INDIAN INSTITUTE

OF

TROPICAL METEOROLOGY

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Contents

1 Introduction

The Indian Institute of Tropical Meteorology is a full time research organisation devoted to pursuit of basic and applied research in the field of Tropical Meteorology. Formerly a part of the India Meteorological Department under the name of Institute of Tropical Meteorology, the Institute was converted into an autonomous organisation registered under the Societies Registration Act of 1860, with effect from 1 April, 1971.

The Institute functions in five scientific Divisions each covering a broad aspect of tropical meteorology, viz. forecasting research, climatology and hydrometeorology, physical meteorology and aerology, instruments and observational techniques and theoretical studies. It also has a Division which looks after the Library, information and publication work.

Research carried out at the Institute is primarily aimed at improving our knowledge and understanding of all aspects of tropical weather. However, India being a predominantly agricultural country, questions such as those of timely forecast of monsoon rain and possible augmentation of rainfall when only a little would otherwise fall are of vital consideration. To these ends, the Institute has taken up studies of such applied problems as short and medium range weather prediction, weather modification, hydrometeorology of river basins, etc. These are problems of national importance. The advents of weather satellites and high-speed computing machines have brought about a renaissance in the field of meteorology. Research work in the Institute takes full advantage of these new facilities.

2. Activities of the Divisions

2.1 Division of Forecasting Research

The Division of Forecasting Research is responsible for development of suitable methods for short and extended range forecasting of atmospheric parameters and circulation systems. It also pursues diagnostic studies concerning various aspects of atmospheric circulation systems having bearing on weather forecasting. The following main projects were pursued by the Division during the period :

(i) Numerical Weather Prediction including objective analysis and data initialisation

(ii) Medium Range Forecasting

(iii) Monsoon Meteorology

(iv) Tropical Cyclones

(v) Synoptic Meteorology including Studies with Satellite Data

(vi) Air-sea Interaction Studies

A brief description of the work done under above projects is given below :-

2.1.1 Numerical Weather Prediction including objective analysis and data initialisation

The following aspects of the problem of numerical weather prediction were under investigation during the period.

2.1.1.1 Prognostic models

Primitive Equation Barotropic Model

A programme for primitive equation barotropic model with the manually analysed wind field as the basic input has been completed. The initial height field needed is derived by solving balance equation. Since the model is programmed for a limited area covering 40°E to 120°E and 15°N to 45°N, the problems of lateral boundary conditions were studied in detail.

The model has been tested successfully on a number of cases involving winter disturbances. The model has been found to forecast satisfactorily the movement of troughs in the westerlies upto 72 hours.

Primitive Equation Two Layer Model

A programme for forecasting the weather over the Indian region by using two layer primitive equation model is under development. The model is programmed in σ co-ordinate system and includes effect of friction as well as parameterisation of cumulus convection.

Quasi-geostrophic Four Level Baroclinic Model

A four level quasi-geostrophic baroclinic model has also been under development. Quasi-geostrophic Omega-equation is solved at 800, 600 and 400 mb levels diagnostically at the initial time and thereafter after covering succeeding time steps. The forecasts are made at 900, 700, 500 and 300 mb levels. The programme is being tested both with the observed height field and the balanced height field derived from the observed wind field as input.

2.1.1.2 Objective Analysis and Data Initialisation Studies

Fourier Analysis Technique in Objective Analysis

Two dimensional Fourier Analysis has been applied for objective analysis of wind field over the Indian region. A generalised and local point Fourier Analysis Technique as applied to meteorological data has been developed and Cressman's method of analysis has been interpretted in terms of it. A series of tests conducted with wind analysis by Fourier technique have been found to give good results over the data region but over the data poor region the analysis remains biassed towards the first guess as in the case of Cressman analysis.

2.1.1.3 Study of errors of manual and objective analysis

In order to objectively assess the subjectivity involved in mannual analysis of the wind field, an experiment was conducted in which an identical 500 mb chart was distributed to 25 experienced analysts. Grid point data were picked out from this set of 25 analyses and root-mean-square deviation of

various analyses, standard deviation of the wind at grid points as well as centres of relative vorticity were determined. It was found that the standard deviation of the manual analysis of the wind field is about 4 m.p.s. which is about the same as the root-mean-square deviation of objective analysis in comparison to manual analysis. A study of Fourier analysis of this set of different analyses is in progress.

2.1.1.4 Statistical Analysis of the Structure of Wind field over India

In order to determine the weight functions for wind analysis objectively, a study on the structure of wind field over Indian region was conducted. Following the work of Russian meteorologists, structure functions and the auto-correlation functions have been computed. It is found that the correlation functions for the wind components are not isotropic. Variation of autocorrelation function with distance is elliptical with the semi-major axis oriented towards the direction of the relevant wind component. Regression equations have been fitted to the variation of these functions with distance.

With the help of the diagnostic information derived from this study, a weighting function for analysis of wind field has been computed.

2.1.1.5 Numerical Solution of Geopotential in the Tropics

Geopotential field is required as initial input for many numerical weather prediction models. In the tropics, however, the network of wind observations is relatively much more dense than that of geopotential observations. It is, therefore, desirable to deduce the geopotential field by utilising available wind data over the tropics. With the view to determine a suitable technique for numerical solution of geopotential, different forms of balance relationships in the tropics with different boundary conditions were examined. Quasi-geostrophic approximation of balance equation has been found to give poor results. Linear balance equation has been found to give satisfactory results. Improvement shown by the non-linear balance equation and vorticity form of divergence equation is not significant. Linear balance equation with appropriate boundary conditions may therefore be regarded a satisfactory relationship for computation of geopotential field from the wind field in the tropics.

2.1.2 Medium Range Forecasting

Medium range forecasting studies made during the period have been based on synoptic climatological approach. The following studies were covered during the period.

2.1.2.1 Representation of 5-day mean 700-mb charts in terms of Orthogonal Polynomials

5-day mean 700-mb charts have so far been used for medium range prediction of rainfall both by statistical and synoptic techniques. For want of proper method for parameterisation of synoptic charts, these techniques could utilise only limited features of these charts for prediction. To overcome this, a scheme for representation of these charts in terms of a limited number of orthogonal polynomials has been developed. It has been found that in all 14 orthogonal polynomials, together representing a surface of degree 4 are sufficient for satisfactory representation of 700 mb charts over Indian region covering area 60°E to 100°E and 5°N to 35°N. These polynomials are together able to account for 90 to 95 percent of variance of height field and 80 to 85 percent of it for anomaly and trend fields. The coefficients of these polynomials which serve as numerical circulation indices have been found to be effective predictors in developing regression equations between the flow patterns and rainfall.

12 years (1958-69) charts have thus been represented and regression equations involving concurrent relationships between 5-day mean 700 mb circulation patterns and 5-day rainfall over different sub-divisions of India are being developed.

2.1.2.2 Synoptic Climatological Features of Bay of Bengal depressions relevant to Medium Range Forecasting

Based on storm and depression track data for years 1891 to 1960, some features of movement of Bay of Bengal depression relevant to medium range forecasting have been examined. For this purpose east coast of India has been divided into different zones and average time taken by the depressions in reaching any location over the country on crossing coast from various coastal zones as well as probability of such depressions has been determined. Behaviour of 10 years' independent depression data for years 1961-70 in relation to these synoptic climatological features shows that information contained in the study can be useful while preparing medium range forecasts.

2.1.3 Monsoon Meteorology

2.1.3.1 Break Monsoon over India

Interruption of monsoon rainfall by prolonged spells of sparse rainfall (break-monsoon) during the mid-monsoon months of July and August over the plains of North India (20°N to 29°N, 75°E to 85°E) has been investigated and a model for vertical circulation during break monsoon situations has been proposed.

2.1.3.2 Influence of Jet Streams on Monsoon Activity

A systematic study of various phases of the south-west monsoon has been under progress. The chief objective is to investigate the influence of upper tropospheric features, particularly the westerly and easterly jet streams in relation to the activity of the monsoon during onset, break, revival and withdrawal of the monsoon. Daily data for tropospheric wind, temperature and moisture field for several years are being studied.

2.1.4 Tropical Cyclones

Main emphasis of studies on tropical cyclones has been on the prediction of their movement and long term trends in their frequency.

2.1.4.1 Prediction of Movement of Tropical Cyclones

The problem of prediction has been studied by Dynamical, Statistical and Synoptic methods.

Dynamical Methods

Non-divergent barotropic and primitive equation barotropic models have been applied to predict movement of tropical cyclones during storm seasons of 1970 and 1971. The average vector error of 24-hr forecasts is found to be about 100 n. miles in both cases.

Primitive equation model was also used on analytical storm data and the forecasts were studied by varying the purturbation field and the basic current separately. It was found that the storm motion is dominantly controlled by the basic current. The study showed that improvement in forecast could result if the basic current in which the storm is

embedded could be determined with sufficient accuracy. As such the storm forecasts are being redone by the 'Steering current method'. In this method the basic current is obtained by Fourier analysis of wind field incorporating wave components whose wave length is larger than 4000 km. The steering current is then forecast employing the primitive equation model and the storm is steered with it.

Statistical Method

Operational forecasts during the storm season of 1971 based on persistence-climatology technique were passed on to the office of Deputy Director General of Observatories (Forecasting), Poona. Since 24-hour pressure changes are synoptically considered useful for storm forecasting work, a series of forecasts for the storms during 1965-1971 were made by objectively incorporating the pressure changes along the coastal belt of India along with persistence and climatology. It was found that the forecast improved in those cases in which the storm crossed the coast but did not show any significant difference in those cases in which the storm either moved parallel to the coast or recurved in the Bay of Bengal.

Synoptic Method

Operational forecasters generally use winds at various levels particularly 500, 300 and 200 mb as the steering current for forecasting the direction of movement of storms/depressions. But experience shows that none of the levels is uniformly useful.

On examination of the pressure-weighted mean winds of 500, 300 and 200 mb in relation to the movement of storms, it is observed that the computed mean wind field gives better estimate of the direction of the movement of storms than the wind at any of these individual levels.

2.1.4.2 Trends and Quasi-biennial oscillation in the series of cyclonic disturbances over the Indian Region

The study of seasonal and annual number of cyclonic disturbances that occurred over the area extending from latitude 5°N to 35°N and longitude 50°E to 100°E for the period of 80 years from 1891 to 1970 shows :-

(i) Significant QBO in the number of SW-monsoon cyclonic disturbances,

and (ii) Falling trend in the number of cyclonic disturbance for southwest monsoon in the present century.

2.1.5 Synoptic Meteorology including studies with Satellite data

2.1.5.1 Weather Analysis and Forecasting over Indo-Tibetan Region

In general synoptic practice the detailed topography of the Tibetan Plateau is ignored and the streamlines and contours at 500 mb are drawn which imply an organised meridional flow of air across Tibet at 500 mb. This study shows that ignoring the Tibetan barriers with elevation over 500 mb renders our analysis unrealistic in as much as the air is considered to flow through the mountain barriers. The need for recognizing the Tibetan barriers in our analysis at 500 mb and revising our current concepts on Indian weather and middle latitude circulation is explained by a series of 500 mb contour charts.

2.1.5.2 Satellite data studies

Data on the oval shaped cloud clusters that formed over the Bay of Bengal and Arabian Sea for the years 1968 and 1969 have been collected. Their size distribution, region of formation and life duration are being studied. Developing and non-developing vortices are separately studied in relation to environmental tropospheric wind field and its kinematic properties have been evaluated.

2.1.6 Air-Sea Interaction Studies

Studies on air-sea interaction covered the influence of ocean in the formation of double equatorial cloud bands in tropical oceans. Storm surges caused by wind stress induced by tropical storms in Indian region have also been studied.

2.1.6.1 Formation and Distribution of Clouds in Tropical Oceans

A study involving ocean-atmosphere interaction was undertaken with a view to understand the formation and distribution of double cloud bands, one on either side of the equator. A comprehensive analysis of the ocean surface temperatures in the major oceans of the globe was undertaken and response of the atmosphere over surfaces of widely contrasting temperatures studied. In particular, the effect of monsoon and cold ocean currents on the distribution of double cloud bands received special attention.

2.1.6.2 Numerical Model for computation of storm surge

The motion of water caused by fluctuations of atmospheric forces is governed by frictional forces arising from the sliding of layers of water on each other. The equations of motion can, therefore, be deduced from those of Navier - Stokes for turbulent incompressible fluid motion on a rotating earth, with simplifying assumptions and boundary conditions Integrating them vertically from the bottom of the seas to the sea surface a system of linear equations of volume transport and continuity are obtained. These are then approximated by a finite difference scheme which is forward in time and centred in space. The surge produced by the severe cyclonic storm of November 1952, which crossed the east coast of India at about 32 km south of the Nagapattinam was calculated. The storm centre was placed in a rectangular basin, 60 km away from the coast so that it crossed the coast about 4 hrs. after the start of the computations. Using wind stress as the forcing function, the maximum surge works out to be 1.83 metres while the reported height was 1.22 mts (4 ft.).

2.2 Division of Climatology and Hydrometeorology

2.2.1 Climatology

The following studies were undertaken under climatology :-

2.2.1.1 Physical Climatology (Mountain Wave)

The problem of 'Mountain wave' with reference to airflow in the Assam hills was studied. The solutions by analytical method were encouraging and the investigations were carried out to compute vertical velocity and displacement of stream lines for several situations in the winter season. The study is now being extended to evaluate the influence or orography on airflow in the monsoon season.

The investigations were carried out to develop a numerical scheme for the solution of the mountain wave equation. A two dimensional linear model in a baroclinic compressible atmosphere was considered. The results obtained so far demonstrate that the scheme is good enough for obstacles of small dimensions.

2.2.1.2 Climatic fluctuations in temperature and rainfall

(a) The trends in climatic elements like rainfall, temperature etc. were studied for individual stations. A study of trends in temperatures has shown that there is a general tendency in annual temperature to increase in industrial cities, like Calcutta, Bombay, Bangalore and Allahabad. The increase varies from 0.8°C to 1.5°C per century. It was also revealed that the QBO (quasi biennial oscillation) is a significant feature of many stations. Spatial and temporal variations of rainfall have shown that some of the stations have periodicity nearing 11 years. It was also observed that there is a general tendency for the increase in annual rainfall over west coast, maximum occurring over the Kathiawar coast.

(b) Surface temperature analysis

Northern Hemisphere mean surface temperatures along the latitude circles of 5° latitude from equator to 60°N have been analysed by Harmonic analysis. The amplitudes and phases of the first 15 harmonics and the variance accounted for by them are given in the analyses.

2.2.1.3 Tropical wave disturbances in the stratosphere

The daily upper wind and temperature data of three tropical stations, east of the Indian ocean region, were analysed to study the large scale wave disturbances in the troposphere and lower stratosphere. Detailed investigations were made by power spectrum analysis. The wave disturbances in the meridional wind component were identified and their association with the disturbances in temperature and zonal wind component and the variation of intensity of these disturbances with increasing latitude were studied. This study has shown that the wave disturbances which were observed over Pacific did also exist over this region.

2.2.2 Hydrometeorology

Under this project several sub-projects were studied and these are briefly described in succeeding paragraphs :-

2.2.2.1 Estimation of probable maximum rainfall (PMP) over North India

On the basis of Hershfield's latest statistical technique which was modified for appropriate use over north India,

rainfall data of about 800 long-period stations was analysed and envelope frequency factors for each Meteorological Division in north India were worked out. With the help of these envelope frequency factors, point PMP estimates for each of the 800 stations in different Meteorological Divisions were worked out and generalised PMP charts were prepared. These charts will be of practical use to design engineers in the design of hydrologic structures where no risks can be undertaken.

2.2.2.2 Estimation of maximum one-day point rainfall of low return periods from the mean annual rainfall

This study was attempted to estimate one-day rainfall of low return periods (viz. 2, 5, 10 and 25 years) from the corresponding mean annual rainfall in the plain areas of north India. Daily rainfall data of more than 830 stations having continuous data of 50 to 70 years were analysed, using the Gumbel technique. Nomograms were then prepared for the different Meteorological Sub-divisions in north India, with the help of which maximum one-day rainfall for low return periods can directly be obtained for plain areas of these sub-divisions. This study has shown that this technique can give reliable estimates of maximum point rainfall (of low return periods) for the whole north India excepting the sub-divisions of Bihar plateau, East Madhya Pradesh, and Orissa. Such studies are normally required for the design of minor hydraulic structures such as culverts, bridges and drainage works.

2.2.2.3 Spatial and sequential distribution of depression/ storms over Indian river basins

This study was carried out for the catchments in peninsular India in earlier years. During the period under review this study was extended to all the 66 river basins in India. In this study the 80-year data (i.e. from 1891 to 1970) of depressions and storms was analysed to study the following aspects of distribution :-

i) Spatial distribution of these disturbances over the Indian area, season wise and annual, using one degree lat. and long. grid squares,

ii) Basinwise distribution of these disturbances,

iii) Probability of occurrence of one or more, two or more, three or more etc. disturbances in various months for those basins which experienced 100 or more disturbances during the 80-year period,

iv) The minimum and average duration (in days) between any two successive disturbances over each of the 66 basins during different seasons, and

v) Mean track of these disturbances during the four monsoon months.

2.2.2.4 Contribution of tropical disturbances to the water resources

This study was undertaken in respect of Ganga basin in India which consists of 21 sub-basins. The amount of rainfall received by each of the sub-basins of Ganga from depressions/storms was worked out assuming that rainfall associated with depressions/storms is confined approximately to a circular area of 300 mile radius around the pressure centres of these disturbances. On the basis of this assumption average annual rainfall due to depressions/storms was worked out for the 10-year period from 1956 to 1965. This study has revealed that the average annual rainfall volume generated by these disturbances is of the order of 78 million acre-feet of water. It was also found that average annual rainfall due to these disturbances is about 8 percent of the normal annual rainfall of the entire Ganga basin.

2.2.2.5 Studies on Indian rainfall

Distribution functions for seasonal (south-west monsoon) and annual rainfall at representative stations in India were obtained. The seasonal and annual rainfall distributions were tested for normality and found to be, in general, not normal. Incomplete Gamma distribution was then fitted and goodness of fit was tested. These tests show that the seasonal and annual rainfall follows Gamma distribution.

Independence of rainfall during monsoon season at representative Indian stations over time scales of 5, 10, 15, 20 and 25 days has been investigated. The study reveals that (i) rainfall over time scales of 5 to 10 days is not pairwise independent for consecutive periods but is pairwise independent for non-consecutive periods, (ii) rainfall over time scales of 15, 20, 25 days is pairwise independent and (iii) rainfall over all the time scales considered in this study is not triplet-wise independent.

2.3 Division of Physical Meteorology and Aerology

2.3.1 Upper Atmosphere

High level warming over the tropics

A programme of studies relating to the upper atmosphere of the tropics at Thumba has shown that warmings, less pronounced than in the case of middle and high latitude stations but of noticeable magnitude, as well as coolings of similar magnitude occurred in the mesospheric and upper stratospheric levels during December 1970 to March 1971, the first winter period when observations were made at the station during all the four months. No prominent change in wind has, however, been observed in association with warmings.

2.3.2 Radiation

2.3.2.1 Radiative heating and cooling

(i) Radiative equilibrium temperature has been computed as a balance between heating due to solar radiation and cooling due to long wave (terrestrial) radiation. It has been found that water vapour alone can account for 96.7 per cent of the temperature distribution of the troposphere, whereas ozone together with carbon dioxide account for the temperature distribution of the stratosphere.

(ii) Infra-red radiative fluxes and cooling rates obtained from radiometer soundings have been compared with the results of computations using numerical methods. Good agreement has been noticed between the observed and computed values of the upward flux. The differences between the observed and computed values of the cooling rate are small in the troposphere but large in the stratosphere.

2.3.2.2 Cloud destabilization

Destabilization of cloud due to long-wave radiation is computed as the difference in the radiative cooling rates across the cloud layer.

It is found that for a given cloud layer, destabilization is less in low clouds than in middle or high clouds. The presence of inversion in lower layers is equivalent to the presence of cloud layer and is associated with weak destabilization.

2.3.3 Atmospheric Optics

2.3.3.1 A new method of measurement of total precipitable water

A portable Sun photometer was constructed to measure the intensities of direct solar radiation in two narrow wavelength bands centred at .9462 and 1.0604 microns simultaneously. The ratio of the intensities becomes a direct measure of the total water vapour in the path of the solar beam. By the application of a square root law for water vapour absorption and by making the best fit with precipitable water calculated from some selected radiosonde data, a technique of rapidly transforming the measured intensities into precipitable water has been developed. The low values of 0.7 to 1.0 cm of water were measured at Poona during January 1972 and high values ranging from 5 to 7 cms, at Delhi during June 1971, these agreeing well with those expected from radiosonde data

2.3.3.2 Spectral measurements of turbidity

The programme of optical investigations of atmospheric aerosols was expanded by the construction of two more photoelectric photometers for the measurements of extinction coefficients in the near infra-red region. The results of simultaneous measurements of extinction coefficients made for 0.4, 0.5, 0.6, 1.06 and 1.63 micron wavelength at Poona during the year have shown that the numerical values of the wavelength exponent for aerosol scattering is less in the infra-red than in the visible region under a variety of atmospheric conditions. Measurements were also made at Delhi and Jodhpur over a two-week period in summer under conditions of high turbidity. These revealed nearly neutral aerosol scattering with wavelength exponent less than 0.3.

2.3.3.3 Studies on skylight distribution

A simple sky photometer capable of measuring the distribution of skylight around the sun at a wavelength of 0.5 micron was designed and constructed. Measurements were made at Poona, Mahabaleshwar, Delhi and Jodhpur on some cloud-free days. The rate of decrease of skylight intensity with angular distance from the sun was found to be appreciably steeper at all the Indian stations than what has been reported in literature for middle and high latitudes. This finding again gives confirmation to the fact that the aerosol size distribution exponent is appreciably smaller in the tropical atmosphere.

2.3.4 Cloud Physics

2.3.4.1 A New Effect of Evaporation on the Freezing of Supercooled Water Drops

Using a simple drop freezing technique, experiments have been conducted on the ice nucleation in supercooled rain water drops under conditions nearly similar to those prevailing in clouds. The results of the experiments indicated that the rain drops freeze more readily under the conditions of simultaneous supercooling and evaporation than under supercooling alone, despite the fact that there was no noticeable difference in the drop temperatures in the two cases. This new effect, reported for the first time, has been called 'Dynamic Effect' of evaporation, and will enable to explain the anomaly reported by other investigators between the ice crystal and ice nucleus concentrations in cumulus clouds.

2.3.4.2 Anomaly of Ice Crystal Concentrations in Clouds

It was generally accepted until recently that each ice crystal in a cloud originates initially on an individual ice nucleus. But, actual field observations made by several investigators have indicated that this is not generally the case. The concentration of ice crystals was found to be greater by about 4 orders of magnitude than that of ice nuclei in some clouds, this anomaly being more marked at warmer temperatures. In an attempt to examine the probable causes for the reported anomaly, laboratory experiments on freezing of rain water drops have been conducted under various conditions of temperatures, and with different solutes. Certain soluble salts like sulphates were found to accelerate remarkably the process of freezing of the drops. This process was found to be more effective at warmer temperatures. Based on certain considerations, the features observed in the laboratory experiments have been interpreted to account for at least part of the anomalous ice crystal concentrations reported in the clouds.

2.3.4.3 Nucleation Studies

(i) Ice nucleation efficiencies of silver iodide and silver iodide systems have been studied with the without soluble salts using drop freezing technique devised for the purpose. The results of the study have brought out that the silver iodide as well as the silver iodide systems nucleate ice phase at warmer temperatures in the presence of soluble salts, like sulphates. The study has also pointed out that the silver iodide system

containing NH_4I is the most active and AgI.KI system is the least active of the three systems studied, namely AgI.NH_4I, AgI.NaI and AgI.KI. A suggestion for producing potential ice nucleant mixes for cloud seeding consisting of iodide systems and soluble salts has been made.

(ii) Portland cement was studied for its ice nucleation ability by the freezing behaviour exhibited of drops produced from aqueous suspension of Portland cement vis-avis of drops produced from suspension of AgI, 2 AgI. NaI and Pb I_2. It is revealing to note that, at temperatures colder than $-5^{\circ}C$, Portland cement is as potent an ice nucleant as either 2 AgI.NaI or PbI_2 which are commonly used in cloud seeding. At temperatures approaching $-5^{\circ}C$ Portland cement alone is effective as ice nucleant but not the latter two. However as compared to AgI, its effect is small at all temperatures considered. The study pointed out that Portland cement has got potential applications in cloud seeding.

2.3.5 Air and precipitation chemistry

Chemical analysis on the concentration of trace gases in the atmosphere such as sulphur dioxide, nitrogen dioxide and total oxidants have been continued at Poona. The chemical composition of rain water samples collected at Poona upto the year 1971 have been analysed. Total concentrations of chloride and ammonia present in gaseous and particulate form have also been measured in the surface air layers at Poona. Analysis of the above data is in progress.

2.3.6 Atmospheric electricity

2.3.6.1 Fabrication of equipment

Portable electronic gadgets using operational amplifiers were constructed and put into operation for the continuous recording of atmospheric potential gradient and point discharge current. Records were obtained during interesting weather situations during the monsoon and winter seasons at Khandala (Lat. 18°, 46', Long. 73°, 22'E, 539 m.A.M.S.L.) and Mahabaleswar (Lat. 17° 56'N, Long. 73° 40'E, 1382 m A.M.S.L.). Analysis of the data is in progress. Work relating to continuous recording of the other parameters is also in progress.

An apparatus was fabricated for the continuous measurement of electric charge on rain drops. The equipment was tested

for its satisfactory working and records were obtained under different weather situations at Poona, Khandala and Mahabaleshwar. Analysis of the data is in progress.

2.3.6.2 Potential gradient in relation to weather

The records of the potential gradient obtained at Poona have been examined in relation to minimum temperature departure from the normal and the wind circulation at 1.5 km. The study has indicated that the variations in the pattern of the potential gradient could be related to the characteristics of the air mass over the region.

2.3.7 Air Pollution

2.3.7.1 Effect of steel mill effluents on rainfall

A study has been undertaken for examining the possible effects of the effluents on rainfall. Rainfall data of a number of stations around the steel industrial complex in the Bihar region of India, for the two representative months of February and August, have been analysed. The analysis showed an appreciable decrease in rainfall, statistically significant, in case of February rainfall. In case of the August rainfall, however, a smaller and statistically not significant decrease was noticed.

2.3.7.2 Urbanisation and rainfall

With a view to examine the possible effects of urbanisation on local weather, a preliminary study on rainfall variations in an urban industrial region (i.e. Bombay) has been made. The rainfall data for the period 1901-69, of three stations in the region downwind of the urban industrial complex at Bombay and of two stations in the nearby non-urban region have been analysed. The study has indicated that during 1941-69 which is period of increased industrialisation the region downwind of the urban industrial complex recorded an increase of rainfall of about 15 percent with respect to the non-urban region. This increase is statistically significant at less than 1 percent level.

2.3.8 Boundary layer studies

2.3.8.1 Numerical simulation

1. A Numerical model simulating the fluxes of momentum, heat and water vapour in the planetary boundary layer taking into

consideration the diurnal variation of radiative heating and also the moisture in the underlying surface is being developed.

2. In addition to the numerical solutions, a study of the analytical solution for the equations of motions applicable to the boundary layer is being pursued with a view to bringing out the diurnal variation of wind profile in the boundary layer and effect of Coriolis force on this variation.

2.3.8.2 Case study of a buoyant plume

The size and height of rise of the buoyant plumes associated with an accidental explosion which took place at Poona in 1971 were estimated making use of the photographs of the plumes. These estimates compared favourably with theoretical calculations based upon the estimates of lapse rate of the atmosphere and the amount of the explosives involved.

2.3.9 Weather Modification

2.3.9.1 Cloud seeding experiment in Delhi region

Cloud seeding experiment using ground based Silver Iodide generator was conducted during December 1971 to March 1972 at Delhi for the fourth successive winter. Of the 22 favourable days obtained during the period, the seeding experiment was done only on 11 days. While the remaining 11 days were kept as control for evaluation of seeding results. Preliminary analysis of the data shows a tendency for increase in rainfall on seeded days.

2.3.9.2 Establishment of new cloud seeding centres

Schemes for establishing two centres for conducting cloud seeding experiments, one near Madras and the other near Poona have been sanctioned by Government. The scheme at Madras provides for seeding of warm clouds from ground-based generators, while the one near Poona envisages similar seeding from aircraft. A small nucleus of staff has been posted at Tiruvallur near Madras. Efforts are being made to secure suitable aircraft facility for conducting seeding operations near Poona. Plans for establishing suitable network of raingauges stations at each of the two centres are in progress in cooperation with India Meteorological Department.

2.3.10 Monsoon studies

2.3.10.1 Estimates of vertical velocities by numerical and analytical methods - a comparison

A comparative study of vertical velocity associated with monsoon depression computed by using a simplified form of ω equation and the more complete geostrophic ω equation has shown that the use of the simplified ω equation will suffice for diagnostic purposes, commensurate with the errors in observation, analysis and numerical methods of computation.

Further, the values of vertical velocity computed using simplified ω equation were checked against estimates derived from Kuo's analytical expression for ω . This study has also indicated that Kuo's theory can be extended to discuss the stability properties and structure of monsoon depressions.

2.3.10.2 Energetics of Monsoon depression

In connection with the study of energy aspects of a monsoon depression from the time of formation to its decay, the various parameters like the vertical velocity, the baroclinicity the generation and conversion of potential and kinetic energies were evaluated for a life cycle of a deep depression in 1969 and the results are under study.

2.3.10.3 Release of latent heat

In this study, vertical velocity was computed by using the vorticity equation for geostrophic motion, the thermodynamic energy equation and the equation of continuity for moisture and thereby incorporating the effect of release of latent heat of condensation. The results are being studied.

2.3.10.4 Simulation of Indian Monsoon

Studies on the simulation of Indian summer monsoon by numerical methods suggest that the existence of strong ocean-continent temperature contrast in the upper troposphere is very essential for the development and maintenance of the monsoon circulation and that such strong temperature contrast is afforded only by presence of the Himalayas. The study has also revealed that the presence of moisture is not the important factor in controlling the monsoon circulation although it is essential for the occurence of rainfall.

2.4 Division of Instruments and Observational Techniques

A brief summary of work carried out in the division with limited staff is given below :-

2.4.1 Development of Meteorological Payload for Rocket

The aim and object of this project is to develop a meteorological payload to be carried aloft by a small and inexpensive rocket to furnish information on wind and temperature over the tropical region of this subcontinent in the altitude range of 30 to 70 kms. Frequent soundings with the rocket borne instruments would enable one to study the changes in the upper air circulation over India accompanying Asian monsoon, the quasi biennial oscillation which profoundly influence the tropical circulation pattern and the phenomena of stratospheric warming, and inter-level relationship and the manner in which it affects the tropical weather.

2.4.1 Laboratory work

Environmental testing

Prior to putting on the rocket, all environmental tests were carried out on the package developed earlier. The shock and vibration tests were carried out at the Defence Laboratories at Bangalore as they have very sophisticated equipment for these tests. Other tests like high heat and sustained acceleration were completed in the Institute itself.

Improvements

Several improvements were carried out in the existing package. These include design of a low dissipation oscillator to avoid self-heating of thermistor; compensation for drift of temperature and adoption of an indigenous variety potting compound developed by and received from the defence laboratories, New Delhi.

Test equipment

Many of the equipment required for testing and checking the performance of the package were not available and had to be specially developed and fabricated in the workshop. A power measuring device employing 'Littlefuse' as bolometer element was designed and fabricated after experimentation on several different types of models. A cavity type frequency meter and a test receiver for 1680 mhz and two battery tests were also constructed and are in regular use.

Investigation

Many investigations were carried out on the package specially on the thermistor temperature sensor. Its stability was checked by subjecting several pieces to repeated calibrations spread over long period. The steady state dissipation constants and other physical characteristics like mass, projected surface of the thermistors were determined experimentally. The solar radiation and infrared emissivities of titanium paint used for coating the thermistor were found out.

A special apparatus was designed to measure automatically the time constant of the thermistors employing a fast recorder.

Several methods for obtaining temperature resistance relationship of the thermistors from two fixed point measurements were tried. The method of evaluation of temperature from two frequency readings from the recorder were also critically examined.

The problem of replacing the heavy pack with an electronic inverter type power supply using low tension battery was explored.

The work on determination of corrections to be applied for various effects to the temperature reading from theoretical considerations is being continued.

2.4.1.2 Simulated testing

Six packages were tested for simulated launching by putting them in a nosecone which was carried aloft by large size balloons. The packages along with parachute were ejected as in an actual rocket flight. The performance of the package and the parachute were found to be satisfactory. Some improvements and modifications were made in the package in the light of experience gained from these trials. These tests were carried out at Thumba.

Parachute

Several types of parachutes were made and tested during simulated launching. These comprise silk and metallised polyester type and pure silk. The radar reflectivity was checked on Cotal radar for maximum range to be expected in actual rocket launching.

The winds obtained from parachutes were compared with winds obtained from the rising balloon.

2.4.1.3 Results achieved

The package developed withstood all ground environmental tests and also ejection tests in simulated launching trials.

The signal strength from the transmitter was found to be adequate and record was obtained for more than 80 minutes on many occasions.

The return echo from parachute was of sufficient intensity for the radar to track it successfully. The observed fall velocity agreed fairly well with predicted value. The winds from parachute compared favourably with the winds obtained by normal rawin or pilot balloon method.

The payload has reached a stage when further work of perfecting it was be possible only when a proper rocket carrier vehicle is made available.

2.4.2 Micrometeorological Data Acquisition System

Design and development work on a micrometeorological data acquisition system, in which outputs from sensors are converted into digital form and then printed on paper charts or stored in magnetic tapes was continued. A data acquisition system normally consists of a large number of printed circuit cards employing solid state devices for carrying out different functions. In a ten channel system the total number of cards would approximately amount to 300. These are progressively made, wired, tested and assembled into the complete system. Last year, about 100 such cards were constructed and 100 more cards have been made this year leaving a balance of 100 more cards to be made for completing the system.

2.4.2.1 Design and Construction

The following new circuits were designed and contructed

i) BCD scaler employing integrated circuits now available indigenously. This results in saving of space.

ii) Cards to function as multiplier units.

iii) Analogue to digital converter units.

iv) Cards for multiplex operation.

After finalisation of design, one hundred new cards were made in the laboratory and their functioning checked thoroughly in the operation mode of the system.

2.4.2.2 Results achieved

One channel out of ten so far assembled was completed and tested rigorously with Beckman anemometer data as input. The system was found to work satisfactorily.

2.4.3 Micrometeorological Instrumentation and Observations

Several new instruments for micrometeorological observational work were designed and constructed. These include, a three channel temperature recorder employing thermistor type temperature sensor for the range 0 to 50°C, which can record temperature with an accuracy of 0.01°C, a four channel wet bulb temperature recorder similar to above and two vertical wind instruments employing light weight spherical sensor. Prototype model of a sensitive anemometer employing new principle of magnetic chopping along with a linear and stable frequency meter was designed. Fabrication of six such anemometers was taken up.

2.4.3.2 UNDP Equipment

All the equipment received under UNDP programme earlier was tested and put into commission except the temperature recorder which was found to be sluggish in response for micrometeorology work.

2.4.3.3 Collaboration

A programme of work was drawn up in collaboration with National Institute of Oceanography, Panaji, Goa for studies in air-sea interaction. A site has been selected in Goa for field observations.

2.4.3.4. Field observations relating to boundary layer

Due to the undulating or hilly nature of the terrain at Poona, a temporary site near Alibag about 90 km. from Poona was selected for undertaking boundary layer observations. The mobile van of the Institute would be utilised for the purpose.

A portable collapsible aluminimum tower 40 ft. high was designed for these field studies. The work would commence after the monsoon rains during 1972.

2.5 Division of Theoretical Studies

2.5.1 Oscillation of Tropical atmosphere

Work was continued on oscillations of the tropical atmosphere. A period of oscillation of about one month was found in the monsoon wind field. The horizontal and vertical structure of the wind field was investigated.

2.5.2 Structure and Energetics of monsoon circulation

Research work was undertaken on the energy conversions in the mean monsoon circulation. It was found that there is large conversion from zonal available potential energy into zonal kinetic energy in the direct mean meridional cell. The circulation in the zonal plane appears to be indirect. The energy conversion between mean and transient motion is small.

Detailed studies on the structure and energetics of monsoon disturbances were completed, utilising the techniques of power-spectrum and cross-spectrum analysis.

Fluctuations in monsoon activity, like breaks, were also studied.

Fitting of analytical functions to the monsoon zonal current was also undertaken.

2.5.3 Pure Rotational Waves versus Rossby Waves

In a non-divergent barotropic fluid, the field quantity 'absolute vorticity' remains constant along the path of a moving parcel. The wave-velocity c is then given by the

well-known Rossby formula

$$U - c = \frac{\beta L_S^2}{4\pi^2}$$

where U is the zonal velocity and Ls is the wave-length of streamlines. It is now shown that there is another class of pure rotational waves in which the individual parcel parameter 'absolute spin' is conserved along the path of a moving parcel. In equatorial regions, such waves move with velocity 'c' given by

$$U - c' = \frac{\beta L_S L_T}{4\pi^2}$$

where Ls is the wave length of stream-lines as before and is the wave-length of trajectory. Constant Absolute Velocity (C.A.V.) trajectory is quite distinct from Constant Absolute Spin (C.A.S.) trajectory except when the wave is stationary. In meteorological literature, C.A.V. trajectory has come to be associated with stationary waves because clear distinction was not made between C.A.V. and C.A.S. trajectories.

From this analysis, it is also inferred that as a class Rossby wave lie between pure rotational and pure gravity waves. For a wide range of wave-length, Rossby waves lie closer to rotational waves than to gravity waves, but at some wave-length, the two waves look very much alike and one can then hardly distinguish between Rossby waves and gravity waves.

2.5.4 Influence functions for Indian area

For a quasi-geostrophic model with Indian conditions, analytical influence functions have been derived for pressure tendency and vertical motion. The influence of diabatic heating and frictional forcings having a meridional and seasonal oscillation has been studied in some detail. The analysis helps in the quantitative understanding of some of the main features of monsoonal circulation over the Indian region, viz. the creation of lows and highs, the easterly jet stream and the direct meridional circulation.

One by-product of this study is that for the same amplitude of a forcing wave, the influence penetrates deeper for those waves for which the horizontal wave-length is larger.

2.6 Library, Information and Publication

2.6.1 Routine activities

The Division continued to do the work of documentation, supply of scientific information, publication of research reports, maintenance of Library and meteorological data, acquiring special data required by Institute scientists. During the year under review, it added 128 books to the library, subscribed to 42 journals and brought out 6 research reports.

2.6.2 Research work

The scientist-in-charge of the Division pursued studies on Climatology of and suitable probability model (for computing probabilities) for monthly rainfall over southeast Asia during summer monsoon season, and on Indian monsoon depressions and associated 24-hour rainfall, and concurrent association between 5-day rainfall during July and 700-mb 5-day mean contour patterns, in addition to his routine duties.

3.1 Papers published in Journals.

Sr. No.	Title of the paper	Author(s)	Journal in which published
1.	Estimating return period of intense rainfall using Alexander's method	O.N.Dhar P.P. Kamte	Ind.J.Met.Geophys., Vol.22, No.1, 1971.
2.	Influence of various physical factors upon the radiative equilibrium of the atmosphere	R.V. Godbole R.R.Kelkar	Ind.J.Met.Geophys., Vol.22, No.2, 1971.
3.	Downward transport of ice-forming aerosol from the stratosphere	P.Satyamurty Bh.V.Ramana-murthy	Ibid.
4.	A Vertical wind measuring instrument	K.G. Vernekar	Ibid.
5.	Evaluation of the use of satellite-photography in determining the location and intensity changes of tropical cyclones in the Arabian Sea and the Bay of Bengal	D.R. Sikka	Ind.J.Met.Geophys., Vol.22, No.3, 1971.
6.	Development of tropical cyclones in the Indian seas as revealed by satellite radiation and television data	D.R. Sikka	Ibid
7.	Seasonal changes in satellite-observed cloudiness and radiometric measurements in the tropical belt of Africa and Asia	D.R. Sikka	Ibid

Sr, No.	Title of the paper	Author(s)	Journal in which published
8.	A study of 6-day mean satellite-derived brightness patterns in relation to upper air circulation features during the 1967 southwest monsoon season.	H.S. Bedi D.R. Sikka	Ind.J.Met.Geophys., Vol.22, No.3, 1971.
9.	Cloud distribution over equatorial Indian ocean as revealed by satellite	K.R. Saha	Ibid.
10.	Mountain waves over northeast India and the neighbouring regions	U.S. De	Ibid.
11.	Estimation of extreme rainfall over North India	O.N. Dhar P.P. Kamte	Ind.J.Met.Geophys., Vol.22, No.4, 1971.
12.	Harmonic Analysis of the mean surface temperature of Northern Hemisphere	G.Appa Rao V.B. Rao	Ibid.
13.	Fluctuations in the seasonal oscillations of temperature in India	P.Jagannathan B.Parthasarathy	Ind.J.Met.Geophys., Vol.23, No.1, 1972.
14.	Concurrent Association between 700-mb 5-day contour patterns and 5-day rainfall anomoly over India during July	D.A. Mooley J. Shukla	Ibid.
15.	Independance of rainfall over Indian subcontinent over time scales of less than a month	D.A. Mooley G.Appa Rao	Ibid.

Sr. No.	Title of the paper	Author(s)	Journal in which published
16.	Estimation of maximum one-day point rainfall of low return periods from mean annual rainfall	O.N.Dhar A.K.Kulkarni	Meteorological Monograph.Hydrology No.1, 1971.
17.	Tornadoes in India	K.R. Saha	Vayu Mandal, Vol.1, No.2, 1971.
18.	A review of Hydro-meteorological activities in India in recent years	O.N. Dhar	Vayu Mandal, Vol.1, No.3, 1971.
19.	Preliminary study of maximum one-day rainfall of different return periods over north Indian plains	O.N.Dhar A.K.Kulkarni Miss N.G. Potnis	Proceedings of the symposium on 'Water Resources' held under the auspices of Indian Institute of Science, Bangalore, May 1971.
20.	A preliminary study of space-time distribution of depression/storm rainfall along coastal Orissa	O.N. Dhar P.R. Mhaiskar	Ibid.
21.	Spatial and sequential distribution of depressions/storms over peninsular India	O.N. Dhar G.C. Ghosh	Ibid.
22.	A study of maximum one-hour rainfall at some selected stations in south India	O.N.Dhar A.K.Kulkarni	Ibid.
23.	Estimation of probable maximum precipitation over the coastal states of Gujarat and Orissa	O.N.Dhar P.P. Kamte Miss N.G. Potnis	Ibid.
24.	An Objective approach to forecasting of 5-day total rainfall of stations in peninsular India	H.N. Bhalme	Ibid.

Sr. No.	Title of the paper	Author(s)	Journal in which Published
25.	A 1680 hz test receiver	K.G.Vernekar L.K.Sadani	J.Inst.Telecom. Engineers, Vol.17, No.9, 1971.
26.	Freezing characteristics of rain water drops at warmer temperatures	A.S.Ramachandra murthy, Bh.V. Ramanamurthy	Proceedings International Weather modification conference, Canberra, 6-11, Sept. 1971.
27.	Reply to comment on paper - On instantaneous distribution of vertical velocity in monsoon circulation	K. R. Saha	Tellus, Vol.23, No.3, 1971.
28.	Wavelength exponent for haze scattering in the tropics as determined by photoelectric photometers	S.Ranagarajan	Tellus, Vol.24,No.1, 1972.
29.	Freezing characteristics of rain water drops with different solutes and their implications on anomalous ice crystal concentration in clouds	A.S.Ramachandra murthy, Bh.V. Ramanamurthy	Tellus, Vol.24, No.2, 1972.
30.	Numerical solution of geopotential with different forms of balance relationship in the tropics	K.R. Saha R.Suryanarayana	J.Met.Soc. of Japan, Vol.49, No.6, 1971.
31.	On weather analysis and forecasting over the Indo-Tibetan Region	K. Raghavan	J.Appl.Met., Vol.11, No.1, 1972.
32.	Application of a primitive equation barotropic model to predict movement of "Western disturbances"	Y.Ramanathan K.R. Saha	J.Appl.Met., Vol.II, No.2, 1972.

Sr. No.	Title of the paper	Author(s)	Journal in which published
33.	Independance of monthly and bi-monthly rainfall over South-east Asia during summer monsoon season	D.A. Mooley	Mon. Wea. Review, Vol.99, No.6, 1971.
34.	Distribution function for seasonal and annual rainfall over India	D.A. Mooley G.Appa Rao	Mon. Wea. Review, Vol.99, No.10, 1971.
35.	Vertical coupling in the Indian summer monsoon	R.N.Keshava-murthy	Nature, Vol.231,No.4, 1971.

3.2 Pre-published research reports

1. "Energetic consistency of truncated model", RR-001.

2. "A note on the turbulent fluxes of heat and moisture in the boundary layer over the Arabian sea", RR-002.

3. "Orthogonal fields of temperature variation over peninsular India" - SR 151.

4. "Simulation of the spectral characteristics of the lower atmosphere by a simple electrical model and using it for prediction", RR-003.

5. "A study of potential evapo-transpiration over Andhra Pradesh", RR-004.

6. "Climatic cycles in India : I. Rainfall", RR-005.

4. Participation in Seminars/Symposia/Meetings and contribution of papers.

4.1 Seminars/symposia/meetings	Names of the persons who attended
i. Water Resources symposium, Bangalore, May 1971.	Shri O.N. Dhar, Shri H.N. Bhalme, Shri P.P. Kamte
ii. Meeting of a study group in Meteorology, Physical Research Laboratory, Ahmadabad, November, 1971.	Dr. Bh.V.Ramanamurthy
iii. Second meeting of a study group in Meteorology, Physical Research Laboratory, Ahmadabad, January, 1972.	Dr. Bh.V.Ramanamurthy
iv. Human Environment with special reference to pollution of atmosphere, land and water, Andhra University, Waltair, January, 1972.	Dr. S.Rangarajan, Shri R.Suryanarayana, Shri L.T. Khemani
v. 59th Session of the Indian Science Congress, Calcutta, February, 1972.	Dr. K. R. Saha
vi. The role of refrigeration and air-conditioning in National Development. Central Mechanical Engineering Research Institute, Durgapur, February, 1972.	Shri B.Parthasarathy
vii. Meeting of computer society of India, Bombay, March, 1972.	Shri R.Suryanarayana
viii. Meteorological aspects of air pollution, Poona, March, 1972.	Dr. S. Rangarajan, Shri R.N.Keshavamurthy, Shri D.R. Sikka, Shri Y.Ramanathan, Shri L.T.Khemani
ix. 7th conferences of Forecasting Officers, Poona, March, 1972.	Shri D.R. Sikka, Shri H.S. Bedi
x. Meeting of the coordination Committee for Voluntary Assistance Programme, Assistance to India, New Delhi, March, 1972.	Shri R.Suryanarayana

4.2 Papers contributed to Seminars/Symposia/Meetings

(A) Water Resources Symposium, Bangalore, May 1971 :-

i. A study of maximum 1-hour rainfall at some selected stations in south India,

ii. An objective approach to forecasting of 5-day rainfall of stations in peninsular India,

iii. A preliminary study of maximum one-day rainfall of different return periods over north Indian plains,

iv. A preliminary study of space-time distributions of depression/storm rainfall along coastal Orissa,

v. Spatial and sequential distribution of depressions/storms over peninsular India,

vi. Estimation of probable maximum precipitation over the coastal states of Gujarat and Orissa.

(B) International weather modification conference, Canberra, Australia, 6-15 September 1971 :-

Freezing of rain water drops at warmer temperatures.

(C) Symposium on "Integrated development of surface and sub-surface water resources", New Delhi, Nov. 1971 :-

i. Probable maximum precipitation over the Brahmaputra basin in Assam,

ii. Estimation of maximum one-day point rainfall of low return periods from the mean annual rainfall over northwest India,

iii. A study of distribution of storms and depressions over major river basins in India during the period 1891 to 1970.

(D) 7th Technical Conference on Hurricanes and Tropical Meteorology, Barbados, December 1971 :-

i. Power spectrum of large scale disturbances of the Indian summer monsoon,

ii. Applicability of Quasi-geostrophic model in the tropics.

(E) Symposium on "Human environment with special reference to pollution of atmosphere, land and water", Andhra University, Waltair, January 1972 :-

i. Rainfall variations in an industrially polluted urban region.

ii. Size distribution of natural aerosols in India as deduced from optical measurements,

iii. Meteorological factors in relation to air pollution potential at some major cities of India.

(F) Symposium on "The role of refrigeration and air-conditioning in the National Development", Durgapur, February 1972 :-

Role of temperature and humidity in air-conditioning in India.

(G) Scientific sessions of the "Seventh Conference of Forecasting Officers," Poona, 25th to 30th March, 1972 :

i. A fine-mesh limited-area primitive equation barotropic model to predict the movement of tropical storms,

ii. Numerical prediction of the movement of tropical storms in the Indian seas by non divergent barotropic model,

iii. Variations in monsoon circulation index in relation to formation and intensification of monsoon depressions,

iv. An objective method of storm forecasting, using synoptic climatological factors,

v. Relation between upper tropospheric wind field and storm movement,

vi. On the distribution of vertical velocity and diabatic heating in the field of a tropical disturbance,

vii. Trends and periodicities in cyclonic disturbances in the Indian region,

viii. Areal distribution of rainfall associated with tropical disturbances on the day of crossing the east coast,

ix. Space time distribution of tropical disturbances over major Indian river basins,

x. Contribution of depressions/storms to the mean annual rainfall of Ganga basin,

xi. Rainfall associated with Indian monsoon depressions.

5. Collaboration with Universities

5.1 Grant of Recognition

(i) One more university, viz., Agra University, recognised the Institute as a centre for research leading to Ph.D. degree, with effect from 12 April 1971.

(ii) The Institute has been recognised as a constituent body of the Poona University with effect from 17.8.1971.

5.2 Scientists of the Institute who have been awarded Ph.D. Degree

(i) Shri R.R.Kelkar, SSA, by Poona University, for his thesis entitled "Role of Radiation in Atmospheric Circulation".

(ii) Shri J.Shukla, JSO, by Banaras Hindu University, for his thesis entitled "Some studies in Numerical Weather Prediction".

5.3 Shri R. Suryanarayana, Senior Scientific Officer, Grade delivered 14 lectures on "Computer Programming and Computer Applications to Meteorology and related numerical analysis" at Andhra University and one lecture on "Computers and their role in science" to participants of the Poona University Summer school in science, on invitation from the Universities.

6. Facilities for research extended to other organisations

6.1 Scientists sponsored by CSIR

(i) Dr. (Mrs) S.M.Gadgil joined the Institute as CSIR Pool Officer on 1.9.1971.

(ii) Shri Murari Lal of Banaras Hindu University joined the Institute as Junior Research Fellow of CSIR on 1.11.1971 and he is working as Senior Research Fellow with effect from 7.1.1972.

6.2 Research Scholars Sponsored by Air India

S/Shri S.Sinha and B.M.Mishra worked as Air India Research Scholars during the year.

7. Visitors

7.1 Scientists

(i) Dr. Thomas Maddock (Jr.) and Prof. Robert Lee Smith, U.S.A., September 1971.

(ii) Prof. A.R. Robinson, Gordon McKay Professor of Geophysical Fluid Dynamics, Harvard University, January, 1972.

(iii) Miss B.Nemeova, State Research Institute for Material Protection, Prague, Czechoslovakia, February, 1972.

(iv) Dr. R.N. Sachdev of Bhabha Atomic Research Centre, Bombay, March, 1972.

7.2 Government of India Officials

(i) Honorable Dr. Karan Singh, Union Minister, Ministry of Tourism and Civil Aviation, New Delhi, 26 August, 1971.

(ii) Honorable Dr. Sarojini Mahishi, Minister of State, Ministry of Tourism and Civil Aviation, New Delhi, 27 August, 1971.

(iii) Shri B.S. Apte, Director, Agricultural Refinance Corporation, Reserve Bank of India, Bombay, 29 January, 1972.

(iv) Shri S.M. Misra and M.L. Gupta, Officers from the Directorate of Agriculture, Punjab, Chandigarh, 28 January, 1972.

8. General

8.1 Management of the Institute

The management of the Institute is vested in a Governing Council consisting of nine members including the Director of the Institute. List of members as on 31.3.1972 is given in appendix I. Council held three meetings during the year, the first on 17-18 June 1971, the second on 14-15 October 1971 and the third on 10-11 February 1972. Among the important matters dealt with were the following :

Appointment of Director , finalisation and approval of draft bye-laws, approval of rules for recruitment and promotion of staff, reorganisation of the activities of the Institute, approval of budget, appointment of an auditor, approval of plan of Institute buildings and residential quarters and approval for acquisition of a high speed third generation computer for the Institute, etc.

8.2 Budget and Accounts

The grant-in-aid received from the Government and the expenditure incurred under Plan and non-plan during the year 1971-72 are as shown in the Table below :

	Grant-in-aid	Expenditure
Plan	Rs. 34,000	Rs. 1,007.85
Non-plan	Rs. 20,93,500	Rs. 20,05,642.22

The Governing Council appointed Messrs P.C.Parmar & Co., 887, Bootee Street, Poona-1 as the chartered accountants to audit the accounts of the Institute for 1971-72.

8.3 Important Staff Changes

(i) Dr. R.Ananthakrishnan, Director, retired from service with effect from 8 April, 1971.

(ii) Shri C.M.Dixit and Dr. R.P.Sarker, Senior Scientific Officers Grade I, were permitted by Government to accept fellowships offered to them by COMISSAO NACIONAL DE ATIVIDADES ESPACIAIS (C.N.A.E.), Brazil. They proceeded on extra-ordinary leave for one year with effect from 21 May, 1971 and 16 May, 1971 respectively.

(iii) Dr. J.Shukla, Junior Scientific Officer, resigned from the service of the Institute with effect from 3 August, 1971 to pursue higher studies in U.S.A.

(iv) Shri K.K.Kapoor, Junior Scientific Officer, joined the Institute on 1st July 1971.

8.4 Awards to Institute Scientists

(i) The fifth Indian Journal of Meteorology and Geophysics Award for the outstanding scientific paper published in the journal during 1968-69 was won jointly by Shri R.V.Godbole, Senior Scientific Officer and Shri R.R.Kelkar, Senior Scientific Assistant of the Institute for their paper entitled "Net terrestrial radiation over India during monsoon". The paper was published in the I.J.M.G., Vol.20, No.1, 1969.

(ii) Shri R.N.Keshavamurthy, Senior Scientific Officer, won the first Desai Award for his paper entitled "Maintenance of mean zonal motion in the Indian Summer monsoon", published in Monthly Weather Review, Vol.96, No.1, 1968, U.S.A.

8.5 Computer

The Institute computer (IBM-1620) worked during the year in two shifts per day and 7 days a week. The number of hours worked during the year was as follows:

Investigation and Research	:	2011 hours
Data processing ...	:	1666 hours
Break-down/Maintenance	:	700 hours
Total		4377 hours

One IBM-029/C-22 (Interpreting Card Punch) machine was purchased during the year.

8.6 Institute Buildings

The Governing Council of the Institute approved provision of floor space of about 70,000 square feet in the first phase of construction of the proposed new building of the Institute at Pashan, Poona. The Senior Architect, CPWD, Bombay was requested to prepare the lay-out plans and drawings. As on 31st March 1972, the matter rested with the Senior Architect. An allocation of Rs.71.23 lakhs has been made by Government for construction of the Institute building and residential quarters under the Fourth Five Year Plan.

9. Research Scientists

Director	:	Vacant
Assistant Director	:	K.R.Saha, M.Sc., D.Phil H.Mitra, M.Sc. Bh.V.Ramanamurthy, M.Sc., Ph.D. G.C.Asnani, M.Sc., Ph.D.
Senior Scientific Officers, Gr. I.	:	C.M.Dixit, M.Sc. R.P.Sarker, M.Sc., D.Phil O.N.Dhar, M.Sc. K.V.Rao, M.Sc. S.Rangarajan, M.Sc., Ph.D. D.A.Mooley, M.Sc., Ph.D. R.N.Keshavamurthy, M.Sc. R.Suryanarayana, M.Sc.
Senior Scientific Officers, Gr.II.	:	D.R.Sikka, M.Sc. R.V.Godbole, M.Sc., Ph.D. K.Krishna, M.Sc. R.K.Kapoor, M.Sc. H.S.Bedi, M.Sc.
Junior Scientific Officer		Y.Ramanathan, M.Sc. K.K.Kapoor, M.Sc. G.Appa Rao, M.Sc. U.S.De, M.Sc. ~~J.Shukla, M.Sc., Ph.D.~~ R.K.Verma, M.Sc. K.G.Vernekar, M.Sc. Smt.A.M.Selvam, M.Sc., Ph.D. P.N.Sharma, M.A., Grad.I.T.E. G.B.Pant, M.Sc. S.Rajamani, M.Sc. S.K.Mishra, M.Sc. H.N.Bhalme, M.Sc. Shyamvir Singh, M.Sc.

APPENDIX I

Name and address of the members of the Governing Council

Dr. P. Koteswaram, Director General of Observatories, Lodi Road, New Delhi 3.	Chairman
Shri S. Ramanathan Joint Secretary Ministry of Tourism and Civil Aviation Sardar Patel Bhavan, Parliament Street, New Delhi 1.	Member
Shri C. Venkataraman, Director (Foreign Trade and Civil Aviation), Ministry of Finance Room No.238-A, Udyog Bhavan, New Delhi 1.	Member
Shri Y.P. Rao, Dy. Director General of Observatories, (Administration), The Observatory, Lodi Road, New Delhi 3.	Member
Shri S. Basu, Retd. Director General of Observatories, L-25 Hauz Khas Enclave, New Delhi 16.	Member
Prof. R. Ramanadham, Head of the Department of Meteorology and Oceanography, Andhra University, Waltair, Andhra Pradesh.	Member
Dr. N. K. Panikkar, Director, National Institute of Oceanography, Panaji (Goa)	Member
Prof. P.R. Pisharoty, Scientist, Physical Research Laboratory Navrangpura, Ahmedabad-9.	Member
Dr. K. R. Saha, Assistant Director, Performing the duties of the Director, Indian Institute of Tropical Meteorology, Poona 5.	Member