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DIVISION OF METEOROLOGICAL PHYSICS

ANNUAL REPORT

1962 - 1963

I INTRODUCTION

Progress made during the past year in the Division's main fields of interest is summarised in the following pages. Although the primary concern is the study of fundamental processes in meteorology, prominence is given to the application of meteorological knowledge to problems of economic importance to Australia, especially those connected with agriculture and the efficient use of water. It is in such spheres that many of the results and techniques deriving from work in the Division's major field of interest, the study of atmospheric turbulence and exchange processes, find ready application. In the same way, whilst the group working in Dynamic Meteorology is interested primarily in fundamental atmospheric mechanics, an emphasis is given to problems of particular interest to Australia.

II DYNAMICAL METEOROLOGY

Fronts and Seabreezes

Midsummer seabreezes have been studied from aerological data from aircraft and pilot balloon ascents along a line normal to a straight coastline and stretching inland over generally featureless terrain. The wind flow patterns so revealed are similar in appearance to flattened forms of the two dimensional vortices obtained in laboratory convection experiments. These vortices propagate inland during the night, and, with diminishing density gradients in

the latter stages of their life cycles, decay under the influence of frictional forces.

There is evidence that in some circumstances summer cold fronts behave in a similar manner. Satellite cloud photographs reveal that there is frequently to be found a well defined, smoothly curved, relatively narrow band of cloud with an area of clear air behind it. On some occasions a second band, approximately parallel to the first (major) one, can also be observed. It is to be expected that relative air motions normal to the fronts should exhibit considerable regularity: in particular ascending air should accompany the cloud bands and descending air the clear areas. Such motion has already been observed in association with summer cold fronts. Attention is now being turned to the practically more important but observationally more difficult problem of deep winter cold fronts.

Rainfall Studies

A continuation of the Australia-wide rainfall association study begun last year has attempted, in a preliminary way, to determine the space and time scales on which anomalies occur: more specifically, over what period in time and over what area an anomaly in monthly rainfall remains of the same sign. These are questions which must be answered if longer range forecasting of rainfall is to be approached systematically. A marked persistence appears down the east coast of the continent in spring and early summer and extends round to Darwin, but there is little evidence of this elsewhere or in other seasons. There is a strong regional bond for summer monthly rainfalls extending throughout north central and most of north eastern Australia, and these rainfalls show a slight but significant association with the Darwin pressure of the preceeding October and November.

In the tropical latitudes of Australia during the monsoon season a large proportion of the total monthly rainfall is recorded during discrete spells lasting several days. Lag sympathies between

daily rainfall averages for areas separated by considerable distances are being examined in an attempt to estimate the relative degree of control by west east moving disturbances on the one hand and north south movements of the convergence zone on the other. A study of pressure correlations and power spectra from an area covering Australasia and extending southwards to the coastline of Antarctica indicates that shifts in the convergence zone are bound up with pressure surges in sub-Antarctic latitudes.

A lunar component of the heavy rainfall which occurs over Mangalore in western India during the southwest monsoon has been found to be statistically significant. There is evidence that the lunar effect is most marked during Quiet Sun years.

Theoretical Studies

Energy transfer between different scales and different types of fluid motion is an important aspect of atmospheric behaviour which is still only imperfectly understood. Examples of the former process are provided on a large scale by energy transfers between planetary waves and on a small scale by energy "cascade" in turbulent motions. Of the latter process the generation of gravity waves by turbulence (and vice versa) is a typical example.

The differential equations of fluid motion are non-linear and intractable; in order to obtain solutions it is necessary to idealize the basic equations, and then use methods of approximation. If the characteristics of the equations that are associated with a particular energy transfer are to be retained, however, care must be exercised in both idealization and method of approximation. In this way relatively simple sets of equations can be derived that are useful in gaining further insight into the complex processes of energy transfer. Two such sets of equations have been considered in detail.

One describes the transfer of energy

between external and internal gravity waves in a stratified liquid. The other is concerned with the motion, under the influence of gravity and the rotation of the earth, of an isolated mass of liquid. Though this represents a very considerable idealization of the atmosphere this system is apparently unique in that the energy transfer between the gravitational pulsation of the system and all other motions can be described exactly.

III GENERAL MICROMETEOROLOGY

The Kerang Expeditions

Reference was made in last year's report to the Division's micrometeorological site at Kerang in Northern Victoria and to the requirements in respect of vegetation cover, obstructions and horizontal uniformity of a site suitable for fundamental work. A theoretical study has now confirmed and emphasised from a numerical point of view the extent of these restrictions.

The analysis of the wind and temperature observations obtained during the 1962 expedition to Kerang has been completed, the results affording good confirmation of the exponential form proposed for the wind profile. They also provide strong evidence of the discriminating influences of buoyancy on the turbulent transfer mechanisms of heat and momentum. The former evinces a greater intensification in lapse conditions and undergoes a more vigorous reduction in inversions than the latter. In both cases the influence of buoyancy increases with height.

The results of a similar expedition undertaken during the early summer of this year have also been analysed and yield confirmatory conclusions. A further series of measurements at this site, with particular emphasis on the properties of the humidity profile in relation to that for momentum, is planned for the coming spring.

The Evapotron - the instrument designed to measure automatically evaporation and sensible heat flux over natural surfaces - has been used during the recent investigations at the site, and the law relating the temperature gradient to the inverse four thirds power of the height firmly established over a considerable range of lapse conditions.

Recordings of temperature fluctuations at 8 m and 15 m under strong convection conditions confirm the existence of "quiet" periods, ranging from a few seconds to nearly a minute, with remarkably steady base temperature. These represent the sinking environment, separating the warm pulses which represent convection plumes. The base temperature is very nearly constant with height. The few available records of wet-bulb temperature display similar "quiet" periods, indicating that the subsiding environment has uniform humidity as well as uniform temperature. In such air layers, a near-vanishing of the average potential temperature gradient is often observed over periods of up to 5 minutes or so, though never over periods of 30 minutes or more which, owing to slow changes of conditions, invariably include samples of different convection behaviour accompanied by a temperature lapse.

The Spectrum Slicer

Although it is now accepted that a very considerable increase in the number of observations from the ocean areas is necessary, the acquisition of certain data at sea is made much more difficult, and sometimes precluded completely, by the lack of a steady platform from which to make the measurements - a ship under way invariably has some disturbing motion. This causes difficulty when measurements of vertical fluxes of heat and momentum are attempted at sea. However, a device named the "Spectrum Slicer" promises to overcome these inherent difficulties by utilising measured values of fluctuations of wind-speed and temperature in selected ranges of high frequency and relating these to the fluxes required. By comparison, the frequencies of the roll and pitch

of the ship are so low as to have no effect on the measurements. Trials made last December with a prototype instrument gave valuable experience with the method and an improved Mark II equipment is now nearing completion.

Whirlwinds

A theoretical treatment of the formation of whirlwinds has led to a criterion which is in good accord with experience. For example, over bare ground on a summer day a wind strength of less than about 1 metre per second is indicated as one of the necessary conditions for the formation of whirlwinds. The treatment throws light on the dynamical interactions between thermal buoyancy, wind turbulence and molecular conduction in conditions of light wind.

IV AGRICULTURAL METEOROLOGY AND EVAPORATION

Lysimeter Installation

Twelve large (six ton) lysimeters, or sunken soil containers carrying a crop representative of their surroundings, have now been used to measure natural evaporation from an irrigation pasture mixture for over four years. Seven of these are continuously weighed by remote recording automatic balances, sensitive to a weight change the equivalent of one thousandth of an inch of water. During the past year two similar balances were constructed for loan to other Divisions (see below). Parts to make up four more units are awaiting assembly.

Where balances are not yet available evaporation is obtained as the difference between input (rainfall plus irrigation) and percolate, assuming constant water storage in the soil. Two small and simply constructed lysimeters have been operated on this system for over two years now, and under conditions of frequent irrigation have shown themselves quite satisfactory for periods of a month or longer. For periods of a week or less, however, the results become very erratic unless weighing is

introduced.

The main results of the first three years of operation, under conditions of unrestricted water supply, have now been evaluated. They show firstly that properly constructed lysimeters can measure natural evaporation with a high degree of accuracy and reliability. However, very promising correlations were found between lysimeter evaporation and that from nearby water tanks, and also that computed by a simple formula from standard meteorological quantities. This suggests the desirability of using lysimeters to "calibrate" simpler devices for routine use.

Secondly, for a good deal of the time, the energy consumed in evaporation was found to exceed the local radiant energy supply. High rates of energy use occurred mainly when the surroundings were dry, with relatively warm dry air blowing over the irrigated area, but also to an appreciable extent even when the nearby countryside was wet, or when the wind came off Port Philip Bay. This indicates a very slow rate of cooling and moistening of the air approaching the lysimeter site, even in passing over large areas of water or moist land.

In addition, it appeared that, under the advective conditions typical of an irrigated area, evaporation from a well-watered pasture surface could consistently exceed that from free water, and even more than that from wet soil. The preliminary finding that this was largely due to differences in effectiveness of exchange between the surface concerned and the atmosphere, and hence to differences in surface roughness, has been confirmed by further tests in which the grass in one half of the lysimeter area was allowed to grow long, and was then found to evaporate up to 30% more than the regularly mown grass in the other half.

During the year, a new design of lysimeter pit and a technique for filling large lysimeters with undisturbed blocks of soil were developed. These permitted the successful installation by this

Division of two complete weighed lysimeters, one in a wheatfield at Canberra for use by the Division of Plant Industry and one under lucerne at Griffith for the Irrigation Research Laboratory.

Other Evaporation Studies

An opportunity arose to check the performance of the Evapotron against the weighed lysimeters at Aspendale. A direct comparison between these two types of instrument is not easily made as the limited response time of its wet bulb element requires the Evapotron to be operated at several metres above ground level - at which height the vapour flux may not be equal to that at the surface at sites with short fetch. Operating on this occasion at a height of 1 m, results from the Evapotron showed that whilst the evaporation figures were deficient as anticipated, the sensible heat flux values (obtained in the case of the lysimeter by utilising simultaneous observations of ground heat flux and radiation) agreed to within about 7%. This supports the idea of using the Evapotron to measure sensible heat flux and by subtracting this and the ground flux from the net radiation, to arrive at a figure for the evaporation.

For many years, the simple evaporation pan has been used to provide an estimate of the evaporation from free water surfaces. Unfortunately, such estimates are subject to a high degree of unknown seasonal and shorter-period variability, mainly on account of the varying relationship between pan and lake water temperatures. A new procedure for estimating lake evaporation from daily pan observations, taking into account measurements of pan and lake water temperatures, is under development. Preliminary indications suggest that it will be possible to estimate monthly lake evaporation to within 10 to 15 per cent from high quality pan observations.

Blue Mould in Tobacco

The investigation of meteorological conditions favouring sporulation of blue mould in

tobacco crops has been continued at Ovens, Victoria, in co-operation with the Victorian Department of Agriculture and aided by funds from the Central Tobacco Advisory Committee. Analysis of the results obtained between 1958 and 1962 shows that the difference between "critical relative humidity" - a function of wind speed, temperature and heat loss from the crop - and ambient relative humidity, provides a practical method of estimating the probability of sporulation occurring. During the period 1962-1963 daily predictions of the likelihood of sporulation, based on synoptic forecasts obtained from the Weather Bureau, have been used to control the application of a fungicidal spray to a test crop. Compared with the results obtained by spraying on a routine weekly basis the findings so far have been encouraging, and the experiment continues.

V RADIATION

The study of radiative flux divergence in the lowest 15 metres of the earth's atmosphere during clear nights has been continued and the results of earlier work confirmed. Periods of radiative warming associated with actual warming were again observed whilst under very stable conditions maximum divergence was frequently found to occur at a height of about 3.5 metres. These effects can only be explained by the presence of other absorbers ("haze") in addition to the atmospheric gases.

Equipment capable of measuring the mean modulus temperature fluctuations ($|\overline{T}|$) at two heights has been developed and put into operation. Initial results show that at times of high radiative flux divergence $|\overline{T}|$ tends to decrease indicating a lessening of turbulent exchange, whilst during periods of radiative warming the ratio of the modulus at 4 m to that at 2 m tends to increase.

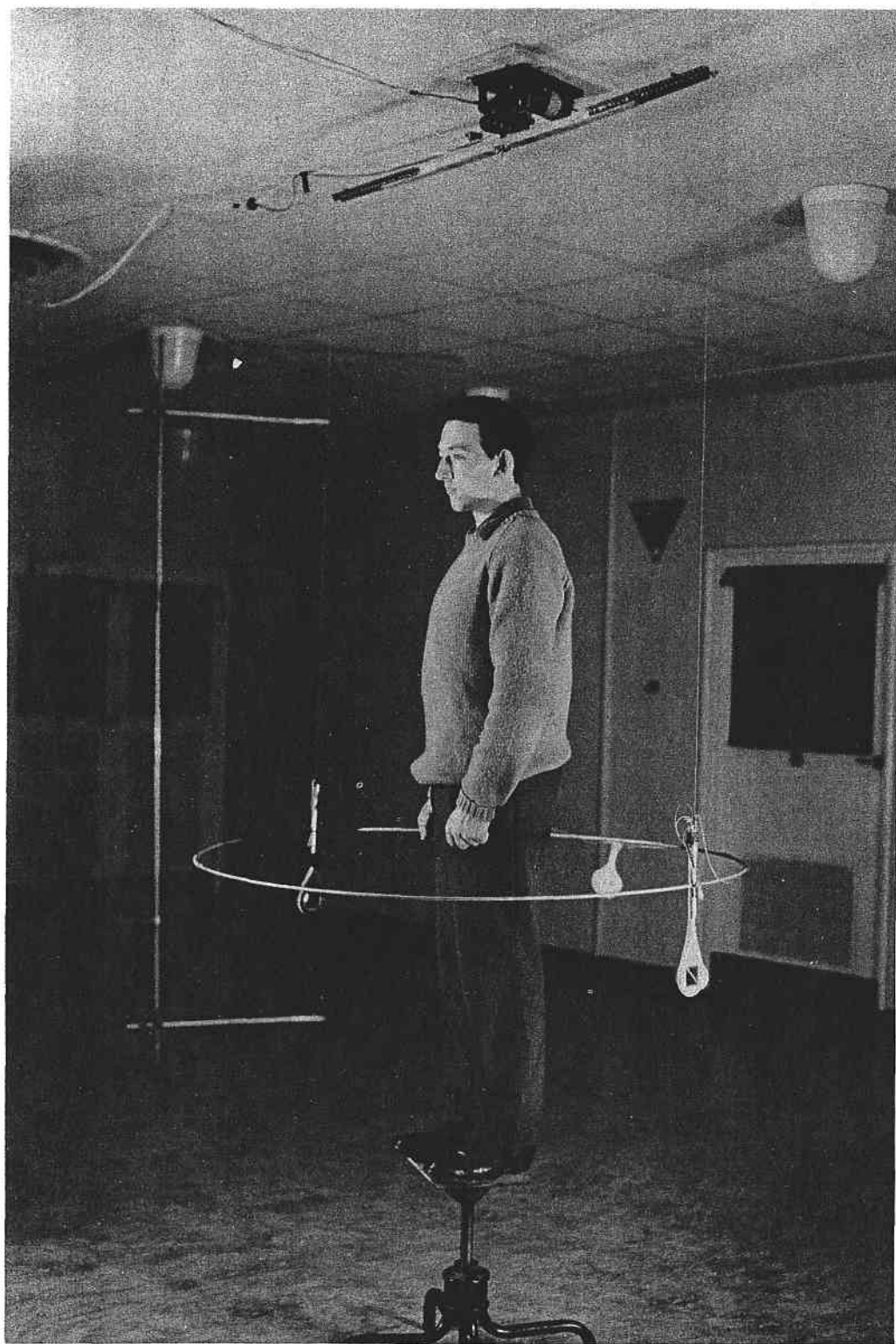
A new, fast and accurate method for the measurement of radiative heat exchange of human subjects has been developed. The equipment comprises two balanced net radiometers, facing each other at the

same level on opposite sides of the subject and moving at a constant speed in a helical path. Each complete scan, which occupies about a minute, thus sweeps out a vertical cylindrical surface enclosing the subject. Noise effects due to the general ambient flux are eliminated by suitable arrangement of the circuit. The results which so far have been very encouraging are consistent with what is generally known about radiative heat exchange under indoor winter conditions. For a clothed subject the radiative heat loss is of the order of half the metabolic rate, whilst for a nude subject (not in thermal equilibrium) it is somewhat over two-thirds the rate. It is proposed to extend the experiment to out-door conditions.

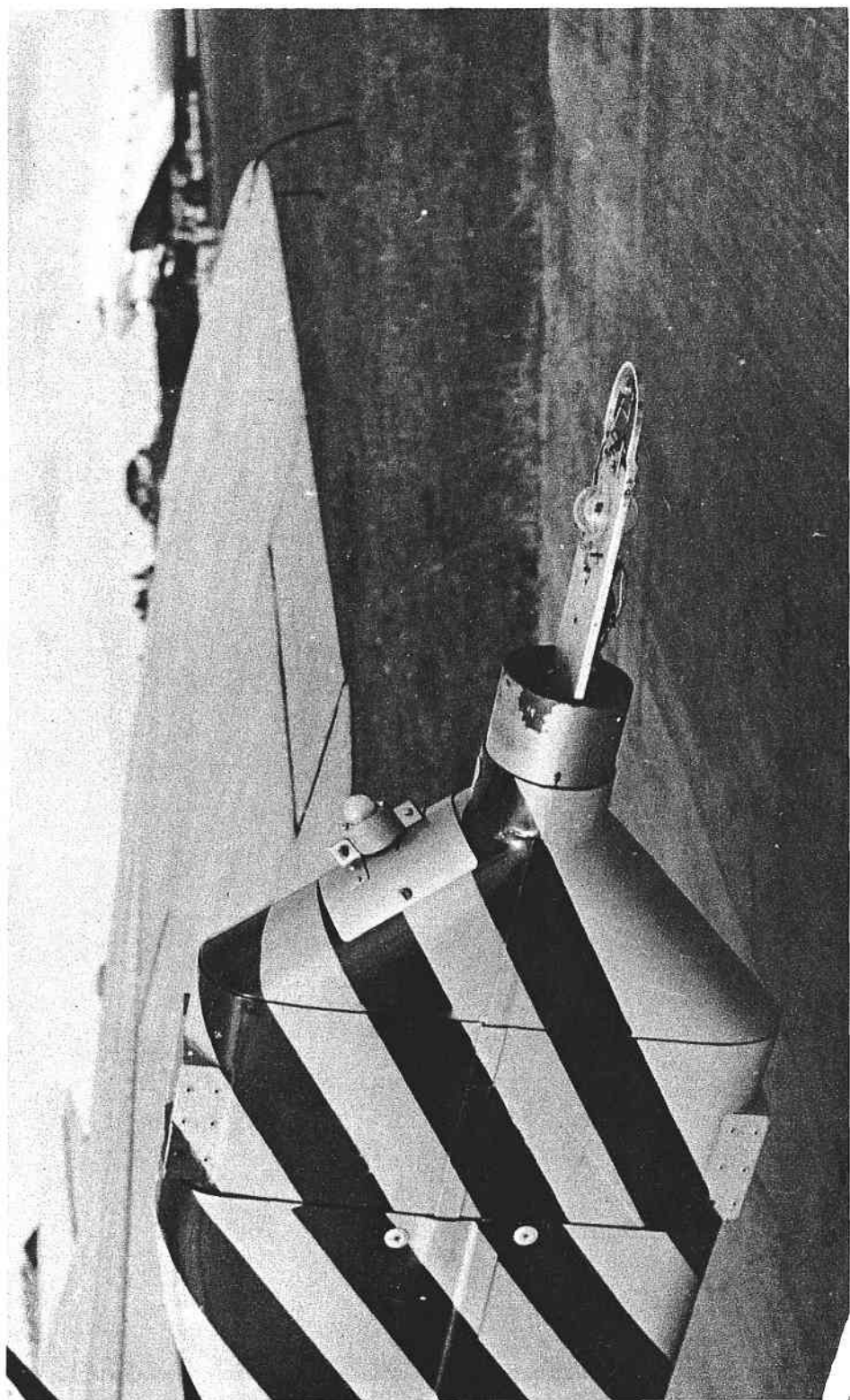
Because of the paucity of radiation observations in this country, especially over sparsely inhabited regions, coupled with the increasing interest in radiation itself, there has been a growing awareness of the urgent need to initiate - even in a limited form - a radiation survey. Now through the good offices of the R.A.A.F. facilities have been provided to start such a survey. The equipment, which will provide measurements of net radiation, upward and downward fluxes of short wave radiation, and photographs from two vertically pointing cameras (one upwards, one downwards) is to be installed on an R.A.A.F. Dakota, and will be operated on routine flights. The instrumentation is now completed and field trials are at present under way.

A combination of two modified net radiometers permitting the measurement of the long-wave balance has been developed. A radiometer of very simple construction and designed for routine use in radiosonde ascents to measure out-going radiation at about 60 mb is at present undergoing tests. It is probable that a modified version of the instrument will have applications in the biological field.

A study has been made of the assumptions behind various empirical formulae used in predicting the amount of downcoming long wave radiation from



Equipment for measuring radiative heat exchange of human subjects.



Net radiometers mounted in the tail of a Dakota.

clear skies. As a result, Swinbank's formula in terms of the 6th power of the screen air temperature has been explained on the basis of known emissivities of water vapour and carbon dioxide after taking account of the correlation between the amount of water vapour in the atmosphere and the surface air temperature. Plans are in hand to examine the validity of this formulation in the extreme regimes found in desert conditions.

VI OZONE

Observations of the total amount of ozone and of its distribution in the atmosphere by the "umkehr" method using a Dobson's Spectrophotometer have been resumed at Macquarie Island. Similar measurements are continuing at Aspendale and Brisbane. Although umkehr measurements are normally only made when the sky is completely clear use is now being made of observations taken under conditions of uniform cloud cover by the application of a correction factor.

Further studies on ozone and weather relationships in the middle latitudes of the southern hemisphere have confirmed the earlier findings. That is to say, total ozone amount is negatively correlated with tropopause height and tropospheric temperature and positively correlated with lower stratospheric temperature. At none of the three sites (Brisbane, Aspendale and Macquarie Island) are there any signs of variation of correlation coefficient with season. However, correlation coefficients are generally smaller at Brisbane than at Aspendale.

An examination of the relevant meteorological parameters at 200 mb has so far failed to reveal that type of oscillation shown by the ozone spring maximum with its periodicity of 24 months. However, it has been noticed that during the period 1957-1962, the higher spring values of ozone occurring during the years 1958, 1960 and 1962 were accompanied by higher temperatures at the 60 mb level.

An interesting relationship between the

mean meridional distribution of total ozone for the European region and severe geomagnetic disturbances has been observed. The latitudinal gradient of ozone decreased to a minimum about 24 hours after the storm, the ozone amount itself decreasing in the region between 50° and 70° N but increasing south of about 50° N.

The computation of the vertical distribution of ozone by "umkehr" method B has been programmed for the CSIRAC digital computer. It is proposed to compute all the umkehr observations currently numbering more than 200 from the three stations, and to study them synoptically.

The development of an ozone sonde of the Brewer type is progressing, an initial exploratory flight having already been successfully carried out.

VII MISCELLANEOUS

The resumption of atomic testing in the Pacific during 1962 provided an opportunity to re-examine features of the radio-active fallout patterns which were observed to follow the 1958 test series. Using considerably improved equipment, the earlier results have been verified. On the average, debris from tests at the equator is detected in Melbourne about 11 weeks after release, whilst the retention of identity by an atomic cloud over a period of several months has again been noticed.

The use of superior equipment has also permitted a detailed investigation of radio-active fallout accompanying individual storms. Preliminary results indicate that fallout during the initial stages of a storm greatly exceeds that during the latter stages. It is hoped that a continuation of this work coupled with radar and radio-sonde observations of the passage of individual storm cells will lead to a greater understanding of the associated circulation pattern and the local interaction between stratosphere and troposphere.

A novel type of anemometer suitable for the measurement of low air speeds (0.05 to 1 m/sec) was designed and constructed for use by the Victorian Department of Agriculture. The requirement was for an instrument capable of measuring the low air speeds around fruit in drying racks. The instrument uses a matched pair of rod thermistors in a bridge circuit with one thermistor heated by a constant current through a resistance winding on it. The bridge out-of-balance current is a measure of the air speed past the thermistors. Suitable circuit design allows the effects of ambient temperature changes to be eliminated in a very simple manner.

Further development of the Sumner long period recorder designed for commercial production has continued, the field trials reported last year on the application of the instrument to record wind speed and direction, evaporation and humidity having been successfully completed. A mast mounted recorder for use by the Department of Civil Aviation has been developed for recording wind elements at heights of up to 50 feet above ground level. Notable features of this instrument are its mobility and capacity to record mean values of wind speed and direction. From the point of view of transport and installation costs it is anticipated that for some purposes the recorder may replace the more usual type of pressure tube anemograph.

The 10 cm weather surveillance radar is now in operation, and is providing information on the structure and lateral extent of rain systems. Although the present range of the equipment is limited to about 40 miles plans to instal an improved aerial system which will considerably increase the range are well advanced. Provision for the installation of a 3 cm wind finding radar is also being made.

The Division's laboratory, which for some time has been registered 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

for the calibration of heat flux plates.

The small group which provides a data processing service within the Division now makes use of the CRL Elliott 803 computer as well as CSIRAC. A universal chart reader has been installed, so that a larger variety of data can be treated, and with greater flexibility. Investigations in which this group has participated include ozone calculations by the "umkehr" method, ozone correlations, upper-wind stress estimation, characteristics of turbulent temperature fluctuations, and lake evaporation calculations.

A modified version of the original platinum resistance thermometer described in the 1961/62 Report and designed for use by the Australian National Antarctic Research Expedition has continued to supply reliable data on the temperature of the Antarctic Ice Cap.

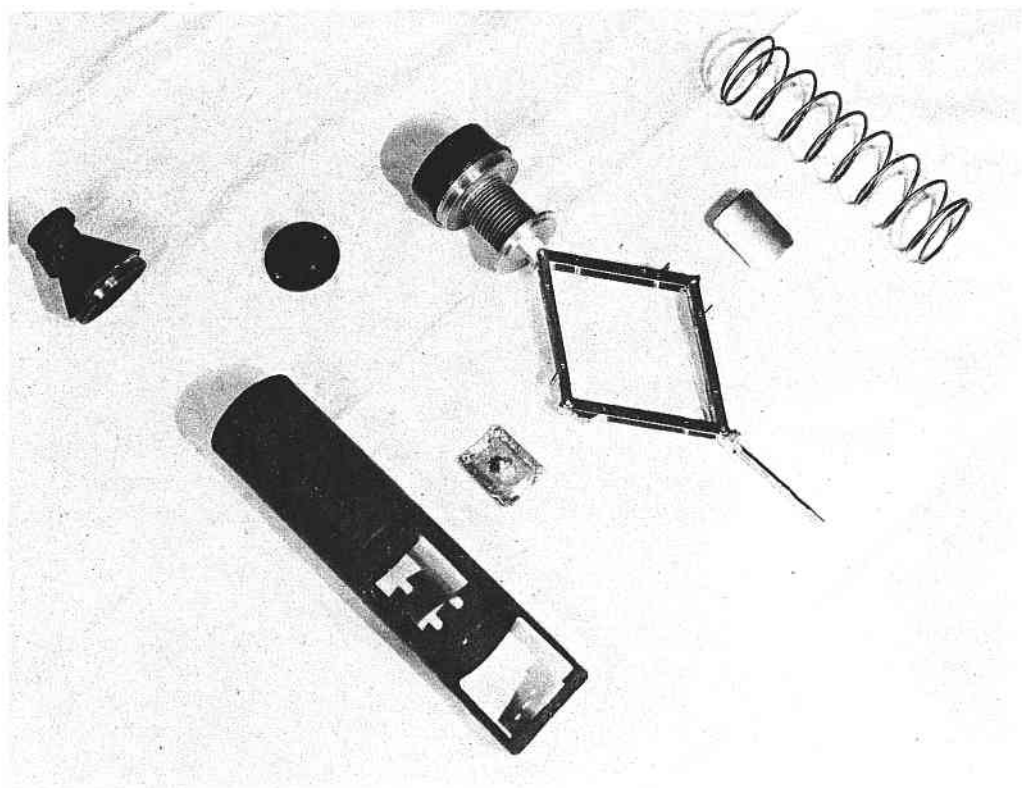
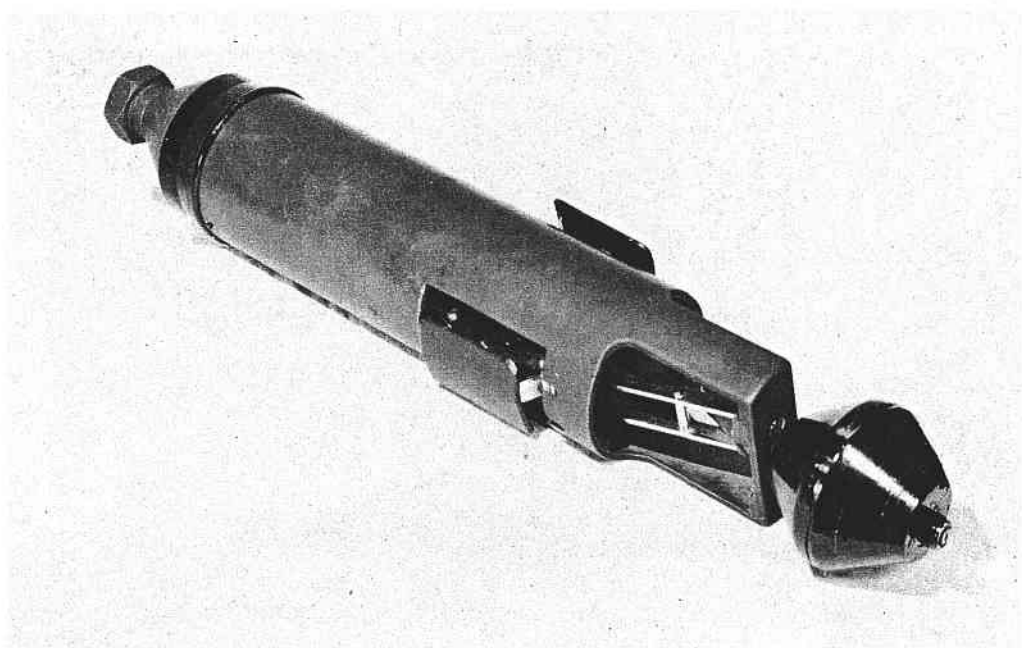
As part of the International Indian Ocean Expedition, equipment permitting the integration of radiation quantities is now ready and awaits installation at Cocos Island and at two coastal stations in Western Australia.

An integrator for multi-channel potentiometric recorders has been developed in such a way as to overcome the spurious counts which normally arise from overshooting.

The Division is collaborating with the Irrigation Research Laboratory, Griffith, in setting up instruments to measure the effect of irrigation on climate at Coleambally.

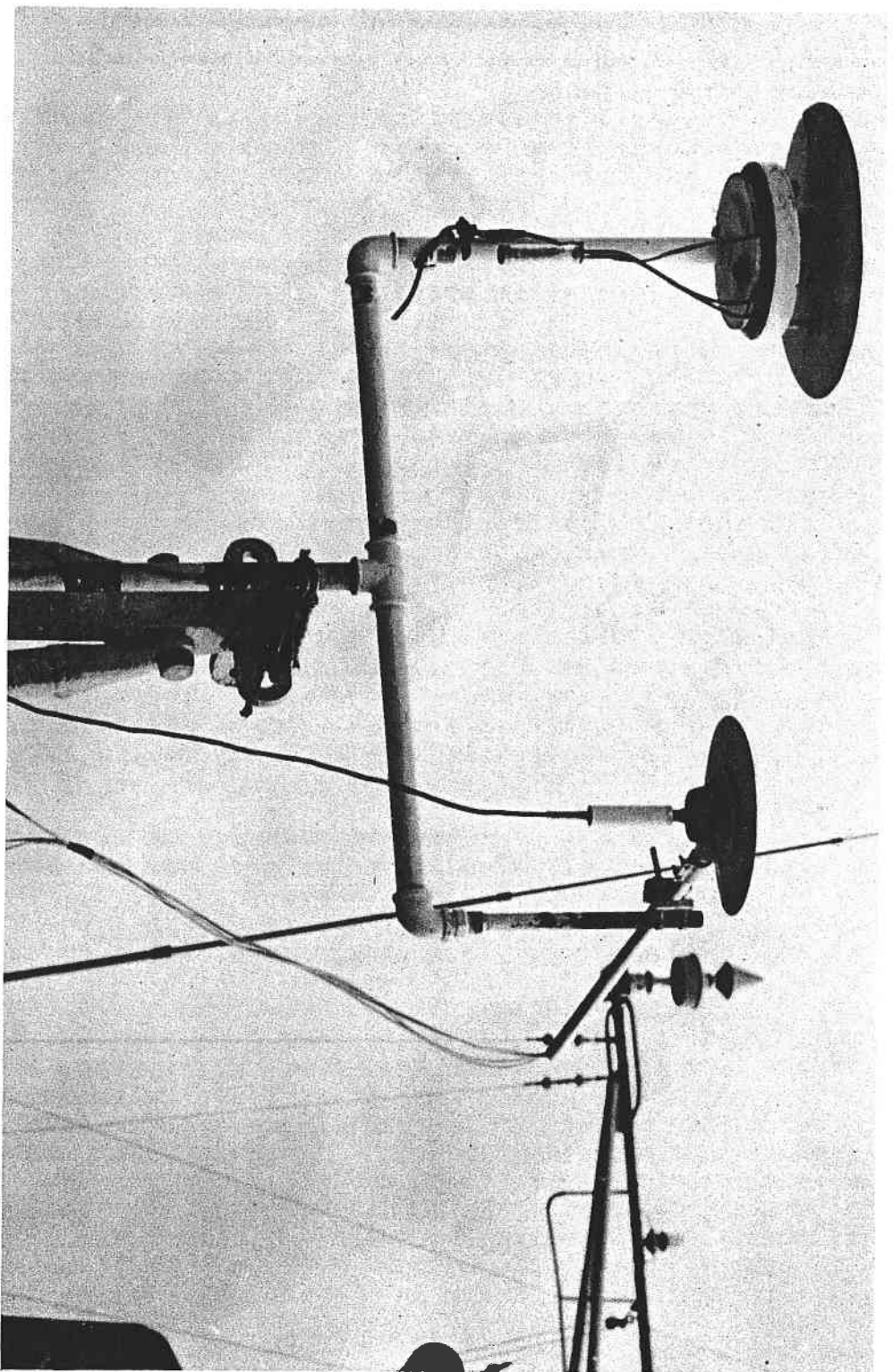
Consultation with the Snowy Mountains Hydro-Electric Authority on the estimation of evaporation from water storages continues.

Working with the Zoology Department of Monash University, a portable 3 cm radar set has been used to investigate the migration of mutton birds from Phillip Island.



The instrument used to measure temperatures in the Ice Cap, Antarctica
Above - Complete, Below - Exploded view.

The International Indian Ocean Expedition: Radiation instruments on board ship.



In collaboration with the Commonwealth Research Station, Merbein, and the State Rivers & Water Supply Commission, an investigation into frost protection of vines by irrigation and rolling in the Merbein area has been concluded, the results being in the course of publication.

VIII ACTIVITIES AND PERSONALIA

Meteorology has always been an international science, and this becomes more evident year by year. During the past year members of the Division have continued to be associated with the various national and international organisations set up 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 the sphere of Oceanic Research, and as a contribution to the meteorological programme of the International Indian Ocean Expedition, members of the Division have taken part in two cruises of the frigates H.M.A.S. "Gascoyne" and "Diamantina" from Fremantle to Singapore and return along the 110°E meridian. The principal object was to secure data on the radiation income of the sea and to relate this to state of sky as recorded by automatic film camera taking exposures at 4 min. intervals. Existing statistics on cloudiness on shipping routes and the wealth of data emanating from TIROS satellite cloud pictures should, together with the new radiation data, considerably improve existing knowledge on the heat economy of the Indian Ocean.

At the invitation of the U.S.A.F. Geophysics Research Directorate, Mr. R.J. Taylor has been working at the Meteorological Research Laboratory, Bedford, Massachusetts on problems of turbulence structure within the lower atmosphere and in the relatively new field of sonic anemometry.

Mr. A.J. Troup has recently concluded twelve months work on analysis at the International

Antarctic Analysis Centre, Melbourne.

At the request of the Meteorology Department, Melbourne University, Dr. D.E. Angus has given an undergraduate course in Micrometeorology for Forestry students, and an expanded postgraduate course for workers in the biological sciences.

In September the Division organized a three-day conference on the microclimate above and within surface vegetation which was attended by about 70 overseas, interstate and local scientists. The topics dealt with plant-environment inter-relations, atmospheric transfer of water vapour and carbon dioxide, general structure and transfer problems above a crop, and radiation and light intensity. A highlight of the conference was the extensive and stimulating discussions which followed the prepared papers.

During the present year, Mr. F.R.E. de Silva is on a tour of duty at Macquarie Island where he has re-installed the Dobson Spectrophotometer and is carrying out routine ozone observations.

From Overseas

Early in the year, Dr. Paul Frenzen, a meteorologist on an extended visit from the Argonne National Laboratory, Illinois, U.S.A. commenced investigations in the inertial sub-range of the turbulence spectrum. Working from the "Spectrum Slicer" on the same problem referred to on page 5, an alternative approach has been developed utilising a device which counts the turbulent fluctuations exceeding specified levels of energy.

Mr. A. Bernstein of the U.S. Weather Bureau has been attached for a twelve months visit investigating flux-profile relationships and the inter-relation between fluxes of different atmospheric properties.

From the Japanese Meteorological Agency, Mr. M. Okamoto, a Fellow of the Australian International Award Scheme, has had his visit extended.

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