

# ANNUAL REPORT 1965-66

## Division of Meteorological Physics

Commonwealth Scientific and Industrial  
Research Organization, Australia  
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## DIVISION OF METEOROLOGICAL PHYSICS

## ANNUAL REPORT

1965 - 1966

## I INTRODUCTION

To achieve a greater understanding of the fundamental processes of meteorology together with the application of this knowledge to problems of economic importance to Australia constitute the Division's two main objectives. In dynamic meteorology, for example, whilst attention is directed primarily to the basic problems of atmospheric mechanics, prominence is given to matters of particular importance 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 are a consequence of the Division's major field of interest, atmospheric turbulence and exchange processes, can be readily applied.

## II DYNAMICAL AND SYNOPTIC METEOROLOGY

The General Circulation

(a) Heat Balance of the Atmosphere over the Antarctic Plateau. The heat balance requirements of the atmosphere overlying the Antarctic plateau have been further investigated, especially during the spring warming of the stratosphere. Consideration has been given to the processes which govern the vertical transfer of heat and an hypothesis developed that vertical mass transfer almost vanishes at the base of the stratosphere. This level - called the "stratobase" - lies at some distance above the upper Antarctic tropopause where, between 40,000 and 50,000 feet above sea level, some of the world's lowest temperatures occur.

The hypothesis has been tested by determining quasi-Lagrangian rates of heat loss by net radiation in the vicinity of the stratobase as it descends during spring warming. These cooling rates are more realistic and in much better agreement with measurements from radiometer ascents at U.S.A. stations in Antarctica than the losses calculated earlier as heat budget residuals involving an artificial constraint at the highest datum level (75,000 feet). Moreover, using this model the computed

vertical motions in the lower stratosphere help to account for the considerable lag between the spring warming and the ensuing major increase in total ozone.

In evaluating the heat budget in the stratosphere it was also necessary to determine the vertical eddy transport of potential heat in terms of enthalpy flux and the conversion of heat into turbulent kinetic energy. One finding is that in the lower stratosphere these two processes mainly derive from large-scale standing eddies associated with, predominantly, ascending motion over western Antarctica and descending motion over the remainder.

(b) Biennial Stratospheric Oscillations south of the Tropics. Wilkes (at  $66^{\circ}\text{S}$ ) is one of the stations maintained by the Australian National Antarctic Research expedition and has a very good record of upper air soundings. From recently completed statistical processing of five years data (1959-63) directed towards a study of heat and momentum transfers, has emerged evidence for a 24-month cycle in the meridional wind component at 60,000 feet. The dynamic links between the quasi-biennial tropical oscillation and the extratropical two-year cycles in wind, temperature and ozone are now being examined, particularly the alternating modes of spring warming in the Antarctic stratosphere.

(c) The Southern Oscillation. The investigations of the Southern Oscillation described in earlier reports have continued. Mean upper winds for Nandi and Fiji for some years have been computed, and from these and thickness gradients between Nandi and Townsville it has been found that the equatorward meridional wind shear between 500 and 300 mb in the south west Pacific is stronger at times of high Southern Oscillation index. This is consistent with the suggestion made in the 1964/5 report that the oscillation is a consequence of variations in a mean toroidal circulation between the eastern and western hemispheres.

Attention has been given to the variation of zonal wind components with Southern Oscillation index. At Canton Island for example the low level (5,000 feet) winds behave as expected, i.e. the easterlies are stronger when pressure is high over the Pacific and low over Australia. At higher levels (200 mb) the variation is in the opposite sense. This latter finding is further evidence of the extensive influence of the Southern Oscillation throughout the troposphere.

(d) Processes of Handover in Scale. The advance of numerical techniques in dynamic meteorology and the exciting prospects of global observation using satellites are forcing meteorologists to work and plan research, in specific terms, towards a considerable extension of the period of detailed forecasts. Questions then arise as to how the fluxes of momentum and energy to and from the surface, which as purely micro-meteorological processes have received much specialist study, become redistributed through the main depths of the atmosphere by processes of larger scale. The handover of flux between different scales of motion thus becomes a problem of some urgency, though it has not yet been well formulated. Various orientation studies bearing on this problem are being carried through in the Division. These include the changes in the scale and pattern of temperature fluctuations with increasing height in the boundary layer; the variation of geostrophic drag coefficient with stability; the conversion of momentum flux from micro-scale to macro-scale within the boundary layer, which is shown to be in close association with the pattern of horizontal acceleration; and a direct estimation of the vertical flux of momentum effected by the typical complex of meridional front and accompanying anticyclone in the southern hemisphere westerlies. It is hoped that these studies will be reported individually in subsequent Annual Reports and that collectively they will provide valuable leads into the wider problem.

#### Wet and Dry Spells and the Drought

A study has been made of the occurrence of spells of wet and dry months (defined according to whether the rainfall was above or below the median) at 13 stations in Northern N.S.W. and Southern Queensland. Persistence from month to month was found for spells of 3 to 6 months duration but not outside these limits. Further confirmation was obtained from an examination of 12 other stations in eastern Australia. There was only a small excess of the longer spells (5 months or more) above chance expectation, i. e. approximately three-quarters of the dry or wet spells could well have occurred in any random sequence of wet or dry months. However, rainfall being a causal phenomenon the near randomness of its monthly sequences does not exclude the possibility of establishing their association with other variables. For the 13 stations studied an association was found between extensive wet and dry spells (i. e. spells of 5 or more months affecting at least 4 stations) and the sea surface temperature at Port Hacking, in the sense that the dry spells were associated with below average sea surface temperature. It was also found that during extensive dry spells the Papeete-Darwin

pressure gradient was below average and for extensive wet spells above average.

During the recent widespread drought which affected eastern and central Australia, including the stations under examination, the sea surface temperatures - in the early stages at least - were, as would be expected from the results just quoted, generally below average. When temporary relief from the drought came to parts of the east coast in June and July, 1965, the temperatures became above average. However, the Papeete-Darwin pressure gradient did not develop the expected anomaly until some months after the extensive dry spell commenced. This suggests that the drought was associated with other anomalies of atmospheric circulation: accordingly pressure anomalies over a large part of the southern hemisphere including Australia are being examined. 200 millibar wind variations over Australia are also being studied and the work continues.

#### Various

Whilst statistics of wind speed, direction and frequency as well as temperature are considered to be an essential part of climatology, the distribution and behaviour of wind shift lines (mainly cold fronts) are not normally included. However, work has now started on the extraction of ten years data for the Australian region, four years having so far been completed.

Recently the opportunity arose to make an observational study of the growth of a well marked squall line, employing radar, time lapse photography and measurements from a surface meso-scale network. One result was that the line squall moved to the left of the upper wind in accordance with the R.S. Browning model for the northern hemisphere.

Re-evaluation of upper wind components relative to the sea breeze or frontal lines from observations obtained on the Coonalpin Downs expedition of 1961, is being carried out in the light of subsequent experience of afternoon convection and its effects on the reorientation of these lines. This is a prerequisite to publication of this extensive body of data.

Overseas experience has indicated that locust swarming is associated with convergence in the wind field and that the rain often associated with this convergence provides favourable conditions for egg laying. A collaborative study by the Anti-Locust Research Centre (U.K.), the Division of Entomology,

and staff of this Division has been made to define more precisely the synoptic situations associated with the swarming of locusts in eastern Australia.

In response to an enquiry from the N.S.W. Department of Agriculture an attempt was made to characterize those synoptic situations which, during the months of February and March of past years gave rise to an inch or more of rain over two or more consecutive days in the Murrumbidgee Irrigation Area. Such conditions are conducive to epidemics of Brown Rot in peaches. Several synoptic types were found, the principal feature being strong north to northwest winds at 500 mb (20,000 feet).

Visual tracking and plotting of rain echoes observed on the radar has continued and more than three years observations obtained. These are being subjected to statistical analysis and a comparison made of the movement of echoes with upper winds as observed in the Melbourne area.

Time lapse films, and visual observation of the movement of rain echoes over Victoria and the adjoining coastal waters of Port Philip Bay backed up by pictures from the weather satellites TIROS VII and VIII, have been used in synoptic studies of fronts and thunderstorm instability lines.

Bright "angel" echoes - a phenomenon rarely seen on a 10 cm radar - have recently been observed with the passage of dry fronts, the reflection being attributed to the presence of extreme humidity gradients associated with the eddy structure of the front.

### III 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 have continued at Aspendale, Brisbane and Macquarie Island in collaboration with the Bureau of Meteorology and the Antarctic Division of External Affairs. The Dobson spectrophotometer at Port Moresby has been recalibrated and transferred to Darwin. Regular observations of total ozone and its vertical distribution at Darwin began in April 1966 and training in observational techniques given to local Bureau of Meteorology staff.

At Aspendale the direct measurement of the vertical distribution of ozone in the atmosphere using Brewer-Mast ozone sondes has continued with regular weekly flights. Additional flights are made during World Geophysical Interval Weeks. Surface ozone measurement using Ehmert's type of equipment continue to be made daily at Aspendale and Macquarie Island.

To determine the night time variation of total ozone, spectrophotometric measurements are being made at Kerang and Hay. Since the full moon is used as a light source the work is conducted north of the Dividing Range where the night skies are relatively cloud free. The results are being analysed.

An earlier report referred to a 26-month oscillation in the Spring ozone maximum at Aspendale and Brisbane for the period 1954/63. Since 1963, however, the cycle has disappeared. In attempting to elucidate this it was discovered that a similar periodicity existed also for the 100 mb temperatures at Laverton, Hobart and Macquarie Island - but again only for the period 1954/63. Since both these years are ones of minimum sunspot activity it is presumed that these results are connected with the solar cycle. More definite conclusions await the collection of further data.

The contributions from lower and middle stratospheric waves to the variation in ozone on both a daily and seasonal basis have been examined by reference to umkehr data and temperatures at the 100 mb and 20 mb levels. The analysis indicates that the short term changes in ozone are governed not only by lower stratospheric waves but also by middle stratospheric perturbations, which are independent of each other most of the time. On a seasonal basis in the middle stratosphere it seems that changes in ozone content are affected by processes other than that of the well known photochemical one. The mechanisms causing daily ozone oscillations are quite different from those responsible for the seasonal oscillations.

The 1964/5 Annual Report referred to a persistent dip in the ozone concentration and mixing ratio at the 50 mb level over Boulder, Colorado, in March and April 1964. Preliminary attempts to explain the dip did so in terms of ozone destruction by volcanic dust from the Mt. Agung eruption in 1963. Since then a more detailed examination has suggested that a quasi-horizontal advection of air, involving a mass transport of ozone between the equator and  $40^{\circ}\text{N}$  could account for the ozone minimum. Backing this up are independent optical observations which clearly demonstrate the presence of advection at the required altitude.



Plans are well advanced for a series of daily ozone soundings from Aspendale in October 1966 when the Bureau of Meteorology expect to make a series of three-hourly radiosonde releases over a four-week period. During the same period the soundings will be extended to take in Hobart, Mt. Gambier and Adelaide and so make possible a detailed examination of the distribution of ozone during the passage of a cold front.

To further our understanding of the synoptic distribution of ozone in middle latitudes the present ozone network is being expanded by the addition of a Dobson spectrophotometer at Hobart. The instrument has been ordered and it is hoped to install it early next year.

### Radioactivity

The routine measurements of total  $\beta$ -activity in rainfall reported in the 1964/5 Report have continued. Although the maximum in late Spring continues to occur, the level of total  $\beta$ -activity has gradually declined since the last equatorial tests of 1962 - although this must be attributed to radioactive decay as well as removal of material from the stratosphere. Based on some measurements of long-lived isotopes in New Zealand it has been suggested that the level of these is actually rising - a result of earlier Russian tests at high Northern latitudes. This implies a link between the two hemispheres, possibly in the upper stratosphere.

The forthcoming French test series in the South Pacific is expected to provide further information on circulation processes. Plans are in hand to step up the sampling programme at this time, and to start collecting air samples.

Measurements of  $\text{Be}^7$  are now being made on a routine basis by means of gamma ray spectroscopy. This particular element is being studied since, being produced almost wholly in the stratosphere, its presence in the troposphere may be used as a measure of the interchange between these two regions. Monthly air samples are obtained at heights of 80,000 feet and 90,000 feet through the courtesy of the Balloon Launching Station of the Department of Supply at Mildura, Victoria, and weekly ground level samples at Aspendale. Other samples were obtained with the assistance of the U.S. Air Force Weather Reconnaissance Flights at East Sale and Avalon, Victoria, up to the time they ceased operations.

Since February 1966, the Division has been acting as an agency of the Atomic Energy Research Establishment, Harwell, England, in the collection of monthly air samples. This forms part of that Organization's global net-work.

#### IV GENERAL MICROMETEOROLOGY AND EVAPORATION

The analysis of the observations from the micrometeorological expeditions to specially selected sites at Kerang and Hay are now almost complete. In particular, the results show that the transfer mechanism for the vertical transport of water vapour from an evaporating surface approximates to that for the transfer of heat, both differing from that for momentum in the sense that the transfer coefficients for the former are greater in lapse conditions.

A number of predictions based on dimensional arguments have been confirmed by the observations. Some of these relationships are useful in checking the consistency and quality of observations for individual expeditions and as between one expedition and another, whilst others have more direct application. For instance, it is possible from one of the dimensionless relationships to estimate the vertical flux of heat given the temperature at two levels above the surface and the wind speed at one level which, the formulation being dependent on a low power of the wind speed, does not require great accuracy in measurement.

Earlier reports have referred to the Division's contributions towards progress in the central micrometeorological problem of determining the basic flux-profile relationships in the lowest few tens of metres of the atmosphere. In particular, the Kerang and Hay expeditions, in which careful attention has been paid to the rigorous experimental requirements, have yielded a large volume of valuable data.

A major difficulty of the problem lies in the proper interpretation of experimental data, particularly as the various unknown quantities which have to be evaluated are interrelated in a complicated way. It has been found possible to overcome this difficulty to a large extent, by developing a scheme of profile analysis methods which have "high resolving power", i.e. which are capable of isolating each required quantity with maximum sensitivity and with minimum sensitivity to errors in other imperfectly known quantities. By applying these methods to the available high-quality data, relationships have been derived which can be adopted with confidence as a basic formulation.

In an independent test, fluxes estimated from measured gradients, using these relationships, were found to be in excellent agreement with measured fluxes.

Knowledge of the basic relationships has two main applications: as a guide towards a better understanding of the physical processes involved, and in the practical evaluation of fluxes from profile measurements, e.g. in determining evaporation from land or water. In addition, such knowledge is needed in certain particular lines of investigation, two of which are currently being pursued. First, the simple bulk aerodynamic formula for evaluating evaporation from a natural water surface has been extended to cover thermally stratified conditions, and tests of the generalized formula are now being carried out using the comprehensive data of the well-known Lake Hefner (U.S.A.) 1950/51 investigation. Second, the operating formulas for the "spectrum slicer" are being generalized so that the instrument may be used in thermally stratified conditions.

Last year's report mentioned the difficulty caused to solar astronomers through "shimmering" of the image as a result of temperature fluctuations in the lower atmosphere, relieved on some occasions by brief but useful periods of excellent seeing. In discussing the meteorological/optical relationships, it was suggested that the spells of temperature quiescence which are encountered when the wind is not too strong should generally be accompanied by excellent seeing if the line of sight slants upwards in the wind direction, but not if its azimuth departs appreciably from the wind direction. A pilot experiment to test the suggested relationships was conducted, in collaboration with the CSIRO Division of Physics, during the March 1965 Hay expedition. Analysis has now been completed, and the results confirm both the occurrence of good seeing during periods of temperature quiescence and the suggested relationship with wind direction. This work helps to establish a firm basis for specifying the meteorological conditions favourable for solar observing.

To find out the effect of weather on the propagation of micro-waves over a water surface, a preliminary study was made during the summer months of the refraction of a radar beam over Port Philip Bay by measuring the intensity of a signal reflected from a pile light some 20 miles away. Although at the time the new antenna system had not been installed, an encouraging degree of correlation was found between echo intensity and air-sea refractive index differences. The work continues.

In the 1963/64 Annual Report, it was mentioned that the instrument designed to measure eddy fluxes in the lower

atmosphere - the Evapotron - had been brought to an advanced state of development. A technical paper describing the technique has been released.

In a further development a new instrument based on the same principle now permits measurements of sensible heat flux to be obtained very simply. The new instrument, called the 'Fluxatron' to distinguish it from the parent, consumes only 2 watts of battery power and is suitable for operation by relatively unskilled personnel. The read-out appears on a single counter as a direct reading of the sensible heat flux.

Extension of the technique to the measurement of the evaporative flux presents no difficulty in principle, but calls for a fast response humidity sensor. Fine-wire wet bulbs were employed in the Evapotron for this purpose but other devices are being explored to see if a satisfactory method can be achieved more simply.

An elementary theory of the thin thermal boundary layer of natural water surfaces, referred to in an earlier report, has been completed. Under commonly encountered conditions, with wind speeds up to a few metres per second, the theory indicates a skin thickness of about 1 mm, and a temperature difference across it of 0.25 to 1 deg. C; with increasing wind speeds, both the thickness and the temperature difference diminish. These theoretical results are in general agreement with the meagre observational evidence available. The results have a direct practical application in the evaluation of lake evaporation by current methods. In these, a knowledge of the true surface temperature is called for, whereas for practical reasons the actual measurement of temperature must be made just below the surface. Fortunately, the percentage error is smallest when the wind is strongest, i.e. generally, when the evaporation is greatest.

In last year's report reference was made to a project involving the energy and water balance of glaciers and snow covered regions. This work has continued and a specially constructed snow lysimeter is currently undergoing weathering trials at Mt. Buller. It is hoped to obtain initial measurements later this winter.

## V AGRICULTURAL METEOROLOGY

### The Lysimeter Installation

The Division maintains twelve large weighing lysimeters (2 sq. metres in area, 1.1 metres deep and 6 tons in weight) filled either with water or soil carrying a crop. Continuously and automatically weighed to 1 part in 140,000, they are employed to study evaporation from natural surfaces. During the first six years of their life a detailed study of water loss from irrigated pasture was made. Two final reports which deal particularly with the change in relative evaporation rate as the soil dries out are now nearing completion.

At the beginning of the year half the lysimeter area was planted to potatoes - a typical row crop - the whole area being subjected to frequent irrigation to maintain evaporation at the potential rate. First indications are that such evaporation is often significantly higher from a potato crop than from a pasture.

Pasture evaporation has been successfully estimated by means of the well-known energy balance and combination methods involving measurements of standard meteorological parameters. From the data so far available it seems likely that such methods may be equally effective with potatoes - at least during the more important stages of growth.

Complementary to the lysimeter investigations has been a series of measurements related to the physiological activity of potato plants designed primarily to improve assessment - as distinct from direct measurement - of crop evaporation. For instance, from a study of the short term variations of such variables as turgidity, water potential, leaf temperature and stomatal diffusive resistance, it is hoped to establish a relationship between them and the plant internal conductance function which enters into one form of the combination formula. Weather conditions likely to affect crop behaviour, especially growth rate and water consumption together with various agronomic properties such as ground coverage are also being followed from day to day.

The hydraulic lysimeter mentioned in the 1964/65 Annual Report has been successfully tested, there remaining only the long term stability test. The instrument, which is of simple rugged construction and inexpensive to produce, requires no power, is not significantly affected by ambient temperature fluctuations and functions reliably to within 0.01" rainfall.

A provisional patent, a prerequisite to the issue of a licence to a commercial manufacturer has been taken out, and an instrument is currently under construction for the Bureau of Meteorology.

### Climatic Effects of Irrigation

As mentioned in earlier reports, the Division is collaborating with the Irrigation Research Laboratory, Griffith, in continuous measurements at Coleambally, N.S.W., over a period of a few years, to evaluate the effect of irrigation on climate. The data obtained so far are now being prepared for comprehensive statistical analysis.

From general considerations of energy balance it may be argued that there will be a rather sharply defined upper limit to which the (screen) temperature will rise above a wet area of sufficient extent. A study of world wide climatic data has been carried out with this point in view, and has identified the limiting temperature as  $92^{\circ}\text{F}$  ( $\pm 1^{\circ}\text{F}$ ). The average daily maximum temperatures, over monthly periods, have been examined and are found to lie within a few degrees below this limit both widely and frequently; higher values are extremely rare. Under drier conditions there is no sharp upper limit and observed values extend well beyond  $110^{\circ}\text{F}$ .

### Transpiration Reduction

The possibility of reducing crop water loss by chemical treatment of the foliage or soil has extremely important implications for agriculture. The glass house trials referred to last year have continued, and confirmed the feasibility of reducing plant evaporation losses, both by spraying leaves with certain types of silicone fluid and by the application of plastic materials. With the soil maintained at field capacity, each treatment significantly reduced transpiration but had little effect on photosynthesis except with heavy applications of silicones, where there was some evidence of plant damage.

As soil moisture content decreased and transpiration from the untreated plants was reduced because of closed stomates, water use differed little between treated plants and controls. However, as the soil dried out still further, the treated plants with their previous lower water use took longer to reach wilting point than the controls.

## Blue Mould in Tobacco

Experiments on the control of Blue Mould previously reported have continued. Daily weather forecasts supplied by the Bureau of Meteorology are used to decide whether test plots shall be sprayed and the incidence of mould on these plots is compared with that on other plots, sprayed either according to different routines or not at all. Unfortunately, relatively little progress has been made during the last few growing seasons as there has been virtually no Blue Mould in the area. Nevertheless, it is proposed to continue to at least the 1966/67 season. The work is being carried out jointly with the Victorian Department of Agriculture at the Tobacco Research Station, Ovens, with financial assistance from the Tobacco Advisory Committee.

## General

Preliminary tests have been carried out on a pilot-model instrument known as an energy partition evaporation recorder designed to record continuously the evaporation from a natural surface. The technique employs a modified form of the well-known energy balance or Bowen ratio method of determining evaporation, the instrument performing all necessary operations automatically. Results have been most encouraging and modifications are planned to make the instrument more compact and suitable for field use.

## VI RADIATION

A study has been made of the effect of Doppler broadening of spectral absorption lines - a consequence of the velocities of the molecules. It shows that for gases uniformly distributed in the atmosphere the Doppler broadening may be neglected even when it is several times greater than that caused by the gas pressure. The theory of the Elsasser absorption band which is applicable to a set of pressure broadened lines has been extended to purely Doppler broadened lines. To evaluate absorption parameters for atmospheric carbon dioxide a very efficient computer routine has been developed. For example, the absorption coefficient for the important infra-red 15 micron band is affected by some 2,000 individual lines so that accurate calculation needs to consider about 10,000 wavelengths. The programme developed can accomplish this on a CDC 3600 computer for one set of conditions in less than 10 minutes. In conjunction with experimental data this should lead to a more exact knowledge of atmospheric radiation processes with particular reference to the higher atmospheric levels where conditions are very different from those in the laboratory.

A knowledge of the energy received on a horizontal surface from sun and sky and its distribution between the various wavelengths is useful for several purposes such as the determination of the turbidity characteristics of the atmosphere, available natural illumination and studies of photosynthesis in plants. Equipment to determine this distribution based on a locally made monochromator has been designed and will shortly be operating. It will provide records of the energy at intervals of one millimicron from 380 to 780 millimicrons, i.e. the visible spectrum (420 - 700 mμ) as well as some of the near ultra-violet and infra-red. These records are obtained on digital magnetic tape thereby permitting a CDC 3200 computer to be used for all data reduction. The equipment, completely automatic in operation, will scan the spectrum at intervals of 7 minutes throughout the daylight hours.

The last Annual Report described the effects on radiation values of the volcanic dust which permeated the earth's atmosphere following the eruption of Mt. Agung, Bali, in 1963. These initial inferences were based on observations made at Aspendale. A survey on a global basis is now under way, preliminary results showing that the northern hemisphere received considerably less dust than the southern hemisphere.

Radiometer calibrations by comparison with secondary standards have hitherto been made using sunlight as the radiation source. This often results in considerable delay owing to the need to await suitable conditions, i.e. clear sky and little haze. However, arrangements are now in hand to install a Xenon arc lamp as a source of radiation sufficiently similar to sunlight for calibration work. The lamp itself is due for delivery shortly and the associated power supplies are being constructed in the Division.

The comparison of four different types of net radiometer, conducted under the auspices of the C.I.M.O. Working Group on Radiation Instruments for General Use, has continued. The German Schulze and British Kew instruments, which are respectively polythene shielded and mechanically ventilated types, were installed at the beginning of 1966 and hourly records from all four pyrrometers are now being taken.

Ultra-violet radiation in the wavelength 0.30 to 0.38 microns is of interest both for its erythral effects on the human skin and for its effect on the weathering of building materials. Facilities have been accorded to the University of Queensland to install an instrument at Aspendale to record this radiation, and the results obtained will be compared with those from similar



equipment in New Guinea and Brisbane. Simultaneously, ultra-violet measurements are being made by an instrument constructed in the Division's laboratory, based on standard pyranometers fitted with suitable glass filters.

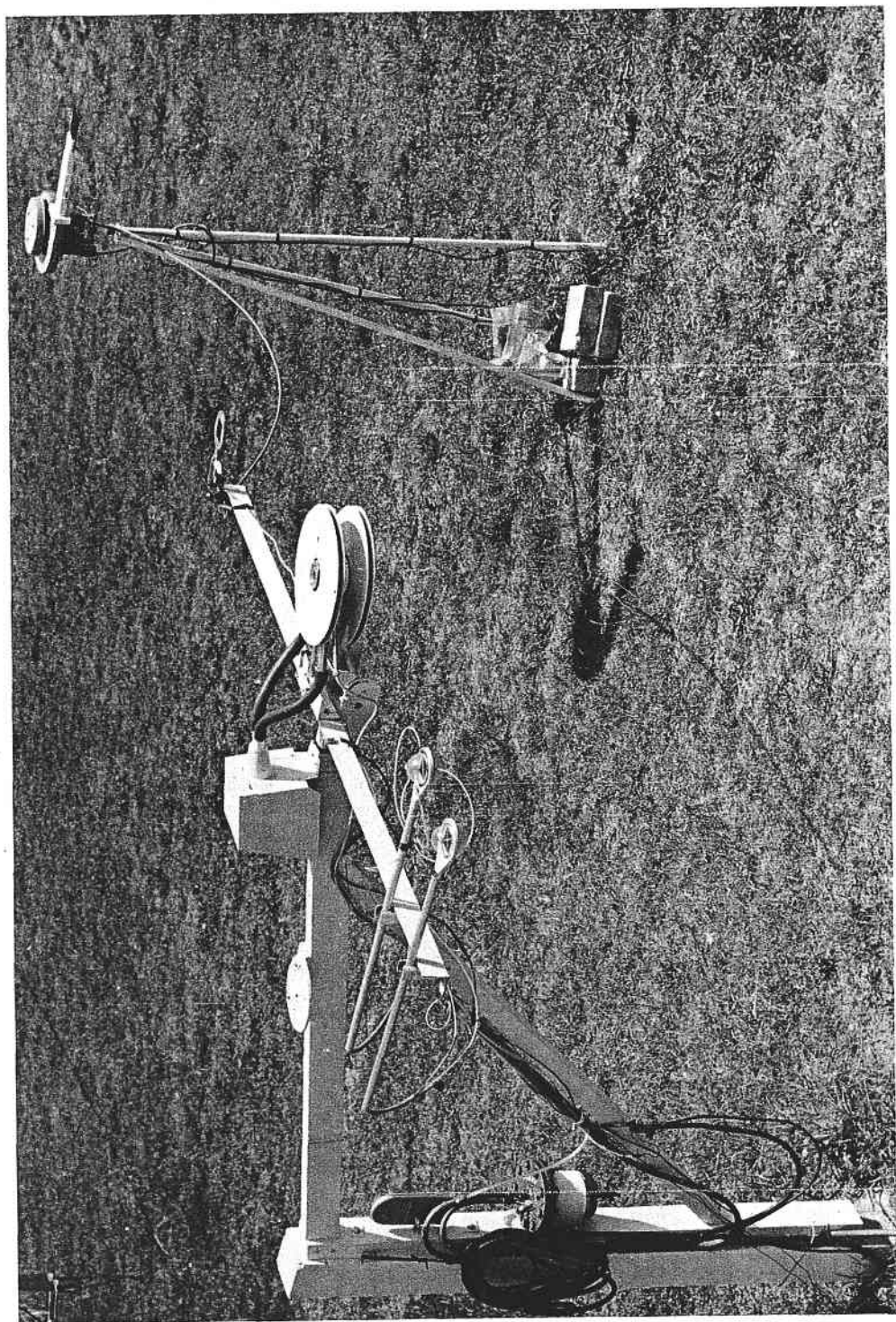
Two new types of radiometer have been developed in the Division. The first instrument converts net radiation to frequency, this being obtained from the difference frequency of two temperature-dependent quartz crystals. An output of this nature avoids problems which can develop in ordinary radiometers as a result of small inductive or thermal voltages, and also enables use to be made of a simple counter to integrate the radiation over a long period of time. Work is now proceeding on the construction of a solarimeter based on the same principle.

The second instrument is noteworthy for the simple design of its element: wire is wound on an anodised aluminium plate and the whole assembly painted black. The plate is mounted at the end of a slightly larger tube, through which air is blown. The air, escaping through the annular gap so created, forms a perpendicular curtain around the plate protecting it from the disturbing effects of natural ventilation. It has been successfully checked against a standard polythene shielded net radiometer: the magnitude of the temperature and windspeed effects are now being assessed.

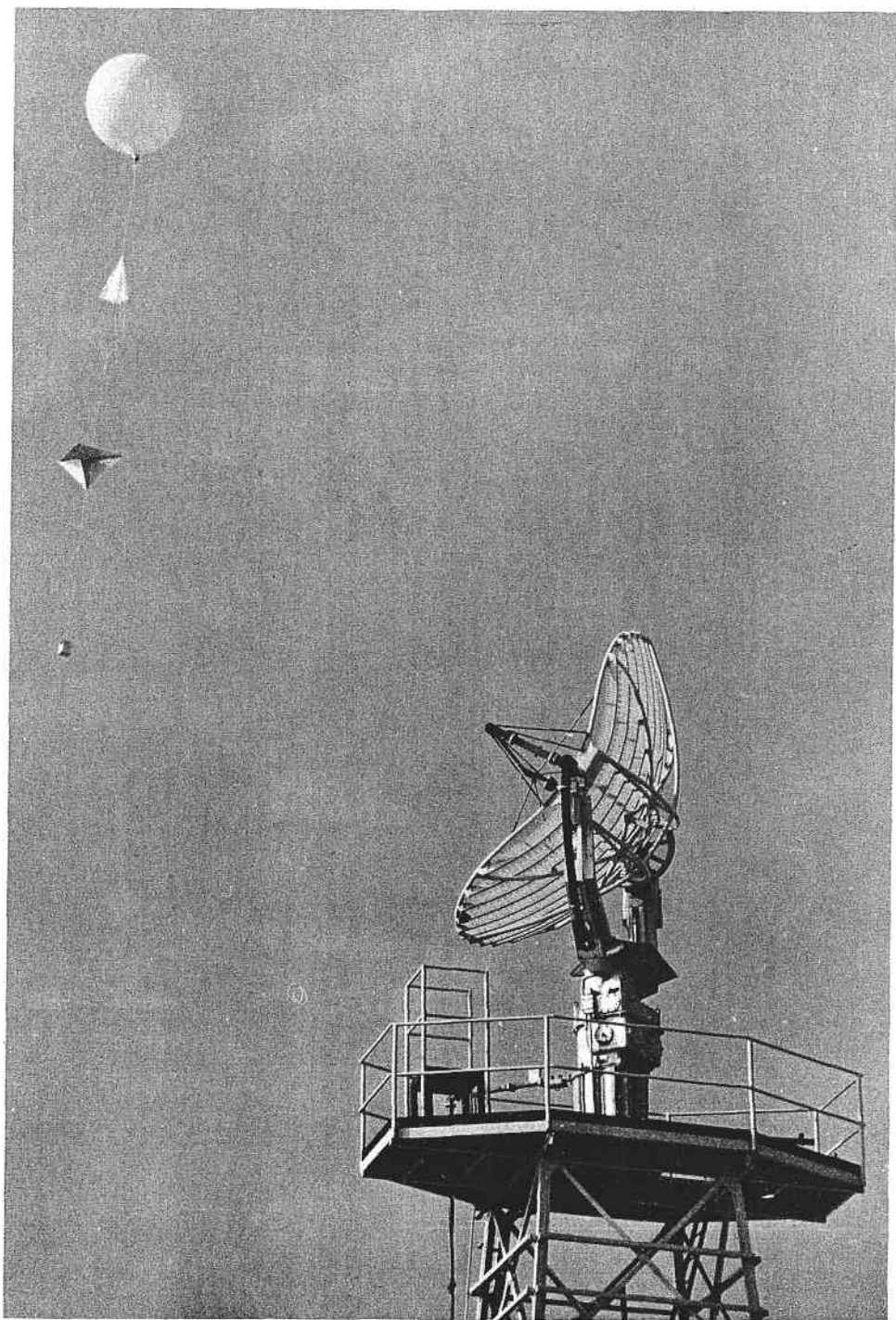
The radiation measurements made under a variety of weather conditions from an R.A.A.F. aircraft over western Victoria and the adjoining coastal waters of Bass Strait, have continued and the total of 50 hours records so far accumulated are being evaluated. The elements measured are net radiation, downcoming and outgoing short wave.

## VII MISCELLANEOUS

Development within the computation and data processing group over the past year now enables it to take full advantage of the facilities provided by the CSIRO computing network, and thereby increase the effectiveness of its service to the Division. In particular, the Division's card punching and analogue-digital conversion equipment have facilitated the automatic processing of much observational data. Standard programmes for a variety of types of calculation have been developed and include for example correlation, spectral analysis, linear regression and curve fitting. Plans for further development are currently directed towards the use of magnetic tape as the most efficient medium for both computer input and high speed data recording.



Aspendale is one of four world centres carrying out a comparison of net radiometers.



An ozone sonde and the 10 cm radar used to track it.

During the year, the group has processed data from a number of investigations, including the statistical analysis of high level wind and temperature observations, a comparison of the transfer mechanisms for heat and water vapour from micrometeorological measurements made at Hay and Kerang, the seasonal and other variations in the distribution of ozone in the upper atmosphere, spectral analysis of vertical wind fluctuations from aircraft motions, and the distribution of radiation under varying conditions of terrain and weather obtained from airborne radiometer measurements.

Currently under way is a collaborative study between the Division of Radiophysics, the Meteorology Department, Melbourne University, and this Division on vertical air velocity components obtained from aircraft and associated ground based observations made simultaneously. The records, made at heights ranging from 50 to 5,000 feet, are being subjected to spectral analysis and a good body of data on the turbulence which an aircraft might expect to encounter in these layers is expected to emerge.

In April, 1966, a new antenna - a  $2\frac{1}{2}^\circ \times 3\frac{1}{2}^\circ$  paraboloid - was installed on the Division's 10 cm radar. Whilst this is not yet fully operational it is sufficiently so for the routine observation of rain echoes, referred to elsewhere in this report, to be resumed. It is already clear that the new antenna gives much better sensitivity and resolution than the early version and rain echoes have been detected and followed at a range of over 200 miles. Work is now in hand to provide additional display facilities.

To assist the Bureau of Meteorology in a study of "sea clutter" observed on radar over the adjacent coastal waters of Port Philip Bay, synchronous observations were made with the radar at agreed times.

A new balloon filling building has recently been completed at the Division's experimental site: it will permit high altitude balloons to be launched in all but the most extreme weather conditions.

To overcome the effects of stray interference such as radio and television transmissions on the testing and calibration of sensitive equipment, a shielded room, electrically continuous and consisting of two integral shells has been built.

To provide a bigger working area and also enable large cup anemometers to be calibrated more satisfactorily than is possible at present with the Division's existing wind tunnel, a new tunnel with a 50% increase in cross section area has been designed: construction in the Division's workshops is well advanced. The tunnel, of the open circuit variety, is 38 ft. long and has two working sections in tandem - the larger working section accommodating air speeds in the range 0 - 15 m/sec while the smaller is suitable for speeds up to 25 m/sec.

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.

Recently the radiosonde frequency allocated to the Division was changed from 72 mcs to 402 mcs. Accordingly, all relevant facilities have been modified, and to provide reception under all conditions, a steerable antenna, as well as vertical pointing and omni-directional systems constructed and installed. The new sonde has also been adapted to marry in with existing airborne ozone measuring equipment.

As part of a raingauge comparison programme sponsored by the World Meteorological Organization, the Division has installed on its observational site, for the Bureau of Meteorology, an international raingauge and an Australian gauge: readings were commenced in December.

The battery-operated microclimate installation mentioned in the last Annual Report, and designed to record various meteorological elements in a eucalypt forest, is now in operation and a joint paper describing it in preparation.

During the year instruments have been lent to the Army Design Establishment to assist in measuring simulated solar radiation in tropical testing chambers, and to the Commonwealth Department of Works to measure solar heat gain through double glazed windows.

Temperature and humidity measuring equipment has been lent to the State Department of Agriculture in connection with an investigation into the incidence of Brown Rot in peaches at Tatura, Victoria.

The Division has continued to advise various bodies on the estimation of evaporation from open water surfaces, as well as meet requests for routine weather observations.

### VIII ACTIVITIES AND PERSONALIA

Always an international science, meteorology continues to grow rapidly in this respect. Members of the Division have continued their association with various organisations, both national and international, which have been formed 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.

Dr. C.H.B. Priestley, Chief of the Division, left Australia in April for Geneva. He attended the third session of the W.M.O. Advisory Committee of which he was elected Vice-Chairman, and the second meeting of the ICSU/IUGG Committee on Atmospheric Sciences. On the return trip he paid brief visits to centres in London and Washington to discuss new approaches to problems in meteorological research.

Last year Mr. W.C. Swinbank attended a symposium on the meteorological results of the International Indian Ocean Expedition and presented an invited paper entitled "Air-sea Interaction". The symposium, held in Bombay, was sponsored jointly by W.M.O. and U.N.E.S.C.O.

In August Mr. R.H. Clarke left for the U.S.A. En route to Washington, where he is spending about a year in the Geophysical Fluid Dynamics Laboratory of the U.S. Weather Bureau, he made a three weeks visit to the National Center for Atmospheric Research, Boulder, Colorado. He is working on computational studies of the general circulation with special reference to the Southern Hemisphere.

During September Dr. A.J. Dyer spent a month overseas, the primary purpose being to present invited papers to the U.N.E.S.C.O. first International Symposium on Eco-Systems at Copenhagen, and the C.A.C.R. Symposium on Atmospheric Chemistry, Circulation and Aerosols at Visby, Sweden. Whilst abroad he took the opportunity to visit a number of scientific institutions engaged in upper air tracer studies and micro-meteorology both in the U.K. and U.S.A.

Spending an initial two months with the U.S. Weather Bureau in Washington, Mr. B.B. Hicks is currently overseas on a temporary appointment with the Argonne National University, Chicago. His interest is in the use of radio active isotopes as tracers of atmospheric motions.

Since September, 1965, Mr. R.J. Taylor has been on secondment to the Department of Meteorology, University of Melbourne, where he is a Senior Research Fellow in Aeronautical Turbulence.

The post-graduate course of lectures in Micrometeorology at Melbourne University continues to be given by Dr. D.E. Angus.

Professor J.A. Businger, on sabbatical leave from the Meteorology Department, University of Washington, recently spent four months with the Division working on the transfer processes of momentum, heat and water vapour in the lower atmosphere.

Mr. Mensah, Agricultural Extension Officer, and Mr. Nahyi, Irrigation Agronomist, both from the Ministry of Agriculture, Ghana, spent six weeks with the Division studying water movement in the soil-plant-atmosphere system. They were in Australia as Fellows of the Special Commonwealth African Assistance Plan.

During February the Division arranged a conference on Instrumentation for Plant Environment Measurements. The main purpose was to enable the increasing number of physicists and biologists who are concerned with instrumentation for environmental studies to come together and discuss on the one hand their requirements, and on the other hand the latest equipment and techniques for meeting such requirements. The topics covered vegetation structure, light interception and growth; radiation and heat exchange; liquid water in the soil and plant; oxygen,  $\text{CO}_2$ , water vapour; data handling. The Conference aroused great interest, a total of 180 scientists from all over Australia attending. The papers presented are to be published shortly in a single volume.

## IX PUBLICATIONS

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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. McLlroy, B.Sc.
Sen. Research Scientist	W. Shepherd, M. Ag. Sc., B.Sc.
Sen. Research Scientist	E.K. Webb, B.A. (Hons.), B.Sc.
Senior Research Fellow	R.N. Kulkarni, M.Sc., Ph.D.
Research Scientist	A.B. Pittock, 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.
Experimental Officer	R.H. Hill, Dip. E.E., B.E.
Experimental Officer	R.R. McGregor, Dip. Appl. Sci.
Experimental Officer	F.J. Maher, A.R.M.T.C.
Experimental Officer	C.J. Sumner, A.M.S.E.
Experimental Officer	A.J. Troup, B.Sc.
Scientific Services Officer	N.E. Bacon, B.Sc.
Scientific Services Officer	P.D. Berwick, B.Sc. (Hons.)
Administrative Officer	F.K. Tighe