Indian Institute of Tropical Meteorology

Annual Report 1997-98

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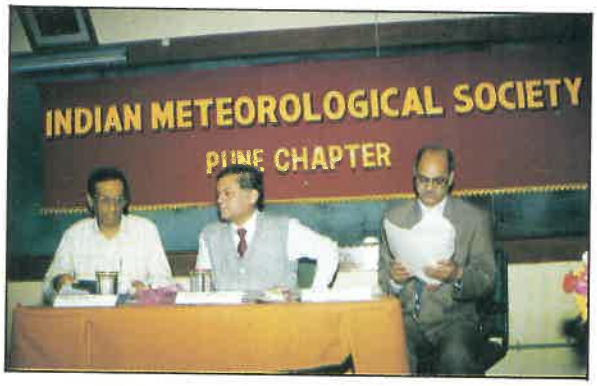
- Dr V.S.Ramamurty, Secretary, Department of Science and Technology, New Delhi visiting the Institute's exhibition at the 85th Session of the Indian Science Congress held at Osmania University, Hyderabad.



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Annual Report
1997-98

Indian Institute of Tropical Meteorology

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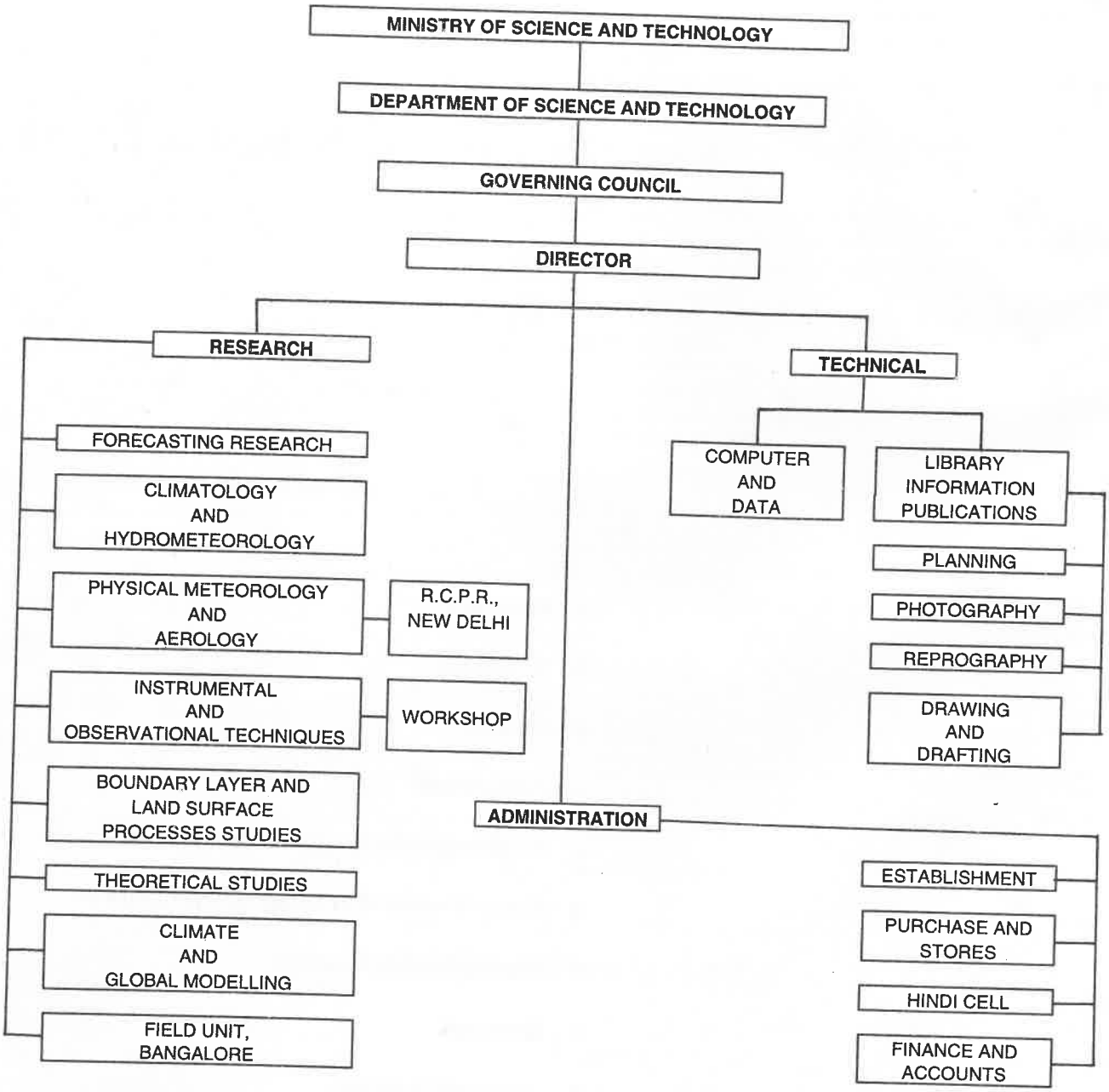
PUNE - 411 008



ORGANIZATIONAL PROFILE

Foreword

The need to understand the mechanisms of monsoon and other weather systems and climate related processes in the tropics took a concrete shape soon after the third WMO Congress in 1959 recommended the creation of meteorological research and training institutes in the tropical countries. The Institute of Tropical Meteorology (ITM) was established by the Government of India on 17 November 1962 as a part of the India Meteorological Department (IMD) at Pune. Subsequently, ITM was made an autonomous research organisation and redesignated as the Indian Institute of Tropical Meteorology (IITM), on 1 April 1971. The Institute has since grown into a leading research centre of international repute in all relevant aspects of atmospheric sciences, particularly those concerning monsoons and tropical climate.

It is my great pleasure to present the Annual Report of the Institute for the year 1997-98. In this golden jubilee year of independence of the country special references are made on various occasions about the role of Science and Technology in the building up of modern India and its achievements. On this occasion, the Institute is proud to have made major contributions to bring India into the frontlines of atmospheric and monsoon research. Meteorology and atmospheric sciences have seen tremendous research and development activities during the last few decades. The Institute has been making all efforts to keep pace with these developments.

This report provides a concise description of the various activities of the Institute. A general overview of the research results is presented in the beginning with a summary of highlights so that it serves the purpose of a reference material with complete list of research publications. Collaboration with other scientific and academic institutions has been very active both nationally and internationally. Many scientific contributions of the Institute have brought awards and recognitions to individual scientists. A high standard of research publications and presentation in symposia and seminars is maintained. Several of the Institute scientists and Research Fellows working under the guidance of Institute faculty have been awarded research degrees. High quality of infrastructural support such as library, computer, internet, accommodation, administration, finance, purchase, recreation, canteen and upkeep of the campus was provided and maintained. We have maintained close interactions with the India Meteorological Department, National Centre for Medium Range Weather Forecasting, Space Application Centre (ISRO), MST Radar Facility, Centre for Atmospheric Sciences, IIT, Delhi, Centre for Atmospheric and Oceanic Sciences, Indian Institute of Science and the Universities of Pune, Banaras and Andhra.

The Institute participated in the implementation/formulation of collaborative research programmes during the year. At international level collaboration in the field of atmospheric sciences with China, Russia, USA and UK are at different levels of implementation. Several dignitories and eminent scientists from India and abroad visited the Institute during the year. Important among these was the visit of Prof. H. Tammet, Tartu University, Estonia under the Visiting Professsorship programme of the Institute. Many Institute scientists visited the centres of studies in atmospheric sciences in

different countries of the world as members of important committees/ delegations as well as to present research papers or to work on the projects of relevance to the Institute. Technical guidance, assistance and support to several scientific organisations have been provided.

One of the important features of the Institute's programmes is the promotion of scientific collaboration with universities and other organisations. Teaching and research support is provided to universities in their M.Sc., M.Tech and Ph.D. programmes. The Institute also provided expertise to various academic institutions and scientific organisations. Institute has been organising human resource development programmes in atmospheric sciences, notable among them, during the year, are the SERC School on Advanced Geophysical Fluid Dynamics and a Short Term Course on Agrometeorology.

While it is satisfying to note the progress made by the Institute over the years, there are still many areas which need further work to refine our understanding of tropical climate/weather and its variation, particularly the Indian summer monsoon. The Institute has several projects on hand and also plans for the future, to address this need. The Institute continues to play an important role in the activities of Inter Governmental Panel on Climate Change (IPCC), International Geosphere Biosphere Programme (IGBP) and Indian Climate Research Programme (ICRP) to ensure national and international coordination of the relevant research programmes.

It is since the last five months that I took over as Director of the Institute. The progress of the Institute reported in this Annual Report is a culmination of the concerted efforts of all employees of the Institute nurtured by the able guidance of my predecessors. In this context I would like to record my sincere appreciation to the efforts of Dr. A.K.Kamra who has been looking after the current duties of the Director till 29th October 1997.

I express my sincere thanks to all employees and request them to maintain the high sense of duties and dedication so as to help the Institute to fulfil its objectives in a more effective manner. The report has been compiled and edited by the Library, Information and Publications Division of the Institute with inputs from all Divisions and Sections. I express my thanks to all Heads of Divisions for providing necessary inputs to this report and to Smt. A.A. Shiralkar, Senior Technical Officer Gr.I and her staff for editorial efforts.

G. B. Pant
Director

Highlights

The Institute has undertaken many scientific research programmes of national and international importance. The highlights of the significant achievements are summarised below :

The impact of the El Nino / La Nina on the Indian Monsoon Rainfall (IMR) was examined during the below and the above normal rainfall epochs (Kripalani and Kulkarni, Weather, 52, 1997, 39-46). Results revealed that the average standardised IMR for the El Nino cases during the below normal epochs was -1.5, whereas it was only -0.4 during the above normal epochs. This suggests that the impact of El Nino on IMR is more severe during the below normal epochs than the above normal epochs. From the rainfall data analysis it appears that perhaps the IMR is tending towards an epoch of above normal rainfall with a turning point around 1990. This may be a possible reason for India not experiencing a drought during the 1997 El Nino episode.

The pentad rainfall anomaly ratio (s) data for 52 blocks (2.5°lat x 2.5° long) over India for the period 1901-1980 for southwest monsoon season were analysed to study the impact of anomalous diabatic heating on the western part of the monsoon trough area in relation to monsoon rainfall activity in subsequent pentads. The five different classes of rainfall anomaly patterns over western part of monsoon trough area showed a definite type of evolution of rainfall activity over India. A typical class of pattern with heavy rainfall over north-west India, which evolves anomalous diabatic heating over the region, is observed to herald a weak or break monsoon condition in subsequent pentads.

The operations of Secondary Data Utilization Centre (SDUC) Workstation have been regularised and 5 INSAT cloud pictures are being archived everyday. The continuous series of daily cloud imageries is being displayed for the reference. During the year, about 750 imageries were archived and stored in the magnetic tape.

The monsoon season of 1997 was monitored day by day utilising the INSAT cloud imageries received through SDUC workstation. Though there were some gaps in the reception of daily data, the delayed onset of monsoon and its characteristic rapid advancement along west coast was brought out by the imageries. This event was demonstrated by using movie loop facility of the workstation. Similarly, various synoptic systems influencing the seasonal rainfall were also monitored and demonstrated to the scientists and the visitors.

Decadal scale variability in the Indian monsoon rainfall seems to be forced by the global scale SST anomalies. The global SST anomalies suggest good rainfall activity with fewer major droughts in India for a decade or two.

Comparison of areal raindepths of 24-26 June 1997 rainstorm with the past severemost rainstorm of 26-28 July 1927 over the North Gujarat region revealed that 1-day duration (25 June) surpassed the areal raindepths of 28 July 1927 rainstorm up to an area of 10,000 km^2 and 2-day duration (24 - 25 June) has exceeded the areal raindepths of 27-28 July 1927 up to 3,000 km^2.

Observations of atmospheric aerosols, ozone and precipitation chemistry carried out onboard ORV Sagar Kanya during its cruise No.123 in the Arabian Sea, Indian Ocean and Bay of Bengal regions during the period 12 May - 15 June 1997 were analysed. It was revealed that the rain water was found to be alkaline and the concentrations of different types of aerosols did not show significant variations as compared to the observations carried out earlier in the above regions. This indicates that there are no marked anthropogenic effects on the marine environment in the three oceanic regions.

The spectroscopic data collected at Iceland station, Reykjavik during the winter season of 1993-94 were analysed and vertical profiles of NO_2 and O_3 were retrieved. It was seen that the amplitude of the variation of NO_2 in the troposphere is more than that in the stratosphere. In case of ozone, an opposite trend was observed. The variations in the distributions of NO_2 and O_3 in the troposphere and stratosphere were explained in relation to the circulation patterns vis-a-vis other meteorological conditions.

Analysis of the continuous record of surface ozone at Pune

during the period of six years from 1991 to 1997 showed that (i) the average of hourly concentration of ozone was 23 ppb during the period of 6 years, (ii) the diurnal variation of ozone showed a peak at 1400 hours IST and followed the trend of diurnal variation of surface temperature, (iii) the annual cycle of surface ozone for each of the individual year depicted maximum concentration in April and minimum in August with an increasing trend in maximum and minimum every year, (iv) the rate of annual increase of ozone was found to be about 7% with the highest rate of increase in summer. The increasing trend in ozone concentration is attributed to the increasing anthropogenic activities around the site.

Measurements of atmospheric electric conductivity and the size distribution of aerosol particles were made onboard the ORV Sagar Kanya during the INDOEX cruise from 17 February to 30 March 1998. Earlier, the measurements of size distribution of aerosol particles were carried out at Thiruvananthapuram from 2-12 January 1998 during the intercomparison campaign under the INDOEX programme.

The Land Surface Processes Experiment funded by the Department of Science and Technology was conducted in the Sabarmati river basin of Gujarat during January 1997 - February 1998. Micrometeorological towers of 9 m height fitted with instruments at 1, 2, 4 and 8 m levels were installed at five stations viz. Sanand, Khandha, Derol, Arnej and Anand located at a spatial scale of ~100 km from one another. Data with a sampling frequency of 1 Hz and 60 sec averages were collected during 13-18 of every month (intensive observation periods (IOP)) for all the months from January 1997 to February 1998. During rest of the days in each month 10 minute averaged data were collected. The data consisted of wind speed, wind direction, temperature, humidity at 4 levels, soil temperature at near the surface, 5, 10, 20, 40, 60 cm and solar terrestrial radiation. Turbulence measurements were taken at Anand using two sonic anemometers at 4 and 8 m levels. Soil moisture at 0-15, 15-30, 30-45, 45-60 cm depth was measured during IOPs using neutron probe, capacitance probe and gravimetric method. Soil heat flux at two depths near the surface was measured at Anand using flux plates. Doppler sodar and Lyman Alpha hygrometer observations were started in February 1998. It was observed that the wind and thermal structure of the atmospheric boundary layer up to a height of 1 km can be monitored continuously with the help of Doppler sodar. Simultaneous recording of fluctuations of vertical wind (sonic anemometer) and humidity (Lyman Alpha Hygrometer) can be used to measure the latent heat flux directly. During every IOP, radiation sensors were calibrated to note down the drift in sensor response due to the continuous exposure to all the weather conditions.

Pilot balloon observations at four stations viz., Sanand, Khandha, Derol and Arnej and RS/RW observations at Anand were taken every day for five synoptic hours by the India Meteorological Department (IMD) during all the IOPs. Satellite observations of vegetation cover over the experimental area were taken by the National Remote Sensing Agency (NRSA), Hyderabad.

Spectral analysis of some of the sonic anemometer data collected during the active monsoon period of 1989 and 1990 under the MONTBLEX studies revealed the existence of buoyant subrange in the vertical wind component spectrum of the convective surface layer.

Development of the nonlinear, balance, multilevel, numerical model was completed in order to understand the rate of nongeostrophic effects in the baroclinic development of monsoon disturbances. It was found that the nongeostrophic effect plays significant role in the development of vertical structure of various low level synoptic scale disturbances.

In order to determine the physical mechanism during the onset of El Nino of 1997, computations of global nonlinear, kinetic energy exchanges into individual triad interactions in frequency domain from surface to 100 hPa, were performed for the period March 1994 to August 1997. The results indicated that the nonlinear barotropic scale interactions of 30-50 day oscillations play a significant role in the onset of El Nino of 1997.

The influence of SST boundary forcings versus initial conditions in the seasonal variability of simulated summer monsoon was examined for 15 monsoon seasons (1977-1993) with 9 member ensembles for each season. The variability due to initial conditions was found to be much larger during El Nino as compared to La Nina years. Overall interannual variability of ensemble mean rainfall is small compared to observations. Real time prediction with Hadley Centre Climate model with persistent SST anomalies of May 1997 indicated .a deficient monsoon rainfall.

A note on " El Nino and Indian summer monsoon rainfall - June to September '97 " was sent to Voice of America, some 100 scientists in America, Europe, Australia and Japan, India Meteorological Department and the Department of Science and Technology, New Delhi by Prof. G. C. Asnani, Honorary Fellow of the Institute mentioning that the downward motion of the Walker Circulation in the western Pacific associated with El Nino of 1997 did not reach India. Over the Indian Ocean, near equator, sea-surface temperature was above normal and the Walker Circulation had rising motion during June to September 1997. Indian summer monsoon rainfall (June to September 1997) was normal, in spite of fears of adverse effect of El Nino.

Appointment of Director

Dr. A. K. Kamra, Deputy Director contiuned to look after the current duties of the Director till 28 October 1997. On appointment as regular Director Dr.G.B. Pant assumed the charge on 29 October 1997.

IITM Silver Jubilee Awards

The Annual Silver Jubilee Awards for the following scientific papers were announced during the year 1997-98 :

- *Study of laser scintillation in different atmospheric conditions,* Raj P.E., Sharma S., Devara P.C.S. and Pandithurai G., Journal of Applied Meteorology, Vol.32, 1993, 1161-1167 (Award for the year 1993).

- *An optical scintillometer for simultaneous measurements of atmospheric* C_n^2 *and winds,* Sharma S., Devara P.C.S., Raj P.E. and Pandithurai G., Journal of the IETE, Vol. 40, 1994,101-104 (Award for the year 1994).

- *Universal spectrum for Interannual variability in COADS global air and sea-surface temperature,* Selvam A.M. and Joshi R.R., International Journal of Climatology, Vol.15,1995,613-623 (Award for the year 1995).

- *Ring-width variations in cedrus deodara and its climatic response over the western Himalaya,* Borgaonkar H.P., Pant G.B. and Rupa Kumar K., International Journal of Climatology, Vol. 16 , 1996, 1409-1422 (Award for the year 1996).

The Awards for the years 1993, 1994 and 1995 were presented by Dr.A.P.Mitra, FRS, Honorary Scientist of Eminence and Senior Homi Bhabha Fellow, National Physical Laboratory, New Delhi at the inaugural function of the Fourth SERC School on Advanced Geophysical Fluid Dynamics held at the Institute on 2 June 1997.

Honour

Dr. A. K. Kamra, Deputy Director has been elected as a Fellow of the Indian Academy of Sciences, Bangalore.

The biographical data of Dr.(Smt.)A. M. Selvam, Deputy Director and Dr. (Smt.) N. A. Sontakke, Junior Scientific Officer have been included in the 15th edition of " Marquis Who's Who in the World 1997 ".

Release of Book

A book entitled, 'Climates of South Asia' authored by Dr.G.B. Pant and Dr.K.Rupa Kumar of the Institute and published by John Wiley and Sons, U.K. was released by Dr.A.P.Mitra, at the inaugural function of the Fourth SERC School on Advanced Geophysical Fluid Dynamics held at the Institute on 2 June 1997.

Visiting Professorship Programme

Prof. Hannes Tammet, Department of Environmental Physics, Tartu University, Estonia visited the Institute during 2-28 January 1998 under the Visiting Professorship Programme of the Institute. During his visit Prof. Tammet delivered a series of lectures on Atmospheric Electricity and had interactions with the scientists of the Institute.

Participation in Expeditions

The Institute's scientists participated in the Cruise No.123 of the ORV Sagar Kanya for a period of one month from 15 May 1997 and took observations onboard the ship in connection with the study of physical, chemical and optical characteristics of aerosols, trace gases and precipitation chemistry over the marine environment.

Under the INDOEX Programme scientists of the Institute took measurements of atmospheric electric conductivity and size distribution of aerosol particles at Thiruvananthapuram and onboard the ship ORV Sagar Kanya during 2-12 January 1998 and 17 February - 30 March 1998 respectively.

Participation in International Meetings

Dr. A. S. R. Murty, Deputy Director attended two meetings viz. (i) 19th Session of the WMO Executive Council Panel of Experts/CAS Working Group on Physics and Chemistry of Clouds and Weather Modification Research at Geneva, Switzerland during 5 - 9 May 1997, and presented the state-of-the art report on warm cloud modification, cold cloud modification, fog modification and reviewed the trends and changing perceptions in weather modification technology, and (ii) 3rd meeting of the Indo - Russian sub - working Group on Meteorology held at Moscow and Nalchik, Russia during 10-16 September 1997.

Dr. A. K. Kamra, Deputy Director participated as a Principal Delegate from India in the Twelfth Session of the Commission for Atmospheric Sciences (CAS) of the WMO at Skopje, Republic of Macedonia during 23 February to 4 March 1998.

Dr. G. B. Pant, Director participated as a Member of the Scientific Steering Committee of a Workshop on Rapid Nonlinear Climate Change organised by the IPCC at Noordwijkerhout, The Netherlands during 31 March to 2 April 1998.

Participation in Bilateral Research Meetings

Dr. G. B. Pant, Deputy Director attended a meeting with the Chinese delegation at the India Meteorological Department, New Delhi during 21-25 October 1997. Various aspects of co-operation in the field of meteorological science and technology between the China Meteorological Administration and the India Meteorological Department were discussed at the meeting. It was agreed that IITM will be one of the collaborating institutes from Indian side for the themes, (i) Monsoon Studies including TIPEX, (ii)Typhoons and Tropical Cyclones, and (iii) Radar Meteorology and Atmospheric Chemistry.

Dr. A. K. Kulkarni, Assistant Director participated in the meeting of Technical Advisory Review Committee (TARC) at the Water and Power Consultancy Services (WAPCOS), New Delhi during 7-10 October 1997 for finalization of the reports on PMP estimation for Chambal, Betwa, Sone, Mahi, Godavari, and Cauveri river basins. A report on 'Estimation of Probable Maximum Precipitation (PMP) for the Krishna River Catchment above the Nagarjunasagar dam' was sent to the Central Water Commission, New Delhi.

A delegation of Institute scientists participated in the Indo-US Workshop on Co-operation in Earth and Atmospheric Sciences organised by the India Meteorological Department, New Delhi and also in a Planning Meeting prior to the Workshop during 8-12 February 1998.

Technical Guidance/Assistance

Technical guidance was provided to the Government of Karnataka (Karnataka Power Corporation Limited) for their proposed cloud seeding operations over the catchment areas of Linganamakki and Supa.

As a part of the IITM-SAC scientific collaboration project on "Atmospheric Aerosol Loading over Land from IRS-P3 MOS Sensor's Data", special observations of atmospheric aerosols using the ground-based lidar and radiometers were carried out at the Institute and Khadakwasla Dam site on the days when the satellite overhead passes were available over Pune.

A field experiment was conducted during 1-5 May 1997 for the Society for Applied Microwave and Electronic Engineering Research (SAMEER) at Mumbai for validation of wind measurements taken on their indigeneously developed doppler sodar with that of the Institute's kytoon system.

Technical guidance was also provided to the Central Sericultural and Training Research Institute, Mysore in the installation of an imported micrometeorological tower.

SERC School

Under the DST sponsored five year cycle of SERC Schools on Advanced Geophysical Fluid Dynamics the Fourth SERC School with special emphasis on Dynamics of Climate and its Variability was held at the Institute during 2 June - 5 July 1997. Dr. A. P. Mitra, FRS, inaugurated the SERC School on 2 June 1997. Forty participants from various universities/ organisations selected on all India basis attended the SERC School. The Valedictory Function of the SERC School was held on 5 July 1997. Dr.V.R. Gowarikar, Vice Chancellor, University of Pune, was the Chief Guest and Shri D.R.Sikka, Retired Director of the Institute was the Chairman of the function. Participants of SERC School were given certificates at the hands of the Chief Guest.

Organisation of Meetings, Trainings, Workshops etc.

Meetings of the Project Advisory and Monitoring Committee for Monsoon and Tropical Climate (MONTCLIM) and the Indian Climate Research Programme (ICRP) of the DST were organised at the Institute on 15 May 1997. The Committee discussed the implementation plan for the ICRP. This was followed by the ICRP meetings on 15 and 16 May 1997. Forty scientists representing research institutions and universities all over the country participated in the meetings.

A meeting was held at the Institute on 13 October 1997 to review the collaboration between IITM and the Space Applications Centre (SAC), Ahmedabad on IRS-P3 data validation experiments and plan activities on the IGBP WG-IV experiment on evolving atmospheric correction scheme for the remote sensed data during 1997 - 2001 .

A short term Training Course on "Agrometeorological Data, Monitoring and Management" for the nodal officers of Agrometeorological Advisory Services of the NCMRWF was organised at the Institute during 8-20 December 1997. The training course sponsored by the DST was attended by twenty scientists from all over India.

Annual Monsoon Workshop -1997 organised by the Indian Meteorological Society, Pune Chapter was held at the Institute on 29 December 1997.

Report on Measurement at Antarctica

A primary report on Atmospheric electrical measurements at Antarctica entitled, "Measurement of the Atmospheric Electric Field, Conductivity and Size Distribution of Aerosol Particles" by Deshpande C. G. and Kamra A.K. was submitted to the Department of Ocean Development, New Delhi.

Reports on INDOEX Results

The following reports on the Institute's participation in the INDOEX expeditions were submitted to the INDOEX India Programme, Bangalore:

- Atmospheric Electric Conductivity and Electric Field in the Indian Ocean as Measured during the Cruise No.120 : Gopalakrishnan V. and Kamra A.K. (Results of Pre-INDOEX Cruise No.120 of ORV Sagar Kanya, Report No. INDOEX - SR - 97 - 03)

- A Preliminary Report on the Aerosol Data Collected during the INDOEX-Intercomparison Campaign at Thiruvananthapuram : Murugavel P. and Kamra A. K. (Intercomparison Campaign of INDOEX at ISRO, Thiruvananthapuram, 6-9 January 1998)

International Day for the Preservation of the Ozone Layer

The General Assembly of the United Nations, by one of its Resolutions, has designated the 16 September of each year as the International Day for the Preservation of the Ozone Layer. 16 September 1997 was the Tenth Anniversary of the signing of the Montreal Protocol for Preservation of the Ozone Layer. The Institute celebrated this Day by organising a popular talk on "The Ozone Crises" by Dr. C. R. Sridharan, Deputy Director General of Meteorology (Retd.), Pune and an exhibition of books, reports, research papers and charts on the Ozone Studies. On this occasion, an article, "Atmospheric ozone, a friend and foe"

by Dr. L. S. Hingane, Assistant Director was also published in 'Pune Herald'.

Participation in the Indian Science Congress

The Institute participated in the Science and Technology Exhibition organised at the 85th Session of the Indian Science Congress held at the Osmania University, Hyderabad during 3-8 January 1998. The theme of the exhibition was "Swarnabharathi Science and Technology".

National Science Day

The Institute organised the National Science Day Celebrations spanning over the period of a week beginning on 23 February 1998. The theme for the celebration was "Fifty Years of Independence". On this occasion an open-house exhibition depicting the research activities of the Institute, and visit of general public and students to laboratories and computer centres were arranged. Two popular lectures viz., (i)Meteorological communications by Prof. Pramod Kale, Director (Retd.), Space Applications Centre, Ahmedabad and (ii) Puzzles of Universe by Prof. Govind Swarup, Professor Emeritus, Giant Meterwave Radio Telescope Project (TIFR) and National Centre for Radio Astrophysics, Pune were organised on 26 and 27 February 1998 respectively. A large number of public, students and media personnel visited the Institute, attended the lectures and had interactions with the scientists.

A National Science Day talk on "Meteorology in the service of mankind" by Dr. G. B. Pant, Director of the Institute was broadcast by the All India Radio, Pune Station at 8:15 PM on 26 February 1998. An interview with the Director on the importance of Science Day was published by the Times of India, Pune Edition.

World Meteorological Day

The Institute organised the celebration of the 38th World Meteorological Day on 23 March 1998. The theme of the Day was "Weather, Oceans and Human Activities". On this occasion, an open-house scientific exhibition was arranged. The Institute was open for the public, students and media people. The response of the visitors was overwhelming. Broadcasting of interview, telecasting of celebration and publication of article, interview and report on the theme of the celebrations were arranged by the respective media. An interview on the theme of the Day by Smt. A. A. Shiralkar, Senior Technical Officer, Gr. I was published by the Times of India, Pune Edition.

Distinguished guest at the Ozone Day Exhibition

Young visitors at the Exhibition on National Science Day

Open House Exhibition on World Meteorological Day

Scientists receiving the IITM Silver Jubilee Awards (from left Dr. P.C.S.Devara, Dr.P.E.Raj, Shri. G.Pandithurai and Smt. R.R.Joshi)

Forecasting Research

The research programmes of the Forecasting Research Division are formulated for understanding and prediction of monsoon on short-, medium-, and long-range scales with the following objectives :

- Study of sensitivity of the global and regional model forecasts to the physical processes
- Study of the planetary boundary layer characteristics
- Application of satellite data in the objective analysis and monsoon studies
- Interannual and longer term variability of Indian monsoon rainfall (IMR) and establishing relation between new predictors.
- The decadal scale variability in ENSO and the North Atlantic Oscillation (NAO)
- Study of association of heat source and moisture sink during June-July with the stagnation of monsoon

NWP Modelling and Model Diagnostics

The limited area model (LAM) was integrated with control and modified physics for five cases of monsoon depressions with data extracted from the daily analyses, provided by the National Centre for Medium Range Weather Forecasting, New Delhi for further evaluation of forecasts with modified physics. The average skill-scores computed, when compared for both the runs, showed an improved forecast for mean-sea-level pressure and temperature which are also found to be statistically significant.

The revised Betts-Miller Scheme suggested by Janjic (1994) was incorporated in the LAM. The model was integrated up to 72 hours using the input data of five depression cases using six sets of adjustment parameters. All these experiments were repeated with the original version of Betts-Miller scheme also. The revised version was found to produce superior forecast results as compared to the original version.

A new boundary layer vertical diffusion parameterization scheme was incorporated in T80 GSM and tested. Preliminary results for a case of monsoon depression over Indian region showed an improved precipitation forecast associated with the depression.

A linear relationship between the height of freezing level (HFL 0°c isotherm height) and the surface meteorological elements viz. dry-bulb temperature (DBT), dew-point temperature (DPT), surface pressure (SP) and rainfall (RF) was studied with the routine daily surface meteorological and radio-sonde observations of 00 and 12 GMT from June to October for 5 years (1988-1992) at some selected Indian stations viz. Ahmedabad, Bangalore, Calcutta and Madras. The results of this study revealed that i) the relationships between HFL and DBT, DPT, SP and RF, in general, are weak and ii)a positive correlation between HFL and RF exists in the monsoon months due to the occurrence of warm rainfall from below the freezing level (4.5 - 6 km), whereas a negative correlation between HFL and RF is found in the month of October. This is mainly due to the cold rainfall from above freezing level (3.5-12 km). The cold rainfall occurs due to convective cloud development with the advancement of North-east monsoon during October which brings cold air mass into the region near Madras and Bangalore.

A semi-permanent trio-system viz., 'heat low' over Sind and Western Rajasthan, 'monsoon trough' along Gangetic plains and 'surface ridge at 74°E' along the Western Ghats and Aravali hill range appears in the lower troposphere up to 700 hPa during the peak summer monsoon period (July-August) over the Indian subcontinent. A small change in the position of the axis of any one of these systems appears to affect the axes of the other two systems which in turn regulate the monsoon circulation over Central India. As the 'induced low pressure areas (ILPA)' move along the monsoon trough (Fig.1), successive changes take place in the triosystem as well as in the transfer properties of the land-air interface all along the monsoon trough region (17-35°N, 60-95°E). In a case study of ILPAs during the period 26 July-10 August 1990 using MONTBLEX-1990 tower observations and daily routine weather data of the India Meteorological Department, it was noted that as long as the

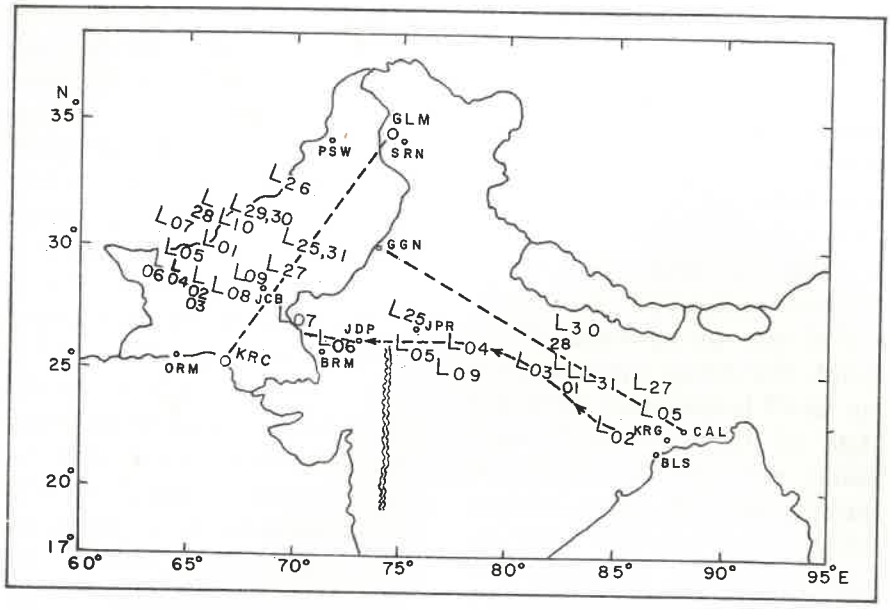


Fig. 1 : Positions of Induced Low Pressure Areas (L) during 25 July-10 August1990 in the monsoon trough region .

surface ridge is strong, it protrudes northwards towards Jodhpur thereby pushing the monsoon current that comes from the north Arabian sea further northwards and bifurcating the southwesterly wind towards the heat low and the other into the monsoon trough. In the presence of such a strong ridge 'short break' like situations develop in the monsoon flow, as a result the monsoon trough shifts further northwards. Large surface dryness appears to prevail in the western sector (Fig.2) of the monsoon trough before ILPA moving into it, followed by the surface wetness during the rainy days. However, in the eastern sector (Fig.3) there existed an uniform wetness with continuous availability of moisture. Surface fluxes of momentum and sensible heat fluxes were strong during non-rainy days in the western sector while they were weak in the eastern sector during the entire period.

Objective Analysis including Satellite Input for NWP Models

Objective analyses of wind field at 850 and 200 hPa for two cases of monsoon depression viz. (i) 2 - 5 August 1988 and

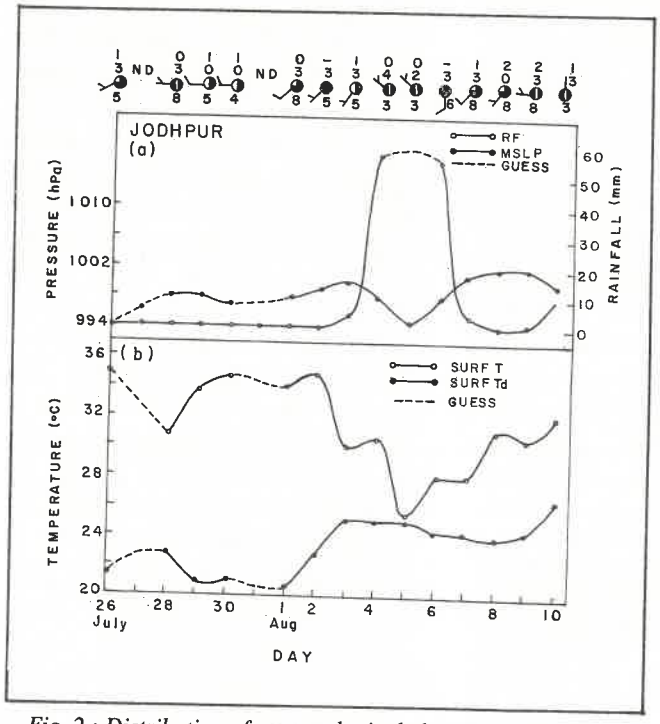


Fig. 2 : Distribution of meteorological elements of 12 UTC during 26 July-10 August 1990 at Jodhpur (Western Sector of monsoon trough)

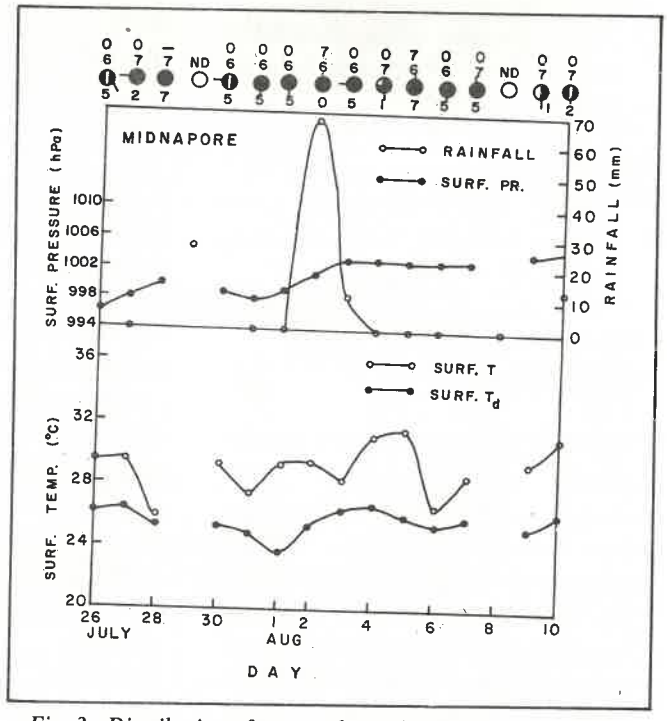


Fig. 3 : Distribution of meteorological elements of 12 UTC during 26 July-10 August 1990 at Midnapore (Eastern Sector of monsoon trough)

(ii) 28-30 July 1991 were made by using optimum non-linear iterative correction scheme. In this scheme the weights of the linear optimum interpolation scheme are modified by using the height field estimated by balance equation. This technique would be useful for handling satellite data like radiance etc. or data having nonlinear relationship with the parameter to be analysed.

A scheme for incorporating the gradient effect of geopotential height for the objective analysis was developed and tested for 4-8 July 1979. Analysis made with this scheme depicts the synoptic situation better than the usual Optimum Interpolation (O.I.) Scheme specifically over data sparse region.

The assimilation of SATEM data for geopotential height field was carried out for 27-31 July 1991 at 700 hPa by the successive approximation method. The analysis showed significant improvement over the conventional O.I. scheme.

Using satellite microwave radiometry data obtained from the Defence Meteorological Satellite Program's (DMSP) satellite, evolution of complete life cycle of monsoon depression (14-16 June 1991) in terms of geophysical parameters (integrated water vapour, surface wind speed, integrated cloud liquid water and precipitation rates) was studied over the Indian region. Intensification of surface winds (12-15ms^{-1}) to the south of low pressure area over a larger oceanic region prior to the formation of depression, higher values of integrated water vapour (60-70 kgm^{-2}) over the central Bay throughout the life cycle of depression and highest values of integrated cloud liquid water and precipitation rates (1.8 kg m^{-2}; 6-15 mmh^{-1}) in the south-west sector of the monsoon depression were the salient features observed in the study.

A comparative study of satellite-derived radiative energy budget parameters such as short-wave radiative heating, longwave radiative cooling and net radiative effect was carried out at each 100 hPa layer from surface to 100 hPa over the domain 40°-100°E and 30°S-30°N for different phases of summer monsoon 1979. Maximum net radiative heating rates of the order of 0.23°c/day, 0.22°c/day and 0.28°c/day at 100-200 hPa and minimum net radiative heating rates of the order of -0.39°c/day, -0.61°c/day at 500-600 hPa layer were found to be associated with pre-onset, onset and post-onset phases of summer monsoon respectively. These satellite-derived radiative energy budget characteristic features were in good agreement with the observed features of the total radiative energy budget over the domain of the study.

Extended Range Prediction

Three snow-depth data sets viz., Nimbus-7 SMMR, NCEP / NCAR Reanalysis and Historical Soviet Snow were compared with the Indian monsoon rainfall variability. All the three data sets showed a high inverse relationship between January snow depth surrounding Moscow and the subsequent Indian monsoon rainfall. The inverse relationship implies that the heavier (lighter) than normal snow depth surrounding Moscow during January leads to a deficient (excess) Indian monsoon rainfall, consistent with the known snow monsoon hypothesis. However, the snow depth variations between Mongolia and Siberia showed inconsistent results, Nimbus-7 SMMR showed significant negative relationship, Soviet snow showed significant positive relationship while the NCEP/NCAR Reanalysis showed insignificant relationship. This also shows that the snow variations over localized regions are more important than that over the entire Eurasia.

The interannual variability of the Indian monsoon rainfall was examined in relation to the summer monsoon rainfall variability over Korea using recent 20 years data (1974-93). The rainfall of Korea for the month of August was found to be inversely related with the All India Monsoon Rainfall, significant at 1% level. Further, the interannual variability of the Outgoing Longwave Radiation (OLR) over the Indo-Pacific region (30°N-30°S, 40°-120°E) was analysed in relation to the summer rainfall (May through September) variability over Korea. Two centres of maximum (concurrent) correlation coefficient were found to be located near 15°N, 65°E and 20°S, 55°E, significant at 5% level, showing a dipole structure of relationship over the region.

The inter-seasonal (winter, spring, summer and fall) rainfall distribution was examined by Empirical Orthogonal Function (EOF) analysis over the eastern equatorial Indian Ocean (10°N to 16°S, 60° to 100°E) using the GPCP (Global Precipitation Climatology Project) pentad rainfall data for the period 1986-1993, derived by the Polar orbiting NOAA satellites. The analysis revealed that the variance explained by the first four EOFs coincides well with the organized rainfall distribution which is associated with the maximum cloud bands formed in the wake of both the northern and southern hemispheres equatorial troughs aligned in an east-west direction.

Thirty years data (1964-1993) of 5-day rainfall over a subdivision, categorised as no precipitation, isolated, scattered, fairly widespread and widespread rainfall as defined by the India Meteorological Department, were used to develop a 5-state, 1st order Markov Chain model and were cross validated on independent data of three years (1994-1997). The Heidke skill score showed the skills varying from 0.1 to 0.34.

The observed frequency distributions of 5-day and 7-day rainfall over 2.5° Lat./2.5° Long. blocks over India were formed to develop the finite state discrete Markov models for different coherent regions of India. This could be an aid to the operational forecasters to predict monsoon rainfall semiquantitatively on medium-range scale with some degree of confidence.

The Indian Monsoon Rainfall series from 1813 to 1994 was subjected to Box-Jenkins methodology after prewhitening it by the application of different filters to eliminate the deterministic components such as ENSO, QBO and sun spot cycles. Results showed that the decadal variability of Indian monsoon rainfall can adequately be modelled by class of Box-Jenkins type of models. In particular, AR(2) to AR(4) models explain over 80% of variance of smoothed Indian monsoon series, irrespective of type of filters used to isolate the stochastic variability of Indian monsoon on decadal time scale.

To investigate the relationship between the NPO (North Pacific Oscillation) and the monsoon rainfall, analysis was carried out for 92 years of data (1906 to 1997). The analysis revealed that during AB mode of NPO (which is defined as the below normal Alaska temperature and Above normal Edmonton temperature), all India monsoon rainfall tends towards positive side of the normal and AA mode (reverse of AB mode), the rainfall tends to the negative side of the normal. The association between these modes and rainfall was tested with chi-square test and it is seen that the relationship is highly significant at 0.1 % level.

The analysis of the decadal scale variability in El Nino Southern Oscillation (ENSO) and North Atlantic Oscillation (NAO) was carried out for 107 years of data (1881-1998) for the four seasons, winter (December-January - February), Spring (March - April - May), summer (June-July-August) and autumn (September-October-November). Analysis revealed that the decadal variability in the southern oscillation is greater in spring when compared with winter, summer and autumn. The decadal variability in the NAO is larger in all the seasons except in spring as compared with the decadal variability in ENSO.

Monsoon Studies and Forecasting

The pentad rainfall anomaly ratio data for 52 blocks (2.5° lat. x 2.5° long.) over India for the period 1901 - 1980 for south-west monsoon season were analysed to study the impact of anomalous diabatic heating on the western part of the monsoon trough area in relation to the monsoon rainfall activity in subsequent pentads. In this study the anomalous diabatic heating was represented by the anomalous heavy rainfall activity. For this purpose a test area was selected extending from 20° to 25°N and 70° to 72.5°E over India. The average rainfall anomaly ratio for the test area in a pentad was categorised in five different classes C1 to C5 with range of values -1 to 1, 1 to 3, 3 to 5, 5 to 7 and >7 respectively. The distribution of pentad rainfall anomaly ratio for the subsequent three pentads was supposed to represent evolution of monsoon rainfall activity in each case. Mean patterns for all the classes were obtained and analysed. The mean pattern of evolution for class C5 showed similarity with evolution

of break phase over India. This analysis distinctly showed two possible ways of tropical mid-latitude interaction over India leading to weak and break phase in class C4 and C5 respectively.

The study on the estimation of heat source (Q_1) and moisture sink (Q_2) over India for June-July 1991 showed that during the onset phase centres of large positive vertically integrated heat source ($<\overline{Q}_1>$) and vertically integrated moisture sink ($<\overline{Q}_2>$) moved northward across the peninsula up to Gujarat. Subsequent to this period, the monsoon trough area and the Head Bay of Bengal showed low positive/negative values of ($<\overline{Q}_1>$) and ($<\overline{Q}_2>$) till 12 July. Fig. 4 shows the 2-day average $<\overline{Q}_1>$ distribution for selected epochs from 5 June to 26 July. Fig. 5 shows the 2-day average relative vorticity ($\overline{\zeta}$) at 700 hPa for the period 5 June to 26 July. The centre of large positive vorticity in association with movement of a low pressure area moved northward during 5-10 June. Subsequently, low positive/negative values of ($\overline{\zeta}$) were observed up to 12 July and large positive values got reestablished in the trough area. The monsoon was observed to stagnate over Gujarat for over 30 days. The study showed that the intense diabatic heating during the onset of monsoon in association with the large amount of rainfall up to Gujarat might have caused the stagnation of monsoon.

The advancement of monsoon, which is crucial for sowing

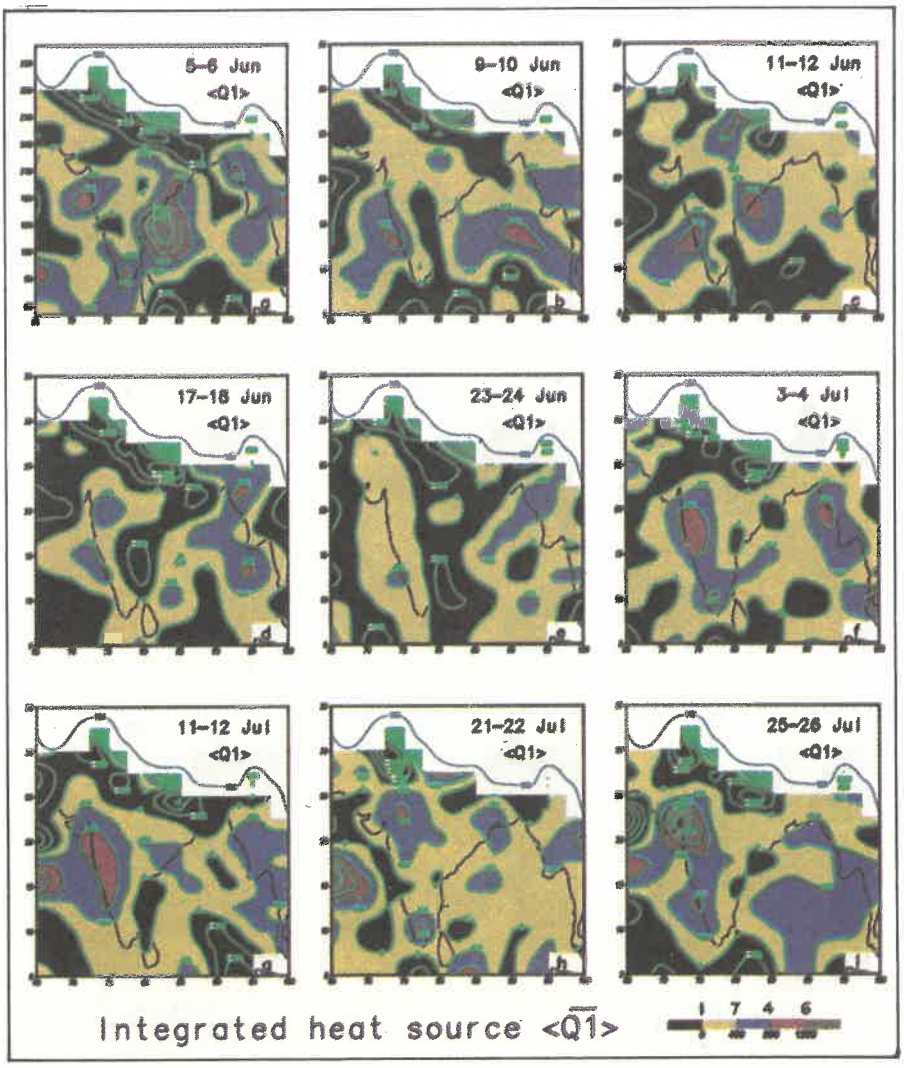


Fig. 4 : Two-day average vertically integrated heat source ($<\overline{Q1}>$) for selected epochs during June-July 1991 (Unit : w/m^2)

operations over different parts of India was studied for the period 1965-1997. The advancement along the west coast of India was found to progress in two stages viz. Tiruvanthapuram to Dahanu (20°N) and then from Dahanu to northwest India; and their durations of advancement are inversely related. The trend in advancement of monsoon over western India indicates speeding up of monsoon towards Gujarat and proceeding rather slowly thereafter, keeping the normal period of coverage from Kerala to northwest India, unchanged during the past three decades.

The spatial coverage of pentad rainfall over the subdivisions of India during summer monsoon (June - September) was examined on the basis of thirty years (1964-1993) data of the spatial states of daily subdivi-

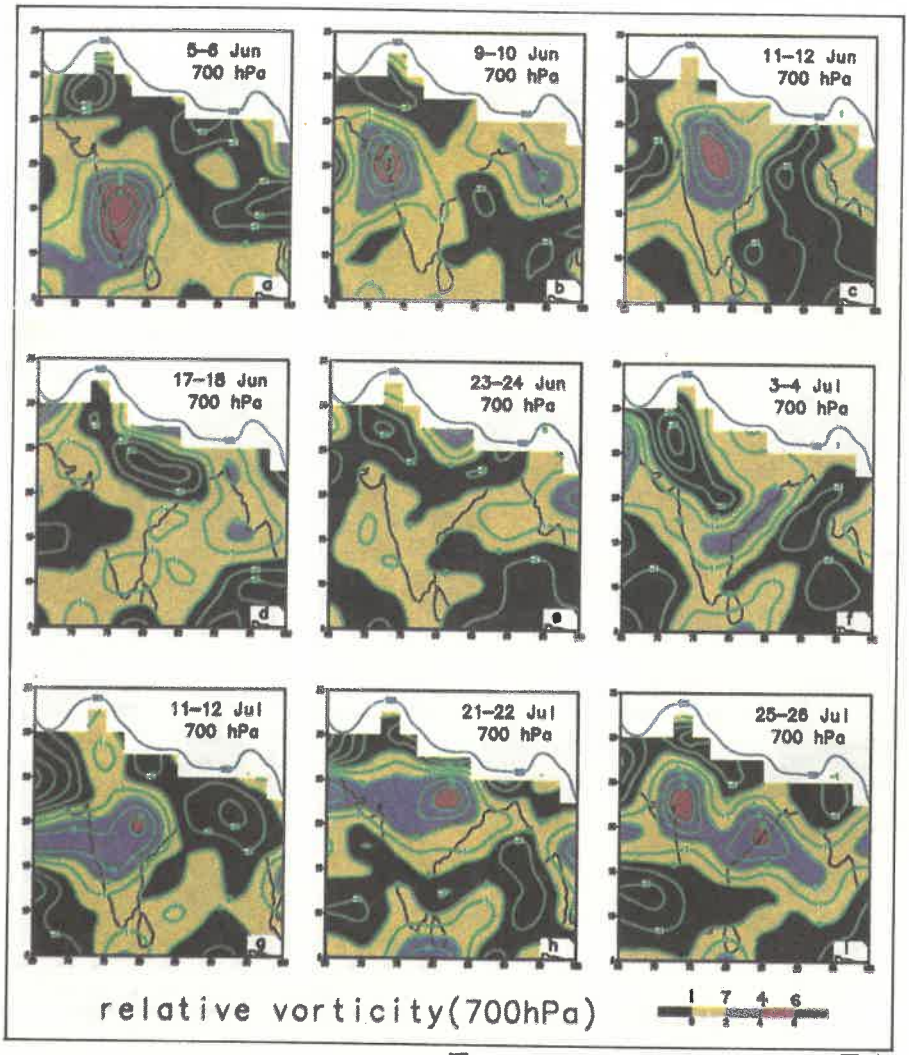


Fig. 5 : Two-day average relative vorticity ($\bar{\zeta}$) at 700 hPa level for selected epochs during June-July 1991 (unit : 10^{-5}/s)

sional rainfall, reported by the India Meteorological Department as : (i) No rain; (ii) Isolated (<25% to 50% area); (iii) Scattered (26% to 50% area); (iv) Fairly Widespread (51% to 75% area); and (v) Widespread (> 75% area).

The pentad rainfall spatial states were derived from the daily data. The first order Markov dependence among them was statistically tested and a five state discrete type Markov Chain model of order one was developed for each subdivision to predict the spatial dependence among the self and mutual states. The stochastic matrix for a subdivision gave the probable evolution of rainfall state, subsequent to known current state. The model was cross-validated on the independent data set of four years (1994-1997).

It was found that the success of the model in predicting the pentad rainfall spatial states over various subdivisions varies from 28% to 67% with skill score up to 0.28.

Daily grid-point u,v, data for the period from 1 June-31 August 1991 for the Global belt between equator and 40°N at 850 hPa were subjected to space and time spectral analysis. The results indicated that (i) the wave number 1 is dominated by 30-40 day oscillations , (ii) short waves are dominated by weekly and bi-weekly oscillations, and (iii) temporal variations of wave number 2 over Region 1 (equator - 20°N) and Region 2 (20° - 40°N) are almost found to be identical.

Energetics, energy conversion processes and transport processes of zonal waves at 850 hPa for the recent monsoon seasons of 1994, 1995 and 1996 were studied. The results indicated that the pattern of energy conversion processes during these three normal rainfall seasons, do not show marked year to year variations. Energy conversion processes over tropical regions are dominated by standing waves extra-tropical (transient waves). Standing waves, 1 and 2 over the regions 10°S - 10°N controls energy conversion processes of the region 10° - 30°N. Transport processes indicate that zonal strip around equator (15°N) represent region of divergence (convergence).

Climatology and Hydrometeorology

Climate is a natural resource that is vital for the availability and quality of food, water, shelter and lifestyle. Climate is also a potential hazard which manifests itself particularly through climate extremes. Therefore, knowledge of climate is necessary to mitigate the consequences of climate hazards, such as droughts and floods.

Variability in the climate over the Indian region on different spatiotemporal scales, particularly the activity of the southwest monsoon, has significant impact on agricultural production, water resources management and overall economy of the country. Currently there is an enhanced emphasis on the studies of global and regional climate change, subject to natural variations on all time scales, with possible alterations by human activities. To assess the magnitude and impact of climatic variations and to develop predictive capabilities, detailed analysis of the climatic records of the recent past, observed as well as proxy, and development of appropriate statistical and dynamical models is essential. Likewise, the analysis of long records of short-duration precipitation data over different river basins of the country is essential for the planning and utilization of water resources of the country.

The research programmes formulated by the Climatology and Hydrometeorology Division for the study of regional climate and climatic change on different time scales and hydrometeorological problems of various regions of the country have the following objectives :

- To construct the longest available homogeneous time series of regional climatic elements from observed meteorological data, historical records and dendroclimatic reconstructions, and to study their behaviour on interannual, decadal and longer time scales

- To develop empirical prediction models for the seasonal total rainfall over the country as a whole and the homogeneous subdivisions of the country

- To make comprehensive analyses and model the global and regional atmospheric and oceanic parameters and their teleconnections with the Indian summer monsoon rainfall, to understand the nature of these relationships and their predictive capabilities

- To assess the numerical simulations of global climate, with particular reference to the simulation of the Indian summer monsoon, by means of model output diagnostics

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

- Estimation of probable maximum precipitation, depth-area-duration analysis of severe rainstorms and development of quantitative precipitation forecast schemes

Climate and Climatic Change

Variability and Prediction of the Northeast Monsoon

Longest instrumental northeast monsoon rainfall (October-December total) series has been reconstructed for six different zones viz., (I) North West India (1844-1996), (ii) North Central India (1842 - 1996), (iii) North East India (1829-1996), (iv) West Peninsular India (1841-1996), (v) East Peninsular India (1848-1996), and (vi) South Peninsular India (1813-1996). The series has also been constructed for the whole India (1813-1996). These different series displayed homogeneous characteristics. Large-scale features of the summer monsoon and the northeast monsoon are significantly positively correlated (CC=0.34). The different circulation parameters that have shown significant correlation with the summer monsoon also showed correlation, albeit weaker in strength, of the same sign with the northeast monsoon.

Low frequency mode fluctuations, obtained through Singular Spectrum Analysis, were extrapolated by carrying out a non-integer harmonic analysis and later by combining these harmonics which showed the highest correlation. Model fitted values (up to 1986), 10 years independently estimated values (1987-1996) and 10 years future predicted values 1997-2006 are shown in Fig. 6 for the different regions of the country.

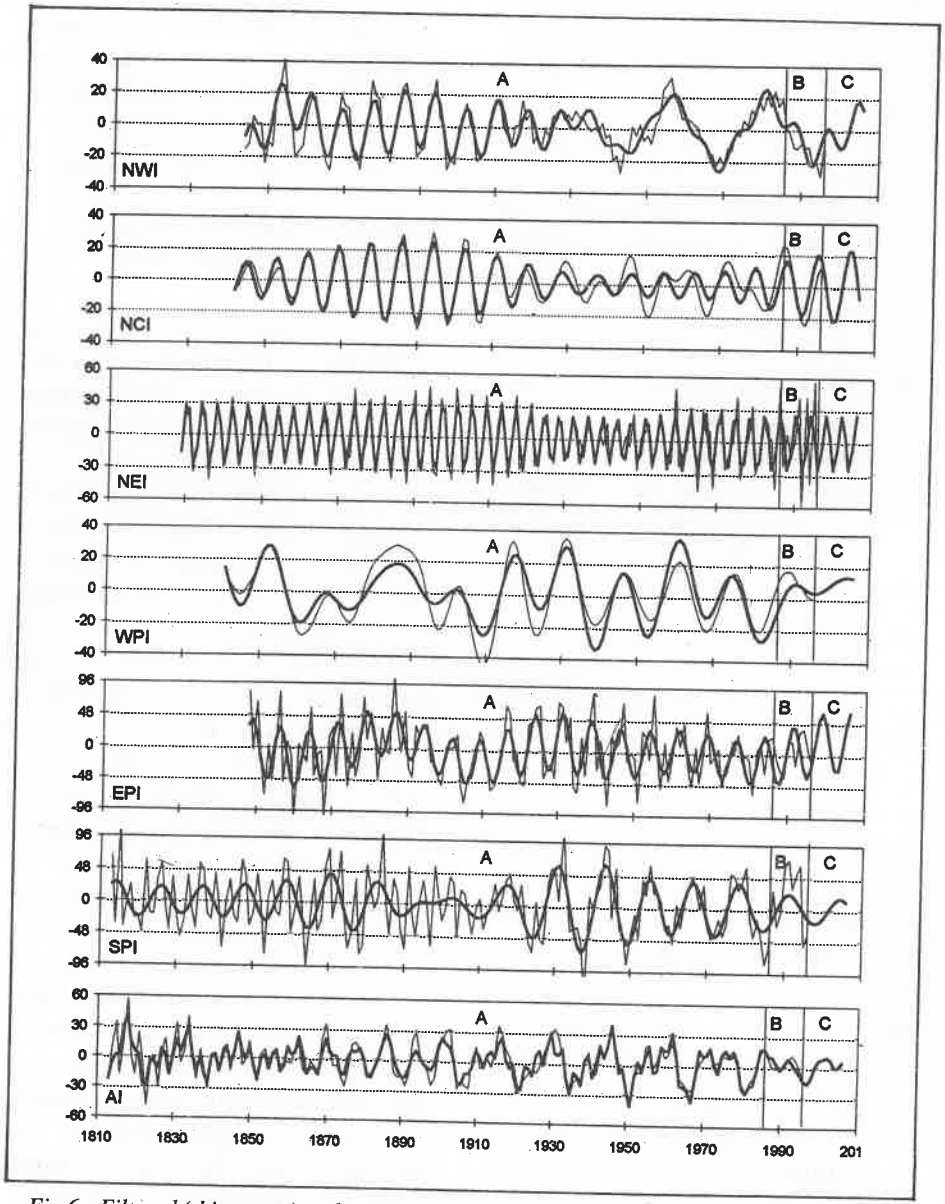


*Fig 6 : Filtered (thin curve) and estimated (thick curve) Northeast monsoon rainfall series of the six zones and the country. **A** : the dependent sample period (from start of the series up to 1986). **B** : independent sample period (1987-1996). **C** : prediction for 10 years future period(1997-2006).*

Decadal Scale Variability of Indian Monsoon Rainfall

Decadal scale variability in Indian monsoon rainfall seems to be forced by global scale SST anomalies. The analyses of SST Index (Southern Hemisphere minus Northern Hemisphere ocean temperature anomalies) for a 120 year period (1871-1990) for three months of monsoon from July to September showed that the two periods viz., 1901-1920 and 1965-1990 in which India witnessed frequent droughts, broadly correspond with warm SST index. The reverse trend of the SST index (cooling) started from 1990 and is likely to continue for one or two decades suggesting good rainfall activity with less frequent droughts for the country.

Falling Trend in the Total Number of Monsoon Storms/Depressions and SST in the Indian Ocean

A significant falling trend in the total number of monsoon storms / depressions for the period 1875-1990 over the Indian Ocean has been revealed by the critical analysis of available data. The fall seems to have begun at the start of the present century. As genesis of storms / depressions depend largely on SST, year to year variations between number of monsoon storms / depressions and seasonal SST were examined. The number of storms are found to be significantly correlated (r=0.49, significant at 99.9% CL) with July to September (JAS) SST over Indian Ocean basin. The smoothed time series of JAS SST over Indian ocean basin also showed strong inverse relationship with number of monsoon storms / depressions. The significant decreasing trend in monsoon storms / depressions

seems to be caused by increasing trend in SST of Indian ocean basin.

Dendroclimatic Analysis

Many tree-ring width index chronologies of Himalayan conifers showed high persistence in the series (high value of lag-1 autocorrelation). This persistence or autocorrelation structure was removed by an autoregressive modelling. It was observed that there is a significant improvement in the common variance and signal to noise ratio after the removal of autocorrelation structure in the series particularly in Cedrus deodara and Picea smithiana ring width index chronologies from Himachal Pradesh and Garhwal-Kumaon region. Such persistence-free tree-ring chronologies form the region improve the statistical signal in the multivariate analysis of dendroclimatic reconstructions. It implies that the persistence-free tree-ring width index chronologies obtained from the autoregressive modelling are more suitable to achieve the robust reconstructions of past summer climate over the region.

Hydrometeorological Studies

During 24-26 June 1997 heavy to very heavy rainfall was reported by many stations over north Gujarat region. This heavy rainfall with consequent flooding in the region resulted in the death of 172 lives and damage of properties worth crorers. This rainstorm was anlaysed to assess its magnitudes of point rainfall as well as areal rainfall by Depth-Area-Duration (DAD) technique. DAD analysis of this rainstorm revealed that over 50,000 km^2 area received 16.0 cm rain in 1-day (25 June), 28.0 cm rain in 2-day (24-25 June) and 38.0 cm in 3-day (24-26 June) duration respectively.

Comparison of areal raindepths of 24-26 June 1997 rainstorm with similar data obtained from the severemost rainstorm of 26-28 July 1927 over the north Gujarat region revealed that 1-day duration (25 June) surpassed the areal raindepths of 28 July 1927 rainstorm up to an area of 10,000 km^2 and 2-day duration (24-25 June 1997) has exceeded the areal raindepths of 27-28 July 1997 up to 3,000 km^2.

The design storm study for the catchment of the Krishna river above the Nagarjunasagar dam was carried out using long period rainfall data (1901-1985) of about 200 rainfall stations. The objective of this study is to provide estimates of design rainfalls for different return periods and probable maximum precipitation (PMP) for durations of 1 to 3 days so that these estimates can be used to check the adequacy of the current spillway capacity of Nagarjunasagar dam. The annual maximum catchment raindepths for the 85-year period and that of 2 and 3-day close to 100-year return period for 1, 2 and 3 - day durations were subjected to Gumbel distribution. This showed that the highest raindepths obtained by the Depth Duration (DD) method for 1-day duration is close to 500 year return period and that of 2 and 3-day close to 100-year return period. The estimates of PMP for 1, 2 and 3-day durations for the Krishna Catchment above Nagarjunasagar dam were found to be 7 cm, 11 cm and 14 cm respectively by adjusting the envelope DD raindepths by the appropriate moisture maximization factor.

Physical Meteorology and Aerology

The Physical Meteorology and Aerology Division has undertaken thrust area research programmes aimed at promoting better understanding of the atmospheric physical phenomena relating to the following topics :

- Physics of monsoon clouds, precipitation mechanisms and atmospheric electrical processes
- Dynamics and thermodynamics of the tropical atmospheric boundary layer
- Theory of deterministic chaos and its applications in atmospheric sciences / atmospheric modelling
- Dynamics of the middle atmosphere vis-a-vis the troposphere - stratosphere coupling /monsoon activity

- Precipitation chemistry, acid rain, atmospheric aerosols and tropospheric chemistry

- Remote sensing of atmospheric aerosols and trace gases using lidar and spectrometric techniques

Studies in Atmospheric Electricity

A study of thunderstorm frequencies over India was carried out using the observational data collected at 78 stations for the period 1970-1980 and the seasonal and latitudinal variations of the thunderstorm activities in the regions were investigated. The thunderstorm frequencies in the summer months (March, April, May) was found to be maximum in the 8°-15°N and decreased with the increasing latitude. During the summer monsoon season (June-September) the latitudinal variations showed an opposite trend. The thunderstorm activity in the Indian region was found to be minimum during the month of January. The monthly time series of the thunderstorm frequency showed a bimodal variation with maxima in the months of May and September.

Radar Study of Rain and Rain-Bearing Clouds

The physical characteristics of convective clouds in the northwest India were studied using radar observations of precipitation echoes from 2467 convective clouds collected during the period 1971-1979. The temporal variations of the frequency of occurrence, diameter (D), height (H) and the aspect ratio (H/D) of radar detected precipitation echoes from convective clouds forming in the Delhi region during the summer monsoon season were investigated. Frequency of occurrence of such precipitation echoes was found to be more in the afternoon and less in the morning. Similar trend was observed in the temporal variations of height and aspect ratio of precipitation echoes of these clouds. On the other hand, diameter of the echoes was found to be maximum in the morning and minimum at the noon. The study also showed that the echo diameter has a linear relationship with its height. The relationship can be expressed by a regression equation, $D = aH+b$, where a and b are the coefficients to describe the equation.

Warm Cloud Modification

Detailed investigations of the cloud physical observations and other data collected during the warm cloud modification experiment conducted by the Institute in the Pune region were carried out. Also, cloud model studies simulating the hygroscopic particle seeding were initiated. These studies clearly indicated that an interdisciplinary approach would be essential for successful warm cloud modification experiments. The results of the Indian field experiment suggested that the warm cloud responses to salt seeding are critically dependent on the cloud physical characteristics e.g., vertical thickness and liquid water content. Clouds with vertical thickness > 1 km, LWC > 0.5 gm m^{-3} when seeded with salt particles (modal size 10 μm; concentration 1 per litre of cloud air) produced increase in rainfall of 24 per cent significant at 4 per cent level. Shallow clouds (vertical thickness < 1 km, LWC < 0.5 gm m^{-3}) when seeded showed tendency for dissipation. The cloud physical observations made in not-seeded (control) and seeded (target) clouds provided the physical evidence in support of the statistical evaluation. Numerical simulation experiments carried out using the 2DTD cloud model (Orville and Kopp, 1977) suggested that hygroscopic seeding of warm clouds under favourable dynamical conditions (convergence at the cloud-base level) would accelerate the collision-coalescence process resulting in the enhancement of rainfall. Moderate convergence at the cloud-base has been found to be essential for the cloud growth and development of precipitation in the real world.

Studies of the Atmospheric Boundary Layer

A study of the convectively driven monsoon boundary layer over the monsoon trough region during the break monsoon was carried out using the aerological observations collected during MONTBLEX-1990. A study of the conserved variable plots for the stations Bhubaneswar, Calcutta and Ranchi revealed that the convective boundary layer was represented by a single mixing line structure with

variability in stability of the mixing line with respect to the position of the monsoon trough. The convective boundary layer observed at Ranchi was found to be more saturated as compared to that observed at Bhubaneswar and Calcutta during the break monsoon conditions.

A study of the low level stability in the monsoon boundary layer over the Arabian region was carried out using the aerological observations collected during Monsoon-77 Experiment. The results of the study indicated that the deep moist convective activity was maximum in the region north of 12°N during the active phase of the monsoon.

Deterministic Chaos

Atmospheric flows exhibit irregular (chaotic) space-time fluctuations on all scales ranging from climate (kilometers-years) to turbulence (millimeters-seconds) and is a representative example of turbulent fluid flows.

Studies carried out at the Institute suggested that the atmospheric flows exhibit long-range spatiotemporal correlations manifested as the fractal geometry to the global cloud cover pattern concomitant with inverse power law form for power spectra of temporal fluctuations on all space-time scales ranging from turbulence to climate. Long-range spatio-temporal correlations are ubiquitous to dynamical systems in nature and are identified as signatures of self-organized criticality. Standard models in meteorological theory cannot explain satisfactorily the observed self-organized criticality in atmospheric flows. Mathematical models for simulation and prediction of atmospheric flows are nonlinear and do not possess analytical solutions. Finite precision computer realizations of nonlinear models give unrealistic solutions because of deterministic chaos, a direct consequence of round-off error growth in iterative numerical computations. Recent studies showed that round-off error doubles on an average for each iteration of iterative computations. Round-off error propagates to the main stream computation and gives unrealistic solutions in numerical weather prediction (NWP) and climate models which incorporate thousands of iterative computations in long-term numerical integration schemes. An alternative non-deterministic cell dynamical system model for atmospheric flows developed at the Institute predicts the observed self-organized criticality as intrinsic to quantumlike mechanics governing the flow dynamics. The model provides universal quantification for self-organized criticality in terms of the statistical normal distribution. Model predictions are in agreement with a majority of observed spectra of time series of several standard climatological data sets representative of disparate climatic regimes. Universal spectrum for natural climate variability rules out linear trends. Man-made greenhouse gas related atmospheric warming will result in intensification of natural climate variability, seen immediately in high frequency fluctuations such as QBO and ENSO and even shorter time scales.

Studies in Upper Atmosphere

A study of the tropospheric and lower stratospheric parameters associated with Mediterranean cyclones was carried out using the monthly mean pressure, temperature and wind data of surface, 500, 100 and 50 hPa for the high, middle and low latitude stations for the period December 1981-January 1982. The above observations were analysed and the investigations were carried out with respect to the cyclone which formed on 20 January 1982 in the Mediterranean sea at 30.0°N and 19.5°E. The study suggested that the cyclonic activity in the Mediterranean region could be associated with (i) the low latitude surface pressure and (ii) the zonal winds at 100 hPa level and reversal in the meridional winds in the stratospheric levels at high latitudes.

Studies in Air Pollution and Atmospheric Chemistry

Observations of Aitken nuclei, total suspended particulates, mass-size distribution of aerosols, surface ozone and precipitation chemistry studies were carried out in the Arabian Sea, Indian Ocean and Bay of Bengal regions onboard the ORV Sagar Kanya Cruise No.123 during 12 May to 15 June 1997.

The preliminary results of the analysis indicated that Aitken nuclei concentrations were in the order of 10 - 10^2 cm^{-3} over the Indian Ocean region (5°N to 5°S). The concentrations of total suspended particulates varied between 29 and 44 $\mu g\ m^{-3}$. Ozone concentration varied from 5 to 25 ppb with an average of 13 ppb over the Indian Ocean. pH of rain water varied from 5.6 to 6.7 indicating alkaline rain.

Analysis of the continuous record of surface ozone at Pune during the period of six years from 1991-97 showed that (i) the average of hourly concentration of ozone was 23 ppb during the period of 6 years, (ii) the diurnal variation of ozone showed a peak at 1400 hours IST and followed the trend of diurnal variation of surface temperature, (iii) the annual cycle of surface ozone for each of the individual year depicted maximum concentration in April and minimum in August with an increasing trend in maximum and minimum every year, and (iv) the rate of annual increase of ozone was found to be about 7% with the highest rate of increase in summer. The increasing trend in ozone concentration is attributed to the increasing anthropogenic activities around the site.

A study of the biogeochemical cycles in the Himalayan Ecosystems has been undertaken in collaboration with the G.B. Pant Institute of Himalayan Environment and Development, Kosi, Almora in Uttar Pradesh. For this study extensive field observations of atmospheric aerosols, precipitation chemistry and trace gases were carried out in the Kosi, Kullu, Manali and Kothi regions during 1993-98. The results of the study indicated that (i) the concentration of trace gases (SO_2, NO_2 and NH_3) was within the range of world background levels, (ii) the average concentration of total suspended particulates was 45 $\mu g/m^3$, whereas, the minimum and maximum concentrations were 24 and 63 $\mu g/m^3$ respectively which are substantialy lower than that in 10 large cities in India (200-600 $\mu g/m^3$), (iii) the mass size distribution of aerosols showed bimodal distribution, (iv) the coarse particles contributed 70% and sub-micron particles 30% of the total mass of aerosols which suggest that the natural sources, mainly soil, dominated the anthropogenic sources, (v) average pH of rain water at Kosi is 5.82 and the individual value varied between 4.9 and 7.1, (vi) average pH of rain water at Tungnath is 5.68 which is around CO_2 equilibrated value (pH=5.65) suggesting that the rain water is not acidic at both the places and the pH of dew water varied from 6.11 to 6.78 with an average of 6.35, (vii) the average concentration of Aitken nuclei was 2282 cm^{-3}, whereas the minimum and maximum concentrations were 1000 and 5070 cm^{-3}, respectively.

Lidar Probing of the Atmosphere

A study of the pre-sunrise and post-sunset differences in the tropical urban aerosol distributions was carried out by conducting coordinated experiments using the Argon ion lidar, spectroradiometer and sunphotometer at the Institute. The results of the study indicated higher aerosol concentrations in the air layers close to the ground, and lower concentrations aloft during the early morning (pre-sunrise) hours. The aerosol distributions during the late evening (post-sunset) showed opposite trend as compared to the morning hours. The variations observed in the aerosol distributions during the morning and evening hours were attributed to the convective activity and the turbulent mixing in the atmospheric boundary layer (Fig.7).

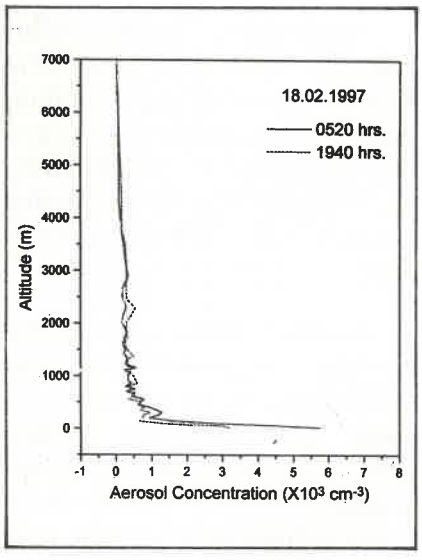


Fig. 7 :Lidar derived vertical distributions of aerosols in the atmosphere during pre-sunrise and post-sunset hours.

Analysis of the lidar aerosol observations made on about 550 days during the ten-year period (1987-1996) at Pune indicated an

increasing trend (~10%) in the aerosol column content which was attributed to the influence of urban activity in the region.

A computer algorithm based on multiple regression method was developed to retrieve total columnar ozone from the spectroradiometric observations in the Chappuis band. Total ozone content in the atmosphere was also determined by using the differential absorption of solar radiation at two wavelengths in and around the Chappuis band from the multiwavelength radiometric observations collected simultaneously. The values of the total ozone retrieved by the above Chappuis band method were found to be higher by about 20% as compared to those obtained from the Dobson spectrophotometer of the India Meteorological Department. The above discrepancy was attributed to the combined effect of greater aerosol optical depth, diurnal variation of aerosol optical depth, the deviation from the assumed power-law relationship used to estimate the change in aerosol optical depth with wavelength, and uncertainty in the values of ozone absorption coefficients.

The association between the space-time evolution of radar tropopause (sharp enhancement in the radar backscattered signal strength) and vertical wind was investigated by conducting special experiments at the Indian MST Radar Facility at Gadanki (13.47°N, 79.1°E), Tirupati, Andhra Pradesh over three diurnal cycles on 17-18, 22-23 and 24-25 November 1994. The results of the study indicated that the atmosphere was more turbulent around midnight on the days of observations which resulted in the weakening of the tropopause (Fig 8). The height averaged vertical wind velocity was maximum preceding and following the occurrence of tropopause weakening. Smaller vertical wind velocity gradients were found to be associated with the stability conditions in the tropopause.

A study was taken up to investigate the effect of polarization on laser light scattering of

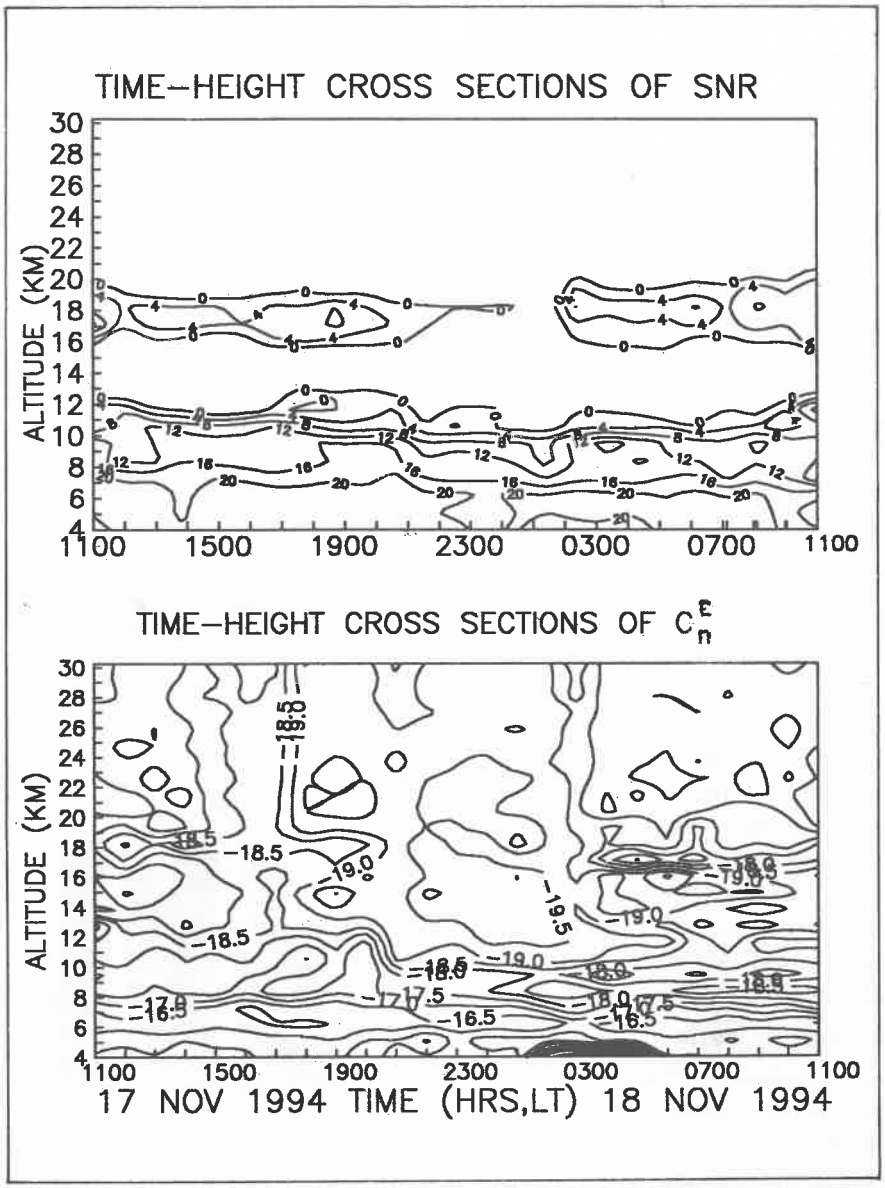


Fig. 8 : Time-height cross sections of signal-to-noise ratio (SNR) and corresponding refractivity turbulence structure constant(C_n^2) as observed with the MST radar on 17-18 November 1994

atmospheric aerosols over Pune. For this purpose, the Argon ion lidar system was operated on about 40 days during April 1997 - January 1998, with its incident laser light at parallel and perpendicular polarization and normalized signal strength profiles were obtained. From these profiles, vertical distributions of both percentage degree of polarization and depolarization ratios were derived. The preliminary results of the study indicated that the variations in the depolarization ratio in the atmospheric boundary layer are larger as compared to those in the free troposphere. The results of the study indicated that the aerosol particles in the boundary layer are more anisotropic. This anisotropic behaviour was found to decrease with altitude and become more prominent in the region of aerosol layer formation.

To understand the atmospheric turbulence around the tropical tropopause the MST Radar backscattered data for seven diurnal cycles (three in November 1994, one in September 1995 and three in January - February 1996) over Gadanki and near coincident radiosonde data at synoptic hours over Chennai during 1994-96 were analysed. The results indicated that (i) the estimated refractivity turbulence structure constant C_n^2 values vary between 10^{-16} and 10^{-20} $m^{-2/3}$ during the experimental period, which is consistant with the results reported by other investigators for tropics, (ii) the vertical distributions of C_n^2 by and large decreases with increase in altitude but enhances significantly at tropopause, (iii) the vertical fine structure of C_n^2 exhibits the presence of strong turbulence layers of few kilometers thick between 6 and 9 km region and thin layers of turbulence (150-300 m thick) throughout the height range during the period of study, (iv) time height cross sections of log C_n^2 during the periods "Tropopause weakening", (v) a fairly good agreement between the vertical profiles of C_n^2 estimated from the radar backscatter echo power and those through model computations based near concurrent radiosonde observations, (vi) the radar derived tropopause heights showed close agreement with those obtained from Radiosonde, within the height resolutions of the sensing techniques (Fig.9) and (vii) diurnal variations of log C_n^2 exhibits marked temporal and spatial variability. These variations at and around the tropopause altitude showed periodical structures, either in-phase or out-off-phase depending upon atmospheric stability conditions.

Spectroscopic Measurements of Atmospheric Minor Constituents

An automatic rotating slit scanning spectrometer for monitoring stratospheric NO_2, O_3, OClO, BrO and tropospheric NO_2, O_3, CH_2O, HONO, SO_2 is under development. The integration of the mechanical components and electronic data acquisition and control has been completed.

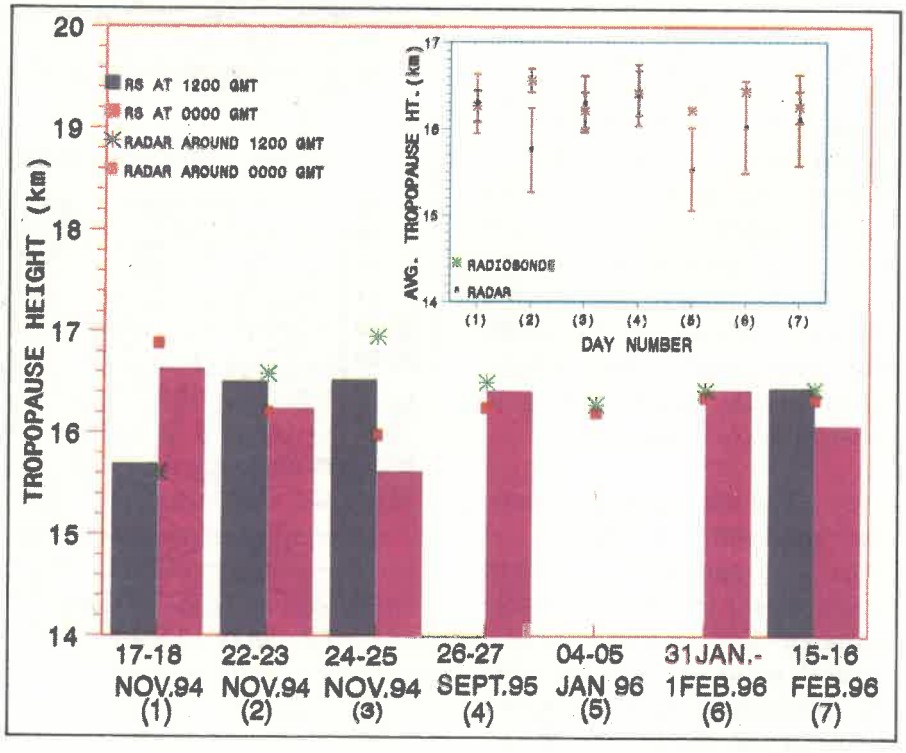


Fig. 9 : Comparison of tropopause heights derived from the MST radar and concurrent radiosonde observations on different experimental days. The inset shows tropopause heights averaged from the data sets for each diurnal cycle.

Spectral technique has been developed for obtaining slant column densities of trace species like NO_2, O_3, O_4, H_2O etc., using differential absorption spectroscopy. This technique was tested by using the observations carried out at the sub-Antarctic station Reykjavik (64°N, 23°W) at twilight hours during the winter of 1993-94. The multiple scattering during twilight period was observed from O_4 variations.

The algorithm to retrieve the vertical profiles of NO_2 and O_3 using twilight spectroscopy has also been developed and tested with the above data. Tropospheric and Stratospheric concentrations of NO_2 and O_3 were separated out using the model vertical profiles. It was observed that stratospheric NO_2 and O_3 are in phase but tropospheric variations of NO_2 are larger as compared to tropospheric O_3 variations (Fig. 10).

A study of the possible anthropogenic effects on the ion chemistry of the troposphere was undertaken using an ion-chemical model. The model involves 20 positive ions and extended down to the surface with a vertical resolution of 1 km. In the ion-chemical scheme, several new alkaline clustered positive ions are proposed which are detected in mass spectrometry measurements as unknown heavy mass peaks but could not be identified. These are formed by the reaction of proton hydrate ions with alkaline compounds

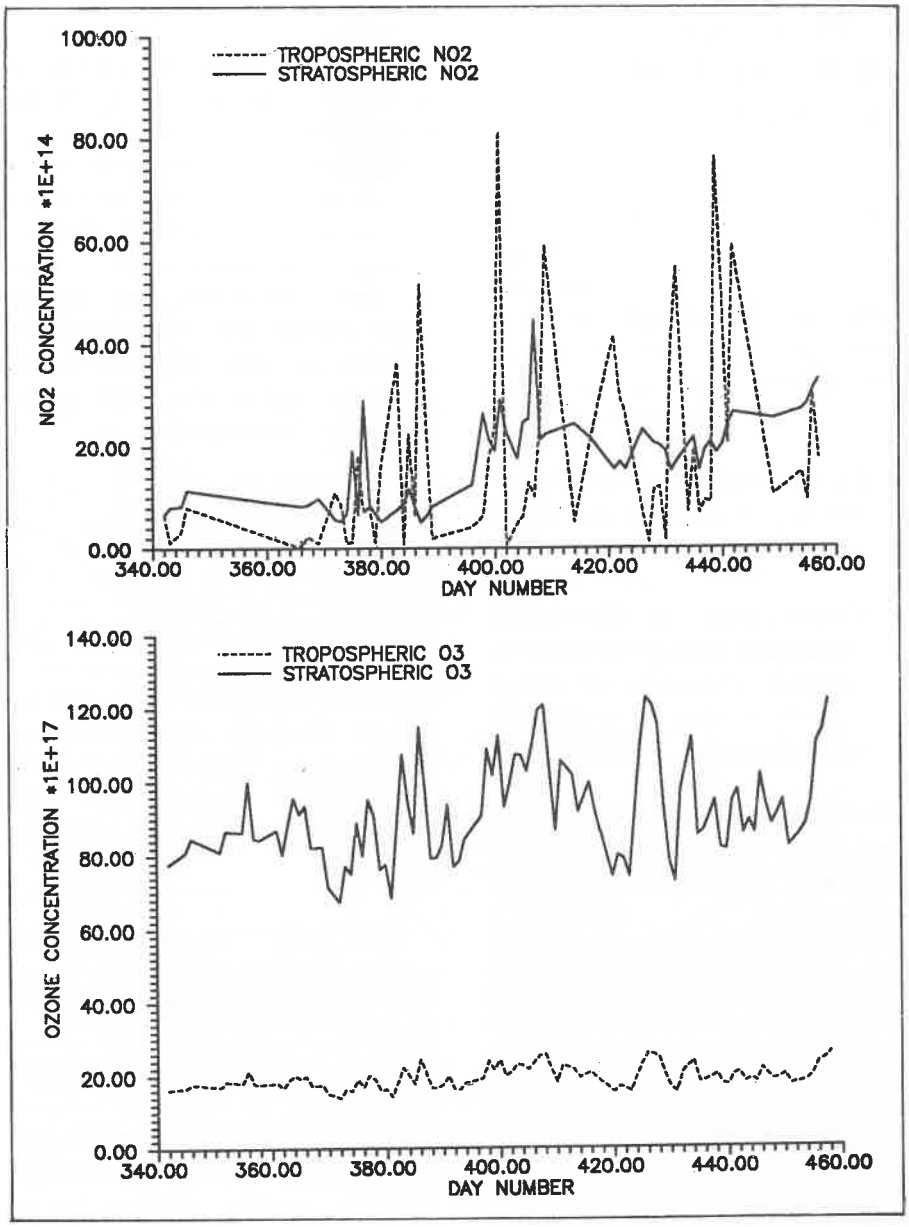


Fig. 10 : Stratospheric and tropospheric contributions of NO_2 and O_3 computed using the algorithm developed at the IITM from the UV-B spectrometer observations carried out at Reykjavik(64°N, 23°W) (Iceland).

(Pyridine, Picoline, Lutidine, Ammonia, Acetone). It was hypothesised that the attachment of the aerosols with the major terminal ions give rise to clustered aerosol ions of the type - H^+ (Aerosol) $(X)_p$ $(H_2O)_n$ (where X may be any alkaline compound). Preliminary results indicated that the lower troposphere (0-4 km) is dominated by the aerosol clustered ions above which pyridinated clustered ions start to dominate up to about 7 km. Acetone clustered ions were found to dominate from 7 to 13 km.

Instrumental and Observational Techniques

The broad scope of the Instrumental and Observational Techniques Division is to design and develop instruments and techniques of observations and to carry out field and laboratory experiments. The current topics identified for research are :

- Development of instruments/ techniques to study the cloud electrification processes
- Development of simulation techniques to study the microphysical processes in cloud physics under a controlled environment

Development of Instruments and Observational Techniques for Cloud Electrification Studies

Data on atmospheric electric field, electric conductivity and the size distribution of atmospheric aerosol particles obtained during the XVI Indian Scientific Expedition to Antarctica (December 1996 to March 1997) were analysed. The data analysis is being further examined to study the behaviour of these parameters in clean atmospheres.

Preliminary analysis of the electric field and conductivity data obtained during the 120th cruise of ORV Sagar Kanya in the tropical Indian Ocean (27 December 1996 to 7 February 1997) showed that the conductivity increases as one moves away from the coast. Further, the conductivity values are found to be much higher in the southern hemisphere than in the northern hemisphere. The aerosol concentrations computed from these data showed a decrease in their concentration as one moves away from the coast and higher values in northern hemisphere than in southern hemisphere. The cause of these differences may be the dominant northeast winds in that season and more land area in the northern hemisphere than in the southern hemisphere.

Vertical profiles of atmospheric electric field and ion densities in the lower atmosphere were calculated for turbulent and non-turbulent atmospheres including the effects of non-uniform ionisation and atmospheric aerosols. The behaviour of electrode effect under such atmospheric conditions was studied with the help of these profiles.

A field experiment was conducted during 8-16 December 1997 at the atmospheric electricity observatory in which simultaneous measurements were conducted of different atmospheric electric parameters alongwith the radon and surface radioactivity, profiles of atmospheric temperature and of submicron aerosol particles. Radioactivity measurements were arranged and conducted by the scientists from Mysore University, under a DST sponsored project.

The aerosol size spectra of submicron particles before and after rainshowers were obtained during 11 post-monsoon thunderstorms to study the capture of aerosol particles by the scavenging mechanism. Analysis of the data showed significant change in aerosol concentration before and after thundershowers.

The charge distributions on raindrops obtained under rainshowers from an induction ring apparatus were compared with those obtained from the particle charge measuring apparatus. The distributions obtained from the two apparatus showed reasonably good agreement.

A spherical antenna of Burke and Few type was installed in the Institute's Atmospheric Electricity Observatory to measure the atmospheric conduction current. Simultaneous measurements with both the plate and the spherical antenna are being made to compare the two instruments.

The ion-aerosol balance equations were solved for multiply charged aerosols to study the steady state charge distribution on them. Calculations predict the formation of higher number of charged particles when the multiply charged aerosols are considered. The variation in polar conductivity with the concentration of aerosols showed a minimum in the conductivity value.

Development of Simulation Techniques for Cloud Physics Studies

The data obtained on the evaporation of the charged and uncharged water drops suspended in a vertical wind tunnel were being analysed using different statistical techniques. To study the evaporation of water drops, the surface temperatures of water drops were

calculated to find out the ventilation coefficients in high humidity conditions.

Size distribution of aerosol particles measured earlier during the field experiments on scavenging of particles by rain, was analysed. The washout coefficients obtained from these experiments were calculated for different rainshowers.

The electrically induced changes in drag force in a mixed thundercloud for different liquid and solid precipitation contents were calculated. The results were being studied to investigate the change in balance levels due to the electrical forces.

Boundary Layer and Land Surface Processes Studies

The broad scope of the Division is to design and develop instruments/techniques of observations and to carry out field and laboratory experimental studies relating to the atmospheric boundary layer and land surface processes. The research programmes identified are :

- Development of instruments / techniques to study the structure of the atmospheric boundary layer
- Conducting field experiments to understand the physics of energy partition at the land-surface interface for various types of soil and vegetation conditions
- Studies of the Atmospheric Boundary Layer Phenomenon related to monsoon variability

Land Surface Processes Studies

Land Surface Experiment data (Tower data at all grid stations at Anand) for the month of February 1997 were distributed to all the participating Institutions viz., Indian Institute of Technology, National Centre for Medium Range Weather Forecasting, Gujarat Agriculture University and Jawaharlal Nehru University after having subjected to quality control checks. Preliminary results showed the diurnal variations of wind, temperature, soil temperature, radiation and surface fluxes indicating the good quality of data. Statistical analysis of surface layer turbulence using the fast response sonic anemometer data showed the systematic variation of variances of wind components (u, v and w) with stability.

Sonic anemometer data from Anand during Land Surface Experiment in July and August 1997 were used to study the surface layer turbulence over cultivated field during monsoon period. The data were examined for some specific days and the characteristics of wind and temperature spectra were studied. The drag coefficient was found to vary with stability.

Land surface is generally heterogeneous and measurement of surface energy fluxes are very difficult and expensive over a large area. Latest GCMs require accurate values of these fluxes. Satellite measurements are considered to provide a potential bridge between the scales of models and ground based observations and may allow the transfer of evaluation methods developed in specific areas to the continental scale. But still the remote sensing method is not fully established because of lack of actual methods and remote sensing comparisons. To achieve this, information from primary radiance measurements need to be empirically validated at a scale representative of global observation from satellites. An empirical relationship between roughness length and normalised difference vegetation index (NDVI) was used for this purpose. The sensible heat flux, calculated using above mentioned roughness length, surface temperature (measured using a IR thermometer) and air temperature (measured from the tower) compared well with heat flux measured from sonic anemometer and tower data.

The surface fluxes of heat and moisture were simulated using one dimensional model. This model utilises the soil moisture and wind profiles in the boundary layer as the input. The parameterisation of surface fluxes of heat and moisture in the one dimensional model takes into consideration the evaporation also. The surface temperature and humidity values were obtained using the surface energy balance. The surface flux values simulated by the model were compared with the estimated values. The results

of the study suggested that the model is capable of simulating the surface fluxes of heat and moisture fairly well in normal conditions. During strong wind conditions, the estimated values exceeded the simulated values. The results also explored the need for proper incorporation of the external forcings into the model.

MONTBLEX Studies

The Doppler sodar data collected during the monsoon season at Kharagpur during MONTBLEX-1990 were used to study the monthly-mean wind field variation in the lower atmospheric boundary layer (ABL). Monthly-mean horizontal winds were found to be westerly / north-westerly in the lower ABL in all monsoon months except August. In August, mean winds near the surface (up to ~600 m) became easterly in response to the monsoon depressions formed in the north Bay of Bengal during 20-31 August (Fig.11).

Sodar (Kharagpur) and radiosonde (Alipore near Calcutta) data of MONTBLEX were used to study the variation of mixed layer depth and convective velocity scale at Kharagpur during the Onset (1-7 June) and Active (5-12 July) phases of monsoon. The mixed layer depth was taken as the height at which an air parcel rising from the surface would first become neutrally buoyant. The mixed layer depth, found from the virtual potential temperature profile of radiosonde, was found to be ~4 km in onset phase and ~500 m in active phase. The convective velocity scale, found from the standard deviation of vertical velocity (sodar) averaged in the height range of 180-990 m for the well-mixed layer, was found to be 1.5 ms^{-1} in onset phase and 1.0 ms^{-1} in active phase.

For the study of structure of the turbulence in the atmospheric surface layer, wavelet transfer technique was applied by using wind and temperature data collected at six observational hours of a day in June 1990 during MONTBLEX-1990 at Kharagpur. The results showed that the eddies exhibit a large temporal variability generating intermittancy in the energy and flux distribution. The quadrant analysis of momentum flux showed that ejections and sweeps account for a substantial part of the total flux. The eddies carry out the ejection and sweep processes selectively in the atmospheric surface layer.

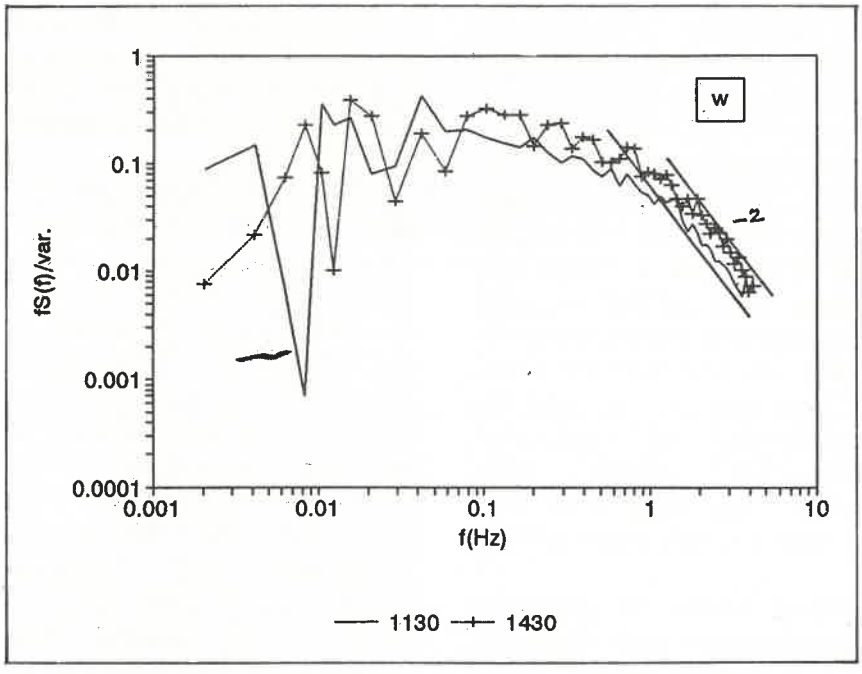


Fig. 11 : Spectrum of vertical component of wind at Kharagpur on 18 August 1990 at 8 m AGL showing buoyant subrange (-2 power law) at high-frequency end in moist convective boundary layer.

Theoretical Studies

The Division conducts theoretical studies and develops models for the study of monsoon and tropical circulation systems. The research programmes are undertaken to investigate the following :

- Role of barotropic, baroclinic and combined barotropic-baroclinic instability mechanisms in the formation and growth of monsoon disturbances

- Global spectral P. E. model for simulation of summer monsoon circulation and determining global energetics in different vertical and time domains

- Diagnostic studies and numerical modelling of the linear and non-linear interactions among different spatial and temporal scales of monsoon flow

- Development of simple reduced gravity and general circulation ocean models for understanding dynamics and physics of Indian ocean circulation

- Development of simple coupled ocean atmosphere model for understanding global circulation

Barotropic and Baroclinic Instability of the Atmospheric Flow

Dynamic instability characteristics of the combined zonal and meridional flow over Arabian Sea and west coast (EQ-25°N, 51°-81°E) prior to formation of tropical cyclone (5-8 June 1994) were studied, using 17 level, quasi-geostrophic, baroclinic model from surface to 200 hPa. Growth rate spectrum for the synoptic scale wavelengths band indicated preferred wavelength to be 1800 km for the channel width 3000 km with an e-folding time 3.7 days. The model was also tested to determine the contribution of baroclinic mechanism in the development of the tropical storm. In the absence of surface friction the preferred wavelength is found to be 1650 km with an e-folding time 3.63 days. By inclusion of Ekman friction the preferred wavelength was slightly enhanced (1800 km) and the growth rate remained same.

Development of the non-linear, balance, multilevel, numerical model was completed in order to understand the role of nongeostrophic effects in the baroclinic development of monsoon disturbances. Instability characteristics of the three cases of monsoon disturbances viz. monsoon depressions, mid-tropospheric cyclone and tropical cyclone were studied. In the case of monsoon depression the non-geostrophic effect enhances the growth rate as compared with the results of pure quasi-geostrophic model. But non-geostrophic effect plays significant role in the vertical structure of the preferred waves for all the three cases.

Three layer balance model was tested to determine the combined barotropic-baroclinic dry instability characteristics of idealised cases of zonally asymmetric flow viz. Upper level easterly alone; Lower level westerly alone and Mean monsoon type flow. The results showed that there are two waves generated by upper level easterly flow. One is the westward propagating upper tropospheric wave of wavelength 4000 km. with phase speed 20.2 m/sec. and time period 2.3 days and the other one is also westward propagating upper tropospheric wave but penetrating up to lower troposphere having wavelength 12,000 km. with phase speed 11.5 m/sec. and time period 12.1 days. Another slowly eastward propagating lower tropospheric wave of wavelength 6500 km. was also generated by the low level westerly flow having phase speed 4.12 m/sec. and time period 18.3 days. All these modes are found to be present when both the upper level easterly and the lower level westerly are taken into consideration i.e. monsoon type flow. From the energetics study it was understood that the barotropic instability plays a dominant role for the above mentioned waves, whereas baroclinic instability plays a stabilizing role for the same.

Simulation of Mean Monsoon Circulation and Predictability of the Monsoon system.

Atmospheric Modelling

The space time analysis of energy interactions by use of TOGA basic III daily wind data was carried out to investigate the role of various dynamical processes influencing the intra-seasonal monsoon variability. The preliminary results showed the strong biweekly oscillation by the long waves of tropical upper troposphere.

A computer program based on Fourier spectral formulae has been developed and tested to determine nonlinear energy exchanges between divergent and rotational motions in the frequency domain for the maintenance of low frequency modes in lower and upper troposphere using TOGA daily wind data for June to August 1988 over global tropics (20°S-30°N).

The nature of the scale interactions among wave components, calculated from the energetics on the Fourier spectral domain, for periods before, during and after the freeze events covering the period 21-30 June 1994, over Southeastern Brazil was studied. The salient feature of the result was that the nonlinear barotropic scale interactions are an important source for the maintenance of the downstream amplification. However, the baroclinic contributions were found to dominate during the freeze events when the large amplitude trough is accompanied by the baroclinic features.

In order to understand the physical mechanism during the onset of El Nino of 1997, computations of nonlinear kinetic energy exchanges into individual triad interactions in frequency domain by use of cross-spectral technique over the globe (90°S - 90°N) at 1000 hPa, 850 hPa, 700 hPa, 500 hPa, 200 hPa and 100 hPa were performed covering the period March 1994 - August 1997. The results revealed that the nonlinear barotropic scale interactions of 30-50 day oscillation played a significant role for the onset of El Nino of 1997.

Ocean Modelling

The 2½ layer thermodynamic ocean model was integrated for 12 years (1982-1993) over north Indian Ocean using interannual surface forcings of momentum and heat fluxes derived from NCEP Reanalysis data. The difference between model produced SST and the observed SST climatology was found to be higher than that (~ 0.5 - 1.0 °C) obtained in the earlier experiment with FSU wind and COADS heat flux data. However, the model produced interannual SST variability was in good agreement with the observed interannual SST (derived from Reynold's reanalysis).

The effect of an idealised moving cyclone on the ocean upper mixed layer was investigated in detail, using the IITM reduced gravity (IRG) model. The oceanic response was found to be assymetric in contrast to symmetric wind forcings. The bias to the right of the track was found in model currents and upper layer thickness deviation (Fig.12). Different sensitivity

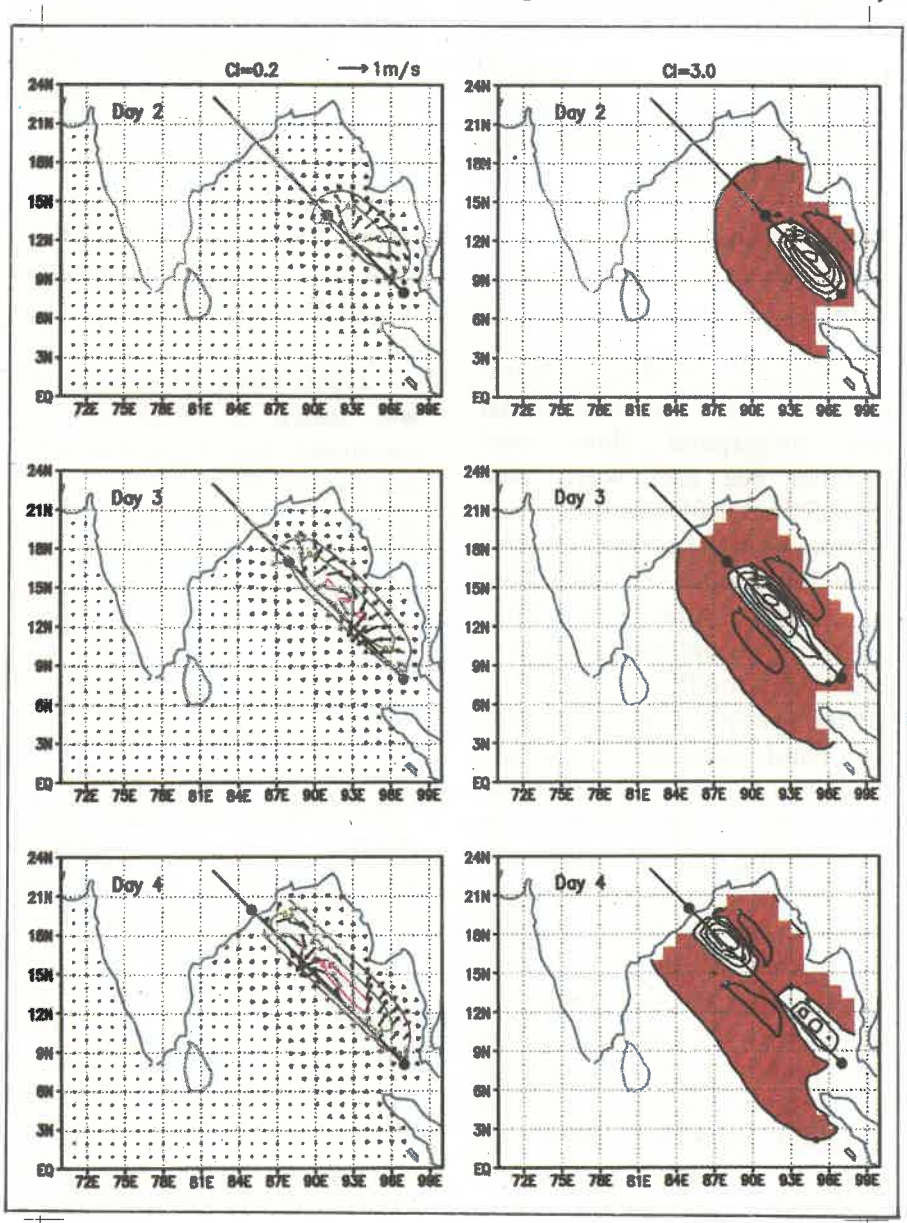


Fig. 12 : The effect of an idealised moving cyclone on the ocean upper mixed layer using IRG model.

experiments were carried out by changing the model parameters viz., intensity, size, speed of cyclone, as well as by changing the parameters and different initial conditions. Linear oceanic response to the changes in the intensity and size of the cyclone was found. Increase in model resolution alongwith decrease in viscosity resulted more cooling of the upper layer and also increase in the right bias in oceanic response. Increase in the initial model phase speed resulted in the wide spreading of energy and hence decrease in the flow intensity and the upper layer deviations.

Development of Simple Models for Climate Study

Using NCEP reanalysis data, the 2½ layer ocean model results were analysed in order to understand the interannual variability in the Bay of Bengal. It was seen that the model simulation for the year 1985 has higher variation from the model climate in the circulation features during pre-monsoon and post-monsoon months in both surface and sub-surface layers. A marked surface cyclonic gyre was found in the model simulation near the Head Bay during May. The east coast surface circulation is southward all along the coast in May-June in contrast to a northward flow as observed in ship drift currents and model climatology. The results are being further analysed for their possible impact on the surface heat content. Satellite derived altimeter data are being used to validate the model results.

Use of National MST Radar Facility in the Cumulus Parameterization Scheme for Indian Monsoon Region

Detailed analysis of the MST Radar common mode data for the period September 1995 to August 1996 was carried out. Wind components (u,v,w) and reflectivity parameters were obtained. The three-layered reflectivity pattern was obtained and was found to be the same as seen in the earlier case. It was proposed that this pattern is associated with the dynamics of inertio-gravity waves combined with Brunt-Vaisala oscillations and Kelvin-Helmholtz waves.

Dynamical Instability of the Tropical Stratosphere

The quasi-geostrophic, multi-level, baroclinic model (with unequal pressure interval in the vertical) which was developed for obtaining the unstable modes of the tropical troposphere and lower stratosphere system, was found to be unfit for providing unstable modes in the lower stratospheric levels. Hence, using the planetary scale of wavelength and phase velocities of Kelvin and MRG waves, the refractive index profiles (Charney-Drazin, 1961) were computed for various cases viz, the easterly and westerly phases of QBO coinciding the summer and winter tropospheric circulations. The direct influence of lower stratosphere on tropospheric weather phenomena, in terms of energy transfer was found to be almost nil. But since this result apparently opposes many of the past observational study results, further studies are currently being carried out including more physics and dynamics.

Development of Advanced Computing Techniques

Detailed background in the field of Artificial Intelligence (AI) has been prepared through computer programming languages PROLOG and LIST. This has been done with a view to explore the possibility of incorporating some features of artificial intelligence in the ongoing process of developing object oriented Scientific Computing Algorithm for Meteorology (SCAM).

Climate and Global Modelling

Recognising the need for a sustained and long term scientific programme to understand the physical and dynamical processes in the climate system, the Institute has established the Climate and Global Modelling Division. The objectives of the division are :

- Comprehensive study of the physical and dynamical processes relating to global and monsoon climate and their variabilities on different time scales

- Development and improvement of physical and mathematical models capable of simulating climate and climate change due to natural and anthropogenic factors and validation of the results of the climate models

Interannual Variability of Simulated Monsoon

The interannual variability of the Indian summer monsoon simulated by the Hadley Centre's Climate Model was examined to assess the possibility of using the model for dynamical seasonal forecasting of monsoon rainfall. Seasonal integrations with observed initial conditions and sea surface temperatures for 15 years were used in the study. For each year 9 member ensemble runs starting from 23 to 31 May initial conditions were made. In addition, an experimental seasonal prediction of the Indian summer monsoon of 1997 was attempted. The impact of recent improvements in the physical parameterization in the model on the monsoon simulation was also examined. Though the model simulates the mean monsoon circulation and rainfall well, the interannual variability is not adequately handled. The model reproduces the correct sign of the rainfall anomalies, when whole of India and the whole of season are considered. However, the spatial distribution of the anomalies over the monsoon region is found to be erroneous during El Nino and La Nina years. The members of each ensemble showed much larger variability in El Nino years (8.6% and 9.6% for 1982 and 1987 respectively), compared to La Nina years (4.2% and 3.1% for 1984 and 1988 respectively) largely due to delays in the monsoon onset over India in some members of the El Nino ensembles. Fig.13 shows the daily time series of rainfall over peninsular India

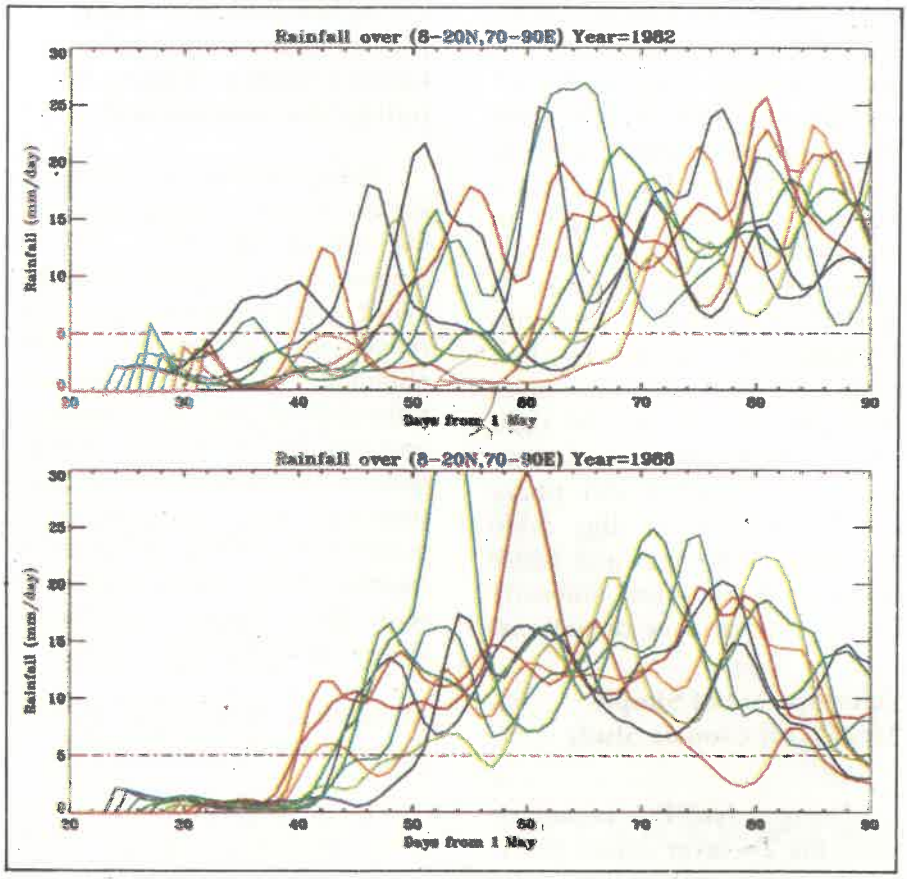


Fig. 13 : Daily time series of area averaged rainfall (mm/day) over the Indian peninsula from 9 ensembles for El Nino year 1982 and La Nina year 1988 (Each colour line represents one initial condition from 23 May).

(8°-20°N, 70°-90°E) for the years 1982 and 1988. The Onset of monsoon in the ensembles of 1982 showed large variation compared to that in 1988. The real time 9-ensemble forecast for the monsoon of 1997 with persistent May SST indicated below average rainfall over India, consistent with the developing El Nino conditions in the east Pacific.

Stationary Wave Anomalies Over the Indian Summer Region

Occurrence of the prominent stationary wave anomalies in the upper troposphere during weak monsoon years was observed. Fig. 14 shows the possible relationship between the upper troposphere circulations during May and the ensuing summer monsoon rainfall activity over India during June to September. Here $-\nabla Q$ is averaged over the domain (70° - 115°E; 0° - 40° N). It is evident that the below (above) normal monsoon rainfall years are generally characterised by cyclonic (anticyclonic) anomalies in the upper troposphere during May. These anomalies manifest in the form of cold cyclonic anomalies over north-west India and adjoining region (Fig.15). Numerical Experiments were carried out using a simple forced divergent barotropic

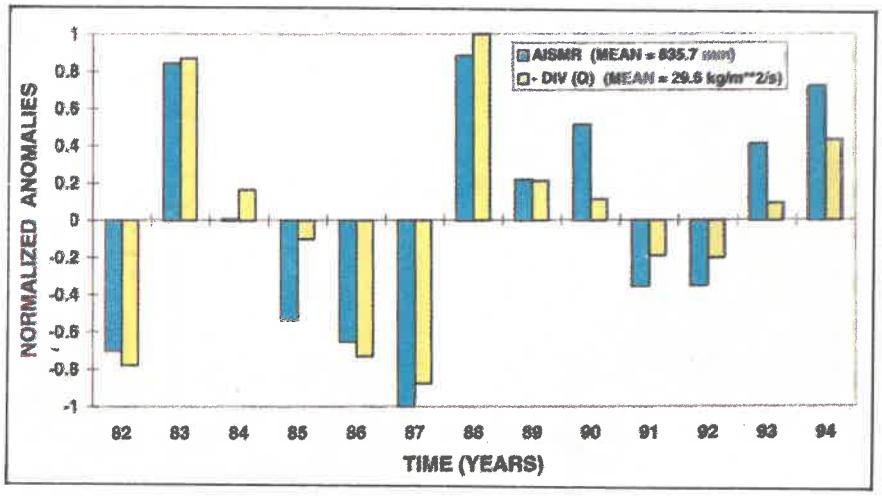


Fig. 14 : Interannual variation of all India summer monsoon rainfall and upper tropospheric mass convergence in May averaged over the domain (70°-115°E, 0°-40°N).

vorticity equation and also with the COLA GCM to understand whether ENSO plays a role in producing weak monsoon years. Fig. 16 shows the observed anomalous divergent circulations during weak monsoon years. The anomalous upper level divergent outflow over the equatorial central-eastern Pacific Ocean induced by the warm ENSO SST anomalies can be seen clearly.

Using the forced divergent barotropic vorticity equation, the rotational response induced by the anomalous divergent forcing was examined. Fig. 17 shows the rotational wind anomalies generated by the anomalous divergent forcing. The occurrence of cyclonic circulation anomalies over northwest India similar to those of weak monsoon years can be seen. It is conjectured that the generation of rotational

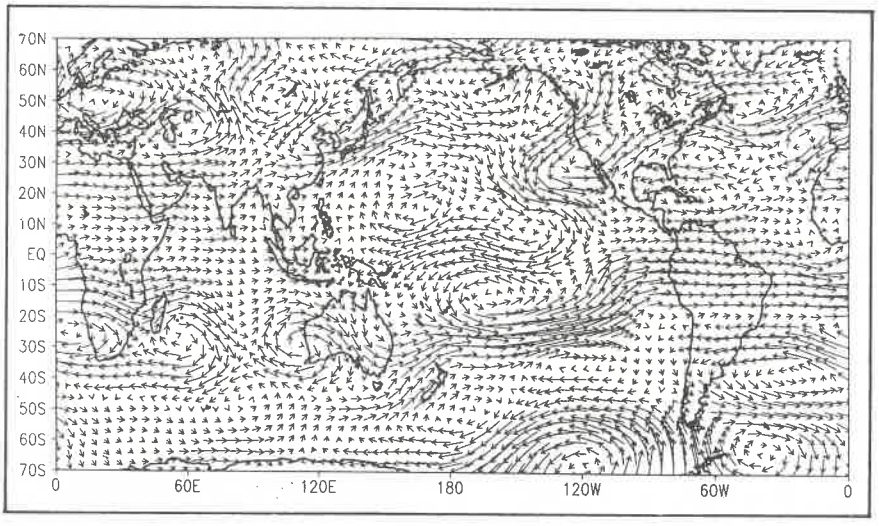


Fig. 15 : Composite of 200 hPa rotational wind anomalies during May in weak monsoon years based on NCEP Reanalysis.

anomalies over northwest India by the ENSO divergent forcing might be through the mechanism of Rossby wave dispersion. The role of Himalayan orography in modulating ENSO induced anomalies over the monsoon region was also studied. Experiments with and without orographic forcing suggested that in the absence of Himalayas, the ENSO induced cyclonic anomalies intrude southward into the monsoon region and weakens the monsoonal circulations significantly. In other words, the presence of Himalayas restricts the ENSO induced anomalies in the higher latitudes itself (Fig.18).

Predictability of All India Summer Monsoon Rainfall

Monsoon circulation is a nonlinear dissipative dynamical system. Its evolution is mainly governed by the boundary forcings where the influence of initial conditions is not insignificant. The General Circulation Model (GCM) experiment was carried out to study the impact of initial conditions on Summer Monsoon Rainfall. Centre for Ocean-Land-Atmosphere COLA) GCM at T30L18 resolution was integrated for monsoon period with nine different initial conditions for observed global sea surface temperature. The monthwise distribution of all India summer monsoon rainfall simulated by the individual ensembles is shown in Fig. 19. The summer monsoon rainfall has been quantified using the two parameters viz. internal variability and spread.

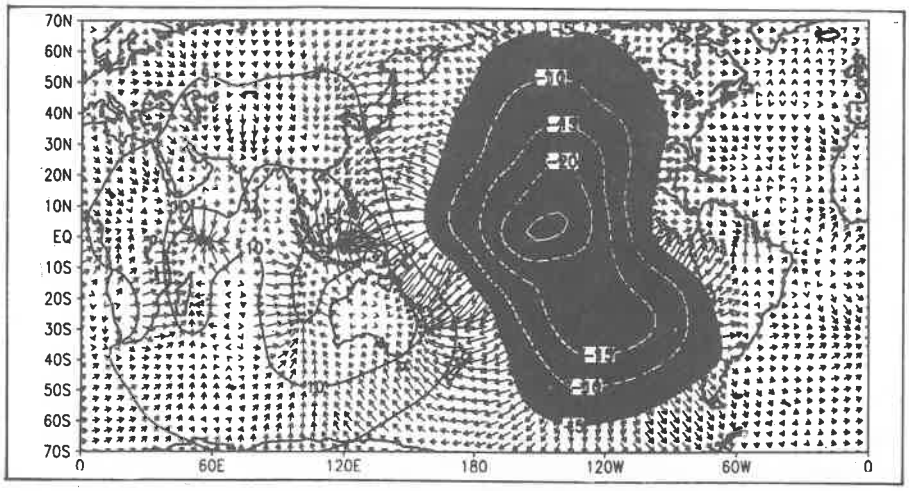


Fig. 16 : Composite of 200 hPa divergent wind anomalies during May in weak monsoon years based on NCEP Reanalysis.

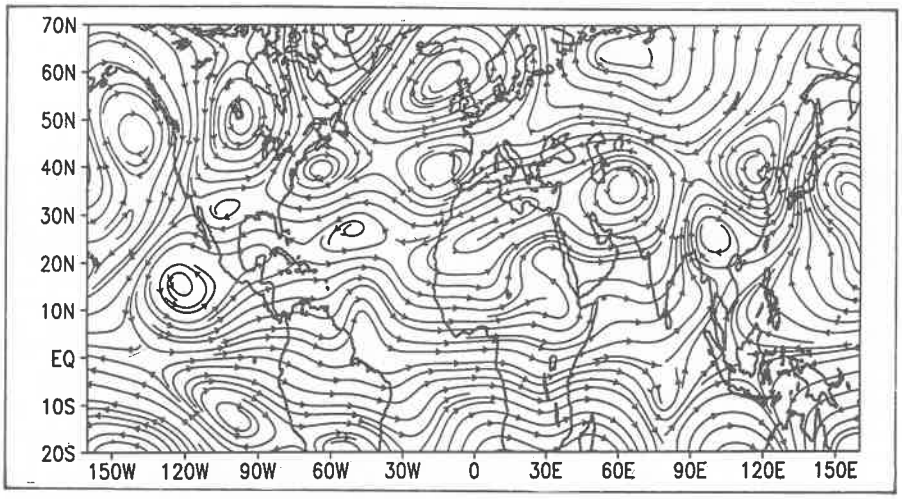


Fig. 17 : Model simulated rotational wind anomalies generated by the anomalous divergent forcing.

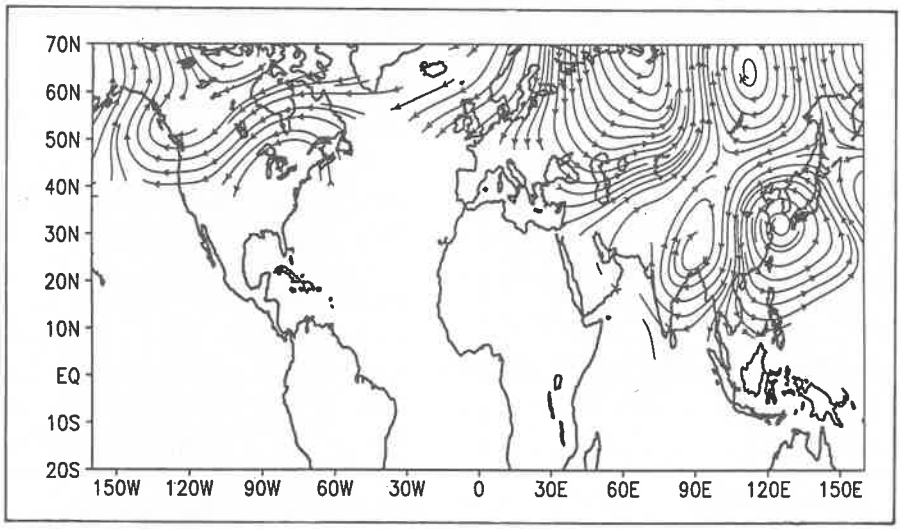


Fig. 18 : Model simulated rotational wind anomalies generated by absence of the Himalayas

The internal variability is the standard deviation of those nine simulations and the spread is given by the equation :

$$\sigma_s = \sqrt{\frac{1}{N^*(N-1)} \sum_{i=1}^{N} \sum_{\substack{j=1 \\ i \neq j}}^{N} (A(i) - A(j))^2}$$

where A (i) is monthly/seasonal rainfall obtained using i^{th} initial condition. The study suggested that there is a large impact of initial conditions on monthly as well as seasonal simulations. Out of nine cases, the simulated seasonal rainfall in 5(4) cases fell in above (below) normal category on the temporal scale. The internal variability was found maximum in the month of June and minimum in the month of September. On spatial scale, the variability was maximum over Bay of Bengal and Arabian Sea. The maximum spread was also found to occur over the oceanic regions. The internal variability was found to decrease with averaging over the number of simulations. It was found that averaging of six simulations reduces the internal variability to 1/e of the original internal variability.

Interannual Variability of Water Vapour Flux over the Indian Summer Monsoon Region

The 13 year (1982-1994) monthly data sets based on NCEP / NCAR Reanalyses (Kalnay et al., 1996) were used to examine the interannual variability (IAV) of water vapour flux over the Indian summer monsoon region. It was found that IAV of the net water

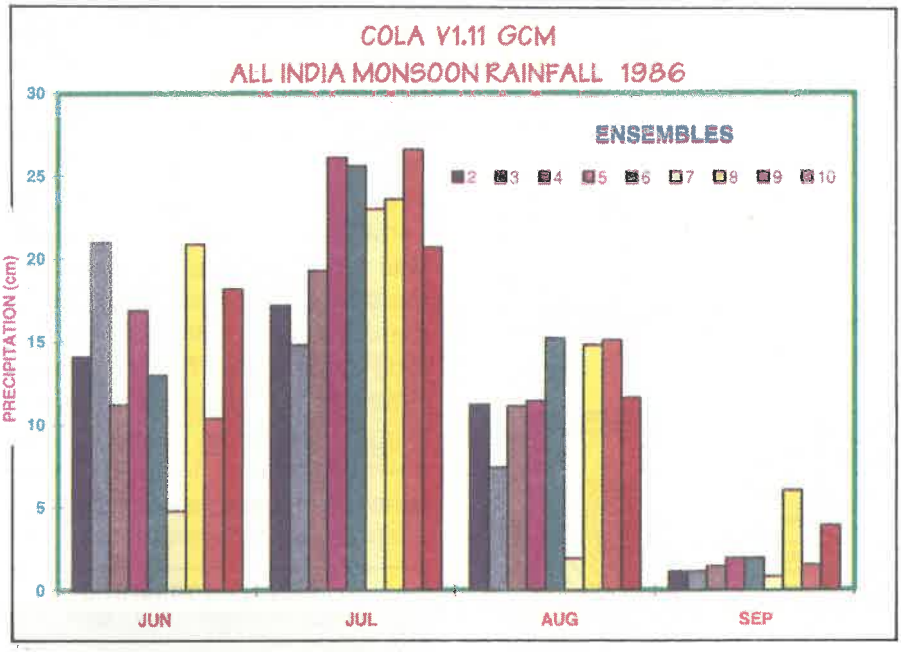


Fig. 19 : Monthwise distribution of all India rainfall for the monsoon months simulated by the individuals ensembles.

vapour convergence over the summer monsoon area, derived from NCEP / NCAR reanalysis, shows an excellent correlation with the IAV of the regional All India Summer Monsoon Rainfall.

An examination of the water vapour transport by large scale atmospheric circulations revealed that the transport is mostly due to the nondivergent circulations. However, the maintenance of water vapour content is primarily accomplished through the divergent circulations associated with the local Hadley and Walker cells. It was found that the IAV of the summer monsoon rainfall over India is largely associated with the IAV of the divergent component of the water vapour transport. The IAV was in turn found to be strongly influenced by the SST anomalies in the tropical Pacific and the south Indian Ocean. Warm SST anomalies over the central and eastern Pacific Ocean and cold SST anomalies in the western Pacific were found to induce large shifts in the monsoonal divergent circulations that adversely affect the net moisture convergence and summer monsoon rainfall over India. Similarly, warm SST anomalies in the south Indian Ocean tend to decrease rainfall activity over India by inducing weaker Hadley type divergent monsoonal circulations. The divergent component of the water vapour transport was found to be a good dynamical measure for the regional scale Indian summer monsoon rainfall activity. Thus, it is vitally important that this divergent mode is accurately represented in the reanalyses data sets. This study also describes a method to derive the divergent component of the water vapour transport by using observed OLR, a proxy for rainfall.

Simulation of monsoon depressions and lows in the Hadley Centre Climate Model

The Hadley Centre Climate Model was initially integrated for the monsoon season of year 1994 with the initial conditions of 1 May 1991 and observed SSTs were prescribed as boundary forcing. The analysed outputs showed that the model is able to simulate the transient disturbances over the Bay of Bengal during monsoon. To study the evolution of transience in this model in detail, the model was integrated for 15 summer monsoons (1979-1993). The daily output was examined for presence of monsoon depressions, low pressure areas and land lows/ depressions over the Indian region by analysing the low level wind field, vorticity at different levels, surface pressure field, precipitation, vertical distribution of temperature anomaly etc. The initial condition for each of these integrations was 23 May and observed SSTs were prescribed as boundary forcing. The model simulates the general morphological features of these disturbances comparable to observations. The time evolution of mean sea level pressure field of a well simulated monsoon depression is presented in Fig.20. The frequencies of the simulated monsoon depressions and low pressure areas are substantially lower than the climatological observed frequencies. This may be due to the lower spatial resolution of the climate model.

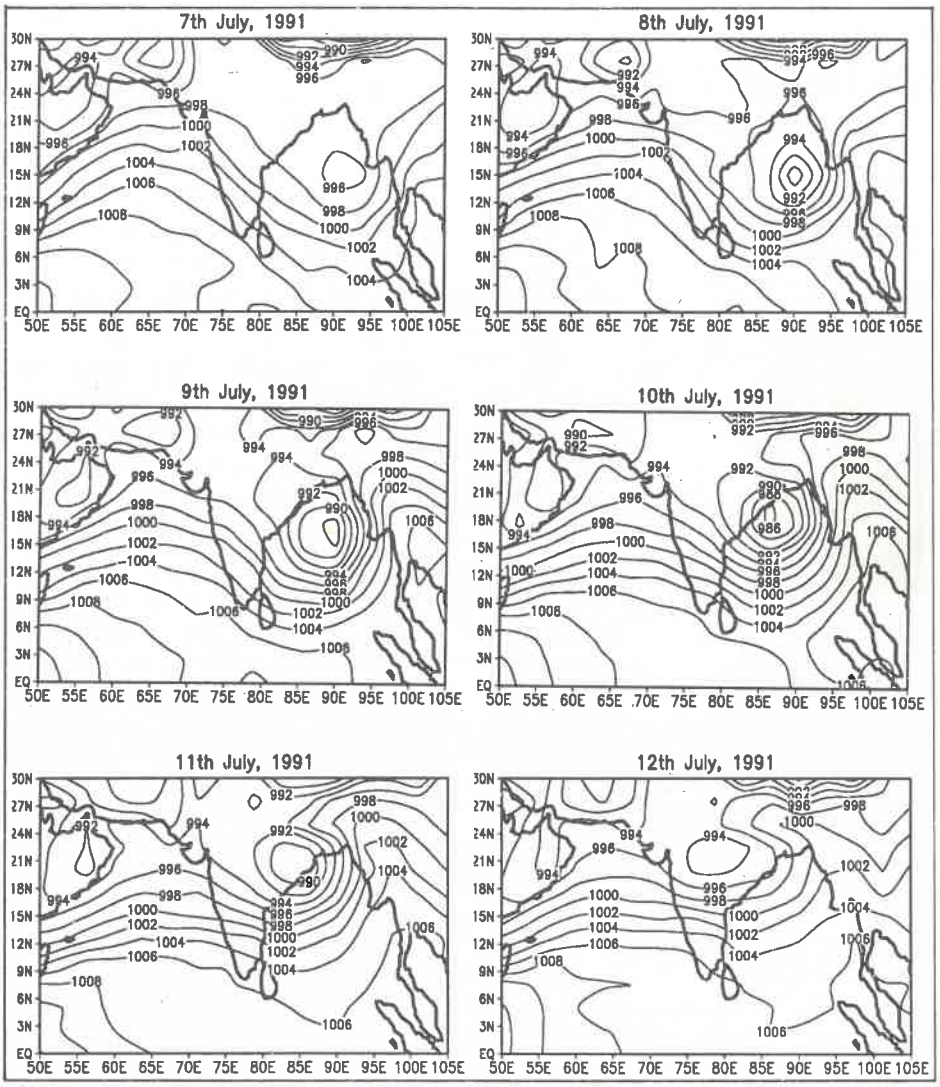


Fig. 20 : Simulated monsoon depression by the Hadley Centre Climate Model. Sea Level Pressure (hPa). Contour intervals at 2 hPa.

Role of Convective Downdrafts in the Interannual Variability of Summer Monsoon

The sensitivity of mean monsoon and its variability simulated by the Hadley Centre Climate Model to changes in convection scheme was examined by integrating the model with and without parameterization of convective down drafts. Summer monsoon seasons of 4 years (1987, 1988, 1991 and 1994) was simulated. These years were selected since they represent the years of large interannual variability. Results of the simulations are compared with NCEP Reanalysis and Xie-Arkin precipitation data.

Analysis of the model output showed that some of the systematic errors in the monsoon simulation of the model are reduced with the incorporation of downdrafts. However, the systematic error of the model by which it simulates stronger low level circulation in El Nino years than in La Nina years was not eliminated. Inclusion of downdrafts improved the rainfall simulation over India. When downdrafts were not included, there was excessive rainfall over west equatorial Indian ocean and less rainfall over India. The interannual variability of simulated rainfall was found to be more realistic in the downdraft runs. For example, the difference (1988-1987) of JJAS total precipitation (Fig.21) is much closer to the observed difference from Xie-Arkin data when downdrafts are included in the convective parameterization.

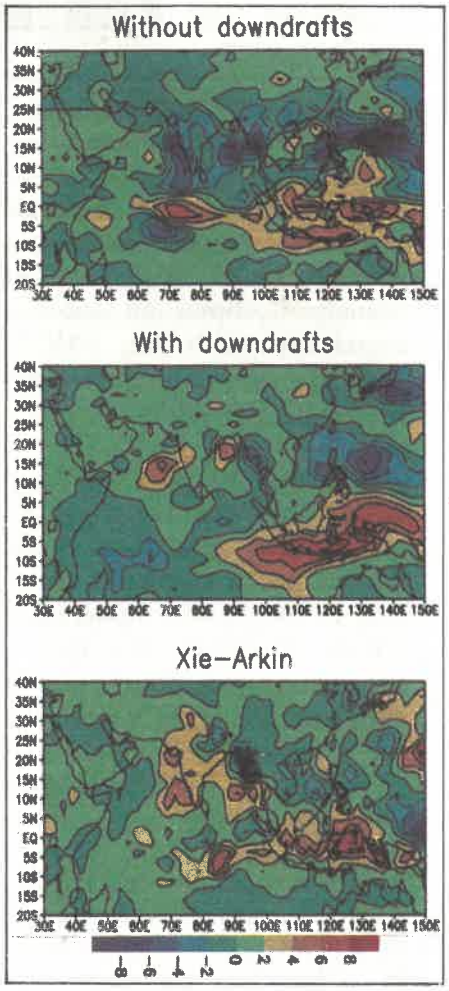


Fig. 21 : Difference (1988-1987) of JJAS total precipitation rate (mm/day) from with and without convective downdraft simulations and Xie-Arkin precipitation data.

Sponsored Projects

In addition to the ongoing research programmes the Institute undertakes sponsored projects for specific studies. Funds for these projects are provided by the respective sponsoring Departments. The details of the sponsored projects are given below:

Sr. No.	Title	Principal Investigator	Period	Grant Rs.(lakhs)	Funding Department
1.	Climate Research (Global Modelling)	Dr.V.Satyan	1994-1999	198.32	DST
2.	Development of an Optimized Parallel Climate Model based on NCMRWF Operational Model (Jointly with IIT, New Delhi and C-DOT, Bangalore	Dr.V.Satyan	1996-1998	2.00	DST
3.	Land Surface Processes Experiment over Sabarmati Region: IITM Component	Shri. K.G. Vernekar	1994-1998	97.00	DST
4.	Rotating Slit Scanning(Automatic) High Light Gathering Power UV-Visible Spectrometer (RSH IS) for Atmospheric Studies	Dr.D.B.Jadhav	1996-1999	9.41	DST
5.	2D-Chemical Modelling of Global Changes Induced Perturbations in Atmospheric Minor Constituents and Ionizations of the Lower and Middle Atmosphere	Dr.G.Beig	1997-2000	6.00	CSIR
6.	U.S.India Co-operative Research: Investigation of Atmospheric Chemistry: Aerosols-Climate Interactions	Dr.P.C.S.Devara	1997-2000	4.00	National Science Foundation, USA
7.	Atmospheric Aerosol Loading Over Land from IRS-P3 MOS Sensors Data	Dr.P.C.S.Devara	1997-2000	5.54	ISRO
8.	One Dimensional Model: Atmospheric Boundary Layer using Land Surface Processes	Dr.S.S.Parasnis	1996-1998	0.97	DST
9.	Synoptic Evolution of Weather over LANDSPEX Area and Role of Land Surface Parameters in Modulating Synoptic Developments.	Shri.D.K.Paul	1997-1999	2.89	DST
10.	Simulation of Surface Wind Stress on Monthly and Seasonal Time Scales using Coupled Atmospheric Ocean Model (CAOM) to Provide Forcing for Driving an Ocean General Circulation Model (OGCM)	Dr.V.Satyan	1997-2002	34.25	DOD
11.	Variability of North Indian Ocean and its Impact on Global Ocean and Understanding the Mechanism of Coastal Circulation Around India	Dr.(Smt.) P.S. Salvekar	1997-2002	34.25	DOD

Field Research Unit

The Field Research Unit of the Institute at Bangalore is involved in carrying out a country-wide Wind Energy Resource Survey Programme since 1986 under a Project financed by the Ministry of Non-Conventional Energy Sources, New Delhi. Under this project, two programmes are being carried out, viz., (i)Wind Monitoring Programme and (ii) Wind Mapping Programme.

Under the **Wind Monitoring Programme,** comprehensive wind resource data from selected stations were collected by using 20/25 m tall guyed mast and microprocessor-based automatic data collection system. The data were analysed and the results were made available to entrepreneurs in the planning and development of wind electric power to augment conventional electric power. Under this programme about 1000 MW of wind generated power systems have been installed in the country. So far, wind data were collected from 300 stations in 17 States and 3 Union Territories. The same are being closed down after collection of data for 2-3 years and newer stations will be commissioned at other locations. Total 43 wind monitoring stations were commissioned during the year besides restarting one of the earlier closed down stations.

Under the **Wind Mapping Programme,** simplified wind speed data were collected from a wider network of stations by using a 5 m tall mast and simple manually read cup anemometers. So far, data have been collected from 595 stations in 20 States. The main purpose of this programme is to establish a wind climatology for the country.

Automatic wind data logging systems with anemometers and wind vanes, and a 50 m tall guyed tubular mast have been acquired for further studies under the projects. In collaboration with the Ministry of Non-Conventional Energy Sources, Government of India a work to carry out the "Micro Surveys" around selected wind monitoring stations using the Wind Atlas Methodology has been taken up.

Computer and Data

Scientific computing is vital for research in Atmospheric Sciences particularly connected with atmosphere modelling. Recognizing the importance of scientific computing for weather forecasting, the Institute has developed modern fast computing facilities for its research work.

The scientists are provided with the on-line access for the Numerical Algorithms Group (NAG) FORTRAN Library installed on the ND - 560 / CX computer system. The software facilities/requirements are being reviewed and additional facilities are planned and updated from time to time.

The ND-560/CX and RISC based HP-9000/735 workstation (with 40 MFLOPS, 112 MB RAM, 16.8 GB disc capacity) are being used extensively by the scientists of the Institute. A line-printer and a Laser-Jet printer are connected to the workstation. Several Personal Computers, with various input / output media like floppy discs, cartridge tapes, CD-ROMs, digital audio tapes etc. are available. Most of the Pentiums and other Personal Computers of the divisions are connected to the Institute's LAN.

In addition to these, a very high end compute server - The Silicon Graphic's Power Challenge has been acquired mainly for the Climate and Global Modelling work. The system consists of 4 CPUs (R-8000) each with a peak performance of 300 MFLOPS, 32 GB hard disk, a central memory of 512 MB and the INDY graphics workstations and powerful software tools like the IRIS showcase, Explorer and Indigo Magic software for developing audio, video and graphics applications.

The Computer Division also provides other technical services to the scientists, viz., collection, archival and retrieval of the meteorological and other related data for the tropics on the regional and global scales. The major databases archived include Comprehensive Ocean Atmosphere Data Set (COADS), the FGGE level III-b data set acquired from the ECMWF, U.K, and the Monthly Climatic Upper Air Data and Radiosonde Data for different stations and periods. The Division holds voluminous data collected during the MONTBLEX Programme. The Division arranges special runs for the long and continuous

uninterrupted computations during the nights and holidays depending on requirements of the scientists.

The Division provides its facilities to other organisations like India Meteorological Department, Universities and also to the research scholars and M.Tech. students undergoing courses connected with atmospheric sciences.

Internet facility through VSAT has been installed and is being extensively used by the scientists of the Institute.

TOGA-I DATA Centre

Funded by the Department of Science and Technology, the Institute had taken up a project in which the data collected during the field phase of the ' Tropical Ocean and Global Atmosphere (TOGA) ' Programme were archived for the convenience of the research scientists in India. Data received from the TOGA Project office on a CD-ROM (575 MB approx.) pertaining to different data sets from various countries consisting of sea surface temperature, winds, wind stress, basic level III analyzed data and supplementary fields data were archived with a special software made available by the TOGA Project Office. This software enables users to graphically view, on a colour monitor, various parameters for selected areas with a provision for data extraction. A PC/AT-386 and a laser printer acquired under this project were being used for the data archival and retrieval work.

DST-MONTBLEX Data Bank

The Institute had also taken up a project funded by the Department of Science and Technology for archiving data collected by various scientific organisations which participated in the Monsoon Trough Boundary Layer Experiment (MONTBLEX). The MONTBLEX data are being supplied to the users on request.

Software Development for Accounts and Management

Programs were developed for fixation of pay as per the recommendations of the Fifth Pay Commission and computation of arrears. Special runs were arranged for this work. Development of Application Software was carried out for the Institute's Accounts Section for its routine work like Pay Roll and its related statements, MIS reports, abstracts and schedules for various categories of staff. The output-data derived from Pay Roll were used for estimation of Income Tax and calculation of Income Tax along with Form-16 for filing the Income Tax returns. Provident Fund slips with interest calculation and Budget estimation were also done for the year 1997-98. Programs have been developed in FORTRAN and C languages in addition to the interpreter languages like AWK under UNIX and dBASE-III+ on Personal Computers. The programs and data are inter-operatable with heterogeneous computer platforms and software running under them. The staff of the Accounts Section were trained to run these programs. Updating of these programs were done from time to time in accordance with the Government orders, rules and regulations.

Library, Information and Publications

The Institute has developed a comprehensive Information System in Meteorology and Atmospheric Sciences. The Institute's Library, Information and Publications Division serves as the Information System with the following objectives :

- Collection, organisation and dissemination of information pertinent to the present and anticipated research needs of the Institute.
- Providing technical services like library, documentation, information, publications, drawing, drafting, micrography and photography to scientists of the Institute.
- Providing facilities for the retrieval and use of information resources.
- Preparing, publishing and presenting various scientific research reports and allied material on the activities of the Institute and keeping liaison with other scientific organisations and universities in India and abroad.

The Library is housed in its newly constructed, separate building. The Library has built an information base of about 25,000 publications consisting

of books, monographs, back volumes of journals, scientific/ technical reports, seminars/ symposia proceedings, reprints, abstracts, bibliographies, global meteorological data, geophysical data, maps, atlases, theses etc. and national / international current journals covering a wide range of subjects in Atmospheric Sciences. The library and information services are provided to the scientists of the Institute as well as to the research community working in the field of Atmospheric Sciences in different organisations. The Library has developed an informal resource sharing network with the libraries of different organisations within India and abroad and also strengthened its information base through the 'Gift and Exchange of Publications Programme' with the national and international organisations.

During the year 97 books and reports in Meteorology and allied subjects were added. 94 periodicals of national / international origin were subscribed to. Reprints of 24 papers authored by the Institute's scientists were also purchased. Several scientific and technical reports were received from other National and International Organisations on complimentary and exchange basis.

The scientists of the Institute are kept abreast of the latest development in their research areas by rendering regularly Information Dissemination Services through the Selective Dissemination of Information (SDI), Current Awareness (CA) and preparation of Documentation lists and Bibliographies (both current as well as retrospective) on different ongoing research projects of the Institute. The photocopies of the articles of interest are provided under the SDI and Resource Sharing Services. On demand, Citation Indexes for the research papers of the Institute's scientists are also prepared.

The Library and Information System has served as resource for literature on Meteorology and its allied subjects. The library is listed in the Directory of Special and Research Libraries in India and the Union Catalogue of Serials and Periodicals. The Library is also an active member- participant of the Resource Sharing Group and the PUNE-NET-a network of Scientific and Technical Libraries in Pune Metropolitan area. The computerised databases for the collection of books and journals have been made available for retrieval at the workstation of the PUNE-NET located at the Bioinformatics Centre of the University of Pune, Pune. Computerised databases for reports and other publications have also been created.

The Division maintained liaison with Institutions, Universities and Ministries. A number of reports on the research activities and plan schemes of the Institute were prepared and sent to the Department of Science and Technology, India Meteorological Department, Universities and Research Institutes.

The Division also provided other technical services like photocopying, microfilming, photography, drafting, drawing, printing and binding to the scientists of the Institute. The Division also arranges programmes for popularisation of meteorology among students and public by organising open day and scientific exhibitions depicting research activities of the Institute on the occasion of important events, such as visits of distinguished scientists and guests, celebration of the National Science Day, World Meteorological Day etc.

Management

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

Administration

The Administration provides support for the personnel management, finance, purchase, stores, capital works and maintenance of buildings.

Personnel Profile

As on March 1998 the Institute had total 298 staff out of which 146 were of Scientific, 38 of Technical, 58 of Administrative and 56 of Non-technical maintenance category.

Status of SC/ST/OBC Reservation

The status of filled positions for SC/ST/OBC is as follows:

	SC	ST	TOTAL
Research	10	4	14
Scientific	6	1	7
Technical	6	1	7
Admin	10	6	16
NTM	19	2	21
TOTAL	51	14	65

Staff changes

Five persons joined and seven left the Institute during the year under different categories.

Shri R. K. Verma, Assistant Director and Shri V. T. Ranpise, Mechanical Assistant retired on 31 May 1997, Dr. S. Rajamani, Deputy Director on 31 August 1997, Dr. S. N. Bavadekar, Assistant Director, and Shri C. G. Kulkarni, Watchman on 31 December 1997 and Shri D.G. Gowalkar, Watchman on 31 January 1998, all on attaining the age of superannuation.

Shri M.Ravichandran, Junior Scientific Officer was relieved to take up the appointment as Senior Project Engineer at the National Institute of Ocean Technology, Chennai with effect from 23 May 1997. Shri B.Y. Gaikwad, Accounts Officer was also relieved to take up the appointment as Staff Administration III (Officer on Special Duty) at the Centre for Materials for Electronics Technology, Pune on deputation basis for one year with effect from 15 November 1997.

Resignations tendered by Shri J.V.Ratnam, IITM Research Fellow and Shri S. Arul Raj, Project Associate were accepted with effect from 20 June 1997 and 11 August 1997 respectively. Shri C.Venkatesan, Research Fellow of the Institute completed his fellowship tenure on 12 March 1998.

Shri V.B. Raut, Laboratory Attendant expired on 18 November 1997.

Employment of Ex-servicemen

Reservation for the ex-servicemen is made at 10 % in Group 'C' and 'D' posts of the Institute. The percentage of ex-servicemen at the Institute vis-a-vis total number of employees in Group 'C' and 'D' are 2.5 and 7 respectively.

Academic Council

The Academic Council is a body consisting of scientists in the grade of Senior Scientific Officer, Gr. I and above. It considers all the matters relating to scientific projects of the Institute and ensures team work and team spirit in the Institute for achieving its aims and objectives. Six meetings of the council were held during the year.

Advisory Committee

The Advisory Committee consisting of the Heads of the Divisions and Deputy Directors considers policy matters of the Institute. During the year four meetings of the Committee were held.

Staff Council

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

Purchase and Stores

The Institute acquired data acquisition and storage systems, accesories to the scientific equipment, office furniture items, personal computers, printers, and enhancing systems and accessories to the existing computer systems.

Official Language Implementation

Hindi Cell is working as per rules and directives regarding Official Language Implementation. Correspondence and regular reports to the Department of Science and Technology,

Department of Official Language and other offices are made in bilingual format. Special attention has been given towards Hindi Training of the Institute's employees as well as promoting the use of Hindi in the working of the Institute. Two employees have successfully completed the Hindi Training arranged under the Hindi Teaching Scheme. One more employee has been sponsored for the training. A special library comprising of over 450 books in Hindi on various subjects is available to the Institute's employees to enrich their Hindi knowledge.

The Institute celebrated Hindi Day on 25 September 1997. Competitions in Elocution, Poetry recitation, Idioms and Phrases, and Speech, all in Hindi, were organised on the occasion. Dr.(Smt.) Rewa Kulkarni, Professor of Hindi, SNDT College, Pune, was the Chief Guest of the function. The Chief Guest delivered a lecture and distributed prizes to the participants of the competitions.

Dr.(Smt.)Rewa Kulkarni delivering a special lecture as the Chief Guest of the Hindi Day Celebration.

Finance

Budget

The main funding agency for the Institute is the Department of Science and Technology, Government of India. Estimates and Actual expenditure for the year 1997-98 are as follows :

(Rs. in Lakhs)

	Plan	Non-Plan
• **Budget Estimates**	145.00	263.00
• **Revised Estimates**	---	300.00
• **Grant Received**	167.75	259.06
• **Actual Expenditure**	167.75	259.06

Shri. Satishchandra Soman delivering a lecture on his adventurous flight by his own single engine aircraft Cessna-172.

IITM Recreation Club

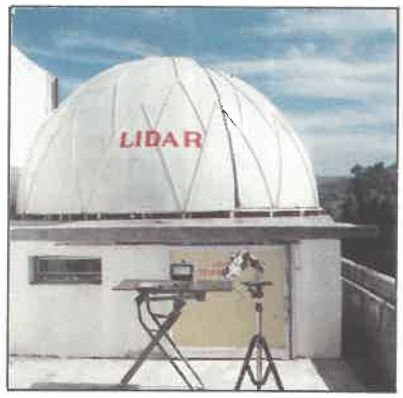
The Recreation Club continued to provide sports and library facilities to the members. 101 books were added to the Library. Annual Sports Tournaments were organised on League basis and prizes to the winners and runners-up were distributed at the hands of the Director.

The Club celebrated the Golden Jubilee of India's Independence. On this occasion, the Club awarded prizes to the children of the Institute's employees who had exhibited excellent performance in different examinations such as S.S.C., H.S.C., Diploma, Graduation, Post Graduation etc. held in the Academic Year 1996-97 under different disciplines. Two Special Guest Lectures on adventurous expeditions were arranged during the year. The Recreation Club started several new activities for the benefit of the Institute's employees.

Shri. Prem Vaidya delivering a lecture on Ganga Expedition "Against the Current".

Field observations in the Kullu region for the study of the Biogeochemical cycles in the Himalayan ecosystem.

Dendroclimatology Laboratory for the study of Tree-ring width analysis



Multi-wavelength radiometer for monitoring Aerosols and Ozone seen in front of the dome.

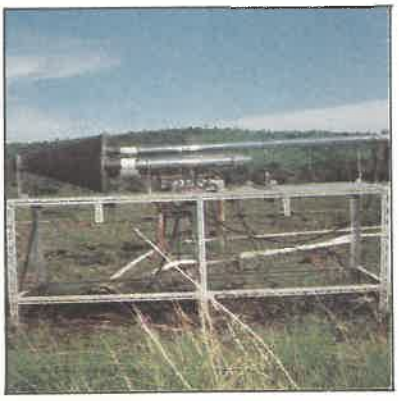
Automatic rotating slit scanning spectrometer for monitoring of trace gases in the atmosphere.

Newtonian type Telescope of the Laser-radar system for remote sensing of atmospheric aerosols.

Cassegrain telescope and associated optical equipment of the Lidar system housed in the dome.

Wind tunnel for the simulation technique for cloud physics studies.

Secondary Data Utilization Centre (SDUC) to receive cloud imageries and meteorological data.



Atmospheric ion counter at the Institute's Atmospheric Electricity Observatory.

Measurement of Aerosol size distribution onboard ORV Sagar Kanya during INDOEX Cruise No.133.

Instrumented tower used in the Land Surface Processes Experiment at Anand, Gujarat.

Measurement of atmospheric electrical conductivity onboard ORV Sagar Kanya during INDOEX Cruise No.133.

Publications

PAPERS PUBLISHED IN JOURNALS

NWP Modelling and Model Diagnostics

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Participation in Meetings

Dr. A.K.Kamra

- Sixth Meeting of the Scientific Advisory Committee of National Centre for Medium Range Weather Forecasting, Mausam Bhavan, New Delhi, 3 April 1997.
- Meeting to Review the Results of Cruise No.120 and the Meeting of National Steering Committee for INDOEX Programme, National Physical Laboratory, New Delhi, 13-14 August 1997.
- 47th Meeting of the Council for Meteorology and Atmospheric Sciences (CMAS), Mausam Bhavan, New Delhi, 23 September 1997.

Dr.G.B.Pant

- Meeting of the Project Advisory and Monitoring Committee for Monsoon and Tropical Climate and the Indian Climate Research Programme of DST, Indian Institute of Tropical Meteorology, Pune, 15-16 May 1997.
- Meeting of Syllabus Committee of Satellite Meteorology Course under U.N. Sponsored Training Programme, Space Applications Centre, Ahmedabad, 4-5 August 1997.
- Meeting of PAC-Integrated Long Term Programme with Russia in the Area of Theoretical and Applied Mechanics, National Aeronautical Laboratory, Bangalore, 8 August 1997.
- Meeting of the Programme Definition Group-CLIMAT SAT, ISRO Headquarters, Bangalore, 22 August 1997.
- 23rd Meeting of the Indian National Committee on Hydrology, National Institute of Hydrology, Roorkee, 26 September 1997.
- Discussion Meeting on Monsoon-Past, Present and Future, Orange County, Bangalore, 19-23 November 1997.
- Meeting on Brain Storming Session, National Centre for Medium Range Weather Forecasting, New Delhi, 6 December 1997.
- Meeting of the Programme Advisory Committee of UN Workshop, Space Applications Centre, Ahmedabad, 8-10 January 1998.
- Meeting of the Indo-US Co-operation in the Field of Atmospheric and Earth Sciences, Mausam Bhavan, New Delhi, 20 January 1998.
- Second Meeting of Project Advisory and Monitoring Committee for MONTCLIM and ICRP, Indian Institute of Science, Bangalore, 21-22 January 1998.
- Seventh Meeting of the Scientific Advisory Committee of National Centre for Medium Range Weather Forecasting, Mausam Bhavan, New Delhi, 2 February 1998.
- 48th Meeting of the Council for Meteorology and Atmospheric Sciences (CMAS), Mausam Bhavan, New Delhi, 22-23 February 1998.
- Meeting of the SASCOM Planning, National Physical Laboratory, New Delhi, 23-25 March 1998.

Dr. A.S.R.Murty

- Third Meeting of the Indo-Russian Sub-working Group on Meteorology, Moscow and Nalchik, Russia, 10-16 September 1997.

Shri K.G.Vernekar

- Meeting of the Project Advisory and Monitoring Committee for Monsoon and Tropical Climate and the Indian Climate Research Programme of DST, Indian Institute of Tropical Meteorology, Pune, 15-16 May 1997.
- Meeting of the Indian Climate Research Programme, University of Pune, Pune, 30 June 1997.

- Meeting of the Review Committee of SAMEER for Doppler Sodar, Society for Applied Microwave Electronics Engineering and Research (SAMEER), Mumbai, 19-20 August 1997.

- Second Meeting of the Steering Committee for the Land Surface Processes Experiment, Department of Science and Technology, New Delhi, 16 September 1997.

- Meeting of the Working Group of Indian Climate Research Programme (ICRP), Department of Science and Technology, New Delhi, 17 September 1997.

- Meeting of the Standing Committee to Review the Land Surface Processes Experiment Project, Department of Science and Technology, New Delhi, 24 September 1997.

- Meeting of the Land Surface Processes Experiment Monitoring Committee, Gujarat Agricultural University, Anand, 18-19 February 1998.

- Meeting of the Progress Review Committee for Project Development of Radio Acoustic Sounding System, Society for Applied Microwave and Electronic Engineering Research (SAMEER), Mumbai, 13 October 1997 and 20 February 1998.

Dr. S.S.Singh

- Meeting of the Experts Group of Scientific Advisory Committee of National Centre for Medium Range Weather Forecasting, Mausam Bhavan, New Delhi, 1 April and 9 December 1997.

- Meeting of the Indo-US Co-operation in the Field of Atmospheric and Earth Sciences, Mausam Bhavan, New Delhi, 20 January 1998.

- Meeting of the GAME (GEWEX Asian Monsoon Experiment), Mausam Bhavan, New Delhi, 20 March 1998.

Dr.P.C.S.Devara

- Second Meeting of the Wind Modelling and Monitoring Group of the University of Pune and ISRO Interaction Programme, University of Pune, Pune, 30 June 1997.

- Meeting on Positioning of UHF Wind Profile/RASS at IITM, Indian Institute of Tropical Meteorology, Pune, 4 July 1997.

- Meeting to review the collaboration between IITM and SAC on IRS-P3 data validation experiments and plan activities on the IGBP WG-IV experiment on evolving atmospheric correction scheme for the remote sensed data during 1997-98 to 2000-2001, Indian Institute of Tropical Meteorology, Pune, 3 October 1997.

- Meeting on Finalisation of specifications of Capital Equipment to be procured under the Scheme Modernisation and Augmentation of Air Pollution Laboratory , Pune, India Meteorological Department, New Delhi, 30 March 1998.

Dr.V.Satyan

- The Mid-term Review of the Climate Research Project, S.V.University, Tirupati, 17-18 June 1997.

Dr.A.K.Kulkarni

- Meeting of Technical Advisory Review Committee Members, Water and Power Consultancy Services (India) New Delhi, 7-10 October 1997.

Dr.(Smt.)P.S.Salvekar

- Meeting of the Department of Ocean Development, C-MMACS, Bangalore, 25-26 February 1998.

Dr.S.S.Parasnis

- Second Meeting of the Wind Modelling and Monitoring Group of the University of Pune and ISRO Interaction Programme, University of Pune, Pune, 30 June 1997.

- Second Meeting of the Steering Committee for the Land Surface Processes Experiment, Department of Science and Technology, New Delhi, 16 September 1997.

- Meeting of Ph. D. Admission Committee, University of Pune, Pune, 22 October 1997 and 11 March 1998.

Shri B.N.Mandal

- Meeting of the Selection Committee for the Recruitment in Group "C" Cadre for the post of Mechanic Gr.II (Driver) in the Office of the DDGF, India Meteorological Department, Pune, 19-20 June 1997.

- Meeting of the Departmental Promotion Committee for consideration of clearance of probation and confirmation of Group "C" employees in the Office of the ADGM, India Meteorological Department, Pune, 20 June 1997.

Dr.P.N.Mahajan

- Meetings of the Departmental Promotion Committee/Review Promotion Committee for posts in Scientific, Technical and Non-Technical Maintenance Categories, India Meteorological Department, Pune, 26 July 1997.

- IRS-P4 (Oceansat-1) Data Utilisation Meet, Space Applications Centre, Ahmedabad, 4-5 September 1997.

Smt.U.V.Bhide

- Annual Monsoon Review Meeting (AMR-98), Regional Meteorological Centre, India Meteorological Department, Chennai, 28 January 1998.

Dr.(Smt.)I.Joshi

- Second Meeting of the Wind Modelling and Monitoring Group of the University of Pune and ISRO Interaction Programme, University of Pune, Pune, 30 June 1997.

Shri R.M. Soni

- Meeting of the Selection Committee for the Recruitment in Grade 'C' cadre for the post of Draughtsman (Mechnical) in the office of the DDGM (Weather Forecasting), India Meteorological Department, Pune, 29 July 1997.

Dr.S.Rangarajan, Field Research Unit

- Meeting on Technological Development Plan for Wind Power, Thiruvananthapuram, 26 April 1997.

- Meeting for the Implementation of Wind Energy Programmes exclusively for the North East Region, Guwahati, 27 February 1998,

Seminars

By Visitors

Dr. Edward R. Cook, *Lamont Doherty Earth Observatory, Columbia University, U.S.A.*

- *Recent dendroclimatic research of Tree Ring Laboratory at Lamont (1 April 1997)*

Dr. Martin Gill, *Hadley Centre for Climate Prediction and Research, U.K.*

- *Simulation of the Asian summer monsoon in the Meteorological Office's Unified Model (3 September 1997)*

Dr. C.R.Sridharan, *DDGM (Retd.), India Meteorological Department, Pune*

The ozone crises (16 September 1997)

Mr. Albert Owino, *Kenya Meteorological Department, Kenya*

- *Dynamics of air flow through mountain gap (27 November 1997)*

Prof. G.V.Rao, *University of St. Louis, USA*

- *Oceanic convection (22 December 1997)*

Prof. Hannes Tammet, *University of Tartu, Estonia*

- *Theory of electrical mobility-I (7 January 1998)*
- *Theory of electrical mobility-II (8 January 1998)*
- *Original instruments in Air Electricity Laboratory, Tartu (9 January 1998)*
- *Estonia, University of Tartu, and Air Electricity Laboratory (12 January 1998)*
- *Measurements in Tahkuse Observatory (13 January 1998)*
- *Environmental importance of air ions (14 January 1998)*
- *Simultaneous measuring of aerosols and radioactivity (15 January 1998)*
- *Models of size distribution of atmospheric aerosols (19 January 1998)*
- *Global variations of atmospheric electricity (20 January 1998)*
- *Theory of atmospheric-electrical antennas (21 January 1998)*
- *Limits of the air ion mobility resolution (22 January 1998)*
- *Multichannel aerosol spectrometer EAS (23 January 1998)*

Prof. Pramod Kale, *Director (Retd.),Space Application Centre, Ahmedabad*

- *Meteorological communications (26 February 1998)*

Prof. Govind Swarup, *Prof. Emeritus, National Centre for Radio Astrophysics(TIFR), Pune*

- *Puzzles of the universe (27 February 1998)*

Shri Prem Vaidya, *Ex. Director/Producer, Films Division of India, Pune*

- *Everest Hero- Sir Edmund Hillary's Ganga Expedition "Against the Current" (18 March 1998)*

By Institute Scientists

Dr. (Smt.) A.A.Kulkarni

- *Advanced statistical techniques (17 June 1997)*
- *Rainfall pattern recognition (12 December 1997)*

Shri L.K.Sadani

- *Turbulence intermittency in the atmospheric surface layer over monsoon trough region (23 June 1997)*

Dr. R.H.Kripalani

- *Madden Julian oscillation (24 June1997)*
- *MJOS in medium range forecasting (9 December 1997)*

Dr. N.Singh

- *On the variability and prediction of the Indian northeast monsoon (6 October 1997)*

Dr. P.C.S.Devara

- *Role of aerosols in meteorology (19 October 1997)*

Shri S.D. Dahale

- *Stochastic models in short range rainfall prediction (15 and 19 December 1998)*

Dr. K. Ashok

- *Some numerical simulation studies of tropical cyclone circulation over the Bay of Bengal (13 January 1998)*

Smt. M.N. Kulkarni

- *Turbulent electrode effect over land surface (14 January 1998)*

Shri C.G.Deshpande

- *Antarctica Expedition: An experience (19 January 1998)*

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Academic Activities

Teaching and Research Support

Lectures delivered for M.Sc./M.Tech.(Atmospheric Sciences), M.C.A., M.C.S. at the University of Pune, Pune

Prof.G.C.Asnani
- Climate and climate variability

Dr.S.S.Singh
- Introduction to NWP

Dr.S.Rajamani
- Objective analysis for NWP

Shri K.G.Vernekar
- Atmospheric boundary layer

Dr.P.C.S.Devara
- Remote sensing of the atmosphere

Dr.(Smt.)P.S.Salvekar
- NWP and climate modelling
- Advanced dynamic meteorology

Dr. R.Vijayakumar
- Thermodynamics

Shri M.K.Tandon
- Principles of programming languages (C++)
- Principles of programming languages (C++ and PROLOG)
- Principles of programming languages (PROLOG and LISP)
- Design and analysis of algorithms
- Programming languages and principles

Shri J.R.Kulkarni
- Dynamic meteorology
- Theory of turbulence

Dr.P.N.Mahajan
- Satellite meteorology

Smt.S.S.Vaidya
- Introduction to NWP

Shri S.K.Behera
- Ocean dynamics

Dr.(Smt.)I.Joshi
- Atmospheric physics
- Dynamics of the ionosphere and magnetosphere
- Optical phenomena of the atmosphere

Dr.(Kum.)P.L.Kulkarni
- Objective analysis and initialization

Shri D.R.Talwalkar
- Objective analysis and initialization

Smt.S.K.Mandke
- Energy balance and radiative convective models

Smt.A.A.Deo
- Dynamical oceanography

Guidance for Research Projects

Dr.G.B.Pant,
Shri. P.Chauhan,
M.Sc.,Kurukshetra University, Kurukshetra

Dr.V.Satyan
Shri K.Satheesan,
M.Tech.,Cochin University of Science and Technology, Kochi

Dr.P.C.S.Devara
Shri K.Ramkrishna,
M.Sc. , Andhra University, Visakhapatnam

Dr.(Smt.)P.S. Salvekar
Kum.M.Mohanty,
M.Tech., University of Pune, Pune

Shri K.N.Rao,
M.Tech.,Andhra University,Visakhapatnam

Dr.D.B.Jadhav
Shri D.Jadhav, Shri N.Shaikh and Shri A.Raut,
M.Sc.,University of Pune, Pune

Dr.R.Vijayakumar
Kum. D. D.Bambaladi,
Advanced Diploma in Computer Software and System Analysis (ADCSSA), Symbiosis Institute of Computer Studies and Research, Pune

Dr.N.Singh
Shri D.V.G.Krishna,
M.Tech., Andhra University,Visakhapatnam

Dr.S.S.Parasnis
Shri B.Singh,
M.Sc.,Kurukshetra University, Kurukshetra

Shri S.Koli,
M.Tech,University of Pune,Pune

Shri J.R.Kulkarni
Shri R.S.Hooda,
M.Sc. ,Kurukshetra University, Kurukshetra

Shri S.P.Suaro,
M.Tech., Andhra University, Visakhapatnam

Dr.P.N.Mahajan
Kum.B.S.Vaidya,
M.Sc., University of Pune,Pune

Dr.(Smt.)I.Joshi
Smt. P.Paul,
Ph.D., University of Pune, Pune

Nomination as External Examiners / Paper Setters

Prof.G.C.Asnani, Hon.Fellow
Ph.D., University of Delhi, New Delhi

Dr.A.S.R.Murty
M.Sc. and Ph.D., Andhra University, Visakhapatnam, Banaras Hindu University, Varanasi and Cochin University of Science and Technology, Kochi

Dr.(Smt.)A.M.Selvam
M.Sc.,Andhra University, Visakhapatnam and Cochin University of Science and Technology, Kochi

Shri K.G.Vernekar
M.Tech.,University of Pune, Pune

Dr.P.C.S.Devara
M.Sc.,University of Pune, Pune, Banaras Hindu University, Varanasi, Andhra University, Visakhapatnam and Gujarat University, Ahmedabad

Dr.(Smt.)P.S.Salvekar
M.Tech.,University of Pune, Pune and Cochin University of Science and Technology, Kochi

Dr.D.B.Jadhav
M.Sc.,Shivaji University, Kolhapur

Dr.S.Sivaramakrishnan
M.Tech.,University of Pune, Pune

Dr.R.Vijayakumar
M.Sc.,University of Pune, Pune

Dr.S.S.Parasnis
M.Tech.,University of Pune, Pune

Dr.D.Subrahmanyam
M.Tech., Andhra University, Visakhapatnam

Dr.R.H.Kripalani
M.Tech., University of Pune, Pune

Shri M.K.Tandon
M.C.S., University of Pune, Pune

Shri J.R.Kulkarni
M.Tech., University of Pune, Pune

Shri S.K.Behera
M.Tech., University of Pune, Pune and Cochin University of Science and Technology, Kochi

Dr.T.Venugopal
M.Phil, Bharathiar University, Coimbatore

Dr.(Smt.)I.Joshi
M.Sc., University of Pune, Pune

Dr.(Smt.)A.A.Kulkarni
M.Tech., University of Pune, Pune

Dr.S.S.Parasnis and **Dr.(Smt.)I.Joshi**
have been recognised as Research Guide for M.Sc. and Ph.D. courses in Physics by the Bharati Vidyapeeth, Pune (Deemed University).

Expertise provided for the Trainings / Workshops etc.

- *Fourth SERC School on Advanced Geophysical Fluid Dynamics: Dynamics of Climate and its Variability, IITM, Pune, 2 June-5 July 1997*

  Dr.G.B.Pant, Dr.H.N.Bhalme, Dr.P.C.S.Devara, Dr.V.Satyan, Dr.A.K.Kulkarni, Dr.L.S. Hingane, Dr.(Smt.)P.S. Salvekar, Dr.R. Krishnan, Dr.N. Singh, Dr.R.H.Kripalani, Dr.P.N.Mahajan, Shri J.R.Kulkarni, Smt.S.S. Vaidya, Dr.G.Beig, Dr.H.P. Borgaonkar, Dr.(Smt.)N.A.Sontakke, Dr.(Smt.) A.A. Kulkarni, Smt.S.K.Mandke and Shri C.Venkatesan

- *Field Observers Training of Hydrology Project at Water and Land Management Institute, Aurangabad, 1 August-28 November 1997*

  Dr.A.K.Kulkarni

- *SAARC Workshop on Long Range Weather Forecasting and Climatic Change, India Meteorological Department, Pune, 16-19 September 1997*

  Dr.H.N.Bhalme

- *A Short-term Training Course on Agrometeorological Data Monitoring and Management, IITM, Pune, 8-20 December 1997.*

  Dr.G.B.Pant, Dr.S.S.Singh, Shri K.G.Vernekar, Dr.H.N.Bhalme, Dr.L.S.Hingane, Shri S.Sinha, Dr.(Smt.)P.S.Salvekar, Shri L.K.Sadani, Dr.R.Vijayakumar, Dr.A.K.Kulkarni, Dr.N.Singh, Dr.M.K.Soman, Dr.S.S.Parasnis, Shri S.S.Aralikatti, Dr.R.H.Kripalani, Shri M.K.Tandon, Shri J.R.Kulkarni, Dr.P.N. Mahajan, Smt.N.R.Deshpande, Dr.(Smt.)N.A. Sontakke, Shri S.D.Dahale, Shri V.R. Mujumdar, Shri S.D.Bansod, and Dr.(Smt.) A.A.Kulkarni

- *UGC Refresher Course in Space Physics, University of Pune, Pune, 30 January- 27 February 1998*

  Prof.G.C.Asnani, Dr.G.B.Pant, Dr.P.C.S.Devara, Dr.R.Vijayakumar and Dr.D.B.Jadhav

Memberships of Scientific Committees

Dr.G.B.Pant

- National Committee of the Indian National Science Academy on the World Climate Research Programme
- Project Advisory Committee on the Theoretical and Applied Mechanics under the ILTP with Russia, sponsored by DST
- Syllabus Committee on Satellite Meteorology and Global Climate under the Centre for Space Science and Technology Education for Asia and the Pacific of the U.N., Dehradun, India
- A Panel on Ocean Environment appointed by the Naval Research Board, Ministry of Defence
- Scientific Steering Committee for the IPCC Workshop on Rapid Non-Linear Climate Change to be organised at Noordwijkerhout, Netherlands, 31 March-2 April 1998

Dr.A.K.Kamra

- Fellow of the Indian Academy of Sciences, Bangalore
- Commission for Atmospheric Sciences of the World Meteorological Organisation

Dr.A.S.R.Murty

- WMO Executive Council Panel of Experts Working Group on Physics and Chemistry of Clouds and Weather Modification Research, Geneva

Dr.S.S.Singh

- National Committee on GAME (GEWEX Asian Monsoon Experiment)
- Expert Group of Scientific Advisory Committee of National Centre for Medium Range Weather Forecasting, New Delhi

Dr.P.C.S.Devara

- Editorial Board of the Journal "Vayu Mandal"
- The New York Academy of Sciences, USA
- Fellow of the Institution of Electronics and Telecommunication Engineers (IETE), New Delhi

Dr.S.S.Parasnis

Member of the Ph.D. Admission Committee for Physics, University of Pune, Pune

Lectures Delivered Outside

Dr.A.K.Kulkarni

- *Hydrometeorology and design storm,* Central Water and Power Research Station, Pune (4 April 1997)
- *Network design*
- *Indian monsoon and rainstorm analysis with special reference to Maharashtra,* Water and Land Management Institute, Aurangabad (15 December 1997-9 January 1998)
- *Indian monsoon and its effect on water resources development*
- *Analysis of severe rainstorms of India* Shivaji University, Kolhapur (6 January1998)

Shri S.K.Behera

- *Simulation of interannual SST in the Indian Ocean*
- *Remote forcing responses on Indian coastal circulation* International Centre for Theoretical Physics, Trieste, Italy (21 April 1997)

Dr.H.N.Bhalme

- *Causes, processes, prediction, monitoring and early warning of droughts*
- *Interannual and decadal scale variability of monsoon* India Meteorological Department, Pune (29 April and 17 September 1997 resply.)

Shri J.R.Kulkarni

- *Parallel processing of GCM* Indian Armament Technology, Pune (13 May 1997)

Dr.R.H.Kripalani

- *Snow-ENSO- monsoon* Centre for Ocean-Land-Atmosphere Studies (COLA), Maryland, USA (3 November1997)

Dr.R.Krishnan

- *Dynamics of ENSO induced teleconnections over the Indian summer monsoon region* International Research Institute for Climate Prediction, Lamont, New York, USA (6 November 1997)
- *Low frequency intraseasonal oscillations of the Indian summer monsoon* Rosenstiel School of Marine Sciences, University of Miami, USA (10 November 1997)

Dr.G.K.Manohar

- *Impact of total solar eclipse on surface atmospheric electricity*
- *Thunderstorm frequencies over India* University of Roorkee, Roorkee (11 and 12 November 1997 resply.)

Dr.M.K.Soman,

- *Seasonal prediction of summer monsoon with Hadley Centre Climate Model* National Centre for Medium Range Weather Forecasting, New Delhi (1 December 1997)

Award of Ph.D. Degree by University of Pune, Pune

Shri K.Krishna Kumar

Seasonal forecasting of Indian summer monsoon rainfall: diagnostics and synthesis of regional and global signal
(Guide : Dr.G.B.Pant)

Shri H.P. Borgaonkar

Tree growth-Climate relationship and long-term climate change over the western Himalaya: A dendroclimatic approach
(Guide : Dr.G.B.Pant)

Shri S. Sivaramakrishnan

Studies on the exchange processes in the convective atmospheric boundary layer in the monsoon trough region
(Guide : Prof.R.N. Keshavamurty)

Smt.N.A.Sontakke

Study of climatic variations and climate monitoring over India and neighbourhood
(Guide : Dr.G.B.Pant)

Smt.S.B.Morwal

Nature and some evolutionary aspects of the monsoon boundary layer
(Guide : Dr.S.S.Parasnis)

Shri R.Vijayakumar

Observations and numerical simulations of the microphysical processes in monsoon clouds
(Guide : Dr.A.S.R.Murty)

Shri P.S.P.Rao

Some studies on the depositions of atmospheric pollutants in different environments in India
(Guide : Dr.P.C.S. Devara)

Shri J.V.Ratnam

Role of nongeostrophic effects on the baroclinic development of the monsoon disturbances
(Guide : Dr.(Smt.)P.S. Salvekar)

Shri C.Venkatesan

Model studies of monsoon variability
(Guide : Prof.R.N. Keshavamurty and Dr.(Smt.) P.S Salvekar)

Shri K.Ashok

Some numerical simulation studies of tropical cyclone circulations over the Bay of Bengal (Andhra University, Visakhapatnam)
(Guide : Prof. D.V.Bhaskar Rao.)

Thesis Submitted for Ph.D. Degree

Shri S.K.Behera

A mathematical modelling of the Indian Ocean and sensitivity studies on dynamics variability and air-sea interactions (submitted to Berhampur University, Berhampur)
(Guide : Dr.(Smt.)P.S. Salvekar)

Shri G.Pandithurai

Lidar and radiometric studies of aerosol and trace gas distributions in the tropical atmosphere (submitted to University of Pune, Pune)
(Guide : Dr.P.C.S.Devara)

Guidance provided to Ph.D. students of University of Pune, Pune

Shri J.K.Sahu,

Air India Research Fellow
Some thermodynamical and forecasting aspects of local severe storms over northwest India
(Guide : Dr.S.V.Singh and Prof.G.C.Asnani)

Mr. Albert Owino,

Kenya Meteorological Department, Nairobi, Kenya
Dynamics of air flow through mountain gap
(Guide : Prof.G.C.Asnani and Dr.(Smt.) P.S Salvekar)

Shri D.N.Nighut,

Lecturer in Physics, Arts, Commerce and Science College Shevgaon, Ahmednagar,
Study of atmospheric aerosol loading using the twilight method
(Guide : Dr.D.B.Jadhav)

Training Undergone

Dr.A.K.Sahai

Condensed Basic Training followed by Advanced Meteorological Training Course,
India Meteorological Department, Pune,
9 September 1996-8 September 1997

Kum.J.S.Pethkar and **Smt.V.V.Sapre**

Training on Unix System Administration,
National Informatics Centre, Pune,
22-24 April 1997

Shri B.D.Kulkarni and **Shri M.N.Patil**

WMO Training on Agrometeorology Related to Extreme Events in India,
India Meteorological Department, Pune,
28 April-10 May 1997

Shri S.D.Bansod, Shri D.R.Kothawale, Shri S.D.Patil, Shri S.B.Kakade, Shri G.R. Chintalu and **Shri R.Ashrit**

Fourth SERC School on Advanced Geophysical Fluid Dynamics: Dynamics of Climate and its Variability,
IITM, Pune,
2 June - 5 July 1997

Shri S.G.Narkhedkar, S.B.Kakade and **S.P.Ghanekar**

Condensed Basic Training followed by Advanced Meteorological Training Course,
India Meteorological Department, Pune,
8 September 1997- 7 September 1998

Smt. R.S.Ovhal

Course on Role of Information Technology and its Advances in Library and Informatiom Science,
University of Pune, Pune,
9-19 December 1997

Shri S.De

Hindi(Official Language) Training,
Hindi Teaching Scheme, January- May 1998

Shri D.R.Kothawale

Short Term Course on Agricultural Production and Protection Meteorology, Centre for Advanced Studies in Agricultural Meteorology,
College of Agriculture, Pune,
16 February - 8 March 1998.

Shri R.M.Khaladkar

Post Graduate Course in Satellite Meteorology and Global Climate,
Space Applications Centre, Ahmedabad,
1 March - 30 November 1998.

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Deputation Abroad

Dr.G.B.Pant,

- Participation in the International Workshop on Dynamics of Land-Use/Land Cover Change in the Hindukush-Himalaya (Chaired a scientific session), Kathmandu, **Nepal** (20-25 April 1997)

- Participation in the Workshop on Rapid Non-linear Climate Change, IPCC (WMO/UNEP), Noordwijkerhout, **The Netherlands** (31 March- 2 April 1998)

Dr.A.K.Kamra

- Visit to the Institute for Advanced Studies in Basic Sciences, Zanjan , **Iran** (18 July-1 August 1997)

- Participation as a Principal Delegate from India in the Twelfth Session of the Commission for Atmospheric Sciences of the World Meteorological Organisation, Skopje, **Republic of Macedonia** (23 February-4 March 1998)

Dr.A.S.R.Murty

- Participation in the Nineteenth Session of the WMO Executive Council Panel of Experts/CAS Working Group on Physics and Chemistry of Clouds and Weather Modification Research, Geneva, **Switzerland** (5-9 May 1997)

- Participation as a Member of the Indian Delegation in the Third meeting of the Indo-Russian Sub- Working Group on Meteorology, Moscow and Nalchik, **Russia** (10-16 September 1997)

Dr.V.Satyan

- Research work under the IITM-Hadley Centre HE Link Programme sponsored by the British Council , Hadley Centre for Climate Prediction and Research, Bracknell, **U.K.** (1 September 1997-30 April 1998)

Dr. M.K.Soman

- Research work under the IITM-Hadley Centre HE Link Programme sponsored by the British Council , Hadley Centre for Climate Prediction and Research, Bracknell, **U.K.** (1 March -31 August 1997)

Dr. K. Rupa kumar, Dr.R.Krishnan and **Dr.R.H.Kripalani**

- Participation in the First WCRP International Conference on Reanalyses, NOAA, Silver Spring, **U.S.A.** (27-31 October 1997)

- Visit to the Centre for Ocean Land Atmosphere Studies (COLA), Silver Spring

- Dr.Krishnan also visited the International Research Institute for Climate Prediction, Lamont, New York and Rosenstiel School of Marine Sciences, University of Miami, **U.S.A.** (1-5 November 1997)

Dr.K.Rupa Kumar

- Visiting Scientist at French National School of Meteorology, Toulouse, **France** (2 June 1997-1 June 1998)

- Participation in the Workshop on Cross Validation, Seattle, **U.S.A.** (23-25 June 1997)

Dr.K.D.Prasad

- Delivering lectures to Graduate Students of the Department of Atmospheric Sciences, Pusan National University, **South Korea** (23 June-23 July 1997)

Shri S.K.Behera

- Participation in the Course on Shallow Water and Shelf Sea Dynamics, ICTP, Trieste , **Italy** (7-25 April 1997)

- Participation as Researcher in the Frontier Research Programme for Global Change, Japan Marine Science and Technology Centre, Tokyo, **Japan** (16 February 1998-15 February 1999)

Dr.G.Beig

- Participation in the 8th Scientific Assembly of IAGA , Uppsala, **Sweden** (9-15 August 1997)

- Participation in the Workshop on Solar Activity Forcing of the Middle Atmosphere, Prague, **Czech Republic** (18-22 August 1997)

Shri D.R. Chakraborty

- Visiting Scientist, Florida State University, Tallahassee, **U.S.A.** (28 October 1997-7 January 1998)

Dr.(Smt.) I.Joshi

- Participation in the INM/ WMO International Symposium on Cyclones and Hazardous Weather in the Mediterranean, Palma De Maallrca, **Spain** (14-17 April 1997)

Dr.K.Krishna Kumar

- Participation in the Workshop on Indices and Indicators for Climate Extremes, NCDC, Ashville, North Carolina. **U.S.A.** (3-6 June 1997)

- Post- Doctoral Research Fellowship at the International Research Institute for Climate Prediction, Lamont Doherty Earth Observatory, Columbia University, New York. **U.S.A.** (9 July 1997- 8 July 1998)

Dr.H.P.Borgaonkar

- Participation in the Southeast Asia Dendro-98 Meeting,Chiang Mai, **Thailand** (16-20 February 1998)

- Participation in the Training in Dendro-climatological Studies at Laboratory of Tree Ring Research, University of Arizona, Tucson and Visit to the Tree Ring Laboratory, Lamont Doherty Earth Observatory, Columbia University, New York, **U.S.A.** (18 March- 21 July 1998)

Dr.(Smt.)A.A. Kulkarni

- Participation in the First GKSS Spring Workshop on Environmental Research, Anthropogenic Climate Change, Lauenburg, **Germany** (20-27 April 1997)

Smt.R.R.Joshi

- Participation in the Mini Workshop on Pattern Formation and Spatio-Temporal Chaos, ICTP, Trieste, **Italy** (28 July-8 August 1997)

Shri S.P.Ghanekar

- Participation in the 5th International Conference on Southern Hemisphere Meteorology and Oceanography, Pretoria, **South Africa** (7-11 April 1997)

Shri M.S.Mujumdar

- Participation in the Workshop on Ocean Atmosphere Interactions in the Tropics and Conference on Warm Climate in the Tropics, ICTP, Trieste, **Italy** (26 May-6 June 1997)

Shri S.Tiwari

- Working in the framework of ICTP, Trieste for Training and Research in Italian Laboratories, **Italy** (8 September 1997- 7 September 1998)

Shri P.Mukhopadhyay

- Participation in the 4th International Summer School in Meteorology (ISSM 97), Krivaja, **Yugoslavia** (1-12 September 1997)

Visitors

International

Dr.Edward R. Cook
Tree Ring Research Laboratory,
Lamont Doherty Earth Observatory,
Columbia University, New York, **U.S.A.**
(1 April 1997)

Dr.M.R.H.Khajehpour
Deputy Director,
Institute for Advanced Studies in Basic Sciences, Zanjan, **Iran**
(13 and 16 June 1997)

Dr.Y. Suboti
Scientist,
Institute for Advanced Studies in Basic Sciences, Zanjan, **Iran**
(8 August 1997)

Dr. Martin Gill
Hadley Centre for Climate Prediction and Research, Bracknell, **U.K.**
(25August-6 September 1997)

Dr.Manuel Gil
Head, LATMOS Instituto Nacional de Tecnica Aeroespatial,
Madrid, **Spain**
(28 November-1 December 1997)

Prof.Alexander Gersten
Ben Gurion University of the Negev,
Israel
(9-11 December 1997)

Prof.G.V.Rao
Professor and Director, Earth and Atmospheric Sciences, Saint Louis University, **U.S.A.**
(22-23 December 1997)

Prof.Hannes Tammet
Department of Environmental Physics,
Tartu University, **Estonia**
(2-28 January 1998)

Dr.Lennart Granat
Associate Professor, Department of Meteorology,
Stockholm University, **Sweden**
(12-16 February 1998)

National

Shri S.Singal
Engineer,
Shri P.K.Datta Roy and **Shri D.K.Gupta**
Consultants,
Water and Power Consultancy Services,
New Delhi
(3 April 1997)

Dr.N.Sen Roy
Director General of Meteorology,
India Meteorological Department,
New Delhi
(29 April 1997)

Dr.A.P.Mitra
Honorary Scientist of Eminence,
National Physical Laboratory,
New Delhi
(2 June 1997)

Dr.D.S.Subhasis Das
Department of Physics,
University of Burdwan,
West Bengal
(3-8 June 1997)

Naval Meteorological Observers (I Class) Sailors
School of Naval Oceanography and Meteorology, Kochi
(6 August and 17 December 1997)

Shri P.K.Datta Roy
Consultant,
Water and Power Consultancy Services , New Delhi,
(1-2 September 1997)

Dr.R.K.Gupta
Scientist,
National Remote Sensing Agency,
Hyderabad
(7 October 1997)

Dr.R.R.Navalgund and
Dr.M.B.Potdar
Scientists,
Space Applications Centre,
Ahmedabad
(13 October 1997)

Post Graduate Medical Students
Department of Preventive and
Social Medicine,
B.J.Medical College, Pune
(11 November 1997)

Dr.S.M.Seth
Director,
National Institute of Hydrology,
Roorkee
(13 November 1997)

Shri P.K.Majumdar
Scientist,
National Institute of Hydrology,
Roorkee, Belgaum Centre
(13 November 1997)

Prof.B.S.N.Prasad, Shri K.Nagaraja and **Shri J.Sannappa,**
Physics Department,
Mysore University,
Mysore
(8-16 December 1997)

Shri C.L.Patel
Chairman, Charatar Vidyamandal,
Gujarat
(18 December1997)

Dr.V.S.Patel
Vice-Chancellor
Dr.N.G.Patel
Head,
Department of Electronics,
Sardar Patel University,
Gujarat
(18 December 1997)

Shri B.Venketesh
Scientist,
National Institute of Hydrology,
Roorkee, Belgaum Centre
(26 December 1997)

M.Sc. and **M.Tech. Students**
Department of Atmospheric Sciences,
Cochin University of Science and Technology,
Kochi
(21 January 1998)

M.Sc. and **M.Tech. Students**
Department of Geophysics,
Banaras Hindu University, Varanasi
(6 and 13 February 1998)

B.Sc.(Agriculture) Students
Regional Agricultural Research Station,
Kerala Agricultural University,
Pilicode, Kerala
(13 February 1998)

Participants of Refresher Course in Space Physics
Department of Physics,
University of Pune, Pune
(16 February1998)

Trainees of a Short-Term Training on Agricultural Production and Protection Meteorology
Centre for Advanced Study in Agricultural
Meteorology,
College of Agriculture,Pune
(5 March 1998)

Indian Air Force Met. Officers
Air Force Administrative College, Coimbatore
(16-17 and 19 March 1998)

✣ ✣ ✣

Audited Statements of Accounts

S.G.GUPTE, B.Sc, FCA
CHARTERED ACCOUNTANTS

Adhar Building, 3rd Floor,
305, Narayan Peth, Opp. Vijay Talkies,
Off Laxmi Road, Pune 411 030.
Tel. No. 451998.

Director
Indian Institute of Tropical Meteorology
Pashan, Pune 411 008

Sub : Verification of Accounts for the financial year ended on 31st March, 1998

Dear Sir,

We have verified the books of accounts of the Institute for the year ended on 31st March, 1998 and have to state that the enclosed Income and Expenditure Account for the year ended on 31st March, 1998 and Balance Sheet as on that date are in agreement with the books of accounts which were produced before us. Our comments and suggestions thereon are as under :

1. **LAND DISPUTE WITH NATIONAL CHEMICAL LABORATORY, PUNE**

It has been revealed from the records that National Chemical Laboratory, Pashan, Pune-8 has encroached on land of about 2.5 acres belonging to IITM, Pashan, which they personify that the said land belongs to them as the disputed land in question has already been accounted for in the books of IITM, Pashan, Pune-8.

2. **ARBITRATION CASE**

The work of the construction of A, B, C type quarters (8 Nos. each) including supply of water and sanitary provisions was assigned by CPWD to M/s Naidu and Company who has given up the work in the half-way stage. The CPWD has requested the Director, IITM, Pashan, Pune -8 to deposit a sum of Rs. 3,48,345.03 to settle the above issue, vide their letter under No. AB/Deposit/89/PCD/89 dated 26th May 1992, and the said payment has been made on 31st March, 1992 to CPWD. CPWD has informed the Director, IITM, Pashan, Pune - 411 008, that an arbitration case has been filed and amount, if received from M/s Naidu and Co., would be returned to IITM Pashan, Pune-8. Follow-up with the CPWD authorities should be strengthened.

3. **FIXED ASSETS**

Physical verification report of the Committee, pertaining to the year 1996-97 was produced to us. A number of articles are reported as " Not available for verification /Missing". No reconciliation has yet been done. Report for the year 1997-98 is awaited.

4. **STORES**

(a) It was pointed out in our report of the previous year, that the person who is in control of stores is also looking after purchase of stores. It is advisable to assign these two functions to two different individuals on permanent basis.

(b) Closing stock of stores include "Non-moving items". Few items are carried since last 8 to 10 years. The value has eroded due to various factors and is practically as good as scrap. Hence, it should be valued accordingly.

5. **SANCTION OF DIRECTOR**

It is noticed that while organising certain symposia/seminars amount has been withdrawn for payment of TA without obtaining sanction of Director. In future, such instances should be avoided.

6. **SIGNIFICANT ACCOUNTING POLICIES**

(a) It is the policy of the Institute to prepare its financial statements on the cash receipts and disbursement basis. On this basis, revenue and related assets are recognised when received rather than when earned. Similarly expenses are recognised when paid; rather than when the obligation is incurred.

(b) The fixed assets are at the original cost. It is the practice of the Institute not to charge the depreciation.

We are thankful to Dr. G.B.Pant, Director, Ms. N. S. Girija, Section Officer, Officiating as Accounts Officer and members of the staff of the Institute for rendering us all possible cooperation in conduct of our audit. We assure you of our best professional services at all times to come.

Yours faithfully,

Sd/-
(S. G. GUPTE)

Place : Pune
Date : 12 May 1998.

STATEMENT SHOWING INCOME AND EXPENDITURE FOR THE YEAR ENDED ON 31 MARCH 1998

Previous Year Rs. Ps.	Expenditure	Plan Rs. Ps.	Non-Plan Rs. Ps.	Total Rs. Ps.
2,75,07,115.40	Payment & Provision for Employees' Remuneration (Annexure 'C')	25,15,182.00	3,43,33,983.50	3,68,49,165.50
36,97,091.88	Administrative Expenses (Annexure 'D')	49,81,750.41	--	49,81,750.41
33,96,091.59	Repairs & Maintenance (Annexure 'E')	25,56,489.31	--	25,56,489.31
32,440.85	Staff Welfare Expenses (Annexure 'F')	56,691.00	--	56,691.00
8,800.00	Honorarium (Annexure 'G')	1,08,830.00	--	1,08,830.00
8,06,475.96	Consumption of Misc. Stores	4,70,246.79	--	4,70,246.79
3,54,48,015.68	**Total**	**1,06,89,189.51**	**3,43,33,983.50**	**4,50,23,173.01**

Previous Year Rs. Ps.	Income	Plan Rs. Ps.	Non-Plan Rs. Ps.	Total Rs. Ps.
3,21,62,000.00	Maintenance Grant from Central Government	1,46,75,000.00	2,59,06,000.00	4,05,81,000.00
9,25,456.61	Interest (Annexure 'A')	--	7,01,646.45	7,01,646.45
2,11,401.78	Income from other sources (Annexure 'B')	--	2,49,185.15	2,49,185.15
6,500.00	Income from sale of : (i) Rainstorm Atlas	--	10,500.00	10,500.00
	(ii) PMP Atlas	--		
21,42,657.29	Excess of Expenditure over Income	--	34,80,841.41	34,80,841.41
3,54,48,015.68	**Total**	**1,46,75,000.00**	**3,03,48,173.01**	**4,50,23,173.01**

For Indian Institute of Tropical Meteorology, Pune

For S. G. Gupte Associates
Chartered Accountants

Sd/-
Accounts Officer

Sd/-
Director

Sd/-
(S. G. Gupte)
Membership No. 30563

Note :- Annexures are not enclosed.

12 May 1998.

BALANCE SHEET AS ON 31 MARCH 1998

Previous Year Rs. Ps.	Funds and Liabilities	Sch No.	Rs. Ps.	Current Year Rs. Ps.
11,17,42,673.38	CAPITAL GRANT		11,17,42,673.38	11,37,29,178.55
	Balance as per last Balance Sheet			
	Add :			
	Received during the year		(+) 21,00,000.00	
	PLAN 21,00,000.00			
	NON-PLAN --			
			11,38,42,673.38	
	Less:			
	Transfer to unutilised Capital Grant		(-) 1,13,494.83	
				67,77,883.53
66,81,118.86	OTHER GRANTS	I		
15,19,910.40	INCOME & EXPENDITURE A/C			
1,20,12,192.64	OTHER LIABILITIES			1,21,38,556.17
	a) Unutilised Grants	II		
14,675.00	b) Security Deposits	III		
	i) From Staff 1,000.00			
	ii) From Others 13,675.00		14,675.00	14,675.00
9,33,097.00	c) Overhead Charges			16,32,131.00
13,29,03,667.28	**TOTAL**			**13,42,92,424.25**

Previous Year Rs. Ps.	Assets	SCH No	Rs. Ps.	Current Year Rs. Ps.
11,17,42,673.38	FIXED ASSETS	IV		11,37,29,178.55
	CURRENT ASSETS			
1,55,254.31	a) Stores in hand		1,42,951.48	
	b) Advances To/For :	V		
29,67,735.49	i)Purchases/Journals		37,92,029.46	
27,56,576.00	ii)Staff		37,62,602.45	
50.80,330.56	iii) C.P.W.D. Pune		43,91,259.04	
3,677.10	iv) C.P.W.D. N. Delhi		3,677.10	
12,32,253.99	v) C.P.W.D. Bombay		17,42,953.99	
60,130.00	c) Deposits	VI	60,130.00	
4,43,173.46	d) Advances receivable in cash or in kind or for value to be received	VII	1,03,637.90	
79,18,500.00	e) Fixed Deposit	VIII	2,000.00	
5,43,363.99	f) Cash & Bank Bal.		46,01,073.27	1,86,02,314.69
--	g) Income & EXP. A/C. Balance as per last Balance sheet		(15,19,910.40)	
	ADD : Excess of Expenditure over Income		34,80,841.41	19,60,931.01
13,29,03,667.28	**TOTAL**			**13,42,92,424.25**

For Indian Institute of Tropical Meteorology, Pune

Sd/-
Accounts Officer

Sd/-
Director

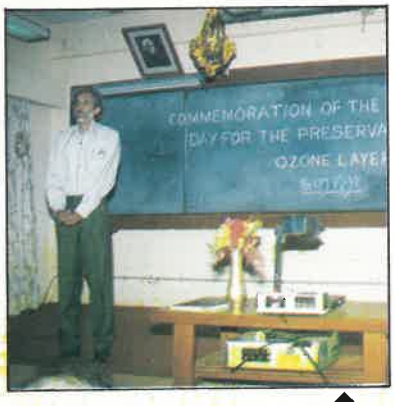
For S. G. Gupte Associates
Chartered Accountants

Sd/-
(S. G. Gupte)
Membership No. 30563

12 May 1998.

Note :- Schedules are not enclosed.

Distinguished Visitors Delivering Lectures



Dr. C.R.Sridharan (Retd. DDGM), India Meteorological Department, Pune.

Prof. G.V.Rao, University of St. Louis, U.S.A.

Prof. S. L. Shah (Retd. Prof.), G.B.Pant University of Agriculture and Technology, Pantnagar.

Prof. Hannes Tammet, University of Tartu, Estonia

Prof. Govind Swarup (Prof. Emeritus), National Centre for Radio Astrophysics (TIFR), Pune

Prof. Pramod Kale(Retd. Director), Space Application Centre, Ahmedabad

Institute's Guest house

Indian Institute of Tropical Meteorology

Dr. Homi Bhabha Road, Pashan, Pune 411 008, India
Telephone : 91-212- 330846 Fax : 91-212- 347825
E-mail : siralkar@tropmet.ernet.in

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