ISSN 0250-6017

Indian Institute of Tropical Meteorology

Pune 411 008 INDIA

ANNUAL REPORT
1989-90

Prof. R. Narasimha, Director, National Aeronautical Laboratory, Bangalore and Chairman of the Committee appointed by D.S.T. to review the work of the Institute, addressing the scientists of the Institute

Shri D.R. Sikka, Director, felicitating Prof. P.R. Pisharoty, at the meeting of the Indo-US Collaborative Programme in Climatic Research held at the IITM during 06-09 November 1989.

CONTENTS

Cover Page Photograph
Institutes' new building at Pashan, Pune

FOREWORD

The potential benefits to agricultural production in India from the monsoon rainfall are enormous. Hence, it is essential to understand the mechanisms of monsoon-related weather systems for advancing our knowledge to predict monsoon rainfall. Similarly, climate-variability has great impact on the economy of the country and there is need to study pollution effects on environment and climate including warming of the atmosphere due to green-house gases.

The research programmes of the Indian Institute of Tropical Meteorology (IITM) cover a wide range of areas in Atmospheric Sciences which are of national and international importance and the highest priority efforts are in the areas of medium-range forecasting, climate variability and environmental pollution. The Institute is closely tied with the National Centre for Medium Range Weather Forecasting (NCMRWF) in its research and operaional activities in which effort has been focussed to improve weather forecasting capability. The Institute has also undertaken major field programmes like the Monsoon Trough Boundary Layer Experiment (MONTBLEX) and the Interaction of the Geosphere-Biosphere Programme (IGBP) for the study of the boundary layer in the monsoon trough region and environmental pollution respectively. In implementing the research programmes the Institute is interacting and collaborating in many ways with the organisations like India Meteorological Department (IMD) and other Institutions engaged in research in Atmospheric Sciences and Universities.

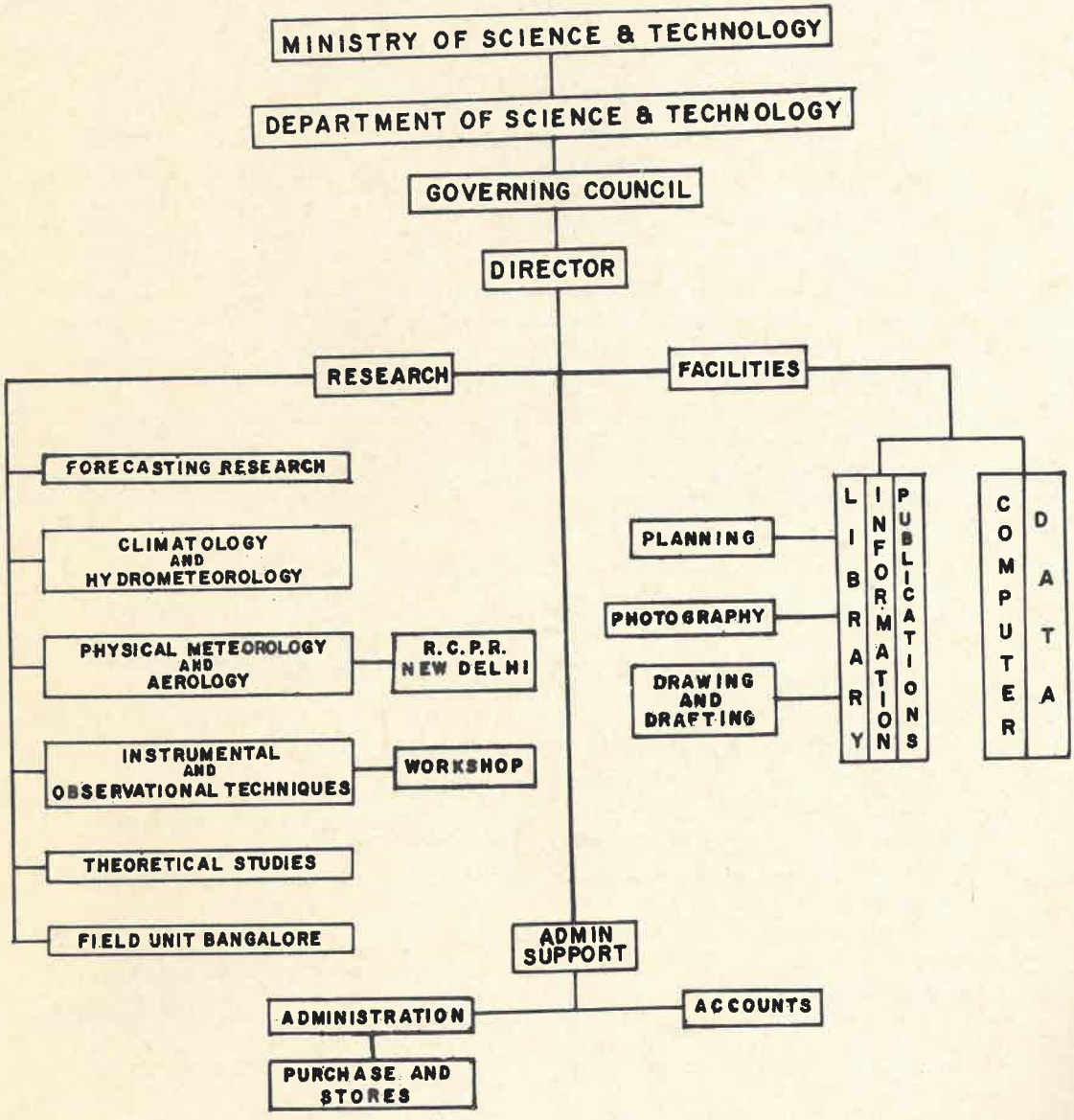
In addition to the major on-going programmes the Institute is making efforts to initiate new programmes particularly in the areas of Atmospheric Chemistry, Radar Meteorology and Remote Sensing of the Atmosphere during the Eighth Plan and regular review of the on-going research projects is carried out to optimise the objectives of the research programmes.

The research output of the Institute remains high and the scientific results summarised in this report are receiving recognition by the scientific community as attested by the awards, fellowships, memberships and prizes received by the Institute's scientists. I am confident that the Institute will continue to serve as a leading research centre in tropical meteorology and a major asset for India in Atmospheric Sciences.

Pune
August 1990

D.R. SIKKA
Director

INDIAN INSTITUTE OF TROPICAL METEOROLOGY



ORGANIZATIONAL PROFILE

1. INTRODUCTION

1.1 Management structure

The Institute functions as an autonomous organisation under the Department of Science and Technology. The management of the Institute vests with its Governing Council at the apex level. The Council is constituted by the Department of Science and Technology (DST) every two years and has five ex-officio members and four scientist-members nominated by the DST. The Director General of Meteorology is the ex-officio Chairman of the Institute's Governing Council. The Institute maintains close collaboration and interaction with other organisations working in the field of Meteorology, particularly with the India Meteorological Department (IMD), National Centre for Medium Range Weather Forecasting (NCMRWF), New Delhi, Indian Institutes of Technology, Universities and other scientific organisations associated with the research work in atmospheric sciences and oceanography.

1.2 Organisation of Research

Research work in the Institute is organised in the following divisions :

i) Forecasting Research
ii) Climatology and Hydrometeorology
iii) Physical Meteorology and Aerology
iv) Instrumental and Observational Techniques
v) Theoretical Studies

Two other divisions viz. (i) Computer and Data (ii) Library, Information and Publications provide necessary scientific/technical support to facilitate research.

The Institute's research programmes are organised under the following broad-based research areas functioning within its scientific divisions.

Sr. No.	Division	Area
1.	Forecasting Research	i) Numerical Weather Prediction ii) Extended Range Prediction iii) Monsoon Studies and Forecasting
2.	Climatology and Hydrometeorology	i) Climate and Climatic Change ii) Hydrometeorological Studies
3.	Physical Meteorology and Aerology	i) Cloud Physics and Weather Modification ii) Environmental Physics
4.	Instrumental and Observational Techniques	i) Development of Instruments for Boundary Layer Studies ii) Instrumentation for Cloud Physics and Weather Modification Studies
5.	Theoretical Studies	i) Studies of Dynamic Instability ii) Simulation of Monsoons and Tropical Circulation Systems.

The thrust of the Institute's scientific research has remained the same as to conduct an integrated programme of applied and fundamental research and development of related atmospheric technology and services to improve the understanding and prediction of atmospheric phenomenon, climate and climatic change, hydrometeorological studies for the utilisation of water resources, atmoshperic environment including boundary layer, atmospheric electricity studies and observations of air quality by conventional and remote sensing techniques.

For the above research work observational and theoretical studies are carried out and field programmes are organised. Major research facilities exist in the form of in-house powerful computer, access to other powerful computers in and around Pune and the Cray XMP-14 Super Computer at the NCMRWF, New Delhi, access to national meteorological data centre of IMD, Pune. Institute's own data sets and specialised laboratory equipment and instrumentation for undertaking field experimental programmes. These specialised facilities are also made available to other sister organisations and research scholars at the Universities having programmes in Atmospheric Sciences.

The Institute during the year acquired the following major equipment required for the research work :

Sr. No.	Equipment
1.	Doppler Sodar System
2.	Spectrometer
3.	Data logger – 2 Nos.
4.	Portable AC Generators – 3 Nos.
5.	Weather Monitors – 2 Nos.
6.	High Volume air sampler
7.	CW Dye-Laser
8.	Unislide Assembly
9.	Scanning System Assembly
10.	Grating Mounts – 2 Nos.
11.	Digital Barometer
12.	Optical Cross Wind Sensor
13.	Air Compressor
14.	Zoom Stereo Microscope

Some of the projects of the Institute generate their own data which are available to other scientists within the Institute as well to interested organisations. Research results are brought to the attention of the scientific community through papers published in scientific journals, proceedings of conferences and symposia, participation of scientists in the national and the international workshops/symposia. The Institute also organises/co-sponsors symposia/workshops on topics of current interest.

1.3 Staff and Budget

1.3.1 Staff

The staff of the Institute consists of 4 categories, viz., (i) Research, (ii) Scientific, (iii) Technical and (iv) Administrative. The planning, organisations and execution of the research programmes in different areas are carried out by the staff in the former three categories and the financial and administrative support is provided by the staff in the fourth category.

As on March 1990 the Institute has respectively 88, 56, 41 and 58 staff members in the four categories mentioned above. In addition, 62 non-technical maintenance staff provide the support required for the maintenance of buildings, gardening etc. The Institute is considering to recruit about 30 staff members in different categories according to a phased recruitment programme.

1.3.2 Budget

Funds for the Institute in the form of Grant-in-Aid are provided by the Department of Science and Technology. In addition, the Institute takes up sponsored projects from other Departments.

The details of the Institute's budget estimates and the actual expenditure for the period 1989-90 are given below :

(Rs. in lakhs)

	Budget estimate 1989-90	Revised estimate 1989-90	Grant including opening balance received from D.S.T.	Actual expenditure	Shortfall in expenditure over grant in aid received
Non Plan	157.00	149.00	148.93	148.93	–
Plan	90.00	85.00	84.84	84.84	–

Zero-based budgeting concept was introduced in the Institute since 1989-90. As a part of this system all the on-going research projects are reviewed internally by an expert committee every year.

1.3.3 Sponsored Projects

The details of the projects, funded by the Department of Science and Technology (DST) and the Department of Environment (DOE) are given below :

Sr. No.	Project	Period	Principal Investigator	Funding Department
1.	Interaction of Atmospheric Chemistry with the Nilgiri Reserve.	1989-1991	Dr. L.T. Khemani, Senior Scientific Officer, Gr. I	DOE
2.	Dendroclimatology Project.	1988-1991	Dr. G.B. Pant, Assistant Director	DST
3.	Medium Range Weather Forecasting Project.	1988-1991	Dr. S.K. Mishra, Deputy Director	DST
4.	Co-ordinated project on Boundary Layer Studies.	1987-1990.	Shri K.G. Vernekar, Assistant Director	DST

1.4 Participation in Bilateral Programmes

The Institute is participating in the following two bilateral programmes :

i) Indo-USSR Long Term Programme,
ii) Indo-US Programme on climate research.

Under the Indo-USSR Programme collaborative research work is being carried out. Three scientists each from the USSR and India exchanged visits to their respective host countries for carrying out the research work.

The Institute is the nodal agency for developing an Indo-US Programme on climate research. Under this programme, six projects have been formulated in which the IITM, IMD, IISc, Bangalore, ISRO (SAC), Ahmedabad, NIO, Goa, are the participating organisations from India. The six projects were finalised during the visit of a team consisting of six U.S. scientists : (1) Dr. A.R. Thomas, (2) Dr. C.M. Bhumralkar, (3) Dr. T.E. Murray, (4) Dr. S.D. Woodruff, (5) Dr. R.M. Davis, (6) Dr. G.V. Rao, to the Institute in November 1989. The Institute is also arranging an Indo-US Workshop on 'Parameterisation of sub-grid processes in Dynamical Models for Medium Range Prediction and 'Global Climate' during 06-10 August 1990. For this purpose various actions were initiated with the principal US scientists who will be participating in the above seminar.

1.5 Review Committee Report

The Department of Science and Technology had constituted an eight member Committee in May 1988 with Prof. R. Narasimha, Director, National Aeronautical Laboratory, Bangalore as Chairman to review the work of the Institute since it was imparted an autonomous status. The Committee has finalised its report during the year under review.

1.6 Awards

Dr. (Mrs.) P.S. Salvekar, SSO I and Dr. S.K. Mishra, D.D. were awarded 14th Mausam Award for 1986-87 for the paper, 'Effect of Ekman boundary friction on the baroclinic growth of monsoon depression', published in Mausam, Vol. 37, 1986. They received the award in person at a function held at Inaia Meteorological Department, New Delhi on 05 March 1990. The award consists of a citation and cash prize.

Shri K.D. Prasad, SSO II and Dr. S.V. Singh, A.D. were awarded IITM Silver Jubilee Research Award 1988 for their paper, 'Large scale features of the Indian summer monsoon rainfall and association with some oceanic and atmospheric variables', published in Advances in Atmospheric Sciences, Vol. 5, No. 4, November 1988.

1.7 Fellowship of Science Academies

Dr. S.K. Mishra, Deputy Director was elected as a Fellow of the Indian National Science Adademy.

1.8 Participation in Scientific Exhibitions/Programmes

The Institute participated in the following scientific exhibitions/programmes arranged to popularise the atmospheric science and create public awareness :

i) 'Science in Everyday Life Exhibition' at Ottapalam, Kerala during 11-14 September 1989 and 'Nehru Kisan Mela' at Allahabad, during 11-19 November 1989, both organised by Department of Science and Technology.

ii) National Science Day celebration on 28 February 1990. A lecture on 'Application of Raman effect in Meteorology' by Dr. H.N. Srivastava, Additional Director General of Meteorology (Research), India Meteorological Department, Pune, was arranged on the occasion.

iii) 'Children Meet Scientists' programme on 29 March 1990 arranged as a part of the National Science Day celebration by the National Council for Educational Research and Training (NCERT).

iv) World Meteorological Organisation (WMO) Day Celebrations on 23 March 1990 by arranging exhibition at the India Meteorological Department, Pune.

1.9 Publication of Brochure

A brochure containing the highlights of different research programmes of different divisions of the Institute, academic activities, research publications, budget and man power has been published.

1.10 Deputation abroad

The Institute deputed abroad 11 scientists during the year to participate in Conferences, Symposia and under bilateral programmes. Financial support for several of these visits came from international scientific organisations.

Sr. No.	Scientist	Place deputed to	Period	Purpose
1.	Shri D.R. Sikka, Director	Hamburg, FRG	i) 11-15 September 1989	Int. Conference on Modelling of Global Climatic Change.
			ii) 18-22 September 1989	8th Session of the Tropical Ocean and Global Atmosphere Programme (TOGA) Scientific Steering Group.
2.	Shri R. Suryanarayana, Deputy Director	Reading, U.K.	i) 11-14 August 1989	Advisory Working Group Meeting of the World Meteorological Organisation Commission for Atmospheric Sciences.
			ii) 15-16 August 1989	European Centre for Medium Range Weather Forecasting.
		U.S.A.	28 September– 14 October 1989	National Oceanic and Atmospheric Administration (NOAA) for preliminary discussion in connection with Indo-US project 'Large scale Ocean Atmosphere Climate Interaction : Data preparation and management.'
3.	Dr. A.S.R. Murty, Deputy Director	Beijing, China	08-12 May 1989	Fifth WMO Conference on Weather Modification and Applied Cloud Physics. He chaired one Session.
4.	Dr. G.B. Pant, Assistant Director	Worcertershire, U.K.	28 November– 03 December 1989	Workshop on 'Observed Climatic Change and Variability' organised by the British Meteorological Office.
5.	Dr. P.C.S. Devara, Assistant Director	Reading, U.K.	31 July– 12 August 1989 & 14-18 August 1989	Fifth Scientific Assembly of the Int. Association of Meteorology and Atmospheric Physics, (IAMAP 1989). Visit to Rutherford Appleton Laboratory and U.K. Meteorological Office, U.K.
6.	Dr. V.N.R. Mukku, Senior Scientific Officer, Gr. II	Reading, U.K.	31 July– 12 August 1989	Fifth Scientific Assembly of the Int. Association of Meteorology and Atmospheric Physics, (IAMAP 1989).
7.	Shri R.K. Verma, Senior Scientific Officer, Gr. I	Hamourg, FRG.	11-15 September 1989	Int. Conference on Modelling of Global Climatic Change and visit to Max-planck Institut fur Meteorologie and Meteorological Institute, Hamburg.
7.	Dr. L.S. Hingane, Senior Scientific Officer, Gr. I	Penang, Malaysia	20-23 February 1990	Int. Conference on Tropical Ozone and Atmospheric Change.
8.	Shri S. Sinha, Senior Scientific Officer, Gr. I Shri M.K. Tandon and Smt. S.S. Vaidya, Senior Scientific Officers, Gr. II	Dept. of Numerical Mathematics, USSR, Academy of Sciences, Moscow	For varying periods between 2-3 months from 18 July 1989	Indo-USSR Integrated Long Term Programme of Co-operation in Science and Technology.

1.11 Memberships of Expert Committees etc.

Following scientists of the Institute were nominated to serve as members on various expert national and international committees.

Sr. No.	Name	Membership
1.	Shri D.R. Sikka, Director	Indian Geophysical Union.
2.	Shri D.R. Sikka, Director, Dr. G.B. Pant, A.D. and Dr. P.R. Rakhecha, SSO I	Experts on the WMO/UNEP Inter-Governmental Panel on Climatic Change (IPCC).
3.	Dr. A.S.R. Murty, D.D.	International Advisory Committee of the 13th Int. Conference on Nucleation and Atmospheric Aerosols (IAMAP/IUGG) to be held at Salt Lake City, USA, during 24-28 August 1992.
4.	Dr. S.K. Mishra, D.D.	i) I-TOGA Modelling Group ii) DST – GFDL Working Group.
5.	Dr. G.B. Pant, A.D.	i) Expert Committee on Palaeo-climate and Environmental Research. ii) Committee for the Implementation of National Co-ordinated Programme on Palaeo-climate and Palaeoenvironmental Research during the 8th Five Year Plan.
6.	Dr. G.B. Pant, A.D., Dr. H.N. Bhalme, A.D and Dr. P.R. Rakhecha, SSO I	Experts for the Bureau of Inter Governmental Panel on Climatic Change (IPCC) in the areas of Climate Modelling, Climatology and Hydrometeorology.
7.	Dr. S.V. Singh, A.D.	International Planning Committee of WMO Training Workshop on Diagnosis and Prediction of Monthly and Seasonal Atmospheric Variations to be held at Nanjing, China, in October 1990.
8.	Dr. P.C.S. Devara, A.D.	Working Group on 'Laser Atmospheric Studies'.

Several other scientists continued to function on national and international committees for which their nominations were received in the earlier years.

1.12 Research Highlights

Extented period simulations of GFDL-GCM made with interannually varying SST over the tropical Pacific were analysed for climatology of the Indian summer monsoon rainfall and its relationship with ENSO. The simulations represented satisfactorily the suppression of monsoon rainfall during the warming phase and enhancement during the cooling phase of the ENSO.

A generalised empirical relationship between monthly satellite derived highly reflective cloud frequencies and rainfall of 8 island stations in Arabian sea and Bay of Bengal was established by using data for the period 1971-1988. The rainfall estimates made during 1987 by using this relationship agreed well with those obtained from INSAT-IB radiance data.

Active association with the work of the National Centre for Medium Range Weather Forecasting (NCMRWF) was maintained for establishing the global analysis forecast system there. For this purpose Shri D.R. Sikka, Director remained actively involved with the work of the NCMRWF.

Probable Maximum Precipitation (PMP) Atlas of the country was published and all the 425 copies have been sold out to user agencies.

Long-range forecast of southwest monsoon rainfall for 1989 based on different techniques developed at the Institute over the years was provided to the India Meteorological Department. An overall indication of 'Normal Monsoon' for the year 1989 given in the month of May was found to be in close agreement with the observed monsoon performance by the end of the season.

Two hundred and fifty tree ring samples collected from Central Himalaya have been used for

reconstructing the summer mean temperature series of the region to late 18th century. Also the climatic significance of stable isotope ratio of hydrogen in tree rings of tropical teak tree was established.

Fifteen severe rainstorms over the country were identified for potential application in the development of water resources projects. The storms were analysed using Depth-Area-Duration (DAD) method. Quantitative precipitation forecast techniques for the Narmada catchment were developed using the multiple regression analysis of dynamical parameters of the atmospheric flow over the region in a sample case for one year.

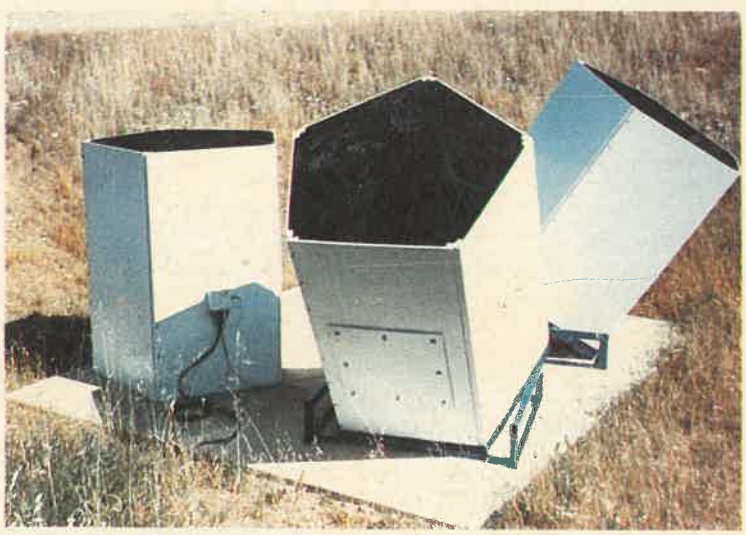
As a part of the studies relating to Atmosphere-Biosphere Interactions, a field observational programme was organised in the Silent Valley, Kerala during December 1989. Under this programme, extensive 24 hour observations of atmospheric total suspended particulates (TSP), Aitken nuclei, atmospheric trace gases (SO_2, NO_2, NH_3 and O_3) were carried out. Analysis of these observations is being carried out for investigating the effects of pollutants on vegetation in the core zone of the Nilgiri Biosphere Reserve.

A Mono-Static Doppler Sodar was acquired by the Institute under MONTBLEX programme for probing the Atmospheric Boundary Layer. The sodar was put into operation at the Institute's campus. MONTBLEX pilot experiment was conducted at I.I.T., Kharagpur in July 1989. Observations on wind, temperature and humidity at different levels upto 30 m height and temperature profiles upto 2 km (using minisondes) were taken. The data were being analysed.

Laboratory experiments to study the breakup of electrically charged and uncharged water drops revealed that the half life for suspension of water drops in wind tunnel decreases with the increase in size or electrical charge of the drop. Theoretical calculations taking into account the size and charge distribution on raindrops indicated that the electrical force acting on raindrops can significantly change the drag force imparted by raindrops to the surrounding air in which they are falling. Such changes in drag force may influence the cloud dynamics. An ion counter to measure concentrations of atmospheric ions having mobility of more than three different values was fabricated and installed. The ion counter is capable of measuring concentrations of ion in the whole range observed in lower atmosphere.

Computations showed that both barotropic and baroclinic energy conversions contributed to the growth of monsoon onset vortex of 1979. A simple mathematical expression was devised to represent the potential vorticity profile of the observed mean tropical easterly jet.

30 m tower installed at IIT, Kharagpur, for Atmospheric Boundary Layer Studies under MONTBLEX project.



Antenna system of the Doppler Acoustic Sounder.

2. RESEARCH

Research activities of the divisions are summarised below :

2.1 Forecasting Research Division

Recognising the potential benefits of weather prediction research towards development of the national economy the following research programmes are formulated by the Division.

* Development of regional NWP models with full physics like, parameterisation of convection; radiation and the planetary boundary layer.

* Objective analyses of meteorological fields like wind, height and humidity fields needed as input for these NWP models. Conventional and satellite derived data are used for the purpose.

* Intraseasonal and interannual variability of monsoon are studied and the empirical techniques are developed for prediction of monsoon rainfall on both these time scales.

* Diagnostic studies are also conducted for understanding the dynamical and physical processes on the regional and planetary scale.

2.1.1 Numerical Weather Prediction

a) Regional NWP modelling with full physics

Improved versions of the physical processes and sponge damping lateral boundary conditions were tested to improve the performance of the regional six level primitive equation model. The application of the sponge damping lateral boundary condition was found to suppress the spurious growth near the boundaries. The physical processes investigated were three versions of the Kuo convection scheme and the effects of the counter gradient terms in the planetary boundary layer.

Three versions of Kuo cumulus convection viz. (i) the moistening parameters 'b' set to zero, (ii) the parameter 'b' computed as a function of mean relative humidity and critical relative humidity after Anthes (1977) and (iii) the parameter 'b' and a mesoscale convergence parameter expressed as functions of pairs of known large scale variables through multiple regression approach, were investigated. The radiative heating/cooling was also parameterised and included in the model. Preliminary results suggested that the Kuo scheme using Anthes criteria produces better forecast.

For parameterisation of the PBL, the constant counter gradient term used earlier on the computation of turbulent heat fluxes was replaced by a functional relation involving turbulent frequency neutral case counter gradient value and vertical gradient of potential temperature and mixing ratio for water vapour. Inclusion of the counter gradient terms considerably improved the forecasts of the south-westerly winds at 850 hPa level over the Arabian sea.

The density field in the upper layers of the Eastern Arabian Sea (5°N-25°N, 55°E-80°E) and the ocean surface wind data for the period 21 May to 3 June 1979 obtained from MONEX and IDWR were utilised for preparing a composite set of 1° Lat./Long. grid point data of density and wind stress fields. The curl of wind stress fields suggest an offshore upwelling along the west coast of India south of lat. 15°N.

b) Objective analysis

The structure and autocorrelation functions for geopotential height, winds and relative humidity fields were computed for all standard levels using daily radiosonde data of 10 July months (1976-1985). The stability of these functions to varying length of data was also examined.

Multiple regression equations were developed for estimating relative humidity at 850, 700 and 500 hPa levels from independent surface weather parameters, viz. total cloud amount, low cloud amount, surface relative humidity and present weather. Objective analysis was made using Optimum Interpolation (O.I.) scheme for the period 4-8 July 1979 by excluding and including these estimated relative humidity data along with radiosonde data. Both the sets of analysis agreed well with the moisture structure inferred from satellite cloud pictures. The R.M.S. errors of analysis varied from 6 to 17%. Reanalysis of relative humidity fields for the same period by modifying the autocorrelation functions to include the effect of wind flow showed marginal improvement in R.M.S. errors.

For including the divergent part of wind in the objective analysis scheme of wind field the satellite derived outgoing longwave radiation fields were used to construct velocity potential fields at 850 hPa and 200 hPa for 6 days, 14-19 June 1979, of the FGGE year.

Satellite derived low and high level cloud motion vectors were compared with wind observations at all levels taken by the USSR research ships during Monex-79. The R.M.S. errors of estimated winds were less than 5 m.p.s. (8 m.p.s.) below (above 500 hPa level).

Empirical relation was developed between monthly highly reflective cloud frequency and monthly rainfall at 8 island stations in the Arabian sea and the Bay of

Bengal using 13 years (1971-1983) of data. Rainfall estimates from this relationship were compared with the quantitative precipitation estimates made from INSAT-IB radiance data for the year 1987 by India Meteorological Department. The isohyetal patterns of both the methods showed almost similar features of high and low rainfall regimes.

2.1.2 Extended Range Prediction

15-year simulations of the GFDL-GCM model run with interannually varying SST in the tropical Pacific were obtained and some aspects of the climatology and the interannual variability of Indian summer monsoon rainfall were investigated. The simulations represented very well the monsoon rainfall climatology and the interrelationships between the phases of the ENSO and the monsoon rainfall. The simulated rainfall agreed well with the observed composite rainfall anomalies during the three ENSO years viz., 1965, 1969 and 1972, over central-northern India but failed to represent the maximum anomalies over north-west India (Fig. 2).

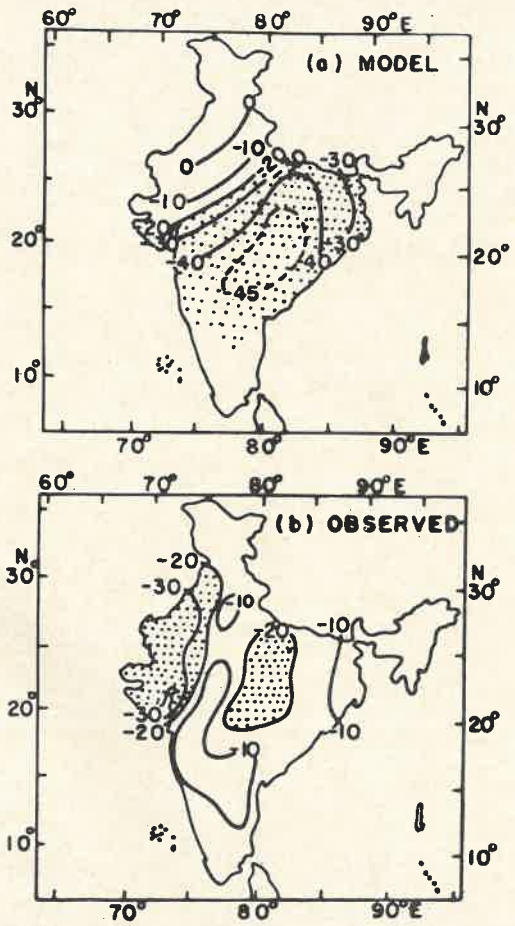


Fig 2 : Average summer monsoon rainfall departure (%) for ENSO years of 1965, 1969 and 1972 : a) model – simulated and b) observed.

Fluctuations in the frequency of droughts in Indian monsoon rainfall were analysed in relation to the warm and the cold epochs in global surface temperature by using the data of the years 1901-1988. A significant increase in the frequency of occurrence of monsoon drought during both the epochs of global warming and cooling is observed.

The long-range forecasts of Indian monsoon rainfall for 1989 over northwest India, peninsular India and all India were prepared by using multiple regression equations. The forecasts for peninsular India and all India agreed well with the observed monsoon rainfall.

The deterministic chaos approach was followed to estimate the dimensions and predictability of the daily monsoon rainfall over Konkan. A strange attractor of fractal dimension 3.5 was identified. The study showed that the predictability of daily rainfall over Konkan is about 4 days.

Spatio-temporal evolutionary features of 5-day OLR fields during summer monsoon over the Indian ocean and west Pacific region were examined by conducting the extended EOF analysis. The results suggest that whereas the coherent OLR anomalies move northward over the Indian ocean, they move northwestward over the west Pacific.

Although Monsoon-1989 appeared normal, when averaged over the entire country, the spatial analysis of rainfall revealed a banded structure over south and east Asia with large deficient rainfall over northwest and adjoining central India. The pattern was in contrast to what is generally observed during monsoon-drought years. Investigations of the global analysis of wind, surface pressure and OLR fields suggest that this anomaly pattern of Monsoon-89 was largely due to southeastward shift in the Hadley circulation over southeast Asia.

2.1.3 Monsoon Studies and Forecasting

Investigations relating to a monsoon depression formed at a least preferred and unusually southern latitude during July 1989 and caused heavy to very heavy rainfall over Andhra Pradesh, Maharashtra and Gujarat region were carried out. Moisture flux during the life cycle of this depression was studied by using the 850 hPa ECMRWF wind field and the moisture parameters derived from the Indian radiosonde data. It was found that the large amount of moisture supply (Fig. 3) both from the Bay of Bengal and Arabian Sea, due to the southward positioning of the depression, maintained its intensity.

Harmonic analysis of the tropical global 200 hPa monthly mean zonal and meridional wind data obtained from National Meteorological Center (NMC), Washington, for two normal (1970, 1971) and two

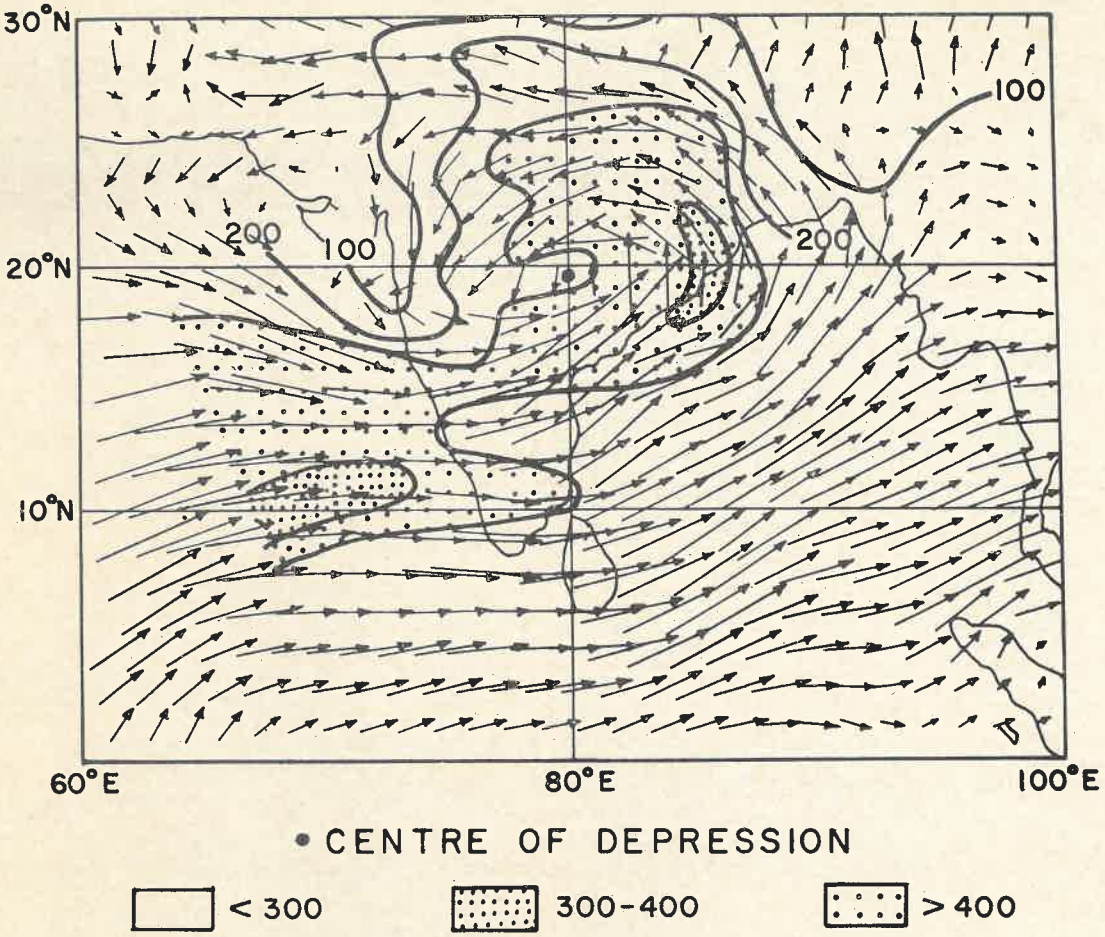


Fig. 3 : Monsoon depression formed on 23 July 1989 12GMT

drought years (1972, 1979) for the months June through August were carried out for investigating the wave activity during years of contrasting monsoon activity. The results showed that during the normal monsoon years the (i) smaller waves are more intense and (ii) the northward transport of momentum is larger particularly by wave number 1 at 20°N lat.

A study of characteristics of the circulation patterns during 'active' (1-15 August 1979) and 'break' (16-31 August 1979) monsoon epochs over India showed that maximum contrast in the circulation occurred at 500 hPa level. It was also revealed that during the 'break' epoch the 500 hPa ridge shifted southward and a mid-latitude westerly trough was obtained over Northwest India.

The interannual variability of monsoon onset and withdrawal phases over India were examined by using data of 20 years (1970-1989). It was found that the monsoon takes on an average 40 days to cover the entire country after its first appearance at the Kerala coast and 30 days in withdrawing from northwest India to a position along 15°N. The standard deviations of the onset and withdrawal processes are respectively 9 and 11 days.

2.2 Climatology and Hydrometeorology Division

Large-scale climatic changes over the Indian region particularly the instances of droughts and floods have profound impact on the over all economy of the country. The primary source of water in India is from the rainfall during the southwest monsoon season which has a high degree of variability in space and time. The climatological and hydrometeorological studies are therefore aimed at :

* Improving the understanding of physical and dynamical factors associated with the abnormalities in the behaviour of the monsoon on intraseasonal, interannual and decadal scales.

* To develop statistical multiple regression models using appropriate parameters to obtain quantitative estimates on seasonal monsoon rainfall.

* To study the probable trends of future climate over period of many decades. For this purpose a variety of meteorological parameters are examined to study the relationship of monsoon on regional and global scales.

* Hydrometeorological analysis of sufficiently long series of rainfall data on different time scales for various river basins of the country for planning and design of the water resource management projects.

* Probable Maximum Precipitation, Depth-Area-Duration Analysis of severe rainstorms and development of quantitative precipitation forecast models for flood forecasting.

2.2.1 Climate and Climatic Changes

a) 30-60 day oscillation and Indian rainfall

The 30-60 day oscillation found in different meteorological parameters over the tropics, were examined in relation to the rainfall over India. The nature and characteristics of the 30-60 day oscillation, its intra-seasonal and interannual variations and its potential for rainfall prediction were examined using daily area averaged rainfall data of three regions (South Kerala, North Kerala and Upper Narmada catchment) for the period 1901-1980. The analyses of the daily rainfall data for the individual years (before and after removal of the annual cycle) have highlighted the large interannual variations in the period and amplitude and phase of the 30-60 day oscillation. The 80-year mean values of variance show a maximum in the 30-60 day period range. However, the standard deviations and the range of extreme values of the 80-year sequence of variance are very large and as such the utility of the 30-60 day oscillation for rainfall prediction over Indian region is limited.

b) El-Nino, Planetary scale waves and Indian summer monsoon rainfall

The relationships between the El-Nino phenomenon and the planetary-scale waves, and the interannual variations in the Indian monsoon rainfall were investigated to understand as to how SST in the equatorial Pacific associated with El-Nino can produce below normal Indian monsoon rainfall. The study suggests that excessive warm SST anomalies associated with El-Nino can increase the sensible heating, evaporation and moisture giving rise to enhanced rainfall in the Eastern Pacific. As a consequence, the planetary-scale waves (integrated wave number 1-3) in the height of 200 hPa pressure level alter the position and amplitude. The marked eastward shift of the ridge over Indian rigion by 30 to 40 degree longitudes leads to displacement of rainfall regions bringing below normal monsoon rainfall over India (Fig. 4a, b).

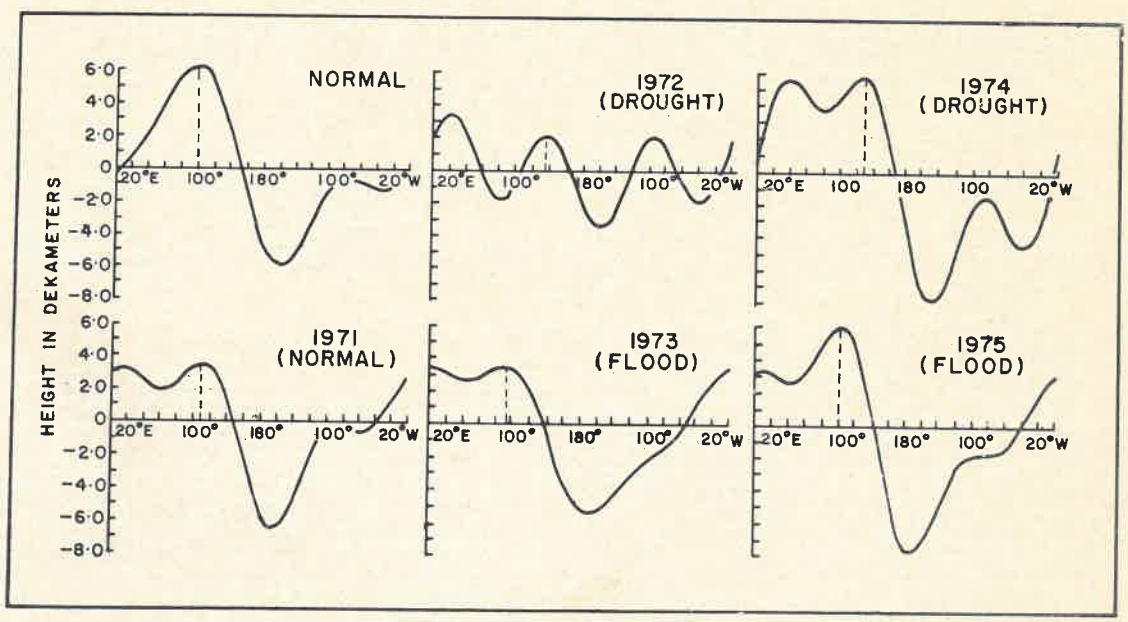


Fig. 4a : The integrated effect of the first three wave numbers of geopotential height field at 200 hPa pressure level in May along a latitude circle of 15°N for climatological normal map and for different years 1971-1975.

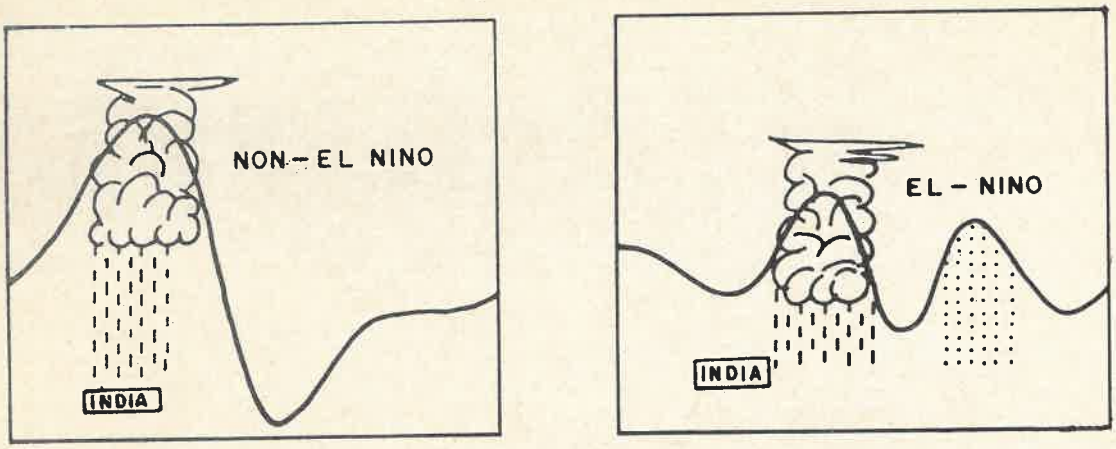


Fig. 4b : Mechanism for below-normal Indian monsoon rainfall during El-Nino. Excessive warm SST anomalies associated with El-Nino induce eastward shift of 200 hPa ridge over Indian region resulting displacement of rainfall regions and bringing below-normal rainfall over India.

c) Long-range forecast for Monsoon-1989

Long-range monsoon season rainfall forecast for 1989 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 normal monsoon rainfall activity for the year 1989, which turned out to be correct.

d) Pressure fluctuations and monsoon

The changes in the evidence of relationship between All-India monsoon rainfall and msl pre-monsoon

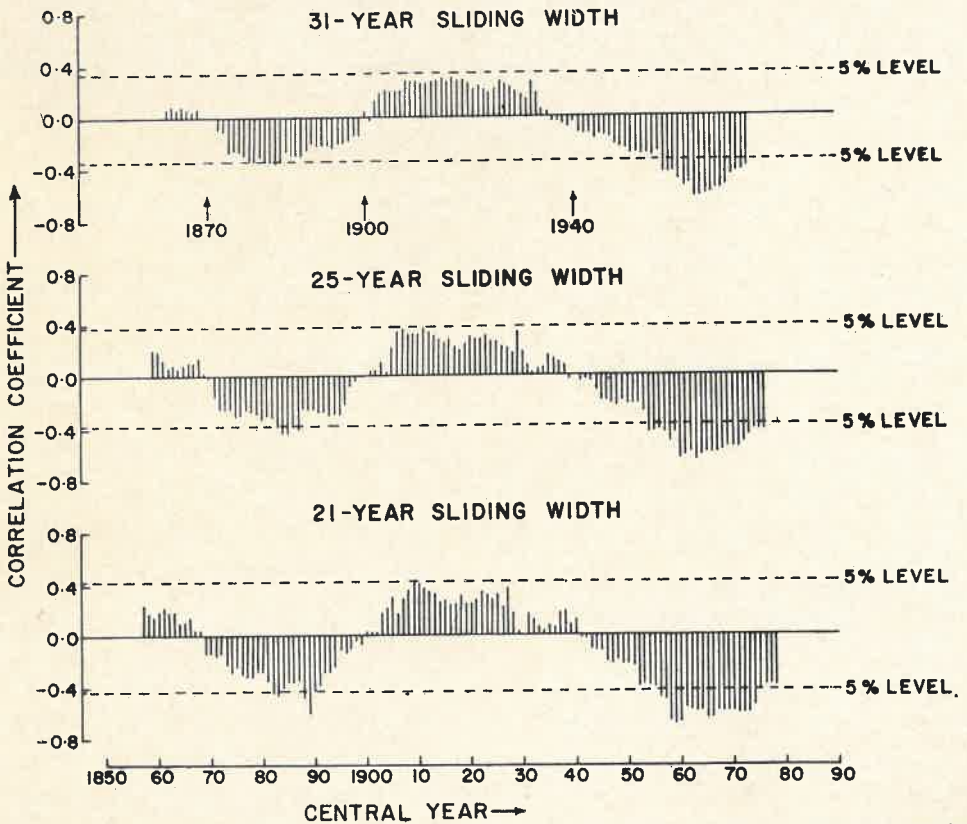


Fig. 5 : Changes in correlation coefficient as a function of time with 21–, 25–, and 31– years sliding window width between all-India summer monsoon rainfall and 0830 IST MSL pressure of Bombay, MAM-DJF (Tendency Parameter) during 1871-1988.

pressure tendency (MAM-DJF) of Bombay for the period 1847-1988 indicated systematic turning points around the years 1870, 1900 and 1940. These climatic periods are identified as 'meridional monsoon period' (1871-1900) and (1941-present) and 1901-1941 as 'Zonal Period' (Fig. 5).

e) Kharif Foodgrain production and All-India rainfall

All-India summer monsoon rainfall is found to be significantly influencing the Kharif season food grain production. Its relationship for the period 1964-1988 showed a high correlation of +0.88. This information can be used for advance estimation of Kharif food grain production superimposed on the Technological trend.

f) Spatial distribution of ozone over India

Detailed analysis of 30 years of ozone data and associated meteorological processes were carried out in the region where global maps of total ozone show a minimum value during the summer of Northern Hemisphere. A well marked trough in the monthly march of total ozone is detected during July and August over the most moist part of the monsoon region. Over India, during the middle part of the monsoon season, the value of total ozone at sub-tropical stations like Delhi and Varanasi are lower than those at tropical station like Kodaikanal and stations lying outside the monsoon trough area; which is further defined as 'Ozone Valley' in the subtropics. The appearance of trough along moist part of monsoon region and ozone valley along monsoon trough may be the result of some unique features of thermal and dynamical processes appearing in that region.

g) Dendroclimatology

A field expedition for the collection of tree-ring cores and discs from old trees of suitable coniferous trees from the forest regions of Central/Western Himalayas was implemented during June 1989. Field team covered forest sites in the hill regions of Uttar Pradesh and Himachal Pradesh. Two hundred and fifty increment cores from old healthy trees of Deodar (Cedrus deodara) and Chir Pine (Pinus roxburghii) were extracted, some of which date back to about 300 years.

Analysis of tree ring samples collected earlier from Kashmir area revealed a significant response of summer temperature to tree growth in the region and this information is used to reconstruct the summer mean temperature series of the region for the last 200 years (Fig. 6).

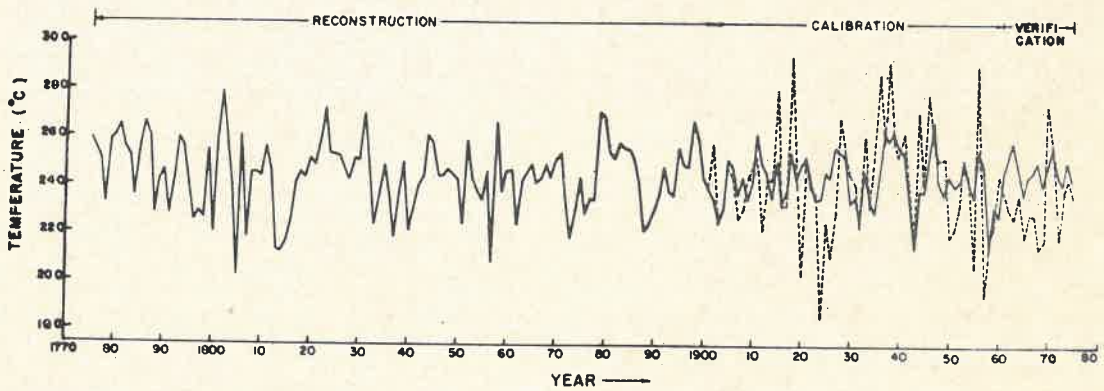


Fig. 6 : Reconstruction of monthly mean maximum for May at Shrinagar, based on ringwidth data of Picea Smithiana at Pahalgam.

2.2.2 Hydrometeorological Studies

a) Depth Area Duration Analysis

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.

b) Severe Rainstorm Analysis

i) A quantitative analysis of the severe rainstorms that occurred over the Western Region of India comprising of the areas of Madhya Pradesh, Gujarat, Saurashtra and Rajasthan since the year 1891 was made by the DAD method. This analysis identified September 1926, July 1941, July 1981 and June 1983 as the most efficient rainstorms over Madhya Pradesh, Gujarat, Rajasthan and Saurashtra regions respectively as these rainstorms gave unprecedented areal raindepths for

1 to 3 days. A detailed examination of these storms with regard to their type, region of influence and topographical controls suggested that these storms can effectively be utilised in design flood studies in the respective areas of their occurrence; however, there appears to be some constraints on the transposition of July 1941 storm.

ii) Unusual rainstorms that have occurred over different catchments of peninsular India were analysed with a view to determine areal raindepths of different sizes and durations. The areal raindepths were then utilized in the estimation of probable maximum precipitation (PMP) for 12 river catchments in peninsular India. The PMP estimates were found to vary between 18-50 cm for 1-day duration, 26-80 cm for 2-day duration and 32-90 cm for 3-day duration. A comparison of PMP estimates for southern river catchments with those of northern river catchments showed that areal PMP of southern catchments are low as compared to northern river catchments.

c) Probable maximum rainfall

i) The maximum 1-day rainfall data for about 70-80 years for 250 observatories were analysed to obtain the estimates of 1-day PMP by Hershfield method and 100-year return period value by extreme value Type-I distribution. These two estimates for each of the stations were expressed as percentages of their respective mean annual rainfall and the spatial variation of these two percentages were displayed in maps with a view to predict PMP and extreme rainfall for a 100-year return period from mean annual rainfall of a station.

ii) A new approach of estimating areal PMP for 1 to 3-day durations was developed for the river catchments of northwestern region of India. The areal raindepths associated with the most efficient rainstorm of this region were first normalised for such factors as storm dew point temperature, distance of the storm from the coast, topography and intervening barrier between rainfall area and the moisture source so as to obtain areal PMP near the coast. These normalised areal PMP estimates can then be applied to any river catchment located in the northwestern region of India.

d) Design storm studies

i) An estimate of PMP likely to be experienced by the Ponniar river catchment upto Sathanur dam site in Tamil Nadu having an area of 11000 km^2 was made by a study of major rainstorms experienced in the homogeneous area in and around the catchment. A survey of daily rainfalls for the period 1891 to 1986 showed that the area had recorded four major rainstorms during the period 6-8 November 1898; 10-12 November 1903; 18-20 May 1943; and 9-11 October 1943. Out of these, the May 1943 storm gave the largest rainfall volume for an area of about 11,000 km^2. The isohyetal patterns of this rainstorm for the period of maximum 1-day and 2-day were transposed over the Ponniar river catchment so as to achieve the maximum average raindepths over the catchment. The transposed raindepths upto the Sathanur dam site for 1 and 2-day durations were found to be 21.2 cm and 28.6 cm respectively. In evaluating PMP for the catchment, the transposed raindepths are to be adjusted by the moisture maximisation factor.

ii) The catchment areal average rainfall for 1 to 3 days durations of Subarnarekha river catchment above Chandil dam site covering an area of about 5660 km^2 was estimated by arithmetic, thiessan isopercental and regression methods. The estimates obtained by these methods were tested against the isohyetal method based on all rainfall stations in the catchment. The areal average rainfall obtained by regression analysis is shown to be the best method for the computation of areal catchment rainfall.

e) Quantitative Precipitation Forecasting Research

Quantitative Precipitation Forecasting (QPF) over Narmada catchment was attempted using multiple regression model. The catchment was divided into five regions for calculation of daily areal rainfall. Antecedent dynamic parameters like relative vorticity, horizontal divergence, vertical velocity and moisture divergence were calculated at different levels at 7 locations along the catchment as test case for June through September 1979. Antecedent parameters in the regression equations, in order of their selection, are 24-hr rainfall, relative vorticity in the lower troposphere, moisture divergence and horizontal divergence accounting for about 65% (ranging between 50-75% over different regions of the catchment) to the variance of the daily rainfall over the catchment.

f) Probable Maximum Precipitation (PMP)

i) Daily rainfall for the period 1901-1970 were scanned to obtain maximum rainfall values for 1 to 5 days durations for each years for about 400 stations uniformly distributed over the Indian region. These data are being further utilized for estimating PMP for longer durations ranging from 2 to 5 days.

ii) The daily rainfall data of 200 stations in different river basins of Maharashtra for a period of 80 years from 1901 to 1980 were analysed with a view to predict 1-day maximum rainfall for different recurrence intervals ranging from 2 to 100 years. Based on these data a family of generalised maps showing the spatial distribution of 1-day maximum rainfall events for different recurrence intervals were prepared. The maximum 1-day rainfall for the different river basins of Maharashtra were found to vary from 8 to 25 cm, 10 to 30 cm, 12 to 40 cm and 15 to 50 cm for 2, 10, 50 and 100-year recurrence intervals respectively.

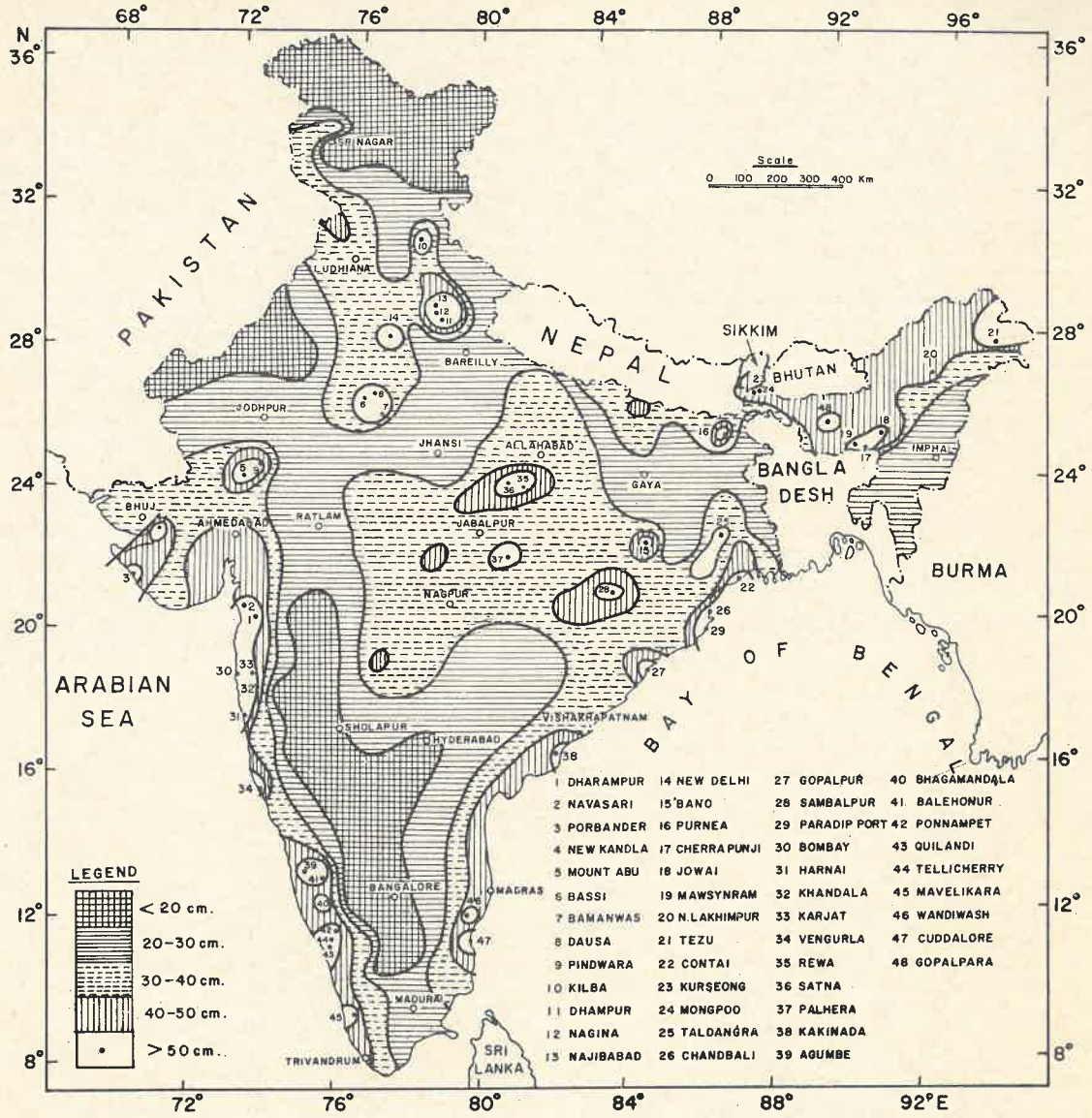


Fig. 7 : HIGHEST RAINFALL FOR 24 HOURS (PERIOD 1875-1982)

iii) Using annual rainfall data from 1871 to 1984 for 306 stations well distributed over India, an Average Probability Diagram (APD) giving estimates of rainfall with varying probabilities of exceedance as a function of the mean annual rainfall was developed. The APD was utilized to study probability distribution of spatial variation of boundaries of different moisture regions of India.

2.3 Physical Meteorology and Aerology Division

The agricultural production in India largely depends on monsoon rainfall. For the understanding of the monsoon related weather systems it is essential to study the physical processes relating to cloud systems, atmospheric boundary layer, upper atmosphere including coupling between troposphere and

stratosphere. For meeting the challenges during years of weak monsoon activity, it is essential to develop weather modification technology for increasing rainfall on local scale through seeding of monsoon clouds. For the understanding of adverse effects of air pollution on ecosystems, climate and ozone depletion it is essential to undertake studies relating to atmospheric aerosols and atmospheric chemistry. The research work of the Division is aimed at advancing the present knowledge in the following topics :

* Documentation and study of the fair weather and cloud electrical characteristics
* Study of the electrical charge generation mechanisms in monsoon clouds and interactions among cloud electrical microphysical and dynamical parameters
* Study of the physical processes relating to clouds and precipitation mechanisms in monsoon clouds
* Documentation and study of the warm cloud responses to salt seeding and study the feasibility of increasing rainfall through cloud seeding techniques
* Studies relating to the atmospheric boundary layer and participation in MONTBLEX
* Study of the deterministic chaos and its applications in Atmospheric Sciences
* Study of the middle atmospheric dynamics and its association with the Indian summer monsoon rainfall
* Atmosphere —Biosphere interactions
* Acid rain in India
* Lidar and spectrometric measurements of atmospheric aerosols/trace gases.

2.3.1 Cloud Physics and Weather Modification

a) Studies in Atmospheric Electricity :

The variations noticed in the atmospheric electric field recorded at Pune during the period 1930-87 were examined in relation to the variations observed in the Angstrom turbidity coefficient (B) and selected meteorological parameters. The monthly and annual mean values of the atmospheric electric field, Angstrom turbidity coefficient (B), rainfall, temperature and relative humidity for the years 1930-38, 1957-58, 1964-65, 1973-74 and 1987 were considered in the study (Fig. 8).

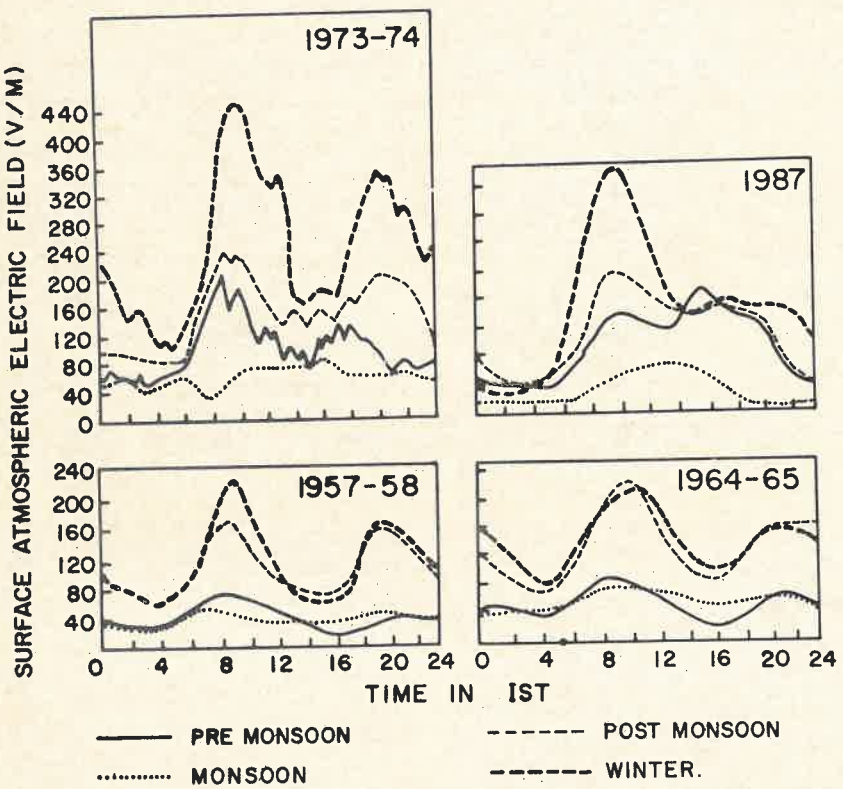


Fig. 8 : Diurnal variation of atmospheric electric field recorded at Pune during different seasons and periods.

Results of the study indicated gradual increases in the atmospheric electric field over the period of study (1930-1987) which are statistically significant at less than 5% level. The Angstrom turbidity coefficient also showed systematic increase during the period of study, which is consistent. The diurnal curve of the atmospheric electric field at the station showed, by and large, a double oscillation, which was observed in the continental environments.

The observations of the point discharge current collected at Pune during 41 thunderstorms which occurred in the pre and post-monsoon seasons of 1987 and 1988 were analysed. Preliminary results indicated the following :

The net point discharge current associated with the thunderstorms occurring in the day-time is significantly higher than that associated with the thunderstorms occurring during night-time.

In the pre-monsoon season the duration of the point discharge current is longer for day-time thunderstorms as compared to the night-time thunderstorms, whereas in the post-monsoon season the duration of the point discharge current is longer for night-time thunderstorms.

The ratios of the net point discharge currents of negative to positive polarity were found to be 0.76 and 0.85 during the pre and post-monsoon seasons of 1987, whereas they were respectively, 1.38 and 1.65 during 1988. These results indicated that during 1987, the earth received less negative charges from the thunderstorms as compared to 1988.

The maximum duration of the spells of point discharge current associated with the thunderstorms occurring in the day-time is about 90 minutes, whereas it is only 30 minutes in case of thunderstorms occurring during night-time.

Radar Study of Rain and Rain-bearing Clouds

A study of the frequency distributions of the heights of the convective clouds in different regions of India during the pre-monsoon season was undertaken. The study is based on the available radar data of heights of such clouds in five regions in India, namely, Gangetic Valley of west Bengal, Brahmaputra valley (Assam), Bombay and adjoining region, Hyderabad and adjoining region, and Delhi and its neighbourhood. The frequency distributions of the heights of the clouds were found to be lognormal in all the places atleast upto a height of 13 km. The observed distribution suggests that the convective clouds grow according to the law of proportionate effects. Deviations of the height distribution from log-normality at higher heights is attributed to the affect of tropopause which inhibits vertical development of clouds.

A study of the size distribution of the rain echoes from precipitating clouds within 100 km around Delhi observed during six monsoon seasons (1967-1972) was carried out. Measurement of the horizontal areas of 16820 echo cases showed a preponderance of echo sizes in the D scale (upto 100 km^2) with relatively small percentage in the C scale (101-1000 km^2) and in the B/C scale (~ 1000 km^2 to 10,000 km^2). The first size scale is generally associated with pure convection while the latter two groups are generally considered as mesoscale. The percentage frequency distribution of the echoes in these three size scales are respectively 85%, 14% and 1%. The largest echo area observed was 7986 km^2.

b) Warm Cloud Modification :

The microphysical characteristics of warm clouds forming over the Arabian sea (maritime) and in the Pune region (inland) were investigated using the aircraft observations obtained during the summer monsoon seasons of 1973, 1974 and 1979. For this study, the cloud drop spectra obtained at different levels inside the clouds were utilised. The results indicated that the microphysical characteristics of the warm clouds in the maritime environment are different from those forming in the inland regions. The concentration of large size cloud drops ($r \simeq 25 \mu m$), liquid water content and the mean volume diameter in maritime clouds are found to be higher as compared to those in inland clouds. The total concentration of cloud drops is lower in maritime clouds. The cloud drop-size distributions are, by and large, bimodal in maritime clouds and unimodal in inland clouds. The cloud drop spectra in both the cases indicate broadening with height.

The observations of cloud drop-size distributions obtained in the seeded (target) and not-seeded (control) clouds collected during the cloud seeding experiments conducted during the summer monsoon seasons of 1981-86 were analysed. The cloud drop-size spectra showed significant variations in target clouds indicating enhancement of the coalescene process in warm clouds following salt seeding (Fig. 9).

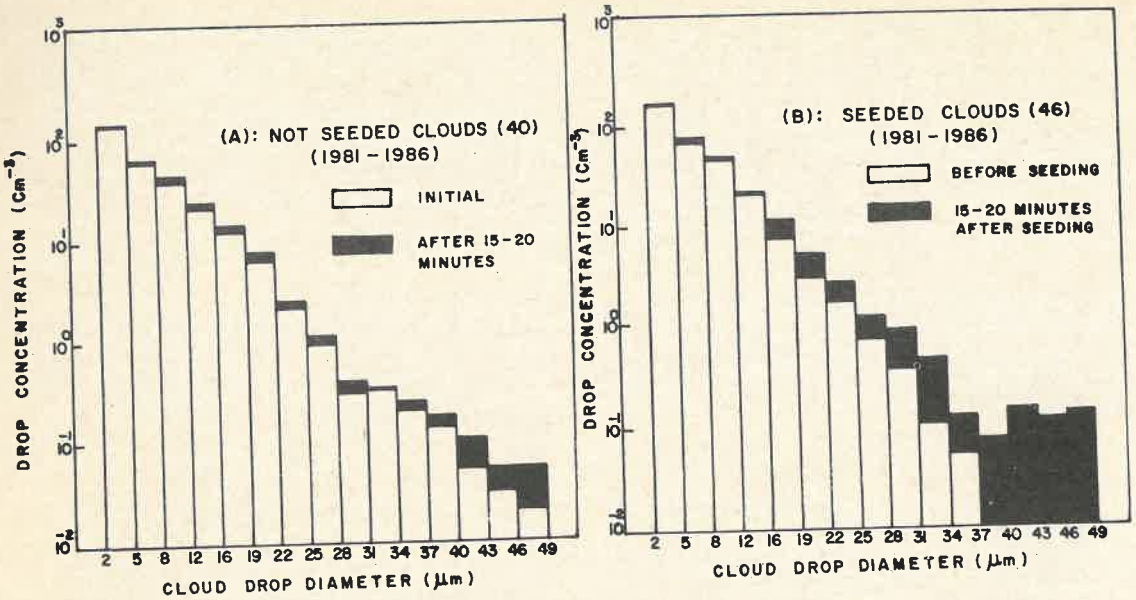


Fig. 9 : Warm cloud responses to salt seeding. Cloud drop spectra (A) Not-seeded clouds, (B) Seeded clouds.

The physical aspects of monsoon clouds and the mechanisms of rain-formation in the clouds were studied using aircraft observations and through the theoretical computations using a simple 1-D model. The results of the study indicate good agreement between the model-predicted cloud physical parameters and the observations.

At the request of Kerala State Electricity Board (KSEB), Trivandrum, a project proposal for undertaking Warm cloud seeding operations using aircraft in the catchment area of the Idukki Reservoir during the summer monsoon season of 1990 was prepared. The project document was sent to the KSEB. Necessary follow up actions for the above project have been initiated.

The Institute is planning to acquire a 5 cm Doppler radar for the study of convective cloud processes and weather modification research. For this purpose necessary technical details and justification for the siting clearance of the 5 cm Radar at the IITM, Pashan, Pune were sent to the Ministry of Communication.

2.3.2 Environmental Physics

a) Studies of the Atmospheric Boundary Layer :

i) Deterministic Chaos : Traditional mathematical models of dynamical systems based on Newtonian continuum dynamics consist of nonlinear partial differential equations which can only be solved numerically using digital computers with inherent roundoff errors. The computed phase space trajectory of the dynamical system, namely, the strange attractor has selfsimilar fractal geometry and is sensitively dependent on initial conditions, a signature of deterministic chaos, i.e., unpredictability of the future state of the system.

Studies relating to the universal algorithm governing deterministic chaos in nonlinear mathematical models of physical system were undertaken. A universal algorithm is developed to show quantitatively that roundoff error related artificial curvature of the strange attractor follows an overall logarithmic spiral pattern with the quasiperiodic Penrose tiling pattern for the internal structure. Further, the steady state fractional roundoff error k in the computation is equal to $1/\tau^2$ where τ is the golden mean $(1 + \sqrt{5})/2$ and k being less than half accounts for the overall recognizable Euclidean geometry of the strange attractor. k is identified as the universal constant for deterministic chaos and it is shown that the Feigenbaum's universal constants are functions of k.

ii) Thermodynamical Characteristics of Atmospheric Boundary Layer : The thermodynamic structure of the Convenctive Boundary Layer (CBL) was investigated using the conservative variable analysis

technique with the aerological observations carried out at Pune during summer monsoon seasons of 1980-81. The preliminary results suggested the following :

The top of the CBL was determined from the height at which minimum values of equivalent potential temperature and saturation pressure difference were observed in their vertical distributions. The top of CBL was found to lie between 700-600 hPa levels.

The air at the CBL top was estimated to have subsided during a period of 3-4 days from level just below the freezing level with a subsidence rate of 30 hPa per day.

Aerological observations collected over Pune during the summer monsoon seasons of 1980 and 1981 were used to study the convective mixing processes during the summer monsoon season. Mixing Line (ML) model of A.K. Betts (1985) for the study of the equilibrium thermodynamic structure for the cloudy boundary layer and the Saturation Point (SP) approach were used to estimate the mixing by convection. The study suggested that the sub-cloud layers were not well-mixed and the deviations of environmental SPs from the ML in the cloud layers could attribute either to the entrainment of air from the cloud top or radiative cooling.

A case study of the convectively driven monsoon boundary layer was carried out using the aerological observations at four stations in the vicinity of the monsoon trough during MONTBLEX 1988. This study suggested that the monsoon boundary layer had double mixing line structure.

b) Studies in Upper Atmosphere

A study was undertaken to examine the mean circulation features of the troposphere over India and the structures of the temperatures and winds of the middle atmosphere over Thumba (8.5°N, 76.9°E) during two contrasting summer monsoon years, 1975 (a very active monsoon year) and 1979 (a very weak monsoon year). The monthly geopotential height and wind data for 700 and 200 hPa for India during July and August to examine tropospheric features, and the weekly M-100 Soviet rocketsonde temperature and wind data for Thumba during the last week of June and the first week of September to examine stratospheric conditions for the two contrasting summer monsoon years were used. The study suggested the following :

The axis of monsoon trough (AMT) at 700 hPa shifted southward in 1975 and northward towards the foot hills of the Himalayas in 1979, from its normal position. Superimposed on the low pressure area i.e. AMT at 700 hPa, a well-defined divergence was noticed at 200 hPa over the northern India in 1975.

The mean temperatures at 25, 50 and 60 km (middle atmosphere) over Thumba were cooler in 1975 than in 1979.

A weak easterly/westerly zonal wind (westerly phase) in 1975 and a strong easterly zonal wind (easterly phase) in 1979 were observed at 25 km with a phase reversal at 50 km.

A physical mechanism has been offered in terms of upward propagation of the two equatorially trapped planetary waves i.e., the Kelvin and the mixed Rossby gravity waves to explain the occurrence of the two spells of strong warmings in mesophere in 1975. Under westerly phase conditions at the lower stratosphere the mixed Rossby gravity waves could propagate upward during 1975 since the Kelvin waves would be mostly trapped in the lower stratosphere by the westerly phase of the QBO. It is conjectured that these mixed-Rossby gravity waves would be absorbed in the stratopause and the lower mesophere in the presence of stronger easterly flow at those levels and transfer their momentum and heat to the predominant easterlies. This process would heat up the lower mesospheric region and give rise to two strong spells of warmings there during 1975.

Another study was undertaken to examine the association between 10.7 cm solar flux of northern winter (Jan.+Feb.) and the total ozone using data for 28 years (1953-1980). Data for 10.7 cm solar flux from published literature and the mean total ozone data for January and February for Arosa (46° 47'N 9° 41'E) and New Delhi (28° 38'N, 77° 13'E) were used for the study. The preliminary results of the study suggested positive relationship at Arosa and no significant relationship at New Delhi. It is reported that interplanetary Magnetic Sector Boundary (MSB) crossing events influence the meteorological parameters. A preliminary examination of the short-term variations in the daily values of the atmospheric total ozone for Ahmedabad (23° 1'N, 73° 37'E) for one year (March 1965—February 1966) and their relationship with interplanetary MSB crossing events suggested an increase in total ozone following 1-2 days of the MSB crossing events.

An investigation on Antarctic Ozone Hole, Aerosol Hole and Condensation Nuclei (CN) suggested a mechanism related to horizontal transport to explain the Ozone Hole and Aerosol Hole. This mechanism has merit of permitting both dynamical and chemical effects to operate simultaneously in the same region. Weak subsidence in the Antarctic vortex suggested that the formation of CN inside the vortex is unrelated to the subsidence and photochemistry. Mid-latitude spring time stratospheric CN events can be explained through a sequence of evaporation of aerosols, transport of aerosol vapours to pole, recondensation and transport back to mid-latitudes after the vortex breakdown.

c) Studies in Air Pollution and Atmospheric Chemistry

i) Dry and Wet Deposition : Measurements of wet and dry deposition of the water soluble components of the atmospheric aerosols were carried out for a period of 5 years from 1984 to 1988 at Pune. The study indicated that the soil and sea salt are the main sources of dry deposition at Pune. The particles released from these natural sources serve as sink mechanisms for the gaseous pollutants (SO_2 and NO_2) through appropriate reactions. SO_4 and NO_3 present in the dry deposition is mostly in the form of salts rather than acids. This inference is also reflected in the pH of rain water which is in the alkaline range.

ii) Acid rain : In connection with the studies of acid rain in India, the rain water samples were collected in the non-urban regions in Punjab (Muktasar) and Bihar (Goraur) during the monsoon season of 1988, and analysed for major ionic components and pH values. The average pH of rain water at Muktasar was 7.34 and the individual pH value varied from 6.77 to 8.12. The average pH of rain water at Goraur was 5.12 and the individual pH varied from 4.28 to 7.59. The significant difference in the pH values in rain water collected at these two sites was attributed to the significant difference in Ca concentrations in the environments of the two regions.

iii) Biogeochemical studies in Nilgiri Biosphere Reserve : To study the interaction of atmospheric chemistry with Biosphere, a field observational programme was undertaken from 6 to 22 December 1989 in the Silent Valley, a core zone of the Nilgiri Biosphere Reserve in Kerala. Measurements of meteorological parameters, Aitken nuclei, Trace gases (SO_2, NO_2, NH_3 and O_3), total suspended particulates and their mass size distribution were carried out round the clock from 10 to 17 December 1989. The analyses of the trace gases data (SO_2, NO_x and NH_3) did not indicate any significant diurnal variation in their concentrations suggesting that the Silent Valley is free from the long range transport of gaseous pollutants. Also, the concentrations of these gases were in the range of world background values i.e., less than 2 $\mu g/m^3$. The analysis of the aerosol data suggests that the ever green forest of the Silent Valley is a major source of sub-micron particles which are released from the vegetation.

iv) Studies in Atmospheric Chemistry : The data collected during a comprehensive programme conducted at Pune during the period from December 1982 to March 1987 were analysed for studying seasonal and annual variations of total oxidant (O_3) and Nitrogen dioxide (NO_2) concentrations with various meteorological parameters. The study revealed the following :

Annual variations showed decreasing trend in NO_2 concentration in the lower atmosphere, whereas total O_3 concentration showed an increasing trend. O_3 is found to be negatively correlated with rainfall and NO_2 shows a positive correlation with rainfall. Maximum values of O_3 and NO_2 are observed under calm wind condition. Variation of these gases with prevailing winds suggest that major sources of O_3 are located to the west of the site of observation while that of NO_2 are located to its east. The concentration of NO_2 (O_3) increases (decreases) with relative humidity. Variation of O_3 with minimum temperature is found to be random while NO_2 shows a decreasing trend. Both O_3 and NO_2 show decreasing trend with increase in maximum temperature.

The concentrations of submicron aerosols in the size range 10^{-7} to 10^{-5} cm, [Aitken Nuclei, (AN)] were measured over the Indian Ocean enroute India-Antarctica-India within 10°E – 70°E longitude zone from about 10°N to 70°S latitude on board MV Thuleland by Centre of Atmospheric Sciences, Indian Institute of Technology, New Delhi during the period from 26 November 1986 to 18 March 1987 as a part of scientific activities in Sixth Indian Antarctic Expedition. Analysis of the data conducted in collaboration with Indian Institute of Technology, New Delhi showed that only in about 25 per cent of the cases; AN count fell below 1000 cm^{-3}. Throughout the tropical trade wind region, the concentrations of AN were relatively stable with an average of about 3000 cm^{-3}. Large AN concentration were found to be associated with higher sea surface temperatures and stronger surface winds in this region. In contrast, the scatter of single observation was found to be remarkable over South Indian Ocean and in Antarctic waters. The average AN concentration over the Indian Ocean to the South of 30°S was of the order of 1500 cm^{-3}. No definite correlation could be established between large AN concentration and sea surface temperature, wind speed or wave height. Period with very low concentrations were, however, associated with clear sky conditions and calm winds or light breeze. Many events of sudden short-lived but large increase in AN concentrations were observed over the South Indian Ocean and in the Antarctic waters and these were always associated with the approach of frontal systems.

d) Lidar probing of the atmosphere

Two lidar systems remained operational at the Institute for the study of aerosol. The following studies were undertaken with the data collected with this set up :

i) A study was undertaken to determine the path averaged and range-resolved atmospheric NO_2 concentration in the surface layer using the Argon ion lidar system. The Differential Absorption Lidar (DIAL) technique was followed for the measurements. The lidar observations collected in the months of April, December 1987 and February-April 1988, by following the path-averaged approach and those collected in the months of December 1988 and February, March 1989 by following the range-resolved approach were used in the study. The study showed that the mean night-time surface NO_2 (obtained from path-averaged observations) concentration varied between 0.01 ppm and 0.085 ppm. The

vertical distribution (obtained from range-resolved observations) of NO_2 concentration indicated higher values suggesting treatment of observations for the scattering effects due to aerosols and air molecules.

ii) A study was undertaken to examine the relative contribution of atmospheric aerosols and air molecules to the mixed character of the tropospheric air. In this study the aerosol mixing ratios (Na+Nm)/Nm were computed using the aerosol number density (Na) obtained from lidar data of light scattering and air molecular number density (Nm) derived from radiometersonde data ot temperature and pressure collected on the days of lidar observations. The seasonal variations of the aerosols mixing ratio profiles (upto 5 km) obtained from the above observations collected during October 1986–September 1988 showed that the ratio values are low during monsoon and high during winter and contribution of aerosols appears to be dominant in the lower levels whereas air molecules seem to be contributing more to the air mass in the upper layers of the atmosphere.

iii) The morphology of the aerosol vertical distributions in the lower atmosphere (upto 3 km AGL) in the Pune region was investigated using the lidar observations collected during October 1986–September 1989. (Fig. 10)

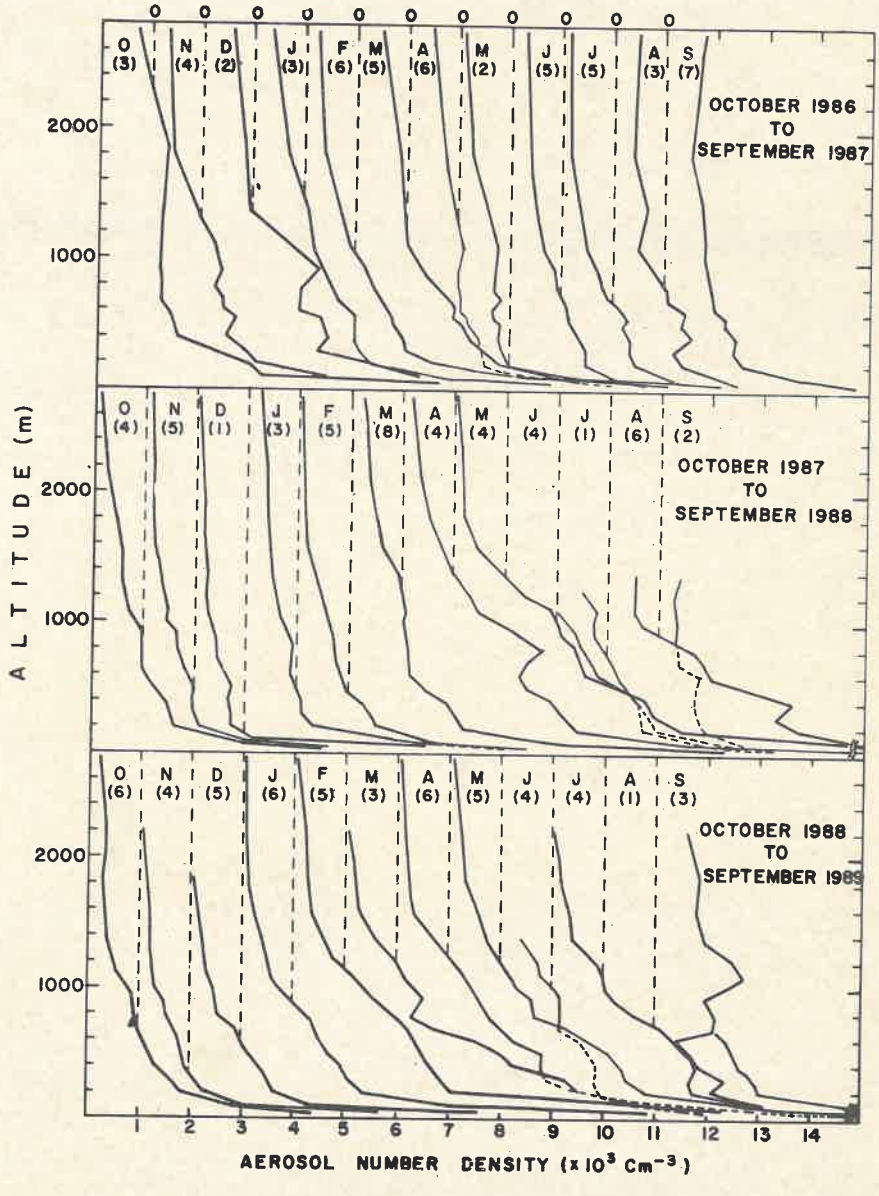


Fig. 10 First Lidar derived aerosol profiles over Pune.

The results of the study suggested the following :

the altitudinal variation and columnar content of aerosols in the 50-2760 m AGL height region show a prominent seasonal dependance;

the aerosols present in the lowest layer (200 m AGL) contribute significantly (about 40%) to the overall aerosol loading; and

the aerosol profiles exhibit thin, intermittent layer structures in the lower atmosphere during the summer monsoon season as compared to winter season.

iv) The depth of the mixing layer and height of the stable layer of the nocturnal boundary layer were studied using a total of 127 lidar-derived aerosol number density profiles obtained in the post-sunset period during October 1986 –June 1989. Normalized Concentration Gradients (NCG) were computed for each aerosol profile. The largest negative NCG nearest the surface marks the mixing depth. The study indicated that the most probable occurrence of the mixing depth varies between 450 m and 500 m AGL during sunset hours in all the seasons. Also, multiple stably stratified aerosol layers (positive NCG) were found to be present above the mixing depth, their maximum frequency of occurrence being around 750 m AGL.

v) Lidar observations have been found useful in deriving information relating to cloud-base heights in the region. The presence of clouds in the volume sampled of the lidar results in enormous increase in lidar backscattered signal strength due to multiple sattering by cloud droplets. Thus the strength of lidar backscatter can be used for remote sensing of the height of the cloud-base. The Argon ion lidar at the Institute was used for the measurement of the heights of the bases of clouds forming during night-time over Pune. Preliminary results of the observations collected during 1987-88 showed that cloud-base heights vary between 500-2200 m AGL during SW monsoon season and between 1100-3700 m AGL during other seasons. The observations also indicated the presence of multi-layer structure of the clouds forming during the SW monsoon season. The results are found to be in agreement with earlier aircraft observations of cloud-base heights over Pune.

e) Spectroscopic Measurements of Minor Atmospheric Constituents

A suitable model was developed for the retrieval of the NO_2 and O_3 data from the spectrometric observations. The physical processes relating to the theory of Rayleigh scattering and the absorption due to NO_2 and O_3 were accounted in the theoretical computations. The amount of scattered intensity reaching the surface of the earth was computed using the Lambert-Beer's law. The ratios of the theoretically calculated evening time and noon time zenith sky spectra were computed at 18 wavelengths in 4368°A to 4485°A spectral region using standard matrix inversion technique. Vertical columnar densities of NO_2 and O_3 were computed using the above technique. The derived total columnar density of O_3 is 0 to 10% which was found to be less than that derived by the Dobson spectrometer. It is proposed that after correction for Fraunhofer Filling and aerosol scattering are incorporated in the model, there may be better agreement between the two methods. The annual variation of the total columnar NO_2 variation measured with spectrometer at the Institute is given in Fig. 11.

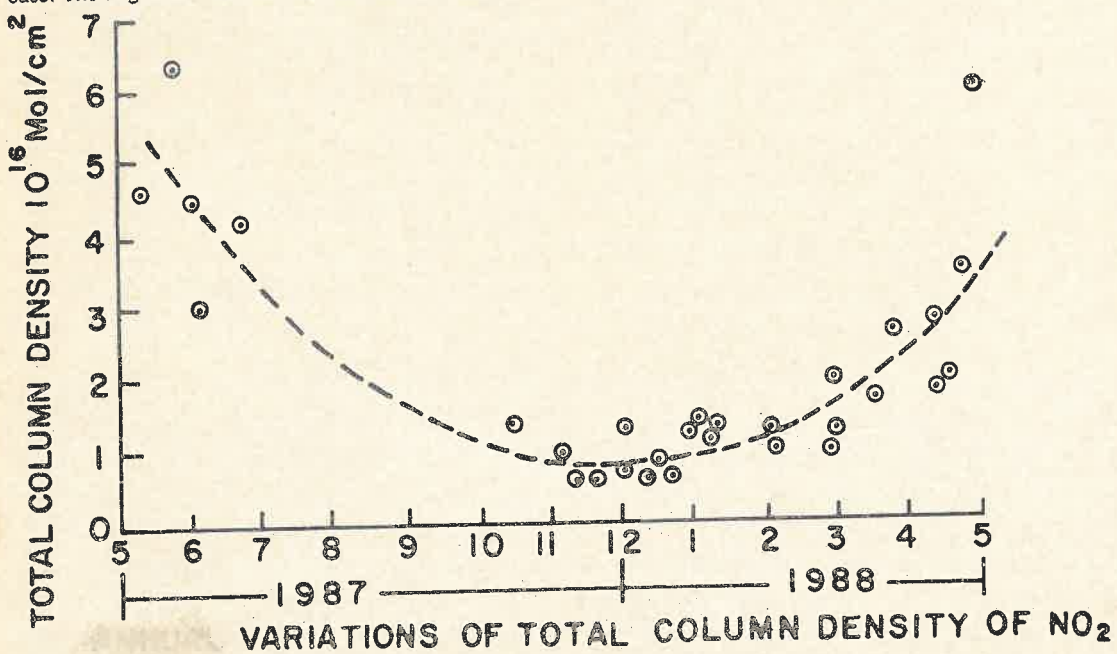


Fig. 11 : Monthly variations of spectrometer derived atmospheric total NO_2 columnar density over Pune for the period May 1987 to May 1988.

The high resolution visible spectrometer developed at the Institute was modified for better resolution and accuracy by adding the fast scanning system. The spectrometer is being deployed for observations.

A crossed Czerny-Turner portable spectrometer was developed for detection of different minor constituents of the atmosphere. The fabrication work of the system was performed by a local firm. The alignment of the system was done by using mercury source. After the alignment, the final positions of all the components were fixed. The wavelength calibration of the system was performed by using mercury vapour lamp and sky spectra. The system is being tested for the observations of atmospheric NO_2 and O_3 to begin with.

2.4 Instrumental and Observational Techniques Division

The broad scope of this division is to :

* Design and develop instruments and techniques of observation for use in cloud physics, atmospheric electricity and atmospheric boundary layer studies.

* Carry out field and laboratory experimental work to understand the structure and dynamics of the troposphere and the stratosphere.

Areas identified for research are :

i) the development of instruments/techniques to study the structure of the atmospheric boundary layers;

ii) the development of instruments/techniques to study the cloud electrification process;

iii) simulation techniques to study cloud physics under a controlled environment.

2.4.1 *Development of Instruments for Boundary Layer Studies*

Study of the Atmospheric Boundary Layer is essential to understand the structure and dynamics of the boundary layer and to parameterise the fluxes of heat, momentum and moisture that serve as an input to the development of large scale weather prediction models. In India, the boundary layer evolving over the monsoon trough region is of particular interest to the meteorologists in view of the convective activity being fully moist towards the eastern end of the trough axis, dry in the western end and alterations between moist and dry processes in the middle part of the trough. A multi-institutional national project titled, 'The Monsoon Trough Boundary Layer Experiment' ('MONTBLEX'), has been formulated and this Institute is playing a principal role in the implementation of the project. The Institute participated in the following activities in respect of MONTBLEX :

i) In April 1989, a training-cum-orientation workshop was organized at IIT, Kharagpur and several Institute scientists participated in the workshop.

ii) MONTBLEX-Pilot experiment was conducted in July 1989, for a period of about nine days during the monsoon, at IIT, Kharagpur site (a gently rolling terrain) where a 30 m tower was installed (in June-July 1988) and fitted with instruments at 1, 2, 4, 8, 15 and 30 m height to measure wind, temperature and humidity using cup and propeller type anemometers, a sonic anemometer (8 m), a hotwire sensor, wind vanes, thermistor and thermocouple wire sensors, humicaps and Lyman α hygrometer. Ten minisondes were released using a 150 gm balloon at an ascent rate of 6 km/hr and the temperature profile measured upto a height of 2 km in the boundary layer. The data obtained from the experiment were processed to compute the fluxes of heat and momentum and the spectral densities. Figure 12 shows a sample power of spectral density of vertical wind component and temperature computed from the sonic anemometer data. It is seen that the spectra depict the $-5/3$ power law of Kolmogoroff in the inertial sub range.

A Mono-static Doppler Sodar was acquired by the Institute, installed at Pashan site (complex) and put into operation. The sodar was calibrated using a kytoon system procured at the Institute for probing the ABL upto a height of 1 km. The horizontal winds as evaluated by sodar agree within 10% with that of kytoon measurements. Routine observations were taken using Sodar at the Institute site which is complex (surrounded by hills along three sides). Observations showed features like the nocturnal boundary layer, the drainage effect, the breaking up of inversion during the early morning and the convective boundary layer (0345-1645 hrs) (Figure 13).

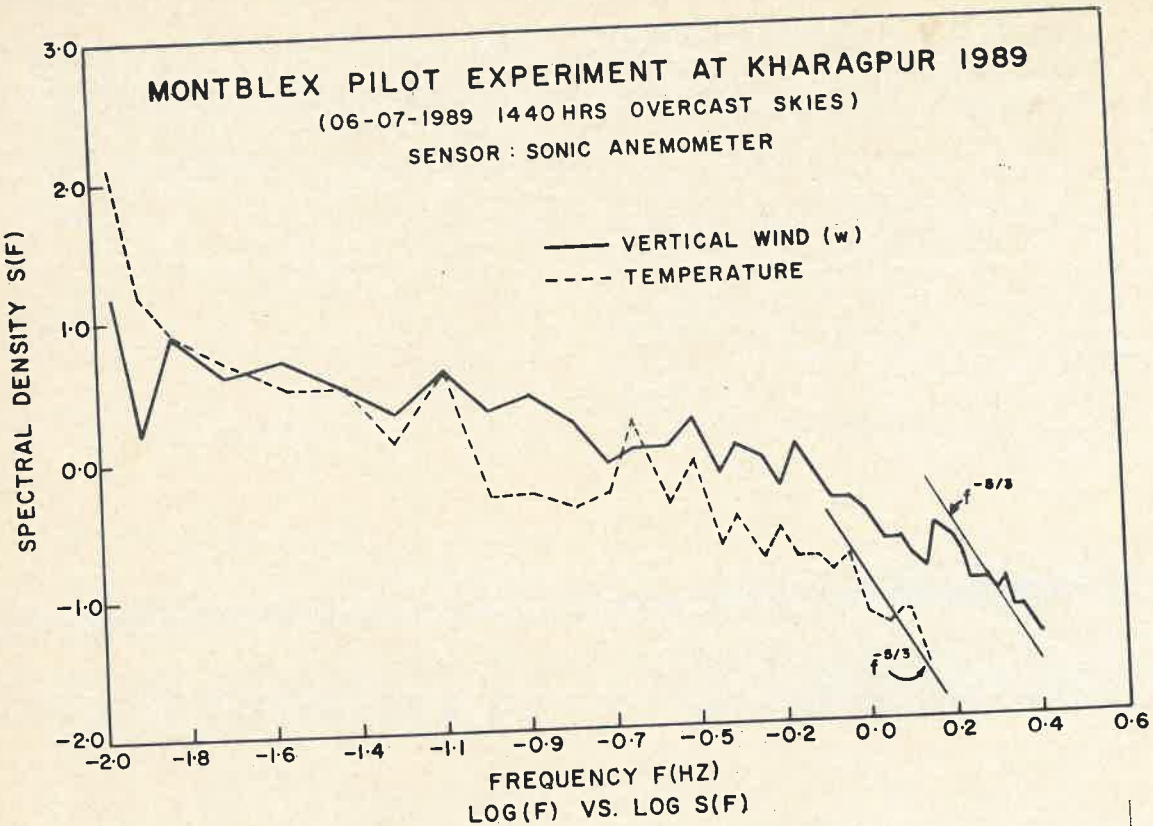


Fig. 12 : Spectra of vertical wind (w) and temperature at 8 mt. agl.

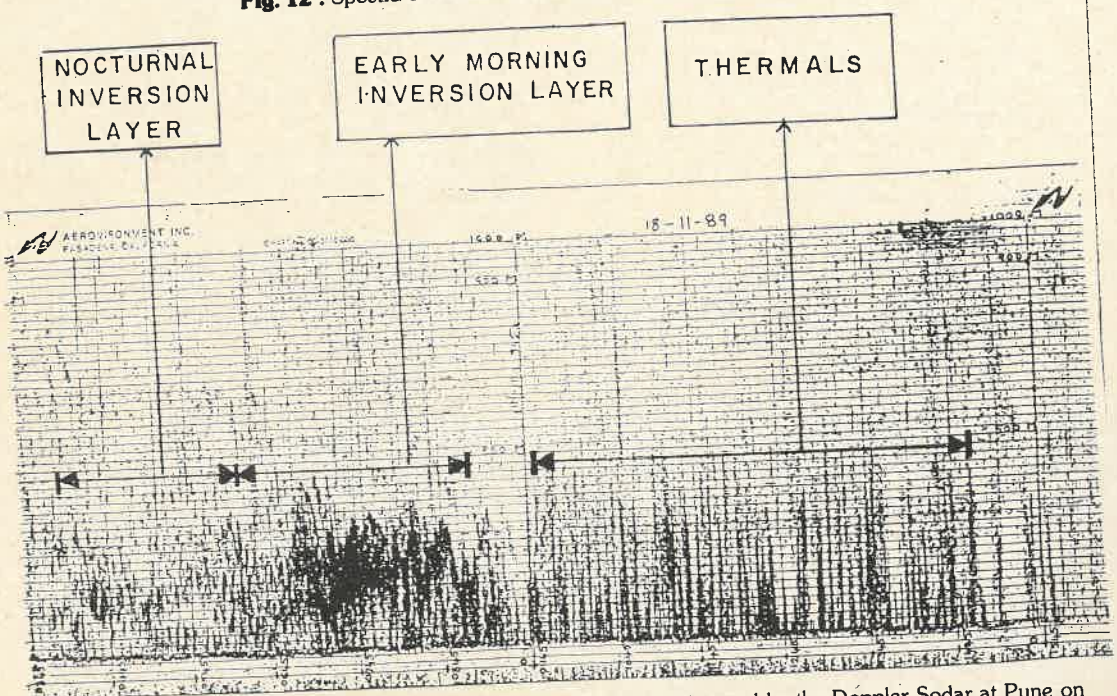


Fig. 13 : Thermal stratification of the atmospheric boundary layer as observed by the Doppler Sodar at Pune on 18 November 1989 during 0345–1645 hrs.

2.4.2 Instrumentation for Cloud Physics and Weather Modification studies

a) Cloud Electrification Studies :

Regular measurements of atmospheric electric and meteorological parameters were made at atmospheric electricity observatory at this Institute. A data logger system to print instantaneous and average values of different atmospheric electrical parameters and a weather monitor were installed and commissioned at this observatory.

An atmospheric ion counter to measure concentrations of ions having more than three different values of critical mobility was fabricated and installed in the observatory. A small a.c. field mill for measurement of space charge density inside the Faraday cage was fabricated.

Laboratory tests on particle charge measuring apparatus were conducted by generating small particles with a monodisperse aerosol generator. The apparatus was recalibrated to measure charge residing on three different categories of particles under rainshowers. The spherical field meter to measure vector electric field in atmosphere was also recalibrated in linear and radial electric fields after modifying it to improve the stability of its different outputs.

Laboratory experiments were conducted in a small vertical wind tunnel to investigate the breakup of electrically charged and uncharged water drops. The experiment revealed that half-life of suspended water drop decreases with the increase in size and charge on the drop. Moreover, the number of smaller droplets produced after the breakup of drop is less when the drop is electrically charged. These experimental results are important in understanding the chain process for formation of rain in clouds.

A theoretical study on the effect of electrical force acting on charged drops in a thundercloud revealed that drag force imparted by raindrops to the surrounding air is significantly affected by the electrical forces acting on these raindrops. These changes in drag force can influence the initiation and development of the downdraft in a thunderstorm.

2.5 Theoretical Studies Division

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 southwest monsoon.

* Develop global spectral models for simulation of monsoon circulation and systems and for investigating the error characteristics in order to improve the model simulations.

* Division also conducts periodic training courses at different levels.

2.5.1 Studies on dynamic instability

Barotropic and Baroclinic Instability of the Atmospheric Flow

The uninitialized ECMWF data of 10-19 June 1979 for the area 15°S–30°N and 30°E–120°E were analysed for all levels to see horizontal continuity of the fields. The energetics, momentum and sensible heat transports in a meridional plane were computed from the above data in order to identify the physical mechanism responsible for the growth and maintenance of monsoon onset vortex during MONEX-79 It was found that in the lower troposphere both barotropic and baroclinic conversions contribute to the growth of monsoon vortex. The available potential energy conversion from zonal to eddy, associated with eddy transport of sensible heat in the vertical dominates over that due to the sensible heat transport in meridional direction. This is in contrast with the mid-latitude systems, where the latter process dominates over the former.

The results of numerical study on nonlinear evolution of an initially unstable barotropic wave superposed on the mean tropical easterly jet over the sphere revealed that during the wave growth (decay) the convergence (divergence) of the wave potential vorticity occurs in the negative region of the meridional gradient of zonal mean potential vorticity so that the negative region is filled up (generated). It was also noticed that wave continues to grow slowly, not exponentially even though the necessary condition of barotropic instability is not satisfied.

A simple mathematical expression was devised to represent the potential vorticity profile of the observed zonal easterly jet over the tropics. This expression was used to estimate the maximum enstrophy which perturbation can attain due to wave zonal flow interaction.

A detailed write up of the initial value and eigen value methods of solving linear dynamic instability problems was prepared as a part of a report on the dynamic instability of tropical zonal flow.

Influence of lower and upper tropspheric jet streams over the Indian monsoon region on the Ekman CISK modes was studied by using the 3-layer equatorial linear balance model. It was found that the westerly jet destabilises the modes, whereas the easterly jet stabilises the modes around wavelength 8000 km. Further, it was noted that the unstable modes associated with the westerly jet are not affected by presence of the easterly jet.

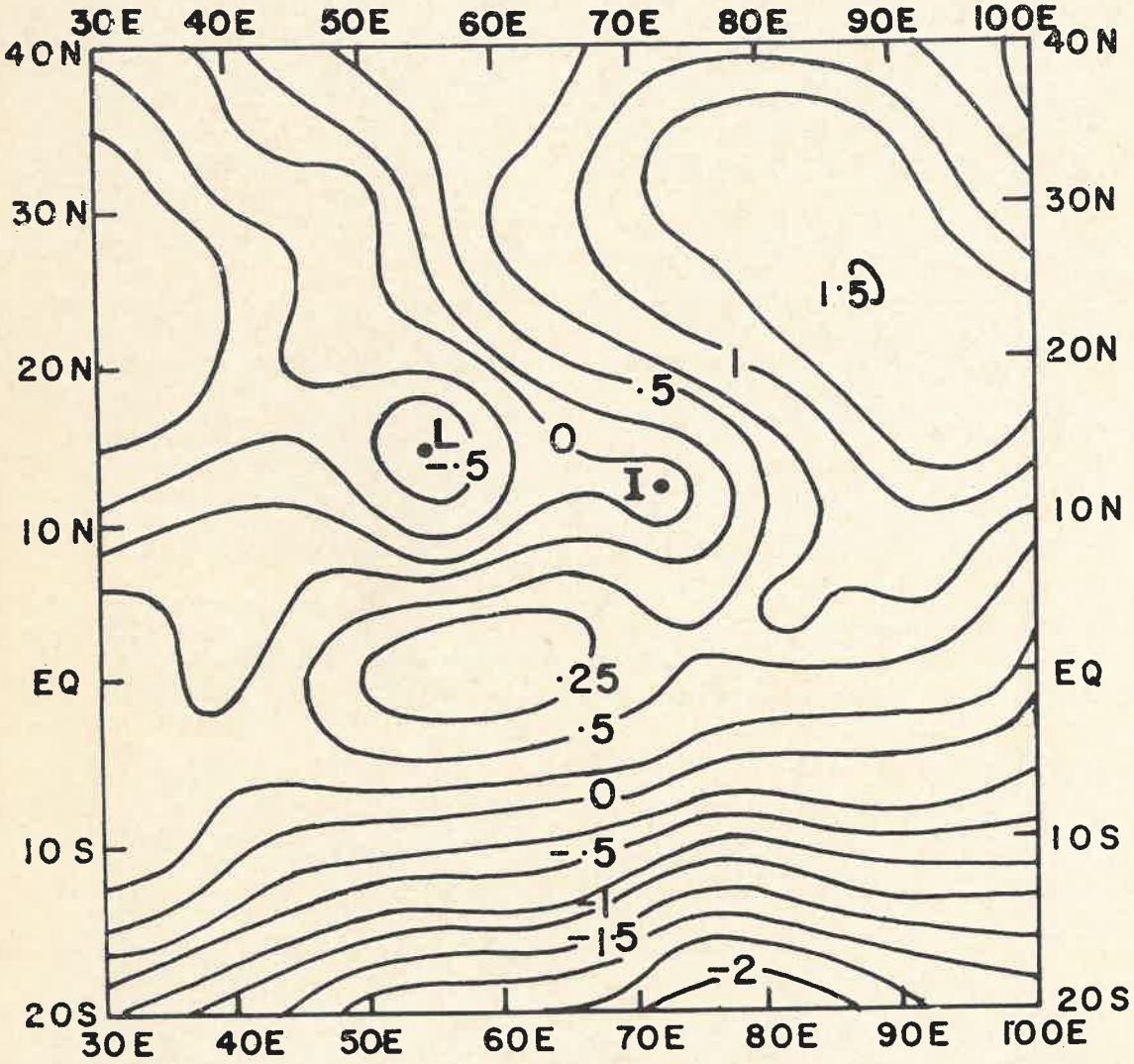
2.5.2 Simulation of Monsoon and Tropical Circulation Systems

Simulation of mean monsoon circulation and predictability of monsoon systems

A write up on theoretical and computational procedure of the parameterisation of long wave (LWR)

and short wave (SWR) radiations, in an NWP model was prepared. CO_2 and H_2O are considered as the sole absorbing/emitting constituents for LWR and Rayleigh scattering is included in SWR calculations.

The input data (expansion coefficients of stream function and velocity potential) for the primitive equation barotropic global spectral model was prepared using initialized FGGE IIB wind data at 850 hPa on 15 June for 00 GMT. A 5-day forecast of the monsoon onset vortex, using the above input data, in the model for T 42 truncation was performed (Fig. 14). The initial geopotential field in the model was computed, using non-linear balance equation. It was seen that the model retained the onset vortex and the flow pattern over the Arabian sea quite well during the period. However, the movement of onset vortex was found correct only during the initial two days of integration.



FORECAST: 48 Hrs. FIELD: STREAMFUNCTION

LEVEL: 850mb. INITIAL TIME: 15-6-79 (1200 GMT)

Fig. 14 : 48 hrs forecast of the monsoon onset vortex 1979 obtained from primitive equation barotropic global spectral model (T 42) 'I' indicates the initial position of the onset vortex streamfunction units : $10^6 m^2 s^{-1}$

Using FGGE IIIb level wind data for the period 22-28 June 1979 (depression in Bay of Bengal) at 700 hPa over latitudinal belt (2°N-32°N) temporal variation of K.E. for various wavenumbers (1-20) were studied. Occurrence of relatively higher variation in the wavenumber 1 to 4 was found. Root-mean-square K.E. for differences between observed wind fields at two consecutive hours (multiple of 12 hrs) were obtained.

In order to study the variability of monsoon in terms of its energy and enstrophy and to determine its characteristic scale, the computer routines were developed to compute the zonal meridional and two dimensional spectra of 1) rotational K.E., 2) divergent K.E., 3) zonal K.E., 4) meridional K.E., 5) total K.E. and 6) enstrophy. Computer routines were also tested using the spherical harmonic coefficients of u and v for 11 June 1979 at 700 hPa level. To establish the power law of K.E. and enstrophy spectra a computer routine is also prepared, using regression method.

The linear normal modes of the atmosphere at rest were determined. The computed vertical and horizontal structure of the normal modes were found to be in agreement with those reported in literature. The accuracy of the computed modes was verified independently by using orthogonality conditions.

2.5.3 Work done under Indo-Soviet Long-term integrated programme :

Problem of Monthly averaged temperature anomalies" was formulated as an application of adjoint method for the soil atmosphere-ocean domain. Unconditionally stable Crank Nicholson finite difference scheme will be used for the temperature integration of the set of governing adjoint prognostic equations of the model. Boundary conditions were defined for the problem and the continuity of certain variables at the interface of different media were tested.

Two numerical models of Dr. Yu.N. Skiba are installed on Institute's ND-560 computer system. These models are (i) 3 dimensional atmosphere-ocean-soil thermal interaction model for Indian region and (ii) model for calculating normal modes on a sphere. These models will be applied for studying the role of energetically active zones of Indian ocean for forming the mean temperature anomalies over India and instability study of non-zonal barotropic flows on a rotating sphere.

A non-linear numerical baroclinic model for the northern part of Indian ocean including Arabian sea and Bay of Bengal is installed on Institute's computer. This model can be used for monitoring the Indian ocean and as an ocean block of a coupled atmosphere-ocean model.

3. ACTIVITIES

3.1 Consultancy Services

Hydrological advice and assistance was provided to the Civil Engineers of Irrigation Department, Govt. of Tamil Nadu for carrying out PMP studies for the catchment of Sathanur dam.

At the request of Executive Engineer, Koyna Dam Project authority, Govt. of Maharashtra, a report giving estimates of 1 to 3 days maximum rainfall for different return periods likely to be experienced during September and October months in the Koyna catchment was prepared and sent to them.

At the request of the Kerala State Electricity Board (KSEB), Trivandrum, a project proposal for undertaking warm cloud seeding operations using aircraft in the catchment area of Idukki reservoir during the summer monsoon of 1990 was prepared.

The Institute's ND-560/CX Computer facility was made available to :

i) India Meteorological Department, Pune
ii) Physical Research Laboratory, Ahmedabad
iii) Soviet Scientists working on projects at the Institute
iv) M.Tech. Students of University of Poona, Pune
v) Ph.D. Students of Cochin University, Cochin and
vi) M.Tech. Students of Andhra University, Waltair.

Assistance was given to execute the Long Range Forecast Model of IMD, Pune on the ND-560/CX System for issuing the seasonal rainfall forecast.

3.2 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 and providing documentation and current awareness service matching with the users' profile.

iii) Rendering Selective Dissemination of Information (SDI) Service on demand through preparation of bibliographies on different research areas in Meteorology and Atmospheric Sciences and Monitoring Institute's exchange programme of publications

iv) Preparation, publication and presentation of various scientific/research reports and allied material on the activities of the Institute and keeping liaison with other scientific institutes—organisations and universities in India and abroad.

v) Rendering necessary facilities for charts, photoprints, slides, microfilms, ammonia prints etc.

3.2.1 Library and Documentation :

During the year, 385 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.

During the year, over 4300 publications including books, journals, data, reports etc., were issued. 345 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 278 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.

Bibliography of papers published on 'Numerical Weather Prediction' during 1980-88 was prepared.

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

3.3 Computer

The Institute's in-house ND-560/CX 32-bit Computer System provides computational support to the scientists. The Computer System works at present from 9 AM to 9 PM. Institute scientists are also provided access to the (i) S-1000 computer system at National Informatics Centre, Pune and (ii) the Cray XMP-14 Super Computer System at the NCMRWF, New Delhi.

The Comprehensive Ocean Atmoshpere Data Set (COADS) comprising of ships surface data from 1854 to 1979 was installed on the System in November 1989 by Mr. Scott Woodruff of Environmental Research Laboratory of NOAA, Boulder, Colorado, USA. A computer program for retrieving the packed binary COADS data was developed. The data are being made available to user-scientists on request. Creation of meteorological data bank for the use of Institute

Dr. Vasant Gowariker, Secretary, DST inaugurating the First National Seminar on Thrust Areas in Atmospheric Sciences held at the IITM during 16-18 August 1989.

Meeting of the Indo-US Collaborative Programme in Climatic Research, 06-09 November 1989.

scientists continues. Scientists are also provided support for accessing the massive data resource at the National Data Centre of the IMD, Pune.

The Fortran Mathematical and Statistical Library of the Numerical Algorithms Group (NAG), UK, was added to the System in November 1989. This has enabled scientists to use efficient statistical and mathematical routines directly.

Collection and validation of Monthly Climatic data (Surface) for 125 stations for 1987 was completed. Monthly Climatic data (upper air) for 10 standard levels in respect of the selected 80 tropical stations for the year 1986, were transferred to a magnetic tape for use of scientists of the Institute.

3.4 Symposia/Conferences supported

The first National Seminar on 'Thrust areas in Atmospheric Sciences' organised by the Department of Science and Technology was held at the Institute during 16-18 August 1989. The seminar was inaugurated by Dr. Vasant Gowarikar, Secretary, DST.

The Institute also co-sponsored the following seminars :

i) Symposium on 'Global Change', Indian Geophysical Union, Hyderabad, during 15-17 March 1990,

ii) Seminar on 'Pollution due to Automobiles', Viswakarma Instutite of Technology, Pune on 14 March 1990 and

iii) Fifth Int. Symposium on 'Acoustic Remote Sensing of Atmosphere and Oceans' National Physical Laboratory, New Delhi, during 06-09 February 1990.

A meeting on Indo-US Collaborative Climatic Research Programme under Indo-US Sub-Commission of the Atmospheric Sciences was held from 06-09 November 1989 at the Institute.

The meeting reviewed the proposals for collaborative Climatic Research Programmes and discussed funding, visits and implementation strategy and laid down some guidelines for principal investigators.

The Institute provided all support to the Pune Chapter of the Indian Meteorological Society to organise a mini-workshop on 'Monsoon-89' on 24 January 1990.

3.5 Man power development

Man power development has received considerable attention during the year.

General purpose training programme for the development of scientific manpower was conducted from 12 June–16 October 1989. 21 officers and research scholars of the Institute attended the training programme.

Fourteen staff members have been sponsored for various training courses in meteorology, advanced computing, mathematical methods, radar meteorology etc.

3.6 Collaboration with Universities

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

Dr. P.C.S. Devara, AD, Dr. D. Subramanyam, SSO I, Dr. L.T. Khemani, SSO I, Dr. S.N. Bavadekar, SSO I and Dr. D.B. Jadhav, SSO I have been recognised by the University of Poona as Post Graduate Teachers in Physics.

The following scientists worked as Examiners/Paper Setters for M.Sc. and Ph.D. degree of different universities :

Name	*Degree*
Shri D.R. Sikka, Director	Ph.D.
Dr. A.S.R. Murty, DD	M.Sc.
Dr. S.K. Mishra, DD	M.Tech.
Dr. H.N. Bhalme, AD	M.Tech.
Dr. P.C.S. Devara, AD	M.Sc.
Dr. D. Subrahmanyam, SSO I	M.Sc.
Dr. L.T. Khemani, SSO I	Ph.D.
Shri R. Vijayakumar, SSO I	M.Tech.
Shri P. Seetaramayya, SSO II	M.Phil.

A number of scientists guided several students from different universities for completing their B.Sc., M.Sc. and M.Tech. project work/dissertations.

3.6.1 Award of Ph.D. Degree :

University of Poona awarded Ph.D. Degrees in Physics to two scientists of the Institute, Shri S.S. Parasnis, SSO II and Miss K. Indira, JSO, for their theses entitled, 'Some Studies on Atmospheric Boundary Layer' and 'Some Aspects of Dynamics of Middle Atmosphere and Monsoon Variability' respectively.

4. ADMINISTRATION

4.1 Capital Works Programme

The construction work of the second phase office building and residential quarters was in progress. An amount of Rs. 23.52 lakhs was deposited with C.P.W.D. for construction of a shed for storing cloud seeding material, a garage and a Community Hall.

4.2 Staff Changes

Three persons joined the staff of the Institute under different categories and 2 left the Institute during the year.

Shri J.T. Titkare, Laboratory Assistant expired on 24 September 1989.

4.3 Staff Matters

4.3.1 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 and for increasing efficiency. The Staff Council met once every month during the year.

4.3.2 Benevolent Fund :

The Institute has introduced the staff Benevolent Fund Scheme for its employees with effect from 01 February 1990. The scheme provides for immediate financial assistance of Rs. 5000/- to the nominee of an employee in the event of his/her death or a suitable amount by way of relief to an employee who is in real distress or has sustained permanent disability.

4.3.3 Pension Scheme :

Approval of the DST was received for the introduction of the Indian Institute of Tropical Meteorology Employees' Pension Scheme for its post-autonomy employees with effect from 01 April 1990. Steps are being taken to implement the scheme from this date.

4.4 Official Language Implementation

During the year, the Institute was notified in the Gazette of India as per Rule 10(4) of Official Language Rules 1976, as more than 80% of the staff have acquired working knowledge of Hindi.

The memorandum of Association, Rules, Regulations and Bye-laws, Institute's Annual Report and Audit Reports were translated into Hindi. Office circulars, orders, minutes of Staff Council meetings and Official Language Implementation Committee meetings were routinely issued bilingually.

Hindi week was celebrated with competitions in essay writing, poetry recitation, noting and drafting. An inhouse workshop was conducted for 26 members of the staff for training in the usage of Hindi in official correspondence

Smt. K.A. Ursekar, and Smt. S.S. Devale, LDCs underwent training in Hindi typing. Shri K.D. Barne and Miss S.R. Kamble, stenographers were sponsored for the Hindi Typing and Shorthand training conducted by Ministry of Home Affairs. A no. of scientists delivered scientific lectures in Hindi on different subjects on various occasions.

Hindi correspondence was increased by 100% over that of the previous year. Assistant Director (Rajbhasha) from the Department of Science and Technology reviewed the implementation of Official Language Rules in the Institute and expressed satisfaction on the progress made.

4.5 Research Fellowships

Shri Hemant Sawant has been awarded I.I.T.M. Research Fellowship with effect from 03 January 1990. Shri Satyendra Sharma has been awarded Air India Research Fellowship with effect from 28 February 1990. The fellowship of Shri E.N. Rajagopal, I.I.T.M. has been extended upto 10 August 1990. Fellowship amount of four IITM Research Fellows has been enhanced from Rs. 1800.00 to Rs. 2100.00 per month after assessing their work.

4.6 Employment of Ex-servicemen

The percentages of ex-servicemen at the Institute vis-a-vis total no. of employees in Groups 'B', 'C' and 'D' are 1.6, 1.0 and 12.9 respectively.

4.7 Special Recruitment Drive for Scheduled Caste/Scheduled Tribe

Action was taken to fill up vacant posts at the Institute reserved for scheduled caste/scheduled tribe candidates for various posts.

4.8 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. During the year the Academic Council met once in a month to review the scientific activities of the Institute.

Hindi Week Celebration. Dr. V.N. Mishra, Deputy Director, Deccan College, Pune, Chief Guest, addressing the participants.

Visit of Dr. Gorakhnath, Director (Rajbhasha), DST, to the Institute on 4-5 December 1989, regarding implementation of official language rules.

5. PARTICIPATION IN SYMPOSIA/CONFERENCES ETC. AND PAPERS PRESENTED

Forecasting Research Division

Symp./Conf. etc. a) Workshop on 'MONTBLEX', I.I.T., Kharagpur, 3-7 April 1989.

Participant(s) —S. Sinha

b) VI Interagency Workshop for Finalising the Cruise Plans of ORV Sagar Kanya and Gaveshani, NIO, Goa, 21-22 April 1989.
—P. Seetaramayya.

c) First Nat. Sem. on 'Thrust Areas in Atmospheric Sciences', Pune, 16-18 August 1989
—S. S. Singh (as rapporteur)

d) Int. Conf. on 'Modelling of Global Climatic Change and Variability', Meteorological Institute, University of Hamburg, FRG, 11-15 September 1989.
—R. K. Verma.

Paper(s) presented i) Interannual variability of Indian summer monsoon response to equatorial Pacific sea surface temperatures as simulated with GFDL-GCM.

Author(s) : R. K. Verma.

e) Workshop on 'Remote Sensing Information Inputs for Ocean Development', NRSA, Hyderabad, 4-10 October 1989.
—S. N. Bavadekar.

f) Mini Workshop on 'Monsoon-89', India Meteorological Society, Pune Chapter, Pune, 24 January 1990.
—S. V. Singh, R. K. Verma and D. K. Paul.

i) Forecasting monsoon rainfall by multiple regression equations.
: S.V. Singh.

ii) Some regional and global climatic anomalies associated with monsoon 89.
: R.K. Verma.

iii) Unusual monsoon depression of 1989.
: D.K. Paul.

g) Nat. Space Science Symp., Nagpur University, Nagpur, 5-9 March 1990.

—P.N. Mahajan, A. Bandyopadhyay and S.G. Narkhedkar.

i) Application of split-explicit scheme of time integration in regional model.
: A. Bandyopadhyay and S.S. Singh.

ii) Objective analysis of relative humidity over Indian region by Optimum Interpolation Method.
: S.K. Sinha, S.G. Narkhedkar, D.R. Talwalkar and S. Rajamani.

h) XXVI Annual Convention of Indian Geophysical Union and Sem. on 'Global Change', NGRI, Hyderabad, 15-17 March 1990.
—V.R. Deshpande and S.B. Kakade.

Participant(s) presented Author(s)

i) Global temperature changes and Indian monsoon.
: S.S. Dugam. S.B. Kakade and R.K. Verma.

ii) On the variability of monsoon onset dates and withdrawal dates over Indian region during 1970-89.
: V.R. Deshpande, V.R. Mujumdar, P.V. Puranik and D.K. Paul.

Climatology and Hydrometeorology Division

Symp./Conf. etc. a) First Regional Workshop on 'Unusual Storm Events and Their Relevance to Dam Safety', Bhubaneshwar, 11-12 May 1989.
—B.N Mandal.

i) Analysis of severe rainstorms of contiguous Indian states.
: O.N. Dhar, A.K. Kulkarni, B.N. Mandal and S.S. Nandargi.

b) Second Regional Workshop on 'Unusual Storm Events and Their Relevance to Dam Safety', Srinagar, 25-28 July 1989.
—P.R. Rakhecha.

i) Probable maximum precipitation in north-west India—a generalised approach.
: P.R. Rakhecha and B.N. Mandal.

c) Nat. Sem. On 'Thrust Areas in Atmospheric Sciences, DST, Pune, 16-18 August 1989.
—G.B. Pant and B. Parthasarathy.

d) Third Regional Workshop on 'Unusual Storm Events and Their Relevance to Dam Safety', Narmadasagar Dam Site, M.P., 27-28 September 1989.
—B.N. Mandal.

i) Case studies of severemost rainstorms over the western region of India.

—O.N. Dhar, B.N. Mandal and S.S. Nandargi.

ii) Outstanding rainstorms of the western region of India—a brief appraisal.
—O.N. Dhar, B.N. Mandal, A.K. Kulkarni and S.S. Nandargi.

e) Nat. Workshop on 'Agrometeorology' Gujarat Agricultural University, Anand, 16-18 January 1990.
—K. Rupakumar

f) Nat. Sem. on 'Radiation and Photochemical Processes', Calcutta, 17-19 January 1990
—L.S. Hingane.

i) A Review Talk on 'Tropical Ozone'
: L.S. Hingane

g) Mini Workshop on 'Monsoon-89', Indian Meteorological Society, Pune Chapter, Pune, 24 January 1990.
—H.N. Bhalme.

i) Evaluation of rainfall forecasts of Monsoon 89 and associated regional global circulations.
: H.N. Bhalme.

Symp./Conf. etc. h) Fourth Regional Workshop on 'Unusual Storm Events and Their Relevance to Dam Safety', Nagarjunesagar Dam Site, A.P., 19-20 February 1990.

Participant(s) —A.K. Kulkarni and B.N. Mandal.

Paper(s) presented Author(s)

i) Analysis of severe rainstorms of the peninsular states for design storm estimation.
: O.N. Dhar, B.N. Mandal, S.S. Nandargi and B.D. Kulkarni.

ii) Brief appraisal of rainstorm studies on coastal areas of India.
: O.N. Dhar, S.S. Nandargi and A.K. Kulkarni.

iii) Initiation of storms studies in India and proposal for countrywide analysis of major rainstorms.
: O.N. Dhar.

iv) Sequential maximisation of rainstorms for PMP estimation of design storm.
: O.N. Dhar and S.S. Nandargi.

v) Unusual rainstorms and their use in the safety of dams.
: P.R. Rakhecha, B.N. Mandal and N.R. Deshpande.

i) Int. Conf. on 'Tropical Ozone and Atmospheric Change', Penang, Malaysia, 20-23 February 1990.
—L.S. Hingane.

j) Nat. Space Science Symp., Nagpur University, Nagpur, 5-9 March 1990
—A.B. Sikder.

i) Interaction between El-Nino and the Indian monsoon rainfall.
: H.N. Bhalme and A.B. Sikder.

k) XXVI Annual Convention of Indian Geophysical Union and Sem. on 'Global Change', NGRI, Hyderabad, 15-17 March 1990.
—N. Singh and N.A. Sontakke.

i) Climatic variations over India as revealed by a century long Instrumental record.
: N.A. Sontakke, D.R. Kothawale and B. Parthasarathy.

ii) Fluctuations of area under arid environment over India.
: N. Singh and S.S. Mulye.

iii) Fluctuations in the rainfall/temperature series during past one century at Hyderabad.
: N.A. Sontakke, A.A. Munot and B. Parthasarathy.

l) Nat. Sem. on 'Hydrology', Telugu Ganga Project Colony, Cuddapah, 24-26 March 1990.
—R.B. Sangam.

i) Case study of 23-25 July 1989 heavy rainspell over Maharashtra.
: A.K. Kulkarni, B.N. Mandal and R.B. Sangam.

Physical Meteorology and Aerology Division

a) Workshop on 'Monsoon-89', IIT, Kharagpur, 3 April 1989.
—S.S. Parasnis.

Symp./Conf. etc. b) 5th WMO Scientific Conf. on Weather Modification and Applied Cloud Physics', Beijing, China, 8-12 May 1989.

Participant(s) —A.S.R. Murty.

Paper(s) presented Author(s)

i) Overview of warm cloud modification research in India.
: A.S.R. Murty.

c) Sem. on 'Global Effects of Air Pollution—an Update and Strategies', Indian Merchants' Chambers, Bombay, 3 June 1989.
—L.T. Khemani.

d) 5th Scientific Assembly of IAMAP, University of Reading, Reading, U.K., 31 July-12 August 1989.
—P.C.S. Devara and V.N.R. Mukku.

i) DIAL measurements of atmospheric NO_2 concentration.
: P.C.S. Devara and P.E. Raj.

ii) Pre-conditioning in the ozone hole region.
: V.N.R. Mukku.

e) First Nat. Sem. on 'Thrust Areas in Atmospheric Sciences', Pune, 16-18 August 1989.
—A.S.R. Murty.

f) Symp. on 'Current Status and Future Perspectives in Solar Terrestrial Physics Research', PRL, Ahmedabad, 28-29 August 1989.
—B.K. Mukherjee.

g) Hindi Sem. on 'Environmental Pollution and Industry', BARC, Bombay, 18-19 September 1989.
—L.T. Khemani.

i) Aamla Varshake Rasyan Aur Antaran (Hindi)
: L.T. Khemani.

h) Nat. Symp. on 'Instrumentation (NSI-14) I.I.Sc., Bangalore, 3-6 October 1989
—A.L. Londhe.

i) Lidar sensing of aerosol layer variations for environmental studies.
: P.E. Raj and P.C.S. Devara.

ii) Portable spectrometer for atmospheric studies in visible region.
: A.L. Londhe, D.B. Jadhav and H.K. Trimbake.

i) Nat. Sem. on 'Radiation and Photochemical Processes of the Environment', Calcutta, 17-19 January 1990.
—L.T. Khemani.

j) Joint Workshop of 'All India Co-ordinate Programme on Ionosphere Thermosphere Study (AICPITS) and Solar Terrestrial Energy Programme (STEP)', Waltair, 27-29 January 1990.
—B.K. Mukherjee.

i) Stratospheric tropospheric coupling.
: B.K. Mukherjee and D.R. Sikka.

k) Workshop on 'Science Communication', AIR, Nagpur, 12-17 February 1990.
—S.S. Parasnis.

Symp./Conf. etc. l) Second Annual Conf. of Indian Aerosol Science and Technology Association on 'Aerosols in Medicine and Industry', BARC, Bombay, 19-20 February 1990.

Participant(s) —L.T. Khemani and G.A. Momin.

Paper(s) presented i) Diurnal variation of Aitken nuclei in the core zone of the Nilgiri-Biosphere Reserve.

Author(s) : G.A. Momin, L.T. Khemani, P.S.P. Rao, P.D. Safai, A.G. Pillai and M.S. Naik.

ii) Mass size distribution of aerosols and their chemical composition over the Bay of Bengal.
: P.D. Safai, L.T. Khemani, G.A. Momin, P.S.P. Rao and M.S. Naik.

m) Nat. Sem. on 'Monitoring Strategies of Environmental Pollution', Waltair, 22-24 February 1990.
—P.C.S. Devara and P.S.P. Rao.

i) Lidar monitoring of urban aerosol layer structure.
: P.C.S. Devara and P.E. Raj.

ii) Impact of Ca and SO_4 on pH of rain water in rural environments in India.
: P.S.P. Rao, G.A. Momin, P.D. Safai, A.G. Pillai, M.S. Naik and L.T. Khemani.

n) Nat. Space Science Symp., Nagpur University, Nagpur, 5-9 March 1990.
—K. Indira and S.M. Sholapurkar.

i) Two years study of day-time and night-time differences in point discharge current in thunderstorms at Pune.
: G.K. Manohar, S.S. Kandalgaonkar and S.M. Sholapurkar.

ii) Variability in the annual total ozone during two solar cycles.
: K. Indira and B.K. Mukherjee.

iii) Variability in rainfall and its association with the stratospheric features.
: K. Indira.

iv) Variations in the atmospheric total ozone during inter planetary MSB crossing events.
: B.K. Mukherjee and K. Indira.

o) Sem. on 'Pollution due to Automobiles', VIT, Pune, 14 March 1990.
—A.S.R. Murty, P.S.C. Devara and L.T. Khemani.

p) 18th Optical Society of India Symp. on 'Optical Science and Engineering', Bangalore, 21-23 March 1990.
—P.C.S. Devara.

i) Some aspects of Rayleigh and Mie scattering in the atmosphere over Pune.
: P.C.S. Devara and P.E. Raj.

Instrumental and Observational Techniques Division

a) Workshop on 'MONTBLEX', IIT, Kharagpur, 3 April 1989.
—K.G. Vernekar and S. Sivaramakrishnan.

Symp./Conf. etc.

b) Sem. on 'Global Electric Circuit', Mysore University, Mysore, 8-9 August 1989.
Participant(s) —A.K. Kamra.

c) Nat. Sem. on 'Thrust Areas in Atmospheric Sciences', Pune, 16-18 August 1989.
—A.K. Kamra and K.G. Vernekar.

d) Symp. on 'Geomagnetism and Aeronomy in Nineties', IIG, Bombay, 28-29 October 1989.
—S. S. Dhanorkar.

e) 5th Int. Symp. on 'Acoustic Sounding', NPL, New Delhi, 6-9 February 1990.
—K.G. Vernekar and L.K. Sadani.

Paper(s) presented Author(s)

i) Characteristics of Doppler Sodar observations at IITM, Pune.
: K.G. Vernekar, L.K. Sadani and S. Saxena.

f) Sem. on 'Pollution due to Automobiles', VIT, Pune, 14 March 1990.
—K.G. Vernekar.

Theoretical Studies Division

a) Instructional Conf. on 'Applied Mathematical Techniques with Special Reference to Modelling in Atmospheric and Oceanic Processes', CAT, Indore, 10-29 April 1989.
—S.K. Mishra, Prem Singh, N.K. Agarwal and M. Mujumdar.

b) Symp. on 'Ocean Science and Technology', Trivandrum, 2 January 1990.
—S.K. Mishra.

c) UGC sponsored Course on 'Fundamentals of Atmospheric Science', I.I.Sc., Bangalore, 12-16 March 1990.
—S.K. Mishra.

d) Sem. on 'Meteorology', Gujrat University, Ahmedabad, 23 March 1990.
—S.K. Mishra

Computer and Data Division

a) Annual Convention of Computer Society of India, Bangalore, 20-23 September 1989.
—C.M. Mohile

Library, Information and Publications Division

a) 35th All India Library Conf., Abasaheb Garware College, Pune, 7-10 November 1989.
—A.A. Shiralkar.

b) XVII All India Conf. of IASLIC, Jaipur, 27-30 December 1989
—B.C. Morwal.

c) Workshop on 'Science Communication', AIR, Nagpur, 12-17 February 1990.
—A.A. Shiralkar.

d) Computer Applications in Library and Information Centres, University of Poona, Pune, 13-23 March 1990.
—A.A. Shiralkar and V.V. Massey.

Director's Participation in Conferences/Symposia

a) Workshop on 'MONTBLEX', IIT, Kharagpur, 03 April 1989.

b) A Session held at India Int. Centre in connection with Nehru Birth Centenary, DST, New Delhi, 2-7 April 1989.

c) Workshop on 'Ocean Atmosphere Coupling and Ocean Dynamics', Bangalore, 18 April 1989.

d) SAARC Workshop on 'Monsoon Forecasting', IMD, New Delhi, 18 January 1990.

d) Symp. on 'Global Changes', Indian Geophysical Union, Hyderabad, 15-17 March 1990.

f) Joint Workshop of All India Co-ordinate Programme on Ionosphere Thermosphere Study (AICPITS) and Solar Terrestrial Energy Programme (STEP), Waltair, 27-29 January 1990.

g) Sem. On 'Pollution due to Automobiles', VIT, Pune, 14 March 1990.

h) UGC Sponsored Programme on 'Fundamentals in Atmospheric Sciences', IISc., Bangalore, 12-16 March 1990.

i) Sem. on 'Meteorology', Gujarat University, Ahmedabad, 23 March 1990.

i) Mid-term appraisal of Tropical Ocean Global Atmosphere.

6. PARTICIPATION IN MEETINGS

Forecasting Research Division

Dr. S.V. Singh, A.D., Shri R.K. Verma, SSO I, Shri D.K. Paul, SSO I, Shri K.D. Prasad, SSO II and Shri R.H. Kripalani, SSO II

Joint Meeting of Scientists under the Inso-US Sub-Commission on Atmospheric Sciences Indian Institute of Tropical Meteorology, Pune, 06-09 November 1989.

Climatology and Hydrometeorology Division

Dr. G.B. Pant, A.D.

i) Meeting of Project Advisory and Monitoring Committee on Agrometeorology, Department of Science and Technology, New Delhi, 29 September 1989,
ii) Annual Meeting of the National Committee on World Climate Research Programme, Indian National Science Academy, New Delhi, 12 March 1990.

Dr. P.R. Rakhecha, SSO I

i) Fourth Meeting of Indian National Committee on Hydrology (formerly HILTECH), Krishi Bhavan, New Delhi, 20 July 1989,
ii) Meeting on the Rationalization of PMP-PMF evaluation procedures for river catchments in India, Central Water Commission, New Delhi, 01 December 1989.
iii) Third Meeting of the INCOLD Sub-Committee on Design Floods, CBIP Office, New Delhi, 03 January 1990.

Physical Meteorology and Aerology Division

Dr. A.S.R. Murty, D.D.
Meeting on Cloud Seeding Programme, Department of Science and Technology, New Delhi, 02 May 1989.

Instrumental and Observational Techniques Division

Shri K.G. Vernekar, A.D.

i) MONTBLEX Monitoring Committee Meetings, Indian Institute of Science, Bangalore, 19 May 1989, 19 September 1989 and 22 December 1989.
ii) Meeting to discuss ship observations during the Main MONTBLEX Experiment, National Institute of Oceanography, Goa, 11-13 December 1989.

Theoretical Studies Division

Dr. S.K. Mishra, D.D.

i) Project co-ordinators' Group for the research projects on NWP, Department of Science and Technology, New Delhi, 01-02 May 1989,
ii) 55th Anniversary Meeting of INSA, Trivandrum, 03-04 January 1990.
iii) DST Working Group on GFDL, Physical Research Laboratory, Ahmedabad, 22 March 1990.

Dr. (Smt.) P.S. Salvekar, SSO I
Board of Studies in Mathematics, University of Poona, Pune, 03 May 1989, 19 September 1989 and 11 December 1989.

Computer and Data Division

Shri R. Suryanarayana, D.D.

i) WMO Commission for Atmospheric Sciences (CAS) Advisory Working Group Meeting, Reading, England, U.K., 11-14 August 1989,
ii) First Meeting to Draw Specifications for the Computer System of India Meteorological Department, India Meteorological Department, New Delhi, 23 December 1989

Library, Information and Publications Division

Smt. A.A. Shiralkar, STO II
Meeting of Heads of Special Libraries in Pune in Connection with Co-operation in Periodicals' Acquisition and Sharing of Resources, National Chemical Laboratory, Pune, 27 October 1989.

Shri D. R. Sikka, Director

i) Meeting with Prof. Sarkisyan of USSR, Department of Science and Technology, New Delhi, 02-07 April 1989.
ii) Meeting in connection with finalisation of cruises of Research Vessels, National Institute of Oceanography, Goa, 20-22 April 1989.
iii) Meetings at Department of Science and Technology, and Centre for Atmospheric Sciences and Indian Institute of Technology, New Delhi, 25 April-05 May 1989.
iv) Meetings of Council for Meteorology and Atmospheric Sciences, New Delhi, 15 May, 31 August and 29 November 1989.
v) IITM Review Committee Meeting, Bangalore, 19 May 1989.
vi) Meetings of Search cum Selection Committee, National Centre for Medium Range Weather Forecasting, 30 May-03 June 1989.
vii) Meeting at Indian Space Research Organisation, Bangalore, 21-23 June 1989.
viii) Meeting at the Department of Environment, New Delhi, 18 July 1989.

ix) Review Meetings on the project 'Thrust areas in Technical Education (Ministry of Human Resources), New Delhi, 30 July—06 August 1989.

x) Zero-Base Budgeting Meeting,
India Meteorological Department, New Delhi,
08 August 1989.

xi) Meeting on India's TOGA Programme,
Department of Science and Technology,
New Delhi, 08 August 1989.

xii) Meeting at University Grants Commission on Meteorological Course, New Delhi, 09 August 1989.

xiii) Meeting on Railway Enquiry Commission about railway accident in Kerala on 8 July 1988, New Delhi, 06 October 1989.

xiv) Meeting of the Committee on Monitoring and Modelling of Sea Level Variation of Department of Ocean Development (DOD),
New Delhi, 26 October 1989.

xv) Project Evaluation and Monitoring Committee (PEMC) Meeting,
Department of Science and Technology,
New Delhi, 27 October 1989 and 22 January 1990.

xvi) Meeting on Parallel Computing,
Department of Science and Technology,
New Delhi, 02 November 1989.

xvii) Meetings of Programme Advisory Committee (PAC) and Hydrometeorology, New Delhi, 19 November to 28 November 1989.

xviii) 13th Meeting of the Scientific Advisory Committee, New Delhi, 30 November 1989.

xix) MONTBLEX Monitoring Committee Meeting,
Department of Science and Technology,
New Delhi, 22 December 1989.

xx) Selection Committee Meeting,
India Meteorological Department, I.M.D.,
New Delhi, 22 December 1989.

xxi) Selection Committee Meeting,
Department of Science and Technology (NCMRWF), New Delhi, 26 December 1989.

xxii) Meetings of DOD Committee for Oceanography Training Programme,
Indian Institute of Science, Bangalore,
02-06 January 1990.

xxiii) Experts' Committee Meeting of Railway Board,
New Delhi, 30-31 January 1990.

xxiv) Meeting of Indian Geophycal Union,
National Geophysical Research Institute,
Hyderabad, 14-15 March 1990.

7. INSTITUTIONAL SEMINARS

Institutional Seminars serve an important function in sharing the results of ongoing research and in updating the information on current research in India and abroad on topics of interest to the Institute.

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

Sr. No.	Speaker	Topic	Date
*1.	Shri P.N. Mahajan, SSO II, IITM	Estimation of vertical distribution of relative humidity using satellite data.	12 April 1989
2.	Dr. S.V. Singh, AD, IITM	Appraisal of Fourth International Meeting on Statistical Climatology held in Rotorua, New Zealand, during 27-31 March 1989.	14 April 1989
3.	Prof. D.T. Rama Bhadran, Prof. of Chemical and Bio-Chemical Engg., South Dokota School of Mines and Technology, USA.	i) Dynamics of atmospheric aerosols. ii) Role of atmospheric modelling in safety simulation and disaster management.	27 April 1989
4.	Dr. A.A. Rama Sastry, Retd. DDGM, I.M.D.	Meteorology in developing countries.	28 April 1989
*5.	Dr. Smt. A.M. Selvam, AD, IITM	Cell dynamical system model for thundercloud electrification.	01 June 1989
6.	Shri J.R. Kulkarni, SSO II, IITM	i) Long range prediction of monsoon. ii) Total angular momentum content of the atmosphere and the monsoon activity. iii) Monsoon sub-divisional rainfall dimensionality and predictability.	05, 07, 09 June 1989 21 June 1989 18 October 1989
*7.	Shri S. Raghavan, DDGM (II and S), IMD, Pune	Meteorological Applications of Radar.	08 June 1989
*8.	Dr. U.S. De, Director (Training), IMD, Pune	Training of Manpower in Meteorology.	23 June 1989
*9.	Prof. R. Ananthakrishnan, Honorary Fellow, IITM	Time and Calendar.	30 June 1989
10.	Shri V.R. Deshpande, SSA, IITM	On monitoring the monsoon 1989—A video recording of weather events.	27 July 1989
11.	Dr. A.K. Karma, DD, IITM	i) Inadvertent Modification of Atmospheric Electricity. ii) Break up of waterdrops.	30 August 1989 08 January 1990
12.	Dr. S.S. Parasnis, SSO II, IITM	Conserved variable analysis for the convective boundary layer structure.	01 September 1989
13.	Dr. S.K. Sinha, JSO, IITM	Use of surface observations to estimate upper air humidity for the objective analysis of relative humidity over Indian region.	01 September 1989

Sr. No.	Speaker	Topic	Date
14.	Smt. P. Mehra, JSO, IITM	Retrieval of total column density of NO_2 and O_3 using visible region spectrospcopic observations.	21 September 1989
15.	Smt. S. D. Bhonde, JSO, IITM	i) Optical path calculations during twilight period and Matrix Inversion Techniques for retrieval of total column density of NO_2 and O_3.	21 September 1989
		ii) Air Pollution model for chemically reactive pollutants.	01 February 1990
16.	Shri G.K. Manohar, SSO II, IITM	i) Off-shore sea surface investigations of electric field in the Indian Sub-continent during 09-20 May 1983.	26 September 1989
		ii) A study of two years point discharge current observations in thunderstorms at Pune and its possible association with Indian SW monsoon.	28 March 1990
17.	Dr. A.A. Korzadze, Academy of Sciences Georgian SSR, Tbilisi, USSR	Mathematical modelling of ocean dynamics.	22 December 1989, 03, 12, 19 January 1990
18.	Dr. Yu.N. Skiba, Dept. of Numerical Methods, Moscow, USSR	i) Theory of conjugate equations and operators.	11, 17, 25 January and 05 February 1990.
		ii) Barotropic dynamics on sphere.	14, 19 February, 08, 19, 29 March 1990
19.	Dr. S.N. Bavadekar, SSO, IITM	The numerical experiments with inclusion of orography in five level P.E. model in pressure co-ordinates for inter-hemispheric region.	18 January 1990
20.	Dr. L.S. Hingane, SSO I, IITM	Modelling of ozone valley along Monsoon Trough	02 February 1990
21.	Shri A.L. Londhe, JSO, IITM	Portable spectrometer.	15 February 1990
22.	Prof. Gerhard Peters, Univ. of Hamburg, Met. Inst., Bundesstrasse	Radio Acoustic sounding and its application.	16 February 1990
23.	Shri G.R. Iyengar, Research Fellow, IITM	Normal Modes and their applications in diagnostic studies of the atmosphere.	20 February 1990

* Special Lecture series on Atmospheric Sciences, was organised as a part of the Jawaharlal Nehru Birth Centenary Celebrations at the Institute.

8. LECTURES DELIVERED OUTSIDE THE INSTITUTE

Forecasting Research Division

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

'Regional model for monsoon prediction', Advance Refresher Course on Short Range Weather Prediction, India Meteorological Department, Pune, 18 April 1989.

Shri R.K. Verma, SSO I

'Interannual variability of Indian summer monsoon response to equatorial pacific SST as simulated with GFDL-GCM', Indian Meteorological Society, Pune, 12 October 1989.

Shri D.K. Paul, SSO I

'Indian Ocean Meteorology', National Institute of Oceanography, Goa, 10 November 1989.

Shri R.H. Kripalani, SSO II

'Organisation of Meteorological data for weather forecasting research', National CODATA Conference-1990, University of Poona, Pune, 05 February 1990.

Climatology and Hydrometeorology Division

Dr. G.B. Pant, A.D.

'Theoretical and observational evidences of climatic change', Colloquium on Environmental Aspects of Climatic Change, University of Calcutta, Calcutta, 20 January 1990.

Dr. H.N. Bhalme, A.D.

'Climate Variability', ICSSR Sponsored Summer Institute organised by Maharashtra Bhugol-Shashtra Parishad, Pune, 14 June 1989.

Dr. B. Parthasarathy, A.D.

'Vagaries of Indian Summer Monsoon Rainfall : Data over a century', National CODATA Conference 1990, University of Poona, Pune, 05 February 1990.

Physical Meteorology and Aerology Division

Dr. B.K. Mukherjee, A.D.

'Stratwarm phenomenon at low latitudes', Symposium on Current Status and Future Perspective in Solar Terrestrial Physics Research, Physical Research Laboratory, Ahmedabad, 29 August 1989.

Dr. P.C.S. Devara, A.D.

'Lidar measurements on tropical atmospheric constituents at Pune, India', Rutherford Appleton Laboratory, U.K., 15 August 1989.

'Lidar sounding of the atmosphere', Cyclone Warning Centre, Visakhapatnam, 23 February 1990.

Dr. L.T. Khemani, SSO I

'Acid rains', Seminar on Global Effects of Air Pollution : An update and strategies. Indian Merchants Chambers, Bombay, 03 June 1989.

Dr. D.B. Jadhav, SSO I

i) 'Atmospheric variations and their effects on future eco-system', ICSSR sponsored Summer Institute organised by Maharashtra Bhugol-Shastra Parishad, Pune, 09 June 1989.

ii) 'Effect of atmospheric pollution on 21st century environment', Dept. of Physics, Shivaji University, Kolhapur, 10 March 1990.

Shri R. Vijayakumar, SSO I

'Meteorological data in weather modification and environmental physics', National CODATA Conference, 1990, University of Poona, Pune, 05 February 1990.

Dr. S.S. Parasnis, SSO II

'Aircraft observation of atmospheric boundary layer', Training cum Orientation Workshop on MONTBLEX, Indian Institute of Technology, Kharagpur, 03-07 April 1989.

Instrumental and Observational Techniques Division

Shri K.G. Vernekar, A.D.

'Doppler sodar and its application' and 'Measurements with Kytoon system', Training cum Orientation Workshop on MONTBLEX, Indian Institute of Technology, Kharagpur, 03-07 April 1989.

Shri Sivaramakrishnan, SSO I

'Boundary Layer Dynamics', Training cum Orientation Workshop on MONTBLEX, IIT, Kharagpur, 03-07 April 1989.

'Hot wire anemometry theory and applications', Department of Mechanical Engineering, Engineering College, Pune, 12 October 1989.

Theoretical Studies Division

Dr. S.K. Mishra, D.D.

'Spectral Methods', Conf. on Applied Mathematical Techniques, Centre for Advanced Technology, Indore 18-20 April 1989.

'Dynamics of synoptic scale motions and their development', UGC Sponsored Course on Fundamentals of Atmospheric Sciences, Indian Institute of Science, Bangalore, 12-16 March 1990.

'Atmospheric Waves', Seminar on Meteorology, Gujarat University, Ahmedabad, 23 March 1990.

Computer and Data Division

Shri R. Suryanarayana, D.D.

'Data Processing for numerical prediction', National CODATA Conference 1990, University of Poona, Pune, 05 February 1990.

Library Information and Publications Division

Smt. A.A. Shiralkar, STO II

'Organisation of atmospheric information system at the IITM', National CODATA Conference 1990, University of Poona, Pune, 05 February 1990.

Shri D. R. Sikka, Director

'Monsoon research' SAARC Workshop on 'Monsoon Forecasting', IMD, New Delhi, 18 January 1990.

'Role of data organisation in monsoon research', National CODATA Conference 1990, University of Poona, Pune, 05 February 1990.

'Recent developments in monsoon meteorology' and 'Research Programmes at IITM and NCMRWF', UGC sponsored programme on 'Fundamentals in Atmospheric Sciences', Indian Institute of Science, Bangalore, 15-17 March 1990.

9. VISITORS

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

Sr. No.	Visitors-Credentials	Date of Visit
A.	**National :**	
1.	Dr. M.S. Narayanan, Dr. P.C. Joshi, Dr. M.M. Ali, Scientists, Space Applications Centre, Ahmedabad.	08-10 May 1989
2.	Dr. S.K. Guha, Joint Director (Retd.), CWPRS, Pune.	20, 28 April, 10 May and 01 June 1989
3.	A batch of students of M.Sc. (Meteorology and Oceanography), School of Marine Sciences, Cochin.	27 June 1989
4.	Two groups of cadets from Geographers' club of National Defence Academy, Khadakwasala, Pune.	16 August 1989 and 14 February 1990
5.	Dr. Vasant Gowariker, Secretary, Dept. of Science and Technology, New Delhi.	16-18 August 1989
6.	Post-graduate medical students of B.J. Medical College, Pune.	17 August 1989
7.	Participants of Familiarisation Programme for Meteorologists, I/C of Agromet Advisory Service, I.M.D.	30 August 1989
8.	S/Shri Sabapathy, Asstt. Executive Engineer and K. Duraimanickram Asstt. Engineer, Govt of Tamil Nadu.	26-29 September 1989, 19-29 December 1989 and 19-23 March 1990
9.	Shri Gorakh Nath Asstt. Director (Hindi) Dept. of Science and Technology, New Delhi.	04-05 December 1989
10.	Dr. B.N. Goswami, Scientist, Centre of Atmospheric Sciences, IISc., Bangalore.	12-14 December 1989
11.	Participants of the Training Course in Micrometeorological Measurements in Agriculture', Centre of Advanced Studies in Agricultural Meteorology, Pune.	23 January 1990
12.	A batch of 5 students of M.Tech. (Atm. Sci.) alongwith Dr. H.S. Ram Mohan, Cochin Univ. of Science and Technology, Cochin, Kerala.	19-21 March 1990
13.	A team of six student officers and one Instructor, Air Force Administrative College, Coimbatore.	20-21 March 1990
B.	**International :**	
1.	Dr. Osman Shinaishin, National Science Foundation, USA.	25 September 1989
2.	A delegation of six scientists from USA, Dr. A.R. Thomas, Dr. C.M. Bhumralkar, Dr. T.E. Murray, Dr. S.D. Woodruff, Dr. R.M. Davis, NOAA, USA and Dr. G.V. Rao, St. Louis Univ., USA.	06-09 November 1989
3.	Dr. Patrick Jeremiah, Visiting Caribbean Scientist, National Institute of Oceanography, Goa.	22 November 1989
4.	A team of U.K. Scientists under the auspices of British Council Division.	08 January 1990
5.	U.S.S.R. Scientists : Prof. A. Kordzadze, Dr. Yu.N. Skiba, Dr. A.L. Brekhovskikh.	For 7 months from December 1989
6.	Prof. Gerhald Peters, Institute of Meteorology, University of Hamburg, Bundesstresse and Dr. Raj Lawrence, Control Data, Singapore.	16 February 1990

Visit of the scientists from U.K. to the Institute on 08 January 1990 under the British Council Overseas Programme Development in Science and Technology.

Meeting with the USSR scientist Dr. A.L. Brekhovskikh on conclusion of his collaborative research work at the Institute.

10. PUBLICATIONS

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

Forecasting Research

Regional NWP Modelling With Full Physics

FR 1. Application of split-explicit scheme of the integration of a regional model ; Bandyopadhyay A. and Singh S.S., Preprint of National Space Science Symposium, Nagpur Univ., Nagpur, 05-09 March 1990, 415-418.

FR 2. Development of regional model with sponge layer near the boundaries : Rajagopal E.N. and Singh S.S., Research Activities in Atmospheric and Oceanic Modelling, Report No. 13, November 1989, CAS/JSC; WGNE, WMO/TD No.. 332, 5.7.

FR 3. Limited area model for monsoon prediction : Singh S.S., Vaidya S.S. and Rajagopal E.N., Advances in Atmospheric Sciences, 7, 1, January,1990, 111-126.

Objective Analysis Including Satellite Input for Regional Models

FR 4. Excitation of low level jet as seen by GOES (IO) satellite off the Somali coast : Mahajan P.N., Mujumdar V.R. and Ghanekar S.P., Advances in Atmospheric Sciences, 6. 4, November, 1989, 475-482.

FR 5. Numerical experiments with inclusion of orography in 5-level primitive equation model in pressure coordinates for interhemispheric region : Bavadekar S.N., Khaladkar R.M., Contributions from IITM, 43, 1989.

FR 6. Objective analysis of relative humidity over Indian region by optimum interpolation method : Sinha S.K., Narkhedkar S.G., Talwalkar D.R. and Rajamani S., Preprint of National Space Science Symposium, Nagpur Univ., Nagpur, 05-09 March 1990, 457-459.

FR 7. On the relationship between satellite observed HRC and rainfall over the Indian Ocean : Mahajan P.N. and Ghanekar S.P., Proc. of the Seminar on Advances in Geophysical Research in India, NGRI, Hyderabad, 08-10 February 1989, 195-199.

FR 8. Scheme for objective analysis of wind field incorporating multiweighting functions in the optimum interpolation method : Sinha S.K., Talwalkar D.R., Narkhedkar S.G. and Rajamani S., Advances in Atmospheric Sciences, 6, 4, November, 1989, 435-446.

FR 9. Use of satellite derived cloud motion vectors for NWP models : Mahajan P.N., Preprint of National Space Science Symposium, Nagpur Univ., Nagpur, 05-09 March 1990, 451-452.

Extended Range Prediction

FR 10. Energetics of the lower stratosphere during the period of stratospheric warming of 1979 : Kulkarni J.R., Iyer U. and Rajamani S., Proc. of Second Workshop on IMAP Scientific Results, Trivandrum, 26-29 April 1989, 15-22.

FR 11. Forecasting seasonal monsoon rainfall over India : Singh S.V., Kripalani R.H., Prasad K.D. and Bansod S.D., Proc. of the Fourth Int. Meeting on Statistical Climatology, Rotorua, New Zealand, 27-31 March 1989, 186-189.

FR 12. Periodicity in peak spells of 5-day rainfall (pentad impulse) during Southwest monsoon over Maharashtra : Dahale S.D., Proc. of the Seminar on 'Advances in Geophysical Research in India', NGRI, Hyderabad, 08-10 February 1989, 63-67.

FR 13. Harmonic analysis of summer wind at 200 mb level during contrasting monsoon years over India : Bawiskar S.M., Awade S.T. and Singh S.S., Proc. of Indian Academy of Sciences, 98, 4, December, 1989, 365-373.

Climatology and Hydrometeorology

Climate and Climatic Change

CH 1. Effect of increasing CO_2 on the stratospheric level of CO and O_3 : Hingane L.S., Advances in Atmospheric Sciences, 6, 3, August, 1989, 390-393.

CH 2. Environmental conservation and climate : Pant G.B., Environmental Issues : Problems and Solutions, Golden Jubilee Publication, Univ. of Kerala, Trivandrum, 1988, 189-203.

CH 3. Interaction between El-Nino and the Indian monsoon rainfall : Bhalme H.N. and Sikder A.B., Preprint of National Space Science Symposium, Nagpur Univ., Nagpur, 05-09 March 1990, 390-394.

CH 4. Surface/upper air parameters for forecasting the Indian monsoon rainfall : Parthasarathy B., Eischeid J.K. and Diaz H.F. : Long Range Forecasting Research Report Series No. 9, WMO/TD No. 261, 1989, 98-102.

CH 5. Variability of Indian Summer monsoon rainfall and its relationship with regional/global circulation features—A review : Parthasarathy B., Long-range Forecasting Research Report Series No. 9, WMO/TD No. 261, 1989, 89-97

CH 6. Analysis of most severe rainstorms of India : Dhar O.N., Kulkarni A.K., Mandal B.N. and Nandargi S.S., Proc. of Seminar on Advances in Geophysical Research in India, NGRI, Hyderabad, 08-10 February 1989, 29-34.

CH 7. Analysis of severe rainstorms of Andhra Pradesh : Dhar O.N., Nandargi S.S. and Kulkarni A.K., Jr. of Applied Hydrology, 2, 1, January, 1989, 55-67.

CH 8. Analysis of severe rainstorms of contiguous Indian states : Dhar O.N., Kulkarni A.K., Mandal B.N. and Nandargi S.S., Proc. of Workshop on Unusual Storm Events and Their Relevance to Dam Safety; Bhubaneswar, 11-12 May 1989, 11-15.

CH 9. Analysis of severe rainstorms of the peninsular states for design storms estimation : Dhar O.N., Mandal B.N., Nandargi S.S. and Kulkarni B.D., Proc. of the Workshop on Unusual Storm Events and Their Relevance to Dam Safety, Nagarjune Sagar Dam Site, A.P., 19-20 February 1990, 35-40.

CH 10. Anomalies in aerological data of Mangalore and Ahmedabad : Ananthakrishnan R. and Soman M.K., Mausam, 40, 3, July, 1989, 279-282.

CH 11. Brief appraisal of rainstorm studies on coastal areas of India : Dhar O.N., Nandargi S.S. and Kulkarni A.K., Proc. of Workshop on Unusual Storm Events and Their Relevance to Dam Safety, Nagarjune Sagar Dam Site, A.P., 19-20 February 1990, 57-59.

CH 12. Case studies of severemost rainstorms over the Western Regions of India : Dhar O.N., Mandal B.N., Kulkarni A.K., and Nandargi S.S., Proc. of Workshop on Unusual Storm Events and Their Relevance to Dam Safety, Narmada Sagar Dam Site, M.P., 27-28 September 1989, 1-5.

CH 13. Design storm estimation for Indian Basins—need for removal of deficiencies and drawbacks : Dhar O.N., Proc. of Workshop on Unusual Storms Events and Their Relevance to Dam Safety, Srinagar, 25-28 July 1989, 23-26.

CH 14. Distribution of rainfall over different sections of Narmada basin associated with biggest floods in recent times : Dhar O.N. and Nandargi S.S., Indian Jr. of Power and River Valley Development, 39, 7, July, 1989, 210-213.

CH 15. Estimation of one-day PMP of stations in India from mean annual and 100 year rainfall : Dhar O.N., Kulkarni A.K. and Mandal B.N., Proc. of Workshop on Unusual Storm Events and Relevance to Dam Safety, Srinagar, 25-28 July 1989, 17-21.

CH 16. Flash flood of August 1979 in the Machhu basin : Rakhecha P.R. and Nandargi S.S., Proc. of Workshop on Unusual Storm Events and Their Relevance to Dam Safety, Narmada Sagar Dam Site, M.P., 27-28 September 1989, 49-52.

CH 17. Floods in Indian rivers during contrasting monsoon seasons of 1987 and 1988 : Dhar O.N. and Nandargi S.S., Hydrology Jr. of IAH, XII, 1 and 2, January-June 1989, 21-34.

CH 18. Further examination of the anomaly in the radiosonde data of Ahmedabad : Ananthakrishnan R. and Soman M.K., Mausam, 40, 3, July, 1989, 283-286.

CH 19. Hydrometeorological studies of Indian rainfall : Dhar O.N., Proc. of National Seminar on New Perspectives in Water Management, Narmada-sagar Dam Site, 15-16 April, 1989, VI 1—VI 9.

CH 20. Initiation of storm studies in India and proposals for countrywide analysis of major rainstorms : Dhar O.N., Proc. of Workshop on Unusual Storm Events and Their Relevance to Dam Safety, Nagarjune Sagar Dam Site, A.P., 19-20 February 1990, 25-28.

CH 21. Interannual variability of the dates of onset of the southwest monsoon over Kerala and variability of monsoon rainfall : Ananthakrishnan R., Soman M.K. and Kumar K.K., Proc. of Workshop on Variability of Tropical Oceans and Atmosphere, IISc., Bangalore, 10-13 February 1987, 5-23.

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CH 23. Maximum persisting dew points during the southwest monsoon season over India : Rakhecha P.R., Deshpande N.R. and Nandargi S.S., Mausam, 41, 1, January, 1990, 140-142.

CH 24. Onset dates of the southwest monsoon over Kerala for the period 1870 to 1900 : Ananthakrishnan R. and Soman M.K., Jr. of Climatology, 9, 1, January-February, 1989, 321-322.

CH 25. Outstanding rainstorms of the Western Region of India—A brief appraisal : Dhar O.N., Mandal B.N., Kulkarni A.K. and Nandargi S.S., Proc. of Workshop on Unusual Storm Events and Their Relevance to Dam Safety, Narmada Sagar Dam Site, M.P., 27-28 September 1989, 19-23.

CH 26. Probable maximum precipitation in northwest India—A generalised approach : Rakhecha P.R. and Mandal B.N., Proc. of Workshop on Unusual Storm Events and Their Relevance to Dam Safety, Srinagar, 25-28 July 1989, 3-8.

CH 27. Sequential maximization of rainstorms for PMP estimation of design storm : Dhar O.N. and Nandargi S.S., Proc. of Workshop on

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CH 28. Some features of heavy rainfall distribution over Narmada basin upto Narmada Sagar dam site in Madhya Pradesh : Dhar O.N., Nandargi S.S., Mulye S.S. and Kulkarni A.K., Proc. of Seminar on Advances in Geophysical Research in India, NGRI, Hyderabad, 08-10 February 1989, 71-74.

CH 29. Some features of periods contributing specified percentages of rainfall to annual total in Kerala, India : Singh N., Kumar K.K. and Soman M.K., Theoretical and Applied Climatology, 39, 3, 1989, 160-170.

CH 30. 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, 9, 5, September-October, 1989, 485-500.

CH 31. 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, 39, 3, 1989, 46-50.

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Physical Meteorology and Aerology

Studies in Atmospheric Electricity

PM 1. Association among geomagnetic activity, atmospheric electric field and selected meteorological parameters : Mehra P., Advances in Atmospheric Sciences, 7, 2, 1990, 171-178.

PM 2. Cylindrical field mill for monitoring three vectors of electric field : Jadhav D.B., Selvam A.M. and Murty A.S.R., Jr. Instruments Society of India, 18, 3, 1988, 193-199.

PM 3. 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., Proc. of the Seminar on Advances in Geophysical Research in India, NGRI, Hyderabad, 08-10 February 1989, 75-80.

PM 4. Effect of thermal power plant emissions of atmospheric electrical parameters : Manohar G.K., Kandalgaonkar S.S. and Sholapurkar S.M., Atmospheric Environment, 23, 4, April, 1989, 843-850.

PM 5. Lunar phases and atmospheric and electric field : Mehra P., Advances in Atmospheric Sciences, 6, 2, 1989, 239-246.

PM 6. Observations of aerosol and atmospheric parameters in different environments : Manohar G.K., Sholapurkar S.M. and Kandalgaonkar S.S., Proc. of First Annual Conference of Indian Aerosol Science Technology Association (IASTA), Pune, 23-24 March 1989, 84-89.

PM 7. Point discharge current observations during two consecutive pre-monsoon thunderstorms of the years 1987 and 1988 at Pune : Manohar G.K., Kandalgaonkar S.S. and Sholapurkar S.M., Proc. of the Seminar on Advances in Geophysical Research in India, NGRI, Hyderabad, 08-10 February 1989, 94-98.

PM 8. Two years study of day time and night time differences in point discharge current in thunderstorms at Pune : Manohar G.K., Kandalgaonkar S.S. and Sholapurkar S.M., Proc. of National Space Science Symposium, Nagpur Univ., Nagpur, 05-09 March 1990, 370-372.

PM 9. Variations in atmospheric electric field at a tropical inland station during 1930-1987 : Kandalgaonkar S.S. and Manohar G.K., Proc. of National Space Science Symposium, Nagpur Univ., Nagpur, 05-09 March 1990. 368-370

Radar Study of Rain and Rain-bearing clouds

PM 10. Radar study of severe thunderstorms around Delhi during summer and monsoon seasons : Chatterjee R.N. and Prem Prakash, Proc. of Seminar on the State of Art in Studies on Nor'westers and Local Severe Storms, Calcutta, 19-21 March, 1989, 221-243.

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PM 11. Association between giant hygroscopic condensation nuclei and meteorological parameters at a tropical station : Pillai A.G. and Selvam A.M., Proc. of the First Annual Conference of Indian Aerosol Science and Technology Association (IASTA) Pune, 23-24 March 1989, 44-46.

PM 12. Certain meteorological features of submicron aerosols at Schirmacher Oasis, East Antarctica : Lal M. and Kapoor R.K., Atmospheric Environment, 23, 4, April, 1989, 803-808.

PM 13. Overview of warm cloud modification research in India : Murty A.S.R., Proc. of Fifth WMO Scientific conference on Weather Modification and Applied cloud Physics, Beijing, China, 08-12 May 1989, 521-524.

Studies of the Atmospheric Boundary Layer

PM 14. Cell dynamical system model for atmospheric low frequency variability : Selvam A.M., Proc. of Fifth Scientific Assembly of IAMAP 1989, Reading, U.K., 31 July-11 August 1989.

PM 15. Cell dynamical system model for deterministic chaos in atmospheric flows : Selvam A.M., Proc. of 7th Int. Conference on Mathematical and Computer modelling, Chicago, Illinois, USA, 02-05 August 1989.

PM 16. Cell dynamical system model for thundercloud electrification : Salvam A.M., Proc. of 1989 Int. Conference on Lightning and Static Electricity, Univ. of Bath, U.K., 26-28 September 1989.

PM 17. Deterministic chaos fractals and quantum mechanics in the atmospheric flows : Selvam A.M., Proc. of Int. Conference of Kinetics of Non-homogeneous Processes, Banff, Canada, 07-13 October, 1989.

PM 18. Deterministic chaos model for the prediction of climatological weather cycles : Selvam A.M., Proc. of 4th Int. Meet on Statistical Climatology (4IMSC), Rotorua, New Zealand, 27-31 March 1989, 195-197.

PM 19. Deterministic chaos model for self-organised adaptive networks in atmospheric flow : Selvam A.M., Proc. of 41 National Aerospace and Electronic Conference (NAECON-89), 22-26 May 1989, Dayton, Ohio, USA, 1145-1152.

PM 20. On the mixing processes in the atmospheric boundary layer : Parasnis S.S. and Goyal S., Proc. of the Seminar on Advances in Geophysical Research in India, NGRI, Hyderabad, 08-10 February 1989, 110-112.

PM 21. Physics of deterministic chaos of atmospheric flows and applications to modelling weather systems : Selvam A.M., Proc. of National Space Science Symposium, Nagpur Univ., Nagpur, 05-09 March 1990, 386-387.

PM 22. Quasicrystalline structure of deterministic chaos in atmospheric flows : Selvam A.M., Proc. of the European Physical Society 9th Gen. Conference on Condensed Matter Division, Nice, France, 06-09 March 1989.

PM 23. Wave cybernetics model for deterministic chaos in atmospheric flows : Selvam A.M., Proc. of Symposium on Chaos Turbulence and Non-linear Variability in Geophysics, XIV Gen. Assembly of the European Geophysical Society, Barcelona, Spain, 13-17 March 1989.

Studies in Upper Atmosphere

PM 24. Association of equatorial wave dynamics with the Indian summer monsoon activity : Bhosale C.S., Reddy R.S. and Mukherjee B.K., Proc. of the Seminar on Advances in Geophysical Research in India, NGRI, Hyderabad, 08-10 February 1989, 68-70.

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PM 27. Pre-conditioning in the ozone hole regime : Mukku V.N.R., Proc. of fifth Scientific Assembly of IAMAP 1989, Reading, U.K., 31 July—11 August 1989, Vol. 1, ME 104.

PM 28. Results of stratwarm campaign during winter of 1985-86 : Mukherjee B.K. and Indira K., Indian Jr. of Radio and Space Physics, 19, 1, February, 1990, 29-37.

PM 29. Solar cycle and Indian rainfall : Reddy R.S., Neralla V.R. and Godson W.L., Theoretical and Applied Climatology, 39, 4, 1989, 194-198.

PM 30. Stratospheric changes and Antarctic ozone : Reddy R.S., Bhosale C.S., Mukku V.N.R. and Mukherjee B.K., Proc. of 3rd Int. Conference on Southern Hemisphere Meteorology and Oceanography, Argentina, 13-17 November 1989, 434-435.

PM 31. Temperature and winds over tropical middle atmosphere during two contrasting summer monsoons, 1975 and 1979 : Mukherjee B.K., Kulkarni C.P., Indira K. and Dani K.K., Advances in Atmospheric Sciences, 6, 3, 1989, 325-334.

PM 32. Variability in the annual total ozone during two solar cycles : Indira K. and Mukherjee B.K., Proc. of National Space Science Symposium, Nagpur Univ., Nagpur, 05-09 March 1990, 287-288.

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PM 36. Chemistry of dry deposition collected at Pune : Khemani L.T., Rao P.S.P., Momin G.A. and Safai P.D., IASTA Newsletter, 2, 3, 1989, 6-10.

PM 37. Diurnal variation of Aitken nuclei in the core zone of Nilgiri Biosphere Reserve : Momin G.A., Khemani L.T., Rao P.S.P., Safai P.D.,

Pillai A.G. and Naik M.S., IASTA Newsletter, 3, 1, 1990, 25-27.

PM 38. Environmental impact of pollution due to automobiles : Khemani L.T., Seminar on Pollution due to Automobiles, VIT, Pune, 14 March 1990, 32-36.

PM 39. Impact of Ca and SO_4 on pH of rain water in rural environments in India : Rao P.S.P., Momin G.A., Safai P.D., Pillai A.G., Naik M.S. and Khemani L.T., Proc. of Nat. Seminar on 'Monitoring Strategies of Environmental Pollution', Ahdhra Univ., Waltair, 22-24 February 1990, 29.

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PM 41. Long term effects of pollutants on pH of rain water 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, 23, 4, 1989, 753-756.

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PM 43. Nature of aerosols and their sources at Trivandrum : Rao P.S.P., Khemani L.T., Momin G.A., Safai P.D. and Naik M.S., Proc. of First Annual Conference of Indian Aerosol Science and Technology Association (IASTA), Pune, 23-24 March 1989, 72-76.

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PM 46. Physical characteristics of total aerosols and their constituents for the study of air pollution at Delhi : Pahwa D.R., Singal S.P., Ojha U.K., Khemani L.T., Safai P.D. and Pillai A.G., Proc. of National Space Science Symposium, Nagpur Univ., Nagpur, 05-09 March 1990, 307-309.

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PM 52. Portable spectrometer for atmospheric studies in visible region : Londhe A.L., Jadhav D.B. and Trimbake H.K. Proc. of National Symposium on Instrumentation (NSI-14), IISc. Bangalore, 03-06 October 1989, 20-21.

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PM 62. Lidar investigations of atmospheric constituents at a tropical station : Devara P.C.S. and Raj P.E., Proc. of First Annual Conference of Indian Aerosol Science and Technology Association (IASTA), Pune, 23-24 March 1989, 27-30.

PM 63. Lidar monitoring of urban aerosol layer structure : Devara P.C.S. and Raj P.E., Proc. of National Seminar on 'Monitoring Strategies of Environmental Pollution', Andhra Univ., Waltair, 22-24 February 1990, 23.

PM 64. Lidar sensing of aerosol layer variations for environmental studies : Raj P.E. and Devara P.C.S., Proc. of National Symposium on Instrumentation (NSI-14), IISc., Bangalore, 03-06 October 1989, 29.

PM 65. On some aspects of diurnal and semi diurnal wind field in the meteor zone : Devara P.C.S., Chandrasekhar G. and Ahmed M.I., Advances in Atmospheric Sciences, 6, 3, 1989, 357-364.

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10.2 List of Papers Accepted for Publication

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Extended Range Prediction

FR 2 Low frequency intraseasonal oscillations in Indian rainfall and outgoing longwave radiation : Singh S.V. and Kripalani R.H., Mausam.

FR 3 Recent monsoon variability in the global climate perspective : Verma R.K., Mausam.

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Printed at Kirloskar Press, Pune 411 037