Indian Institute of Tropical Meteorology

Pune 411 005 INDIA

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Dr. Vasant Gowariker Secretary, DST visits the Institute.

Cover page photograph is part of the Institute's Pashan complex, Pune

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Introduction

The Institute functions as a national centre for atmospheric research in the country. Research work in the Institute in several critical areas is carried on within its scientific divisions. Each scientific division comprises research projects in which groups of scientists are actively engaged. The division of Library, Information and Publication provides technical support. Computer section provides support for meeting the computational and data requirements of the researchers. Administration and Accounts Sections provide the requisite support in their respective areas. The Institute continued to maintain its tempo of activities and further strengthened its research base during the year 1986-87.

The Institute has introduced from this year a Visiting Professorship Programme under which an eminent Scientist in any of the different disciplines of Atmospheric Sciences from abroad is invited to deliver lectures in the field of his specialisation and interact with its scientists in the ongoing projects. Prof. Richard L. Pfeffer, Director, Geophysical Fluid Dynamics Institute, Florida State University, USA visited the Institute during 1-19 December 1986 under this programme. During his stay he delivered six lectures on scale analysis, energetics and general circulation of the atmosphere. The lectures were also attended by the scientists of the India Meteorological Department, Pune. Prof. Pfeffer also gave a seminar on 'Some aspects of the dynamics of hurricane formation', under the auspices of the Indian Meteorological Society. The relevance and feasibility of establishing a fluid dynamics laboratory in the context of research in monsoon dynamics, was discussed with him. The visit proved to be immensely useful to the Institute.

The Institute has been participating in Programme-1 and Programme-2 of the Indo-US Monsoon Research Programme under the Science and Technology Initiative. Under this programme, several US Scientists visited the Institute and the Institute's Scientists also visited the research centres in USA. The Institute also continued to collaborate fruitfully with the USSR under the programme of co-operation in Science & Technology between India and USSR. Shri D.K. Paul, a scientist of the Institute visited Moscow as a member of the official delegation led by Dr. R.P. Sarker, Director General of Meteorology. The delegation signed a protocol for collaborative research.

Scientists of the Institute continued their active collaboration with national and international organisations. During the year some of the scientists have won important recognition for their work. Dr. S.K. Mishra, Assistant Director was elected as Fellow of the Indian Academy of Science, Bangalore. Shri R. Suryanarayana, Assistant Director was elected as a member, Advisory Working Group of the Commission for Atmospheric Sciences (CAS) of the World Meteorological Organisation (WMO). This is a recognition of India's important role in international research programme on atmospheric sciences. The Commission is the highest international scientific body

which formulates and overviews research programmes under the aegis of WMO. Dr. G.B. Pant, Assistant Director was invited to work as a member of the Editorial Board of the Journal of Climatology of the Royal Meteorological Society, U.K. for a three years' term. Dr. A.S.R. Murty, Assistant Director was also invited by the Committee on Nucleation and Atmospheric Aerosols of the International Commission on Cloud Physics to be a member of the International Advisory Committee for the 12th International Conference on Atmospheric Aerosols and Nucleation. Dr. L.T. Khemani, Senior Scientific Officer was invited by the Organisation of the International Conference on the 'Unity of Sciences' to present a paper at its session held at Washington D.C. during November, 1986. The Conference discussed various environmental problems under the aegis of "Committee VII Global 2000 Revisited to Re-assess Man's Impact on Space Ship Earth." Dr. Khemani's work in India has suggested that alkaline properties of the fine soil dust over India are responsible for neutralising the acidic effect resulting from anthropogenic gaseous pollutants.

The Institute celebrated the National Science Day on 28th February 1987. A popular lecture on 'Prof. Raman : His personality and Scientific achievements' delivered on the occasion by Prof.R.Ananthakrishnan, former Director and Honorary Fellow of this Institute, who had the privilege of being associated with the Nobel Laureate as one of his students during the Thirtees.Subsequently, the lecture delivered by Prof R.Ananthakrishnan was published in a brochure. A Scientific Exhibition was arranged on the day which attracted a large number of students and other members of the public. A scientific film on 'The Monsoon Experiment' in which the Institute actively participated during 1979 was also shown.

The Government of India is planning to set up a National Centre for Medium Range Weather Forecasting (NCMRWF) and Development of Agro-meteorological services. The Institute has been involved in the planning process for this centre. I was a member of the committee constituted by the Department of Science & Technology (DST) for the preparation of a detailed project report on the establishment of the Centre. The report is under the consideration of the DST. As a first step towards the setting up of the Centre, the DST organised a workshop on ''Numerical Weather Prediction'' at the Centre of Atmospheric Sciences, IIT, New Delhi. Scientists of the Institute were invited to deliver lectures at the Workshop.

The Department of Environment invited the Institute to participate in the scientific programme for investigations of ecological processes in the Nilgiri Biosphere Reserve. A plan of action for the Institute's participation in the programme was prepared. The Institute has also proposed a research programme to the DST on the investigation of the atmospheric boundary layer within the monsoon trough over the Gangetic valley during the monsoon seasons of 1988 and 1989. The programme is under review.

The Indian Middle Atmosphere Programme (IMAP) is another major national Scientific Programme in which the Institute has been actively participating for some years. The results of the startwarm campaign, conducted during January-March, 1986 over Thumba under the ISRO-SCHCNE collaborative programme, were presented on 23-24, February, 1987 in a meeting called by the programme authorities. A proposal for conducting another experiment during 1987-88 winter, using additional M-100 rockets, has been accepted by the IMAP-C Committee.

A super-mini computer system manufactured by Norks Data of Norway was acquired through the Electronics Corporation of India Limited. The Computer is under installation and will upgrade the in-house Computer facilities for research. A terminal was established in the Institute's campus to have an access to the super computer facility of the National Informatics Centre, Pune.

The construction work for the second phase of the office buildings and other ancillary works is making good progress.

An exhaustive review of all the research projects was conducted by the Academic Council during January-March, 1987. During the review, the Project leaders made detailed presentations highlighting (i) the achievements of projects in meeting their objectives (ii) scientific publications and (iii) future plan of work including suggestions for possible modification/revision in the objectives of the Projects in the light of the experience gained and recent developments. The project reviews created considerable enthusiasm, led to inter-action among the Institute scientists and provided an opportunity for stimulating discussions. A report on the reviews of the Projects was appreciated by the Governing Council.

Scientists of the Institute contributed 60 research papers to scientific journals of national/international standing and published 35 research papers in the proceedings of different symposia/seminars.

I took over the charge of the Institute from the Chairman of the Governing Council in September 1986. I am happy to note that the Institute has been endeavouring its best to reach the goals set before it. The achievements during the current year reflect the effort towards gaining accelerated progress.

D.R. SIKKA
Director
Indian Institute of Tropical Meteorology, Pune.

1. Research Highlights

A 6-level Primitive Equation (PE) model, which includes several physical effects, was successfully integrated up to 24 hrs. Under the Indo-US STI Programme on monsoon research, a ten level quasi-lagrangian PE model was also successfully integrated.

A physical package for the 5-level global spectral model was developed. The package includes the sub-grid scale and land surface processes but excludes the radiation calculations for the present.

Analysis of data on the sea surface temperature (SST) anomalies over the south central Indian ocean during late northern winter and spring revealed significant positive correlations with the ensuing summer monsoon seasonal rainfall of India. The ralationship can be used alongwith other parameters to provide a long-range forecast of monsoon rainfall.

The cloud seeding experiment in the Baramati and Sirur regions of Maharashtra state for the monsoon season of 1986 was carried out on 24 days during the period 22 July - 5 September 1986.

An analysis of the field observations collected in the downwind and upwind regions (within a radius of 3 km) of the Indraprastha thermal power plant in Delhi during the summer monsoon seasons of 1985 and 1986 suggested that the traces of acid rain can occur within a distance of 100 m downwind of the stacks of the thermal power plant on about 40% of the rain occasions. Precipitation samples collected from different places in India have shown that execpt in the very close proximity to large industrial complexes, the rainwater samples are non-acidic. It is suggested that the alkaline properties of the fine soil dust over India are responsible for neutralising the acidic effects of anthropogenic gaseous pollutants.

An automatic sun-tracking type radiometer with three sensors was designed and fabricated and data for direct, global and diffused radiation were collected for three months with a view to studying atmospheric turbidity.

It was found that the atmospheric space charge close to the ground surface in a stable atmosphere may be stratified in two layers of opposite polarity. Further, the negative space charge in the atmospheric mixing layer may be large enough to suppress or even to reverse the polarity of fair weather potential gradient on earth surface.

A barotropic non-linear stability analysis of tropical easterly jet over the sphere was performed. It was shown that the long period oscillation (25-35 days) in the tropics can also arise due to the zonal-wave and wave-wave interaction.

A computer code was developed for the solution of Poisson equation, based on Fourier series method.

2. Research

2.1 Forecasting Research - I

The research activities of the division were mainly devoted to (i) the development of multi-level primitive equation (P.E.) forecasting model suitable for monsoon regime, (ii) Extended range forecasting research for diagnosis of the variability of monsoon and its prediction and (iii) studies with the data collected during special monsoon experiments. Results of the research are briefly discussed in the following sections:

2.1.1 *Numerical Weather Prediction*

a) A six-level P.E. model was under development in the Division taking into consideration the various physical processes such as large scale condensation, dry convective adjustment, cumulus convection, boundary layer fluxes of heat, momentum and moisture and smoothened orography. The model was integrated up to 24 hrs by using objectively analysed data for 7 July 1979 on the domain extending from 12°S to 40°N and 45°E to 120°E. The model predicted the flow patterns satisfactorily. However, the rainfall rates were underestimated.

Towards the formulation and testing of a regional model under Indo-US STI Programme on monsoon research, the ten-level quasi-lagrangian P.E. model was successfully integrated up to 24 hrs using input of 28 May 1979. The results showed satisfactory forecast of the large scale features.

To study further the effect of high orographic barrier on flow, a three level P.E. model was integrated up to five days with initial westerly wind of 10 ms^{-1} with no shear and maximum orographic height of 5 km. The forecast results show formation of an upstream ridge and a downstream trough.

b) Objective analysis

Univariate optimum interpolation objective analysis schemes were developed for the analysis of surface pressure and relative humidity fields for the month of July. The scheme performed satisfactorily on several test runs. A multivariate optimum interpolation scheme for wind, temperature, height and moisture fields at different levels was developed.

c) Initialization

The bounded derivative method of initialisation was applied to the shallow water equations, which included the effects of orography. Initial test runs performed with the analytical data were not successful in reducing the amplitude of the gravity waves. The solution of the elliptic equation, expressing the height field in terms of the wind field, used as an input, was examined.

2.1.2 Extended Range Prediction

a) Synoptic-climatological studies for extended range prediction

Inter-annual and longer-term variability of surface air temperature anomalies over the Northern and Southern Hemispheres, the Arctic and Antarctic regions and those of the summer monsoon seasonal rainfall over India, were investigated. While the Northern Hemispheric temperature showed characteristic fluctuating epochs, the Southern Hemispheric temperature showed a continuous warming trend. The Northern Hemispheric winter temperature anomalies during the recent period showed positive significant correlations with the rainfall. On decadal scale, the cool (warm) Northern Hemispheric temperature epochs were associated with low and variable (high and stable) monsoon rainfall.

Correlation mapping analysis between the monthly Sea Surface Temperature Anomaly (SSTA) data of the Indian ocean, extracted for a period of 30 years (1930-1979) from the comprehensive ocean atmosphere data set (GFDL, USA), and the summer monsoon rainfall over India revealed significant correlations. The South Central Indian ocean SSTA during late winter and spring showed positive significant correlation, while the northern Indian ocean SSTA during and specially the follwing monsoon showed negative significant correlation.

b) Statistical-dynamical Prediction

Relationships of some large scale

atmospheric/oceanic parameters, viz. (i) Southern Hemispheric surface air temperature, (ii) lower level (850-500 hPa) and upper level (500-200 hPa) thicknesses over six equatorial zones, (iii) Pseudo stress fields at 10°N, 140°E, and 10°N, 140°W and (iv) mean sea level pressure at Truk and Talara with the all India monsoon rainfall were examined by utilising 25-35 years' monthly data. Some of these parameters brought out useful predictive lag relationships. However, most of these parameters showed stronger relationships when the monsoon rainfall is lagging rather than when it is leading. Associations of some of these parameters with the monsoon rainfall over 7 homogeneous regions and 4 significant empirical orthogonal functions (EOF's) of the monsoon rainfall were also examined. Significant associations were found for the coefficients of first Eigenvector and rainfall over the Central and South India only.

2.1.3 Monex studies

Oceanic features and cloudiness patterns associated with the prime eddy off the Somali coast during the summer monsoon 1979 were investigated using the visible and infra-red satellite imageries and the SST data reported by research ships. The study revealed that low level convection is enhanced over the warm waters of the prime eddy. The study also revealed that upwelled cold waters encircle the eddy to mark its boundary.

The advance of southwest monsoon over India during monsoon-77 was examined in relation to the SST distribution over the Arabian sea and the Bay of Bengal during the period 21 April to 8 June 1977. The analysis of the time sequence of 10-day mean SST, prepared from the data published in the Indian Daily Weather Report (IDWR) revealed that very warm waters (31-34°C) south of 15°N played a prominent role in the formation of synoptic scale disturbances which led to the onset and advance of monsoon over India during the year.

The temporal variation of the equivalent potential temperature (θc) in relation to the convective weather was studied utilising the Soviet research ship data available during the Monex-79. The study showed that during active convection, the vertical gradient of θc is less marked in the lower and middle troposphere due to the abundant moisture present in these layers.

The anomalous behaviour of monsoon during the onset, advance, active, break and withdrawal phases was investigated utilising the analysis of satellite data together with the pressure and wind analyses for some typical monsoon years of 1973, 1979, 1983 and 1985. The causes that led to the following types of anomalous monsoon behaviour were identified :

i) Multiple monsoon onset in 1973,

ii) Delayed onset, prolonged break and early monsoon withdrawal during 1979,

iii) Delayed monsoon onset and uninterrupted monsoon activity in 1983 and

iv) Stagnation in the advance of monsoon in 1985.

Seasonal and annual rainfall of Maharashtra and its subdivisions (Konkan, Madhya Maharashtra, Vidarbha and Marathwada) were fitted with Gamma distribution. Stability of the parameters was examined by increasing the sample size. The stability was achieved around 50-70 years.

2.2 Forecasting Research II

This division conducted research on the energetics of the monsoon. Some of the studies were carried out under the ISRO-SCHCNE collaborative research programme on monsoon.

2.2.1 Studies in the energetics of the atmosphere

The kinetic energy over the peninsular India was studied for the period June-1979, using RS/RW data. The main findings are :

i) The generation and dissipation terms in the kinetic energy (K.E.) equation are the main contributing terms in the budget.

ii) The contributions from the horizontal and vertical fluxes of K.E. are small. Their contribution increases when the synoptic scale

systems are present along the periphery of the region.

iii) There is transfer of K.E. from the subgrid scale to the grid scale which can be inferred from the occurrence of positive dissipation.

2.2.2 Studies under ISRO-SCHCNE Collaboration on Monsoon

Analysis of the circulational and energetic characteristics for the troposphere and the lower stratosphere for January and February, 1979 and that of the energetic characteristics, from 100hPa to lower stratosphere for all the latitudes during the preceding months of a good monsoon year 1983 and that of a bad monsoon year 1979 were undertaken.

2.3 Climatology & Hydrometeorology

The climatology branch of this Division is basically working on studies relating to large scale droughts over India:

i) Vagaries of the Indian summer monsoon,

ii) Studies in Palaeo-climatology and climate change.

The hydrometeorological branch of the Division has laid emphasis on the studies relating to Probable Maximum Precipitation (PMP) estimation and analysis of severe rainstorms and floods. The results achieved under different studies are summerised below.

2.3.1 Studies of large-scale droughts over India

a) Longitudinal shift of planetary waves and droughts/floods in India

Occurrences of large-scale droughts/floods in India were investigated with emphasis on causal understanding of these extreme climatic events in terms of upper tropospheric geopotential field. Examination of 200-hPa charts of Northern Hemisphere for the month of May for the period 1971-75 revealed presence (absence) of marked cellular feature in the tropics during flood (drought) years. Spatial spectral analysis of 200-hPa contour field in tropics suggested the prominence of planetary wave numbers 1 and 2 during flood years, while these waves become markedly weaker with eastward shift by about 10-20° longitude during drought years over India.

b) 10 hPa wind at Balboa and implications for forecasting

The interannual variability of the Indian monsoon (June-September) was examined in relation to the monthly zonal wind anomaly for 10-hPa (30 km) and 30 hPa (24 km) at Balboa for the 28 years period 1958-85. The fluctuations in the zonal wind anomalies in January at 10-hPa appear to be highly related to the monsoon rainfall, with rainfall tending to be less (more) than normal during easterly (westerly) anomaly, suggesting some predictive value for the monsoon rainfall. The zonal wind anomalies at 10-hPa lead those at 30-hPa by 6 months. This lead-time is consistent with the well-known downward phase propagation in the OBO of tropical stratospheric wind with a speed of 1km/month. Large-scale flood never occurred during the easterly wind anomalies and drought almost never occurred during the westerly wind anomalies during January at 10-hPa at Balboa. The zonal wind anomaly of January at 10-hPa provides a longer lead time than any other antecedent parameter reported previously. A drought/flood probability forecast could be prepared based on this information.

2.3.2 Vagaries of the Indian Summer Monsoon

a) Equatorial Sea Surface Temperature and Indian Monsoon

Statistical relationships of the Indian summer monsoon rainfall with the El-Nino (1871-1985) and the sea surface temperature at Puerto Chicama (7° 42'S, 79° 27'W) (1925-1980) were studied. During strong/moderate El Nino events, All-India summer monsoon rainfall was found to be 11% below normal (significant at 0.1% level). SST during May over Puerto Chicama shows a significant correlation coefficient of -0.5 with the All-India monsoon rainfall. This correlation has good spatial coherence, covering about 60% of the country's area and as such may be useful for long range prediction purpose.

b) All India foodgrains production and monsoon rainfall

All-India summer monsoon rainfall was found to be significantly influencing the total annual foodgrains production in the country, after removing the technological trend. A regression equation between the two series, $P = 0.74R + 2.5$ (P = Annual foodgrains production index; R = All-India summer monsoon rainfall departure from normal), was found significant at 0.1% level and it explained 54% of the variance in P during the period 1961-1985.

2.3.3 Studies in Palaeo-climatology

a) Tree rings and climate

Statistical techniques of response functions and stepwise multiple regression analysis were used in attempting a reconstruction of the All-India summer monsoon rainfall from a dendroclimatically reconstructed data series on Wright's Southern Oscillation index over the past 400 years. The response functions showed good similarity with the relationships as shown by the original Southern Oscillation index.

2.3.4 Climatic change

a) Land-use pattern and climate of Rajasthan desert

Climatic changes in and around Rajasthan desert during the 20th century were examined. Under this study, the rainfall and temperature data during the period 1901-1982, were examined in the light of change in land-use pattern through artificial irrigation during the same period. The results indicate a gradual decreasing trend in the mean annual surface air-temperature which is mainly contributed by the SW-monsoon season. The mean annual and SW-monsoon seasonal rainfall series over most parts of the region indicates a conspicuous increasing trend.

b) Rainfall variability

Fluctuation characteristics in the individual areal maximum rainfall series ranging from 1 to 30 day durations of south and north Kerala were studied using 80-years' rainfall data from 1901 to 1980 for 75 stations. The trend analysis showed a significant decreasing tendency in the individual maximum rainfall series of 1-3 day durations in North Kerala and 1 to 30-day durations (excepting 3 to 8-day) in south Kerala. As regards annual rainfall, a significant decreasing trend in south Kerala and no trend in north Kerala were found.

c) The trend in the southwest monsoon and annual rainfall series of 14 stations along the east coast of India lying between the latitudes 8°N to 22° 30'N were studied using the rainfall data of the 80 years' period from 1901-80. The trend analysis showed a significant decreasing tendency in annual rainfall of Nagapattanam and Cuttack and in the monsoon rainfall of Nagapattanam and Visakhapatnam. However, Balasore rainfall during the monsoon season showed an increasing tendency. No other station showed either decreasing or increasing tendency in rainfall over the recorded period.

2.3.5 Basin rainfall studies for the development of water resources

Maximum and probable maximum precipitation (PMP)

Areal probable maximum precipitation (PMP) for area of 1300, 2600 and 5000 sq. km. for different locations in Madhya Pradesh was estimated by using a combination of point PMP and depth-area model. The study showed that estimates of areal PMP for 1300, 2600 and 5000 sq.km. were found to lie between 43-76 cm, 41-74 cm and 39-70 cm respectively for one-day duration. The areal PMP for these areas were utilised to prepare three separate generalized charts.

Based on long-period rainfall data of 1891 to 1970, generalized charts of the highest observed 1-day point rainfall, 50-years and 100-years 1-day rainfall and probable maximum rainfall (PMP) for 1-day were prepared for the state of Madhya Pradesh. This study revealed that in this region the highest 1-day rainfall at individual stations varies from 20 to 50 cm. Rainfall of 50-years return period varies from 20

to 35 cm while for 100-years it varies from 20 to 40 cm. It was seen that the point PMP over this region varies from 50 to 80 cm for 1-day duration.

Severe rainstorms of July, 1924, Nov., 1925 and May, 1941 which occurred over Kallada catchment (Kerala) were applied to estimate probable maximum precipitation (PMP) for the Kallada catchment upto Parappar dam site. The PMP for 1, 2 and 3 day durations were found to be 28.3, 46.0 and 66.6 cm respectively.

The severe rainstorm of 28 to 30 Aug., 1982 which occurred over the Mahanadi basin was transposed over the Kharkai catchment so as to estimate the PMP depths for 1 to 3 day durations. The PMP estimates were found to be 62, 83 and 97 cm for 1, 2 & 3-day durations respectively.

Depth-area-duration model of severemost rainstorm which occurred in July, 1927 over Gujrat region was developed to convert the storm centre rainfall to areal rainfall. The model was used to estimate areal PMP for different areas ranging from 1300 to 13000 sq. km. The areal PMP for 1300, 2600 and 13000 sq. km. were worked out to be 75, 70 and 50 cm respectively. These estimates were found to be in close agreement with those obtained by the physical method.

2.3.6 Analysis of rainstorms

a) Severe rainstorms, which affected the state of Madhya Pradesh during the past 90 years period from 1891 to 1980, were analysed. The rainstorm of 19-21 September, 1926 was found to be the most severe one over the state. This rainstorm generated 31.2 cm of rainfall over an area of 130,000 sq.km in 3 days duration.

b) Analysis of severe floods

A catalogue of highest ever recorded floods in 52 major Indian rivers at 212 gauge sites were prepared on the basis of flood data up to the year 1985. It was found that these floods exceeded their danger levels by 0.15 m to 18.10 m. Out of these,6 rivers and at 8 gauge sites the floods exceeded danger levels by more than 10 metres. The worst flood years of the country were found to be 1973, 1975, 1978 and 1982. Bihar, Uttar Pradesh and Assam were the worst flood-affected States of India.

2.3.7 Onset of the monsoon over Kerala.

The rainfall characteristics over south Kerala during May and June were studied using the 80-years rainfall data of 44 stations from 1901-1980. Objective criteria for fixing the onset date of monsoon were developed and the onset dates were fixed for the individual years of the 80-year period. The mean onset date of SW monsoon over South Kerala was found to be 30 May with a standard deviation of $\pm$ 8.8 days.

2.4 Physical Meteorology & Aerology

The main thrust of research under the division of Physical Meteorology and Aerology has been on (i) atmospheric physics (ii) cloud physics and dynamics (iii) boundary layer structure and turbulence theory (iv) studies in upper atmosphere with special reference to the Indian Middle Atmosphere Programme (v) weather modification (vi) studies in air pollution and acid rain and (vii) LIDAR probing of the atmosphere. Chief features of the research achievements are discussed below:

2.4.1 Cloud Physics and Weather Modification

a) Studies in Atmospheric Electricity

An indigenously developed cylindrical field mill, which can measure the three components of the electric field was tested by comparing its performance with that of a conventional instrument consisting of an electrometer and a radioactive sensor.

The records obtained from both the instruments showed a good degree of agreement. Observations of atmospheric electric field at Pashan are continuously being recorded for generating a new data set. These data and the data sets obtained earlier during the period 1969-77 will be utilised for the study of the variations in the electric field on climatic scale. Also, similar observations of atmospheric electric field were initiated at the Rain and Cloud Physics Research Centre, New Delhi.

Simultaneous measurements of electrical charges carried by cloud/rain drops, corona current, electrical conductivity, vertical air velocity and cloud liquid water content were made on 25 days in the Deccan Plateau region using the Dakota aircraft chartered for the Institute's warm cloud modification experiment.

Analysis of the extensive aircraft measurements of cloud electrical, microphysical and dynamical parameters, carried out in monsoon clouds during the past few years have suggested the following :

i) Cloud electrical activity is found to increase with the liquid water content (LWC) and updraft speed.

ii) The horizontal structure of the air flow inside the cloud has consistent variations with positive and negative vertical air velocity representative of ascending and descending currents. Fast upward/downward transport of the electrical charges takes place through the above ascending/descending currents. Regions of ascending currents are associated with high LWC and negative cloud drop charges, while the regions of the descending current are associated with the lower LWC and positive cloud drop charges.

b) Radar Study of rain and rain-bearing clouds.

A study of the vertical growth, decay rate and duration of convective clouds was undertaken using the radar observations relating to 67 convective clouds which formed around Delhi during the pre-monsoon and monsoon seasons of 1980-82. Results indicate that the mean growth rates for the pre-monsoon and monsoon seasons are 4.8 and 4.6 m sec^{-1} respectively. Similarly, the cloud decay rates were respectively 3.9 and 5.4 m sec^{-1}. The average durations of the cells for the pre-monsoon and monsoon seasons were found to be 47 and 40 minutes respectively.

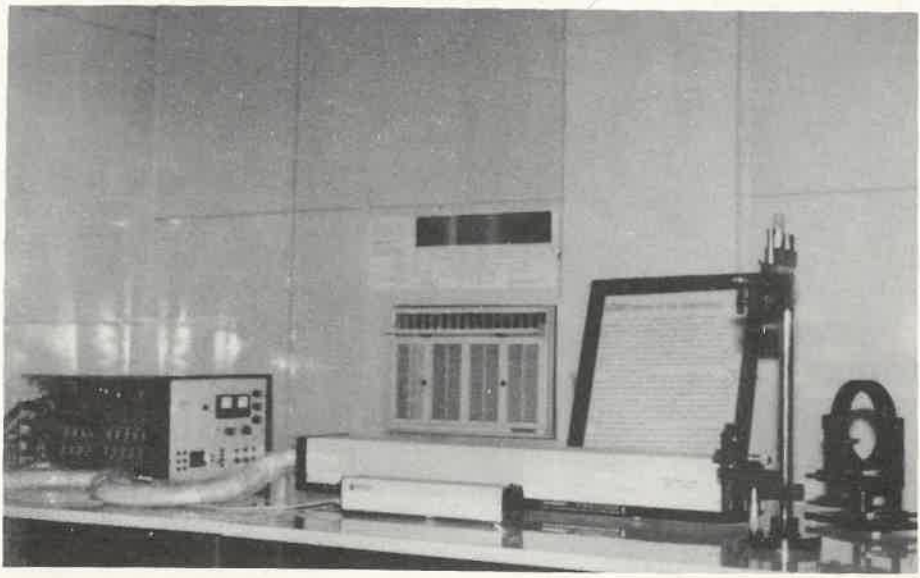
A comparative study of the vertical growth rates of 24 convective clouds, observed within 50 km around Delhi during the monsoon seasons of 1980-82, and the thermodynamical properties associated with these clouds was made. For this purpose, two thermodynamical parameters, viz. cloud base temperature and conditional instability in the lower troposphere (850-500 hPa) on days of their occurrence were computed from radiosonde ascents. The study showed that the growth rates are positively correlated to the cloud base temperature as well as with the conditional instability.

A study on the spatial distribution and echo configuration of 710 severe storms (echo-top heights $\geqslant$ 12 km), observed within 100 km around Delhi during the summer (March-May) and monsoon (June-September) seasons of the 20-years period (1959-78) was made. It was found that during summer the storm echoes were randomly distributed. However, during the monsoon season the echo distribution was non-uniform. Echo configuration of these storms showed that in 65 per cent cases, they were associated with one or more neighbouring echoes; in 26 per cent cases, they were part of line echoes and only in 9 per cent cases, storm echoes were completely isolated. Further, echo configuration of the storms in relation to their vertical extents showed that the storm cells generally have a tendency to organise themselves in squall line as their heights increase.

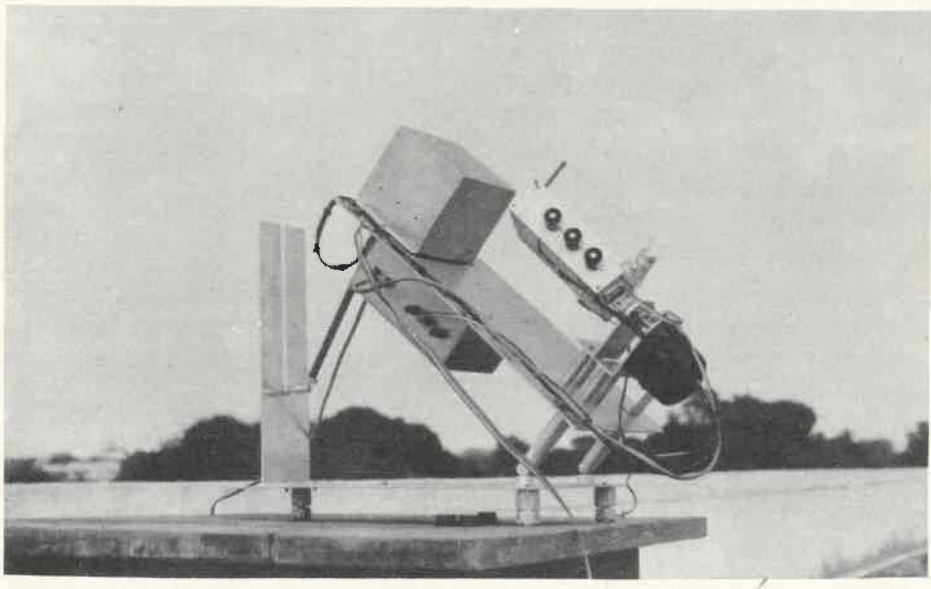
c) Studies in cloud microphysics and investigations of the feasibility of increasing rainfall by cloud seeding.

The warm cloud modification experiment in Maharashtra State for the 11th monsoon season commenced on 22 July 1986 and concluded on 5 September 1986. The experiment was carried out on 24 days utilising about 62 hours of aircraft flying time. Extensive cloud physical observations were carried out during the experiment.

A detailed analysis of the rainfall data and cloud physical observations collected during the warm cloud modification experiment carried out in Maharashtra State during the 11-summer monsoon seasons (1973-74, 1976, 1979-86) was completed. The results of the statistical



Argon ion and Helium-Neon laser systems being used at the Institute for remote sensing of atmospheric aerosols.



Three channel radiometer with sun tracking facility.

analysis relating to area seeding days (when all the clouds present in the experimental area were seeded) indicated increase in rainfall by 23.9% which is significant at 4% level. The results of the analysis of the cloud physical observations obtained from seeded and not-seeded clouds showed marked differences. These observations provided the physical basis for the efficacy of warm cloud modification through salt seeding.

2.4.2 Environmental Physics

a) Studies of the Atmospheric Boundary Layer

Simultaneous high resolution observations of temperature, humidity and vertical air velocity in clear-air and cloud-air were carried out in the atmospheric boundary layer over the Deccan Plateau region on 25 days during the monsoon season of 1986 using the aircraft chartered for the Institute's warm cloud modification experiment.

Until about 10 years ago, scientists like Landau have viewed turbulence as a succession instability arising through variations in the parameters, giving rise to harmonics of ever increasing number of instability frequencies. In the recent past there have been significant achievements in the theory of turbulence and the scenarios of turbulent motion tend to be much simpler in conception. The present scenario of turbulence envisages the passage to chaos as a succession of bifurcators or frequency halving, which is generally known as ''Period Doubling'' This view of the development of turbulence has now received impressive experimental support from many different branches of science.

The potential applications of the period doubling in atmospheric sciences were identified recently by some of the scientists. One of the most recent attempts in the above direction is the application of ordinary set of differential equations in place of the classical Lorenz's three-dimensional set of ordinary differential equations generally adopted for the numerical modelling of the atmospheric fluid flows.

Theoretical investigations in the above new area of atmospheric turbulence were initiated at the Institute and considerable progress has been achieved in the recent past. Results obtained so far indicate that the macroscopic phenomenon of atmospheric turbulence, which appears to show chaos, is described in terms of equations which define the time evolution of the atmospheric weather systems at the microscopic level. Observations of thermodynamic parameters in the troposphere and stratosphere, and measurements of plasma irregularities in the ionosphere and magnetosphere indicate existence of a scale invariant atmospheric eddy energy continuum spectrum following the power law f^{-n}, where 'f' is the frequency and 'n' the exponent. Also, some of the recent investigations showed that self similarity implied in the scale invariant eddy energy structure was also reflected in the observed universal fractal geometry of the global cloud cover pattern. From the study undertaken at the Institute, it is now shown that the observed scale invariant eddy continuum evolves from the turbulence basically by the universal period doubling route to chaos. Also, the universal Feigenbaum's constants 'a' and 'd' (which define the path to turbulence) are computed using the theory of chaos for the large eddy evolution in the turbulent atmospheric boundary layer. These values are respectively 2.5 and 4.1 and they are in agreement with those reported by Feigenbaum derived from the theory of non-linear transformation.

Study of the variations of 'u' (zonal) and 'v' (meridional) components of wind at surface, 40m, 150m, 340m (above ground level) at Pune during the summer monsoons of 1976, 1979 and 1980 was carried out using the pilot ballon wind observations. The results suggested the following:

(i) The frequency distribution of 'u' component was unimodal at surface and it gradually transformed to multimodal at 340m level in all the years. This feature was not observed in the case of 'v' component which showed unimodal character at all levels.

(ii) Spectrum analysis of the 'u' component showed that the smaller periods of 2-3 and 3-5 days were prominent in the years 1976 and

1980. This feature was absent in 1979.

(b) Studies in Upper Atmosphere

The aerosols in the middle atmosphere influence the incoming solar radiation vis-a-vis the climate. During the period of strong volcanic eruptions, the aerosols are transported from the lower level to the middle atmosphere. In order to examine the variations noticed in the rainfall following the volcanic activities, a study was undertaken using the northeast monsoon season (November and December) rainfall of 15 stations in Sri Lanka and the data of Volcanic Explosivity Index (VEI) relating to eruptions within 20°N to 20°S for a period of 112 years (1869-1980). The study suggested that 50-80% of the cases of volcanic eruptions have been found to be associated with the deficient rainfall during 1-2 years following major volcanic eruptions. occurrence of the deficient rainfall to the north of the Inter Tropical Convergence Zone (ITCZ) over Sri Lanka, after the eruption of the low-latitude volcanoes, could be attributed to the southward shift of the ITCZ due to depletion of the solar radiation caused by the aerosols released in the stratosphere by the strong volcanic eruptions.

The possible association between the inter-annual variability (IAV) and quasi-biennial oscillation (QBO) in the lower stratosphere was investigated using (i) the zonal wind data at 30 mb for July-August for Balboa (9°N, 80°W), (ii) the percentage departures of the rainfall over India during June-September for the 21-years period commencing from 1958 and (iii) the intensity of the polar vortex derived from the anomaly in the geopotential heights at 30 mb in the northern hemisphere during winter (November-March) for the 21 years period commencing from 1957-58. The results of the study indicated the following :

i) The interannual variability in the intensity of the polar vortex during winter is associated with the phases of the low-latitude quasi-biennial oscillation in zonal wind during the following summer on more than 70 percent of the occasions.

ii) The phases of the low-latitude quasi-biennial oscillation in zonal wind during summer have been associated with the summer monsoon activity over India on 62 per cent of occasions.

iii) There is an association amongst the interannual variability in the strength of the polar vortex during winter, the low-latitude quasi-biennial oscillation in the zonal wind and the monsoon rainfall over India during the following summer on 43 percent of occasions.

A formal proposal for conducting another 'stratwarm' campaign during the winter of 1987-88 in collaboration with USSR was sent to the Chairman, IMAP-C Working Group on Atmospheric Structure and Dynamics for consideration at the ISRO-SCHCNE meeting.

c) Studies in Air Pollution

Aircraft observations of atmospheric aerosols and collection of cloud/rain water samples from seeded and not-seeded clouds were organised on 25 days as part of the Institute's warm cloud modification experiment. Also, similar observations were organised across the Western Ghats during the two aircraft ferry flights i.e. from Bombay to Pune on 4 July and from Pune to Bombay on 10 September during the year 1986. Analysis of these observations was undertaken. It is envisaged to investigate the aerosol/chemical state of the atmosphere vis-a-vis cloud formation and precipitation development.

Field observations in the vicinity of the Indraprastha thermal power plant in Delhi were organised during the summer monsoon seasons of 1985 and 1986 for monitoring the occurrence of acid rain in the region. Analysis of the rain water samples collected, indicated traces of acid rain within a distance of 100m in the downwind of the stacks of the thermal power plant on 41% and 38% of the rain occasions respectively during 1985 and 1986. The pH value of rain water varied from 4.7 to 5.5 when traces of acid rain were noticed. The observations in the downwind and upwind regions up to a maximum of 3 km indicate no trace of acid rain and the pH values of rain water varied between 6.0 and 8.6. These results corroborate with the earlier

finding that the phenomenon of acid rain is highly localised and confined to an area within 100m of the stacks. Similar observations carried out at Agra near Taj Mahal during the summer monsoon seasons of 1985 and 1986 indicated no trace of acid rain which also confirms the results of an earlier study.

Chemical analysis and pH measurements of a large number of rain water samples collected at 7 rural stations in the semi-arid region at the Deccan Plateau during the 4 consecutive monsoon seasons (1979-1982) suggested the following :

1) The pH of rain water is highly alkaline and the values vary from 6.4 to 7.8. Soil oriented elements show good correlation ($r \sim 0.6$) with pH values of rain water. The high concentration of soil-oriented elements, specially calcium, is found to play an important role in neutralising the acidity of rain water and maintaining alkaline pH.

2) The contribution of atmospheric aerosol of natural sources (sea and soil) to the chemical composition of rain water is more than that of the anthropogenic origin.

d) LIDAR Probing of the Atmosphere

Theoretical computations relating to design of telescopes required for Lidar system were carried out. The performance of lidar system during different atmospheric conditions was evaluated, using the theoretically predicted aerosol vertical distributions reported by other investigators.

Lidar observations of atmospheric aerosols were carried out on 20 days and 15 days using Helium-Neon and Argon-ion laser systems respectively. The aerosol vertical distributions obtained from the Helium-Neon lidar observations in the lowest layer (up to 300m above ground level) showed the aerosol number density variations from 4.4×10^3 to 2×10^2 cm^{-3}. Similarly, the vertical profiles (up to 5.5 km above ground level) obtained from the Argon Ion lidar observations showed the aerosol number density variation from 1×10^2 to 5×10^3 cm^{-3}. The variations in the aerosol distributions were found to be in agreement with those reported by the other investigators from their numerical models. A detailed study for the interpretation of the space-time variations of the aerosol number density vis-a-vis atmospheric stability conditions was in progress.

2.5 Instrumental & Observational Techniques

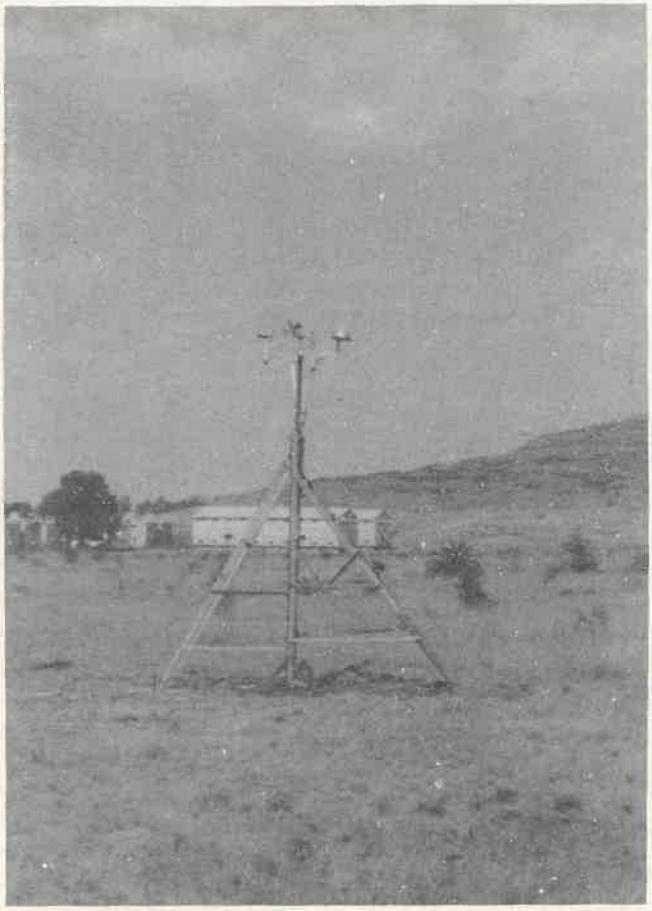
The research activities of the Division of Instrumental and Observational Techniques have been focussed on studies on (i) testing rocket payload, (ii) atmospheric electricity and (iii) development of special instruments for boundary layer studies and organisation of a national experiment to study the atmospheric boundary layer in the region of the monsoon trough over the country. The important results are discussed below:

2.5.1 Development of meteorlogical payload for rockets and satellites

A set of active and passive electronic components for rocket payload was screened at Vikram Sarabhai Space Centre (VSSC), Trivandrum. 1680 MHz miniature transistorized transmitters were got fabricated at M/s United Systems Engineers, Hosur, Tamil Nadu and their performance was evaluated. Two transmitters with their modulating circuits were tested, for vibration and temperature response corresponding to various altitude levels, at the Inspectorate of Electronics Laboratory, Bangalore. Power and frequency spectrum tests were made at the factory in Hosur, Tamil Nadu. Random vibration test at the frequency range 10-2000 Hz at 50 g was made at the Armament Research and Development Establishment, Pune.

2.5.2 Development of instruments for boundary layer studies

Micrometeorolgical observations on instantaneous temperature, along wind and vertical components of wind and wind direction, at 4.2 m above ground over a complex terrain at the Institute's building at Pashan, were taken for a period of 12 days in April 1986. The digital data obtained during 7-9 April were used to



Instrumental mast for measuring wind (u, w components) and temperature at 4 m above ground.

estimate the heat flux by eddy correlation technique. Analysis revealed that to obtain a smooth change in diurnal heat flux, an averaging time of 30-40 min would be sufficient. Cup anemometers (magnetic chopping type) with different arm lengths and a six channel recorder for recording the outputs of anemometers were developed and calibrated in the wind tunnel of the Indian Institute of Science, Bangalore. A frequency to voltage converter circuit for the anemometer output was developed and tested.

A temperature transducer using thermocouple was fabricated to get an amplified output from 10 mV/°C to 100 mV/°C. A quantum sensor (0.4 - 0.7 μm band) and a photometric sensor with a peak at 0.55 μm band were exposed to study the incident, diffuse and scattered solar radiation. For these measurements, a sun tracking device to orient the above sensors towards sun was developed and fitted to a platform.

2.5.3 Instrumentation for cloud physics and weather modification studies

Field measurements of space charge concentration were carried out near the ground, to study the effect of electric field and air pollution on space charge. Vector electric fields were measured with a spherical field-mill in fair weather. Electrical charges on particles of different sizes were measured during some showers with particle charge measuring apparatus. Precipitation current and corona current were also measured simultaneously. Data collected from the above measurements were analysed. An instrument was fabricated to measure the charge and size of various precipitation particles.

2.5.4 Instrumentation for cloud physics and weather modification studies

To understand the effect of electric field on the shapes of charged and uncharged water drops, an experiment was conducted in a vertical wind tunnel. Data obtained in the above experiment were analysed and a doctoral thesis on distortion of drops under different electrical stresses was finalised and submitted to the University of Poona.

Experiments to study the stability of charged and uncharged water drops in different electric fields were carried out in the vertical wind tunnel. Samples of fragmented drops were collected on filter papers and the spot-sizes calibrated.

2.6 Theoretical studies

This Division has been mainly devoted to the investigations relating to determine the dynamic instability of the monsoon flow and simulation of monsoon circulation with computer models. Main research results are discussed in the following paras :

2.6.1 Studies on Dynamic Instability

a) Barotropic and baroclinic instability of the atmospheric flow

A problem was formulated to study the role of ageostrophic effects on the barotropic instability characteristics of the tropical easterly jet. In this connection, equations for irrotational and non-divergent components of kinetic energy were derived. The computations revealed that the non-divergent part of the motion receives kinetic energy from the basic flow and a small fraction of it is transferred to the irrotational part of the motion.

The barotropic global spectral model, which had been developed earlier, was adapted for a study to understand the role of wave-wave interaction and diffusion in the development of disturbances along the easterly jet. Oscillations with varying period between 25-35 days were found for the case of wave-wave interaction experiments. A uniform period of oscillation was noticed for the case of zonal-wave interaction experiments.

The numerical model for studying the linear barotropic instability of an asymmetric monsoon zonal flow was further tested and shortcomings were rectified. In connection with the preparation of basic state for the study, it was realised that the departure of zonal wind from its average, instead of the zonal wind itself, satisfies the conditions imposed by the prescribed boundary conditions for computation

of the stream-function

The combined barotropic baroclinic CISK balance model on equatorial ß-plane was utilised to obtain the growth rates and phase speeds of the unstable waves for the lower tropospheric westerly jet, the upper tropospheric easterly jet individually and the full profile in the meridional plane. The above computations were repeated without CISK process in the model and it was found that the two jets and CISK have different and somewhat mutually independent modes of instability. A barotropic non-linear stability analysis of tropical easterly jet over the sphere was also performed.

b) Barotropic and baroclinic instability of atmospheric flow in the summer monsoon (MONEX Studies)

FGGE level IIIb data (wind and height) sets at standard levels were interpolated by using cubic spline technique at 50 mb interval for 3-11 July 1979 for the area 5.6°S - 30°N and 75°E - 105°E. Day-to-day barotropic and baroclinic energy conversions were computed utilising the interpolated data. It was found that on 5 July the initial low pressure area in the Bay of Bengal formed due to the barotropic instability mechamism. However its growth to depression stage on 7 July occurred due to the baroclinic instability.

2.6.2 Simulation of Mean Monsoon and Tropical Circulation System.

a) Simulation of mean monsoon circulation

A physical package for the 5-level global spectral model was developed and tested by using the idealised data. The package includes the sub-grid scale and land surface processes. The land surface processes include the prognostic equations for ground temperature, soil moisture and snow amount. The diurnal cycles of the ground temperature and soil moisture are considered. In order to incorporate the effect of topography in the model, spherical harmomic analysis of global topographic height and that of the smoothed data were performed for the rhomboidal truncation at 85. The spectral coefficients explain more than 95% of the observed variance. The package does not include radiation for the present.

b) Study of error characteristics in numerical models for simulation and their relation to atmospheric predictability

A study regarding the propagation of initial error on different spatial and temporal scales and its contribution to the predictability of synoptic scale monsoon disturbances was in progress. In order to determine the initial input for the numerical experiment, the streamfunction and velocity potential fields were computed at 850,700, 200 and 100 mb over the Bay of Bengal (0° - 30°N, 75°E-105°E) for 4 July 1979 by using the Block Cyclic Reduction method. Results showed that the zonal wind is dominated by the rotational part while for the meridional wind, both the divergent and rotational parts are equally important.

A problem was formulated to study some properties of solutions to atmospheric and oceanic dynamics equations at different latitudes. The rate of decay of wind and pressure fields at mid-latitudes due to turbulent frictional force was studied using the appropriate boundary conditions.

3. Collaboration with Universities and other Scientific Institutions

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

3.1 Collaboration with Universities

The Institute has been collaborating since July 1984 with the University of Poona in teaching a course on Atmosheric Physics in the second year of M.Sc. degree. A number of scientists from the Institute including the Honorary Fellow, are participating in the teaching programme on a part-time honorary basis. The University has appreciated the Insitute's co-operation in this matter.

Dr. S.K. Mishra, A.D., Dr. A.k. Kamra, A.D., Dr. G.B. Pant, A.D., Dr. B.K. Mukherjee, SSO I and Dr. (Mrs) P.S. Salvekar, SSO II participated in this teaching programme of M.Sc. (Physics) course of University of Poona, Pune.

The University of Poona has submitted a proposal to the University Grants Commission (UGC), to start a post-M.Sc. course in Atmospheric Physics and had requested the UGC to sanction faculty positions to conduct this course. The course would be introduced after the approval by the UGC. The University sought the Institute's co-operation in setting up the post-M.Sc. course on a firm footing by providing teaching and laboratory help, if needed.

Dr. S.N. Bavadekar, SSO I, was associated with the committee for framing the syllabus of the paper, 'Meteorology and Space Physics' for the T.Y.B.Sc. course of the University of Poona.

Under the guidance of the scientists of the Institute, five students, two from Fergusson College, Pune, one from Wadia College, Pune and two from University of Poona carried out their projects for the partial fulfilment of their B.Sc. and M.Sc. degree courses respectively.

Dr. D. Subrahmanyam, SSO I, was appointed as one of the Chief examiners for M.Sc. (Meteorology and Oceanography) by the Andhra University, Waltair for the year 1986-87.

Dr. S.K. Mishra and Dr. G.B. Pant, Assistant Directors and Dr. B.K. Mukherjee, SSO I, were recognised as post-graduate teachers in Physics by the University of Poona.

3.1.1 Submission of Thesis to University of Poona

Name	Thesis	Degree
Shri D.V. Ahire, Ex-Research Scholar	Behaviour of charged and uncharged water drops under different eletrical stresses.	Ph.D.
Shri P.R. Rakhecha, SSO I	On some Hydrometeorological studies of the Indian rainfall.	Ph.D.
Miss S.S. Goyal, S.A.	Some physical and thermodynamical aspects of the atmospheric boundary layer and monsoon clouds.	M.Sc.

3.2 Fellowship of Science Academy

Dr. S.K. Mishra, Assitant Director has been elected as a 'Fellow of Indian Academy of Seiences' Bangalore.

3.3 Collaboration with Institutions/Organisations

Staff members of the Institute attended the computer training courses NEC-S-1000/10 and the SUPER 32/60 conducted by the National Informatics Centre, Pune, and the Electronics Corporation of India Ltd., Hyderabad during the period 2-20 June 1986 and 17-29 November 1986 respectively.

3.4 Other Academic Activities

Technical guidance on the estimation of Probable Maximum Precipitation (PMP) for the Parapper Dam on Kallada river in Kerala and Icha Dam on Kharkai river in Bihar were provided to the engineers from the Irrigation Departments of Govt. of Kerala and Govt. of Bihar respectively.

Dr. A.S.R. Murty, A.D. was invited by the Committee on Nucleation and Atmospheric Aerosols of the International Commission on Cloud Physics to join as a member of the International Advisory Committee for the 12th International Conference on Atmospheric Aerosols and Nucleation to be held during 21-28 August 1988 at Vienna, Austria.

Dr. G.B. Pant, A.D. received an invitation to work on the Editorial Board of the Journal of Climatology (A journal of the Royal Meteorological Society, U.K.) as member for three years from October 1987.

Research activities of the Institute were displayed in an exhibition organised by the India Meteorological Department, Pune during 23-25 March 1987 to commemorate the WMO day.

Two research proposals were received from the Earth and Atmospheric Science Division of D.S.T. for evaluation by Dr. G.B. Pant, A.D.

A status report on research in Climate and Climatic change at the Institute was prepared by Dr. G.B. Pant, A.D., a member of the sub-committee constituted by National Committee on the World Climate Research Programme for the purpose of preparing a National Report on the Subject.

Dr. A.K. Kamra, A.D. and Dr. S.V. Singh, A.D. delivered lectures for the training programme of the India Meteorological Department.

At the request of the Director, Central Board of Irrigation and Power, New Delhi,a paper entitled,'Meteorology of heavy rainfall over the Garhwal-Kumaon Region of the Himalayas' by O.N. Dhar, A.K. Kulkarni and P.R. Rakhecha was sent for the workshop on 'Flood estimation in the Himalayan region' held at Roorkee in June 1986.

3.5 Participation of the Institute in Scientific Programmes of National Importance

a) National Centre for Medium Range Weather Forecasting (NCMRWF)

On nomination by the Secretary, DST, Shri. D.R. Sikka, Director, was involved in the drafting of a detailed project report for the establishment of NCMRWF and development of Agro-met services, which is an S and T project in Mission mode.

b) Monsoon Trough Boundary Layer Experiment (MONTBLEX)

A meeting was convened by the DST at the Indian Institute of Science, Bangalore, under the Chairmanship of Prof. R. Narasimha, Director, National Aeronautical Laboratory, Bangalore, to consider a National Programme for Atmospheric Boundary Layer Research. The Institute's Scientists proposed a scientific plan for undertaking a special experiment for the study of atmospheric boundary layer in the region of monsoon trough over India. The proposal was endorsed by the committee. A detailed project document was prepared by the Institute's scientists for consideration of the DST. Under the experiment, measurements have been suggested at three locations within the monsoon trough viz. i) the eastern part of the trough (West Bengal) dominated by moist convection, ii) in the western

Prof. and Mrs. Pfeffer with the Academic Council

Prof. and Mrs. Riehl with the Acadamic Council.

region of the trough (Rajasthan) where dry convection prevails and iii) within the central region (Uttar Pradesh) where moist and dry convective processes interchange during active and break monsoon conditions respectively. Details of the instruments required for the measurements have also been worked out in consultation with the scientists of the Indian Institute of Science, Bangalore. The project is under the consideration of the DST.

c) Climate-Vegetation Interaction in Nilgiri Biosphere Reserve

The Department of Environment, Govt. of India has set up Biosphere Reserves in different parts of the country for investigations of ecological processes. One of the reserves has been established in the Nilgiris areas covering the states of Kerala, Karnataka and Tamilnadu. The Department of Environment has identified the Institute as one of the Organisations to participate in this scientific programme. The Institute scientists visited the Indian Institute of Science, Bangalore and held discussions with Prof. Madhav Gadgil, Head, Centre for Environmental studies for participation in a possible programme on the 'Climate-Vegetation interaction in the Nilgiri Bisophere Reserve'. Emphasising the need for such studies as a part of the International Geosphere - Biosphere Programme, a note has been submitted to the Indian National Science Academy (INSA), New Delhi.

d) Indian Middle Atmosphere Programme

The results of the Stratwarm Campaign, conducted during January-March 1986 over Thumba, under ISRO-SCHCNE collaborative programme, were presented in the meetings of IMAP-C held at Bangalore during 23-26 February 1987 by the Chief Convener of the campaign Dr. B.K. Mukherjee, Senior Scientific Officer - Gr. I of the Institute. The convener's proposal for conducting another experiment during 1987-88 winter using 16 additional M-100 rockets has been accepted by the IMAP-C Committee.

Director as a member of the Programme Management Board (PMB) of IMAP-C proposed for inclusion of this Institute as an organisation involved in the measurements of tropospheric aerosols by LIDAR to extend aerosol measurement work being conducted by IMAP-C using LIDAR. The proposal was accepted by the Committee.

e) Snow Water Chemistry

Special field observations of snow sampling at the High Altitude Research Laboratory at Gulmarg, Srinagar were organised during the winter season of 1986-87. During the above field programme, 31 samples of snow were collected under different meteorological conditions. It is envisaged to study the chemistry of the snow water vis-a-vis the atmospheric pollution in the region.

3.6 Institute's Visiting Professorship Programme

The Institute has initiated a Visiting Professorship programme under which it invites a distinguished scientist from abroad to spend a few weeks to a few months at the Institute for lecturing in one's area of specialisation and also for interacting with the Institute's scientists in their research pursuit. Under this programme, Prof. R.L. Pfeffer of the Geophysical Fluid Dynamics Institute, Florida State University, visited the Institute as its first Visiting Professor during 1-19 December 1986.

4. General

4.1 The Governing Council

The administration and management of the Institute is vested in its Governing Council which consists of 9 members including the Director of the Institute.

The Council held two meetings during the year at the India Meteorological Department, New Delhi and at the Institute at Pune on 26 November 1986 and 27 March 1987 respectively.

4.2 Staff Council

The Staff Council is an elected body representing all employees of the Institute in different categories. It acts as a forum for discussion on matters of common interest to the employees and for increasing efficiency. It meets under the Chairmanship of the Director. The Council held nine meetings during the year.

The extended term of the Sixth Staff Council expired on 14 January 1987 and the Seventh Staff Council was duly elected. It held its first meeting on 15 January, 1987. Shri. S. Sinha, SSO-II was unanimously elected as Secretary. The new council met once every month. It discussed several matters including improvements in the canteen facilities at Pashan & in reactivation of the recreation club. Suggestions were received from the Secretary of the Staff Council regarding changes in the recruitment and promotion rules.

4.3 The Academic Council

The Academic Council, a body constituted by the Governing Council, functions to advise the Director on all matters relating to scientific projects of the Institute and to ensure team work within the Institute for achieving its aims and objectives. During this year, the council held 9 meetings. Some of the important matters discussed by the council were :

Review of all the ongoing projects of the Institute;
A project proposal on ''Study of Atmospheric Boundary Layer in the Monsoon Trough Region'' to be funded by the Department of Science & Technology;
A project proposal for the study of the ''Environmental Physics and Chemistry'' under the Nilgiri-Biosphere Reserve Programme of the Department of Environment;
Internal review of scientific papers before their communication to journals.

4.4 Meetings of Heads of Divisions

The Heads of Divisions of the Institute meet once in a month or more frequently if so required, to take a review of all aspects of the work. Twelve such meetings were held in 1986-87 in which important issues about the scientific and organisational activities of the Institute were discussed.

4.5 Appointment of Director

Shri. D.R. Sikka, Assistant Director, who was on deputation to the TOGA project, assumed the charge of the post of Director of the Institute with effect from 15 September 1986.

4.6 Review of Research Projects

A review of all research projects in the Institute was conducted under the auspices of the Academic Council of the Institute. A report on the review was placed before the Governing Council by the Director. The Council took note of the progress made by the Institute under its various projects.

4.7 Celebration of the National Science Day

To commemorate the birth anniversary of Prof. C.V. Raman, the National Council for S and T Communication (DST), Govt. of India, have decided to celebrate 28 February every year as the National Science Day. The Institute organised a function in which Prof. R.Ananthakrishnan, a student of Prof. Raman, gave a lecture on 'Prof. C.V. Raman : His Personality and Scientific Achievements'. An exhibition showing the activities of the Institute was also organised on this day. A large number of students and public visited the exhibition.

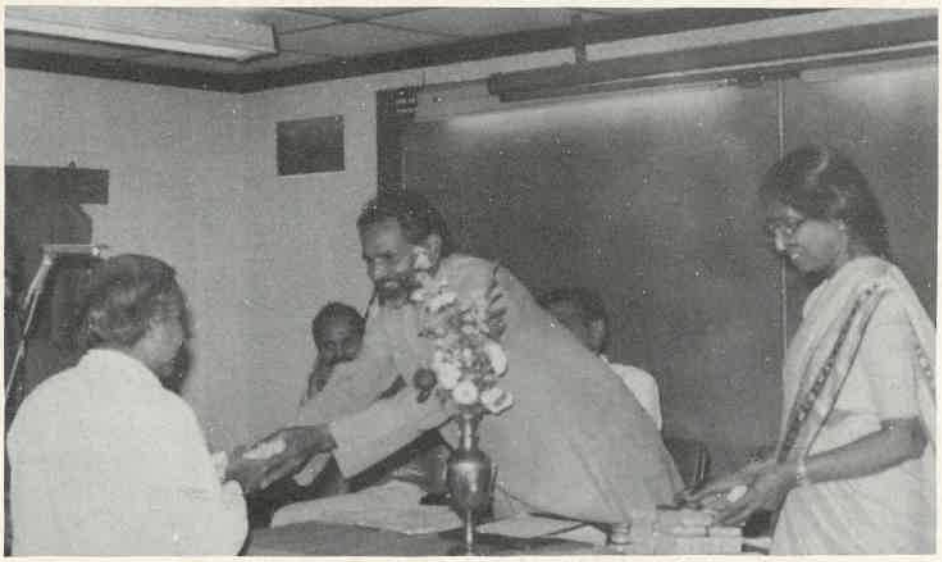
4.8 Institutional membership

The Institute enrolled itself as an Institutional

National Science Day

Participants in the Exhibition at the Institute's Pashan Complex, Pune.

'Hindi Day'



Prize distribution on the Hindi Day

Member of the Indian Science Congress Association, Calcutta and the British Library, Pune.

4.9 Appointment of Scientific Pool Officer

With effect from 28 April 1986, Dr. L.S. Laxminaraynan joined the Institute as Pool Officer of the Council of Scientific and Industrial Research.

4.10 Construction

The construction work of the 2nd phase of the office building commenced on 9 August 1986. The work was in progress and expected to be completed within 2 years. The construction of the Guest House and Director's quarters was in progress and expected to be completed during the year 1987-88. The construction work of the Hostel building and a building to house the Power sub-station of 500 KVA was completed.

4.11 Facilities

4.11.1 Library, Information and Publications

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

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

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

iii) Dissemination of appropriate scientific information;

iv) Documentation and current awareness services and

v) Preparation, publication and presentation of various scientific/research reports and allied materials projecting the activities of the Institute.

Formulation of various plan documents and monitoring of the on-going plan projects are also dealt with by this Division.

a) Library :

During the year,124 books in Meteorology and allied subjects were added and 86 periodicals of national and international repute were subscribed to.

A number of scientific/technical reports were also added to the Library. Reprints of papers authored by the Institute's scientists and published in different scientific journals of national and international standing were procured. Inter-library loan facilities are arranged through the courtesy and co-operation of a large number of research libraries in the country.

b) Information Service :

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

4.11.2 Computer Facilities :

The in-house IBM-1620 computer worked during the year as follows :

	Hrs	Mts
Institute's Jobs	638	45
Data Processing of India Meteorological Department	46	30
Breakdown/Maintenance	392	35

Special efforts were made to enhance the computer facilities at the Institute. A terminal connected to NEC S-1000/10 computer system of National Informatics Centre, Pune was installed in the Institute's building at Pashan, Pune.

The Super 32/60 computer system from Norks Data of Norway was delivered by the Electronics Corporation of India Ltd. The site preparation and airconditioning work was in progress. With the installation of this system, the in-house computational power available to the Institute's scientists would be considerably enhanced.

A computer program for retrieving packed binary global FGGE-II B data was developed. A suitable computer program for spectrum analysis for climatological studies was developed using Non-Integer Technique. The program was tested with 70 years' July-rainfall series of some stations

and with the 70 years'Annual sunspot numbers. A cycle of 103 years, significant at 10% level, was found for sunspot series, which is close to the 10-years cycle obtained by using Maximum Entropy Method.

Monthly Climatic Data (Surface) for the selected 113 tropical stations for the period 1971-84, available in the data bank of the Institute, were re-arranged year-wise. Collection of the data for the year 1985 was completed.

Collection and punching of monthly climatic data (upper air) for the ten standard levels in respect of the selected 80 tropical stations were continued. Punching of the data for the year 1982 was completed.

4.12 Deputations abroad

Shri R. Suryanarayana, Assistant Director was deputed to represent India at the 9th Session of the WMO Commission for Atmospheric Sciences held at Sofia, Bulgaria from 6 to 17 October 1986. He was elected as Co-Chairman to conduct the proceedings of the Commission. At the end of the session he was elected as a Member of the Advisory Working Group of the Commission. India got this honour for the first time since the inception of the Commission 33 years ago.

Dr. G.B. Pant, Assistant Director was deputed for a period of 56 days from 16 October 1986 to Lamont Doherty Geological Observatory, NY Palisadeny, U.S.A. for study and visit under the Indo-US STI Programme in monsoon research.

Dr. S.V. Singh, Assistant Director was deputed to attend the first WMO Conference on Long Range Forecasting at Sofia, Bulgaria, during 29 September to 3 October 1986.

Shri D.K. Paul, Senior Scientific Officer, Grade II was deputed to attend an official level meeting on Meteorology under the Indo-USSR Programme of co-operation in Science and Technology held in Moscow, USSR during 8-15 November 1986.

Dr. L.T. Khemani, Senior Scientific Officer, Grade II was invited to participate in the 15th International Conference on the Unity of the Sciences (ICUS) held at Washington, U.S.A. during 26-30 November 1986. He presented a scientific paper entitled, 'Role of alkaline particulates on pH of rain water and implication for control of acid rain.'

Dr. S.Rajamani, Senior Scientific Officer, Grade I was granted extra-ordinary leave for a period of one year with effect from 12 May 1986 to enable him to accept a post-doctoral Research Associateship on Monsoon Circulation and Energetics in the Department of Geological & Geophysical Sciences, University of Wisconsin, Milwaukee, U.S.A.

Dr. B. Parthasarathy, Senior Scientific Officer, Grade I was granted extra-ordinary leave for a period of one year with effect from 22 September 1986 to enable him to accept a Post-doctoral visiting fellowship at the co-operative Institute of Research in Environmental Sciences (CIRES), University of Colorado, Boulder, U.S.A.

Dr. R.S. Reddy, Senior Scientific Officer, Grade II, now on a Visiting Fellowship in the field of Solar Terrestrial Physics and Meteorology at the Atmospheric Environment Service, Environment Canada was granted extension of extra-ordinary leave for one year with effect from 18 November 1986.

4.13 Field Research Unit at Bangalore

The field research unit of the Institute headed by Scientist-in-charge, Prof. A. Mani, is located in Bangalore. The unit undertakes sponsored research projects from various departments of Government of India and State Governments.

The Department of Non-Conventional Energy Sources accorded formal sanction for carrying out wind energy survey projects in Andhra Pradesh and Rajasthan. This is in addition to ongoing surveys in four States viz. Tamilnadu, Orissa, Gujrat and Maharashtra. Projects for wind mapping work in Tamilnadu, Andhra Pradesh, Orissa, Karnataka, Madhya Pradesh and Rajasthan were approved by the Department of Non-Conventional Energy Sources and necessary funds were sanctioned to the various Energy Development Agencies and I.I.T.M., Field Research Unit.

27 sets of Wind Resources Data loggers with sensors and accessories were imported from U.S.A. and 12 sets of Digital wind recording systems complete with sensors and accessories were obtained from indigenous suppliers for installation at 36 wind measuring stations in 4 states. 15 portable hand held anemometers, manufactured by DEUTA WERKE, were imported from West Germany for supply to various State Energy Development Agencies.

20m high instrumented masts were installed at thirty selected sites in Tamilnadu, Orissa, Gujrat and Maharashtra during the period. Each mast has 2 sets of anemometers and windvanes at 10m and 20m levels and a data logger to store the information in Eprom chips. Orders were placed for 22 sets of wind recording systems for installation in Andhra Pradesh and Rajasthan.

Nine sites for installation of instrumented masts in Andhra Pradesh were selected after detailed survey in collaboration with National Aeroanutical Laboratory. Sites selected for the establishment of wind mapping stations in Andhra Pradesh were inspected to determine their suitability.

4.14 Official Language Implementation

During the year, a large number of circulars were issued bilingually in Hindi and English. Institute's Annual Report and Audit reports, legal agreements, oaths and monthly progress reports were translated into Hindi. Letters drafted in Hindi were sent to various Central and State Government Offices in the Hindi speaking areas.

A Hindi library is being maintained in the Institute from which books of high literary merit are issued to the staff.

Hindi week was celebrated with great enthusiasm. Hindi essay contest, debate, poetry recitation and noting and drafting contests were organised. The prizes and certificates were given away at a function on the final day by the Chief Guest Dr. Keshav Prathamveer, Head of Hindi Department, A.M. College, Pune.

Four quarterly meetings were held to review the progress in the implementation of official language. A workshop was organised for in-house training in the use of Hindi in official files where the staff evinced keen interest.

One LDC passed the Hindi typewriting examination conducted by the Department of Official Lanauge with 95% marks. Two other staff also acquired proficiency in Hindi by passing the prescribed examination.

4.15 Employment of Ex-Servicemen

Reservation for ex-servicemen is made as per rules, in the case of groups 'C' and 'D' posts of the Institute. The percentage of ex-servicemen vis-a-vis total number of employees in groups 'B', 'C' and 'D' at the Institute was as follows :

Group 'B' - 3
Group 'C' - 1
Group 'D' - 14

4.16 Budget

The budget estimates and actual expenditure for the Institute for the period 1986-87 are given below :

(Rs. in lakhs)

	Budget Estimates 1986-87	Revised Estimates 1986-87	Actual Expenditure	Shortfall in expenditure over Grant-in-aid received.
Non-Plan	141.00	143.00	129.85	0.15
Plan	115.00	105.00	98.42	—

Audit on the accounts of the Institute by the financial year 1986-87 was conducted by M/s. G.D. Apte and Co., Chartered Accountants, Pune.

5. Visitors

A) National

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

Sr. No.	Visitors-Credentials	Date of Visit
1.	Shri A.D. Mohile, Director of Hydrology, Central Water Commission, New Delhi and Shri Abraham Varghese, Superintending Engineer, Kallada Project, Kerala.	13-24 May 1986
2.	Dr. R.P. Sarker, Director General of Meteorology, Chairman, Governing Council, Indian Institute of Tropical Meteorology, Pune.	23-27 May, 22-25 August, 17 & 30 October, 10 December 1986
3.	Dr. P. Chandrasekhar, Joint Director, National Informatics Centre, New Delhi.	5 June 1986
4.	Dr. V. Gowariker Secretary, Government of India, Department of Science and Technology, New Delhi.	10 July 1986
5.	Dr. D.K. Rakshit, Director, Department of Science and Technology, New Delhi and Member of Governing Council, IITM.	12 July 1986
6.	Shri. D.B. Sehgal, Joint Secretary (Admin.), Department of Science and Technology, New Delhi.	1-2 August 1986
7.	Scientists participating in the WMO/IMD Workshop on Training of Instructors of RA-II/RA-V.	29 October 1986
8.	Dr. N.G. Perur, Vice Chancellor and Professor M.C. Varshneya, Physics Department, M.P.A.U., Rahuri	18 November 1986
9.	A Group-Naval Met. Observer, I Class, School of Naval Oceanology and Meteorology, Cochin.	27 November 1986
10	Shri S.D. Bhargava, Director, Central Water Commission (CWC), New Delhi. Shri E.V. Jagannathan, Deputy Director, CWC, New Delhi. and Shri. N.K. Kapoor, Superintending Engineer, Nanded Dam Circle II, Bhopal.	11 December, 1986
11.	Shri T.S. Prasad Scientist 'C', Water Resources Division, National Remote Sensing Agency, (NRSA) Hyderabad.	28-30 January 1987

12. S/Shri. J.P. Varma, Chief Engineer, G.N. Pandya, Supdt. Engineer. and P.N. Biswas, Executive Engineer, Subarnarekha Multipurpose Project, Bihar. — 25 February 1987

13. Shri. M.N. Seetharaman, Assistant Director & Head, Information Centre for Aeronautics, National Aeronautical Laboratory, Bangalore. — 5 and 6 March 1987

14. A group of Trainee Officers and One Instructor, Air Force Administrative College, Coimbatore, — 23-25 March 1987

15. Captain R.N. Dogra Aviation Advisor, Government of Gujarat — 26 March 1987

16. Shri K.G. Ramanathan Secretary, Agriculture and Rural Development, Government of Gujarat. — 26 March 1987

B) International

Sr. No.	Visitor-Credentials	Date of Visit
1.	Academician V.E. Zuev, Director, Institute of Atmospheric Optics, Tomsk, Siberia, USSR.	6-8 April 1986
2.	Prof. Herbert Riehl, Eminent Tropical Meteorologist of USA.	9-13 April 1986
3.	Dr. K. Kurihara, Japan Meteorological Agency, Tokyo.	24-26 April 1986
4.	Prof. T.N. Krishnamurty and Prof. (Mrs.) Ruby Krishnamurty, Florida State University, USA.	30 June 1986
5.	Dr. Klaus Hormann, Professor and Director, Department of Geography, University of Kiel, F.R. Germany.	14-15 July 1986
6.	Dr. William Merrel, Asstt. Director, Directorate for Astronomical, Atmospheric, Earth and Ocean Sciences, National Science Foundation, Washington.	19 November 1986
7.	Dr. Pamela Stephens, National Science Foundation, USA.	19 November 1986
8.	Dr. A.H. Oort, U.S. Scientist, Geophysical Fluid Dynamics Lab., Princeton University, U.S.A	19-22 November 1986
9.	Prof. Richard L. Pfeffer, Director, Geophysical Dynamics Institute, Florida State University, Tallahassee, U.S.A.	1-19 December 1986
10.	Dr. A.F.E. Zagni, World Bank Expert on Hydrology, New Delhi.	6 December 1986
11.	Dr. M.B. Mathur, National Meteorological Centre, NOAA, Washington D.C., U.S.A.	24 February - 5 March 1987,

6. Institutional Seminars

The following seminars were organised under the Institute's seminar series.

Speaker	Topic	Date
Dr. Ramesh R., Physical Research Laboratory, Ahmedabad.	i) Stable isotopes in Climatology;	2 April 1986
	ii) Climate information from Indian trees.	25 September 1986
Prof. V.E. Zuev, Academician, USSR.	Laser sounding of the atmosphere.	8 April 1986
Prof. H. Riehl, USA.	Formation of tropical cyclones.	10 April 1986
Prof. K. Kurihara, Japan.	Operational long-range weather forecasting in Japan	25 April 1986
Prof. T.N. Krishnamurty, F.S.U., USA.	Air-sea interaction on the time scales of 30 to 50 days.	30 June 1986
Prof. (Mrs.) Ruby Krishnamurty, FSU, USA.	Turbulence transition..	30 June 1986
Prof. R. Ananthakrishnan, IITM, Pune.	i) Onset phase of the SW Monsoon over south Kerala;	21 August 1986
	ii) Anomalies in the aerological data of some Indian stations.	20 February 1986
Dr. S.V. Singh, IITM, Pune	i) Forecast of the Indian monsoon using some new parameters;	24 September 1986
	ii) Experience of first WMO Conference on long-range forecasting held at Sofia, Bulgaria, September, 1986.	23 October 1986
Prof. K.N. Rao	Rainfall of India.	12 November 1986
Dr. A.H. Oort, Scientist, U.S.A.	Climate variability.	20 November 1986
Dr. S.C. Seth, Dy. Secretary, D.S.T.	Future Scan and perspective planning.	17 December 1986
Dr. John Revfeim, Met. Service, New Zealand	Some alternative distribution for fitting to maximum values and the physical interpretation.	18 December 1986

Prof. R.L. Pfeffer, Director, Florida State University, U.S.A.	i) Scale analysis - I.	2 December 1986
	ii) Scale analysis - II,	4 December 1986
	iii) Forced and free meridional circulation - I,	9 December 1986
	iv) Forced and free meridional circulation - II,	11 December 1986
	v) Energetics of the atmosphere - I,	16 December 1986
	vi) Energetics of the atmosphere - II.	18 December 1986
Shri. R. Suryanarayana, IITM, Pune	Deliberations of Commission for the Atmospheric Sciences, IX	29 December 1986
Dr. L.S. Hingane, IITM, Pune	i) Effect of increasing CO_2 on the stratospheric level of CO and O_3 - I;	13 January 1987
	ii) Effect of increasing CO_2 on the stratospheric level of CO and O_3 - II.	13 March 1987
Dr. M.B. Mathur, Meteorologist, National Meteorological Centre, USA.	Numerical prediction of hurricanes.	4 March 1987
Prof. M.M. Seetharaman, Head, Information Centre for Aeronautics, National Aeronautical Laboratory (NAL), Bangalore.	i) Information Management and Technology;	5 March 1987
	ii) On line Information Retrieval System and Services in NAL.	6 March 1987

7. Participation in Symposia/Seminars

Sr. No.	Name of the Symp.	Participant(s)	Papers presented, if any.
1.	Int. Sem. on 100 years of Long-range forecasting of monsoon rainfall, Indian Meteorological Society, New Delhi, 16-18 April 1986.	Ananthakrishanan R., Pant G.B. & Verma R.K.	i) Interannual variability of the Antarctica temperature & its relationship with the monsoon rainfall – Verma R.K., Dugam S.S. & Subramaniam K. ii) Long-range forecasting of monsoon rainfall on the basis of its relationship with the northern hemispheric surface air temperature anomalies. – Verma R.K., Subramaniam K., Dugam S.S. & Kakade S.B. iii) Long-term variability of some important parameters of Indian summer monsoon – Pant G.B., Parthasarathy B. & Borgaonkar H.P. iv) Some observational aspects of the variability of the summer monsoon circulation & rainfall over India during 1978, 1979 and 1980 – Ananthakrishnan R. & Soman M.K.
2.	III Int. Conf. on Statistical climatology, Vienna, Austria, 23-27 June 1986.	Kamte P.P.	i) Kutzback EOFs of summer monsoon circulation and rainfall fields over India – Kamte P.P., Singh S.V. & Kripalani R.H. ii) Potential predictability of 70 hPa height and rainfall fields over the Indian and adjoining region during the summer monsoon season – Kripalani R.H., Kamte P.P. & Singh S.V.

3.	Workshop on Flood estimation in the Himalayan region, Roorkee, 25-26 September 1986.	Rakhecha P.R.	Meteorology of heavy rainfall over the Garhwal – Kumaon region of the Himalayas – Dhar O.N., Kulkarni A.K. & Rakhecha P.R.
4.	VI Int. Conf. on Geochronology, Cosmochronology, Isotope - Geology, Cambridge, U.K., 30 June - 4 July 1986.	–	Climatic significance of δD and $\delta^{13}C$ in teak trees from the Indian west coast. – Ramesh R., Bhattacharya S.K. & Pant G.B.
5.	Symp. on Hydrology with colloquium on water logging and drainage, Bhopal, 15-17 July 1986.	Kulkarni A.K. & Mandal B.N.	i) Brief appraisal of severe rainstorms of Madhya Pradesh region for optimum development of its water resources – Dhar O.N., Mandal B.N. & Mulye S.S. ii) Estimation of areal probable maximum precipitation (PMP) in the region of Madhya Pradesh – Rakhecha P.R., Mandal B.N & Sangam R.B. iii) Highest ever recorded floods in the major Indian rivers – Dhar O.N., Mulye S.S. & Mandal B.N. iv) Preparation of generalized charts of maximum and probable maximum one-day point rainfall for the Madhya Pradesh region – Dhar O.N., Kulkarni A.K. & Kulkarni B.D.
6.	Int. Symp. on Chapman Conf. on El-Nino, Guayaquill, Equador, 27-31 October 1986.	–	El-Nino and Indian monsoon rainfall statistical relationship – Parthasarthy B. & Sontakke N.A.
7.	National Symp. on Instrumentation (NSI-11) National Geophysical research Institute (NGRI),Hyderabad , 1-4 October 1986.	Jadhav D.B. & Raj P.E.	i) Cylindrical field mill monitoring of three vectors of electric field – Jadhav D.B., Selvam A.M. & Murty A.S.R. ii) Designing of high light gathering power and high resolution infrared spectrometer for atmospheric and laboratory studies – Jadhav D.B.

			iii) Microprocessor controlled three colour twilights photometer – Jadhav D.B. & Trimbake H.K.. iv) Opto-electronic system for the study of comet Halley – Devara P.C.S. & Raj P.E. v) Phase sensitive detector and their applications in radio wave direction finding system – Rao V.L., Devara P.C.S. & Ahmed M.I.
8.	First WMO Conf. on Long range forecasting, Sofia, Bulgaria, 29 September – 3 October 1986.	Singh S.V.	Predictive relationships of some new and other recent parameters with monsoon rainfall – Singh S.V. & Prasad K.D.
9.	IX Session of the WMO Commission for Atmospheric Sciences, Sofia, Bulgaria, 6-17 October 1986.	Suryanarayana R.	–
10.	Indo-US programme in the field of Monsoon, Lamont Doherty Geological Observatory, USA, 16 October 1986 onwards.	Pant G.B.	Deputed for a period of 56 days under the Indo-US STI Programme for Monsoon Research.
11.	Workshop on Numerical weather prediction, Dhaka, Bangladesh, 18 October - 12 November 1986.	Lakshminarayanan E.S.	Properties of solutions to equations of atmospheric and oceanic dynamics – Lakshminarayanan E.S.
12.	DST sponsored seminar series on 'Global climate system & climate variability' under Indo-US-STI monsoon research programme, Physical Research Laboratory, Ahmedabad, 7-14 November 1986.	Verma R.K., Sinha S. & Kulkarni J.R.	Interannual & longer term variability of monsoon and climate variability – Verma R.K.
13.	Int. Conf. on the Unity of Sciences (ICUS XV) Washington D.C., USA, 27-30 November 1986.	Khemani L.T.	Role of alkaline particulates on pH of rainwater and implication for control of acid rain – Khemani L.T.

14. Workshop on Multiparameter Doppler weather radar for India, Indian Institute of Science, Bangalore, 8-10 December 1986.	Sikka D.R. & Sharma P.N.	Research programmes of the Indian Institute of Tropical Meteorology – Sikka D.R.
15. WMO/FAO/RA-II/RA-V regional Workshop on Drought and desertification, India Metrological Department, Pune, 10-16 December 1986.	Bhalme H.N. & Rupa Kumar K.	Large scale droughts/floods & the teleconnections of the southern oscillation, El–nino phenomena – Bhalme H.N.
16. Seminar on Communication in Library Organisations, University of Poona, Pune, 12-13 December 1986.	Massey V.V. & Morwal B.C.	–
17. Int. Symp. on 'Palaeoenvironmental changes in Asia during last 4 million years', Physical Research Laboratory, Ahmedabad, 15-20 December 1986.	Rupa Kumar K.	i) δD variations in teak tree reflect long-term monsoon trend – Ramesh R., Bhattacharya S.K. & Pant G.B. ii) Statistical model of climate reconstruction using tree ring data – Pant G.B., Rupa Kumar K. & Borgaonkar H.P.
18. Workshop cum seminar on 'Satellite meteorology and interpretation technique', Indian Institute of Science, Bangalore, 22-27 December 1986.	Paul D.K. & Mahajan P. N.	Unusual behaviour of monsoon – Paul D.K. & Sikka D.R.
19. National Workshop on Basic Physics of Monsoon, Indian Institute of Technology, Kharagpur, 27-30 December, 1986.	Sikka D.R.	Interannual variability of monsoon – Sikka D.R.
20. 74th Session of Indian Science Congress, Bangalore, 3-8 January 1987.	Sadani L.K.	–

21. Indian Geophysical Union Seminar on 'Geophysics and environment', National Geophysical Research Institute, Hyderabad, 21-22 January 1987.	Verma R.K., Devara P.C.S., Jadhav D.B., Kulkarni A.K., Mahajan P.N., Singh N., Rao P.G. & Deshpande V.R.	i) Fluctuation of the Somali Jet as seen through GOES (I-O) Satellite during Summer Monex - 79 – Mahajan P.N., Mujumdar V.R. & Ghanekar S.P. ii) Generalized maps of point PMP as percentages of mean annual rainfall and 100 years rainfall for peninsular India – Kulkarni A.K., Mandal B.N. & Dhar O.N. iii) Remote sensing of lower aerosols in the atmosphere using a bistatic Helium - Neon lidar – Devara P.C.S. & Raj P.E. iv) Remote sensing possibility with high spectral resolution multispectral Fraunhofer line discrimination by fluorescence property of the scatterer – Jadhav D.B. & Shephard G.C. v) Secular changes of rainfall along the east coast of India – Rao P.G. vi) Short-term climatic fluctuations and monsoon – Verma R.K., Subramaniam K., Dugam S.S. & Kakade S.B. vii) Some aspects of hydroclimatic changes in Kerala (India) – Singh N. & Soman M.K. viii) Stability of climatic parameters using statistical model - a case study with Maharashtra rainfall. – Deshpande V.R.
22. Workshop on Large scale variability of the tropical atmosphere and oceans, Indian Institute of Science, Bangalore, 10-13 February 1987	Sikka D.R., Sinha S., Rupa Kumar K., Totagi M.Y. & Soman M.K.	Episodic nature of planetary scale tropical cloudiness : Observations and sensitivity experiments with the GCM – Sikka D.R.

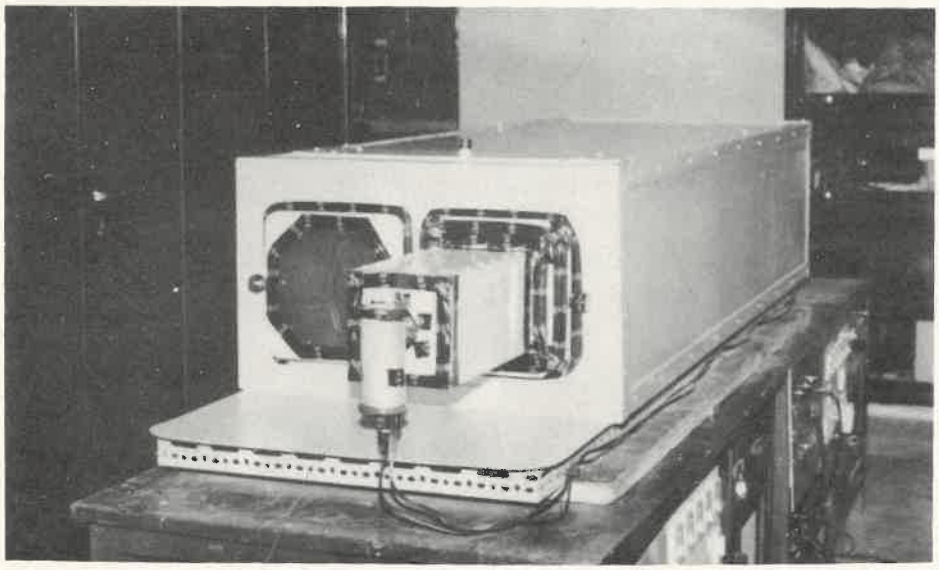
23. Symposium on Short-term variability of physical oceanographic features in the Indian waters, National Physical & Oceanographic Laboratory, Cochin, 19-20 February 1987.	Seetaramayya P. & Mahajan P.N.	i) Identification of prime eddy over the Western Indian ocean through satellite imageries – Mahajan P.N. ii) Local variation of sea surface temperatures (SST) and the associated summer monsoon onset during Monex-77 – Seetaramayya P. & Mullan A.H. iii) Storm induced vertical thermal variations (warming and cooling) in the Eastern Arabain sea during Monex-79 – Seetaramayya P. & Mullan A.H.
24. Seminar on State of Art in the study of Norwesters and severe storms, University of Calcutta, 19-21 March 1987.	Chatterjee R.N.	Radar study on severe thunderstorms around Delhi during summer and monsoon seasons – Chatterjee R.N. & Prem Prakash
25. Workshop on Dynamics of tropical cyclones, Institute for Coastal and Offshore Research, Andhra University, Waltair, 22-27 March 1987.	Seetaramayya P. & Salvekar P.S.	Dr. Salvekar P.S. delivered a lecture on 'Dynamics of monsoon depression – baroclinic mechanism
26. Tenth Forecasting Officers Conference, India Meteorological department, Pune, 27-30 March 1987.	Sinha S. & Mahajan P.N.	–
27. Training programme on Numerical Weather Prediction, Indian Institute of Technology, New Delhi, 18 March - 17 April 1987.	Lakshminarayanan E.S. & Tandon M.K.	

8. Participation in Meetings

Sr. No.	Meeting	Participant
1.	Cloud physics and local severe storms, New Delhi, 10 April 1986.	Murty, A.S.R.
2.	Programme Adivsory Committee (PAC) on Atmospheric Sciences of the DST, New Delhi, 11 April 1986	Murty A.S.R.
3.	Evaluation of the performance of 1680 MHz transistorized thermistor, IMAP office, Bangalore, 10-12 June 1986.	Vernekar K.G.
4.	Review of the projects under Indo-US STI monsoon, Indian Institute of Technology, New Delhi, 15-21 June 1986.	Singh S.S.
5.	Dynamical modelling & numerical weather prediction, Indian Institute of Technology, New Delhi, 16-20 June 1986.	Singh S.S.
6.	PAC on Atmospheric Sciences of the DST, New Delhi, 14 July 1986.	Murty A.S.R.
7.	Selection of Scientists by UPSC, New Delhi, 18 July 1986	Vernekar K.G.
8.	Indo-USSR Collaboration programme in Science & Technology (Meteorology), Indian Institute of Technology, New Delhi, 22-25 July 1986.	Paul D.K.
9.	Hydrometeorology panel of the High level technical committee on Hydrology, National Institute of Hydrology, Roorkee, 14 October 1986.	Rakhecha P.R.
10.	Review on the development of IITM payload, Tata Institute of Fundamental Research, Bombay, 24 October 1986.	Sikka D.R. & Vernekar K.G.
11.	Meeting with Russian Scientist Dr. Zakharov in connection with the work to be carried out about the energy aspects of the troposphere and lower stratosphere, Bangalore, 1-4 November 1986.	Kulkarni J.R.
12.	Indian Academy of Sciences, Varanasi, 5-11 November 1986	Sikka D.R.

13.	Council for Meteorology & Atmospheric Sciences, India Meteorological Department, New Delhi, 20 November 1986 and 20 January 1987.	Sikka D.R.
14.	Meteorology under Indo-USSR Co-operation programme in Science & Technology (Meteorology), Moscow & Leningrad, USSR and Arctic & Research Institute, 10-14 November 1986.	Paul D.K.
15.	Preparation of Detailed Project Report for the establishment of National Centre for Medium Range Weather Forecasting and Agro-met Services, New Delhi, 18-23 December 1986.	Sikka D.R.
16.	Scientific Advisory Committee of the Centre for Atmospheric Science, Indian Institute of Technology, New Delhi, 24 December 1986.	Sikka D.R.
17.	74th Session of Indian Science Congress, Bangalore, 1-9 January 1987.	Sadani L.K.
18.	Visit of Academician Marchuk, from USSR, Indian Institute of Science, Bangalore, 3 January 1987.	Sikka D.R.
19.	Preparation of Detailed Project Report for the establishment of National Centre for Medium Range Forecasting and Agro-met Services, 5 January 1987.	Sikka D.R.
20.	Data exchange related to the Indo-US STI programme, Department of Science & Technology, New Delhi, 21 & 22 January 1987 & 3-6 February 1987.	Singh S.V & Bhalme H.N.
21.	Expert Committee for Instruments, Indian Institute of Technology, New Delhi, 22 January 1987.	Vernekar K.G.
22.	i) Programme on Atmospheric Boundary Layer Studies & ii) Nilgiri-Biosphere programme, Indian Institute of Science, Bangalore, 9-12 February 1987	Sikka D.R. & Vernekar K.G.

23.	Meeting with Director of Hydrometeorology, India Meteorological Department, New Delhi, 15-24 February 1987.	Rakhecha P.R.
24.	Formulation of a project for the Monsoon Trough Boundary Layer Experiment, Indian Institute of Science, Bangalore, 23-25 February 1987.	Vernekar K.G.
25.	Second meeting of SAC/PMB of IMAP-C & Second Joint meeting of IMAP-C working groups, Bangalore, 25-26 February 1987.	Mukherjee B.K.
26.	Joint meeting of PMB : IMAP-C ISRO, Bangalore, 26 February 1987.	Sikka D.R.



High resolution visible spectrometer being developed at the Institute for the monitoring of atmospheric minor constituents.

9. Publications

9.1 Papers Published

9.1.1. Papers published in journals

1. Aeronomic reactions of ozone in the stratosphere and troposphere: Hingane L.S., Archiv fur Meteorologie Geophysik und Bioklimatologie, Sr. B., 36, 2, 1986, 147-156.

2. Aircraft observations of hygroscopic and ice-nuclei at a tropical station: Paul S.K., Sharma S.K., Selvam A.M. & Murty A.S.R., Jr. de Recherches Atmospheriques, 19,3, July-September, 1985, 323-327.

3. Analysis of 1982 heavy rainstorm over lower Mahanadi catchment: Rao P.G., Rakhecha P.R. & Ramana Murty K.V., Indian Jr. of Power and River Valley Development, 36, 5&6, May-June, 1986, 165-167.

4. Analysis of persistence of rainfall over India: Singh S.V. & Kripalani R.H., Jr. of Climatology, 6,6, November-December, 1986, 625-639.

5. Application of the extended empirical orthogonal function analysis to inter-relationships and sequential evolution of monsoon fields: Singh S.V. & Kripalani R.H., Monthly Weather Review, 114, 8, August, 1986, 1603-1610.

6. Baroclinic energetics and zonal plane distribution of monsoon disturbances: Salvekar P.S. & Mishra S.K., Pure & Applied Geophysics, 123, 1985, 448-462.

7. Burst of Indian summer monsoon as revealed by GOES Satellite during Monex - 1979: Mahajan P.N., Mujumdar V.R. & Ghanekar S.P., Advances in Atmospheric Sciences, 3, 4, 1986, 514-519.

8. Characteristics of cloud-drop spetra in tropical warm clouds: Paul S.K., Pillai A.G., Selvam A.M. & Murty A.S.R., Pure & Applied Geophysics, 123, 1985, 930-940.

9. Design & fabrication of high light gathering power monochromator: Jadhav D.B. & Tillu A.D., Jr. of Optics, 15,2, April-June, 1986, 54-61.

10. Effect of Ekman friction on the baroclinic growth of monsoon depression: Salvekar P.S. & Mishra S.K., Mausam, 37,2, April, 1986, 147-152.

11. Estimates of heat and moisture over the Indian monsoon trough zone during monsoon 1979: Kulkarni P.L., Mausam, 37,4, October, 1986, 533-536.

12. Exchange of heat and momentum between ocean and atmosphere in relation to monsoon depression during Monex-79: Seetaramayya P. & Master A.H., Meteorology and Atmospheric Physics, 35, 1-2, 1986, 59-63.

13. Extension of equatorial easterlies at 150 mb level towards India in relation to the south-west monsoon: Patil S.D., Hingane L.S. and Rupa Kumar K., Mausam, 37, 4, October, 1986, 543-544.

14. Fluxes of sensible and latent heat at the air-sea interface over the equatorial Arabian sea during Monex-79: Bhide U.V., Nagar S.G., Mahajan P.N. & Sikka D.R., Current Science, 55,15 August, 1986, 699-701.

15. Forecasting of monsoon performance over India: Bhalme H.N., Jadhav S.K., Mooley D.A. & Ramana Murty Bh.V., Jr. of Climatology, 6,4, July-August, 1986, 347-354.

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9.2.1 Papers accepted for publication in journals

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Appendix I

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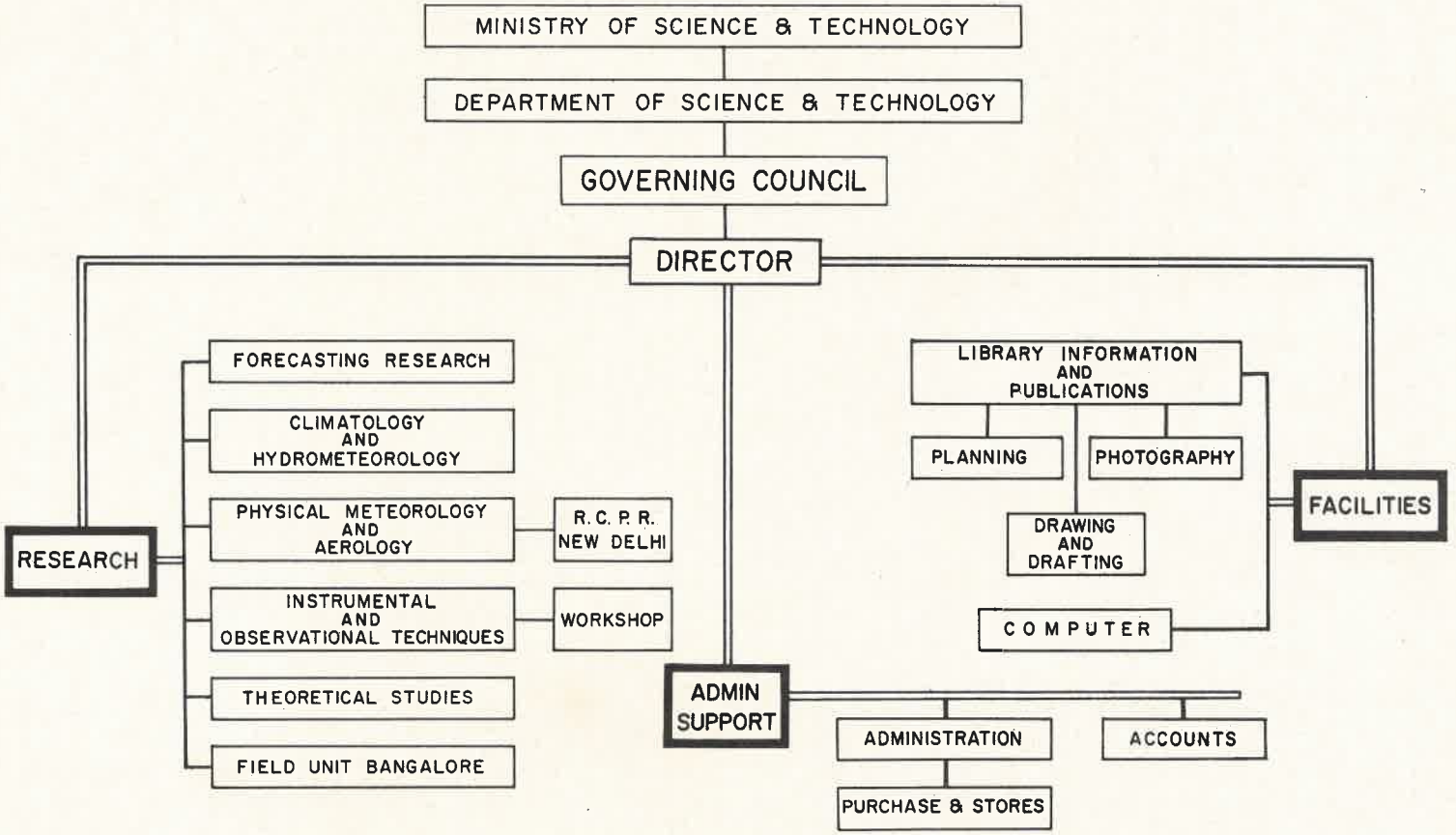

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