ANNUAL REPORT 1964-65

Division of Meteorological Physics

Commonwealth Scientific and Industrial
Research Organization, Australia
Melbourne 1965

CONTENTS

DIVISION OF METEOROLOGICAL PHYSICS

A N N U A L R E P O R T

1964 - 1965

I INTRODUCTION

A greater understanding of the fundamental processes of meteorology and the application of this knowledge to problems of economic importance to Australia constitute the Division's two main objectives. In the case of the former, the group working in Dynamic Meteorology, while directing its attention primarily to the basic problems of atmospheric mechanics, gives prominence to matters of particular interest to Australia. In Applied Meteorology the accent is on agriculture and the efficient use of water. It is in such spheres that many of the results and techniques which stem from the work of the Division's major field of interest, atmospheric turbulence and exchange processes, can be readily applied.

II DYNAMICAL METEOROLOGY AND THE GENERAL CIRCULATION

The General Circulation

(a) Vertical Momentum Flux. Of recent years there has been increasing recognition of the general circulation of the atmosphere as the most significant unsolved problem in meteorology. Nations of the Southern hemisphere must have a special interest in this area. The advent of the satellite offers hope that eventually the whole of the atmosphere will be brought under observation, and the first experiments to this end are being prepared. A high degree of international collaboration will be required for their ultimate success.

The stage is also set for preparatory work in other directions and an essential part of the problem is the manner in which the interactions at the surface influence the life history of disturbances on the synoptic scale (long waves, anticyclones, depressions, etc.). The question stands athwart any substantial prospect of extending detailed scientific weather forecasting beyond its present limitation of two or three days. As successive Annual Reports show, the Division's contribution towards knowledge of the surface interactions has been a major one. The complex task of applying this knowledge to the larger-scale phenomena must now be faced and will involve the collaboration of experts in micrometeorology and large scale dynamics.

In the lowest layers, near the surface, transfer of momentum occurs by small eddies, but needs to be expressed in terms of the larger-scale parameters: these may be identified as the nature (roughness) of the surface, the latitude, the free air velocity, and the static stability through a fairly deep boundary layer. The latter can account for a variation in stress, previously little known, but which now can be estimated as at least ten fold and possibly a hundred fold. Detailed relationships are being sought from an initial body of experimental data obtained at Hay this year.

The flux of momentum through the greater depth of the boundary layer and on into the free atmosphere must be by circulation patterns of larger size, perhaps progressively so, but again the details are quite obscure. However a critical examination of special soundings through Australian cold fronts indicates that the meridional front sequence, with its asymmetrical distribution of upward and downward motion, is an important factor. These fronts are typical of the Southern hemisphere westerlies while Northern hemisphere fronts, though typically of different structure, also have significant asymmetry. Such

results if confirmed must be incorporated in numerical forecasting techniques since the motions responsible for vertical flux must be correctly portrayed in the modelling. These questions of flux on various scales, here illustrated for momentum (and see under "Jet Streams" below), exist also in the context of heat and water vapour transport, and it is hoped to give them increased attention in the coming years.

(b) The Southern Oscillation. The studies of the Southern Oscillation referred to in the previous report have been continued and consideration given to the processes which govern the oscillation and to the regions of particular importance to its maintenance.

An hypothesis that the so-called oscillation is a consequence of variations in a mean toroidal circulation between the eastern and western hemispheres in low latitudes has been developed and is being tested by studying surface pressure and upper level wind and temperature relationships. Available upper air data indicate that the air over the Indian Ocean and adjacent land areas is warmer than that over the eastern Pacific, notably in the layer between 500 and 200 mb (20,000 to 40,000 ft.). This results, in the presence of ascending air, for which there is external evidence, in a slow ageostrophic drift from west to east at these levels, which is compensated by a return flow at low levels near the earth's surface. Anomalies in the circulation would be linked with those of surface pressure.

An examination of the operative synoptic and physical processes involved point to the South-East Pacific as the area responsible for the initiation and maintenance of the Oscillation. Here fluctuations in the south-east trade winds result in corresponding variations in the production of

cyclonic vortices downstream in the West Pacific, with subsequent effects on areas still further west. Further, the persistence of atmospheric circulation anomalies over a number of months at certain times of the year is thought to be due to the existence of relatively large areas in the South-East Pacific where sea temperature is lower than air temperature; such a situation tending to retard the dissipation of an anomaly which has occurred. The transmission of anomalies westward is strikingly illustrated by the high (negative) correlation between winter pressures over central Chile and those over Darwin six months later.

(c) Antarctica and the Heat Balance. An important aspect of the southern hemisphere circulation is the heat exchange between the principal radiation sink in the atmosphere over Antarctica and its surroundings. In the annual heat balance the required southward heat transport can be fairly assessed from daily soundings of temperature, wind and pressure-height at some twelve Antarctic stations, in terms of a toroidal circulation and of transfer by standing and transient synoptic-scale eddies. During the spring season when, in the Antarctic stratosphere, temperatures rise by an average of 30°C or more, heat gains were found to be much in excess of those required for this warming and the radiation loss combined. The discrepancy is thought to be due to the poorly understood vertical heat transfer processes which are linked with the disappearance of the high winter tropopause and the lowering of the principal Antarctic tropopause. A study of the synoptic-scale patterns of the tropopause complex is being made.

Furthermore, the asymmetrical location of Antarctic plateau with respect to the Pole - and thus the radiation sink - was found to be relevant to apportioning the heat transfer precisely among the aforementioned three mechanisms.

Jet Streams

Further study of jet stream turbulence has shown that sub-synoptic scale eddies account for a quite large downward flux of zonal momentum in the layer of strong shear below the jet, and a smaller upward flux above it. Values of energy dissipation inferred from serial wind soundings were compatible with those measured by an aircraft in an adjacent downstream area of clear air turbulence.

An empirical linear relation between stability and the square of wind shear suggests that significant turbulence is generated only when the shear exceeds a threshold value of about 6 kt per thousand feet. The turbulent transfer coefficient for momentum was indicated to be two to three times that for heat in statically stable conditions above and below the jet. The possibility of gravity waves playing an important role in the genesis of clear air turbulence is indicated by the close correspondence between the maximum of the Scorer wave parameter and the layer in which clear air turbulence was observed by the aircraft.

Various

To check a suggestion in the literature that there is a marked seven year regularity in Hobart rainfall resulting from a similar one in east coast cyclone frequency, some aspects of Hobart rainfall have been examined. Daily rainfall at Hobart has been related to the direction of the mean sea level geostrophic wind. In respect of rainfall amount, both westerly and south-easterly winds are important. "Easterly rain", though infrequent and very variable is about equal in amount to the more dependable "westerly rain".

An examination of other stations in Tasmania, including those on the north and west

coasts, shows the same seven year regularity in June as has been found for Hobart although to a lesser degree - suggesting a primary mechanism of high level disturbances. Investigation shows that with the Hobart rainfall, the seven years regularity has phase opposite in April to that in March and June, and is absent in May.

The success of gliding operations in thermals on sunny days depends partly on the height to which soaring is possible. A study of the heights reached by gliders during competitions has revealed a fairly close correspondence with the depth of convection as judged from morning temperature soundings and subsequent surface temperatures. At gliding competitions held at Benalla, Victoria, in January last about eighty per cent of the surface net radiation was utilized in modifying the temperature structure within the convective layer.

The weather surveillance radar is operating successfully and the plotting of rain areas in plan continues. The existing meso-scale network of three long term rain and temperature recorders on the Mornington Peninsula is to be augmented by another two, data from this network being used to relate surface measurements to radar echoes of rain.

III GENERAL MICROMETEOROLOGY AND EVAPORATION

Two field expeditions were conducted during the year, one in September 1964 to Kerang, Victoria, and the other in March 1965 to Hay, New South Wales.

The September experiment over lush green pasture was directed towards elucidation of the relationship between the flux of water vapour and that of heat and momentum as studied in previous expeditions. Earlier attempts to accomplish this were unsuccessful because of the extreme accuracy called for in the measurement of water vapour. However, with the utmost care devoted to the

instrumentation, results have been obtained which suggest a close link between the transfer of heat and water vapour. For purposes of comparison the March experiment was conducted in extremely dry conditions, and in an endeavour to extend the profile measurements into regions of stronger instability the mast height increased from 16 to 32 metres. A large body of valuable data has been obtained and the analysis of this is currently being pursued.

As a further stage in investigations of temperature structure in conditions of strong convection, recordings were made during the Hay expedition of temperature fluctuations at heights of 8, 16, and 31 m. A mode of behaviour previously found at heights of a few metres and more was again encountered on a number of occasions, namely, the appearance of temperature-quiescent intervals ranging from a few seconds up to a minute or so, which represent the undisturbed air sinking around rising warm convection plumes. More refined equipment was used on this expedition, and it is expected that the full analysis of the records will yield more detailed information than has been gained so far.

Such investigations not only provide essential evidence towards a basic understanding of the atmospheric convection process, but also have an immediate practical application to optical observing through the atmosphere, in particular to solar observing. The turbulent fluctuations of temperature cause severe "shimmering" of the image but, under suitable conditions, the temperature-quiescent intervals provide temporary good seeing of adequate duration for solar observations. From the investigations, in conjunction with theoretical considerations, it is possible to specify the circumstances in which intervals of good seeing may be encountered. Favourable conditions entail light wind, smooth terrain, high telescope, and sun downwind from the observer - see illustration facing page 8.

Work has continued on improving the Spectrum Slicer, the instrument which, from an unsteady platform such as a ship, is capable of obtaining the vertical fluxes of heat and momentum in the air over the sea. As a result of further field trials, initially at Kerang and later at Hay, it was found necessary to improve the stability of calibration of the equipment as well as to refine the methods of checking the calibrations themselves. Extensive rebuilding and testing in the field has now been completed and work over water is planned to commence in September.

IV AGRICULTURAL METEOROLOGY

The Lysimeter Installations

The sixth year of operation of the Aspendale lysimeter installation has seen the termination of its first major programme. Twelve large outdoor soil containers (5' 10" in diameter, 4' deep and 6 tons in weight) continuously and automatically weighed to 1 part in 140,000 have been employed to study evaporation from open water, bare soil, and one single type of growing surface, namely irrigated pasture.

During 1964 the analysis was completed and a comprehensive report published. This related potential evaporation from well-irrigated grass, to the main meteorological governing factors. During the summer and autumn of 1964-65 further drying trials were conducted, during which first one half of the experimental area, and then the other, was allowed to dry out while the remainder was kept fully irrigated. Comparison of the evaporation rates from the dry and wet areas confirmed last year's results showing that for a shallow-rooted crop, such as grass, actual evaporation departs from the potential rate within a few days of the cessation of irrigation, and is reduced progressively as the average soil moisture content in the root zone continues to decrease.

Analysis of these more recent data is nearly

complete and it is already apparent that behaviour during the drying phase can be adequately accounted for by adding to the already established combination formula (which relates potential evaporation to routine measurements of various meteorological elements) one simple term. This term involves the average internal (stomatal) water vapour conductance of the leaves, which is assumed to be effectively governed by the prevailing soil moisture content in the root zone. Daily values of the latter can be obtained from a single initial measurement of soil moisture followed by progressive adjustments based on the calculated daily evaporation.

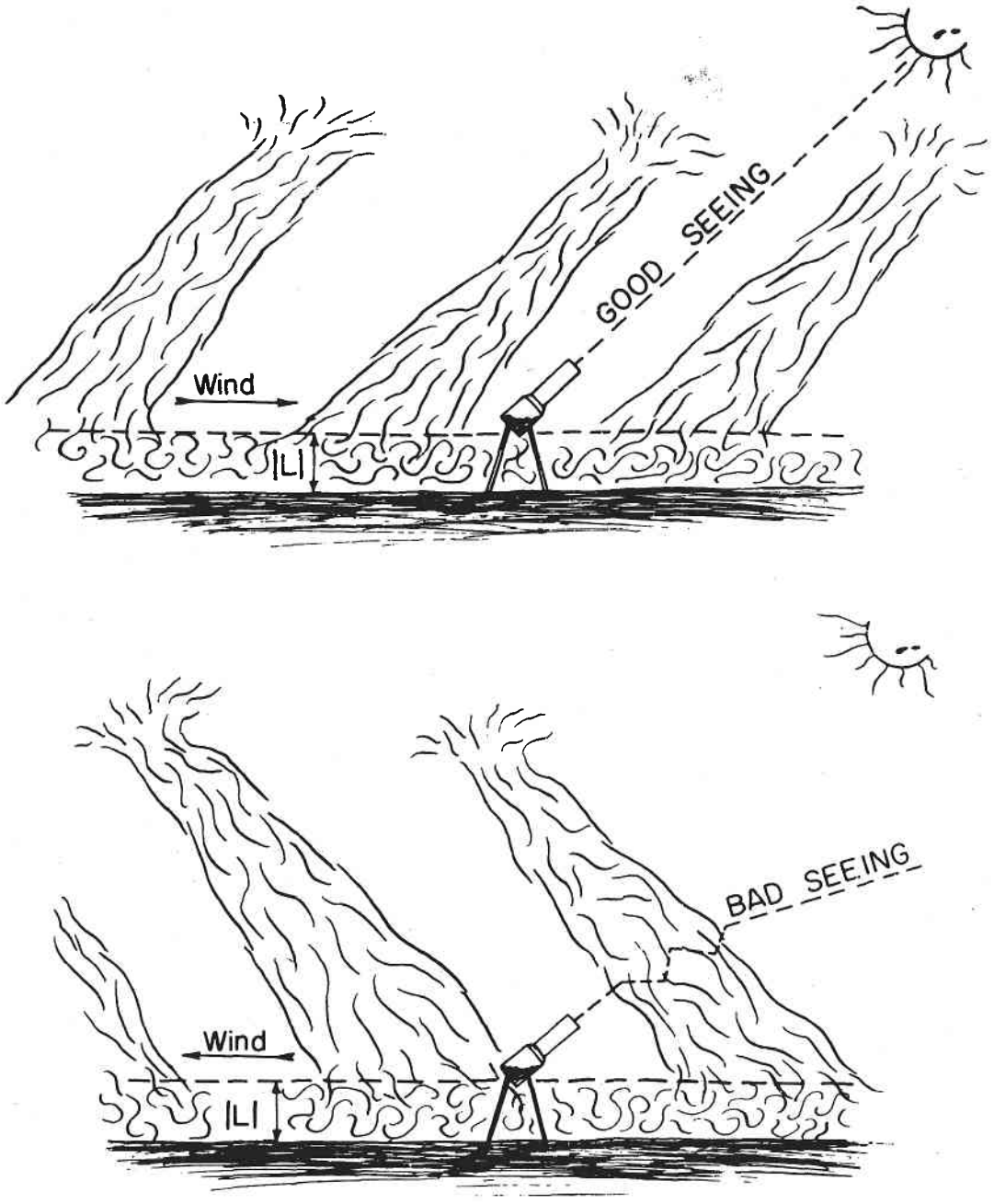
With the immediate objective of the pasture evaporation programme now achieved, half the lysimeter area has been prepared for a new crop. Potatoes have been selected not only because of their economic importance but also because their leaf structure is eminently suited to the intensive studies of plant water content and stomatal behaviour planned to commence this summer.

The development of an inexpensive hydraulic lysimeter for agricultural purposes, referred to in the last annual report, is now well advanced and a complete instrument is currently undergoing trials in the field. The hydraulic/pneumatic system, which requires no electric power, operates a remote pressure sensing device from which all significant temperature effects have been removed. Plans for the construction of an assembly to weigh a 30 ton soil sample have been drawn up for the Victorian State Agricultural Department who propose to use the system in a peach orchard.

In considering the water and energy balance of glaciers and snow covered regions evaporation is an important but often neglected factor. A joint project with the Department of Meteorology, Melbourne University, has been started at Mt. Buller to examine two methods of determining the rate of evaporation from snow. One is a direct approach involving the

CALIBRATING RADIOMETERS

The Division is an accredited agency of the National Association of Testing Authorities.



ATMOSPHERIC TRANSPARENCY

Thermal convection plumes travelling in the wind past a telescope, with suggested relationship of seeing quality to sun-wind orientation. The stronger the wind, the greater is the height of the lower layer which the telescope must surmount to reach the "clear" air between the plumes.

Reproduced by courtesy of Applied Optics.

installation of specially designed snow lysimeters and the other an indirect one requiring measurements of radiation, wind, temperature and humidity, employing instruments especially modified for snow conditions.

Transpiration Reduction

The possibility of reducing crop water loss by chemical treatment of the foliage or soil has extremely important implications for agriculture. Glass-house trials with a leaf spray have been conducted this year on sugar beets and potatoes. The soil in which both the treated and the control plants were grown was maintained at approximately field capacity, and treatment was found to give a significant reduction in transpiration (up to 20%) for a given weight of dry matter produced. Further trials are planned in the glasshouse at lower moisture content, out of doors under field conditions, and with different spraying materials.

Blue Mould in Tobacco

With financial assistance from the Tobacco Advisory Committee and in co-operation with the Tobacco Research Station of the Victorian Department of Agriculture, the experiments on the control of blue mould in tobacco, referred to in last year's report, have been continued.

In normal commercial practice the spread of blue mould is controlled by a weekly application of fungicidal spray, irrespective of weather conditions. In the work referred to here, daily weather forecasts supplied by the Bureau of Meteorology were used by this Division to decide whether or not to spray the test crop. Unfortunately, no blue mould at all was experienced this year and the results therefore are inconclusive. The work continues during the coming season.

General

A computer programme suitable for use with

the C.D.C.3200 (one of the machines in the C.S.I.R.O. computer network) has been drawn up, permitting both potential and actual evaporation to be computed from simple routine meteorological measurements plus, in the case of the latter, occasional soil moisture measurements. This method employs the combination formula which has been found most useful in the past in summarising weather-water relationships of pasture at Aspendale.

With computer analysis to speed the working up of large amounts of data, it now becomes feasible to apply this method to routine field measurements of evaporation elsewhere. However, with markedly different types of vegetation further checks against lysimeters, or other reliable methods of determining evaporation, will first be necessary.

V RADIATION

Under the auspices of the C.I.M.O. Working Group on Radiation Instruments and Observations for General Use a comparison of different types of net pyrradiometer is being carried out. Tests have commenced with the Australian (Funk) instrument and the Russian Yanishevsky whilst the British Kew and German Schulze will be added shortly. The work of comparison at Aspendale is running concurrently with similar investigations at three other centres - Poona, Hamburg and Leningrad.

Development of a laboratory artificial light source with which to calibrate radiometers and referred to in the previous report has gone according to plan. The device employs a high intensity light source and an oscillating mirror to provide uniform illumination. Comparisons between instruments calibrated directly by solar beam and those using artificial light show that the laboratory source gives results reliable to within $\pm 1\frac{1}{2}\%$ despite the fact that the spectral distribution is not identical in the two cases. The possibility of improving the spectral

distribution by replacing the tungsten filament element with a Xenon arc is now being investigated.

During August 1964 the Division's Ångström pyrheliometer - the Australian standard solar radiation measuring instrument - was taken to Davos, Switzerland, to participate in the Second International Comparison of Working Standard Pyrheliometers at which eleven countries were represented. As a result of these comparisons the calibration constant of the Australian instrument was corrected by 0.7%.

Analysis of records of solar and long-wave radiation taken on Indian Ocean Cruises of H.M.A.S. Diamantina and Gascoyne during the International Indian Ocean Expedition are well advanced and are expected to be completed in the next few months.

During the year an electronic D.C. voltage indicator was developed for the integration of solar radiation. Designed to operate with the Funk net radiometer and Sumner long term recorder, the integrator can operate for three months unattended. Transistors are employed throughout and the power consumption is about 150 m watts. Integration is achieved by the well established principle of capacitative feedback around a D.C. amplifier, an unusual feature of the instrument being a novel circuit permitting readout by means of pulses operating an electromagnetic counter. Both positive and negative voltages up to a maximum of 30 mV can be accommodated.

Preliminary field trials at Aspendale over a period of two months have yielded radiation values agreeing to within 2 to 3% of those obtained by standard methods. Further field tests are now being conducted in the more difficult environment of the Snowy Mountains. A prototype commercial model is already being made and will be available soon for assessment and testing.

During the current year assistance has been provided to the Department of Civil Aviation in efforts to measure solar radiation falling on aircrew in the cockpits of Boeing 707 jet aircraft, and to the State Electricity Commission of Victoria in assessing the effectiveness of radiation screens as a means of reducing the thermal stress on fitters working in the boilerhouse at the Morwell Generating Station.

VI UPPER ATMOSPHERE STUDIES

Ozone

Observations of the total amount of ozone and of its vertical distribution in the atmosphere by the "umkehr" method using Dobson Spectrophotometers were continued at Aspendale, and at Brisbane and Macquarie Island in collaboration with the Bureau of Meteorology and the Antarctic Division of the Department of External Affairs, respectively. All three instruments have been recalibrated.

The programme of measuring the vertical distribution of ozone in the atmosphere directly by soundings from Aspendale has been brought into operation successfully, a Brewer type ozone sonde being employed. Flights are made on all Regular Geophysical Days (one per week) with some additional soundings during World Geophysical Interval weeks.

An ozone observing station equipped with a Dobson Spectrophotometer was established at Port Moresby (9.5°S, 147.2°E) in New Guinea in April 1965, and local Bureau of Meteorology staff trained in its operation. This addition to the network of ozone observing stations close to the 140°E meridian in the Australian region will greatly assist the study of the synoptic distribution of atmospheric ozone in this region, as well as contributing to the knowledge of atmospheric ozone over the equatorial region in the southern hemisphere.

This year has seen the completion of the calibration programme for all Dobson Spectrophotometers in the Australian region. This includes instruments from the New Zealand Meteorological Service, the Weapons Research Establishment, Salisbury, as well as that loaned by the U.S. Weather Bureau and now in New Guinea. The instrument belonging to the New Zealand Meteorological Service has recently been brought into commission and personnel from that Service advised in its operation.

Measurements to determine the ozone content at the surface level by chemical method using Ehmert's type of apparatus have been started at Macquarie Island.

Analysis of the meridional distribution of ozone associated with severe geomagnetic storms during 1961 has confirmed the results reported earlier; namely, that the meridional gradient of ozone reaches its minimum 24 hours after the storm. As variations in ozone concentration are not related to systematic changes in upper level circulation patterns it has been suggested that such ozone changes may result from the destruction of ozone by the introduction of light scattering material in the atmosphere.

The analysis of the vertical distributions of ozone computed from umkehr observations made at Aspendale, Brisbane and Macquarie Island has been taken a step further, the results indicating that the biennial oscillation in the Spring level of ozone takes place mostly above 24 km. A stratospheric circulation model consistent with the isentropes at these levels has been postulated.

A persistent dip in the ozone concentration and mixing ratio was observed at the 50 mb level over Boulder, Colorado, in March and April 1964. It has been suggested that this dip was due to the destruction of ozone by a layer of volcanic dust

originating from the eruption of Mt. Agung in Indonesia in March 1963. Based on this a model for the dust layer at that level has been worked out.

Radioactivity

The routine measurement of the total β-activity occurring in rainfall has continued and the seasonal effect of a maximum in late Spring and early Summer referred to in earlier reports been confirmed. Analyses of upper air soundings made by the U.S. Atomic Energy Commission reveal that stratospheric transfer processes are complex. Thus, although the first arrival of fission debris from an equatorial test appears to take place in the upper troposphere or lower stratosphere with a transit time to 38° S of approximately six weeks, the major arrival of debris does not occur until after about 6 months and is associated with transfer at an even higher level.

Similar rates of transport have been inferred from observations of volcanic dust following the volcanic eruption of Mt. Agung, Bali, in March 1963. Radiation records at Aspendale demonstrate the presence of a maximum quantity of dust at a high level between July and September 1963. On cloudless days a reduction of 25% in the direct solar beam and a two-fold increase in diffuse radiation has been observed, the maximum reduction in total radiation being 7%. Radiation levels have still not returned to the pre-1963 level.

Processes involved in the scavenging of radioactive particles by rain have been evaluated theoretically and nucleation is considered to be the major effect. Detailed measurements of the deposition of radioactivity during a number of storms have been made and the high concentrations observed soon after the onset of rain can be readily explained in terms of this theory.

The programme to measure Be-7, the element

which being produced almost wholly in the stratosphere can be used to obtain a measure of troposphere-stratosphere interchange is now well under way. By courtesy of the U.S. Air Force Weather Reconnaissance Flights based at East Sale and Avalon, Victoria, regular samples of particulate matter from high altitudes are now being obtained. In addition, similar samples are being obtained from the Mildura area through the good offices of the Department of Supply. This Department operates a programme of high altitude balloon flights, regular ascents being made to over 80,000 ft.

VII MISCELLANEOUS

The small data processing group has continued to provide a valuable service for the Division. Development within the group over the past year has been directed mainly towards taking full advantage of the new C.S.I.R.O. computing facilities. To this end, the Fortran programming language has been adopted, and an I.B.M. card punch has been installed in addition to the existing punched tape equipment. A machine for punching sprocket holes along the edges of recorder charts has been built, its primary application being the preparation of chart records for accurate processing on the Division's analogue-digital conversion equipment.

Work undertaken by this group has included spectrum analyses of vertical velocity and temperature fluctuations obtained by aircraft traverses through a convection layer; statistical analyses of Antarctic wind and temperature data; evaluation of evaporation over crops; preparation of radiation tables; treatment of wind data, and the numerical solution of a theoretical formulation in an investigation of the jet stream. Processing of various data from the Hay expedition has also been carried out.

There is increasing interest on the part of biologists in relating specific plant and crop

processes to the micrometeorological environment, and this Division continues to provide advice on environmental instrumentation and measuring techniques.

In particular, advice has been given on methods of recording and integrating global and net radiation above and within a crop, together with details of a self-contained automatic battery operated system to record net radiation, air temperature gradients, humidity, wind speed, soil moisture and temperature from the root zone to above the canopy (175 ft.) in a eucalypt forest.

Development of the Sumner long period recorder has continued and further sensing devices have been designed to satisfy requests from various organizations. This instrument is now accepted as a useful investigational tool for providing records of a number of different variables where remoteness and inaccessibility preclude the use of more conventional instruments. The system is now used extensively by the Commonwealth Bureau of Meteorology, the Tasmanian Hydro Electrical Authority and numerous other organizations. Overseas agents have been appointed in a number of countries and instruments are being exported.

In particular, McGill University, Canada, and Ohio State University, U.S.A., have each been supplied with three instruments for glaciological work during the coming northern winter in northern Canada and Alaska. These instruments have been specially developed to operate in the extremely cold and rugged conditions likely to be encountered: they must however be regarded as still in the experimental stage.

A new type of sunshine sensing device for use with the recorder has been developed and is currently being tested on Mt. Kosciusco in co-operation with the Snowy Mountain Authority.

Facilities were made available to the State Electricity Commission of Victoria at the Division's experimental site at Edithvale to study the response of certain structures to wind gusts in strong wind conditions. A recording hot-wire anemometer was made for this work and the various strain-gauge and wind speed recordings have been transferred to punched tape using the Division's digitising equipment. The object of the work is to provide basic information for the design of electricity transmission lines and pylons.

The Division's laboratory, registered for a number of years by the National Association of Testing Authorities as an accredited testing authority in the fields of low-speed anemometry and atmospheric radiation instruments, has continued to provide this service. A similar service is provided in respect of heat flux plates.

The movement of beach sand around the Melbourne bayside has aroused considerable interest during the past year. Detailed analyses of Aspendale winds and other relevant meteorological data have been provided to bayside councils and the Board of Works.

The Division has continued to advise various other bodies on the estimation of evaporation from open water surfaces.

VIII PERSONALIA

Meteorology, always essentially an international science, continues to grow rapidly in this respect. During the year members of the Division have continued their associations with the various national and international organizations which have been established to deal with problems of Antarctic Research, Dynamic Meteorology, Ozone, Evaporation, Hydrology, Special Radiation Instruments and Observations, Plant Injury and Air Pollutants, Oceanic Research and Space Research.

In January Dr. C. H. B. Priestley, Chief of Division, left Australia to attend meetings of the W.M.O. Advisory Committee and the newly-formed U.G.G.I. Committee on Atmospheric Sciences at Geneva. En route he accepted an invitation to visit and lecture at the Institute of Tropical Meteorology, Poona and the Meteorological Service of India. Whilst in Europe he spent two weeks visiting the British Meteorological Office and other meteorological centres in the United Kingdom.

Later in the year Dr. Priestley visited Quebec, Canada, to attend the International Symposium on the Design of Hydrological Networks and present the "keynote" paper on the Effects of New Instrumentation on Network Planning for Evaporation. A few days later in Moscow he presented a paper to an International Symposium on the Dynamics of Large-Scale Processes in the Atmosphere, organized by the International Commission for Dynamic Meteorology, and attended the second meeting of that Commission.

In September, Mr. W. C. Swinbank attended a meeting of the International Ozone Commission in Albuquerque, New Mexico. This was followed by a meeting in Santa Fe, convened by the Committee on Atmospheric Sciences of the National Research Council of the U.S. Academy of Sciences, to discuss the further requirements for a global ozone observation programme. On the return journey he visited research centres in the U.S., Canada (where he gave an invited lecture to the Canadian Branch of the Royal Meteorological Society) and the United Kingdom.

As a result of his published work in fluid dynamics, Melbourne University has conferred on Mr. F. K. Ball the degree of Doctor of Science.

Dr. Ball recently completed a twelve months period of secondment as an Honorary Research Fellow at the Australian National University where he worked on problems in theoretical fluid dynamics. Shortly afterwards he left Australia to take up a

temporary appointment as Assistant Director of Research in Dynamical Meteorology at Cambridge University. He will be away for two years and will work in the field of geophysical fluid dynamics.

Mr. I. C. McIlroy has returned from the U.S. where he worked for ten months at the U.S. Water Conservation Laboratory, Tempe, Arizona, and at the University of California, Davis, on the measurement of evaporation from crops.

Dr. R. N. Kulkarni who recently completed a three year Fellowship with the Division has been re-appointed as a Senior Research Fellow and will continue his work in the field of atmospheric ozone.

To take part in and extend the work of the ozone programme, Dr. A. B. Pittock has recently taken up an appointment as a Research Scientist.

In November 1964, Mr. W. Shepherd joined the Division, transferring from C.S.I.R.O. Fodder Conservation Section. As part of the agro-meteorological group he will be concerned initially with transfer of water through leaves, and responses of plants to water stress.

Dr. T. G. Kyle, from the University of Denver, has recently taken up a three year appointment as a Research Fellow in Atmospheric Radiation.

Early in the year Dr. B. J. Mason, Professor of Cloud Physics at the Imperial College of Science and Technology, London, on a visit to Australia spent a short time with the Division discussing problems of mutual interest. Professor Mason highlighted his stay by giving two addresses on the Electrification of Thunderstorms and the Recent Developments in the Physics of Clouds, Rain and Snow.

Dr. K. M. King, Associate Professor at the

Ontario Agricultural College, Guelph, Canada, recently completed a four and a half months visit to the Division, during which time he worked on problems associated with the measurement of the fluxes of heat, water vapour and momentum.

Mr. P. S. Harihara Ayyar, a Colombo Plan Fellow from the Agricultural Meteorology Division of the Indian Meteorological Service, Poona, has completed a six months visit to Australia. His work embraced agricultural and micrometeorological problems generally, with a special emphasis on evaporation. Although spending the major portion of his time at Aspendale, he visited numerous other centres engaged in related work.

Once again, a postgraduate course of 25 lectures in Micrometeorology, and a shorter undergraduate course for Forestry Students, has been given at Melbourne University by Dr. D. E. Angus.

In the latter half of the year, in collaboration with the Department of Meteorology, Melbourne University, Mr. R. J. Taylor gave a postgraduate course of lectures on the theory of turbulence.

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X STAFF

Chief	C.H.B. Priestley, M.A., Sc.D., F.A.A.
Chief Research Scientist	W.C. Swinbank, M.Sc.
Sen.Prin.Research Scientist	E.L. Deacon, B.Sc.
Prin. Research Scientist	F.K. Ball, D.Sc.
Prin. Research Scientist	A.F.A. Berson, Dr.Phil.
Prin. Research Scientist	R.H. Clarke, B.A., M.Sc.
Prin. Research Scientist	A.J. Dyer, M.Sc., Ph.D.
Prin. Research Scientist	R.J. Taylor, M.Sc.
Sen. Research Scientist	D.E. Angus, Ph.D.
Sen. Research Scientist	I.C. McIlroy, B.Sc.
Sen. Research Scientist	W. Shepherd, B.Ag.Sc., B.Sc.
Sen. Research Scientist	E.K. Webb, B.A.(Hons.), B.Sc.
Research Scientist	A.B. Pittock, M.Sc., Ph.D.
Senior Research Fellow	R.N. Kulkarni, M.Sc., Ph.D.
Research Fellow	T.G. Kyle, M.Sc., Ph.D.
Experimental Officer	B.G. Collins, B.Sc.
Experimental Officer	A.C. Dilley, B.Sc.
Experimental Officer	B.B. Hicks, B.Sc.