

COMMONWEALTH



OF AUSTRALIA

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

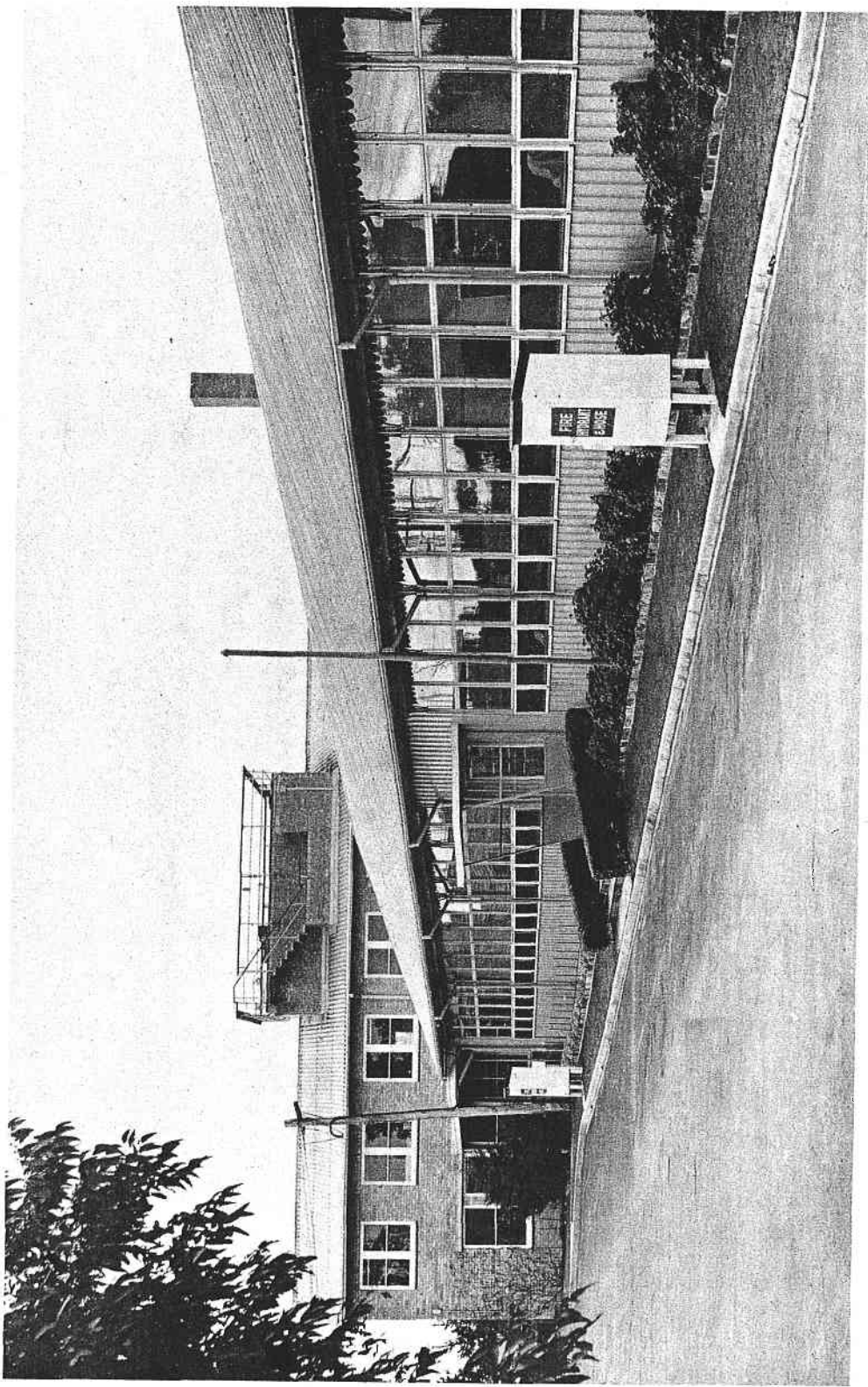
DIVISION OF METEOROLOGICAL PHYSICS

ANNUAL REPORT

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MELBOURNE

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Divisional Headquarters, Aspendale, Victoria.

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DIVISION OF METEOROLOGICAL PHYSICS

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

1961 - 1962

I G E N E R A L

Progress made in the Division's principal fields of interest during the past year is reported and summarised in the following pages. Whilst the primary concern is in the study of fundamental processes in meteorology, considerable attention is devoted to the application of meteorological knowledge to problems of economic importance to Australia, more particularly those arising in agriculture and in the efficient usage of water. Many of the results and techniques deriving from the Division's major field of interest, the study of atmospheric turbulence and exchange processes, here find ready application. Similarly, whilst the group working in Dynamic Meteorology is interested primarily in fundamental atmospheric mechanics, an emphasis is given to problems of particular interest and application to Australia.

II D Y N A M I C A L M E T E O R O L O G Y

Fronts and Inversions

The work on summer fronts and sea-breezes, involving the processing of large amounts of data, is proceeding. The vertical motion fields deduced from pilot balloons have been supported by aircraft results, which yield much greater complexity. The humidity field is often found to be distorted in the manner expected from earlier work with balloons. In co-operation with the Division of Radiophysics, aircraft traverses measuring vertical wind and temperature have been made through the less accessible but in some respects more important, winter cold fronts.

The same aeroplane was used to explore the temporal and spatial variations in the sub-tropical temperature inversion over inland Australia, during a period of rapid increase in turbulent mixing. This work showed the rise in inversion height predicted theoretically and delineated some of the eddies responsible.

Severe Local Wind Storms

Severe local wind storms, on the scale of hundreds of yards, cause considerable structural damage, and occasionally loss of life, in the settled parts of Australia. A survey of all available information on these storms has shown that destructive tornadoes on the North American pattern, although they have been known to occur, are very rare. Most of the storms reported have maximum wind velocity well under 100 miles per hour. The investigation has afforded some insight into the mechanism producing such storms, which are often connected with fronts and thunderstorms, and some rules for their prediction emerge.

Pressure Waves from Explosions

Pressure waves emanating from nuclear explosions were detected at Aspendale, and the time of arrival here and at other world stations related to the global wind distribution. The effective level of the wind was shown by observation, supported by theory, to lie in a height range embracing the tropopause.

Upper Level Wind Streams in the Tropics

Earlier work has shown that variations in the westerly component of wind at 40,000 to 50,000 ft. were linked with the date of monsoon onset and with rainfall. Studies of upper flow characteristics in these regions are limited by sparseness of data, but the computation of correlograms of westerly flow at the 200 mb level has been carried out for a number of stations in and adjacent to the monsoon area. Energy spectra reveal predominant time scales of from

ten to sixteen days, although true periodicities probably do not exist.

Cross correlations in general between adjacent stations in 200 mb zonal flow are small, due to wide separation, and appear to depend on the location of station pairs relative to the mean flow pattern. Lagged cross correlations have been computed for some pairs, and are being examined for their information relating to the dimensions and movement of disturbances.

Association Studies in Australian Rainfall

Developing the use of the association coefficient as a tool suited for a wide survey of simultaneous and lag relationships, a comprehensive analysis has been made of 70 years of monthly values of Darwin rainfall and pressure. A very marked and lengthy persistence in pressure has been verified. The level of persistence in rainfall from month to month is very low, but there is a consistent (negative) association of rainfall with the pressure of prior months, which in several instances appears to lie above or near the margin of usefulness in forecasting. Wider regional surveys between monthly rainfall and pressure of Australian stations, and between simultaneous rainfall in different regions, is in hand.

Ocean Influences

In some places, e.g. the Extended Forecast Branch of the U.S. Weather Bureau, persistence studies such as the above are complemented by physical considerations such as energy feedback from the atmosphere to the underlying medium, especially the thermally active (mixed) layer of the ocean. For countries in the Southern hemisphere with its relatively small land coverage the storage of heat in the ocean should be a particularly important factor in long-range forecasting.

During his stay at the U.S. Weather Bureau Dr. Berson made an investigation, both from data and theoretically, of the effects of anomalous

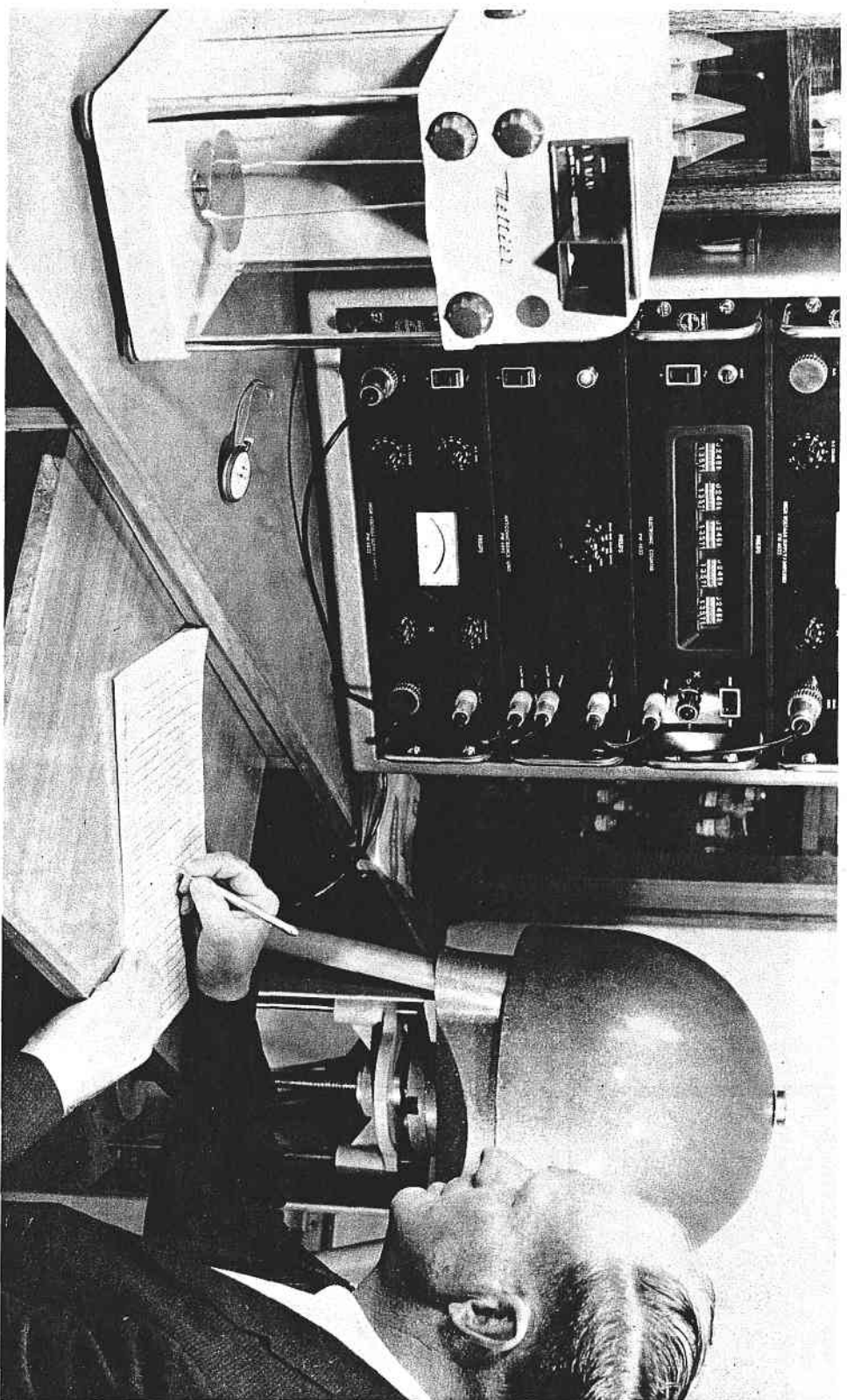
large-scale wind systems on the heat budget of the mixed layer in middle latitudes. Results of this study for the North Pacific Ocean indicate that during autumn and winter flux divergence of heat due to anomalous ocean current activity goes partly into producing temperature anomalies, partly into excess or deficit of heat emission to the atmosphere (conduction and evaporation) in such a manner as to meet the basic requirements for the generation of energy feedback loops.

A theory has been developed for forced thermal waves in the mixed layer. It predicts the time of response or period as a function of the amplitudes of the forcing wind stress and temperature anomalies, and of wavelength. Resonance with the forcing field would occur for retrogressive waves of observed lengths at periods from several months to a few years depending mainly on the stress amplitude and the meridional ocean temperature gradient. The theory helps to explain the remarkable persistence of sizeable sea surface temperature anomalies observed in parts of the Pacific and Atlantic Oceans.

Theoretical Studies

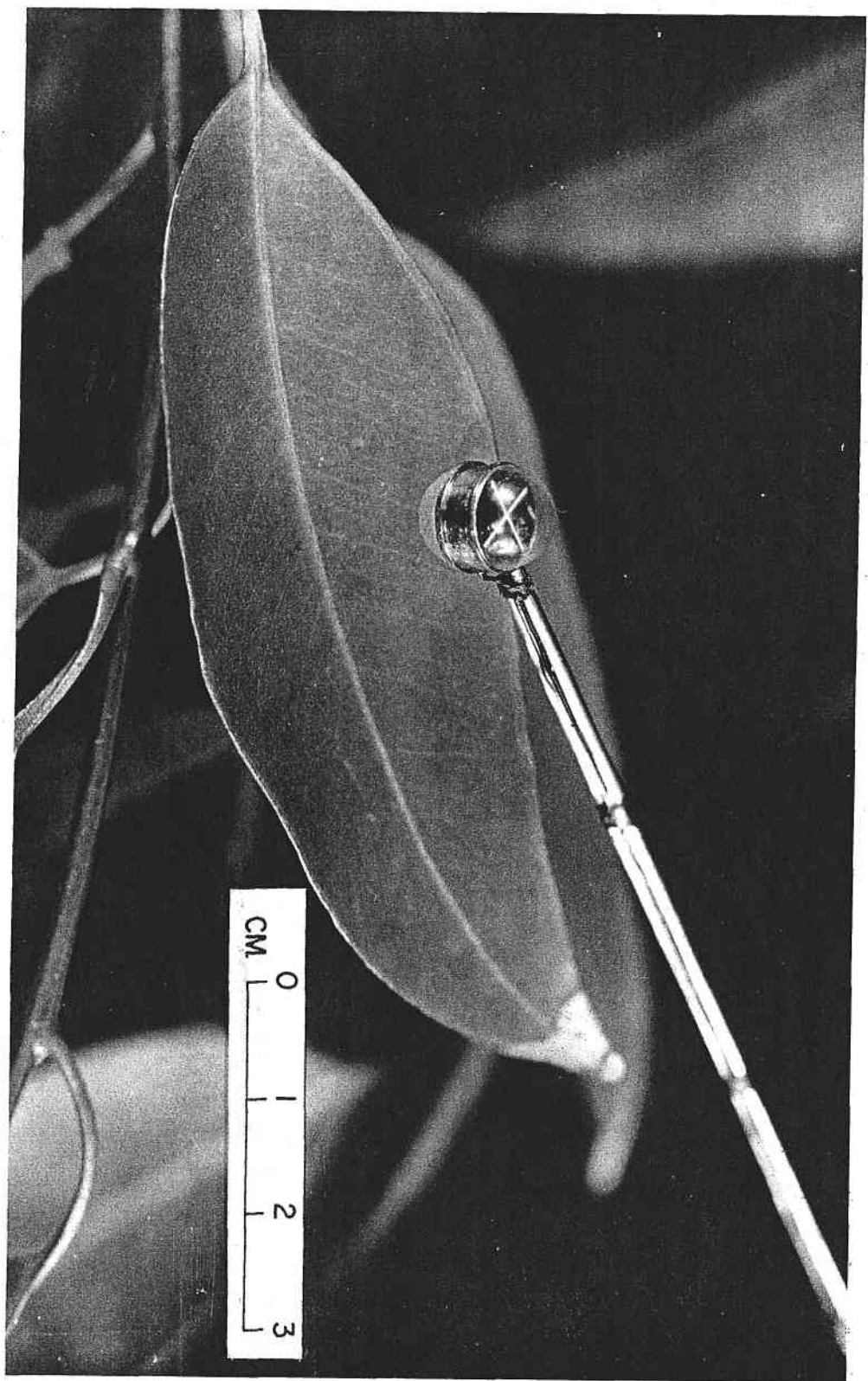
The equations of fluid dynamics, and hence also of dynamical meteorology, are difficult because they contain products of unknown quantities. In most theoretical work these non-linear terms are either neglected or approximated to obtain linear equations, which means that physical phenomena that are essentially non-linear in character may escape theoretical description. Studies on some aspects of the non-linear theory of simple atmospheric motions have brought to light some of these phenomena, for example the occurrence of resonant interactions on a very large scale. These interactions cause a rapid transfer of energy between planetary waves of different wave length and could be associated with the sudden development of a short wave flow pattern.

Wave motions of smaller scale are evidently responsible for some of the complexities in the neighbourhood of cold fronts. One of these is represented by gravity waves moving rapidly along



Measuring the radio-activity content of rain water

Miniature Net Radiometer



a frontal surface and producing marked ground level pressure oscillations. The waves were shown to be unstable, and to be conditioned by dynamic instability of the frontal surface, due to strong vertical shear.

III MICROMETEOROLOGY

The analysis of wind observations secured from cruises of F.R.U. Derwent Hunter has been completed. An important outcome is that the drag of the wind on the sea is found to be very nearly proportional to the square of the wind speed over the range 8-30 knots.

Turbulence theory predicts that, in the inertial sub-range of the turbulence spectrum, certain relationships should exist between the vertical fluxes of heat and momentum and the intensity of the fluctuations of temperature and wind. Instrumentation is being constructed to exploit these relationships for the measurement of the exchange of heat and momentum between the atmosphere and the ocean. Prototype equipment for preliminary calibrating tests over land is reaching completion.

During the summer a series of soundings of wind and temperature structure up to a height of 16 m. was made at a field station near Kerang, some 200 miles north of Melbourne. This expedition was undertaken to elucidate some of the major outstanding problems in the study of the turbulent exchange of properties between the air and the underlying surface and was designed to secure observations of the high quality necessary for this purpose. A prime requirement in such work is a site possessing the characteristics of horizontal uniformity, freedom from obstruction, a well defined surface of short sparse vegetation and absence of larger scale gravity circulations such as sea breezes. The site at Kerang meets this specification, and the valuable body of data obtained in a variety of stability conditions is now undergoing analysis.

Further field trials of the "Evapotron", the automatic instrument for measuring evaporation from natural surfaces, were carried out in mid-1961 at Davis, California in a joint programme with the University of California. The experiments, which were supplemented by observations of evaporation from a large lysimeter, confirmed the ability of the instrument, based on the "eddy-correlation" principle, to provide an accurate measure of evaporation when the extent of uniform fetch is adequate to the height of operation of the instrument (at present 4 m.). With lesser fetches, the indications are proportionately in error, the discrepancy being accountable in terms of horizontal gradients of humidity. These results emphasise the need for sufficient fetch for the instrument or, if this is necessarily limited, the need to work at lower levels with the consequent requirement of faster instrumental response.

Viscous dissipation has been estimated from wind fluctuation records made at three heights on a radio mast near Sale, Victoria, and the variation with height compared with other estimates made elsewhere. For heights up to 100 metres the proportionality between dissipation and the cube of the wind speed has been confirmed.

A theoretical study, supplemented by wind tunnel experiments, has been made of the adjustment of the neutral wind profile to a change of surface roughness. The results obtained indicate that the profile is readjusted up to a height of approximately 0.01 times the distance from the transition.

The problem of thermal convection in the presence of wind shear is being studied theoretically with results showing encouraging agreement with observation.

Reports of persistent heavy dewfalls along the N.W. coast of Australia were investigated during an expedition in May, when dewfall was measured by means of a small weighed lysimeter. Analysis of the results, which appear to confirm the occurrence of heavy dewfalls, is proceeding.

IV METEOROLOGY FOR AGRICULTURE

Lysimeter Installation

This has been the third year of operation of the lysimeters at Aspendale. These comprise twelve cylindrical concrete pots (5'10" diameter, 4' deep) sunk in concrete pits flush with the ground. Five carry a pasture cover, three bare soil and the remainder contain water. In seven cases, evaporation is remotely measured by automatic balances placed underneath the pots, these being sufficiently sensitive to measure the loss in weight over periods less than one hour under strong evaporation. The water loss from the remainder is measured as input minus percolation, but similar balances are under construction for these units.

For comparison, two smaller unweighed grass covered pots alongside have been operating for over a year. These are modified oil drums sunk directly into the ground and, although erratic over periods much less than a month, they have, under conditions of plentiful water supply, proved just as useful as the large units for longer term evaporation studies.

In order to study evaporation under conditions where water supply is not limiting, the lysimeters have been used under frequent irrigation. Certain of the conclusions which have emerged should apply to most irrigated crops. Firstly, evaporation rates have exceeded the radiant energy supply, confirming the importance of advected energy when a moist area is surrounded by drier and warmer terrain. Secondly, long-term evaporation from well-watered mown grass exceeds that from water, and still more that from moist bare soil, probably reflecting the varying ability of surfaces of different roughness to extract energy from the warmer advected air. The reality of the effect is supported by the results of further experiments showing that evaporation rates increase with length of grass.

During the year a more natural regime was

introduced, and a study commenced into the effect of soil moisture depletion on evaporation rate.

Blue Mould in Tobacco

The study of this problem has been continued in the Ovens Valley with the co-operation of the Victorian Department of Agriculture and with the help of a further grant from the Tobacco Advisory Committee. Sufficient micro-meteorological data are now available for a thorough analysis and comparison with pathological observations of the propagation of blue mould. This is now being undertaken.

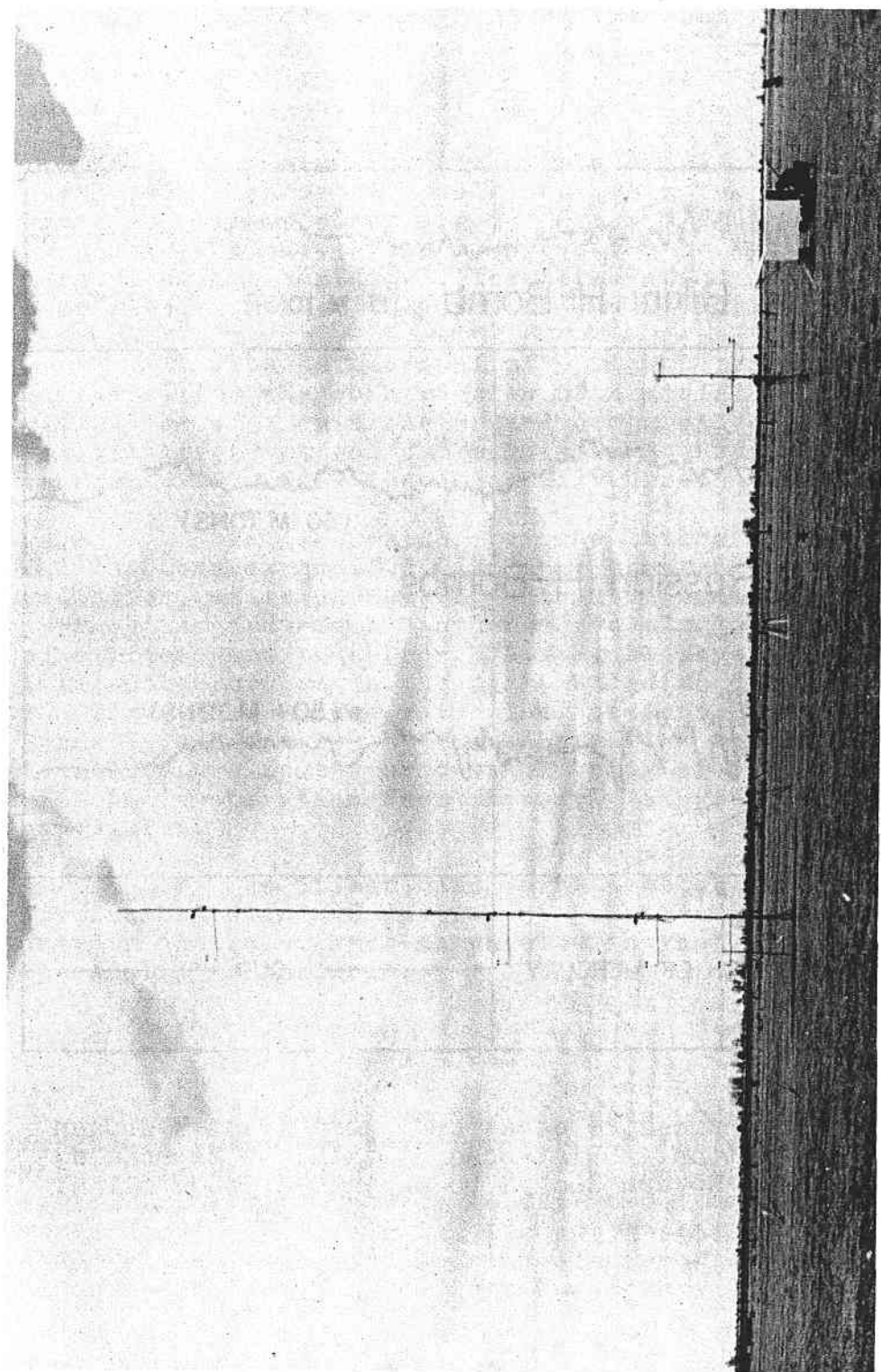
Frost Prevention

Experiments on the prevention of frost in vines by soil treatment have been carried out in collaboration with the Commonwealth Research Station, Merbein, and the State Rivers and Water Supply Commission. Plots were given varied combinations of cultivation, rolling and watering, the experimental work now having been completed and a preliminary assessment of results made. Small but significant reductions in the frost risk are achieved by rolling and by watering, the two in combination providing as much as 1° F improvement in the temperature as measured at screen level.

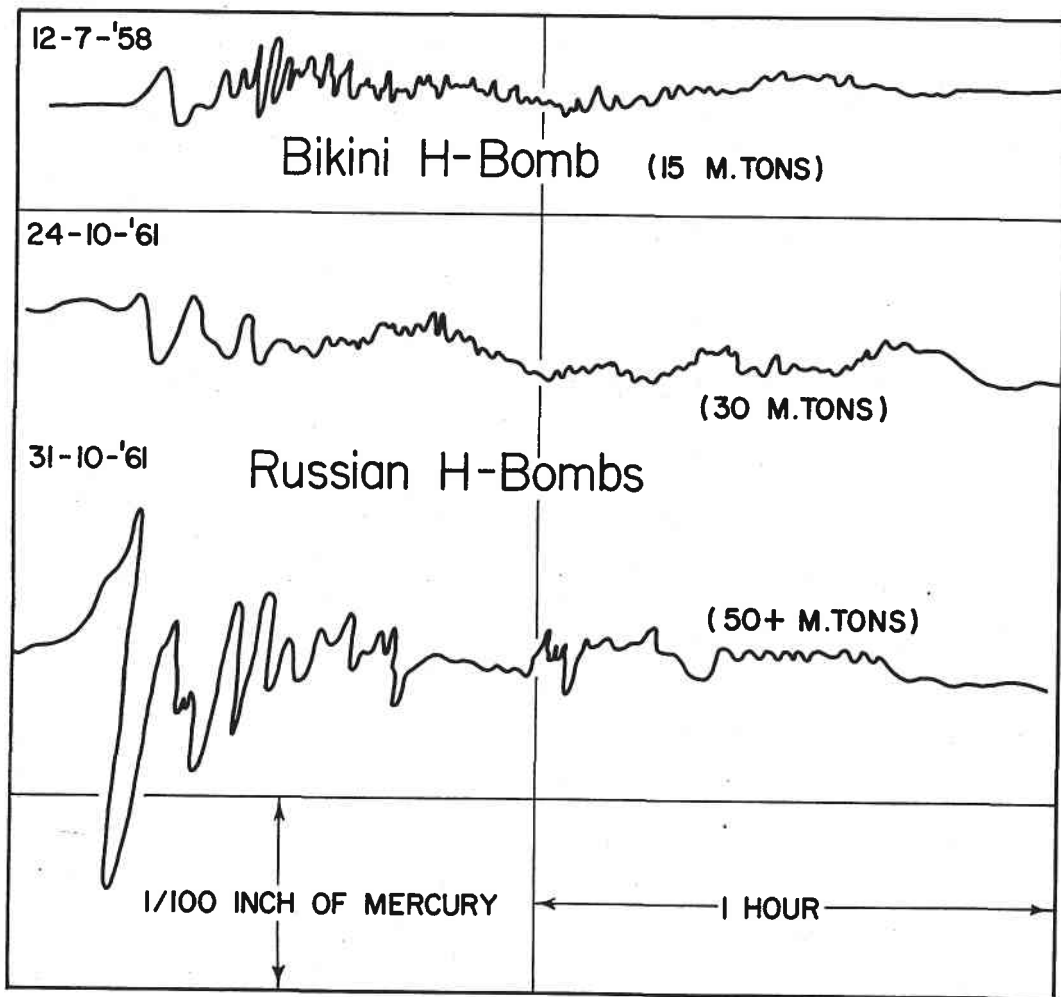
V RADIATION

Further studies of the radiative flux divergence in the lowest 15 m. in the air over open grassland during clear nights have confirmed the previous findings of a maximum divergence at about 3.5 m. Ascribing to haze on such nights the difference between the measured divergence and that computed from the known atmospheric absorption properties, it is possible to determine the vertical distribution of the haze. The necessary computations are now being carried out with the aid of an electronic computer.

Evaluation of the first three years of



Site for micro-meteorological investigations
at Kerang, Northern Victoria



Atmospheric pressure waves from some great Hydrogen bomb explosions. Distances: Bikini to Aspendale, 3600 miles; Novaya Zemlya to Aspendale, 8800 miles.

Aspendale radiation observations has been completed and, after correction to climatological mean hours of sunshine, reveals some differences from figures for this area given in the literature.

An empirical relationship has been developed which provides a close estimate of the sky radiation during clear nights in terms of the screen temperature alone, and which requires no explicit account of the humidity. The formulation applies over wide ranges of temperature and humidity.

The development of a ribbon thermopile has permitted the construction of a miniaturised net radiometer of 1 cm diameter and comparatively high sensitivity ($3 \text{ mv/cal/cm}^2/\text{min}$). This instrument is manufactured under licence in Melbourne.

In preparation for the International Indian Ocean expedition (1962-64) observations of radiation, state of sky (by automatic camera), sea surface temperature and other meteorological quantities were made from H.M.A.S. Diamantina during a two-month cruise in the eastern Indian Ocean and the Timor Sea. Three radiation stations, one at Cocos Island and two at West Australian coastal locations are in the process of being equipped and will be in operation from the early stages of the expedition.

The Silver Disc Pyrheliometer used as the New Zealand standard instrument for their radiation network has been inter-compared with that used for the Australian network.

VI OZONE

A general survey of ozone observations at Aspendale, Brisbane and (for part of the period) at Macquarie Island during IGY and IGC has been made in particular with reference to day-to-day and seasonal variations. The analysis, including that of "umkehr" observations at Aspendale, reveals important differences from the Northern Hemisphere in both

vertical and horizontal distribution of ozone. At Macquarie Island (54°S) the amount of ozone in all seasons exceeded that in lower latitudes and over the Antarctic. Furthermore, there was generally more ozone in the middle latitudes of the Southern hemisphere in summer, autumn and early winter than in the Northern hemisphere, whereas the spring maxima were more or less the same for both.

At all three stations, total ozone amount was generally negatively correlated with the tropopause height and the tropospheric temperature, and positively correlated with the lower stratospheric temperature. There are indications of a 24 month cycle in the total ozone content at both Aspendale and Brisbane, though the period of observation (6 years) is not long enough for positive conclusions.

Studies of the vertical distribution of ozone at Aspendale show that most of the day-to-day and season-to-season variations in total ozone content occurred in the 12-24 km. region. These results are being studied in relation to the transport mechanisms in the lower stratosphere.

Investigation into the vertical distribution by the "umkehr" method has been intensified at Aspendale and is being extended to Brisbane in collaboration with the Commonwealth Meteorological Bureau. It is proposed to supplement these studies with observations from a chemical ozone sonde of the Brewer type now being developed at Aspendale.

Arrangements are well forward to resume observations with a Dobson spectrophotometer at Macquarie Island at the end of this year.

VII MISCELLANEOUS

Measurements of the radio-active content of rain at Aspendale are continuing. The level has been falling steadily since soon after the suspension

of nuclear testing in 1958, no fall out positively associable with the Russian tests of October, 1961 having been detected. Preliminary results following the resumption of American tests at Christmas Island in April, 1962 are in accord with earlier findings following the 1958 series. The installation of special low level beta counting equipment is now completed, which will make possible more accurate determinations of radioactivity, especially at low levels.

The installation of the 10 cm surveillance radar is almost completed, and it is hoped to bring this equipment into operation later this year. Development of the wind-finding radar is being continued concurrently.

A small group within the Division provides a data processing and programming service for the machine CSIRAC which has been used in a number of research projects including studies of fronts, ozone correlations, rainfall correlations and the spectrum of temperature fluctuations.

The Division's laboratory has been accepted by the Council of the National Association of Testing Authorities, and authorised for the calibration of atmospheric radiation instruments. It continues to provide a similar service by approval of the same authority in the field of low-speed anemometry.

Development of the Sumner Recorder for long period unattended operation has continued and several new applications have been worked out. Field trials are now in progress on models designed to record height of water table, evaporation from a standard tank, relative humidity, wind speed and direction, and barometric pressure. Results indicate that these modified models will soon be ready to go into production.

An instrument designed for the integration of small direct current signals (down to 0.5μ amp) has now gone into commercial production.

An improved version of the instrument designed for Melbourne University to measure temperature gradients to a depth of 200 feet in the ice cap of Antarctica has been built and is now installed at Wilkes, where it is reported to be working satisfactorily.

Replacement radiosondes and kites have been constructed and sent to Mawson, Antarctica, for the study of katabatic winds there.

Two electrical resistance thermometers were designed and made for the Department of National Development for the measurement of air temperature from a helicopter in connection with the use of altimeters in a mapping survey.

In addition to the foregoing services, various bodies have been supplied with technical advice or the loan of equipment, inter alia the State Electricity Commission, University of Melbourne Engineering Department, Department of Civil Aviation, School of Public Health and Tropical Medicine, and the Faculty of Architecture, University of Adelaide.

An informal advisory service in the fields of agricultural and micro-meteorology has continued to be used by various Divisions of C.S.I.R.O. and other government Departments, and this year has extended overseas to projects in Tunisia and Egypt.

VIII EXTERNAL ACTIVITIES AND PERSONALIA

Meteorology requires a high level of international activity and organisation, and it touches on other subjects of which the same is true. In each subject the international work is regulated through an appropriate National Committee, and members of the Division took part in the work of the Committees for Hydrology, Antarctic Research, Geodesy and Geophysics, Meteorology, Oceanic Research and Space Research. Officers also continued their services directly on international bodies. In

addition to those noted in previous reports, Dr. C.H.B. Priestley served on the Joint Working Party of the International Antarctic Analysis Centre, and Mr. A.J. Troup commenced a period of nine months as a member of the analysis and research staff of the Centre: Dr. J.P. Funk was appointed to a new WMO Working Group on Special Radiation Instruments and Observations; and Mr. E.L. Deacon to the SCOR Sub-Committee on Meteorology for the International Indian Ocean Expedition (1962-1964).

The year was marked by an increasing exchange of international visits. Dr. R.N. Kulkarni came from the Tata Institute of Fundamental Research, Hyderabad, to take up a Research Fellowship in work on the ozone problems of Australia and the Southern hemisphere. Mr. M. Okamoto, from the Meteorological Training College of the Japanese Meteorological Agency, commenced a period of advanced work and training in the field of turbulence and micro-meteorology. A large number of overseas meteorologists paid shorter visits to the Division for discussions and lectures, among them a number of those coming to Australia for the International Conference on Cloud Physics in September, 1961.

Dr. A.F.A. Berson spent nine months in Washington at the invitation of the U.S. Weather Bureau, working on problems of atmosphere-ocean interaction in its relation to long range forecasting. He visited other groups in the Eastern U.S.A., the International Meteorological Institution in Stockholm, the Swedish Meteorological and Hydrological Institute in Stockholm, and the Malayan Meteorological Service. He and Mr. Webb attended the Pacific Science Congress in Honolulu in 1961.

Mr. E.L. Deacon attended International Symposia on Problems in Turbulence and their relation to Geophysics (Marseilles) and on Climatic Change with particular reference to the Arid Zone (Rome). Between these symposia he visited research centres in Britain and Germany concerned with ocean-atmosphere interaction and attended the meeting of the IAMAP ad hoc Committee on this subject.

Dr. A.J. Dyer spent most of 1961 at the University of California, Davis under a U.S. Signal Corps project concerned with the study of evaporation and acted as consultant for brief periods to other university departments and to the U.S. Department of Agriculture.

Mr. W.C. Swinbank attended the UNESCO Conference on the Methodology of Eco-Physiology at Montpellier, France, and subsequently made a lecture tour of the United States under the auspices of the American Meteorological Society.

Mr. E.K. Webb worked for 8 months on micrometeorological research at Pennsylvania State and Johns Hopkins Universities, supported by funds from the U.S. Air Force, Geophysics Research Directorate, and the Ford Foundation. The return journey was broken for discussion of problems of mutual interest with workers in various institutions in Britain, Germany and Israel.

IX PUBLICATIONS

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