters in different environments
: G.K. Manohar, S.M. Sholapurkar and S.S. Kandalgaonkar.

(viii) Origin of calcium in marine aerosol over the Arabian sea
: M.S. Naik, L.T. Khemani, G.A. Momin and P.S.P. Rao.

(ix) Regional aerosol chemistry of the Nilgiri Biosphere Reserve
: P.D. Safai, L.T. Khemani, G.A. Momin, P.S.P. Rao and M.S. Naik

(x) Study of aerosol loading using twilight method
: D.B. Jadhav and A.L. Londhe.

(xi) Survey of vehicular lead deposition in Pune city
: P.N. Patil, L.T. Khemani, G.A. Momin, P.S.P. Rao, P.D. Safai and A.S. Gadgil.

(xii) Variation of laser-return signal strength from atmosphere with scattering angle
: P.E. Raj and P.C.S. Devara.

Instrumental and Observational Techniques

a) Second Workshop on IMAP Scientific Results and the 1st meeting of Study-cum-Task Team for instrumentation for Atmospheric Science and Meteorology, Vikram Sarabhai Space Centre, Trivandrum, 26-29 April 1988.
—K.G. Vernekar

b) MONTBLEX - Pilot Experiment, Indian Institute of Technology, Kharagpur, 6-17 August 1988
—K.G. Vernekar, L.K. Sadani, S. Sivaramakrishnan and Brij Mohan.

Symp./Conf. etc. c) Workshop on 'Low level wind shear in relation to aviation', India Meteorological Department, Pune, 14 December 1988
— K.G. Vernekar.

d) 76th Session of Indian Science Congress, Madurai, 7-12 January 1989
— S. Sivaramakrishnan.

e) 1st Annual conf. of Indian Aerosol Science and Technology Association (IASTA) on 'Aerosol Science - A perspective on Research and Development in India', IITM, Pune, 23-24 March 1989
— A.K. Kamra and C.G. Deshpande.

Paper(s) presented (i) Simultaneous measurements of atmospheric electric space charge at three locations having different atmospheric nuclei concentration

Author(s) : C.G. Deshpande, S. Dhanorkar, A.B. Sathe and A.K. Kamra.

Director's Participation and Presentation of Papers

a) Indo-Soviet Seminar on 'Pressing Problems of Computing Mechanics and Mathematical Modelling', Moscow, 23-29 May 1988.

(i) A review of numerical models as applied to diagnosis and prediction of monsoon as developed by IITM.

: D.R. Sikka.

b) Int. TOGA SSG meeting, Cairns, Australia, 11-15 July 1988

(i) Failure of monsoon over India in 1987

: D.R. Sikka

c) First National Workshop on Indian Geosphere-Biosphere Programme (IGBP), New Delhi, 17-19 August 1988.

d) Conference on 'Nehru Centenary Celebrations', Department of Science & Technology, New Delhi, 15-16 December 1988.

e) 76th Session of Indian Science Congress, Madurai, 7-12 January 1989.

f) French Festival in India - Symposium on Resource Management of Space, New Delhi, 6-7 February 1989.

(i) Development in Monsoon Meteorology and Prediction

: D.R. Sikka

g) Prof. P.R. Pisharoty's Birthday Symposium, Physical Research Laboratory, Ahmedabad, 9 February 1989.

h) Symposium on 'Monsoon Meteorology and Remote Sensing', Ahmedabad, 10-11 February 1989.

(i) Short and Medium Range Weather Forecasting

: D.R. Sikka

i) 2nd Indo-Soviet Symposium, National Aeronautical Laboratory, Bangalore, 15-17 February 1989.

5 A. Int. Symp. on 'Monsoon Understanding and Prediction', IITM, Pune, 23-28 Nov. 1988.

Papers presented by Institute scientists

i) Barotropic spectral modelling of nonlinear interactions for transient waves in tropical easterly jet

: S.K. Mishra.

ii) Fluctuation of regional scale atmospheric features in relation to monsoon activity

: D.K. Paul, V.R. Mujumdar, P. V. Puranik, S.P. Ghanekar, V.R. Deshpande and D.R. Sikka.

iii) Low frequency interseasonal oscillations and their potential in medium range forecasting

: S.V. Singh.

iv) Middle atmospheric dynamics and monsoon variability

: B.K. Mukherjee.

v) Monsoon trough boundary layer experiments

: A. Prabhu and K.G. Vernekar.

vi) Possible causes of large scale droughts/floods in India - Implications for forecasting

: H. N. Bhalme.

vii) Radar study of the thunderstorms around Delhi, north India during monsoon season

: R.N. Chatterjee and Prem Prakash.

viii) Recent monsoon variability in the Global climate perspective

: R.K. Verma.

ix) Regional model for monsoon prediction

: S.S. Singh, S.S. Vaidya and E.N. Rajagopal.

x) Vagaries of Indian Summer Monsoon rainfall and its relationships with regional/global circulations

: B. Parthasarathy.

6. PARTICIPATION IN MEETINGS

Forecasting Research

Shri D.K. Paul, SSO I
Meeting on Indo-US Sub-commission Programme, Indian Institute of Tropical Meteorology (IITM), Pune, 22 August 1988

Shri J.R. Kulkarni, JSO
Meeting with Soviet Scientists Dr. Yu. P. Kashelkov and Dr. A.A. Krivolutsky and other Indian scientists under ISRO-SCHCNE Collaboration Programme Theme, 1,
Physical Research Laboratory (PRL), Ahmedabad, 7-10 June 1988.

Climatology and Hydrometeorology

Dr. G.B. Pant, A.D.
i) Review Committee Meeting, Birbal Sahani Institute of Palaeobotany (BSIP), Lucknow, 5 April 1988.
ii) INSA National Committee on World Climate Research Programme, Indian National Science Academy (INSA), New Delhi, 16 March 1989.

Physical Meteorology and Aerology

Dr. A.S.R. Murty, D.D.
i) Meeting on 'Cloud Seeding Programme', Department of Science and Technology (DST), New Delhi, 22 September 1988.

Dr. B.K. Mukherjee, SSO I
i) Meeting with Soviet Scientists Dr. Yu. P. Kashelkov and Dr. A.A. Krivolutsky and other Indian scientists under ISRO-SCHCNE Collaboration Programme Theme 1, Physical Research Laboratory (PRL), Ahmedabad, 7-10 June 1988.
ii) Steering Committee meeting on 'World Ionosphere/ Thermosphere Study (WITS), Indian Institute of Geomagnetism (IIG), Bombay, 1 February 1989.
iii) Working Group and Programme Management Board meeting of IMAP-C, Indian Middle Atmosphere Programme (IMAP) Office, Bangalore, 6-8 February 1989.

Dr. L.T. Khemani, SSO I
i) Editorial Board meeting of the News Letter of Indian Aerosol Science and Technology Association (IASTA), Bombay, 28-29 September 1988.
ii) Meeting organised by Bombay Suburban Electric Supply Ltd., (BSES), Bombay, 23-25 October 1988.
iii) Meeting in connection with the clearance of the thermal power plant project at Dahanu, Dept. of Environment, Mantralaya, Bombay, 26 October 1988.

Dr. R.S. Reddy, SSO II
Steering Committee Meeting on 'World Ionosphere/ Thermosphere Study (WITS)', Indian Institute of Geomagnetism (IIG), Bombay, 1 February 1989

Instrumental and Observational Techniques

Shri K.G. Vernekar, A.D.
i) Meetings of ADCOS Study cum Task Team for Instrumentation for Atmospheric Science and Meteorology (ASTIASM), Indian Institute of Science (I.I.Sc.), Bangalore, 7-9 September 1988.
ii) Third meeting of ASTIASM, Indian Middle Atmosphere Programme (IMAP) Office, Bangalore, 15 October 1988.
iii) Expert Committee meeting on Instrumentation required for All India Coordinated Project on Himalayan Glaciology, DST, New Delhi, 2-4 January 1989.

Theoretical Studies

Dr. R. Ananthakrishnan, Hon. Fellow and
Dr. S.K. Mishra, D.D.
i) Meetings of the Co-ordination Committee for M.Tech. course in Atmospheric Physics, University of Poona, Pune, 19 May and 20 June 1988.

Dr. (Mrs.) P.S. Salvekar, SSO I
Meetings of the Board of Studies in Mathematics, University of Poona, Pune, 13 September 1988 and 6 January 1989.

Shri D.R. Sikka, Director
i) Official Meeting, Department of Science and Technology (DST), New Delhi, 20 April 1989.
ii) Meeting on Ozone depletion and global warming, Ministry of Environment and Forests, New Delhi, 5-6 May 1988.
iii) Data requirement for National Centre for Medium Range Weather Forecasting (NCMRWF), New Delhi, 11-14 May 1988.
iv) Meeting of the Committee on the Location of National Centre for Medium Range Weather Forecasting, (NCMRWF), New Delhi, 11-14 May 1988.
v) Meetings on Cyclones Probing Aircraft and Working Group on Data for Medium Range Forecasting, Department of Science & Technology (DST), New Delhi, 19-20 July 1988.
vi) 2nd meeting of the Programme Advisory Committee on Atmospheric Sciences, Indian Institute of Science (I.I.Sc.), Bangalore, 29-31 July 1988.

vii) Meeting of the Planning Commission, Working Group on Meteorology for the 8th Five Year Plan and discussions in connection with Institute's Plan and other research projects, India Meteorological Department (IMD) and Department of Science and Technology (DST), New Delhi, 8-10 August 1988.

viii) Meeting of the International TOGA Scientific Steering Group in Cairns, Australia, 11-15 July 1988.

ix) Meeting to plan India's National TOGA Programme, New Delhi, 14-24 September 1988.

x) Co-ordination Committee of the MONTBLEX, Indian Institute of Technology (IIT), Kharagpur, 14-24 September 1988.

xi) Meeting to review Cloud Seeding Programme, Department of Science and Technology (DST) and India Meteorological Department (IMD), New Delhi, 14-24 September 1988.

xii) Meeting to review Norwester Project, Department of Science and Technology (DST), New Delhi, 4-5 October 1988.

xiii) Meeting regarding location of a thermal power plant at Dahanu, Bombay Suburban Electric Supply Ltd., Bombay, 24 October 1988.

xiv) Meeting of the Working Group on Meteorology for 8th Five Year Plan, India Meteorological Department (IMD), New Delhi, 6-8 November 1988.

xv) Meeting of Scientific Advisory Committee of the Centre of Atmospheric Sciences, Indian Institute of Technology (IIT), New Delhi 28 November-4 December 1988.

xvi) Meeting of the Project Evaluation and Monitoring Committee of the DST, 3 February 1989.

xvii) Meeting of the Council for Meteorology and Atmospheric Sciences, India Meteorological Department, New Delhi, 7 February 1989.

7. INSTITUTIONAL SEMINARS

The following seminars were organised under the Institute's Seminar series :

S.No.	Speaker	Topic	Date
1.	Prof. R. Ananthakrishnan, Hon. Fellow, IITM	Second law of Thermodynamics - its implications and applications	08, 15 April and 10 May 1988
* 2.	Dr. S.V. Singh, AD, IITM	Interseasonal Oscillation of monsoon rainfall and 40 day oscillation	19 April 1988
* 3.	Dr. B.K. Mukherjee, SSO I, IITM	Role of planetary waves in the dynamics of the middle atmosphere	29 April 1988
* 4.	Shri R.K. Verma, SSO I, IITM	Long range forecasting of monsoon based on some recent studies	10 June 1988
5.	Shri K.D. Prasad, SSO II, IITM	Prediction of monthly and seasonal summer monsoon rainfall over India	10 June 1988
6.	Dr. L.S. Hingane, SSO I, IITM	Meridional reversal of total 0_3 over India	27 July 1988
7.	Dr. I. Pittalwala, USA	Spatial and temporal variation in United States, Sunchine	03 August 1988
8.	Prof. S. Gadgil, IISc., Bangalore	Simple model of Hadley Circulation	23 August 1988
9.	Dr. V.N.R. Mukku, SSO II, IITM	* i) Ozone hole and stratospheric condensation nuclei events ii) An interpretation linking large scale dynamics with global electrical parameters.	25 August 1988 16 September 1988
10.	Dr. G.B. Pant, AD, IITM	Mechanism of climatic change : Some signals from tropical forecasts (in Hindi)	29 August 1988
11.	Dr. D.B. Jadhav, SSO I, IITM	i) Remote sensing of atmospheric constituents using high resolution spectroscopic techniques ii) Studies in atmospheric spectroscopy at Rutherford Appleton Laboratory, U.K. and NCAR, USA iii) Atmospheric chemistry and climate (in Marathi)	06 September 1988 01 February 1989 27 February 1989

* These seminars were arranged under the Institute's programme of 'Silver Jubilee Celebration'.

S.No.	Speaker	Topic	Date
12.	Dr. S. Rajamani, AD, IITM	Some dynamical aspects to monsoon system	08 September 1988
13.	Dr. A.S.R. Murty, DD, IITM	WMO consultation on Weather Modification Activities for ASIAN countries held at Bangkok, Thailand	06 October 1988
14.	Dr. R.S. Reddy, SSO II, IITM	Middle atmospheric studies	07 October 1988
15.	Dr. Kamal Puri, Bureau of Meteorology, Australia	i) Review of current status of tropical NWP ii) GCM type studies using global spectral model	08 December 1988 15 December 1988
16.	Dr. Yu. N. Skiba, USSR Academy of of Sciences, Australia	The application of conjugate equation method for analysis of atmosphere - ocean heat interaction model	30 December 1988
17.	Shri S.S. Parasnis, SSO II, IITM	Artificial rain (in Marathi)	27 February 1989
18.	Dr. (Mrs.) A.M. Selvam, AD, IITM	The applications of deterministic chaos in the numerical weather prediction and climate models	10 March 1989
19.	Shri S.M. Bawiskar, SSA, IITM	Large scale tropical circulation features during the contrasting Indian monsoon years (A fourier representation).	28 March 1989
20.	Dr. H.N. Srivastava, Director (ESS), DST, New Delhi	DST coordinated programmes in Meteorology and Earth Science	30 March 1989

7 A. LECTURES DELIVERED OUTSIDE THE INSTITUTE

Forecasting Research Division

Dr. S.S. Singh, A.D.

Two lectures on 'Regional models' in the SAARC Workshop on NWP, Mausam Bhavan, New Delhi, 2-3 November 1988.

Dr. S. Rajamani, A.D.

Twelve lectures on 'Optimum Interpolation Scheme for Objective Analysis', National Centre for Medium Range Weather Forecasting (NCMRWF), New Delhi, 16 Feb - 01 March 1989.

Shri P.N. Mahajan, SSO II

'Forecasting Research with Satellite input, Meteorological Data Utilization Centre (MDUC), New Delhi, 11-15 April 1988.

Climatology and Hydrometeorology Division

Dr. G.B. Pant, AD

Understanding monsoons, Deccan College, Pune, 18 July 1988.

Dr. K. Rupa Kumar, SSO II

Two lectures on 'Statistical techniques used in agrometeorology', Workshop-cum-Seminar on Agrometeorology, India Meteorological Department (IMD), Pune, 9 and 16 June 1988.

Shri D.R. Sikka, Director

i) Invited talk on 'Climate modelling', 76th session of Indian Science Congress, Madurai, 8 January 1989.

ii) Invited talk on 'Development in monsoon meteorology and prediction', Festival of France 1989, New Delhi, 7 February 1989.

8. VISITORS

List of distinguished scientists and officials who visited the Institute during the year is given below :

A. National :

Sr. No.	Visitors - Credentials	Date of Visit
1.	Dr. R.R. Yadava, Junior Scientific Officer, Birbal Sahani Institute of Palaeobotany, Lucknow	20 March-11 April 1988
2.	Dr. U.C. Mishra, Head, Air Monitoring Section, Bhabha Atomic Research Centre, Bombay	29 April 1988
3.	Miss Pratima Naidu, Executive Engineer, Central Design Organisation, Govt. of Maharashtra, Nasik.	11 May 1988
4.	Dr. K. N. Raja Rao, Director (Engineering Faculty), Water and Land Management Training and Research Institute, Hyderabad	24-25 May 1988
5.	Mrs. P.G. Meena, Research Scholar, University of Cochin, Cochin	23-30 June 1988
6.	Shri. Gopalkumar, Hydrologist, Kuttanad Water Balance Study Project, Trivandrum.	18 July 1988
7.	Shri N.V.K. Murty, Director and four other members, Nehru Centre (Discovery of India Project) Bombay	20 July 1988
8.	Prof. S. Gadgil, Indian Institute of Science, Bangalore	23-25 August 1988
9.	Shri N.P. Vithal, Chief Commissioner of Railway Safety, Lucknow	16 September 1988
10.	Dr. M.V. Bapat, Agro-Climatic Regional Planning Unit, Planning Commission, Govt. of India (Ahmedabad Branch), Ahmedabad	20 September 1988
11.	Dr. Pradeep Kumar, Pool Officer, Dept. of Physics, University of Roorkee, Roorkee.	20-24 September 1988

B. International :

I	1.	Dr. S.J.P. Paluikof/ T. Holt, Climatic Research Unit, University of East Anglia, U.K.	16-17 November 1988
	2.	Dr. V.N. Lykossov, Dr. V.L. Perov, Dr. Y.N. Skiba and Dr. Prof. A.S. Sarkisyan All from the Dept. of Numerical Methods, Moscow, U.S.S.R.	16 December 1988 6 January 1989 & 9-12 January 1989

II Visitors during the Int. Symp. on 'Monsoon : Prediction and Understanding', 23-28 November 1988 :

1. Dr. J.E. Ahlquist, Florida State University, U.S.A.
2. Dr. C.M. Bhumralkar, National Oceanic and Atmospheric Administration (NOAA), U.S.A.
3. Dr. D.L. Cadet, Director of Research, Centre National de la ReCherche Scientifique (CNRS) Dynamic Meteorological Laboratory, France
4. Dr. T.C. Chen, Department of Earth Sciences, Iowa State University, U.S.A.
5. Dr. J.A. Colon, Meteorologist (Retd.), Weather Service Forecast Office, U.S.A.
6. Dr. L.D. Devkota, Univ. of Kathmandu, Nepal

7. Dr. (Mrs) L. Dumenil,
University of Hamburg,
Federal Republic of Germany

8. Dr. J. S. Fein,
National Science Foundation
U.S.A.

9. Dr. J.O. Fletcher
National Oceanic & Atmospheric
Administration (NOAA),
U.S.A.

10. Dr (Mrs) Catherine Gautier,
California Space Institute,
Scripps Institution of Oceanography,
California, U.S.A.

11. Dr. Z. Janjic
Federal Hydrometeorological
Institute, Belgrade, Yugoslavia.

12. Dr. J.H. Karas,
Univ. of East Anglia,
U.K.

13. Dr. K. Kato,
Water Research Institute of
Nagoya University,
Japan

14. Dr. T.N. Krishnamurti,
Department of Meteorology,
Florida State University,
U.S.A.

15. Dr. J. Kuettner,
National Centre for Atmospheric
Research (NCAR),
U.S.A.

16. Dr. J. Labrousse,
World Meteorological Organisation,
Geneva, Switzerland

17. Dr. Chen Longxun,
Academy of Meteorological
Sciences,
State Meteorological
Administration,
People's Republic of China

18. Dr. R.V. Madala,
Naval Research Laboratory,
U.S.A.

19. Dr. M.B. Mathur,
National Meteorological Center,
Washington D.C.,
U.S.A.

20. Dr. J. Matsumoto,
University of Tokyo,
Japan.

21. Dr. T. Murakami,
Department of Meteorology,
University of Hawaii,
U.S.A.

22. Dr. K. Puri,
Bureau of Meteorology Research Centre,
Melbourne,
Australia

23. Dr. M.K. Ramamurthy,
University of Illinois,
U.S.A.

24. Dr. A. A. Ramasastry
Abu-Dhabi

25. Dr. G.V. Rao,
St. Louis University,
U.S.A.

26. Dr. P. Sankaran,
Malaysian Meteorological Service,
Malaysia

27. Dr. J. Shukla,
Centre for Ocean-Land-
Atmosphere Interactions,
Department of Meteorology,
Univ. of Maryland,
U.S.A.

28. Dr. E. Smith,
Department of Meteorology,
U.S.A.

29. Dr. C.R.J. Somerville,
Scripps Institution of
Oceanography, California,
U.S.A.

30. Dr. M. Sugi,
Japan Meteorological Agency,
Tokyo,
Japan

31. Dr. K.R. Walters,
Information Retrieval Manager,
Scott AFF,
U.S.A.

Fig. 12 Dr. S.J.P. Paluikof & Dr. T. Holt, from Climatic Research Unit, U.K. in a meeting with Director.

Fig. 13 Dr. Kamal Puri, Bureau of Meteorology Research Centre, Australia, delivering a lecture.

C. Visiting Professor

Dr. Kamal Puri, Bureau of Meteorology, Research Centre, Melbourne, Australia, visited the Institute as a Visiting Professor during 5-21 December 1988. He delivered. six lectures on Spectral modelling and Initialisation and two seminars on "GCM type studies using Global Spectral Model' and 'Review of Current Status of Tropical NWP' respectively. He discussed the non-linear normal made initialisation at depth. Scientists from IMD, IISc., PRL, IIT (Delhi) and University of Poona also attended these lectures.

9. GENERAL

9.1 The Governing Council

The administration and management of the Institute is vested in its Governing Council which consists of 9 members including the Director of the Institute. The council held two meetings during the year at New Delhi and Pune on 29 October 1988 and 30 March 1989 respectively. A list of the members is given in Appendix.

9.2 Staff Council

The Staff Council is an elected body representing all employees of the Institute in different categories and acts as a forum for discussion on matters of common interests to the employees. During the year, nine meetings of the Staff Council were held.

The 8th Staff Council of the Institute has been reconstituted with effect from 16.2.89 for a period of two years.

9.3 Meetings of Heads of Division

The Heads of the Divisions of the Institute meet as and when required to take a review of all aspects of work. Eight such meetings were held during the year.

9.4 Academic Council

The Academic Council consisting of the research officers in the grade of Senior Scientific Officer, Gr. I and above, considers all matters relating to scientific projects of the Institute and ensures team work for achieving its aims and objectives.

The Academic Council generally meets once in a month to review the scientific activities of the Institute. Twelve such meetings were held during the year. Matters discussed at the meeting included progress of Institute's scientific activities, Institute's participation in different research programmes at the national and international levels, Institute's role in development of atmospheric sciences in the universities and other similar matters.

9.5 Awards

The paper entitled, 'A Primitive equation barotropic instability study of monsoon onset vortex, 1979' - by S.K. Mishra, M.D. Patwardhan and L. George, published in Quarterly Journal of Royal Meteorological Society, Vol. 111, April 1985, won the Second SAARC Regional Award. Dr. S.K. Mishra, DD and Smt. L. George, SSO II received the award at a function held at New Delhi on 4 November 1988. This Award consists of a citation, medal and cash.

The paper entitled, 'Energetics of the monsoon circulation over South Asia pt. I : Diabatic heating and the generation of available potential energy, pt. II : Energy terms and energy transformation terms' by S. Rajamani published in Mausam, Vol. 36, 1985, won the 13th Mausam Award for the two year period 1984-85.

9.6 Printing of the Atlas on Probable Maximum Precipitation

Sixteen maps showing the Probable Maximum Precipitation (PMP), covering the entire country, were finalised and given for printing in the form of an atlas.

Fig. 14 A Scientific Exhibition arranged at the time of National Science Day.

9.7 Celebration of National Science Day

The Institute celebrated National Science Day during 24 to 28 February 1989. As this year happens to be the birth centenary year of Pandit Jawaharlal Nehru, the activities and programmes were organised with emphasis on children as well as on Nehru's vision of science. Under the programme, several scientific lectures were given in Hindi, Marathi and English by Institute's scientists. Science quiz programme for children, Scientific film shows and an Open House Scientific Exhibition were also organised.

9.8 DST's Review Committee for the Institute

A formal Government Communication, constituting a Review Committee for IITM was received from the DST on 27 May 1988. A meeting of the Review Committee was held at the Institute on 23 Nov. 1988. The Committee formed two sub-committees -one to review the Divisions of Forecasting Research, Climatology and Hydrometeorology, Theoretical Studies and Computer and the other one to review the Divisions of Physical Meteorology and Aerology and Instrumental and Observational Techniques. The first sub-committee met on 20-21 January 1989 and reviewed the work of the Forecasting Research Division, Climatology and Hydrometeorology Division, Theoretical Studies Division and the Computer Division.

Fig. 15 Prof. P. Koteswaram speaking at the Institute during review of Weather Modification Project.

9.9 Deputations abroad

1. Dr. A.S.R. Murty, DD.
WMO consultation on 'Weather Modification Activities for ASIAN Countries' Bangkok, Thiland, April 1988 (WMO Sponsorship)

2. Shri D.R. Sikka, Director
i) Participation in Indo-Soviet Seminar on 'Pressing problems of computing mechanics and mathematical modelling', Moscow, 19 May - 1 June 1988 (Govt. of India, DST sponsorship)

ii) Participation in Int. Conf. on 'Tropical Meteorology', Brisbane, 4-8 July 1988 and VII session of TOGA SSG, 11-15 July 1988, Cairns, Australia (WMO Sponsorship)

3. Shri K.D. Prasad, SSO II
Participation in Int. Conf. on 'Tropical Meteorology', Brisbane, 4-8 July 1988

4. Dr. L.S. Hingane, SSO I
Participation in 'Quadrannial ozone symp', Gottingen, FRG, 8-13 August 1988

5. Dr. D.B. Jadhav, SSO I
i) Familiarisation with the latest trends in the field of Remote Sensing of Atmospheric Trace Constituents, Rutherford Appleton Laboratory, Oxford, U.K., 18 October 1988-22 November 1988.

ii) National Centre for Atmospheric Research (NCAR) Laboratory, Boulder, Colorado, USA, 22 November 1988 - 27 December 1988.

6. Dr. S.V. Singh, AD
To chair a session at the Fourth Int. meeting on Statistical Climatology, Rotorua, New Zealand, 27-31 March 1989.

9.10 Training

Shri Swadhin Kumar Behera, Senior Scientific Assistant has been sponsored for condensed Basic Training Course followed by Advanced Meteorological Training Course, at India Meteorological Department, Pune with effect from 12 Sept. 1988.

Dr. S.K. Mishra, DD attended the Sixth Training Programme on 'Manpower Planning for Scientific and Technical Personnel' at the Institute of Applied Manpower Research, New Delhi during 22 August - 1 September 1988.

Shri P.N. Mahajan, SSO II attended a training course in 'Satellite Oceanography' held at 'National Institute of Oceanography', Goa during 14-23 November 1988.

Shri D.R. Chakraborty, JSO, attended the lecture series on 'Methematical Modelling' by Prof. A.S. Sarkisyan at NIO, Goa, during 6-10 March 1989.

Scientists of the Institute attended the following computer training courses :

i) Two weeks course on 'SINTRAN Operating System' conducted by the Electronics Corporation of India Ltd., held at the Institute during 29 February - 12 March 1989

ii) Five days training course on 'Personal Computers' conducted by National Informatics Centre, Pune, during 23-28 May 1988.

iii) Five weeks training course on the 'Use of ND-560 Computer System' organised at the Institute during 4 July - 5 August 1988.

iv) One week training course in Super-Computer CRAY X-MP/14 in New Delhi during 17-24 January 1989.

9.11 Library, Information and Publications Division

To help the scientists in their pursuit of research, the Division of Library, Information and Publications provides necessary scientific and technical services by way of :

i) Procuring books, journals, data etc. for the Institute's Library;

ii) Dissemination of appropriate scientific information;

iii) Providing documentation and current awareness service matching with the users' profile;

iv) Rendering Selective Dissemination of Information (SDI) Service on demand through preparation of bibliographies on different research areas in Meteorology and Atmospheric Science;

v) Monitoring Institute's exchange programme of publications;

vi) Preparation, publication and presentation of various scientific/research reports and allied material projecting the activities of the Institute;

vii) Formulation of Institute's plan documents and monitoring of the on-going plan projects;

viii) Keeping liaison with other scientific institutes, organisations and universities in India and abroad,

ix) Rendering necessary timely facilities viz. preparation of drawings, tracings, diagrams, charts, photoprints, slides, microfilms, ammonia prints etc.

9.11.1 Library and Documentation

9.11.1.1 *British Council's ODA Book Presentation Programme*

Institute's library received books worth approx. Rs. 90,000/- from the British Deputy High Commission under the British Council's ODA Book Presentation Programme. Efforts were taken to select and acquire appropriate titles of interests to the Institute scientists as per the norms laid down by the British Council. A good number of books were received. These would prove to be very useful for the Institute's scientists.

9.11.1.2 Acquisition

During the year, 124 books in Meteorology and allied subjects were added and 82 periodicals of national/international repute were subscribed to. A number of scientific/technical reports were also added to the library. Reprints of 20 papers authored by the Institute's scientists and published in different scientific journals and proceedings of national and international repute were procured.

9.11.1.3 Services

During the year, over 3500 publications including books, journals, data, reports etc. were issued. A large number of reference queries were also answered.

Inter-Library loan facilities were arranged for the Institute's scientists through the courtesy and co-operation of a large number of research and academic libraries in the country. Institute's library also extended its co-operation to other libraries by issuing publications on loan.

243 reprints of scientific papers authored by Institute scientists were supplied, on request, to the scientists/research workers of other Institutions in the country as well as abroad.

Photocopies of 587 pages of scientific material from the Publications available in the Institute's library were sent to scientists/research workers of other Institutions on their request.

Institute scientists were kept abreast of the latest developments in their research areas by way of rendering 'Current Awareness Service' through the regular and timely supply of photocopies of content pages of latest issues of scientific periodicals received in the library. This service has further been improved by supplying the photocopies of content pages of journals matching with the users' interest profile.

Preparation of bibliographies on the research areas in the field of Meteorology and Atmospheric Science was introduced as a first step towards Selective Dissemination of Information (SDI) service. A bilbliography of important papers published on 'Thunderstorm' was prepared and distributed to the Institutions and individual scientists. A list of published research papers authored by the Institute scientists on data collected during Monsoon Experiment was compiled and sent to the India Metrological Department, New Delhi.

Library facilities were made available to the scientists of the India Meteorological Department, Pune and to the students of the University of Poona, Pune undergoing post graduate courses in Atmospheric Sciences. Several distinguished scientists/research workers from India and abroad also availed the Library facilities during the year.

9.11.2 Information and Publications

A number of periodical informative reports and special reports were prepared and sent to the Department of Science and Technology, India Meterological Department, Universities and Research Institutes.

Two research reports authored by the Institute's scientists were brought out under the series, 'Contributions from the IITM, Pune' :

i) RR-042 - Project report on multidimensional initialization for NWP models - S. Sinha

ii) RR-043 - Numerical experiments with inclusion of orography in five level P.E. model in pressure-coordinates for interhemispheric region - S.N. Bavadekar & R.M. Khaladkar

9.12 Field Research Unit

The Bangalore Field Reserch Unit organizes and conducts wind energy surveys in the country under a project financed by the Department of Non-Conventional Energy Sources, Government of India. Suitable stations for wind monitoring were earlier established in 4 states viz. Tamilnadu, Gujarat, Orissa and Maharashtra and the programme has since been extended to Andhra Pradesh and Rajasthan. With 28 additonal stations in Karnataka, Kerala, Lakshadweep and Andamans and Nicobars, there will be 88 wind monitoring stations in the country. Each station has a 20m tall instrumented mast with wind sensors at 2 levels, 10m and 20m and a data logger to store the data. The data stored in EPROM chips are collected every 2 months and processed on computer at Bangalore.

Wind mapping programmes were planned at 420 stations in 14 states, viz. Tamilnadu, Andhra Pradesh, Karnataka, Madhya Pradesh, Orissa, Gujarat, West Bangal, Uttar Pradesh, Bihar, Maharashtra, Meghalaya, Himachal Pradesh, Tripura and Kerala, using 5m tall instrumented masts and data were processed at Bangalore. Of these, 170 are now in operation.

9.13 Other Matters

9.13.1 Capital Works Programme

The construction work of the left wing of the second phase office building and that of the guest house was completed and these were taken over from C.P.W.D. authorities.

An amount of Rs. 67.81 lakhs was deposited with C.P.W.D. for construction of additional staff quarters of Type II and IV, Community Hall, garage for Mini Bus, compound wall and an additional septic tank.

9.13.2 Official Language Implementation

Consequent upon Parliamentary Official Language Review Committee's visit to the Institute in October 1987, the work of making bilingual forms and standard drafts was continued.

The Institute's Annual Report and Audit Report were translated into Hindi. Hindi books, of scientific nature, of general interest and of high literary merit were also acquired.

A Hindi workshop covering 30 working hours was organised for 55 class I and II Scientific Officers.

The Hindi Week was celebrated from 16 to 21 September 1988 with competitions in elocution, poetry recitation, noting and drafting in Hindi and essay writing.

The Institute's Official Language Implementation Committee worked with zeal towards implementation of Rajbhasha. The members of the Committee addressed the scientists and staff members on scientific and general topics in Hindi during the Science Day and Nehru Centenary Celebrations organised in February 1989.

On the whole, there was considerable progress in the implementation of the Govt. instructions regarding the use of Hindi in official work.

9.13.3 Staff Changes :

26 persons joined the Staff of the Institute under different categories and 7 members of Staff left the Institute during the year.

Shri M.D. Kesavan, Purchase and Stores Officer passed away on 26 February 1989. Shri S.K. Sharma, Mechanical Assistant died in a tragic road accident at Pune on 11 February 1989. The Institute suffered a great loss in the death of these two employees.

9.13.4 Budget

The budget estimates and actual expenditure for the Institute for the period 1988-89 are given below :

Rs. in lakhs

	Budget estimates 1988-89	Revised estimates 1988-89	Grant including opening balance received from DST	Actual expenditure	Shortfall in expenditure over grant in-aid received
Non Plan	158.00	170.67	165.67	165.61	0.06
Plan	76.00	73.00	71.56	71.41	0.09

9.13.5 Employment of Ex-Servicemen:

Reservation for Ex-Servicemen is made at 10% in Group 'C' and 'D' posts of the Institute. The percentage of Ex-Servicemen at the Institute vis-a-vis total number of employees in Group 'B', 'C' and 'D' is as follows :

Group 'B' .. 1.4%
Group 'C' .. 1.0%
Group 'D' .. 12.9%

10. PUBLICATIONS

List of papers published in Journals/Proceedings of Symposia/Conferences etc.

Forecasting Research

Extended Range prediction

FR 1. Monsoon rainfall and southern oscillation responses in the pressure over the northern Indian Ocean : Prasad K.D. and Singh S.V., Advances in Atmospheric Sciences, 5, 2, May, 1988, 243-251.

FR 2. Large scale features of the Indian Summer Monsoon rainfall and their associations with some oceanic and atmospheric variables : Prasad K.D. and Singh S.V., Advances in Atomspheric Sciences, 5, 4, 1988, 499-513.

Climatology and Hydrometeorology

Climate and Climatic Change

CH 1. Climatic changes in and around the Rajasthan desert during the 20th century : Pant G.B. and Hingane L.S., Jr. of Climatology, 8, 4, July-August, 1988, 391-401

CH 2. Climatic Significance of $D\delta$ variations in a tropical tree species from India : Ramesh R., Bhattacharya S.K. and Pant G.B., Nature, 337, 6203, 12 January, 1989, 149-150.

CH 3. Long-term variability of the Indian summer monsoon and related parameters: Pant G.B., Rupa Kumar K., Parthasarathy B. and Borgaonkar H.P, Advances in atmospheric Sciences, 5, 4, 1988, 469-481.

CH 4. Long-term variations of surface air temperature at major industrial cities of India : Rupa Kumar K. and Hingane L.S., Climatic Change, 13, 1988, 287-307.

CH 5. Prediction of All-India summer monsoon rainfall with regional and large-scale parameters : Parthasarathy B., Diaz H.F. and Eischeild J.K., Jr. of Geophysical Research, 93, D5, May 20, 1988, 5341-5350.

CH 6. Regression model for estimation of Indian food grain production from summer monsoon rainfall : Parthasarathy B., Munot A.A. and Kothawale D.R., Agricultural Forest Meteorology, 41, 1, 1988.

CH 7. Role of Ozone in the sodium and hydroxyl nightglow : Hingane L.S., Advances in Atmospheric Sciences, 6, 1, February, 1989, 88-89.

CH 8. Statistical models of climate reconstruction using tree ring data : Pant G.B., Rupa Kumar K. and Borgaonkar H.P., Proc. of Indian National Science Academy, 54, 3, 1988, 354-364.

CH 9. Teleconnection between Argentina pressure and Indian summer monsoon : Parthasarathy B., Eischeid J.K. and Diaz H.F., Second Inter American and CONGEMENT V., Buenos Aires, Argentina, December, 1987, 4.6.1-5.6.5

Hydrometeorological Studies

CH 10. Review of recent hydrometeorological studies on Indian rainfall : Dhar O.N., Kulkarni A.K. and Mandal B.N., Hydrology, XI, 1, January-April 1988, 1-12.

CH 11. Estimation of PMP for Kallada basin located in Western Ghats of Kerala : Dhar O.N., Nandargi S.S. and Kulkarni A.K., Transactions of Inst. Indian Geographers, 9, 2, 1987, 1-12.

CH 12. Flood routing for the Dhalegaon-Babli reach of river Godavari : Rao P.G. and Ramana Murty K.V., Mausam, 39, 4, October, 1988, 433-434.

CH 13. Hydroclimatic fluctuations of the upper Narmada catchment and its association with break-monsoon days over India : Singh N., Soman M.K. and Krishna Kumar K., Proc. Indian Academy of Sciences (Earth and Planetary Sci.) 97, 1, July, 1988, 87-105.

CH 14. On association between the amount and frequency of daily rainfall distribution at Indian station : Ananthakrishnan R. and Soman M.K., Current Science, 7, 16, 20 August, 1988, 877-882.

CH 15. Precipitation network design : Rakhecha P.R. and Deshpande N.R., Jalvigyan Sameeksha, 11, 2, 1987, 56-75.

CH 16. Rainstorms which contributed greatest areal raindepths in Andhra Pradesh : Dhar O.N., Nandargi S. and Kulkarni A.K., Indian Jr. of Power and River Valley Development, 38, 9, September, 1988, 261-268.

CH 17. Some observational aspects of variability of the summer monsoon circulation and rainfall over India during 1978, 1979 and 1980 : Ananthakrishnan R. and Soman M.K., Vayu Mandal, 17, 3 and 4, July-December, 1987, 75-86.

CH 18. Statistical distribution of extremes of rainfall at Colaba, Bombay : Singh N., Mausam, 40, 1, 1989, 85-90.

CH 19. Some hydrologic characteristics and modelling aspects of a small catchment in southern India : Rao P.G., Mausam, 39, 3, July, 1988, 249-256.

CH 20. Onset of southwest monsoon over Kerala, 1901-1980 : Ananthakrishnan R. and Soman M.K., Jr. of Climatology, 8, 3, May-June, 1988, 283-296.

CH 21. Stanford watershed model and its application to waterlogging problems : Rao P.G., Ind. Jr. of Power and River Valley Development, XXXVIII, 5, May, 1988, 163-I.

Physical Meteorology and Aerology

Studies in Atmospheric Electricity

PM 1. Possible solar influence on atmospheric electric field : Sikka P., Selvam A.M. and Murty A.S.R., Advances in Atmospheric Science, 5, 2, May, 1988, 217-228.

Radar study of Rain and Rain-bearing clouds

PM 2. Precipitation initiation mechanisms in clouds over north India : Chatterjee R.N., Prakash P., Singh G. and Kapoor R.K., Proc. Tenth Int. Conf. on Could Physics, Bad Hamburg (FRG), 15-20 August, 1988, 57-60.

PM 3. Radar Study of severe thunderstorms around Delhi, northern India, during the monsoon season : Chatterjee R.N. and Prem Prakash, Jr. of Atmospheric Research, 22, 4, January, 1989, 373-384.

PM 4. Study of tall convective storms in North India during summer : Chatterjee R.N., Prem Prakash and Kapoor R.K., Book entitled 'Microwave Remote Sensing in the Earth System', A. Deepak Publishing, Hompton, Virginia, 1989, 163-172.

Studies of the Atmospheric Boundary Layer

PM 5. Diurnal variation of total ozone over Thumba : Vijayakumar R., Proc. of workshop on IMAP Scientific Results, SPL, Trivandrum, 26-29 April 1988, 76-80

Studies in Air Pollution

PM 6. Atmospheric particle size distribution and their chemical composition in India : Khemani L.T., IASTA Newsletter, 1, 2, December, 1988, 8-10.

Lidar Probing of the Atmosphere

PM 7. Atmospheric Aerosols : need for their study in India : Devara P.C.S., IASTA Newsletter, 1, 2, December, 1988, 11-15.

PM 8. Multiwavelength lidar measurements of aerosols in the lower atmosphere : Devara P.C.S., Raj P.E. and Londhe A.L., Book entitled 'Atmospheric Aerosols and Nucleation', Eds : Wagner P.E. and Vali G., Springer Verlag, New York, 1988, 213-214.

PM 9. Remote sounding of aerosols in the lower atmosphere using bistatic CW Helium-Neon lidar : Devara P.C.S., Raj P.E., Jr. of Aerosol Science, 20, 1, 1989, 37-44.

PM 10. Some results of photometric observations of Comet Halley : Devara P.C.S., Raj P.E., Jr. of Optics, 16, 4, October-November, 1987, 93-97.

Spectroscopic Measurements of Atmospheric Constituents

PM 11. Designing of high light gathering power and high rsolution infrared spectrometer for atmospheric and laboratory studies : Jadhav D.B., Jr. of Instrument Society of India, 18, 1, 1988, 38-45.

Instrumental and Observational Techniques

Development of Instruments for Boundary Layer Studies

I & OT 1. Experimental determination of sensible heat flux over a complex terrain by eddy correlation programme : Sivaramakrishnan S., Vernekar K.G. and Brij Mohan, Jr. Indian Institute of Science, 68, 1988, 3 and 4, 129-136.

10.2 List of Papers Accepted for Publication

Forecasting Research

Numerical Weather Prediction

FR 1. Excitation of low level jet as seen by GOES (I-O) satellite off the Somali Coast : Mahajan P.N., Mujumdar V.R. and Ghanekar S.P., Advances in Atmospheric Sciences.

FR 2. Limited area model for monsoon prediction : Singh S.S., Vaidya S.S. and Rajagopal E.N., Advances in Atmospheric Sciences.

FR 3. Scheme for objective analysis of wind field incorporating multi-weighting functions in the optimum interpolation method : Sinha S.K., Talwalkar D.R., Narkhedkar S.G. and Rajamani S., Advances in Atmospheric Sciences.

Climatology and Hydrometeorology

Climate and Climatic Change

CH 1. Climate over India during the first quarter of the nineteenth century : Pant G.B., Parthasarathy B. and Sontakke N.A., "The year without summer? Climate in 1816'., An international meeting, Ottawa, Canada., 25-28 June 1988.

CH 2. Environmental conservation and climate : Pant G.B., National seminar on Environmental issues : Problems and solutions, Golden Jubilee Seminar, University of Kerala, Trivandrum, 7-10 October 1988.

Hydrometeorological Studies

CH 3. Analysis of most servere rainstorms of India : Dhar O.N., Kulkarni A.K., Mandal B.N. and Nandargi S.S., Seminar on Advances in Geophysical Research in India, NGRI, Hyderabad, 8-10 February 1989.

CH 4. Anomalies in the Aerological data of some Indian stations : Ananthakrishnan R. and Soman M.K., Mausam

CH 5. Appraisal of precipitation distribution in Jammu and Kashmir State : Dhar O.N., Mandal B.N. and Kulkarni B.D., II National Symposium on Hydrology, Jammu, January, 1989.

CH 6. Effect of increasing CO_2 on the Stratospheric level of O_3 and CO : Hingane L.S., Advances in Atmospheric Sciences

CH 7. Further examination of the anomaly in the aerological data of Ahmedabad : Ananthakrishnan R. and Soman M.K., Mausam.

CH 8. On the statistical distribution of daily rainfall and its association with the coefficient of variation of rainfall series : Ananthakrishnan R. and Soman M.K., Jr. of Climatology.

CH 9. Review of recent hydrometeorological Studies of Indian rainfall : Dhar O.N., Kulkarni A.K. and Mandal B.N., Hydrology

CH 10. Some features of periods contributing specified percentages of rainfall to annual total in Kerala, India : Singh N., Krishna Kumar K. and Soman M.K., Theoretical and Applied Climatology.

CH 11. Study of extreme point rainfall over Jammu and Kashmir : Rakhecha P.R., Mandal B.N. and Sangam R.B., II National Symp. on Hydrology, Jammu, January 1989.

CH 12. Study of heavy rainfall distribution over the intermediate catchment of the Narmada basin between Narmada Sagar and Sardar Sarovar dam sites : Dhar O.N. and Nandargi S.S., Indian Jr. of Power and River Valley Development.

CH 13. Study of rainspells associated with the worst floods in the Jhelum river : Dhar O.N. and Nandargi S.S. II National Symp. on Hydrology, Jammu, January, 1989.

Physical Meteorology and Aerology

Studies in Atmospheric Electricity

PM 1. Case study of a census of cloud liquid water content, corona current and droplet charge in small cumuli and stratocumulus clouds near Pune during monsoon of 1981 : Kandalgaonkar, S.S., Sholapurkar S.M. and Manohar G.K., Seminar on Advances in Geophysical Research in India, NGRI, Hyderabad, 8-10 February 1989.

PM 2. Diurnal and seasonal variation of surface atmospheric electric field and its association with meteorological parameters at Pune : Kandalgaonkar S.S., Sholapurkar S.M. and Manohar G.K., Seminar on Advances in Geophysical Research in India, NGRI, Hyderabad, 8-10 Feburary 1989.

PM 3. Effects of thermal power plant emissions on atmospheric electrical parameters : Manohar G.K., Kandalgaonkar S.S., Sholapurkar S.M. and Mehra P., Atmospheric Environment

PM 4. Lunar phases and atmospheric electric field : Mehra P., Advances in Atmospheric Sciences.

PM 5. Observations of aerosol and atmospheric electric parameters in different environments : Manohar G.K., Sholapurkar S.M. and Kandalgaonkar S.S., First Annual Conference of Indian Aerosol Science and Technology Association (IASTA) on 'Aerosol Science - A perspective on Research and Development in India', IITM, Pune, 23-24 March 1989.

PM 6. Point discharge current observations during two consecutive pre-monsoon season thunderstorms of the years 1987 and 1988 at Pune : Manohar G.K., Kandalgaonkar S.S., Seminar on Advances in Geophysical Research in India, NGRI, Hyderabad, 8-10 February 1989.

PM 7. Three stage model of cloud electrifications : Mukku V.N.R., Proc. 8th Int. Conf. on Atmospheric Electricity, Uppasala, Sweden, 1988.

Radar Study of Rain and Rain bearing clouds.

PM 8. Radar Study of thunderstorms around Delhi, north India during monsoon season : Chatterjee R.N. and Prem Prakash, International Symposium on Monsoon Understanding and Prediction, IITM, Pune, 23-28 November 1988.

Weather Modification

PM-9 Association between giant hygroscopic condensation nuclei and meteorological parameters at a tropical station :. Pillai A.G., First Annual Conference on Indian Aerosol Science and Technology Association (IASTA) on 'Aerosol Science - A Perspective on Research and Development in India', IITM, Pune, 23-24 March 1989.

PM-10 Overview of warm cloud modification research in India : Murty A.S.R., Fifth WMO Scientific Conference on Weather Modification and Applied Cloud Physics, Beijing, 8-12 May 1988.

Studies of the Atmospheric Boundary Layer

PM-11 Deterministic chaos model for cloud growth processes and interaction with environment : Selvam A.M., Fifth WMO Scientific Conference on Weather Modification and Applied Cloud Physics, Beijing, 8-12 May 1988.

PM-12 Dynamics of non-linear effects in optical processes : Selvam A.M., Jr. Luminescence.

PM-13 On the mixing processes in the atmospheric boundary layer : Parasnis S.S. and Goyal S.S., Seminar on Advances in Geophysical Research in India, NGRI, Hyderabad, 8-10 February 1989.

PM-14 Thermodynamic features of the atmospheric boundary layer during summer monsoon : Parasnis S.S. and Goyal S.S., Atmospheric Environment.

Studies in Upper Atmosphere

PM-15 Association of equatorial wave dynamics with Indian summer monsoon activity : Bhosale C.S., Reddy R.S. and Mukherjee B.K., Seminar on Advances in Geophysical Research in India, NGRI, Hyderabad, 8-10 February 1989.

PM-16 El-Nino and Ozone variability : Indira K. and Mukherjee B.K., Quadriennial ozone symposium, University of Gottingen, FRG, 8-13 August 1988.

PM-17 Middle atmosphere dynamics and monsoon variability : Mukherjee B.K., International Symposium on Monsoon : Understanding and Prediction, IITM, Pune, 23-28 November 1988.

PM-18 On the relationship between the equatorial lower stratosphere and Indian monsoon activity : Reddy R.S., Mukherjee B.K., Khandekar M.L., Neralla V.R. and Godson W.L., International Seminar on Hydrology with Colloquium on Water Resources Problems of South Asian Countries, Visakhapatnam, 20-23 October 1988.

PM-19 Ozone hole re-examined : Mukku V.N.R., Workshop on Antarctic studies, NPL, New Delhi, 3-5 May 1988.

PM-20 Solar Cycle and Indian rainfall : Reddy R.S., Neralla V.R. and Godson W.L., Jr. of Applied and Theoretical Climatology.

PM-21 Temperature and winds over tropical middle atmosphere during two contrasting summer monsoon - 1975 and 1979 : Mukherjee B.K., Kulkarni C.P., Indira K., and Dani K.K., Advances in Atmospheric Sciences.

PM-22 Wind and temperature structure of the tropical middle atmosphere during 1980-87 a period of erratic behaviour of summer monsoon over India : Mukherjee B.K., Indira K. and Dani K.K., COSPAR Symposium on The Middle Atmosphere after MAP, Finland, 18-23 July 1988.

Studies in Air Pollution

PM-23 Certain meteorological features of submicron aerosols at Schimacher Oasis-East Antarctica : Lal M. and Kapoor R.K., Atmospheric Environment.

PM-24 Chemical composition of fresh snow over Gulmarg : Khemani L.T., Momin G.A., Rao P.S.P., Safai P.D., Kapoor R.K. and Prem Prakash, First Annual Conference of Indian Aerosol Science and Technology Association (IASTA) on "Aerosol Science - A perspective on Research and Development in India", IITM, Pune, 23-24 March 1989.

PM-25 Inter-monsoonal variability of natural and anthropogenic aerosol in rainfall chemistry, within 10-Km distance : Momin G.A., Khemani L.T., Rao P.S.P., Safai P.D., Singh G. and Naik M.S., First Annual Conference of Indian Aerosol Science and Technology Association (IASTA) on 'Aerosol Science - A perspective on Research and Development in India', IITM, Pune, 23-24 March 1989.

PM-26 Long term effeects of pollutants on pH of rainwater in India : Khemani L.T., Momin G.A., Rao P.S.P., Safai P.D., Singh G., Chatterjee R.N. and Prem Prakash, Atmospheric Environment.

PM-27 Measurement of pH and chemical analysis of rain water in rural area of India : Naik M.S., Khemani L.T., Momin G.A. and Rao P.S.P., Acta Meteor Sinica.

PM-28 Nature of aerosol and their sources at Trivandrum : Rao P.S.P., Khemani L.T., Momin G.A., Safai P.D. and Naik M.S., First Annual Conference of Indian Aerosol Science and Technology Association (IASTA) on Aerosol Science -A perspective on Research and Development in India, IITM, Pune, 23-24 March 1989.

PM-29 Origin of calcium in marine aerosol over the Arbian Sea : Naik M.S., Khemani L.T., Momin G.A., Rao P.S.P. and Safai P.D., First Annual Conference of Indian Aerosol Science and Technology Association (IASTA) on 'Aerosol Science' - A perspective on Research and Development in India', IITM, Pune, 23-24 March 1989.

PM-30 Physical and chemical characteristics of atmospheric aerosols : Khemani L.T., Series on Env. Control Tech., Gulf Publ.

PM-31 Regional aerosol chemistry of the Nilgiri Biosphere Reserve : Safai P.D., Khemani L.T., Momin G.A., Rao P.S.P. and Naik M.S., First Annual Conference of Indian Aerosol Science and Technology Association (IASTA) on Aerosol Science - A perspective on Research and Development in India, IITM, Pune, 23-24 March 1989.

PM-32 Role of alkaline particulates on pH of rain water and implications for control of acid rain : Khemani L.T., Global 2000 revisited or reassessing man's impact on space ship earth Ed : Ellsaesse H.W., Paragon House, N. York.

PM-33 Spread of acid rain in India : Khemani L.T., Momin G.A., Rao P.S.P., Safai P.D., Singh G. and Kapoor R.K., Atmospheric Environment.

PM-34 Survey of vehicular lead deposition in Pune City : Patil P.N., Khemani L.T., Momin G.A., Rao P.S.P., Safai P.D. and Gadgil A.S., First Annual Conference of Indian Aerosol Science and Technology Association (IASTA) on Aerosol Science - A perspective on Research and Development in India, IITM, Pune, 23-24 March 1989.

Lidar Probing of the Atmosphere

PM-35 Active remote sensing of atmosphere using laser : Devara P.C.S., Jr. of Scientific and Industrial Research.

PM-36 Effect of size parameter and refractive index on atmospheric aerosol profiles retrieved from bistatic lidar measurements : Devara P.C.S., Raj P.E. and Londhe A.L., Jr. of Optics.

PM-37 Laser radar monitoring of tropospheric aerosols : Devara P.C.S., Raj P.E. and Londhe A.L., Indian Jr. of Radio and Space Physics.

PM-38 Lidar investigation of atmospheric constituents at a tropical station : Devara P.C.S. and Raj P.E., First Annual Conference on Indian Aerosol Science and Technology Association (IASTA) on Aerosol Science - A perspective on Research and Development in India, IITM, Pune, 23-24 March 1989.

PM-39 On the height-time variation of aerosol layered structure in the lower troposphere : Devara P.C.S. and Raj P.E., Seminar on Advances in Geophysical Research in India, NGRI, Hyderabad, 8-10 February 1989.

PM-40 Remote sensing of atmospheric NO_2 concentration in the surface layer using the Argon Ion lidar system at Pune : Devara P.C.S. and Raj P.E., Atmospheric Environment.

PM-41 Seasonal variations of lidar derived aerosol content in the lower layers of the atmosphere : Raj P.E. and Devara P.C.S., Seminar on Advances in Geophysical Research in India NGRI, Hyderabad, 8-10 February 1989.

PM-42 Some results of lidar aerosol measurements and their relaionship with meteorological parameters : Raj P.E. and Devara P.C.S., Atmospheric Environment.

PM-43 Space-time variations of wind features in meteor ozone during vernal equinox over high-mid latitudes : Devara P.C.S., COSPAR Symposium on The middle atmosphere after MAP, Finland, 18-23 July 1988.

PM-44 Variation of laser return signal strength from atmosphere with scattering angle : Raj P.E. and Devara P.C.S., First Annual Conference of Indian Aerosol Science and Technology Association (IASTA) on Aerosol Science- A perspective on Research and Development in India, IITM, Pune, 23-24 March 1989.

Spectroscopic Measurements of Atmospheric Constituents

PM-45 High resolution spectroscopic techniques for remote sensing of atmospheric constituents, oceanic mixed layer and land resources by satellite : Jadhav D.B. and Londhe A.L., Seminar on Advances in Geophysical Research in India, NGRI, Hyderabad, 8-10 February 1989.

PM-46 Preliminary observation of total Column density of Nitrogen dioxide over Pune : Londhe A.L., Trimbake H.K., Bhonde S.D. and Jadhav D.B., Seminar on Advances in Geophysical Research in India, NGRI, Hyderabad, 8-10 February 1989.

PM-47 Study of aerosol loading using twilight method : Jadhav D.B. and Londhe A.L., First Annual Conference of Indian Aerosol Science and Technology Association (IASTA) on Aerosol Science - A perspective on Research and Development in India, IITM, Pune, 23-24 March 1989.

INSTRUMENTAL AND OBSERVATIONAL TECHNIQUES

I & OT-1

Charge transfer by point discharge below duststorms : Kamra A.K., Geophysical Research Letters.

I & OT-2

Observations of some atmospheric electrical parameters in the surface layer : Dhanorkar S., Deshpande C.G. and Kamra A.K., Atmospheric Environment.

I & OT-3

Wind tunnel studies of the shape of charged and uncharged water drops in the absence or presence of an electric field : Kamra A.K. and Ahire D.V., Atmospheric Research.

THEORETICAL STUDIES

TS-1 Efficient accurate direct solution of Poisson's equation for computation of meteorological parameters : Chakraborty D.R. and Salvekar P.S., Advances in Atmospheric Sciences

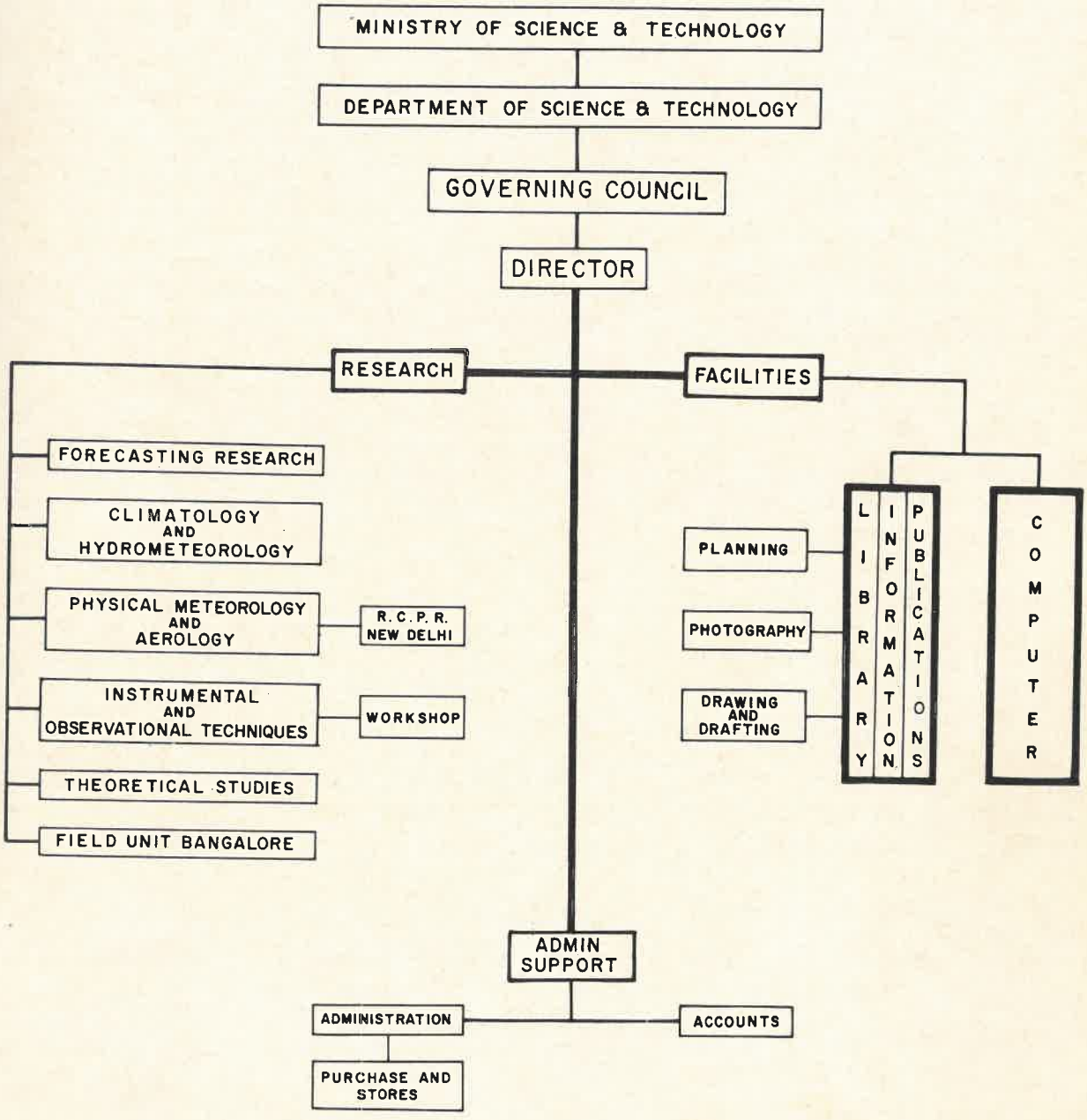
Appendix I

GOVERNING COUNCIL

1.	Dr. R.P. Sarkar, DGM, India Meteorological Department, Mausam Bhavan, Lodi Road, New Delhi - 110 003.	Chairman upto 31-12-1988
2.	Dr. S.M. Kulshrestha, ADGM (I) Performing current duties of DGM, India Meteorological Department, Mausam Bhavan, Lodi Road, New Delhi - 110 003.	Chairman from 1-1-1989
3.	Dr. M.N. Qureshy, Adviser, Department of Science & Technology, Technology Bhavan, New Mehrauli Road, New Delhi - 110 016.	Member
4.	Shri B.K. Chaturvedi, Jt. Secretary (Finance) & Financial Adviser, Department of Science & Technology, Technology Bhavan, New Mehrauli Road, New Delhi - 110 016.	Member
5.	Prof. R.N. Keshavamurty, Physical Research Laboratory, Navrangapura, Ahmedabad - 380 009.	Member
6.	Dr. V.K. Aatre, Director, R & D Organisation, Naval Physical & Oceanographic Laboratory, Cochin - 682 004.	Member
7.	Prof. Madhav Gadgil, Head, Centre for Ecological Sciences, Indian Institute of Science, Malleswaram, Bangalore - 560 012.	Member
8.	Prof. R. Narasimha, Director, National Aeronautical Laboratory, Kodihalli, Bangalore - 560 017	Member
9.	Shri D.R. Sikka, Director, Indian Institute of Tropical Meteorology, Pune - 411 005.	Member
10.	Shri D.W. Kshirsagar, Administrative Officer, Indian Institute of Tropical Meteorology, Pune - 411 005.	Non-Member Secretary

INDIAN INSTITUTE OF TROPICAL METEOROLOGY

(ORGANIZATIONAL PROFILE)



Dr. J.O. Fletcher, NOAA handing over a set of magnetic tapes containing Comprehensive Ocean Atmospheric Data, to the Director during the International symposium on Monsoon : Understanding and prediction.

Children performing on the occasion of the celebration of National Science Day and Nehru Birth Centenary at the Institute.

A view of the proceeding of the DST Review Committee on the work of the Institute.

Prof. P.R. Pisharoty, the founder Director of the Institute,
Planting a Sapling at the Institute.

Printed By Parshuram Process, Pune 4